NSTX-U cryo/particle control discussion #8

December 19, 2012

- What have we done, or plan to do to be responsive to PAC questions, and in prep for 5 year plan?
- Particle control presentation will need to incorporate lithium granule injector results, and lithium pumping persistence results
- Can / should we motivate NSTX-U cryo configuration using FNSF design?
  - How do we reduce uncertainty in heat and particle flux widths (and pumping projections) in extrapolating to FNSF?

Draft PAC-33 agenda and speakers

PAC dates: February 19-21, 2013

PAC meeting will effectively be dry-run for 5 year plan review

• Program overview	Jon Menard
• Upgrade progress, facility and diagnostic prep, budget	Masa Ono
• Initial Operations Plan, Scenarios and Control	Stefan Gerhardt
• Macroscopic Stability	Jack Berkery
• Non-axisymmetric control coil (NCC) applications	Jong-Kyu Park
• Transport and Turbulence	Yang Ren
• Energetic Particles	Mario Podesta
• HHFW and ECH / EBW	Gary Taylor
• Solenoid Free Start-up and Ramp-up	Roger Raman
• Long-term issues and strategy for boundary and PMI	Rajesh Maingi
• Pedestal, SOL, Divertor	Vlad Soukhanovskii
• Cryo-pumping and particle control	John Canik
• Materials and Flowing liquid Li module development	Mike Jaworski

Select PAC-31 report comments related to design and strategy for NSTX-U cryo-pumping

- **“In addition, pumping will be more efficient with increasing particle recycling in a divertor geometry with close-fitting side walls. Optimization of the divertor geometry should be studied to improve particle control”**

- “The ability to achieve fully non-inductive operation and maximize off-axis neutral beam current drive will be greatly enhanced by good density control. While delivering this level of density control may be possible with Li divertor operation, this capability has not been demonstrated thus far in NSTX. The PAC recommends that the NSTX-U team develop an implementation strategy that provides definitive results at minimum risk on each of these”

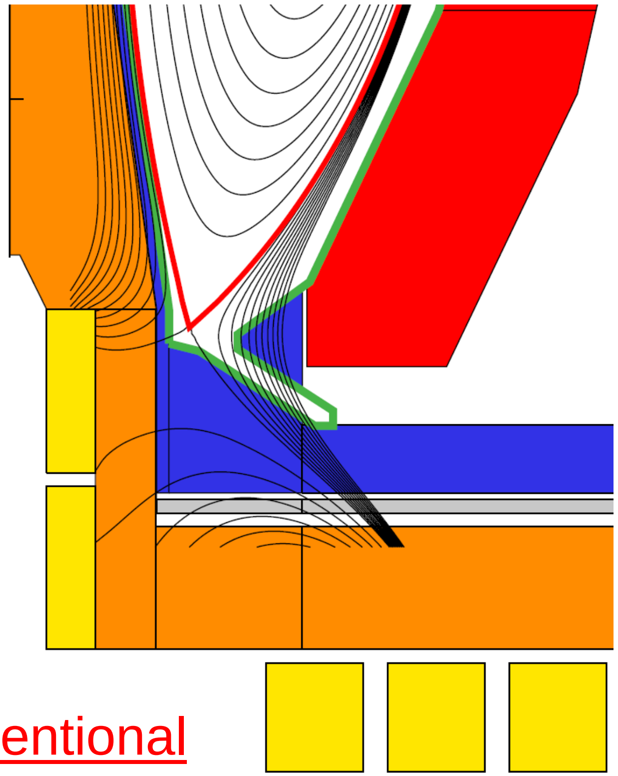
PAC-31: Next steps for particle control analysis during Upgrade outage

- Cryo-pumping design
  - Confirm plenum optimization using SOLPS (B2-EIRENE)
    - More comprehensive treatment of neutral transport (beyond first-flight)
    - Can treat radiative/detached divertor
  - Investigate design details of chosen plenum geometry
    - Is clearing area currently occupied by divertor tiles feasible?
    - Prepare for engineering design
- Lithium persistence for long-pulse (with ELMs)
  - Further modeling with 2D fluid codes (UEDGE/SOLPS/OEDGE)
    - Recycling analysis for high-δ, longer pulse ELM-free discharges
    - Analysis of long, ELMy discharge
  - Extrapolation to NSTX-U
    - Longer pulse, higher NBI particle input
- Begin studying compatibility/interaction of cryo and lithium pumping
  - Could lithium coat the pumping surface?
  - What plenum pressure can be achieved with SOL modified by lithium coatings (e.g., λ_q, P_{div}/P_{tot}, n_e)

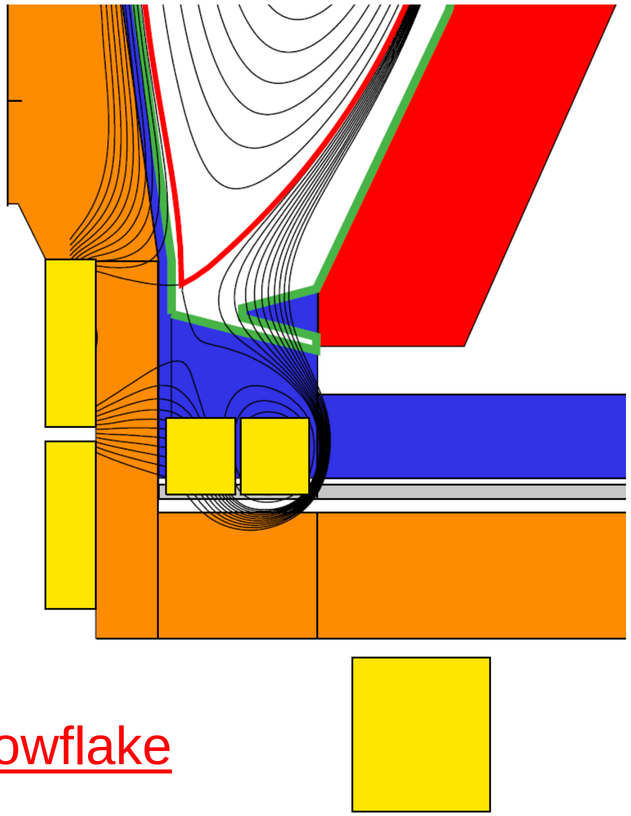
PAC-31: Plans for years 1 and 2 of NSTX-U operation

- Validate physics design of cryo-pump
  - Measure plasma parameters at likely pump entrance location
    - Document Γ, T_e as I_p, P, flux expansion, etc are varied
  - Perform engineering design (begin during outage with incremental funding)
- Particle control with lithium coatings
  - Develop ELMy scenarios with lithium coatings
    - Assess ELM triggering with thick lithium coatings
    - Perform experiments with controlled scans lithium deposition amounts (including none), document recycling and ELM characteristics
    - Test passivation of lithium with D_2 glow for control of pumping properties
    - Optimize lithium deposition (ELMs vs. pumping), combine with impurity control techniques (snowflake, gas puff, etc.) towards long-pulse
  - Test persistence of lithium coatings
    - Measure recycling characteristics as power, ion flux, pulse length are varied
    - Use rapid SGI gas pulses to measure SOL pump-out vs time within shot
  - Later stages: measure impurity behavior with Li on Mo tiles

Divertor PF coil configurations identified to achieve high δ while maintaining peak divertor heat flux < 10MW/m^2



Field-line angle of incidence at strike-point = 1°



Conventional

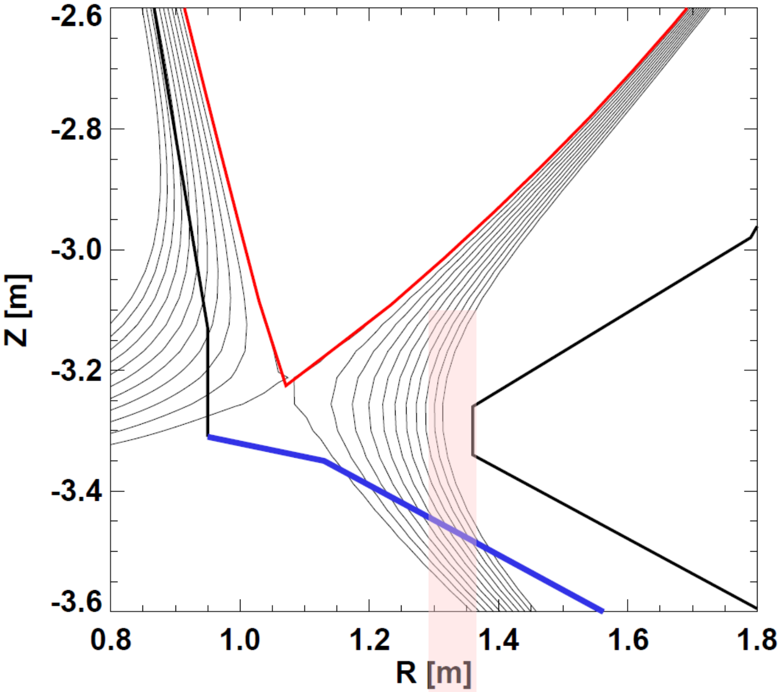
- **Flux expansion = 15-25, δ_x ~ 0.55**
- **1/sin(θ_{plate}) = 2-3**
- **Detachment, pumping questionable**
  - **Future: assess long-leg, V-shape divertor (JA)**

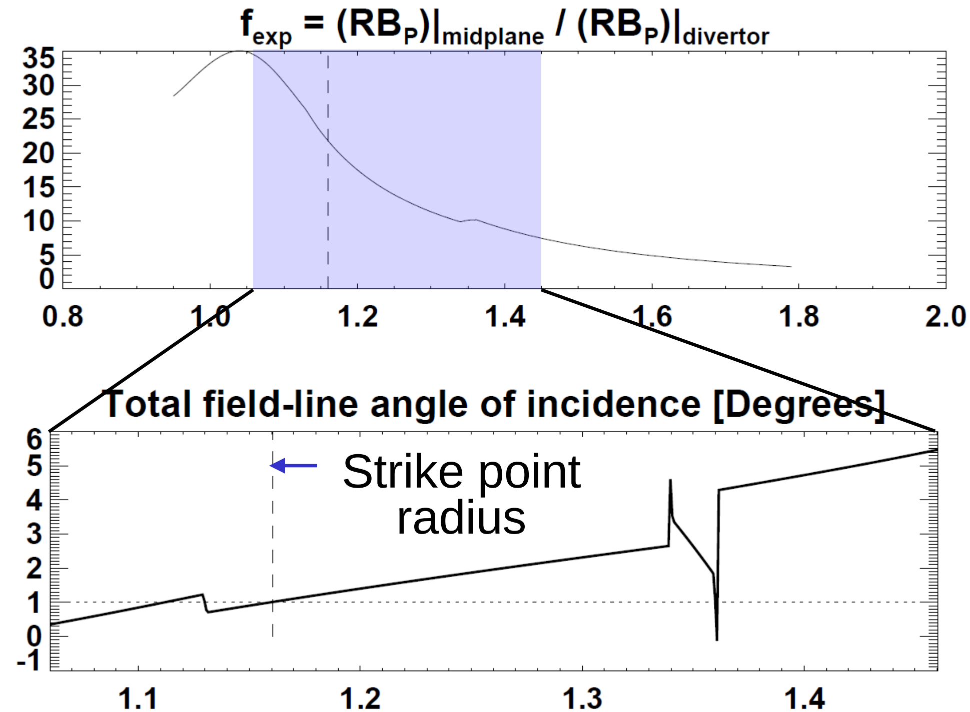
Snowflake

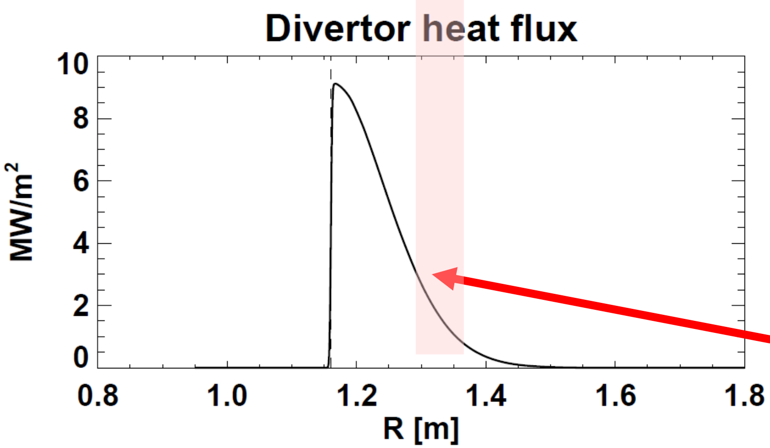
- **Flux expansion = 40-60, δ_x ~ 0.62**
- **1/sin(θ_{plate}) = 1-1.5**
- Good **detachment (NSTX data)** and cryo-pumping (NSTX-U modeling)

• Will also test liquid metal PFCs in NSTX-U for power-handling, surface replenishment

Parameters and profiles for conventional divertor
(using simple exponential heat-flux profile in R=1.6m ST-FNSF)





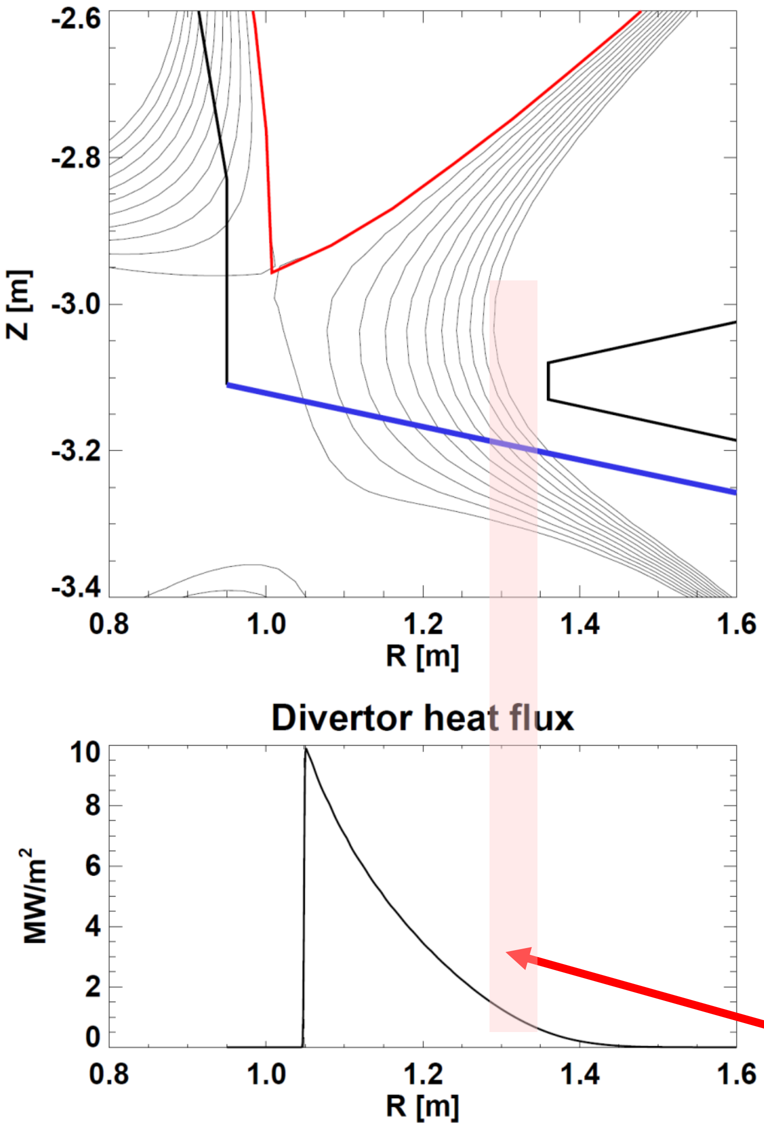


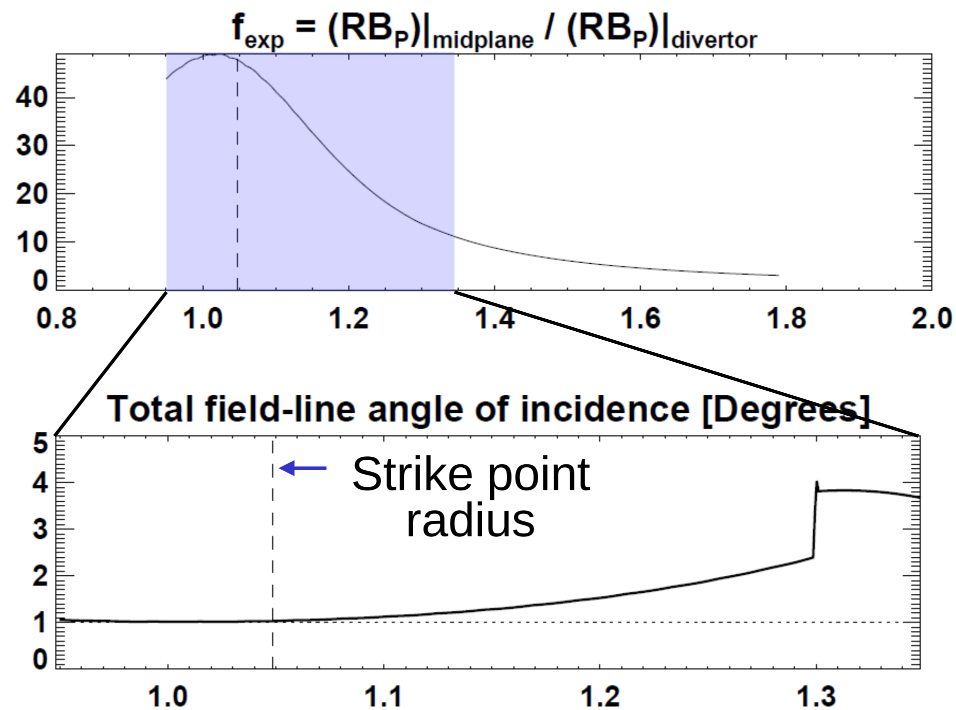
$$\text{Peak } q_{\perp\text{-div}} \approx \frac{P_{heat}\,(1-f_{rad})\; f_{obd}\; \sin(\theta_{pol})}{2\pi R_{strike}\; f_{exp}\; \lambda_{q\text{-mid}}\; N_{div}}$$

- P_{heat} = 115MW, f_{rad}=0.8, f_{obd}=0.8, $\sin(\theta_{pol})$ = 0.39
- R_{strike} = 1.16m, f_{exp} = 22, $\lambda_{q\text{-mid}}$ =2.7mm, N_{div} = 2

NSTX-U simulations find $q_\perp$ at pump entrance should be ≥ 1-2MW/m² for efficient pumping → guesstimate $R_{entrance}$ ~ 1.3m for R=1.6m ST-FNSF

Parameters and profiles for snowflake divertor
(using simple exponential heat-flux profile in R=1.6m ST-FNSF)





$$\text{Peak } q_{\perp\text{-div}} \approx \frac{P_{heat}\,(1-f_{rad})\,f_{obd}\,\sin(\theta_{pol})}{2\pi R_{strike}\,f_{exp}\,\lambda_{q\text{-mid}}\,N_{div}}$$

- P_{heat} = 115MW, f_{rad}=0.8, f_{obd}=0.8, $\sin(\theta_{pol})$ = 0.87
- R_{strike} = 1.05m, f_{exp} = 50, $\lambda_{q\text{-mid}}$ =2.7mm, N_{div} = 2

Snowflake would also want divertor cryo-plenum entrance radius $R_{entrance}$ ~ 1.3m for R=1.6m ST-FNSF