May 2007 ILC Positron Systems Update

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SLAC

May 31, 2007

Baseline Source Only

Nominal Source Parameters

Parameter	Symbol	Value	Units
Bunch Population	N_b	$2x10^{10}$	#
Bunches per pulse	n_b	2625	#
Bunch spacing	t_b	369	ns
Pulse repetition rate	f_{rep}	5	Hz
Injection Energy (DR)	E_0	5	GeV
Beam Power (x1.5)	P_o	300	kW
Polarization e-(e+)	P	80(30)	%

Baseline Positron Source Layout

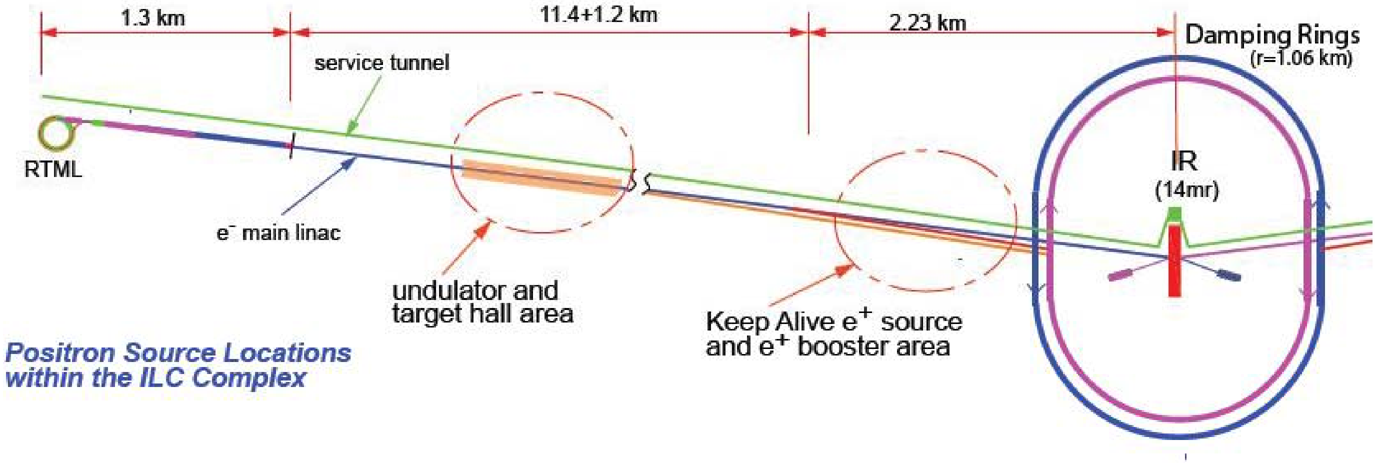


FIGURE 2.3-1. Layout of the Positron Source in the ILC

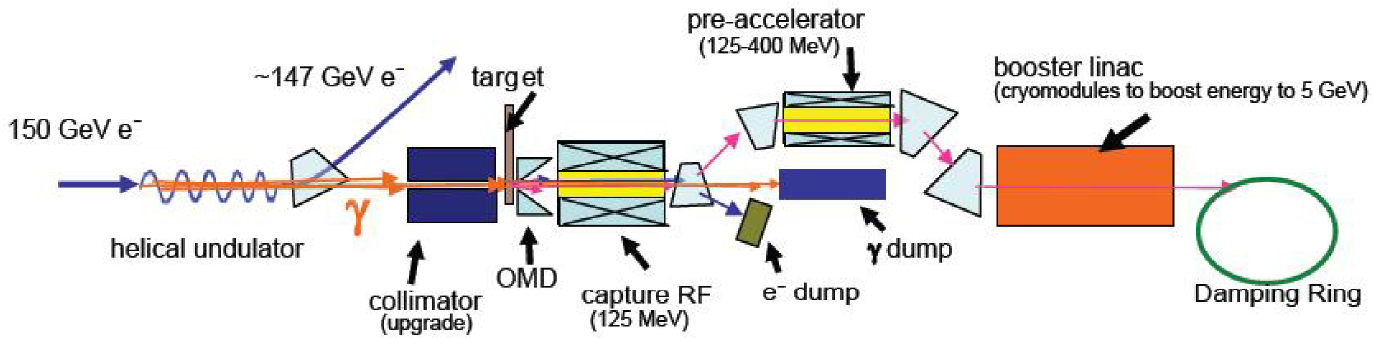


FIGURE 2.3-2. Overall Layout of the Positron Source

Baseline e+ / US Institutions

- Institutions doing substantial work on ILC baseline e+ development
  - SLAC
    - overall coordination & leadership
    - define parameters
    - target hall, remote handling, activation
    - beamline optics and tracking
    - NC L-Band accelerator structures and RF systems
    - Experiments – E166, FLUKA validation experiment
  - LLNL
    - target simulations (thermal hydraulics and stress, rotodynamics, materials)
    - target design (testing and prototyping)
    - pulsed OMD design
  - ANL
    - optics
    - tracking
    - OMD studies
    - eddy current calculations
  - Cornell
    - undulator design, alternative target concepts

Baseline e+ / European Institutions

- Institutions doing substantial work on ILC baseline e+ development
  - CCLRC-Daresbury
    - undulator design and prototyping
    - beam degradation calculations
  - CCLRC-RAL
    - ~~**remote handling**~~
    - ~~eddy current calculations~~
    - ~~target hall activation~~
  - Cockcroft and Liverpool University
    - target design and prototyping
  - DESY-Berlin
    - target hall activation
    - spin preservation
    - photon collimation
    - E166

Baseline e+ / Asian Institutions

- Institutions doing substantial work on ILC baseline e+ development

ILC Positron Source

WBS Overview FY08/09

- WBS 2.4 Design
- WBS 2.4.1 EDR
- WBS 2.4.2 Systems Engineering
- WBS 2.4.3 Civil Facilities Systems Coordination
- WBS 2.4.4 System Modeling
- WBS 2.4.5 Remote Handling

- WBS 3.4 Research and Development
- WBS 3.4.1. Undulator
- WBS 3.4.2. Target
- WBS 3.4.3. Optical Matching Device
- WBS 3.4.4 Normal Conducting RF Structures

ILC Polarized Positron System Technical Milestones

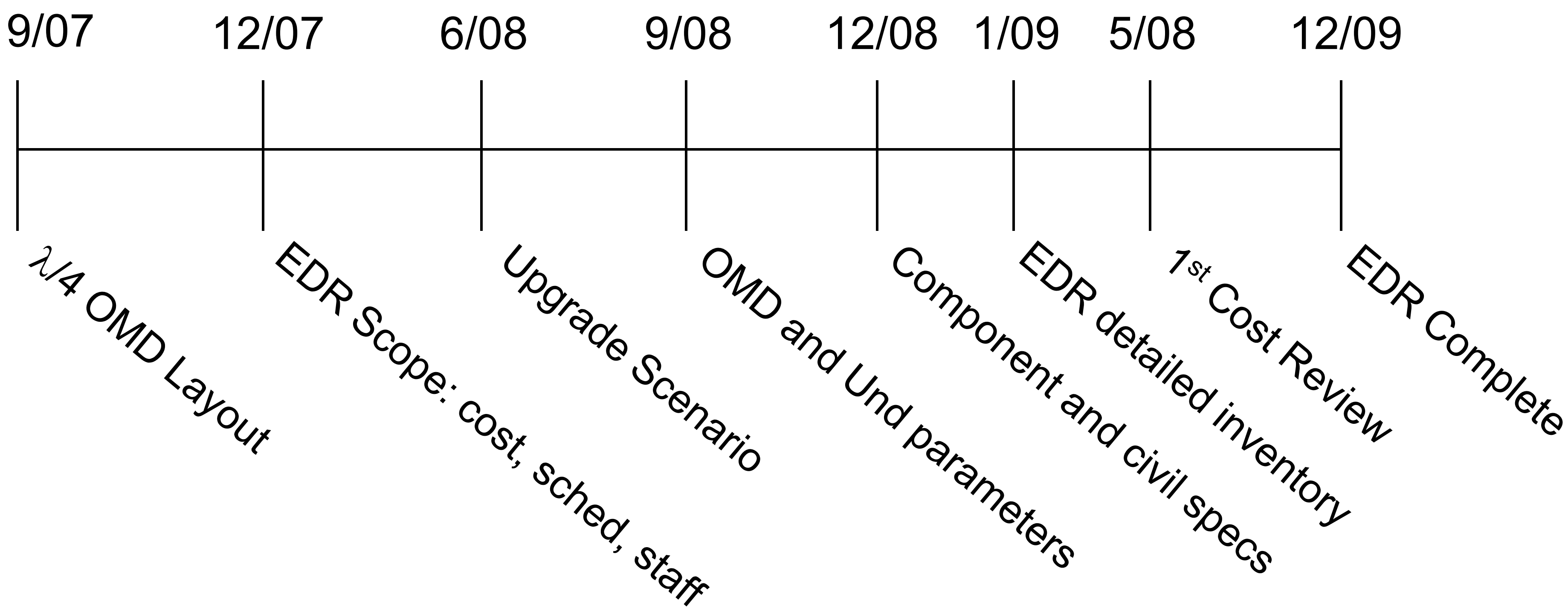
- 1. Demonstrate undulator parameters
- 2. Demonstrate NC SW structure hi power rf performance
- 3. Spinning target pre-prototype demonstration
- 3. Eddy current measurements on spinning target
- 4. Selection and Technical design of Optical Matching Device
- 5. System engineering for e+ source remote handling
- 6. System engineering for photon dump
- 7. System design compatibility with ILC upgrade scenarios: polarization and energy

ILC Positron EDR Milestones

- Sep 07: Full layout with $\lambda/4$ XMFR OMD
- Dec 07: EDR Scope definition: design depth and breadth, cost, schedule, staff
- Jun 08: Full upgrade scenario: polarization and ILC energy
- Sep 09: OMD selection (dc immersed, pulsed FC, $\lambda/4$ XMFR), Und parameter selection
- Dec 09: Freeze layout, full component and civil specifications (yield, overhead, remote handling, upgrades)
- Jan 09: EDR detailed component inventory
- May 09: First cost review
- Dec 09: Deliver EDR and preconstruction work plan

ILC Positron System EDR Timeline

(need Systems Engineering in FY08)



Select Positron References, 1

- ILC RDR Positron Chapter:
  http://media.linearcollider.org/report-apr03-part1.pdf sec. 2.3, pg. 45 ff
- ILC Positron Source Collaboration Meetings
  1st meeting at RAL September, 2006: http://www.te.rl.ac.uk/ILC_Positron_Source_Meeting/ILCMeeting.html

  2nd meeting at IHEP, Beijing January, 2007 : http://hirune.kek.jp/mk/ilc/positron/IHEP/
- ILC Notes
  1. ILC Target Prototype Simulation by Means of FEM Antipov, S; Liu, W; Gai, W
     [ILC-NOTE-2007-011] http://ilcdoc.linearcollider.org/record/6949

  2. On the Effect of Eddy Current Induced Field , Liu, W ; Antipov, S; Gai, W
     [ILC-NOTE-2007-010] http://ilcdoc.linearcollider.org/record/6948

  3. The Undulator Based ILC Positron Source: Production and Capturing Simulation Study – Update,
     Liu, W ; Gai, W [ILC-NOTE-2007-009] http://ilcdoc.linearcollider.org/record/6947
- Other Notes
  1. F.Zhou,Y.Batygin,Y.Nosochkov,J.C.Sheppard,and M.D.Woodley,"Start-to-end beam optics development and multi-particle tracking for the ILC undulator-based positron source", slac-pub-12239, Jan 2007.
     http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-12239.pdf

  2. F.Zhou,Y.Batygin,A.Brachmann,J.Clendenin,R.H.Miller,J.C.Sheppard,and M.D.Woodley,"Start-to-end transport design and multi-particle tracking for the ILC electron source", slac-pub-12240, Jan 2007.
     http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-12240.pdf

  3. A.Mikhailichenko, " Liquid metal target for ILC*."*. Jun 2006. 3pp.
     Prepared for European Particle Accelerator Conference (EPAC 06), Edinburgh, Scotland, 26-30 Jun 2006.
     Published in *Edinburgh 2006, EPAC* 816-818

Select Positron References, 2

- Other Notes, cont'd

4. A.A. Mikhailichenko <http://www-spires.slac.stanford.edu/spires/find/wwwhepau/wwwscan?rawcmd=fin+%22Mikhailichenko%2C%20A%2EA%2E%22>, "Test of SC undulator for ILC.",Jun 2006. 3pp. Prepared for European Particle Accelerator Conference (EPAC 06), Edinburgh, Scotland, 26-30 Jun 2006.
   Published in *Edinburgh 2006, EPAC* 813-815.

5. A.Mikhailichenko, "Issues for the rotating target", CBN-07-02, 2007, http://www.lns.cornell.edu/public/CBN/2007/CBN07-2/CBN07-2.pdf

6. A.Mikhailichenko, "Positron Source for ILC:A perspective", CBN-06-06, 2006, http://www.lns.cornell.edu/public/CBN/2006/CBN06-1/CBN06-1.pdf

7. Preliminary Investigations of Eddy Current Effects on a Spinning Disk, W.T. Piggott, S. Walston, and D. Mayhall. UCRL-TR-224467, Sep. 8, 2006

8. Positron Source Target Update, W.T. Piggott, UCRL-PRES-227298, Jan. 16, 2007.

9. Computer Calculations of Eddy-Current Power Loss in Rotating Titanium Wheels and Rims in Localized Axial Magnetic Fields. D.J. Mayhall, W. Stein, and J. Gronberg, UCRL-TR-221440, May 17, 2006

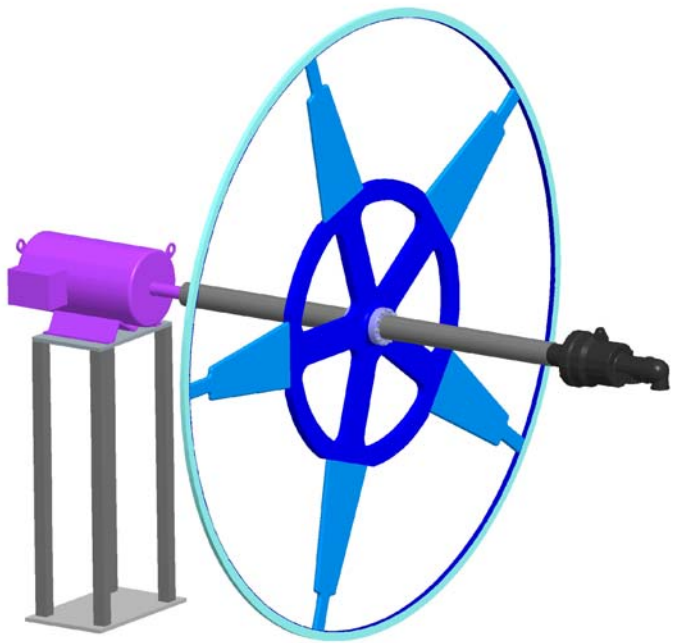
10. A Preliminary Low-Frequency Electromagnetic Analysis of a Flux Concentrator, D.J. Mayhall, UCRL-TR-221994, June 13, 2006

Target Progress

- Baseline target/capture
  - RAL, ANL and Cornell have done Eddy current simulation which produce consistent results with multiple codes. Estimates for power dissipation in the target are >100kW for a constant field and are considered excessive.
  - Evaluation of ceramic target material is on-going. No conclusions.
  - Radiation damage of the superconducting coil is still TBD but may not be worthwhile unless a solution can be found for the eddy currents.
  - ANL simulation of beam heating in windows shows that an upstream window is feasible but a downstream window is not.
- Alternative target/capture
  - Capture efficiency for the lithium lens focusing and ¼ wave solenoid is still TBD
  - Thermal heating and stress for the lithium lens is still on-going.
  - Thermal stress calculation for the liquid metal target is still on-going

Baseline Target Design

- Wheel rim speed (100m/s) fixed by thermal load (~8% of photon beam power)
- Rotation reduces pulse energy density from ~900J/g to ~24J/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.

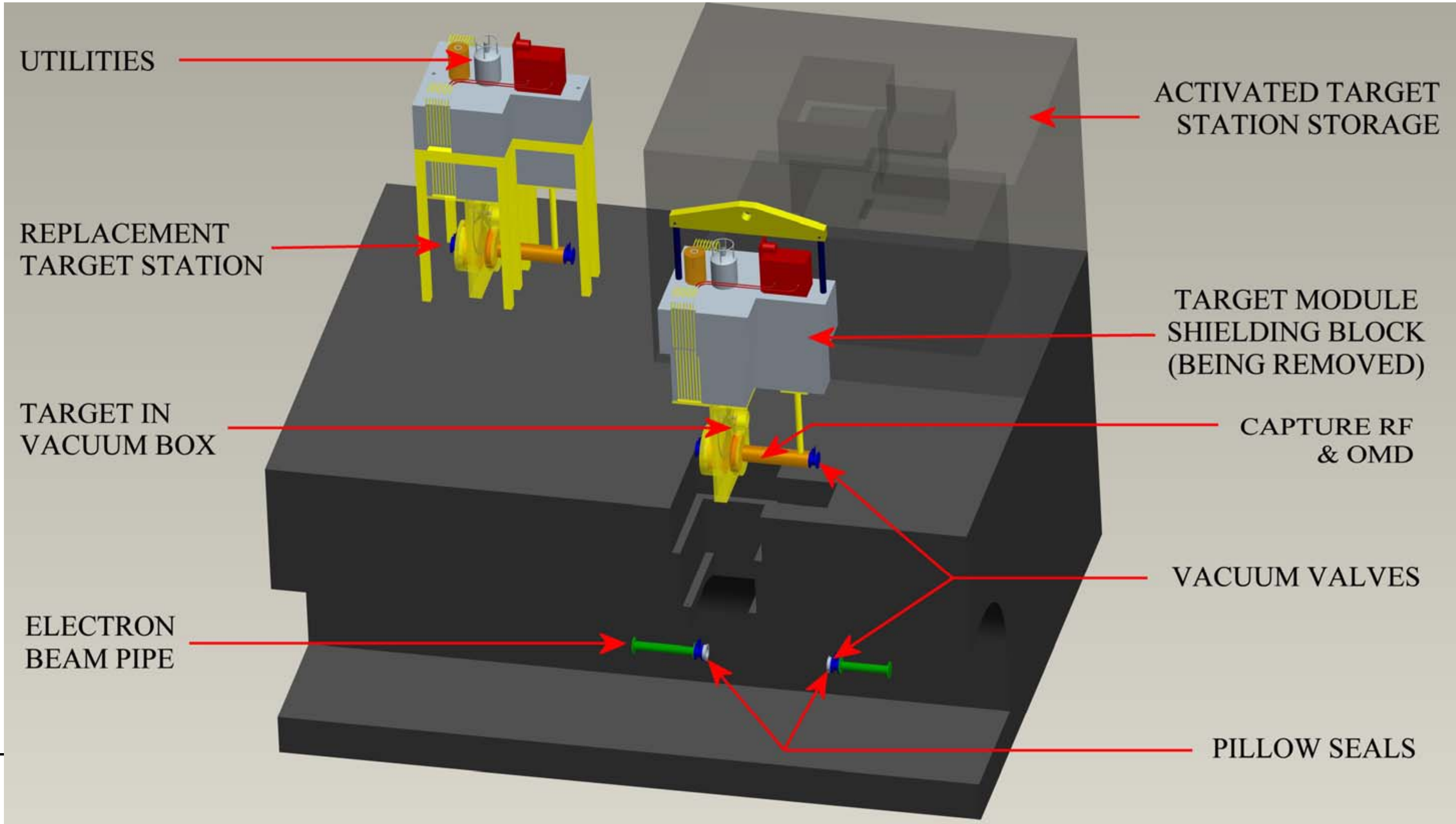


T. Piggott, LLNL

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

Target Remote Handling

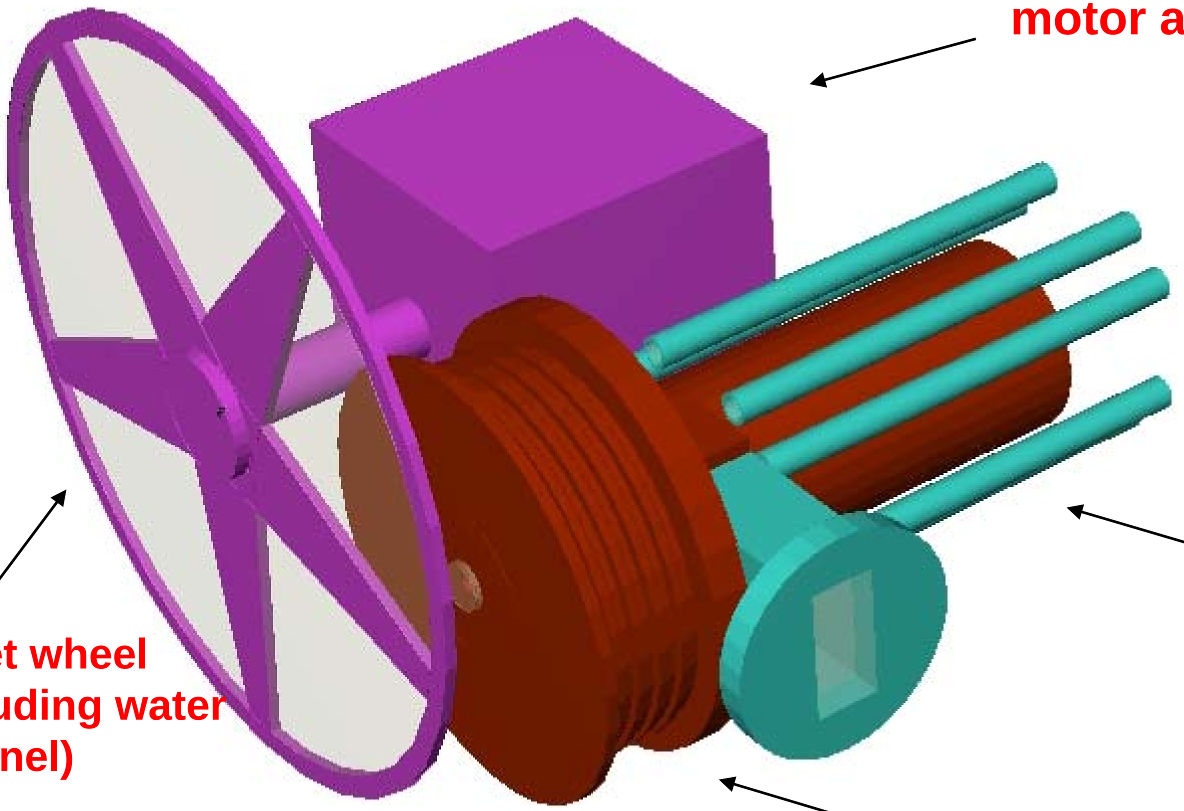
Estimated 53 hour replacement time



Activation Simulations

- New target geometry (mostly) migrated to FLUKA
- Simulations will begin at DL shortly as well as DESY/Z

L. Fernandez-Hernando, DL



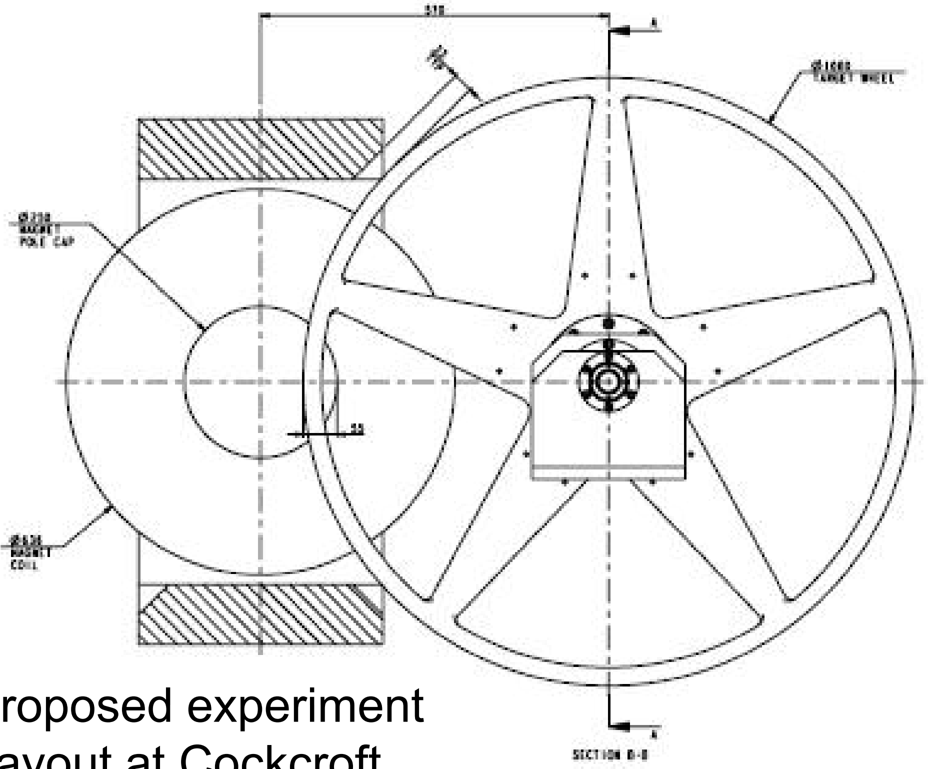
OMD

- Plans and Actions (baseline target/capture):
  - ANL will simulate eddy currents in the pulsed magnet configuration.
  - UK will evaluate suitability of non-conducting materials for the target
  - Daresbury/Cockroft/RAL will spin a one meter target wheel in a constant magnetic field and will measure the forces.
    - Eddy simulations will be calculated and benchmarked against this configuration
- Plans and Actions (alternative targets/capture):
  - ANL will determine the capture efficiency for ¼ wave focusing optics and lithium lens.
  - LLNL will evaluate the survivability of lithium lens to beam stress
  - Cornell will specify an initial design of a liquid metal target. LLNL will calculate the Stress-strain behavior of the outgoing beam window.

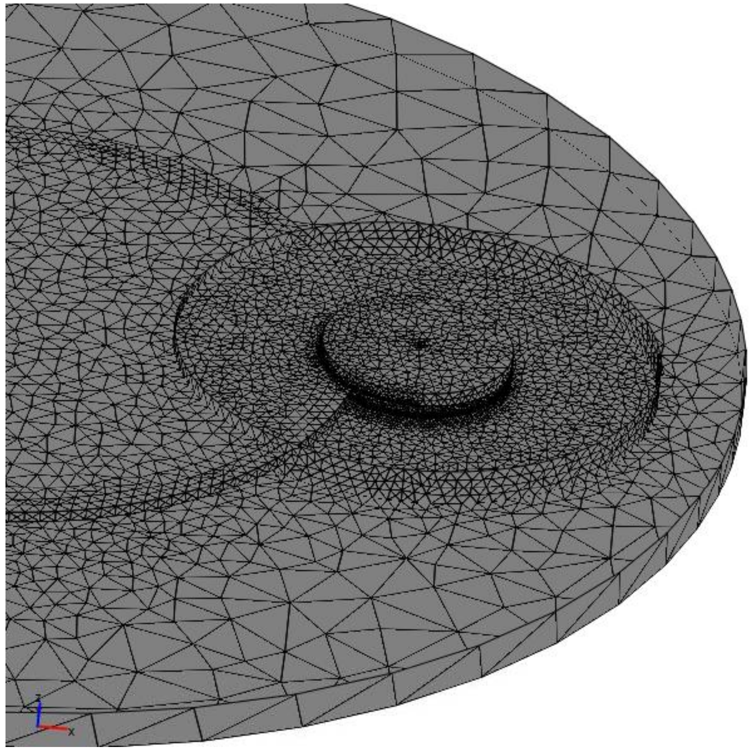
Optical Matching Device (OMD)

- Optical Matching Device
  - factor of 2 in positron yield (3 if immersed target)
  - DC solenoid before target or pulsed flux concentrator after target
  - Pulsed device is the baseline design
- Target spins in the magnetic field of the OMD
  - Eddy currents in the target – need to calculate power
  - Magnetic field is modified by the eddy currents – effect on yield??
- Eddy current mitigation
  - Reduce amount of spinning metal
  - Do experiment to validate eddy current calculations
  - Look for low electrical / high thermal conductivity Ti-alloys
  - Other materials such as ceramics
  - No OMD
    - Use focusing solenoidal lens (1/4 wave) – lower fields
    - OMD is upgrade to polarization!!!!!

Eddy Current Experiment

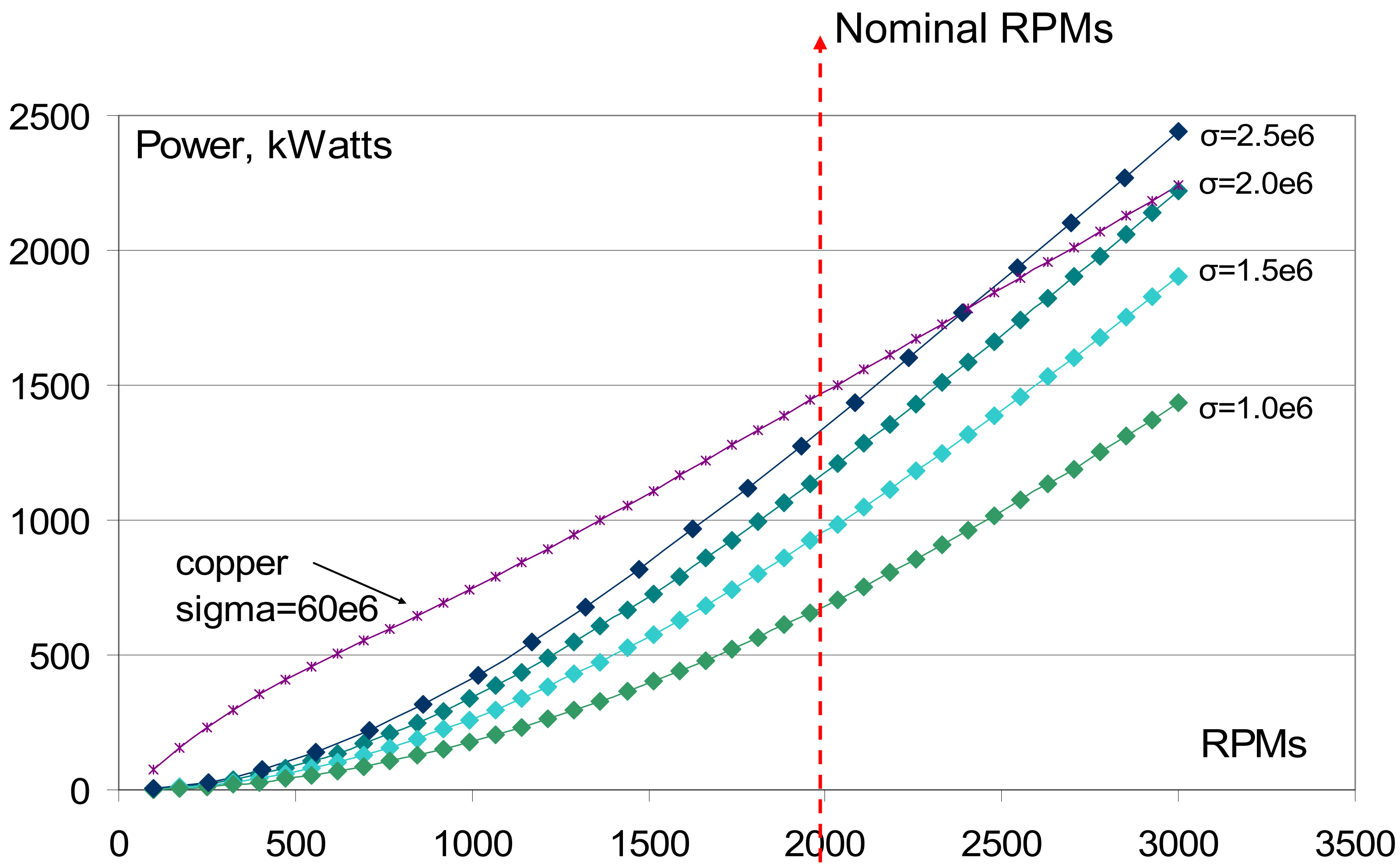


Proposed experiment Layout at Cockcroft Institute/Daresbury (this summer)



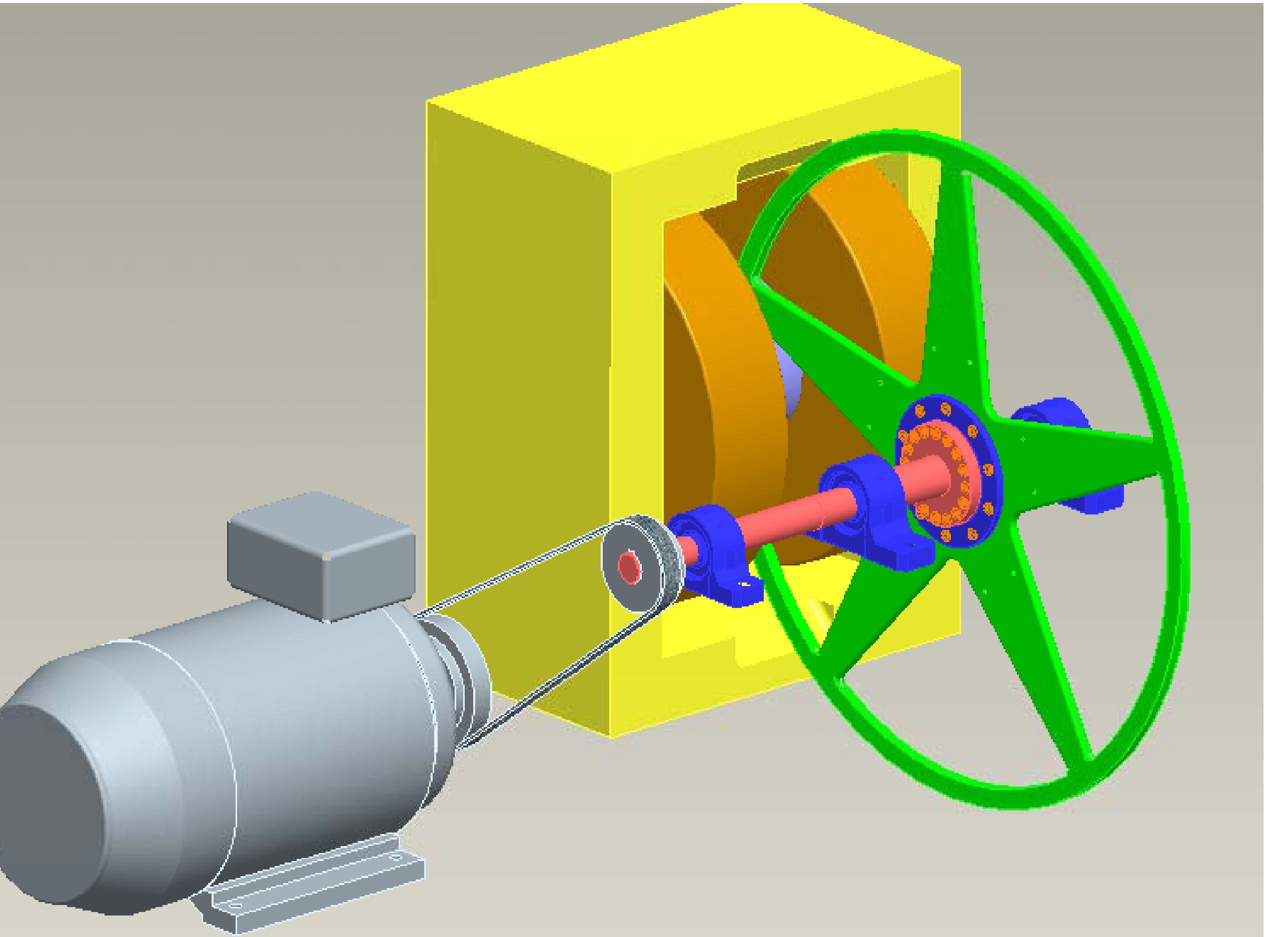
Eddy current calculation mesh - S. Antipov, W. Liu, W. Gai - ANL

Calculated Eddy Current Power



Prototype Target Wheel with Belt Drive

K. Davies, DL



Equilibrium temperature of wheel in air using 1.5T field at 2000rpm ~ 500K !

Shows vacuum feedthroughs replaced with cheaper (and stiffer) Plummer block assemblies.

It has not yet been decided whether to use a direct-drive or belt-drive motor.

Instrumentation includes: torque sensor, remote temperature gauges and accelerometers.

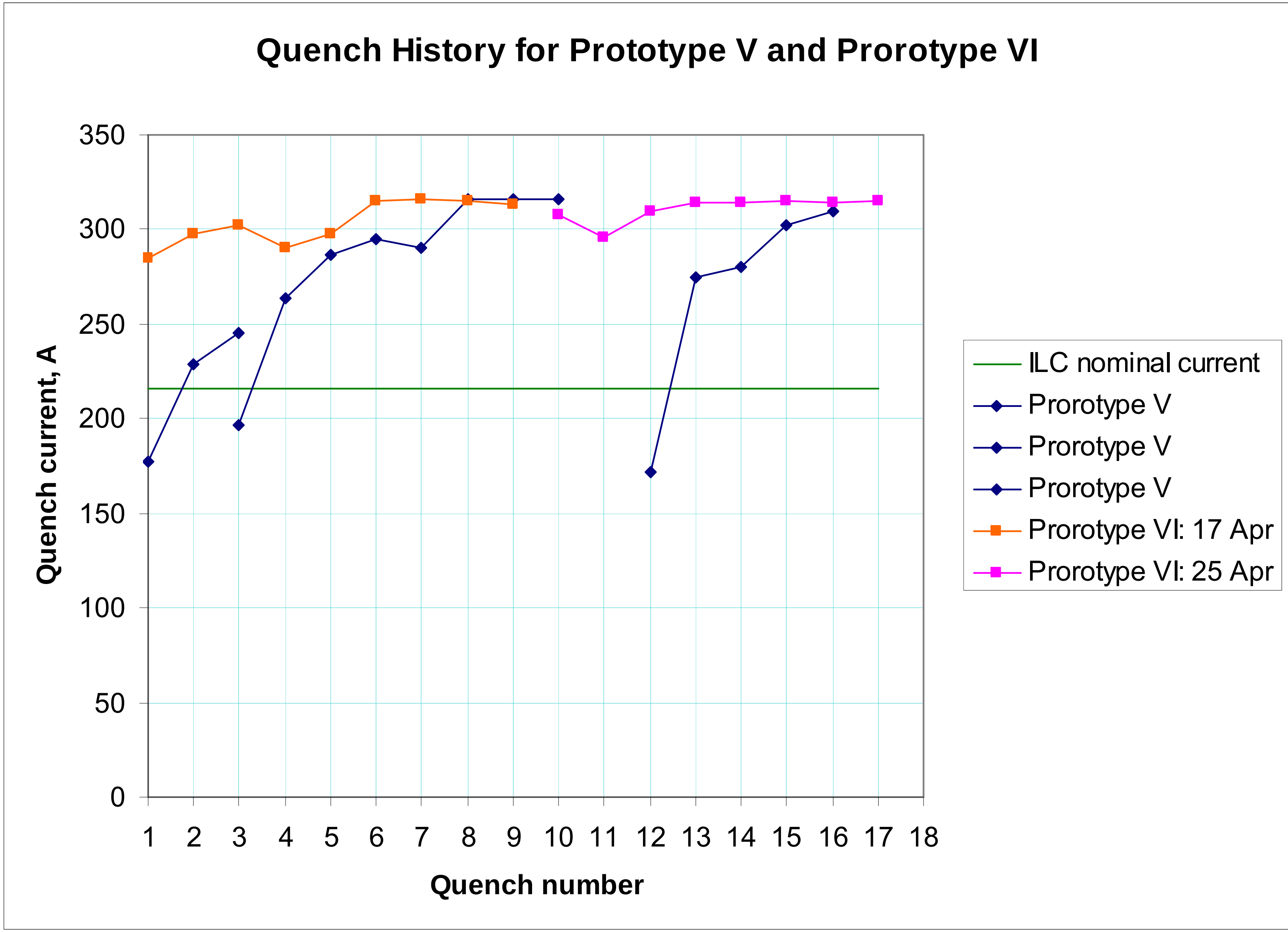
Undulator Challenges (JC)

- High fields
  - Pushing the limits of technology
- Short Periods
  - Shorter periods imply higher fields
- Narrow apertures
  - Very tight tolerances - Alignment critical
- Cold bore (4K surface)
  - Cannot tolerate more than few W of heating per module
- Minimising impact on electron beam
  - Must not degrade electron beam properties but have to remove energy from electrons
- Creating a vacuum
  - Impossible to use conventional pumps, need other solution
- Minimising cost
  - Minimise total length, value engineering

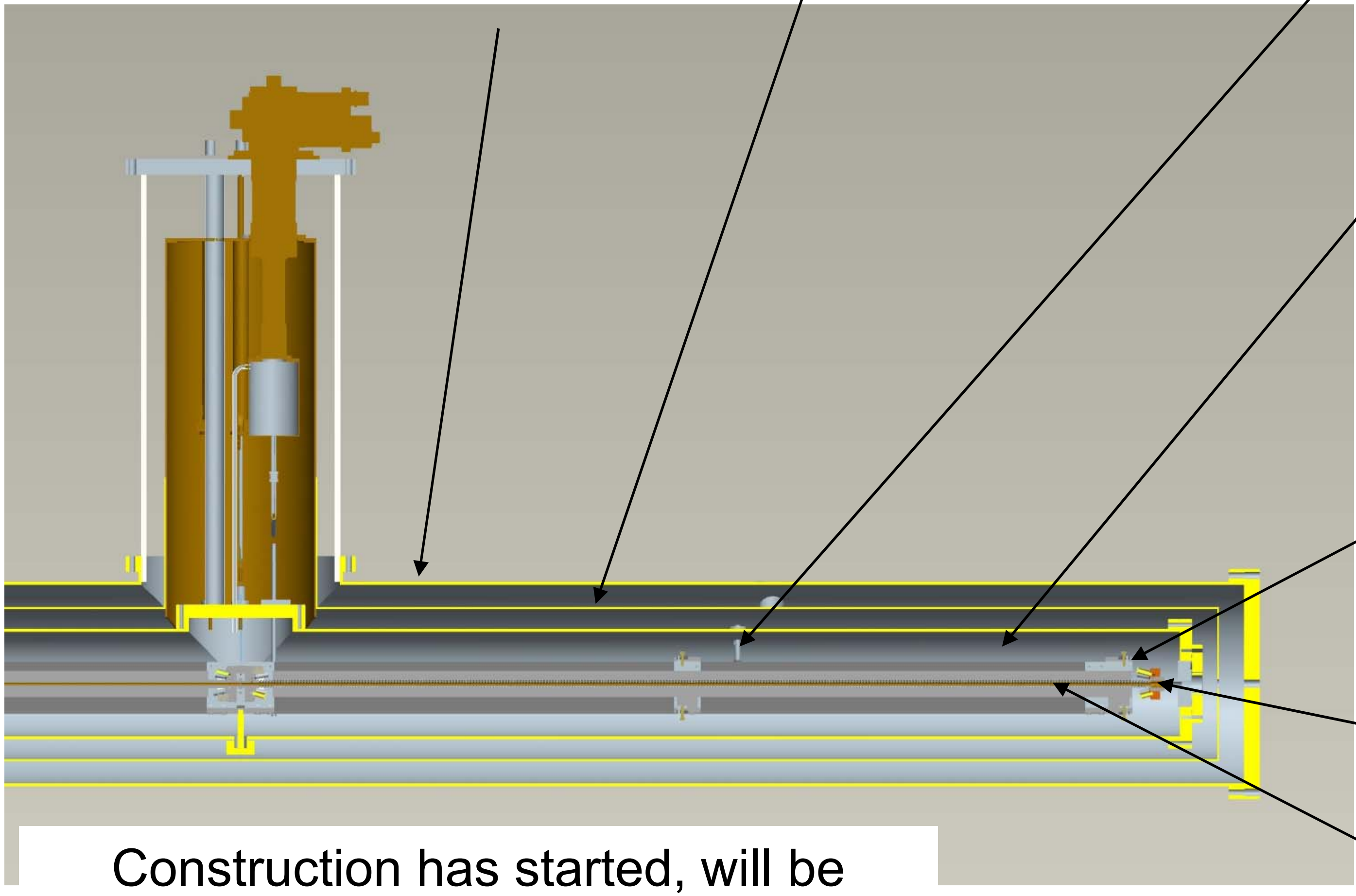
UK Undulator Prototypes Matrix

	I	II	III	IV	V	VI
Former material	Al	Al	Al	Iron	Iron	Prototype VI is re-wound and re-impregnated Prototype V
Length, mm	300	300	300	300	500	
Pitch, mm	14	14	12	12	11.5	
Groove shape	rectangular	trapezoidal	trapezoidal	trapezoidal	rectangular	
Winding bore, mm	6	6	6.35	6.35	6.35	
Vac bore, mm	4	4	4	4.5 (St Steel tube)	5.23* (Cu tube)	
Winding	8-wire ribbon, 8 layers	9-wire ribbon, 8 layers	7-wire ribbon, 8 layers	7-wire ribbon, 8 layers	7-wire ribbon, 8 layers	
Sc wire	Cu:Sc 1.35:1	Cu:Sc 1.35:1	Cu:Sc 1.35:1	Cu:Sc 1.35:1	Cu:Sc 0.9:1	
Status	Completed and tested	Completed, tested and sectioned	Completed and tested	Completed and tested	Completed and tested	

Prototype VI quenches



UK 4m Prototype Module

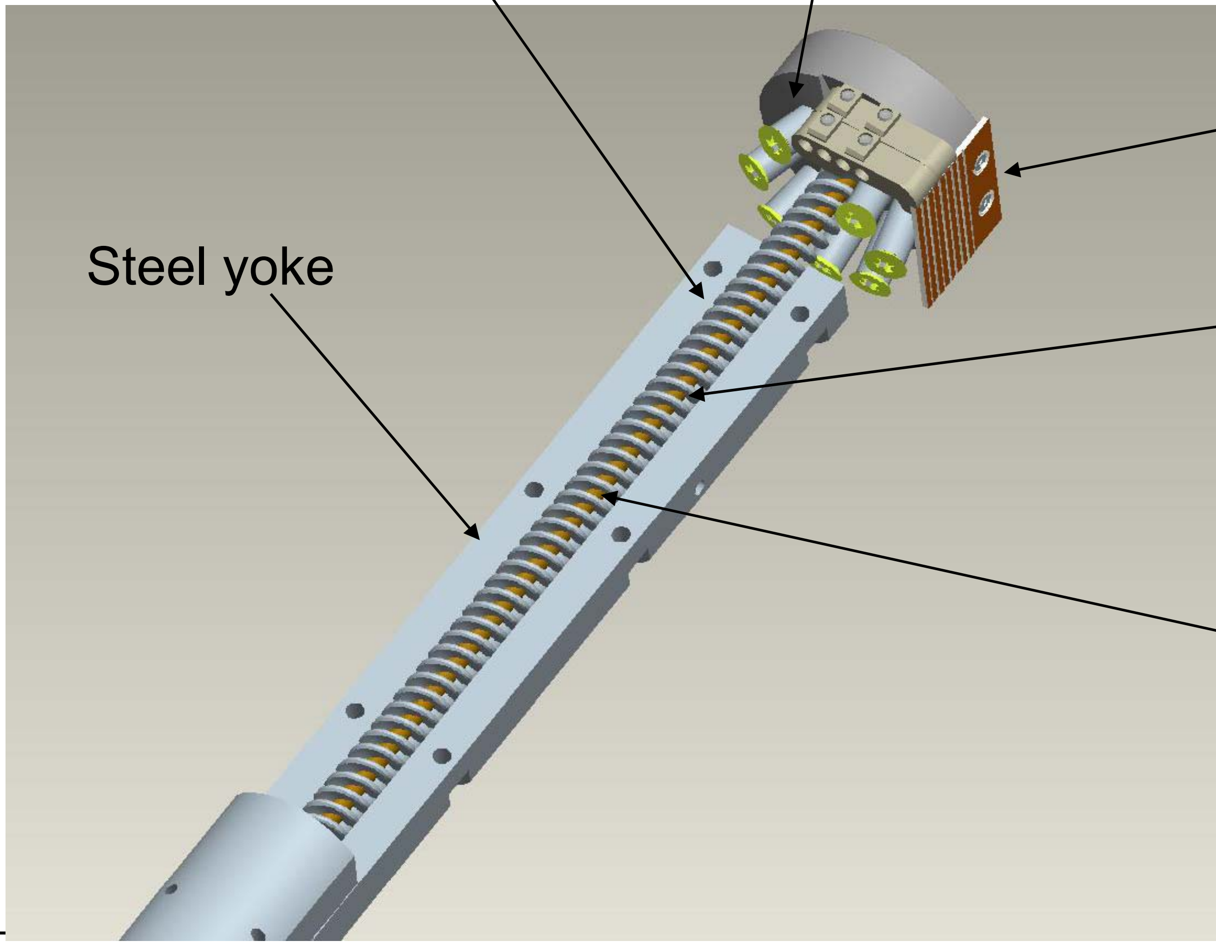


Construction has started, will be complete by Autumn 07

Magnet Design Concept

Steel Yoke. Provides 10% increase in field and mechanical support for former

Winding pins



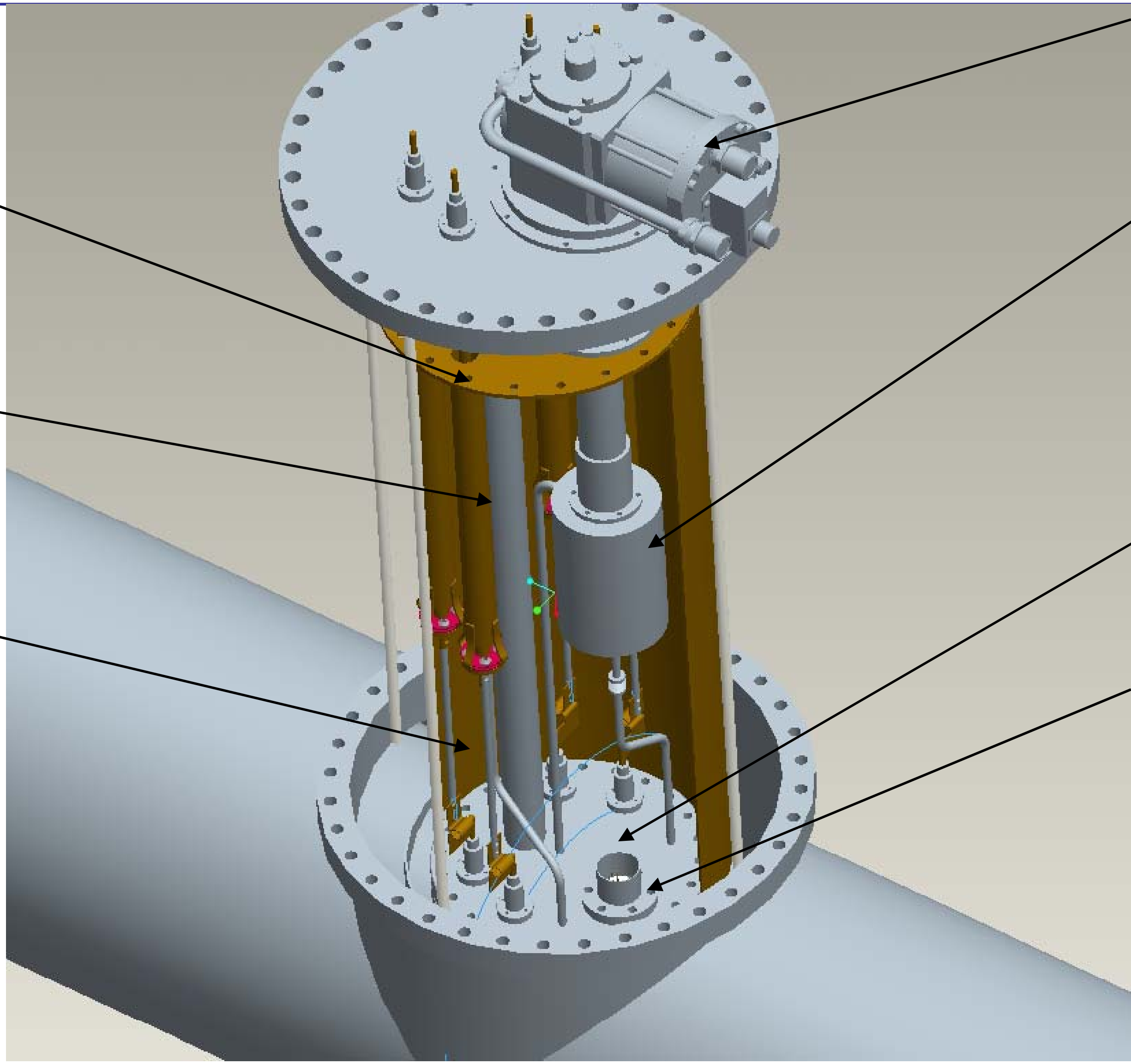
Steel yoke

PC board for S/C ribbon connections

2 start helical groove machined in steel former

Cu beam pipe, with conductor wound on to tube OD

Cryostat Turret



STATUS OF CORNELL UNDULATOR PROTOTYPING

Alexander Mikhailichenko, Maury Tigner

Cornell University, LEPP, Ithaca, NY 14853

A superconducting, helical undulator based source has been selected as the baseline design for the ILC. This report outlines progress towards design, modeling and testing elements of the needed undulator. A magnetic length of approximately 150 m is needed to produce the desired positron beam. This could be composed of about 50 modules of 4 m overall length each.

This project is dedicated to the design and eventual fabrication of one full scale, 4 m long undulator module. The concept builds on a copper vacuum chamber of 8 mm internal bore

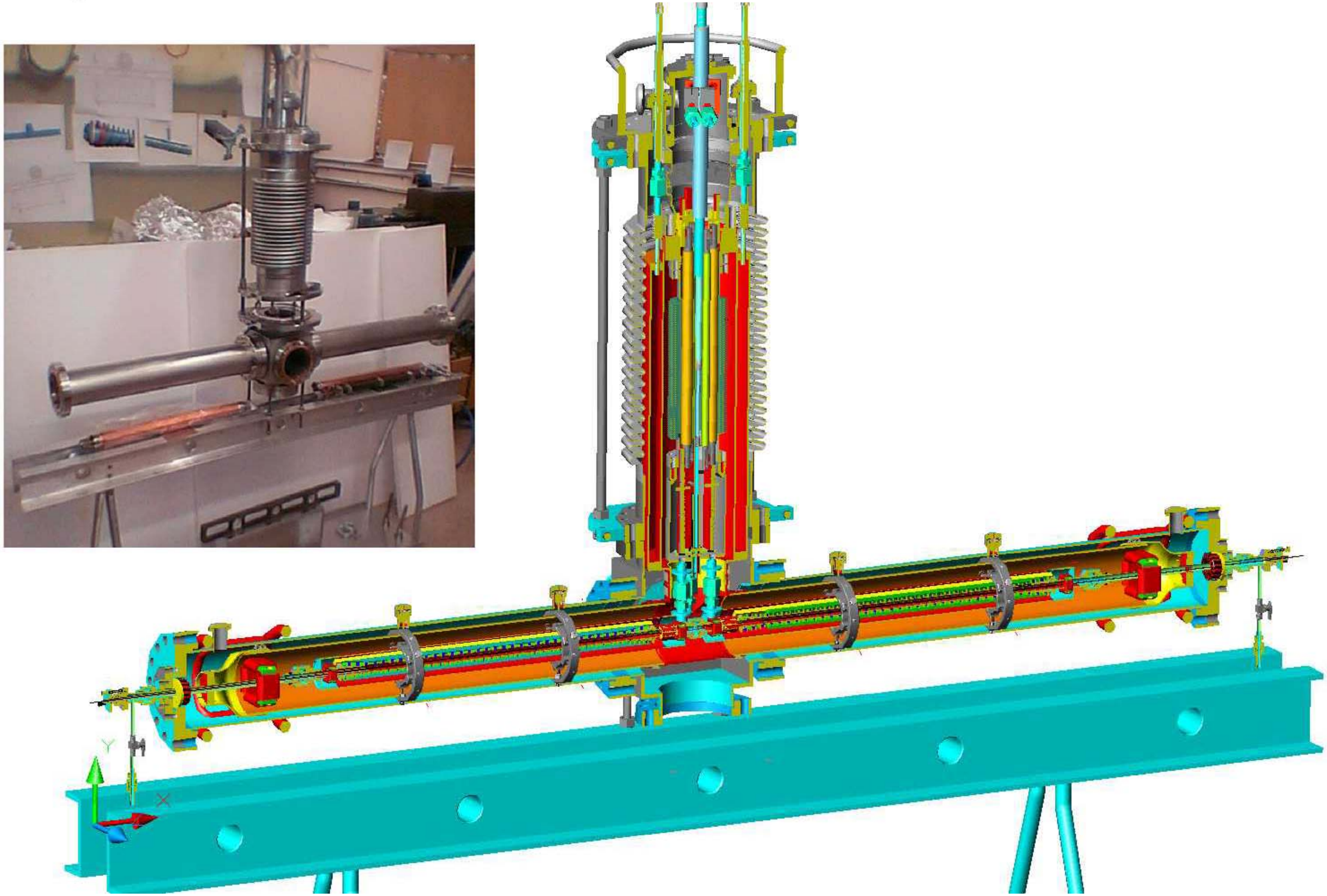


Fig.1;Extensible prototype concept for ILC positron undulator . Diameter of cryostat =102mm

Undulator cold mass design

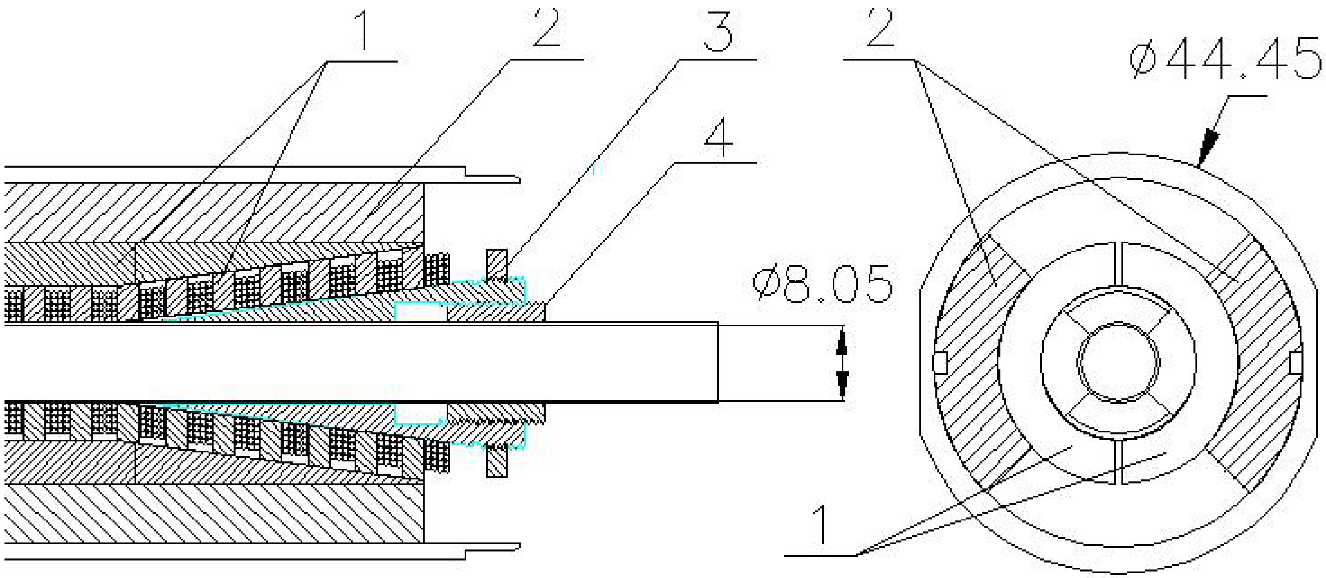


Fig.2:Details of design. 1–Iron yoke, 2–Copper collar, 3, 4–trimming Iron nuts. Inner diameter of Copper vacuum chamber is 8mm clear.

Several 40 cm long undulator models with 10 and 12 mm period, Ø 8 mm clear bore have been made and measured. See Table

OFC vacuum chamber, RF smoothness

SC wire	54 filaments	56 filaments	56 filaments
# layers	5*	6*	9** (12***) +sectioning
λ=10 mm	K=0.36 tested	K=0.42 tested	K≈0.5 (calculated)
λ=12 mm	K=0.72 tested	K=0.83 tested	K≈1 (calculated)

*) Wire – Ø0.6 mm bare; **) Wire – Ø0.4 mm bare; ***) Wire – Ø0.3 mm bare

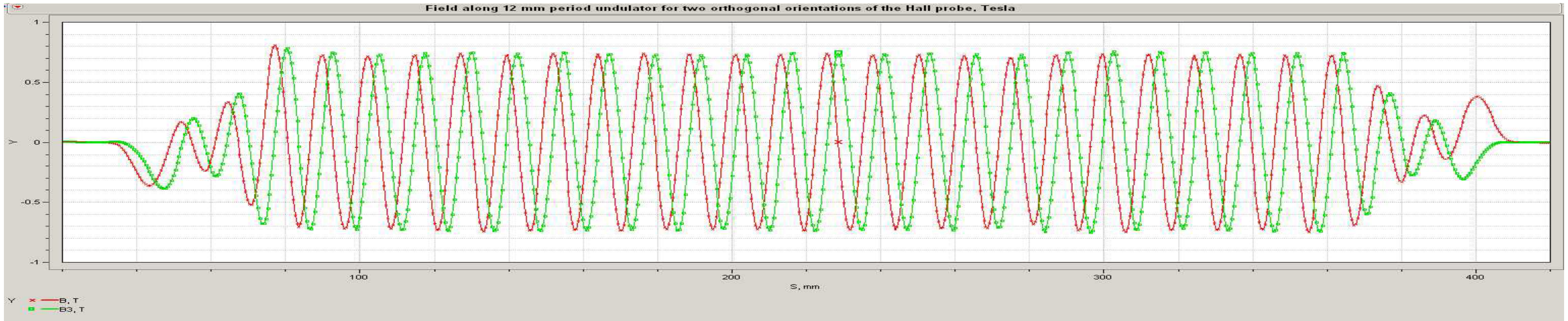


Fig.3: Field profile – conical ends. 6 layer, 12 mm period – orthogonal hall probes. 1Tesla full scale

For aperture diameter 5.75 mm we expect: for period 8mm – K~0.4 ; for period 10mm -K~0.9

•Progress to Date

•An overall concept design for the module as shown in Fig. 1 has been developed. The design is very compact, having an outside cryostat diameter of 100 mm. Standard size plumbing components are used throughout. Figure 1 shows the cross section design for tapered end coils.

•We have made optimization studies for undulators having 10 and 12 mm period with 8 mm clear bore and wound with various commercially available wires.

•Technology for fabrication of the undulator has been reduced to practice including winding of the wire and the helical iron yoke as well as procedures and apparatus for measuring the field distribution at the operating temperature.

•Several 40 cm long undulator models with 10 and 12 mm period, 8 mm clear bore have been made and measured.

Summary Page for the Capture RF

Topic Action Items:

C. Capture RF

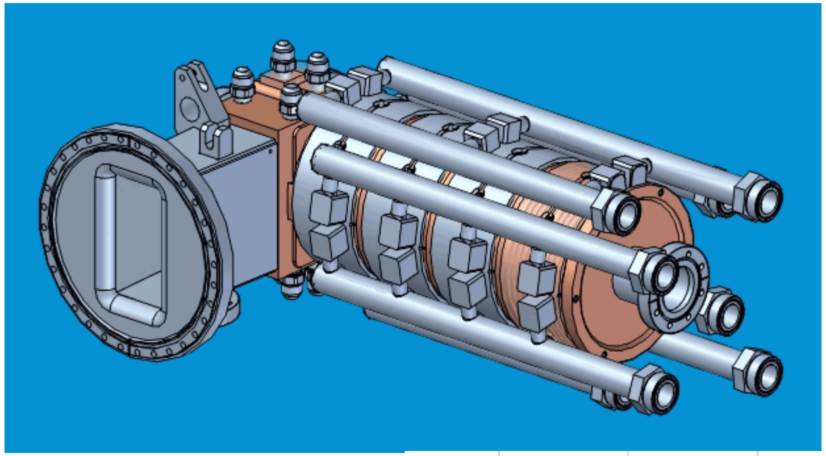
1. Progress

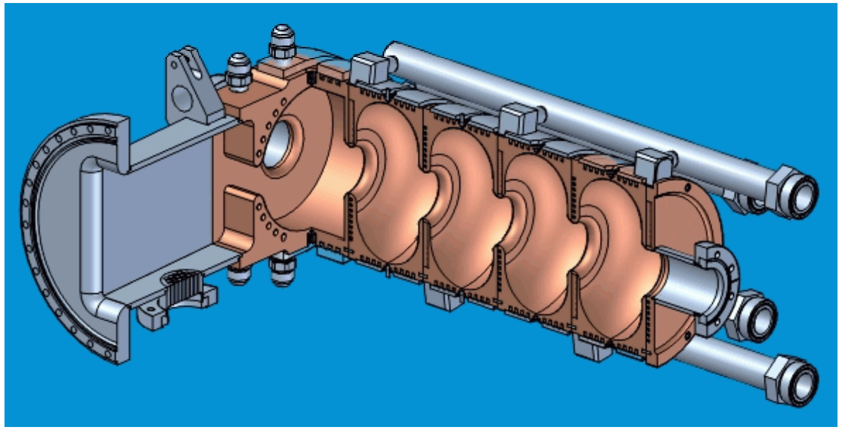
   Five-cell L-Band SW Test Structure
   - Microwave QC for all accelerator cells and assemblies has been completed.
   - As a last assembly, the coupler assembly has been delayed. Now the final machining for cell profile is nearly finished.
   - We plan to have a stack measurement starting from next week.
   - The final structure assembly will be done in February of 2007. Then, the microwave tuning, characterization as well as high power test will proceed.

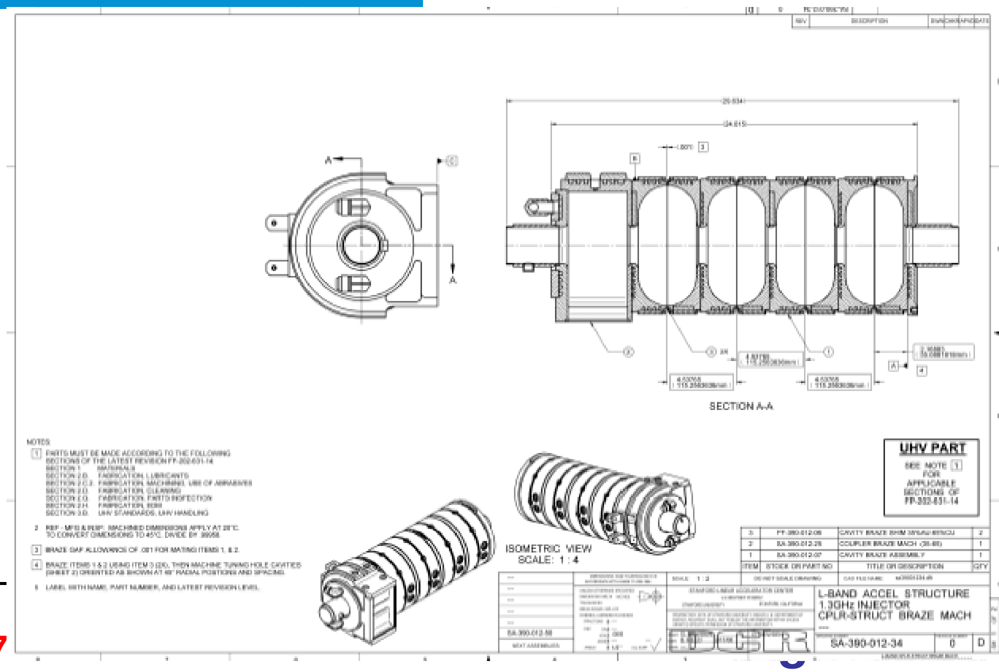
   L-Band RF Windows
   - Two windows have been completed and are under high power test.
   - All of other three sets of window parts are ready to assembly.

2. In the process of cost estimation and drafting for RDR, the RF system configuration and detailed parts count have been carefully studied.

Prototype Positron Capture Section

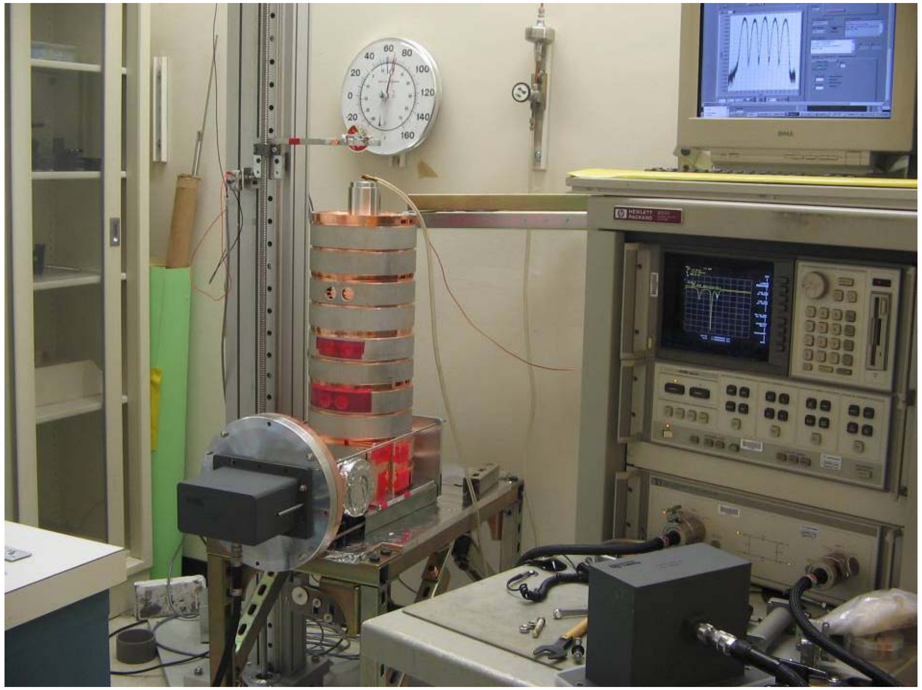




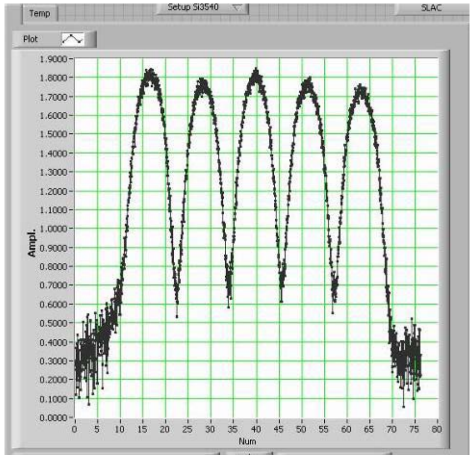


Preliminary Microwave Checking

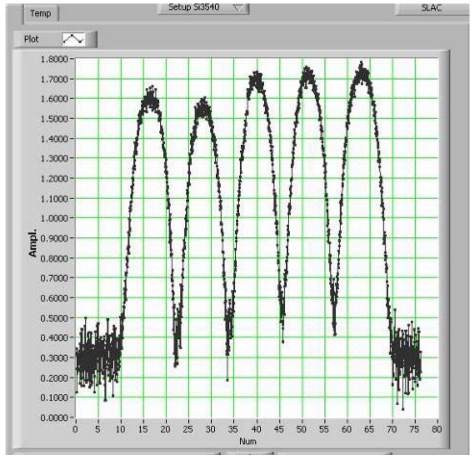
Measurement Setup for the Stacked Structure before Brazing without Tuning



Field Plots for Bead Pulling Two Different Frequencies Showing the Correct Cell Frequency and Tuning Property.

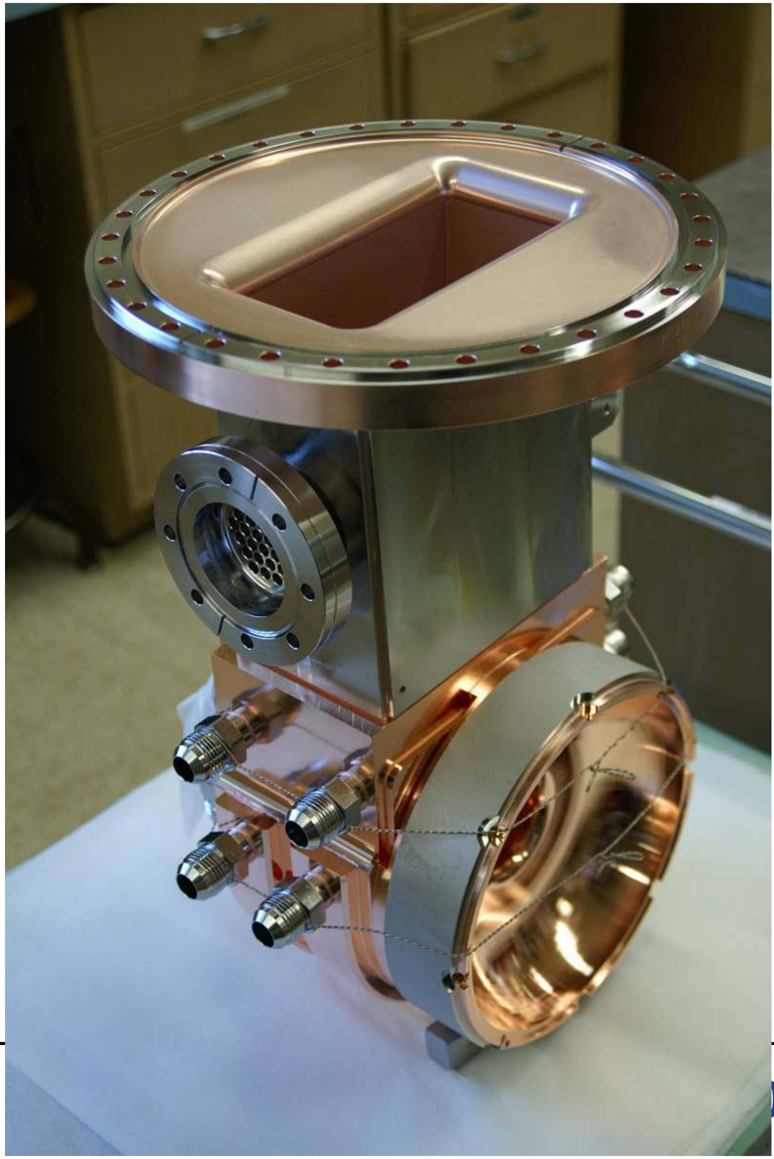


1300.175 MHz
at 20° C, N_2



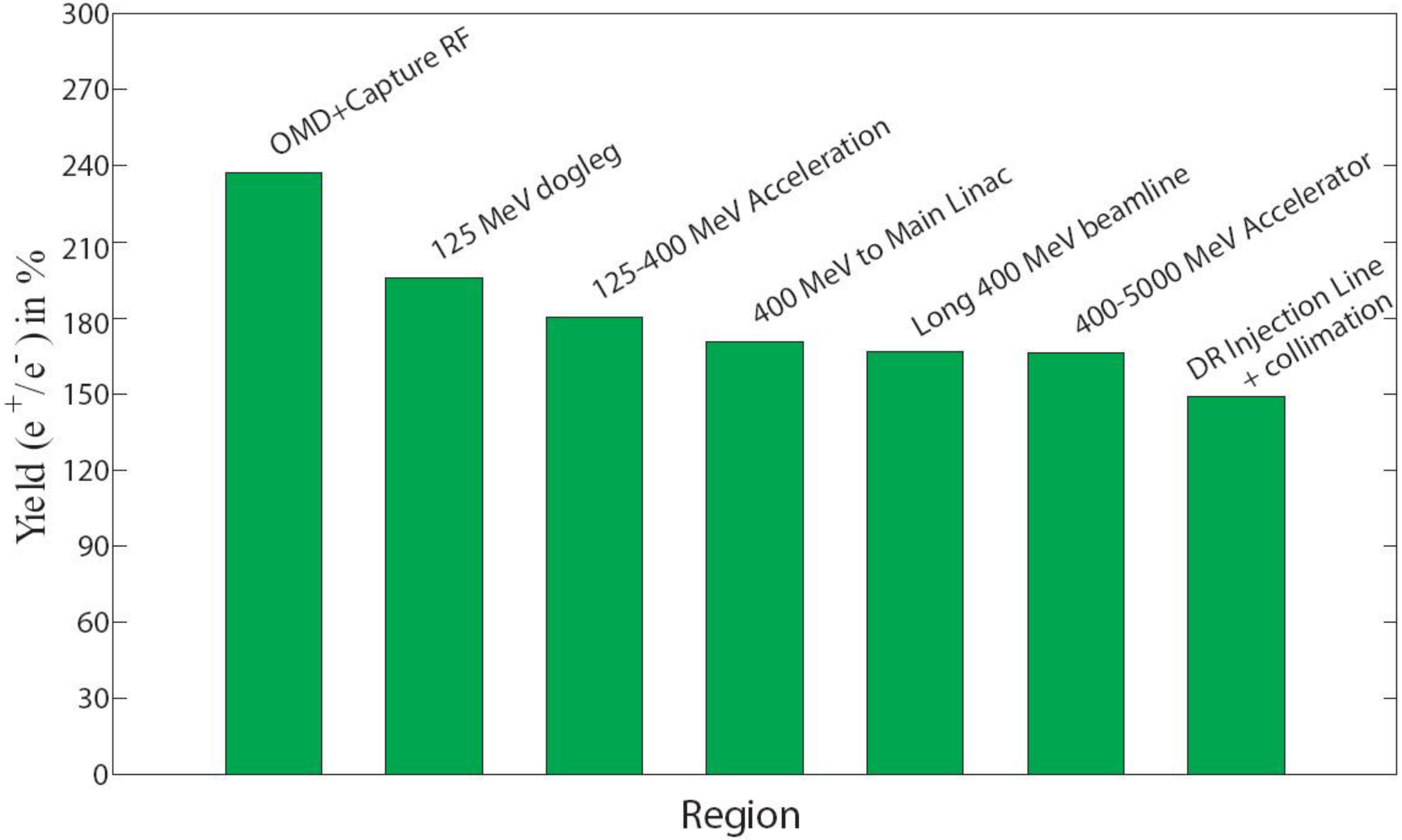
1300.125 MHz
at 20° C, N_2

Brazed Coupler and Body Subassemblies Ready for Final Brazing



Optics

- Source optics laid out. Need to look at details
  - Beam loss and collimation
  - Component interferences (target halls, DR injection)
  - Refine and document optics and beam physics



FLUKA Validation Experiment

Radiation Protection Dosimetry (2005), Vol. 116, No. 1–4, pp. 12–15
doi:10.1093/rpd/nci052

BENCHMARK STUDIES OF INDUCED RADIOACTIVITY PRODUCED IN LHC MATERIALS, PART II: REMANENT DOSE RATES

M. Brugger[1], H. Khater[2], S. Mayer[1], A. Prinz[2], S. Roesler[1,*], L. Ulrici[1] and H. Vincke[2]
[1]CERN, CH-1211 Geneva 23, Switzerland
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ELSEVIER Nuclear Instruments and Methods in Physics Research A 484 (2002) 680–689
www.elsevier.com/locate/nima

Induced radioactivity of materials by stray radiation fields at an electron accelerator

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Received 25 July 2001; received in revised form 29 August 2001; accepted 9 September 2001

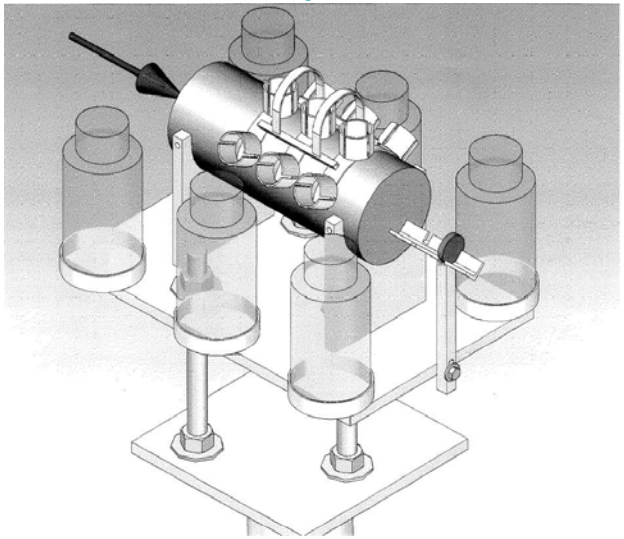
Measurements of induced radioactivity activity and residual dose rates at an electron accelerator

– PROPOSAL –

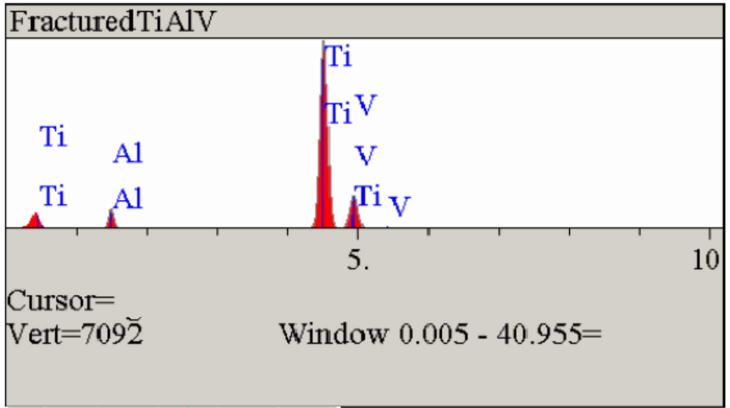
H. Brogonia, A. Fassò, M. Kerimbaev, C. Hast, J. Liu, S. Rokni, H. Tran - SLAC
M. Brugger, S. Roesler, H. Vincke - CERN

FLUKA Validation Experiment

- SLAC/CERN Collaboration (RP groups)
  - Validation of FLUKA activation calculations
    - 100 W
    - 30 GeV electron beam in ESA at SLAC
    - Cylindrical copper dump
    - Samples around the dump (including a Ti-4V-6Al)
    - Look mr/hour and gamma spectrum from irradiated samples
  - Data taken, analysis in progress
  - http://www-group.slac.stanford.edu/esh/rp/rpg/T-489



Preliminary Data: Ti and Ti-alloy (jcs)



Surface and Materials Science

Elt.	Line	Intensity (c/s)	Error 2-sig	Atomic %	Conc	Units	
Al	Ka	110.28	2.711	8.097	4.719	wt.%	
Ti	Ka	1,522.85	10.075	88.049	91.040	wt.%	
V	Ka	61.64	2.027	3.854	4.241	wt.%	
				100.000	100.000	wt.%	Total

kV 15.1
Tilt 30.0°
Elapsed Livetime 60.0

setup is different from ILC case,
samples irradiated from secondaries