Conceptual Evaluation of Measurement of |B(R)| for Determination of q(R) on ITER

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12TH ITPA Topical Group Meeting Spring 2007
March 26-30, 2007
Princeton, NJ

Polarimetry MSE will be difficult, can |B(R)| work?

- MSE based on pitch angle measurements relies on polarization preserving mirrors, and is expected to be challenging on ITER
- Previous efforts on JET (Wolf et. al. 1993) made |B(R)| measurements and observed pressure changes, but not used for reconstruction
- Can a |B(R)| profile be used instead of pitch angle profiles?
- L. Zakharov has modeled sensitivity of current/pressure profile to |B| using profile perturbation / SVD response code
- Jill will go into more detail in second part of this talk
- Breakout discussion Tues. 3:20PM

MSE-LP $\tan(\gamma_{meas}) = \dfrac{E_{hor}}{E_{ver}} = \dfrac{|(1-\hat{\mathbf{E}}\cdot\mathbf{z})\mathbf{E}\times\mathbf{s})\times\mathbf{s}|}{|(\hat{\mathbf{E}}\cdot\mathbf{z})\mathbf{E}\times\mathbf{s})\times\mathbf{s}|} \sim \dfrac{B_v}{B_T}$ $\mathbf{E} = (\mathbf{v}\times\mathbf{B}) + \mathbf{E}_r$

MSE-LS $\dfrac{|\mathbf{E}|^2}{|\mathbf{v}|^2} = B^2 - (\hat{\mathbf{v}}\cdot\mathbf{B})^2$ $B^2 = B_t^2 + B_z^2 + B_r^2$

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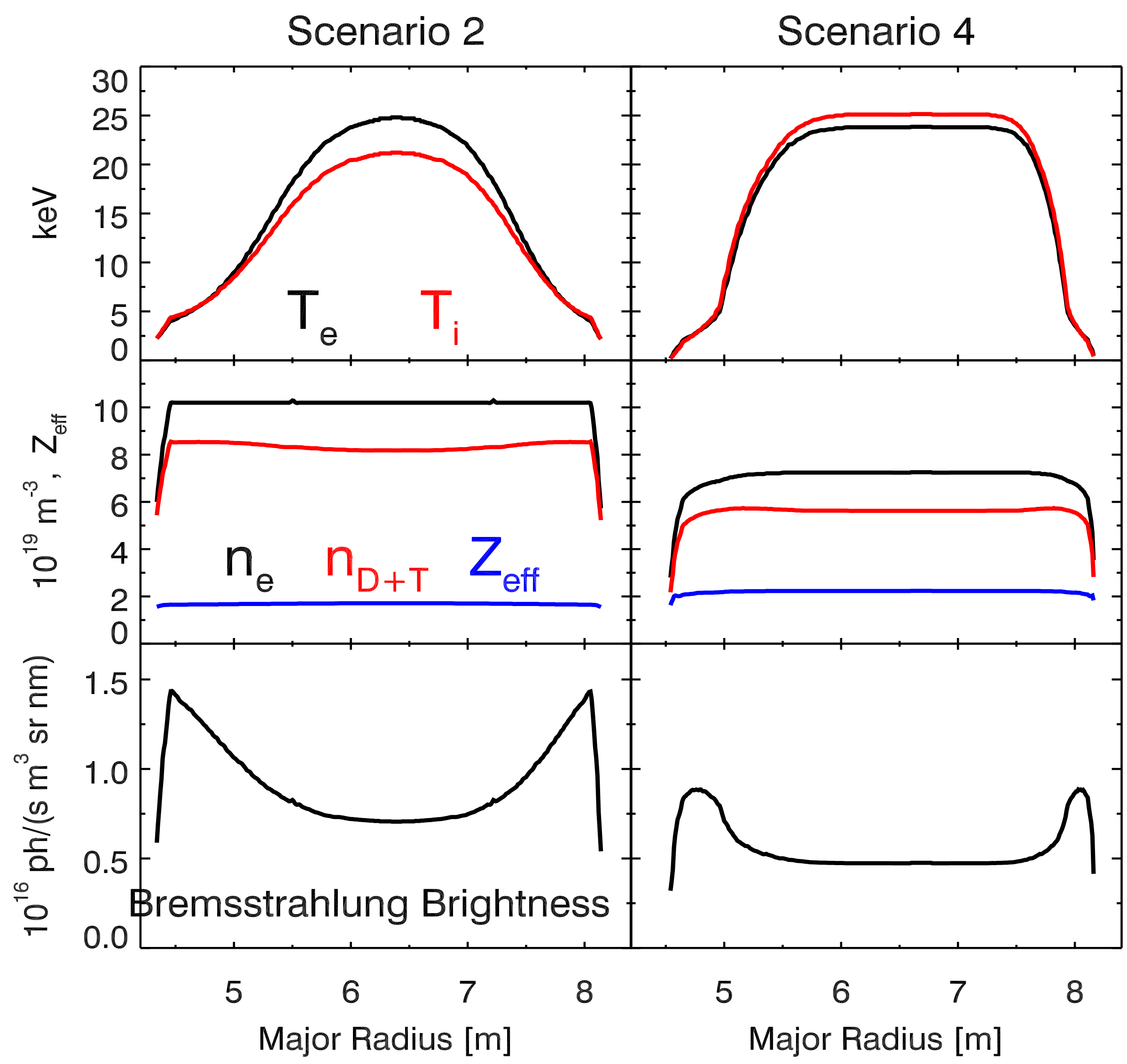
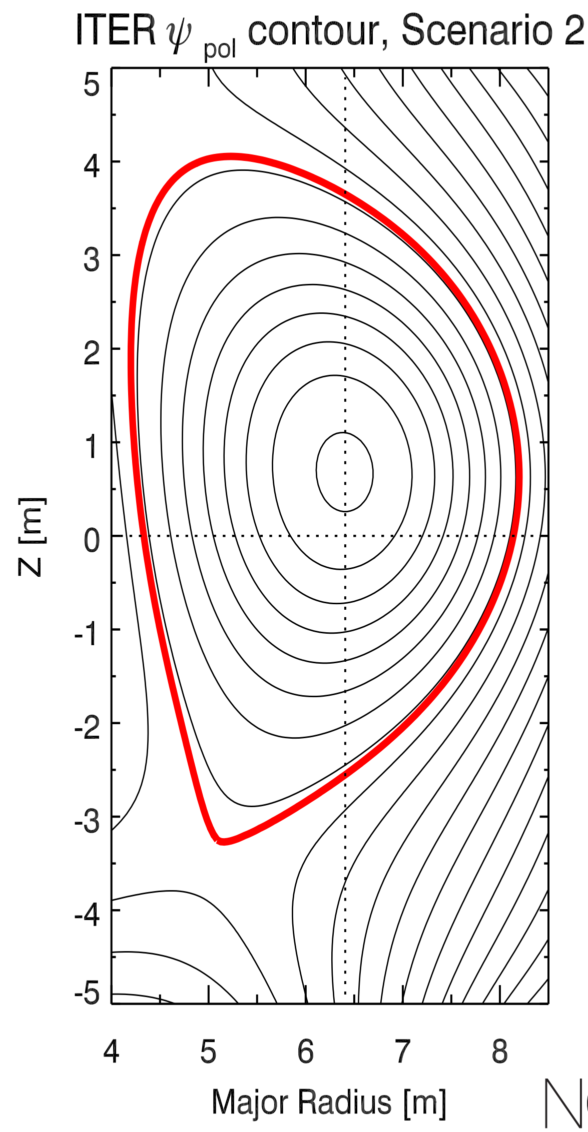
Scope of work / Outline

- Scope of work is to determine the achievable accuracy of a |B(r)| measurement using spectroscopic methods
- Task list and outline of the two part talk:
  - – Obtain ITER HNB specifications, plasma parameters, viewport geometries
  - – SimMSE code developed to simulate actual observed signal using realistic beam spectra including bremsstrahlung for actual sightlines
  - – Assess accuracy of |B(R)| measurement using viable spectroscopic techniques
  - – Share data with reconstruction experts to determine level of constraint on q(R)
    - L. Zakharov – Sensitivity of current profile to |B(R)|

ITER equilibria and profiles

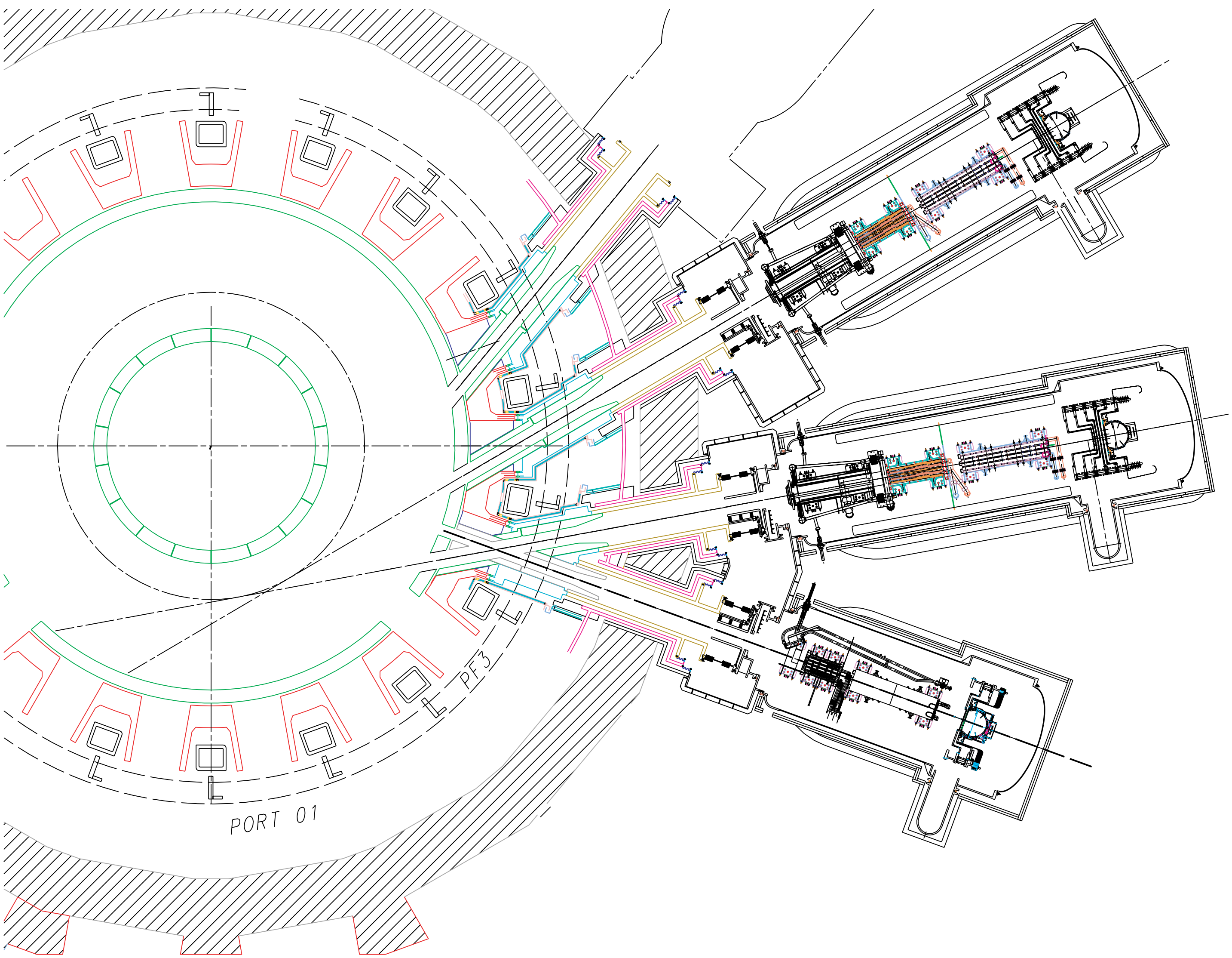
- Both available ITER plasma profiles and equilibriums used
- Scenario 2 (15MA, Q=10, 400s, P_{fus}=400MW)
- Scenario 4 (9MA, weak RS, 3000s,Q=5,P_{fus}=300MW)
- Flux quantity plasma profiles flux mapped to R,Z





ITER Heating Beam Geometry

- ITER currently has two, 16.7MW, 1MeV D heating beams at Ports 4 and 5 (HNB4, HNB5)
- Variably inclined for on and off-axis current drive



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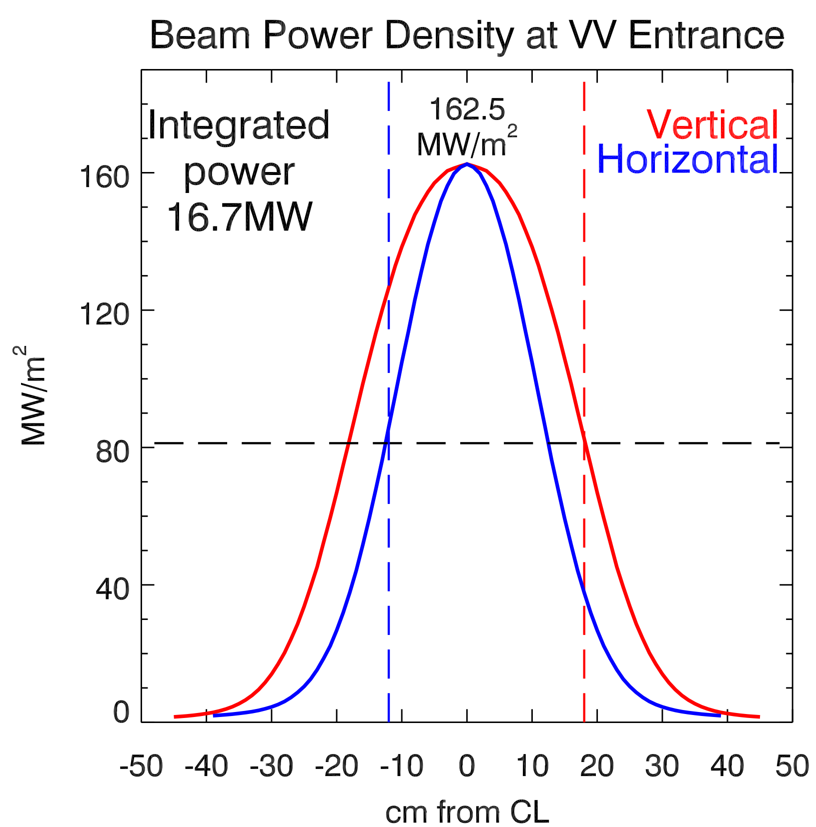
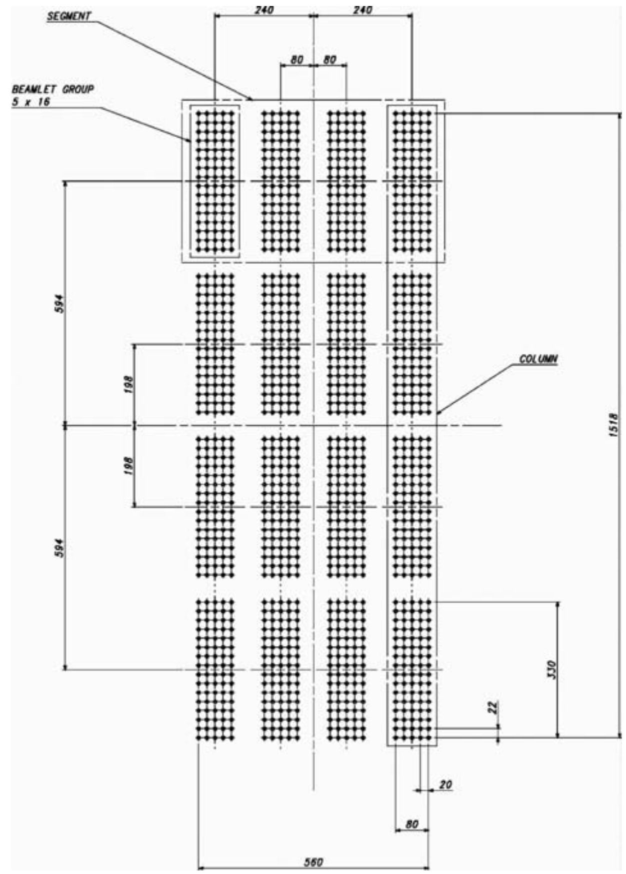
ITER Heating Beam Profile

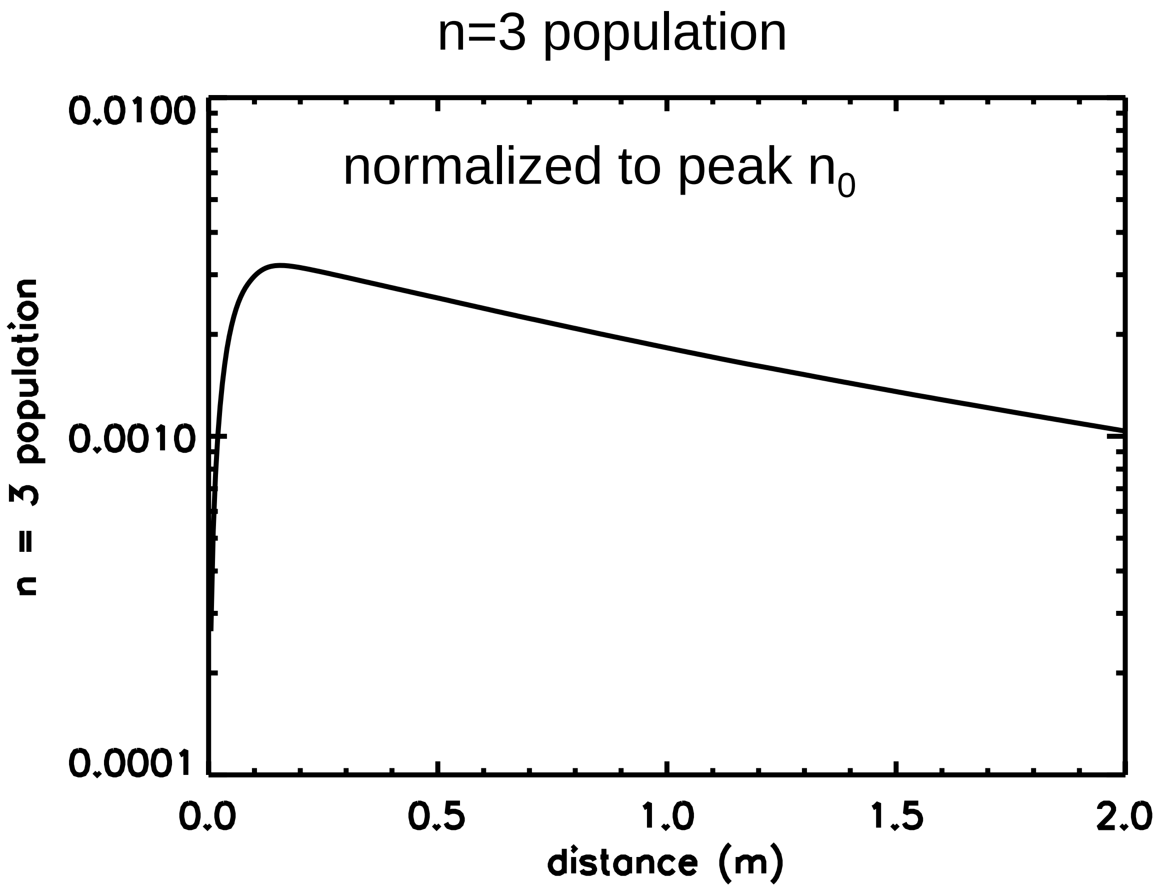
- HNB accel grid has 1280 beamlets arranged as 16 beamlet groups
- Beamlet group focusing results in 16 different beam injection angles
- Beam power density profile modeled at entrance to VV
- Beam power launched as rays into toroidal grid, tracking injection angle





CRM of excited neutral densities

- A Collisional Radiative Model (n=1 to n=7) was used to determine the equilibrium n=3 fraction as a function of beam trajectory using mapped plasma parameters
- Autoionization by Stark field at n>6 is accounted for in CRM



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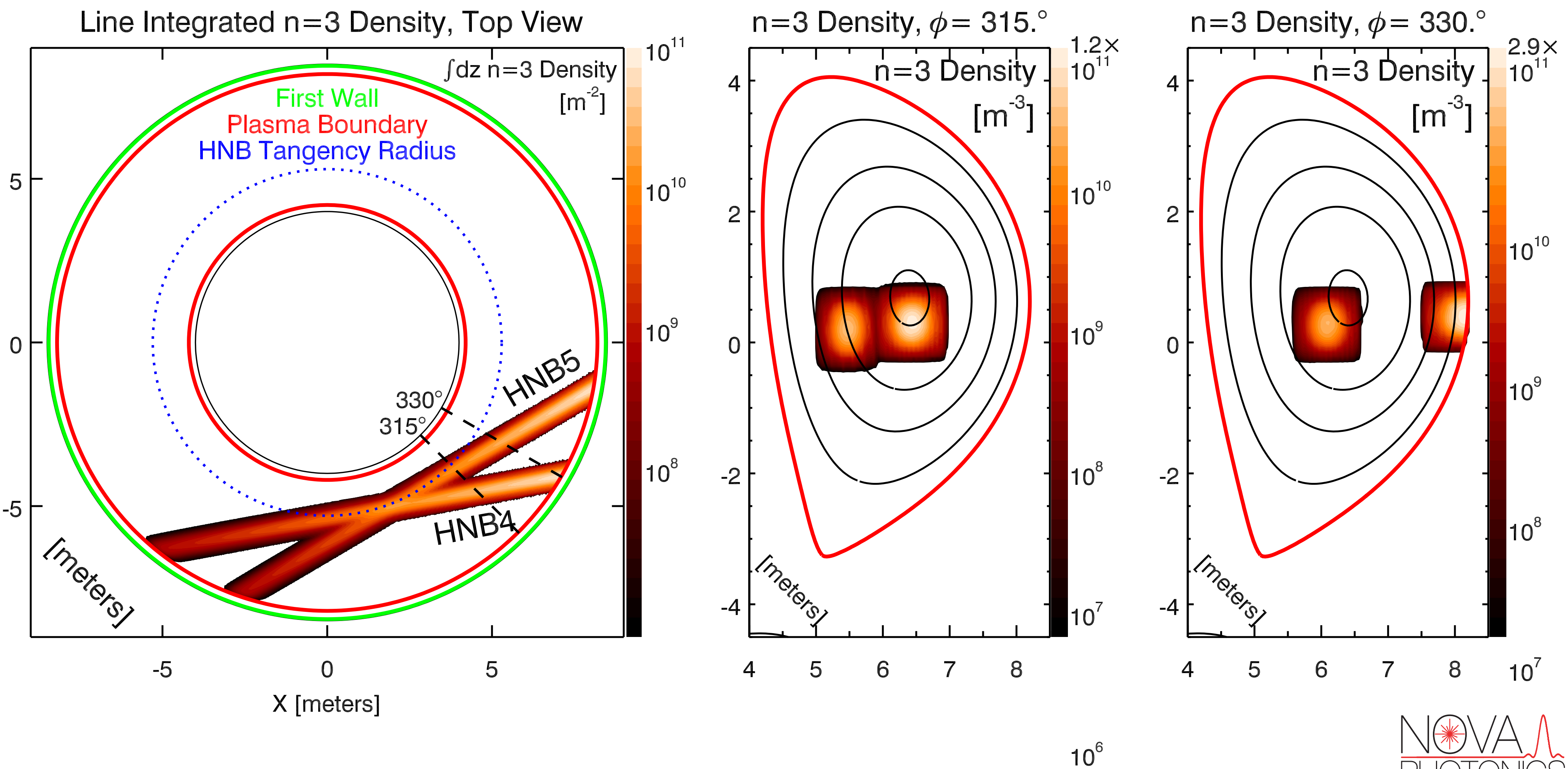
Neutral n=3 density profiles

- Beam rays attenuated through plasma using flux mapped profile quantities
- Excited fraction is calculated using collisional-radiative modeling
- Results is 3D model of excited state densities with beamlet angles



Atomic physics effects

- Linear and quadratic Stark effect includes as a function of position, beam angles
- Doppler shift variation due to beamlet angles
- Removal of σ_0 degeneracy by quadratic Stark effect included
- *Polarimetry package has been completed*
- *Ability to project polarization pattern and sightline integrate for arbitrary viewing geometry*
- *Stokes vector propagation through mirror reflections, including non-ideal 2D mirror properties straightforward to implement*

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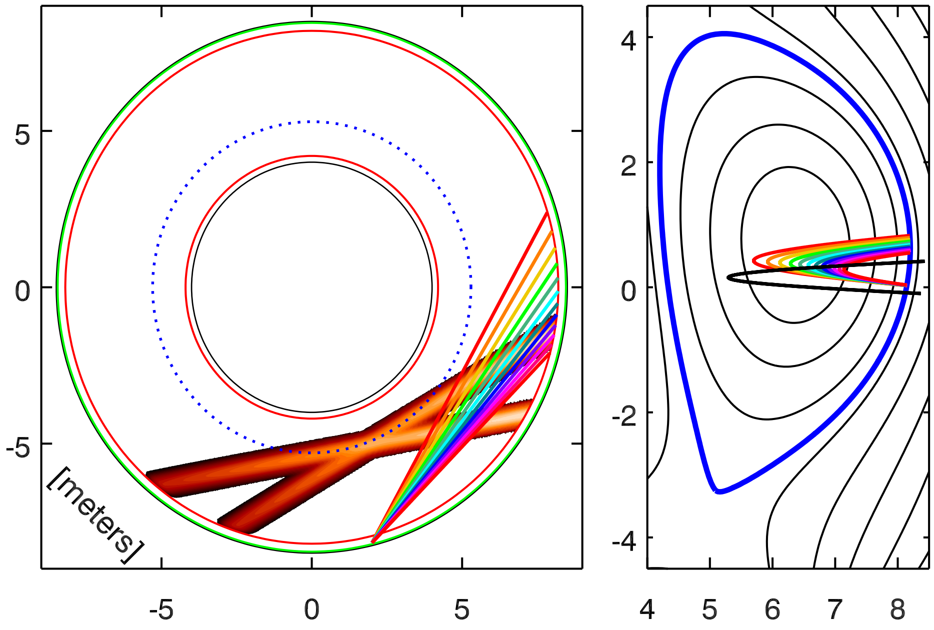
Viewing Ports Considered

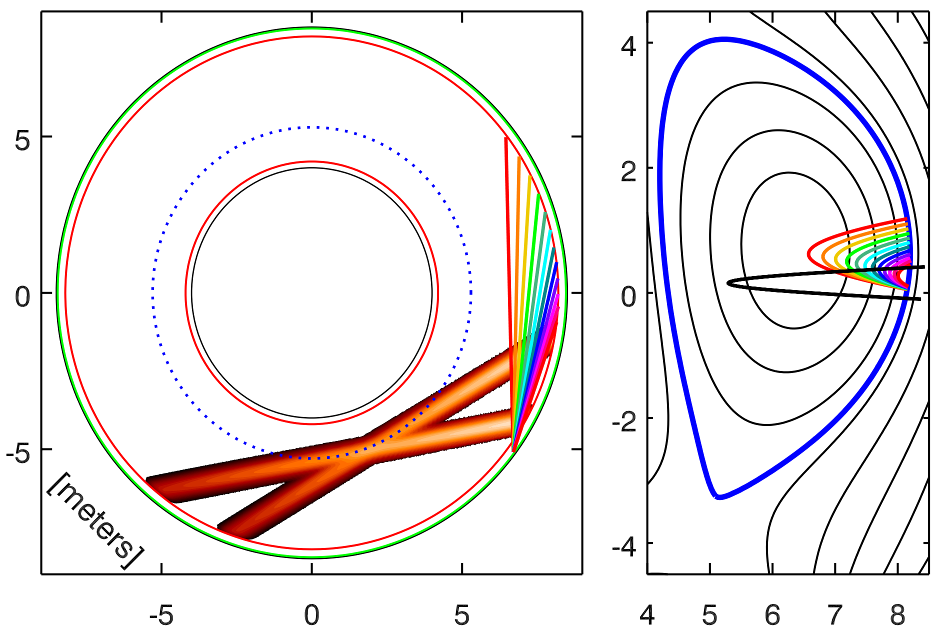
Port 1 viewing NB4 | Port 1 viewing NB4



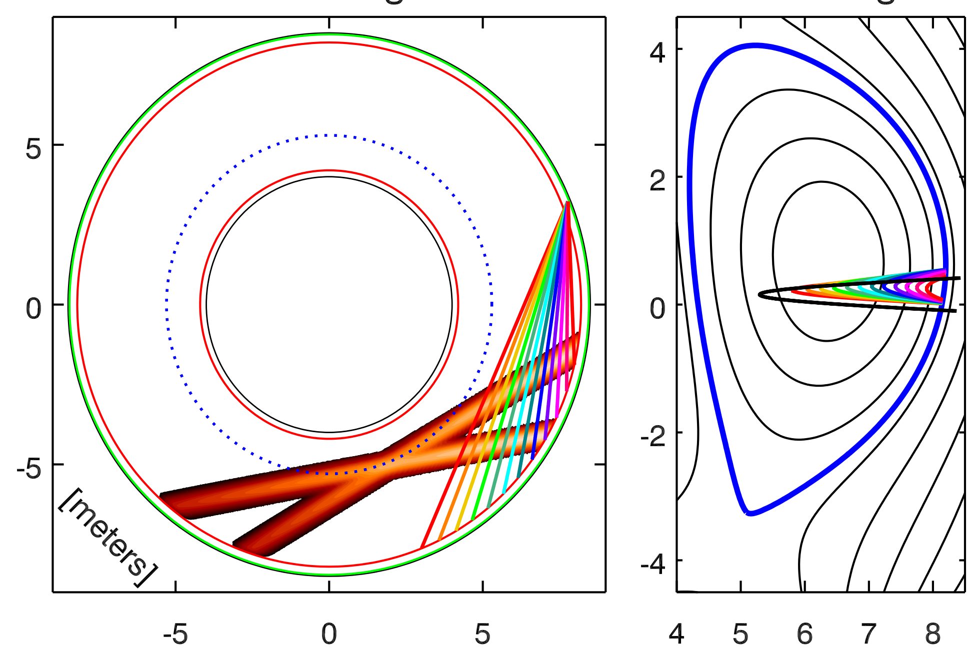
Considered sightlines from
Ports 1,3,6
Current MSE design:
CORE views at Port 1 → HNB4
EDGE views at Port 3 → HNB5

Midplane aperture assumed
Sightline assumed aimed at HNB axis

Port 3 viewing NB5 | Port 3 viewing NB5



Port 6 viewing NB5 | Port 6 viewing NB5



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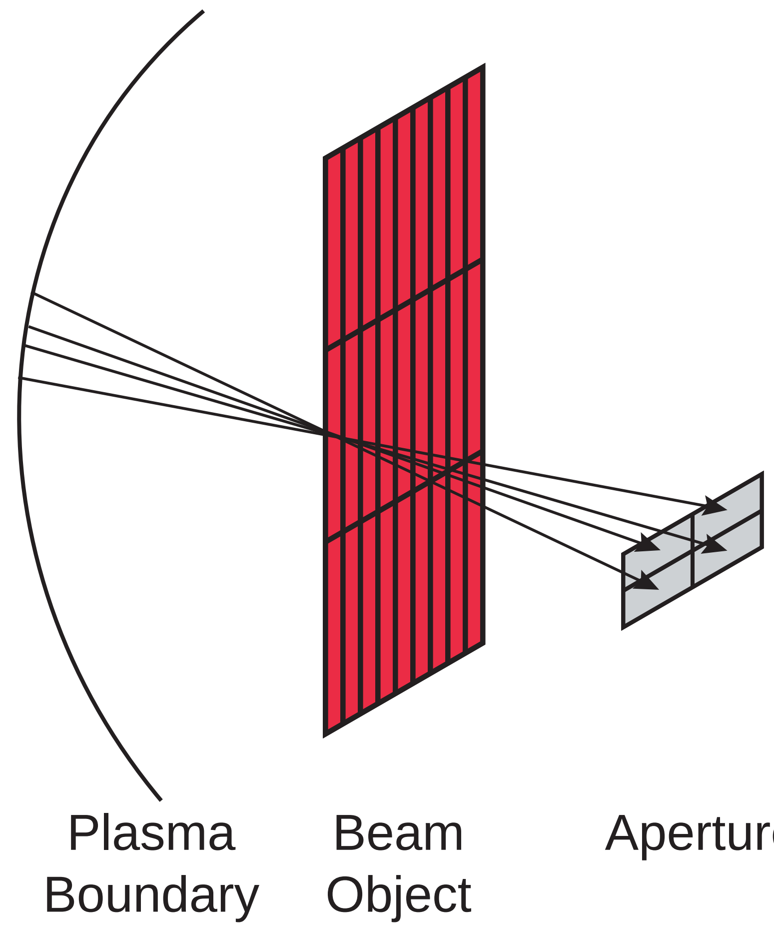
Object / Aperture Treatment

- Aperture size taken from 2003 Malaquias design
- Object chosen to maximize photon count (10cm x 40cm)
- Finite element analysis of aperture and object
- Geometric broadening, volume integrated radial resolution
- Etendue kept identical for all channels (fan minimum)



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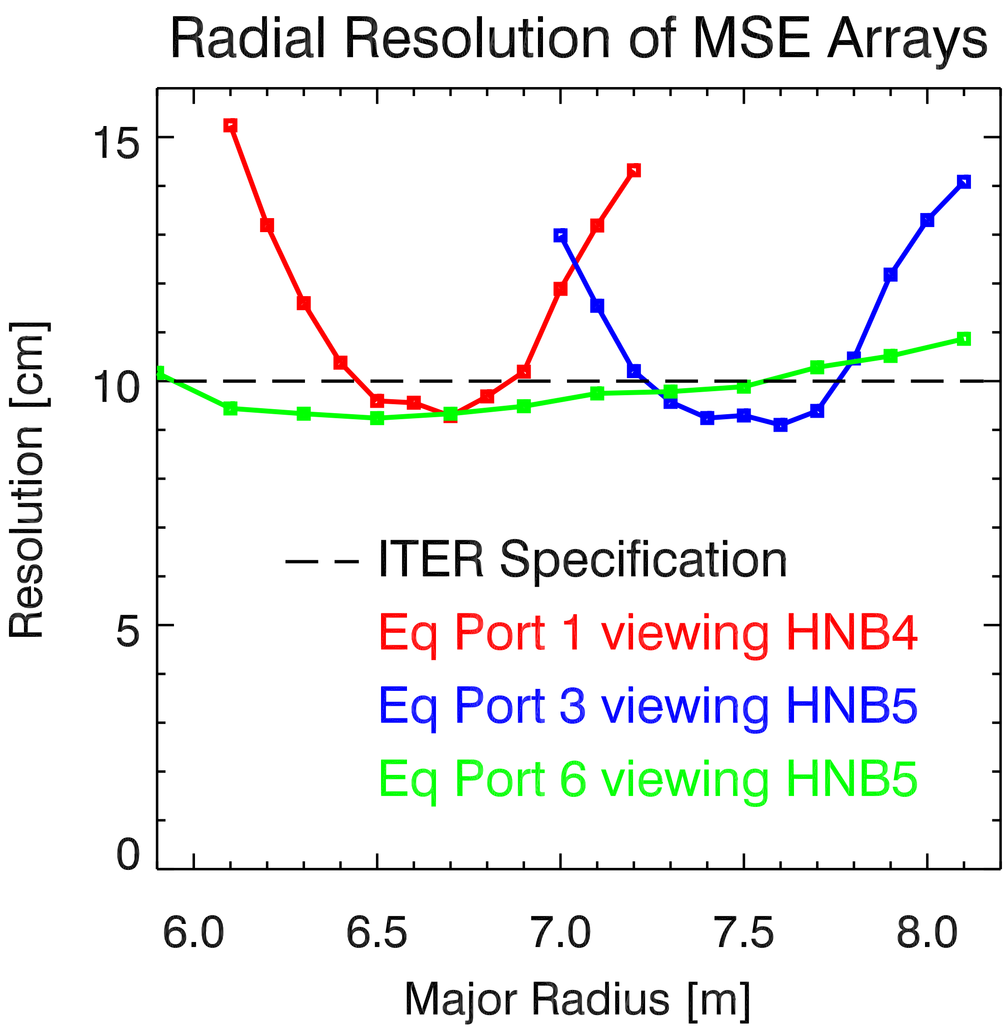
Radial Resolution

- Current design uses separate Edge and Core views
- Does not satisfy ITER spec'ed MSE resolution for all radii
- Similar to previous works (Lotte, Hawkes, 2004), but extended to finite object size
- Full width, 1/e of observed intensity profile using 10x40cm object size
- Single view from Port 6 would provide necessary resolution across outboard minor radii



Broadening mechanisms considered

Mechanism	Width
Beam Energy Ripple (V. Toigo, Dec 2006)	~0.3Å
Beam Divergence	~0.5Å
Variations of B along sightline	~0.5Å
Geometric Broadening	~2Å
Doppler + **v**×**B** variation due to beamlet angle variation	~3Å
Total	**~4Å**

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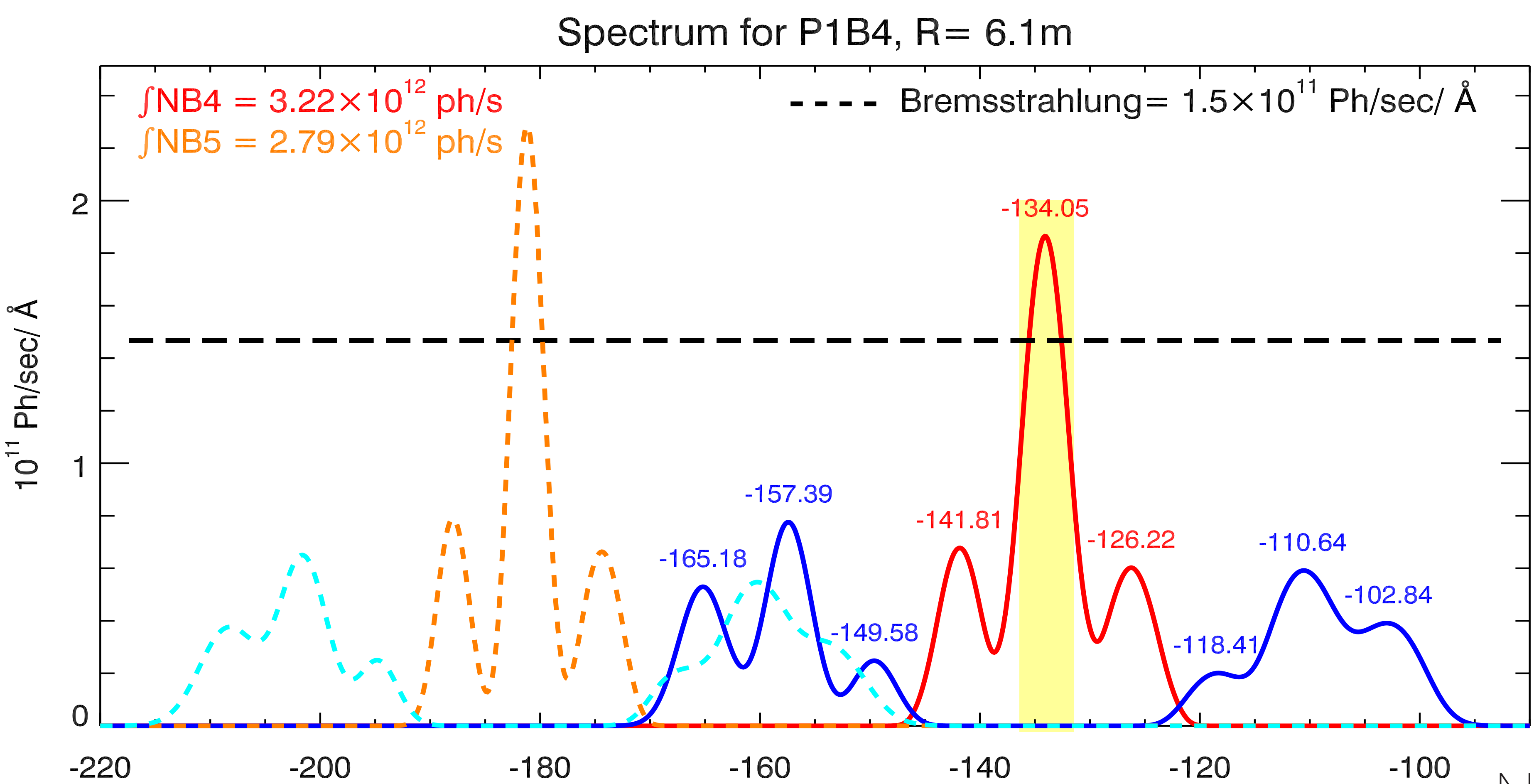
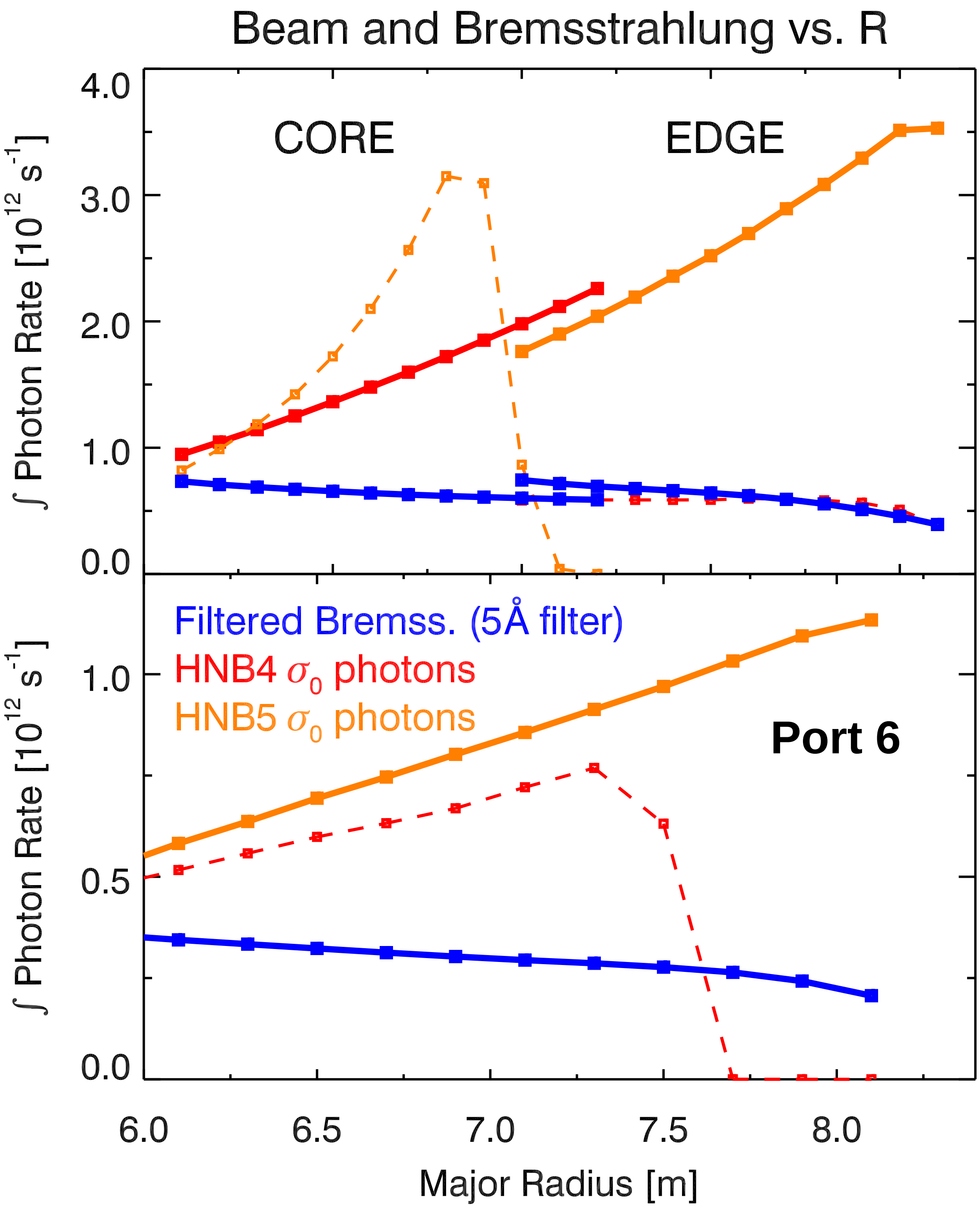
Final spectra at aperture

- Finite element volume integrated result
- Each SL has differing line widths, separations
- Simulated absolute intensity at 1st mirror, (photons/second/Angstrom)
- Etendue for modeled aperture and object size included in calculation
- Significant spectral overlap between HNB4 and HNB5



Polarimetry signal to Bremsstrahlung ratios



- Integrate the σ_0 Stark line using a 5Å filter
- S/B ratio optimized by using only σ_0 component
- S/B ratio reduced significantly over many channels if wider filter is used
- CORE/EDGE design has similar S/B but more photons
- Aperture etendue kept identical for all views
- Beam is further away Port 6 views

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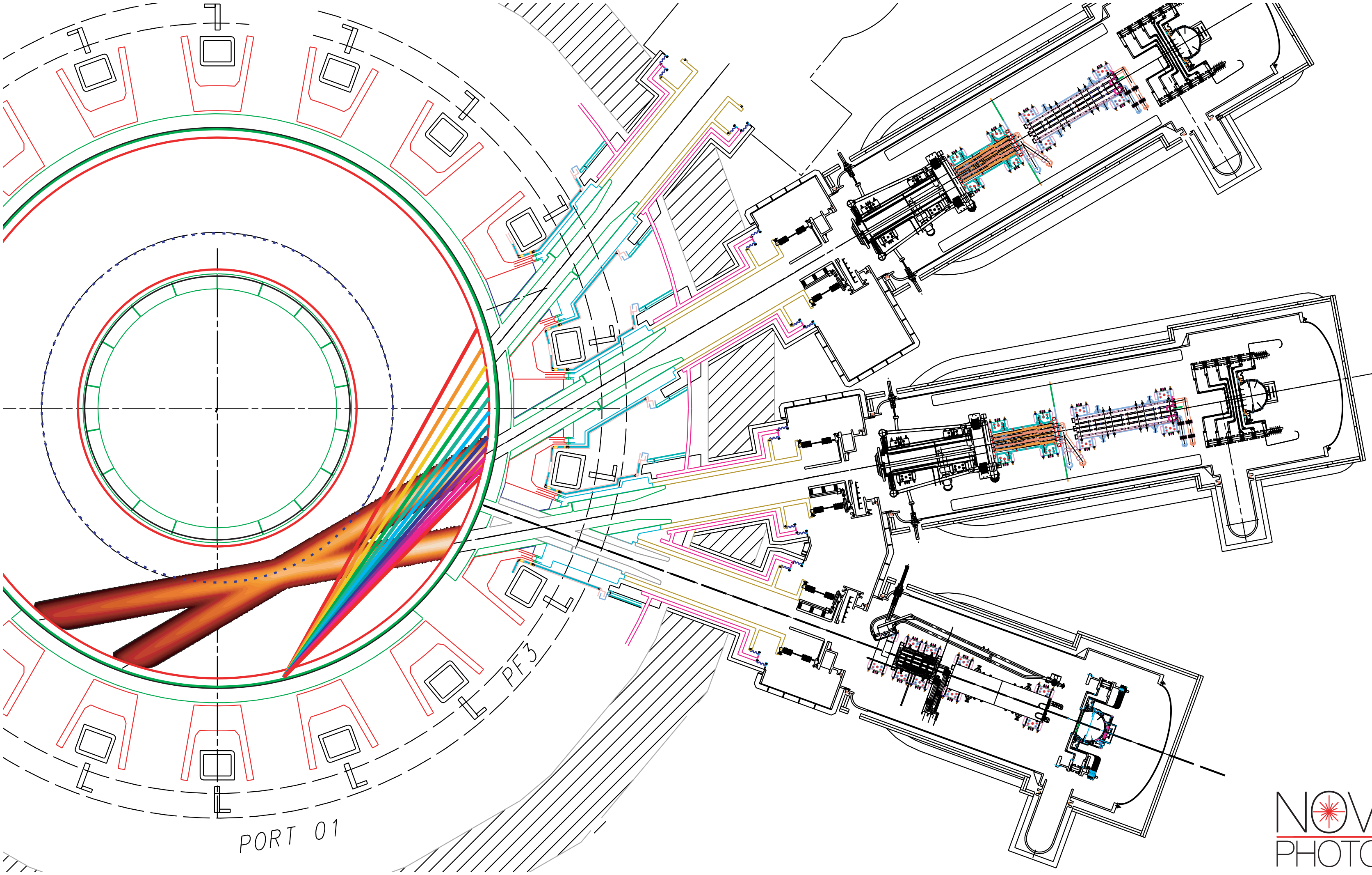
SimMSE Results

- Accurate 3D beam model & viewing geometry using ITER equilibria/profiles
- Complete atomic simuation of spectral features including all broadening effects
- Volume integrated MSE spectra and *polarization pattern*
- *Ray-tracing through non-ideal mirror reflections*
- *MSE optimization/sensitivity studies possible*



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