New Measurements of Fast-ion Transport

by
B. Heidbrink[1]

**with R. Fisher[2], M. García-Muñoz[3], B. Grierson[4],
G. McKee[5], R. Moyer[6], C. Muscatello[1], D. Pace[1]
W. Solomon[4], B. Tobias[7], M. VanZeeland[2],
Y. Zhu[1], and the DIII-D Team**

[1]*University of California, Irvine*
[2]*General Atomics*
[3]*Max Planck Institute, Garching*
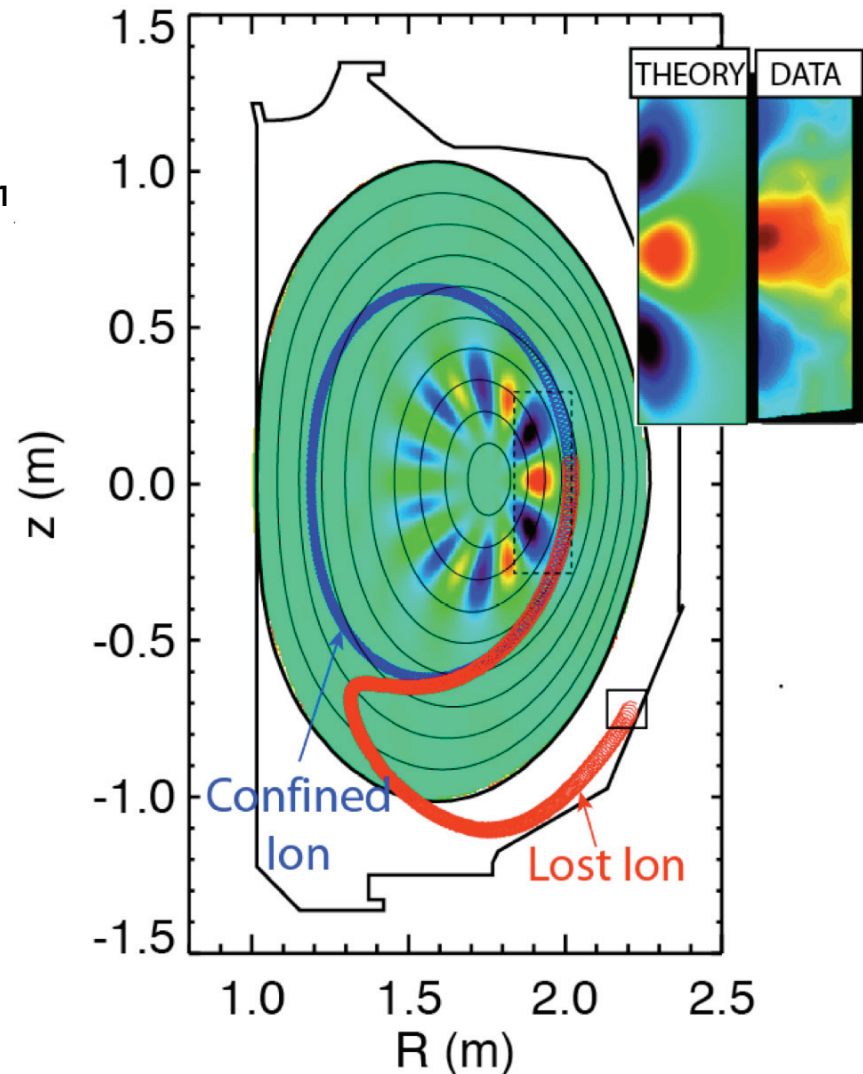[4]*Princton Plasma Physics Laboratory*
[5]*University of Wisconsin, Madison*
[6]*University of San Diego, California*
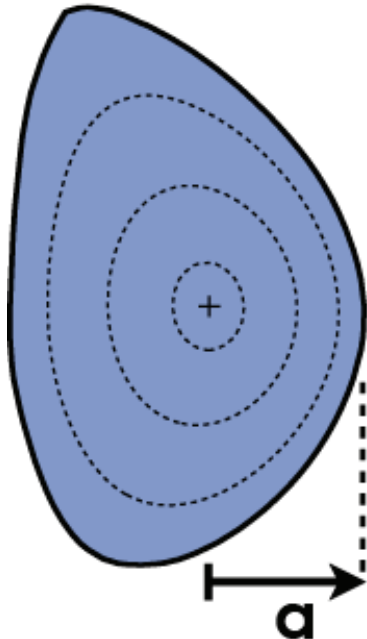[7]*University of California, Davis*

**Presented at the
52nd Annual Meeting of
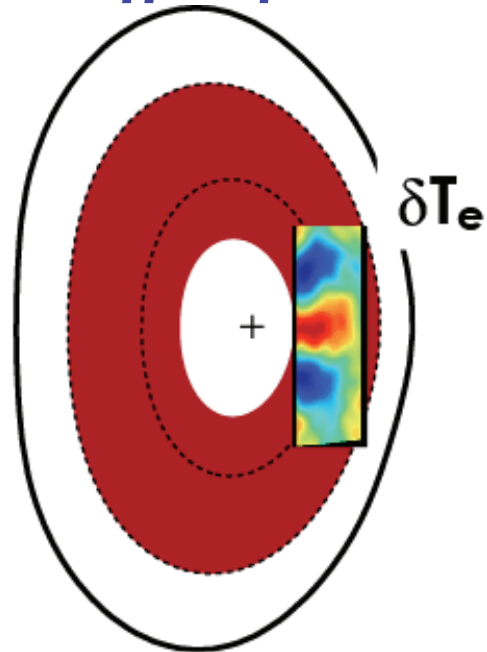the APS Division of Plasma Physics
Chicago, Illinois**

November 8-12, 2010

Measured Transport by Many Instabilities

n=0,1

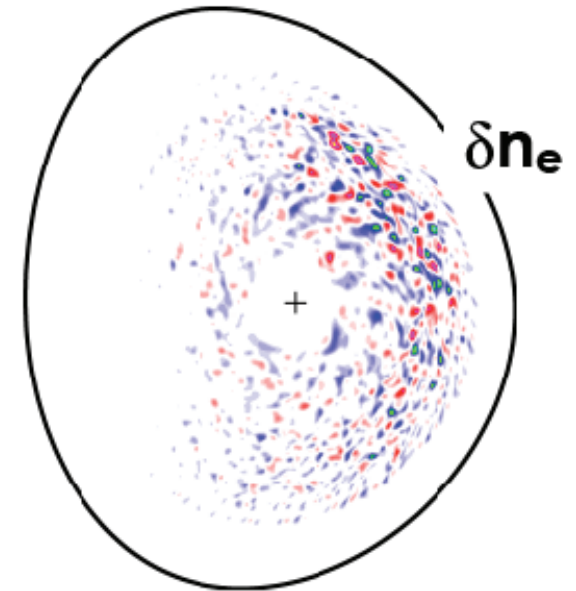

- Sawtooth
- Tearing Modes
- Off-axis Fishbone
- E-GAM

n ~ 4

δT_e

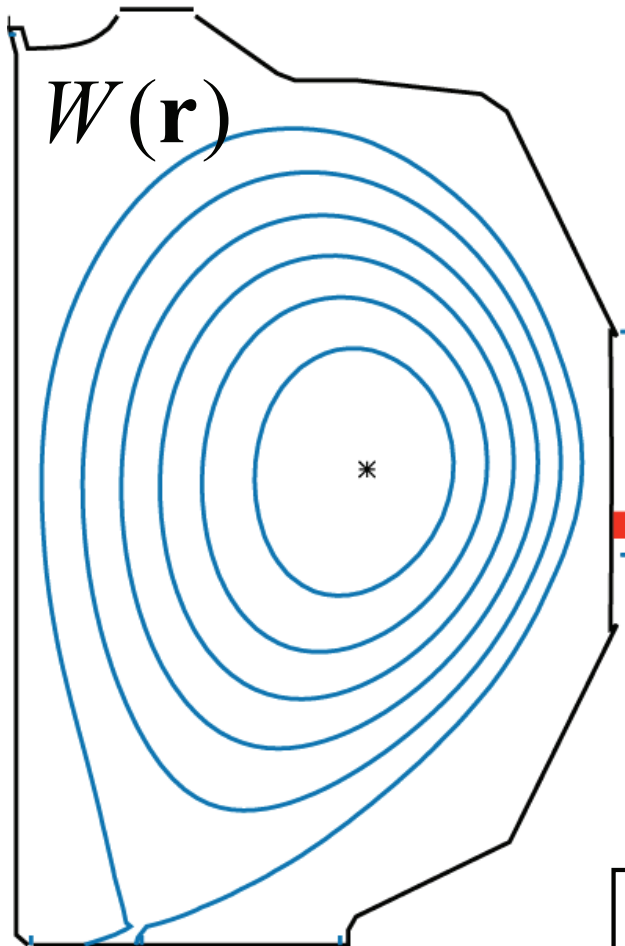*Alfvén Eigenmodes*

- TAEs
- RSAEs
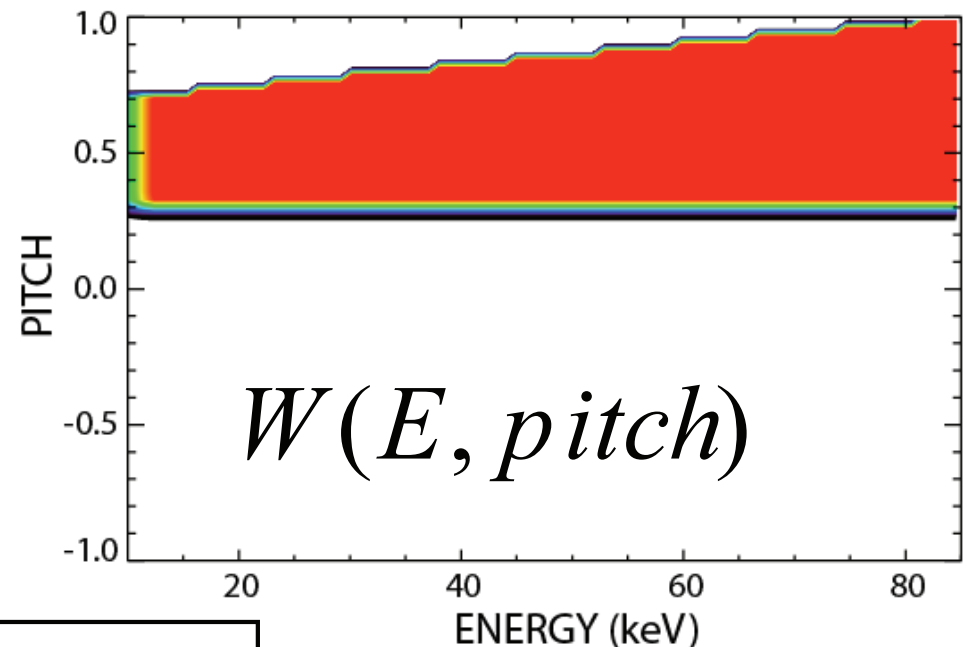- BAAEs

High n

δn_e

- Drift-wave turbulence

Every Fast-ion Diagnostic Measures Part of Phase Space

$$Signal = \int d\mathbf{r} \int dE \int d(v_{\parallel}/v)\, W(\mathbf{r}, E, (v_{\parallel}/v))\, F(\mathbf{r}, E, (v_{\parallel}/v))$$
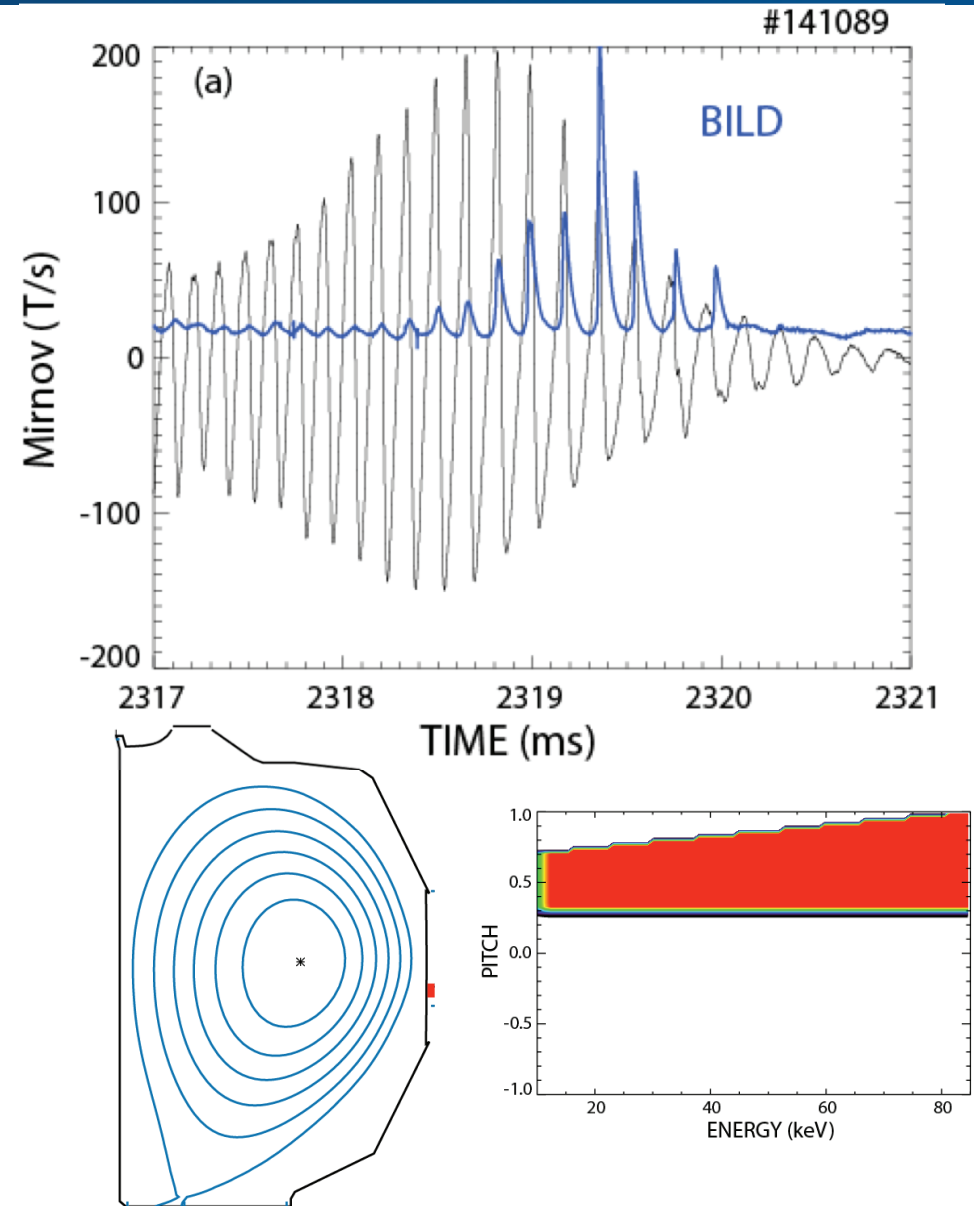
$W(\mathbf{r})$

W = weight function

F = distribution function

$W(E, pitch)$

PITCH

ENERGY (keV)

Beam ion loss detector (BILD)
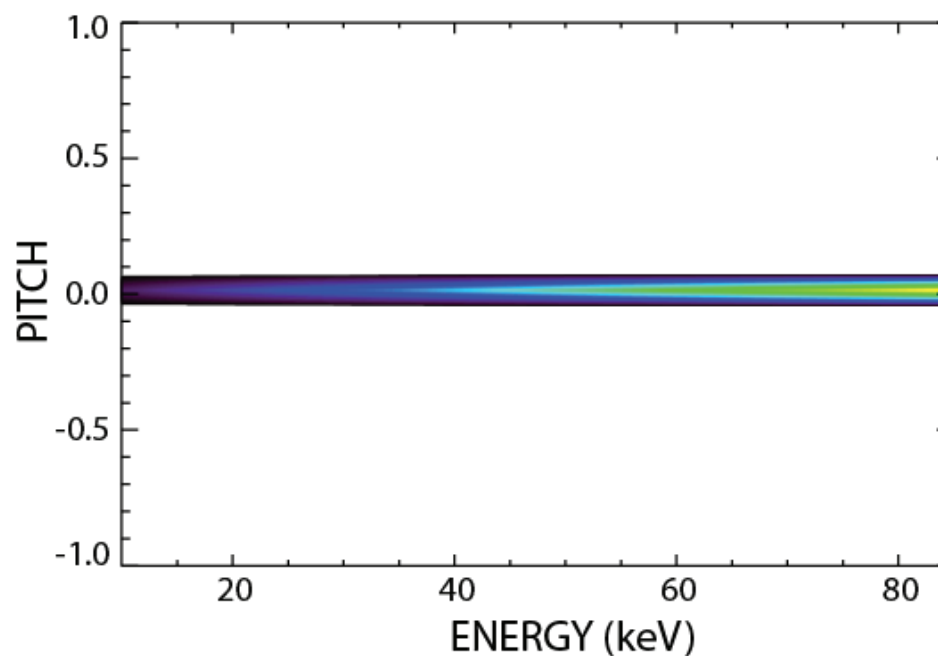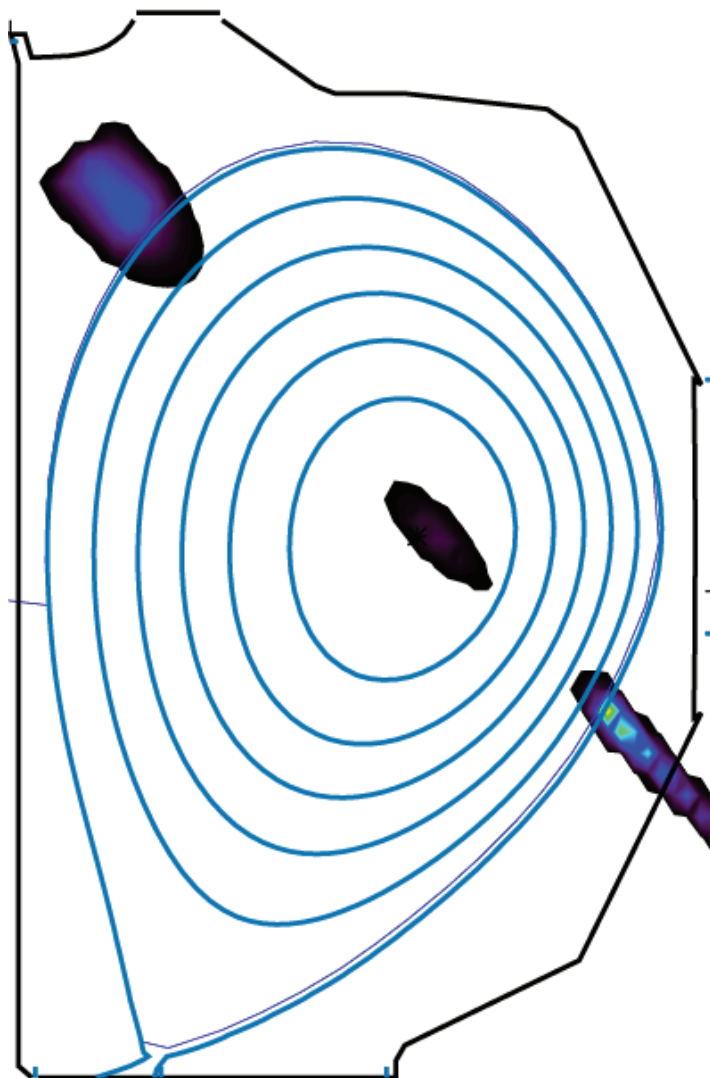
DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

Off-axis Fishbones Cause Coherent Losses of Beam Ions

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

- **TI2.005**

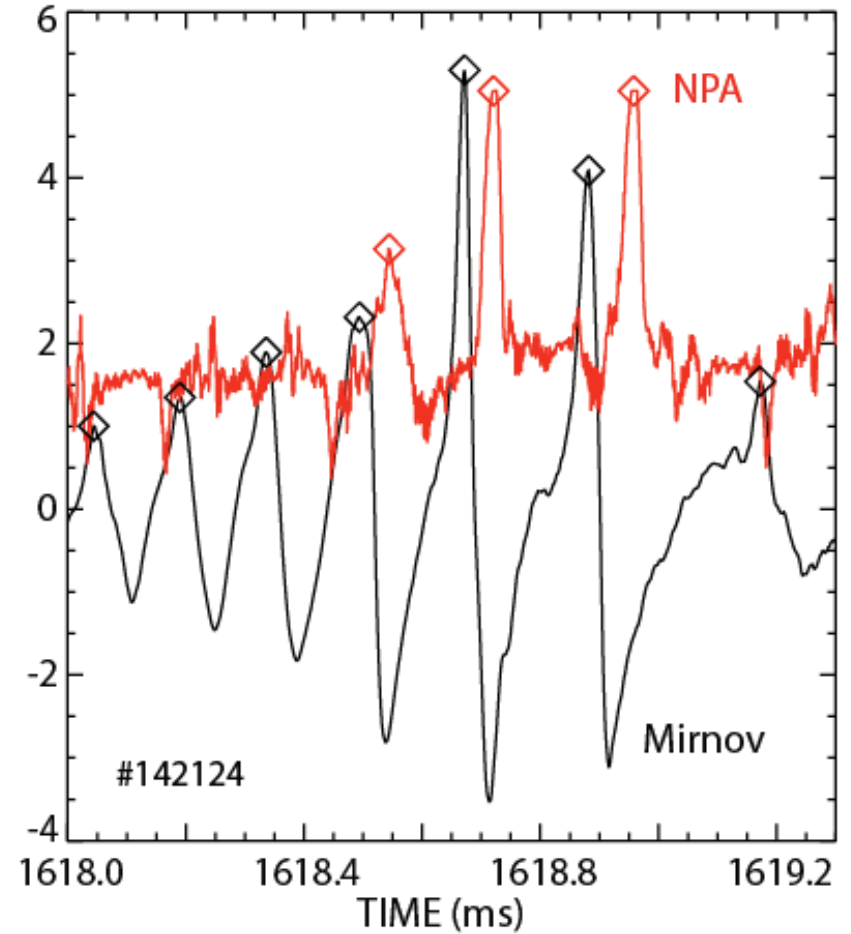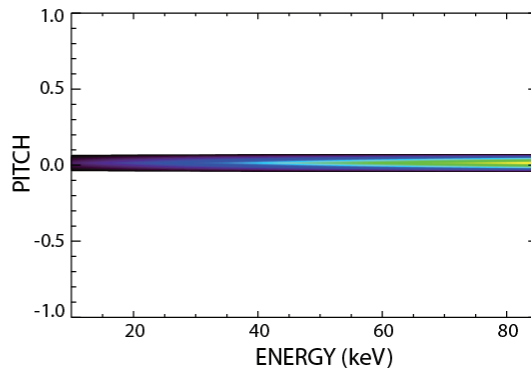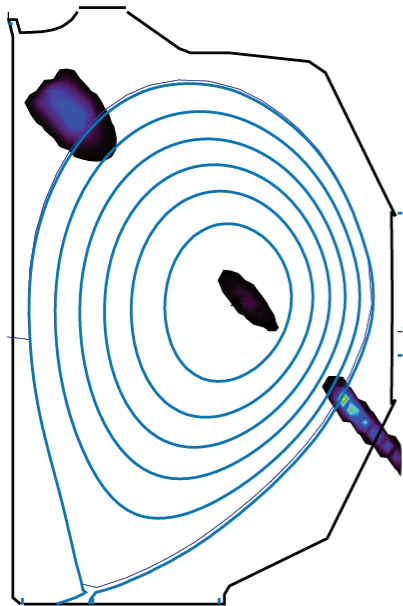# Solid-state Neutral Particle Analyzers Also Measure Beam-ion Losses

- Detectors operate in current mode

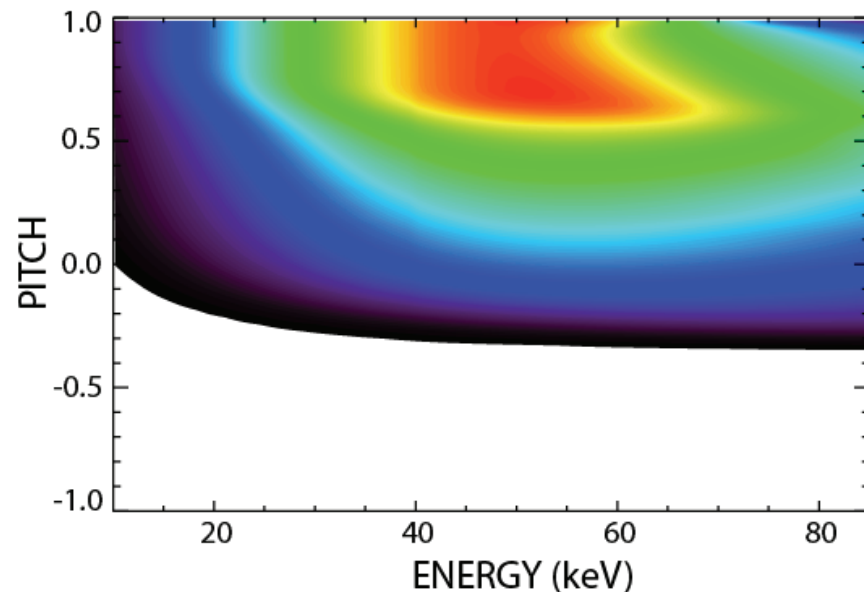- Both "active" (core) and "passive" (edge) signals
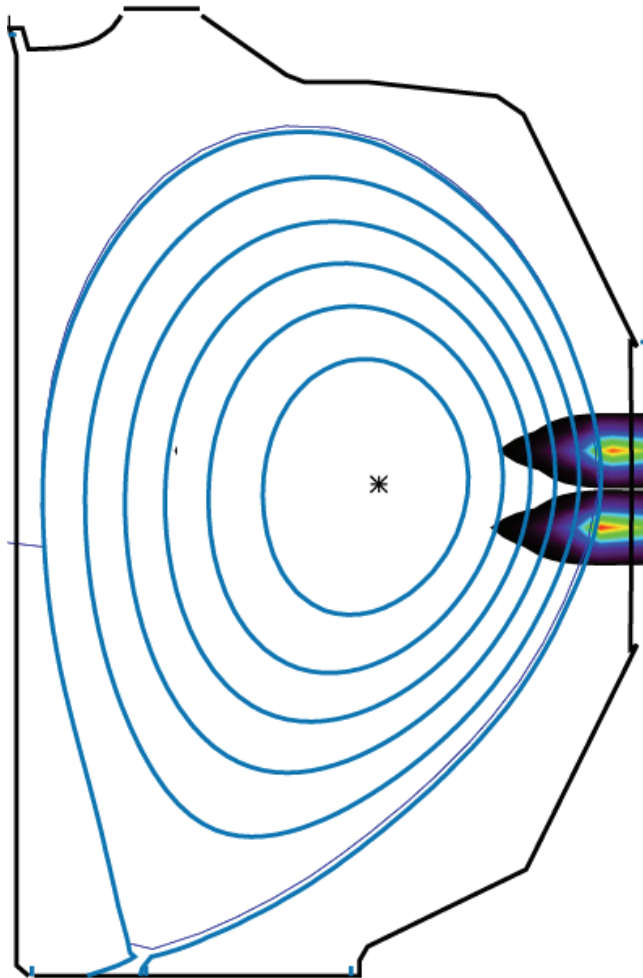

- XD9.004

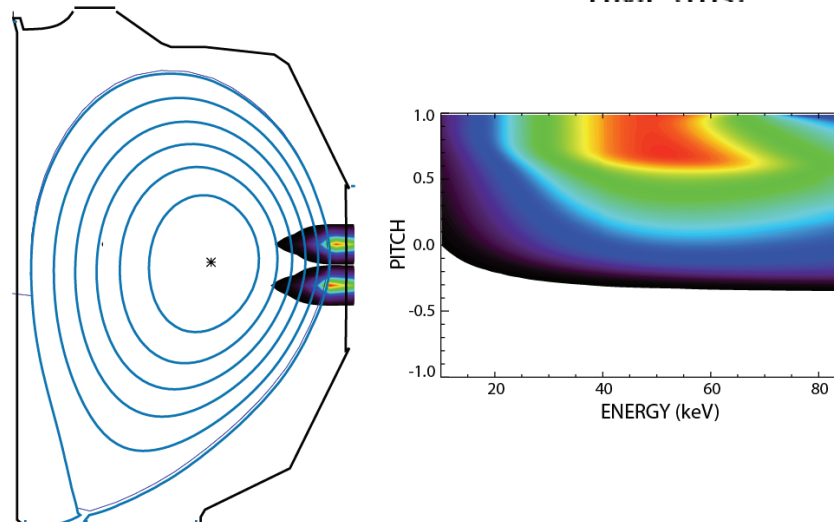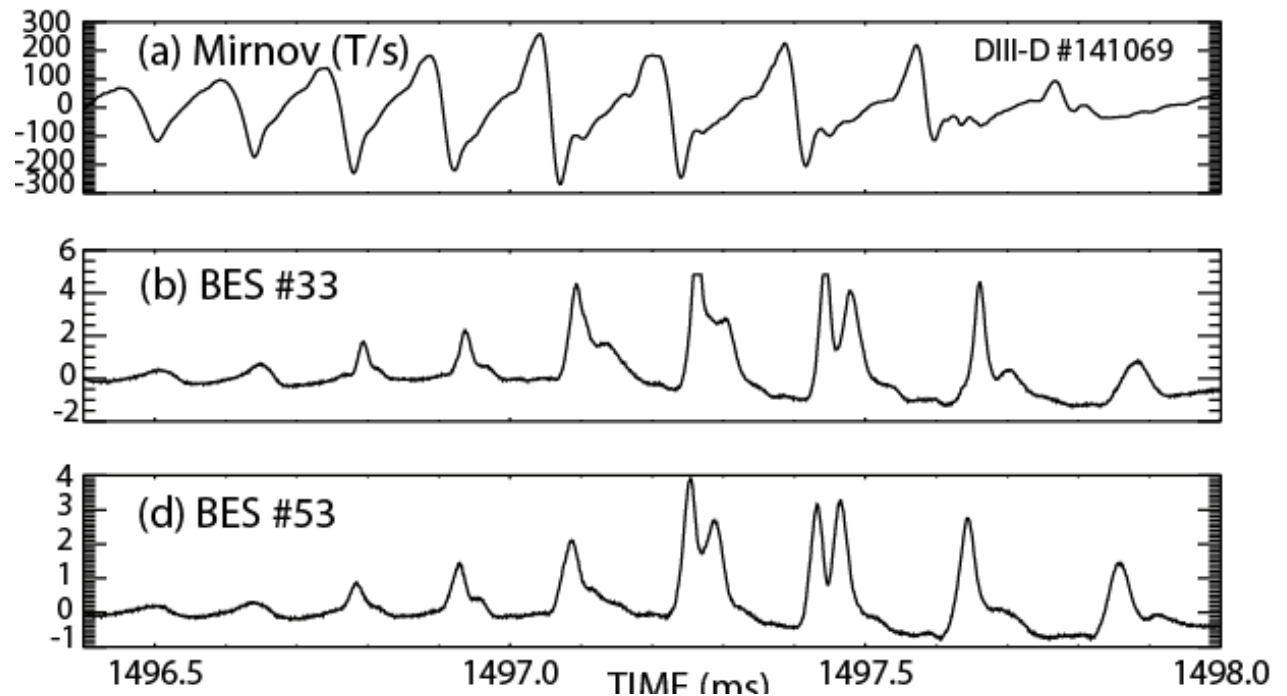# Solid-state Neutral Particle Analyzers Also Measure Beam-ion Losses

- **XD9.004**

Lost Fast Ions Cause Spikes In "BES" Signals

- "BES" normally measures fluctuations in beam emission

- Expelled fast ions produce fast-ion D_α (FIDA) light in edge

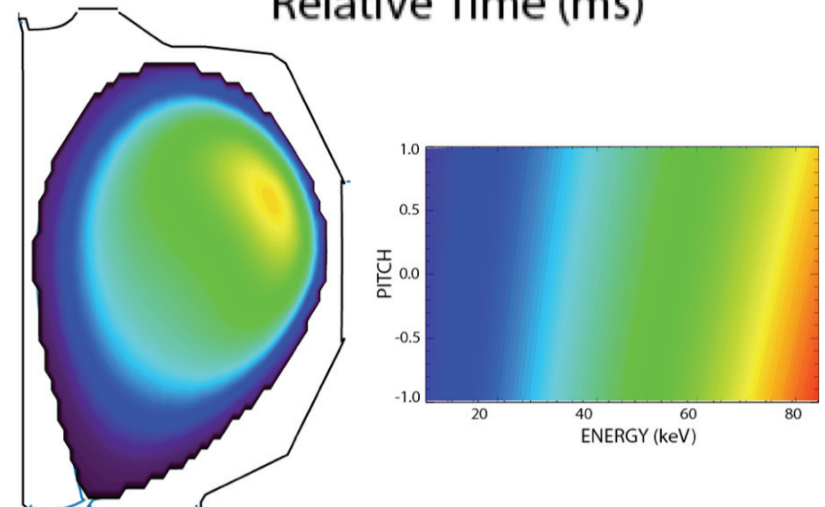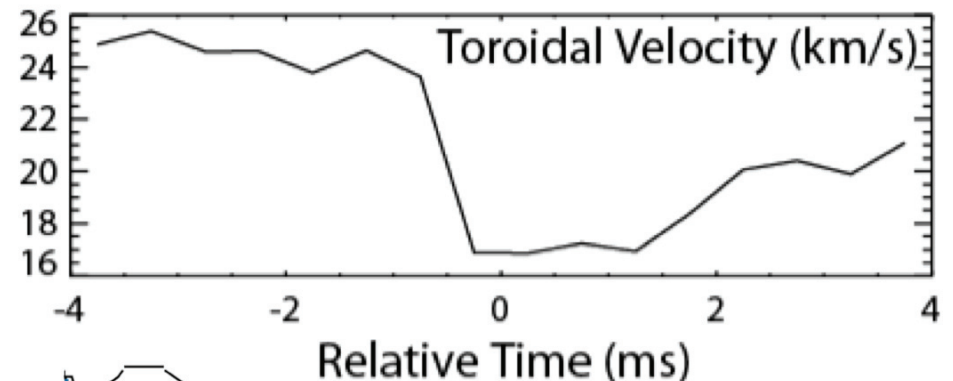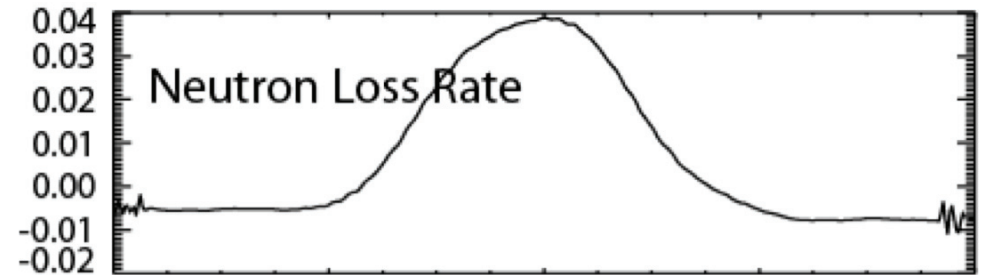# Lost Fast Ions Cause Spikes in "BES" Signals

- **No beam in sightline on this shot**

- **Lost FIDA signal larger than BES**

- **Can compromise eigenfunction measurements**
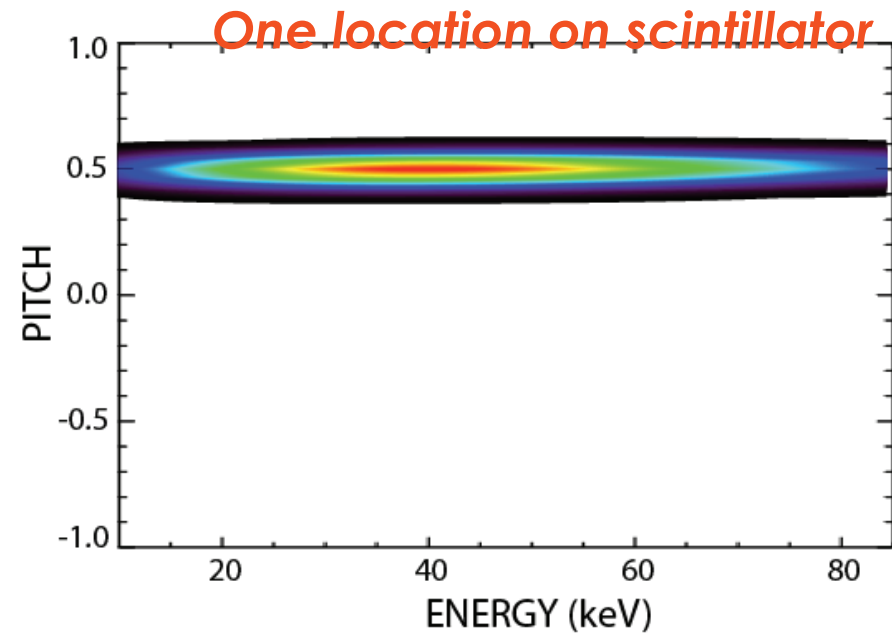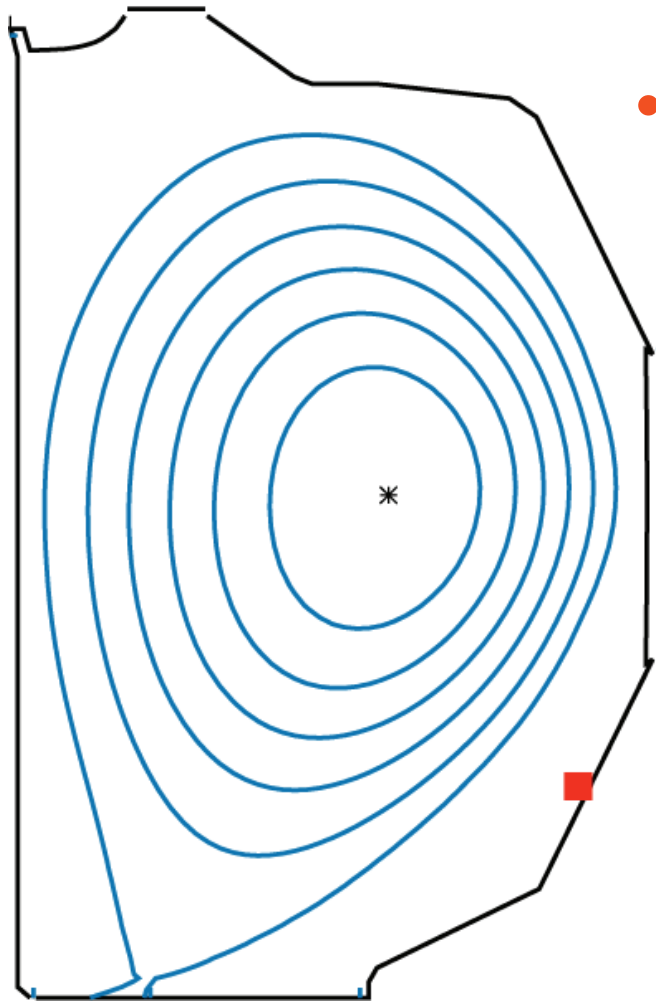
- **Heidbrink, PPCF, submitted**

Non-ambipolar Losses Cause Sudden Drop in Electric Field → Toroidal Rotation

- **Total fast-ion loss rate inferred from slope of neutrons**

- **Conditionally average 8 similar bursts**

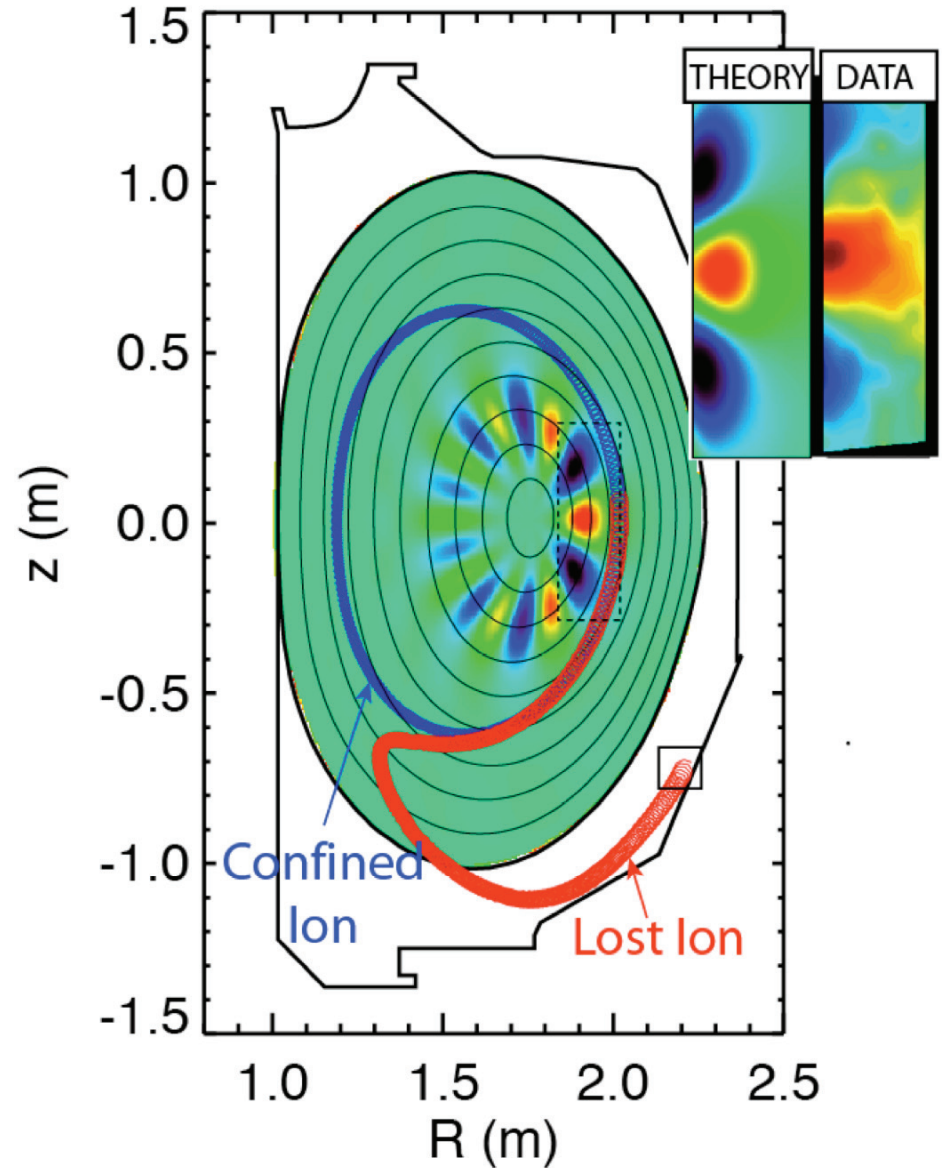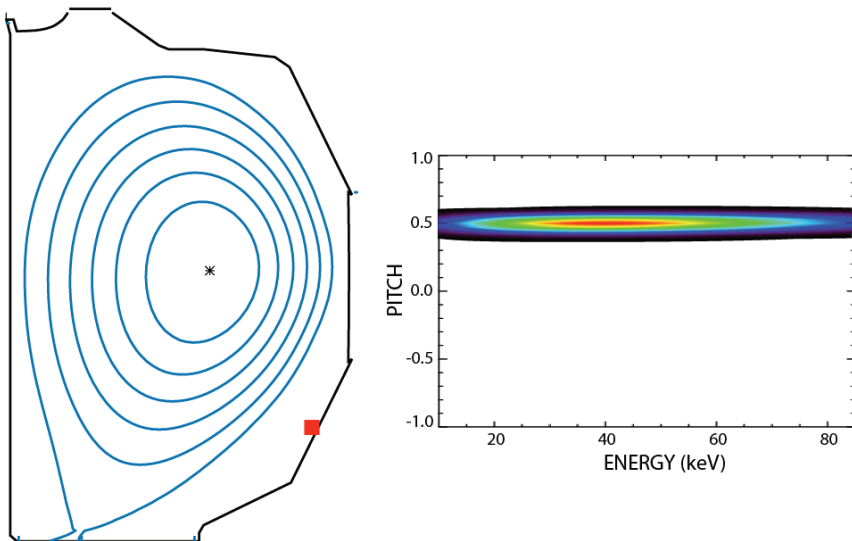- **CER channel near q=2 surface (where mode amplitude peaks)**

Fast-ion Loss Detector (FILD) Resolves Pitch

- **Scintillator loss detector**

- **UP9.55**

One location on scintillator

DIII-D
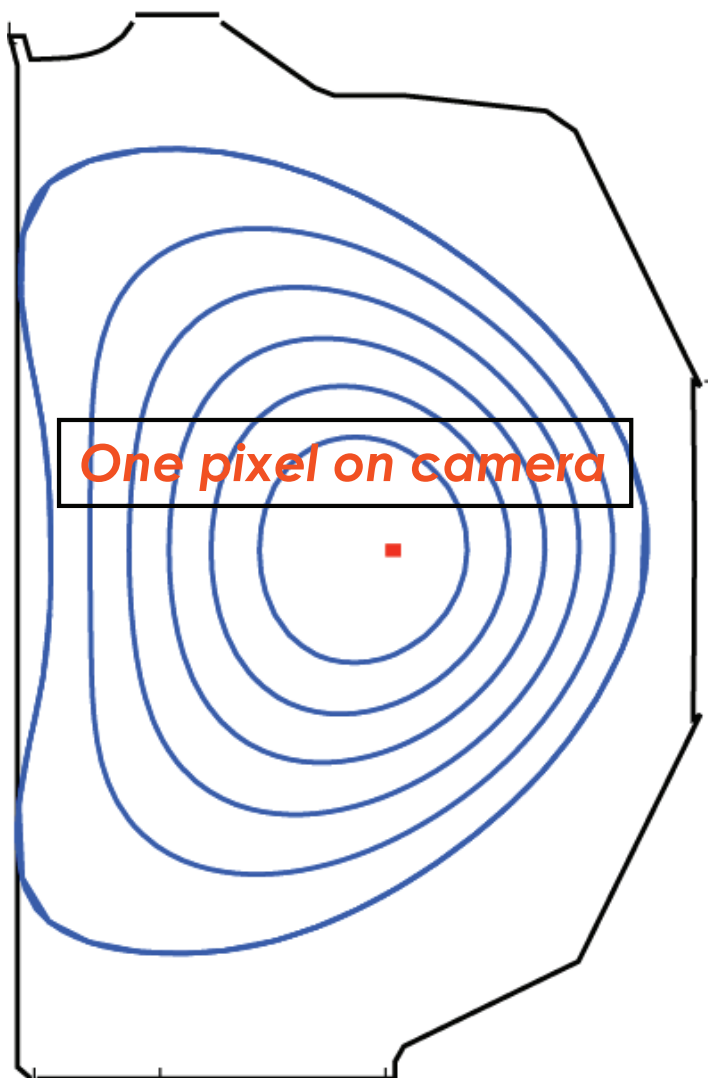NATIONAL FUSION FACILITY
SAN DIEGO

FILD Measures Coherent Losses from Alfvén Eigenmodes

- **ECE-imaging measures 2D structure of modes GI2.002**

- **FILD measurements establish loss mechanism TI2.001**

THEORY | DATA

Confined Ion

Lost Ion

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

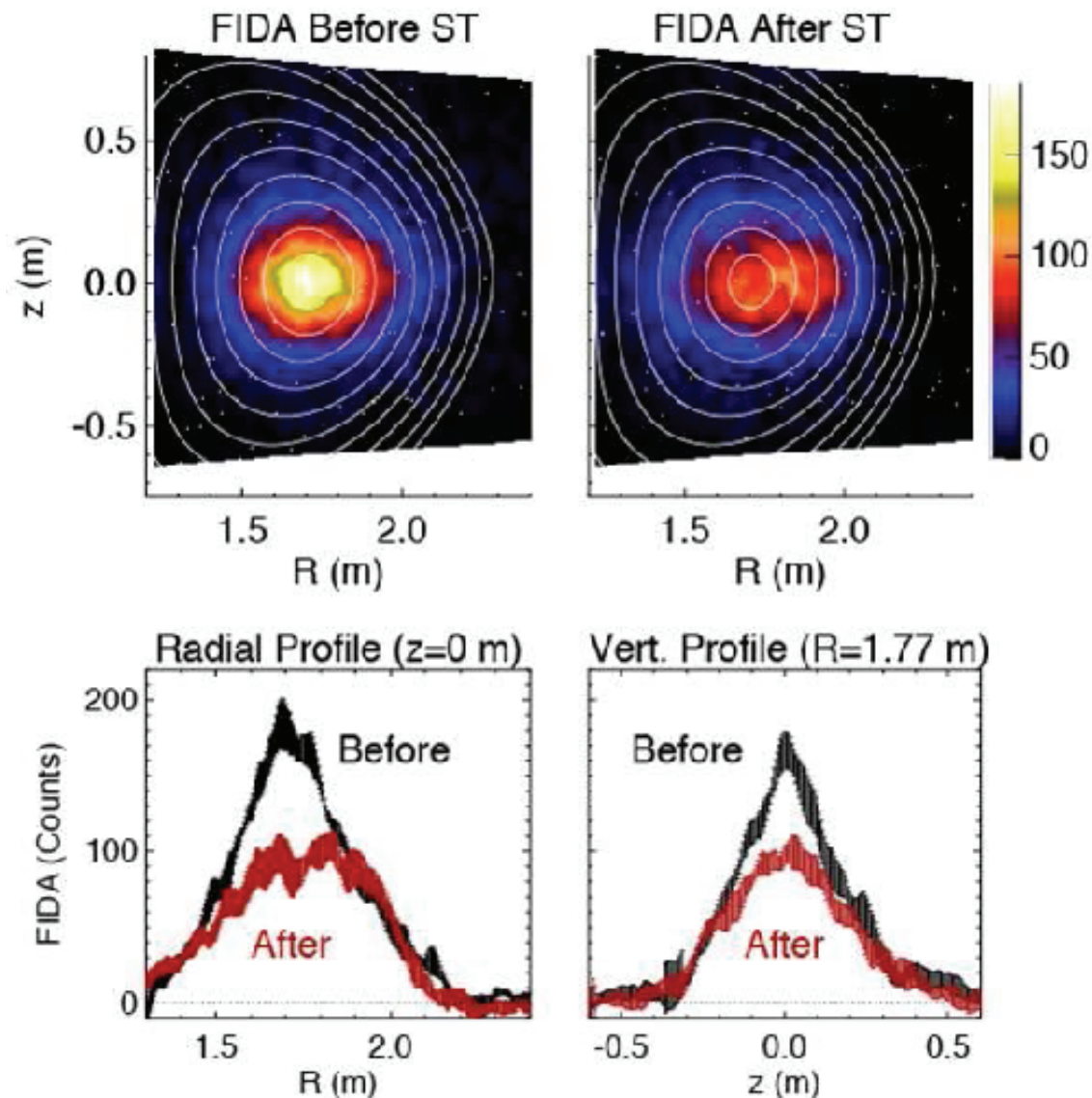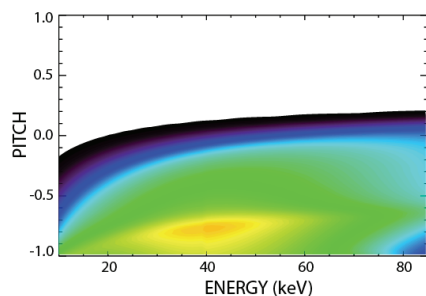# Sawtooth Crash Causes Large Reduction in Central Fast-ion Density

- **FIDA imaging* measures counter-going ions with excellent spatial resolution**
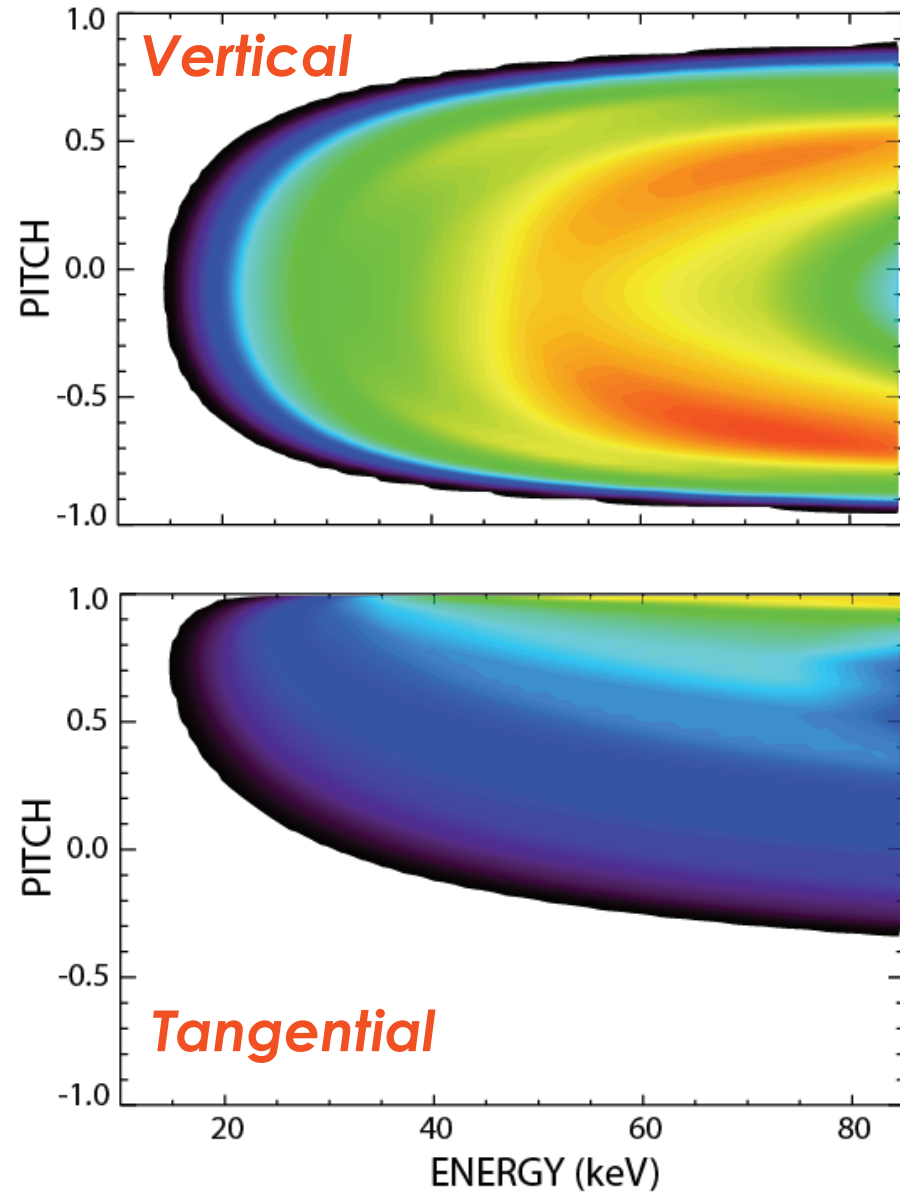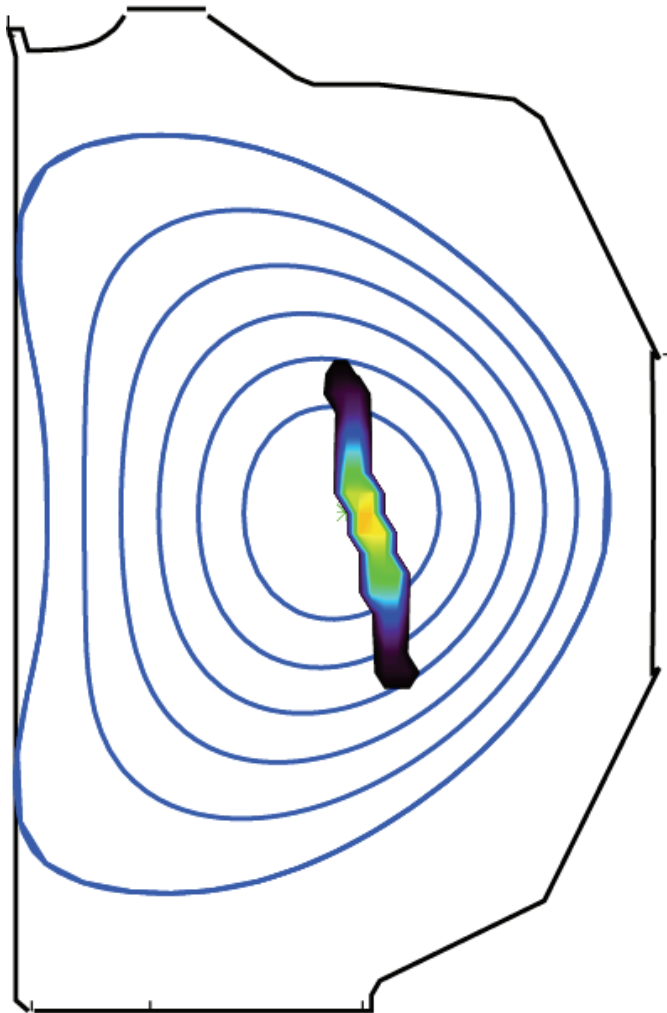
One pixel on camera

Van Zeeland, PPCF 51(2009) 055001.

Sawtooth Crash Causes Large Reduction in Central Fast-ion Density
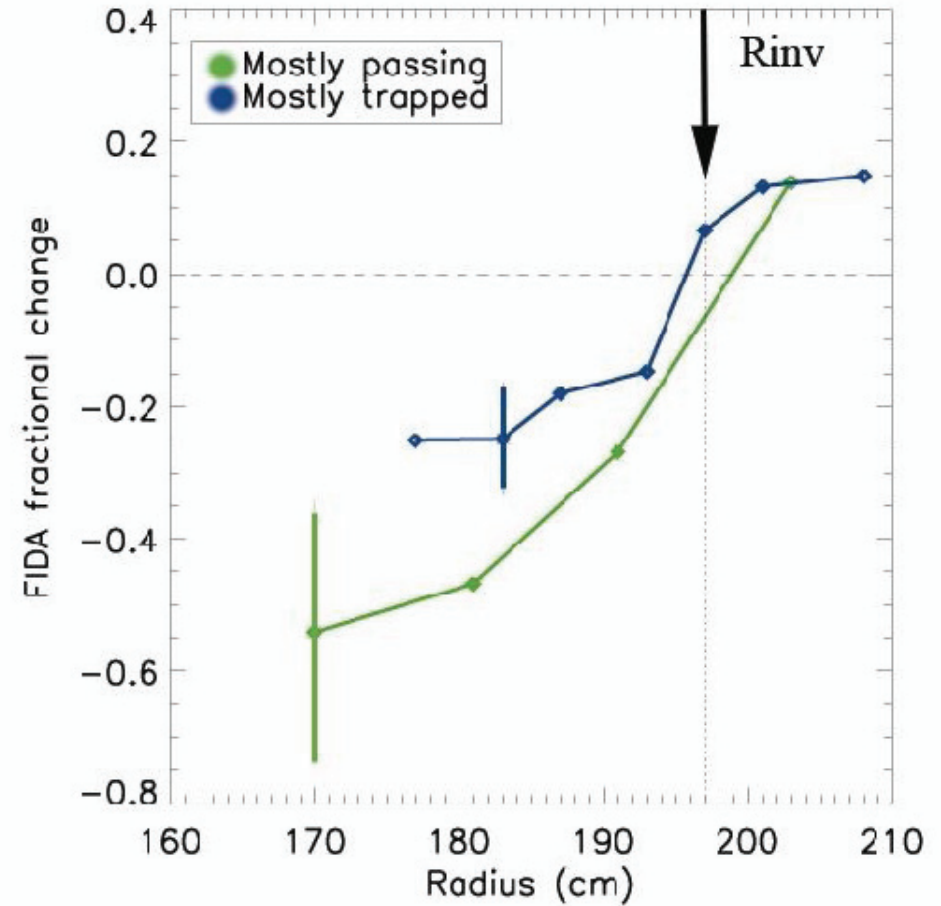
• UP9.56

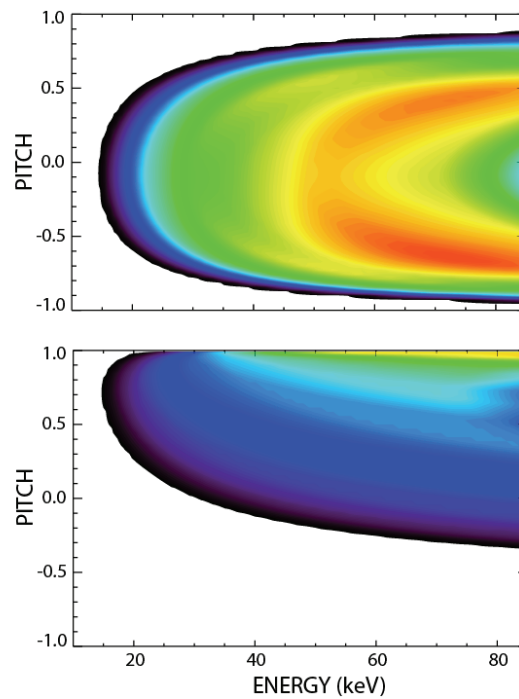B. Heidbrink/APS/November 2010
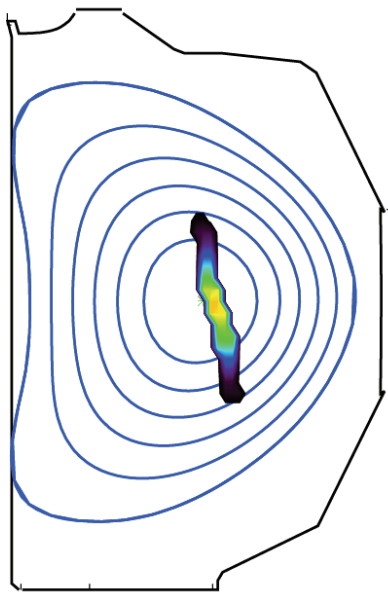
296-10/BH/rs

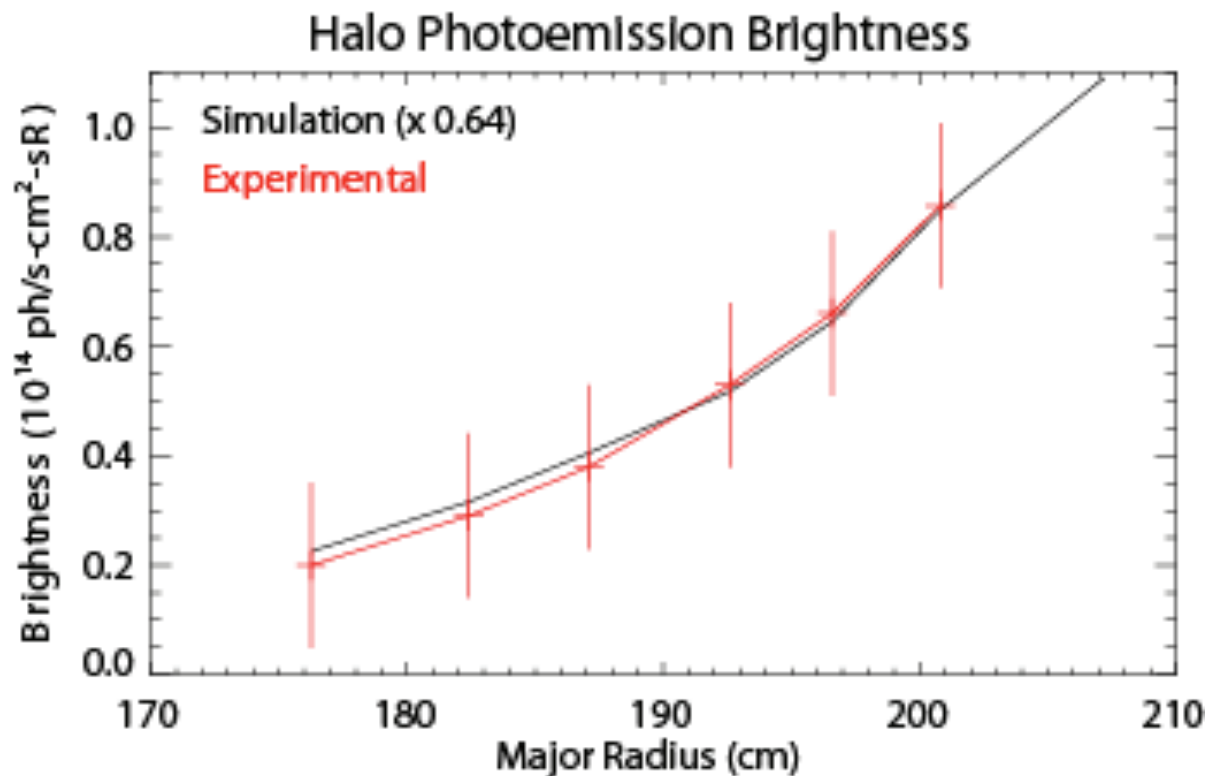# New Tangential FIDA View is More Sensitive to Passing Particles

New FIDA Views Show Passing Particles Are Affected More Than Trapped Particles
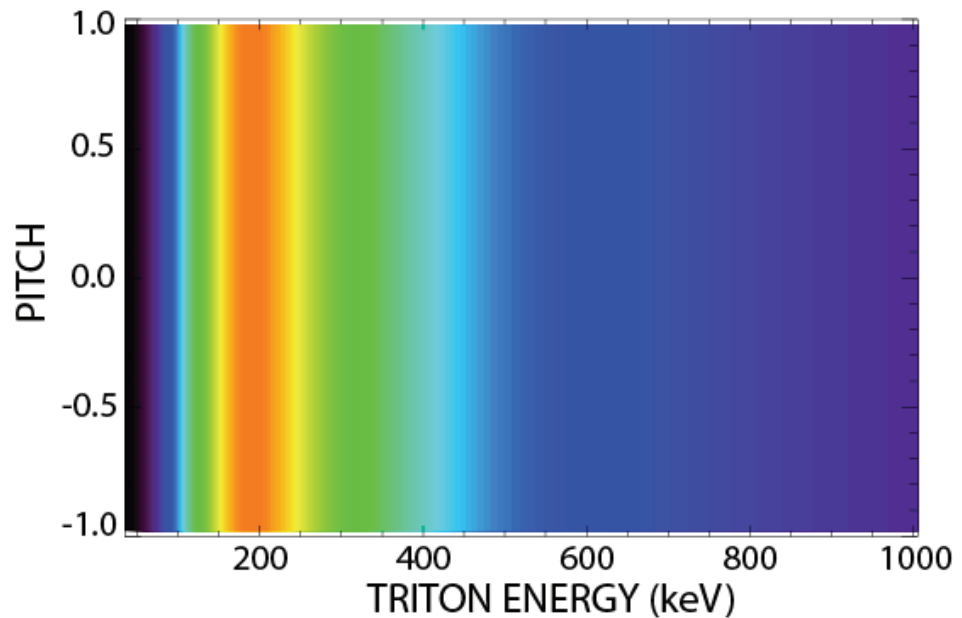
• UP9.56

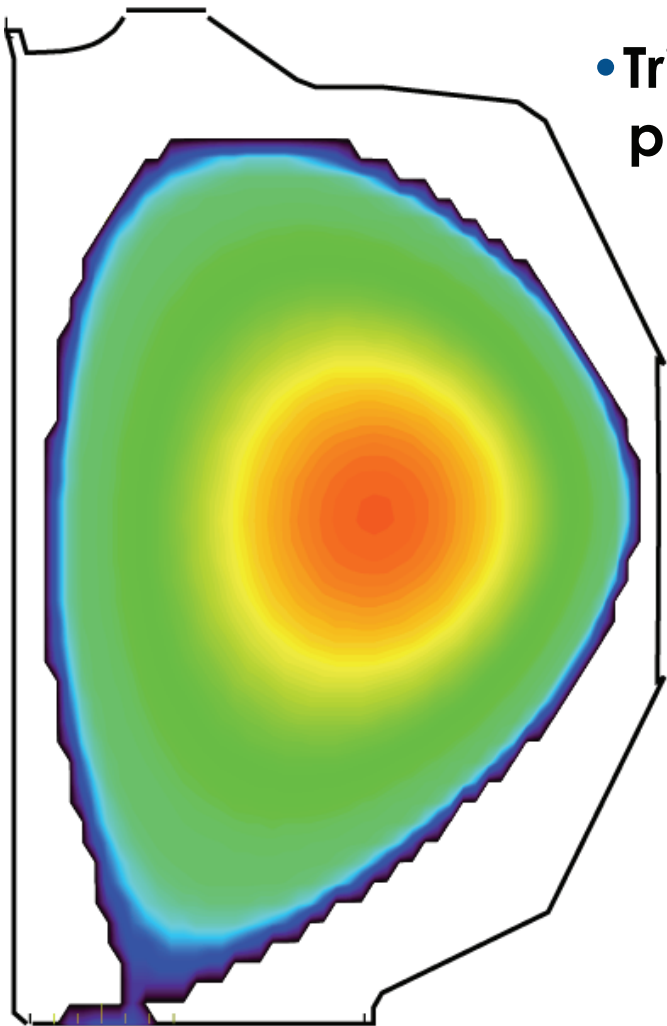# Measure Neutral Halo Density to Validate FIDA Simulations

Halo Photoemission Brightness

- **Sightlines miss injected neutrals**
- **Halo neutrals that surround beam produce signal**
- **Shape in excellent agreement but absolute magnitude is off**
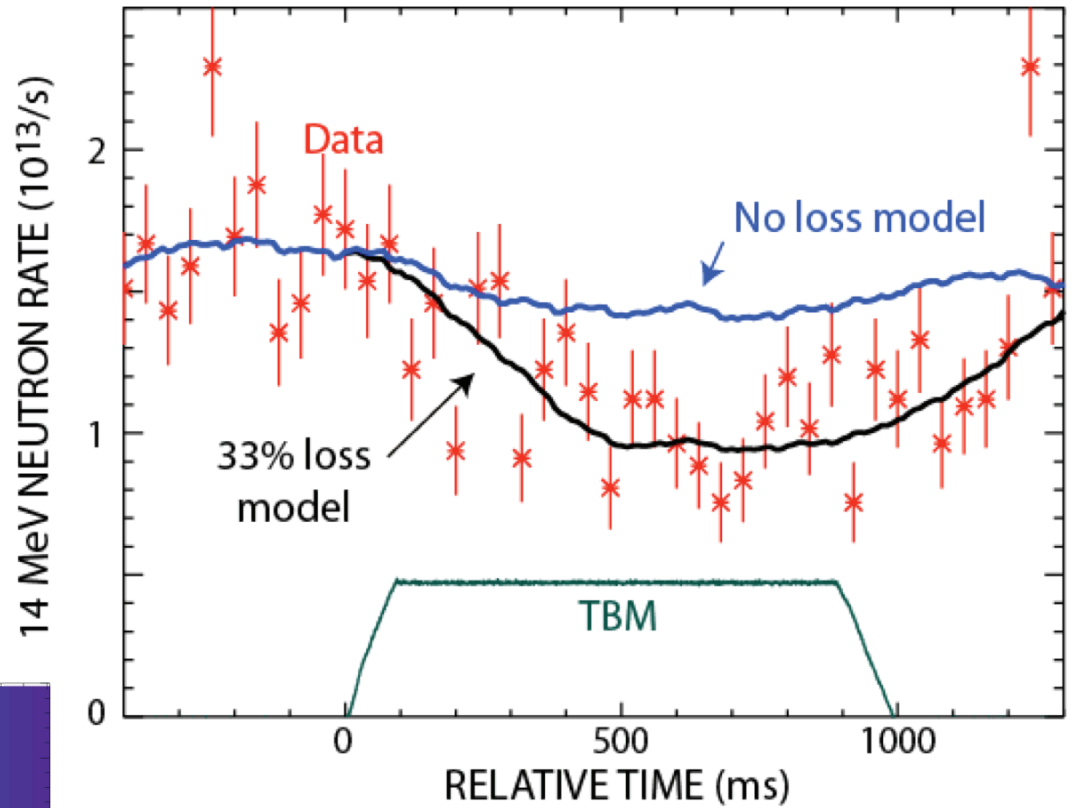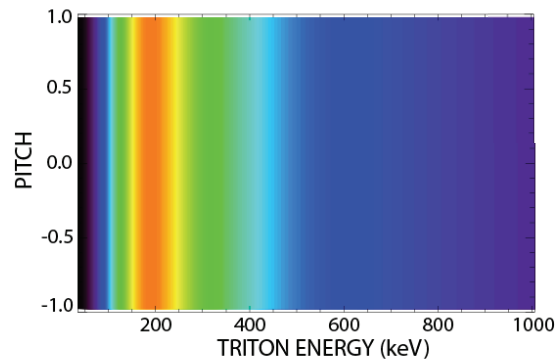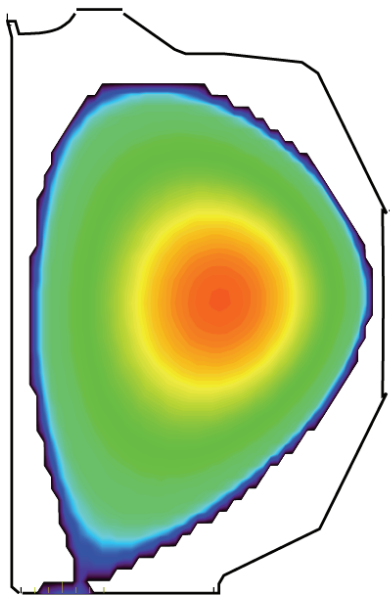- **GP9.64**

Measure 14 Mev Neutrons to Assess the Confinement of 1.0 Mev Tritons

- D-D reactions produce 1.0 MeV tritons

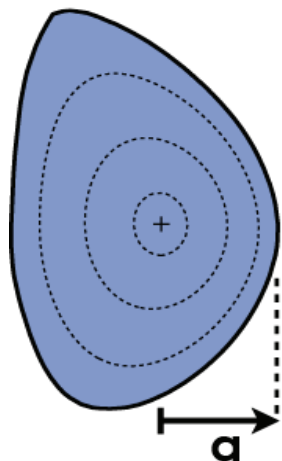- Tritons that reach peak of D-T cross section produce 14 MeV neutrons

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

Test Blanket Module (TBM) Causes Loss of 1.0 Mev Tritons
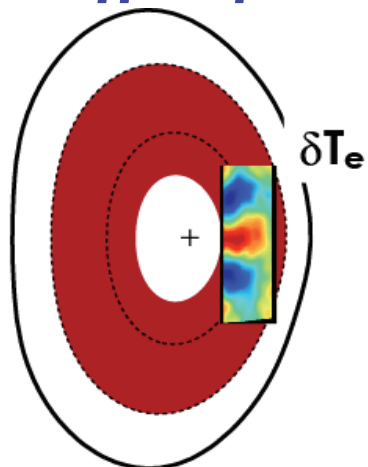
- **UP9.57**

More Details in Presentations Later this Week

$n=0,1$

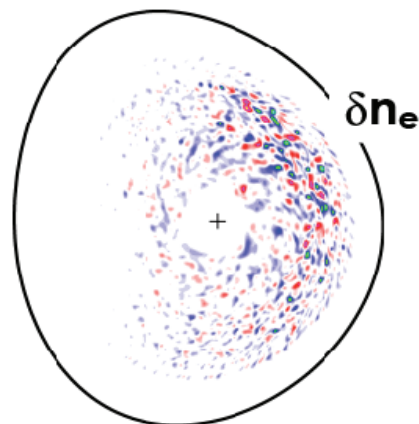- Sawtooth **UP9.56**
- Off-axis Fishbone **TI2.005**

$n \sim 4$

δT_e

Alfvén Eigenmodes **TI2.001, GI2.002**

δn_e

Drift Waves **UP9.54**

Diagnostics

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

Test Blanket Module UP9.57, X04.004

B. Heidbrink/APS/November 2010

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

UCIrvine University of California, Irvine