Particle Assimilation Study During Shattered Pellet Injection (SPI) on DIII-D

by
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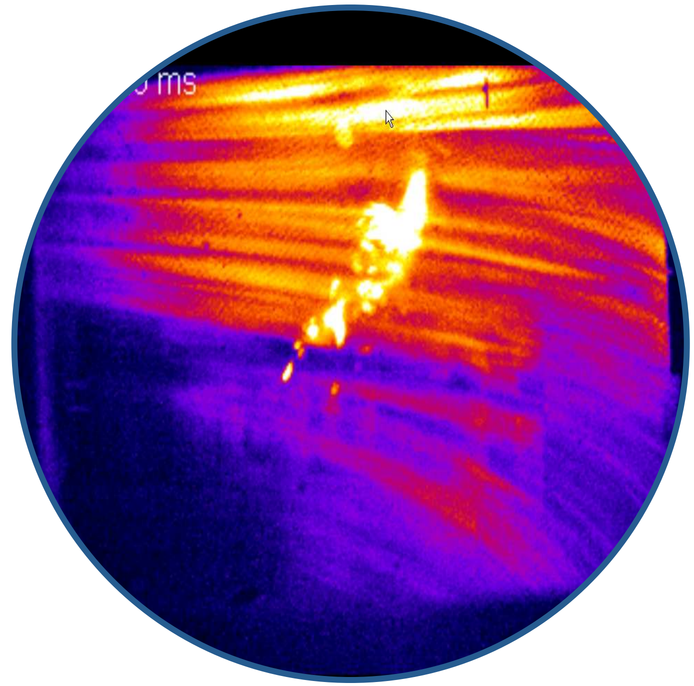

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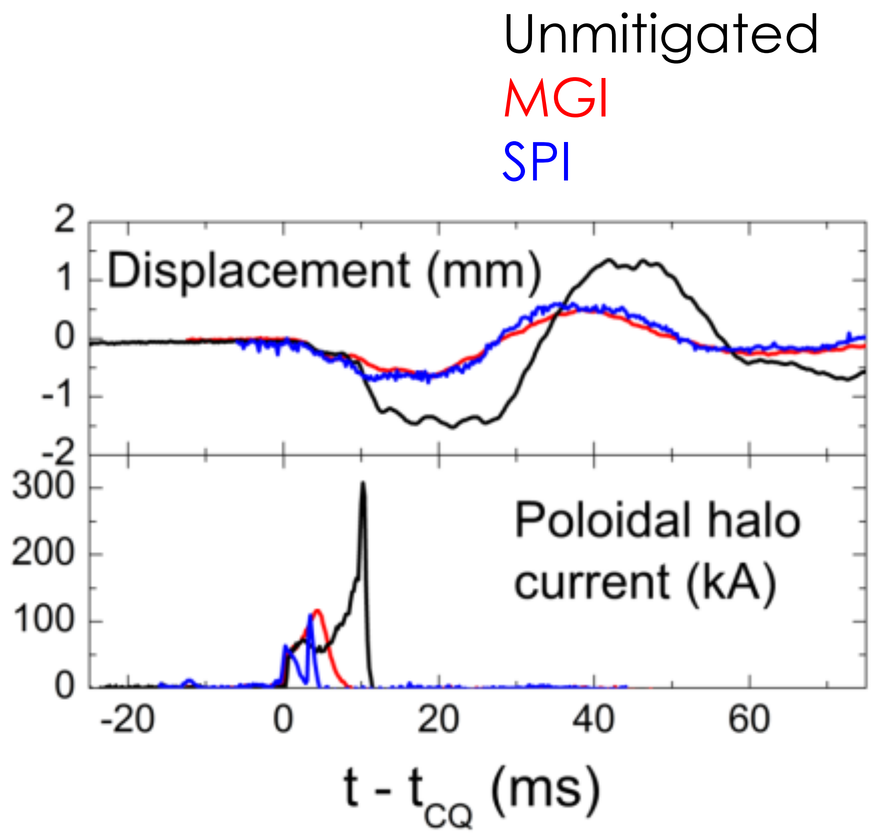
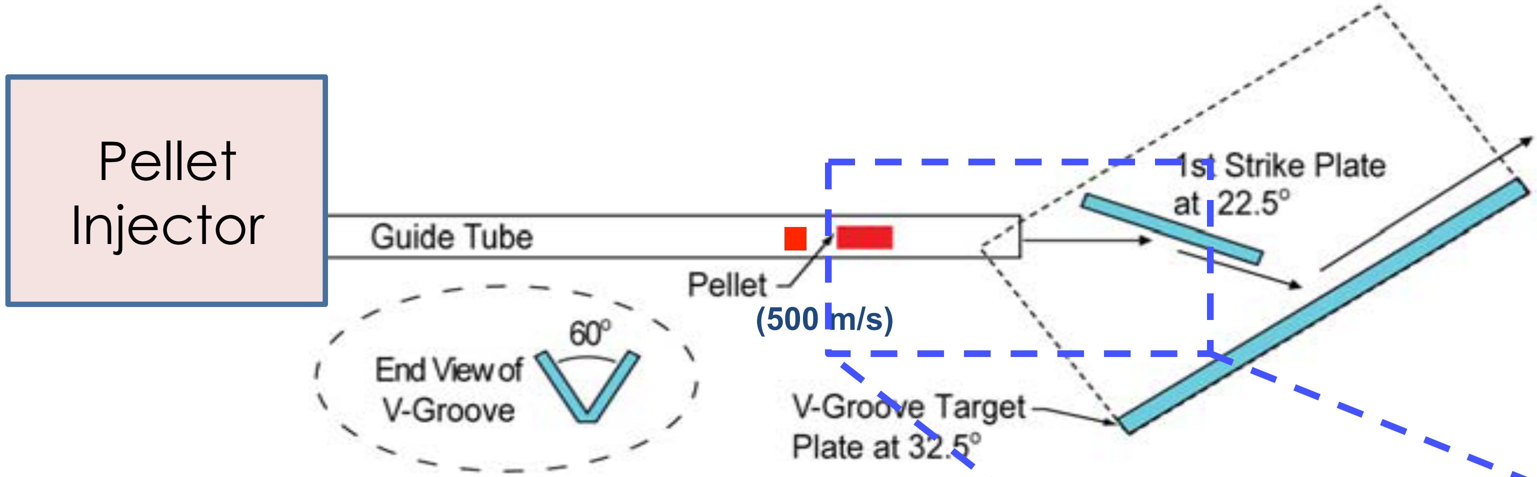
OAK RIDGE National Laboratory

Massive Particle Injection for Disruption Mitigation on ITER

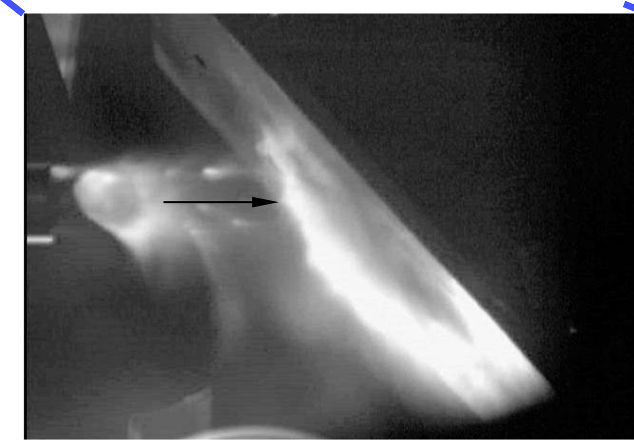
- **Massive particle injection is one of the major mitigation systems planned on ITER**
- **Proven mitigation of heat loads and forces**
- **Possibility of mitigating runaway electron at high density**
- **But maximum densities achieved using massive gas injection (MGI) is ~10 times too low**



A New Method has been Designed: Shattered Pellet Injection (SPI)

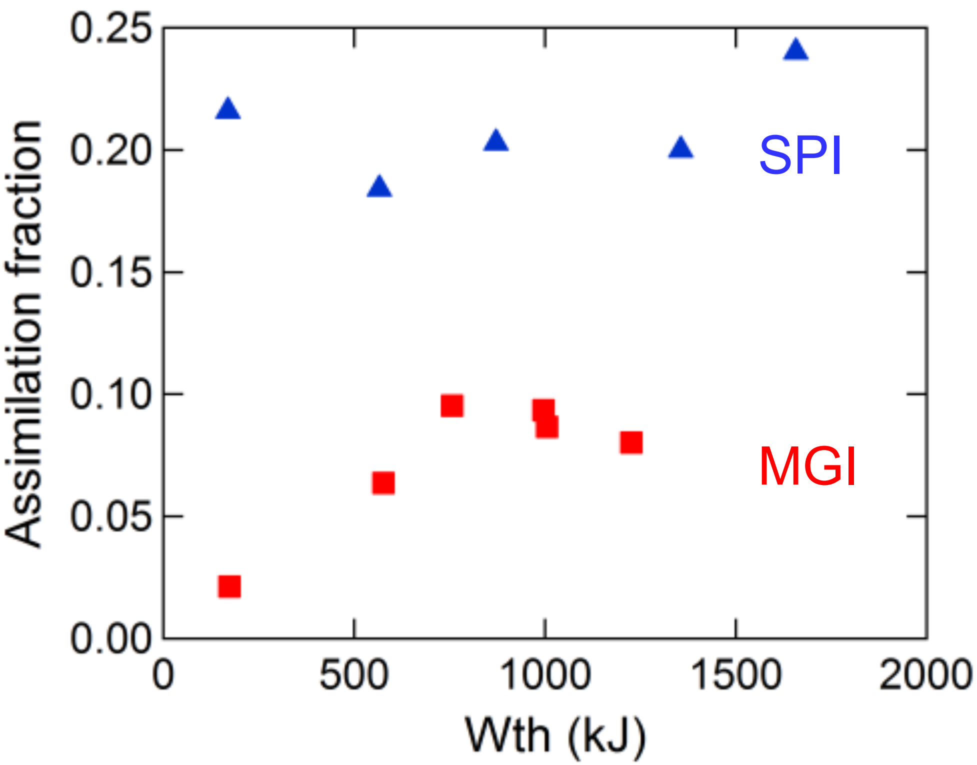


- Large cryogenic pellet: 15mm x 20mm cylinders D_2 in DIII-D (3000 torr.L or 400 Pa.m ^{3})
- Pellets shattered before entering the plasma by bouncing on 2 plates to increase the surface area for faster ablation
- In these experiments, the pellet systematically broke in 2 pieces generating 2 successive injections



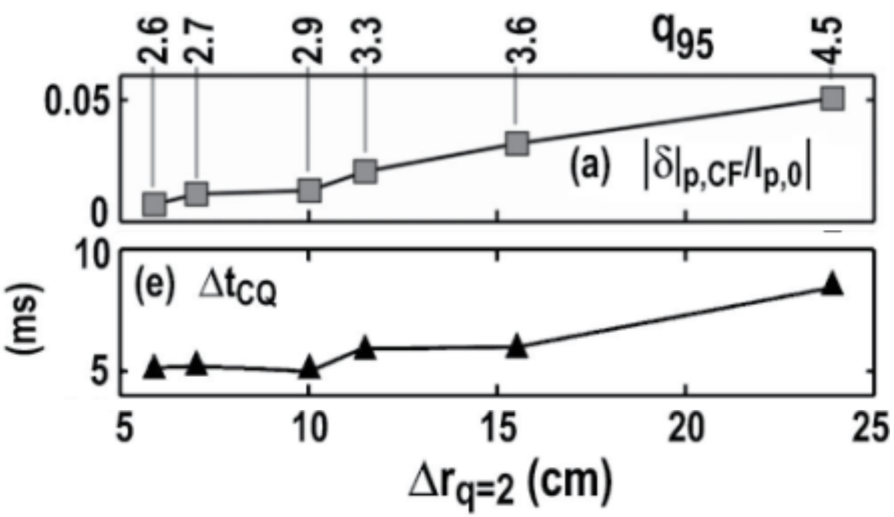
Earlier Results Showed Better Assimilation than Massive Gas Puff

- **Faster and higher particle assimilation for SPI compared to MGI**
- **Unlike MGI, the assimilation fraction of SPI does not depend on the thermal energy content of the plasma**
- **What is the mechanism dominating the assimilation process for SPI ? (MHD ?)**



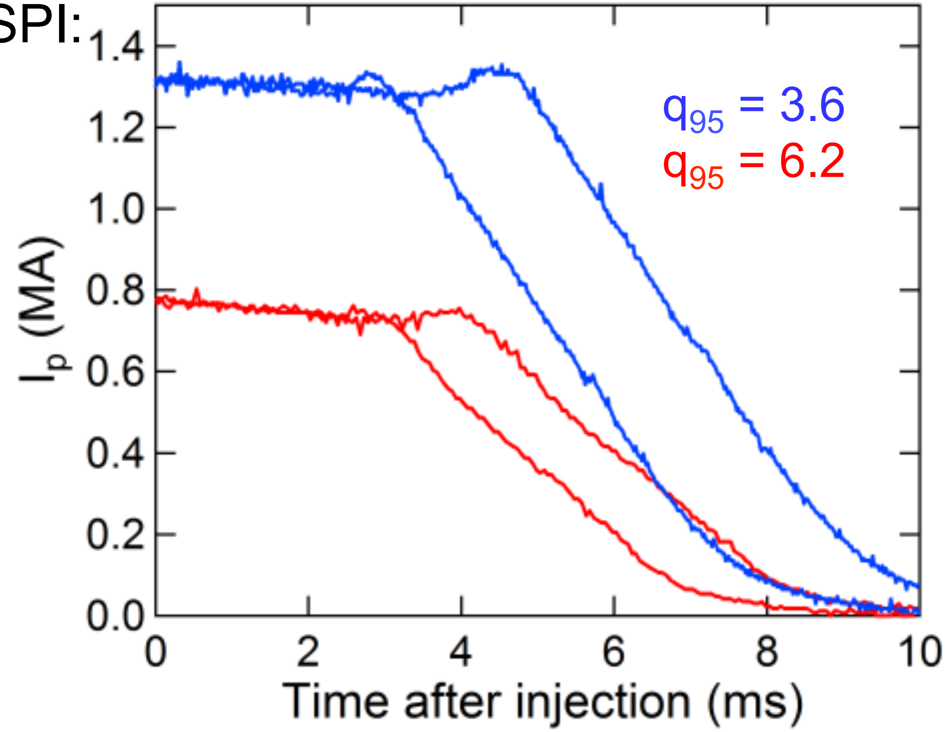
The Current Quench Onset Time Does Not Depend on the q_{95} Unlike MGI

MGI:



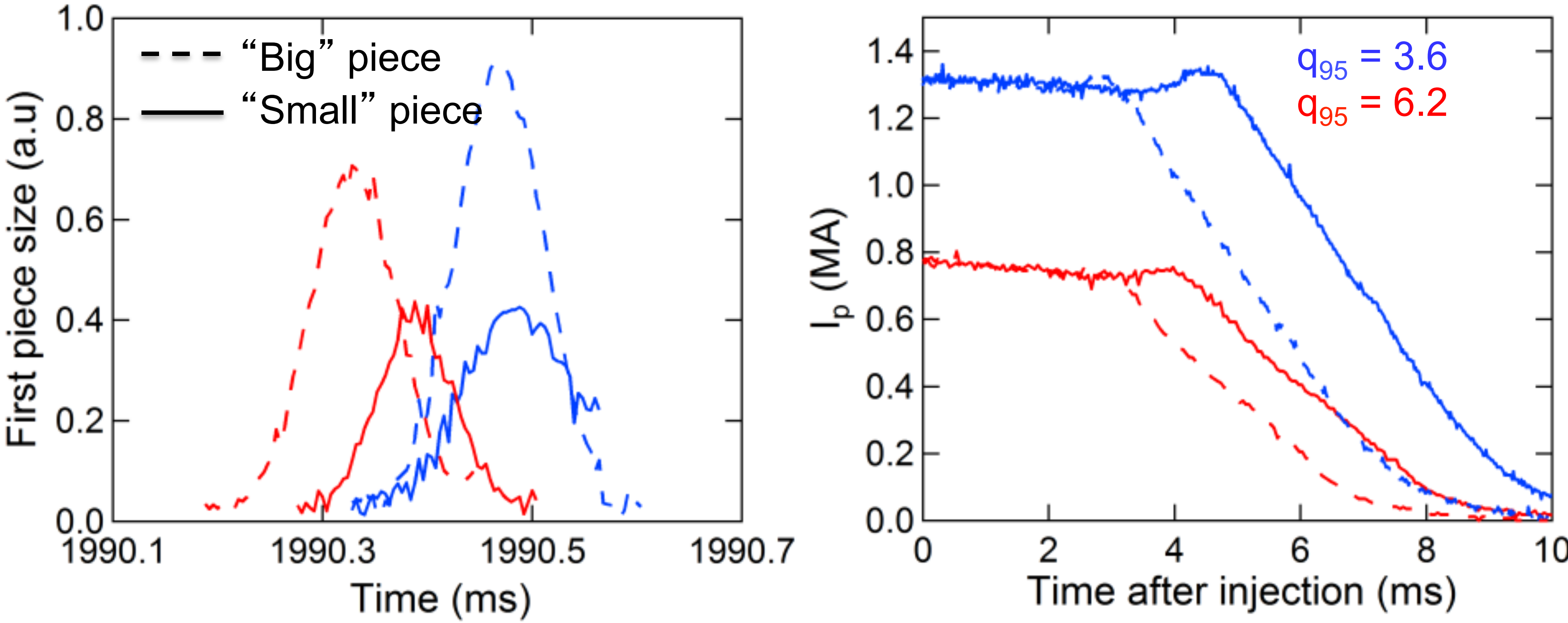
E. Hollmann et al. PoP (2007)

SPI:



- **CQ onset time for MGI observed to be faster for low q_{95}**
- **SPI Shutdown process different: no sign of a cold front propagating inward triggering the shutdown when reaching q=2**

Current Quench Onset Time Influenced by the Size of the First Piece Entering the Plasma



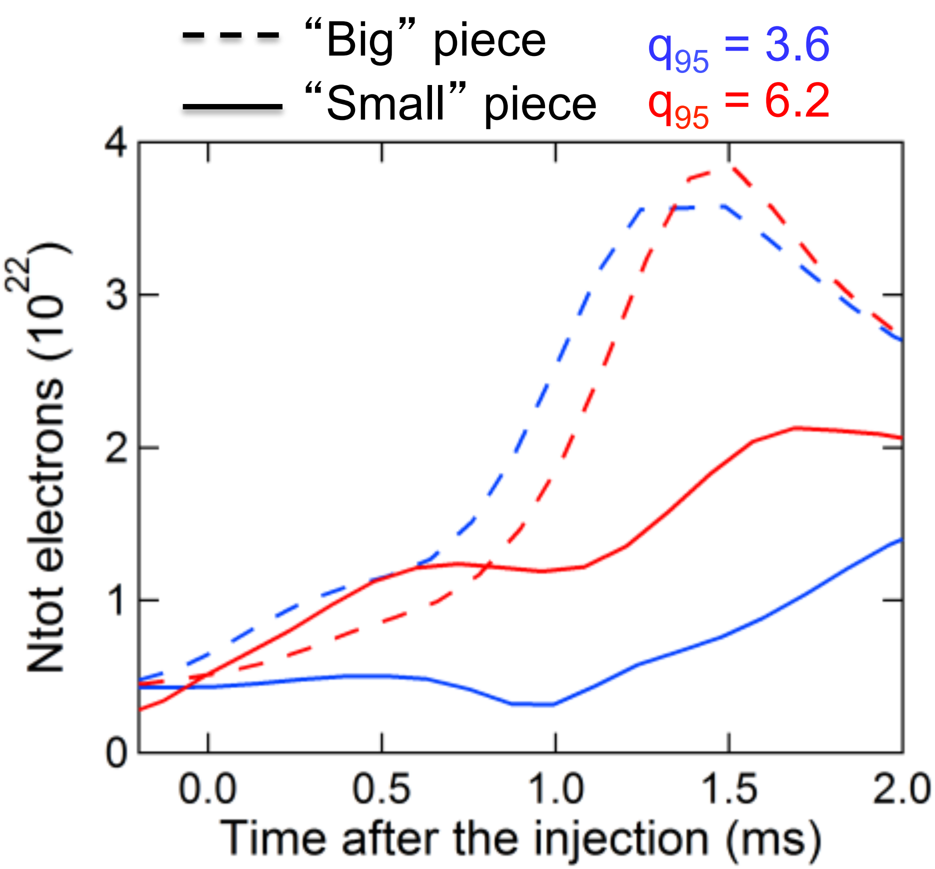
- **SPI injections often result in 2 successive injections at slightly different times**
- **The size of the 1st injection (1st piece shattered) entering the plasma changes the onset time of the current quench: bigger injection induces a faster CQ onset**

Initial Assimilation Related to the size of the First Piece Reaching the Plasma

- **No influence of the q_{95} on the assimilation efficiency**

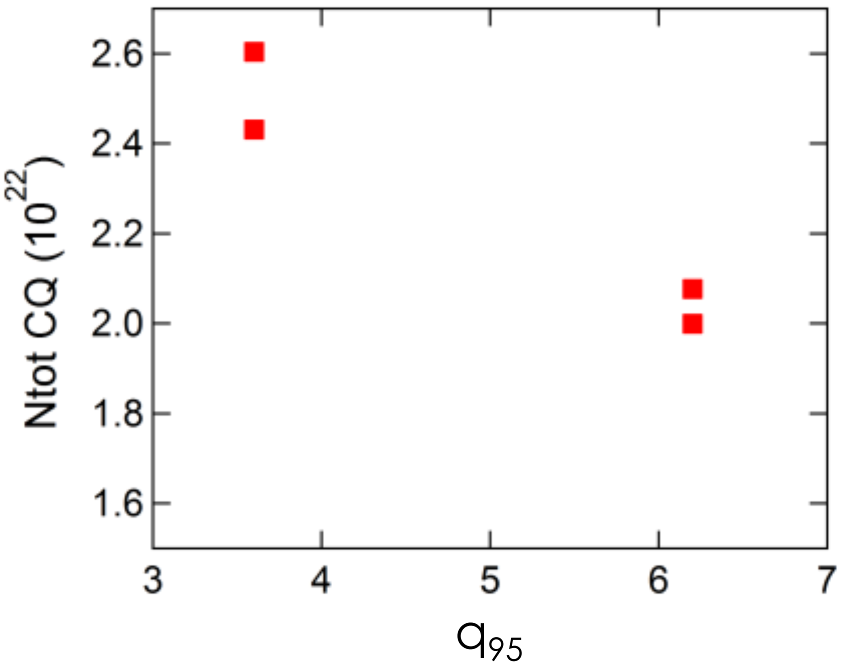
- **Large first injection (first broken piece) yields higher initial density**

- **MHD does not appear to play a significant role because no effect of q_{95}**



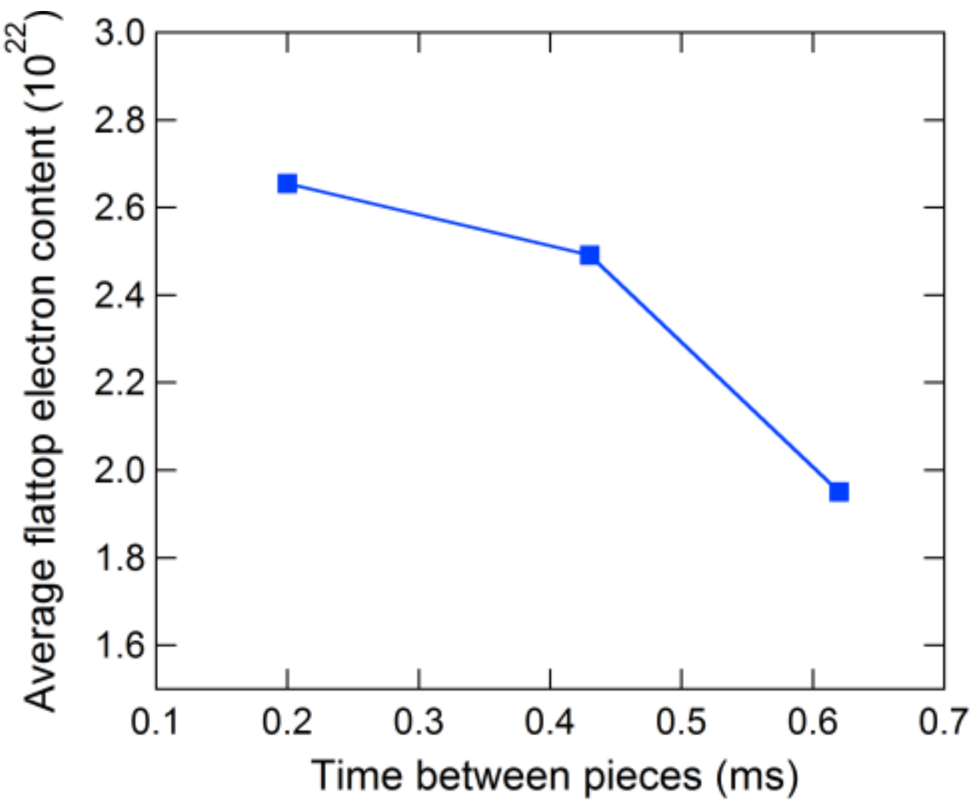
Current Quench Electron Density Affected by q_{95}

- **Low q_{95} yields a higher electron content**
- **Behavior might not be related to MHD**
  - Particles already in the plasma
  - MHD would expel particles out
- **Reaching a maximum in assimilation determined by pressure balance between the core and the edge? Confinement effect?**



Assimilation Not Affected by Multiple Injections

- **Injection within 0.5 ms yields same assimilation as one piece**
- **When pieces are further apart, the final electron content drops**
- **0.5 ms is the approximate duration of the thermal quench: correlation?**
- **Multiple injection possible without lowering the assimilation efficiency on ITER?**



Summary

- **The shutdown process induced by SPI is different from MGI**

- **The size of the initial fragment determines the initial shutdown parameters**
  - CQ onset time
  - Initial density

- **The CQ particle content of the plasma appears to reach a maximum determined by q_{95}**

- **Multiple injections yield the same assimilation one larger injection if within 0.5 ms on DIII-D (correlation with TQ duration?): Possibility of multiple injections on ITER?**