ILC Positron Source Collaboration Meeting – Session Summaries

Zeuthen 7 – 9 April 2008

The meeting web site can be found here
https://indico.desy.de/internalPage.py?pageId=1&confId=586.

The agenda is here
http://ilcagenda.linearcollider.org/conferenceOtherViews.py?view=standard&confId=2639.

Sessions were held on:

Collimation
Undulator
Compton Source
Target
Polarisation
Remote Handling
Source Modelling
OMD/Capture Optics

Below are brief summaries of each session.

Collimation

Adriana Bungau (CI) gave a status report of the low-power photon-collimators in the undulator lattice. The current work is based on the collimator specifications previously calculated by O. Malyshev et al in 2006 (see EUROTeV Report 2006-086) in order to maintain a vacuum at the level of 10^{-7} T by preventing photodesorption of cyrosorbed hydrogen from the inner surface of the undulator beampipe. The collimators will be approx 10m apart.

Since March Adriana has been working on building the collimator geometry into Geant4 and interfacing to the helical undulator photon distributions. The study depends on realistic simulation of photons emitted at wide angles from the central beam-axis. After initial studies using photon spectra from SPECTRA, the SPUR code will be used. Need to optimise distance at which first collimator is required and then look at energy deposition, etc in order to optimise geometry and materials. Report expected in June for EPAC.

Ian Bailey (CI) gave a status report on the high-power photon collimator that sits directly upstream of the photon production target and is intended to i) scrape the beam to protect instrumentation, etc in the target station and ii) adjust the polarisation of the beam. In the latter (upgrade) case the power load on the target may be up to 100kW. Here too, realistic undulator photon spectra are important as the polarisation of the photon beam is a function of angle. Following initial studies last year in which a collimator geometry was studies in FLUKA, Lei Zang at the University of Liverpool has been looking at aspects of the undulator spectra. Report expected in June 08 for

EPAC. Lei will attend the next FLUKA school in June 08. The default plan beyond this is for Lei to assess the collimator energy deposition, heat load, activation etc.

Undulator Session Summary

The UK group (Daresbury and Rutherford) reported on the progress made in the manufacture and testing of the 4m cryomodule. All of the major components and tooling is now at RAL except the LHe bath which is well advanced. Both 1.75m undulators have been manufactured and the first one has finished vertical tests. The test results are very good, the magnet reached full design field (0.86T) without quenching. The period has been measured (from field zero crossing points) to be 11.48 +/- 0.02mm and the peak field at the nominal current of 215A to be 0.88 +/- 0.014T. Many repeat scans have been taken and show repeatability from scan to scan but not from one orientation to the next. Data that is (naively) corrected for voltage offset at zero field points shows trajectory errors at the exit of the undulator of ~5μm in both planes without any assumed dipole correction. Quench tests at high current have established stable operation at ~1.1T. The complete cryomodule is expected to be completed by end June 08.

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.

Outstanding issues for the undulator that were raised include:

1. An undulator beam test will be essential at some stage.

2. Horizontal magnet field tests are also essential at some stage.

3. The cryomodules need to be engineered for industrial production and long term operation.

4. The intermodule sections need to be engineered (both room temperature sections and cold to cold transitions).

5. The magnet field data should be used as the basis for generating realistic spectral data to be used in future source simulations.

Compton Source Session Summary

R&D on 2 and 4 mirror cavity systems was reported by A. Variola (LAL). The 2 mirror system has 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 so this is also being worked on and will be installed into ATF later.

Damping ring stacking studies are being carried out by F. Zimmermann and A. Vivoli. Initially large (76%) injection losses were found when using similar assumptions as used previously for Snowmass 2005 simulations. Improving the energy pre-compression, additional damping wigglers and more installed RF voltage seem to help to reduce these losses significantly (down to 11%). There are many other possible options to be tried, including a pre-damping ring.

V. Yakimenko reported on the linac based compton source which uses a CO2 regenerative amplifier laser system. 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 that were raised include:

1. Continue DR stacking studies and work with DR group to ensure optimum solution.
2. Continue cavity stability tests at LAL and KEK.
3. Laser demonstration needed.
4. ATF experimental work to continue.
5. 2010 demo of high gamma flux at ATF.

Target

Stefan Hesselbach from Durham reported on the theoretical description of the positron production processes that take place within the target wheel. The polarised photon beam that is used could produce destructive thermal shocks in the target wheel. A possible solution to use a liquid metal target such as Bi-Pb or Hg. The e^+ / e^- production simulations in GEANT and FLUKA use quasi-classical approximations but have be tested against data. The simulations to date include the undulator, target, lens and accelerating structures. 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.

The work by S.Riemann, A.Schalicke and A.Ushakov focussed on the simulations of the conventional vs the undulator based designs of the positron source. The positron yield (14.54 e^+/e^- , 2.35 e^+/e^-) and capture efficiency (34.2% , 63.7%) have been calculated for the two designs (respectively) with a pulsed flux concentrator. A helical undulator 71.9m in length with a k=0.92, λ=11.5mm, and a photon collimator aperture of 4.6mm gives a e^+ polarisation of 45%. The baseline conventional source gives no polarisation. The maximum deposited energy in a stationary target simulation is 2.7 times higher for the conventional source over the undulator solution, and the activation is 2.5 times higher (for example, after 1 hours cooling after switch off). However it was shown that a pure tungsten target has an activation 10 times lower than the baseline W25Re conventional target.

The status of work at Lawrence Livermore National Lab was presented by Tom Piggott, Jeff Gronberg and Lisle Hagler. LLNL calculations into the wheel stresses agree with RAL and they plan to do damage simulations as an input to the design of the experimental guarding and assist with the analysis of the vibrational and eddy current data from the experiment. So far their single pulse simulations show favourable results but these need to be extended to include more pulses using different codes and formulation including varying cooling scenarios and exploring multi-phase effects in titanium. Simulation work will include studying material property changes due to the thermal cycling and fatiguing and radiation damage and the engineering aspects of the water feed-throughs. Radiation studies have yielded a value of 0.1 displacements per atom per year damage. The effects of the increased strength and loss of ductility this causes will now be studied.

Leo Jenner gave a presentation on behalf of the team working at Daresbury (Ian Bailey, Jim Clarke, Ken Davies, Andy Gallagher, Don Clarke) on the target prototype experiment. Water and electricity services have been re-routed to the machine area, the Ti alloy wheel has been manufactured and installed with motor and torque transducer. The magnet support stand has been manufactured and guarding scheme designs have been sent out for purchase, although the cooling system has not yet been fully incorporated. So far the thermal temperature transducers have been fully interfaced to LabVIEW, as has field measurement and control. The torque transducer operates at the required 3.54 kHz using proprietary software as do the accelerometers which show good frequency response in a calibration test using tuning forks. When the local guarding is in place, the experimental plan is to perform a systematic scan over field and angular velocity from 0–1 Tesla and 0–2000 rpm. Torque and temperature readings will be used to benchmark simulations and long term stability of wheel operation will be studied.

Polarization

Polarization

With the baseline design given in the RDR the positrons will be polarized at a level of roughly 30%. With a bunch compressor the capture efficiency can be increased by a factor of two and the positron polarization could reach 45% (see A. Ushakov's talk). Positron polarization is not foreseen in the baseline documents but it is possible to fulfill the baseline requirements by destroying the polarisation completely. Otherwise it is desired to exploit positron polarization for physics measurements.

In any case the positron polarization should be measured at the IP either to verify that the positron beam is fully depolarized or to know the polarization with high precision.

If the positron polarization will be kept for physics, the helicity has to be reversed frequently and spin rotators before and after the damping ring are needed. It must be ensured that the positron spin survives to the DR. No reversal of the positron polarisation would increase the uncertainty for relevant physics observables substantially and would be worse than running without positron polarization. The frequency of the helicity flip depends on the time stability and reproducibility of the

machine parameters as luminosity and polarization. For the first years of running it might be sufficient to reverse the helicity after hours or days via switching the polarity of the solenoids. But to be superior to results expected at the LHC at that time, it should be possible to flip the helicity of the positrons with sufficiently high frequency. Details must be considered in collaboration with experts on polarization measurements at the IP.

Action items
• Write a brief report justifying the need for 5Hz positron spin flipping at some point and ability to reverse.
• Design the scheme to destroy the polarization completely in the damping ring.
• Optimise spin rotator design (working at 125 MeV instead of 5 GeV).

Tools for design and performance studies
Geant4 with polarization extension is used for spin tracking at the positron source and to design the low energy positron polarimeter. Future applications could also be the spin transport through the undulator.

Action items
• Maintenance and validation of Geant4 with polarization.
• Comparison of yield and polarization results with other codes.

Polarimetry
A Bhabha polarimeter at 400 MeV has been suggested by the LEPOL group to measure the positron polarization at the source. The Bhabha asymmetry corresponding to the positron polarization can be determined using the scattered electrons only. Studies are ongoing to optimize the polarimeter layout including spectrometer magnet and detector. Further work is needed for a reliable target design. A simulation of the polarization uncertainty to be reached with the Bhabha polarimeter is still to be done.

After the damping ring, before the main linac the positron polarization can be checked with a Compton polarimeter. To save costs the laser of the laser wire system should be used. The concrete design can only be prepared in close contact with the laser wire group.

For both polarimetery options, Bhabha and Compton, a more realistic background study is needed.

Action items
• Complete studies for the Bhabha polarimeter.
• Contact laser wire group, try to find agreement on possibilities of collaboration.

Polarization modelling
The high precision for physics at the ILC implicates a very demanding modelling of polarization in the machine. All depolarization effects have to be accurately calculated and a precise spin tracking is required already for the baseline design. This work has to be done for the electrons as well as the positrons.

Action items

• Theoretical studies to describe spin precession in strong fields.
• Inclusion of second order depolarization process.

Remote Handling

Ian Bailey gave a summary talk of the current remote-handling situation. There has been no progress since the last meeting on the remote-handling design itself which is the same as that in the RDR (53 hour changeover). RAL has staff effort available after Summer '08, but no funding for this project. ORNL have no funding. There are no plans to address remote-handling activities in Japan, although the alternative source (Keep-alive source) will also require remote-handling. It was decided that it would be useful to see estimated activation numbers for the alternative source.

There are several activities related to the remote-handling that are ongoing. Andriy's activation simulations continue to be refined. Latest results show that energy compression may increase the capture efficiency (positrons into damping ring acceptance) allowing the undulator-length to be reduced and dropping the equivalent dose rate from the target wheel to 250 (90) mSv / hour after 1 hour (1 week) of shutdown. Depending on how quick a changeover is required, it may be possible to eliminate some elements of the remote-handling given these activation levels.

A test of BN windows is envisaged at KEKB. It is not clear how applicable these results will be to the ILC regime.

Source Modelling

Emittance evolution of the electron beam through the undulator has been studied by ANL. The code Elegant has been used and 6 undulator parameter sets examined. Without energy spread the emittance decreased by ~1% in both planes. With energy spread included the change was still at the % level but showed an increase in the vertical plane for 300m long undulator, this has been cross checked against an analytical model. The group has also started to look at Quad-BPM misalignments in the undulator section.

Geant4 now includes 6 polarisation processes (added by DESY Z) and can also now handle particle motion in electric and magnetic fields. The polarisation results have been well tested as part of the E166 analysis. The undulator source (target & capture sections) have been modelled and should be benchmarked against other codes.

Outstanding issues that were raised include:

1. Write-up of undulator emittance effect
2. Benchmark G4 polarisation/yield against other codes
3. Study activation of linac after target, copper vs aluminium

OMD/Capture Optics

A report was presented by A. Mikhailichenko on the design of a liquid Li lens for the capture optic. Average scattering of particles in the Lithium was shown to be much less than the angular spread of the beam. Average heating of solid Beryllium windows for a single train was shown to be 83°C, which added to the Lithium temperature of 170°C is below the melting point of Beryllium.

Outstanding issues raised concerned the long and short term survivability of the lens:

1. Stress-strain in the beryllium windows through the heating cycle and long term thermo-mechanical damage
2. Shockwaves and cavitation in the liquid Li and their effect on the windows
3. Radiation damage in the windows from photon-nucleon scattering from the Compton beam.

Capture optic options which do not place material in the path of the beam include a quarter wave transformer and a pulsed flux concentrator. The quarter wave transformer has lower capture efficiency but is similar to currently produced solenoids. It is expected to be a viable option. 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.