Status Update
18MW ILC Beam Dump Design

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Outline

- Introduction.
- Mechanical Design Concept.
- Beam Parameters used for FLUKA studies.
- FLUKA studies.
- Thermal-hydraulic studies (conjugate heat transfer).
- Summary.

Introduction

ILC Beam Dump Design Team

- **SLAC National Accelerator Laboratory:**
  J. Amann, R. Arnold, D. Walz, A. Seryi
- **Bhabha Atomic Research Centre:** P. Satyamurthy, P. Rai, V. Tiwari, K. Kulkarni

Starting Point for Work

- SLAC 2.2 MW Water Dump, The Stanford Two-Mile Accelerator,
- R.B. Neal Ed, (1968).
- High Power Water Beam Dump for a LC, M. Schmitz,
- TESLA Collaboration Meeting, 16 Sept 2003.
- ILC Main Beam Dumps -- Concept of a Water Dump,
- D. Walz Snowmass, 18 Aug 2005.
- Dumps and Collimators, ILC Reference Design Report, 2007
- T. Davenne, O. Caretta, C. Densham and R. Appleby, Pressure Transients in the ILC Beam Dump, LC-ABD Collaboration meeting, Birmingham University, 17 April 2008

Introduction

The task force team studied the various aspects of the SLAC's 2.2MW water beam dump and used it as the starting basic reference design for an ILC Beam dump, since it has all features required of an ILC beam dump (but at a lower power level) but proven design. This includes the use of a vortex-like flow pattern to dissipate and remove the energy deposited by the beam, the beam dump entrance window and its special cooling method, a remote window exchange mechanism, a hydrogen re-combiner, handling of radioactive ^{7}Be, a tail catcher to attenuate the residual beam energy remaining after the vortex flow region, as well as related primary and secondary cooling loops.

Mechanical Design Concept

- The 18MW LC beam dump mechanical design is driven by parameters and constraints developed from FLUKA simulations, CFD thermal hydraulic simulations and analytic calculations.

- The existing 2.2MW SLAC beam dump provides a baseline mechanical design to consider features which might be incorporated into the 18MW beam dump mechanical design concept.

- The first step in creating a mechanical design concept for the beam dump is to establish the basic mechanical design parameters of the beam dump vessel and thin window.

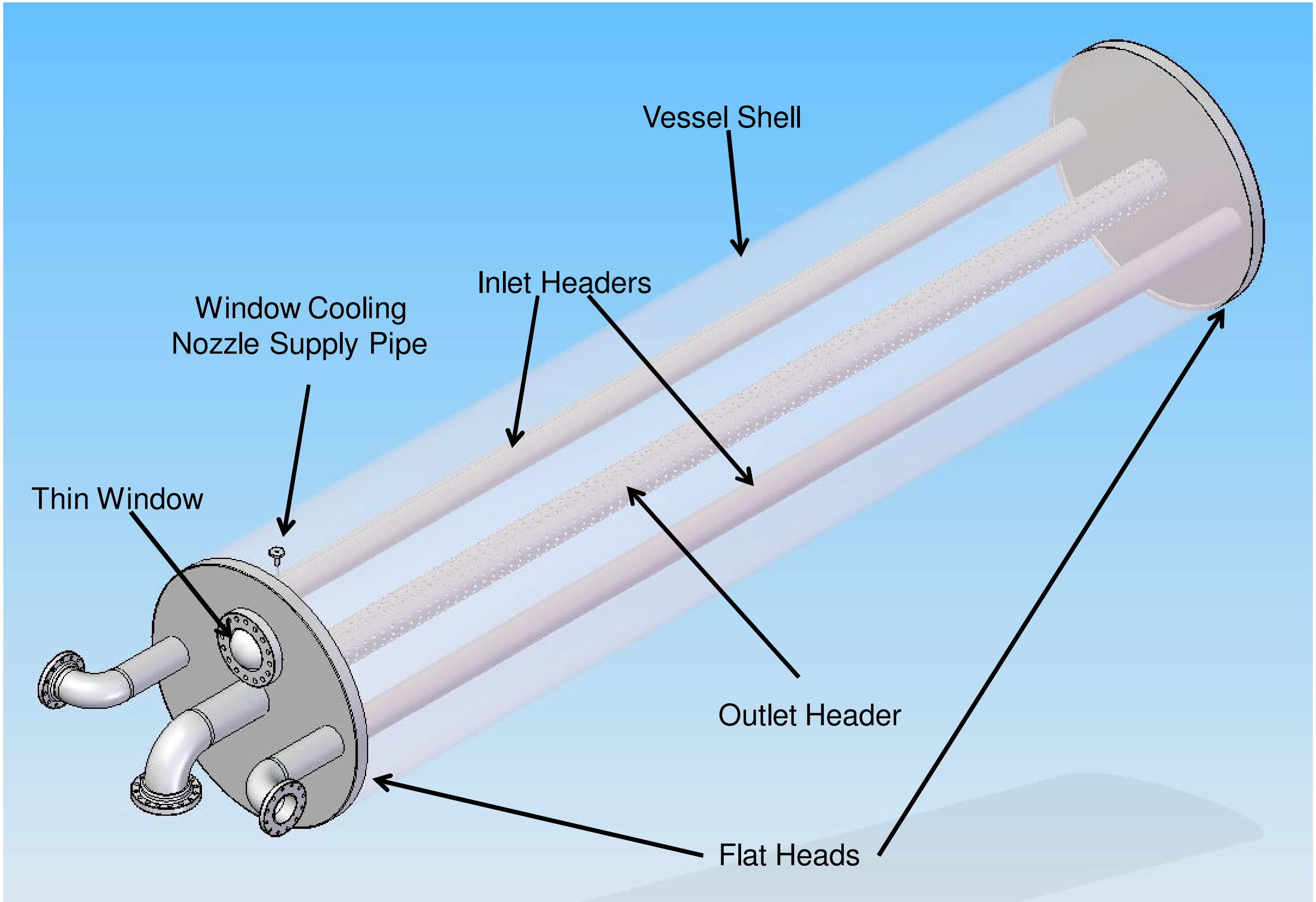
- The beam dump is a pressurized vessel containing heated and radioactive water and consequently for operation within the USA, must conform to the design and safety standards of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code.

Mechanical Design Concept

Table of Beam Dump Design Parameters and Constraints

Operating Parameters	
Maximum Operating Temperature	<180℃
Maximum Operating Pressure	20bar or 290psi
Minimum Operating Pressure	10bar or 145psi
Beam Dump Vessel	
Internal diameter	1.8m
Length	10m
Beam Dump Inlet Headers	
2 @ Up beam end of vessel	8" (203mm) ID with longitudinal slots
Inlet header location	0.7m from center on horizontal plane
Beam Dump Outlet Header	
1 @ Up beam end of vessel	10" (254mm) ID with perforations all around
Outlet header location	Center axis of vessel
Beam Dump Thin Window	
Hemispherical shape	Pressure on concave side
Internal diameter	300mm
Maximum thickness	1mm
Window location	0.35 - 0.45m from center of vessel vertical plane
Window cooling	Single water jet

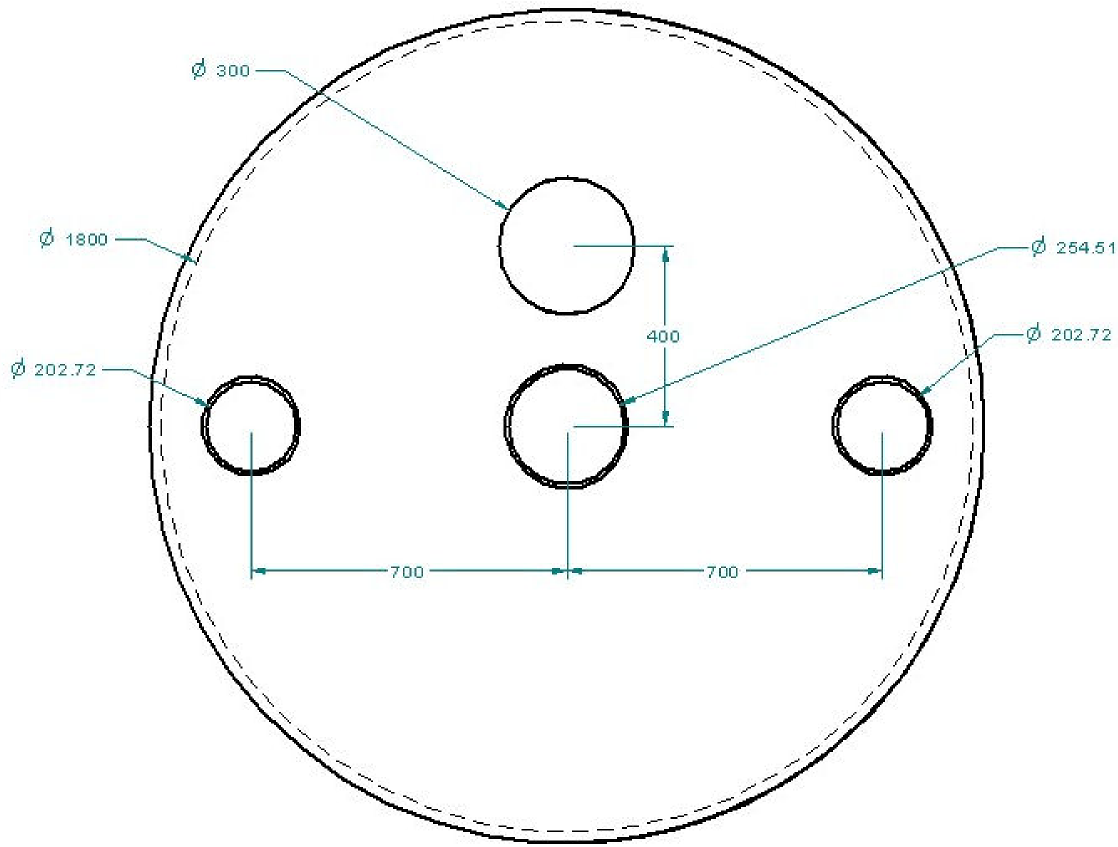
Mechanical Design Concept



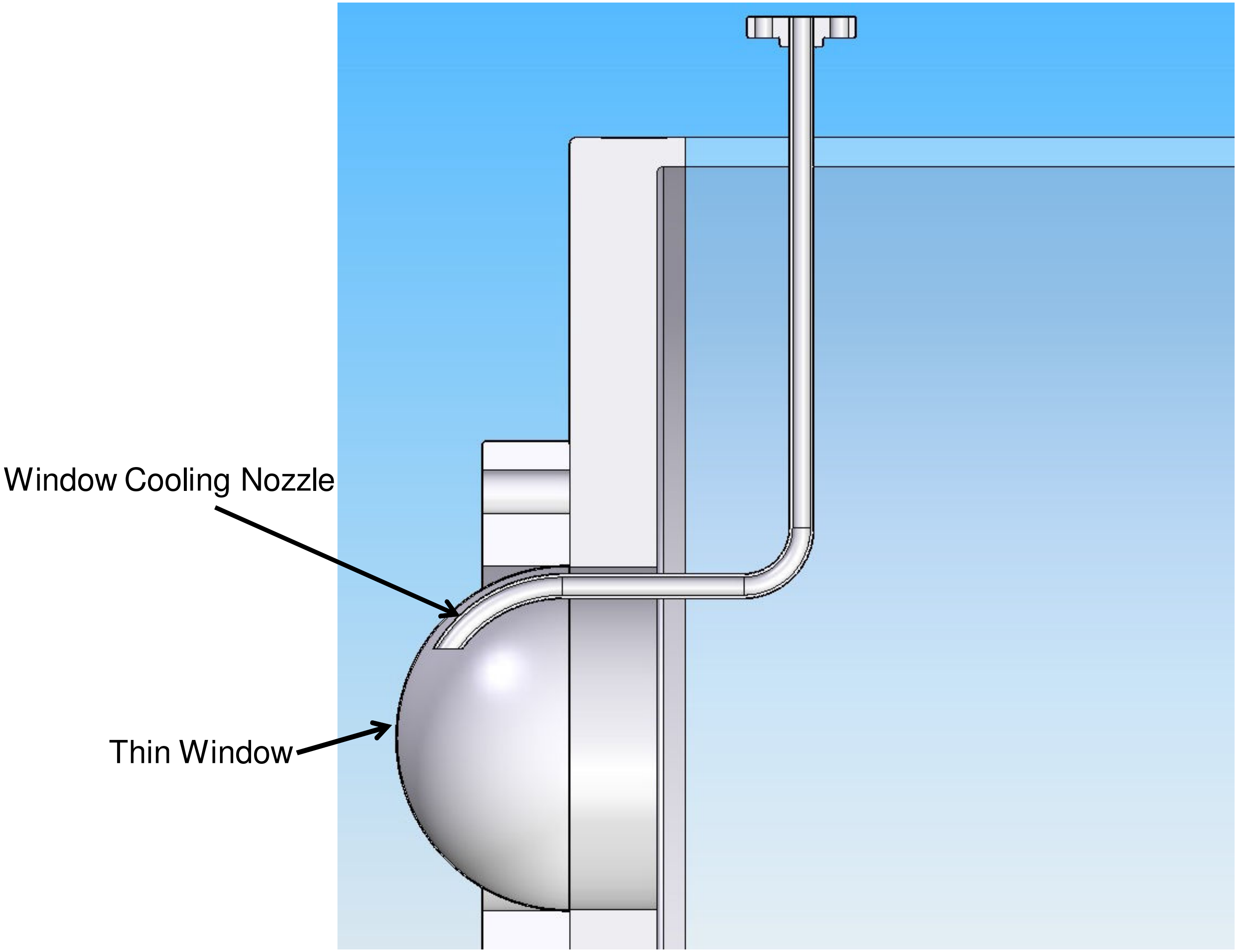
Mechanical Design Concept

Mechanical Design Parameters
(ASME BPVC Div. VIII)

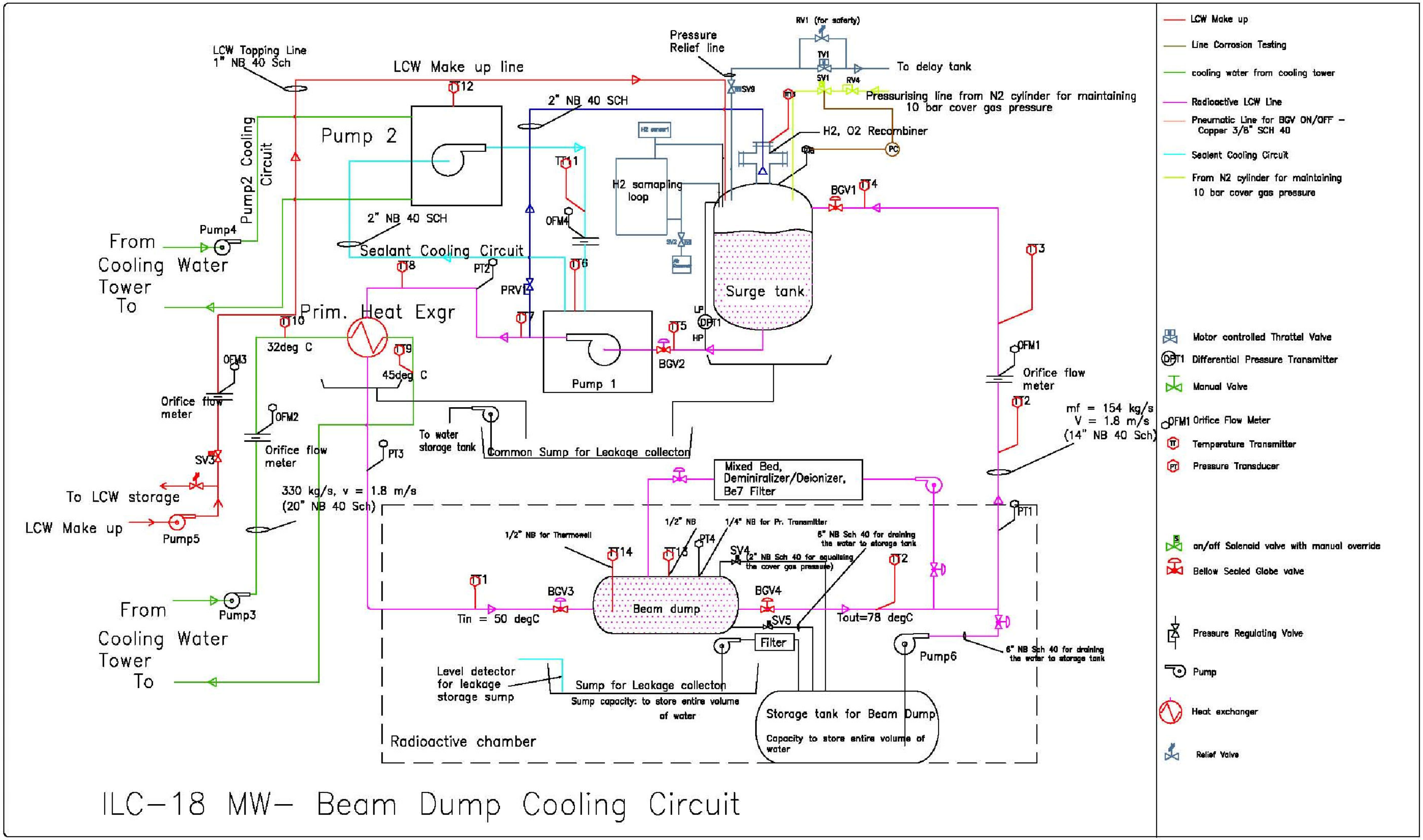
- Vessel Material – 316LN
- Minimum Shell Thickness – 21mm
- Minimum Flat Head Thickness – 70mm
- Window Material – Ti-6Al-4V
- Max. Design Pressure, 1mm Thick Hemispherical Window – 32bar or 464psi



Mechanical Design Concept



Coolant Loop

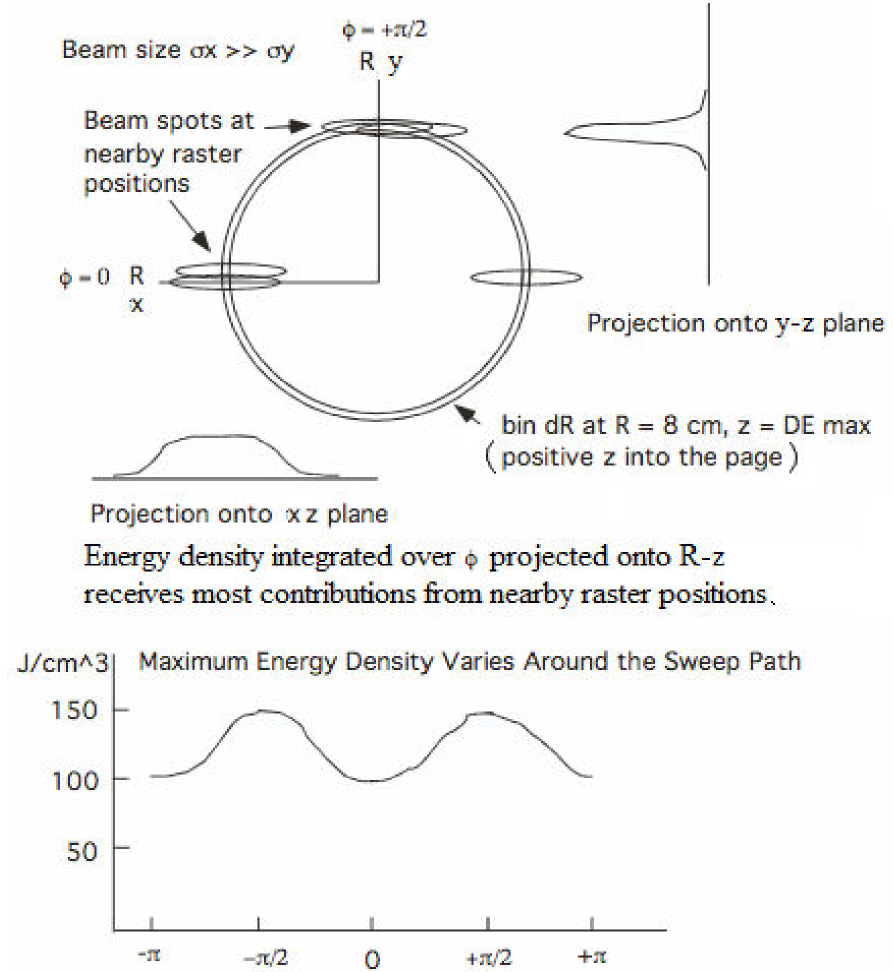


Beam Parameters

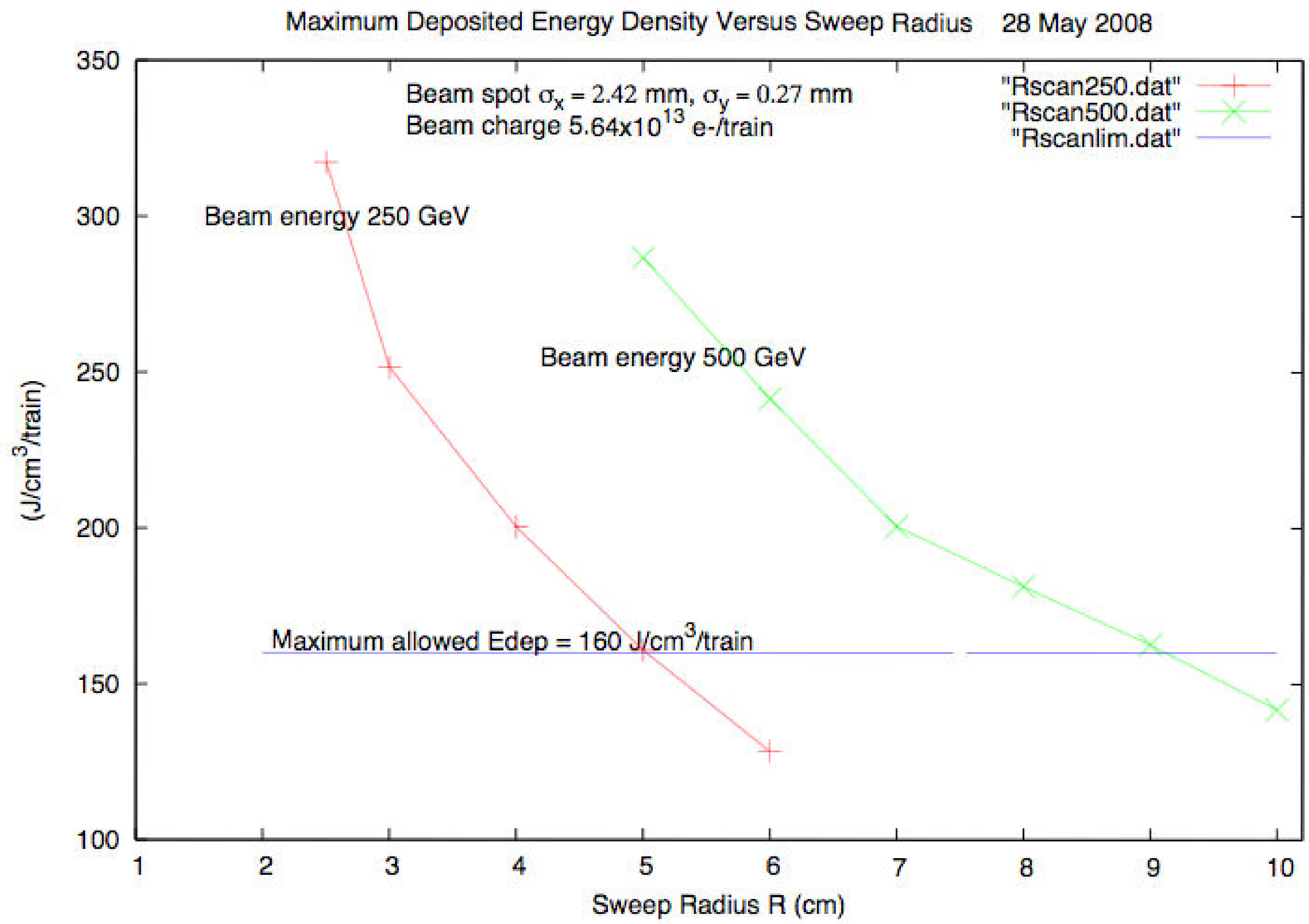
The following beam parameters have been taken as reference for designing the beam dump:

Electron/Positron energy:	500 GeV
Number of electrons/positrons per bunch:	2×10^{10}
Number of bunches per train:	2820
Duration of the bunch train:	0.95 ms
Beam size:	$\sigma_x = 2.42$mm
	$\sigma_y = 0.27$ mm
Energy in one bunch train:	4.5 MJ
Number of bunch trains per second:	4
Beam power:	18 MW
Beam sweep radius:	6 cm

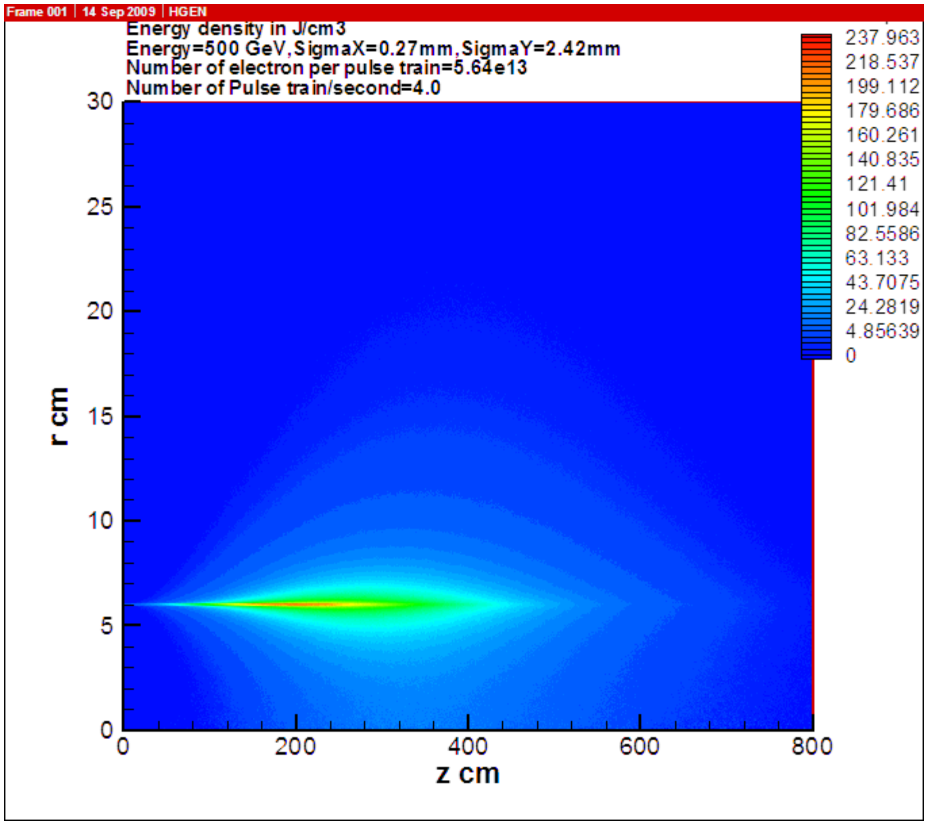
Energy Density Modulation Around Sweep Path



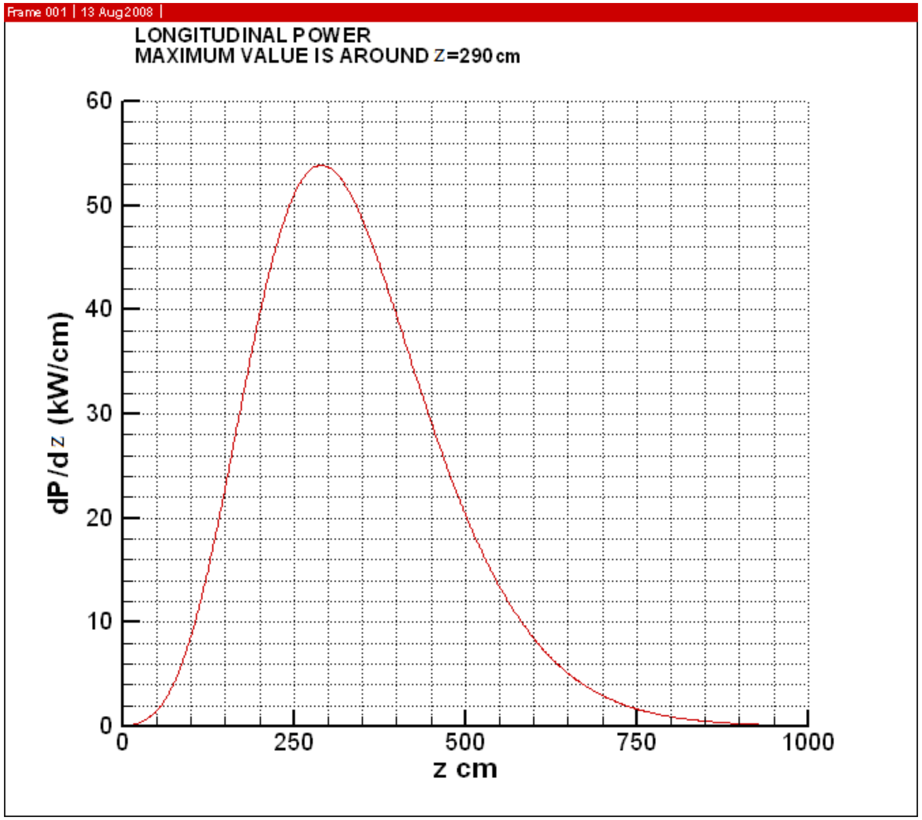
Interaction of electrons/positrons with Beam Dump



Interaction of electrons/positrons with Beam Dump

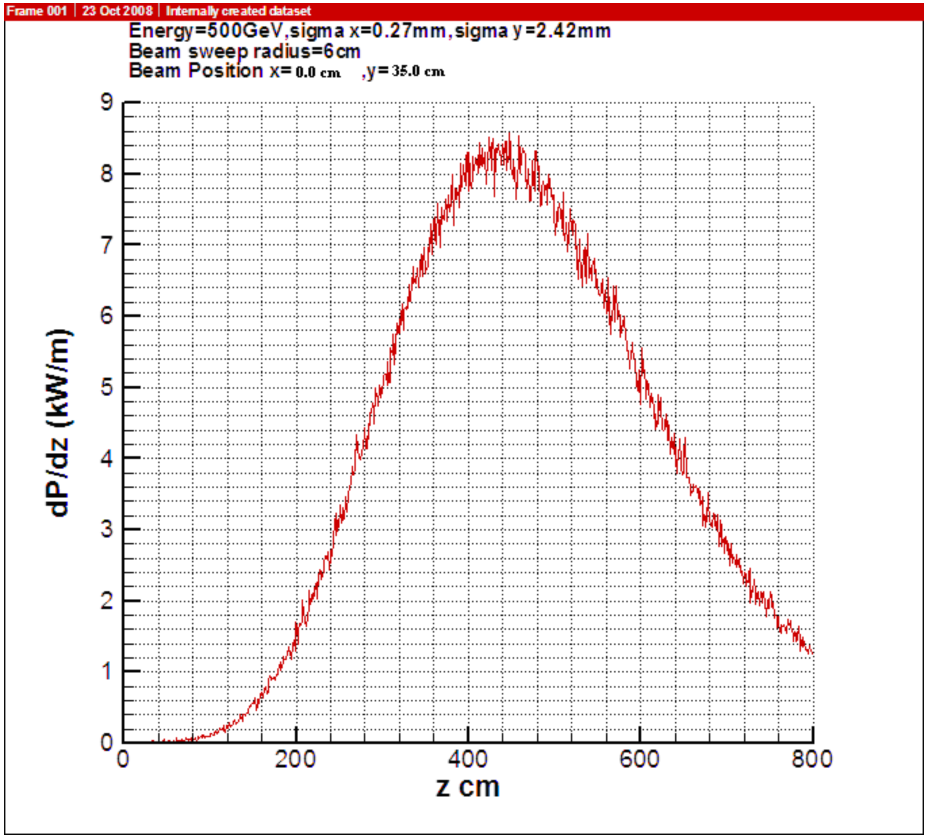


Energy deposited by one bunch train in the water (beam travelling along z-axis) max @ z=1.8m

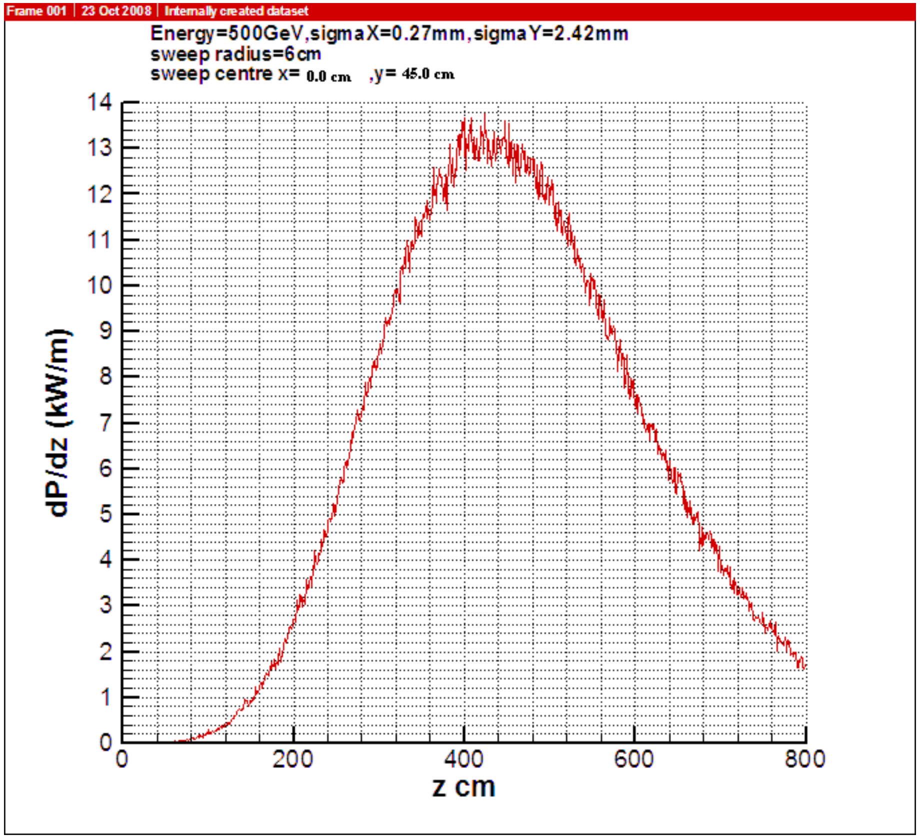


Radially integrated longitudinal linear power density max @ z=2.9m

Longitudinal Power Density in Vessel Wall (20mm thick 316L SS)

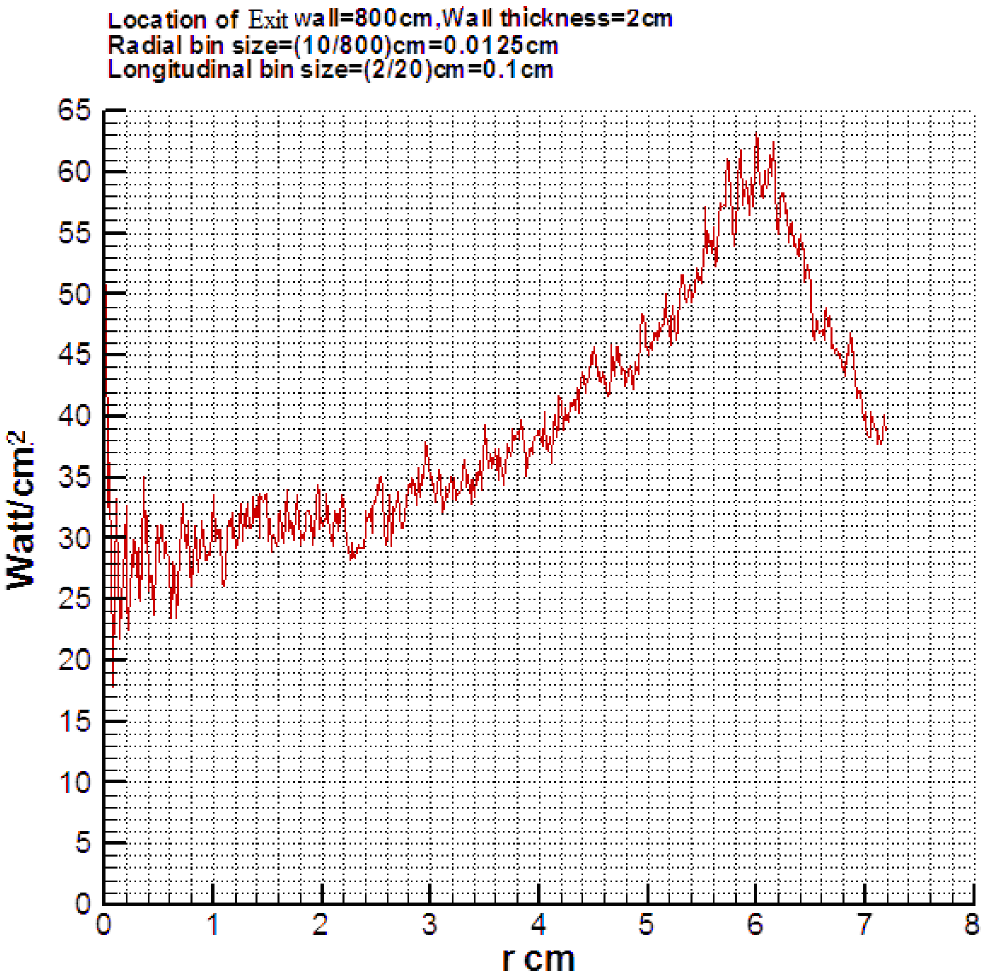


Beam @ r=45cm



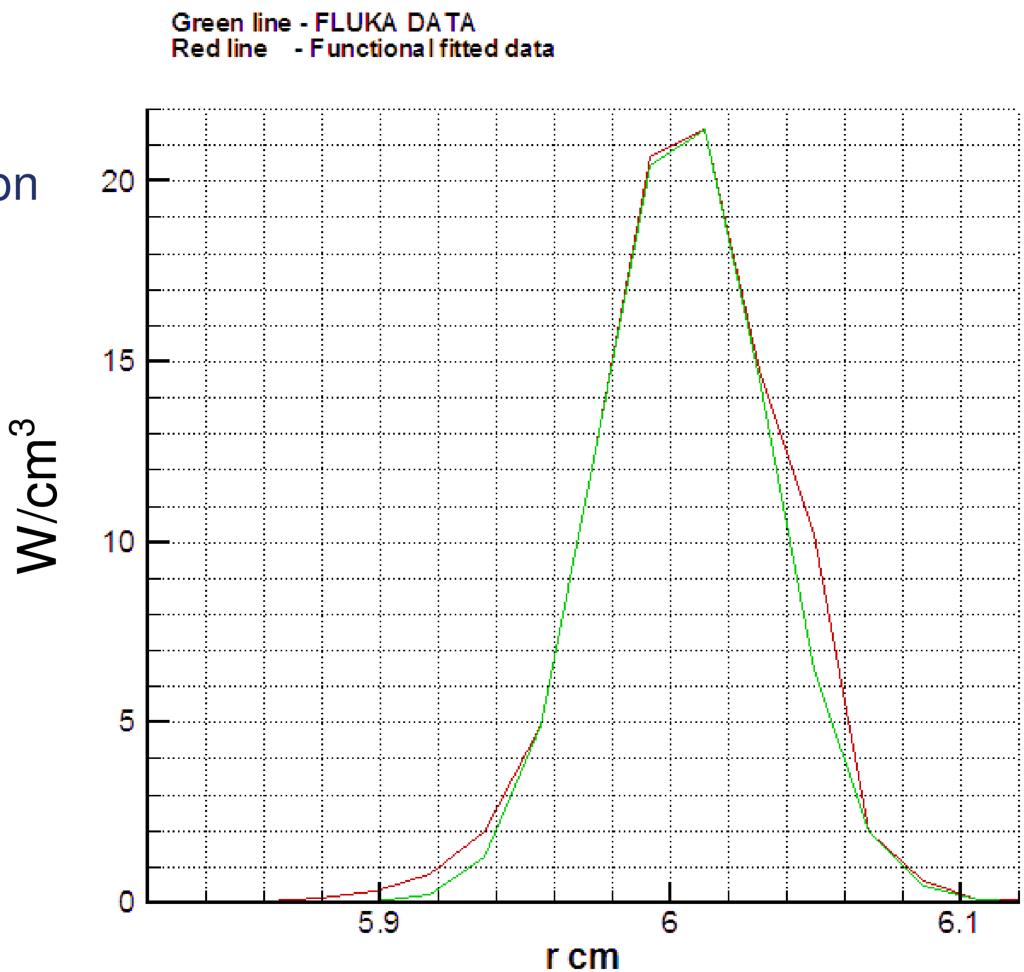
Beam @ r=35cm

Heat Flux – Down Beam Head



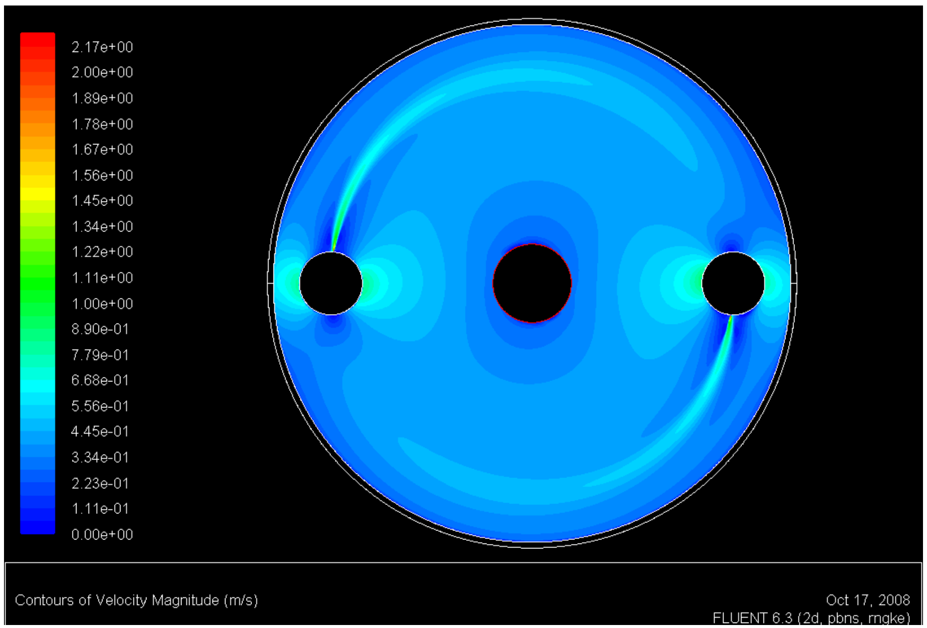
Interaction of electrons/positrons with Beam Dump

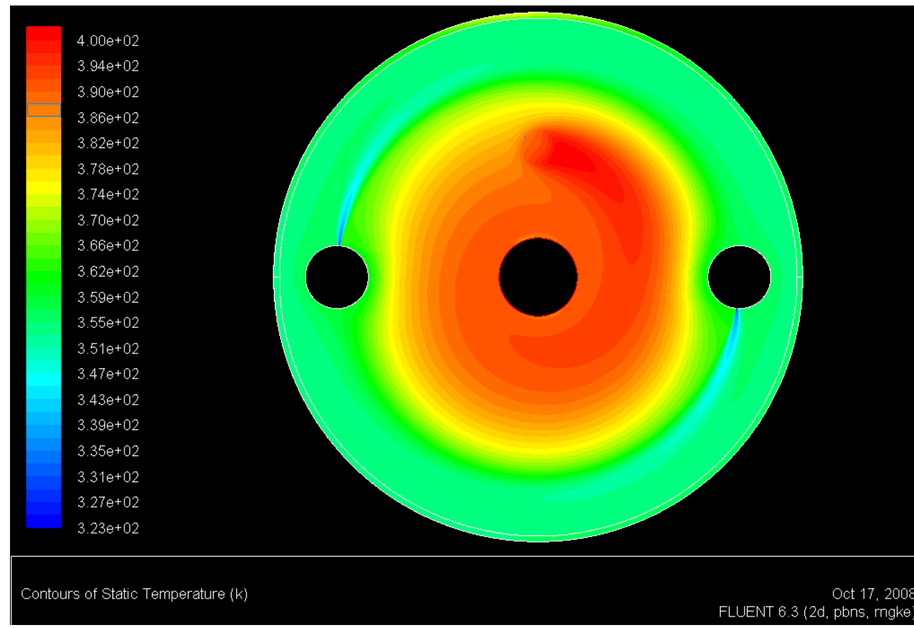
- A FLUKA analysis was carried out to determine the beam power distribution in the thin window.
- The total power deposited is ~25 W with a maximum power density of $21 W/cm^3$.
- Functional fitted data is the input for the CFD analysis.



Thermal hydraulic Studies(by FLUENT)

Total mass flow rate of water taken was 190kg/s. Water inlet was assumed to be at 50^{0}C as dictated by the primary coolant loop. The bulk outlet temperatures would be ~73^{0}C for 18 MW average beam power. The water inlet velocity at the slit exit is 2.17 m/s.



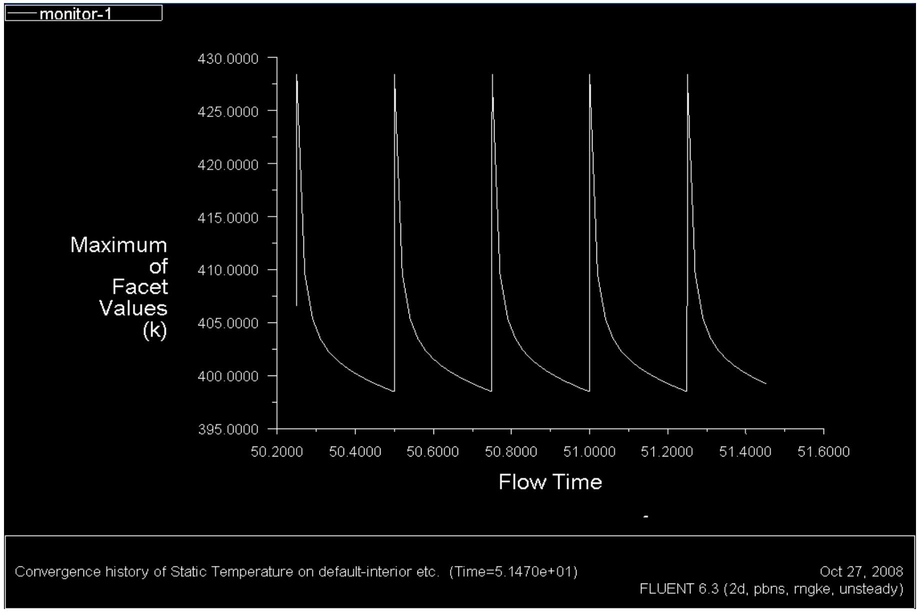


Velocity contours at z = 2.9m

Steady state temperature distribution at z = 2.9m (Max average temperature : 127^{0}C)

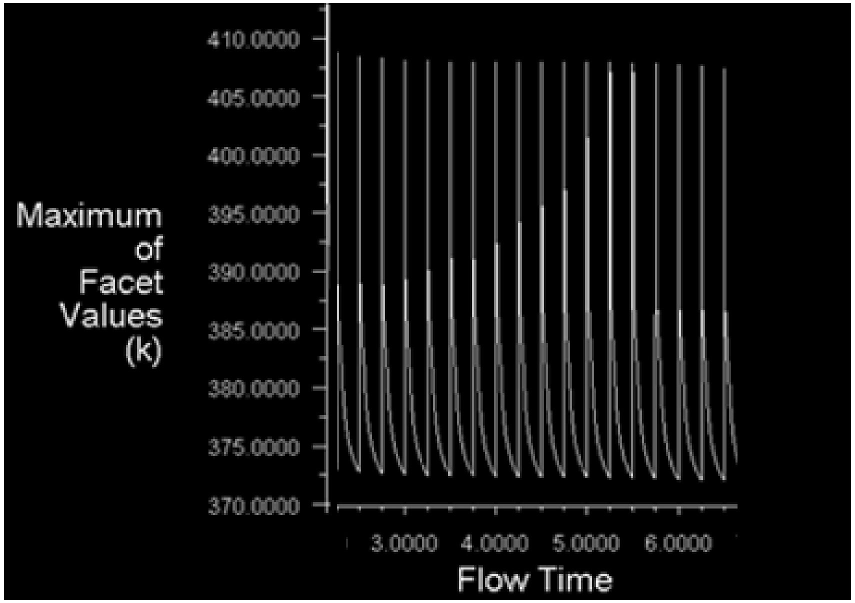
Thermal hydraulic Studies-cont.

Maximum temperature variation as a function of time at z = 2.9m



Maximum temperature ~155^{0}C and variation with time ~30^{0}C

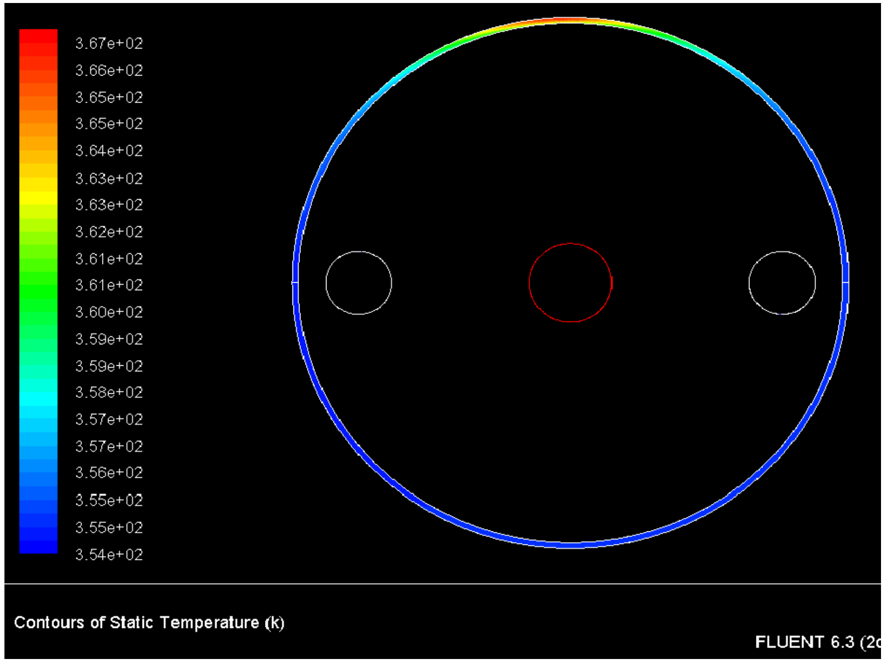
Maximum temperature variation as a function of time at z = 1.8 m



Maximum temperature ~135^{0}C and variation with time ~36^{0}C

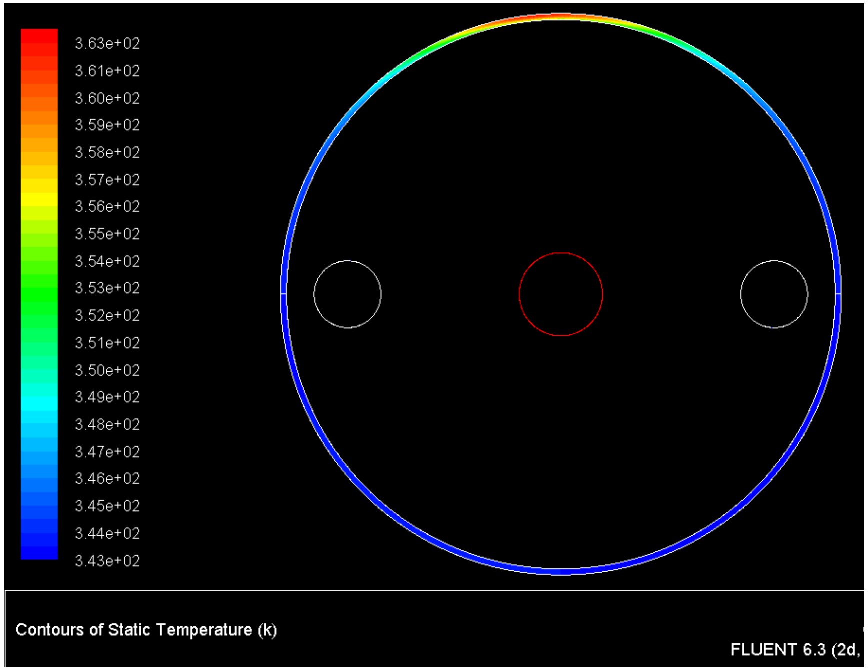
Thermal hydraulic Studies-cont.

Temperature distribution in the vessel at z = 2.9m for the 0.45m radial beam location



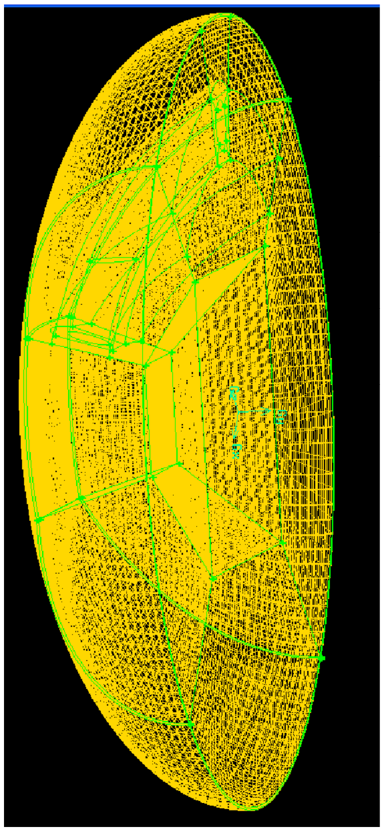
max vessel temperature - 94^0 C
min vessel temperature - 81^0C

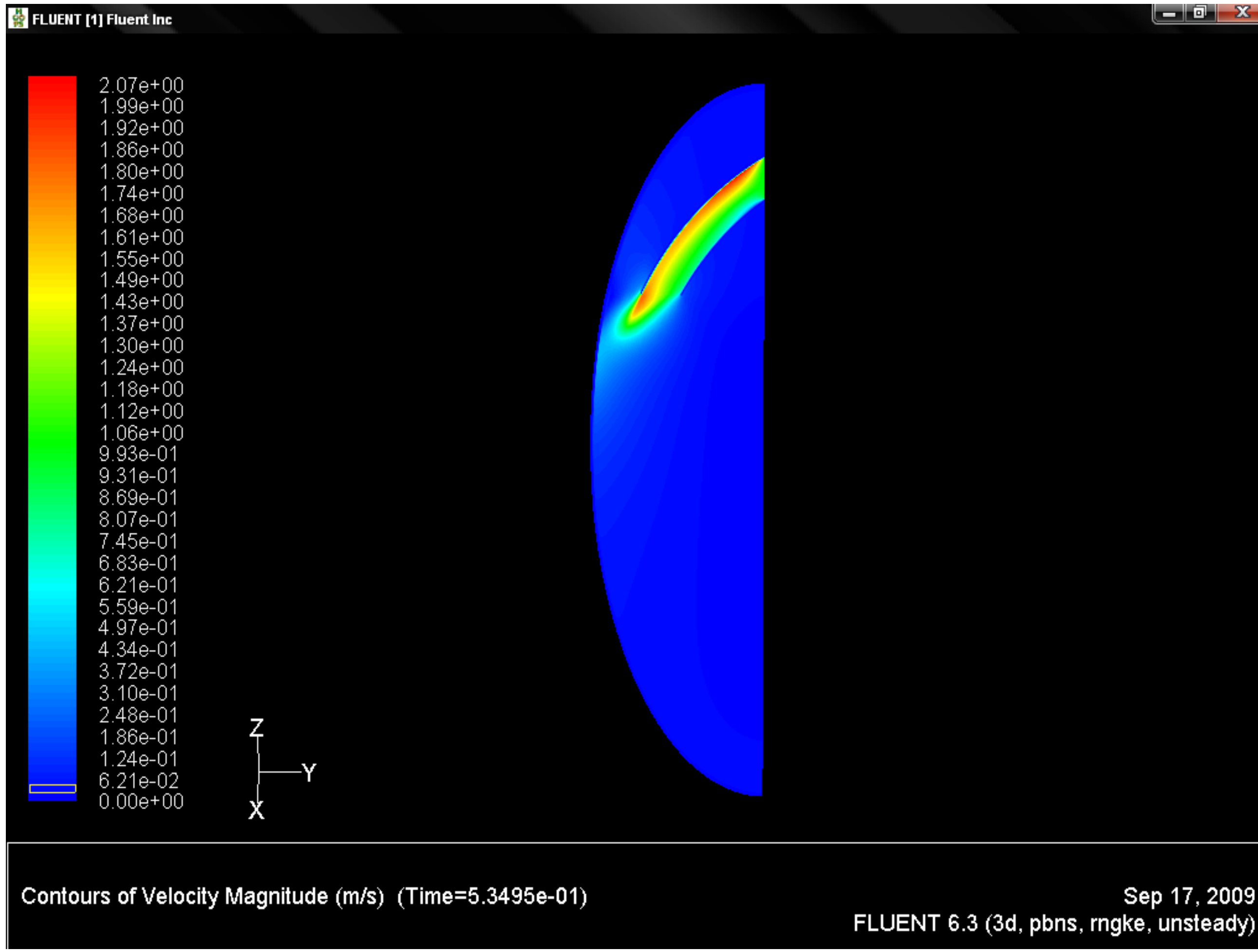
Temperature distribution in the vessel at z = 4.2m for the 0.45m radial beam location



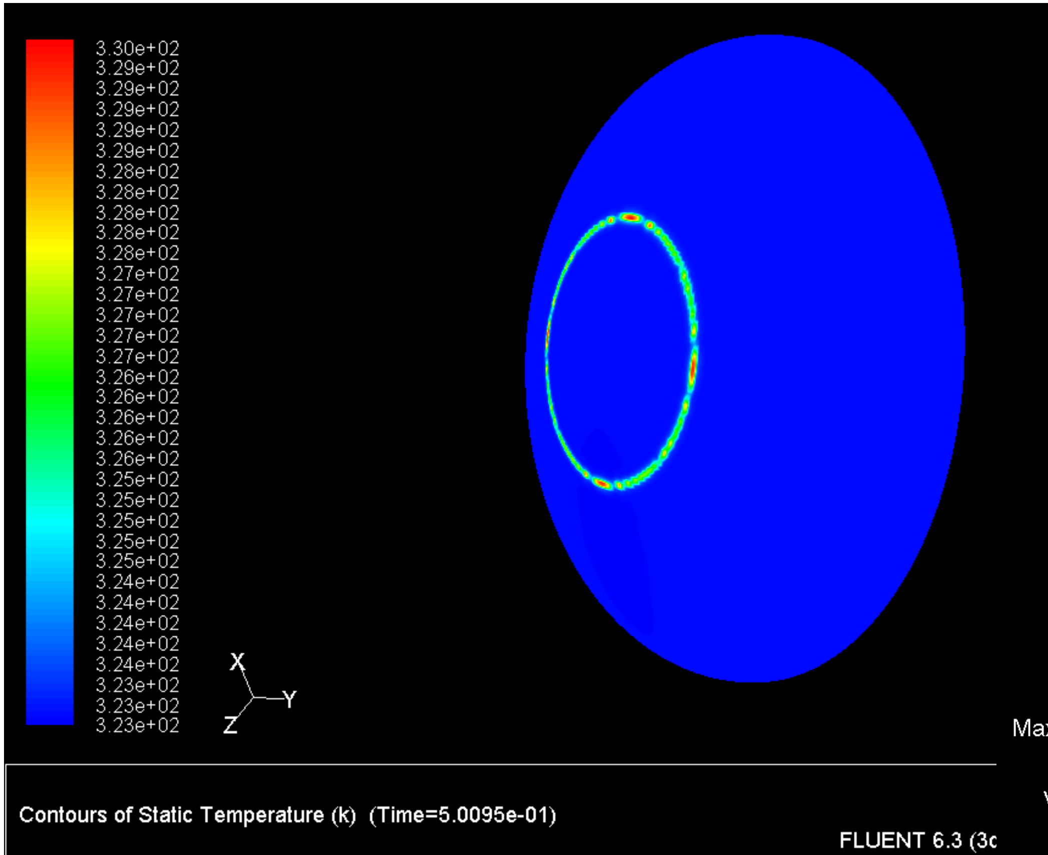
max vessel temperature - 90^0 C
min vessel temperature - 70^0C

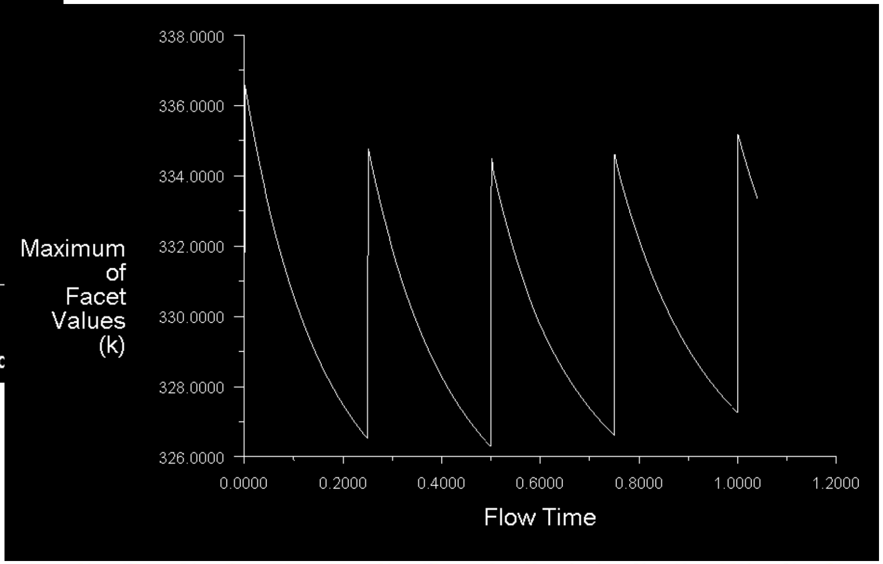
Window Cooling - Work In Progress

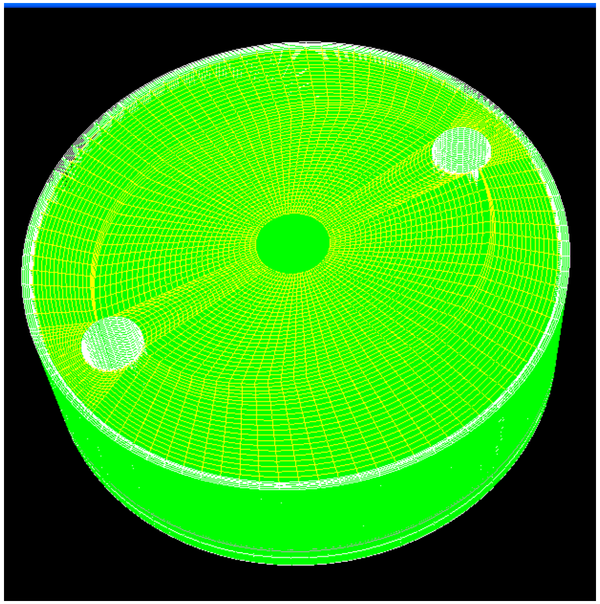




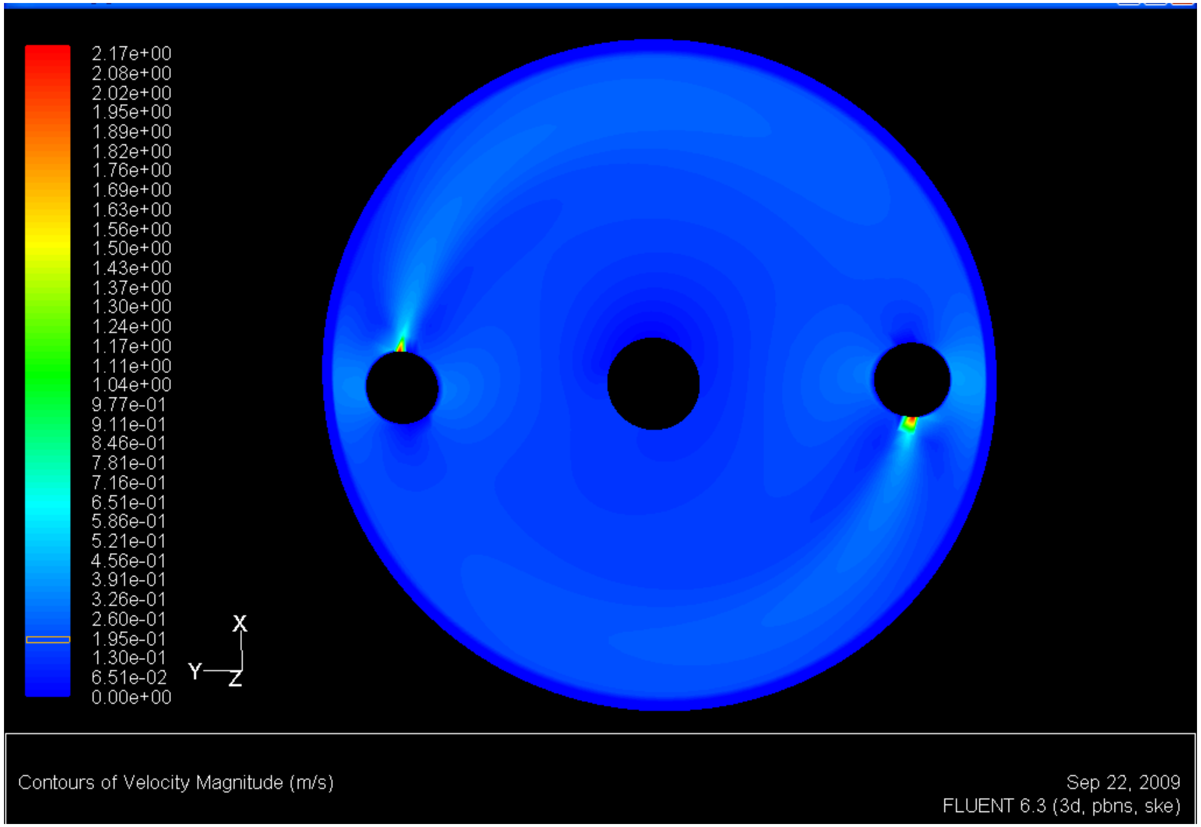
Window Cooling - Work In Progress





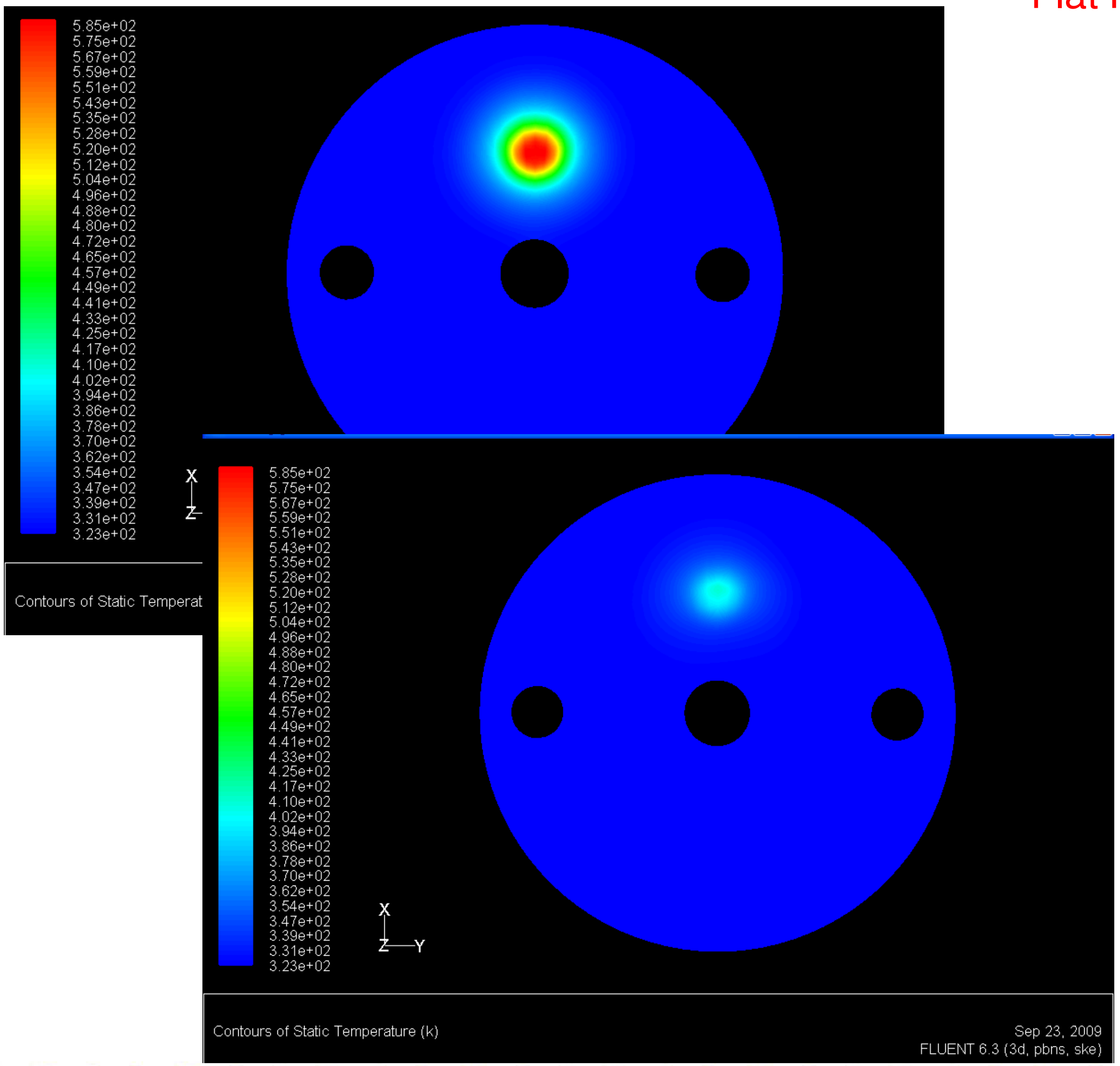


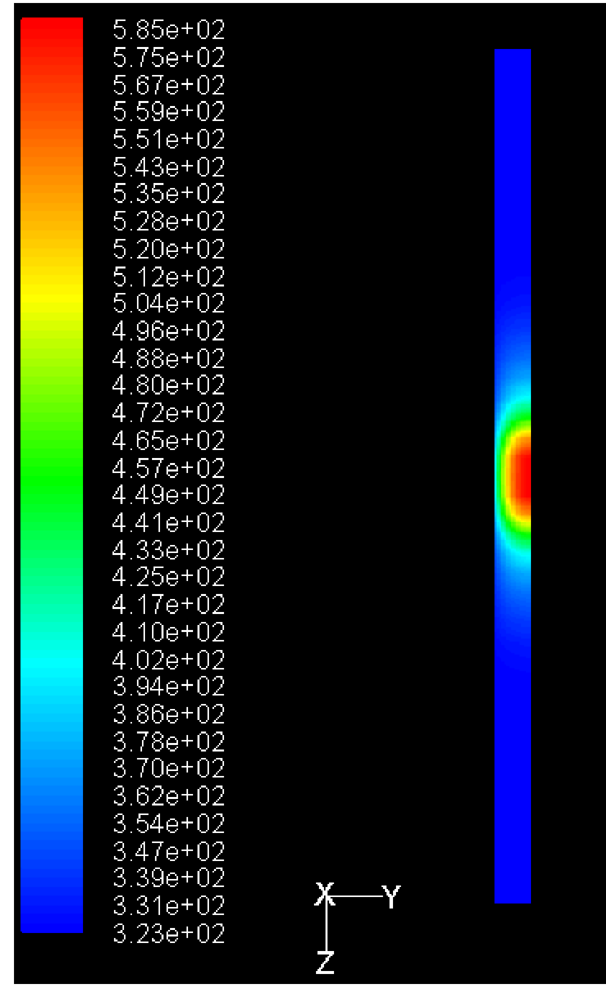
Flat Head Cooling - Work In Progress



Thermal hydraulic Studies-cont.

Flat Head Cooling - Work In Progress



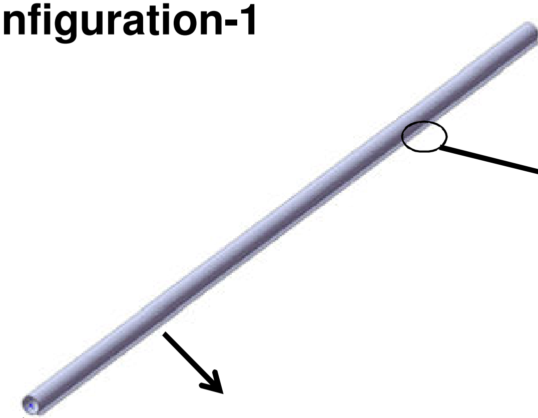


Design of Inlet Headers

Flow analysis in the Header indicated that there was significant velocity component along z- direction (v_z) in the initial exit region of the Header, reducing the required outlet v_Φ (Φ component of the velocity). In order to enhance (v_Φ) and reduce the v_z , two alternative approaches are currently being considered; i) providing flow blocks at various locations in the exit slit of the Header, ii) providing water to the Header by multiple pipes along the z. The final configuration will be based on the outcome of this analysis.

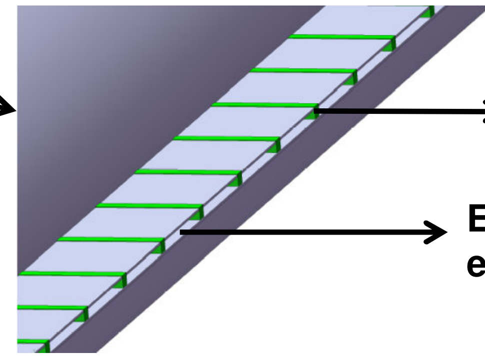
Inlet header studies-(In progress)

Configuration-1



Water outlet

Water inlet

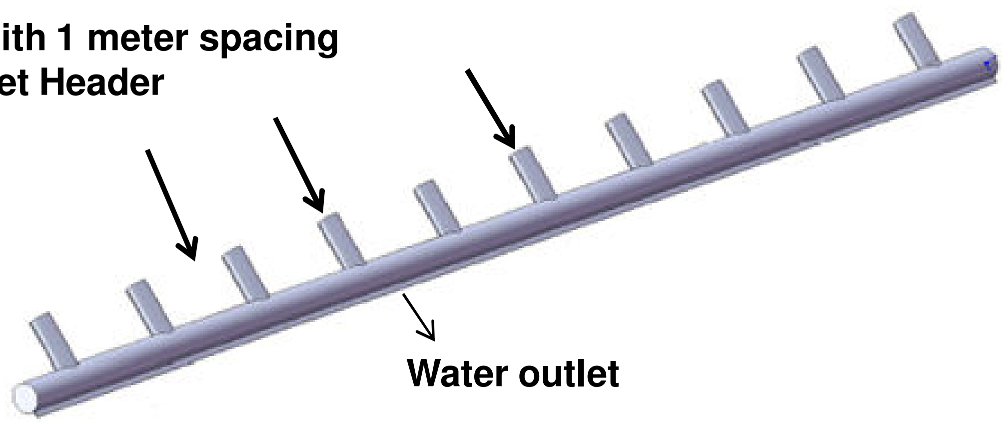


Flow blocks each of width of 5mm

Exit nozzle of inlet header each of length 95mm

Configuration-2

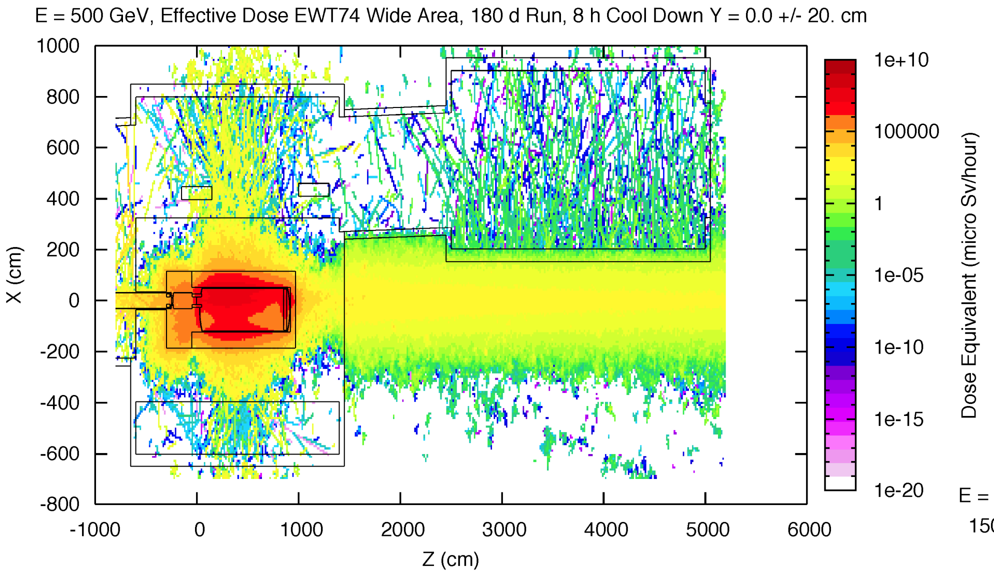
water inlet pipes with 1 meter spacing along the water inlet Header

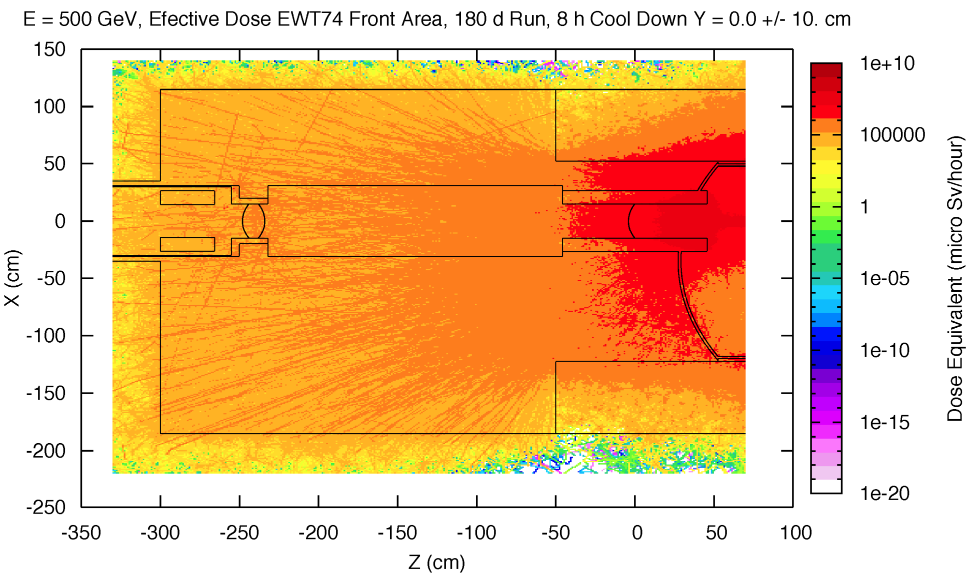


Water outlet

FLUKA Studies

Preliminary Activation Studies – First Design Concept





Summary

- Mechanical design concept under development.
  - Basic mechanical parameters established. More detailed analysis of inlet header in progress
  - Window sealing design and remote exchange system still needs work.
  - Preliminary process design complete.
- Thermal-hydraulic studies nearly complete.
  - Beam dump parameters determined by physics.
  - Inlet headers, outlet header, and window locations optimized.
  - Working to finalize window cooling and down beam head cooling.
- Shielding design and overall system integration still needs work.
- Future work we feel is critical.
  - Build a scaled down version of beam dump to verify FLUENT studies.
  - Beam damage testing of thin window materials.