ILC Positron Source Collaboration Meeting

(7-9 April 2008)

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23 May 2008

http://indico.desy.de/conferenceDisplay.py?confId=586

Purpose of the April Meeting

- Review studies since the last meeting (Sept 07)
- Assess R&D requirements for whole of positron source
  - **Generate prioritised list**
  - **Take account of reduced resource level when estimating timescales**
- Assess possible cost reduction measures
- Discuss new work breakdown structure
- **Topics**
  - **Collimation**
  - **Undulator**
  - **Compton Source**
  - **Target**
  - **Polarisation**
  - **Remote Handling**
  - **Source Modelling**
  - **OMD**

The RDR Parameters

Nominal Positron Source parameters († upgrade values).

Beam Parameters	Symbol	Value	Units
Positrons per bunch at IP	n_b	2×10^{10}	number
Bunches per pulse	N_b	2625	number
Pulse repetition rate	f_{rep}	5	Hz
Positron energy (DR injection)	E_0	5	GeV
DR transverse acceptance	$\gamma(A_x+A_y)$	0.09	m-rad
DR energy acceptance	δ	$\pm$ 0.5	%
DR longitudinal acceptance	A_l	$\pm3.4 \times \pm25$	cm-MeV
Electron drive beam energy	E_e	150	GeV
Electron beam energy loss in undulator	ΔE_e	3.01	GeV
Positron polarization †	P	$\sim$60	%

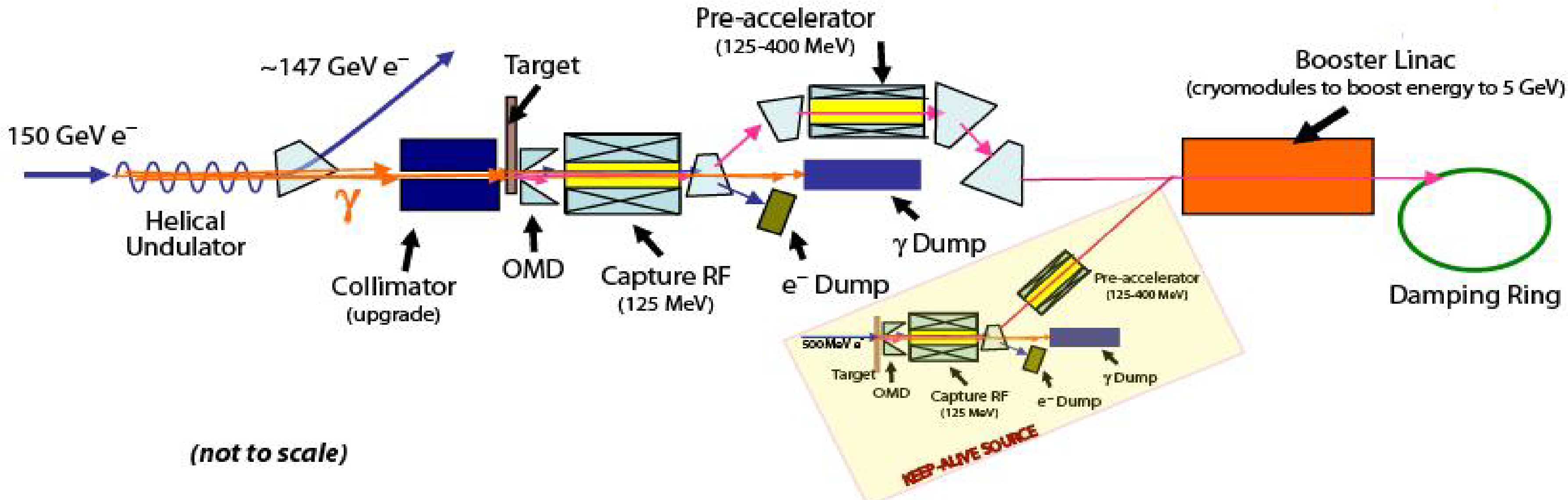
Positron overhead of 50% after the target

- ➔ 3×10^{10} e^+ per bunch at 400 MeV

Positron overhead of 25% at the Damping Ring

- ➔ 2.5×10^{10} e^+ per bunch within the DR acceptance

RDR Source Layout



- Photon beam generated in helical superconducting undulator at 150 GeV
- Photon beam transported ~400m beyond undulator and then impinges on Ti alloy target (0.4 rad lengths, 1.4cm)
- Positrons captured with optical matching device and accelerated with NCRF Linac with solenoidal focussing to 125 MeV
- Any electrons and remaining photons are then separated
- Positrons further accelerated with NCRF Linac with solenoidal focussing to 400 MeV
- Transported at 400 MeV for ~5km
- Accelerated to 5GeV in SCRF Linac and injected into DR

Collimation

Low-power photon-collimators in the undulator lattice

- current work is based on collimator specifications previously calculated by O. Malyshev et al in 2006 (see EUROTeV Report 2006-086):
    - maintain a vacuum at the level of 10^{-7} T by preventing photodesorption of cyrosorbed hydrogen from the inner surface of the undulator beampipe.

- Now: building the collimator geometry into Geant4 and interfacing to the helical undulator photon distributions.
- study depends on realistic simulation of photons emitted at wide angles from the central beam-axis.
    - **optimise geometry and materials.**
    - **Report expected in June for EPAC**

Collimation

High-power photon collimator

- sits directly upstream of the photon production target and is intended to
  - scrape the beam to protect instrumentation, etc in the target station and
  - adjust the polarisation of the beam.

    in that (upgrade) case the power load on the target may be up to 100kW. → realistic undulator photon spectra are important as the polarisation of the photon beam is a function of angle.

- Initial studies with collimator geometry in FLUKA
- Now: also aspects of the undulator spectra
  - collimator energy deposition, heat load, activation etc.
- Report expected in June 08 for EPAC

Undulator

- 42 x 4m cryomodules (42 x 3.5 = 147m active length)
- Vacuum pumps, photon collimators, quads,
  BPMs installed every 3 cryomodules in room temp sections
- Corrector magnets in every cryomodule

Undulator Parameters	Symbol	Value	Units
Undulator period	λ	1.15	cm
Undulator strength	K	0.92	
Undulator type		helical	
Active undulator length	L_u	147	m
Field on axis	B	0.86	T
Beam aperture		5.85	mm
Photon energy (1^{st} harmonic cutoff)	E_{c10}	10.06	MeV
Photon beam power	P_γ	131	kW

Undulator Session Summary (UK)

UK group (Daresbury and Rutherford):

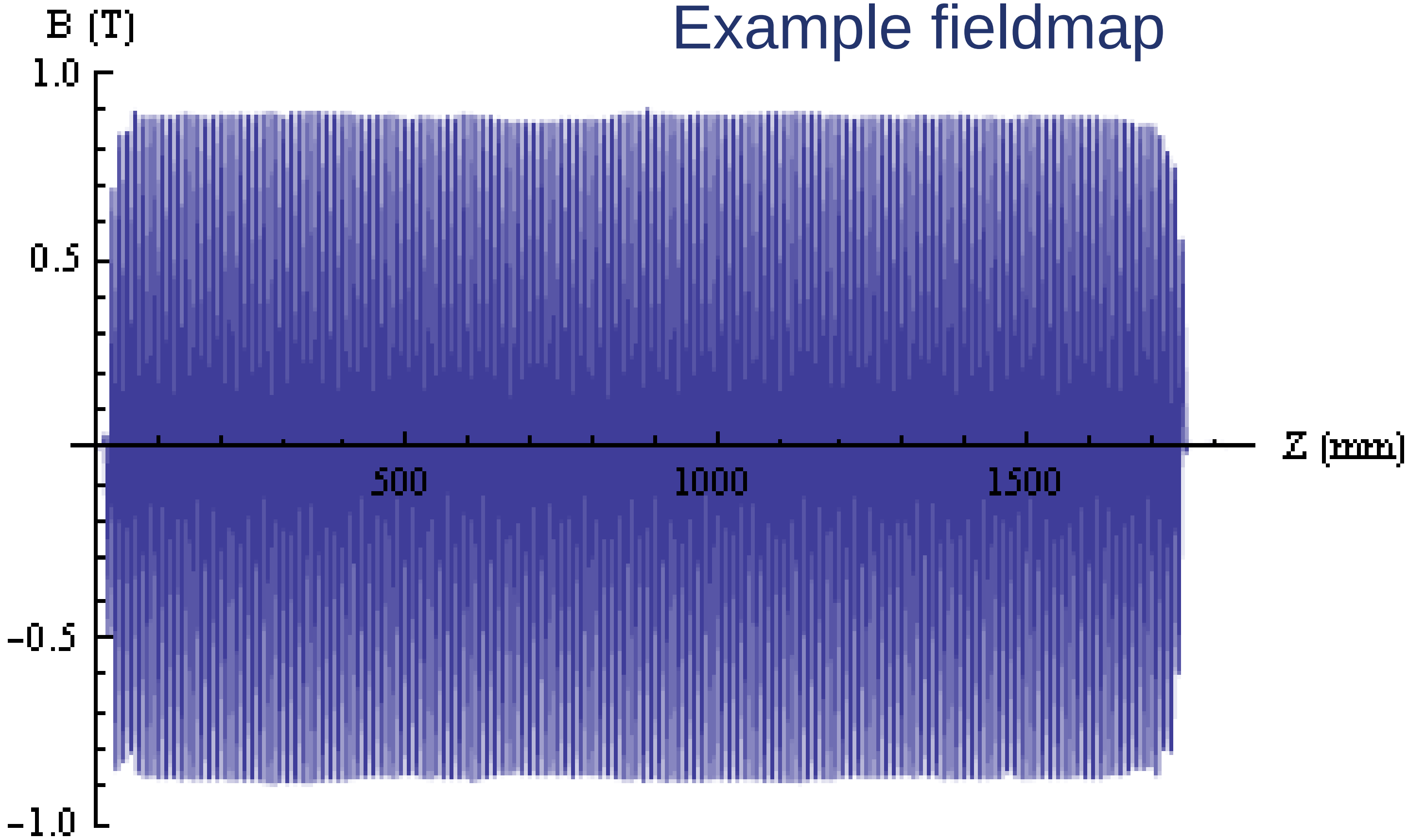
- Several short prototypes were tested
- STFC are building a full scale 4m undulator module
  - **2 x 1.75m undulators**
    - **both have been manufactured**
    - **the first has finished vertical test**
  - **RDR parameters**
  - **now focus on design, manufacture and testing of 4m cryomodule**

- Very good test results:
  - **magnet reached full design field (0.86T) without quenching**
  - **Quench tests at high current → stable operation at ~1.1T**
  - **complete cryomodule is expected by end June 08**

UK Vac Vessel, Turret, Und II

UK Measurements Taken - Magnet 1

Example fieldmap



Measured period (from field zero crossing points): 11.48 +/- 0.02mm
peak field at the nominal current of 215A: 0.88 +/- 0.014T.

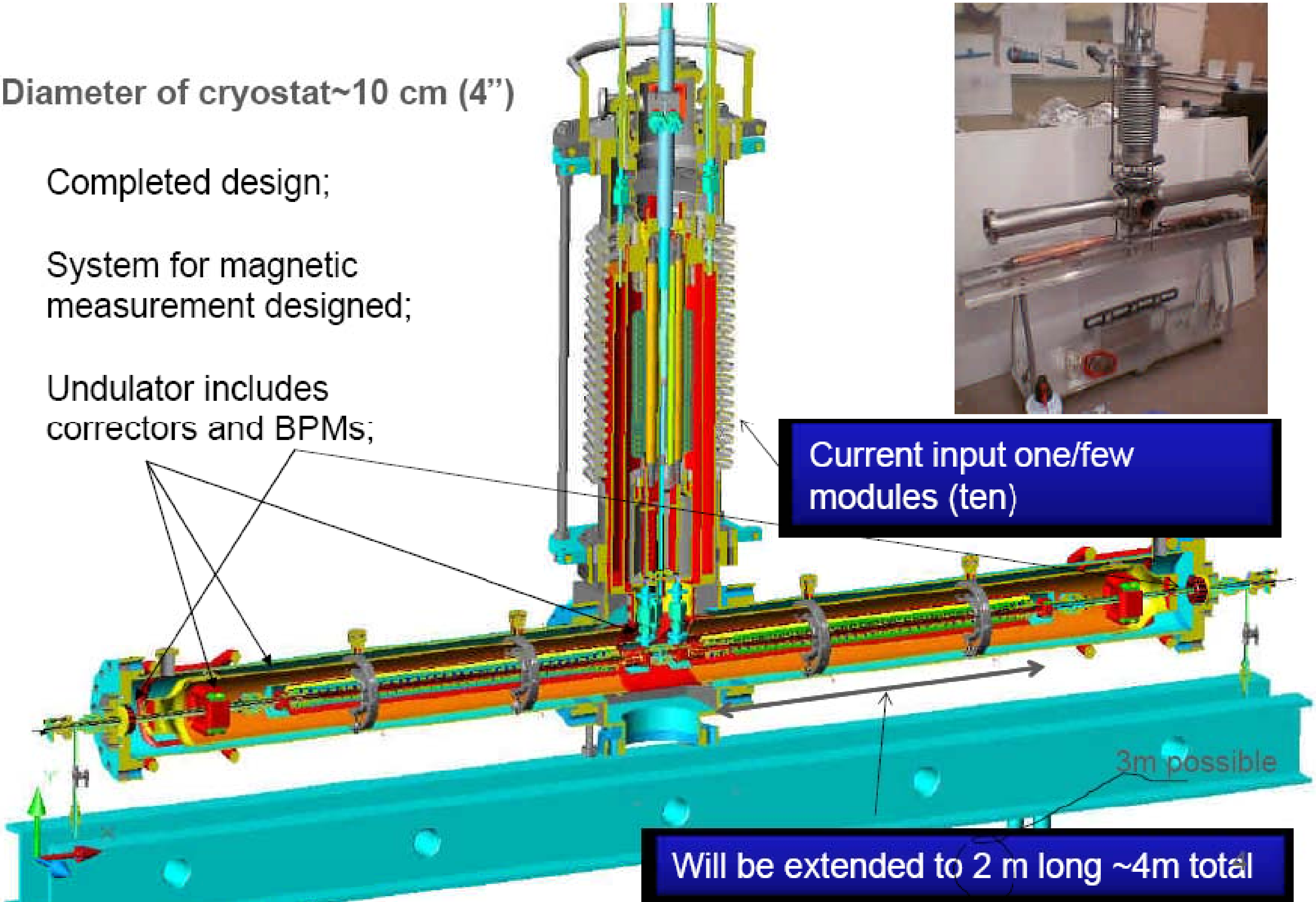
Cornell Undulator

Diameter of cryostat~10 cm (4”)

Completed design;

System for magnetic measurement designed;

Undulator includes correctors and BPMs;



Current input one/few modules (ten)

Will be extended to 2 m long ~4m total

Undulator Session Summary (Cornell)

- Cornell undulators have achieved
  - **K=1.48 for a period of 13.5mm (measured) and**
  - **K=0.7 for a period of 10mm (simulated), both with a winding bore of 6.35mm.**
- A full scale cryomodule design has been generated with a cryostat diameter of only 10cm.
- Long (2 to 3m) formers have been manufactured by industry.
- Pumping of the LHe has been tested (to lower the temperature) and been shown to give a field increase of ~10%.

- Unfortunately all ILC positron source activities are presently stopped at Cornell.

Undulator Session Summary

Outstanding issues for the undulator include:

- undulator beam test will be essential at some stage.
- horizontal magnet field tests are also essential at some stage.
- cryomodules need to be engineered for industrial production and long term operation.
- The intermodule sections need to be engineered (both room temperature sections and cold to cold transitions).

- Simulations:
  - **"Real" Undulator spectrums required for modelling of source**
  - **magnet field data should be used as basis for generating realistic spectral data to be used in future source simulations**
  - **Alignment requirements justified/jitter studies/impact on polarisation**

Compton Source Session Summary

R&D on 2 and 4 mirror cavity systems (reported by A. Variola).

- **2 mirror system achieved finesse of ~1200, new mirrors are needed for 10^4 – 10^5, and this has been installed in ATF.**
- **Some problems have been encountered trying to establish feedback loops and a good laser match.**
- **A 4 mirror system is more stable when trying to achieve smaller spot sizes → this is also being worked on and will be installed into ATF later.**

Damping ring stacking studies (F. Zimmermann and A. Vivoli).

- **Initially large (76%) injection losses were found when using similar assumptions as used previously for Snowmass 2005 simulations.**
- **these losses seem to be reduced sigificantly (down to 11%) by**
  - Improving the energy pre-compression,
  - additional damping wigglers and
  - more installed RF voltage
- **There are many other possible options to be tried, including a pre-damping ring.**

Compton Source Session Summary (cont.)

Linac based compton source with CO_2 regenerative amplifier laser system. (Yakimenko)

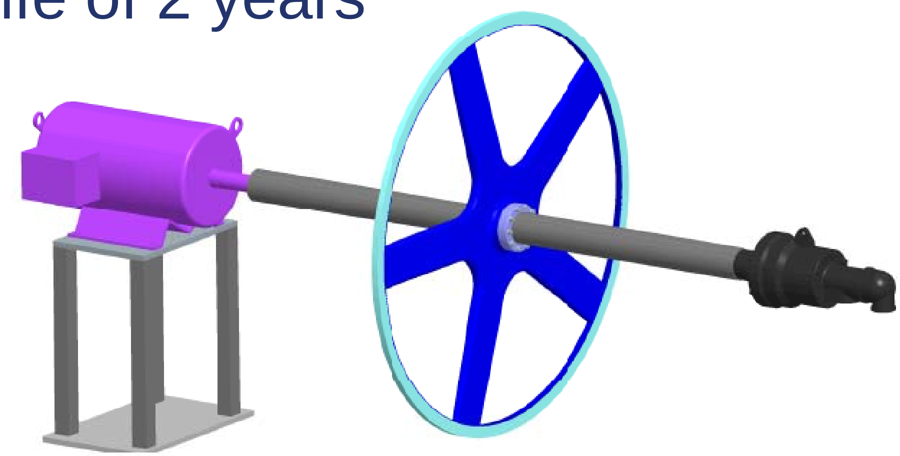
- Modelling of the short pulses in an isotopic gas mixture has started.
- Injection into a regenerative amplifier using germanium is planned to start soon.

Outstanding issues:

- Continue DR stacking studies and work with DR group to ensure optimum solution.
- Continue cavity stability tests at LAL and KEK.
- Laser demonstration needed.
- ATF experimental work to continue.
- 2010 demo of high gamma flux at ATF.

Target

- 1m diameter spinning wheel
- Rim & spokes not solid disk to mitigate eddy current effects
- Designed for operational life of 2 years

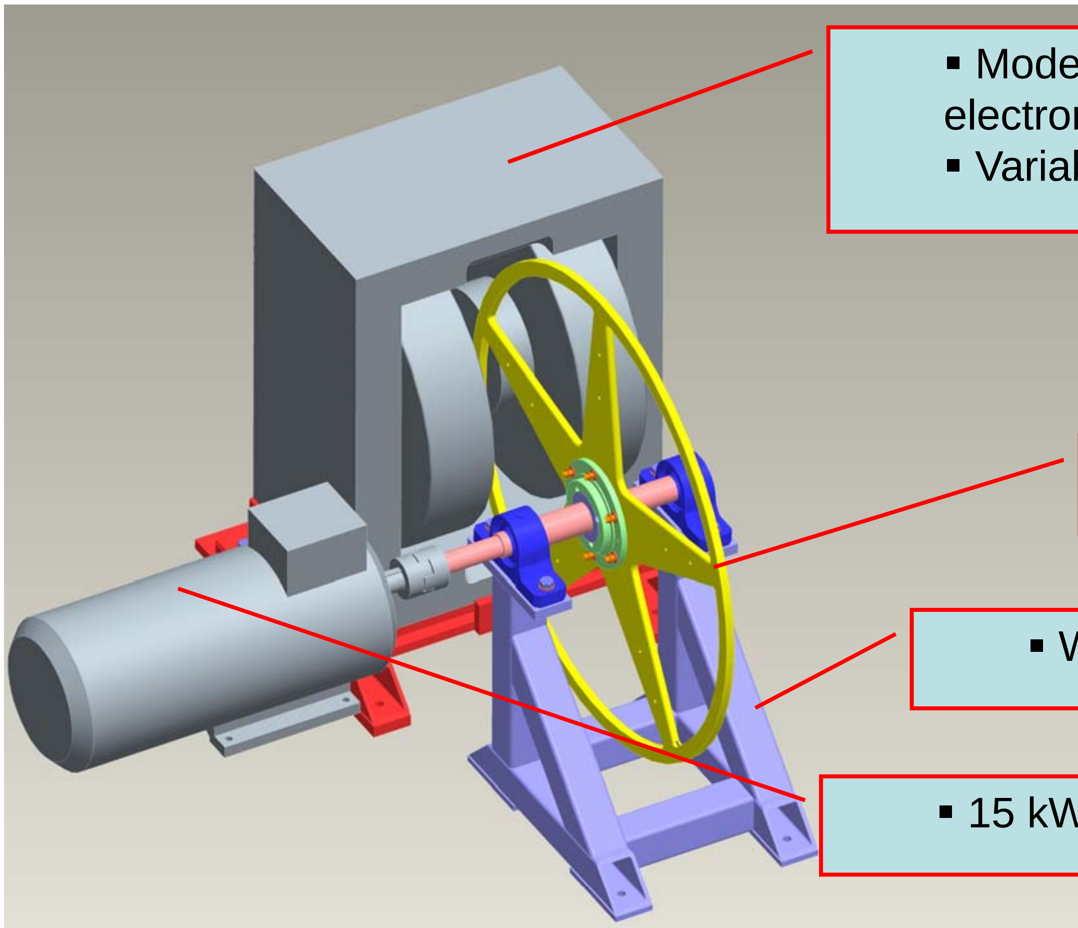


Target Parameters	Symbol	Value	Units
Target material		Ti-6%Al-4%V	
Target thickness	L_t	0.4 / 1.4	r.l. / cm
Target power adsorption		8	%
Incident spot size on target	σ_i	> 1.7	mm, rms

Prototype Design

Prototype I - eddy current and mechanical stability

Ken Davies - Daresbury Laboratory



- Model 3474-140 GMW water-cooled electromagnet
- Variable pole gap (0mm to 160mm)

- Ti alloy wheel.

- Wheel support stand.

- 15 kW drive motor (Control Techniques)

UK Prototype

Target

- Complete Eddy current tests at Daresbury
- Generate simulations to compare with experimental results
- Pressure shock wave analysis and numerical modelling
  - **Simulations of the pressure shock waves using hydrodynamic modelling at Cornell suggests the Ti target would not survive.**
  - **Further simulation will be carried out to verify this. The validity of the quasi-classical approximations used will be checked as well as the theoretical description of the beam intensity / polarisation and the implications of using an imperfect undulator.**
  - Alternative liquid metal (BINP/KEK tests)
- Guarding thickness verification (LLNL)
- Ensure consistency between ANL/DESY simulations
  - **Energy compression before DR**
- Lifetime studies of target (LLNL)
- Engineered solution, including prototype tests – water, vacuum, …

Polarization

RDR design (but not baseline!!) → **positrons will be polarized** (~30%)

- **With energy compression positron polarization could reach 45%**

- Requirements of baseline documents can be fulfilled by destroying the polarisation completely → scheme will be worked out
- In any case - measurement of e+ polarization at IP
- If e+ polarisation is kept
  - → **helicity reversal is needed**
  - → **spin rotation (Optimise spin rotator design working at 400MeV instead of 5 GeV).**
- frequency of the helicity flip:
  - **depends on the time stability of luminosity and polarization**
  - **first years of running: helicity reversal after hours might be sufficient**
  - **But: to be superior to LHC results, helicity flip with sufficiently high frequency should be possible**
  - ➔ **evaluate consequences of 'slow' reversal**

Tools for design and performance studies: Geant4 with polarization

- **Maintenance and validation of Geant4 with polarization.**
- **Comparison of yield and polarization results with other codes.**

Polarization

Polarimetry at low energies

– **Bhabha polarimeter at 400 MeV suggested**
  - Optimization of polarimeter layout including spectrometer magnet and detector.
  - Further work for a reliable target design.

– **Compton polarimeter after DR, before ML**
  - save costs using the laser of the laser wire system
  - realistic performance study
  - to be done in collaboration with laser wire group

Polarization modelling

– **All depolarization effects have to be accurately calculated**

– **precise spin tracking is required already for the baseline design.**

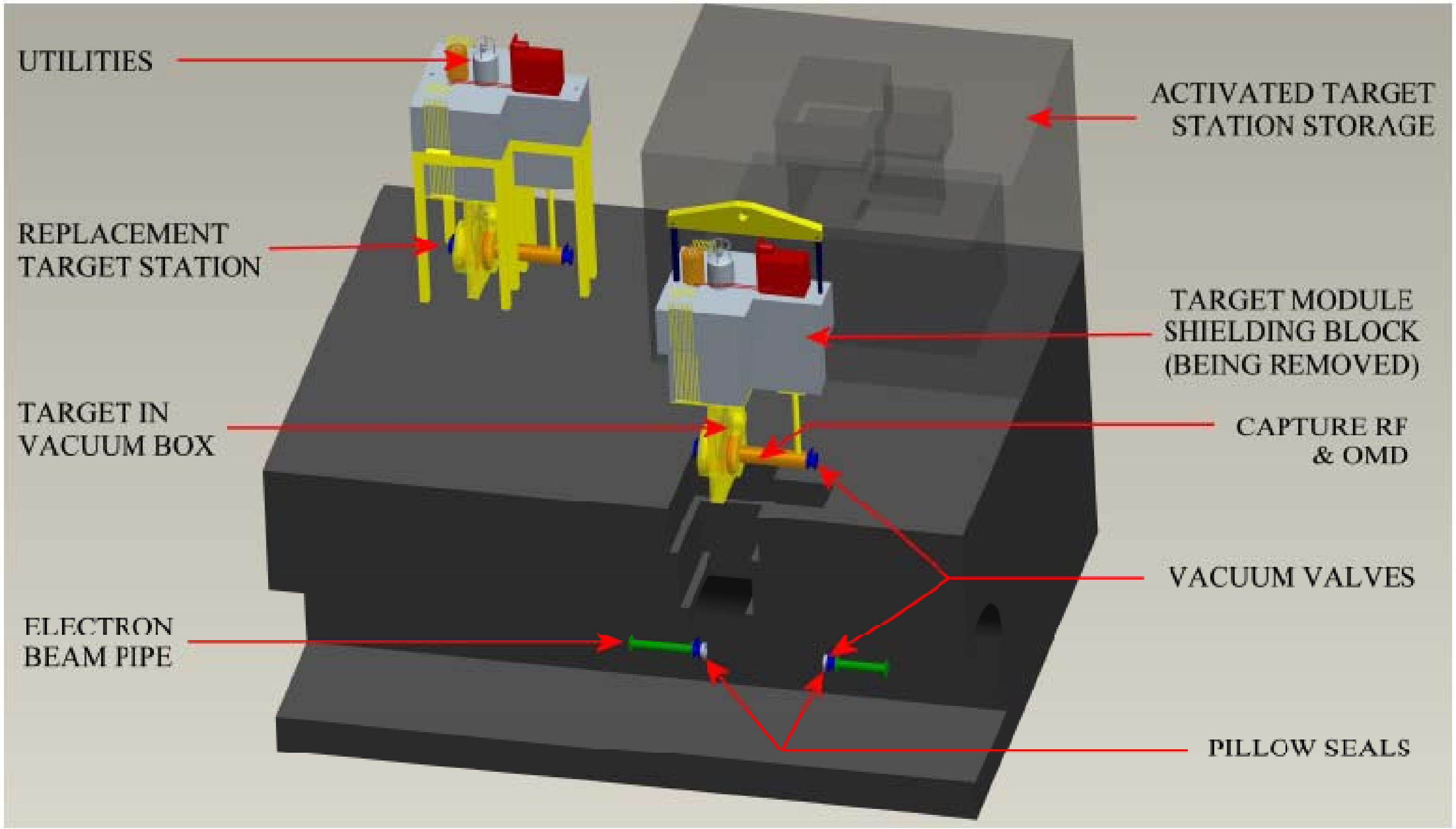
– **This work has to be done for the electrons as well as the positrons.**

➔

- **Theoretical studies to describe spin precession in strong fields.**
- **Inclusion of second order depolarization processes**

Remote Handling

- Needed for target, OMD, NCRF linacs
- Change over time for target ~ 2days
- Also needed for KAS Target



Remote Handling

No progress since last meeting on the RH design itself (same as in RDR)

- **RAL has staff effort available after Summer ’08, but no funding; ORNL have no funding.**
- **No plans to address remote-handling activities in Japan, although the alternative source (Keep-alive source) will also require remote-handling.**

➔ **It would be useful to see estimated activation numbers for the alternative source.**

Ongoing activities:

- Activation simulations continue to be refined.
- Latest results (increase of capture efficiency by energy compression):
  - **Possibly reduced undulator-length**
  - **dropping the equivalent dose rate from the target wheel to 250 (90) mSv / hour after 1 hour (1 week) of shutdown.**
  - **Depending on required time for changeover it may be possible to eliminate some elements of the remote-handling**

Remote Handling (contd.)

- **Ongoing work and questions**
  - **Preliminary use of detailed target model in FLUKA**
  - **Collimator in RH**
  - **Activation of water**
  - **Shielding thickness around target etc**
  - **RH scenarios refined**
    - Changeover times (requirement ties in with lifetime of kit in RH)
    - Replacement of pillow seals?
    - RH for auxiliary source (KEKB?)
  - **Need engineered design compatible with source layout (remove inconsistencies!)**

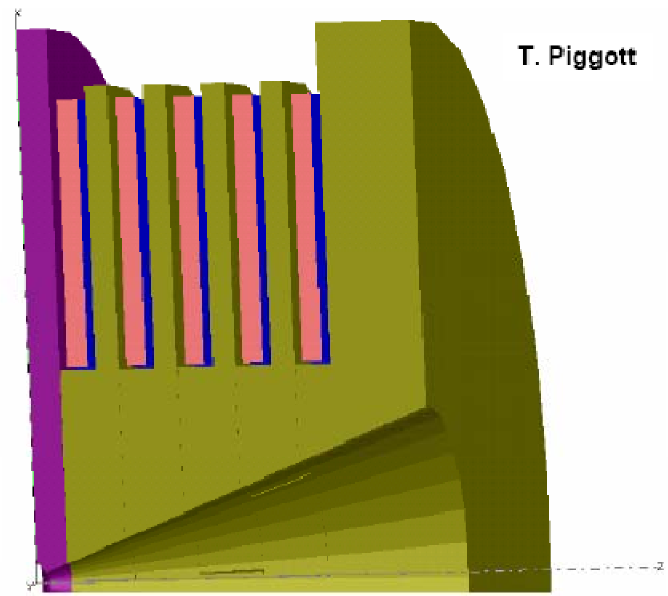
Source Modelling

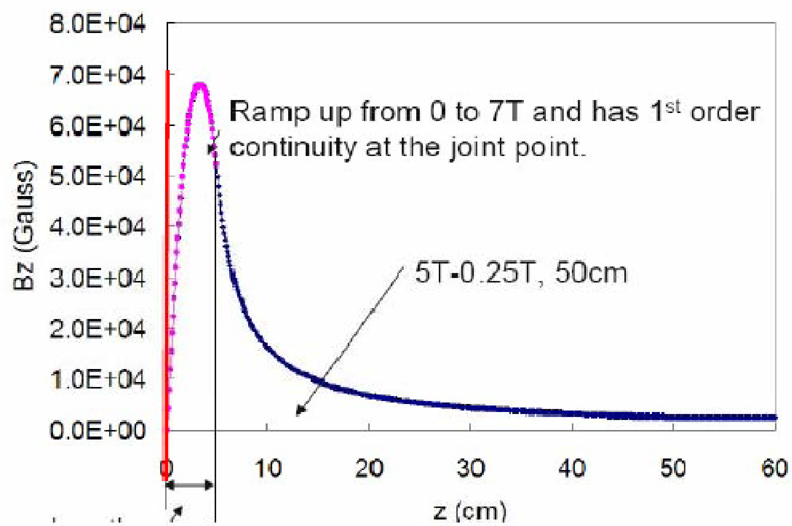
- Emittance evolution of the electron beam through the undulator has been studied by ANL.
  - **code Elegant**
  - **Without energy spread emittance decreased by ~1% in both planes.**
  - **With energy spread change was still at the % level but showed an increase in the vertical plane for 300m long undulator,**
  - **ANL group has also started to look at Quad-BPM misalignments in the undulator section.**
- Geant4 now includes polarisation processes and can also handle particle motion in electric and magnetic fields.
  - **polarisation results have been well tested as part of the E166 analysis.**
  - **undulator source (target & capture sections) have been modeled and should be benchmarked against other codes.**

- Outstanding issues that were raised include:
  - **Write-up of undulator emittance effect**
  - **Benchmark G4 polarisation/yield against other codes**
  - **Study activation of linac after target, copper vs aluminium**
  - **Re-evaluate undulator K if target/OMD changes**
  - **Ongoing yield/polarisation evaluation with source design evolution**

Optical Matching Device

- Increases capture efficiency from 10% to as high as 40%
  - **Depends on scheme selected**
- Flux Concentrator



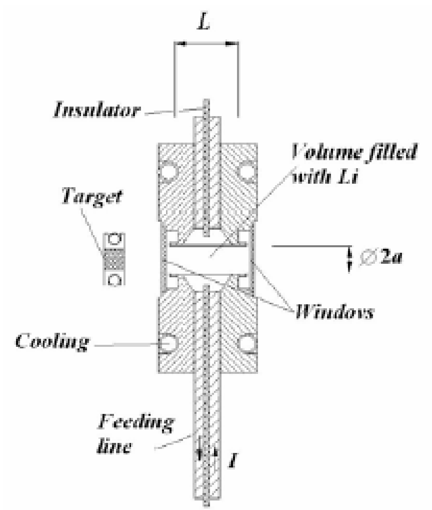


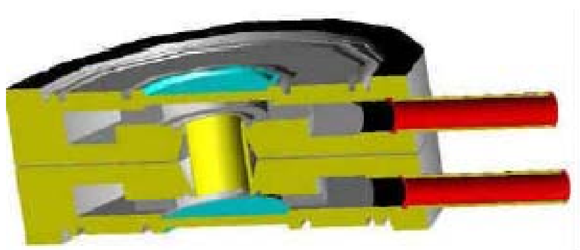
W. Liu

- Reduces magnetic field at the target
  - **Reduced capture efficiency, 21%**
- Pulsed flux concentrator used for SLC positron target
  - **It is a large extrapolation from SLC to ILC**
  - **1µs -> 1ms pulse length**

OMD, Lithium Lens

Proposed by Cornell, up to 40% capture





Mikhailichenko CBN 08-1

- Most mature OMD design we have
- Some engineering questions related to survivability:
  - **What is the radiation damage in the windows from photo-nuclear reactions?**
  - **What is the stress-strain in the windows from heating?**
  - **Does thermal cycling cause fatigue?**
  - **Is there cavitation in the liquid metal?**
    - If yes, will this erode the windows?

OMD Summary

- Li Lens
  - **Evaluate level of radiation damage in window & implications for lifetime**
  - **Stress-strain in window**
  - **Thermal cycling fatigue**
  - **Cavitation wear on windows**
  - **Proton beam tests?**
  - **Contact experienced Li lens experts to discuss this idea**
  - **KEKB BN window tests (liquid lead target)**
- Flux Concentrator
  - **Need feasible design**

    (The pulsed flux concentrator is an extrapolation from a device used for a hyperon experiment and requires a serious engineering effort before its viability can be evaluated.)

Keep Alive Source (KAS)

- RDR: KAS is incorporated into the design
  - **KAS uses 500 MeV electron drive beam which impinges on W-Re target**
  - **Positrons from KAS are accelerated to 400 MeV and then share common SCRF Linac to reach 5 GeV**
  - **KAS designed to generate 10% bunch intensity for full bunch train (2625 bunches) at 5Hz**

➔ Remove keep alive source, auxiliary source only

Cost Issues

- Re-establish RDR "Baseline" Cost
- Change undulator location to end of main linac
- Change underlying assumption of yield of 1.5 e^+ in DR for every e^- in undulator
- Reduction of DR acceptance allowed – discuss with DR experts
- Reduce undulator chicane offset from 2.5m to <1m
  - **Use dog-leg instead (linacs no longer coaxial)**
  - **Use 3 bump insert**
- Maximise e^+ polarisation to increase effective luminosity, enabling scaling back of ILC parameters
- Remove keep alive source, auxiliary source only
- Maximise yield (eg Li lens, energy acceptance)

Critical R&D

- Priority 1 – major impact on feasibility/performance
  - **Target**
  - **OMD (Li lens & Flux Concentrator)**
  - **Remote Handling design**
  - **SW NC Linac**
- Priority 2 – Necessary but not expected to be critical
  - **High power photon collimator design**
  - **Undulator beam tests**
  - **SCRF Linac designs**
- Alternative - Compton Source
  - **Stacking, cavity stability, laser, ATF demo, …**
- Our new motto from this week
  - **"Maximise the yield, minimise the cost"**