Options for low energy spin manipulation

Ken Moffeit, *SLAC*

2009 Linear Collider Workshop of the Americas
29 September to 3 October 2009

K. Moffeit, D. Walz, M. Woods, *Spin Rotation at lower energy than the damping ring,* ILC-NOTE-2008-040, February 2008

K. Moffeit, *Spin Rotation before the Damping Ring*, Workshop on Polarization and Energy measurements at the ILC 9-11 April 2008, IPBI TN-2008-3, April 2008

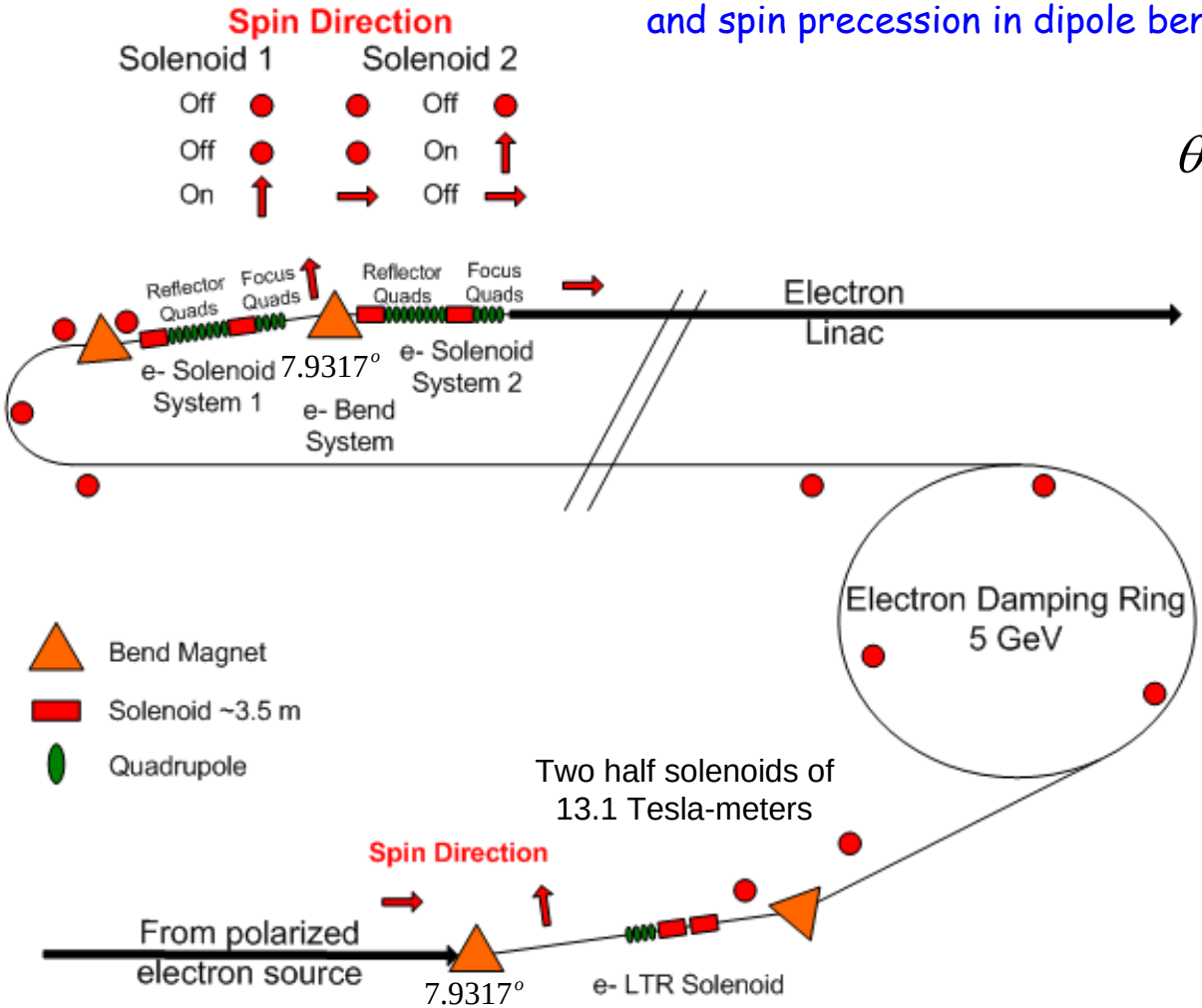
Reference Design Report Damping Ring and Spin Rotation Systems

Requirements:

•Rotate spin to the vertical before damping ring so polarization is not destroyed during damping.

•Rotate spin after the damping ring to have the desired polarization at the e^+e^- IP, e.g. longitudinal polarization at IP. To avoids spin diffusion depolarization effects locate RTL spin rotation system after transport to beginning of main linac.

Spin rotation is done with a combination of spin rotation solenoids and spin precession in dipole bends



θ_{spin} Is rotated 90° in a solenoid field of 26.2 Tesla-meters at 5 GeV

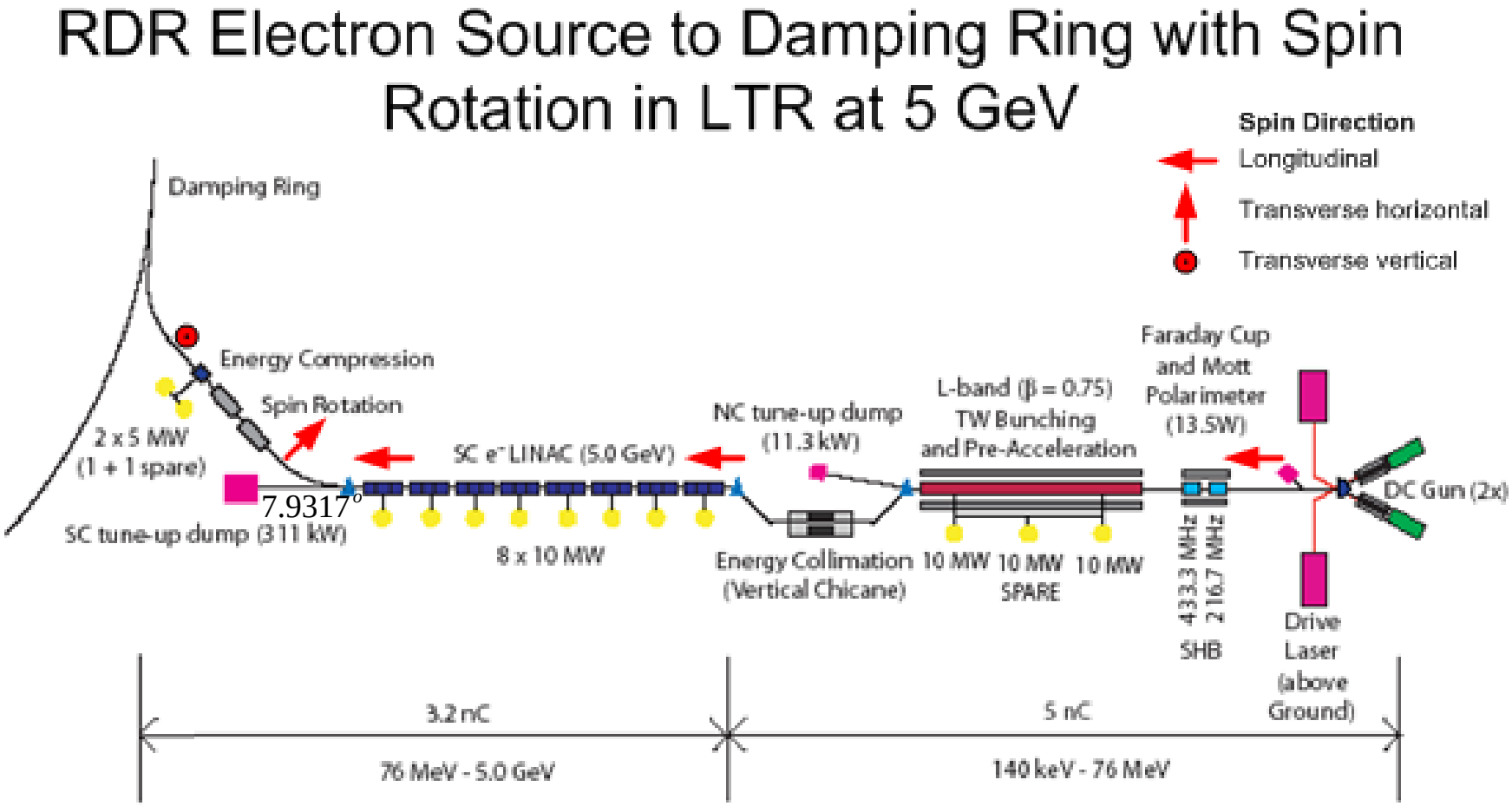
Spin Precession ahead of momentum direction change

$$\theta_{spin} = \gamma \frac{g-2}{2} \cdot \theta_{bend} = \frac{E(GeV)}{0.44065} \cdot \theta_{bend}$$

$$\theta_{spin} = 90^o = \frac{5.0}{0.44065} \cdot 7.9317^o$$

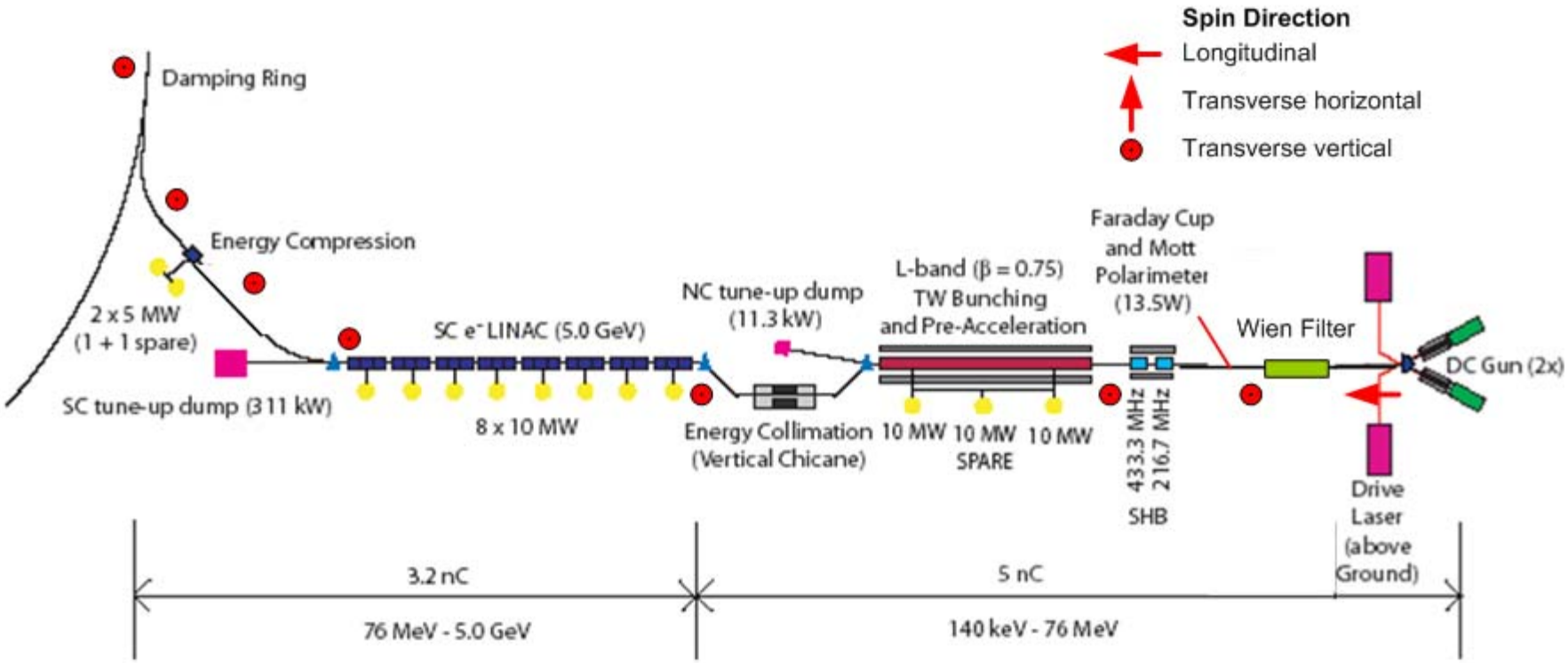
Current plans for electron Beam Spin Rotation before the damping ring

Spin direction must be normal the damping ring plane to preserve polarization while the beam is being damped, i.e. rotate longitudinal spin produced at the source into the vertical direction

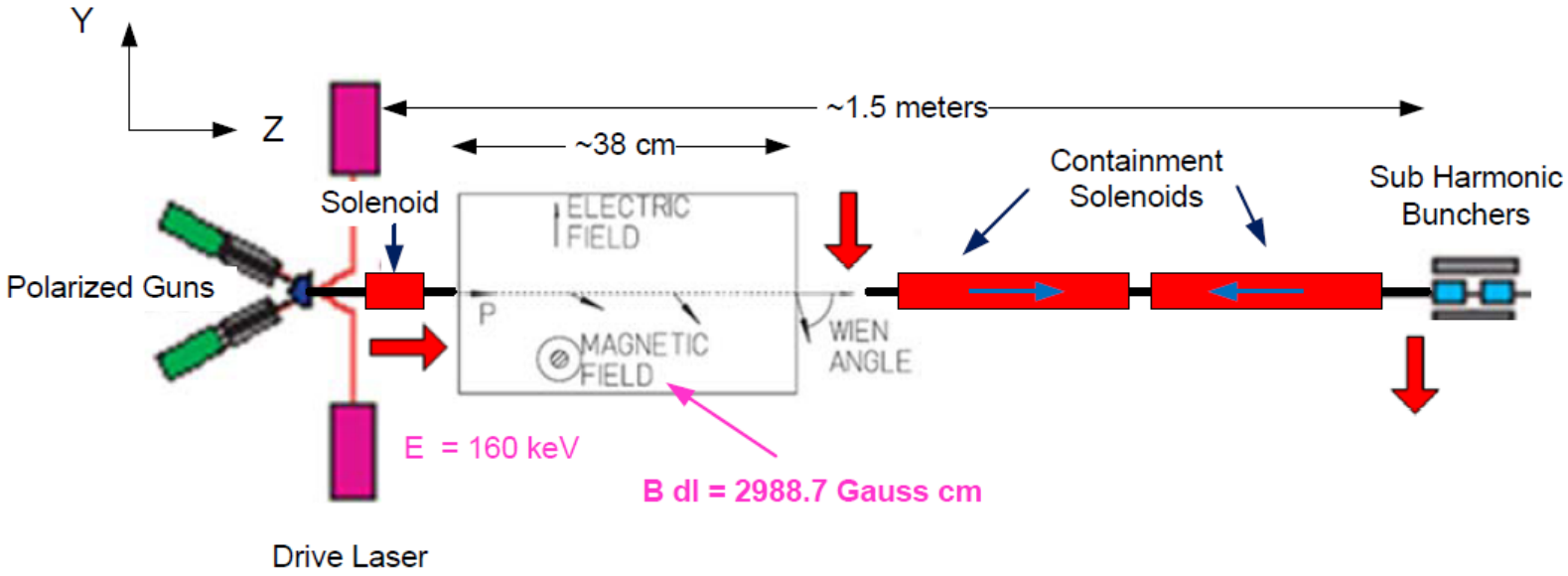


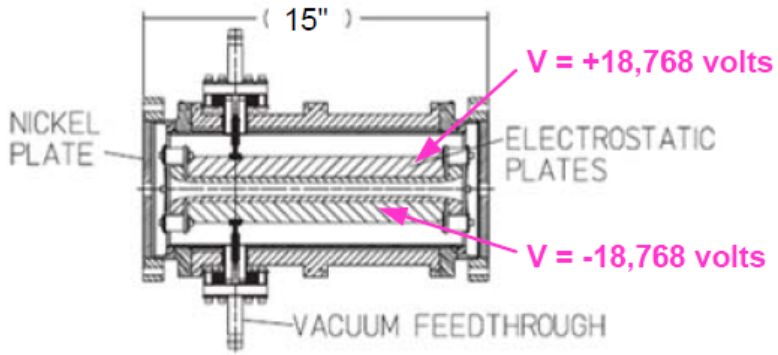
Requires two 13.1 tesla-meter superconducting solenoids after a bend of 7.9317^{o}

Spin Rotation near polarized electron gun with Wien Filter



Proposal to rotate spin direction to the vertical near polarized electron Source



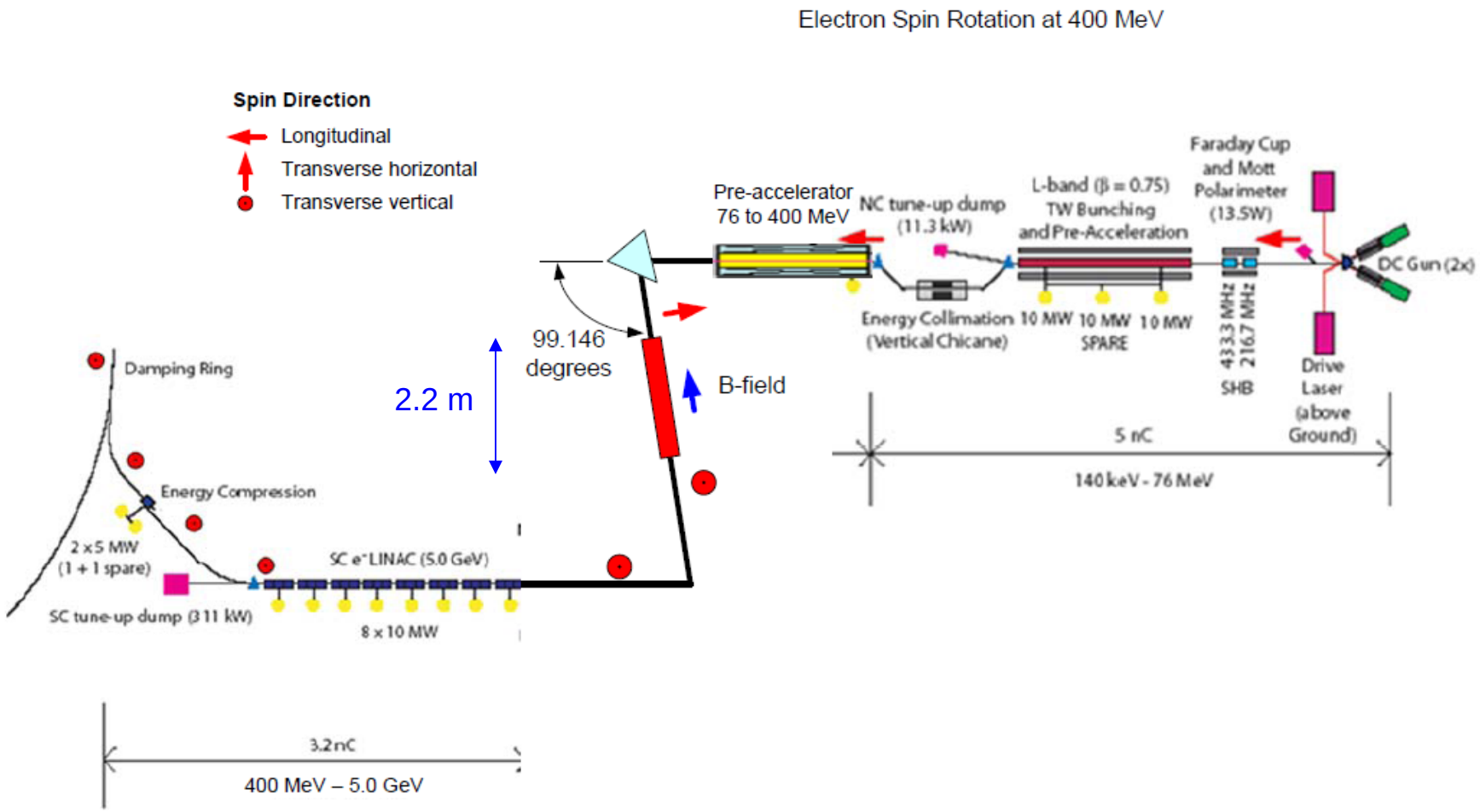


Wien filter spin manipulator
The magnet is not shown in the cutaway view

ILC source may run above **200 keV** to reduce space charge effects.
E=200keV has **B dl ~ 3600 Gauss cm** and **V=+/- 24,253 volts**

C. Y. Prescott, SLAC Engineering Note 71, 8 Feb 1977

Alternate Method is to rotate spin of the electron beam to the vertical at 400 MeV



After a bend of 99.146° a copper wound solenoids of 2.096 Tesla meters (2.2 meters long with axial field of 9.53 Kilogauss in 2" bore) can rotate the spin from the transverse horizontal direction to the vertical. Focussing elements will probably be needed on each side of the solenoid.
This may fit in a 5 meter tunnel without need for offsetting tunnels by placing everything before 400 MeV on one side of the tunnel and the accelerator to 5 GeV on the other side.

Positron Beam Spin Rotation and Helicity Selection before the positron damping ring

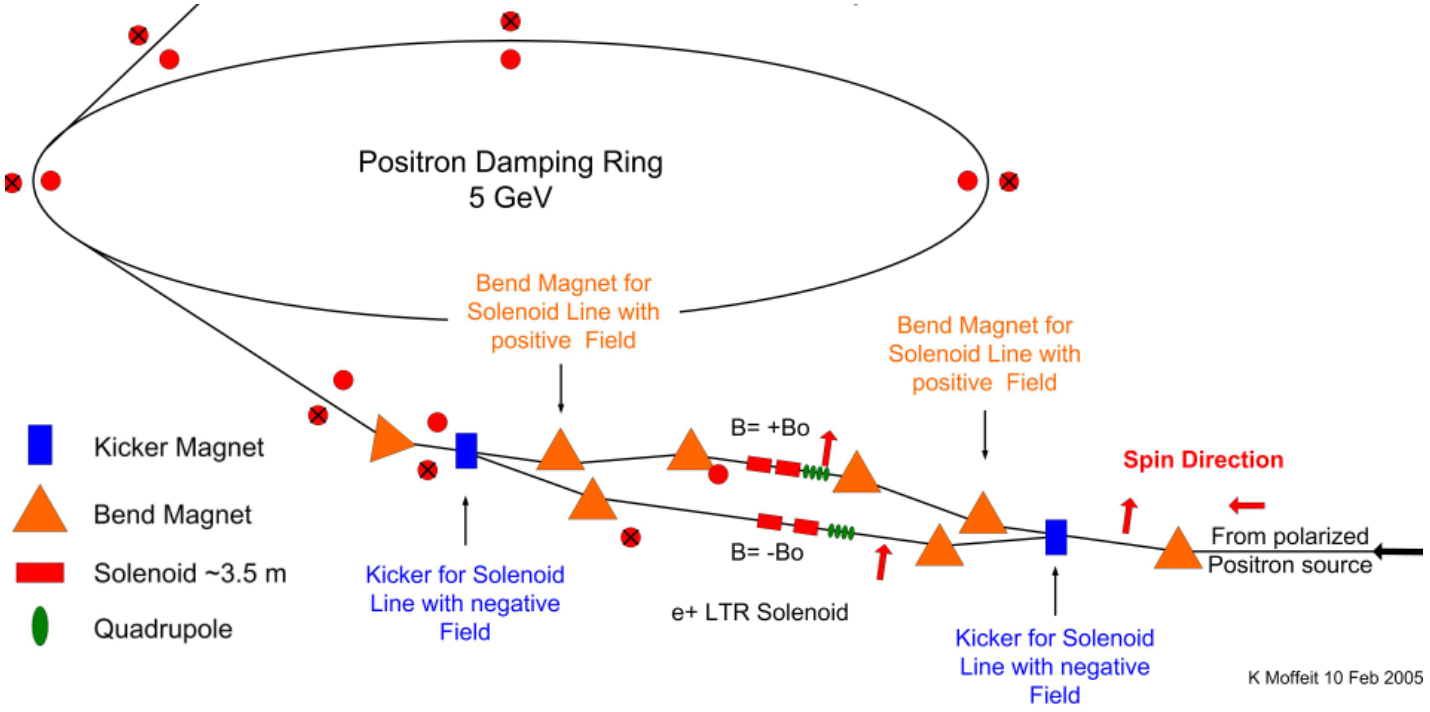
Requirements:

- Rotate longitudinal polarization from positron source to the vertical
- Select the helicity of the positron beam for each pulse train.

In the current baseline design the positron helicity can only be slowly reversed by changing the polarity of the superconducting solenoids. Slowly means every few days or weeks. This does not satisfy the demands of the precision physics program, which needs positron helicity reversals train-to-train as it is done for electrons.

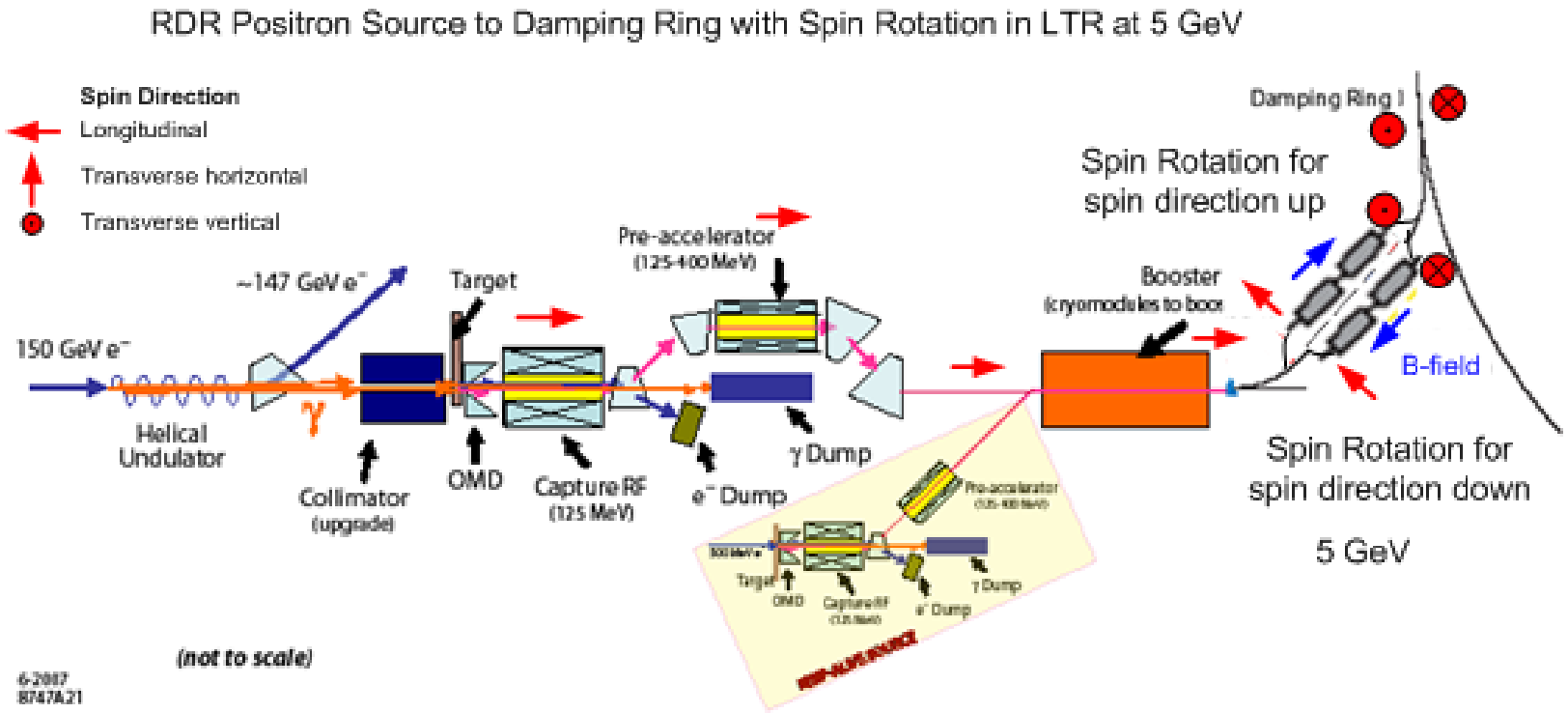
Helicity Flipping

Parallel beams lines have + and - solenoid magnetic field.
Kicker magnets select the beam line with the opposite solenoid magnetic field.



K. Moffeit, P. Bambade, K. Moenig, P. Schuler, M. Woods, "Spin Rotation Schemes at the ILC for Two Interaction Regions and Positron Polarization with both Helicities", LCC-159, SLAC-TN-05-045, February 2005.

Current plans for positron spin rotation before the Damping Ring

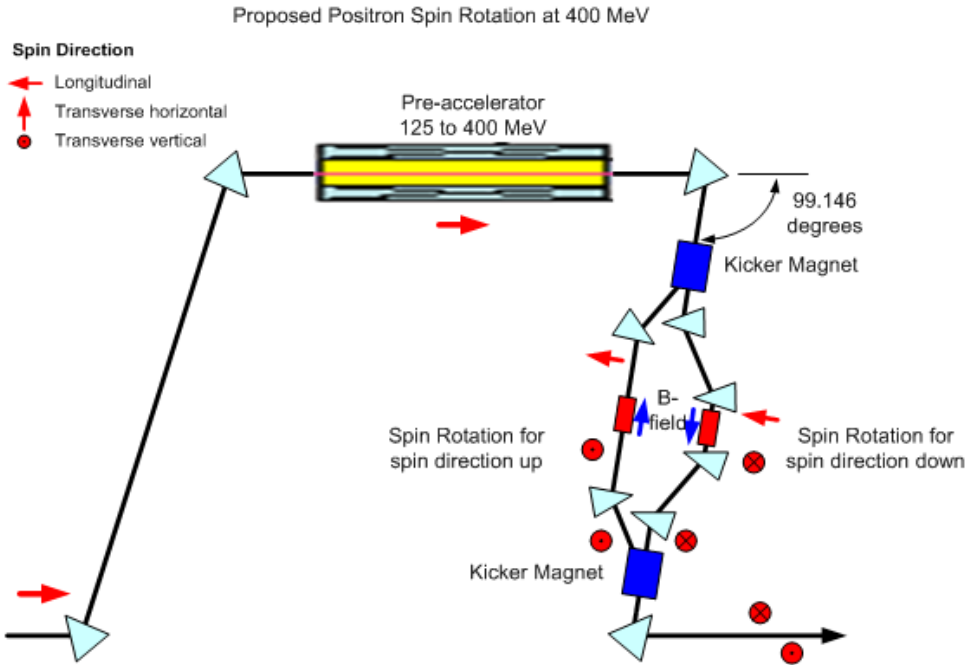


At 5 GeV 4 superconducting solenoids each with 13.1 Tesla meters are required for spin rotation to the up or down spin direction.

Helicity Selection

Damping Ring type kicker magnets needed to do helicity selection before the damping ring into parallel beam lines. Tunnel length and width to obtain separation of parallel beam paths at solenoid positions will be needed.

Spin Rotation for positrons directly following Pre-accelerator when beam energy is 400 MeV

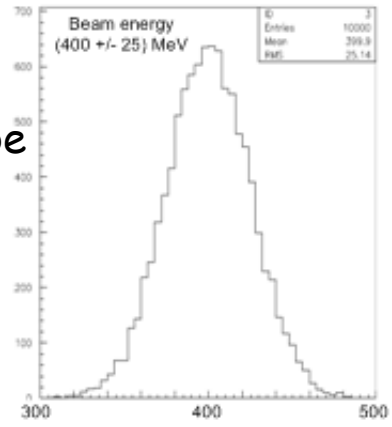


After a bend of 99.146 degrees a copper wound solenoid of 2.096 Tesla meters 2.2 meters long with an axial field of 9.53 Kilogauss will rotate the spin from the transverse horizontal direction to the vertical. Criteria for the kicker magnets for spin flip and tunnel space is much less demanding at 400 MeV than at 5 GeV.

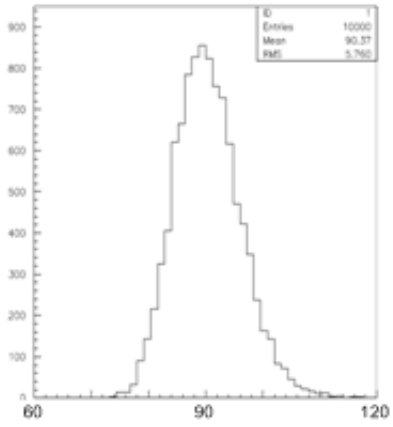
Concerns:

Energy Spread at 400MeV may be as large as +/- 25MeV

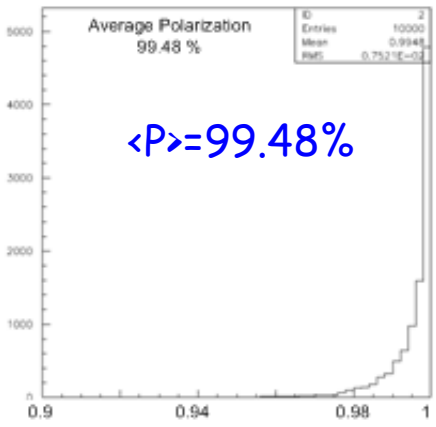
- Depolarization: only 0.52%
- Positron beam loss in 99.146 deg bends and parallel spin rotation lines needs study



Energy



Spin Rotation Angle



Polarization

<P>=99.48%

IPBI_TN-2008-1. ***Spin Rotation at lower energy than the damping ring,*** K. Moffeit, D. Walz and M. Woods, ILC-NOTE-2008-040 February 2008.

Conclusions

The costs and performance requirements for the spin rotation systems before the damping ring will be less demanding at lower energy than at the damping ring energy of 5 GeV.

Positron Beam Spin Rotation and Fast Helicity Selection

- Copper-wound solenoids for the spin rotation solenoids 2.2 meters long with a bore of 2" can be used for the positron beam at 400 MeV.
- The angle the beam leaves the spin rotation system is required to be in the plane of the damping ring. The tolerance on the angle alignments is ~ 3 degrees resulting in a depolarization of 0.1%.
- A system to randomly select the helicity of the positrons at the e+e- IR is given. Such a scheme is important to minimize systematic errors in the measurement of polarization asymmetries. At 400 MeV the parallel beam lines and kicker magnets will be much simpler than at 5 GeV.

Electron Beam Spin Rotation

Rotate the spin vector to the vertical at very low energy (~150 keV) for the electrons near the polarized gun using a Wien filter.

- The spin rotations systems presented here are conceptual designs. A more detailed optics design, including simulating performance and overall operation, will be needed.