Cattle Movement Network of Germany and its Relation to Epidemic Spreading:
Simulation, Overview, Future

by Jason Bassett
March 19, 2019,
Freie Universität, Berlin

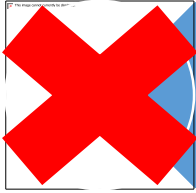# BVD (Bovine Viral Diarrhea) Background

Non-transmissible to humans

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Persistently infected animals

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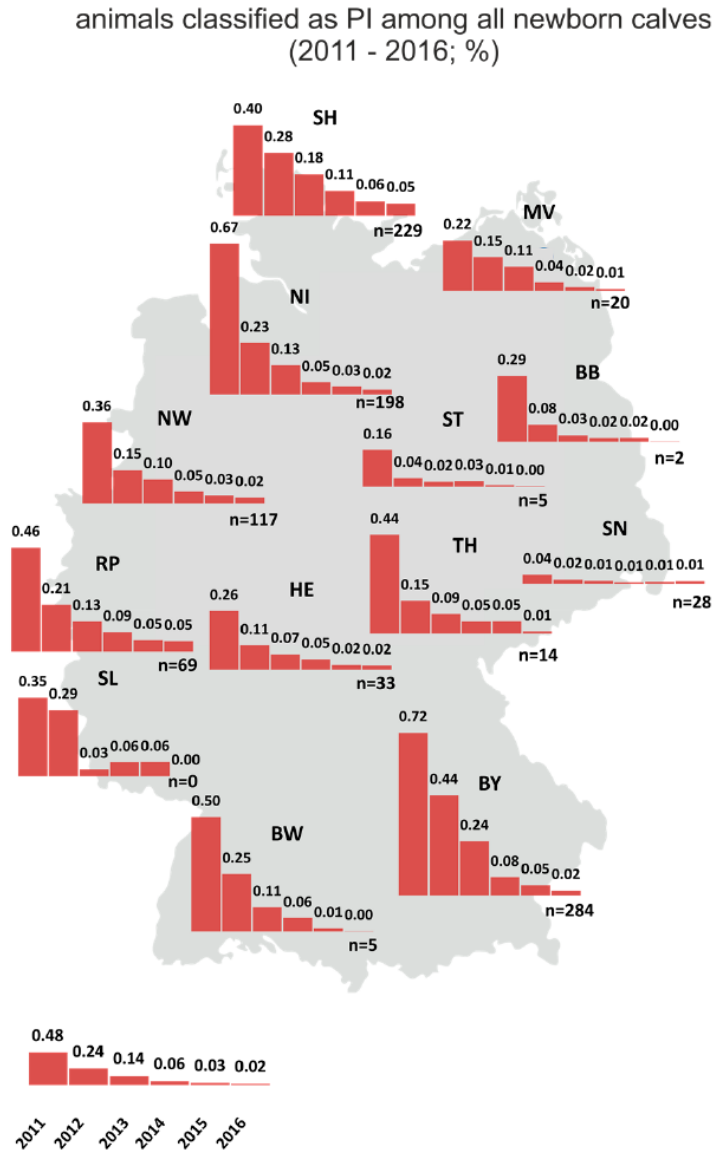Contact-based transmission

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Persistently infected animals
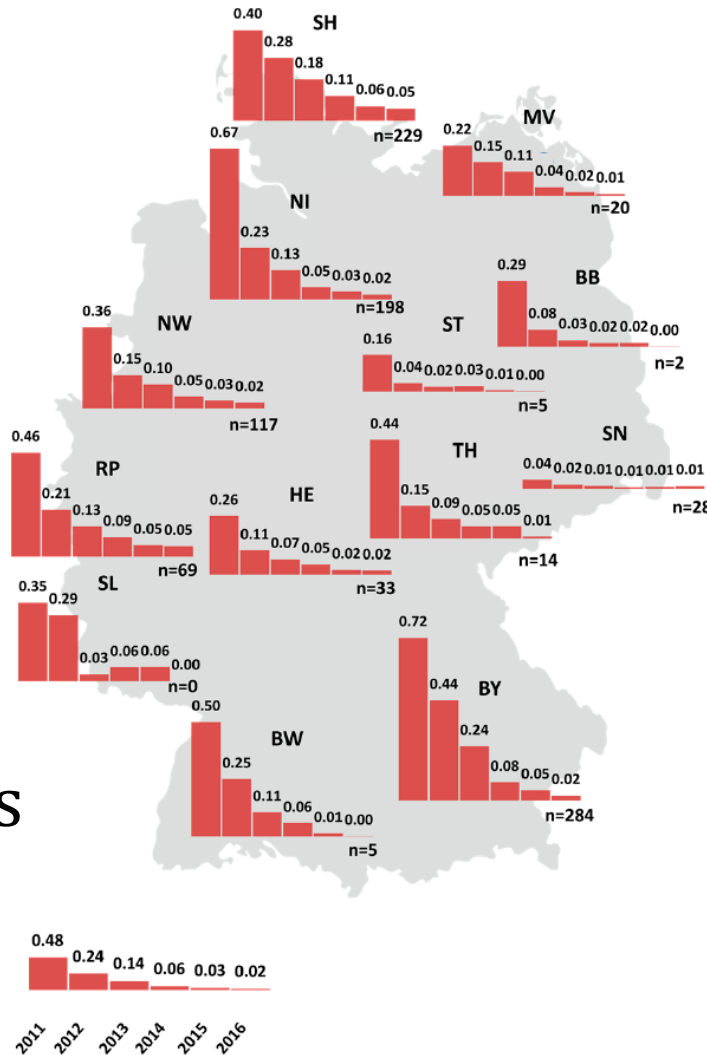
Loss of cattle and milk yield

German Biosecurity Measures Since 2011

animals classified as PI among all newborn calves
(2011 - 2016; %)

$\sim 10^7\ animals$

German Biosecurity Measures Since 2011

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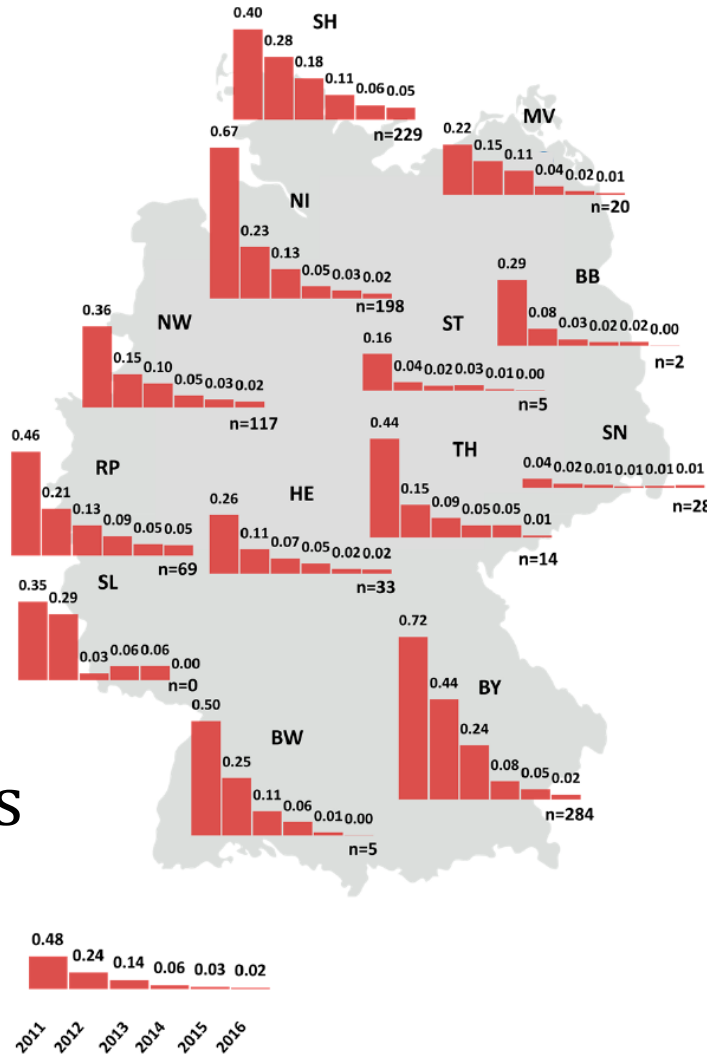(2011 - 2016; %)
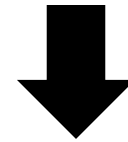
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K. Wernike et al.,
Pathogens, 6(4):50,
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Six Years (2011--2016) of Mandatory Nationwide Bovine Viral Diarrhea Control in Germany -- A Success Story

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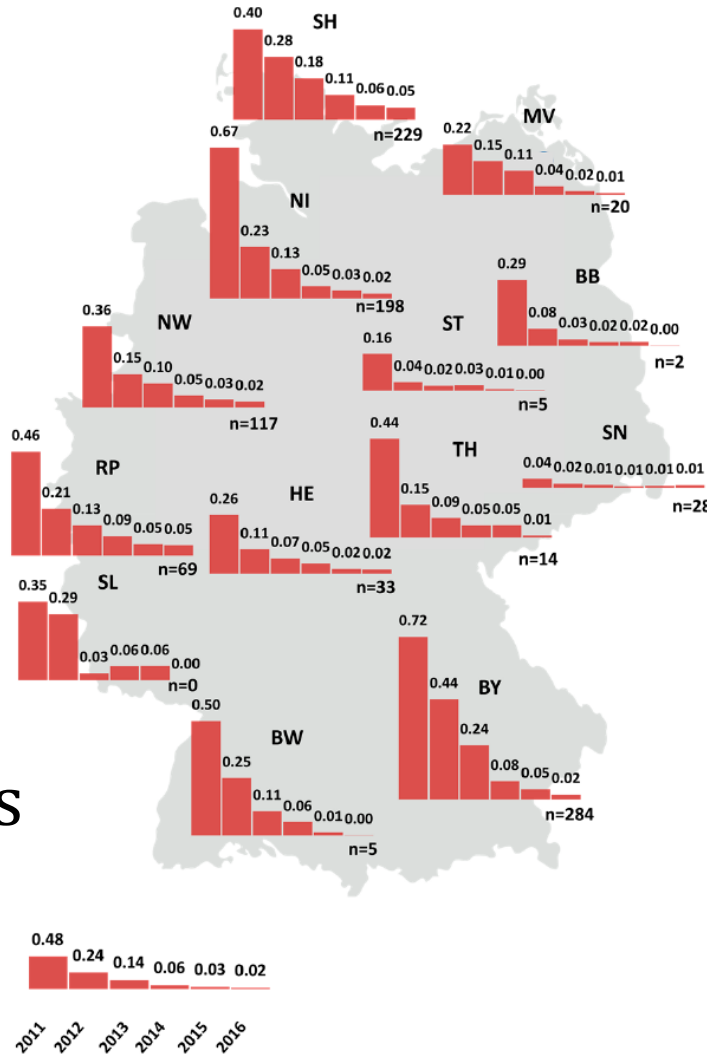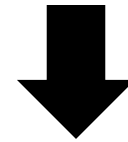
BUT WE CAN DO BETTER!

Model Overview

Hierarchical agent-based

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Stochastic (breeding + infectious features)

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Event-driven

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Farms and their populations (data-driven)

Model Overview

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Event-driven

Animal source + Animal sink

Farms and their populations (data-driven)

Supply/demand network structure (filters) following fixed population per farm rule

Baseline (in-Farm) Dynamics (SIR... mostly)
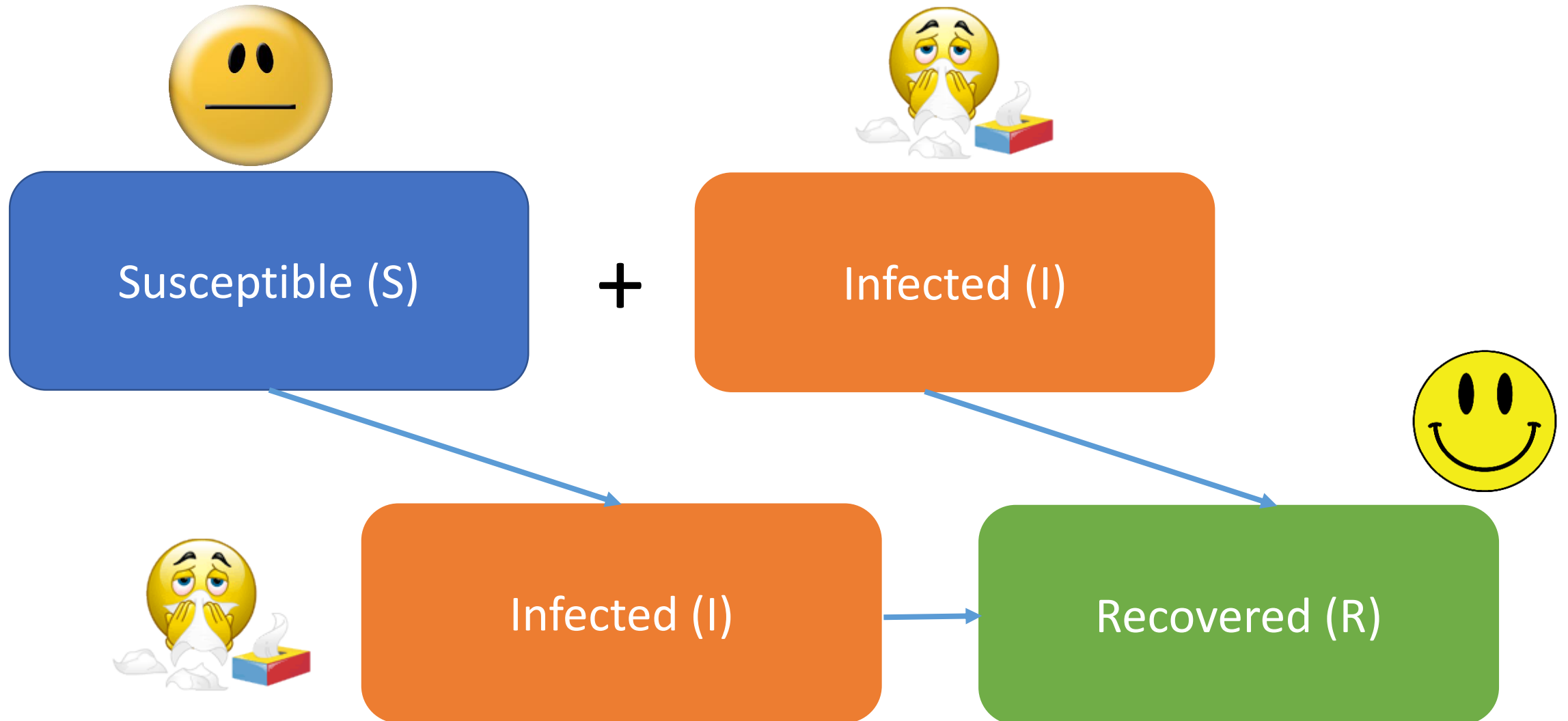
Infected = Transiently + Persistently

Infected (I)
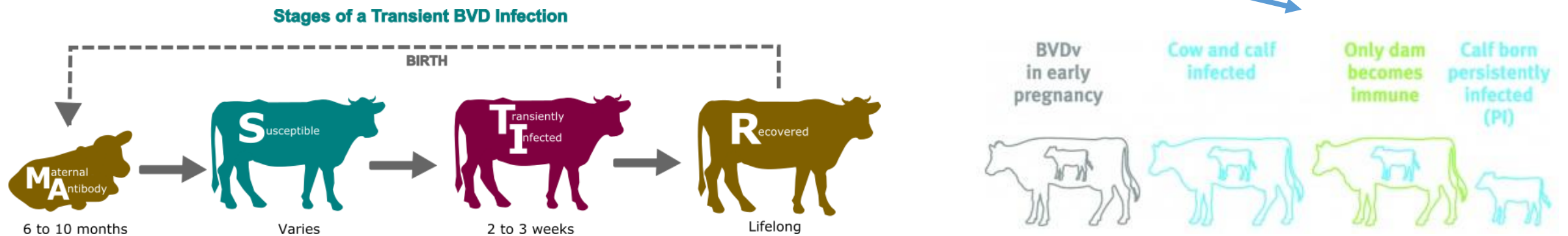
Stages of a Transient BVD Infection

BIRTH

Maternal **A**ntibody
6 to 10 months

Susceptible
Varies

Transiently **I**nfected
2 to 3 weeks

Recovered
Lifelong

BVDv in early pregnancy

Cow and calf infected

Only dam becomes immune

Calf born persistently infected (PI)

System Dynamics (SIRP for BVD)

Horizontal Transmissions

$$S + I \xrightarrow{\beta_I} I + I$$

$$\xrightarrow{\gamma} R + R$$

$$S + P \xrightarrow{\beta_P} I + P$$

$$\xrightarrow{\gamma} R + P$$

$$R \xrightarrow{\mu} S$$

calf   mature

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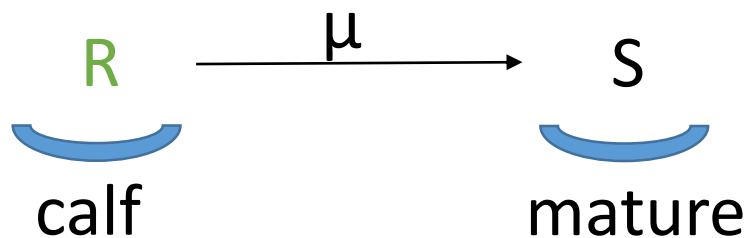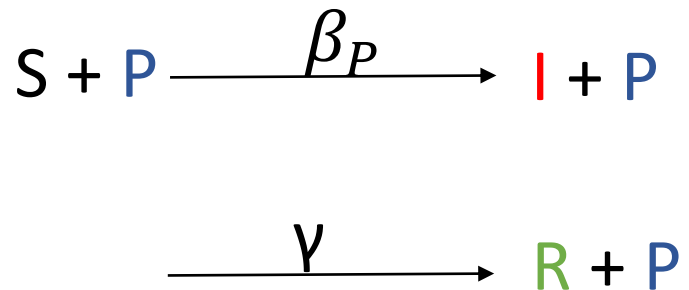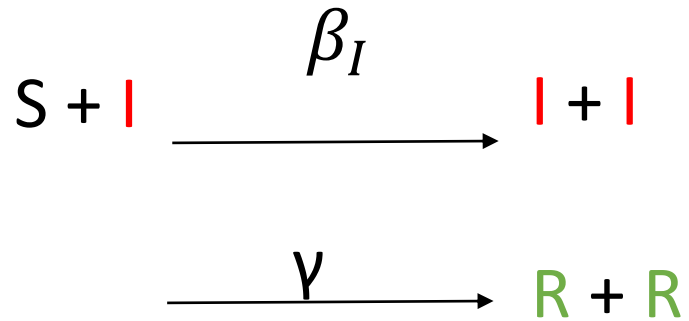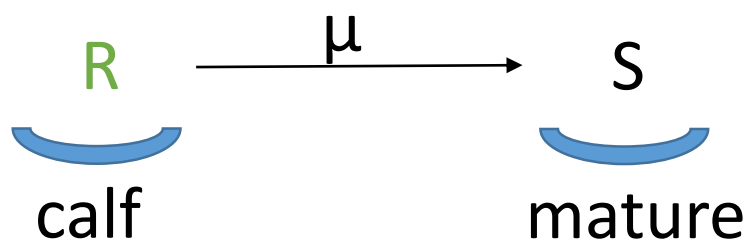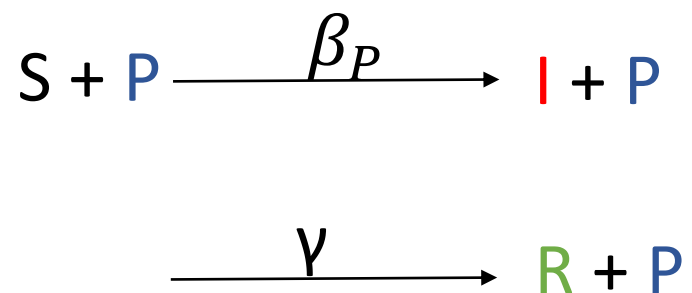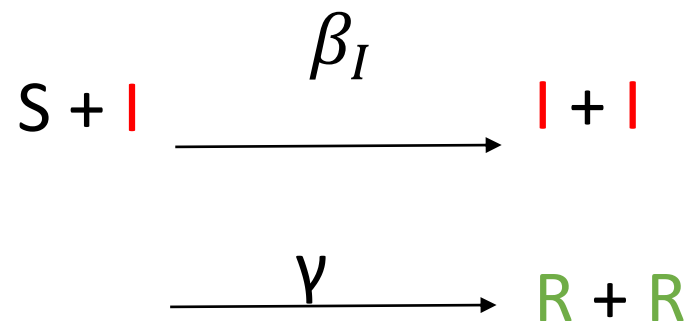
Vertical Transmissions

$$S \xrightarrow{k, \tau} S + S$$

pregnant   mother   calf

$$I \xrightarrow{k, \tau, \tau_1, \tau_2, \gamma} \begin{cases} R + R \\ \\ R + P \end{cases}$$

$$R \xrightarrow{k, \tau} R + R$$

$$P \xrightarrow{k, \tau} P + P$$
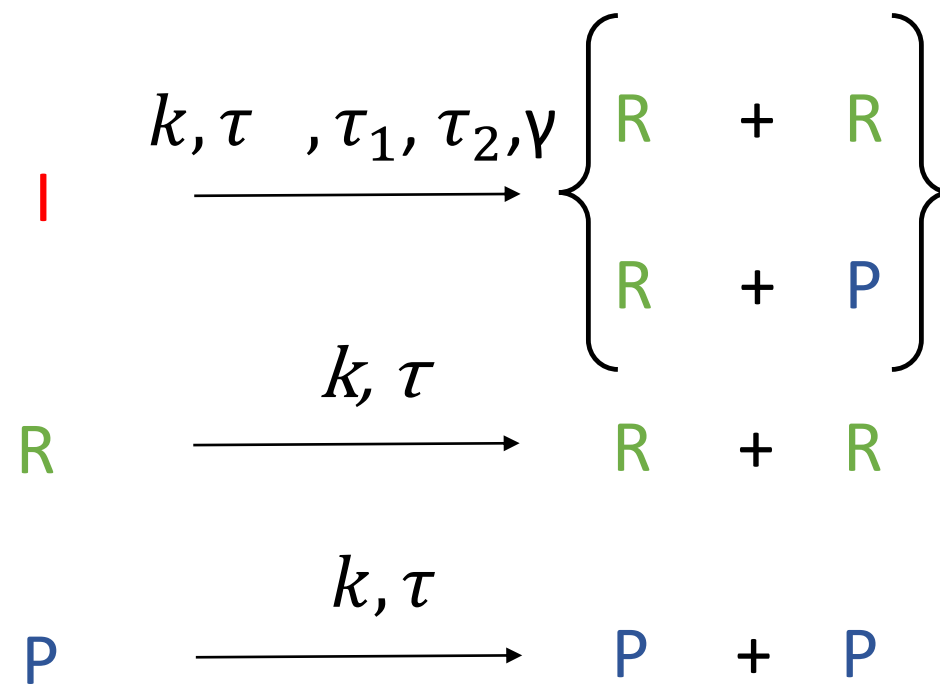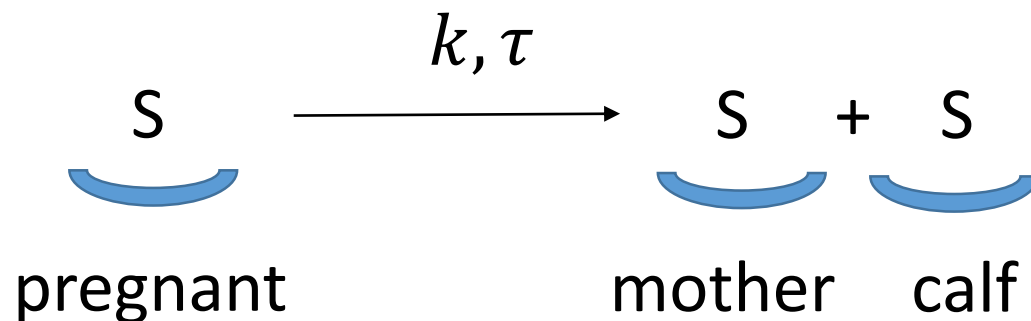
System Network and Dynamics

Farms/Premises as nodes

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Animal movements as edges

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Constant quota mechanism + Market = network config.

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Additional features

- Ag + Ab Testing (sensitivity analysis for TP)
- Vaccination (sensitivity analysis)
- Farm quarantine

System Network and Dynamics

Farms/Premises as nodes

Animal movements as edges

Constant quota mechanism + Market = network config.

Bassett J., Blunk P., Isele T., Gethmann J. and Hövel P.; An agent-based model for bovine viral diarrhea; 2018; arXiv: submit/2509648

Additional features

- Ag + Ab Testing (sensitivity analysis for TP)
- Vaccination (sensitivity analysis)
- Farm quarantine

Model Setup and Initialisation

Farm size distribution of TH magnitude (≈350,000 animals / ≈1,600 farms)

≈55 years of simulation≈11 cows' life-cycles

2% PI-infected farms at start

Expert opinion and literature for parameters

Simulation Plan

Some individual state programmes

27 years

Scenarios	Timeline (in days)					
	0	10,000	12,006	12,373	12,738	20,000
1	STR 1					
2	STR 2					
3	STR 3					
4					STR 1	
5				STR 4		
6				STR 5a		
7				STR 5b		
8				STR 6a		
9				STR 6b		
10				STR 7		
11				STR 8		
12			STR4		STR8	
13			STR4		STR9	

13 Scenarios made of 11 strategies (STR)

With J. Gethmann And C. Probst (FLI)

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Some individual state programmes

Federal programme

27 years   2011-2016

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Simulation Plan

Some individual state programmes — 27 years

Federal programme — 2011-2016

Predictions — 22 years

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Infectious Global Population Fractions
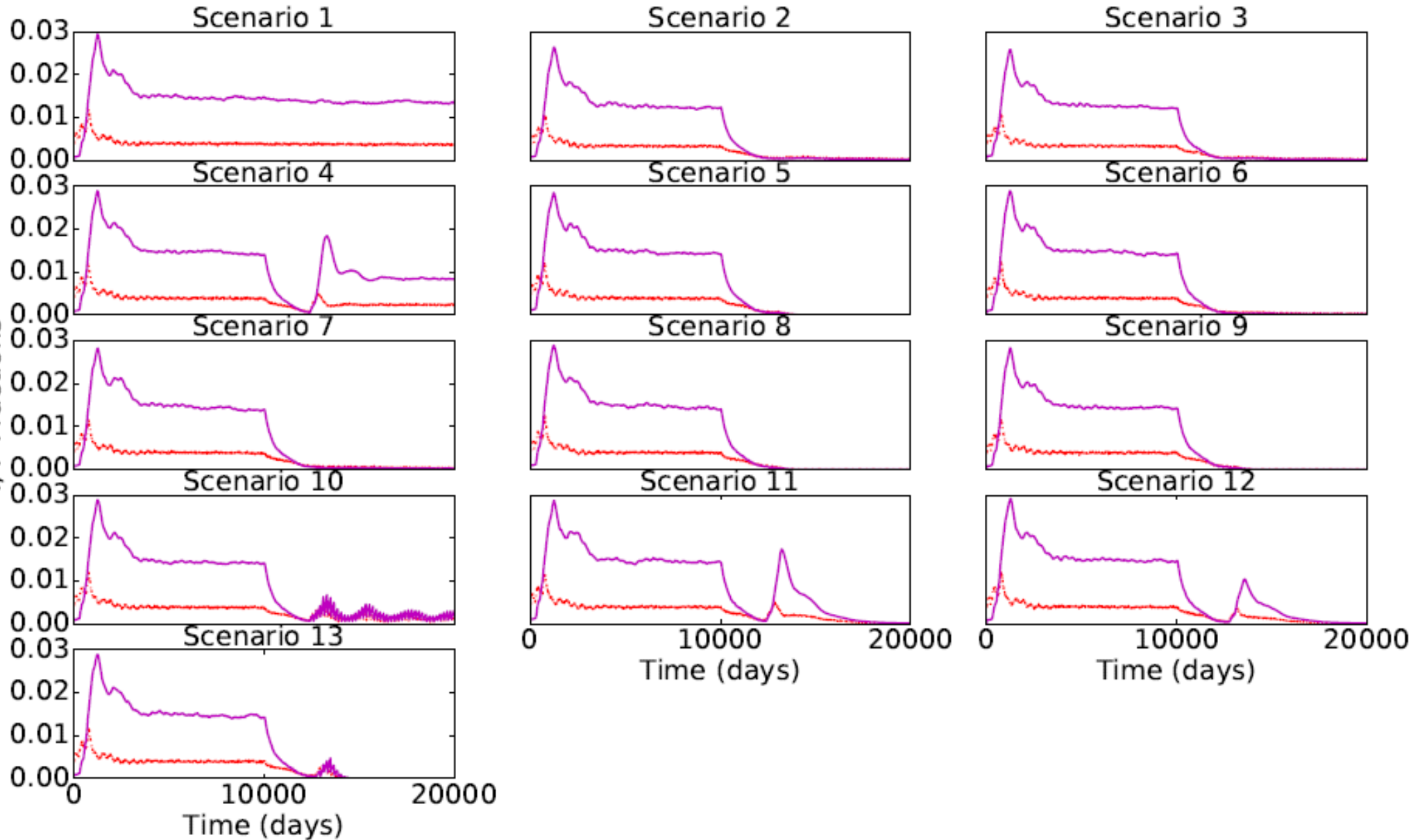
PI

TI

PI Distribution per Farm at Final State
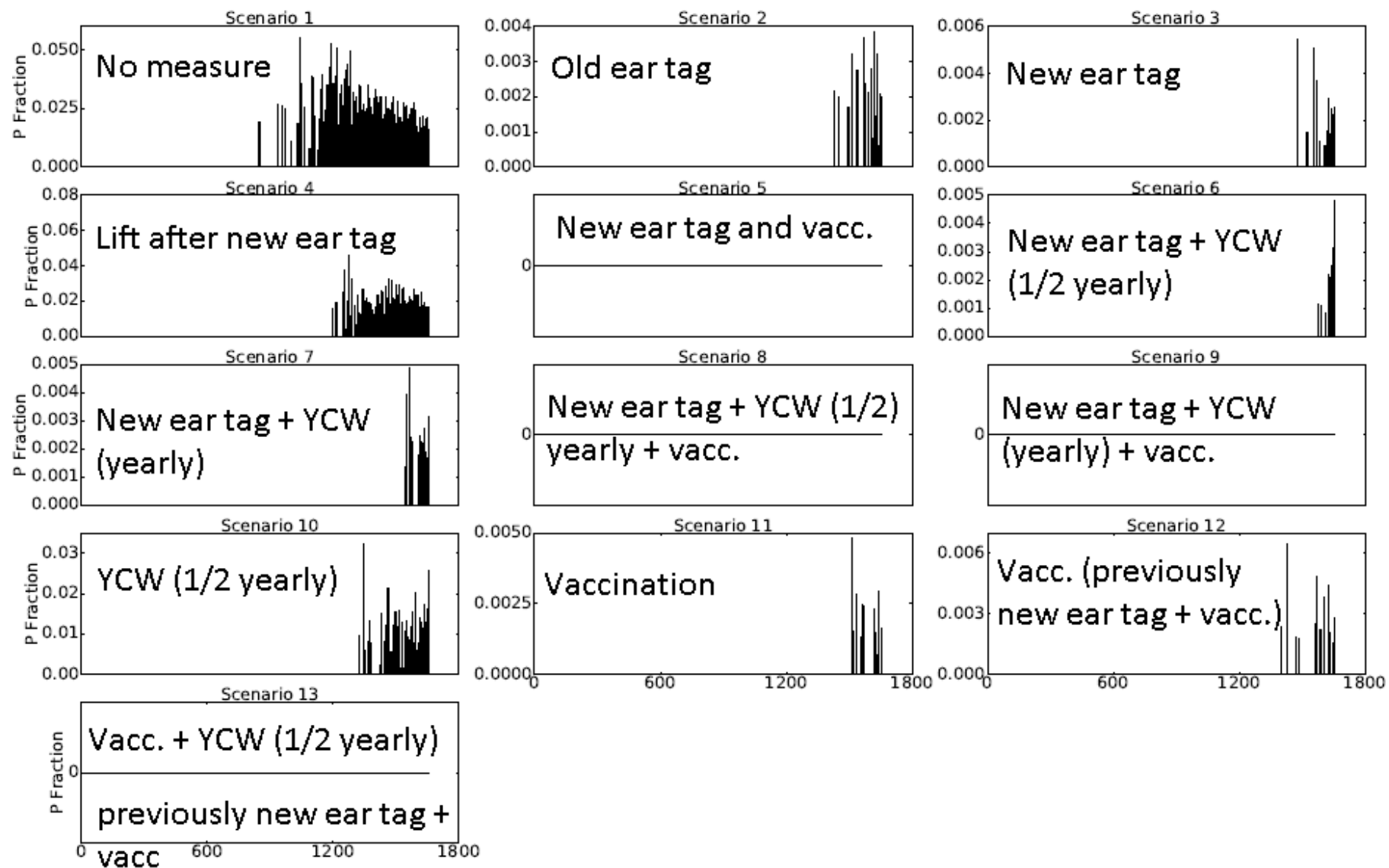
Outlook

Publish the results (further statistical analysis)!

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Risk analysis of network

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Extend code (e.g. system as one farm, farm weights for trading, unit testing)

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Heuristic methods for network rewiring

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Extend code (e.g. system as one farm, farm weights for trading, unit testing)

Further sensitivity analysis

Heuristic methods for network rewiring

More (E.U.) countries?

For Contributions (C++)...

Yperidis / **bvd_agent_based_model**
forked from Gerungofulus/bvd_agent_based_model

👁 Unwatch ▾ 1   ★ Star 0   ⑂ Fork 4

‹› Code   ⓘ Issues 4   ⑂ Pull requests 0   ▥ Projects 0   ▦ Wiki   ▥ Insights   ⚙ Settings

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🕐 **163** commits   ⑂ **1** branch   ◇ **0** releases   👥 **3** contributors   ⚖ **MIT**

Branch: master ▾   New pull request   Create new file | Upload files | Find File | Clone or download ▾

This branch is 154 commits ahead of Gerungofulus:master.   ⑂ Pull request   ▣ Compare

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⬤ jbassett Introduced a new event class for tests so as to output the farm ID wi... ⋯   Latest commit f08f993 on Nov 16, 2018

📁 .idea   Introduced a new event class for tests so as to output the farm ID wi...   4 months ago

📁 .svn   Inititial commit   2 years ago

Thank you for your attention!
Questions?

Supported by the FLI, TU Berlin and the DFG in the framework of the collaborative Research Centre 910