

Dual Shattered Pellet Injection (SPI) Experiments with identical pellets on DIII-D

by

J. L. Herfindal¹, D. Shiraki¹, L. R. Baylor¹,
E. Hollmann³, C. Marini³, Ž. Popvić⁴,
N. Eidietis², A. Lvovskiy²

¹Oak Ridge National Laboratory

²General Atomics

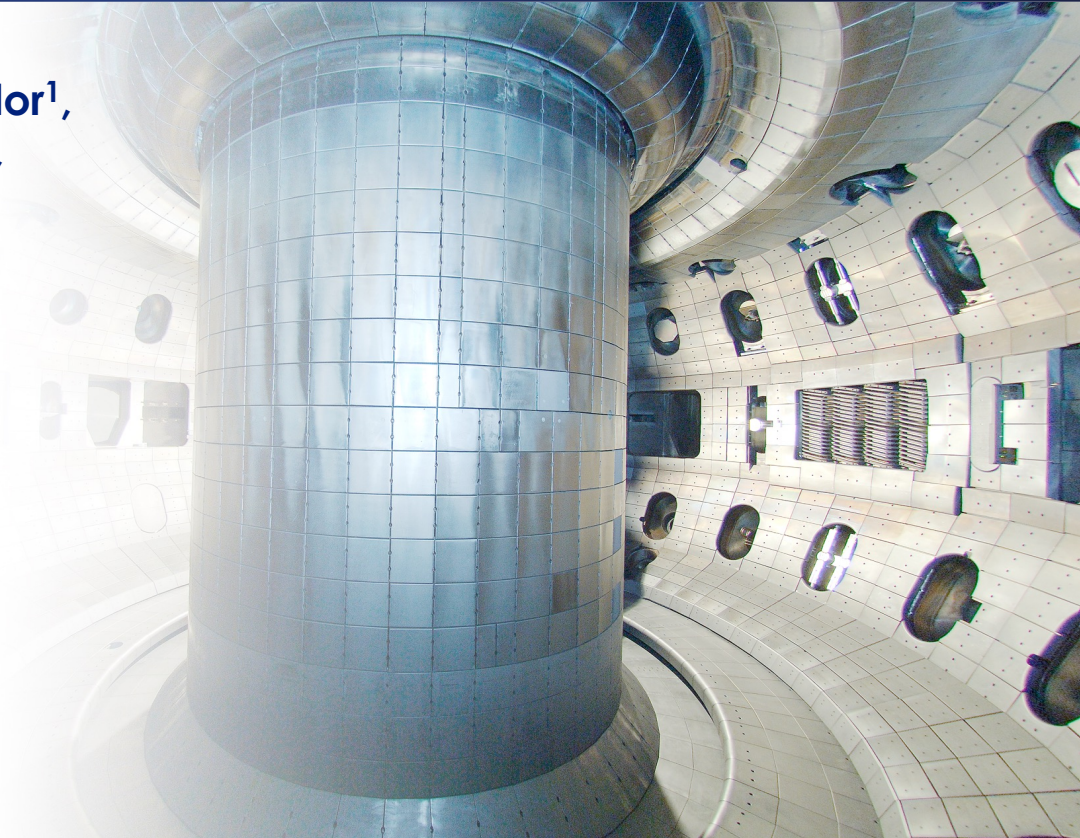
³University of California San Diego

⁴Oak Ridge Associate Universities

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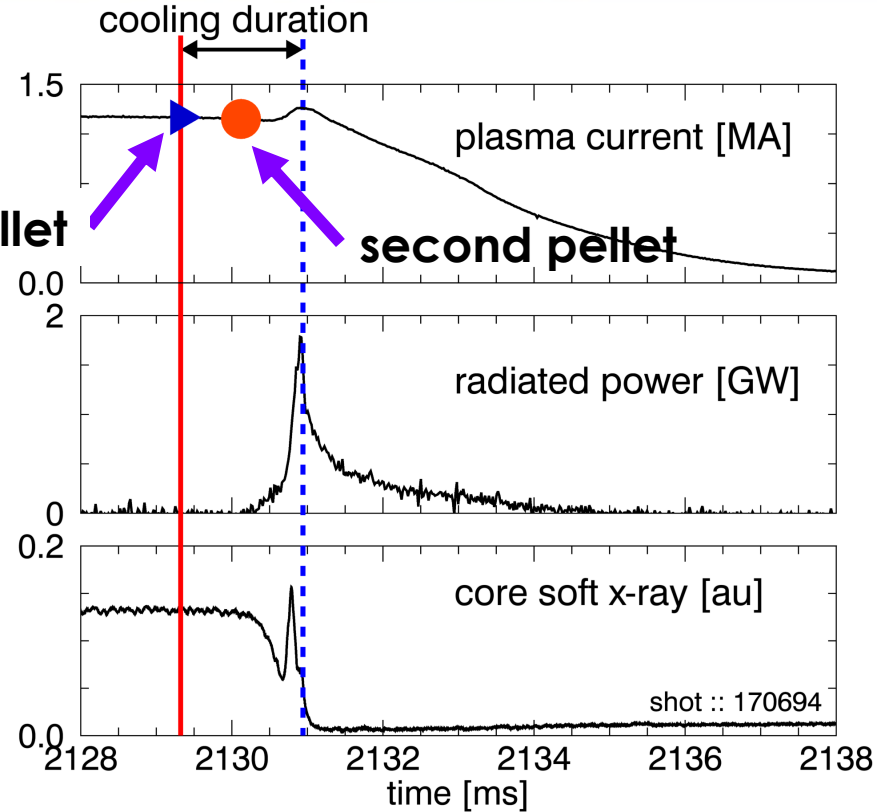
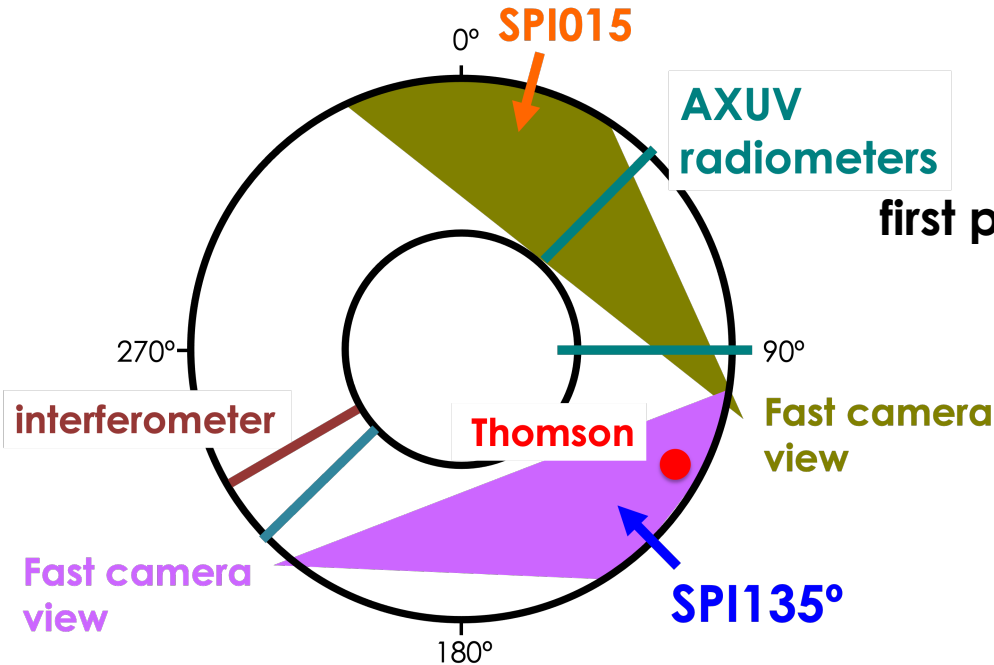


Summary

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- No change in cooling duration
- Similar CQ duration observed
- Thomson electron density measurements illustrate the highly non-axisymmetric nature of SPI injection
- Initial interferometer n_e measurements increase corresponding to where the field lines intersect interferometer chords
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Two SPI systems allow injection from two toroidal locations

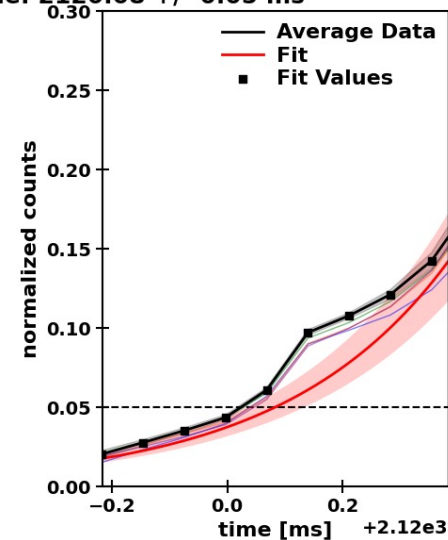
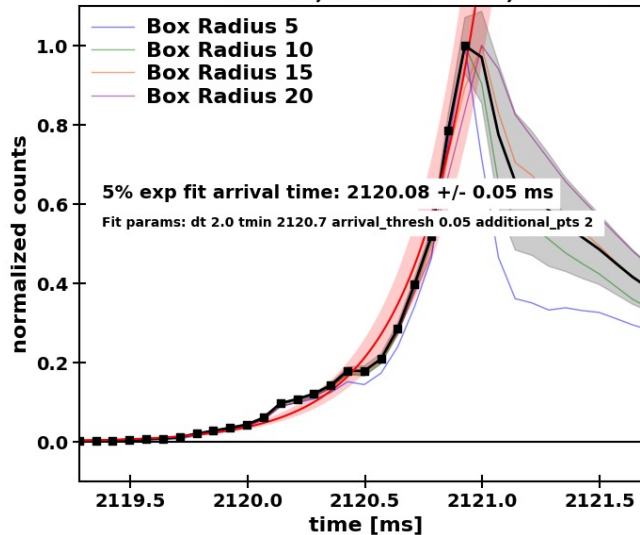
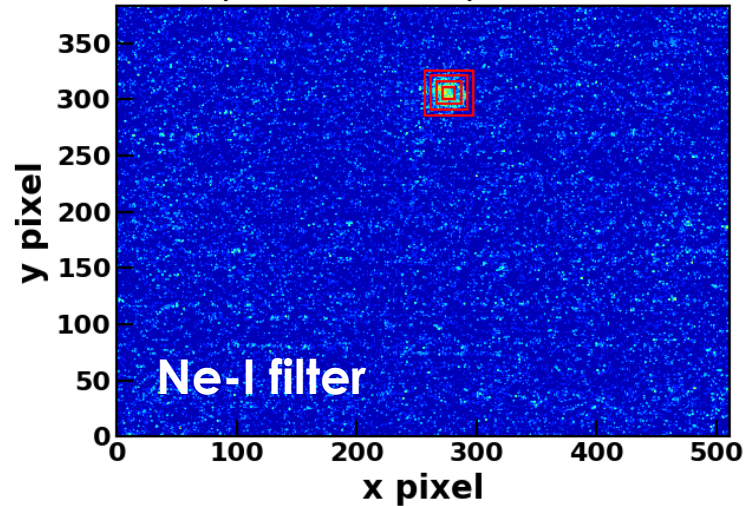


- Both pure Ne pellets, same speed
- Conducted in one day, same target plasma

Pellet arrival time found through analysis of photodiodes, fastcamera, and microwave cavity data

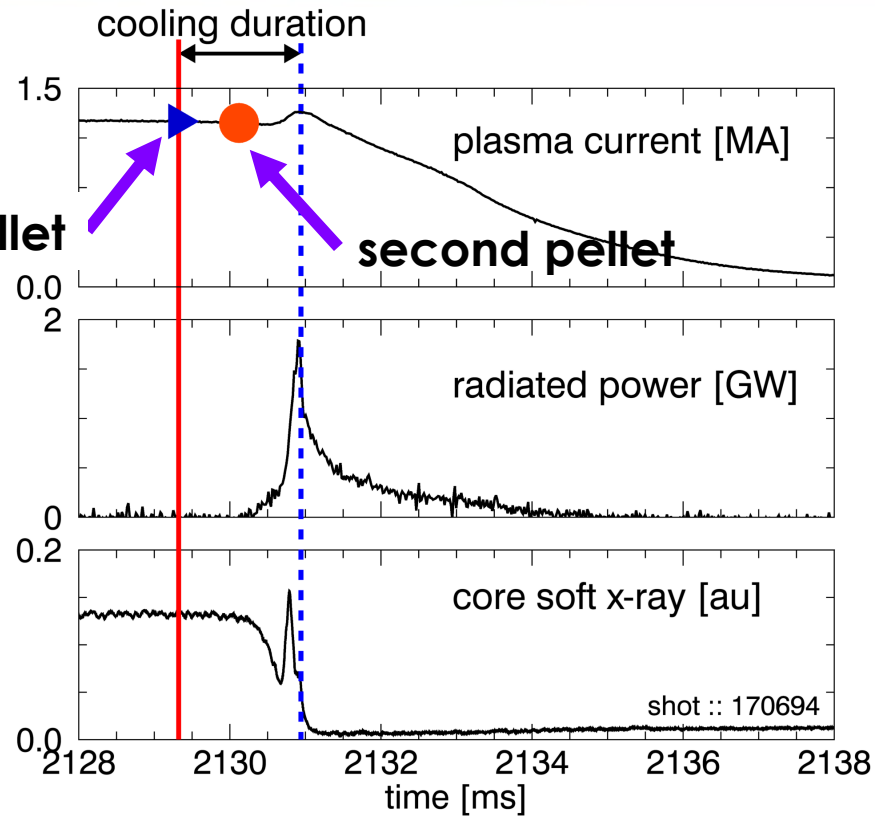
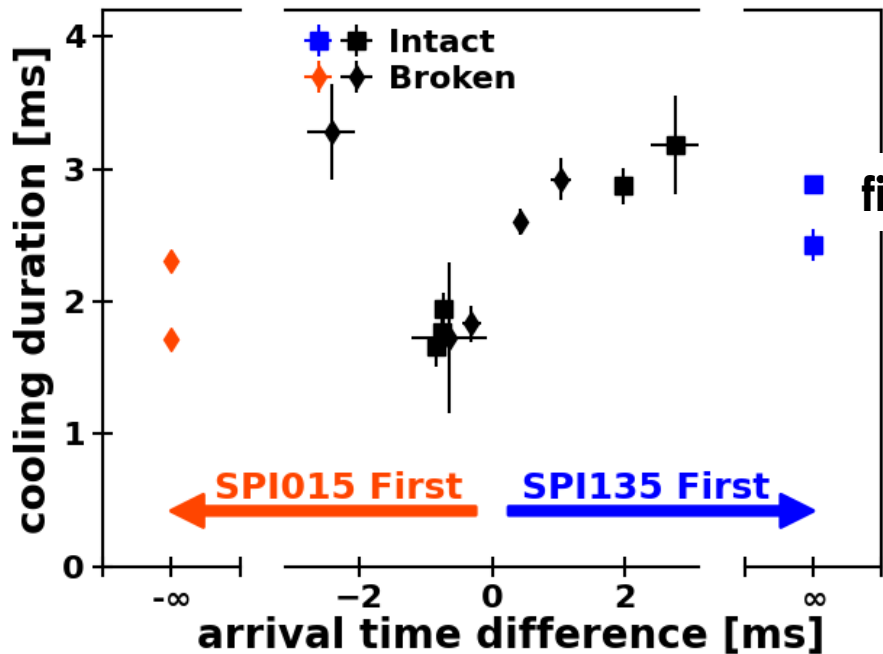
SPI135, shot: 184421, arrival time: 2120.08 +/- 0.05 ms

SPI135, Shot: 184415, t = 2122.53 ms



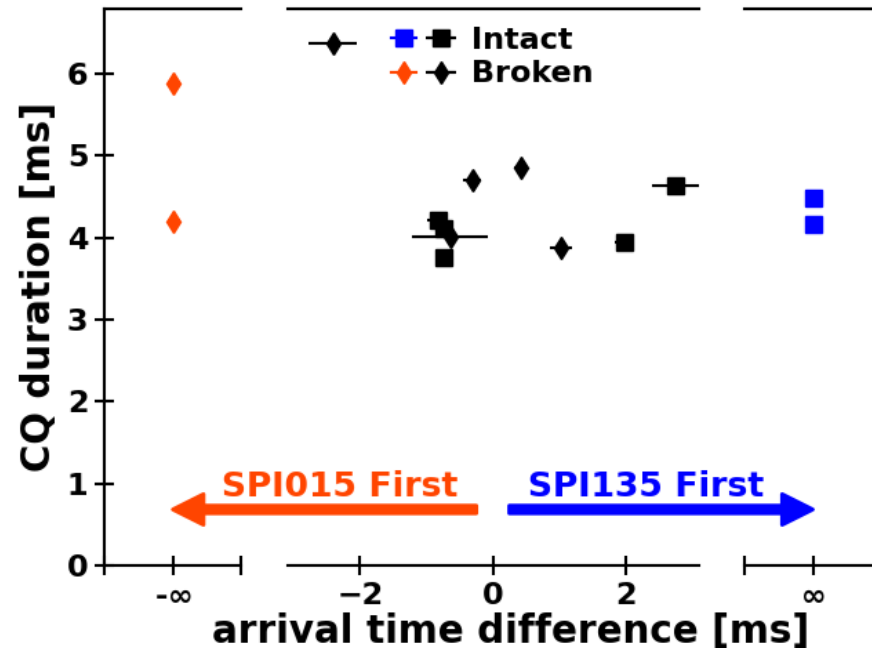
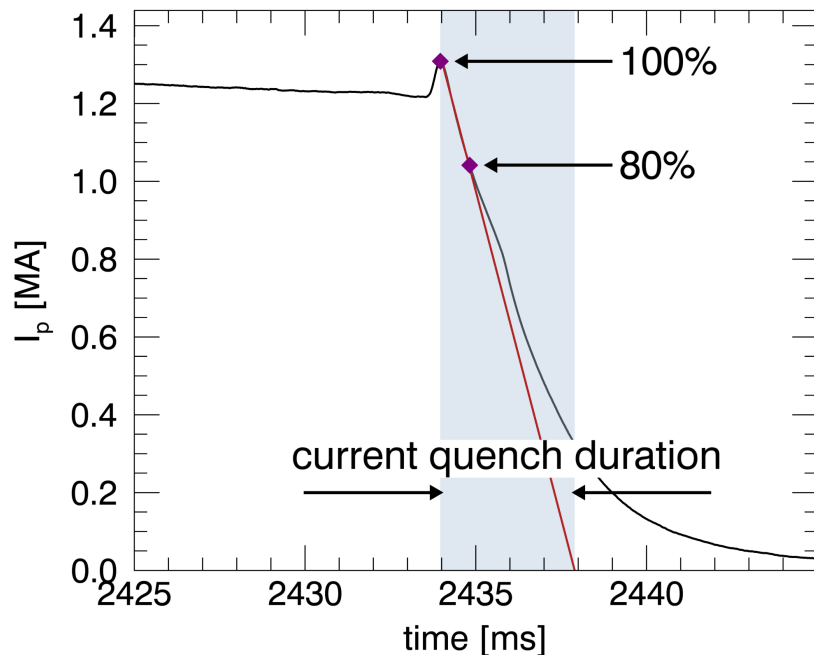
- Summed counts from different 4 different box sizes are averaged together
- Exponential fit performed on the normalized average
 - $y = b * \exp(mx) \rightarrow \ln(y) = mx + \ln(b)$
- Arrival time determined when the fit is at 5% threshold
 - Systematic method also matches arrival time determined “by eye”

Cooling duration discrepancy between injectors but no clear decrease for dual pellets



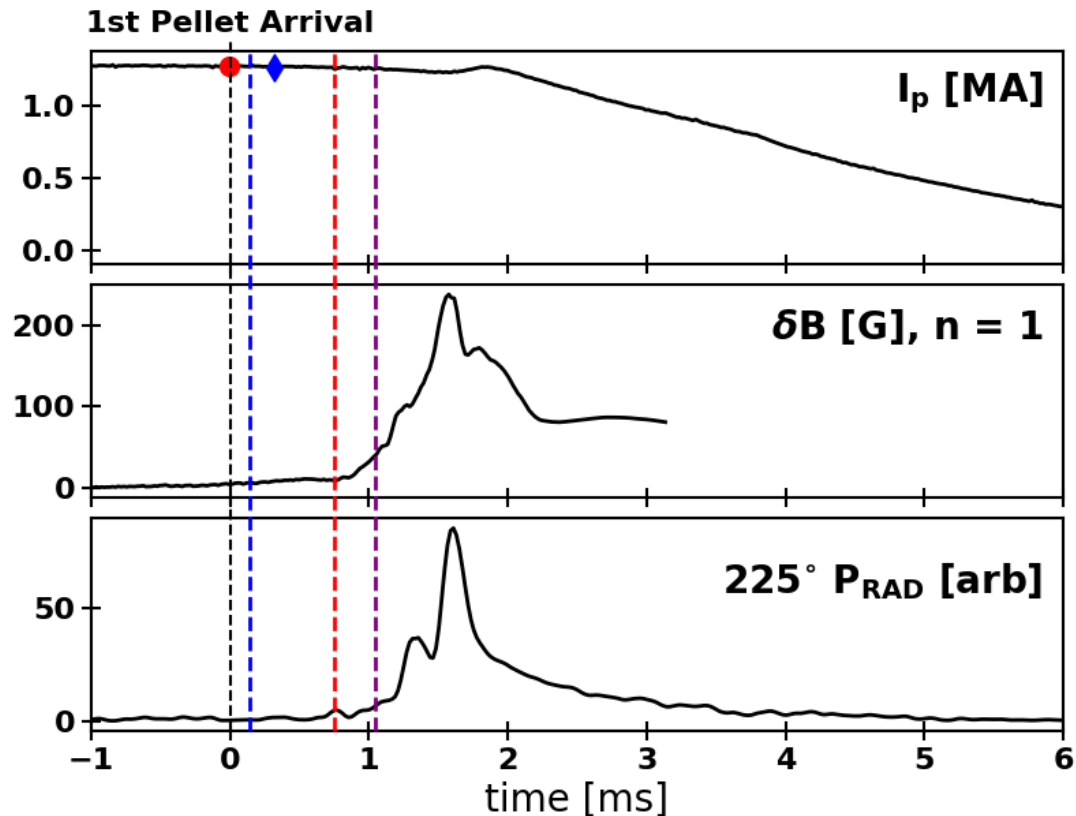
- This is still puzzling to me; it is small but measurable

Similar CQ duration suggest plasma cooled similarly between single and simultaneous injection

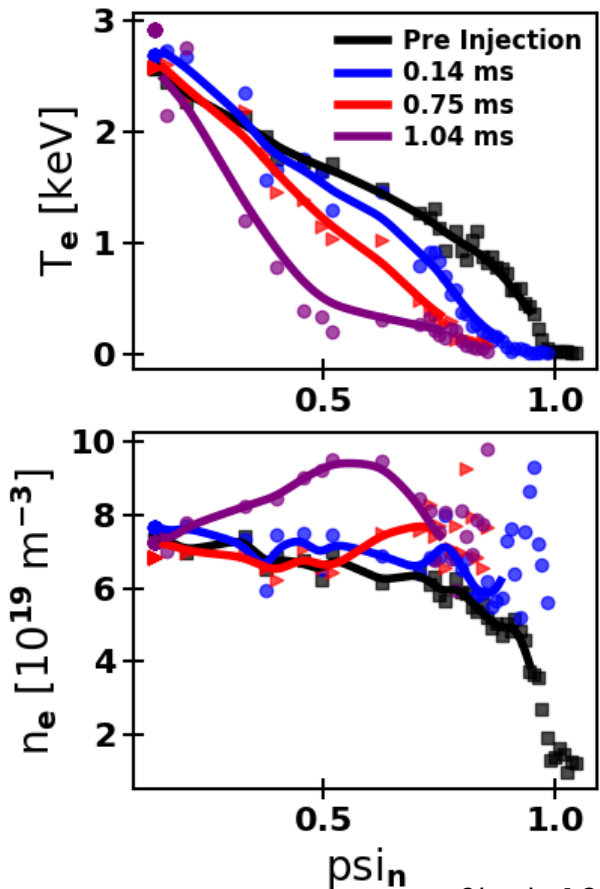


high rad → lower T_e → higher η → shorter CQ

Thomson captures a dual SPI shutdown

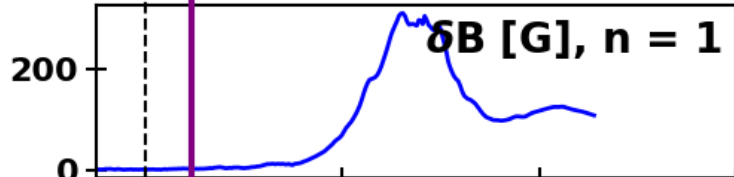
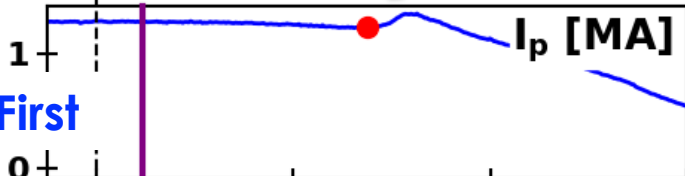
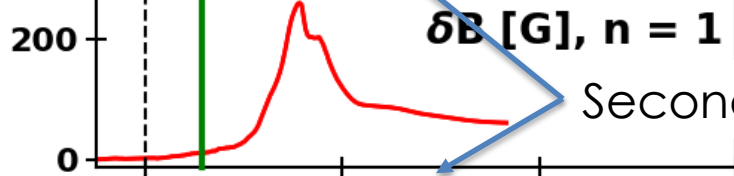
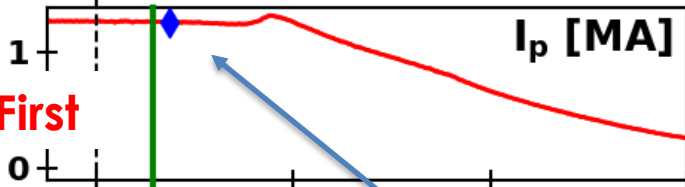


- SPI015 broken, $dt = -0.3$ ms

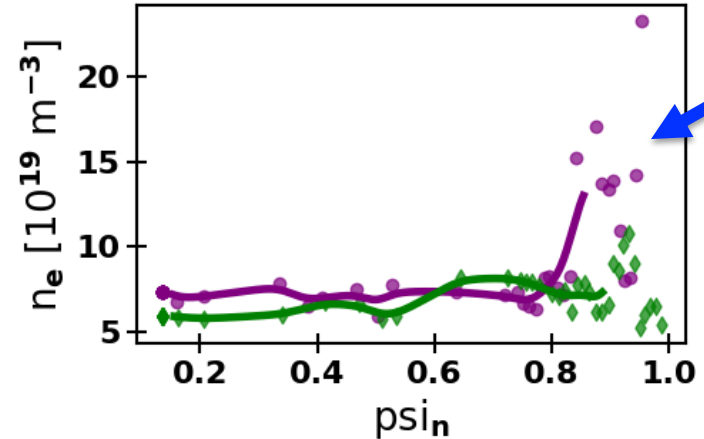
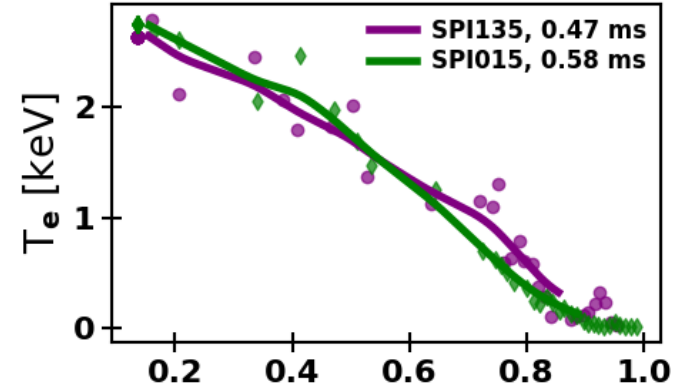


Greater edge density spike observed in Thomson for SPI135 first compared to SPI015 first mitigations – Why?

1st Pellet Arrival

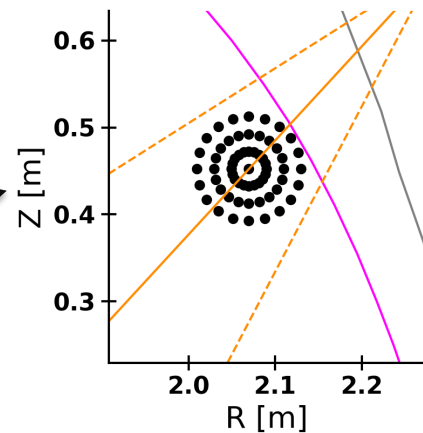
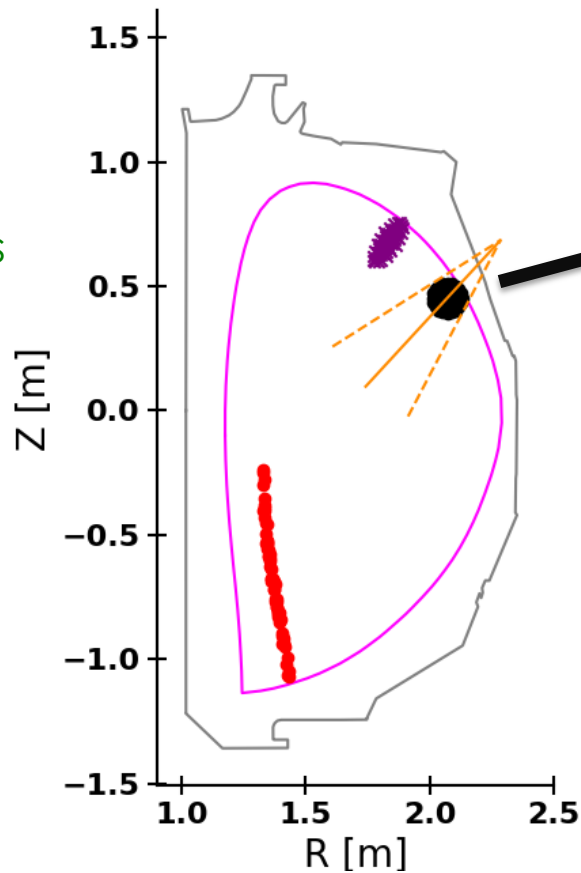
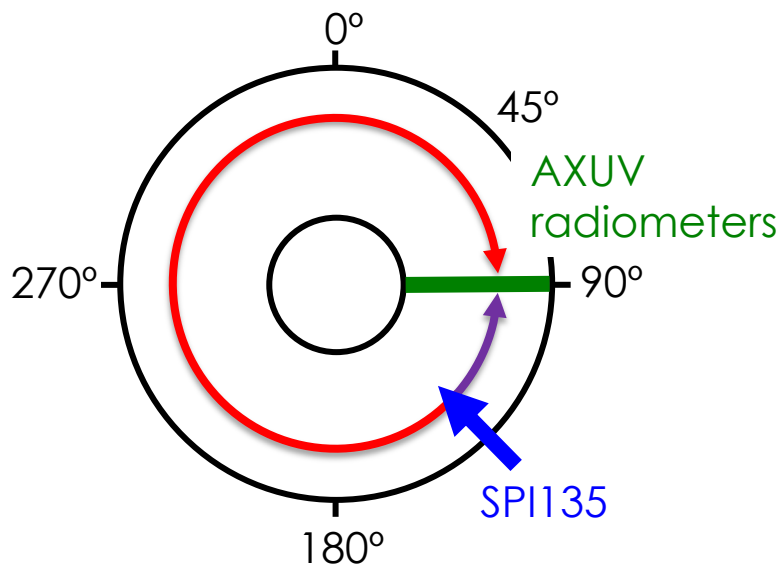


time [ms]

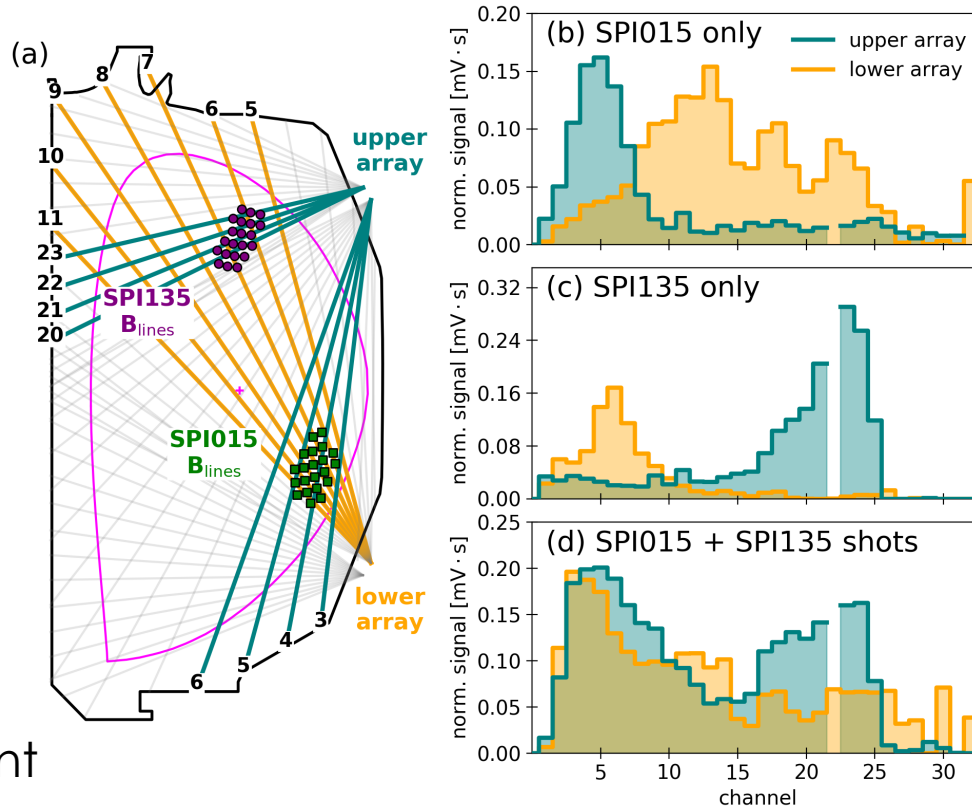


Shots: 184414 (SPI135), 184421 (SPI015)

Field line trajectory computed from each SPI injection point

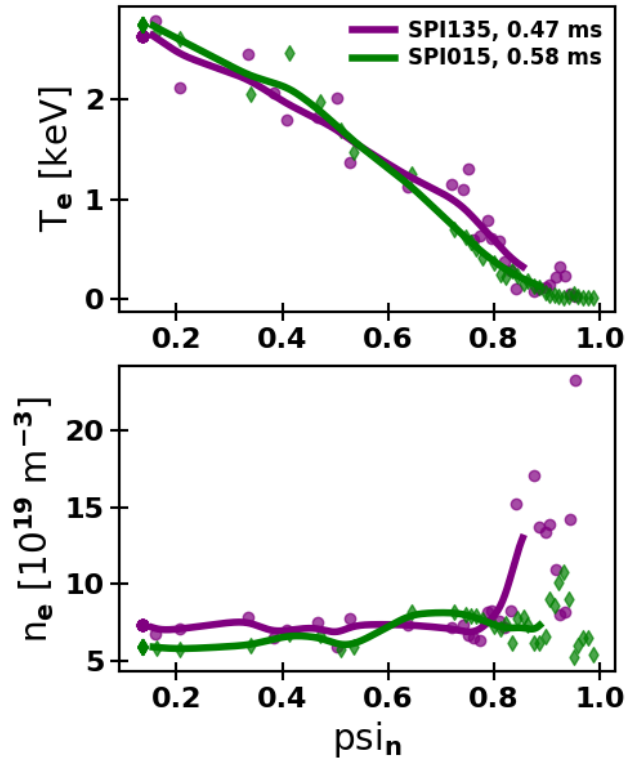
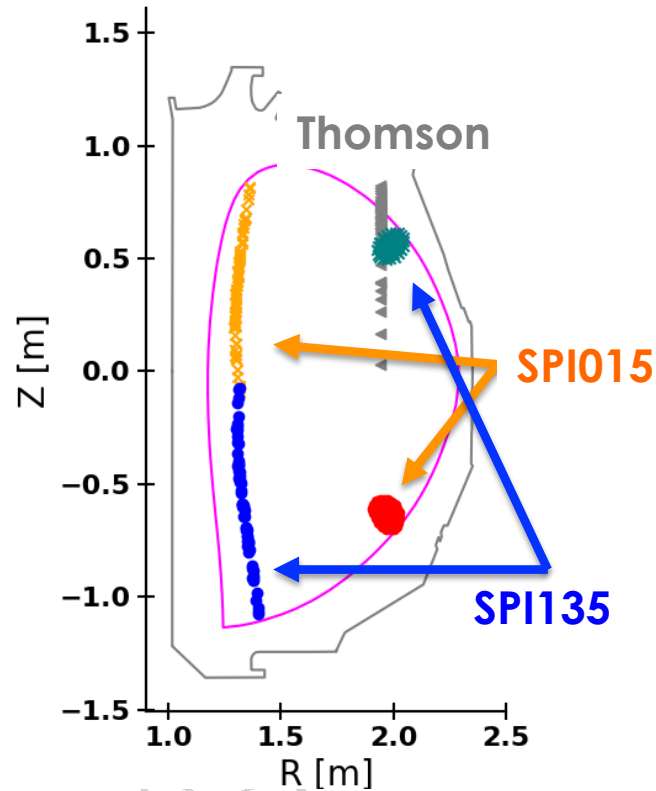


Injected impurities initially follow field lines near injection location



Previous experiment

Discrepancy most likely due to diagnostic location



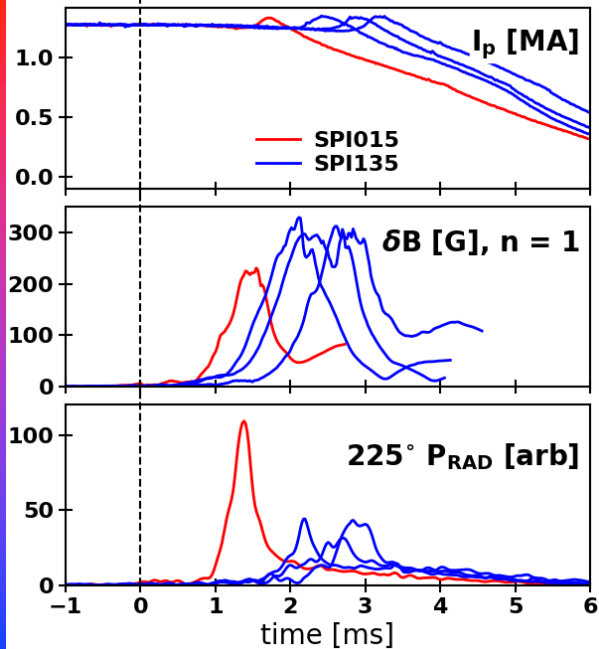
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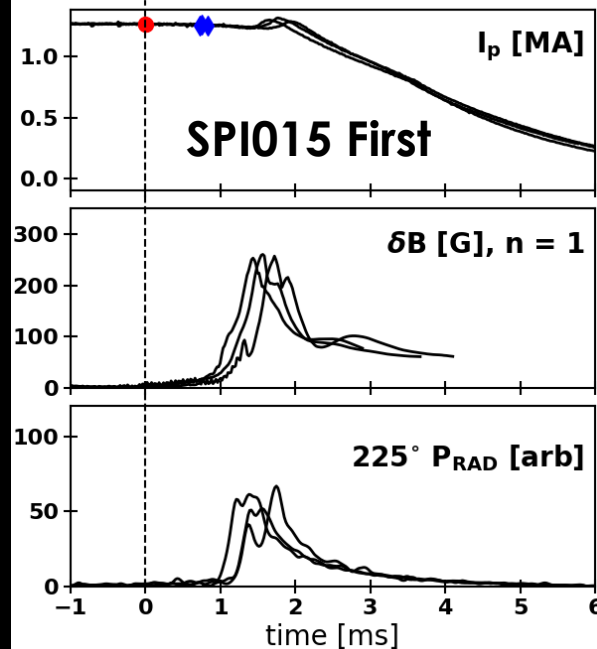
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Four types of shots used to compare effects of dual pellet injection

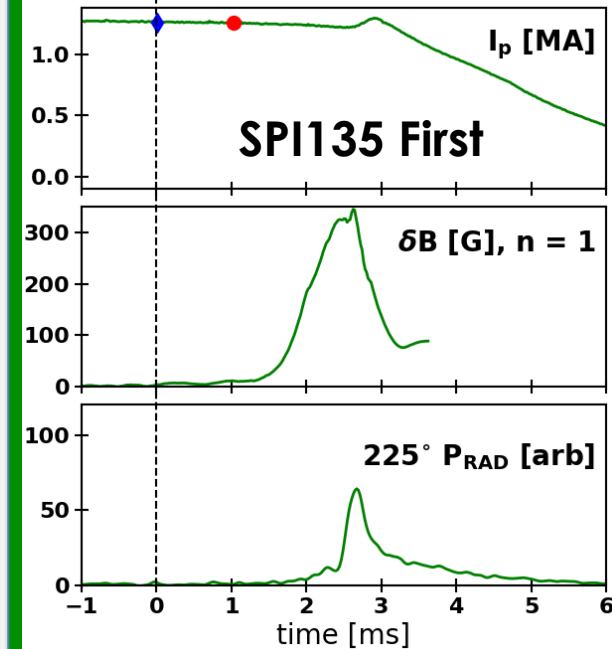
1st Pellet Arrival



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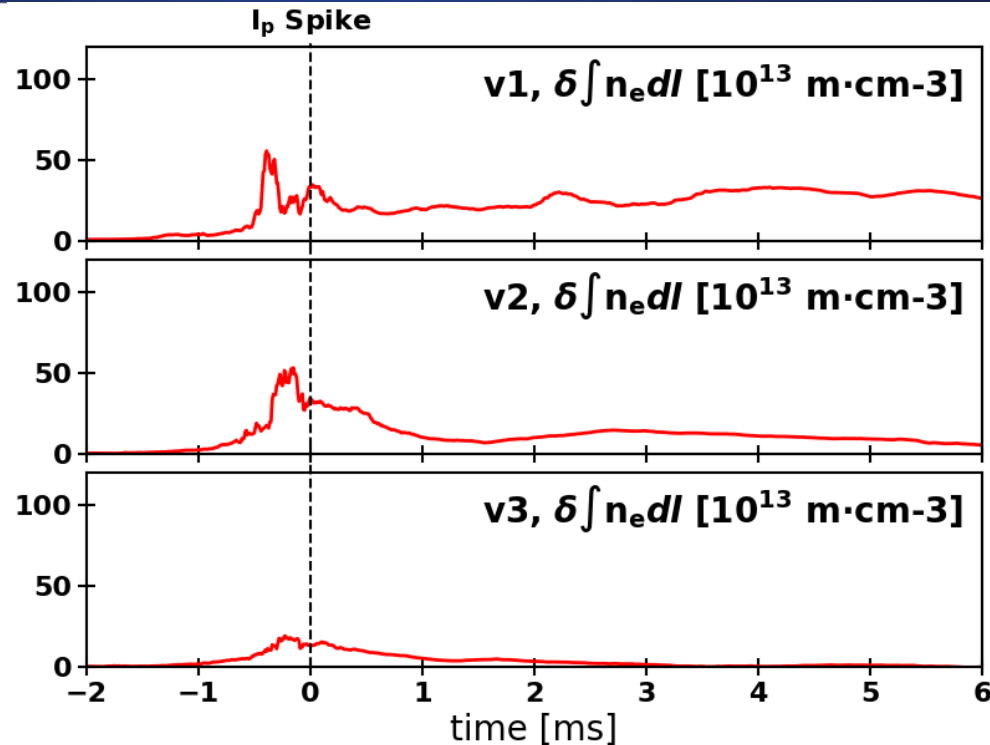
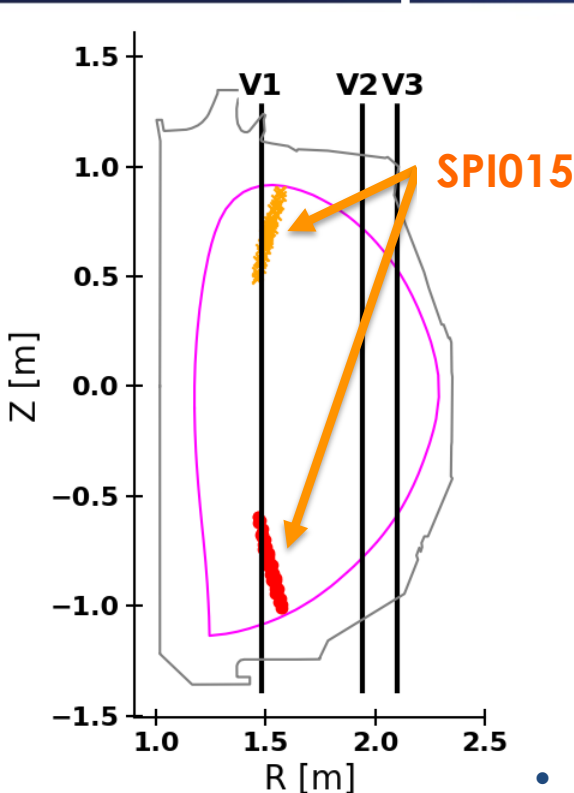


- **SPI015 broken**

- **SPI135 arrives: 62%, 57, 50% through CD**
- **Both good pellets**

- **SPI015 arrives: 65% through CD**
- **SPI015 Broken**

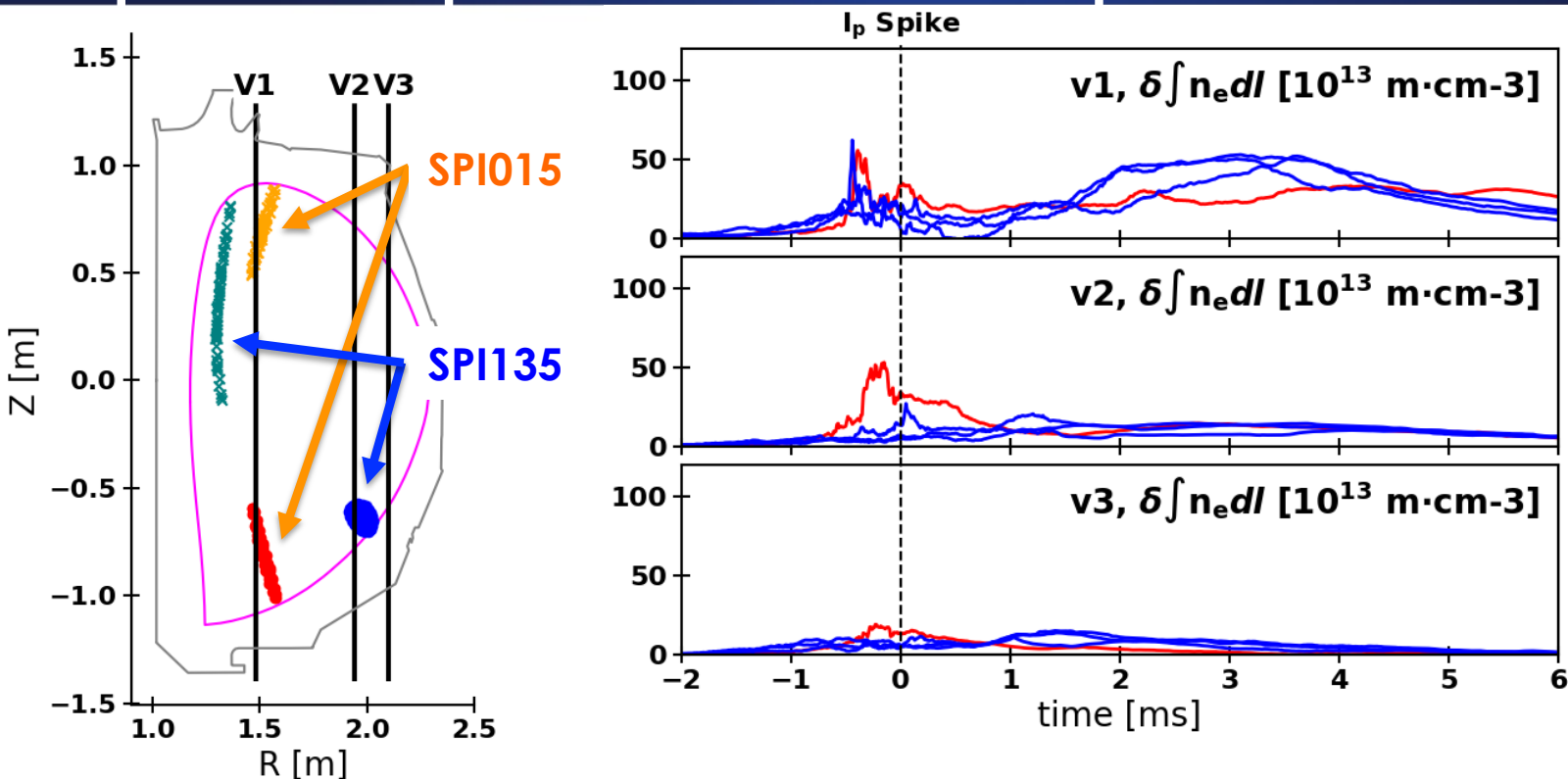
Interferometer shows a slight increase in V1 prior to TQ end compared to other chords



SPI015
only

- Early increase in the chord that intersects injection field lines
- SPI015 is a broken, half-size pellet

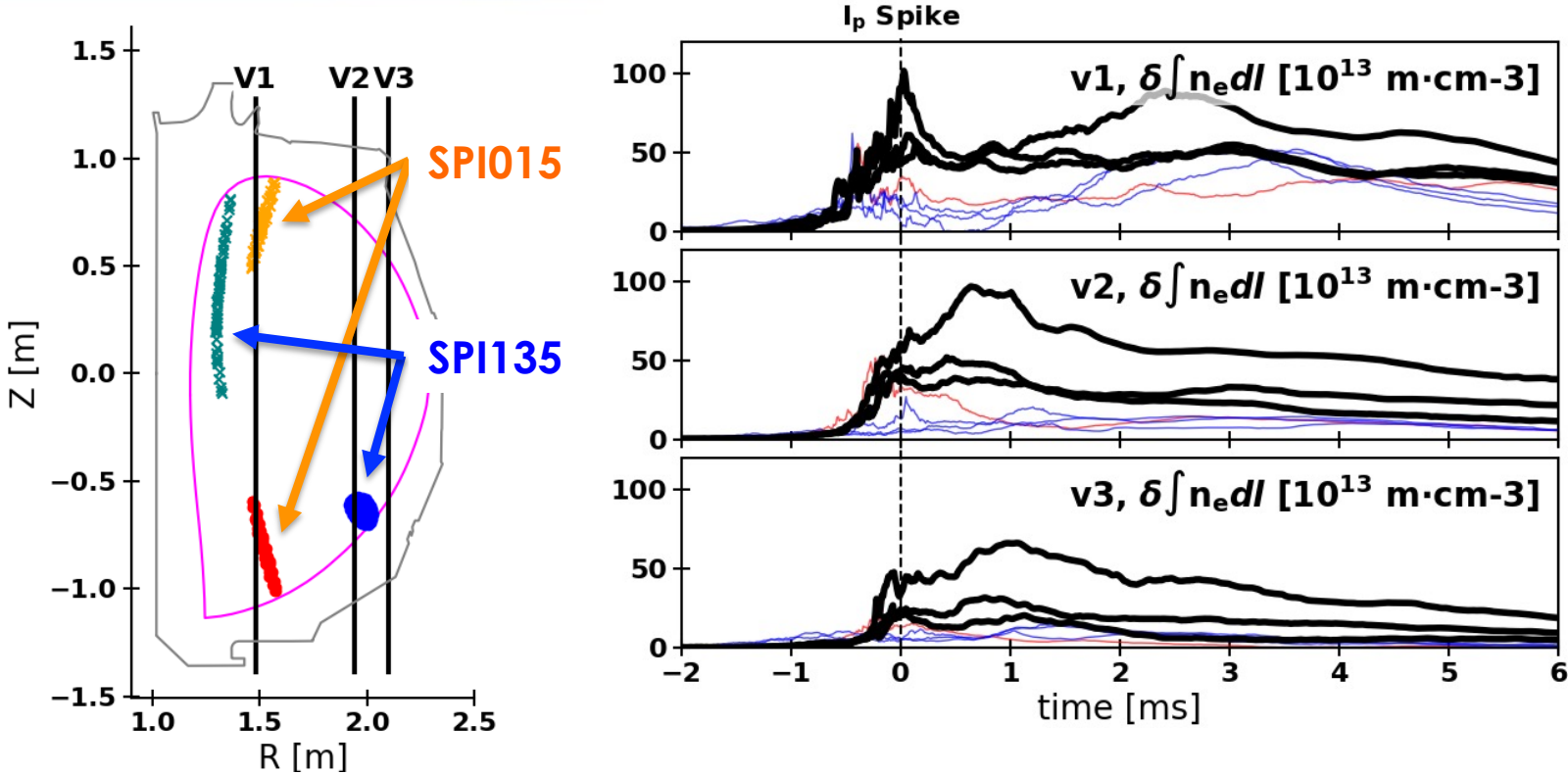
Similar density increases between a half-size SPI015 pellet compared to a full SPI135 pellet



SPI015
only

SPI135
only

Dual good pellets show a significant increase in electron density

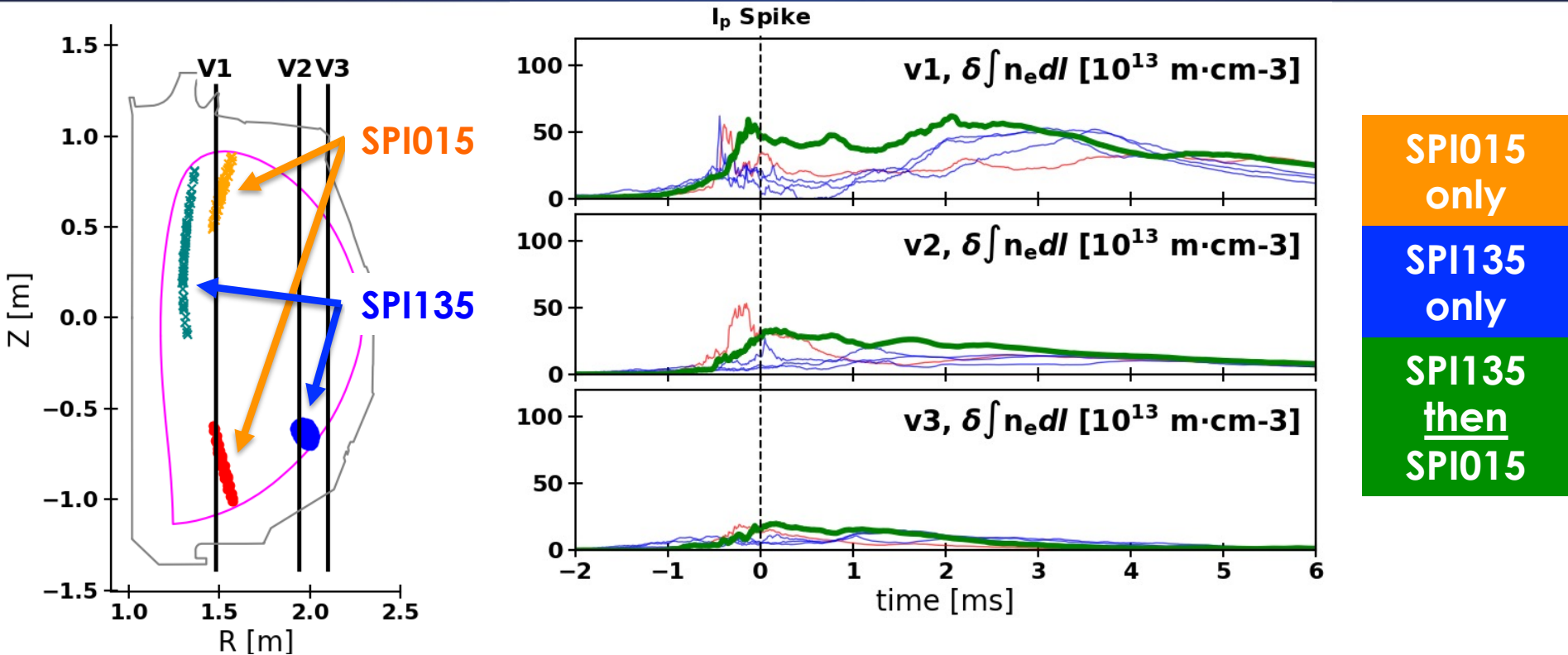


**SPI015
only**

**SPI135
only**

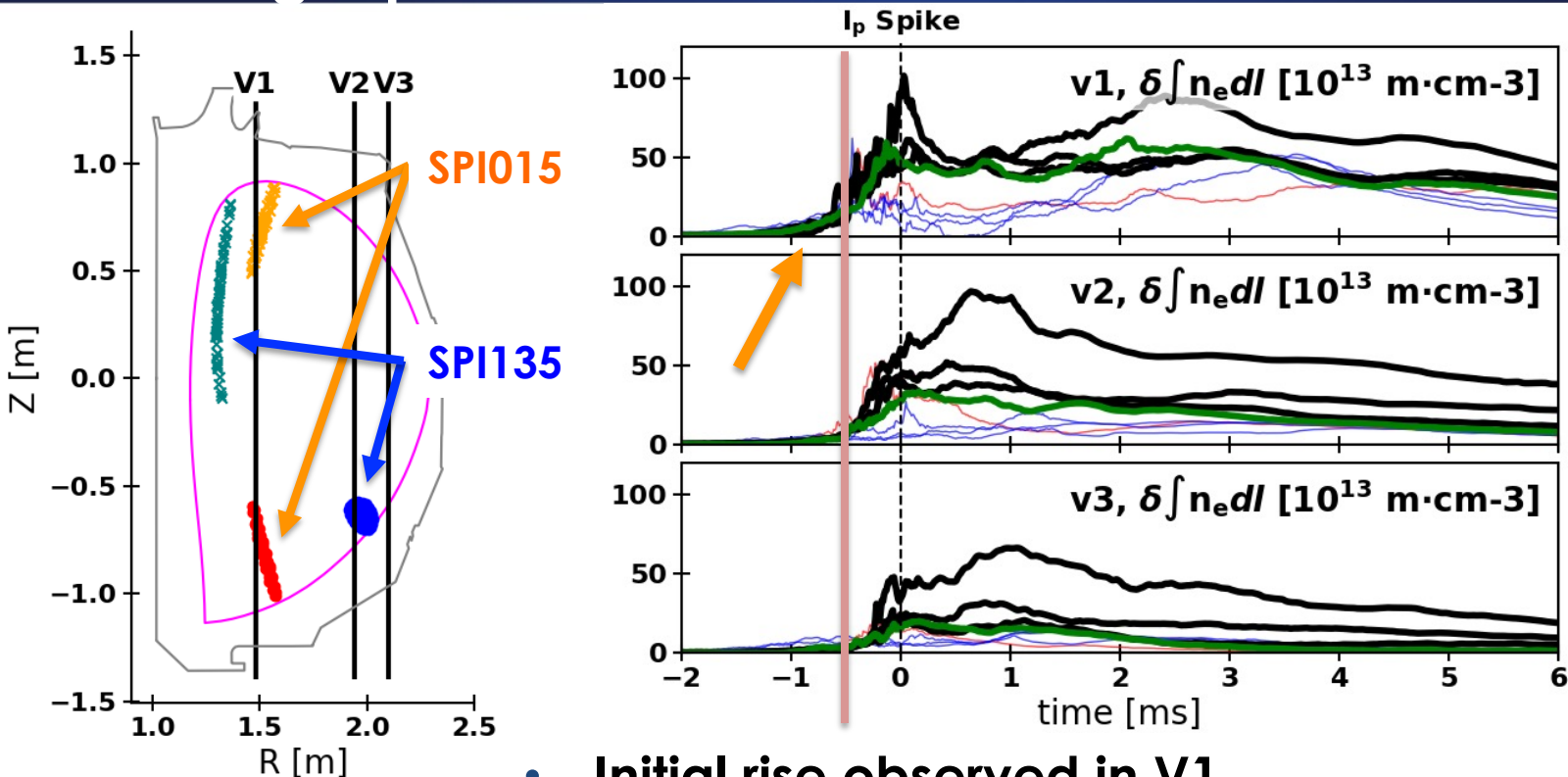
**SPI015
then
SPI135**

Similar density increases for dual pellets if SPI135 arrives first



- SPI015 is a broken, half-size pellet

Dual pellets result in a ~3x density increase compared to single pure Ne SPI



SPI015
then
SPI135

SPI135
then
SPI015

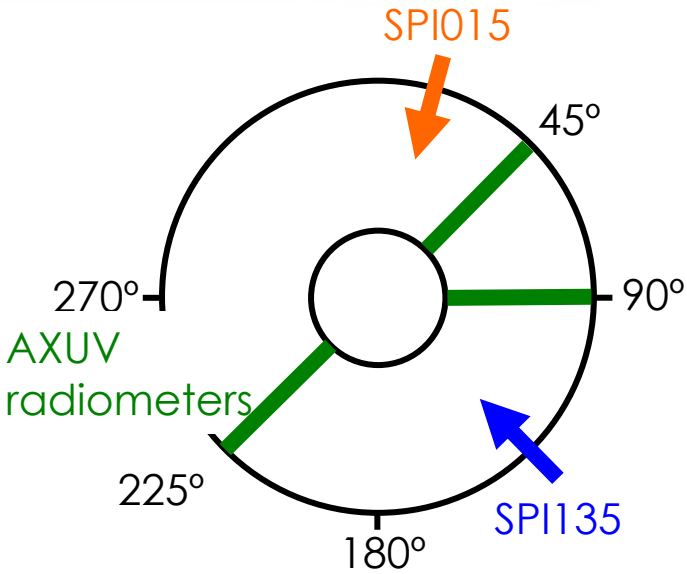
- Initial rise observed in V1

Summary

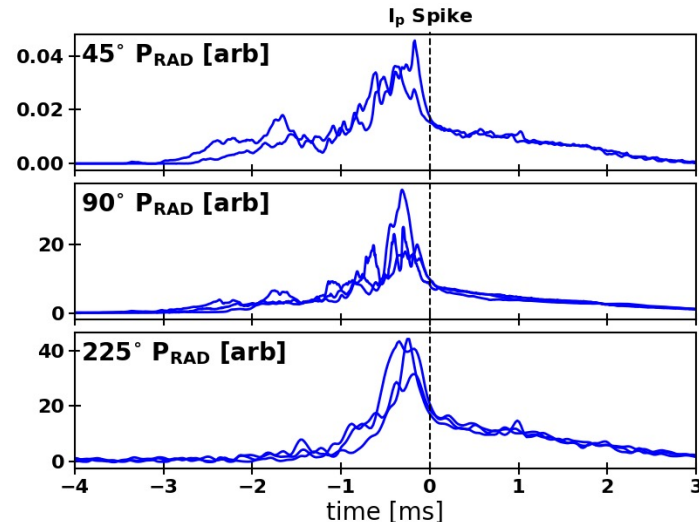
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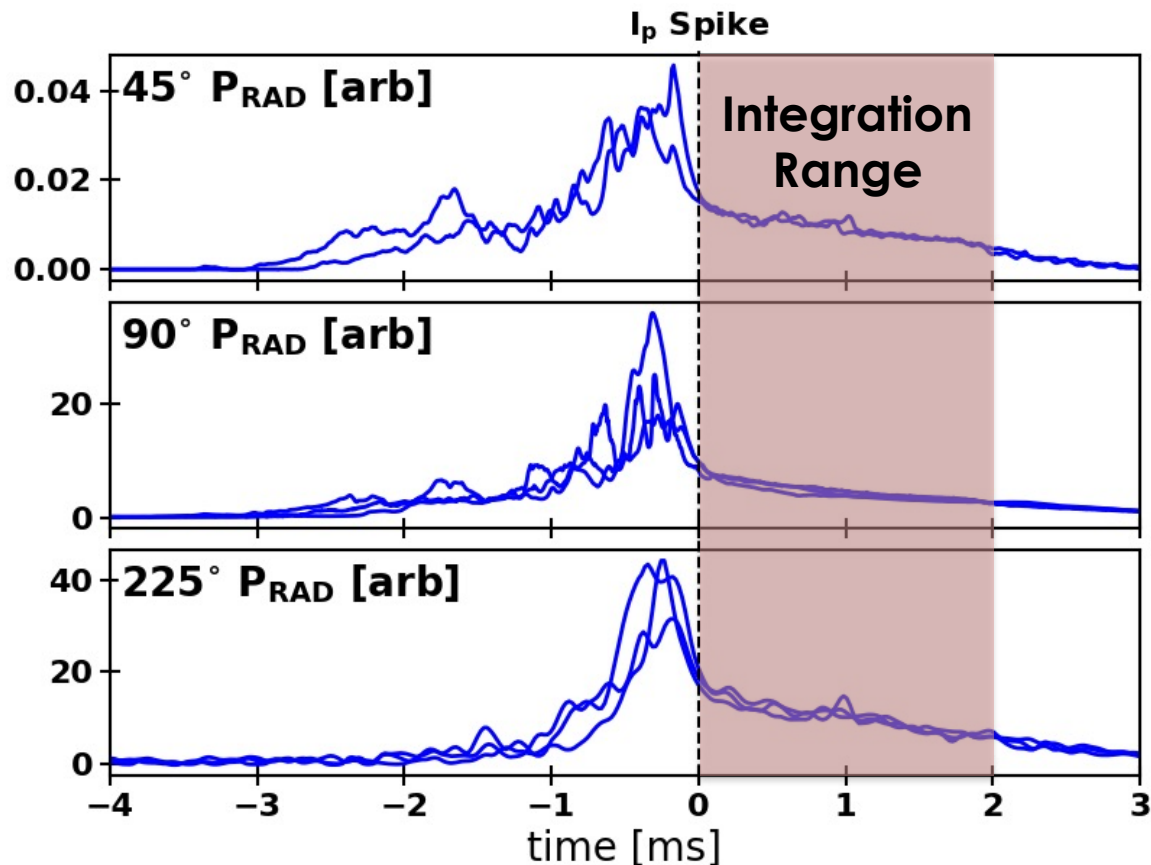
DIII-D has 4 radiometers fan arrays used to find total radiated power at each toroidal location



- Radiated power is reconstructed from the inversion of AXUV diode array measurements assuming most of the emission is near the separatrix (the 'mantle' model)¹



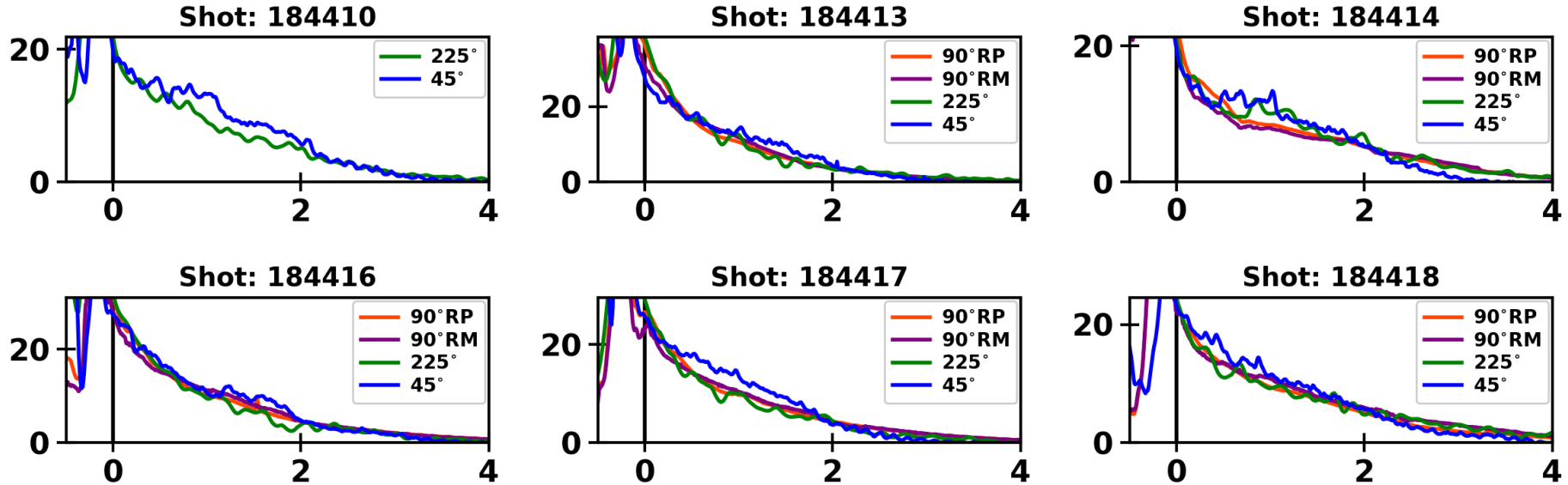
Scaling factors found between each array for each shot in order to compare radiated energy at each location



- Integrated power ratios are computed for each shot then averaged to find a scaling factor

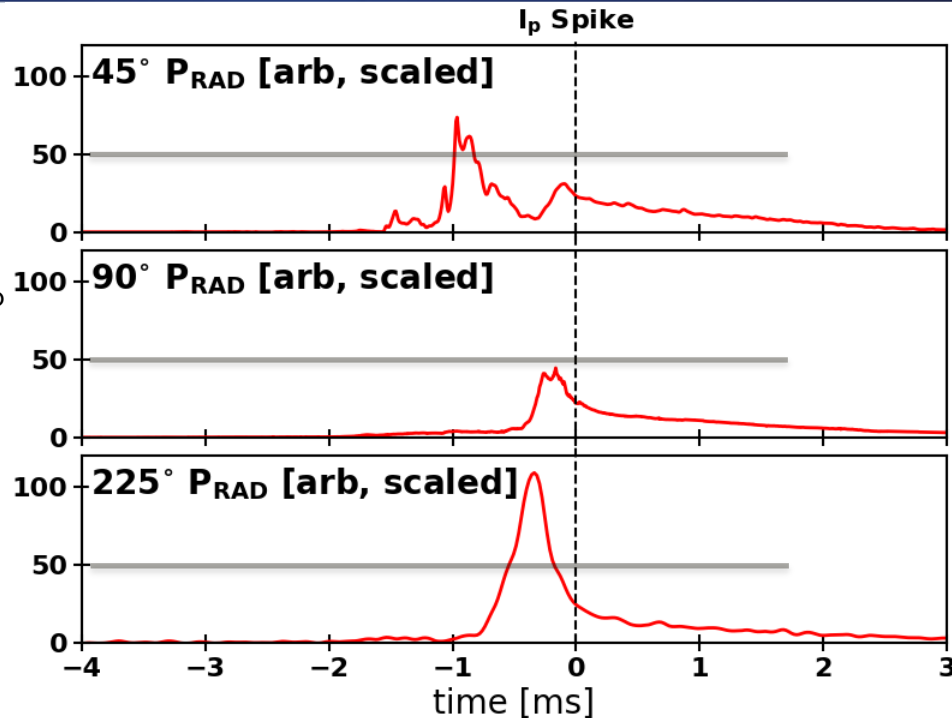
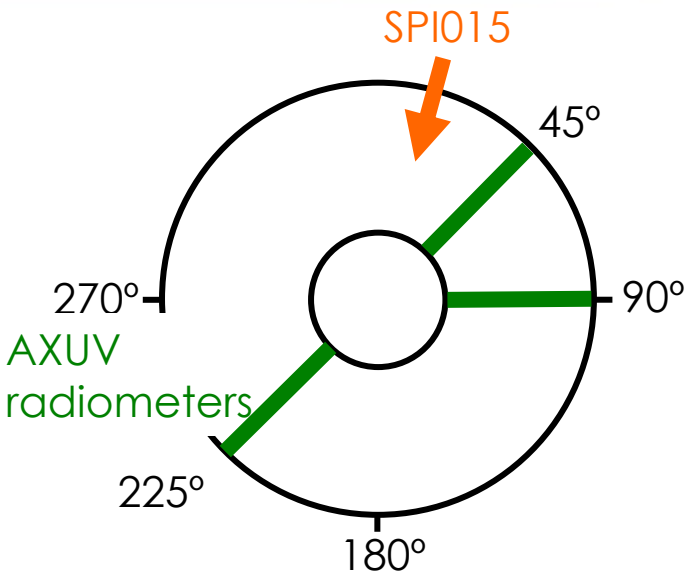
$$s_{45} = \frac{\int_0^2 P_{\text{RAD},45} dt}{\int_0^2 P_{\text{RAD},225} dt}$$

Toroidally symmetric assumption appears to be a great one for DIII-D mitigated disruptions



- These shots consist of a variety of SPI135 only, SPI015 only, and dual pellets
- Now we can directly compare peak powers and total energy between radiometers for this runday

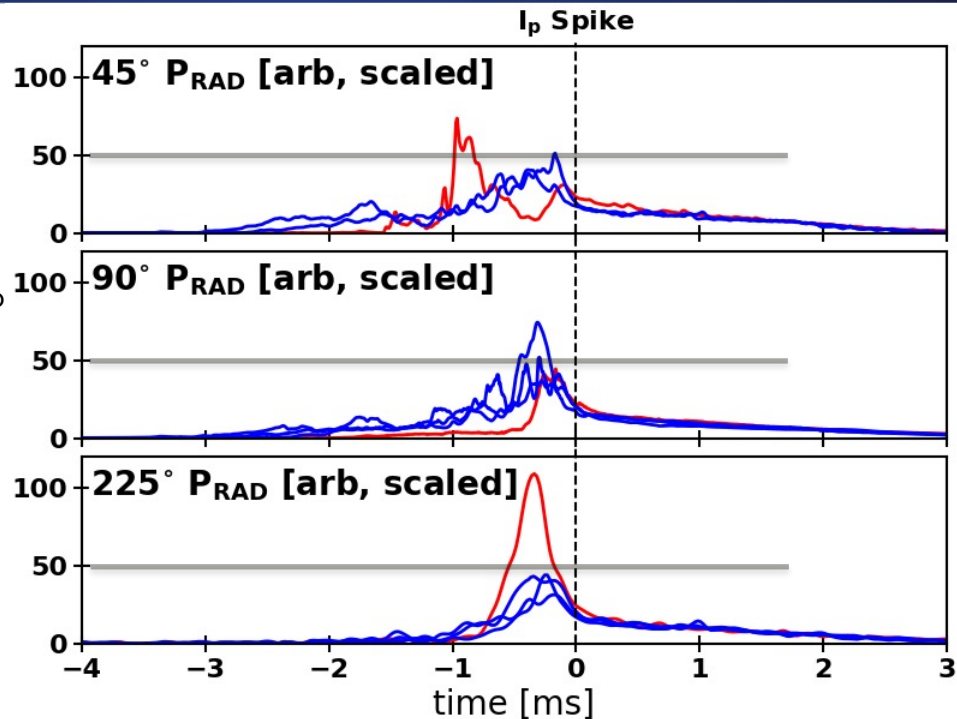
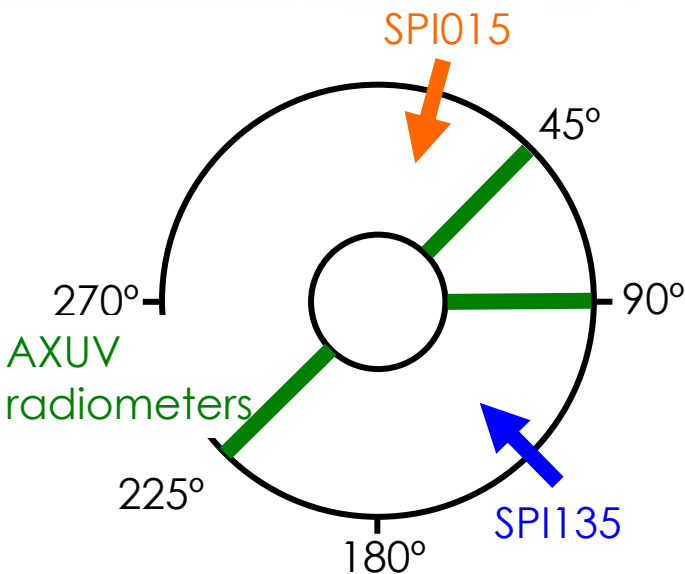
Initial rise at 45° followed by a large spike at 225° with minimal radiation at 90° observed for SPI015



SPI015
only

- This was a broken pellet

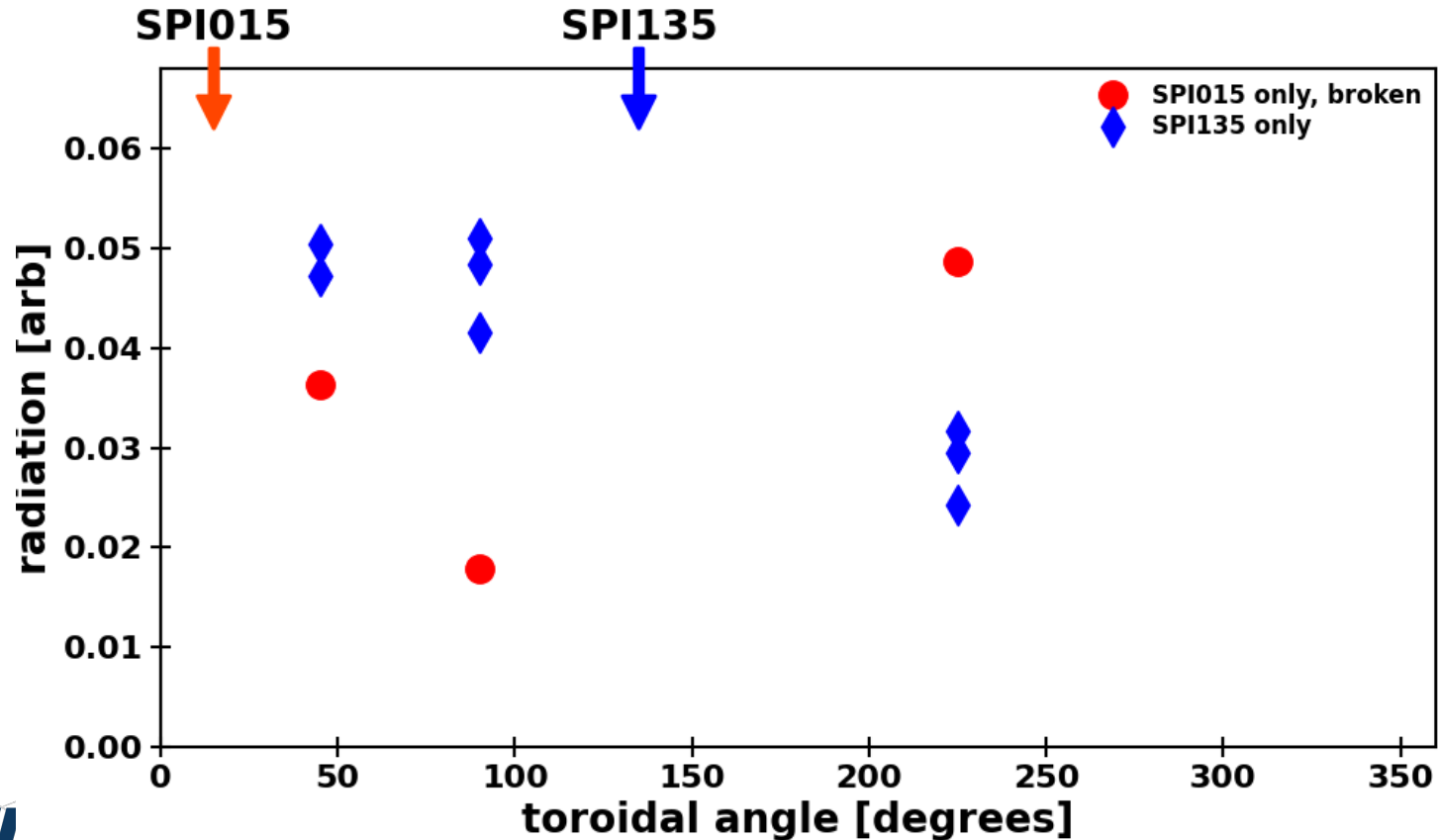
Radiated power increases similarly at 45° and 90° ending with similar peak radiation at all three locations



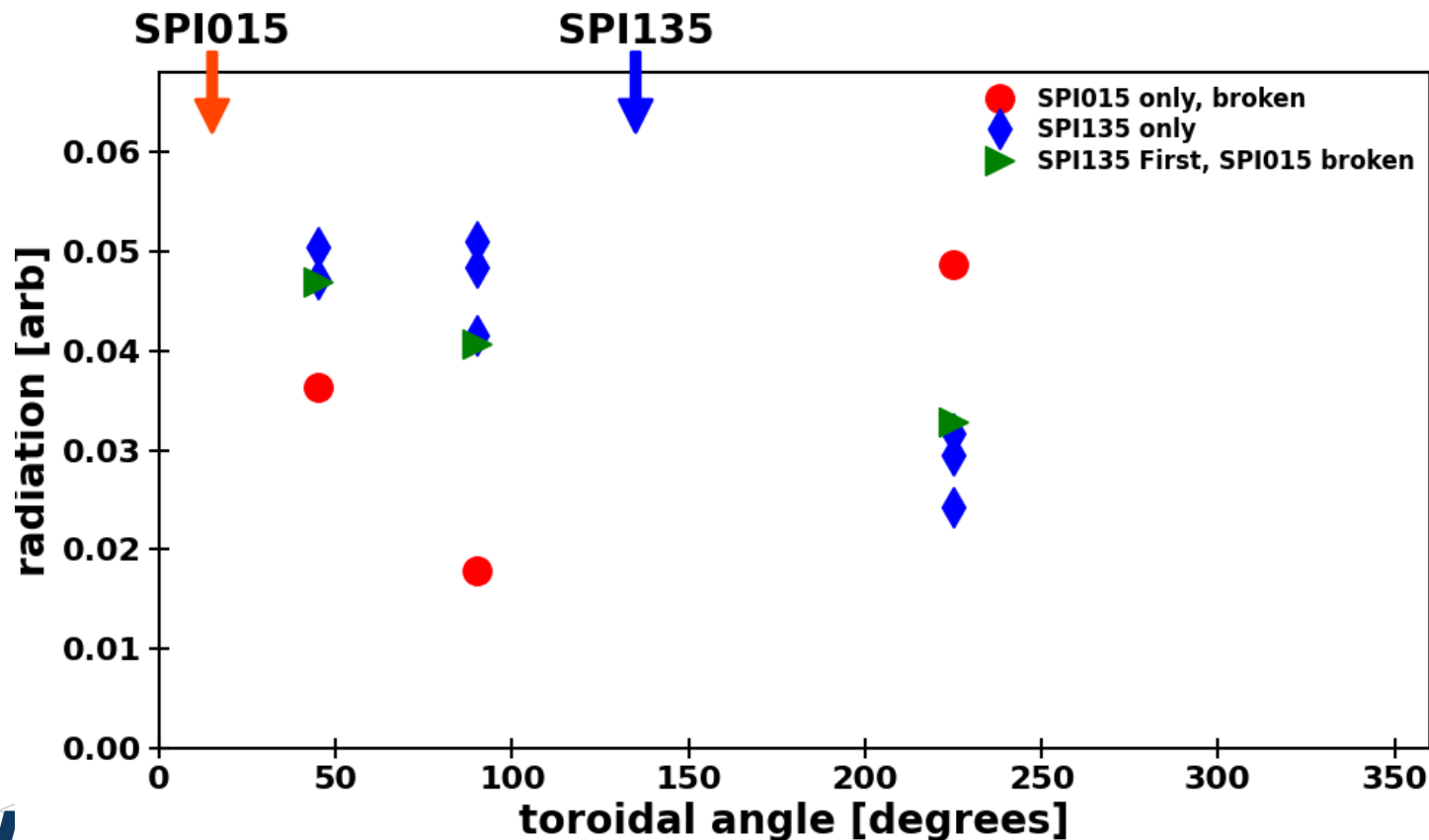
SPI015
only

SPI135
only

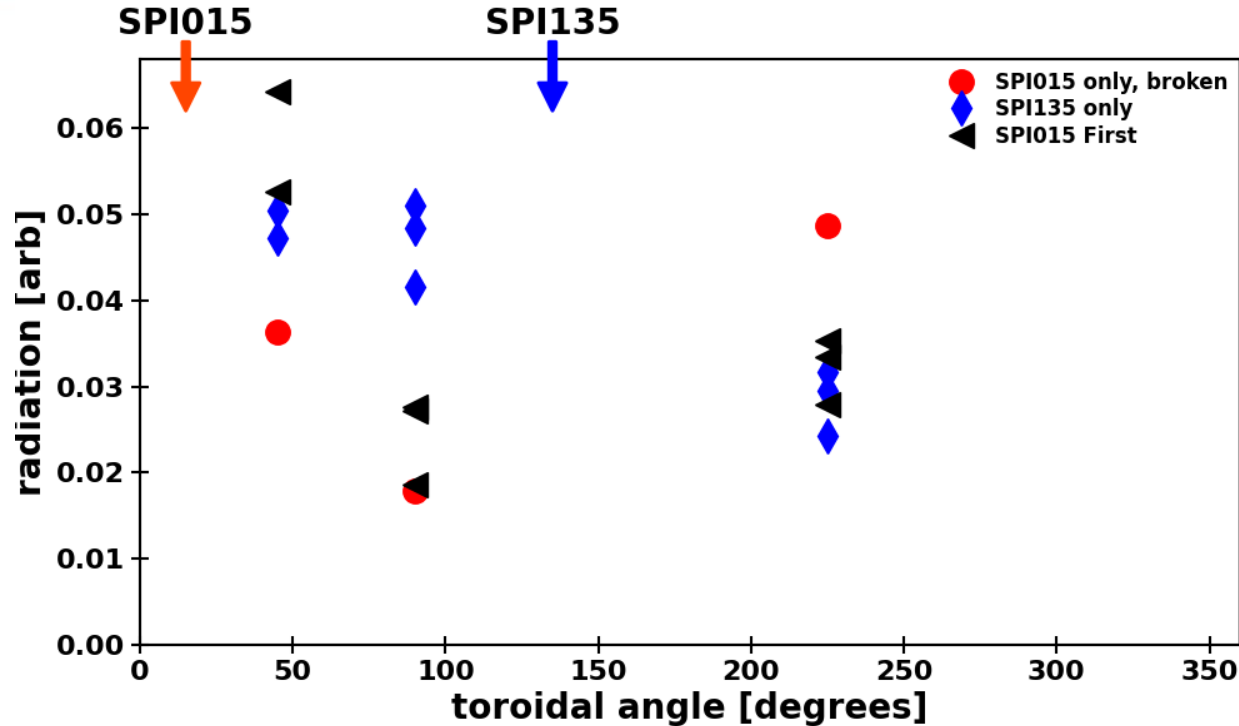
Radiated energy peaks in the counter-clockwise direction from the injection port



Radiated energy profile for SPI135 first discharges is similar to SPI135 only mitigations



SPI015 first may not show a decrease in toroidal peaking



- These are the only dual pellet cases where both pellets are intact

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