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The Edge Physics Program During Initial Operation in NCSX

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UT-BATTELLE
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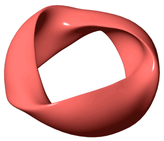
NCSX Programmatic Edge Physics Goals in FY11

(Merged goals from old 1.5MW and 3MW phases)

- Demonstrate basic real-time plasma control (I_P, n_e, R? Iota??)
- Characterize confinement and stability
  - Variation with global parameters, e.g. iota, shear, Ip, density,rotation...
  - Sensitivity to low-order resonances
  - Operating limits
- Investigate local ion, electron, and momentum transport and effects of quasi-symmetry
- Test MHD stability at moderate β, dependence on 3D shape
- Characterize SOL properties for different 3D geometries, prepare for the first divertor design
- Explore ability to generate transport barriers and enhanced confinement regimes (H-modes, conditioning for ITBs)

OUTLINE

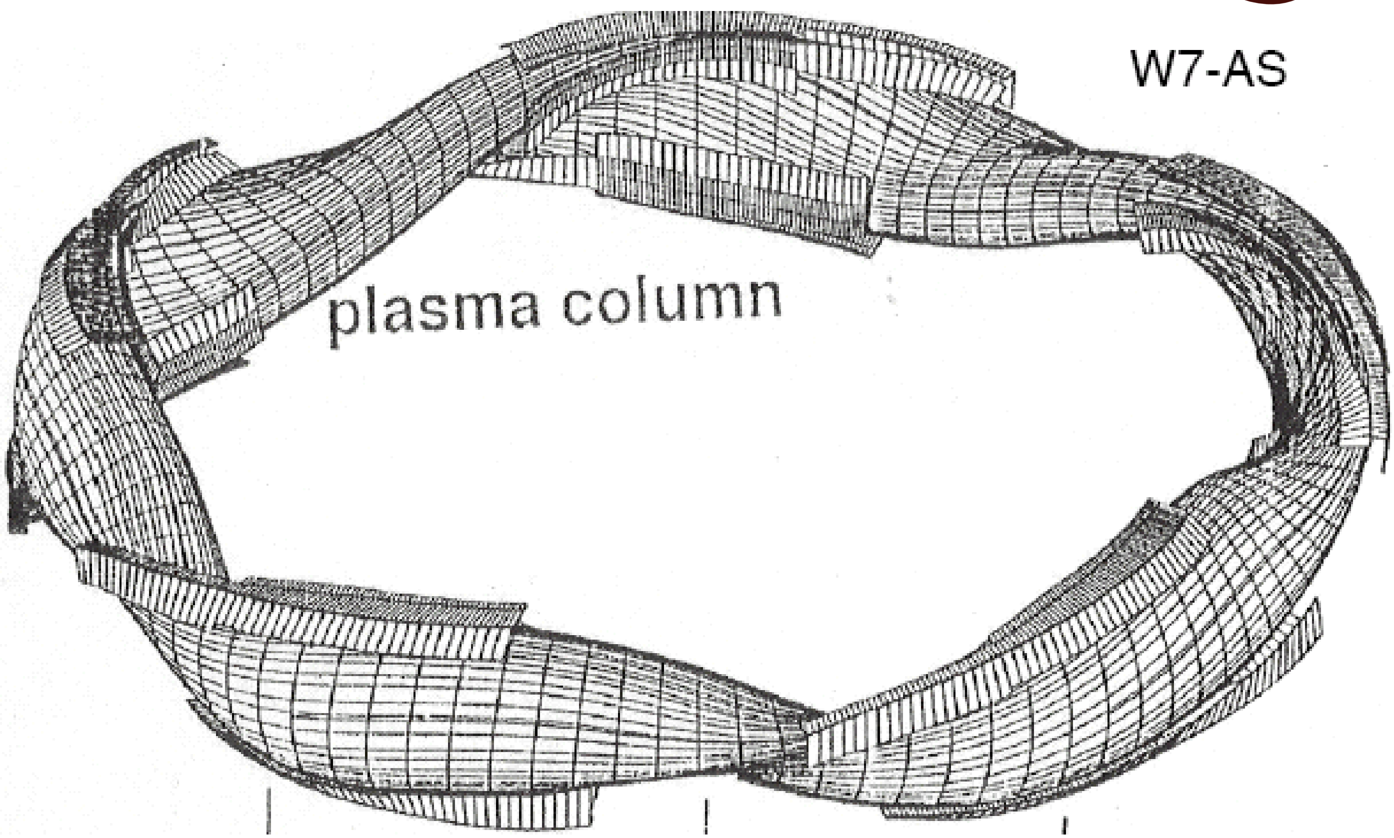


<u>1. Characterize SOL properties for different 3D geometries</u>

- Goal is to prepare for the first divertor design, with installation of additional PFCs in FY13
- Dependence of heat and particle flux profiles at plasma facing components (PFC) on discharge configuration
- Power accountability studies
- Edge and SOL width studies

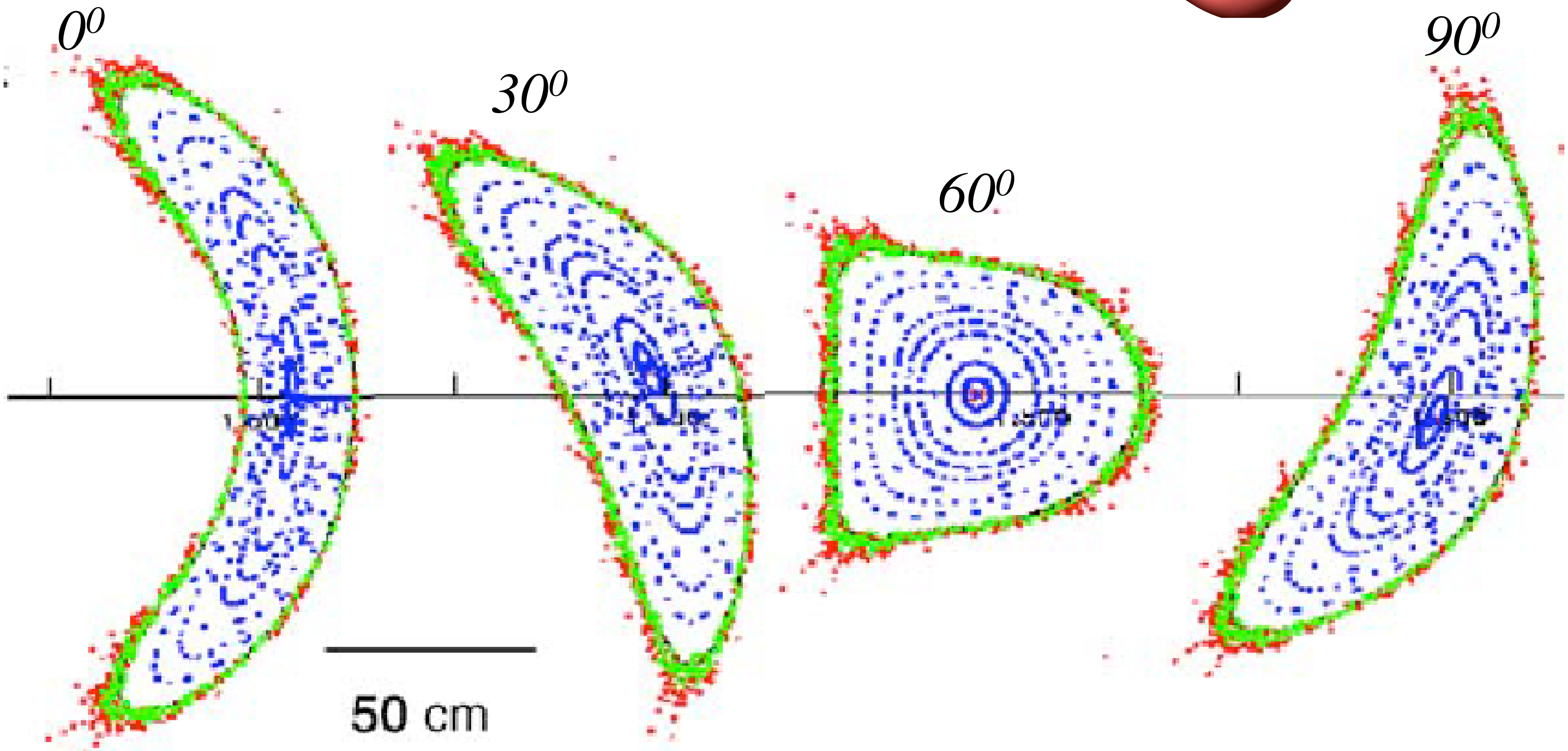
2. Enhanced confinement regimes

Toroidally localized PFCs are sufficient to capture bulk of the heat flux in stellarators



Preliminary NCSX calculations for guidance: PFC design extends toroidally +- π/6 from banana cross section with poloidal length of either 10 or 15 cm

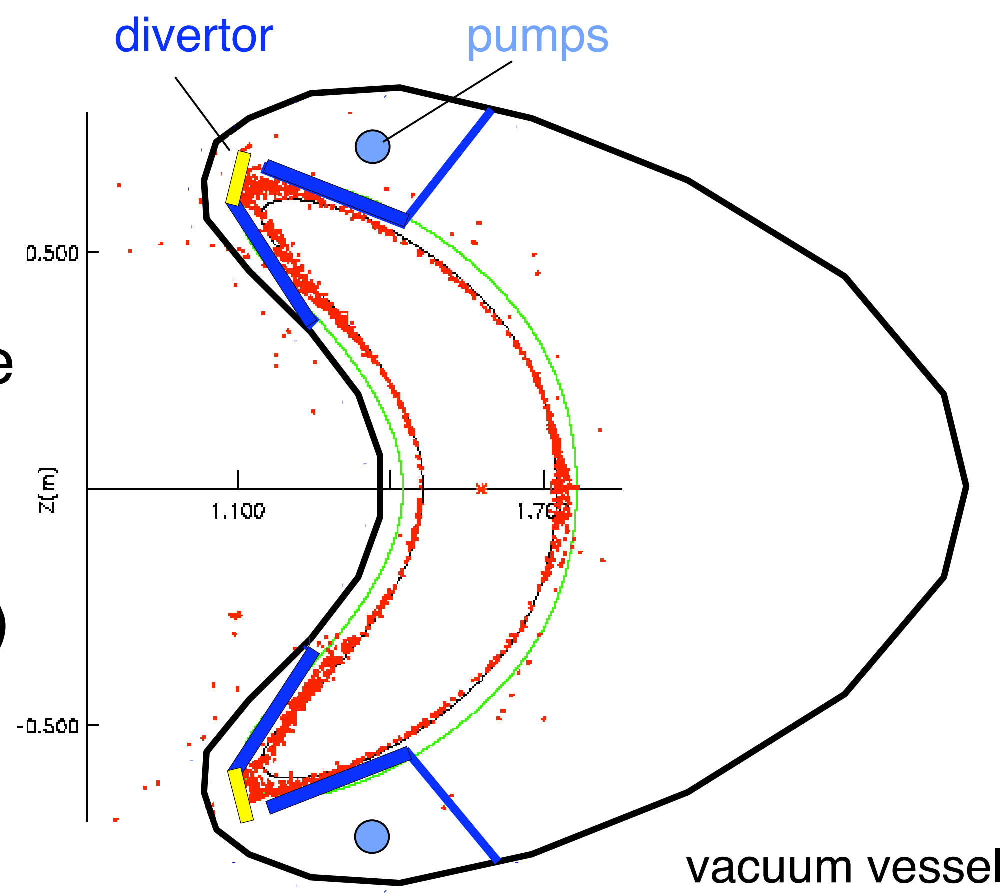
PFCs in the elongated cross-section should intercept most of the field lines, owing to high flux expansion



- **Field line tracing done with two different code packages**
- **Green (red) field lines launched at inner (outer) midplane**

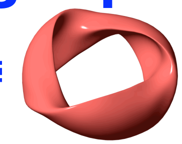
Divertor Concept: Strong flux expansion in banana tips allow isolation of plasma/wall interactions

- Divertor similar to expanded boundary tokamak configurations
- NCSX plan calls for ~ 1/3 PFC coverage by FY11, more later
- *PFC material likely to be graphite (high-Z still possible)*
- *Choice of pumping scheme undecided: Li and/or cryo*
- Option to run with T_{wall}~220^0 C

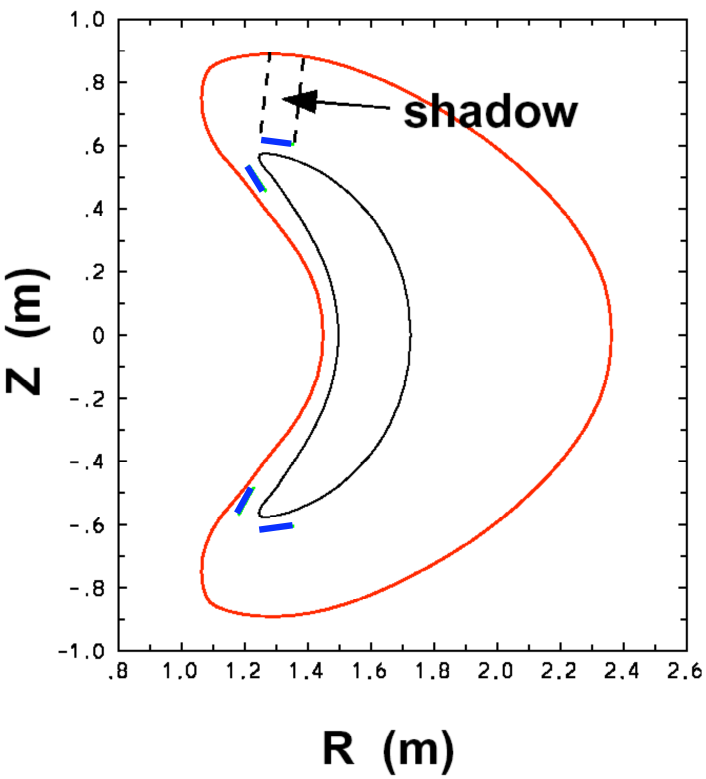


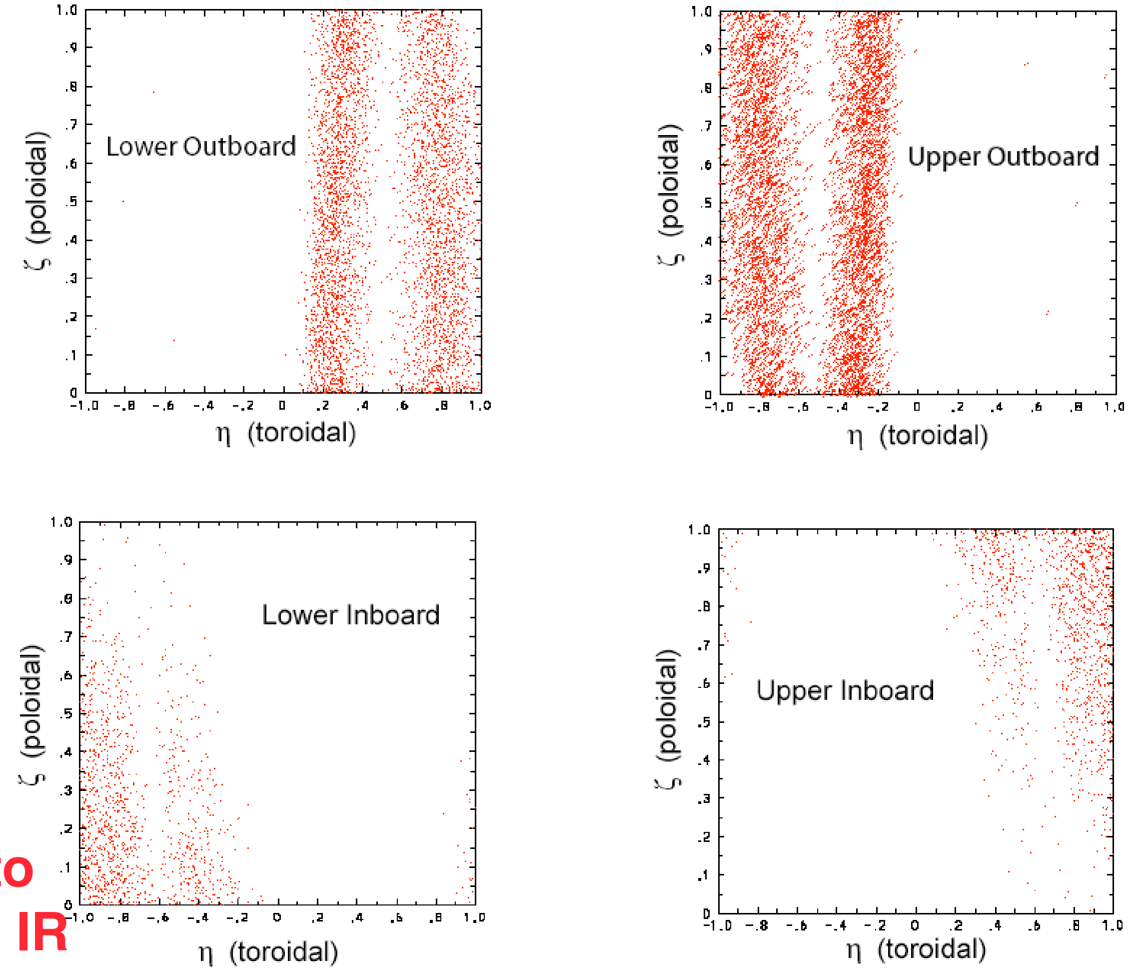
A. Grossman
P. Mioduszewski

Preliminary result: outboard PFCs capture most of the field lines (PIES: 10 cm poloidal length plates)



Center at Φ = 0

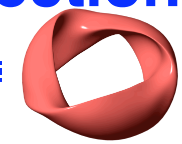




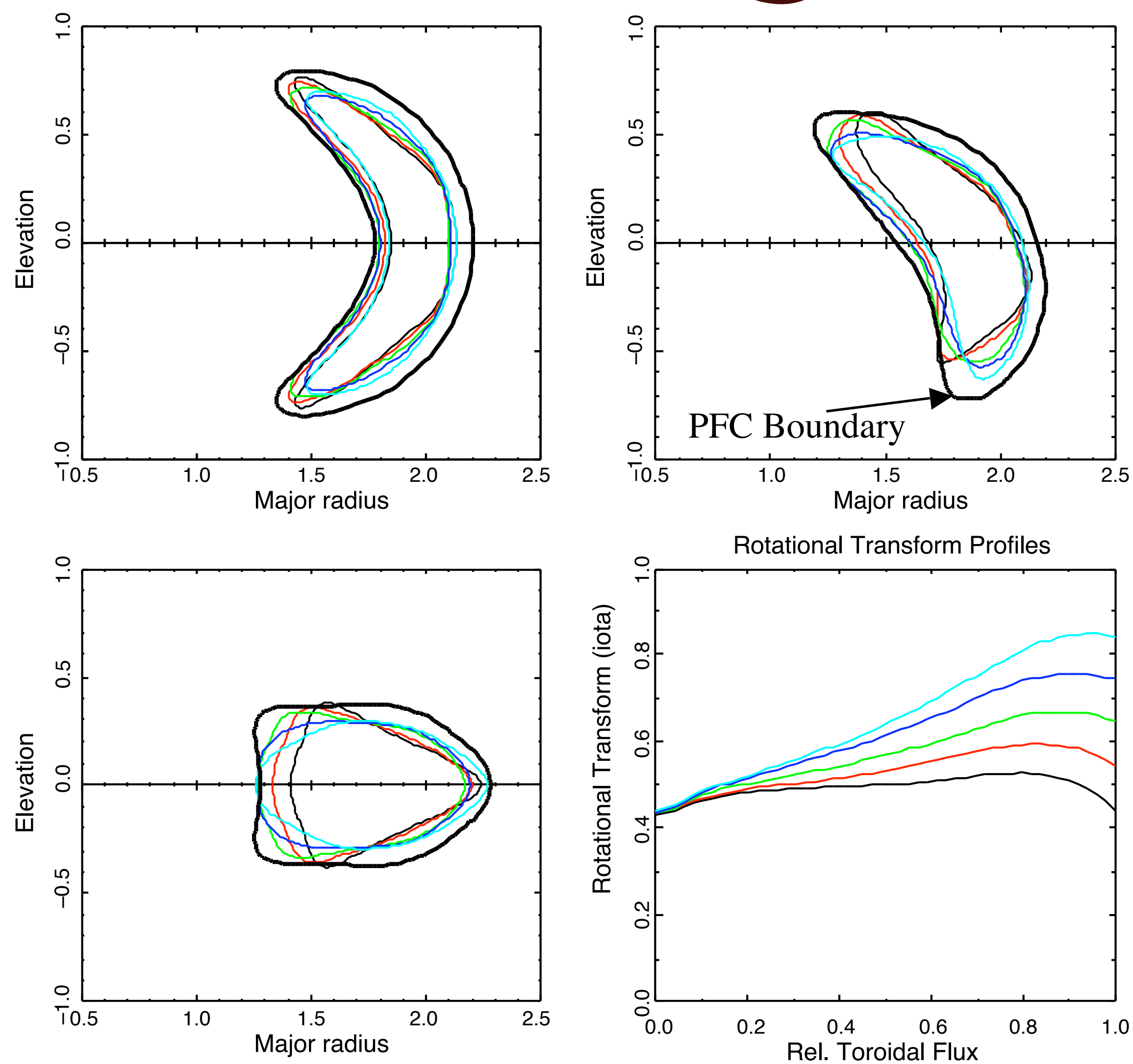
- Deposition footprints need to be compared with data from IR cameras and Langmuir probes

β increases counter-clockwise from midplane

Plasma shape in elongated cross-section less sensitive to external changes than other cross-sections



- Design for first PFCs is a balance between protecting the wall and maintaining shape flexibility
- Variations shown on the right due to different coil currents to control magnetic shear at fixed plasma current and profiles
- Similar results obtained when I_p or β lost suddenly
- Plots are with old vacuum vessel (actual one larger)



β=0, full current

Outline

1. Characterize SOL properties for different 3D geometries

- ➢ Goal is to prepare for the first divertor design, with installation of additional PFCs in FY13
- Dependence of heat and particle flux profiles at plasma facing components (PFC) on discharge configuration
- Power accountability studies
- Edge and SOL width studies

2. Enhanced confinement regimes

Power Accountability Studies in FY11 will help prepare for 6 MW operation in FY13

Goal: assess balance between radiation and heat flux to PFCs over variety of conditions, using

- IR cameras on multiple ports for heat flux
- Langmuir probes with fixed sheath transmission factors, for cross check on heat flux
- Bolometry (mapped to flux surfaces) for radiated power
- V3FIT (or direct diamagnetic loop analysis) to get dW/dt, + package to get NBI deposition

FY11: 3 MW NBI + 0.6 MW ECH; FY13: 6 MW NBI+ECH

Edge and SOL width studies motivate diagnostic package

Included in the FY11 baseline diagnostics plan:

- Langmuir probes in PFCs - 5 at inner target and 5 at outer target, spaced ~ 1 cm apart
- IR cameras - heat flux profiles mapped to flux surfaces
- Thomson and CHERs - upstream data points for simulation of the scrape-off layer with semi-analytic 2-point models and more detailed models

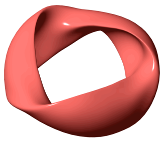
- Reflectometry: high spatial and time resolution n_e profiles*
- Reciprocating Langmuir probe*

*** not presently in FY 11 plan**

Divertor Development Time Line

- FY07-FY09 - continue field line mapping calculations
- FY10 - install up to 1/3 coverage of wall with PFCs:
  1. NBI armor
  2. In center region with small plasma-wall gap
  3. In elongated cross-section for catching heat flux
- FY09-11 - implement 3-D edge plasma transport code, e.g. collaborate on EMC3-EIRENE (used in W7-AS, W7-X; TEXTOR, Tore Supra, DIII-D)
- FY11 - measure heat and particle flux profiles at PFCs and compare with calculations
- FY11-12 - finish design and install divertor plates

Outline



Characterize SOL properties for different 3D geometries

Enhanced confinement regimes

- Development and evaluation of wall conditioning techniques, including neutral and impurity control
- Evaluation of conditions required to access enhanced confinement regimes

PPPL PRINCETON PLASMA PHYSICS LABORATORY

ornl OAK RIDGE NATIONAL LABORATORY

Variety of wall conditioning techniques and diagnostics will be evaluated in FY11

1. Techniques
- Boronization
- Helium Glow Discharge Cleaning
- 150 deg. C bake

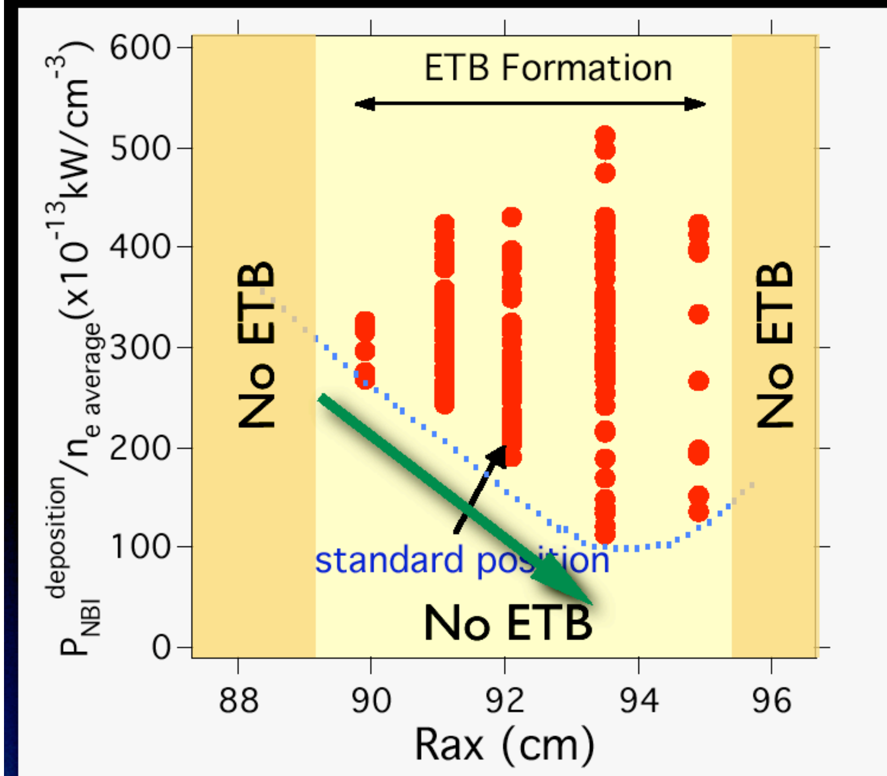
2. Diagnostics
- VuV survey spectrometer
- Filterscopes
- Filtered 2-D and 1-D CCD cameras
- CHERs and VB for Z_{eff}
- Wall coupons

Access Conditions for Enhanced Confinement Regimes will be Investigated in FY11

- Power threshold - P_{LH} for NCSX ~0.4-0.5 MW (3e19 m^{-3}, 1.2T) using most recent scaling from ITPA CDM group
  - CHS P_{LH} close to ITPA scaling (magnitude and exponents)
  - ➢ How does P_{LH} scale? How much does τ_E increase?
  - ➢ Access - same Iota window resonance condition as other stellarators or wider access as in tokamaks?
  - ➢ NCSX designed for toroidal flow - assess importance of v_ϕ^{SOL} in setting P_{LH}, as proposed by C-MOD
- Assess "Shape" or shear dependence for H-mode access

Access Conditions for Enhanced Confinement Regimes will be Investigated in FY11

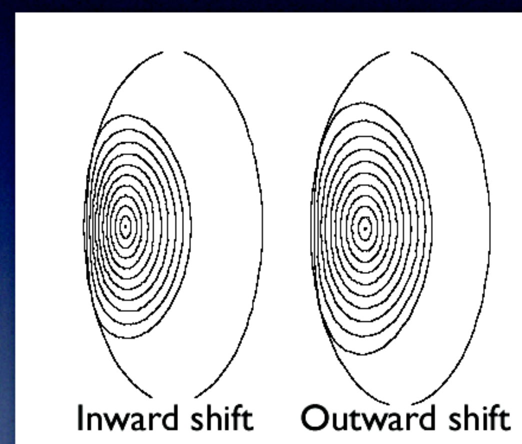
B_T=0.88T



Power threshold decreases with outward shift.

ETB has been observed from 89.9cm to 94.9cm.
ETB is disappeared by outward shift form 94.9 cm or inward shift from 89.9 cm.

CHS L-mode confinement is degraded by the outward shift due to increase of ripple.



Edge studies during FY11 NCSX operation guide prioritization of early diagnostics

PFC heat and particle flux profiles	IR cameras, Langmuir probes, 2-D and 1-D Visible cameras
Power accountability studies	+ Bolometry
Edge and SOL width studies	+ Edge Thomson and CHERs
Development and evaluation of wall conditioning techniques	+ Filterscopes
Access conditions for enhanced confinement regimes	Edge Thomson, CHERs

Summary and Conclusions

- The NCSX Edge Physics program plan will address the high level programmatic goals set for FY11
  - ➢ Plan motivates prioritization of early diagnostics

- The NCSX research prep team seeks your feedback
  - ➢ Expressions of interest for collaboration to help us develop the NCSX program letter (FY 08)

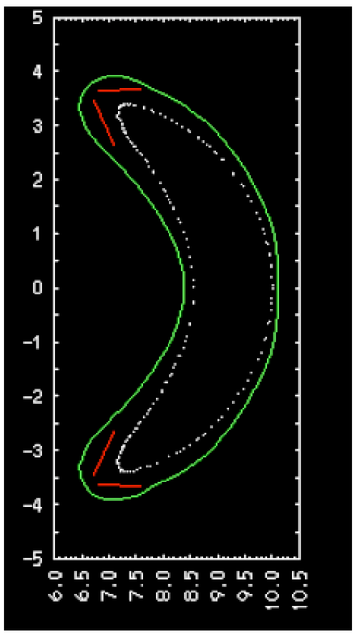
Backup

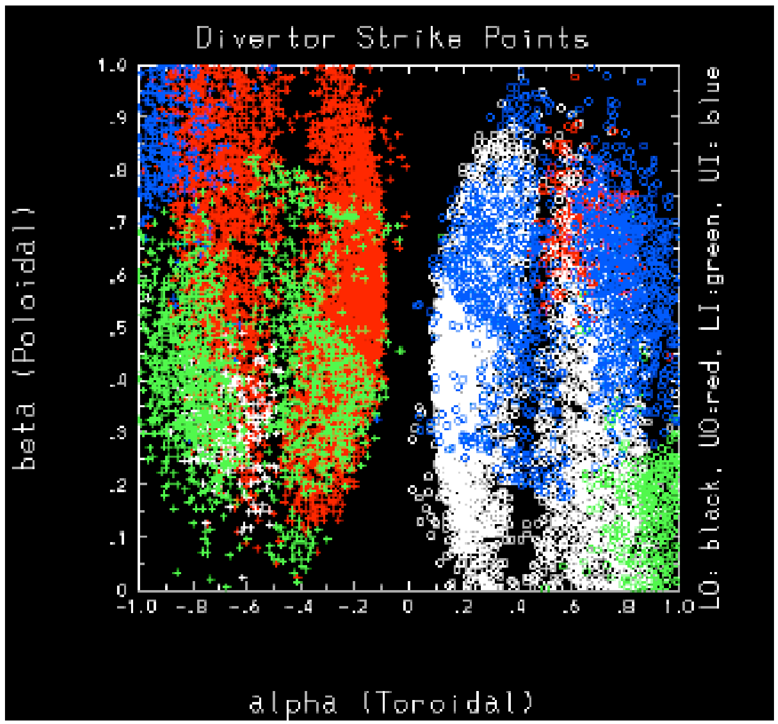
Preliminary result: field lines prevented from hitting the wall with either the 10cm or 15cm poloidal length plate

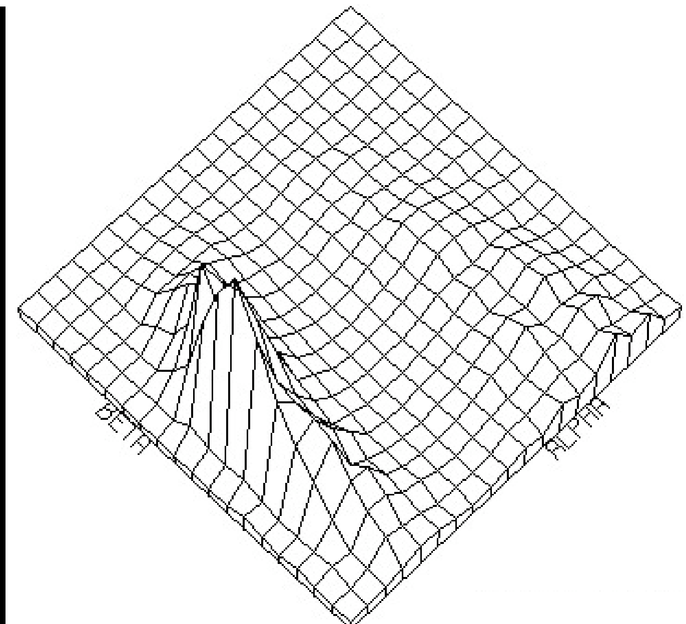
Field line termination	10 cm wide plate (%)	15 cm wide plate (%)
Hit any divertor	70	82
Hit lower outboard divertor	30	38
Hit upper outboard divertor	25	24
Hit lower inboard divertor	9	10
Hit upper inboard divertor	6	11
Entered Divertor shadow region	29	17
Length > 1000m (stopped following)	1	1
Hit vacuum vessel wall	0	0

- **PIES with 1m²/sec field line diffusion, field lines launched at $\phi=0^0$**
- **Plate extended by 2.5cm on each end for 15 cm case**
- ***Will repeat with launches from multiple toroidal angles* (*ARIES-CS calculations shows ~8-10% of field lines go to the wall)***

ARIES-CS calculations showed a distributed deposition pattern with field lines launched at several toroidal angles







p(max)/p(avg) ~ 15

TK Mau, T. Kaiser

NCSX Edge physics program will contribute to important ARIES-CS R&D needs

- NCSX program will develop a workable divertor design with moderate size and power peaking, that controls impurities
  - Divertor power loading in ARIES-CS predicted to be high
  - ✓ NCSX program will provide test of field line tracing procedure as a viable design tool in the same divertor concept as ARIES-CS
  - ✓ NCSX program will provide cross-comparison with 3-D edge plasma transport calculation

- NCSX program will look to demonstrate regimes with minimal power excursions onto the first wall

- NCSX program will characterize operational limits by assessing whether the edge density imposes a limit on the density operating window