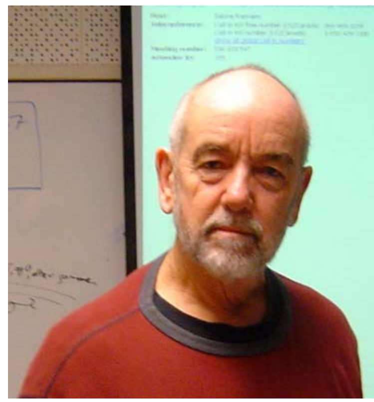
Spin rotation issues in CLIC

CLIC-08

14-17 October 2008

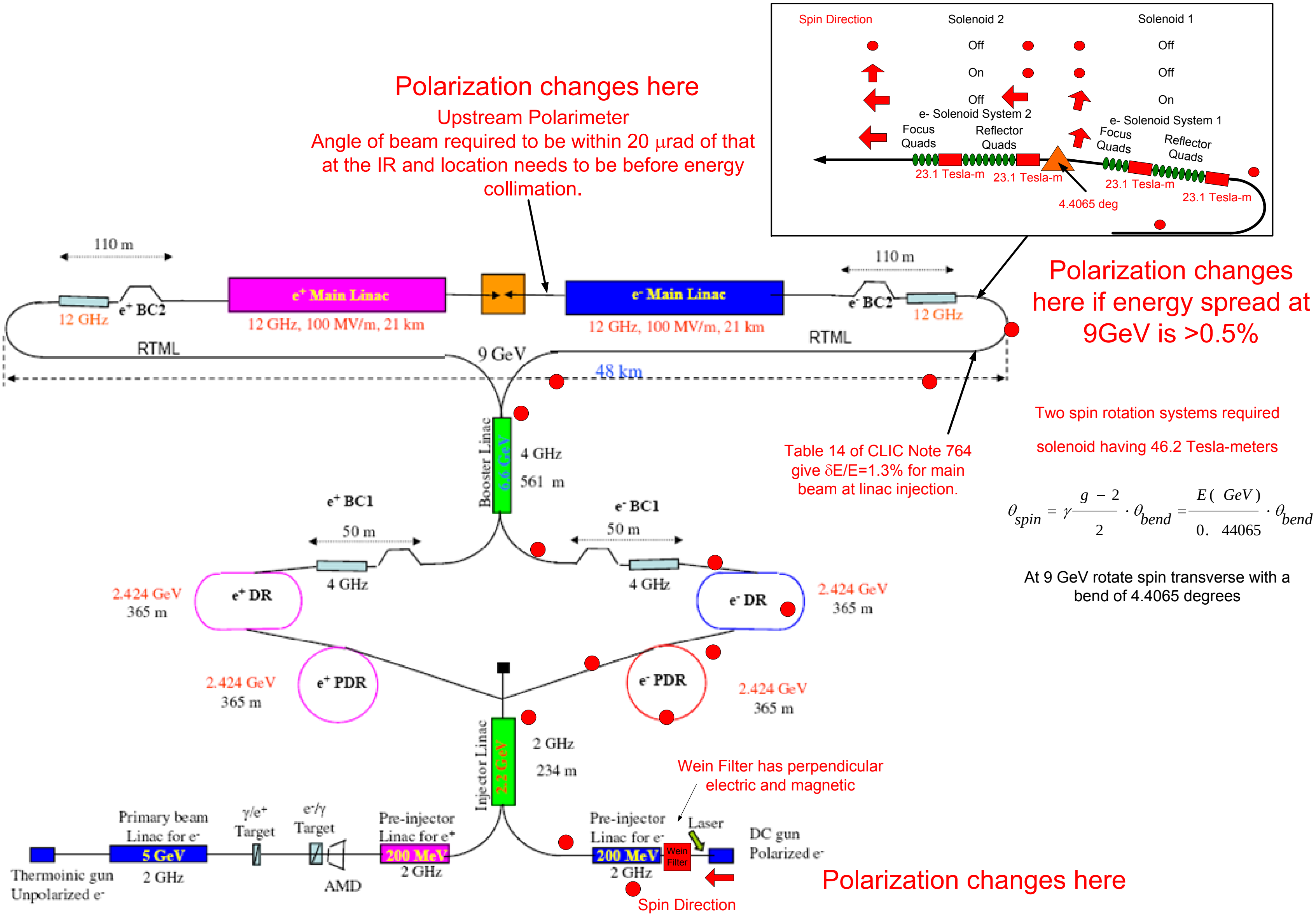


Ken Moffeit

SLAC

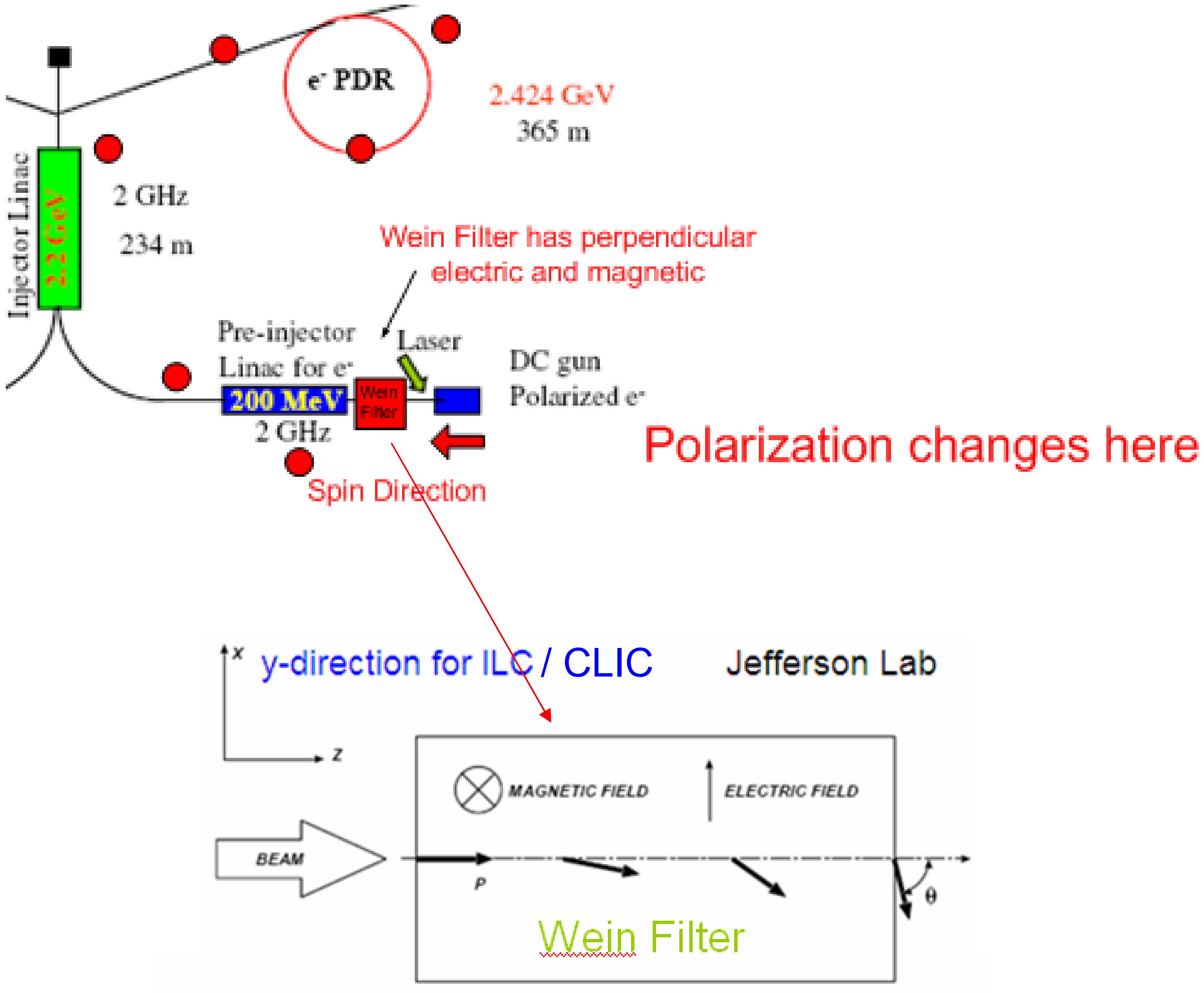
October 15, 2008

Polarization at CLIC



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

Spin Rotation at e⁻ Source



Longitudinal depolarization due to energy spread in reverse bend at 9 GeV

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

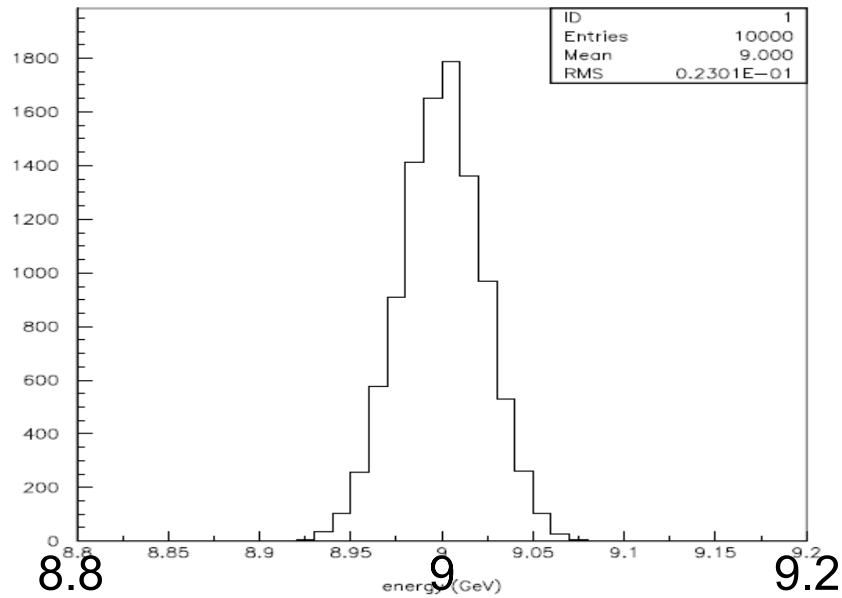
dE/E at 9 GeV	Mean longitudinal or transverse horizontal polarization after 90 deg bend (note: vertical spin component will not be depolarized)
0.25%	99.6%
0.5%	98.6%
1.0%	94.0%
1.3%	90.8%

- Spin diffusion in the 90 degree turnaround at 9 GeV due to an energy spread of less than 0.5% will not be a problem.
- The energy spread at 9 GeV is given as 1.3% in the CLIC-Note-764. Such a large energy spread will destroy the polarization.
- Conclusion: CLIC will have to do the spin rotation after the reverse bend unless energy spread at 9GeV is less than 0.5%

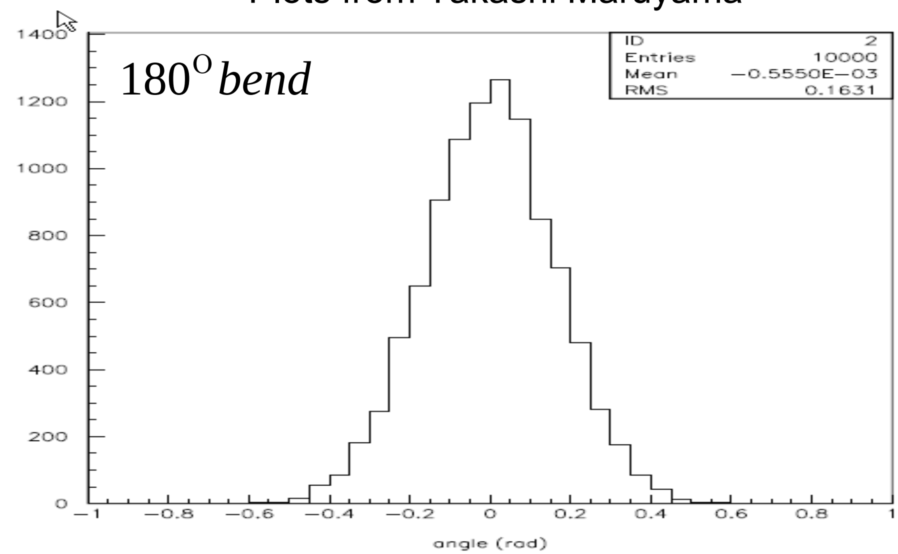
Beam energy 9 GeV

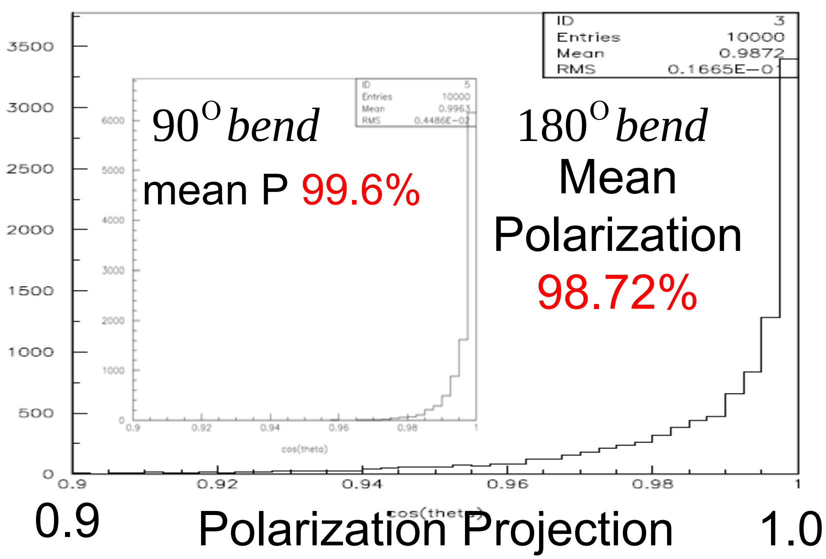
Energy spread 0.25%

Plots from Takashi Maruyama

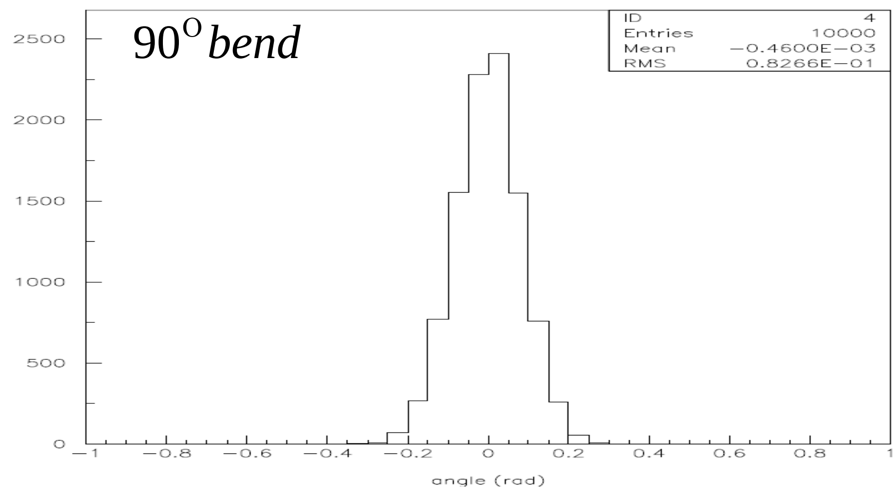


Energy in GeV





Polarization Projection

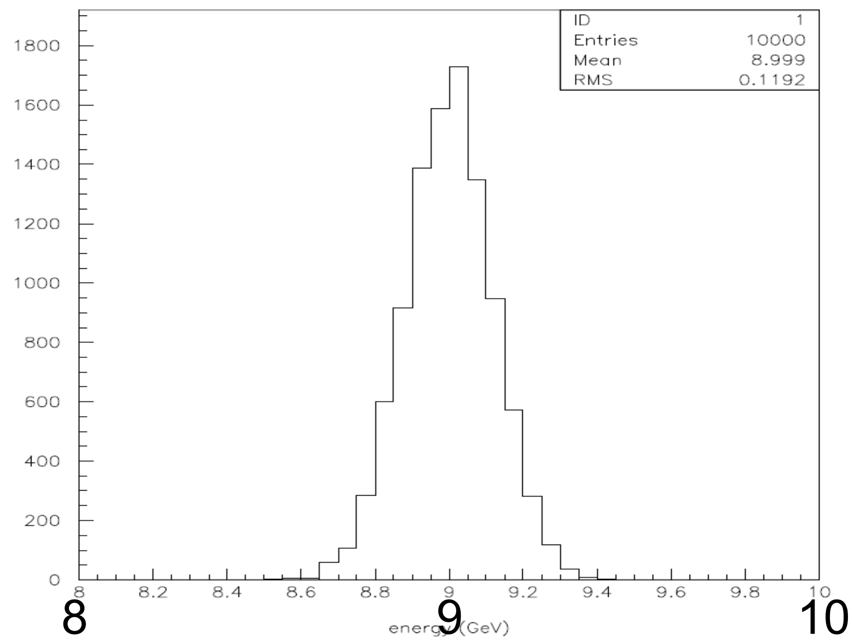


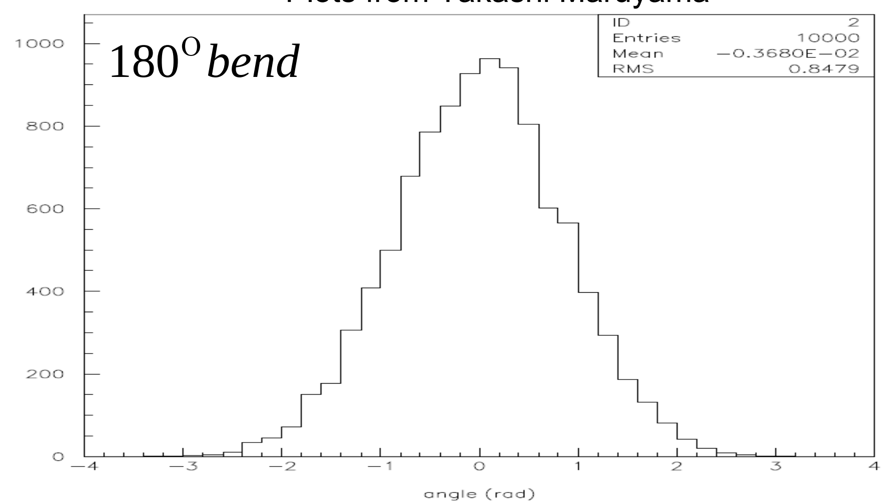
Spin direction angle (radians)
after reverse bend

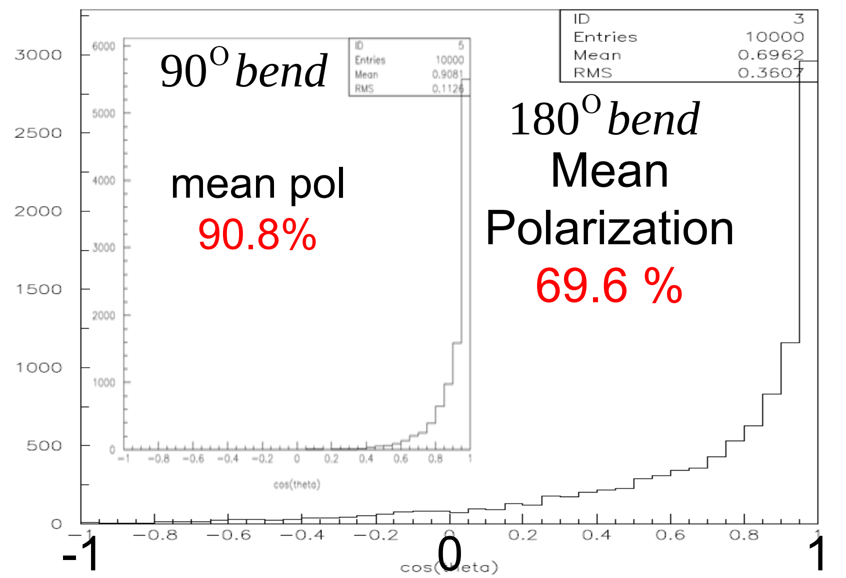
Beam Energy 9 GeV

Energy spread 1.3%

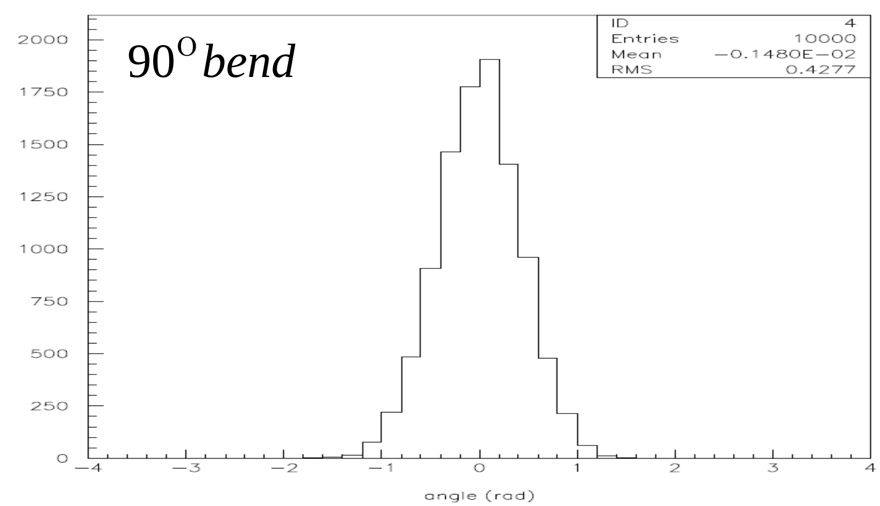
Plots from Takashi Maruyama







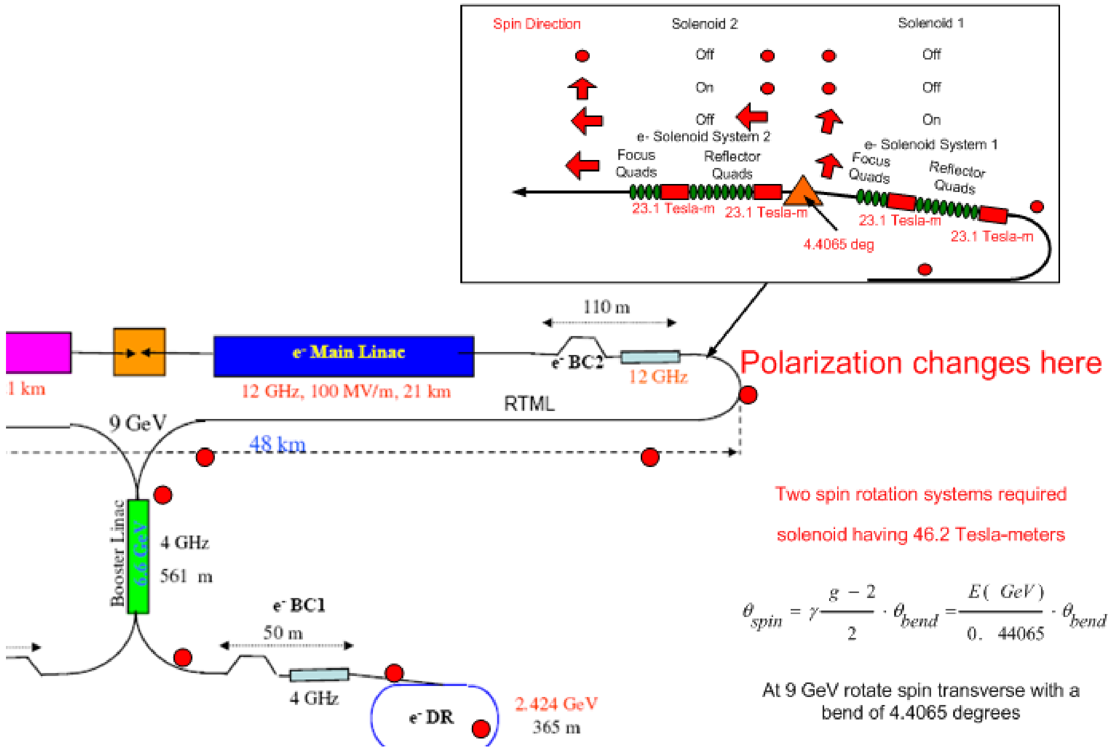
Polarization Projection



Spin direction angle (radians) after reverse bend

Large spin diffusion !!!

Spin Rotation at 9 GeV



Note:

•Difficulty and cost of the 46.2 T-m superconducting spin rotator system.

•Requires a 9 GeV flat-beam spin rotation system proposed by Paul Emma, which, includes half solenoids with a reflector beam line between them to eliminate cross plane coupling and focusing elements to remove the focusing effects of the solenoid (NLC-Note-7 Dec 1994).

Spin Diffusion Comments

Requirements to do spin rotation after damping ring at energy of 2.424 GeV

•Booster linac perpendicular to main linac implies only 90 deg bend causes spin diffusion (this helps reduce spin diffusion problem with large energy spread). The spin diffusion effects due to the other two 90 deg bends cancel each other.

•Spin diffusion depolarization on longitudinal and transverse horizontal polarization due to energy spread at 9 GeV must give polarization >99% at injection to linac. This means that the energy spread at 9 GeV must be less than ~0.5%.

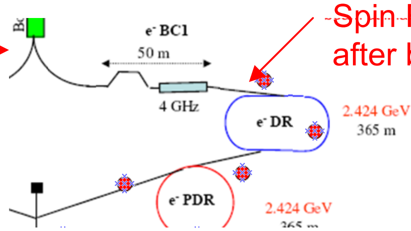
•Correlation of spin direction and energy will effect luminosity weighted polarization at IR. This needs to be studied.

•Note that 1.9% energy spread at 2.424 GeV gives the same spin diffusion after a 90 deg bend as 0.5% energy spread at 9 GeV, i.e. one can tolerate a larger energy spread at 2.424 GeV than at 9 GeV.

•Table 14 of CLIC-Note-764 gives energy spread as 0.134% in the damping ring. An energy spread this small will give 100% transmission of all components of the polarization in a 90 deg bend at 2.424 GeV.

•CLIC will induce a large energy spread before the BC-1 bunch compressor, probably by running the 4GHz cavity on the 0 crossing just prior to BC-1. This will give a large E-z correlation to allow the bunch compression in BC-1, and there will be a significant energy spread for the 90-degree bend into the booster linac.

Spin Rotation here after 90 degree bend allows a larger energy spread. A rough calculation shows that dE/E<6% at E=2.424 GeV would give depolarization less than 1% in the solenoids and the ~16.36^{o} bend to rotate the horizontal spin 90^{o} to longitudinal if spin rotation is done after the 90 deg bend and before entrance to booster linac. Needs more study!



Spin Rotation here requires energy spread after bunch compression <1.9%

Bottom line: Physics requires $\geq 0.99 \times P_{e^-}^{Source}$ at injection to main linac.

Angle tolerances at Compton IP and IR due to spin precession considerations

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

$$= 3404.06 \cdot \theta_{bend} \ at 1.5 TeV$$

Change in spin direction for various bend angles and the projection
Of the longitudinal polarization. Electron beam energy is 1.5 TeV.

Change in Bend Angle	Change in Spin Direction	Longitudinal Polarization Projection
100 μrad	340.4 mrad (19.5 degrees)	94.26%
50 μrad	170.2 mrad (9.75 degrees)	98.55%
25 μrad	85.1 mrad (4.87 degrees)	99.64%
10 μrad	34.04 mrad (1.95 degrees)	99.94%

Polarization measurement precision is <0.25%

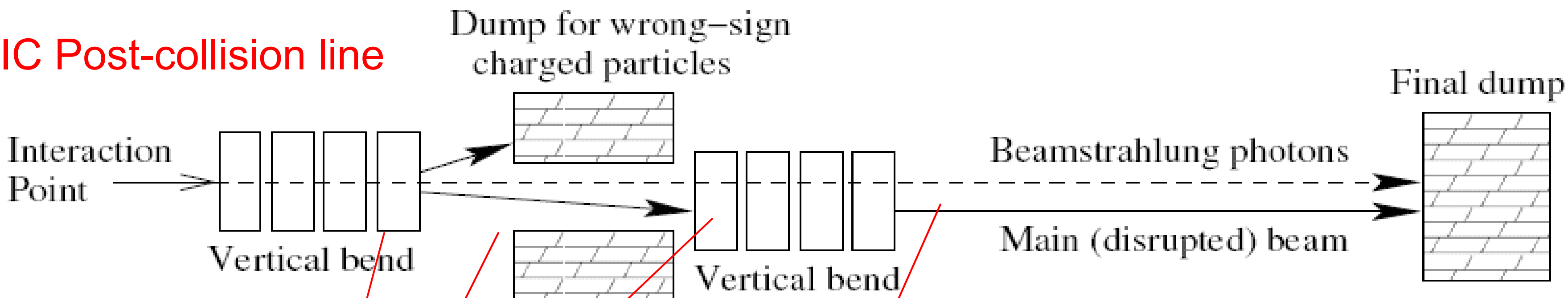
Implies angle at Compton IP and IR is aligned to better than 20 μrad.

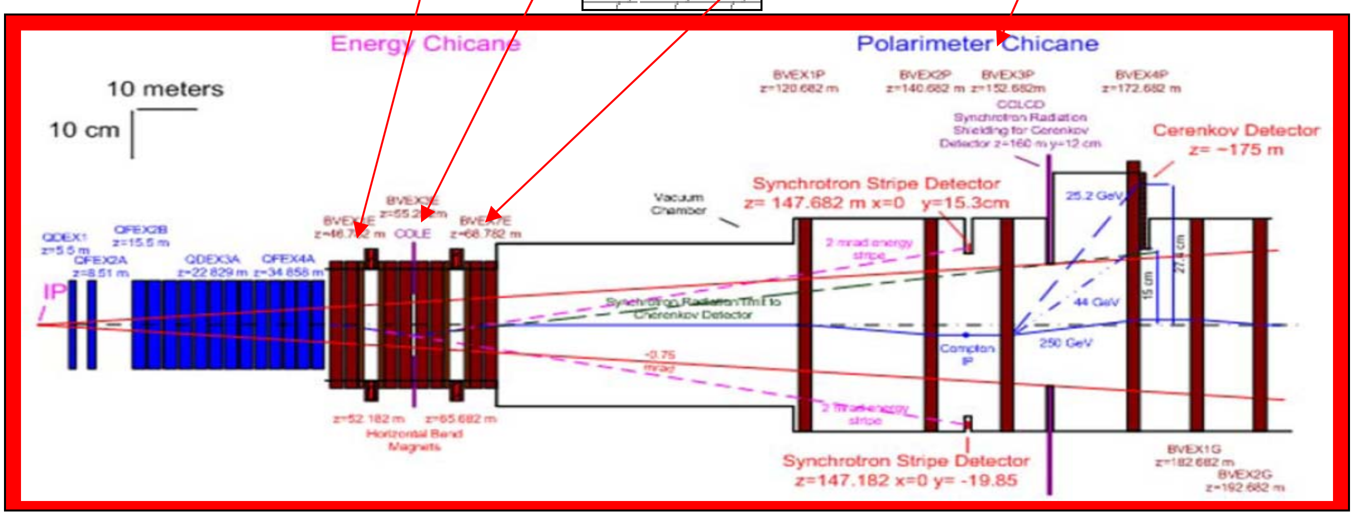
Polarimeter needs to be before energy collimator to clean up Compton electrons.

Extraction Line Polarimeter

•Allows ILC type extraction line polarimeter and energy measurement below ~500 GeV beam energy. Important to understand systematic errors of upstream polarimeter.
•At 1.5 TeV polarization and energy can be measured with beams out of collision at low rate of ~1 hertz. Energy measurement may be possible at all energies to 1.5 TeV.
•Magnet apertures may be larger than ILC
•Costs ~$5 million for polarimeter. Add costs for quads and energy chicane.

CLIC Post-collision line





May be a challenge due to pairs and high beamstrahlung tail.

Laser Wire Detector

IPBI TN-2008-2
ILC-Note-2008-041
March 11, 2008

Synchrotron Backgrounds for Laserwire Detector In Upstream Polarimeter Chicane

M. Woods and K. Moffeit, SLAC

Abstract
Synchrotron radiation (SR) backgrounds for the Laserwire Detector in the upstream "Polarimeter" chicane are estimated, due to the first dipoles in the chicane. For nominal (RDR design) operation at 250 GeV, the SR critical energy is 4.1 MeV and the total SR power incident on the laserwire detector is $\sim 5.5 \cdot 10^{-6}$ of the beam power. A laserwire detector in the 0-degree line will have unacceptably large backgrounds. A preferred solution is to instead detect the Compton-scattered electrons.

Synchrotron radiation backgrounds in 0-degree line will give unacceptably large backgrounds in a photon laser wire detector.

A preferred solution is to detect the Compton-scattered electrons.

Conclusions

• Spin rotation near electron source to direction perpendicular to damping ring using Wein filter.

• Spin rotation after damping ring at 2.424 GeV requires energy spread at 9 GeV during reverse bend be less than ~0.5% and booster linac be perpendicular to main linac.

Requirements on the energy spread at 2.424 GeV for less than 1% depolarization:

$\delta E/E < 1.9\%$ if spin rotation is done before 90 deg bend at entrance to booster linac

$\delta E/E <$ ~6% if spin rotation is done after 90 deg bend at entrance to booster linac.

• Spin rotation at 9 GeV after reverse bend requires two spin rotation systems each with two superconducting solenoids of 23.1 tesla-meters.

• Bottom line: Physics requires $\boxed{\geq 0.99 \times P_{e^-}^{Source}}$ at injection to main linac.

• Beam direction at upstream Compton IP must be the same as the beam direction at the IR within 20μrad. Compton polarimeter must be upstream of energy collimator.

• Downstream polarimeter in extraction line useful for understanding systematic errors in polarization measurement. Energy measurement downstream also useful for physics.