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Validity of models for Drecier generation of runaway electrons in dynamic scenarios

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Outline

- Aim of the study
- Modelling parameters
- Modelling tools
- Results
- Connection to system theory
- Summary

Aim of the study

- Motivation: **correct choice of models** is important **in** (integrated) **modelling**
- Investigate the validity of models with different sophistication in various scenarios
- Aimed to span a **wide parameter space** with the density and temperature values used in the simulations
- These parameters are still physically relevant:
  - Low density discharge, LD
  - Start-up, SU
  - End of disruption, ED
  - Start of disruption, SD

	Low density discharge (LD)	Start–up phase (SU)	End of disruption (ED)	Start of disruption (SD)
Density [m^{-3}]	$5 \cdot 10^{17}$	$5 \cdot 10^{17}$	10^{20}	10^{20}
Temperature [eV]	10000	300	300	10000

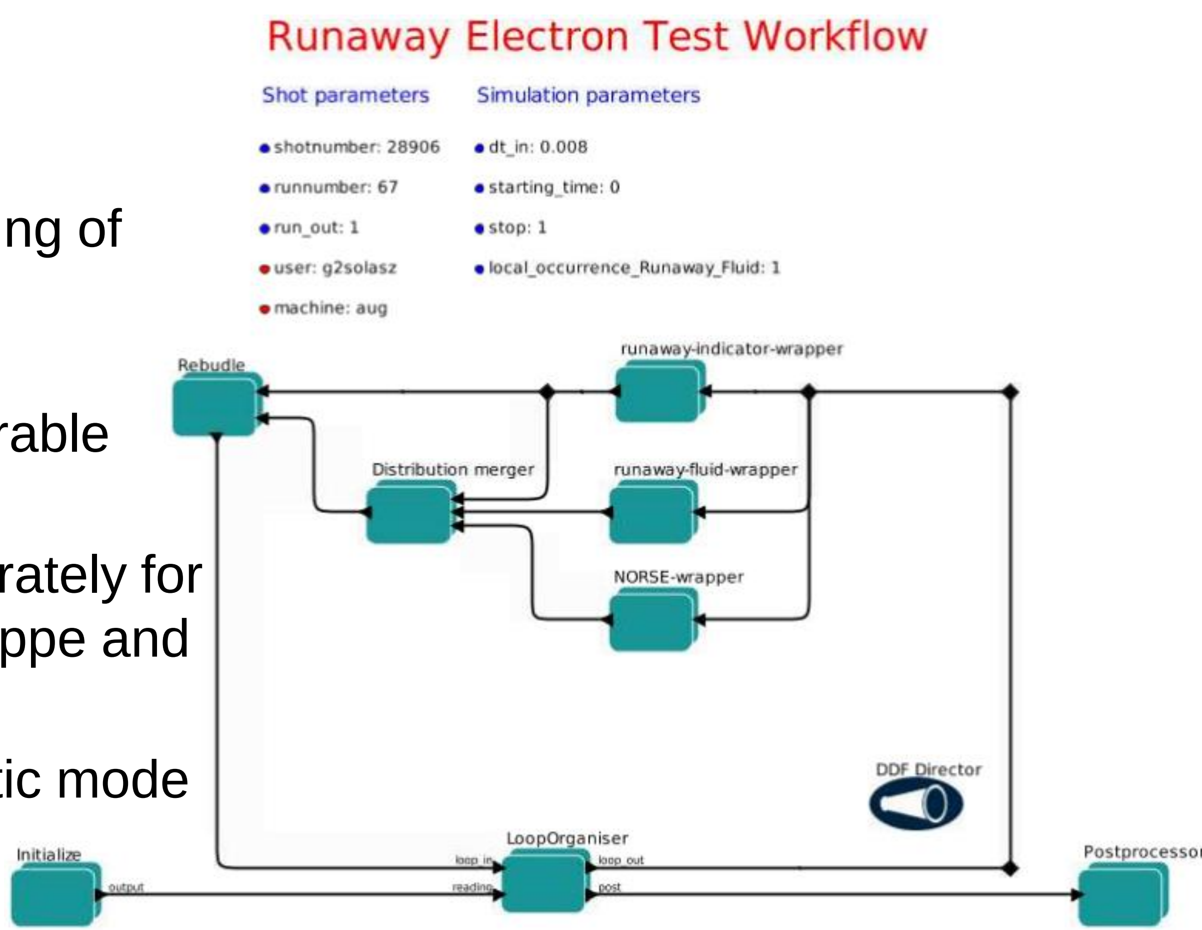
Modelling parameters

- Magnetic field = 0 T
- Effective charge = 1
- Chosen electric field
  - Moderate runaway generation ⟶ avoid slide-away
- Jump in the electric field
  - Motivated by system theory
- Every other parameter is constant

	Low density discharge (LD)	Start–up phase (SU)	End of disruption (ED)	Start of disruption (SD)
Electric field [V/m]	$2.81 \cdot 10^{-3}$	$2.96 \cdot 10^{-2}$	3.66	$4.38 \cdot 10^{-1}$
Critical field [V/m]	$5.06 \cdot 10^{-4}$	$4.16 \cdot 10^{-4}$	$6.98 \cdot 10^{-2}$	$8.77 \cdot 10^{-2}$
Normalized electric field [-]	5.55	71	52.5	5
Coulomb logarithm [-]	19.9	16.3	13.7	17.2
Collision time at critical velocity [s]	$2.58 \cdot 10^{-1}$	$6.84 \cdot 10^{-3}$	$6.42 \cdot 10^{-5}$	$1.74 \cdot 10^{-3}$

Runaway Electron Test Workflow

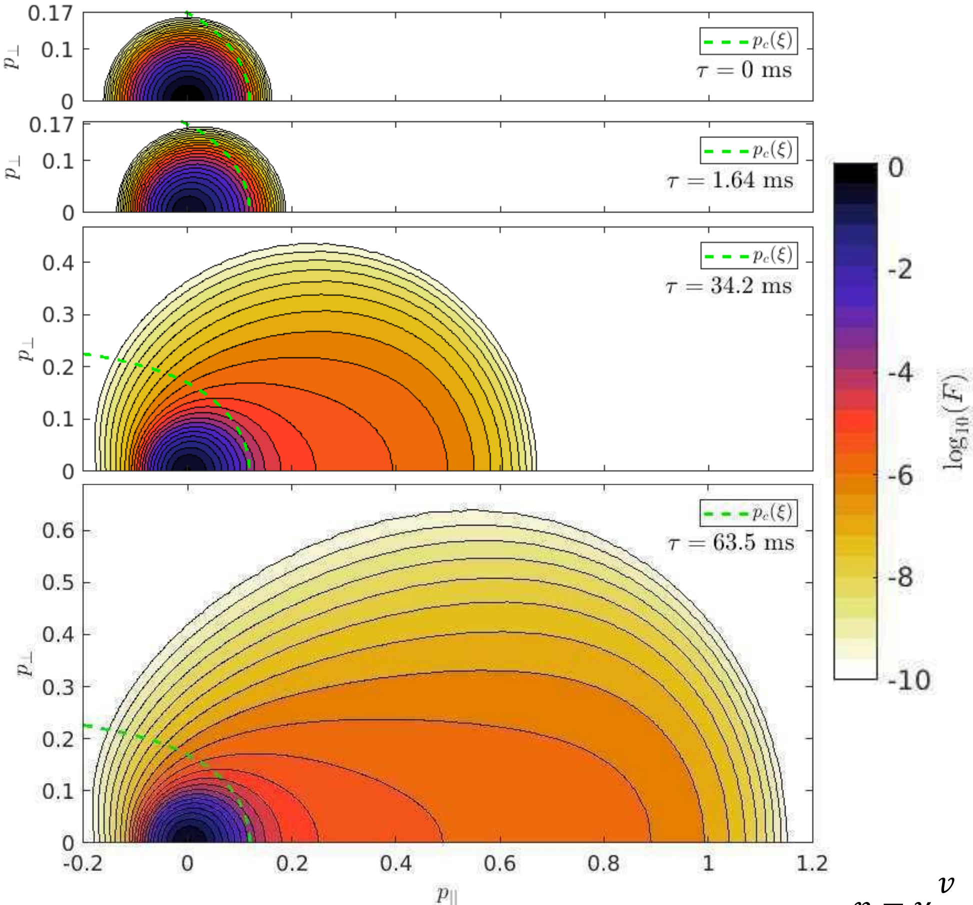
- Dedicated workflow for testing runaway electron models
- Contains:
  - Runaway Fluid
  - NORSE[1]
- Allows for parallel running of the codes with identical input parameters
- Output is easily comparable – HDF5
- DREAM[2] was run separately for current study, by M. Hoppe and O. Embreus
- DREAM ran in full kinetic mode



[1] Stahl et al. CPC (2017)
[2] Hoppe et al. CPC (in preparation) (2021)

Distribution function - SU

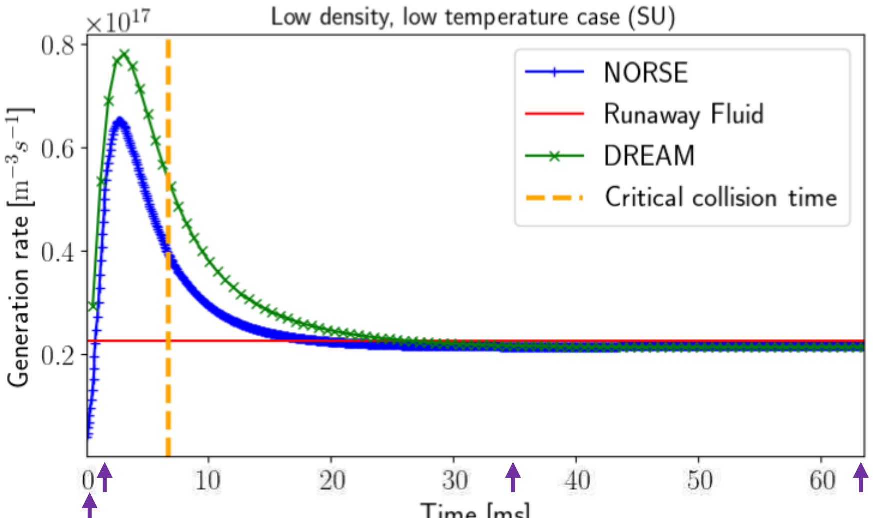
- NORSE distribution in the start up case in four different times
- Initial shift
  - Introduced electric field creates a Spitzer-like distribution
- Dreicer generation forms a high energy particle population

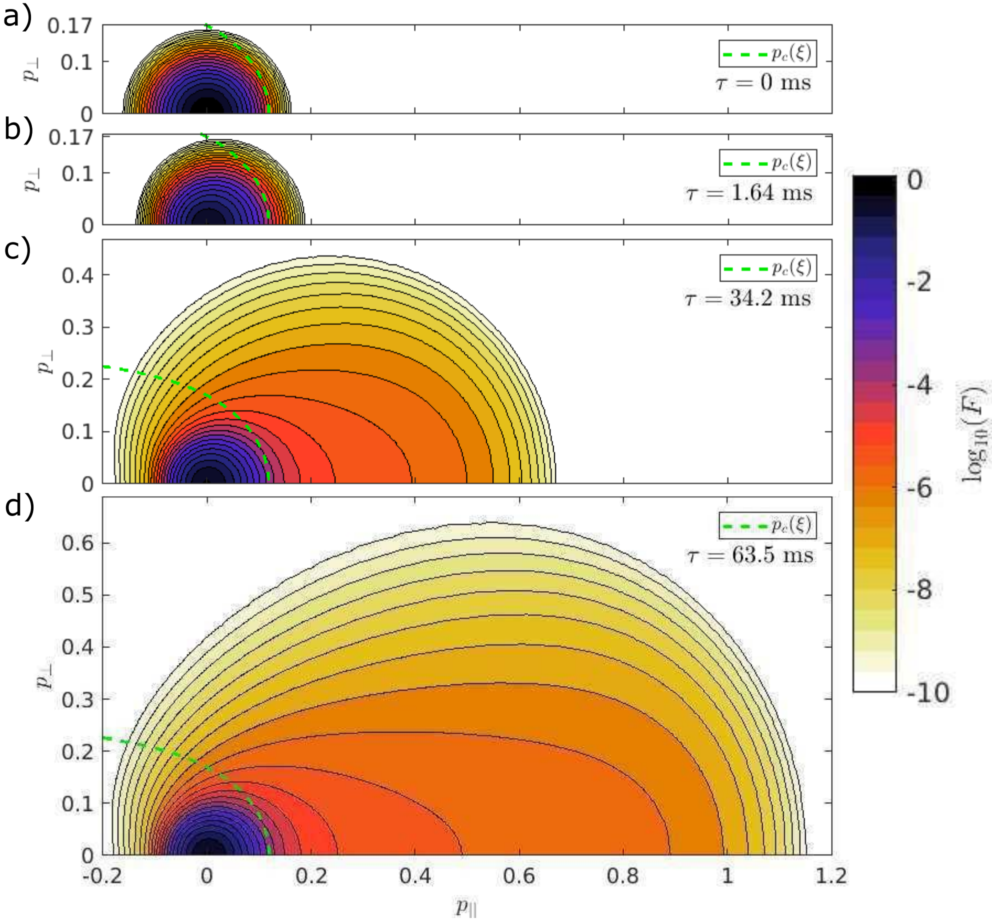


$$p = \gamma \frac{v}{c}$$

Generation rate - SU

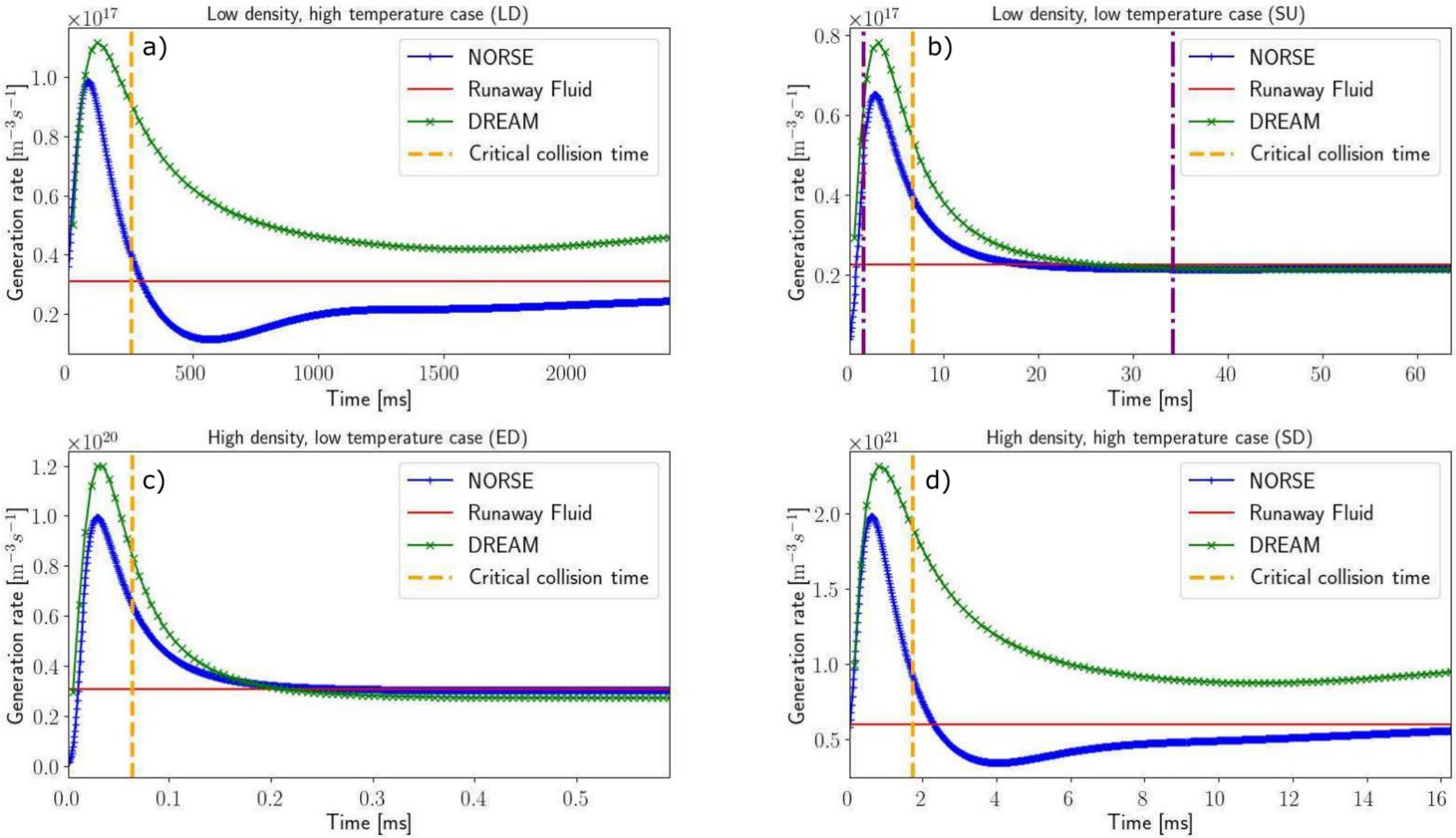
- The **initial shift causes a jump** in the generation rate
- This later relaxes to the analytical generation rate
- The times are shown where the distribution is plotted





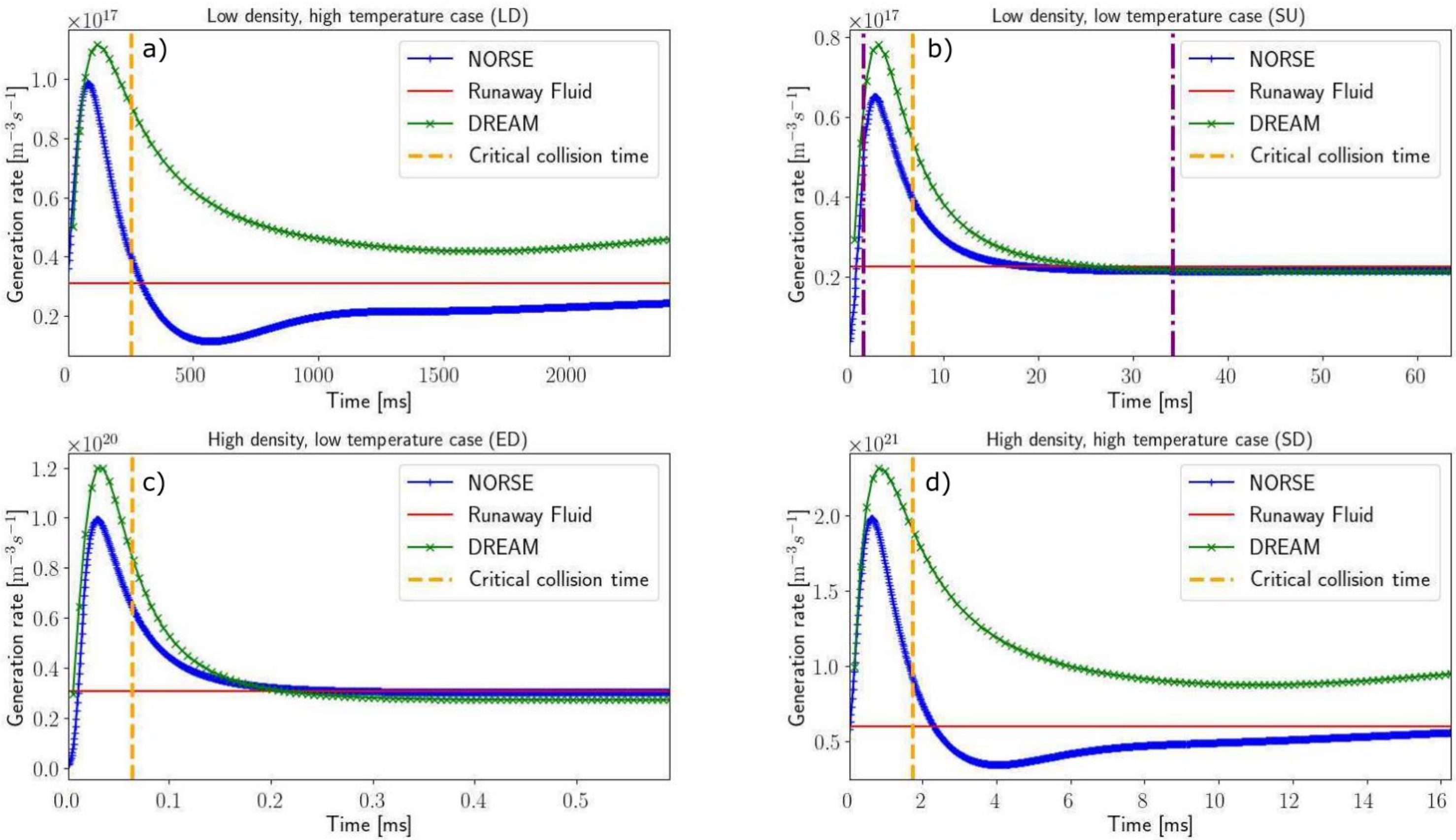
Generation rate

- The time scale of the peak can be related the **collision time at the critical velocity**
- The absolute time scale can largely vary in the different scenarios



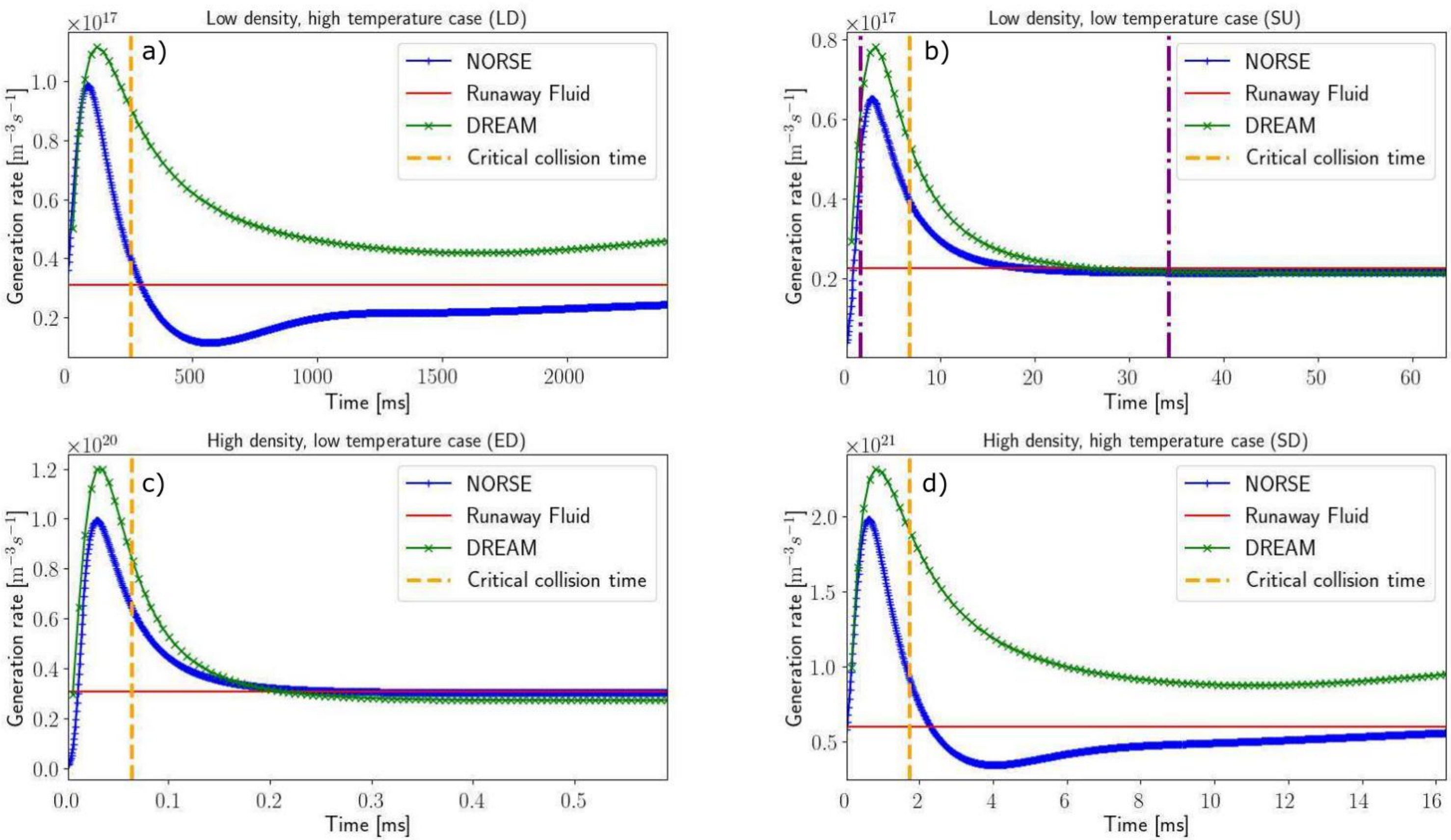
Generation rate

- NORSE undershoots the analytical value in two cases
- DREAM calculates larger generation rate than NORSE
  - Different definition of runaway boundary



Relation to system theory

- Behavior of system can be characterized by the response to a step function
- Similar features are observed



Summary

- Used a dedicated runaway electron test workflow
  - Reduced kinetic solver (Runaway Fluid)
  - Non-linear kinetic solver (NORSE)
  - + Linearized kinetic solver (DREAM)
- Investigated the behavior of Dreicer generation due to a jump in the electric field
- A peak appears in the generation rates in all cases – kinetic effect
- The time scale of the peak can be related to the collision time at the critical velocity
- Kinetic modelling is required for processes faster than this timescale
- System theory characterizes system response to step function in input parameters with simple quantities

S. Olasz, O. Embreus, M. Hoppe, M. Aradi, D. Por, T. Jonsson, D. Yadikin, G.I. Pokol, *EU-IM Team, Validity of models for Drecier generation of runaway electrons in dynamic scenarios*, accepted by Nuclear Fusion (2021), https://doi.org/10.1088/1741-4326/abf0de

Backup slides

Runaway density