INSTITUTE OF PLASMA PHYSICS
OF THE CZECH ACADEMY OF SCIENCES

Temporal characteristic of ELMs on COMPASS tokamak

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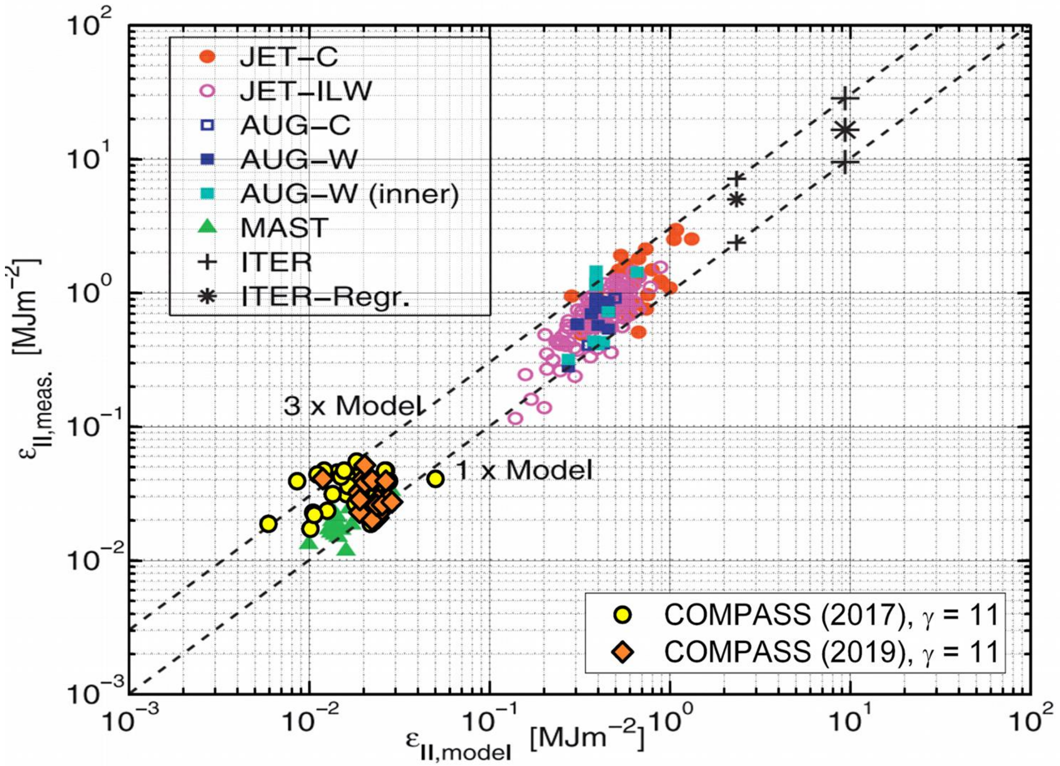
MINISTRY OF EDUCATION, YOUTH AND SPORTS

ELMs problematic for next step in fusion

What are ELMS?

- Plasma instabilities that form at the pedestal in tokamaks
- Carrying important portion of confined plasma energy (up to 10%)
- Large energy and particle fluxes to the divertor

Current status: Eich model valid for parallel and collisionless transport along field lines



T. Eich et al., NME, 12 (2017), 84-90.
J. Adamek et al., NF, 57 (2017), 116017.

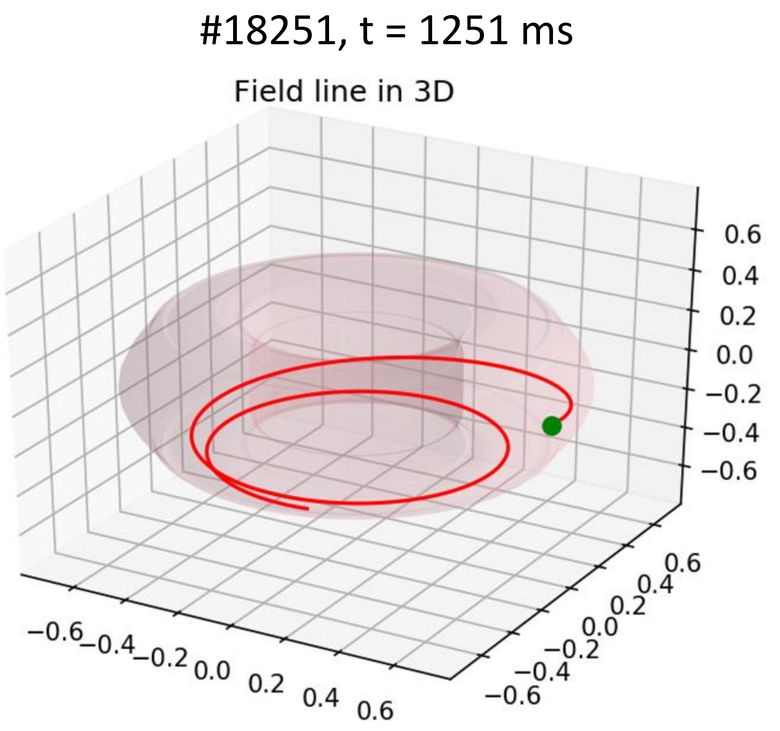
Main goal: find out if the connection length is given by ergodized or non-ergodized magnetic field lines during ELM rise period→ ELM heat loads dominated by parallel transport.

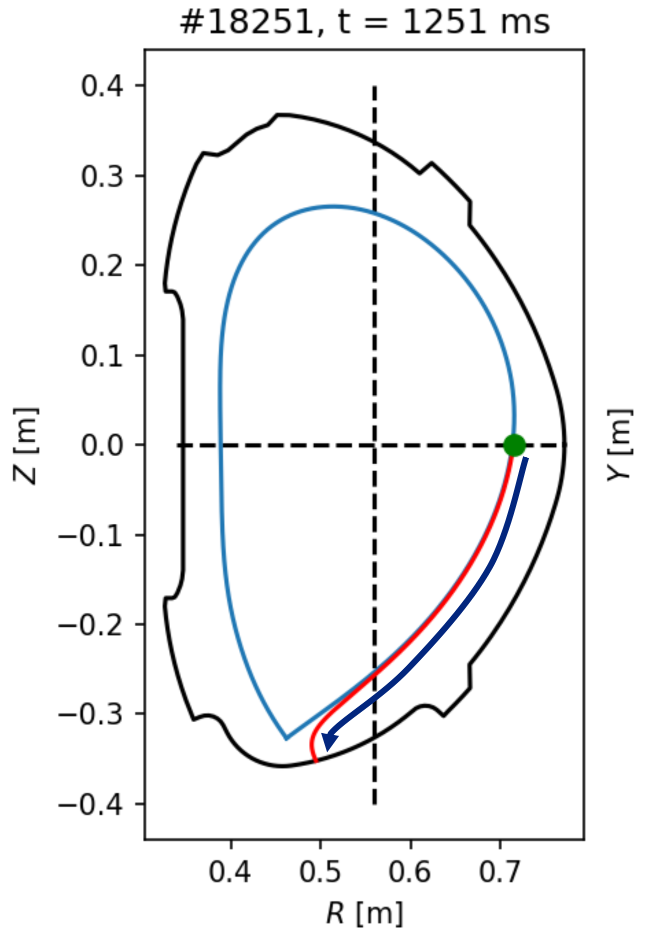
PATH OF THE ELMS

- Formed in the pedestal
- From upstream to divertor, along field lines
- Ion sound speed assumption

$$\tau_{\|} = \frac{L}{\sqrt{(T_e + T_i)/m_d}}$$

L: connection length by PLEQUE





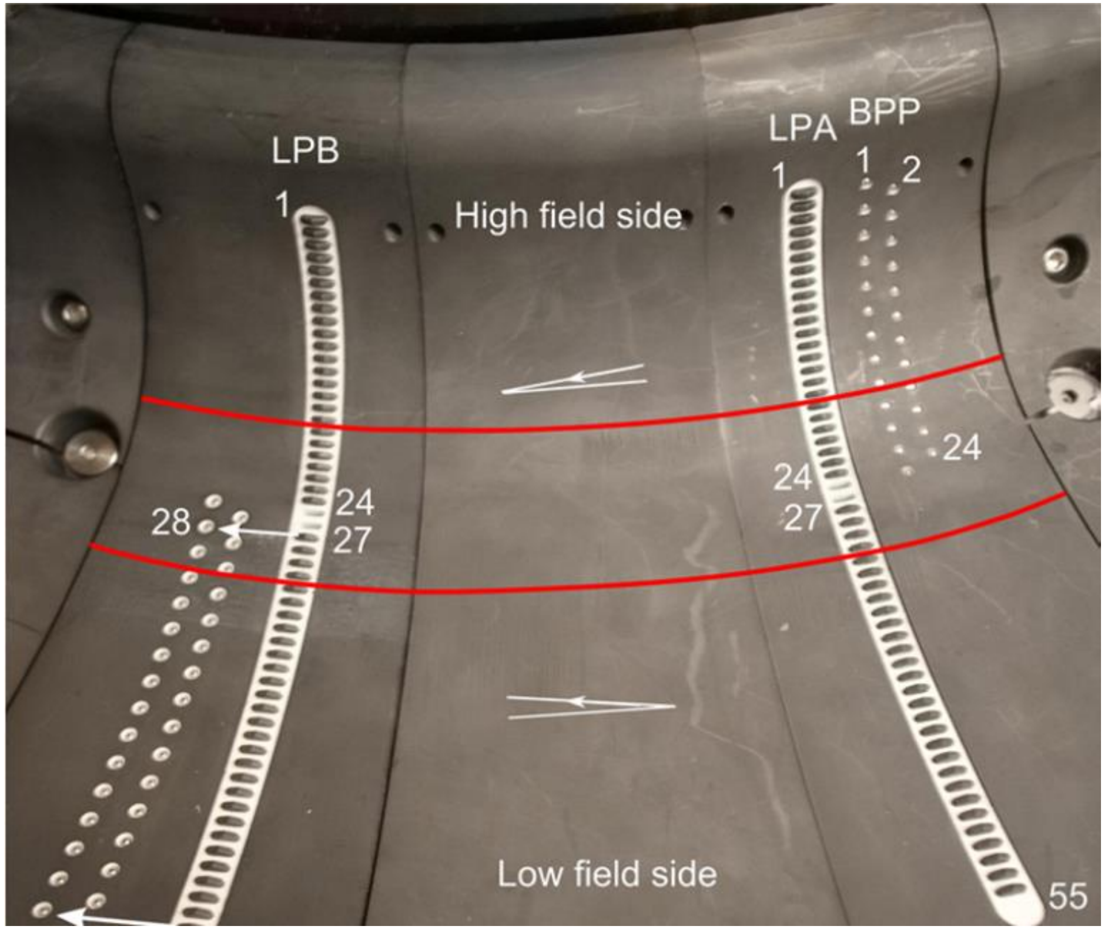
DIAGNOSTIC: DIVERTOR PROBES

Electronics sampling at 4MHz

- #Probe > 27 (Low Field Side)
- BPP$\longrightarrow V_{BPP} \sim V_p$
- LPB$\longrightarrow V_{LPB} = V_{fl}$
- LPA$\longrightarrow I_{LPA}(-270) \sim I^i_{sat}$

Evaluated Quantities

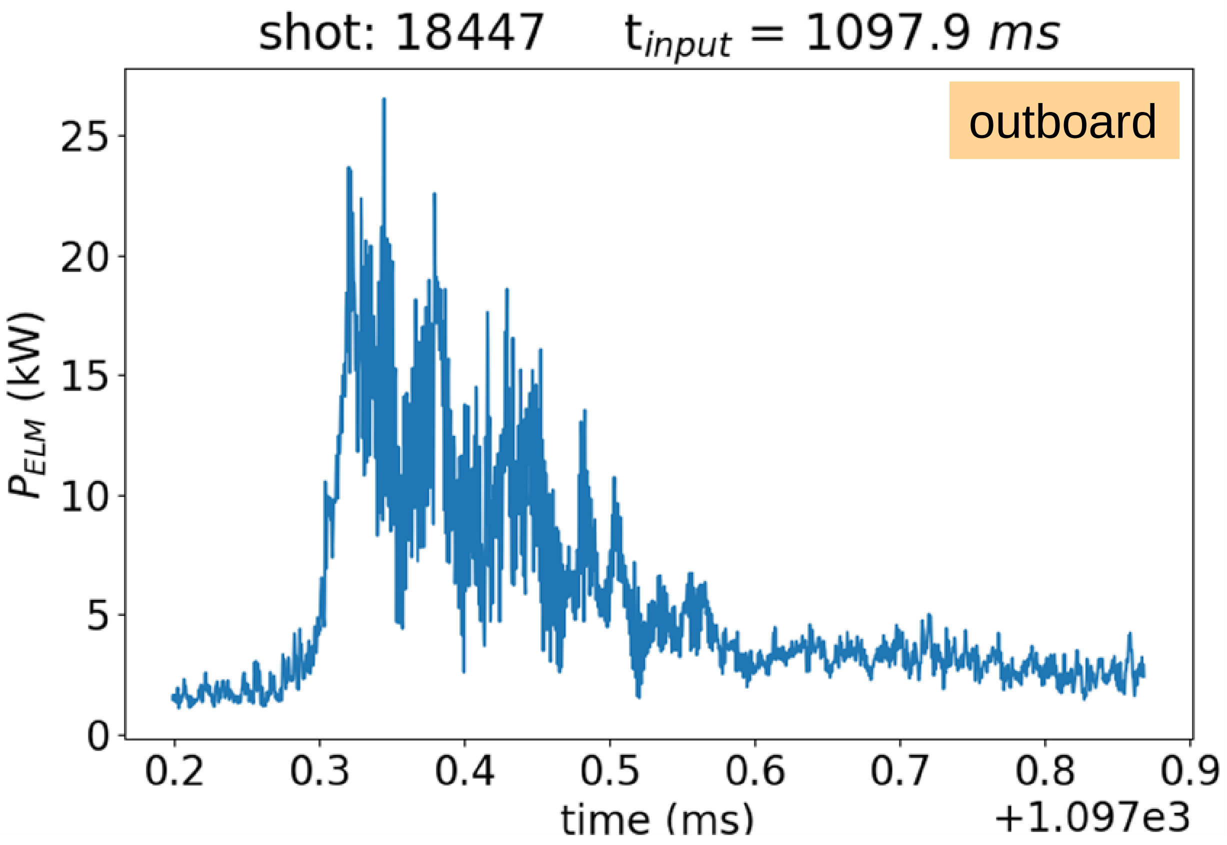
- $T_e = (V_{BPP} - V_{fl})/(\alpha_{LP} - \alpha_{BPP})$
  with: $\alpha_{LP} = 2.0$ & $\alpha_{BPP} = 0.6$
- $Q_{\parallel} = \gamma\, I^i_{sat}\, T_e/A_{probe}$
  with: $\gamma = 11$ & $A_{probe} = 2.8\ \mathrm{mm}^2$

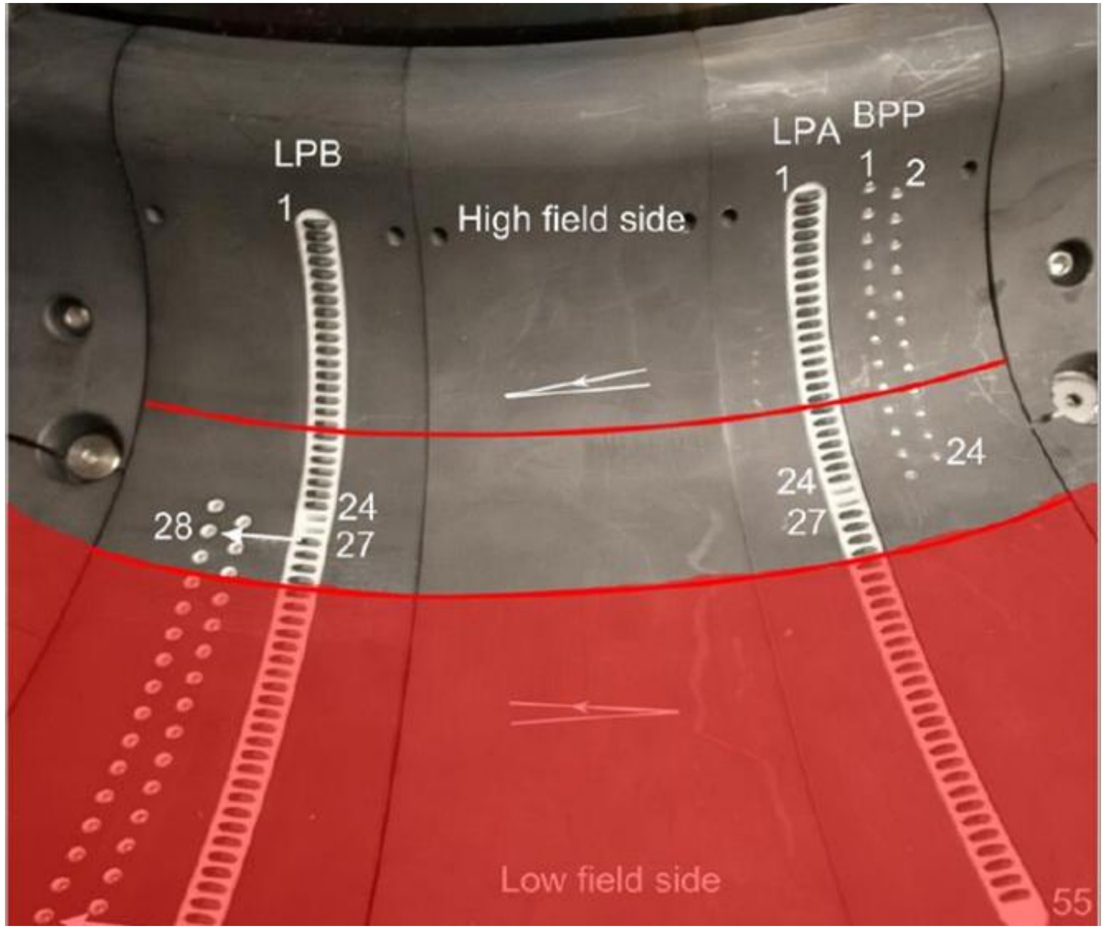


Adamek J. et al 2017 Nucl. Fusion **57** 116017

DIAGNOSTIC: DIVERTOR PROBES

$$P_{ELM}(t) = 2\pi \int R Q_{\parallel}(t)\, dR$$





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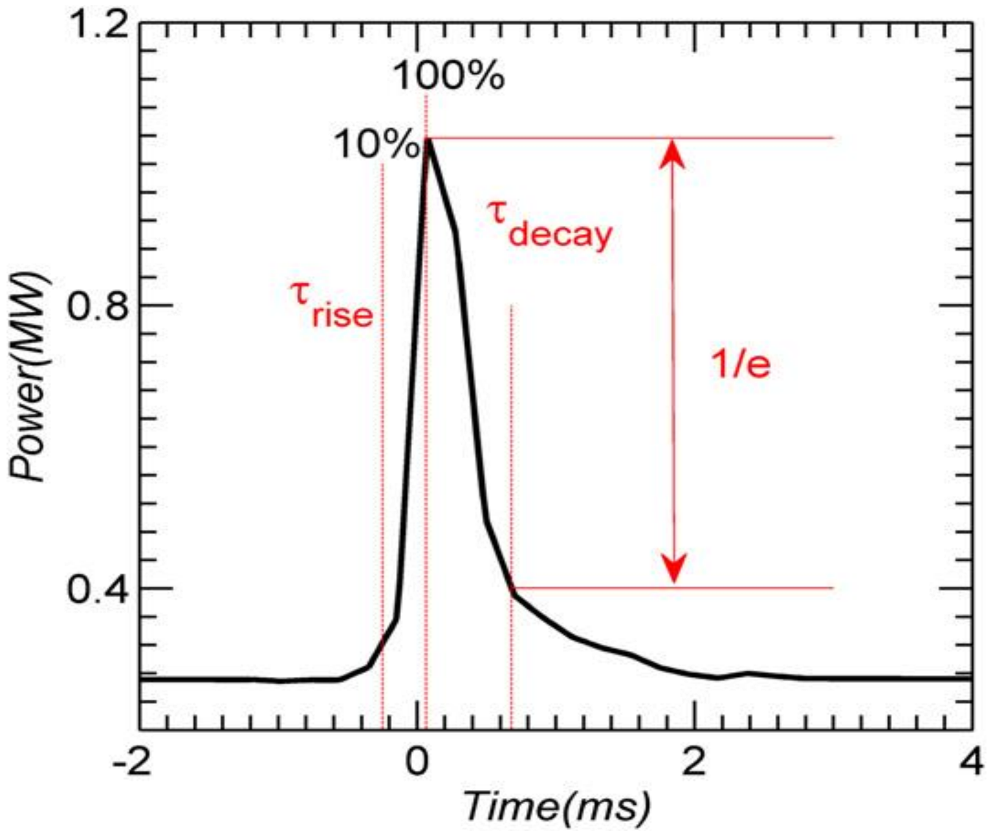
ELM CHARACTERISTIC TIMES

Low temporal resolution (4 kHz)
HL-2A

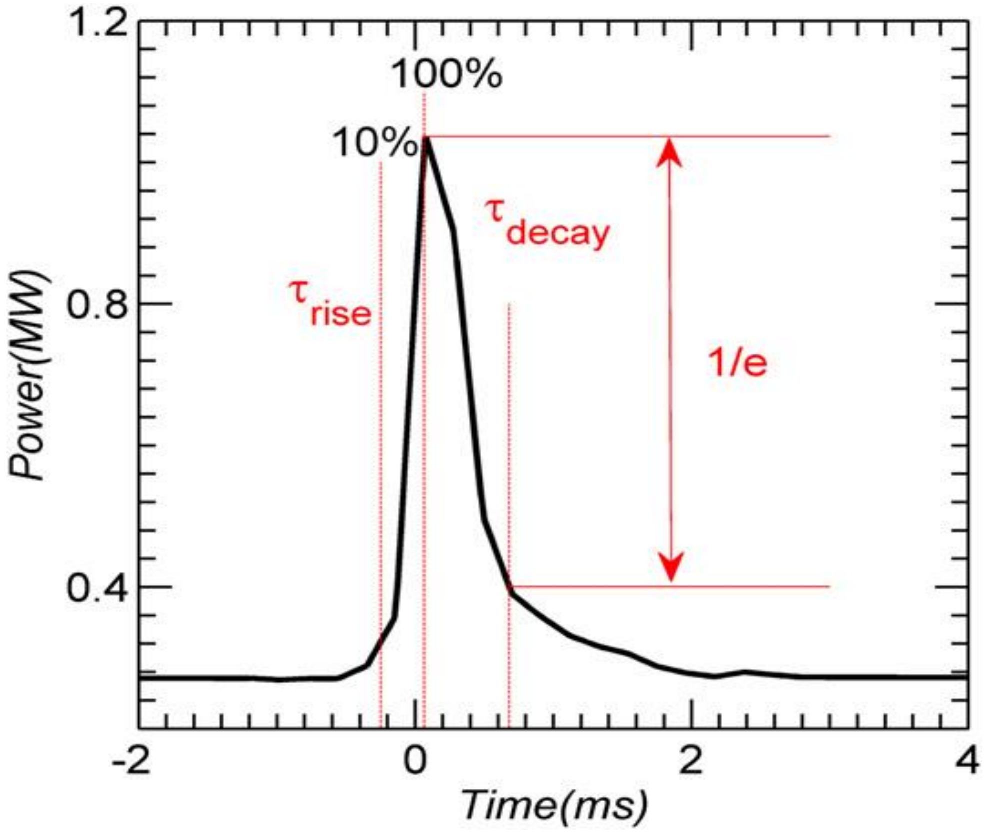


J.M. Gao et al., NF 61 (2021), 066024

- HL-2A tokamak (China)
- IR camera measurements
- Conditional averaged ELM
- τ_{rise} : (10-100)% of the max of the ELM
- τ_{decay} : exponential fit that starts at the max

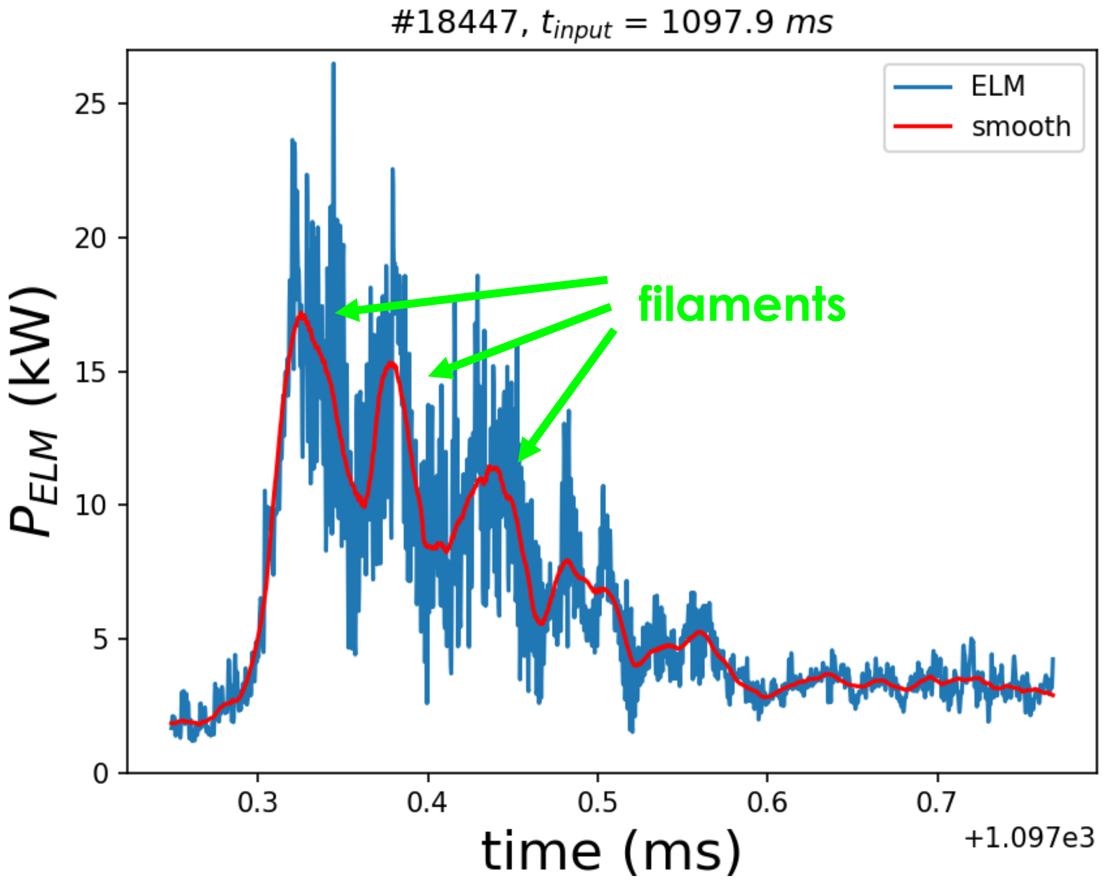
ELM CHARACTERISTIC TIMES

Low temporal resolution (4 kHz)
HL-2A



J.M. Gao et al., NF 61 (2021), 066024

High temporal resolution (1 MHz), single ELM
COMPASS



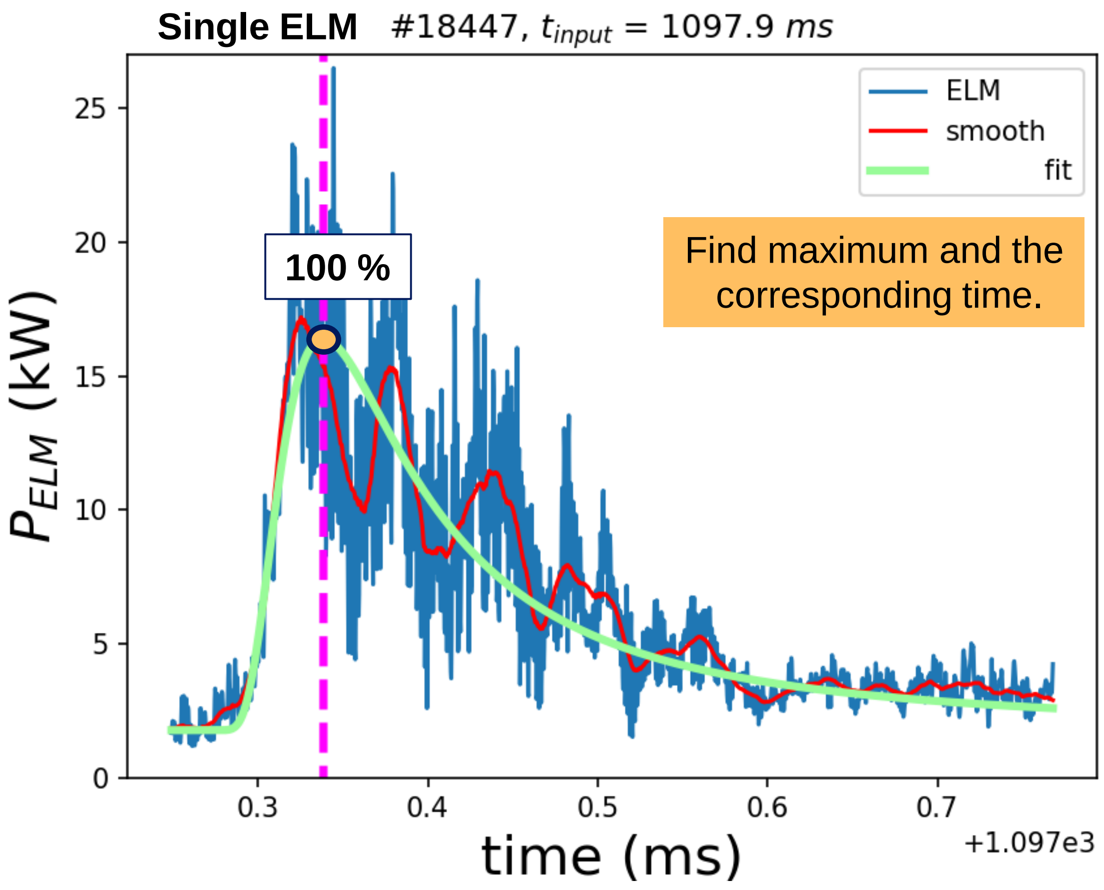
FITTING FUNCTION

- Model for the temporal evolution of the ELMs
- It assumes Maxwellian distribution for particles that propagate “force-free-way” along B to the SOL
- Fits very well to the data

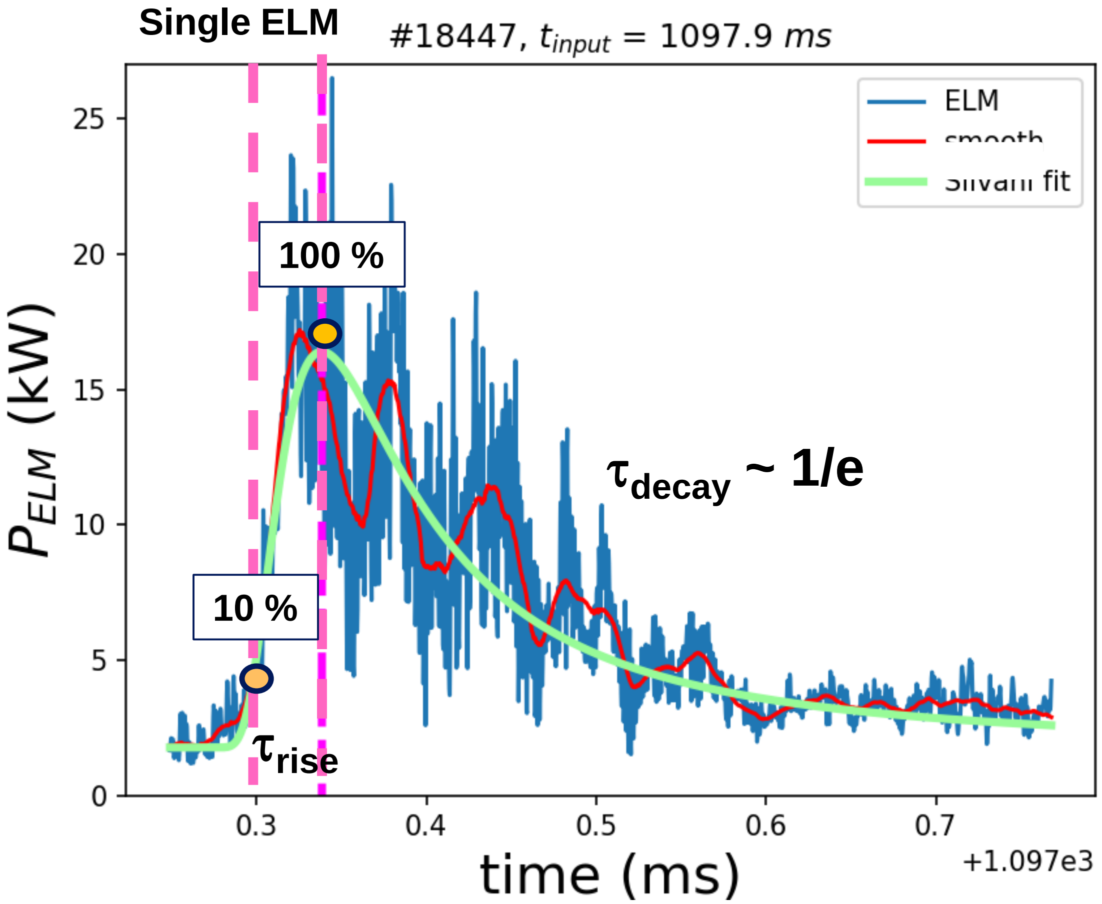
$$q(t) = \frac{2E}{3\sqrt{\pi}}\left[1+\left(\frac{\tau}{t}\right)^2\right]\frac{\tau}{t^2}\exp\left[-\left(\frac{\tau}{t}\right)^2\right]+q_{\mathrm{BG}}$$

W. Fundamenski and R. A. Pitts, PPCF 48 (2006)109–56

D. Silvagni et al 2020 Nucl. Fusion 60 126028

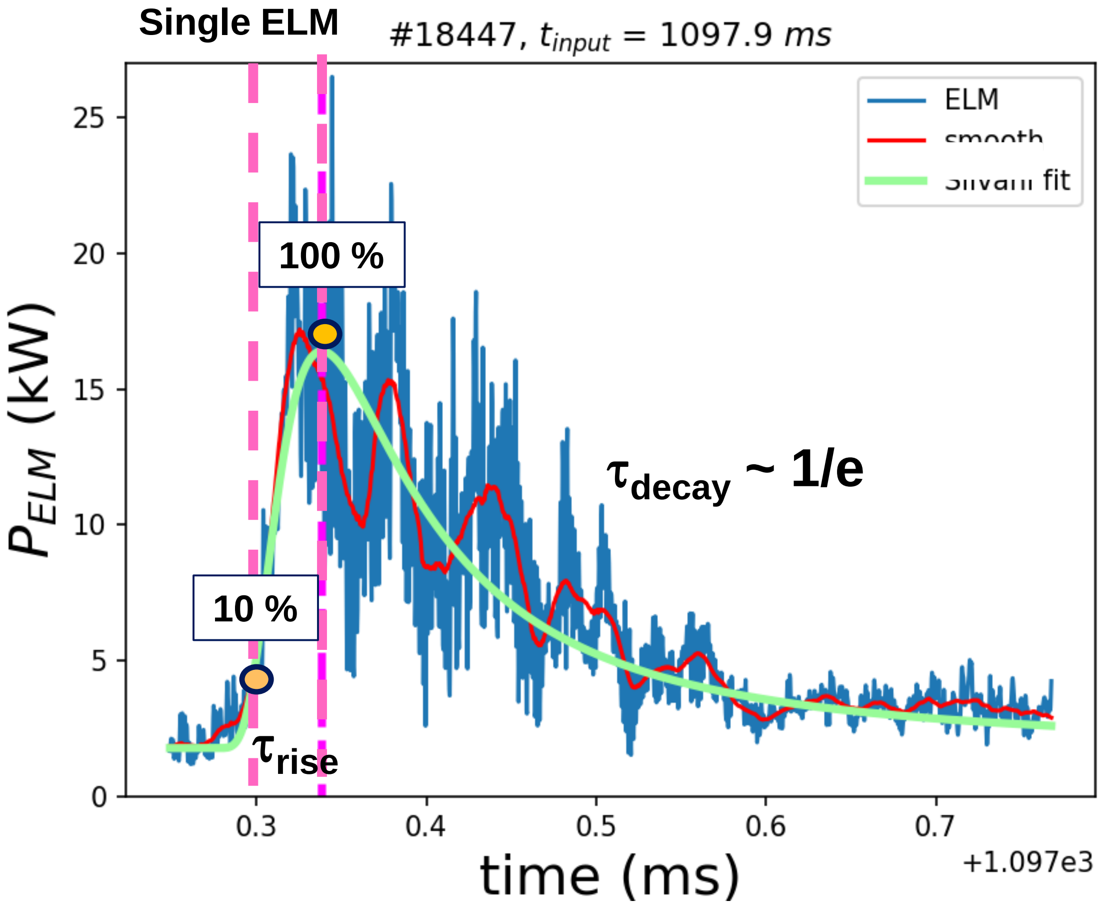


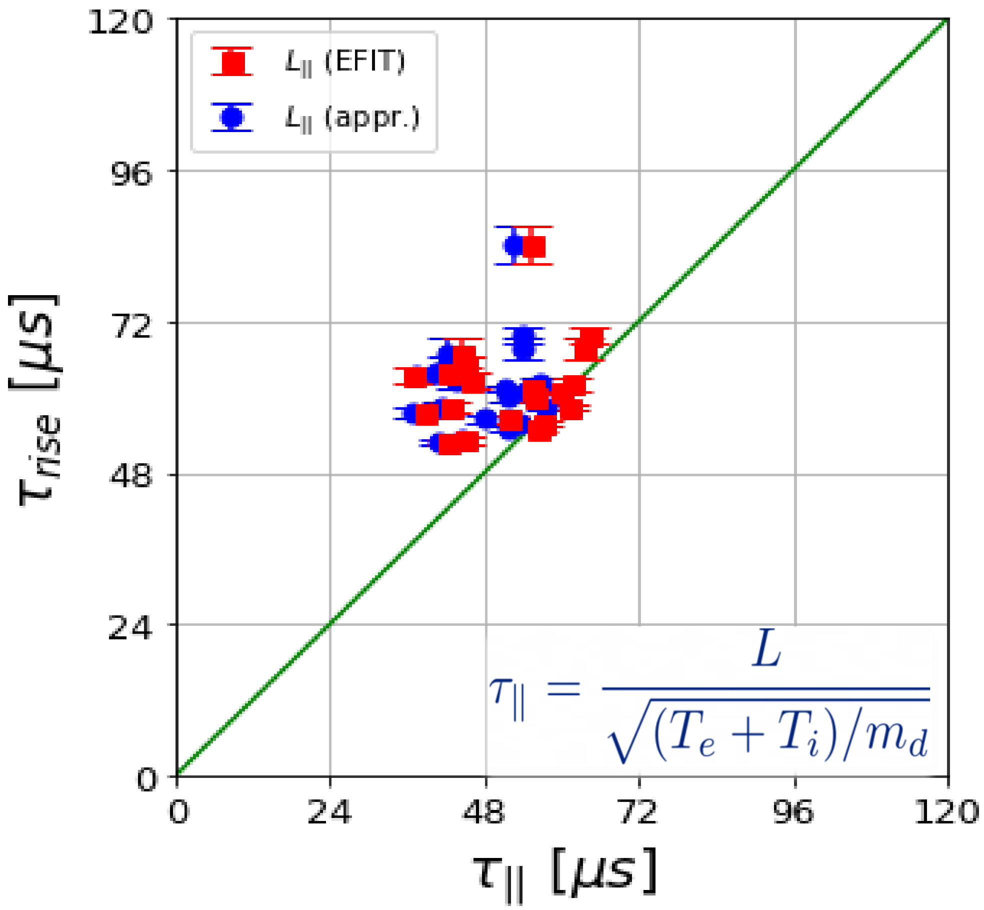
ELM CHARACTERISTIC TIMES



20 ELMs events from different shots #18232 - #18611.
TS data already published in J. Adamek et al., NF 60 (2020)

ELM CHARACTERISTIC TIMES





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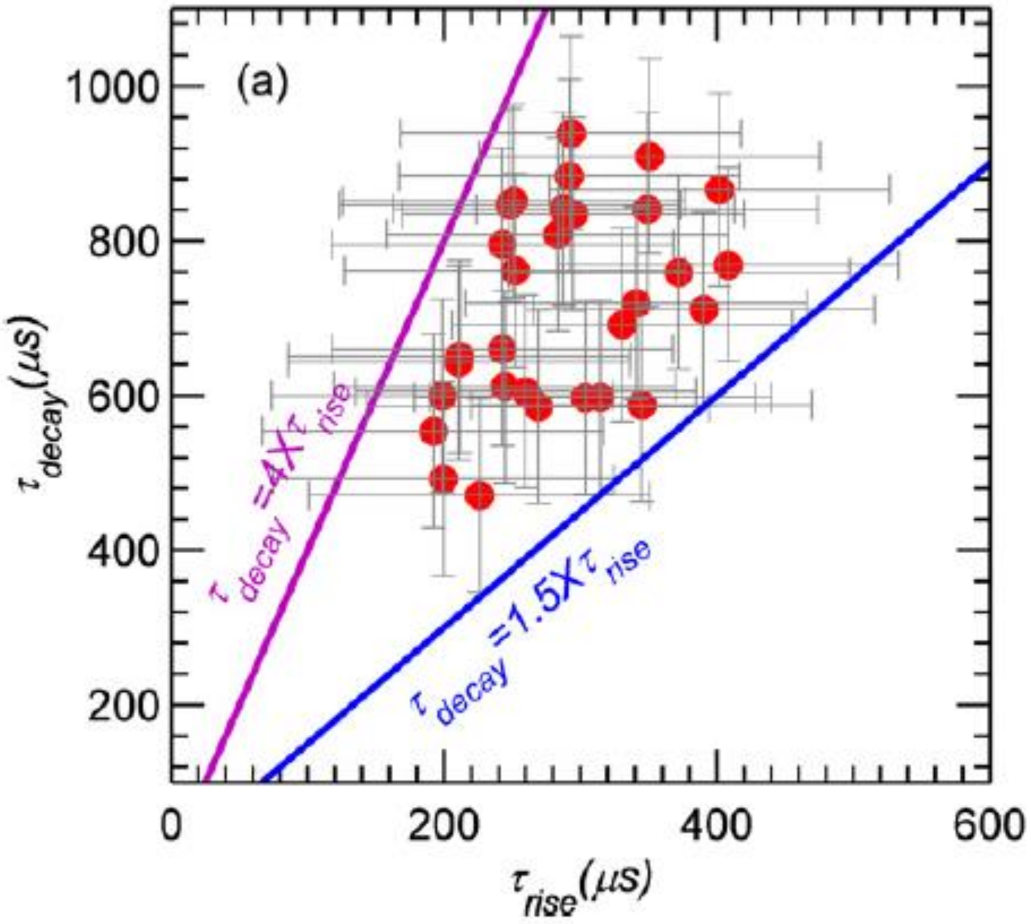
$L_{||}(\text{appr.}) = 2\cdot\pi\cdot R_{LCFS}\cdot q_{95}/3$ on LFS

ELM CHARACTERISTIC TIMES

HL-2A



HL-2A: J.M. Gao et al., NF 61 (2021), 066024

We have analyzed 154 single ELM events within 29 H-mode discharges

ELM CHARACTERISTIC TIMES

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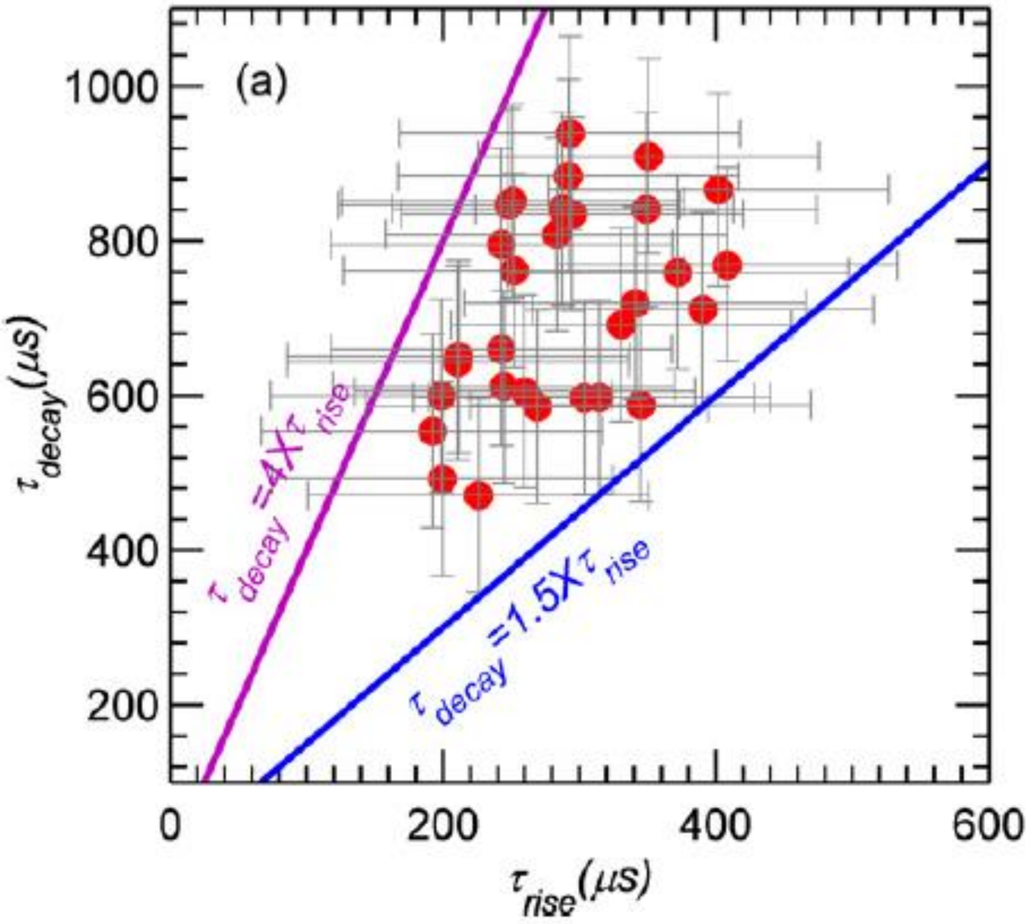

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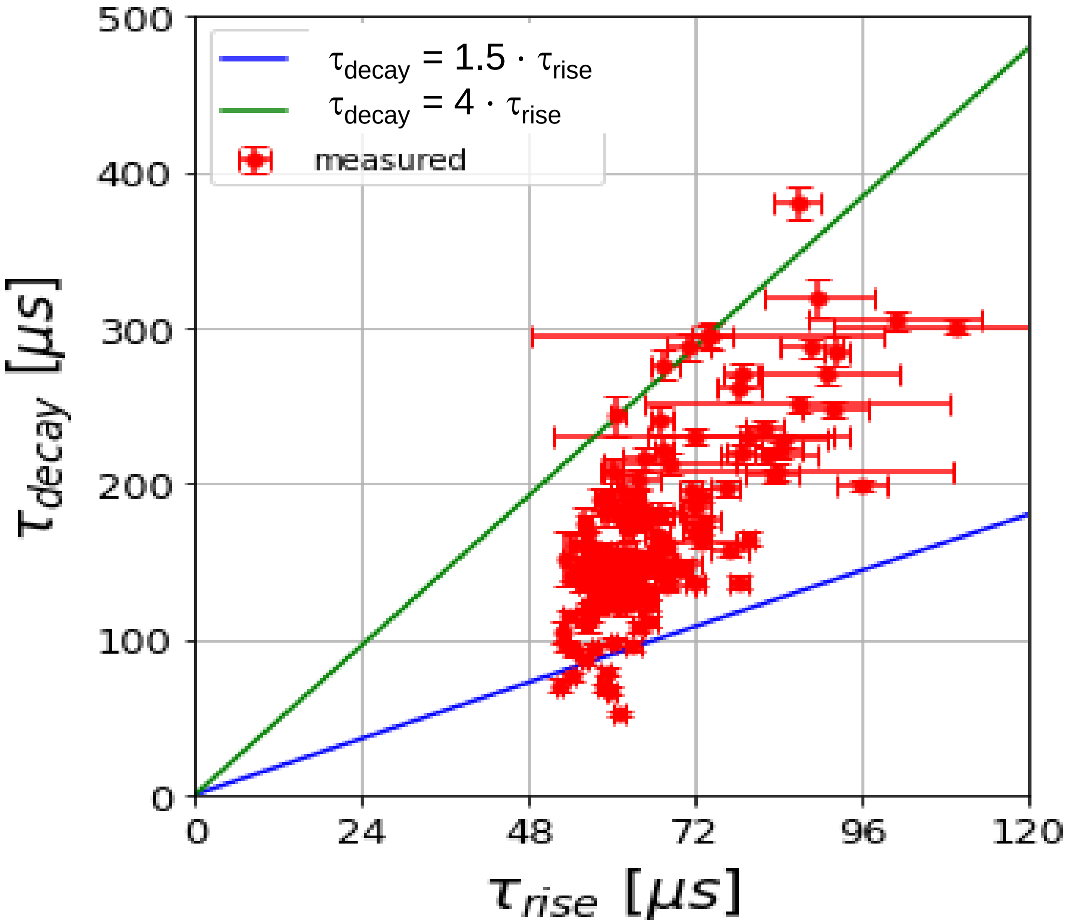
COMPASS



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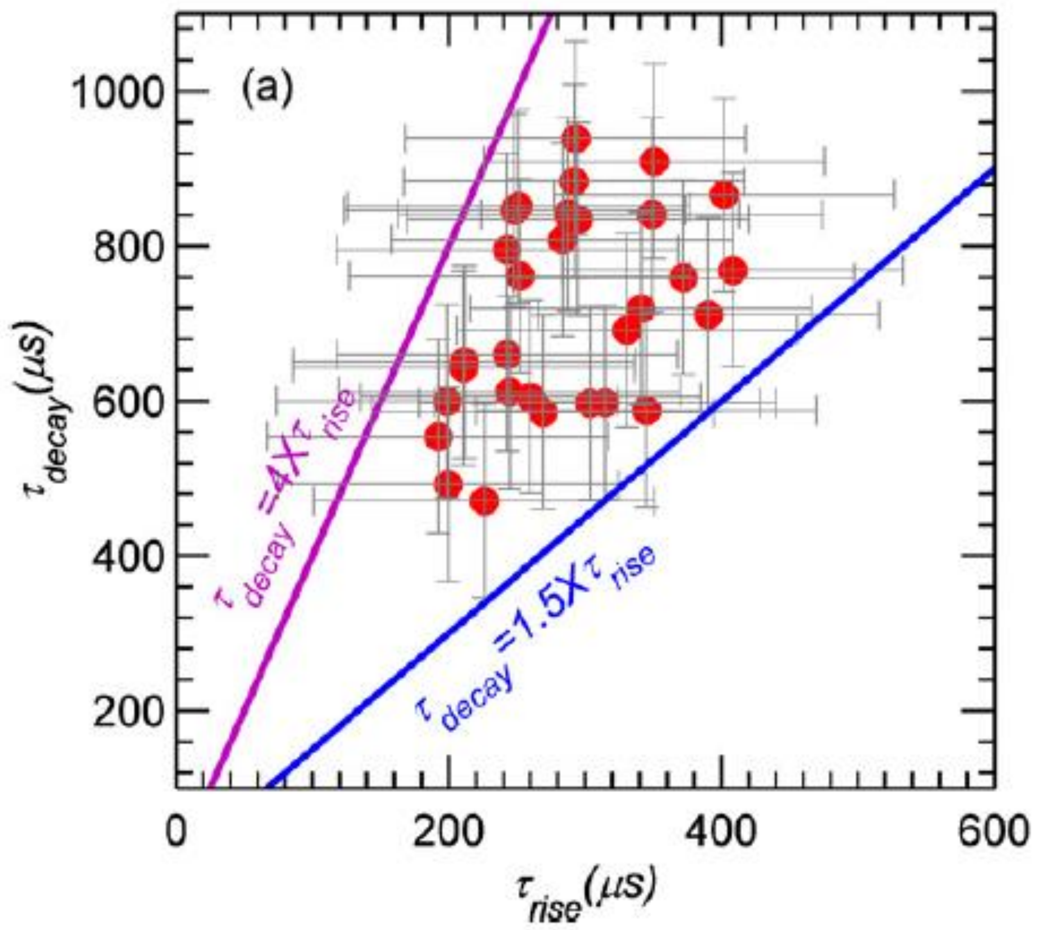

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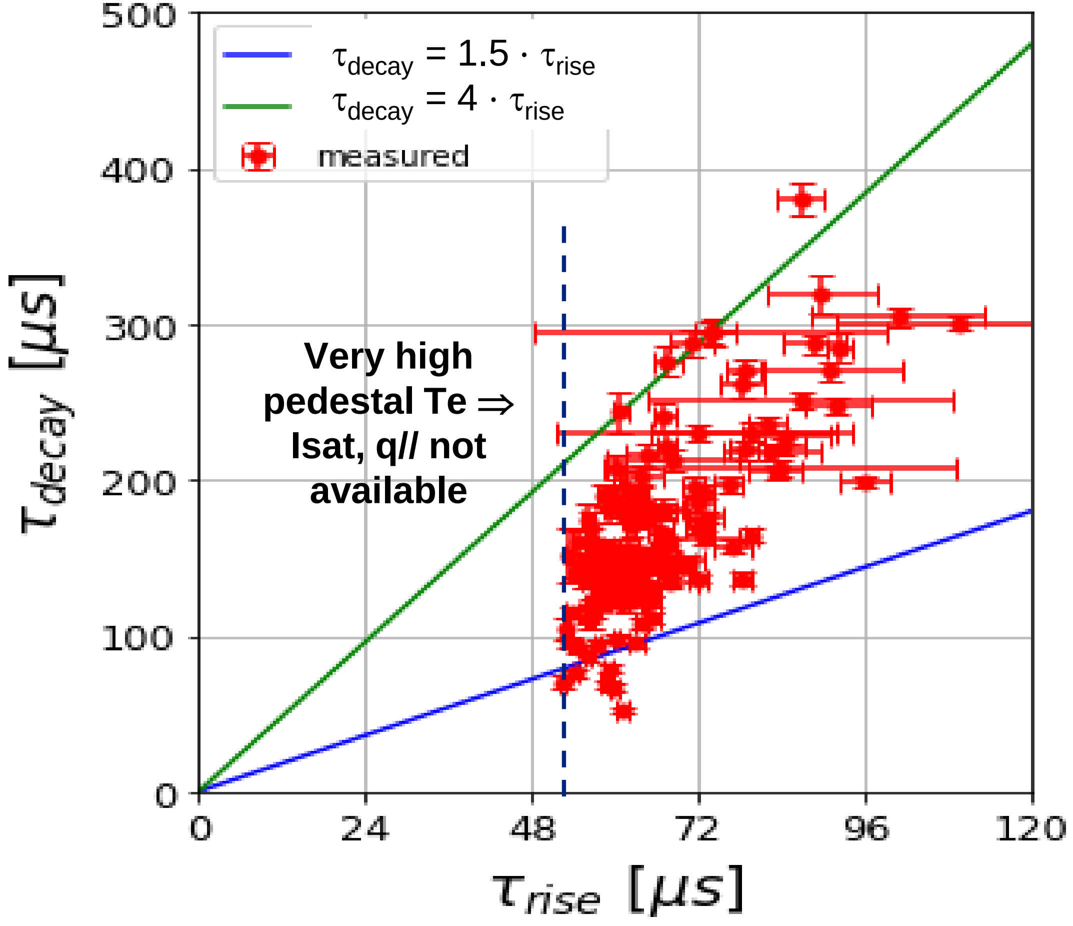

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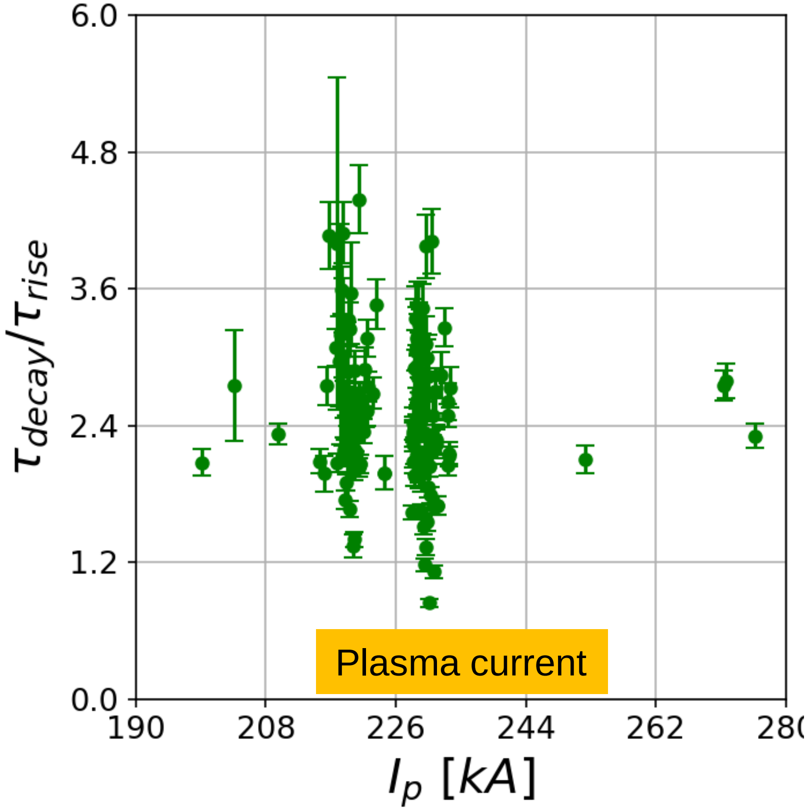
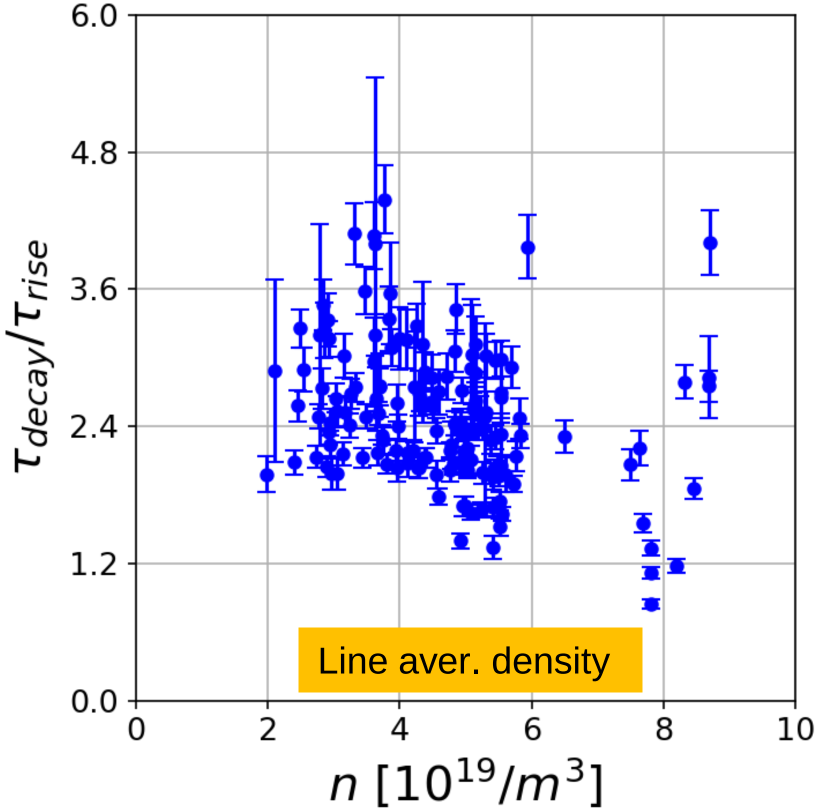
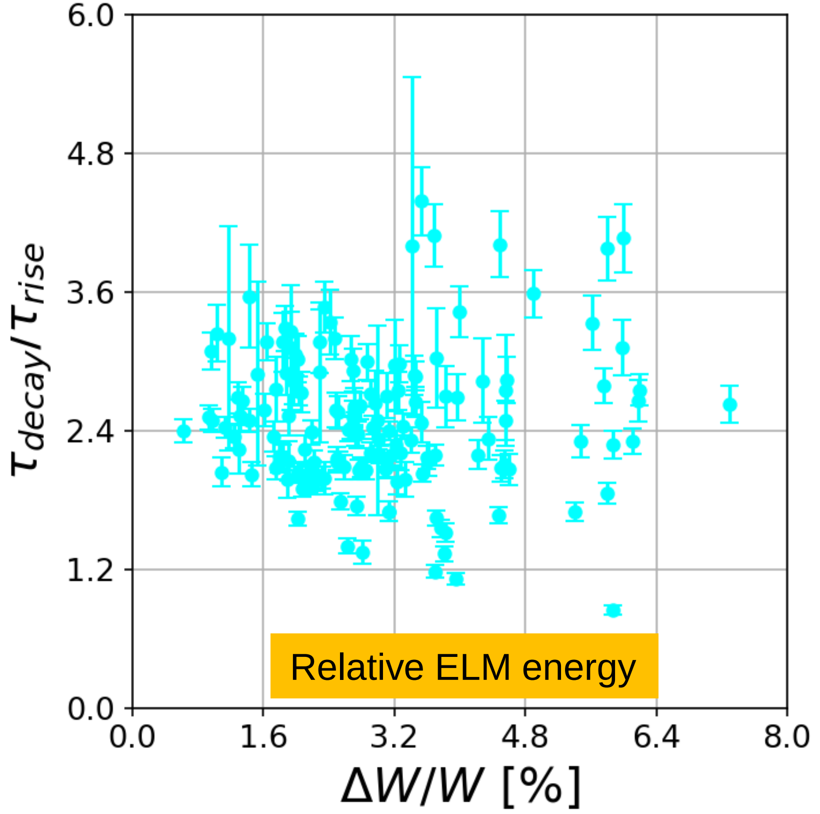
ELM CHARACTERISTIC TIMES VS DIFFERENT PARAMETERS







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CONCLUSIONS

- $\tau_{rise} \approx \tau_{\parallel}$ with connection length given by EFIT or simple formula $2 \cdot \pi \cdot R_{LCFS} \cdot q_{95}/3$
- **non-ergodized magnetic field lines during ELM rise time**
- ELM heat loads dominated by parallel transport → Eich model hypothesis satisfied

Duration of the ELM heat load

- τ_{decay} / τ_{rise} is found to be within the range 1.5 – 4 as similarly on HL-2A tokamak
- τ_{decay} / τ_{rise} seems to be independent on the plasma current, relative ELM energy, but it is slightly reduced for higher line averaged density