

GKSL aus Repeated Interactions + VERIFIKATION

Trace-out & Raten GKSL & Fits **Verification Suite** Export

Verification Suite (CPTP/Choi, GADC-Fit, Semigroup, Spohn, MCWF≈GKSL)

A) Choi + CPTP (ein Kollisionsschritt)

TP-Defekt $\|\Sigma K^\dagger K - I\|$

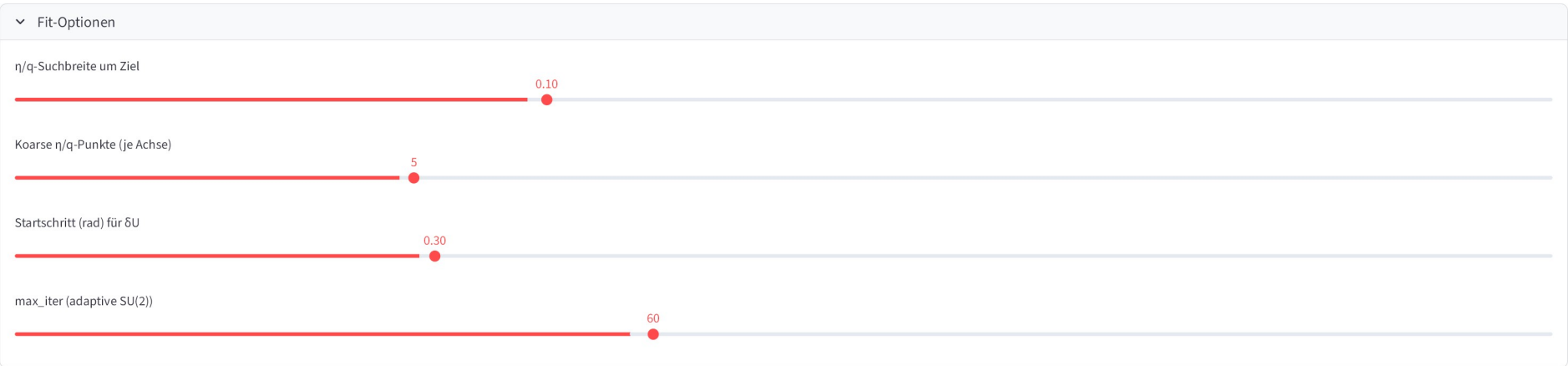
1.570e-16

Choi min-Eig (≥ 0 erwartet)

5.241e-06

OK Ziel: TP-Defekt = 0, minEig(Choi) ≥ 0

B) GADC-Fit (ein Schritt) — basis-aligned + adaptive



Ziel $\eta = \sin^2\theta$

0.009967

Ziel $q = p_{\text{exc}}(\beta, \omega)$

0.119203

$\min \|\Delta\text{Choi}\|_F$

3.846e-16

η^*

0.009967

q^*

0.119203

$\Delta\eta = 0.000\text{e}+00$, $\Delta q = 0.000\text{e}+00$

OK Ziel: $\eta \approx \sin^2\theta$, $q \approx p_{\text{exc}}(\beta, \omega)$ und ΔChoi minimal

C) Semigroup-Test (GKSL): $\Phi_{\{t+s\}} \approx \Phi_t \circ \Phi_s$ (affine PTM)

Zeit t

1.00

Zeit s

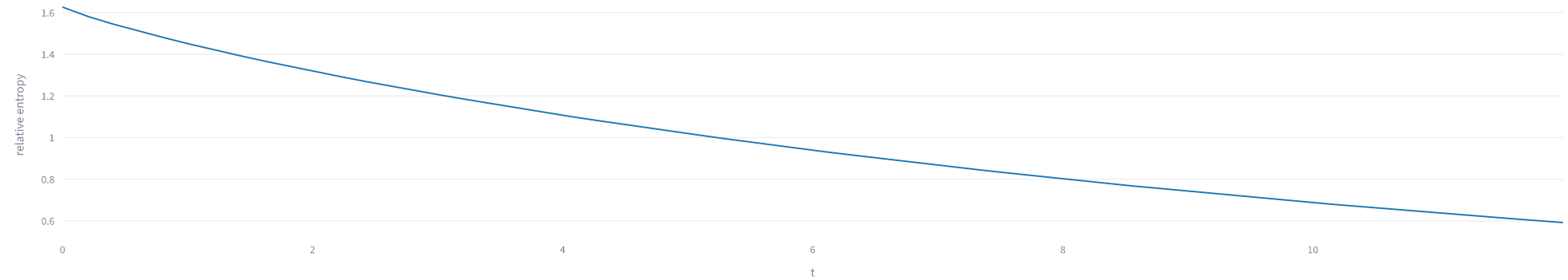
0.60

Semigroup-Defekt $\|T(t+s) - T(t)T(s)\|_F$

7.159e-15

OK Ziel: Semigroup-Defekt = 0

D) Gibbs-Fixpunkt & Spohn-Monotonie

 $\min D(\rho||\rho_\beta)$

0.592114

 $\max D(\rho||\rho_\beta)$

1.626928

 $\max d/dt D(\rho_t||\rho_\beta)$

-4.438e-02

OK Ziel: $\max d/dt D \leq 0$ (Spohn)

E) Trajektorien (MCWF) vs. GKSL

Parameter & Start

Anzahl Trajektorien

400

dt (Trajektorien)

0.010

t_max (Trajektorien)

2.00

Seed

7

MCWF vs GKSL (Endzeit) — Trace distance

5.730e-03

OK Ziel: Trace distance → 0 (ntraj↑, dt↓)

Konvergiert gegen 0 für ntraj↑ und dt↓.

Supplementary: Methodik, Zielwerte & Primärquellen (A–E)

A) CPTP & Choi (Kraus) — Ziel: TP-Defekt = 0; minEig(Choi) ≥ 0.

$$\Phi(\rho) = \sum_i K_i \rho K_i^\dagger, \quad \sum_i K_i^\dagger K_i = 1, \quad C_\Phi = \sum_i \text{vec}(K_i) \text{vec}(K_i)^\dagger \succeq 0.$$

B) Generalized Amplitude Damping (GADC) — Ziel: $\eta \approx \sin^2 \theta$, $q \approx p_{\text{exc}}(\beta, \omega)$; Basis-Ausrichtung + adaptive Vor/Nach-Unitäre.

C) GKSL-Semigruppe (affine PTM) — Ziel: $\Phi_{t+s} = \Phi_t \circ \Phi_s \Rightarrow \|T(t+s) - T(t)T(s)\|_F = 0.$

D) Gibbs-Fixpunkt & Spohn — Ziel: $\max_t \frac{d}{dt} D(\rho_t \| \rho_\beta) \leq 0$ (numerisch bis auf Toleranz).

E) MCWF ≡ GKSL im Mittel — Ziel: Trace-Distance($\langle \text{Traj} \rangle$, GKSL) → 0 für $n_{\text{traj}} \uparrow$, $dt \downarrow$.

Zielwerte dieses Runs

$\theta = \text{g_}\tau_{\text{int}}$	$q_{\text{target}} = p_{\text{exc}}(\beta, \omega)$	$\gamma \uparrow / \gamma \downarrow - e^{\wedge \{-\beta \omega\}}$ (Ziel)
0.100000	0.119203	0
$\eta_{\text{target}} = \sin^2 \theta$	KMS-Ziel $e^{\wedge \{-\beta \omega\}}$	
0.009967	0.135335	

OK-Schwellen (Verification)

A) TP-Defekt ≤ 1e-12; minEig(Choi) ≥ -1e-12

B) $|\eta^* - \eta_{\text{target}}| \leq 1\text{e-}03$; $|q^* - q_{\text{target}}| \leq 1\text{e-}03$; $\min \|\Delta \text{Choi}\|_F \leq 5\text{e-}03$

C) Semigroup-Defekt ≤ 1e-02

D) $\max d/dt D(\rho_t \| \rho_\beta) \leq 1\text{e-}06$

E) Trace-Distance($\langle \text{Traj} \rangle$, GKSL) ≤ 1e-02

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Primärquellen & Referenzen (mit URLs)

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<https://link.aps.org/doi/10.1103/RevModPhys.70.101>
- GADC (Kraus-Form & Parametrisierung): PennyLane-Doku »GeneralizedAmplitudeDamping«.
<https://docs.pennylane.ai/en/stable/code/api/pennylane.GeneralizedAmplitudeDamping.html>