Initial Experimental Measurements of Beam Ion Confinement

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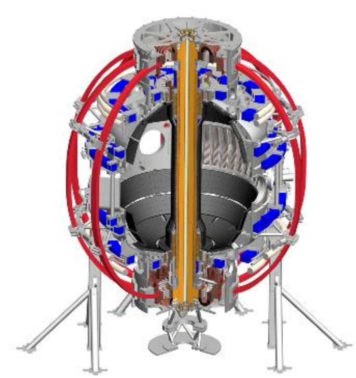


Beam Ion Confinement is Initially Assessed in XMP 110 (FIDA/SSNPA Checkout)

- XMP 110 was partially completed, XP1522 (beam ion confinement) was not performed due to NB 1A and MSE unavailability.

Plasma conditions

- Center-stack limited L-mode plasma, B_t=0.65T, I_p~0.7MA, NB 1B, 1C, 2A, 2C
- Neutron rate dominated by beam-plasma reactions

Beam blips (~20ms pulses)

- E_{inj}=65keV (March 30) and E_{inj}=85keV (June 28)
- Rise depends on number of confined beam ions injected $\propto \frac{dn_f}{dt} n_i < \sigma v >$
- Decay depends on slowing down & losses on $t_{slowing\text{-}down} \propto T_e^{3/2} / n_e$

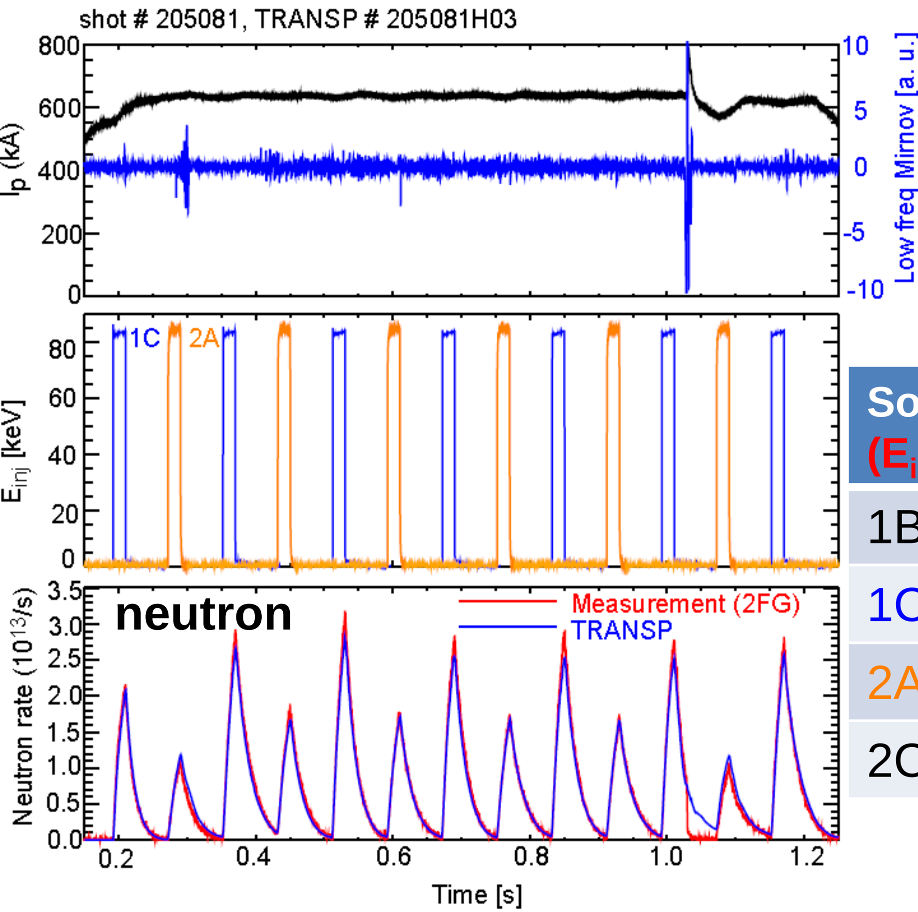
measure neutron rise & decay and compare with TRANSP prediction

Relatively long (100ms, >fast ion slowing-down time) pulses

- E_{inj}=65keV (April 1)

Measure beam ion profile and compare with FIDAsim modelling

At E_{inj}=85keV, Neutron Rise and Decay Rate Agree with TRANSP Modelling

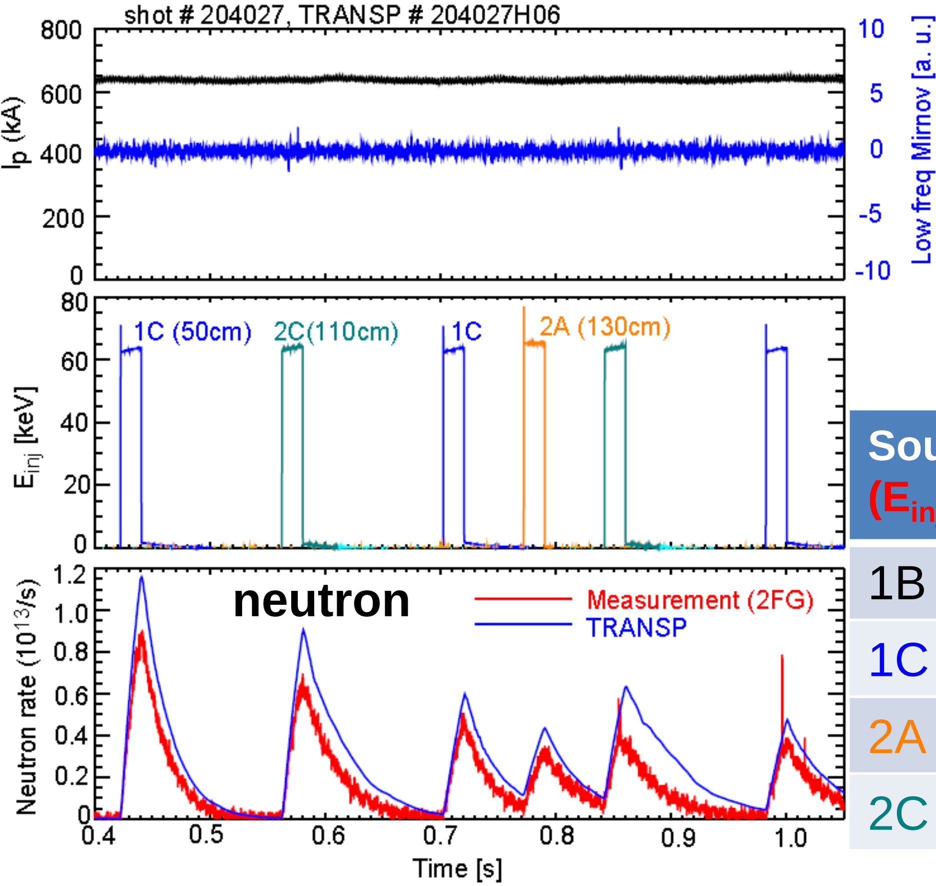


- Exclude bad blips with strong MHD
- TRANSP: Classical simulations (no ad hoc fast-ion diffusion), T_i=T_e, Z_{eff}=1.5, EFIT01
- 1C (R_{tan}=50cm), 2A R_{tan}=130cm

Source (E_{inj}=85keV)	Neutron Rise (Exp/TRANSP)	Neutron Decay (Exp/TRANSP)
1B (R_{tan} 60cm)	0.82 +/- 0.10	1.01 +/- 0.14
1C (R_{tan} 50cm)	1.05 +/- 0.07	1.05 +/- 0.13
2A (R_{tan} 130cm)	1.04 +/- 0.06	1.04 +/- 0.11
2C (R_{tan} 110cm)	0.83 +/- 0.09	0.94 +/- 0.17

For E_{inj}=85keV, beam Ions are well confined based on neutron decay

At E_{inj}=65keV, Relatively Large Discrepancy between Measurements and TRANSP Modeling



- TRANSP: Classical simulations, $T_i=T_e$, Z_{eff}=1.5, EFIT01
- Not much MHD
- Use "1de_zns" neutron signal cross calibrated to fission detector

Source (E_{inj}=65keV)	Neutron Rise (Exp/TRANSP)	Neutron Decay (Exp/TRANSP)
1B (R_{tan} 60cm)	0.48	1.01
1C (R_{tan} 50cm)	0.52 +/- 0.02	0.84 + /- 0.27
2A (R_{tan} 130cm)	0.47 +/- 0.02	0.94 +/- 0.04
2C (R_{tan} 110cm)	0.49 +/- 0.02	0.77 +/- 0.09

- **Large discrepancy in neutron rise, depends on absolute neutron rate**
- **~20% discrepancy in neutron decay**

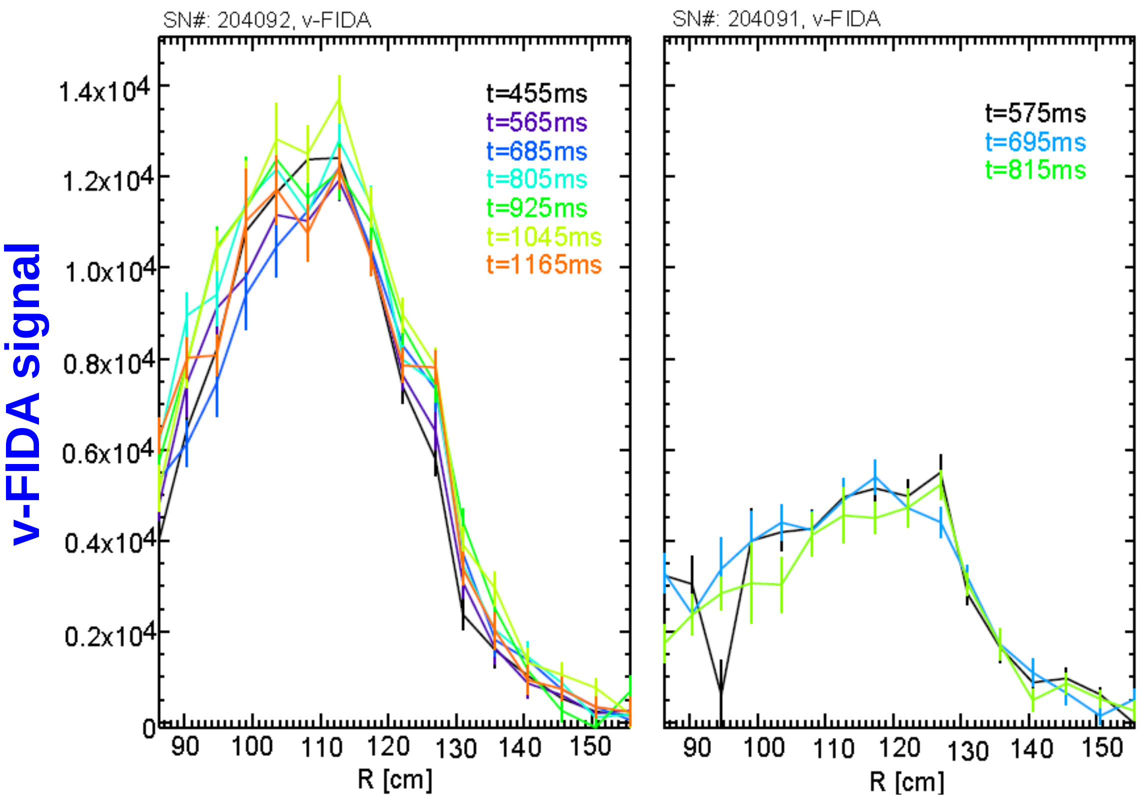
Possible Reason for Discrepancies for Neutron Rise and Decay for E_{inj}=65keV Case

- Reasons for Rise discrepancy $rise \propto \frac{dn_f}{dt} n_i < \sigma v >$
  - Z_{eff}: currently assuming z_{eff} =1.5, need to increase z_{eff}
  - Beam species mix (especially full energy component) possibly need to lower f_{full}
  - Neutron calibration uncertainties
  - Equlibrium
  - Large "Prompt" Fast ions-losses ions must escape in <1ms
  - Density unlikely, increasing n_e makes decay discrepancy worse

- Reasons for Decay discrepancy $decay \propto T_e^{3/2} / n_e$
  - Fast-ion Losses on 10 ms timescale possible, huge edge neutral density/wall condition, error fields, MHD
  - Electron Temperature maybe, but at low T_e, measured decay agrees with TRANSP
  - Density unlikely, decreasing n_e makes rise discrepancy worse

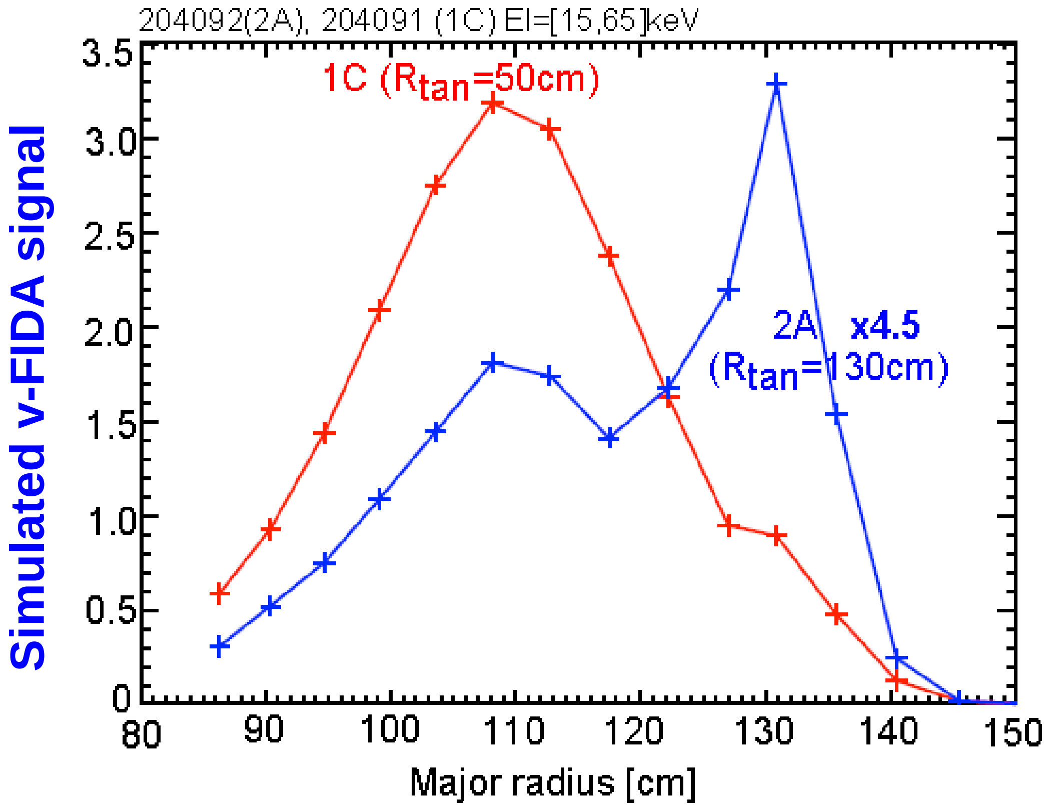
Measured v-FIDA Profile and Peak Position Shift Outward when Injecting NB 2A

1C (R_{tan}=50cm) 2A (R_{tan}=130cm)



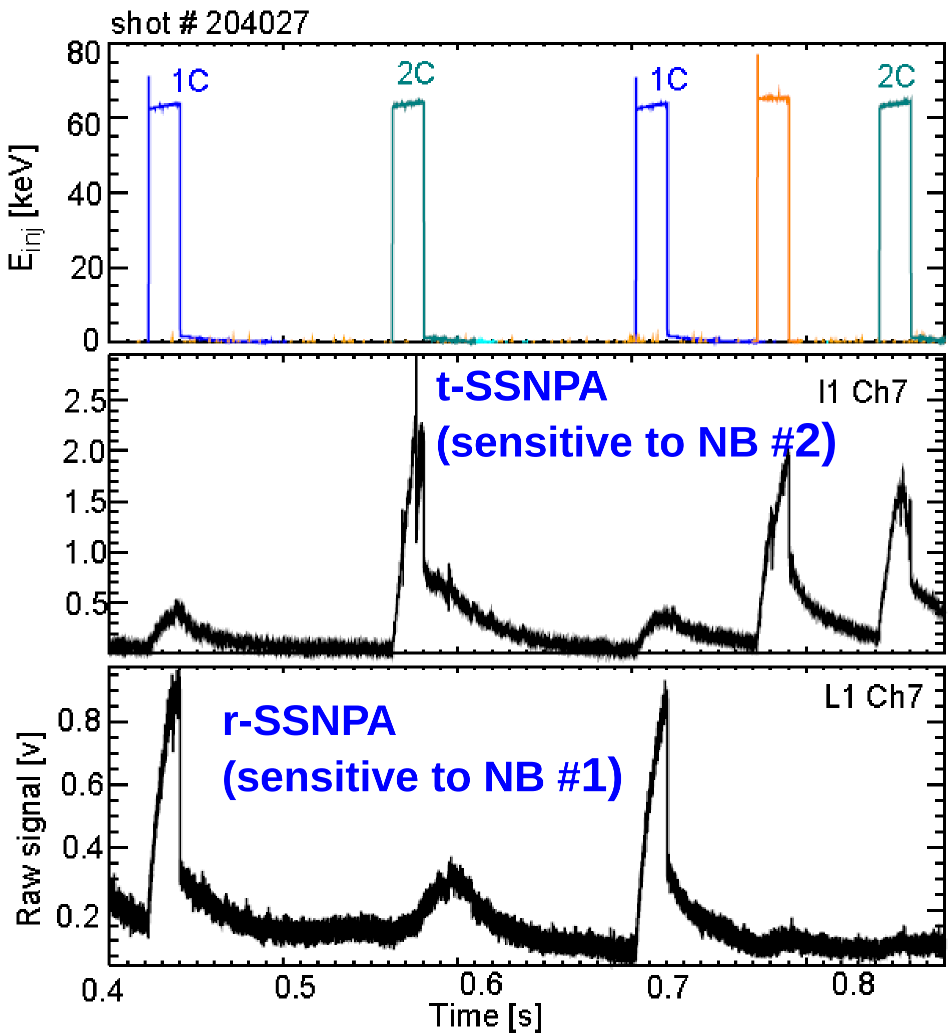
- 100ms pulses of 1C/2A
- Weaker signal w/ 2A due to
  - Less beam deposition
  - Less fast ions w/ large V_{perp}
- T-FIDA shows similar trend, but data quality is worse

Preliminary FIDASIM Simulations Show Similar Trend as Measurements



- Similar features as measurements
- Edge neutral contribution to FIDA signal is **NOT** included yet

Analysis of SSNPA Data is Under Way



- Neutral flux rise and decay contain information on beam ion confinement
- Detailed analysis will be performed after
  - Spatial calibration (in progress)
  - relative intensity calibration
- In FY17, add new pulse-counting mode SSNPA to measure fast ion energy spectrum

Summary

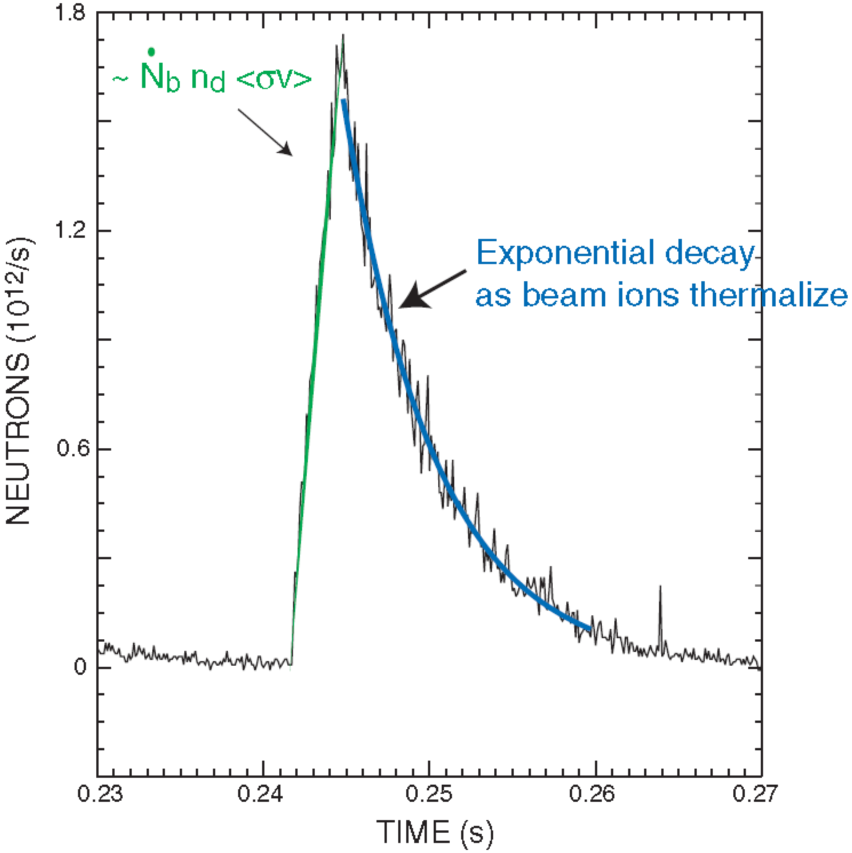
- At high injection energy (85keV), beam ions are well confined based on neutron decay.

- At the low injection energy (65keV), the measured neutron rise is lower and the measured decay rate is slightly faster than TRANSP predictions. Potential reasons are uncertainties in Z_{eff}, E_{full} fraction, $S_{neutron}$, edge neutrals.

- Comparisons of measured FIDA and SSNPA with simulations are in progress.

Backup Slides

Beam-blip Technique Measures Prompt and Delayed Losses

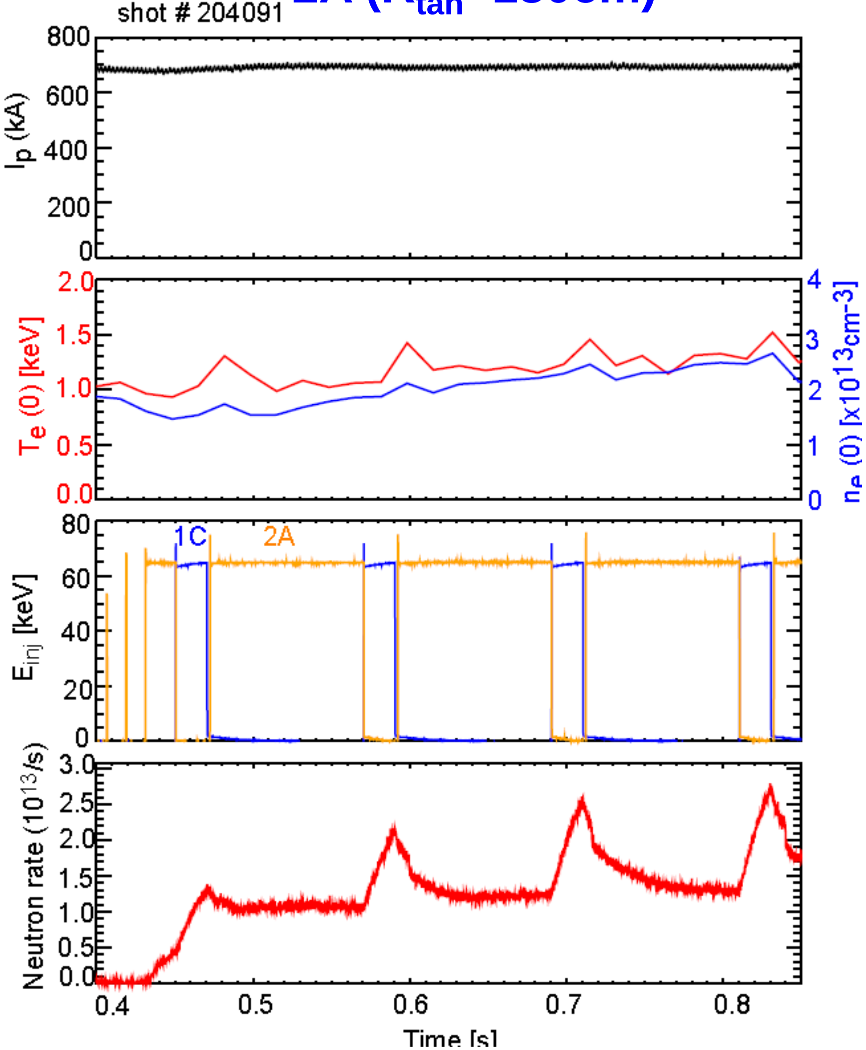


Nucl. Fusion 43 (2003) 883.

- **Use rise and decay rate of $S_{neutron}$ to infer beam ion confinement**
  - Dominated be beam-plasma reactions $S_n \sim n_f n_d < \sigma v >$
  - Rise depends on number of confined beam ions injected $\propto \frac{dn_f}{dt} n_i < \sigma v >$
  - Decay depends on slowing down & losses on $t_{slowing\text{-}down} \propto T_e^{3/2} / n_e$
- **Compare neutron rise and decay with TRANSP predictions**

204091 (2A) vs 204092 (1C)

2A (R_{tan}=130cm)



1C (R_{tan}=50cm)