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The E166 experiment

undulator based polarized positron source for the ILC

What is E166?

It is a proof-of-principle experiment for a new type of positron source! New sources are necessary for the planned positron current in the ILC...

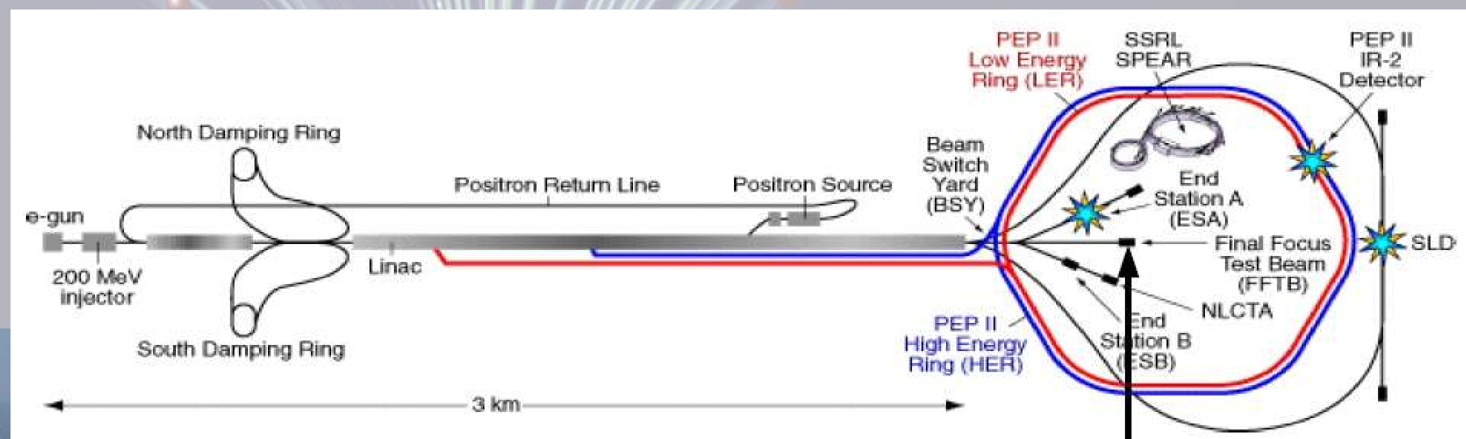
...and it's polarized!

- does this principle work?
- what is the degree of polarization?

who and where? :

- ~ 50 persons from 13 universities as well as SLAC, DESY, KEK

- experimental setup was located in the FFTB at SLAC



FFTB

Timeline of E166 :

- main principle first mentioned in 1970s
- first proposal to SLAC in 2001
- two runs in 2005 (june and september)
- about 12GB of raw data in ~ 3000 runfiles
- complete simulation of the setup with GEANT4
- experiment (and FFTB...) dismantled in spring 2006
- analysis of data is still in progress

ILC International Linear Collider

Ideal: ILC with polarized e^+ *and* e^- beams

- Higher effective polarization
- Increased signal to background in SM-tests
- Enhancement of effective luminosity
- Precise analysis of many kinds of non-standard couplings
- The option to use transversely polarized beams

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Why polarized? :

background and luminosity:

P_{e^-}	P_{e^+}	$e^+e^- \to W^+W^-$	$e^+e^- \to ZZ$
0	0	1.0	1.0
0.8	0	0.2	0.76
−0.8	0	1.8	1.25
0.8	−0.6	0.1	1.05
−0.8	0.6	2.85	1.91

P_{e^-}	P_{e^+}	RL	LR	RR	LL	$P_{\rm eff}$	$\mathcal{L}_{\rm eff}/\mathcal{L}$
0	0	0.25	0.25	0.25	0.25	0.	0.5
−1	0	0	0.5	0	0.5	−1	0.5
−0.8	0	0.05	0.45	0.05	0.45	−0.8	0.5
−0.8	+0.6	0.02	0.72	0.08	0.18	−0.95	0.74

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Why polarized? :

search for new physics:

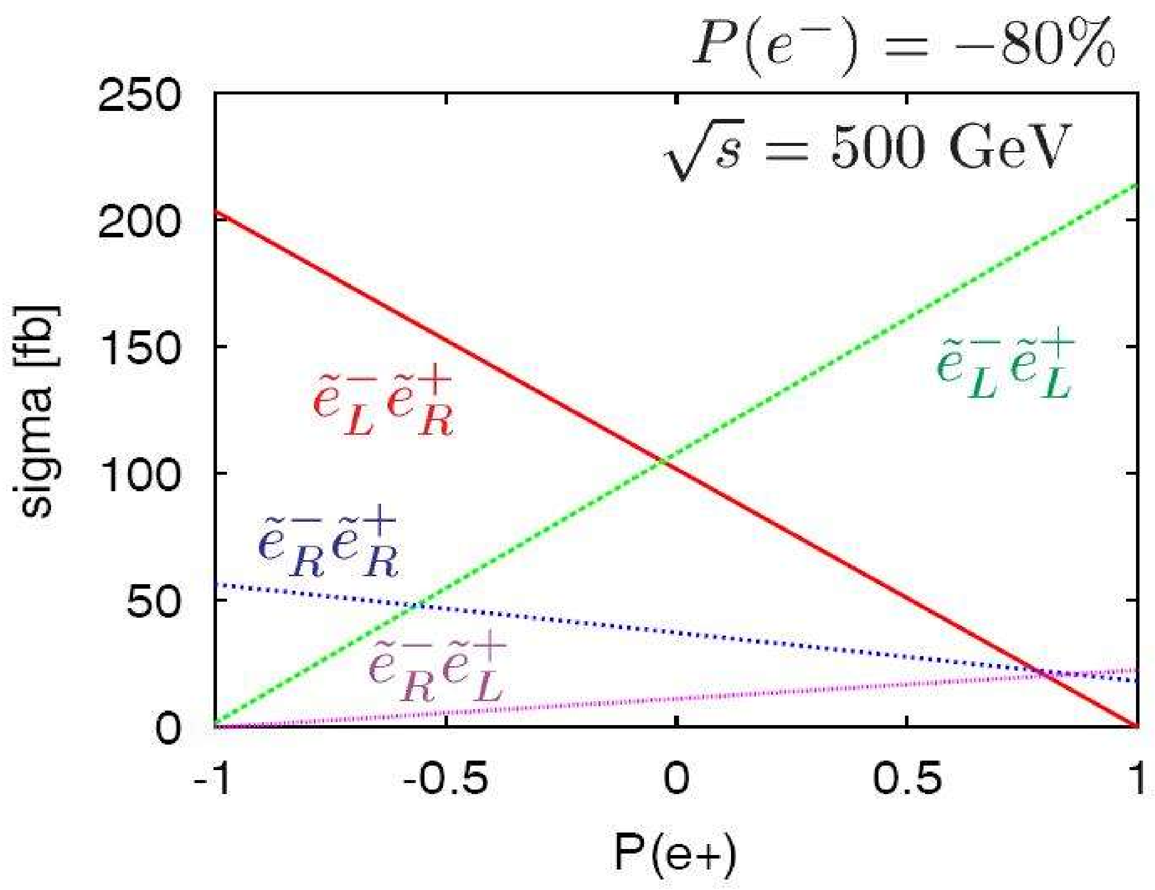
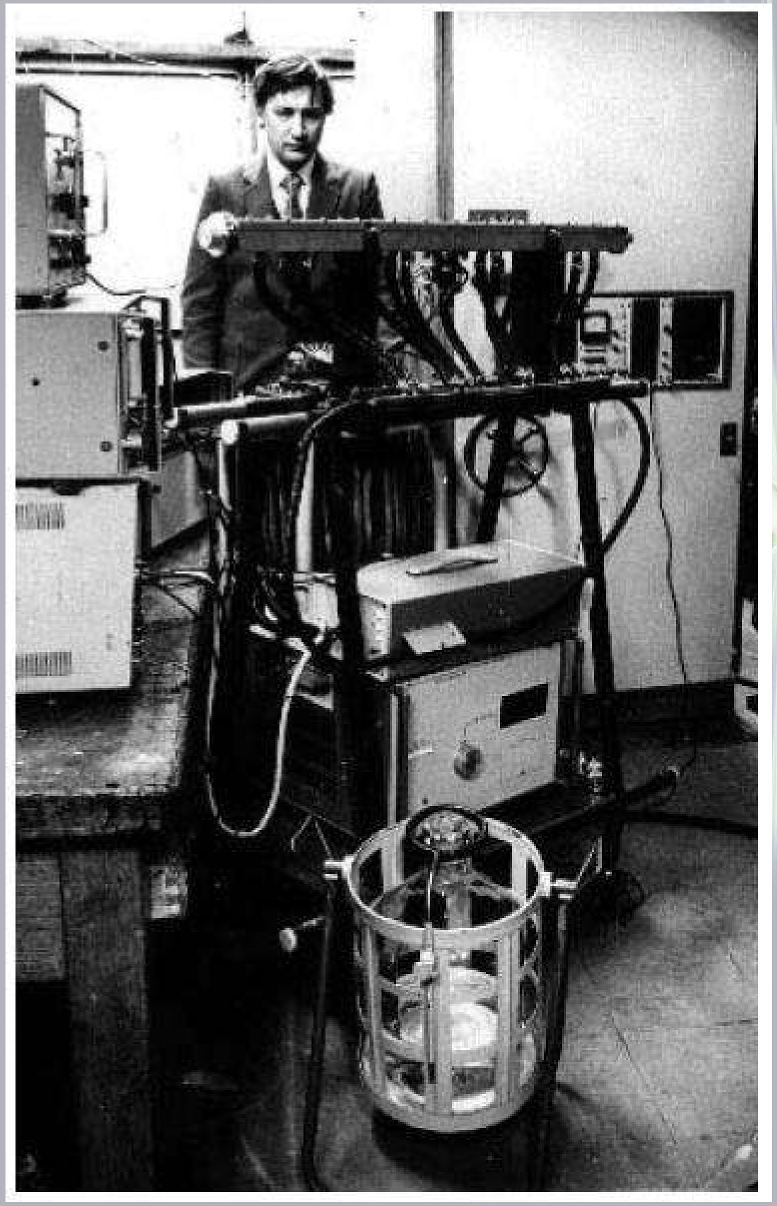


Figure 4: Separation of the selectron pair $\tilde{e}^-_L \tilde{e}^+_R$ in $e^+e^- \to \tilde{e}^-_{L,R}\tilde{e}^+_{L,R}$ with longitudinally polarized beams in order to test the association of chiral quantum numbers to scalar fermions in SUSY transformations [13].

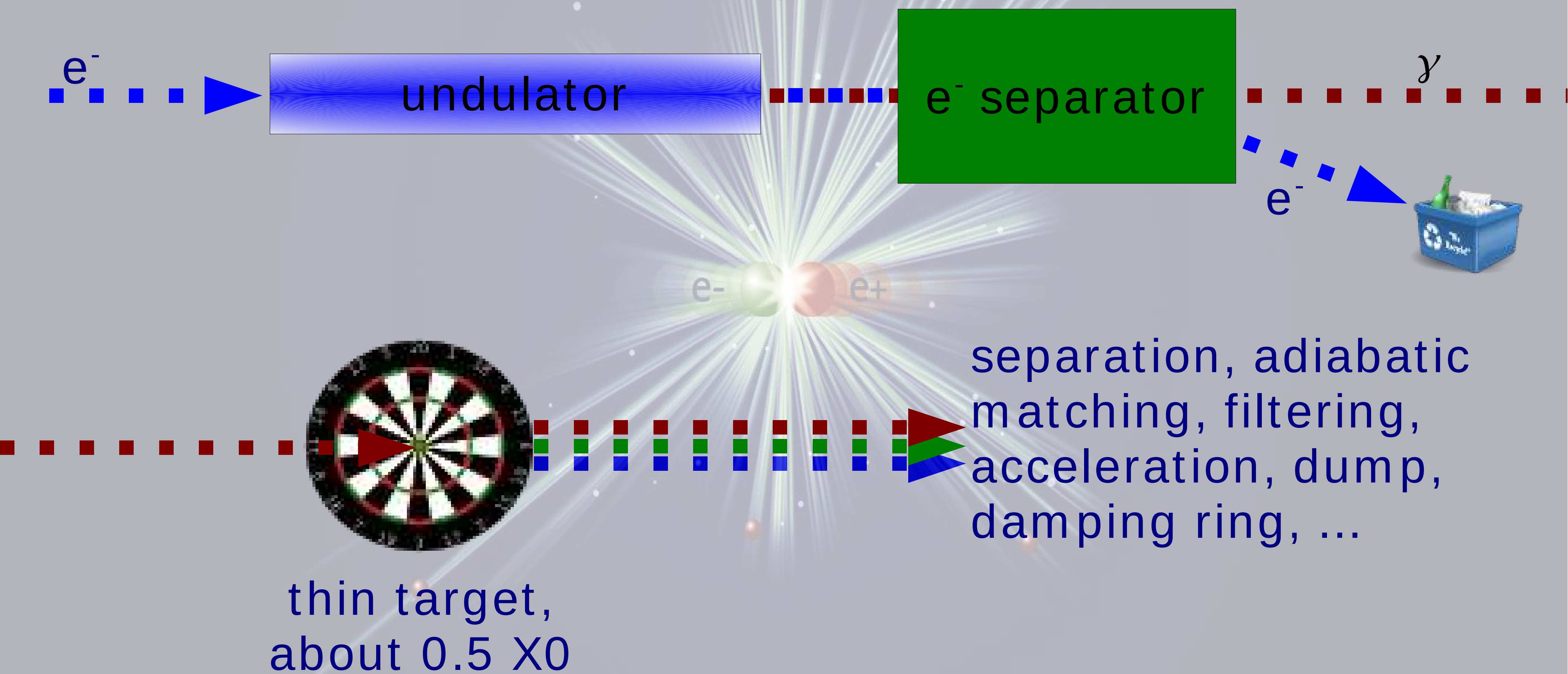
The helical undulator



First proposed by Mikhailichenko und Balakin in 1979:

The Conversion System for Obtaining High Polarized Electrons and Positrons, Budker Institute of Nuclear Physics, Preprint BINP 79-85 (1979)

The basic principle:



50 GeV e$^-$ E - 166 10 MeV γ
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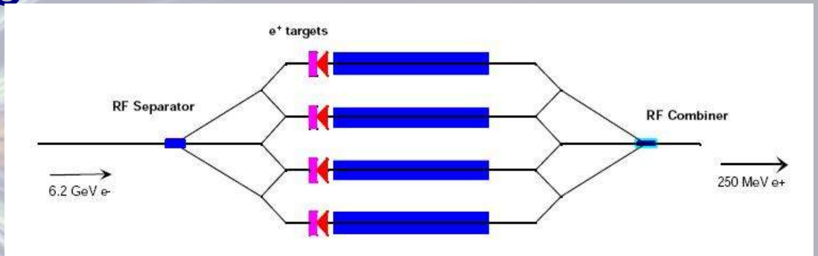
Why using an undulator?

Conventional positron source:

- unpolarized
- target > 5 X0
- very high energy deposition in target (heatload)
- complex target, e.g. rotating WRe-Disc

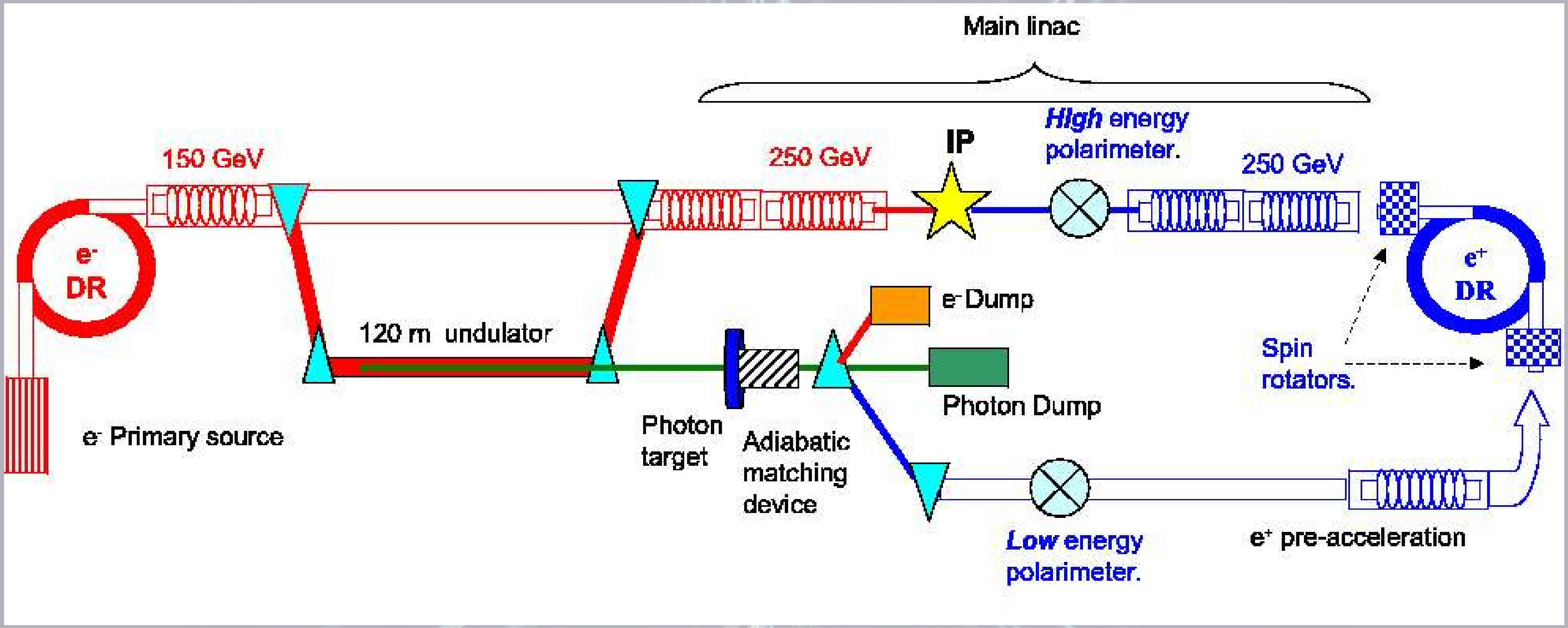


3 out of 4 target system schematic

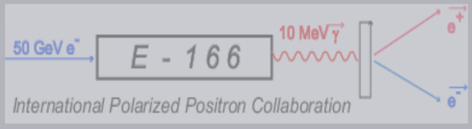
Source with helical undulator:

- polarized
- target ~ 0.4X0
- small energy deposition in target (ILC won't kill it...)
- simple target (thin target, no switchyard necessary)

And in ILC?



Main linac
150 GeV
250 GeV
IP
High energy polarimeter.
250 GeV
e- DR
e+ DR
120 m undulator
e- Dump
Spin rotators.
Photon Dump
e- Primary source
Photon target
Adiabatic matching device
Low energy polarimeter.
e+ pre-acceleration



50 GeV e-
E - 166
10 MeV γ
e+
e-
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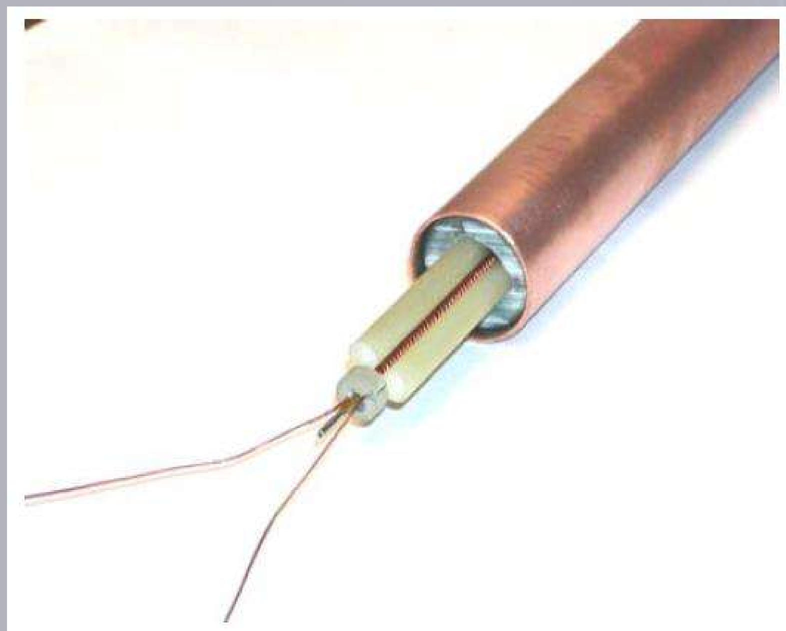
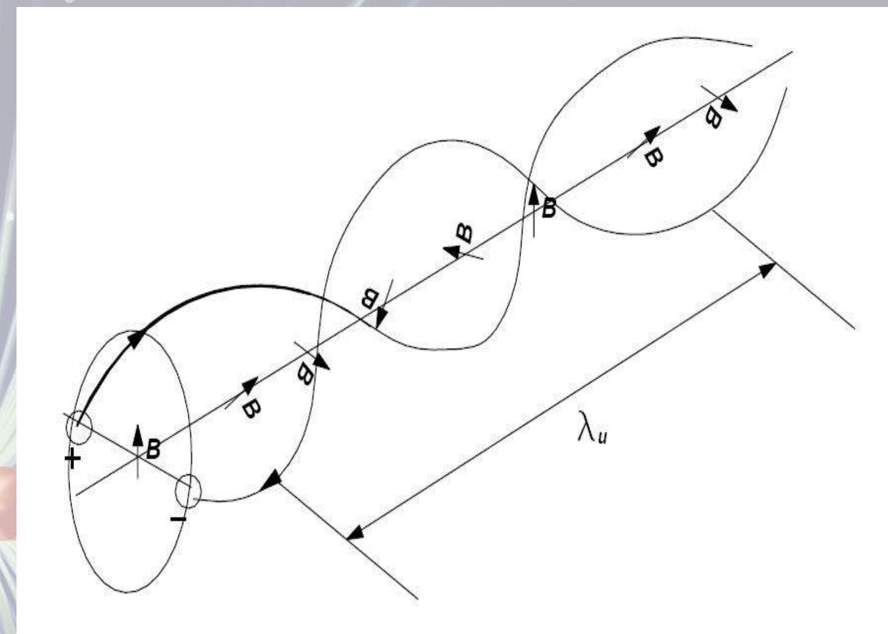
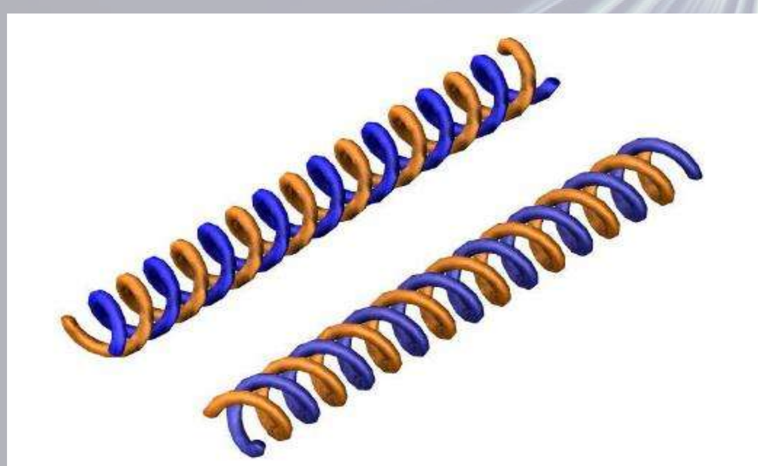
The helical undulator...





Helical undulator is a bifilar helix with opposed currents.

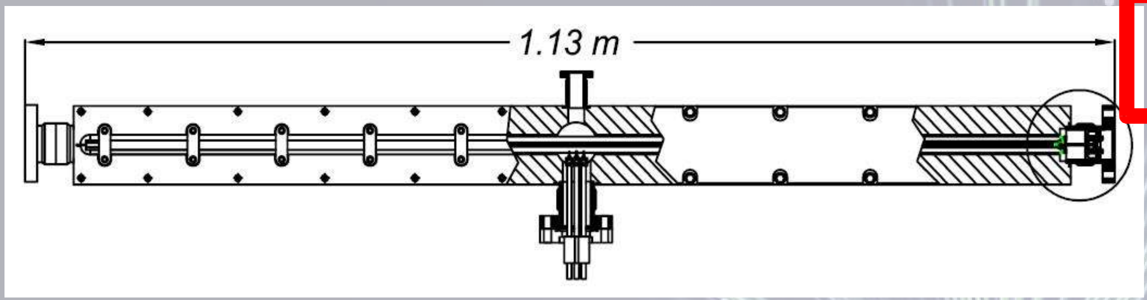


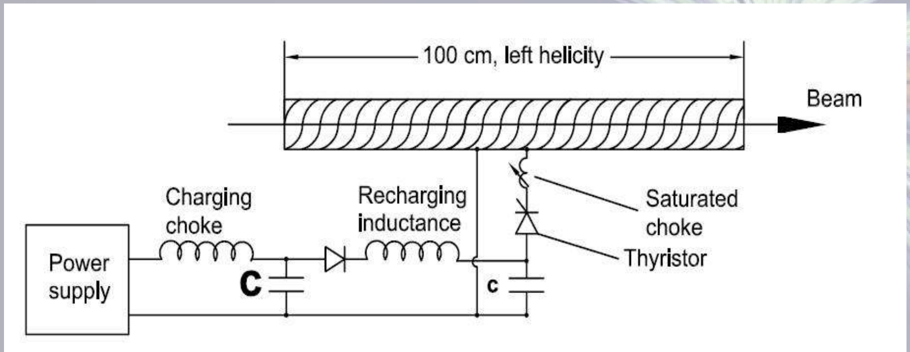
(Color) Bifilar helixes having opposite helicities.

sensitive mechanics, line of sight about 0.7mm!

The helical undulator:

Technical details:

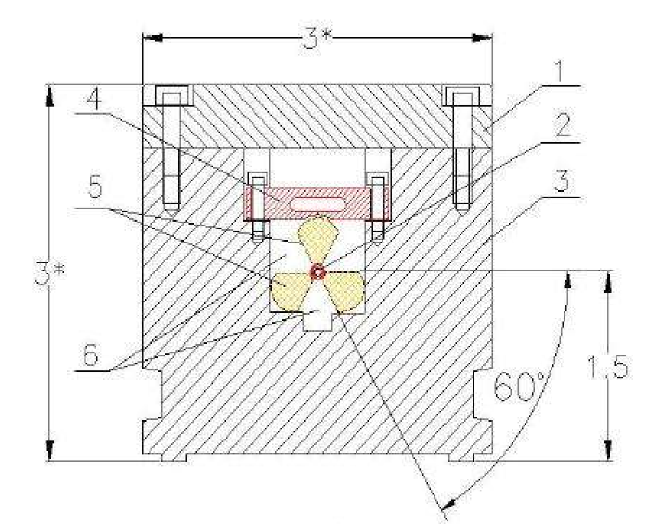




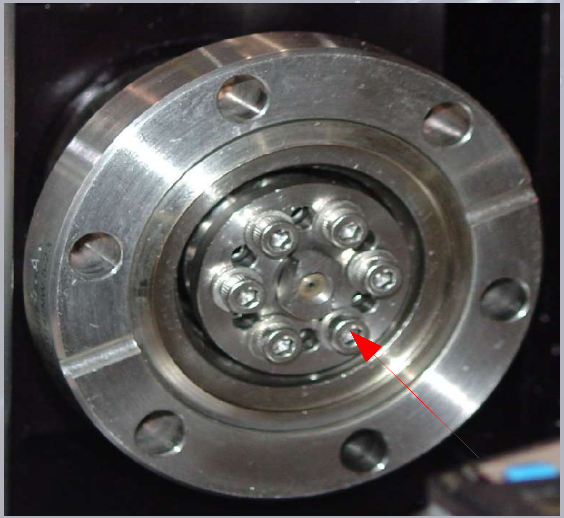
Parameter	Units	Value
Number of Undulators	–	1
Length	m	1.0
Inner Diameter	mm	0.89
Period	mm	2.4
Field	kG	7.6
K Undulator Parameter	–	0.17
Current	Amps	2300
Peak Voltage	Volts	540
Pulse Width	μs	30
Inductance	H	0.9×10^{-6}
Wire Type	–	Cu
Wire Diameter	mm	0.6
Resistance	Ω	0.110
Repetition Rate	Hz	30
Power Dissipation	W	260
ΔT/pulse	^{0}C	2.7

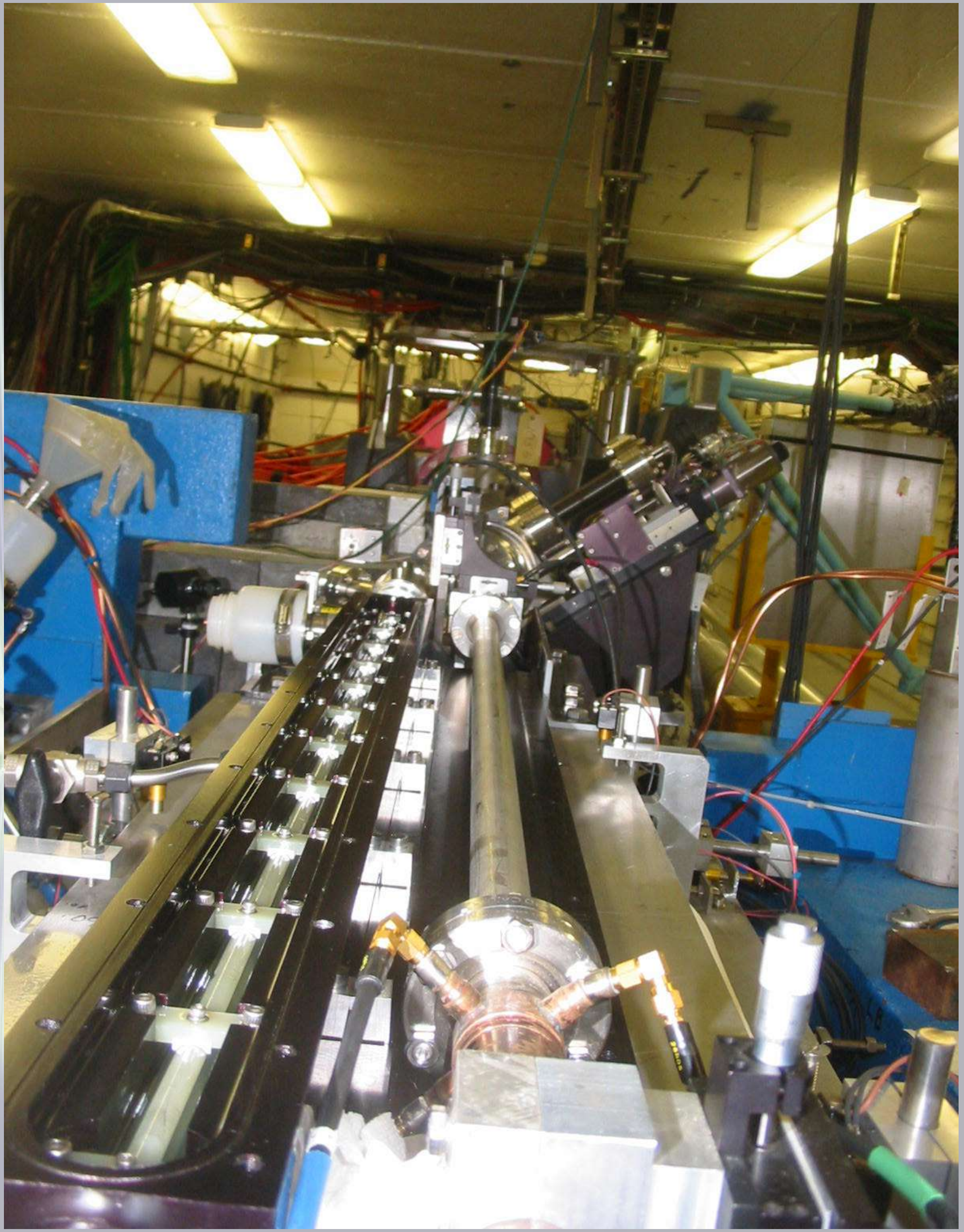
Low emittance beam necessary!

The helical undulator:



Cross-section of undulator, Fig.5. Two G10 rods are based in corners of long groove. Third rod with help of springing bars 4 compresses the windings to the other two ones. 1 –is a cover, 2 –is bi-helix. 3 –is a corps, 5 –are G10 rods, 6 –is filled with coolant. Parts 1, 3 made from Aluminum.





Needs cooling!

The helical undulator:

Produced radiation:

- first approximation in beam direction:
- @SLAC: E~ 50GeV results in ~ 10MeV photons

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

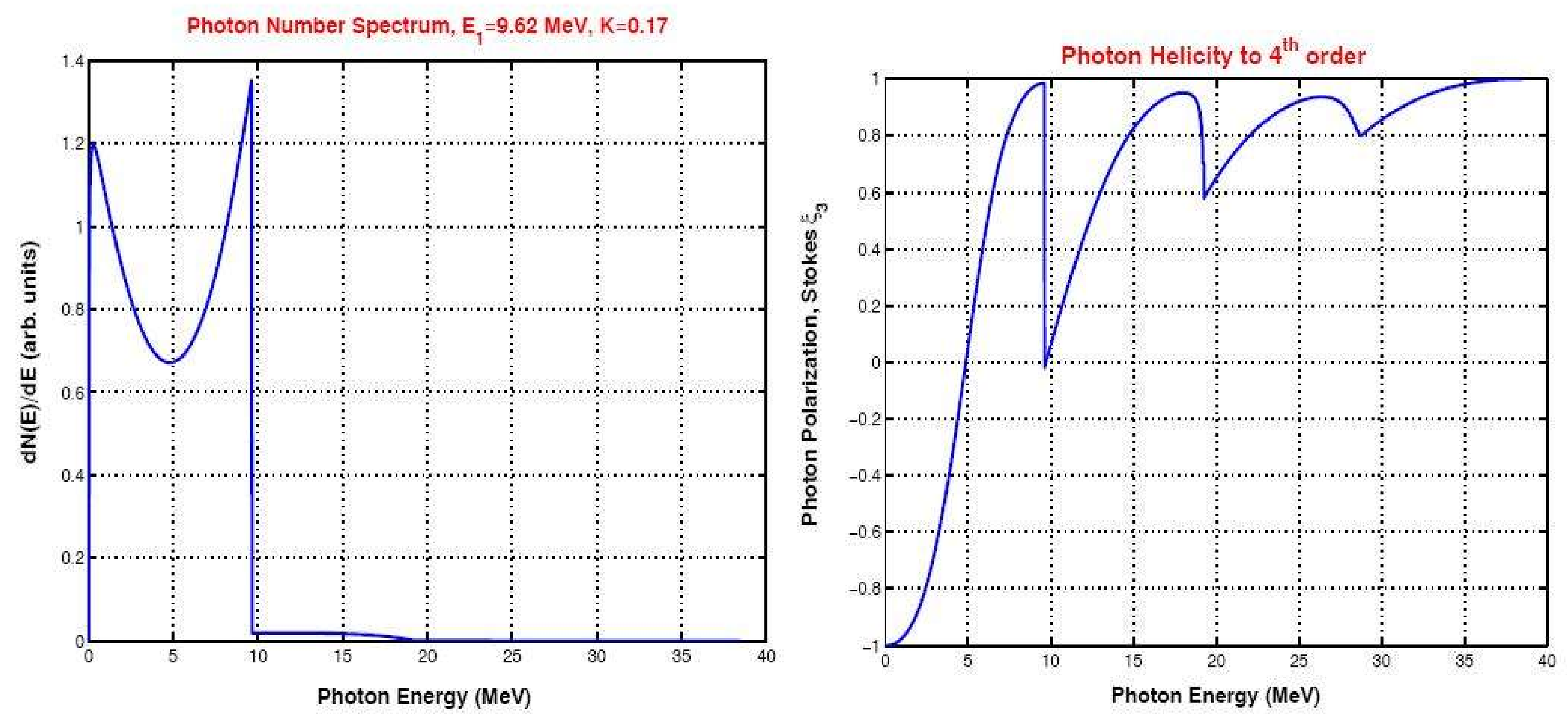
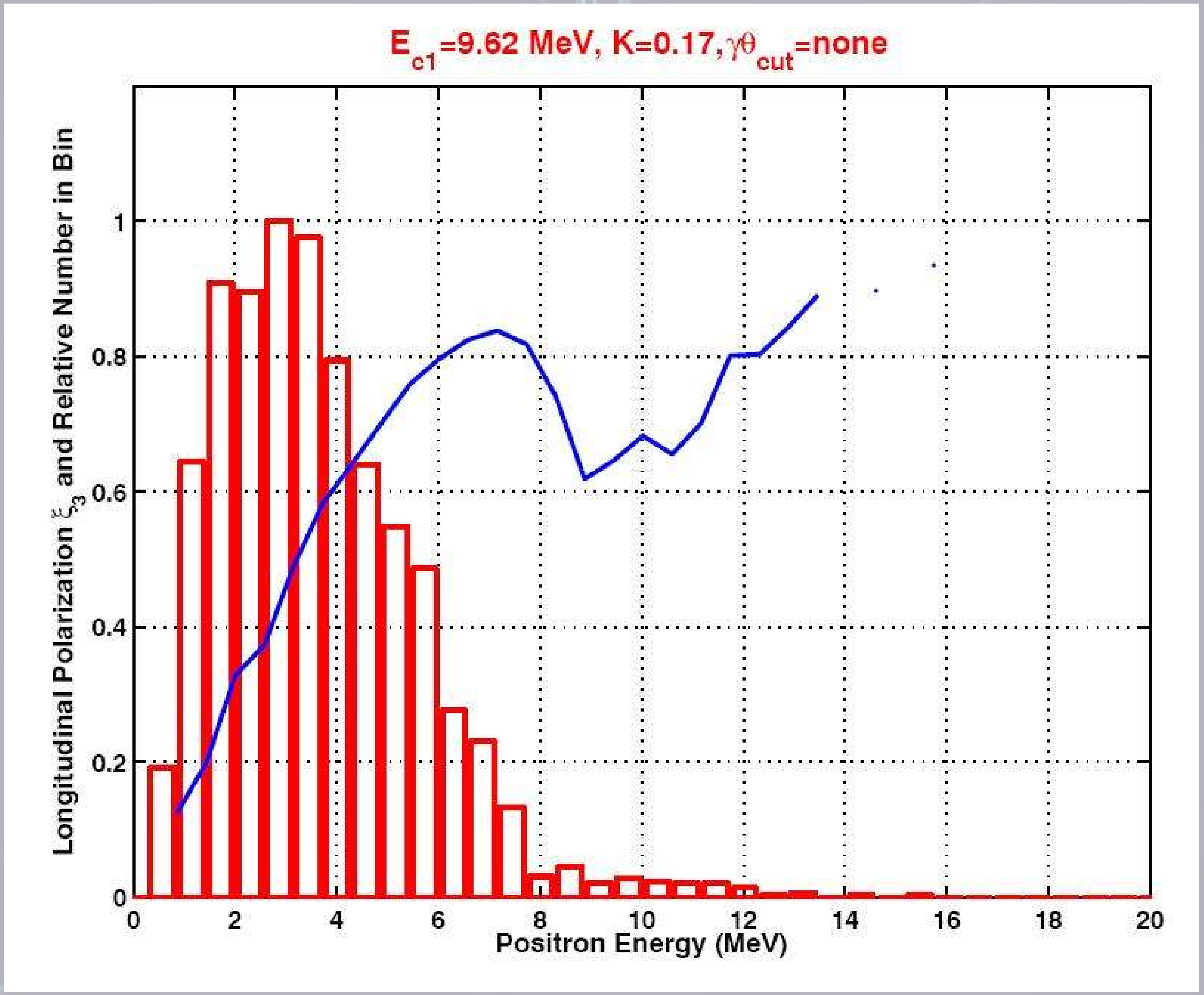


Figure 6: **(a)** The photon number spectrum, intensity spectrum, of undulator radiation, integrated over angle, for electron energy $E_e = 50$ GeV, undulator period $\lambda_u = 2.4$ mm and undulator strength parameter $K = 0.17$. The peak energy E_{c10} of the first harmonic (dipole) radiation is 9.62 MeV. **(b)** The polarization P_γ of the undulator radiation as a function of energy.

The helical undulator:

Produced radiation:



The helical undulator for the ILC:

- E166 competes with LASER-backscattering sources for use in the ILC

- E166 has to proof its principle and give a hint on its efficiency and the degree of polirization

- No advice on technical details of an ILC-scale positron source can be given

Parameter	Units	TESLA*	NLC	FFTB
Beam energy E_e	GeV	150-250	150	50
N_e/bunch	–	3×10^{10}	8×10^{9}	1×10^{10}
N_{bunch}/pulse	–	2820	190	1
Pulses/s	Hz	5	120	30
Undulator type	–	planar	helical	helical
Undulator strength K	–	1	1	0.17
Undulator period λ_u	cm	1.4	1.0	0.24
1^{st} Harmonic cutoff, E_{c10}	Mev	9-25	11	9.6
dN_γ/dL	photons/m/e^-	1	2.6	0.37
Undulator length L	m	135	$132^\dagger$	1
Target material	–	Ti-alloy	Ti-alloy	Ti-alloy
Target thickness	rad. len.	0.4	0.5	0.5
Yield	e^+/photon (%)	1-5	$1.5^\ddagger$	0.5
Capture efficiency	%	25	20	–
N_+/pulse	–	8.5×10^{12}	1.5×10^{12}	2×10^{7}
N_+/bunch	–	3×10^{10}	8×10^{9}	2×10^{7}
Polarization P^+	%	–	40-70	40-70

$*$ TESLA baseline design; TESLA polarized e^+ parameters (undulator and polarization) are the same as for the NLC.
† A length of 132 m is required for a unity gain $e^- \to e^+$ system. An undulator length of 200 m is under consideration in order to provide 50% overhead in positron production.
‡ Includes the effect of photon collimation at $\gamma\theta_{cut} = 1.414$.

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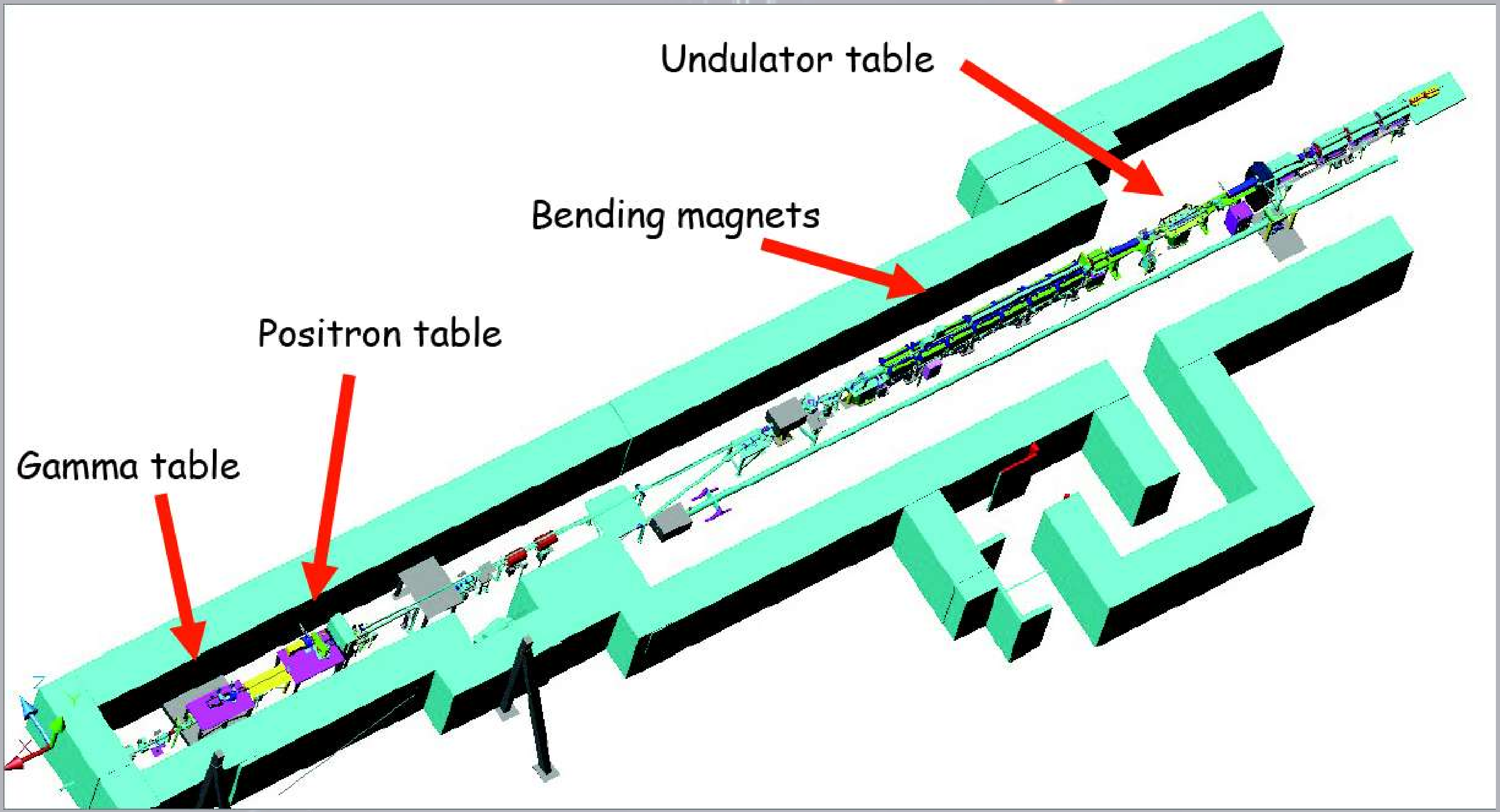
The setup…



50 GeV e⁻ E - 166 10 MeV γ

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The setup:

50 GeV e⁻ E - 166 10 MeV γ e⁺ e⁻
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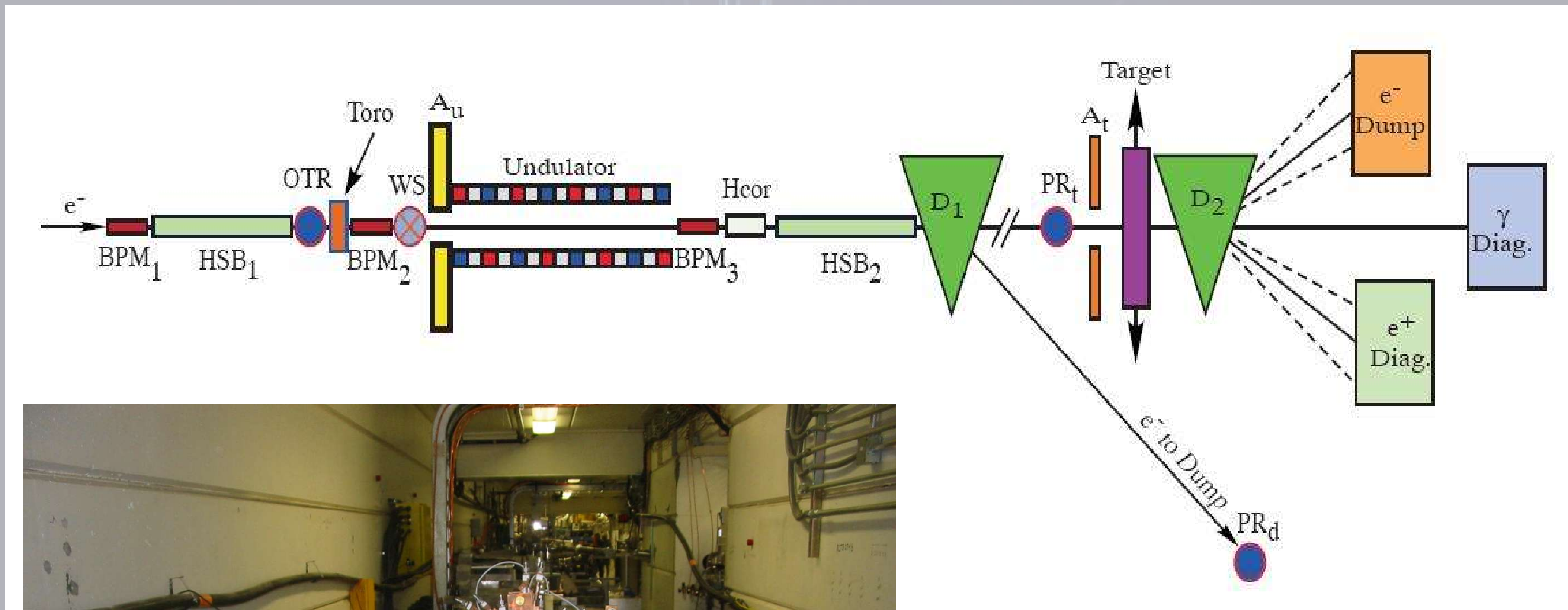
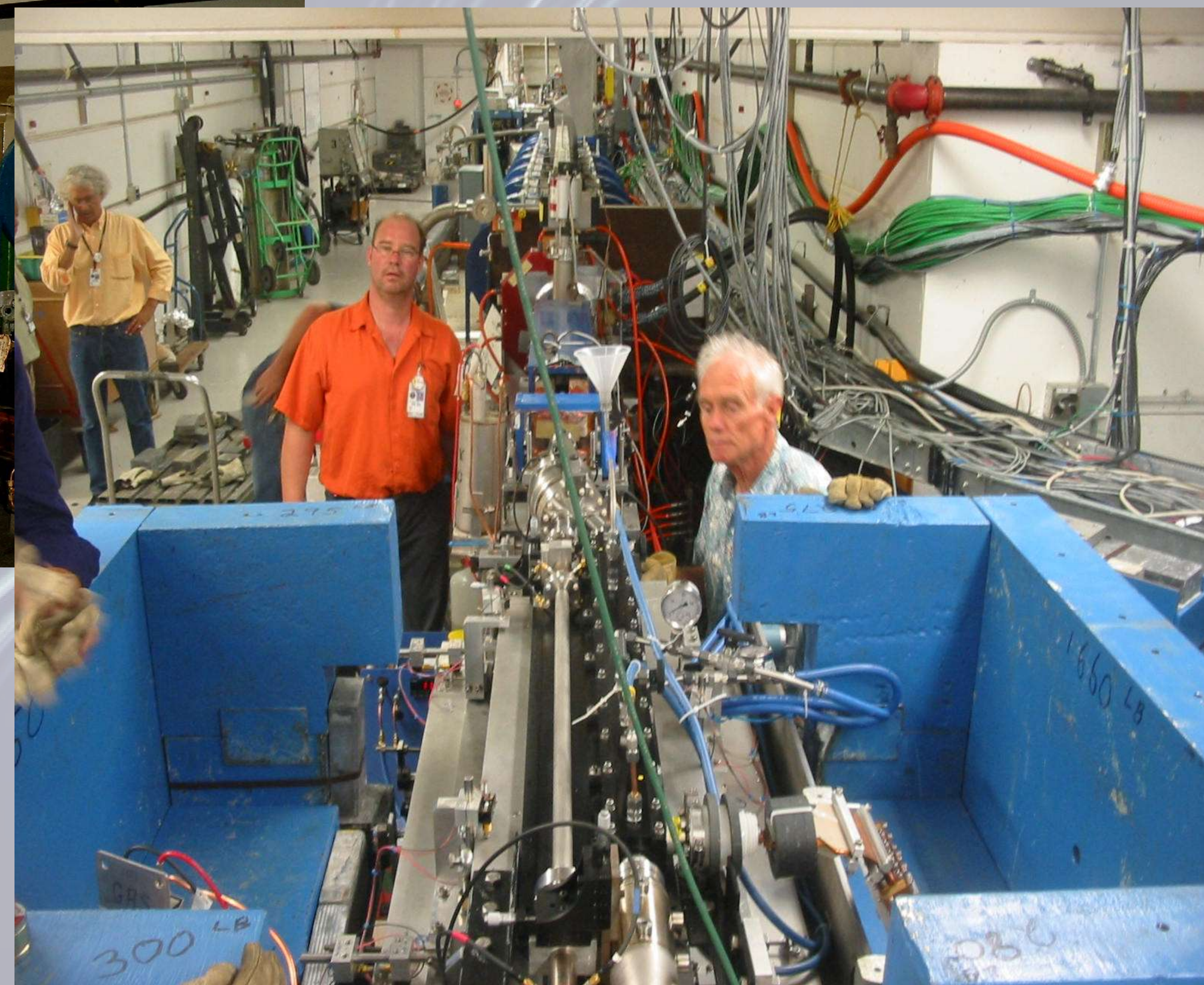
The setup:

FFTB at SLAC, 50GeV e^- @ 1 or 10 Hz :



The setup:



50 GeV e^- E - 166 10 MeV γ e^+ e^-

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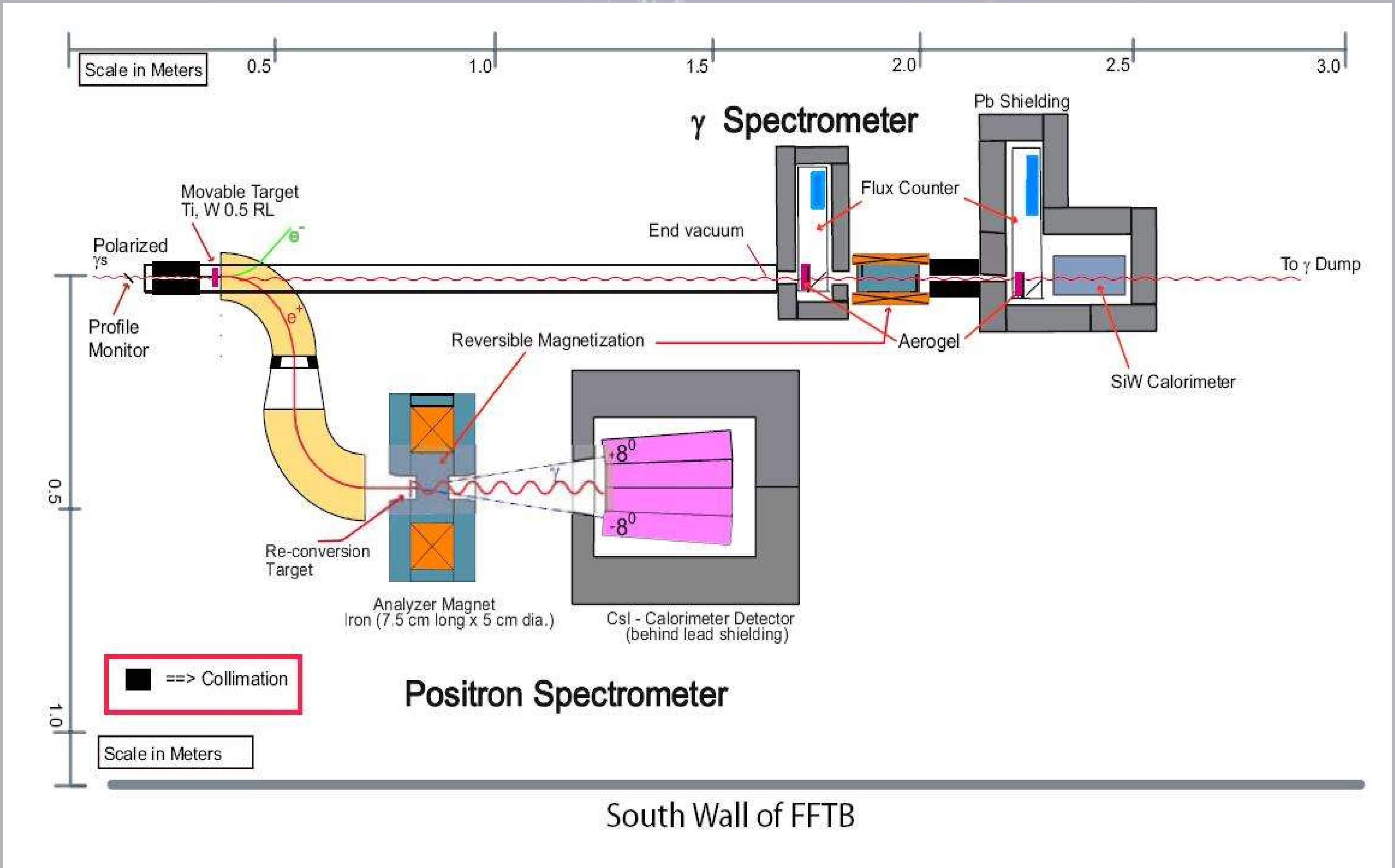
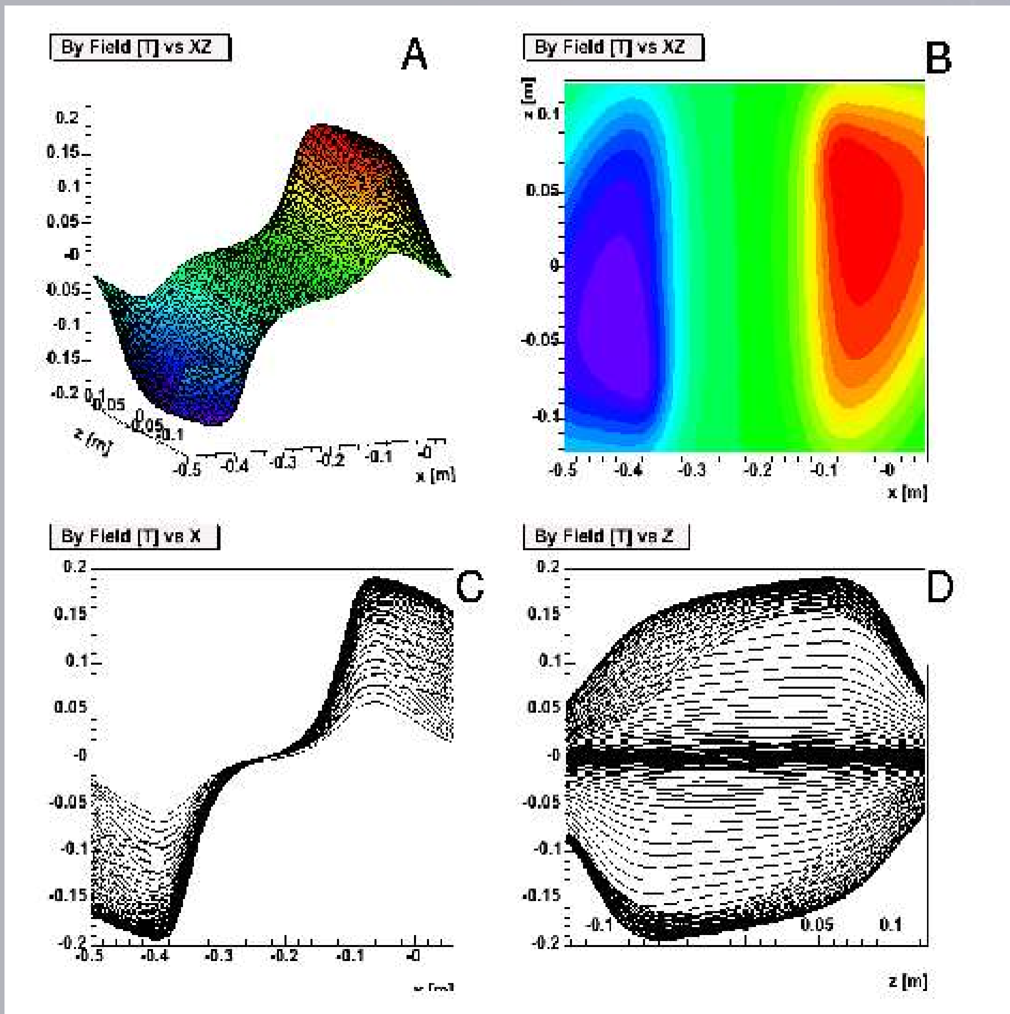
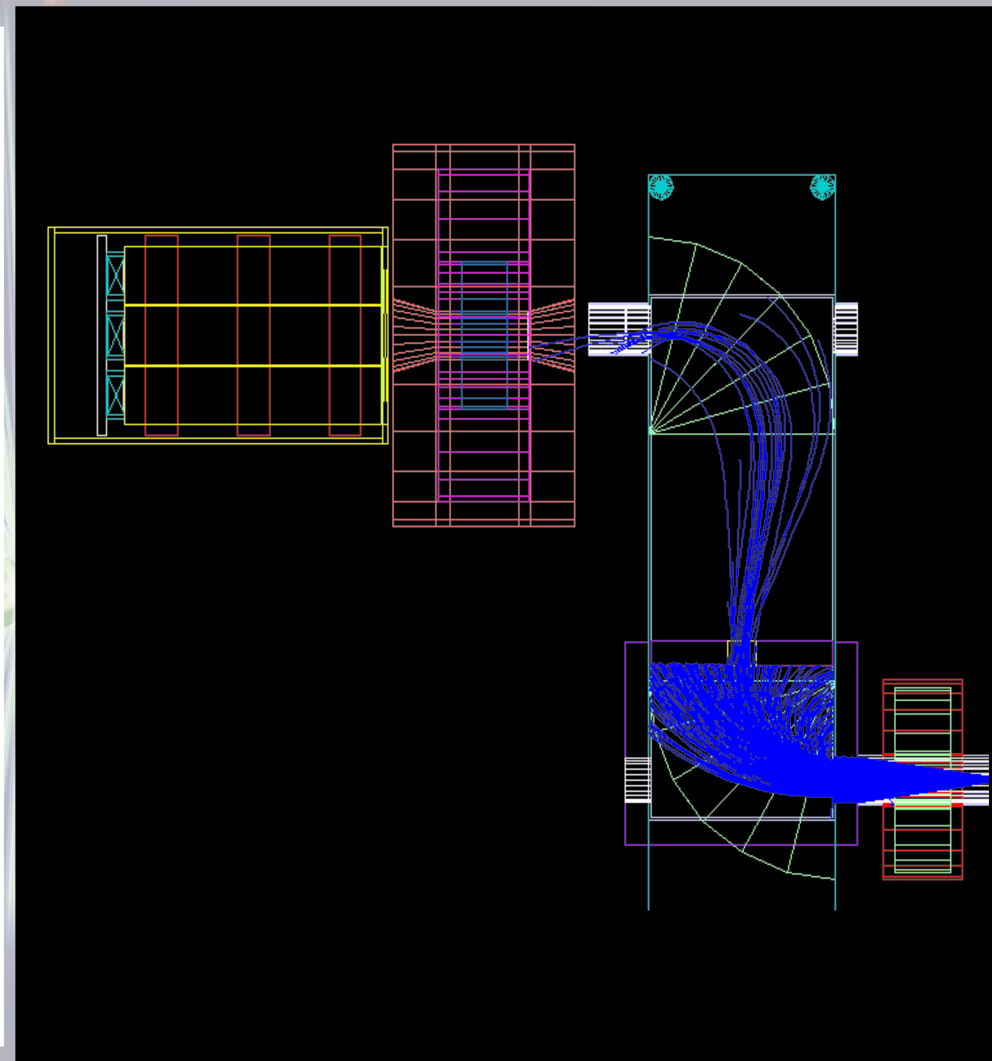
The setup:

The analysis part in detail:

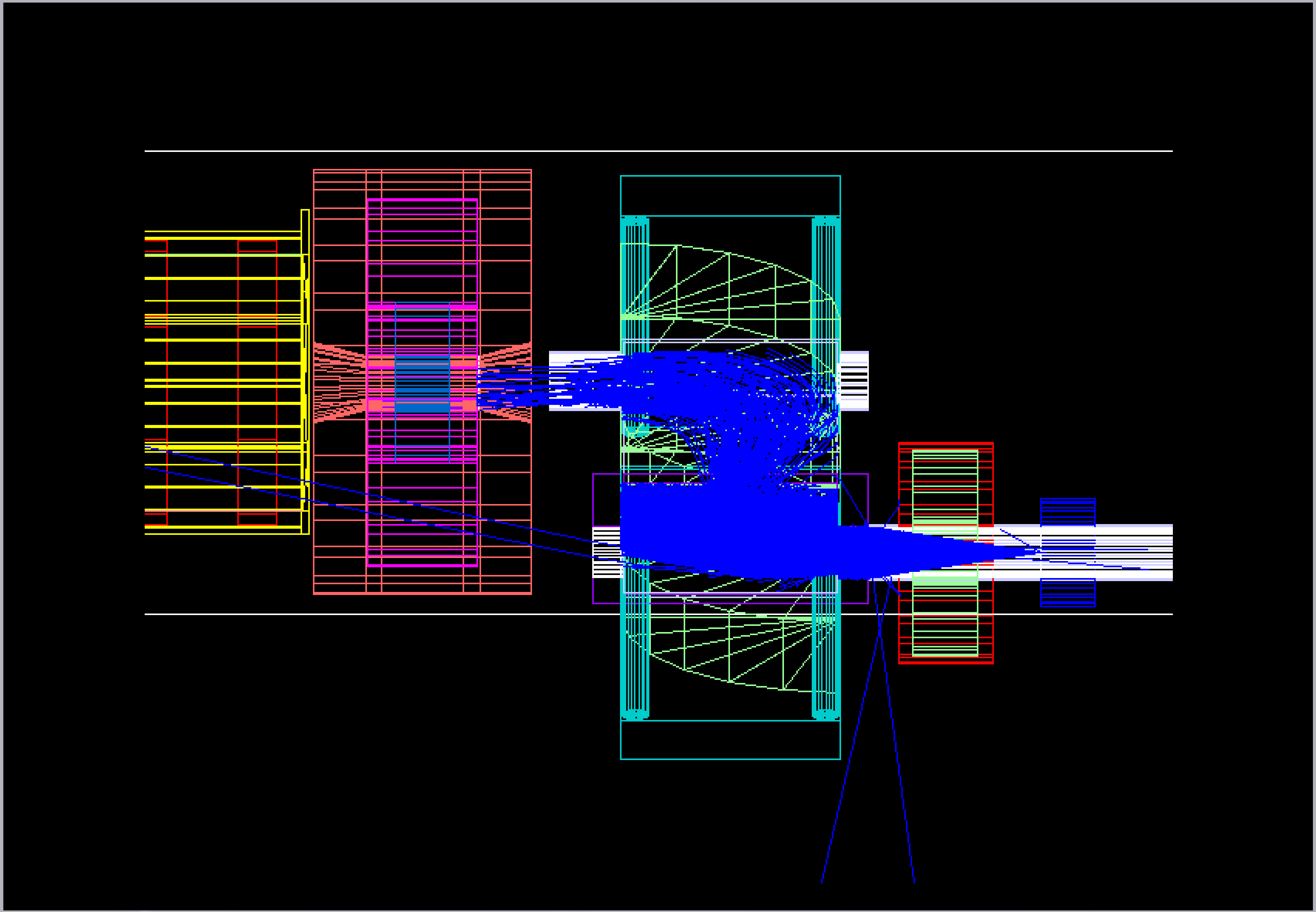


E166 spectrometer and calibration:





E166 spectrometer and calibration:

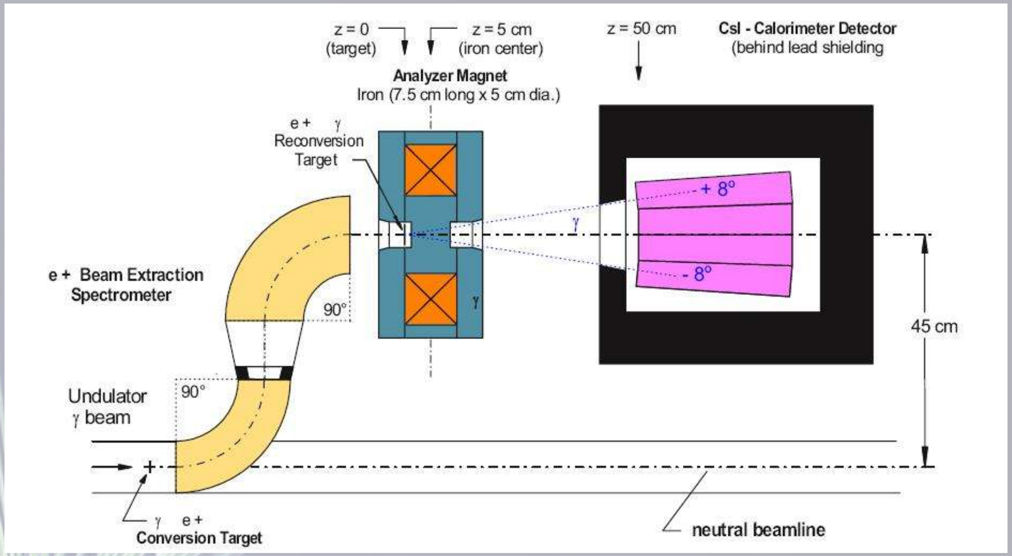


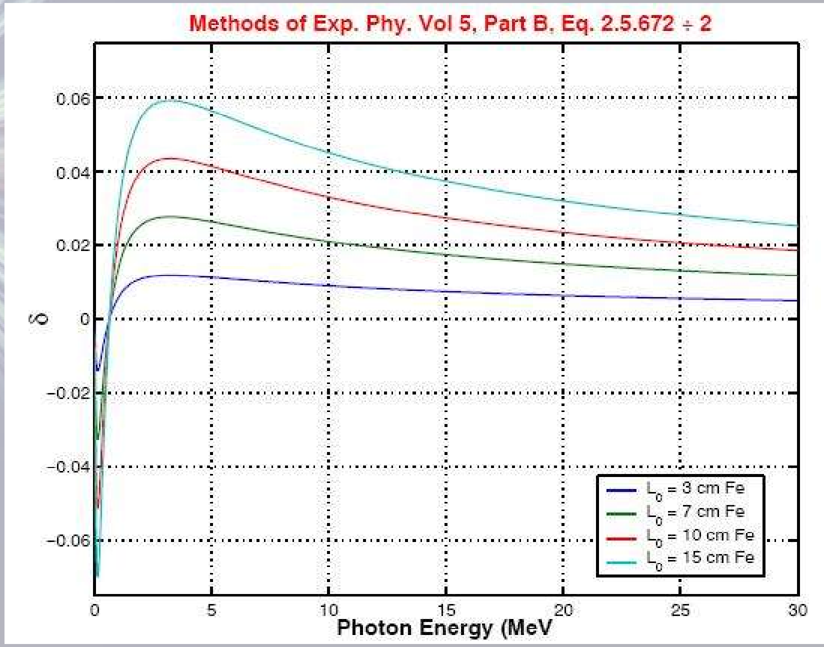
The setup:

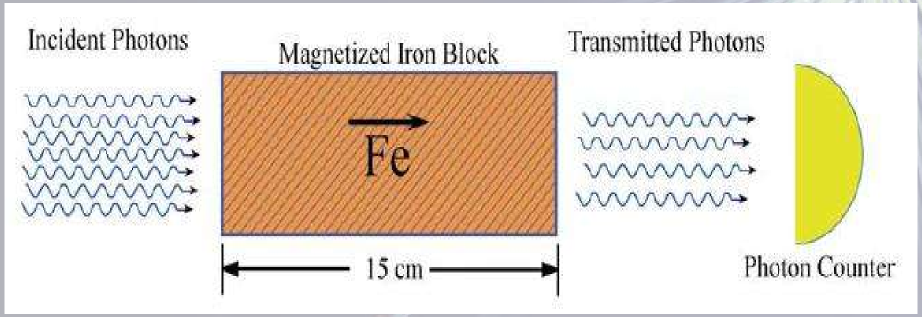
The positron-polarimetry:

- Polarimetry uses spin-dependent Compton crossection, measures asymmetry

- Compare with Goldhaber-experiment







$$\delta(L) = \frac{T^+(L) - T^-(L)}{T^+(L) + T^-(L)} = \tanh(nLP_eP_\gamma\sigma_P) \approx nLP_eP_\gamma\sigma_P$$

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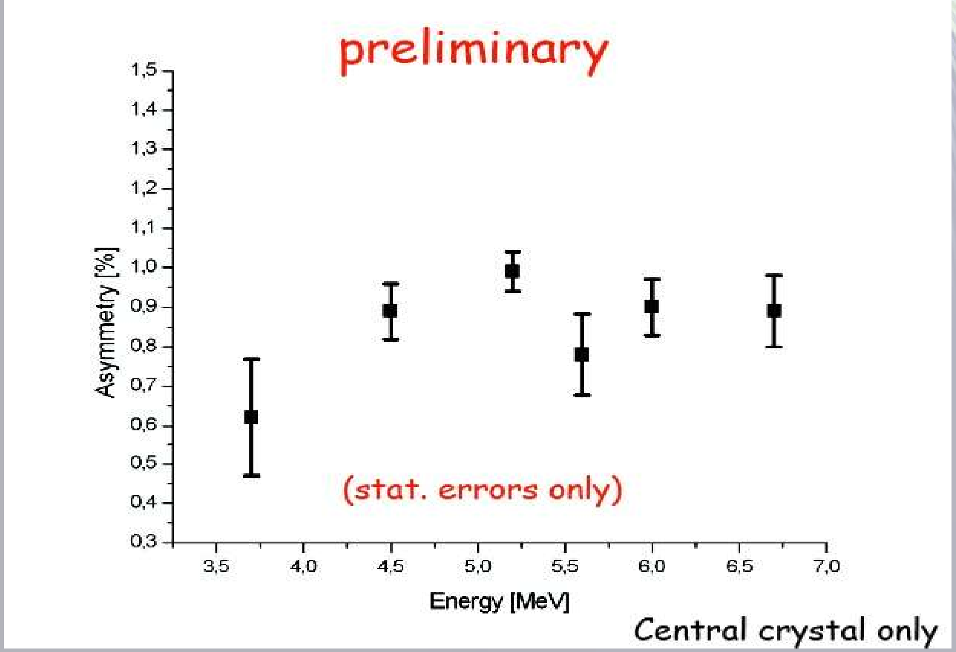
Some preliminary results of E166:

- Helical undulator works and produces circularly polarized photons!
- Asymmetries measured for 6 different positron energies
- Asymmetries are in the expected range
- Analysis and simulation with GEANT4 is still in progress



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

50 GeV e⁻ — E - 166 — 10 MeV γ — e⁺ e⁻

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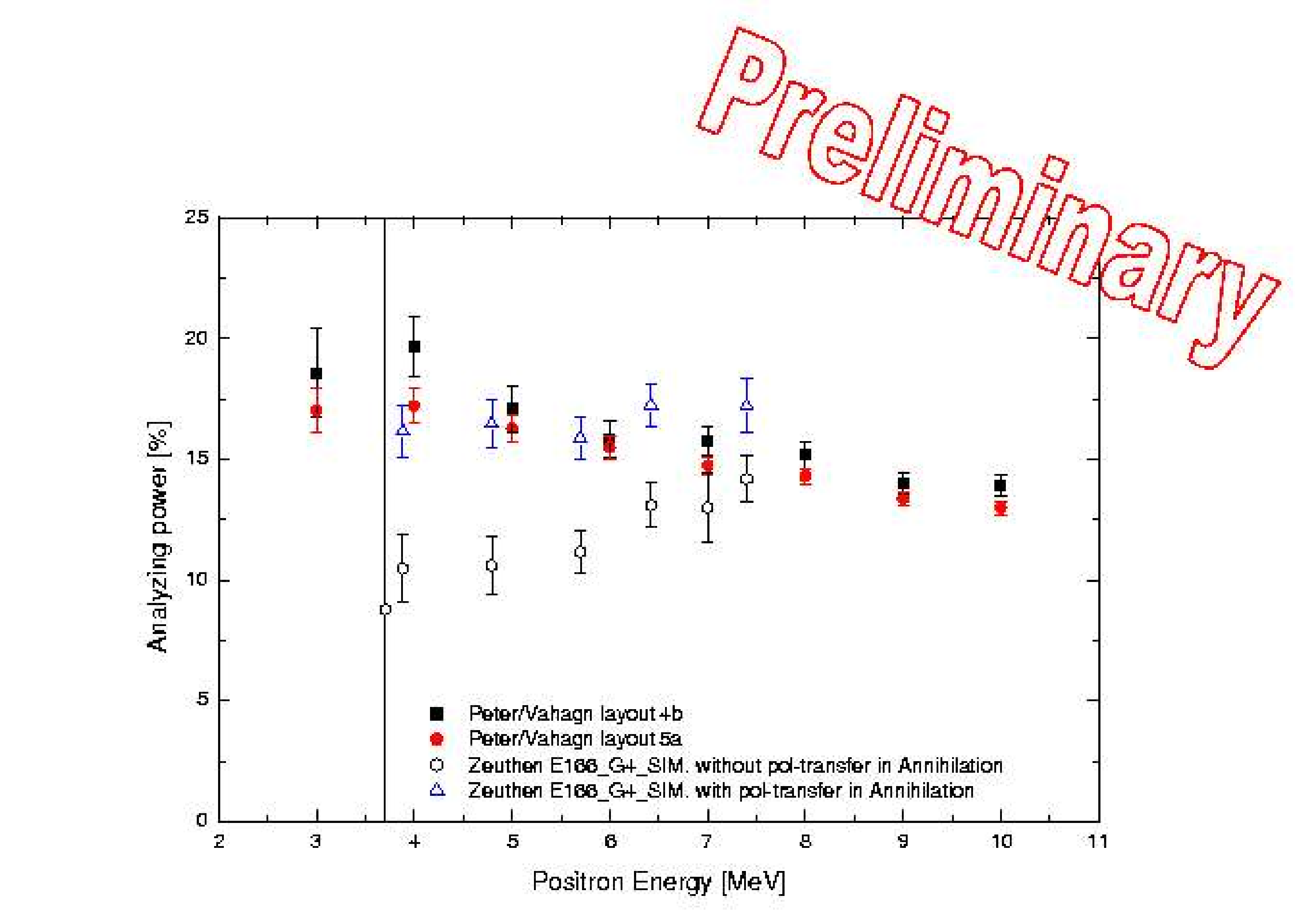
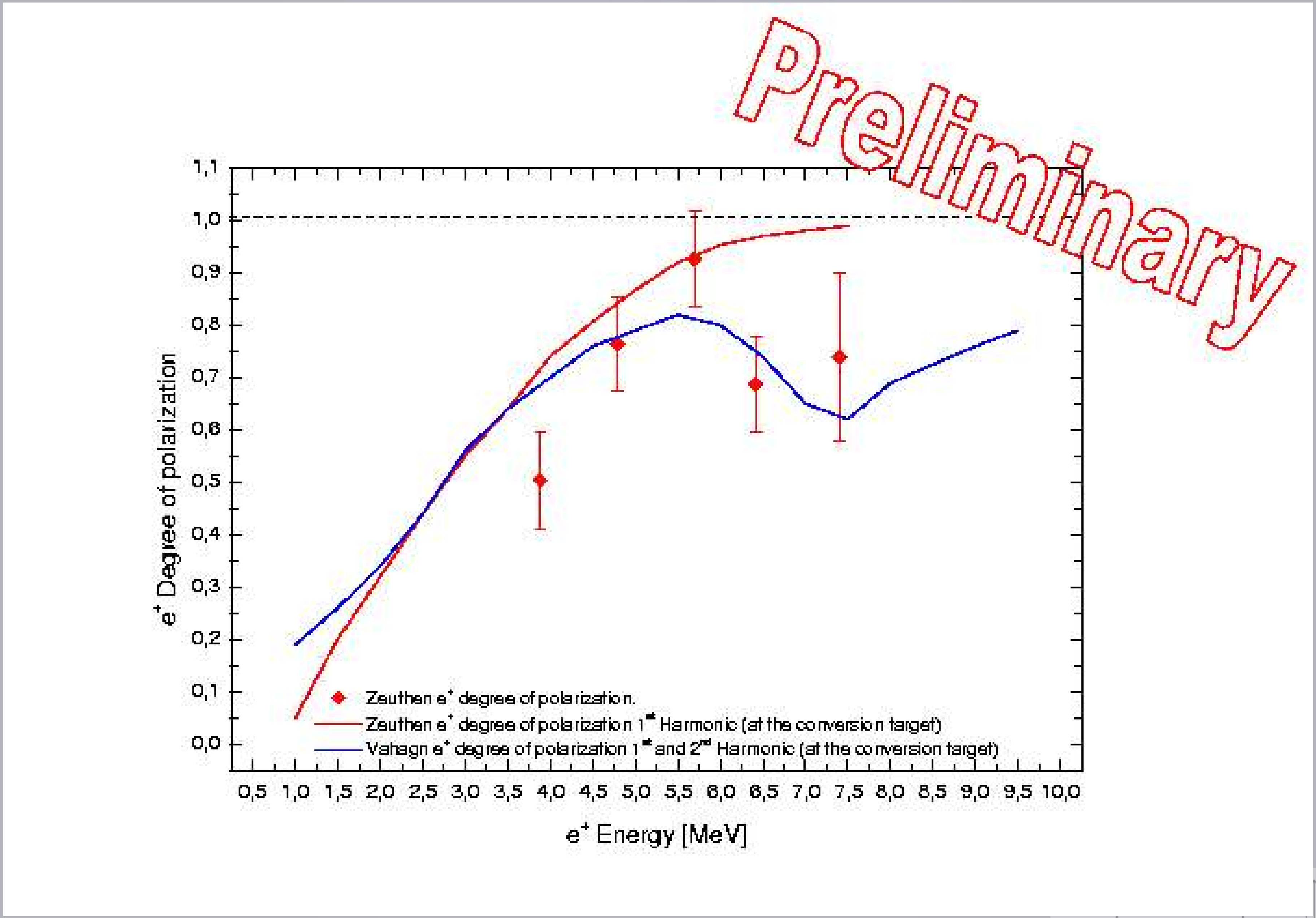
Some preliminary results of E166:



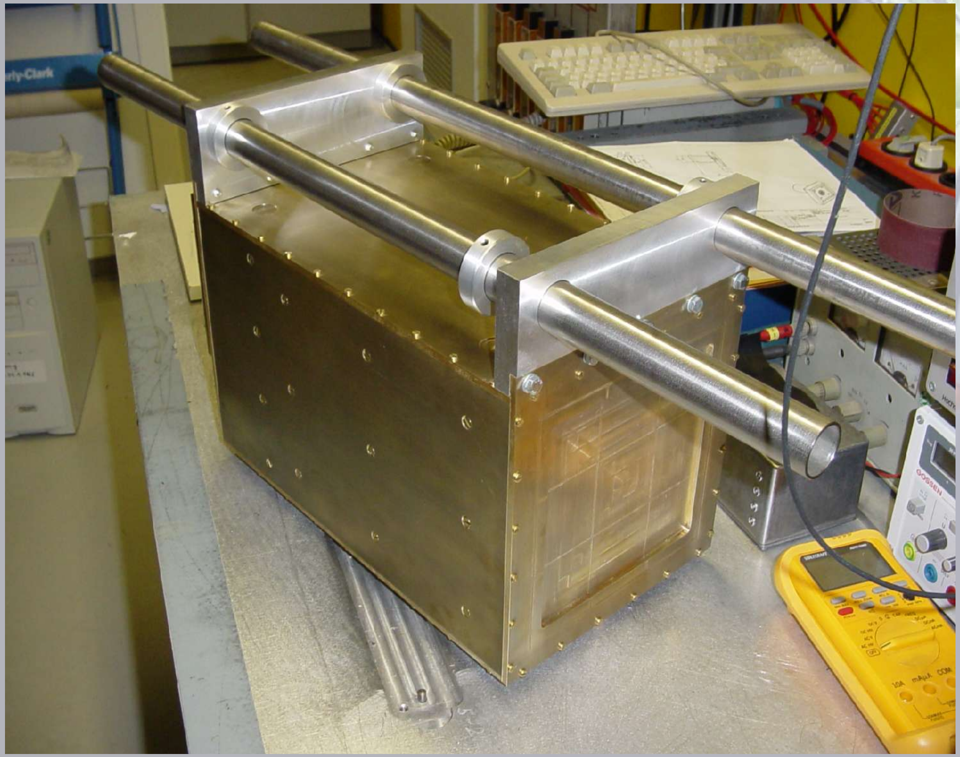
Some preliminary results of E166:

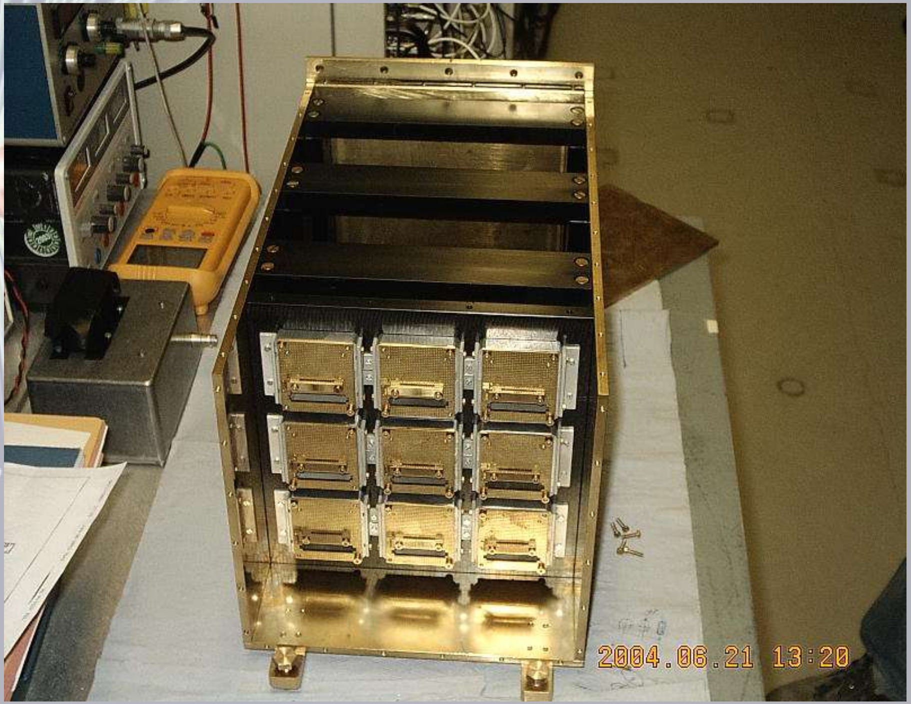


The setup:

The CsI-calorimeter:

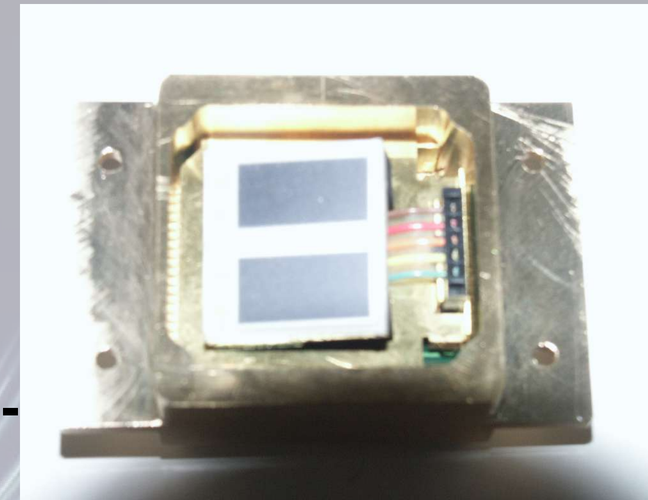
- 3x3 matrix of CsI(Tl)-crystals
- CsI(Tl): high energy resolution (~ 5%) at E~ 1GeV
- 2 photodiodes per crystall
- photodiodes and amplifiers out of BaBar-inventories

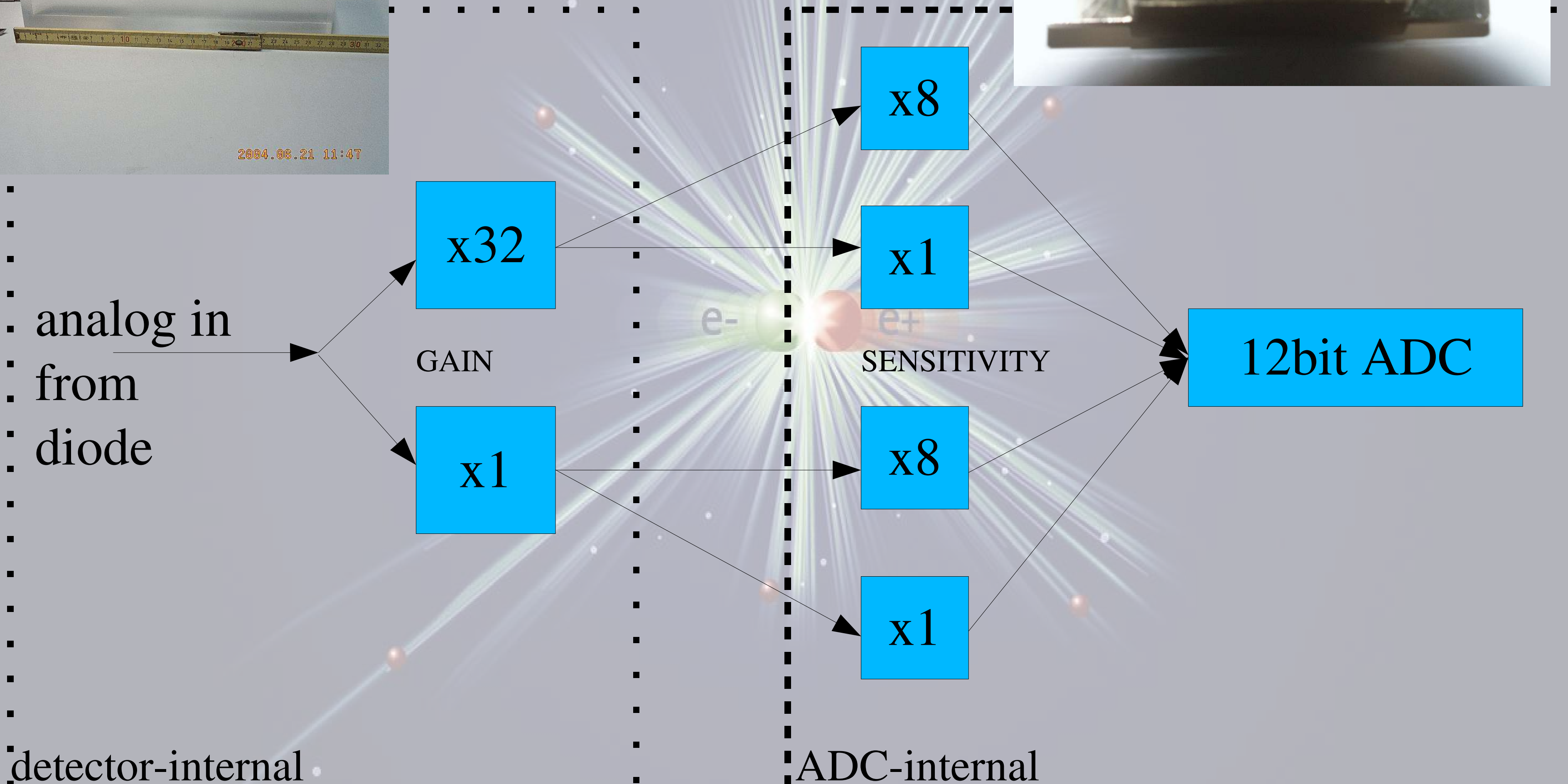




The setup:

Detector-electronics:





My diploma thesis: *Calibration of the E166 CsI-calorimeter*

Analysis of run files with focus on:

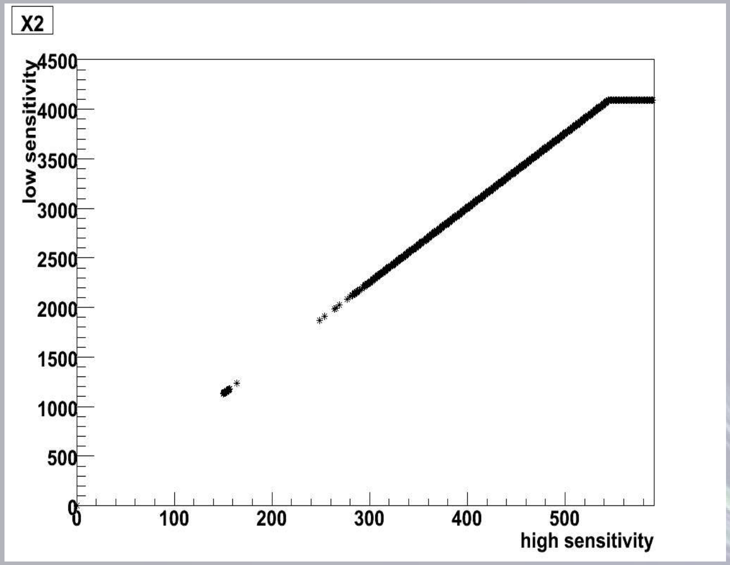
- improved pedestals
- precise measurement of amplifier slopes
- calculation of high-resolution values

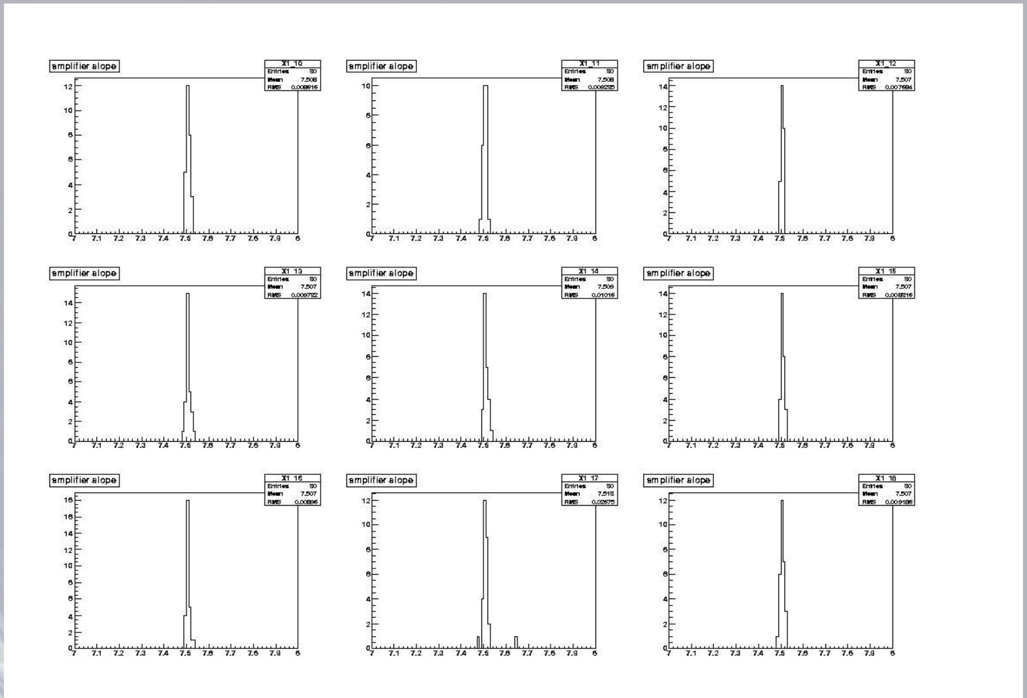
Simulation of cosmic muon events with GEANT4:

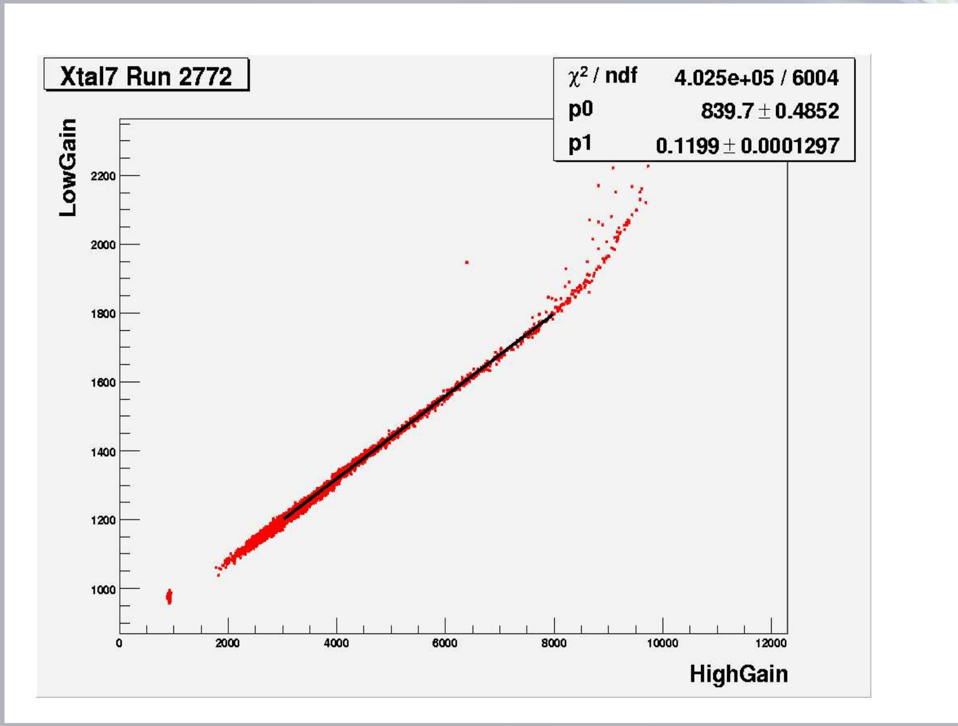
- implementation of cosmic muon generator
- implementation of cosmic trigger in geometry

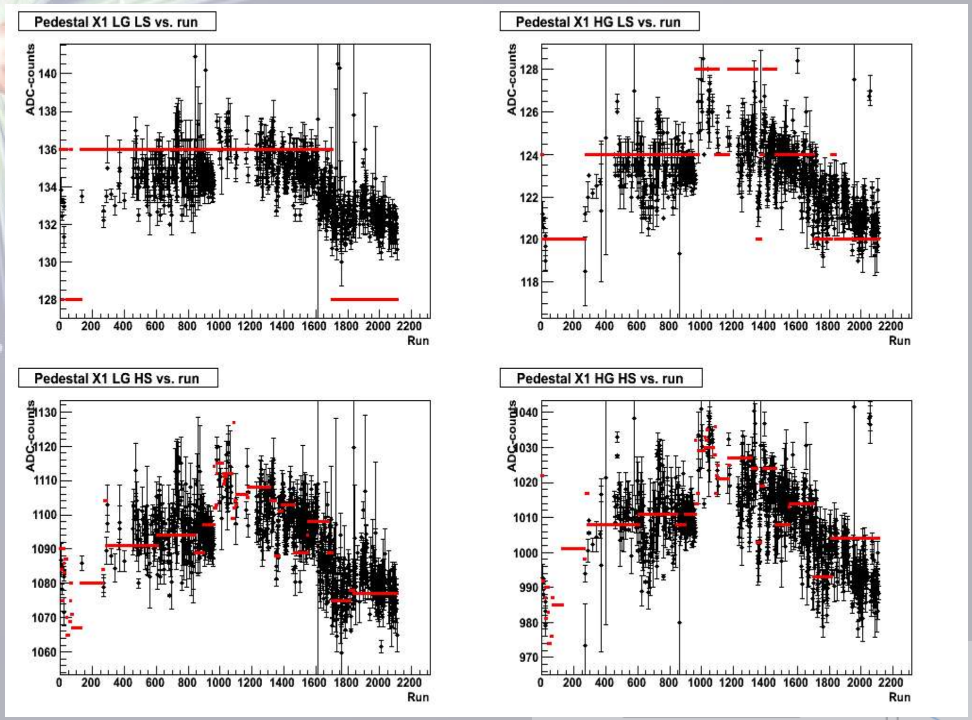
Testbeam run in Hamburg to check linearity

My diploma thesis:



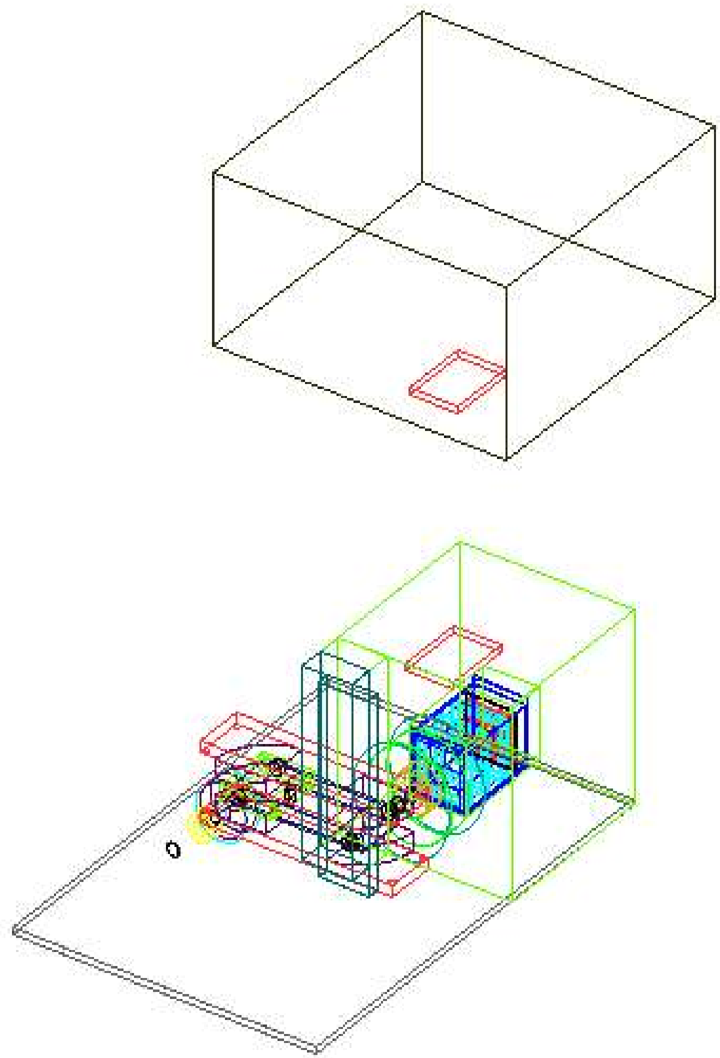


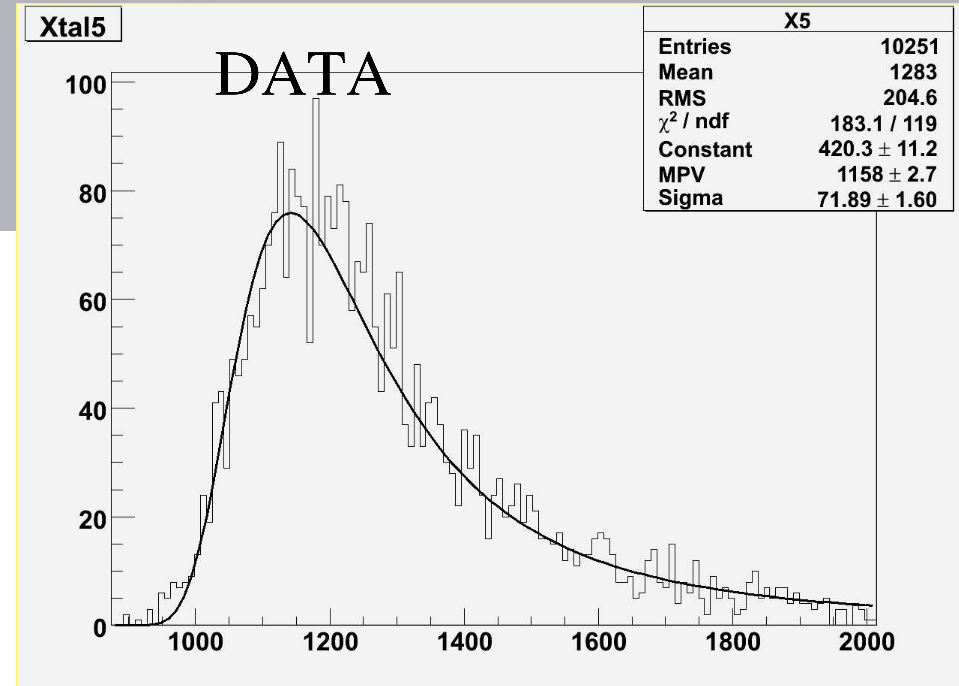


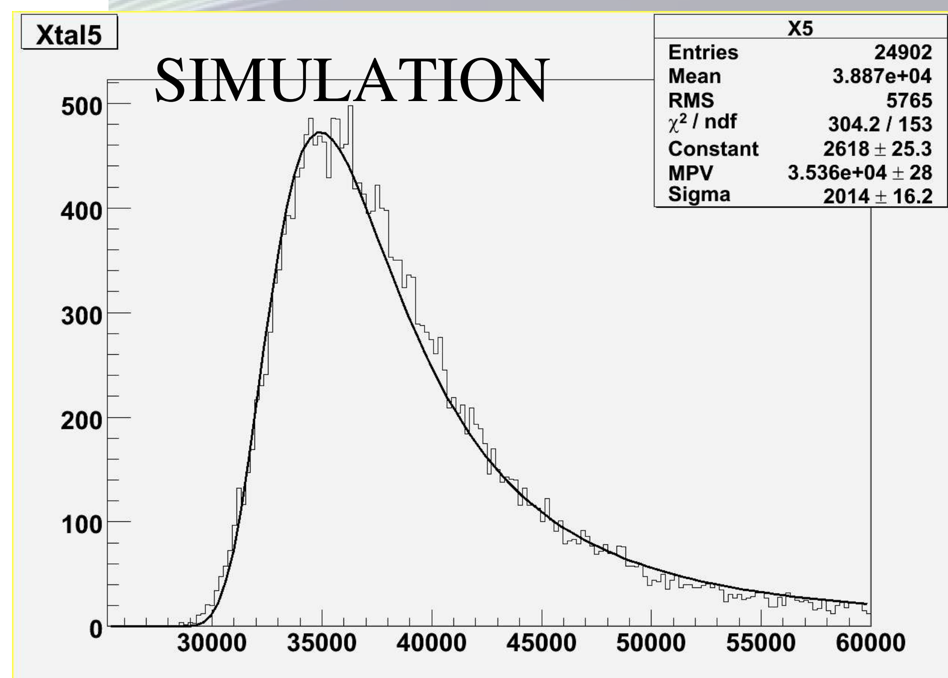


My diploma thesis:

Simulation with GEANT4 and calibration with cosmic muons:







Conclusion:

My work for E166:

- Determination of amplifier slopes has been finished, with a precision better or equal to 2.5%

- Simulation with GEANT4 has been finished, first calibration with cosmic muon runs done at SLAC has been published

This week:

- Testbeam run in testbeam-area 22 at DESY Hamburg