

Upstream Polarimeter Update

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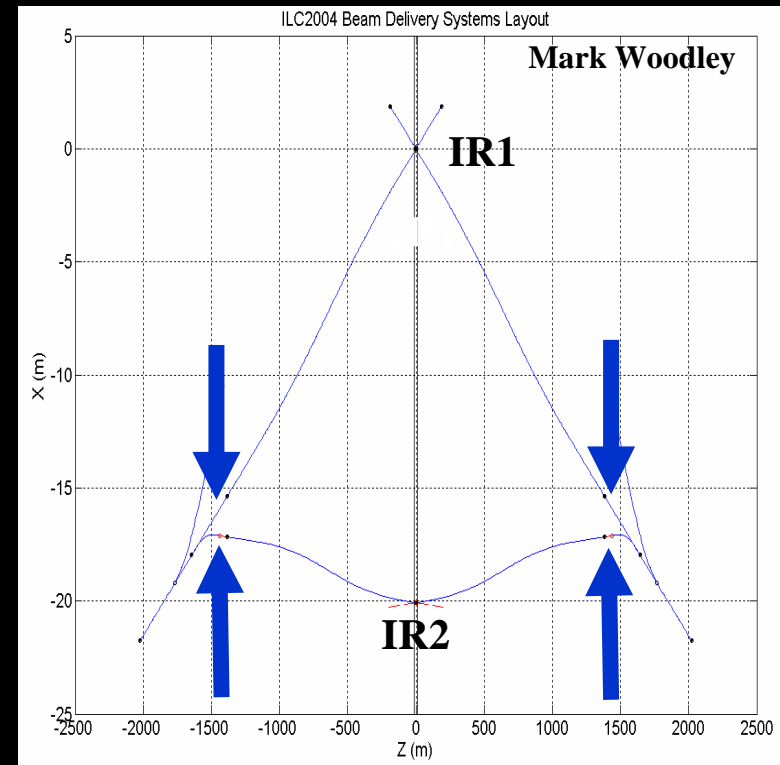
Introduction & Overview

- Compton polarimetry basics I, II, III
- laser parameters
- Tesla design & chicane design

4-Magnet Chicane

- general layout & properties
- movable laser beam
- vacuum chambers
- electron detector
- some simulation results
- synchr. radiation & emittance growth
- remaining issues

Summary & Conclusion



Compton polarimetry basics I : Kinematics

$$\omega + E = \omega_0 + E_0 \simeq E_0$$

$$\varkappa = \frac{4E_0\omega_0}{m^2} \cos^2(\theta_0/2) \simeq \frac{4E_0\omega_0}{m^2}$$

$$y = 1 - \frac{E}{E_0} = \frac{\omega}{E_0}$$

$$r = \frac{y}{\varkappa(1-y)}$$

$$\theta_\gamma = \frac{m}{E_0} \sqrt{\frac{\varkappa}{y} - (\varkappa + 1)}$$

$$\theta_e = \frac{y}{1-y} \theta_\gamma$$

$$\omega_{max} = E_0 \frac{\varkappa}{1 + \varkappa}$$

$$E_{min} = E_0 \frac{1}{1 + \varkappa}$$

E_0 (GeV)	λ (nm)	ω_0 (eV)	\varkappa	ω_{max} (GeV)	E_{min} (GeV)
45.6	1064	1.165	0.813	20.4	25.2
	532	2.33	1.63	28.3	17.3
	266	4.66	3.25	34.9	10.7
250	1064	1.165	4.46	204	46
	532	2.33	8.92	225	25
	266	4.66	17.8	237	13
400	1064	1.165	7.14	351	49
	532	2.33	14.3	374	26
	266	4.66	28.6	386	14

Compton polarimetry basics II :

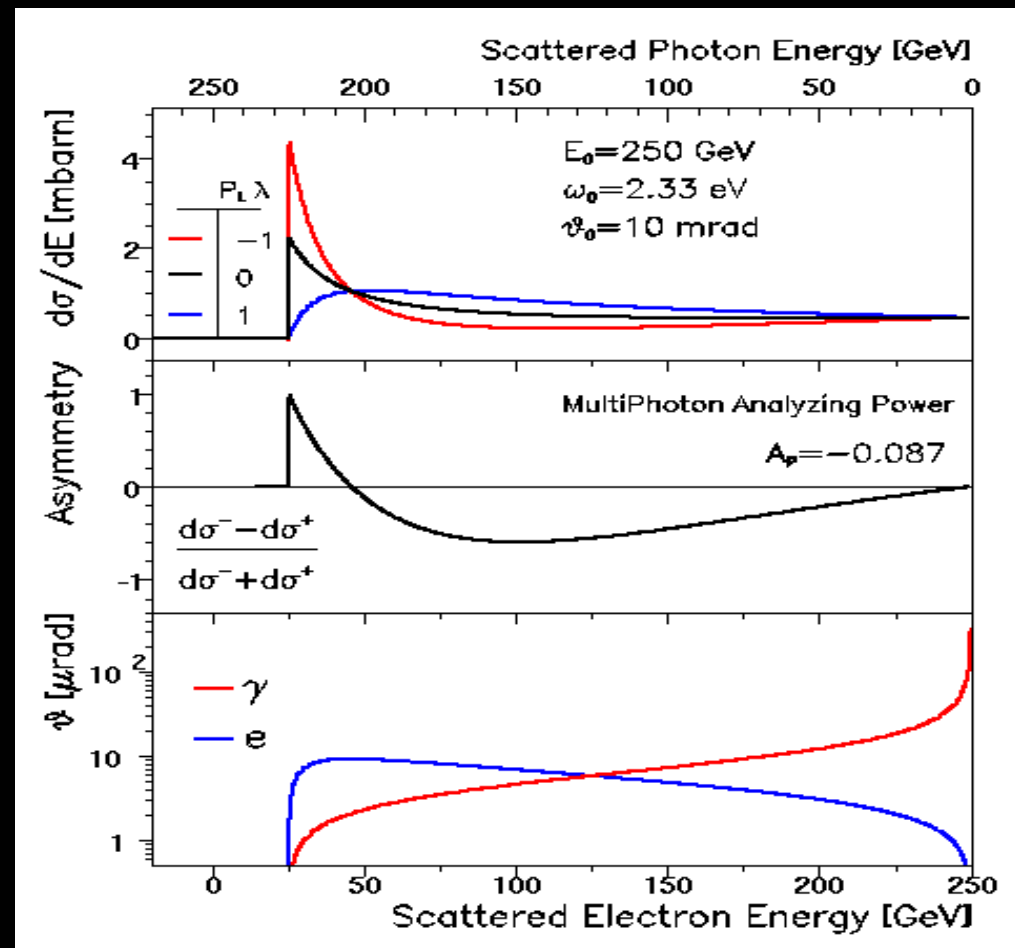
cross sections,
spin asymmetry,
scattering angles

$$-1 < P < +1$$

$$-1 < \lambda < +1$$

$$\vartheta_e^{\max} = 2 \omega_0 / m$$

$$A = \frac{d\sigma^- - d\sigma^+}{d\sigma^- + d\sigma^+}$$



$$\frac{d\sigma}{dy} = \frac{2\sigma_0}{x} \left[\frac{1}{1-y} + 1-y - 4r(1-r) + P\lambda r x(1-2r)(2-y) \right]$$

Compton polarimetry basics III: luminosity for pulsed lasers

$$\mathcal{L} = f_b N_e N_\gamma g$$

f_b = bunch crossings per sec
 N_e, N_γ = no. of e, γ per bunch
 g = geometry factor
 $\sigma_{x\gamma}, \sigma_{y\gamma}$ = transverse laser beam size
 $\sigma_{z\gamma} = c \sigma_{t\gamma}$ = laser pulse length
 θ_0 = laser crossing angle

$$\mathcal{L} = \frac{\mathcal{L}_{max}}{\sqrt{1 + (0.5 \theta_0 \sigma_{z\gamma} / \sigma_{y\gamma})^2}}$$

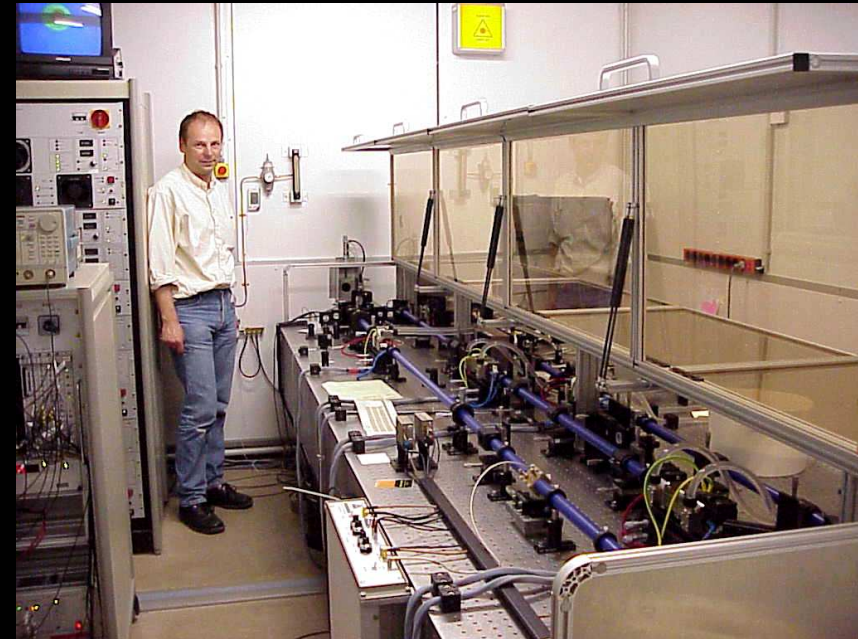
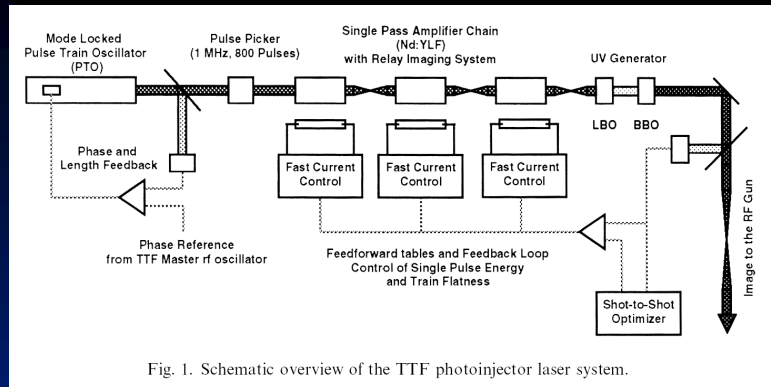
$$\mathcal{L}_{max} = \frac{f_b N_e N_\gamma}{2\pi \sigma_{x\gamma} \sigma_{y\gamma}}$$

$$g = \frac{1}{2\pi \sigma_{x\gamma} \sigma_{y\gamma} \sqrt{1 + (0.5 \theta_0 \sigma_{z\gamma} / \sigma_{y\gamma})^2}}$$

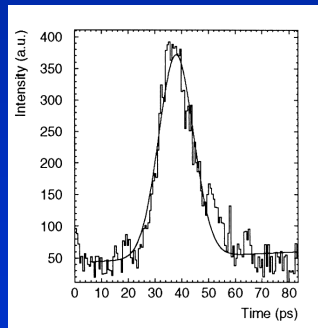
$\sigma_{t\gamma}$ (ps)	$\sigma_{z\gamma}$ (mm)	$\mathcal{L}/\mathcal{L}_{max}$		
		3 mrad	10mrad	30mrad
0	0	1.000	1.000	1.000
5	1.5	0.999	0.989	0.912
10	3.0	0.996	0.958	0.743
15	4.5	0.991	0.912	0.505
20	6	0.984	0.857	0.486
30	9	0.965	0.743	0.347
40	12	0.941	0.640	0.268
50	15	0.912	0.555	0.217
100	30	0.743	0.316	0.110
1000	300	0.110	0.033	0.011
10000	3000	0.011	0.003	0.001

⇒ effectiveness of laser degrades with increasing pulse length & crossing angle

Laser for TTF injector gun



regen. multi-stage Nd:YLF ampl.
(built by Max-Born-Inst.)
operates at nominal pulse &
bunch pattern of TESLA



$$\sigma_t = 8 \text{ ps}$$

S. Schreiber et al.
NIM A 445 (2000) 427

Vienna – Nov. 14-17, 2005
ILC Workshop - 2005

K. Peter Schöler
Upstream Polarimeter Update

Laser parameters

for TESLA TDR (2001), we assumed TTF-style laser of variable wavelength:

configuration	E_0 (GeV)	$\langle I_e \rangle$ (μA)	λ (nm)	ϵ_γ (eV)	$\langle P_L \rangle$ (W)	j_γ (μJ)	\mathcal{L} ($10^{32} cm^{-2} s^{-1}$)
TESLA-500	250	45	532	2.33	0.5	35	1.5
TESLA-800	400	45	1064	1.165	1.0	71	6.0
Giga-Z	45.6	45	266	4.66	0.2	14	0.2

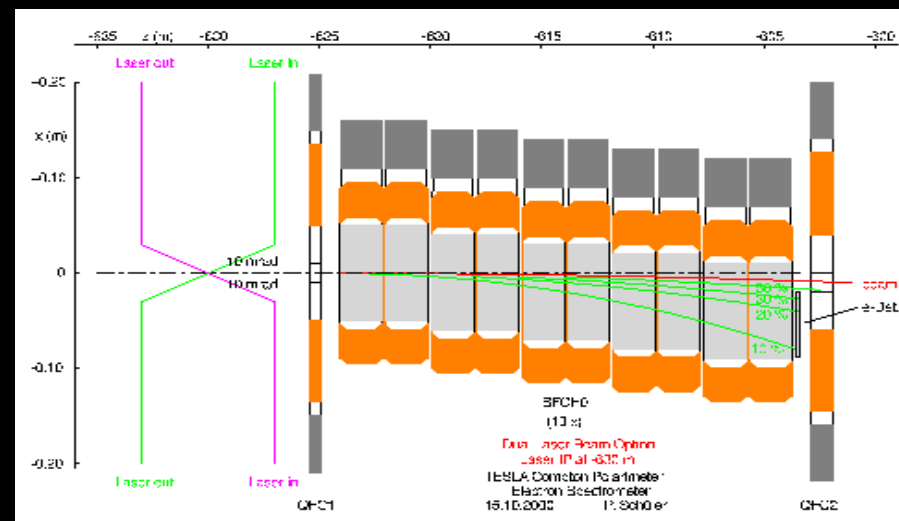
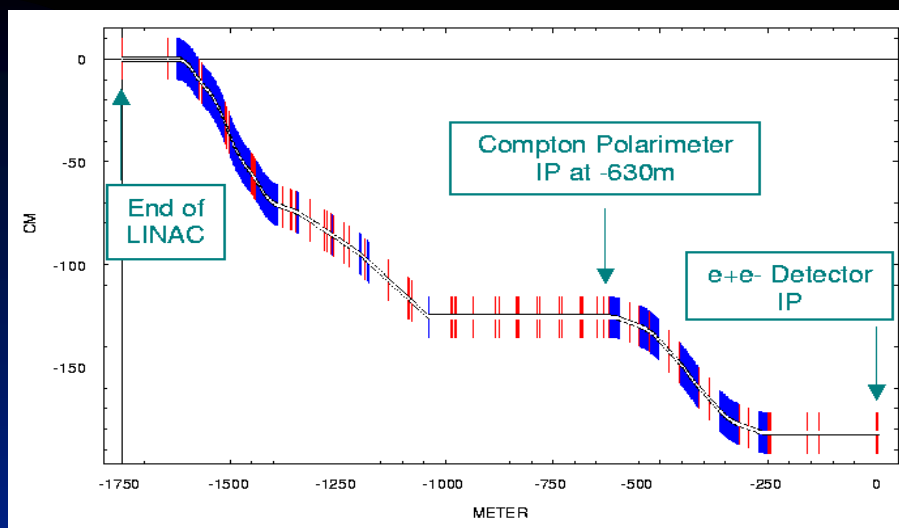
β green
 β IR
 β UV

Table 9: Reference parameters for statistical tables.

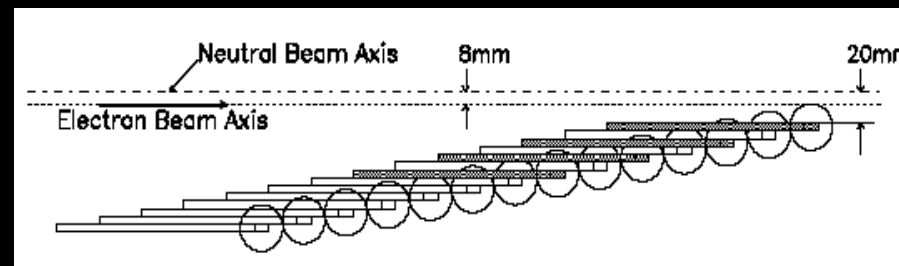
will employ similar laser for ILC chicane polarimeter,
but can operate with green line at all ILC beam energies

Tesla design

V. Gharibyan, N. Meyners, K.P. Schüler,
www.desy.de/~lcnotes/notes.html, LC-DET-2001-047

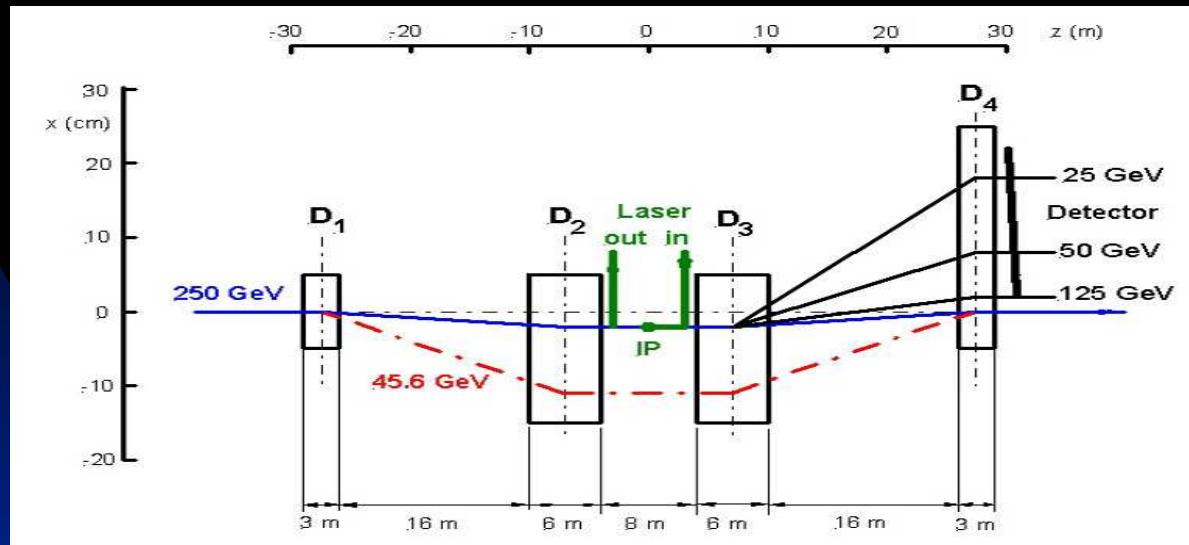


	e^+/e^- beam	laser beam
energy	250 GeV	2.3 eV
charge or energy/bunch	$2 \cdot 10^{10}$	$35 \mu\text{J}$
bunches/sec	14100	14100
bunch length σ_t	1.3 ps	10 ps
average current(power)	$45 \mu\text{A}$	0.5 W
$\sigma_x \cdot \sigma_y$ (μm)	10 · 1	50 · 50
beam crossing angle	10 mrad	
luminosity	$1.5 \cdot 10^{32} \text{cm}^{-2} \text{s}^{-1}$	
cross section	$0.136 \cdot 10^{-24} \text{cm}^2$	
detected events/sec	$1.0 \cdot 10^7$	
detected events/bunch	$0.7 \cdot 10^3$	
$\Delta P/P$ stat. error/sec	negligible	
$\Delta P/P$ syst. error	$\sim 0.5\%$	



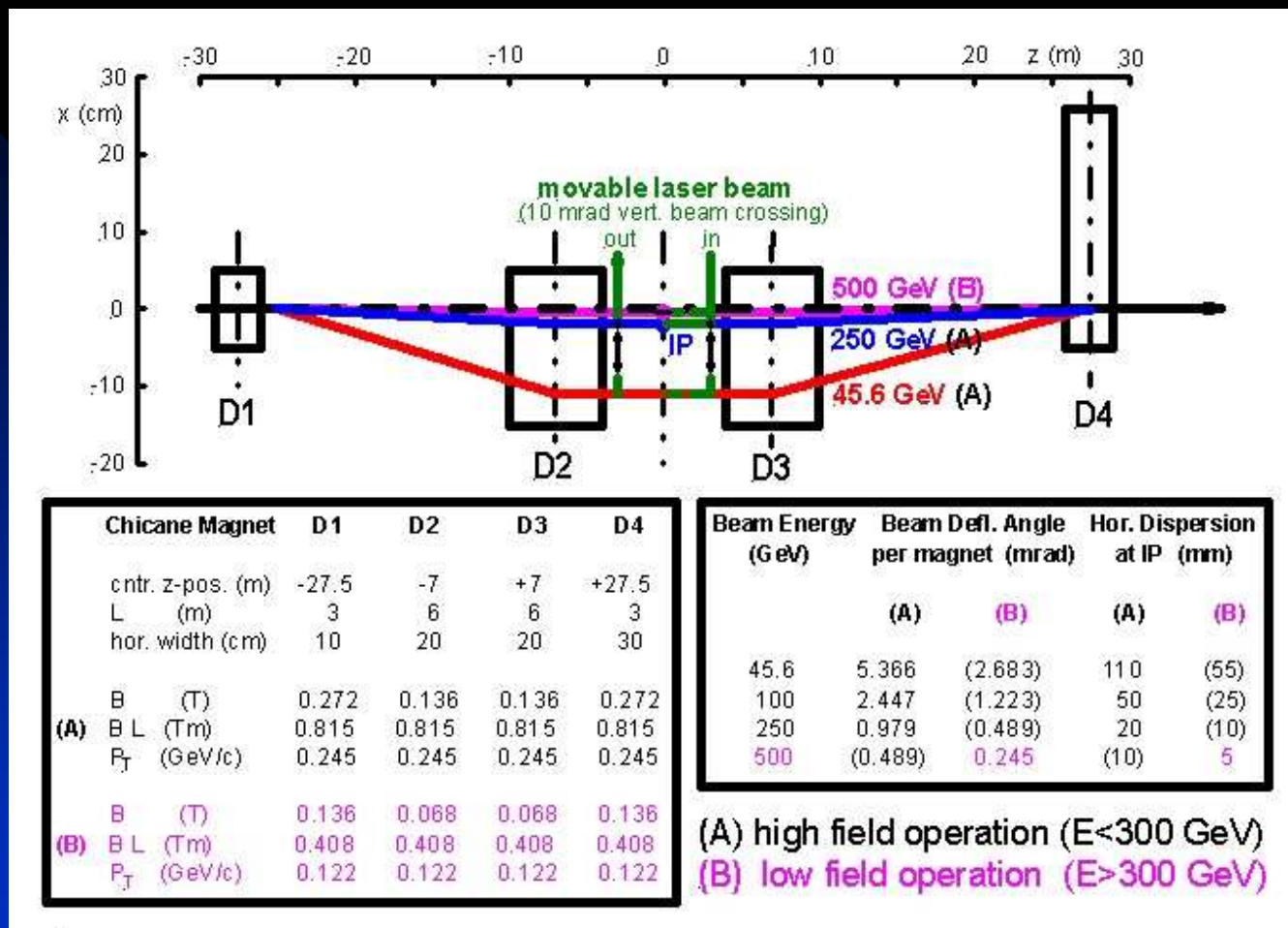
- minimal space & no special magnets
- need to change laser wavelength to UV for z-pole running

Chicane Design



- essential for downstream polarimetry (separates Compton electrons from low-energy disrupted beam background), but advantageous also for upstream polarimetry
- requires ~ 60 meters length
- constant field settings $\int B dl$ over wide range of energies
- good acceptance of Compton spectrum at all energies without changing laser wavelength
- laser crossing (Compton IP) at mid-chicane

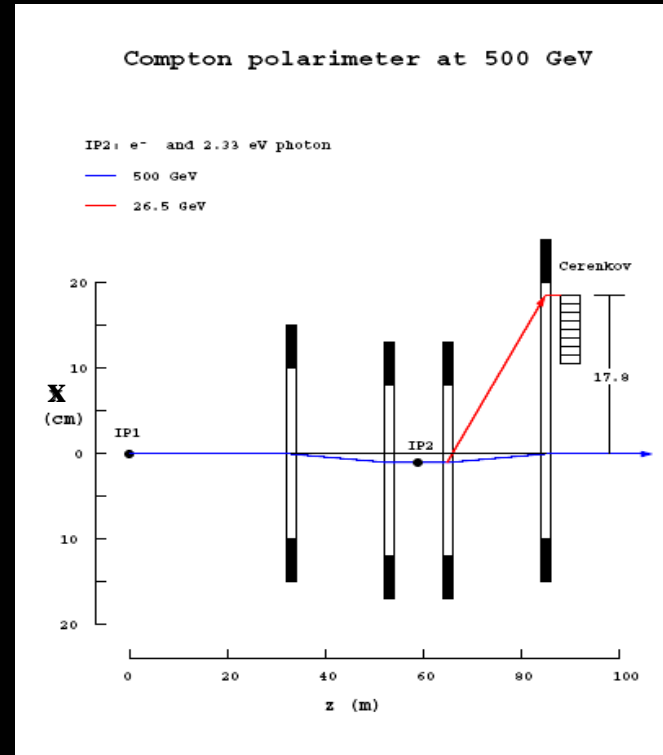
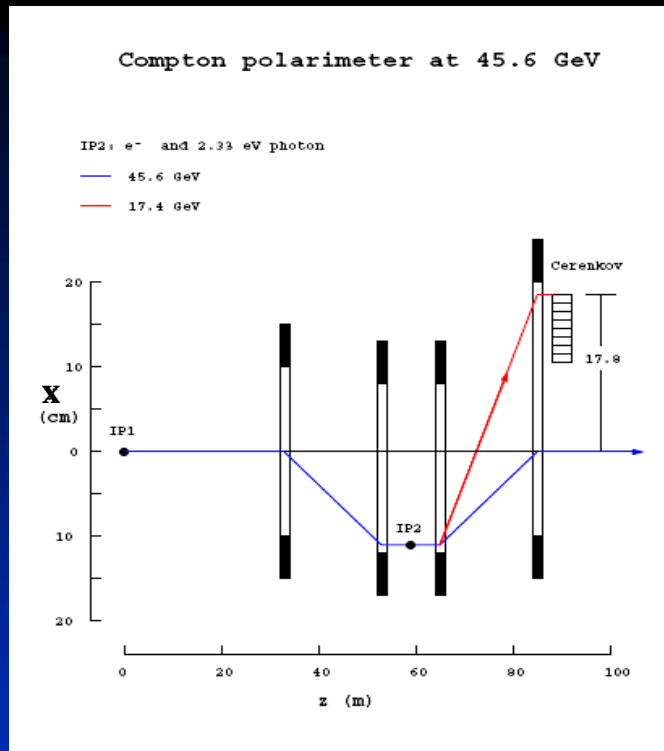
4-Magnet Chicane: general layout



2 operating regimes depending on beam energy

Chicane properties

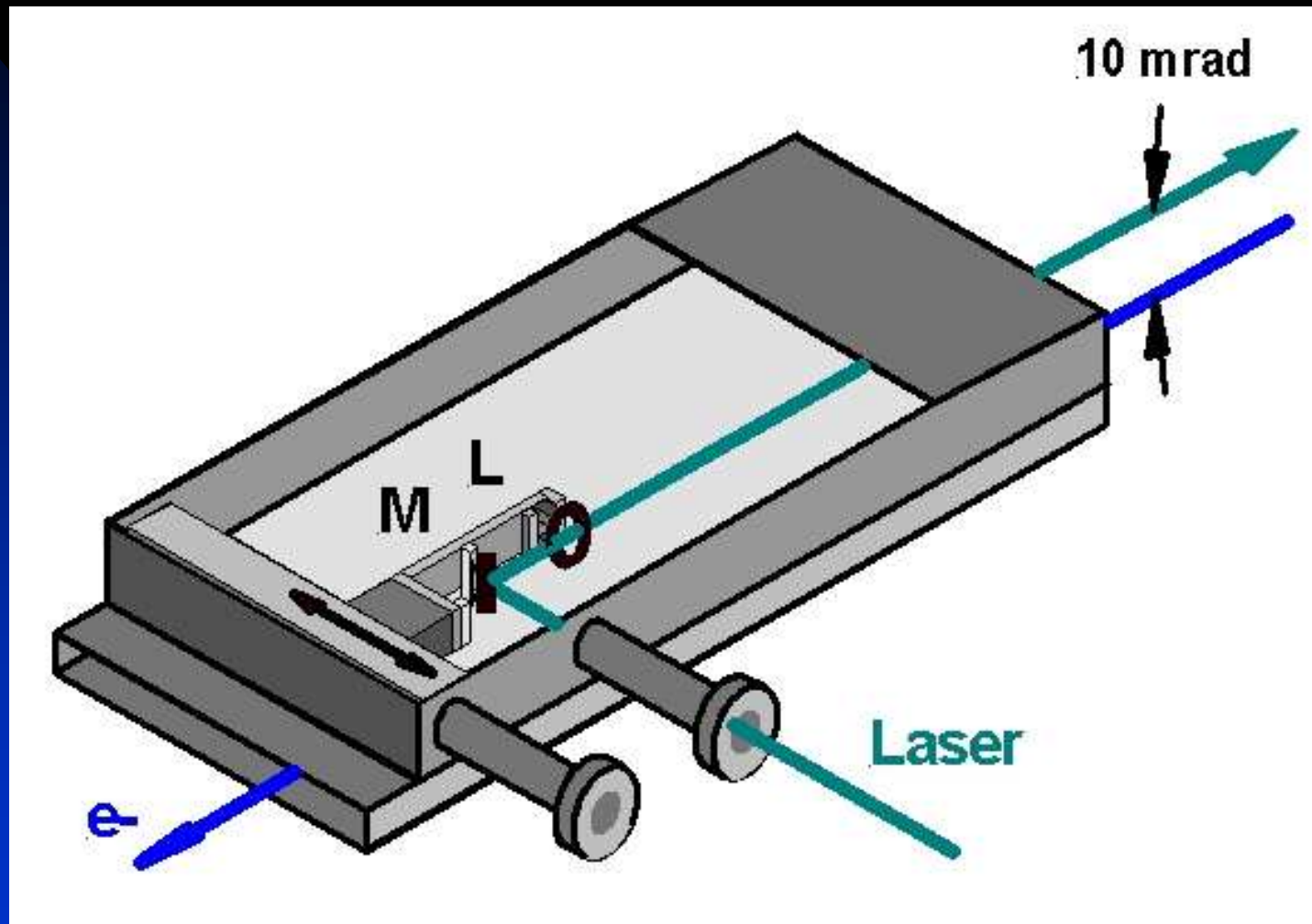
(see talk of W. Oliver,
MDI workshop, SLAC, Jan. 2005)



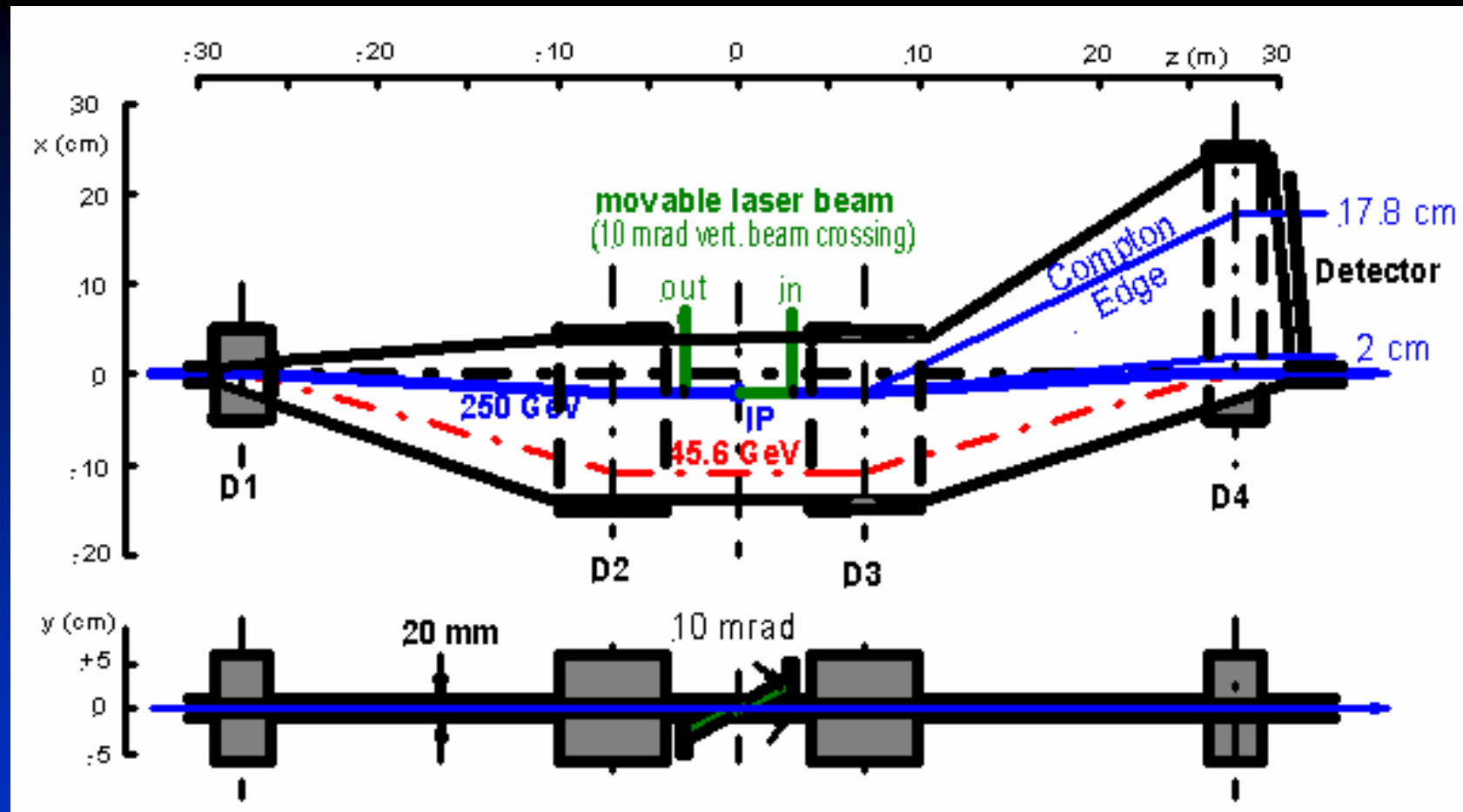
$X_{\max} = 4 \omega_0 p_T L / m^2 \quad \beta$ position of Compton edge is independent of beam energy

e.g. $X_{\max} = 17.8 \text{ cm}$ for $\omega_0 = 2.33 \text{ eV}$, $P_T = 0.25 \text{ GeV}/c$, $L = 20 \text{ m}$

movable laser beam

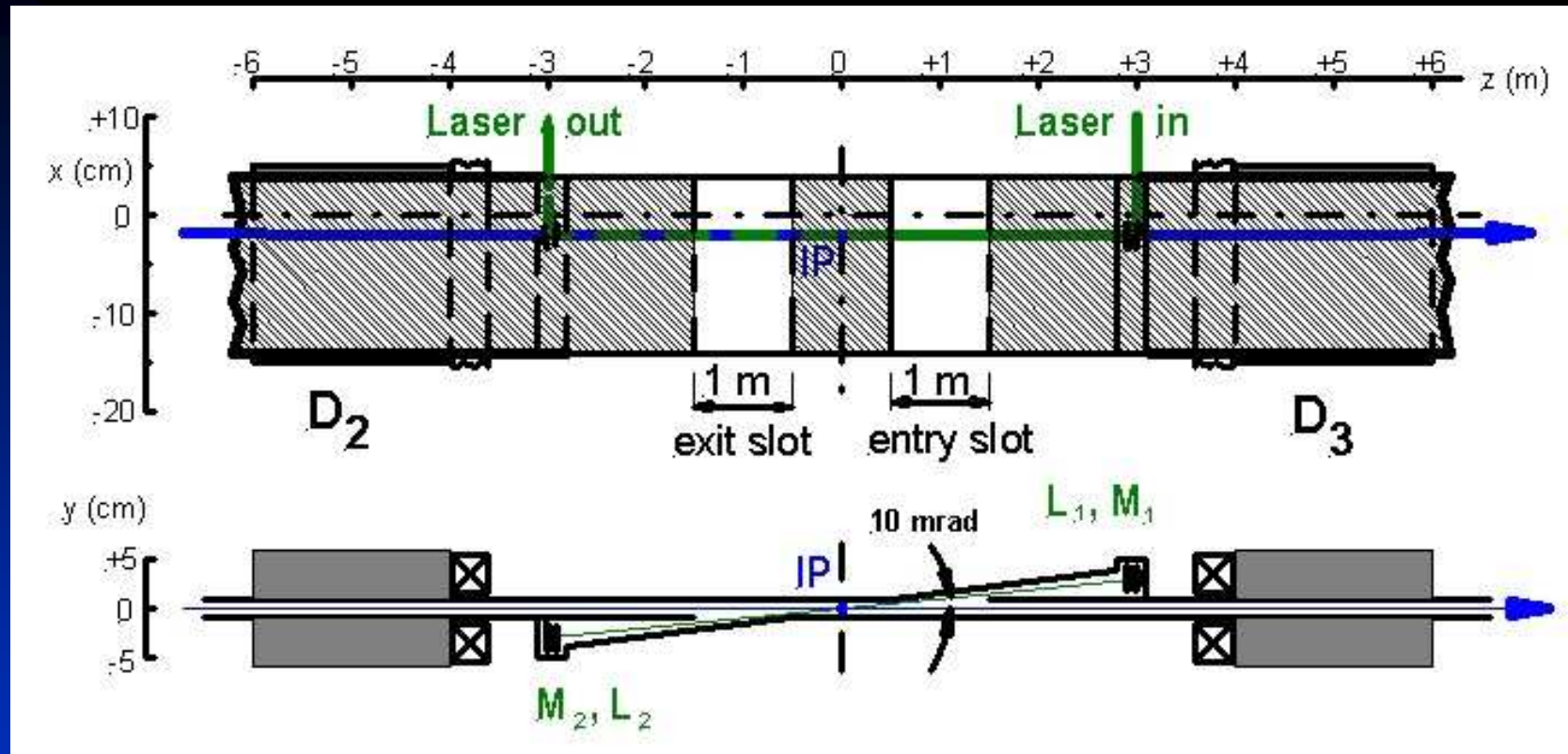


Vacuum Chamber Overview



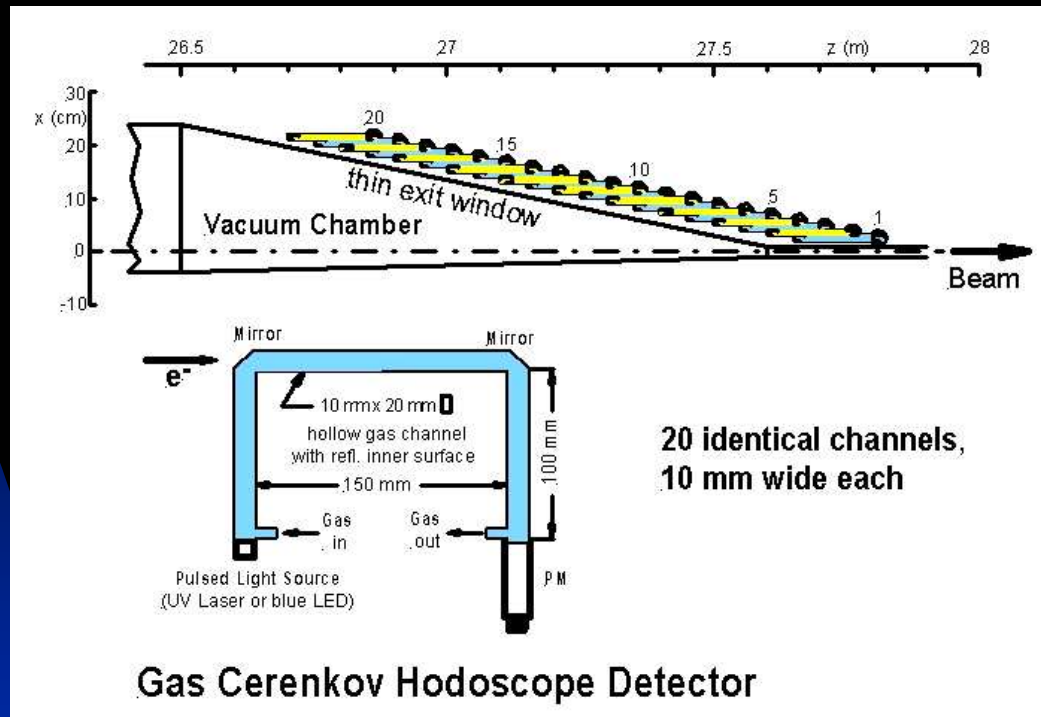
chambers are tapered to minimize wake fields

Vacuum Chamber Detail



laser beam crossing requires ~ 1 m long insertion/exit slots along z
 à need evaluation of wake field effects: Igor Zagorodnov, in progr.

Electron Detector



- design similar to gas Cerenkov employed in SLD Compton polarimeter
- C_4F_{10} gas (~ 10 MeV threshold)
- detector will be immune against low-energy and diffuse background (syn. rad.)
- do not need explicit preradiator, due to high intrinsic event flux (less cross talk)
- 20 channels, 10 mm wide each, will cover a large fraction of the Compton spectr.
- $E_{\max} / E_0 = 85\%; 50\%; 16.5\%$ at $E_0 = 45.6; 250; 500$ GeV (with $x_{\min} = 20$ mm)

some simulation results I

input parameters

0.5×10^6	no. of Compton evt's per polarity
676749.	random seed
2.33	laser photon energy (eV)
250.	electron energy (GeV)
10.	crossing angle (mrad)
1.50	luminosity ($10^{32} / \text{cm}^2 / \text{sec}$)
0.250	chicane transv. mom. kick (GeV/c)
2.	magnet length (m)
20.	cntr. dist. magnets 1&2 (3&4) (m)
10.	cntr. distance magnets 2&3 (m)
0.7	dist. mag. 4 edge to det. ch. n (m)
20	no. of det. channels (max. 100)
10.	det. channel x-size (hor.) (mm)
20.	det. channel y-size (vert.) (mm)
150.	det. channel length along z (mm)
20.	distance det. ch. 1 to beam (mm)
50.	z-dist. btw. det. channels (mm)
1.	meas. time for stat. error (sec)
0.80	beam pol. to calculate stat. error

$$E_0 = 250 \text{ GeV}$$

$$\omega_0 = 2.33 \text{ eV (green laser)}$$

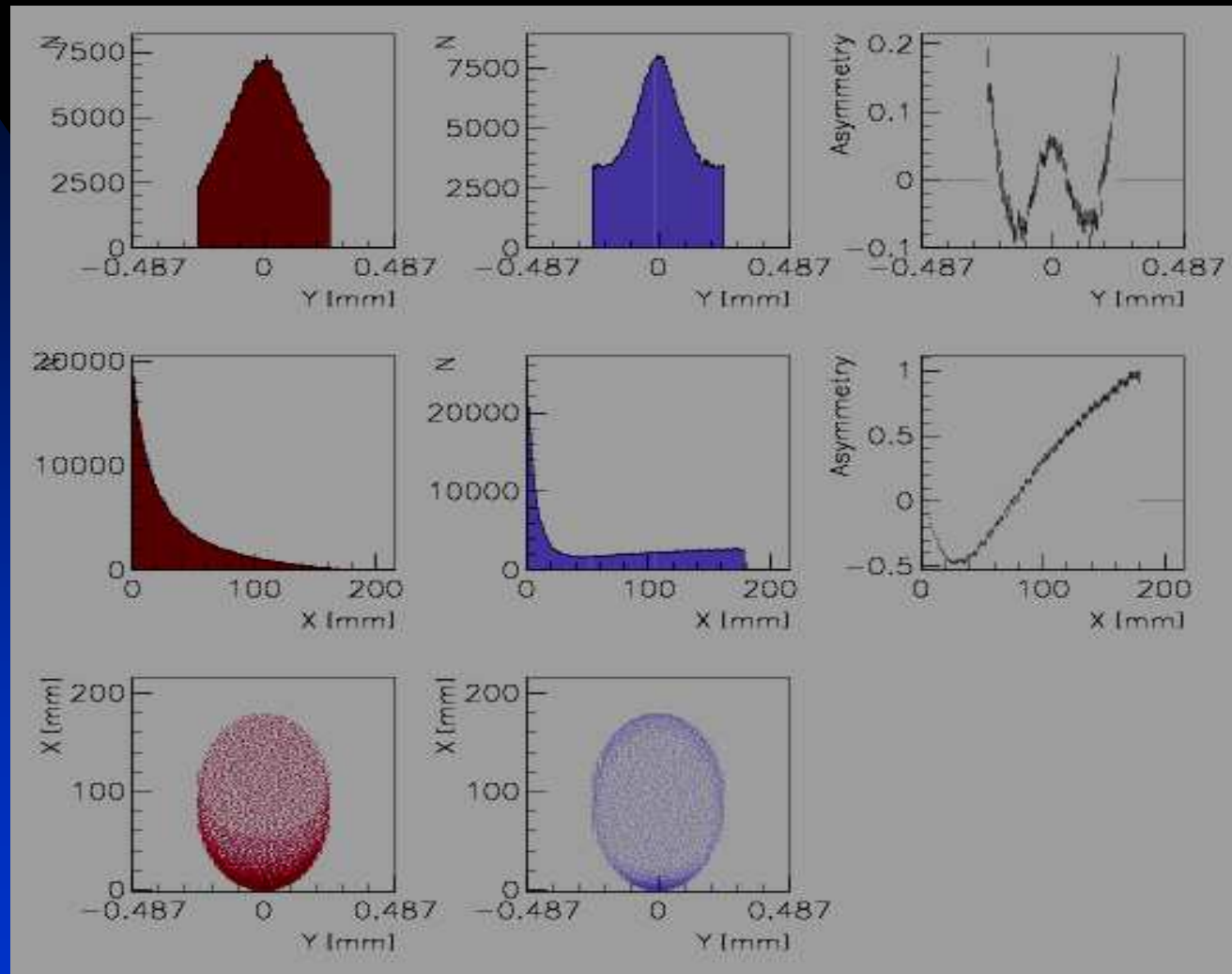
$$\mathcal{L} = 1.5 \times 10^{32} / \text{cm}^2 / \text{sec}$$

results

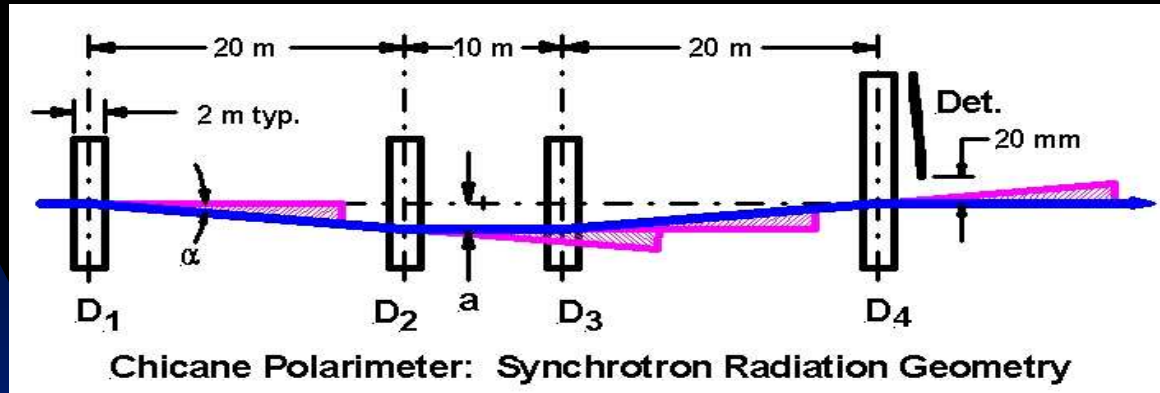
Ch. #	x [mm]	N+	N-	A	Rate*A ²	Rate [MHz]	dP/P [%]
1	25	60,682	23,368	-0.444	0.337	1.710	0.228
2	35	45,868	17,348	-0.451	0.262	1.287	0.260
3	45	35,673	16,012	-0.380	0.152	1.052	0.335
4	55	28,337	16,029	-0.277	0.069	0.903	0.486
5	65	22,996	16,956	-0.151	0.019	0.813	0.924
6	75	18,333	17,876	-0.013	0.000	0.737	11.521
7	85	15,248	18,744	0.103	0.007	0.692	1.466
8	95	12,025	19,818	0.245	0.039	0.648	0.646
9	105	9,881	20,480	0.349	0.075	0.618	0.473
10	115	7,815	21,525	0.467	0.130	0.597	0.370
11	125	6,246	21,961	0.557	0.178	0.574	0.324
12	135	4,849	22,795	0.649	0.237	0.562	0.289
13	145	3,479	23,315	0.740	0.299	0.545	0.266
14	155	2,385	23,821	0.818	0.357	0.533	0.250
15	165	1,346	24,171	0.895	0.416	0.519	0.238
16	175	457	20,900	0.957	0.398	0.435	0.249
17	185	0	0				
18	195	0	0				
19	205	0	0				
20	215	0	0				

overall stat. error: dP/P = 0.082%
for dT = 1 sec

some simulation results II



synchrotron radiation



E [GeV]	α [mrad]	a [mm]	ΔE / el. per magnet (3m/6m)		ΔE / sec [kJ]	total power (4 magnets) [kW]
			[MeV]	[mJ]		
45.6	5.5	110	0.6 / 0.3	2 / 1 (*)	0.03 / 0.015 (**)	0.08
100	2.5	50	2.9 / 1.5	9 / 4.5	0.13 / 0.065	0.27
250	1.0	20	18.3 / 9.2	59 / 30	0.83 / 0.415	2.49
500	0.25	5	36.7 / 18.4	117 / 59	1.65 / 0.825	4.96

(*) 2×10^{10} el./bunch

(**) $5 \times 2,820 = 14,100$ bunches/sec

emittance growth

from synchrotron radiation

E_{beam} [GeV]	E_{cm} [GeV]	$\Delta\varepsilon_x/\varepsilon_x$ [%]	dispersion [mm]	chicane operation
250	500	0.49	20	(A)
500	1,000	0.07	5	(B)

based on DIMAD tracking by Mark Woodley
for actual chicane geometry

remaining issues

- **wake field calculations: interpretation of num. results**
- **chicane bunch (de)compression effects**
- **alignment issues: BPM's, surveying techniques**
- **engineering of magnets, vacuum chambers, optics, etc**

summary & conclusion

- **we have extended our upstream polarimeter study and adopted the chicane spectrometer design**
- **chicane simplifies laser requirements: single green wavelength will accommodate all beam energies**
- **all essential results from earlier TESLA study remain valid**
- **detailed engineering still to be done**