New Measurements of Fast-ion Transport

by
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Measured Transport by Many Instabilities

- Sawtooth
- Tearing Modes
- Off-axis Fishbone
- E-GAM

\( n=0,1 \)

- \( n \sim 4 \)
- \( \delta T_e \)
- \( \delta n_e \)

\( \text{Alfvén Eigenmodes} \)
- TAEs
- RSAEs
- BAAEs

\( \text{High } n \)

\( \text{Drift-wave turbulence} \)
Every Fast-ion Diagnostic Measures Part of Phase Space

\[ \text{Signal} = \int d\mathbf{r} \int dE \int d(\nu_\parallel / \nu) \ W(\mathbf{r}, E, (\nu_\parallel / \nu)) \ F(\mathbf{r}, E, (\nu_\parallel / \nu)) \]

\[ W = \text{weight function} \]

\[ F = \text{distribution function} \]

**Beam ion loss detector (BILD)**
Off-axis Fishbones Cause Coherent Losses of Beam Ions

- Particles expelled in a "beacon" with a fixed phase relative to the wave

- T12.005
Solid-state Neutral Particle Analyzers Also Measure Beam-ion Losses

- Detectors operate in current mode
- Both “active” (core) and “passive” (edge) signals

• XD9.004
Solid-state Neutral Particle Analyzers Also Measure Beam-ion Losses

• XD9.004
Lost Fast Ions Cause Spikes In “BES” Signals

- “BES” normally measures fluctuations in beam emission
- Expelled fast ions produce fast-ion $D_\alpha$ (FIDA) light in edge
Lost Fast Ions Cause Spikes in “BES” Signals

- No beam in sightline on this shot
- Lost FIDA signal larger than BES
- Can compromise eigenfunction measurements

- Heidbrink, PPCF, submitted
Non-ambipolar Losses Cause Sudden Drop in Electric Field $\rightarrow$ Toroidal Rotation

- Total fast-ion loss rate inferred from slope of neutrons
- Conditionally average 8 similar bursts
- CER channel near $q=2$ surface (where mode amplitude peaks)
Fast-ion Loss Detector (FILD) Resolves Pitch

- Scintillator loss detector
- UP9.55

One location on scintillator
FILD Measures Coherent Losses from Alfvén Eigenmodes

- ECE-imaging measures 2D structure of modes GI2.002
- FILD measurements establish loss mechanism TI2.001
Sawtooth Crash Causes Large Reduction in Central Fast-ion Density

- FIDA imaging* measures counter-going ions with excellent spatial resolution

*Van Zeeland, PPCF 51(2009) 055001.
Sawtooth Crash Causes Large Reduction in Central Fast-ion Density

- UP9.56
New Tangential FIDA View is More Sensitive to Passing Particles

- Vertical
- Tangential

ENERGY (keV)

PITCH

DIID-D
NATIONAL FUSION FACILITY
SAN DIEGO

B. Heidbrink/APS/November 2010
New FIDA Views Show Passing Particles Are Affected More Than Trapped Particles

• UP9.56
Measure Neutral Halo Density to Validate FIDA Simulations

- Sightlines miss injected neutrals
- Halo neutrals that surround beam produce signal
- Shape in excellent agreement but absolute magnitude is off
- GP9.64
Measure 14 Mev Neutrons to Assess the Confinement of 1.0 Mev Tritons

- D-D reactions produce 1.0 MeV tritons
- Tritons that reach peak of D-T cross section produce 14 MeV neutrons
Test Blanket Module (TBM) Causes Loss of 1.0 Mev Tritons

- UP9.57
More Details in Presentations Later this Week

- Sawtooth UP9.56
- Off-axis Fishbone TI2.005
- $n=0,1$

- $n \sim 4$
- Alfvén Eigenmodes TI2.001, GI2.002
- Drift Waves UP9.54

- Test Blanket Module UP9.57, X04.004

**Diagnostics**
- Solid state neutral particle analyzers XD9.004
- Fast-ion loss detector UP9.55
- FIDA modeling BP9.64, GP9.64, JP9.24