

Tobias Wulf

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Bachelorarbeit

Winkelmessung durch magnetische Sensor-Arrays und
Toleranzkompensation mittels Gauß-Prozess

Fakultät Technik und Informatik
Department Informations- und Elektrotechnik

Faculty of Computer Science and Engineering
Department of Information and Electrical Engineering

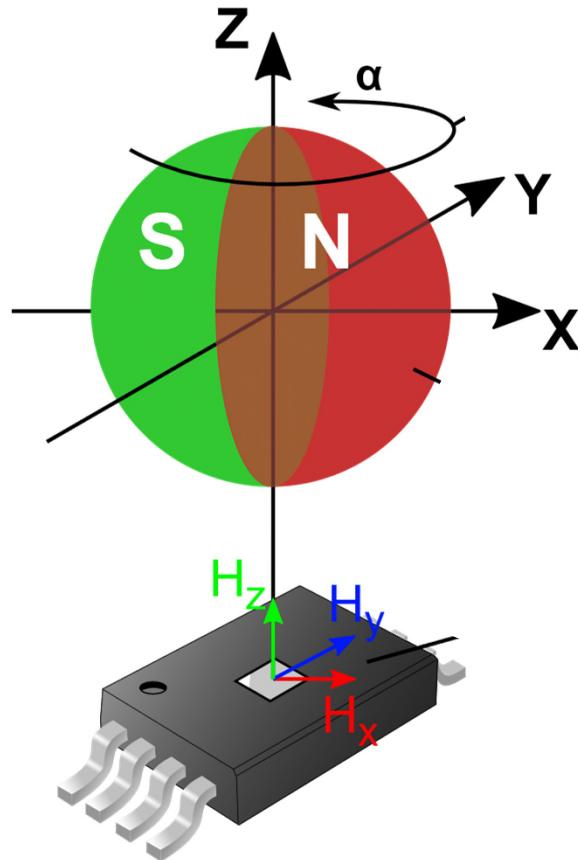
Übersicht

- Applikation
- Kennfelder
- Datenadaption
- Gauß-Prozesse

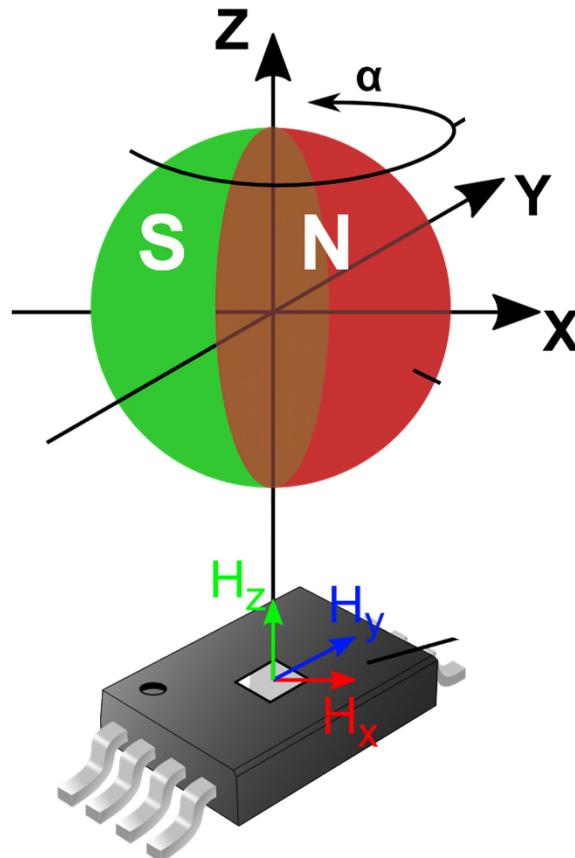
Übersicht

- Applikation
- Kennfelder
- Datenadaption
- Gauß-Prozesse
- Software-Aufbau
- Simulation – Sensor-Array
- Simulation – Gauß-Prozesse
- Erprobungsexperimente
- Zusammenfassung

Applikation

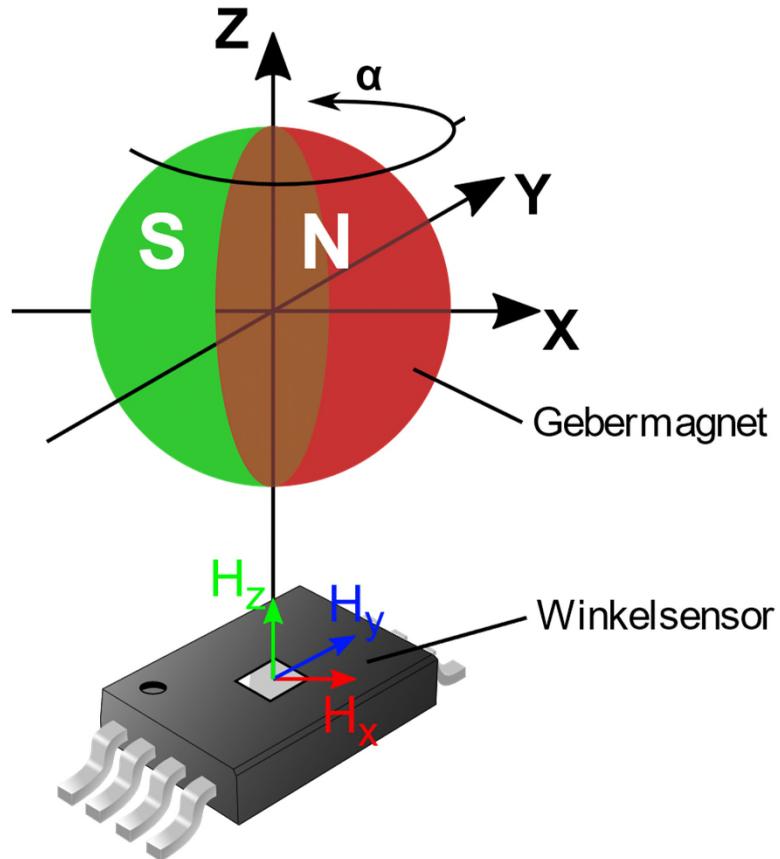


Applikation



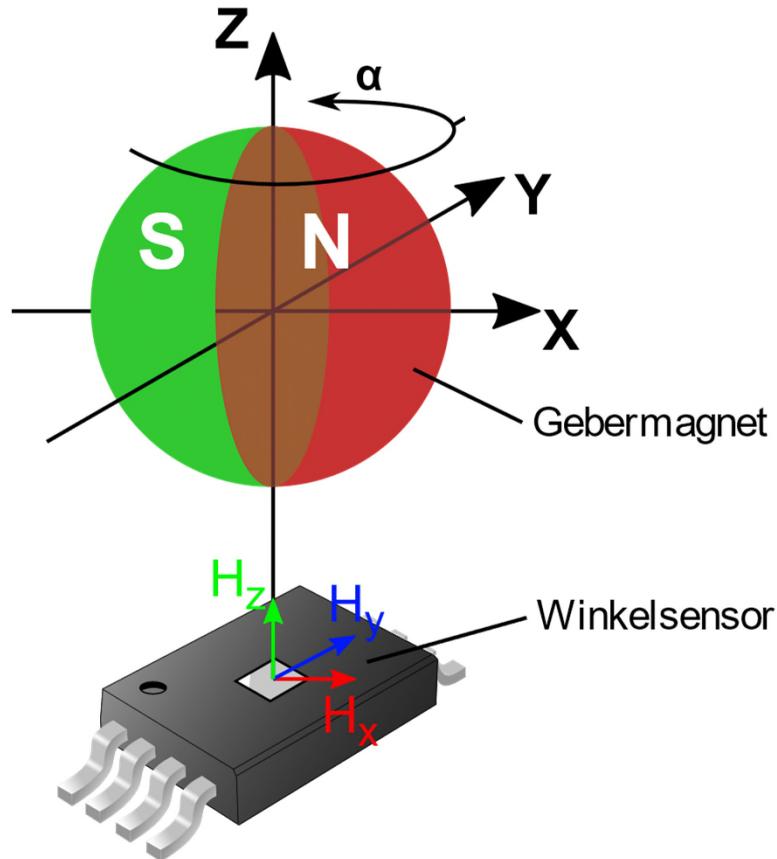
- Kontaktlose Winkelmessung

Applikation



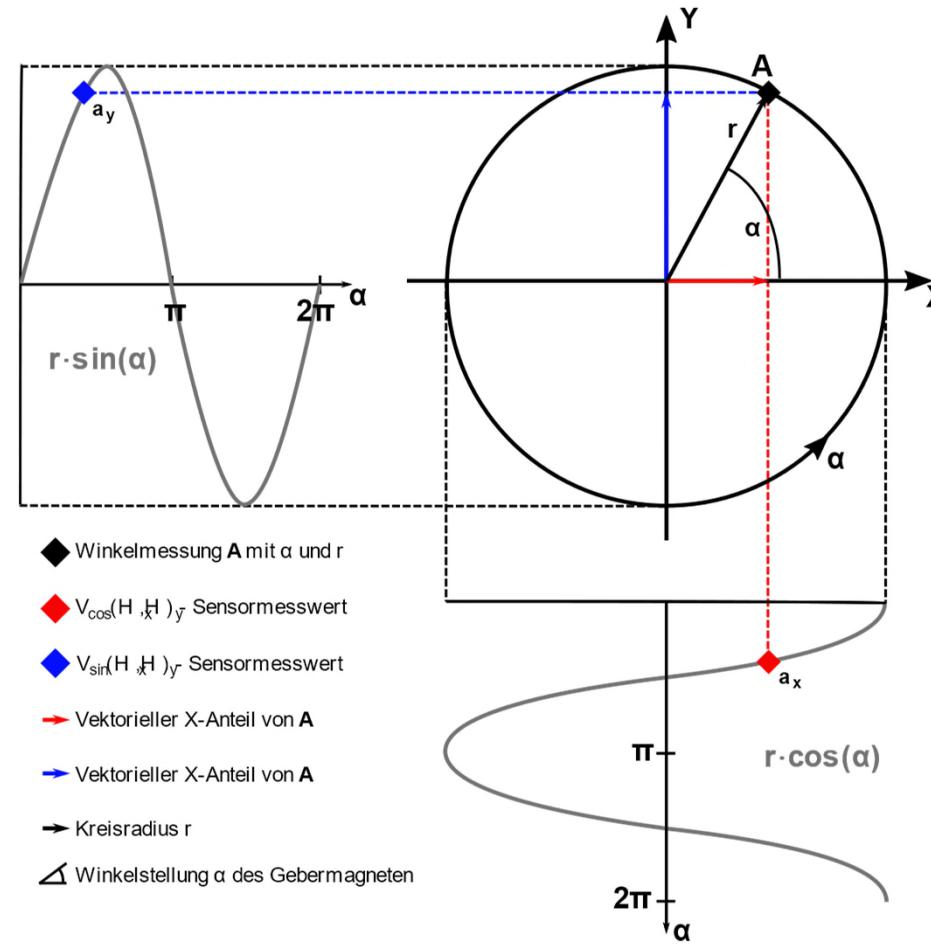
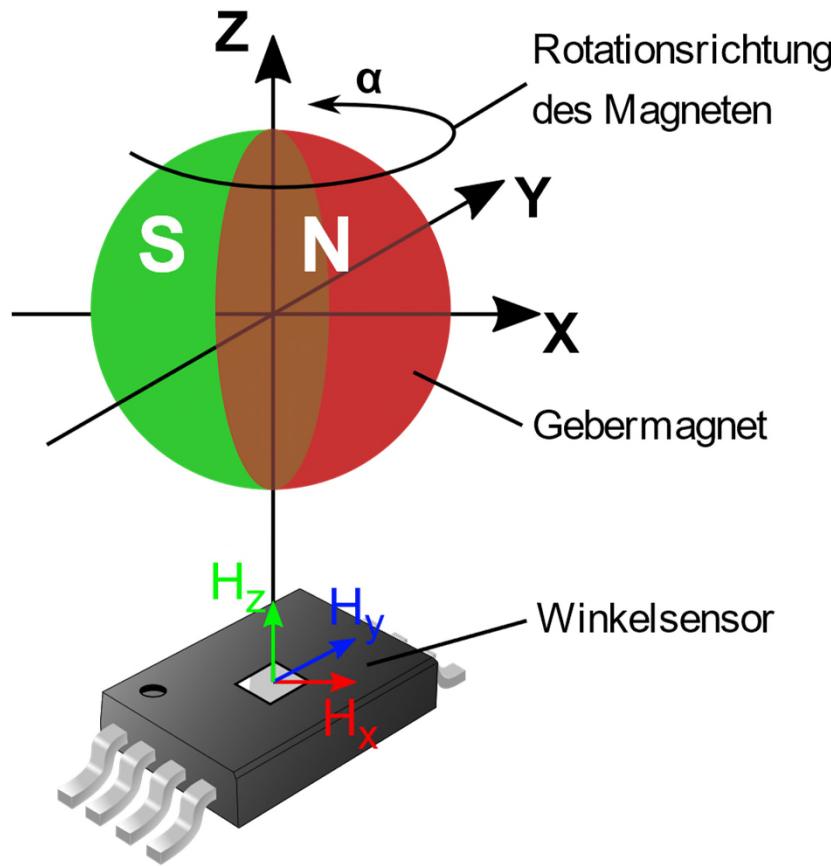
- Kontaktlose Winkelmessung
- Winkel encodiert durch Magnetfeld

Applikation

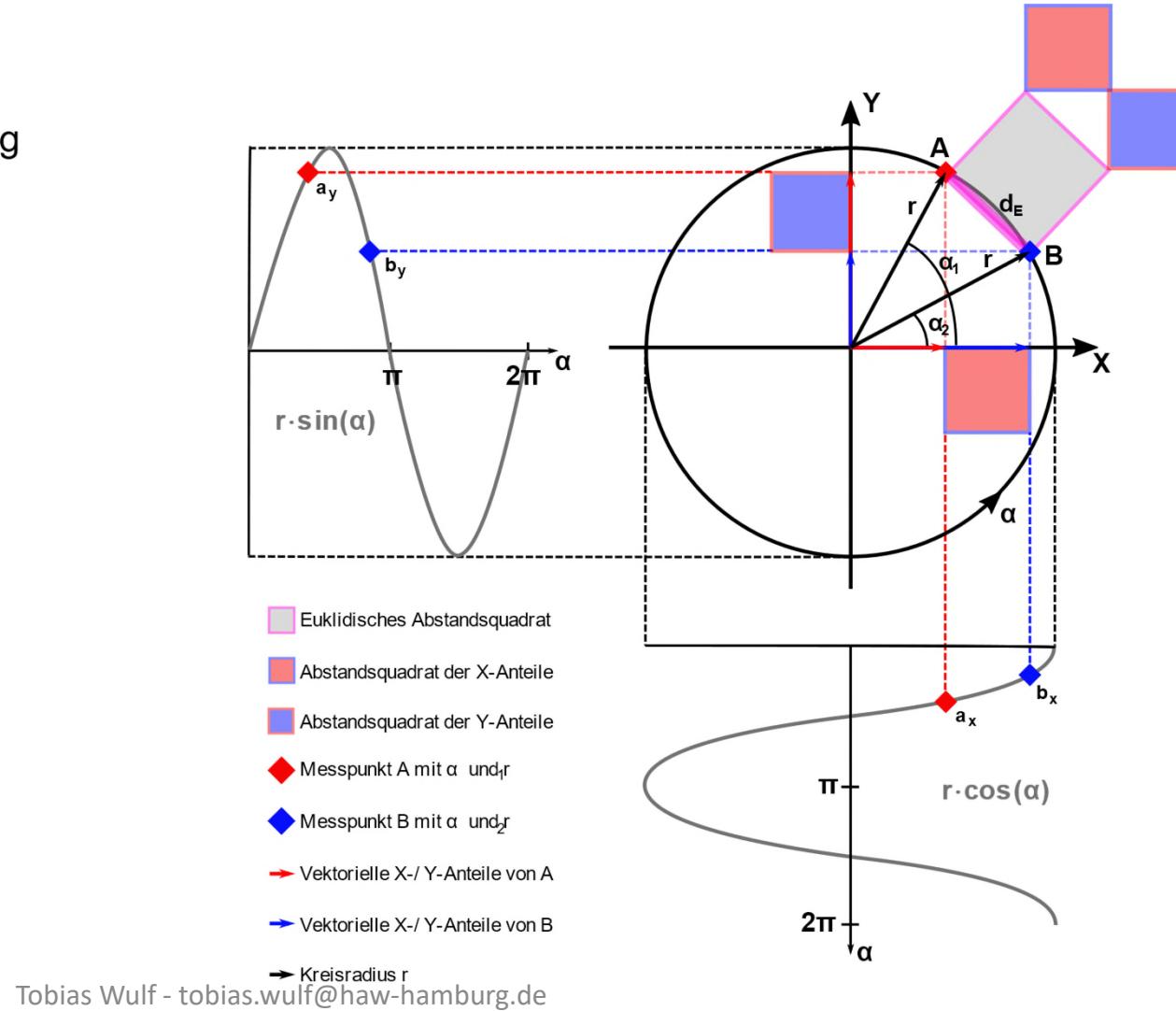
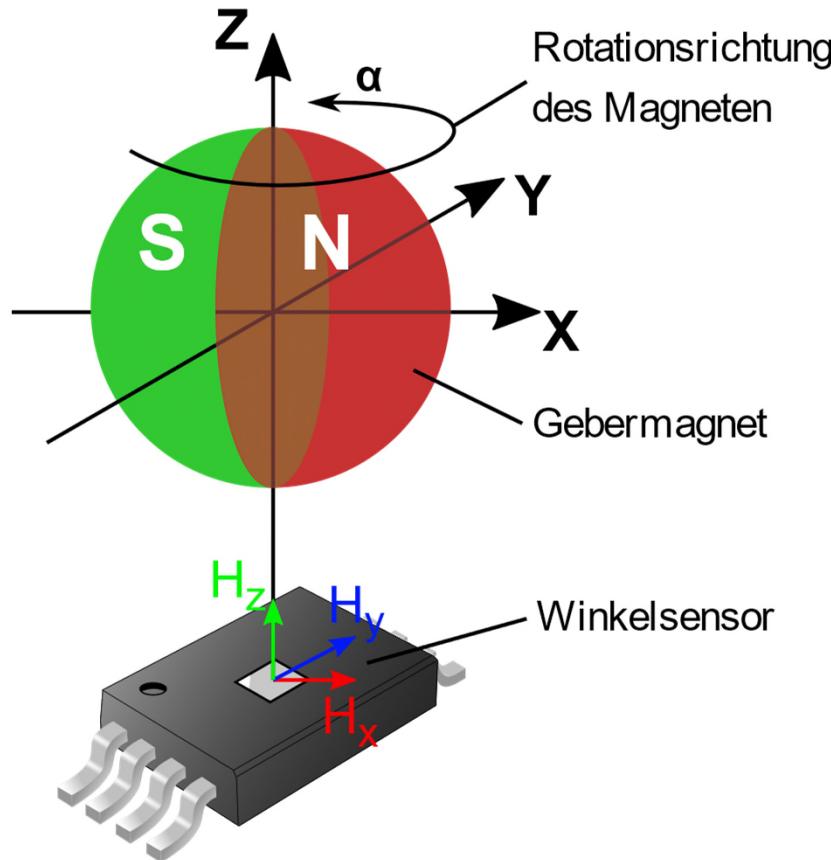


- Kontaktlose Winkelmessung
- Winkel encodiert durch Magnetfeld
- Feldstärkenmessung in X-/ Y-Richtung

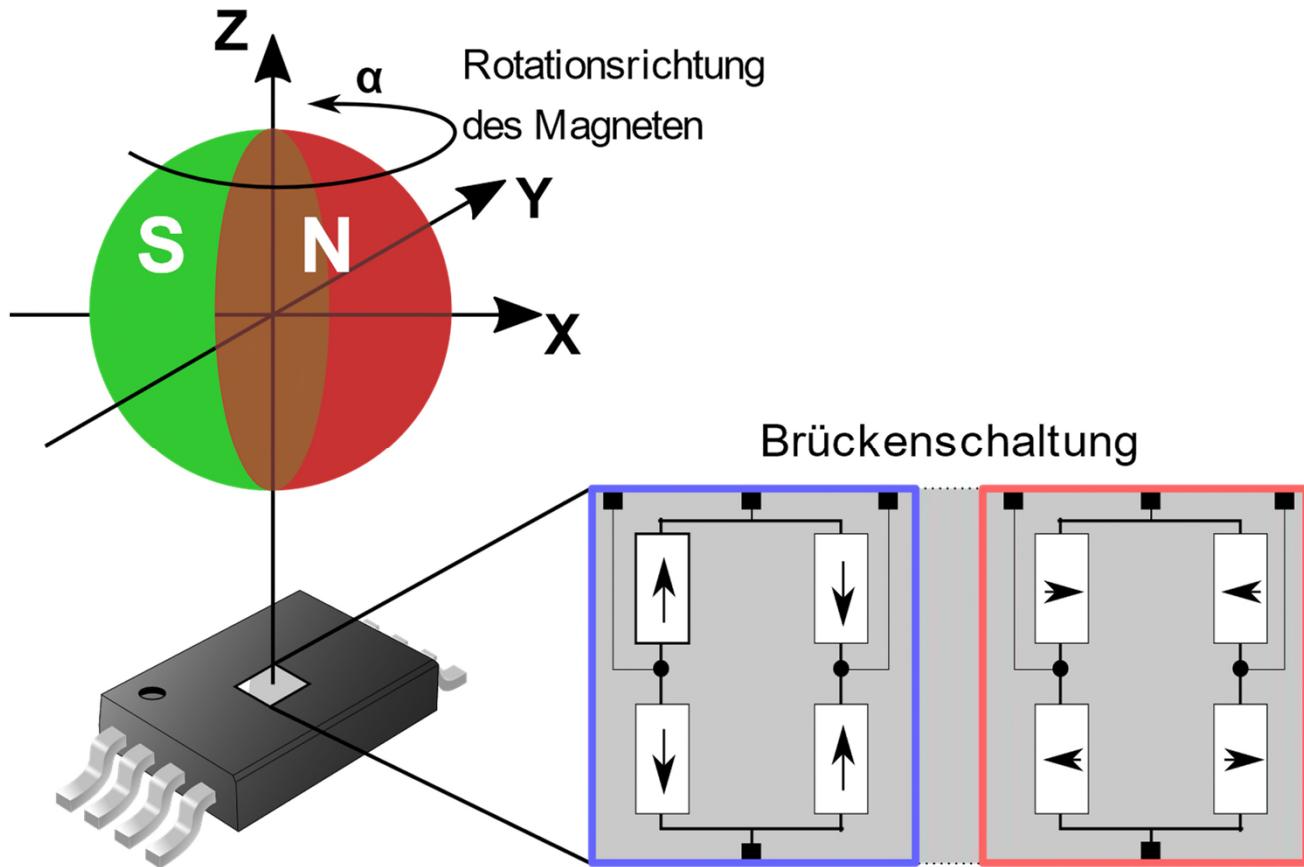
Applikation



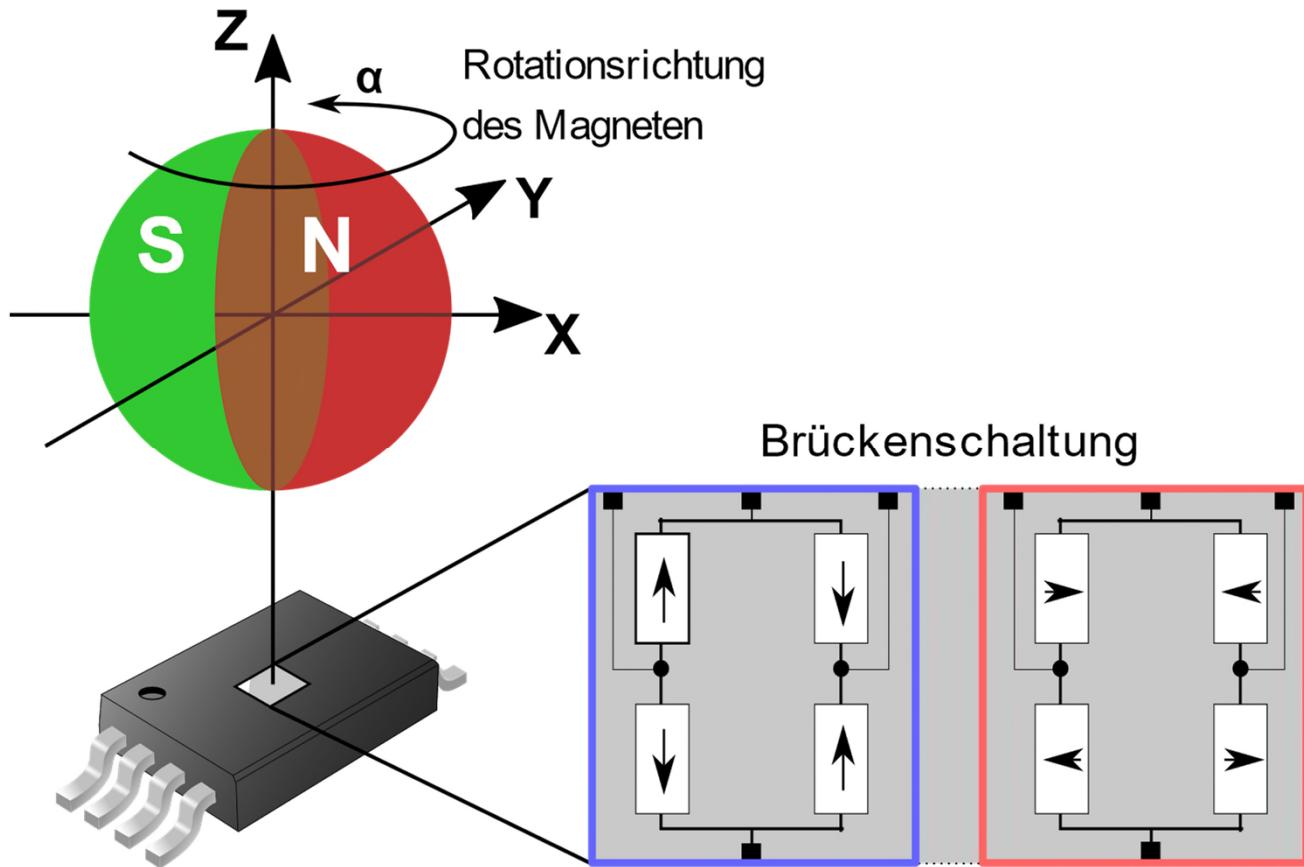
Applikation



Applikation

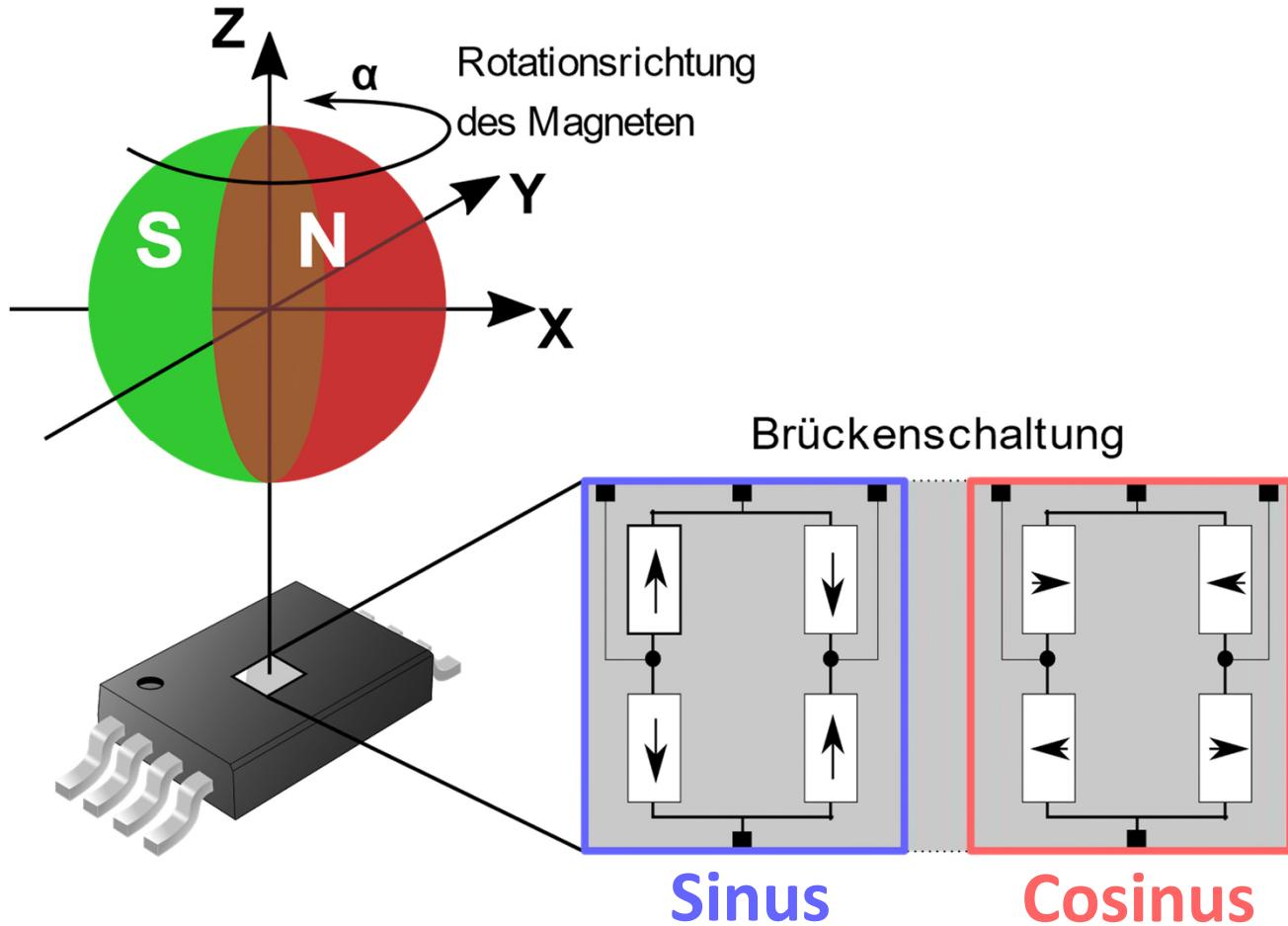


Applikation



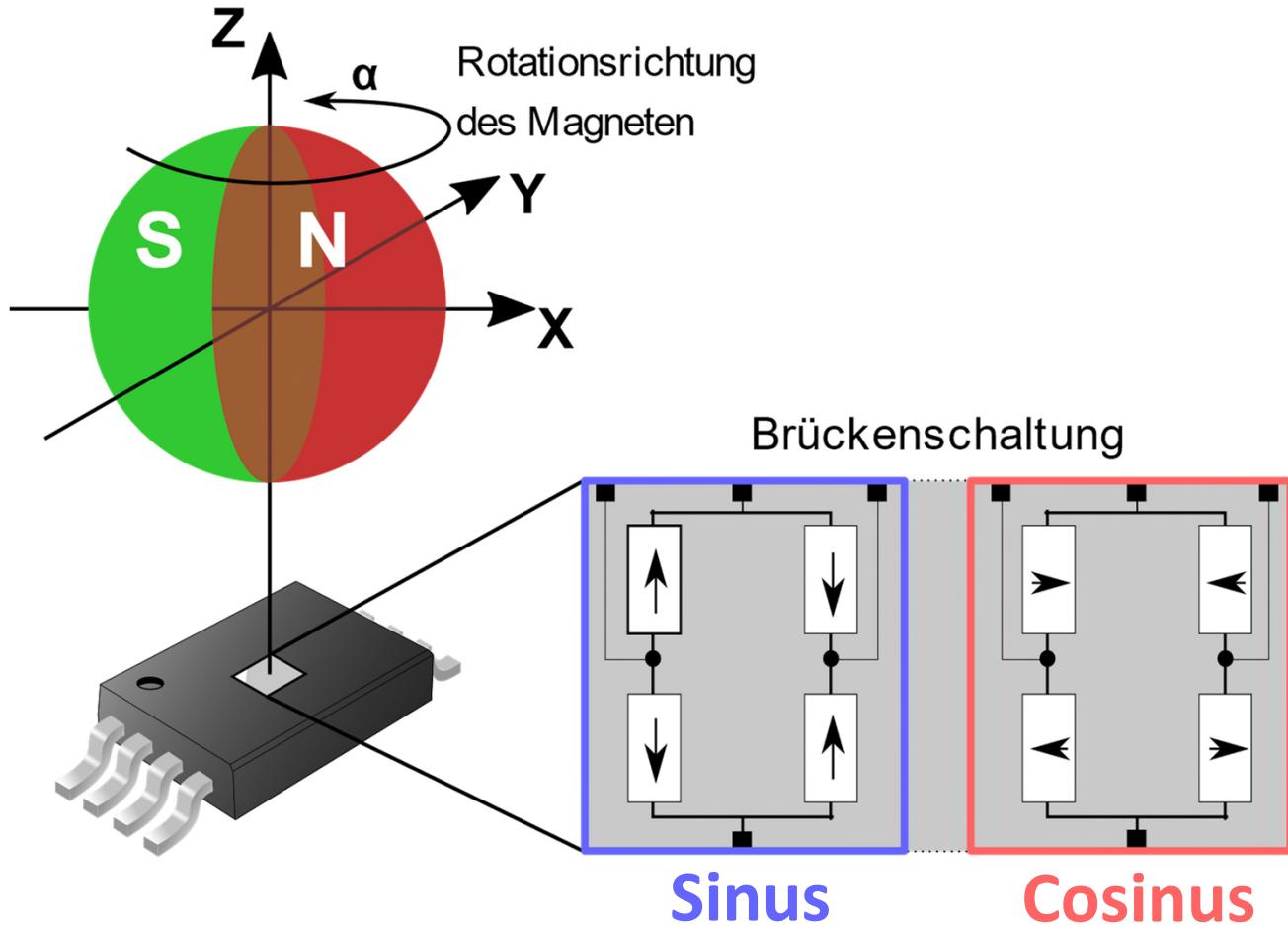
- TMR-Sensor

Applikation



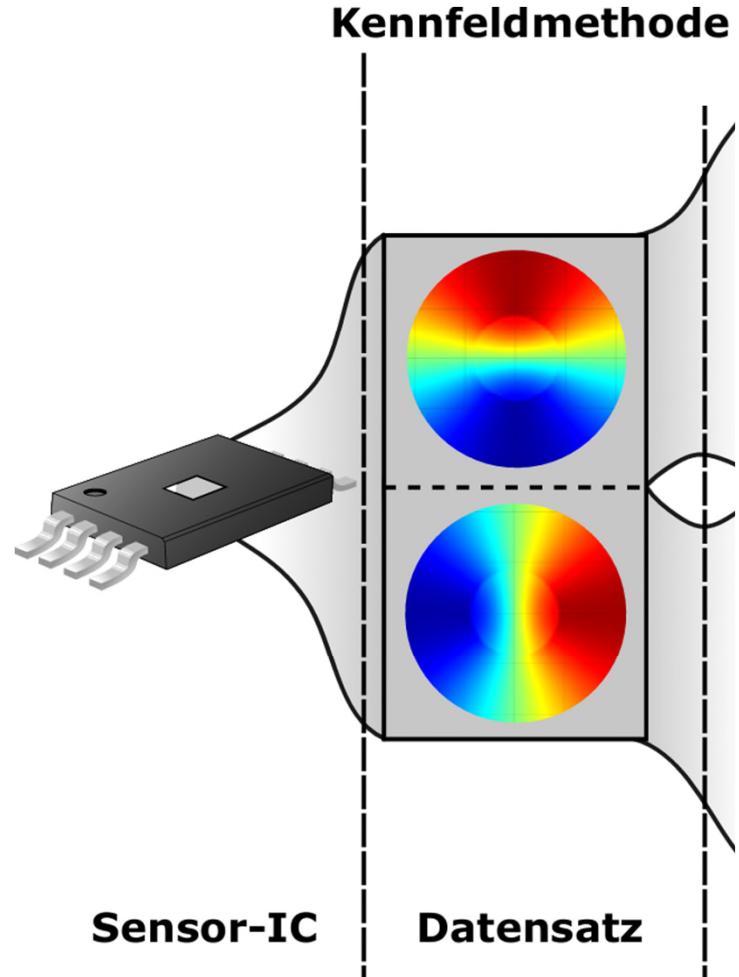
- TMR-Sensor
- Wheatstone'sche Messbrücken

Applikation

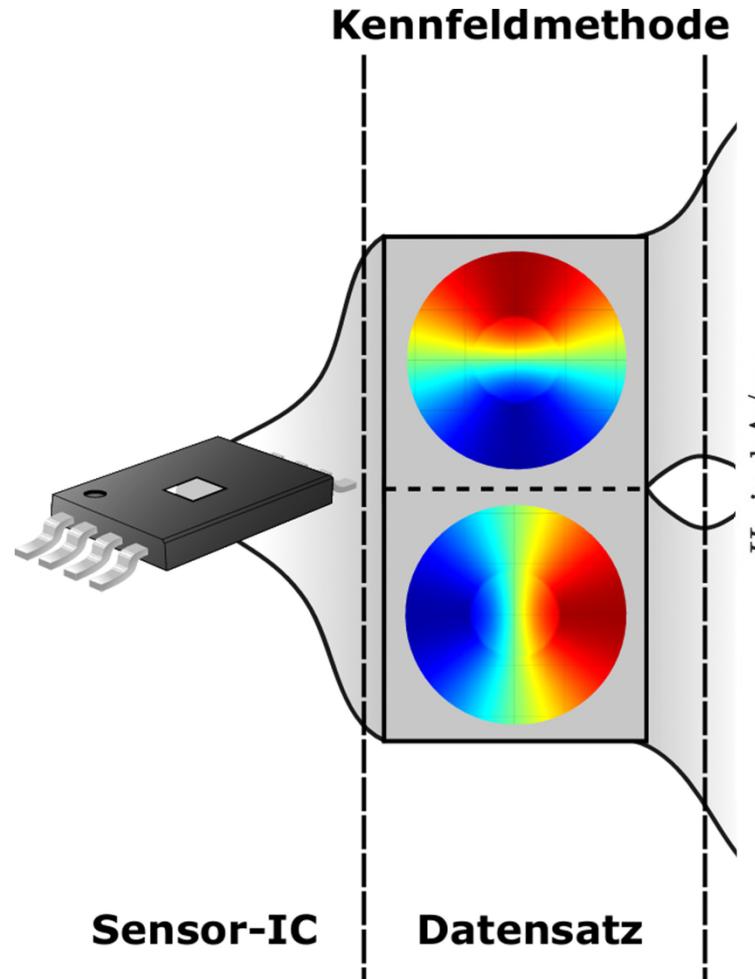


- TMR-Sensor
- Wheatstone'sche Messbrücken
- 90° verdreht zueinander
- 360° Periodizität

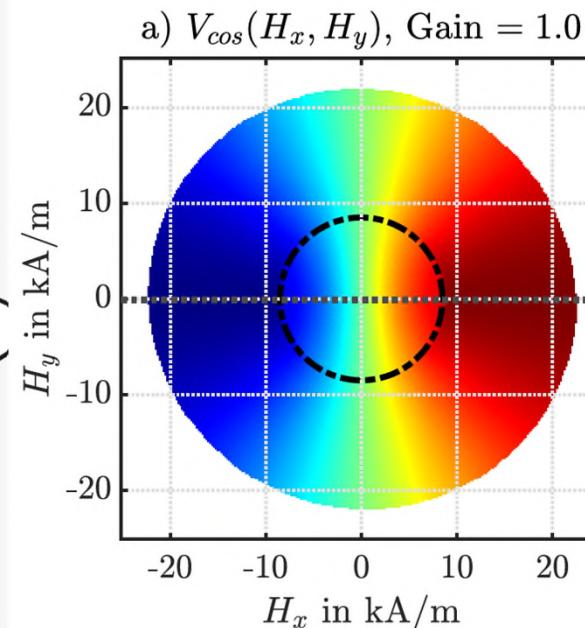
Kennfelder



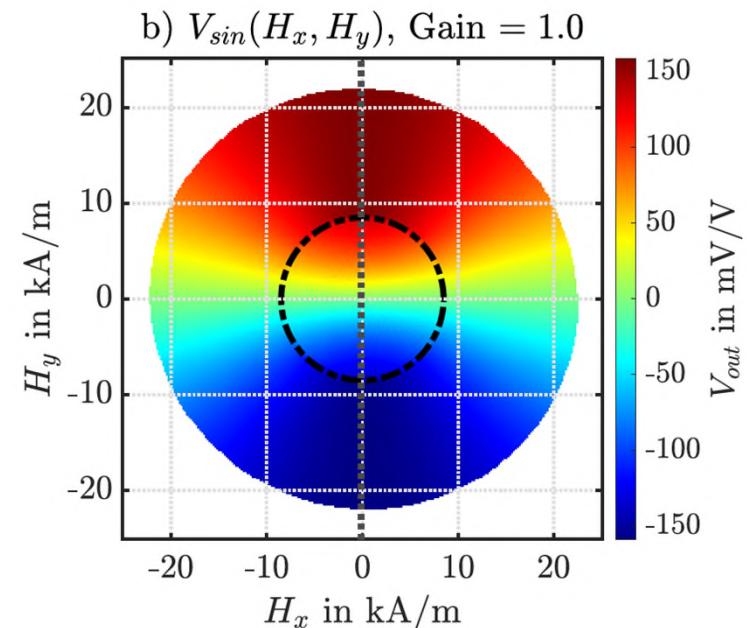
Kennfelder



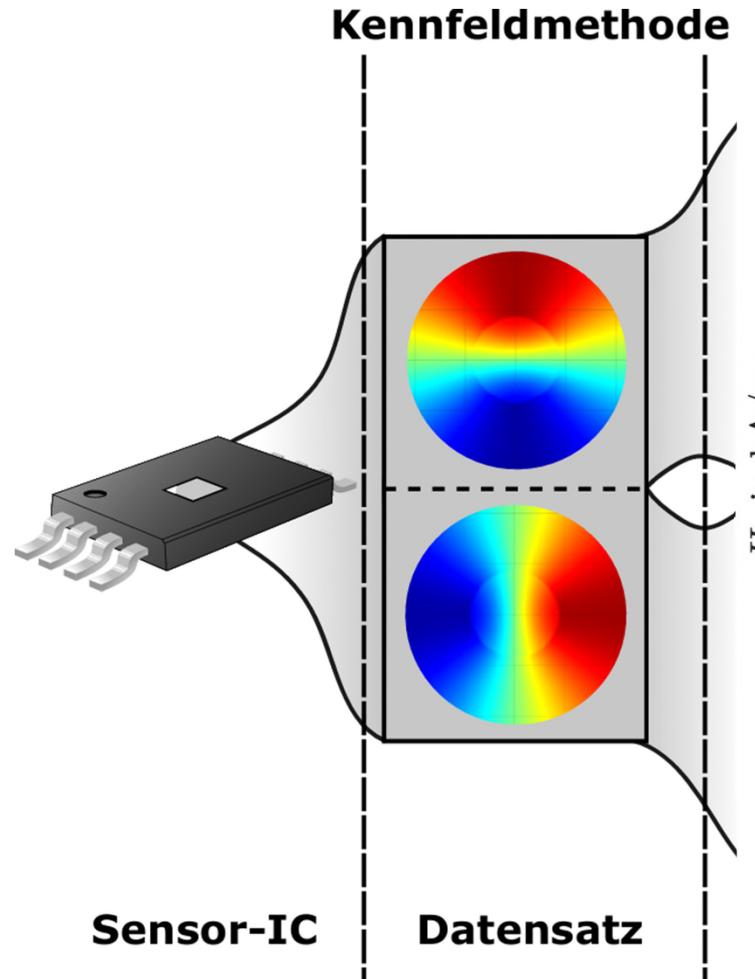
360° Periodizität



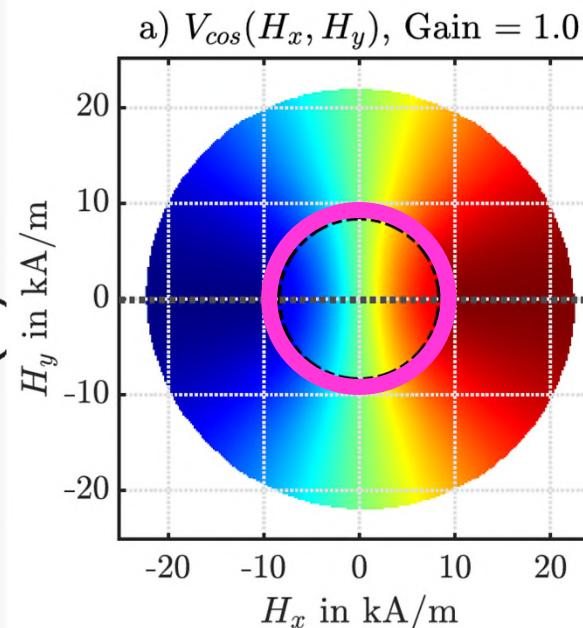
90° verdreht



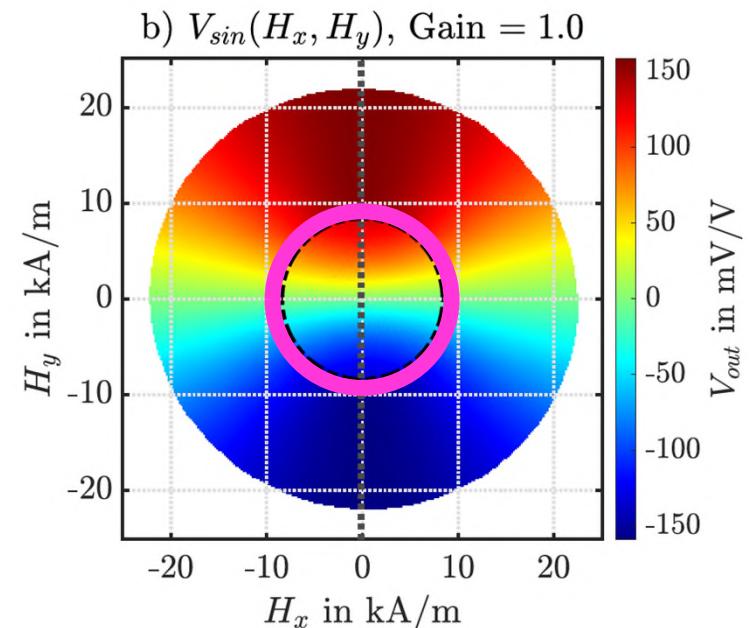
Kennfelder



360° Periodizität

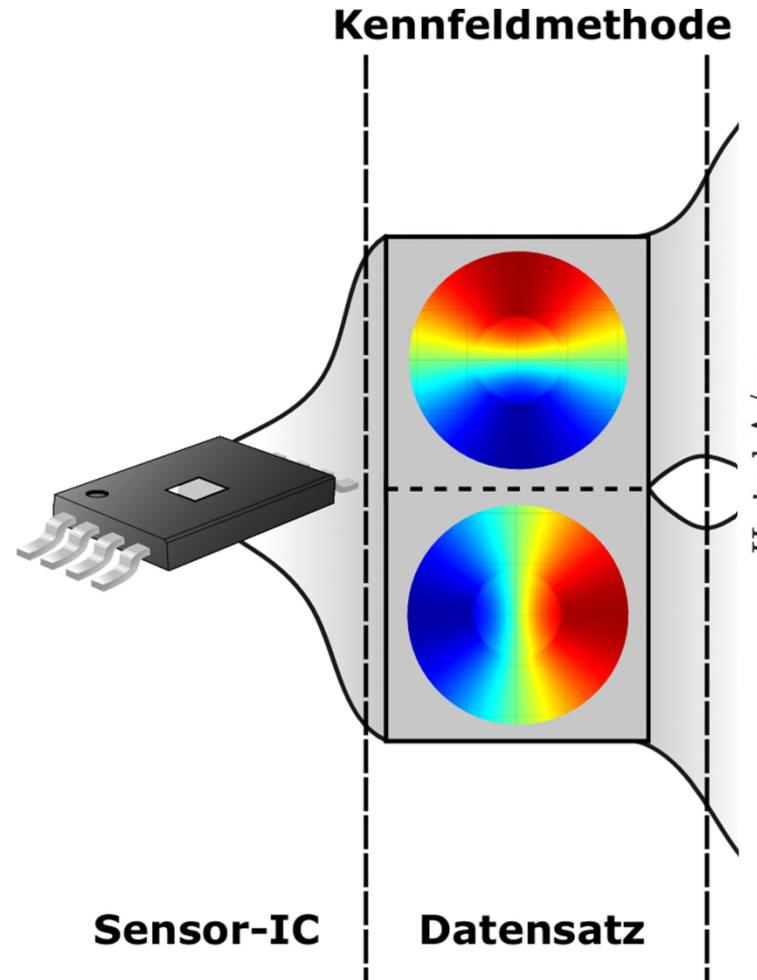


90° verdreht

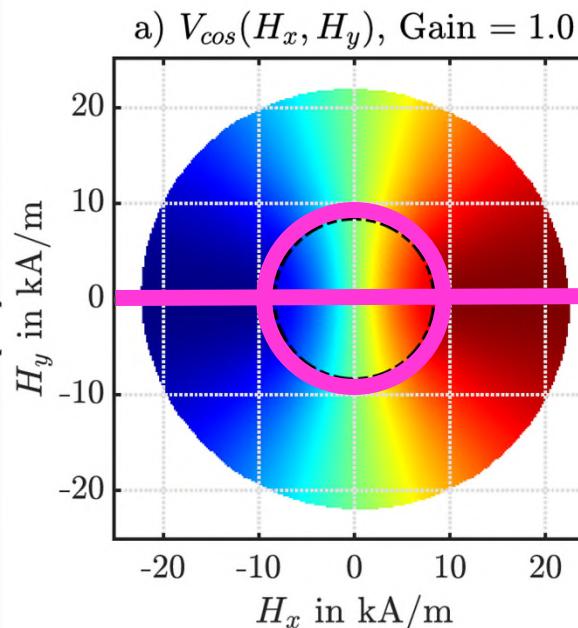


Lineare Plateaus

Kennfelder

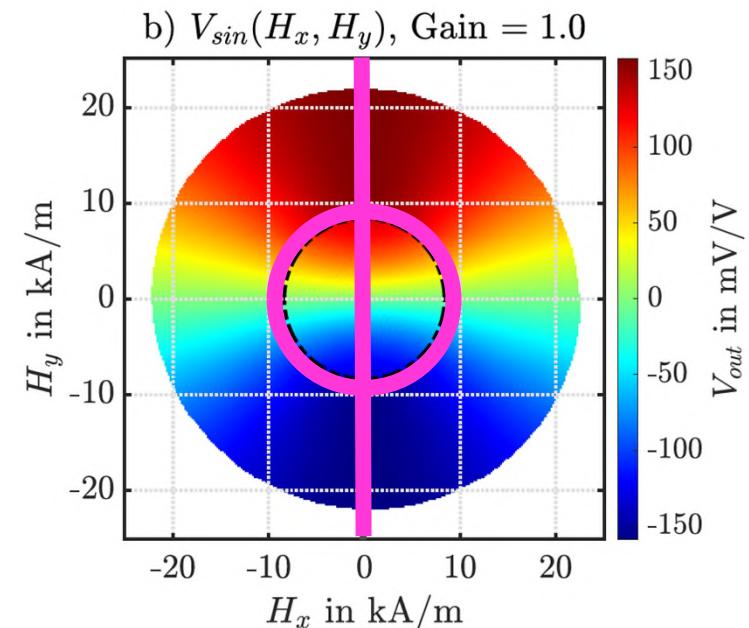


360° Periodizität



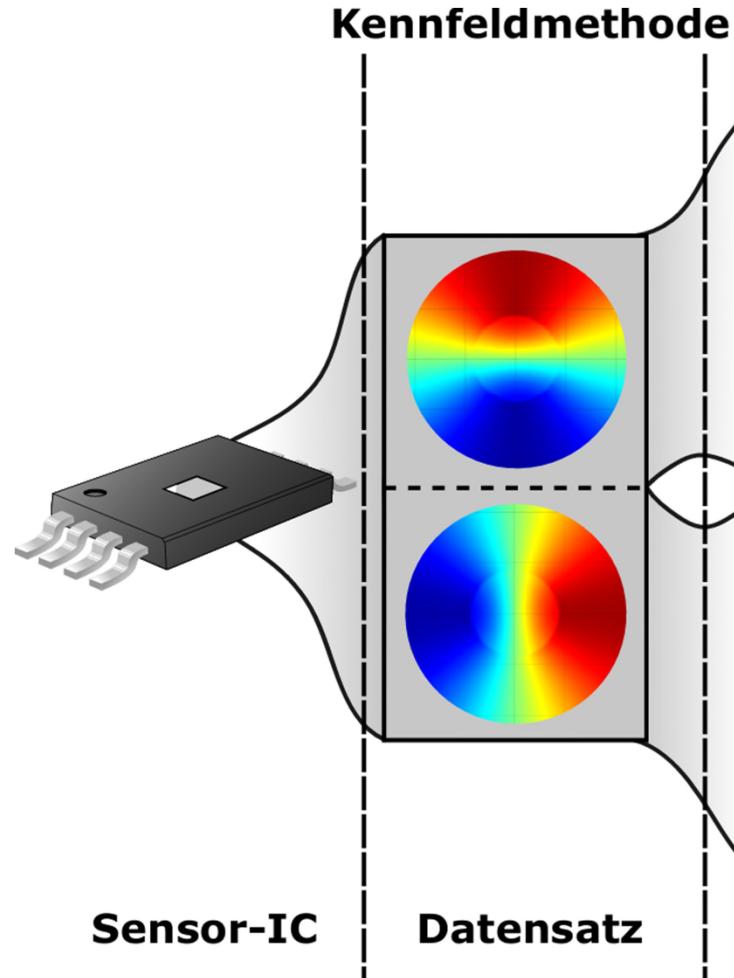
Lineare Plateaus

90° verdreht

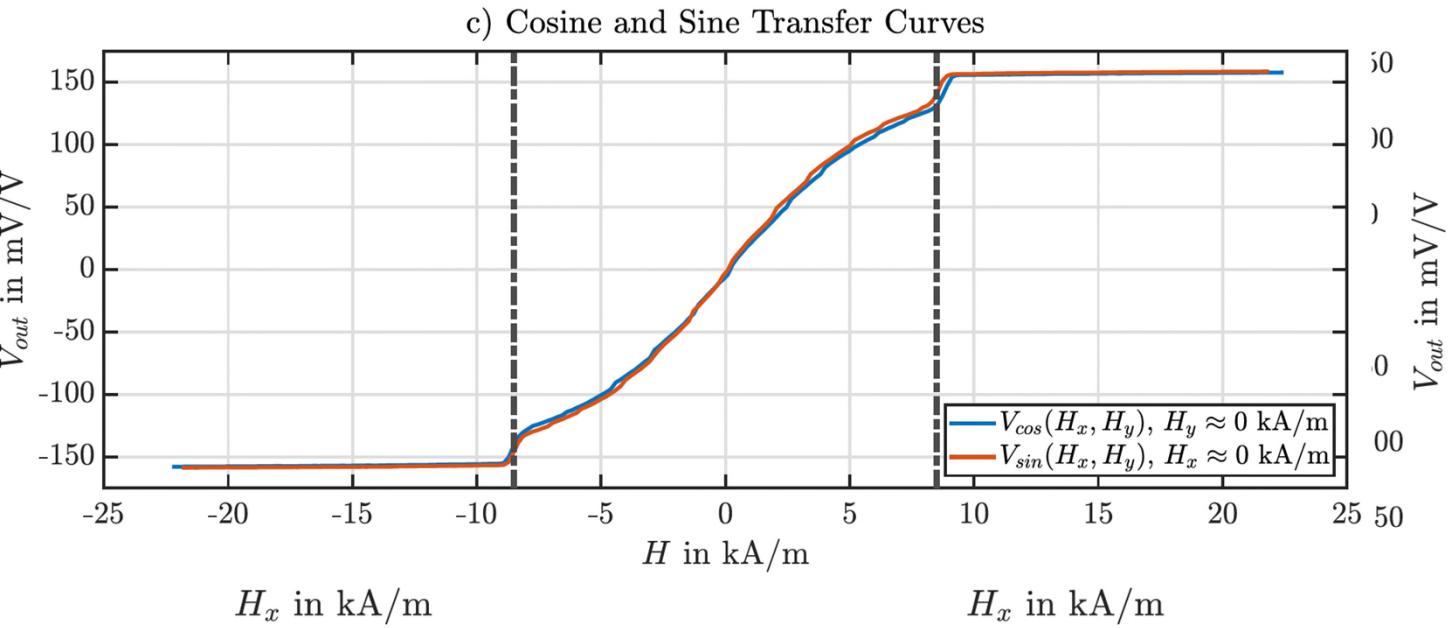


Transferkurven

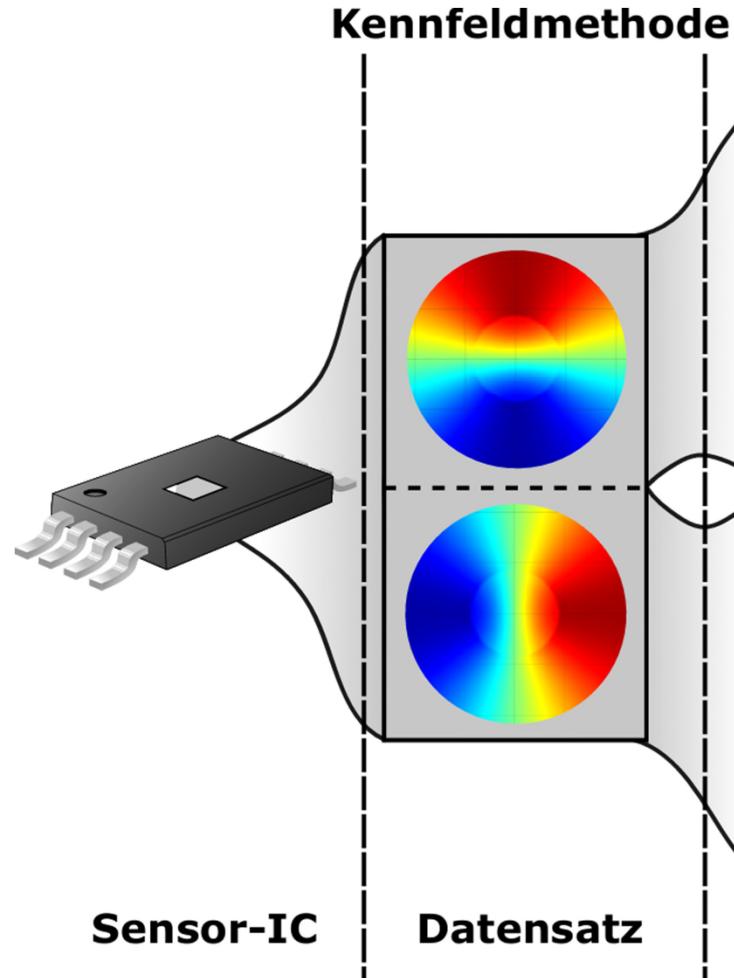
Kennfelder



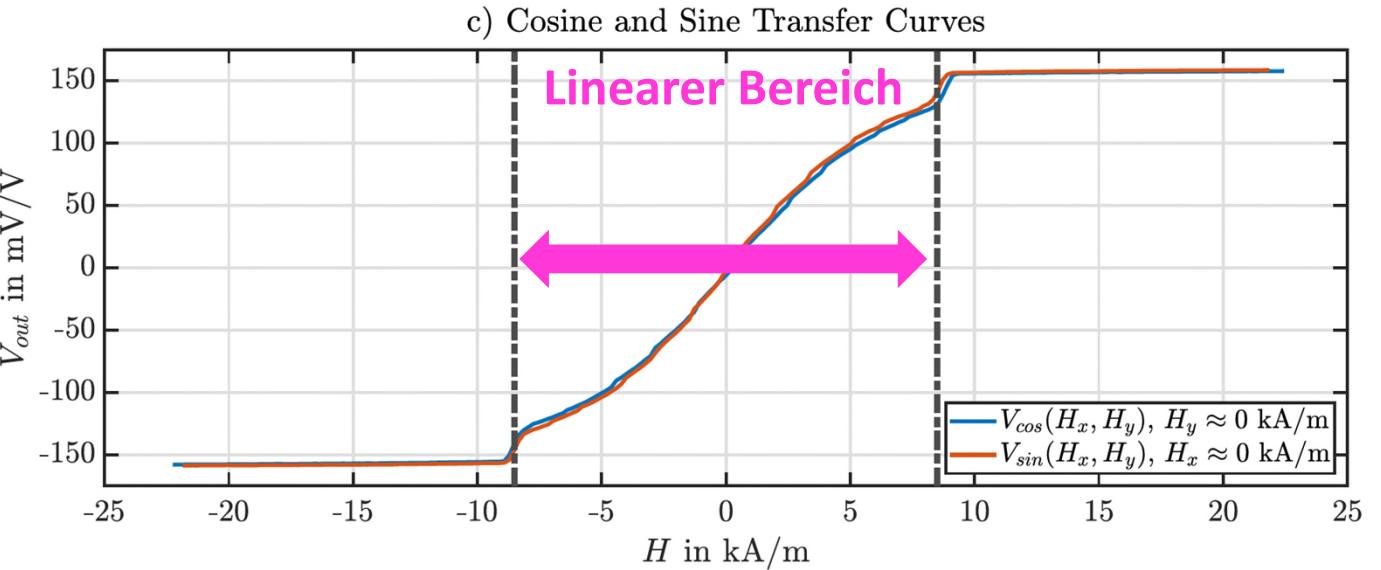
Transferkurven als Quer- bzw. Längsschnitte



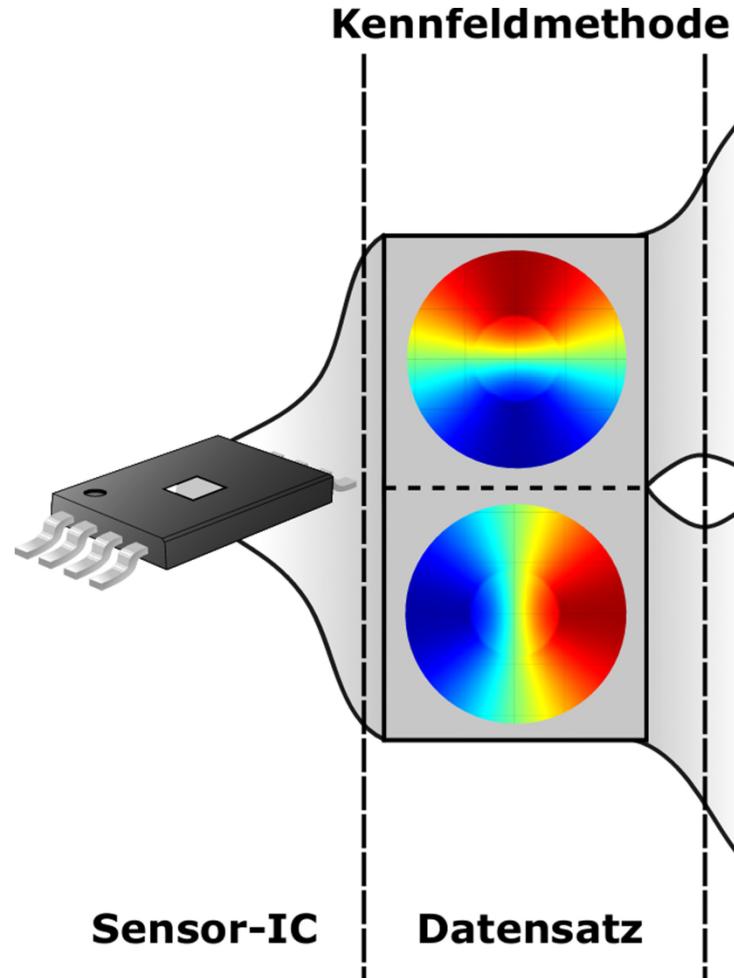
Kennfelder



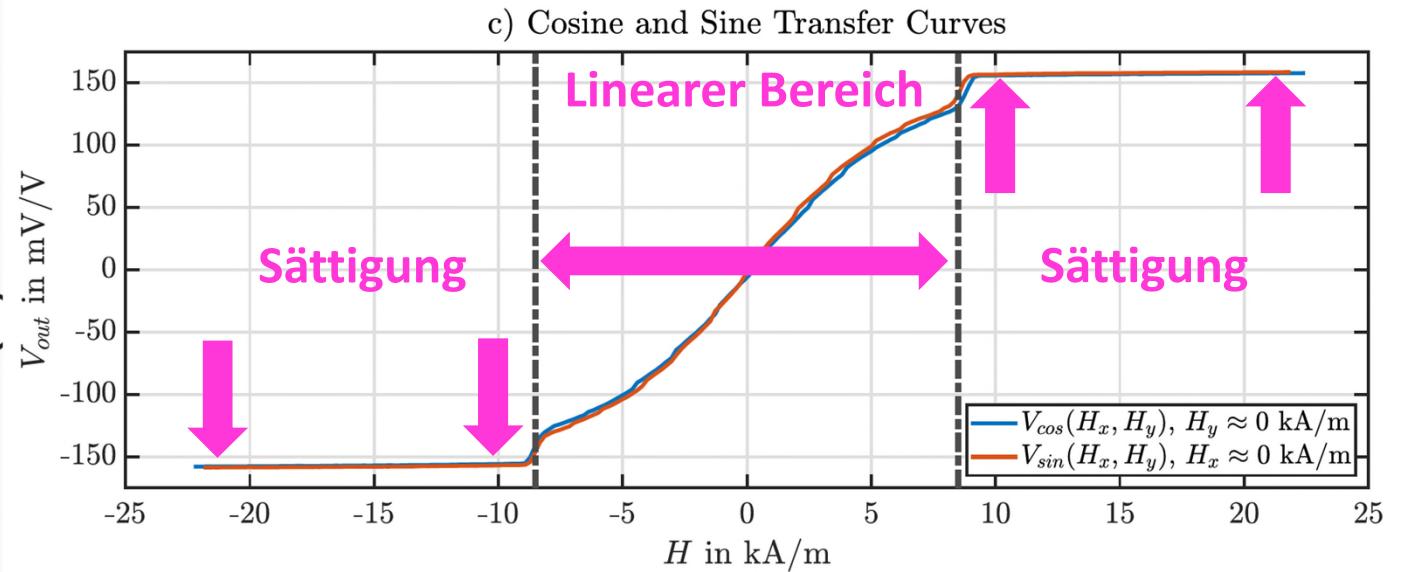
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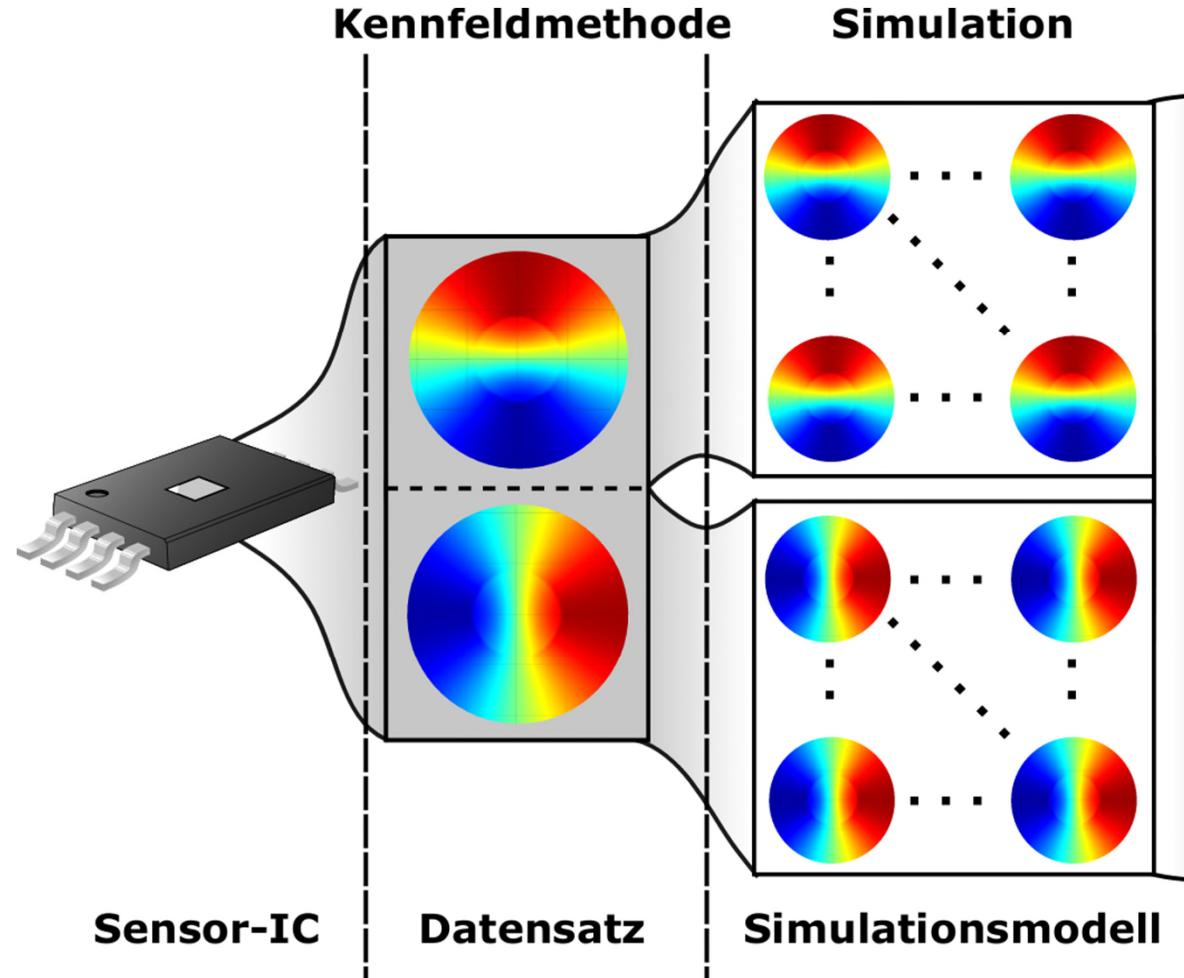
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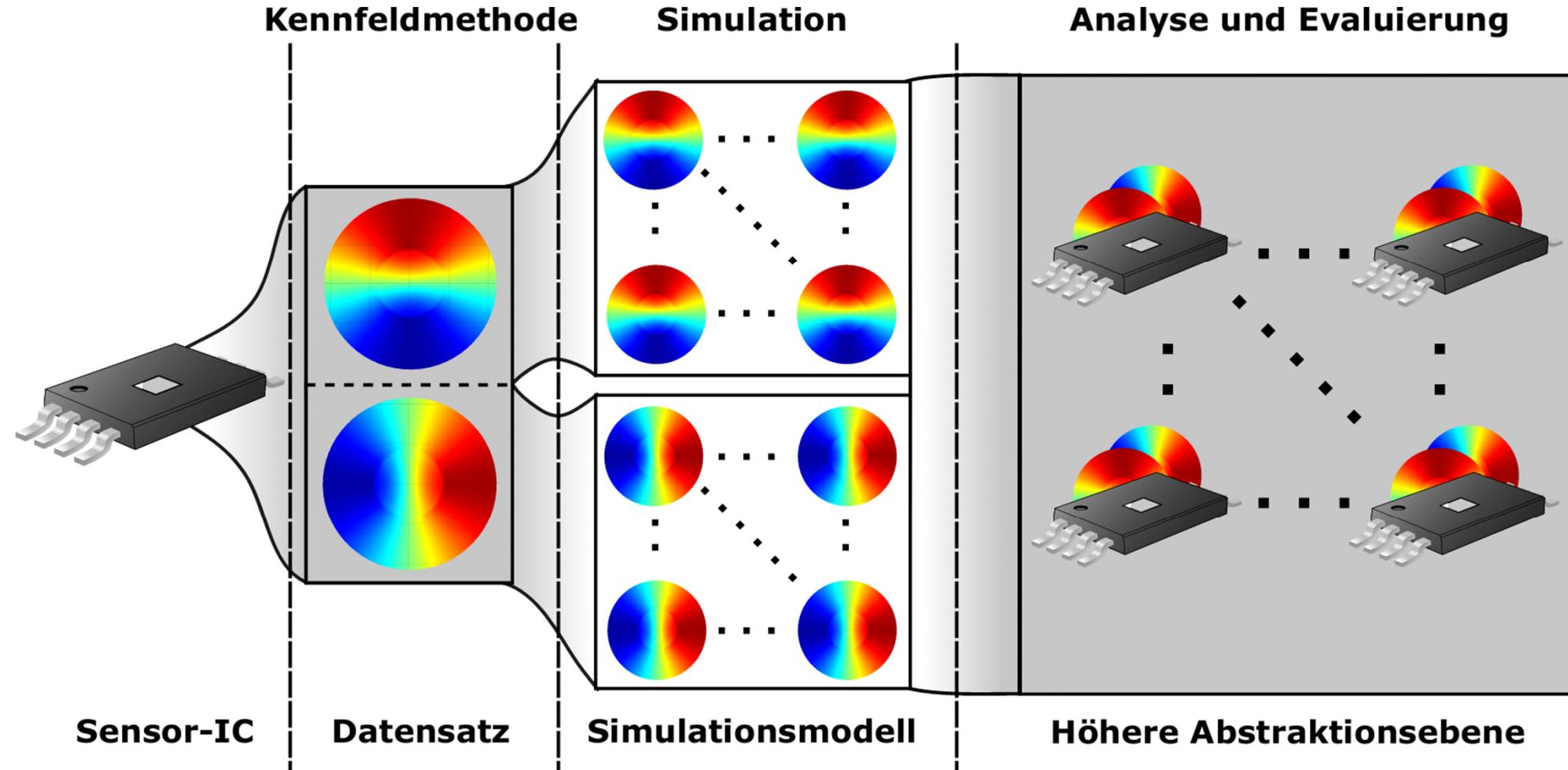
Transferkurven als Quer- bzw. Längsschnitte



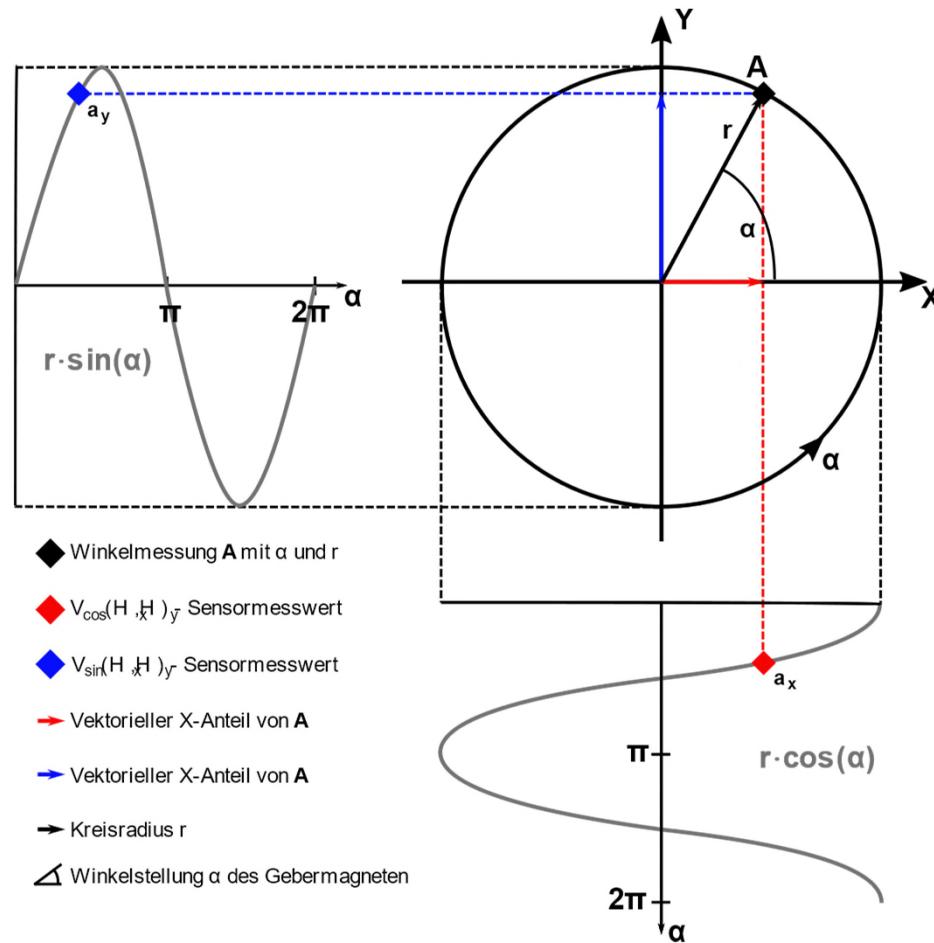
Kennfelder



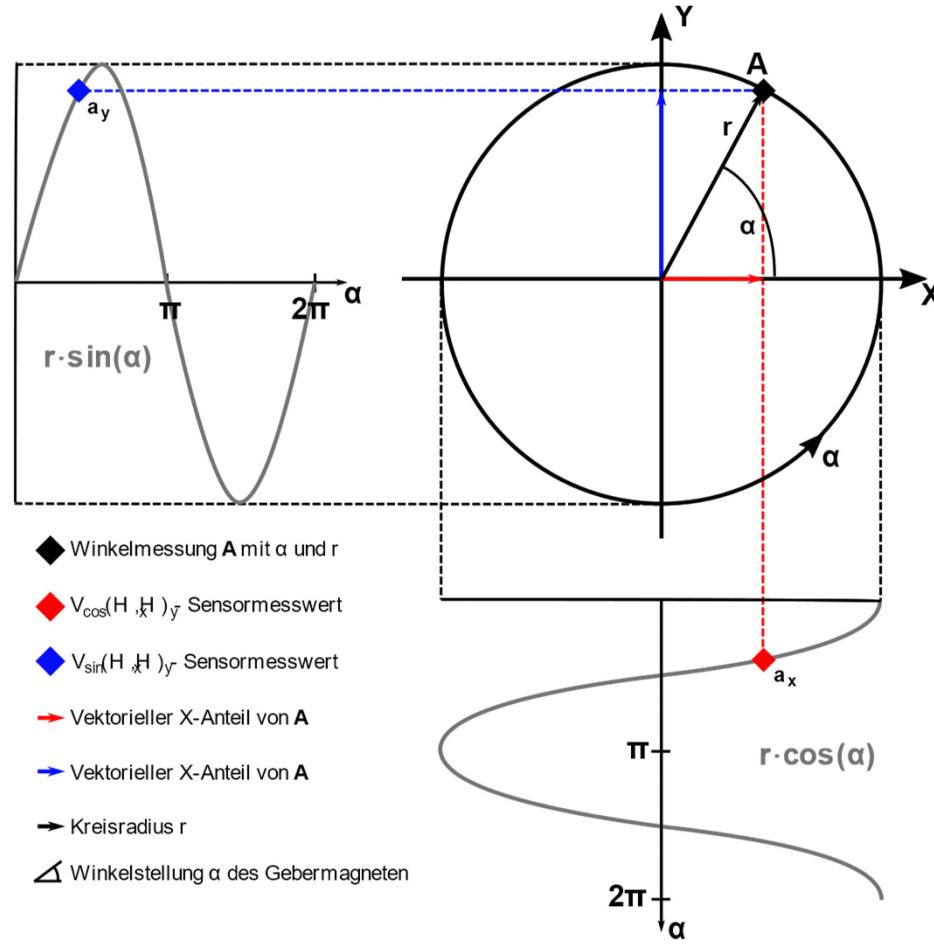
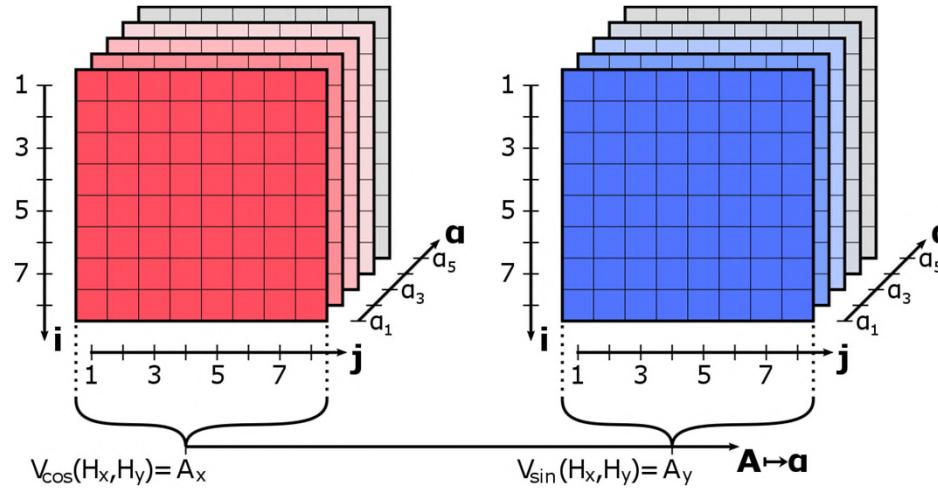
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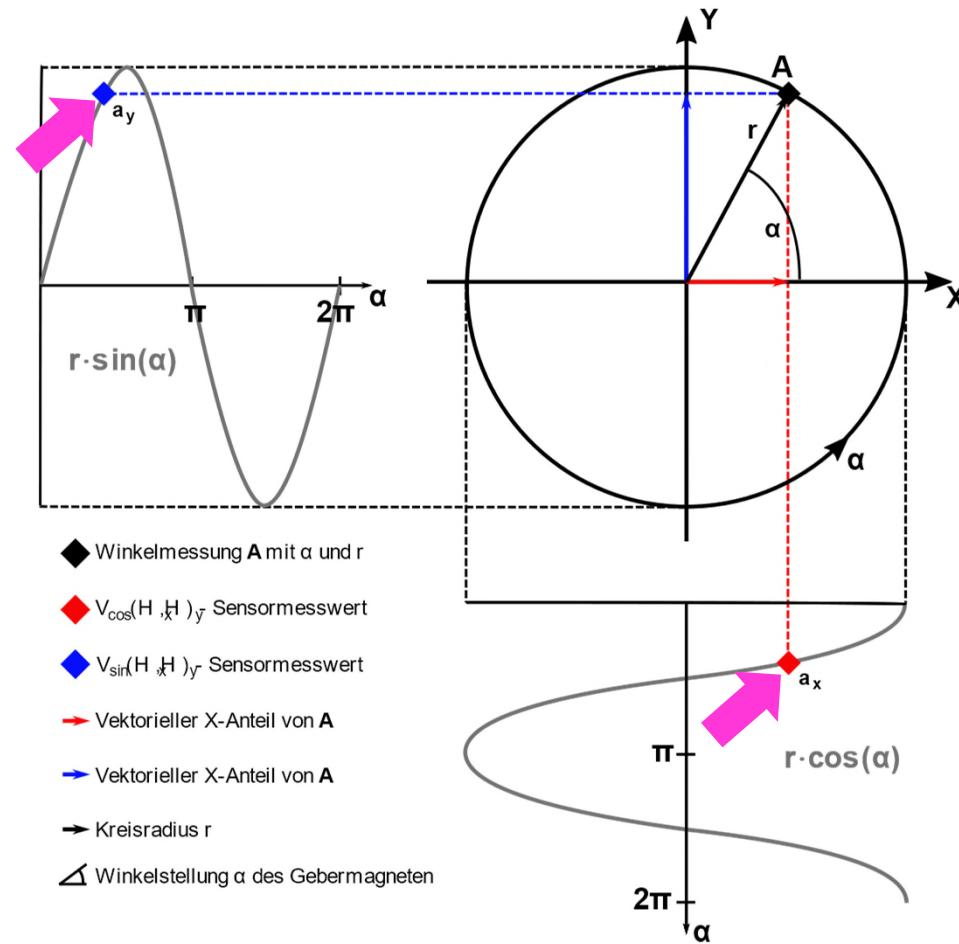
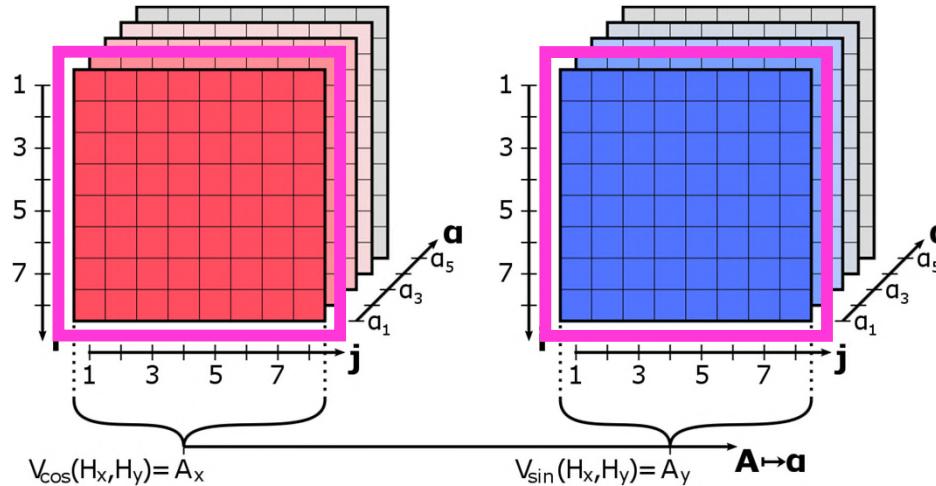
Datenadaption



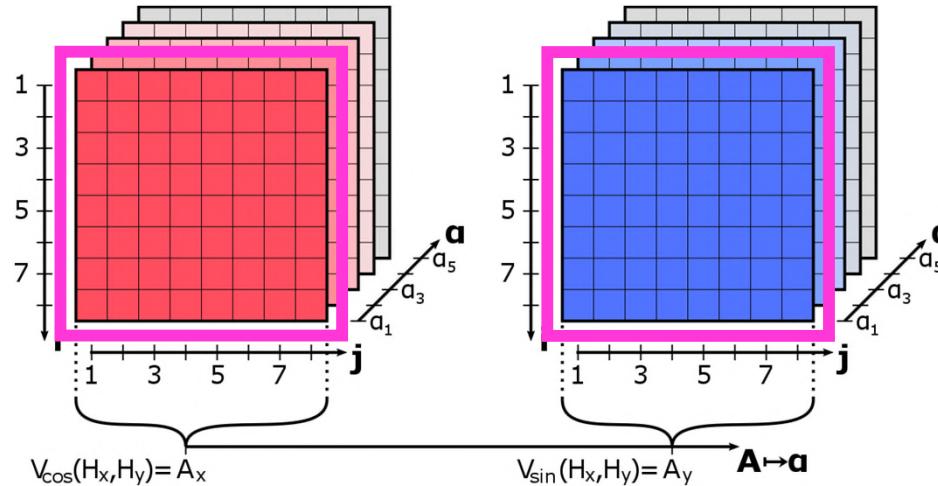
Datenadaption



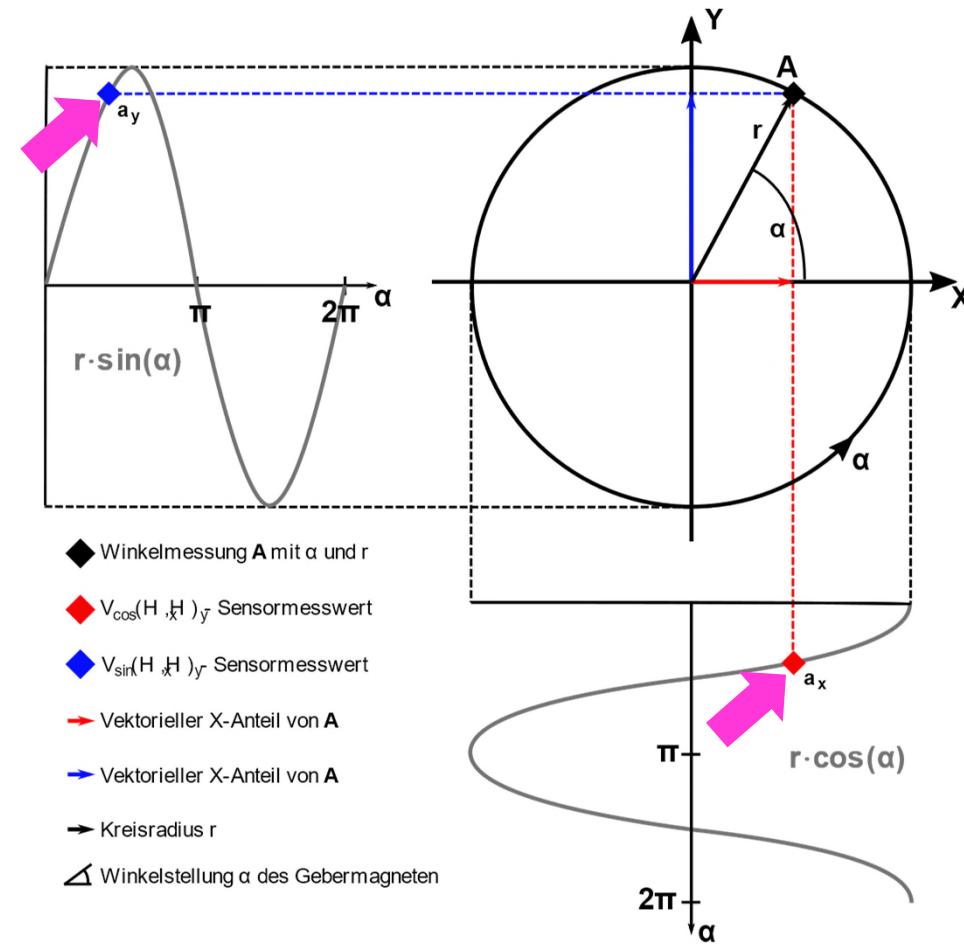
Datenadaption



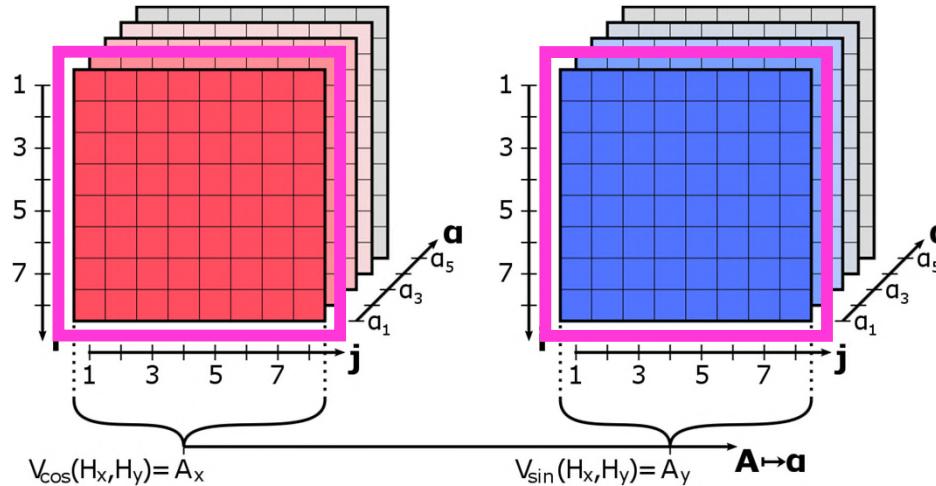
Datenadaption



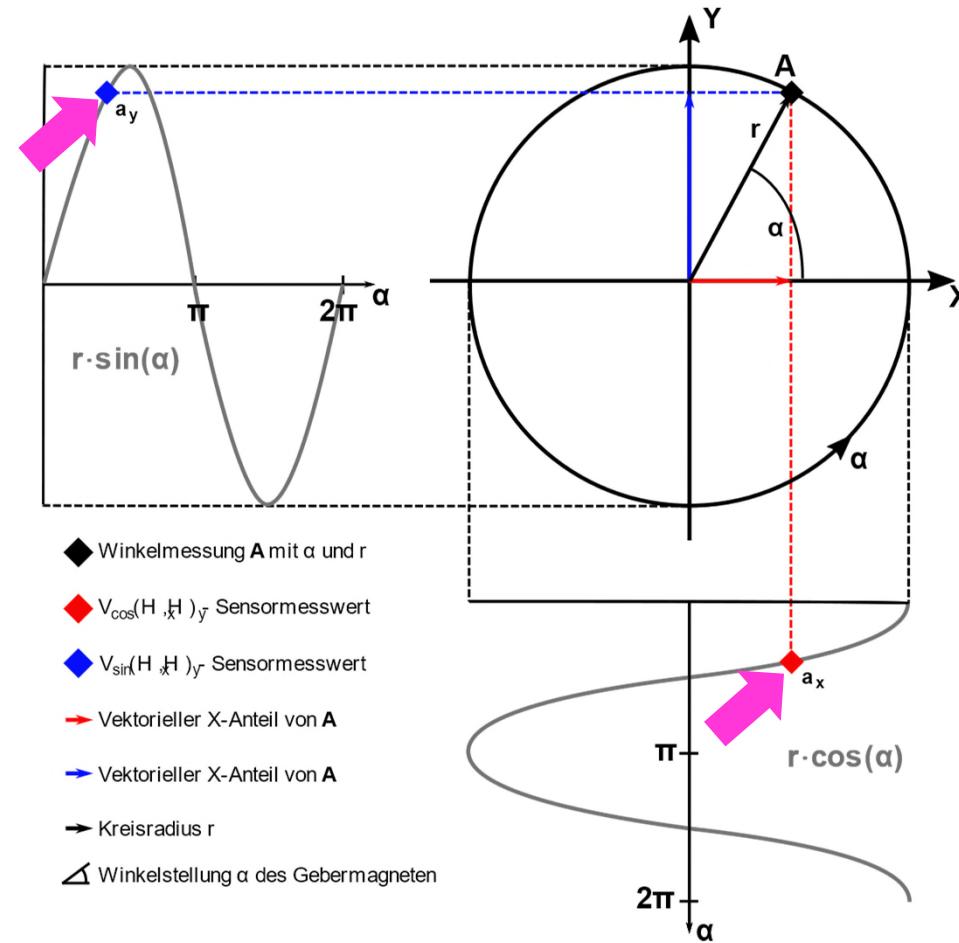
- Arrays als lange Vektoren



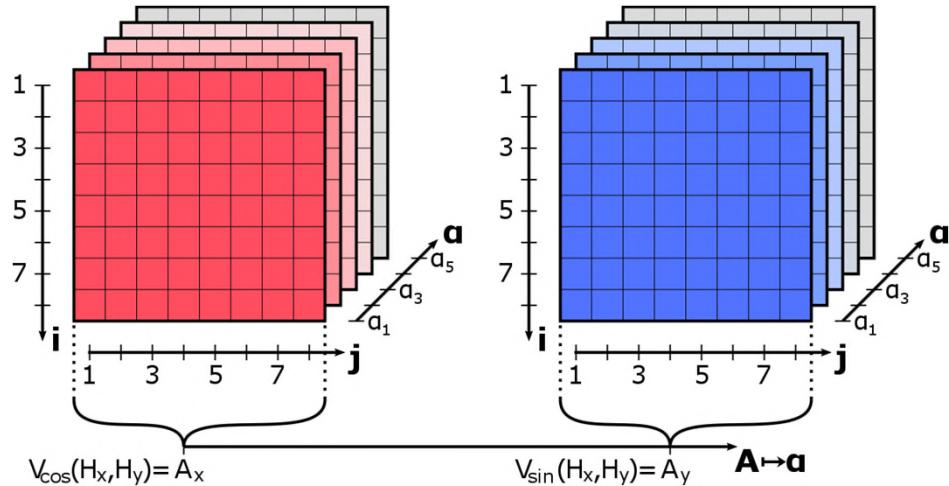
Datenadaption



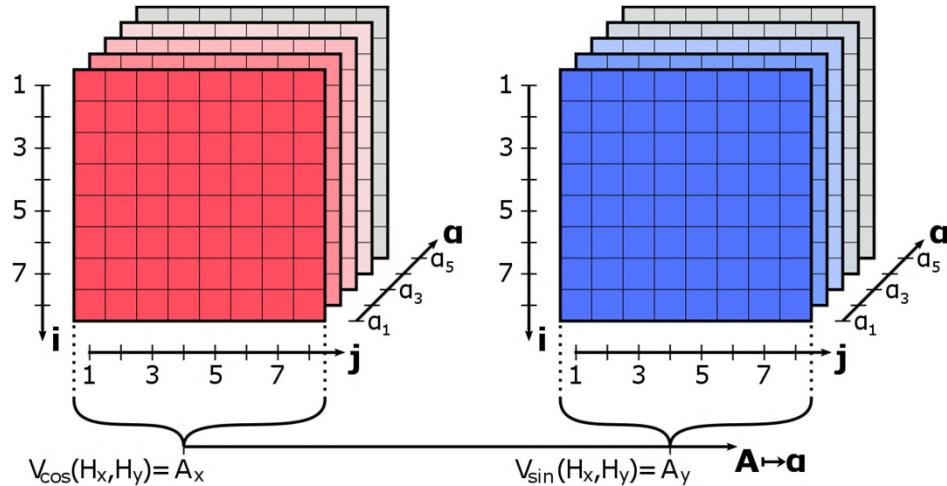
- Arrays als lange Vektoren
- Frobenius-Norm



Gauß-Prozesse

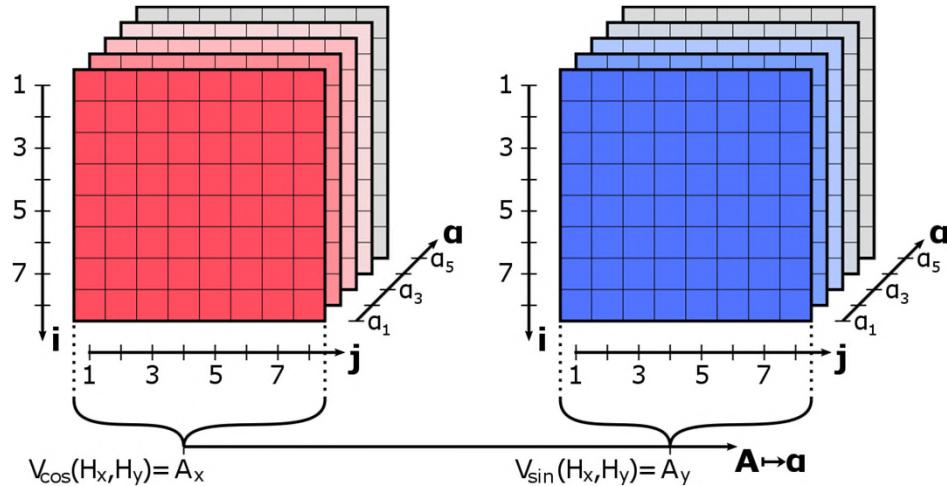


Gauß-Prozesse



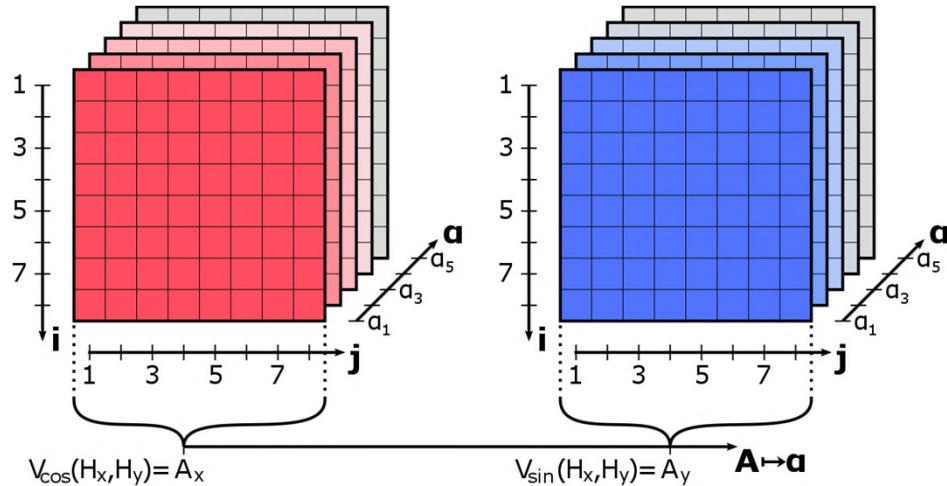
- Lernen über Trainingsdaten

Gauß-Prozesse



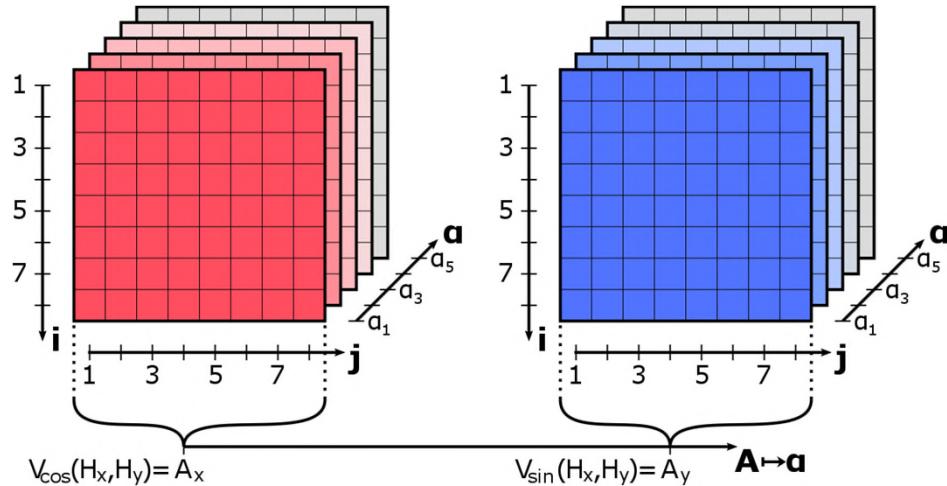
- Lernen über Trainingsdaten
- Anpassung über Testdaten
- Optimieren über Parameter

Gauß-Prozesse



- Lernen über Trainingsdaten
- Anpassung über Testdaten
- Optimieren über Parameter
- Vorhersage durch Stützwerte

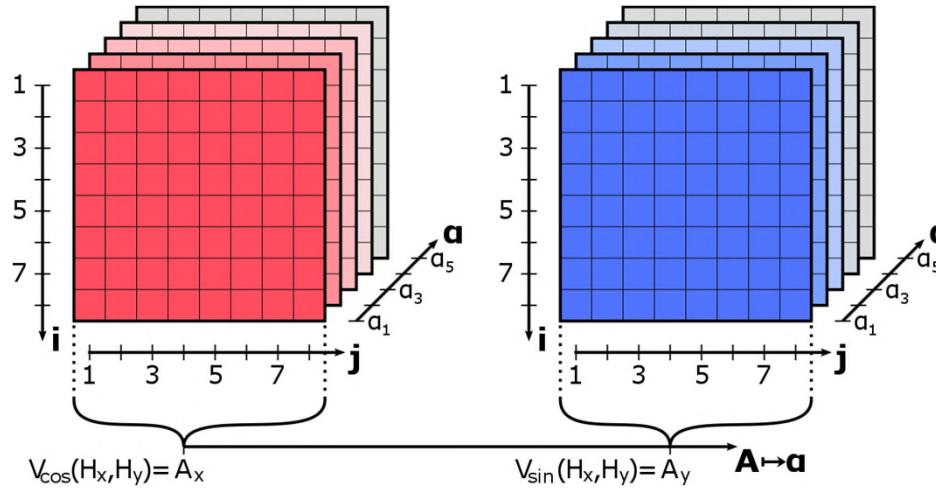
Gauß-Prozesse



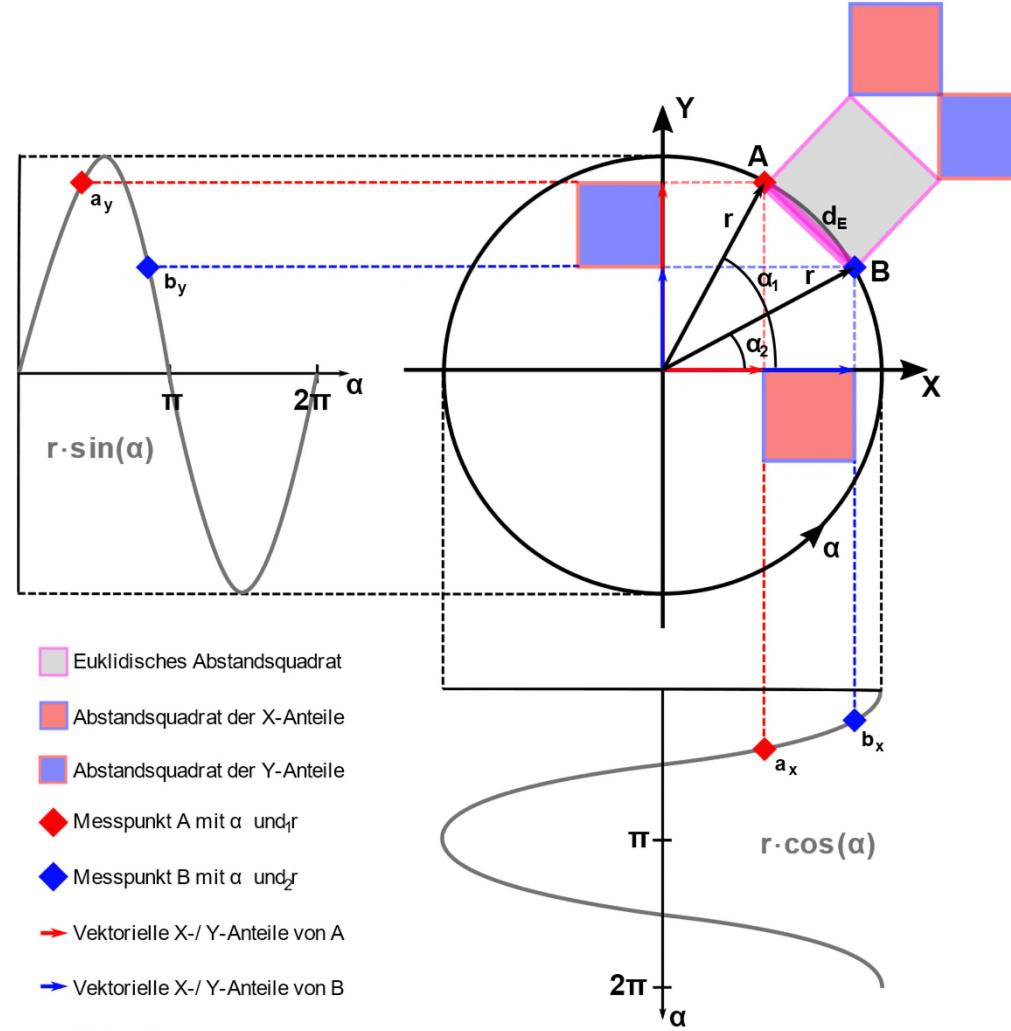
- Lernen über Trainingsdaten
- Anpassung über Testdaten
- Optimieren über Parameter
- Vorhersage durch Stützwerte

Kovarianzfunktion (Kernel) ist Verhaltensmaßgebend!

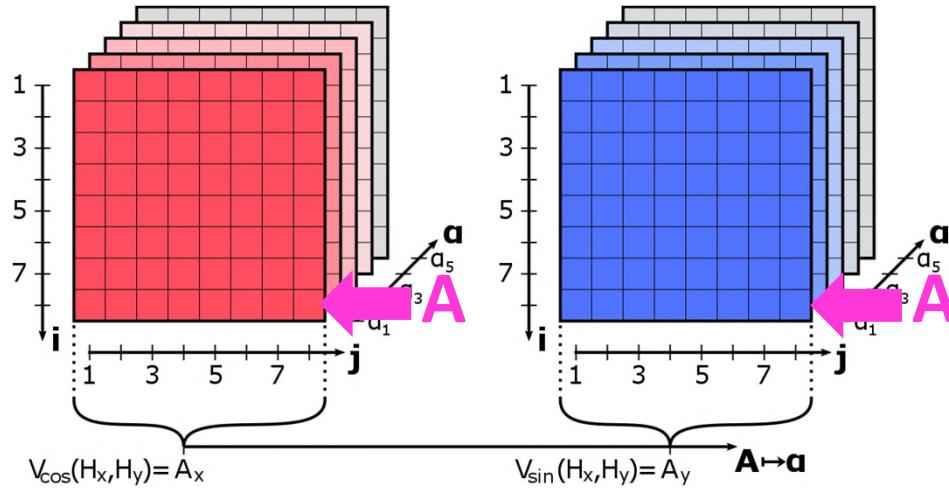
Gauß-Prozesse



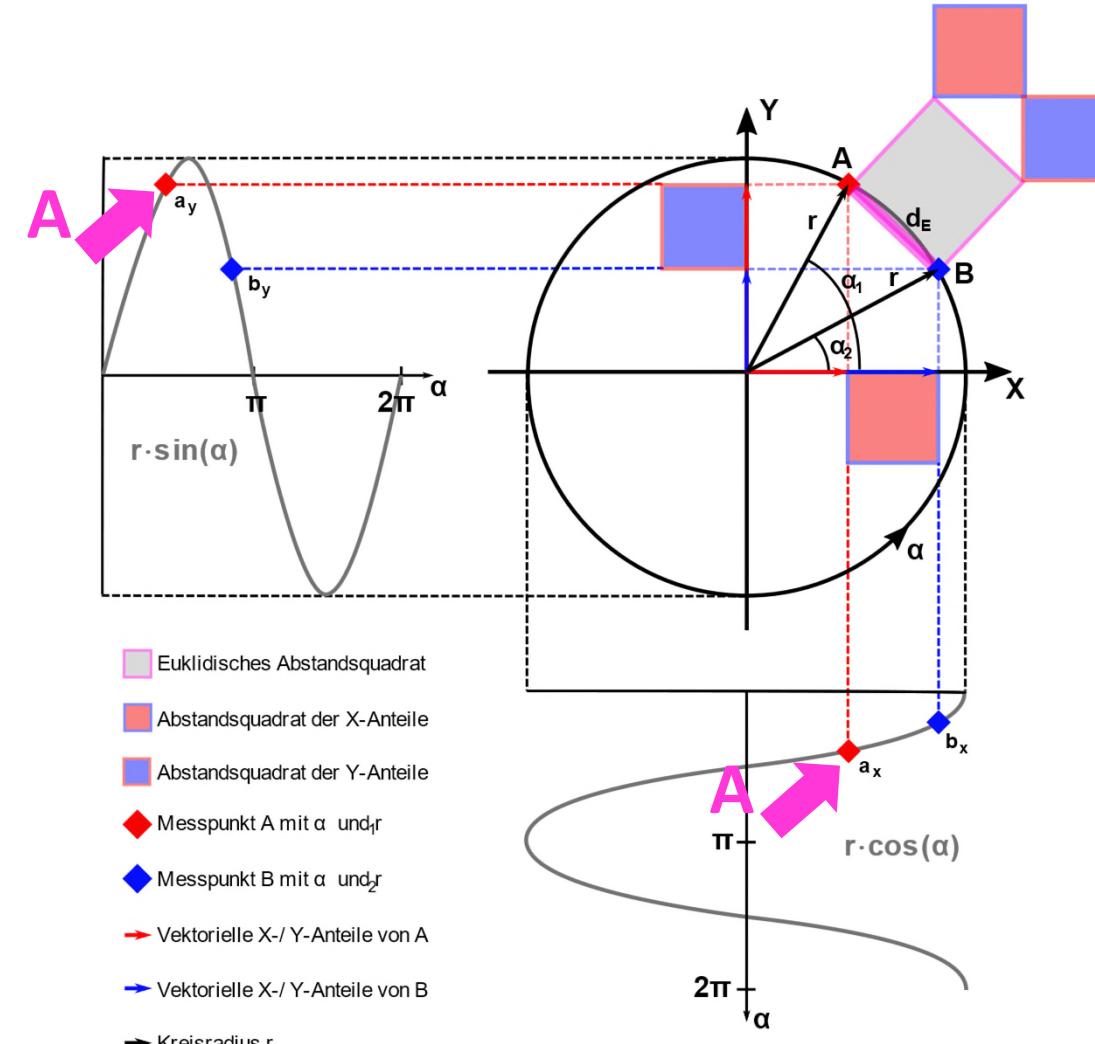
$$d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle$$



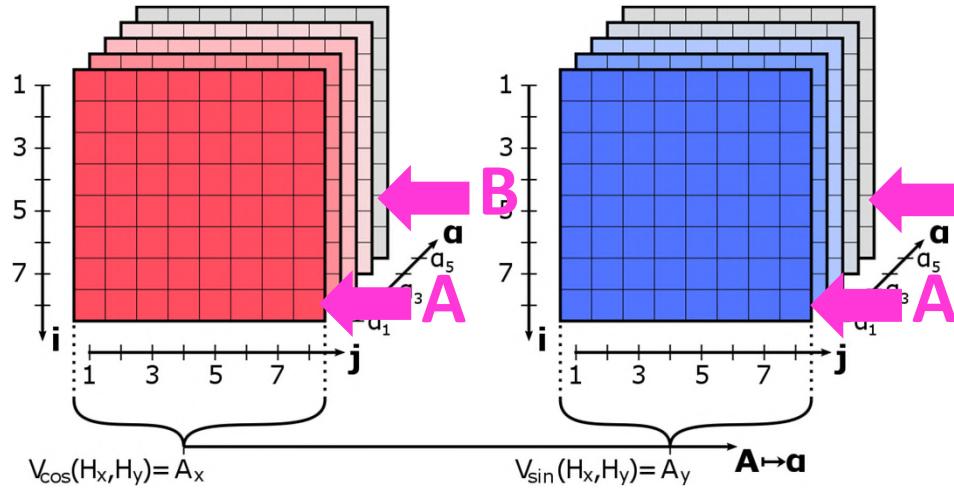
Gauß-Prozesse



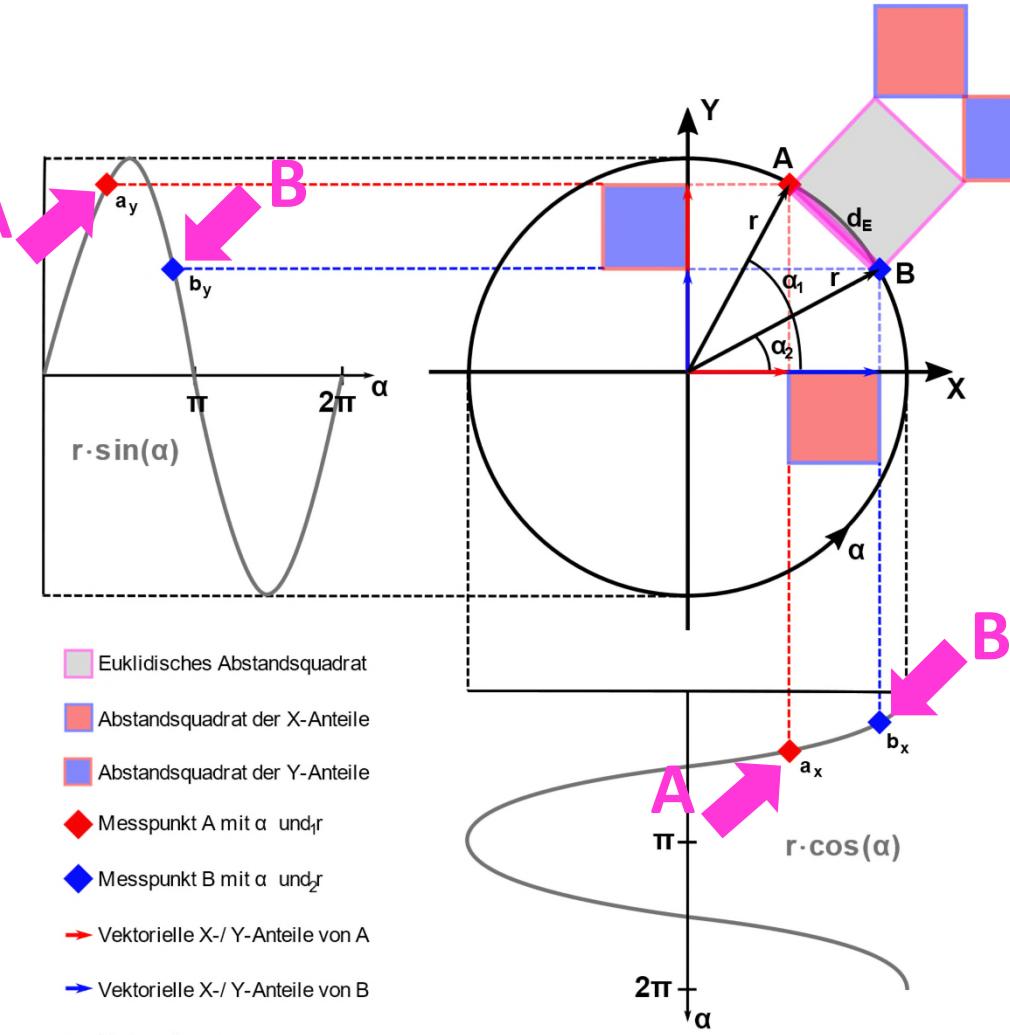
$$d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle$$



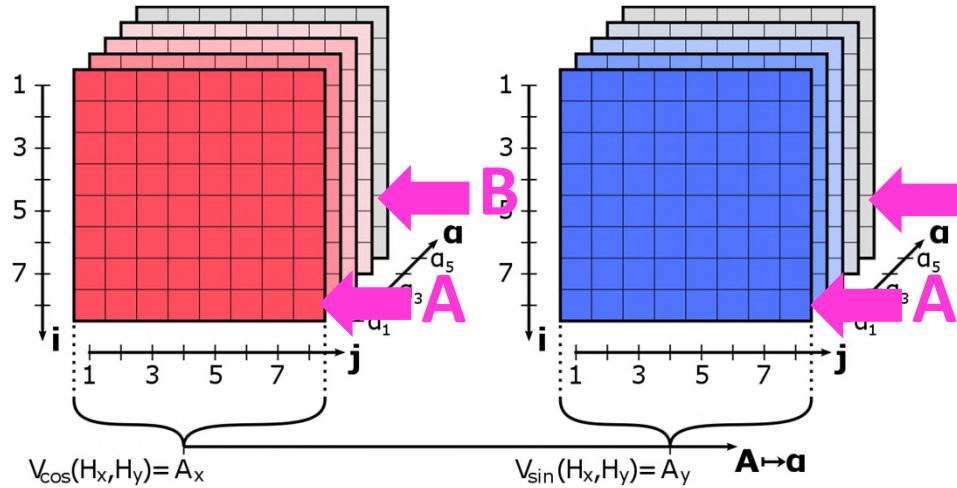
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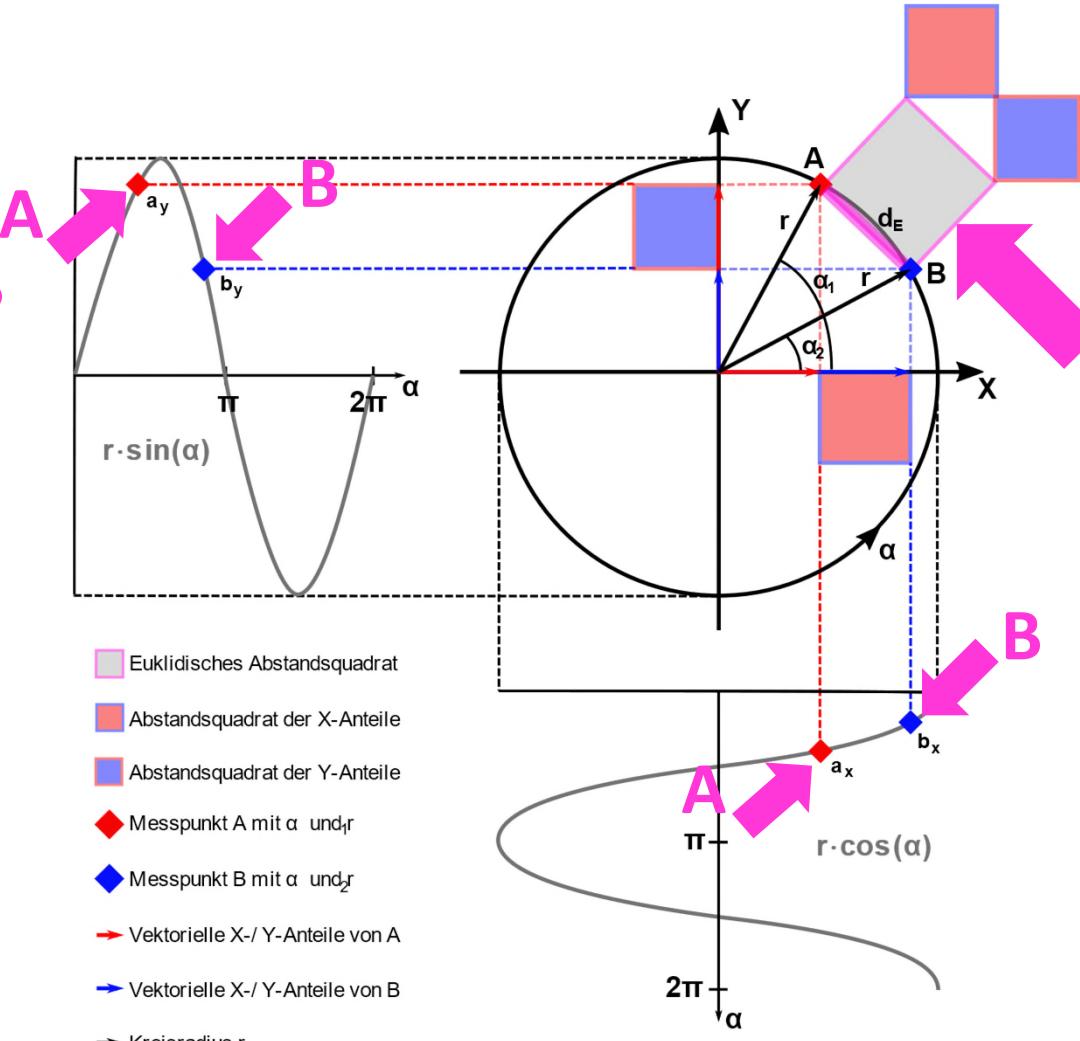
$$d_x^2 \langle A, B \rangle$$



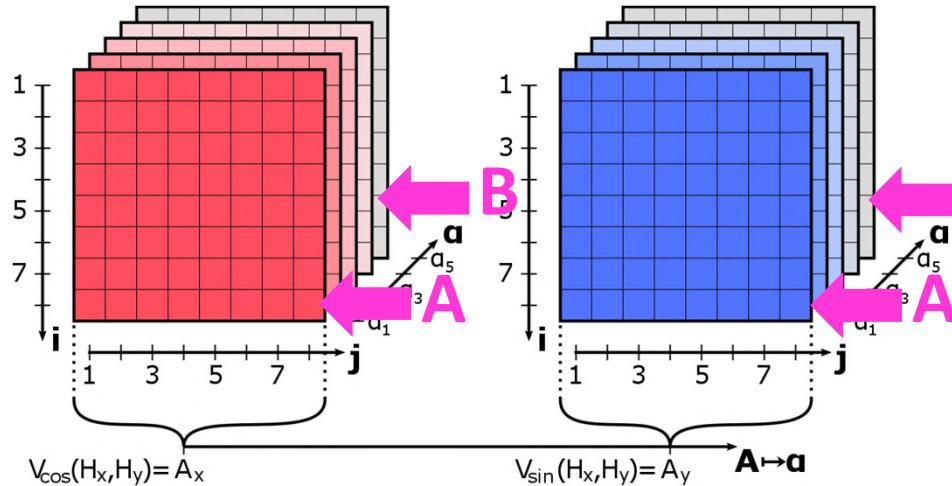
Gauß-Prozesse



$$d_x^2 \langle A, B \rangle$$

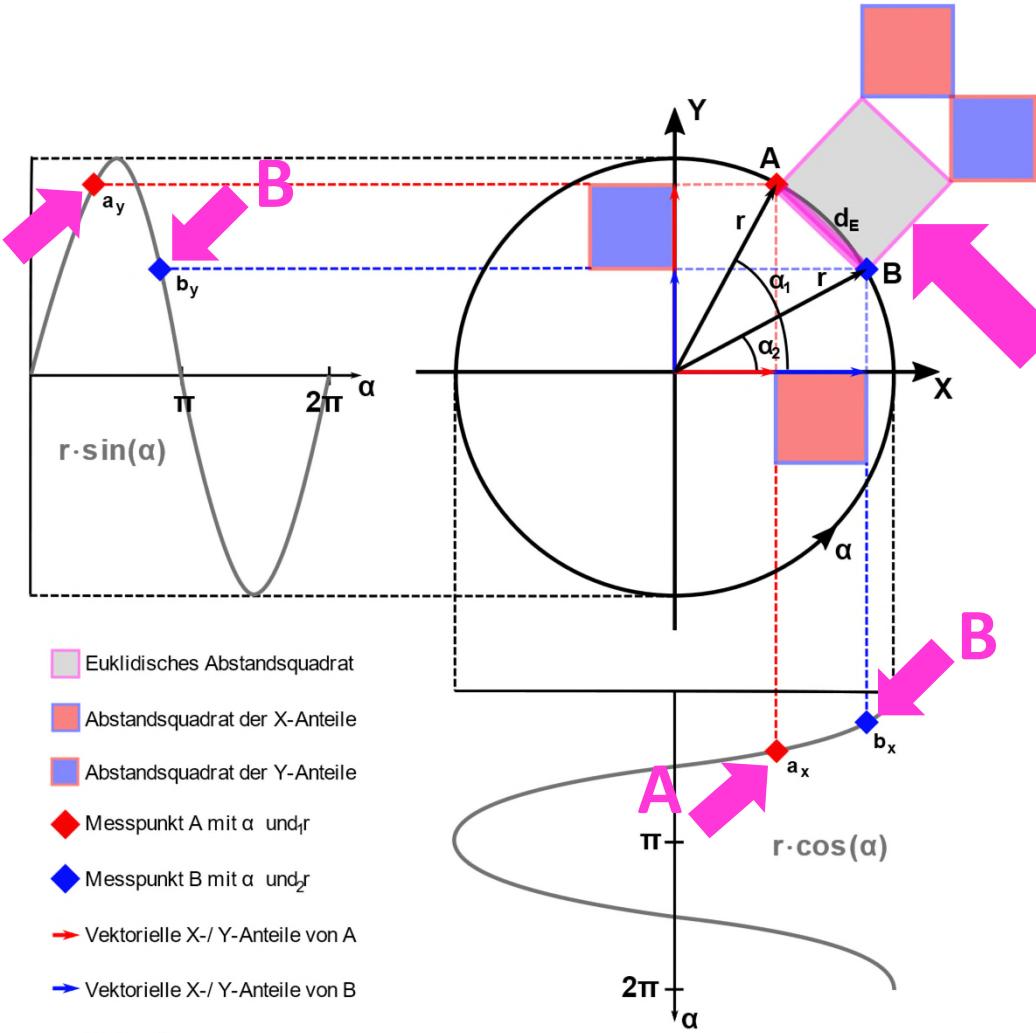


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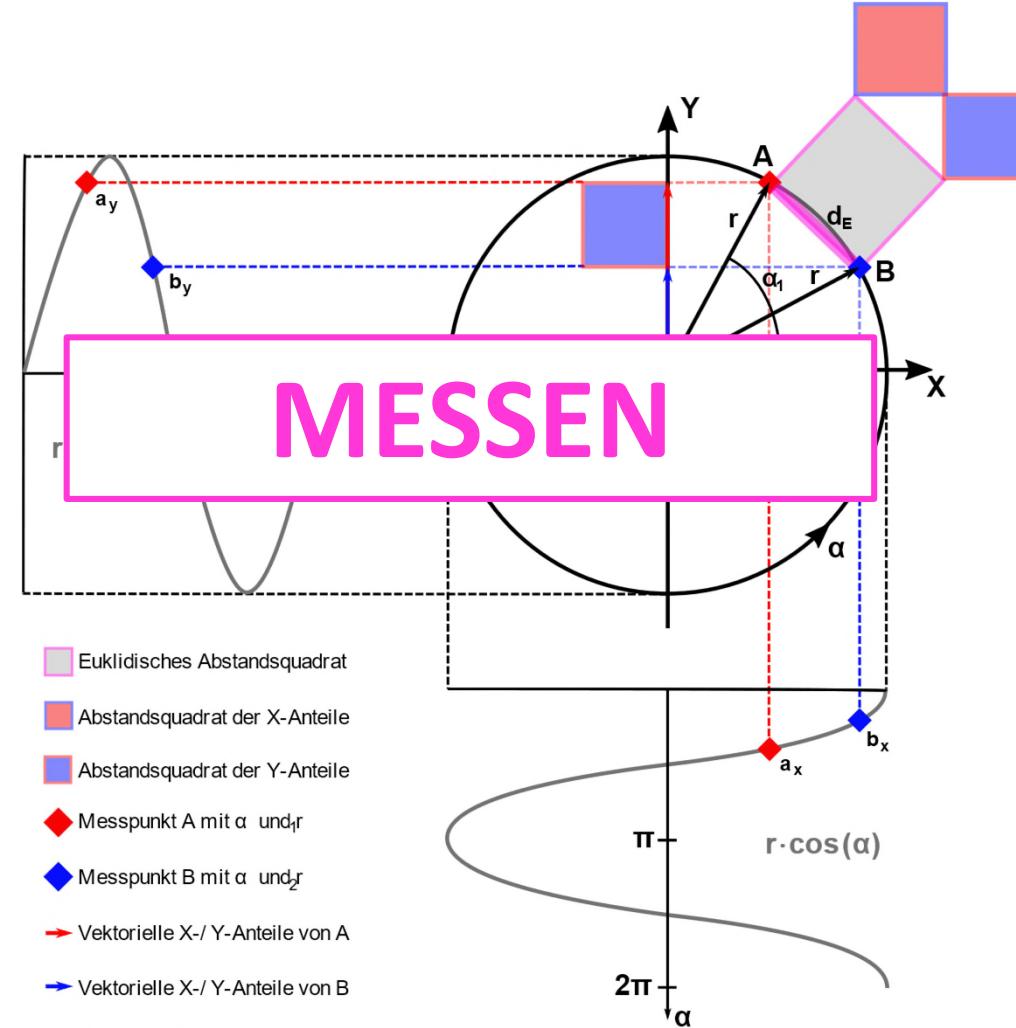
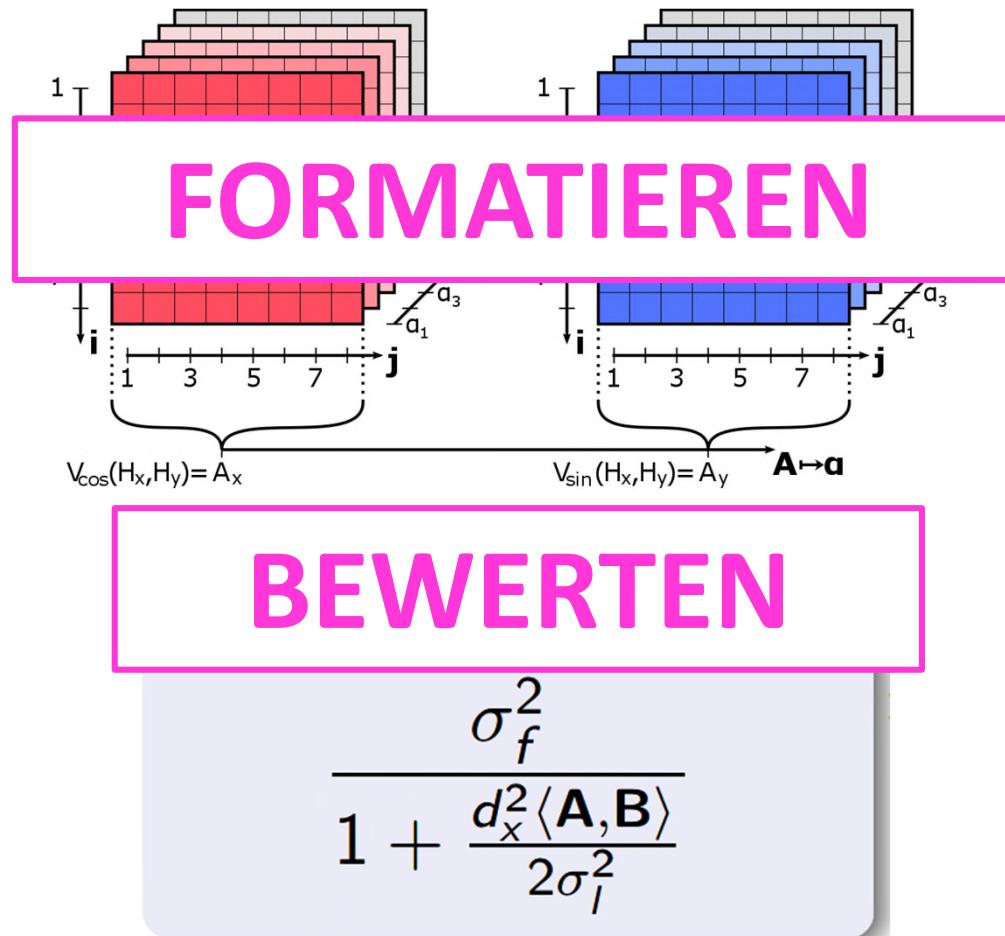


Fractional Kernel

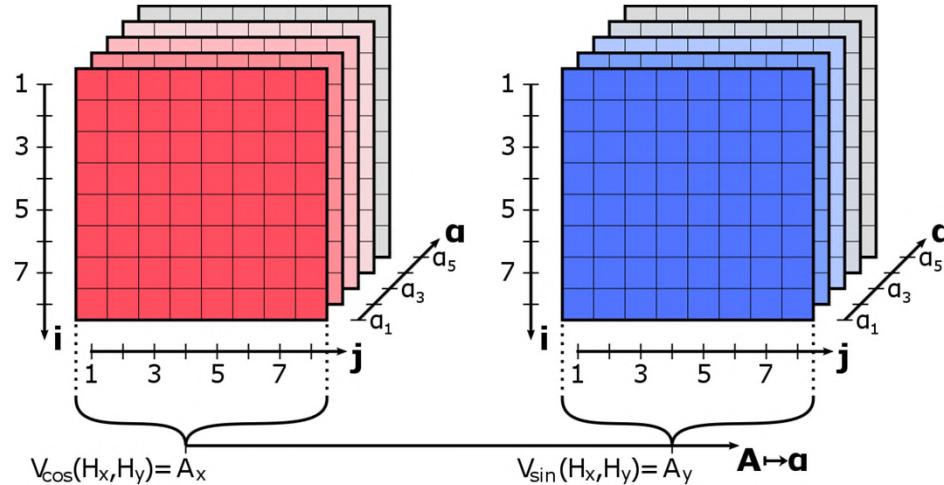
$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$



Gauß-Prozesse

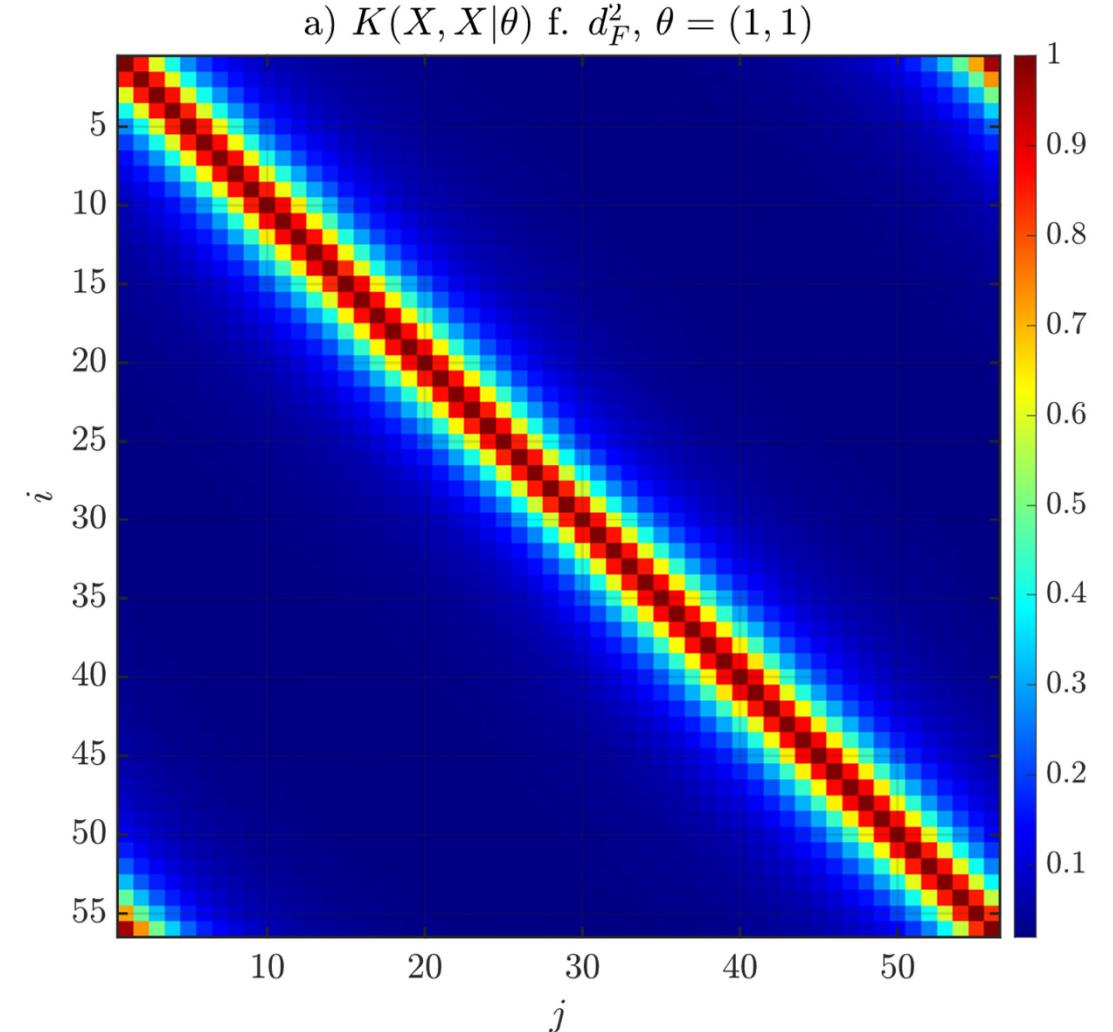


Gauß-Prozesse

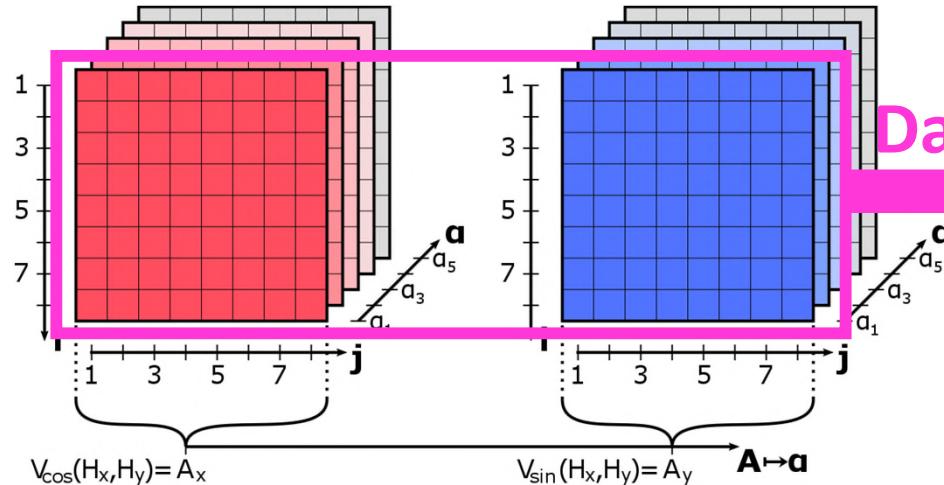


Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

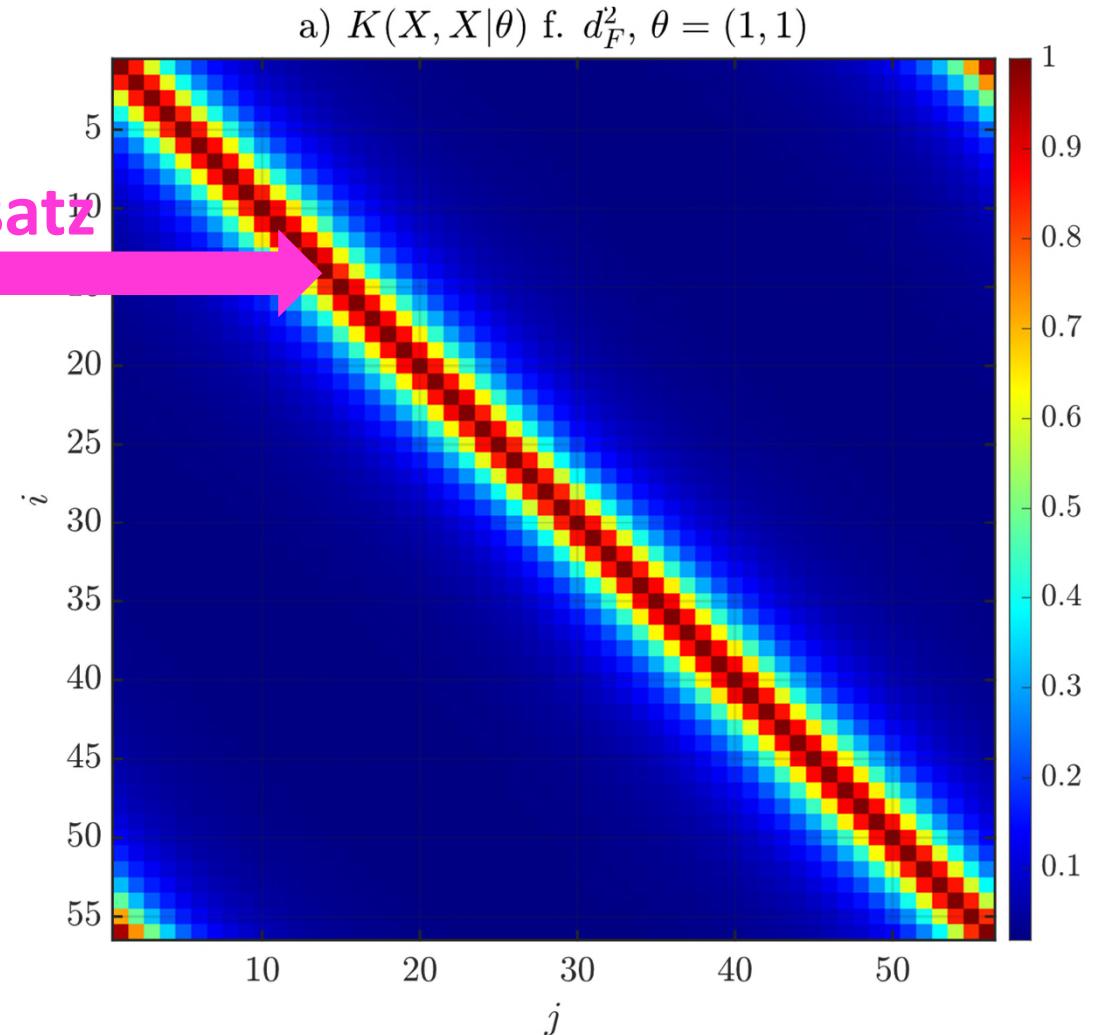


Gauß-Prozesse

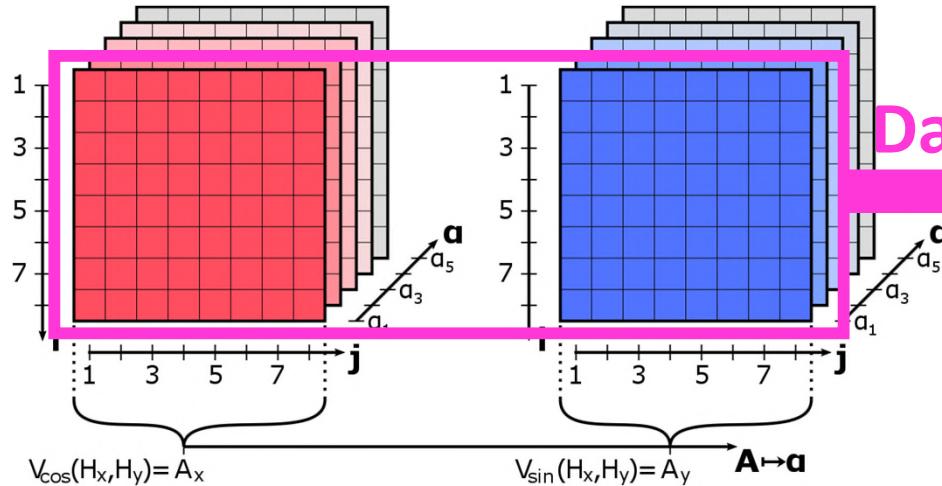


Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

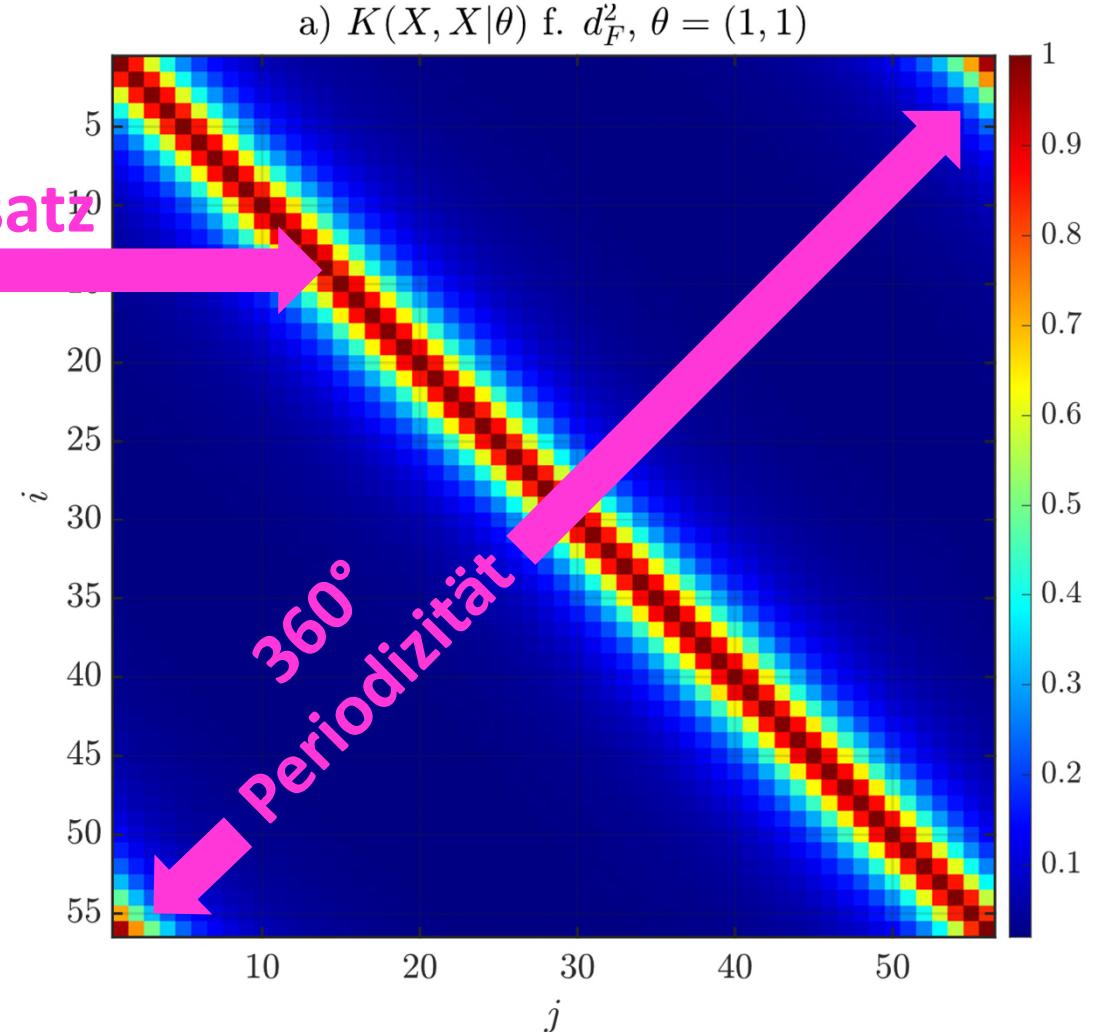


Gauß-Prozesse



Fractional Kernel

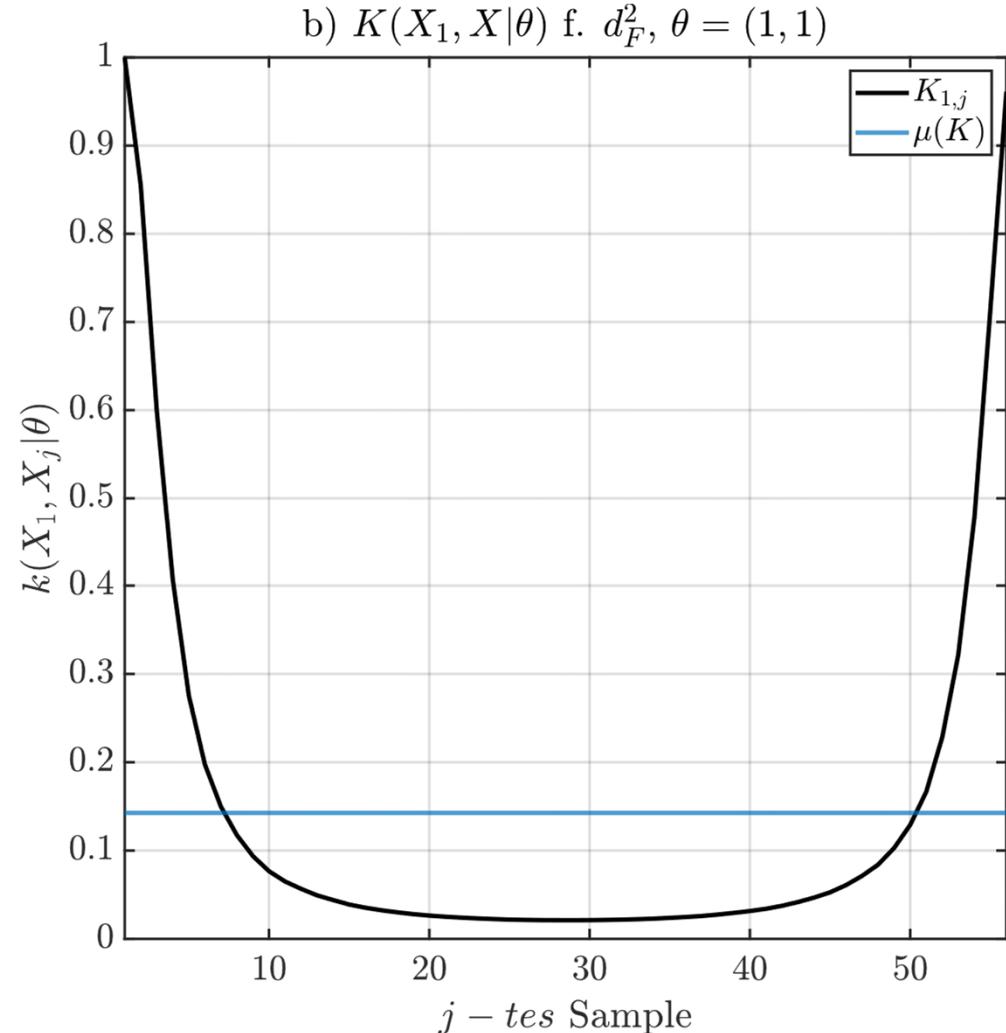
$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$



Gauß-Prozesse

Fractional Kernel

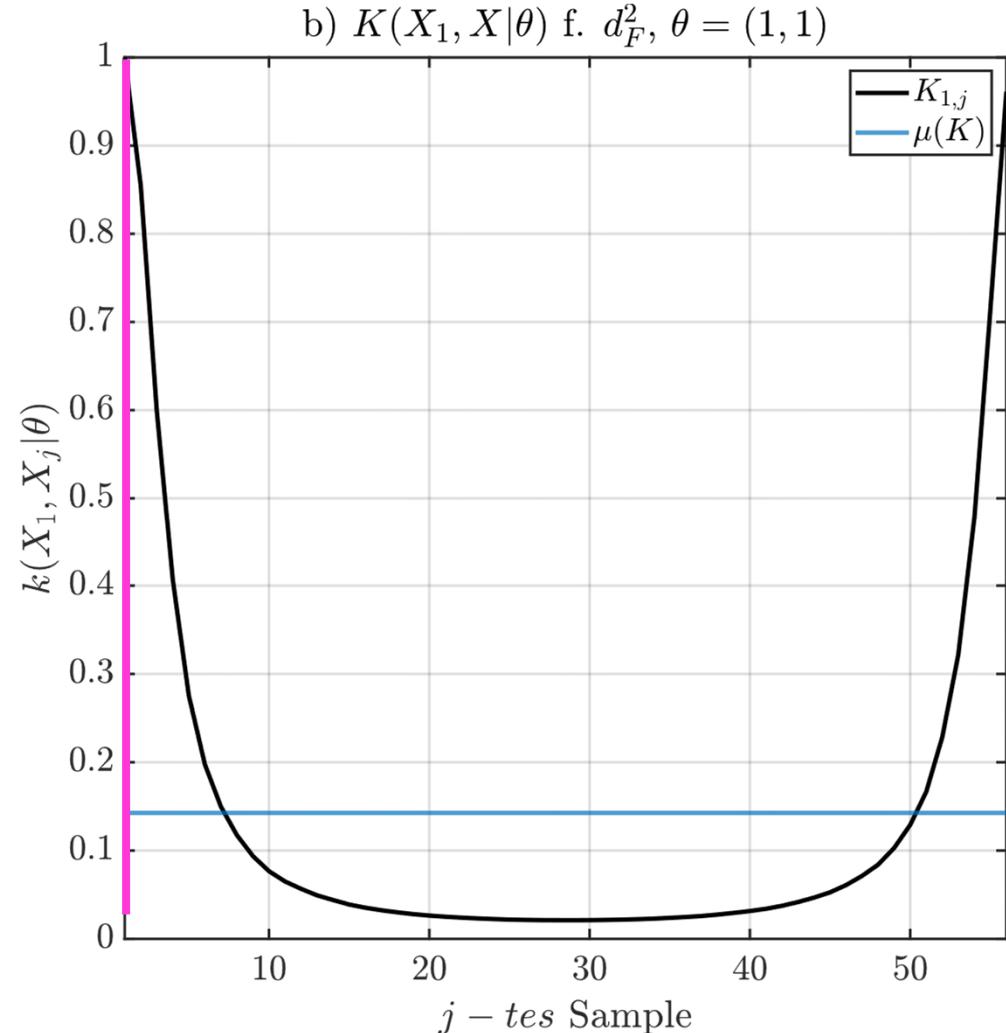
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Gauß-Prozesse

Fractional Kernel

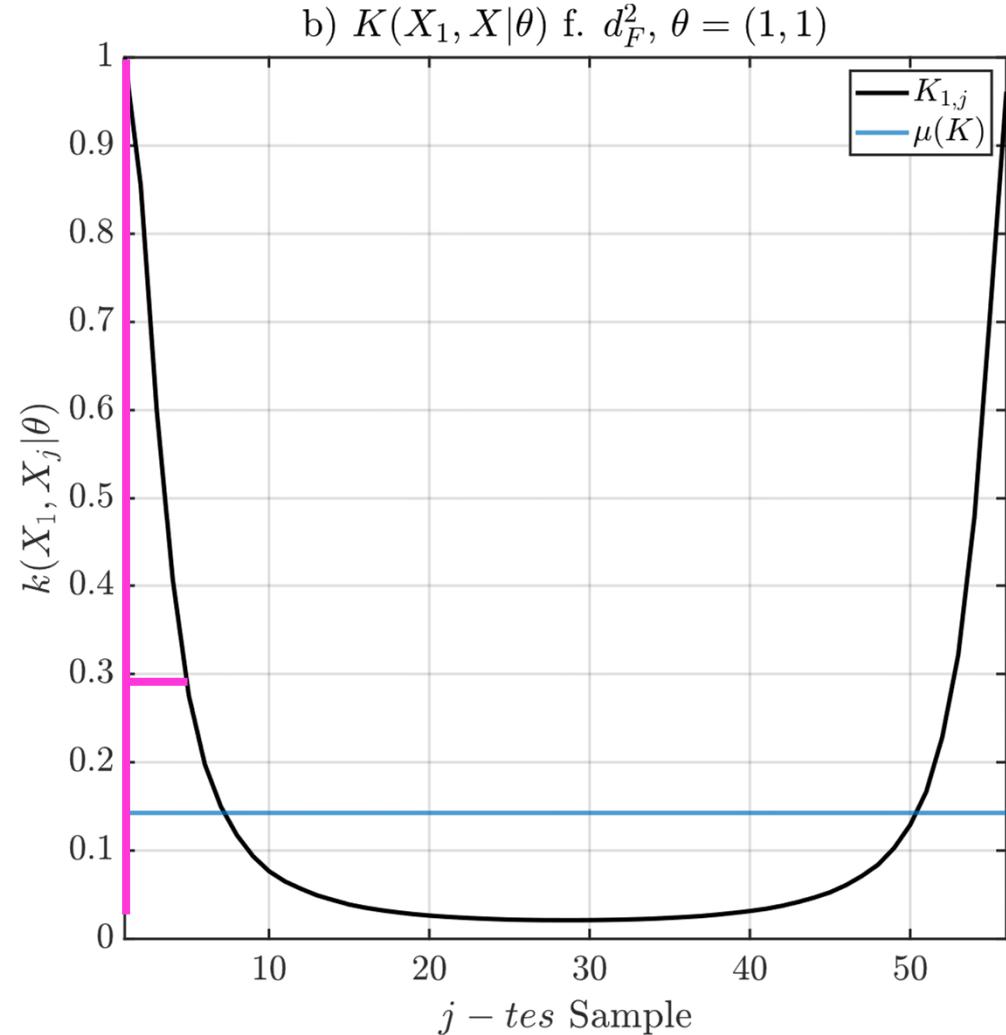
$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$



Gauß-Prozesse

Fractional Kernel

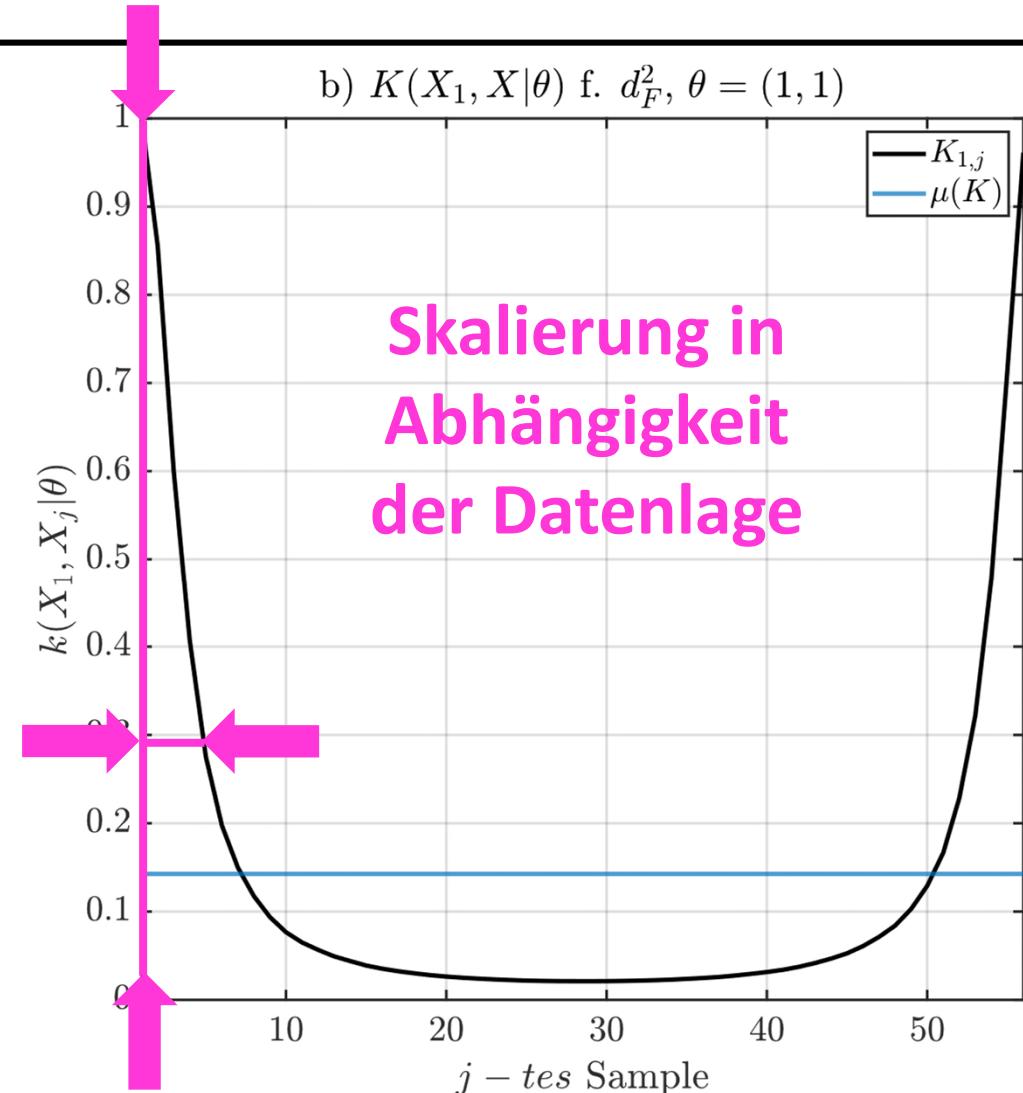
$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$



Gauß-Prozesse

Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

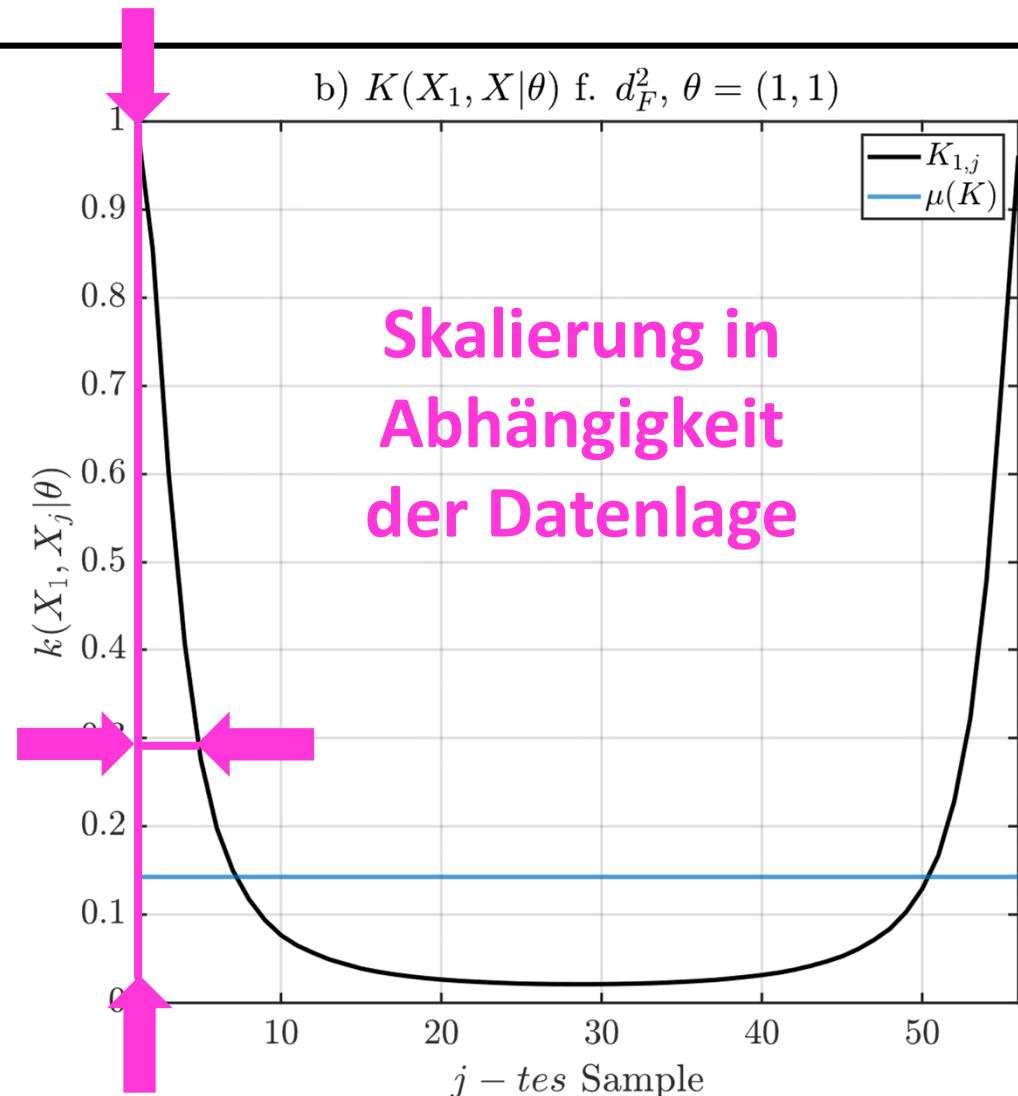


Gauß-Prozesse

- Kontrolle über Einflussnahme

Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

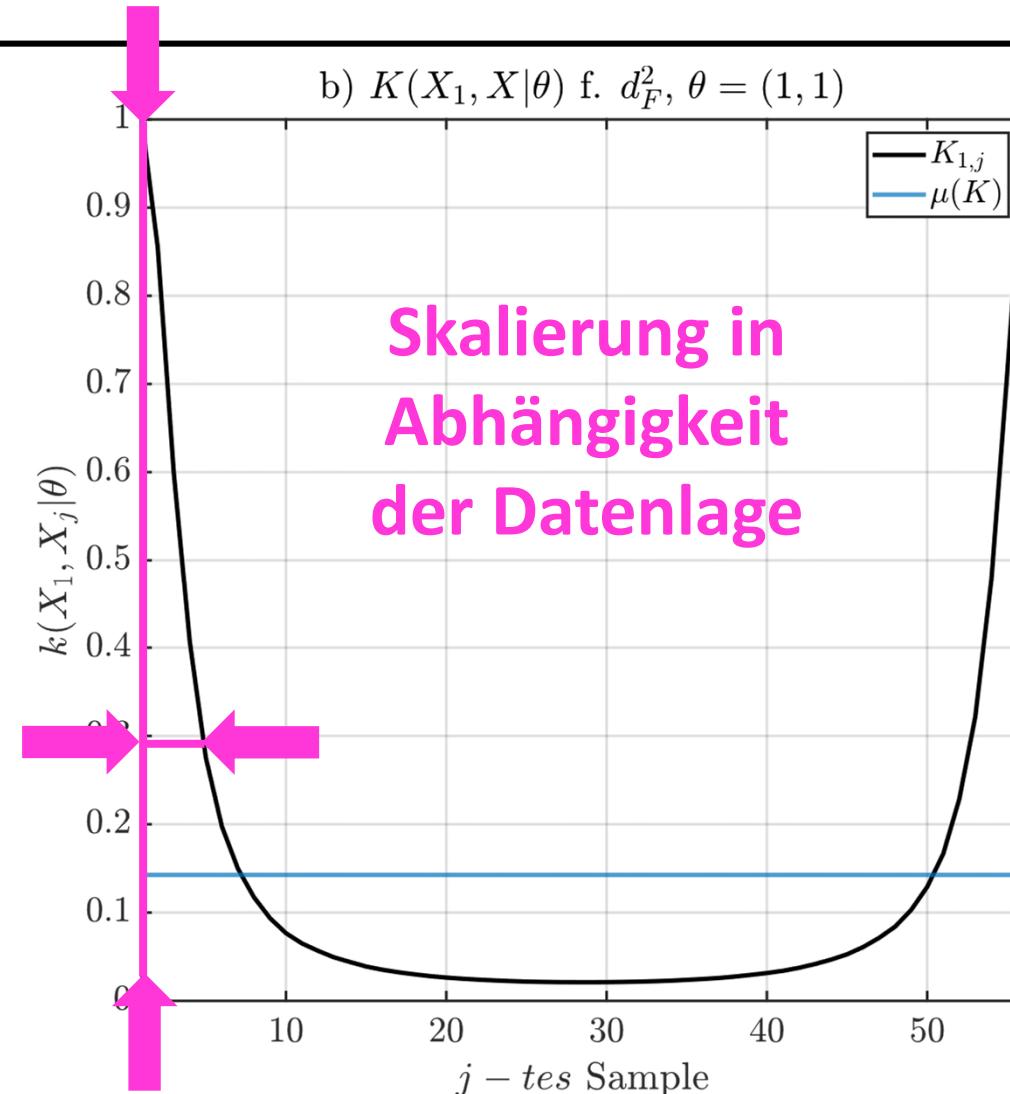


Gauß-Prozesse

- Kontrolle über Einflussnahme
- Datenfit über Plausibilitäten

Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

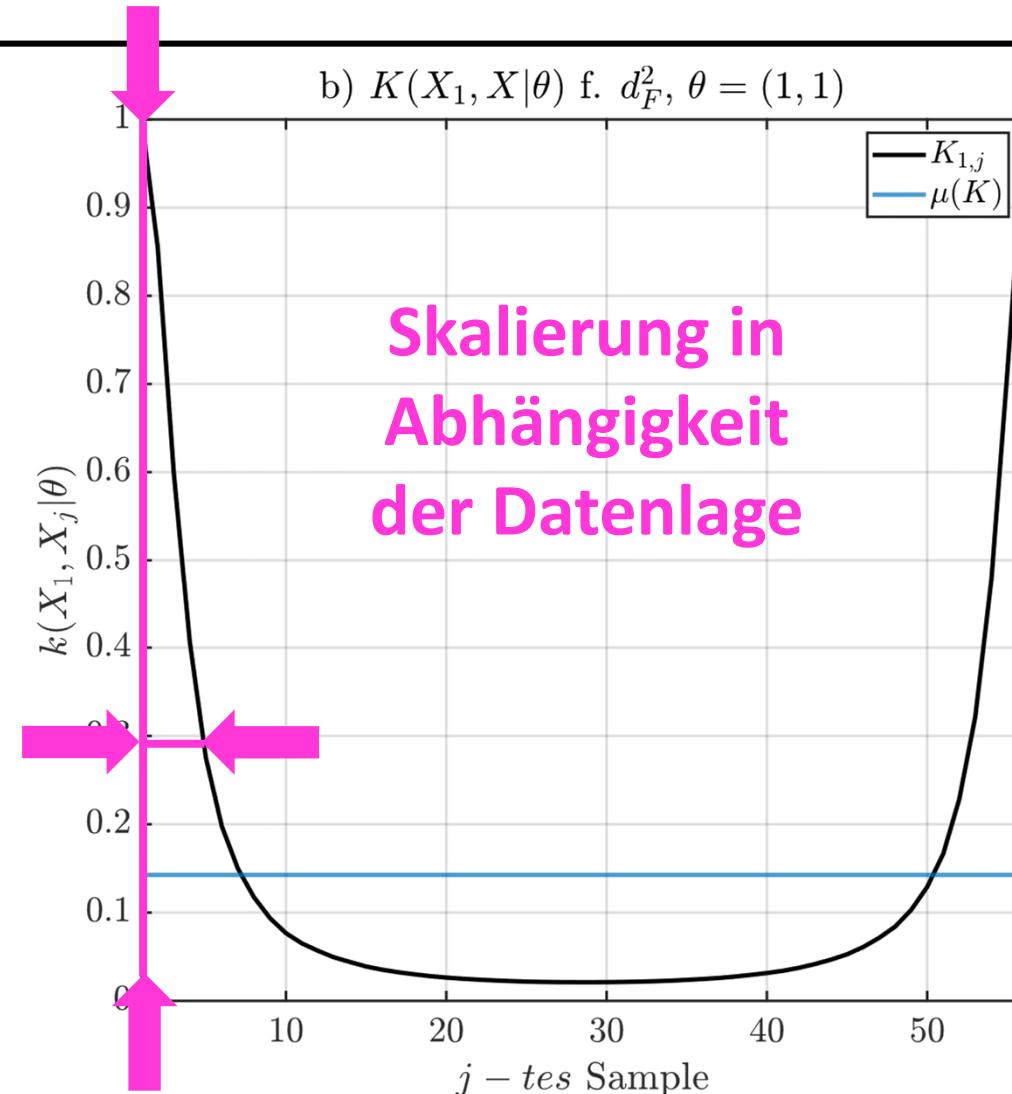


Gauß-Prozesse

- Kontrolle über Einflussnahme
- Datenfit über Plausibilitäten
- Modellgeneralisierung über Verluste

Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

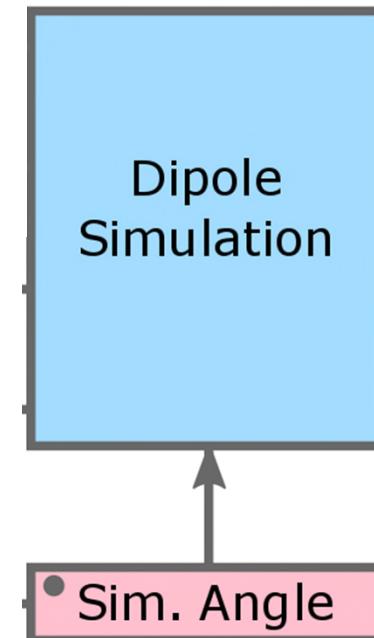


Software-Aufbau



Software-Aufbau

Sensor Array
Generate Data

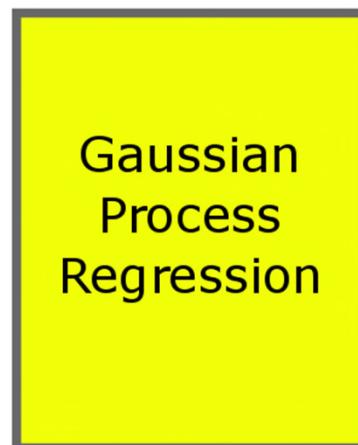


Physical
Simulation

Software-Aufbau

ASIC Model

Analyze Data

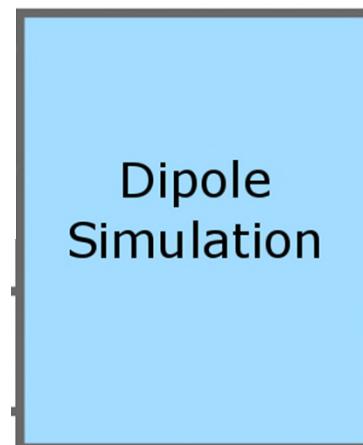


Pred. Angle

Mathematical Simulation

Sensor Array

Generate Data



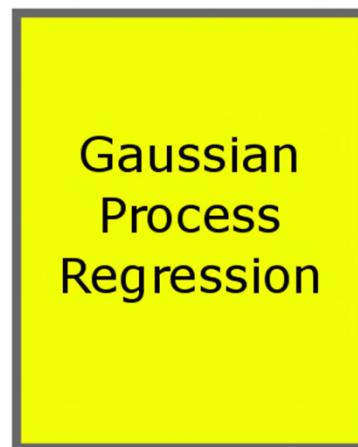
Sim. Angle

Physical Simulation

Software-Aufbau

ASIC Model

Analyze Data

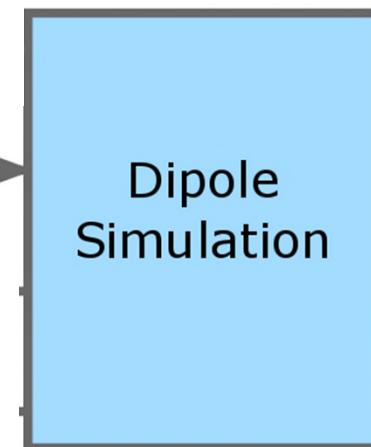


Pred. Angle

Mathematical Simulation

Sensor Array

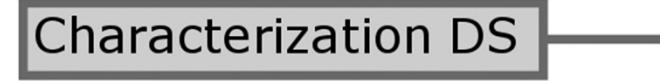
Generate Data



Sim. Angle

Physical Simulation

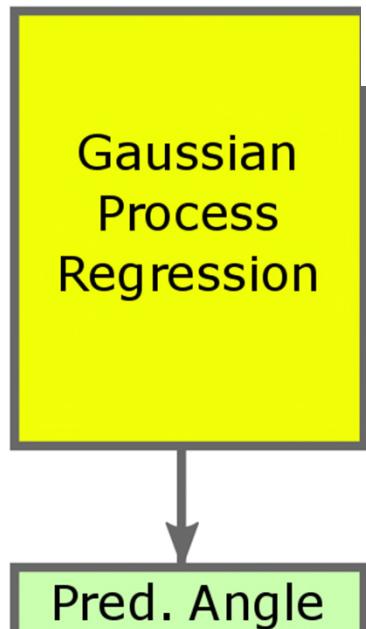
Characterization DS



Software-Aufbau

ASIC Model

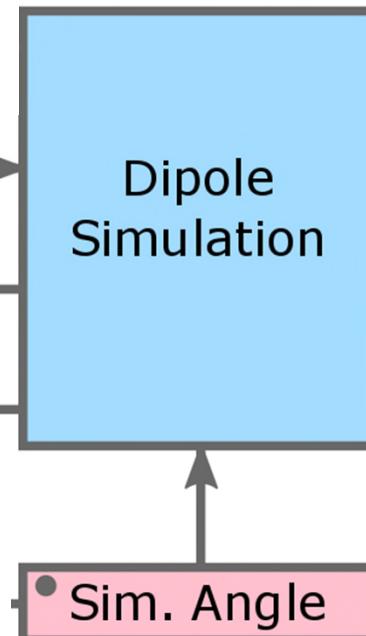
Analyze Data



Mathematical
Simulation

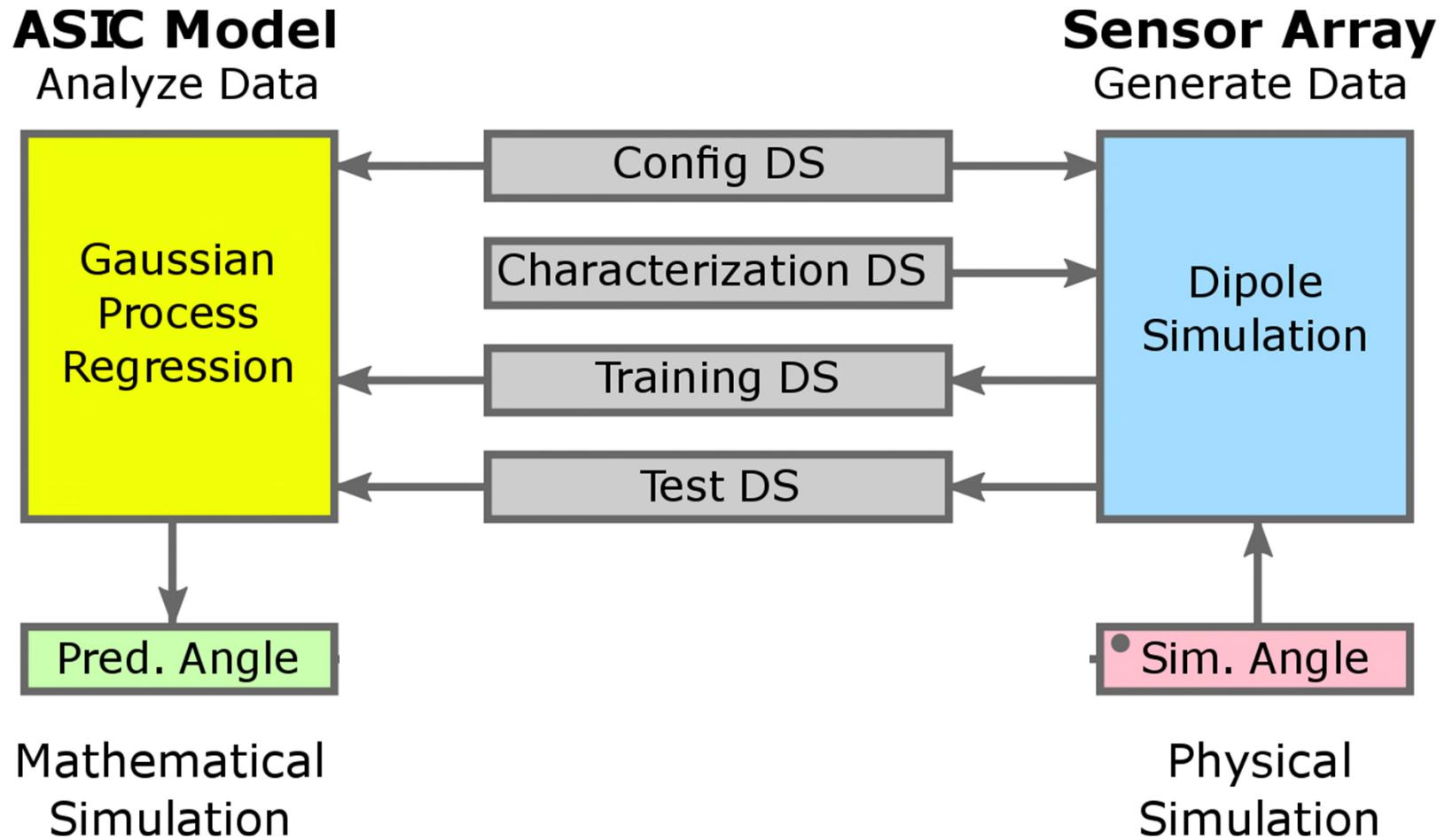
Sensor Array

Generate Data

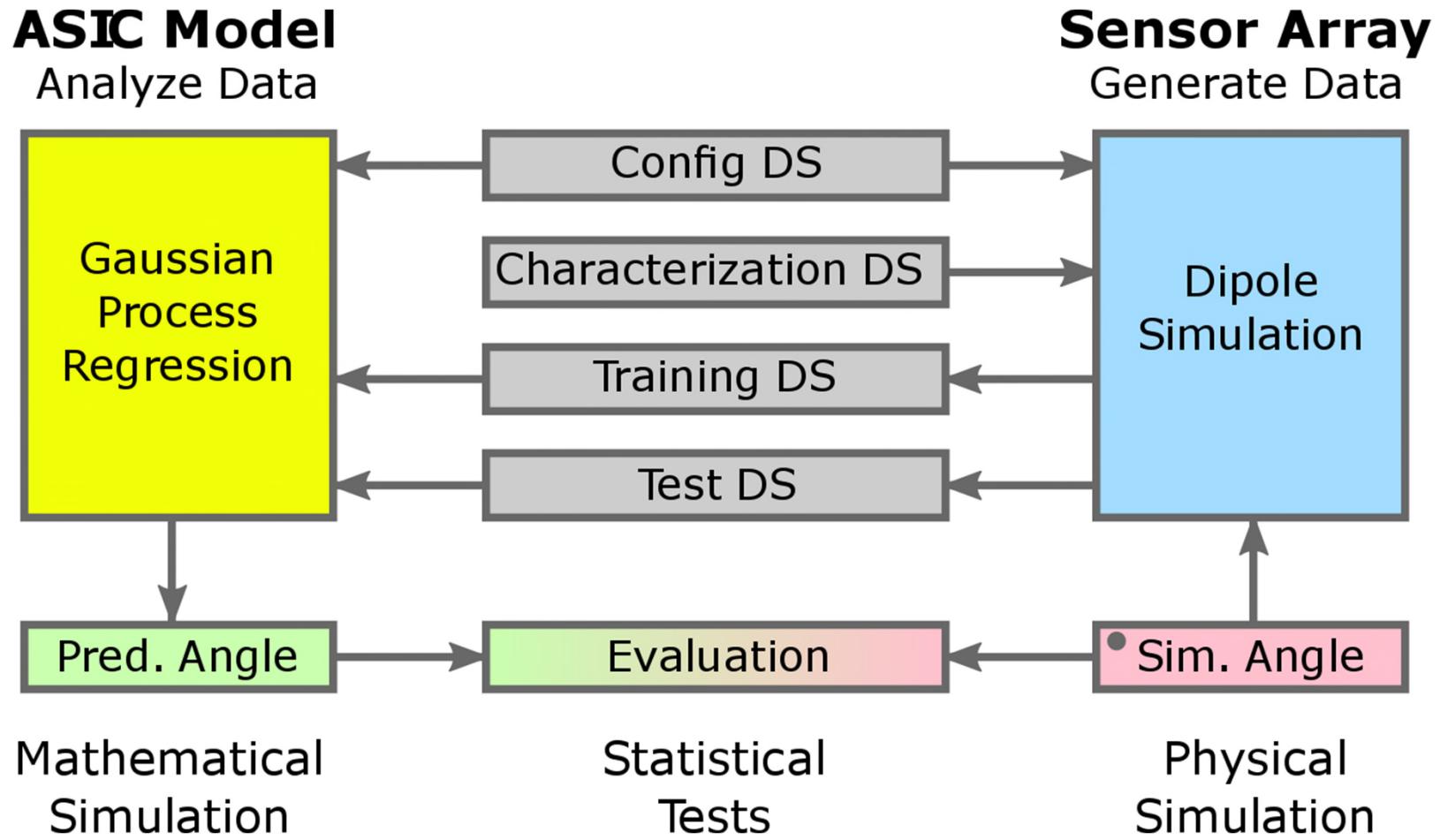


Physical
Simulation

Software-Aufbau

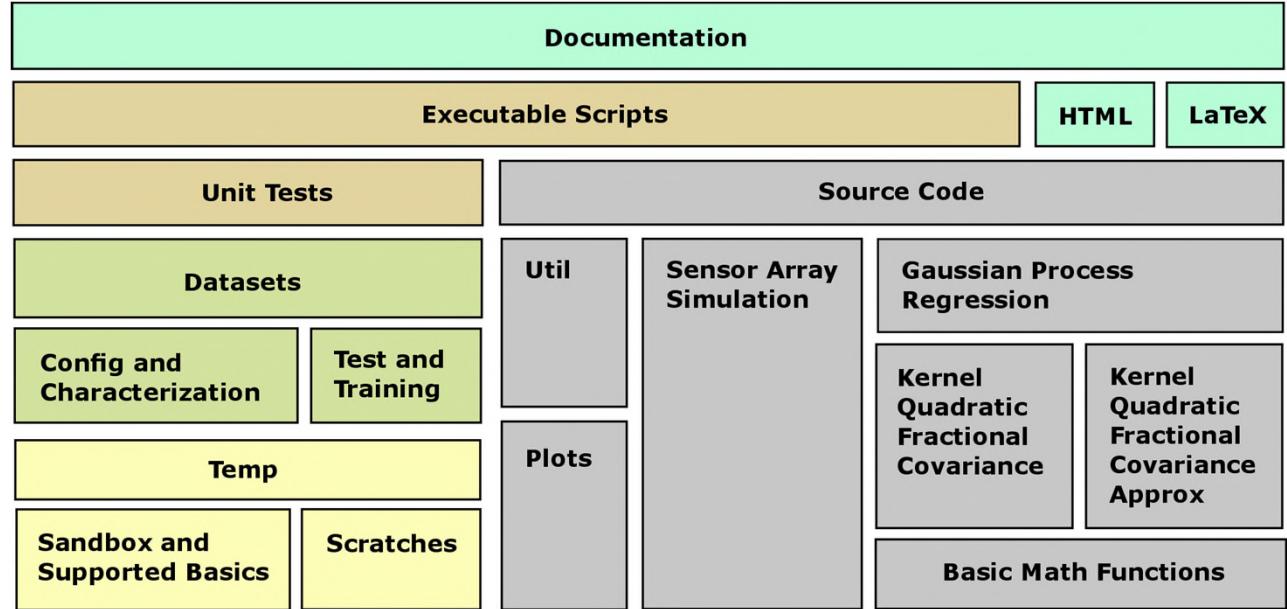


Software-Aufbau



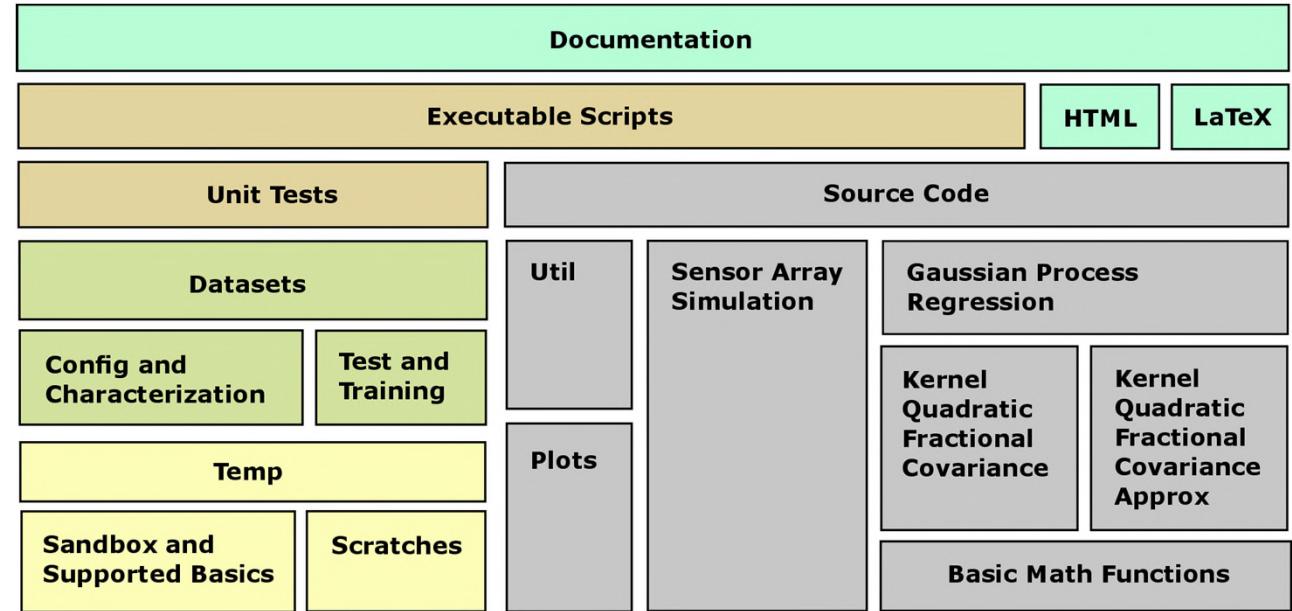
Software-Aufbau

- Modularer Aufbau



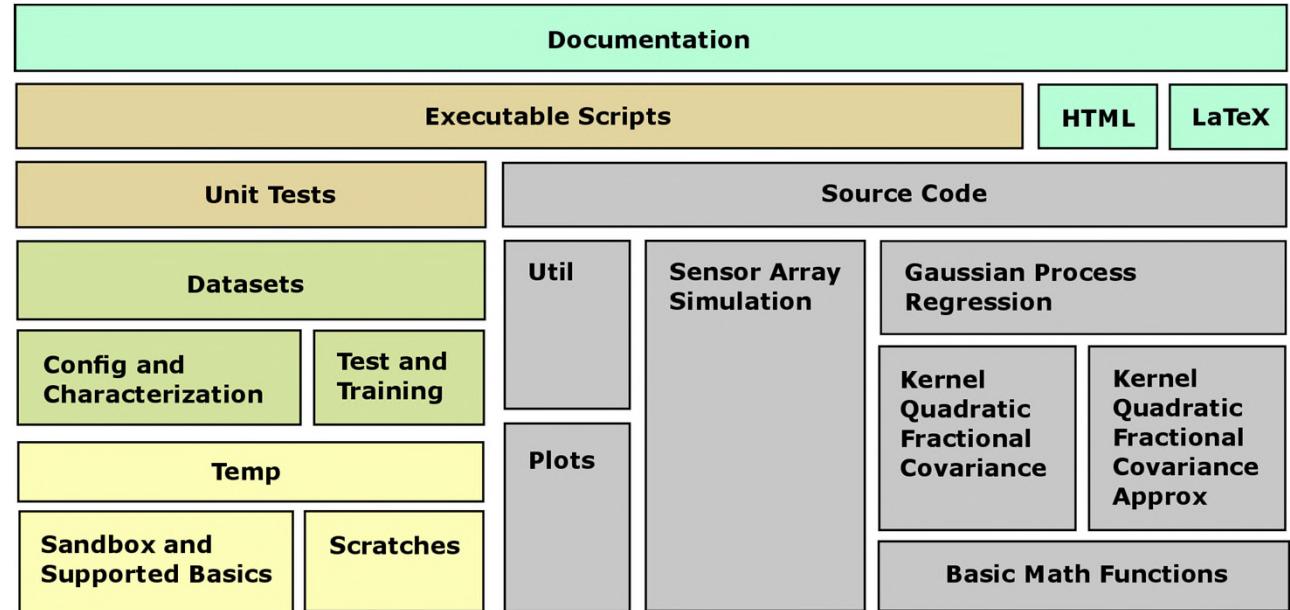
Software-Aufbau

- Modularer Aufbau
- Wiederverwendbarkeit
- Erweiterbarkeit

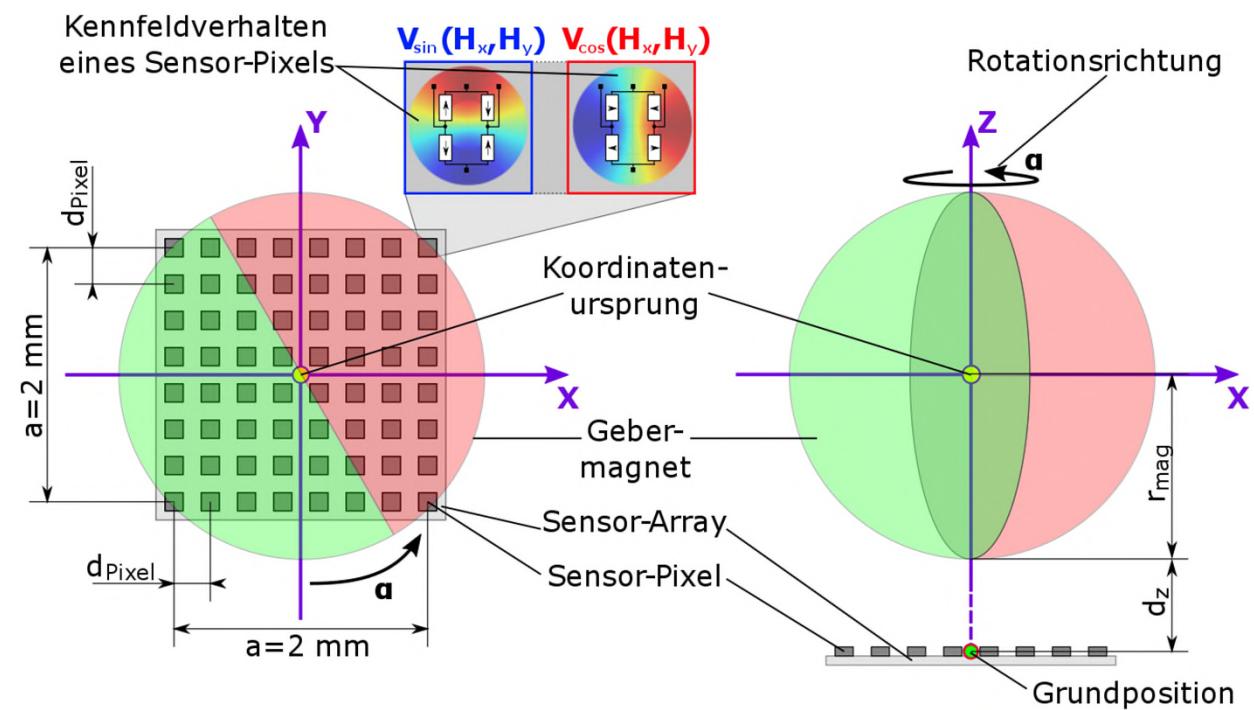


Software-Aufbau

- Modularer Aufbau
- Wiederverwendbarkeit
- Erweiterbarkeit
- Integration
- Dokumentation

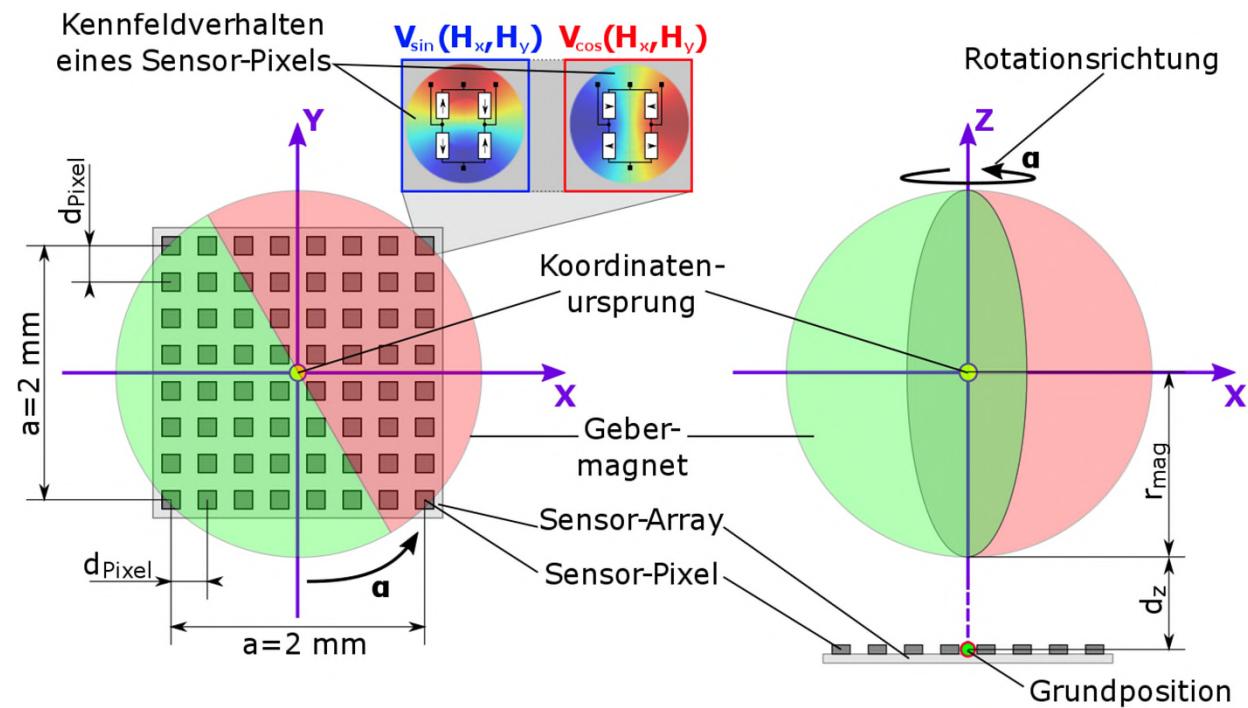


Simulation – Sensor-Array



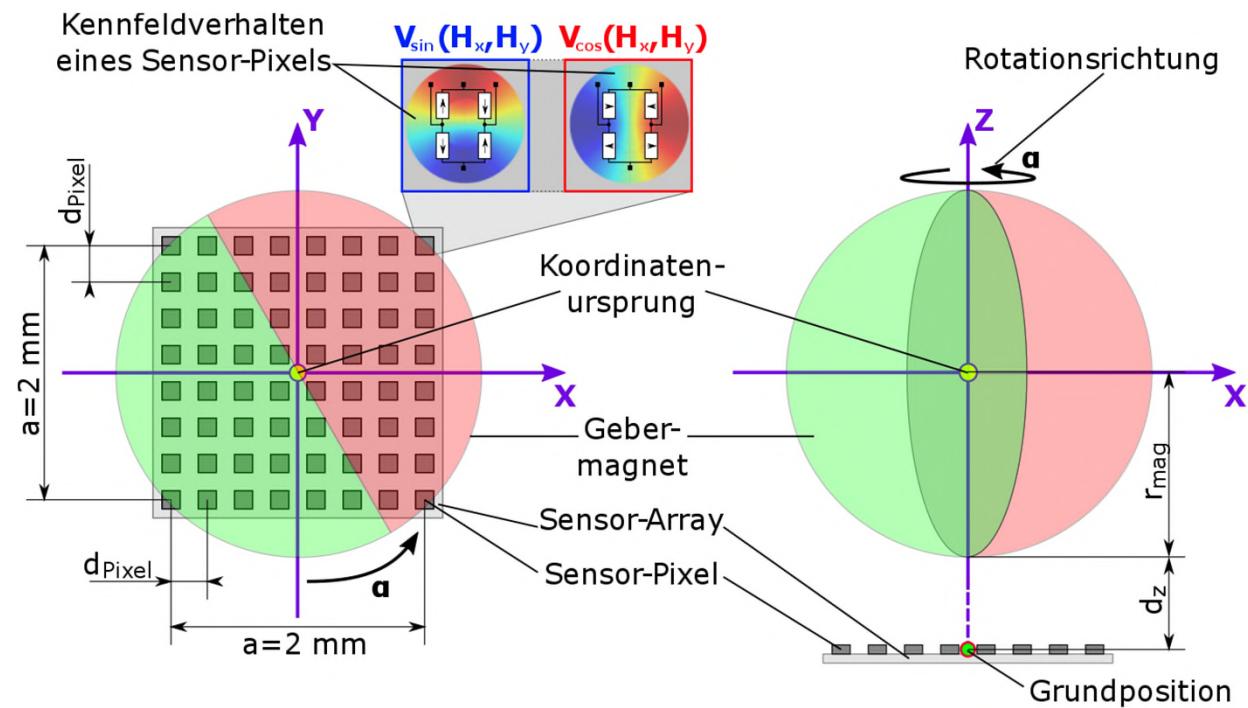
Simulation – Sensor-Array

- Konfiguration von Abmaße,
Position, Anordnung und
Spannungsversorgung

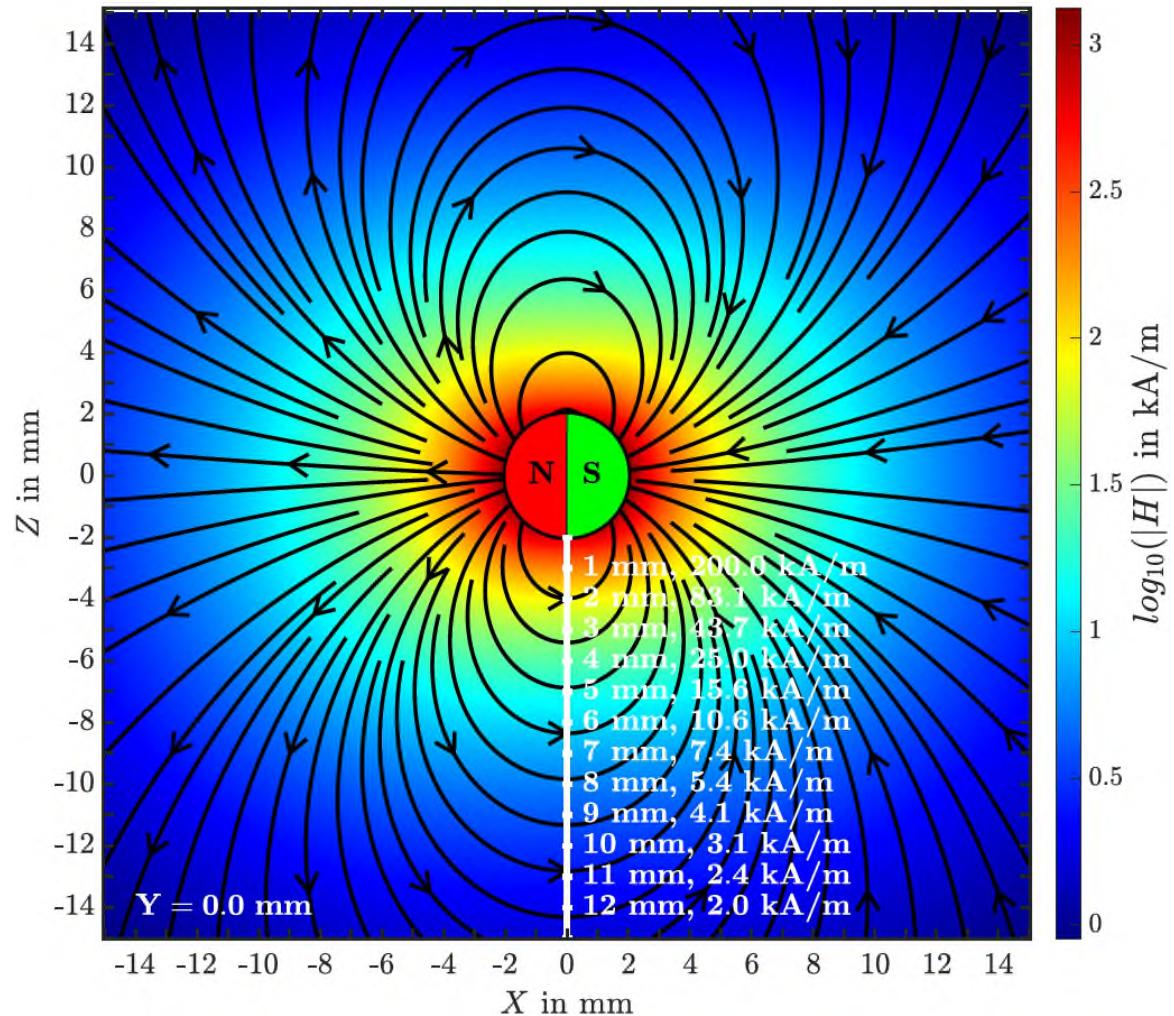


Simulation – Sensor-Array

- Konfiguration von Abmaße,
Position, Anordnung und
Spannungsversorgung
- Festlegen des Startpunktes
bzw. Ruhelage

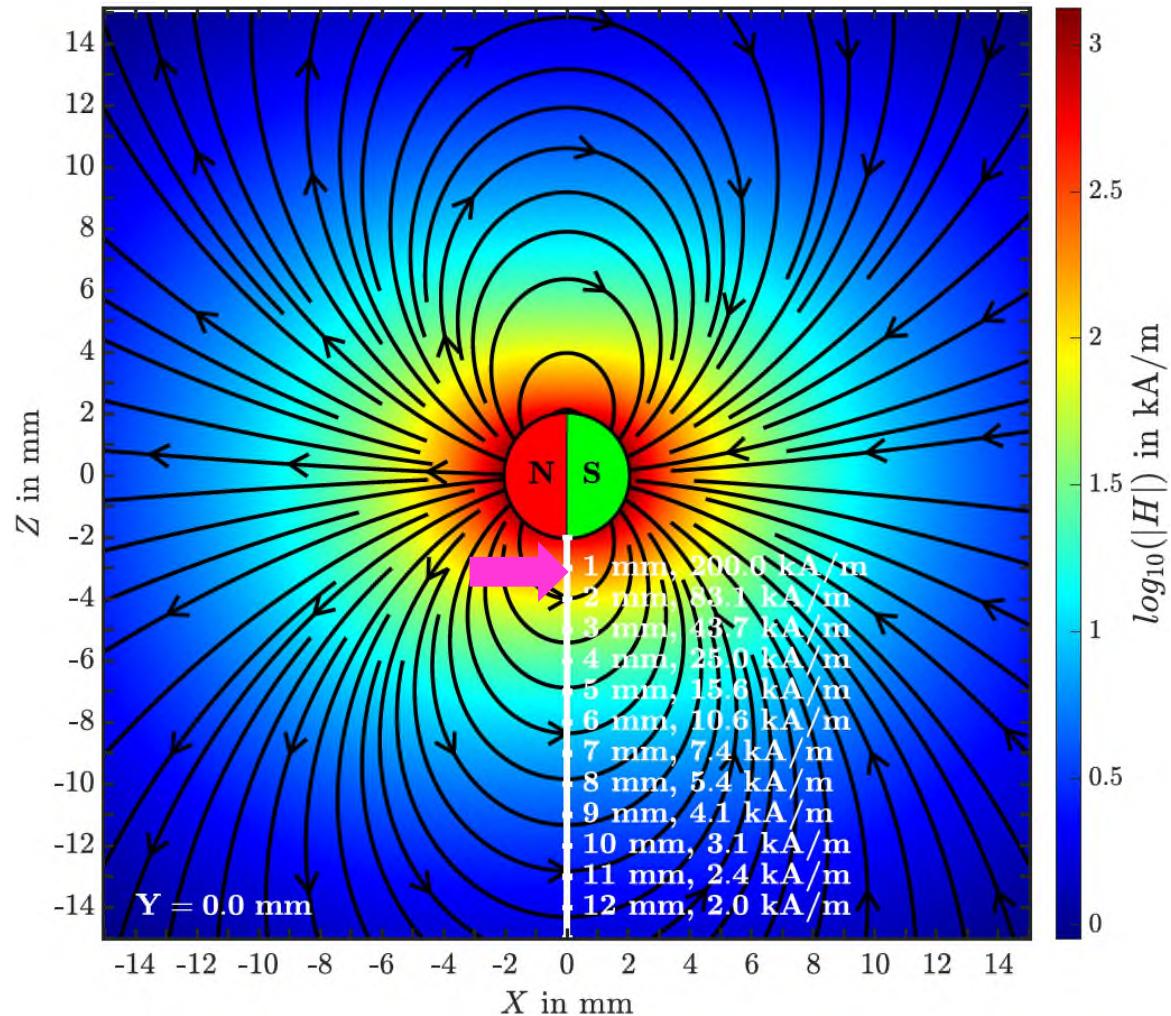


Simulation – Sensor-Array



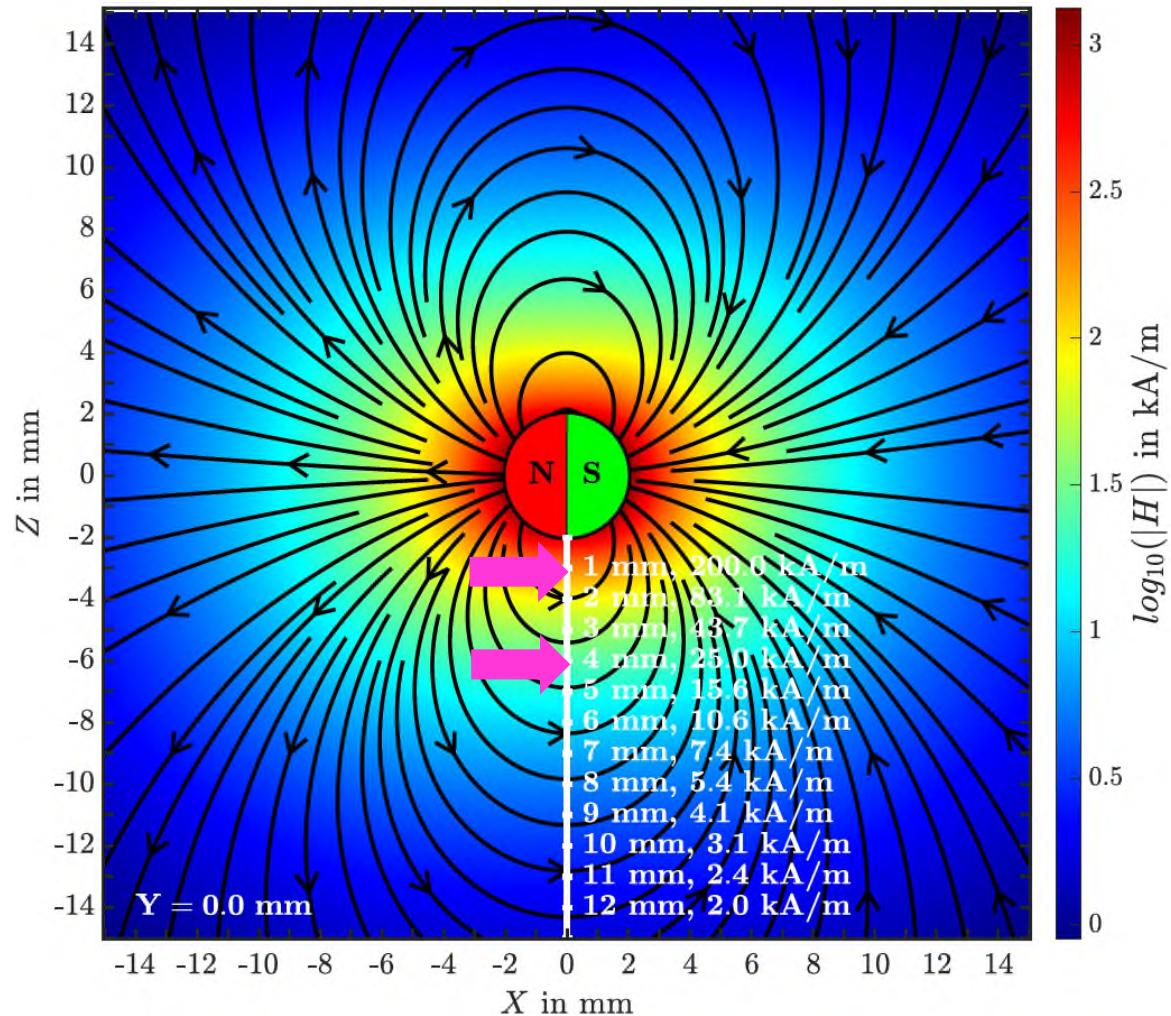
Simulation – Sensor-Array

- Konfigurierung der Prägung
bei 1 mm und 200 kA/m



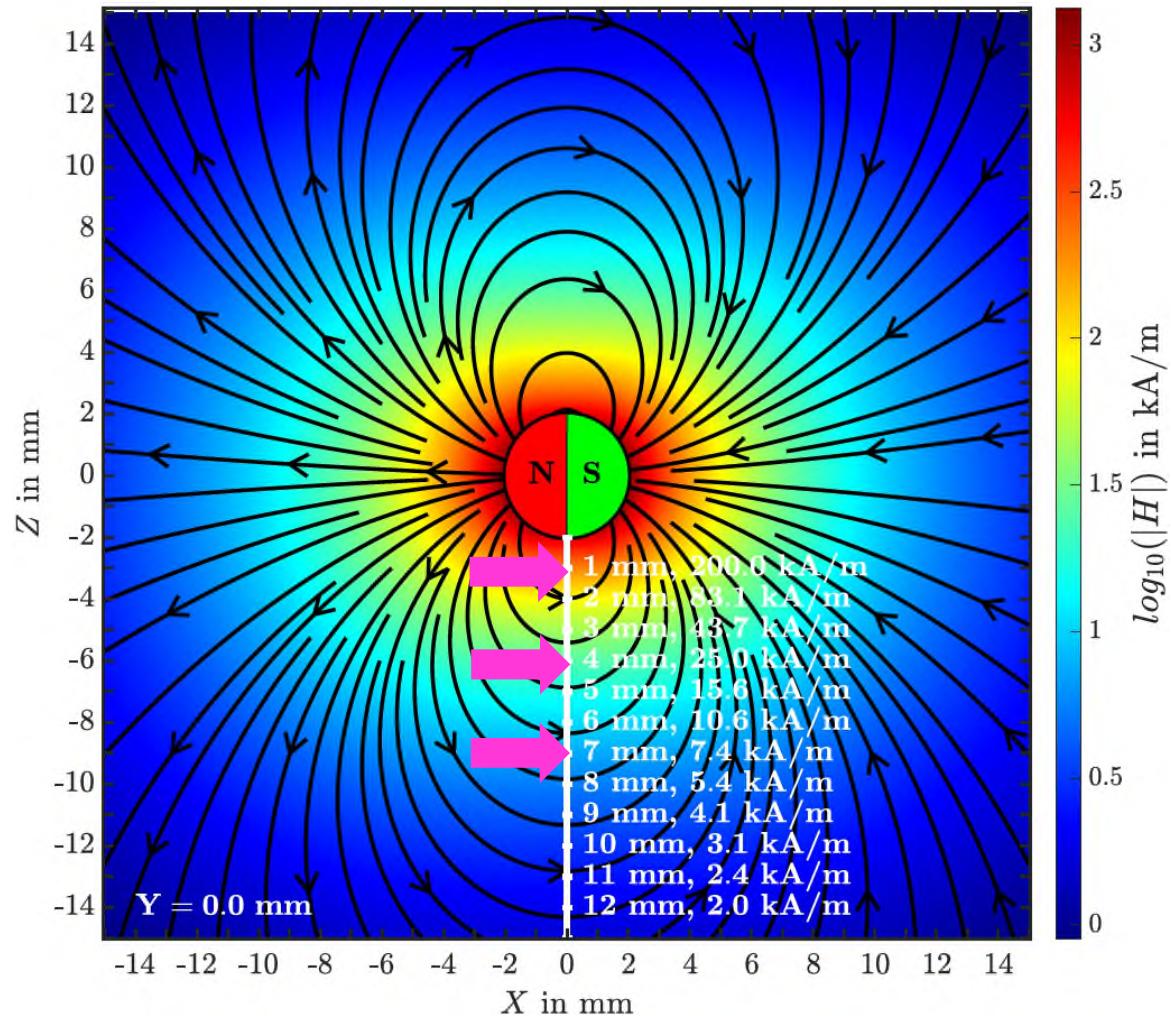
Simulation – Sensor-Array

- Konfigurierung der Prägung bei 1 mm und 200 kA/m
- Mindestabstand bei 4 mm und 25 kA/m

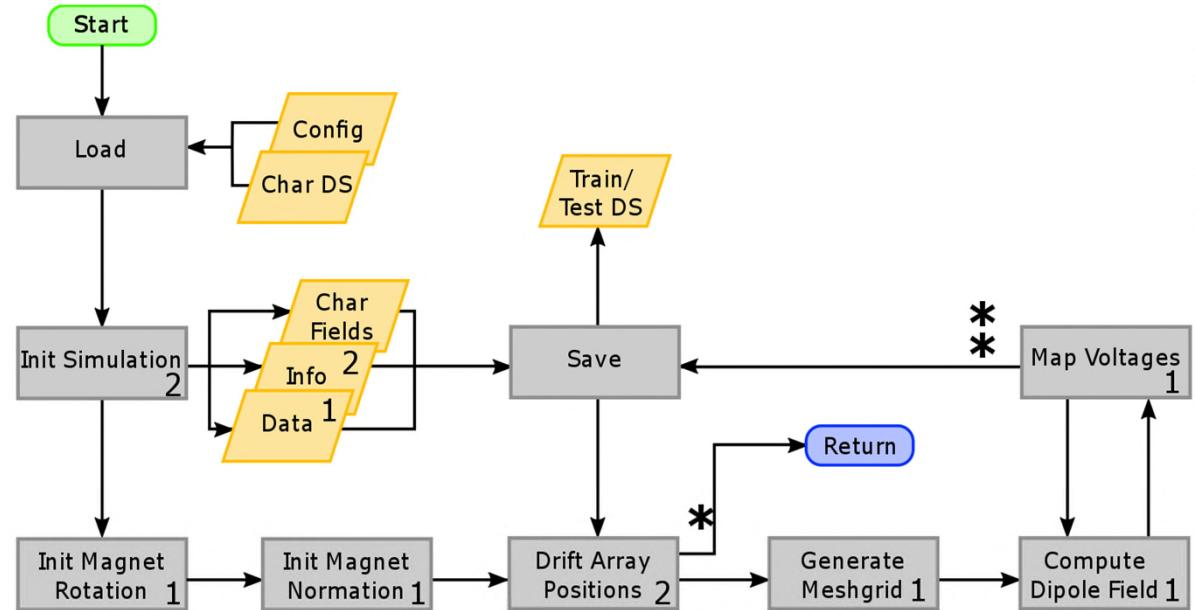


Simulation – Sensor-Array

- Konfigurierung der Prägung bei 1 mm und 200 kA/m
- Mindestabstand bei 4 mm und 25 kA/m
- Linearer Bereich bei 7 mm und 7,4 kA/m



Simulation – Sensor-Array

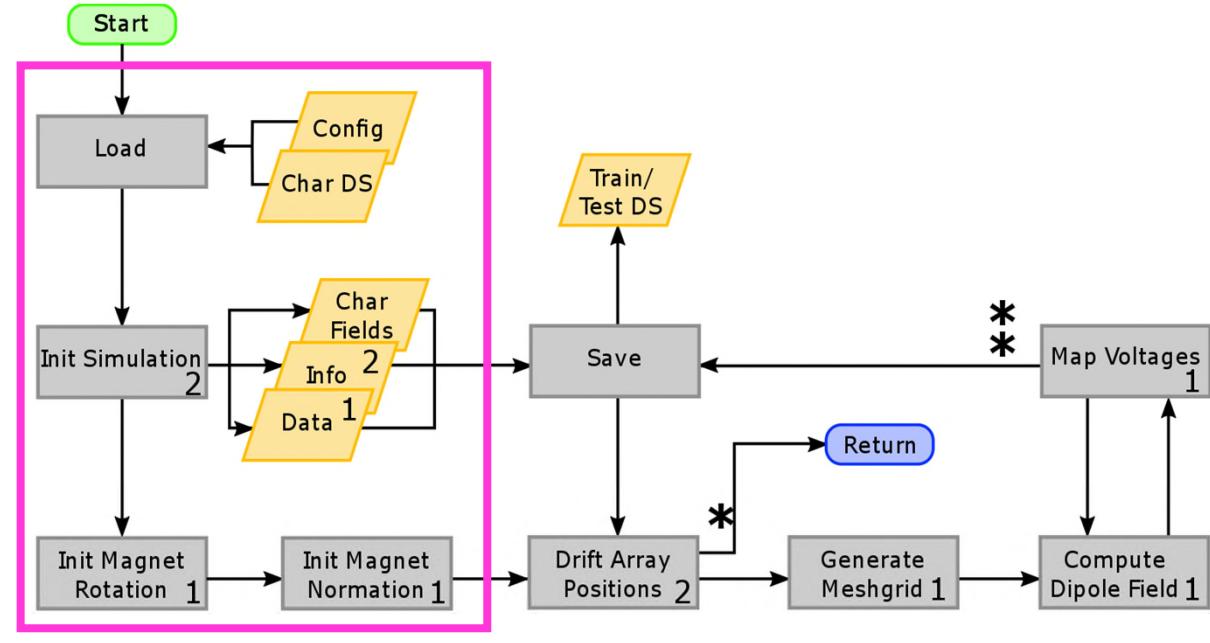


Legende

[Green rounded rectangle]	Prozessstart	[Yellow rounded rectangle]	Datensatz, Datenstruktur
[Blue rounded rectangle]	Prozessende	[Grey rounded rectangle]	Prozessschritt
*	Alle Positionen	1	Schreibt in Data-Container
**	Alle Winkel	2	Schreibt in Info-Container

Simulation – Sensor-Array

- Laden und initiieren der Simulationsparametern

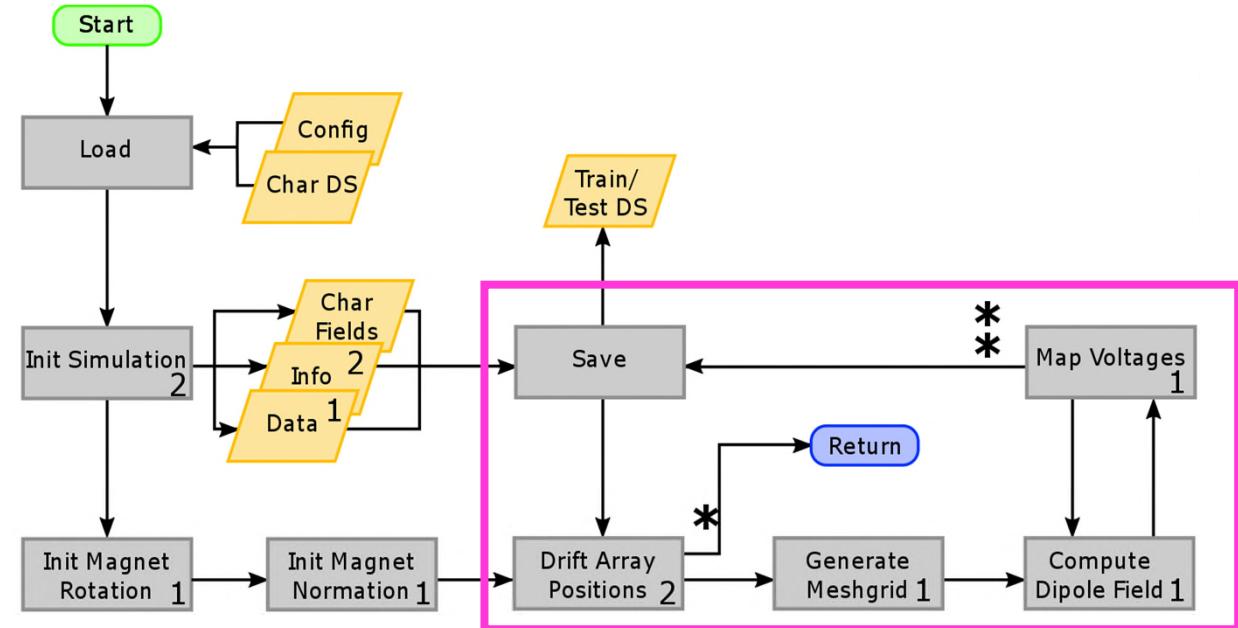


Legende

[Green rounded rectangle]	Prozessstart	[Yellow rounded rectangle]	Datensatz, Datenstruktur
[Blue rounded rectangle]	Prozessende	[Grey rounded rectangle]	Prozessschritt
*	Alle Positionen	1	Schreibt in Data-Container
**	Alle Winkel	2	Schreibt in Info-Container

Simulation – Sensor-Array

- Laden und initiieren der Simulationsparametern
- Durchführung in For-Schleifen

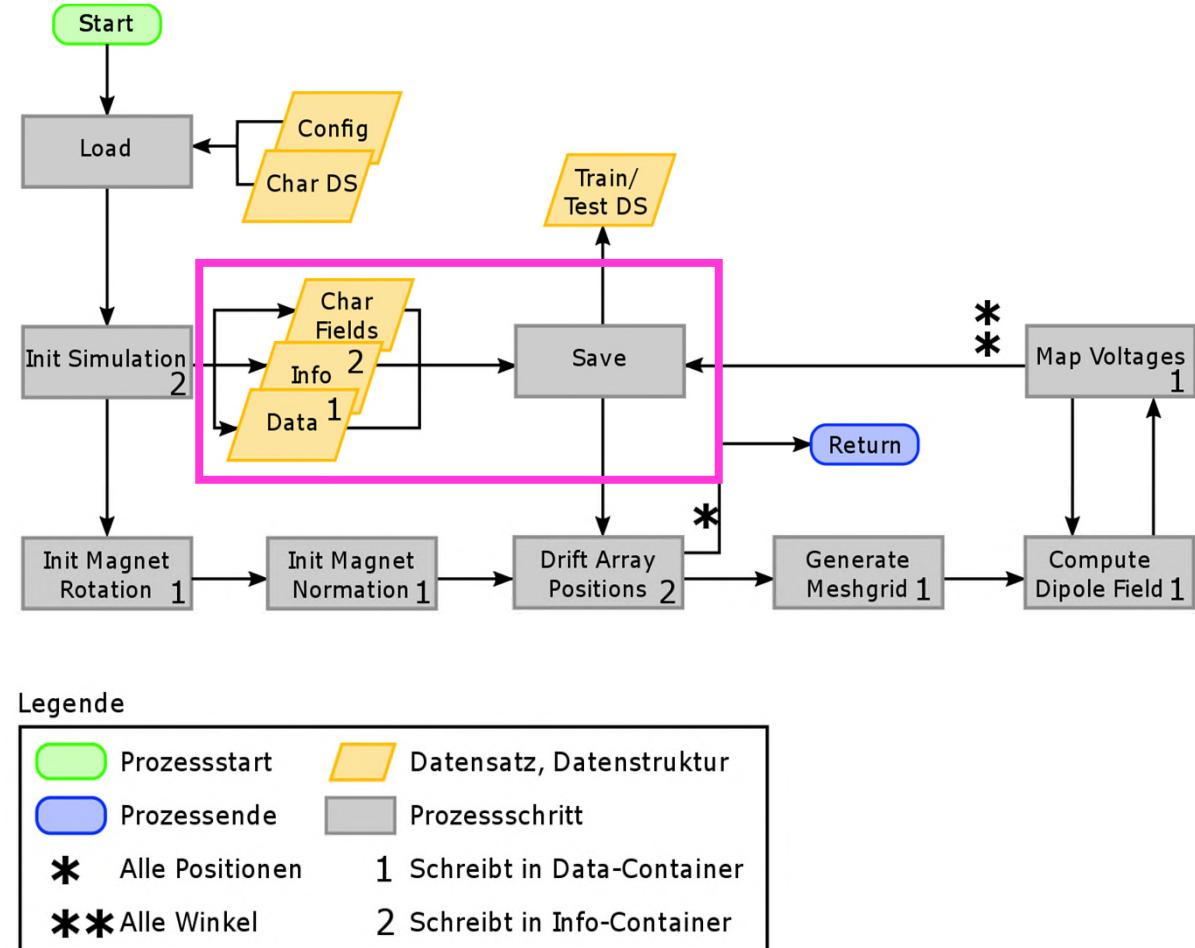


Legende

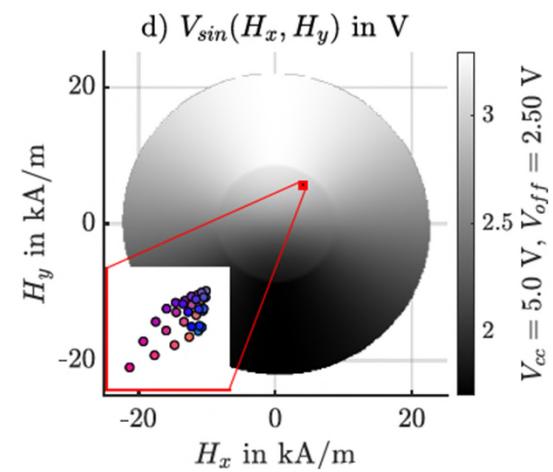
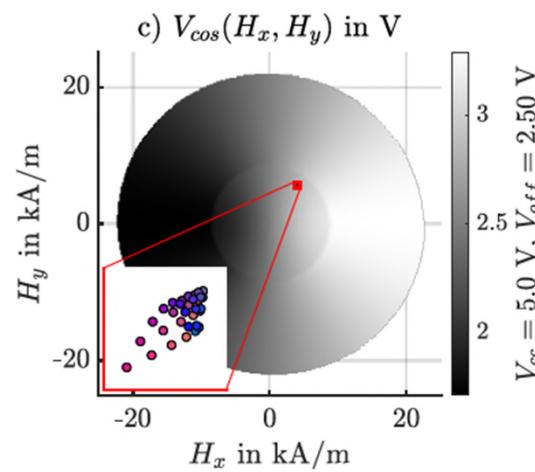
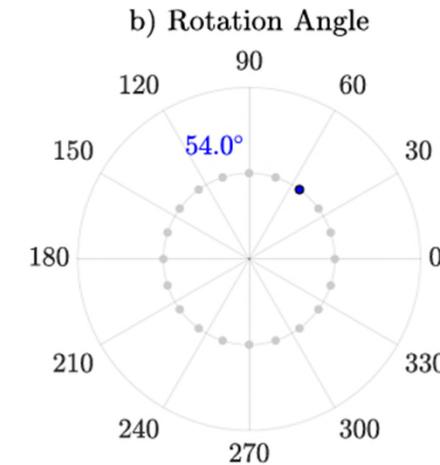
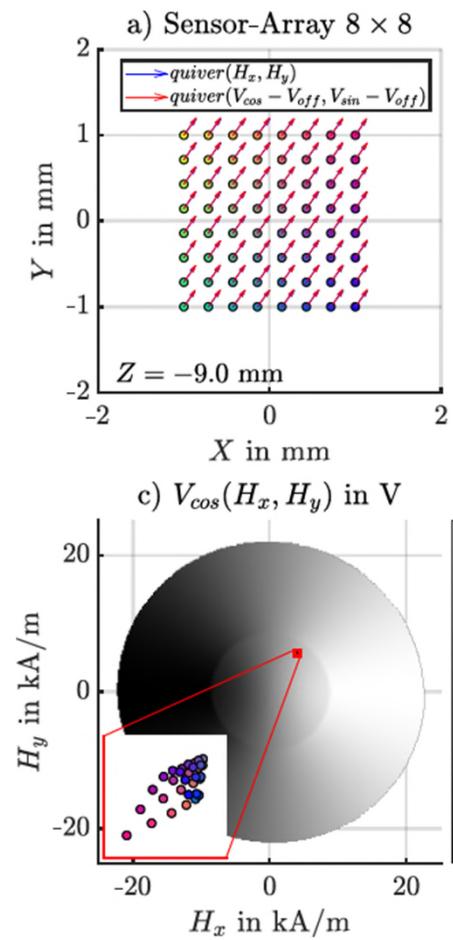
[Green rounded rectangle]	Prozessstart	[Yellow rounded rectangle]	Datensatz, Datenstruktur
[Blue rounded rectangle]	Prozessende	[Grey rounded rectangle]	Prozessschritt
*	Alle Positionen	1	Schreibt in Data-Container
**	Alle Winkel	2	Schreibt in Info-Container

Simulation – Sensor-Array

- Laden und initiieren der Simulationsparametern
- Durchführung in For-Schleifen
- Speichern der Datencontainer

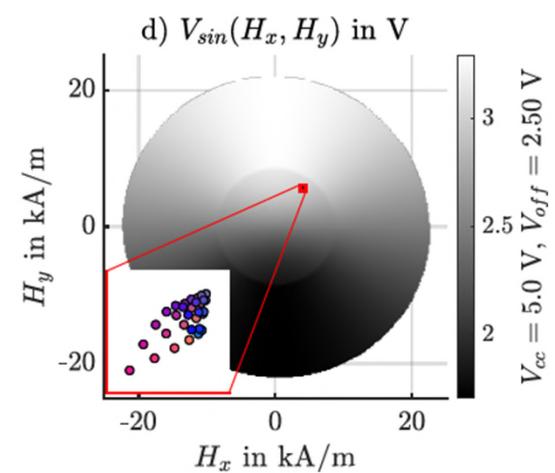
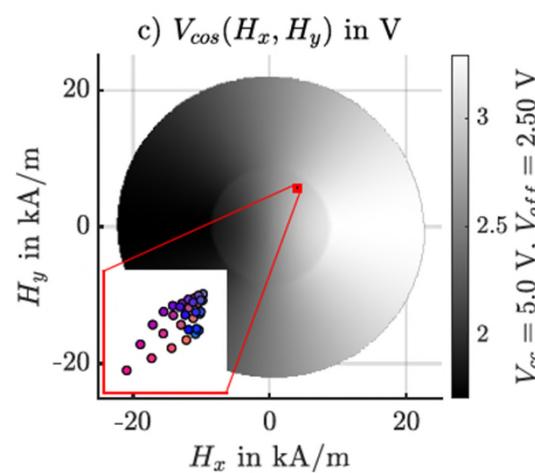
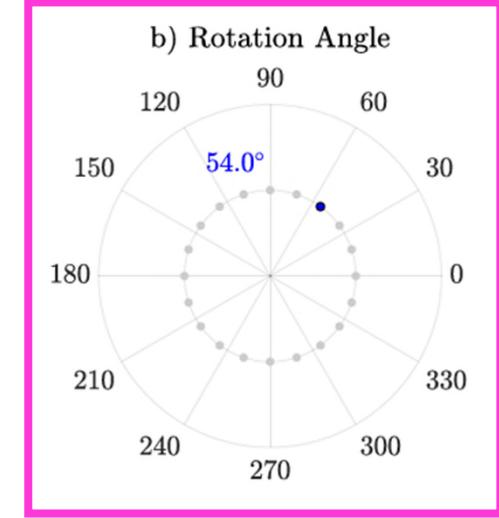
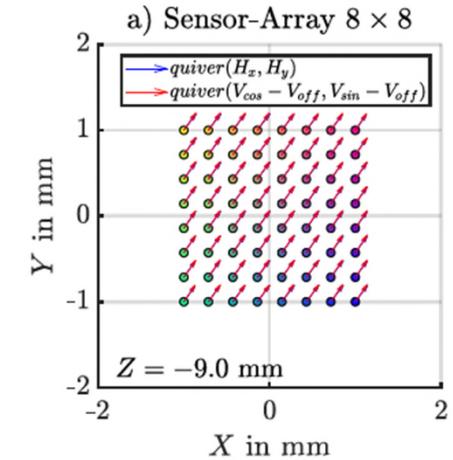


Simulation – Sensor-Array



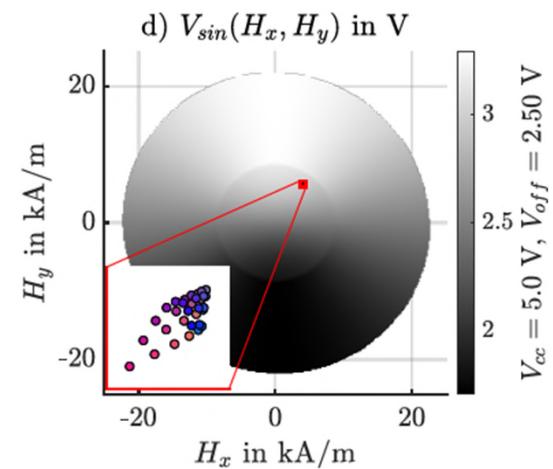
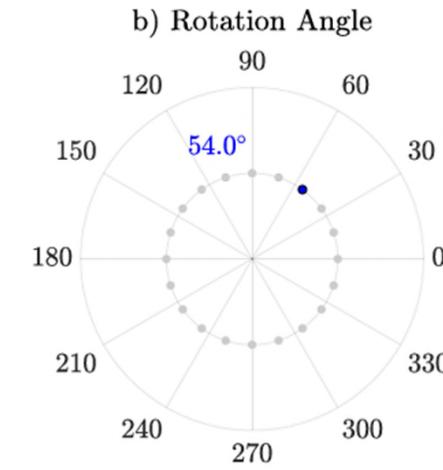
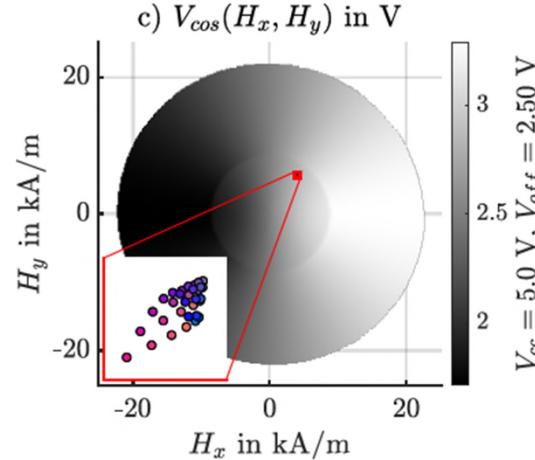
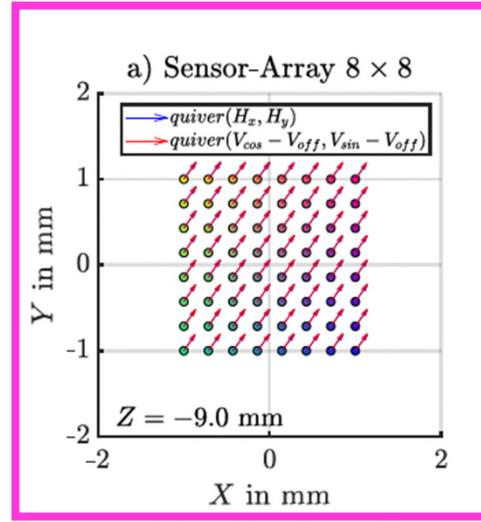
Simulation – Sensor-Array

- Eingabe – Simulationswinkel



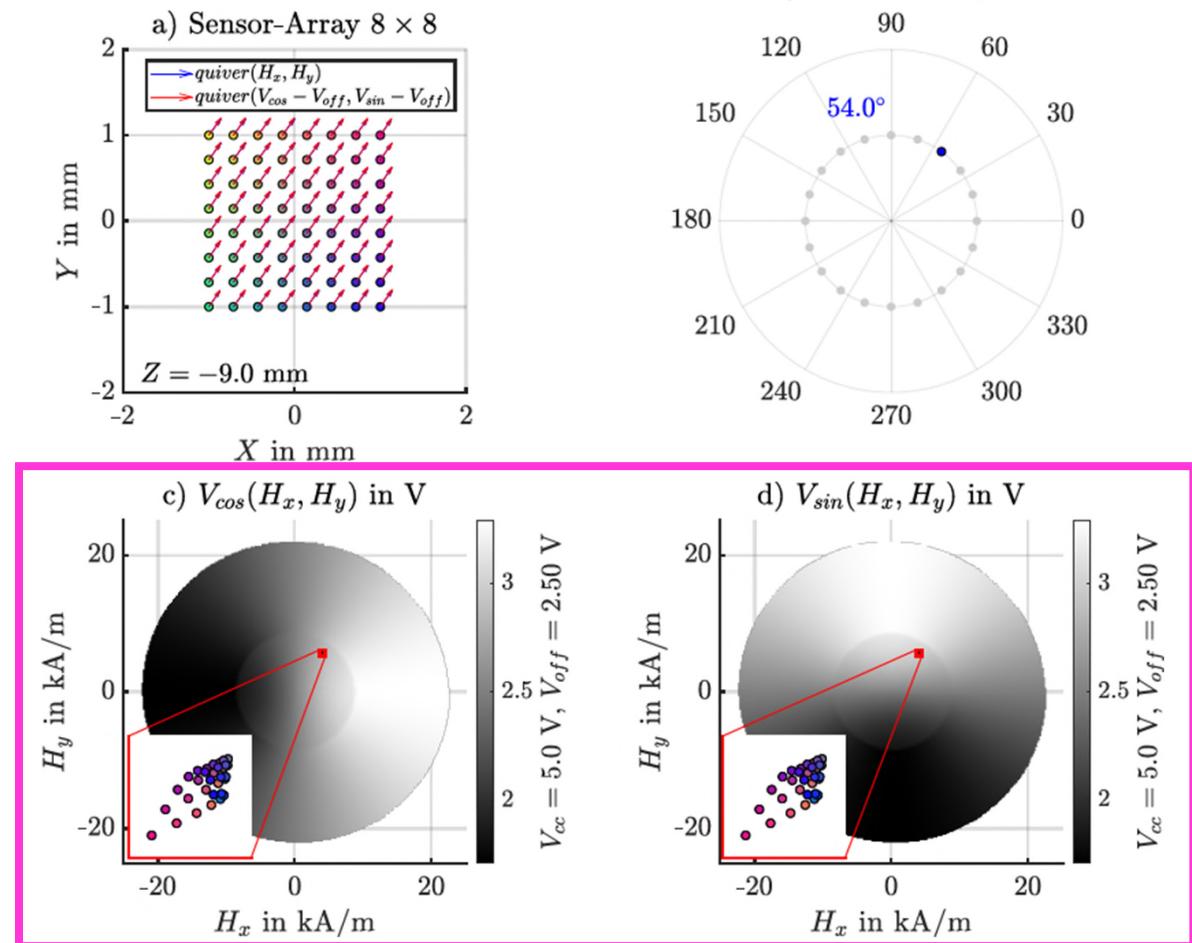
Simulation – Sensor-Array

- Eingabe – Simulationswinkel
- Meshgrid – Berechnungen an Sensor-Pixel



Simulation – Sensor-Array

- Eingabe – Simulationswinkel
- Meshgrid – Berechnungen an Sensor-Pixel
- Mapping – Entnahme von Referenzspannungen



Simulation – Gauß-Prozesse

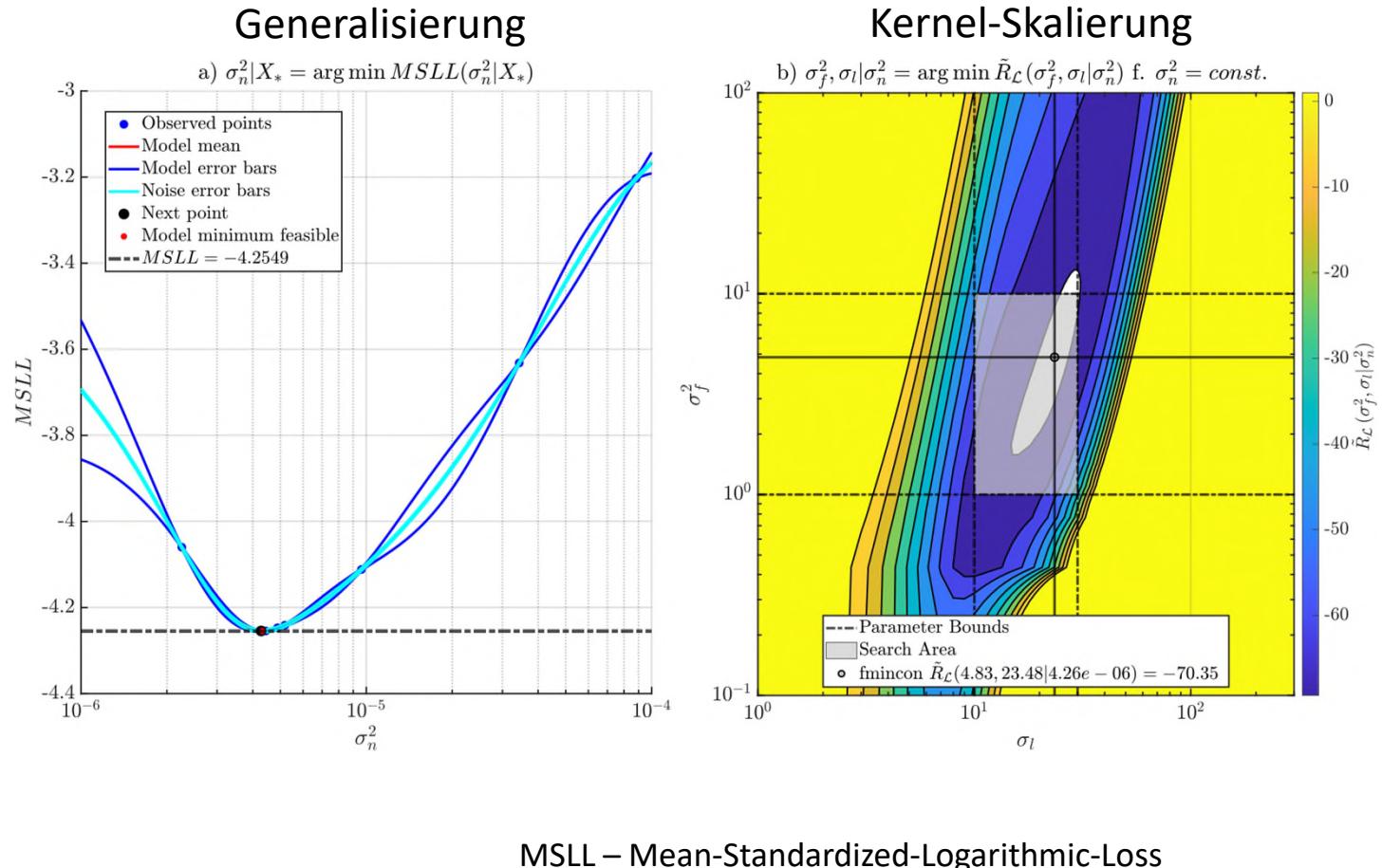


- Koniguration

MSLL – Mean-Standardized-Logarithmic-Loss

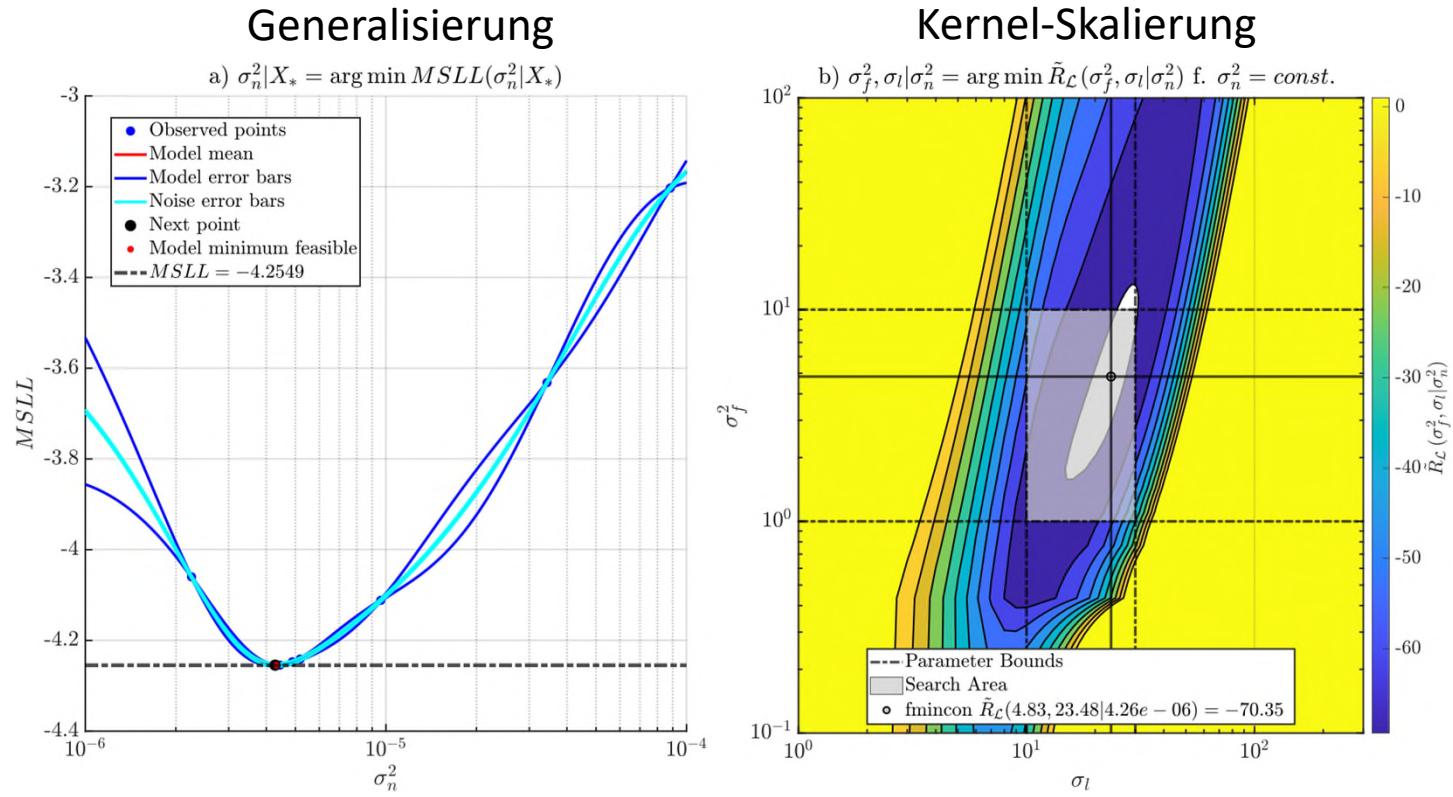
Simulation – Gauß-Prozesse

- Konfiguration
 - Kernel-Modul
 - Mittelwertbildung



Simulation – Gauß-Prozesse

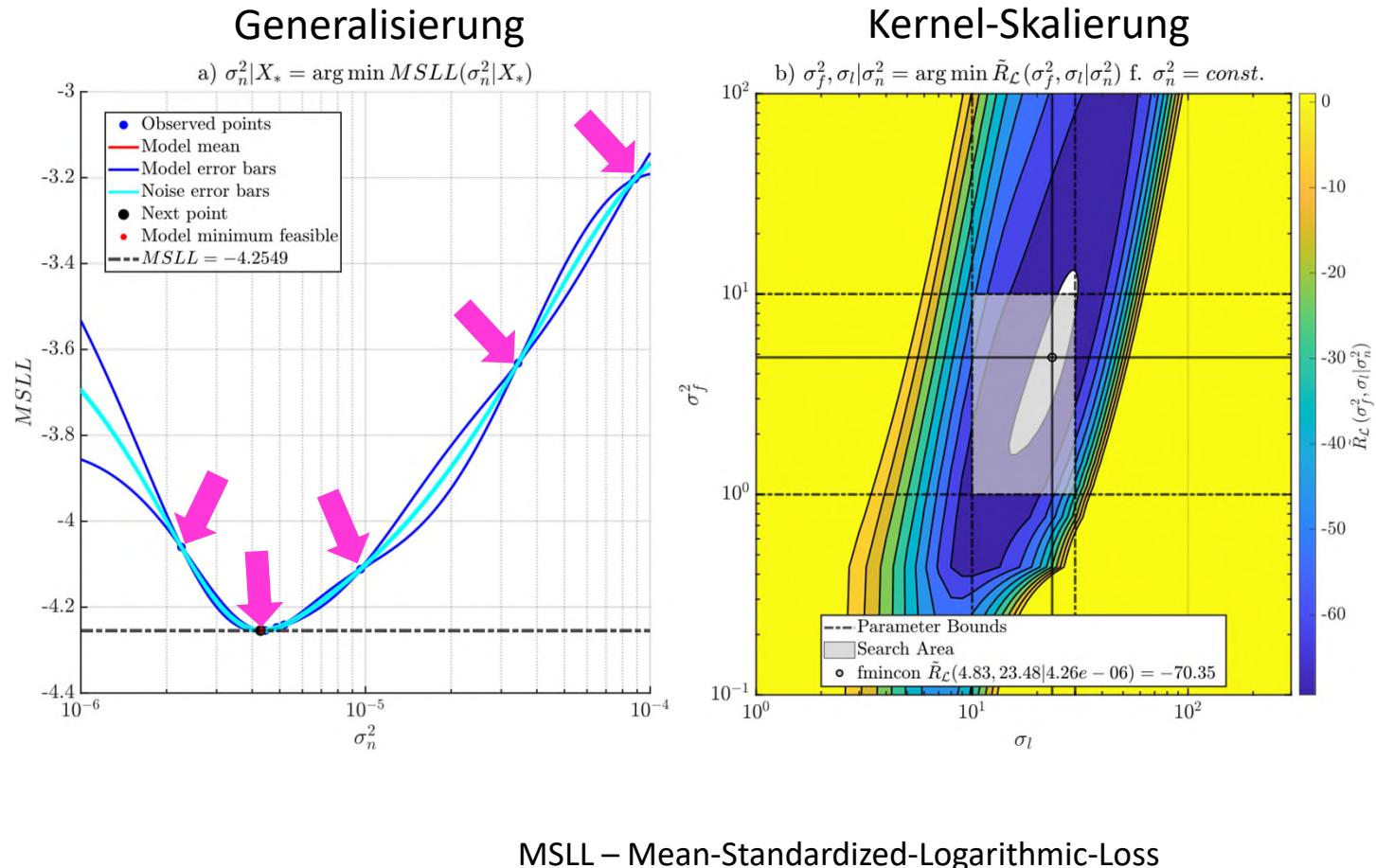
- Konfiguration
 - Kernel-Modul
 - Mittelwertbildung
 - Verlustberechnung



MSLL – Mean-Standardized-Logarithmic-Loss

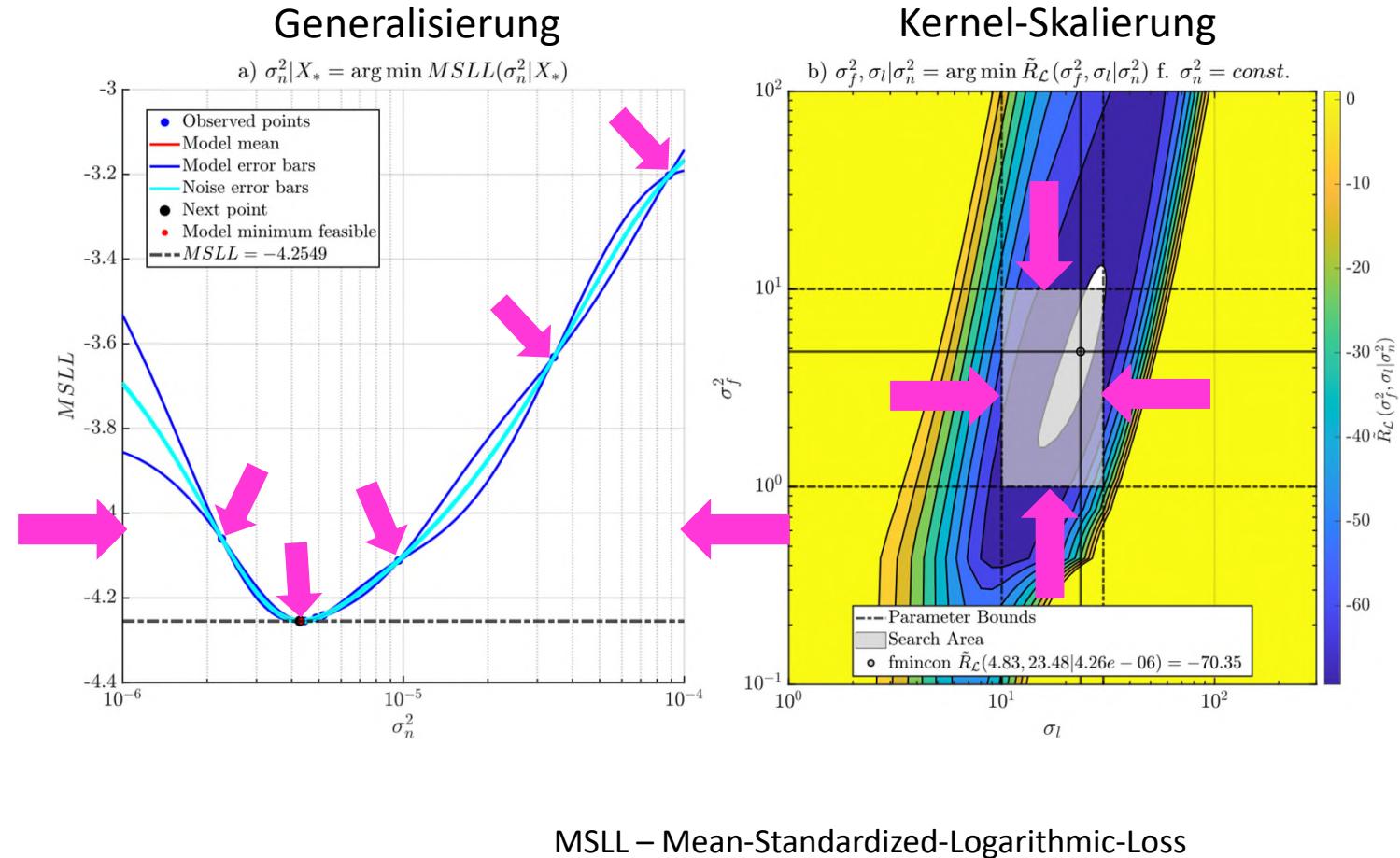
Simulation – Gauß-Prozesse

- Konfiguration
 - Kernel-Modul
 - Mittelwertbildung
 - Verlustberechnung
 - Durchlaufanzahl



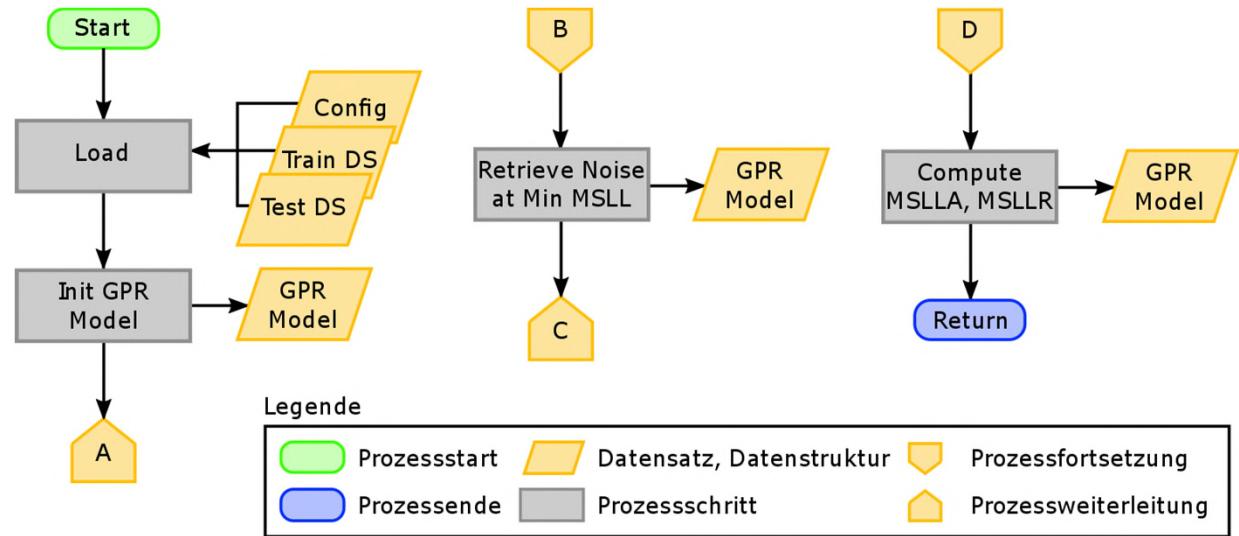
Simulation – Gauß-Prozesse

- Konfiguration
 - Kernel-Modul
 - Mittelwertbildung
 - Verlustberechnung
 - Durchlaufanzahl
 - Parametergrenzen



Simulation – Gauß-Prozesse

- Trainingsphase



GPR – Gaussian Processes for Regression

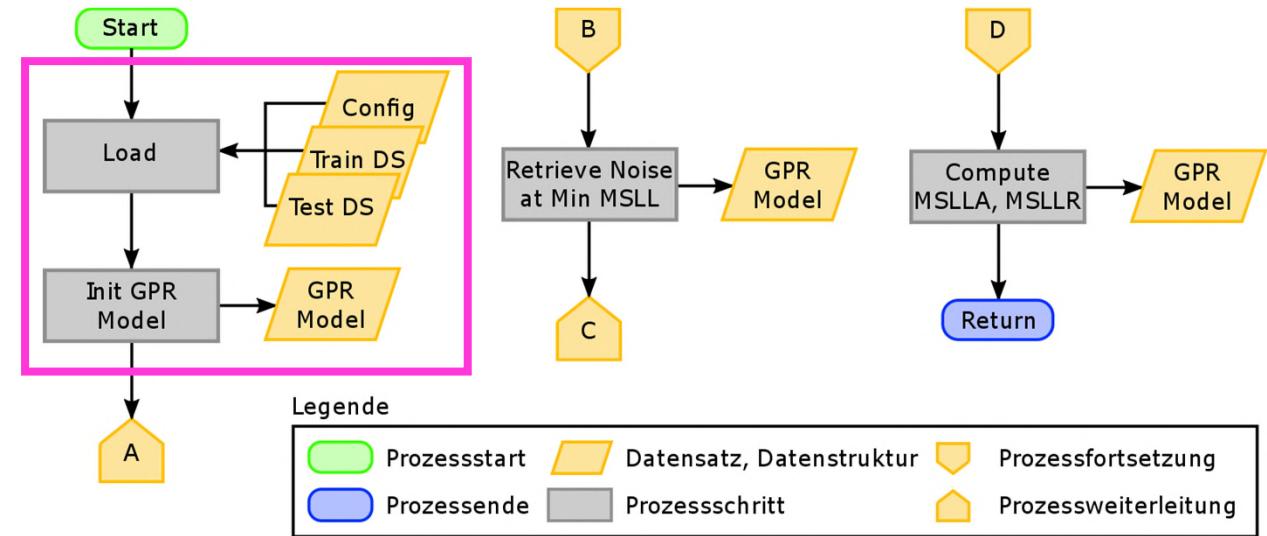
MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Simulation – Gauß-Prozesse

- Trainingsphase
 - Laden und Initialisierung



GPR – Gaussian Processes for Regression

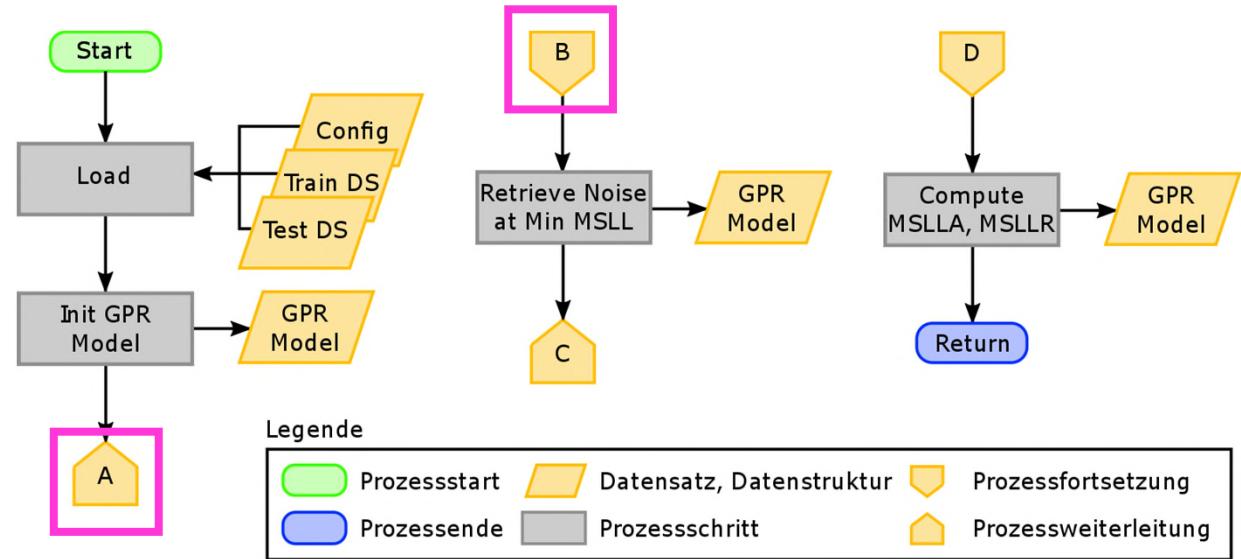
MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Simulation – Gauß-Prozesse

- Trainingsphase
 - Laden und Initialisierung
 - Generalisierung mit eingebetteter Skalierung



GPR – Gaussian Processes for Regression

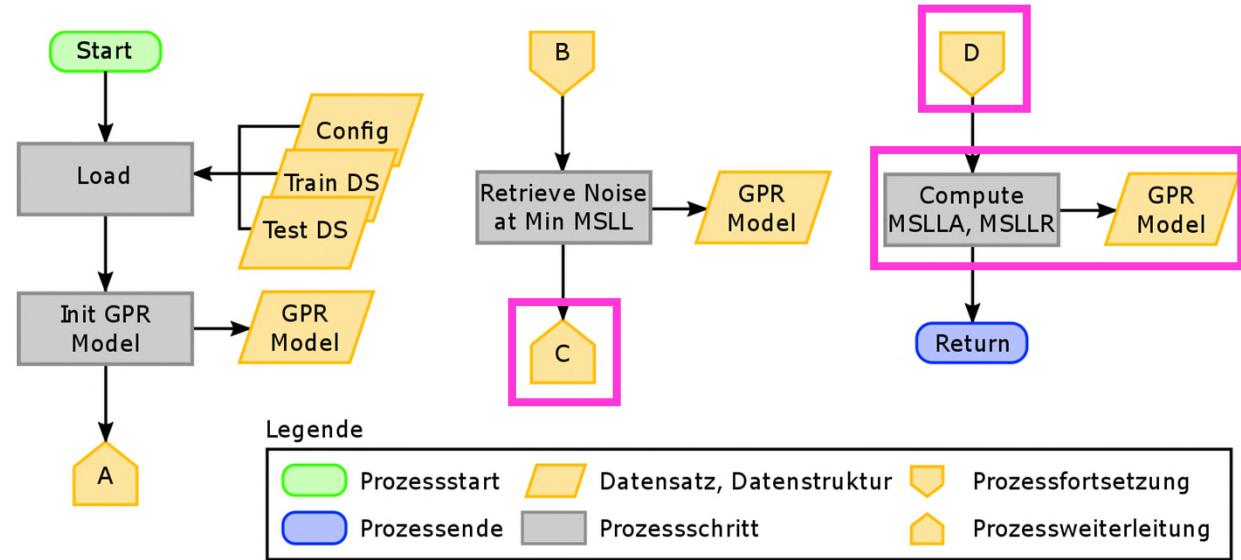
MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Simulation – Gauß-Prozesse

- Trainingsphase
 - Laden und Initialisierung
 - Generalisierung mit eingebetteter Skalierung
 - Finale Skalierung und Bewertung



GPR – Gaussian Processes for Regression

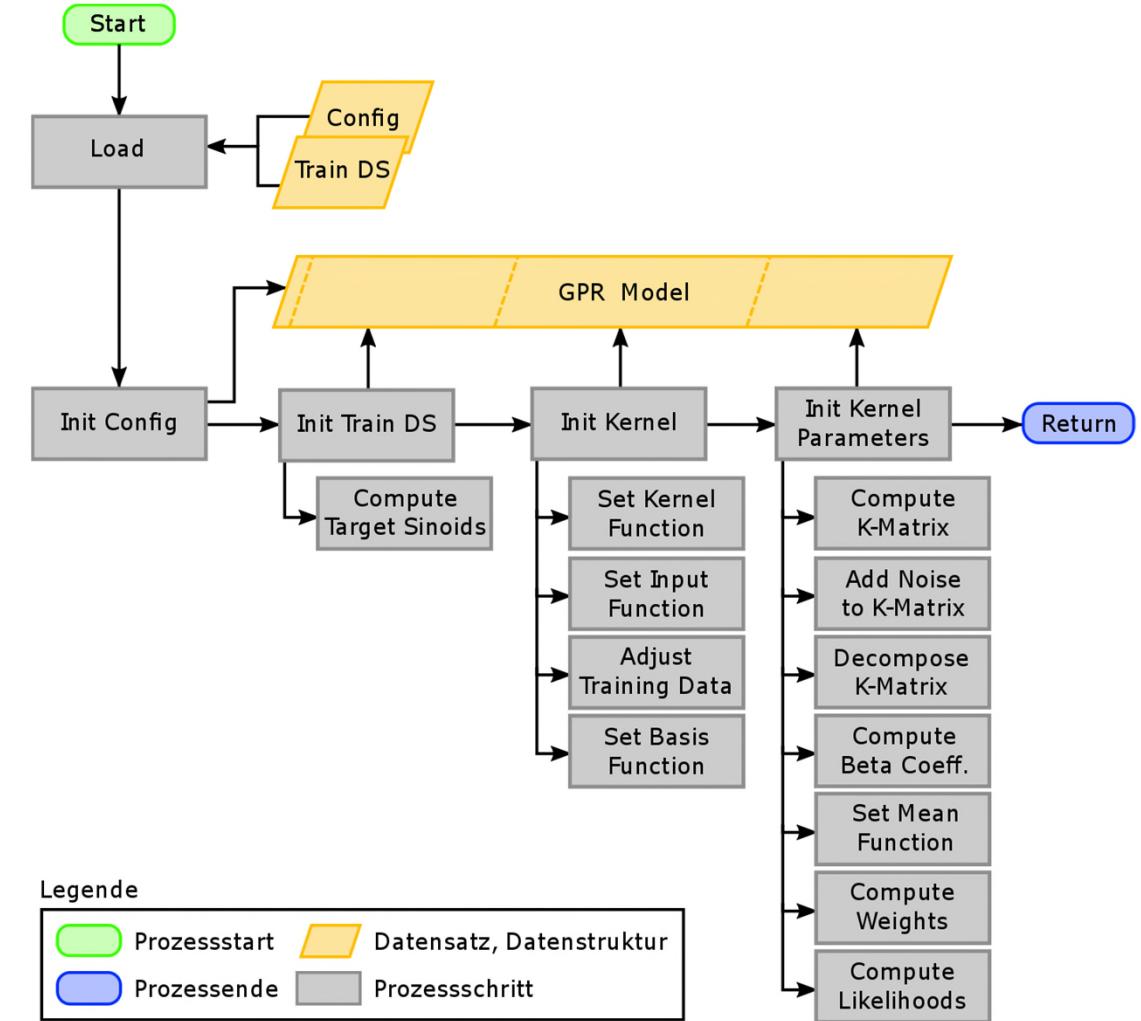
MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Simulation – Gauß-Prozesse

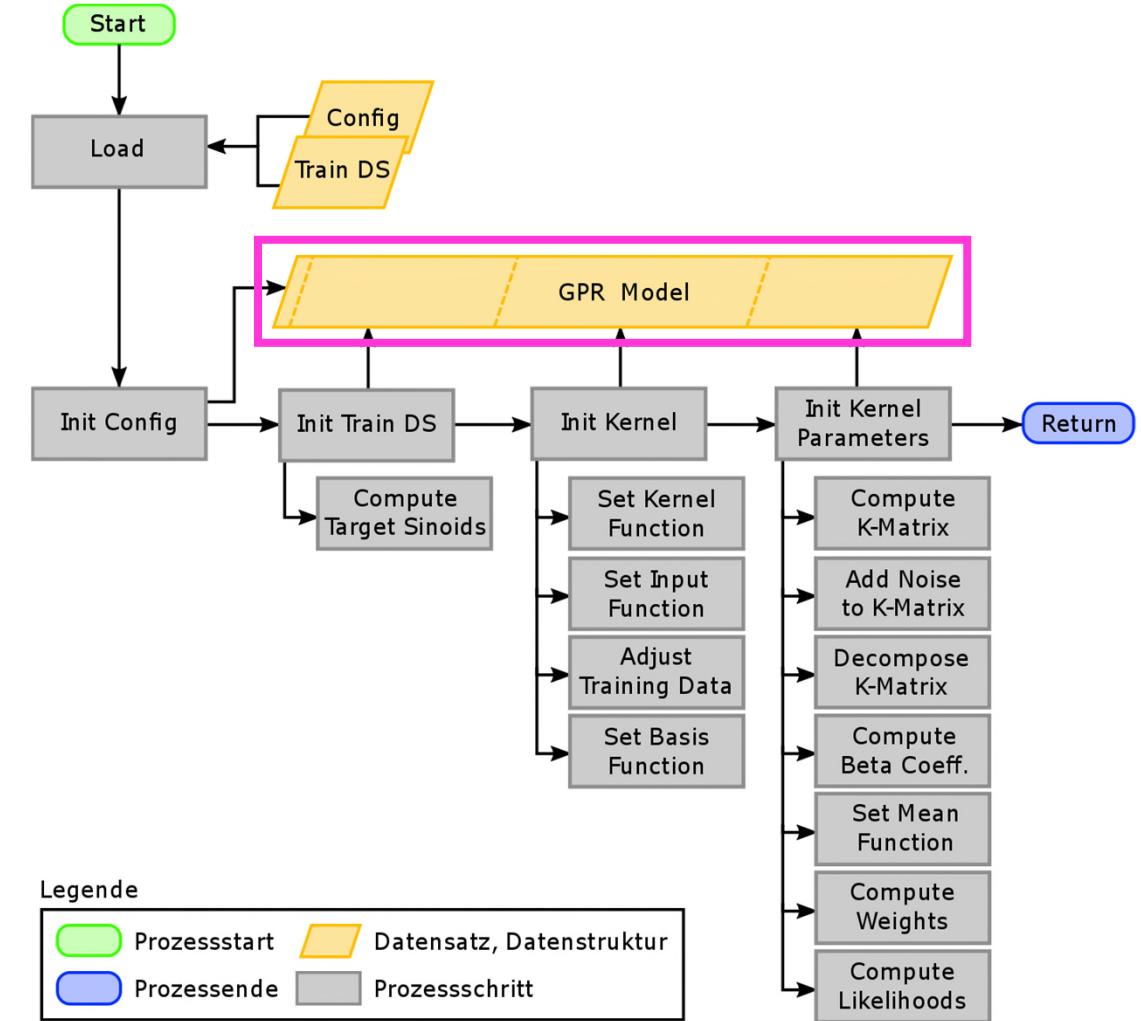
- Sequenzielle Initialisierung



GPR – Gaussian Processes for Regression
DS – Dataset

Simulation – Gauß-Prozesse

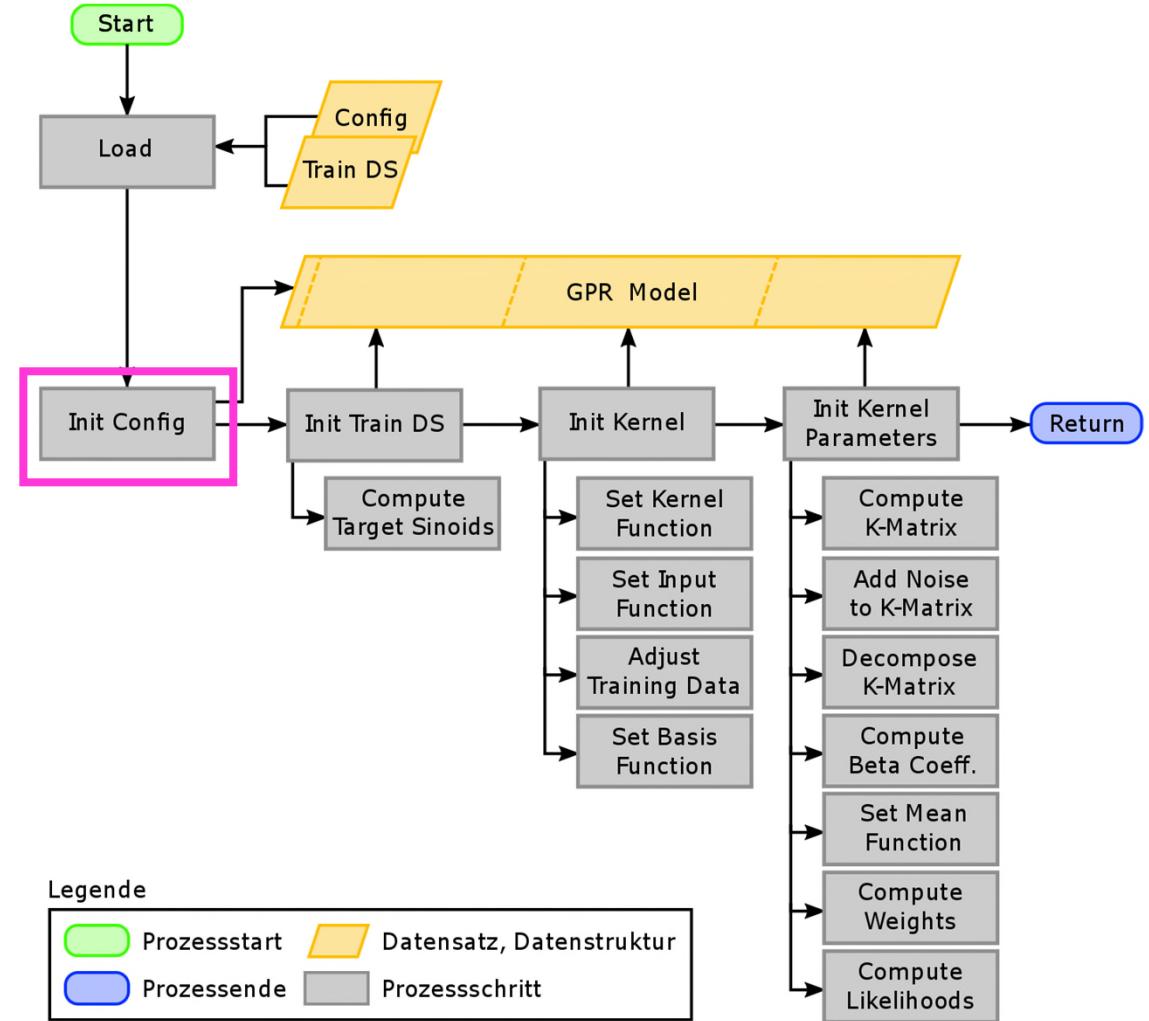
- Sequenzielle Initialisierung
 - Struct-basiertes Modell



GPR – Gaussian Processes for Regression
DS – Dataset

Simulation – Gauß-Prozesse

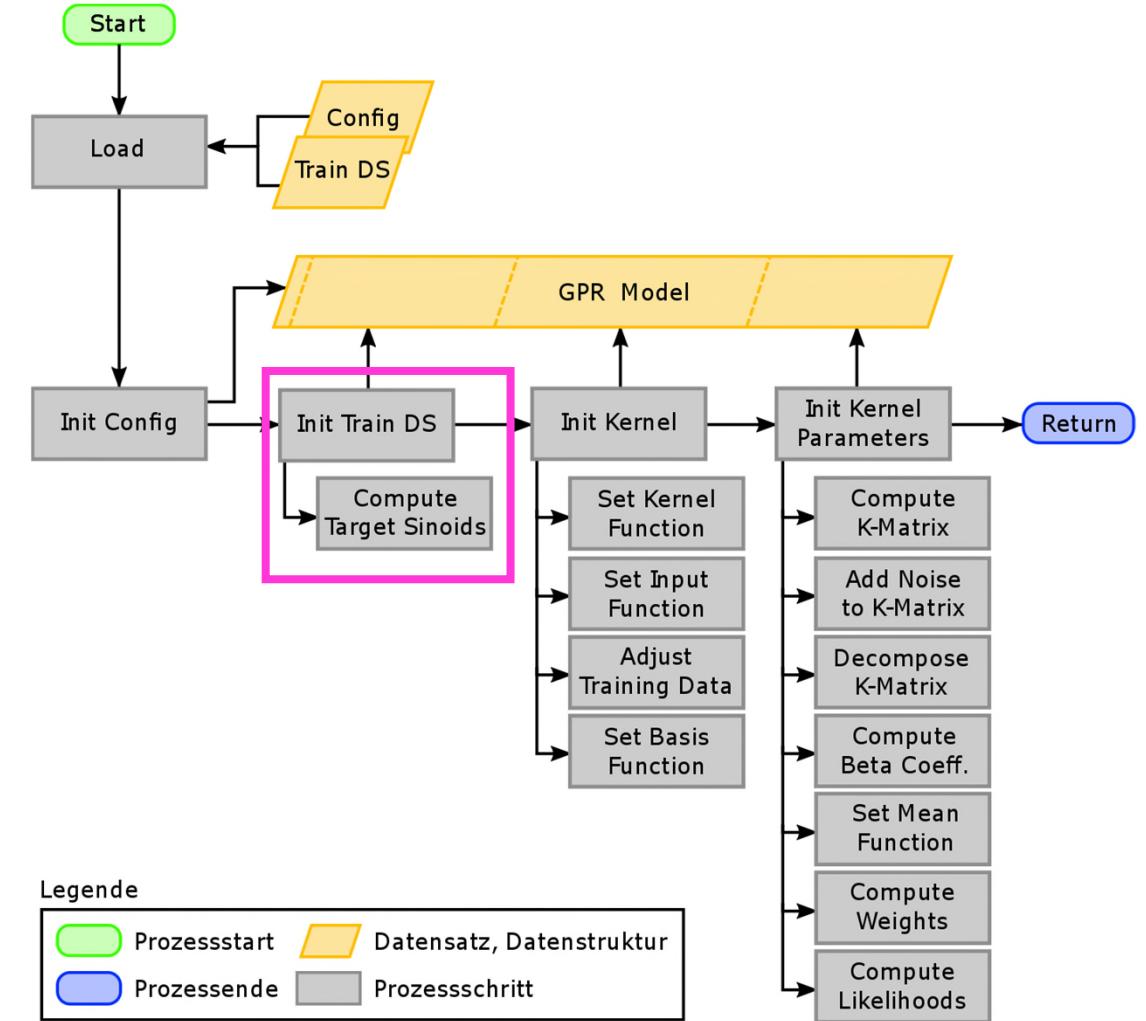
- Sequenzielle Initialisierung
 - Struct-basiertes Modell
 - Konfigurierung Framework



GPR – Gaussian Processes for Regression
DS – Dataset

Simulation – Gauß-Prozesse

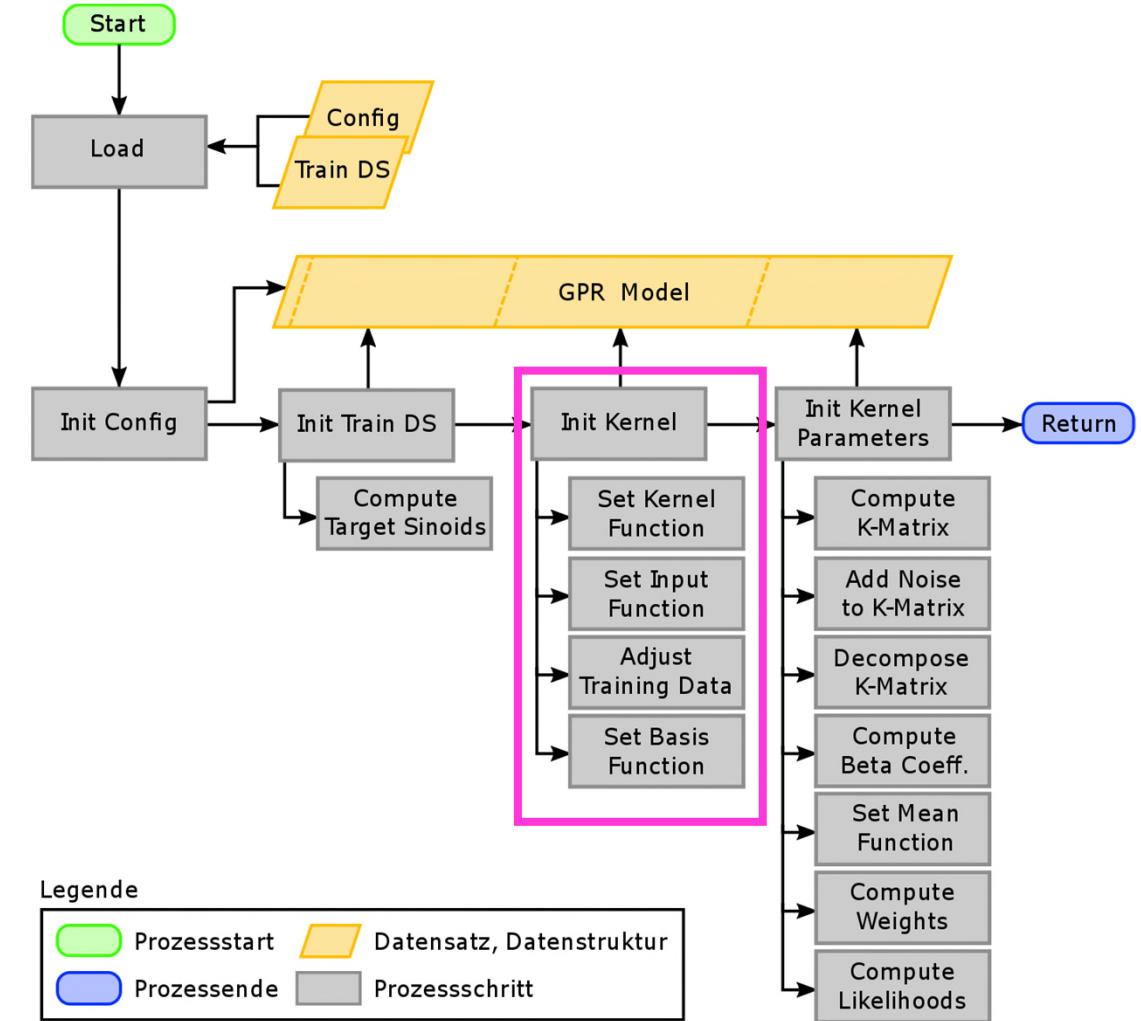
- Sequenzielle Initialisierung
 - Struct-basiertes Modell
 - Konfigurierung Framework
 - Anlegen von Referenzen



GPR – Gaussian Processes for Regression
DS – Dataset

Simulation – Gauß-Prozesse

- Sequenzielle Initialisierung
 - Struct-basiertes Modell
 - Konfigurierung Framework
 - Anlegen von Referenzen
 - Laden der Funktionalität

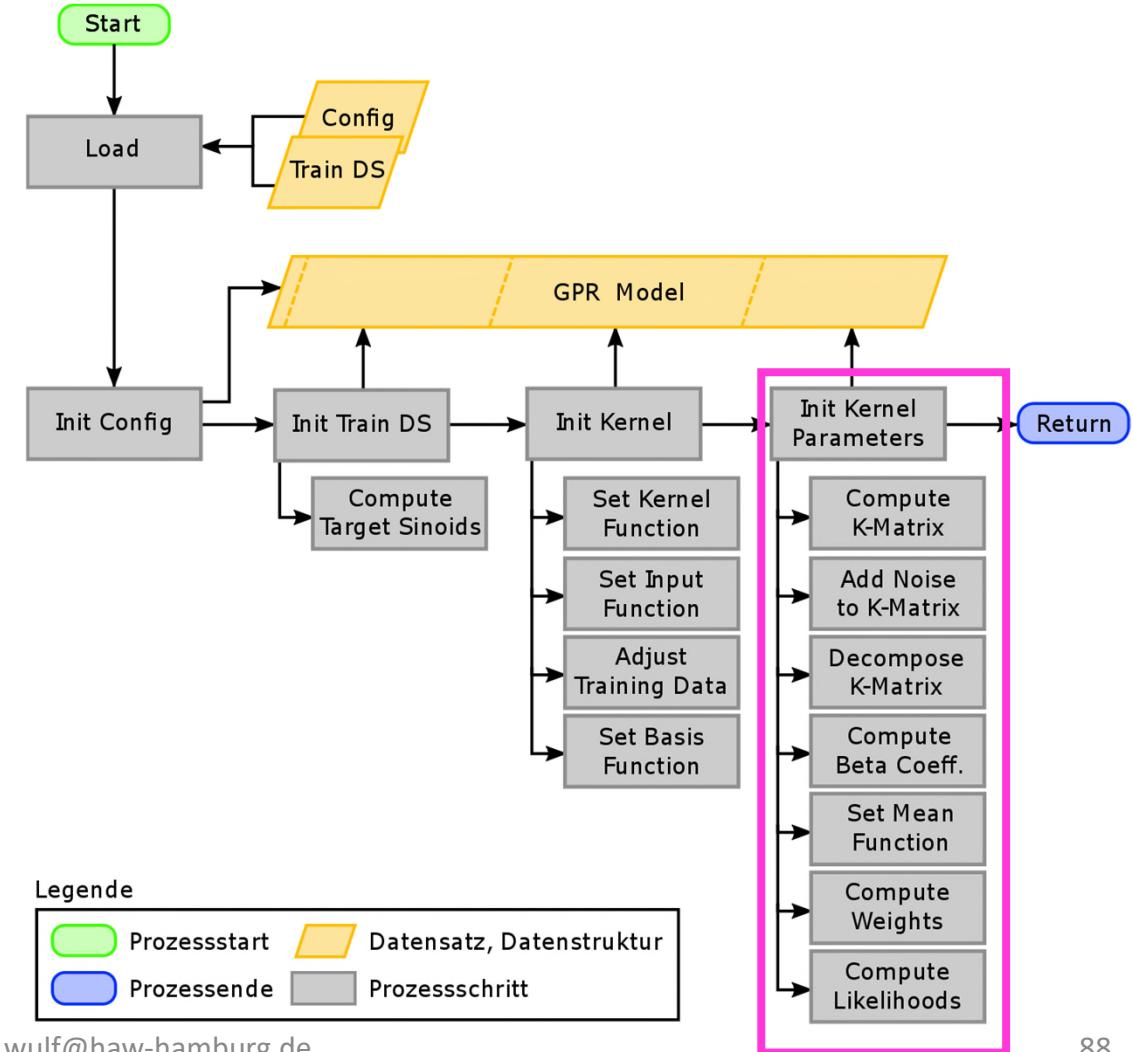


GPR – Gaussian Processes for Regression
DS – Dataset

Simulation – Gauß-Prozesse

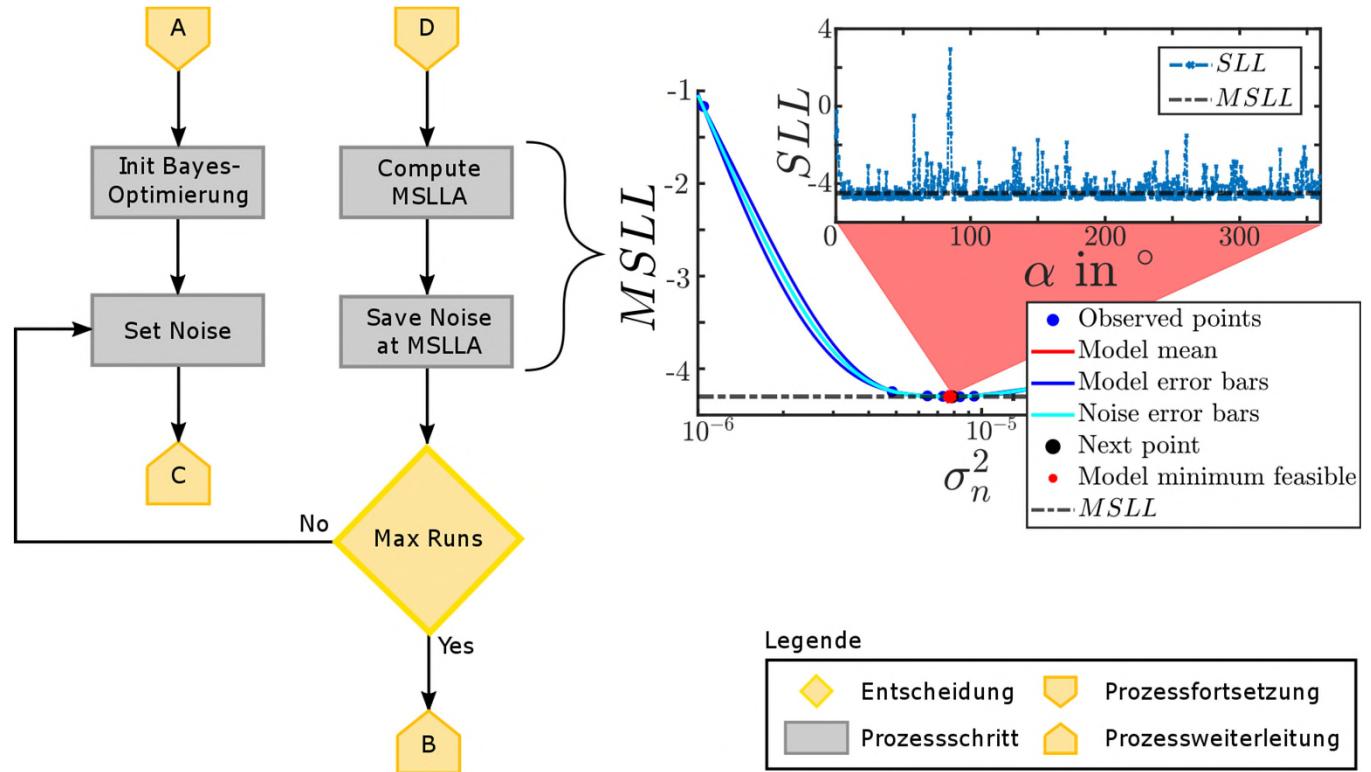
- Sequenzielle Initialisierung
 - Struct-basiertes Modell
 - Konfigurierung Framework
 - Anlegen von Referenzen
 - Laden der Funktionalität
 - Modellparametrierung

GPR – Gaussian Processes for Regression
DS – Dataset



Simulation – Gauß-Prozesse

- Generalisierung



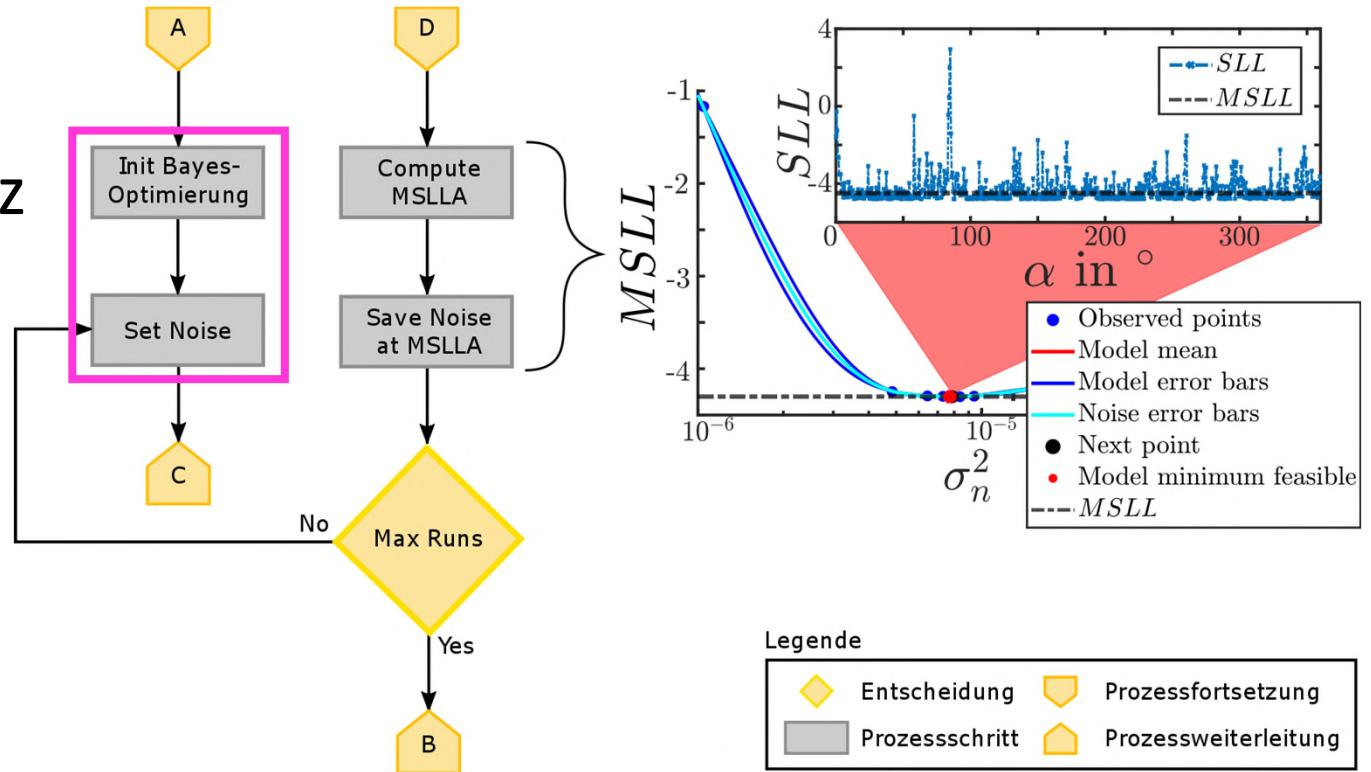
SLL – Standardized-Logarithmic-Loss

MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

Simulation – Gauß-Prozesse

- Generalisierung
 - Setzen der Noise-Varianz



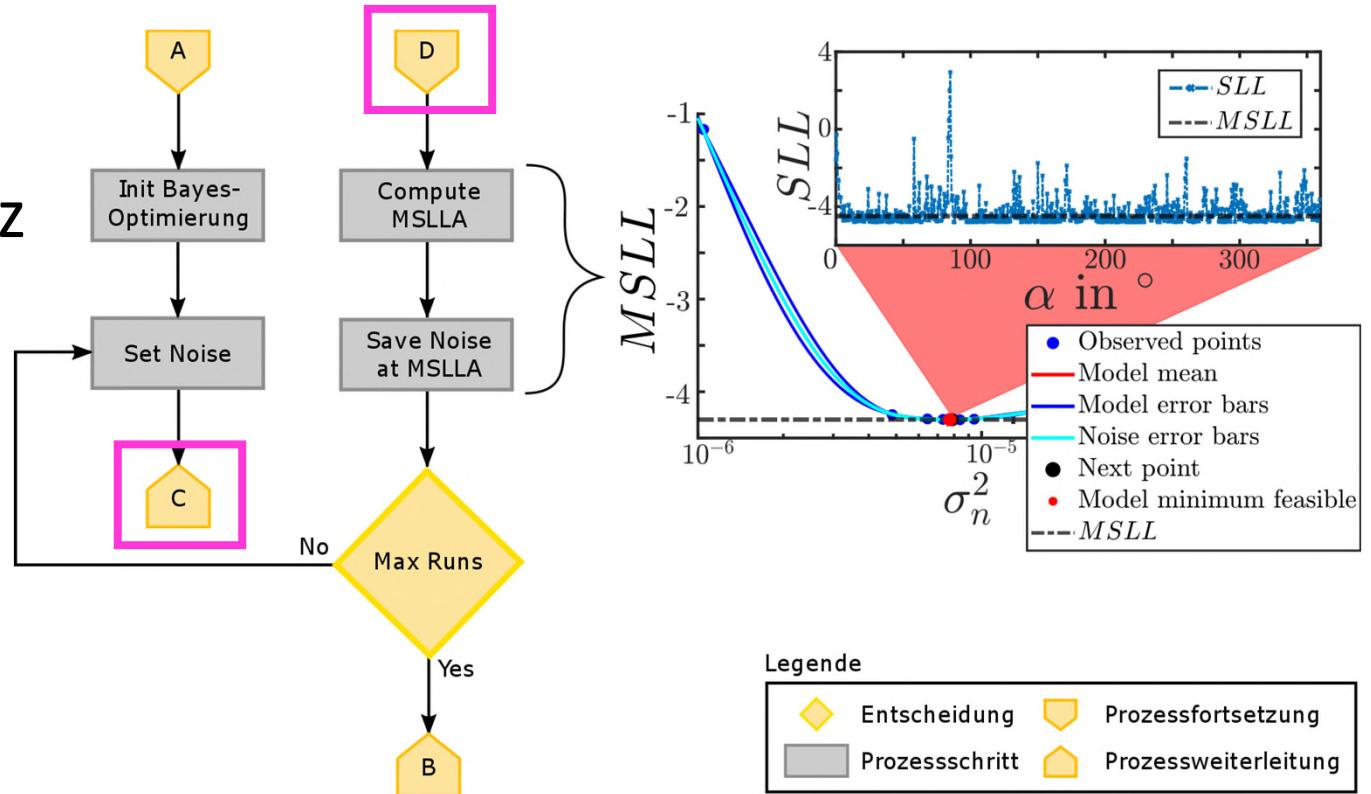
SLL – Standardized-Logarithmic-Loss

MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

Simulation – Gauß-Prozesse

- Generalisierung
 - Setzen der Noise-Varianz
 - Kernel-Skalierung



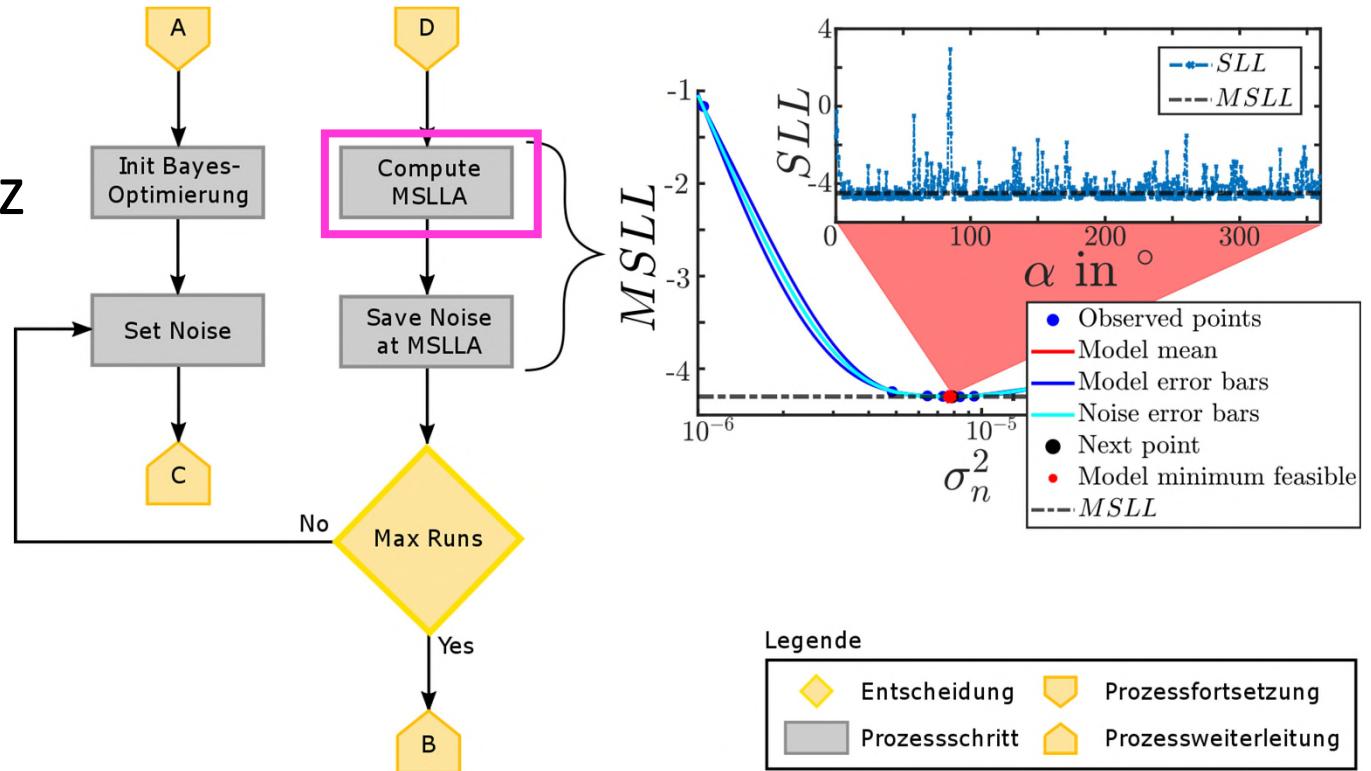
SLL – Standardized-Logarithmic-Loss

MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

Simulation – Gauß-Prozesse

- Generalisierung
 - Setzen der Noise-Varianz
 - Kernel-Skalierung
 - Verlustberechnung



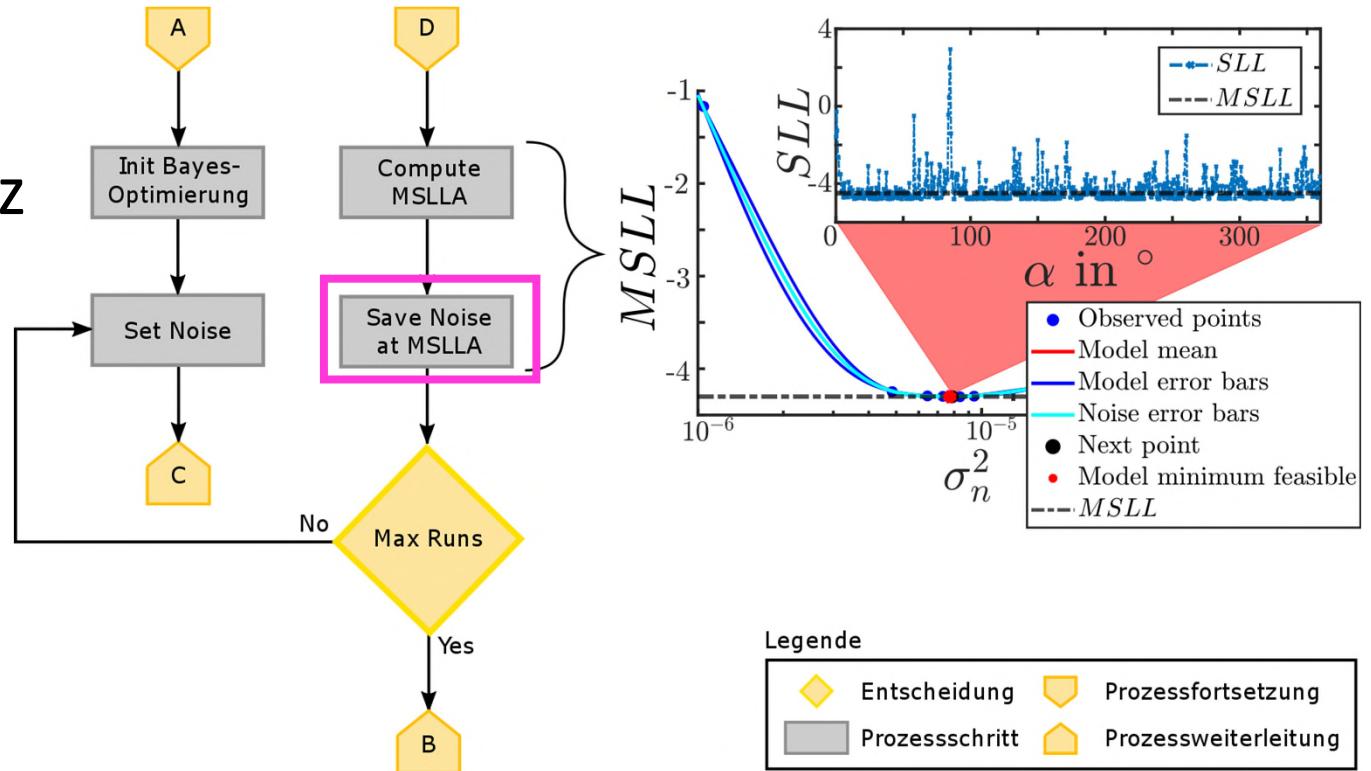
SLL – Standardized-Logarithmic-Loss

MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

Simulation – Gauß-Prozesse

- Generalisierung
 - Setzen der Noise-Varianz
 - Kernel-Skalierung
 - Verlustberechnung
 - Speichern



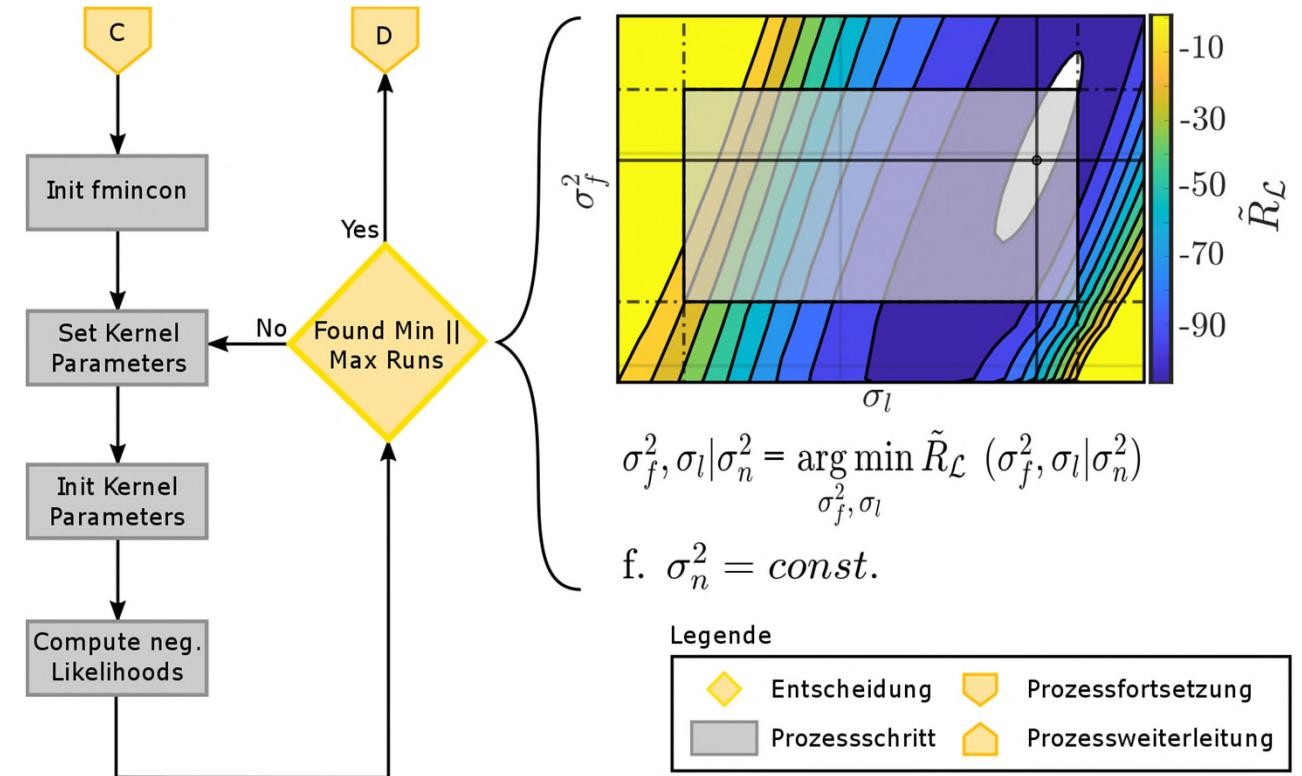
SLL – Standardized-Logarithmic-Loss

MSLL – Mean-Standardized-Logarithmic-Loss

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

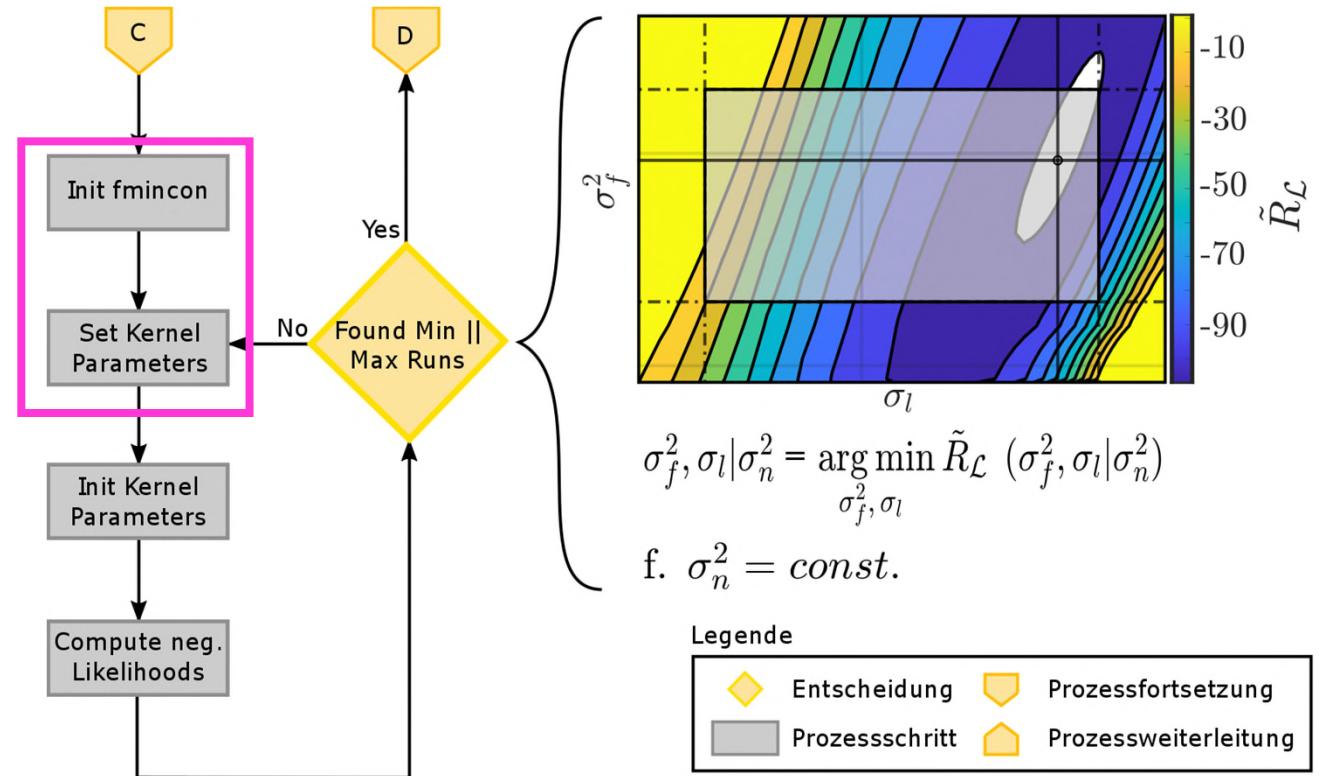
Simulation – Gauß-Prozesse

- Kernel-Skalierung



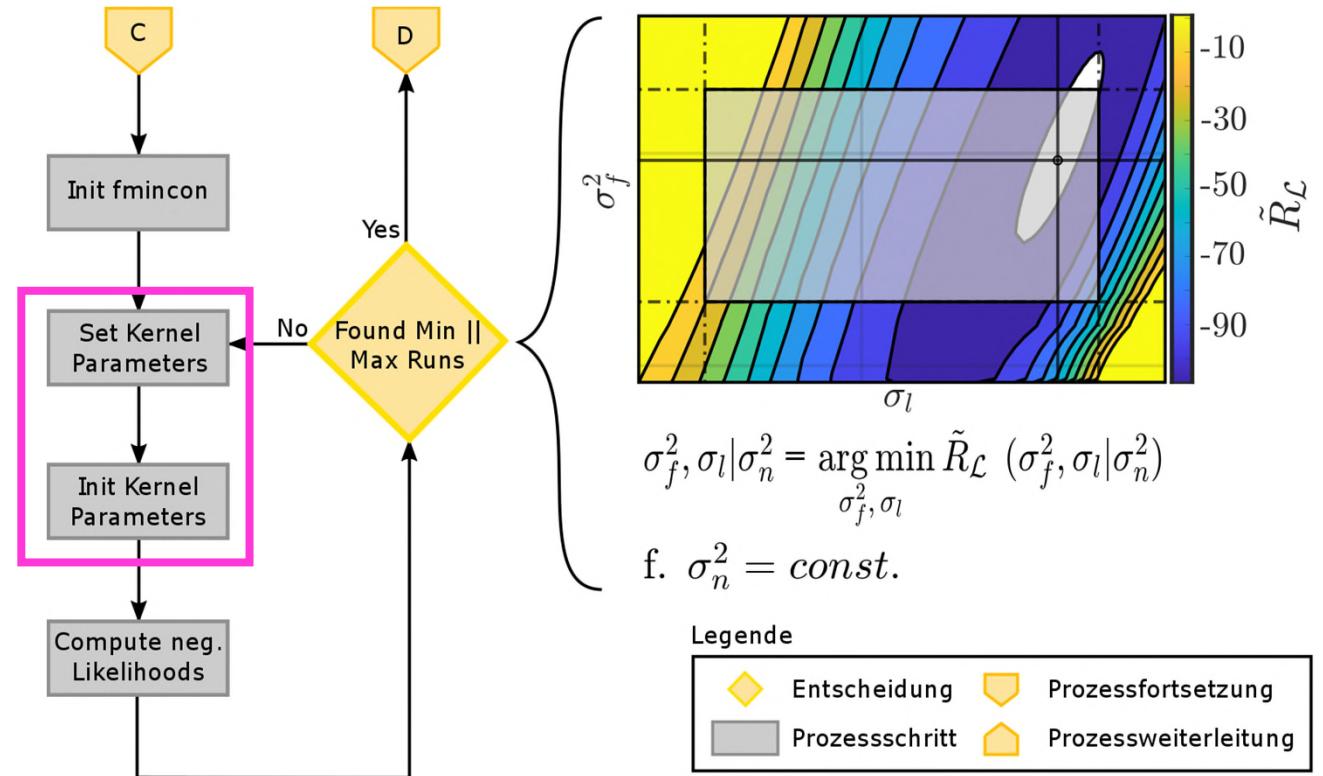
Simulation – Gauß-Prozesse

- Kernel-Skalierung
 - Setzen der Parameter



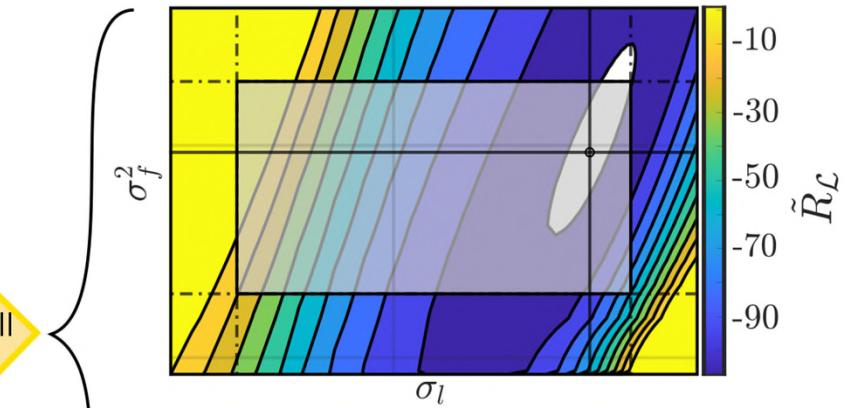
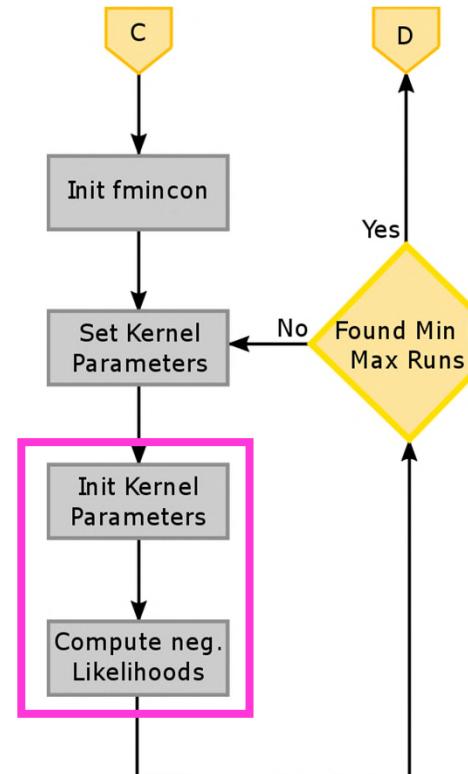
Simulation – Gauß-Prozesse

- Kernel-Skalierung
 - Setzen der Parameter
 - Teilreinitialisierung



Simulation – Gauß-Prozesse

- Kernel-Skalierung
 - Setzen der Parameter
 - Teilreinitialisierung
 - Plausibilitätsberechnung



$$\sigma_f^2, \sigma_l | \sigma_n^2 = \arg \min_{\sigma_f^2, \sigma_l} \tilde{R}_{\mathcal{L}} (\sigma_f^2, \sigma_l | \sigma_n^2)$$

$$\text{f. } \sigma_n^2 = \text{const.}$$

Legende

	Entscheidung		Prozessfortsetzung
	Prozessschritt		Prozessweiterleitung

- Arbeitsphase

- Arbeitsphase
 - Ausrichtung des Modells wird von Innen nach Außen umgelegt

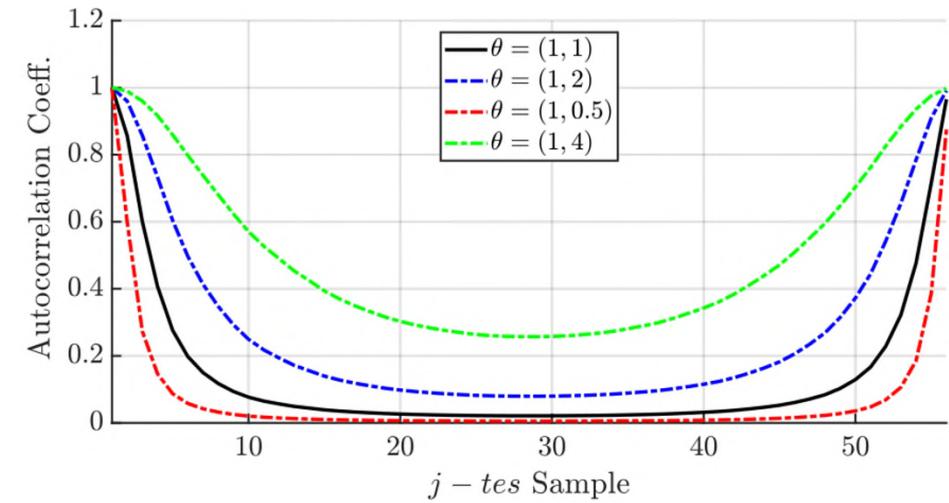
- Arbeitsphase
 - Ausrichtung des Modells wird von Innen nach Außen umgelegt
 - Minimale Parametrierung und funktionaler Aufbau der Vorhersage

- Arbeitsphase
 - Ausrichtung des Modells wird von Innen nach Außen umgelegt
 - Minimale Parametrierung und funktionaler Aufbau der Vorhersage
 - Vorhersage ausgeführt Frame für Frame oder blockweise

- Arbeitsphase
 - Ausrichtung des Modells wird von Innen nach Außen umgelegt
 - Minimale Parametrierung und funktionaler Aufbau der Vorhersage
 - Vorhersage ausgeführt Frame für Frame oder blockweise
 - Ergebnisse, Derivate und Qualitätskriterien als Vektoren ausgegeben

Erprobungsexperimente

- Skalierung der Kovarianzfunktion



— SLLA	- - SLLR	— MSLLA	- - MSLLR
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SLLA – Standardized-Logarithmic-Loss-Angle

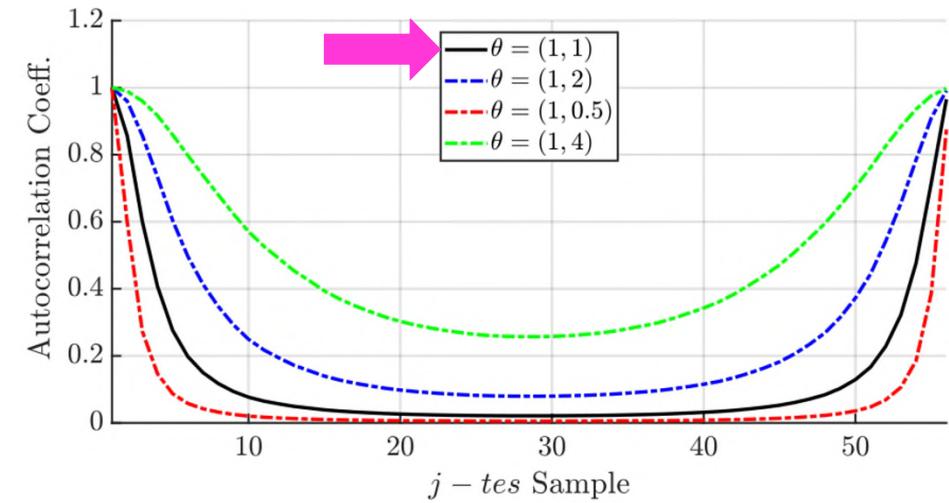
SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung



— SLLA --- SLLR — MSLLA - MSLLR

SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Ausgeschaltet



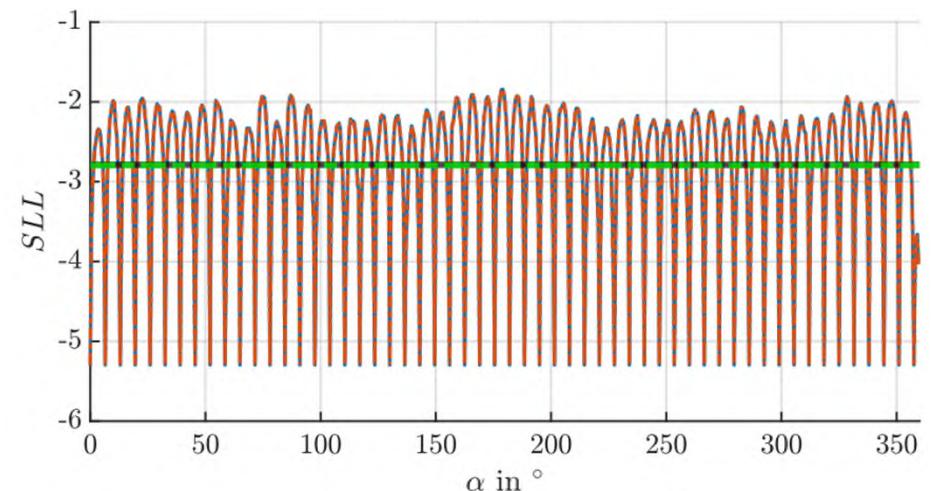
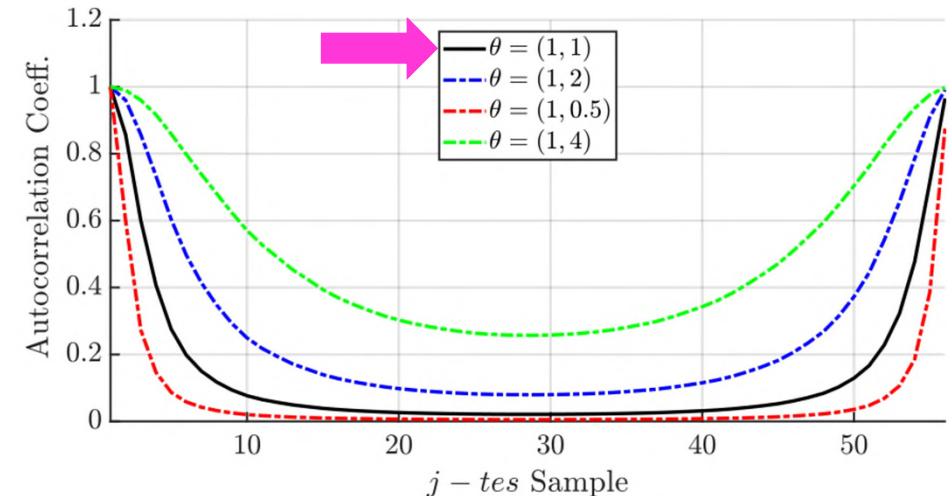
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Ausgeschaltet



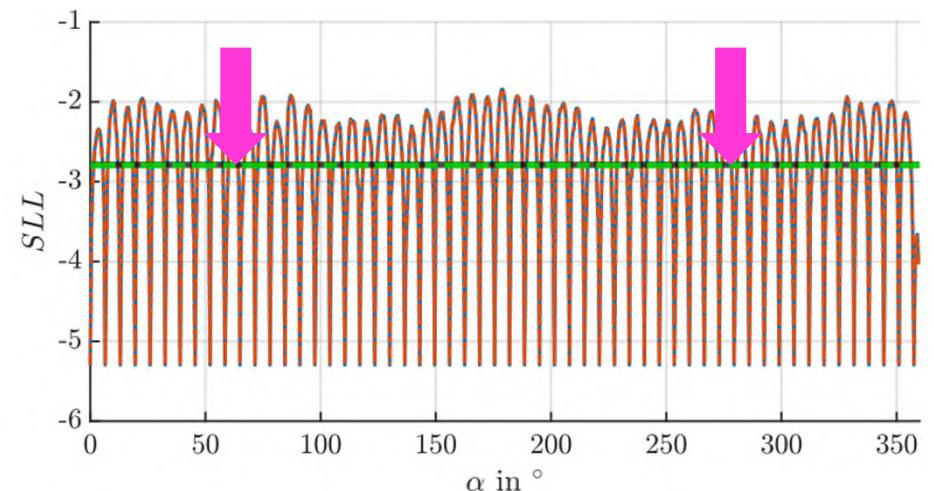
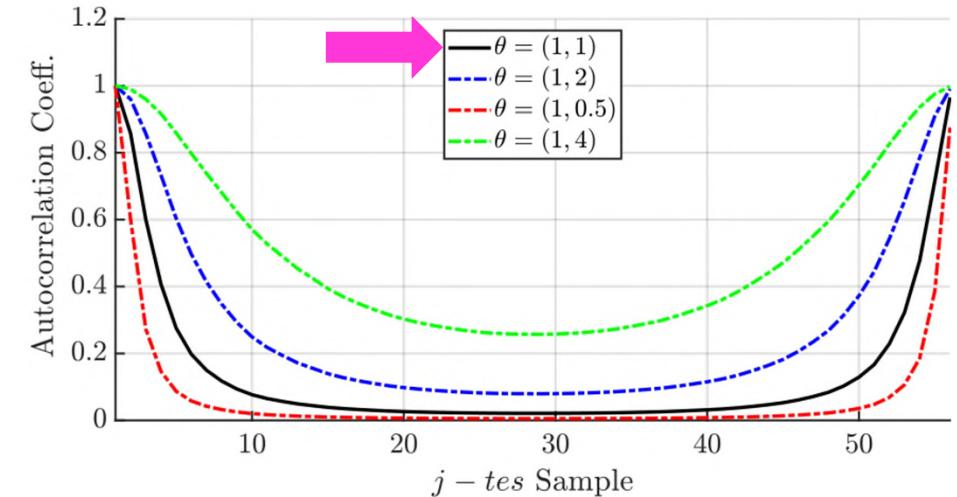
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Verschlechtert

SLLA	SLLR	MSLLA	MSLLR
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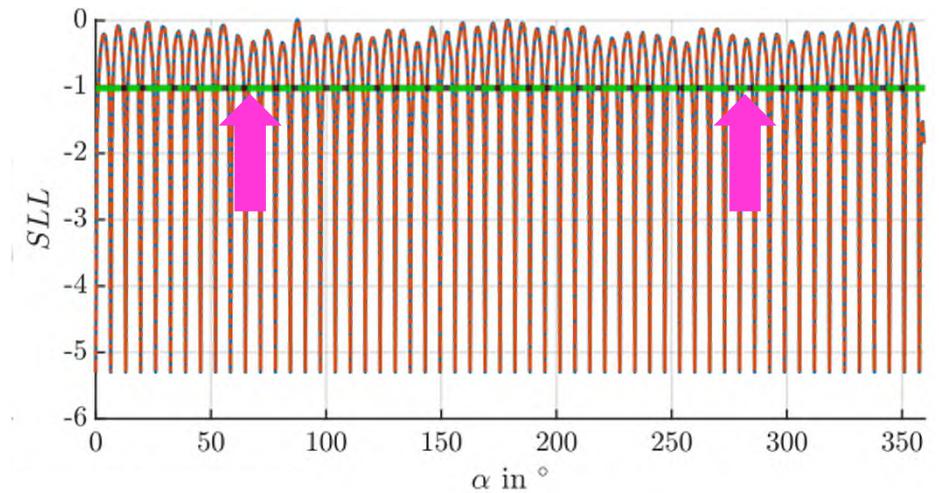
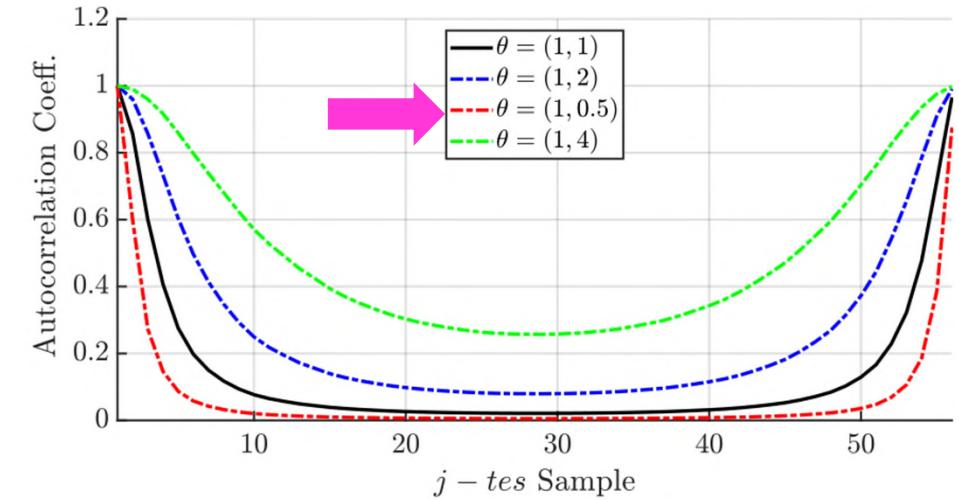
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Verbessert



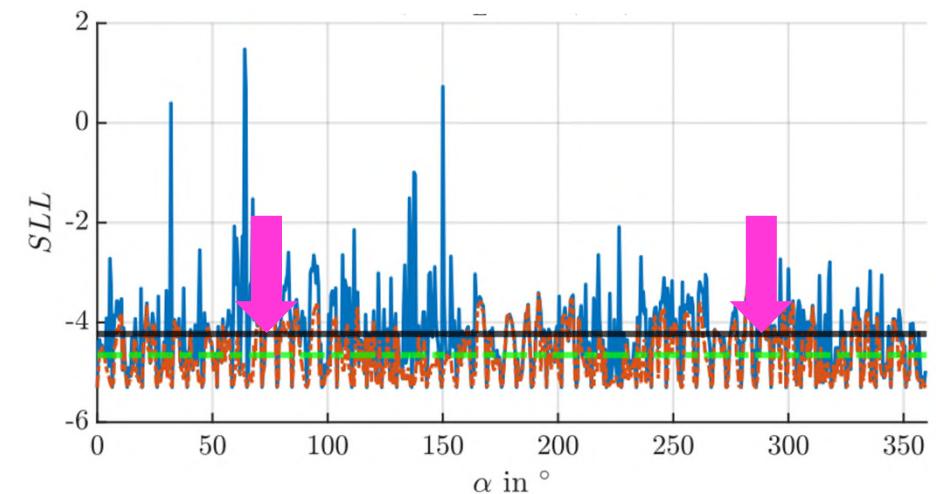
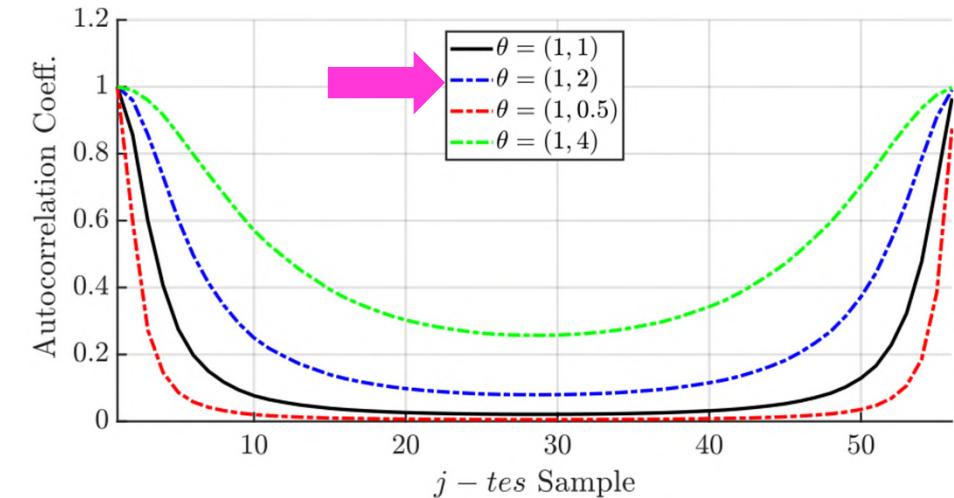
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Verbessert



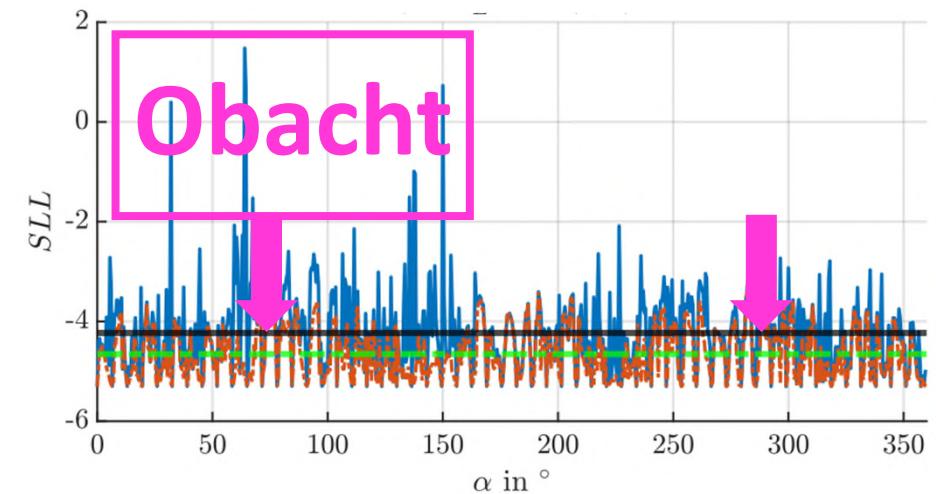
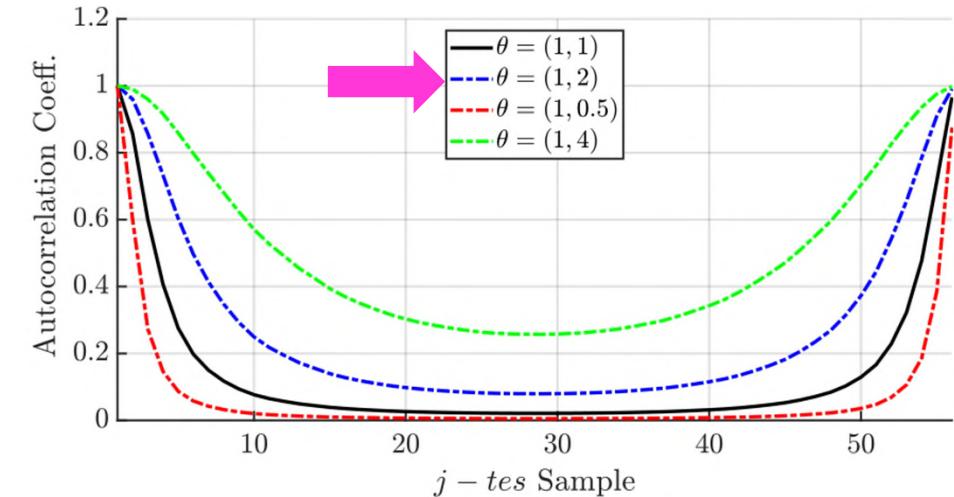
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Optimierbar



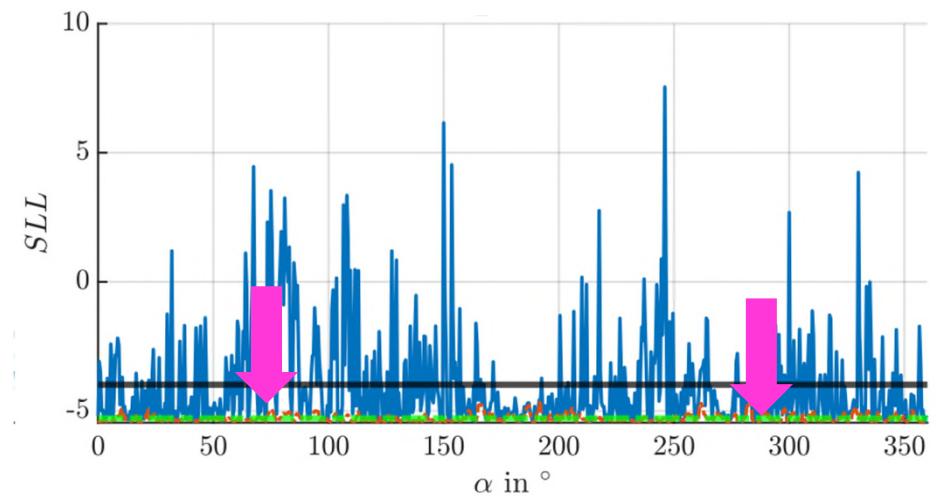
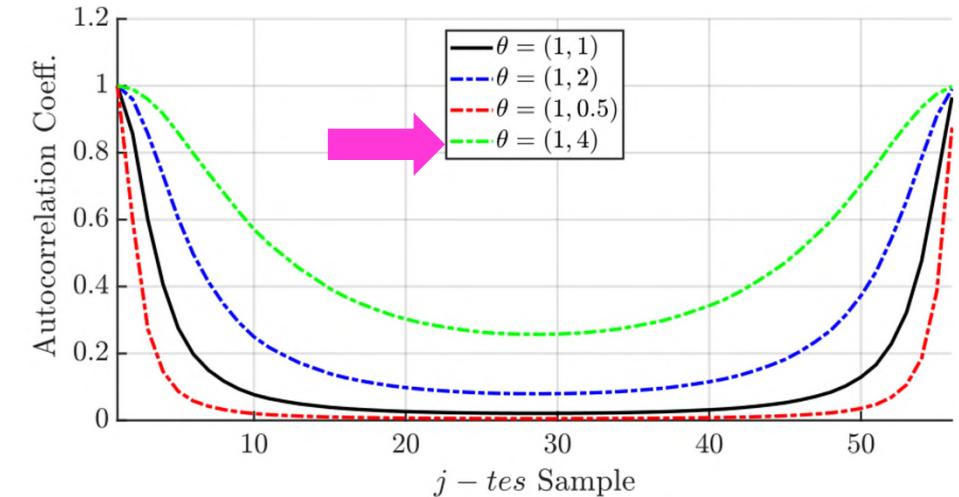
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

- Skalierung der Kovarianzfunktion
 - Empirisch ohne Optimierung
 - Bewertung der Generalisierung

Optimierbar



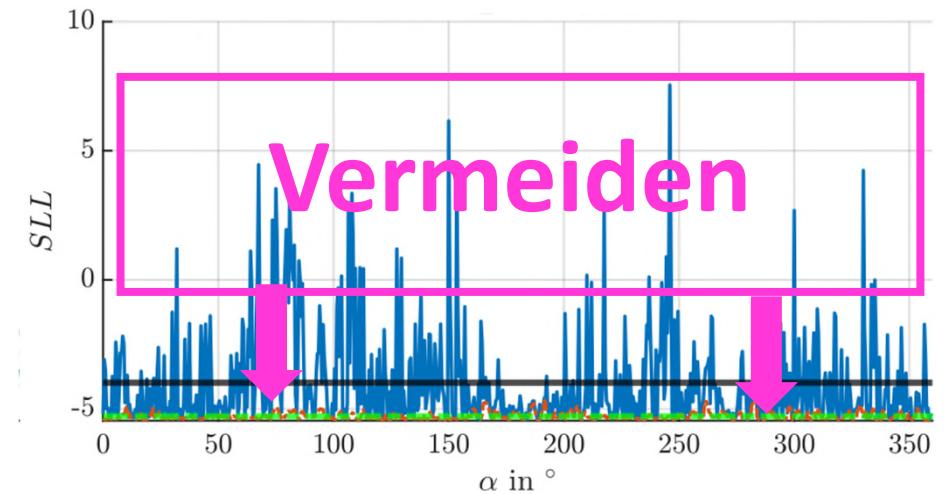
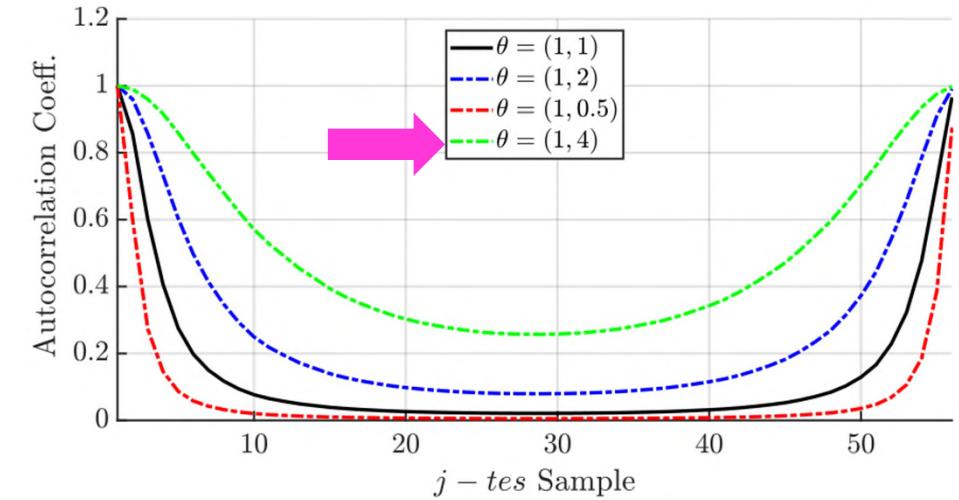
SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

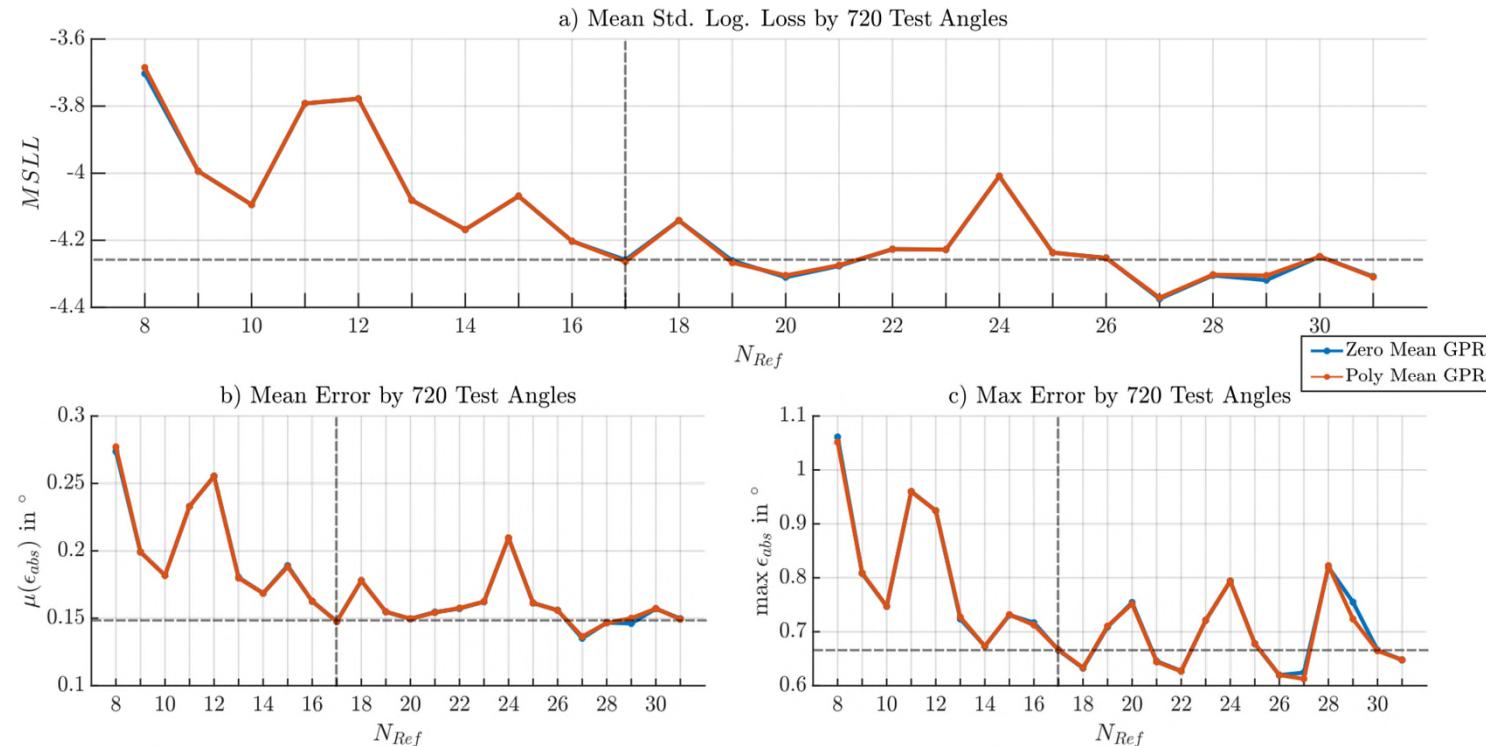
MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

02.07.2021



Erprobungsexperimente

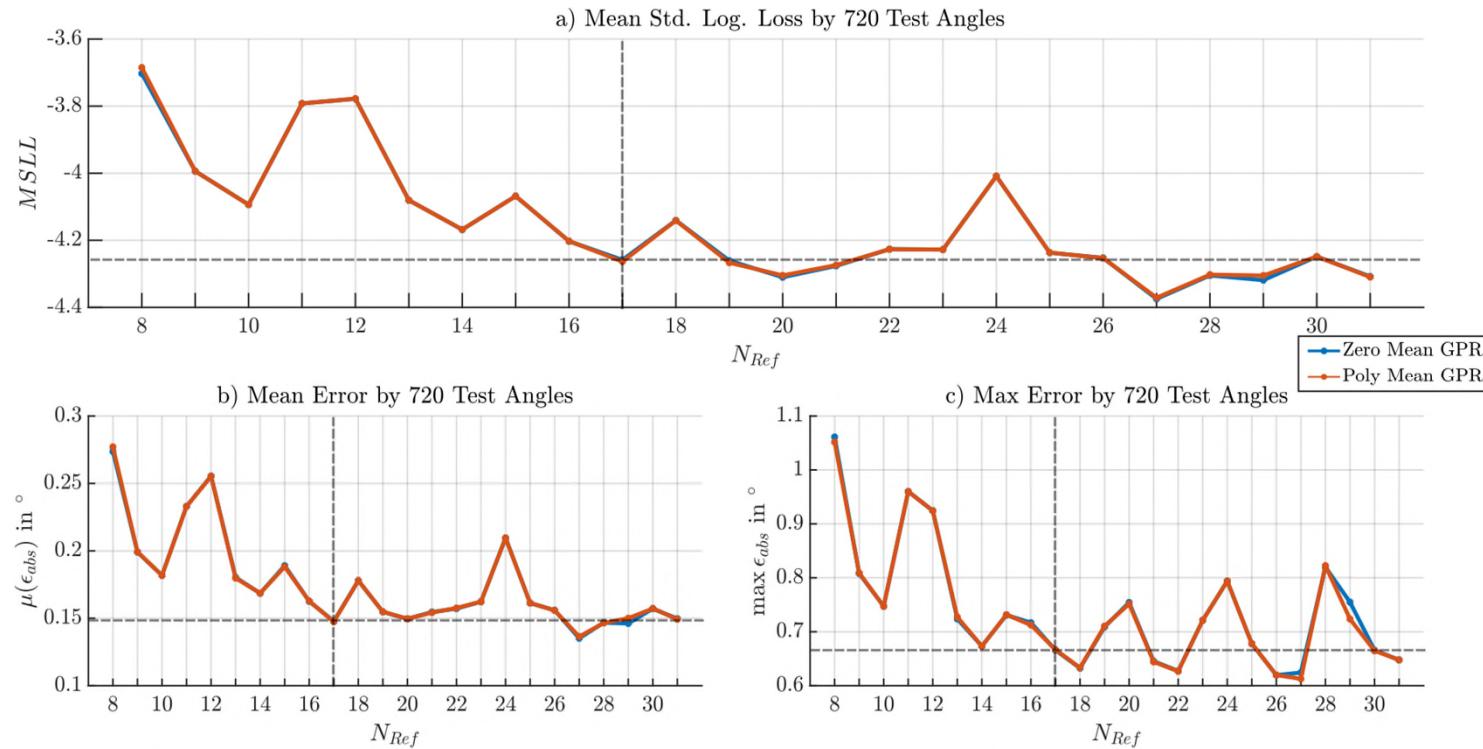
- Kompromissbildung



MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

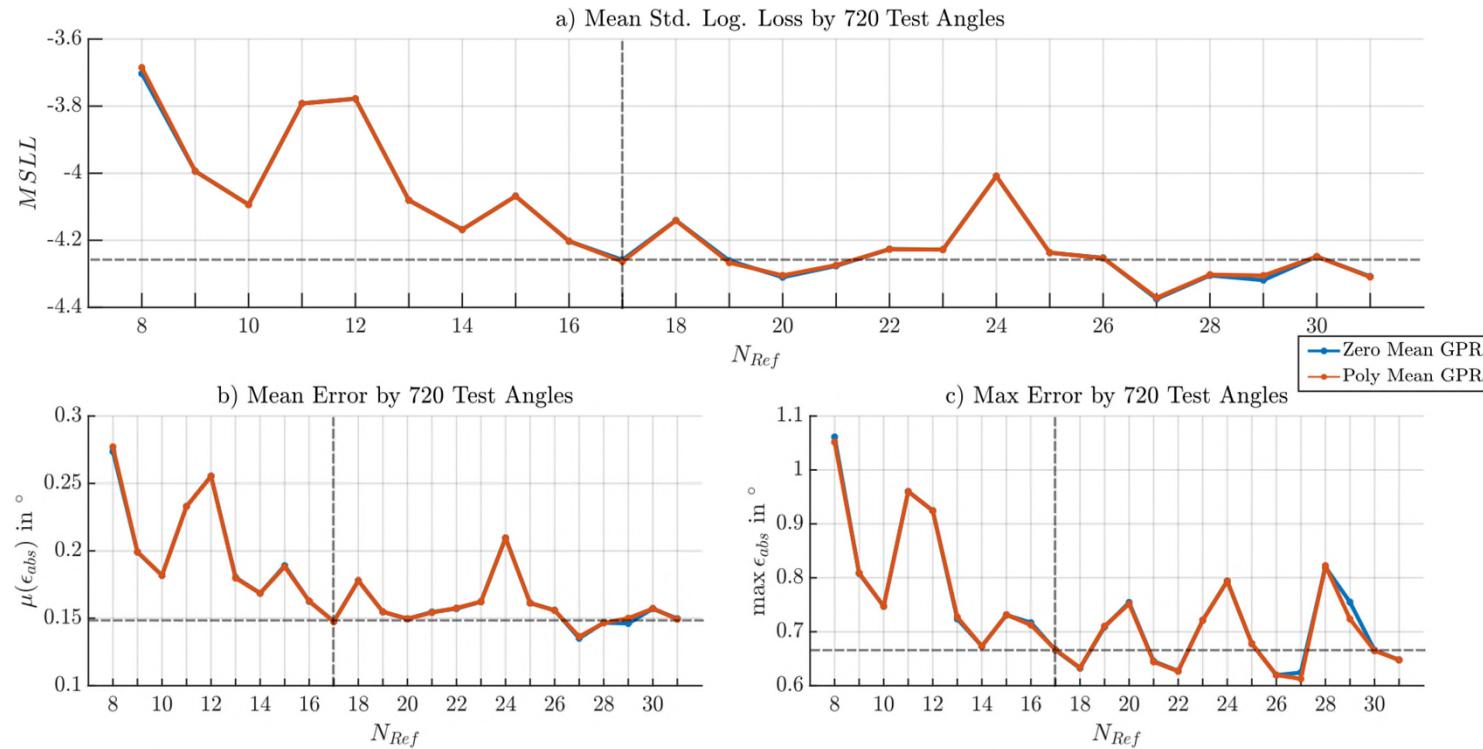
- Kompormissbildung
 - Optimierung zusschalten



MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

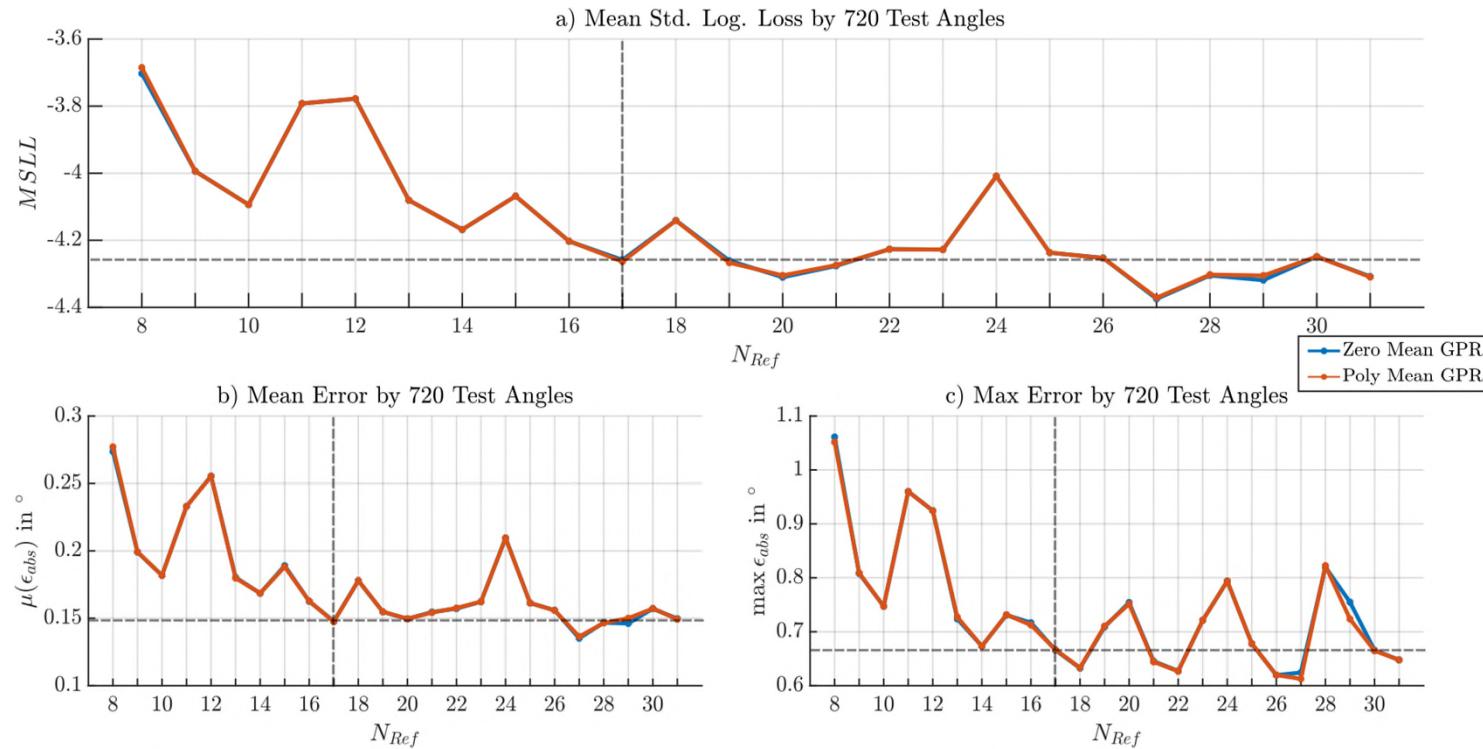
- Kompromissbildung
 - Optimierung zusschalten
 - Ressourceneinsparung



MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

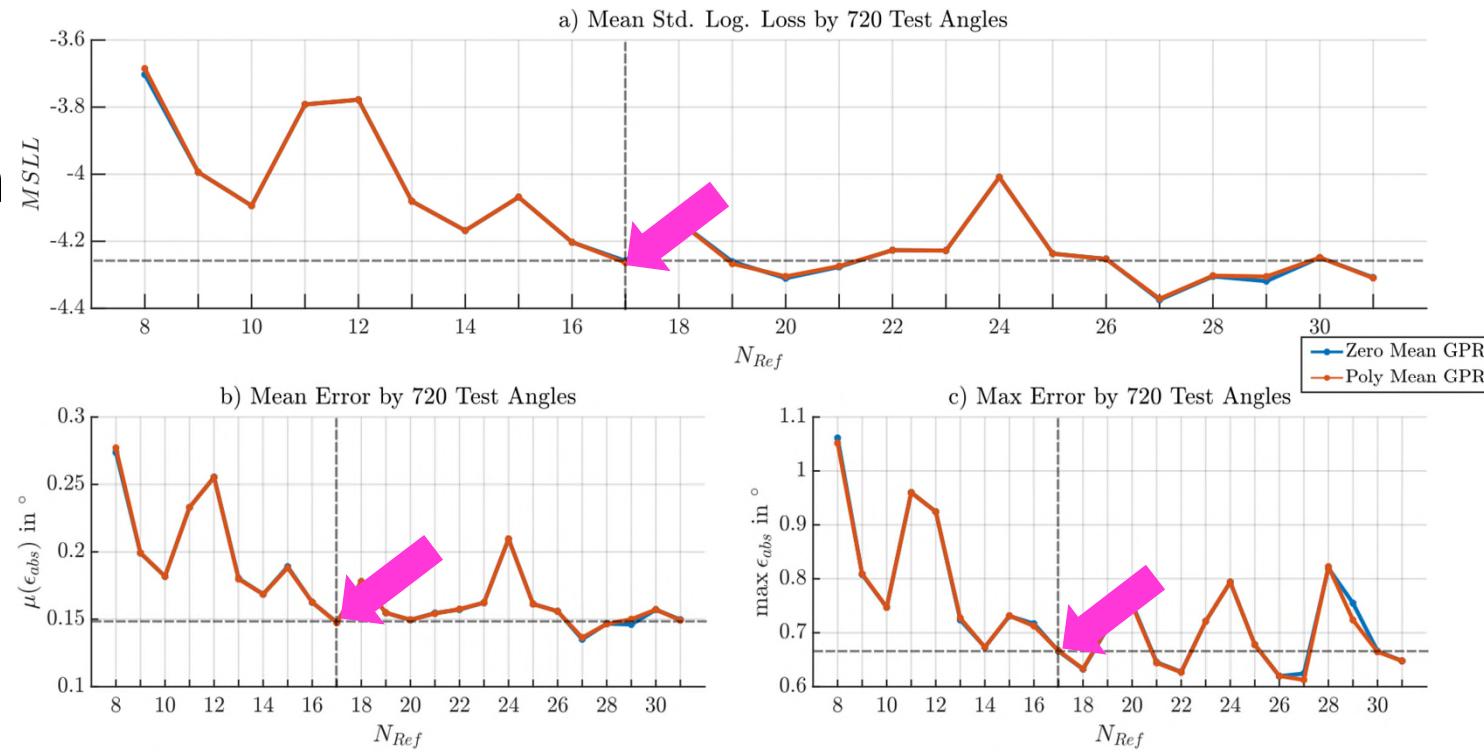
- Kompromissbildung
 - Optimierung zusschalten
 - Ressourceneinsparung
 - Aufwandabschätzung



MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

- Kompromissbildung
 - Optimierung zusschalten
 - Ressourceneinsparung
 - Aufwandabschätzung
 - Gleichgewicht zwischen Fehlern und Verlusten

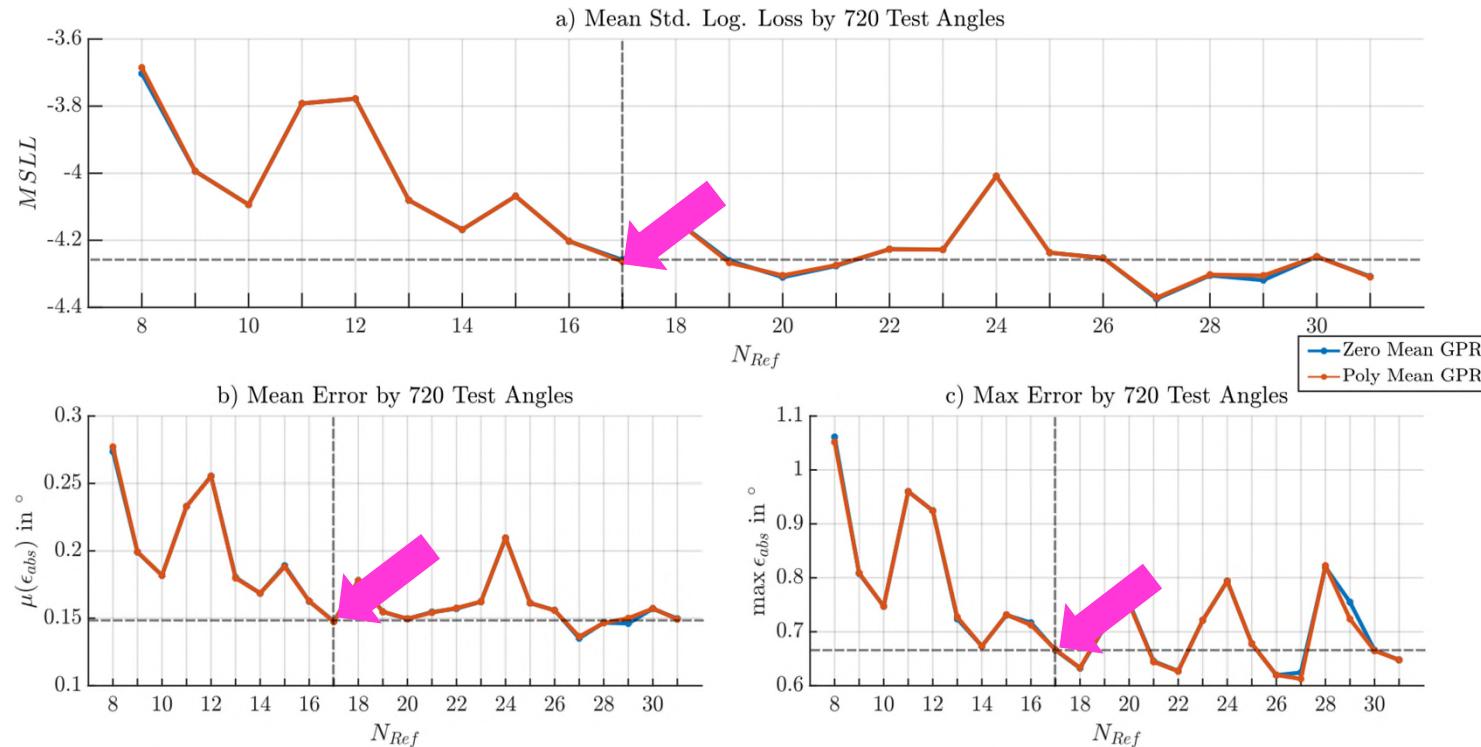


MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

17 Referenzwinkel

- Kompromissbildung
 - Optimierung zusschalten
 - Ressourceneinsparung
 - Aufwandabschätzung
 - Gleichgewicht zwischen Fehlern und Verlusten



MSLL – Mean-Standardized-Logarithmic-Loss

Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



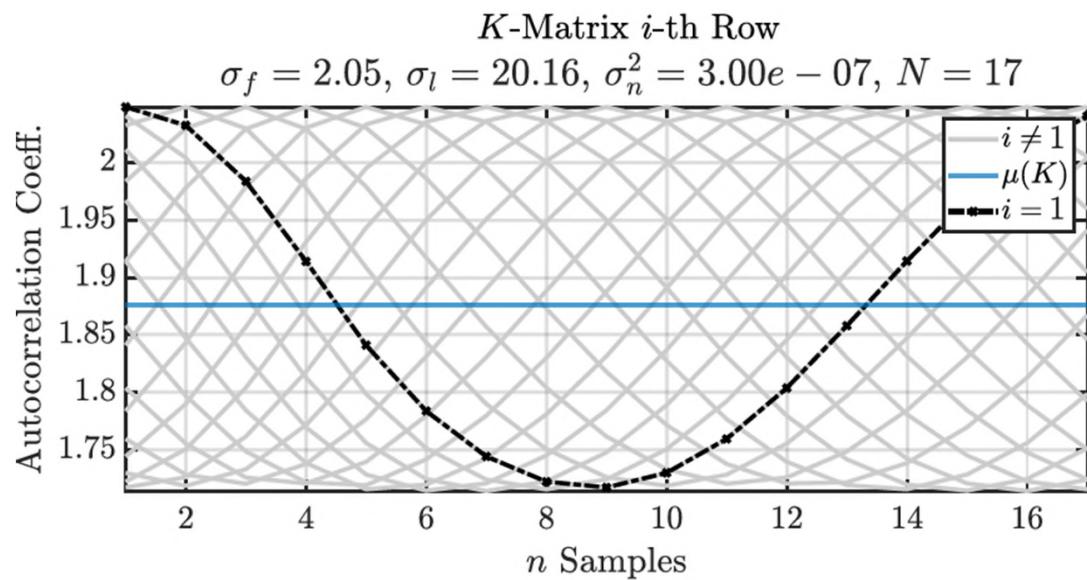
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

- Verschoben in X-/ Y-Richtung
- Abstand verringert
- Magnet verkippt

Erprobungsexperimente

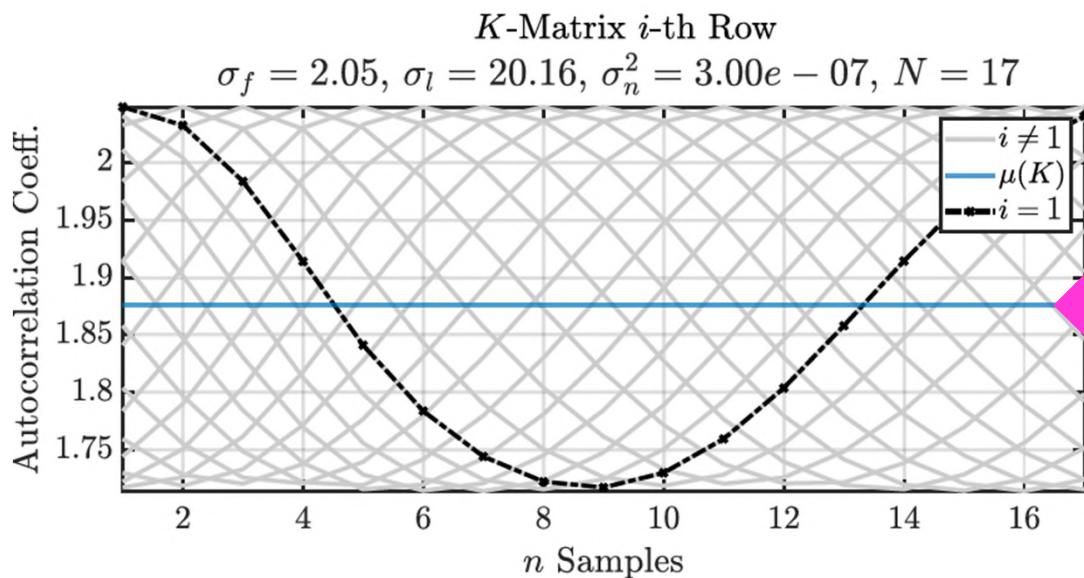
Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



- Verschoben in X-/ Y-Richtung
- Abstand verringert
- Magnet verkippt

Erprobungsexperimente

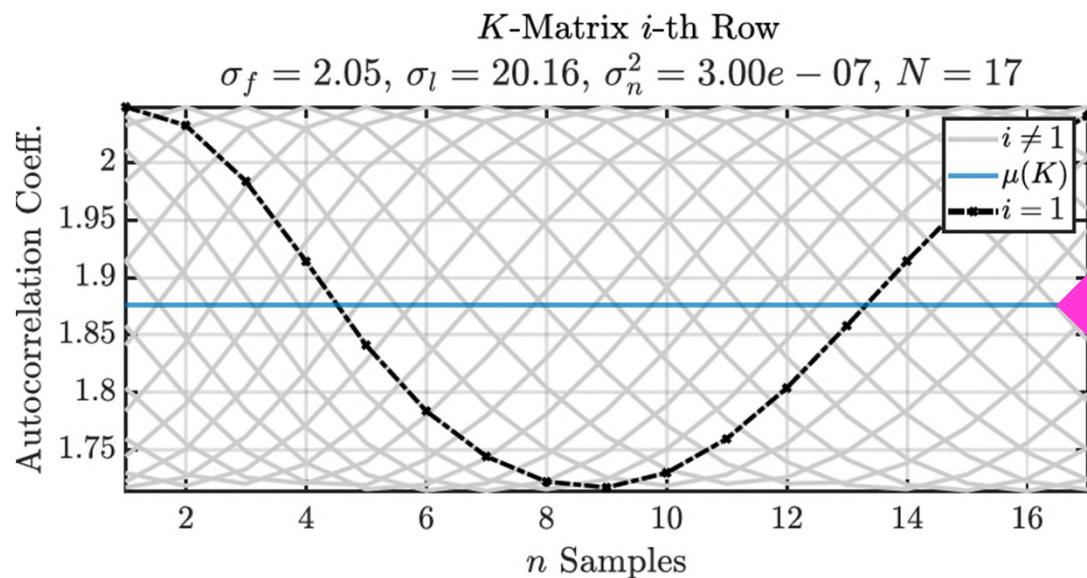
Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



- Verschoben in X-/ Y-Richtung
- Abstand verringert
- Magnet verkippt
- Ausgleich zwischen Referenzen

Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

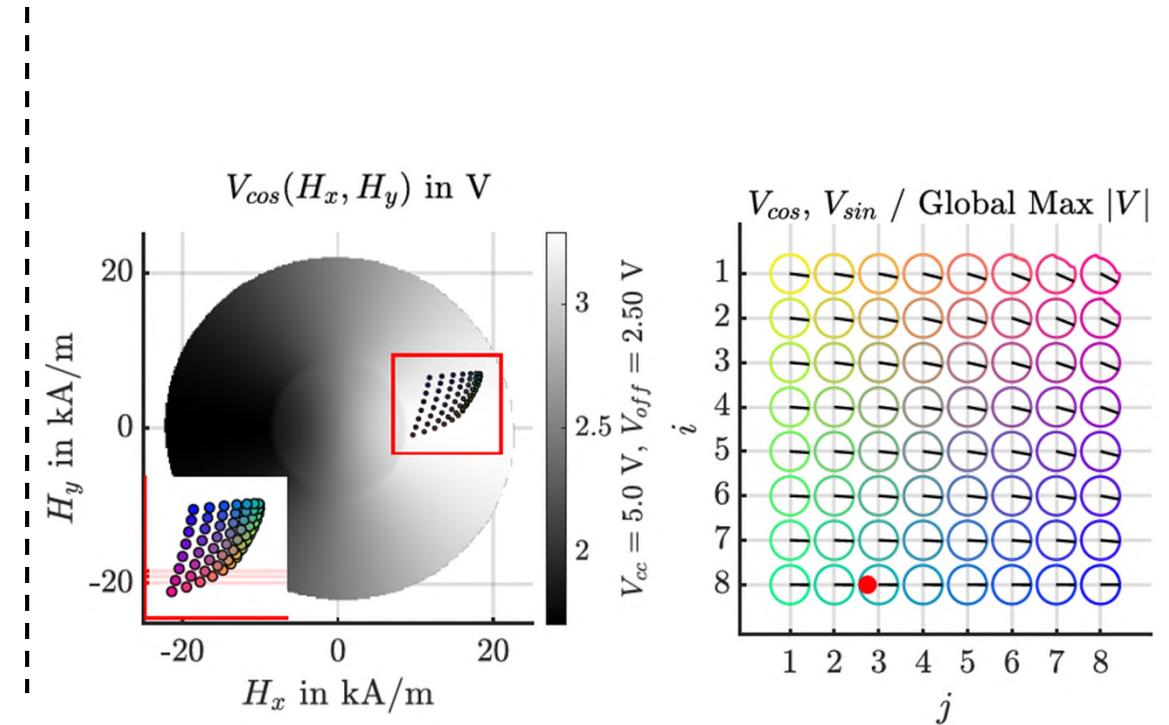
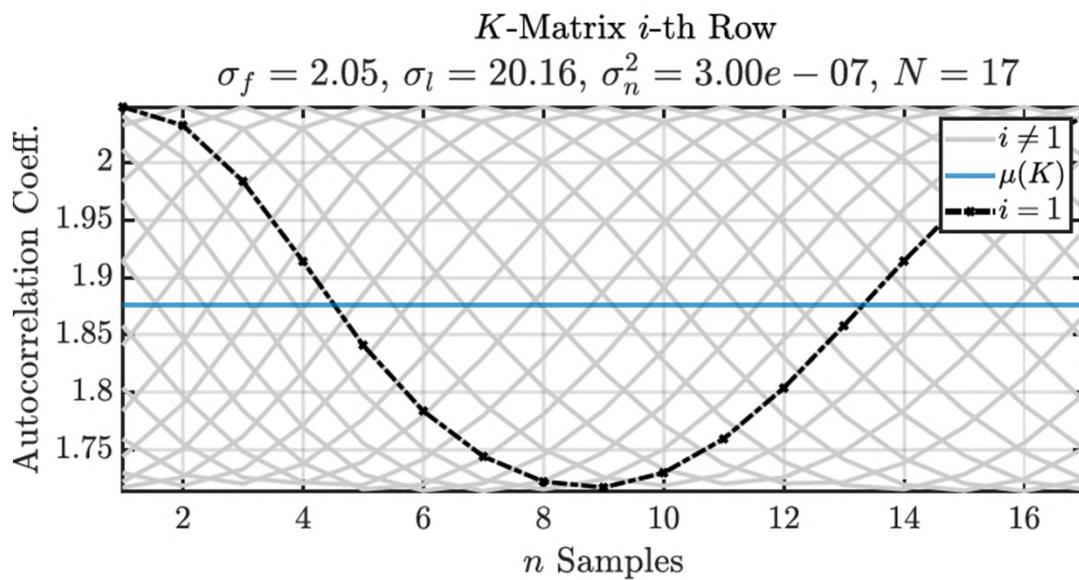


- Verschoben in X-/ Y-Richtung
- Abstand verringert
- Magnet verkippt
- Ausgleich zwischen Referenzen
- Skalierung ca. 1:10

Gute Voraussetzungen

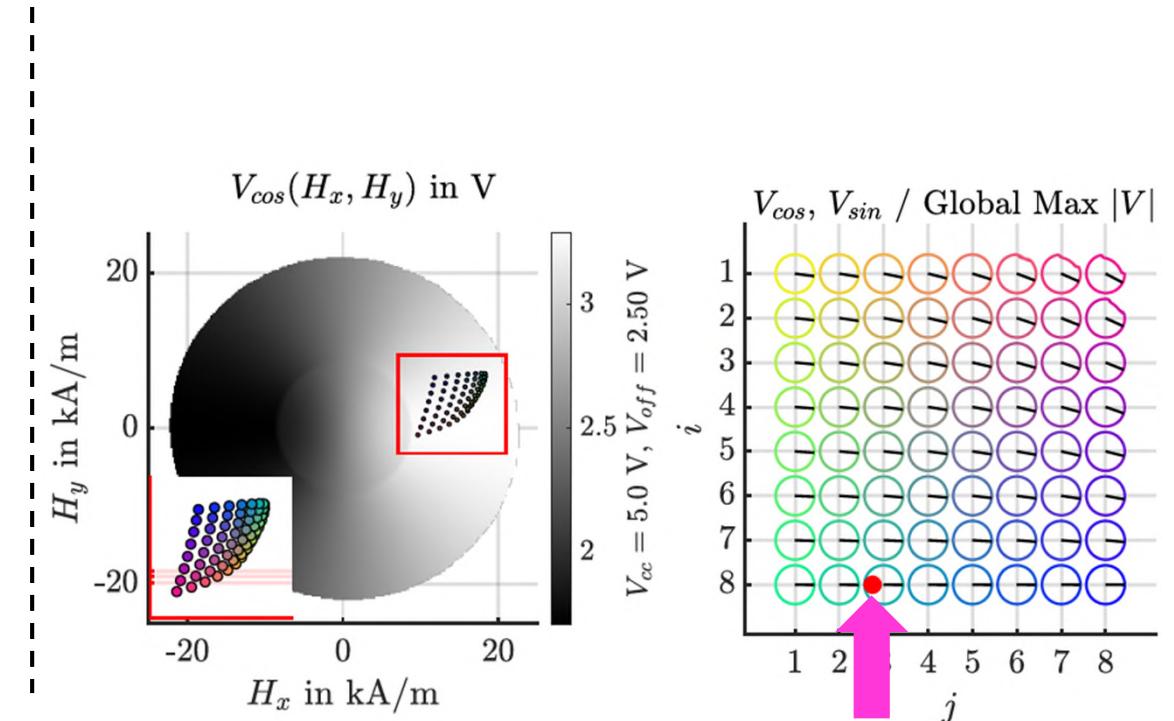
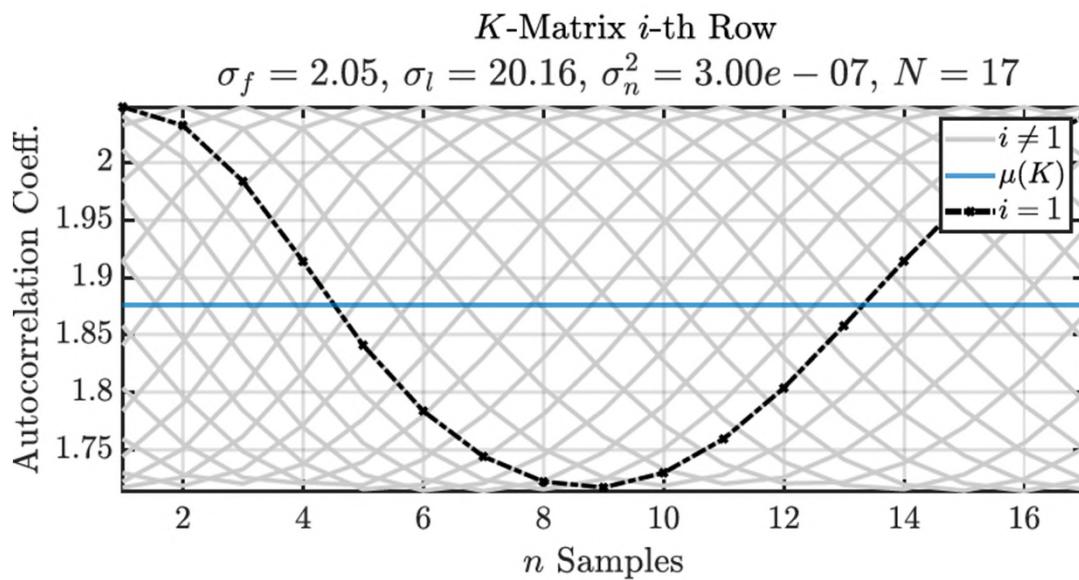
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



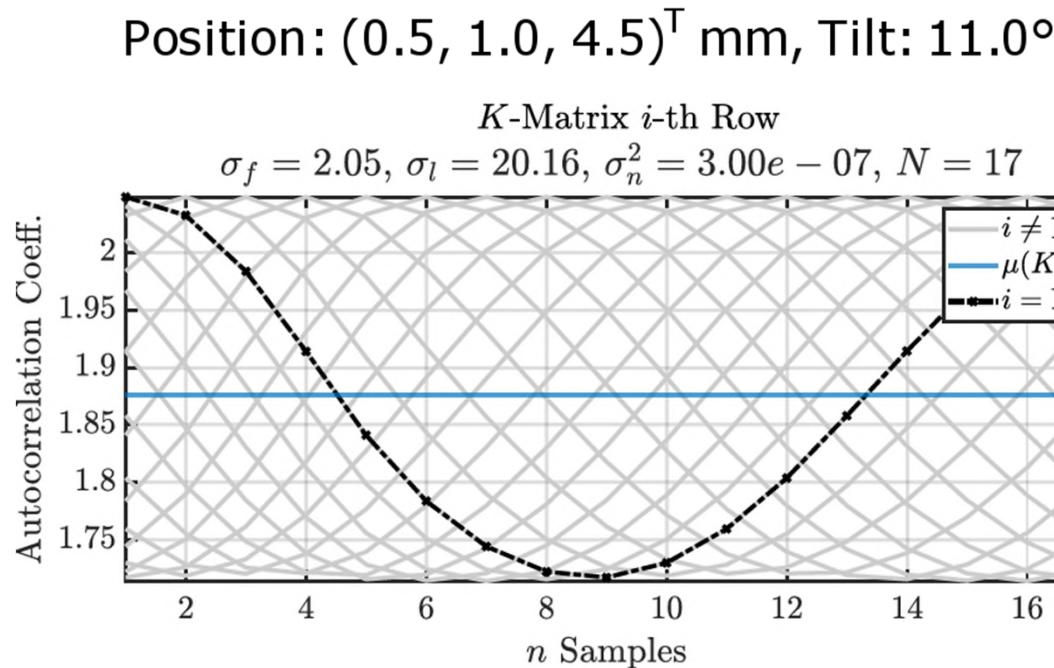
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



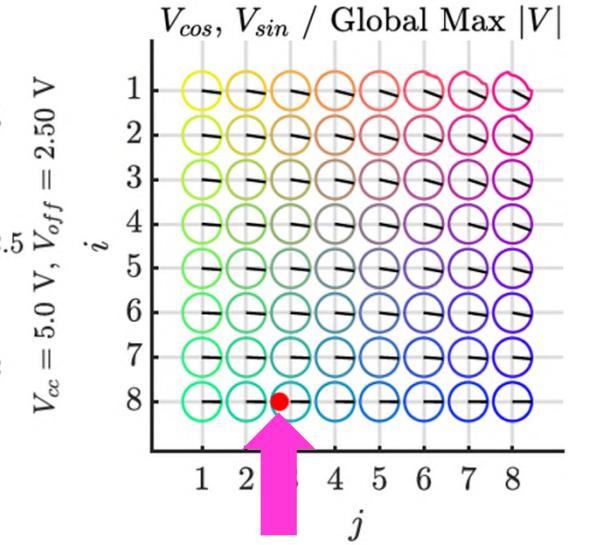
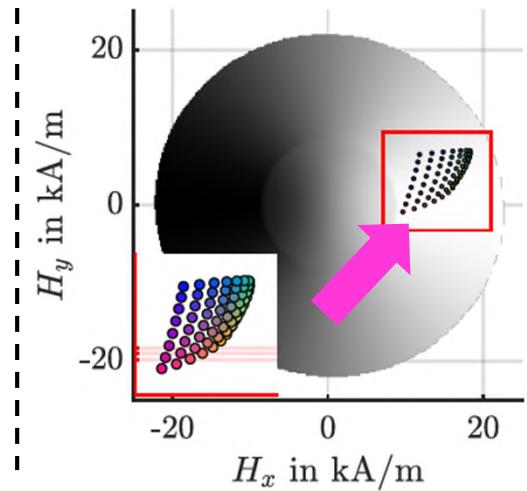
Magnet in Randlag
zum Array

Erprobungsexperimente



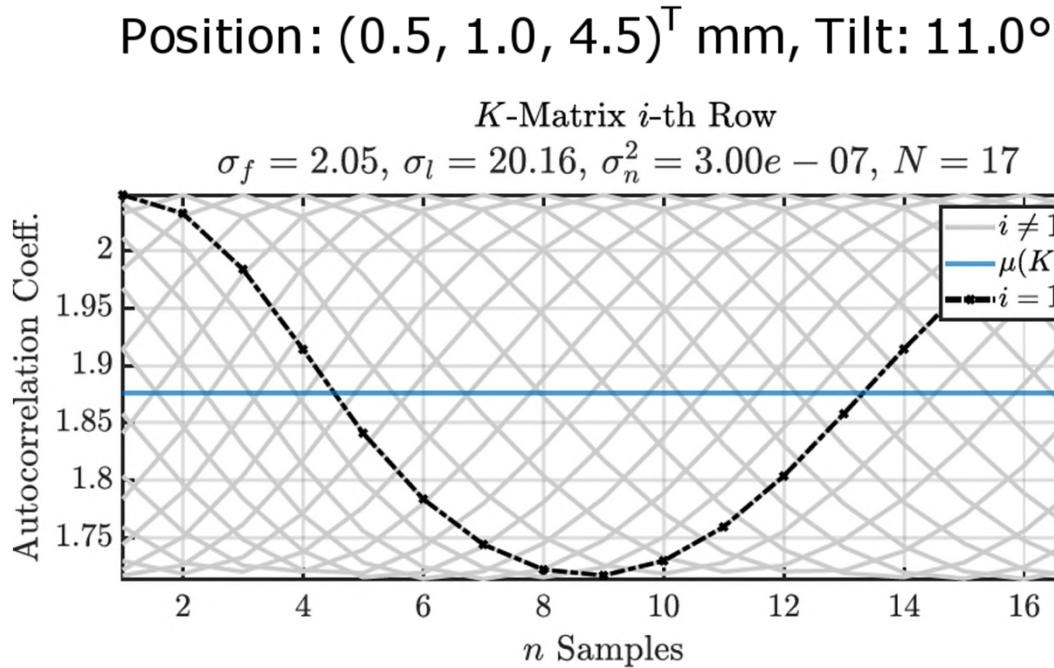
Sättigung +
Streuung

$V_{cos}(H_x, H_y)$ in V



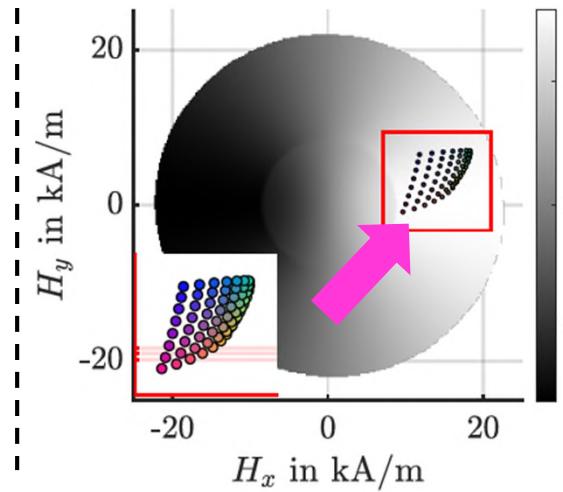
Magnet in Randlag
zum Array

Erprobungsexperimente

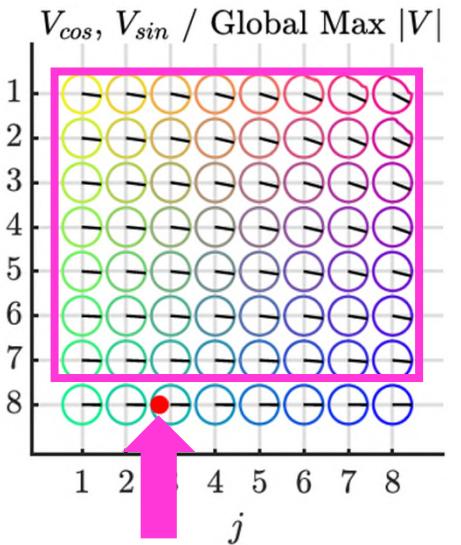


Sättigung +
Streuung

$V_{cos}(H_x, H_y)$ in V

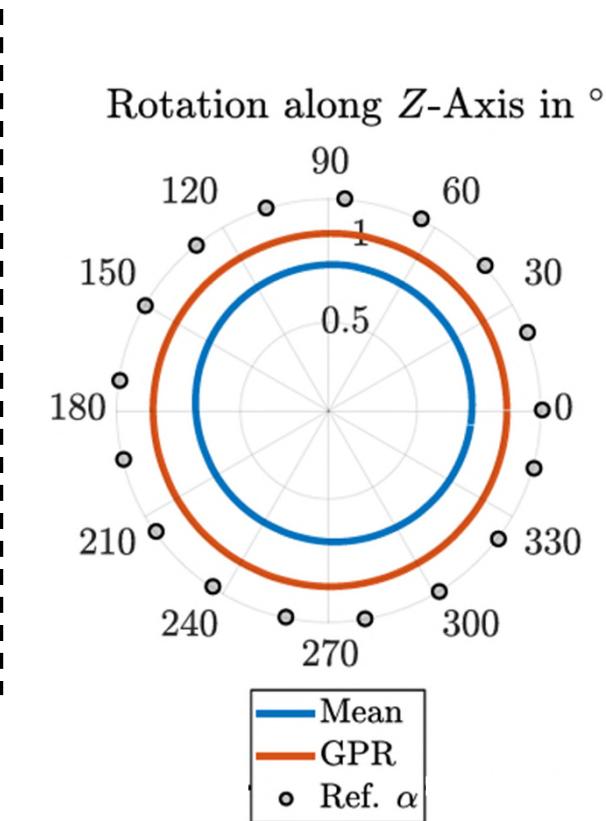
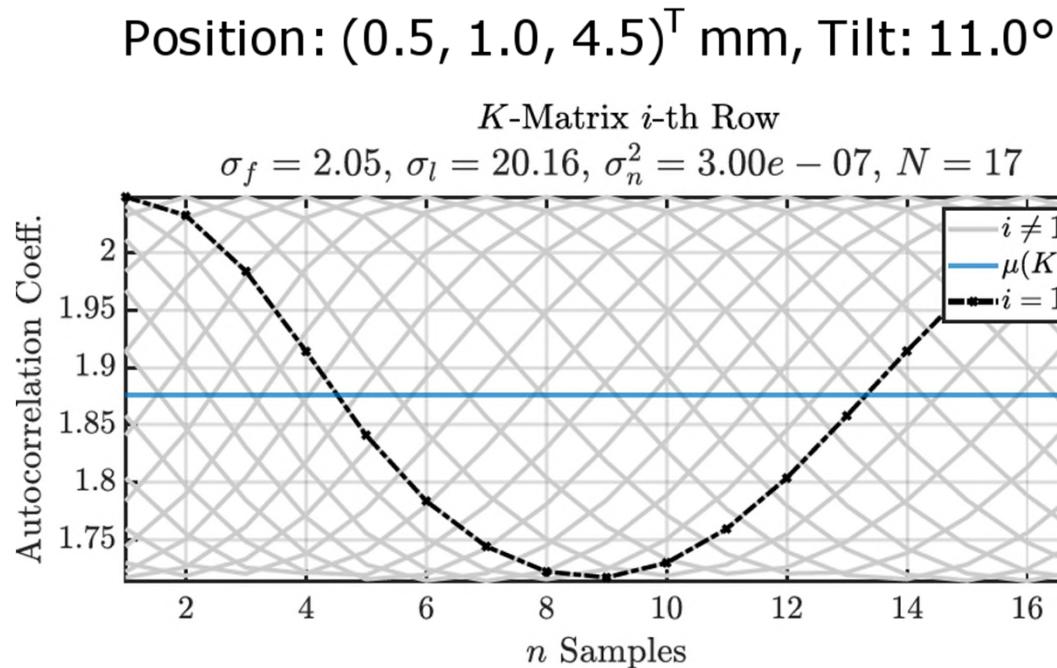


Verfälschte Winkel

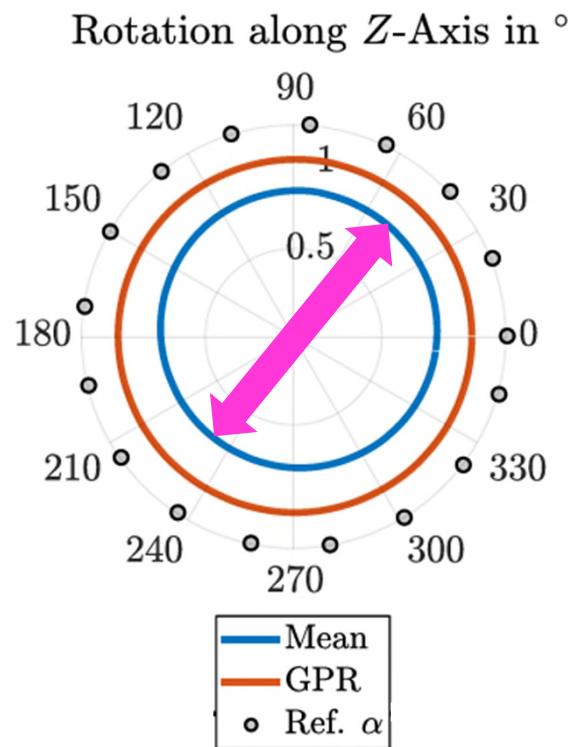
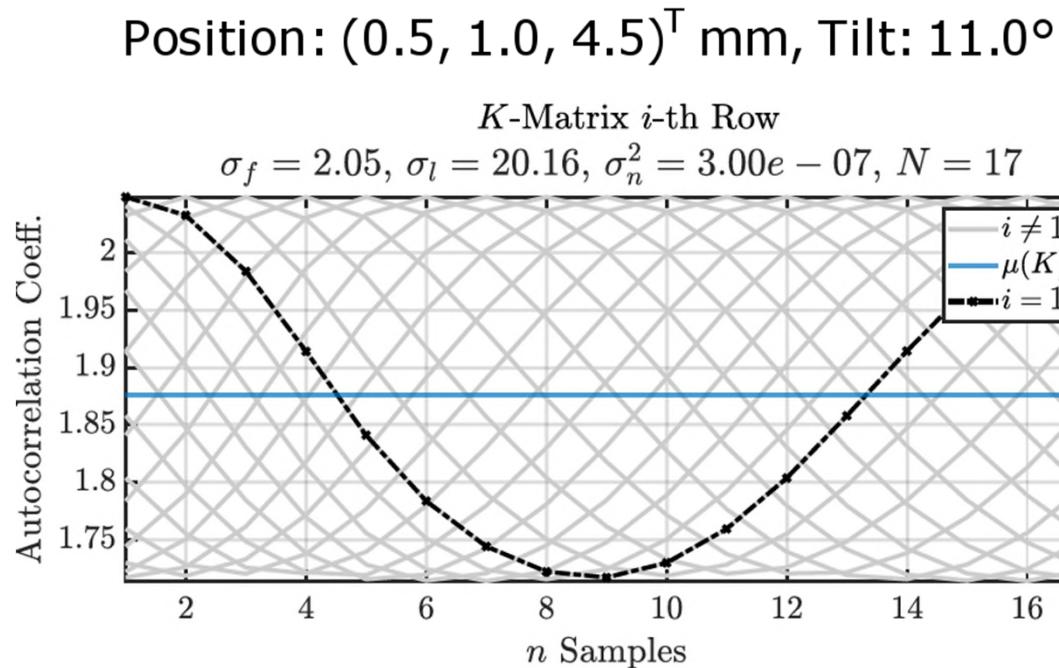


Magnet in Randlag
zum Array

Erprobungsexperimente

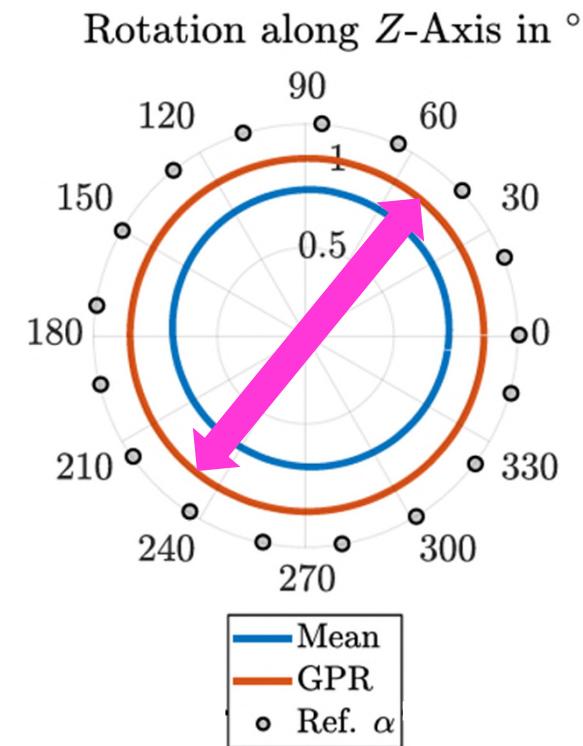
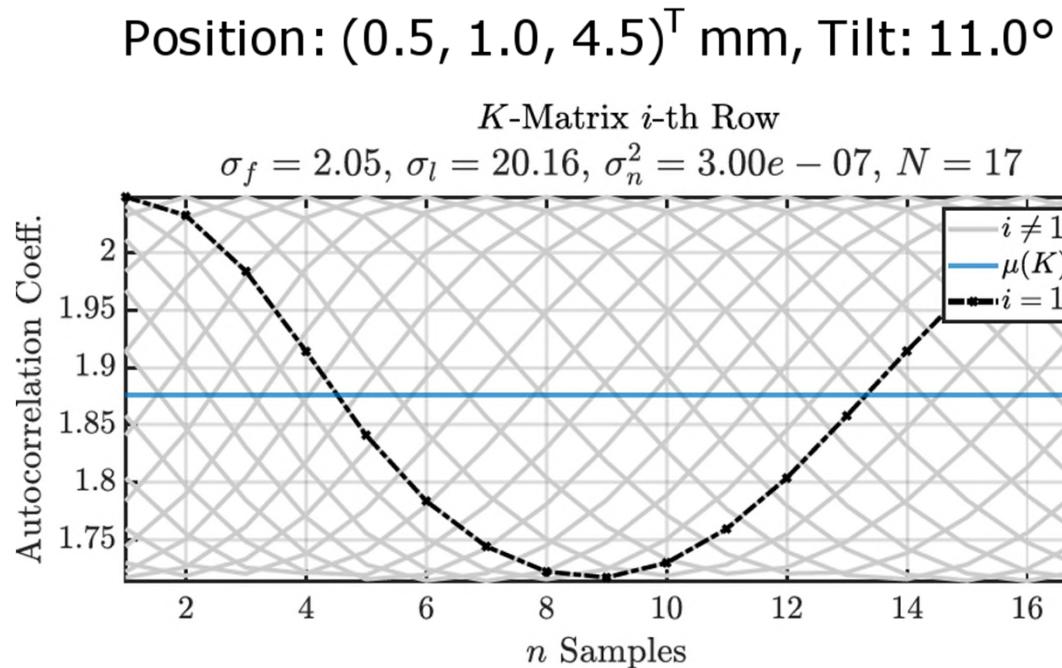


Erprobungsexperimente



- Einfacher Mittelwert verschoben

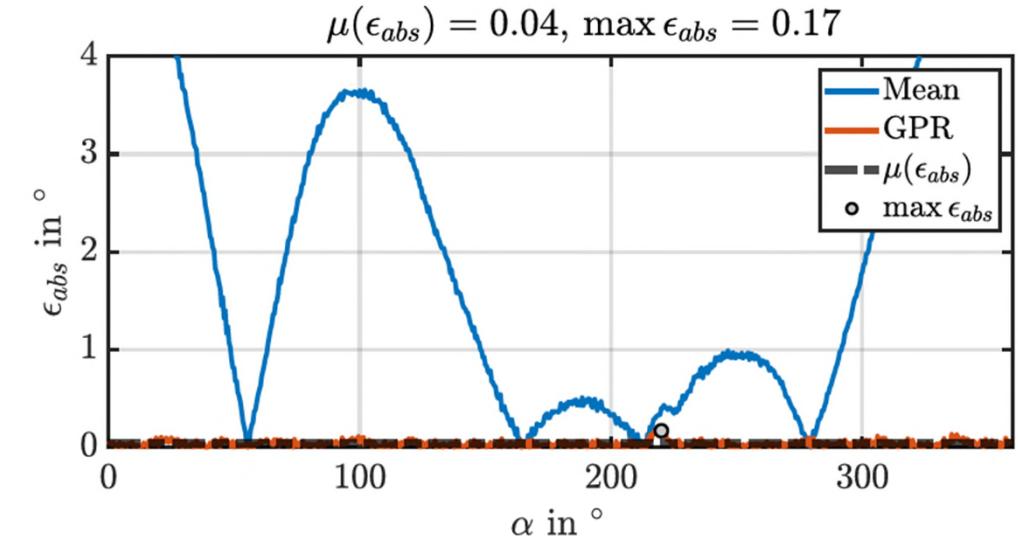
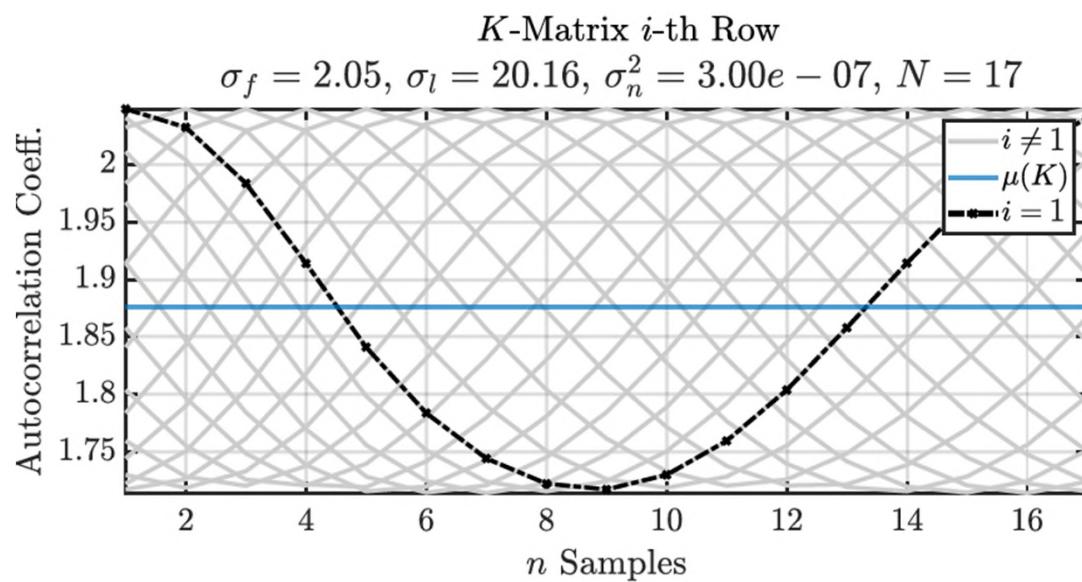
Erprobungsexperimente



- Einfacher Mittelwert verschoben
- Regression schafft den Ausgleich

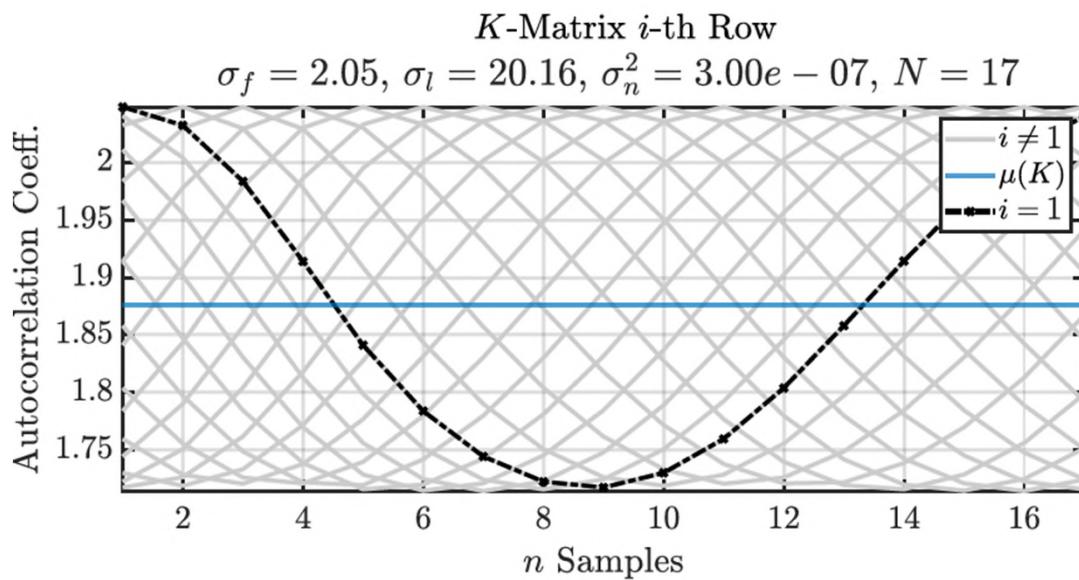
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

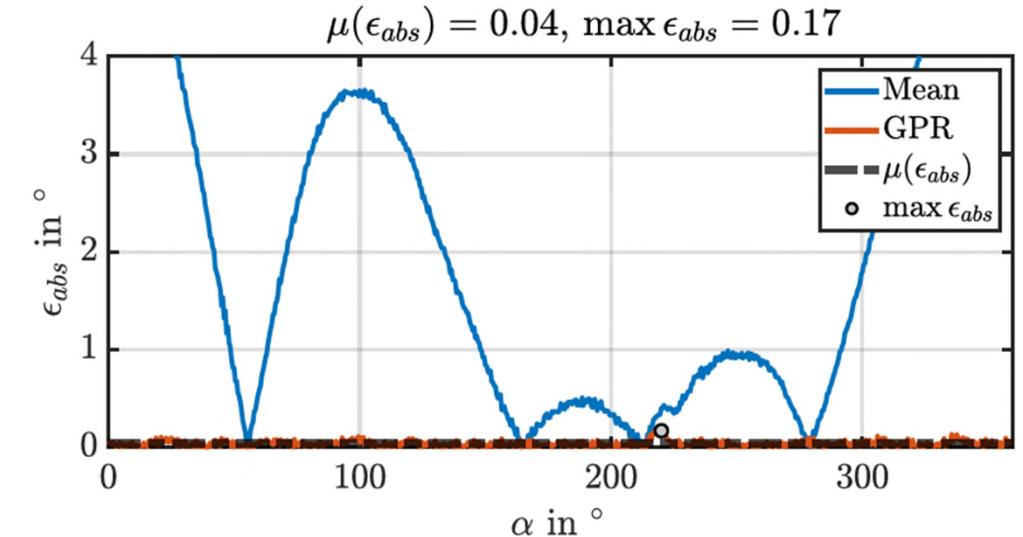


Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

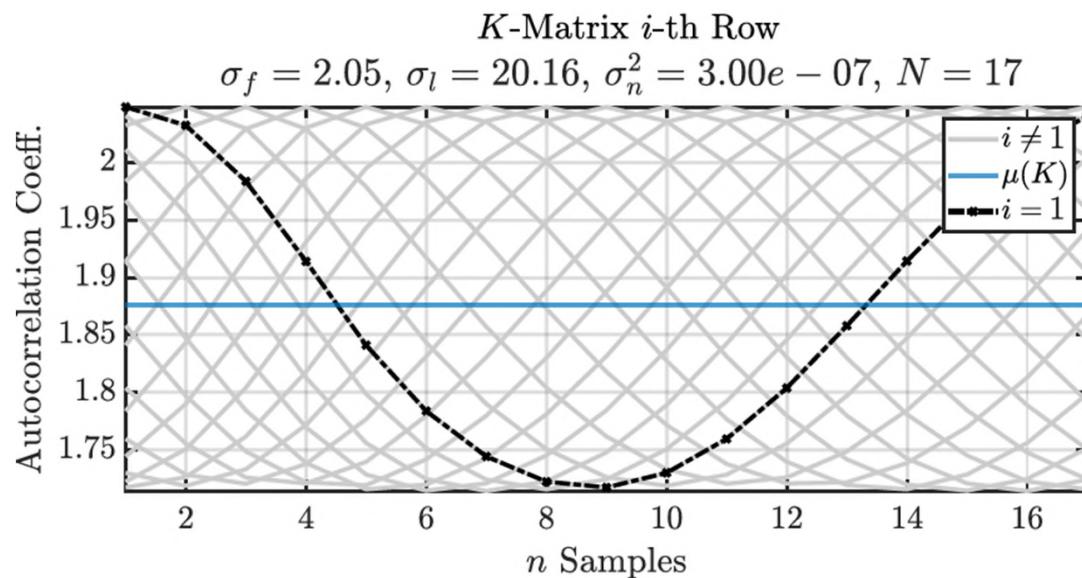


Geringe Winkelfehler über volle Rotation

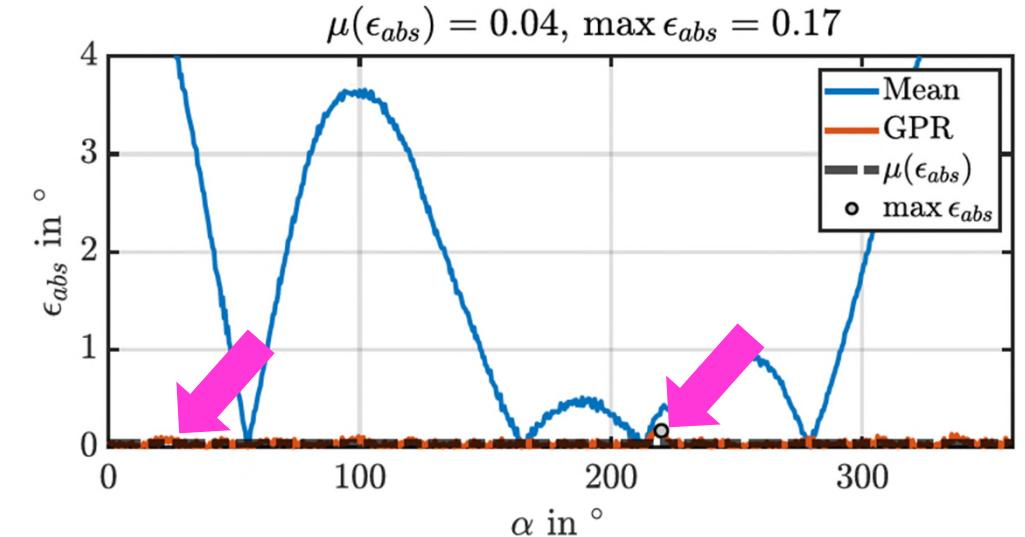


Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



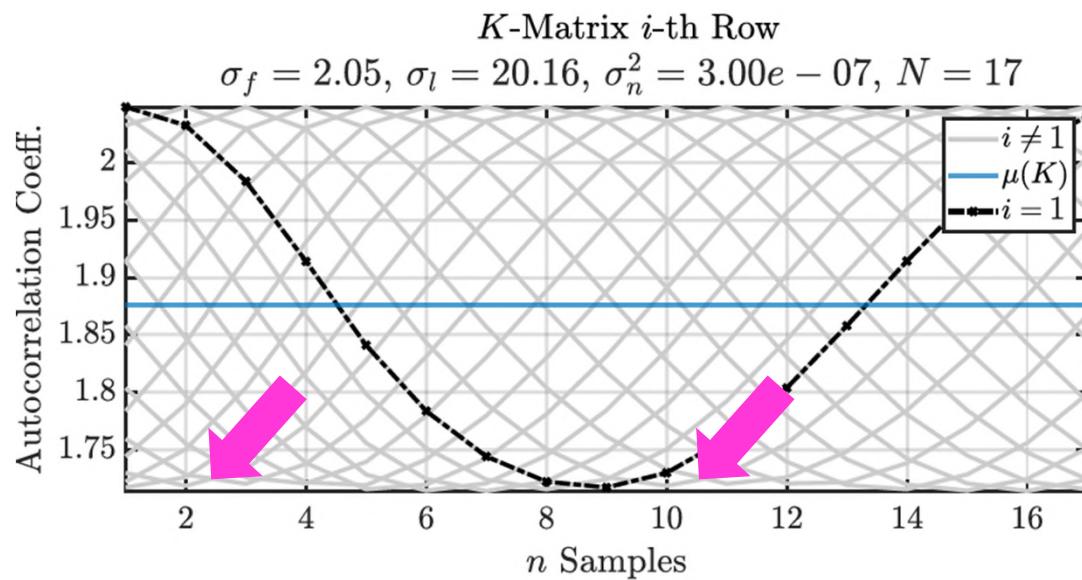
Geringe Winkelfehler über volle Rotation



Leichte Schwankungen

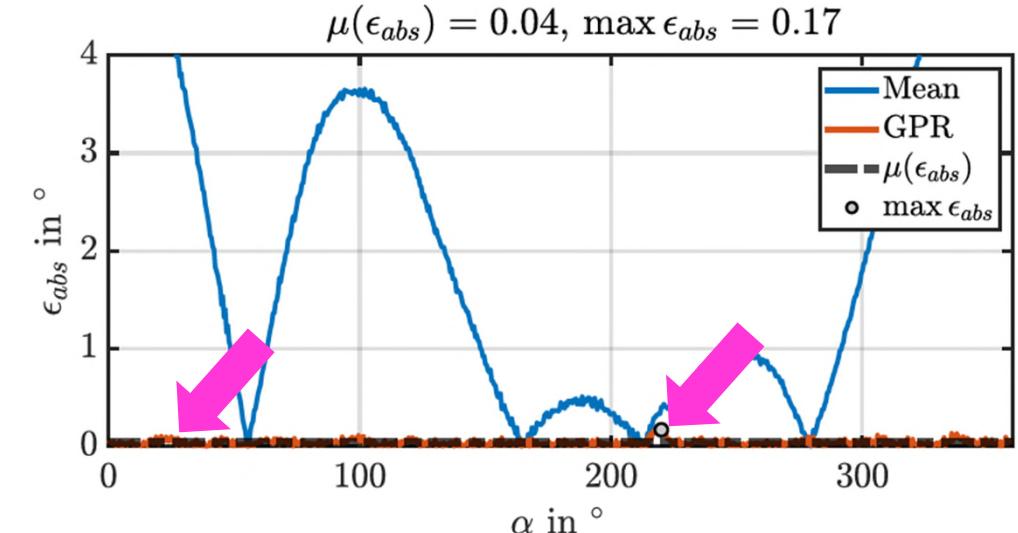
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung

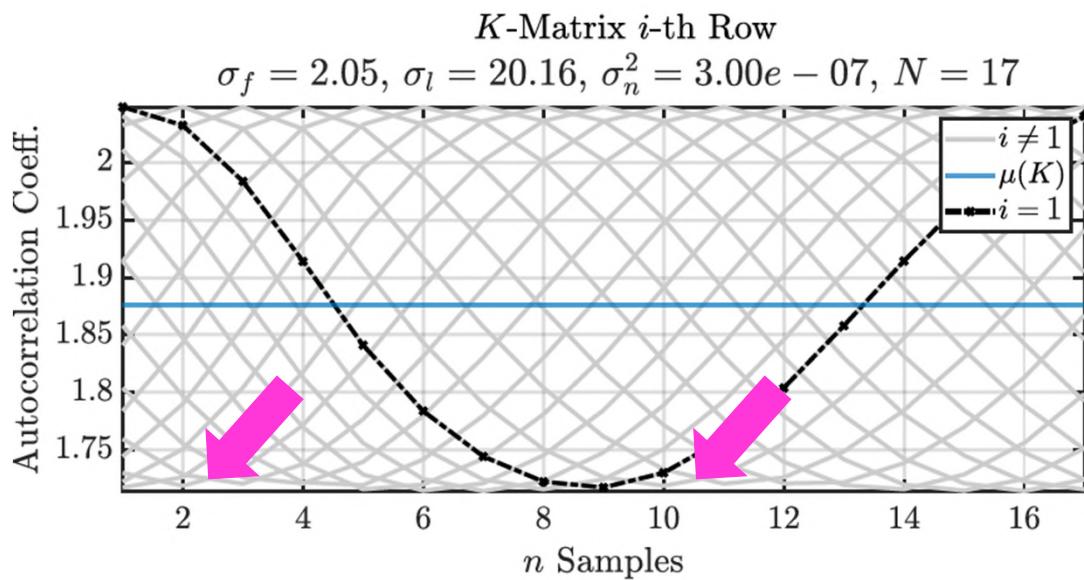
Geringe Winkelfehler über volle Rotation



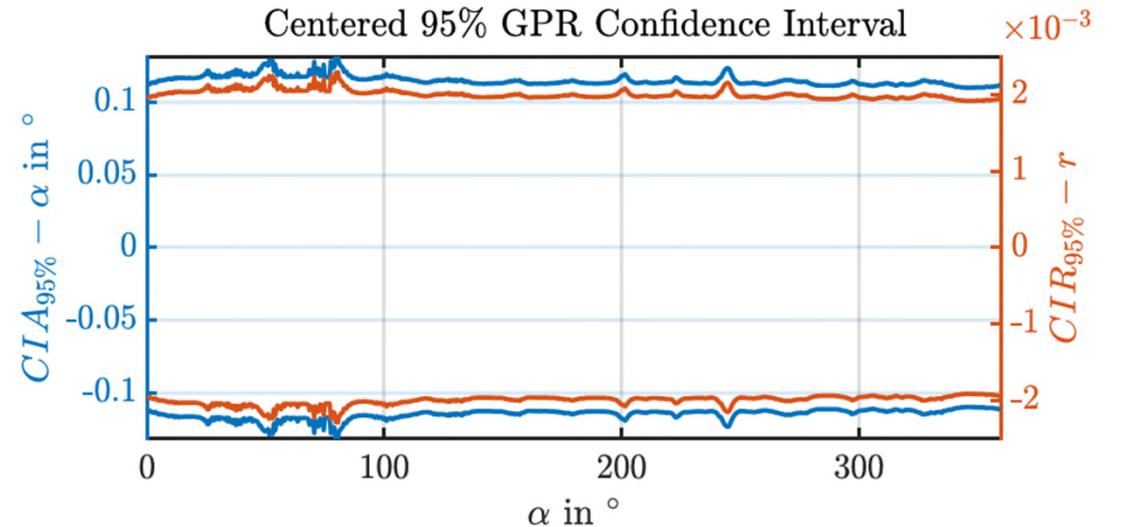
Leichte Schwankungen

Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung

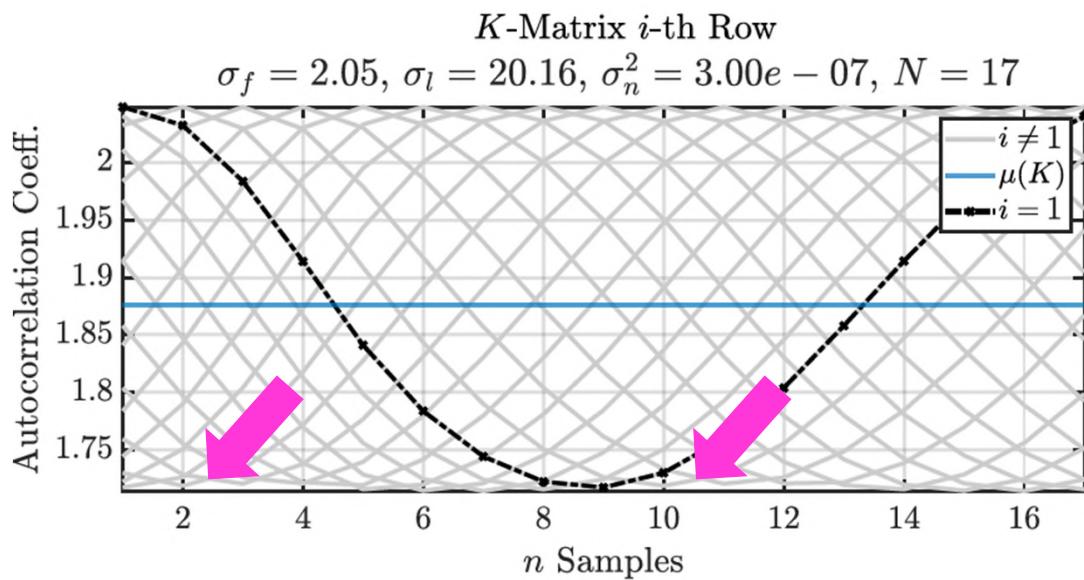


Hohes Vertrauen, enge Intervalle

CIA – Confidence-Interval-Angle
CIR – Confidence-Interval-Radius

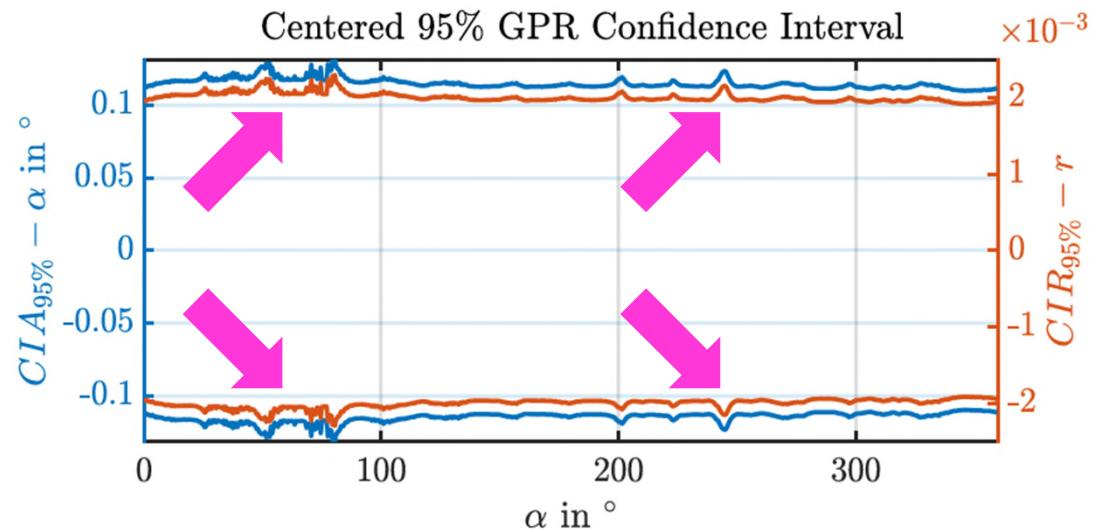
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung

Anzeige der Abdeckungslücke

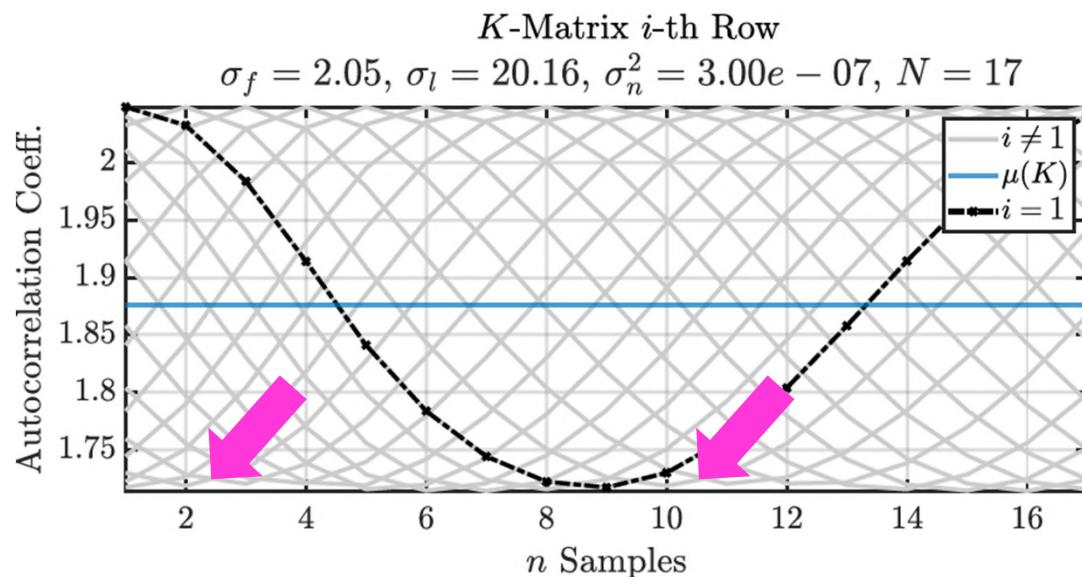


Hohes Vertrauen, enge Intervalle

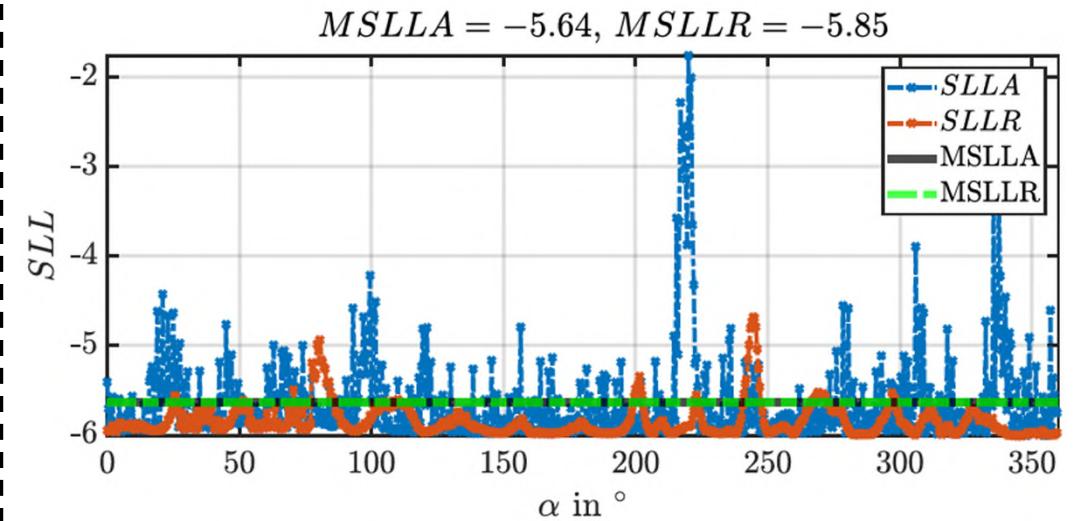
CIA – Confidence-Interval-Angle
CIR – Confidence-Interval-Radius

Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung



SLLA – Standardized-Logarithmic-Loss-Angle

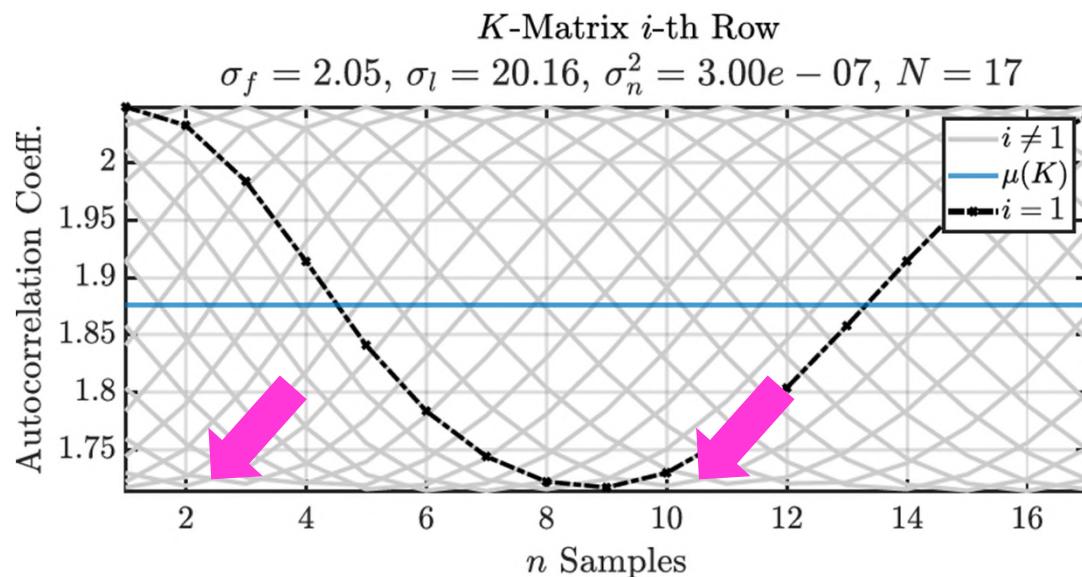
SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

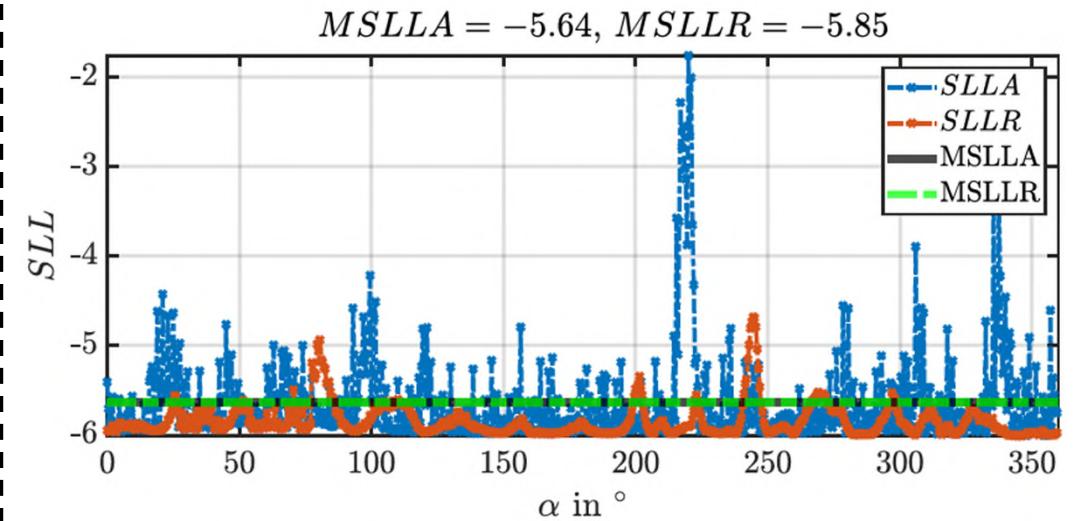
MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung



Starke Generalisierung

SLLA – Standardized-Logarithmic-Loss-Angle

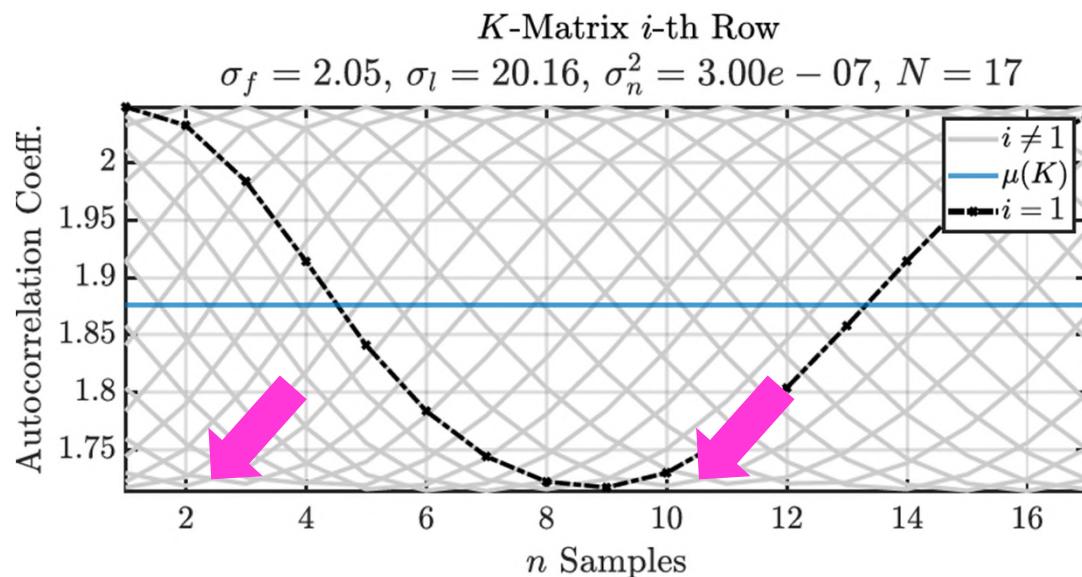
SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

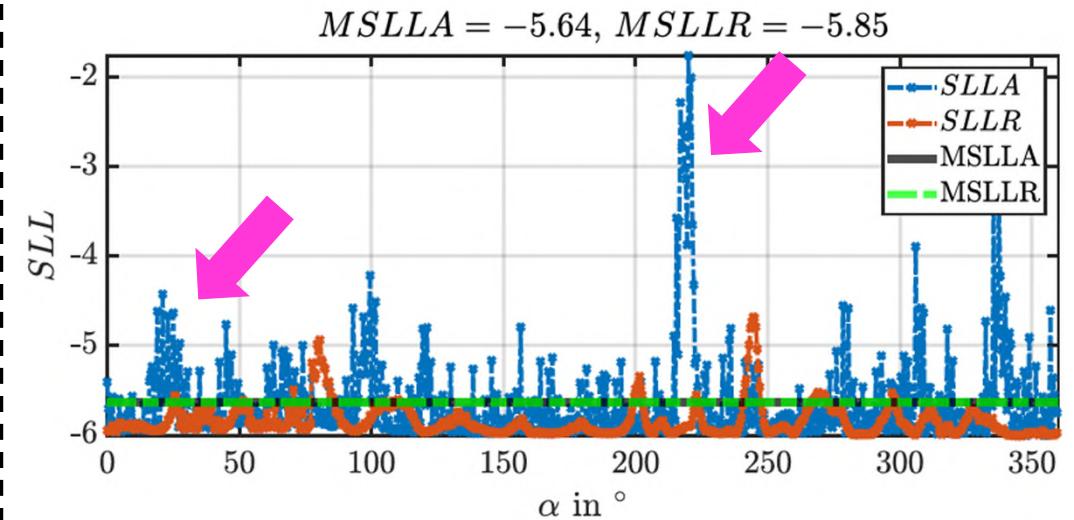
Erprobungsexperimente

Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



Leichte Anhebung, Lücke in Abdeckung

Abdeckungslücke schwächt Generalisierung



Starke Generalisierung

SLLA – Standardized-Logarithmic-Loss-Angle

SLLR – Standardized-Logarithmic-Loss-Radius

MSLLA – Mean-Standardized-Logarithmic-Loss-Angle

MSLLR – Mean-Standardized-Logarithmic-Loss-Radius

Zusammenfassung



- Erreichtes
- Offene Punkte

Zusammenfassung

- **Erreichtes**
 - Simulations-Framework
 - Erweiterbarkeit
- **Offene Punkte**

Zusammenfassung

- **Erreichtes**
 - Simulations-Framework
 - Erweiterbarkeit
 - Skalierbarkeit
 - Generalisierung
- **Offene Punkte**

Zusammenfassung

- **Erreichtes**
 - Simulations-Framework
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 - Generalisierung
 - Toleranzkompenstation
- **Offene Punkte**

Zusammenfassung

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 - Verfahrensminimierung
 - Hardwarenahe Bibliotheken

Zusammenfassung

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 - Verfahrensminimierung
 - Hardwarenahe Bibliotheken
 - Anbindung an Realdaten
 - Große Charakterisierung

Zusammenfassung

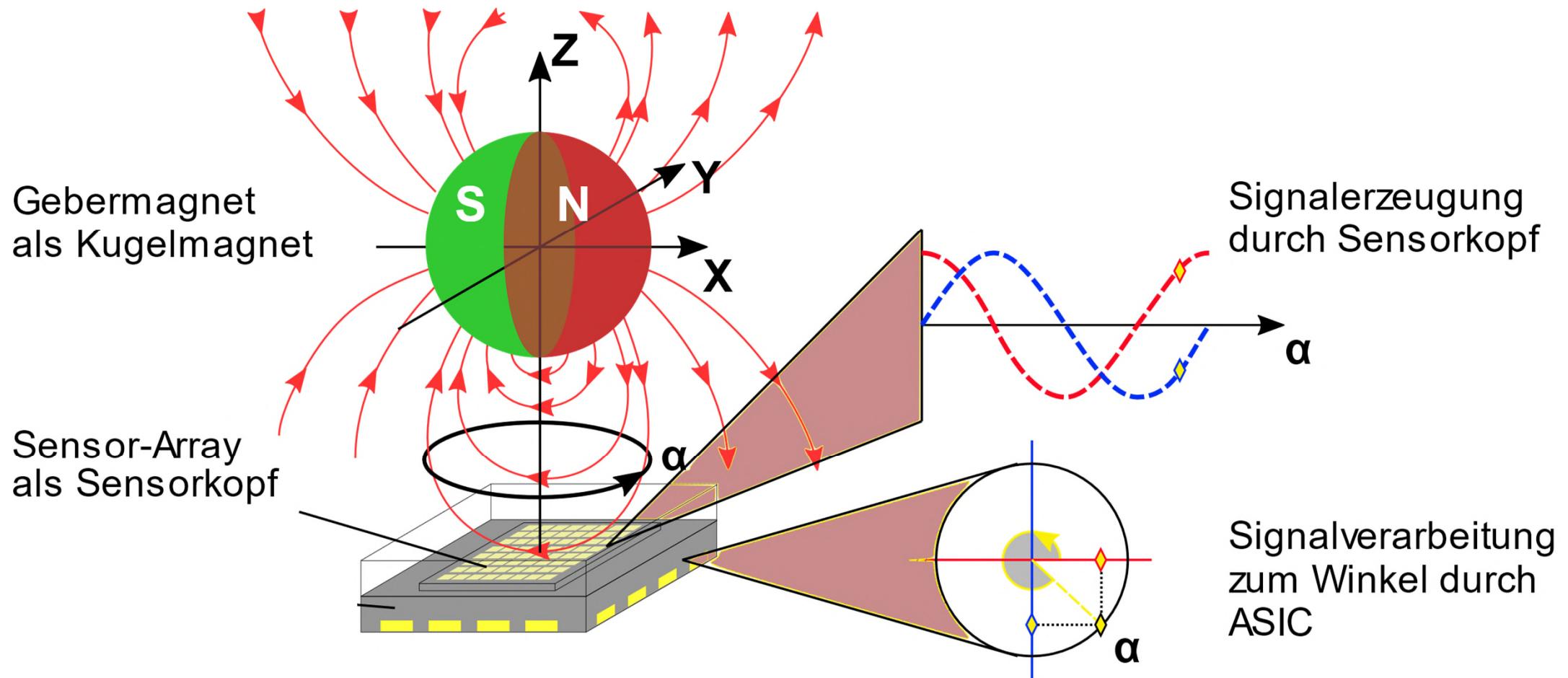
- **Erreichtes**
 - Simulations-Framework
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 - Verfahrensminimierung
 - Hardwarenahe Bibliotheken
 - Anbindung an Realdaten
 - Große Charakterisierung
 - Zirkuläre Statistik

Ende

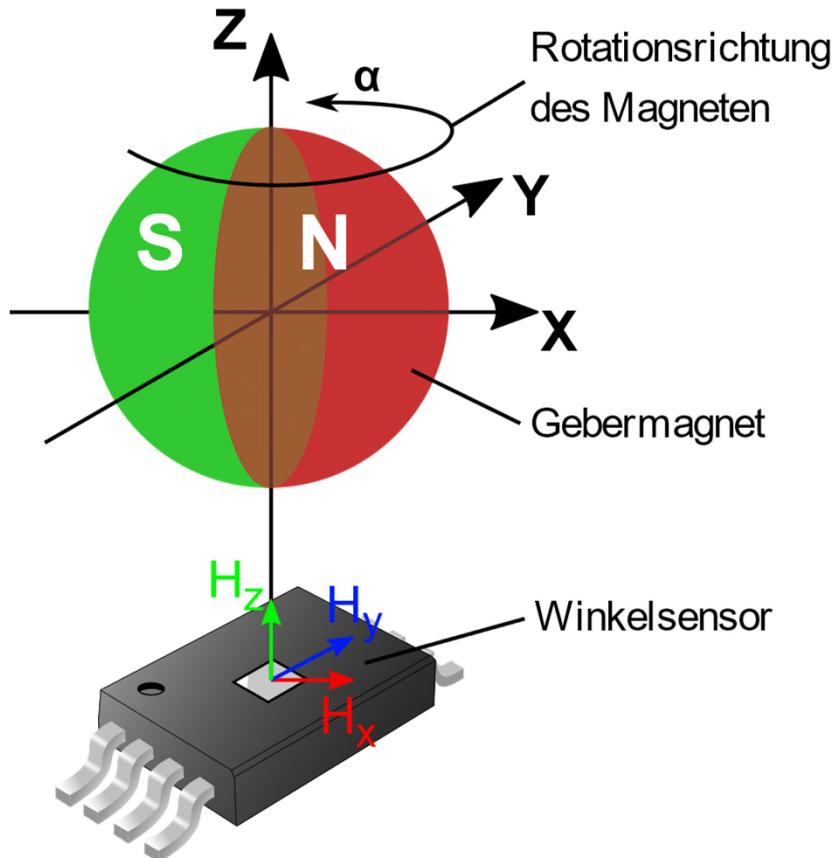


Vielen Dank!

Applikation



Applikation



Winkelmessung

$$\underbrace{\begin{pmatrix} H_x(\alpha) \\ H_y(\alpha) \end{pmatrix}}_{\text{Gebermagnetfeld}} \Rightarrow \underbrace{\begin{pmatrix} V_{\cos}(H_x, H_y) \\ V_{\sin}(H_x, H_y) \end{pmatrix}}_{\text{Winkelsensormesswerte}} = \underbrace{\begin{pmatrix} r \cdot \cos(\alpha) \\ r \cdot \sin(\alpha) \end{pmatrix}}_{\text{Kreisdarstellung}} = \begin{pmatrix} a_x \\ a_y \end{pmatrix} = \underbrace{\mathbf{A}(\alpha)}_{\text{Winkelmessung}}$$

Orthogonalität der Messwerte

$$V_{\cos}(H_x, H_y) \perp V_{\sin}(H_x, H_y) \Leftrightarrow \mathbf{A} \mapsto \alpha$$

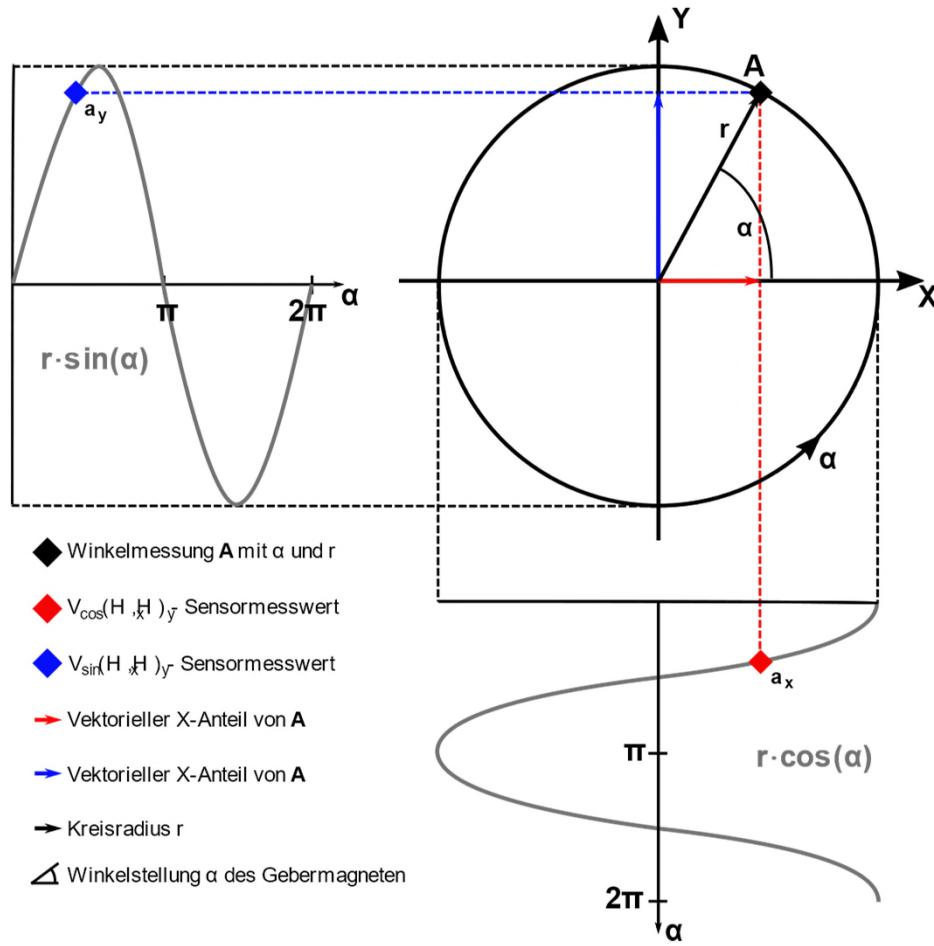
Applikation

Radius

$$r = |\mathbf{A}| = \sqrt{a_x^2 + a_y^2}$$

Winkel

$$\alpha = \begin{cases} \arctan2(a_y, a_x) & \text{f. } a_y > 0 \\ \pi & \text{f. } a_y = 0 \\ \arctan2(a_y, a_x) + 2\pi & \text{f. } a_y < 0 \end{cases}$$



Applikation

Winkelmessungen

$$\mathbf{A} \mapsto \alpha_1 \quad \mathbf{B} \mapsto \alpha_2$$

Radius

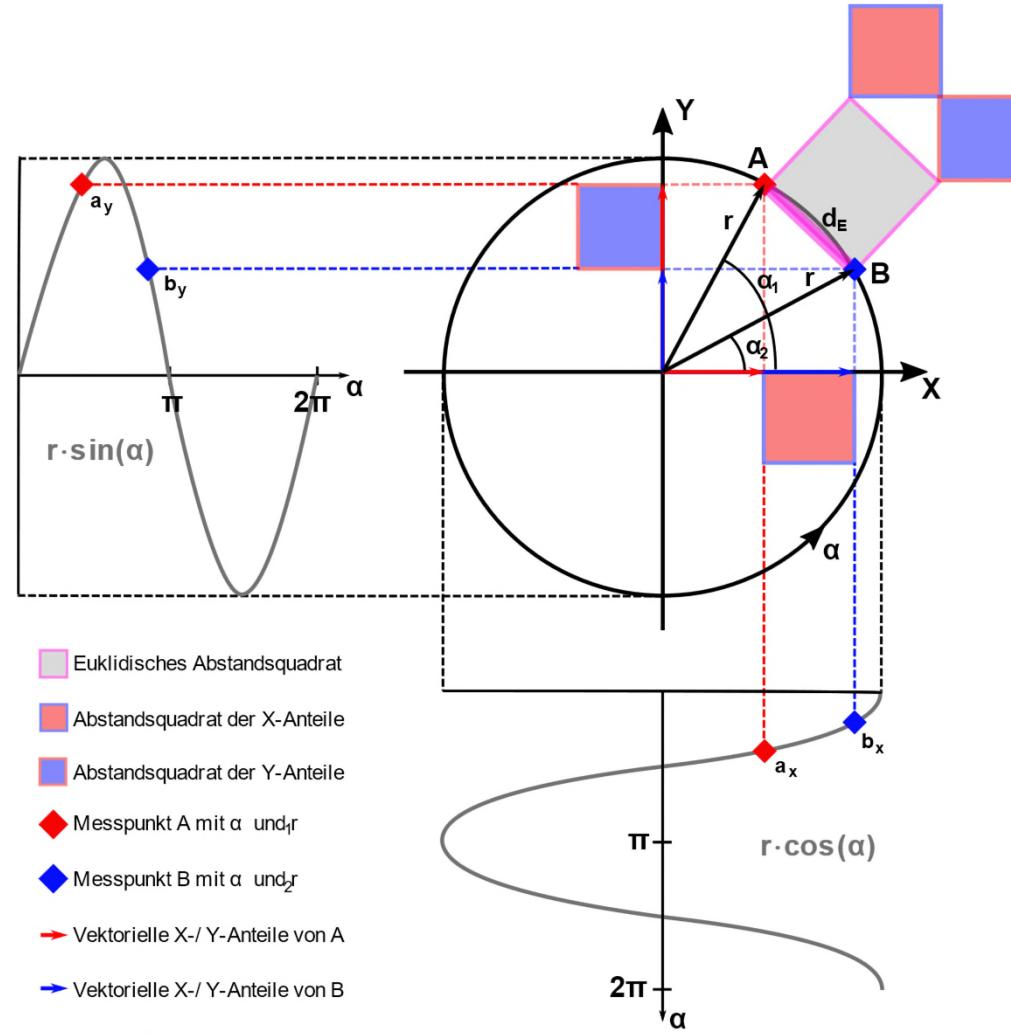
$$r = |\mathbf{A}| = |\mathbf{B}| = \text{konst.}$$

Euklidischer Abstand

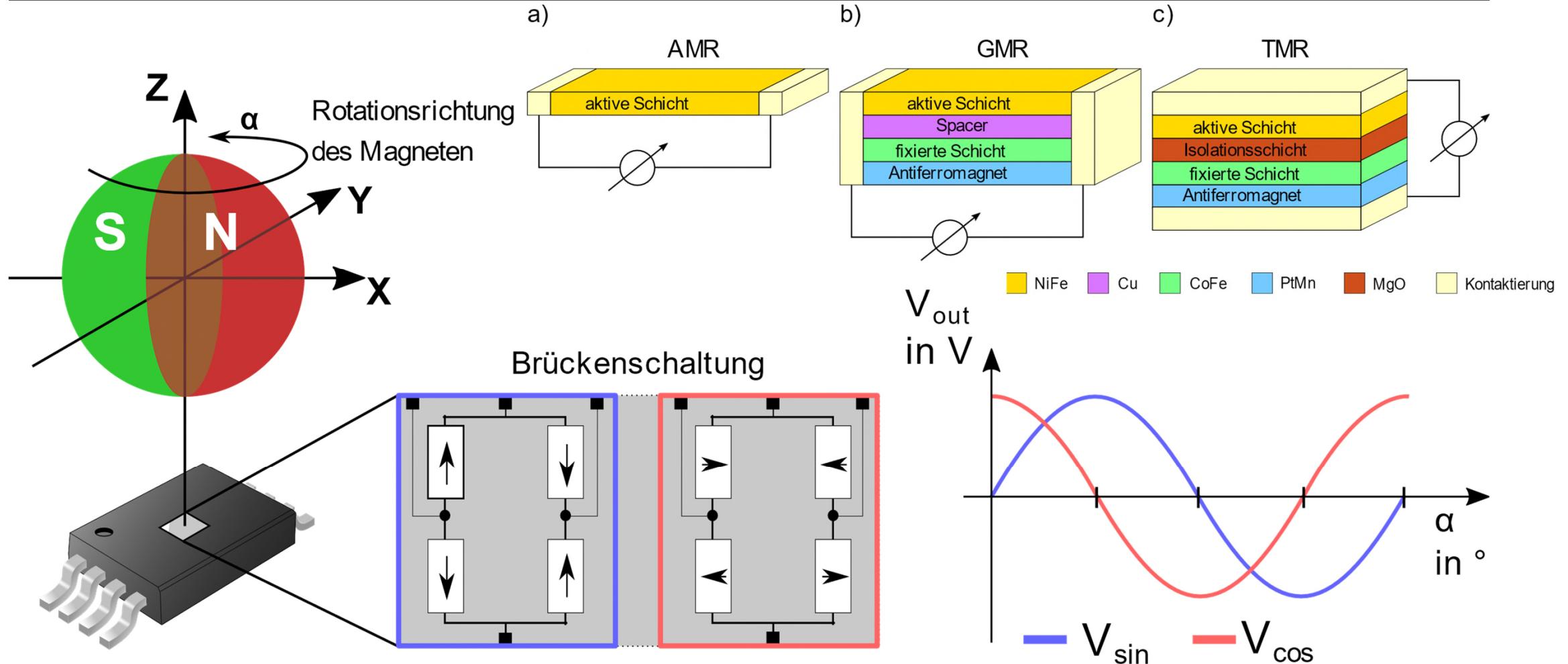
$$d_E(\mathbf{A}, \mathbf{B}) = \sqrt{(a_x - b_x)^2 + (a_y - b_y)^2}$$

Abstandsquadrat

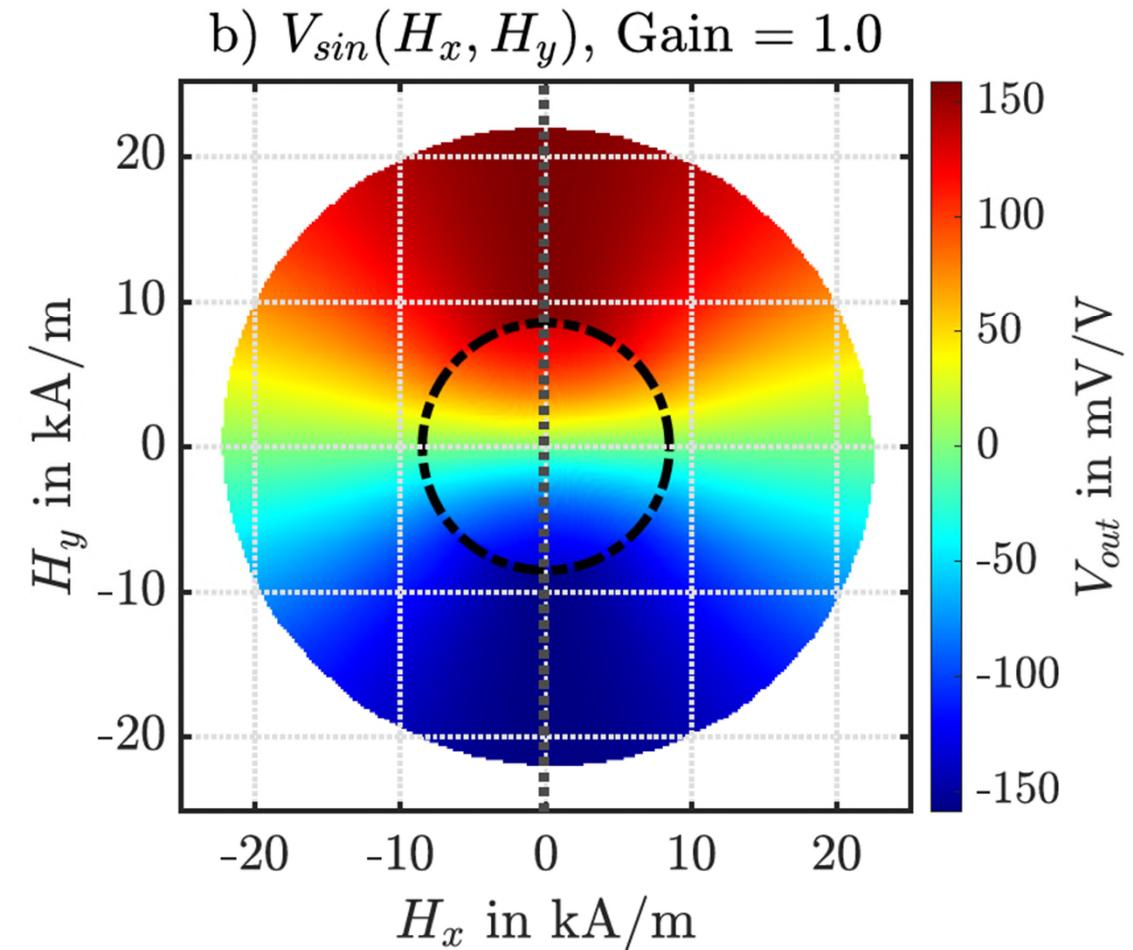
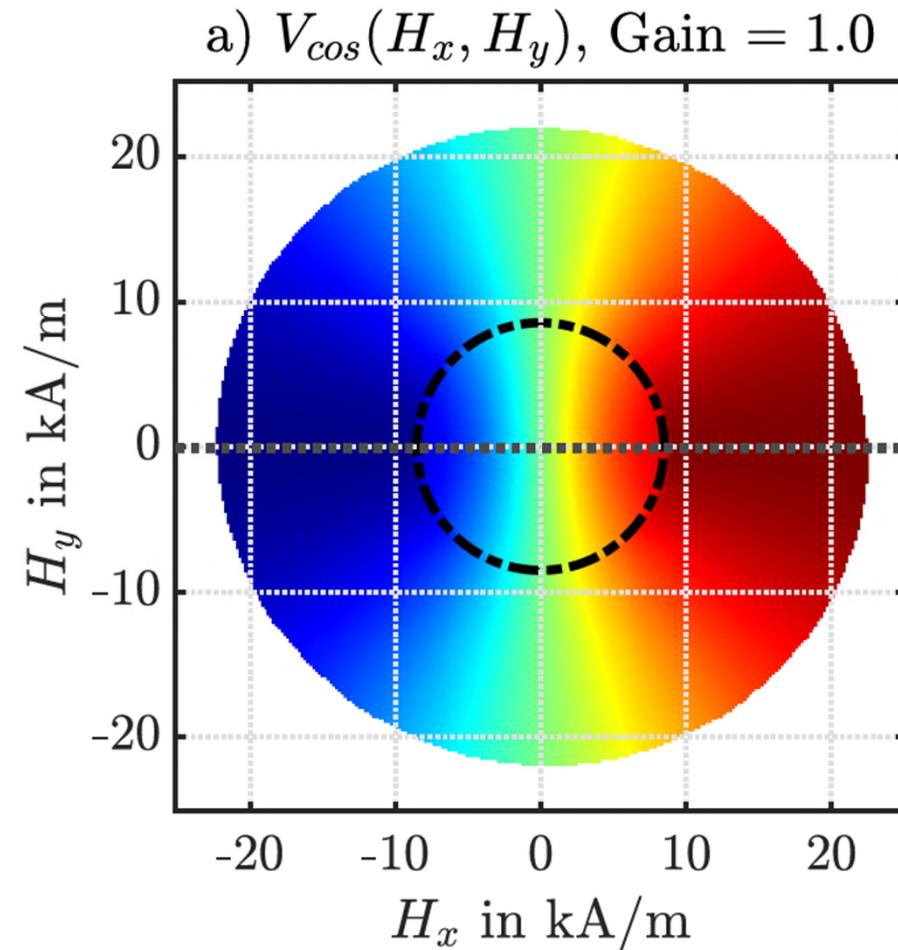
$$d_E^2(\mathbf{A}, \mathbf{B}) = (a_x - b_x)^2 + (a_y - b_y)^2$$



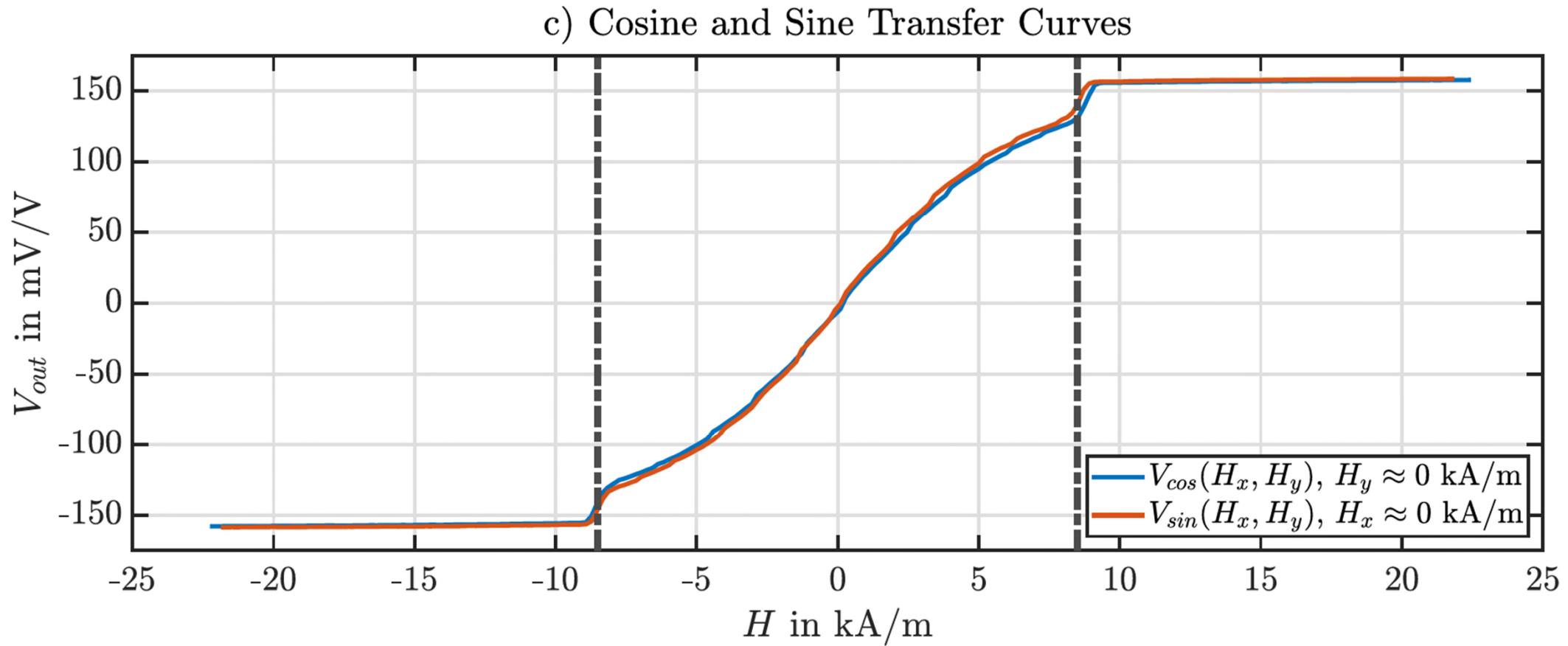
Applikation



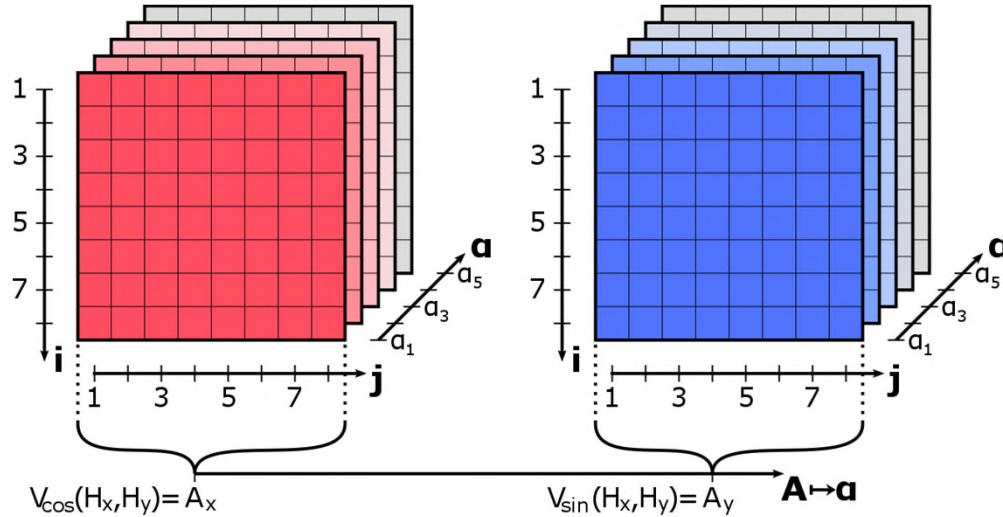
Kennfelder



Kennfelder

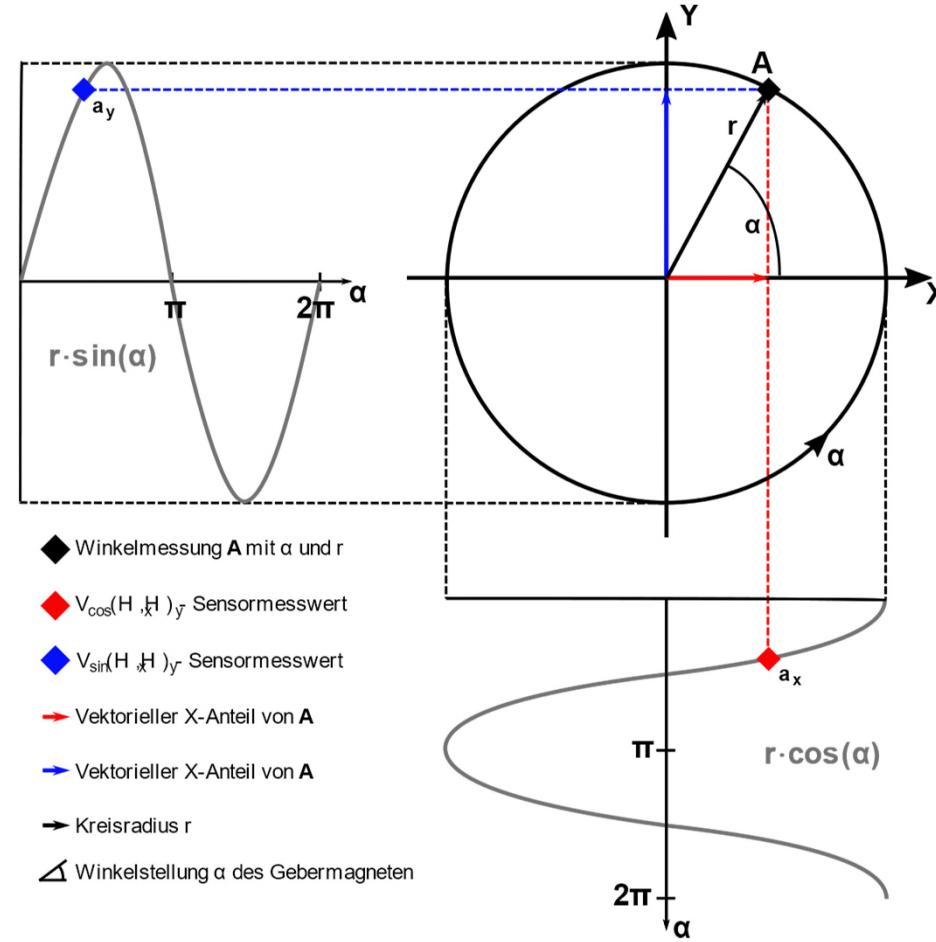


Datenadaption

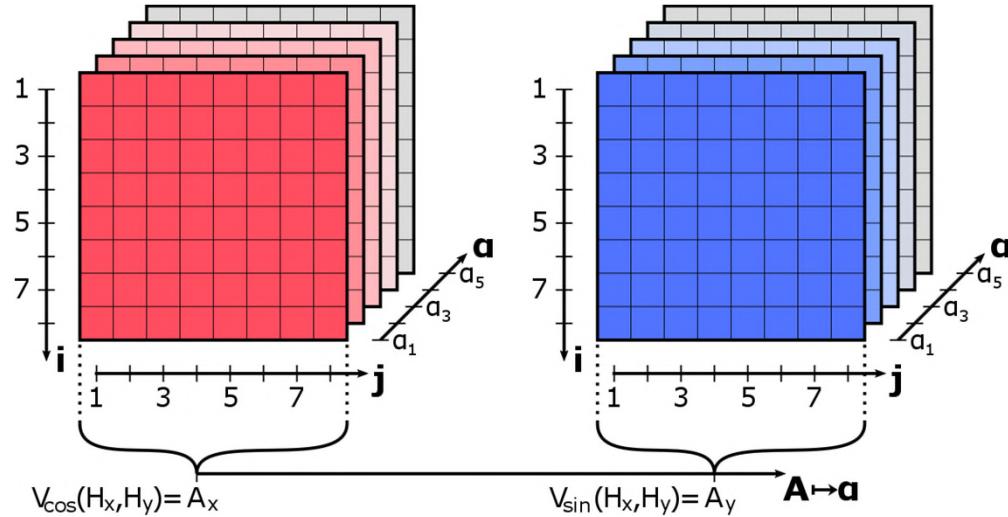


Vektor-2-Norm² f. j-te Spalte

$$\|\mathbf{A}_x\|_F = \sqrt{\sum_{j=1}^n \|A_{xj}\|_2^2}$$

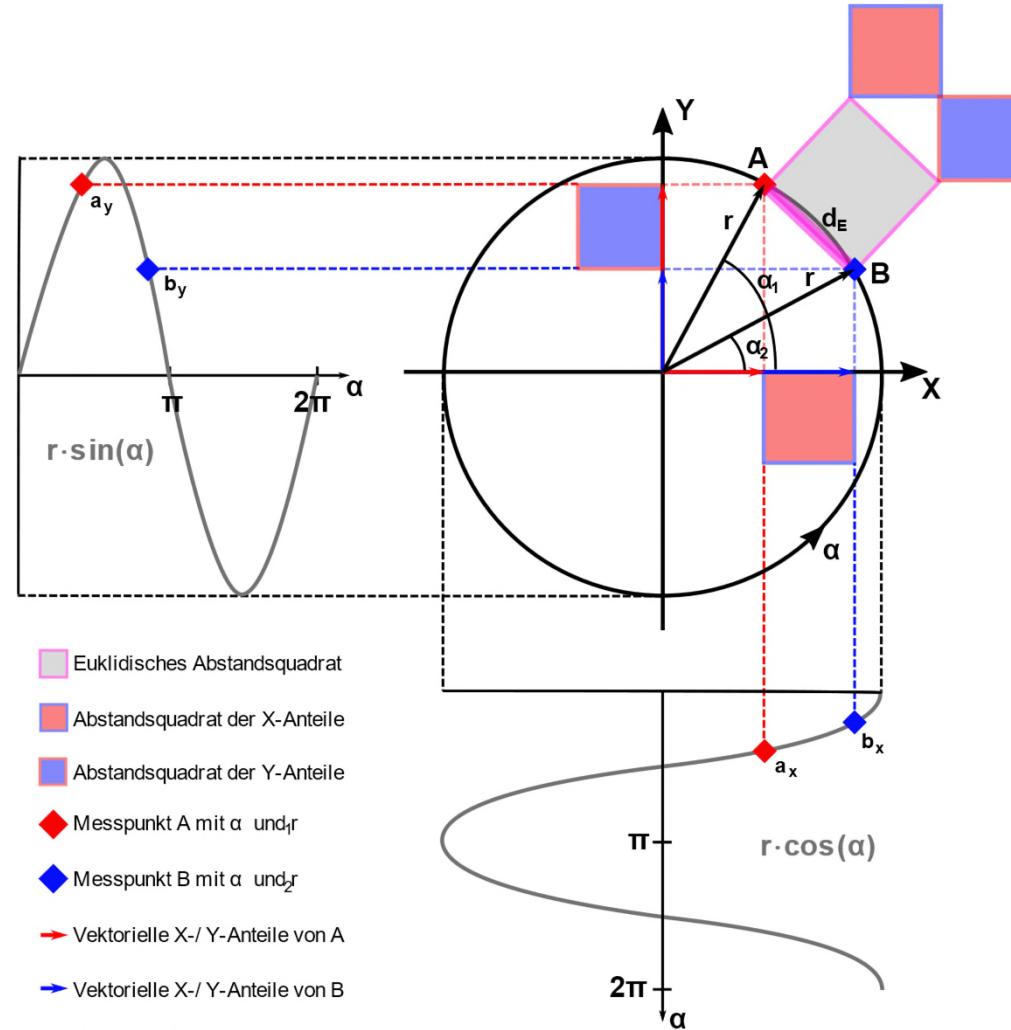


Datenadaption



Aufbau über euklidischen Abstand

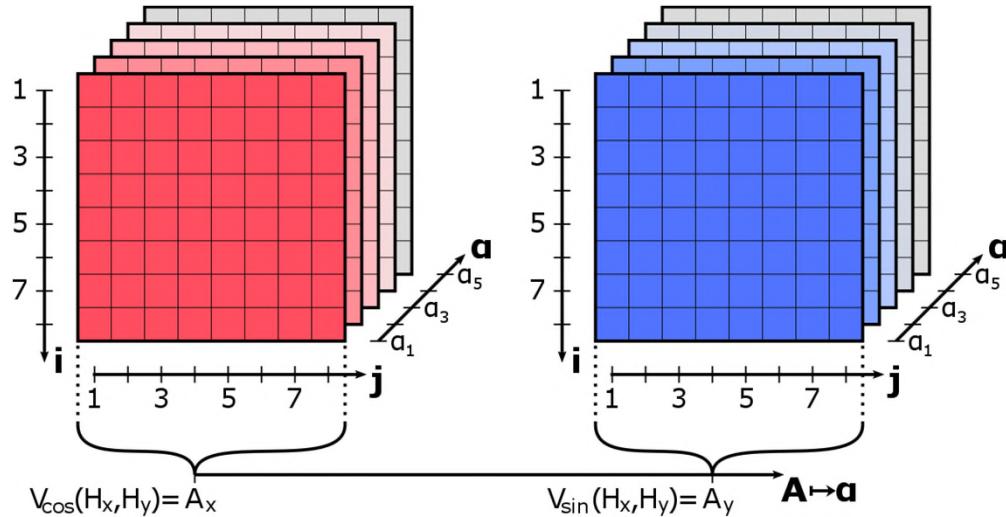
$$\begin{aligned}
 d_E^2(\mathbf{A}, \mathbf{B}) &= (\|\mathbf{A}_x\|_F - \|\mathbf{B}_x\|_F)^2 + (\|\mathbf{A}_y\|_F - \|\mathbf{B}_y\|_F)^2 \\
 &\leq \\
 d_F^2(\mathbf{A}, \mathbf{B}) &= \|\mathbf{A}_x - \mathbf{B}_x\|_F^2 + \|\mathbf{A}_y - \mathbf{B}_y\|_F^2 = \|\mathbf{A} - \mathbf{B}\|_F^2
 \end{aligned}$$



Datenadaption

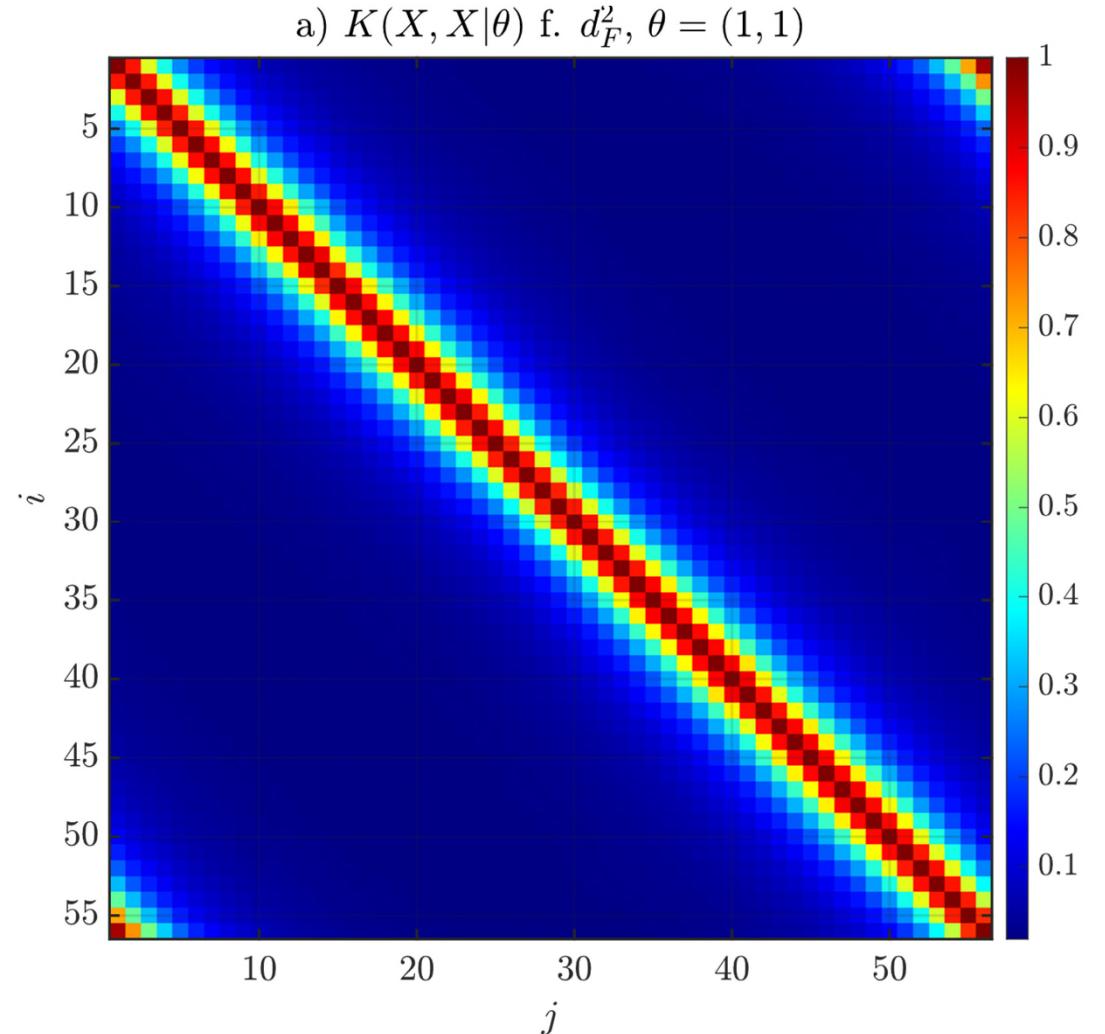
Vektor-2-Norm	\Rightarrow	Frobenius Norm
$\mathbf{A} = (a_x, a_y)$	\Rightarrow	$\mathbf{A} = [\mathbf{A}_x, \mathbf{A}_y]$
\downarrow		\downarrow
$\ \mathbf{A}\ _2 = \sqrt{\sum_{i=1}^n A_i ^2}$	\Rightarrow	$\ \mathbf{A}_x\ _F = \sqrt{\sum_{j=1}^n \ \mathbf{A}_{xj}\ _2^2}$ f. j-te Spalte
\downarrow		\downarrow
$d_E^2(\mathbf{A}, \mathbf{B})$	\Rightarrow	$d_F^2(\mathbf{A}, \mathbf{B})$
$=$		$=$
$\ \mathbf{A} - \mathbf{B}\ _2^2$	\Rightarrow	$\ \mathbf{A} - \mathbf{B}\ _F^2$
$=$		$=$
\vdots		$\ \mathbf{A}_x - \mathbf{B}_x\ _F^2 + \ \mathbf{A}_y - \mathbf{B}_y\ _F^2$
\vdots		\geq
$(a_x - b_x)^2 + (a_y - b_y)^2$	\Leftrightarrow	$(\ \mathbf{A}_x\ _F - \ \mathbf{B}_x\ _F)^2 + (\ \mathbf{A}_y\ _F - \ \mathbf{B}_y\ _F)^2$
\downarrow		\downarrow
$r = \mathbf{A} = \sqrt{a_x^2 + a_y^2}$	\Rightarrow	$\ r\ _F = \ \mathbf{A}\ _F = \sqrt{\ \mathbf{A}_x\ _F^2 + \ \mathbf{A}_y\ _F^2}$

Gauß-Prozesse

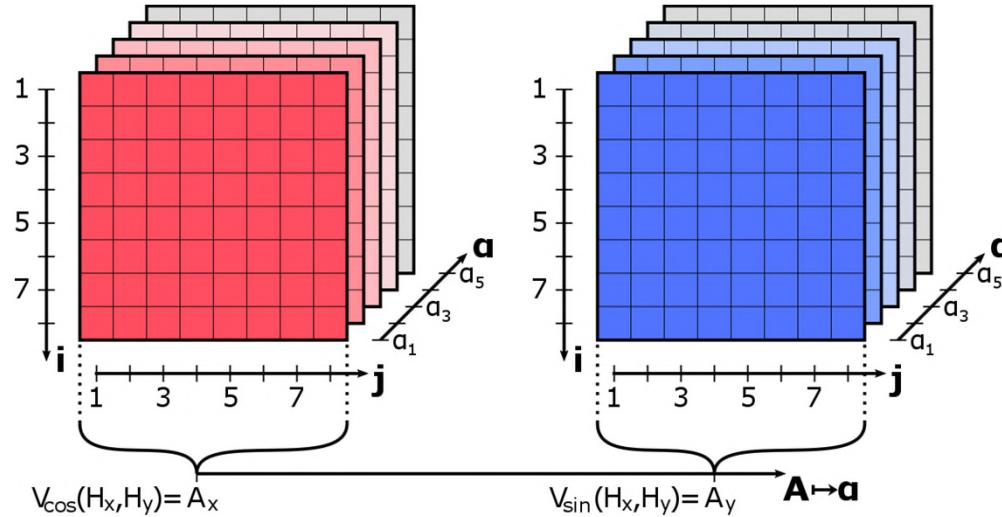


Fractional Kernel

$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$

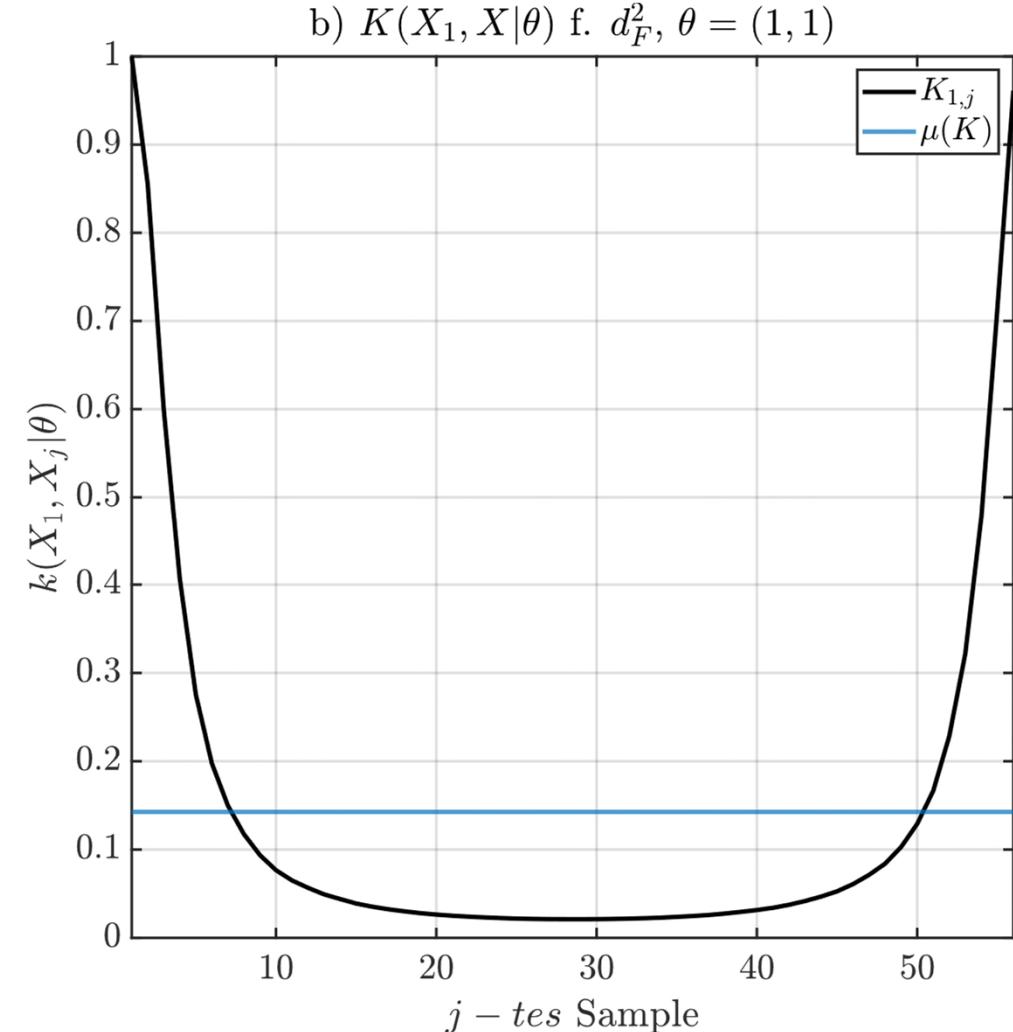


Gauß-Prozesse

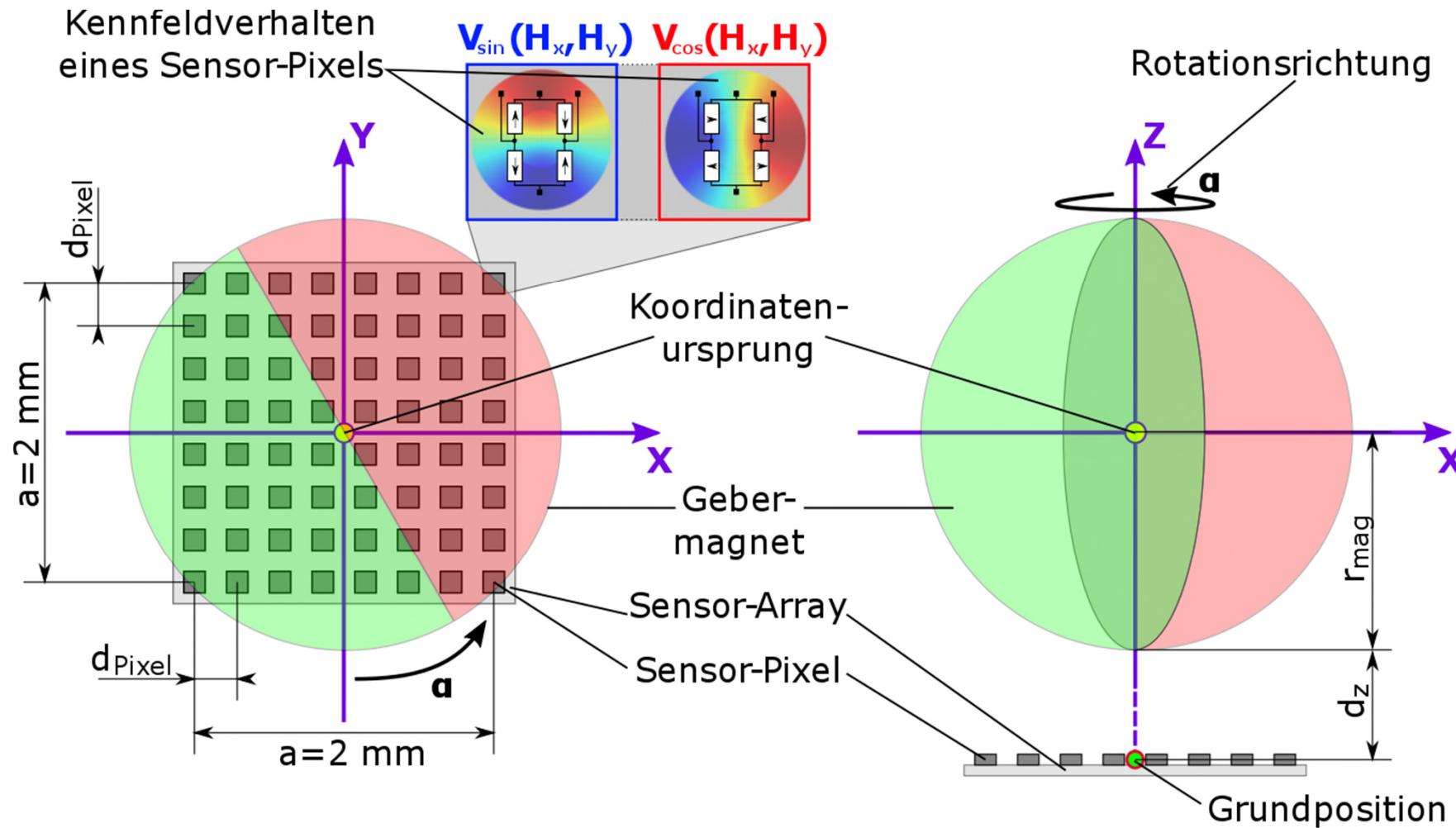


Fractional Kernel

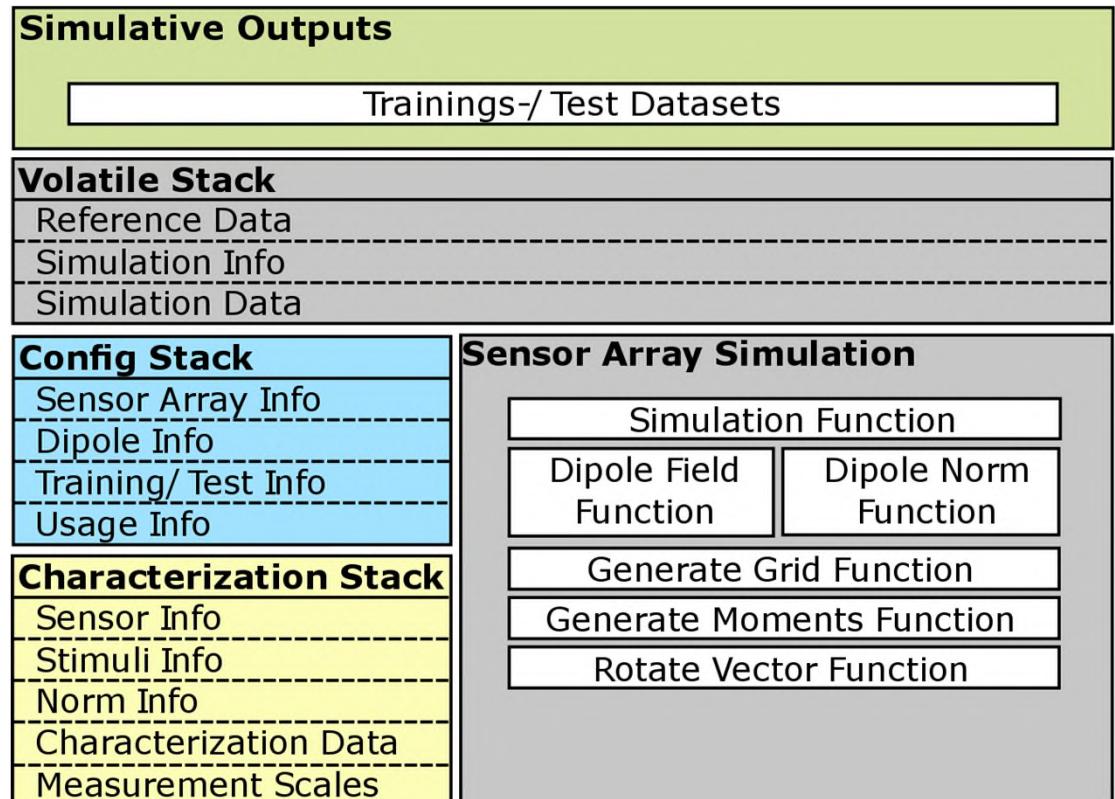
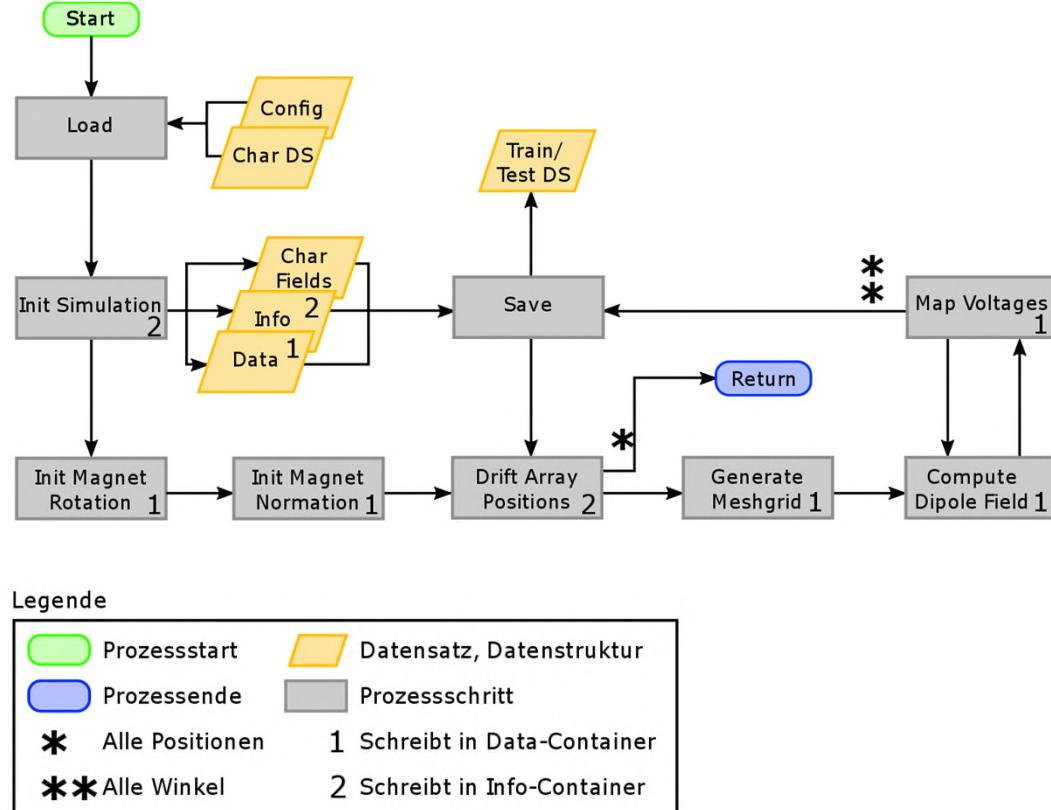
$$\frac{\sigma_f^2}{1 + \frac{d_x^2 \langle \mathbf{A}, \mathbf{B} \rangle}{2\sigma_I^2}}$$



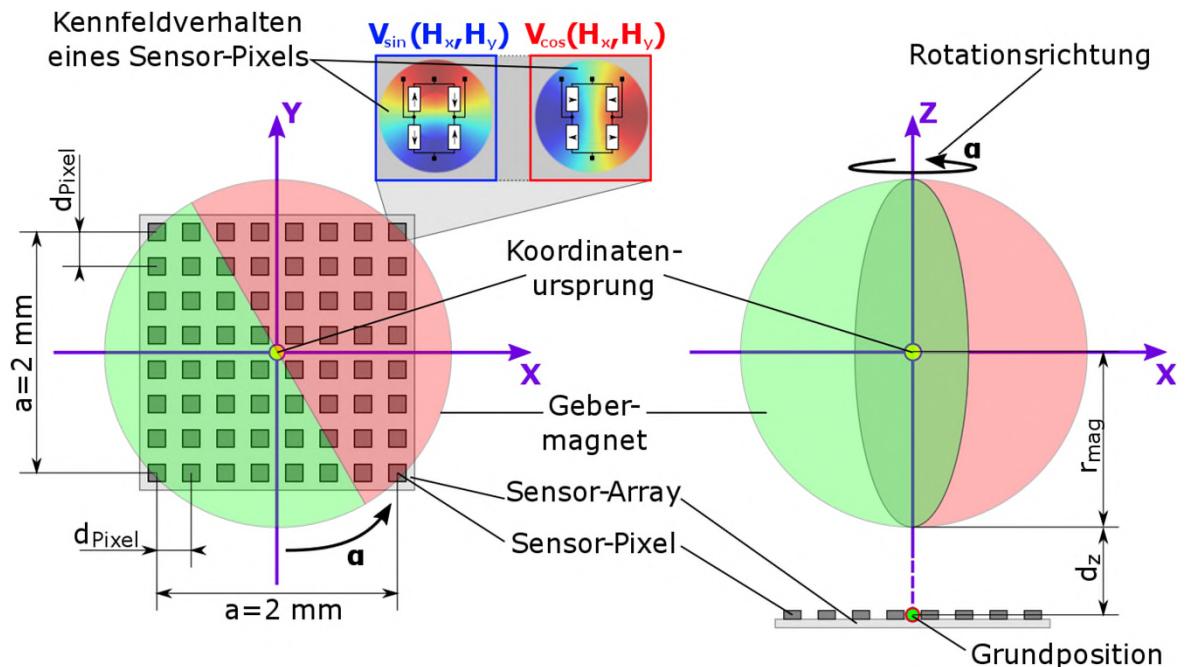
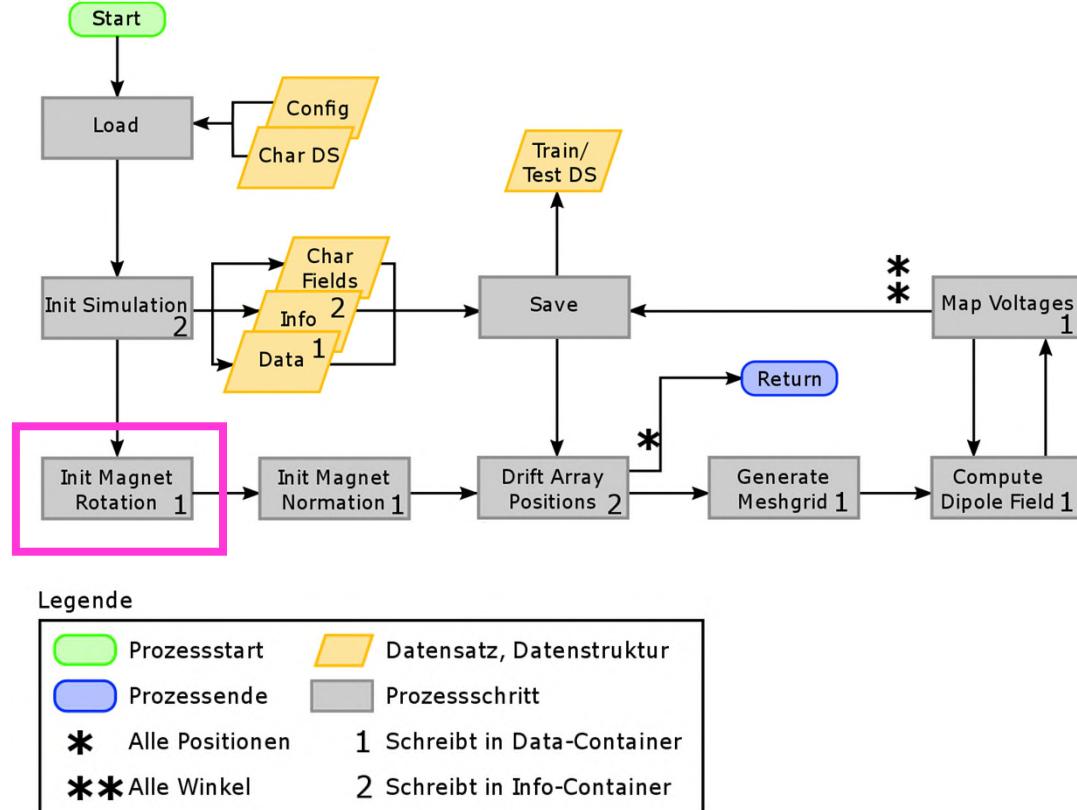
Simulation – Sensor-Array



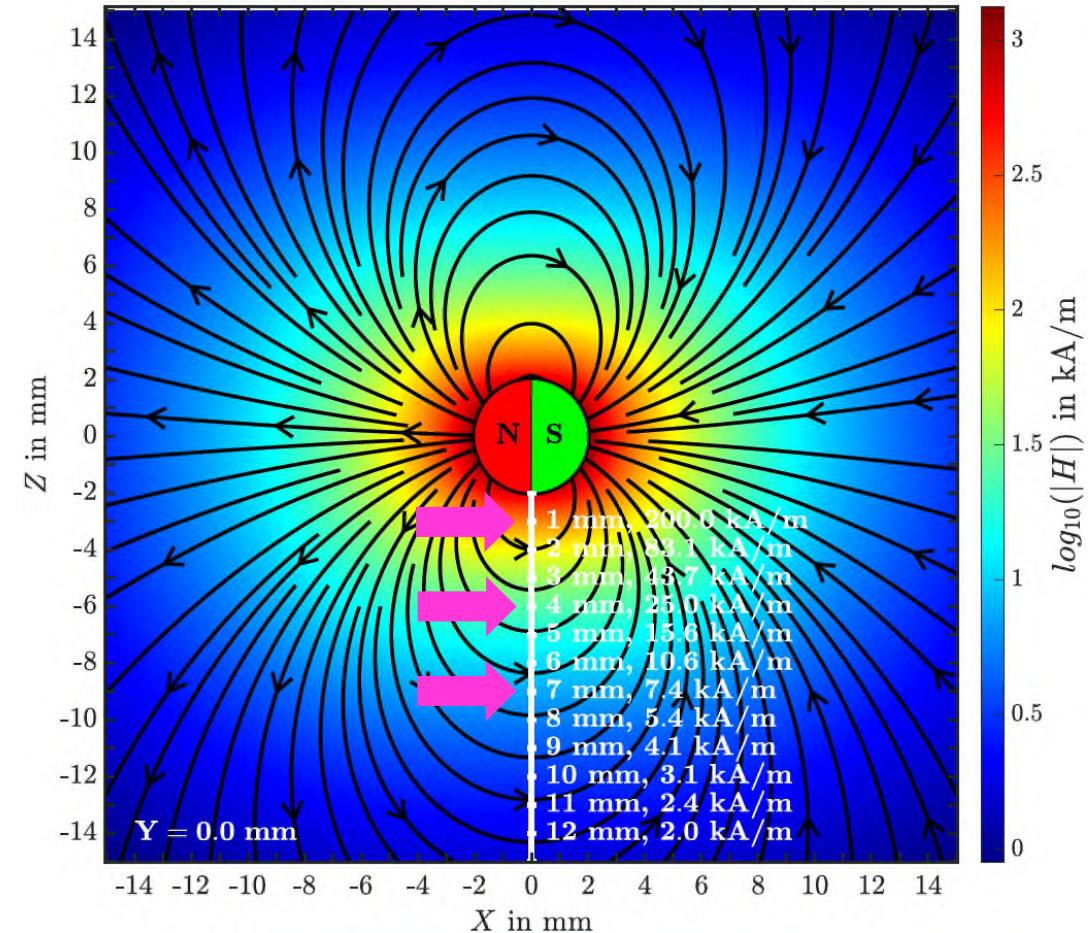
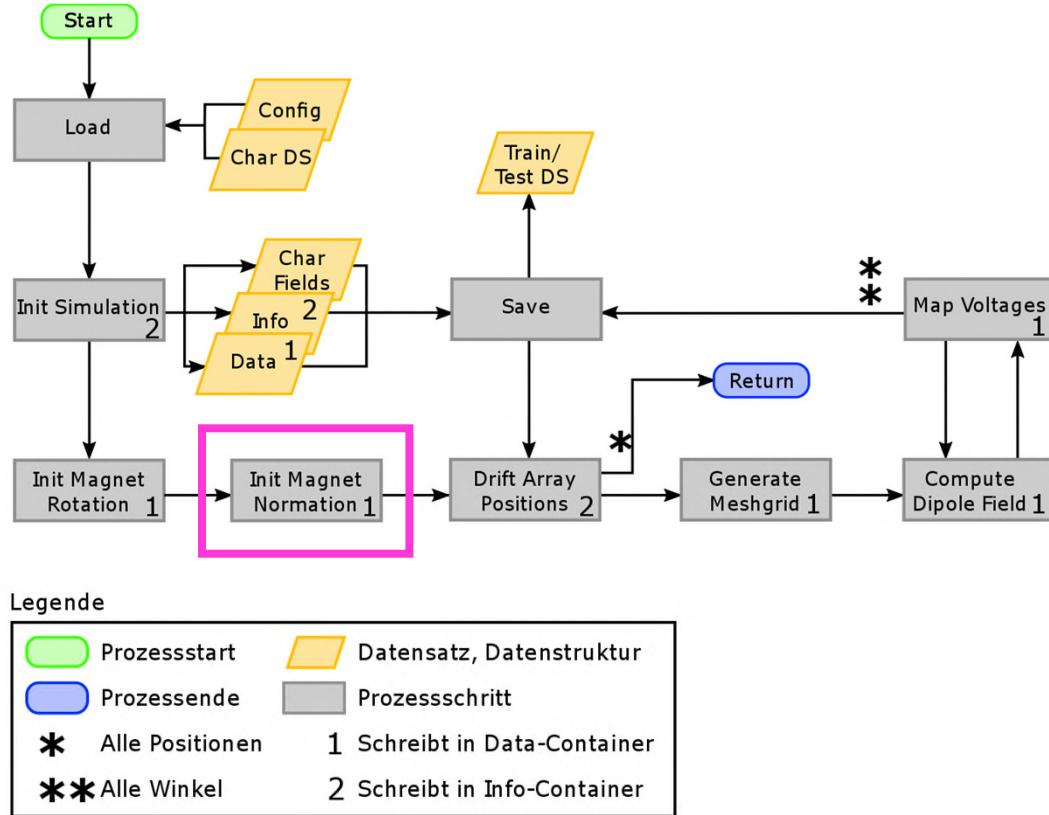
Simulation – Sensor-Array



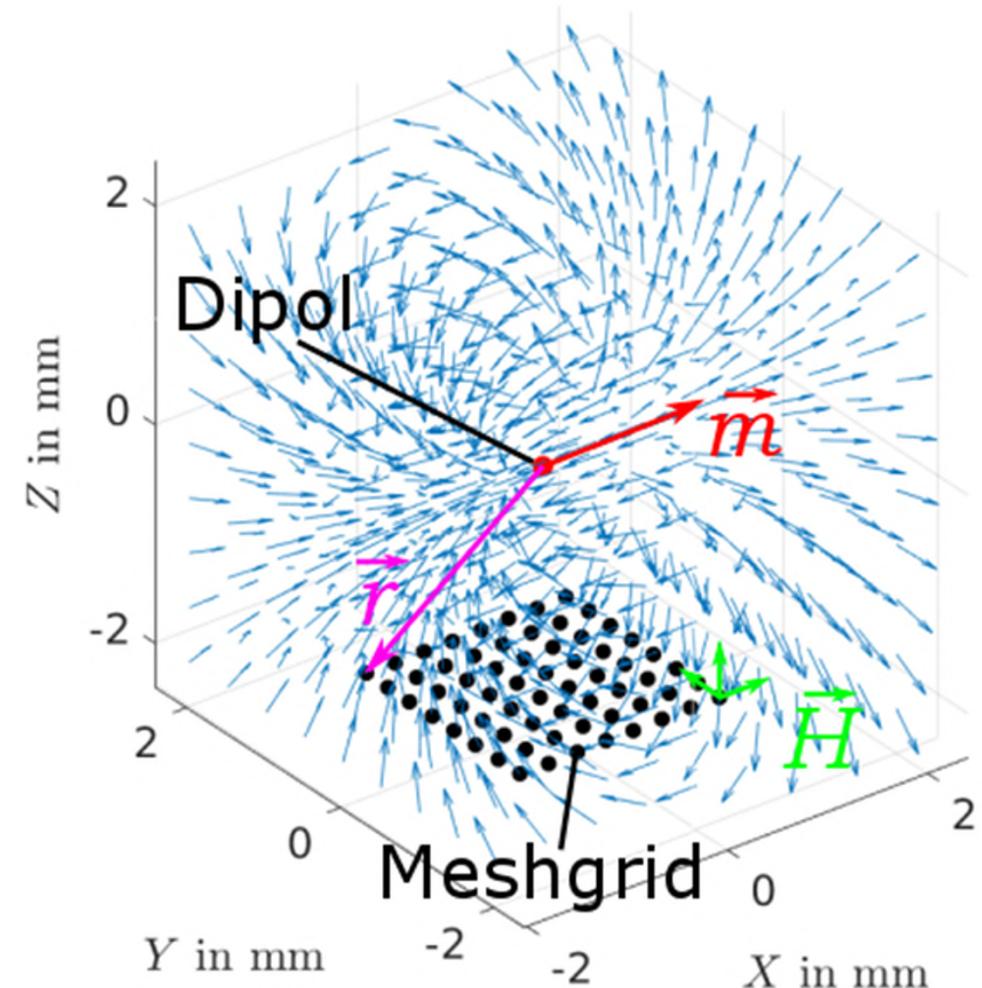
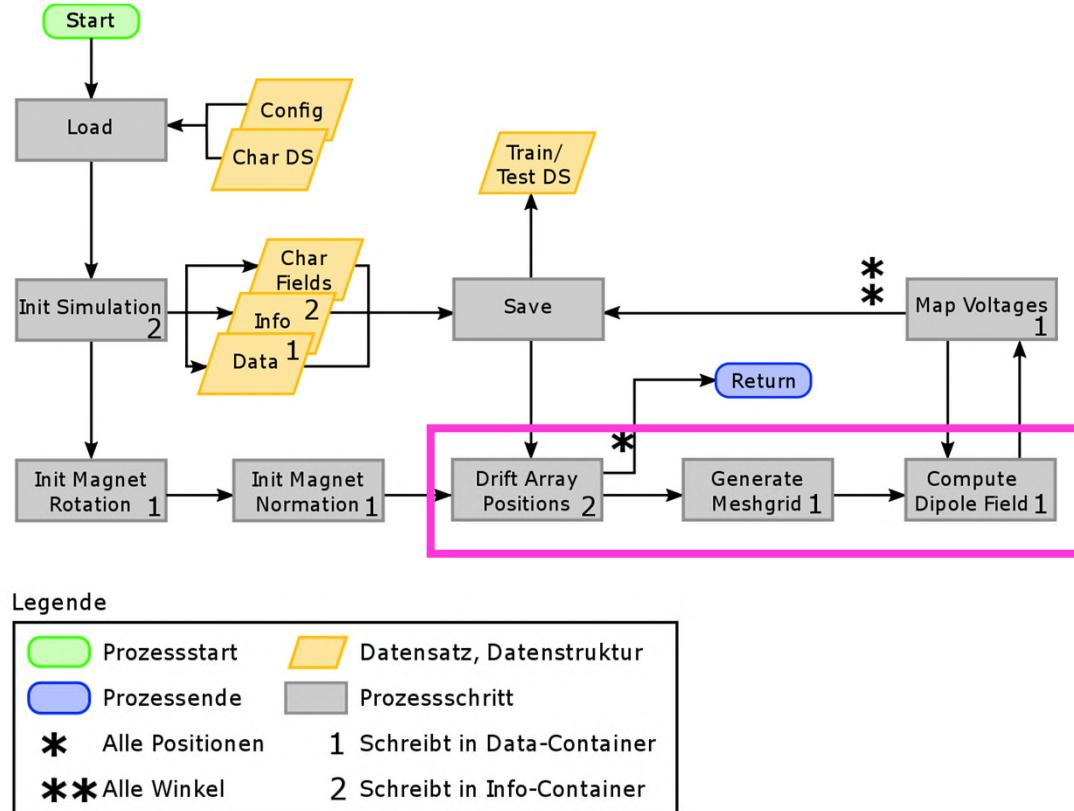
Simulation – Sensor-Array



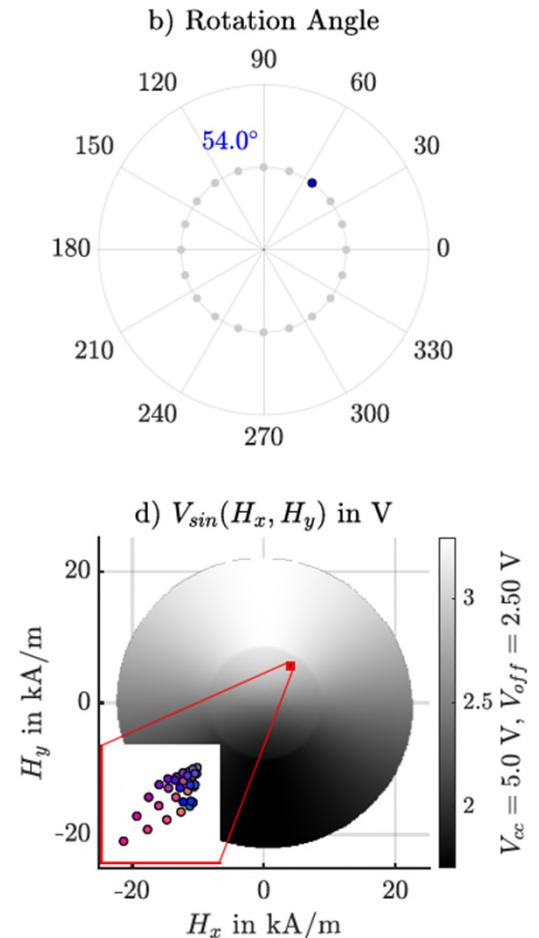
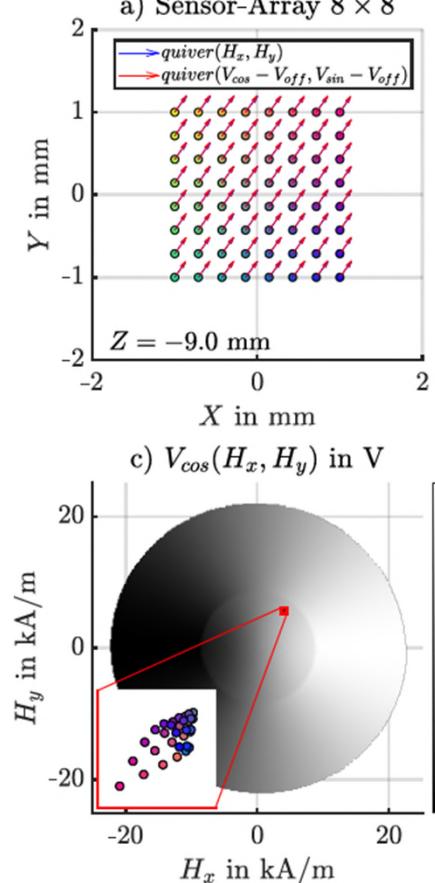
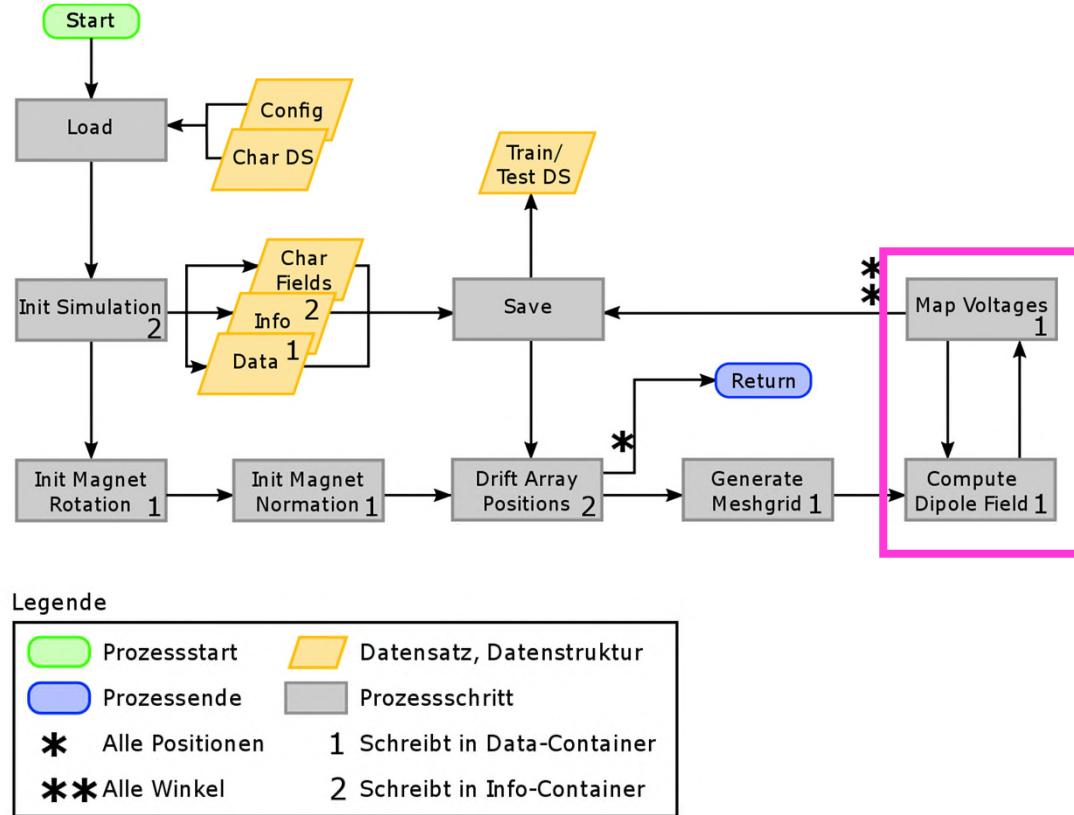
Simulation – Sensor-Array



Simulation – Sensor-Array

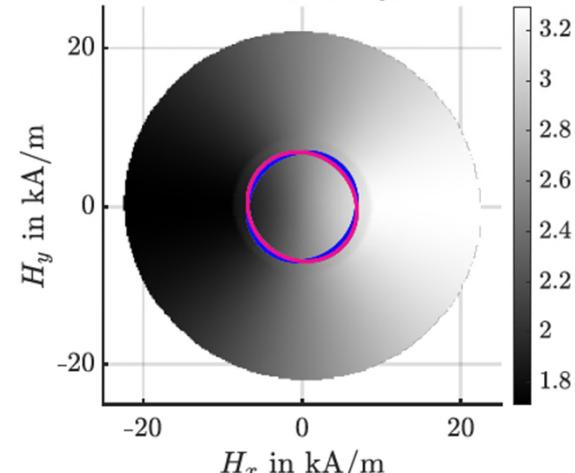


Simulation – Sensor-Array

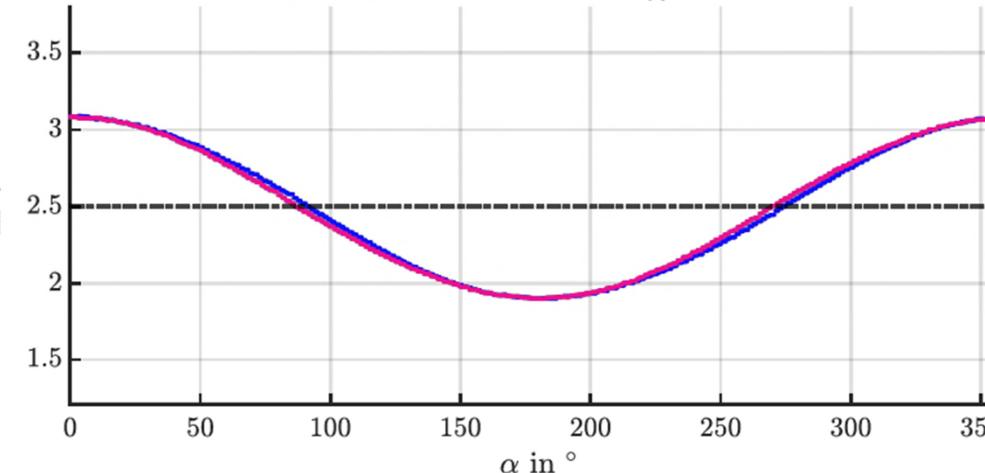


Simulation – Sensor-Array

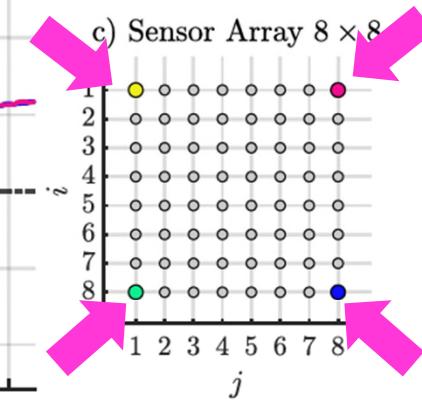
a) $V_{cos}(H_x, H_y)$



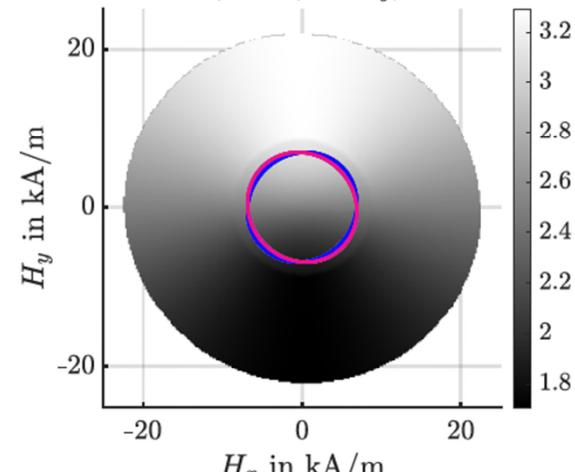
b) $V_{cos}(\alpha)$ f. $V_{cc} = 5.0$ V, $V_{off} = 2.50$ V



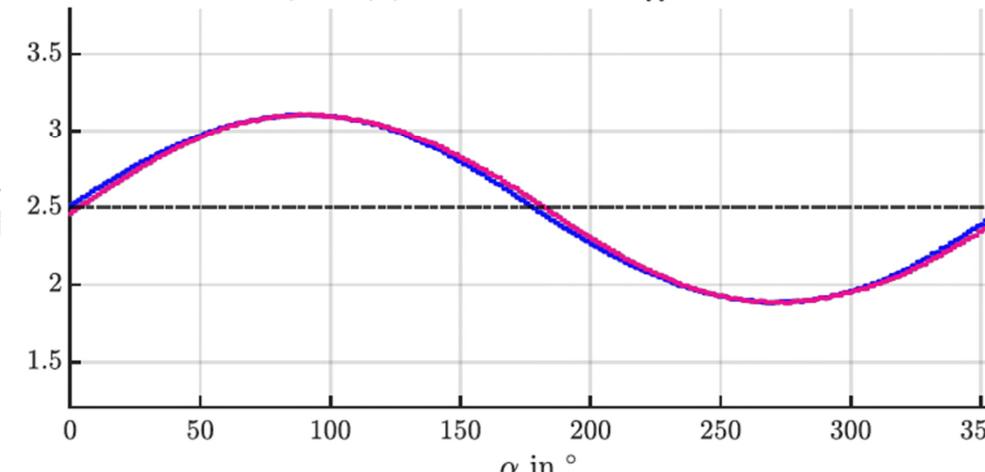
c) Sensor Array 8×8



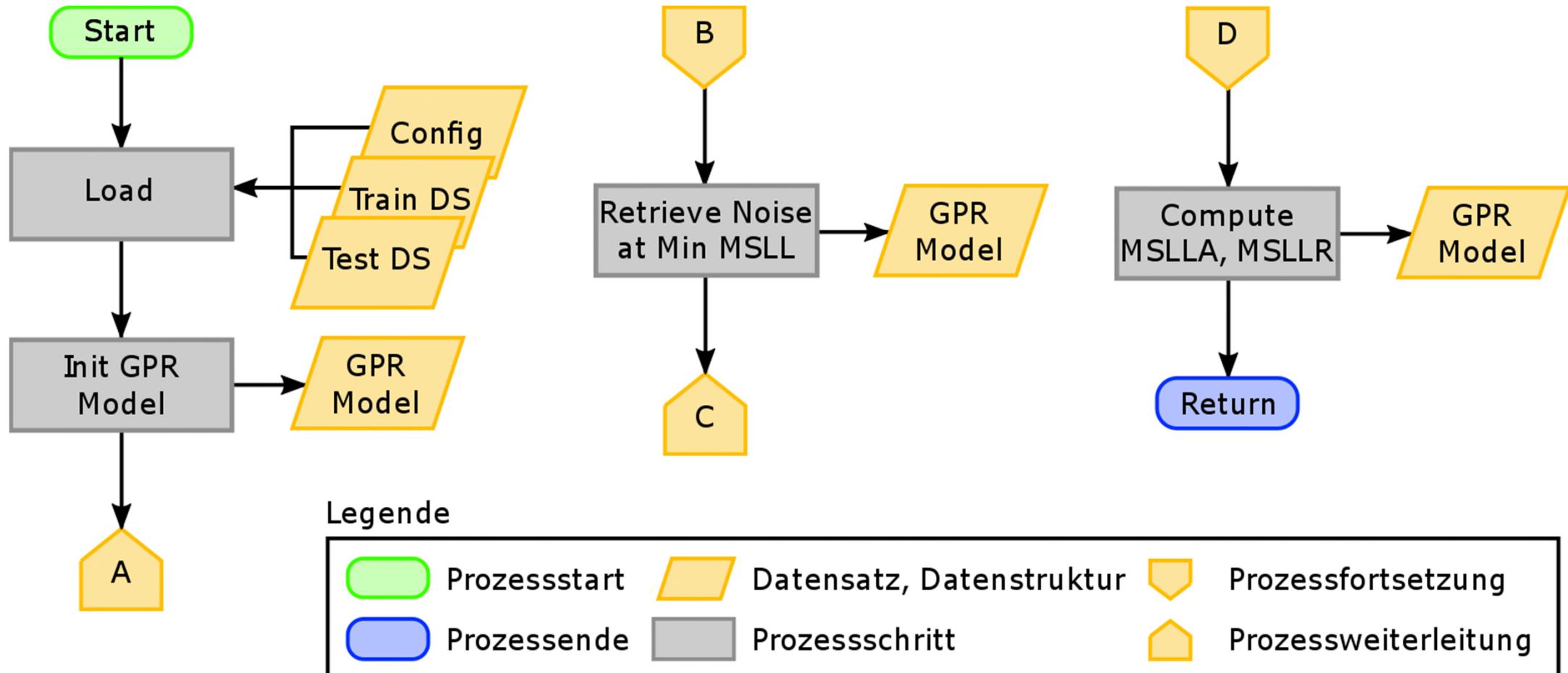
d) $V_{sin}(H_x, H_y)$



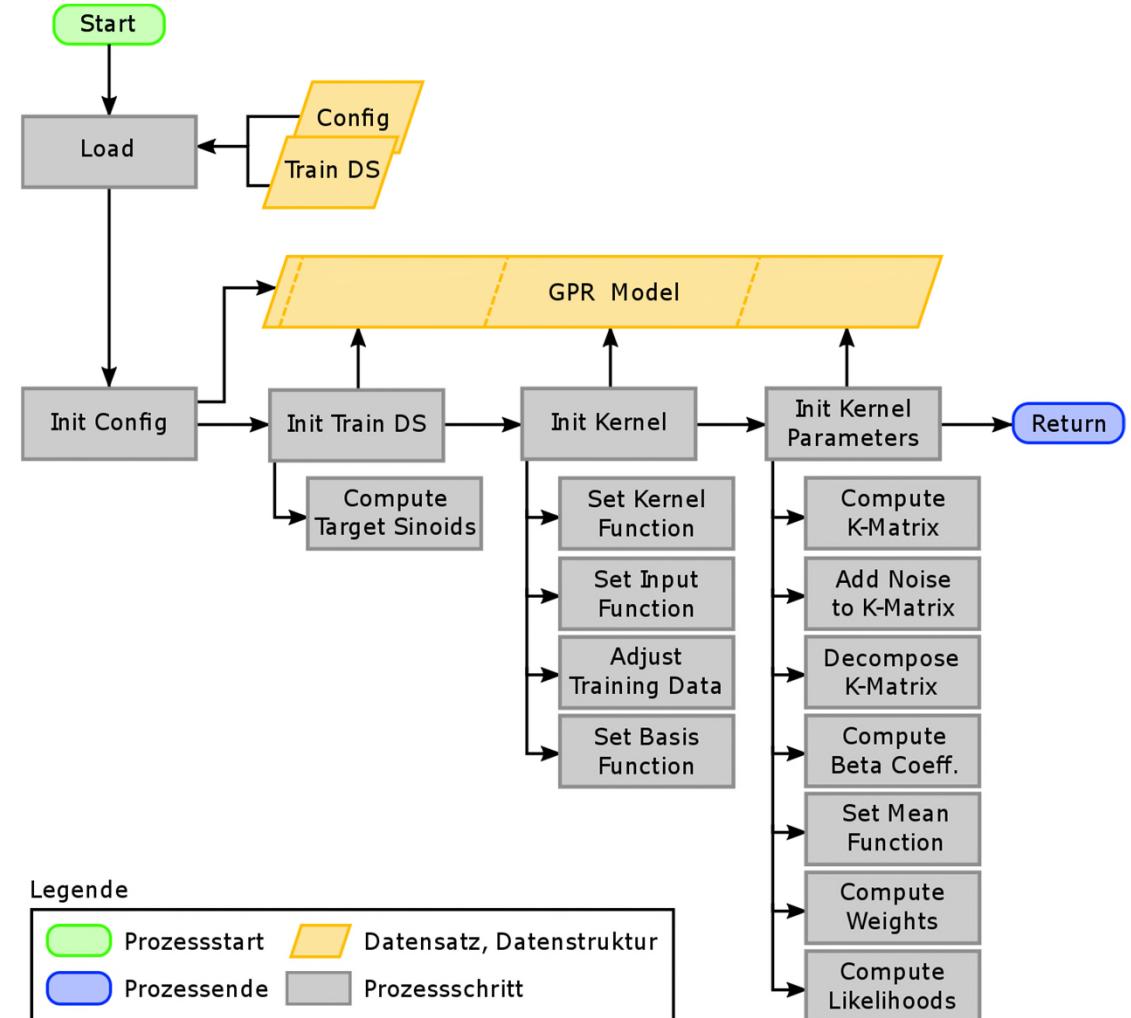
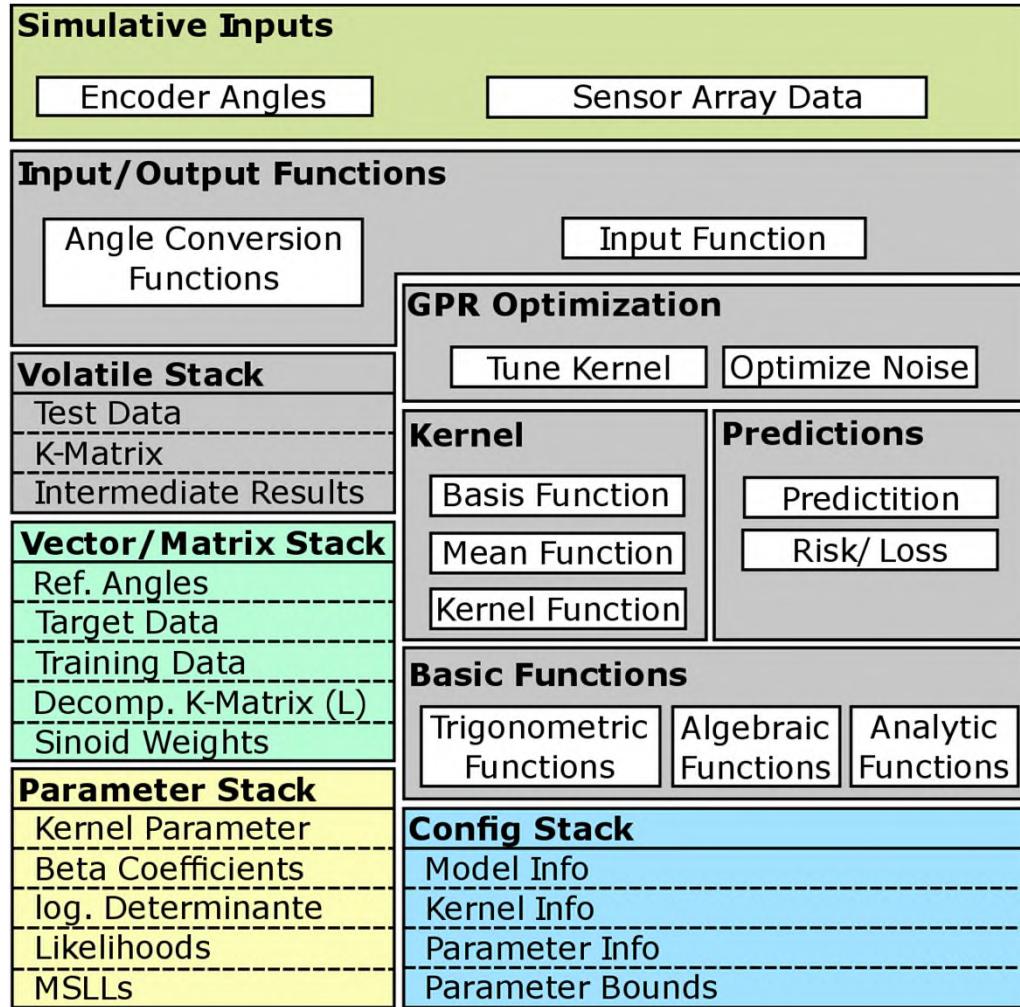
e) $V_{sin}(\alpha)$ f. $V_{cc} = 5.0$ V, $V_{off} = 2.50$ V



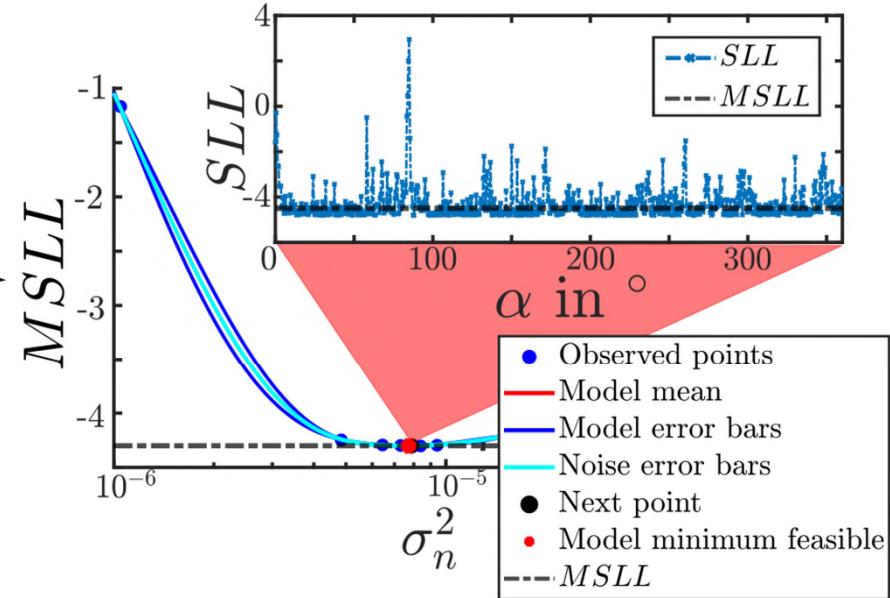
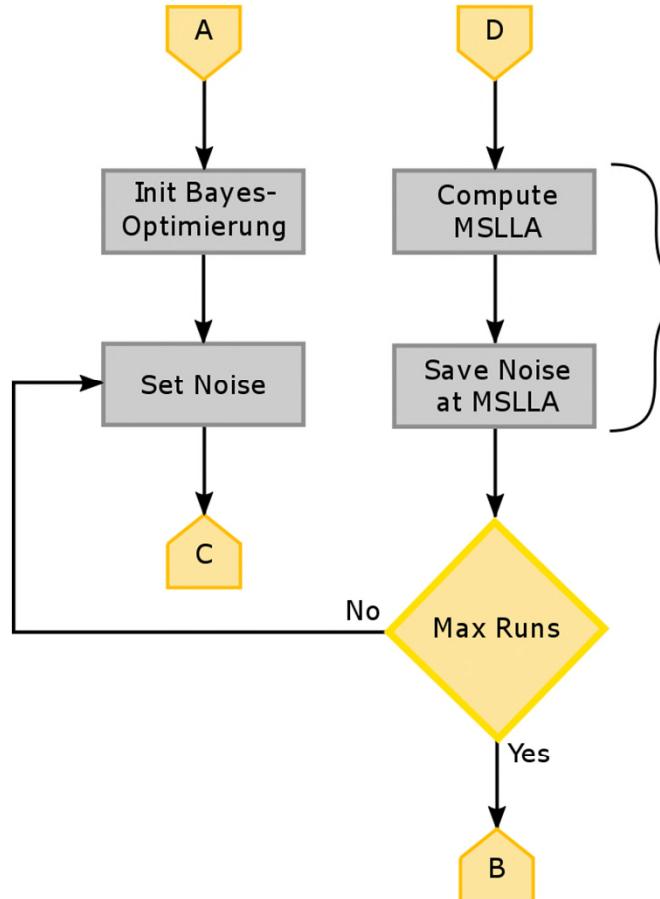
Simulation – Gauß-Prozesse



Simulation – Gauß-Prozesse



Simulation – Gauß-Prozesse



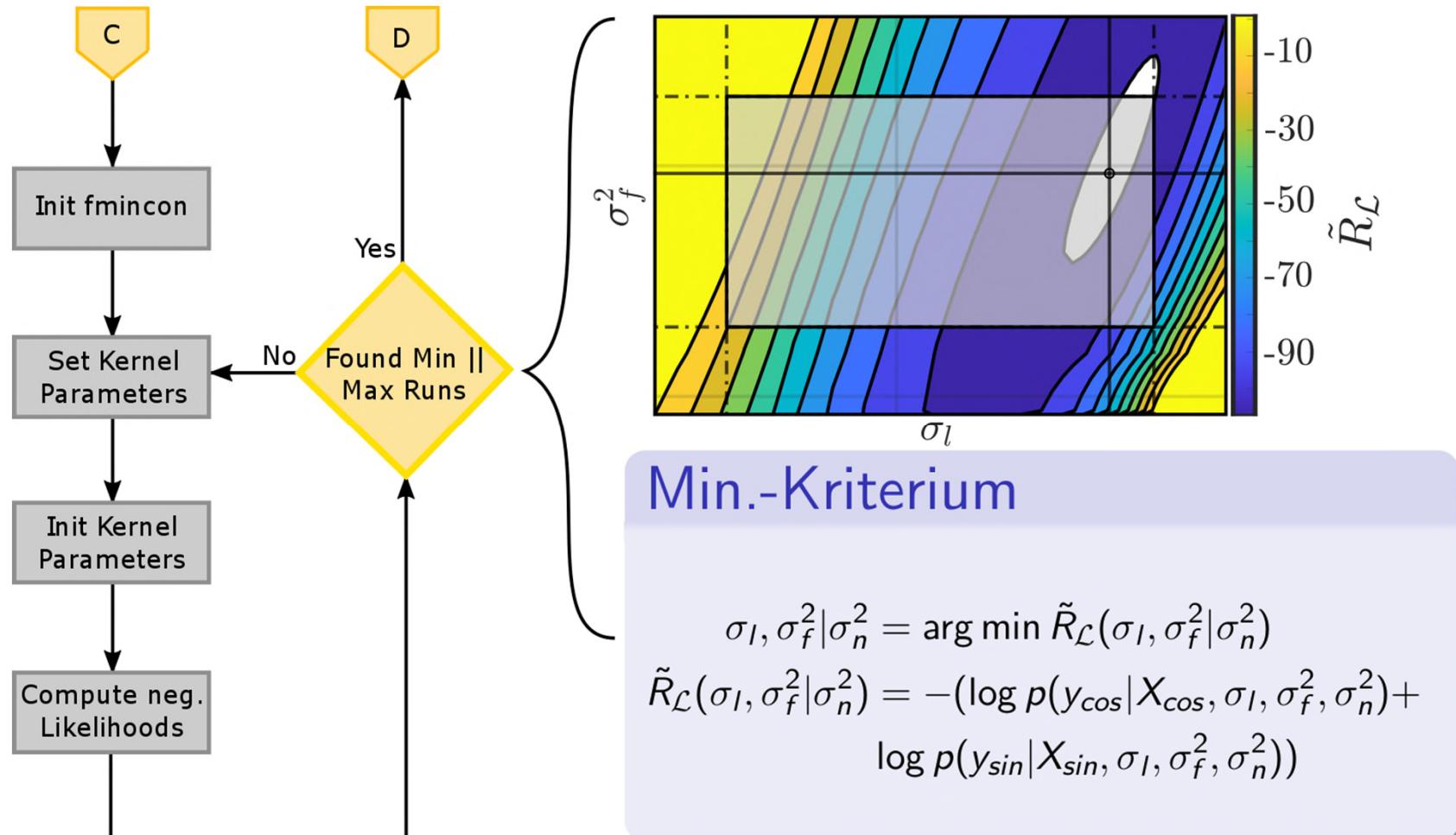
Min.-Kriterium

$$\sigma_n^2 | \mathcal{D}, \alpha_* = \arg \min MSLLA(\sigma_n^2 | \mathcal{D}, \alpha_*)$$

$$SLLA = 0,5 \cdot \left(\log(2\pi\sigma_*^2) + \frac{(\alpha - \alpha_*)^2}{\sigma_*^2} \right)$$

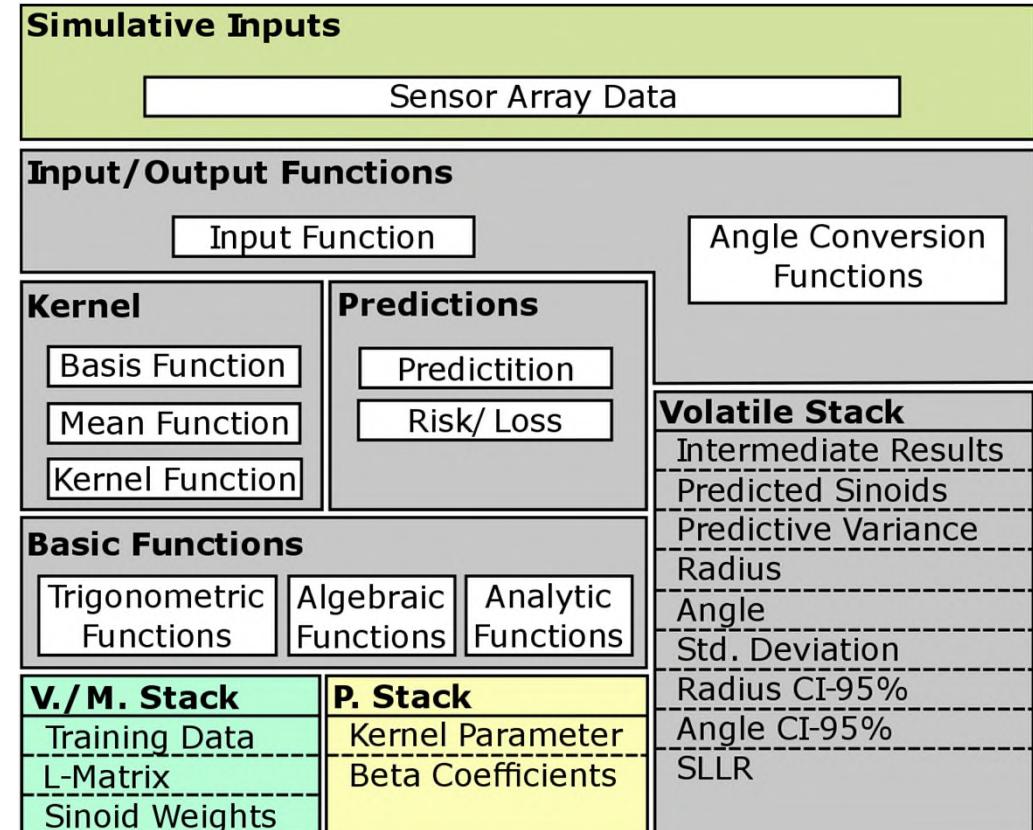
$$\sigma_*^2 = \sigma_n^2 + V_*$$

Simulation – Gauß-Prozesse

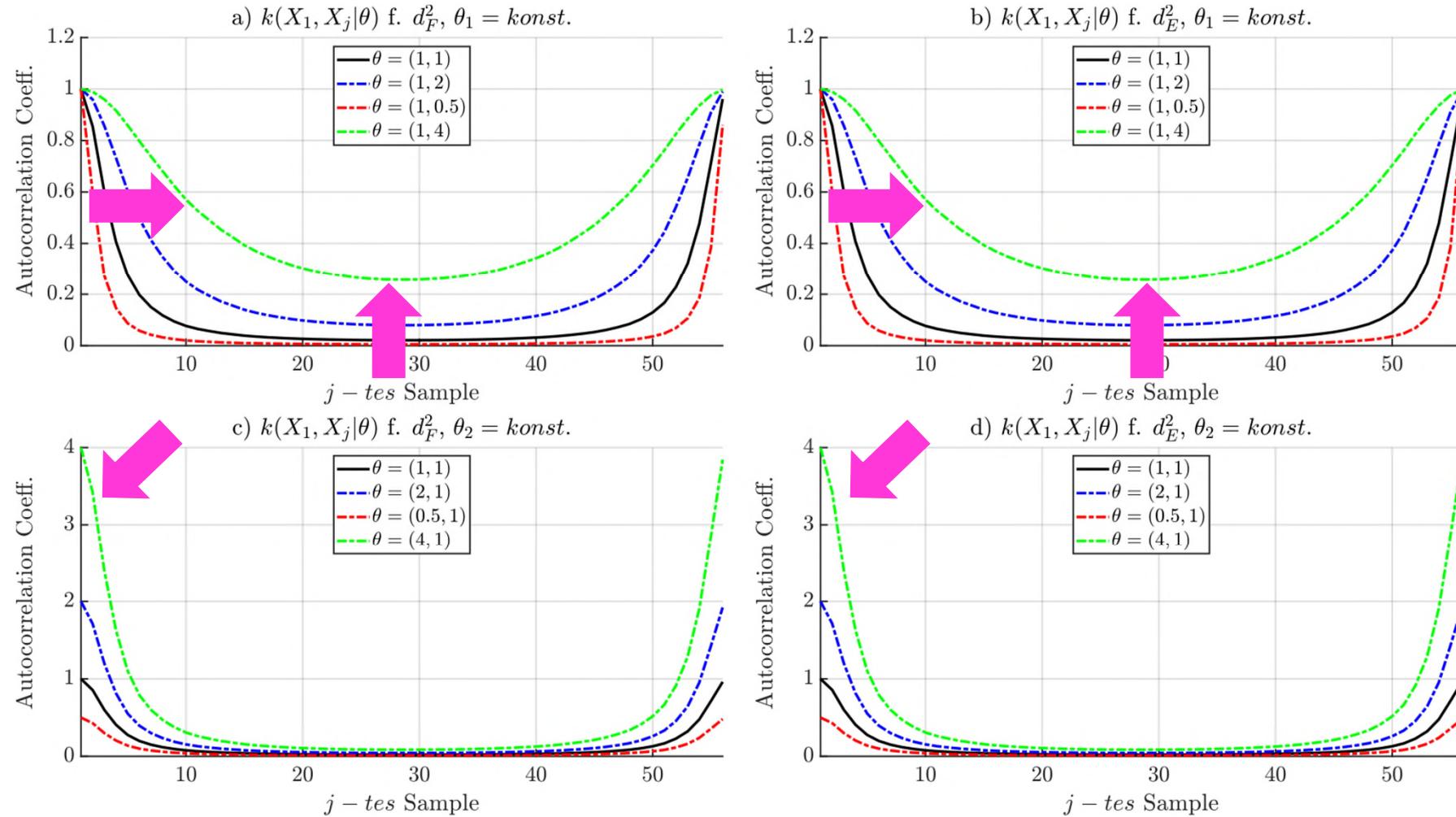


Simulation – Gauß-Prozesse

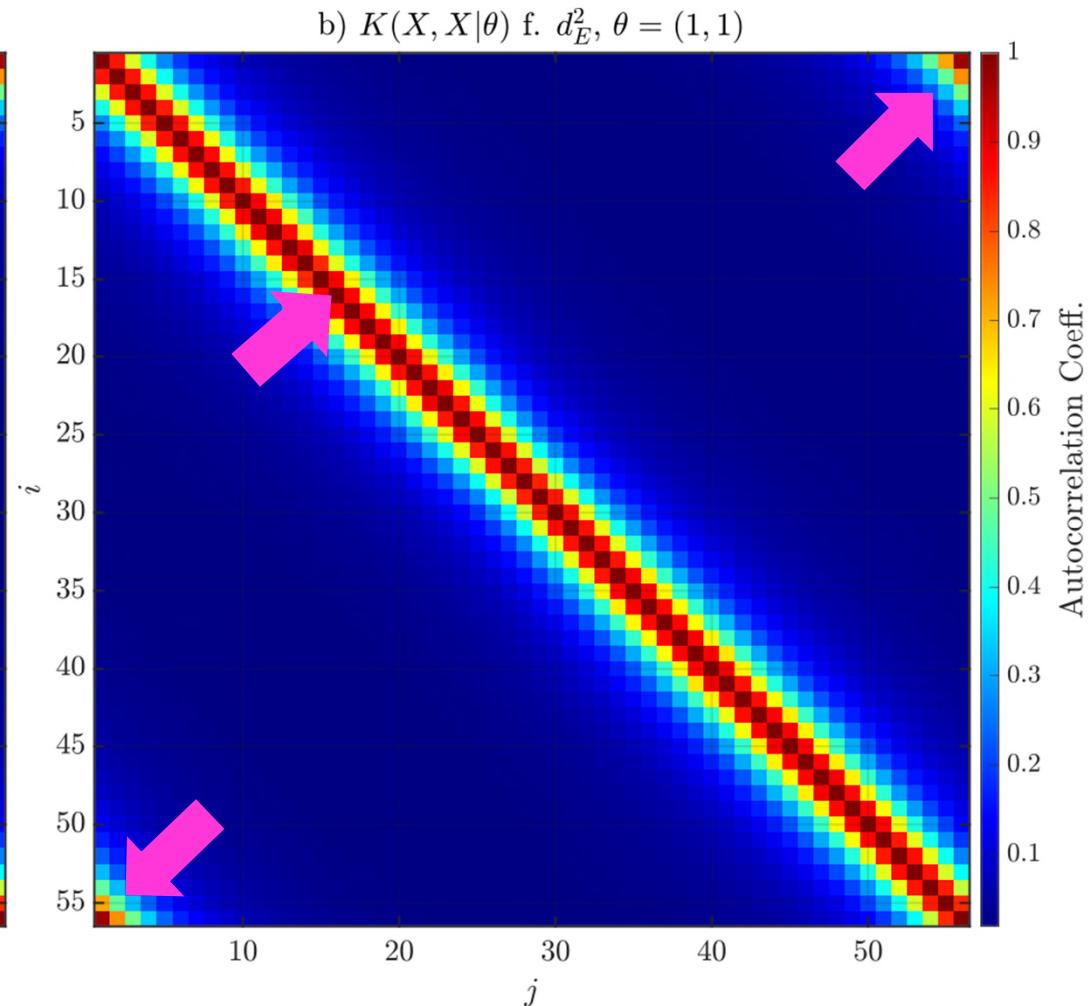
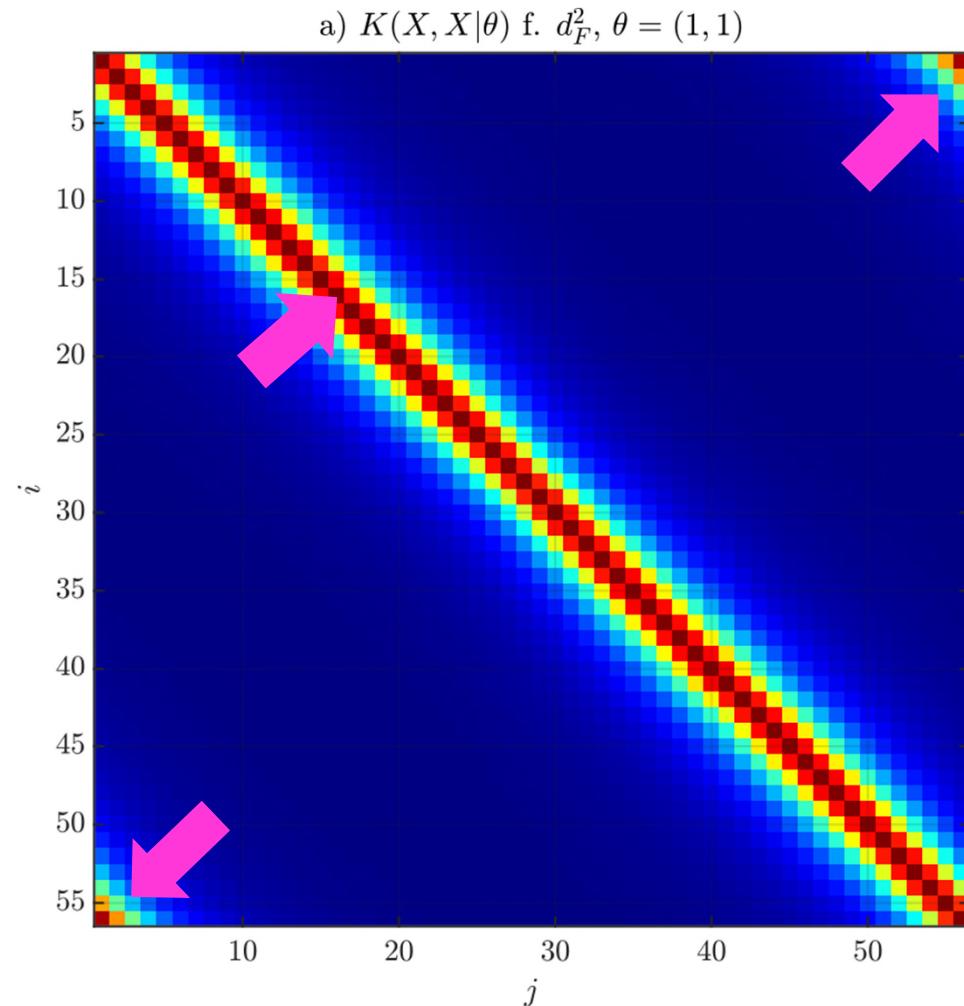
- Ausrichtung umgelegt
- Minimale Parametrierung
- Funktionaler Aufbau
- Vorhersage und Derivate
- Qualitätskriterien



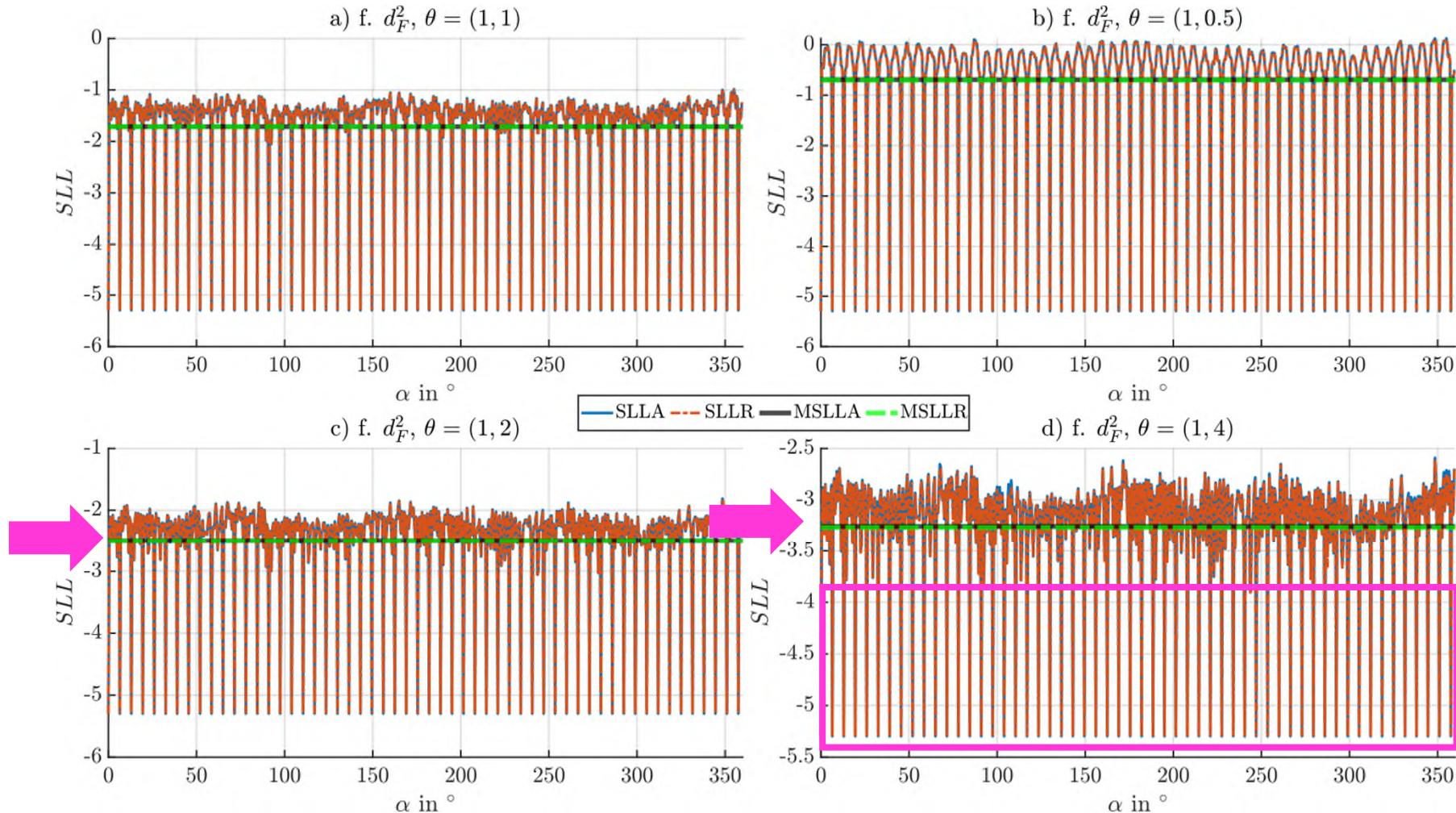
Kernel-Vergleich



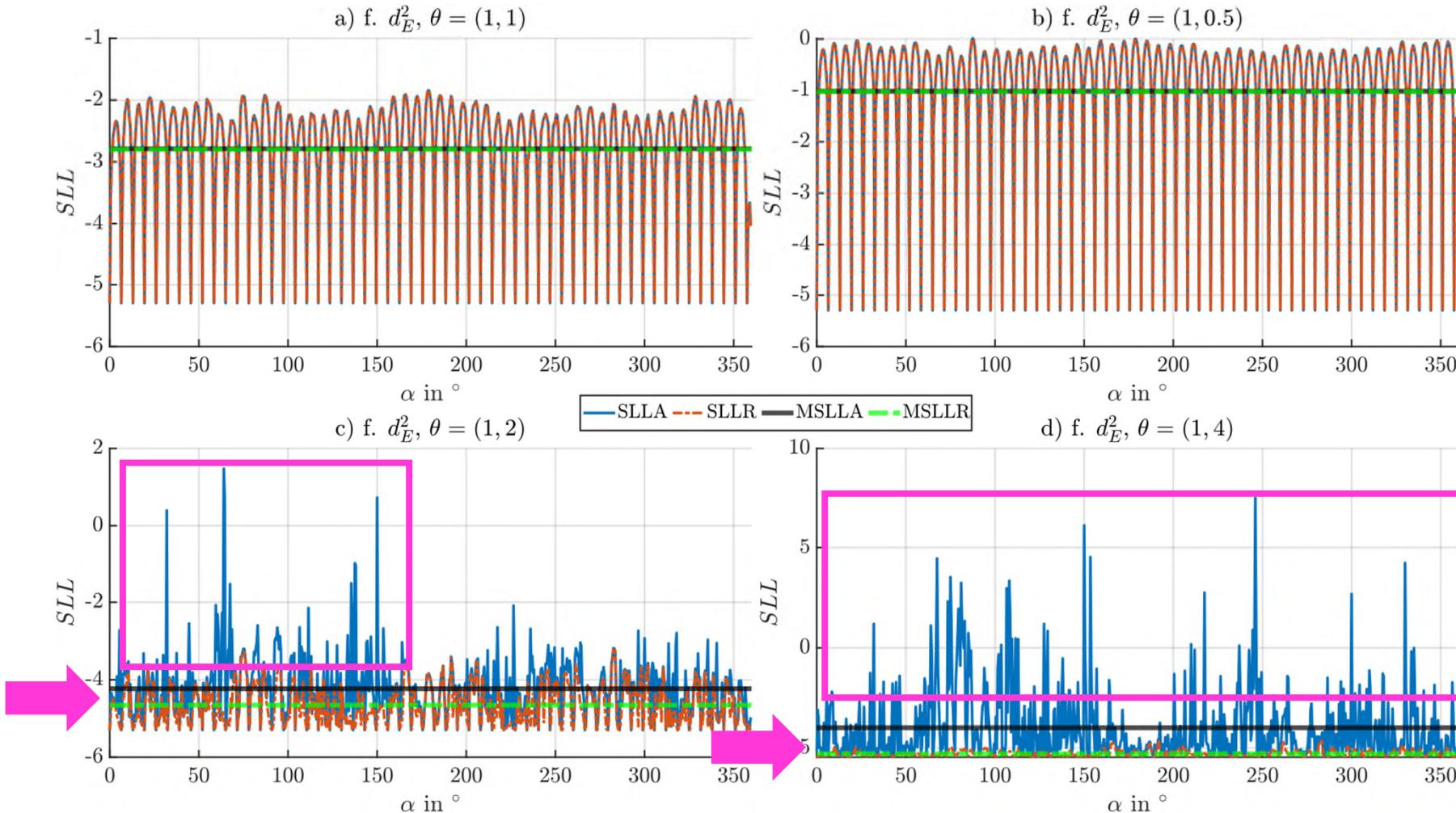
Kernel-Vergleich



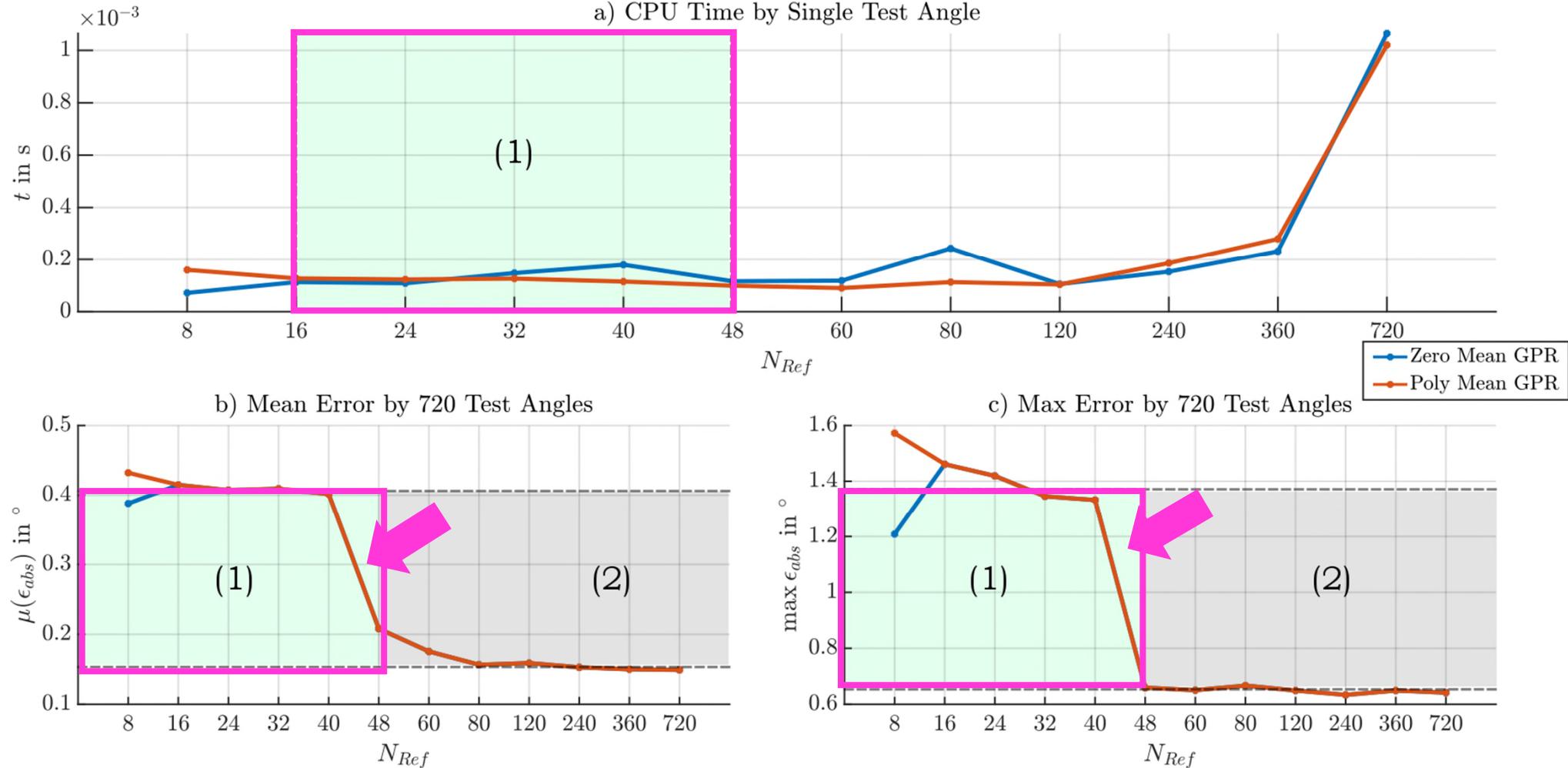
Kernel-Vergleich



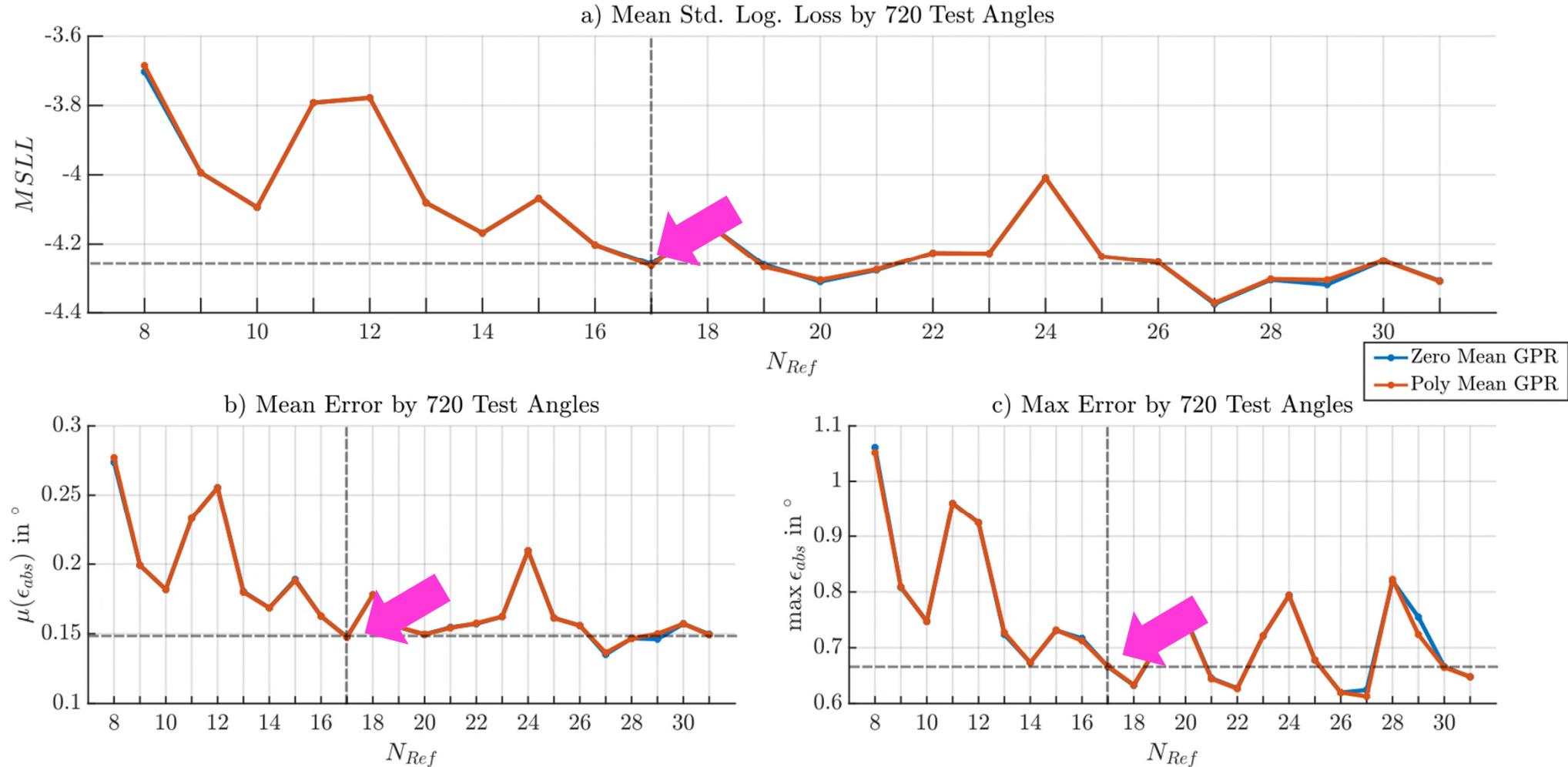
Kernel-Vergleich



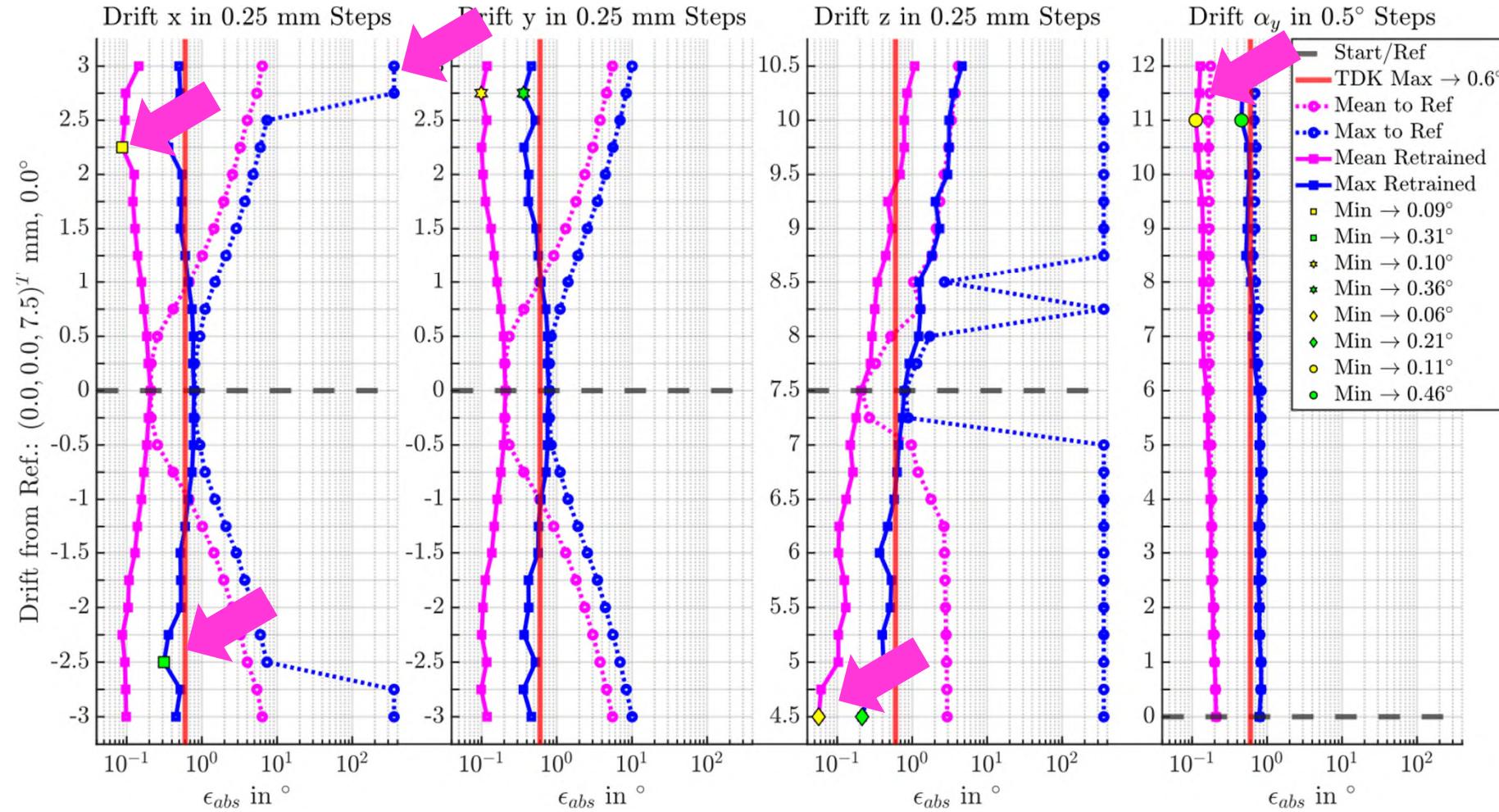
Kompromissbildung



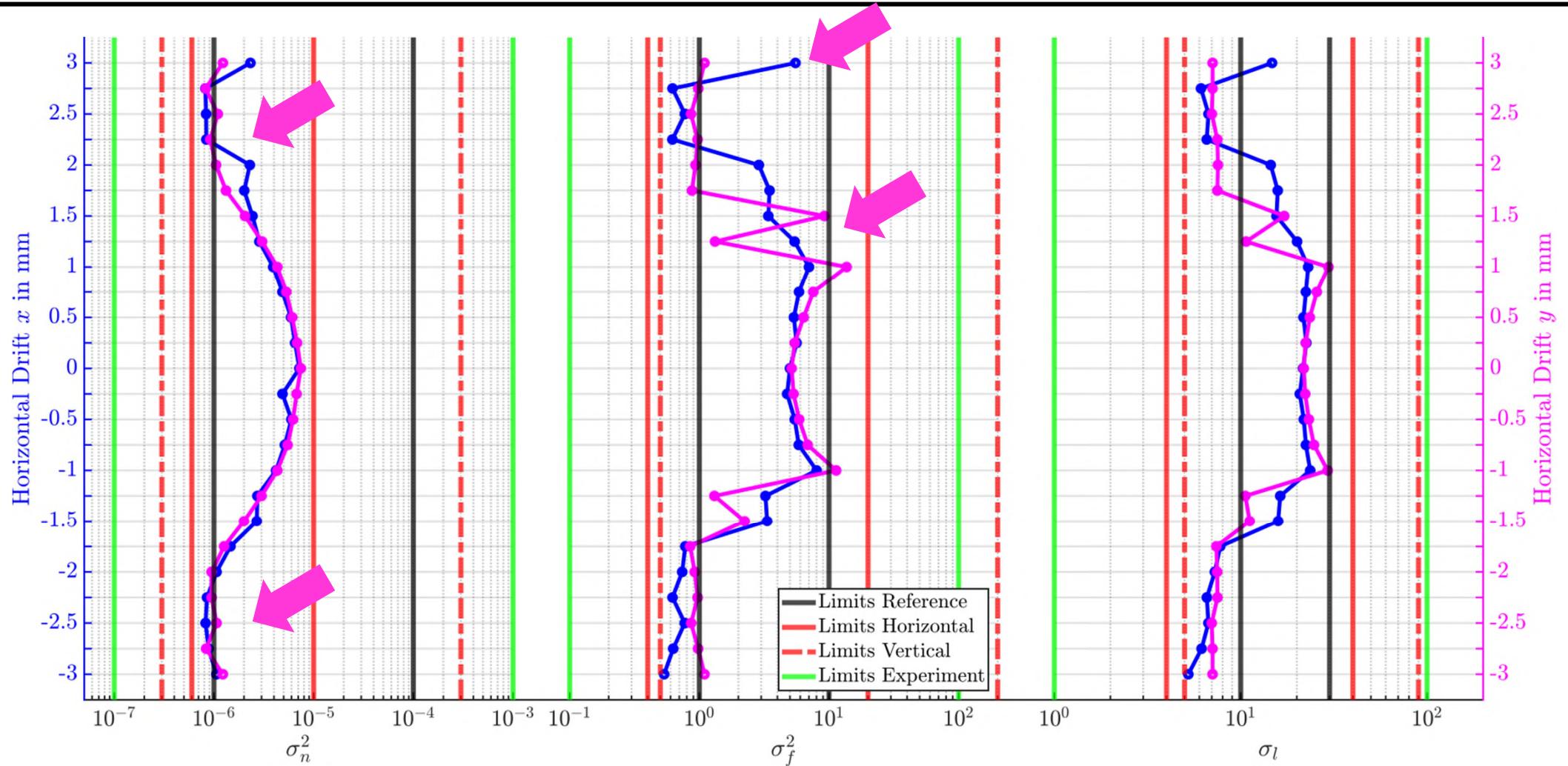
Kompromissbildung



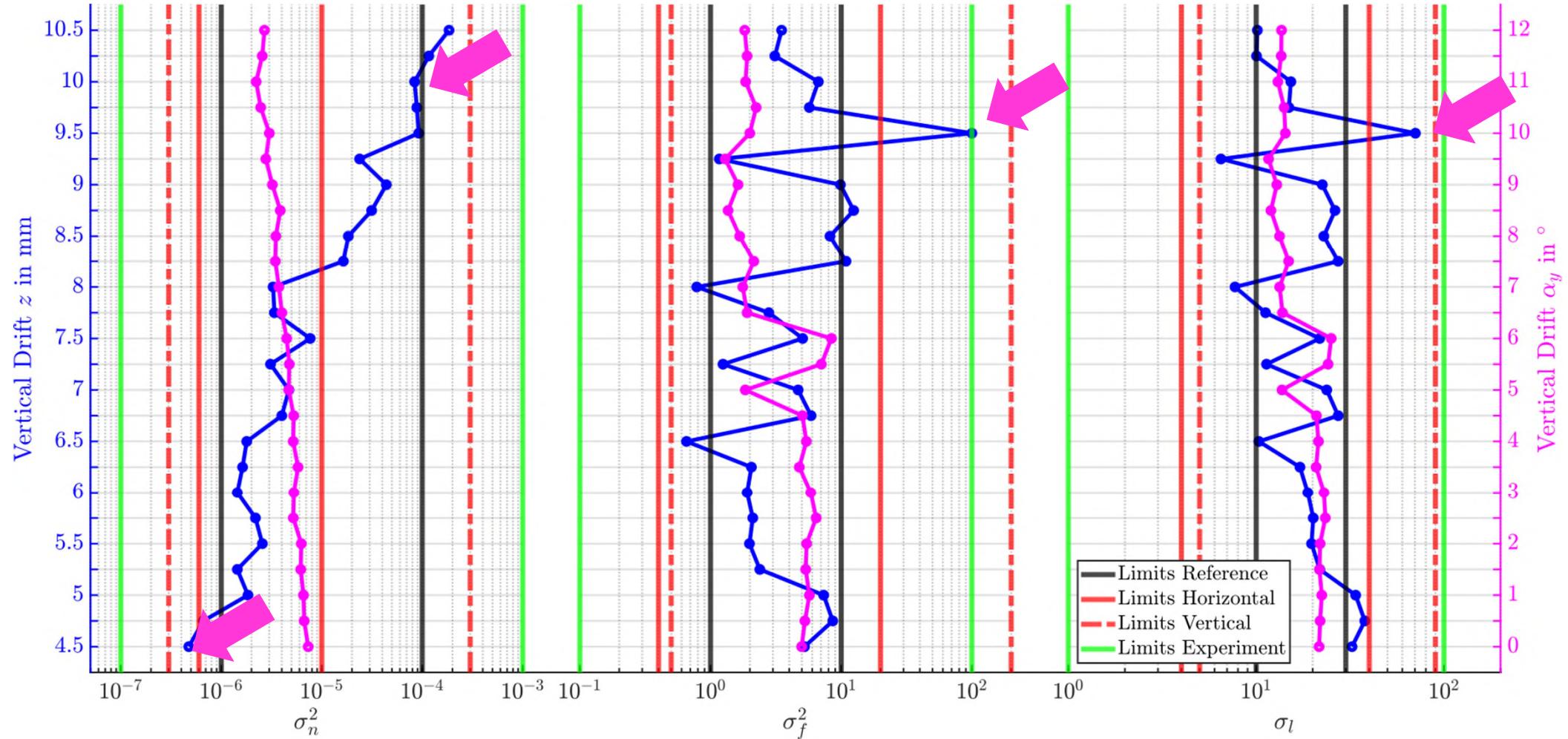
Einfache Driftexperimente



Einfache Driftexperimente

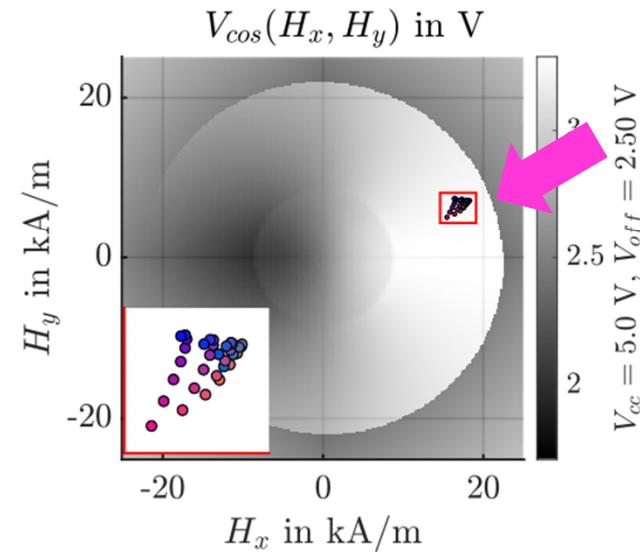


Einfache Driftexperimente

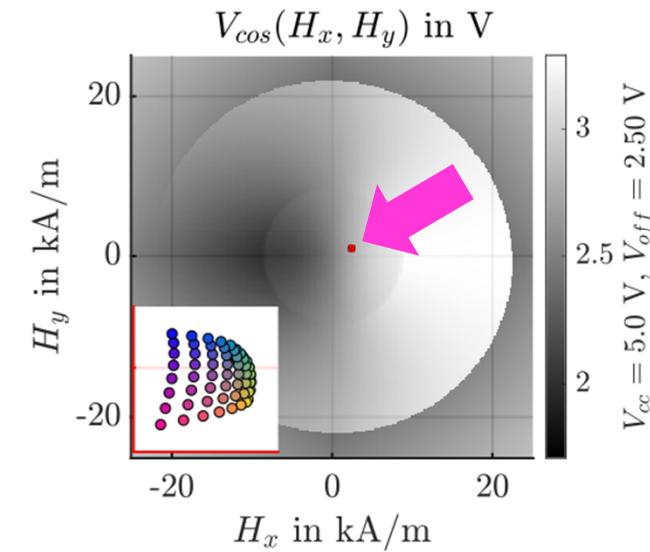


Einfache Driftexperimente

a) Drift in z 4.5 mm

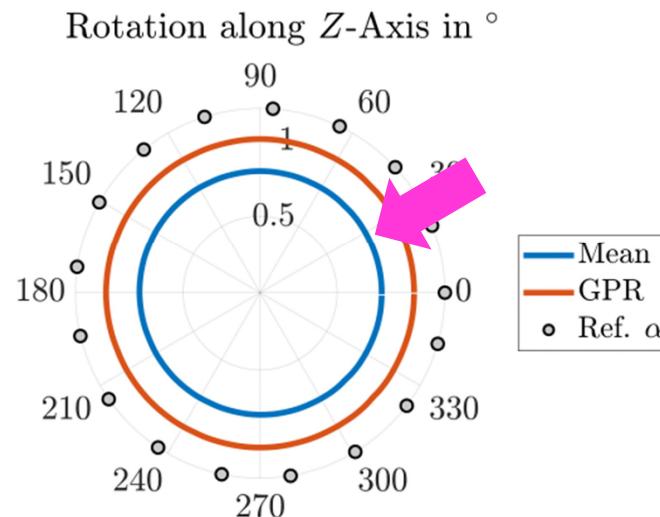


b) Drift in z 10.5 mm

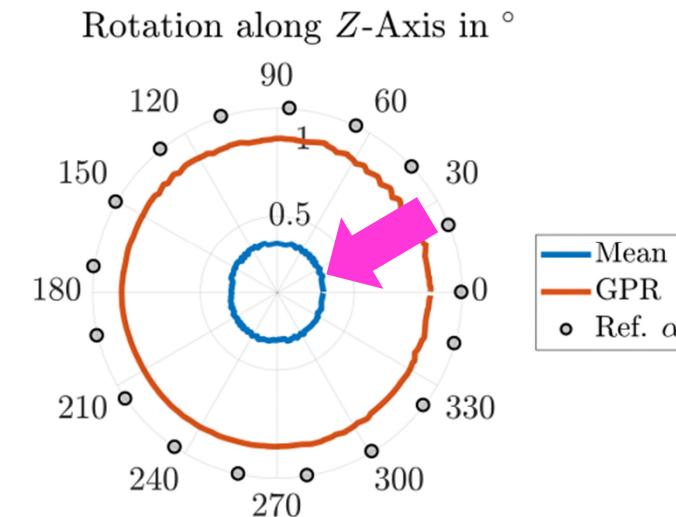


Einfache Driftexperimente

a) Drift in z 4.5 mm

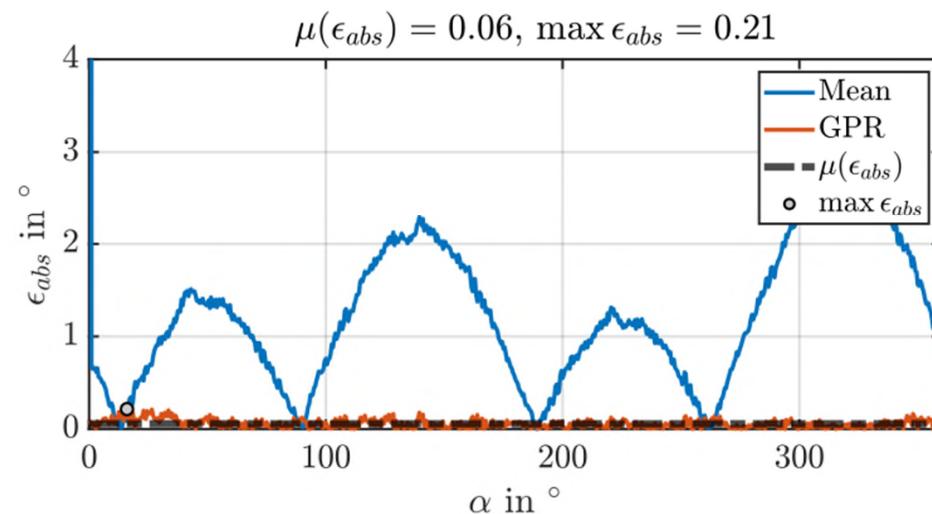


b) Drift in z 10.5 mm

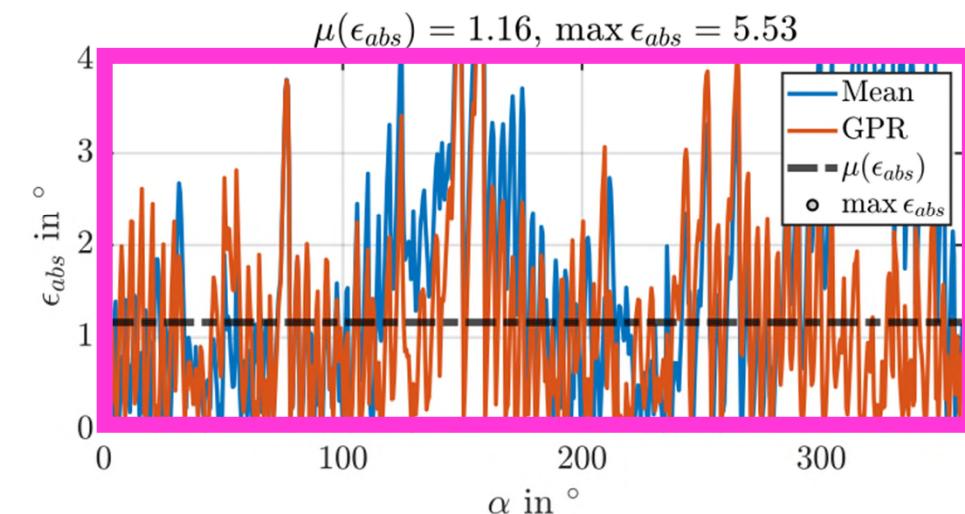


Einfache Driftexperimente

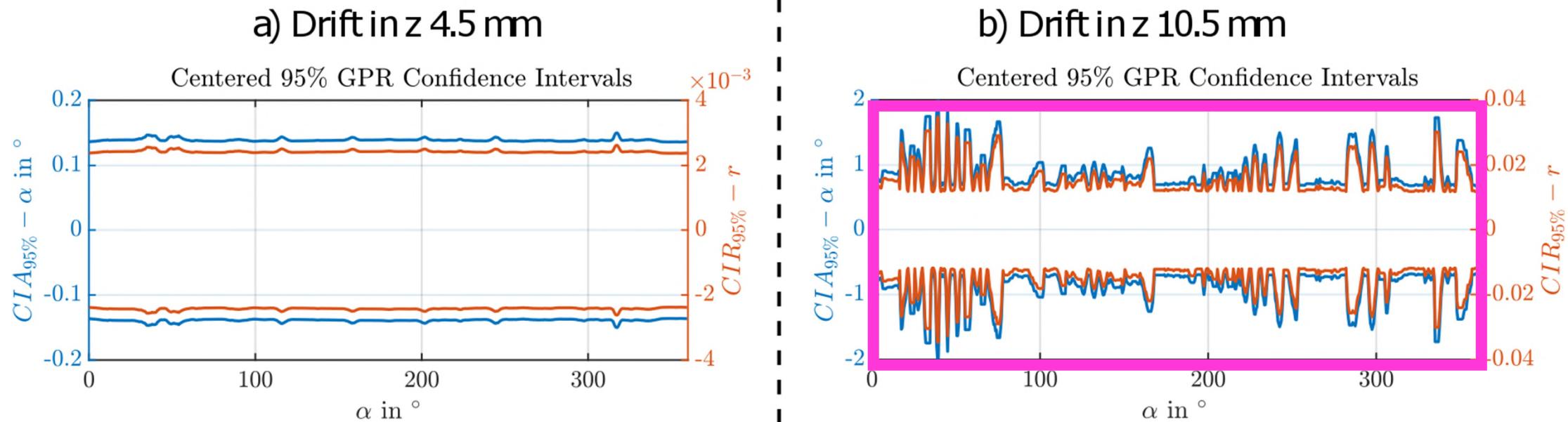
a) Drift in z 4.5 mm



b) Drift in z 10.5 mm

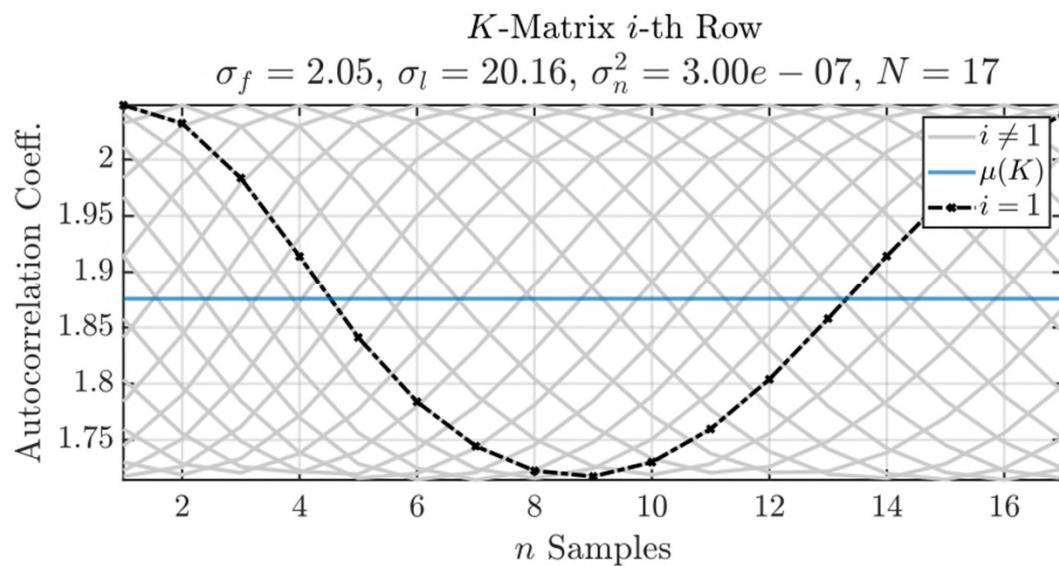


Einfache Driftexperimente

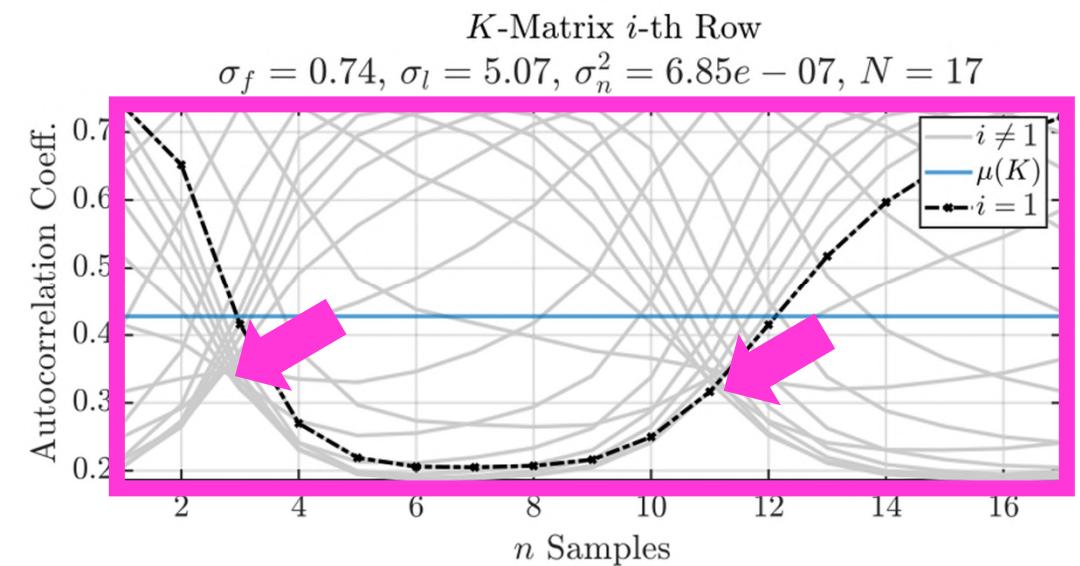


Kombinierte Fehllage

a) Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

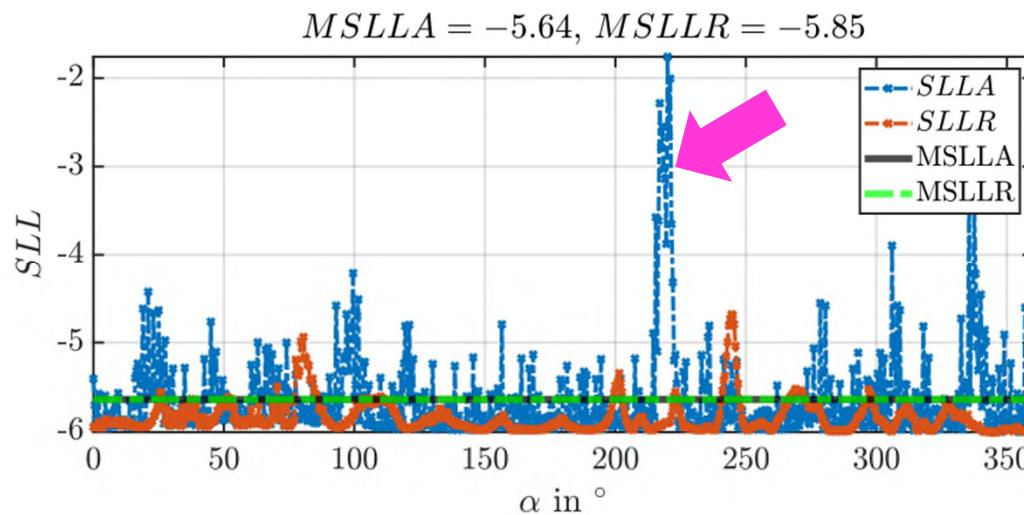


b) Position: $(2.5, 2.0, 4.5)^T$ mm, Tilt: 11.0°

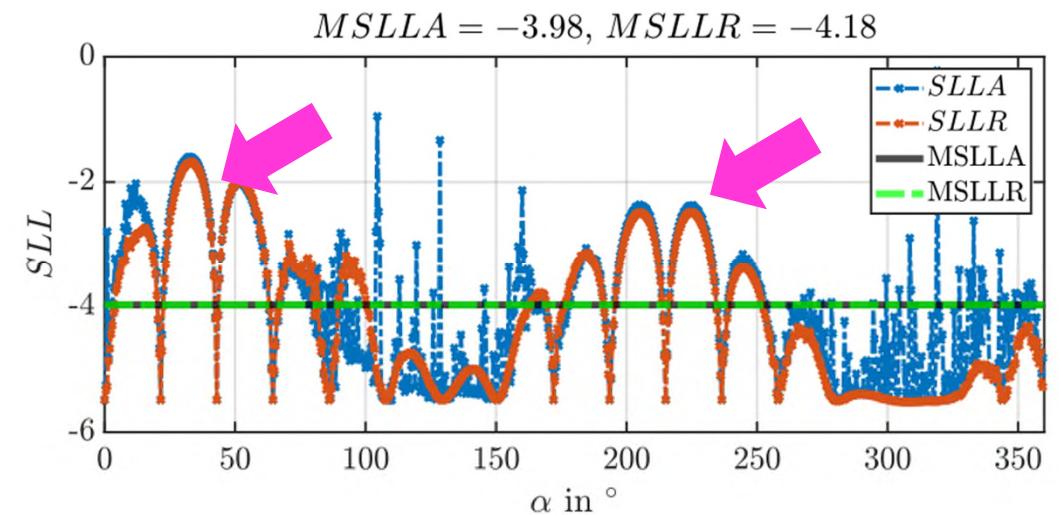


Kombinierte Fehllage

a) Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

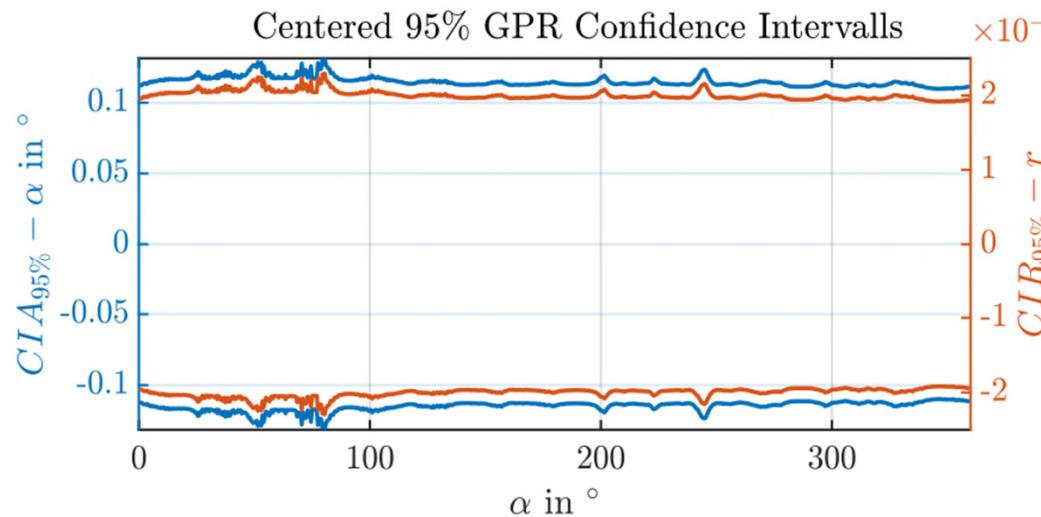


b) Position: $(2.5, 2.0, 4.5)^T$ mm, Tilt: 11.0°

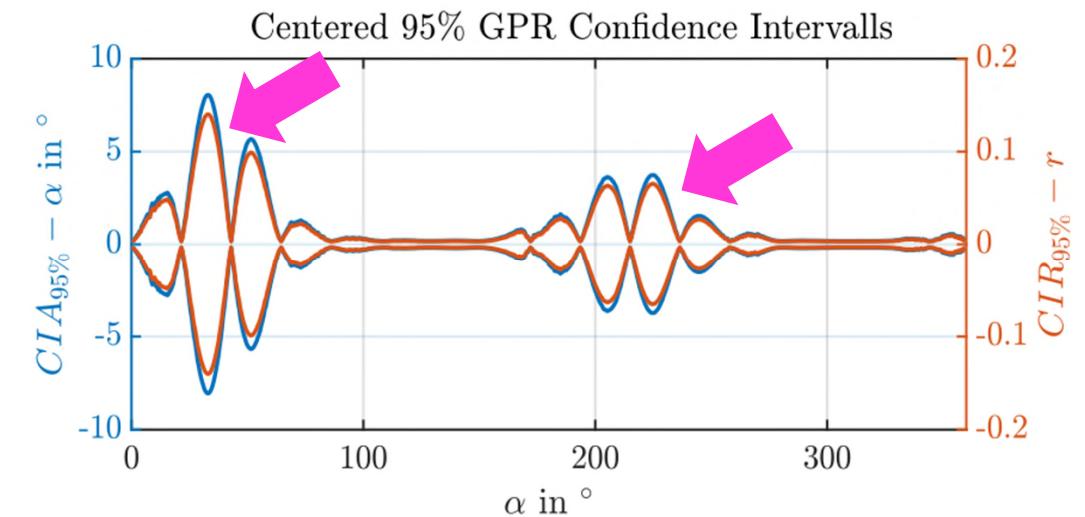


Kombinierte Fehllage

a) Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°

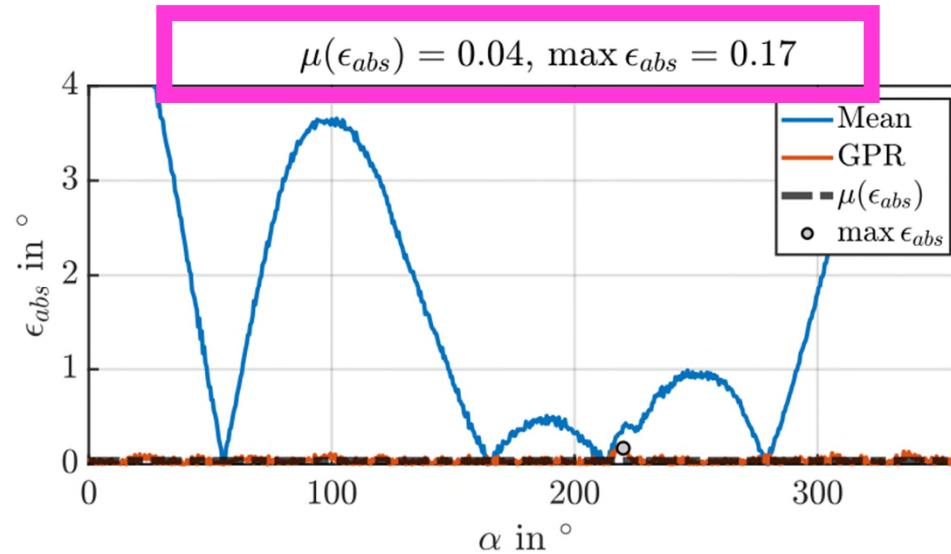


b) Position: $(2.5, 2.0, 4.5)^T$ mm, Tilt: 11.0°

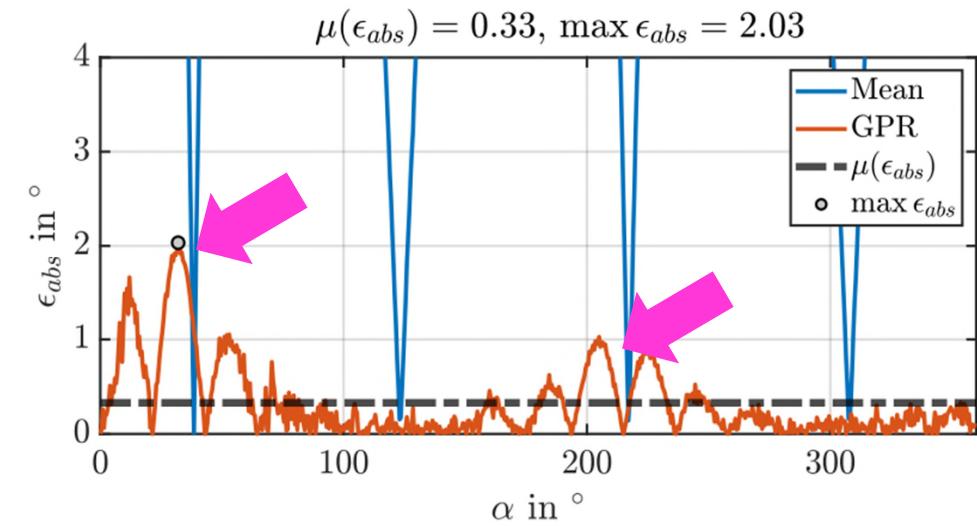


Kombinierte Fehllage

a) Position: $(0.5, 1.0, 4.5)^T$ mm, Tilt: 11.0°



b) Position: $(2.5, 2.0, 4.5)^T$ mm, Tilt: 11.0°



Kombinierte Fehllage

