NSTX-U

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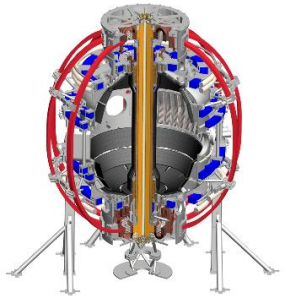
Fusion Energy Sciences

Update on Activities and Action Items for PFCR Working Group

M.L. Reinke

PFCR-WG
B-252
6/14/17

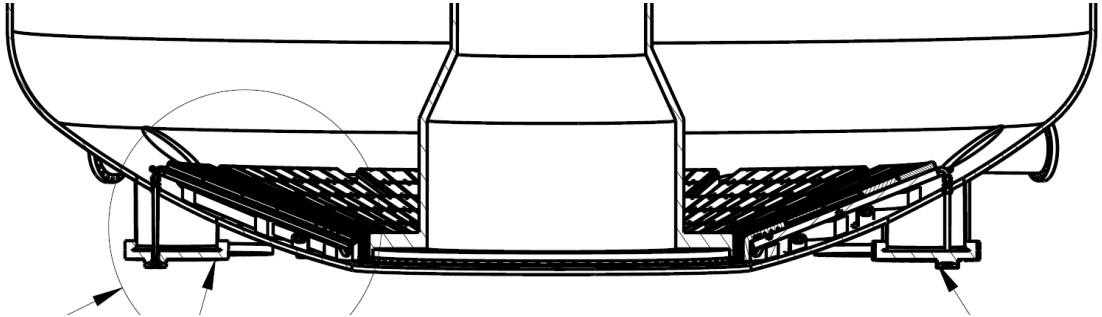
PPPL

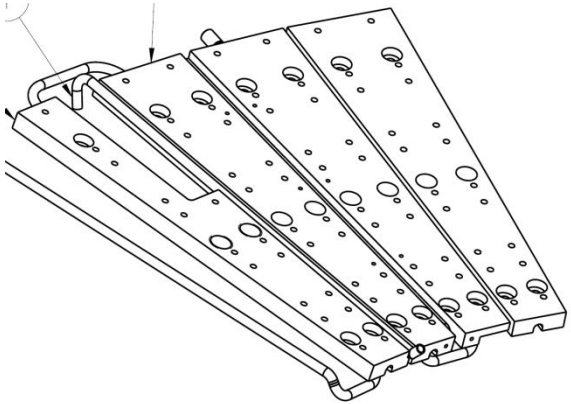


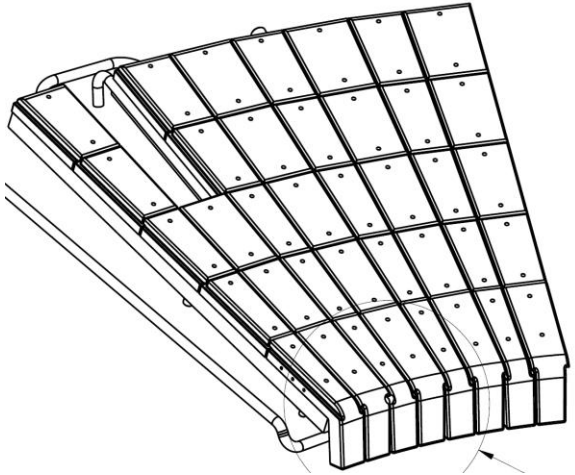
Goals of this Meeting

- present analysis from PFCR-MEMO-005 on impact of faceting on OBD heat flux (Reinke)
- discuss PFC ‘scenarios’ currently under consideration
- review in-progress MEMOs and open ACTION ITEMS
  - Gerhardt: time evolving equilibrium:

Effect of OBD Faceting

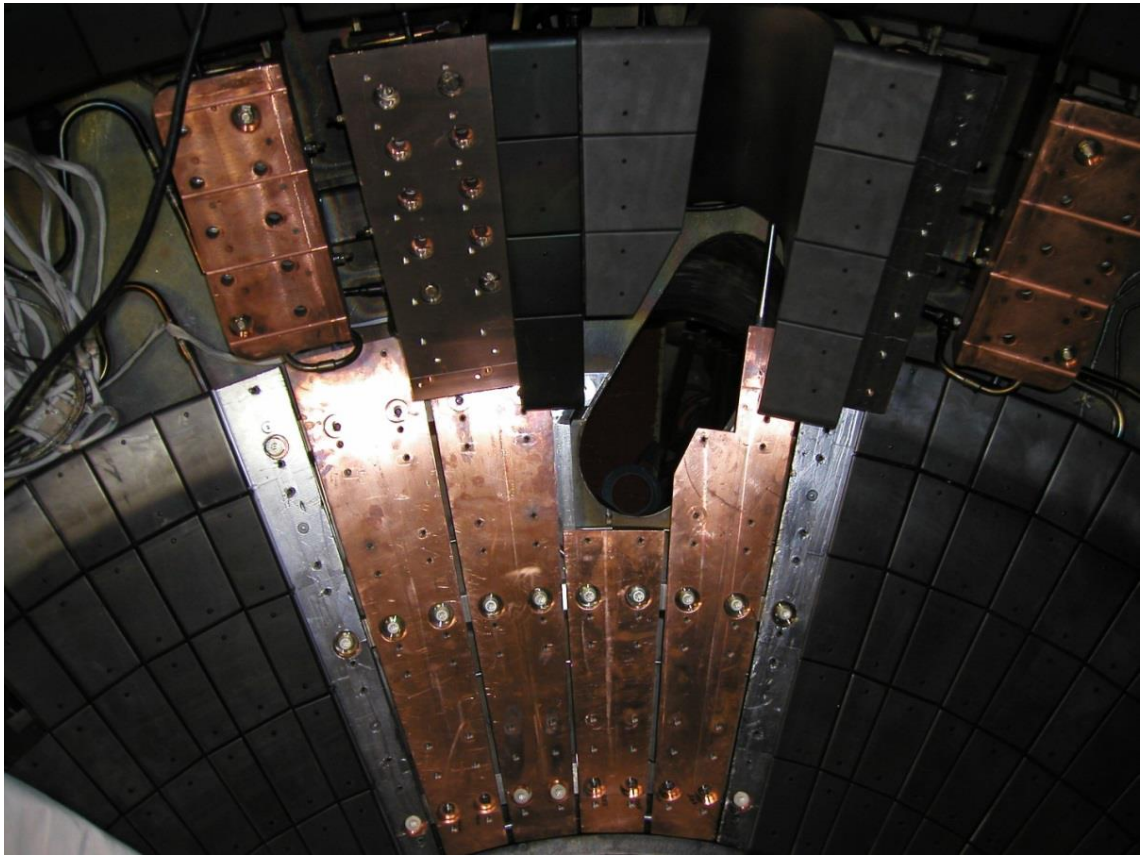






- OBD surface is not axisymmetric
  - 48 flat plates
  - $\theta_{surf} = 21.5^{o}$

Effect of OBD Faceting



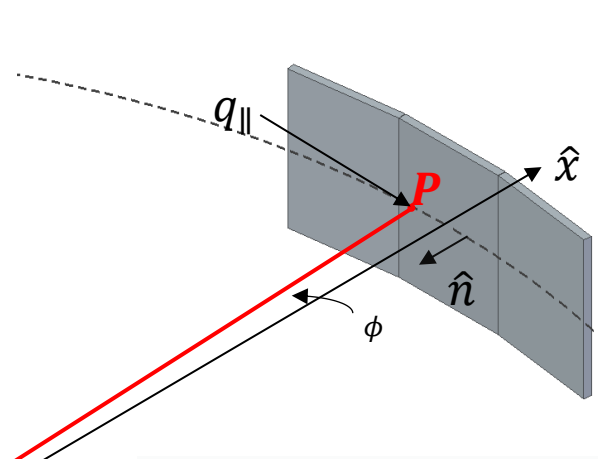
- OBD surface is not axisymmetric
  - 48 flat plates
  - $\theta_{surf} = 21.5^{o}$
- non-axisymmetry due to ‘BBQ rails’
  - upcoming metrology
- PFCR-WG asked by engineering to look into how faceting impacts surface heat flux

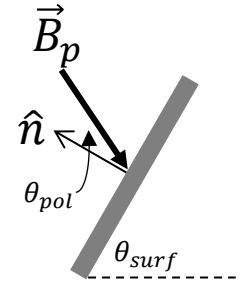
Define Geometry & Calculate $\hat{B} \cdot \hat{n}$

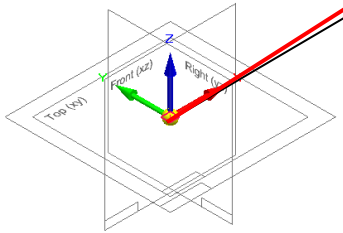
$$\hat{B} = \frac{B_R}{B}\hat{R} + \frac{B_\phi}{B}\hat{\phi} + \frac{B_Z}{B}\hat{Z}$$

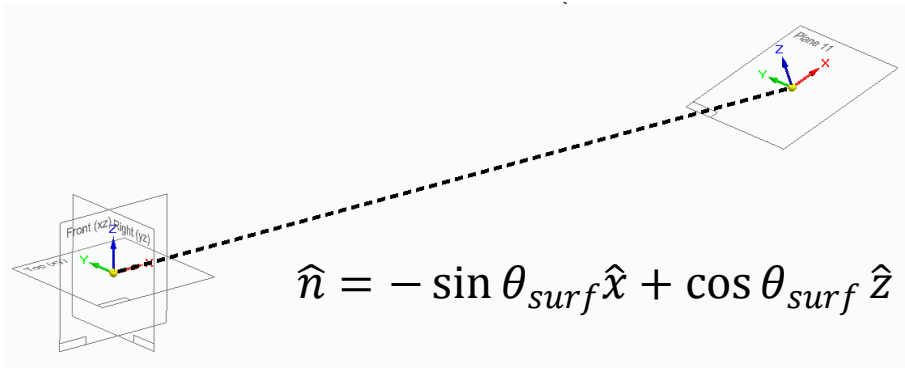
$$B_R = B_p \sin(\theta_{surf} + \theta_{pol})$$
$$B_Z = -B_p \cos(\theta_{surf} + \theta_{pol})$$

$$\boldsymbol{q_{PERP} = q_{\parallel}\hat{B} \cdot \hat{n}}$$







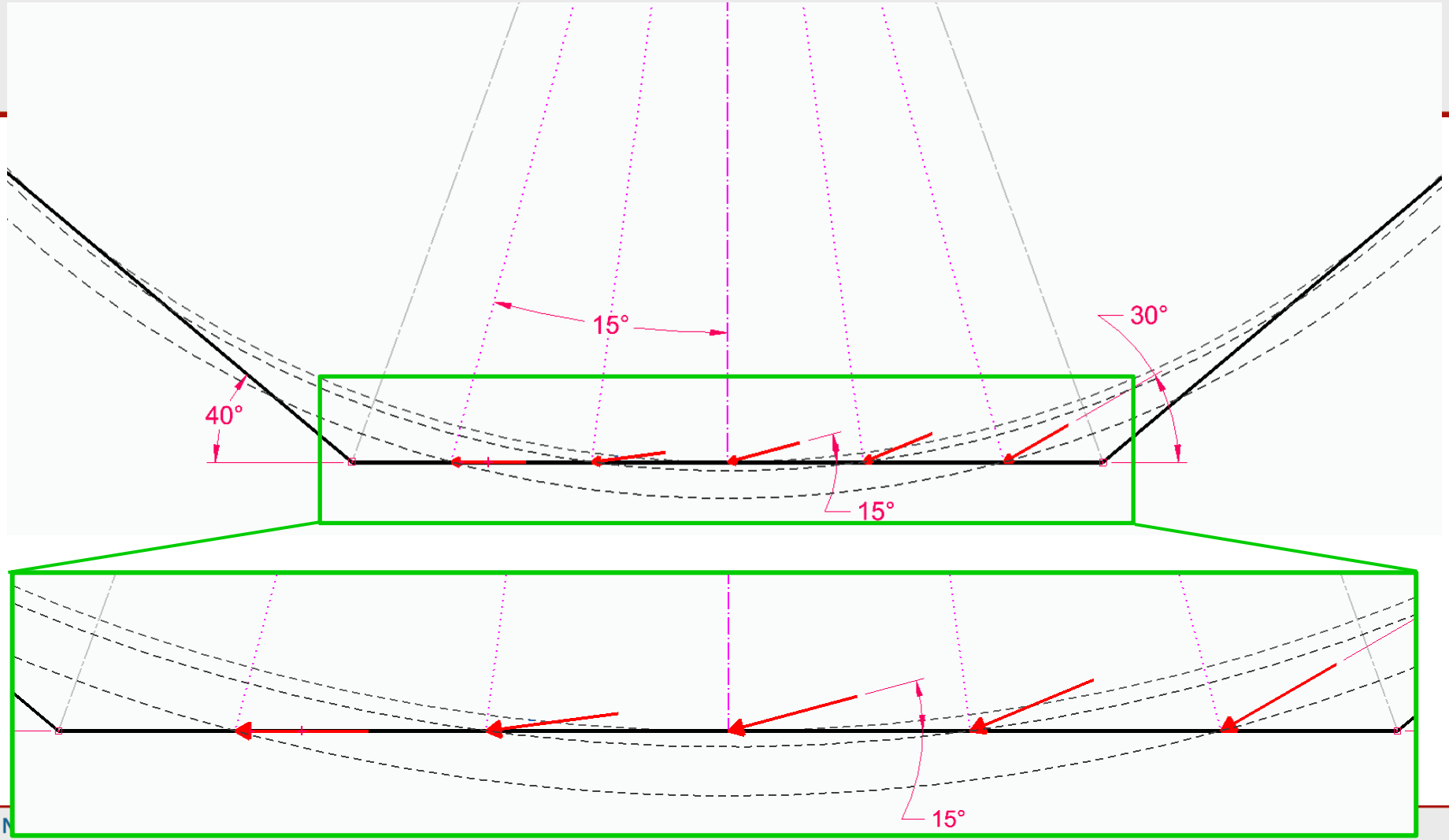


$$\hat{n} = -\sin\theta_{surf}\hat{x} + \cos\theta_{surf}\,\hat{z}$$

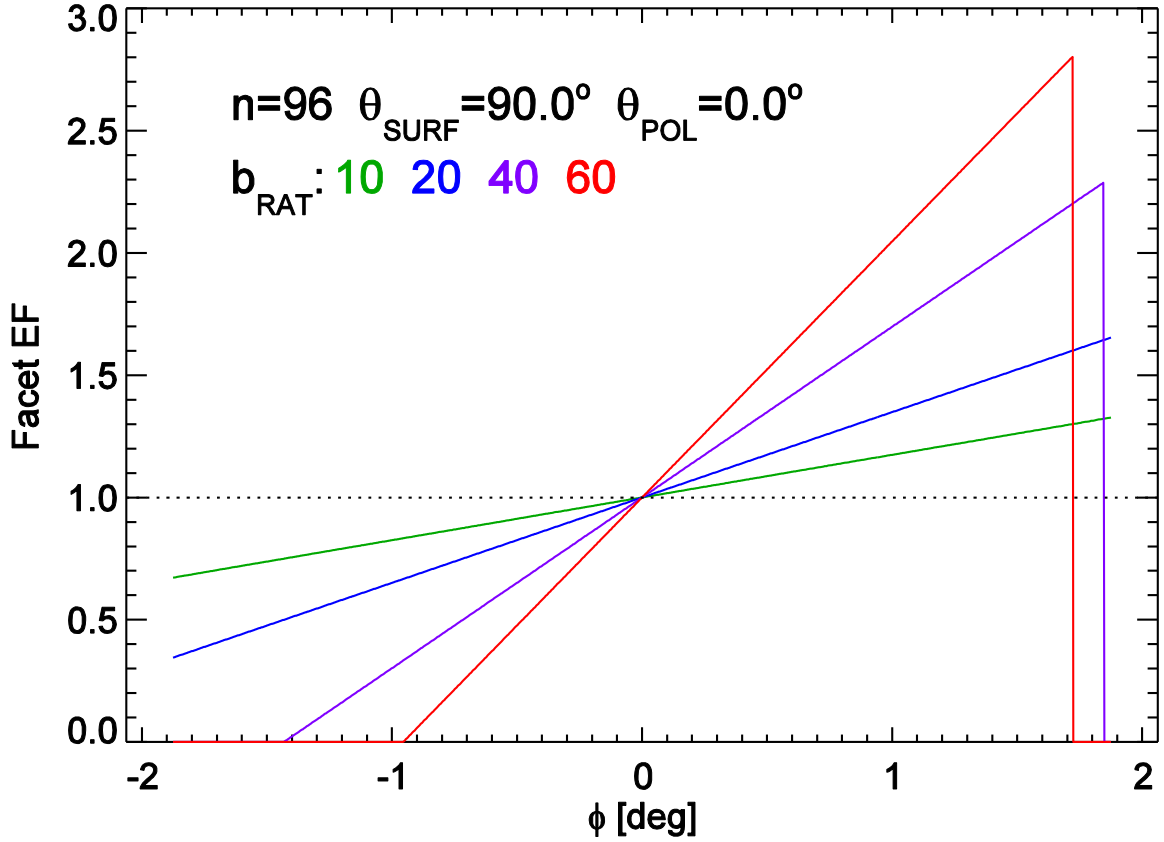
Examine Limiting Cases

$$\hat{\boldsymbol{B}} \cdot \hat{\boldsymbol{n}} = -\frac{\boldsymbol{\sin\theta_{surf}}}{\sqrt{\boldsymbol{1+b_{rat}^2}}}\left[\boldsymbol{\sin(\theta_{surf}+\theta_{pol})\cos\phi - b_{rat}\sin\phi + \frac{\cos(\theta_{surf}+\theta_{pol})}{\tan\theta_{surf}}}\right]$$

- define $b_{rat} = B_\phi / B_P$
- for $\theta_{surf} = 0$, $|\hat{B} \cdot \hat{n}| = \cos\theta_{pol} / \sqrt{1 + b_{rat}} = \cos\theta_{pol} \sin\alpha$
- $\theta_{surf} = \frac{\pi}{2}, \theta_{pol} = 0 \left(\hat{B} \cdot \hat{n}\right) / \left(\hat{B} \cdot \hat{n}\right)_{\phi=0} = \cos\phi\left(1 - \frac{\tan\phi}{\tan\alpha}\right)$
  - indicates that something unexpected will happen for $\phi > \alpha$


15°
30°
40°
15°
15°

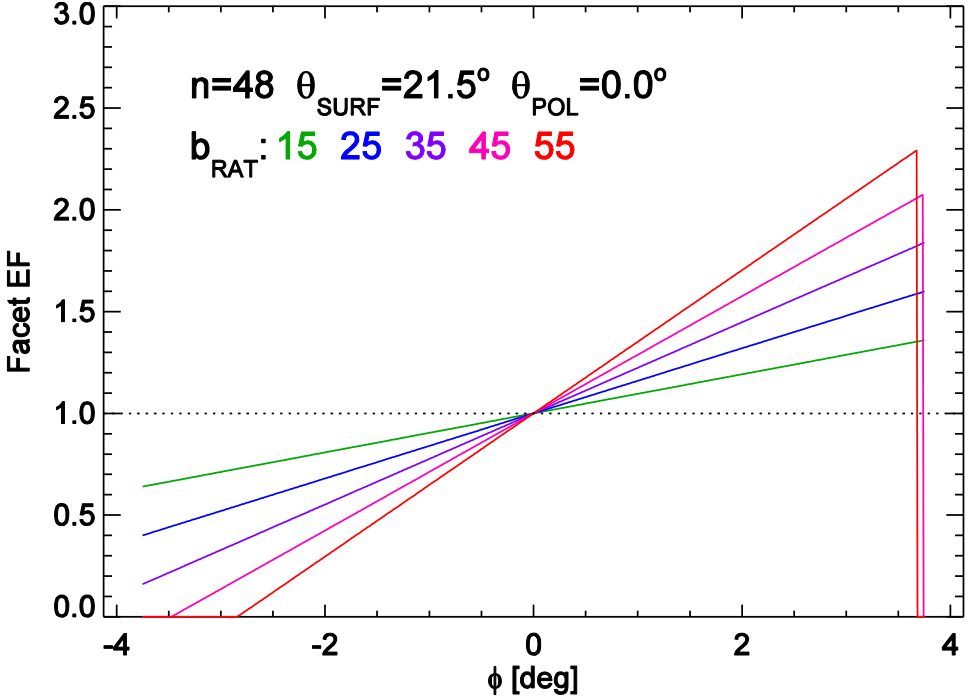
Ex: Vertical Plate w/ 96 Facets

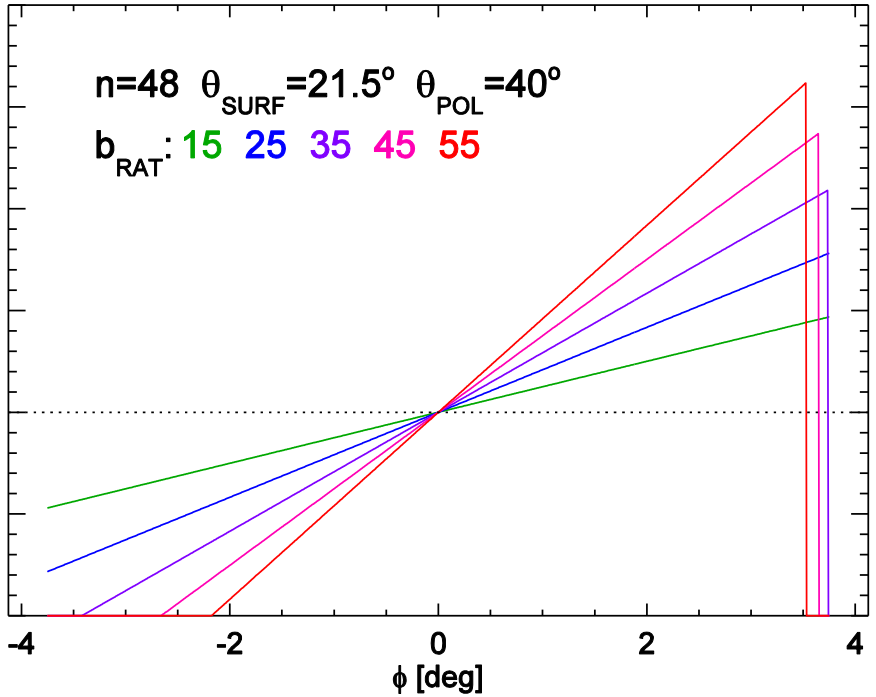


- $EF \equiv \left(\hat{B} \cdot \hat{n}\right)/\left(\hat{B} \cdot \hat{n}\right)_{\phi=0}$
- heat flux on the surface varies linearly
  - can confirm result with power balance
- shadowed areas develop that are asymmetric
  - standard fish-scaling would make this worse

NSTX-U OBD EF ~ 2.0 for Small Field Line Angles

- $b_{rat} = B_\phi / B_P$ and for $\theta_{pol} = 0$, $\boldsymbol{b_{rat} = 15, \alpha = 3.8^o}$ $\boldsymbol{b_{rat} = 55, \alpha = 1.05^o}$





Implications of Analysis

- are there experimental measurements to confirm this?
- the impact of faceting needs to be added to other features that are impacting heat peak heat flux
  - impact of 'BBQ Rail' non-axisymmery? Additional fish-scaling?
- can reduce the impact by increasing the # of facets and/or shaping surface to be non-planar (this is what C-Mod did)
  - this must be added to cost of other activities to make the OBD-R1 and/or OBD-R2 'high heat flux handling'
    - could we defer such an upgrade and make the OBD good enough to handle 'spillover' from an improved IBDH?

PFC “Scenarios”

- based on choosing paths for various regions of divertor
  - ‘qualify’: calculate and/or mechanically test what limits the presently implemented tiles can take
  - ‘modest improvement’: keep overall tile envelope/design but remove and replace (new graphite, change ‘t-bar’, pins, etc.), targeting 3.5-4.0 MW/m^2 while meeting halo current spec.
  - ‘full design’: major new design, optimizing for high heat flux requirements (small cubes, possibly carbon-carbon composites)
    - may need to realign the BBQ rails for the outboard divertor
- cost (money, FTE, personnel types) for each option was estimated, collected to form ‘scenarios’
  - exercise shows we need many more engineers than we have

PFC Scenarios And Normalized Costs

Scenario	CSFW	IBDH	IBDV	CS-A	OBD-R1	OBD-R2	OBD-R3/5	OBD Align	Weeks	Cost
0 : do everything	Full	Full	Full	Full	Full	Full	Full	Yes	1.00	1.00
1: full halo + critical surfaces	Improve	Full	Full	Improve	Full	Full	Improve	No	1.00	0.76
J: full halo + optimized high-δ	Qualify	Full	Full	Improve	Improve	Improve	Improve	No	0.94	0.55
X: full halo + optimized horiz. target	Qualify	Full	Improve	Improve	Improve	Improve	Improve	No	0.94	0.52
2: full halo + improvements	Qualify	Improve	Improve	Improve	Improve	Improve	Improve	No	0.84	0.45
3: partial halo + some improve.	Qualify	Improve	Qualify	Improve	Improve	Qualify	Qualify	No	0.84	0.29

- duration (weeks) and cost ($$) normalized to ‘do everything’
  - talk w/ Stefan or Jon regarding details of absolute numbers
  - working idea would be to bring J,X,2, or 3 up to ‘Scenario 1’ in the future
- all ask for somewhere between 0.7-1.4 FTE of physics
- no monitoring systems included, but its on spreadsheet

Review On-Going Work

- for people present, please summarize what's being worked on and progress being made
  - MEMOs
  - ACTION ITEMS

PFC Requirements Working Group Charges

1. ~~define which (additional) parameters need to be specified in an updated requirements document for the NSTX-U PFCs~~
2. facilitate generation of updated requirements utilizing:
   a) available reduced models, empirical scalings, boundary simulations
   b) ultimately, a validated model for specifying heat loads to all plasma facing components for arbitrary NSTX-U scenarios
3. in preparation for operations, develop:
   a) instrumentation plan for intra and inter-shot PFC monitoring
   b) a reduced model for heat loading for pre-shot planning
   c) guidance on how to best integrate monitoring with operations
   d) control, diagnostic requirements for real-time heat-flux control
4. work closely with engineers and analysts to develop and implement requirements

http://nstx-u.pppl.gov/program/working-groups/pfc-requirements-working-group