Beam Dumps
WP10

Contents

ILC BDS KOM
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Beam Dumps Work Programme submitted to UK funding agency (PPARC) in July 06

- Design study of candidate window materials.
- Design and optimisation of geometry of window for water dump in order to minimise thermal fatigue, pressure and shock wave stresses. Estimation of window lifetime with reference to radiation damage.
- Specification, design and participation in on-line experiments using electron beams to simulate power deposition, thermal and stress wave profiles in prototype window materials
- Design and full model of internal water circulation system within beam dump vessel using Computational Fluid Dynamic codes in order to maximise efficiency of heat transfer and minimise possibility of local boiling.
- Outline design of remote handling systems for replacement of critical components e.g. window, de-ionising system and catalytic recombination components.
- Specification of services requirements for all beam dump specific items.
- Full costing of baseline design, in accordance with GDE guidelines
- Assessment of costs for disposal of activated water and associated materials only
- Investigation of gas dump alternative design including assessment of operating limits of window and jacket materials
- Feasibility study of a differentially pumped windowless system
- Simulation of heat flow through surrounding jacket to water system
- Investigation of alternatives to iron jacket and Ar gas core in order to minimise length and cost of dump, by consideration of various material combinations e.g. Cu and refractory metals, and using higher Z noble gases.
- Outline design of the optimised and possibly hybrid alternative design, including gas and water cooling and maintenance systems including remote handling where necessary.
- Costing of alternative design, in accordance with GDE guidelines
- Full comparison of alternative design with water baseline with regard to cost, technical reliability and risk assessments, including a critical assessment of preferred technology choice.
- Study of lower power tune-up beam dumps with specification of technology choices for different powers

NEGOTIATED UK WORK-PLAN FOR 2007-2010
Funded April 2007 – March 2008 only

Deliverables for 2007/8 will include:

1. Detailed study of shock wave generation in baseline water beam dump, resulting from a single rastered non-disrupted bunch train

   Fluka Energy Deposition + Autodyne dynamics calculations underway

2. Study of effect of above on beam window, in addition to direct shock generation in window material by beam

   No work started yet

3. If as expected the above study indicates a serious problem for the ILC dumps, a study for the SLC beam parameters will be undertaken to illustrate why shock wave generation is not a problem for the SLC

   Continuation of work started in 1

4. Consider methods of mitigating shock wave effects, e.g. with bubble generation or by vessel wall geometry

   Preliminary predictions of the effect of bubble dynamics + potential knowledge transfer from collaboration with Southampton University

5. If above work discovers a show-stopper for the baseline water dump technology, a new initiative will be initiated to consider new beam dump ideas and technologies

   High power targets group involved with investigating fluidised solids as an alternative target design, this could also be investigated as an alternative dump

6. Prepare report of status of baseline technology and of preferred beam dump technology

   Report not started yet, due end of march 08

Motivation to study Pressure Waves

-Challenging window design, 30cm diameter, 10 bar pressure
-Tesla study raised concerns about transient pressures

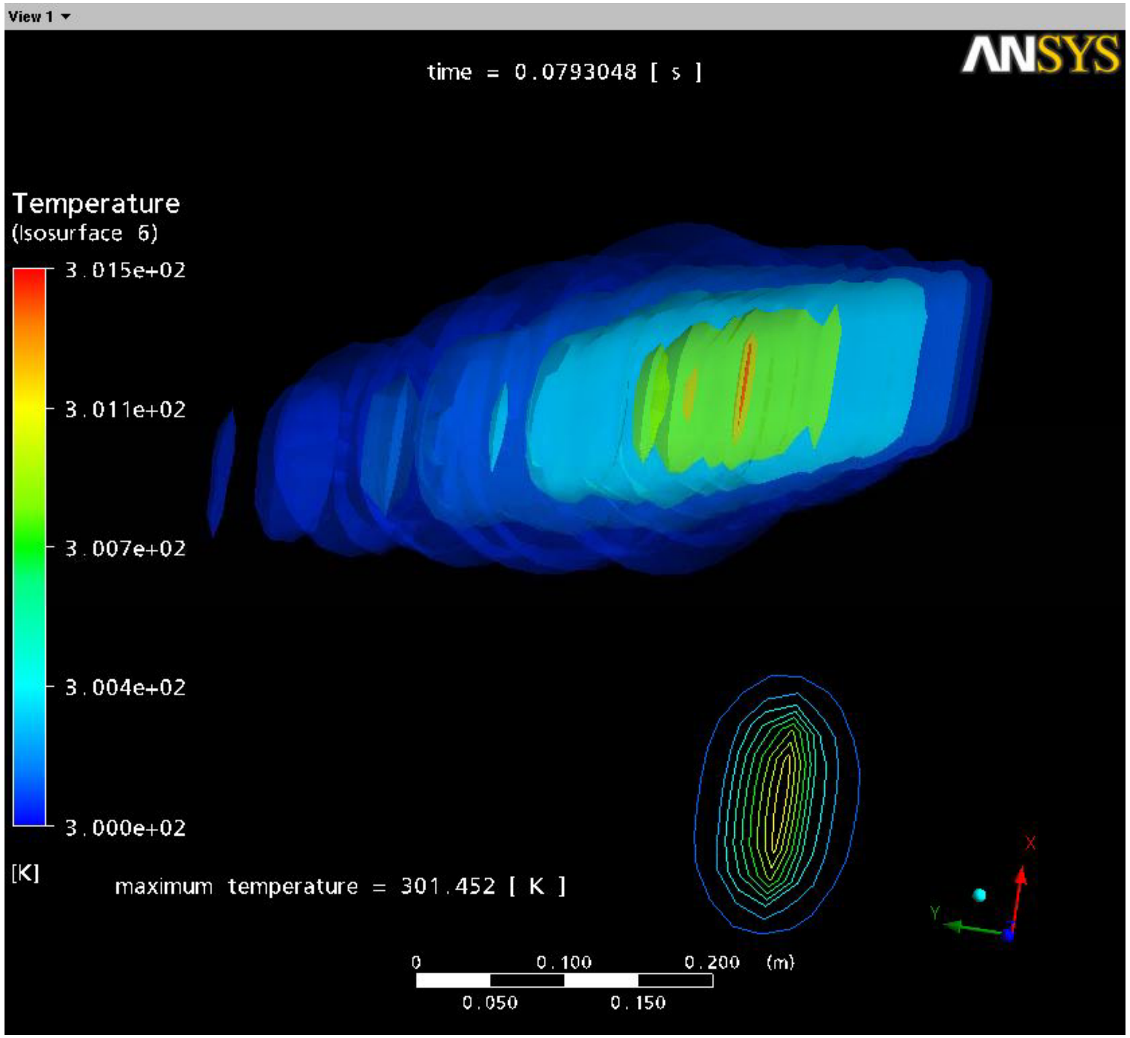
-Pressure Vessel and Shockwave Issues in the ILC Main Beam Dumps D. WALZ May 25, 2007

"For stainless steel (type 316-L) the yield strength is 30,000 psi and the tensile strength is 70,000 psi. Thus, making no allowances for pressure surges, the vessel provides a safety factor, S, of 5.
The temperature rise will give rise to a thermal pressure wave or shock wave, propagating radially outward at the velocity of sound in water, ~1500 m/s near operating temperature. The intensity of the pressure wave decreases as 1/r; **the wave will reach the dump vessel wall (closest approach) in tmin = 45 cm/ 1500 m/s ≡ 30 ms** and the point of **furthest approach in tmax = 105 cm/ 1500 m/s ≡ 70 ms**. The pressure wave will be reflected from the dump vessel wall and dissipate its energy. **Because of the specific geometry, there is NO CHANCE of these waves superimposing and shortly thereafter causing a rarefaction zone on the beam trajectory axis**.
Pressure wavelets from individual bunches will propagate outward as more bunches arrive. At the end of a bunch train, after 1ms, the wavefront will have propagated 1.5cm outward. After 200 ms most of the energy in the previous bunch train's pressure waves has been dissipated into heat and the process starts (fresh) anew. As the water velocity in the dump is assumed to be 1.5 m/s transverse to the beam direction, the water volume exposed to the bunch train will have moved 30cm in 200ms.
With the safety factor of 5 (see above) and shock wave arrival and reflection spread out over 70-30=40ms, a ¾ inch thick wall looks fine; a 1 inch thick wall would add even more conservatism."

What is safety factor for the window?
Pressure wave arrival spread over 0.6m/1500m/s=0.4ms.
Initial wave front will have propagated 1.5m within 1ms so pressure waves will superimpose.
No advantage of moving water in terms of pressure waves.

Progress so Far - Energy deposition

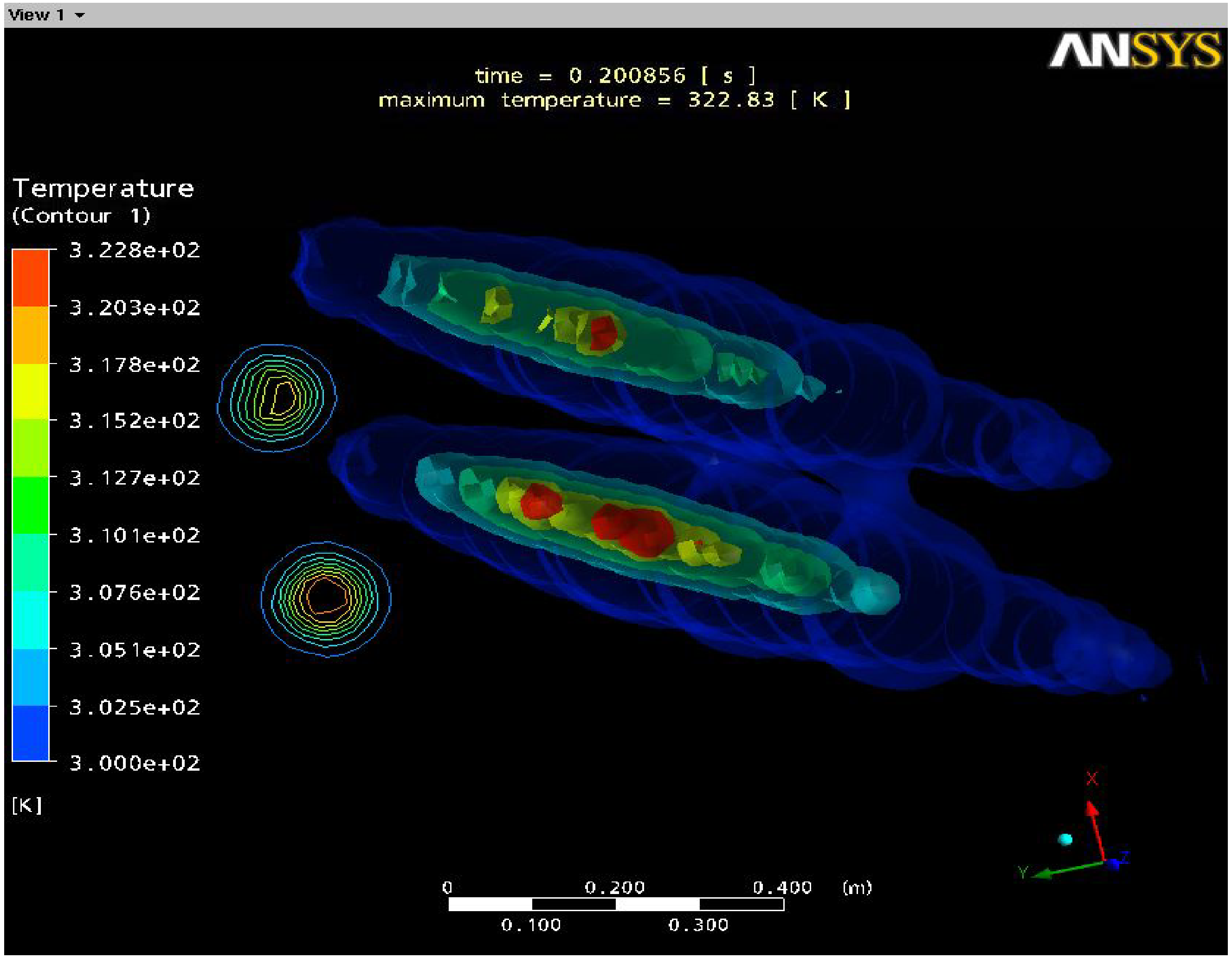
Thermal trace of SLAC beam

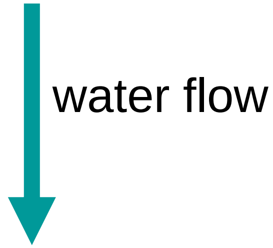


water flow

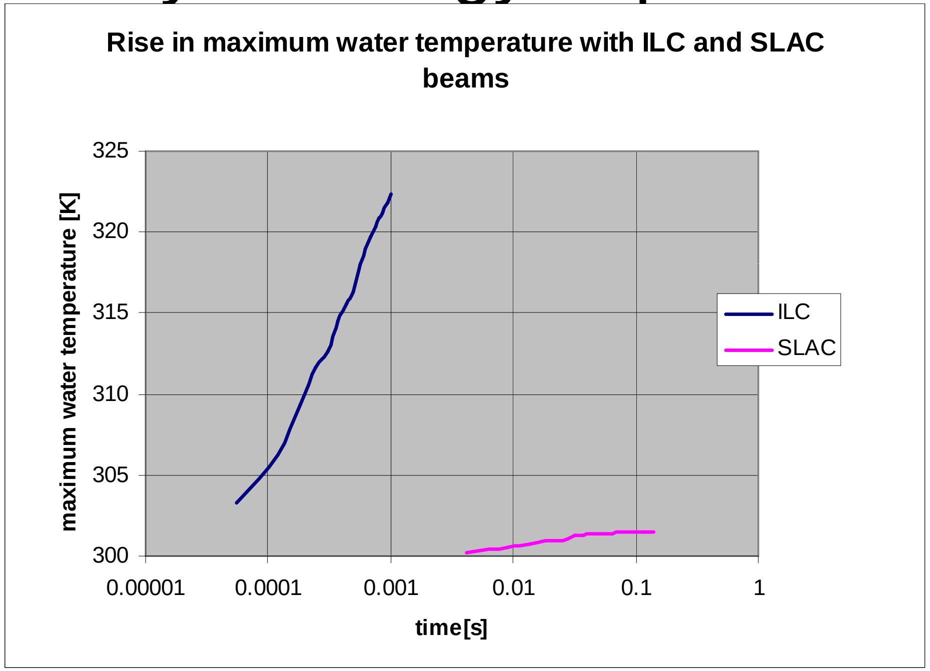
Progress so Far - Energy deposition

Thermal trace of ILC beam





Summary of energy deposition study



How to get from Energy Deposition to Pressure Waves ?

Calculation must include

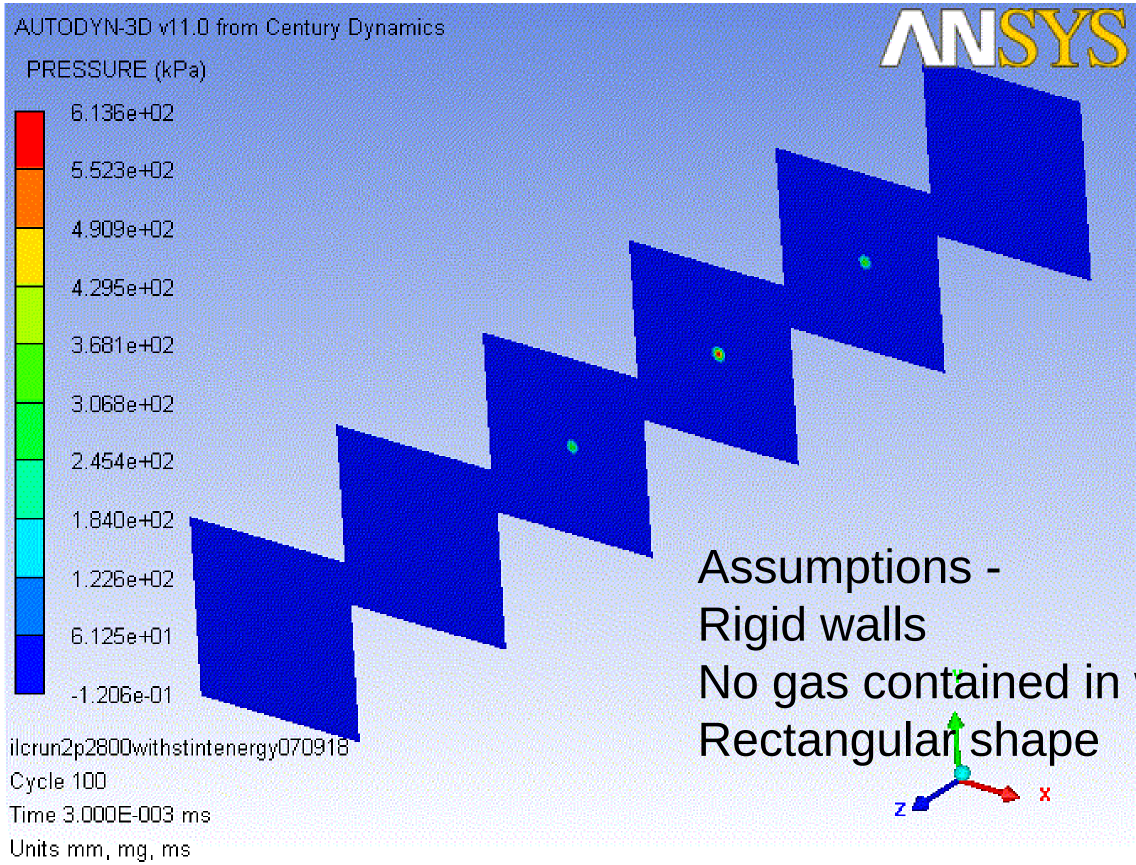
- Time and spatial description of energy deposition as an input
- Compressibility of water and evolution and reflection of pressure waves
- Non linear capability, phase change + shocks

Autodyne

- Explicit code
  - Stable with non-linearity such as phase change and shock waves
  - Small time step defined by Courant number ensures capture of pressure waves
- Database of material strength models
- Database of Equations of state for materials in shock compression

Progress so Far - Fluka ⇨ Autodyne

Pressure due to 1 bunch train (almost!)

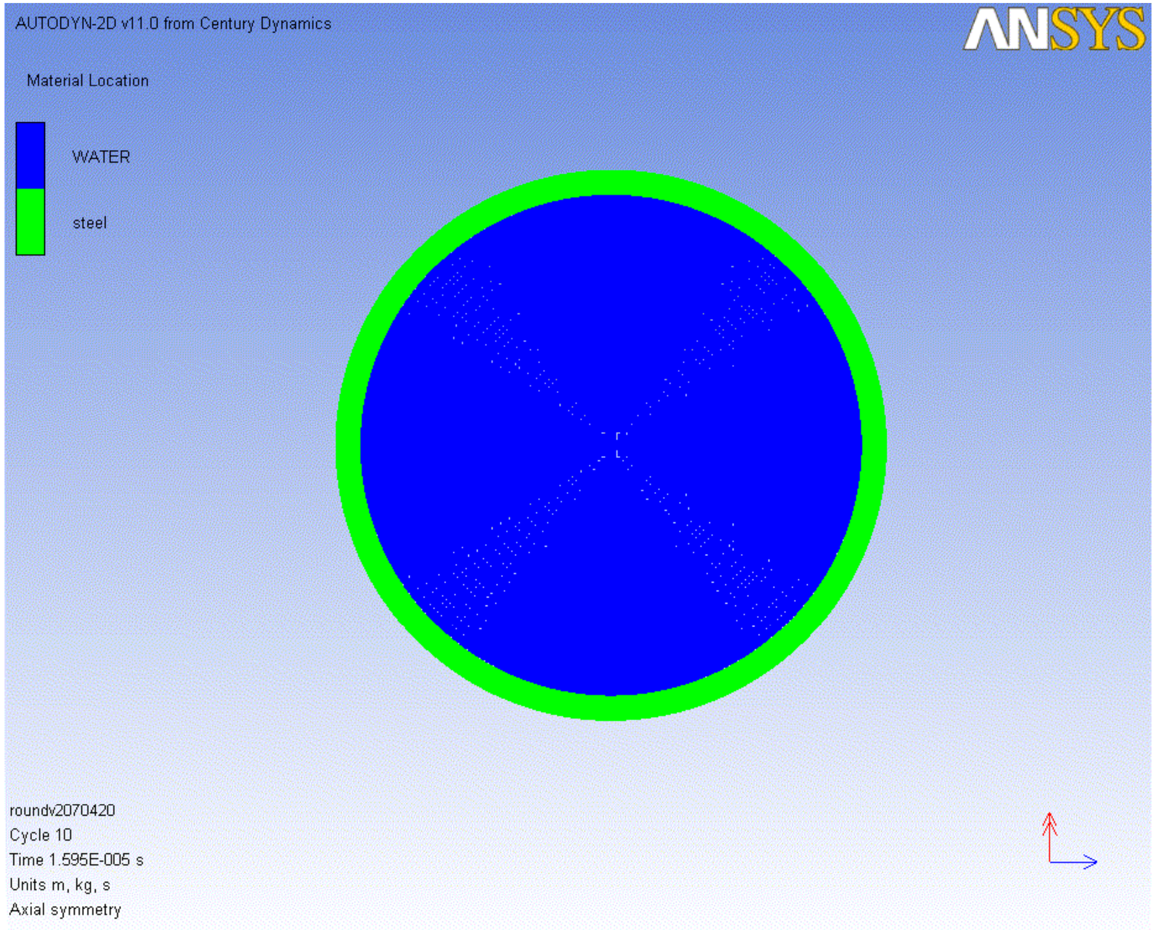


Assumptions -
Rigid walls
No gas contained in water
Rectangular shape

Questions
Pressure at window?
Can 5Hz pressure pulse cause vibration and fatigue?
How important is elasticity of the dump walls?
How much difference does gas in the system make?

Pressure wave Mitigation

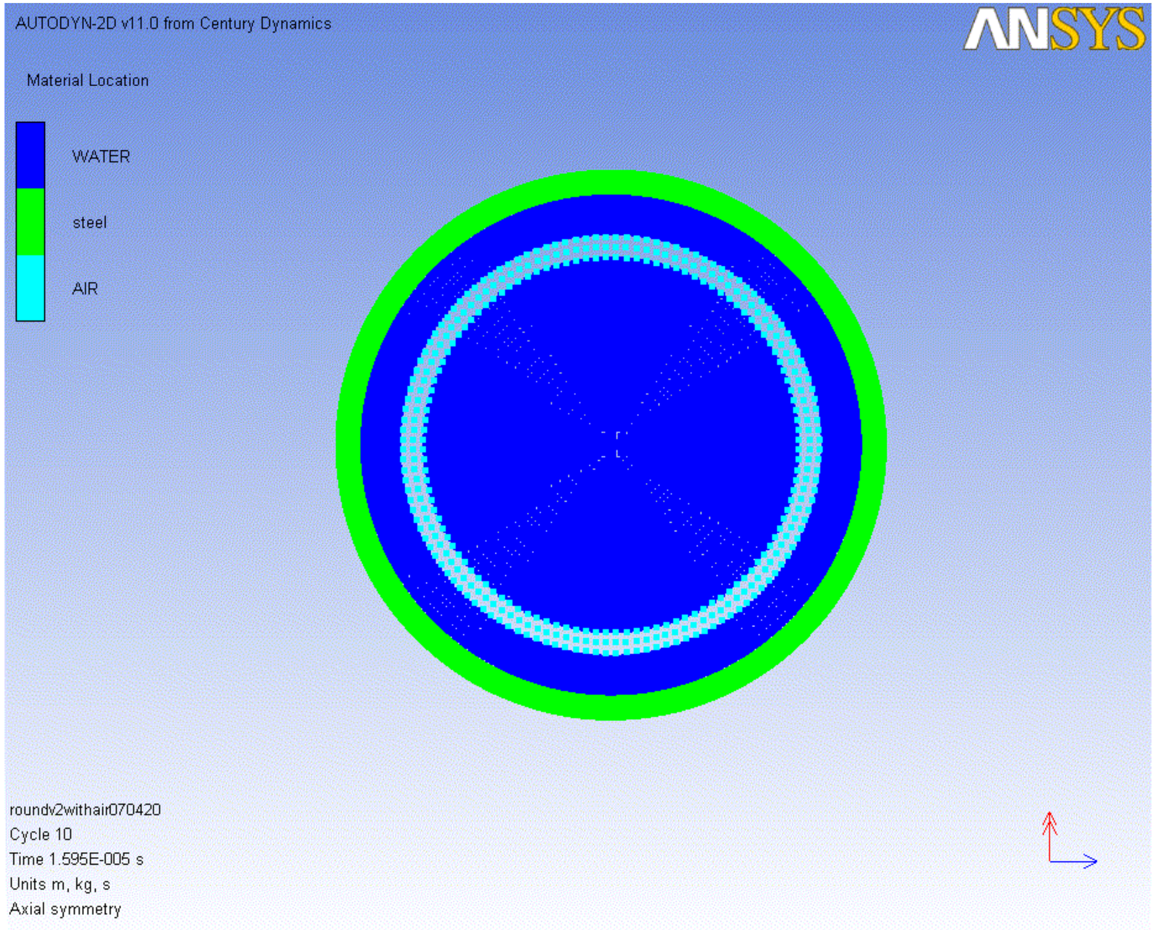
Reflected pressure wave



Walls of tank subjected to high pressures

Pressure Wave Mitigation

Arrested pressure wave



Ring of gas stopped pressure wave before reaching tank walls

Summary of Progress so Far

- Fluka and Autodyne have been used as a method for predicting the hydrodynamic behaviour of a liquid when penetrated by a high energy particle beam.
- Preliminary predictions suggest the walls of the beam dump will be subjected to a pressure pulse of ~3bar. This will occur at a frequency of 5Hz.
- The peak pressure reaching the walls of the beam dump will be dependant on the presence of gas in the water

Work to complete deliverables by march 08

- Continue Fluka and Autodyne modeling of ILC beam dump up to several ms
- Create Autodyne model of SLAC beam dump for comparison

  -As part of the detailed study into pressure waves in the water beam dump, tension levels in the fluid will also be studied to indicate if cavitation will happen.
- Create a fluid-structure interactions model to consider the stress in the window and the effect of accounting for elasticity of the beam dump.
- Finally use results of the theoretical analysis to report on if pressure waves caused by the beam will pose a risk to the beam dump window.

  -As part of the report discuss the feasibility of pressure wave mitigation methods or alternative dump designs such as a fluidised particle bed.

Expression of Interest

BDS Tasks

This work package will concentrate on critical technical issues related to the ILC Beam Dumps, in particular the interaction point charged particle dumps but will also investigate the **beamstrahlung dumps and positron source photon dumps.**

1.The focus of the work will be the study of shock waves generated in the water of the main charged particle dumps, their effect on the beam windows, and the possible mitigation of these effects.

2. Energy deposition calculations in beam dump water and window materials.

3. Numerical simulations of effects of power deposition and generation of shock waves in beam dump water and windows

4. Experimental program to benchmark simulations.

Set up experiment with water in a beam?

5. Lifetime experimental tests of candidate window material samples.

'Shock fatigue' testing of window material

6. Study of alternative beam dump technologies, e.g. fluidized particle beds, noble gas based dump.

Perhaps a fluidised particle bed could make for a compact dump design for ILC or other facilities

7. Deliverables: reports on all the above