EDR Positron Source KoM,
CI, Oct 2007

Pair-Production Target

Ian Bailey

University of Liverpool / Cockcroft Institute

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

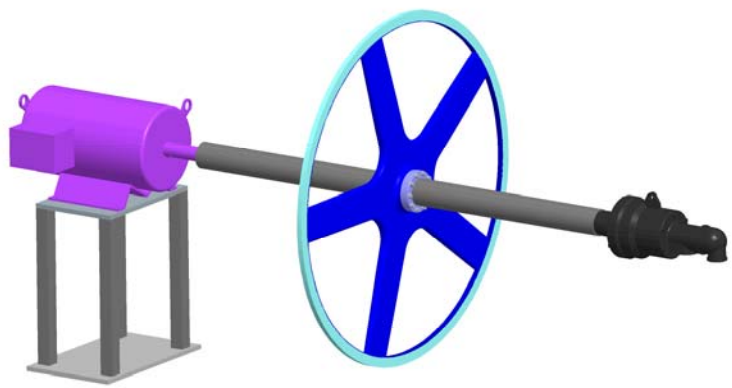
•Wheel diameter (~1m) fixed by radiation damage and capture optics

•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.



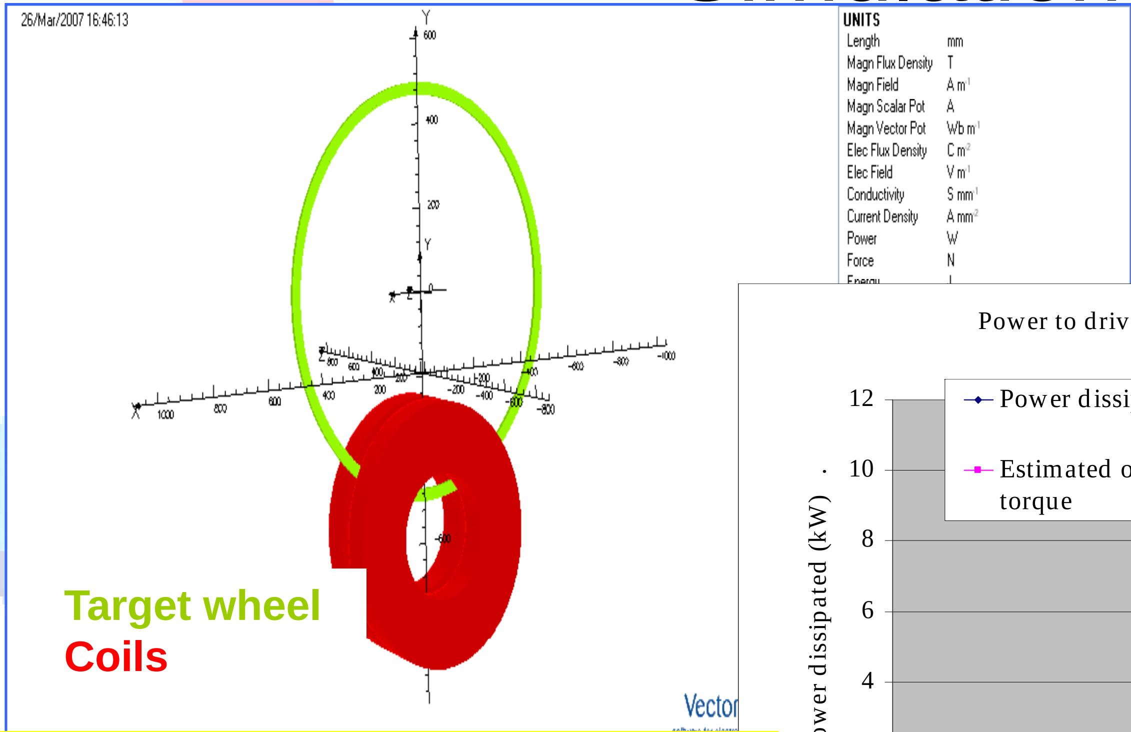
T. Piggott, LLNL

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

Current Baseline Target Activities

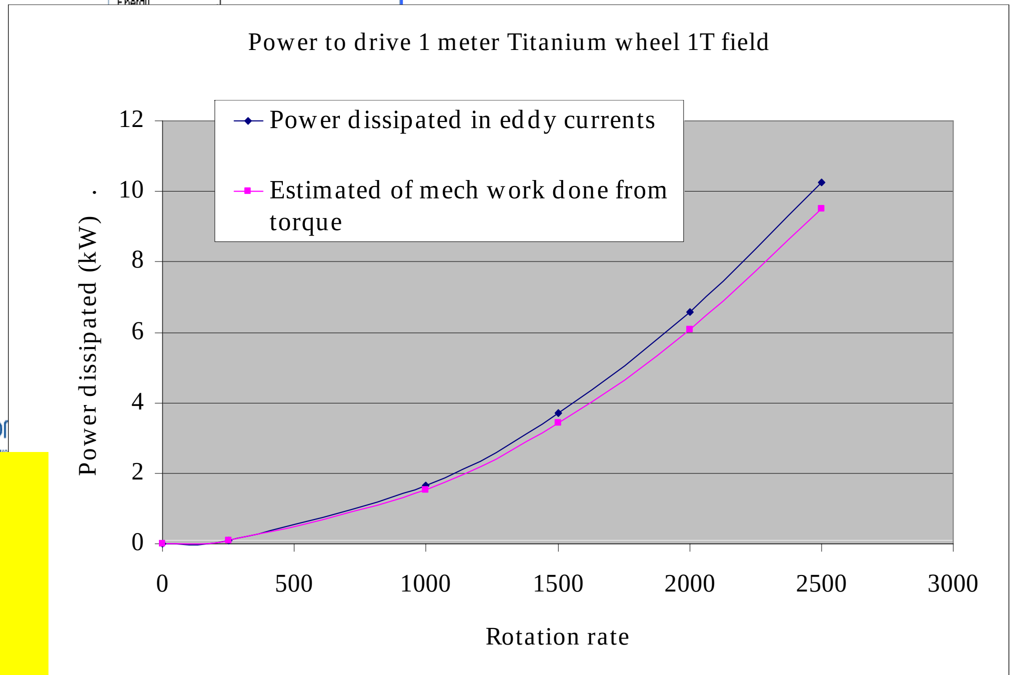
- Prototyping
- Simulation
  - Eddy currents
  - Rotordynamics
  - Fatigue modelling (microstructure)
  - Thermal modelling
  - Thermal stress simulations (shock waves)
  - Radiation damage modelling
  - Activation modelling (see target hall)

RDR Target Wheel Eddy Current Simulations



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

J. Rochford, RAL

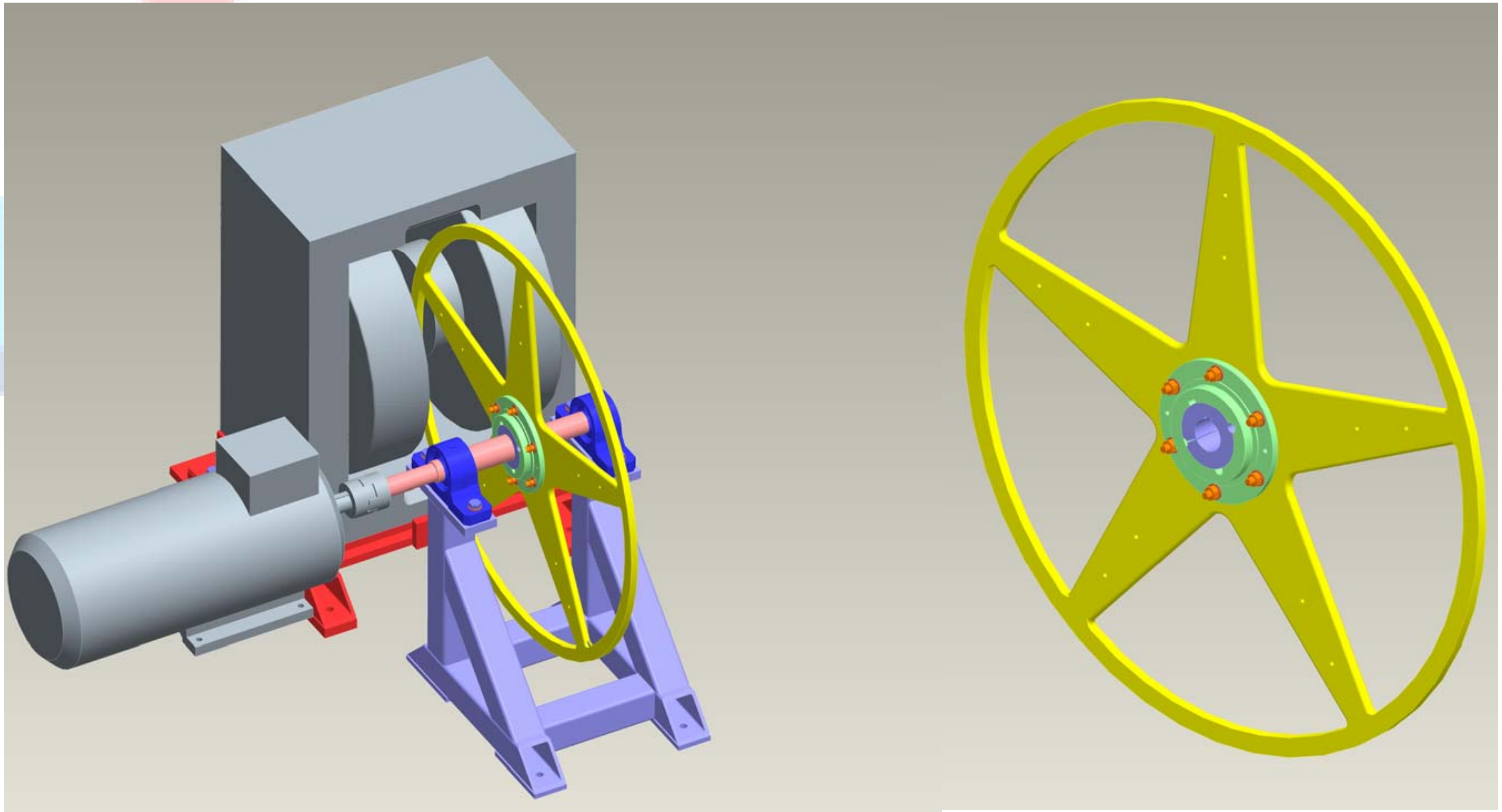


- **For 1T field at ~2000rpm**
  - **RAL predicts ~6.6kW**
  - **ANL predicts ~9.5kW**
  - **LLNL predicts ~15kW?**
- **Difference not yet understood…**

⇒ Alternative capture optics, alternative materials, prototyping

Target Prototype Design

Prototype I - eddy current evaluation



Ken Davies - Daresbury Laboratory

Target Prototyping Status

- Experimental area at DL allocated
  - Area caged. Services (water cooling, etc) available.
- Magnet has been sourced
  - Model 3474-140 GMW water-cooled electromagnet
  - Variable pole gap (0mm to 160mm)
- Drive motor (15kW) purchased
  - Interlock circuit designed and under construction
- Ti alloy wheel is being manufactured
  - Delivery expected in next couple of weeks
  - Also possible Al wheel (grade 5083).
- Assembly to begin Oct '07
- Most instrumentation ordered
  - DAQ design still being finalised
- Cooling system not yet designed
  - Rim temperature estimated to reach 200°C for convective cooling in air.
- Guarding being designed

Experiment Programme

- Balancing and initial commissioning ~Nov 07
- Operation of wheel without magnet ~Dec 07
  - Calibrating transducers and DAQ

Cooling needed

- Operation of wheel in magnetic field ~Jan to Mar 08
  - Systematic scan of field strength (0T to 1T in 0.2T steps)
  - Systematic scan of ang. vel. (0rpm ro 2000rpm in 50rpm steps)
  - Avoiding critical speeds.
  - Torque and temperature readings to be compared with the predictions of computer simulations.
  - Optionally scan immersion depths
- Long-term operation of wheel to monitor stability ~Apr 08
- Additional investigations using aluminium wheel
- Experiment complete by May 08.

Flywheel Critical Speeds
(Stainless Steel Drive Shaft)

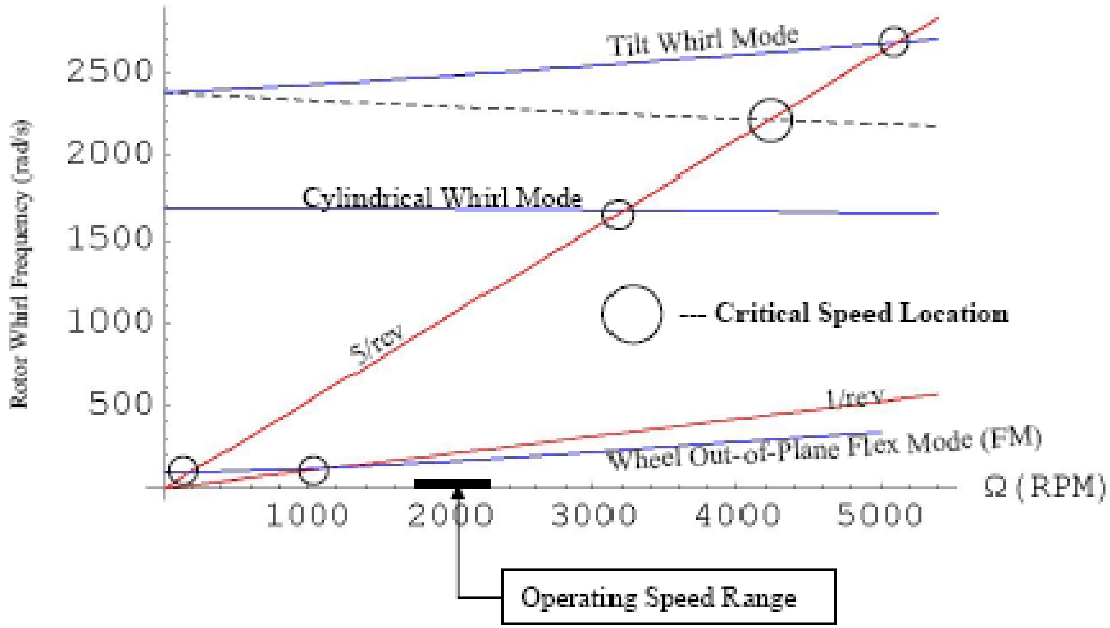
Nominal Design Basis Bearing + Mount Stiffnesses

Support Translational Stiffness = 1,000,000 lbf/in   Support Rotational Stiffness = 10,000 lbf*in/rad

Sources of Rotor Excitation

- Lorentz Force @ 5/rev
- Unbalance @ 1/rev

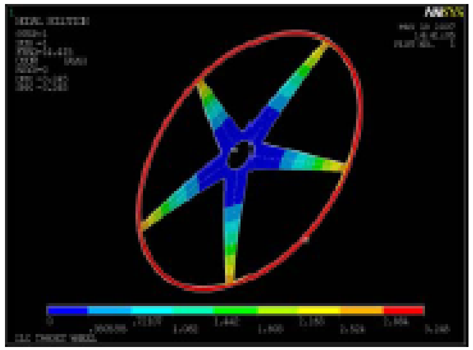
Campbell Diagram



Major Critical Speeds

- 1st Wheel FM @ ~ 200 RPM
- 2nd Wheel FM @ ~ 1100 RPM
- Cylindrical Whirl @ ~ 3200 RPM
- Forward Tilt Whirl @ ~ 5000 RPM
- Reverse Tilt Whirl @ ~ 4200 RPM

Wheel Out-of-Plane Flex Mode



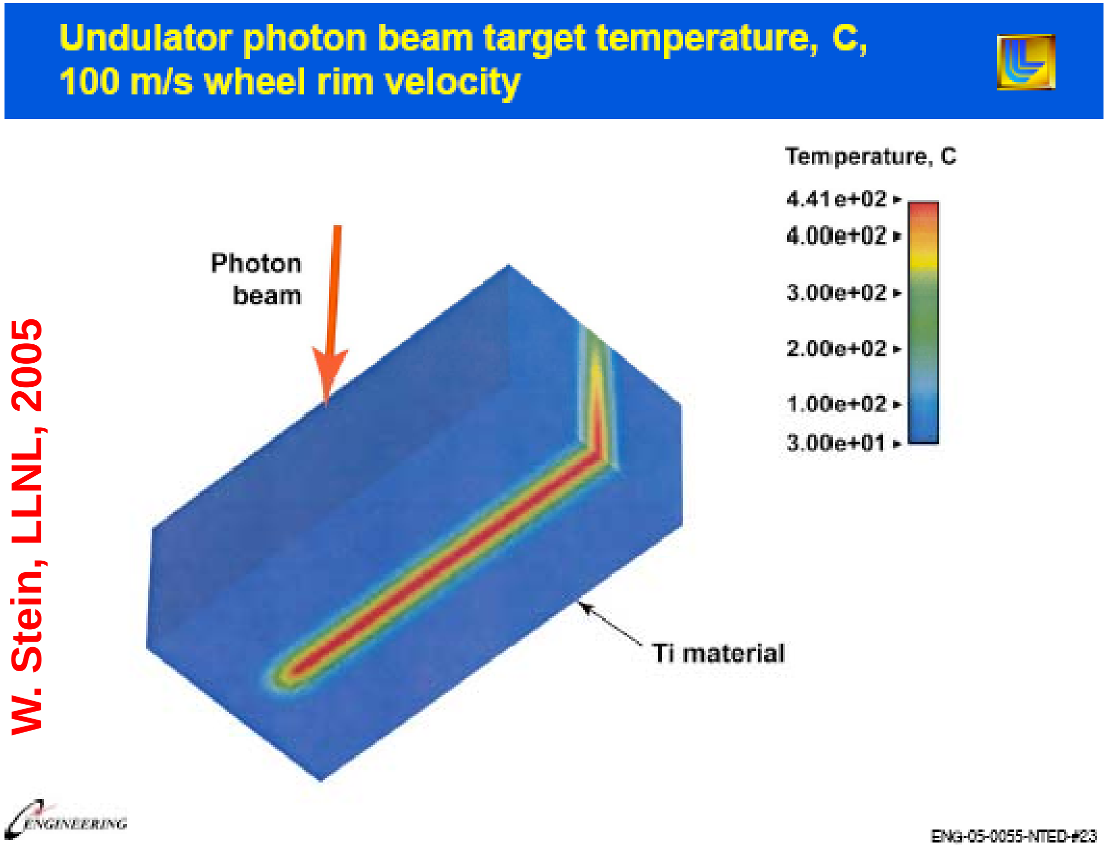
- **All critical speeds sufficiently far removed from operating speed range**

Figures show rotordynamics for prototype

(same studies carried out for RDR target wheel)

T. Piggott, L. Hagler LLNL

Thermal Stress / Shock



W. Stein, LLNL, 2005

TOPAZ-3D and DYNA-3D simulations

- **Rapid energy deposition generates a pressure shock wave**
- **Maximum stress is experienced at the back surface of the target**
- **For older beam parameters (small beam spot), peak stress was ~4x10^{8}Pa**
- **This is a factor of two below the yield stress**
- **Simulation is being re-evaluated with updated parameters and target design.**
- **Disagreement between Cornell and LLNL results**

Outstanding issues that could lead to design change

- Target shock wave studies
  - Beam tests (TTF?)
- Eddy currents and target immersion
- Downstream beam window survival
  - Gas cooling between two windows?
- Vacuum studies
- Rotating coupling performance / radiation hardness
- Water union and cooling channels
- Radiation damage studies
  - Wheel size

} Alternative target materials

Alternative Targets and Materials

- Machiolated Ti alloy rim (eddy current studies)
- W-Re
  - LLNL studies indicate shock wave problems
- Hybrid
  - E.g. W-Re wheel with Ti alloy rim
  - How to cool rim?
- Ceramics (eddy current studies)
  - Initial study carried out at RAL

Continue in EDR phase

- Graphite
  - High density graphite wheel exists at BINP
  - Radiative cooling
  - Probably not suitable for ILC
- Liquid metals
  - Cornell Pb-Bi and Hg designs (cavitation and window survival)
  - BINP liquid Pb design (not suitable for ILC)

Target EDR Phase

- Scope of work package
  - Everything inside the target vacuum vessel excluding the capture optics
- Drive
- Cooling
- Target wheel
- Vacuum Vessel/ Hall Integration
- Instrumentation/Controls

Drive

- Vibration/Rotordynamics
- Ferrofluidic seals
- Mechanical Simulations
- Drawings

Cooling

- Water union coupling to driveshaft
- Cooling channel techniques
- Drawings
- Simulation
- Alternatives
  - Radiative cooling (of Ti alloy)

Target Wheel

- Physics simulations
- Thermal/Mechanical simulation
- Failure analysis
- Material property changes (thermal/radiation degradation)
- Design & drawings

Instrumentation/Controls

- Accelerometers/vibration sensing
- Torque transducer
- Temperature sensing
- Cooling flow sensors
- Motor diagnostics
- Coupling with fast/safety controls and shutoffs
- Design and specification

Vacuum Vessel/ Hall Integration

- Vacuum seals
- Vessel design
- Achievable vacuum studies
- Coupling with services
- Beam windows

Summary

- Current initatives need to continue into EDR phase
  - Eddy currents
  - Thermal studies (material tests, etc)
- New initiatives required
  - Vacuum studies (seal tests, etc)
  - Instrumentation and controls
- Could organise work by system or by issue