Positron Source Technology R&D

Jeff Gronberg / LLNL

November 11, 2010

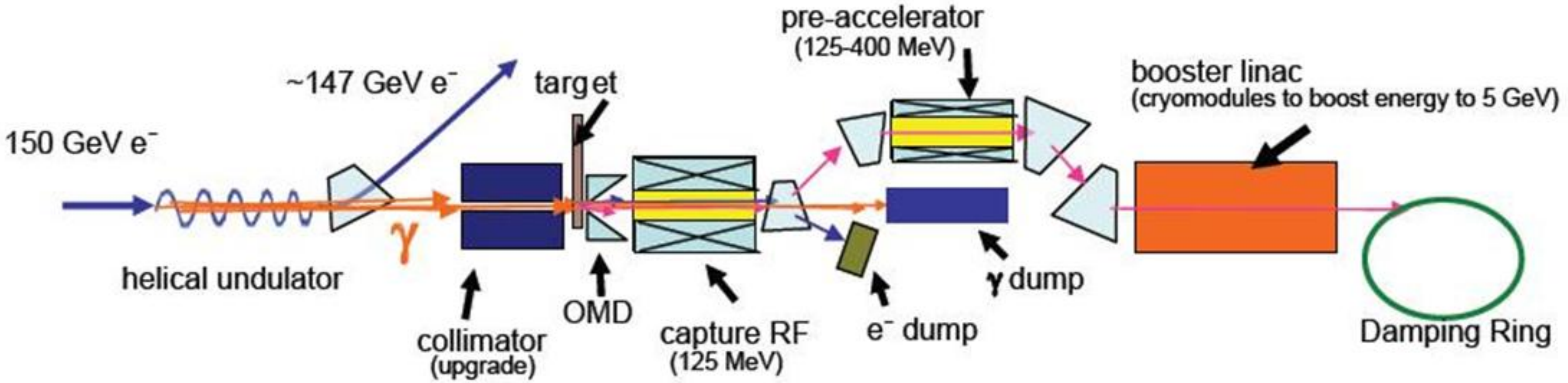
ILC PAC meeting – Eugene Oregon

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

ILC has a new approach to positron generation using helical undulators to create a photon beam

Helical undulator to generate a circularly polarized photon beam

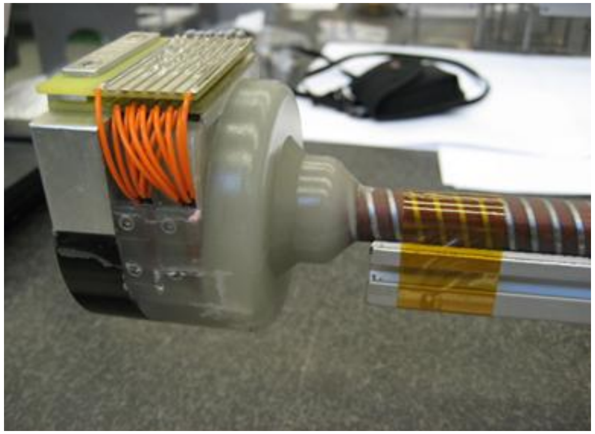
Optical Matching Device to get high capture efficiency

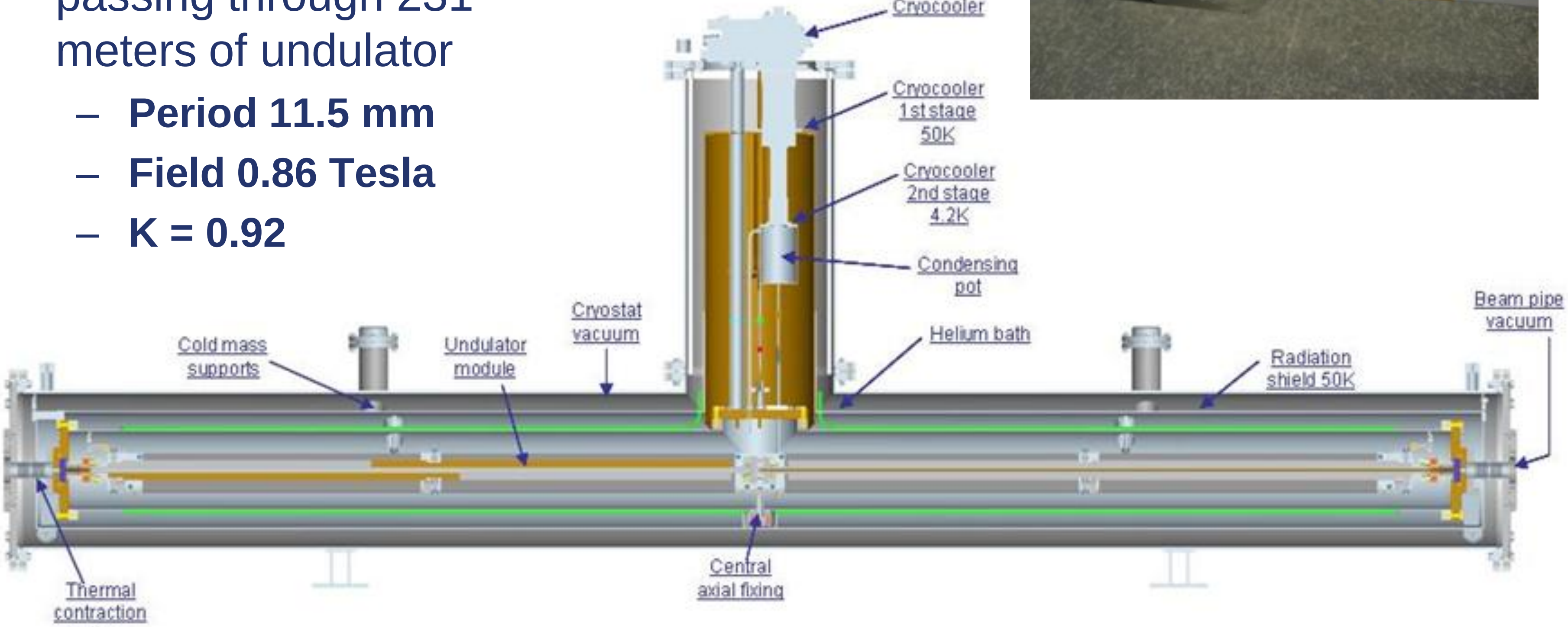


Rotating target to smear out the long 1ms pulse

Helical collaboration is designing and prototyping a 4 meter undulator unit

- Alternating helical windings carry opposite currents
- 150 GeV electron beam passing through 231 meters of undulator
  - **Period 11.5 mm**
  - **Field 0.86 Tesla**
  - **K = 0.92**

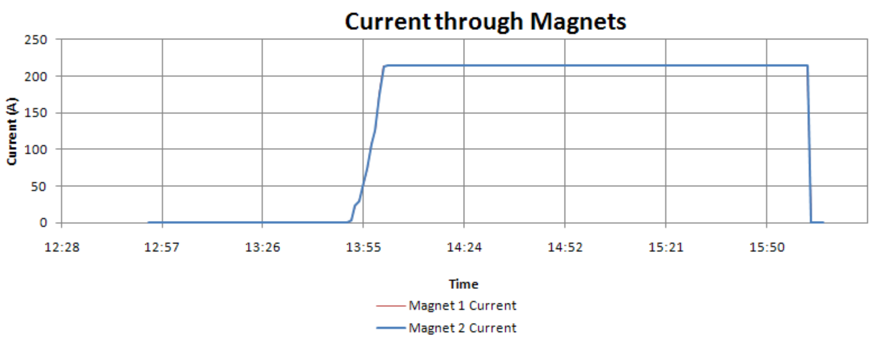


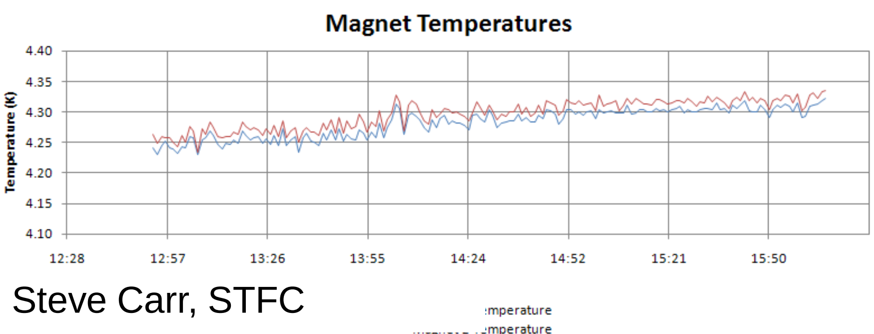


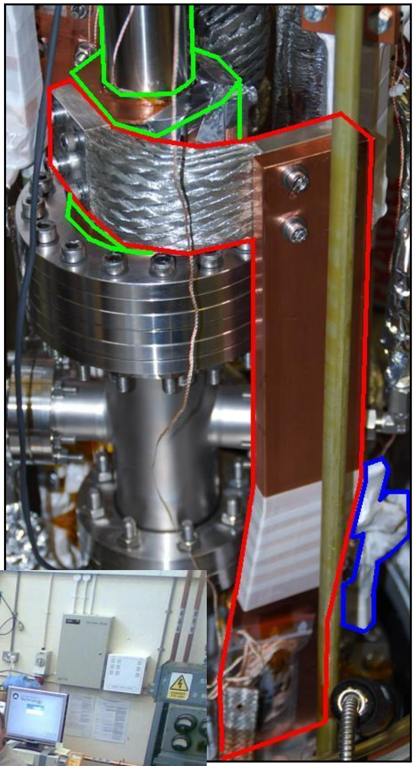
Owen Taylor, HELICAL collaboration, 6th ILC positron source meeting

Undulator Cryomodule Prototype

- **Both undulators now powered individually and together at 215 A (0.86T) – stable for 2 hours**
- Both also powered at 252A for > 1hour but then **lead quenched above top plate**
  - **Not enough margin on top plate temperature at high current?**
  - **No magnet quenches so far**





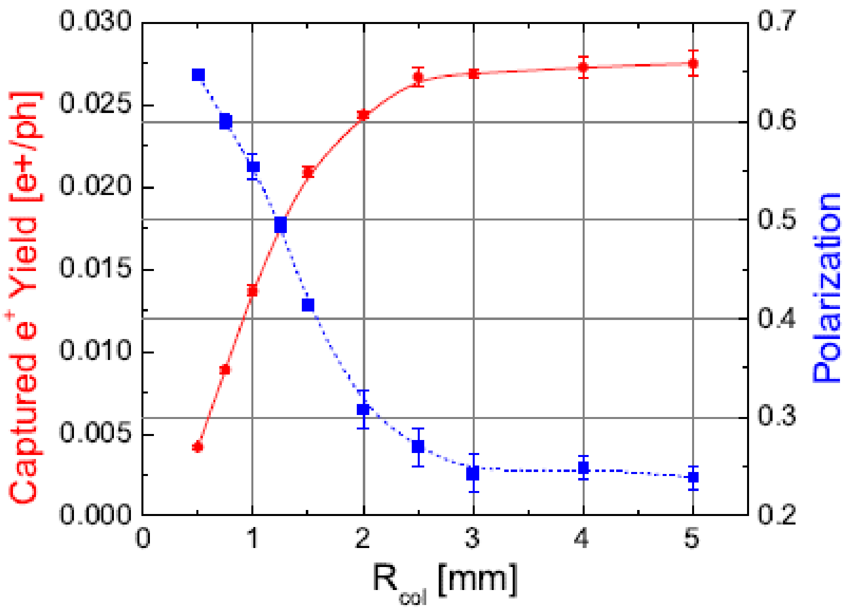


Steve Carr, STFC

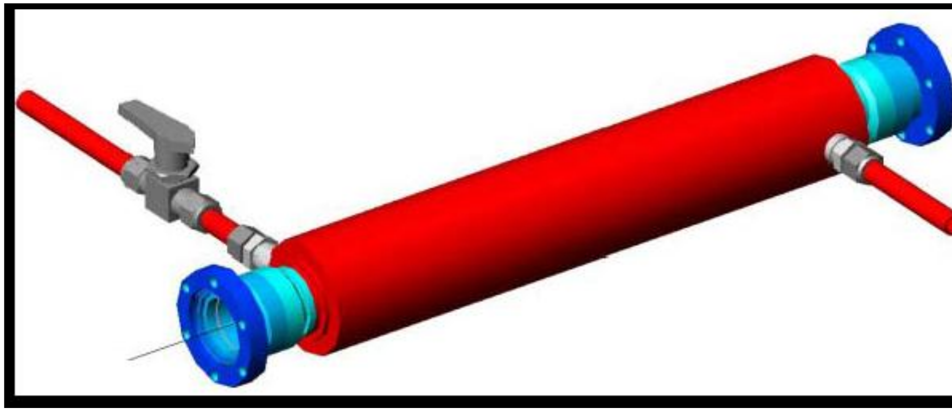
Photon Collimator

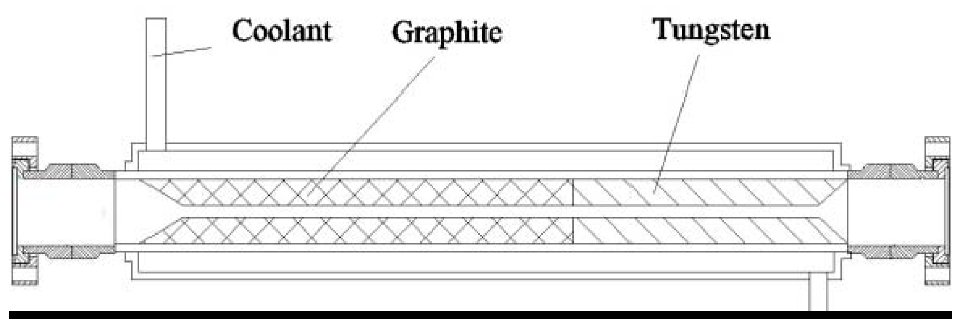
Recommendation from ILC positron source meeting in Durham (2009) was to include a tungsten/graphite collimator of radius 2mm.

Yield and Polarization vs Aperture Radius of Photon Collimator



A. Ushakov, DESY

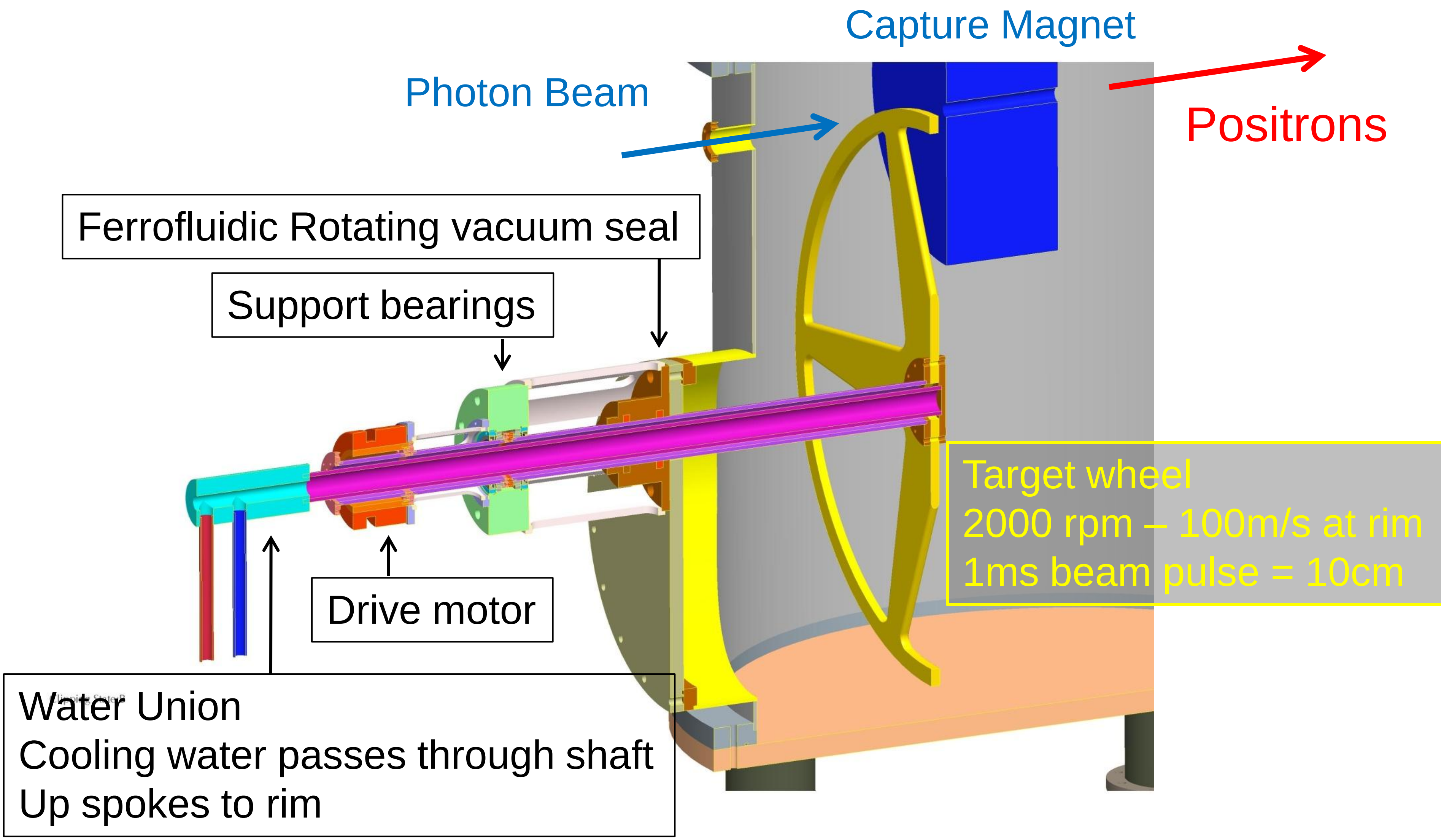




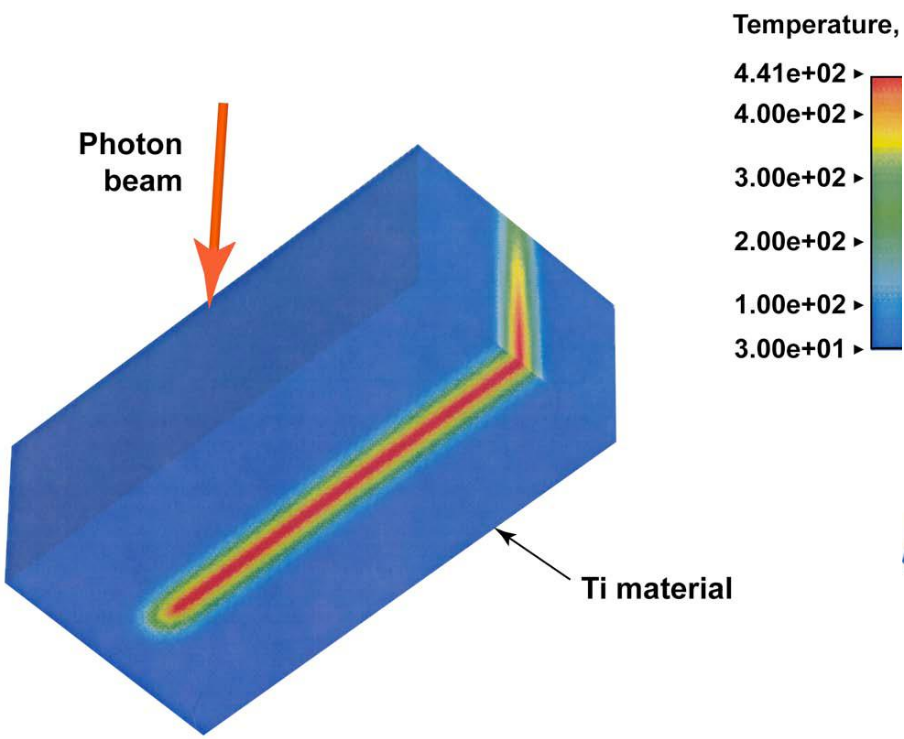
Same specification works for SB2009 (2.5kW in collimator)

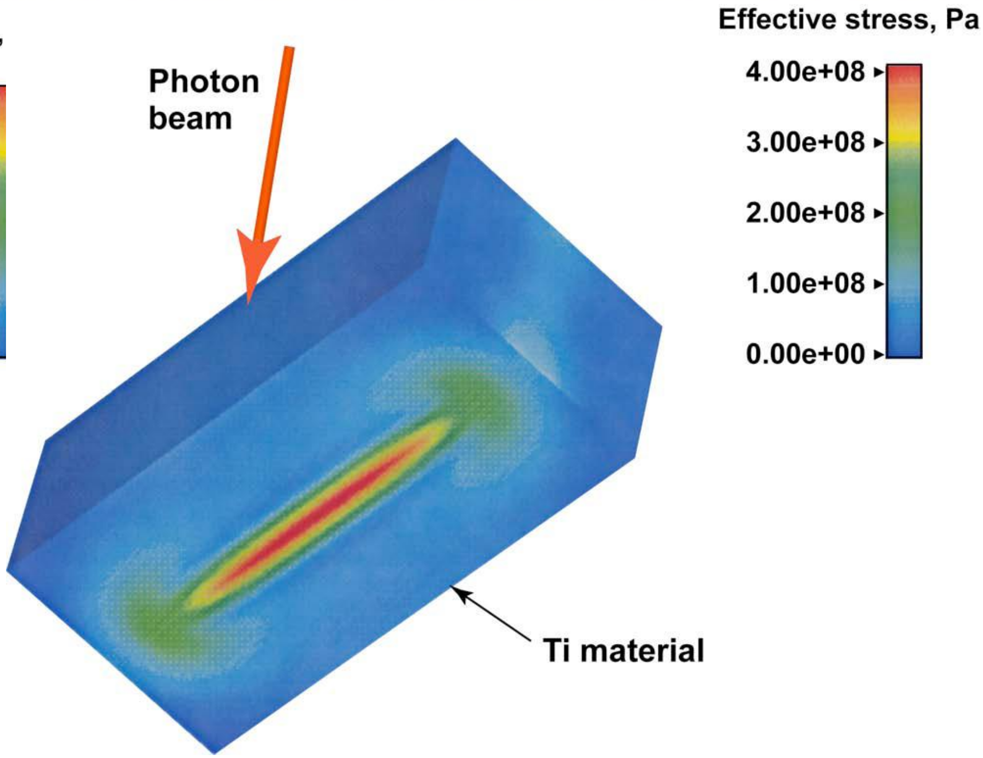
https://znwiki3.ifh.de/LCpositrons/CollimatorDesign

Basic layout of the target



Rotation disperses the energy of the 1ms pulse over 10cm of the rim





- 100 m/s rim speed
- Maximum temperature is 441C

- Yield strength of Ti is 12.0e8 Pa
- Calculation give 4.0e8
- Maximum radiation damage 0.5 displacements per atom per year of operation

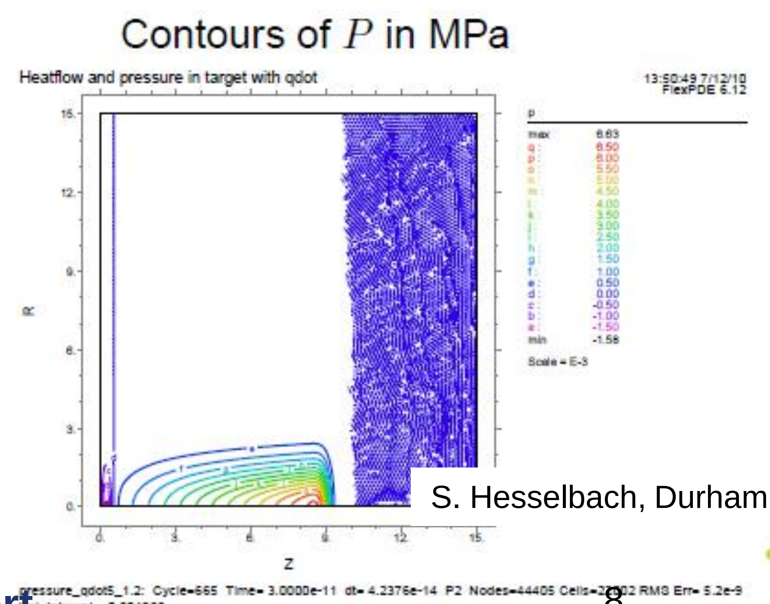
Werner Stein, LLNL, Daresbury positron workshop 2005

Shockwaves in the target

- Energy deposition causes shockwaves in the material
  - **If shock exceeds strain limit of material chunks can spall from the face**
- The SLC target showed spall damage after radiation damage had weakened the target material.

- Initial calculations from LLNL had shown no problem in Titanium target
- Two groups are trying to reconfirm result
  - **FlexPDE (S. Hesselbach, Durham → DESY)**
  - **ANSYS (L. Fernandez-Hernando, Daresbury)**
  - **No definative results yet**
- Investigating possible shockwave experiments
  - **FLASH(?)**
  - **https://znwiki3.ifh.de/LCpositrons/TargetShockWaveStudy**

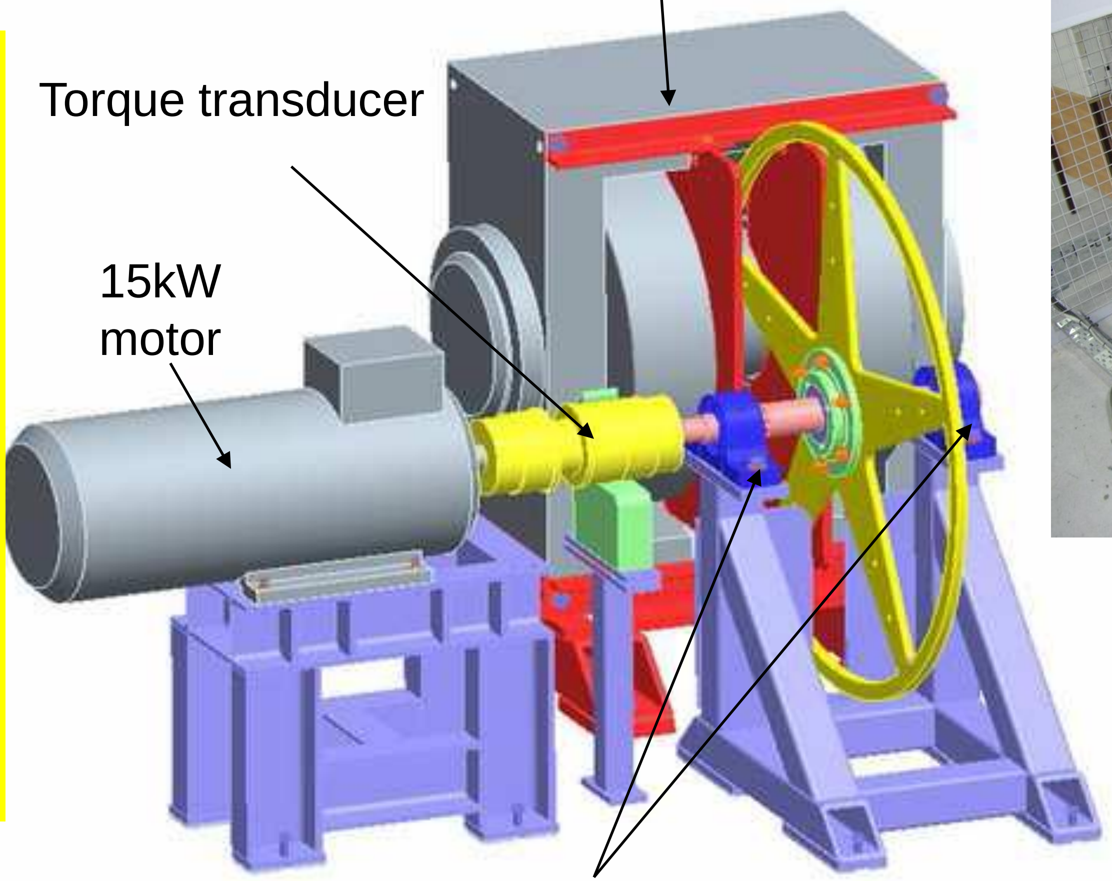

SLC positron target after decommissioning



S. Hesselbach, Durham

Prototype I - eddy current and mechanical stability

Ken Davies - Daresbury Laboratory



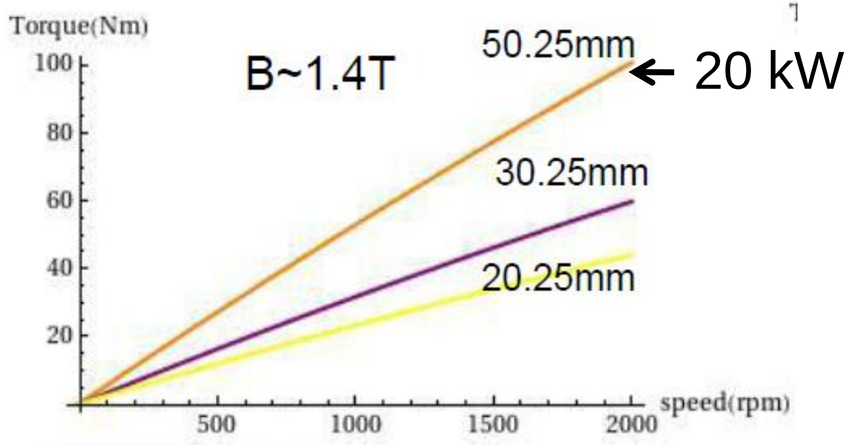
Daresbury Prototype Target wheel
Solid Ti - No cooling

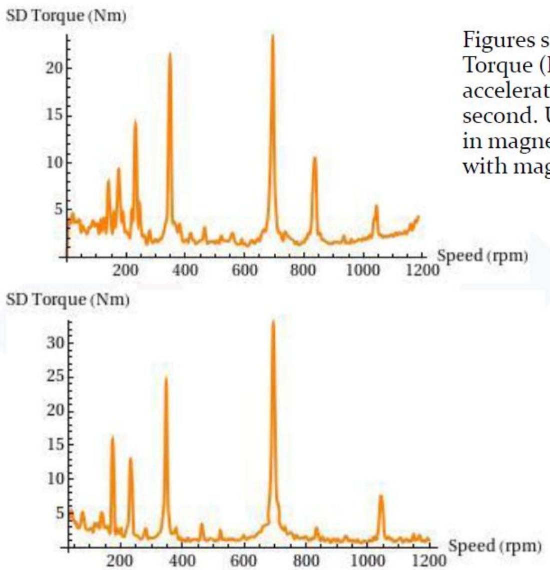
- Test – Rotordynamics
- Test – Mechanical stability
- Benchmark – Eddy current heating from capture magnet

Ian Bailey, ILC collaboration meeting 2010

Prototype I has finished data taking and has been a success

- Eddy current losses have been benchmarked. Stray fields from the capture magnet of 1.4T can be accommodated.
  - **Eddy current simulations are still not very accurate**
- Resonances in the wheel are consistent with predictions
- No problems with the rotating target up to 1800 rpm
  - **Higher speeds were not feasible in air**



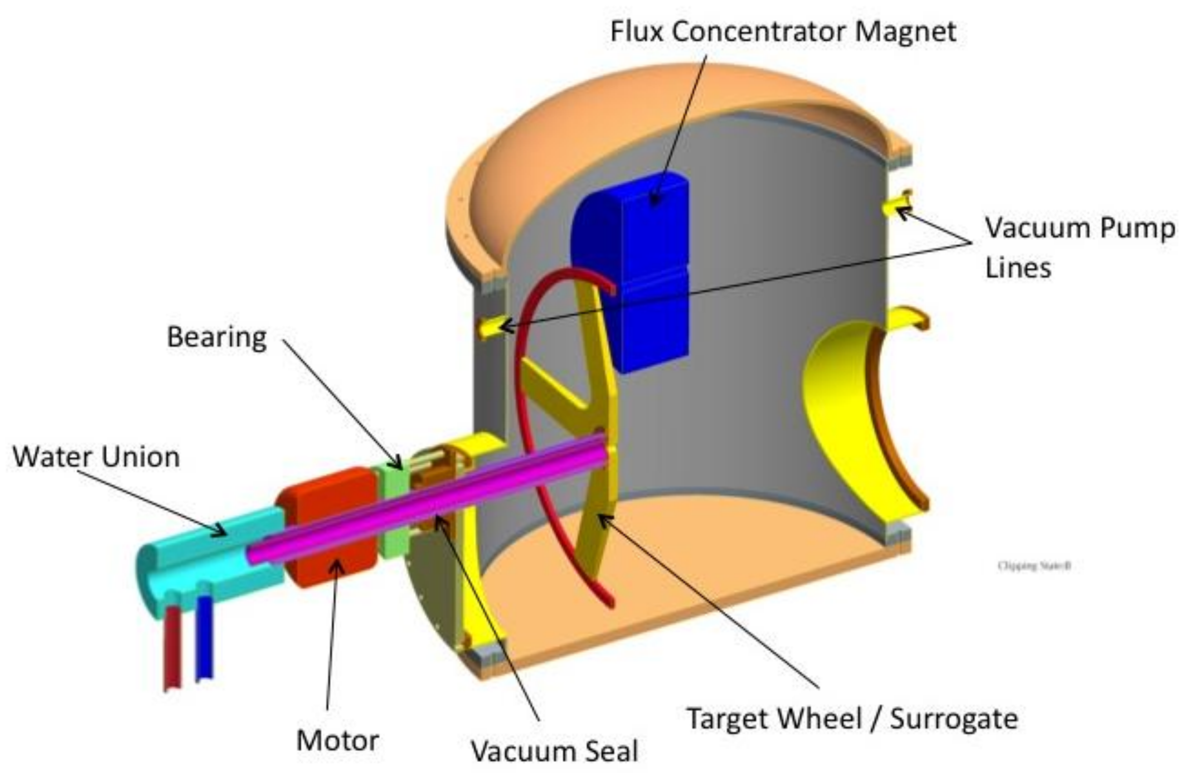


Figures show Standard Deviation in Torque (Nm) measured whilst accelerating at average rate of 6.6 rpm / second. Upper plot obtained with 50A in magnet coils. Lower plot obtained with magnet unpowered.

Ian Bailey, 6th positron source collaboration meeting 2009

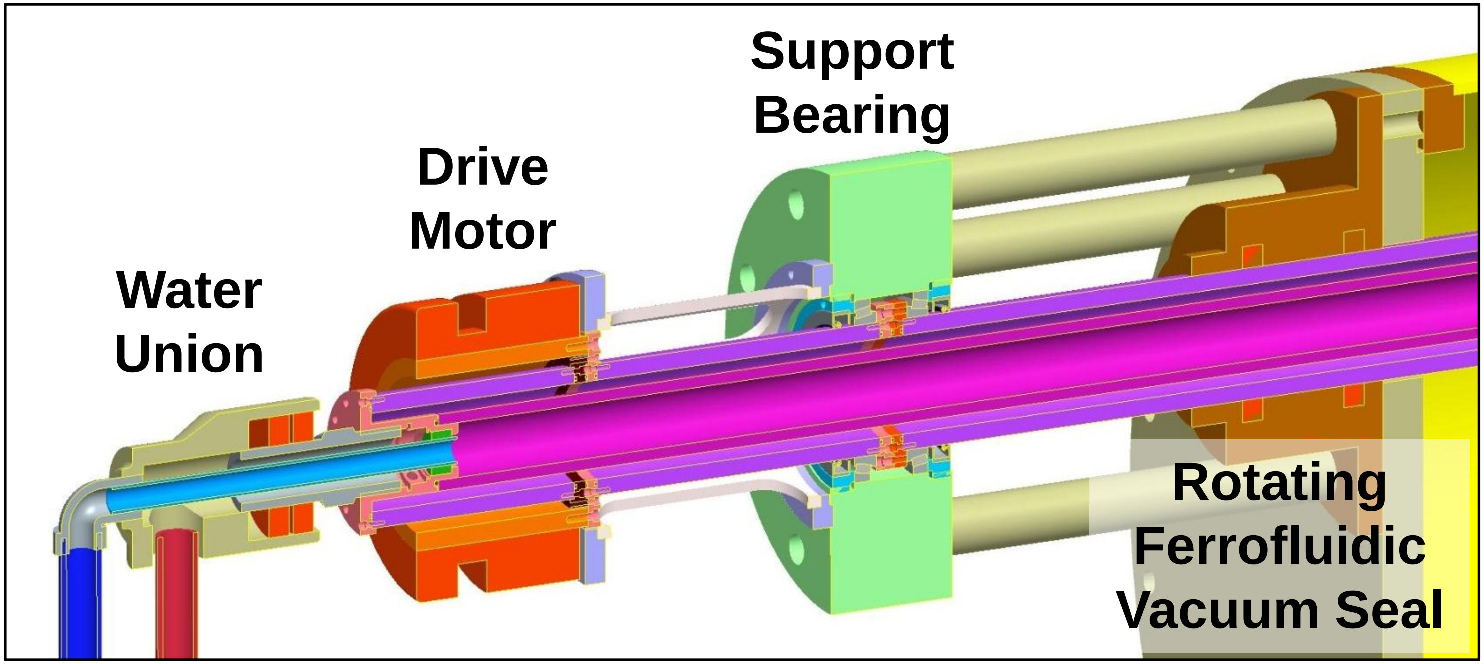
Target Prototype

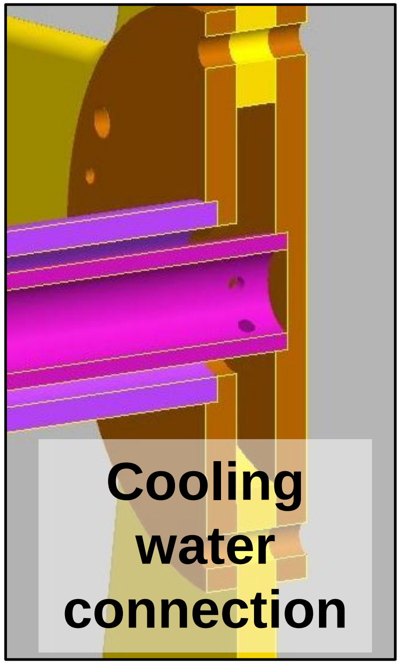
Prototype II - Rotating vacuum seal test



- Current design has rotating ferrofluidic vacuum seals
- Cooling water flows along the shaft
- Test leakage of vaccum/fluids from:
  - **Vibration**
  - **Magnetic field effects**

Vacuum seal test





- Altered layout after discussions with Rigaku
- Single-shaft design, larger bore
- Hollow shaft motor Rigaku has used previously
- Water union may not be in this test configuration
    - Daresbury prototype wheel does not have cooling channels
    - Water in shaft only

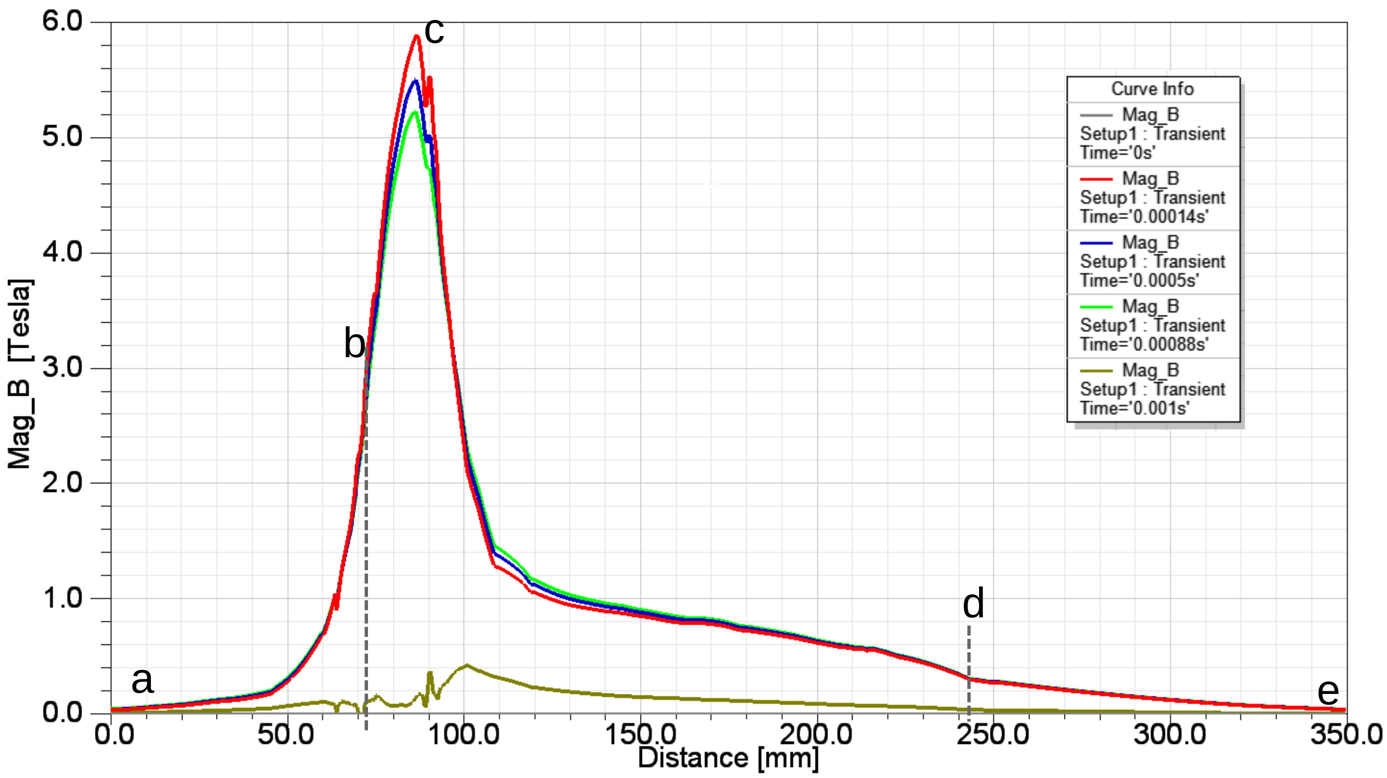
Vacuum seal test

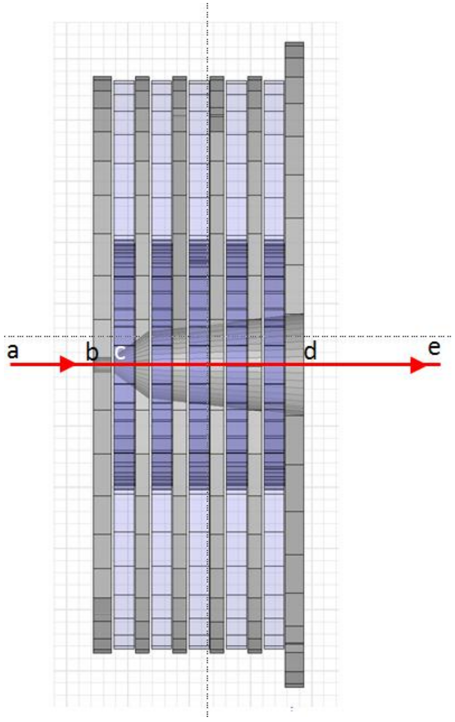
- Rotordynamics analysis and design for cantilevered layout
  - **Changed layout from Daresbury test**
  - **Requires re-evaluation of vibration modes due to new components and configuration**
- Diagnostics setup (pressure sensors, filter and witness plate chemical analysis, mechanical behavior)
- Developing drawings
- Acquire LLNL ES & H approval for operating plan

Cryogenic Pulsed Flux Concentrator

- Flux Concentrator is the RDR baseline
  - **The more conservative QWT was used for recent studies**
- 1 millisecond pulsed flux concentrator is desired to increase capture efficiency
  - **Reduced number of undulators**
  - **Lower photon beam power on target**
    - Reduced stress and power on target
    - Reduced radiation load on target
    - Reduced radiation load in the accelerating sections
- Previous liquid nitrogen cooled, 40ms pulsed flux concentrator built and operated by Brechna at SLAC
  - **We have started from that design**

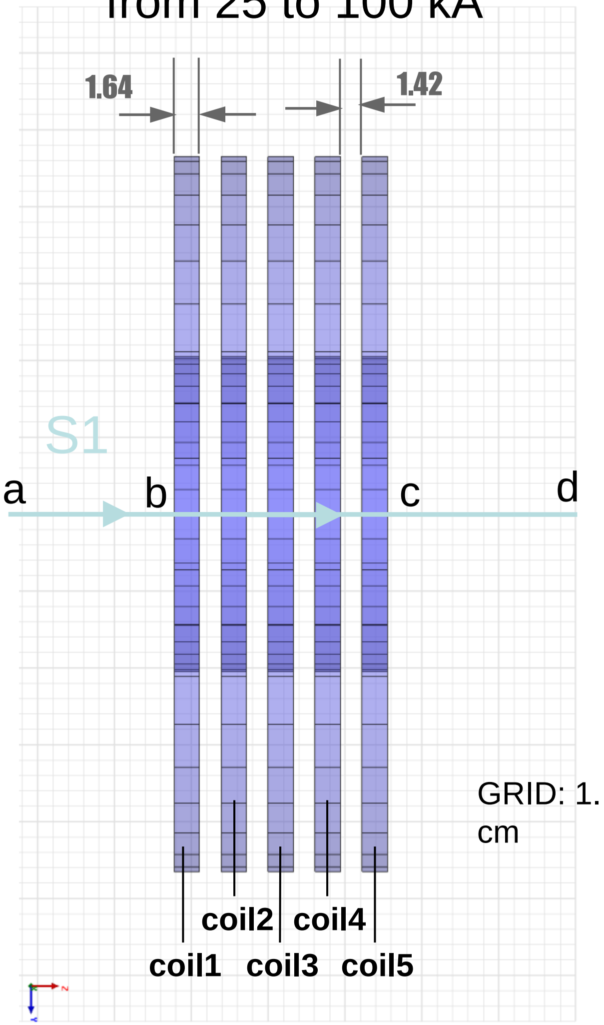
Flux concentrator has a large field after the target that tapers off



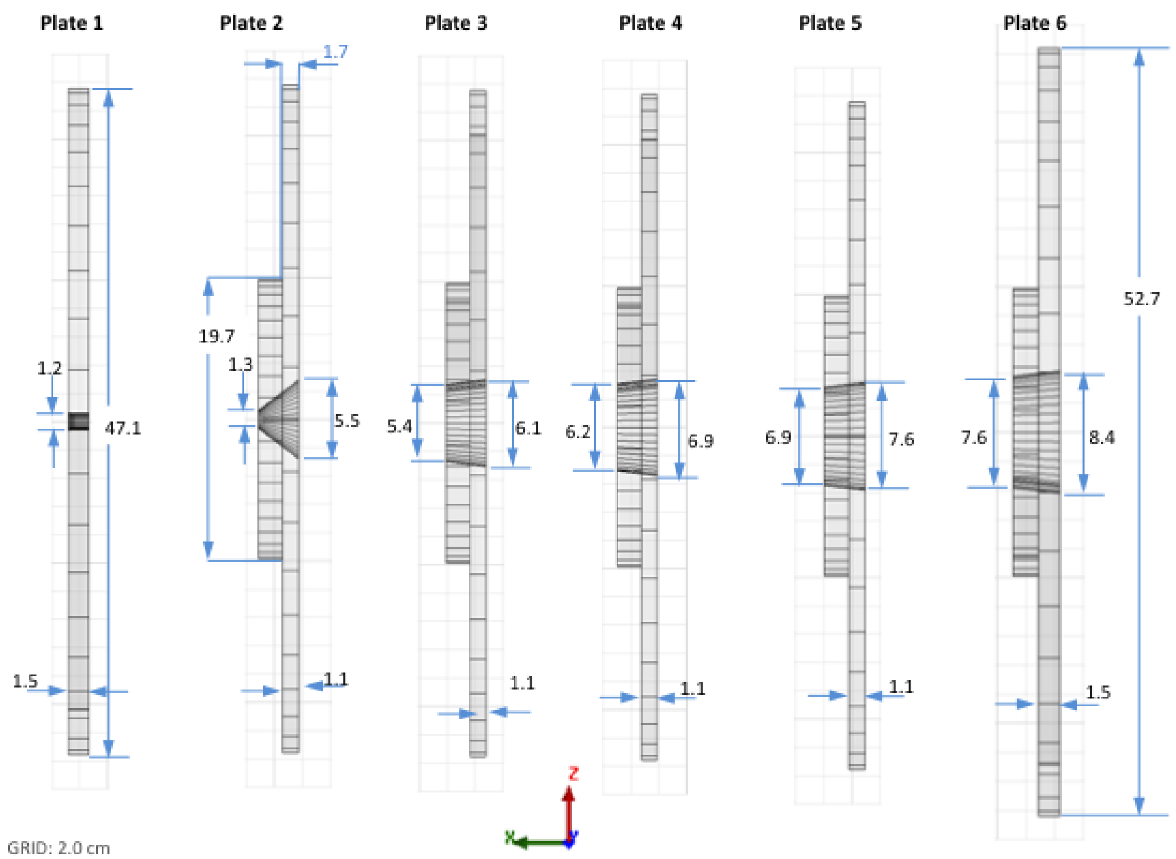


Concentrating plates shape the field

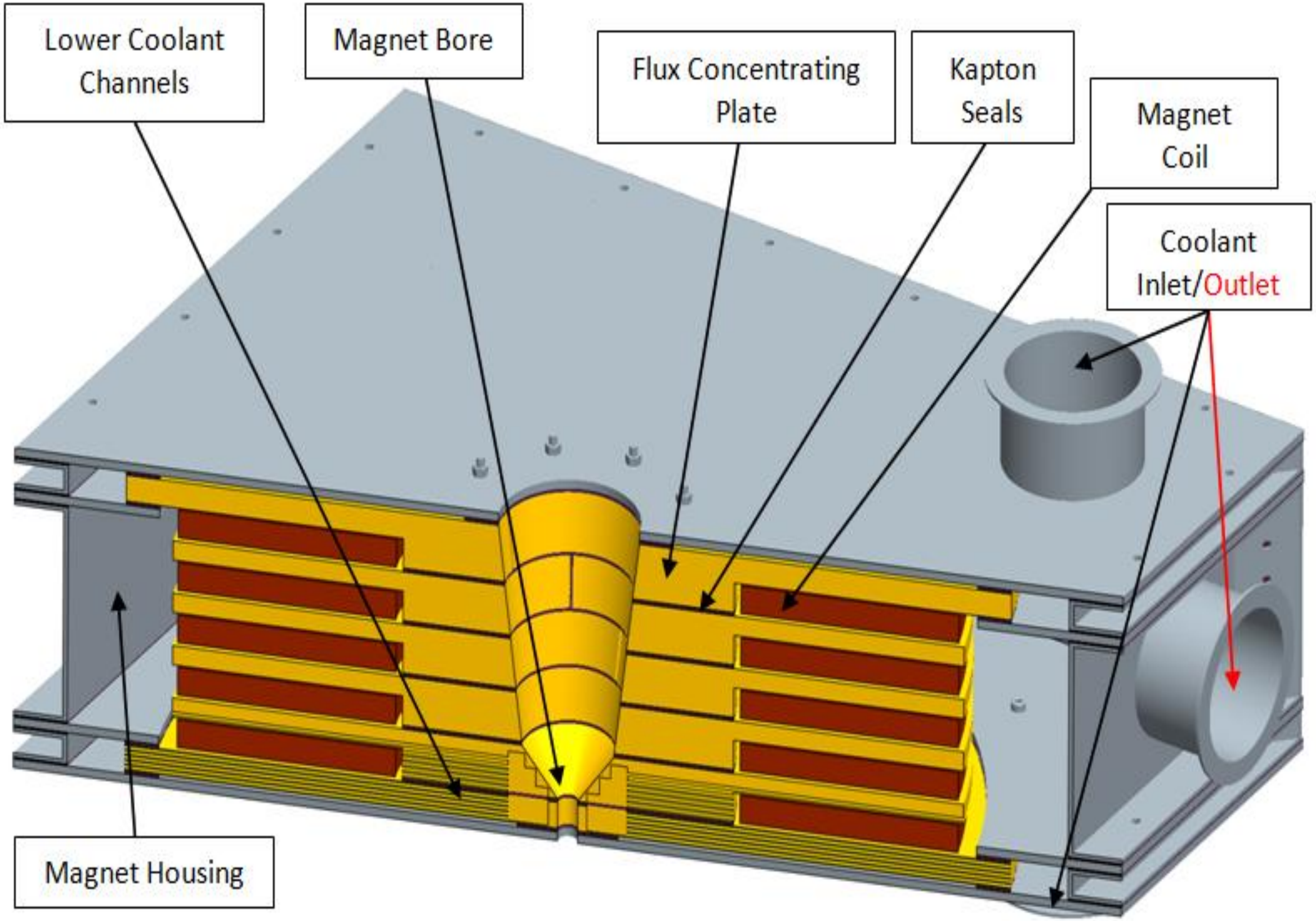
Energizing coils carry from 25 to 100 kA



Concentrating plates have a radial slit to force the currents to flow around the bore

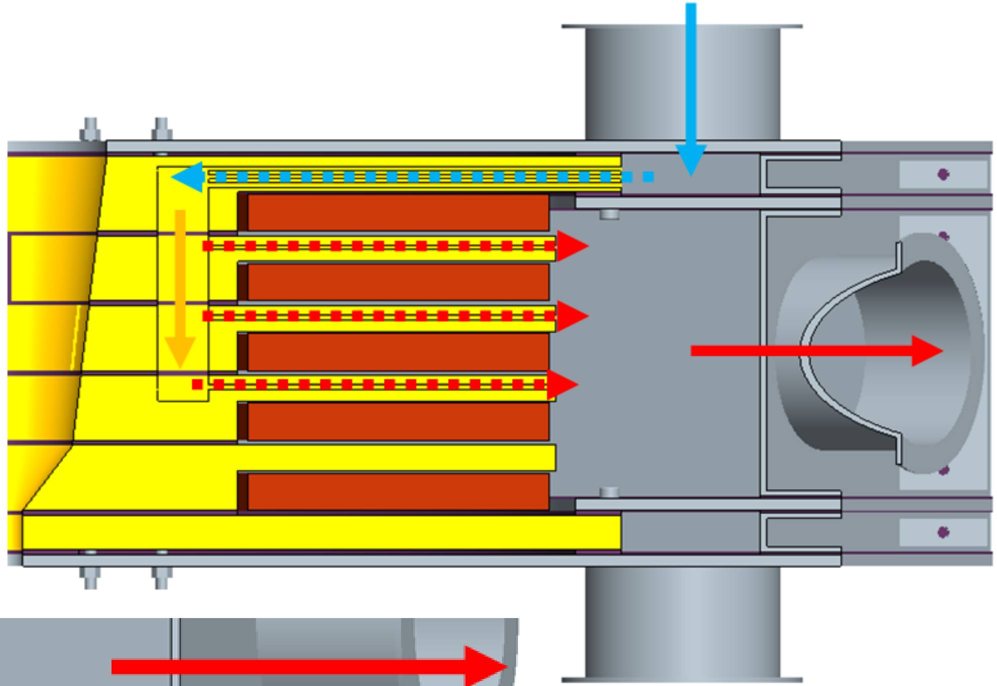


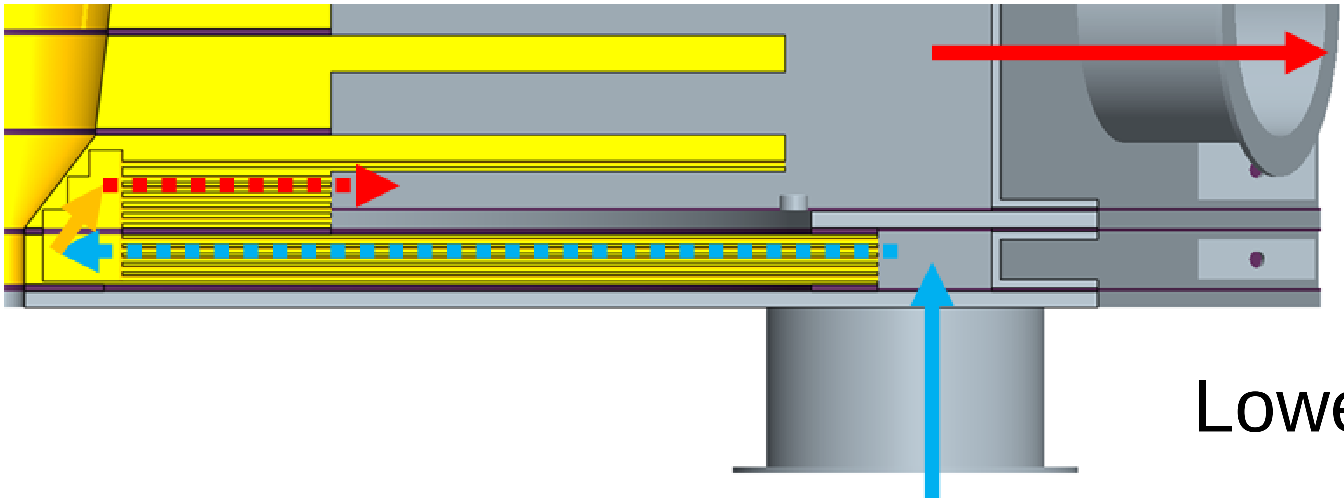
Flux concentrator layout



Cooling flow pattern

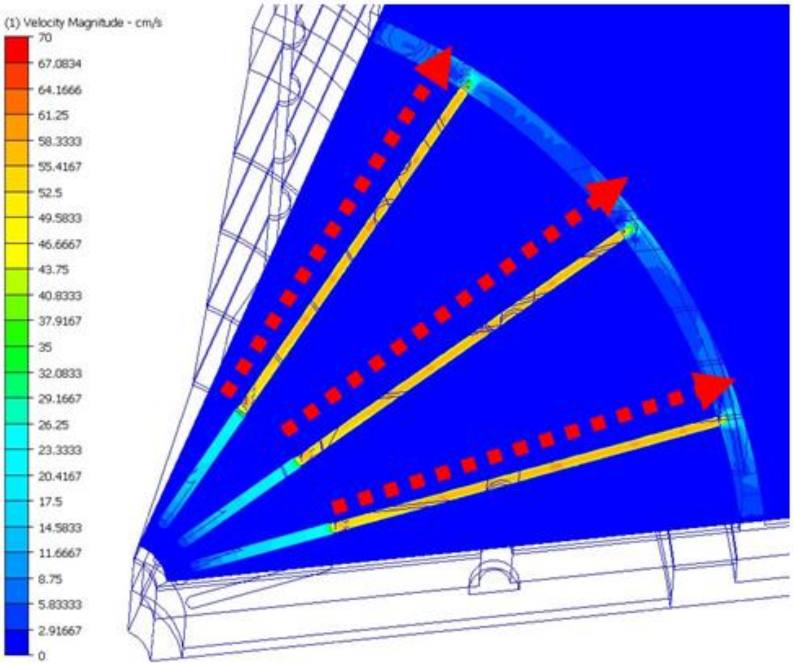
Upper Four Disks

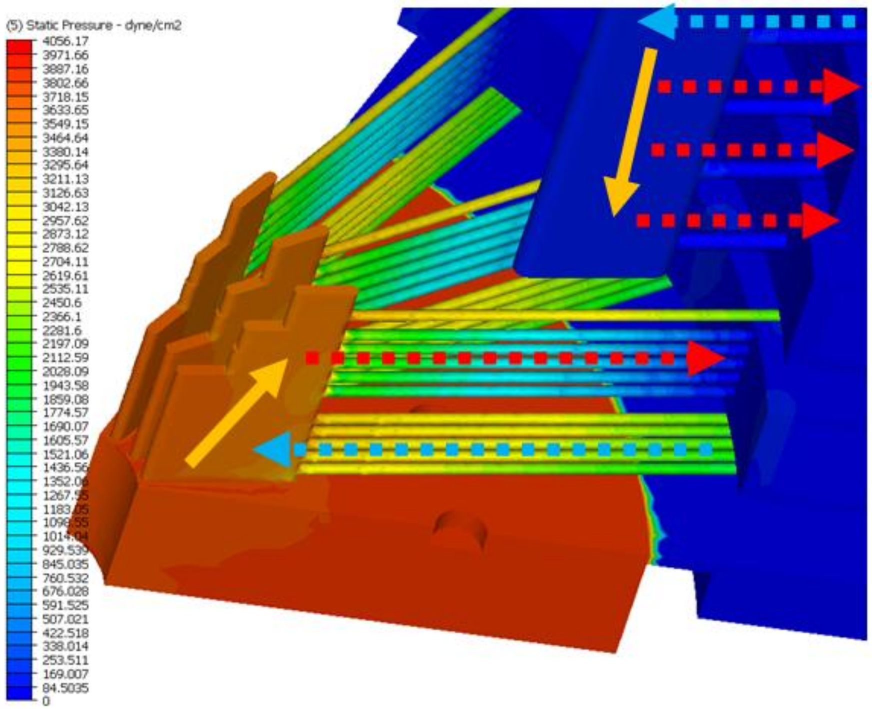




Lower Two Disks

Fluid velocity and pressure

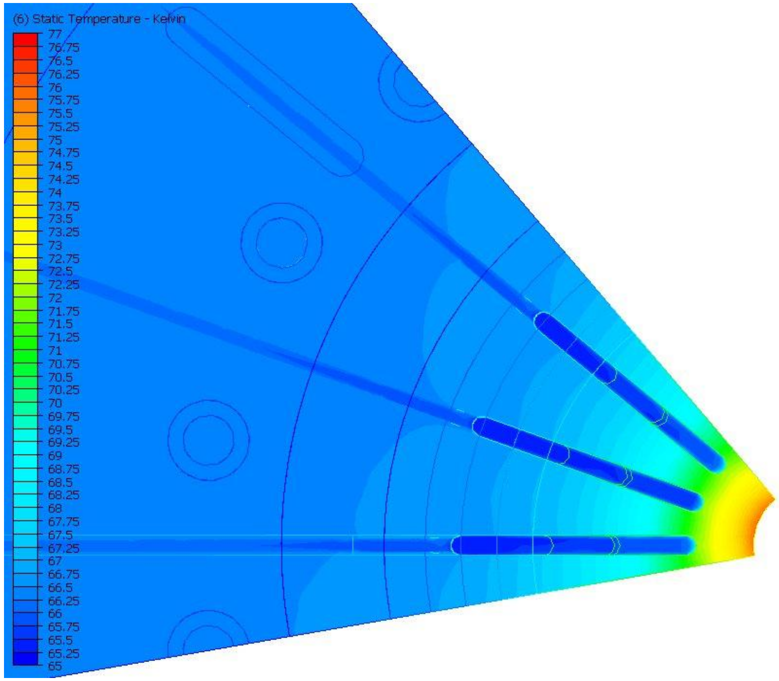


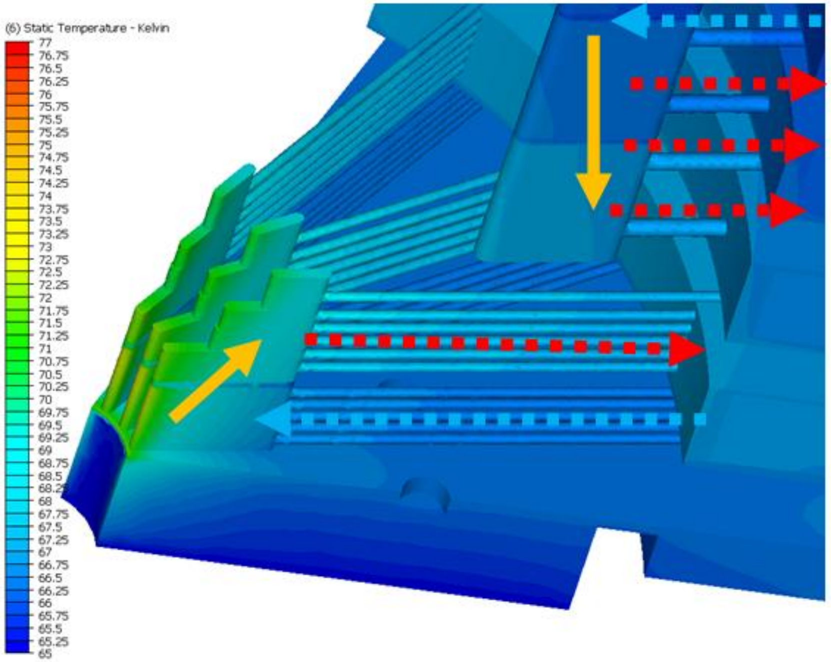


Flow Velocity

Pressure

Temperatures





Prototyping plan

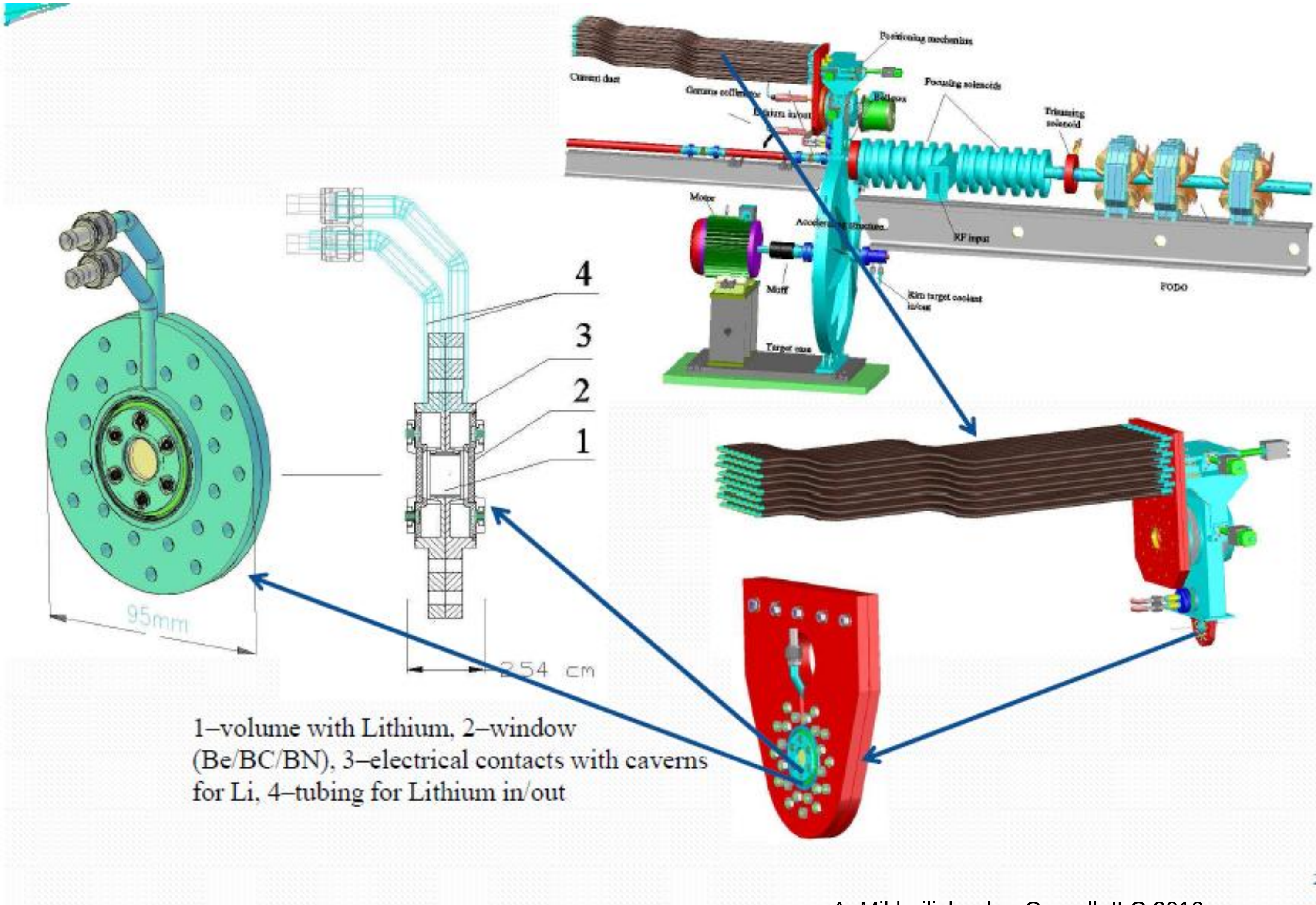
- Finalizing design choices:
  - **Electric insulation material for radiation resistance**
  - **Energizing coil configuration with impedance matched to pulse forming network to create 1 ms flat top**
- Prototyping stage 1:
  - **Build prototype and pulse at room temperature with low duty cycle**
- Prototyping stage 2:
  - **Cool with liquid nitrogen, run with low duty cycle, minimal refrigeration plant**
  - **Verify pulse length and flat top**
- Planning to reach this point by 2012
- Prototyping stage 3:
  - **Full refrigeration plant**
  - **Operate at full duty cycle**

Alternative Positron Source Designs

- Effort is ongoing around the world on many alternatives to the baseline
  - **Alternative targets**
  - **Shorter period undulators**
  - **New magnetic capture optics**
  - **Drive beams with different pulse structures**
  - **New ways to produce photon beams through Compton scattering**
    - Recirculating rings
    - Energy recovery linacs

- As is usually the case when you try to make one part of the system easier something else gets harder

Lithium lens is a novel alternative for the optical matching device



A. Mikhailichenko, Cornell, ILC 2010

Advanced Conventional e+ Source for ILC

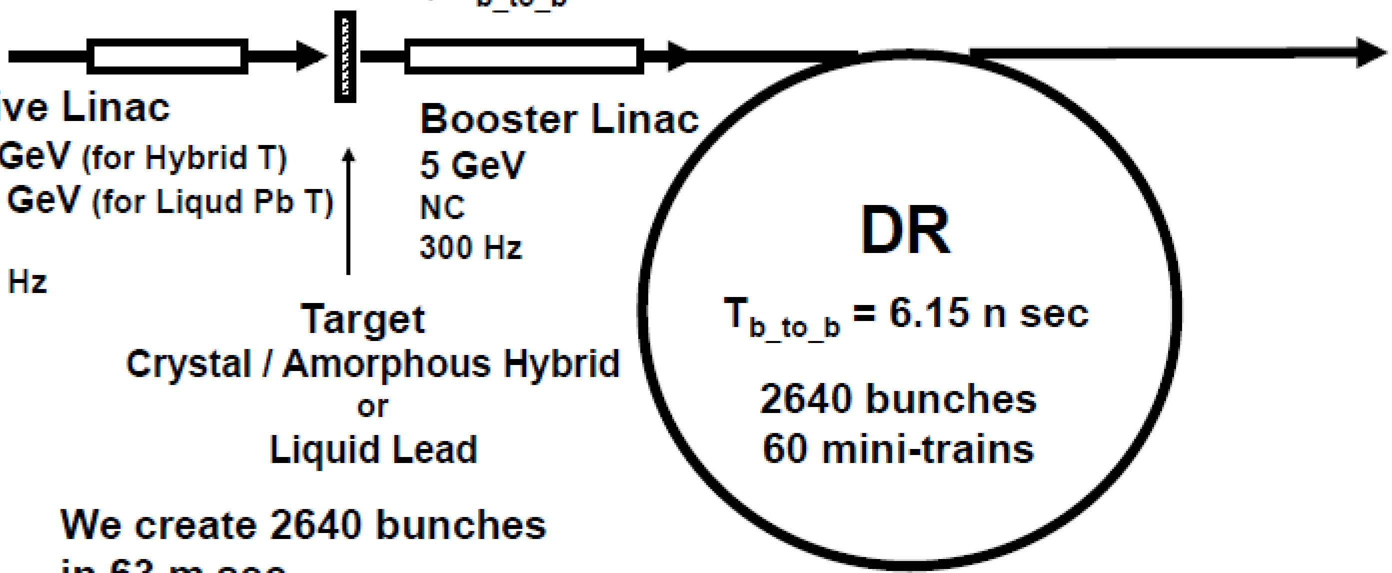
Crystal/Amorphous Hybrid Target or Liquid Lead Target
Normal Conducting Drive and Booster Linacs in 300 Hz operation

e+ creation

20 triplets, rep. = 300 Hz
- triplet = 3 mini-trains with gaps
- 44 bunches/mini-train, $T_{b\_to\_b}$ = 6.15 n sec

go to main linac

2640 bunches/train, rep. = 5 Hz
- $T_{b\_to\_b}$ = 369 n sec



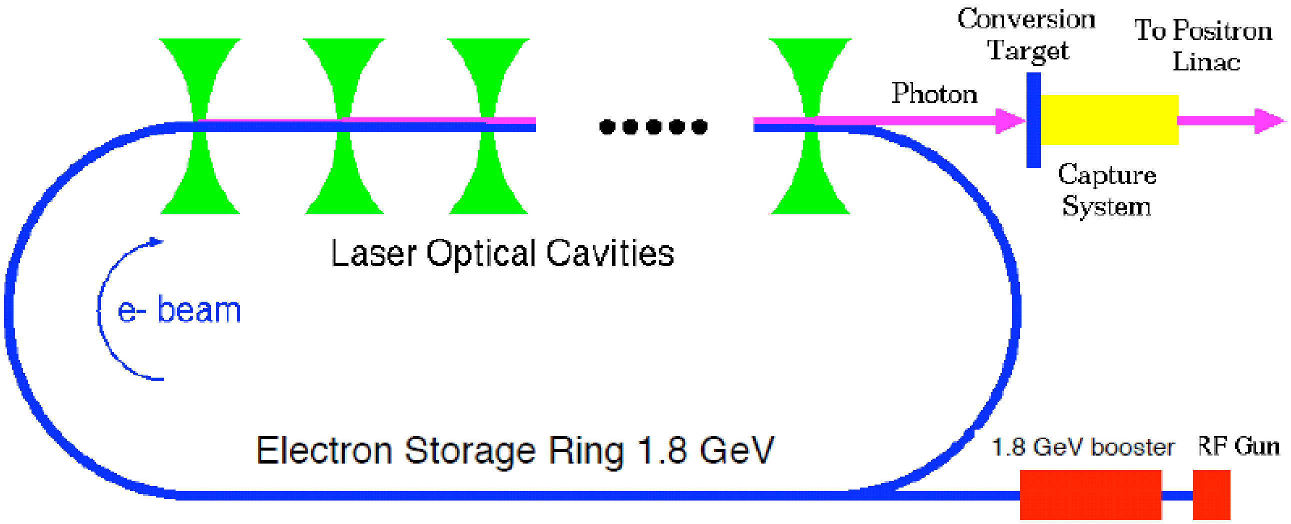
We create 2640 bunches in 63 m sec

Time remaining for damping = 137 m sec

J. Urakawa, 6th ILC positron source meeting

Compton scattering from lasers is another idea to produce a photon beam

- Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.
- 5.3 nC 1.8 GeV electron bunches x 5 of 600mJ stored laser -> 2.3E+10 γ rays -> 2.0E+8 e+.
- By stacking 100 bunches on a same bucket in DR, 2.0E+10 e+/bunch is obtained.



T. Omori, Daresbury positron source meeting 2008

Status & Plans

- Helical Undulators have been prototyped and demonstrated
- Photon collimator is designed, no issues foreseen
- Rotating Target initial prototype is completed
  - **Rotordynamics are good**
  - **Mechanical stress is acceptable**
  - **Eddy current effects have been benchmarked**
- Rotating Target vacuum prototype is beginning
  - **Test ferrofluidic rotating vacuum seal**
  - **Cooling water couplings**
- Pulsed flux concentrator is under design
  - **Initial tests at low rep rate without cooling**
- Alternatives continue to be developed around the world