Fast-ion D_α (FIDA) Measurements of Fast-ion Transport by Low-Frequency MHD
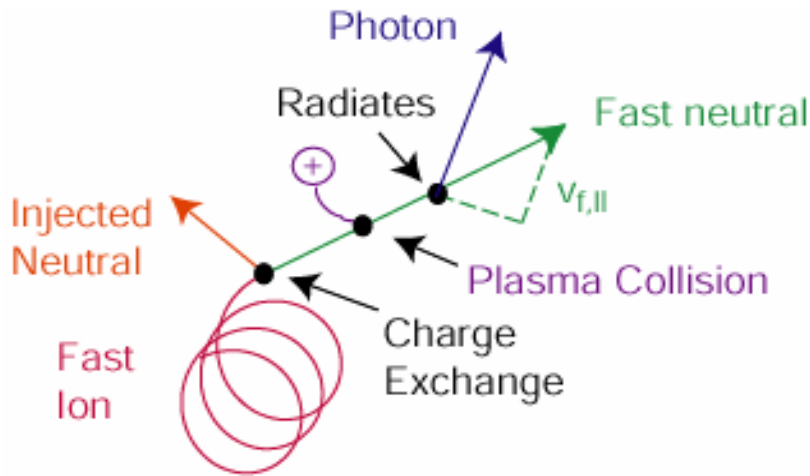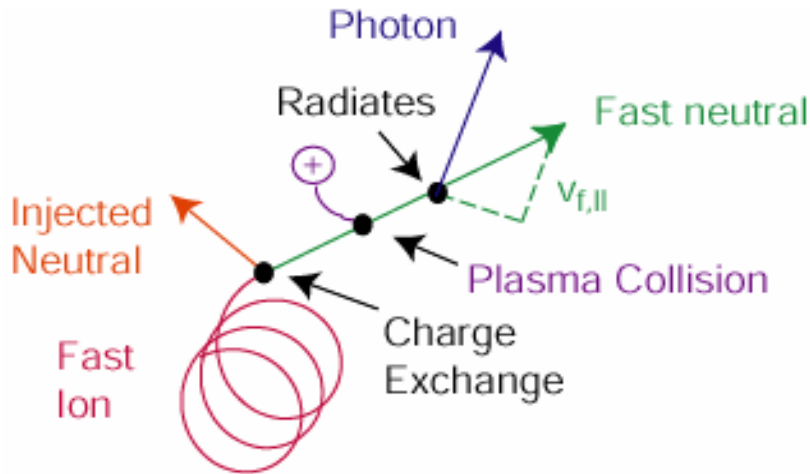
W. Heidbrink, R. Bell, Y. Luo[*], E. Ruskov, W. Solomon, K. Burrell[*], D. Liu

[*](DIII-D only)

- DIII-D examples

- NSTX hardware plans

# Fast-ion D$_\alpha$ (FIDA) Diagnostic Measures Light from Reneutralized Fast Ions

- A type of Charge Exchange Recombination Spectroscopy

- Use vertical view to avoid bright interferences

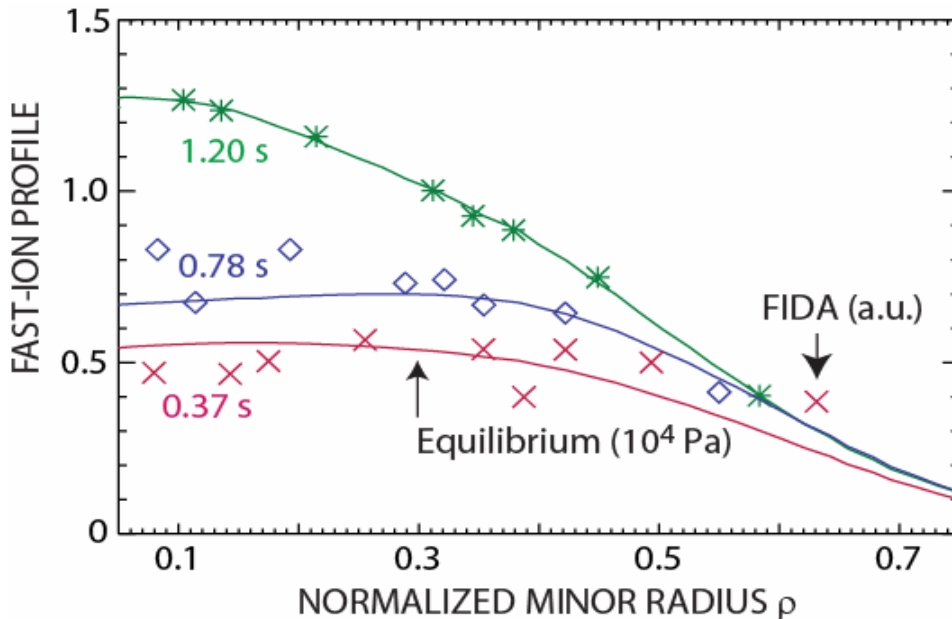- Exploit large Doppler shift (measure wings of line)

- Background subtraction usually dominates uncertainty

- Achieved resolution: ~ 5 cm, ~ 10 keV, 1 ms.

Heidbrink, PPCF 46 (2004) 1855; Luo, RSI (2007) in press.
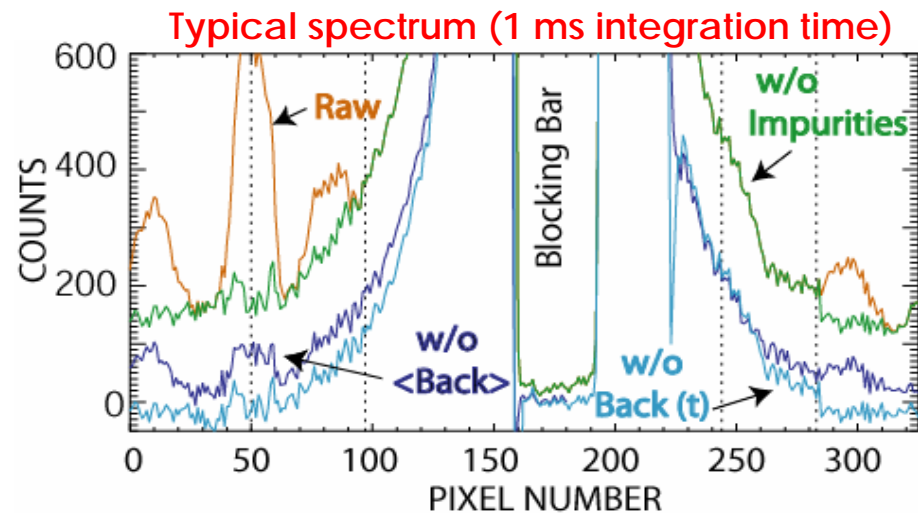
# FIDA Spatial Profile Measures Redistribution
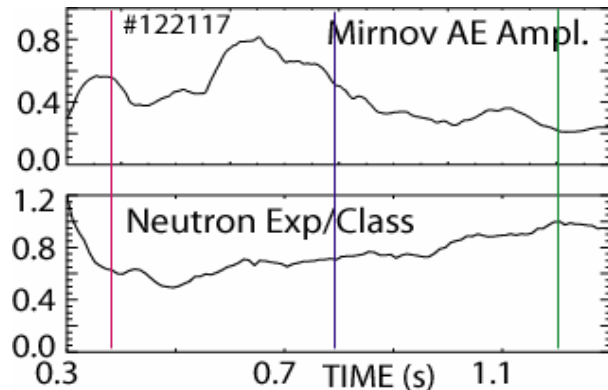
- Volume-averaged neutron rate is below the classical TRANSP prediction during the strong Alfven activity

- During the strong Alfven activity, the fast-ion profile is nearly flat

- Recent Hybrid Work: Look for redistribution as $q_0 \rightarrow 1$

*Heidbrink, IAEA (2006); to be submitted to PRL*

Fast-ion Transport Broadens the Profile of Neutral-Beam Driven Current
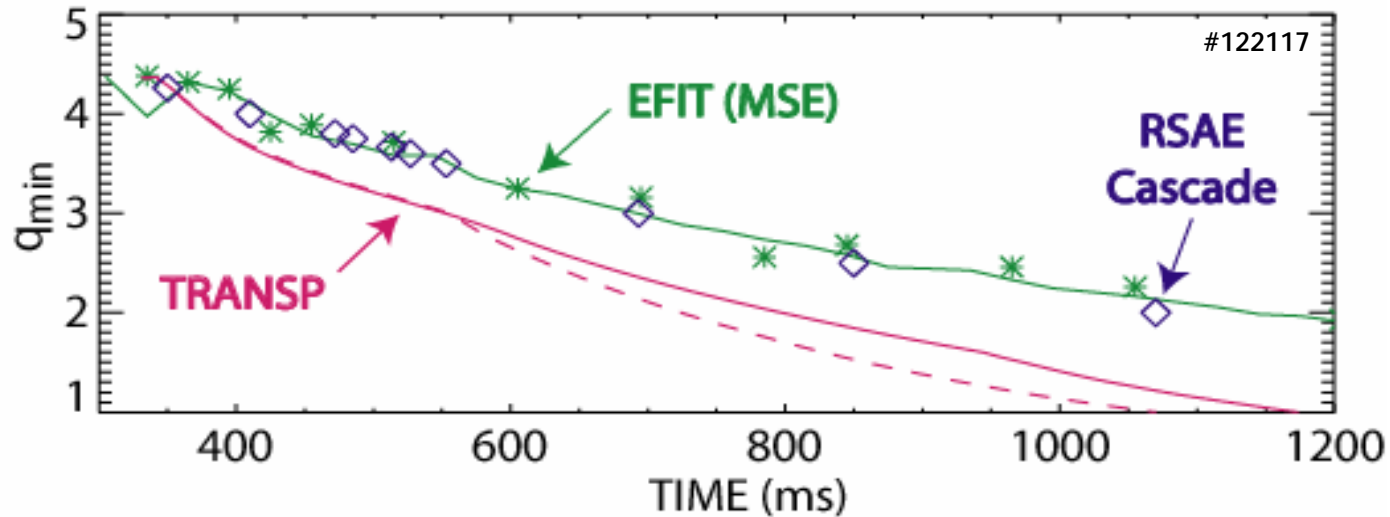
- The current diffuses more slowly than classically predicted

- Independent determinations of q_{min} from MSE-based equilibrium reconstructions and from the RSAE integer q crossings agree

- Effect not seen in lower-power shot with weak Alfven activity

- Apparently co-circulating fast ions that move to $\rho \sim 0.5$ broaden the NBCD profile.[*]

Wong, PRL 93 (2004) 085002; Wong, NF 45 (2005) 30.

# Changes in spectral shape can indicate spatial transport
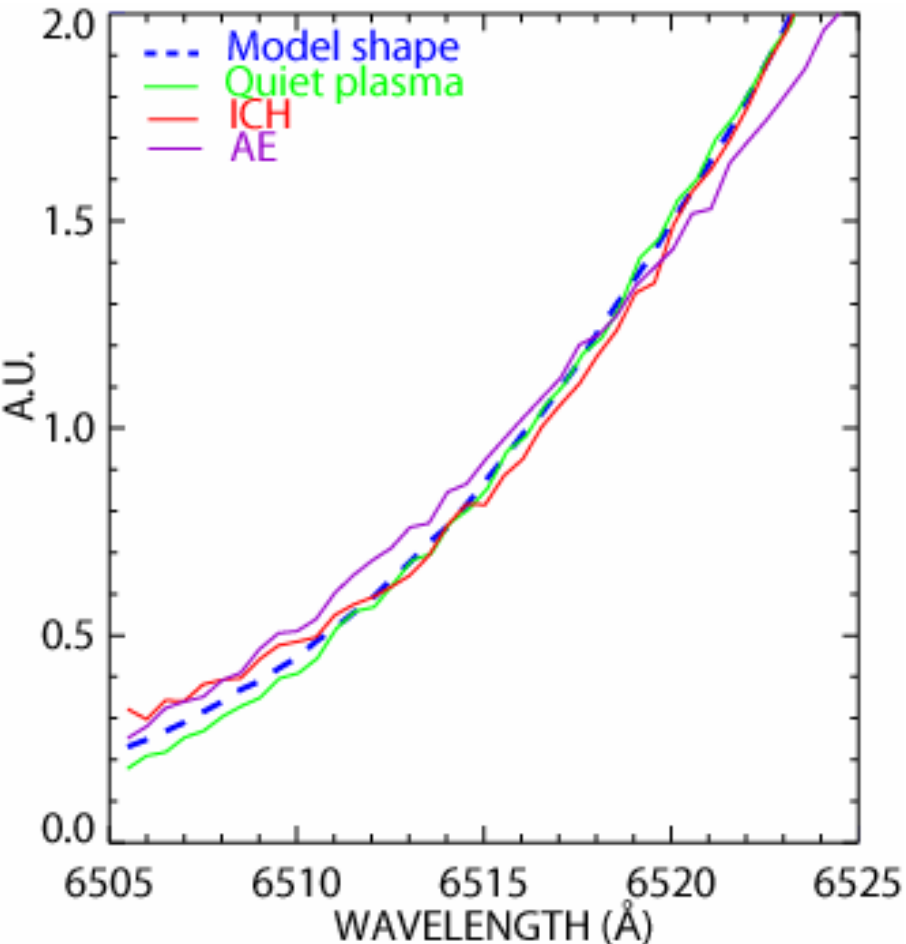
← Increasing Eperp

- Model shape is the average of several spectra with quiet plasmas.
- In quiet plasmas, the spectral shaped is remarkably consistent
- The ICH case: high energy fast ions are accelerated.
- The AE case: Fast ions from the core region (that pitch-angle scatter more) are expelled.

Velocity distribution is usually determined by Coulomb collisions, but can be altered by spatial transport

NSTX Instruments: Bandpass for Time, Spectrometer for Energy/Space
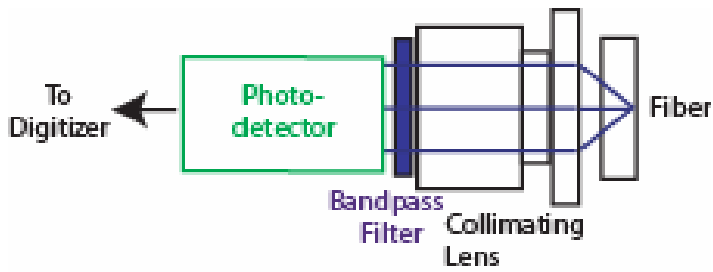
- Bandpass system integrates over wavelength--optimized for temporal resolution (< ms)--for bursting MHD
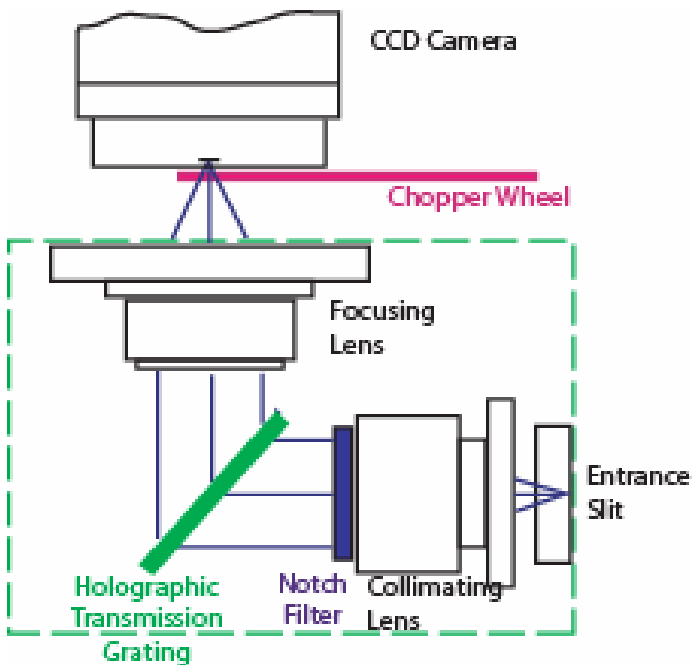
- Simulation code adapted; NPA module added; accommodate ORBIT output

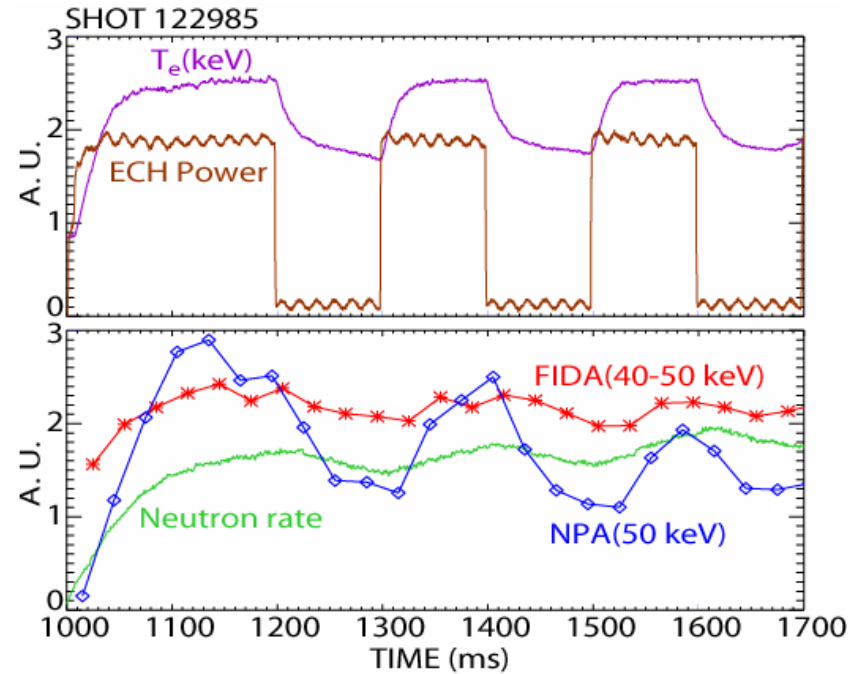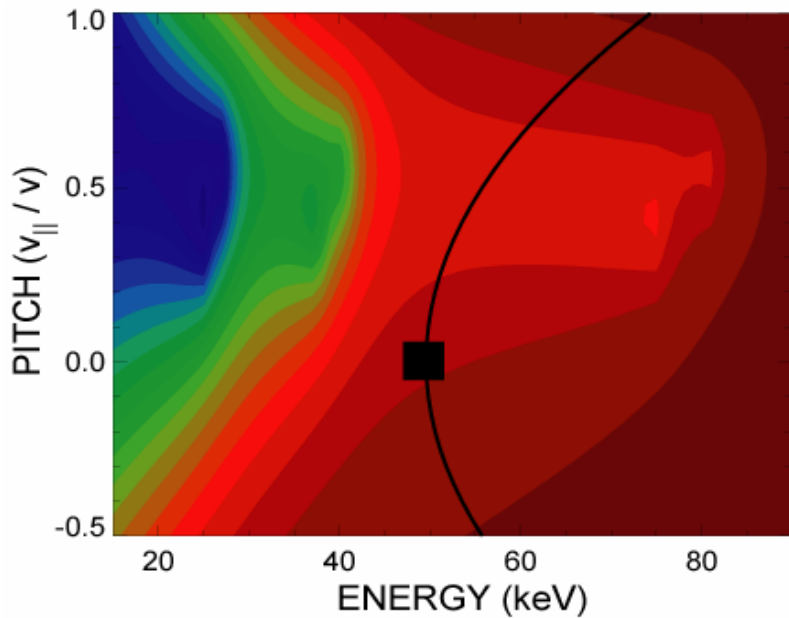- Install Bandpass hardware in March

- Postdoc (Mario Podesta) starts in May

- Spectrometer measures full spectra across profile (10 ms)

- Spectrometer operational at end of 2008 campaign?

Heidbrink, RSI 77 (2006) 10F120.

Backup Slides

Different Fast-ion Diagnostics Weight Phase Space Differently

FIDA: $\lambda \rightarrow V_z \rightarrow$ Perpendicular energy

- A curve in (E,pitch) space contributes to a particular λ
- Higher energies also contribute but more weakly
- Atomic cross sections also influence weighting
- NPA measures a "point" in velocity space

Complementarity of Fast-ion Diagnostics

Diagnostic	Velocity Space	Configuration Space
Neutrons	High-energy weighting	Volume-average
Pressure	Energy weighting	~ 5 cm
FIDA	v_z component	5 cm x 30 cm
Neutrals	Point	Beam footprint
Loss	Narrow in pitch	Orbit average

Averages are useful for bulk effects on plasma;

Local phase-space measurements isolate physics.