The E166 Experiment
Polarised positrons for the ILC

Andreas Schälicke
for the E166 collaboration

POSIPOL 2006, Geneva

Outline

- Proposal
- Helical Undulator
- Compton transmission polarimeter
- Experimental setup
- Preliminary results
- Summary

The E166 Experiment

Proposal:

- Demonstration of polarised positron production with a helical undulator

Status:

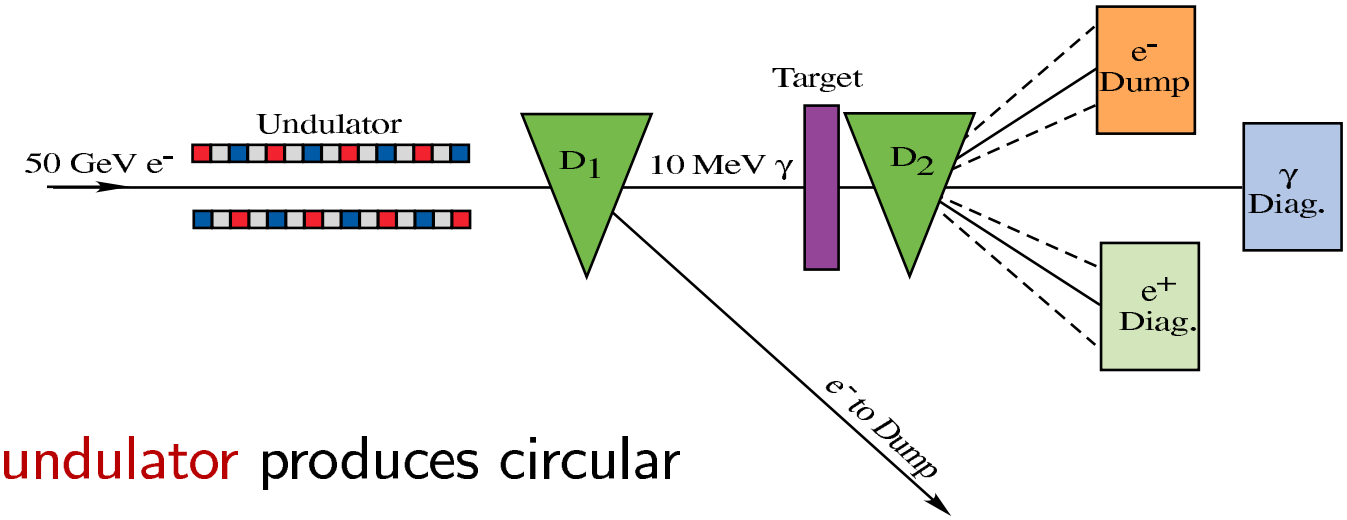
- approved in June 2003
- two runs, June and September 2005
- ≈ 8.5 million events on tape
- analysis is ongoing

Collaboration:

- about 50 people
- 15 institutes
- from 3 continents

G. Alexander *et al.*, 2003, SLAC-PROPOSAL-E-166.

Schematic layout



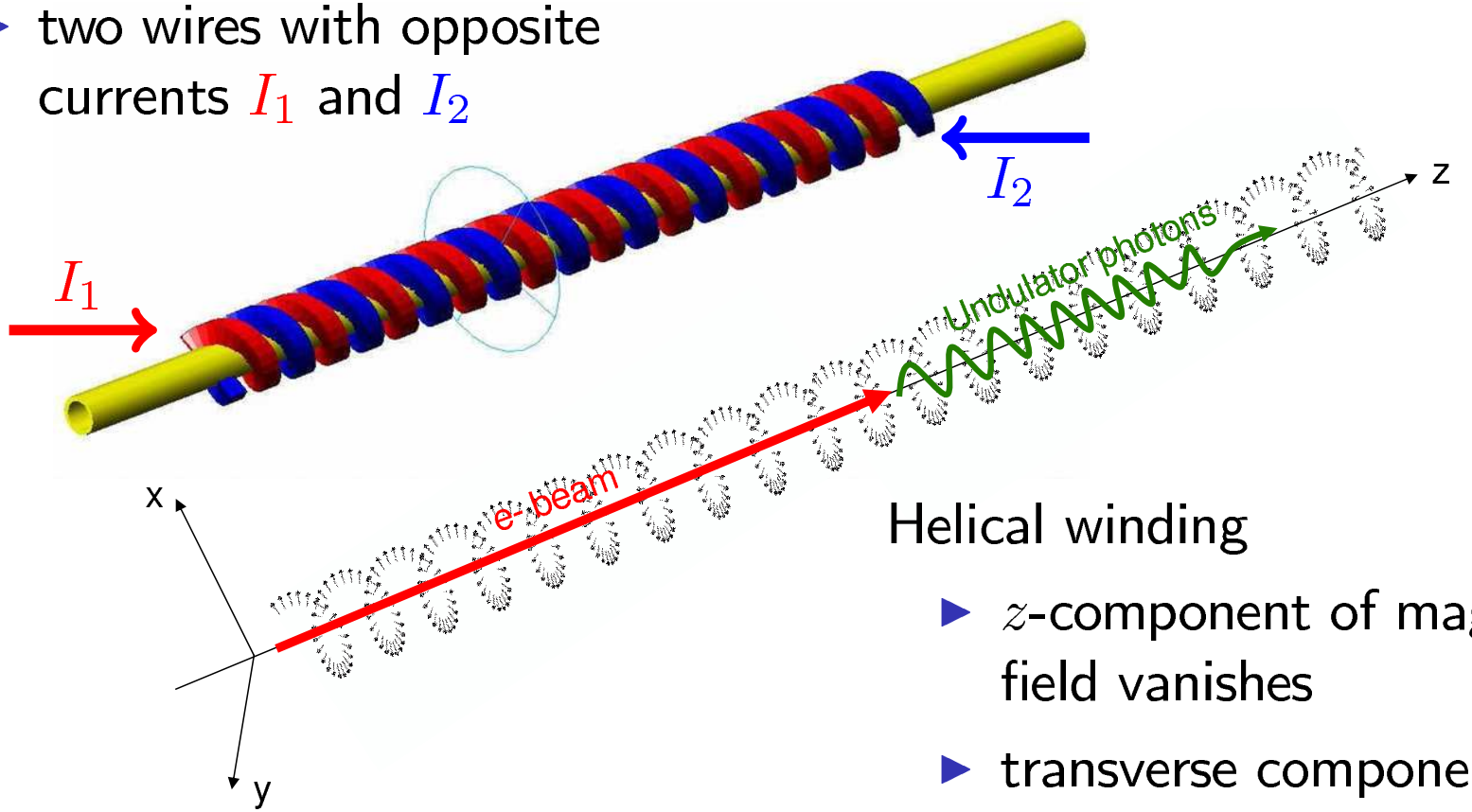
- 1 meter helical undulator produces circular polarised photons
- utilizing 50 GeV electron final focus test beam (FFTB) at SLAC
- photons are converted to positrons in thin W-target
- measurement of photon and positron polarisation by Compton transmission polarimetry

Helical Undulator

Balakin and Michailchenko, BINP 79-85 (1979).

Helical winding

- two wires with opposite currents I_1 and I_2



Helical winding

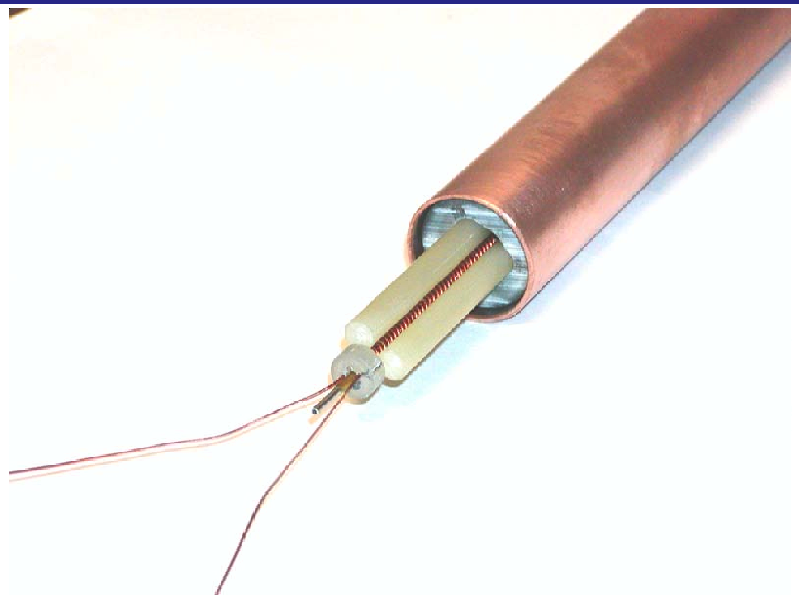
- z-component of magnetic field vanishes
- transverse component $\longrightarrow$ helical profile

Undulator parameter

$$E_\gamma^{\text{cut}} \approx \frac{2\gamma^2 hc}{\lambda_u} \frac{1}{1+K^2}$$

$$K = \frac{2\pi e B_0 \lambda_u}{mc^2}$$

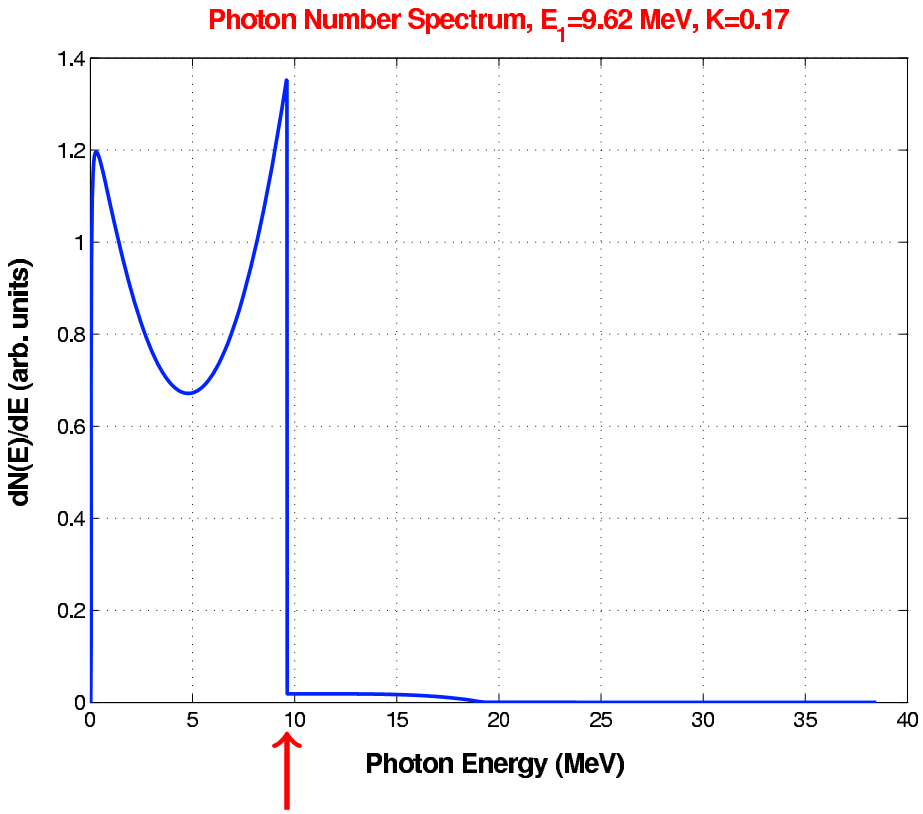
$$\frac{dN}{dL} = \frac{4}{3} \frac{\pi\alpha}{\lambda_u} \frac{K^2}{1+K^2}$$



E166 Undulator

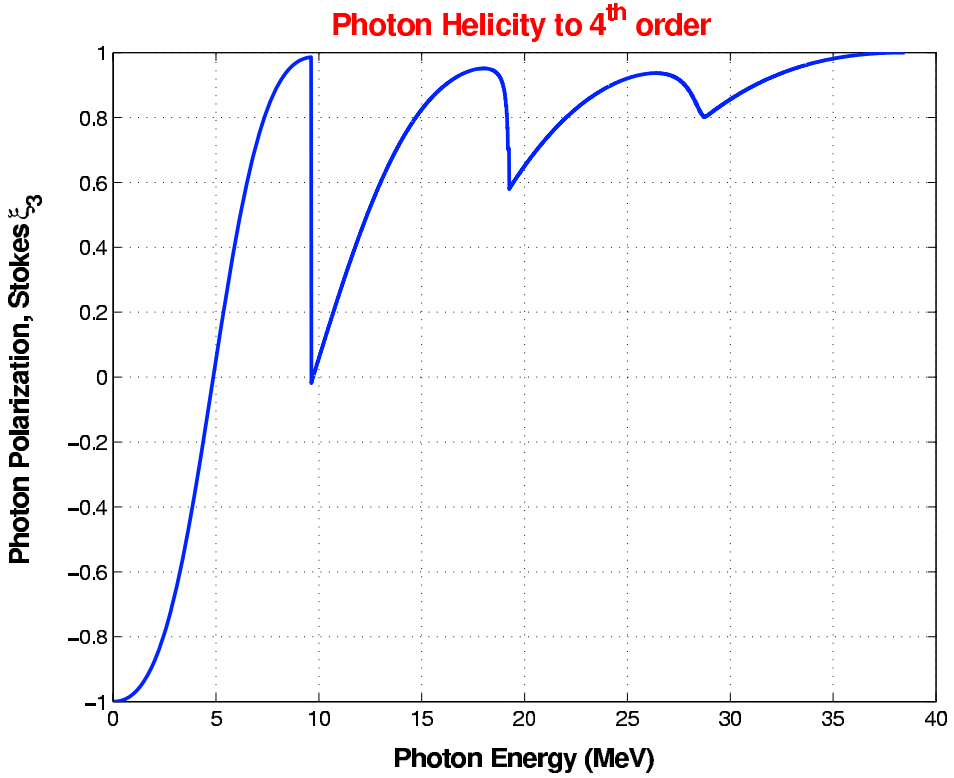
Length L	1.0 m
Period λ_u	2.4 mm
Inner radius r_u	0.9 mm
On-axis field B_0	0.75 T
Current I	2.3 kA
1st harmonic energy	8.3 MeV

Energy spectrum

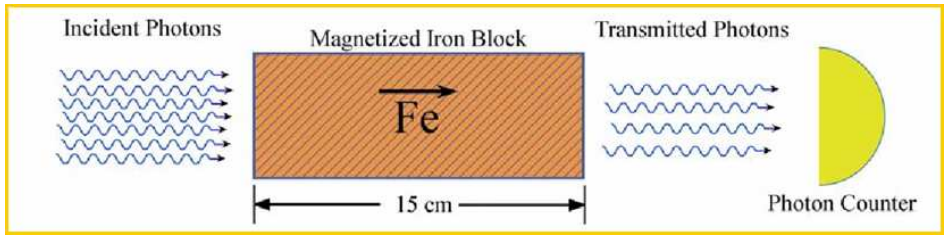


1st Harmonic

Degree of polarisation



Compton transmission polarimetry



$$\sigma_{tot} = \sigma_{phot} + \sigma_{comp} + \sigma_{pair} \quad \text{with} \quad \sigma_{comp} = \sigma_0 + P_\gamma P_e \sigma_{pol}$$

Transmission

$$T^{\pm}(L) = e^{-nL\sigma} = e^{-nL\left(\sigma_{phot}+\sigma_{pair}+\sigma_0\right)} e^{\pm nL P_\gamma P_e \sigma_{pol}}$$

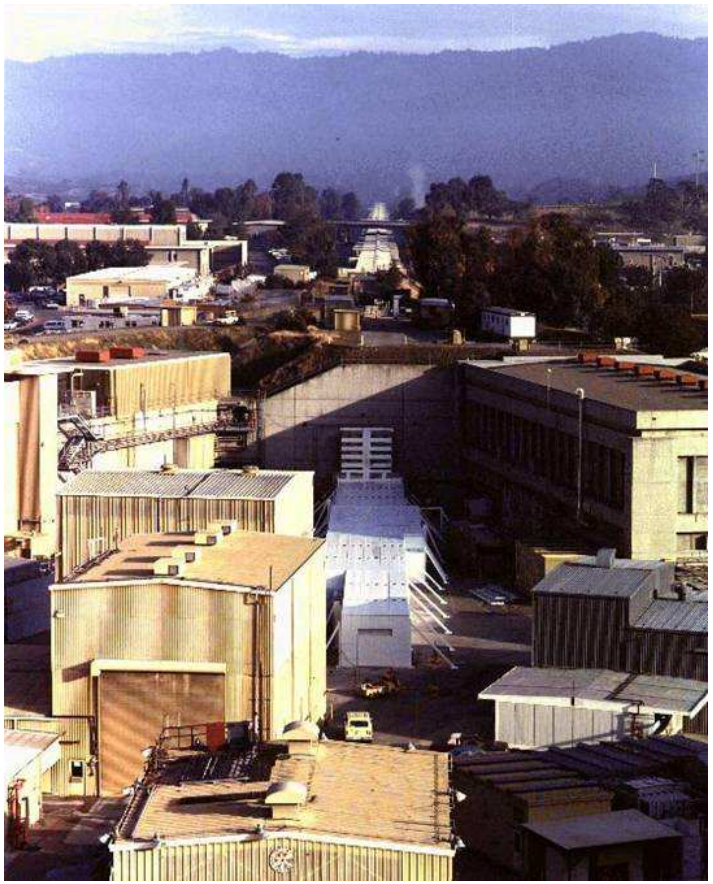
Asymmetry

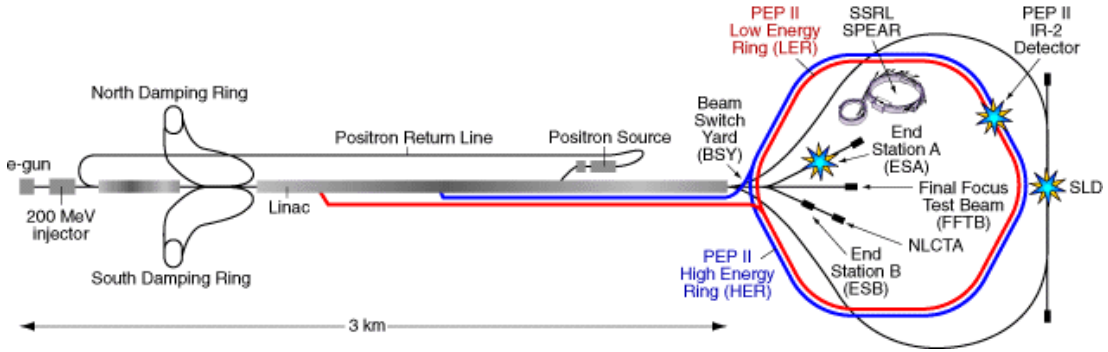
$$\delta(L) = \frac{T^+ - T^-}{T^+ + T^-} \approx nL P_\gamma P_e \sigma_{pol}$$

Photon Polarisation

$$P_\gamma = \frac{\delta}{nL\sigma_{pol}P_e} = \frac{\delta}{A_\gamma P_e} \qquad A_\gamma = \text{Analysing power}$$

SLAC FFTB:

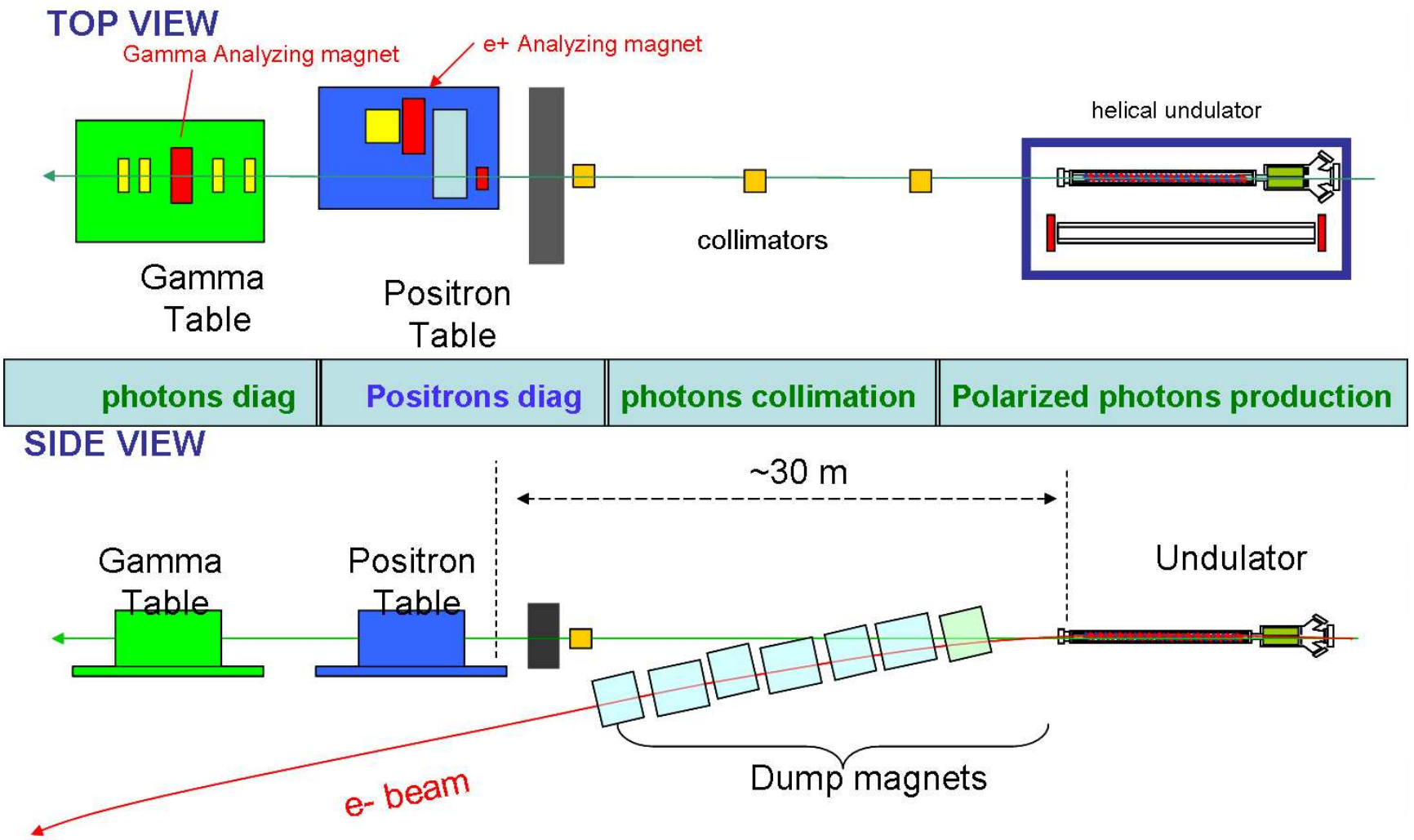




Final Focus Test Beam

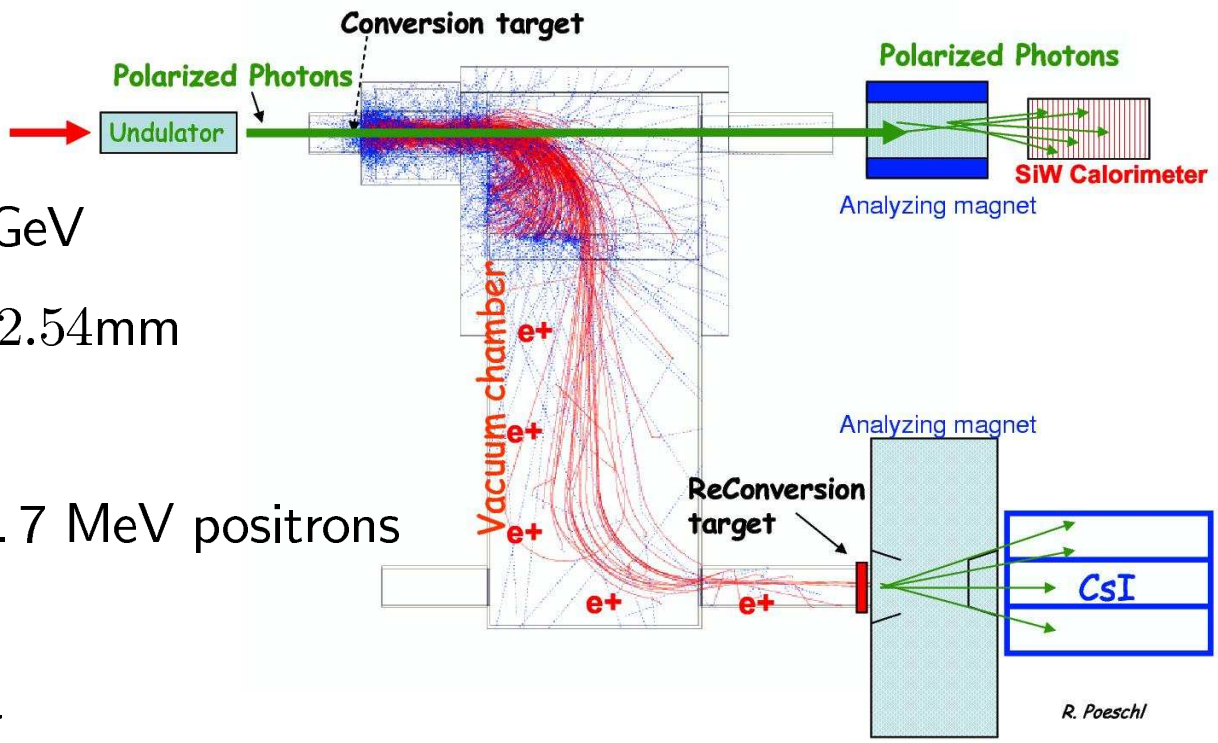
- beam energy $E_{\mathrm{beam}} = 46.6\,GeV$
- electrons/bunch $n_e = 0.5 \cdot 10^{10}$
- beam size $\sigma = 40\,\mu m$
- rep. rate 10Hz

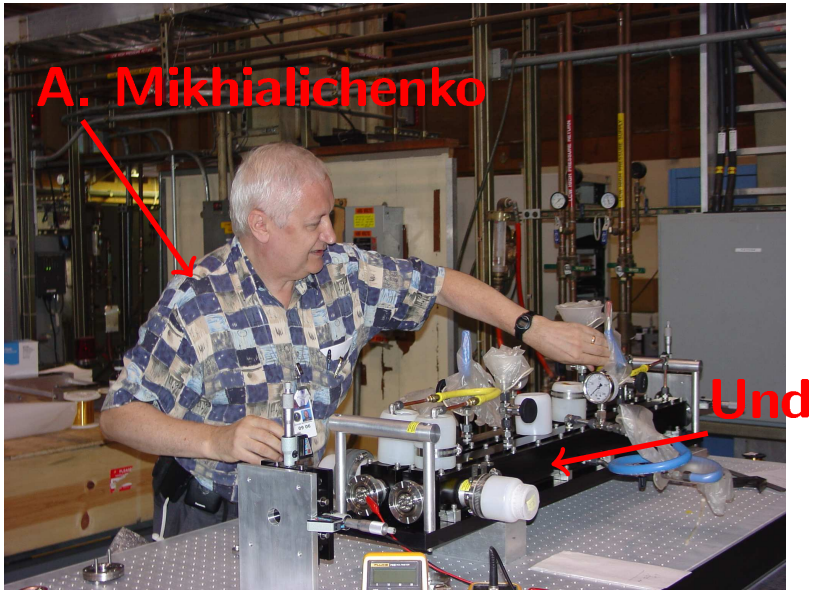
Experimental setup

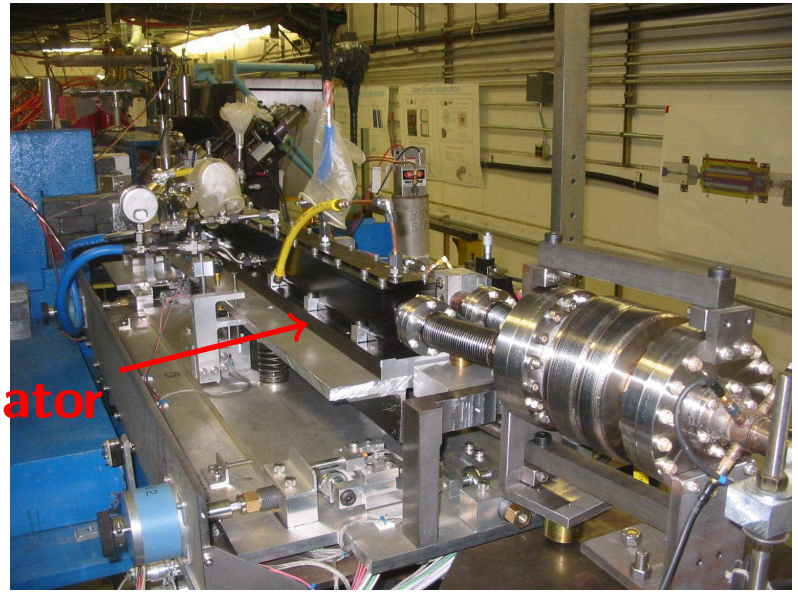


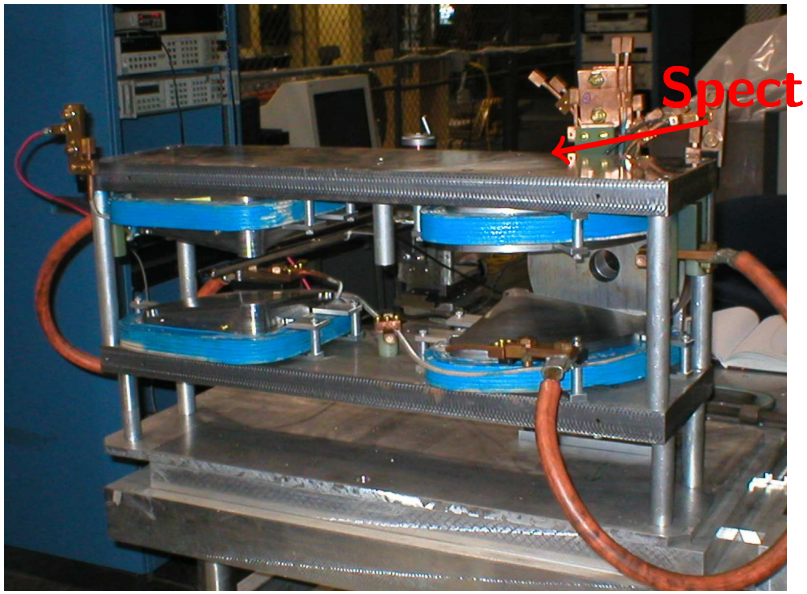
Experimental setup

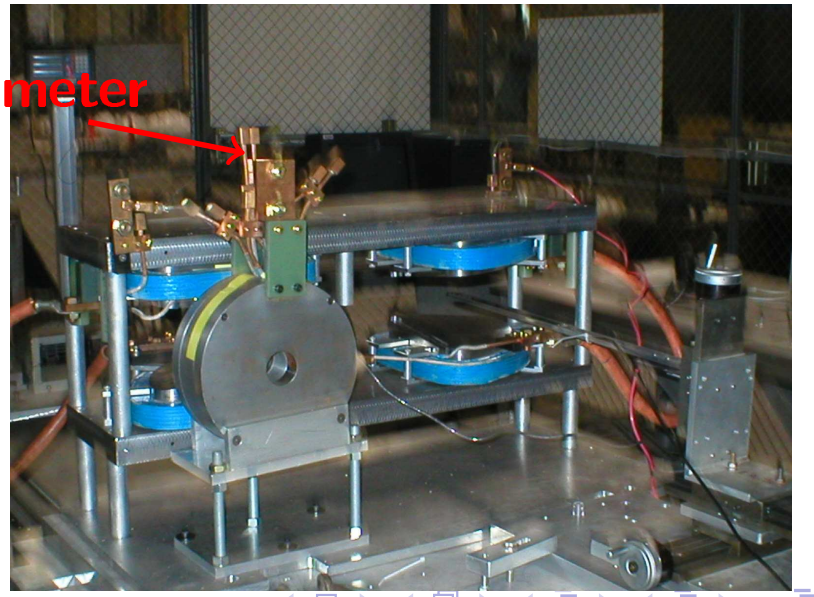
- initial e^- beam at 46.6 GeV
- helical undulator period 2.54mm
- W target $.25\,X_0 \approx 1$mm
- spectrometer selects $3\ldots7$ MeV positrons
- reconversion to photons
- magnetised iron analyser
- CsI calorimeter




A. Mikhialichenko


Undulator


Spectrometer



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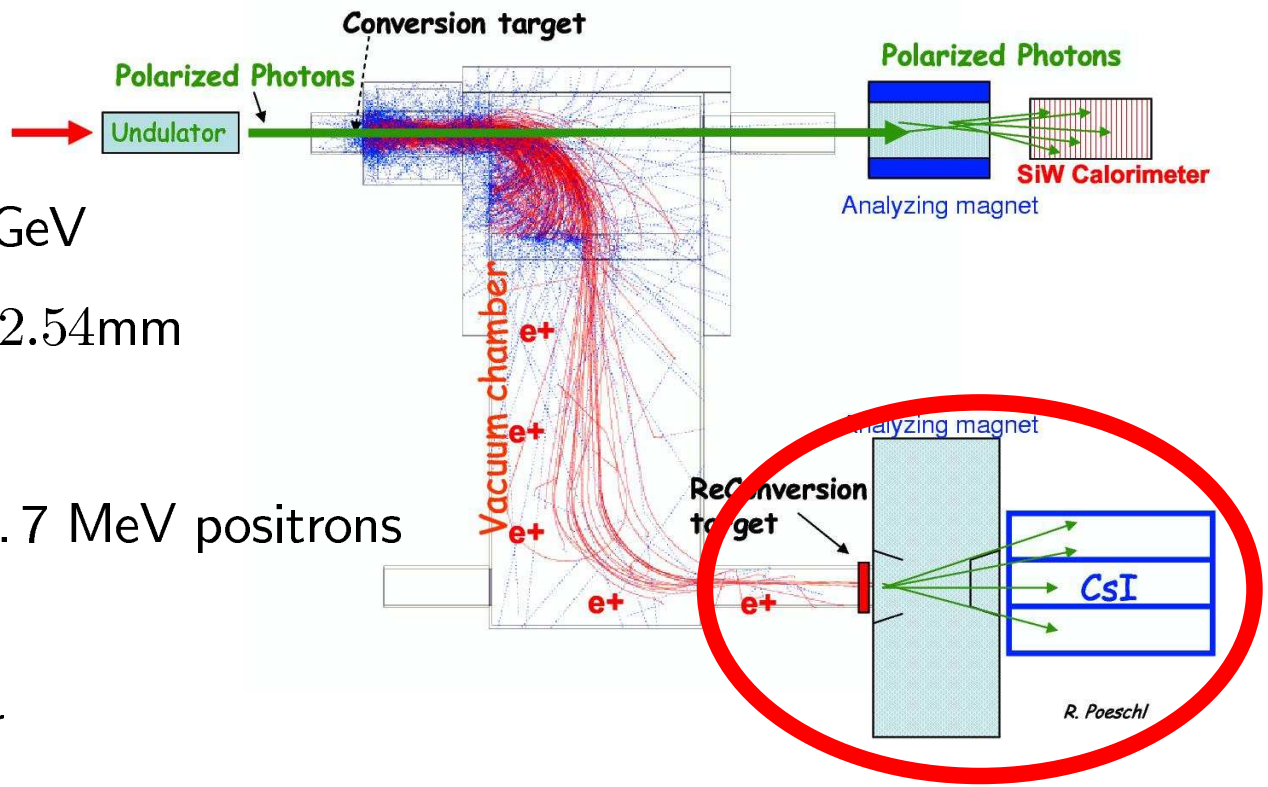
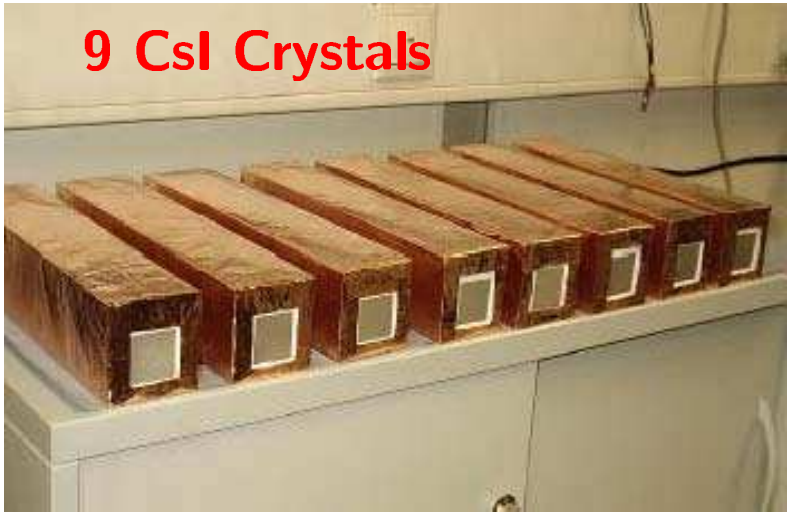
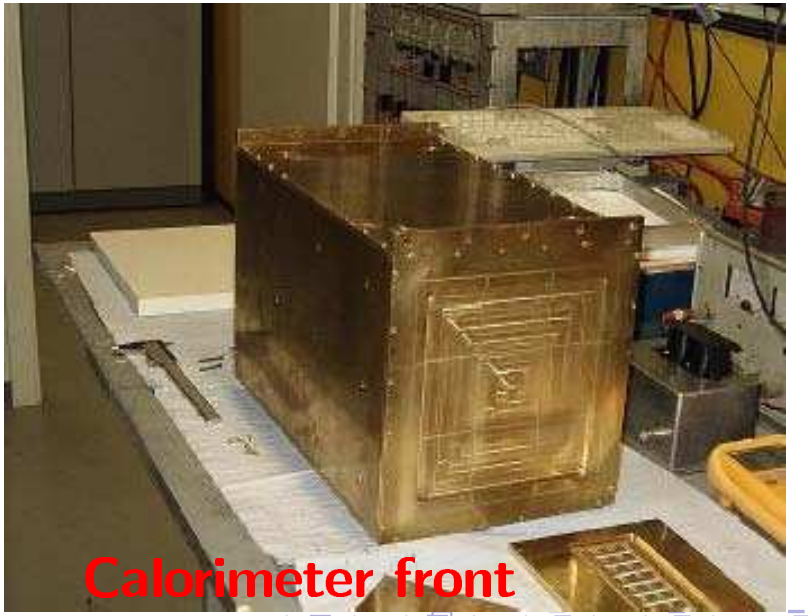
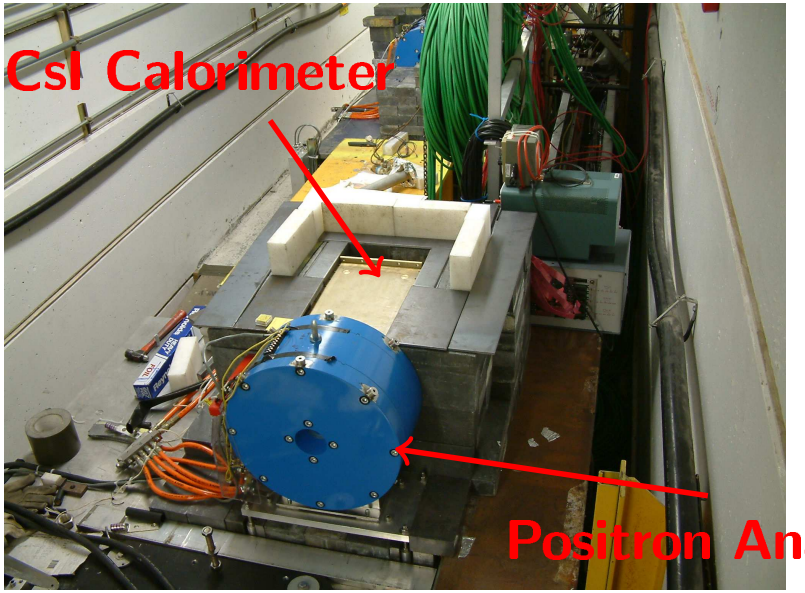


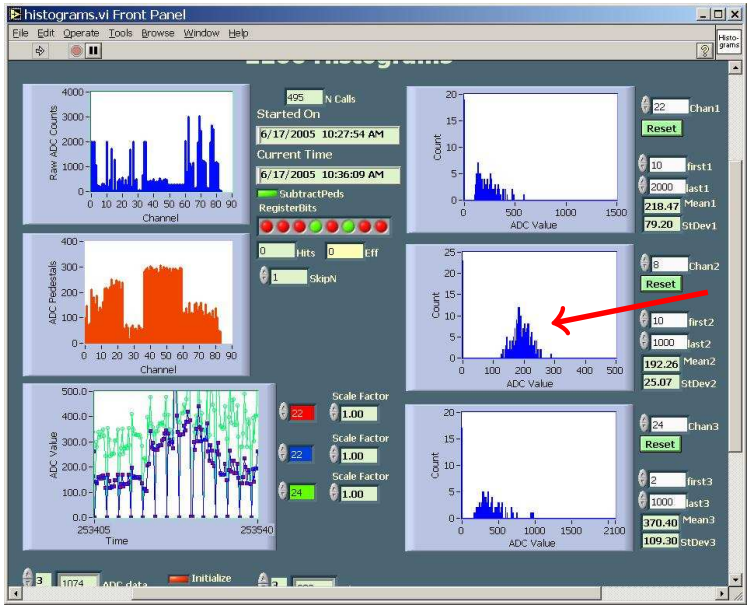

9 CsI Crystals


Calorimeter assembly

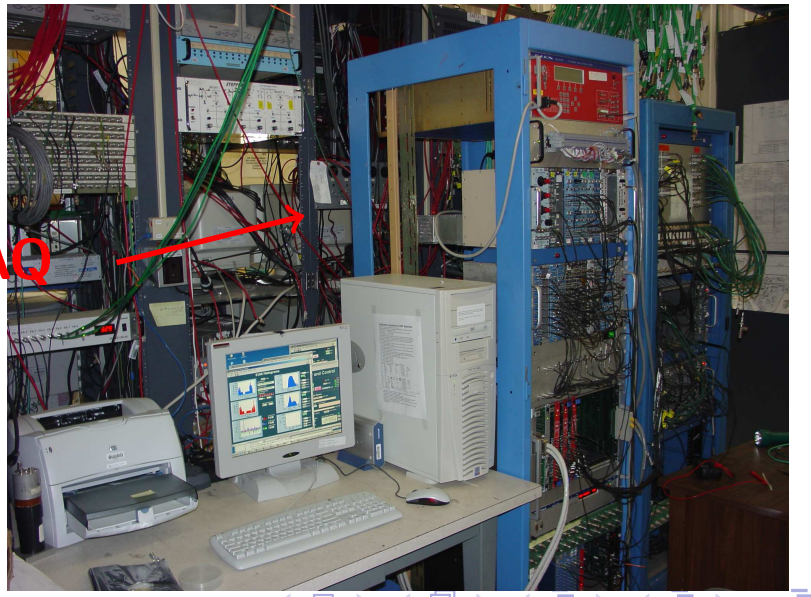

Calorimeter back


Calorimeter front


CsI Calorimeter
Positron Analyser Magnet

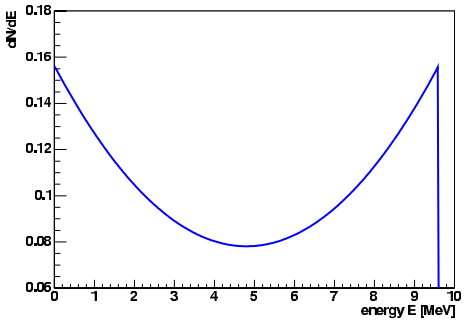

histograms.vi Front Panel
File Edit Operate Tools Browse Window Help
Started On
6/17/2005 10:27:54 AM
Current Time
6/17/2005 10:36:09 AM
Raw ADC Counts
ADC Pedestals
ADC Value
Count
Channel
Time
Reset
Initialize

DAQ

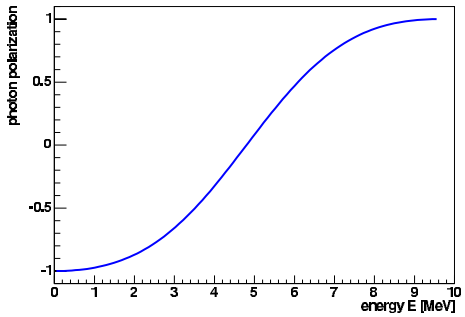


Expected positron polarisation

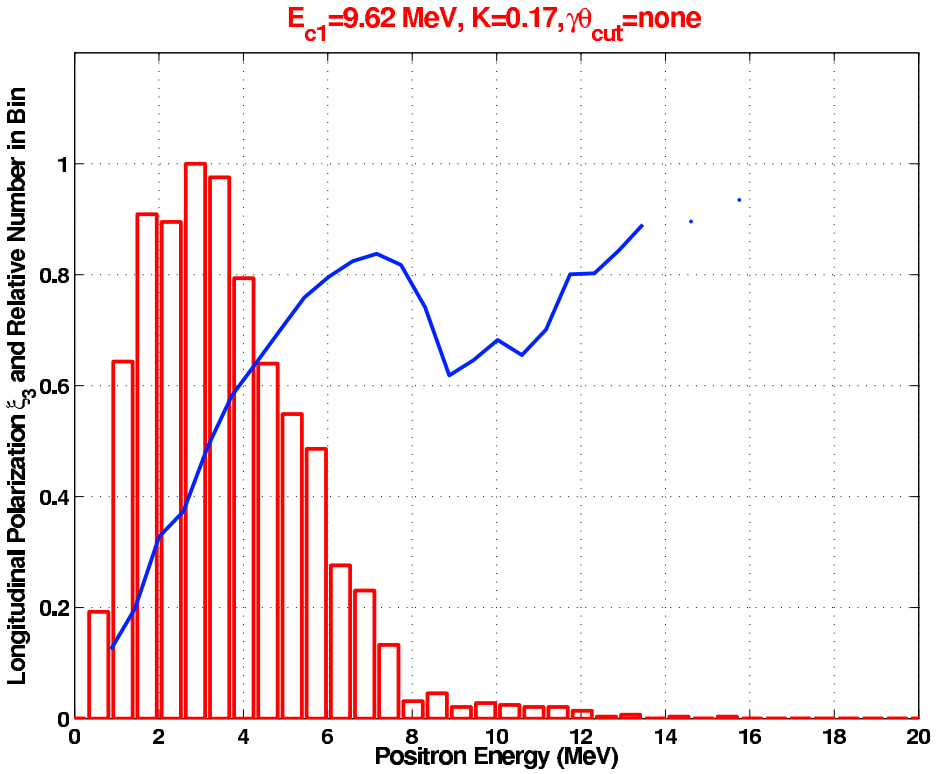
γ energy



γ polarisation



e^+ energy & polarisation



Positron analysing power

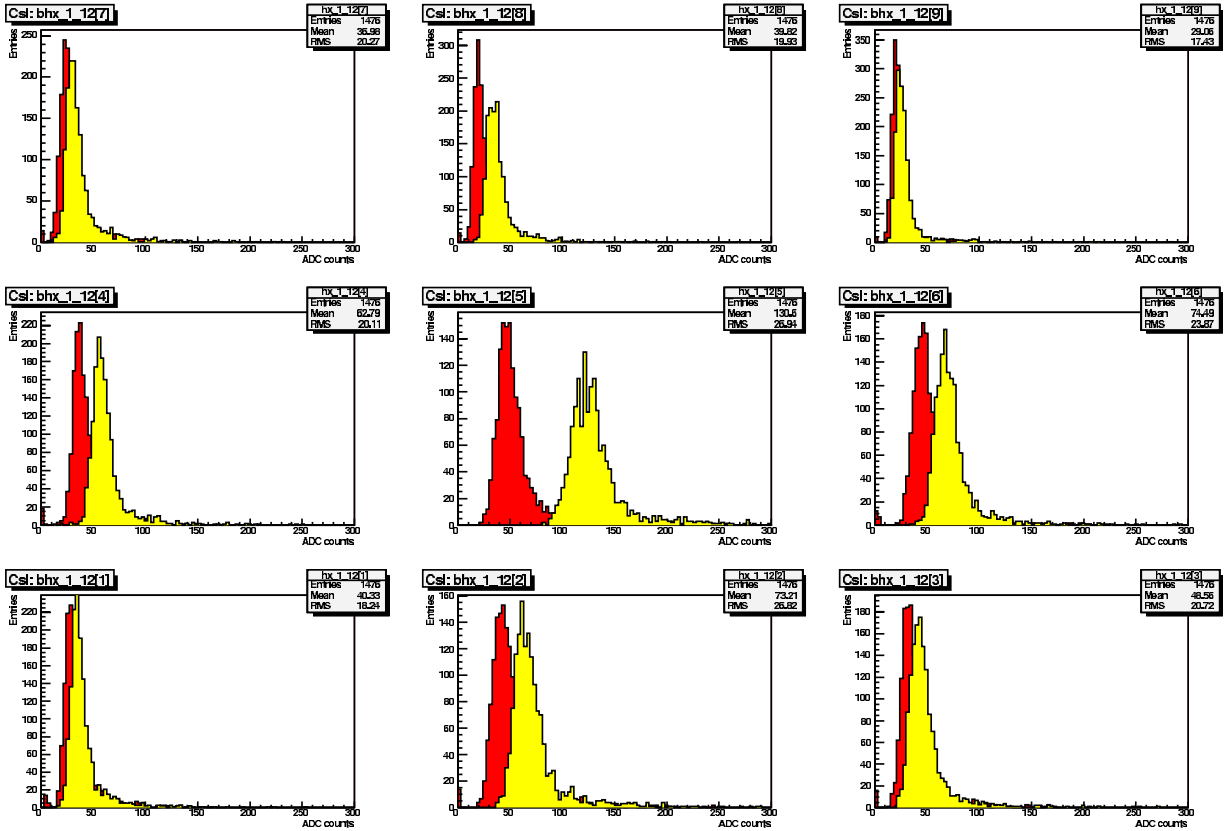
Positron Energy (MeV)	Positron Pol. P_{e^+} (%)	Positron Asym. δ (%)	Analysing Power A_{e^+} (%)
3	42	0.55	18.6
4	61	0.84	19.7
5	69	0.82	17.0
6	78	0.87	15.9
7	84	0.93	15.8
8	77	0.82	15.0
9	64	0.63	14.0
10	68	0.66	13.9

Expected Positron polarisation (Geant3 simulation based on experimental setup of the proposal)

measurements of small asymmetries most challenging task of the E166 experiment

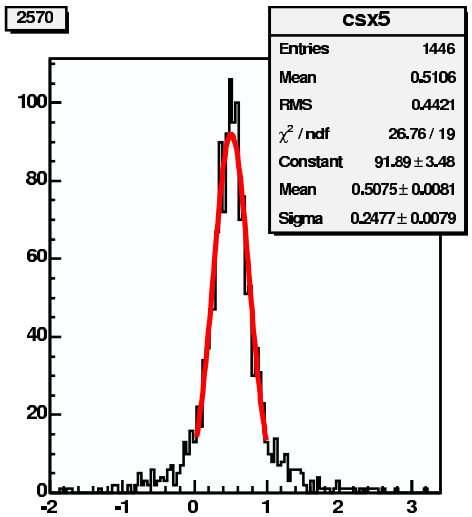
Preliminary results

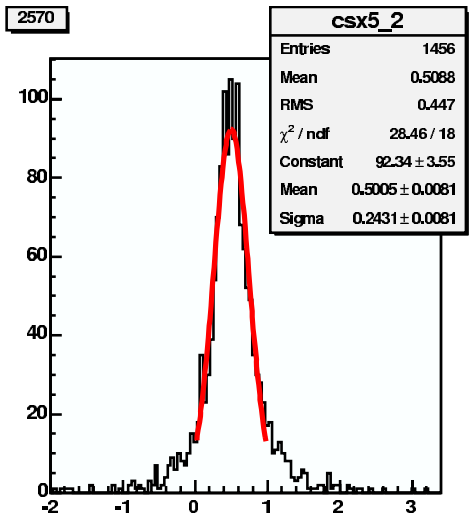
Energy deposition in CsI crystals

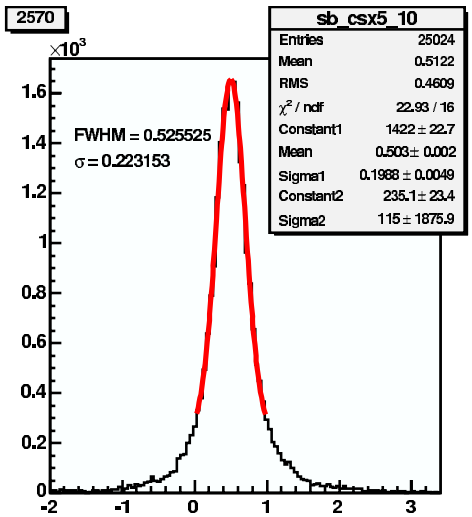


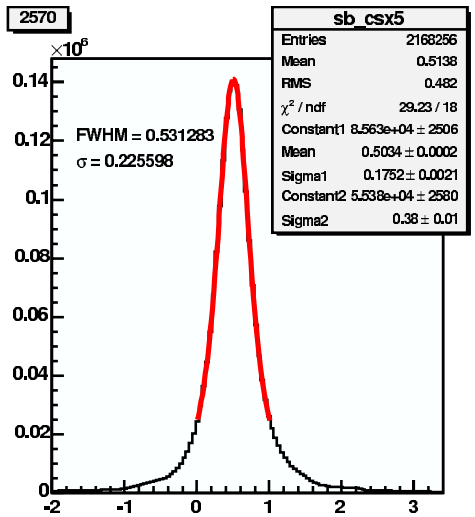
- all 9 crystals see positron signal
- good signal background separation in central crystal
- detail analysis needed to obtain asymmetry

Background substraction



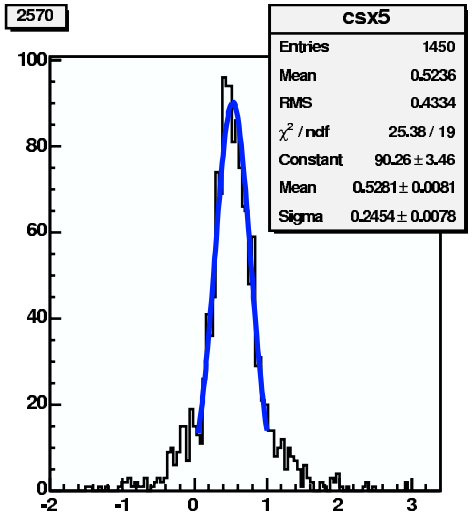


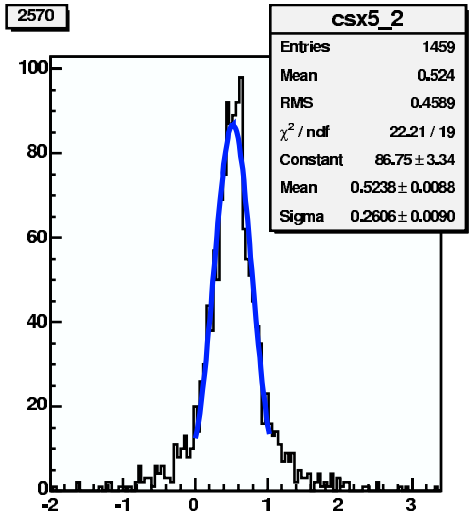


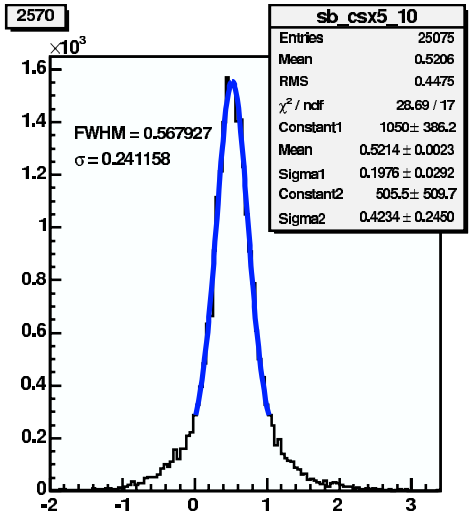


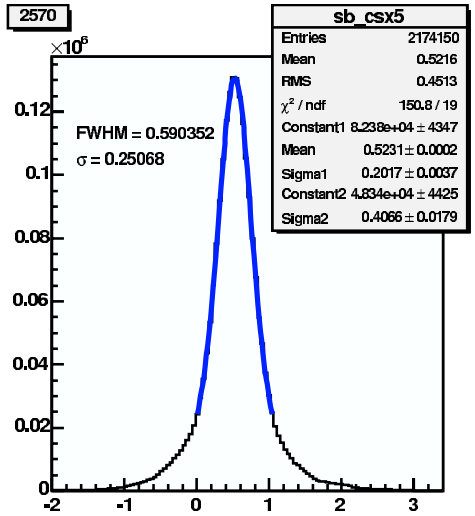
- analyser polarity is fliped from plus to minus
- different analysis methods and cuts give similar results

Background substraction







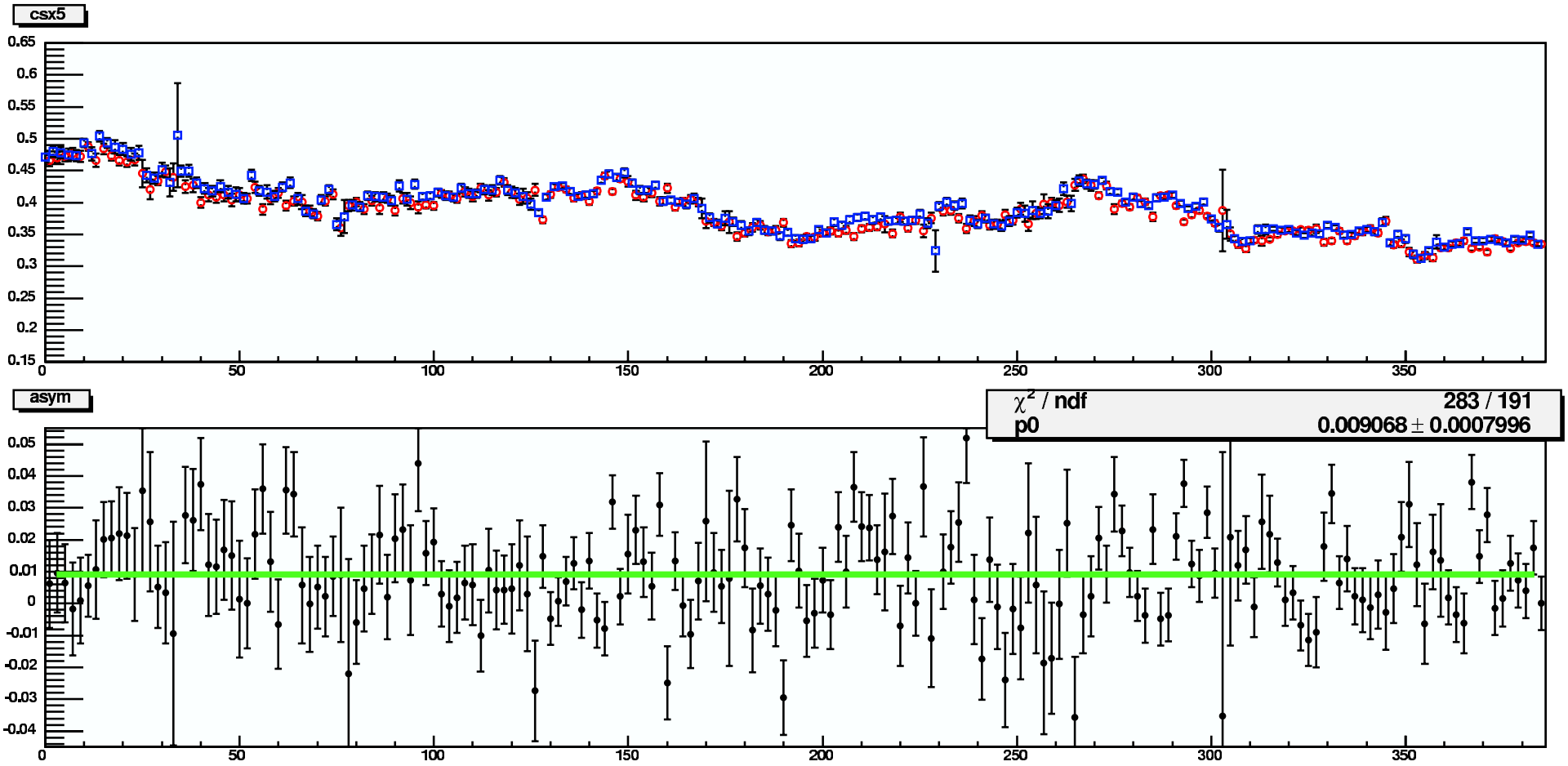


- analyser polarity is fliped from plus to minus
- different analysis methods and cuts give similar results

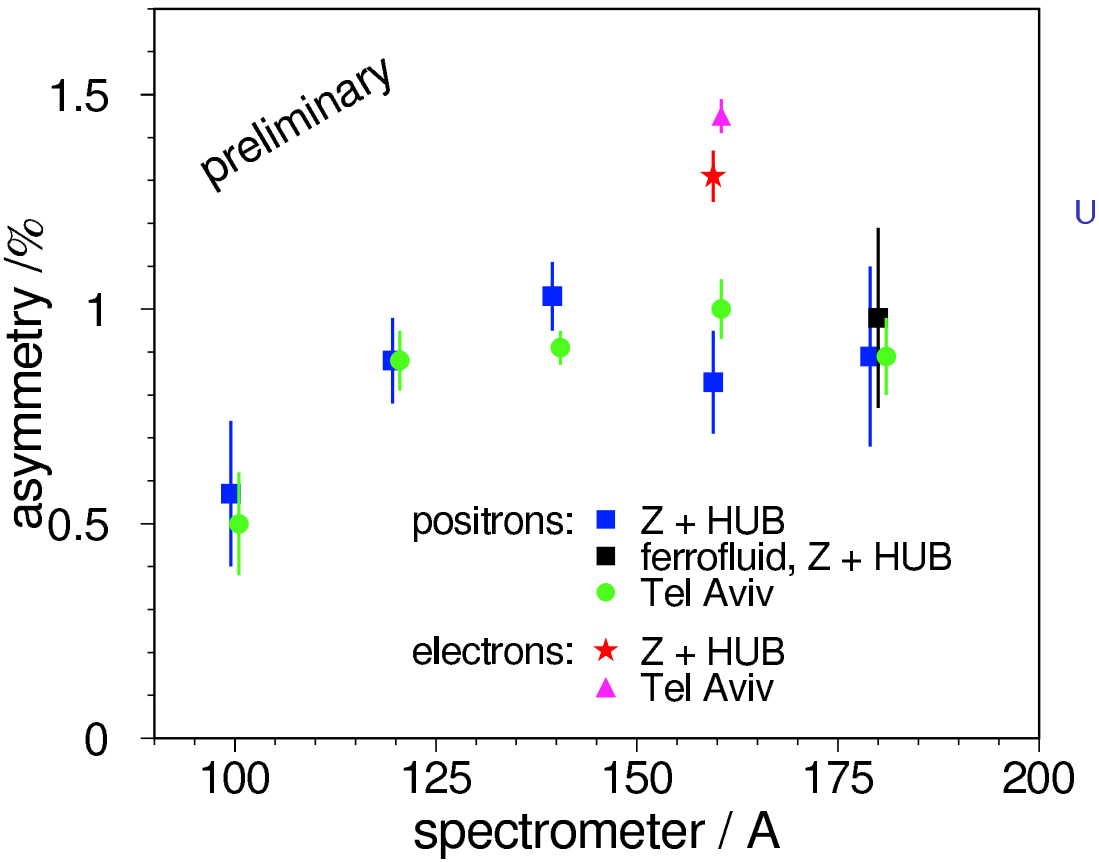
Preliminary results

Spectrometer current : 120 A

approx. number of signal points : $550\,000$



Positron/Electron asymmetries



Gamma asymmetry

	measured Asym.	Geant3 simulation
Aerogel	3.50 %	3.54 %
SiW-Cal	3.52 %	3.22 %

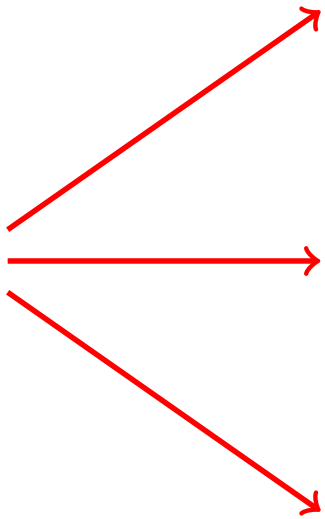
Univeristy of Tennessee, DESY

- asymmetries in expected range
- independent analyses get compatible results
- systematic studies ongoing

What about the degree of polarisation?

Photon Polarisation

$$P_\gamma = \frac{\delta}{A_\gamma P_e}$$



Asymmetry δ
OK

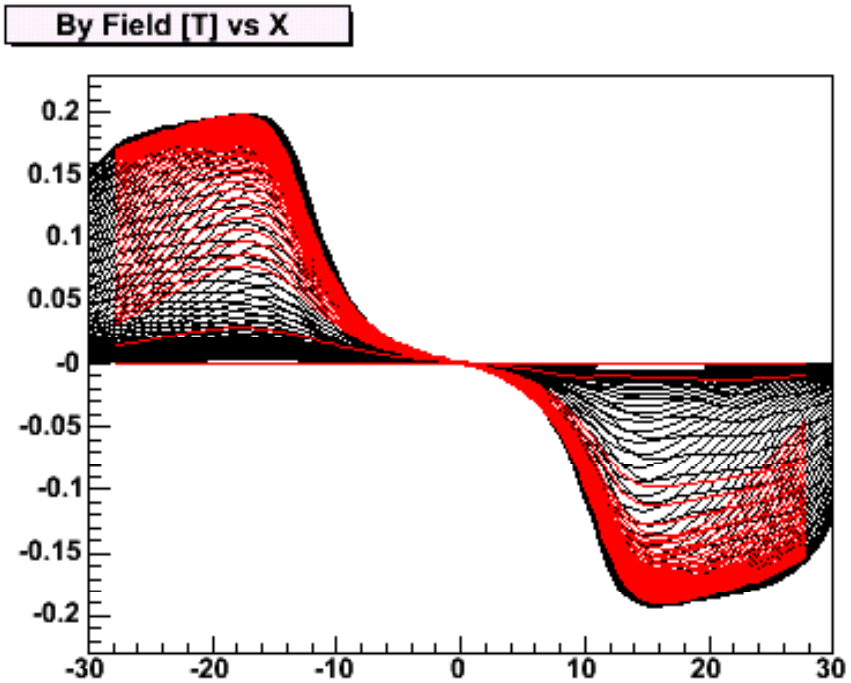
Analysing power A_γ
needs simulation!

Target polarisation P_e
OK

Geant4 simulation of complete E166 setup on the way

E166 Spectrometer

- Calculation
  MERMAID field map calculation.
  Cornell University
- Measurement
  field measurement at SLAC
- Simulation
  E166 Geant4 simulation
  DESY, Zeuthen



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  E166 Geant4 simulation
  DESY, Zeuthen

Spectrometer current I_S (A)	Lens current I_L (A)	Positron energy E_{e+} (MeV)
100	175	4.0
120	200	4.8
140	225	5.6
150	240	6.0
160	250	6.4
180	275	7.2

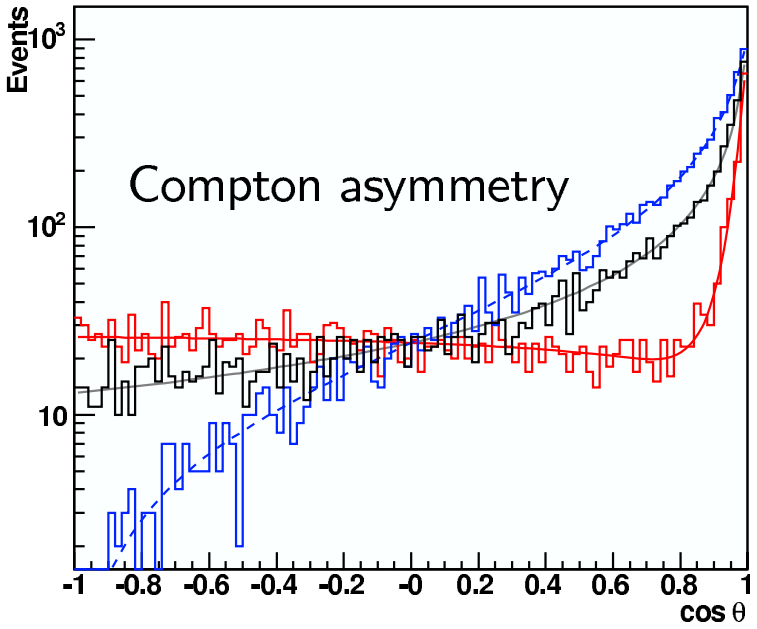
Polarisation extension to Geant4

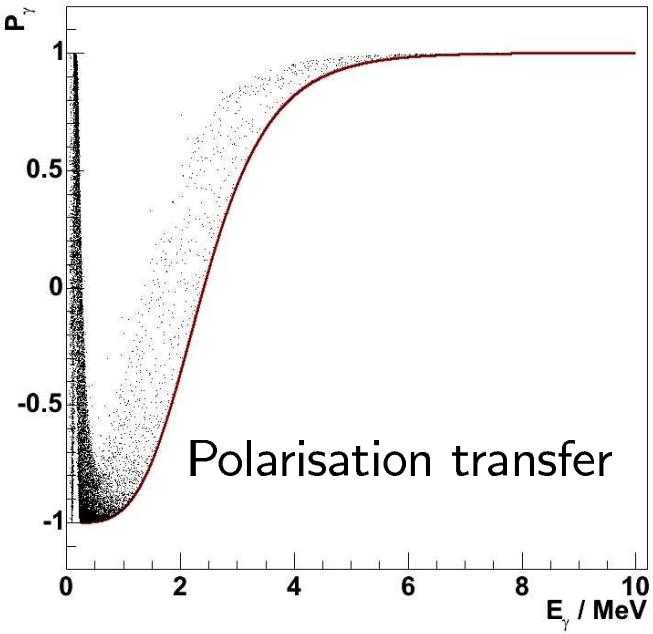
Polarimetry of electrons and positrons

- Compton scattering
- Bhabha/ Møller scattering
- Annihilation into photons

Polarisation transfer

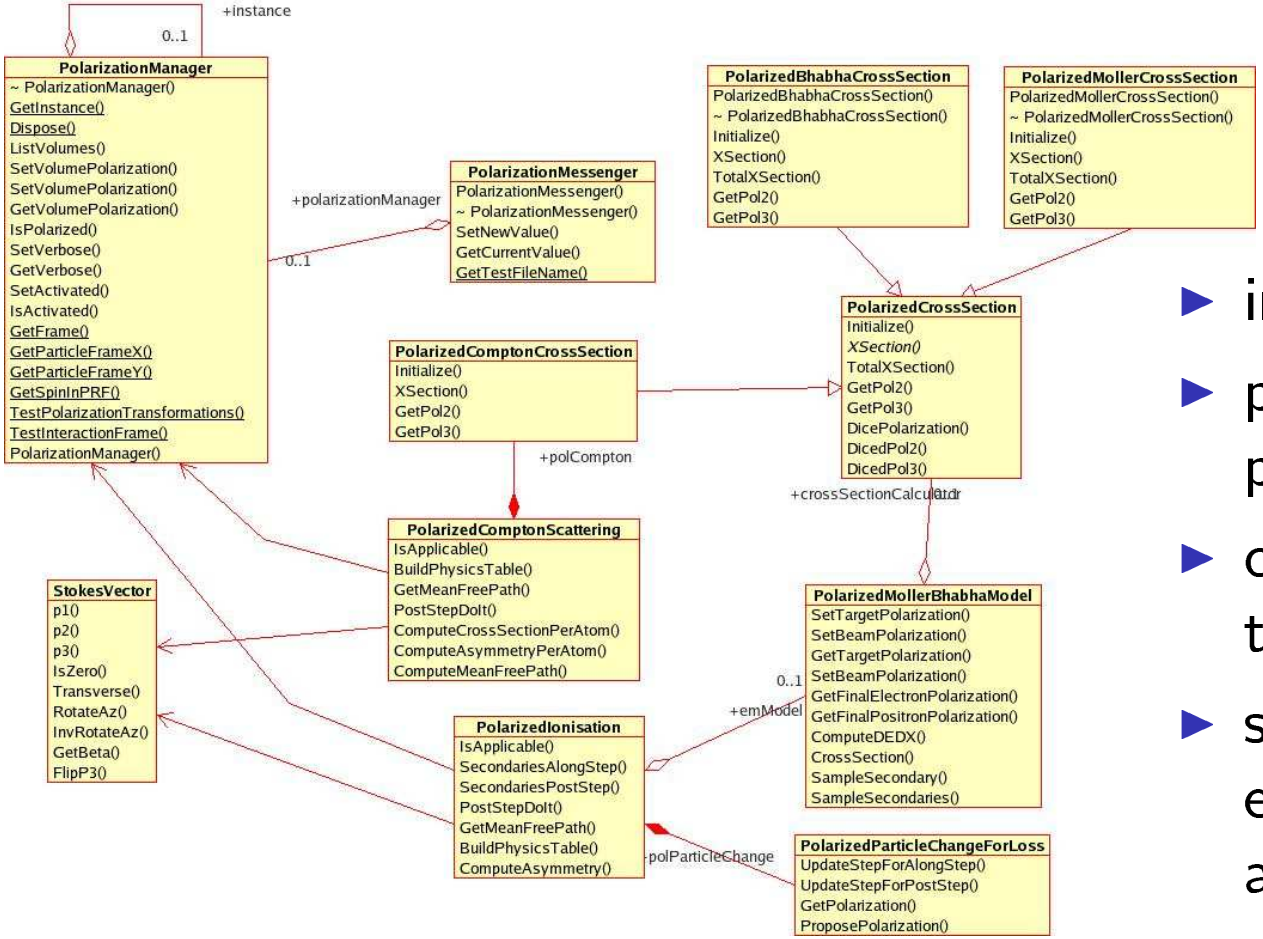
- Bremsstrahlung
- Pairproduction
- ...





R. Dollan, K. Laihem and A. Schälicke, arXiv:physics/0512192.

Polarisation Library for Geant4



- independent library
- provides polarised QED process
- can assigns a polarisation to any logical volume
- simple to include in existing Geant4 application

Summary & Outlook

- E166 experiment
  - demonstration of undulator based positron source
  - sucessful runs in June and September 2005
  - asymmetry measured at 6 positron energies
- E166 analysis
  - asymmetry data analysis ongoing
  - results in aggreement with expectations
  - field map measurement of spectrometer completed
  - analysing power will be recalculated with Geant4
- Next steps
  - determine real positron polarisation
  - write publication


E166 collaboration
Helical Undulator based polarized positron source for the ILC
50 GeV e⁻
E - 166
10 MeV γ
International Polarized Positron Collaboration