Compton Scattering and Beam Energy Measurements*

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- Beam Energy Requirements
- Compton Scattering Basics
- Why it doesn't work

* I thought I had a good idea ...

`http://physics.uoregon.edu/~torrence/talks/CLCW02`

Precision Electroweak

Weak Mixing Angle

	$\Delta \sin^2\theta_W^{eff}$	ΔE_{beam} [MeV]	ΔE_{beam} [ppm]
SLD	0.00027	25	500
e^- only	0.00005	~ 5	100
Blondel	0.00002	~ 2	40

e^- only

- 50M events
- $P_{e^-} = 80\%, P_{e^+} = 0\%$
- $\delta P_e / P_e = 0.25\%$

Blondel scheme

- ~100M events
- $P_{e^-} = 80\%, P_{e^+} = 50\%$

W Threshold

$\Delta E_{beam} < 5$ MeV [50 ppm]

Beam Energy Needs

Weak Mixing Angle

e^- only: $\Delta E_{beam} < 5$ MeV [100 ppm]

Blondel: $\Delta E_{beam} < 2$ MeV [40 ppm]

⇛ Can use lineshape to calibrate E_{beam}?

WW Threshold

$\Delta E_{beam} < 5$ MeV [50 ppm]

⇛ Low beamstrahlung needed

Top Mass

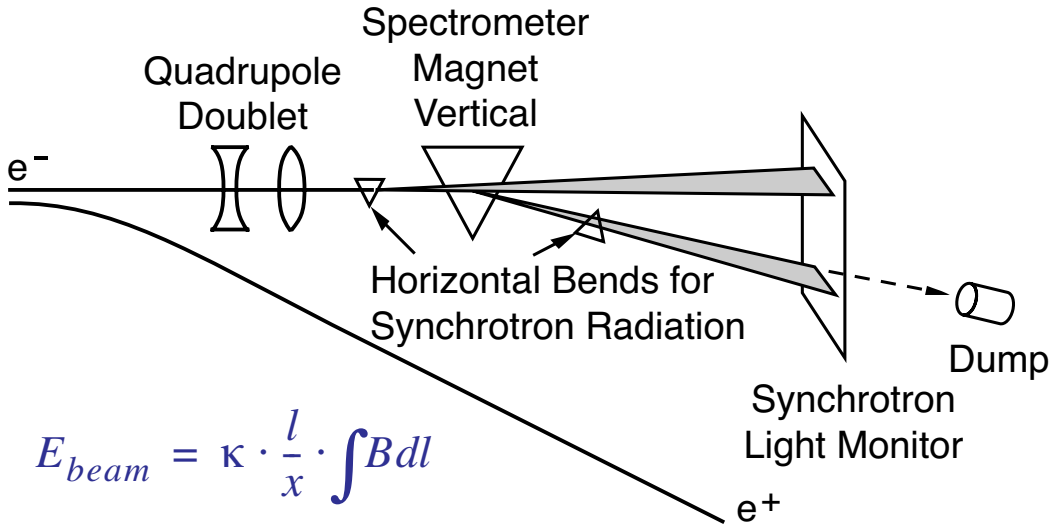
40 MeV in $10fb^{-1}$ [230 ppm]

Higgs Mass

~ 50 MeV (Direct Reconstruction)

⇛ 100-200 ppm 'adequate' for HE running

Meet the WISRD



$$E_{beam} = \kappa \cdot \frac{l}{x} \cdot \int Bdl$$

SLC Parameters at 50 GeV

$$\int Bdl = 3.05 \text{ Tesla meters}$$

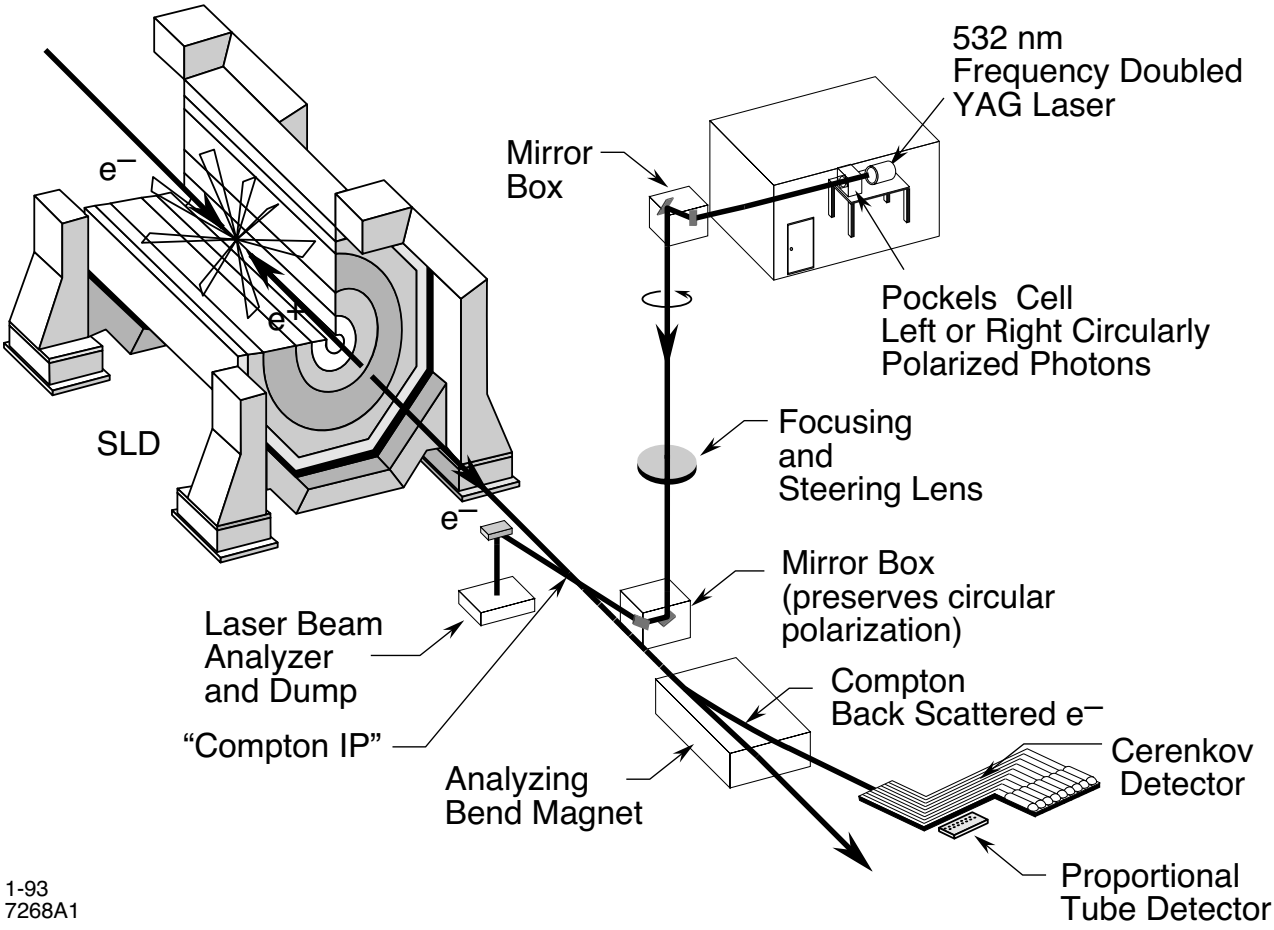
$l = 15$ meters $\qquad x = 27$ cm at 50 GeV

Systematic Errors per Beam

$\Delta\int Bdl$:	100 ppm
Alignment:	190 ppm
Detector - IP:	135 ppm
Total:	250 ppm ⇛ 12.5 MeV at 50 GeV

⇛ Can probably improve below 200 ppm up to 200 GeV

Compton Polarimetry



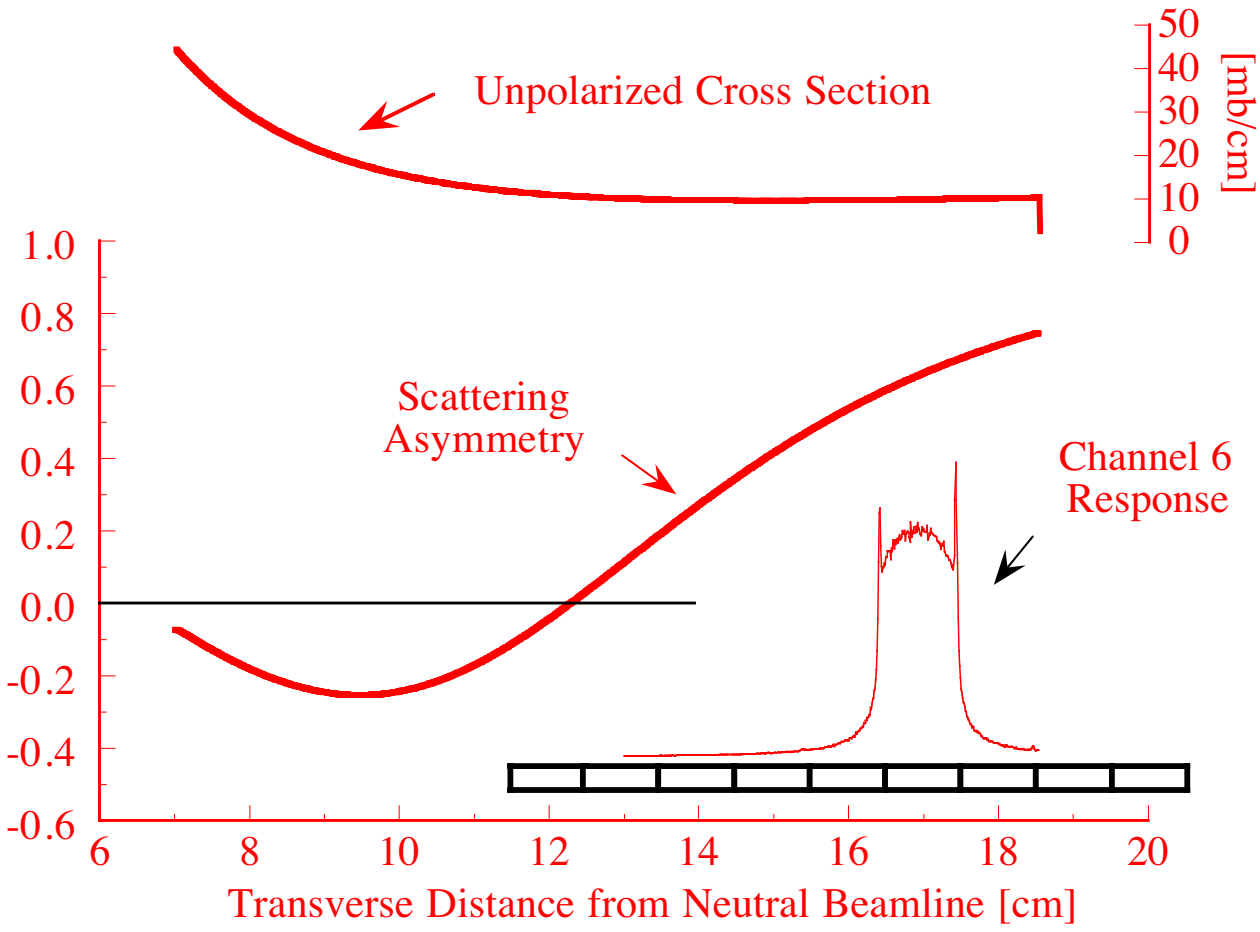
Compton Kinematics

$$y \equiv \left[1 + \frac{4KE}{m_e^2}\right]^{-1} = E'_{min}/E$$

$$x \equiv \left[1 + y\left(\frac{E\theta_K}{m_e}\right)^2\right]^{-1} = K'/K'_{max}$$

(Lab Frame Coordinates)

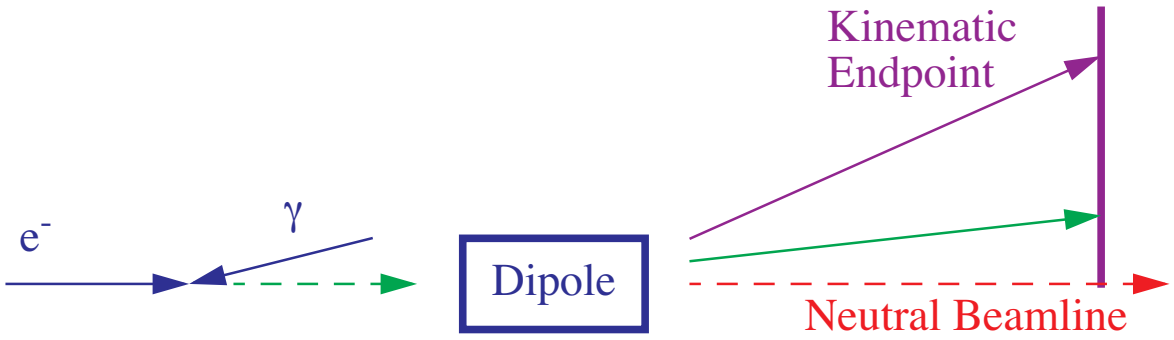
Scattered Electrons



- Kinematic Endpoint $E'_{min} = yE$
- Endpoint Asymmetry $A^z_{e\gamma} = \dfrac{1-y^2}{1+y^2}$
- Asymmetry crossing $x = (1+y)^{-1}$, $\theta_K = m_e/E$

⇛ Can we use these features to measure E?

Endpoint Position



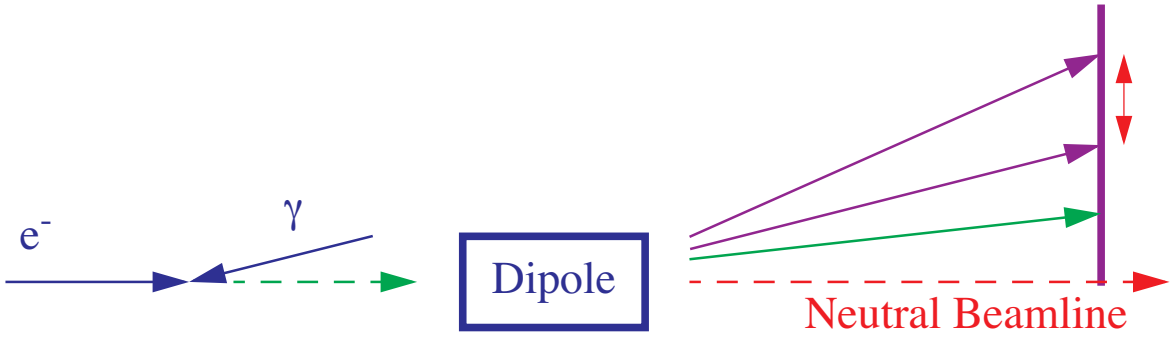
$$\frac{dE'_{min}}{dE} = y^2$$

E [GeV]	y	E'_{min} [GeV]
50	0.359	18.0
100	0.219	21.9
200	0.123	24.6
400	0.066	26.2

(Assume K=2.33 eV throughout)

- Poor analyzing power
- Difficult to measure absolute position
- Must take out beam motion

Endpoint to zero crossing



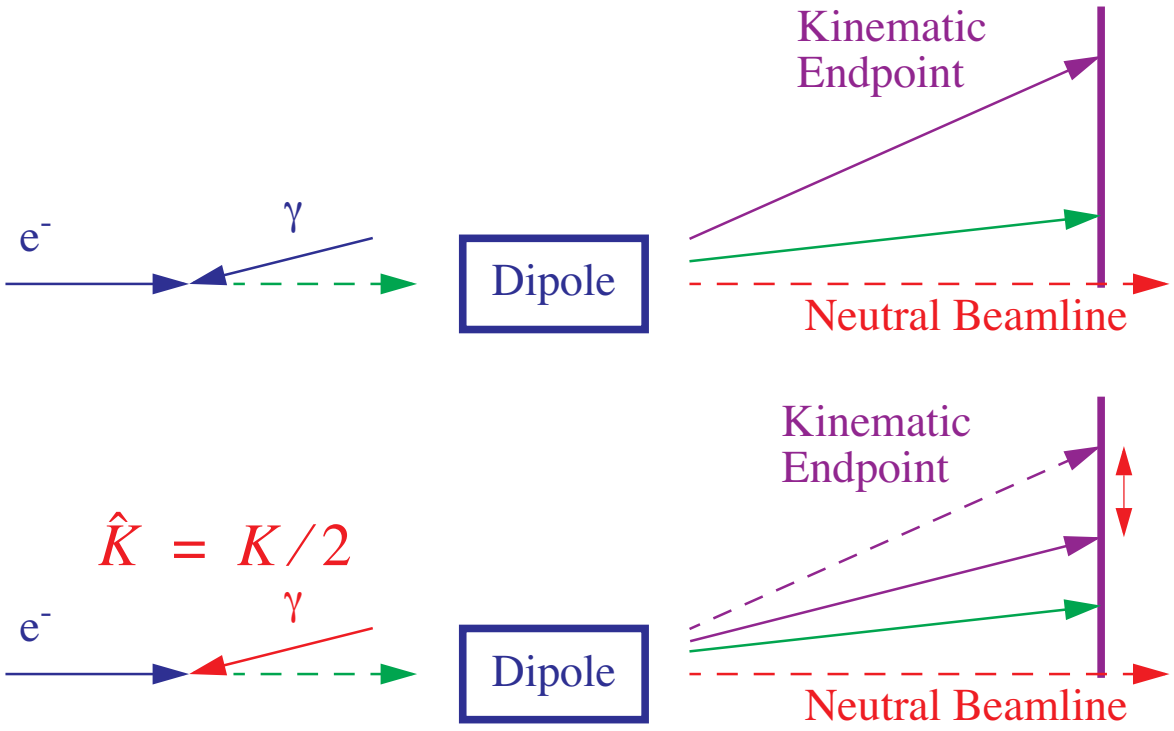
Zero asymmetry $E_0' = \frac{2y}{y+1}E$

E [GeV]	y	E'_{min} [GeV]	$\frac{2y}{y+1}$	E'_0 [GeV]
50	0.359	18.0	0.528	26.4
100	0.219	21.9	0.359	35.9
200	0.123	24.6	0.219	43.8
400	0.066	26.2	0.123	49.2

$$\frac{1}{E'_{min}} - \frac{1}{E'_0} = \frac{2K}{m_e^2}$$

⇛ Independent of beam energy!

Vary photon energy



$$\text{New Endpoint } \hat{y} = \left[1 + \frac{2KE}{m_e^2}\right]^{-1} = \frac{2y}{y+1}$$

Same energy as zero crossing!

Energy independent for any $\hat{K}$

$$\frac{1}{E'_m} - \frac{1}{\hat{E}'_m} = (1-z)\frac{4K}{m_e^2} \text{ where } \hat{K} = zK$$

Use scattered photons?

$$x \equiv \left[1 + y\left(\frac{E\theta_K}{m_e}\right)^2\right]^{-1}$$

Maximum $\theta_K = m_e/E$

E [GeV]	θ_K [μRad]	$R(100m)$ [mm]
50	10.2	1.02
100	5.1	0.51
200	2.6	0.26
400	1.3	0.13

- Need 100 ppm on 1 mm radius (at 100 m)
- Beam divergence will smear this out
- Longer drift possible?

Conclusions

Beam Energy Requirements

- 200 ppm for High Energy running
- <50 ppm for precision EW

Current Proposals

- WISRD (SLC-style)
- BPM spectrometers (LEP-style)

Compton Scattering

- Interesting kinematic properties
- Potentially useful for polarization

⇛ Unsuitable for Beam Energy Measurements

Other Possibilities

- Bhabha/Møller scattering
- ???