Polarized positrons with the E-166 Experiment

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On behalf of the
E-166 collaboration

E - 166
International Polarized Positron Collaboration

Outline

- The goal of E-166
- The helical undulator
- Photon transmission polarimetry
- The E-166 setup
- Data taking
- First results on photon and positron asymmetries

E-166

- Demonstration experiment to proof the possibility, to produce polarized positrons using a helical undulator
- Collaboration of >50 people from 17 Institutions 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

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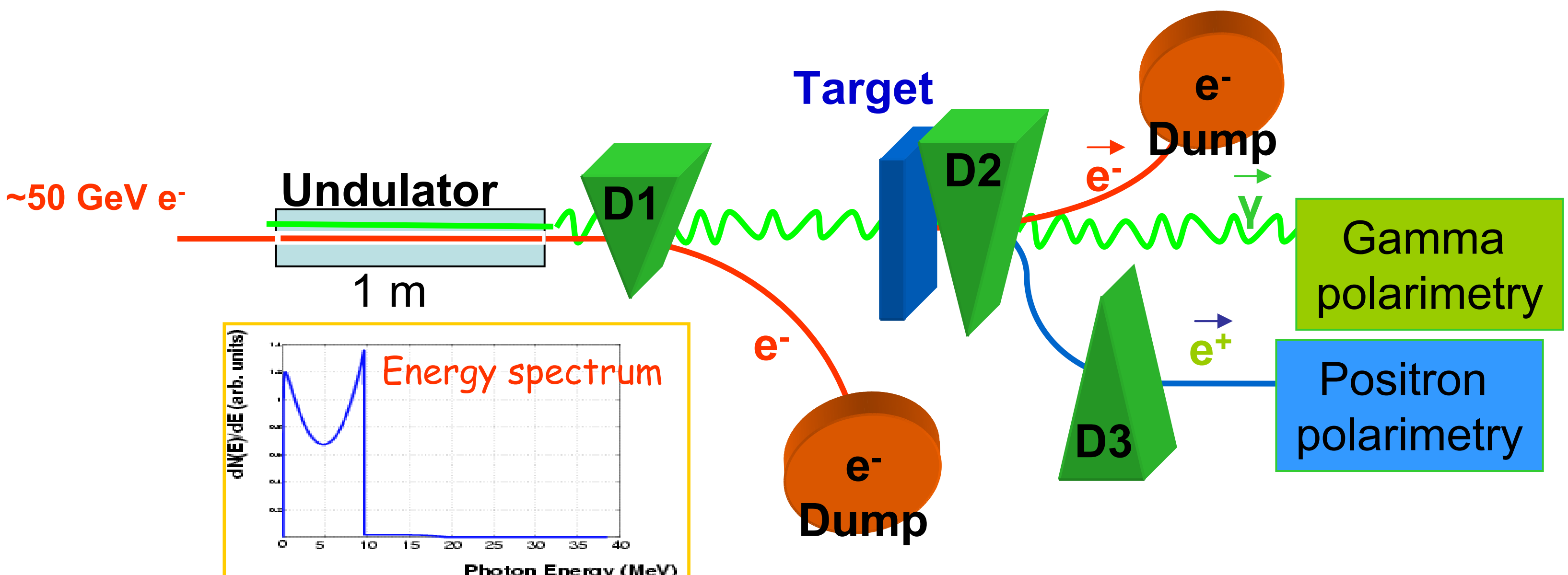
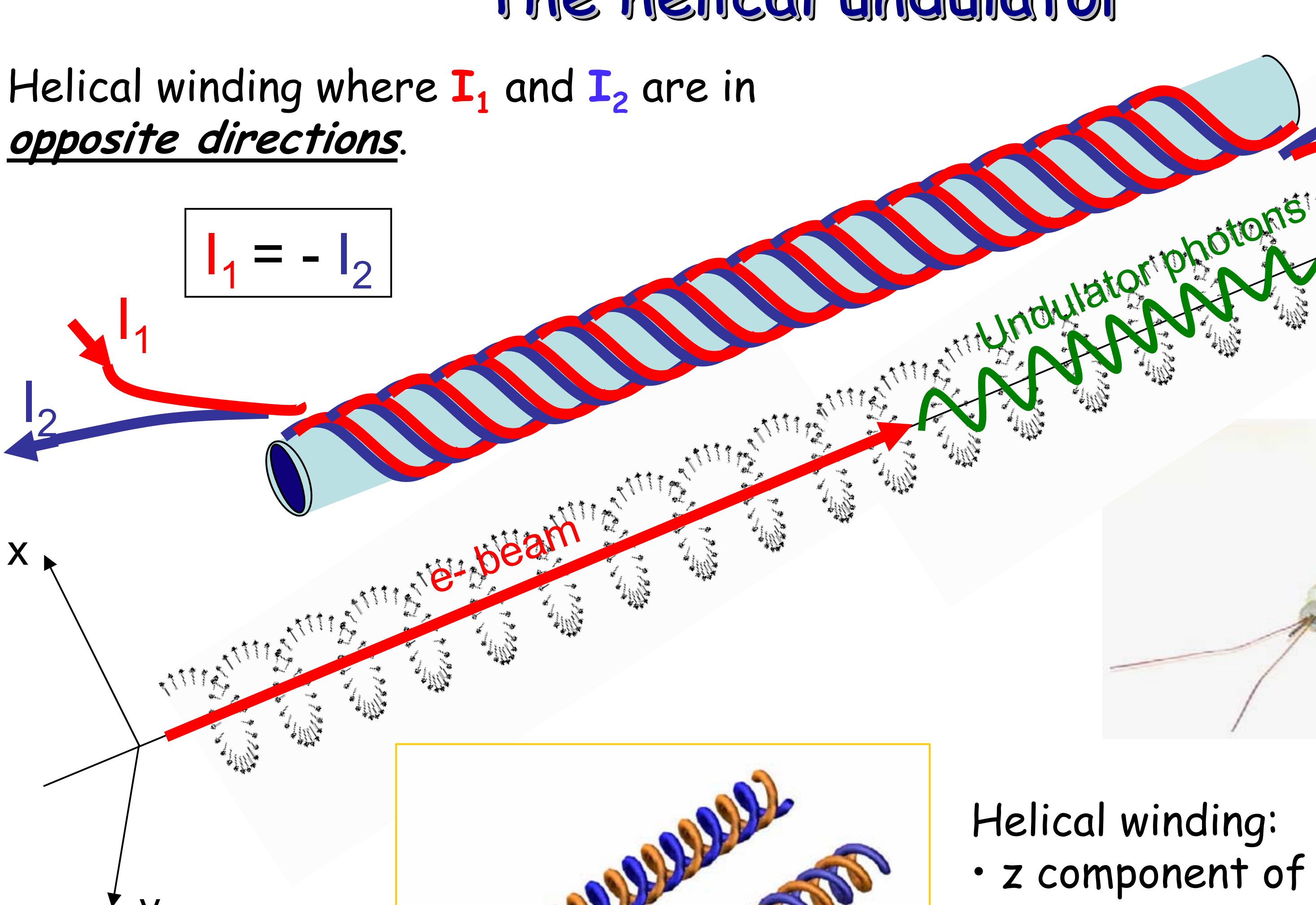
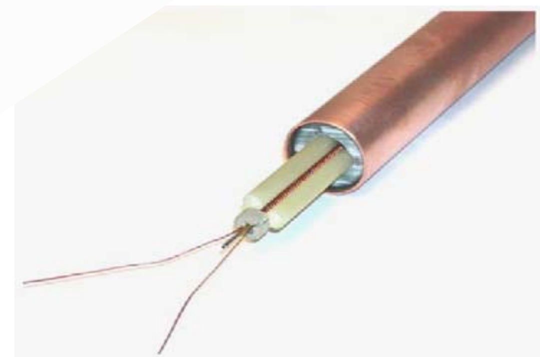


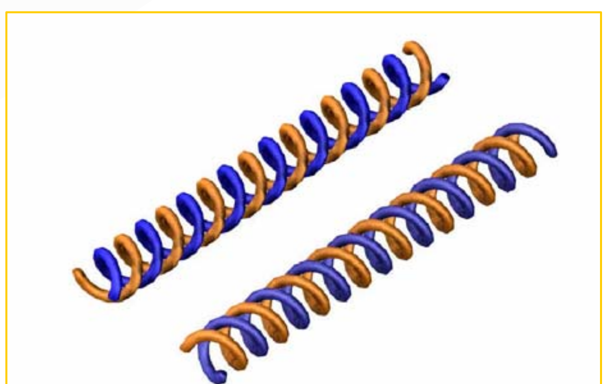
The helical undulator

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

$$I_1 = - I_2$$



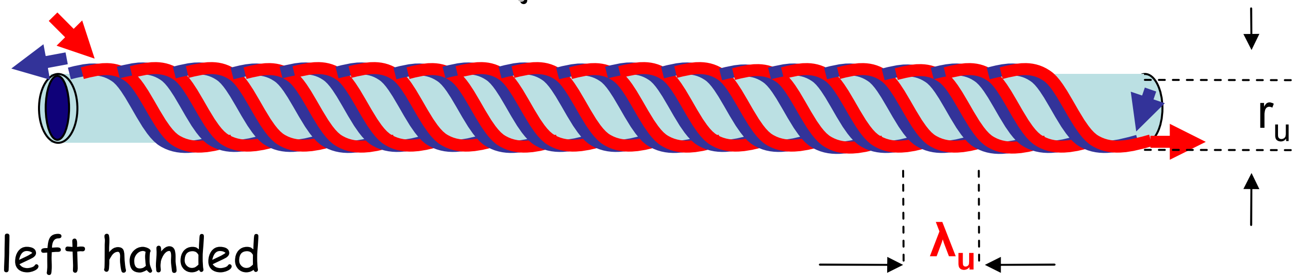




Helical winding:

- 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	**2.4mm**
On axis field	0.76 T
K factor	**0.17**
$E_0=\omega h$ (Energy cut-off 1st harmonic)	**9.6 MeV** (50GeV e- beam)
Feeding current	~ 2 kA
Rate	up to 30 Hz
Heating/pulse	~3 degC

r_u Undulator aperture	0.88 mm

K - factor (Undulator strength)

$$K = \frac{eH\lambda_u}{2\pi mc^2} \cong 93.4 H[T]\lambda_u[m]$$

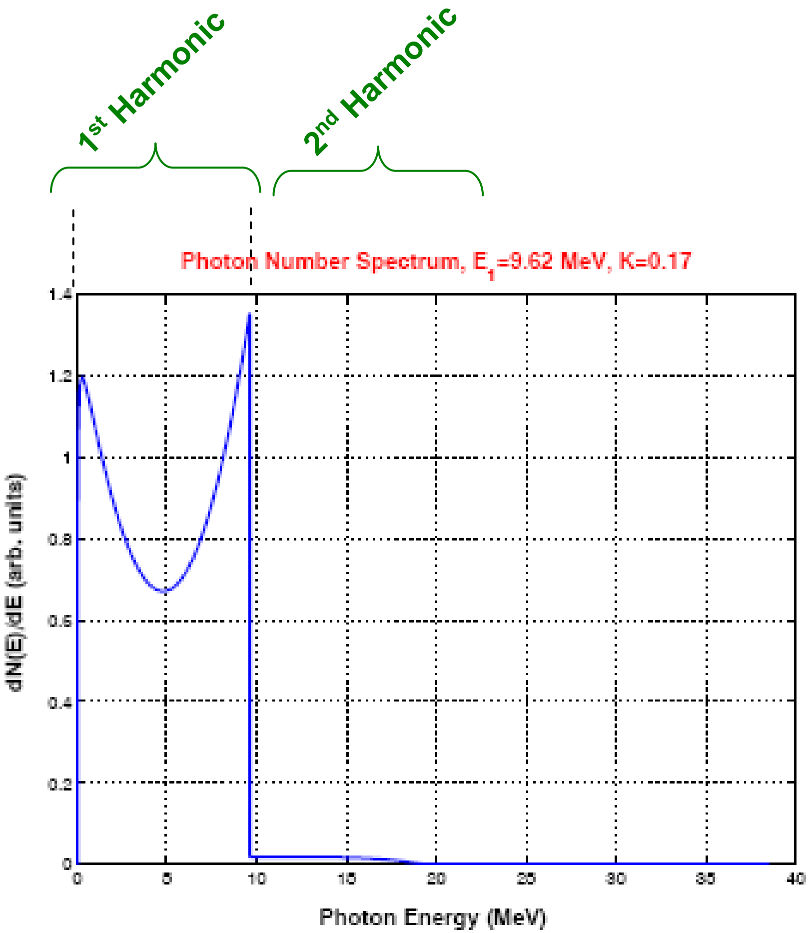
The average photon polarization depends on the angular photon selection (**K** factor) and also on the quality of the photon collimation (before the conversion target).

First harmonic Energy cut-off

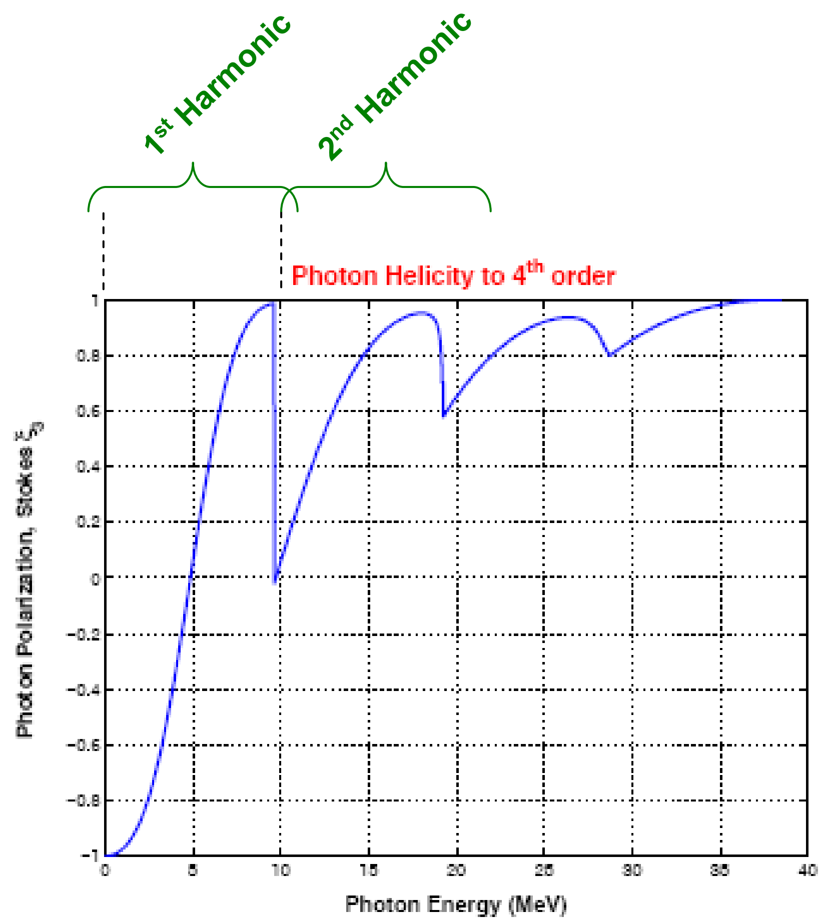
$$E_0 \approx \frac{2\gamma^2 hc}{\lambda_u}$$

Photon intensity - inverse proportional to the undulator aperture.

Photon Energy and Polarization

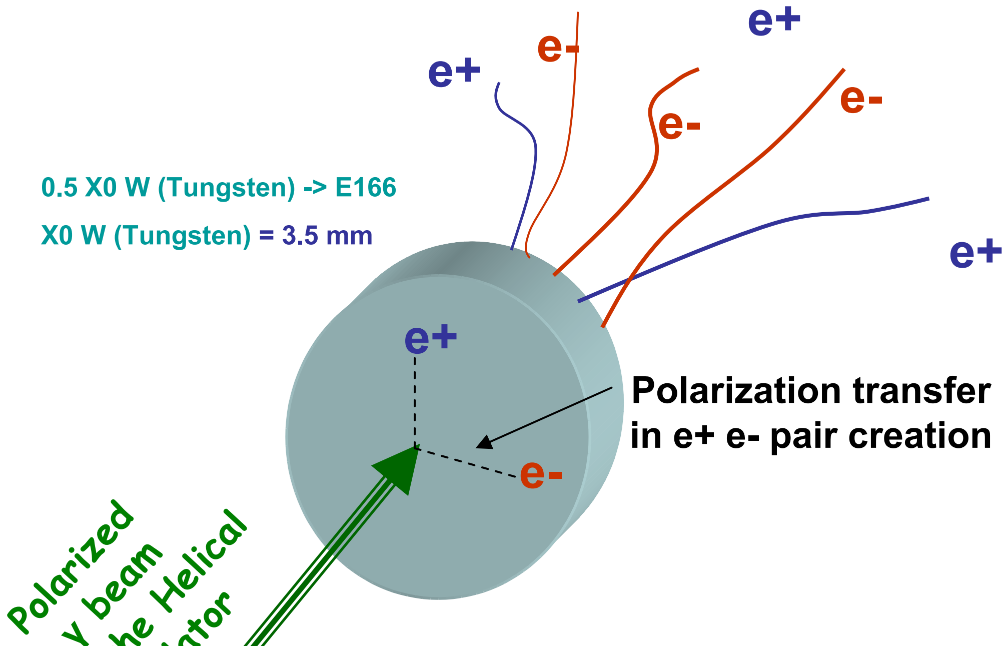


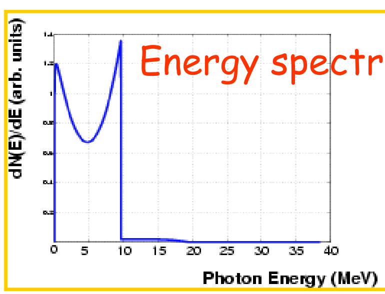
Undulator Photon energy spectrum

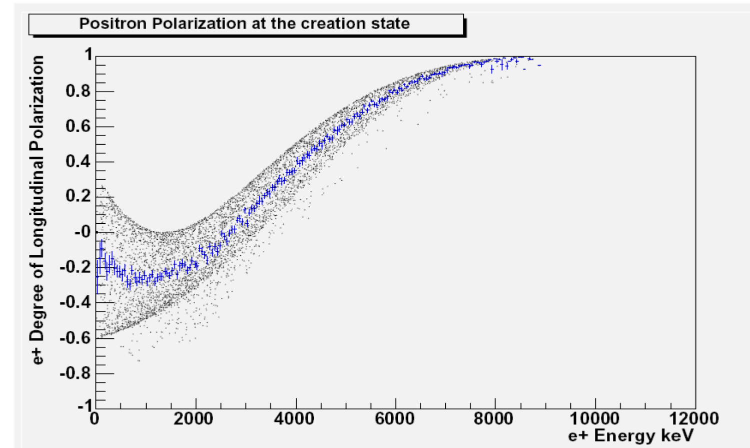


Undulator Photon degree of polarization

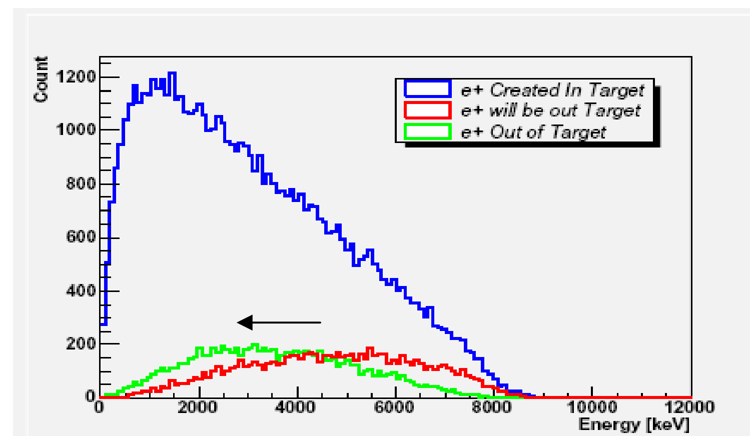
The Positron production target







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



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

50 GeV e⁻ E - 166 10 MeV γ

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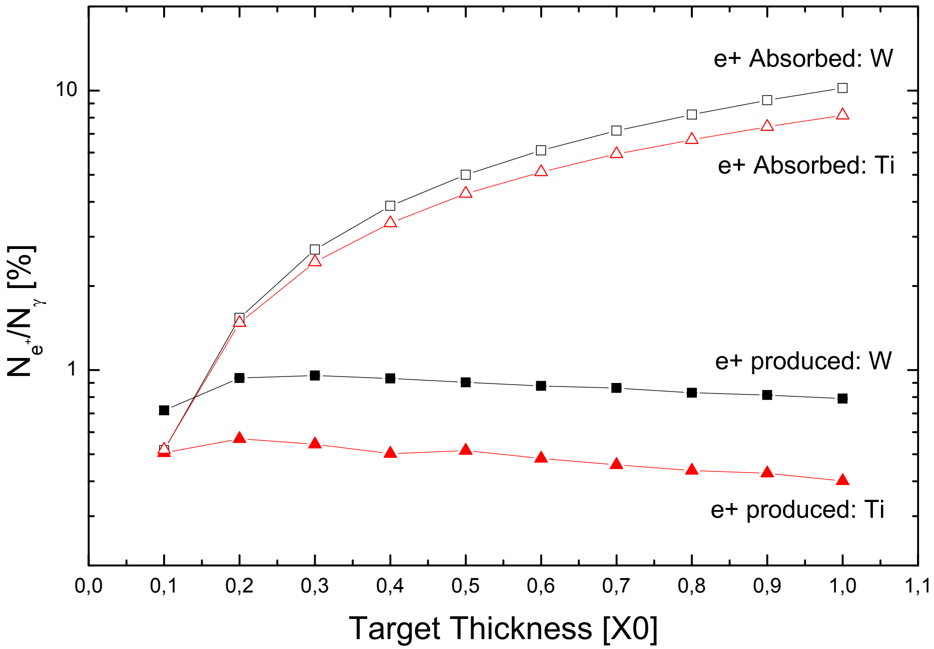
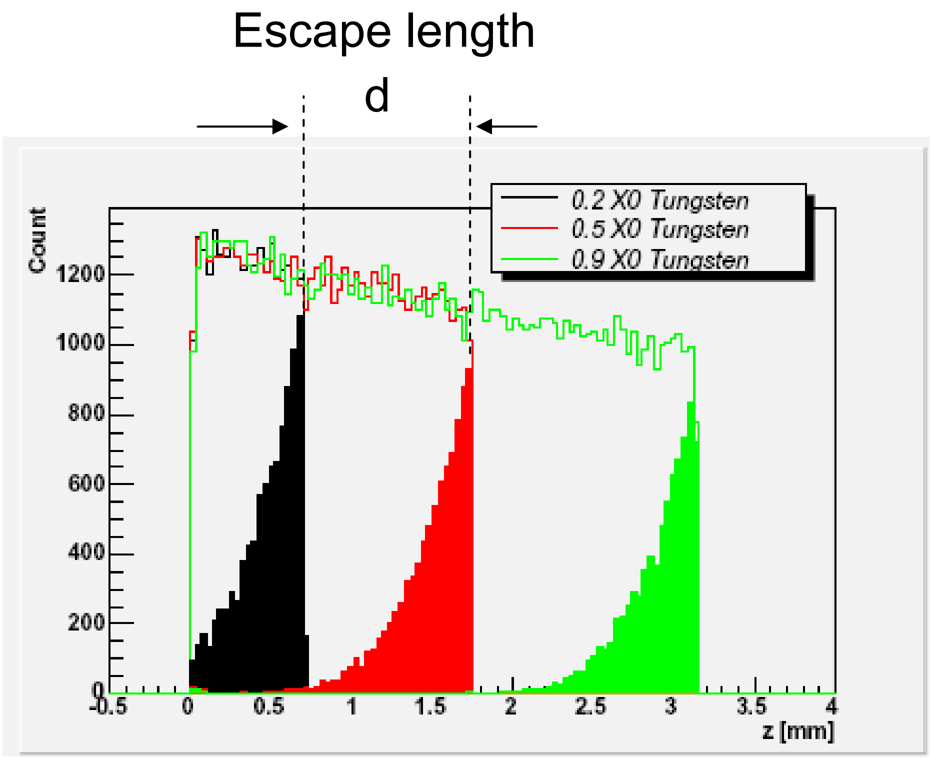
Production efficiency

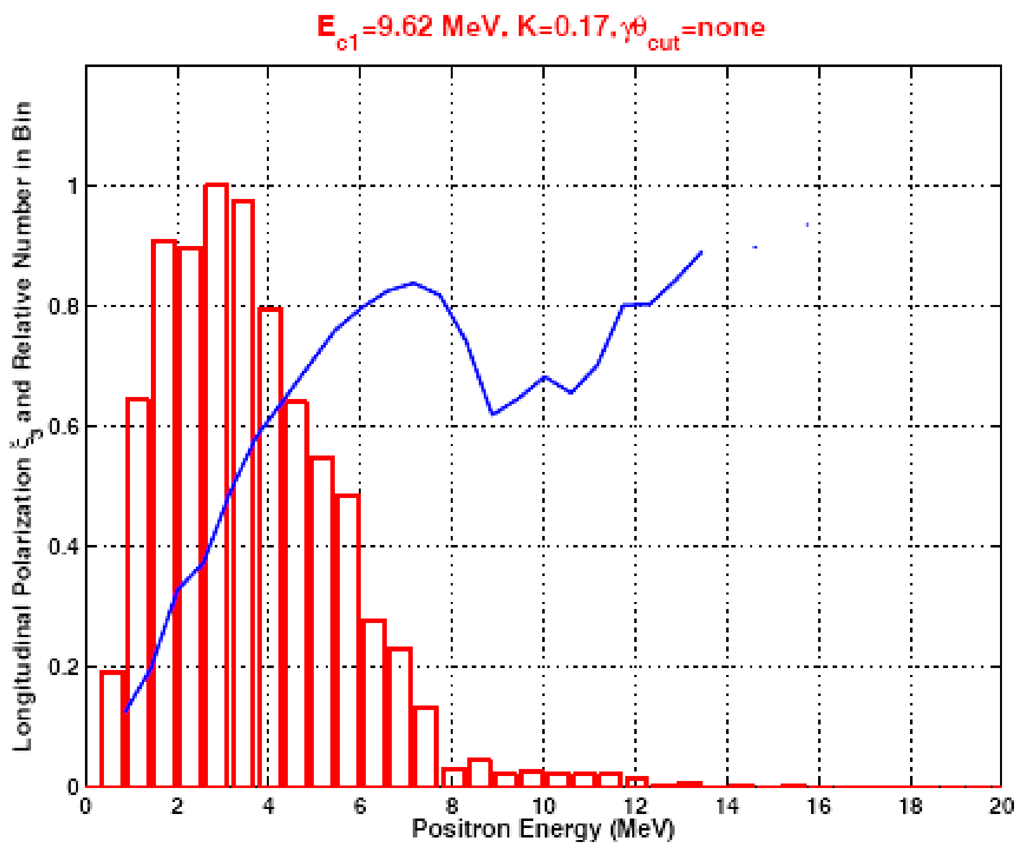


Positron production efficiency (positron yield)
$N_{(e+)} / N_{(gamma)}$



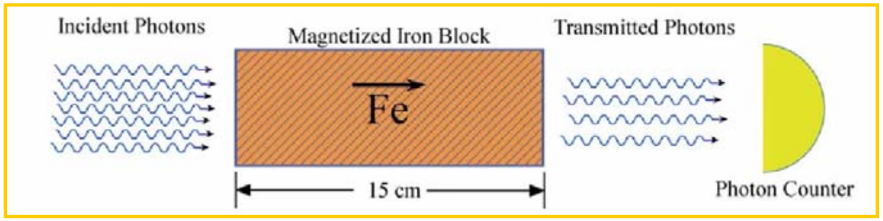
e+, z distribution (in the W target) For different target thickness

Expected Polarization



Expected positron polarization vs. positron energy

Photon transmission polarimetry



Transmission:

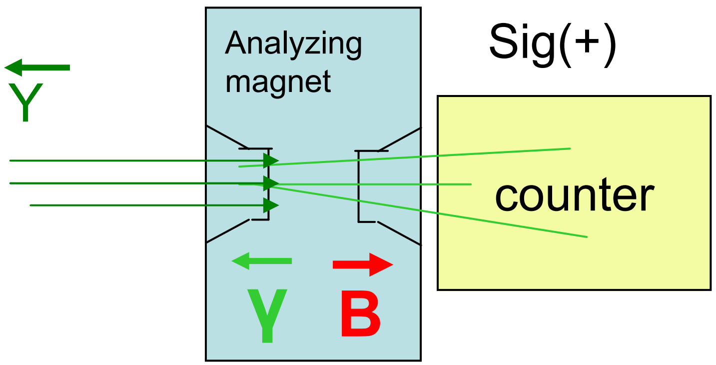
$$T(L) = e^{-nL(\sigma_{phot}+\sigma_{pair}+\sigma_{comp0})}\, e^{\pm nLP_\gamma P_e \sigma_{pol}}$$

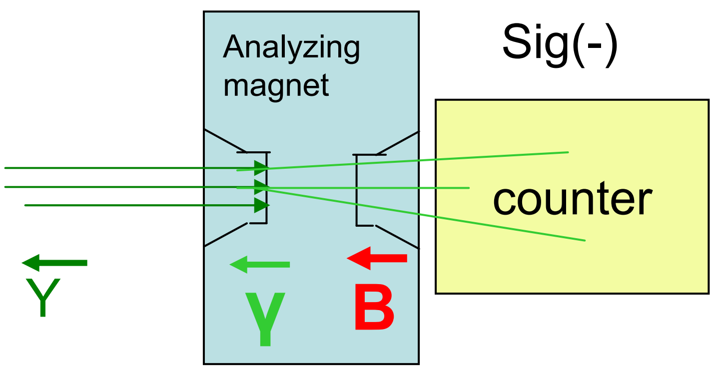
Asymmetry:

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

By knowing *Pe* => *Pγ* can be calculated:

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





E166 measures

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

Positron Analyzing Power

Positron Energy E_{e^+} (MeV)	Positron Polarisation P_{e^+} (%)	Positron Asymmetry δ (%)	Analyzing 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 asymmetries and analyzing power versus positron energy

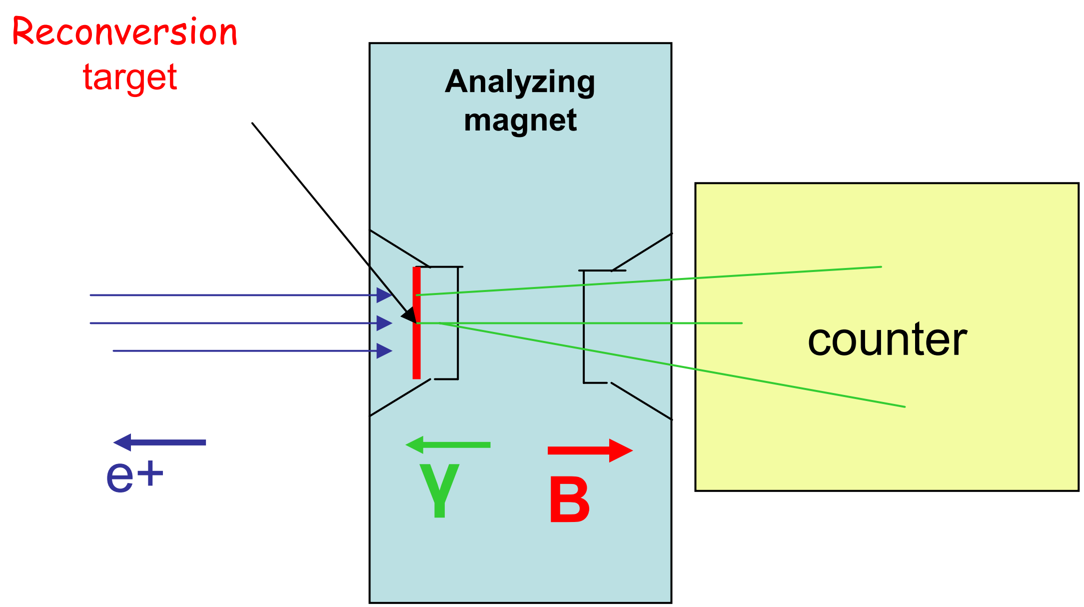
G3 simulation based on the experimental setup of the proposal

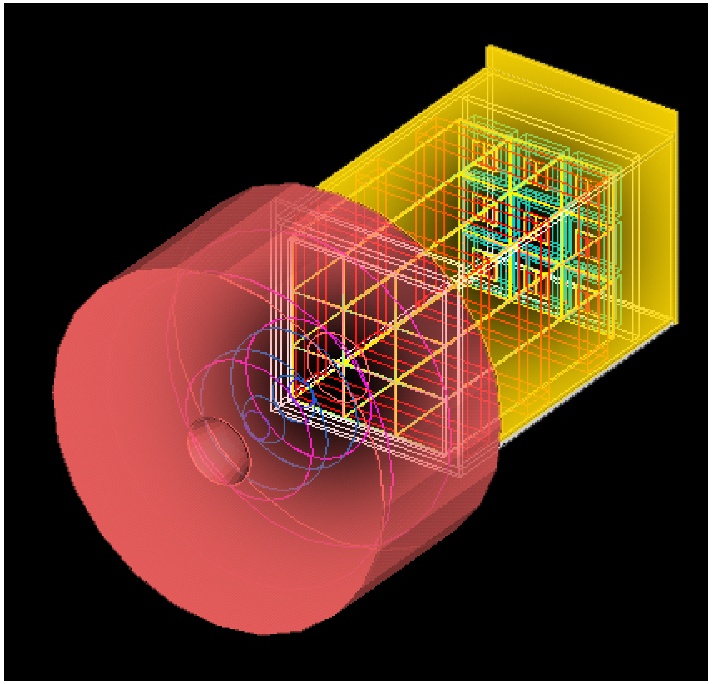
V. Gharibyan

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

Measure the asymmetries

Positron Polarimetry is similar to the photon Polarimetry.
In a reconversion target the positrons are reconverted
via Bremsstahlung and anihilation into photons.

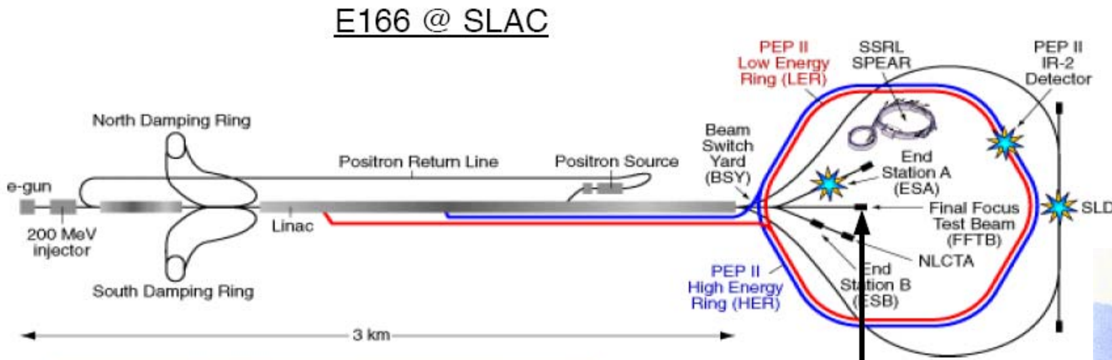




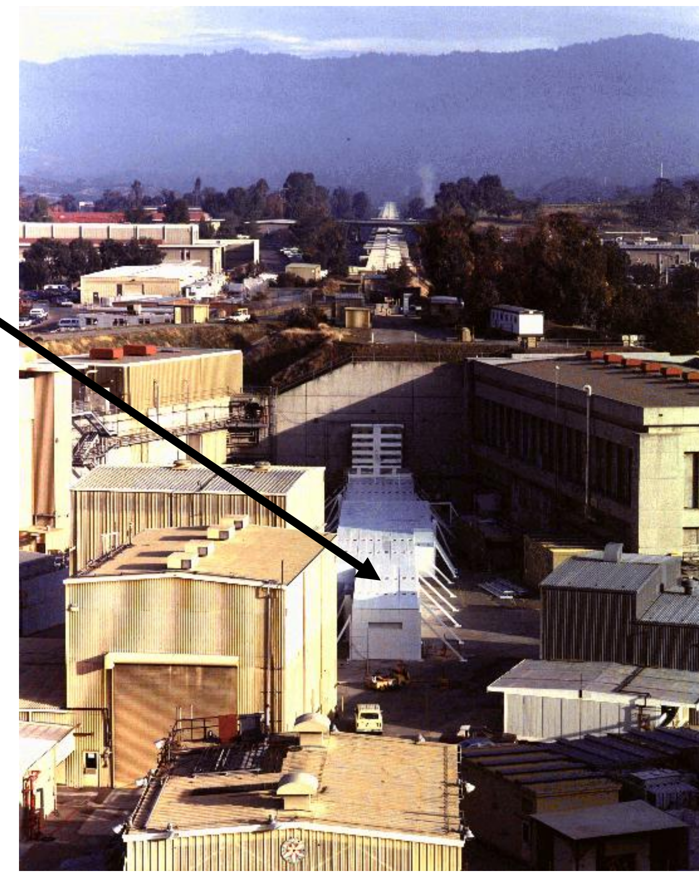
$$Asym = \frac{Sig(-) - Sig(+)}{Sig(-) + Sig(+)}$$

The asymmetry is measured
by flipping the magnet polarity.

E-166 in the FFTB



We are here !
(FFTB @ SLAC)

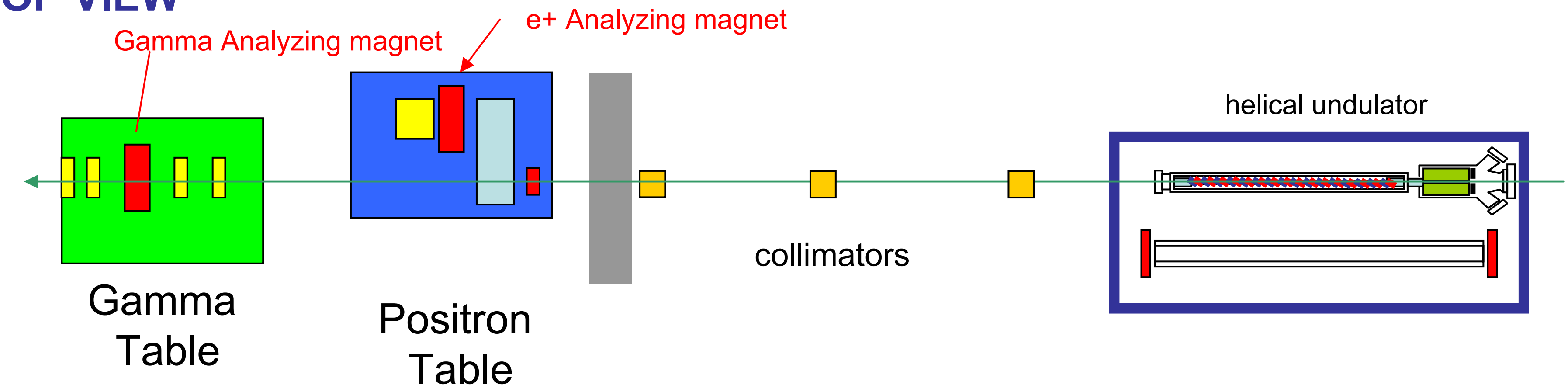


running parameters:

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

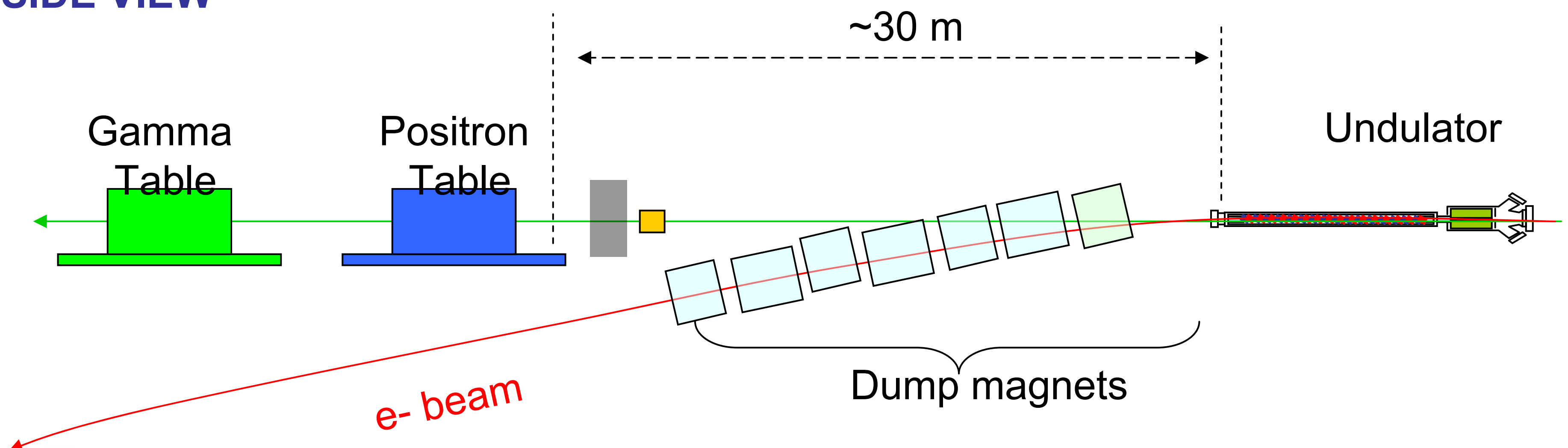
E166 setup in the FFTB

TOP VIEW

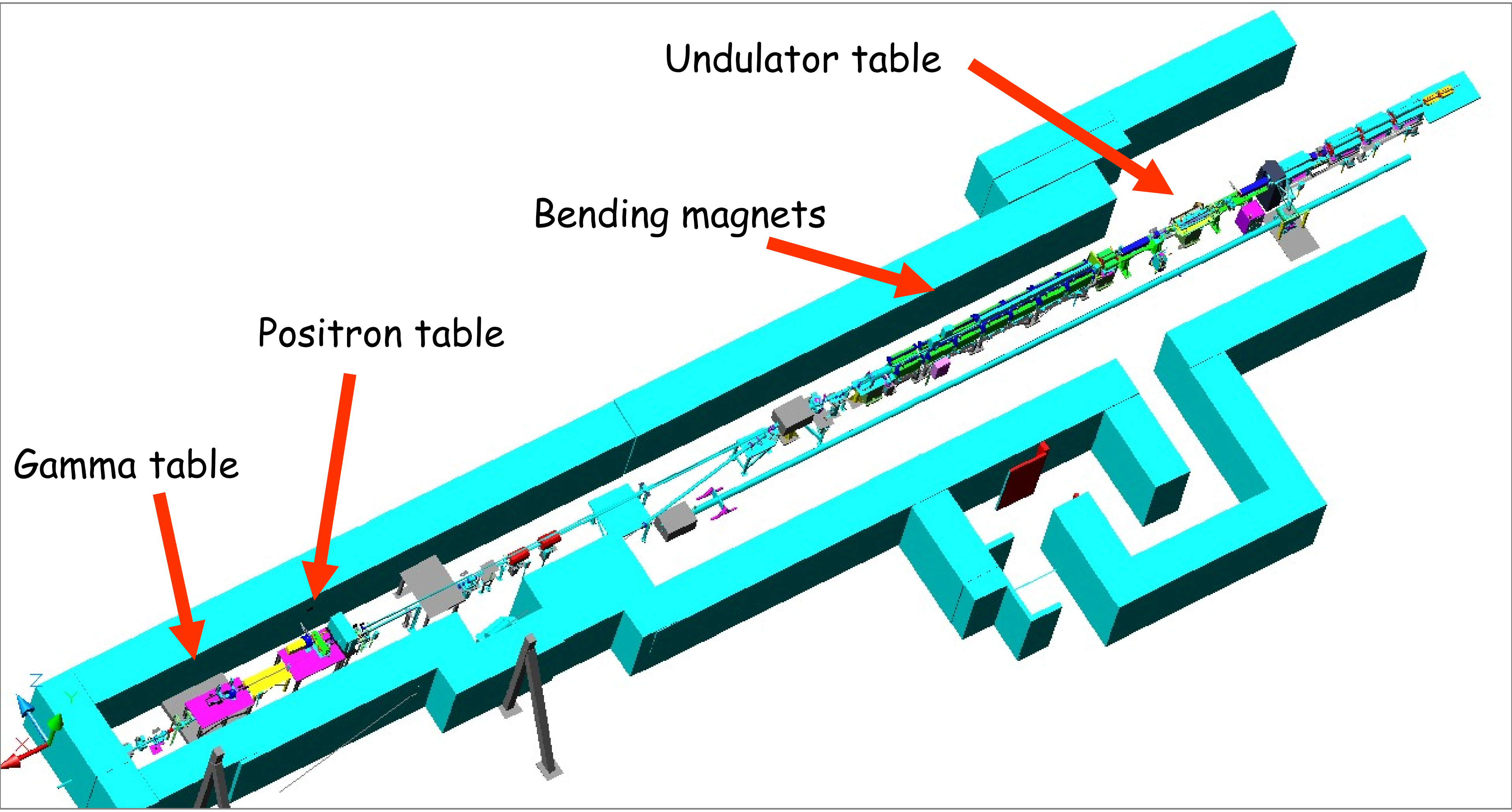


photons diag	Positrons diag	photons collimation	Polarized photons production

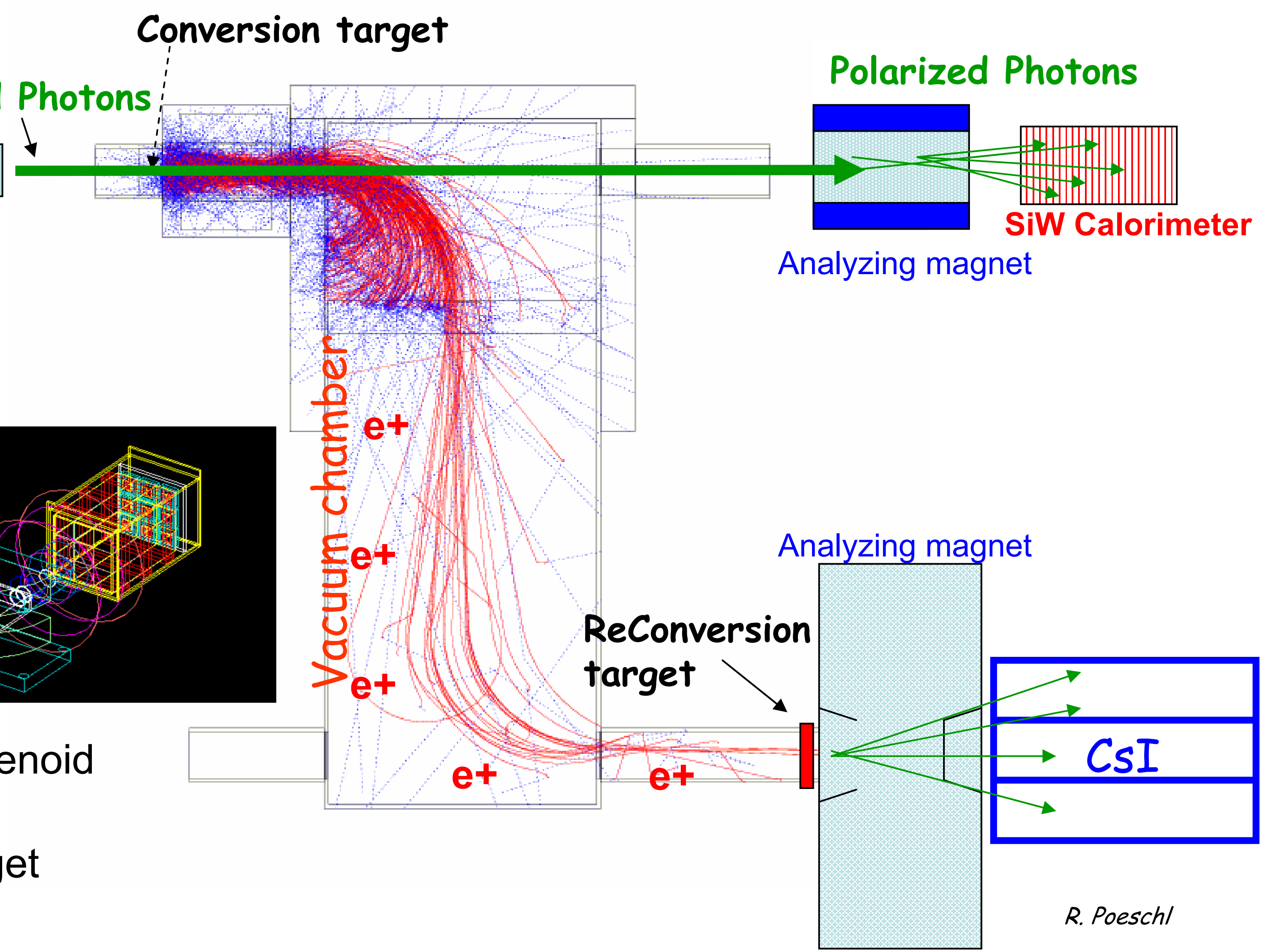
SIDE VIEW



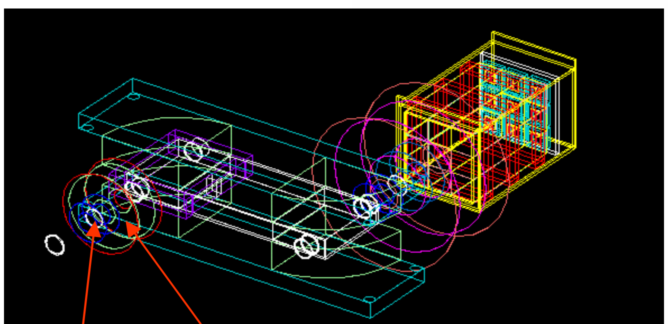
E166 setup in the FFTB



The spectrometer



K. Laihem



The Undulator setup

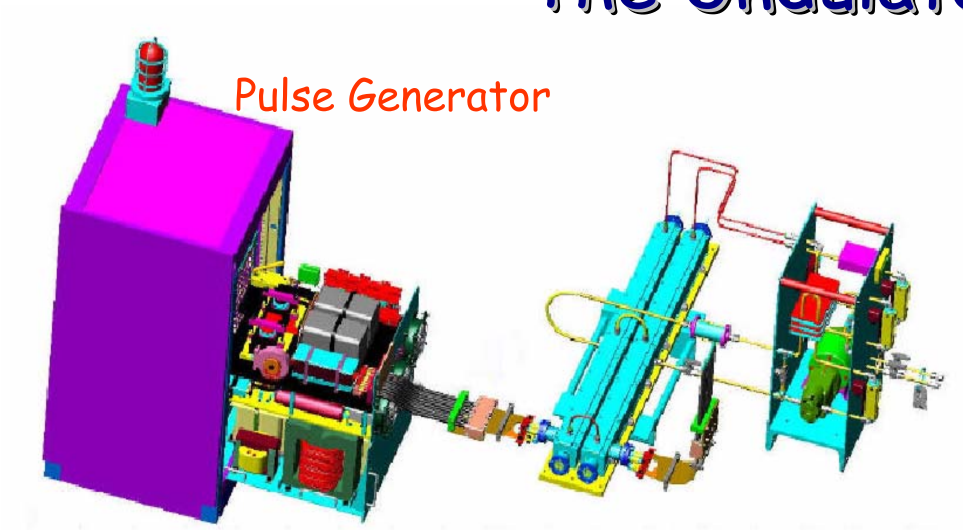
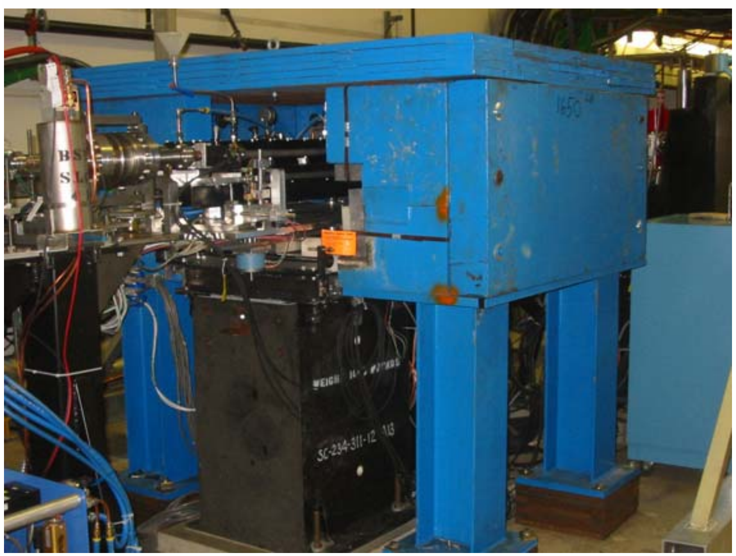


Figure 1: General view to the undulator set, pulser and hydraulic system.



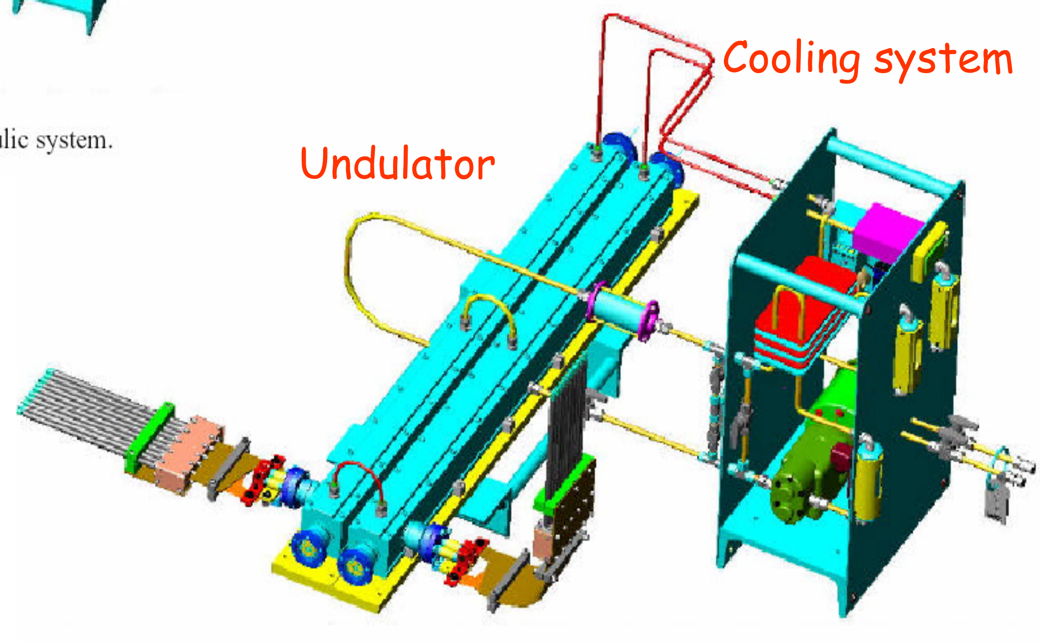
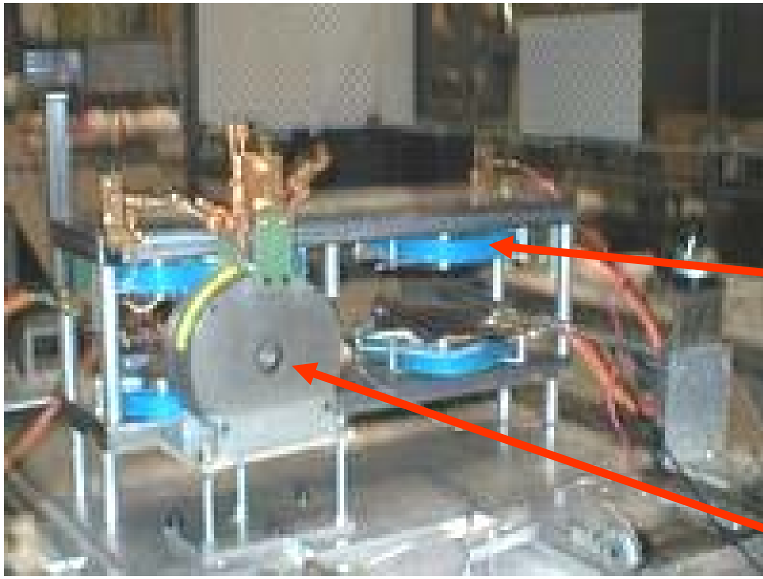
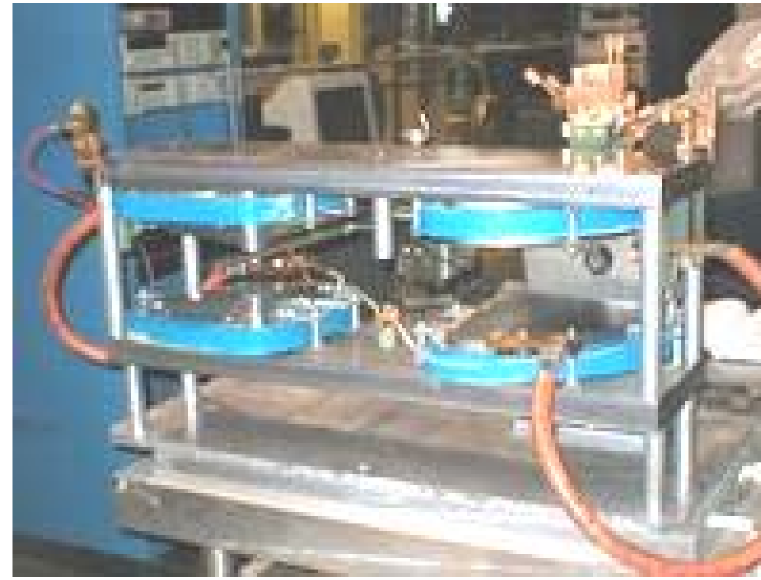


Figure 3: The undulator set and the hydraulic post.

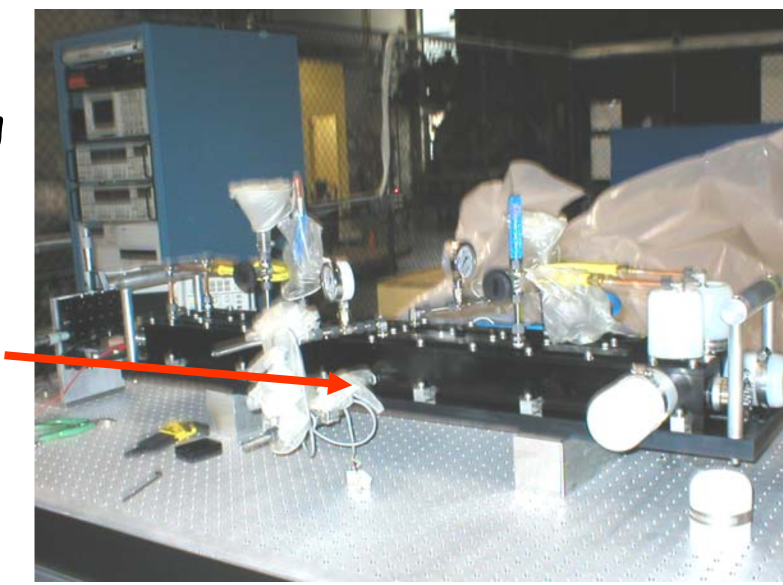
Setup





Bending Magnets

Solenoid

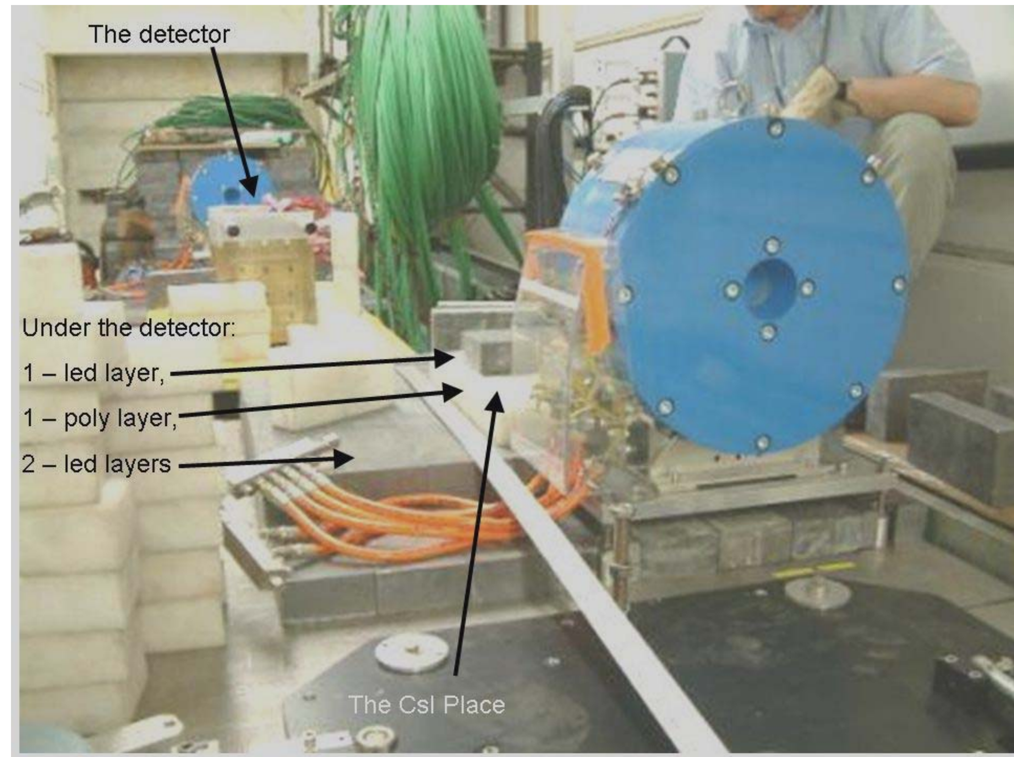


Analyzing Magnet

Helical Undulator

Setup

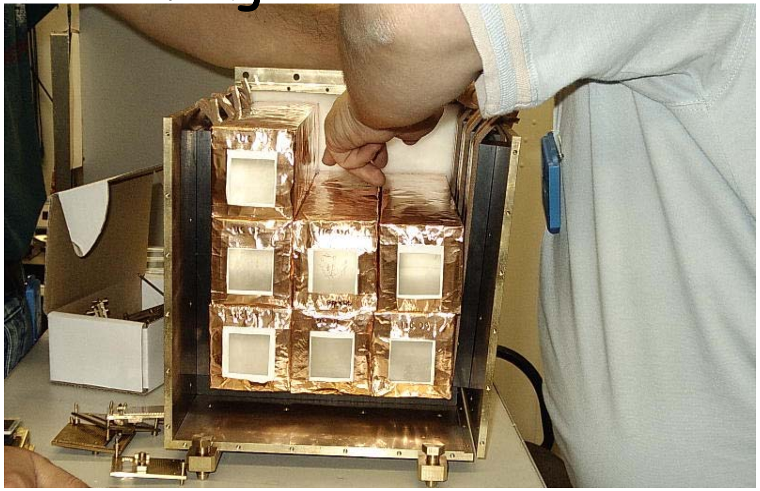
The Photos magnet
The Detector ¾ shielded
Positron spectrometer place

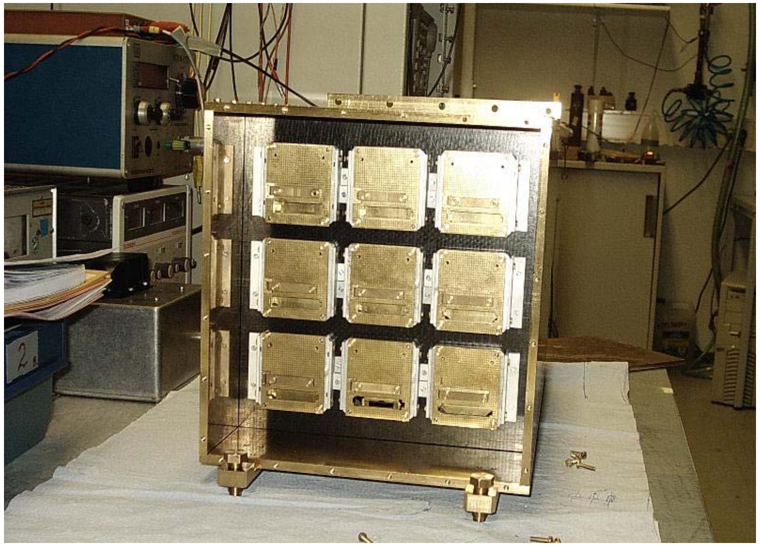


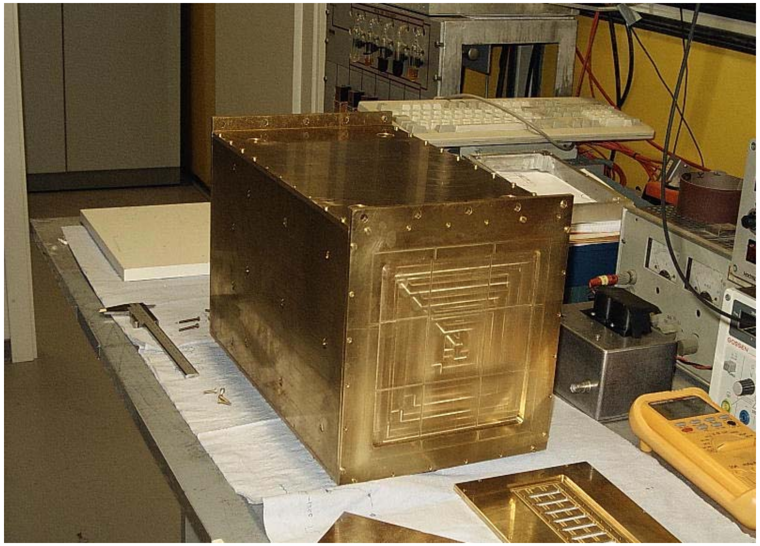
The detector
Under the detector:
1 – led layer,
1 – poly layer,
2 – led layers
The CsI Place

The CsI-Calorimeter

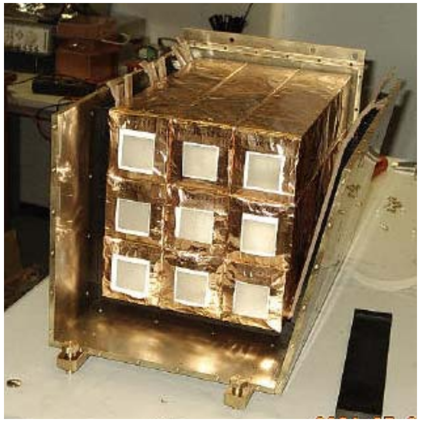
3x3 CsI crystals in a brass housing

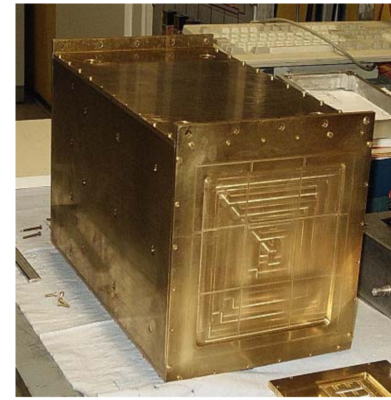


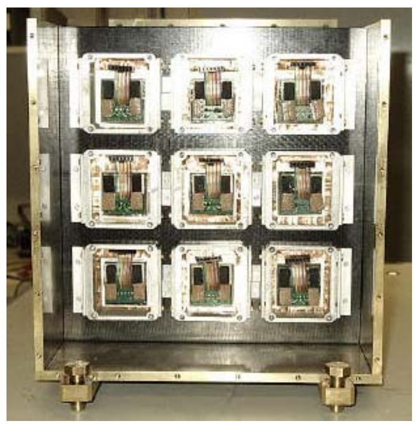




The CsI-Calorimeter







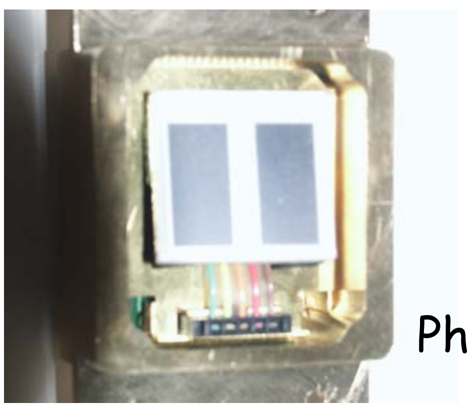


Photo diodes

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

Data taking

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

Data taking

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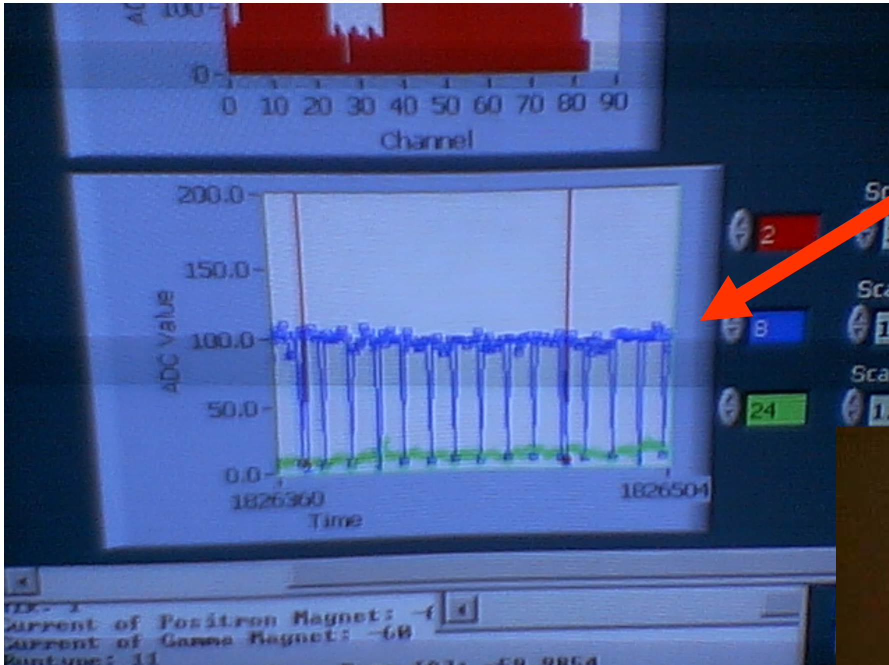
Data taking scheme:

- 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

Data taking



Signal : Undulator on/off

No beam

50 GeV e⁻ E - 166 10 MeV γ

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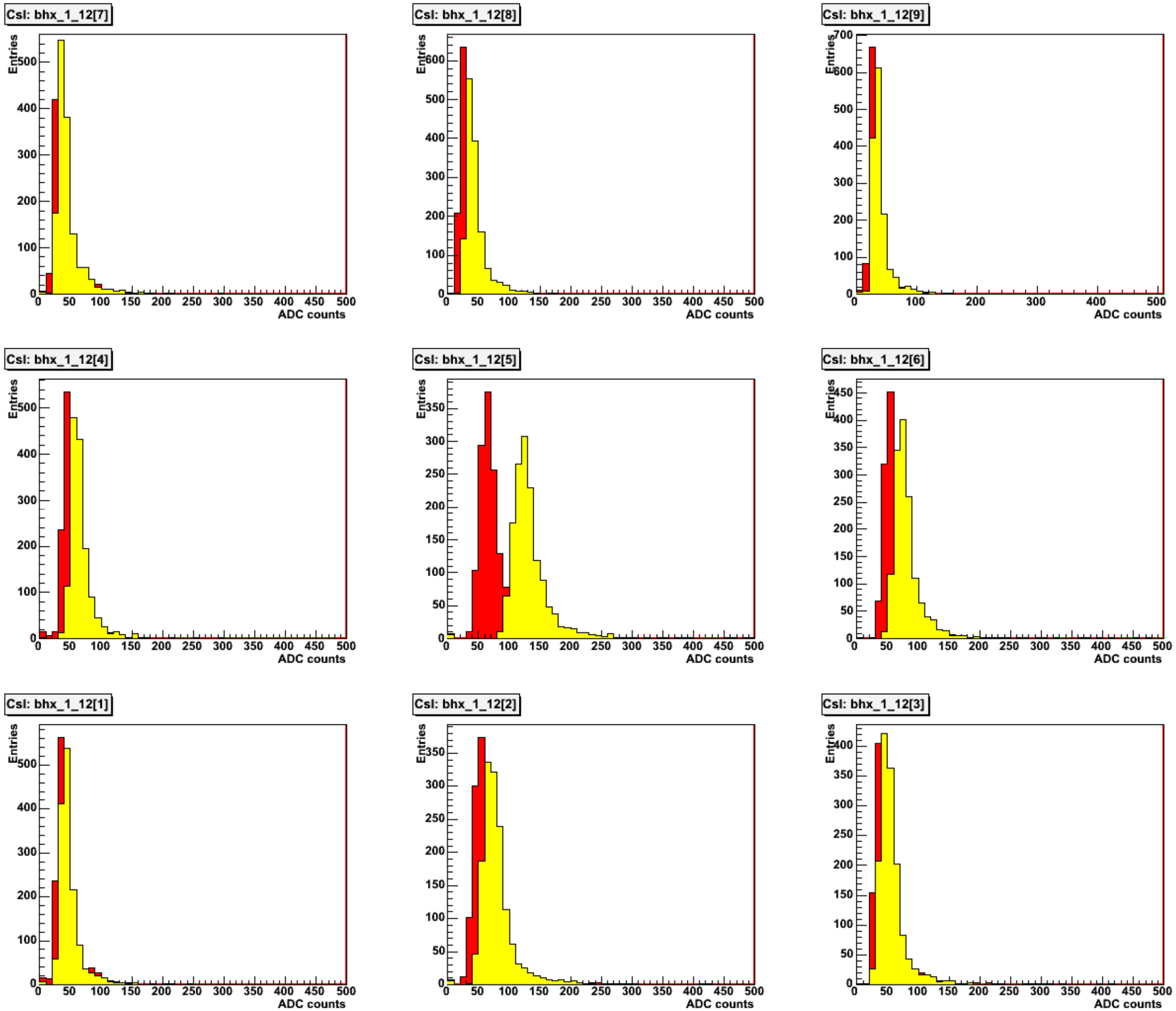
Collected positron data

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

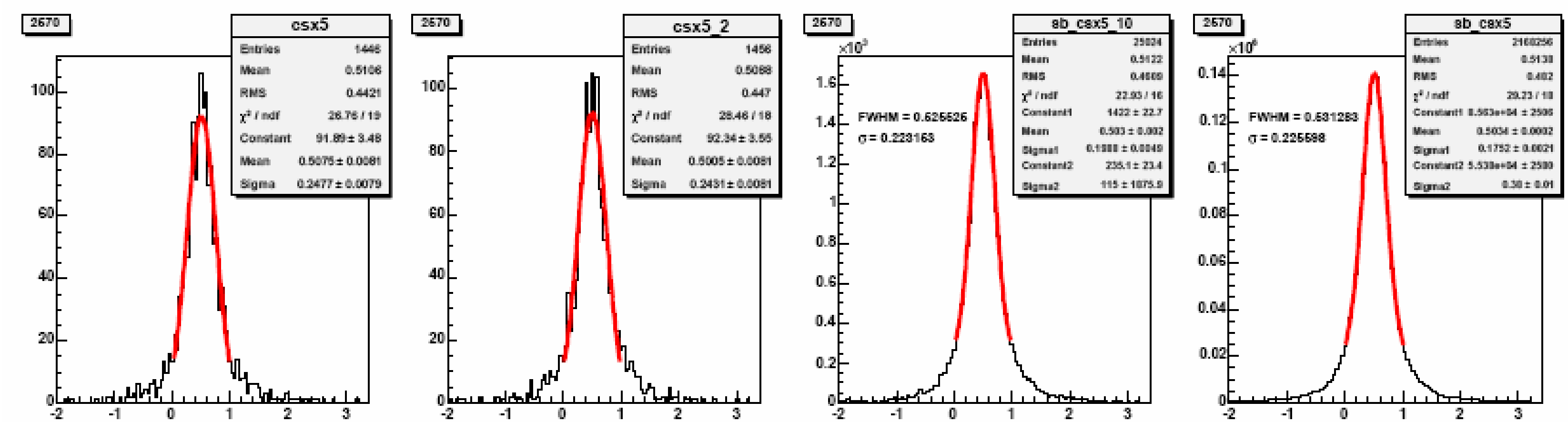
How we obtain the asymmetries



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

The signals

The signals after substracting the background
for different methods



A. Schälicke

Photon Asymmetries

preliminary

Photon asymmetries from June data
measured with 2 Detectors:

W. Bugg

Photon Calorimeter : 3.52 % ± 0.15 %

Aerogel Counter : 3.50 % ± 0.40 % (stat. errors only)

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Expected photon asymmetries for 5 MeV eff. threshold:

Beam Energy [GeV]	Aerogel AG2	W-Si Cal. GCAL
46.6	3.54	3.22 *)

(G3 Simulation)
V. Gharibyan

*) energy weighted with
calorimeter response function

Positron Asymmetries

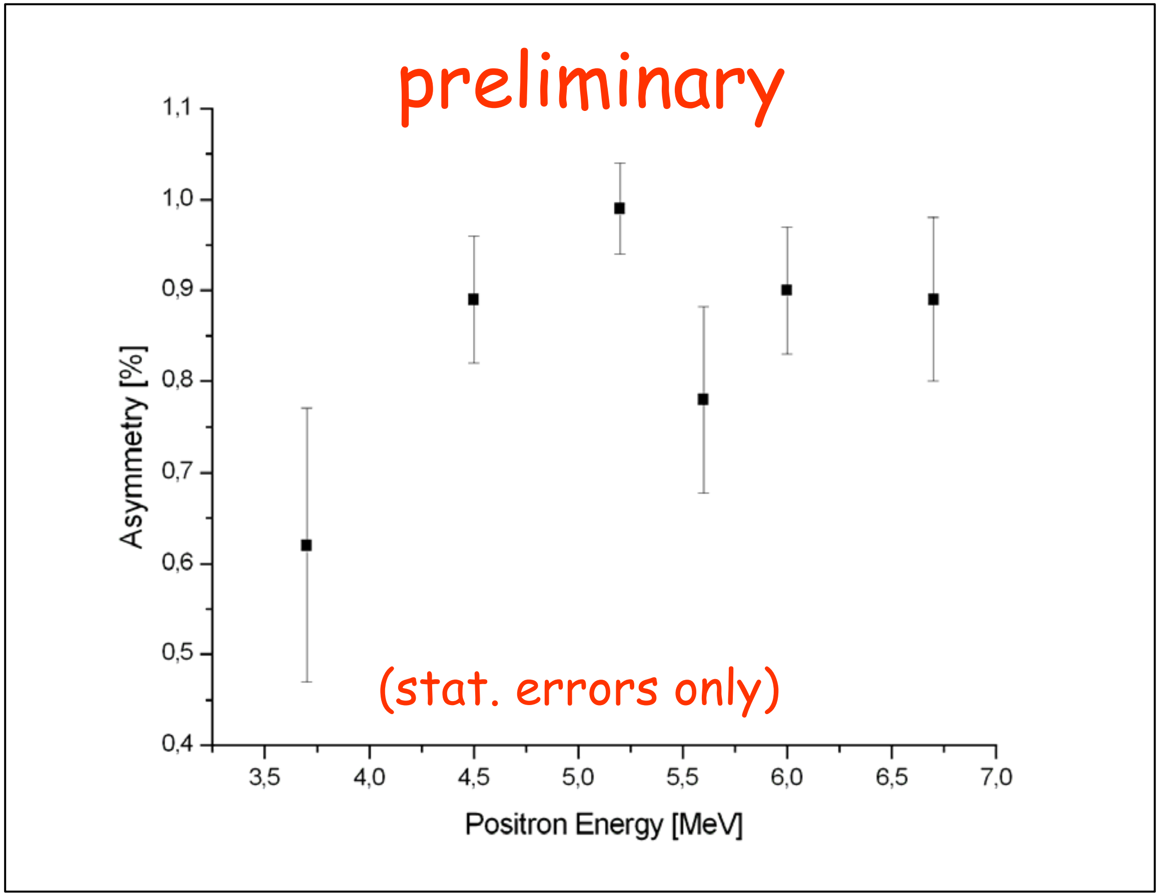
preliminary

Spectrometer Current [A]	Positron Energy [MeV]	Measured Asymmetry δ (%)	Asymmetry error (stat. only)
100	3.7	0.62	0.15
120	4.5	0.89	0.07
140	5.2	0.99	0.05
150	5.6	0.78	0.10
160	6.0	0.90	0.07
180	6.7	0.89	0.09

A. Schälicke

(stat. errors only)

Positron Asymmetries



Summary

- E-166 was running and 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…