APEX Task 3c: Divertor Integration

SNL, ORNL, UCLA , ANL, others

Richard Nygren, leader/presenter

E-Conference *August 13 and 15, 2002*

Contributors:

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Task 3 Divertor Integration

Progress - August 2002

Deflected stream option (FW flow)

- ***Divertor configuration***
- ***Heat removal***
- ***Pumping/Drain***
- ***Outstanding issues (RF system, surface waviness, ..)***
- ***Report (draft circulated for comment)***

For November Meeting 2002

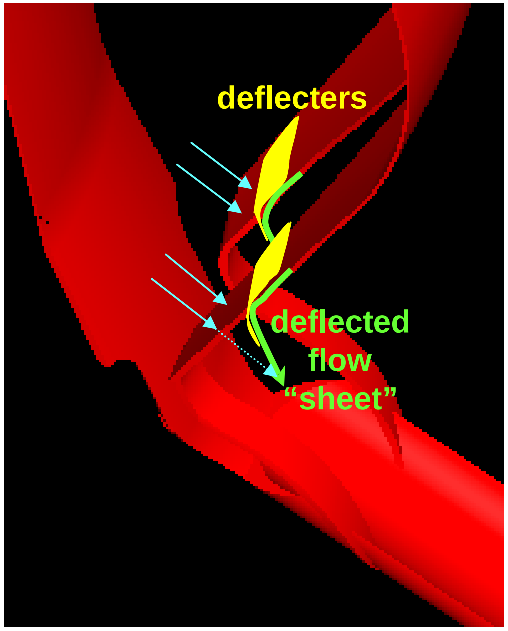
- ***Divertor configuration with CAD drawings***
- ***Pumping for parallel stream or droplet concepts***
- ***RF system layout for divertor cassette***
- ***Report and paper on ARIES/CLIFF/Flinabe***

Divertor Configuration

Deflected stream option (FW flow)

- ***Utilized decay of turbulence per Sergey***
- ***Refined specifications for target location***
- ***Working to integrate preferred location***

- **Review the rationale for deflected stream**
- **Show impact of enhanced k_{eff} (turbulence)**
- **Show mechanical design in progress (CAD drawings by PJ Fogarty)**
- **List current issues to be resolved**



Opt1 FW flow→ divertor

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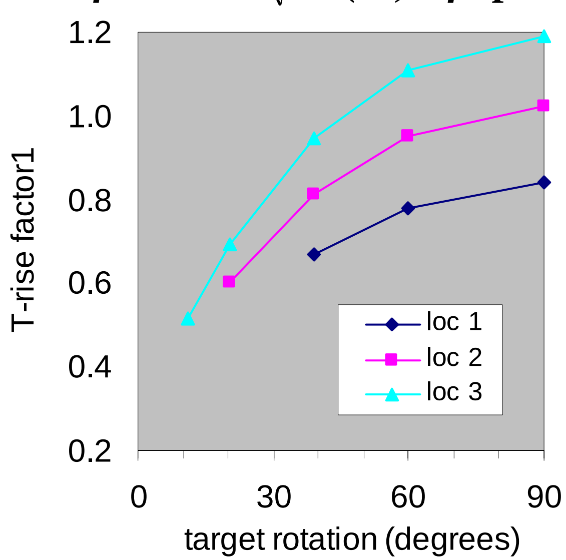
Divertor Configuration

Simple dependence on angle and flux expansion presented previously.

$$T_{surf,rise} \cong \frac{q}{k}\sqrt{\frac{\kappa t}{\Pi}} \quad with \quad t = \frac{L_0\, flxp}{\sin(\theta)v}$$

$$T_{surf,rise} \cong q^* \sqrt{\frac{L_0}{\Pi \rho C_p}} \sqrt{\frac{\sin(\theta)}{flxp}} \sqrt{\frac{1}{kv}}$$

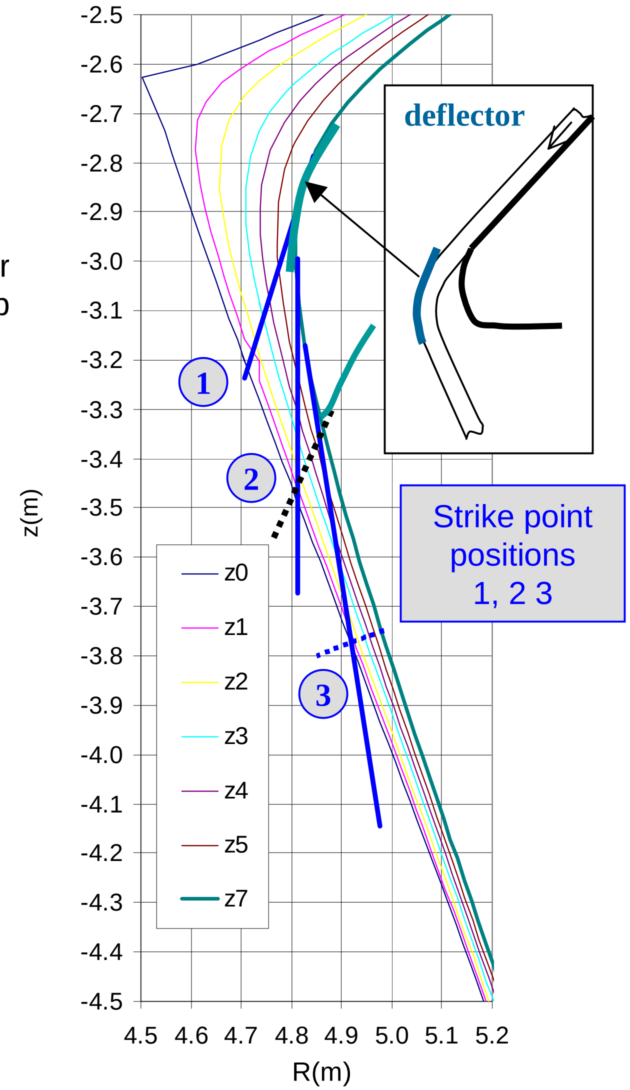
$$\boldsymbol{T - factor1 \cong \sqrt{\sin(\theta)/\ flxp}}$$



At an angle >40°, T-factor1 is lowest for Pos. 1.

Position 3 has lowest possible angle.

Portion of Roglien /Bulmer (LLNL) flux map for ARIES-RS with a single null divertor



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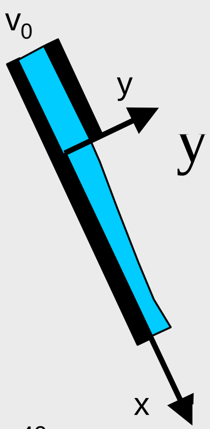
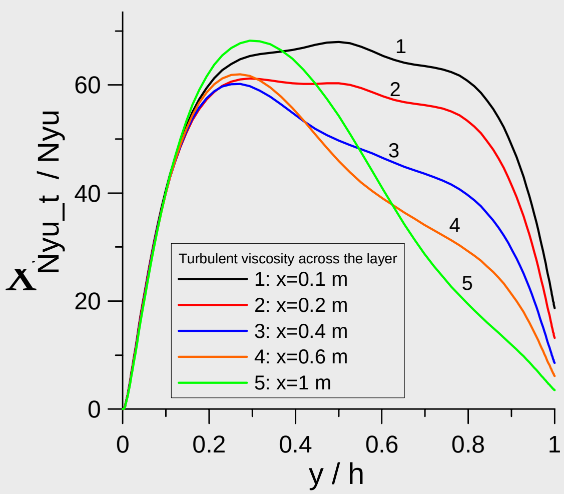
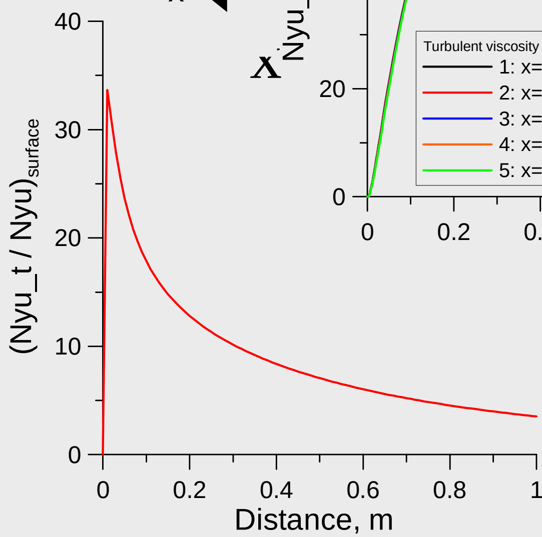
Sergey's model

10 m/s = v_0 (fully dev. turbulent profile)
2.3cm = initial flow thickness
10T = magnetic field (spanwise)
62°= inclination
1m = flow length
(downstream of nozzle outlet)

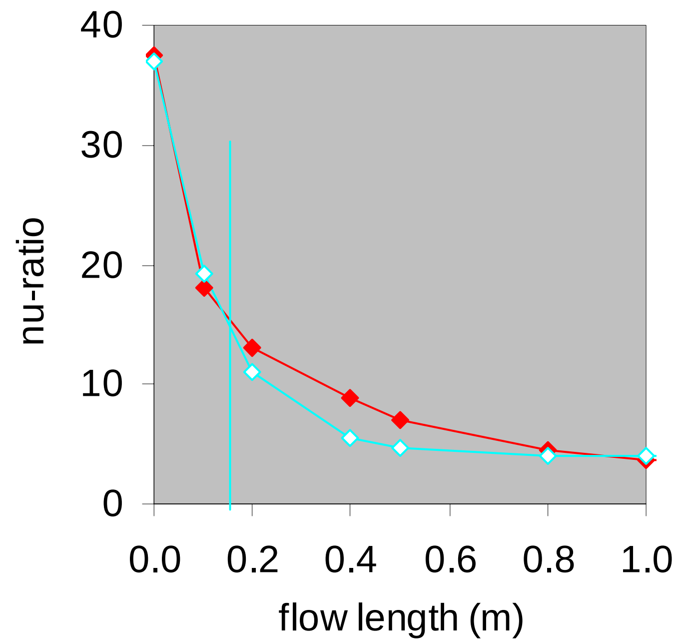






Model by Smolentsev (UCLA)

The closer to the deflector, the higher the effective thermal conductivity in the >1mm layer below the free surface.



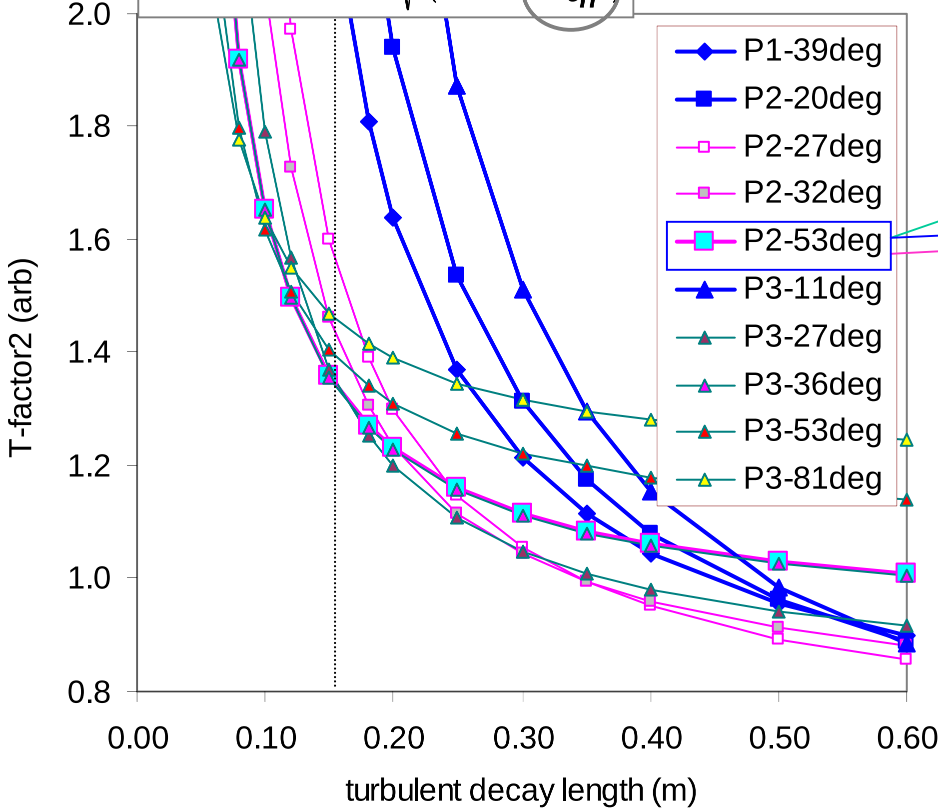
Decaying turbulence of free surface vs. distance from the deflector Smolentsev calculation (red) *equation (3.7+33.8exp[-x/0.14] overlaid (aqua)*

Impact on Design:
Strike point must be 15cm or less from the deflector

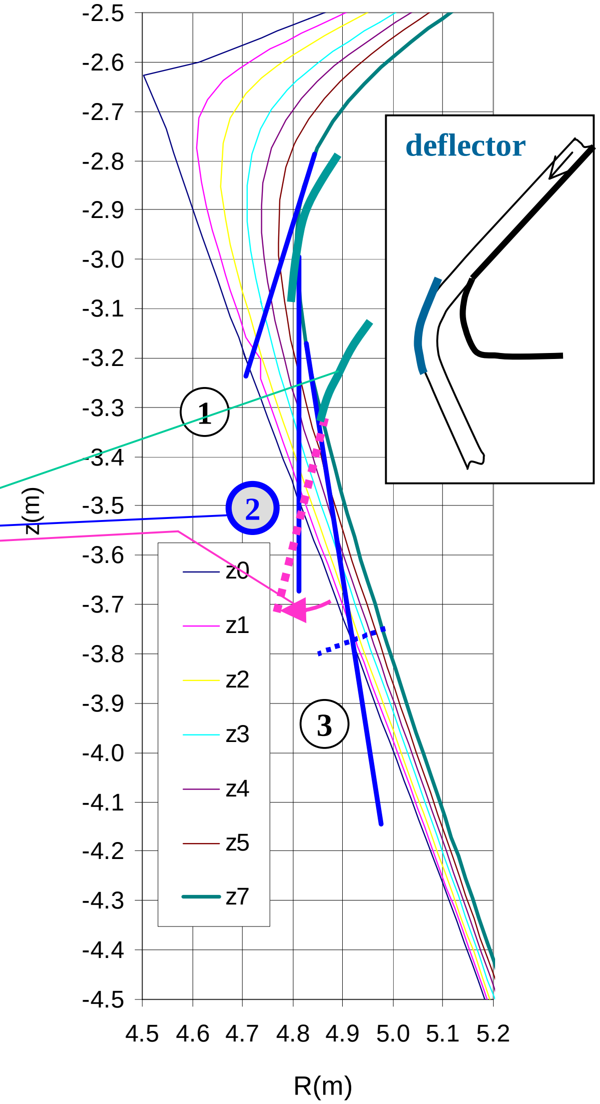
APEX Divertor Configuration

Include turbulent decay in T-factor.

$$T - factor2 \cong \sqrt{\frac{\sin(\theta)}{(flxp * k_{eff})}}$$



Portion of Roglien /Bulmer (LLNL) flux map for ARIES-RS with a single null divertor

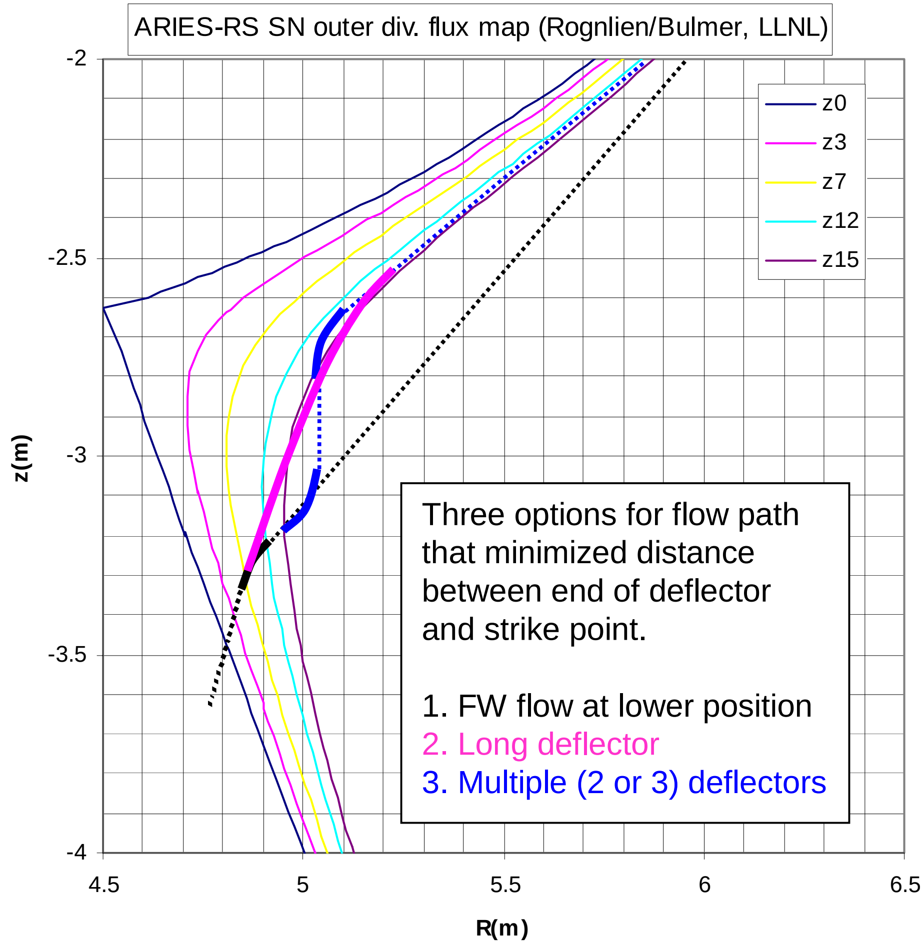


Divertor Configuration

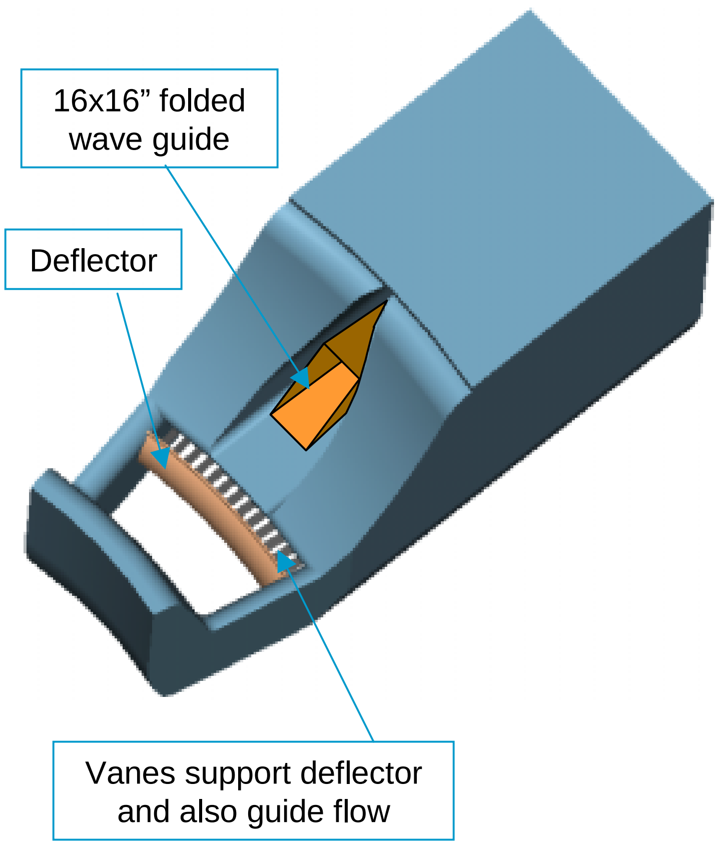
A *single small deflector* is simplest.

A *long deflector* keeps the FW flow along the same flux surface but requires a large surface area of structure.

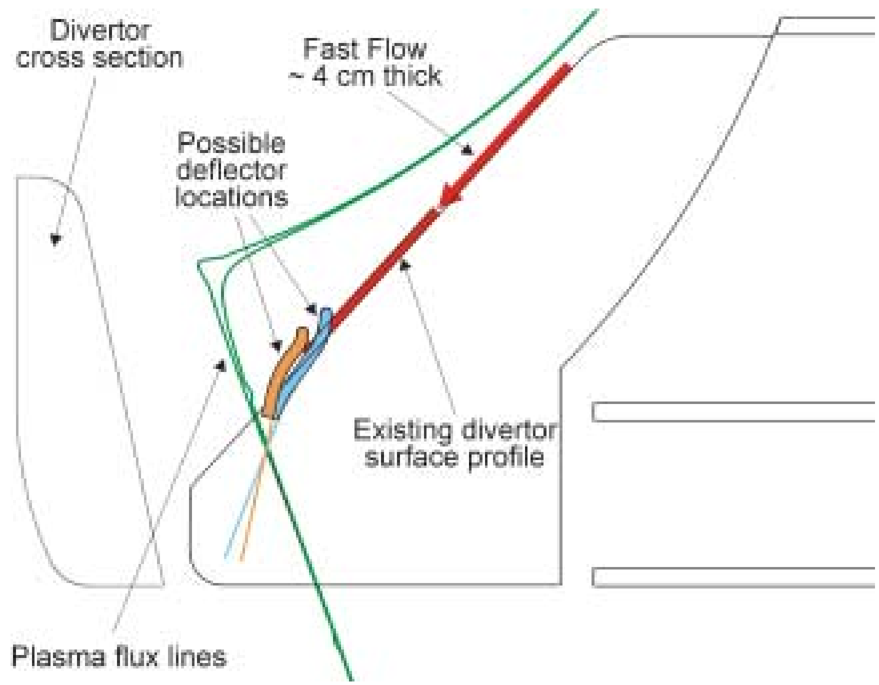
Multiple deflectors gives a more complex arrangement but may help move flow toroidally to cover the exit flow around the RF ports and guide flow to create openings for pumping.



Divertor Configuration



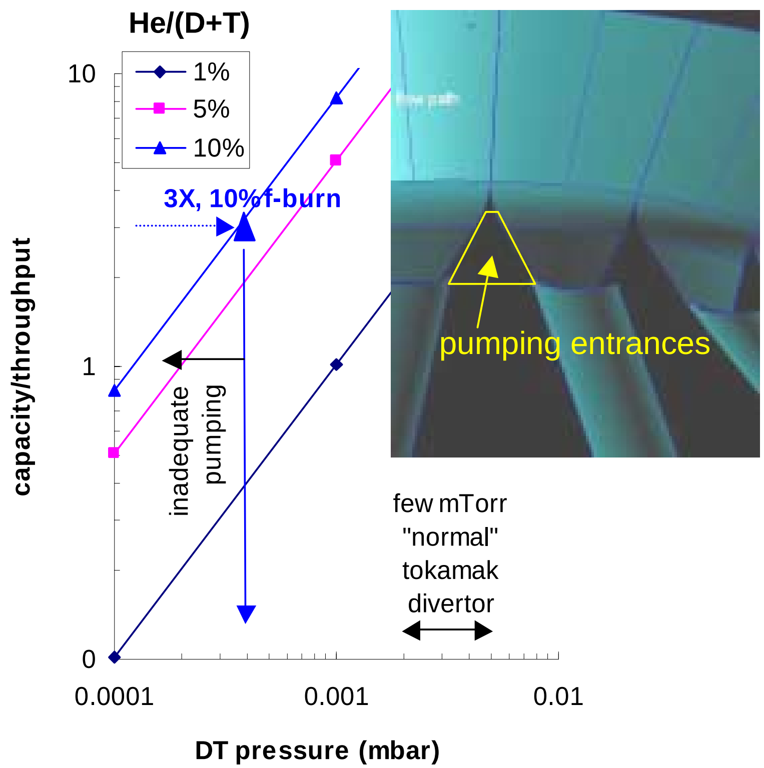
Deflector for strike point Position 2 (majenta line in previous figure)



Views of "sled" for divertor cassette.
CAD Drawings by PJ Fogarty (ORNL)

Pumping and Drain

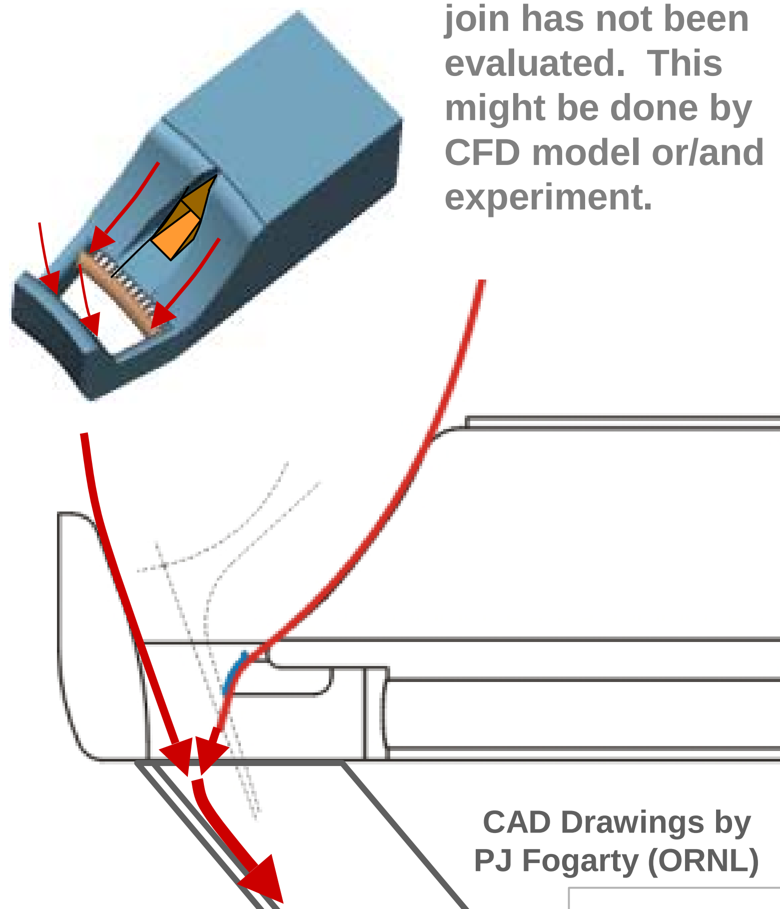
Pumping is adequate. Work continues on novel concepts to pump He.



DT fueling + D puffing - burn/2 - deposition defines exhaust pumping needed.

Space for drain is adequate.

Splashing where divertor streams join has not been evaluated. This might be done by CFD model or/and experiment.



CAD Drawings by PJ Fogarty (ORNL)

Divertor Integration Issues

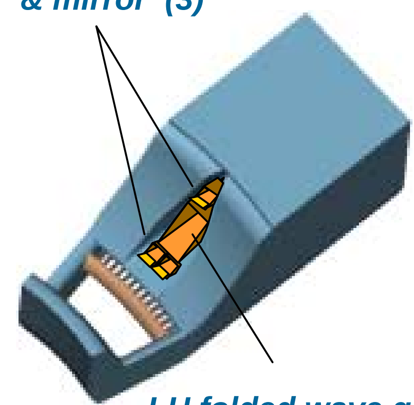
Location of the RF Systems

- *Housed in the divertor cassette if possible*
- *LH current drive needs proximity to plasma*
- *ECH needs waveguides and mirrors*

Draft tech. note on divertor functions (july02)

Dick Majeski quickly responded. (Thanks)

Majeski/Nelson/Fogarty are defining the requirements (power, area, …)



CAD Drawings by PJ Fogarty (ORNL)

Surface Waviness

- *Sergey's work indicates enhanced k of ~X2*
- *Richard's hot spot analysis indicates locally peaked heat loads*

Richard will develop evaluation of effect of multiple hot spots.

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Divertor Integration Issues

Flow model of divertor flow and drain

- *CFD2000 models of heat load on flat Li stream (Youchison) and Li flow from high compression nozzle (Brantley)*
- *CFD models are needed*

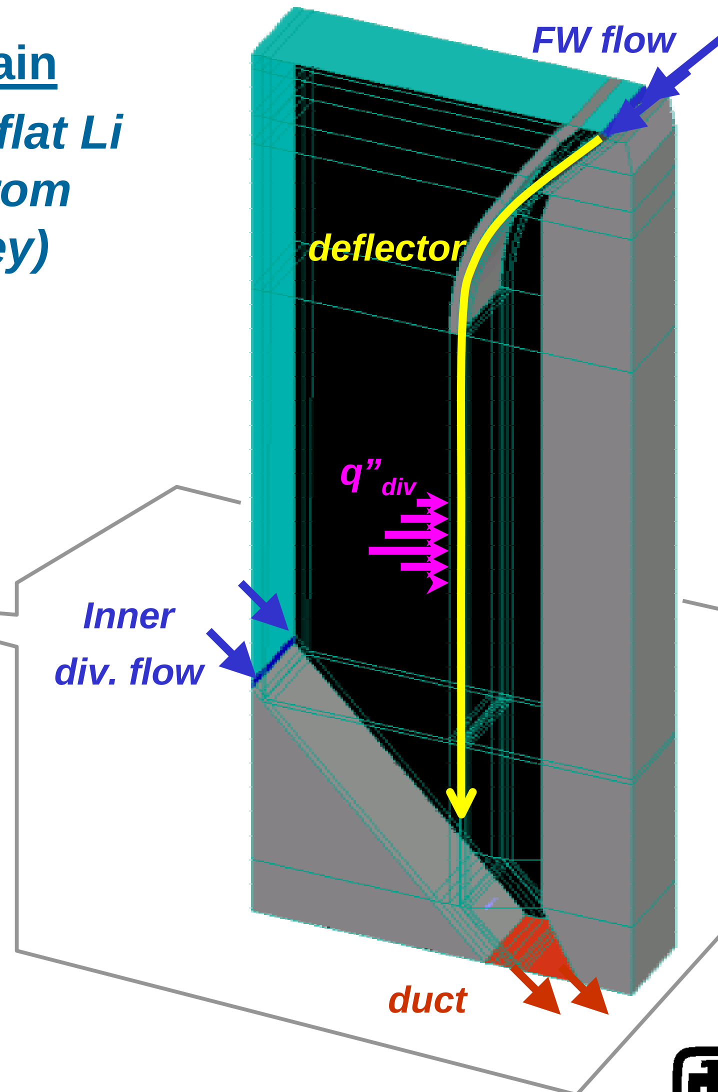
  a. flow around RF penetration

  b. flow through deflector/vanes

  c. flow in duct (joining streams)

Richard will model drain.

(Developer had problem here.)

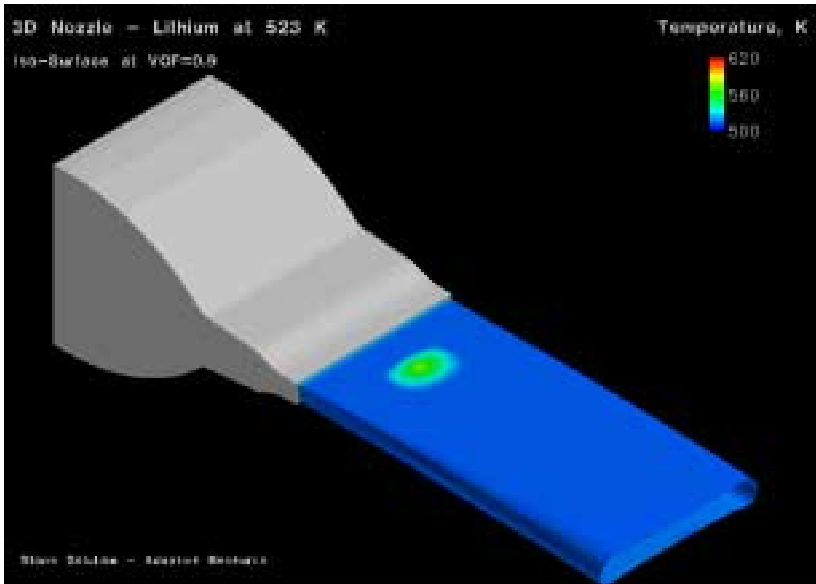


Documentation Overdue

- *Report (draft circulated)*

Richard will write report & paper.

Flow Modeling with CFD2000



CFD2000 3-D model of Li stream with applied heat flux by Dennis Youchison (Sandia)

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Divertor Integration Issues

Depth of engineering Details for Design Integration

- ***Approach A: more options, less in-depth engineering***
- ***Approach B: fewer options, more in-depth engineering***

  a. time on detailed design & engineering specifications

  b. resources and scheduled time for design analysis

  c. frequent interaction to resolve issues in design integration

We should pause to consider our approach in FY03.

Richard's evaluation: Task 3 was heavier on engineering in our first couple of years and lighter during FY02.

We need to discuss whether
(a) we **CAN** do adequate design integration (resource issue) and
(b) we **WILL** do adequate design integration (our commitment).