Concerns on Integration of An APEX Divertor

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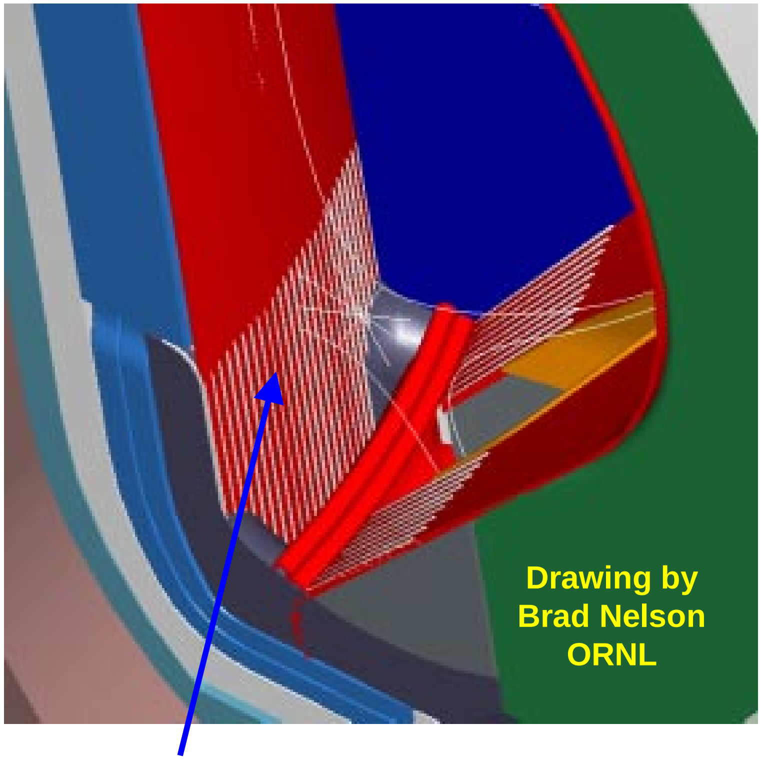
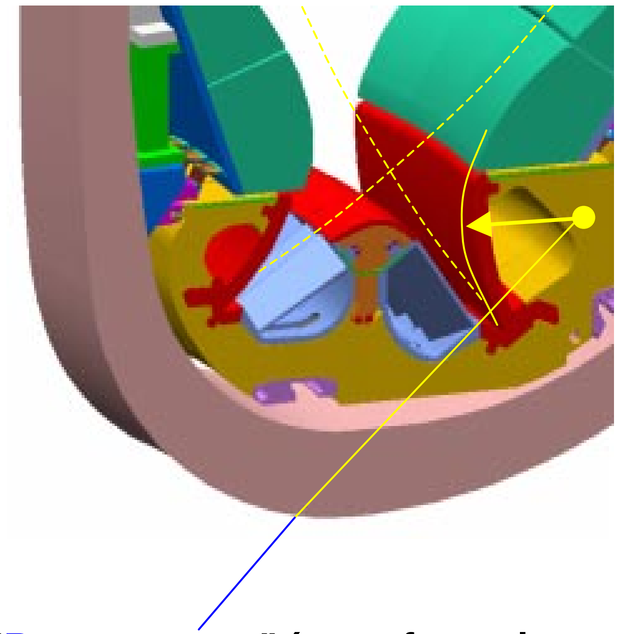


"flow convertor" modifies flow for divertor

- **Plumbing/configuration**
- **Heat load**
- **D/T and He pumping**
- **Safety & Maintenance (not covered)**



- "Reverse curve" (away from plasma as in ITER divertor) is not possible for inertially controlled flows.
- Available space in the divetor of a high power density reactor such as ARIES RS is a sever limitation.

configuration issues

- space requirements
- conductance for He pumping
- modified first wall stream or "separate" divertor flow
- flux expansion
- incline of liquid surfaces

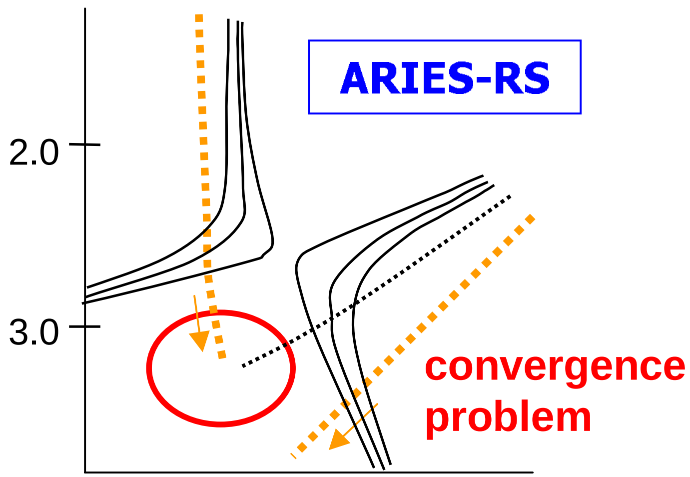
thermal-hydraulic issues

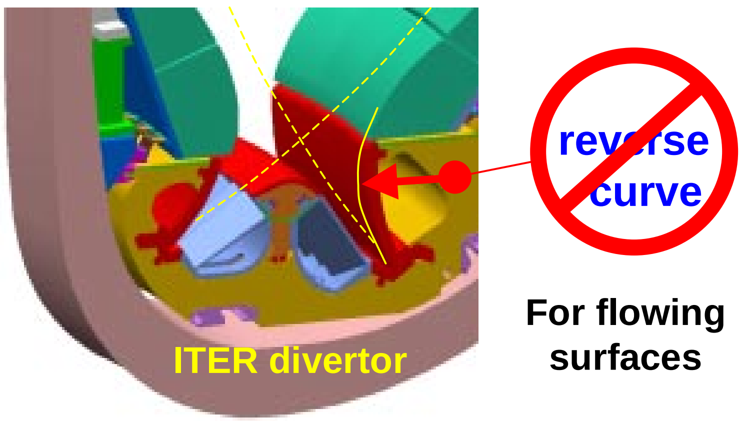
- improving thermal mixing
- nozzle design (separate divertor)
- ∇B MHD effects

plasma physics issue

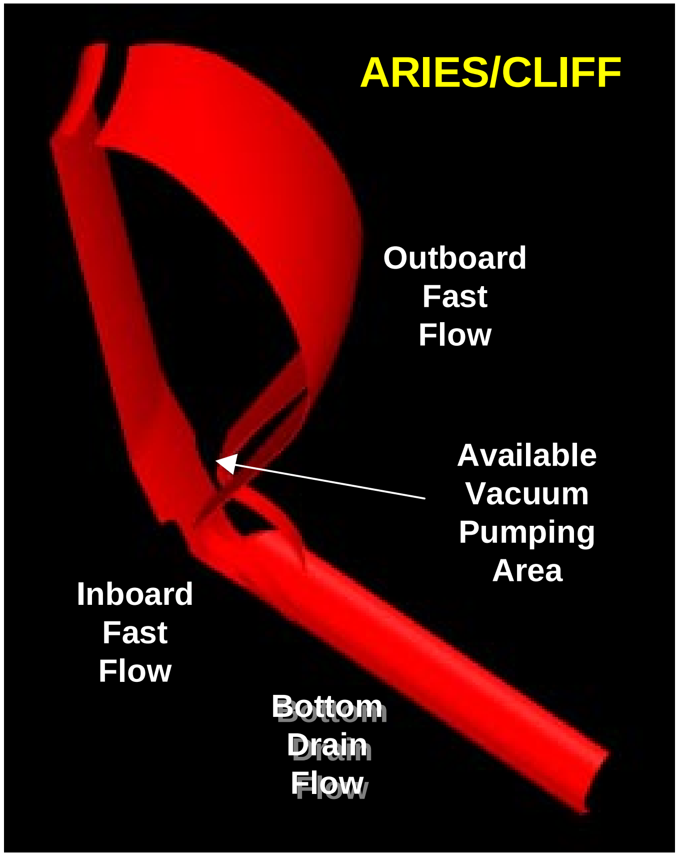
- He neutral pressure for pumping
- Is a droplet divertor feasible? (large λ_q - "diffuse" scrape-off)

Simplest Case: Extended First Wall Flows





For flowing surfaces



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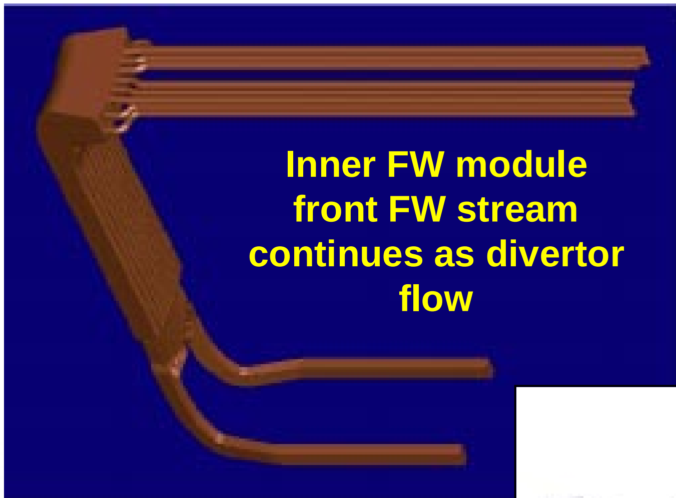

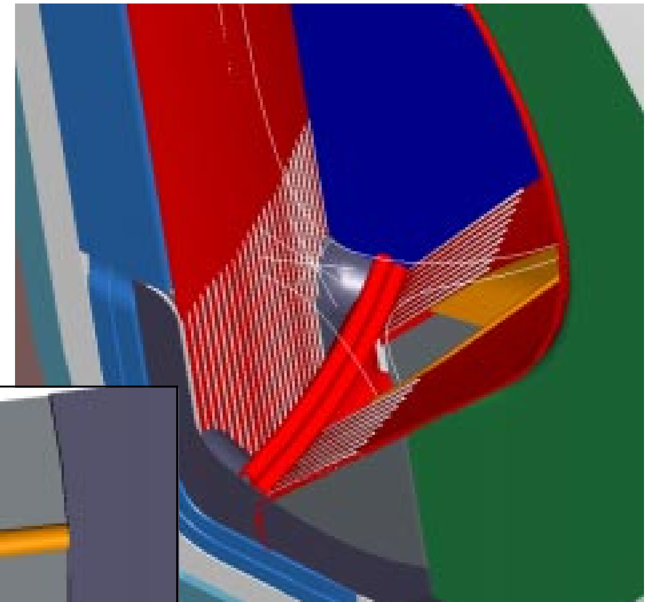

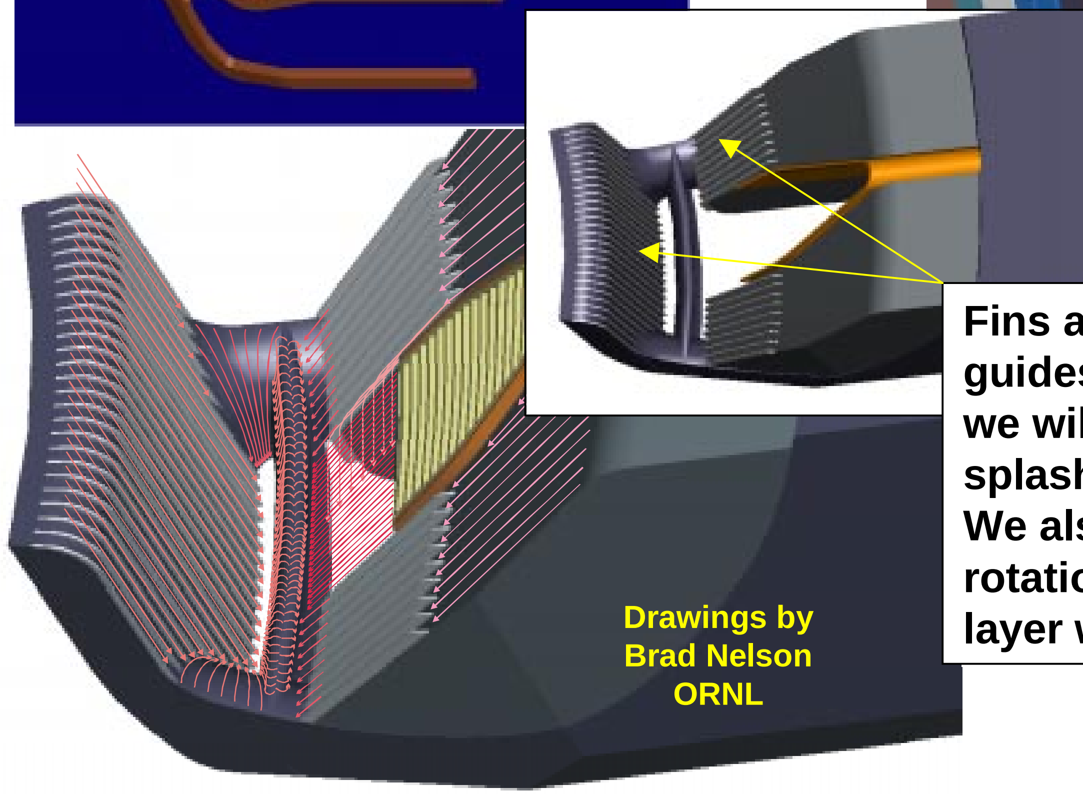

Fins are "stand ins" for flow guides. Below strike point, we will guide flow to reduce splash on edge of collector. We also want large cell flow rotations to mix the surface layer with the bulk fluid.

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Heat Removal

ARIES-RS Fusion Power	2171 MW	
Pdiv (10% P-alpha)	43.3 MW	

	inner	*outer*	
R-div	4.1	4.9	m
f-rad-div	7.5%	7.5%	
fraction to outboard	**40%**	**60%**	
HF,100% toroidal div.	**12.1**	**22.3**	MW/m^2
toroidal coverage	**100%**	**40%**	
HFpeak-div, particles	**12.1**	**55.8**	MW/m^2
Pdiv-particles	**16.0**	**24.0**	MW/m^2
Prad-div	**1.25**	**0.80**	MW/m^2
Total Power, Divertor	**42.10**		MW/m^2
Missing radiation	**0.00**	**1.20**	MW/m^2
incline, to flux surface	90	90	degrees
lambda1a-target	0.029	0.021	m
lambda1b-target	0.130	0.200	m
lambda2-target	0.0073	0.0053	m
hot flow length	0.051	0.035	m
Adiv-footprint	1.32	0.43	m^2
rad div length	1	1.35	m
HFdiv, rad	0.05	0.05	MW/m^2
q1a/q-peak	85%	95%	
q1b/qpeak	15%	5%	

configuration issues

- **conductance for He pumping vs. toroidal coverage of outer div.**
- **flux expansion**
- **incline of liquid surfaces**
- **modified first wall stream or "separate" divertor flow**

thermal-hydraulic issues

- **improving thermal mixing**
- **nozzle design (separate divertor)**

plasma physics issue

- **He neutral pressure for pumping (low recycling case)**
- **Is a droplet divertor feasible? (large λ_q - "diffuse" scrape-off)**

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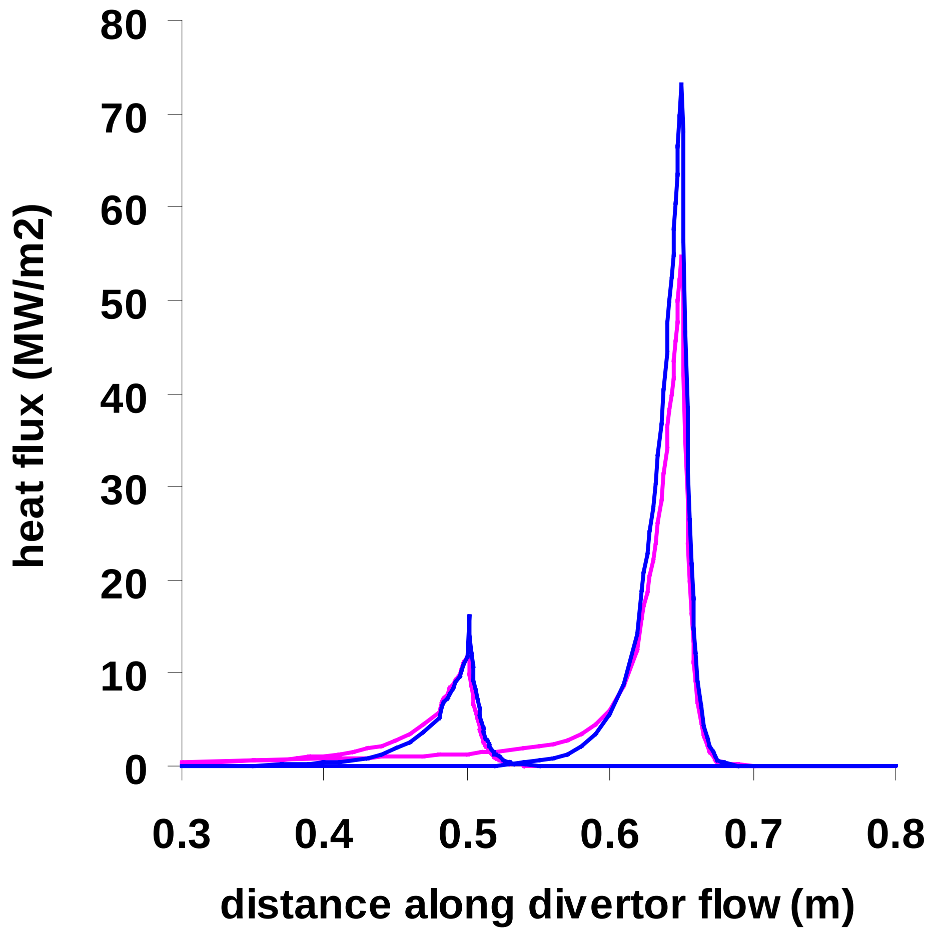
Divertor Heat Flux Profiles



CLIFF/ARIES Divertor Heat Loads

	inner	*outer*
Qpeak=	12.1	55.8
q1 =	10.3 (85%)	53.1 (95%)
q2=	1.80 (15%)	2.80 (5%)
lam1=	0.0290	0.0210
lam2=	0.13	0.2000
q3=	12.1	55.8
lam2=	0.0073	0.0053

toroidal surf outer= 0.4

- 40/60 inboard/outboard
- 7.5% Qdiv-rad

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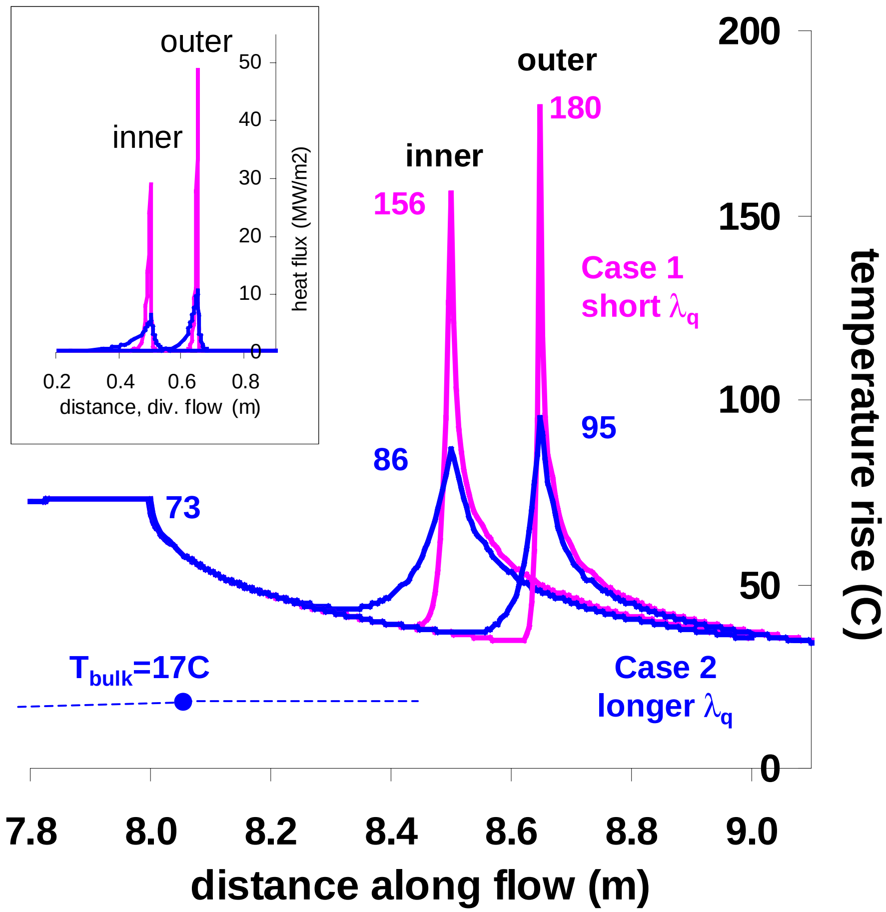
Surface Temperature in Divertor

(different case than previous slide)

calculations by Sergey Smolentsev, UCLA



Preliminary Conclusions:

- Strongly peaked heat load (short λ_q) lead to high peak temperatures.
- Even for unmodified flow, thermal mixing (k-ε model) decreases the thermal gradient from first wall heating.
- For $\lambda_{q\text{-mid}}$ of 2cm (Case 2) the temperature rise in the divertor adds only 13C or 22C (inner/outer).

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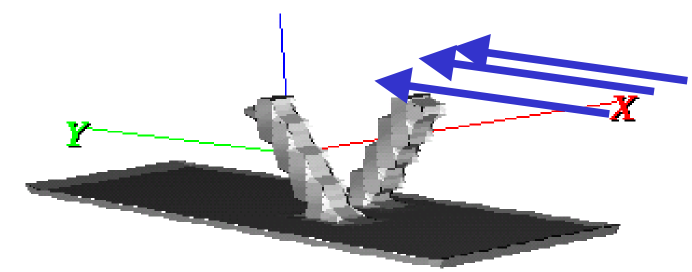
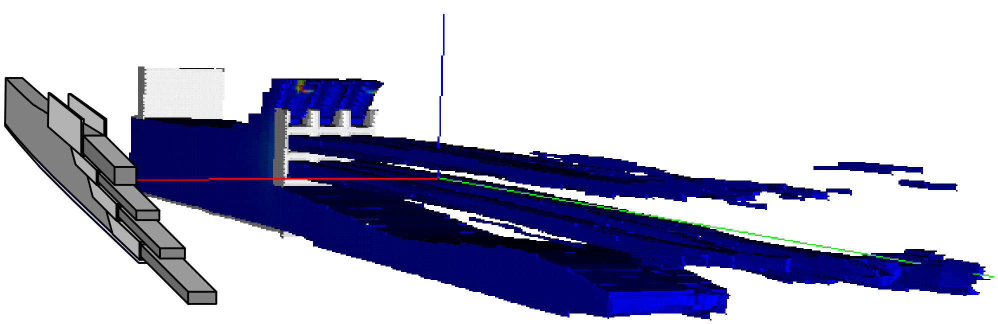
Modified Flow

Analyses by
Karani Gulec, UCLA



Fins to promote large cell fluid rotation



Screen for fluid breakup to generate droplets

Flow Issues:

promote turbulence

- ***Mix surface stream by some large scale fluid motion.***

form droplets

- **Is a scheme with natural break-up possible?**
- **Introduce a nozzle (separate structure and stream)**

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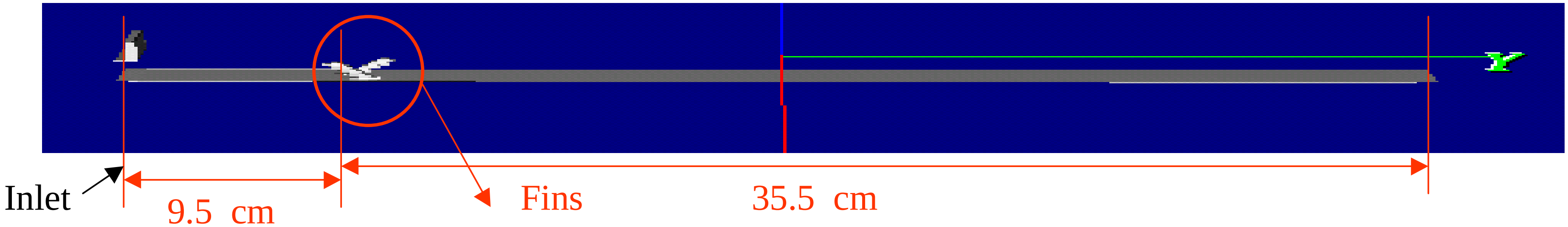
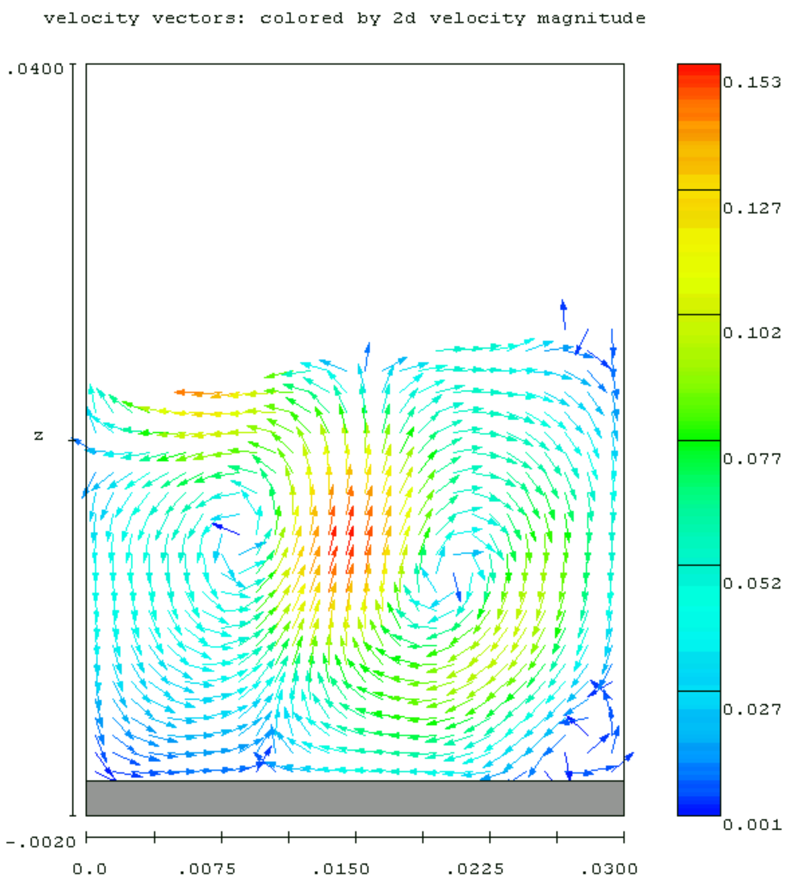
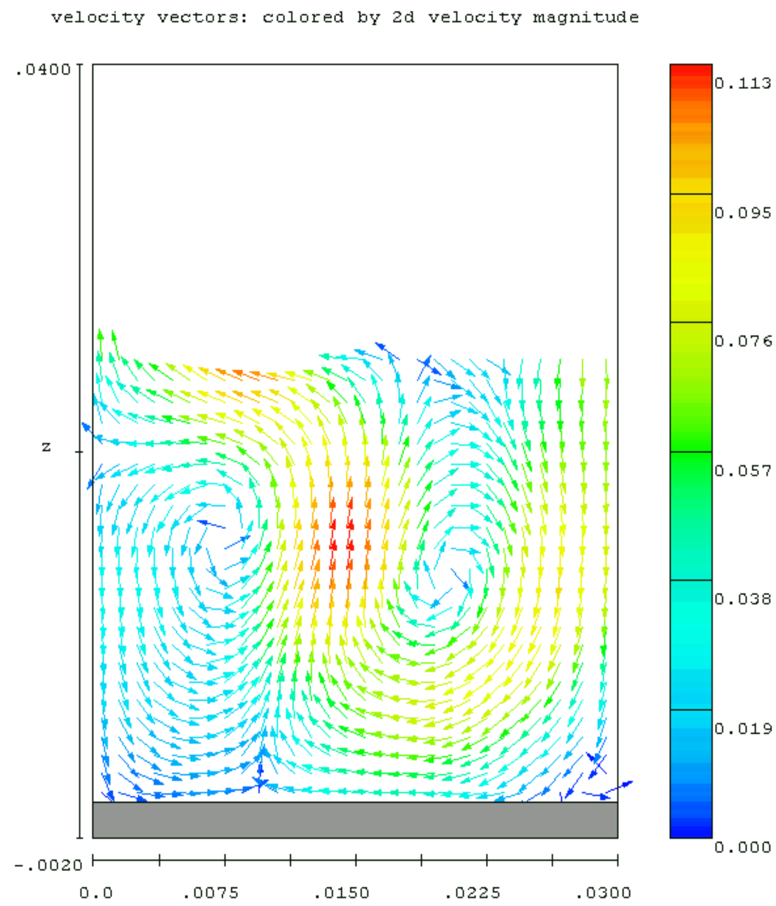
Preliminary Results by Karani Gulec, UCLA

2-D VELOCITY VECTORS ON PLANES PERPENDICULAR TO THE FLOW DIRECTION





32 cm away from inlet



38 cm away from inlet

Near Term Plans

Divertor Heat Load
- *Revise thermal calculations (consistent with edge model)*
- *Complete trade-off study on toroidal coverage & pumping*

Divertor Collector & Flow
- *Work out outer divertor flow*
- *Utilize thermal mixing ideas*

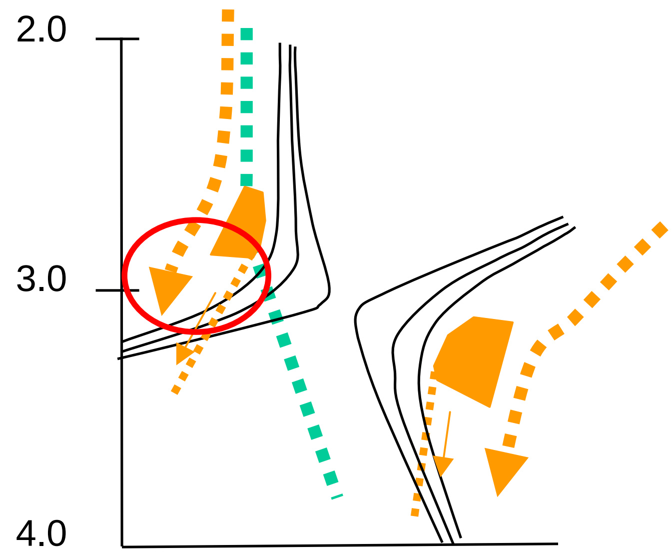
He & D/T Pumping
- *Complete trade-off study*

Thermal & Hydraulic Analyses
- *Thermal mixing study*
- *Droplet generator*
- *Working fluid (Sn-Li?)*
- *Thermal-hydraulic cases*

Longer Term Plans

Divertor Collector & Flow
- *Separate outer divertor flow*

Thermal & Hydraulic Analyses
- *Droplet generator*
- *Working fluid (Sn-Li?)*



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