ORNL/KSTAR Collaborations

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Oak Ridge National Laboratory, Oak Ridge, TN, USA;

USA-Korea Workshop on
Opportunities for Fusion Science and
Technology Collaborations with KSTAR
15 - 16 Sept, 2009
San Diego, CA
USA

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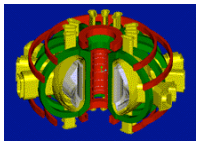

UT-BATTELLE

ORNL Support for Diagnostics on KSTAR

- **ORNL participation in first plasma on KSTAR June & July 2008**
  - ORNL filterscope used to monitor H-alpha and impurities (He, C, O, VB) during first plasma operation
  - Filterscope already capable of 10 minute pulse lengths with automatic gain control
- **ORNL continuing support for KSTAR Operation in 2009-2010**
  - ORNL labsphere purchased to perform absolute calibration of H-alpha and filterscope channels in Fall 2009 (preparation for next KSTAR experimental campaign)
  - Obtained additional Visible Bremstraahlung filters for measuring Zeff profile on KSTAR with filterscopes
  - Obtaied fiber splitters to permit simultaneous He, C, O, and VB measurements on current K STAR H-alpha channels using ORNL filterscope
- **ORNL preliminary design of divertor filterscope system for monitoring impurities and recycling in KSTAR divertor**
- **ORNL proposing "Ohmic H-mode" experimental campaign as a research thrust during near term circular plasma operation (led by J-W Ahn - ORNL post-doc)**
  - Will need major wall conditioning (will need anyway for later shaped and diverted plasmas)
    - H glow, He glow, boronization, etc.
  - Should be obtainable within next 2 years befor divertor ready, will utilize existing diagnostics
  - ORNL filterscope will be one of first diagnostics to see H-mode
- **ORNL & PPPL have prepared preliminary design for CER/MSE diagnostic for KSTAR (Bay M).**
  - Similar to system that ORNL & PPPL have installed on JET and NSTX.
  - What is current interest in continuing this effort? US-DOE effort not expected to increased. How do we proceed
- **U. of Wisconsin BES diagnostic included in Bay M design (G. McKee)**
  - What is current interest in continuing this effort?
- **ORNL can provide support for pellet fueling and disruption mitigation on KSTAR**
  - Currently no funding for this activity

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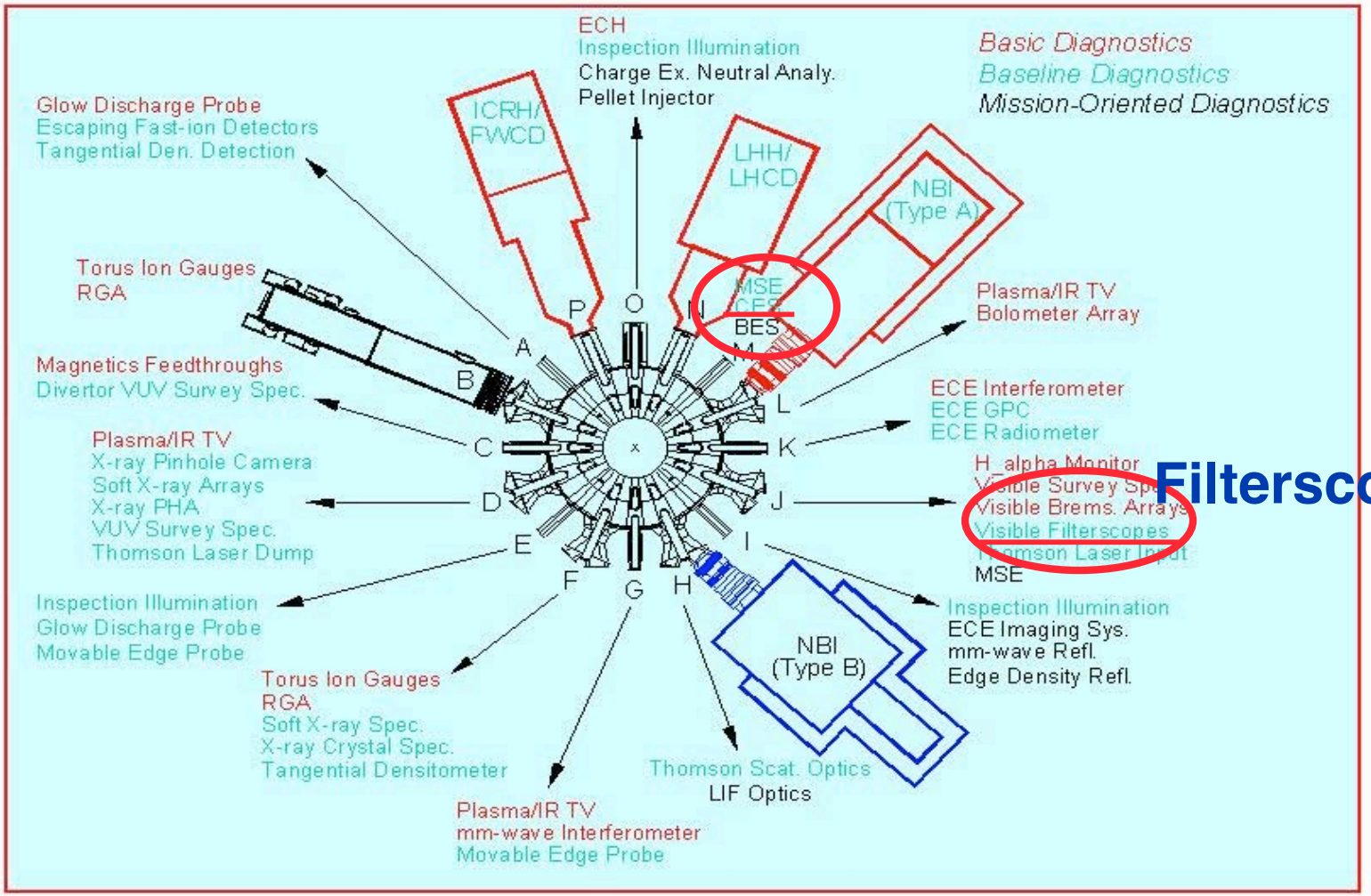
KSTAR Diagnostic Layout



CER(beam) -

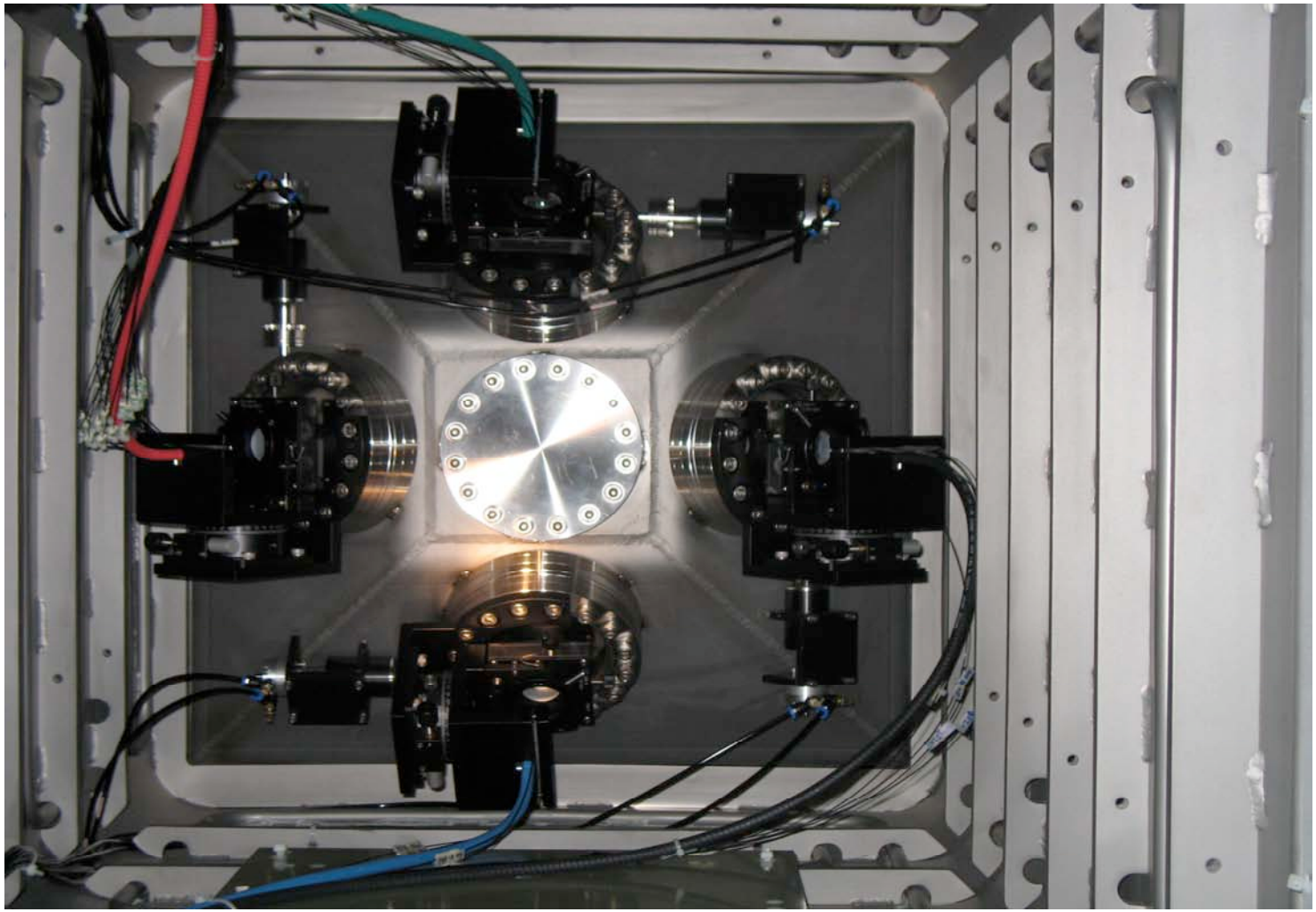
Filterscope -

Filterscope

- Bay M used for MSE and CER

H-alpha and ORNL Filterscope Viewing Optics on KSTAR (BAY M)

ORNL Support for first plasma on KSTAR



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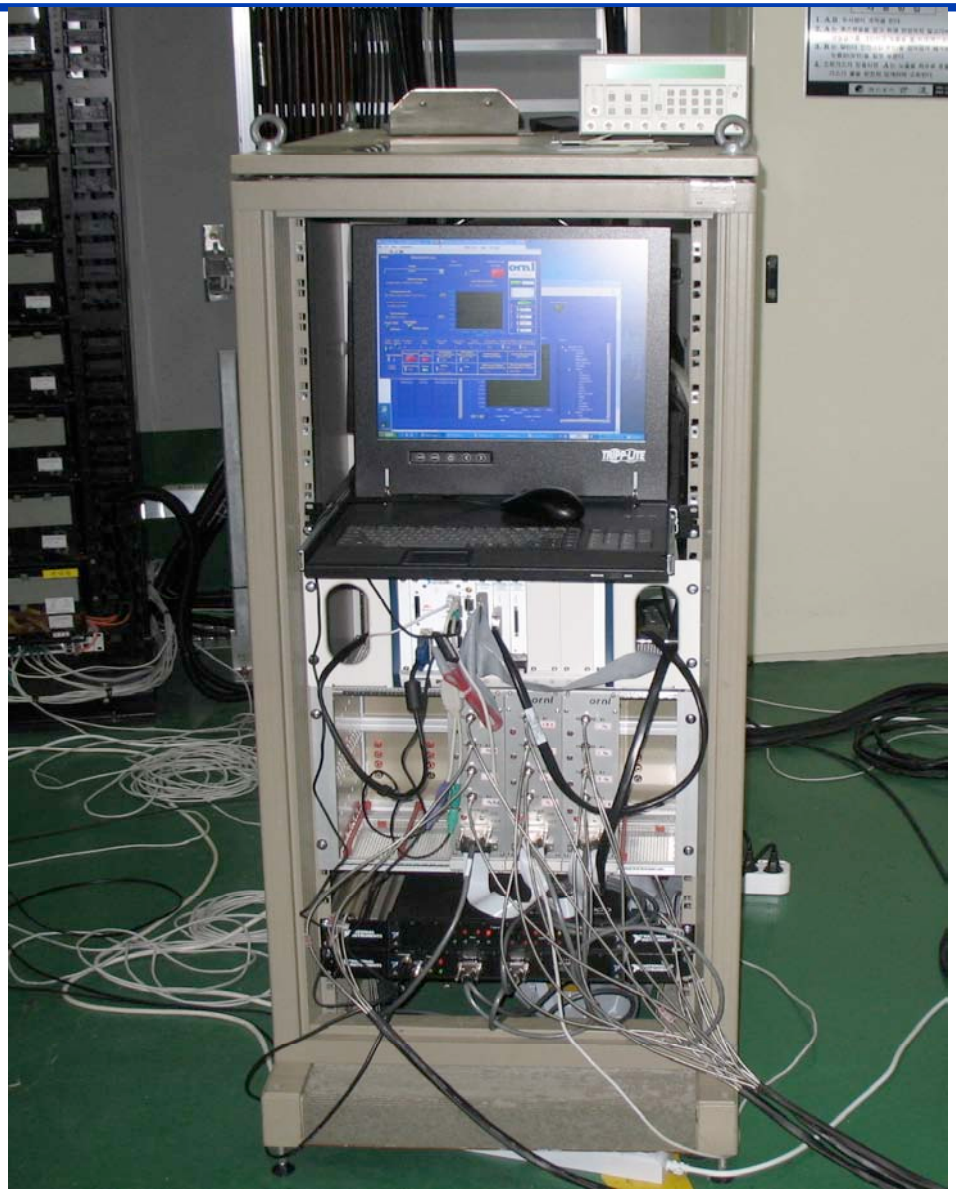
ORNL FILTERSCOPE
Data Acquisition System



Used during
First KSTAR Plasm
June-July 2008

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ORNL Team with Dr. Na

- First Plasma June 2008 -

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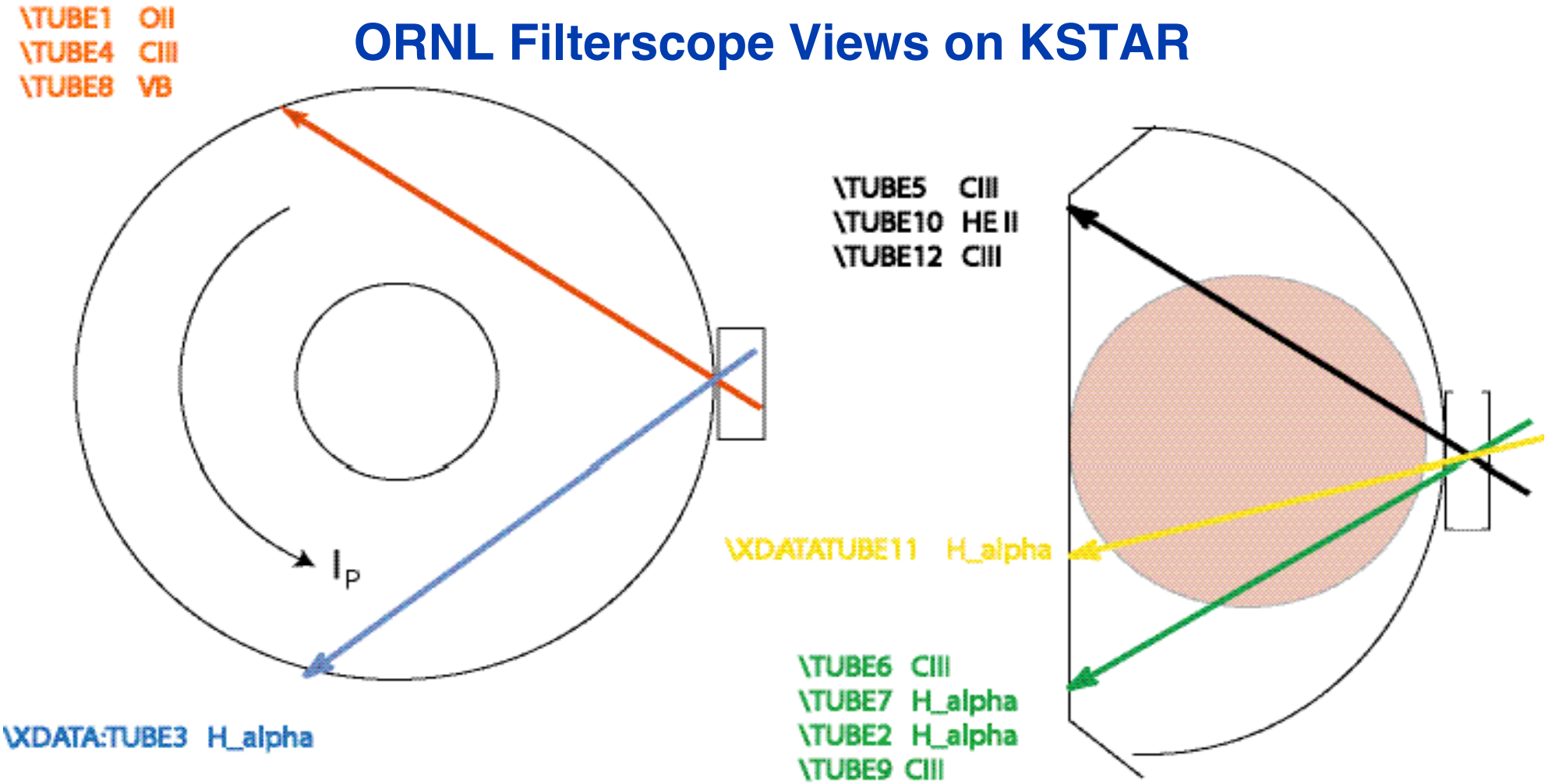
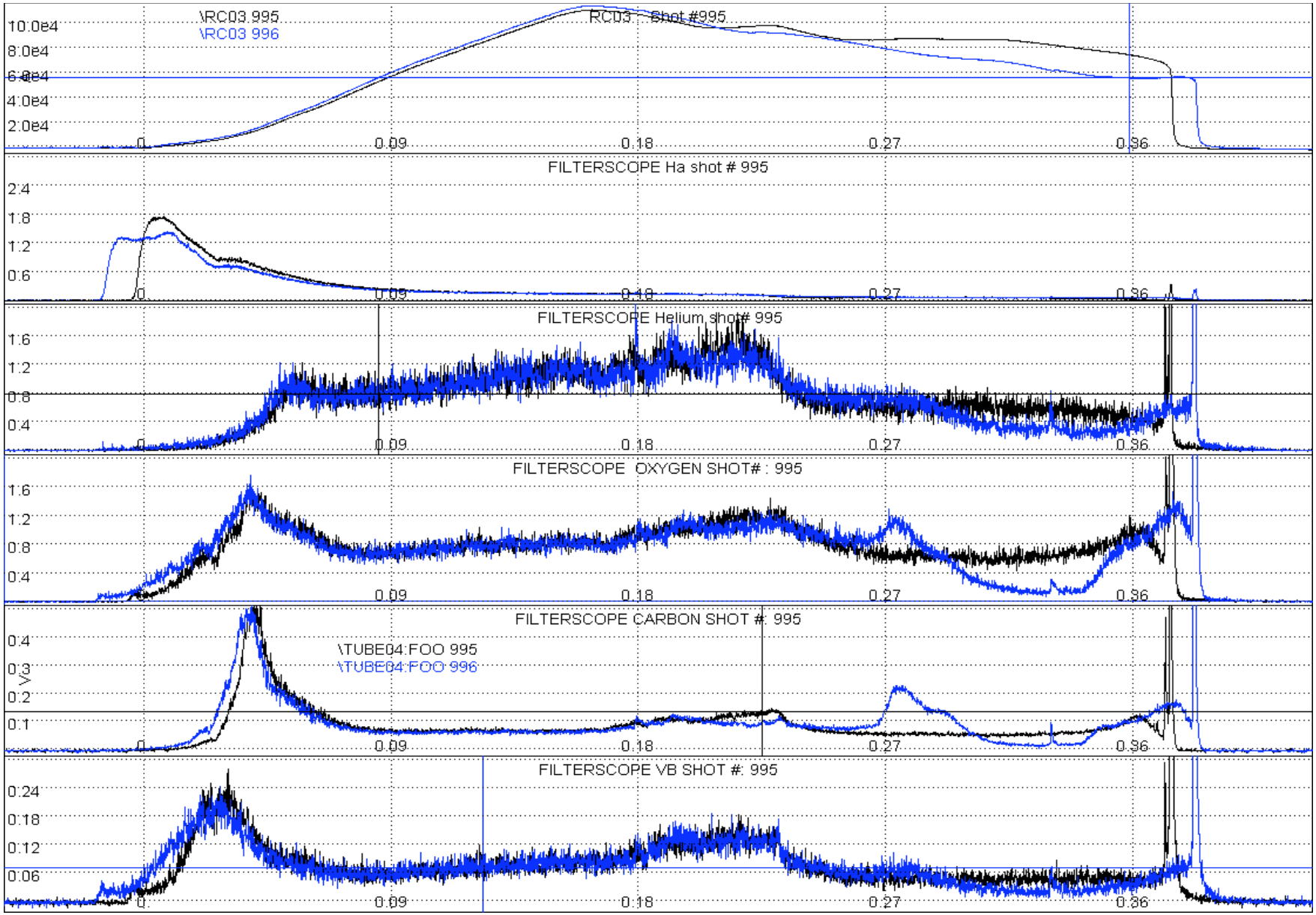
ORNL Filterscope Views on KSTAR

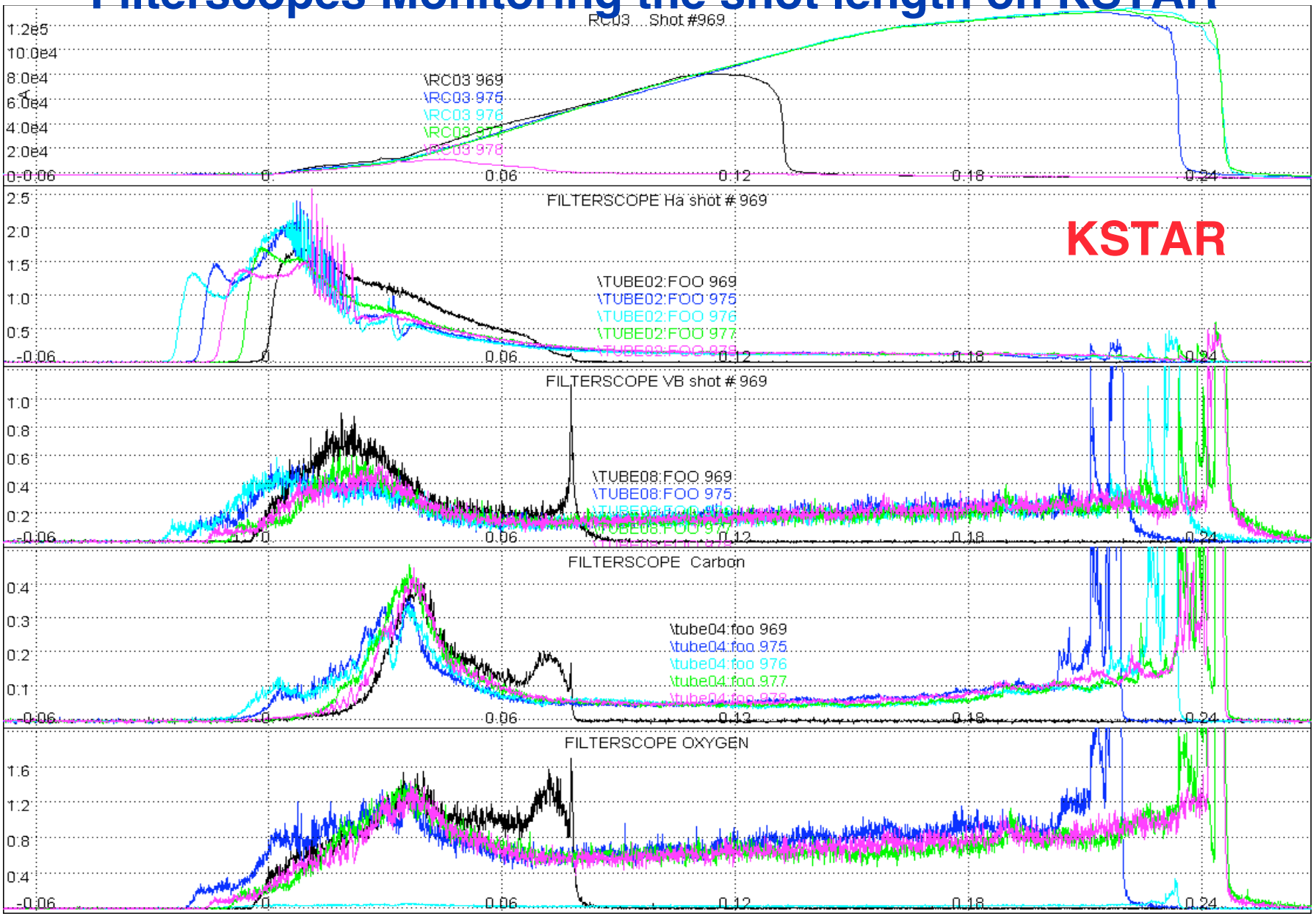


KSTAR FILTERSCOPES

Plasma Movement to inner wall increases Carbon **KSTAR** 995, 996



Filterscopes Monitoring the shot length on KSTAR



Shots 969, 975, 976,977,978

Looking Ahead to a KSTAR Divertor

- **What would a filterscope system look like for monitoring impurities and Hydrogen recycling in the divertor?**

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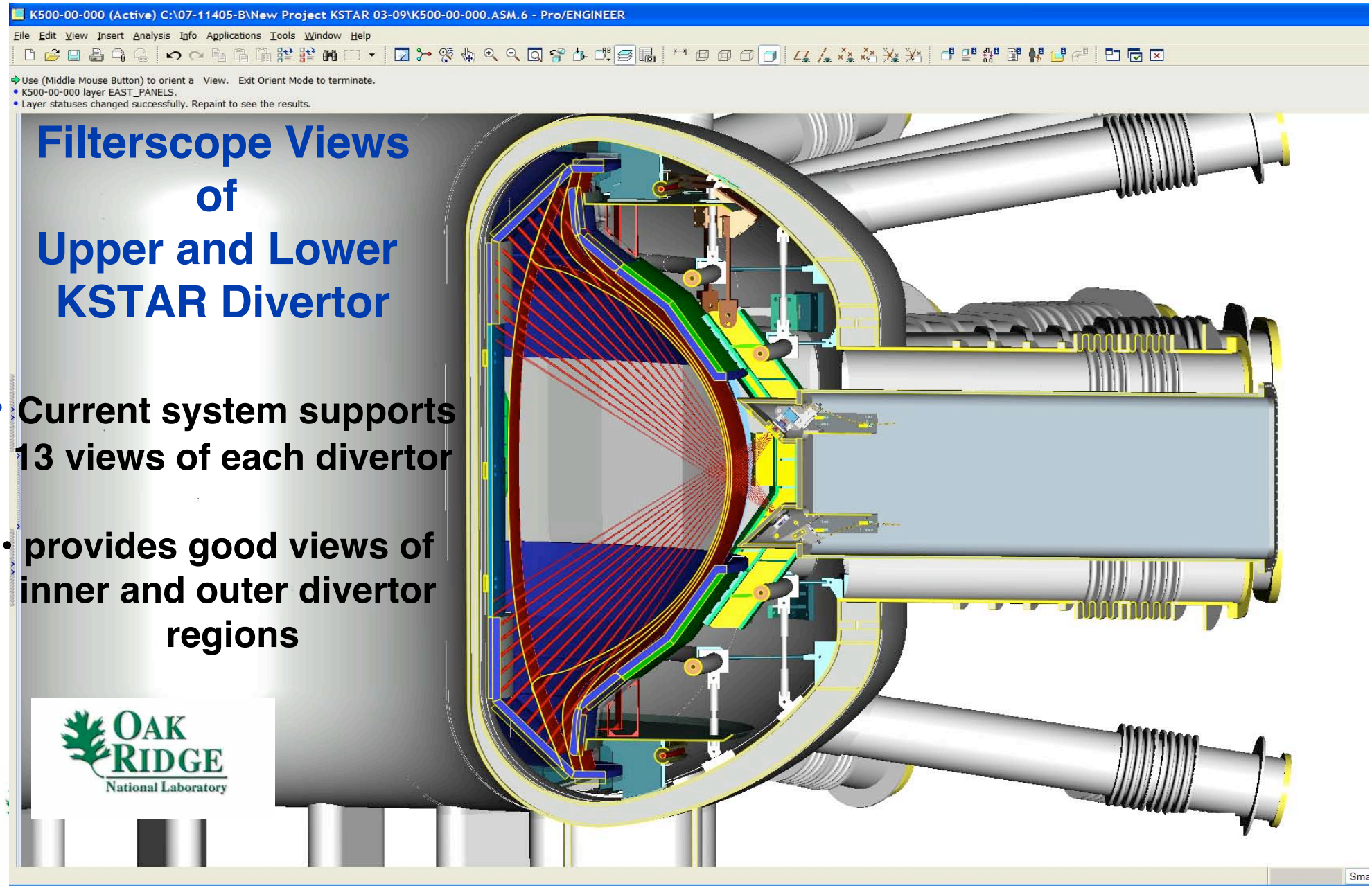
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Filterscope Views of Upper and Lower KSTAR Divertor
Current system supports 13 views of each divertor
provides good views of inner and outer divertor regions
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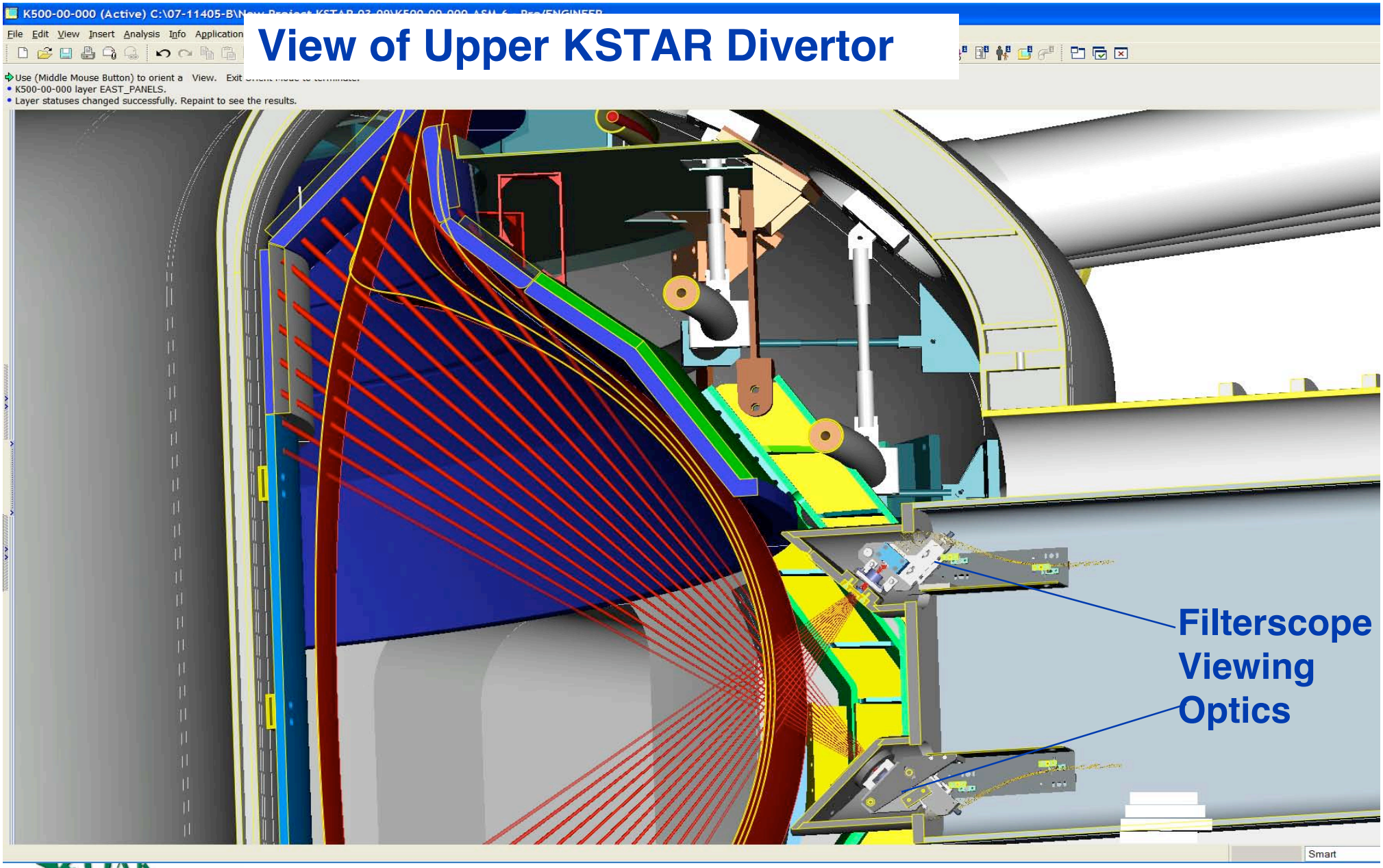
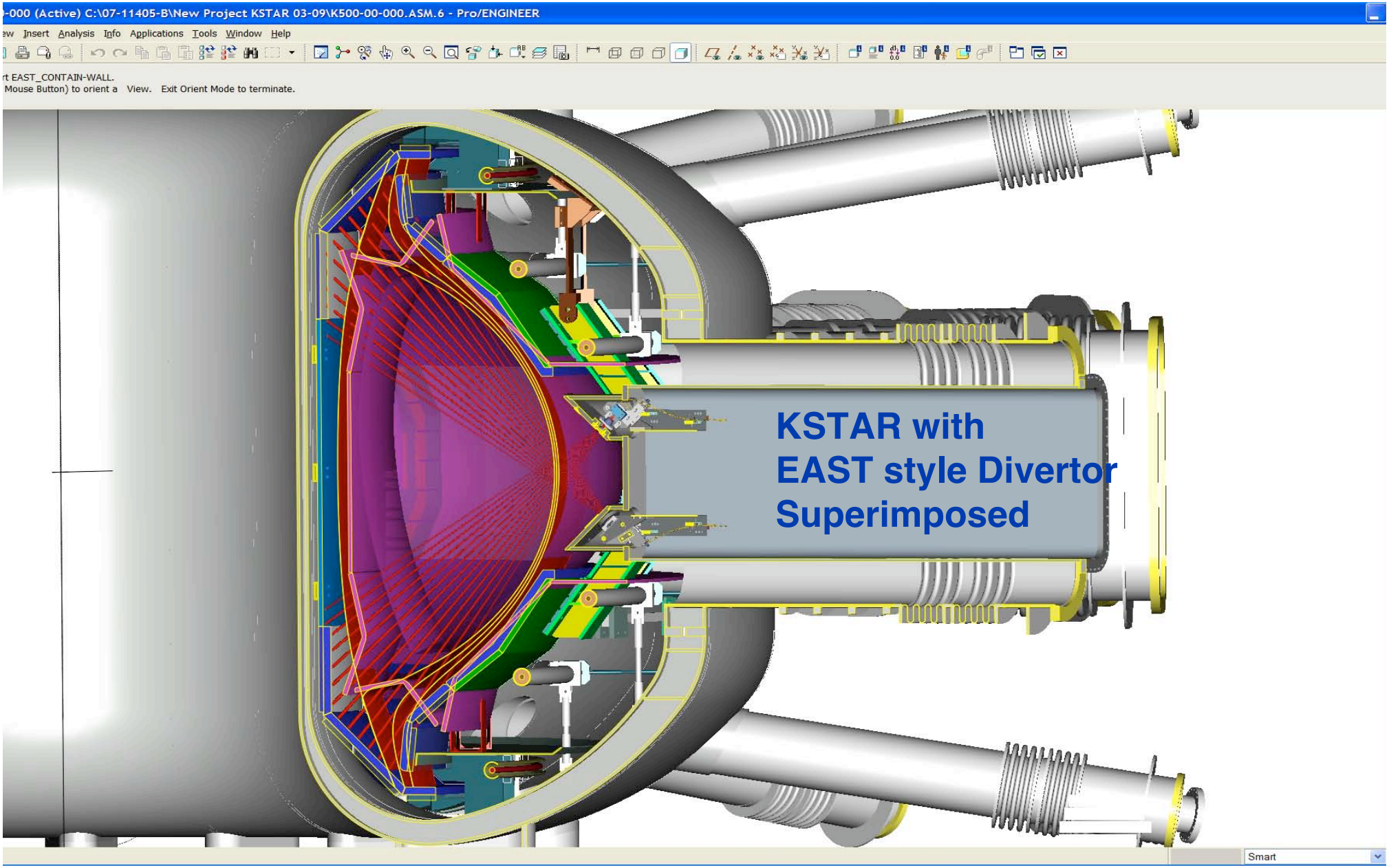
View of Upper KSTAR Divertor





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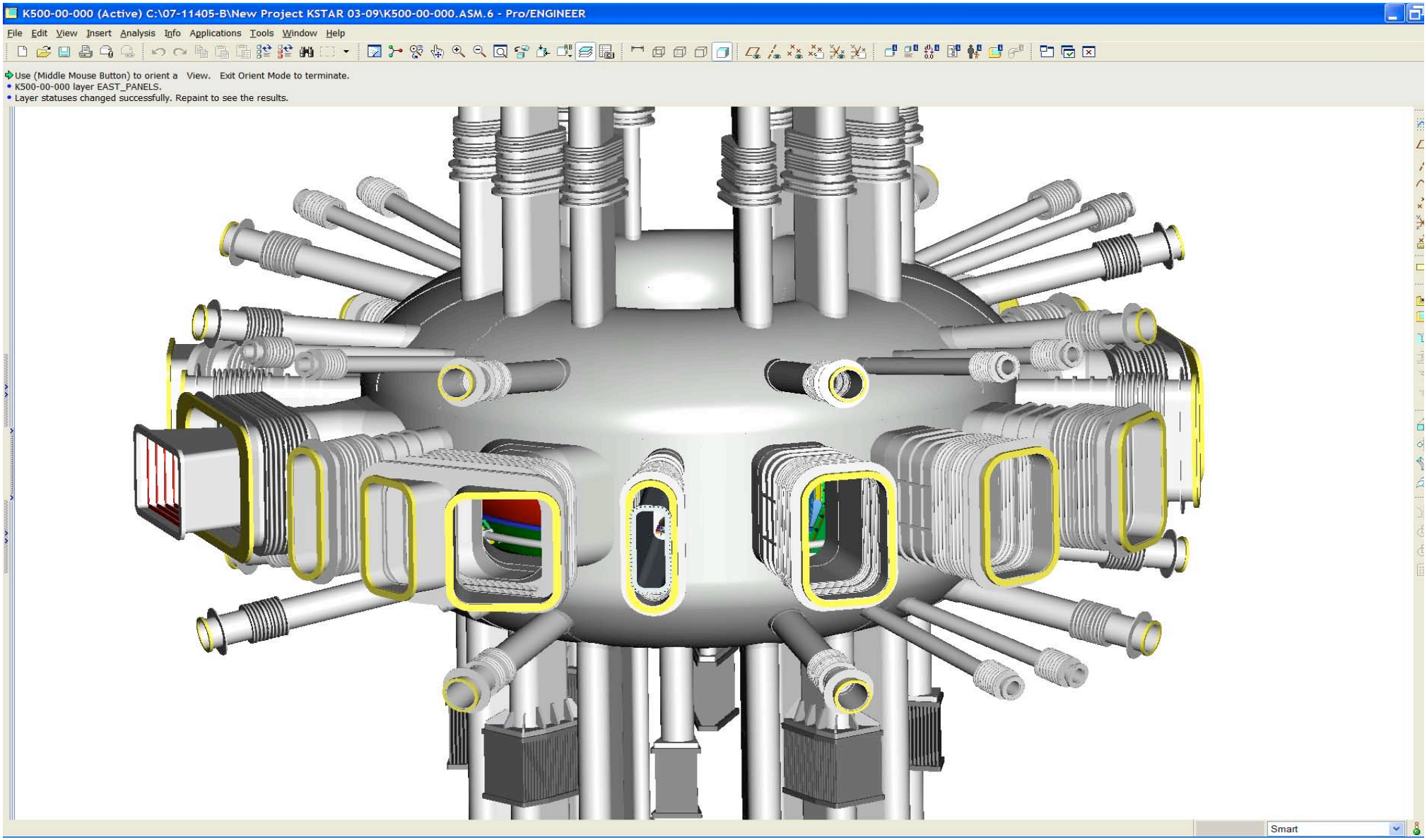

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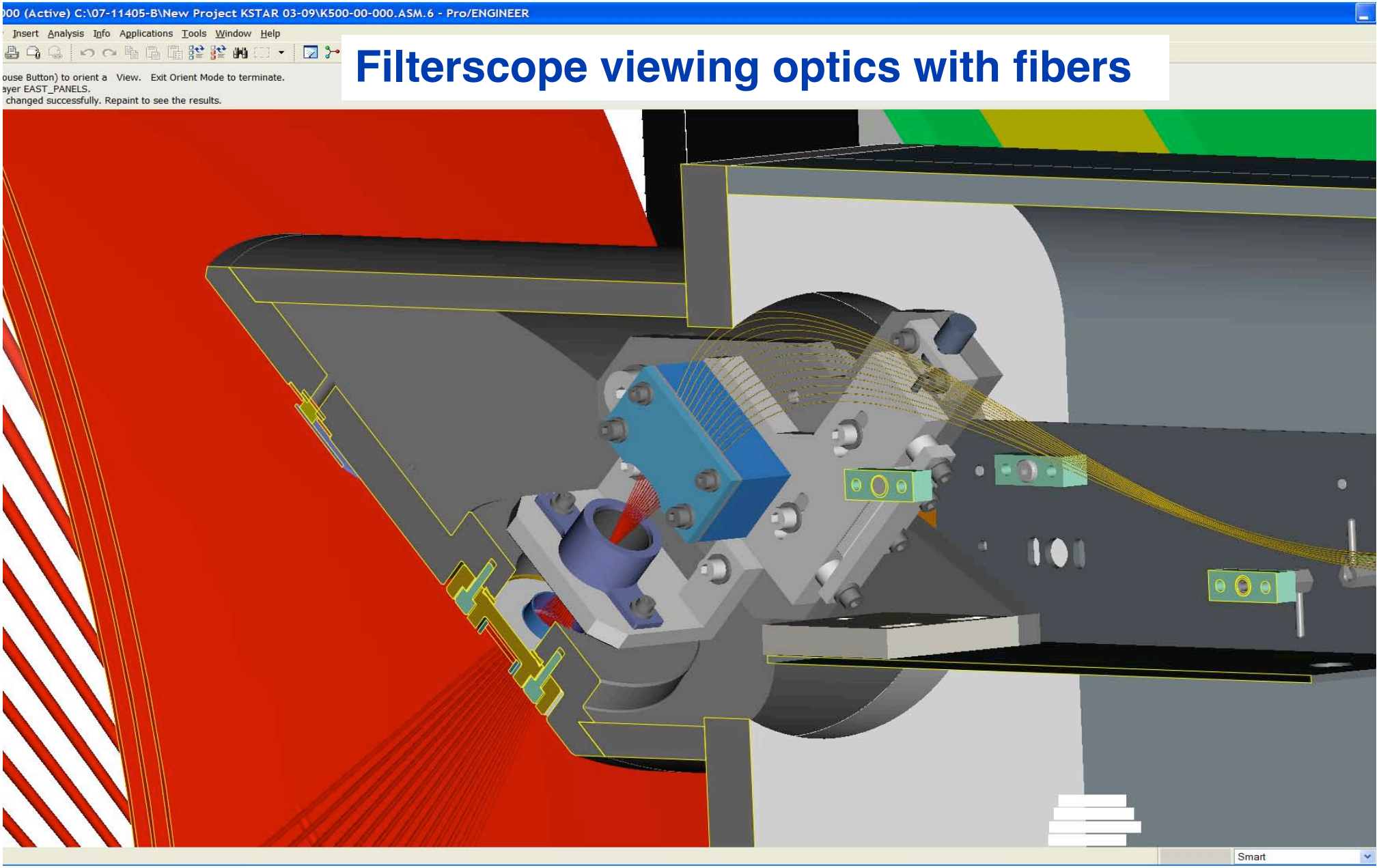
Filterscope viewing optics with fibers



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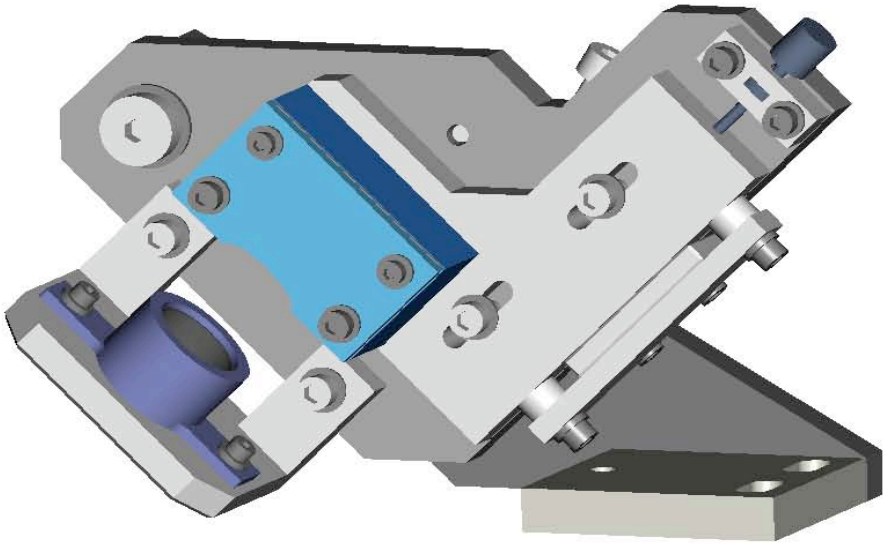
Filterscope Viewing Optics and fiber holder for KSTAR



Smart

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Filterscope Summary

- Filterscopes provide a convenient, reliable, and compact diagnostic for monitoring visible line radiation.
- Currently monitoring He, H, O, C, and VB
- Filterscope signals are absolutely calibrated using ORNL labsphere, allowing long-term shot comparisons, and quantification of plasma edge conditions, and comparison of recycling sources.
- ORNL fiber splitters ready for installation. Will provide additional impurity monitoring and Zeff profile measurement
- ORNL has preliminary design of filterscope optical system for monitoring recycling and impurities in KSTAR divertor. (Similar design could provide heat flux measurements in divertor)
- System has been tested for steady state operation at 100kHz for 10 minute discharges with up to 128 input channels.

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ORNL Collaboration on “Ohmic H-mode” for KSTAR

May provide interesting results for a near term IAEA Meeting

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Test various recipes for obtaining "Ohmic H-mode" on KSTAR (NSTX, TEXTOR, TUMAN-3,…)

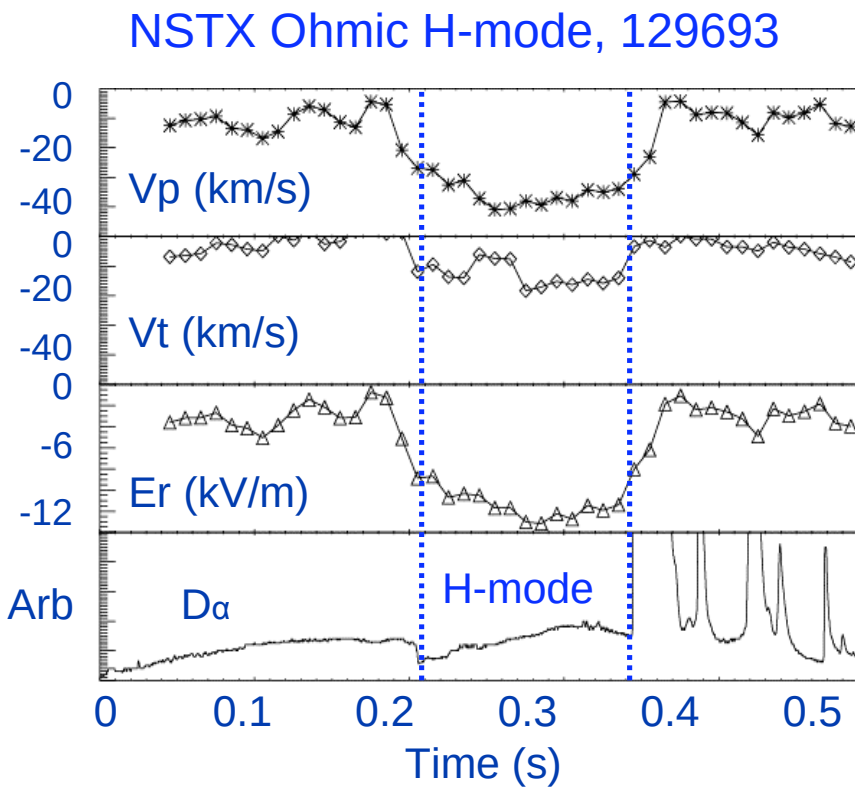
Filterscope first diagnostic to see H-mode

- **Wall conditioning**
  - **Selection and sequence of gas for GDC, combined with bakeout and boronization**
- **Sharp inboard gas puffing**
  - **Steepen density gradient**
- **Low Bt and density**
  - **$P_{L\text{-}H}$ scaling law,**

$$P_{th} = 1.38(\bar{n}_e/10^{20})^{0.77} B_t^{0.92} R^{1.23} a^{0.76} MW$$

- **Higher power density**
  - **Shift plasma toward inner wall**

    → minor radius magnetic compression, resulting in smaller plasma
  - **Ip ramp up for higher Ohmic power**
- **ECH and/or ICRH heated H-mode plasmas**



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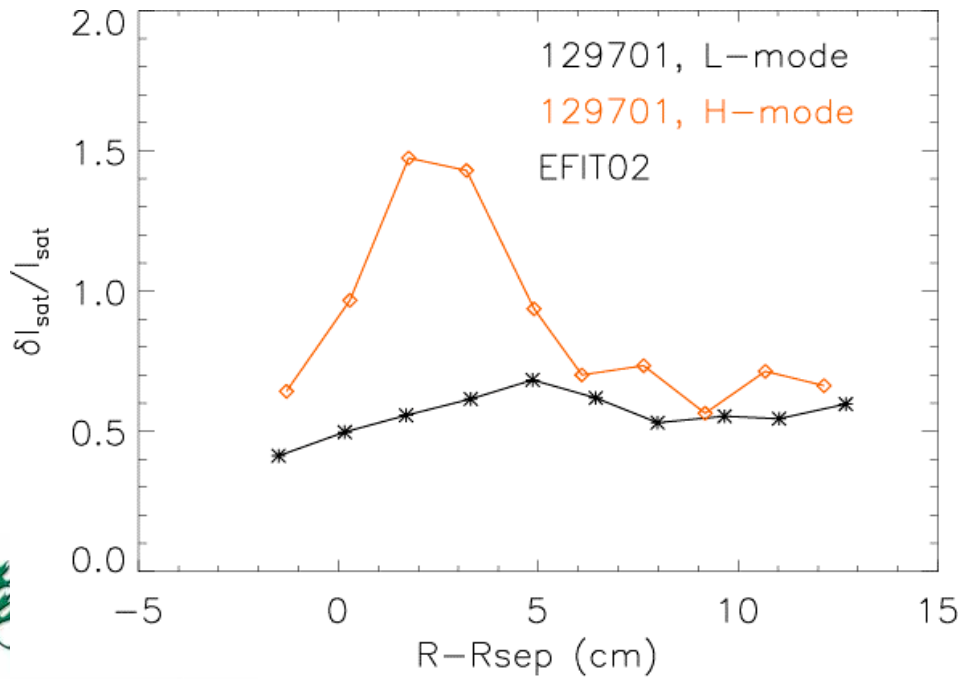
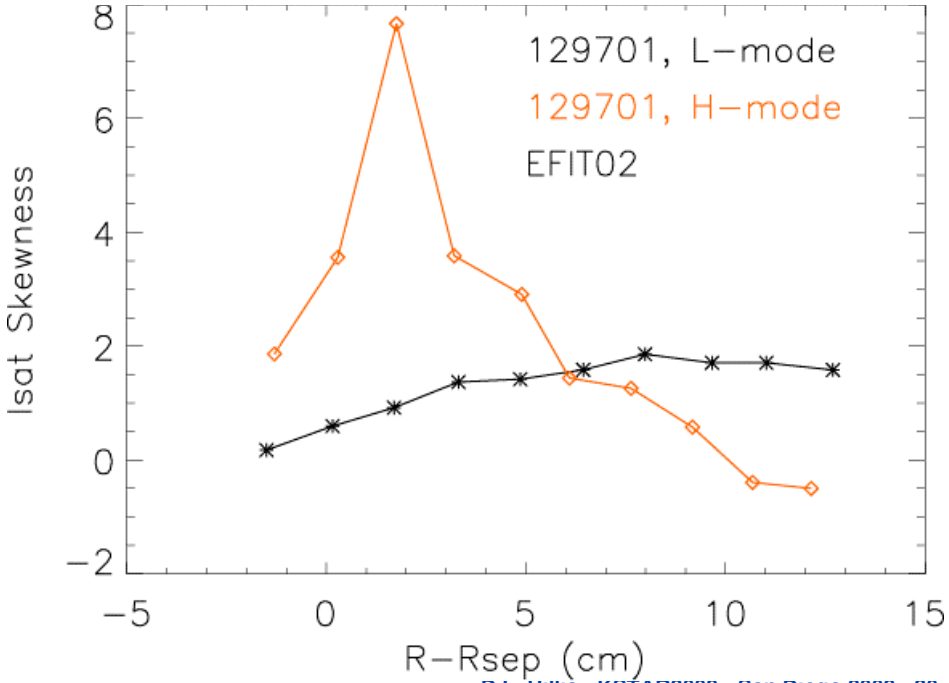
Probe Measurements can improve understanding of Ohmic H-mode

- **Low power and limited plasma is ideal for reciprocating probe measurement**
  - **Well defined LCFS and deeper probe plunge**
  - **Rotation physics by Mach probe, connection to L-H transition**
  - **Turbulence characteristics by Isat data**
  - **Probe head upgrade in future? Stress measurements, etc**

Probe measurement for Ohmic H-mode in NSTX





Diagnostic Initiatives after Neutral Beam Installation

- CER/MSE
- BES
- Pellet fuelling
- Disruption mitigation

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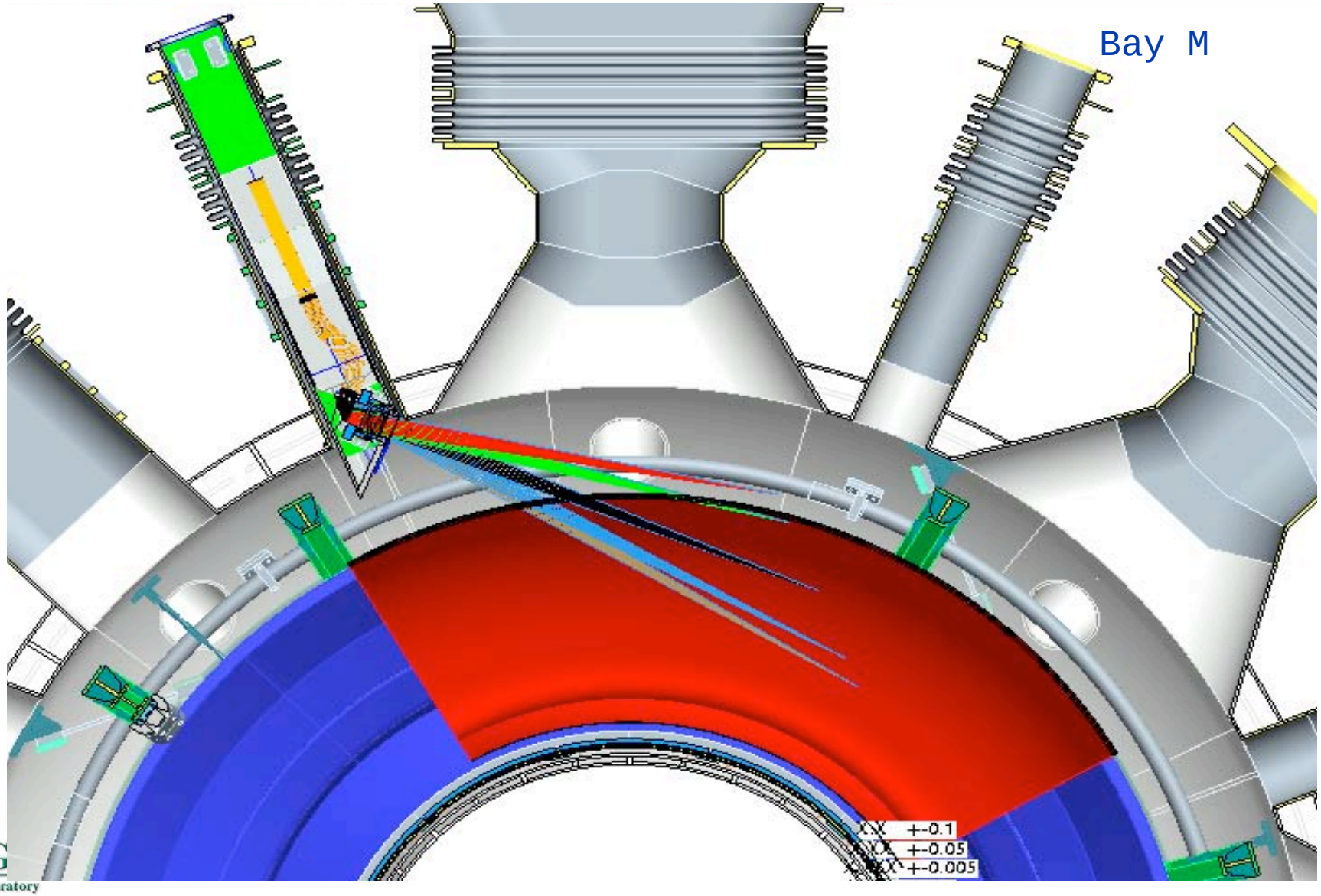
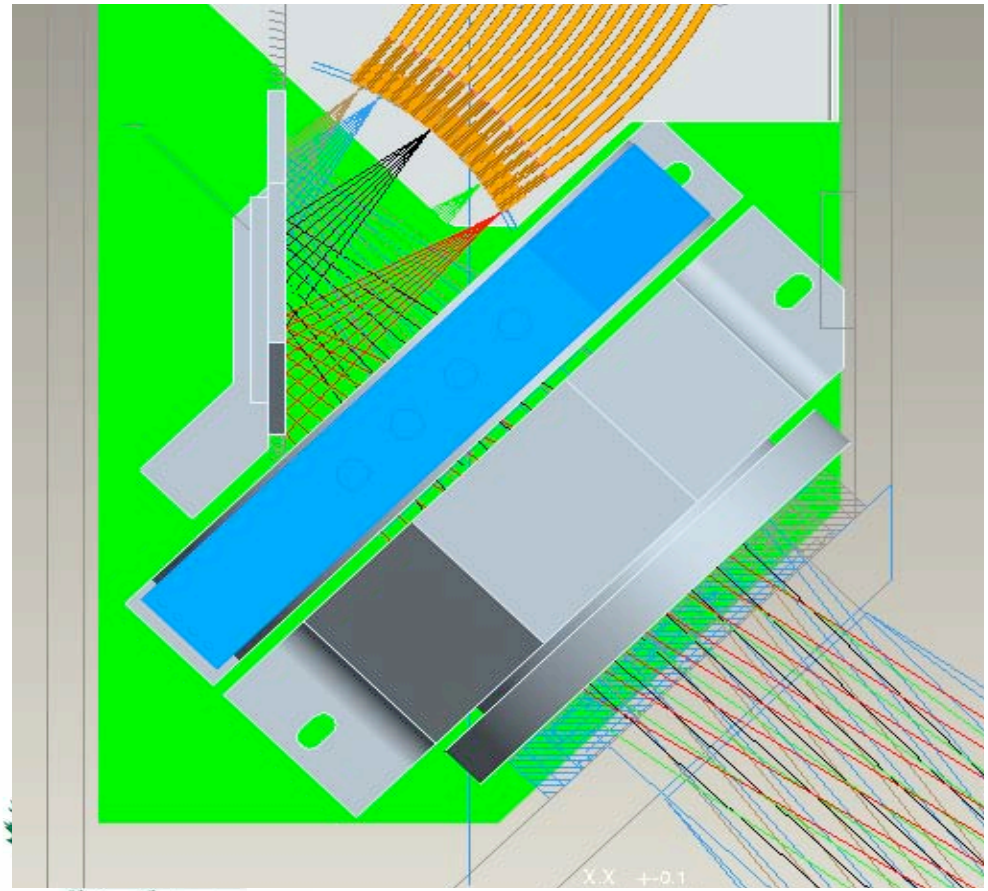
CER/MSE Radial Views based on Ray Tracing

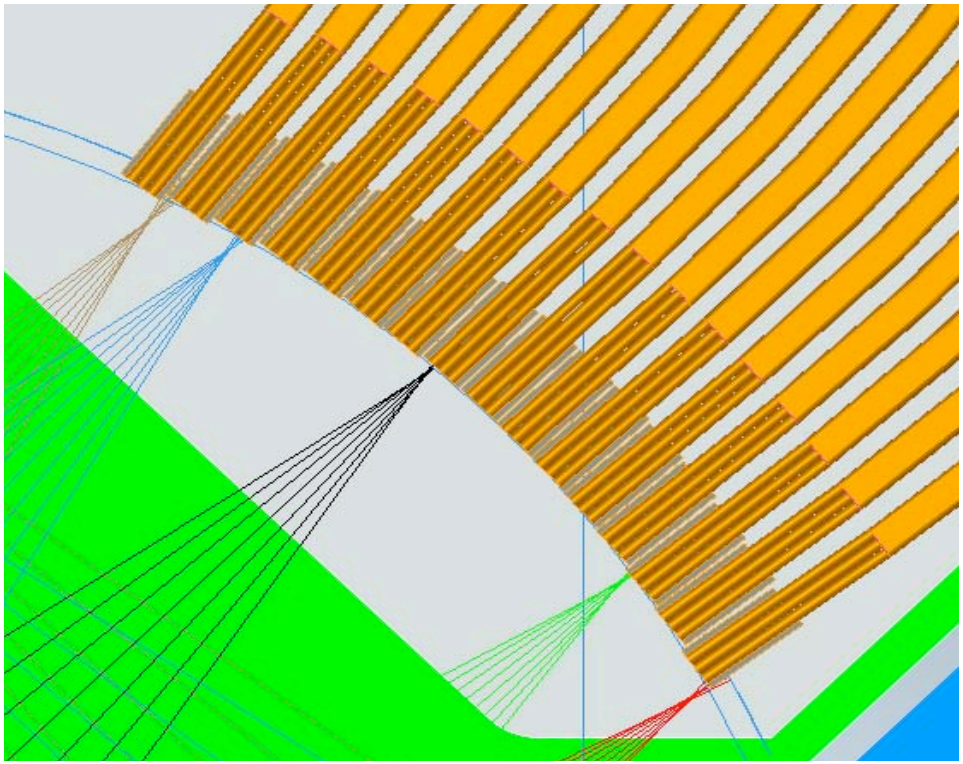


Optics Design and Ray Tracing for the CER/MSE Diagnostics

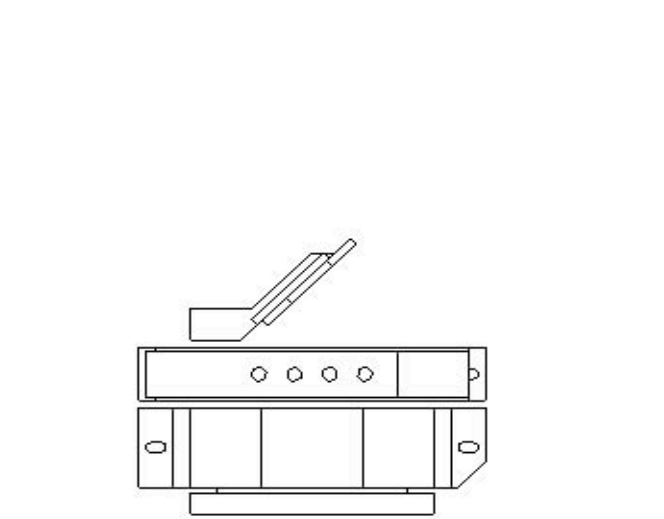
Optical components

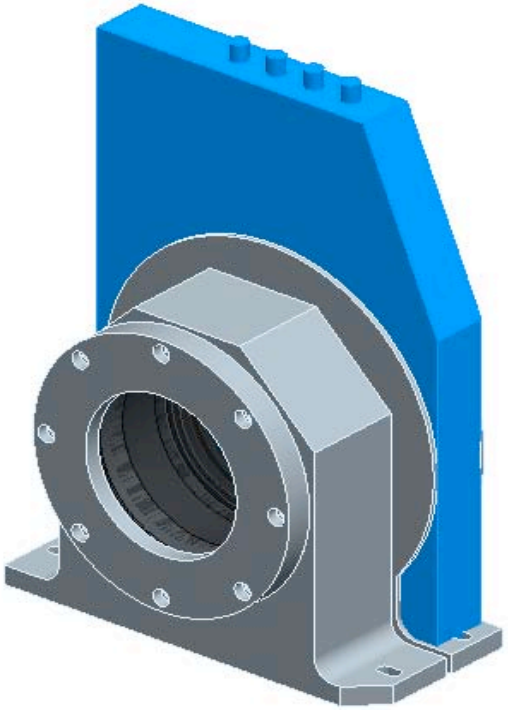


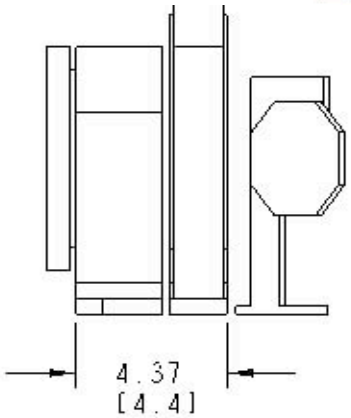
Fiber bundles

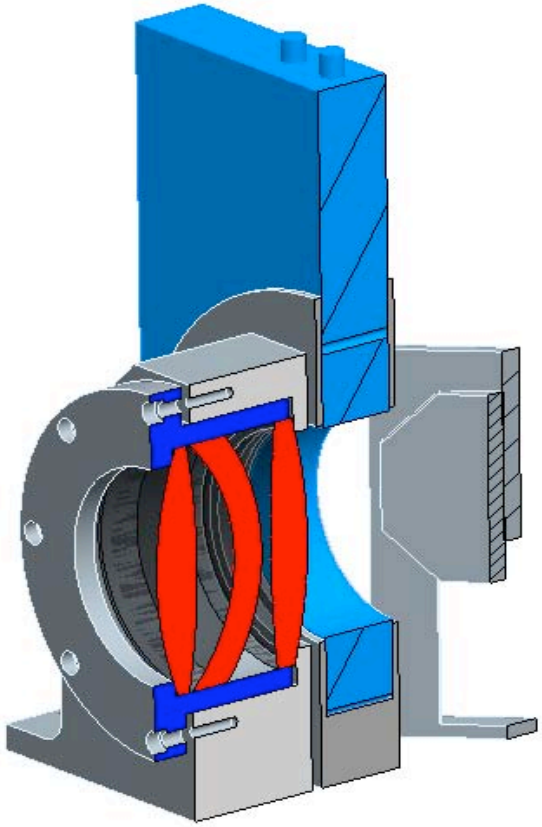


CER/MSE Optical Arrangement for KSTAR









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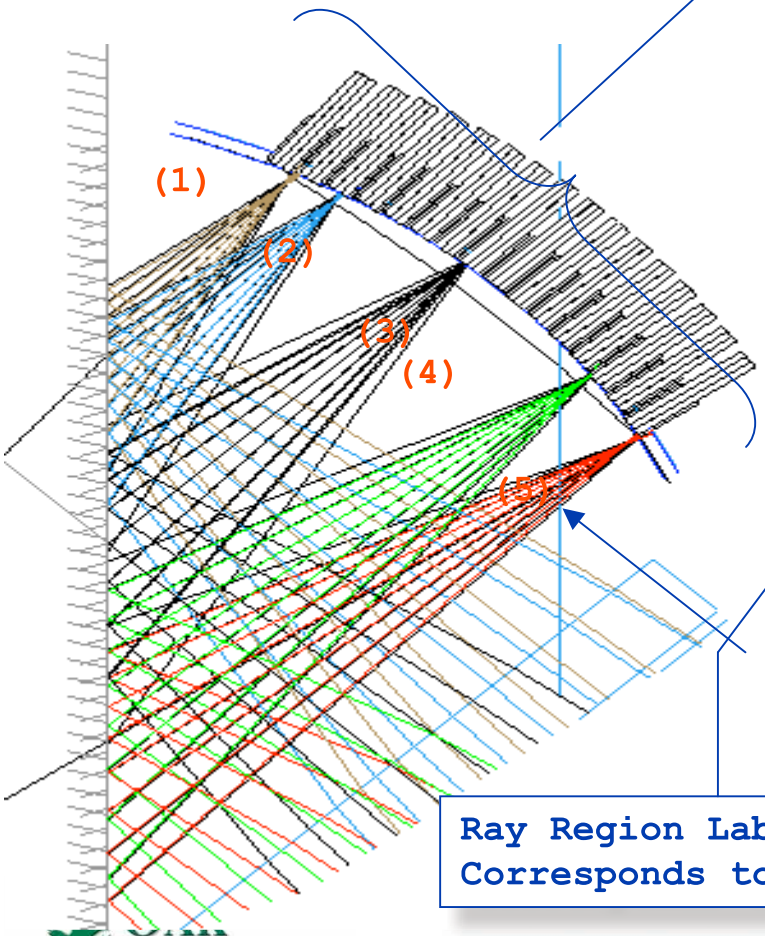
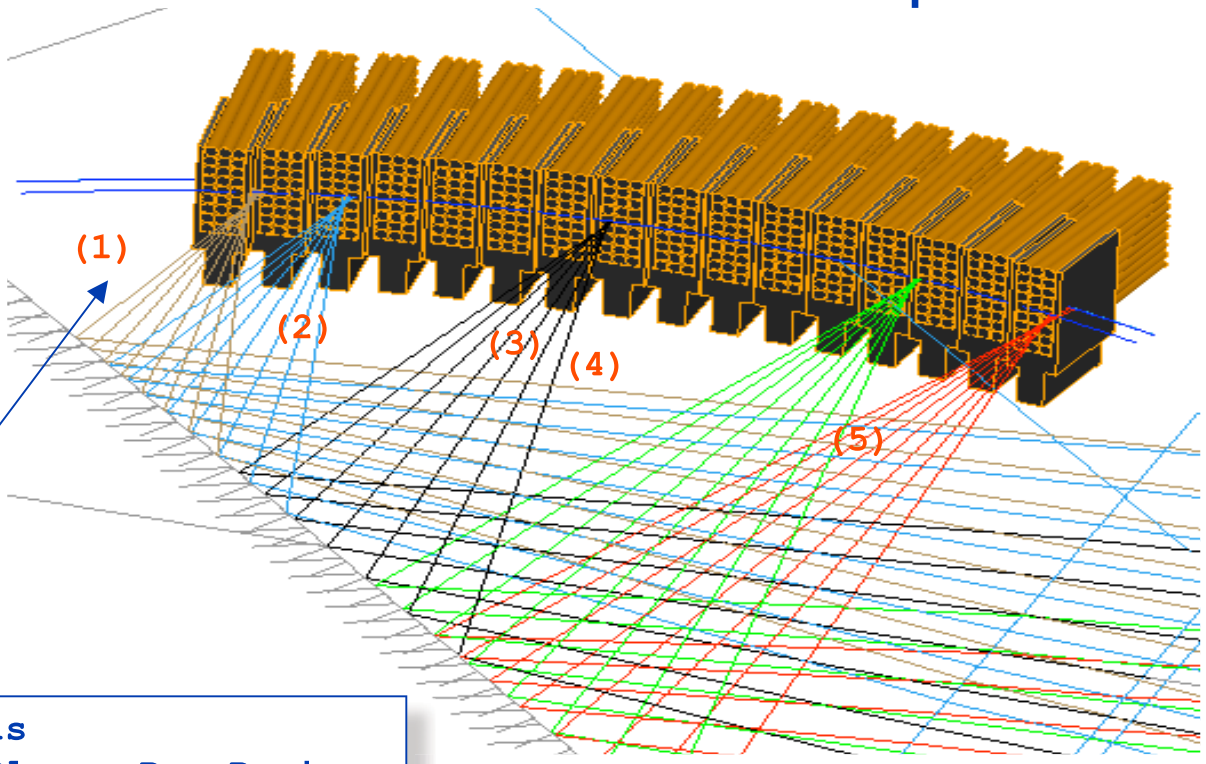
Layout of CER/MSE Fiber Bundles based on Ray Tracing

16 Fiber Bundles (Ferrules)
27 Fibers per Bundle =
432 Total Fibers

Fibers are 1mm fused silica quartz



Top View



Isometric View

Ray Region Labels
Corresponds to Plasma Ray Regions

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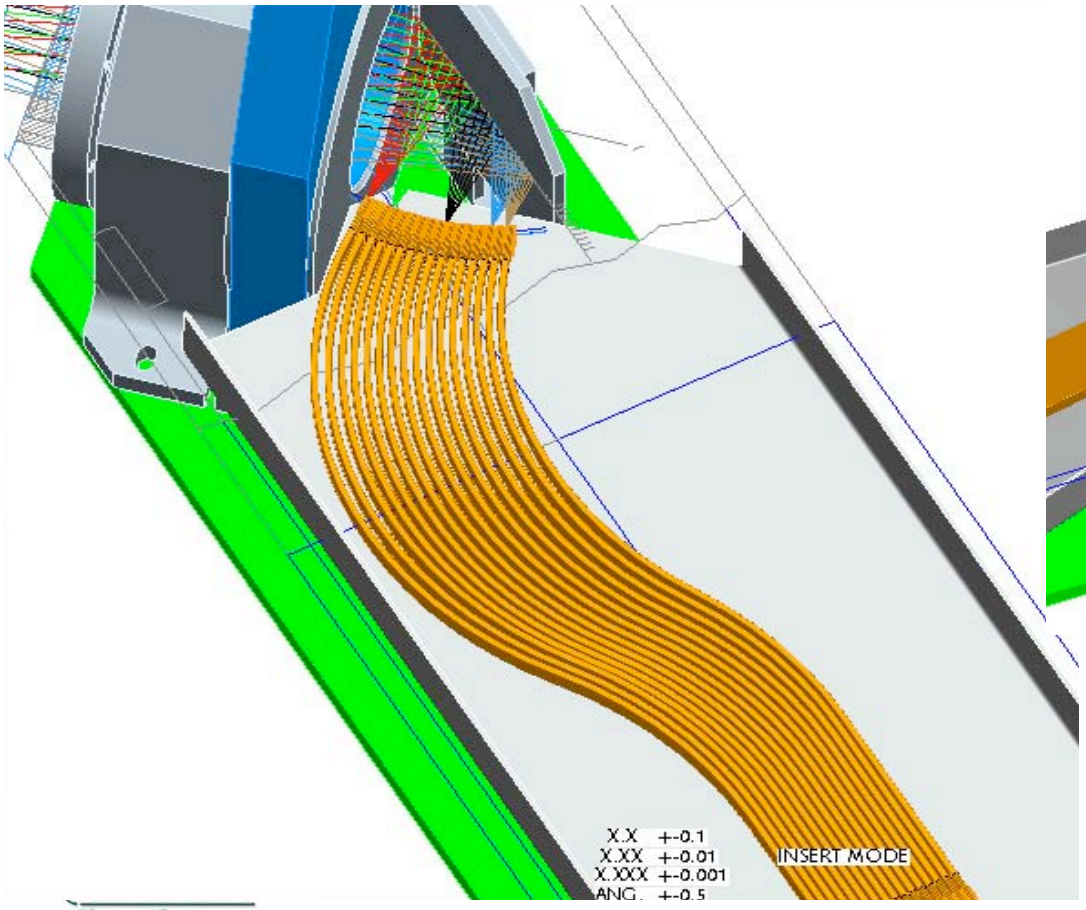
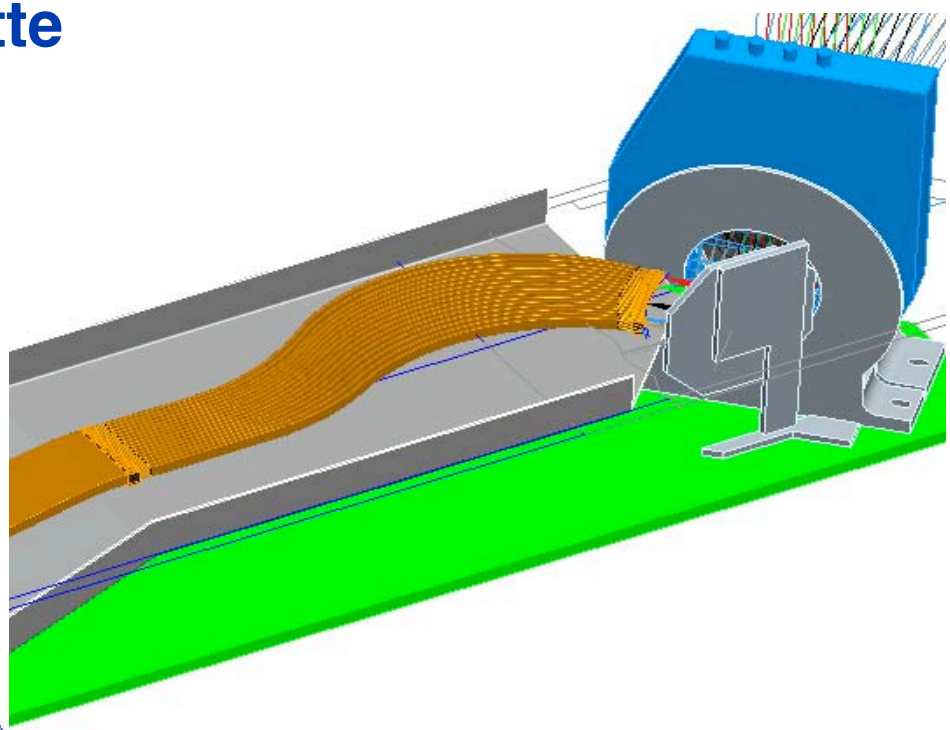
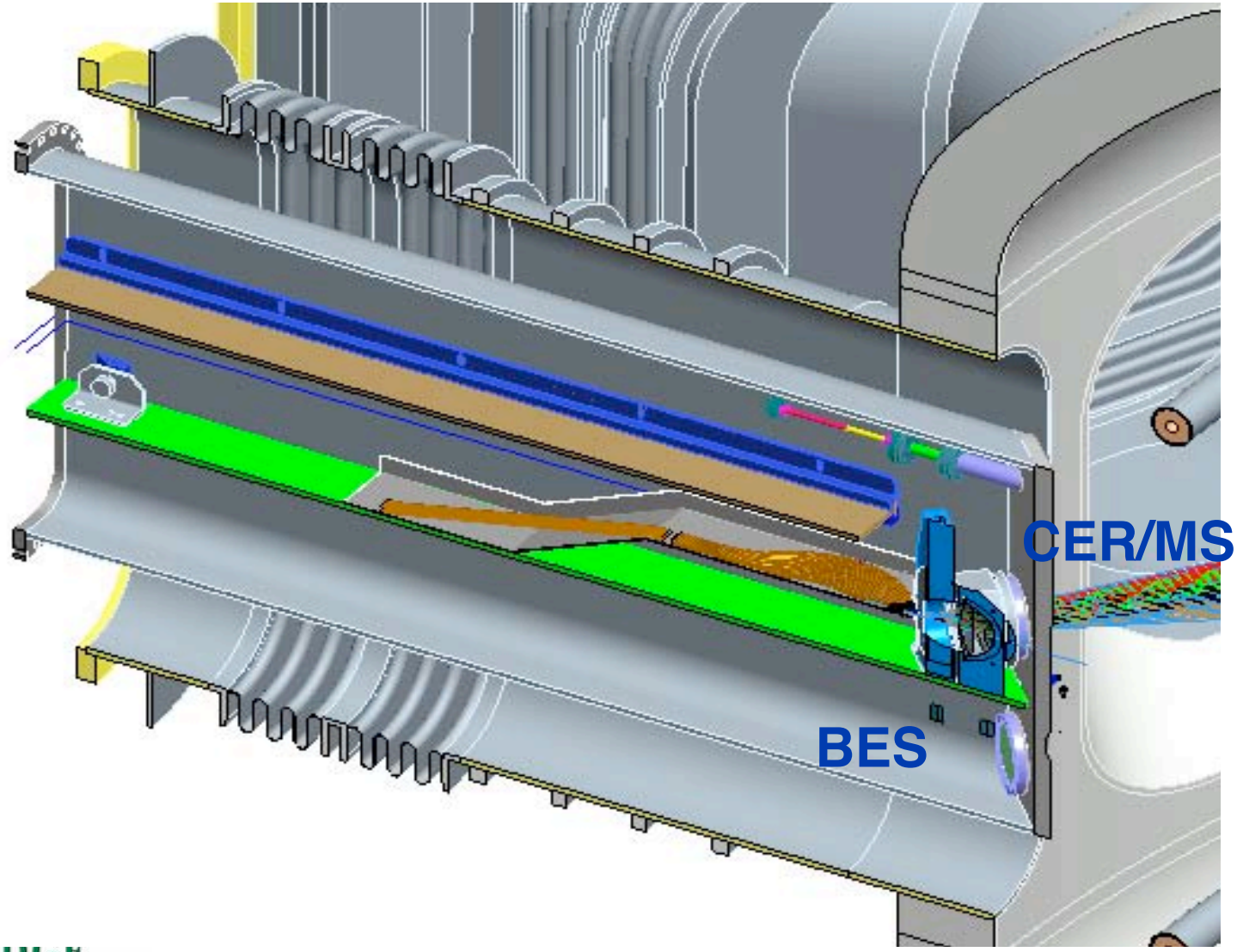
Removable Optics Table with CER/MSE

- **All optics and fibers are aligned outside Cassette then they slide into Cassette**





Cutaway View of the CER/MSE Cassette Bay M



CER Summary

- The US could provide a new high throughput CER Diagnostic system to KSTAR for :
  - Total Cost: ~ $2.1 M
- 3 year program (needs to begin soon)
  - Year 1 - complete design
  - Year 2 - purchase hardware, construct, and test
  - Year 3 - install and commission
- US has completed a rather complete preliminary design for both CER and MSE
  - ORNL has preliminary design for CER
    - Ray tracing completed - front end optics & preliminary design completed - lens specified
    - Need update on understanding of which NBI sources to be used (KSTAR Beams or Japanese Beams)
    - Completed Preliminary layout of front end optics assembly in Bay M Cassette with ProE model
  - Completed preliminary design concept for CER and MSE system
    - What is current plan for building KSTAR diagnostics(like CER & MSE)
      - Building the hardware is only a minor consideration
        - calibration, data analysis, commissioning, data integrity
        - US could play a major role
        - will take 3 years to bring MSE and CER systems online
        - To have profile measurements when they will be needed to meet physics needs for KSTAR, the MSE and CER 3 year program needs to start soon (probably during the next year)
  - What is US role in KSTAR physics program? On the US side - if KSTAR is only interested in US delivering a diagnostic design without participation in the KSTAR physics program, then the US interest will be low.
  - Beyond FY2009 - US-DOE funding is not expected to increase for KSTAR. Can US expect KSTAR support for beginning the detailed design of the MSE and CER systems?
  - How do we proceed?

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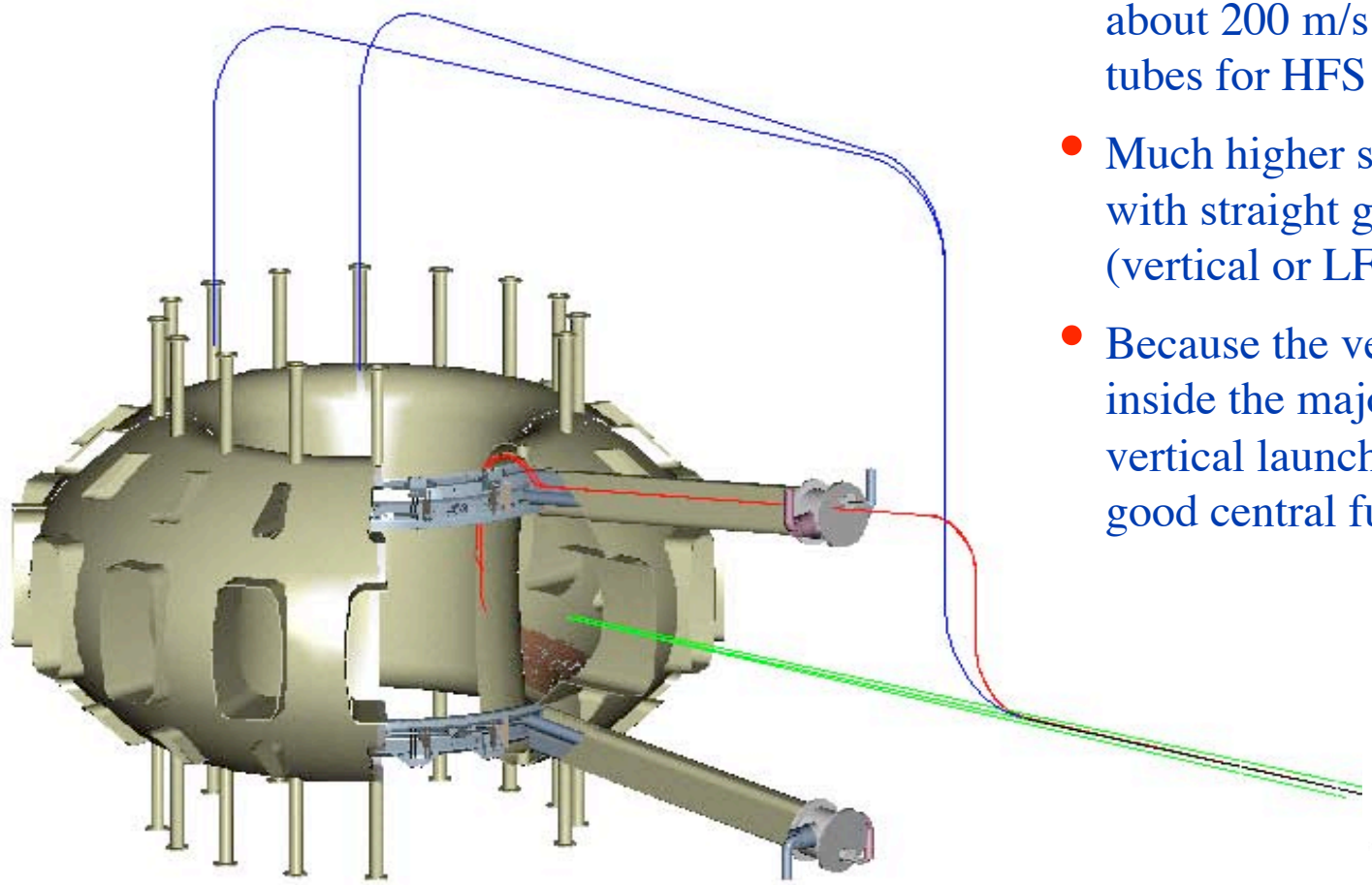
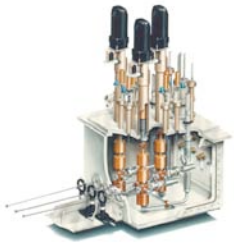
Pellets for KSTAR

Pellet launch paths into KSTAR could be similar to those previously proposed for the FIRE design





- Pellet speed typically limited to about 200 m/s for curved guide tubes for HFS launch
- Much higher speeds possible with straight guide tubes (vertical or LFS launch)
- Because the vertical port is inside the major radius, straight vertical launch may provide good central fueling

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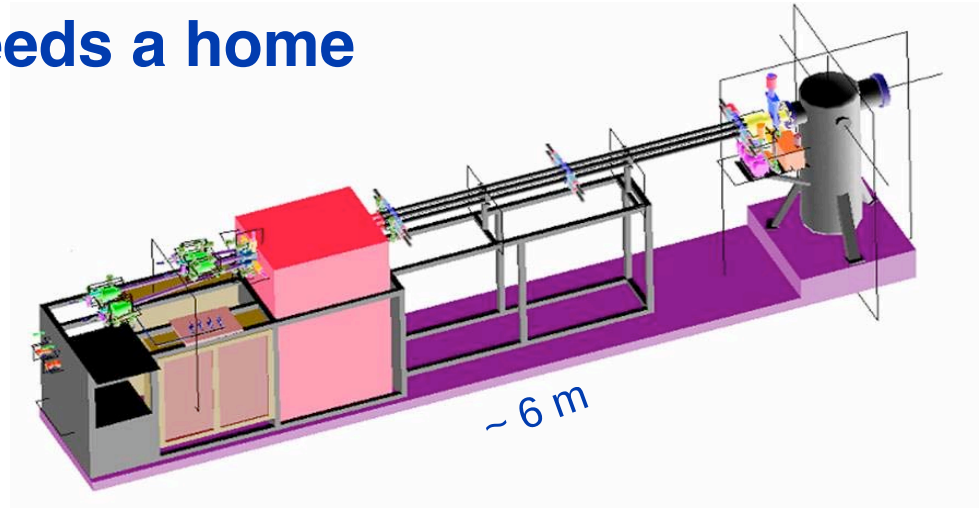
Prototype high-speed injector being developed for IGNITOR could be useful tool for KSTAR

Available and needs a home



- 4-barrel pipe-gun injector is being developed by ENEA/ORNL
- System has 4 pellets that can be sized from 1-5 mm
- Acceleration options: punch, single-stage pneumatic, or two-stage pneumatic (speed range ≈100-4000 m/s)
- System includes pellet diagnostics, injection line, guide tubes, control system
- Would make a nice system to investigate pellet physics before a higher throughput system were employed
- Particularly attractive for high-speed pellet or impurity injection (possibly even "killer" pellet for disruption mitigation)

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History of KSTAR/ORNL "Dialogue" on Pellet Fueling

- November 2005: Dr. W. Kim (KSTAR) contacted Dr. S. Milora (ORNL), expressing interest in ORNL pellet injection systems and requesting preliminary cost estimates for various options applicable for KSTAR
- December 2006: ORNL provided some preliminary cost estimates to Dr. W. Kim for four possible pellet injector systems (ORNL contact - Dr. L. Baylor)
  - ⇨ IGNITOR prototype injector ($300K)
  - ⇨ Pellet injector in a suitcase ($550K)
  - ⇨ Repeating gas gun injector - 2 guns ($1.2M)
  - ⇨ Steady-state gas gun injector - 2 guns ($2M)

  At that time, Dr. Kim requested a formal quotation with breakdown of individual systems; ORNL responded that more detailed information from KSTAR on various systems (pumping, cryogenic, instrumentation&controls, data acquisition, etc.) was needed before this exercise could be done
- January 2006: Some correspondence on curved guides for KSTAR
- Everything has been on hold since last contact awaiting more input from KSTAR

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