Downstream extraction line Polarimeter

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Goal for Polarimeter Accuracy is <0.25%

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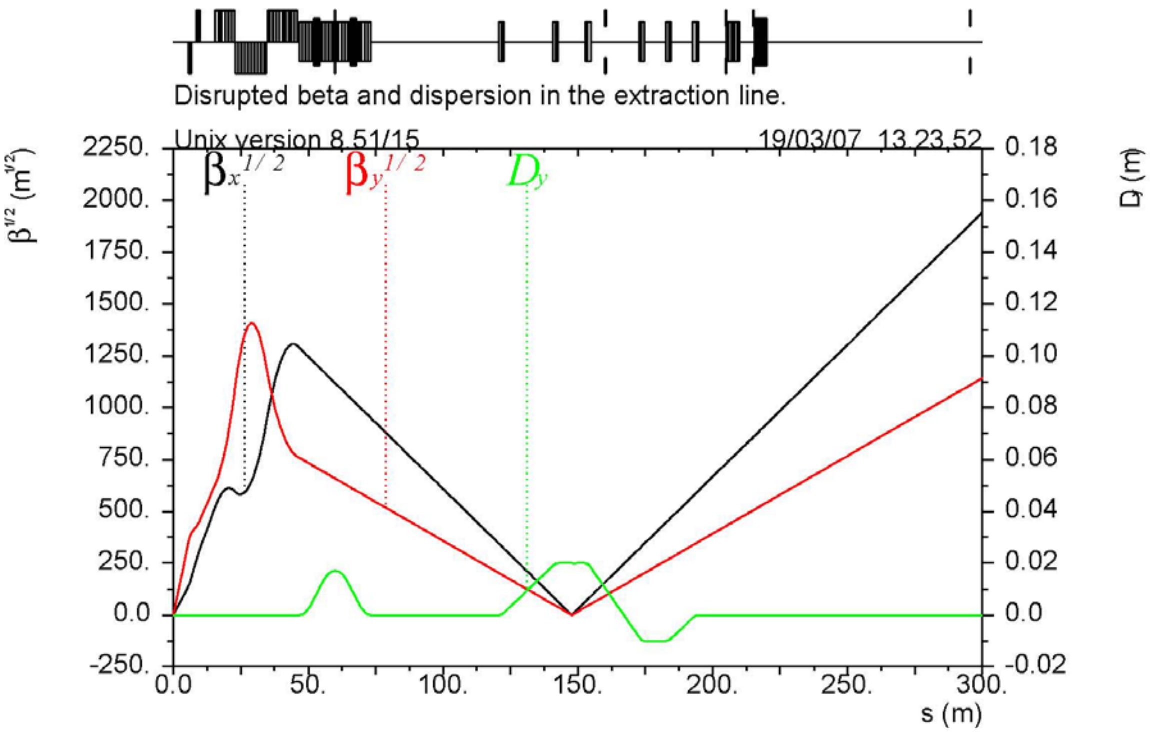
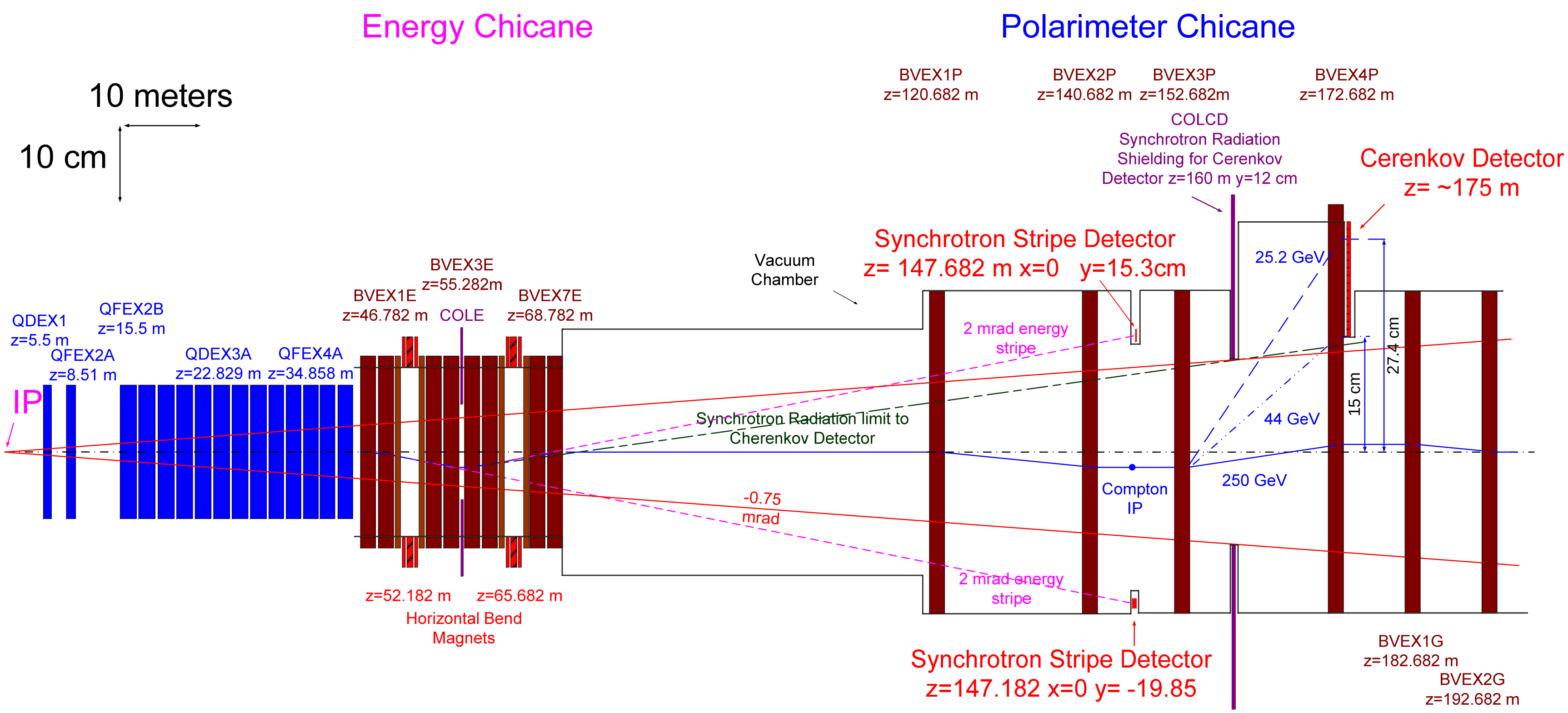
Workshop on Polarization and Energy measurements at the ILC
9-11 April 2008
Zeuthen

Proposal to modify the polarimeter chicane in the ILC 14 mrad extraction line, K. Moffeit et al. SLAC-PUB-12425, IPBI TN-2007-1 March 2007.

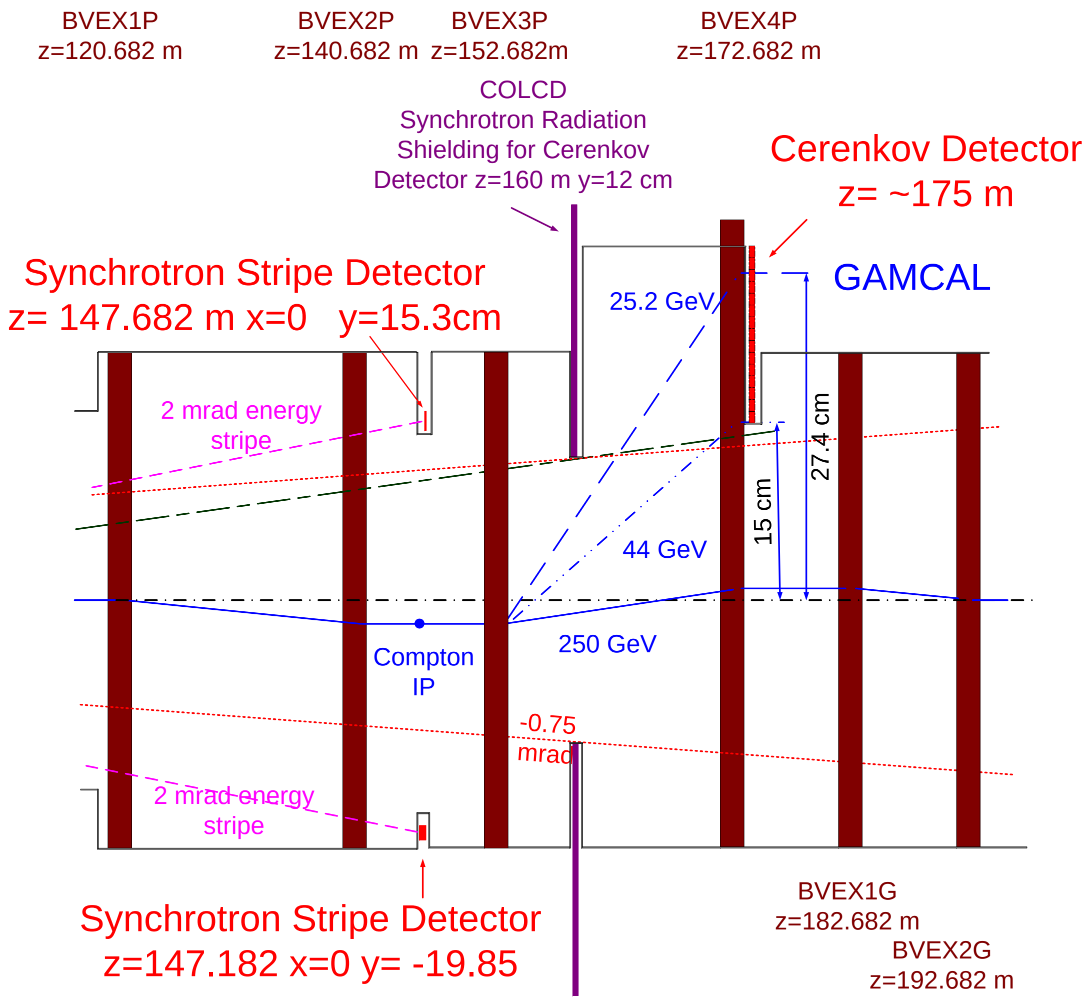


Optical β functions and vertical momentum dispersion Dy in the 14 mrad extraction line from IP to the dump, shown for the 250 GeV nominal disrupted beam.

14 mrad extraction line

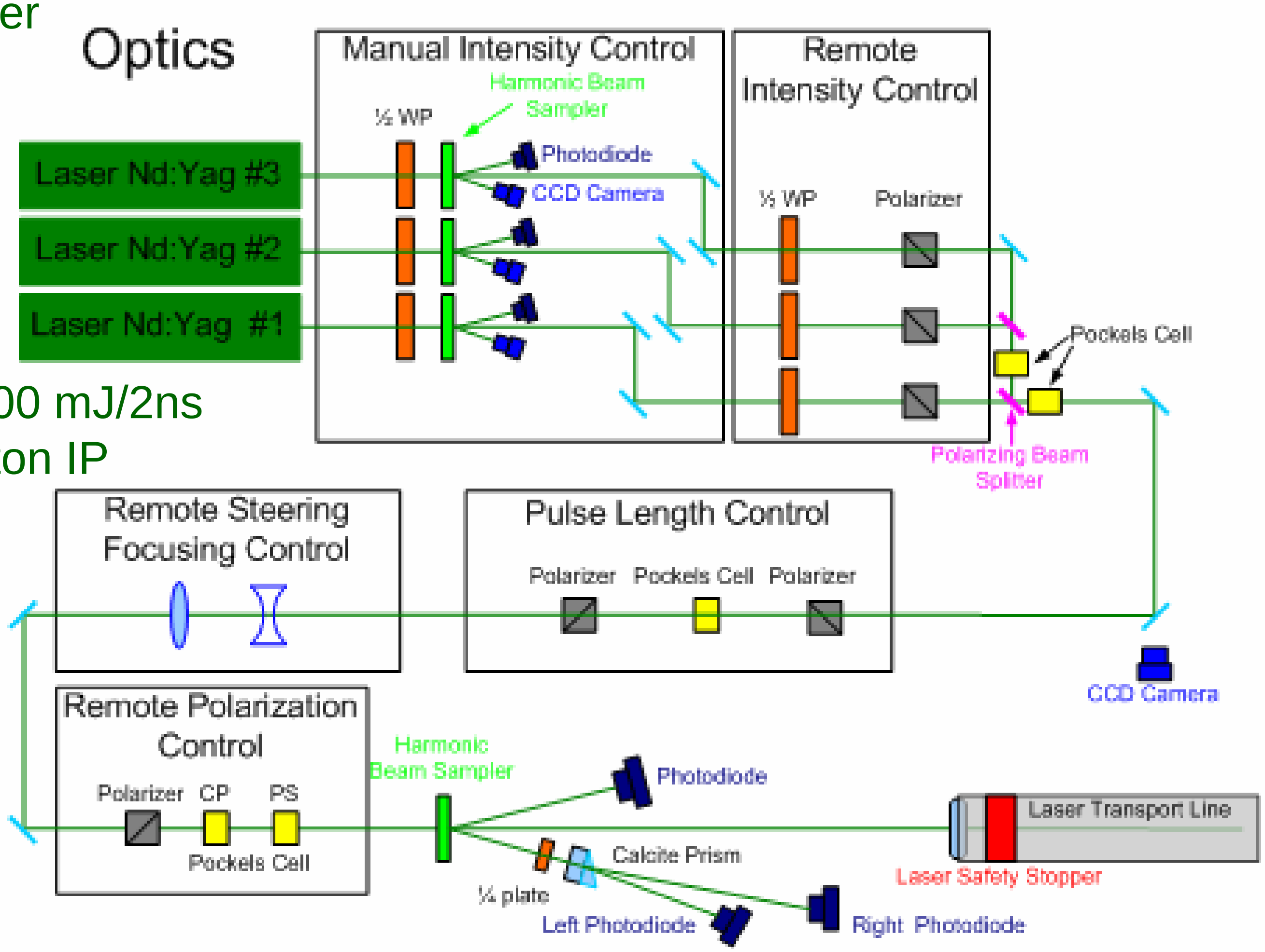


Polarimeter Chicane



Laser Optics Bench

Continuum Powerlite 8000
YAG Laser
10 Hz
6ns wide
532 nm
600 mJ



Need ~100 mJ/2ns
at Compton IP

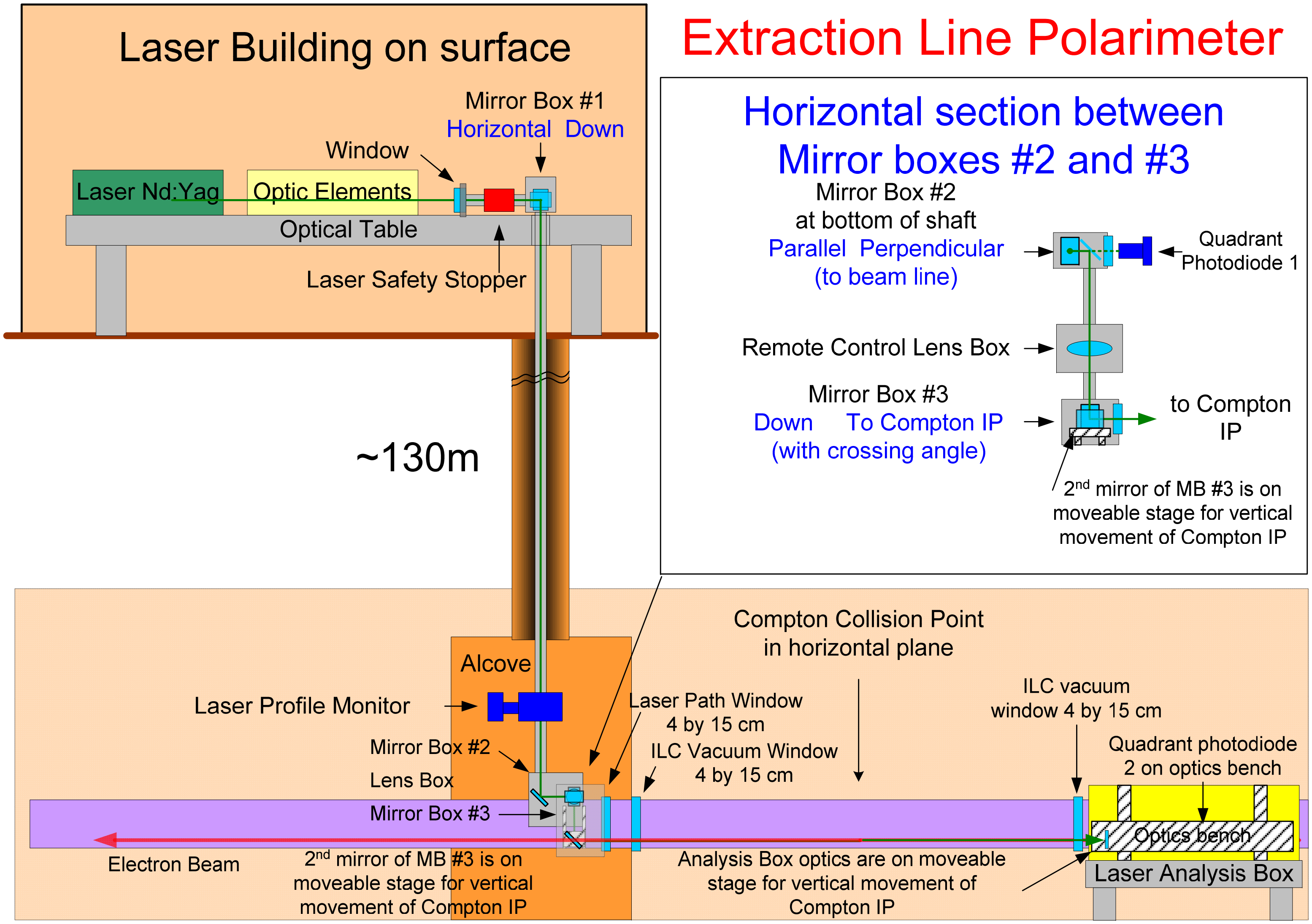
1% measurement every minute
3 bunches per train

1% measurement every hour
180 bunches per train

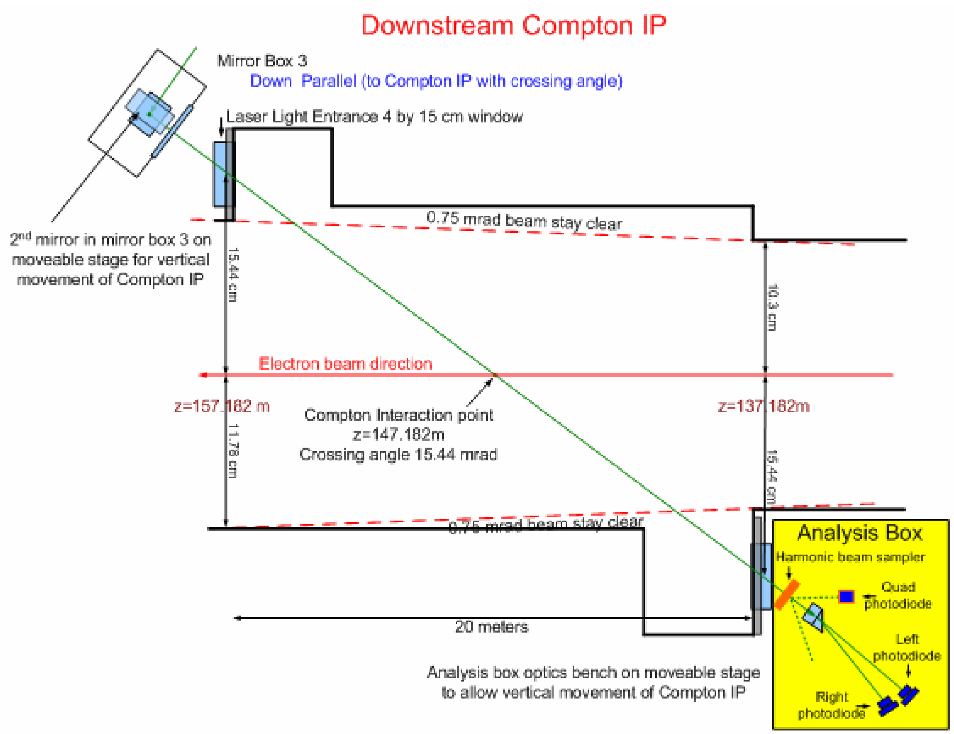
1% measurement every day
all bunches of train

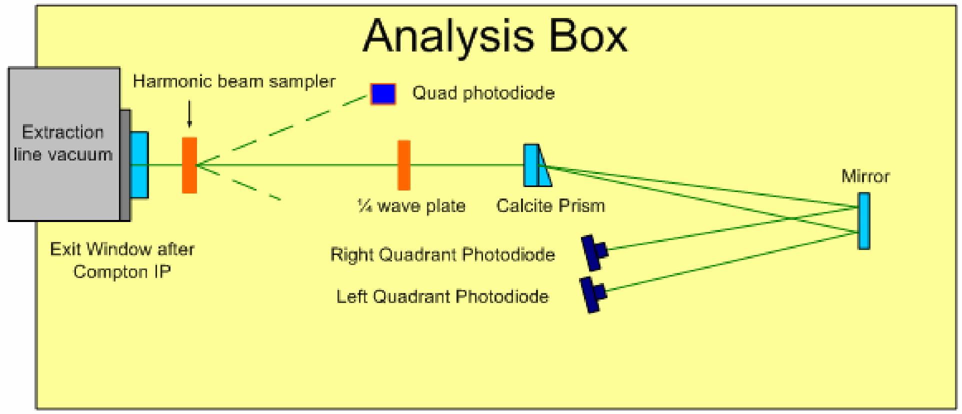
Will investigate availability of a mode-locked laser with ~50 picosec wide pulse width.

Laser Transport

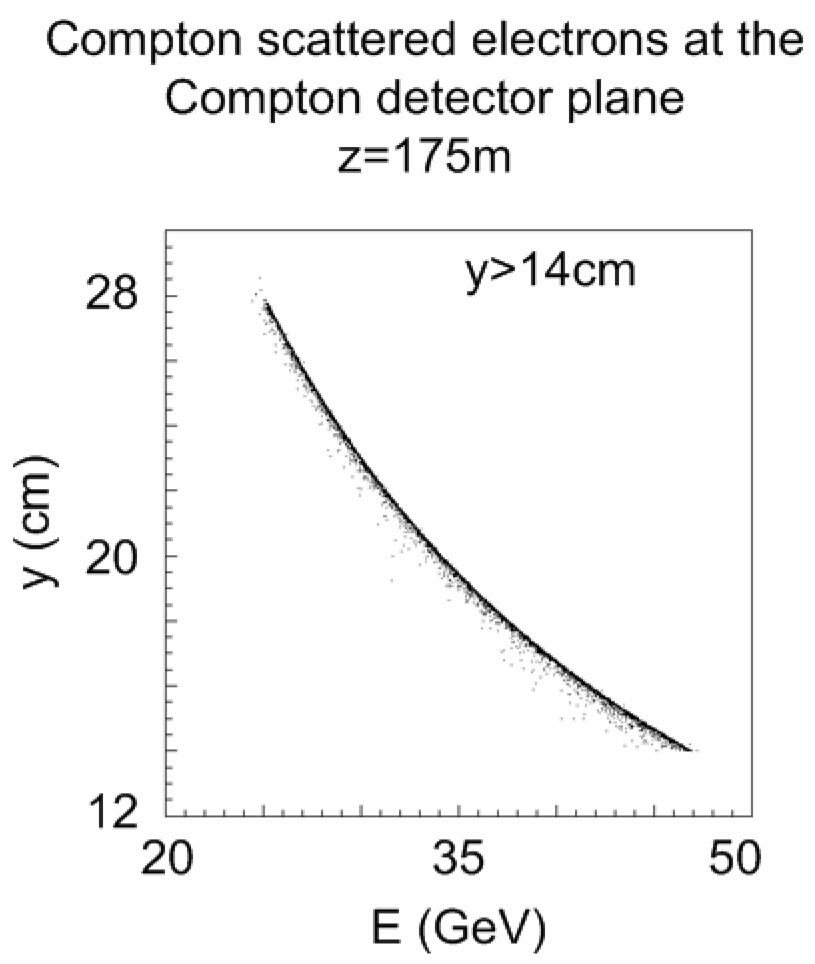


Compton IP



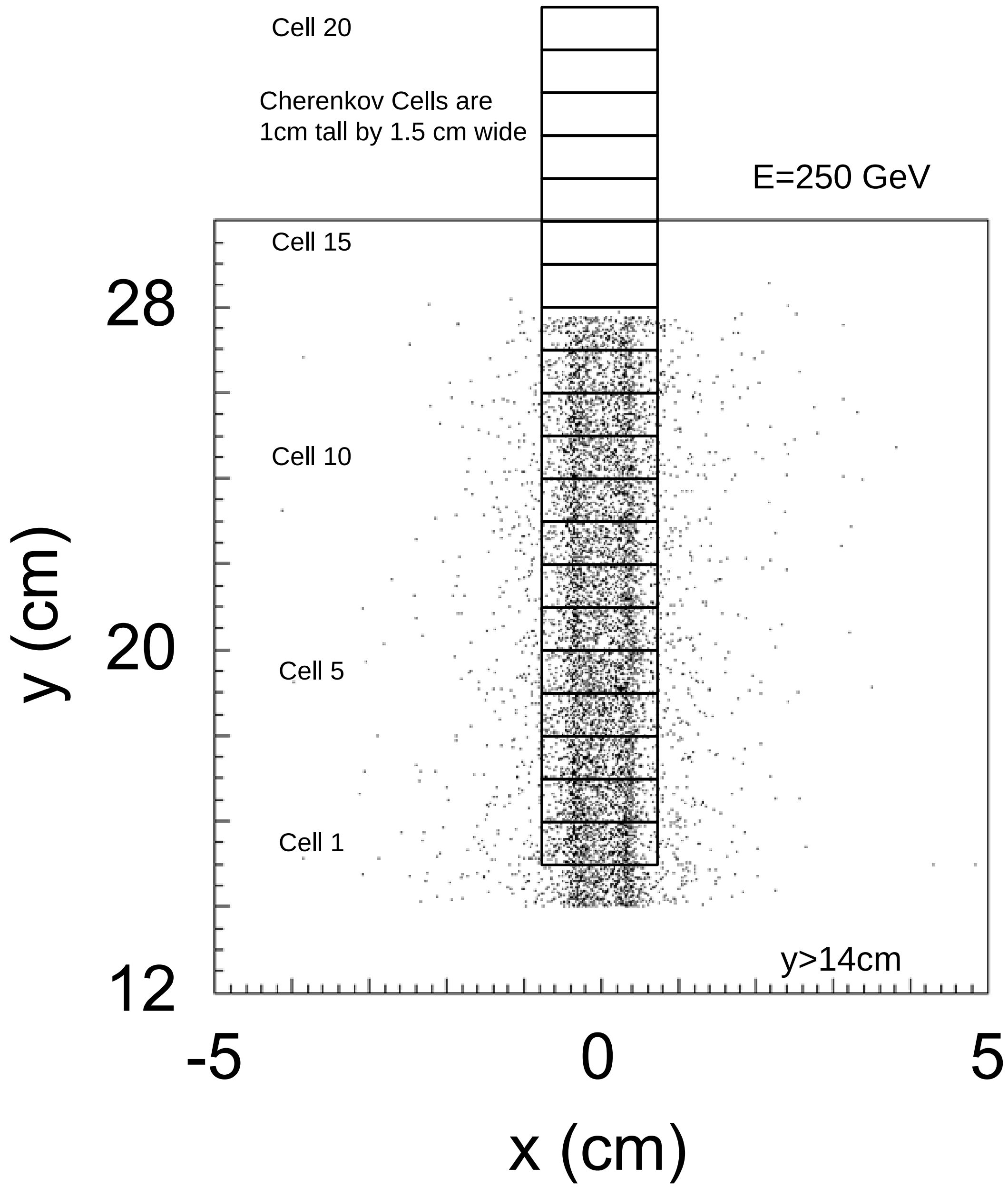


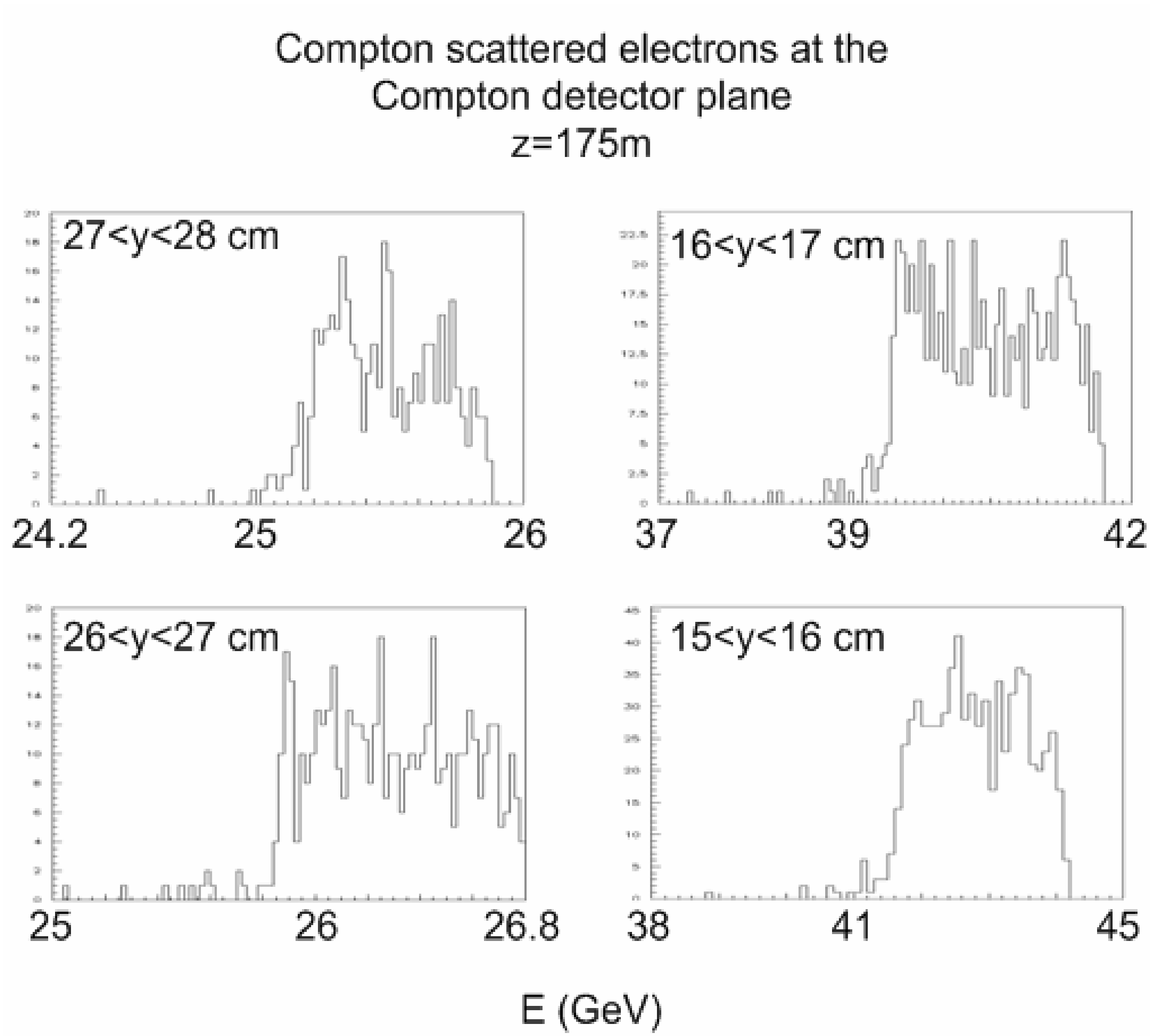
$$R^{eff} = \frac{300 \cdot scattered \cdot electrons}{cm} \bullet \left(\frac{100\,\mu m}{\sigma_y}\right) \bullet \left(\frac{15.44 mrad}{\theta_{cross}}\right) \bullet \left(\frac{E_{laser}}{100 mJ}\right) \bullet \left(\frac{2n\sec}{t_{FWHM}}\right)$$



Energy versus y for the Compton scattered electrons at the Compton Detector plane (z = 175m) for beam energy of 250 GeV.

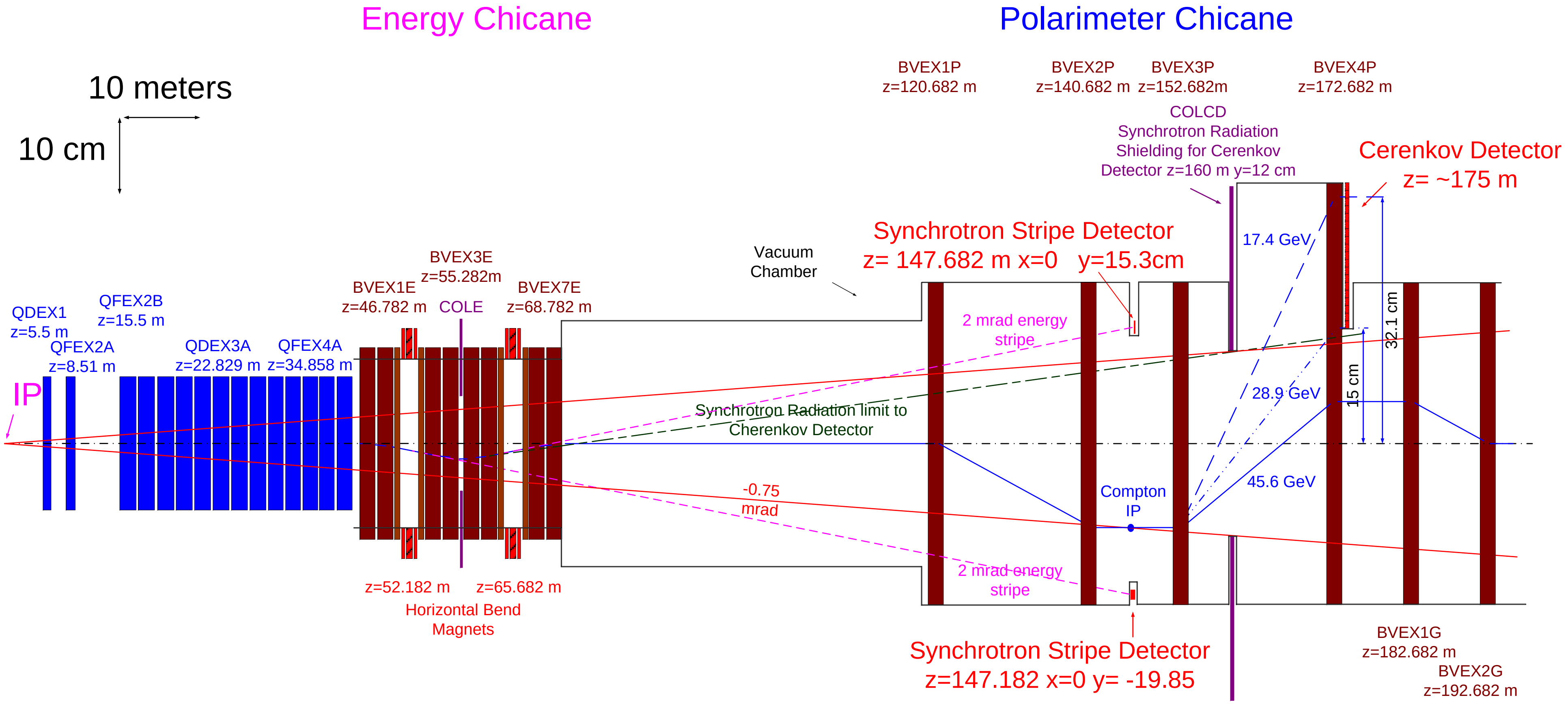
Compton scattered electrons at the Compton detector plane z=175m





Energy distribution for Compton scattered electrons for different selections in y.

Proposed Chicane at 45.6 GeV



Note with magnets 3 and 4 of the polarimeter chicane fixed at a field of 1.5 times that of magnets 1 and 2 the position of the backscattered electron in the Cherenkov detector will be dependent on beam energy.

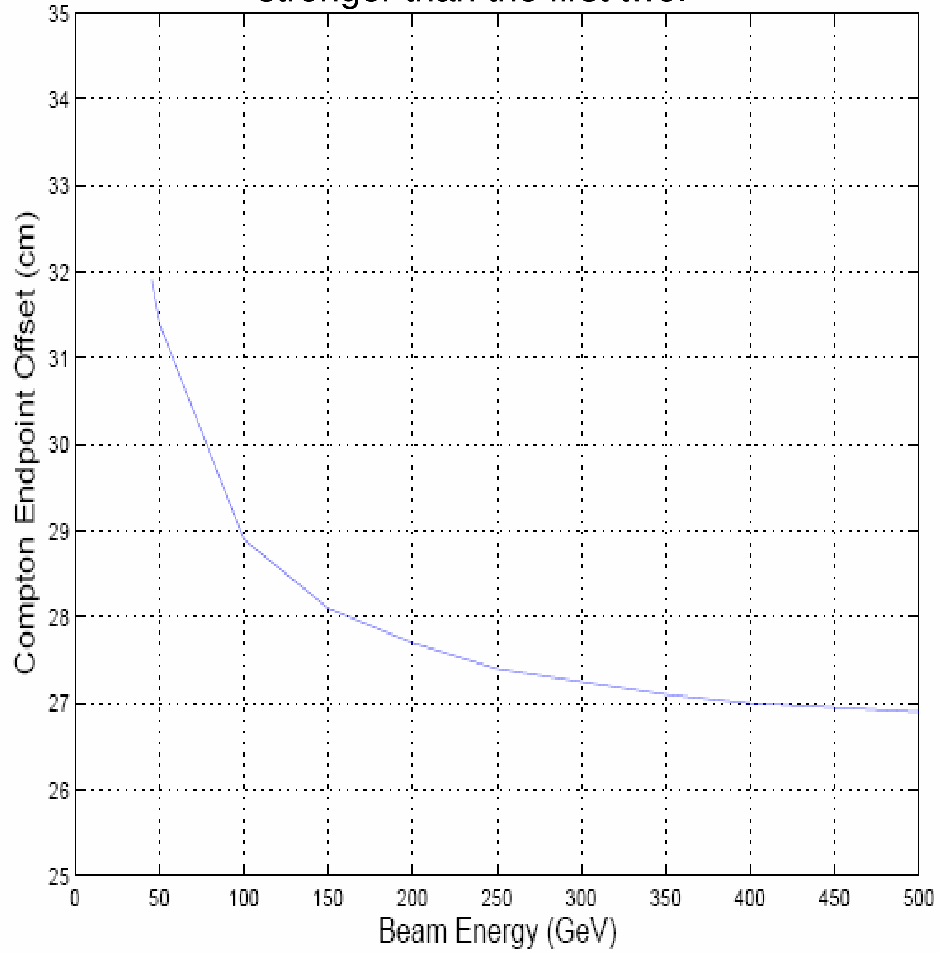
Backscattered electrons Vertical Offset at the Cherenkov detector

At 45.6 GeV y =32.1 cm

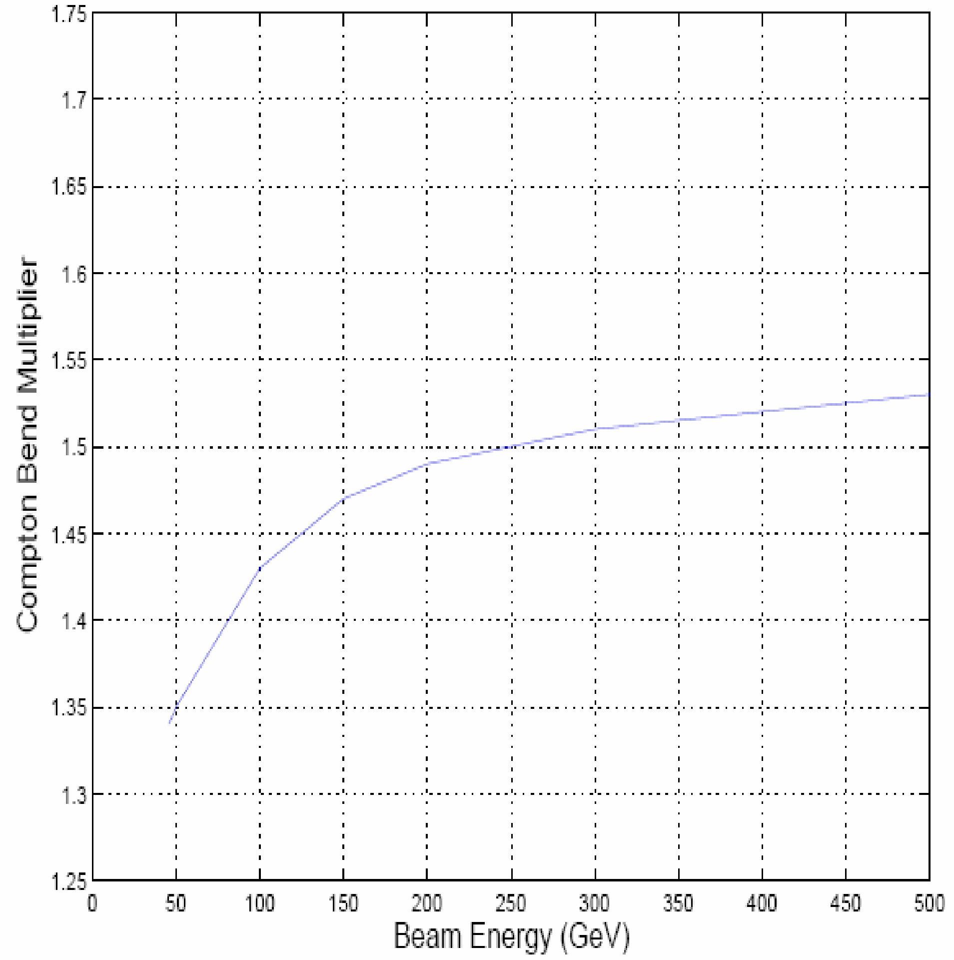
At 250 GeV y=27.2 cm

Beam Energy and Compton Endpoint

Vertical offset of the Compton endpoint for a fixed-field chicane with 20mm dispersion at 250 GeV and the last 2 polarimeter "chicane" magnets 50% stronger than the first two.



Scaling Multiplier of the last two dipoles to keep the Compton edge at 27.4cm from beamline



Beam Losses and Backgrounds

Nominal beam option cs11

Study 1: 35k beam particles gives no losses

No particles are lost from the 34883 beam particles from the nominal beam option cs11 between the e+e- interaction point and the end of the six-magnet polarimeter chicane at z = 195 m.

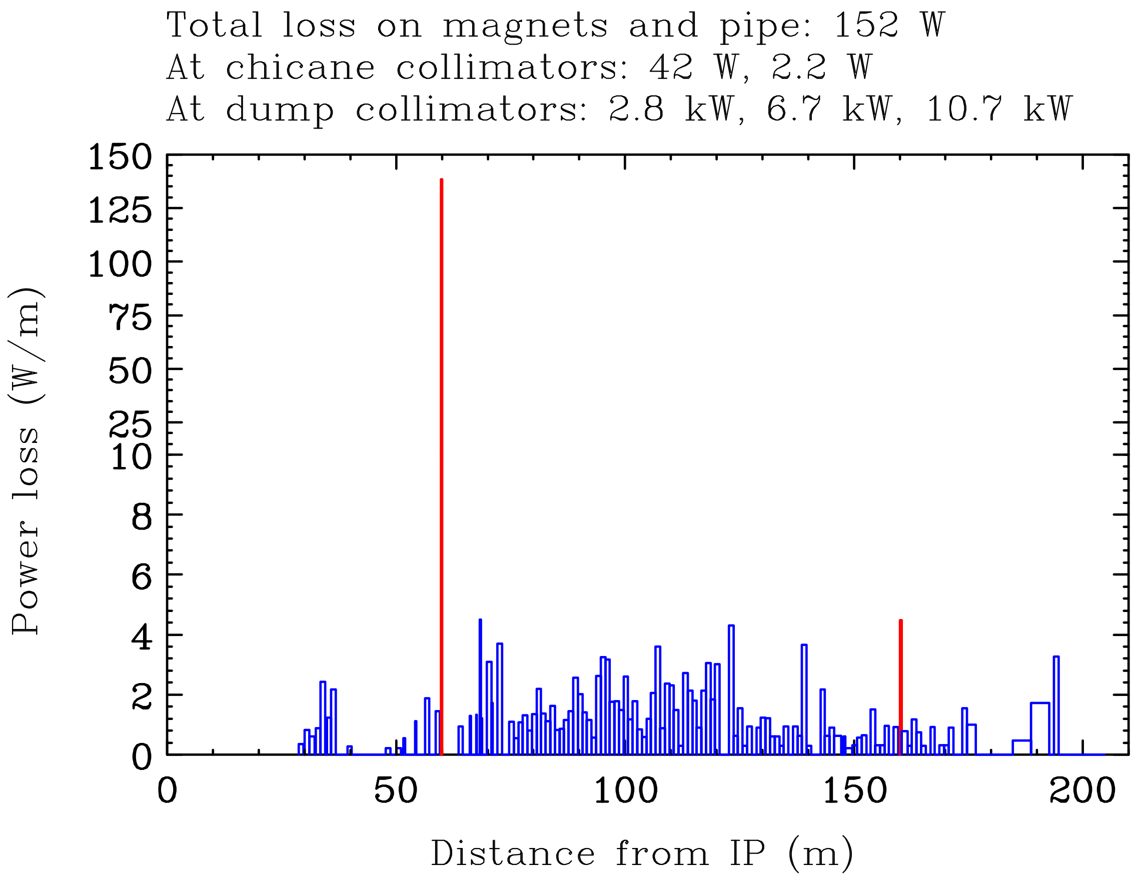
There are no background particles above y = 4 cm. The first cell of the Compton Cherenkov detector begins at y = 15 cm.

Study 2: 17.6 million beam particles studying tails.

No beam tail particles with energy less than 65% and/or x-y angles > 0.5 mrad were lost between the IP and z = 195 m.

The proposed modified six-magnet chicane transports the nominal ILC beam as efficient as the original design.

Beam loss with worse case having large disruption



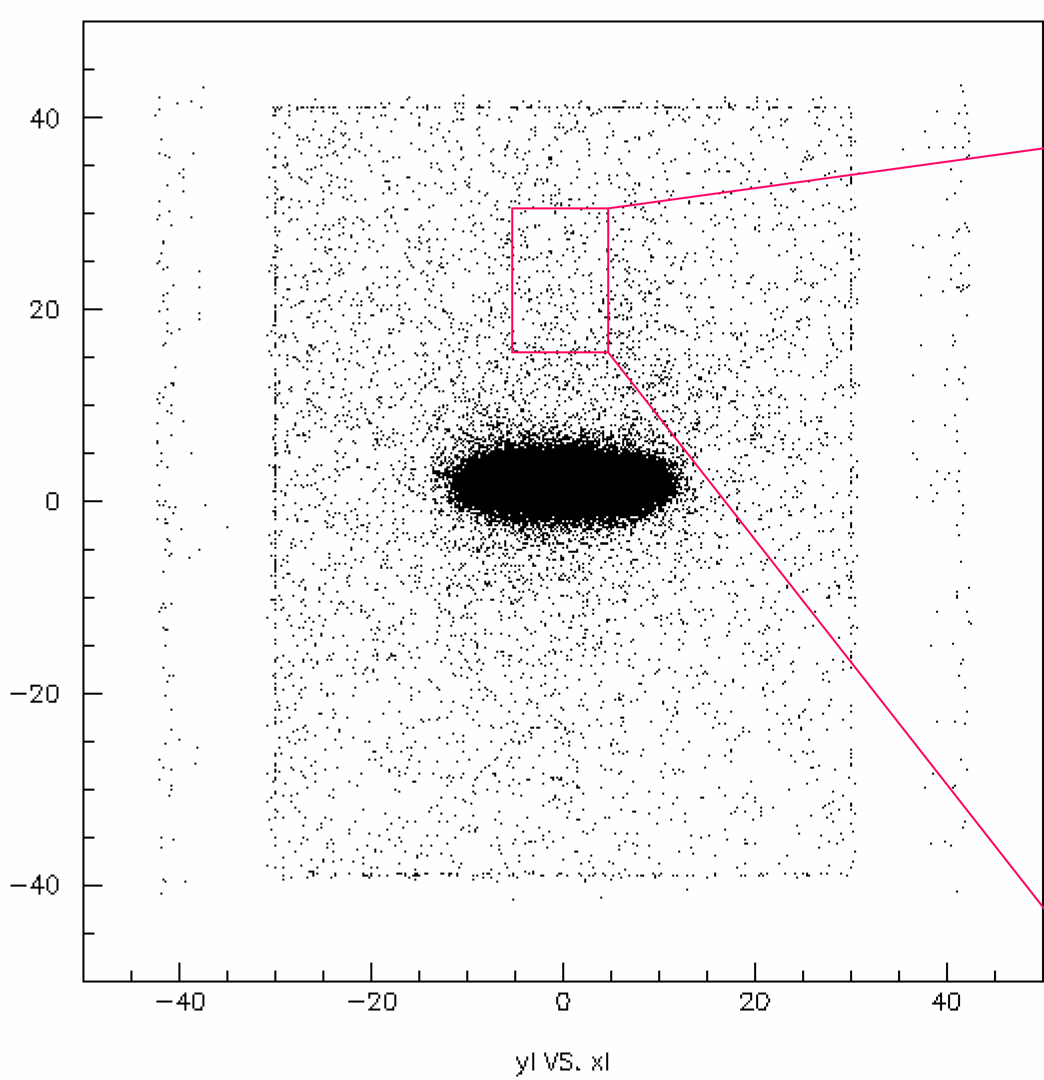
Longitudinal density of the primary beam loss for the ILC low beam power parameter option “cs14” at 250 GeV beam energy. The two red lines show loss on the energy and polarimeter chicane collimators.

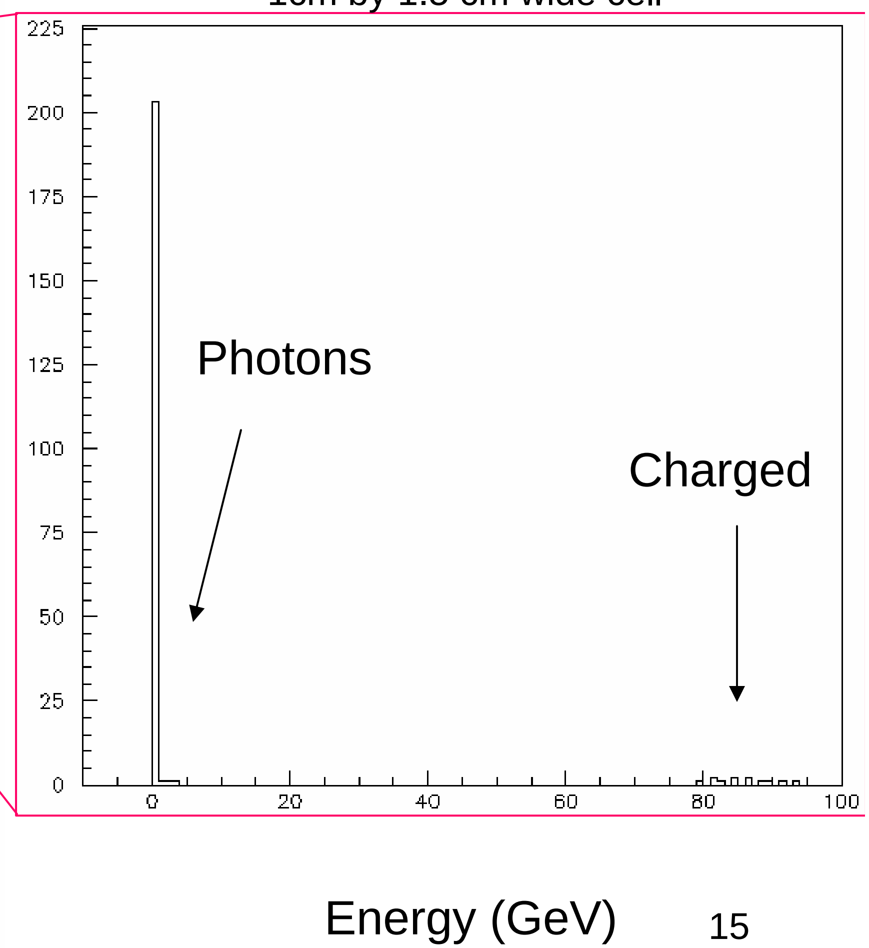
Low power option cs14 tail file with E<162.5 GeV or $\theta > 0.5$ mrad

From 17.45 million beam particles

Background at the Cherenkov Detector per 2×10^{10} beam particles

92 charged / sq cm and 1558 photons / sq cm
Compared to ~300 Compton electrons per 1cm by 1.5 cm wide cell





Beam Losses and Backgrounds

Low power option cs14 has much larger beam disruption

Study 1: 17.45 million beam particles studying tails of beam

The low energy tail of the disrupted beam in the low power option cs14 was also studied corresponding to total 17.45 million beam particles. There are 0.0096% lost particles between the e+e- IP and the Compton detector plane (an additional 0.00005% are lost between the Compton detector plane and z = 195 m).

The lost particles produce backgrounds at the Compton detector of photons and charged particles.

Extrapolating to a beam of 2*10**10 particles the backgrounds would be ~1650 per centimeter squared (each Cherenkov cell is 1cm by 1.5cm). Most of this background are photons and only a small fraction will convert to e+e- pairs in the material before the Cherenkov detector. In addition, 56% of the background particles are photons of energy less than 15 MeV and will not give Cherenkov light.

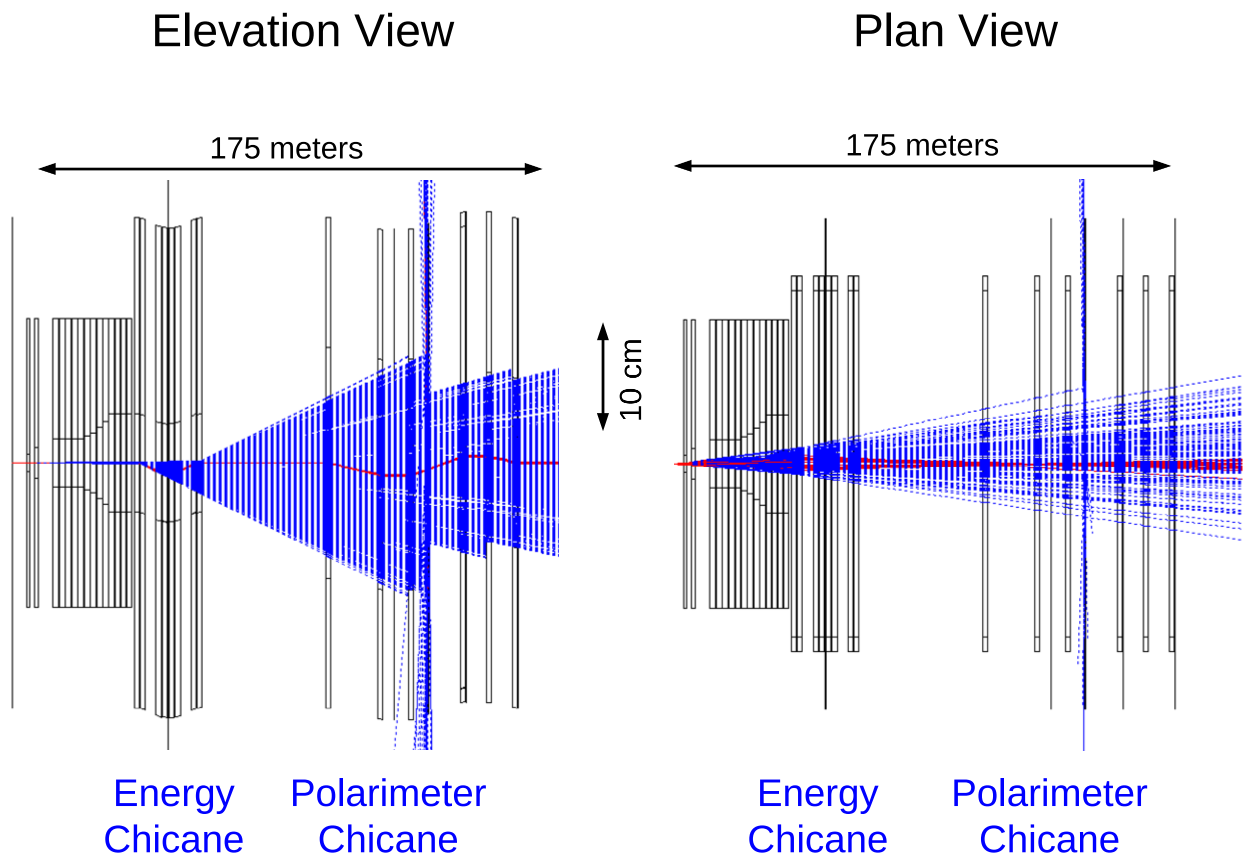
The backscattered electron counting rate is high for the proposed Compton Polarimeter with about 300 Compton electrons per 1cm by 1.5 cm Cherenkov detector cell.

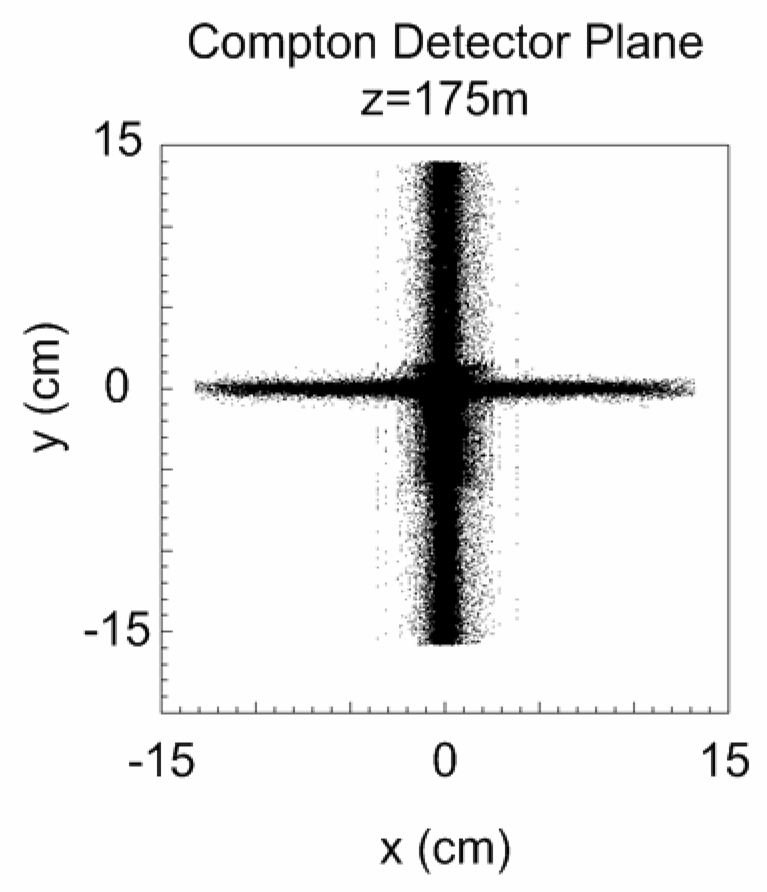
Therefore the backgrounds from secondary interactions should be small compared to the signal even for the Low Power beam parameter running.

Synchrotron Radiation

20 beam tracks

Modified 14 mrad Extraction Line at 0.5 TeV CMS





Distribution of x vs y at the Compton detector plane for synchrotron radiation photons generated from the upstream magnets.

The sharp cutoff at 14 cm is the shadow from the special collimator located at z = 160 m.

There are no synchrotron radiation photons above 14.04 cm.

Systematic Errors

- The physics of the Compton scattering process is well understood in QED, with radiative corrections less than 0.1%
- Detector backgrounds are easy to measure and correct for by using laser off pulses;
- Polarimetry data can be taken simulatanously with physics data;
- The Compton scattering rate is high and small statistical errors can be achieved in a short amount of time (sub-1% precision in one minute is feasible);
- The laser helicity can be selected on a pulse-by-pulse basis;
- The laser polarization is readily determined with 0.1% accuracy.

Expected Polarimeter Systematic Errors

Uncertainty	**$\delta P/P$**
Detector Analyzing Power	0.2%
Detector Linearity	0.1%
Laser Polarization	0.1%
Electronic Noise and Background Subtraction	0.05%
TOTAL	0.25%

Conclusions

•The modified extraction line with two additional magnets improves the acceptance of the Compton scattered electrons. This allows detection over a larger part of the Compton electron energy spectra.

•The backscattered electrons are further away from the beam pipe by ~10 cm. The beam transport through the modified extraction line is efficient.

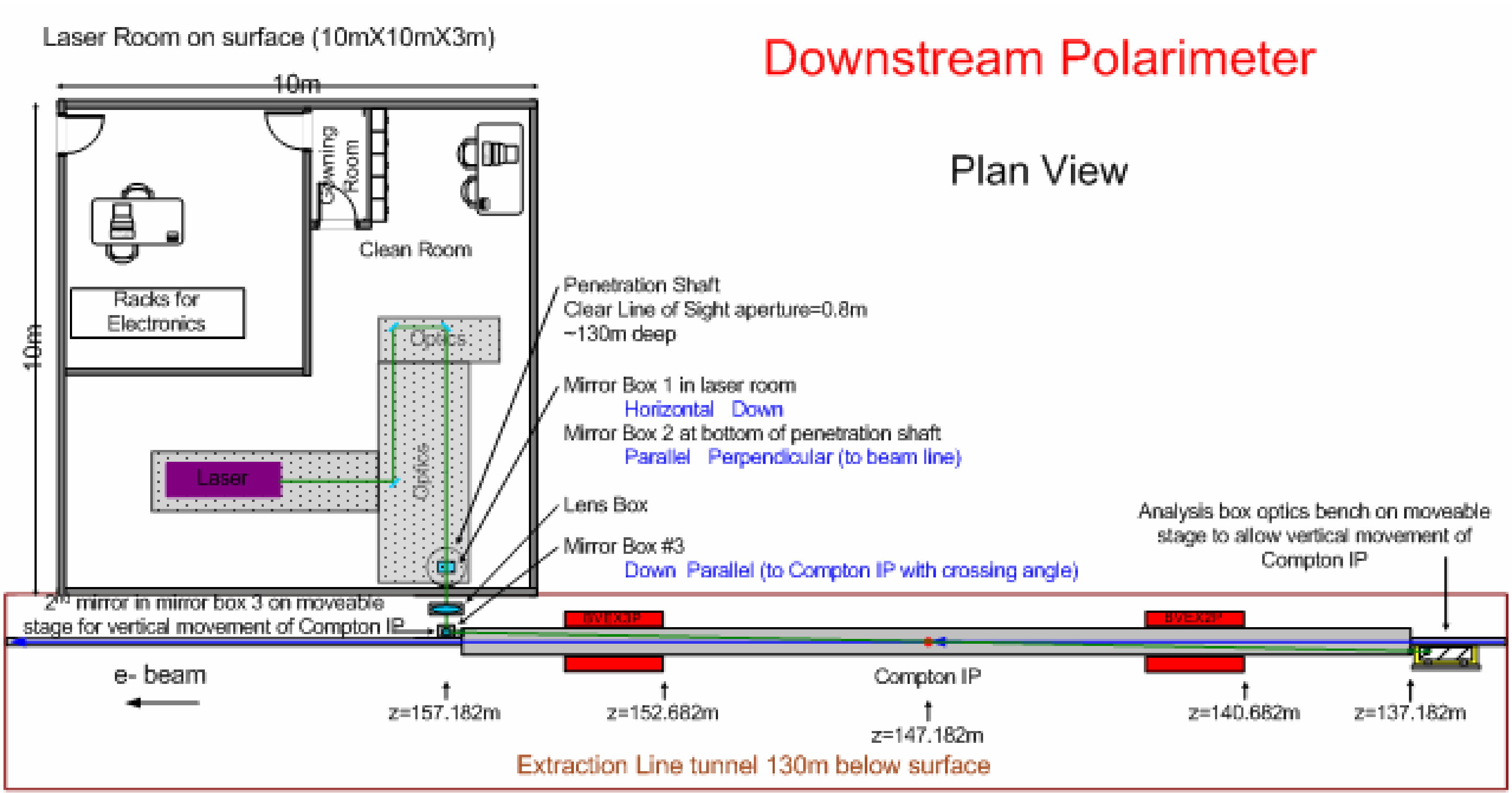
•Backgrounds from synchrotron radiation produced upstream of the Cherenkov detector and from lost particles along the beam line are small compared to the Compton scattered electron signal.

Future Studies:

•Beam gas backgrounds.
•Realistic design of vacuum chamber and studies of backgrounds.
•Design for laser entrance and exit with movable Compton IP.

Extra Slides

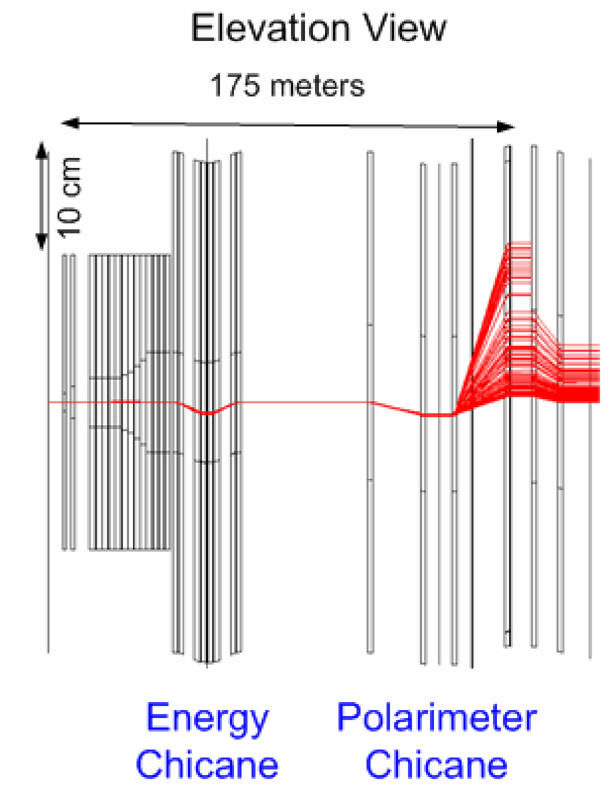
Laser light transport



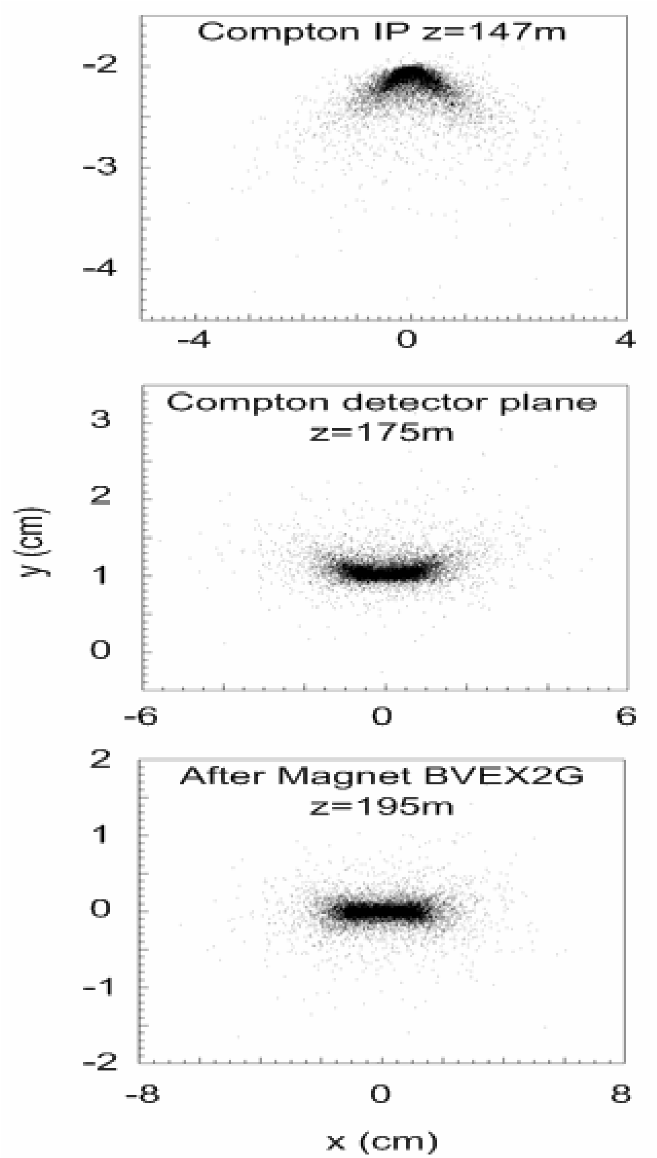
Compton Electrons generated at Compton IP

Modified 14 mrad Extraction Line

0.5 TeV CMS



GEANT generated drawing of the beam line elements with 100 beam tracks shown. At the Compton IP each beam track is changed into a Compton scattered electron. The Compton scattered electrons with low enough energy to exit the beam pipe are detected in the Compton Cherenkov detector located at z = 175 m.



Distribution of x vs y for the extracted beam electrons at the Compton IP, the Compton detector plane and at the end of magnet BVEX2G.

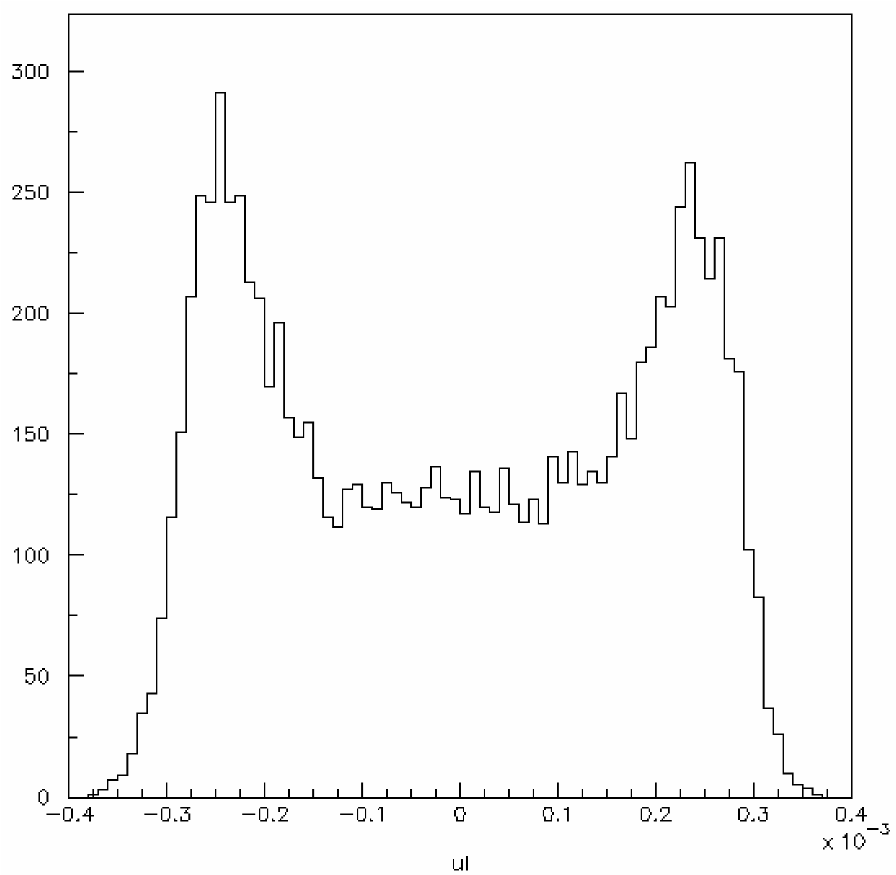
Quad name	Qty	L (m)	G (T/m)	R (mm)
QDEX1 (SC)	1	1.060	100.00	15
QFEX2A (SC)	1	1.200	23.08	26
QFEX2B,C,D	3	2.143	11.19	42
QDEX3A,B	2	2.106	11.93	42
QDEX3C	1	2.106	10.89	46
QDEX3D	1	2.106	9.63	52
QDEX3E	1	2.106	8.08	62
QFEX4A	1	1.945	7.11	71
QFEX4B,C,D,E	4	1.945	5.94	85

Parameters of the extraction quadrupoles at 250 GeV

Bend name	Qty	L (m)	B (T)	Half-gap (mm)	Diagnostics
BVEX1E,2E,…,8E	8	2.0	0.4170	85	Energy
BVEX1P,2P	2	2.0	0.4170	117	
BVEX3P	1	2.0	0.6254	117	Polarimeter
BVEX4P	1	2.0	0.6254	132	
BVEX1G,2G	2	2.0	0.4170	147	GAMCAL

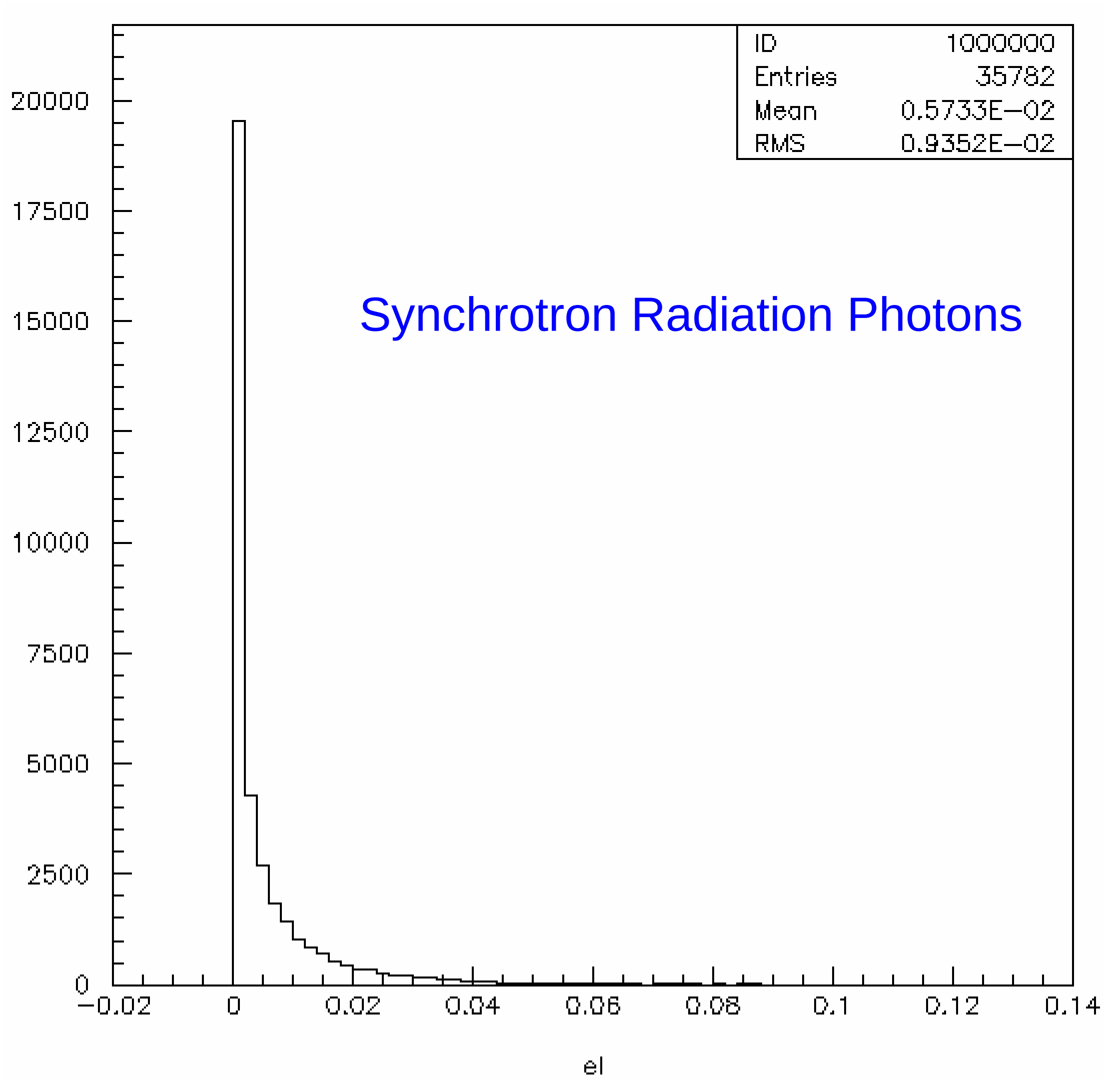
Parameters of the chicane bends at 250 GeV

X-angle as the disrupted beam leaves the e+e- IR



Note: The synchrotron radiation from the beam tracks as they enter the first quadrupole would only project to <7cm in the horizontal at the Cherenkov detector plane. So the synchrotron radiation for abs x >7 cm at the Cherenkov detector plane comes from the orbit of the beam in the quads.

Energy distribution for synchrotron radiation photons for y>10 cm at the Compton Detector Plane.



E (GeV)