Power and Particle Handling in NCSX

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Objectives

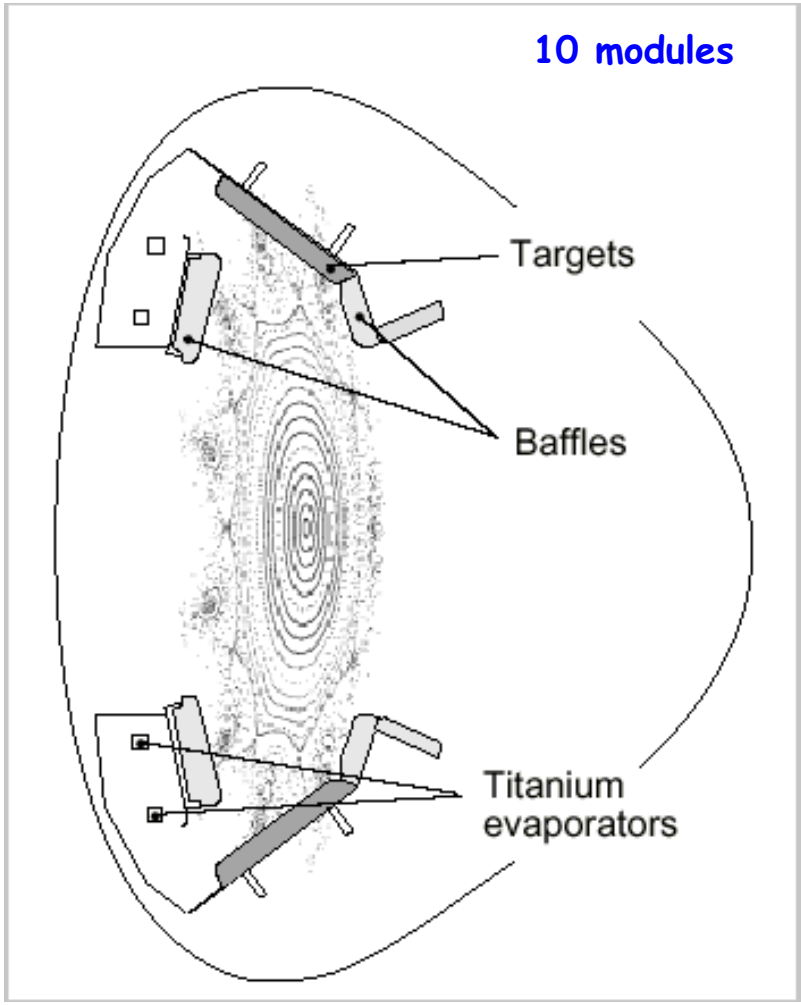
- The plasma boundary program provides opportunities for improving the NCSX plasma performance by controlling impurity production and neutrals recycling.
- Impurity control is achieved by materials choice (low-Z, high-Z ?) and PFC design which provides controlled surfaces for plasma-wall interactions.
- Recycling control is achieved by moving the recycling sources away from critical locations of the plasma and by wall conditioning and pumping.

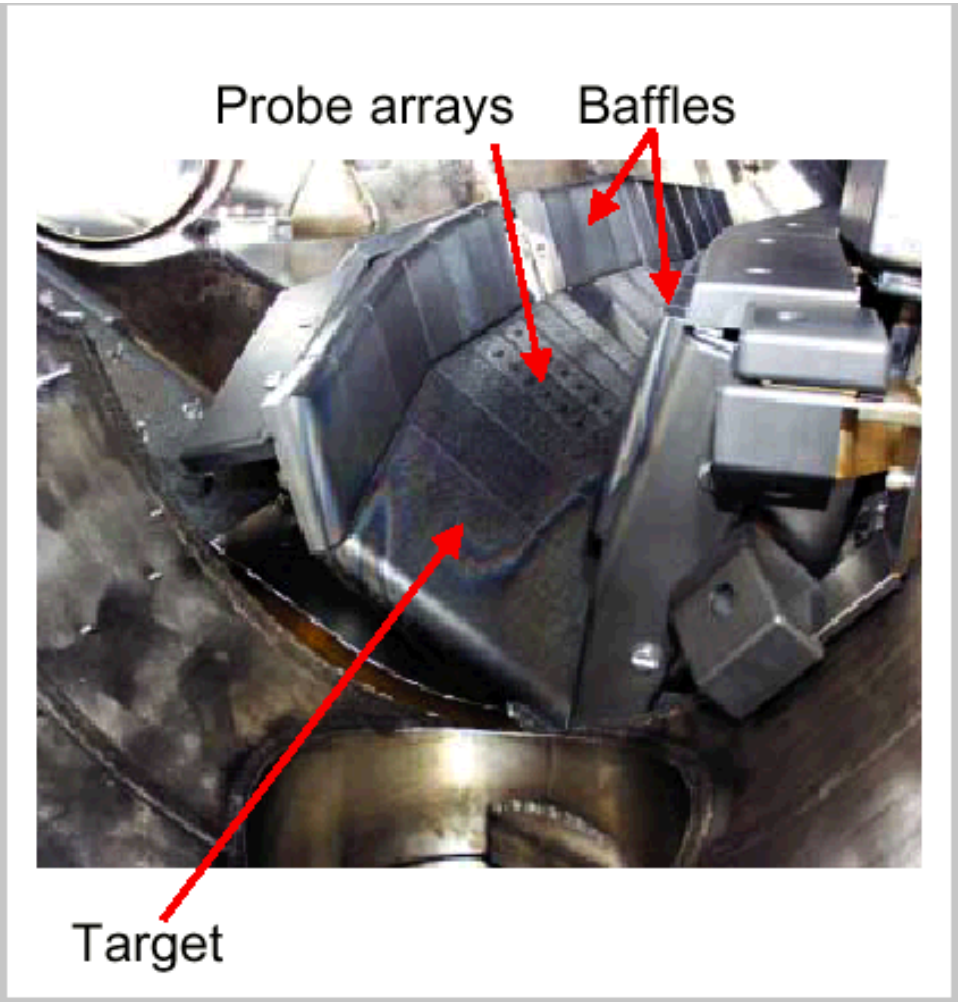
Summary of Recent Results With Divertor Operation on W7-AS

- The new divertors enable access to a new regime with NBI at very high density (up to $\bar{n}_e \sim 3.5 \times 10^{20}\ m^{-3}$) with promising confinement properties:
  - τ_E increases steeply with density,
  - τ_p and τ_{imp} decrease with increasing density ($\tau_{imp} \sim \tau_E$ at highest density)
- Record value of <ß> ~ 2.7% achieved (at B = 1.25 T)
- Full density control already without Ti- gettering.
- Quasi-steady state operation also including partial detachment.
- Radiation stays always peaked at the edge.
- Plasma heating at extremely high density by HF (EBW 140 GHz) is successfully demonstrated.

courtesy of P. Grigull

W7-AS Divertor Configuration





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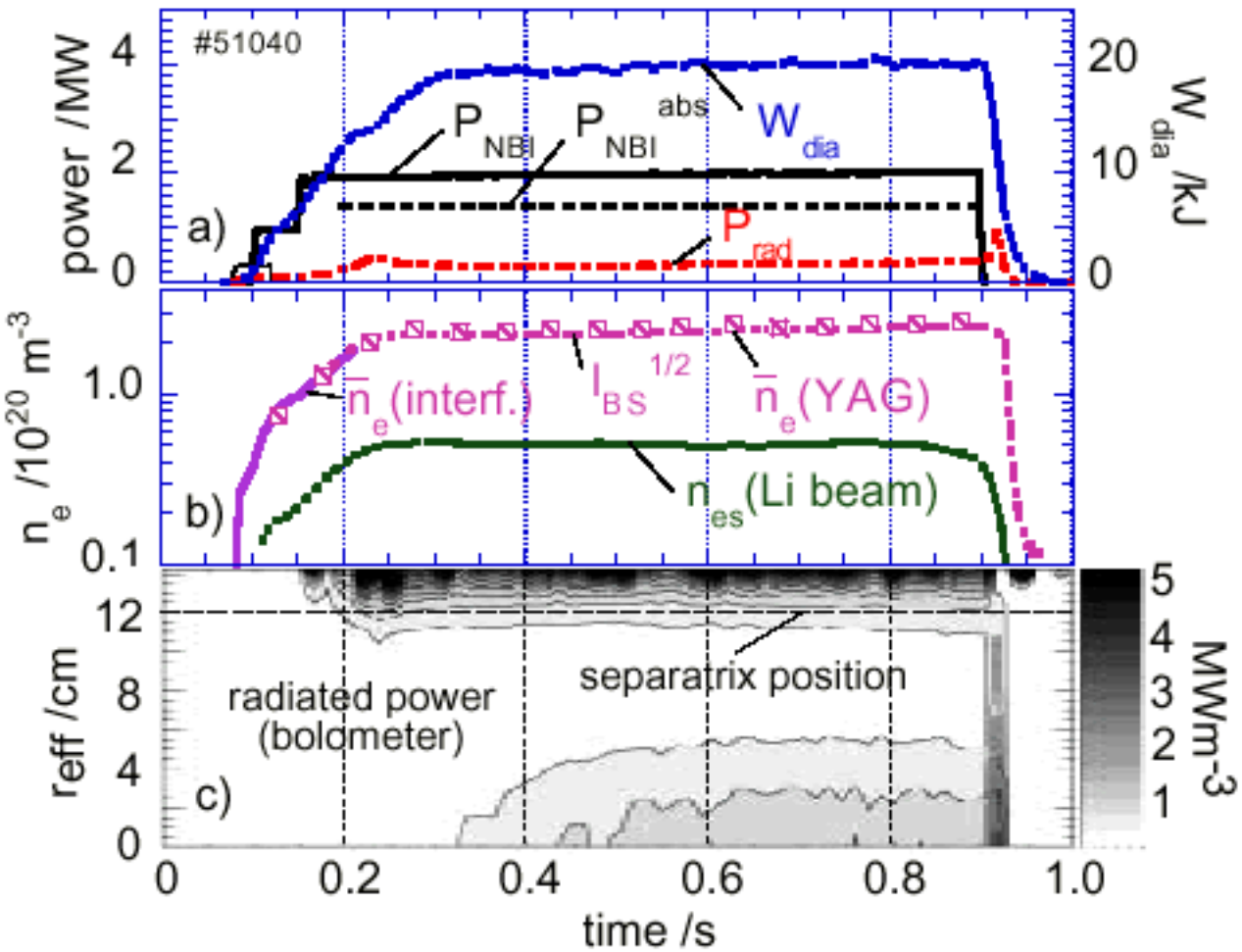
With the New Divertor, High-Density NBI Discharges Can Be Maintained in Quasi-Stationary Operation



- n_e = 2.5x10^{20} m^{-3}
- T_{es} = 90 eV
- T_e (0) = 450 eV

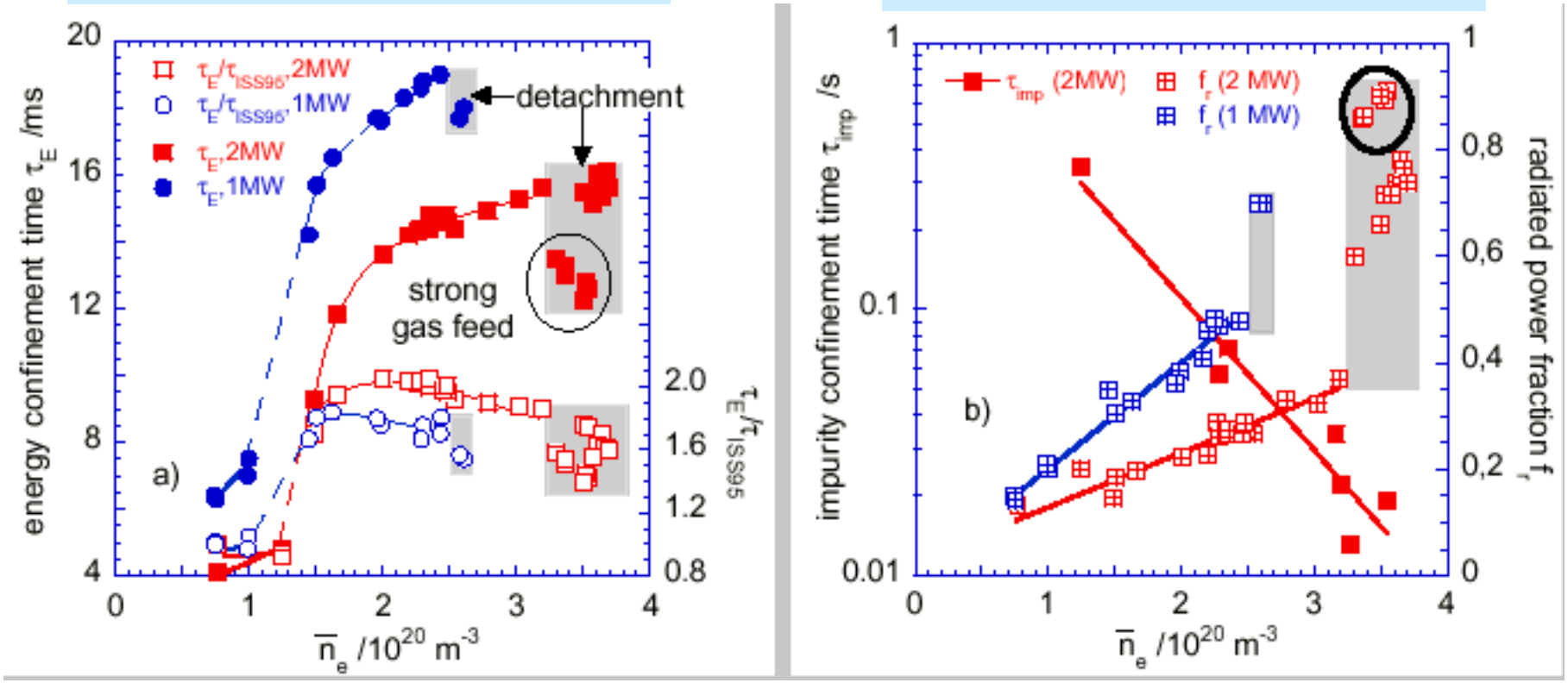
- moderate radiation level
- strongest radiation from the very edge

courtesy of P. Grigull

Energy Confinement Increases and Particle/Impurity Confinement Decreases With Increasing Density

- τ_E increases steeply with density and then tends to saturate,
- degradation in partially detached states is only marginal.

- τ_{imp} decreases steeply with increasing density,
- radiated power fractions are moderate in attached- and up to 90% in partially detached states



courtesy of P. Grigull

Implications for NCSX

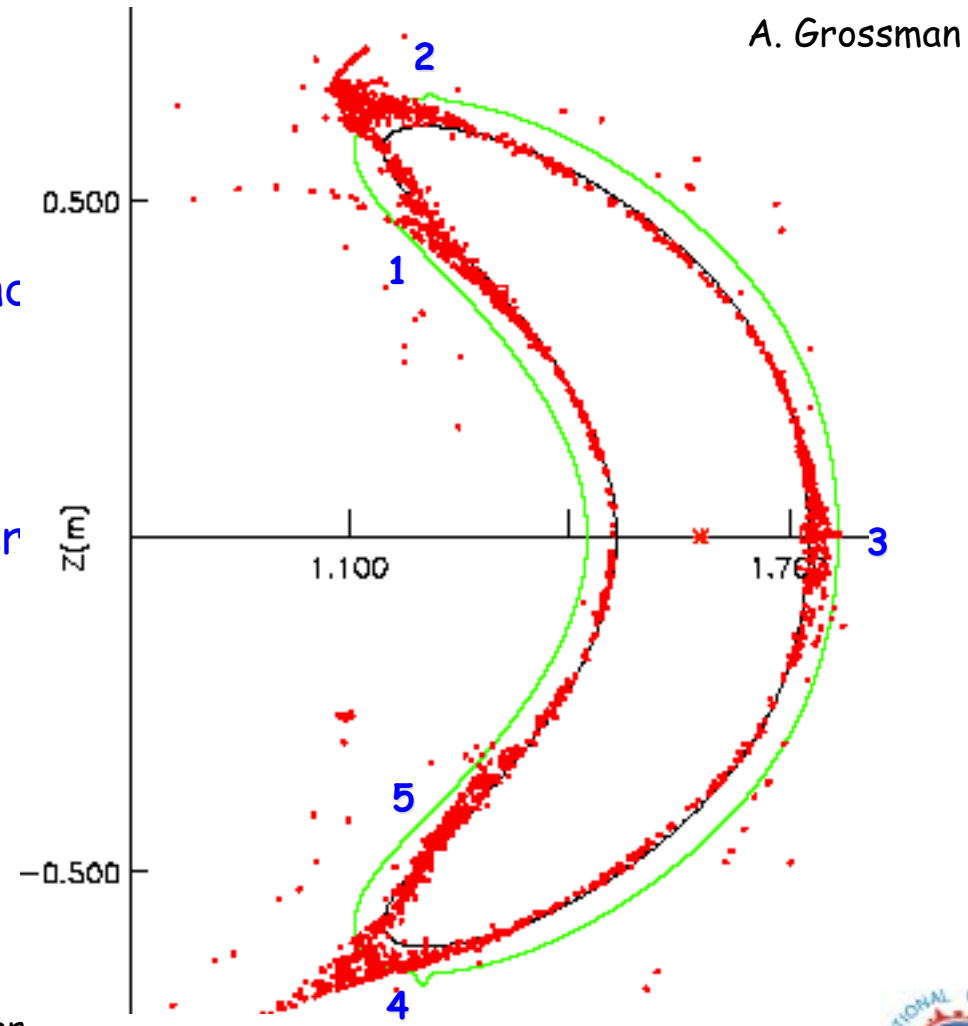
- First divertor operation on W7-AS has demonstrated the potential of island divertors for performance improvement in stellarators:
- Systematic control of plasma-wall interactions leads to the observed performance improvement:
  - control of island-wall interaction surfaces (graphite)
  - heat removal on well-controlled surfaces
  - trapping of impurities in the divertor plasma
  - baffling of neutrals at their source (divertor plate)
- Although the NCSX configuration differs from that of W7-AS, the W7-AS results provide a compass for the direction of our boundary program.

The key for achieving good plasma performance in NCSX early on is to implement edge control with divertor-like configurations, commensurate with our respective knowledge of the boundary.

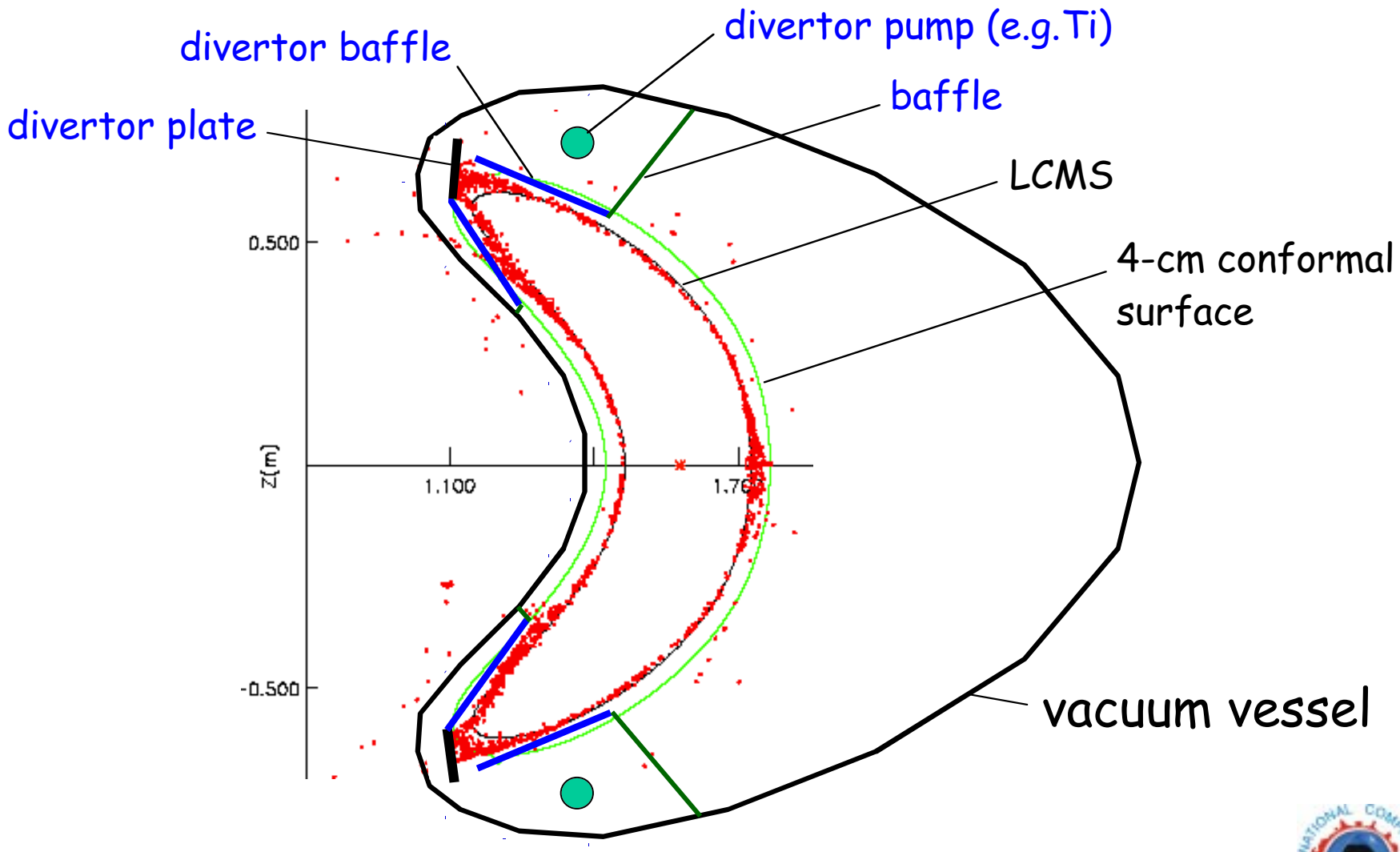
Connection Lengths and Plasma Boundary Configurations Are Explored With Field-line-following Codes

- Poincaré plots, generated with the MFBE* and Gourdon codes, at ϕ=0 cross-section show flux expansion/ clusters (islands?) which can be used for power anc particle control.
- Example shows 1.4m/18-coil configuration. 60 field-lines wer started at the outer midplane (0-4cm) and followed for 20 revolutions (Lc~200m).
- Connection length calculations needed to determine shape of the vacuum vessel.

*E. Strumberger

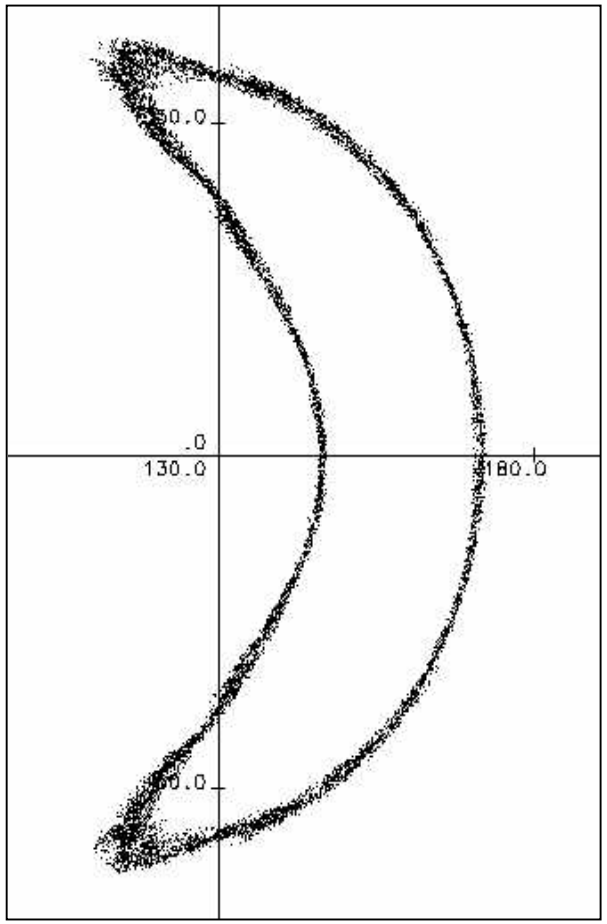


Future Upgrade: The Modified Vacuum Vessel Can Accomodate Pumped Divertor Hardware



Initial Results of Poincaré Plots With Field-Line Diffusion-
Field-Lines Launched Just Inside the Last Closed Magnetic Surface

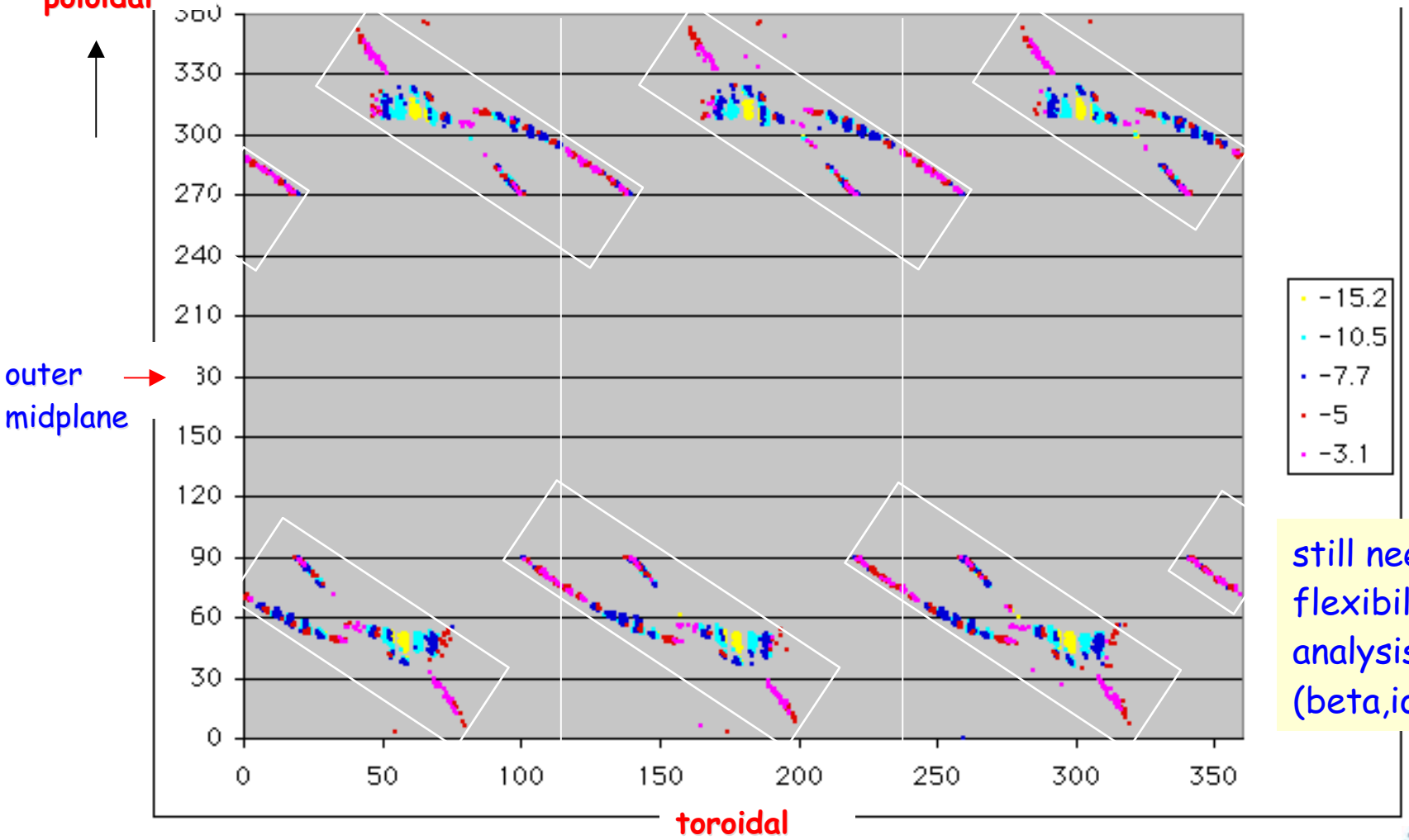
A. Koniges



Field-line expansion at tips of bean section looks promising for divertor operation.

Initial Foot-Prints Used For Divertor Plate Design Indicate Nearly Full Toroidal Coverage of Divertor

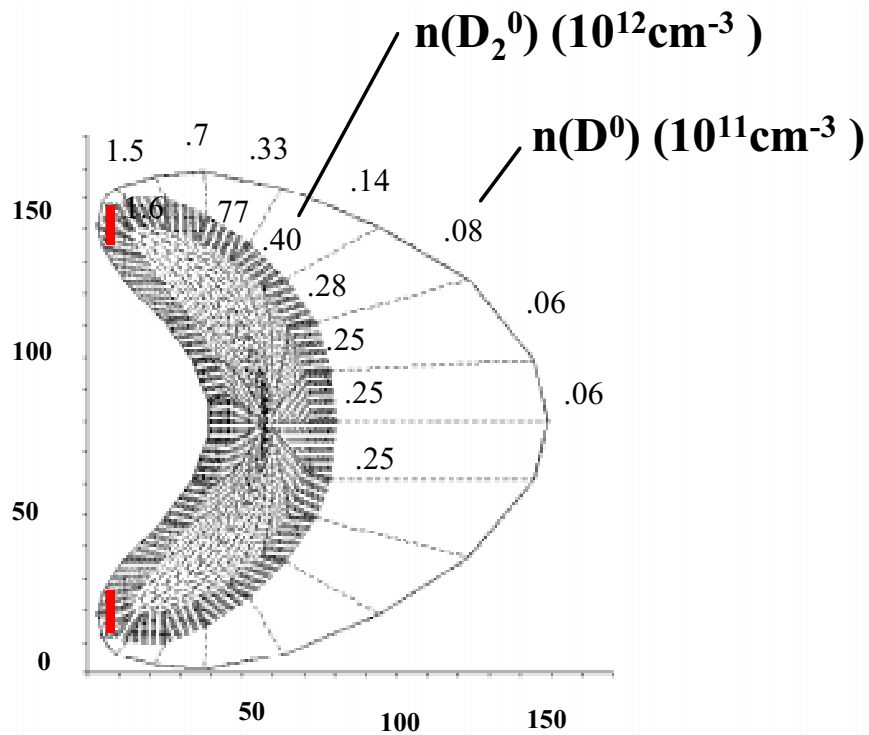
A. Koniges



still needs flexibility analysis! (beta,iota)

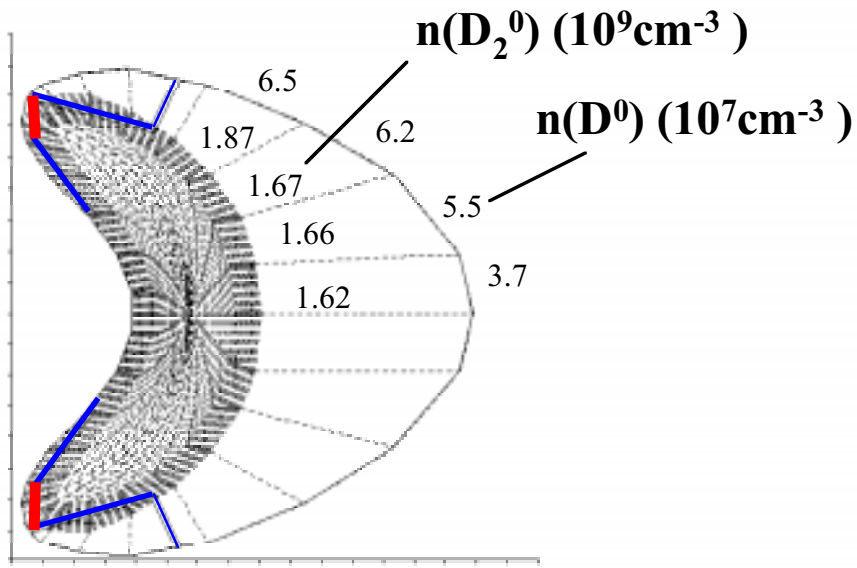
Neutral Densities Are High at ϕ=0 With Un-Baffled Divertor Plate

- The SOL grid surfaces are formed by interpolation between the LCFS and an approximately conformal surface that coincides with the vacuum vessel on the inboard side of the plasma.
- Recycling is assumed to be from the vertical target plates only.
- With 6.25×10^{21} D^+/s incident on each plate, the maximum pressure in the vacuum region is 5×10^{-5} Torr.



Divertor Baffles Are Effective in Reducing Neutral Density at ϕ=0 Cross-Section

- The presence of a divertor baffle reduces the neutral pressure in the mid-plane region.
- The maximum pressure in the vacuum region is few * 10^{-8} Torr.
- Since SOL attenuation of the recycling flux can be very strong, these results clearly point to the need for and importance of an edge/SOL transport model in order to adequately address fueling and CX power loss issues.



Edge Plasma Transport and Profile Modeling

Status:

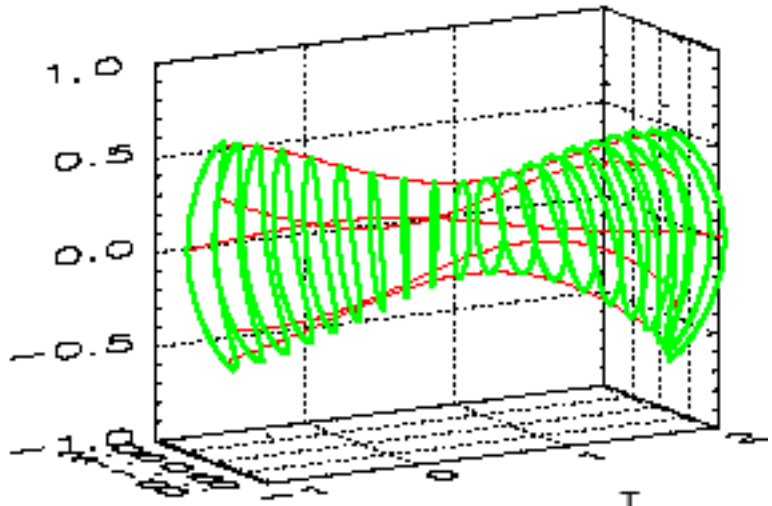
M. Umansky

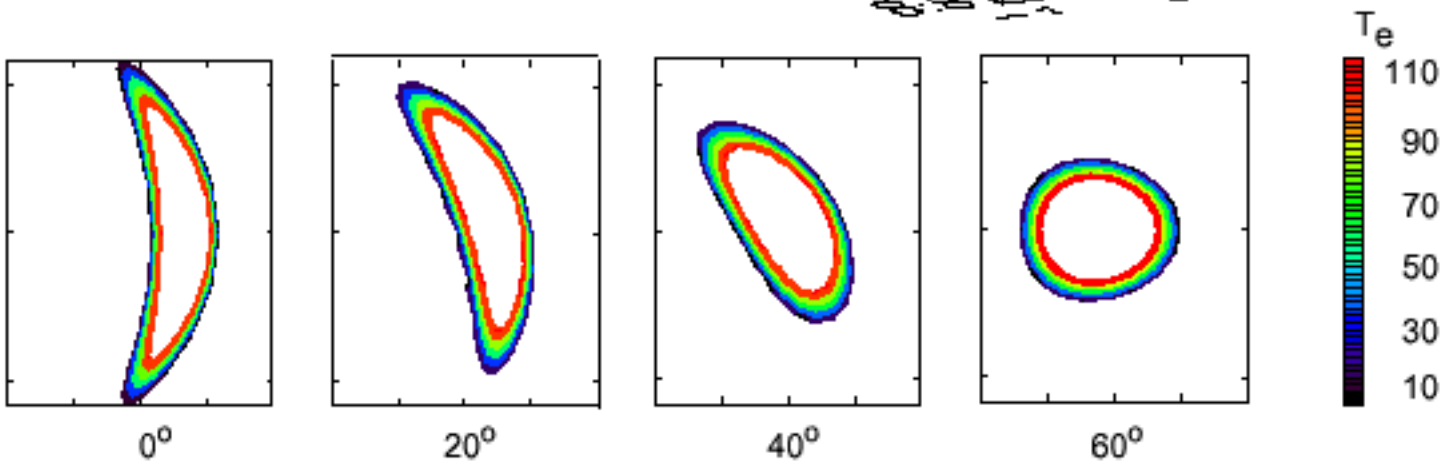
- Two-point analytic model for temperature at separatrix and wall

- Collaborating with IPP-Greifswald on 3D transport code BORIS by leveraging their ~5 FTE effort

-- benchmarked 1D solutions with coupled n, $u_{||}$, T_e, T_i with UEDGE

-- incorporated 3D NCSX geometry and solved Te equation





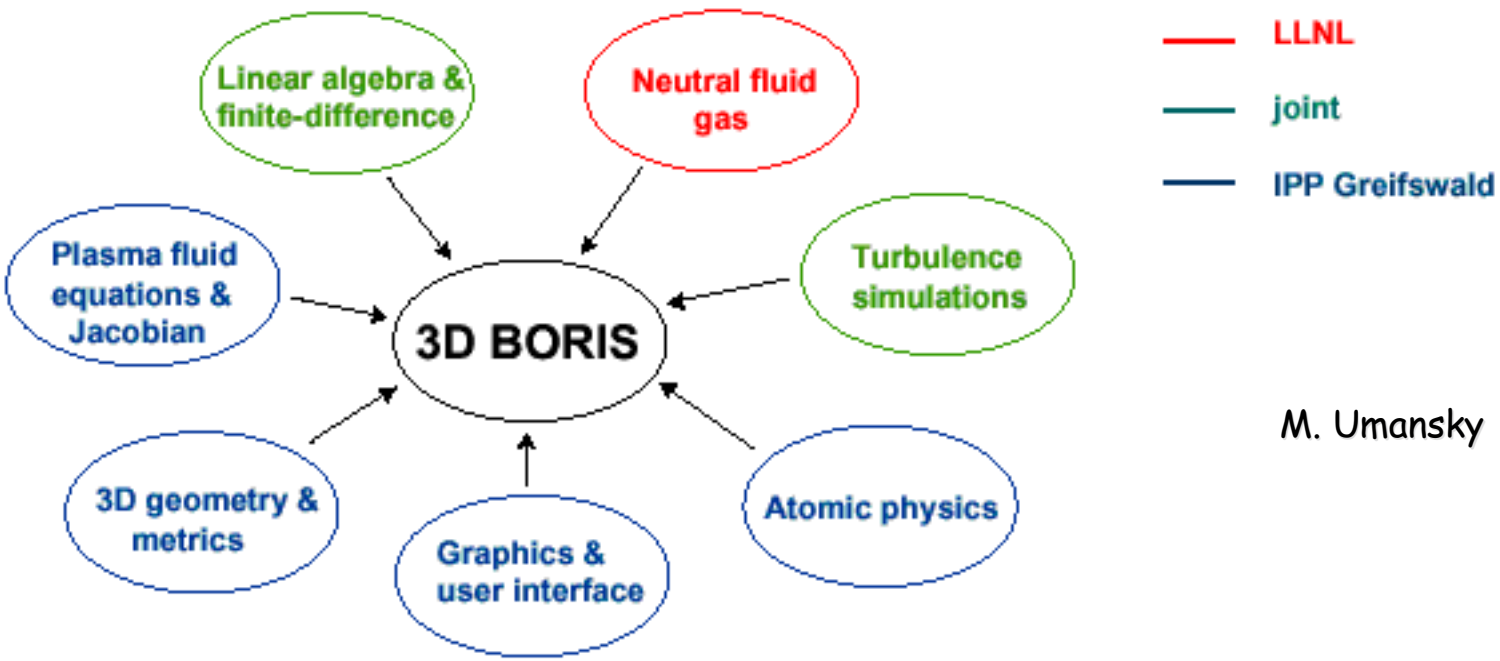
Plans by March 2002

- Benchmark BORIS with UEDGE in 2D torus approximating NCSX

- Implement coupled fluid neutral/plasma models in BORIS

- Quantify additional edge-plasma diffusion from stochastic magnetic fields via field-line-tracing

- Provide initial 3D NCSX plasma edge profiles for DEGAS modeling; compare heat loads with field-line-tracing



M. Umansky

Plans for the Conceptual Design Review

Workplan (1.4m plasma and 18-coil field):

A. Apply Gourdon code with diffusion to completely map-out field line excursions for vacuum vessel shape.

B. Generate foot-prints on conformal wall and then (iteratively) on divertor plates for the design of divertor location/shape and baffles.

C. Field-line and foot-print mapping for range of iota, beta, and edge turbulence/diffusion for configurational flexibility.

D. Develop model calculations to guide the design of divertor baffles for neutrals control: 2-D in progress and 3-D calculations planned.

E. Develop 3-D edge plasma model in collaboration with IPP Greifswald

F. Analyze power deposition patterns for fast particles.

Summary

- Power and particle control provide essential tools for improving plasma performance in stellarators, as recently demonstrated in W7-AS.
- As in tokamaks, divertor-like plasma boundary operation offers the greatest potential for controlling impurities and neutrals.
- The stochastic edge of NCSX offers sufficiently long connection lengths and areas of flux expansion suitable for divertor operation.
- Starting NCSX neutral beam operation with conformal wall armor, serving as initial divertor, will provide early-on impurity and neutrals control as well as reduction of particle confinement.