Fast-ion profiles in quiet plasmas

- FIDA* introduction
- Magnitude and shape comparison
- Parametric dependences and corroborations
- Spatial profiles

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**Heidbrink, PPCF 46 (2004) 1855;*

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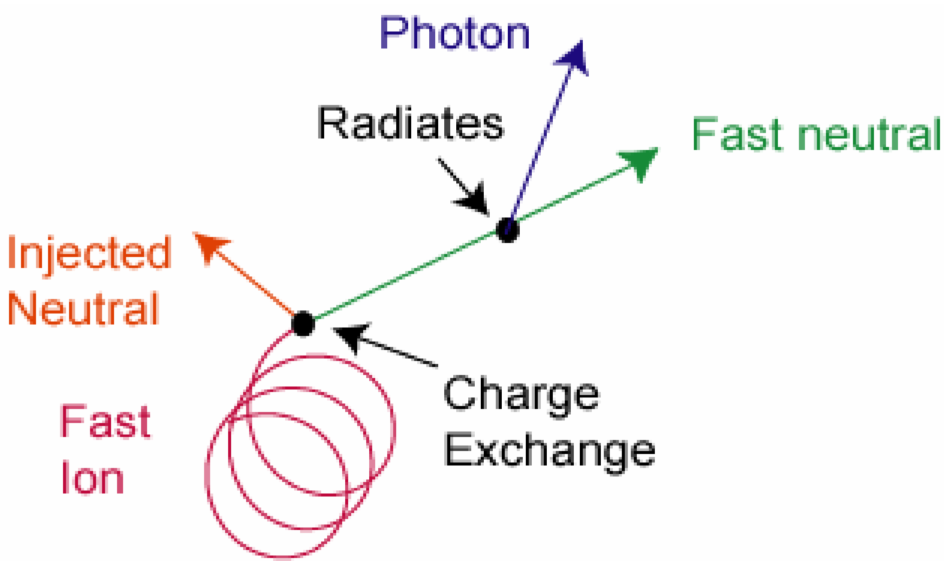
D_α light from neutralized fast ions

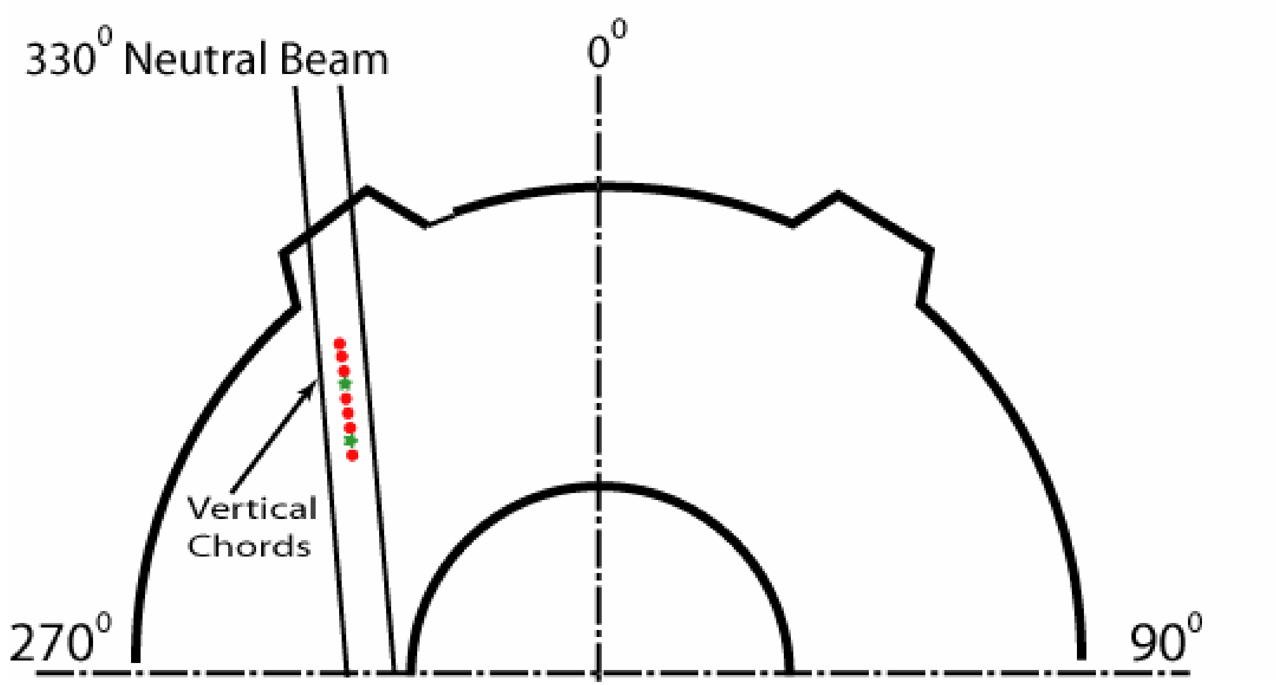


$D^+ + D^0 \Rightarrow D^{0*} + D^+$

$D^{0*} \Rightarrow h\nu + D^0$

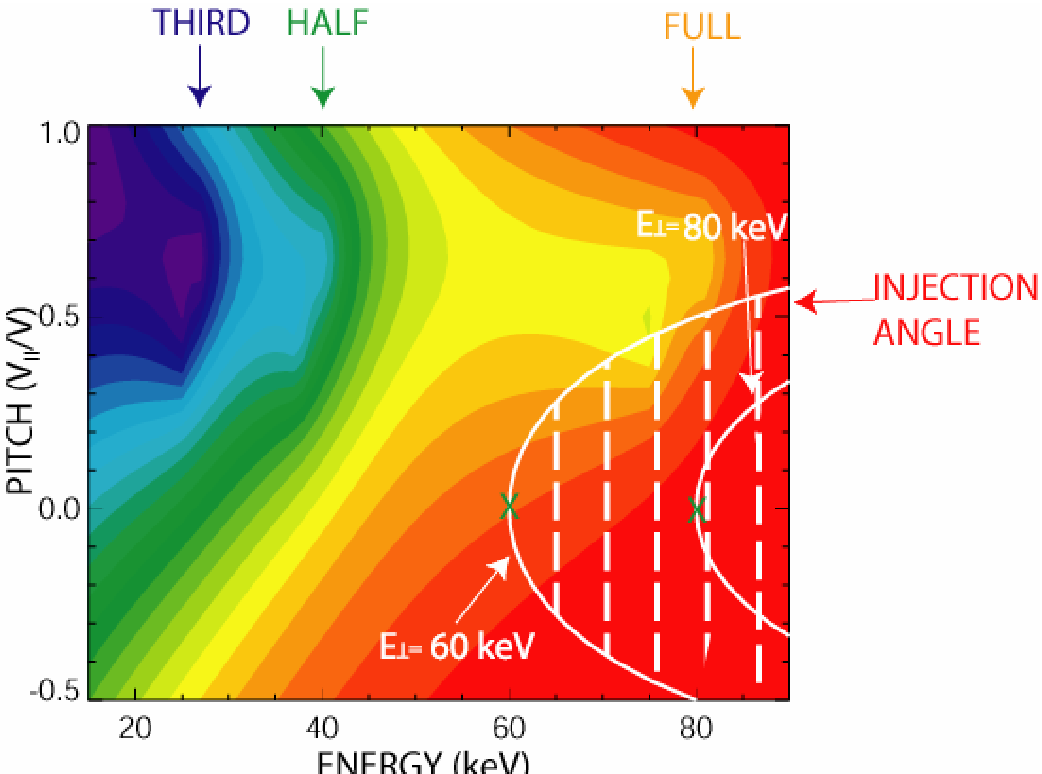
- **Charge exchange light S_{FIDA}□$n_b n_f \langle\sigma v_{rel}\rangle$. S_{FIDA}/n_b: FIDA density.**
- **Wavelength determined primarily by Doppler shift. One velocity component measured.**
- **Cross section depends on relative velocity. Spectral shape distorted.**

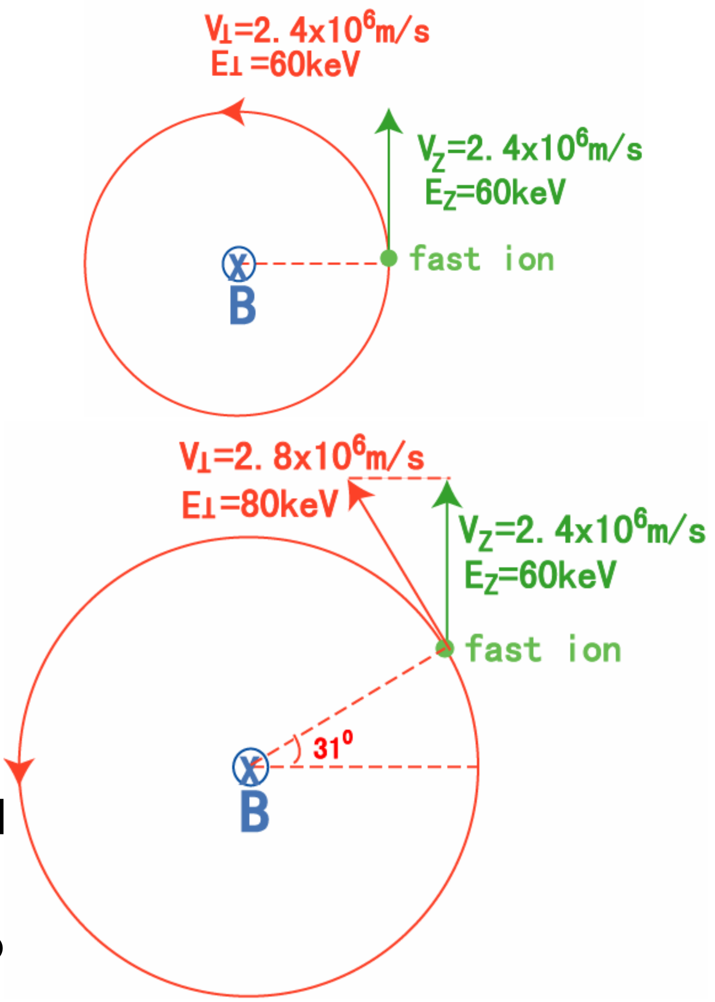
FIDA fiber views



- Dedicated 2-channel system measured full spectra
- Partial spectra from 7 vertical channels on selected discharges

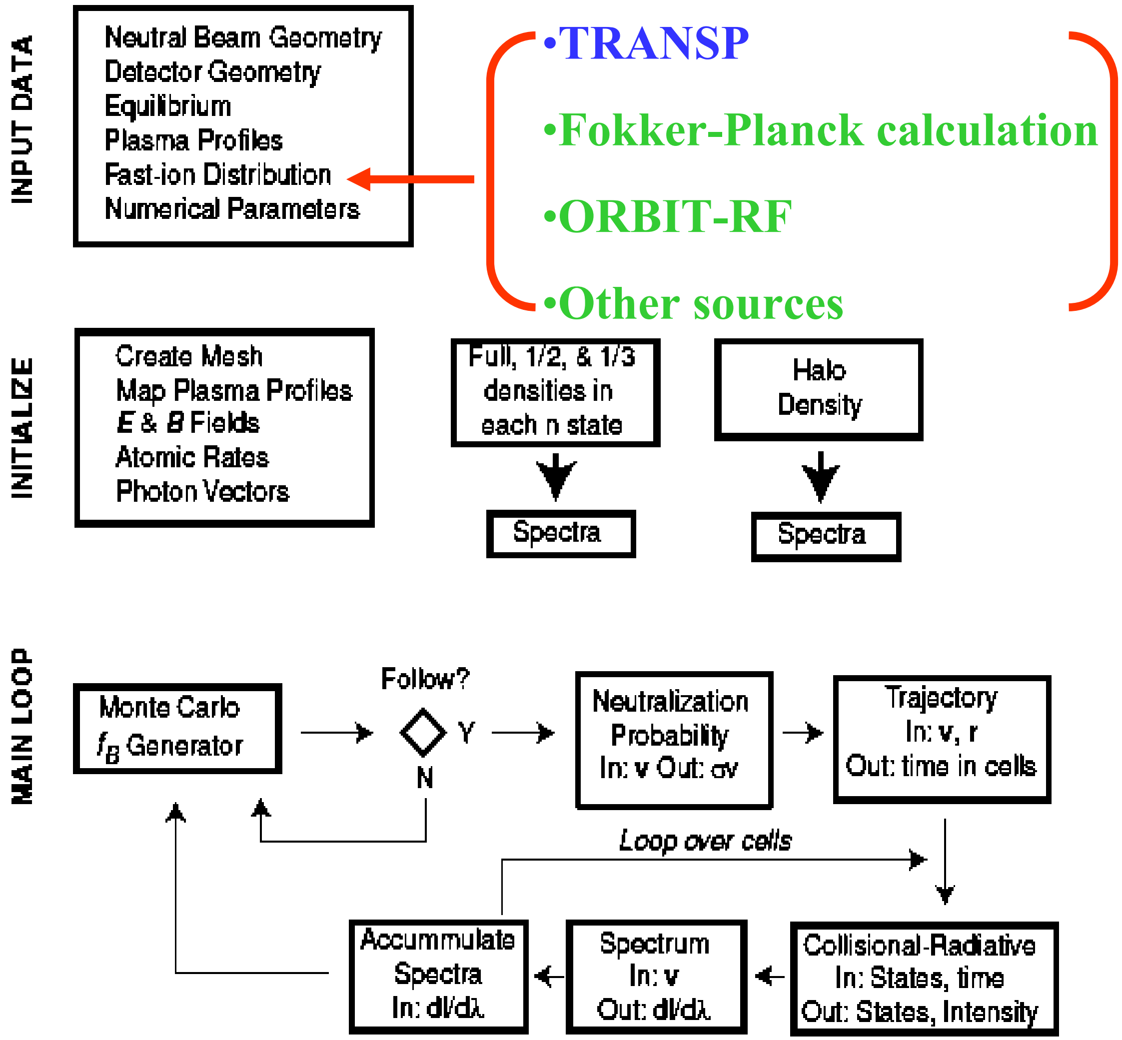
Vertical views measure one component of perpendicular energy





- $\lambda \rightarrow E_\lambda$ (E_Z) $\rightarrow$ perpendicular energy
- A curve with constant perpendicular energy and enclosed area contribute to a particular λ
- Overall weight of each fast ion is product of gyro phase weight and atomic cross section weight

Monte Carlo code simulates expected signal



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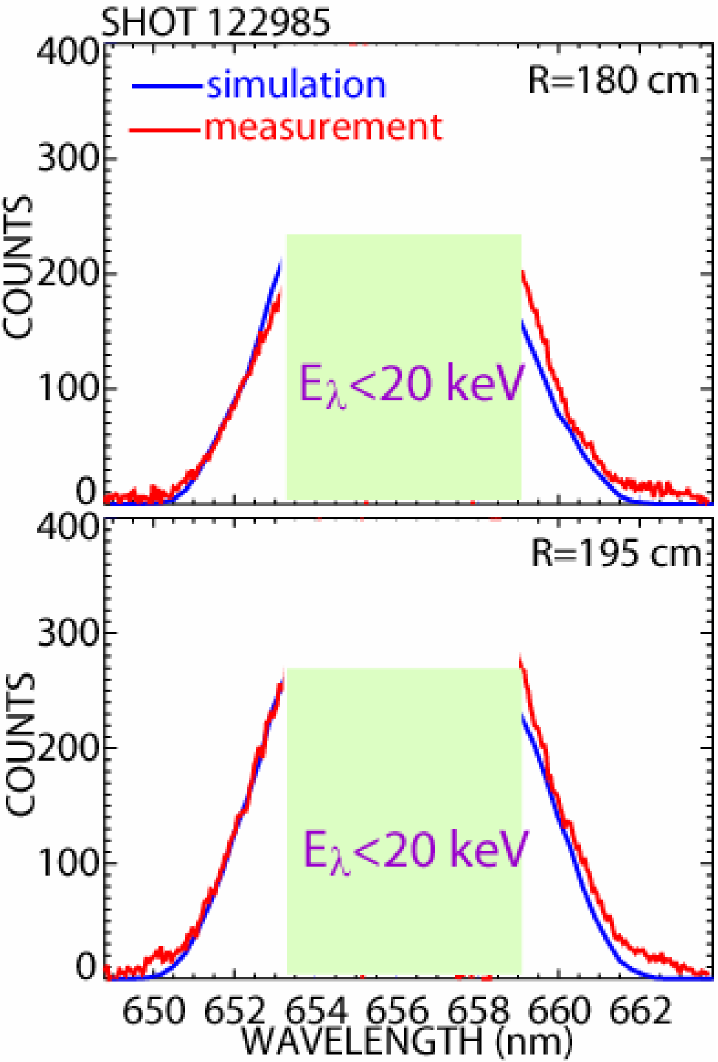
Both magnitude and shape of spectra agree well

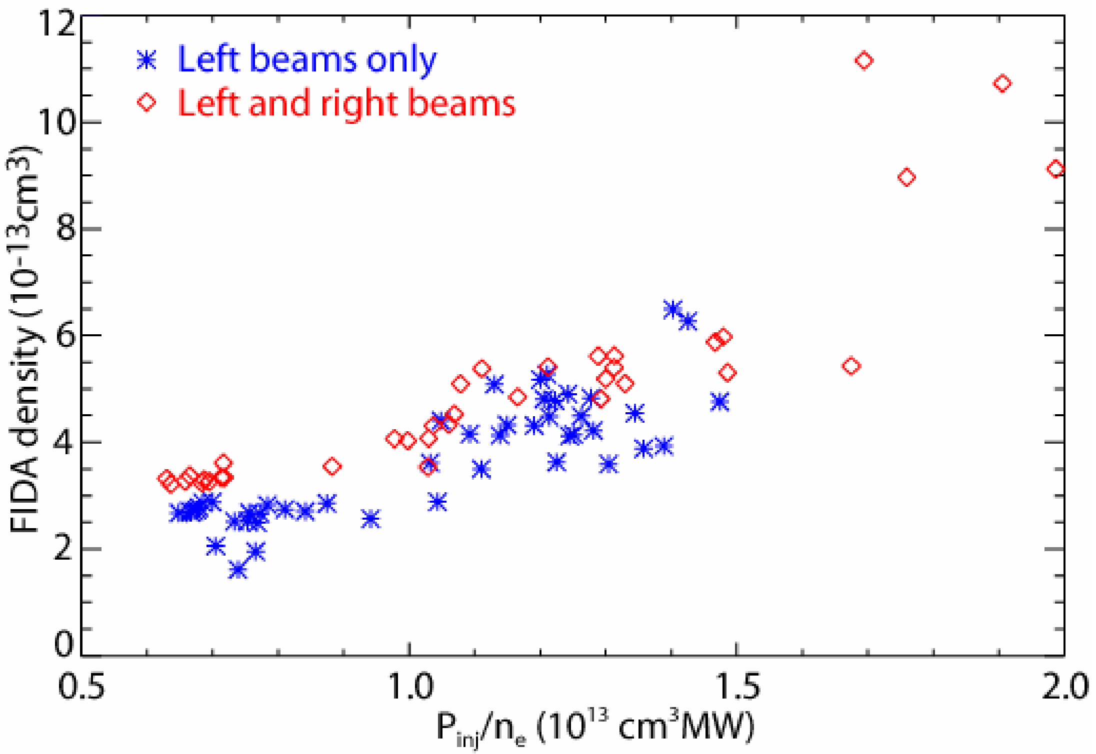


- **Intensity calibration allows direct magnitude comparison.**
- **For the 180 cm chord, simulated spectrum is scaled by 0.75 to get the agreement. 20-30% magnitude difference is reasonable provided errors in data processing, intensity calibration, plasma profiles input to TRANSP and the simulation code, etc.**
- **Excellent shape agreement validates TRANSP fast-ion velocity space model and atomic cross sections in the simulation code.**
- **The result benchmarks both the simulation code and the diagnostic.**

Classical theory of fast ions

- Fast ions are born with an initial energy and pitch by neutral beam injection
- Fast ions slow down through coulomb collisions with electrons and thermal ions
- Fast ions pitch angle scatter through coulomb collisions with thermal ions
- Fast-ion density is proportional to the product of the beam power and the slowing down time, which is $P_{inj}f(T_e)/n_e$

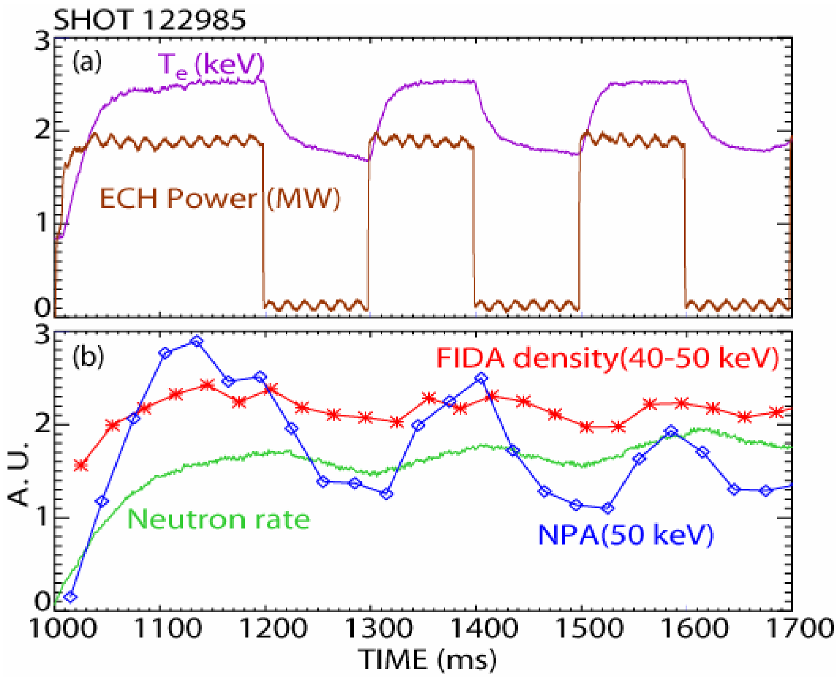
FIDA signal increases with beam power and decreases with left fraction

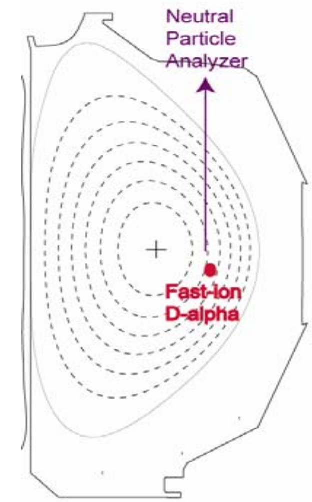


- FIDA density (FIDA/n_b) is proportional to fast-ion density
- P_{inj}/n_e is also proportional to fast-ion density if T_e held constant
- Electron temperature is held to be between 2 keV and 3 keV because of limited database entries

- Strong correlation observed between FIDA signal and beam power
- Signal increased with right beam source

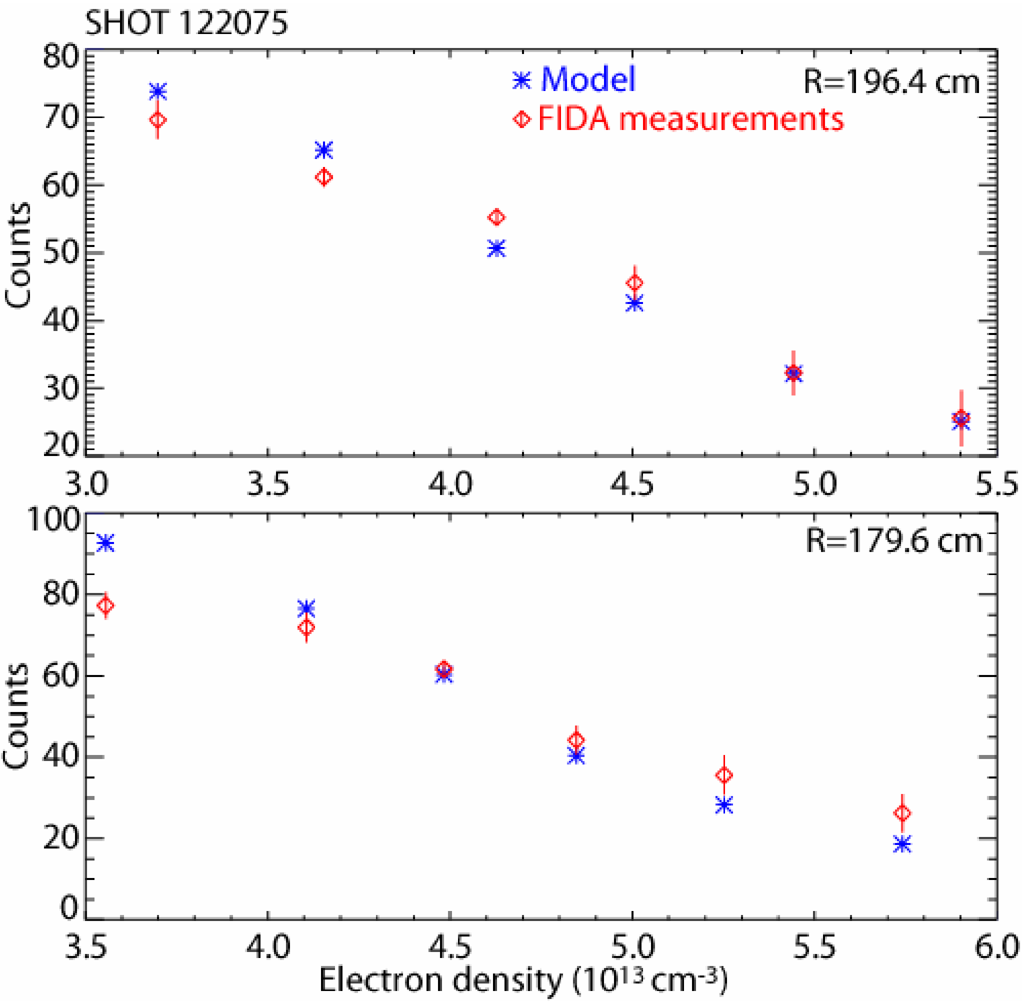
FIDA signal is less sensitive to pitch-angle scattering than neutral particle analyzer signal





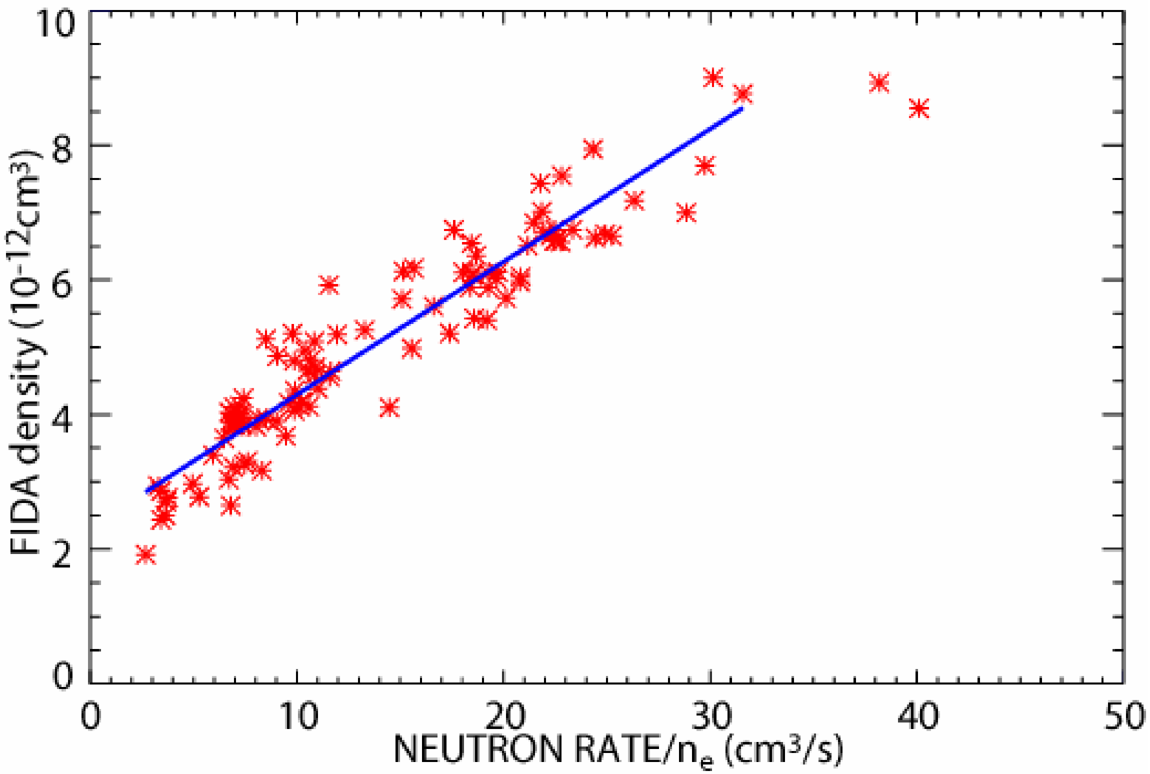
- The FIDA signal increases with T_e because of the longer slowing down time (higher fast-ion density) and more pitch angle scattering (more perpendicular energy)
- The FIDA signal is less sensitive because FIDA measures a collection of fast ions in velocity space, while NPA measures a point in velocity space. Neutrons also average in velocity space.

Electron density dependence agrees with a simple model



- The model: product of total neutral density, deposition rate of full energy component, and slowing down time.
- All atomic physics neglected, which is legitimate when the velocity distribution doesn't change and only signal level is concerned. One free parameter in the model.
- Good agreement between the FIDA measurements and the model.

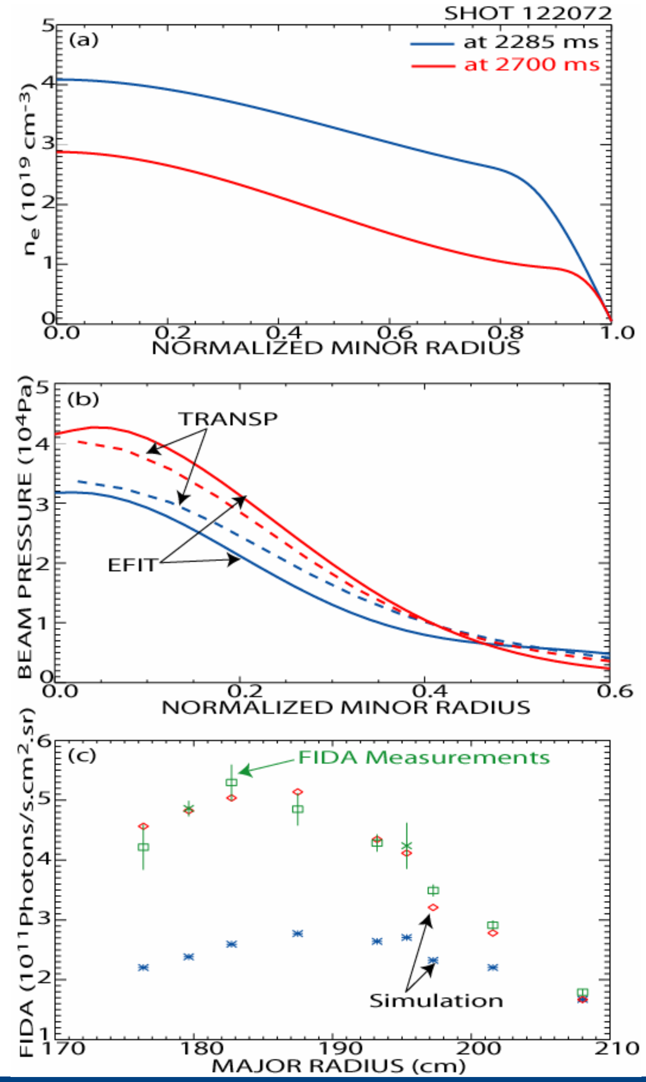
Neutron diagnostic corroborates FIDA measurements



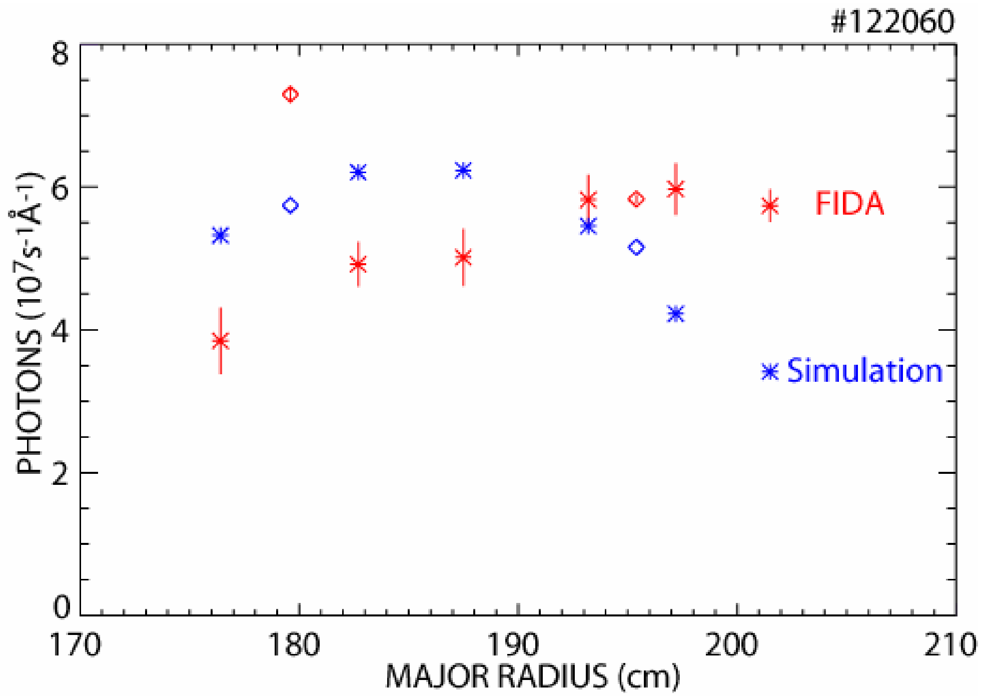
- **Neutron rate/n_e is proportional to fast-ion density if beam-thermal nuclear reaction dominates**
- **A linear relationship is observed**

FIDA relative radial profile agrees well with TRANSP prediction

- Fast-ion distributions from TRANSP are dumped to the simulation code.
- Simulated profiles are higher as expected at the later time when electron density is lower.
- At the early time, FIDA profile is normalized to the simulated profile.
- At the later time, FIDA profile agrees with the simulated profile.
- Radial profile of fast-ion pressure inferred from kinetic EFITs (MSE data) are also consistent with TRANSP.



FIDA absolute radial profile is more challenging



- Simulated FIDA profile looks reasonable.
- The absolute magnitudes are within 30%. Not bad considering all the uncertainties.
- The profile shape doesn't agree with the simulation.
- The difference between CCD channels and Reticon channels suggests that the intensity calibration is problematic.
- Future prospect is good with careful intensity calibration.

FIDA diagnostic successfully benchmarked

- Excellent spectral shape agreement (Coulomb collision model validated).
- Reasonable magnitude agreement
- Expected parametric dependences
- Corroborated by other fast-ion diagnostics
- Good relative radial profile (beam-ion diffusion coefficient within 0.1 m^2/s).