IP Polarization Measurement

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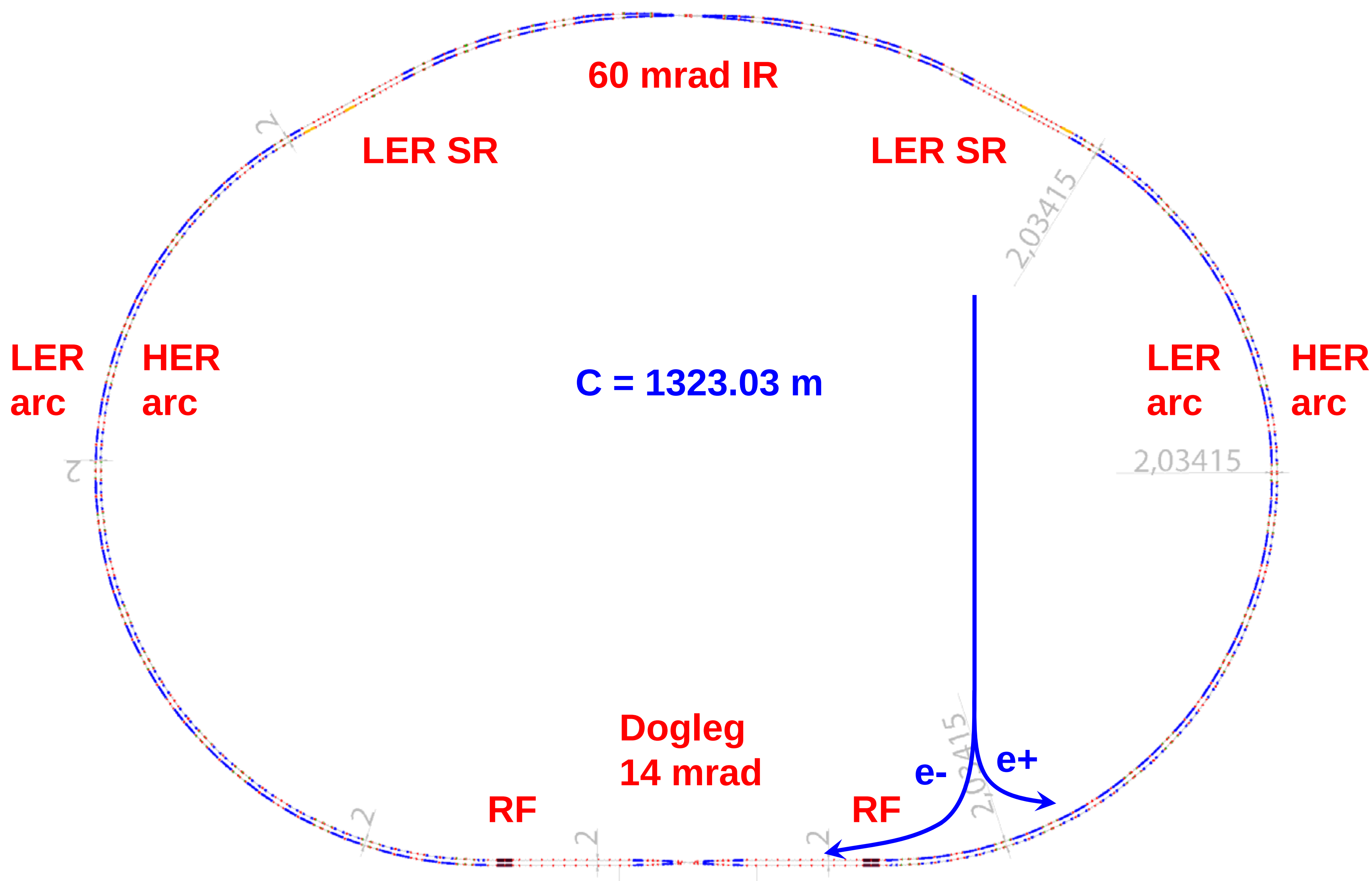
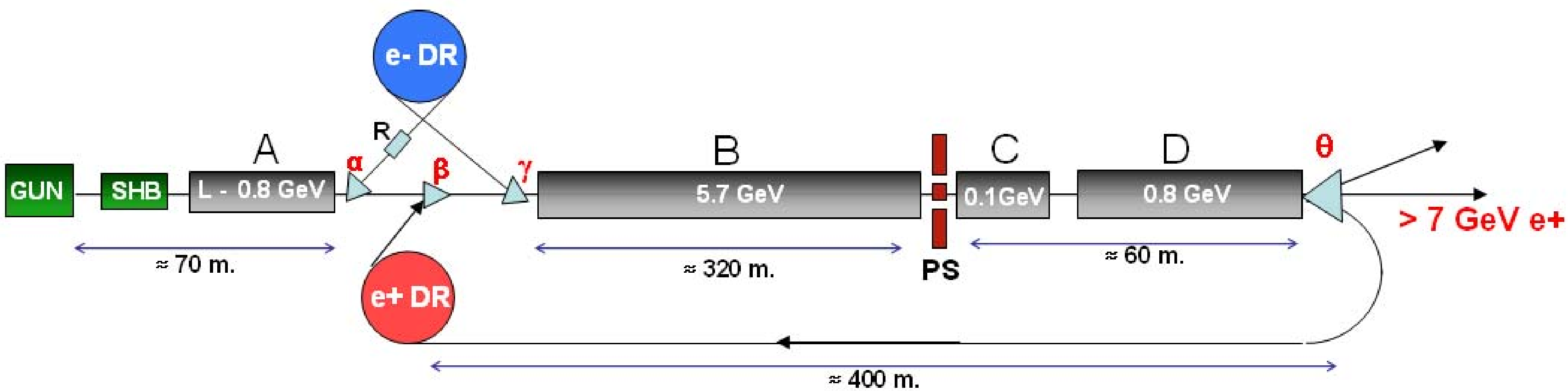
The requirements for a polarization SuperB facility include:

- A stable longitudinal direction for spin at the IP;
- A depolarization time longer than one beam lifetime;
- Fast switching of the sign of the polarization, within or less one beam lifetime;
- The ability to provide arbitrary filling patterns, e.g., it would be very useful to have opposite polarizations in neighboring RF buckets;
- Polarization of the electron beam in the initial design, with the possibility of positron polarization as an upgrade; and
- High degree of polarization.

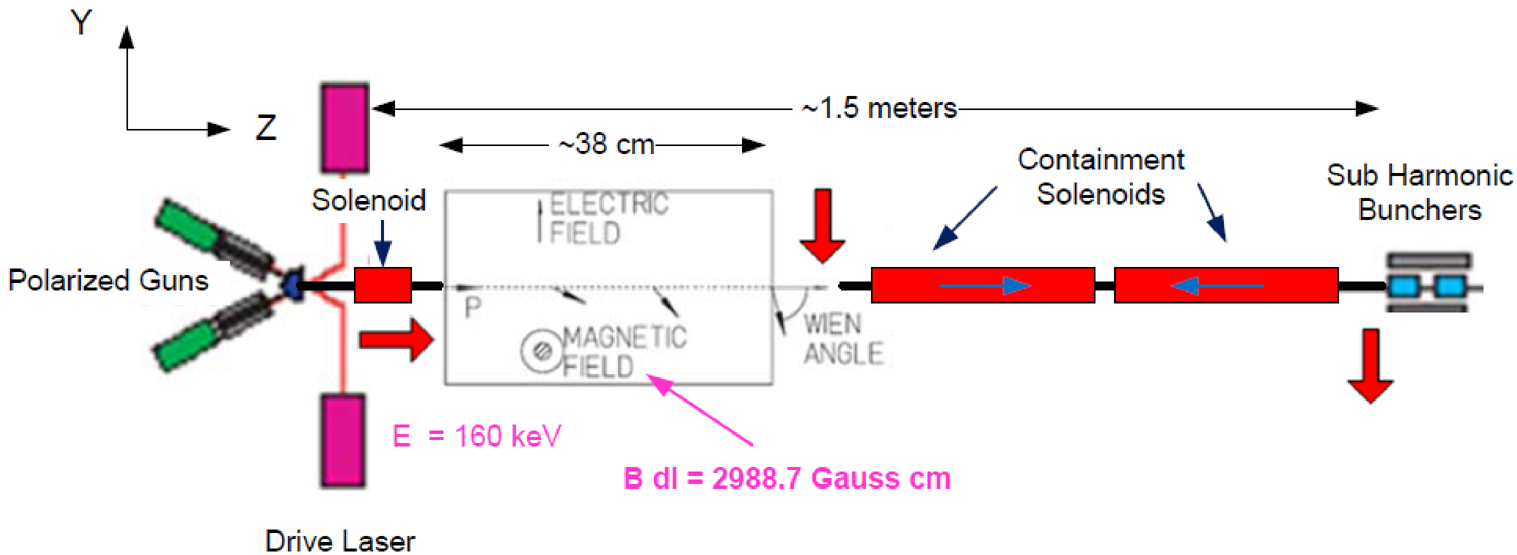
Latest Ring Layout

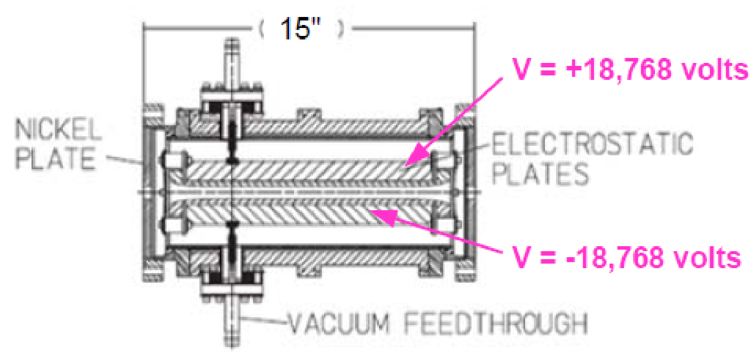


To preserve polarization spin must be normal to plane of damping ring and main ring arc bends.



Spin Rotation to the Vertical at Polarized Gun with Wien Filter Energy is



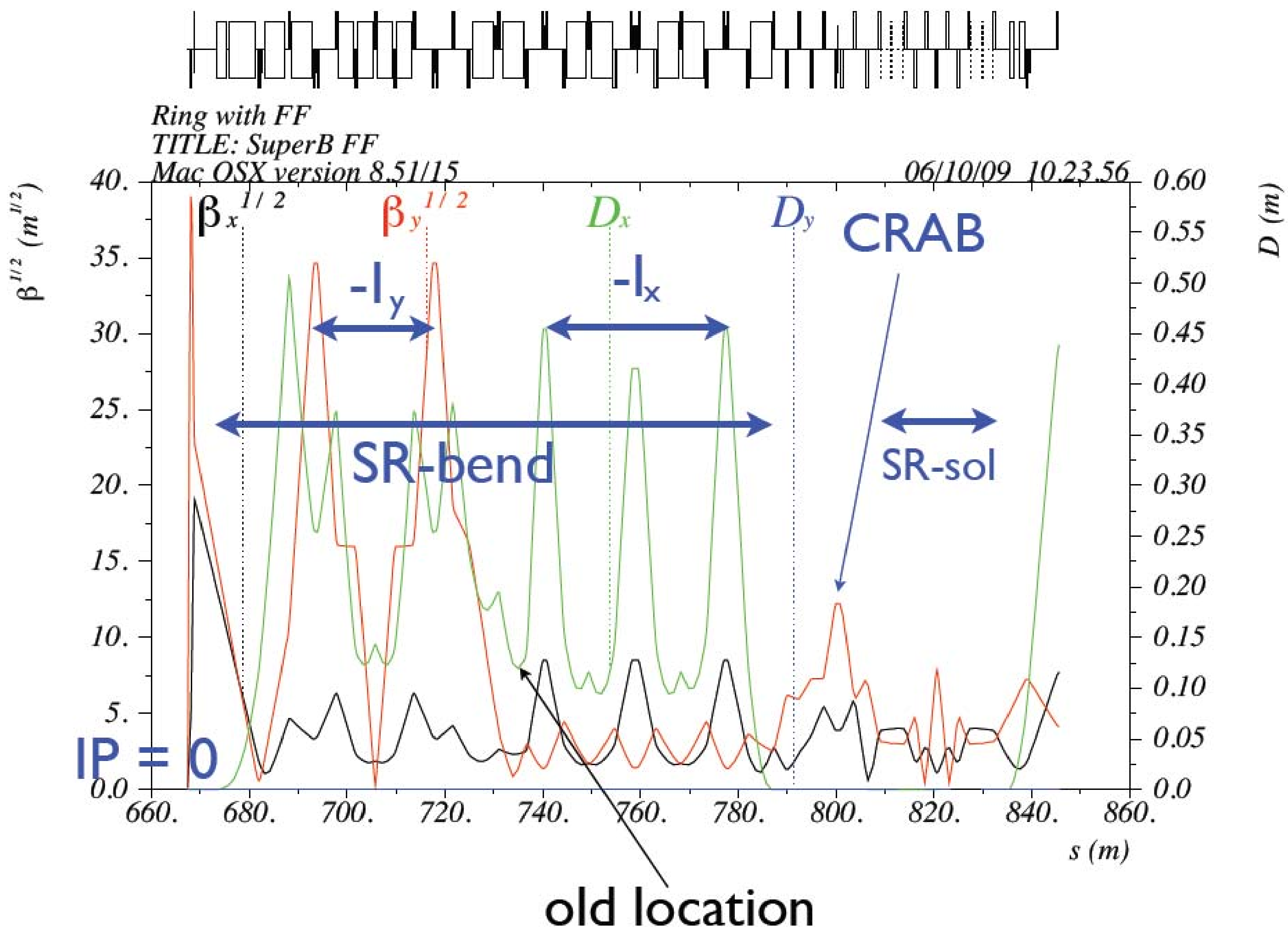


Wien filter spin manipulator
The magnet is not shown in the cutaway view

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

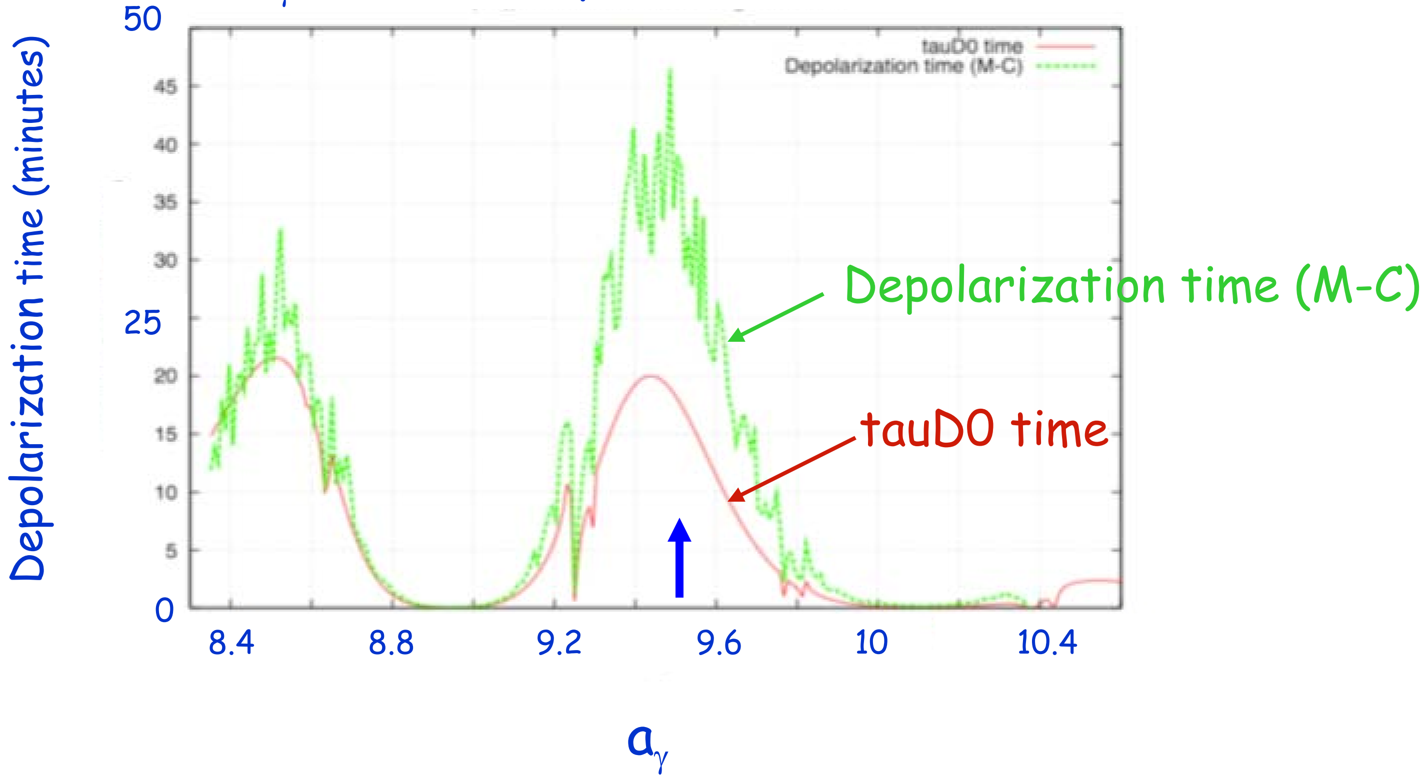
LER SR in "New Short" Lattice V2.01.002



Walter Witten: Spin Rotators in LER

Depolarization time in LER vs misaligned lattice

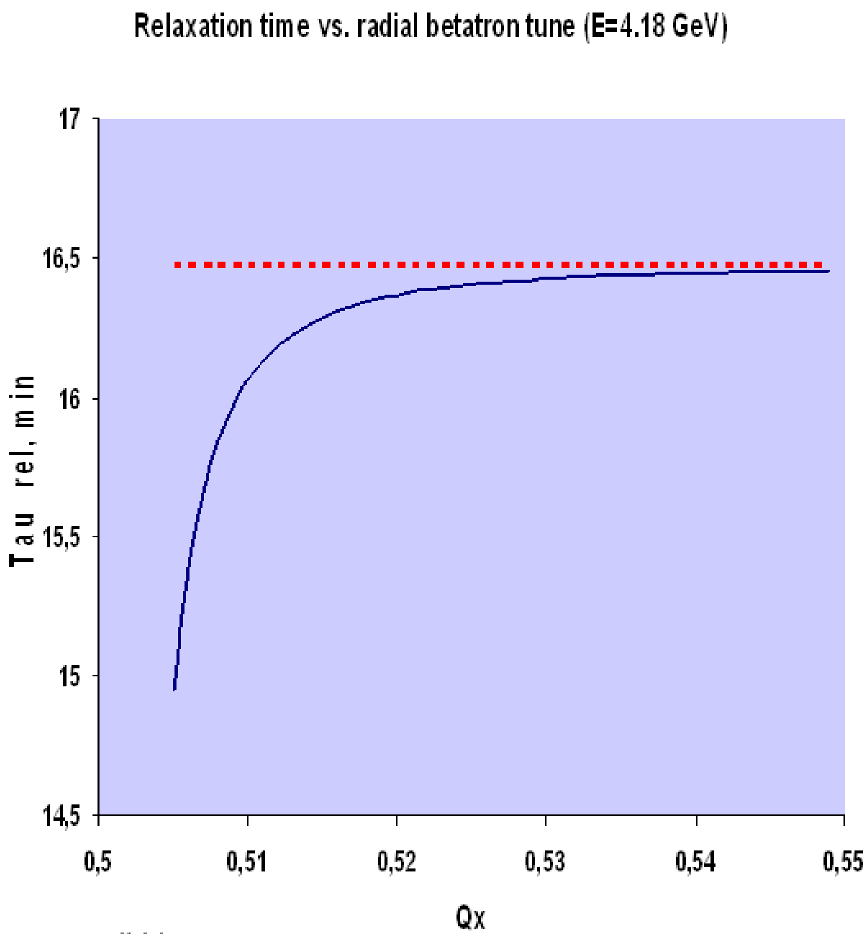
a_γ=9.5 corresponds to E=4.18 GeV

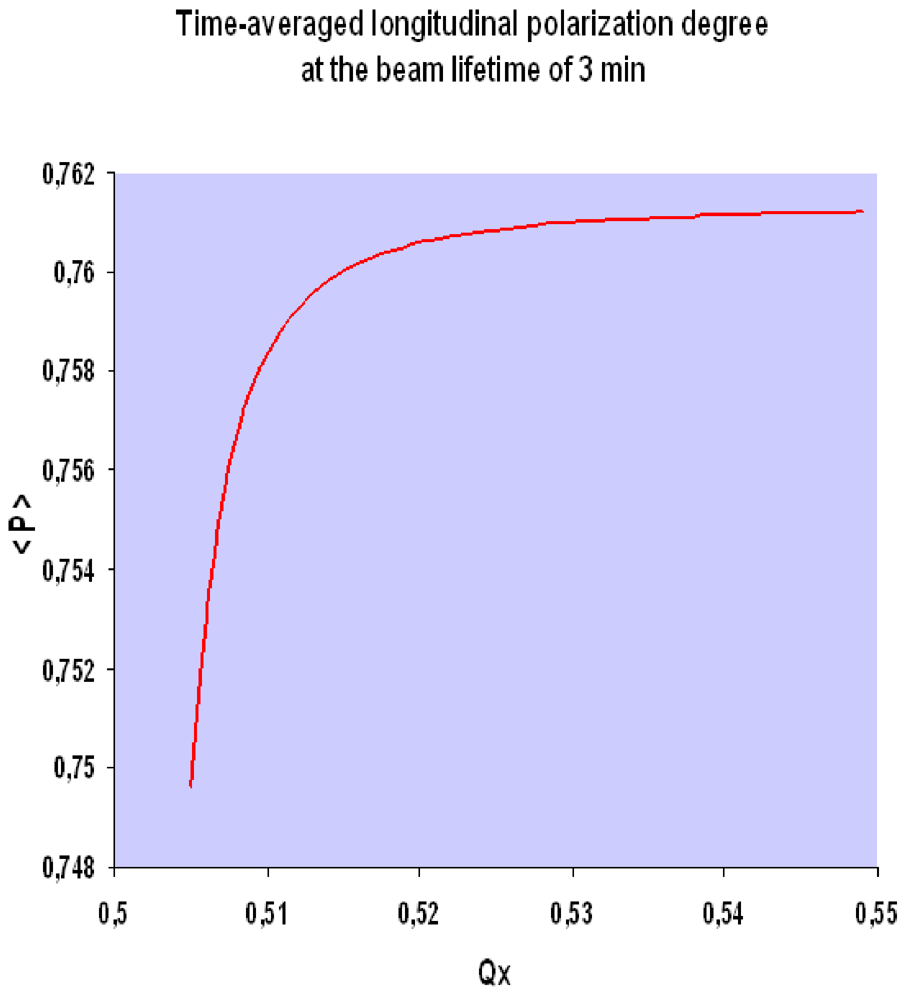


Using DESY spin-tracking code. Uli Wienands

Calculation of the steady longitudinal polarization degree for the 2009 SuperB project (LER E=4.18 GeV)

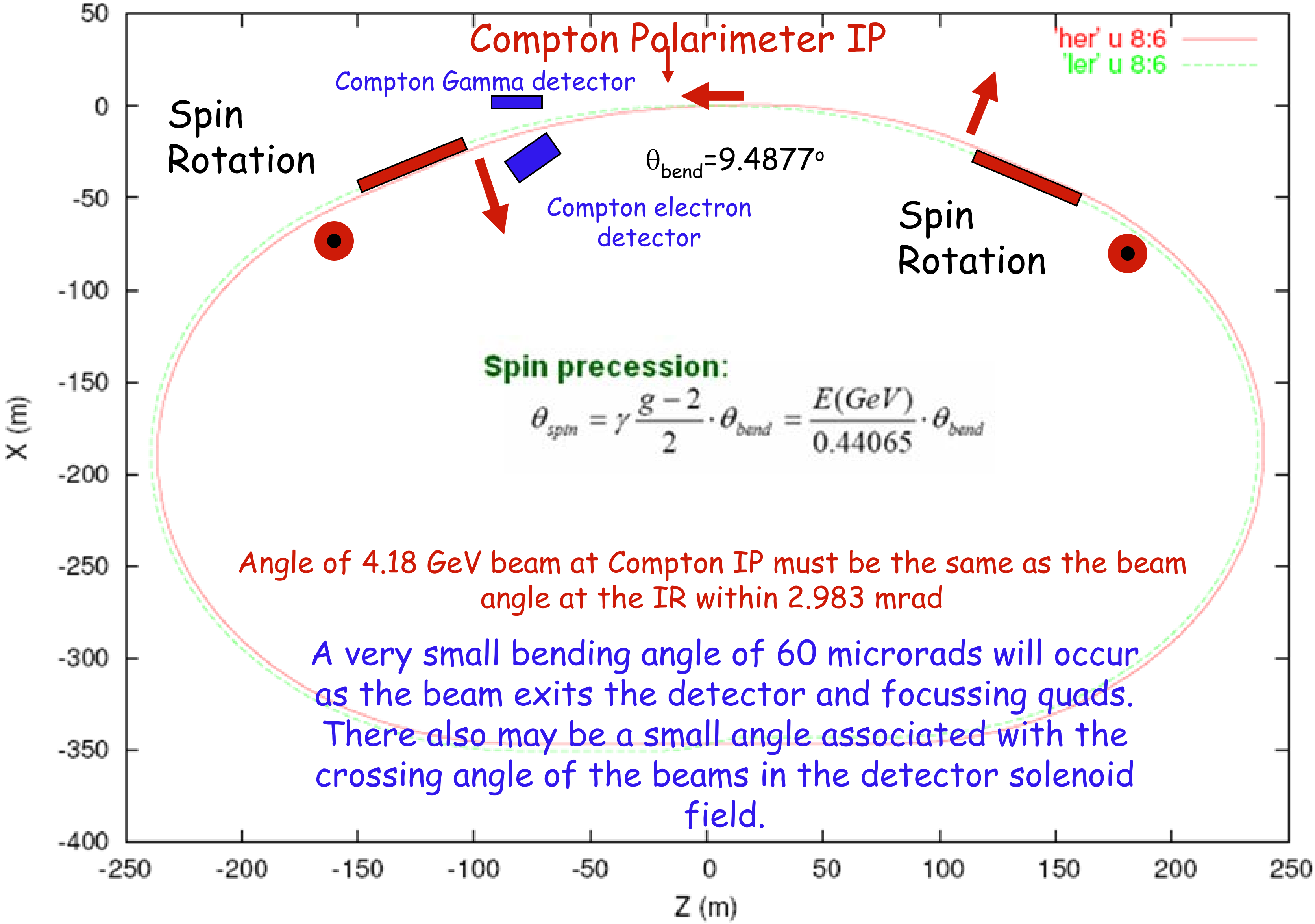
- **SLAC-Frascati variant of the spin rotator insertion**
- **Betatron contribution account based on *S. Nikitin/SB-NOTE-ACC- 2008- 001***





S.A. Nikitin 21.09.09

Main Ring


Compton Polarimeter IP
Compton Gamma detector
'her' u 8:6
'ler' u 8:6
Spin Rotation
θ_{bend}=9.4877°
Compton electron detector
Spin Rotation
Spin precession:
$\theta_{spin} = \gamma \frac{g-2}{2} \cdot \theta_{bend} = \frac{E(GeV)}{0.44065} \cdot \theta_{bend}$
Angle of 4.18 GeV beam at Compton IP must be the same as the beam angle at the IR within 2.983 mrad
A very small bending angle of 60 microrads will occur as the beam exits the detector and focussing quads. There also may be a small angle associated with the crossing angle of the beams in the detector solenoid field.
X (m)
Z (m)
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-250
-200
-150
-100
-50
0
50
100
150
200
250

Polarimeter

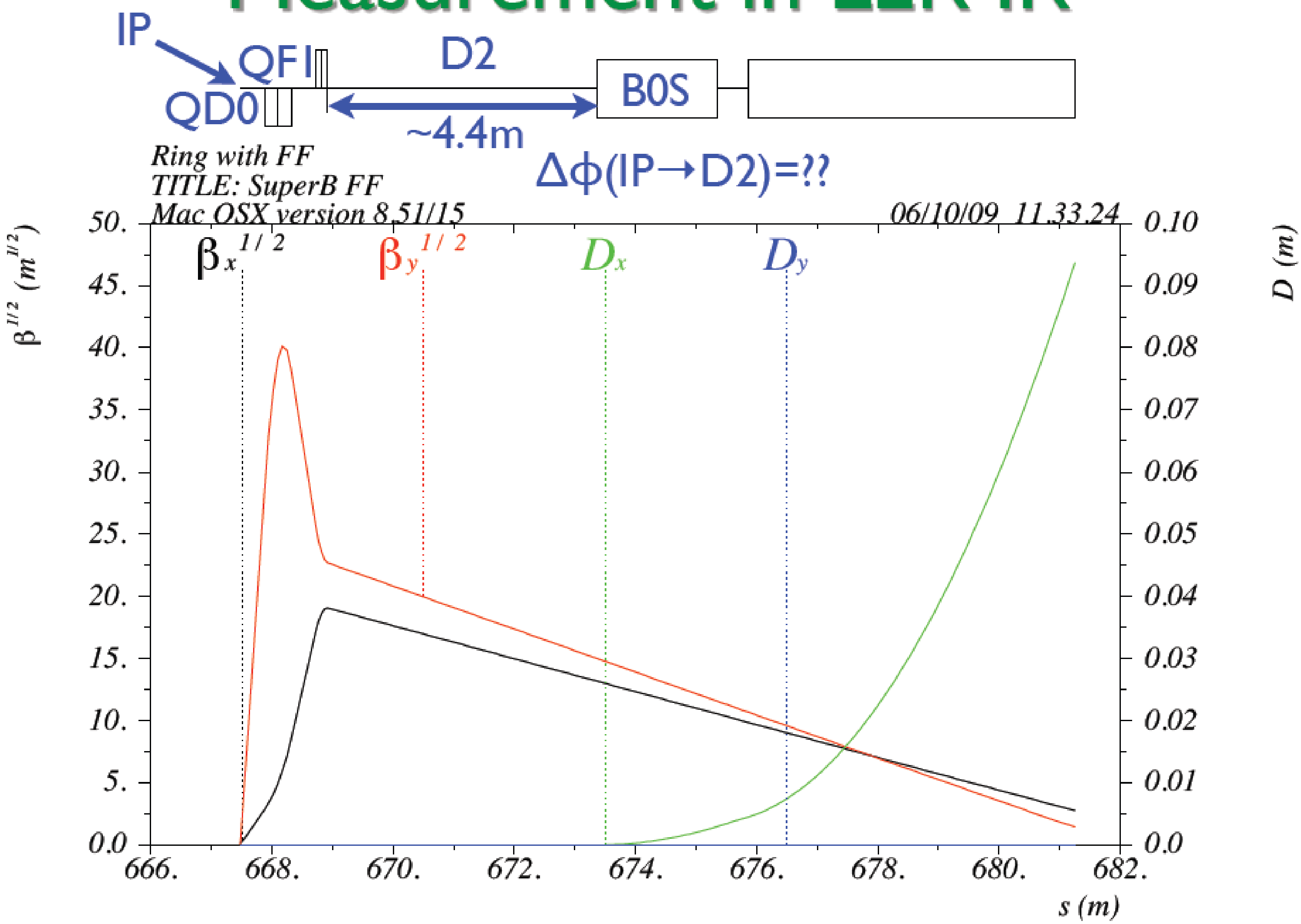
Measure polarization for each bunch in the ring allowing helicity selection for each bunch. Bunches are separated by 4.2nsec (2.1 nsec possible in future). Bunch length of beam is ~15 picosec. Compton gamma and electron detectors must have time resolution <2 nsec.

Compton scattering of polarized laser light on polarized electron beam is non-invasive and allows fast measurement of the polarization for each bunch in the ring.

Direction of beam at Compton IP must be the same as at the Interaction Region to within 2.983 mrad.

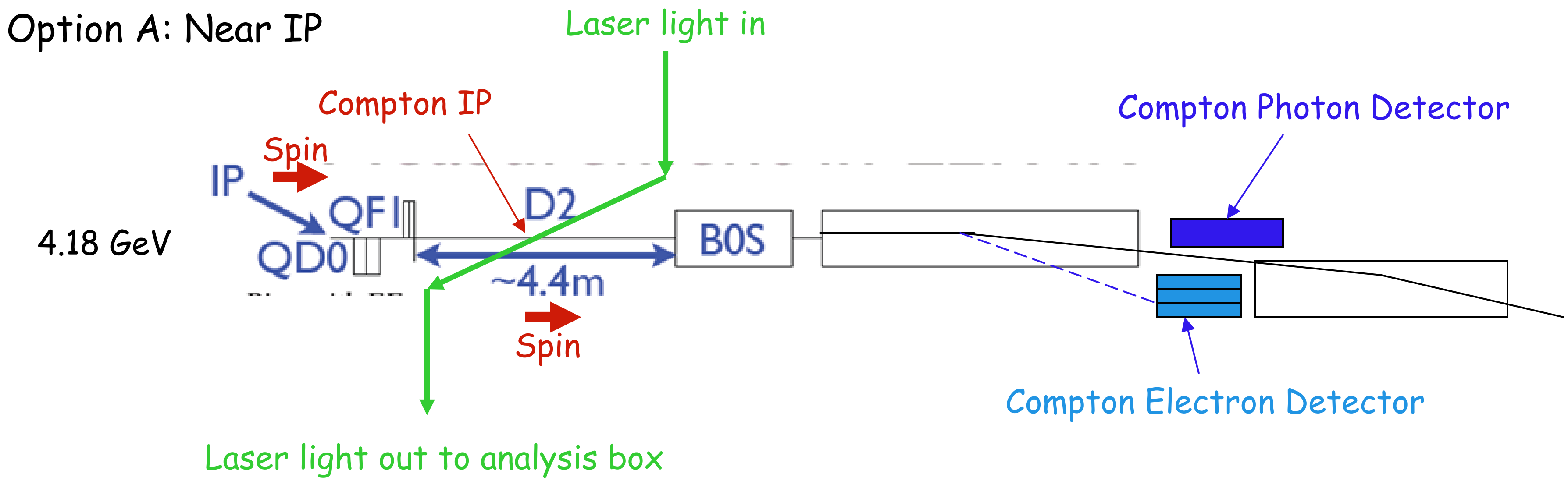
Preferable to measure polarization asymmetry for both Compton scattered electrons and gammas.

Possible Location for Polarization Measurement in LER IR



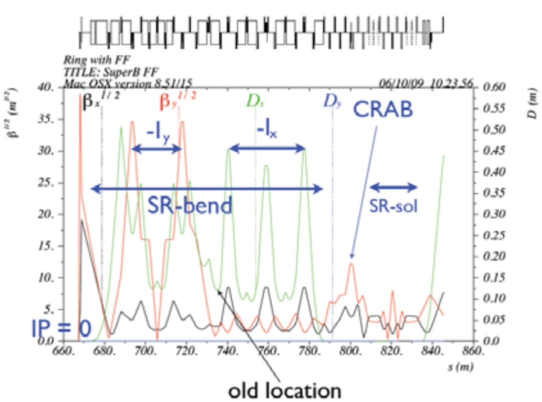
Walter Witten: Spin Rotators in LER

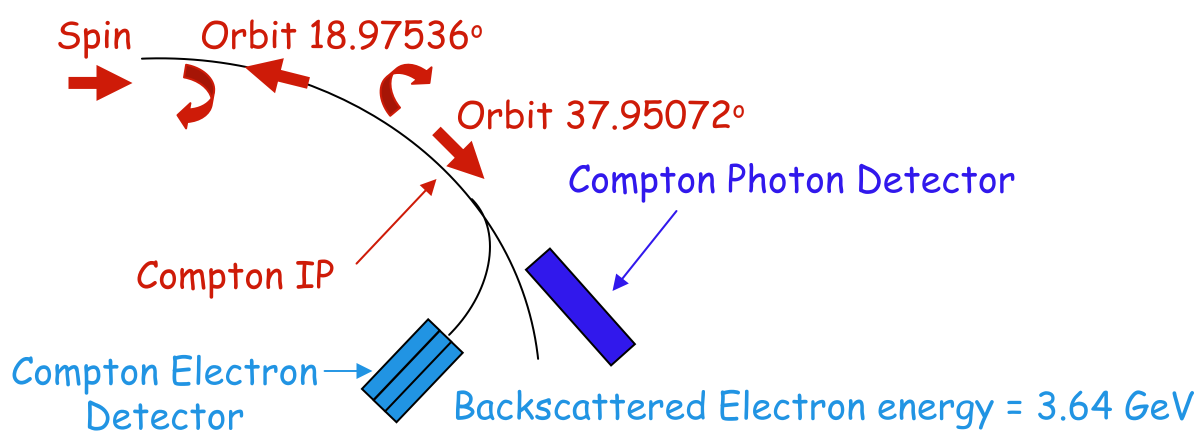
Compton Polarimeter



Pros: Near IR   Cons: Beam size large. Backgrounds from beamstrahlung large. Crossing angle ~50 mrad.

Option B: Compton IP after n*pi spin rotations between IP and solenoid section

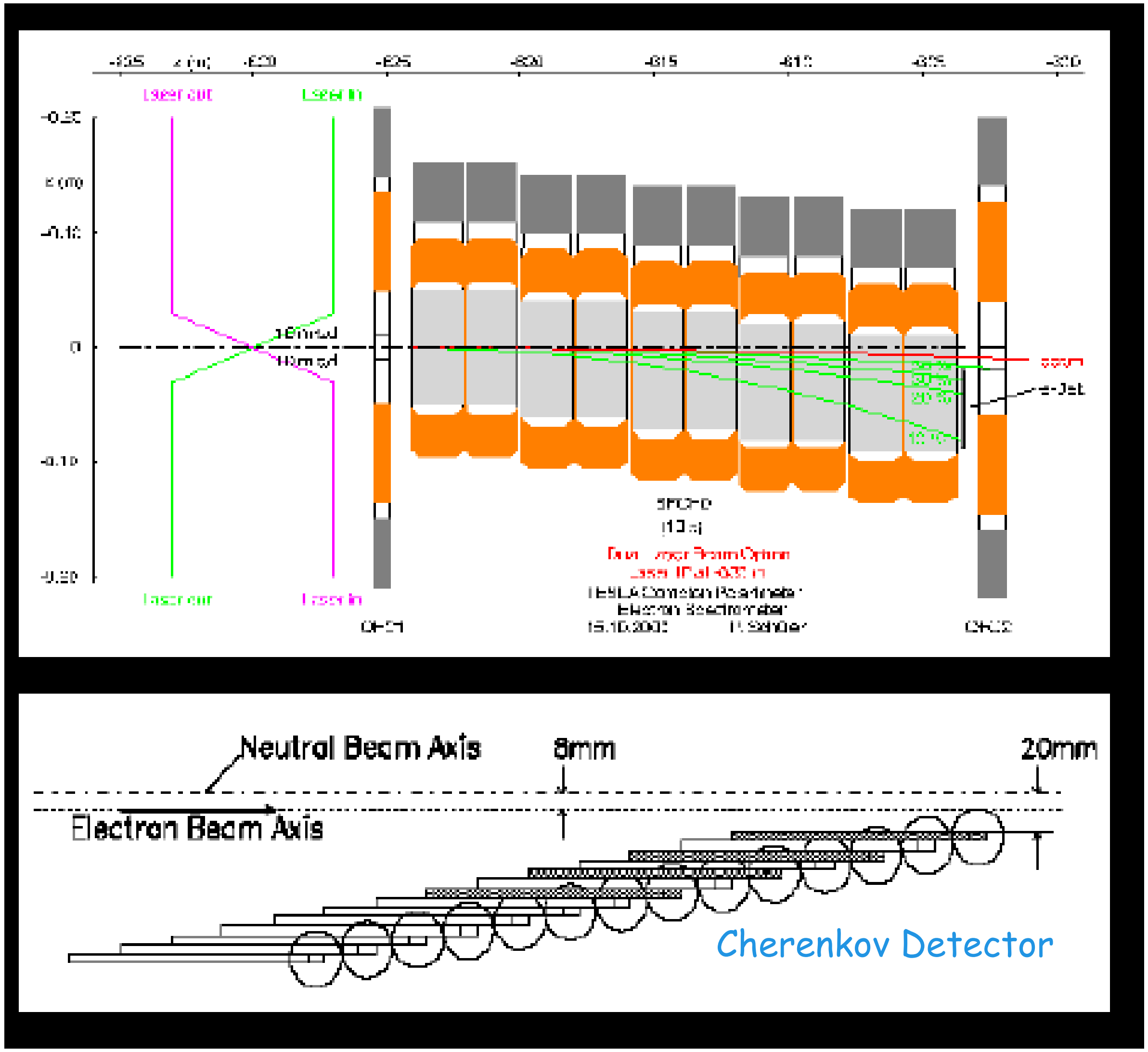




Pros: Beam size small~100μm. Backgrounds small. Smaller Compton Crossing angle due to larger spacing for Compton IP.   Cons: After n*pi spin rotations Systematic error due to uncertainty in n*pi spin rotations between IP and Compton IP. Uncertainty in electron beam orbit angle < 2.983 mrad

Compton Electron Detection

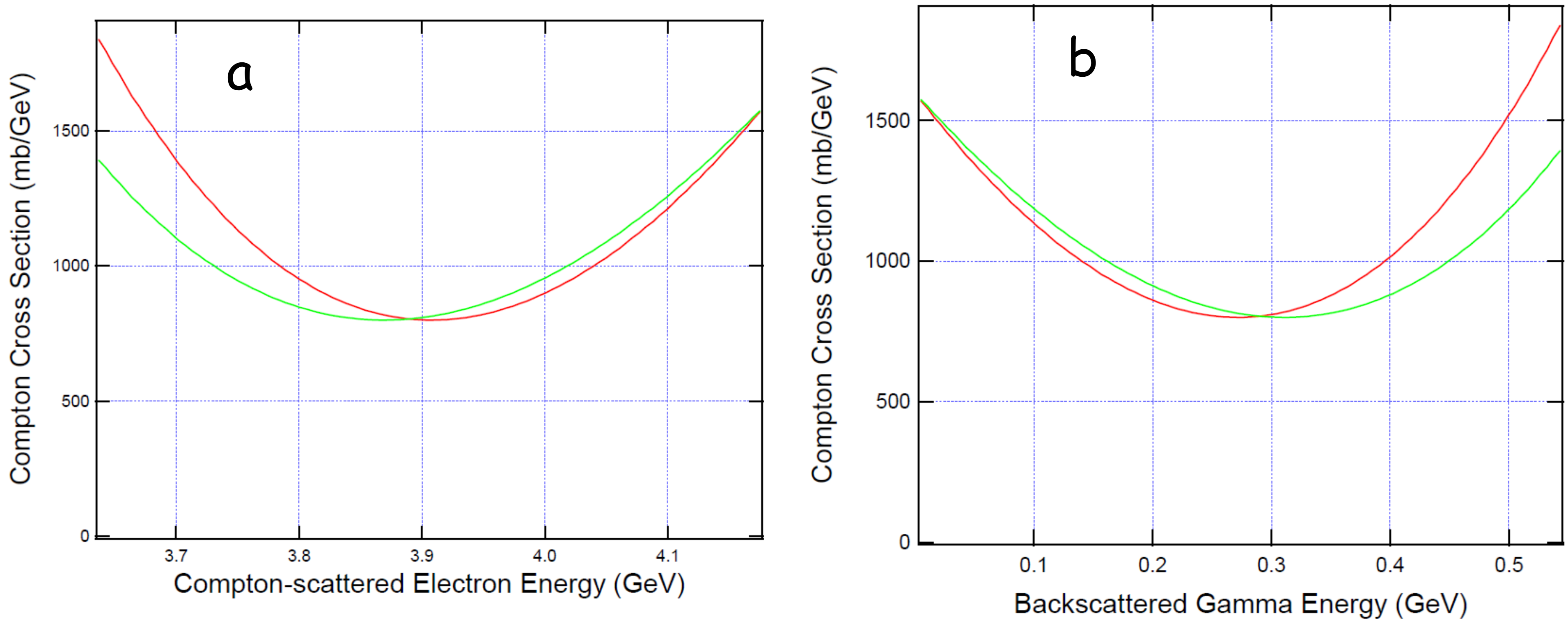
At 4.18 GeV beam on 2.33eV laser gives 3.64 GeV backscattered e-



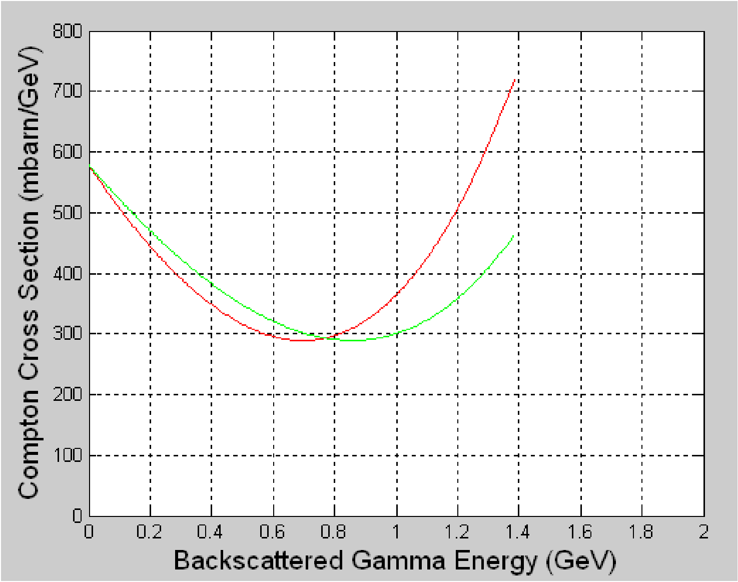
Tesla scheme: Dimension, # of bend magnets, etc different at SuperB with 4.18 GeV LER beam

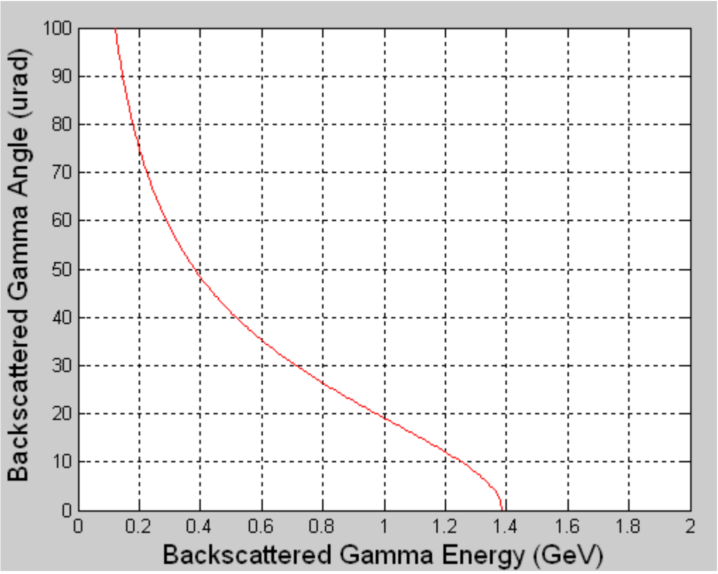
Compton Differential Cross Section

Endpoint asymmetry is ~0.15 at 4.18 GeV

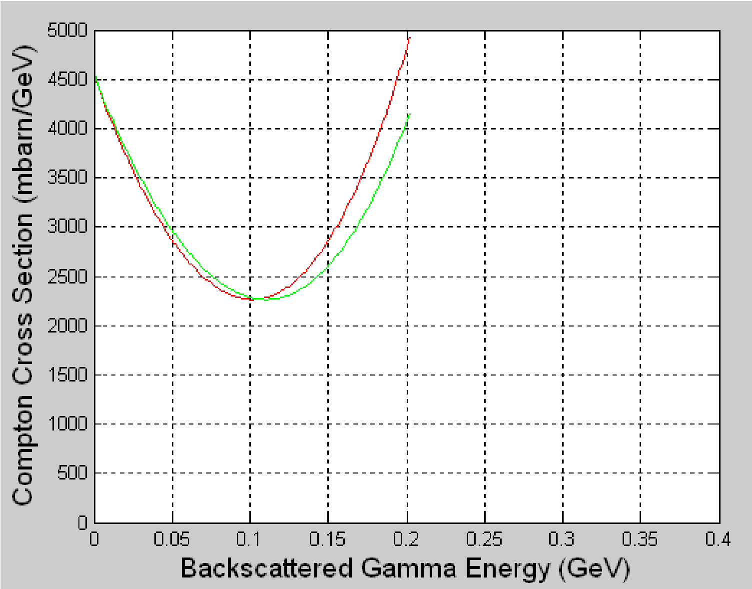


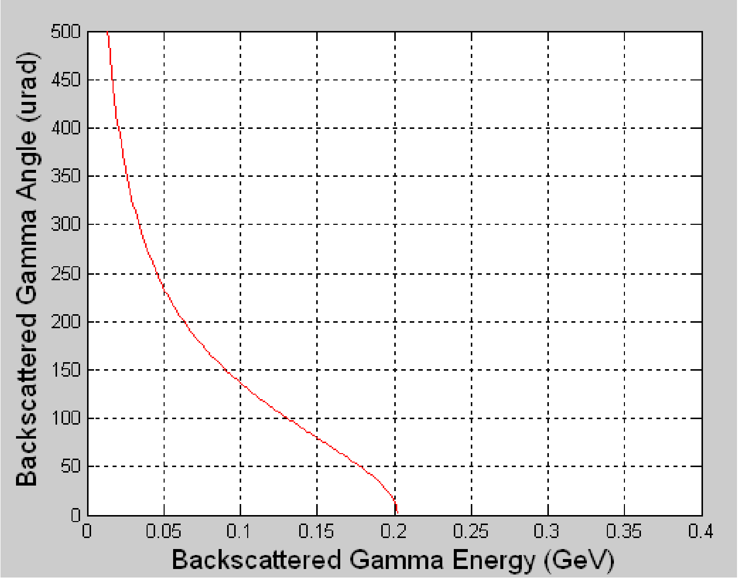
Compton differential cross section versus scattered
(a) electron energy (b) Gamma energy
for same (red curve) and opposite (green curve) helicity configuration of laser photon (2.33 eV) and beam electron (4.18 GeV).





Beam Energy: 7 GeV, Laser photon: 2.3 eV





Beam Energy: 2.5 GeV, Laser photon: 2.3 eV

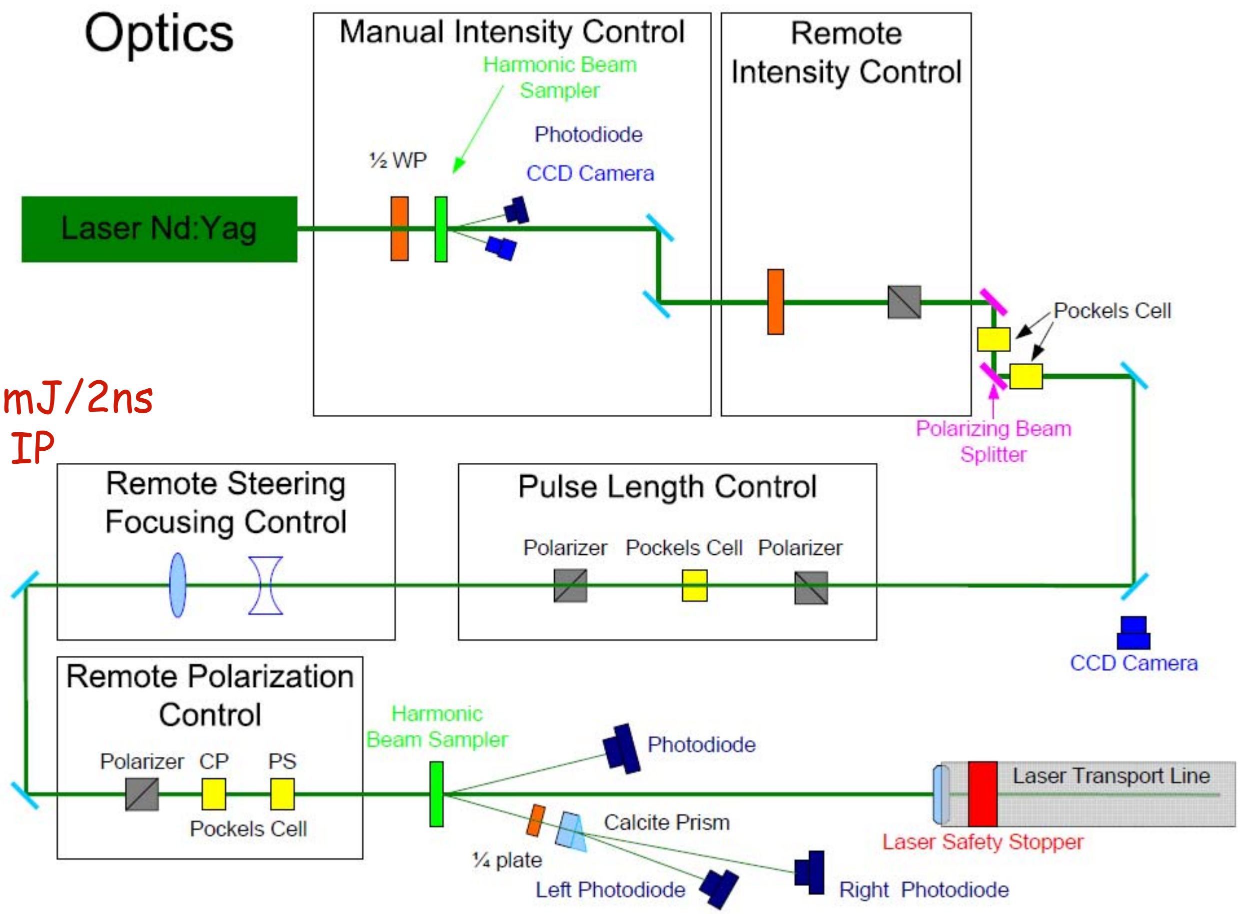
Compton Kinematics

Beam Energy (GeV)	Compton Gamma Wmax (GeV)	Analyzing Power Max	<Analyzing Power> Flux weighted	<Analyzing Power> Energy weighted	Compton Electron Energy (GeV)
250	224.48	0.98	-0.15	-0.068	25.19
45.6	28.25	0.75	0.042	0.179	17.35
27.5	13.62	0.59	0.063	0.187	13.88
7	1.40	0.22	0.043	0.096	5.60
4.18	0.54	0.137	0.030	0.064	3.64
4	0.50	0.13	0.029	0.061	3.50
2.5	0.20	0.084	0.020	0.040	2.29

Laser Optics Bench

YAG Laser
100 Hz
<2ns wide
532 nm
100 mJ

Need ~100 mJ/2ns
at Compton IP



1% measurement on a single bunch in the ring every ~5 seconds

Will investigate availability of a mode-locked laser with ~35 picosec wide pulse width.

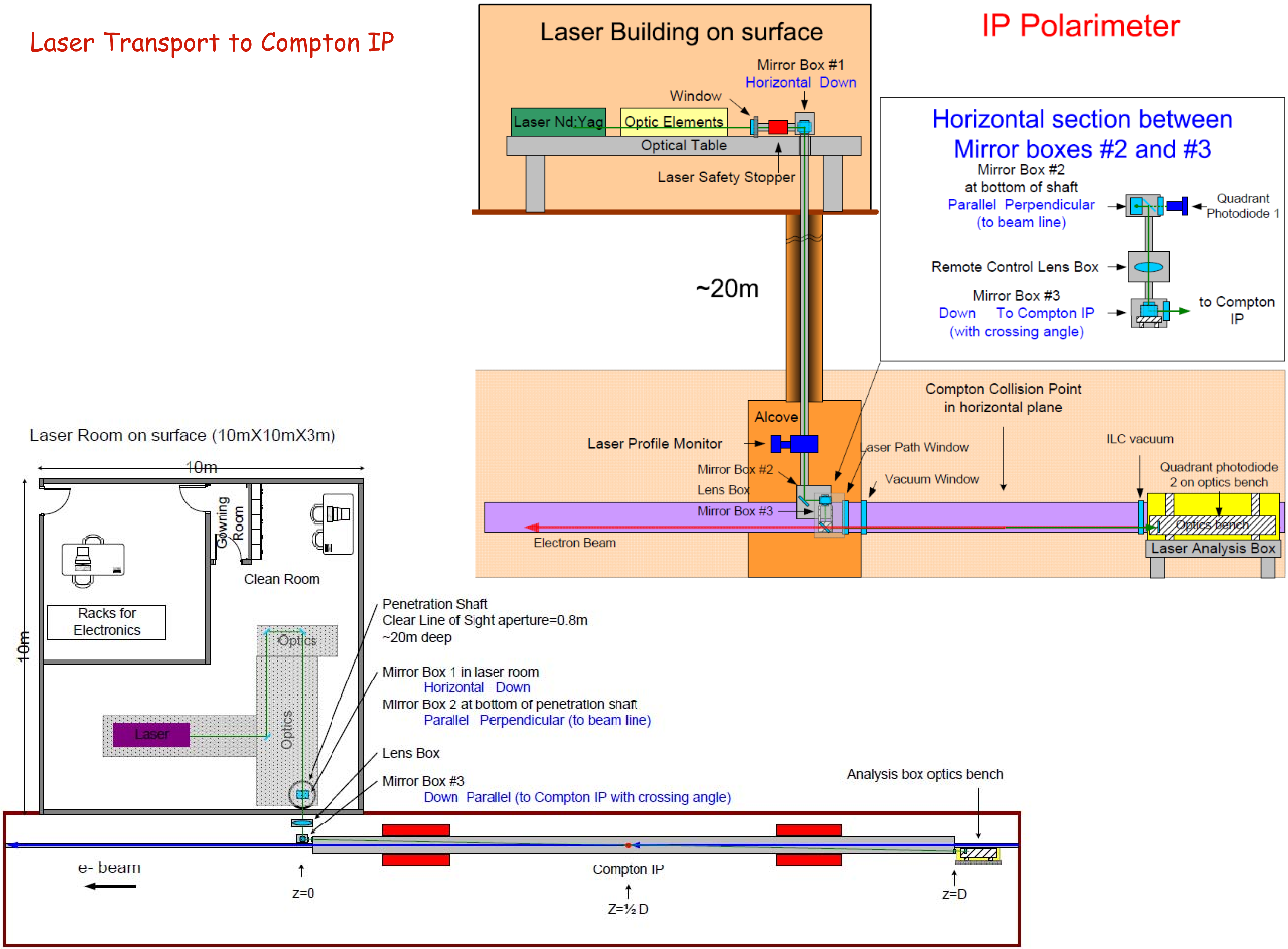
Recent new product from Quantel Pizzicato B

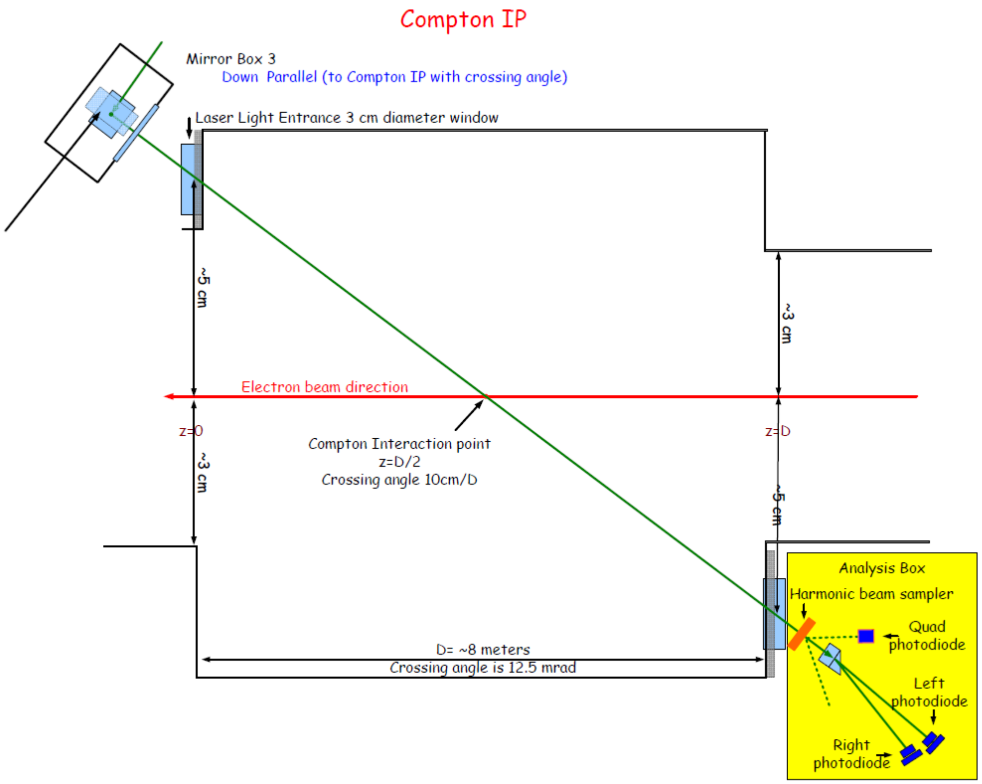
- -30 mJ pulse energy at 532 nm (2.33 eV)
- -20 Hz operation
- -35 picoseconds

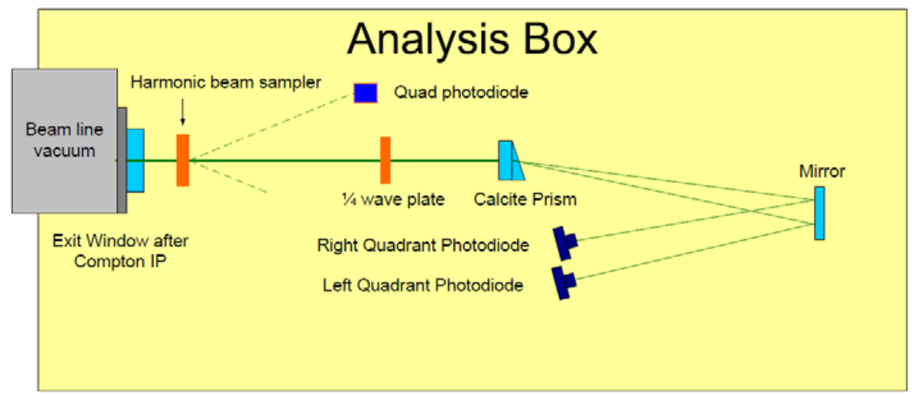
Note: each bunch in ring has σ_z=5mm or ~15 picoseconds

Laser Transport to Compton IP

IP Polarimeter







LER at 4.18 GeV

$$R^{eff} = \frac{300 \cdot scattered \cdot electrons}{cm} \bullet \left(\frac{100\mu m}{\sigma_y}\right) \bullet \left(\frac{15.44 mrad}{\theta_{cross}}\right) \bullet \left(\frac{E_{laser}}{100 mJ}\right) \bullet \left(\frac{2n\sec}{t_{FWHM}}\right)$$

Compton IP near IR:	Near IR 3 mm	~25 mrad	35 picosec possible
Compton IP after n*pi spin rotations:	100 μm	~12.5 mrad	35 picosec possible

Experiment Cost: Laser, optics on laser bench, optics in analysis box, optic elements in laser transport line, Compton gamma and Compton electron detectors, local data acquisition.

Super B project Costs:
Pays for laser building, penetrations, beam line elements, vacumn system, Laser safety system, ie all infrastructure

Conclusions

Spin rotation to the vertical at polarized electron gun.

Helicity selected randomly for each bunch in the ring.

Compton Polarimeter IP

Option A: Near IR

Spin direction the same as at IP

Backgrounds large from beamstrahlung
Electron beam large ~few mm
Laser light crossing angle with electron beam large

Option B: Between IR and solenoid section where spin has rotated n*pi
(note: 180° spin rotation is after beam orbit direction change of 18.97536°)

Backgrounds small
Electron beam size small ~100μm
Crossing angle can be smaller if ~8 meter drift space for Compton IP can be found.

Systematic error due to uncertainty in n*pi spin rotations between IR and Compton IP. Uncertainty in electron beam orbit angle needs to be less than 2.983 mrad

Spin rotation to the vertical at polarized electron gun. Polarimeter detectors must have time resolution less than 2nsec so that the polarization of each bunch can be measured.

Compton gamma detector and possibly Compton electron detector.