Key luminosity issues of the positron source

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Outline

- POSIPOL 2013 Summary
- Undulator
- Photon Collimator
- Spinning Wheel Target
- Material(TargetCollimator) Test
- Flux concentrator
- 300Hz truly conventional Source

POSIPOL 2013

- POISIPOL 2013 has been held at ANL 9/4/2013-9/6/2013
- Key issues of Positrons source for LC were discussed along with some other positron source applications.

Major Concerns on positron sources

- Issues on moving forward on the current LLNL test.
  - Approaches are still viable?
  - Funding
  - Technical support
- Alternative target design for undulator sources
  - Differential pumping,
  - Other type of targets?
- Alternative scheme:
  - 300 Hz
  - How to do a technical design?
  - Resources on the technical design?

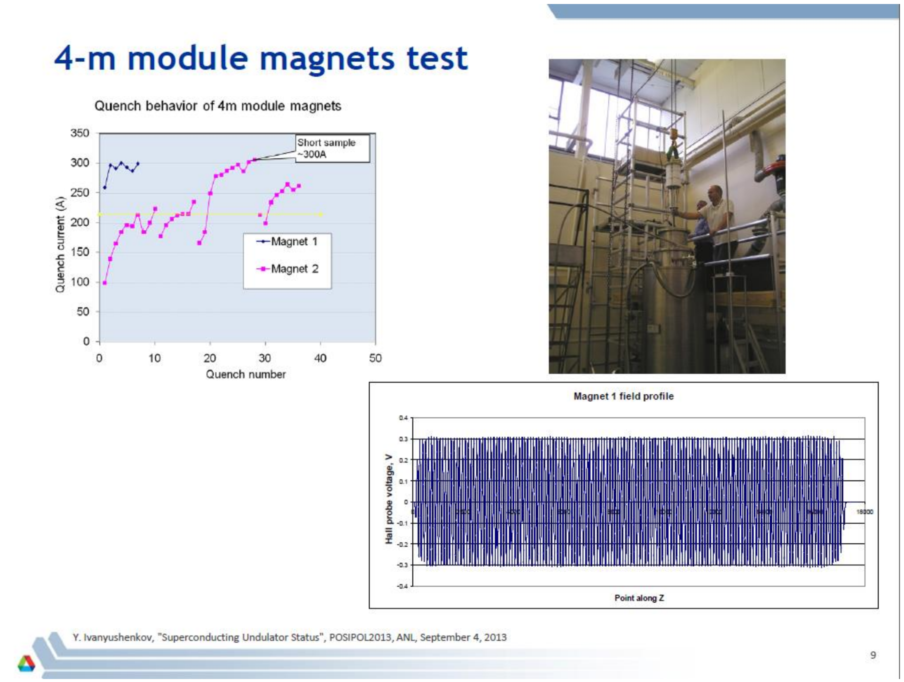
Existing (unsolved) Issues for Undulator based source

- Beam dynamics, (OK)
- Undulator (OK? Or @95%)
- Target (heating and shocks)
  - Good? No issues? No critical problems (97%), there is rooms for further improvements.
- Target support vacuum chamber, test at LLNL.
  - Life time of the vacuum seal (short time survival, but long term > a few weeks with vacuum spikes, no clear path forward at this point), no radiation damaging testing yet. , and
  - Cooling water impact on wheel dynamics (simulation should be done).
  - Rotating Seal leak tests at KEK planned.
  - New ideas: Non-contact (differenetial pumping), support, radiation cooling. Many others (later in the talk).
- OMD, (OK)
- Accelerator (NC)
  - SLAC test showed 14 MV/m.
- Interfacing with damping ring (OK)

Conventional Source (300 Hz)

- 6 GeV drive beam generation (OK? We have a design that will work Sband)
- Target: Shocks, stresses, cooling (use SLC solution), slow rotating target wheel in vacuum, or pendulum, easier to seal). Need some engineering studies, require 5 m/s.
- AMD, easy, existing (higher field next year, no issues at this point).
- Beam capturing Linac
  - 300 Hz linac (hybrid L and S?)
  - Un-even beam loading, and energy compensation, RF gymnastics (solution exists, although may not be optimized).
  - Interface between L-band and S-band (bunch compressor?) A detailed beam dynamics simulation is required.
  - Costing according to ILC methodology.
- Interface with damping ring simulation.
  - to be done.

Undulator



- 4-m module fabricated and cryogenic tests were done at RAL
- 4-m module magnets has been done at RAL
- Shorter period with higher field helical undulator is desired to for luminocity at lower Ecm.
- No one is known to be working on the developing of shorter period helical undulator with higher field.

Photon collimator

Photon collimator for Polarization upgrade

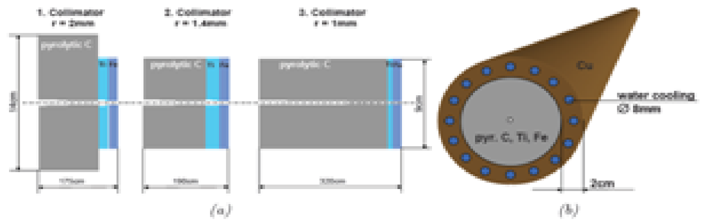


Figure 4.12. Basic layout of the multi-stage photon collimator at the positron source: (a) longitudinal section; (b) three-dimensional CAD model showing copper lading and water-cooling channels.

Parameter	Unit					L upgrade
Centre-of-mass energy	GeV	200-250	350	500	500	500
Drive-electron-beam energy	GeV	150	175	250	250	250
Undulator K value				0.92		
Undulator period	cm			1.15		
Positron polarisation	%	55	59	50	59	50
Collimator-iris radius	mm	2.0	1.4	1.0	0.7	1.0
Active undulator length	m	231	196	70	144	70
Photon beam power	kW	98.5	113.8	83	173	166
Power absorbed in collimator	kW	48.1	68.7	43.4	121	86.8
Power absorbed in collimator	%	48.8	60.4	52.3	70.1	52.3

- A photon collimator is not required for the TDR baseline
- As part of positron source upgrade study, DESY team developed a photon collimator design. With the designed photon collimator, positron source polarization can be increased from ~30% up to 50-60% depending on the colliding beam energy

- Photon collimator is an important part for positron source polarization upgrade.
- DESY has a preliminary design.
- Detail engineering design and prototyping is needed while not funded

Positron Source Spinning Wheel Target

- Prototype has been built and tested for eddy current issue.
- Vacuum seal test of supporting shaft was not very successful. The current prototype is not robust enough for production system.
- Still need to demonstrate full wheel with cooling channel.
- Not funded for further test and demonstration?

Material Test

Energy deposition at the ILC e+ source

- Energy deposition in target (Ti target wheel, Ø = 1m, 2000rpm)
  - Peak energy deposited density (PEDD) per bunch train
    - 67.5 J/g (101.3 J/g h.lumi) ⇔ ΔT_{max} = 130K (195K)
  - Energy deposition per bunch:
    - 0.31 ... 0.72J ⇔ $\Delta T \approx O(1K)$
  - Polarization upgrade to 50% or 60% increases E_{dep} and PEDD
  - Fatigue limit Ti (ANSYS): T = 600 K (fatigue Yield strength = 340 Pa)
- Energy deposition in collimator
  - Collimator is partial photon beam dump, absorbs up to 50% of γ beam power
  - Design strongly coupled to drive e- beam energy
    - Details see Friedrich's talks at POSIPOL, LCWS and ECFA workshops
- Dynamic response to energy deposition
  - energy deposition ⇔ within picoseconds
  - temperature rise ⇔ instantaneous with energy deposition
  - material stress ⇔ nanoseconds - microseconds ⇔ pressure waves
  - relax time ⇔ O(μs – s) depending on load

  → superposition of stress (?)

response in material depends on beam energy, deposited energy, bunch/pulse length, material parameters, ...

→ Results are not easy to scale

Material Test

Material Response at ILC e+ source

- Expect stress waves in the elastic domain
  - Relatively low deposited energy density
  - Thermal 'shocks' do not exceed fatigue limits; target and collimator design parameters are chosen accordingly
  - Radiation damage (dpa due to neutrons, hardening, activation, etc) seems ok

- But: can we trust the 'given' material limits?
  - Tested / measured using mechanical methods, no particle beams
  - What is the 'fatigue limit' ?

Some experiences exists (material test experiments at SLAC, KEK, FLASH, CERN):

Material test

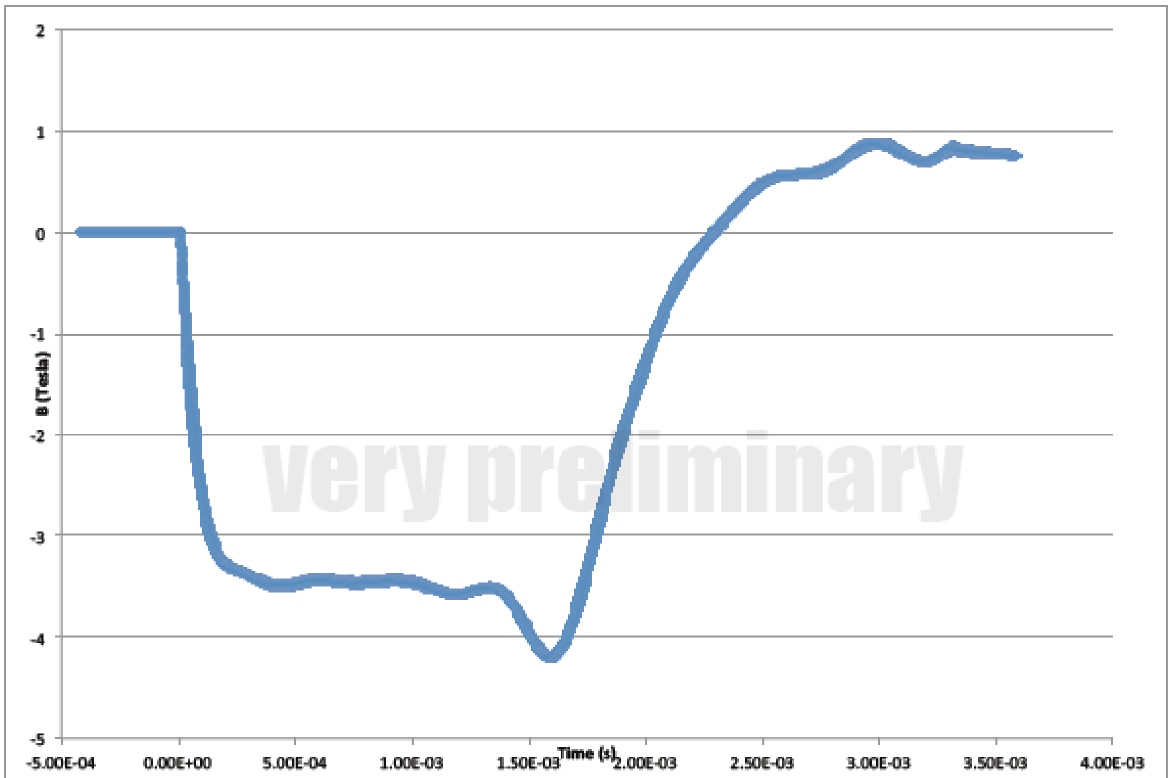
Summary

- Material tests are useful (not only for the e+ source design)
- Material test at FLASH and PITZ are considered in more detail
  - FLASH is user facility; requires from our side beamline + instrumentation
  - PITZ is a test facility, would allow first tests, but has lower energy and intensity than FLASH
  - radiation aspects are crucial
- Material test at CTF3 :
  - Further studies required (including radiation safety)
- Future work
  - Simulations and cross checks to understand and improve our simulations
  - Dynamic response from material which could be measured PITZ/FLASH/CLIC
  - Take into account experiences of other experiments and studies (e.g. HiRadMat)
  - Experimental setup

  Proposal
  - Design and construction of test setup
  - Support in 2014: DESY (Zeuthen) some money, (limited) manpower,
    BMBF (German ministry of science): some manpower
- Contributions (ideas, manpower, material etc.) are very welcome

Flux Concentrator

The magnetic field has a 1 ms flat top



Flux concentrator

Pulsed Flux Concentrator Summary

- We have demonstrated the full field with a 1 ms flat top.
  - Improvements to the pulse forming network should reduce the ripple

- Things we still need to do:
  - Construct and install the ceramic spacing disks
    - metal spacers distort the magnetic field temporal profile
    - we used plastic spacers for the current test
  - Run for an extended period at 5 Hz, full average power with cooling
  - Design the first plate to shield the gap from radiation

300Hz alternative source target

Conclusion

- SLAC target gives a bench mark for the true conventional target

- The pendulum target could be the best solution for beam line vacuum, but the material's mechanical properties failed completely!

- A rotating wheel (⌀200mm) with up to v = 5m/s rim velocity reach the SLAC conditions for the proposed 300 Hz scheme

- The opening of the Optical Matching Device (12mm) is close to the beam diameter (10mm FWHM). Due to the close distance to the target (5mm) an overload of the OMD could occur. Hence, positron capture is an open issue.

300Hz Conventional Source

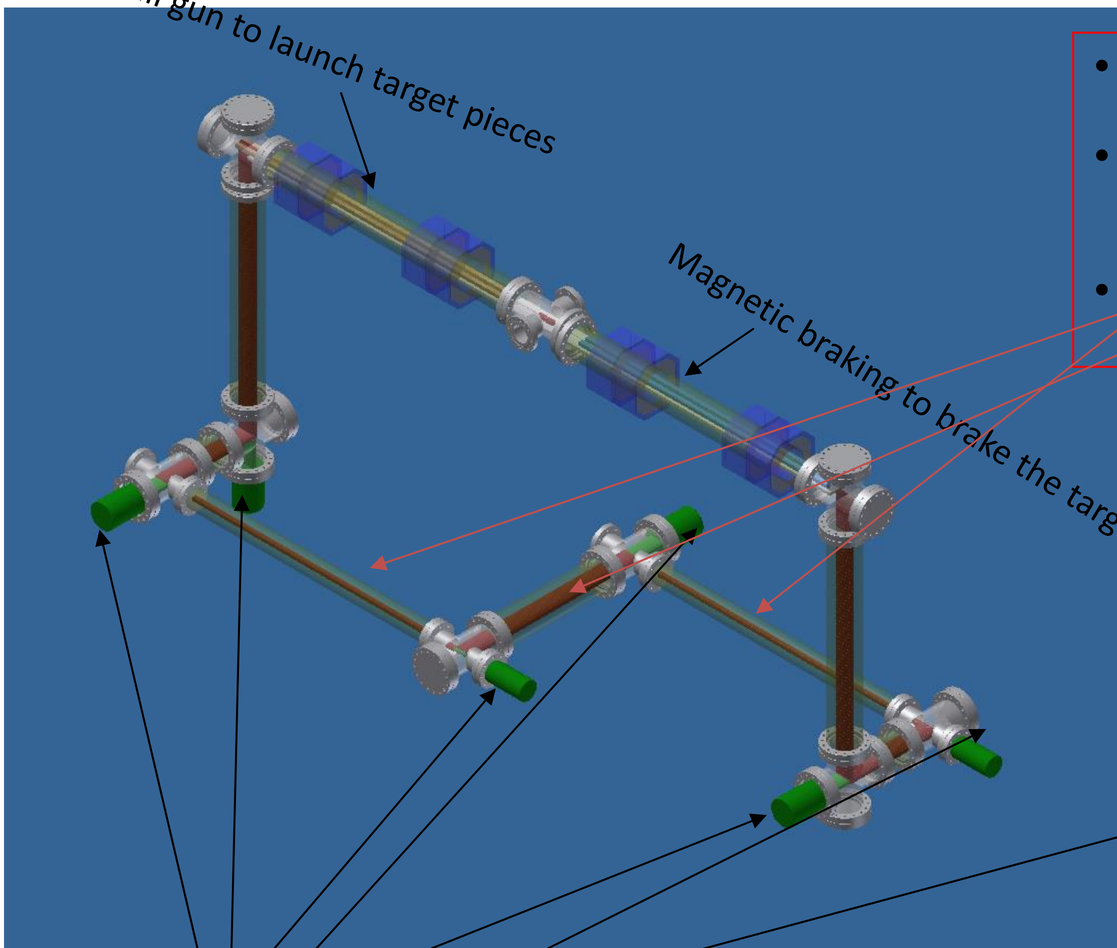
R&D Issues of the Conventional Source

- “conventional” but still needs some more R&D
- High current, high rep rate driver linac
- Moving target
- Flux concentrator
- Booster linac
- Overall simulation

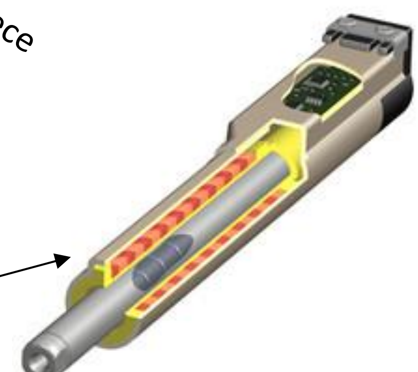
Alternative undulator based target studies

Developing a self loading machine gun in vacuum

Concept illustration

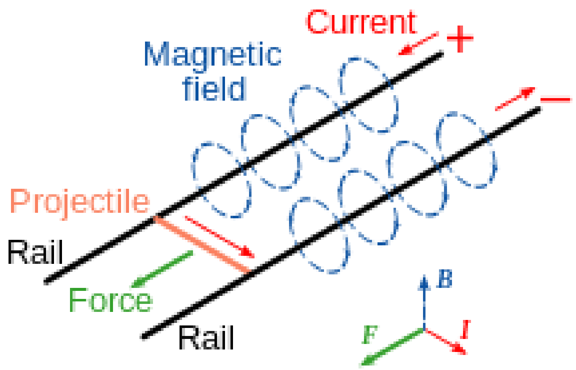


- Conduction cooling via the bottom of target.
- Inspection and replacing of damaged target can be easily done on along this path.
- Path can be easily adjusted to increase the cooling time.



Commercially available

Parameter estimation of the Rail gun for launching target



External permanent magnetic field will be applied to improve

- With the following assumptions:
  - length of rail 100cm, target bullet 1.4cmx1.4cmx6cm and rail has same cross section of target bullet
  - 1T external magnetic field and copper rail
- We estimated that:
  - The current required to accelerate the target from 0 to 50m/s is about 4.5kAmps
  - The average heating power of gun is about 700W

Braking for target bullet

- We have multiple options in slowing down the target bullet
  - Eddy current only braking
  - Magnetic braking with external power source
  - Magnetic braking without external power source
- All of the above options are good candidate We can pick any one and then do the designing

Cooling of the target bullet

- Cooling will be done in the recycling line using conduction cooling. The cooling time can easily be designed to ~60s by adding more turnarounds in this line.
- Accurate calculation of the cooling time requires numerical simulation due to the non-uniform energy deposition in target bullet.
- We can over estimate it by assuming that the bullet got heated up 200^{o}C above room temperature uniformly. In such exaggerated case, the cooling time required to cool it back down to 25^{o}C using 10^{o}C cooling agent outside on bottom of the recycling line can be estimated as about 46 seconds.
- We have plenty of time to cool the bullet down.
- Inspection and replacing damaged bullet can be easily adapted in the recycling line.

Transferring of target bullet

- Transferring of target bullet is done via actuators driven by linear motors.
- Taking the worst case scenario, friction coefficient of 0.9 for rubbing contact of untreated surface without lubricant, it needs 38N to overcome the friction. The works need to be done will be less than 0.52J per movement, or about 2.5W of power.
- The loading actuator raise the weight of about 50 target pieces, 28N, by 1.4cm each time. The works need to be done will be about 0.39J per movement, or 2W of power.
- Transferring the bullets inside the system should be quite easy.

Comments/Summary

- We only had a few tests at LLNL, there are many improvements can be made.
- If all the motors and mechanical parts can be placedin a rough vacuum, a good differential pumping can be achieved.
- Alternative target (not the scheme), can also be studied and tested.

- Many technical aspect of the conventional source need to be studied, system tests are alos needed.
- It is challenging, but working with good engineering team ($$$$), I am optimistic.