

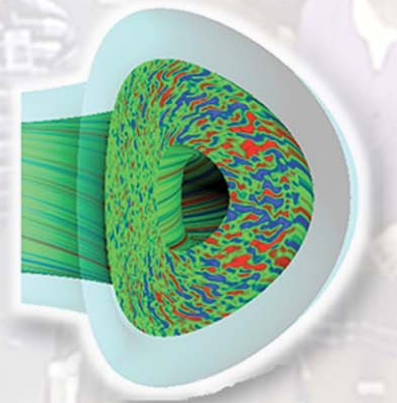
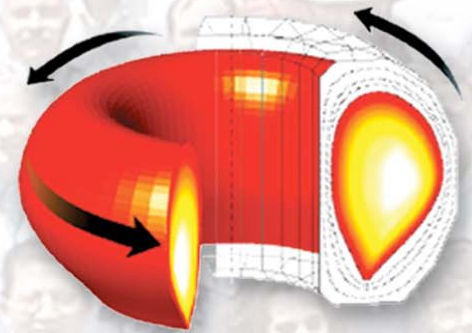
Diagnostic Plans

by
R. Boivin



Presented to
DIII-D Program
Advisory Committee

January 31–February 2, 2006

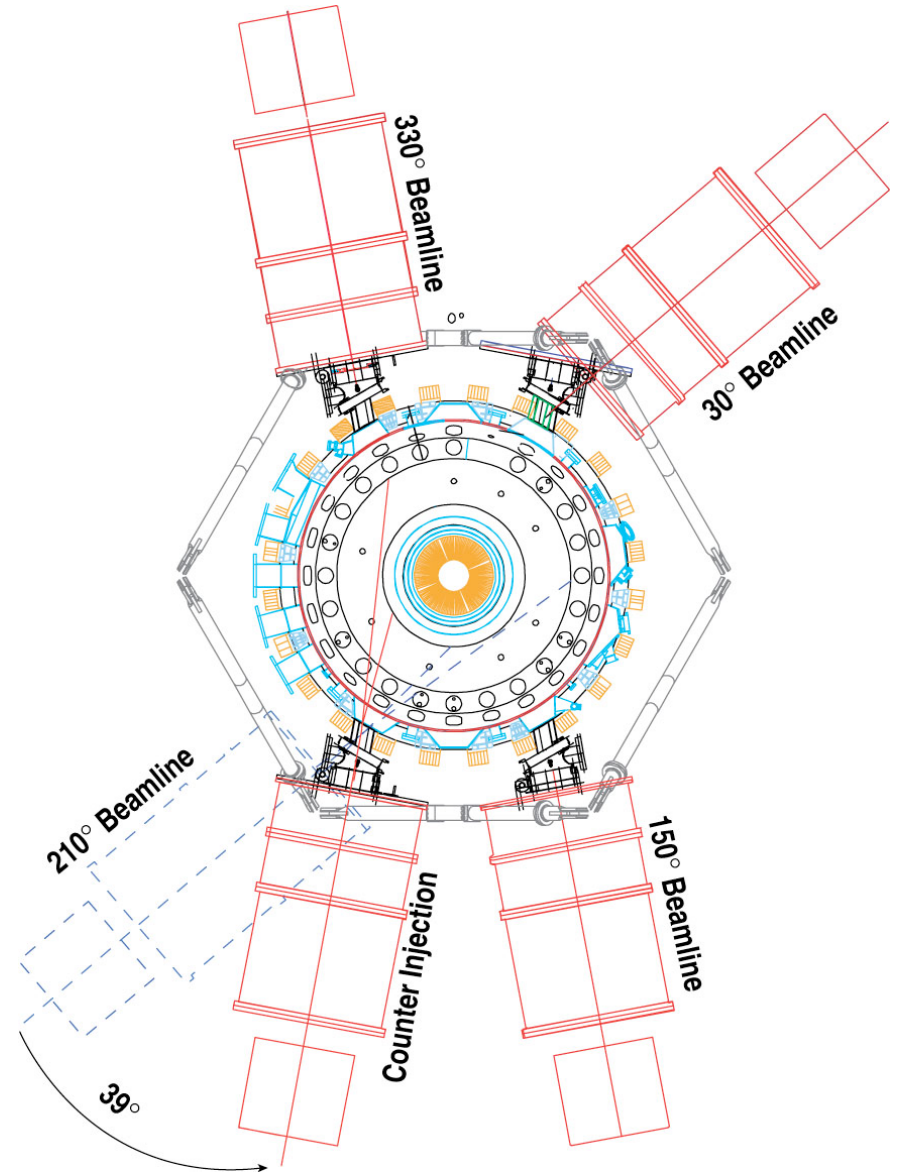


Introduction - Outline

- The LTOA has been a great challenge and an exciting opportunity
- Virtually all systems have been impacted, the wide majority with significant upgrades
- Final challenge is to bring all those changes to “production” for the physics campaign
- Opened up many opportunities for ITER specific R&D
- **OUTLINE**
 - Review Impacts from beam rotation and divertor mods
 - Cover all significant changes
 - Details given in following talks

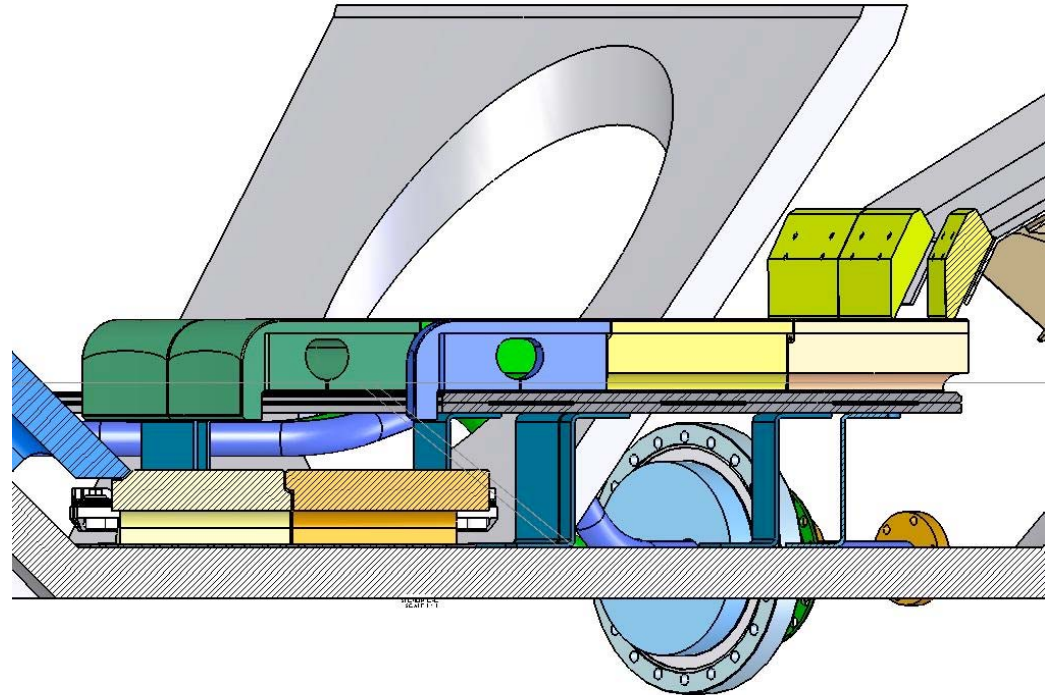
210 NB rotation - Successful relocation - Upgrade

- FIR scattering ✓
- Neutron station ✓
- ECE ✓
- VUV camera ✓
- DISRAD II ✓
- Active NPA ✗



Divertor Mods - Successful Implementation

- Divertor Thomson ✓
- Langmuir Probes ✓
- Magnetics ✓
- DiMES ✓
- X-pt scanning probe ✓
- Thermocouples ✓
- Halo Current Monitor ✓
- Tile Current Monitor ✗



Many Additional Significant Upgrades have been achieved during the LTOA

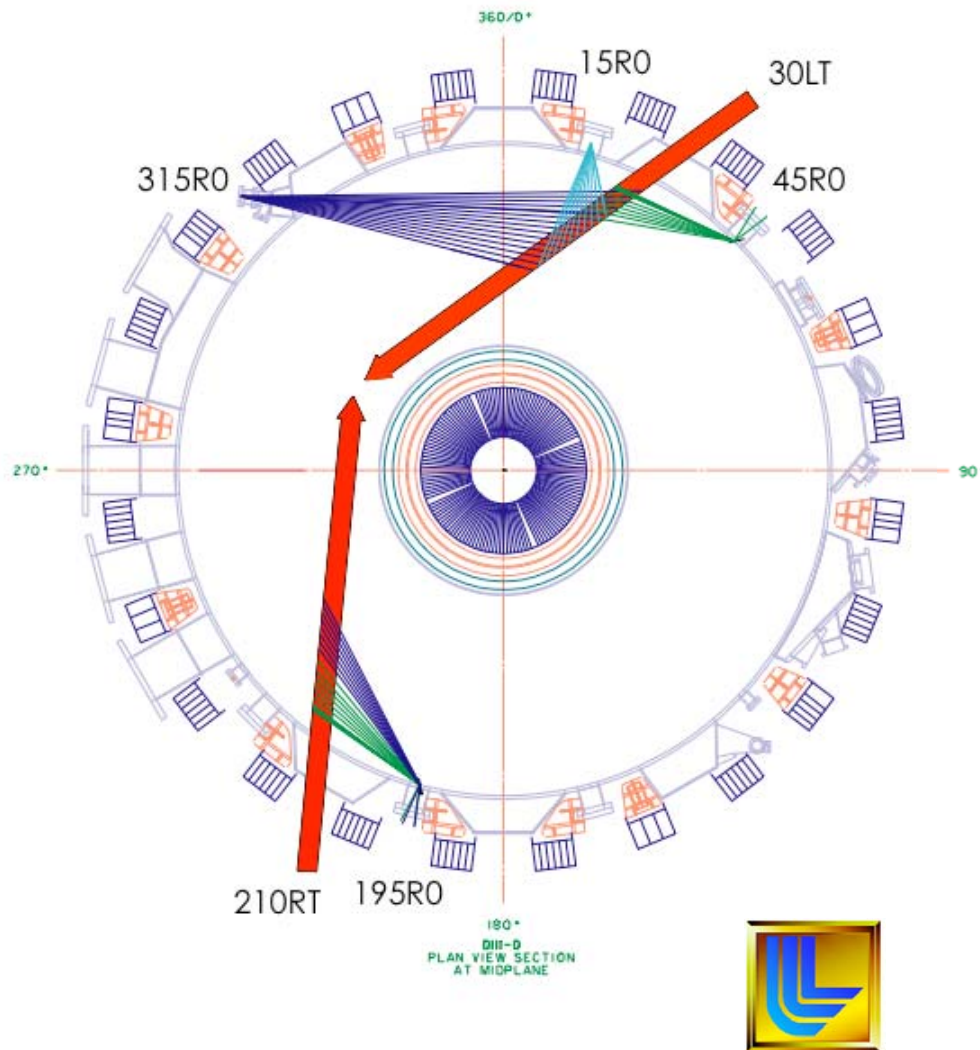
- **New Systems**

- New counter MSE system (24 chords)
- New counter CER system (8 chords)
- New poloidal SXR (2 systems, 60 chords)
- BES upgrade (double high-sensitivity chords)

- **ITER diagnostic support (examples)**

- New Current Profile Diagnostic (B Stark)
- Quartz Micro-balance
- Significant development in fast ion diagnostics
- Mirror testing

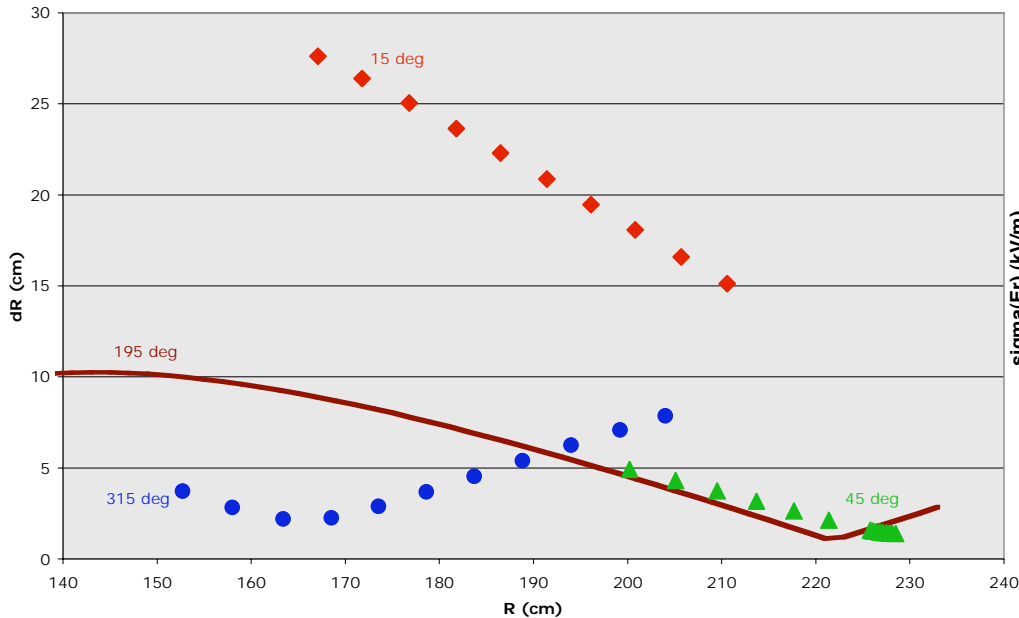
24 Additional MSE Channels Viewing 210 Beam will Provide Improved EFIT



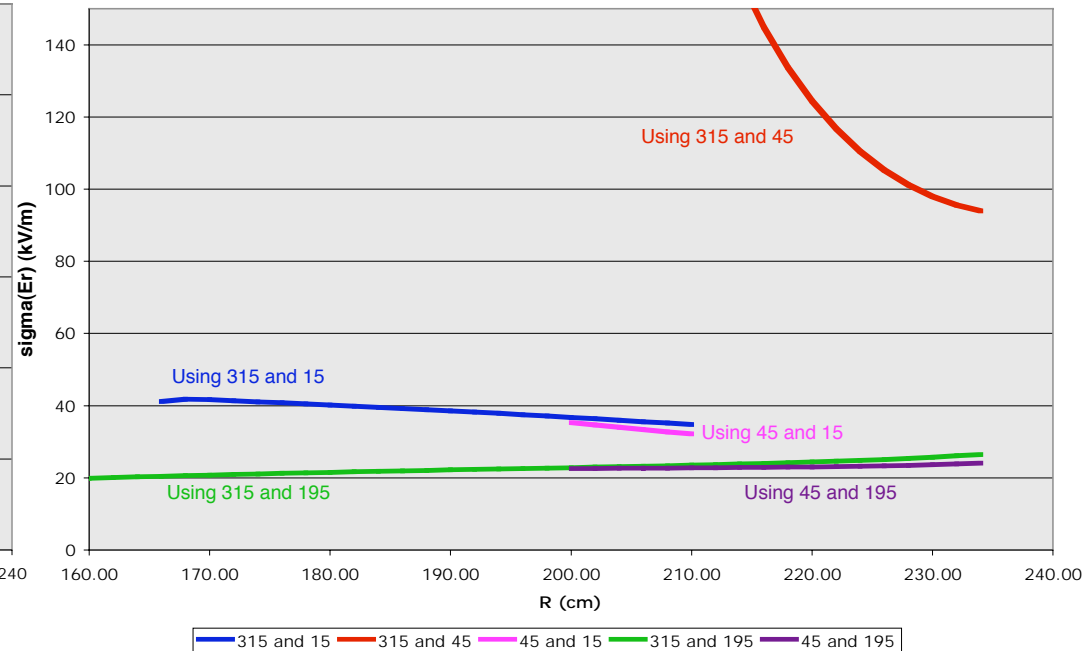
- **8 New Core**
 - $(1.675 \leq R \leq 2.00 \text{ m})$
- **16 New Edge**
 - $(2.00 \leq R \leq 2.28 \text{ m})$
 - All operational in FY06
- **Improvements:**
 - $\delta R \sim$ factor of 3
 - $\sigma(E_r) \sim$ factor 2 in core, factor of 5–6 in edge
 - $\sigma(B_z) \sim$ about 20–30%

The New MSE System Would Bring New Tools in Physics Understanding

Radial Resolution of MSE Sightlines



Er uncertainty including the new array at 195 degrees



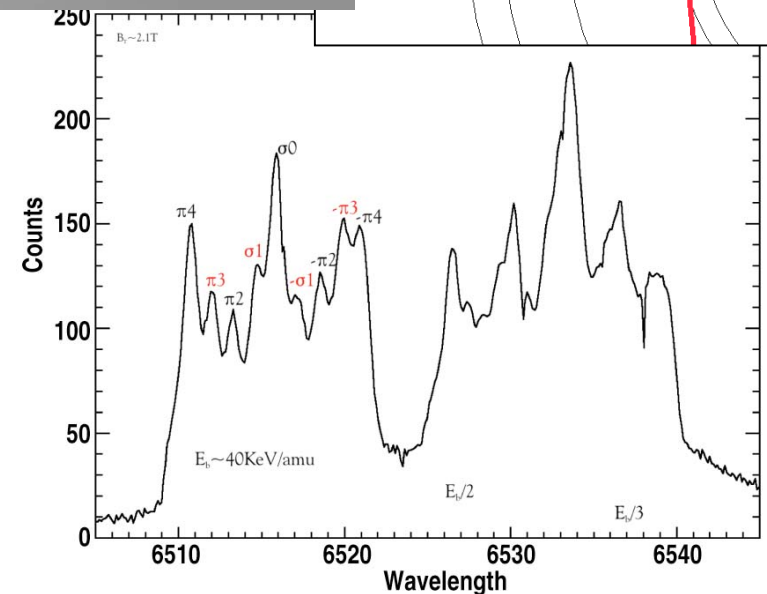
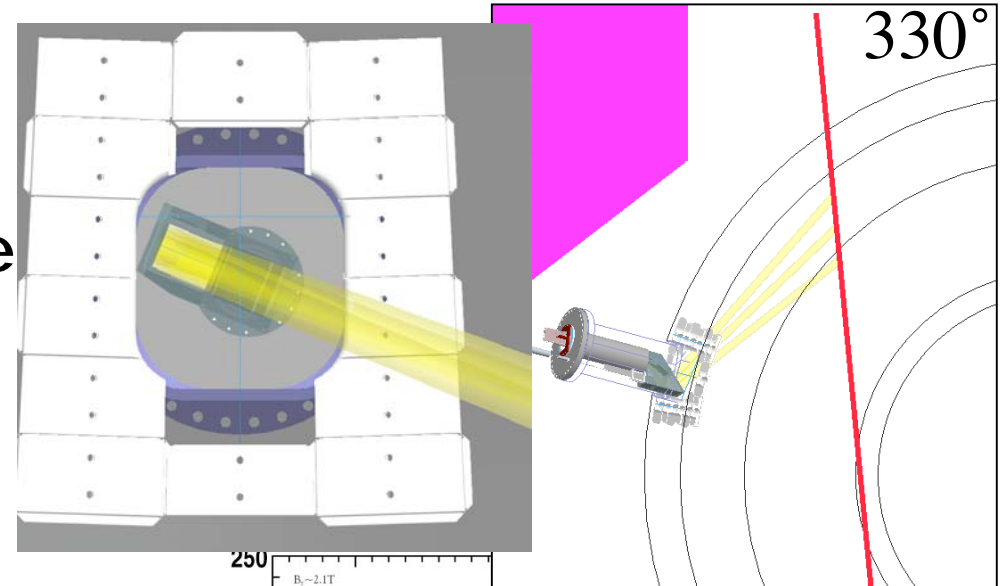
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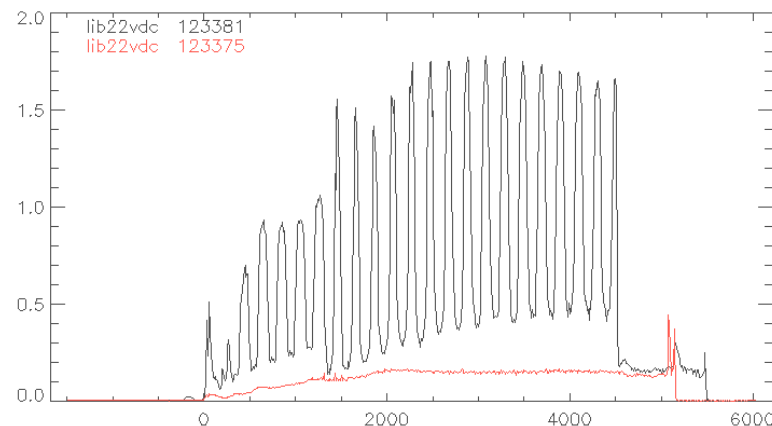
New Technique: $|B|$ and B_θ/B_T from Stark Split D_α Emission

- $|B|$ gives information on internal field structure
- B_θ/B_T can be obtained from the σ_1 and π_3 Stark components
- Expected sensitivity:
 - $|B| \sim 0.07$ T ($0.004B_T$)
 - $B_\theta/B_T \sim 0.01$ (2%)
 - Pitch angle $\sim 0.6^\circ$
- Spatial resolution $\sim 1.5\text{--}5.0$ cm
- Student thesis work (N. Pablant)
- ITER relevant diagnostic



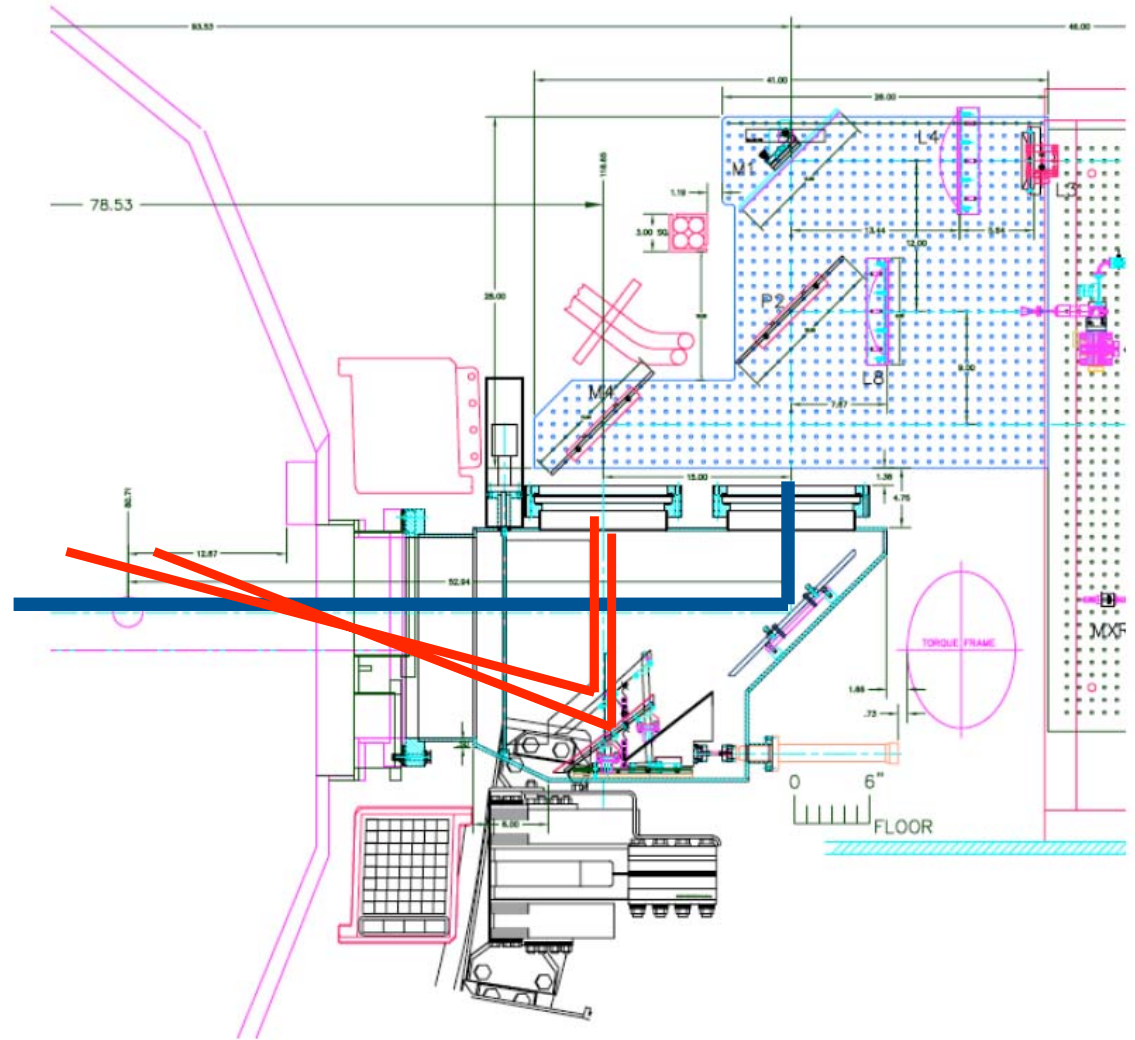
Lithium Beam System: Increase S/N and Reliability

- **Continue to increase S/N and reliability**
 - Differential pumping in beamline to improve beam transmission
 - Mirror replacement
 - Replace some (ancient) power supplies
 - Manufacture new β -eucryptite for ion sources
 - Addition of a viewing dump at 75R+1 (front of bolo)
- **Implement capability to modulate beam electrostatically**
 - Improved background rejection-reduces error bars



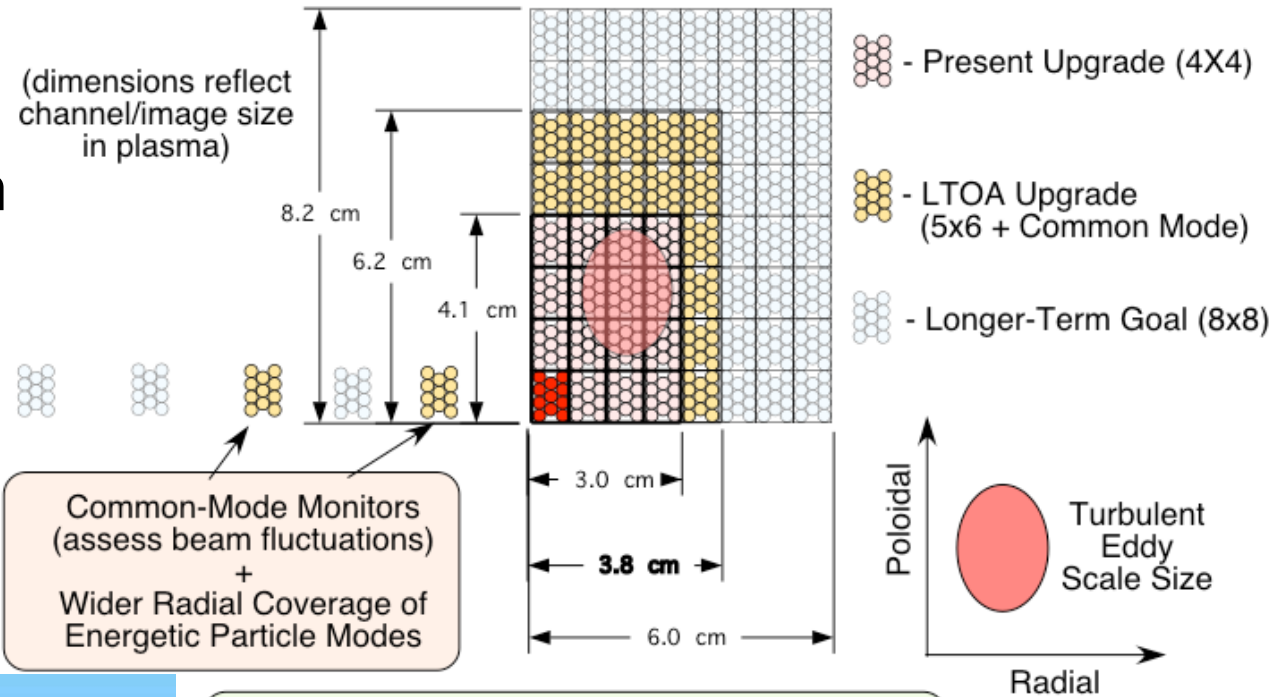
The Relocation of the FIR Scattering System will Also Bring Additional k Coverage and More Flexibility

- FIR scattering measures low ($0-1 \text{ cm}^{-1}$) and intermediate k ($5-15 \text{ cm}^{-1}$) density turbulence
- mm-wave backscatter measures high k density turbulence ($\sim 40 \text{ cm}^{-1}$)
- Add ability to scan radial position of scattering volumes
- Add remote control capability to k scan



The BES System is Being Significantly Upgraded

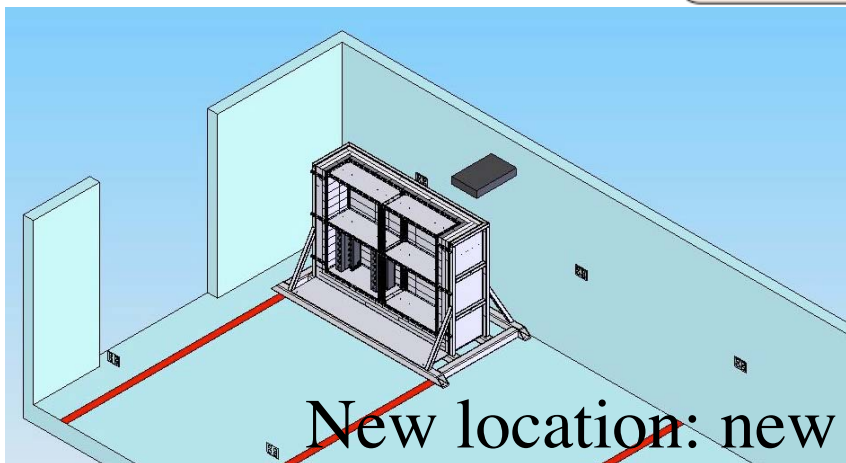
New fibers and optical systems allow for much better S/N ratio (improved by more than a factor of 30).



- Improve sampling of 2D correlation function
- Shot-to-Shot Radial Scan Capability



Addition of 16 high sensitivity channels



New location: new lab

Many Other Diagnostics Are Being Upgraded for Turbulence Characterization

- **Phase Contrast Imaging**

- Continue development of rotating mask (pitch angle discrimination)



- **Correlation reflectometer system:**

- New compact solid-state sources replacing BWO tubes
- Utilize new PPPL receiver to expand frequency coverage for edge pedestal and ITB measurements



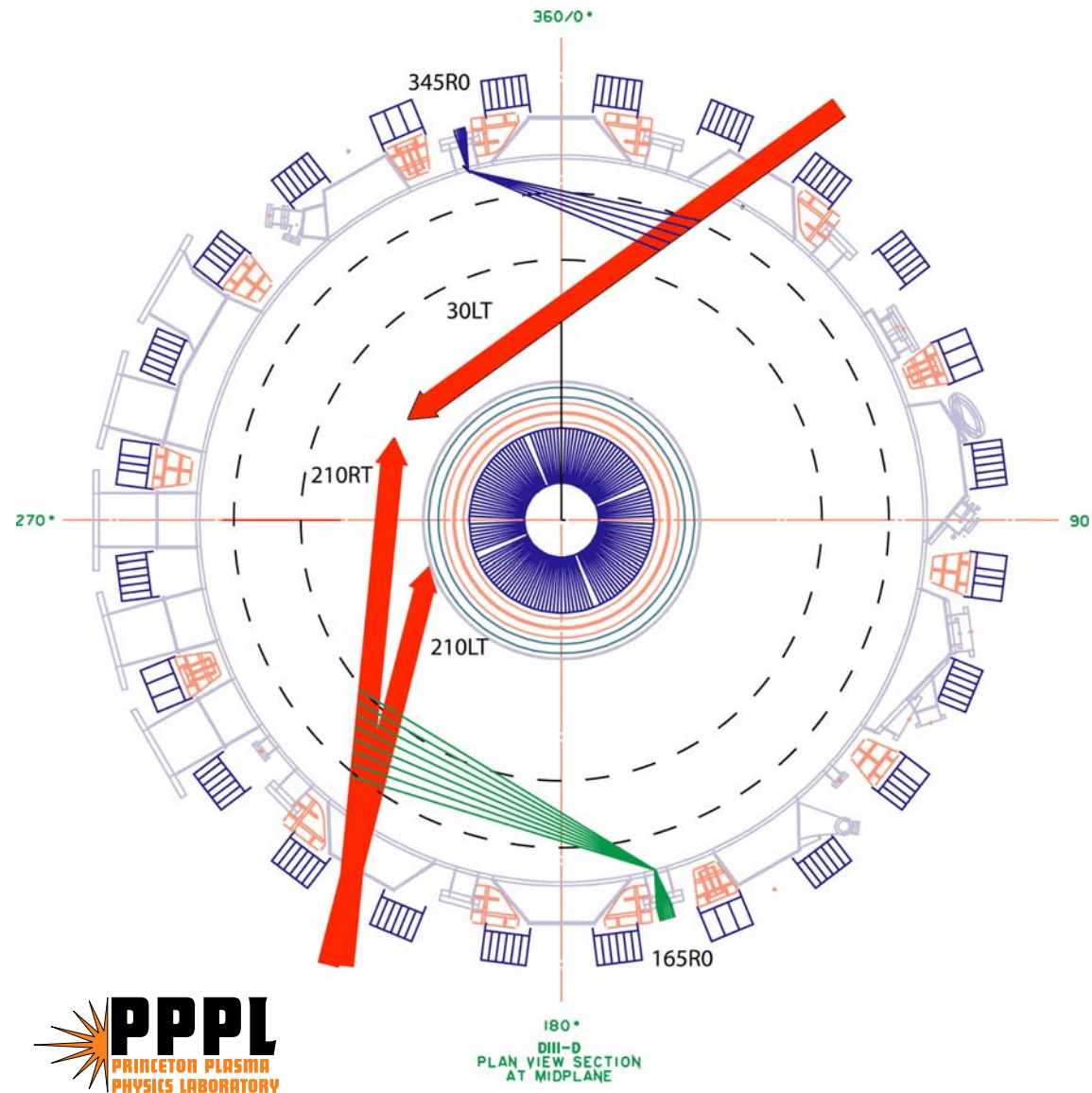
- **Replacement of fixed frequency homodyne reflectometer channels:**

- New quadrature systems with additional measurement capabilities successfully tested in 2005 (shared with profile reflectometer, had to choose which measurement)
- New permanent, non-shared, installation in 2006, starting with 65 GHz channel, more channels to be added over time.

- **Microwave scattering (R+1 port) available**

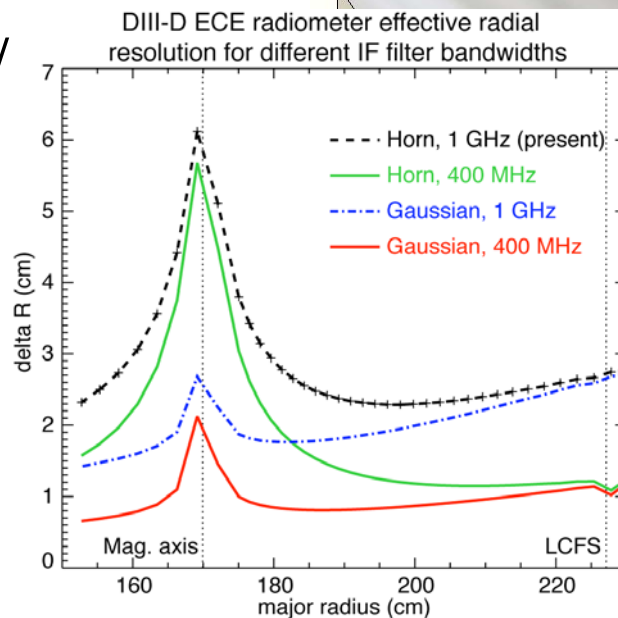
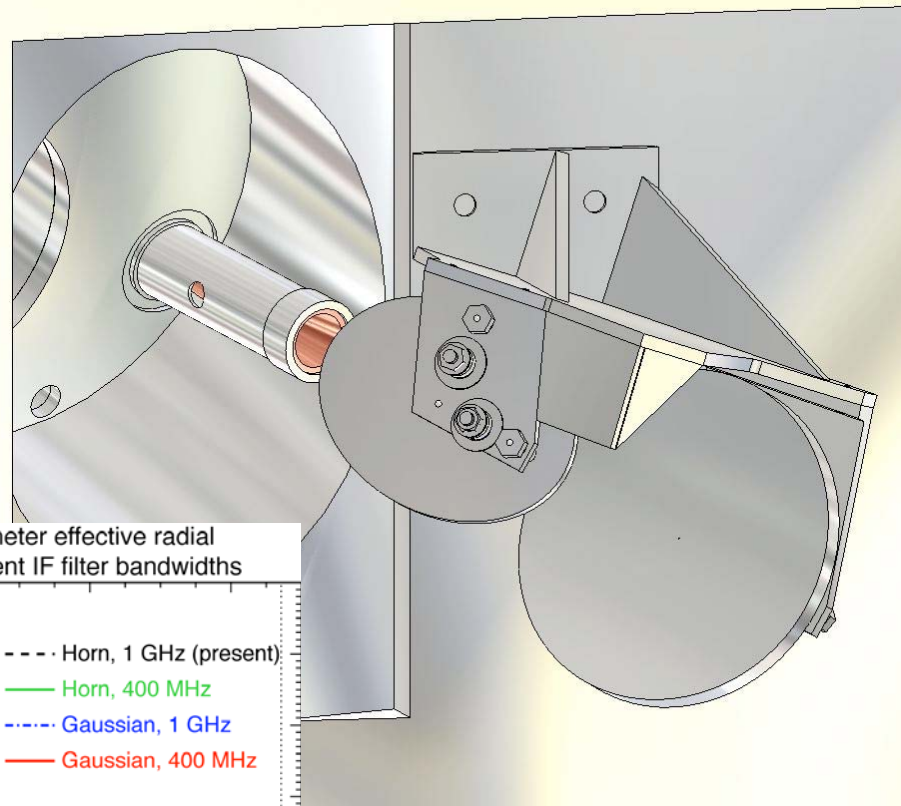
Counter-CER: Add Eight New Tangential Views, Looking at Counter Beam Line- Better rotation characterization

- Comparing views looking at co vs. counter beams:
 - Difference of two views ~2x cross-section correction → HUGE!
- View 210 beams from 165R0
 - Essentially duplicate central tangential system viewing 30LT from 315T0 and 345R0
- New views will couple to new Sarnoff CCD detectors



Relocated ECE Antenna Brings in Better Resolution and Time Response

- ECE radiometer upgrade
 - Δz , $\Delta\phi$ determined by antenna pattern, ΔR by IF bandwidth
 - Shown is typical radial coverage at $B_T = 2.0$ T
 - 400 MHz filters already installed for chs 1-16



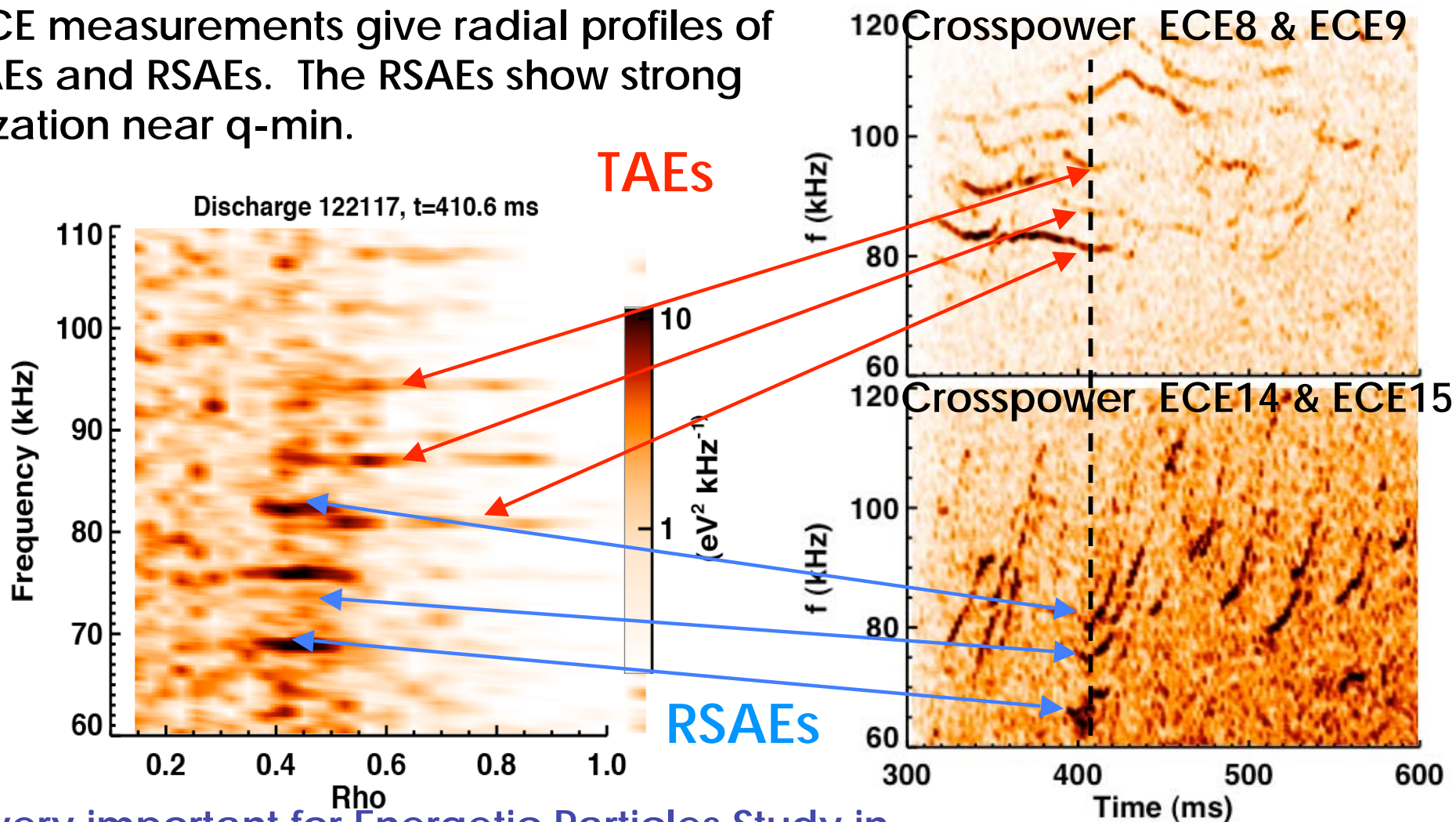
University of Maryland



Transport

The ECE Upgrade Allows New Insights into Energetic Particles Physics

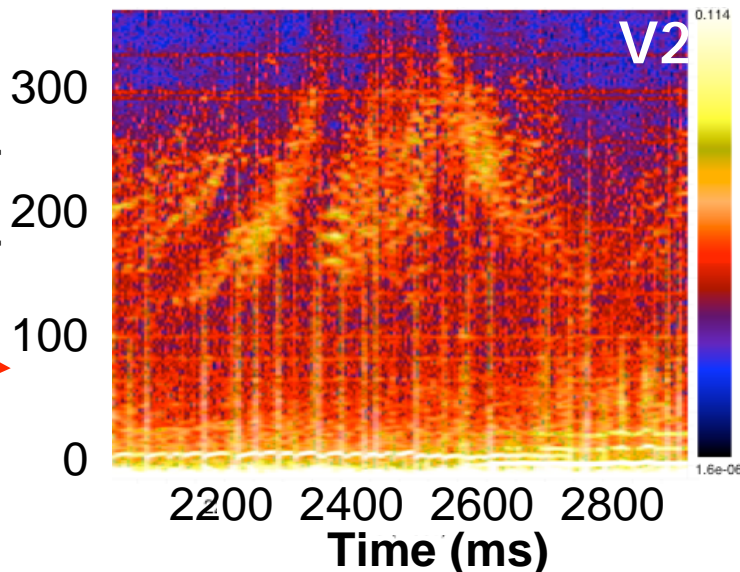
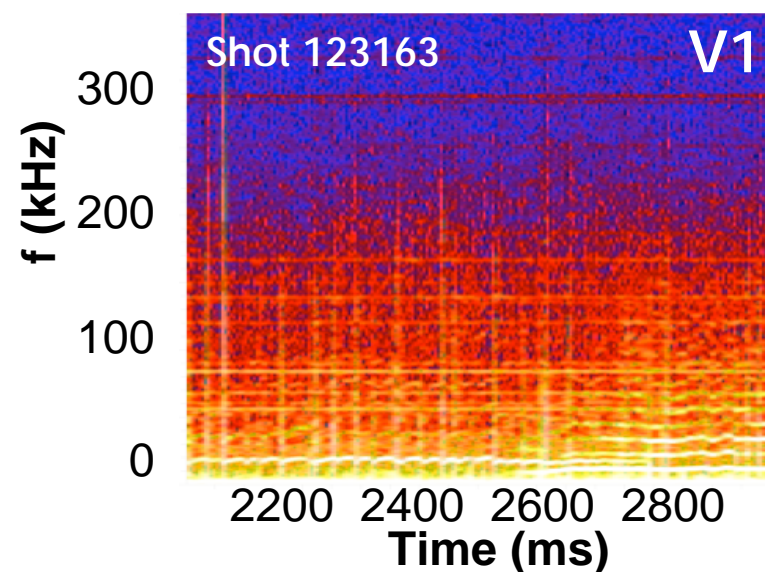
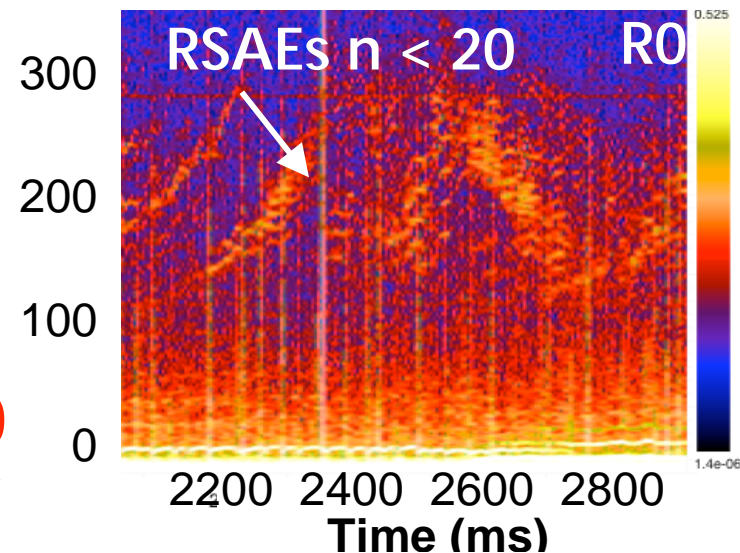
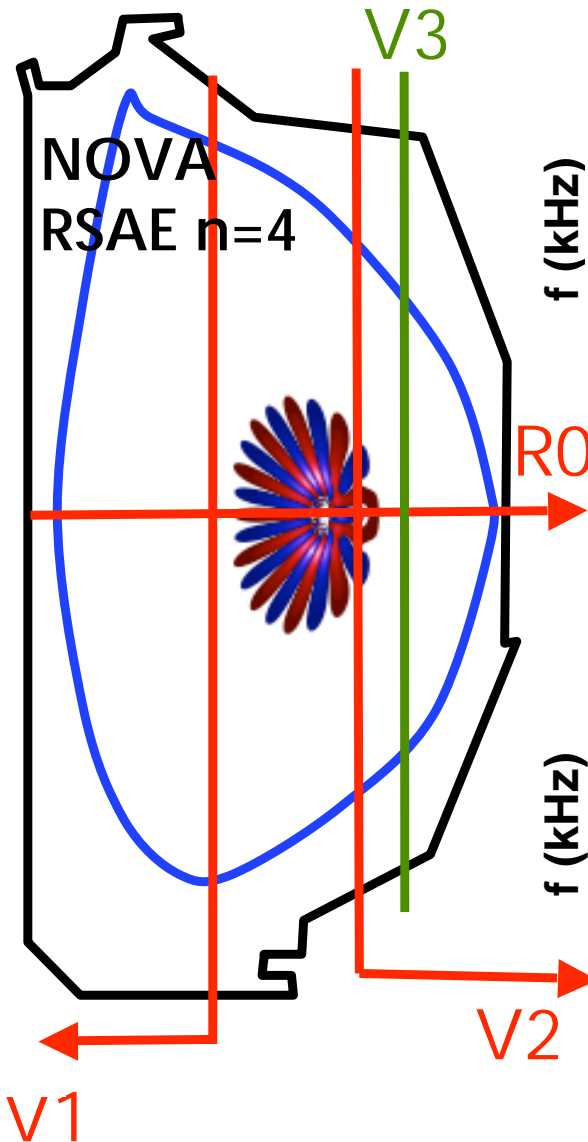
The ECE measurements give radial profiles of the TAEs and RSAEs. The RSAEs show strong localization near q-min.



This is very important for Energetic Particles Study in ITER- ...and the ECE is a US package!

Various CO₂ Interferometer Sightlines Provide Information About Spatial Structure of RSAE and q-Profile

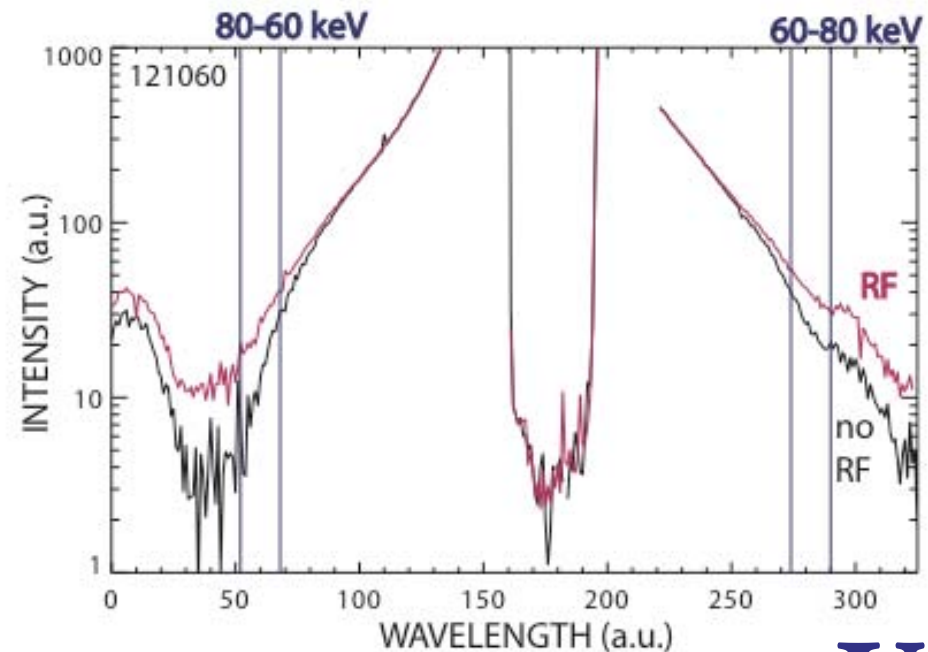
For this reverse-central shear discharge, the RSAEs are apparent on only the radial and innermost vertical interferometer chords - *radially localizing them*



We Are Continuing the Development of the Fast Ion Profile Diagnostic

- **Fast Ion Profile diagnostic**
 - Installed 4 dedicated fibers/chords for this system
 - 3 on CER view at 345°
 - 1 on MSE holder at 15°
 - Modelling well under way
 - Student thesis' work (Yadong Luo)
 - ITER relevant development
 - Relocated to new BES room

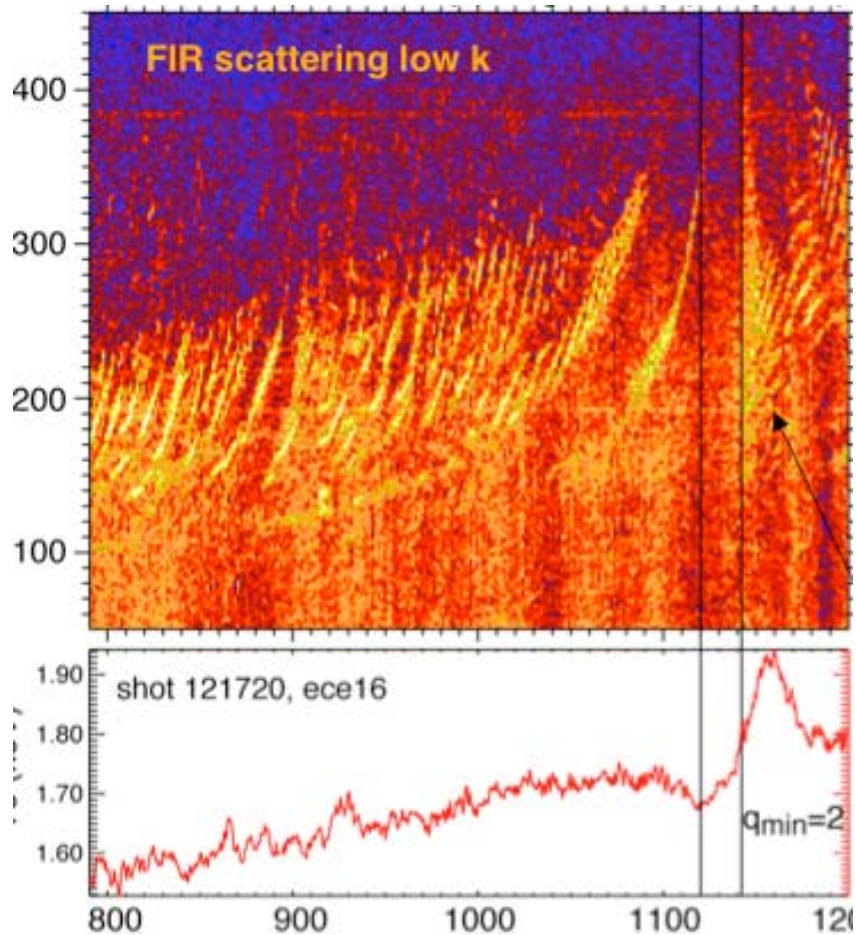
D-Alpha Spectrum:
Perpendicular Fast-ion Tail
during 60 MHz ICH



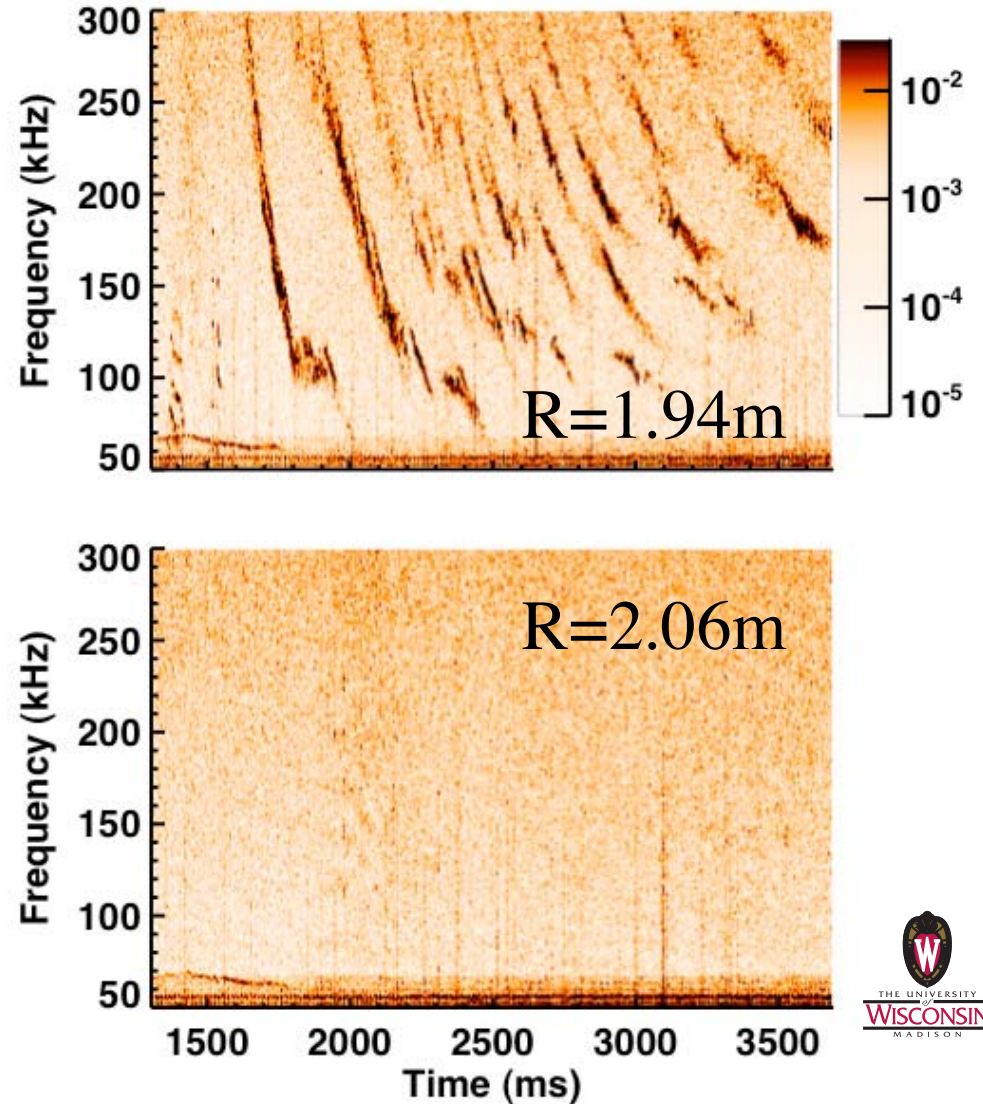
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FIR Scattering and BES Are Other Significant Tools for Alfvén Studies

FIR scattering diagnosis



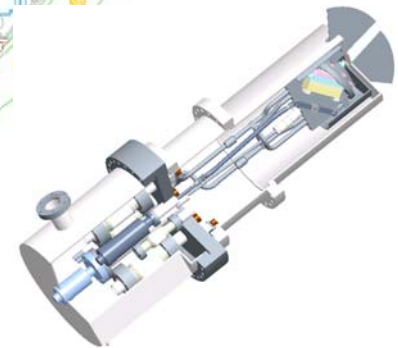
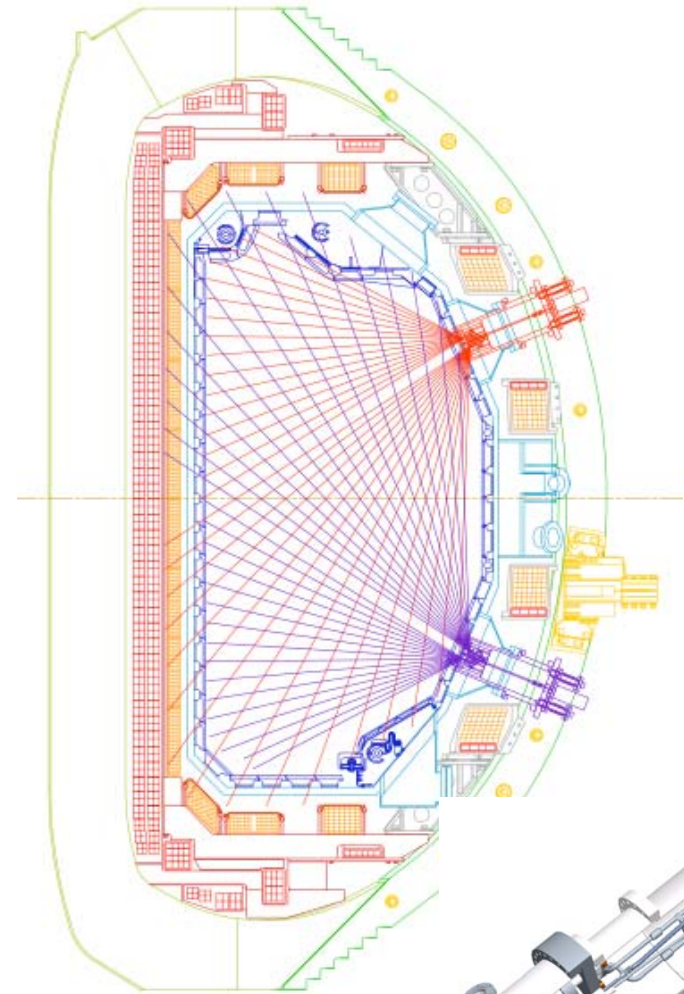
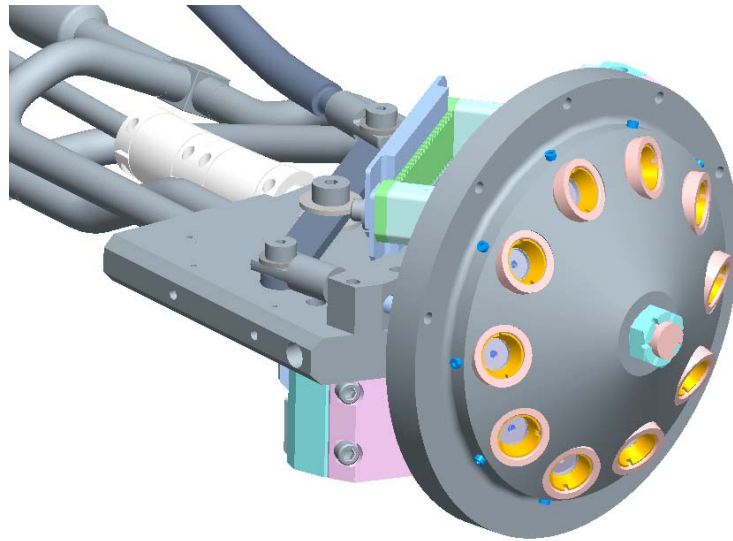
BES localization of mode



Energetic particles

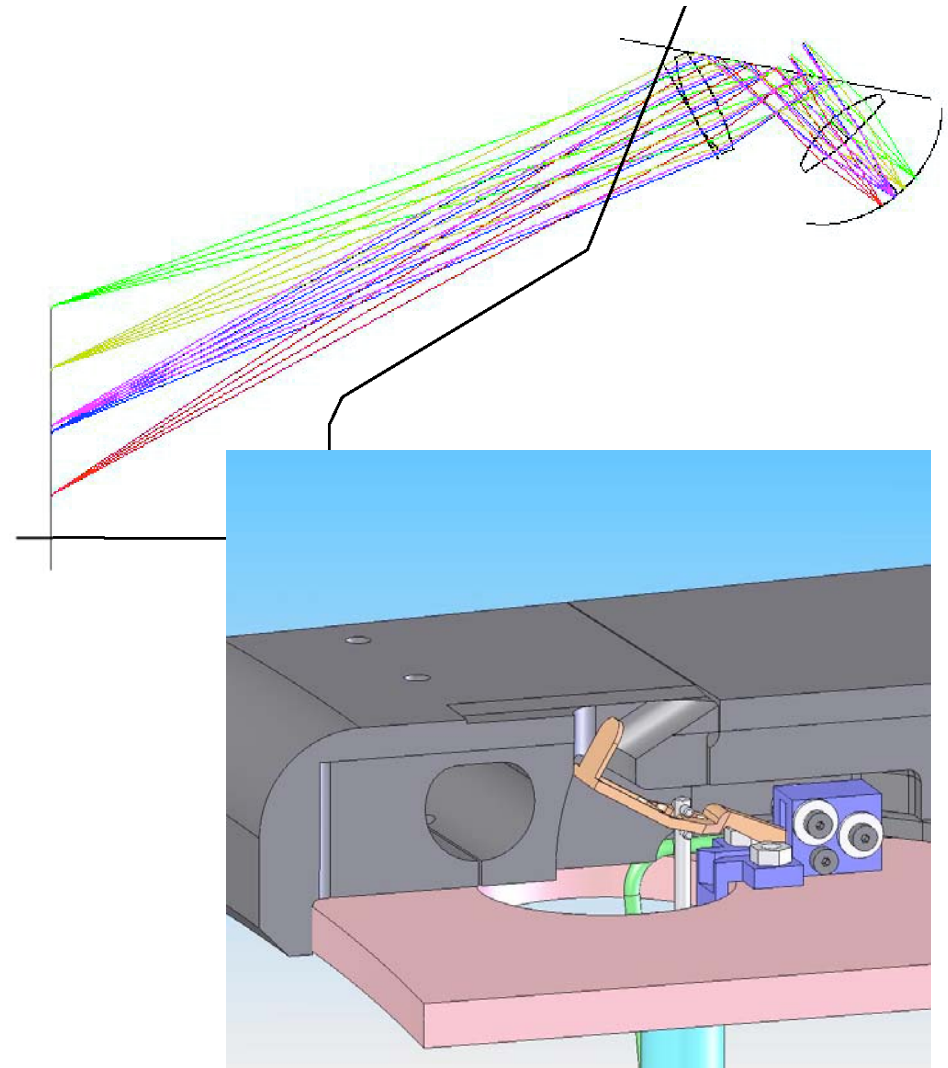
A Redesigned Poloidal SXR Array Will Bring New Capability for Stability Studies

- Poloidal SXR system was the oldest system on DIII-D
 - Showed signs of failure
- Upgrades
 - New system can also bring better characterization of disruptions (DISRAD system-UCSD) -> 3 systems
 - Filter wheel make it flexible and powerful (no filter, thin and thick diamond)



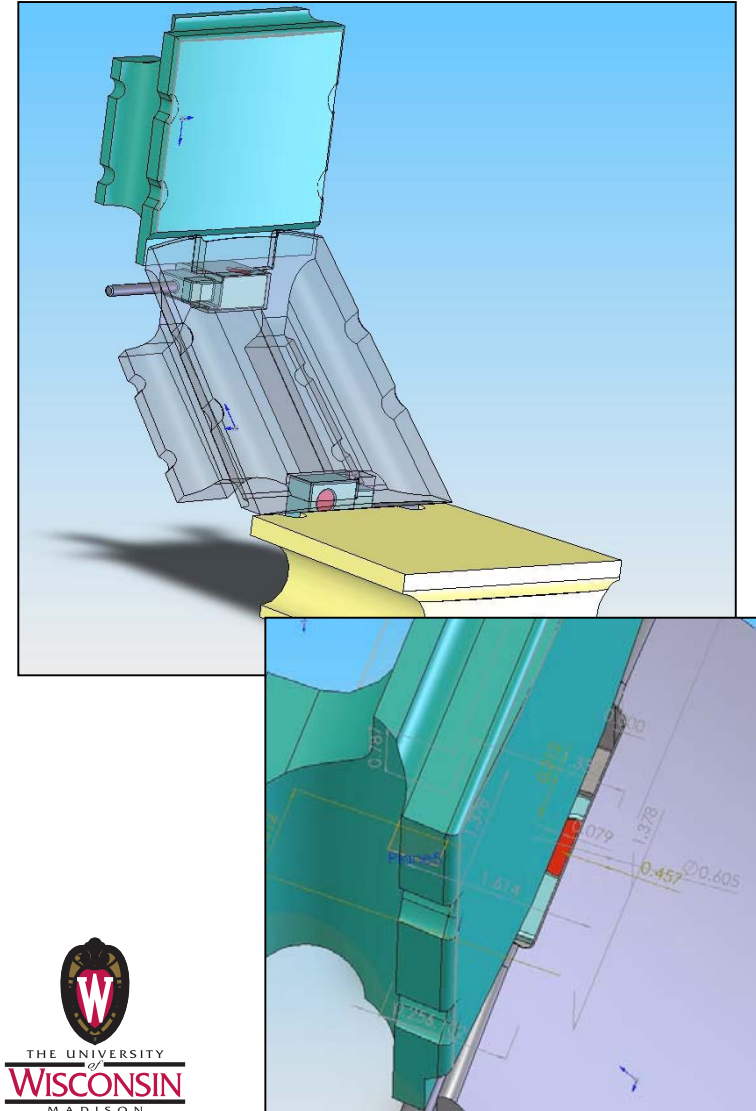
The Modification of the the Lower Divertor Enables a Significant Upgrade of the Thomson System

- New alignment target
- Viewing optics modified and updated (correct misalignment)
- More flexibility in viewing chords above new shelf
- In parallel, continue a major effort in redesigning electronics and DACQ



The Addition of Quartz Micro-balance in Lower Divertor Will Help in Diagnosing Carbon Migration

- Measure material deposition (e.g. Carbon) in real-time
- 2 locations behind the 45deg tile (newly contoured)
- Electronics in vertical port (30V-1)
- Critical diagnostic for ITER related R&D

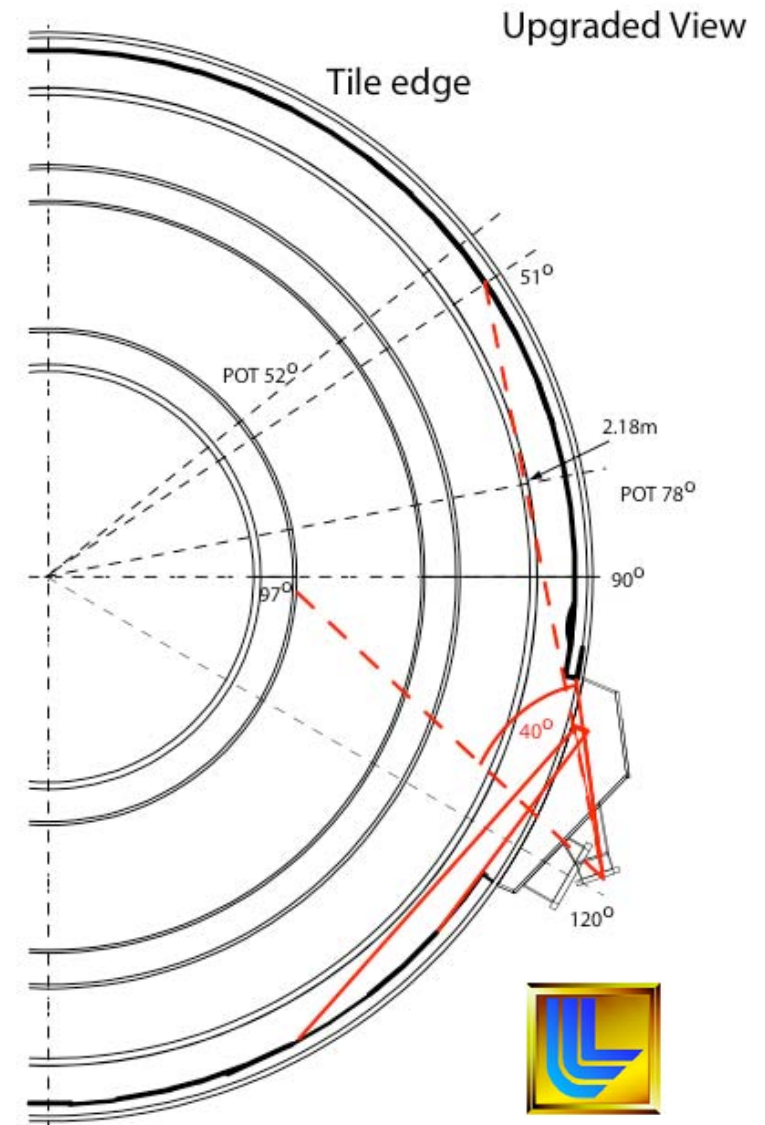


Forschungszentrum Jülich



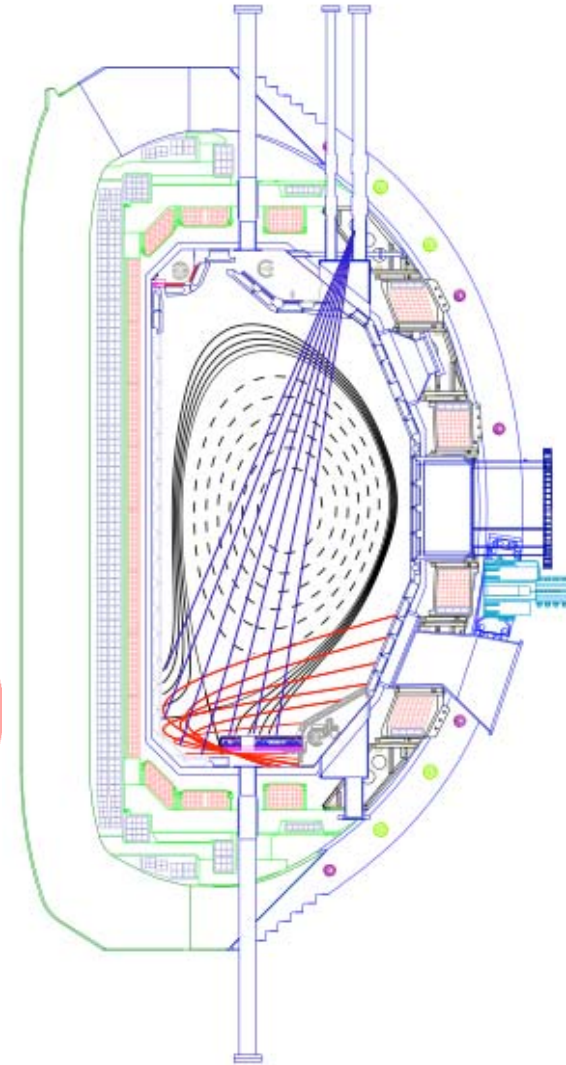
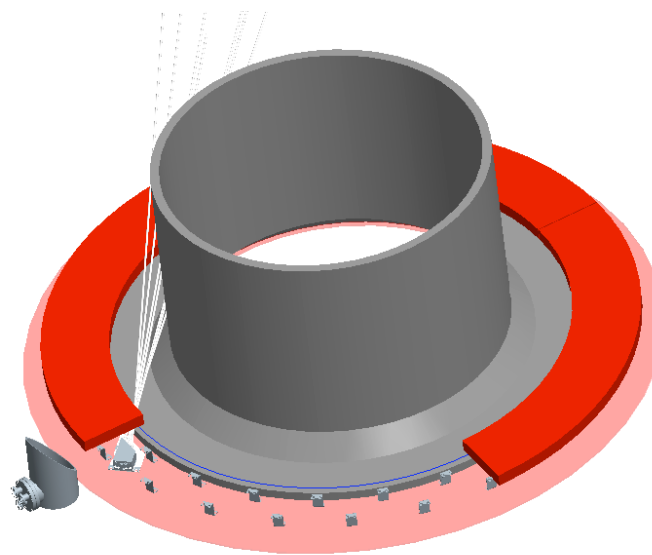
We Are Increasing Coverage in Edge Imaging

- Limited OUTER midplane view, limited set of experimental data
- Question: Can we simultaneously measure the emission from the OUTER midplane SOL region with ONE camera?
- Solution: In-vessel mirror at 105/R0 BES shutter (c.f. car: forward panorama view, rear view using mirrors)
- Also, we are adding a camera at 165R0 to image plumes from a inner wall gas fuelling
- Increase coverage of tangential fast framing camera (UCSD)



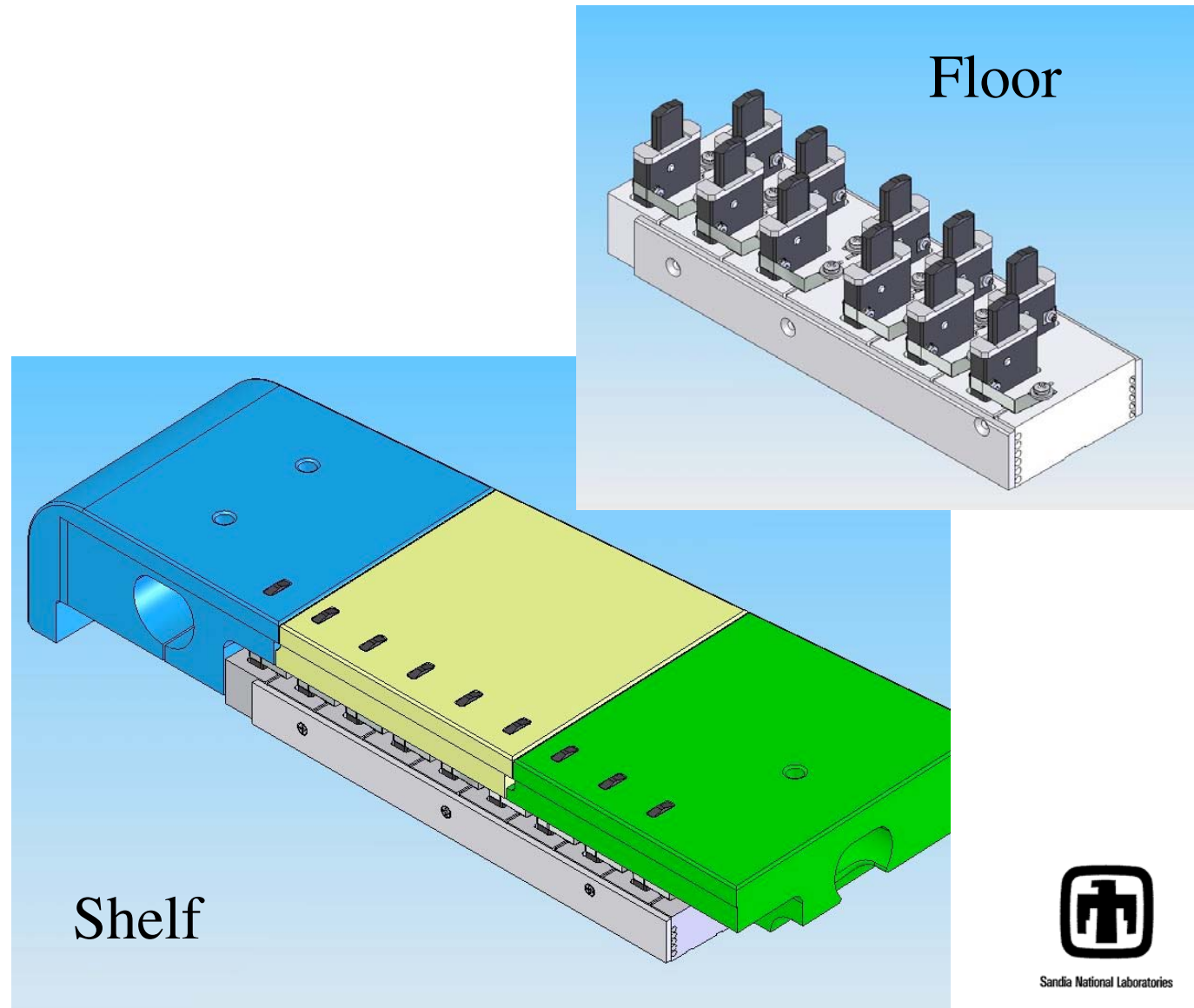
The New Divertor Shelf Brings in New Capabilities for Optical and Spectroscopic Diagnostics

- Filterscope view rearranged from top, MDS spectrometer from below
- New shelf gives new access to inner leg and private flux region
- Will be a component of measuring flows in the divertor region
- Will take advantage of the newly contoured tiles
- New telescope will help develop (ITER) relevant diagnostics in divertor area



The Coverage in Fixed Langmuir Probes Has Been Expanded With the New Lower Divertor

- New shelf and floor probes (total of 20)
- Better radial coverage
- More modular design
- 45° and Inner Wall probes under consideration for next opening



The Scanning Probes Have All Been Upgraded

- **DiMES**
 - Modifications to hydraulics (extended height)
 - Continue mirror testing (ITER)
 - Porous Plug experiments
- **X-pt probe**
 - Extension of height
- **Midplane scanning probe**
 - Addition of airlock
 - Becomes MiMES
 - Considering addition of view (optical)



University of California
San Diego

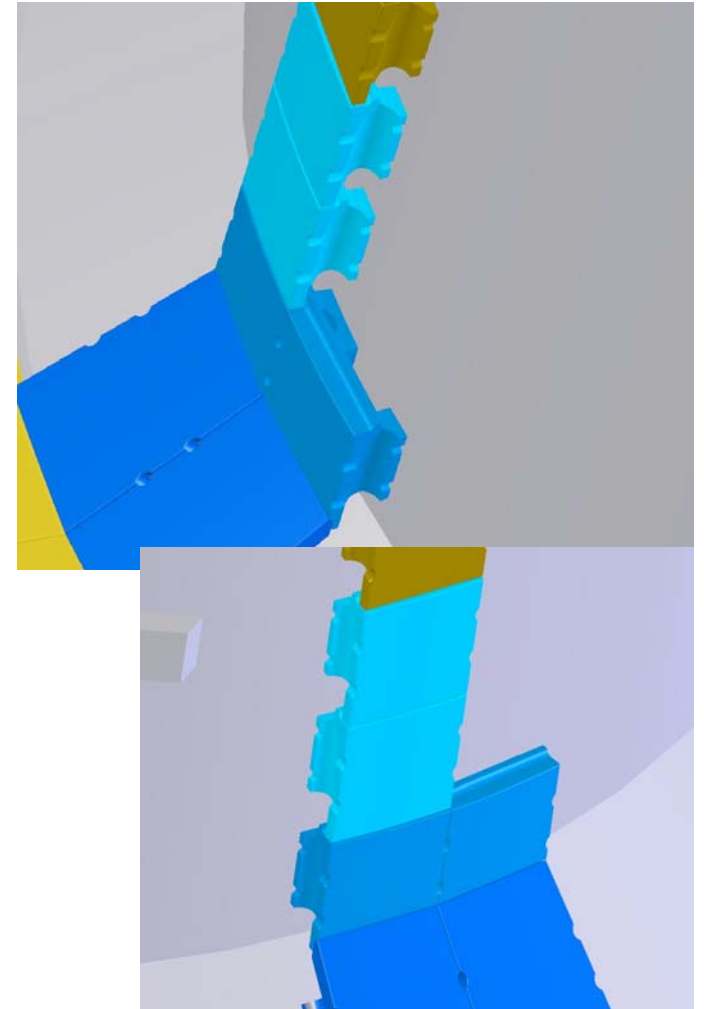


Sandia National Laboratories

Many Other Tools Have Been Added During the LTOA

- Massive Gas Puffing System
- Fast pellet dropper
 - 30-50 Hz ELM control pellet injection
- The bottom 3 rows of innerwall and the 45deg (angled) tiles have been contoured
 - Better diagnosis in lower divertor
- Lithium pellet injector will be reinstalled as time allows during campaign

oml



Summary

- The Long Torus Opening Activities brought in many new tools for exciting and relevant physics
- Many of these tools have direct impact on ITER in the short and long term, both in terms of scientific output but also in specific ITER diagnostic issues.
- Major upgrades can be found in the turbulence, profiles, energetic particles and lower divertor (boundary) areas.