Polarised Positron Source Target and Collimator

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EUROTeV: WP4 (polarised positron source) PTCD task

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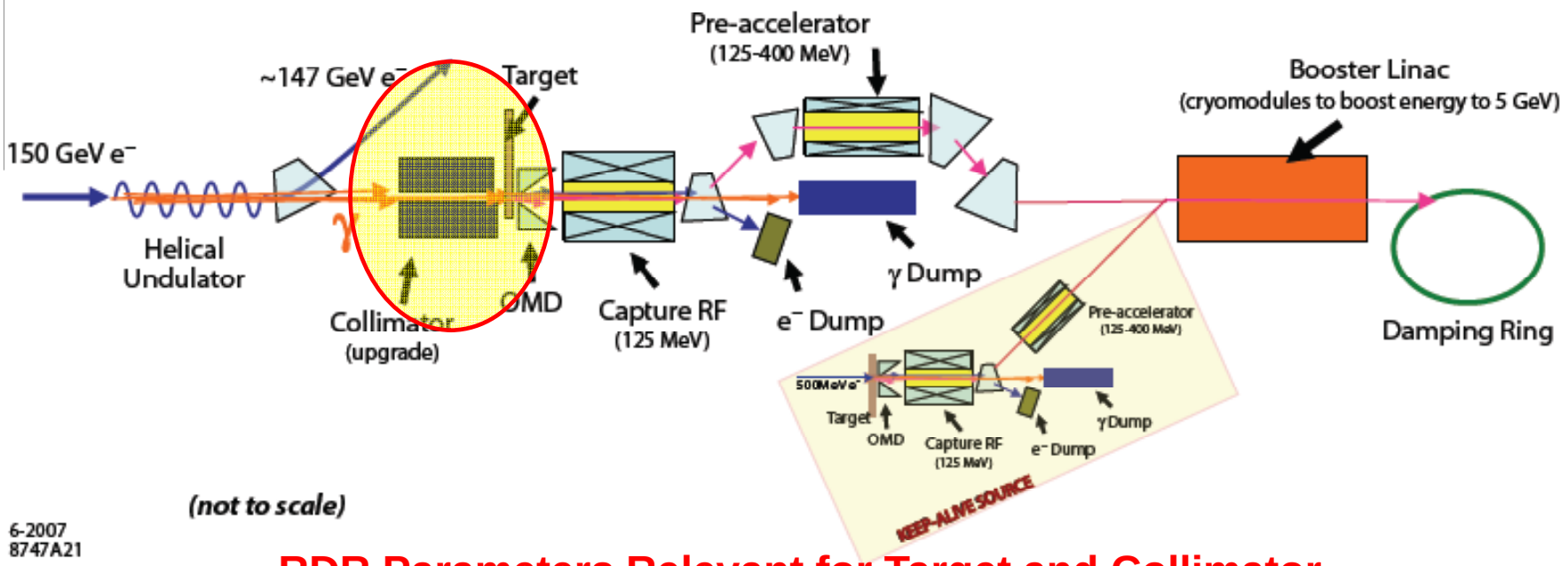
In collaboration with

Jeff Gronberg, Tom Piggott (LLNL)

Vinod Bharadwaj, John Sheppard (SLAC)

PPS Schematic - ILC RDR

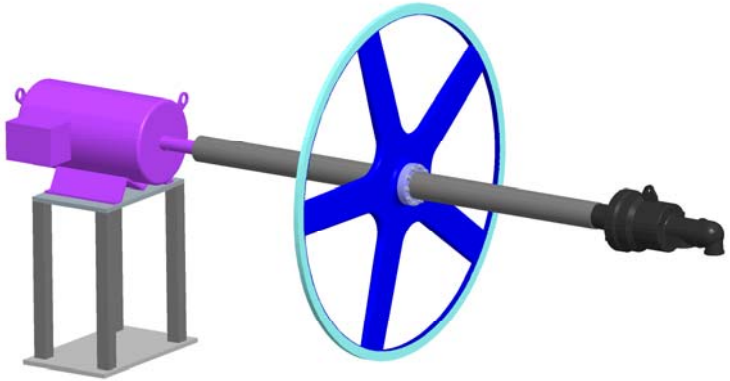


RDR Parameters Relevant for Target and Collimator

- **Centre of undulator to target: 500m**
- **Active (K=0.92, period=1.21mm) undulator length: 147m**
  - **Photon beam power: 131kW (~doubled if QWT adopted)**
  - **First harmonic: 10MeV**
  - **Beam spot: >1.7 mm rms**

RDR Target Design

- **Wheel rim speed (100m/s) fixed by thermal load (~8% of photon beam power)**
- **Rotation reduces pulse energy density (averaged over beam spot) from ~900 J/g to ~24 J/g**
- **Cooled by internal water-cooling channel**
- **Wheel diameter (~1m) fixed by radiation damage and capture optics**
- **Materials fixed by thermal and mechanical properties and pair-production cross-section (Ti6%Al4%V)**
- **Wheel geometry (~30mm radial width) constrained by eddy currents.**
- **20cm between target and rf cavity.**
- **Axial thickness ~0.4 radiation lengths.**



T. Piggott, LLNL

Drive motor and water union are mounted on opposite ends of through-shaft.

Current PTCD-Related Positron Source Activities Summary

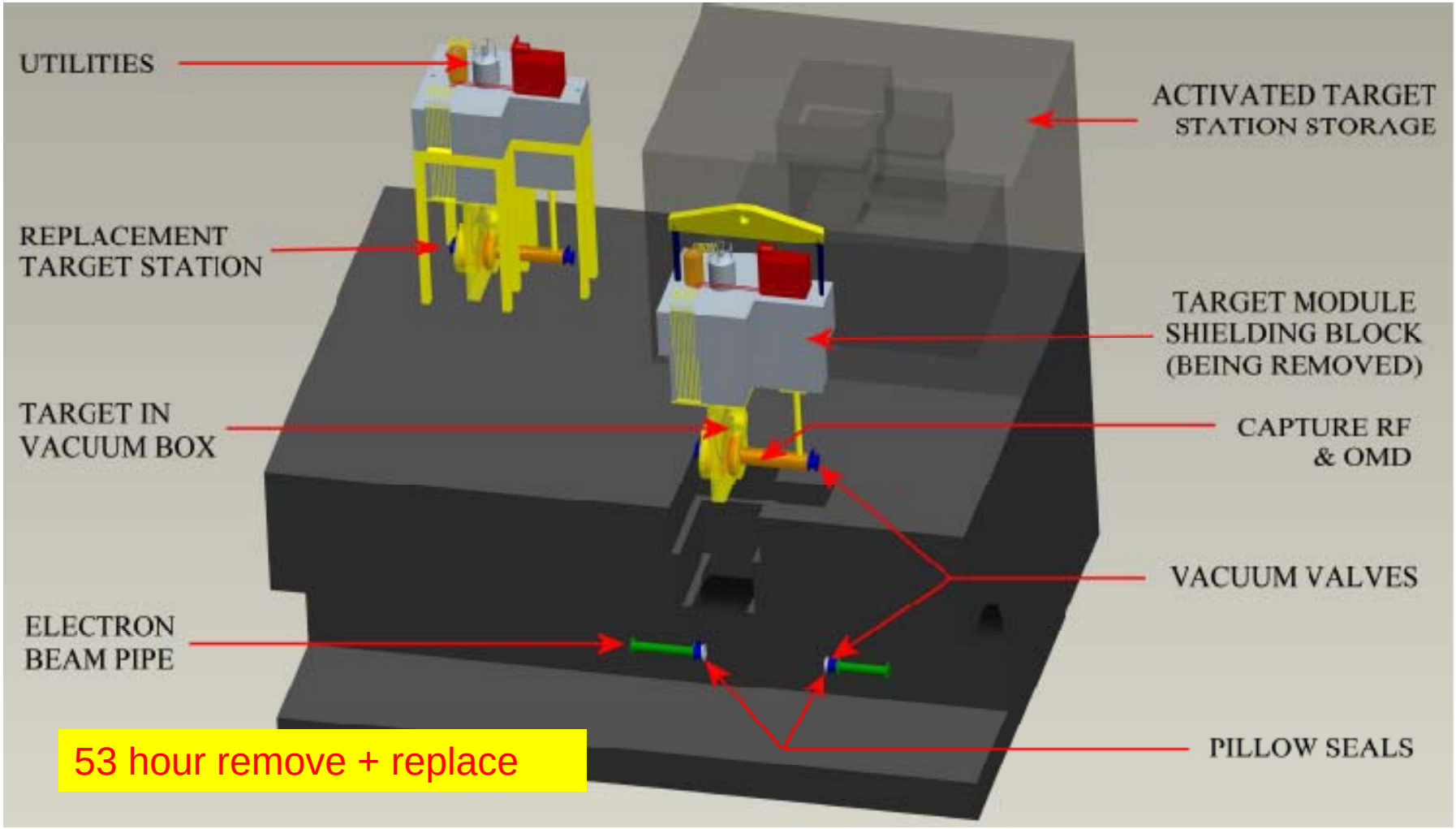
- Target Station Remote-Handling
- Target Prototyping
- Target Simulation
  - Eddy current
  - Rotordynamics
  - Mechanical stability
  - Thermal modelling
  - Thermal stress simulations (shock waves)
  - Radiation damage modelling (see PPMODL)
  - Activation modelling (see PPMODL)
- Photon Collimator Design
- Photon Collimator Simulation
  - Thermal modelling
  - Activation modelling
  - Photon beam modelling

See Andriy's PPMODL talk.

red ⇒ lead role

orange ⇒ support role

Target Station - Remote Handling



RAL report produced - July 2007

No further staff effort available at RAL.

Design based on target hall with footprint ~100m^2

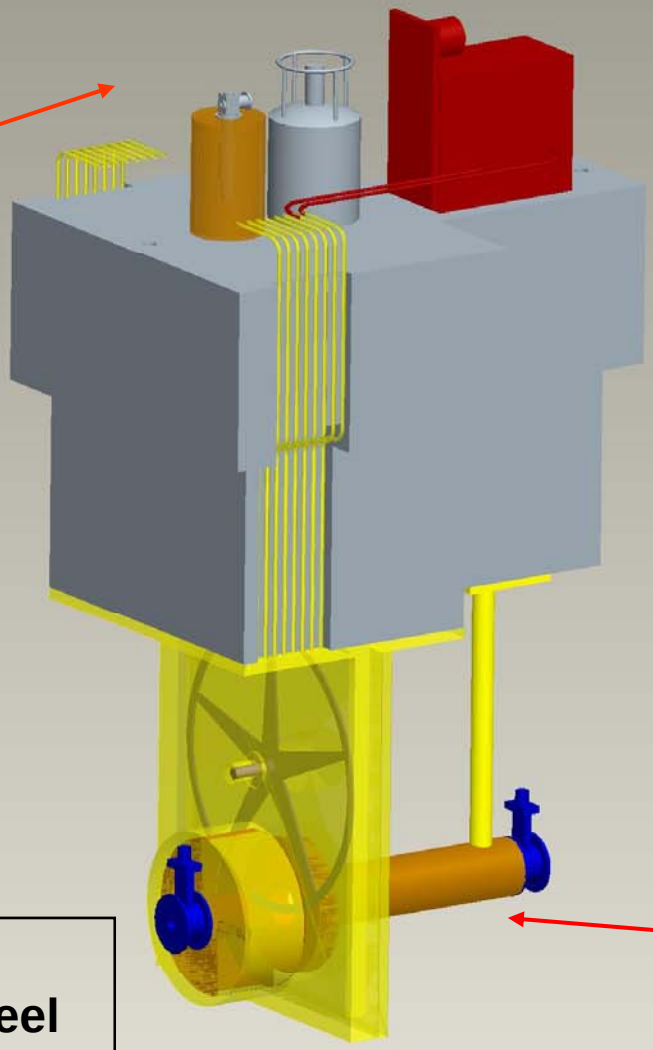
Remote-Handling Module and Plug

Cryocooler

(if required)

+ vacuum pump

+ water pump

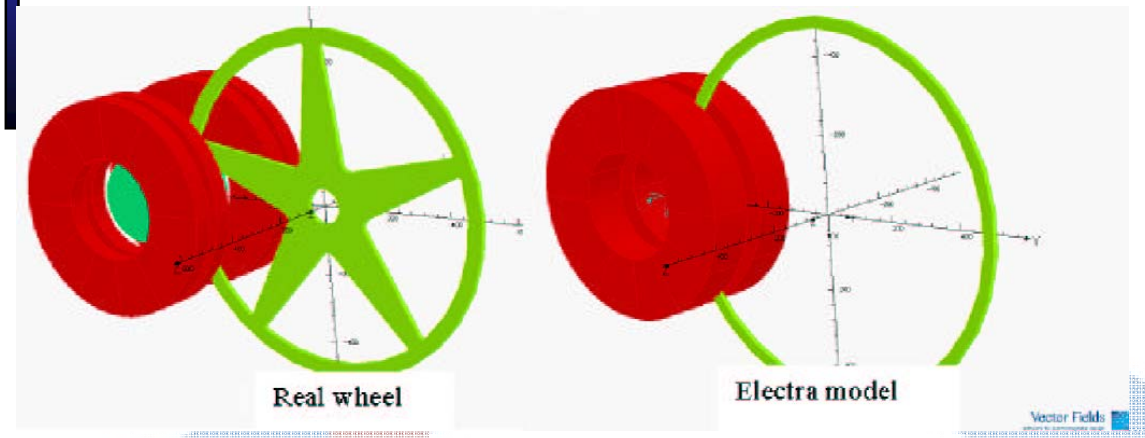


M. Woodward, RAL

Details of vertical drive for target wheel not yet considered.

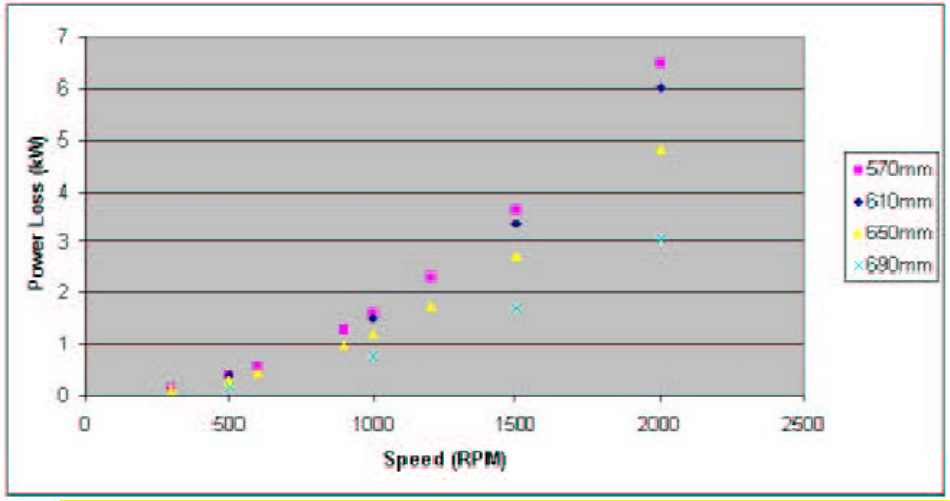
Module contains target, capture optics and first accelerating cavity.

Target Wheel Eddy Current Simulations



Immersed target ⇒ up to a factor 2.5 increase in capture efficiency c.f. QWT

L. Jenner, J. Rochford

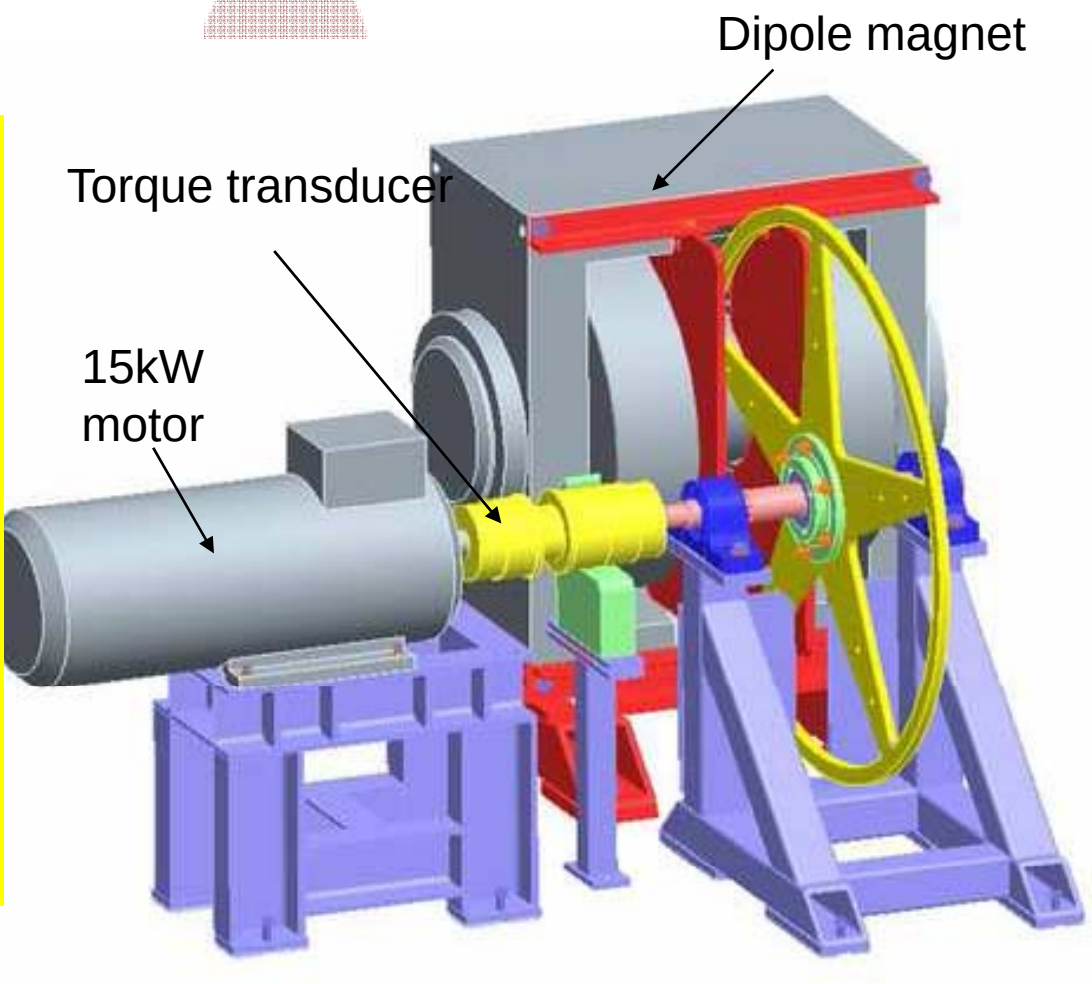


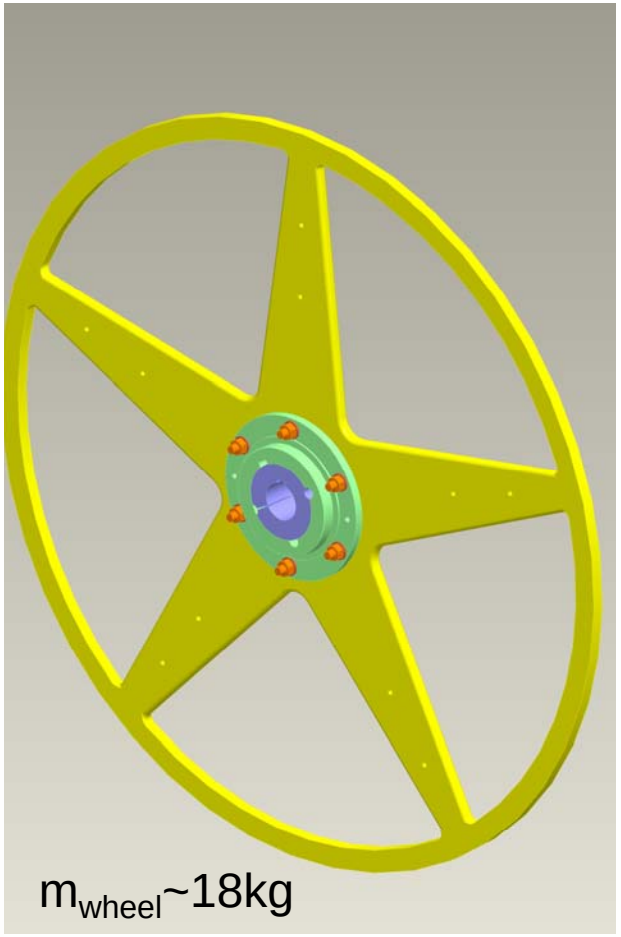
- **For 1T static field at ~2000rpm**
  - **RAL predicts ~6.6kW**
  - **ANL predicts ~9.5kW**
    - **S. Antipov PAC07 proceedings**
  - **LLNL predicts ~15kW?**
- **Difference not yet understood…**

⇒ Alternative capture optics, alternative materials, prototyping

Target Prototype Design

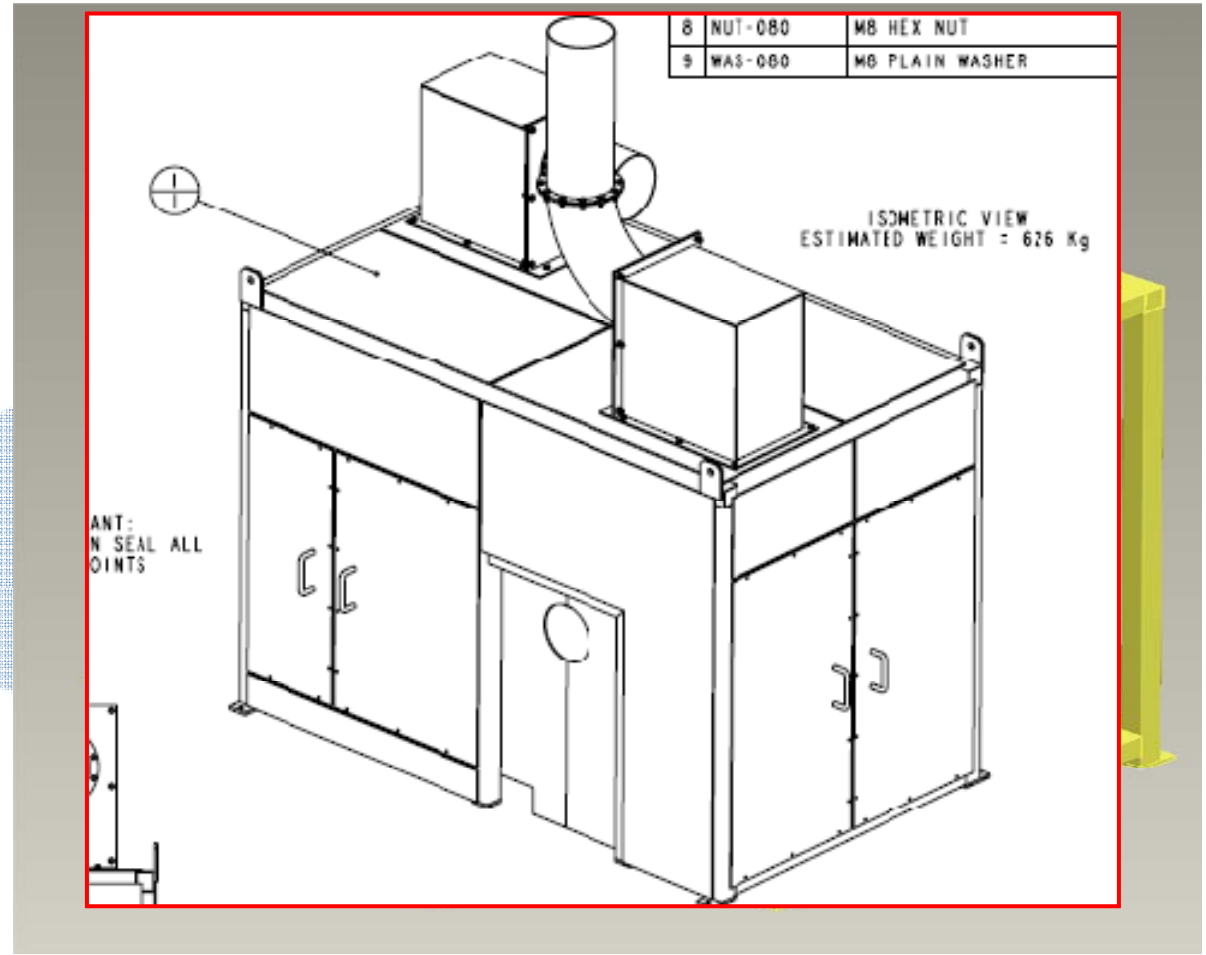
Prototype I - eddy current and mechanical stability





Ken Davies - Daresbury Laboratory

Target Prototype with Local Guarding Support Structure



Wheel design supported by rotordynamic and fatigue calculations from LLNL. Cross-checks carried out at RAL.

Guarding design supported by FEA studies at LLNL and analytical studies at the CI.

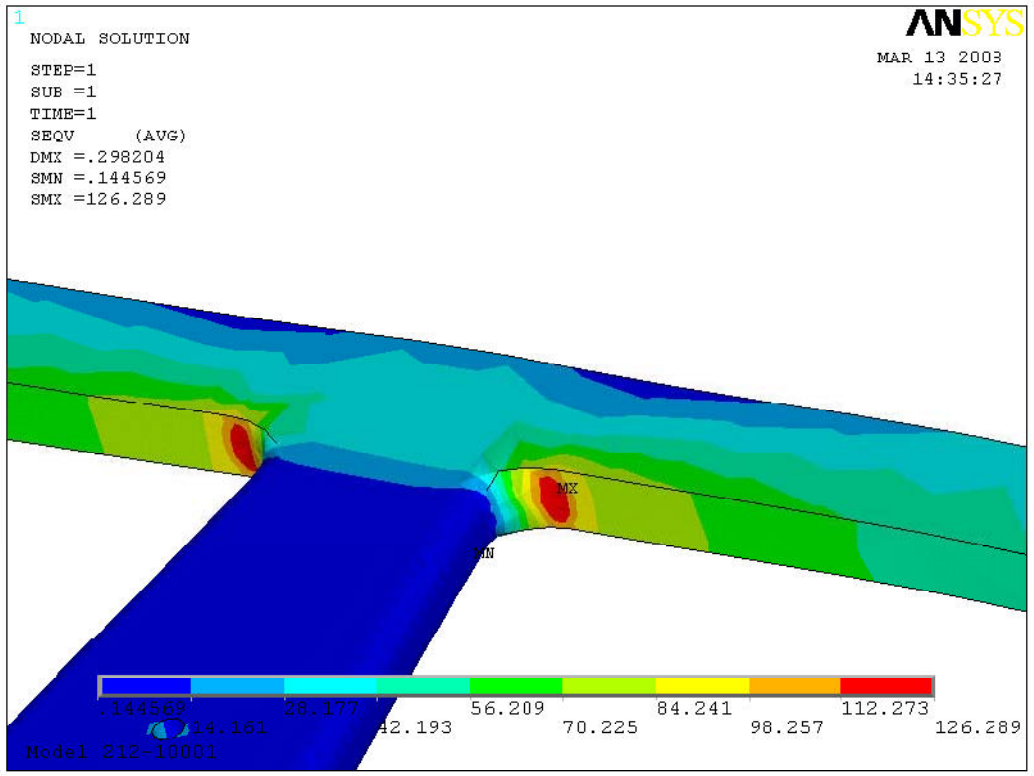
Ken Davies - Daresbury Laboratory

Mechanical Stresses on Target

Updated ANSYS simulation predicts maximum stress of 126MPa at 2000rpm.

Minimum tensile strength of grade 5 titanium alloys is 960Mpa.

In agreement with earlier LLNL simulations.



Chris Nelson - Rutherford Appleton Laboratory

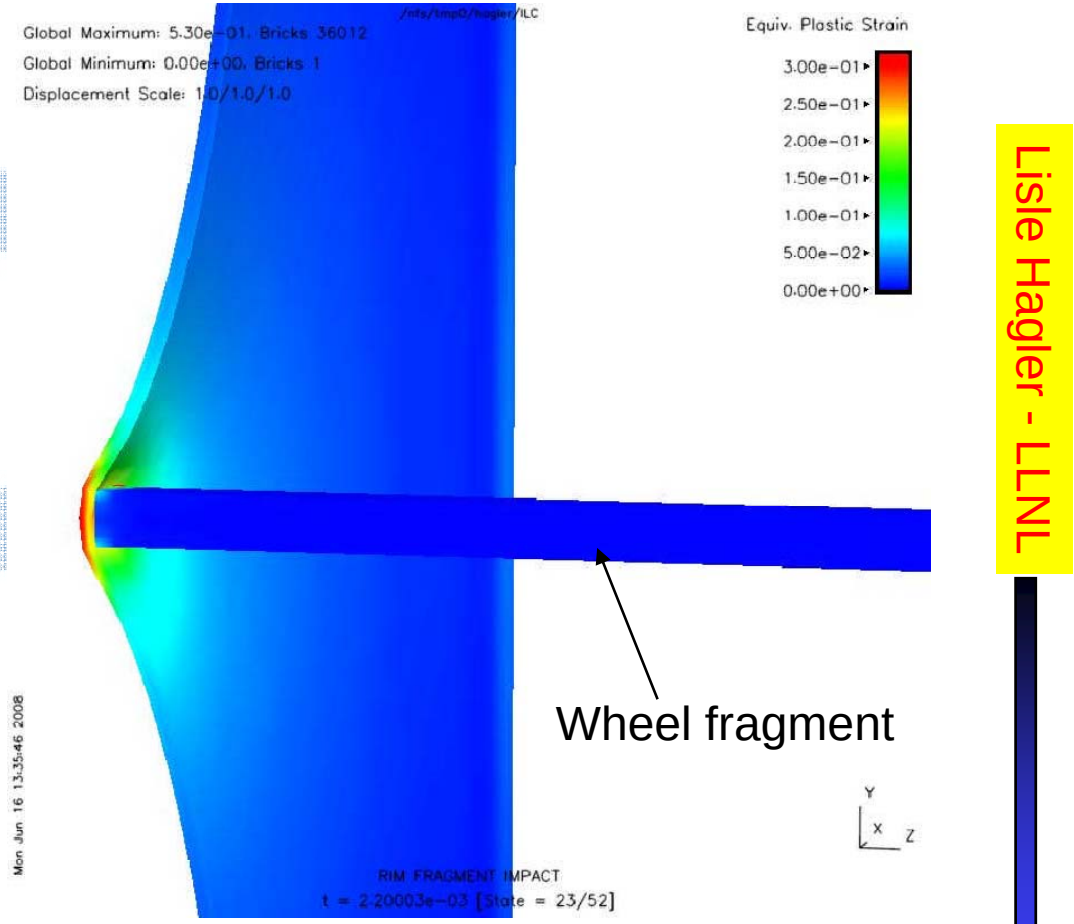
Shielding Thickness Determination

LLNL FEA model evaluation of mild steel SA-350, mild steel S275 and 304 stainless steel.

Final recommendation was for 5mm thick 304 stainless steel.

Recommendation supported by Aleksevski-Tate numerical model for erodable projectile striking semi-infinite target.

Additional sand bags will be used to protect personnel.



Lisle Hagler - LLNL

Target Prototyping Status

- Prototype funding in place until end 2008.
- Experimental area at DL allocated and caged (Summer 2007)
- Services rerouted (water and electricity)
- Magnet awaiting installation
  - model 3474-140 GMW water-cooled electromagnet
  - variable pole gap (0mm to 160mm)
- Drive motor (15kW) installed
- Ti alloy wheel manufactured and installed
  - Also possible Al wheel (grade 5083).
- DAQ design finalised
  - Accelerometers installed and **interlock fitted**.
  - **Torque transducer arrived Feb 08. Calibration ongoing.**
  - **Thermal cameras being evaluated (L. Zang + L. Jenner)**
  - Hall probes available
- Cooling system designed
  - Rim temperature estimated to reach 200°C for convective cooling in air.
- Local guarding designed (delivery expected 5th Sep 08)

Target Prototype Area

Limited to operating at speeds of 60 rpm or less due to health and safety regulations until guarding installed.

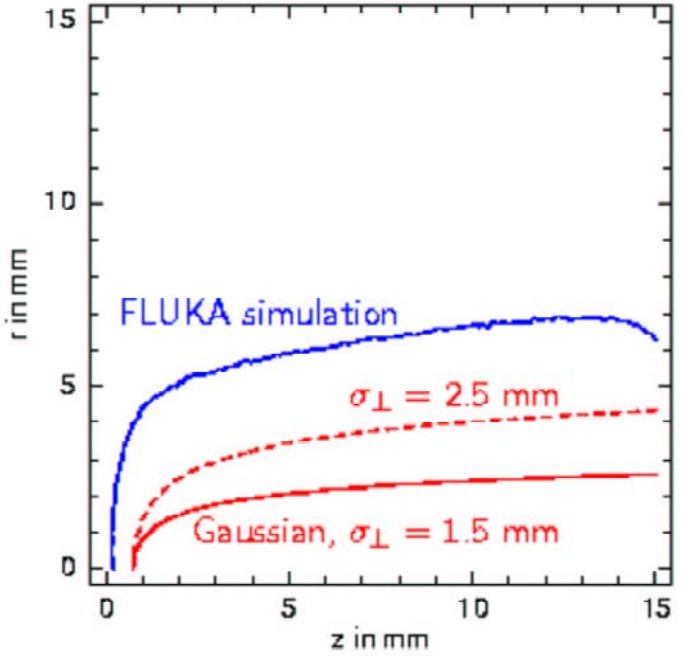
Leo Jenner - University of Liverpool

Experiment Programme

- Balancing and initial commissioning ~Nov 07
- Operation of wheel without magnet ~Dec 07
  - Calibrating transducers and DAQ
- Operation of wheel in magnetic field ~Oct to Dec 08
  - Systematic scan of field strength (0T to 1T in 0.2T steps)
  - Systematic scan of ang. vel. (0rpm to 2000rpm in 50rpm steps)
  - Avoiding critical speeds.
  - Torque and temperature readings to be compared with predictions.
  - Immersion depths
- Additional investigations using aluminium wheel or modifying conductivity of wheel rim also possible.
- Experiment complete by Dec 08.

Thermal Shock Studies

- Target survivability concerns raised by A. Mikhailichenko at ANL positron source meeting in September ’07.
- Simulations showed target failure after one pulse due to negative pressure developed by shock wave on downstream side of target.
- In contradiction with earlier studies by LLNL (e.g. LCC-0088, W. Stein et al).
- S. Hesselbach at Durham has started a study of this issue.
- Initial test of Cornell model assumptions suggests that the density of deposited energy is over-estimated.
- Further modelling ongoing.



Contours showing 90% energy deposition for a FLUKA simulation and the Cornell Gaussian assumption.

PTCD Deliverables Status

- No formal deliverables, but we had planned to deliver four reports:
- Report on conversion target analyses.
  - Work complete (RDR).
- Engineering design of conversion target
  - Many engineering drawings already exist.
  - Cannot be a final design as too many open questions for positron source.
  - EUROTeV work focussed on prototype (EUROTeV-2008-028)
  - Hope to produce final EUROTeV report by end of year
- Report on collimator analysis (EUROTeV-2008-029)
- Engineering design of collimator
  - Low priority for positron source.
  - Completion in 2008 not envisaged.

Beyond EUROTeV

- Determine optimal target wheel material and expected lifetime.
  - Study short time-scale processes (energy deposition and shock wave dynamics).
  - Study long time-scale processes (effects of prolonged radiation, stress and heating).
  - Investigate alternative target materials.
- Validate target wheel design: cooling system, etc
  - Rotating-coupling validation (vacuum, radiation, and magnetic field).
  - Water-union validation
  - Cooling channel validation (prove manufacturing process and cooling rates)
  - Evolve target wheel drawings.
- Determine target wheel environment: vacuum studies, etc
  - Beam windows studies
  - Vacuum simulations.
  - Vacuum design.
  - Target assembly drawings.
- Design instrumentation and control systems
  - Instrumentation design
  - Control system design

Exploring opportunities on CLIC positron source.