Supported by Office of Science

Plans for Edge Studies in NCSX

Rajesh Maingi

Oak Ridge National Laboratory

For the NCSX Research Team

NCSX PAC-8 Meeting
Princeton, NJ
Nov. 9, 2006

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)

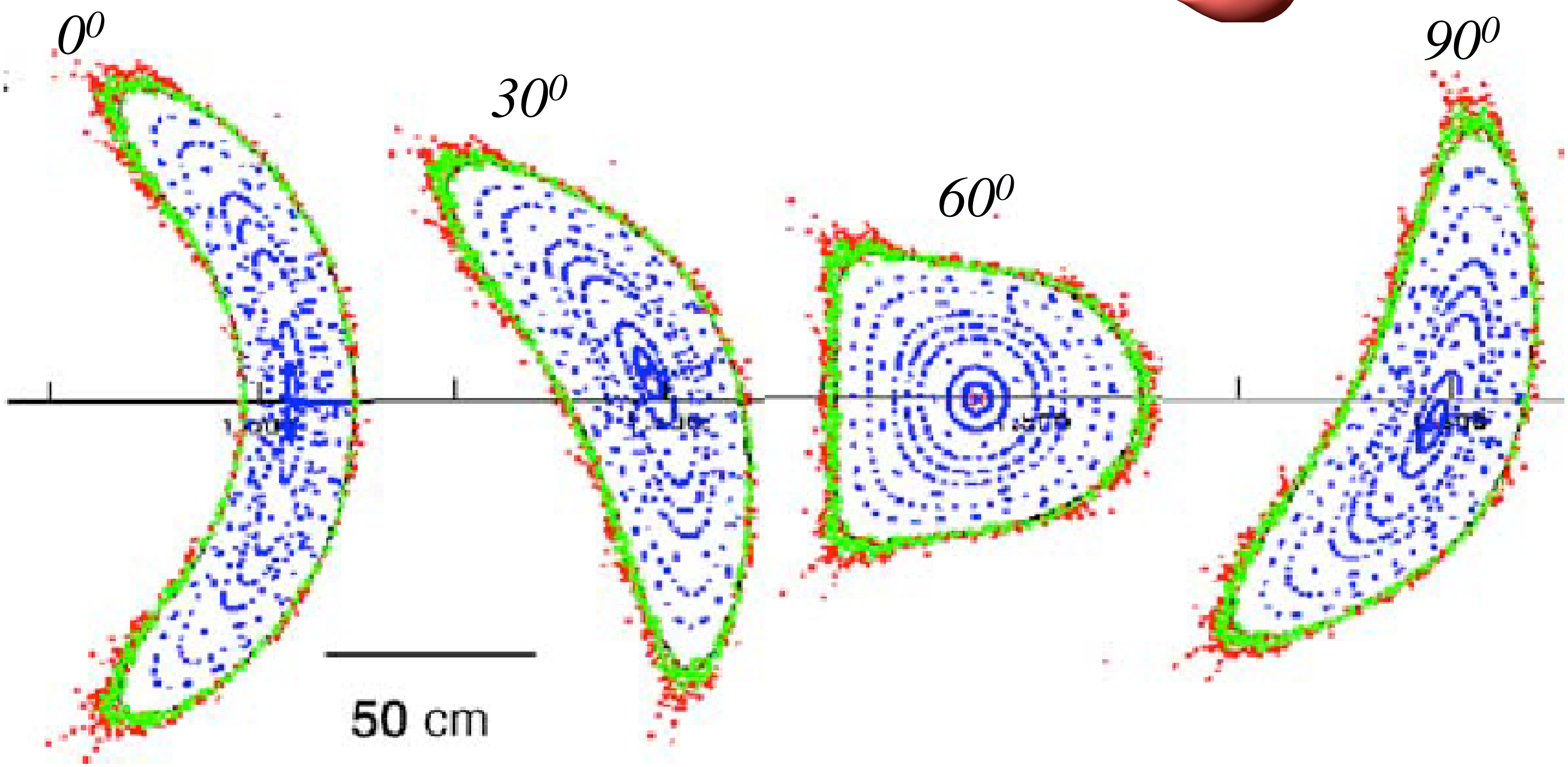
Planned edge studies during FY11 NCSX operation encompass two main areas

1. Characterize SOL properties for different 3D geometries

- Goal is to prepare for the first divertor design, with installation of additional hardware 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

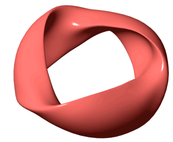
2. Enhanced confinement regimes

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

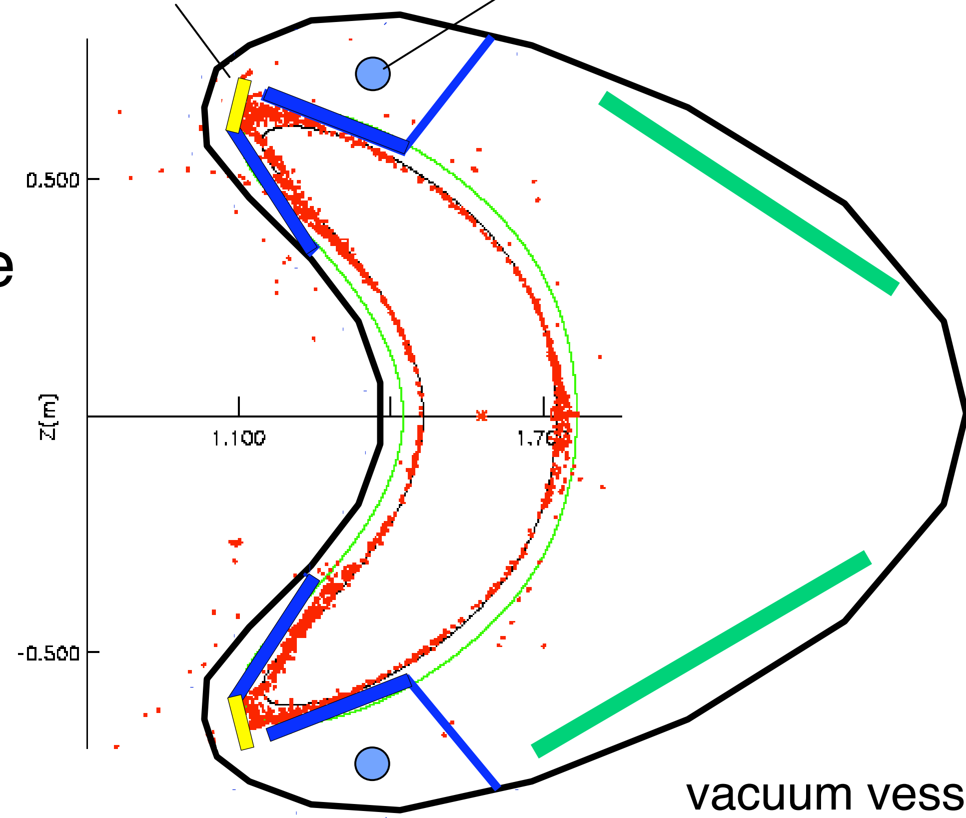


- Green (red) field lines launched at inner (outer) midplane
- Field line tracing done with two different code packages

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

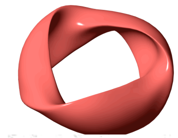


- Divertor similar to expanded boundary tokamak configurations
- NCSX plan calls for ~ 30% PFC coverage by FY11, more later
- *PFC material has not been chosen yet: low-Z or high-Z possible*
- *Choice of pumping scheme undecided: Li and/or cryo*
- Option to run with T_{wall}~220^0 C

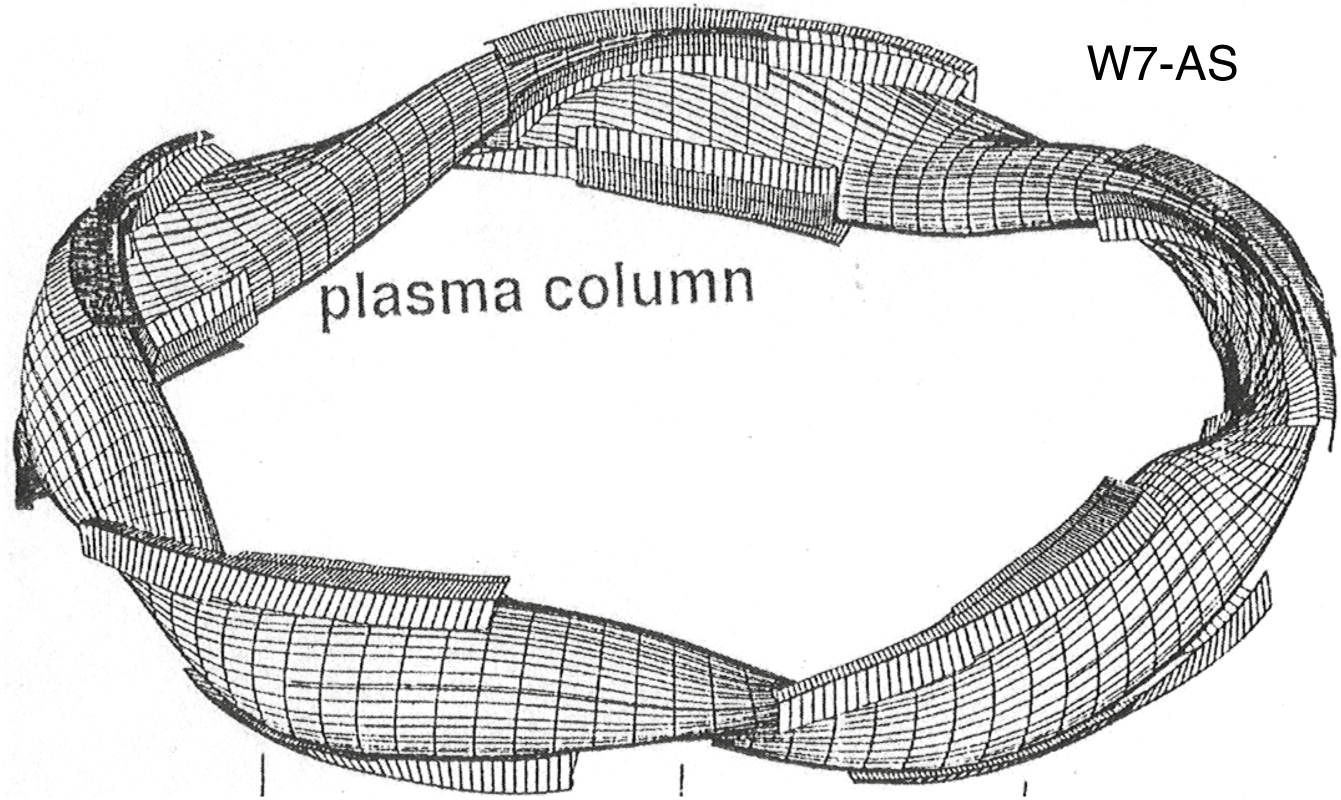


A. Grossman
P. Mioduszewski

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

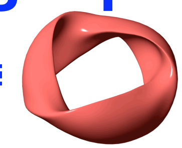


W7-AS

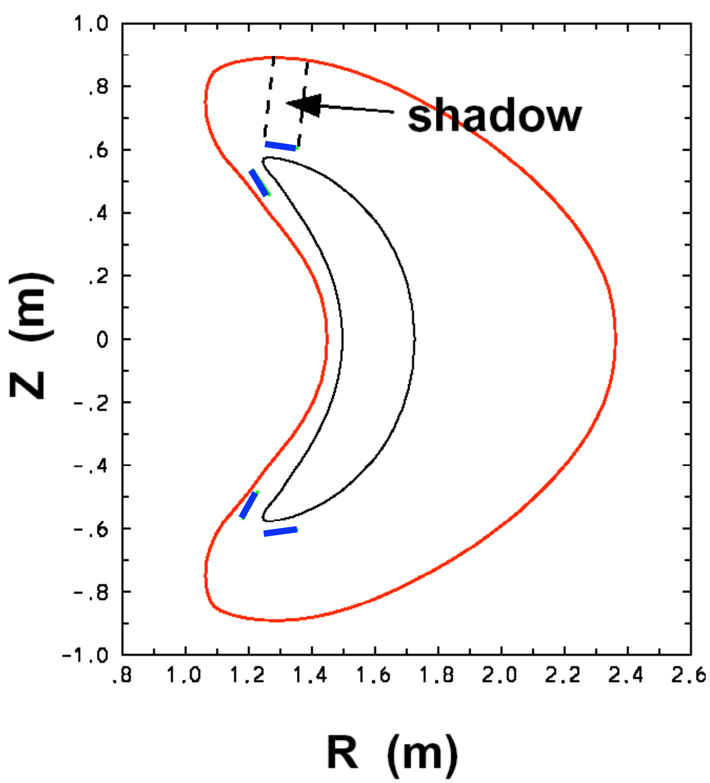


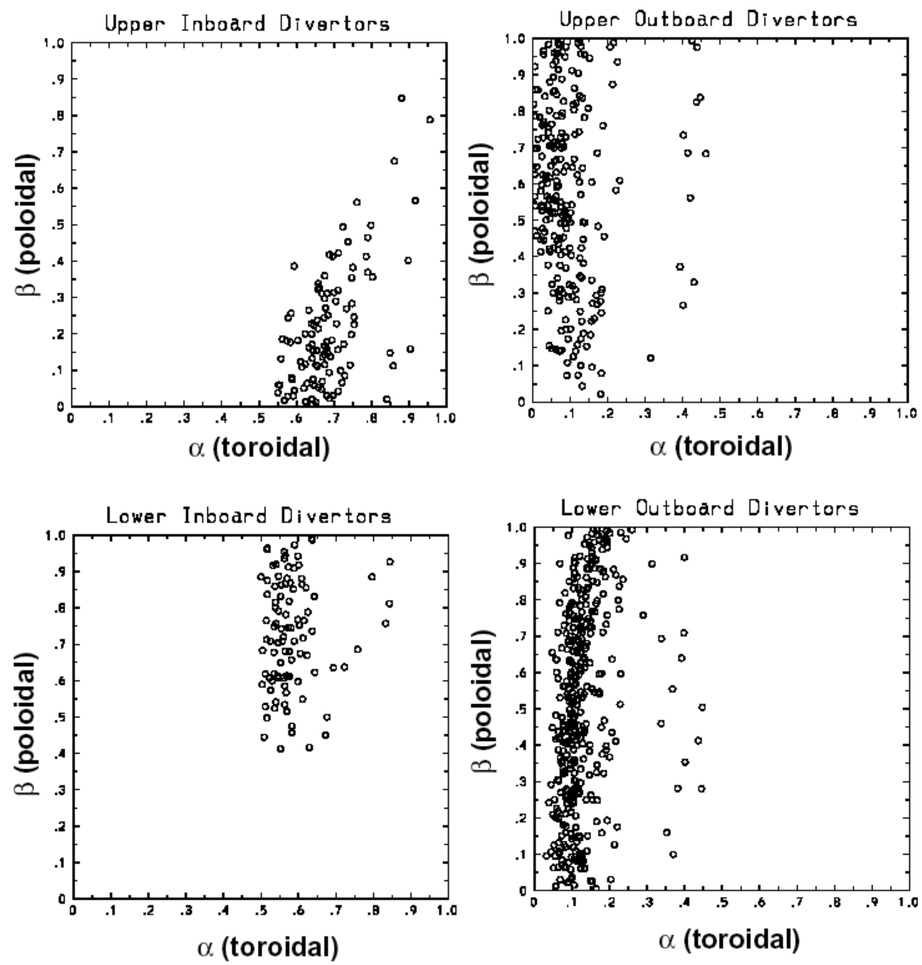
Preliminary NCSX calculations for guidance: PFC design extends toroidally +- $\pi/6$ from banana cross section with poloidal length of either 10 or 15 cm

Preliminary result: outboard PFCs capture most of the field lines (PIES: 15 cm poloidal length plates)



Center at Φ = 0





- Deposition footprints need to be compared with data, 3D plasma transport code

β increases counter-clockwise from midplane

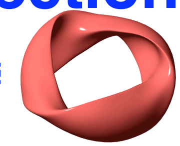
Kaiser APS2006, Maingi EPS2006

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

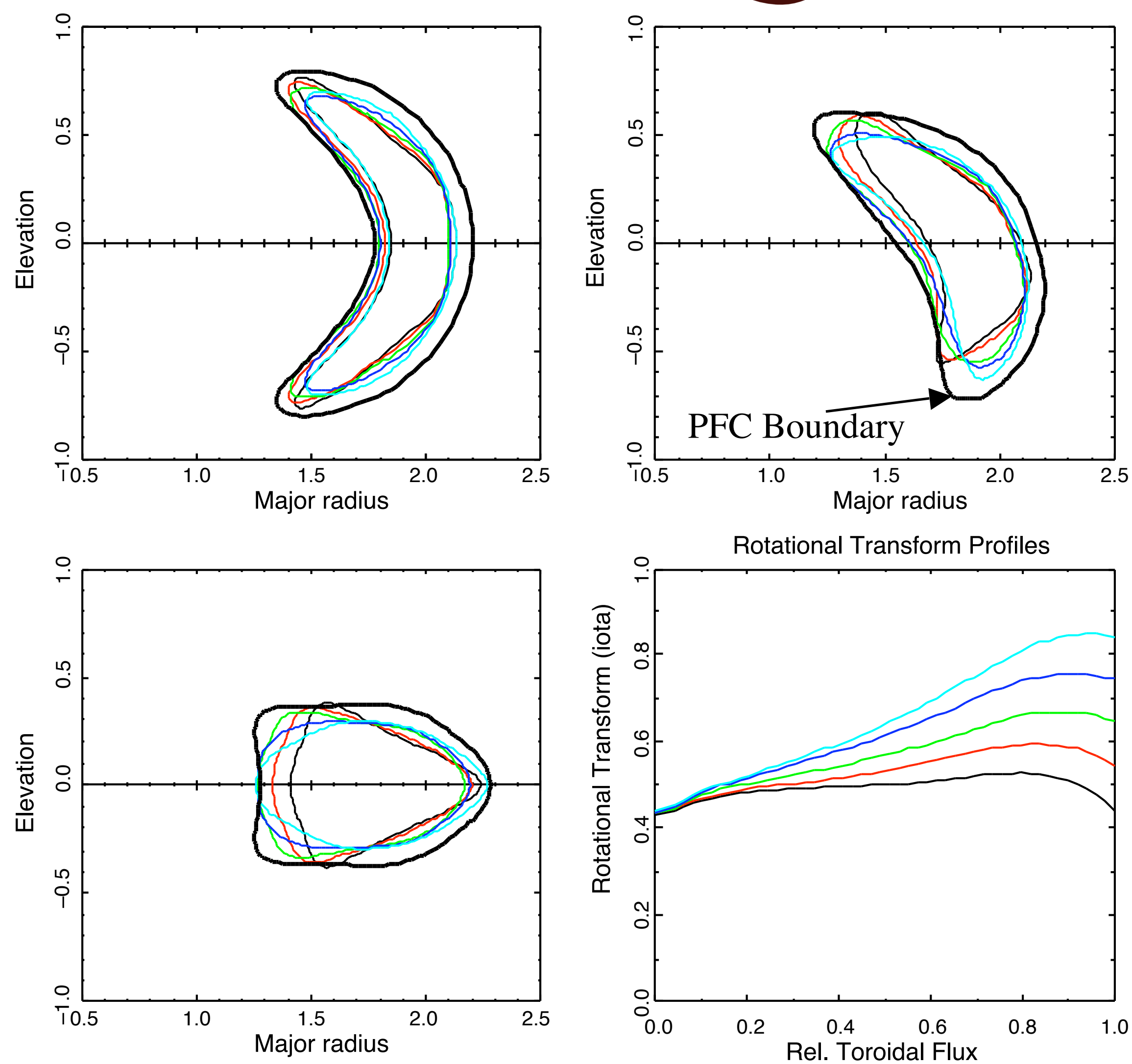
Field line termination	10 cm wide plate (%)	15 cm wide plate (%)
Hit any divertor	70	82
Hit lower outboard divertor	30	38
Hit upper outboard divertor	25	24
Hit lower inboard divertor	9	10
Hit upper inboard divertor	6	11
Entered Divertor shadow region	29	17
Length > 1000m (stopped following)	1	1
Hit vacuum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

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



- Field line capture efficiency of PFCs in these cross-sections should be relatively insensitive to input variations
- 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

Maingi PAC8 p.9

Outline

1. Characterize SOL properties for different 3D geometries

- ➢ Goal is to prepare for the first divertor design, with installation of additional hardware 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 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*

*** may be possible in FY 11**

Divertor Development Time Line

- FY07-FY09 - continue field line mapping calculations
- FY10 - install up to ~ 30% 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 (W7-AS, W7-X)
- 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

<u>Enhanced confinement regimes</u>

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

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
  - How does P_{LH} scale?
  - Iota window - same resonance condition as other stellarators or wider access as in tokamaks?
- Assess "Shape" or shear dependence for H-mode access
- Machine designed for toroidal flow - assess importance of flow in setting P_{LH}, as proposed by C-MOD

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

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

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 Edge Physics program plan will contribute strongly to the ARIES-CS R&D needs