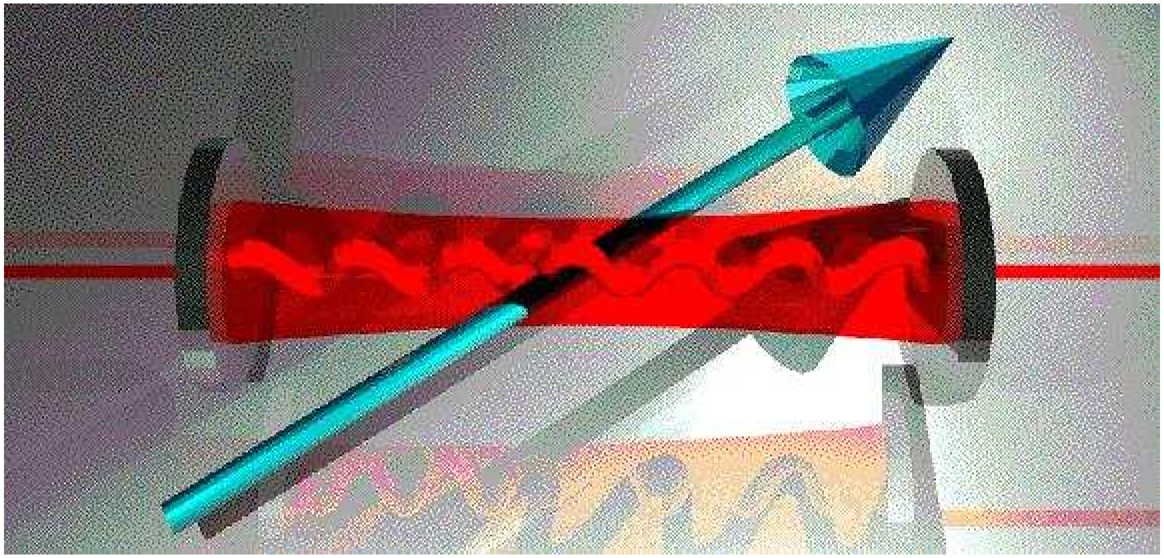
Compton polarimetry at JLAB hall A



Introduction

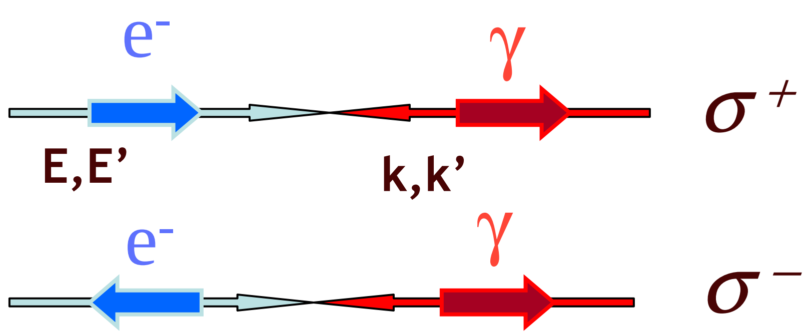
- ~5 years technical developments. Quite complex apparatus .
  (Sorry Pr. Sick, we couldn't make it simple).

- Chicane and γ detector commissioned during HAPPEx in 1998,
  led to 3-4% uncertainty (M.Baylac thesis).

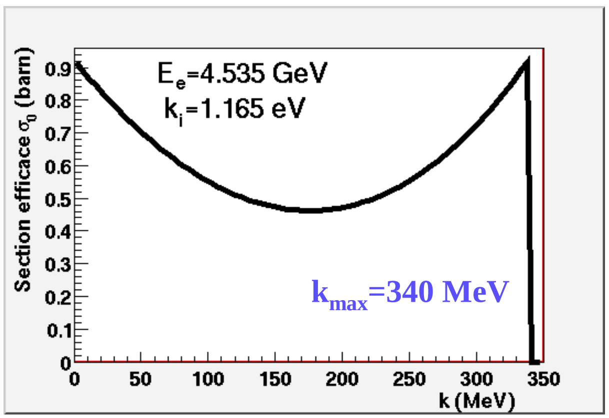
- In 2000, e- detector operational. New analysis method provided high precision measurements at 4.5 GeV (S.Escoffier thesis)

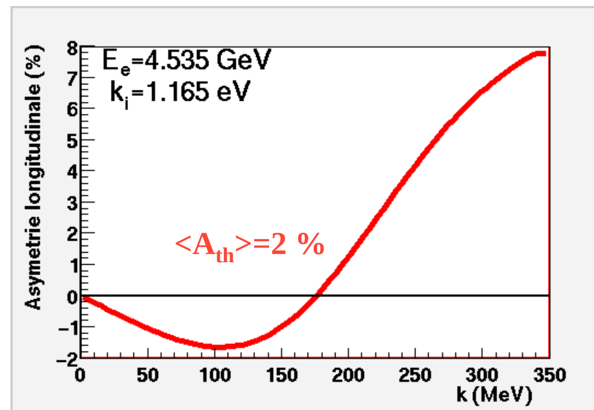
- "Online" analysis using the electron detector available since last year.

Compton kinematics



$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_\gamma \times P_e \times \langle A_{th} \rangle$$

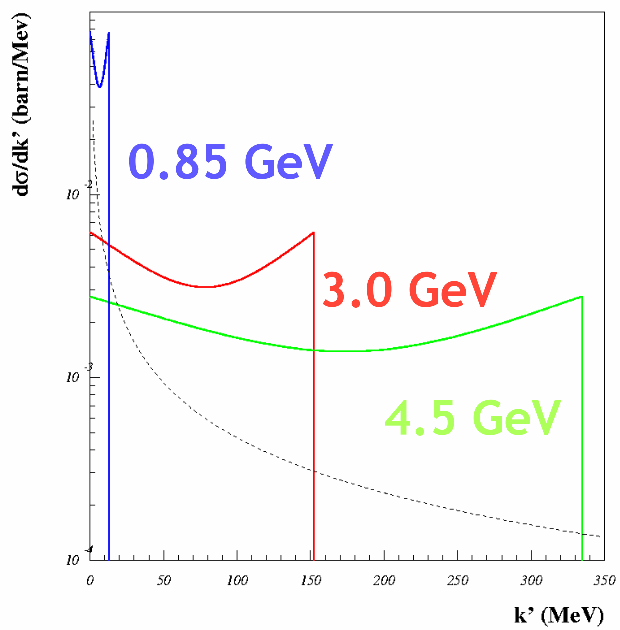




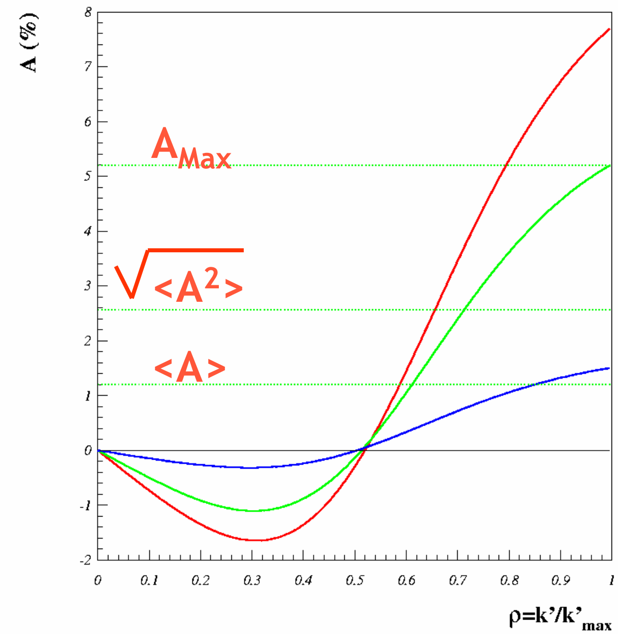
- Differential measurements provide higher <A>
- High threshold can improves stat. convergence

Scaling Laws

σ_{tot} ~ cst



A α k x E

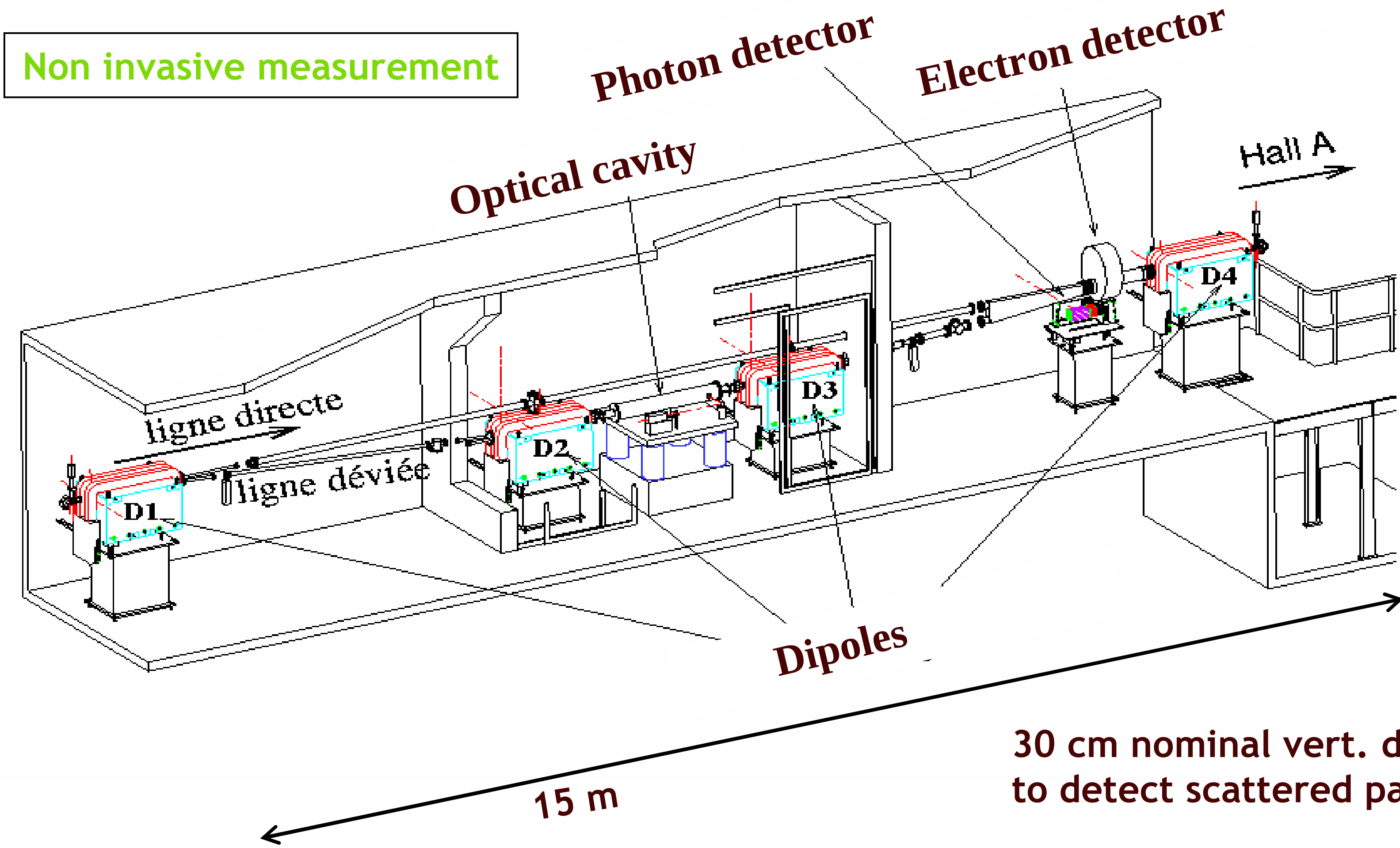


- Run-time for a given stat. accuracy scales with $[\sigma \times A^2]$ or $[k^2 \times E^2]$
- Syst. Error would mostly scale with <A>

➡Figure of Merit strongly depends on k and E.

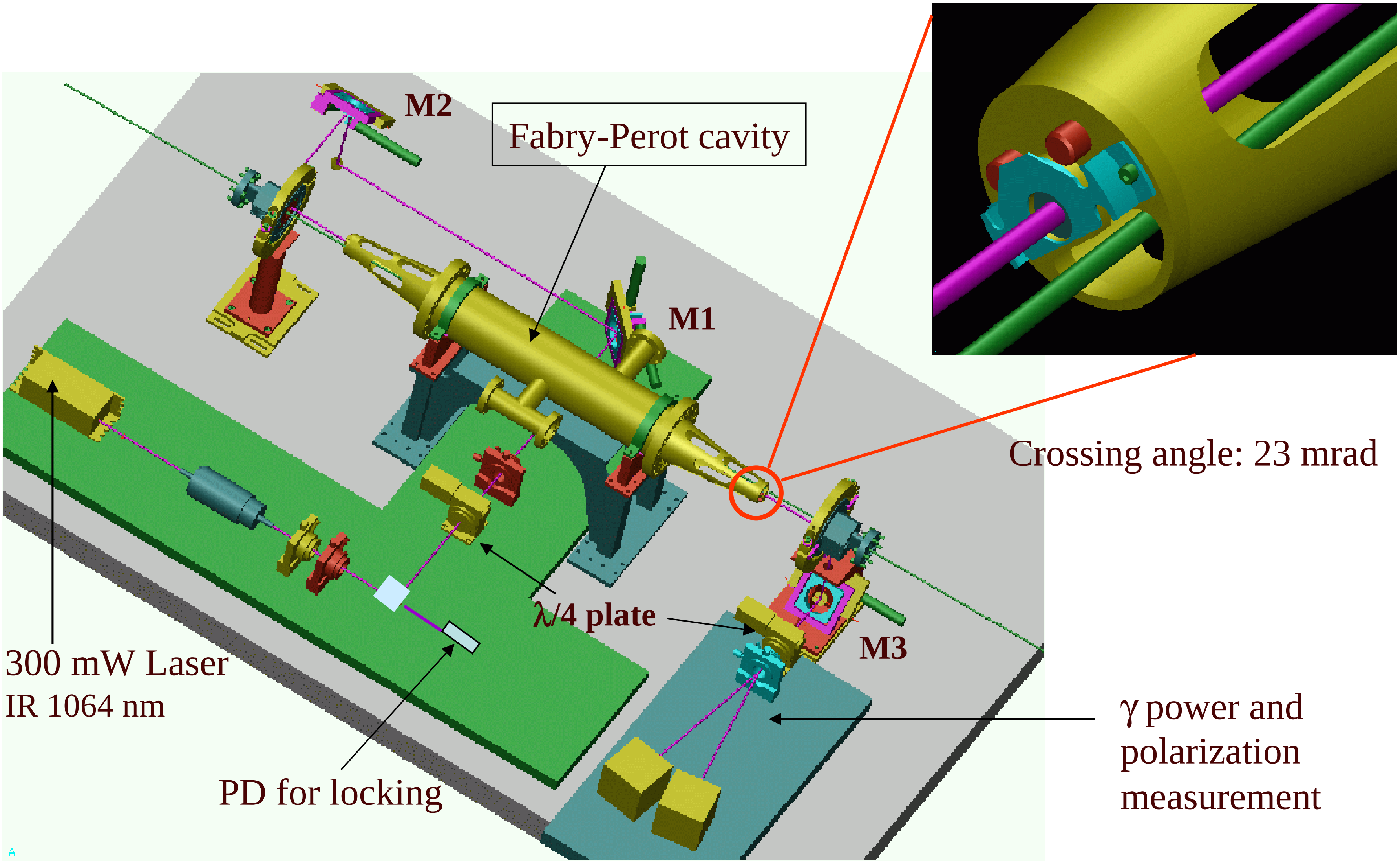
Compton Polarimeter setup

Non invasive measurement

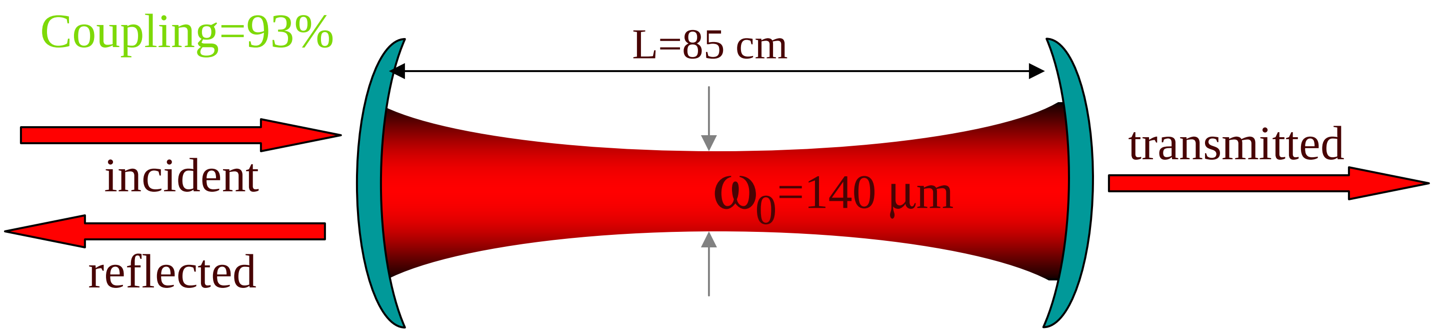


30 cm nominal vert. deviation to detect scattered particles.

Optical setup

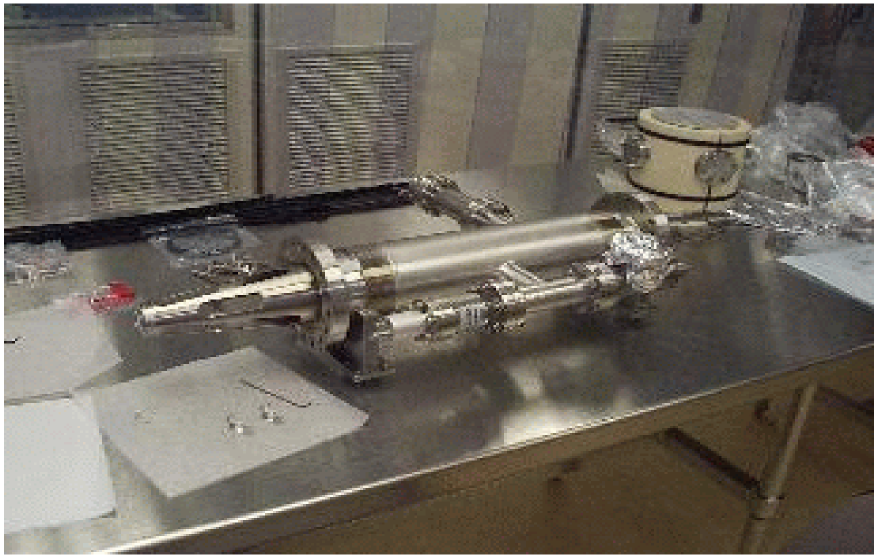


The Fabry-Perot cavity

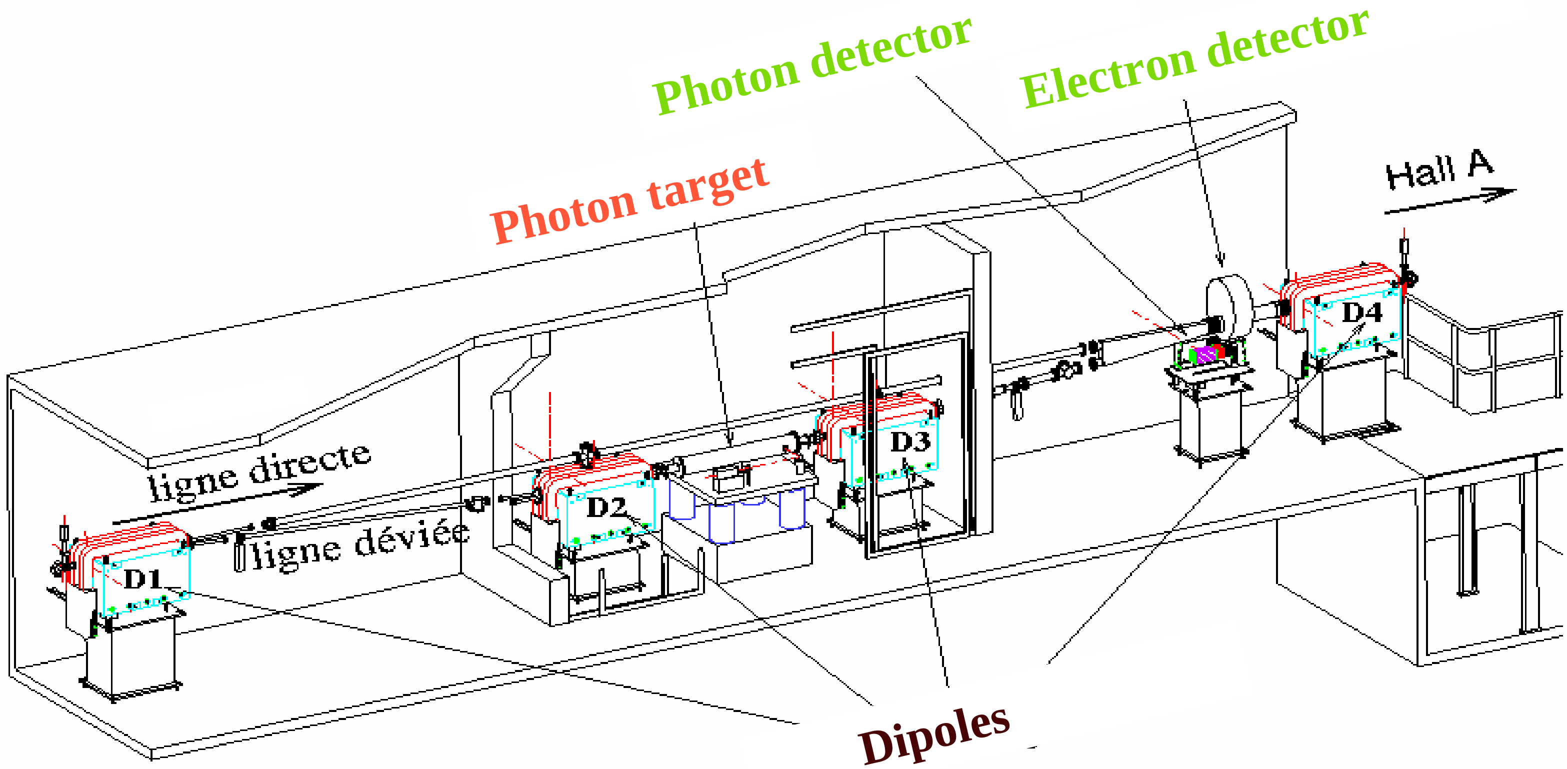


High quality mirrors:
ϕ=5 mm, R_c=0.5 m
T=110 ppm, L=10 ppm
$\varphi_r = 10^{-6}$ rad

Gain ≈ 7000
P_{cav}=1500 Watt
Polarization: 99.6%

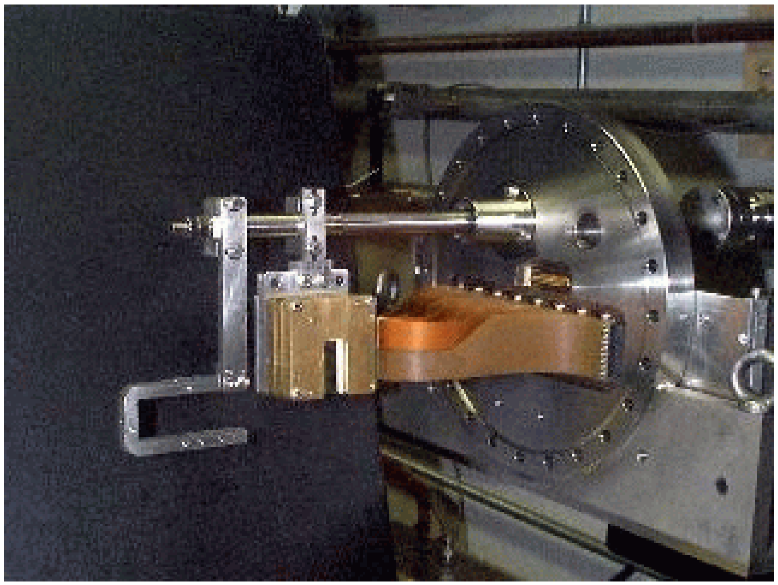


Compton Polarimeter setup



-> e^- and γ detection

Electron detector



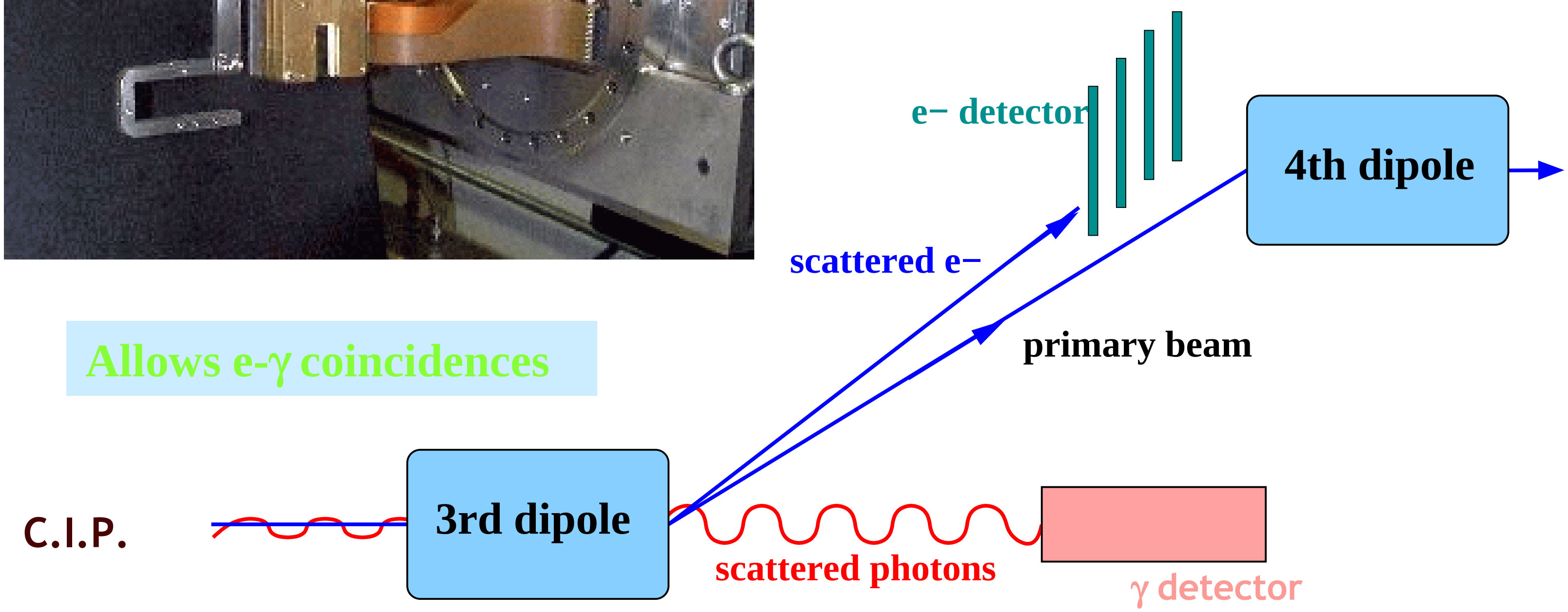
4 planes of 48 silicon strips

-Width : 650 µm

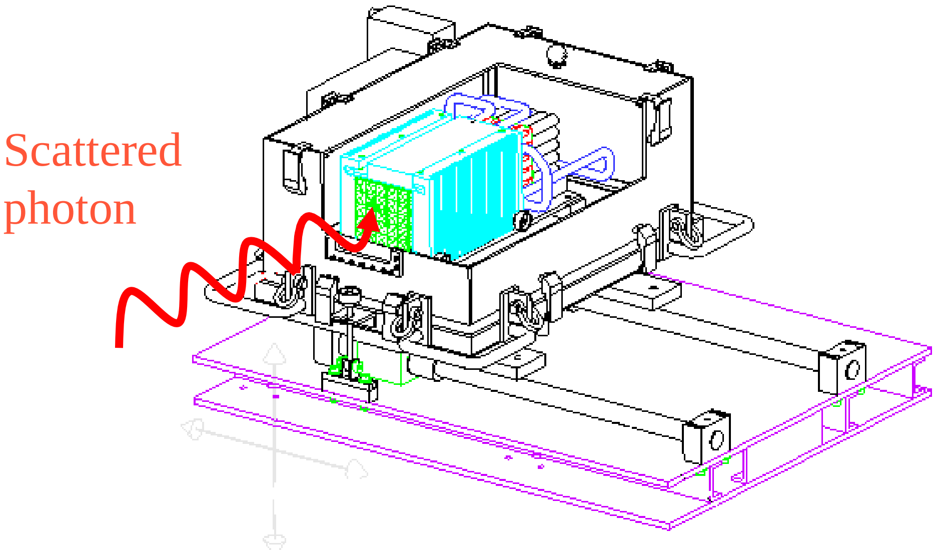
-Energy range for 1 strip:

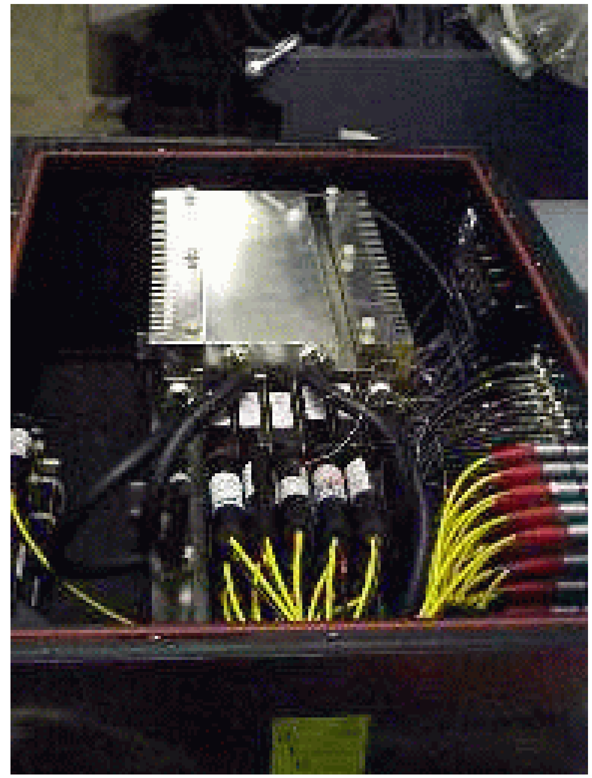
~ 0.13% of E_{beam}

Allows e-γ coincidences



Photon calorimeter





25 $PbWO_4$ scintillators (2x2x23 cm^3)

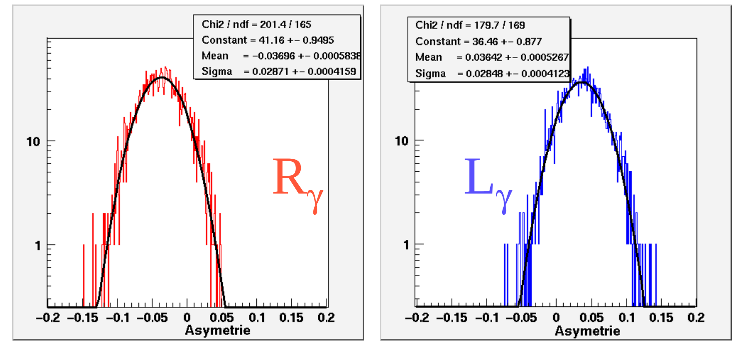
- *Fast response*
- *Compact (χ_0=0.85cm, R_M=2.2cm)*
- *Rad hard*

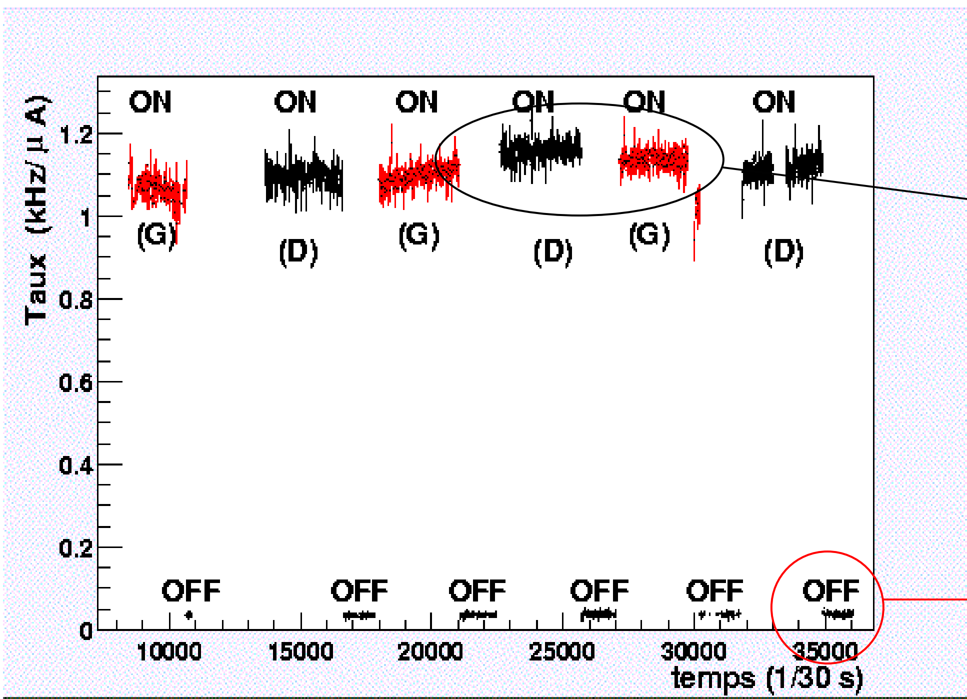
So far, used only the central crystal of the 5 x 5 matrix

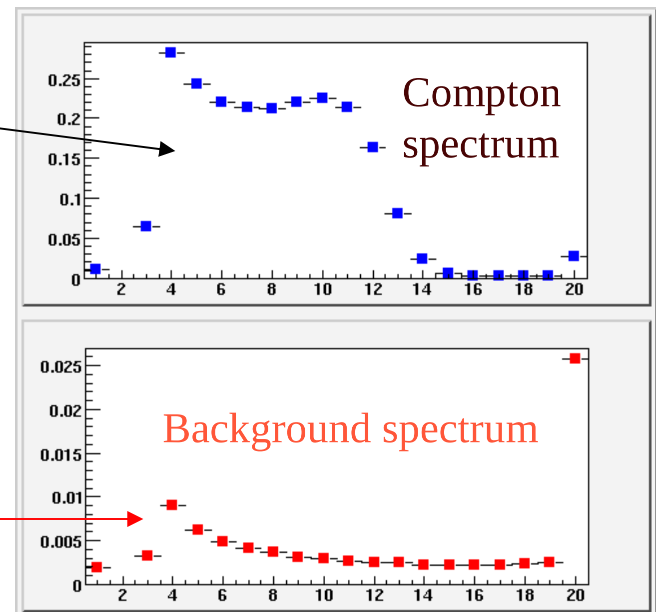
Data taking

Control of the syst. from e- beam:

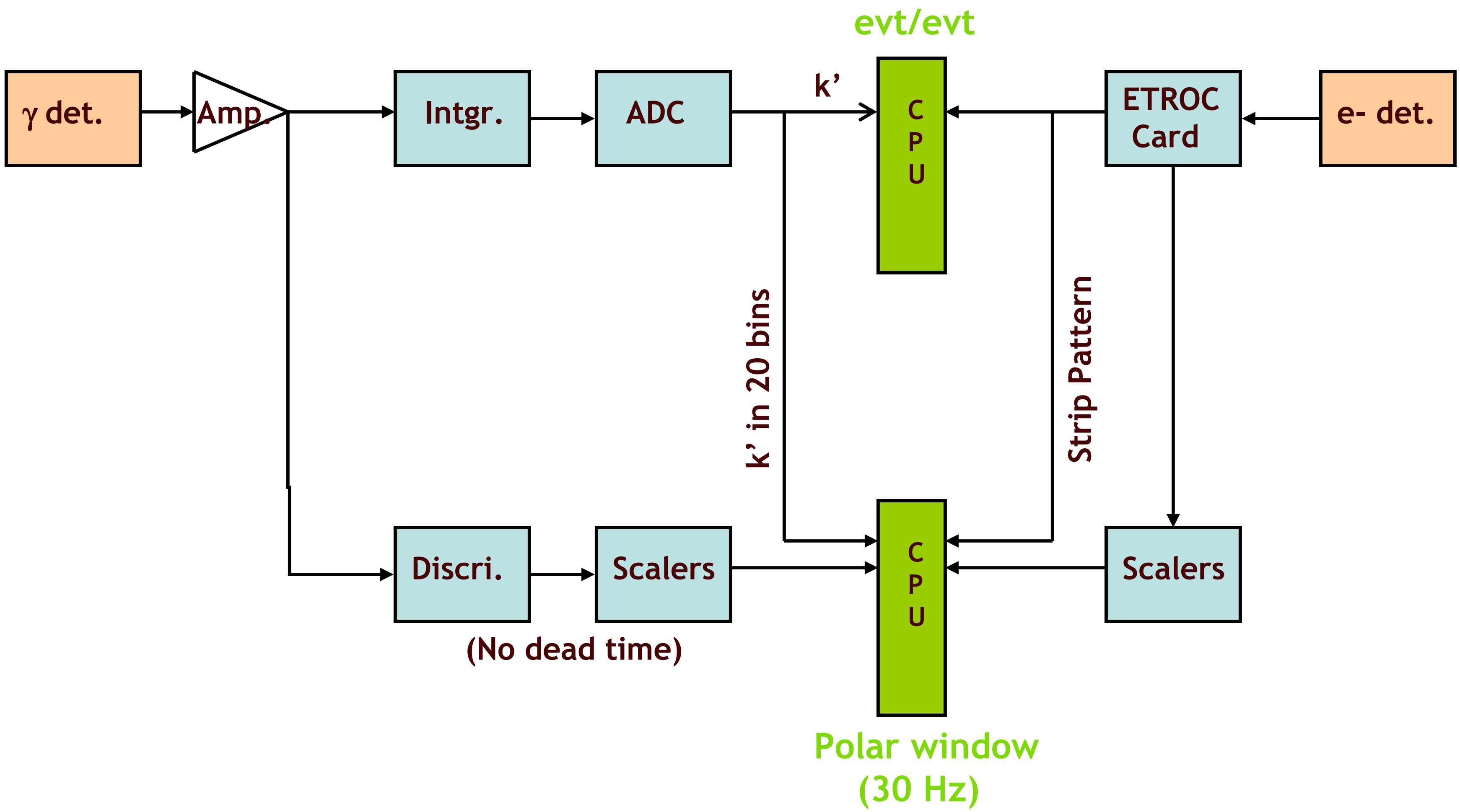
- Laser ON/OFF periods
- Photon polarization reversal







Data Acquisition

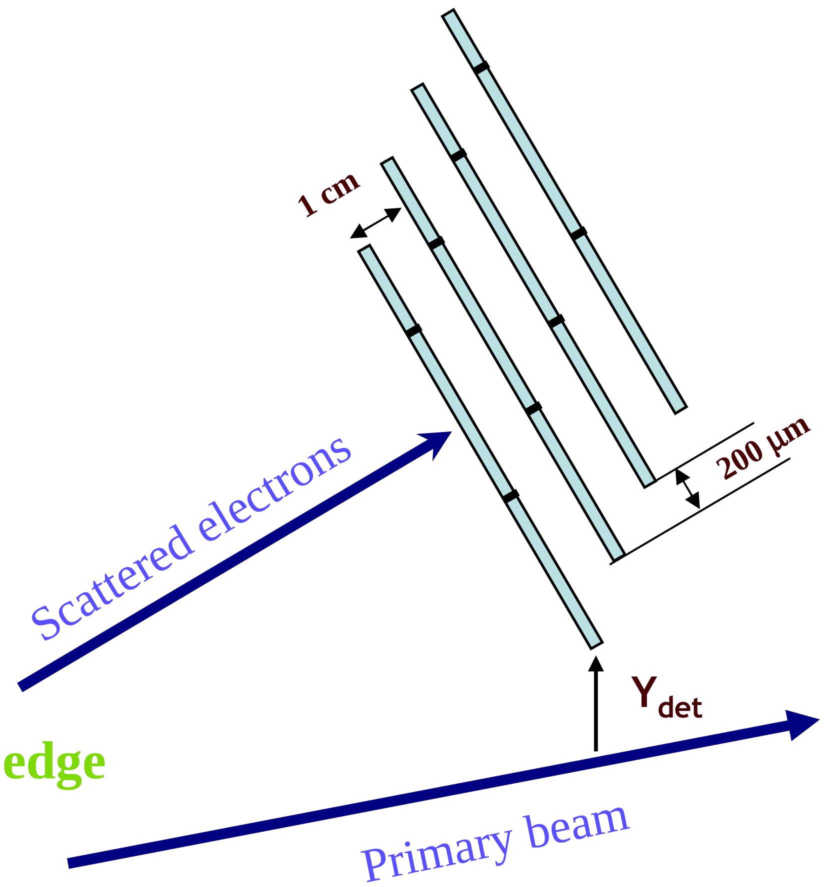


Electron only analysis

Differential measurement

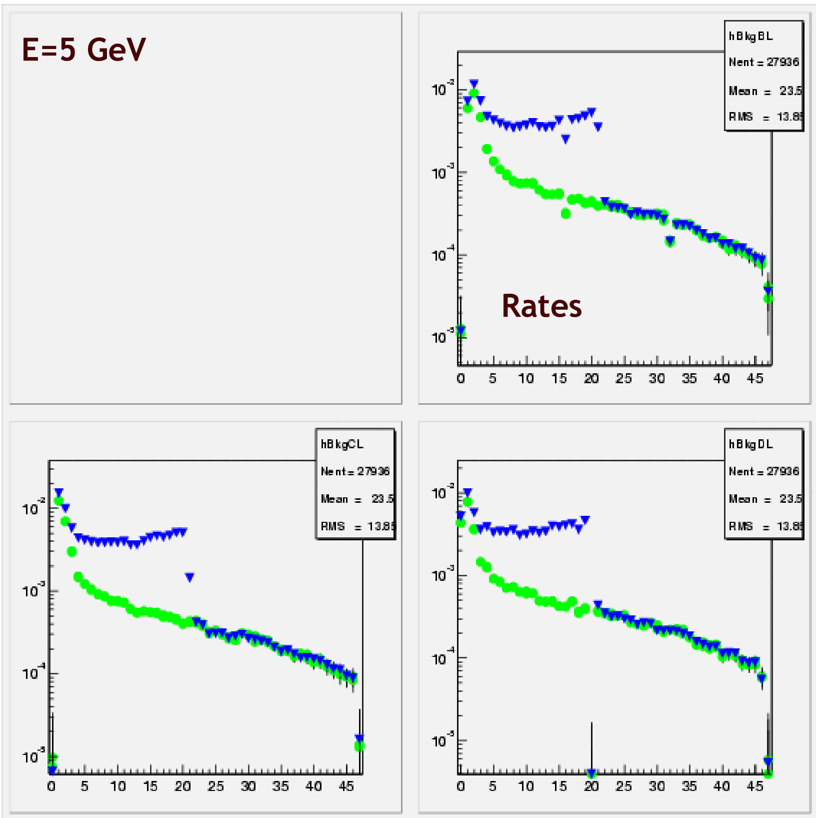
$$A_{\exp}^{i} = P_{\gamma} \times P_{e}^{i} < A_{L}^{i} >$$

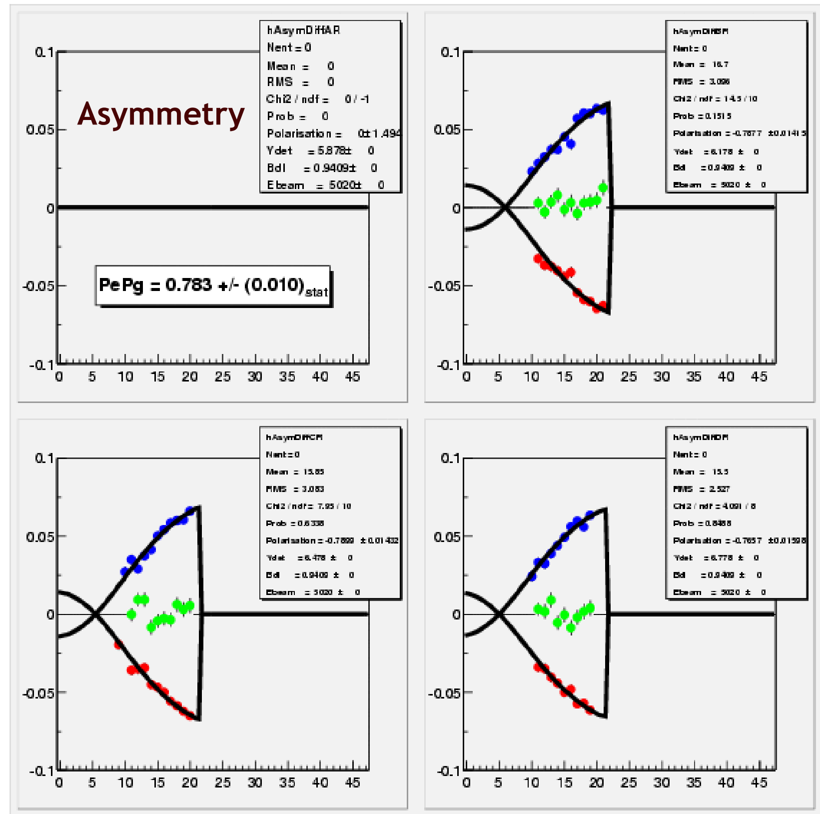
$$< A_L >_i = \frac{\int_{E_i^{\min}}^{E_i^{\max}} \frac{d\sigma_0(E_i)}{dE_i} A_L(E_i) dE_i}{\int_{E_i^{\min}}^{E_i^{\max}} \frac{d\sigma_0(E_i)}{dE_i} dE_i}$$



-Energy calibration from Compton edge
-Good resolution and efficiency

Electron only analysis



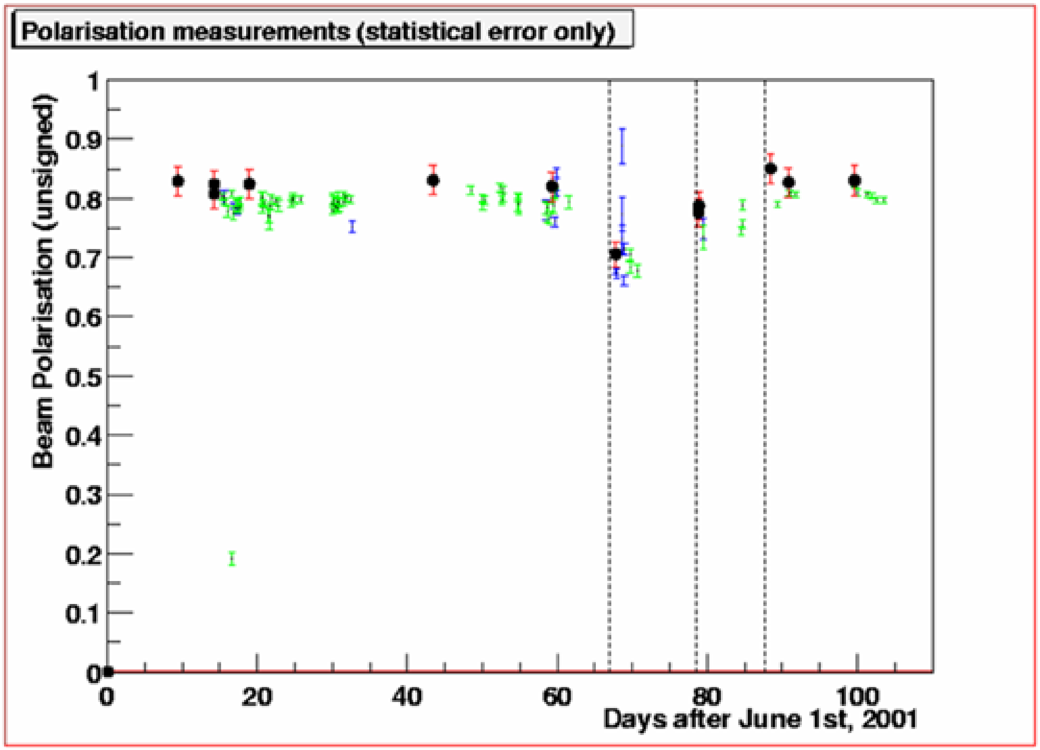


Electron only analysis

- Y_{det} ⇔ energy cut (E>2.5 GeV)
- Simple and fast analysis implemented "online"
- Main syst. error from calibration:
  $\Delta P_e/P_e \sim 2\ \Delta Y/Y$ with $\Delta Y=+/-100\ \mu m$
  limited by strip size, detector orientation and beam size.

E_{Beam} (GeV)	k'_{Max} (MeV)	A_{Max} (%)	Y_{Max} (mm)	$\Delta P_e/P_e$ (%) (for $\Delta Y=+/-150\ \mu m$)
0.85	12.7	1.5	3.5	8.6
1.00	17.6	1.8	4.2	7.1
2.00	69.1	3.5	8.4	3.6
3.20	173	5.6	13.4	2.2
6.00	582	10.2	25.1	1.2

A1n & g2 experiments



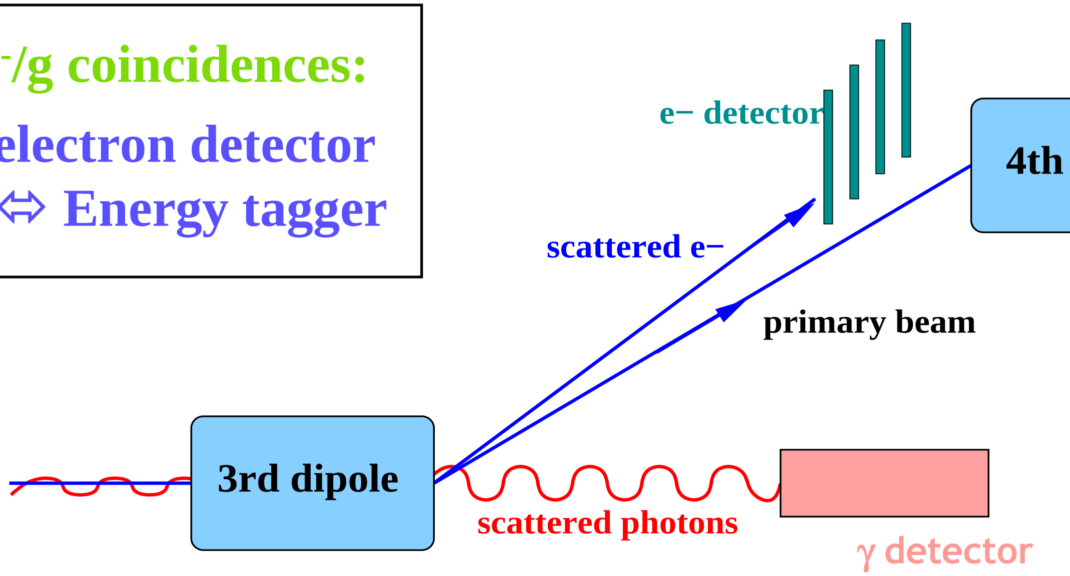
Compton is ~4% lower than hall A Moller

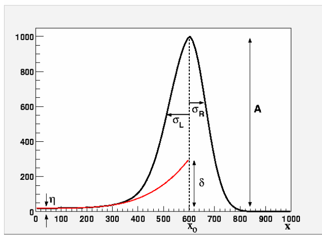
“Response Function” analysis

(S. Escoffier)

e⁻/g coincidences:

electron detector
⇔ Energy tagger



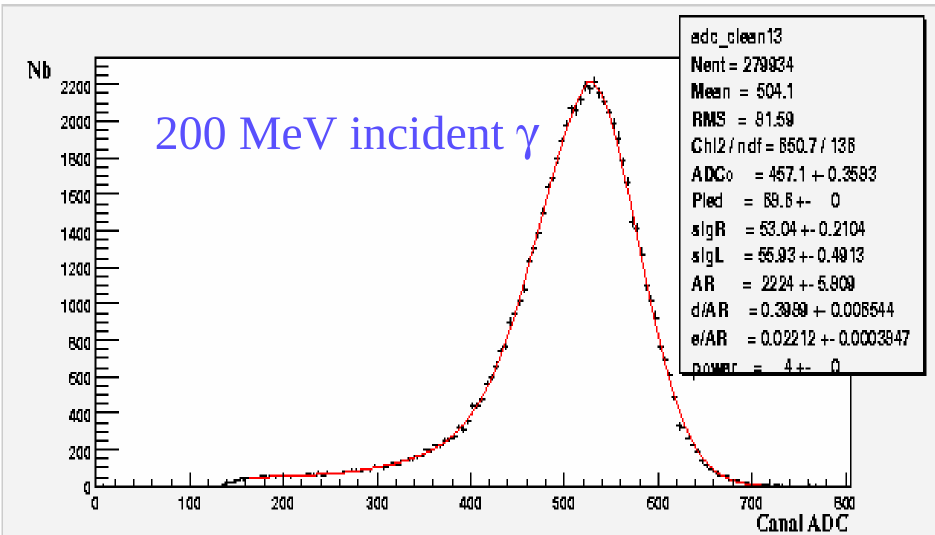


➡ semi-integrated measurement using photon events above an optimized threshold.

"Response Function" analysis

Response function of the calorimeter:

Fit data for each electron strip:



- **Asymmetric profile due to energy leakage on the sides of the central crystal**
- **Ad hoc parameterization**

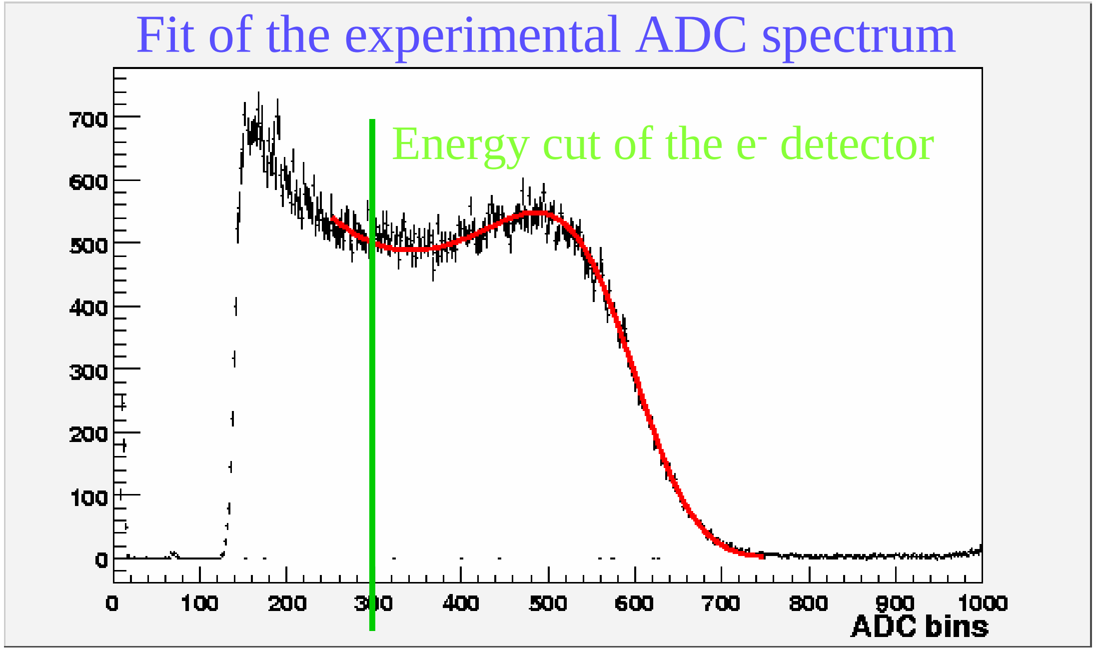
$$g_R(x) = A e^{-\frac{(x-x_0)^2}{2\sigma_R^2}}$$

$$g_L(x) = A\left[(1-\delta)e^{-\frac{(x-x_0)^2}{2\sigma_L^2}} + \eta + (\delta-\eta)\frac{x^4}{x_0^4}\right]$$

➡ **Normalized response function : g(ADC,k)**

"Response Function" analysis

Energy calibration:



$$\frac{d\sigma(ADC)}{dADC} = \int_0^{k\max} \frac{d\sigma_0(k)}{dk} g(ADC,k)dk$$

Good agreement with experimental spectrum

➔Reference runs + λ parameter fit to correct for gain drifts:

$$g(ADC,k) \Rightarrow g(ADC/_{\lambda},k)$$

"Response Function" analysis

Determination of the analyzing power $<A_{th}>$:

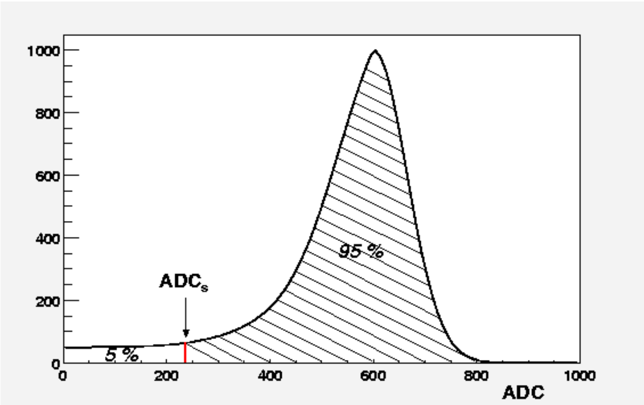
$$< A_{th} >= \frac{\int P(k) \frac{d\sigma_0(k)}{dk} A(k)dk}{\int P(k) \frac{d\sigma_0(k)}{dk} dk}$$

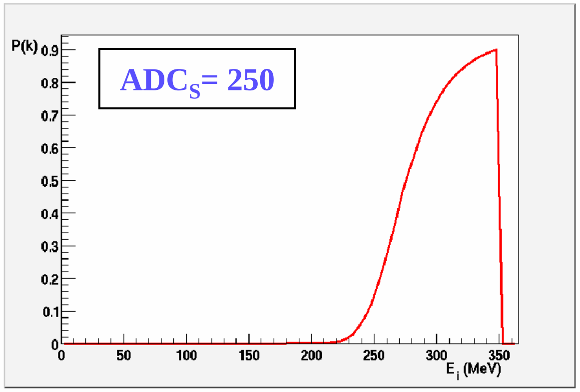
with

$$P(k) = \frac{\int_{ADC_s/\lambda}^{\infty} g(ADC,k)dADC}{\int_0^{\infty} g(ADC,k)dADC}$$

Probability of being detected above threshold ADC_s for incident energy k.

ADC range divided in bins of 50 channels
-> "software" threshold to reduce stat. and syst. errors





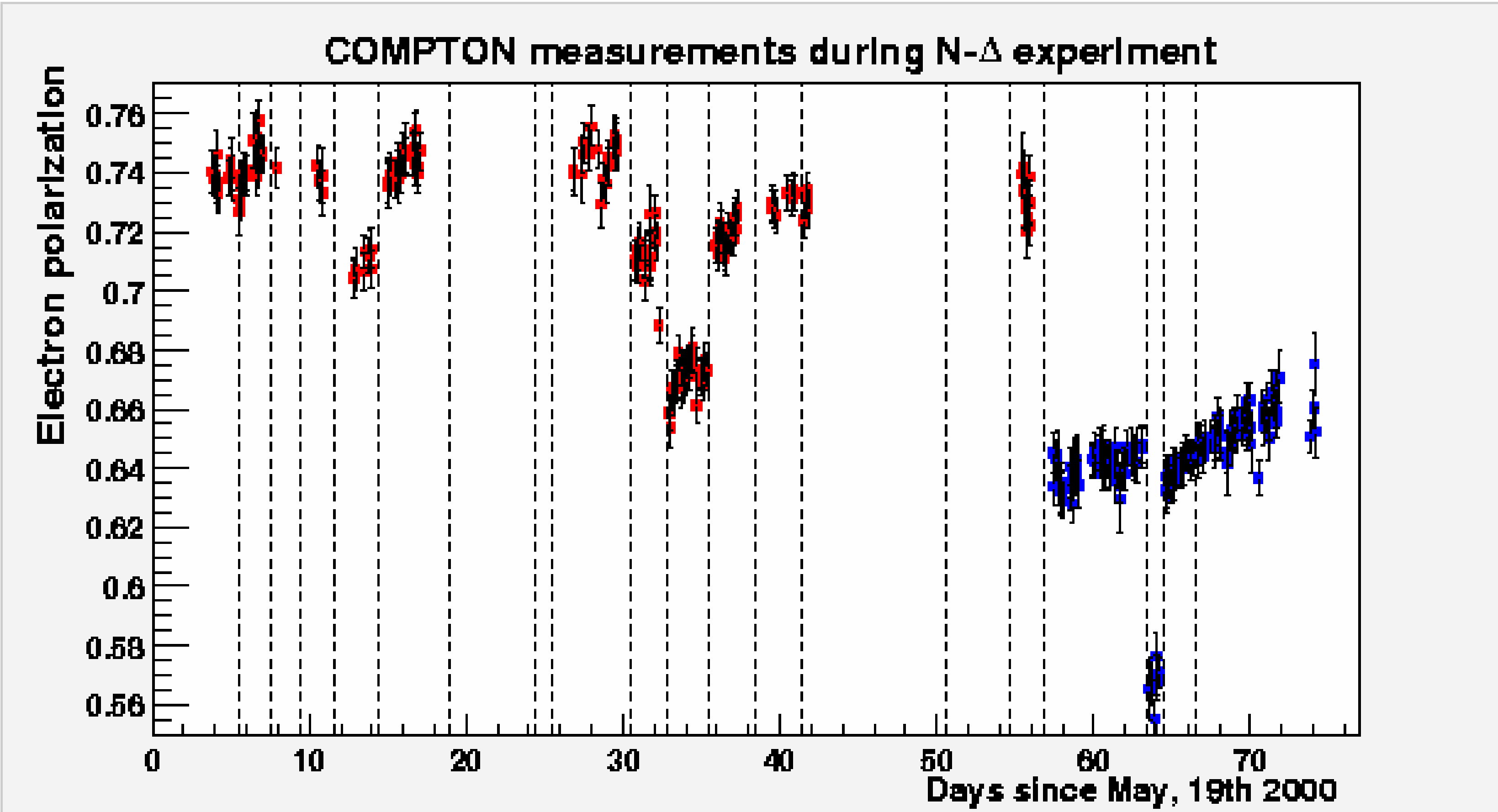
Error budget for N-Delta and GeP

	Error source	Typical run	Correlated	Uncorr.
A_{exp}	Positions and angles	0.45%		0.45%
	Events selections	0.10%		0.10%
	Dead time	0.10%	0.10%	
	Intensity asymmetry	0.05%		0.05%
	Background asymmetry	0.05%	0.05%	
Laser beam	Polarization $P\gamma$	0.45%	0.45%	
Analyzing Power	Parameterization	0.45%	0.45%	
	Calibration	0.60%	0.60%	
	Pile up	0.45%		0.45%
	Radiative corrections	0.26%	0.26%	
Systematics		1.10%	0.84%	0.64%
Statistics (40 mn)		0.80%		0.80%
TOTAL		1.4%		

Measurements during N-Delta

330 measurements within 60 days

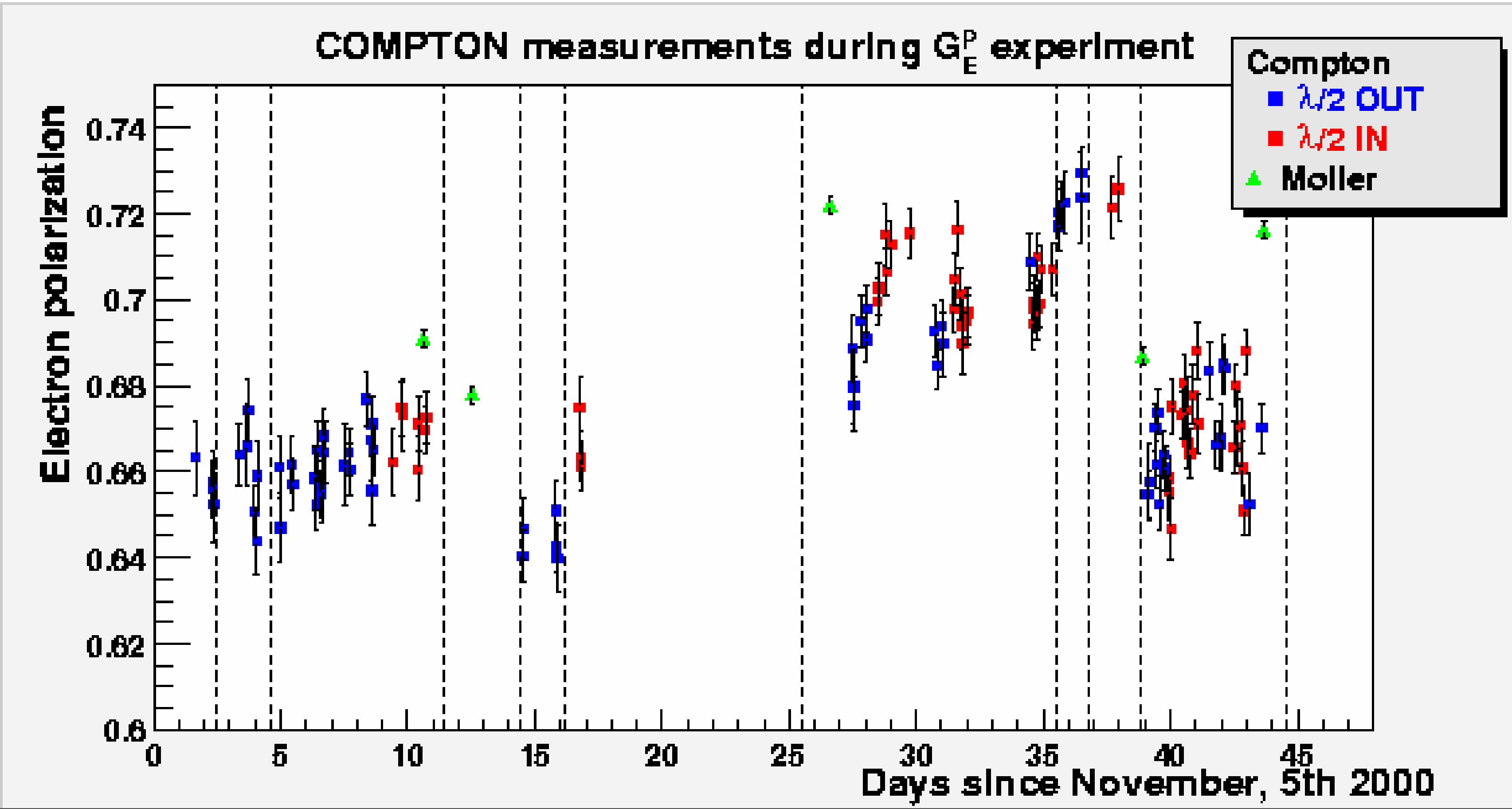
1% relative uncertainty for monitoring



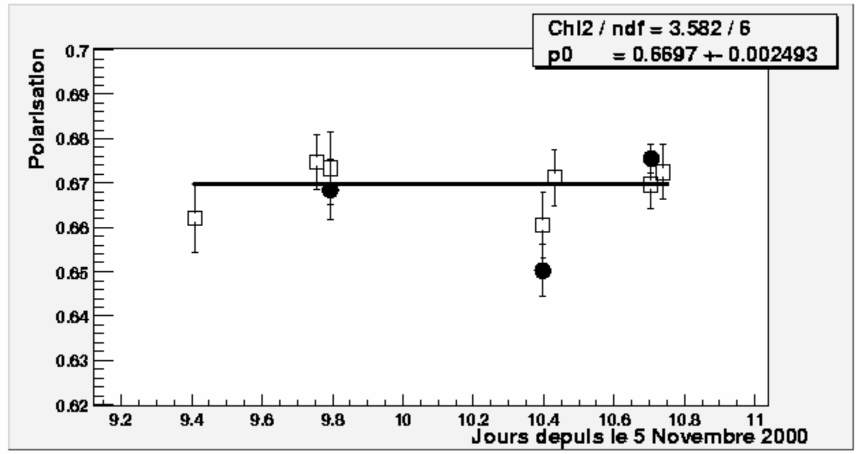
Measurements during GeP

120 measurements within 45 days

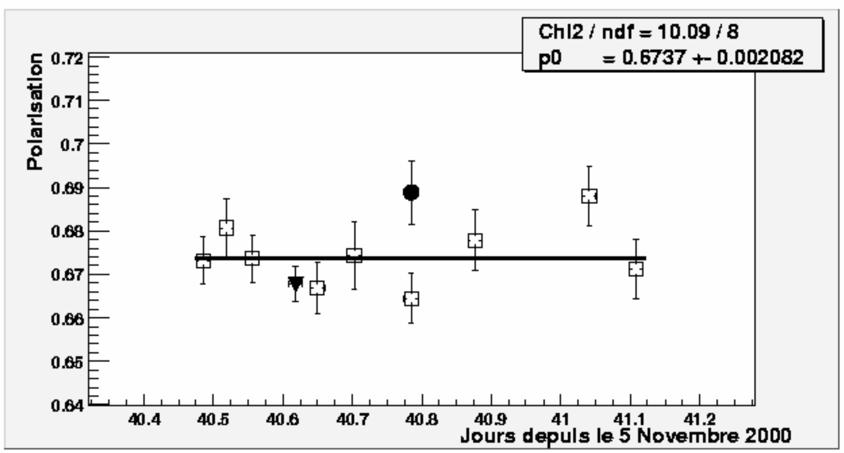
Comparison with Moller

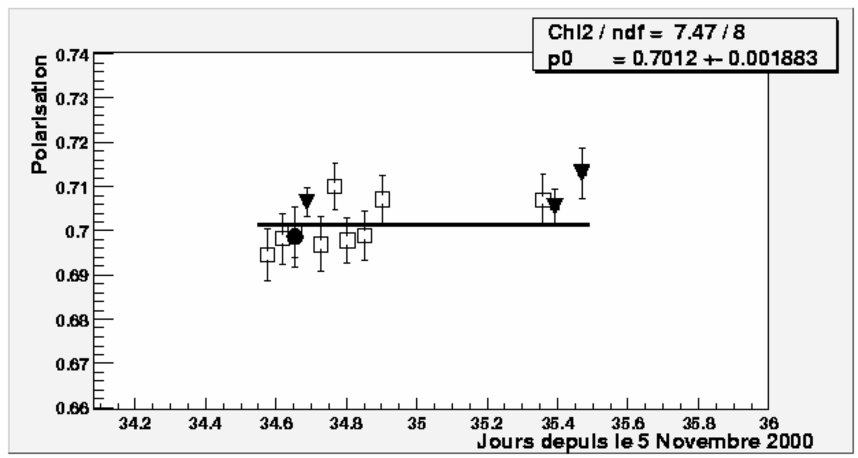


Electron & photon measurements



Statistically compatible

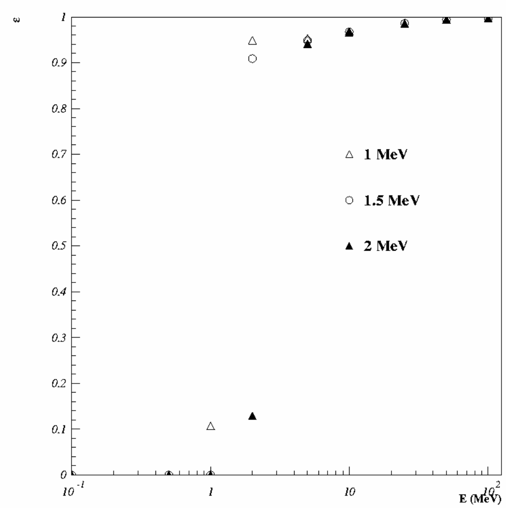




Photon only

Integration method with low threshold

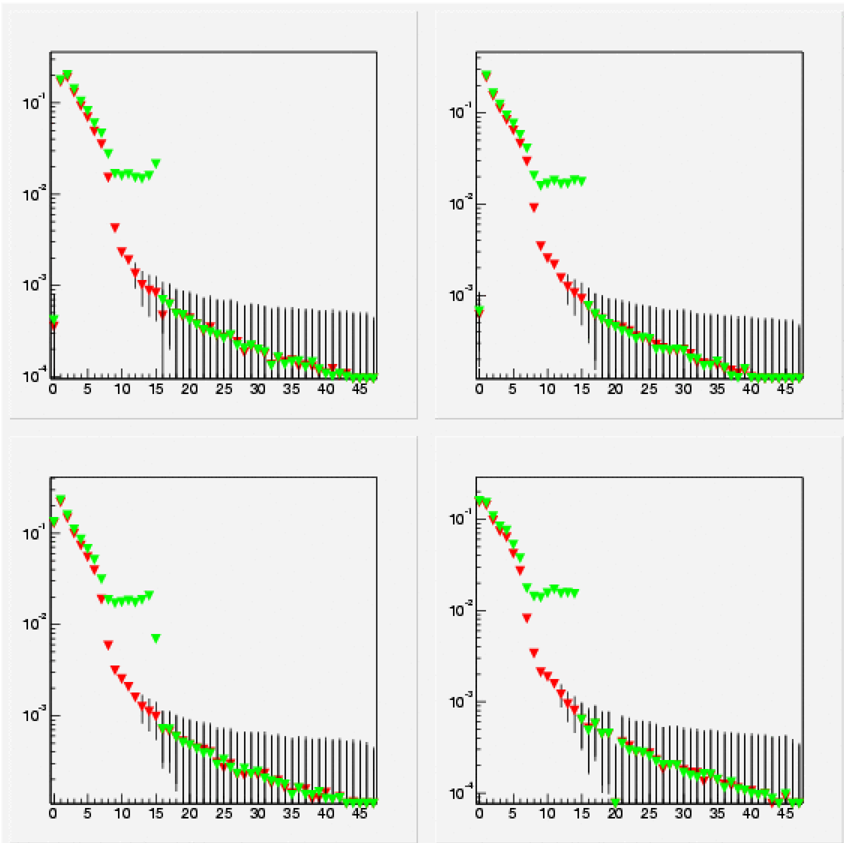
- Not sensitive to calorimeter resolution if thres<<k'_{Max}
- No dead time
- P(k) reduces to detection efficiency



$$< A_{th} >= \frac{\int P(k) \frac{d\sigma_0(k)}{dk} A(k) dk}{\int P(k) \frac{d\sigma_0(k)}{dk} dk}$$

- Difficult for low energy beam: threshold~100 keV and <A> small
- Probably 2-3% measurement at Happex kinematics
- Tests with LSO and BaF2 crystal being analyzed.

Background in detectors



S/B used to be 20 for 2 years but the setup very sensitive to beam halo

- Material close to the beam axis.
- Compton rates are 10^{-10} of beam intensity.

- First results from commissioning of the e- detector 3.5 mm away from beam show a 10^{-9} halo (factor 10 too big).

- Leakage from hall C observed.

- Possible fix:
  - Upstream quad and/or collimator
  - Find key parameter in beam tune?

Status

- Fabry-Perot cavity is operational and stable since 1999
- Powerful monitoring of the beam polarization in the hall A running conditions.
- Typical total uncertainty whithin 40 mn at 4.5 GeV and 40 μA is:

$$\sigma_{Pe}=1.1\ (syst) + 0.8\ (stat)=1.4\%$$

- Two complementary methods **(Electrons and Photons)** statistically compatible.
- Background level an order of magnitude too high over last year.

High Energy

- The “response function” analysis should provide sub-% measurement at 6GeV and above thanks to the large analyzing power

- Calibration of the electron detector can be improved by a factor 2 using narrower strips.

- Magnets limited to 8 GeV. Simpler 12 GeV upgrade is to reduce the vertical dispersion from 30 to 20 cm

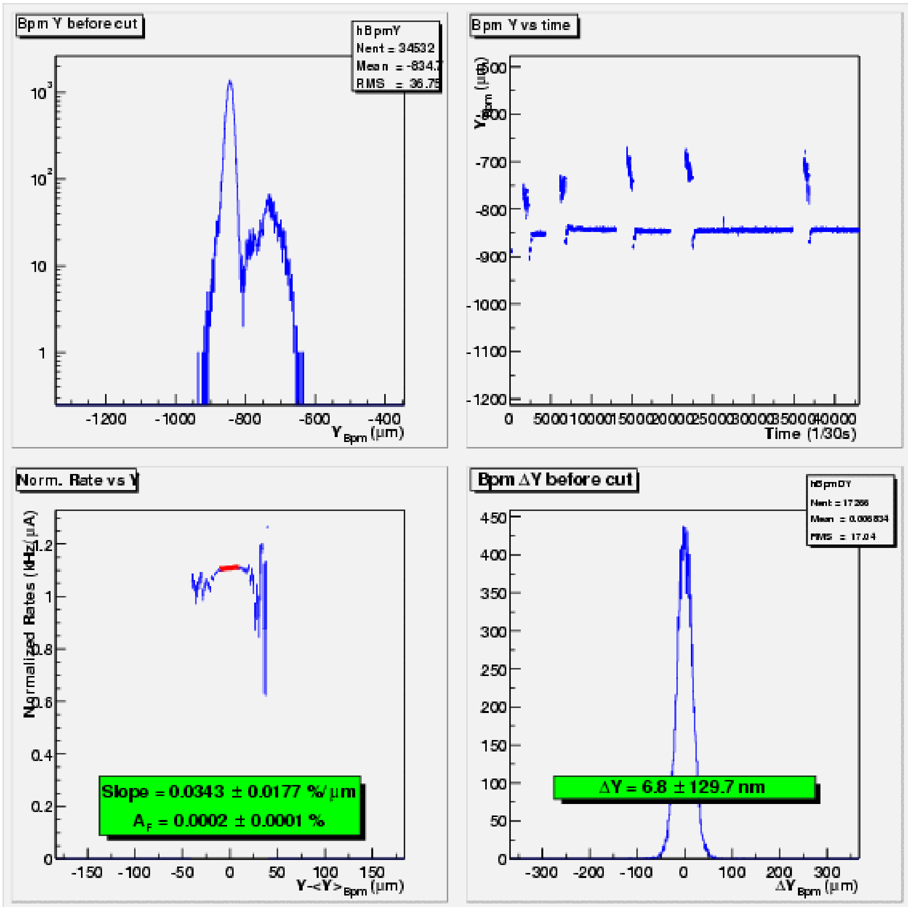
Low Energy

- e^- detector 3.5mm away from the beam is in principle operational down to 0.85 GeV but then very sensitive to beam halo.
- G detector alone is not accurate enough because of the uncertainty on the resolution.
- Integration method need threshold ~100 keV difficult to achieve and control.

➨ **Need several hardware improvements:**

- **Go to green laser (factor 2 in the total error) - Big work!**
- **Use strip of 300 or 200 μm - Easy**
- **Use bigger (~5cm) crystal to minimize leakage - Easy**

Beam position differences



$$A_{Pos} = \frac{1}{N_0} \frac{\delta n}{\delta y} \Delta y$$