

Status Update

18MW ILC Beam Dump Design

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

ILC Beam Dump Design Team

- **SLAC National Accelerator Laboratory:**
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- **Bhabha Atomic Research Centre:** P. Satyamurthy, P. Rai, V. Tiwari, K. Kulkarni

Starting Point for Work

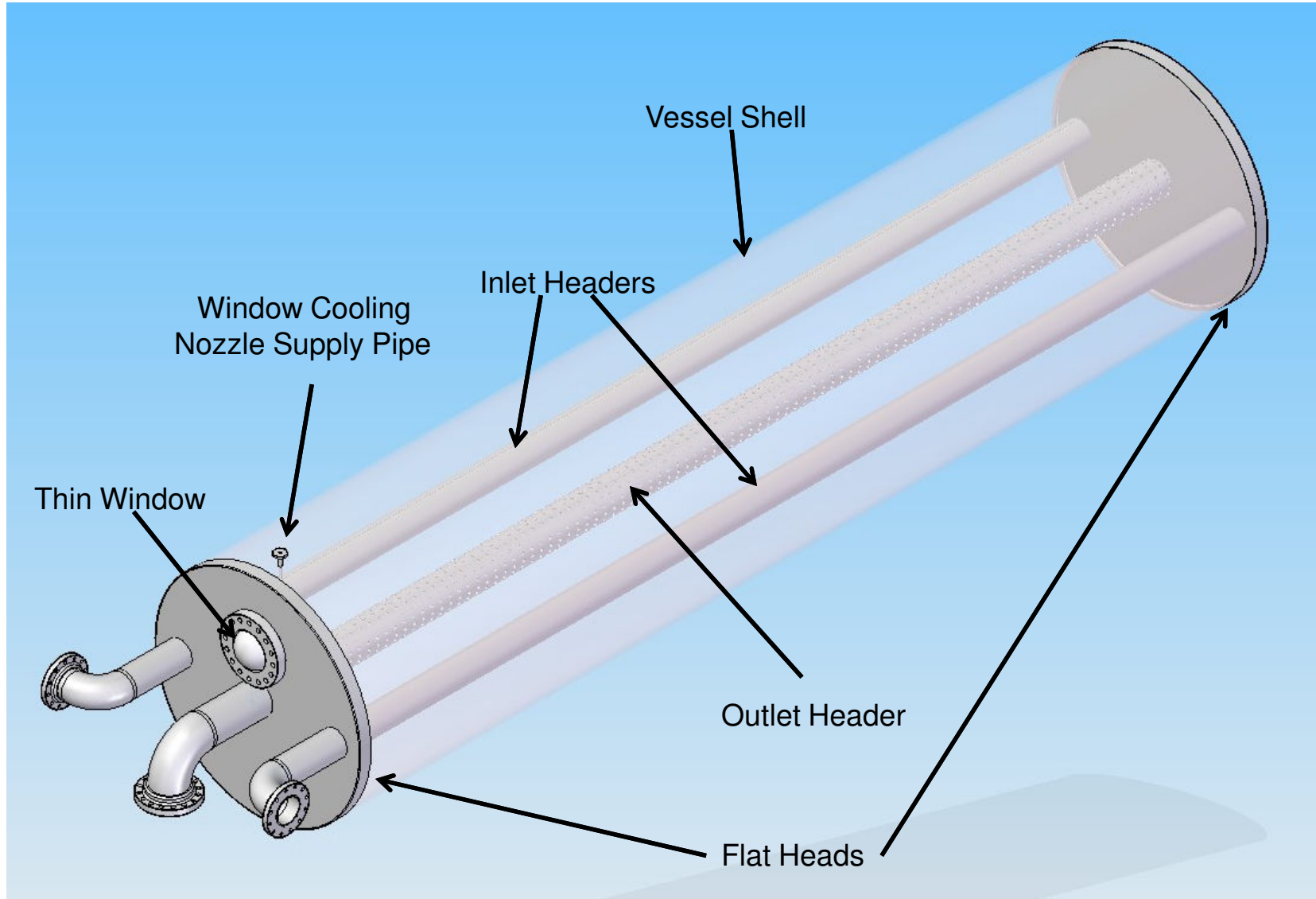
- SLAC 2.2 MW Water Dump, The Stanford Two-Mile Accelerator,
R.B. Neal Ed, (1968).
- High Power Water Beam Dump for a LC, M. Schmitz,
TESLA Collaboration Meeting, 16 Sept 2003.
- ILC Main Beam Dumps -- Concept of a Water Dump,
D. Walz Snowmass, 18 Aug 2005.
- Dumps and Collimators, ILC Reference Design 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

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 ^7Be , a tail catcher to attenuate the residual beam energy remaining after the vortex flow region, as well as related primary and secondary cooling loops.

- 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.

Table of Beam Dump Design Parameters and Constraints

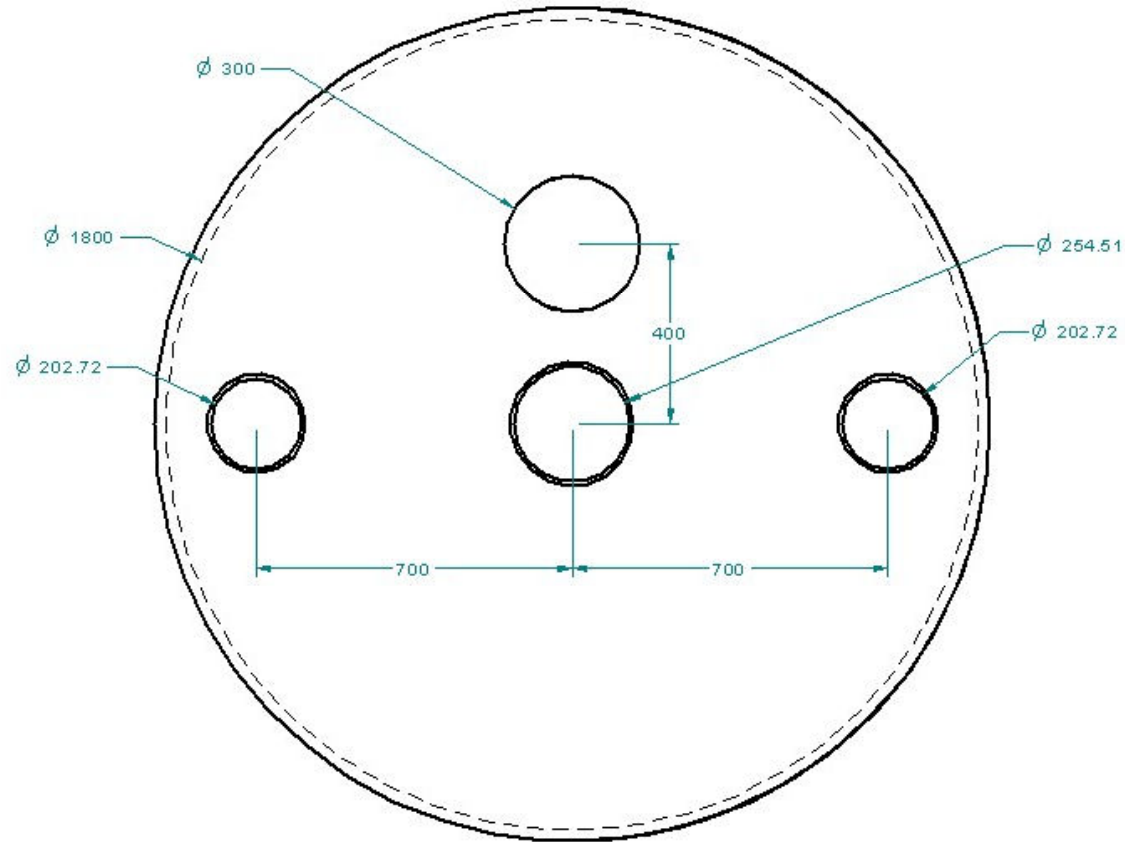
| | |
|--------------------------------|---------------------------------------------------|
| Operating Parameters | |
| Maximum Operating Temperature | 200 °C |
| Maximum Operating Pressure | 20bar or 290psi |
| Minimum Operating Pressure | 10bar or 145psi |
| Beam Dump Vessel | |
| Internal diameter | 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 Parameters

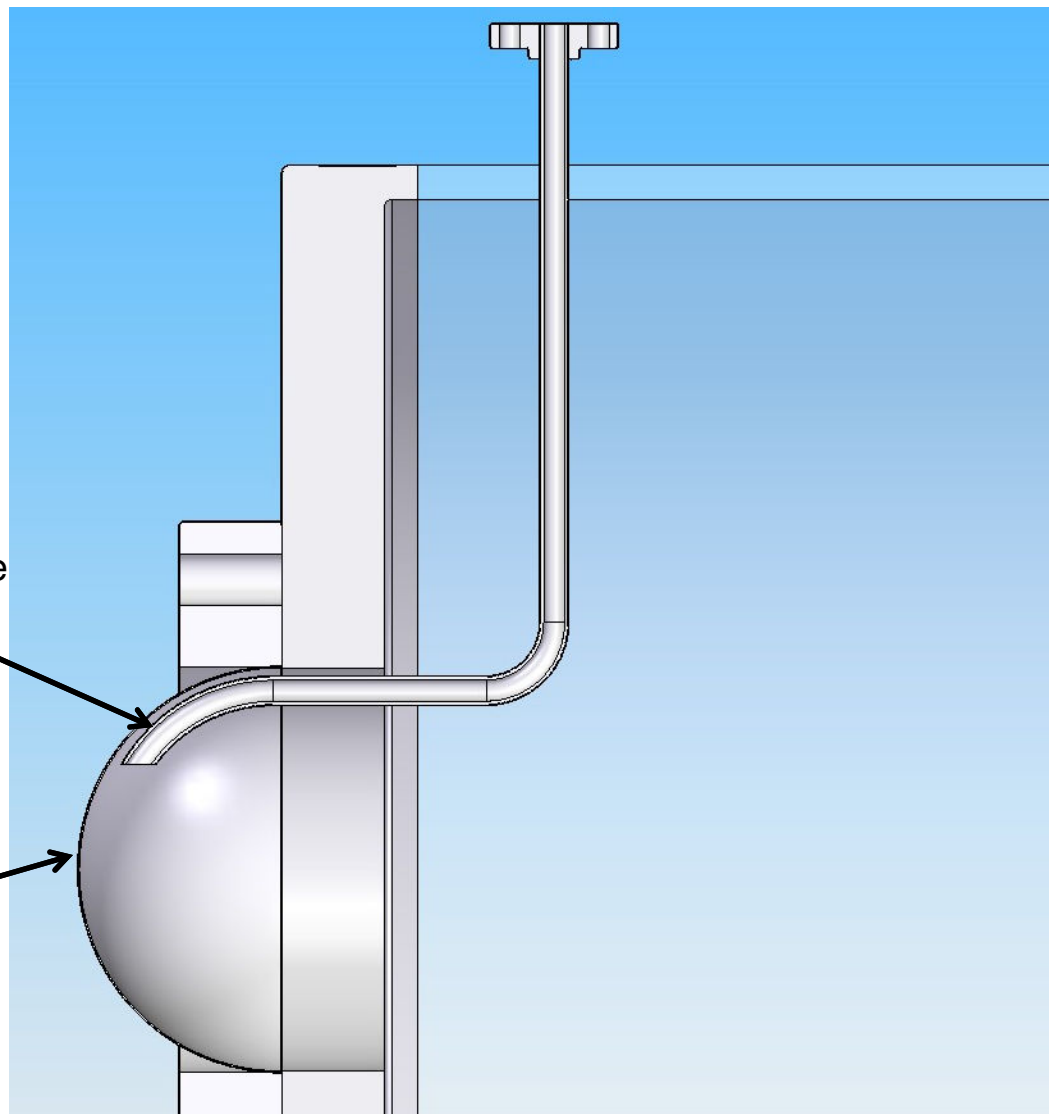
(ASME BPVC Div. VIII)

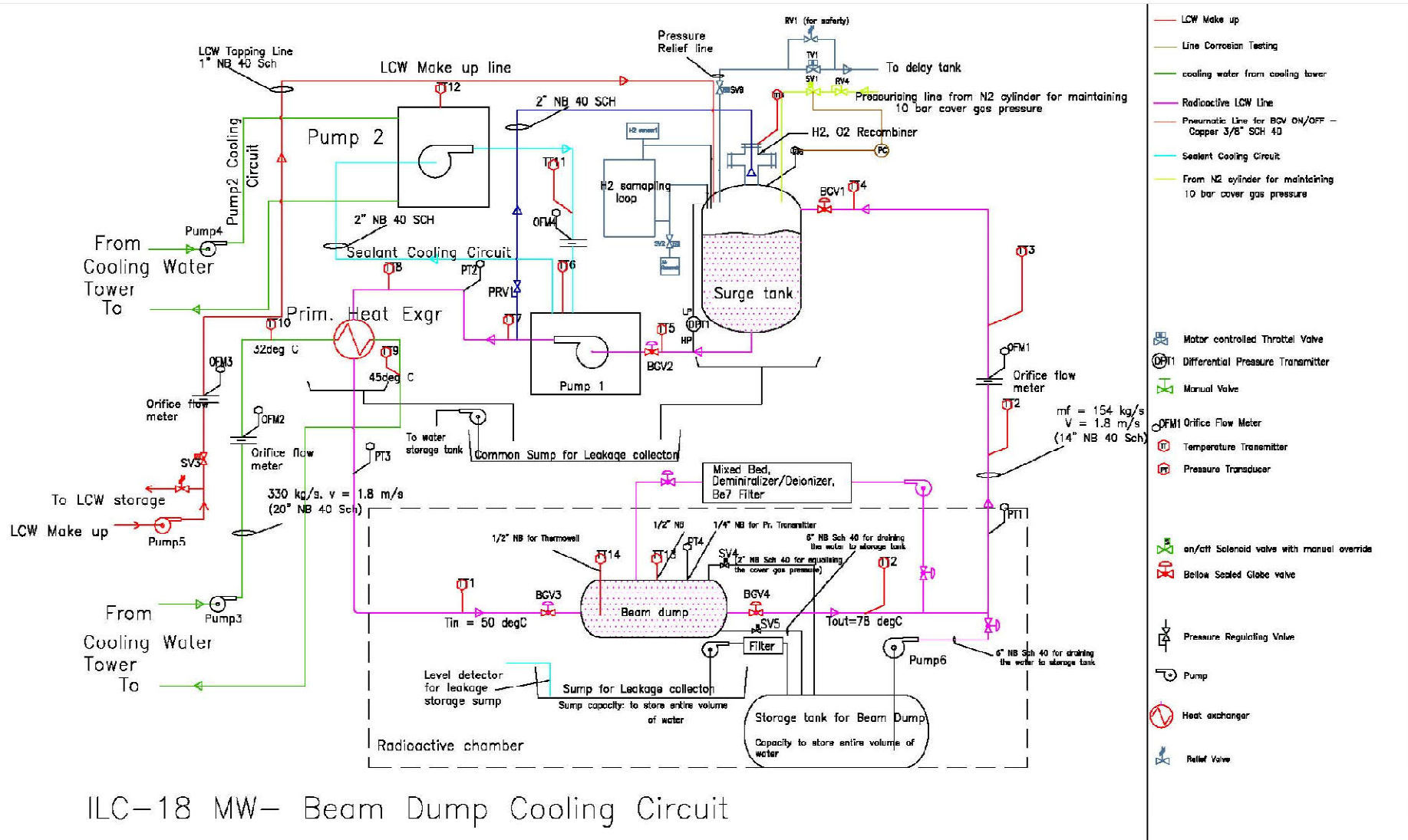
- Vessel Material – 316LN
- Minimum Shell Thickness – 21mm
- Minimum Flat Head Thickness – 70mm
- Window Material – Ti-6Al-4V
- Max. Design Pressure, 1mm Thick Hemispherical Window – 32bar or 464psi



Window Cooling Nozzle

Thin Window



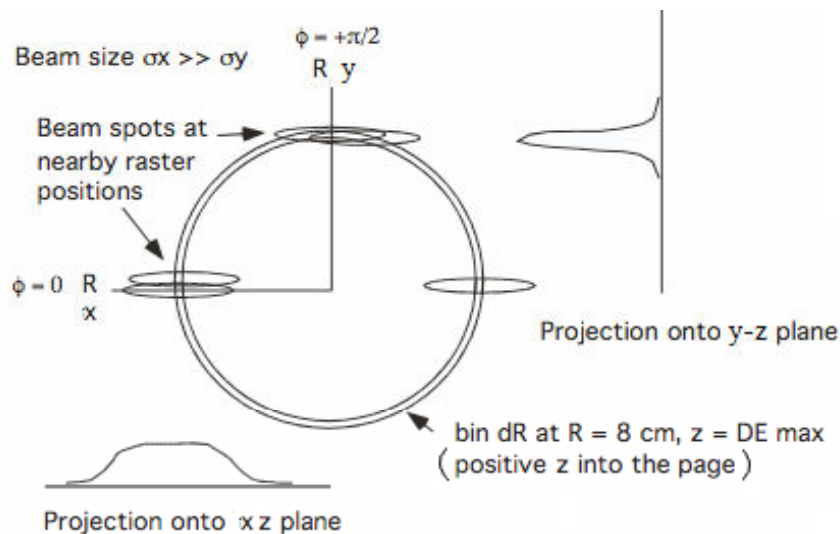


ILC-18 MW- Beam Dump Cooling Circuit

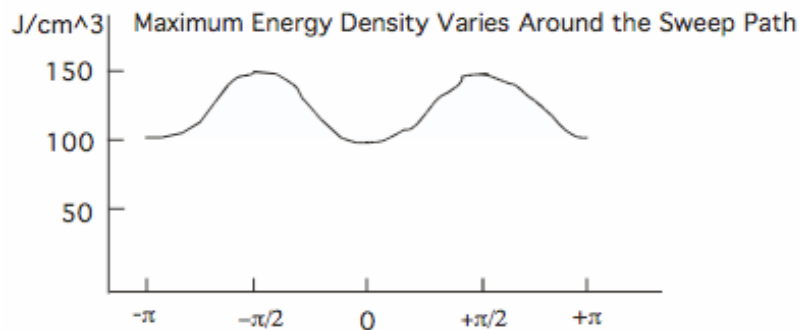
The following beam parameters have been taken as reference for designing the beam dump:

| | |
|------------------------------------------|--------------------------------------------------------------|
| 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: | $\sigma_x = 2.42 \text{ mm}$ $\sigma_y = 0.27 \text{ mm}$ |
| Energy in one bunch train: | 4.5 MJ |
| Number of bunch trains per second: | 4 |
| Beam power: | 18 MW |
| Beam sweep radius: | 6 cm |

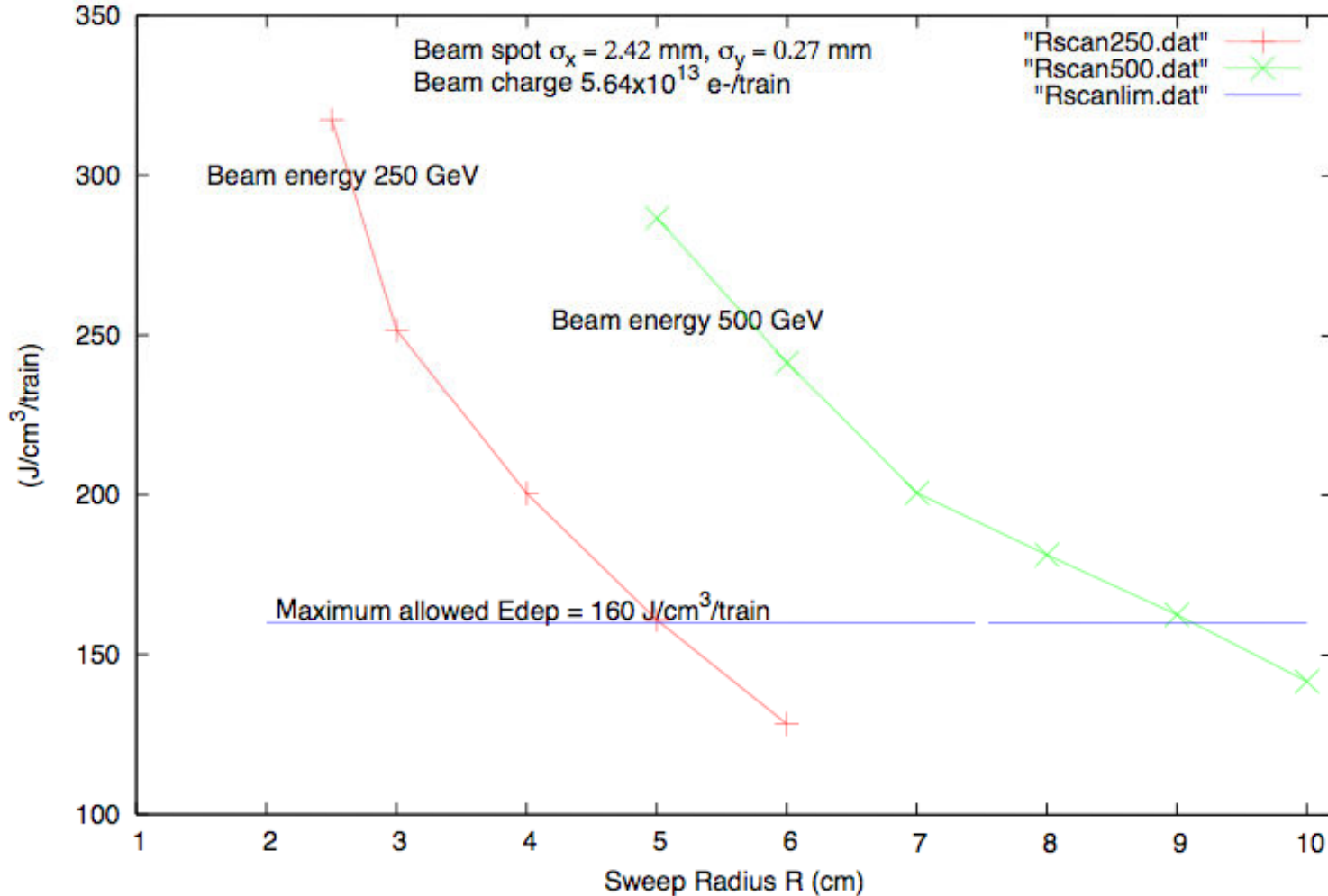
Energy Density Modulation Around Sweep Path

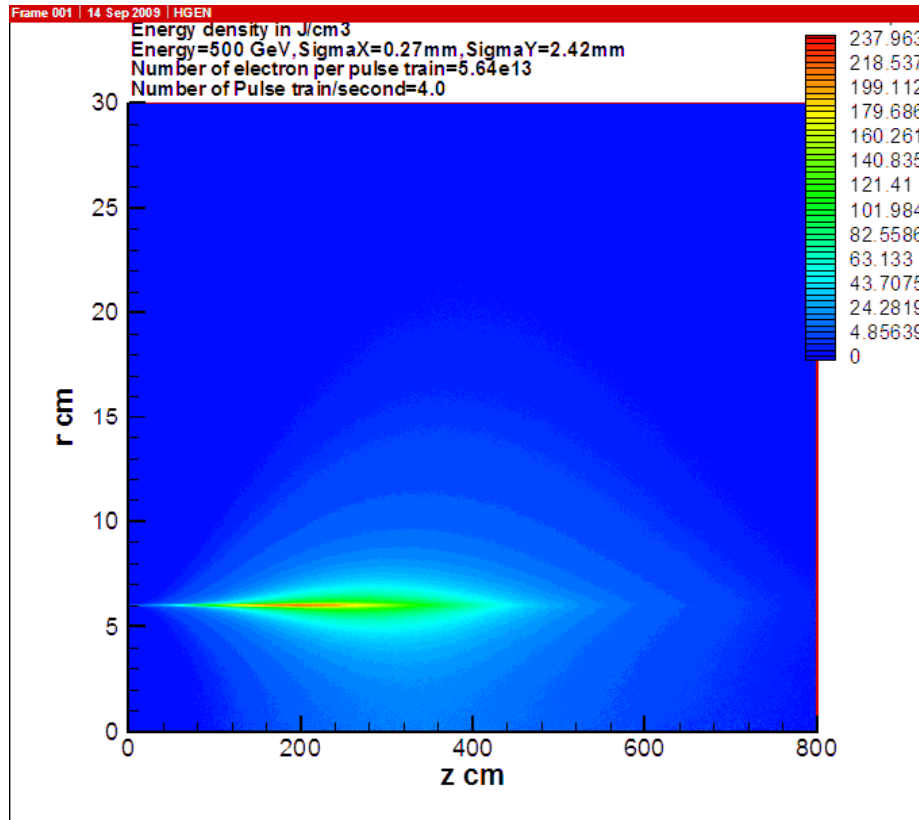


Energy density integrated over ϕ projected onto R - z receives most contributions from nearby raster positions.

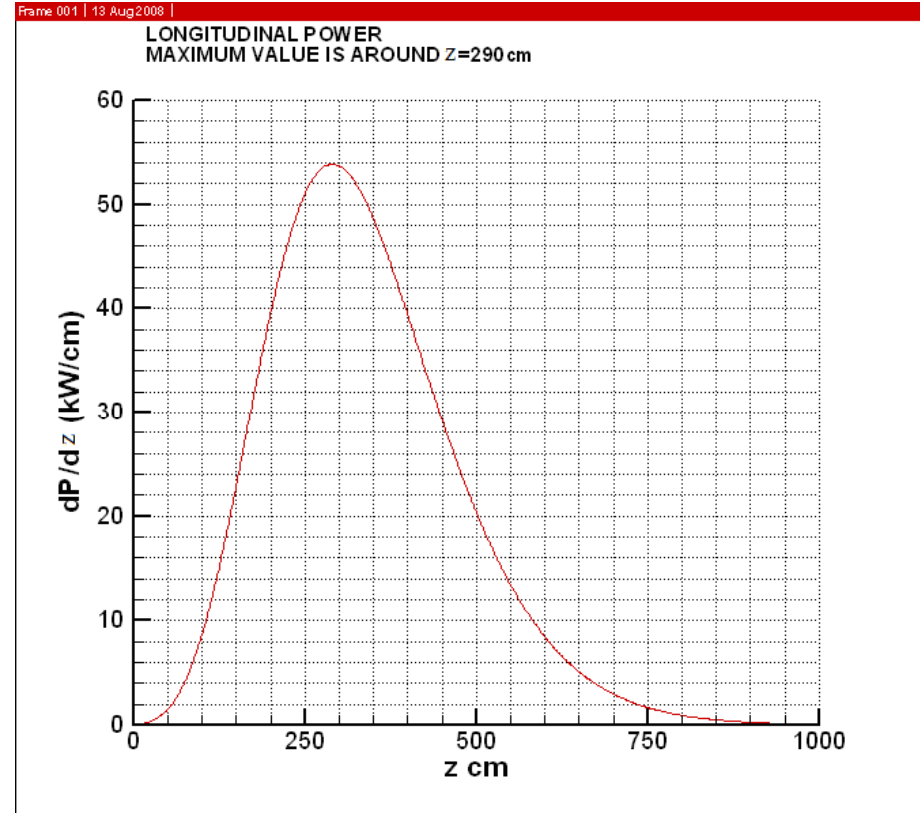


Maximum Deposited Energy Density Versus Sweep Radius 28 May 2008



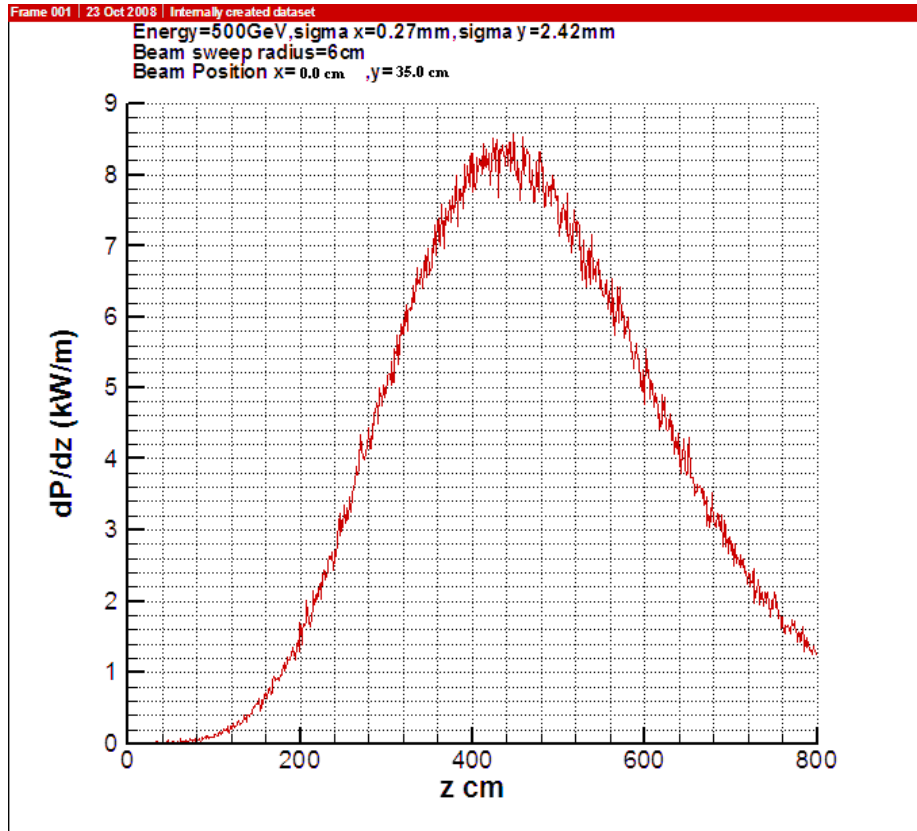


Energy deposited by one bunch train in the water
 (beam travelling along z-axis) max @ z=1.8m

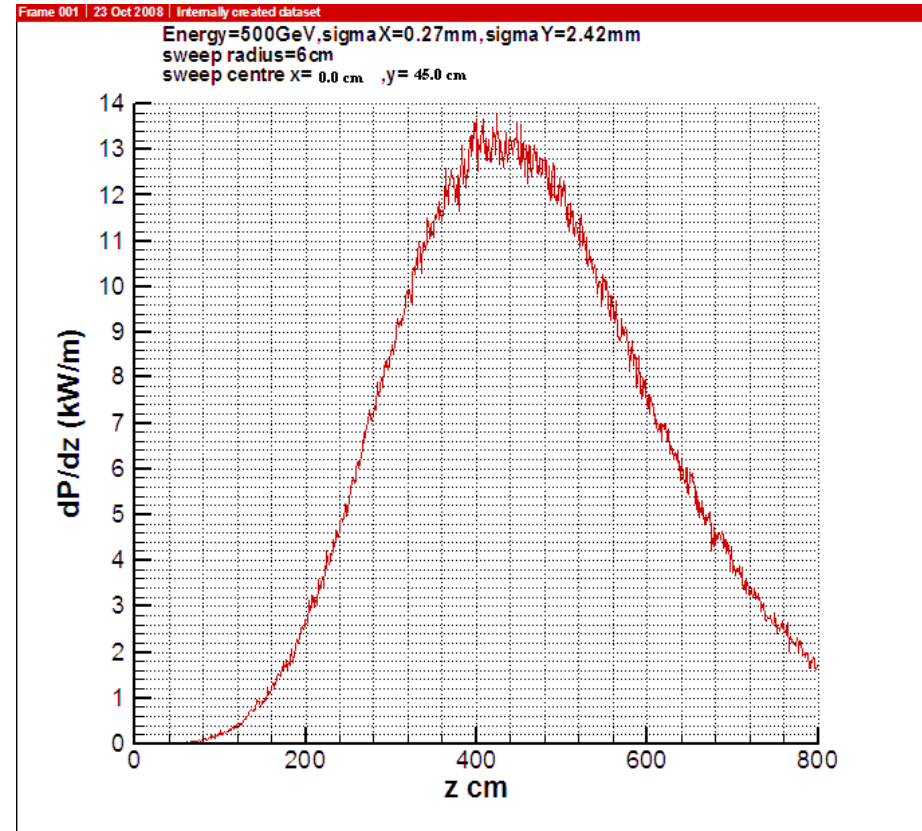


Radially integrated longitudinal linear power
 density max @ z=2.9m

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



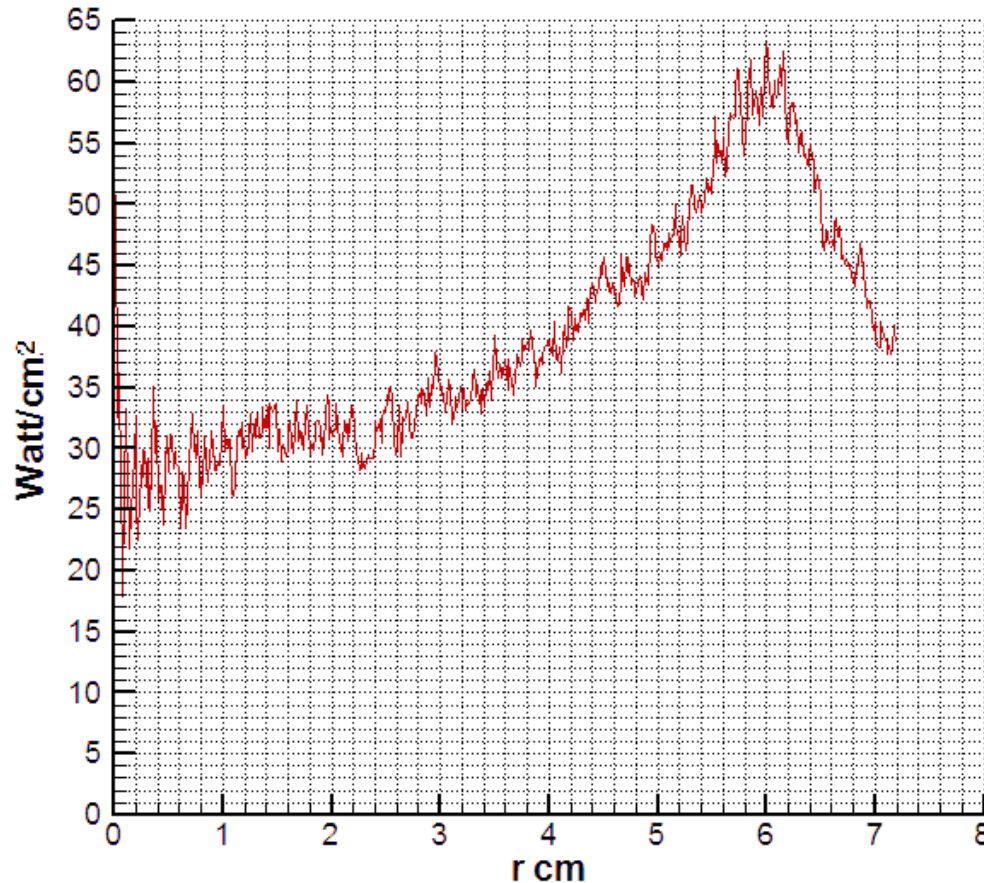
Beam @ r=45cm



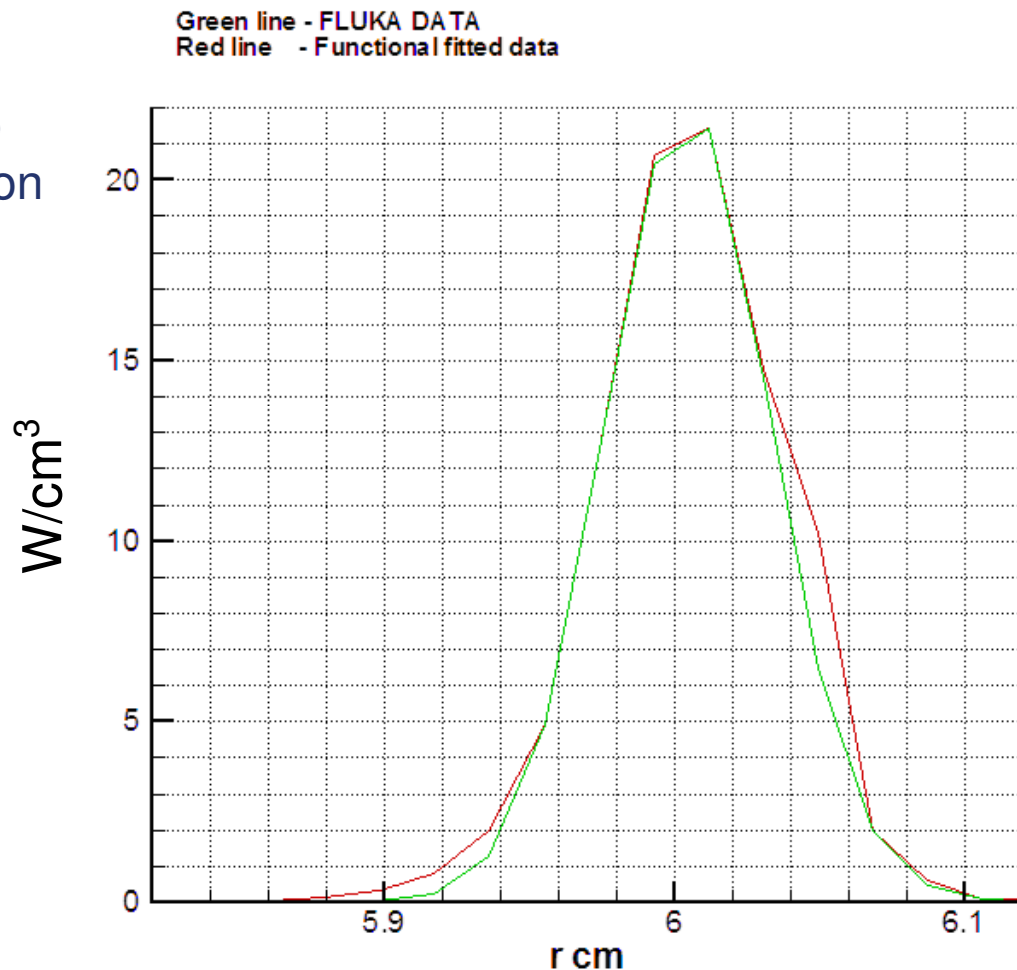
Beam @ r=35cm

Heat Flux – Down Beam Head

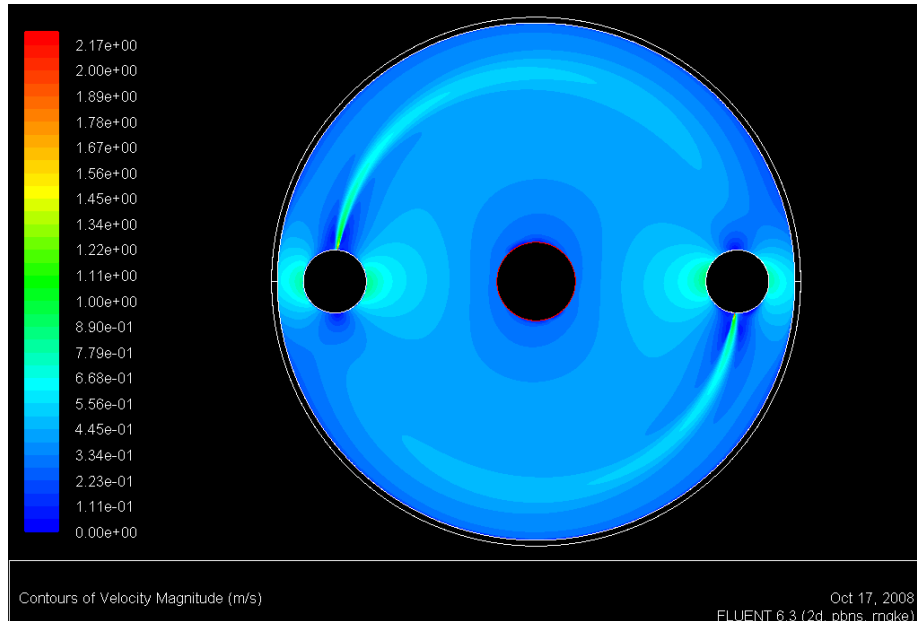
Location of Exit wall=800cm, Wall thickness=2cm
 Radial bin size=(10/800)cm=0.0125cm
 Longitudinal bin size=(2/20)cm=0.1cm



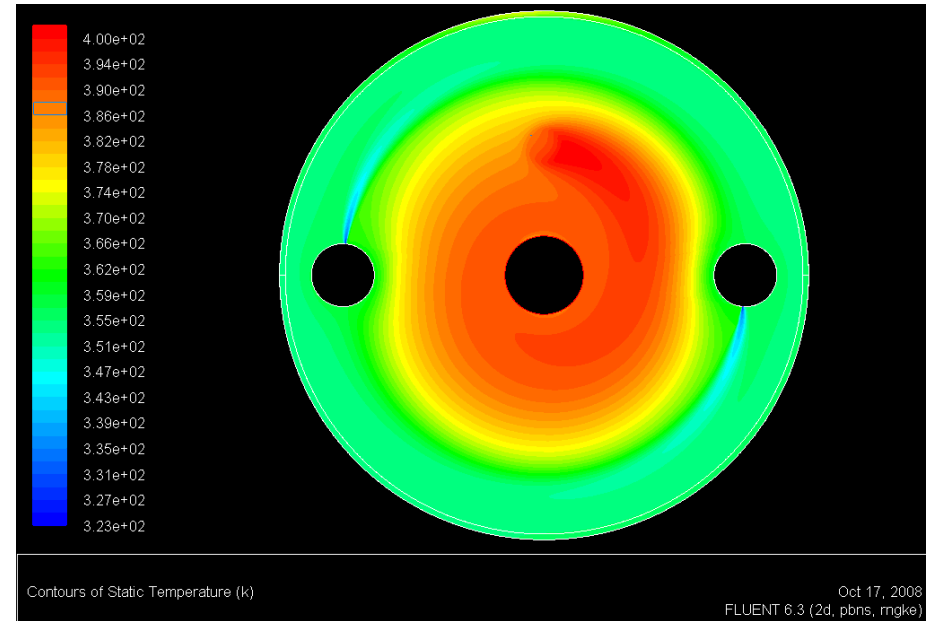
- A FLUKA analysis was carried out to determine the beam power distribution in the thin window.
- The total power deposited is ~ 25 W with a maximum power density of 21 W/cm^3 .
- Functional fitted data is the input for the CFD analysis.



Total mass flow rate of water taken was 154kg/s. Water inlet was assumed to be at 50°C as dictated by the primary coolant loop. The bulk outlet temperatures would be 78°C for 18 MW average beam power. The water inlet velocity at the slit exit is 2.17 m/s.



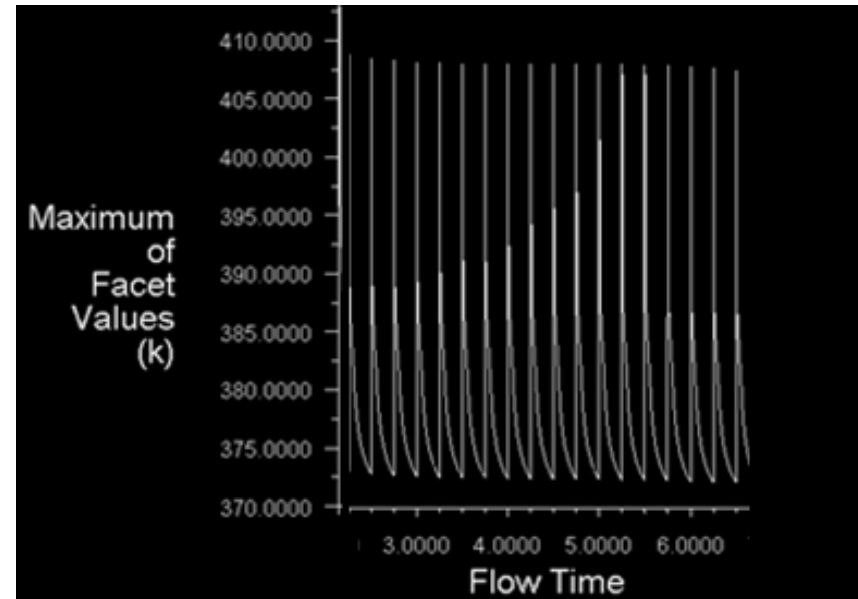
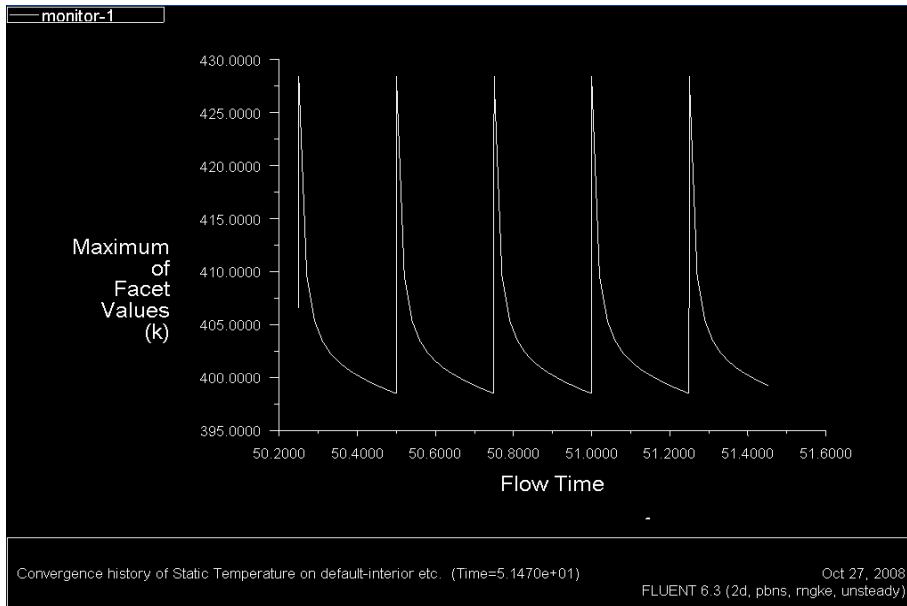
Velocity contours at $z = 2.9\text{m}$



Steady state temperature distribution at $z = 2.9\text{m}$
(Max average temperature : 127°C)

Maximum temperature variation as a function of time at $z = 2.9\text{m}$

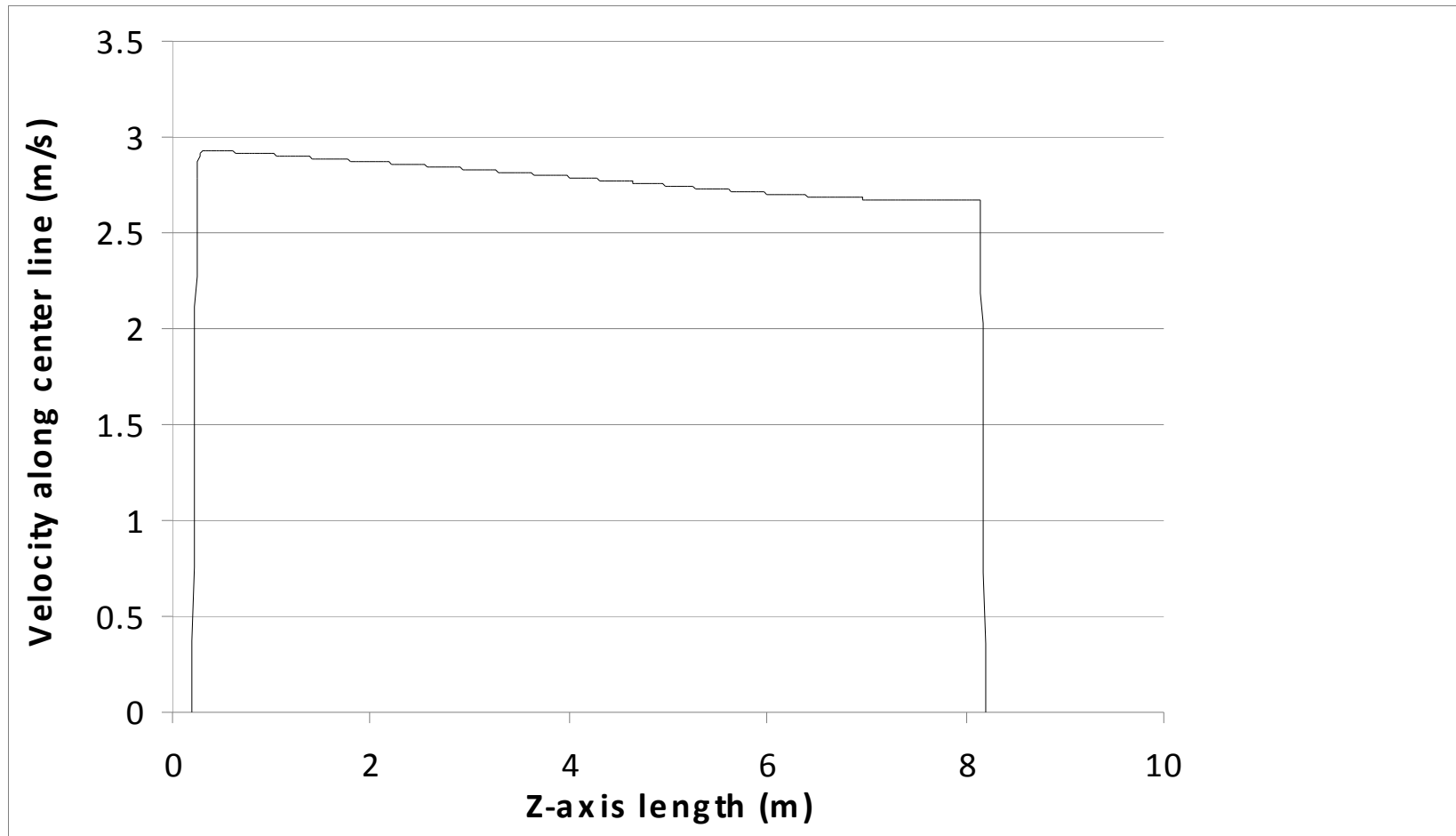
Maximum temperature variation as a function of time at $z = 1.8\text{ m}$



Maximum temperature $\sim 155^{\circ}\text{C}$ and variation with time $\sim 30^{\circ}\text{C}$

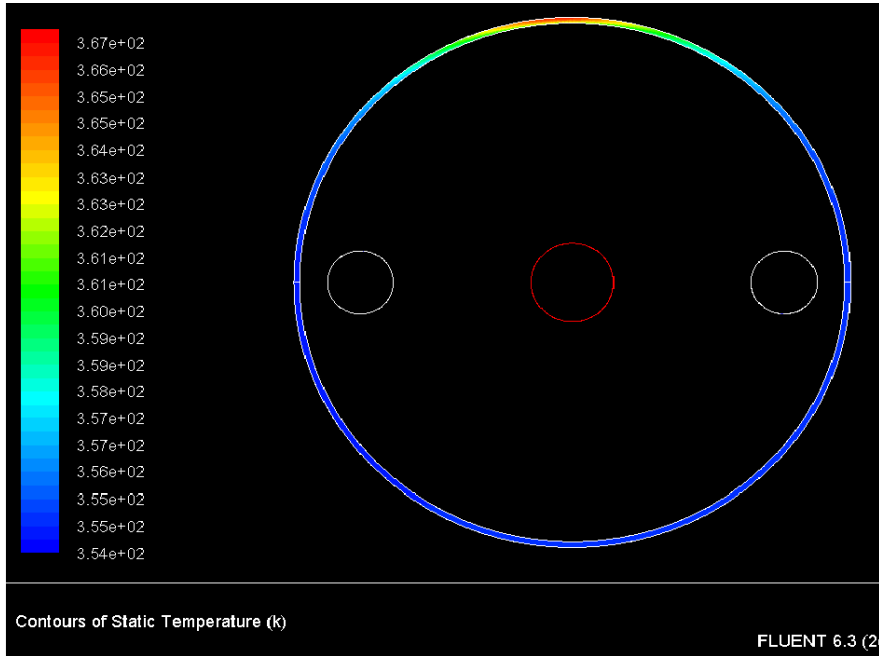
Maximum temperature $\sim 135^{\circ}\text{C}$ and variation with time $\sim 36^{\circ}\text{C}$

Variation of inlet velocity at inlet exit along length of header.



Temperature distribution in the vessel at $z = 2.9\text{m}$ for the 0.45m radial beam location

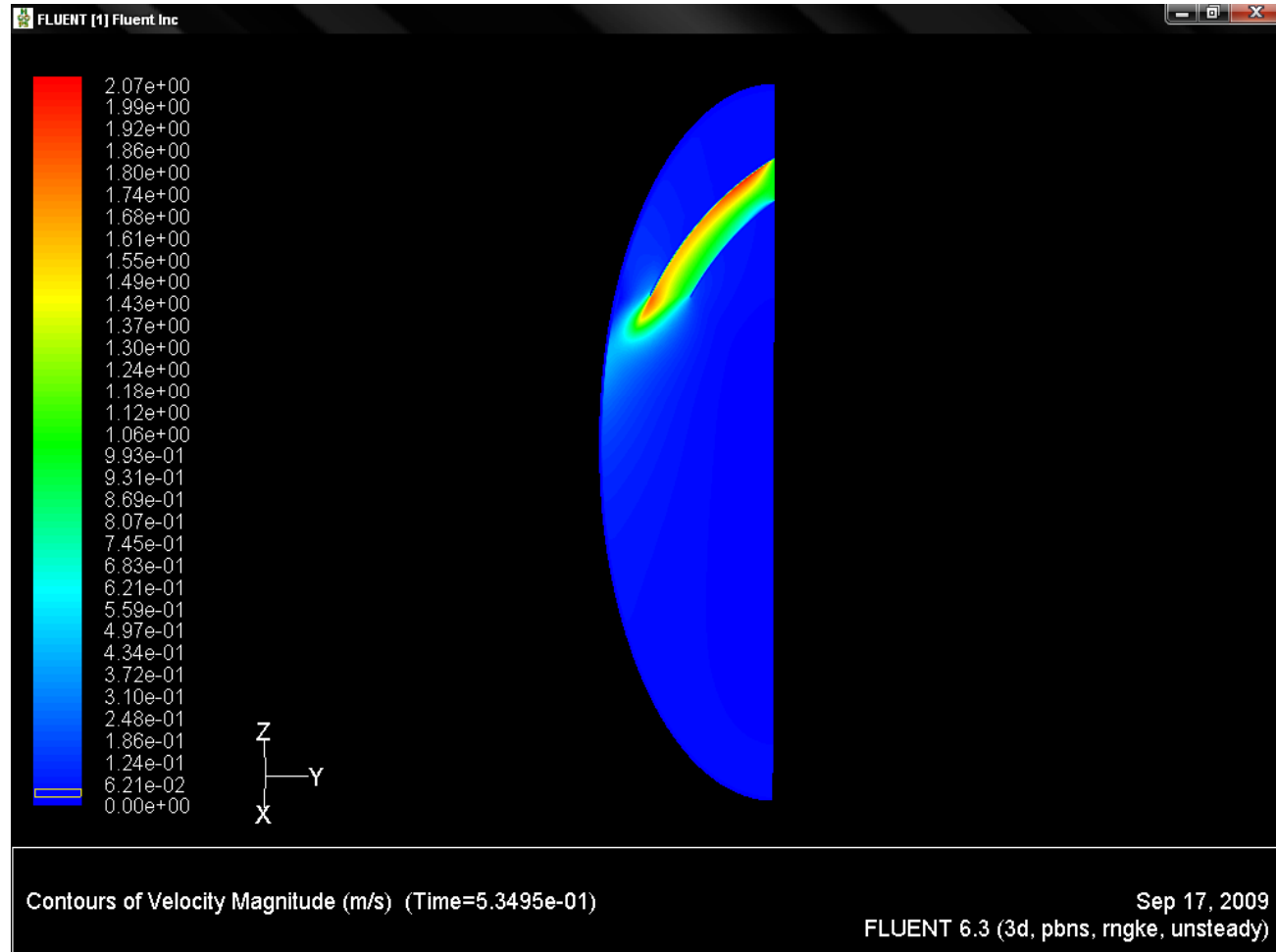
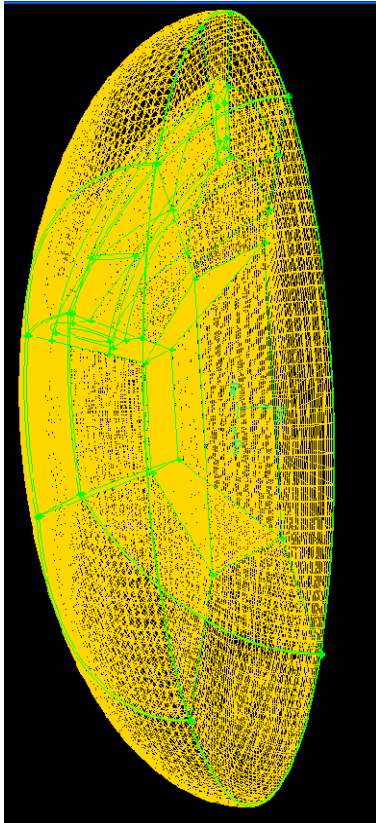
Temperature distribution in the vessel at $z = 4.2\text{m}$ for the 0.45m radial beam location



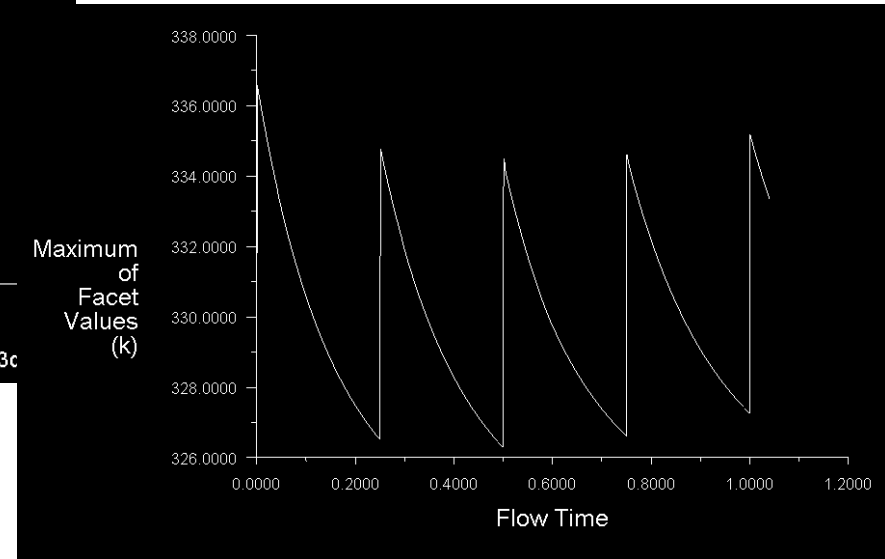
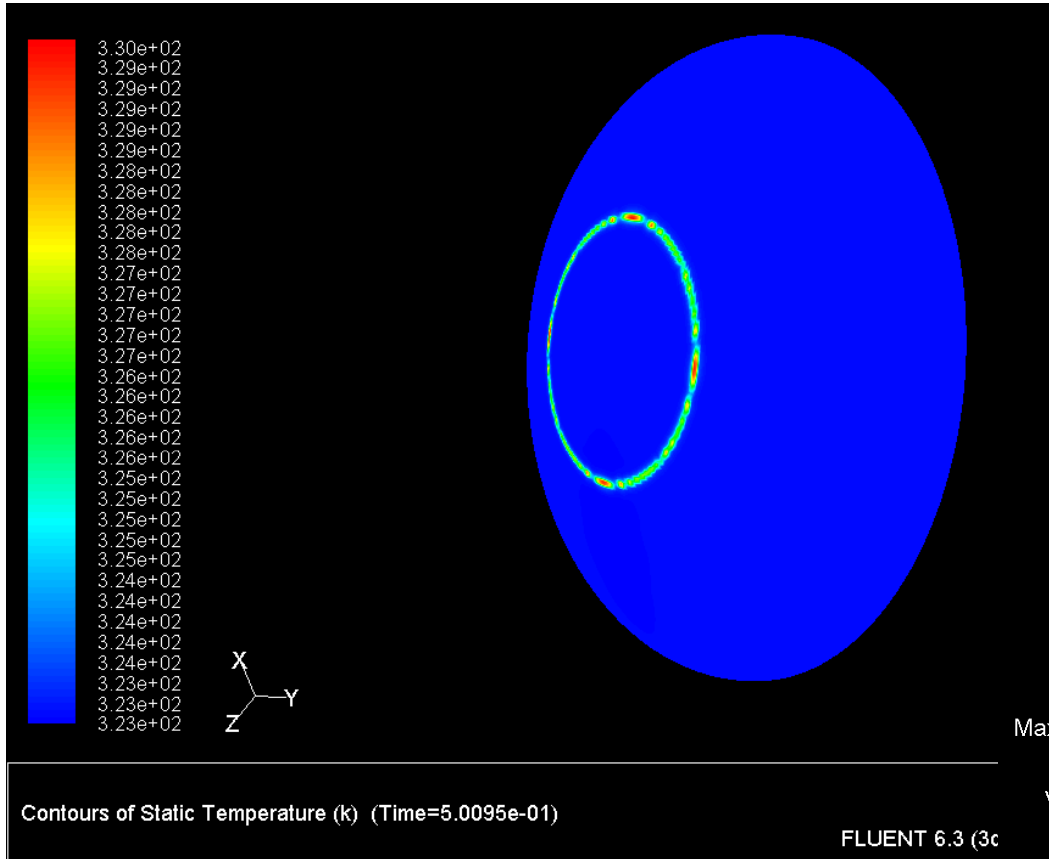
max vessel temperature - 94°C
 min vessel temperature - 81°C

max vessel temperature - 90°C
 min vessel temperature - 70°C

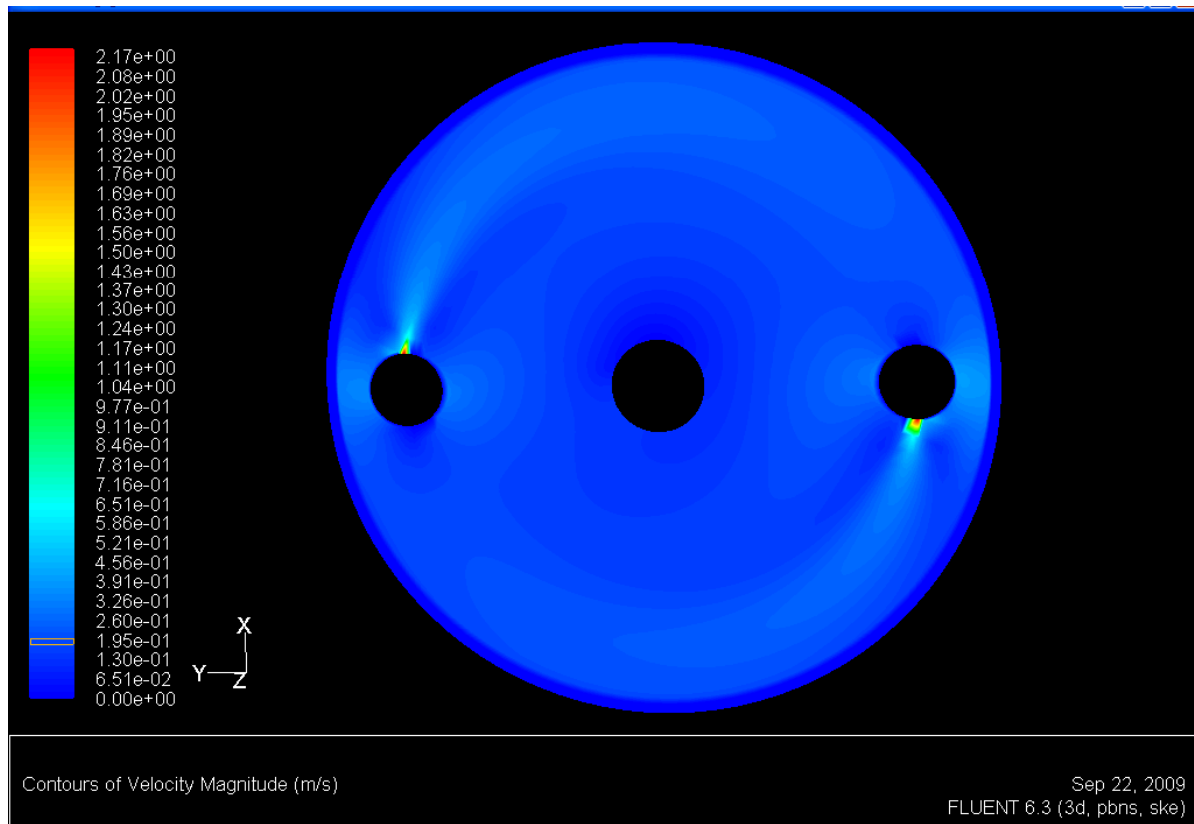
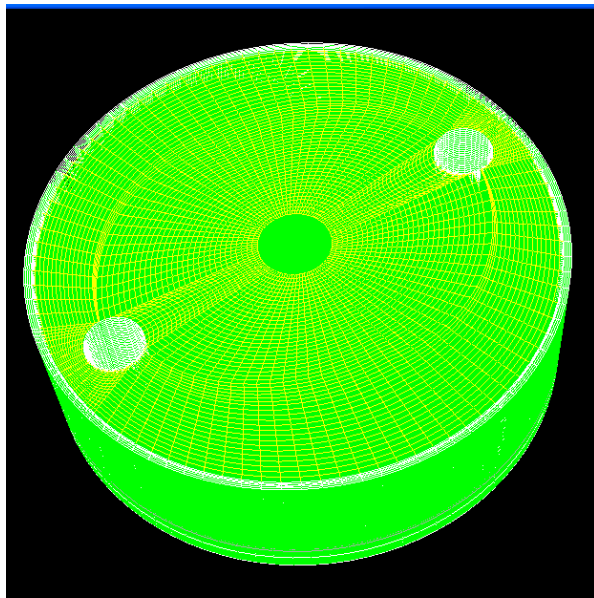
Window Cooling - Work In Progress



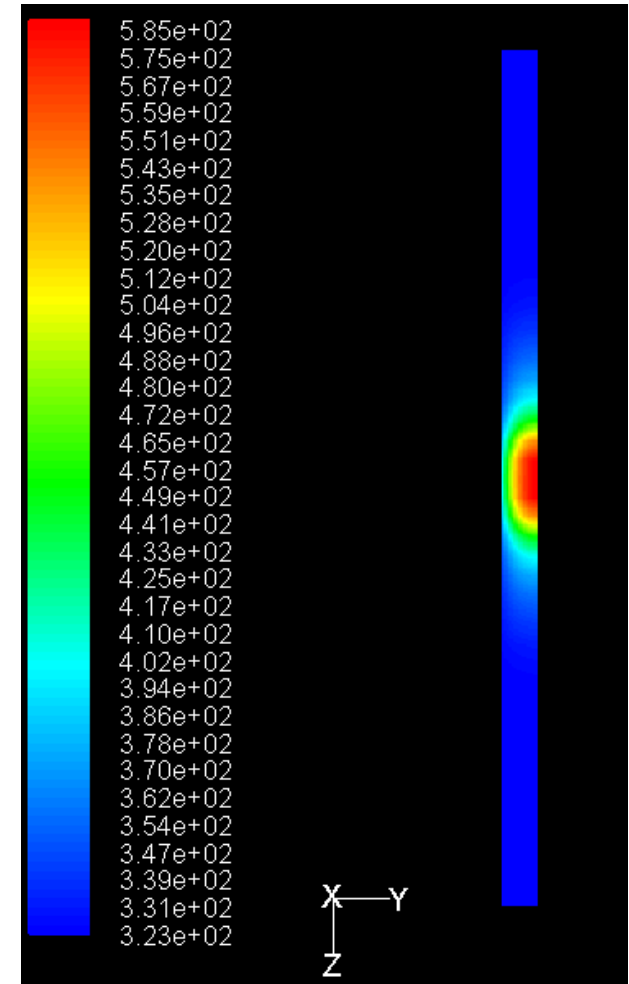
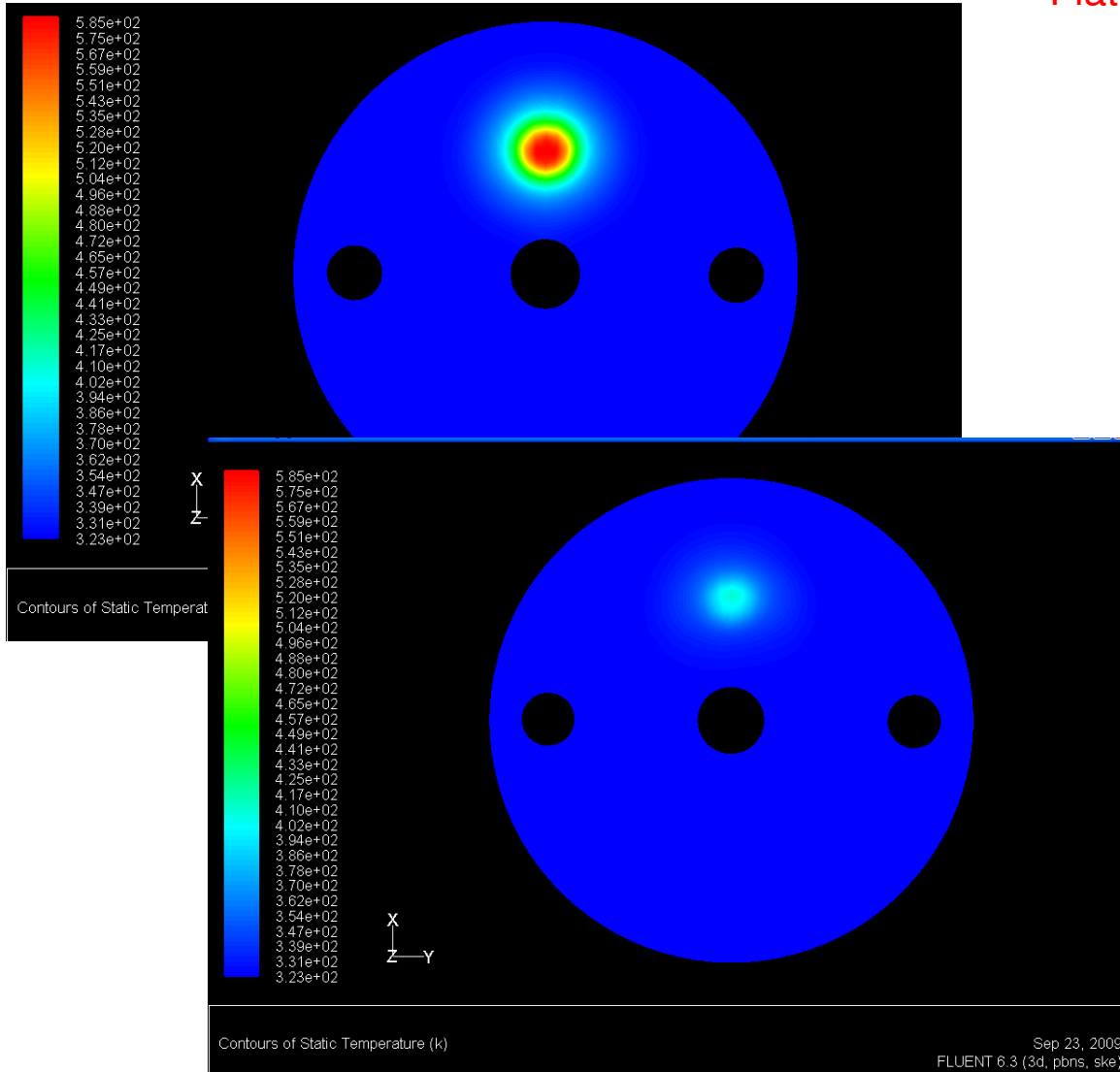
Window Cooling - Work In Progress



Flat Head Cooling - Work In Progress

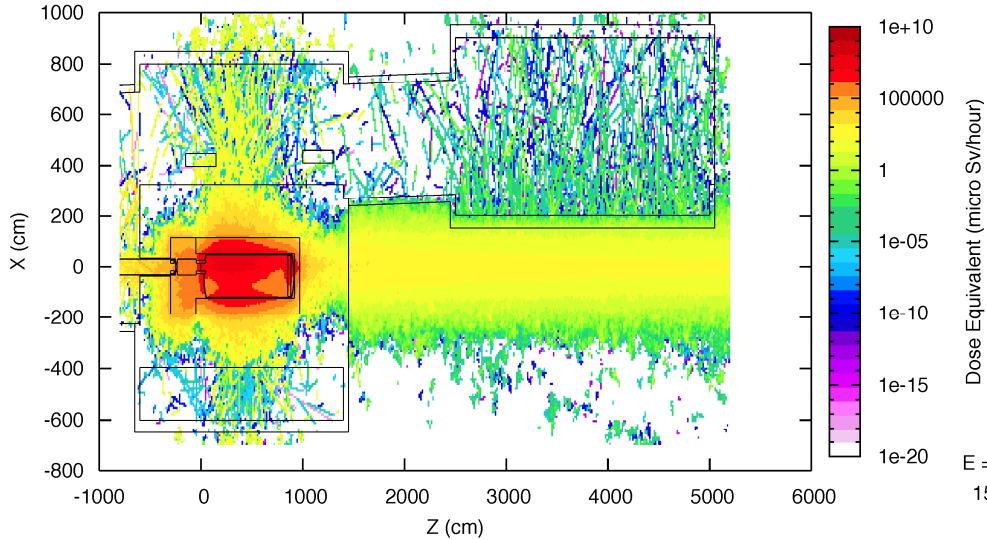


Flat Head Cooling - Work In Progress

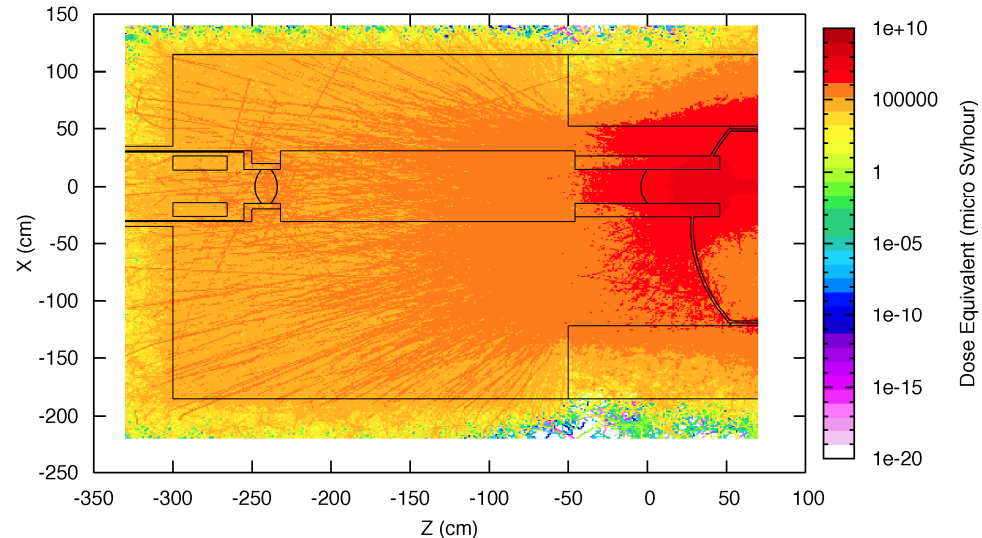


Preliminary Activation Studies – First Design Concept

E = 500 GeV, Effective Dose EWT74 Wide Area, 180 d Run, 8 h Cool Down Y = 0.0 +/- 20. cm



E = 500 GeV, Effective Dose EWT74 Front Area, 180 d Run, 8 h Cool Down Y = 0.0 +/- 10. cm



- Mechanical design concept under development.
 - Basic mechanical parameters established.
 - Window sealing design and remote exchange system still needs work.
 - Preliminary process design complete.
- FLUKA and FLUENT 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.



Bonus Slides



Variation of inlet velocity at inlet exit along length of header.