Performance of Extraction Line Energy Spectrometers and Polarimeters at 500 GeV and 1 TeV Center-of-Mass Collision Energy

Ken Moffeit BDIR Session

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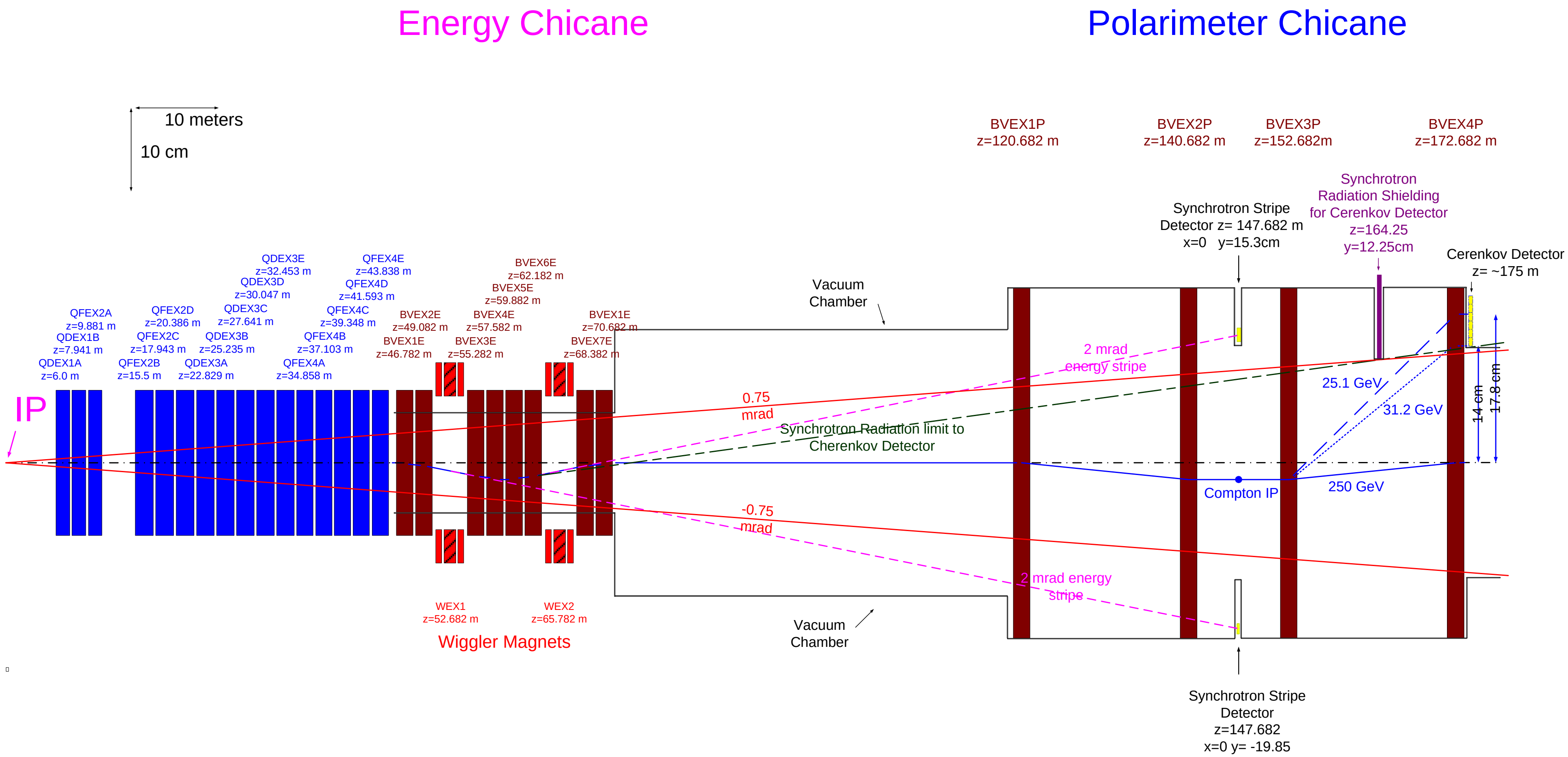
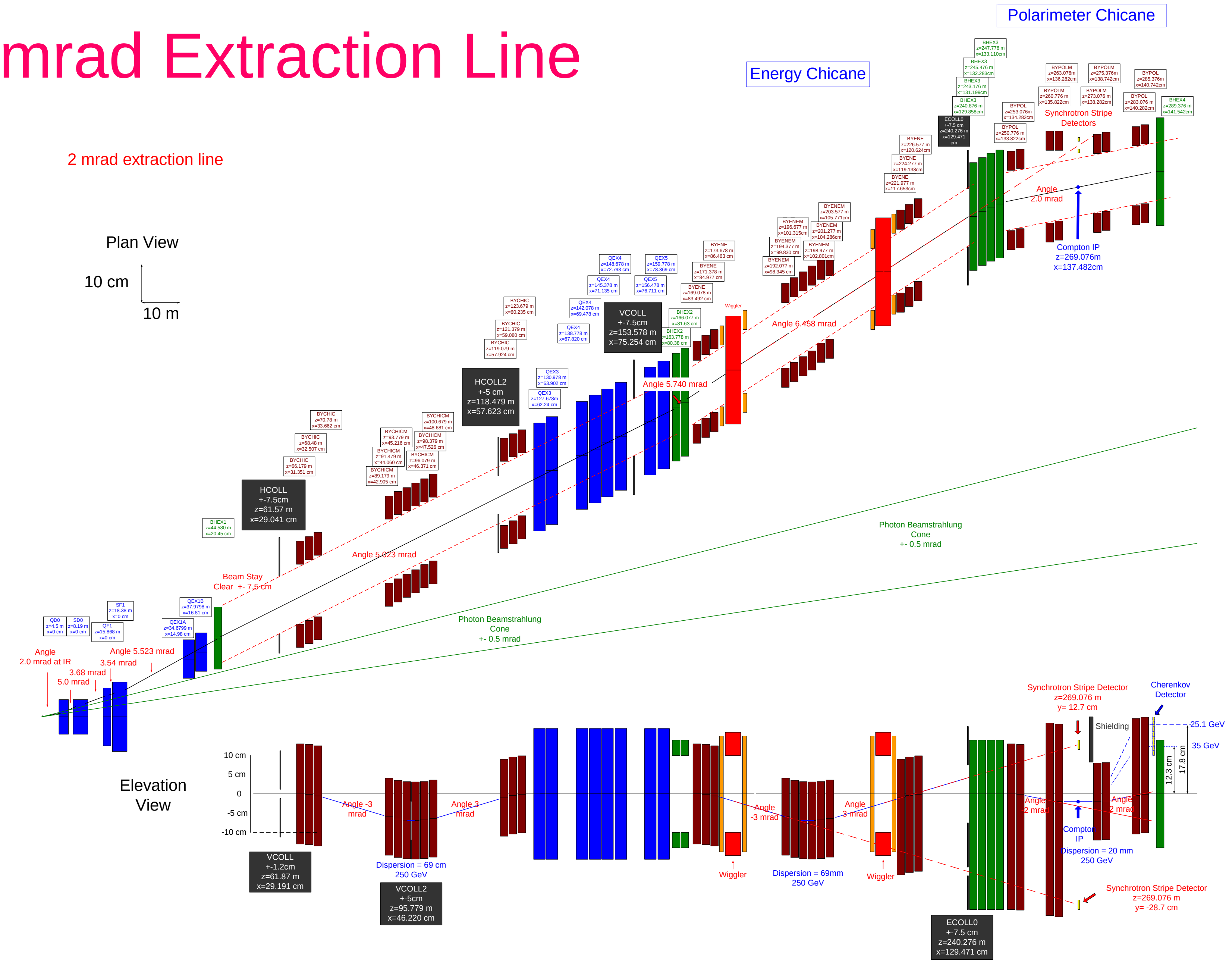
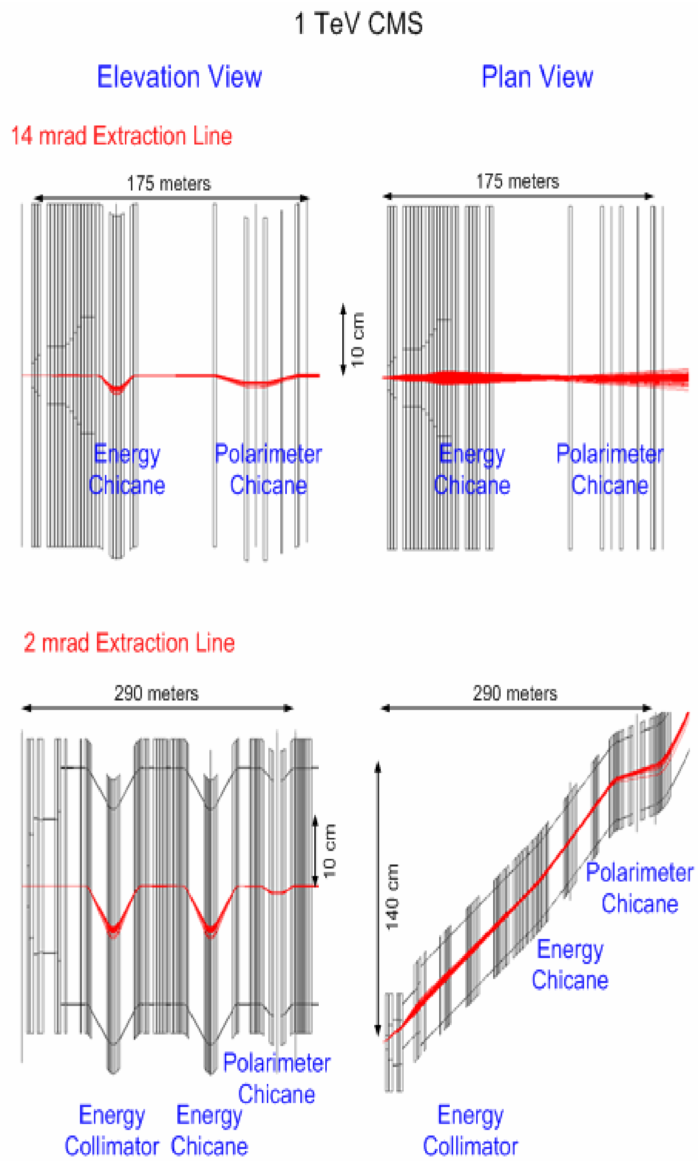
14 mrad Extraction Line



2 mrad Extraction Line



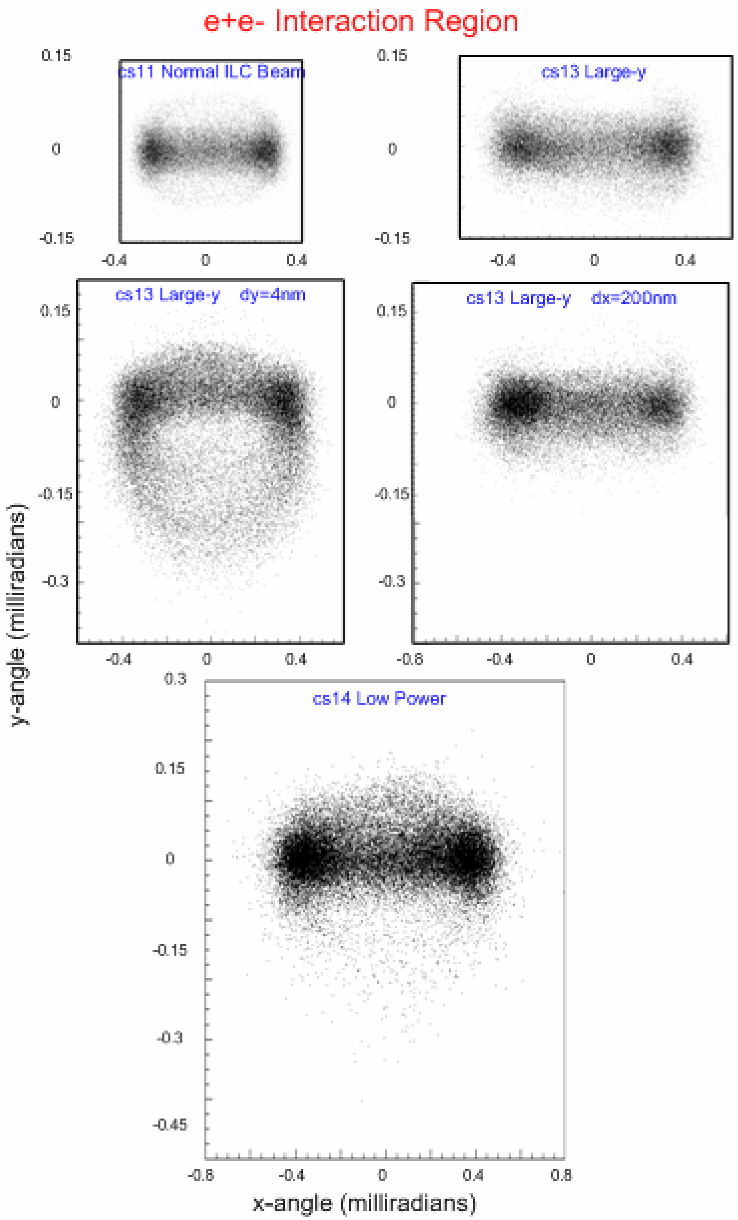
The extraction line transport is simulated using the program GEANT



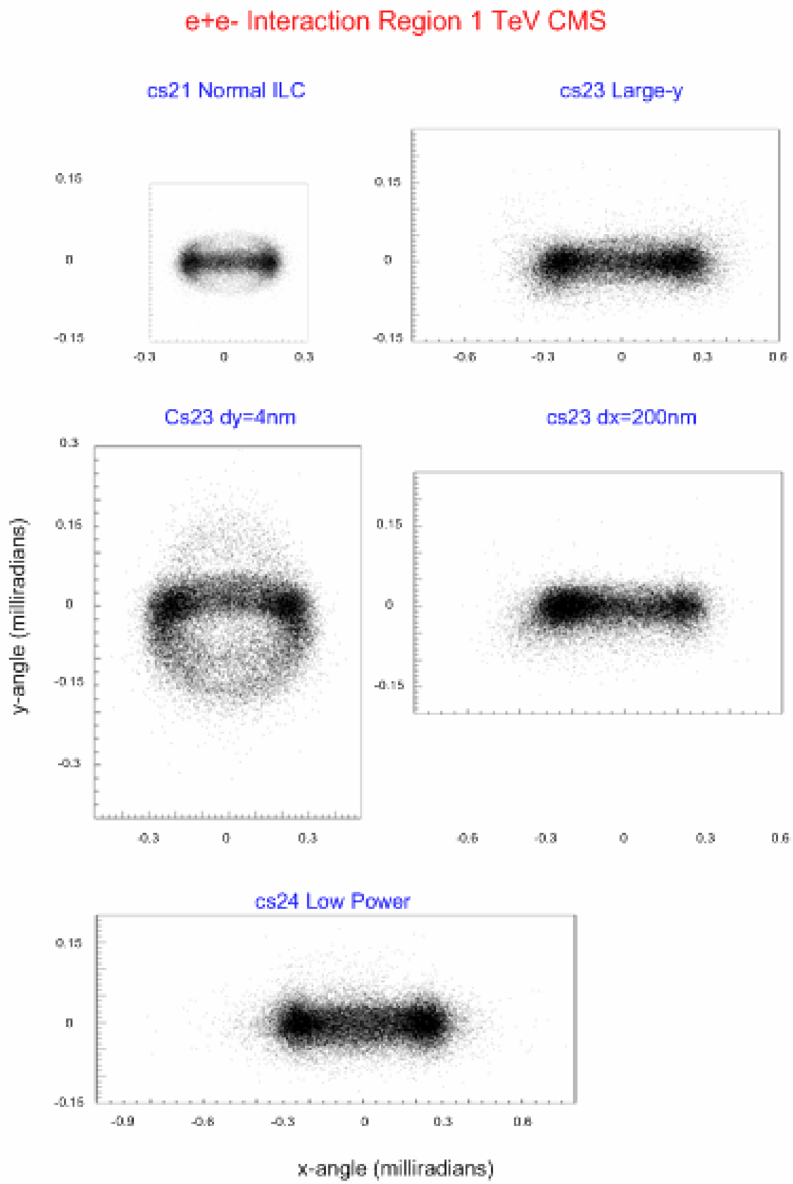
Disrupted beam events were taken from files prepared by Andrei Seryi.

Name	**File**	**σ_x (nm)**	**σ_y (nm)**	**σ_z (nm)**	**E (Mean) (GeV)**	**E (RMS) (GeV)**
Normal ILC	cs21	554	3.5	300	475.5	40.72
Large-y	cs23	367	7	600	463.0	47.54
Large-y dy=4nm	cs23_dy4				461.5	48.23
Large-y dx=200nm	cs23_dx200				464.4	46.38
Low Power	cs24	350	2.7	200	439.6	73.94

0.5 TeV CMS



1 TeV CMS



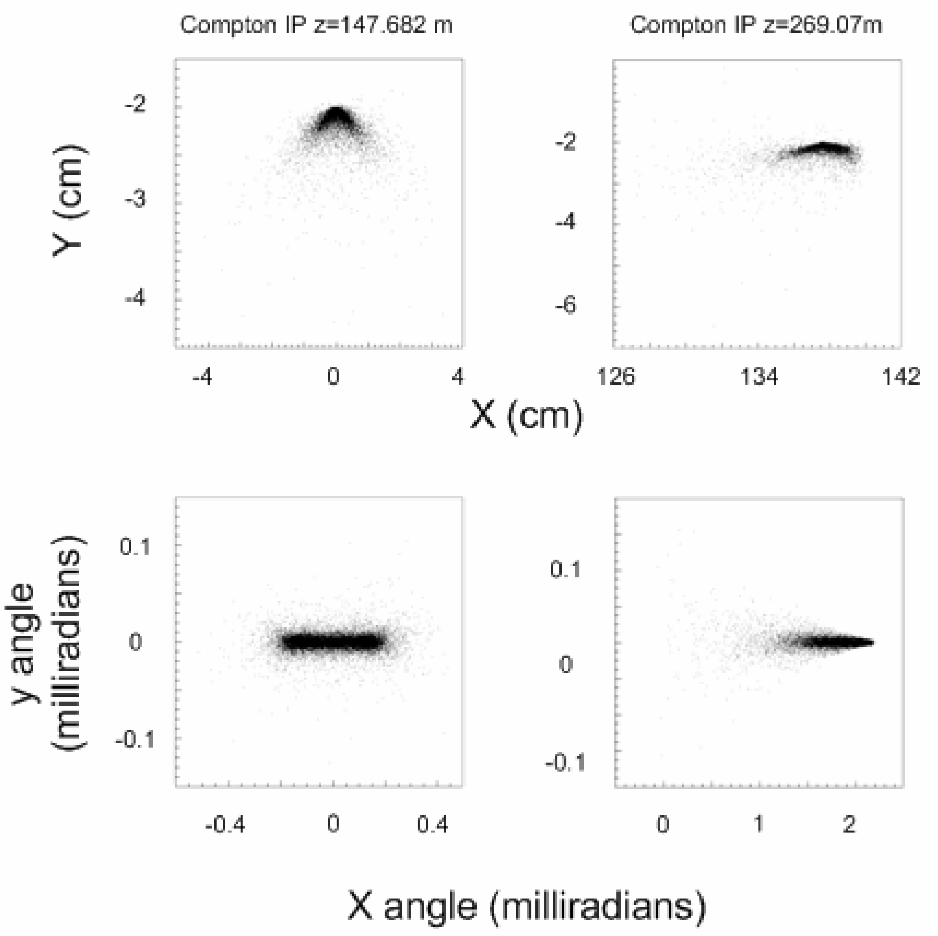
Normal ILC Beam

0.5 TeV CMS

Compton IP

14 mrad: No beam particles lost between IR and Compton IP

2mrad: 3 out of 30,000 beam particles lost between IR and Compton IP

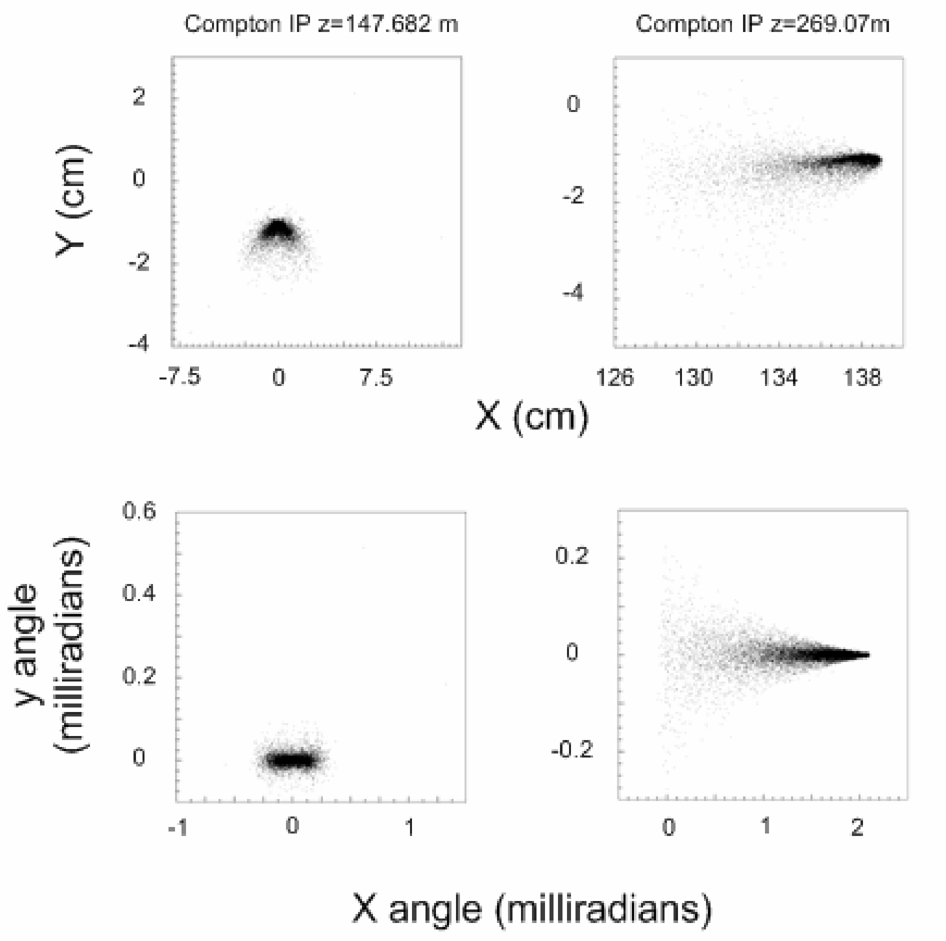


1 TeV CMS

Compton IP

14 mrad: No beam particles lost out of 29921 between IR and Compton IP

2mrad: 261 out of 34907 beam particles lost between IR and Compton IP

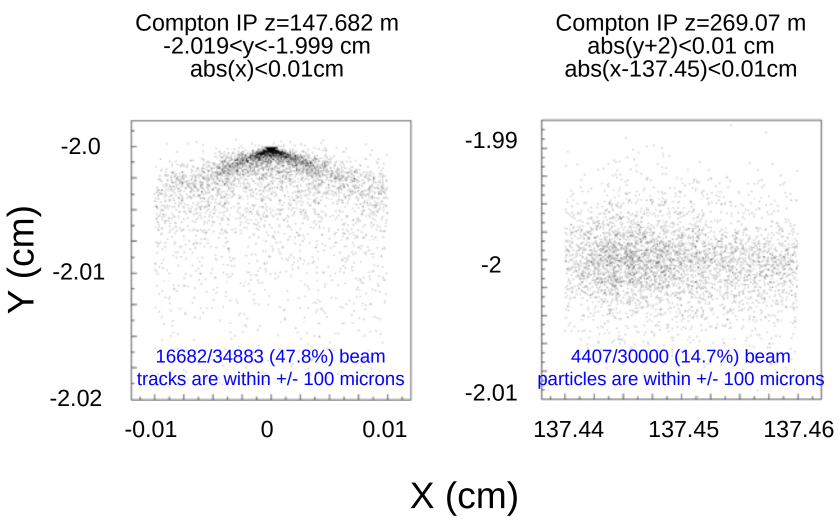


Beam within +-100 microns of the peak

0.5 TeV CMS

Compton IP

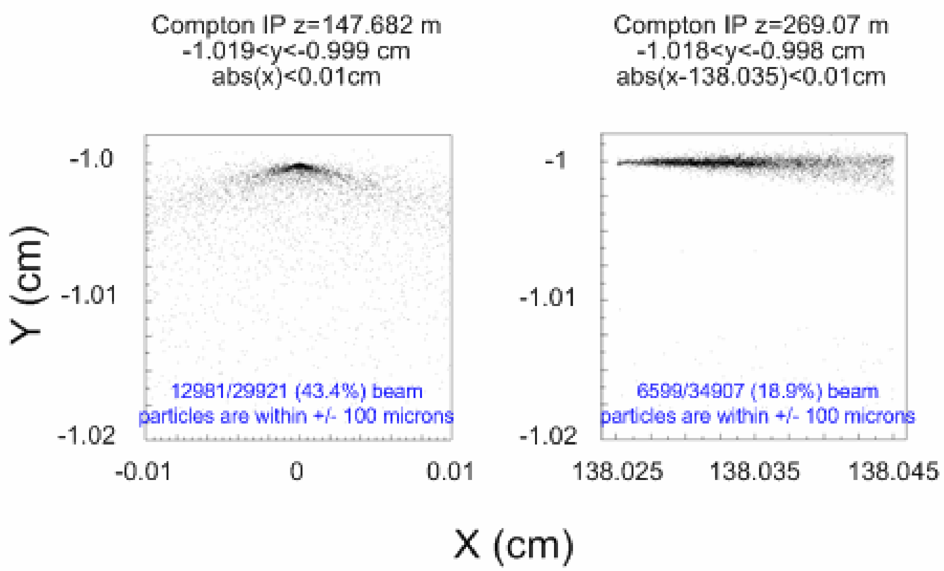
14 mrad | 2mrad



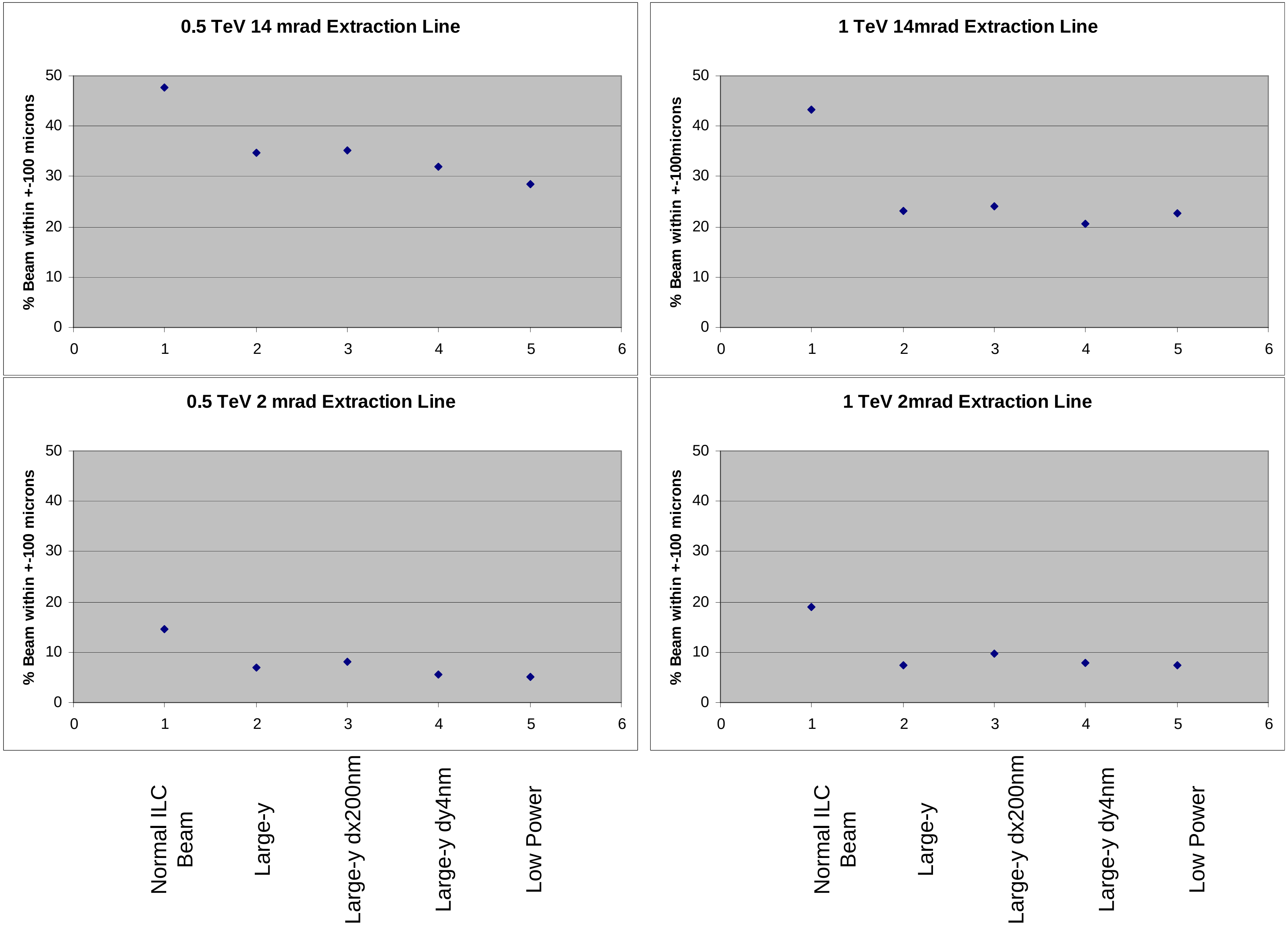
Dispersion = -2 cm

Compton IP
1TeV CMS

14 mrad | 2mrad



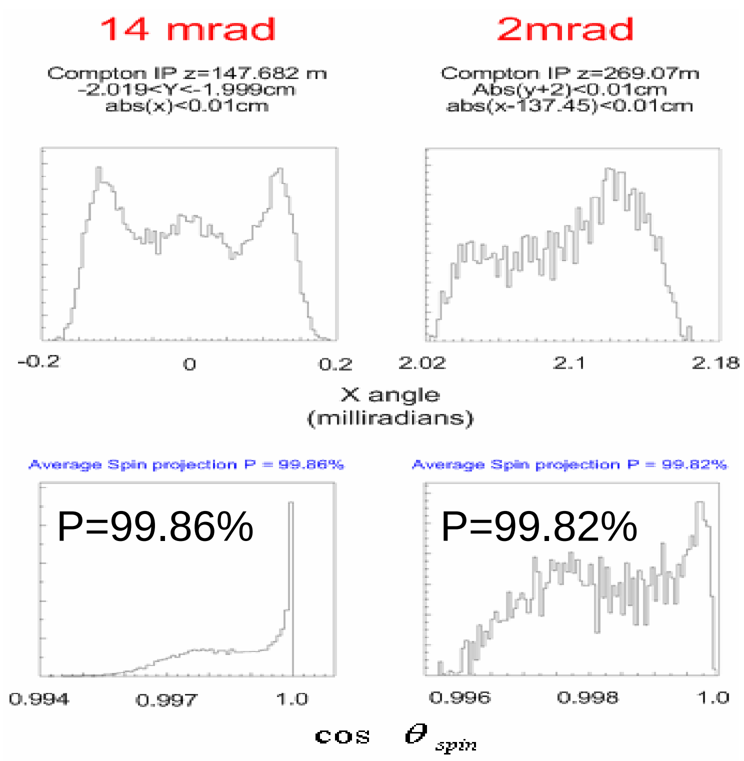
Dispersion = -1 cm

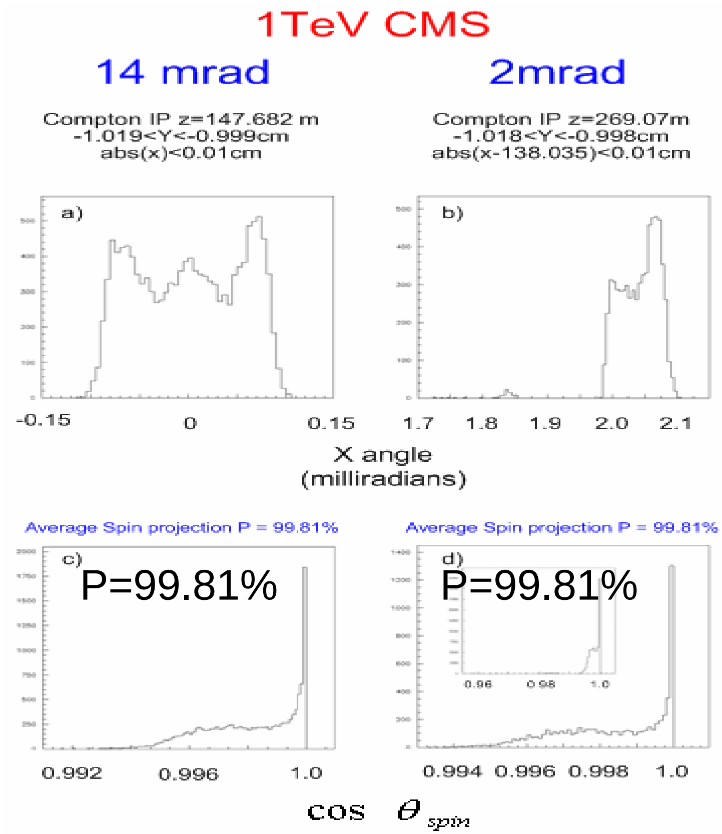

0.5 TeV 14 mrad Extraction Line
1 TeV 14mrad Extraction Line
0.5 TeV 2 mrad Extraction Line
1 TeV 2mrad Extraction Line
% Beam within +-100 microns
% Beam within +-100microns
0
10
20
30
40
50
0
1
2
3
4
5
6
Normal ILC Beam
Large-y
Large-y dx200nm
Large-y dy4nm
Low Power

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

50 μrad bend gives 56.7 mrad change in spin direction and P= 99.84% at 500GeV

0.5 TeV CMS





$$P_{LuminosityWeighted} = Cos(\theta_{SpinLuminosityWeighted}) = Cos\left(\frac{E(GeV)}{0.44065} \cdot \frac{1}{2}\theta^{IR}_{x-angle}\right)$$

$$P_{LuminosityWeighted} = 99.84\% \qquad\qquad P_{LuminosityWeighted} = 99.80\%$$

Beam accepted within +-100 microns about the peak and polarization projection

0.5 TeV CMS   14 mrad extraction line   1 TeV CMS

Condition (file name)	%Beam within +-100microns in x & y	Luminosity Weighted Polarization at the IR	Polarization Projection
Nominal Beam Condition (cs11)	47.8	99.84 %	99.86 %
Large y (cs13)	34.7	99.68 %	99.74 %
Large y horizontal offset 200nm (cs13_dx200)	35.3	99.68 %	99.73 %
Large y vertical offset 4nm (cs13_dy4)	32.0	99.72 %	99.74 %
Low Power (cs14)	28.4	99.67 %	99.69 %

Condition (file name)	%Beam within +-100microns in x & y	Luminosity Weighted Polarization at the IR	Polarization Projection at the Compton IP
Nominal Beam Condition (cs21)	43.4 %	99.80 %	99.81 %
Large y (cs23)	23.2 %	99.43 %	99.55 %
Large y horizontal offset 200nm (cs23_dx200)	24.1 %	99.33 %	99.54 %
Large y vertical offset 4nm (cs23_dy4)	20.7 %	99.43 %	99.55 %
Low Power (cs24)	22.7 %	99.50 %	99.55 %

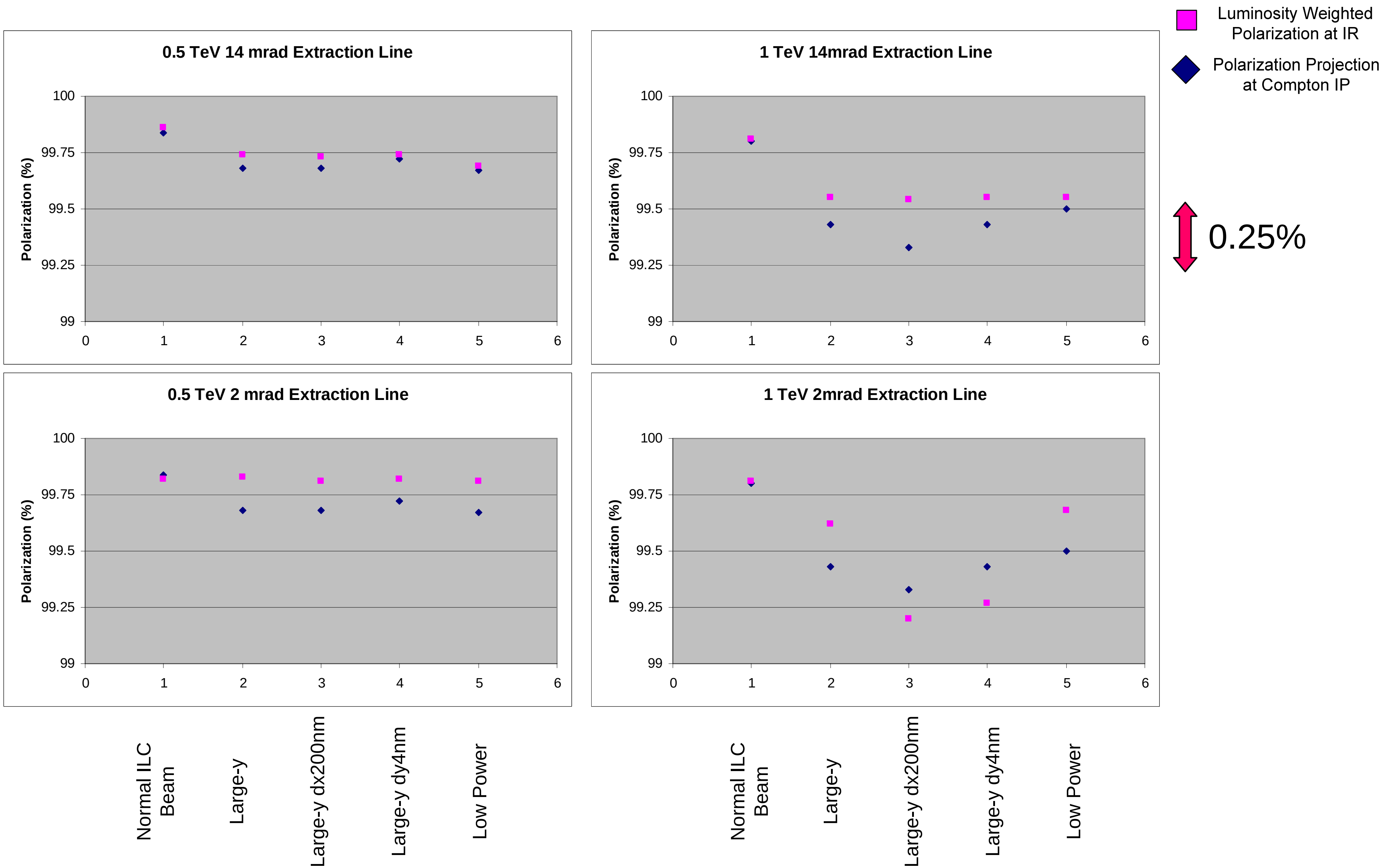
2 mrad extraction line

Condition (file name)	%Beam within +-100microns in x & y	Luminosity Weighted Polarization at the IR	Polarization Projection
Nominal Beam Condition (cs11)	14.5	99.84 %	99.82
Large y (cs13)	6.9	99.68 %	99.83
Large y horizontal offset 200nm (cs13_dx200)	8.2	99.68 %	99.81
Large y vertical offset 4nm (cs13_dy4)	5.6	99.72 %	99.82
Low Power (cs14)	5.0	99.67 %	99.81

Condition (file name)	%Beam within +-100microns in x & y	Luminosity Weighted Polarization at the IR	Polarization Projection at the Compton IP
Nominal Beam Condition (cs21) **abs(x-138.035)<0.01cm**	18.9 %	99.80 %	99.81 %
Large y (cs23) **abs(x-138.041)<0.01cm**	7.3 %	99.43 %	99.62 %
Large y horizontal offset 200nm (cs23_dx200) **abs(x-138.041)<0.01cm**	9.8 %	99.33 %	99.20 %
Large y vertical offset 4nm (cs23_dy4) **abs(x-138.040)<0.01cm**	7.8 %	99.43 %	99.27 %
Low Power (cs24) **abs(x-138.039)<0.01cm**	7.3 %	99.50 %	99.68 %

Polarization at Compton IP within 0.21% of the Luminosity weighted Polarization

Polarization at Compton IP within 0.21% of the Luminosity weighted Polarization



Beam Losses

from the e+e- IR to the Compton Detector Plane

0.5 TeV CMS

14 mrad Crossing Angle Extraction Line

Condition (file name)	Losses	# Beam	Lost Beam
Normal ILC Beam Condition (cs11) cs11 tail1 < 0.65E0 or angle > 500mrad	0 0	34883 $1.8*10^{6}$	$<0.5*10^{-4}$ $<10^{-7}$
Large y (cs13)	0	34907	$<0.5*10^{-4}$
Large y horizontal offset 200nm (cs13_dx200)	0	34898	$<0.5*10^{-4}$
Large y vertical offset 4nm (cs13_dy4)	0	34923	$<0.5*10^{-4}$
Low Power (cs14)	4	34913	$1.1*10^{-4}$

2 mrad Crossing Angle Extraction Line

Condition (file name)	Losses	# Beam	Lost Beam
Nominal Beam Condition (cs11) cs11 tail1 < 0.65E0 or angle > 500mrad	5 4604	34883 $1.8*10^{6}$	$1.4*10^{-4}$ $2.6*10^{-4}$
Large y (cs13)	32	34907	$9.2*10^{-4}$
Large y horizontal offset 200nm (cs13_dx200)	32	34898	$9.2*10^{-4}$
Large y vertical offset 4nm (cs13_dy4)	29	34923	$8.3*10^{-4}$
Low Power (cs14)	437	34913	1.25%

Beam Losses

from the e+e- IR to the Compton Detector Plane

1 TeV CMS

14 mrad Crossing Angle Extraction Line

Condition (file name)	**Losses**	**Beam**	**Lost Beam**
Nominal Beam Condition (cs21) cs21 tail1 < 0.65E0 or angle > 500mrad	0 57	29921 $3.2 * 10^6$	$<0.6 * 10^{-4}$ $1.8 * 10^{-5}$
Large y (cs23)	3	29916	$1.0 * 10^{-4}$
Large y horizontal offset 200nm (cs23_dx200)	2	29918	$0.7 * 10^{-4}$
Large y vertical offset 4nm (cs23_dy4)	3	29928	$1.0 * 10^{-4}$
Low Power (cs24)	186	34905	0.53 %

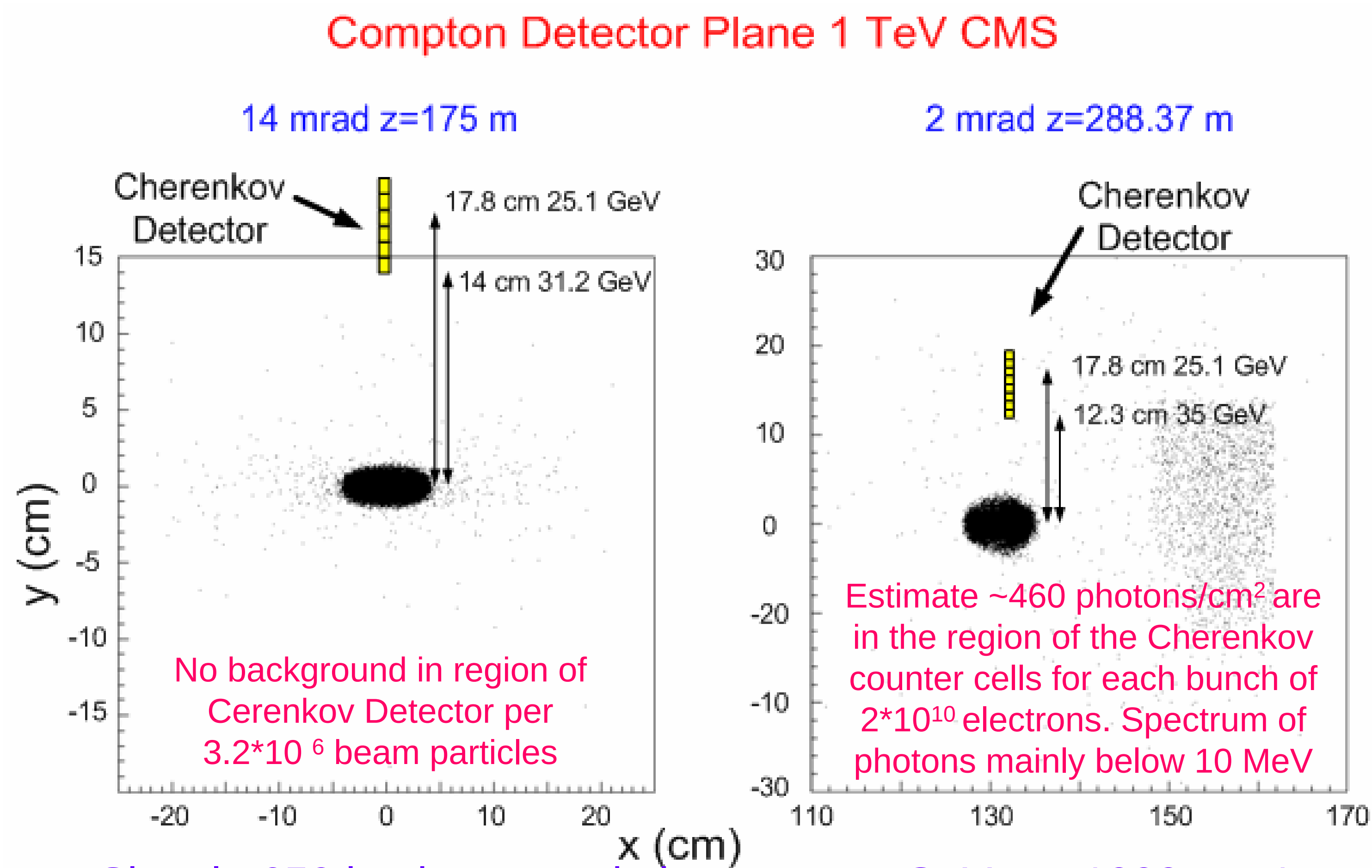
2 mrad Crossing Angle Extraction Line

Condition (file name)	**Losses**	**Beam**	**Lost Beam**
Nominal Beam Condition (cs21) cs21 tail1 < 0.65E0 or angle > 500mrad	261 28,263	34907 $3.9 * 10^6$	0.75 % 0.72 %
Large y (cs23)	494	34901	1.42 %
Large y horizontal offset 200nm (cs23_dx200)	355	34904	1.02 %
Large y vertical offset 4nm (cs23_dy4)	507	34915	1.45 %
Low Power (cs24)	2545	34905	7.29 %

Beam Loss Background at Cherenkov Detector

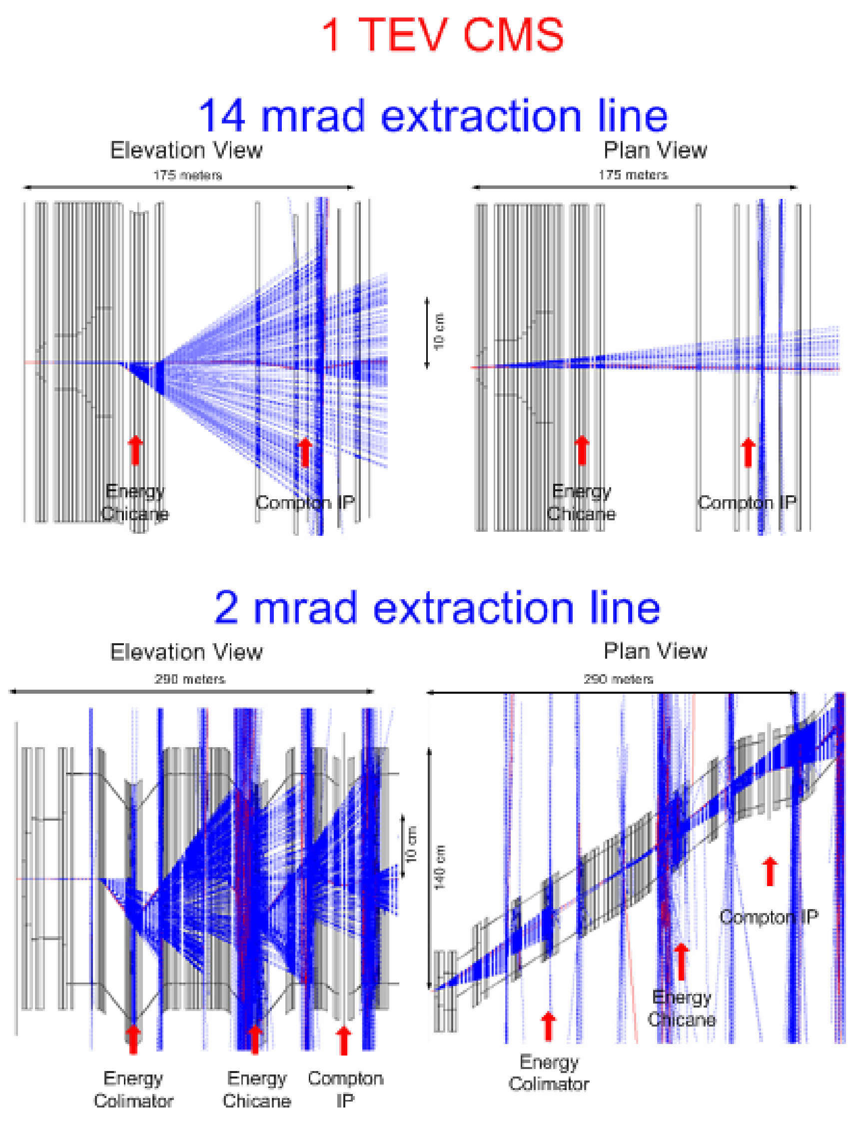
14 mrad extraction line
loss of 1.8*10-5 of the 3.2 million original beam tracks

2 mrad extraction line
loss of 0.72% of the 3.92 million original beam tracks



Compton Signal ~650 backscattered electrons per GeV or >1000 per 1cm cell

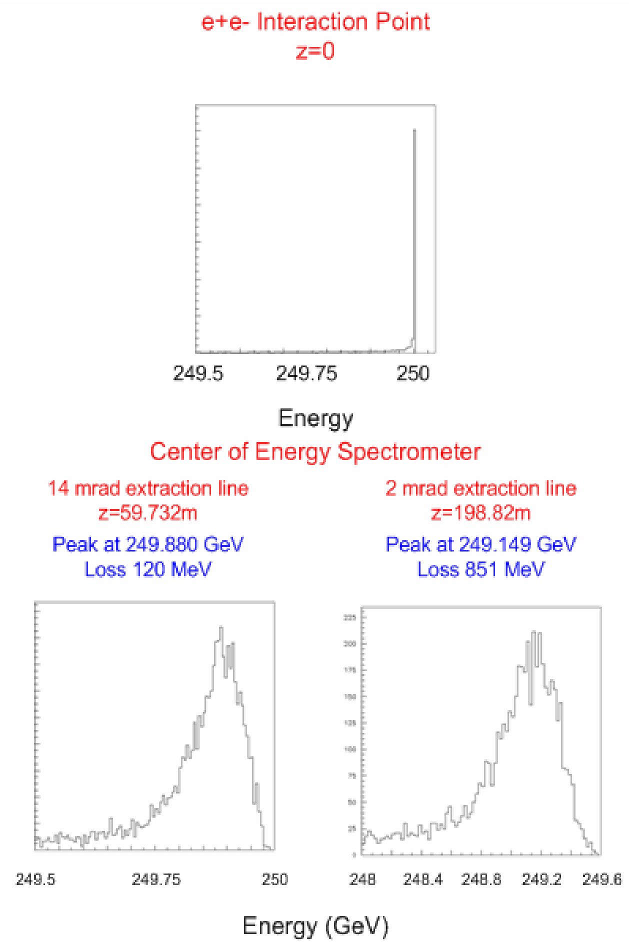
Synchrotron Radiation



Synchrotron Radiation

Energy Loss from Synchrotron Radiation between the e+e- IR and the Center of the Energy Chicane

0.5 TeV CMS



14 mrad Crossing Angle Extraction Line 0.5 TeV CMS

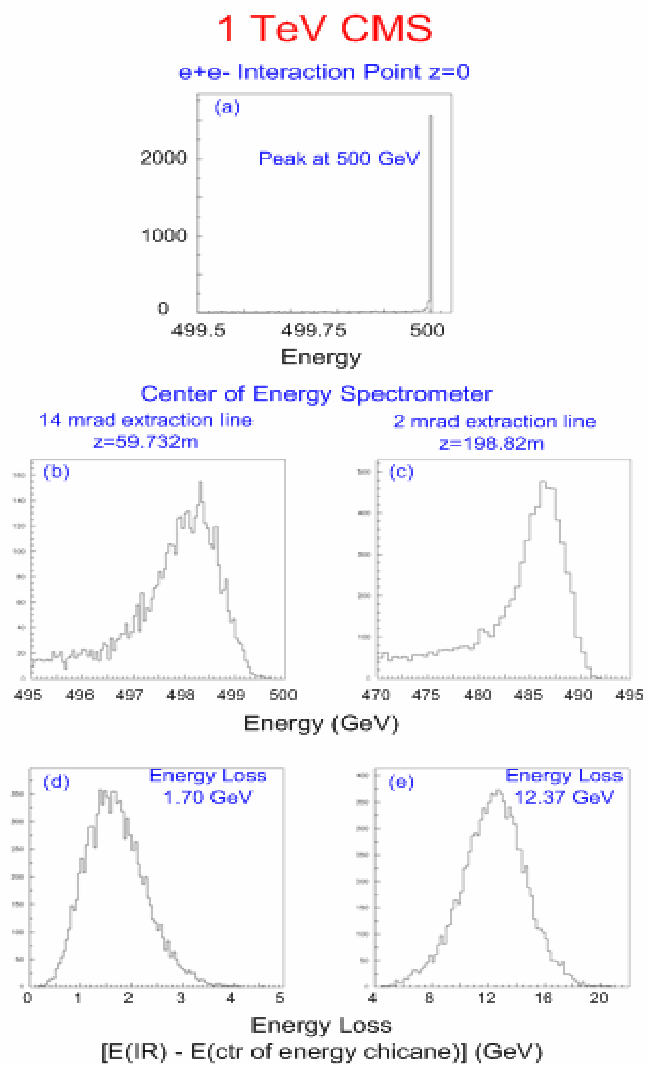
Condition (file name)	Energy Loss (MeV)	Energy Loss (MeV) for E>240GeV
Nominal Beam Condition (cs11)	117	120
Large y (cs13)	121	125
Large y horizontal offset 200nm cs13dx200	121	124
Large y vertical offset 4nm cs13dy4	121	125
Low Power (cs14)	117	126

2 mrad Crossing Angle Extraction Line 0.5 TeV CMS

Condition (file name)	Energy Loss (MeV)	Energy Loss (MeV) for E>240GeV
Nominal Beam Condition (cs11)	829	851
Large y (cs13)	831	852
Large y horizontal offset 200nm (cs13_dx200)	806	827
Large y vertical offset 4nm (cs13_dy4)	832	854
Low Power (cs21)	802	862

Synchrotron Radiation

Energy Loss from Synchrotron Radiation between the e+e- IR and the Center of the Energy Chicane



14 mrad Crossing Angle Extraction Line 1 TeV CMS

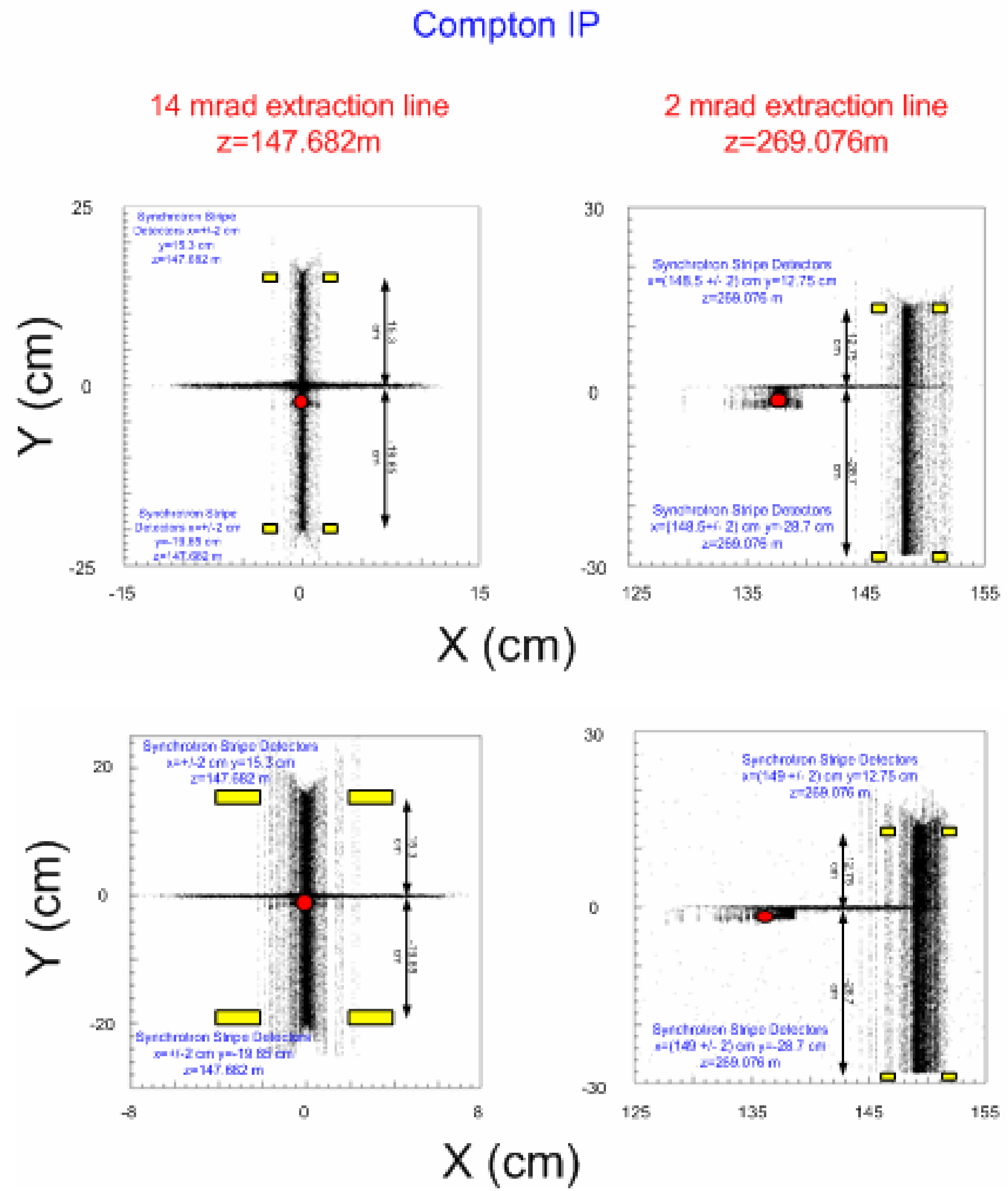
Condition (file name)	Energy Loss (GeV)	Energy Loss (GeV) for E>480 GeV
Nominal Beam Condition (cs21)	1.70	1.83
Large y (cs23)	1.71	1.86
Large y horizontal offset 200nm (cs23_dx200)	1.72	1.87
Large y vertical offset 4nm cs23dy4	1.70	1.85
Low Power (cs24)	1.56	1.87

2 mrad Crossing Angle Extraction Line 1 TeV CMS

Condition (file name)	Energy Loss (GeV)	Energy Loss (GeV) for E>480 GeV
Nominal Beam Condition (cs21)	12.37	13.13
Large y (cs23)	12.16	13.08
Large y horizontal offset 200nm (cs23_dx200)	11.75	12.71
Large y vertical offset 4nm cs23dy4	12.04	12.99
Low Power (cs24)	11.62	13.16

0.5 TeV CMS

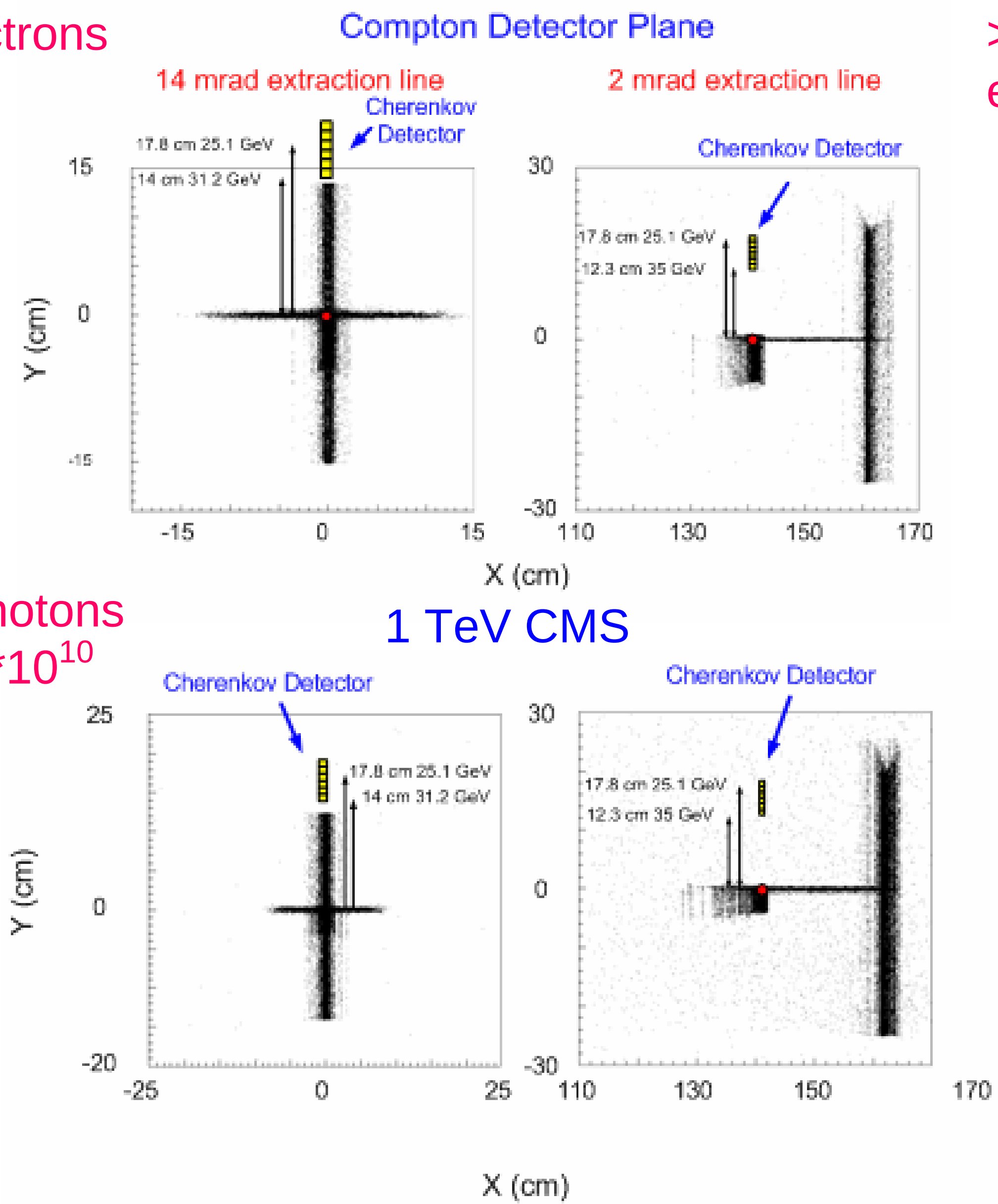
1 TeV CMS



$<10^4/cm^2$ photons per $2*10^{10}$ electrons

0.5 TeV CMS

$0.1*10^6/cm^2$ photons >15MeV per $2*10^{10}$ electrons



$<2*10^4/cm^2$ photons >15MeV per $2*10^{10}$ electrons

$1.6*10^6/cm^2$ photons >15MeV per $2*10^{10}$ electrons

Scattered synchrotron radiation photons give background in the region of the Cherenkov detector

Conclusions

14 mrad extraction line

0.5 TeV CMS

- Performance of Energy Spectrometer and Polarimeter Meets Goals

1 TeV CMS

- Performance of Energy Spectrometer and Polarimeter Meets Goals
- Large background from scattered synchrotron radiation photons at the Cherenkov Detector
- Concern about large beam losses for Low Power beam parameters

2 mrad extraction line

0.5 TeV CMS

- Performance of Energy Spectrometer and Polarimeter Meets Goals
- Large background from scattered synchrotron radiation photons at the Cherenkov Detector
- Concern about large beam losses for Low Power beam parameters

1 TeV CMS

- Performance of Polarimeter Meets Goals for Normal ILC Beam Parameters
- Performance of Energy Spectrometer does not meet goals
- Large background from scattered synchrotron radiation photons at the Cherenkov Detector
- Extreme concern about very large beam losses

Conclusions

14 mrad extraction line 0.5 TeV CMS

•Core of beam within +-100microns has 48% of the beam.

•The polarization projection at the Compton IP is in good agreement with the luminosity weighted polarization at the e+e- interaction region. A precision measurement of +-0.25% will be possible.

•No beam losses from e+e- IR to Compton detector plane out of 17.6 million beam tracks for Normal ILC and Large-y beam parameter data sets. The Low Power beam parameter data set has losses of $1.1 * 10^{-4}$.

•Beam energy loss due to synchrotron radiation to the middle of energy chicane (z=59.7 m) is ~120 MeV and shows small variations of less than 10 MeV with different beam parameter conditions for the disrupted beam.

•The collimator at z=164.25 meters needs to be designed. It absorbs the synchrotron radiation above the 0.75 mrad beam stay clear allowing the Cherenkov detector to begin at y~14 cm. Background from scattered synchrotron radiation occurs at the Cherenkov detector and will require careful design of the collimation and shielding.

•Performance of Energy Spectrometer and Polarimeter Meets Goals

14 mrad extraction line

1 TeV CMS

•Core of beam within +-100microns has 43% of the beam. The large-y and low power parameter data sets have a lower Compton luminosity by a factor 2.

•The polarization projection at the Compton IP is in good agreement with the luminosity weighted polarization at the e+e- interaction region. A precision measurement of +-0.25% will be possible.

•Beam losses of $1.8*10^{-5}$ occur between the e+e- IR and the Compton detector plane for the Normal ILC beam parameter data set. Beam losses are also small but not negligible for the Large-y beam parameter data set. There are large losses of 0.53% of the beam for the Low Power beam parameter data set that will require insertion of a new collimator between the e+e- IR and the Compton detector plane or an increase in the beam stay clear from 0.75 mrad.

•Both the Normal ILC and Large-y beam parameter data sets have beam energy losses of ~1.70 GeV due to synchrotron radiation in the magnets between the e+e- IR and the middle of energy chicane with variations less than 20 MeV. The Low Power beam parameter data set has beam energy loss due to synchrotron radiation of 1.56 GeV or 140 MeV less than the other data sets. This is due to the larger beamstrahlung energy tail having smaller synchrotron radiation losses. Measuring the high energy part of the beam energy spectrum will allow the energy loss due to synchrotron radiation to be understood to the precision required.

•The collimator at z=164.25 meters absorbs the synchrotron radiation above the 0.75 mrad beam stay clear allowing the Cherenkov detector to begin at y~14 cm. Background from scattered synchrotron radiation is very large at the Cherenkov detector and will require careful design of the collimation and shielding ($<2*10^4$ /cm^2 photons >15MeV per $2*10^{10}$ electrons).

•Performance of Energy Spectrometer and Polarimeter Meets Goals

•Large background from scattered synchrotron radiation photons at the Cherenkov Detector

•Concern about large beam losses for Low Power beam parameters

2 mrad extraction line 0.5 TeV CMS

•There are large beam losses between e+e- IR and Compton detector plane (>$2.6*10^{-4}$ are lost) giving secondary backgrounds of mainly photons in the region of the Cherenkov Detector. The Low Power beam parameter data set has beam losses ~ 1.25% giving very large backgrounds at the Cherenkov detector.

•A small percentage of beam is hit by laser spot +-100 microns (~15%) at the Compton IP and results in low Compton luminosity.

•The polarization projection at the Compton IP is in good agreement with the luminosity weighted polarization at the e+e- interaction region. A precision measurement of +-0.25% will be possible.

•There are large beam energy losses (~850 MeV) due to synchrotron radiation between IR and the center of the energy chicane at z=198.82 meters. Beam collision jitter in the horizontal plane of 200 nanometers gives changes in the beam energy loss due to synchrotron radiation of ~25 MeV comparable to the goal of the precision measurement of the energy.

•Synchrotron radiation at Cherenkov Detector is favorable. The detector only sees the synchrotron radiation from the magnets of the polarimeter chicane, and this is contained between -9 and +2 cm. The first cell of the Cherenkov Detector starts at +10 cm. Background from scattered synchrotron radiation occurs at the Cherenkov detector and will require careful design of the collimation and shielding ($0.1*10^6$ /cm^2 photons >15MeV per $2*10^{10}$ electrons).

•Performance of Energy Spectrometer and Polarimeter Meets Goals
•Large background from scattered synchrotron radiation photons at the Cherenkov Detector
•Concern about large beam losses for Low Power beam parameters

2 mrad extraction line

1 TeV CMS

- There are large beam losses between the e+e- IR and the Compton detector plane (0.74% of the beam is lost for the Normal ILC beam parameter data set) giving secondary backgrounds of mainly low energy photons with energy <10 MeV. For the Low Power beam parameter data set 7.3% of the beam is lost giving large backgrounds at the Cherenkov detector.

- At the Compton IP only 18.9% of the beam with Normal ILC beam parameters is contained within +-100microns of the peak giving a lower luminosity for Compton scattering of the laser light on the disrupted electron beam.

- The polarization measurement at the Compton IP is within the desired precision of +- 0.25% of the estimated luminosity weighted polarization.

- There are large beam energy losses (12.4 GeV) due to synchrotron radiation between IR and the center of the energy chicane at z=198.82 meters. Beam collision jitter in the horizontal plane of 200 nanometers gives large variations in the beam energy loss due to synchrotron radiation of ~450 MeV. The collision offset data from instruments near the e+e- interaction region can be used to reduce the uncertainty in the synchrotron radiation loss due to horizontal jitter.

- Synchrotron radiation at Cherenkov Detector is favorable, but, scattered synchrotron radiation photons give large background in the region of the Cherenkov detector ($1.6*10^6$ /cm^2 photons >15MeV per $2*10^{10}$ electrons).

- Performance of Polarimeter Meets Goals for Normal ILC Beam Parameters
- Performance of Energy Spectrometer does not meet goals
- Large background from scattered synchrotron radiation photons at the Cherenkov Detector
- Extreme concern about very large beam losses