EPFL

Disruption Thermal Load Mitigation With JET SPI

U. Sheikh[1], D. Shiraki[2], R. Sweeney[3], P. Carvalho[4], S. Jachmich[5], E. Joffrin[6], M. Lehnen[5], J. Lovell[3], E. Nardon[6], S. Silburn[4] and JET contributors[7]

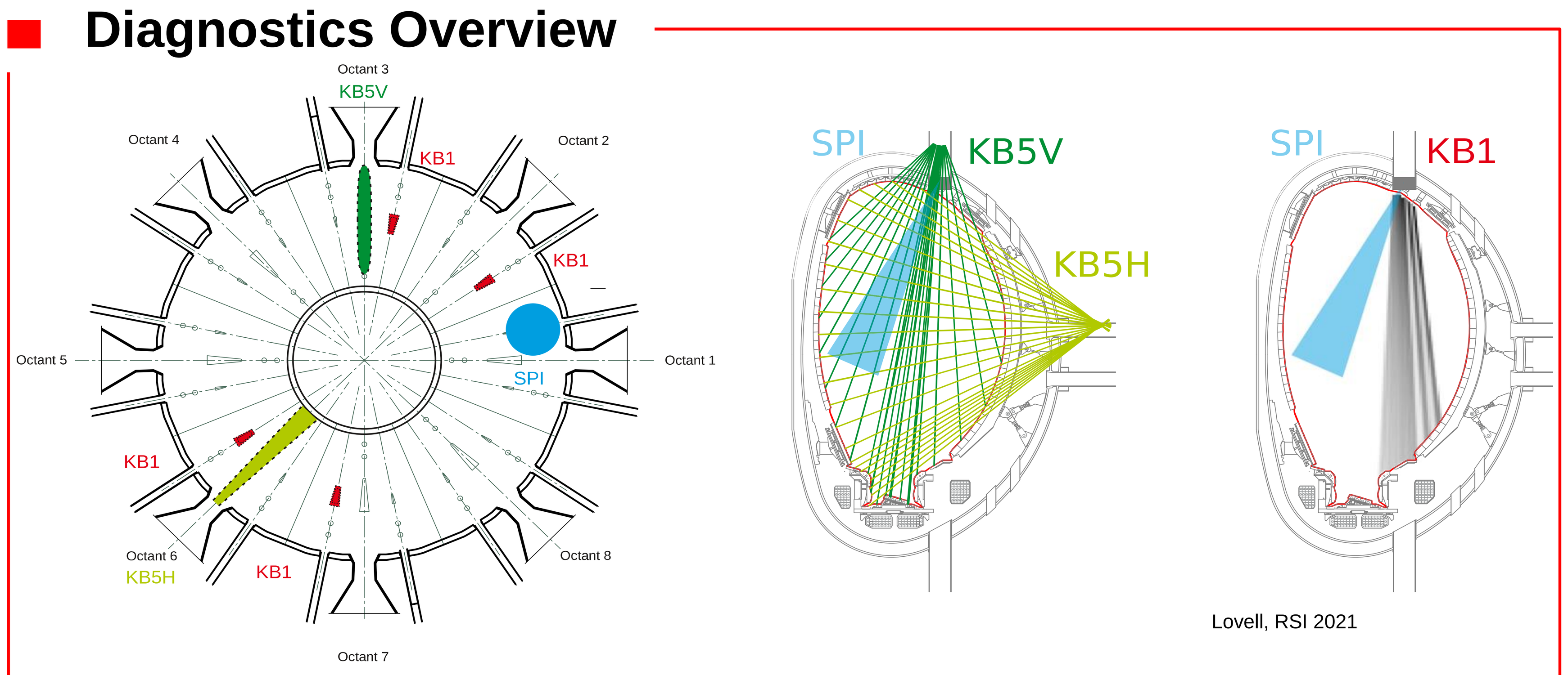
1) Ecole Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), Switzerland
2) Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA
3) Massachusetts Institute of Technology, Cambridge, MA 02139, USA
4) CCFE, Culham Science Centre, Abingdon, Oxon, OX14 3DB, United Kingdom of Great Britain and Northern Ireland
5) ITER Organization, route de Vinon sur Verdon, 13115 St Paul Lez Durance, France
6) CEA, IRFM, F-13108 Saint Paul Lez Durance, France
7) See the author list of 'Overview of JET results for optimising ITER operation' by J. Mailloux et al to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)

Introduction

- ❑ Disruption mitigation remains a critical, unresolved challenge for ITER
- ❑ Mitigation target is 90% of stored thermal energy (W_{th})
  - ❑ Need to validate SPI as viable ITER DMS
- ❑ Decreasing f_{rad} with increasing f_{th} observed on JET with MGI
  - ❑ This trend was not reproduced on AUG (Sheikh NF 2020)
- ❑ Explored with JET SPI in this work

$$f_{rad} = \frac{W_{rad}}{W_{mag} + W_{th} - W_{coupled}} \qquad f_{th} = \frac{W_{th}}{W_{mag} + W_{th} - W_{coupled}}$$

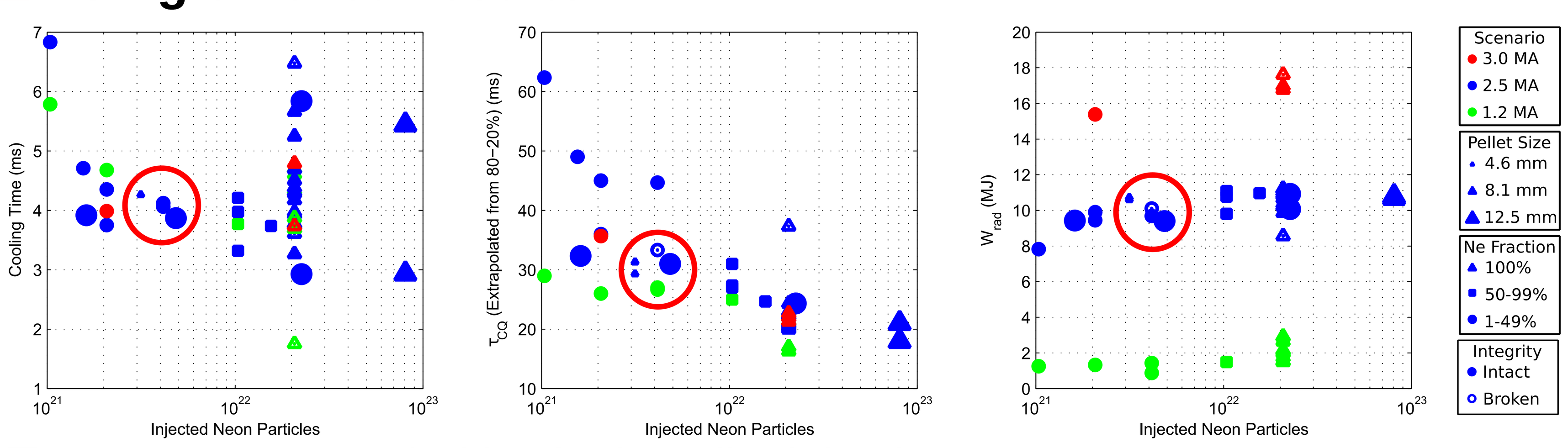
Diagnostics Overview



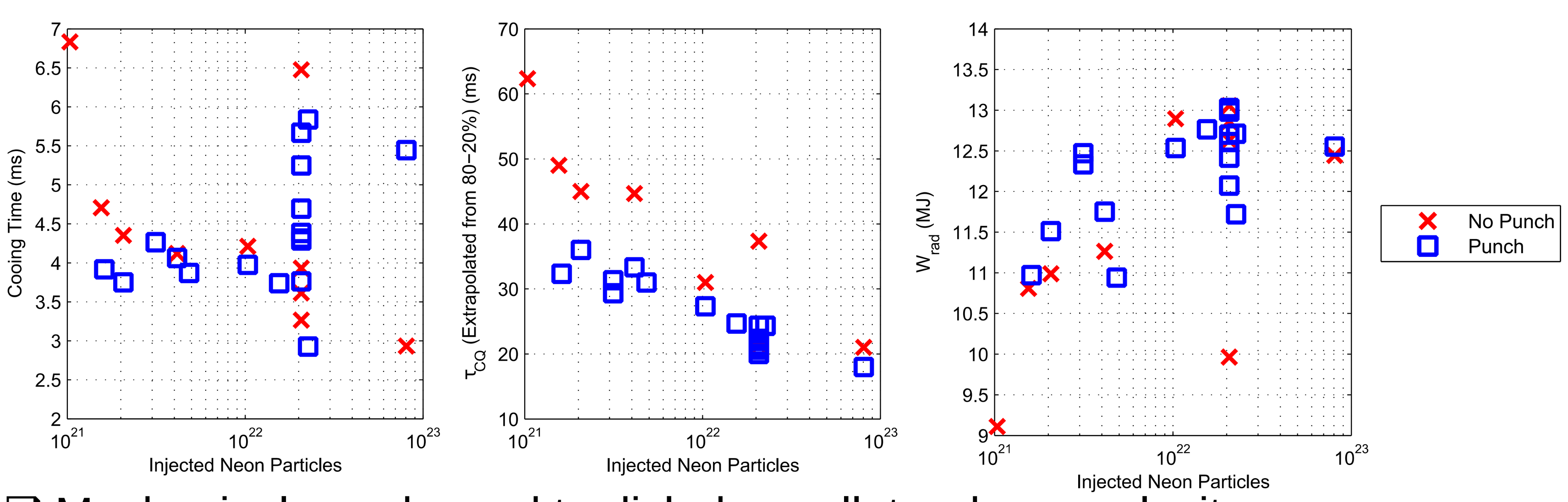
Lovell, RSI 2021

- ❑ Radiated energy measured with bolometers
  - ❑ Weighted integration method applied due to high asymmetries
- ❑ Heat flux and density measurements unusable in mitigated disruptions

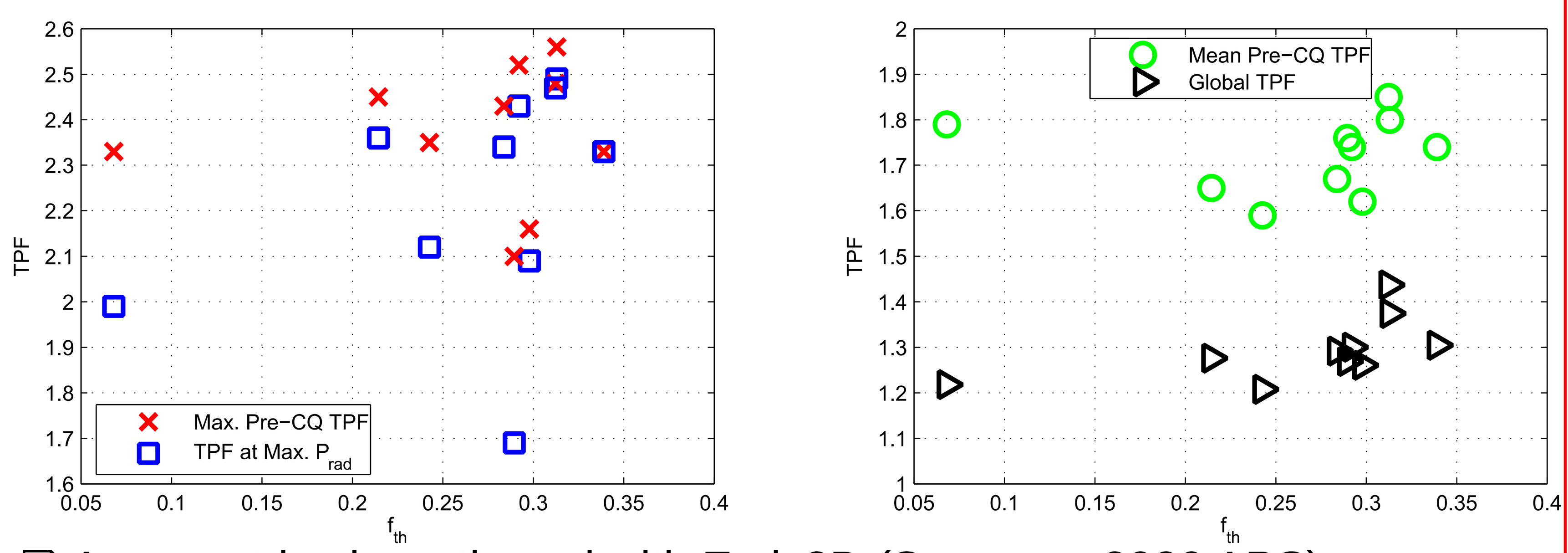
Single Pellet Results



- ❑ Neon content varied in single pellet injections
- ❑ CQ duration and cooling time vary with neon particles injected
- ❑ W_{rad} saturates when total W_{th} is radiated (1e22+ inj. Neon particles)
- ❑ Increased deuterium quantity at fixed neon content does not influence mitigation efficiency
  - ❑ Three pellet sizes with fixed neon content in red circles

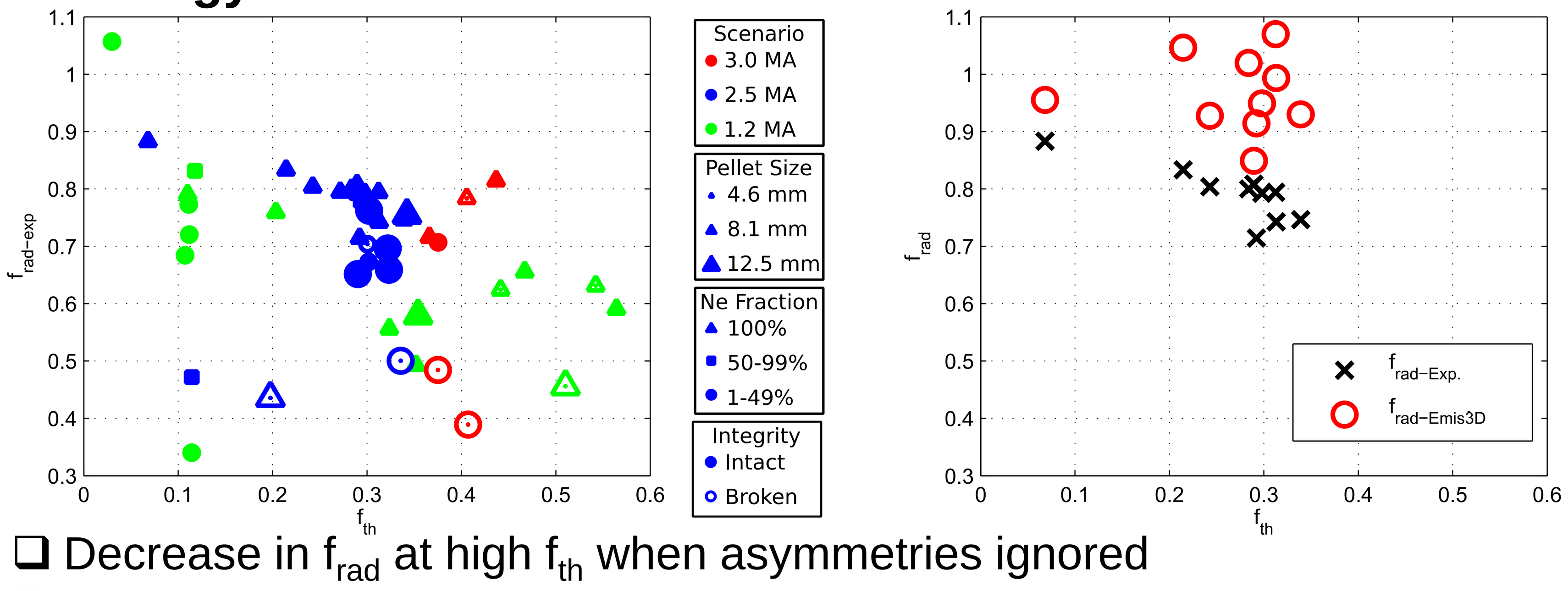


- ❑ Mechanical punch used to dislodge pellet reduces velocity
  - ❑ Larger pellet fragments after shattering (GEBHART 2021)
- ❑ CQ duration reduced with punch -> higher impurity assimilation
  - ❑ Does not influence cooling time or radiated energy



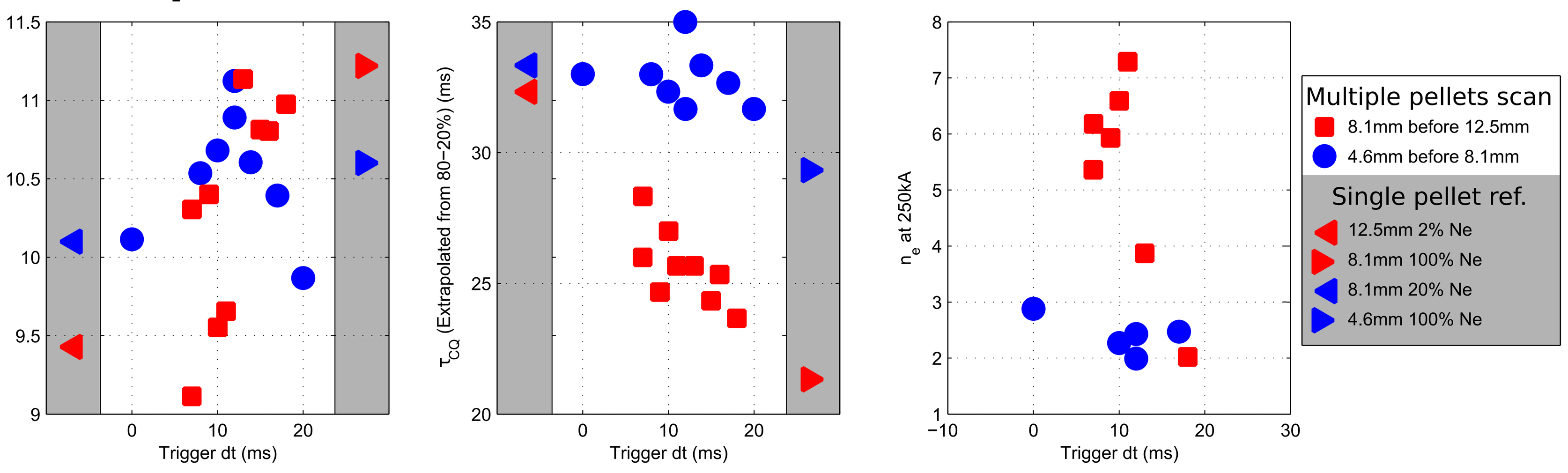
- ❑ Asymmetries investigated with Emis3D (Sweeney, 2020 APS)
  - ❑ Toroidal peaking factor (TPF) = emission in SPI sector / toroidal mean
- ❑ Peak TPF up to 2.6, pre-CQ average up to 1.9 (ITER limit is 2.0)
- ❑ Lower global TPF at low f_{th}
  - ❑ Higher fraction of total W_{rad} radiated symmetrically during CQ at low f_{th}

Energy Balance



- ❑ Decrease in f_{rad} at high f_{th} when asymmetries ignored
- ❑ Accounting for asymmetries removes negative trend
  - ❑ Constant f_{rad} maintained with 100% neon pellets in 2.5MA scenario
  - ❑ **Indicates SPI performance does not degrade at high f_{th}**
  - ❑ Large scatter attributed to the under-constrained Emis3D analysis

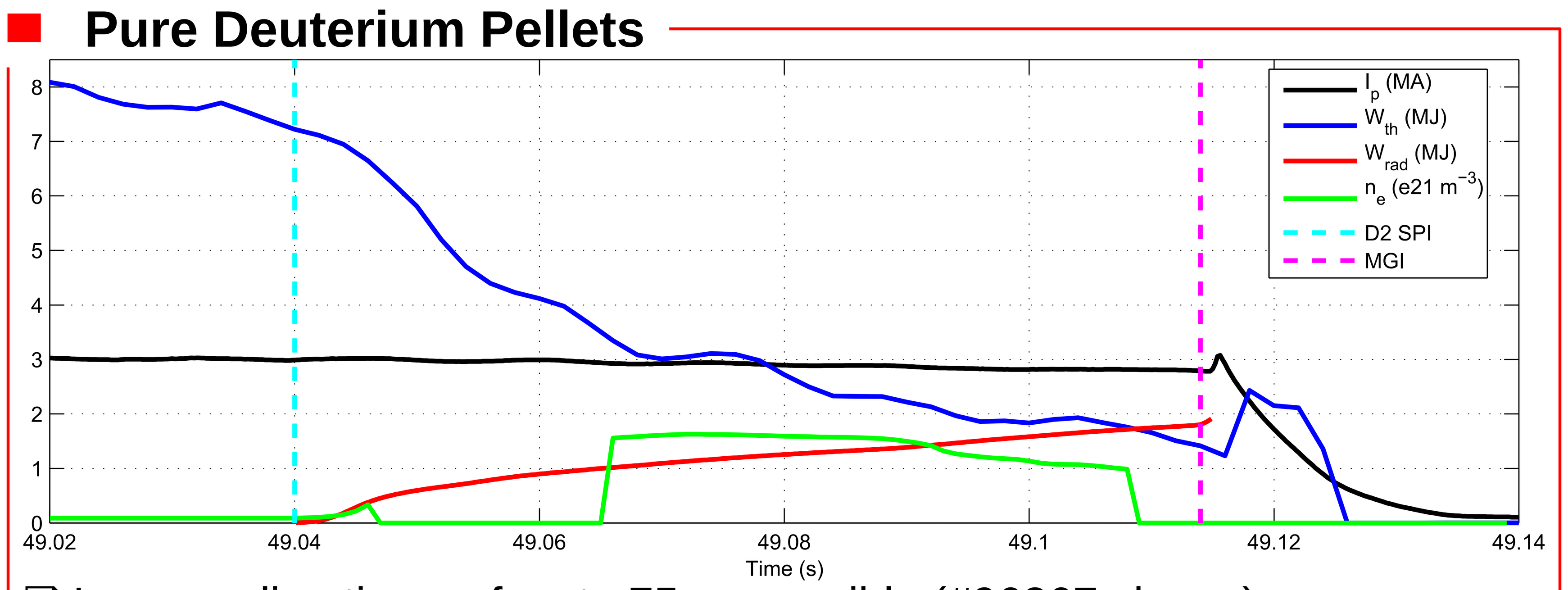
Multiple Pellets Results



- ❑ Slower 8.1mm pellet fired first, scan bound by single pellet references
- ❑ Arrival delay influences W_{rad}, CQ duration and density increase
  - ❑ Deuterium can be assimilated from a pellet arriving after an initial neon pellet -> Increased plasma density during CQ

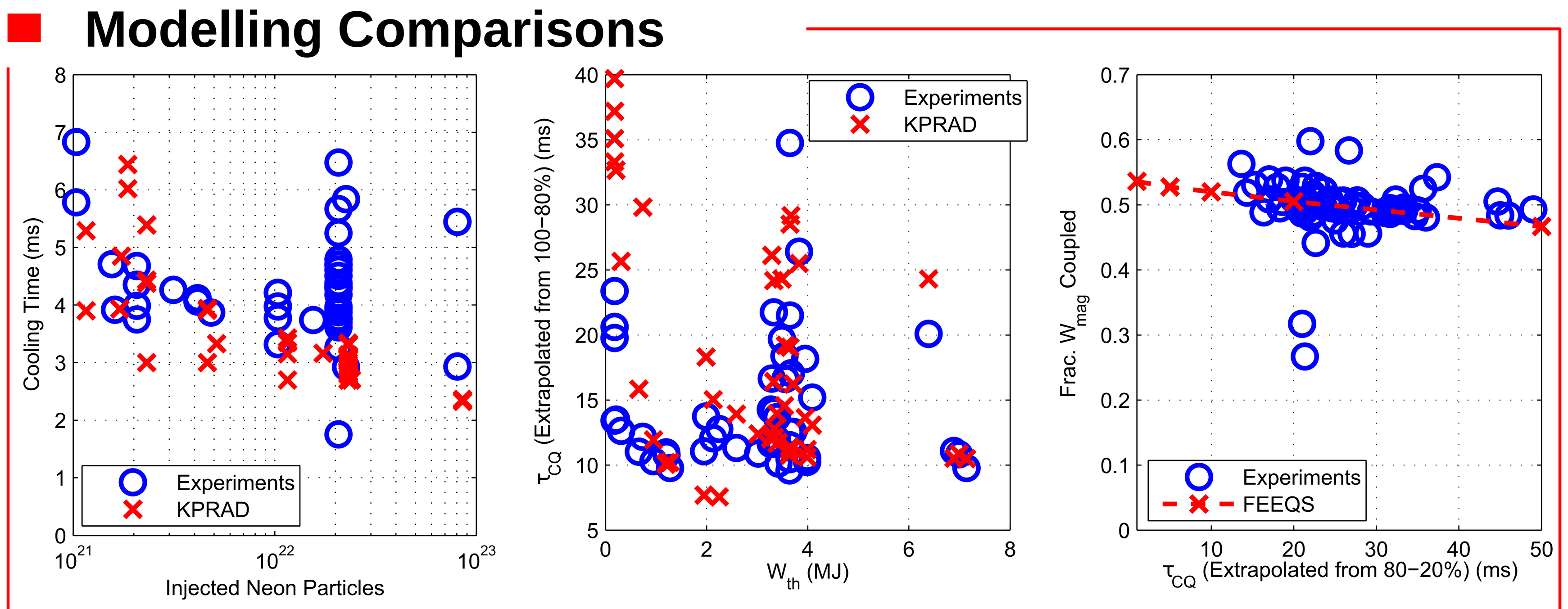
	Composition			Total neon injected
	12.5mm pellet	8.1mm pellet	4.6mm pellet	
Larger pellets scan	2% Ne, 98% D	100% Ne		2.2 x 10^{22}
Smaller pellets scan		20% Ne, 80% D	100% Ne	7.3 x 10^{21}

Pure Deuterium Pellets



- ❑ Long cooling times of up to 75ms possible (#96867 shown)
- ❑ Gradual decrease in W_{th} of up to 80%
- ❑ Cooling time appears to be limited by n=1 instability growth

Modelling Comparisons



- ❑ FEEQS simulations agree well with coupled magnetic energy estimates
- ❑ KPRAD captures cooling time and CQ duration at high W_{th}

Conclusions

- ❑ CQ duration and cooling time vary with neon particles injected
- ❑ Saturation of W_{rad} indicates total W_{th} radiated at 1e22+ inj. neon particles
  - ❑ Slower pellets (punched) have higher impurity assimilation
- ❑ Mitigation performance maintained at high f_{th} if asymmetries considered
  - ❑ Large uncertainties remain due to limited diagnostics
- ❑ Multiple pellet injection can be used to tailor mitigation
  - ❑ Deuterium pellets trailing neon pellets can be assimilated
- ❑ Pure D2 pellets produce long cooling times with gradual reduction in W_{th}
- ❑ KPRAD modelling successfully reproduces SPI shutdowns at high W_{th}

Swiss Plasma Center

EUROfusion

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