A Test Experiment for a Polarized Positron Source - E-166 at SLAC

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Outline

- Why polarized beams at the ILC
- The goal of E-166
- The helical undulator
- Positron production
- Photon transmission polarimetry
- The E-166 setup
- Data taking
- First results on photon and positron asymmetries

Wy both beams polarized at the ILC ?

- increased signal to background in studies of SM-Physics
- enhancement of the effective luminosity
- Precise analysis of many kinds of non-standard couplings (larger reach for non-SM physics searches)
- higher effective polarization
- improved accuracy in measuring the polarization

Example - Effective Polarization

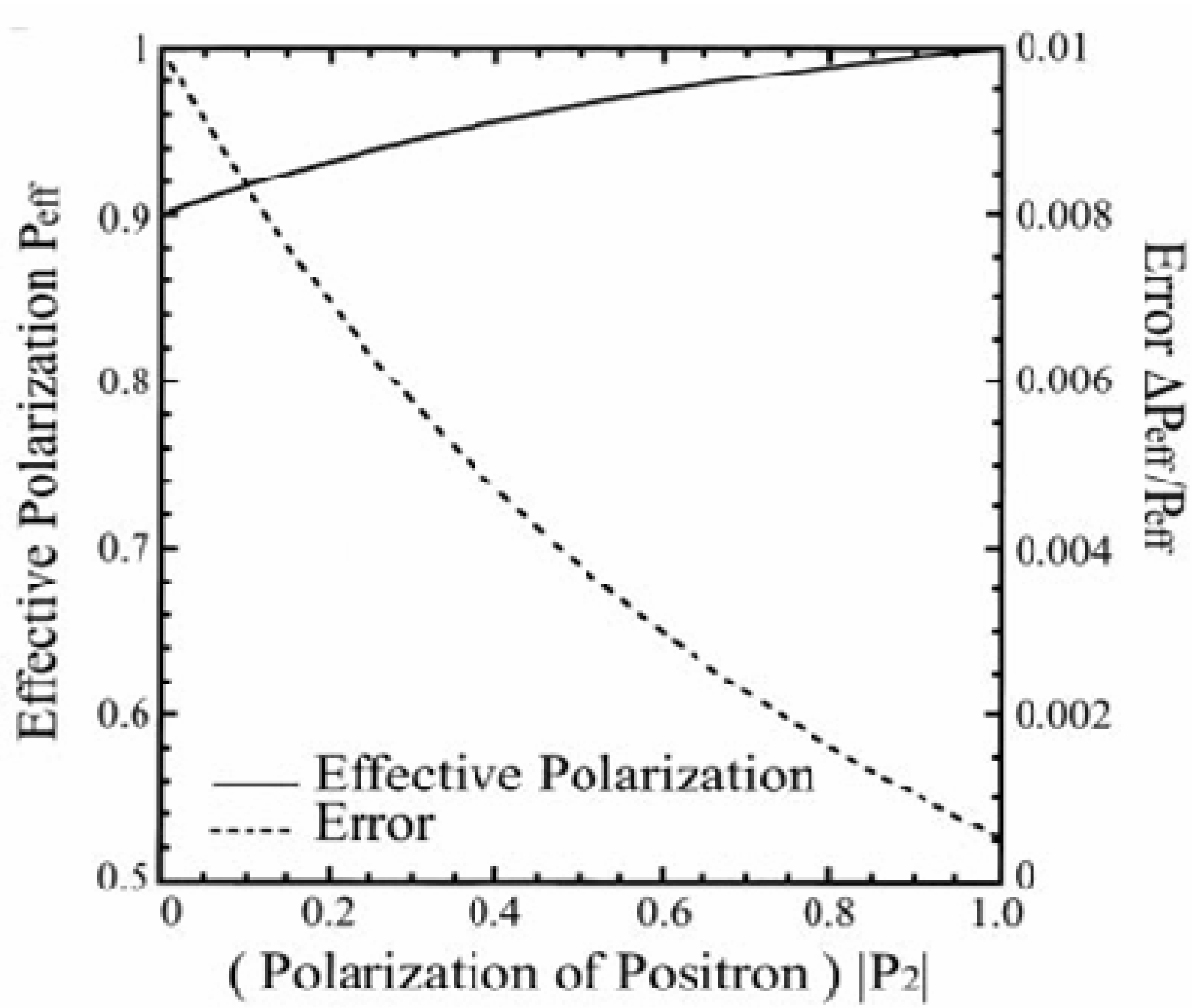
$$P_{eff} = \frac{P_{e^-} - P_{e^+}}{1 - P_{e^-} P_{e^+}}$$

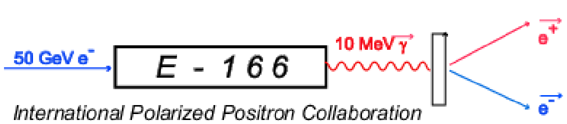
Error scales with $1 - P_{eff}$

Effecitve polarization for various e^- and e^+ polarizations:

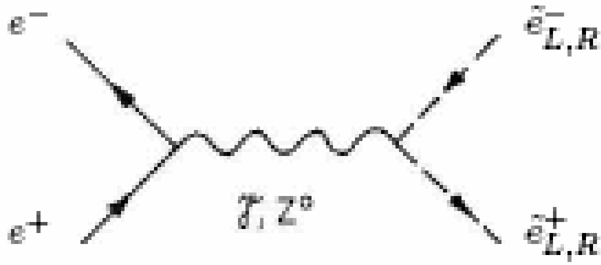
	P_{e^-} = +/- 0.8			P_{e^-} = +/- 0.9		
P_{e^+}	0	-/+ 0.4	-/+ 0.6	0	-/+ 0.4	-/+ 0.6
$\|P_{eff}\|$	0.80	0.91	0.95	0.90	0.95	0.97
$1-\|P_{eff}\|$	0.20	0.09	0.05	0.10	0.05	0.03

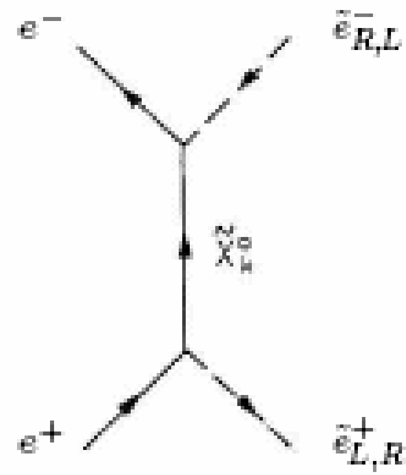
Eff. Polarization (e^- Pol. = 90%)

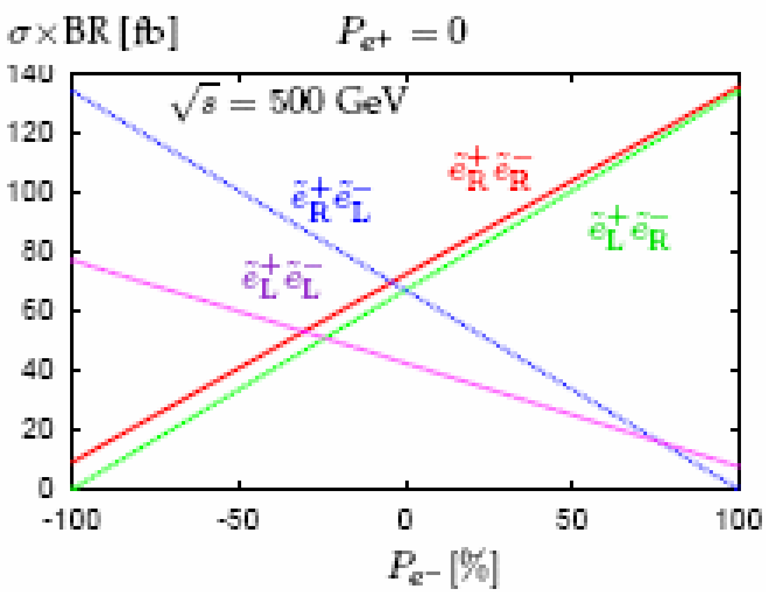


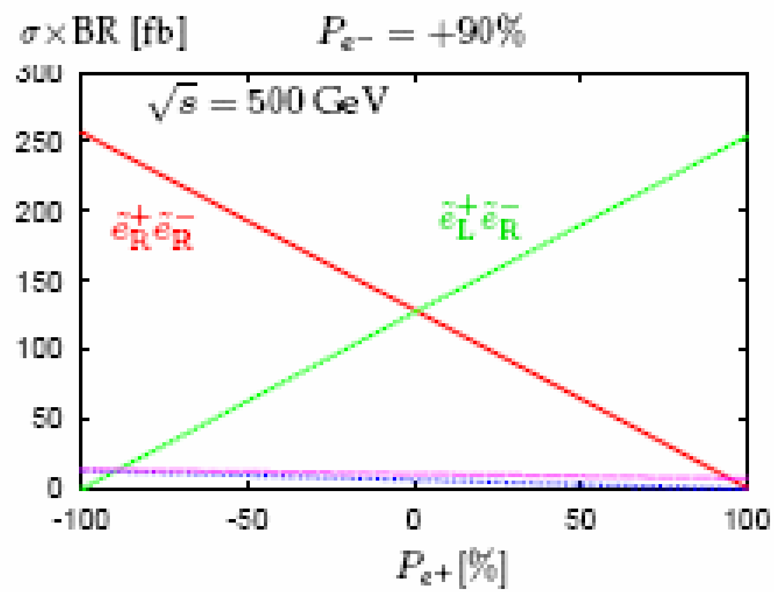


Selectron production in e^+e^-



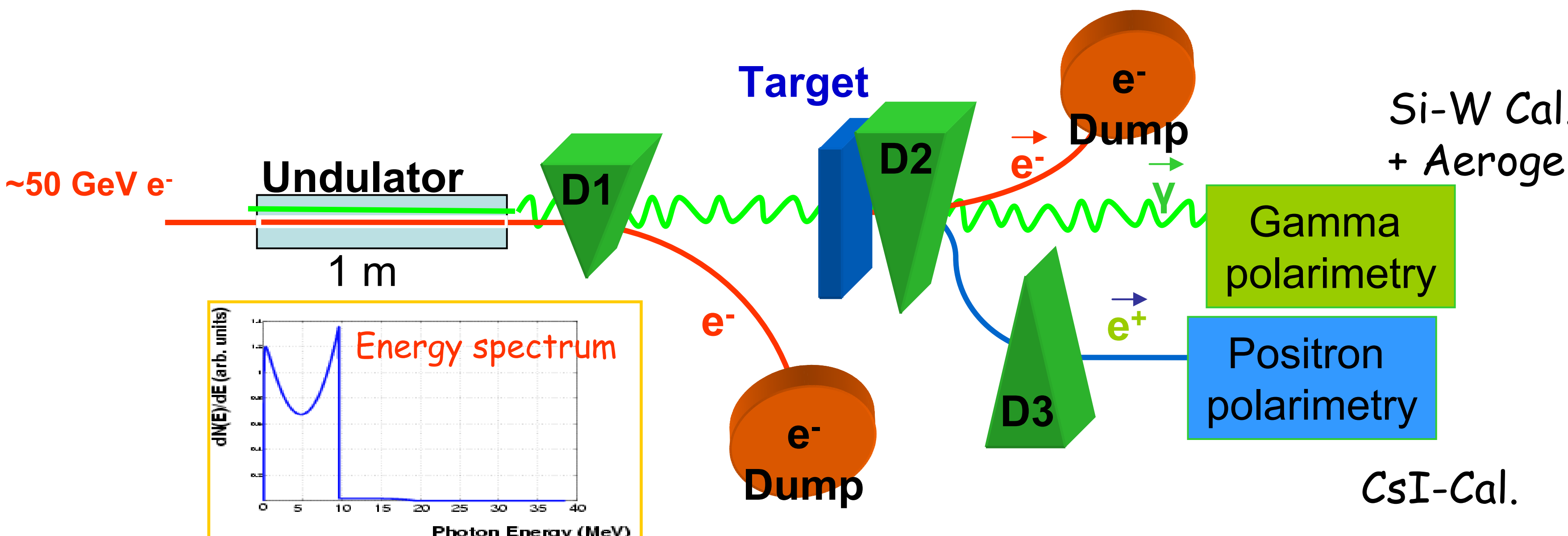




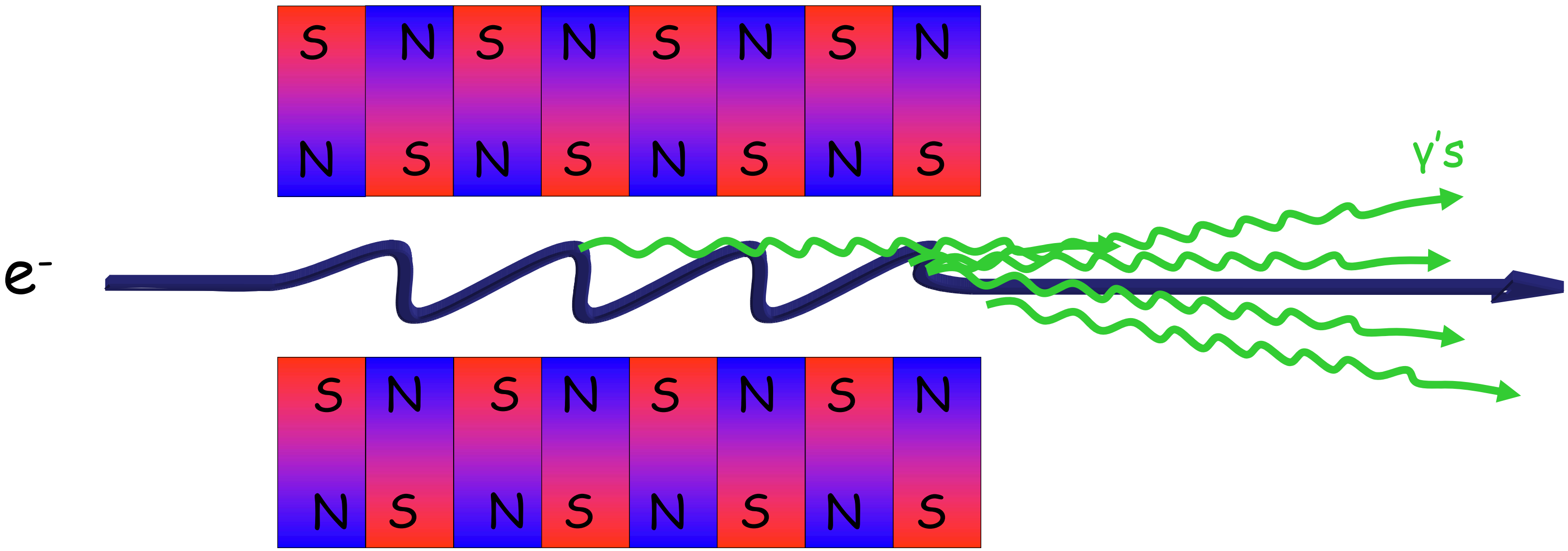


E-166

- Demonstration experiment to proof the possibility, to produce polarized positrons using a helical undulator
- Collaboration of >50 people from 3 continents
- In the final focus test beam (FFTB) at SLAC with ~50 GeV (unpolarized) electrons
- 1 m long helical undulator produces circular polarized photons
- Conversion of photons to positrons in thin W-target
- Measurement of polarization of photons and positrons by Photon transmission method



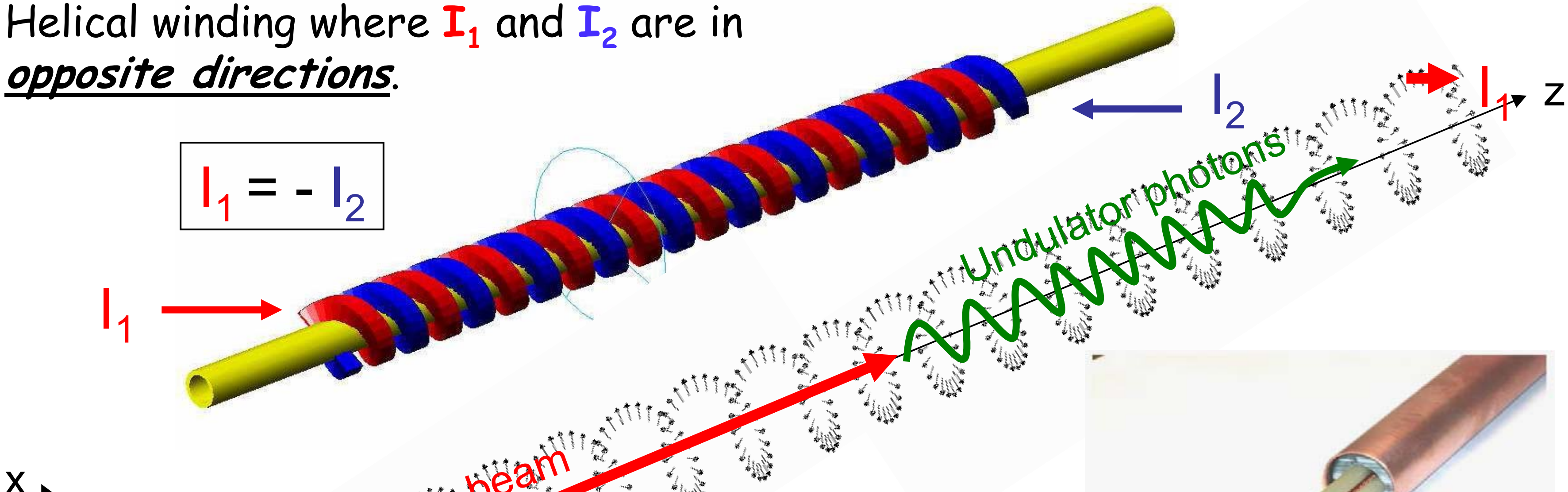
Undulator Principle

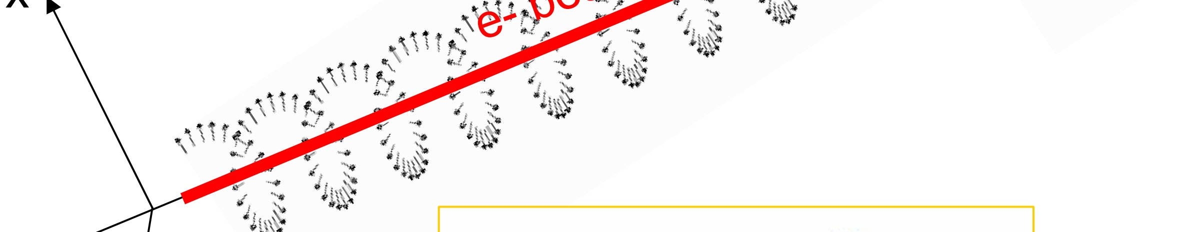


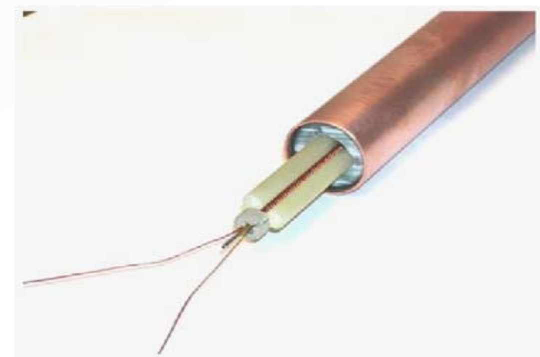
- electrons traverse periodic magnetic structure
- photons are emitted

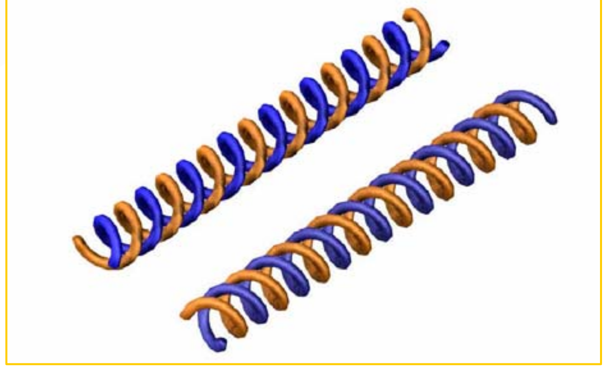
The helical Undulator

Helical winding where I_1 and I_2 are in ***opposite directions***.





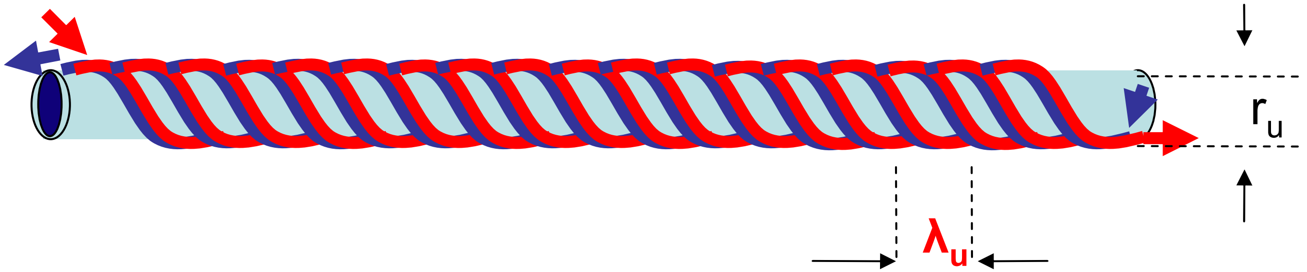




Helical winding:

- z component of the induced magnetic field cancels
- remaining magnetic field describes a helical profile

Undulator Parameters



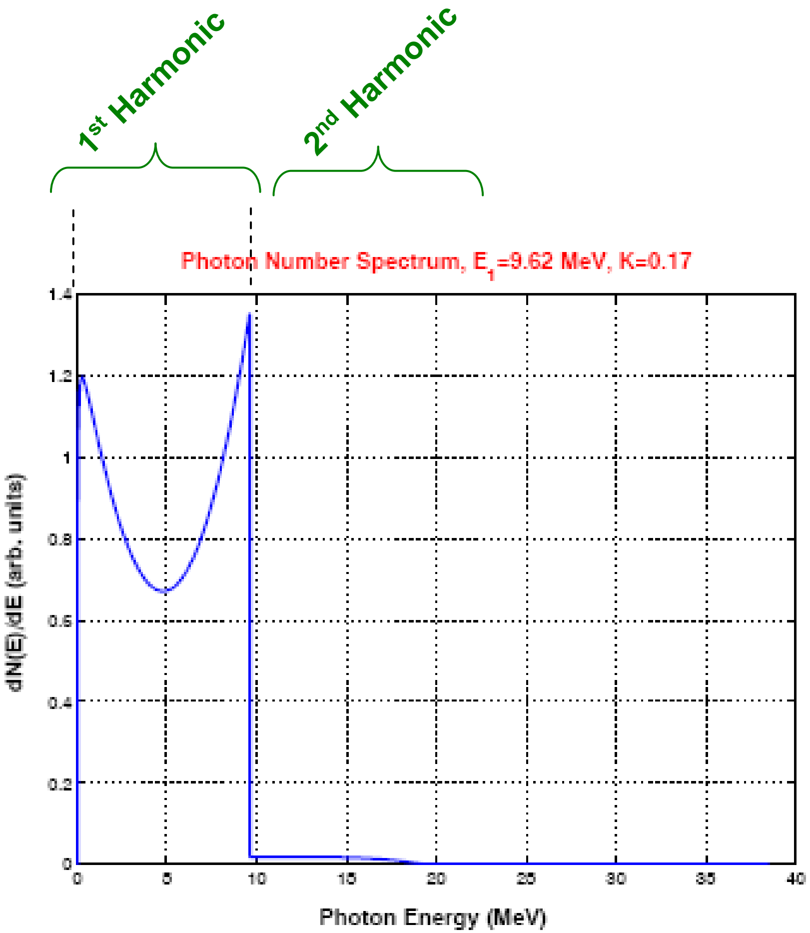
wound left handed

Parameter	Value
Period λ_u	**2.54mm**
On axis field	0.76 T
$E_{\gamma c}$	**9.4 MeV**
Feeding current	2.3 kA
Heating/pulse	~3 degC

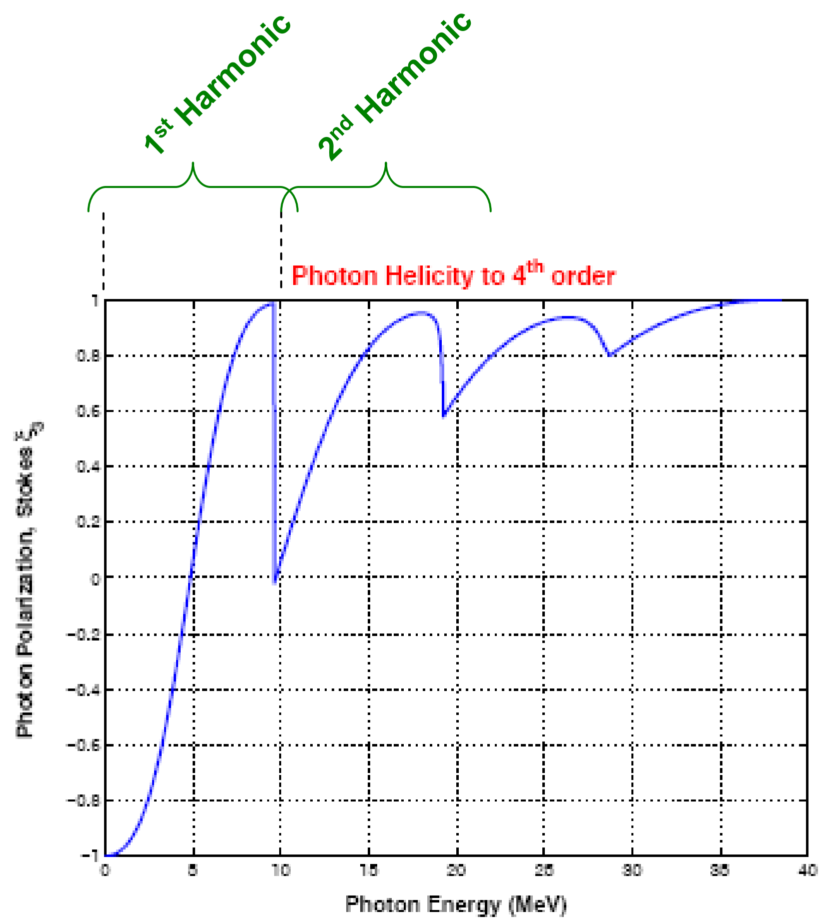
r_u Undulator aperture	0.88 mm

$$E_{\gamma c} \sim \frac{E_{beam}}{\lambda_u}$$

Photon Energy and Polarization

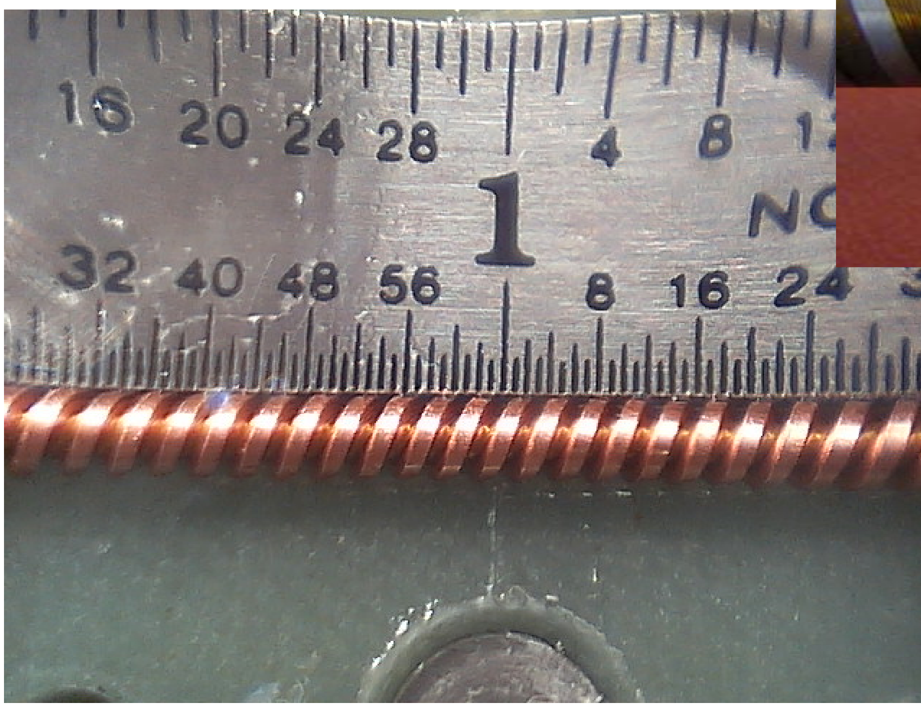


Undulator Photon energy spectrum

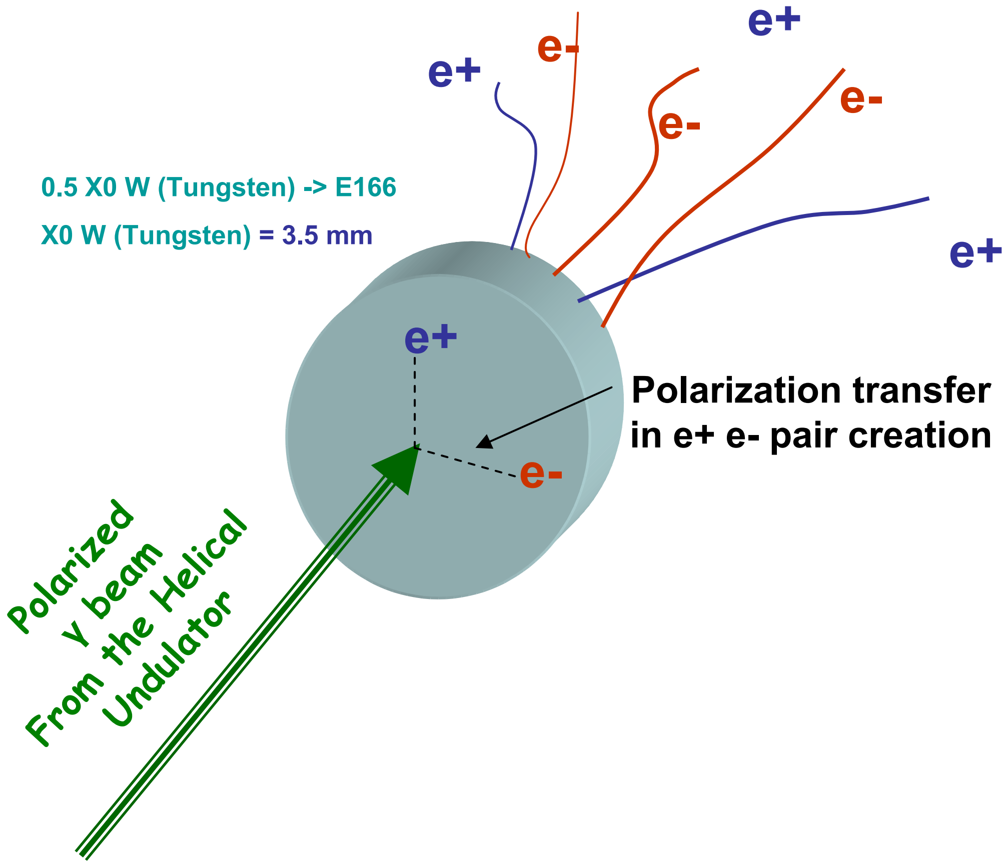


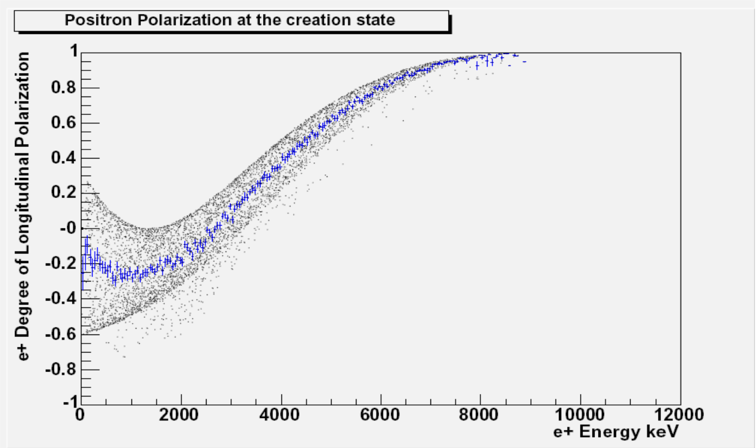
Undulator Photon degree of polarization

Undulator Windings

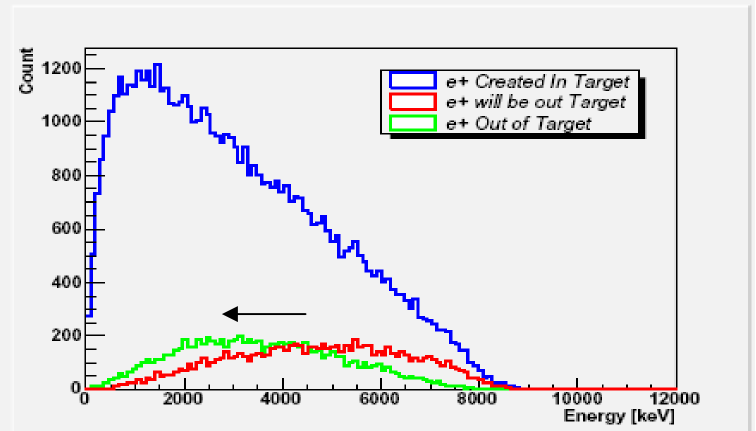


The Positron Production Target



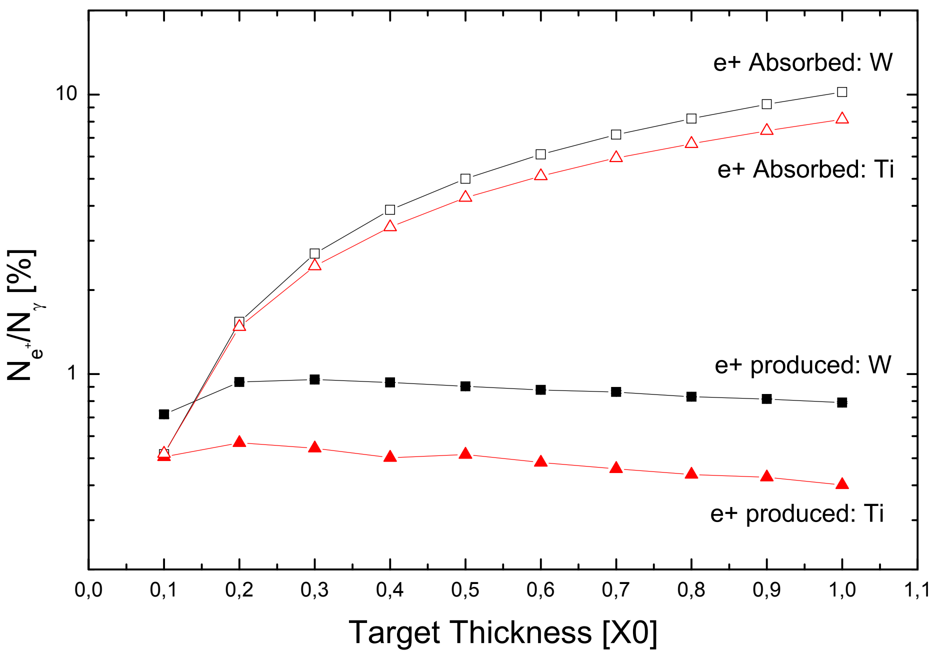


Positron Polarization profile created by the undulator photons (**creation point**)



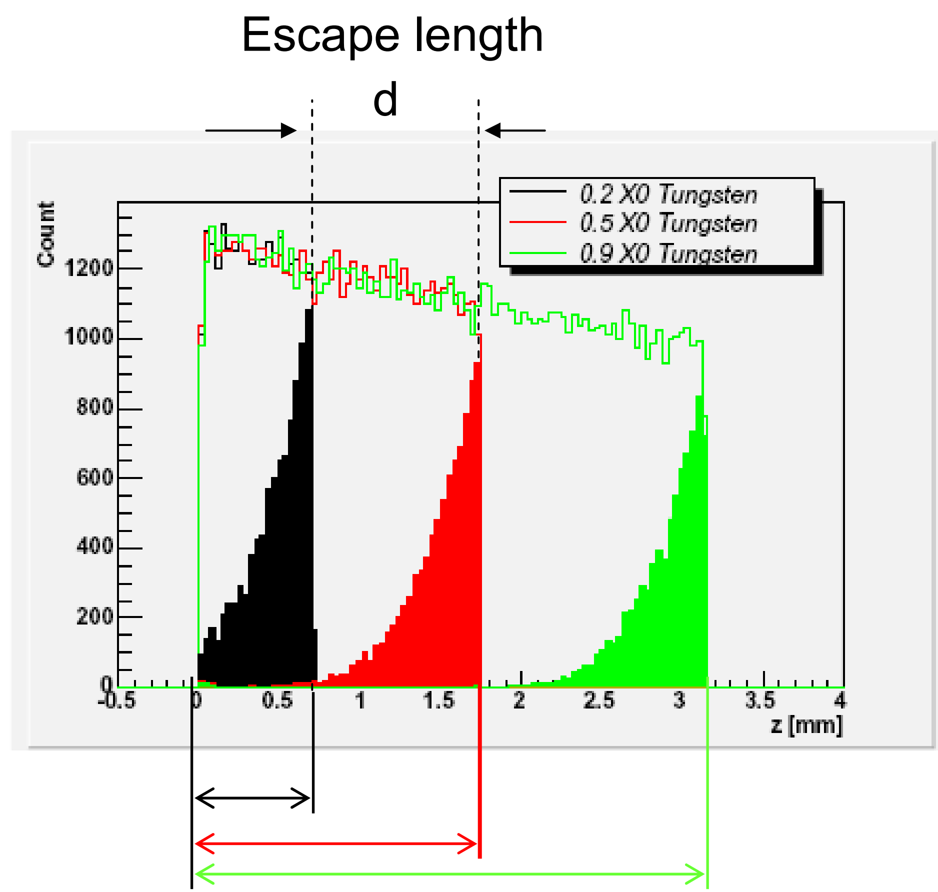
e+ Energy distribution (in and out the 0.5 X0 W target)

Production Efficiency



Positron production efficiency (positron yield)

$N_{(e+)} / N_{(gamma)}$

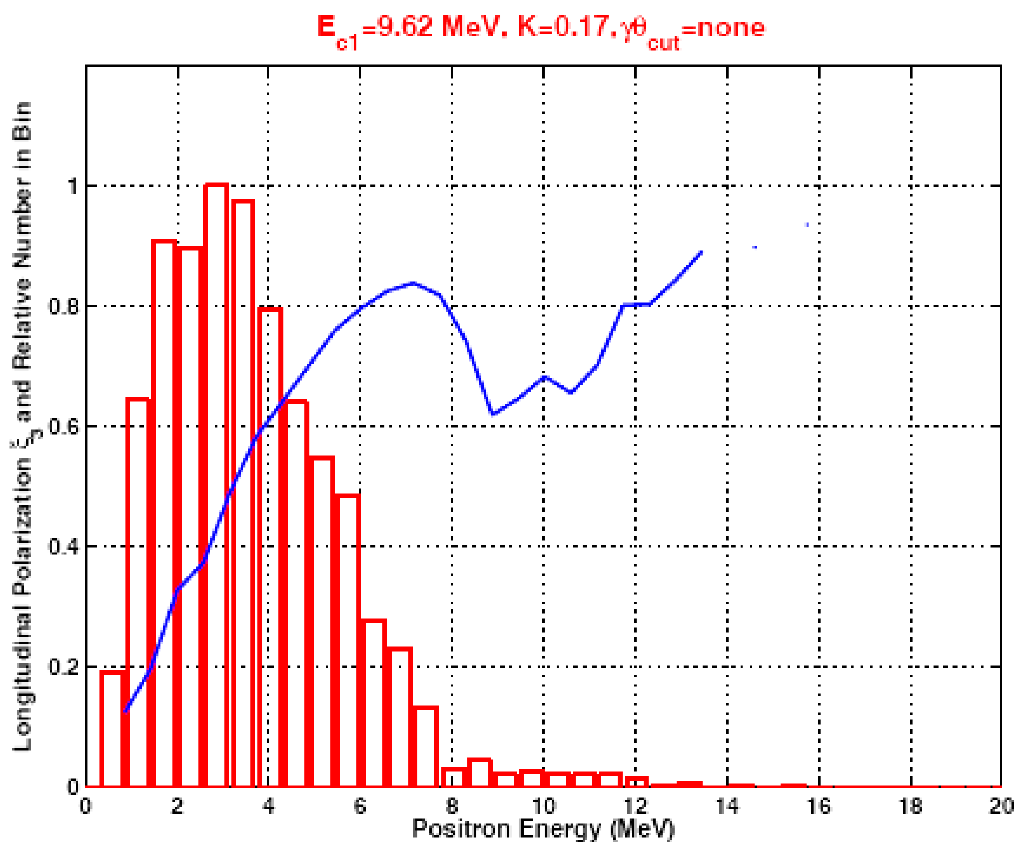


e+, z distribution (in the W target) For different target thickness

50 GeV e⁻ E - 166 10 MeV γ e+ e⁻

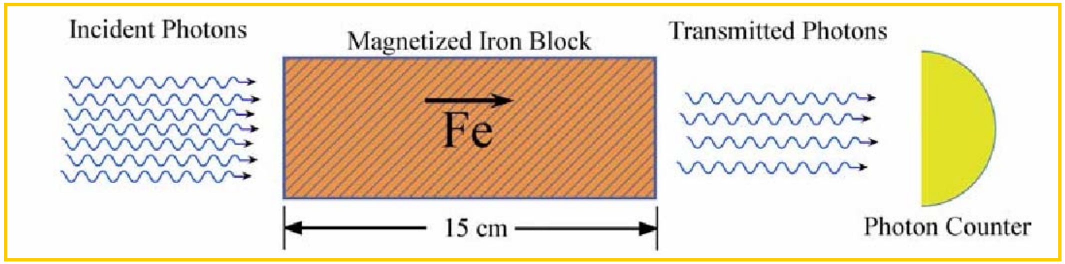
International Polarized Positron Collaboration

Expected Polarization

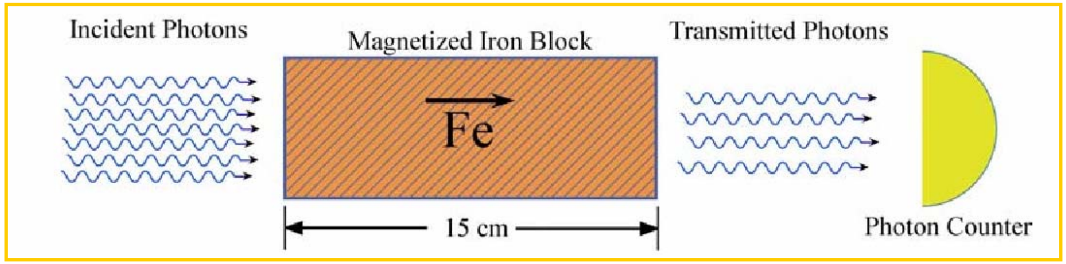


Expected positron polarization vs. positron energy

Transmission Polarimetry

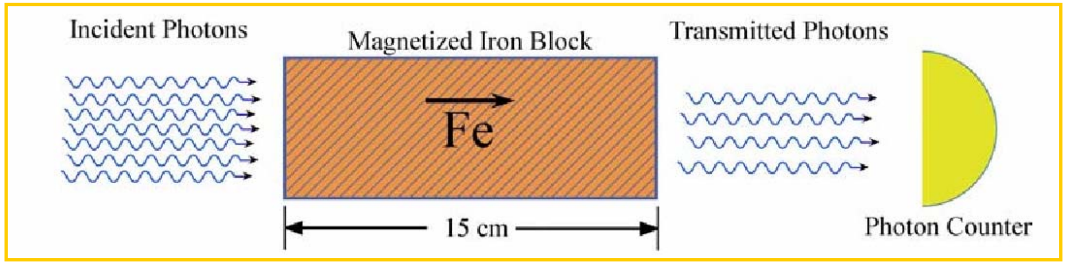


Transmission Polarimetry



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

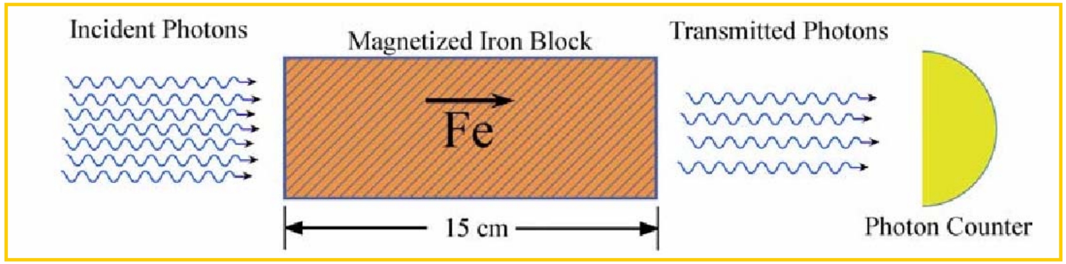
Transmission Polarimetry



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

$$T^{\pm}(L) = e^{-nL\sigma} = e^{-nL(\sigma_{phot}+\sigma_{pair}+\sigma_0)} e^{\pm nLP_\gamma P_e \sigma_{pol}} \qquad \text{Transmission}$$

Transmission Polarimetry



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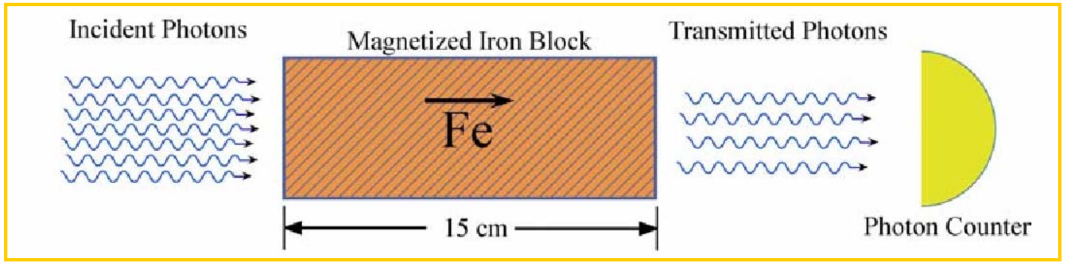
$$T^{\pm}(L) = e^{-nL\sigma} = e^{-nL(\sigma_{phot} + \sigma_{pair} + \sigma_0)} e^{\pm nLP_\gamma P_e \sigma_{pol}}$$ Transmission

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

Transmission Polarimetry



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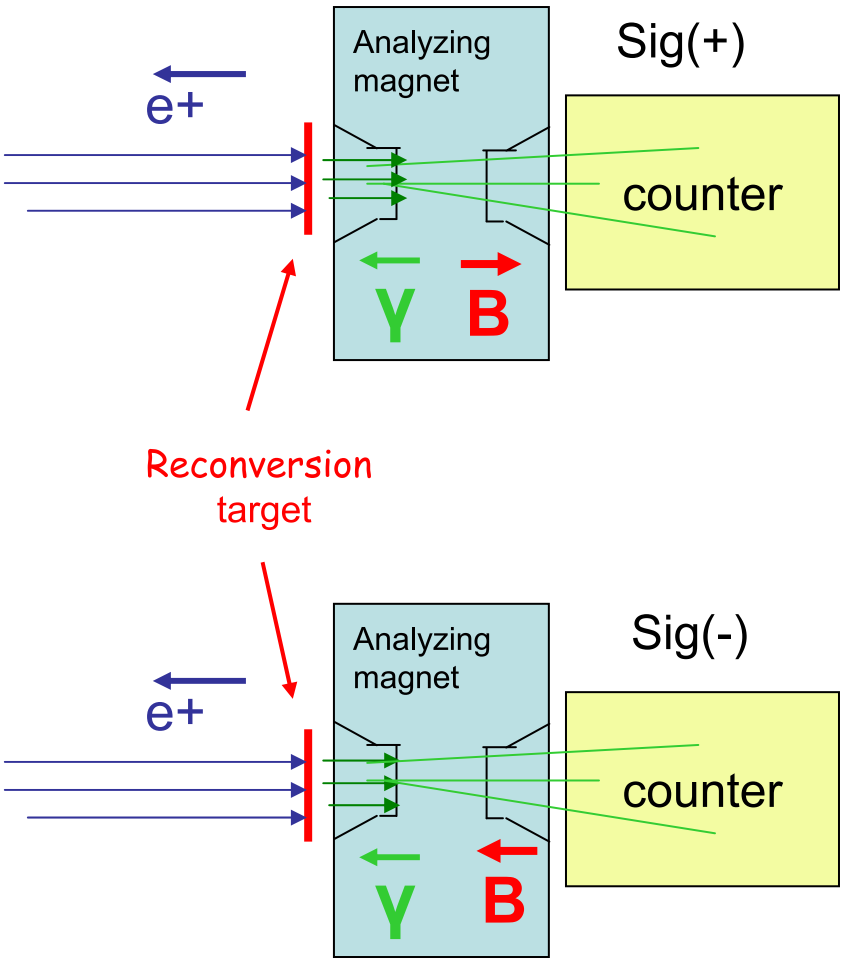
$$P_\gamma = \frac{\delta}{nL\sigma_{pol} P_e} = \frac{\delta}{A_\gamma P_e}$$ Photon Polarisation

Transmission Polarimetry



- Magnetization of the analyzer magnets flipped
- compare two states

E166 measures :

$$Asym = \frac{Sig(-) - Sig(+)}{Sig(-) + Sig(+)}$$

Expected Asymmetries

Positron Energy E_{e^+} (MeV)	Positron Polarisation P_{e^+} (%)	Positron Asymmetry δ (%)
3	42	0.55
4	61	0.84
5	69	0.82
6	78	0.87
7	84	0.93
8	77	0.82
9	64	0.63
10	68	0.66

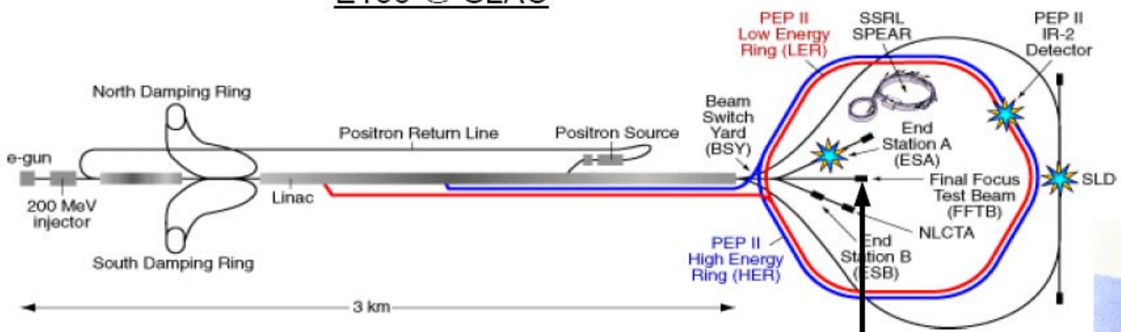
Expected asymmetries power versus positron energy

G3 simulation based on the experimental setup of the proposal

Most challenging task for E166
was to measure asymmetries ≤1% in the CsI - Calorimeter

E-166 in the FFTB

E166 @ SLAC

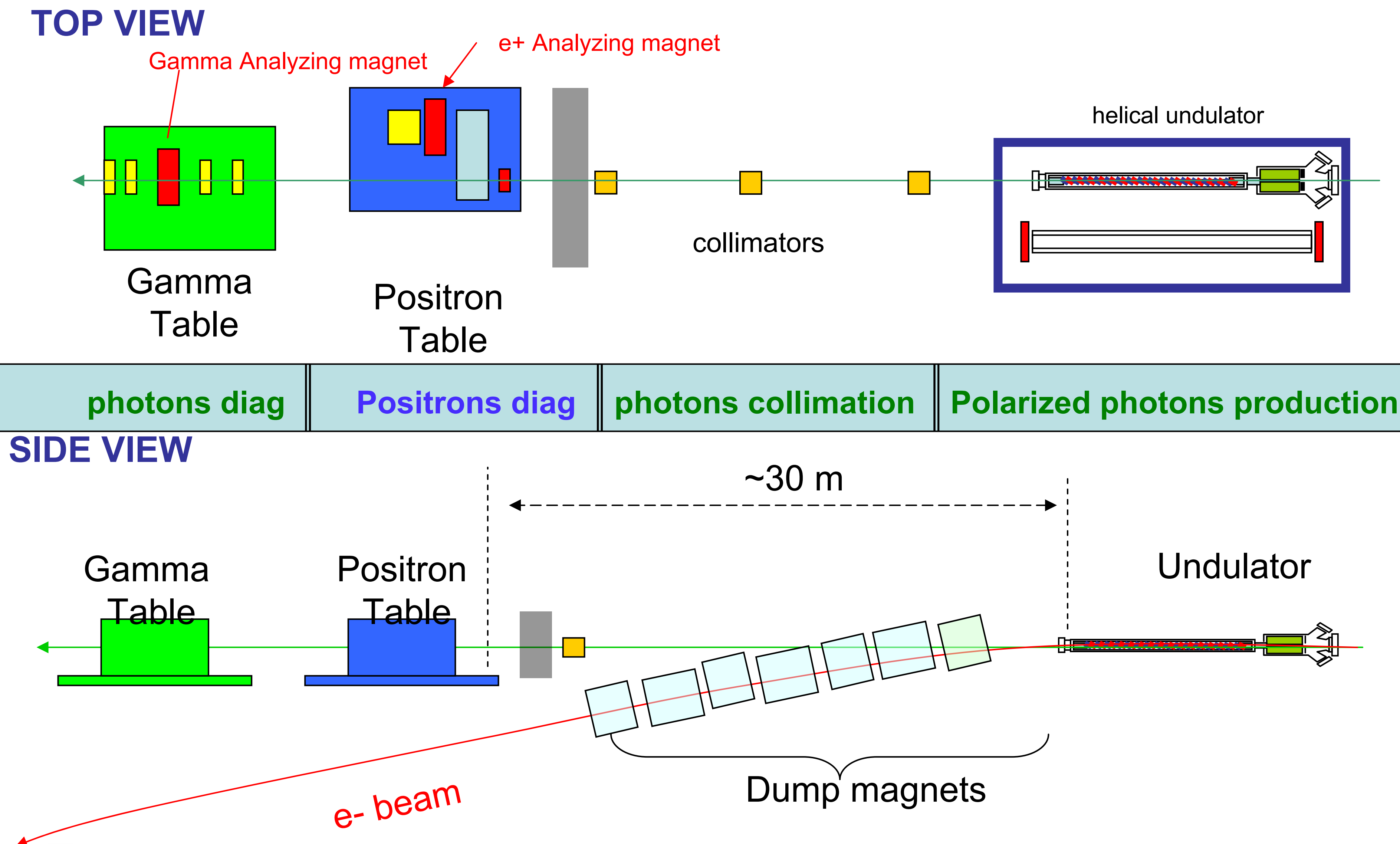


We are here !
(FFTB @ SLAC)

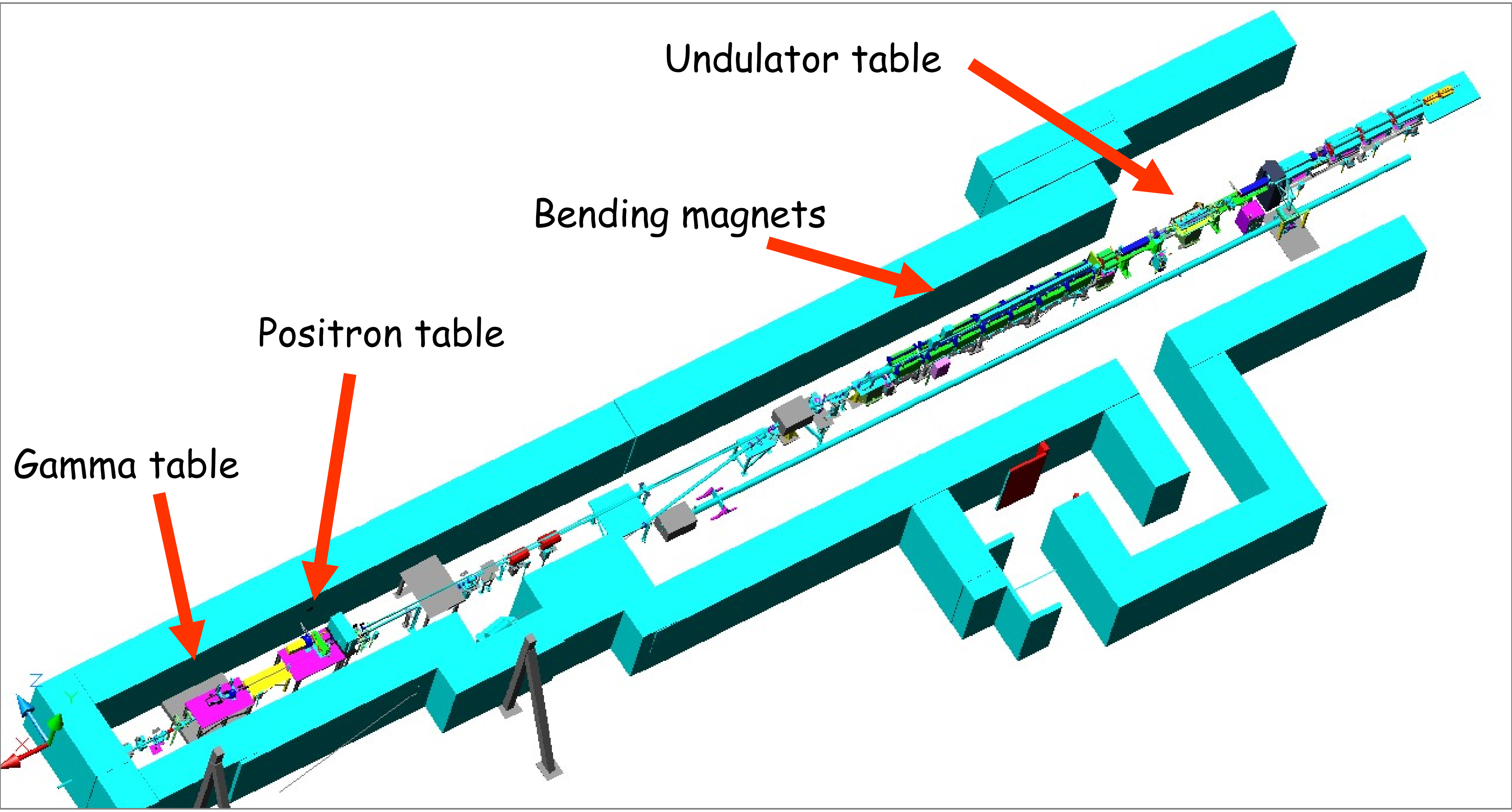
running parameters:

- beam energy: 46.6 GeV
- rep. Rate: 10 Hz
- N_{e^-}/pulse: ~10^{10}

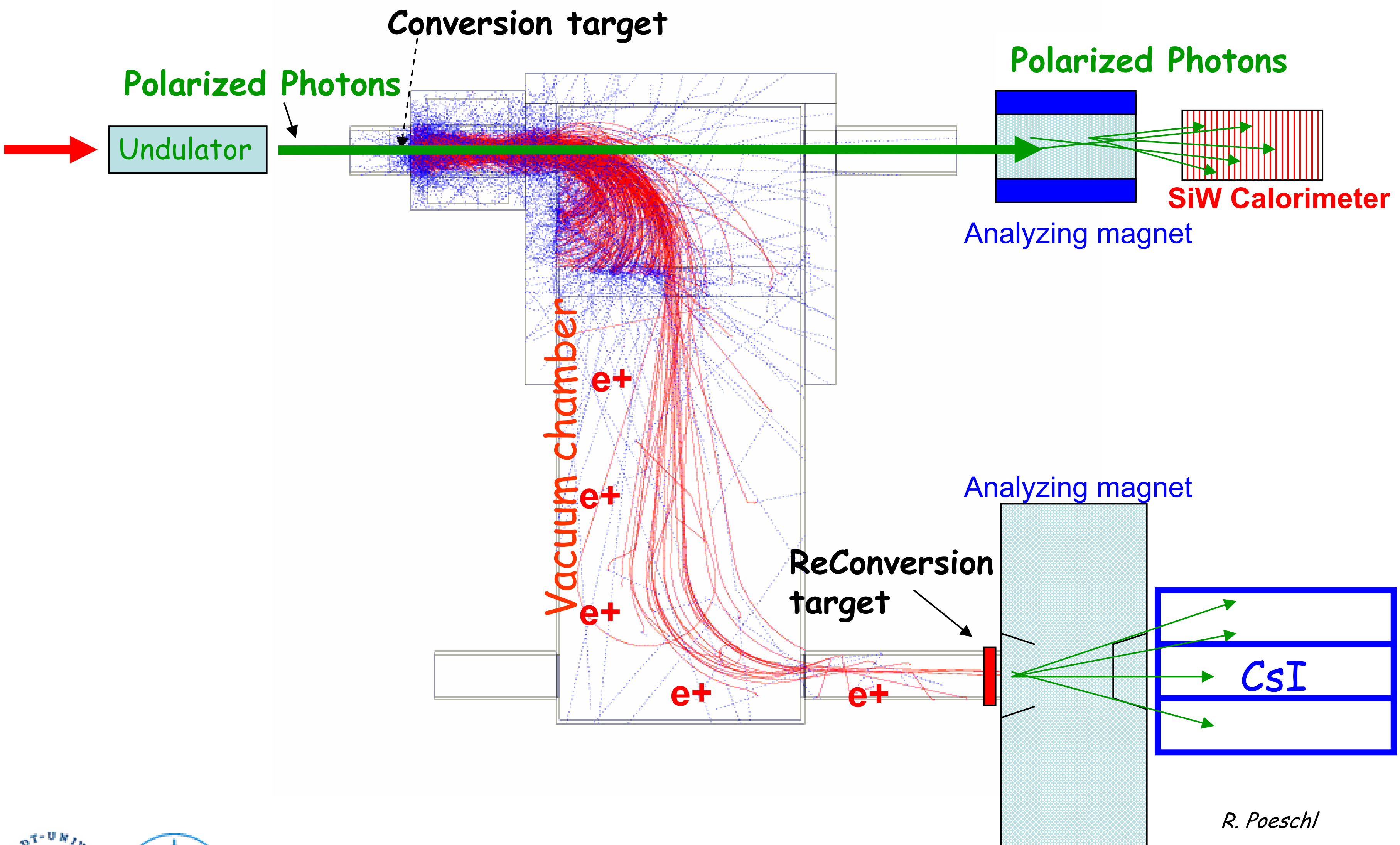
E166 setup in the FFTB



E166 setup in the FFTB

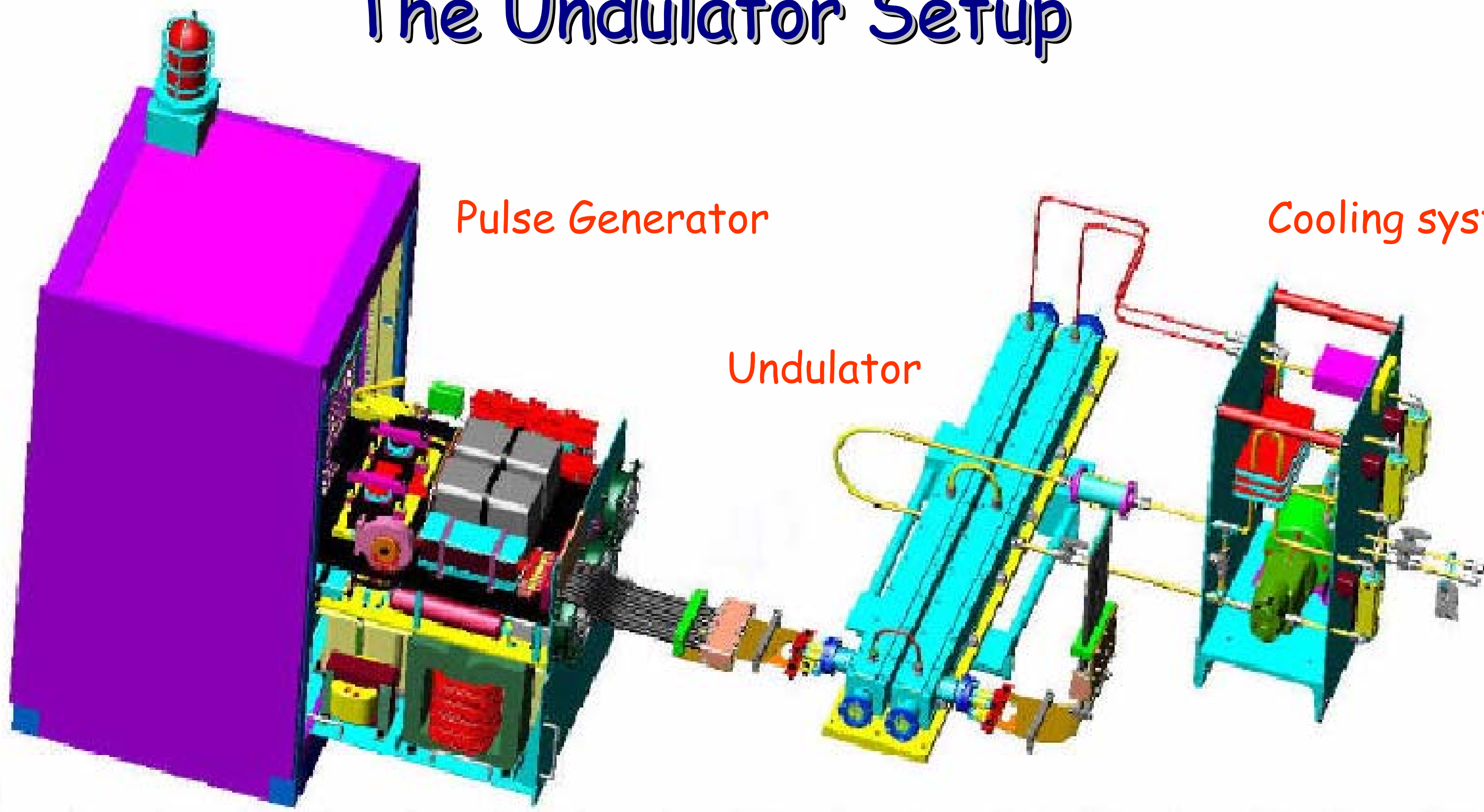


The Spectrometer



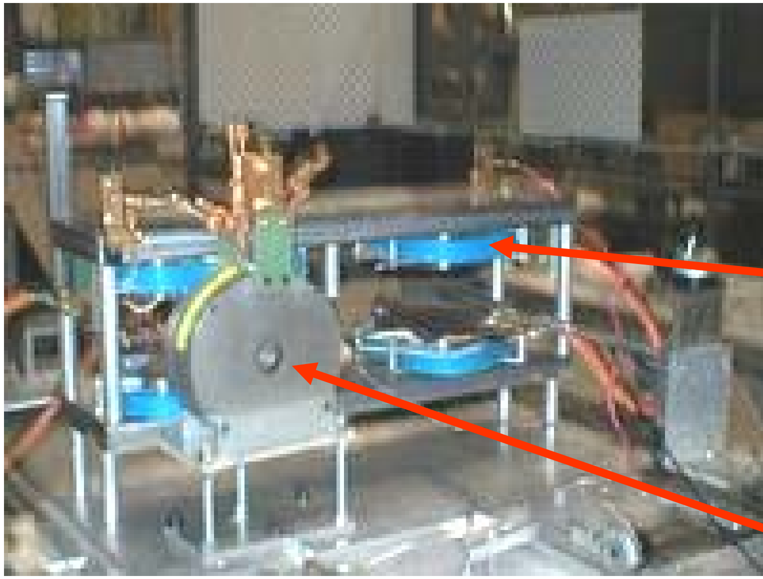
R. Poeschl

The Undulator Setup



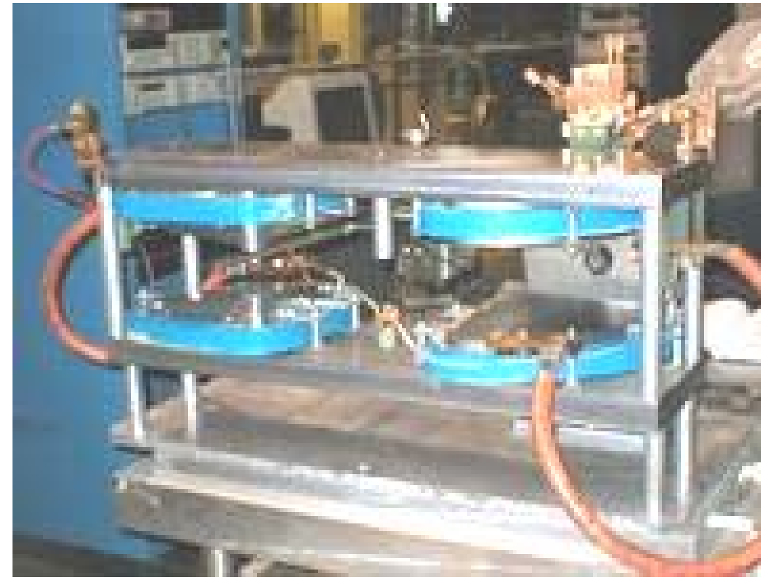
General view to the undulator set, pulser and hydraulic system.

Setup



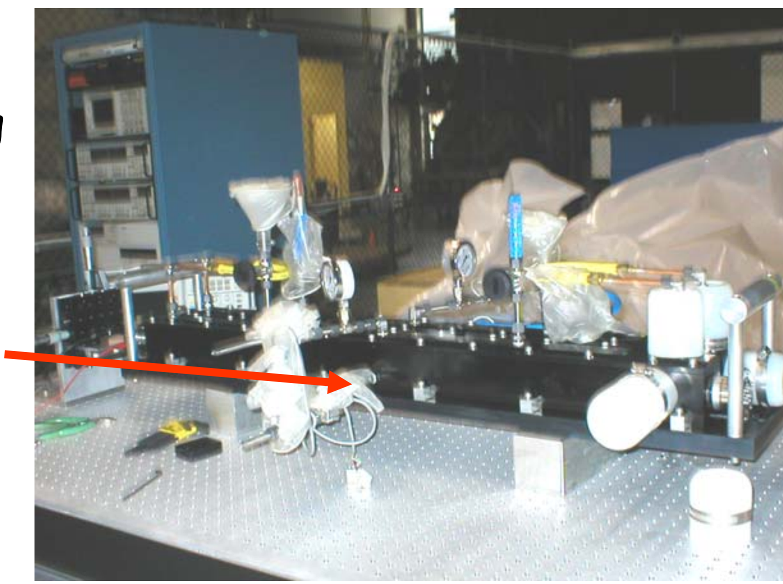
Bending Magnets

Solenoid



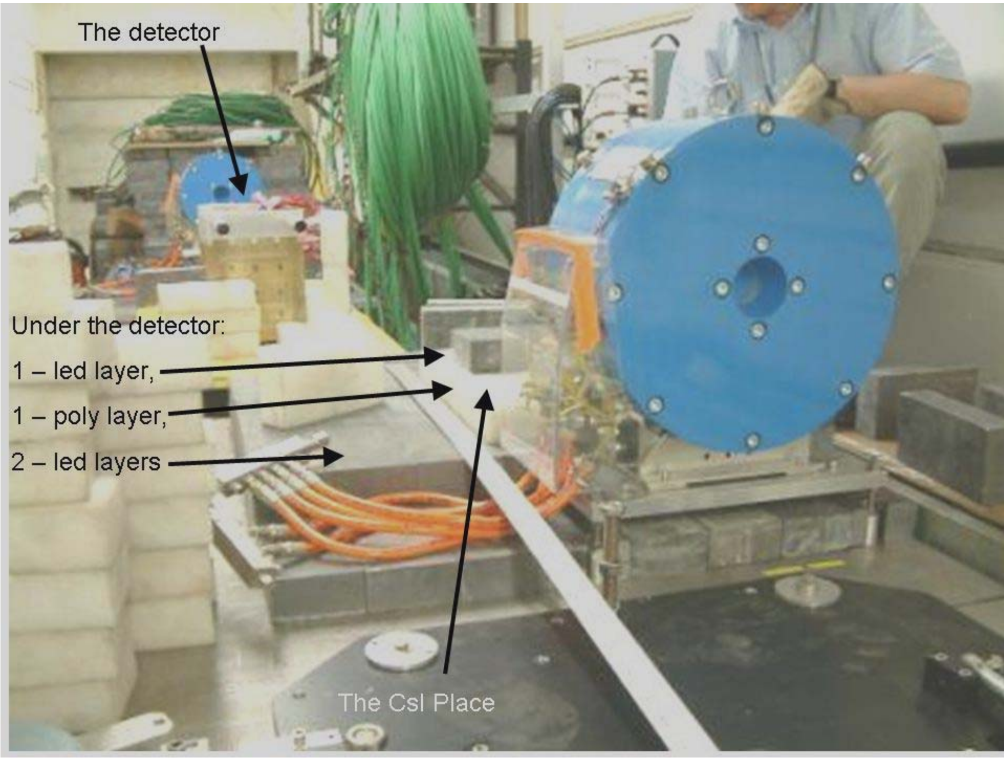
Analyzing Magnet

Helical Undulator



Setup

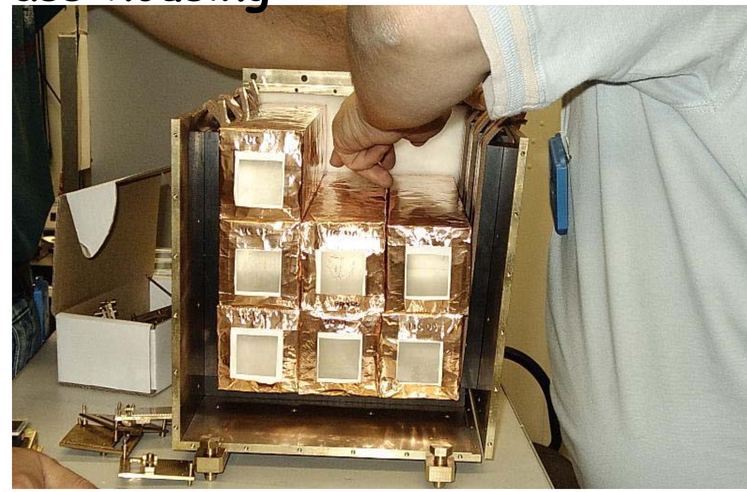
The Photos magnet
The Detector ¾ shielded
Positron spectrometer place

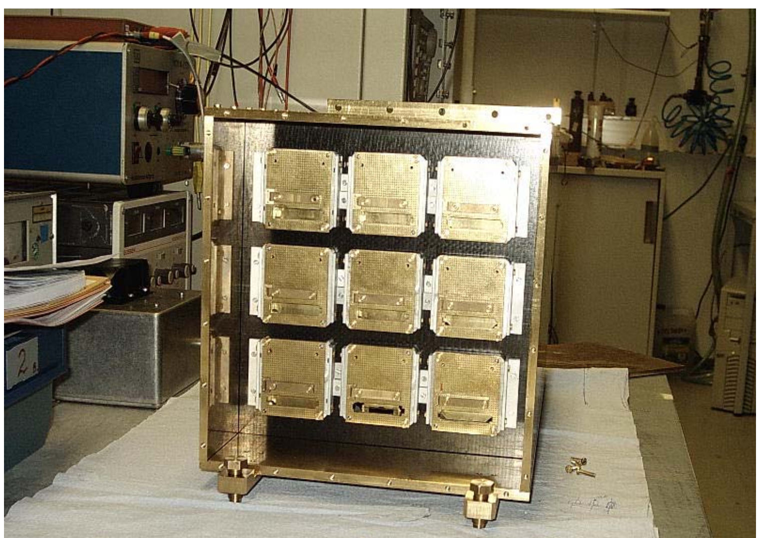


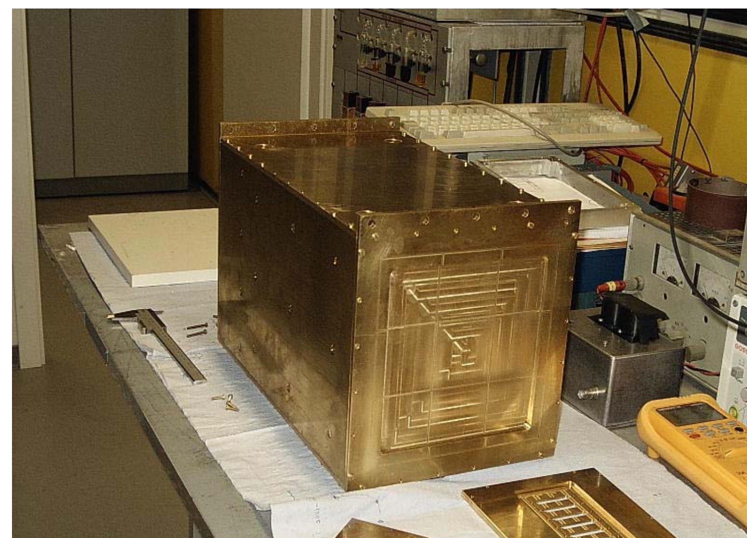
The detector
Under the detector:
1 – led layer,
1 – poly layer,
2 – led layers
The CsI Place

The CsI-Calorimeter

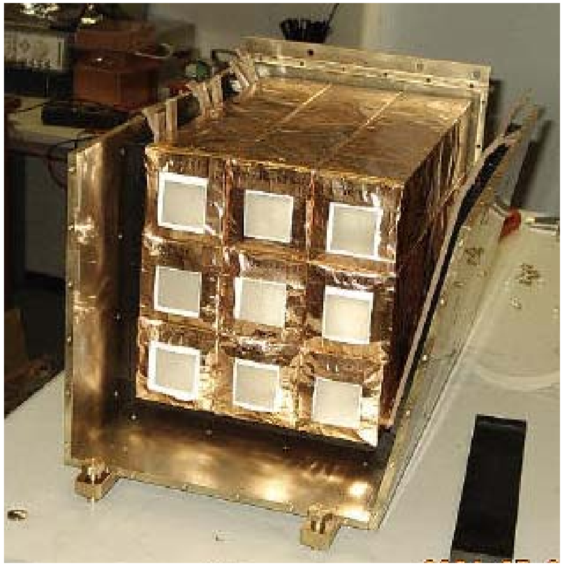
3x3 CsI crystals in a brass housing







The CsI-Calorimeter



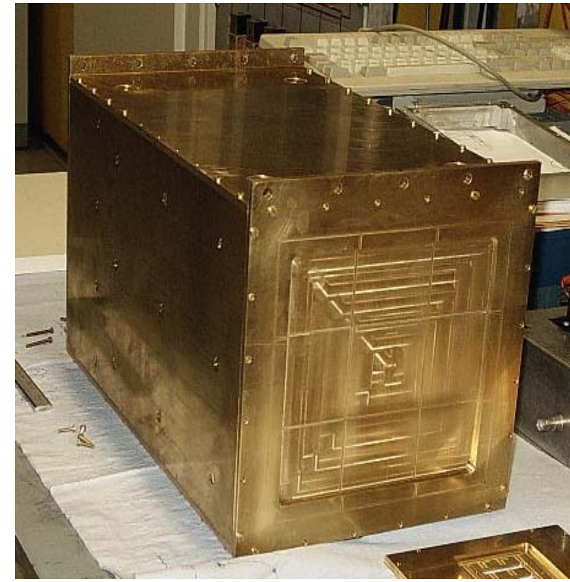
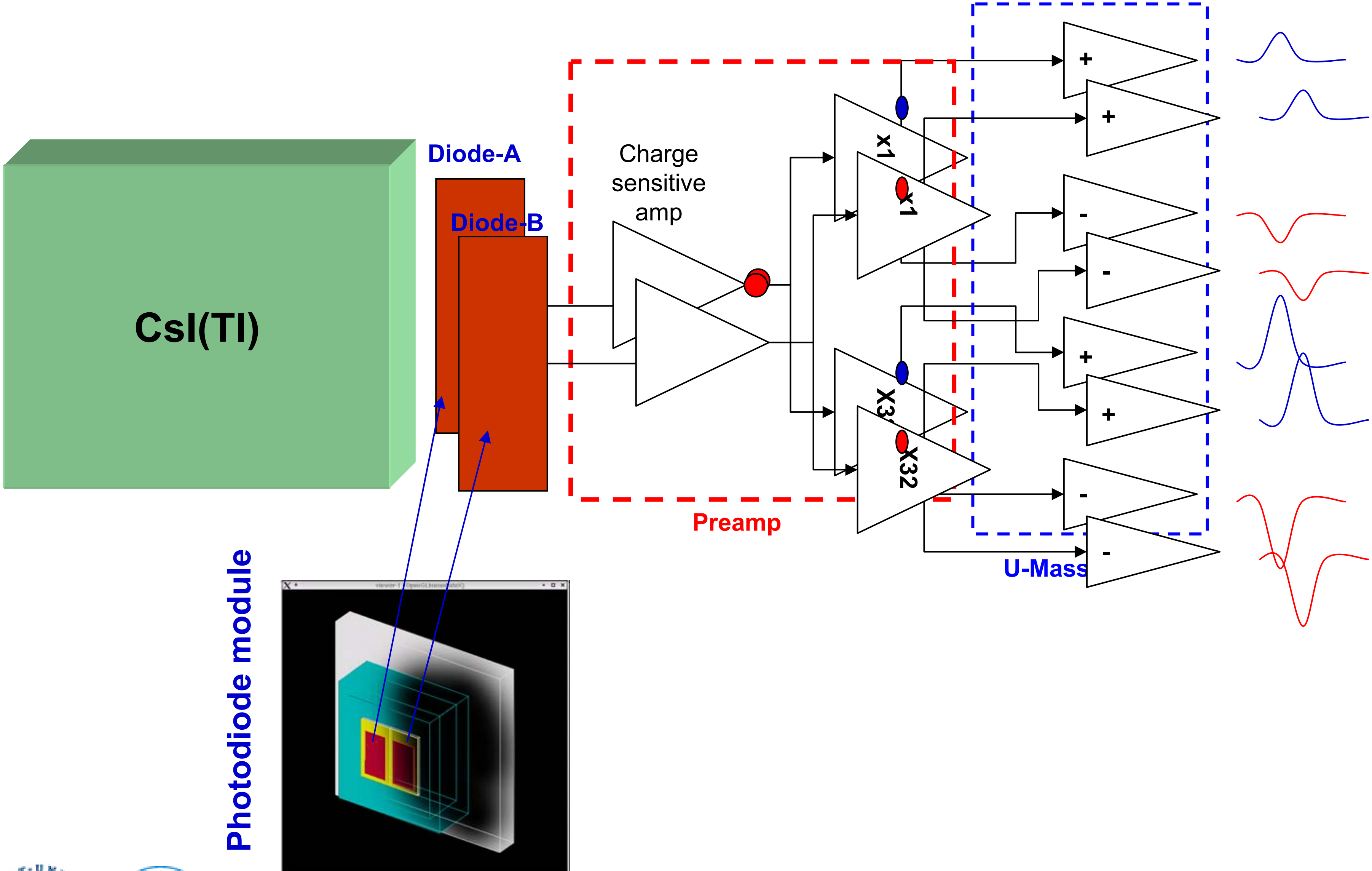


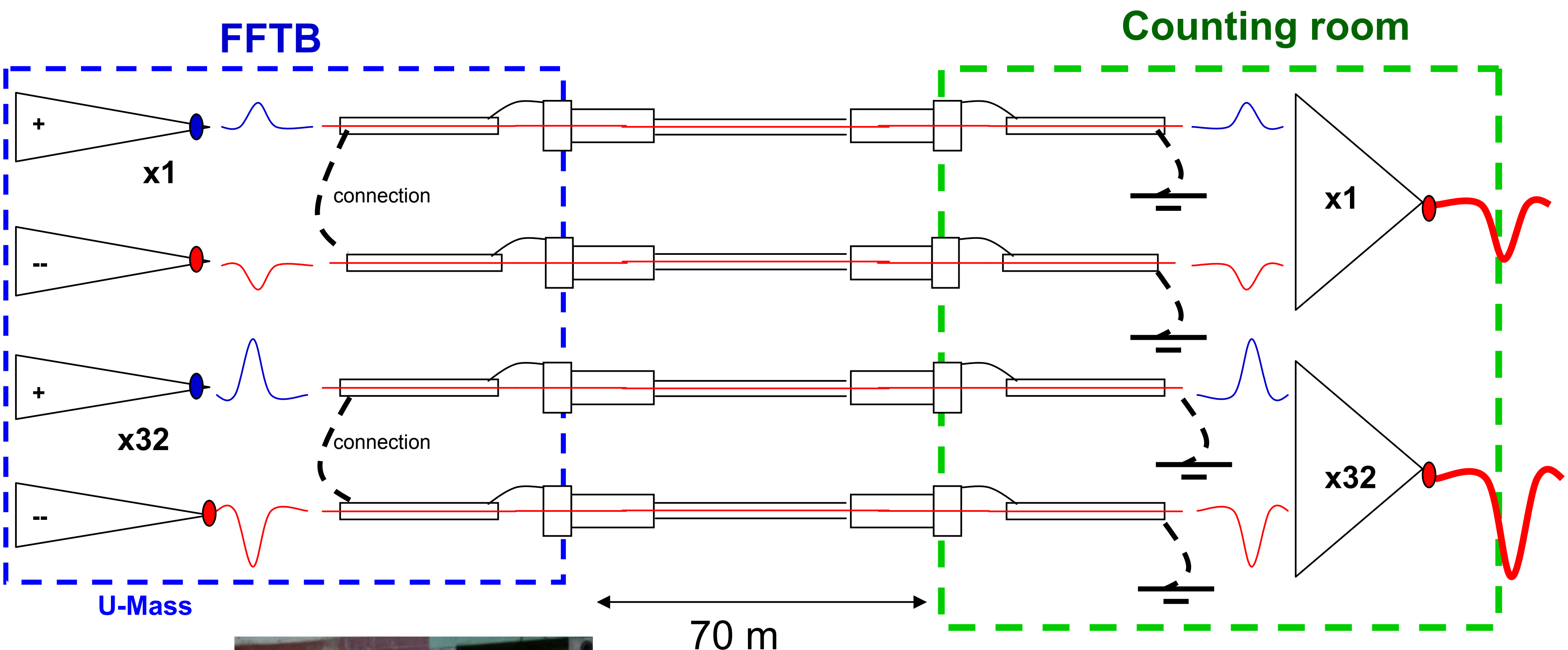
Photo diodes

- every crystal is read out by 2 Si-PD's
- we are reading analog signals

CsI - Calorimeter Readout

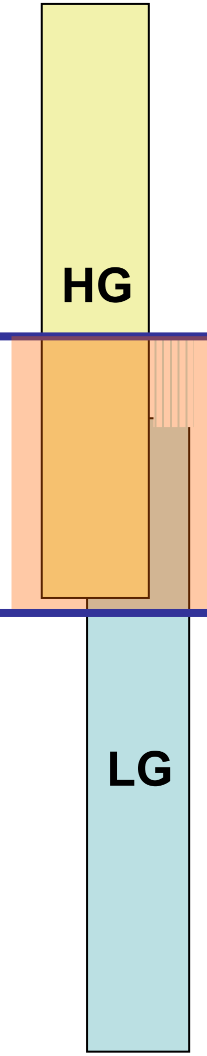


Readout 2



Summing amplifier

Calibration Procedure



60Co source ~ 1.2 MeV

228Th source ~2.8 MeV

Good for the correlation

cosmic muons **~38.8 MeV/Crystal**
Monte Carlo

Beams >~ 1 GeV **1 GeV**

DESY Hamburg **6 GeV**

SALC E166 **7 GeV**

Good for the calibration

Data Taking

- Original plan: two running periods in October 2004 and January 2005
- June 2005: first run of E-166
- September 2005: second run

Data Taking

- Original plan: two running periods in October 2004 and January 2005
- June 2005: first run of E-166
- September 2005: second run

Data taking scheme:

- Beam energy 46.6 GeV
- 10 Hz beam
- Undulator at 10 Hz
- Every 2nd pulse – undulator off time

-> "undulator on"-event followed by "undulator off"-event

Collected Positron Data

Spectrometer set for	No. of beam pulses collected
5.6 MeV	$2.0 * 10^5$
5.2 MeV	$3.1 * 10^6$
3.7 MeV	$1.2 * 10^6$
4.5 MeV	$1.2 * 10^6$
6.0 MeV	$1.2 * 10^6$
6.7 MeV	$1.0 * 10^6$

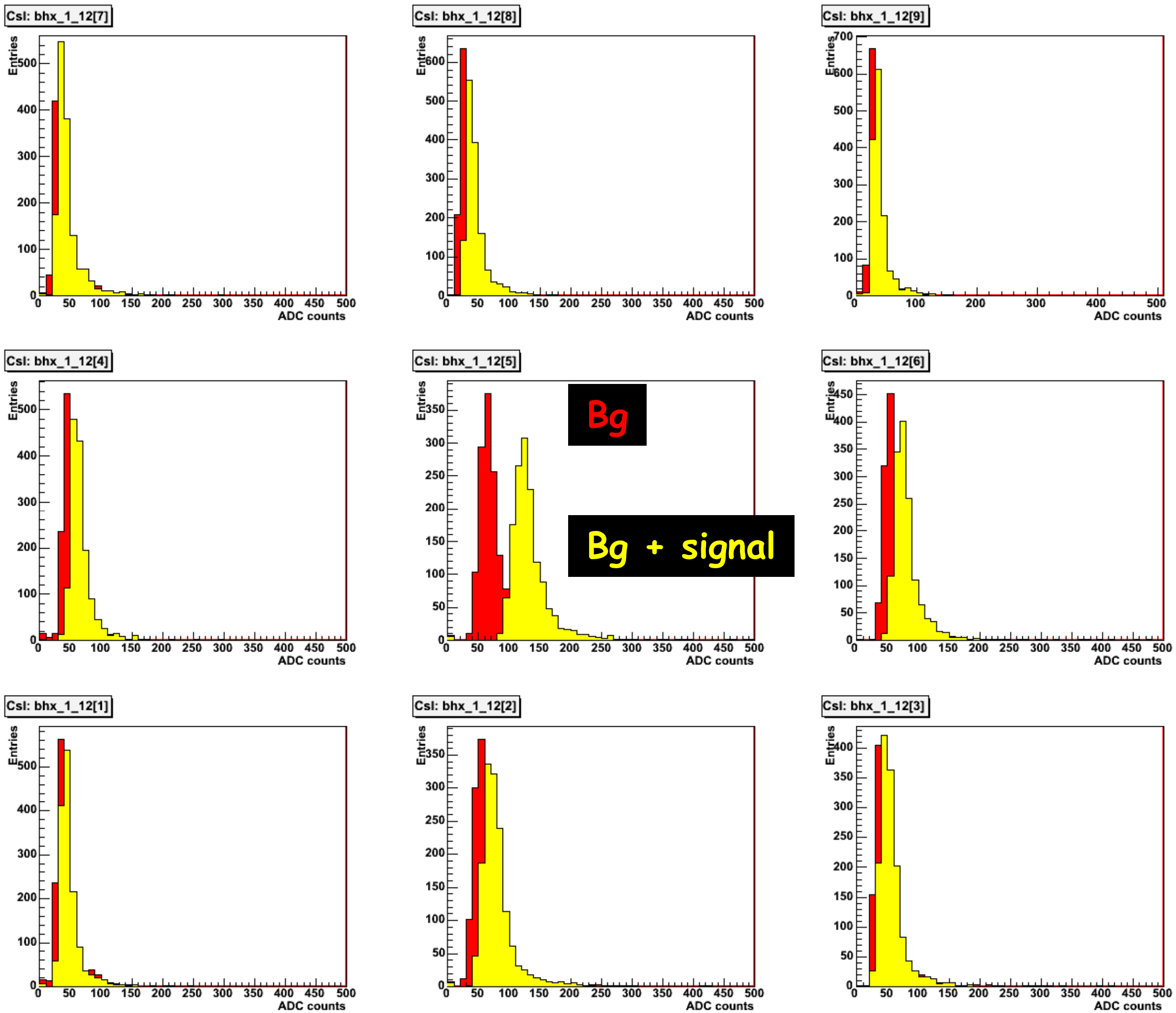
Combined June- and September run

Collected Positron- and Electron Data

Spectrometer set for	No. of beam pulses collected
5.6 MeV	$2.0 * 10^5$
5.2 MeV	$3.1 * 10^6$
3.7 MeV	$1.2 * 10^6$
4.5 MeV	$1.2 * 10^6$
6.0 MeV	$1.2 * 10^6$
6.7 MeV	$1.0 * 10^6$
6.0 MeV	$6.9 * 10^5$

Combined June- and September run

How we obtain the Asymmetries



- substract background-from signalevents
- average over certain bg-range
- test statistical methods with toy-monte carlo
- calculate the asymmetry between the two magnetization states

Photon Asymmetries

preliminary

Photon asymmetries from June data
measured with 2 Detectors:

Photon Calorimeter : 3.52 % ± 0.15 %

Aerogel Counter : 3.50 % ± 0.40 %

(stat. errors only)

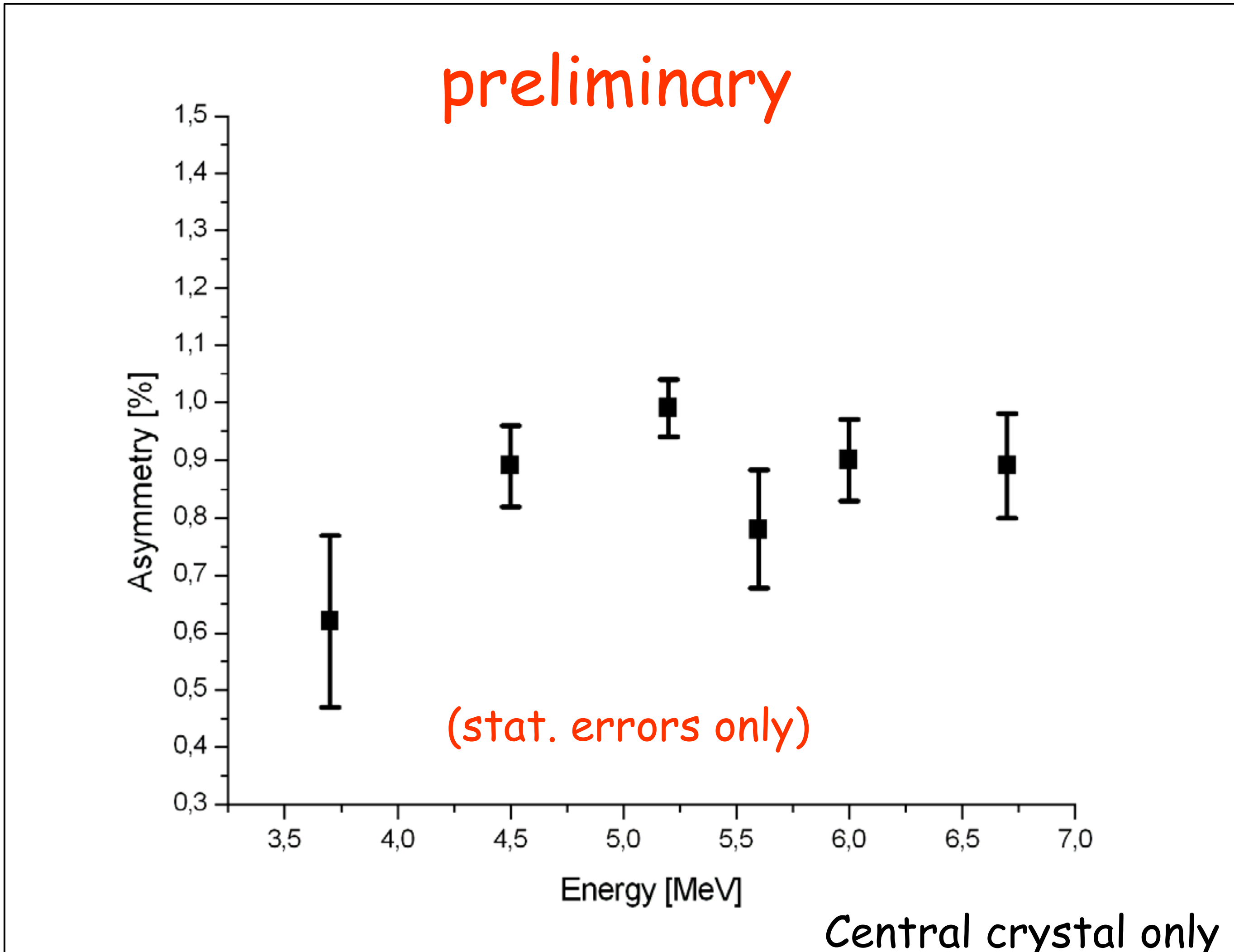
Photon Asymmetries

preliminary

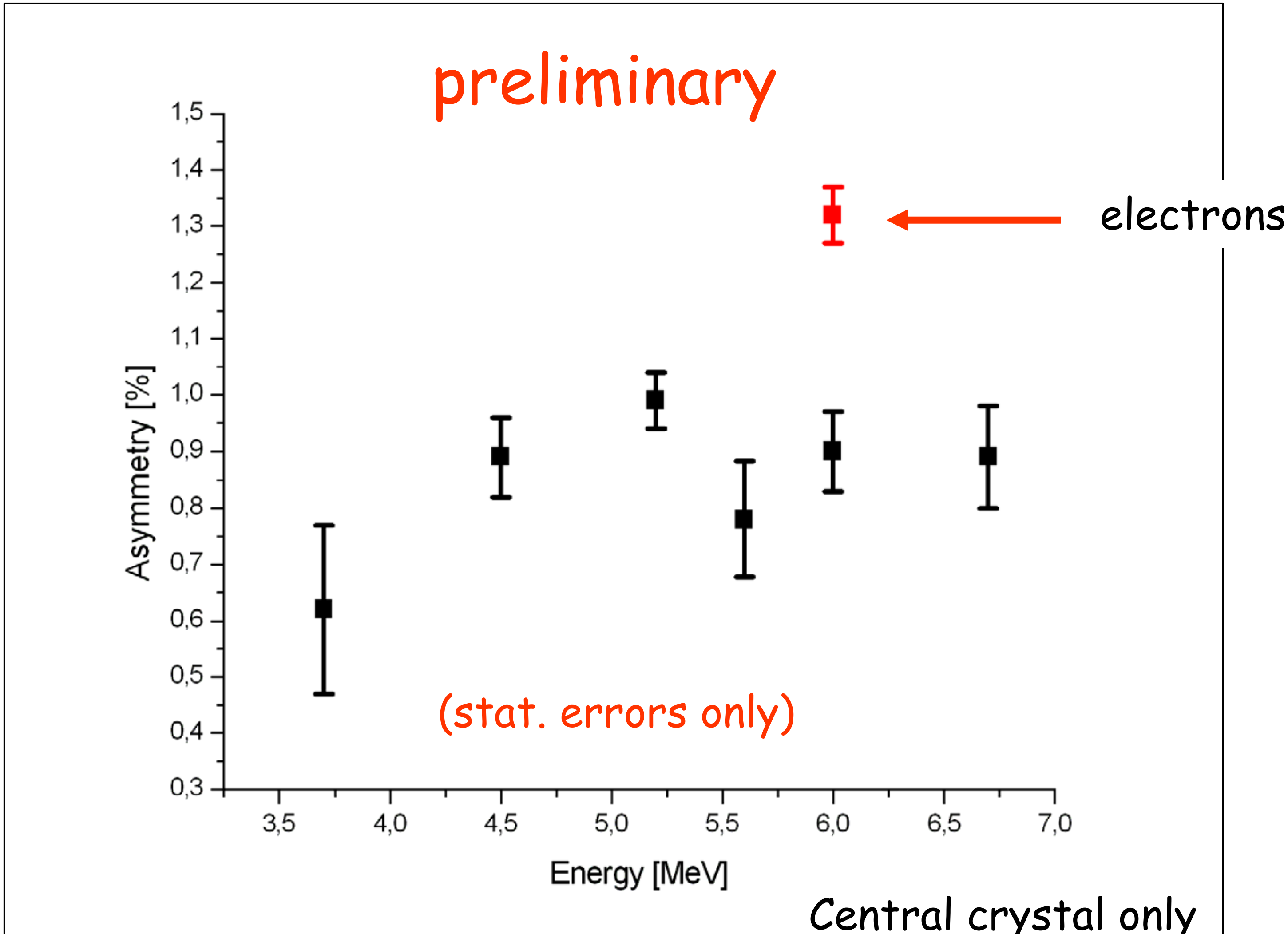
Photon asymmetries from June data measured with 2 Detectors:		Expected from G3 Sim. (46.6 GeV beam energy):
Photon Calorimeter :	3.52 % ± 0.15 %	3.22 %
Aerogel Counter :	3.50 % ± 0.40 %	3.54 %

(stat. errors only)

Positron Asymmetries



Positron Asymmetries + Electron Asymmetry



Summary

- E-166 produced data with good quality
- The helical undulator was working
- We did a first analysis of the data and the asymmetries are in the expected range
- It still takes some time to come up with a number for the photon and positron polarization
- More simulation work has to be done
- The data analysis is ongoing…