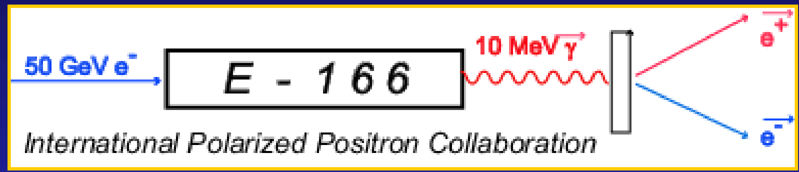
Status Report of E166



"Polarized Positrons for Future Linear Colliders"

by
Thomas Schweizer
Humboldt University Berlin
for the E166 collaboration

Introduction

- Overview and purpose of E166
- The production of polarized positrons
- The polarization measurement of positrons
- Technical challenges
- Status of subcomponents
- Summary and time schedules

E - 166

International Polarized Positron Collaboration

E166 Collaboration

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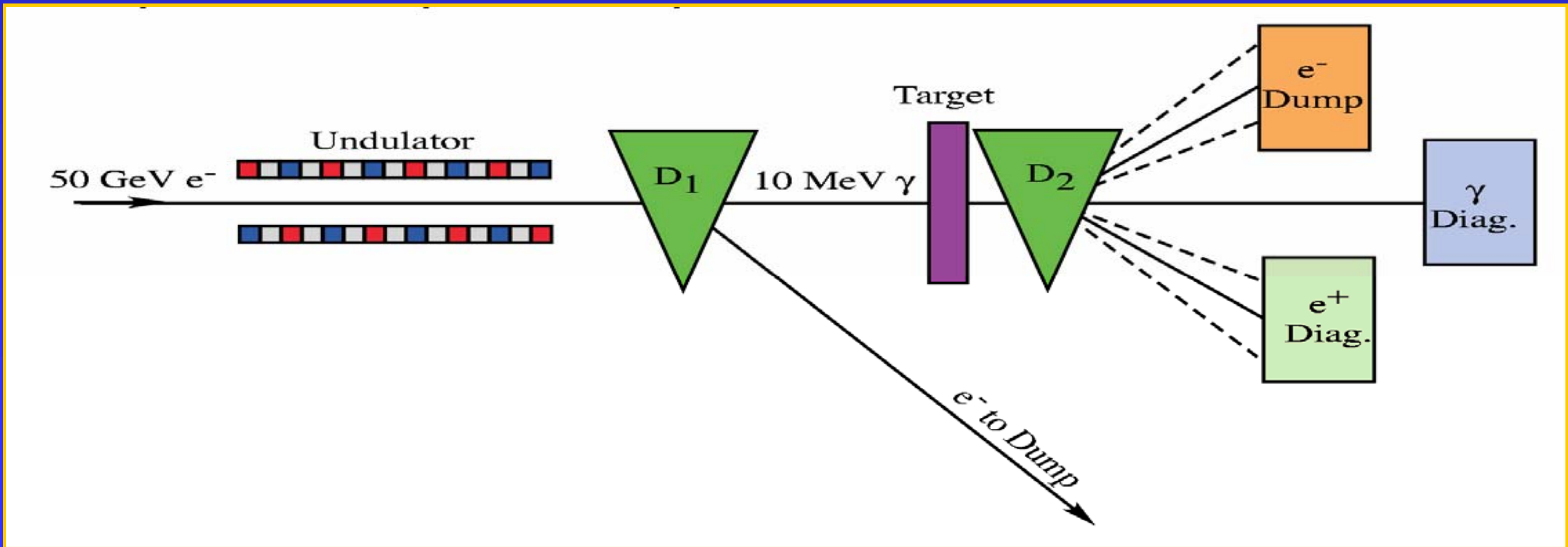
- About 45 members from 16 institutions:
- Brunel, CERN, Cornell, DESY, Durham, Jefferson, Humboldt, KEK, Princeton, South Carolina, SLAC, Tel Aviv, Tokyo M.U., Tennessee, Wasada, Yerevan
- From all three regions (Asia, Europe, the Americas)

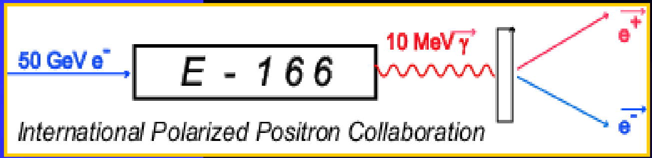
Overview of E166

- Demonstration experiment for production of polarized e^+
- Final focus test beam (FFTB) at SLAC with 50 GeV electrons
- 1 m long helical undulator produces circular polarized undulator radiation 0-10 MeV (Balakin & Mikhailichenko 1979)
- Conversion of photons to positrons in 0.5 X0 Ti-target
- Measurement of polarization of photons and positrons by Compton transmission method



Need for demonstration

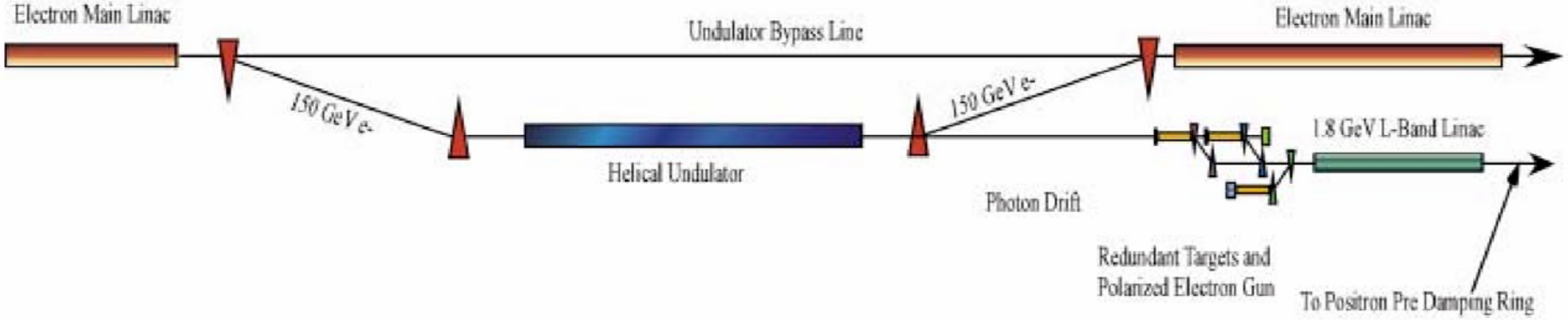
- The polarization of the positrons depends on the polarization transfer in pair production
- Fronsdal & Ueberall (1958); Olsen & Maximon (1959)
- In order to understand the experimental difficulties in undulator based production of polarized positrons we need the experiment
- The design of a linear collider (with or without polarized positron) may depend on this knowledge
- E166 aims for a precision of 5 % in the measurent of the polarization of the positrons. That it sufficient to demonstrate that undulator based production of polarized positrons works



Polarized positrons at linear colliders

- The >150 GeV electron beam itself is used for the production of polarized positrons
- Electron beam passes a 200m helical undulator (50% surplus)
- After conversion, the positrons are captured and accelerated
- They collide with a later e^- bunch train

Design for NLC



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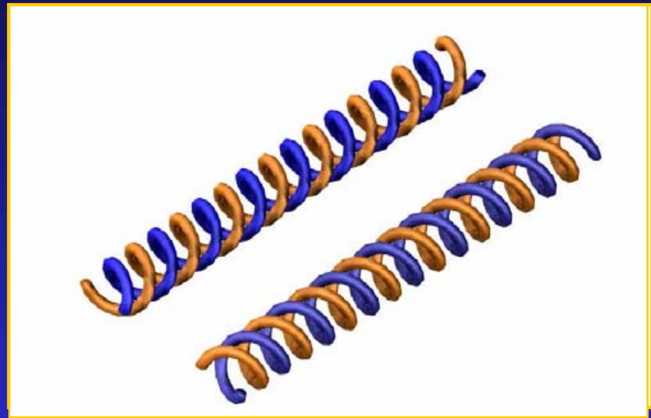
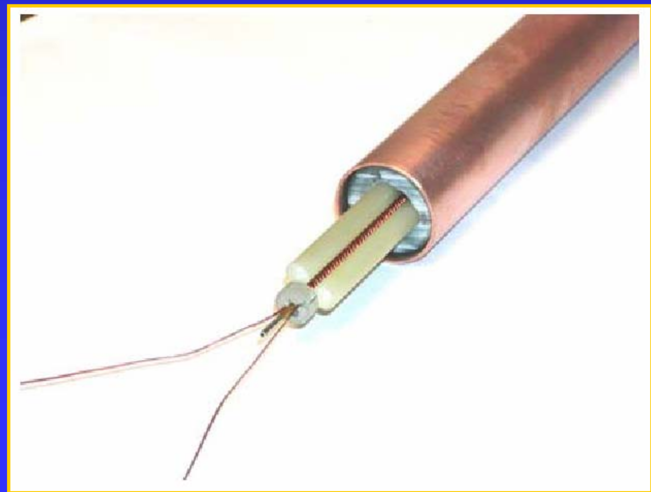
The helical undulator

- Rotating magnetic field
- Wire wound helically
- Inner diameter 0.89 mm (E166)
- Magnetic field: 0.76 T (E166)
- Pulsed current: 2300 A
- Rate 30 Hz (E166)



Parameter	TESLA	E166
Length	~200 m	1 m
Beam	~200 GeV	50 GeV
Period	14 mm	2.4 mm
Strength K	1	0.17
Cutoff	~20 MeV	9.6 MeV
Positrons/ bunch	3×10^{10}	2×10^{7}



50 GeV e⁻ → E - 166 → 10 MeV γ → e⁺ / e⁻

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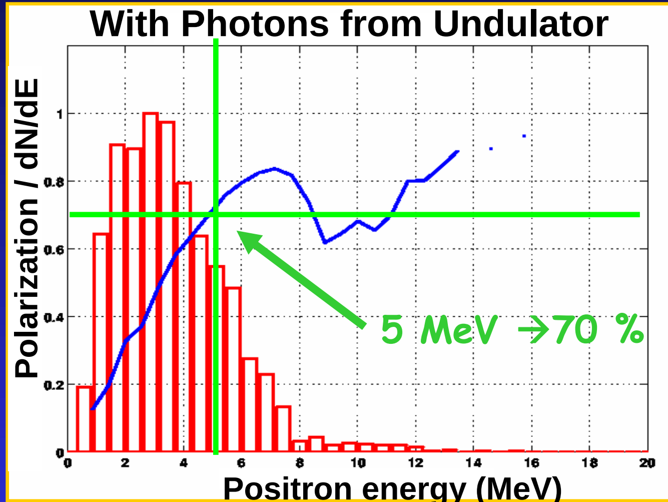
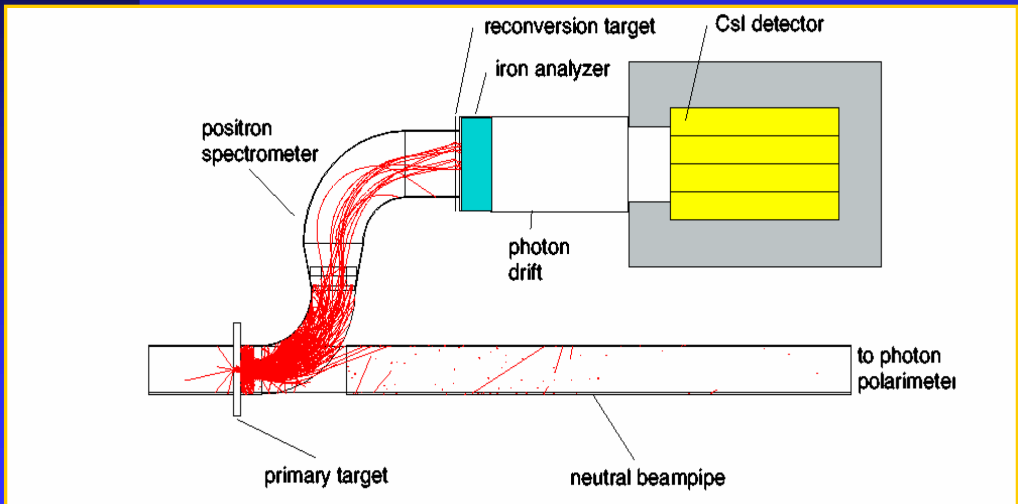
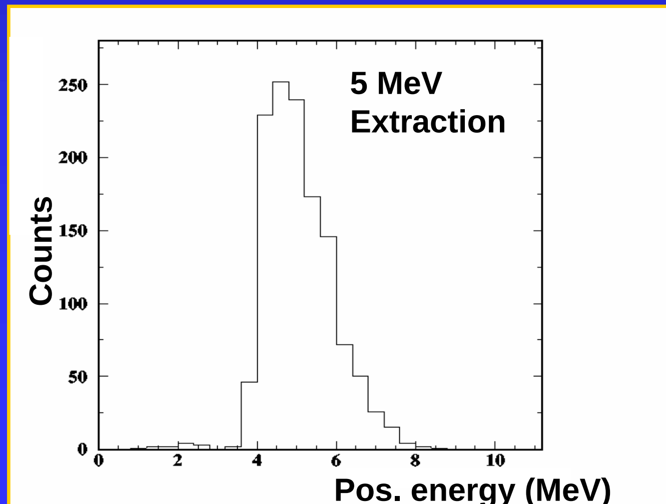
Target and spectrometer

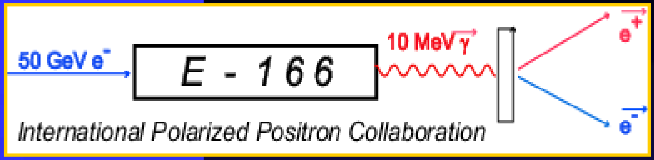
- Target: Ti or W-Re, yield 0.5 %
- Energy spectrometer: spread 20%

Material	Polarization
Ti 0.25 X0	52 %
Ti 0.5 X0	53 %
W-Re 0.5 X0	49 %



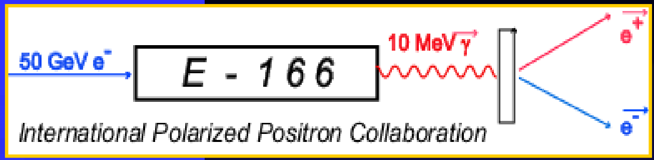






The Polarization Measurement

- Compton transmission method



Photon Transmission Polarimetry

- Compton scattering depends on polarization photon and e^-
- Either measurement of scattered photons or of unscattered photons: simpler setup
- Attenuation:

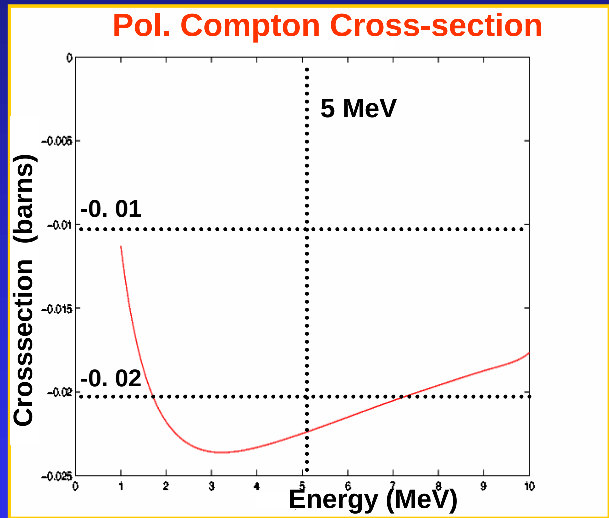
$$T(L) = e^{-nL(\sigma_{phot} + \sigma_{pair} + \sigma_{comp0})} e^{\pm nLP_{\gamma}P_e\sigma_{pol}}$$

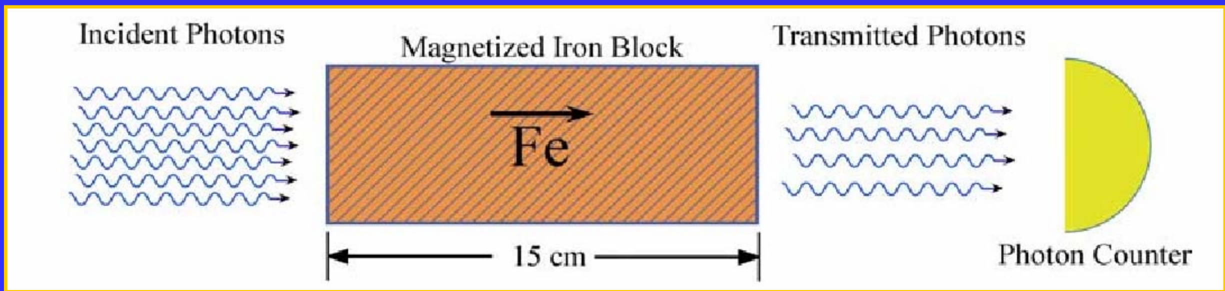
- Asymmetry:

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

- By knowing P_e => P_{γ} can be calculated:

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





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

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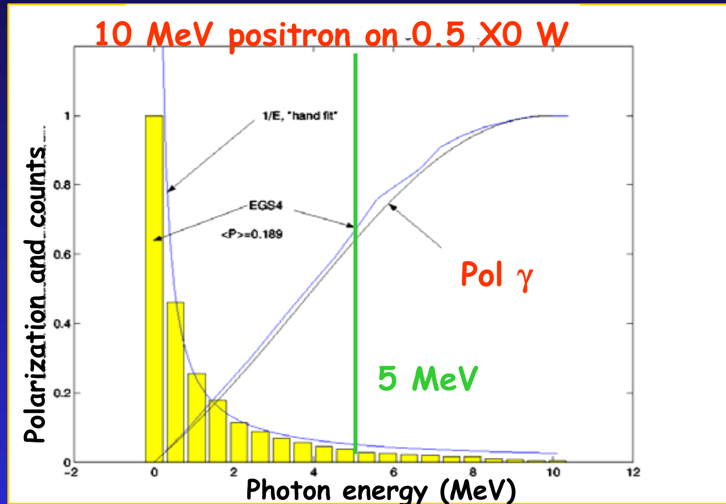
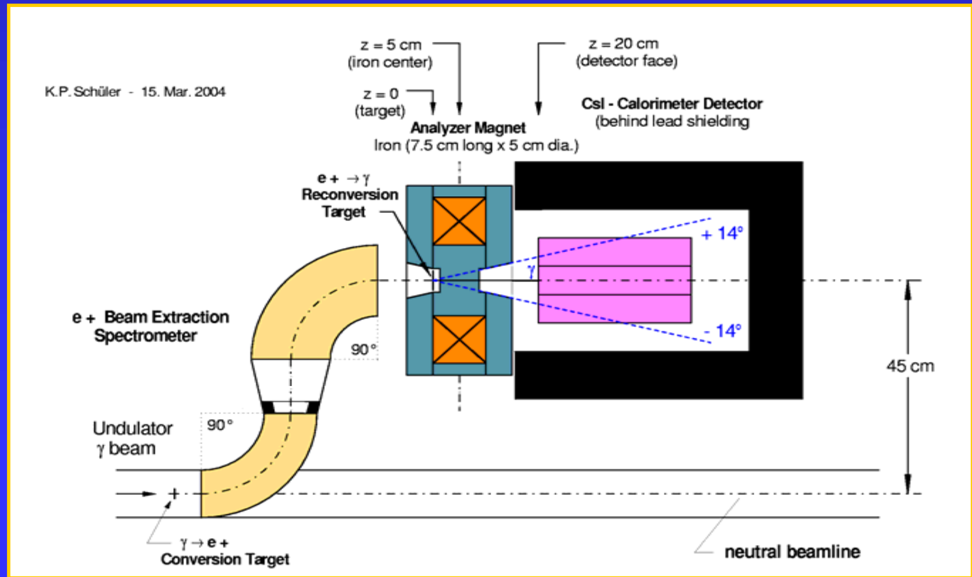
Polarimetry of positrons

- Longitudinal polarized positrons are re-converted to circular polarized bremsstrahlungs-photons in reconversion target (W with 0.5 X0)
- Polarization of photons measured by transmission polarimetry
- Energy weighted signal in CsI calorimeter (background supress.)
- Eff. analyzing power A_{e+} is determined by MC simulation

$$P_{e^+} = \frac{\delta}{P_{e^-} A_{e^+}}$$





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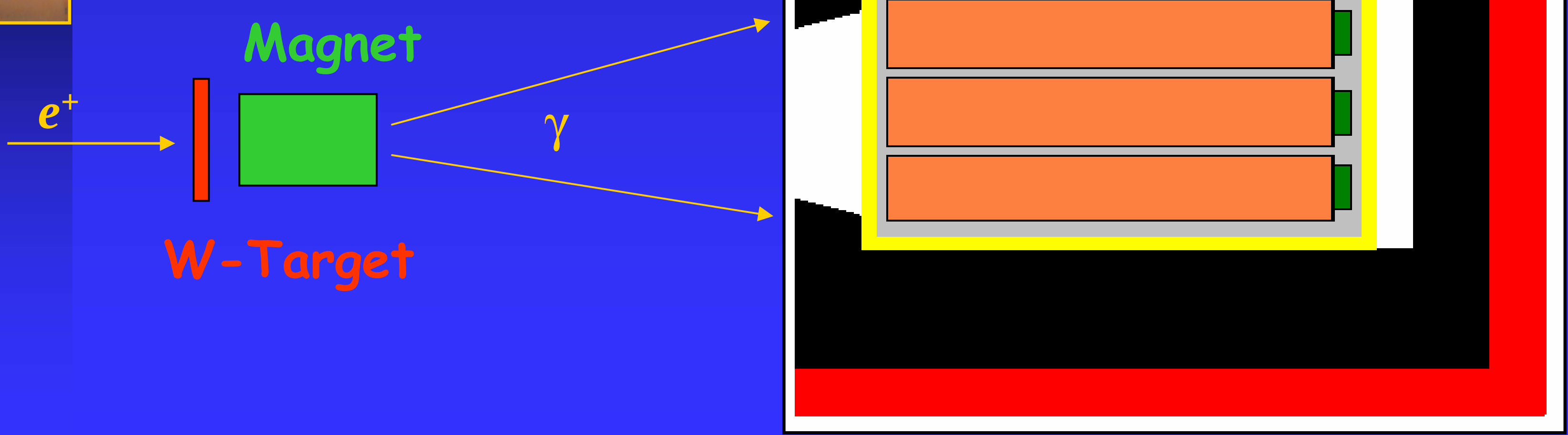
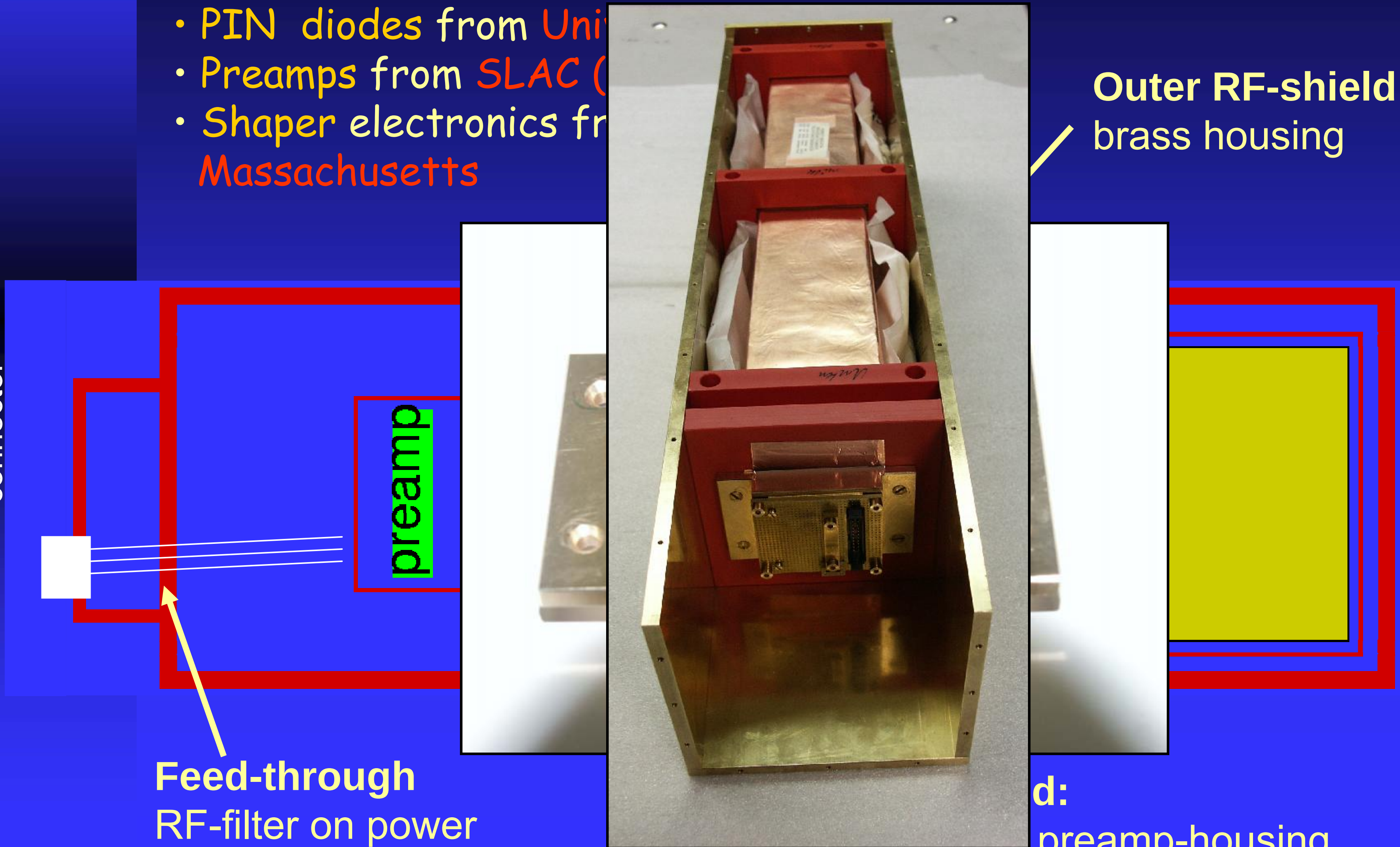
CsI Calorimeter

- „DESY Zeuthen and Humboldt University Berlin"
- Pack 3 x 3 crystals in a stack
- CsI crystals: ~ 6 cm X 6 cm X 28 cm from DESY
- ~1600 Re-converted photons -> ~ 6.1 GeV
- Readout by PIN diodes (large linear dynamic range)
- 14 degrees aperture



PIN diode readout of prototype

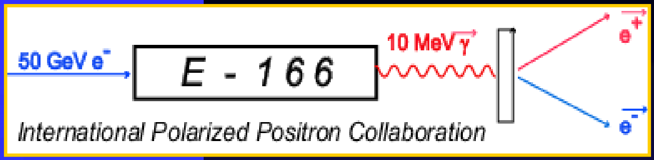
- PIN diodes from Uni
- Preamps from SLAC (
- Shaper electronics fr
  Massachusetts



Outer RF-shield:
brass housing

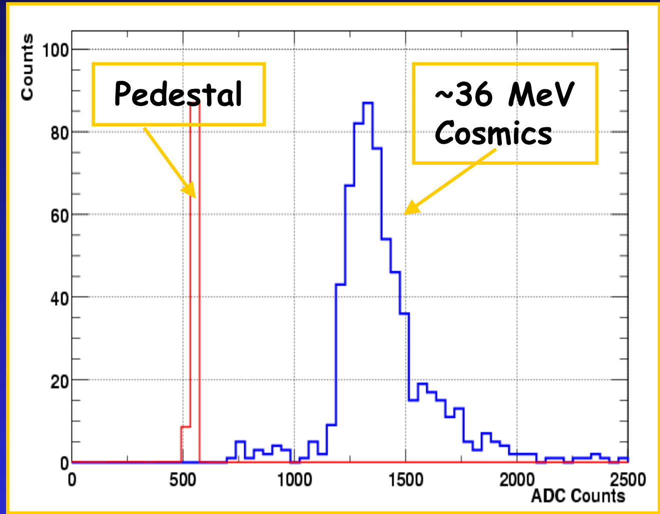
Feed-through
RF-filter on power

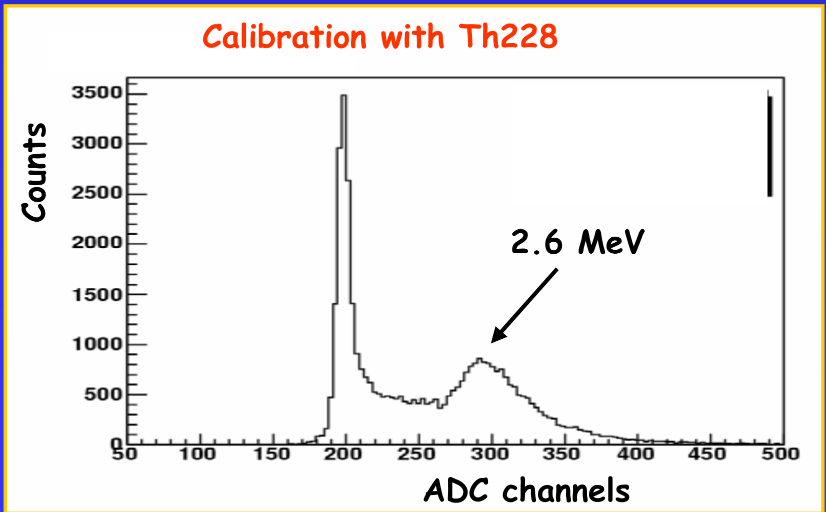
d:
preamp-housing

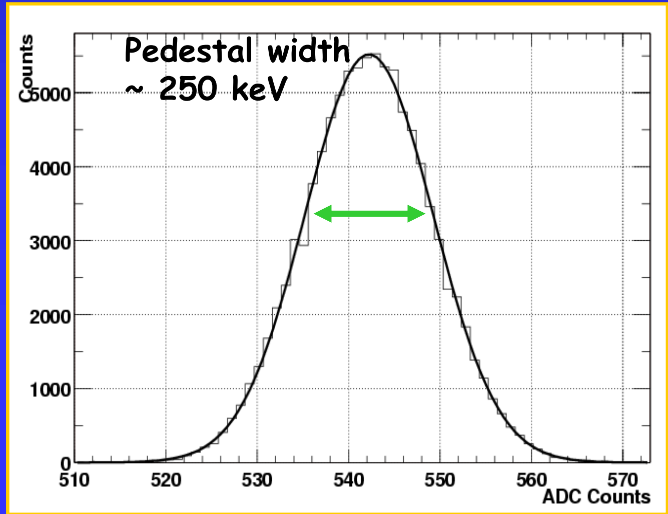


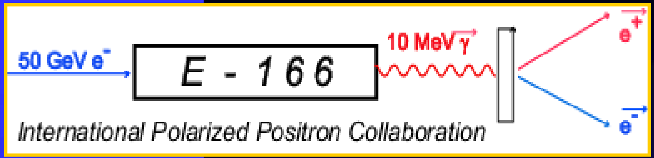
Calibration: Th228 and Cosmics

- Calibration with Th228: 2.6 MeV line
- Calibration with Cosmics: MC studies: Peak at ~36 MeV
- Energy resolution ~250 keV
- Signal at ~6 GeV
- Linear dynamic range -> 10 GeV



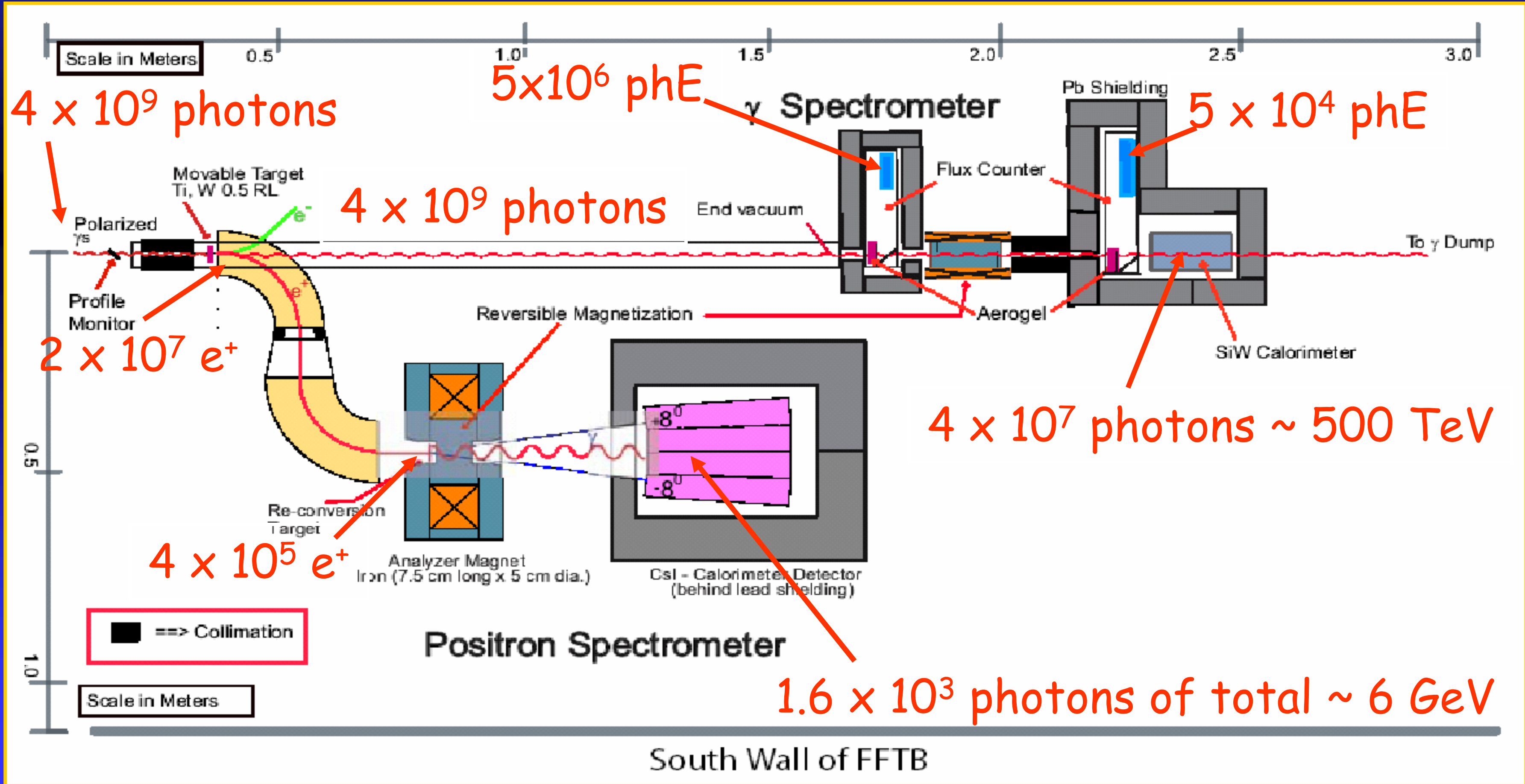






Reminder: Experimental setup

- Now: Gamma spectrometer



50 GeV e⁻ E - 166 10 MeV γ

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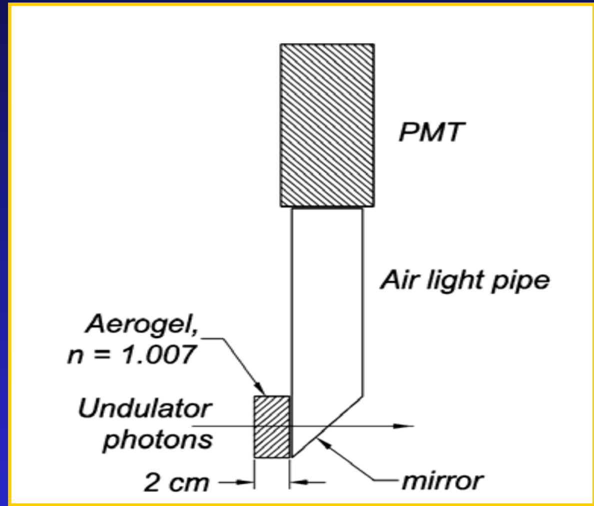
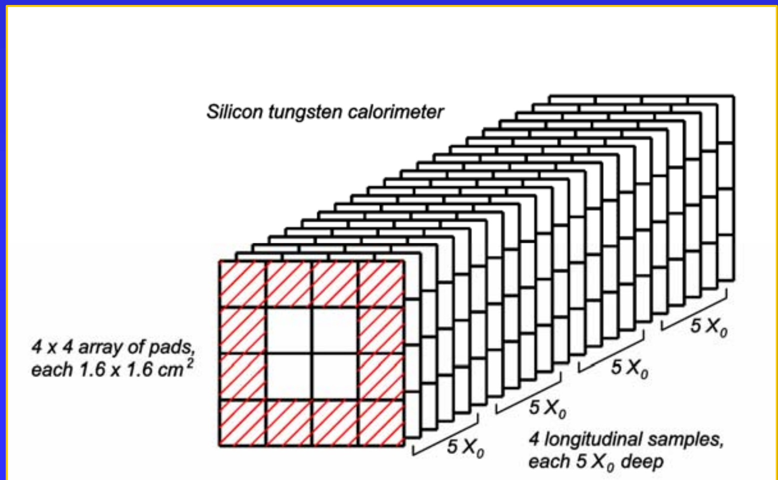
Aerogel flux counters and Si-W calorimeter

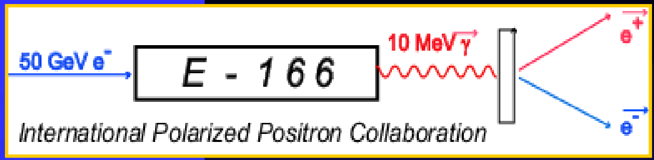
- Aerogel energy threshold: 4.3 MeV
  - Photon flux measurement
- Si-W calorimeter
  - 4 x 4 Stack of 20 plates of W (1 X0 thickness)
  - Up to 500 TeV signal
  - Total energy of undulator photons





Experimental challenges

- Large angular distribution of positron production
  - Collection efficiency and transport efficiency of positron transport system
- Large angular distribution of re-converted photons
  - Needs large aparture of CsI calorimeter (~14 degrees)
  - Signal (not scattered photons) mixes with Compton scattered photons (background)
  - Effective analyzing power of positron polarimetry needs to be determined by complicated MC-simulations
- Control of large background close to beampipe
  - Electrons scatter at undulator and back splash from e^- beam dump
  - Optimized beam and strong shielding
  - Parasitic testrun for background measurement



Status of Subcomponents

Component	Status	Institution
Helical undulator	0.5 m prototype	„Cornell University"
Positron transport system	In design	„Princeton University"
Analyzer magnets	In construction	„DESY Hamburg"
CsI calorimeter	Prototype	„DESY Zeuthen/ Humboldt Unversity Berlin
Si-W calorimeter	Ready	„University Tenesse"
Aerogel counters	Ready	„Princeton University"
DAQ and Readout	Ready	„SLAC"

Conclusions

- E166 is a demonstration of production of polarized positrons for future linear colliders
- Uses the 50 GeV FFTB at SLAC
- Approved by SLAC in June 2003
- All components or prototypes work properly
- Installation of total experiment in FFTB tunnel in August 2004
- First data taking run in October 2004
- Second data taking in February 2005

The end

…

Backup slides

- ------------------------

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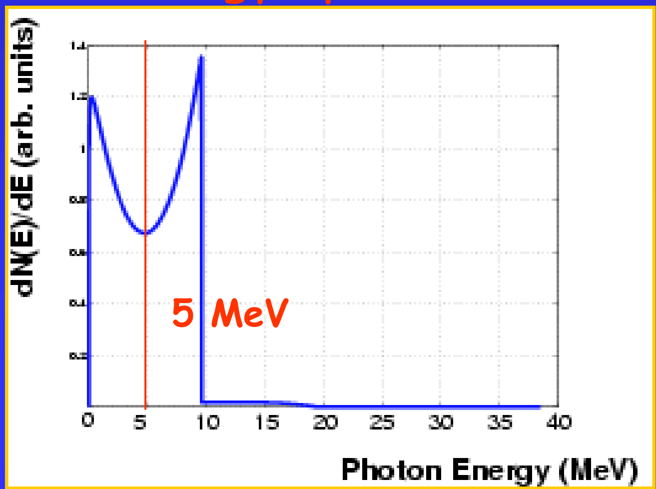
Undulator radiation

- Produced photons, cutoff and polarization

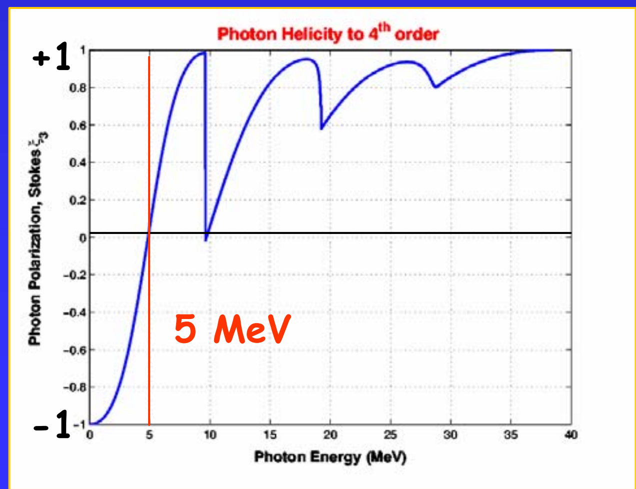
$$\frac{dN_\gamma}{dL} = \frac{30.6}{\lambda[mm]} \cdot \frac{K^2}{1+K^2} \frac{phot}{m\ e^-} = 0.37 \frac{phot}{m\ e^-}$$

$$E_C = 24[MeV] \frac{(E_e/50[GeV])^2}{\lambda\,[mm](1+K^2)} = 9.6\ MeV$$

Energy spectrum



Polarization



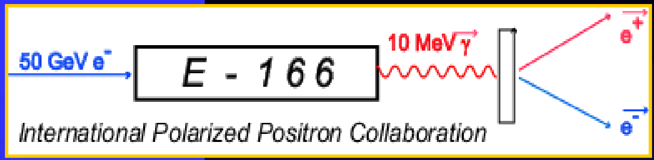
Background run results

- Uses the FFTB of 28 GeV at SLAC
- Detectors installed in tunnel
- Runs in parallel with current experiments
- Measures the background for all detectors

Detector	Expected signal	Max. allowed background	Measured background
CsI calorimeter	6 GeV	100 MeV	
Si-W calorimeter	500 TeV	25 TeV	
Aerogel upstream	2×10^9 phot	1×10^8 phot	
Aerogel downstream	5×10^7 phot	3×10^6 phot	

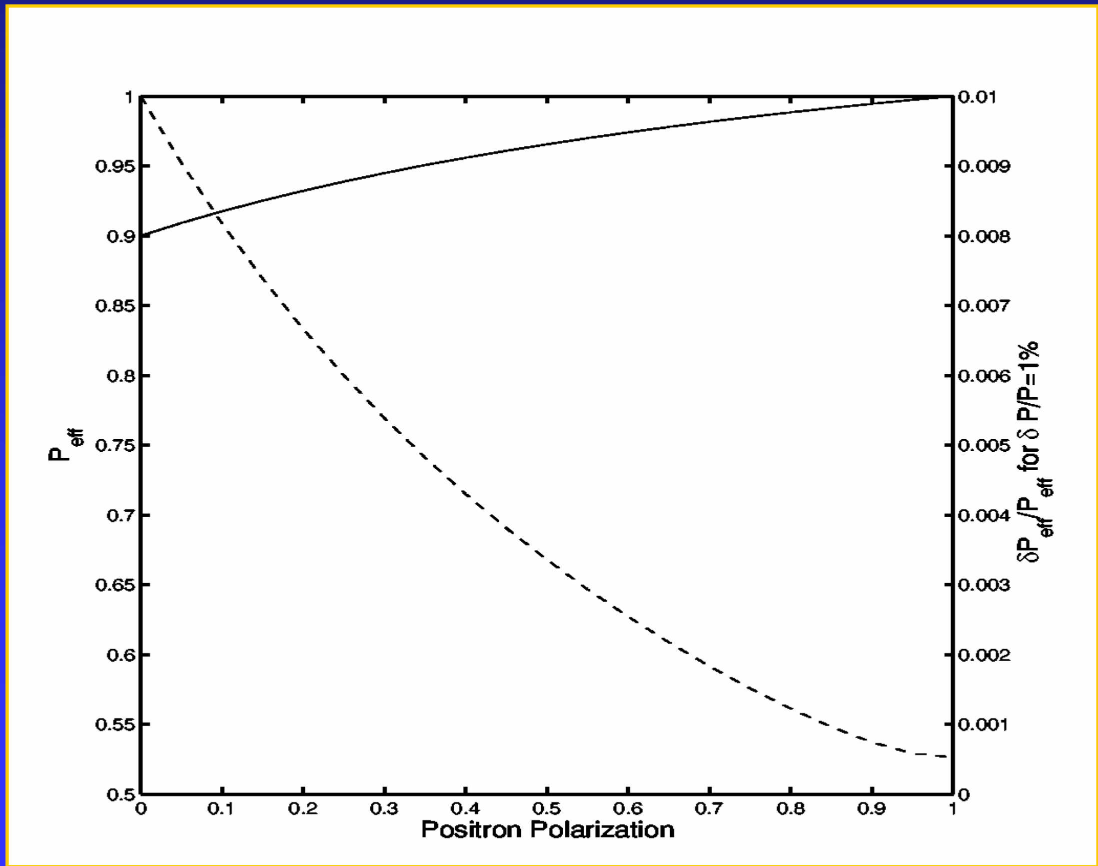
Physics arguments for polarized positrons

- Polarized e^+-beams in addition to polarized e^--beams offer:
  - Higher effective polarization and decreased error in electroweak asymmetry measurements
  - Selective enhancement (or reduction) of many SM and non-SM processes:
(e^+e^-->WW,Z,ZH couple only to $e^+_L e^-_R$ and $e^+_R e^-_L$)
  - Acess to many non-SM couplings
  - For physics using transversly polarized beams both beams e^+ and e^- must be polarized:
New physics eg. extra dimensions
  - Improved accuracy in measuring polarization



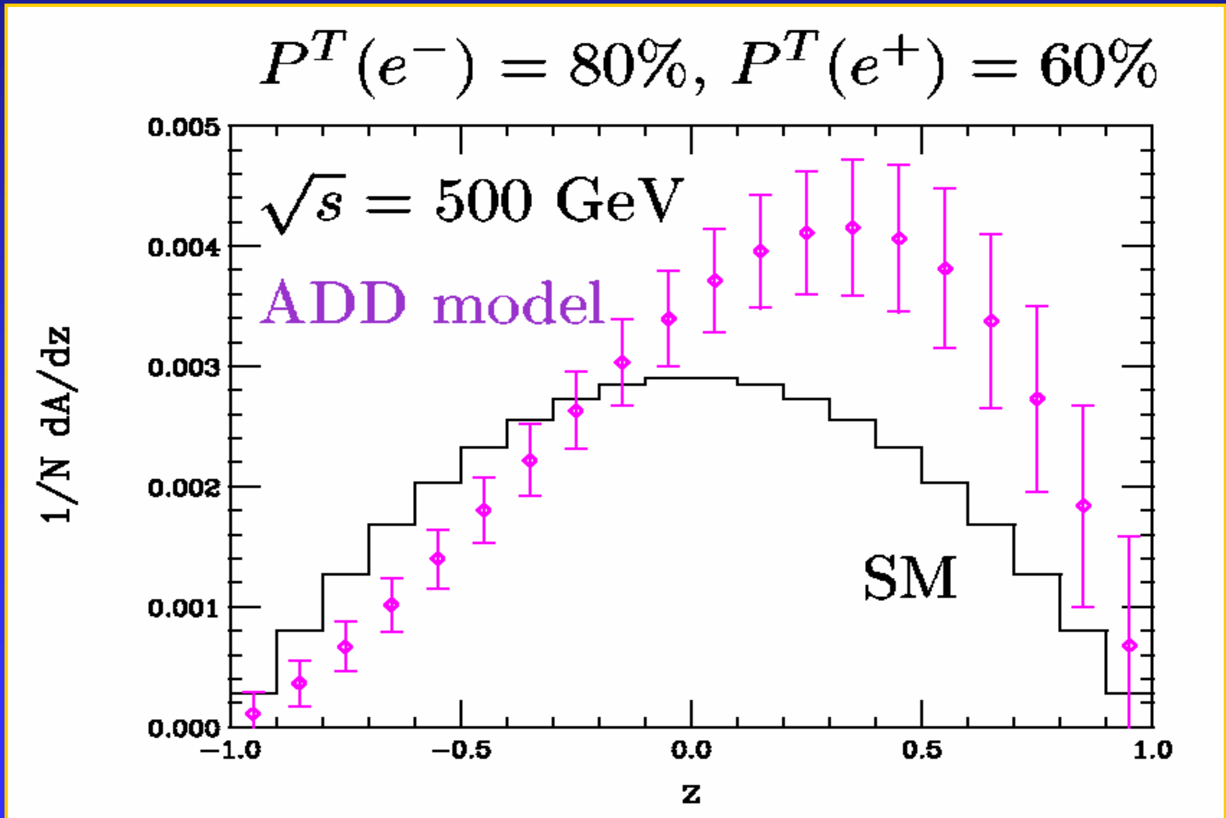
Higher effective polarization

- Two polarized beams result in a higher efective polarization and lower errors in electroweak asymmetry measurements



Search for extra dimensions

- Transverse polarization of both beams allows separation of new physics, eg. extra dimensions



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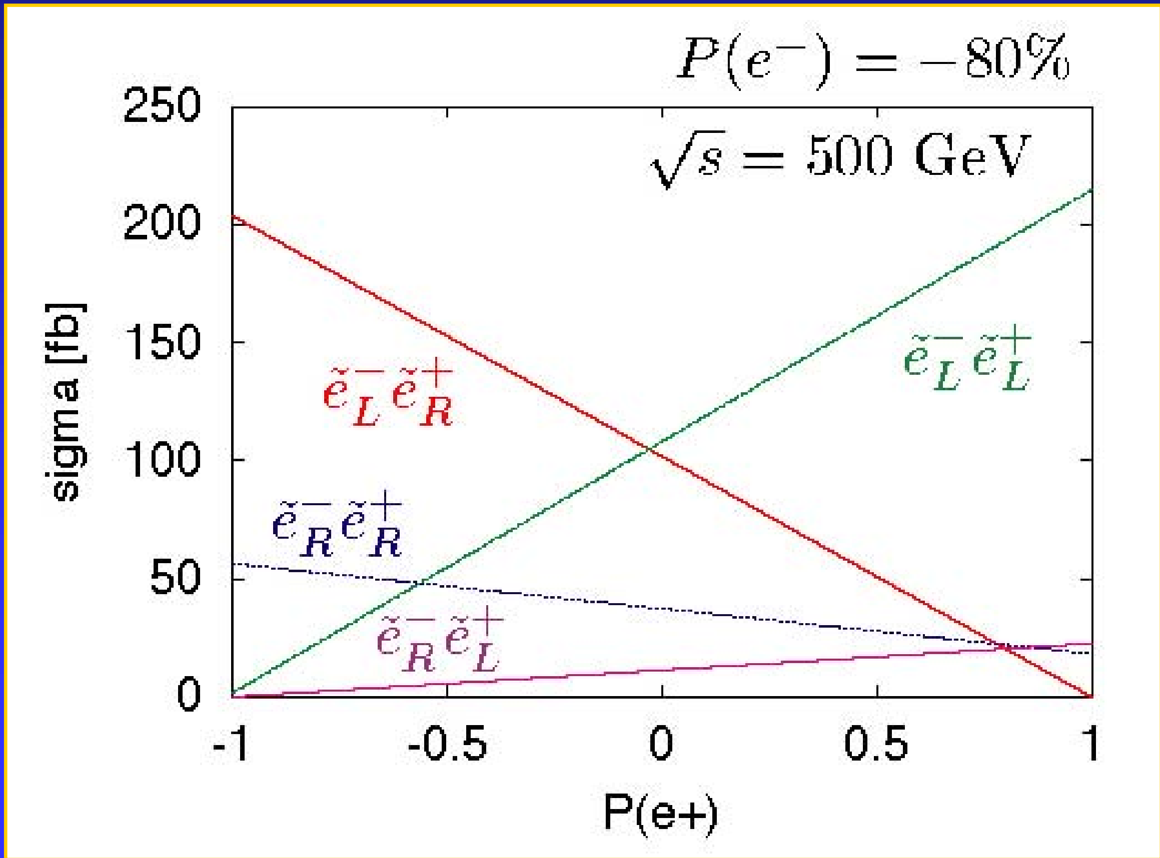
SUSY physics

- Separation of selectron pairs in $e^+e^- \rightarrow \breve{e}^-_{L,R}\ \breve{e}^+_{R,L}$



50 GeV e⁻ E - 166 10 MeV γ e⁺ e⁻
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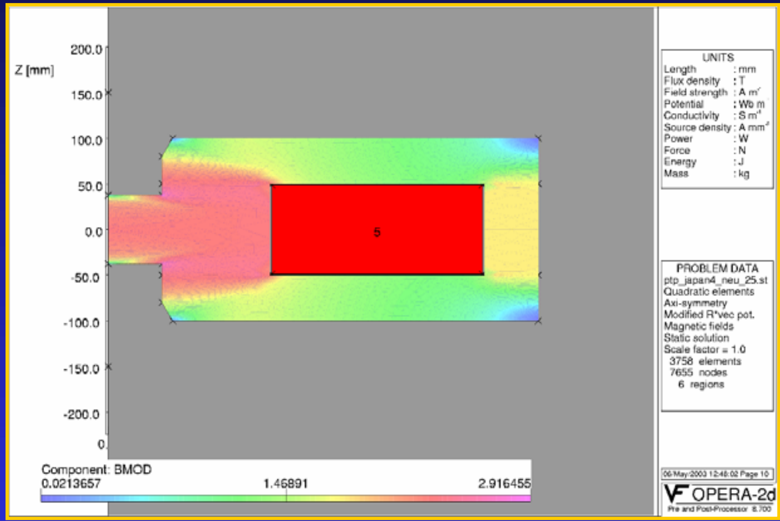
Analyzer magnets

- The knowledge of magnetisation of the analyzer magnet strongly influences error in polarimetry
- Magnetisation is given by

$$P_e = 2 \cdot \frac{g' - 1}{g'} \cdot \frac{M}{n\mu_B} \cong \frac{2}{26} = 7\%$$

- Error must be $P_e < 5\%$



„DESY Hamburg, Germany“

- Coil operated at 100A
- Photon analyzer: 5 cm x 5 cm x 15 cm
- Positron analyzer: 5 cm * 5 cm * 7.5 cm

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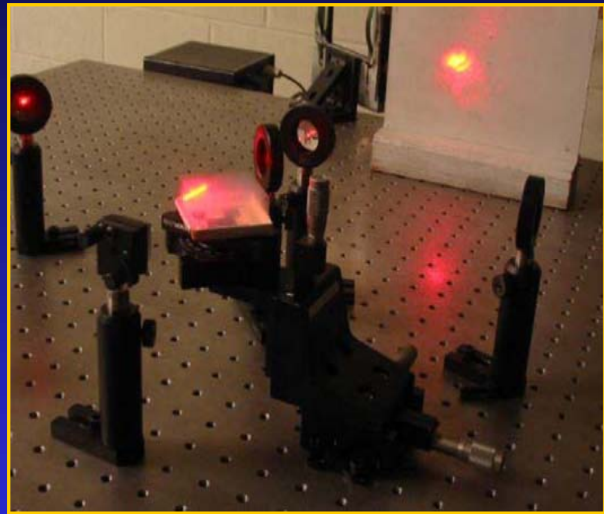
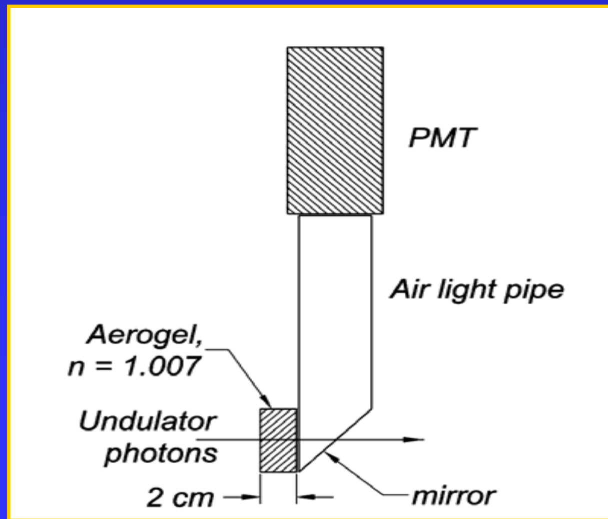
Aerogel flux counters

- „Princeton University“
- Counters from BELLE experiment
- Aerogel produces Cherenkov light
- Energy threshold: 4.3 MeV
- Conversion probabilty: 0.0003
- Extremly low refraction index 1.007





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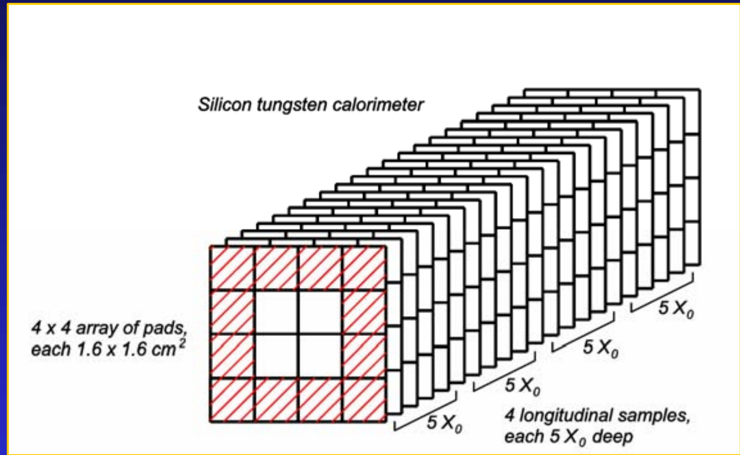
Si-W Calorimeter

- „University Tenessee“
- Total absorption calorimeter
- From E-144 design
- Stack of 20 plates of W (1 X0 thickness)
- 4 x 4 array
- Up to 100 TeV signal
- total energy of undulator photons



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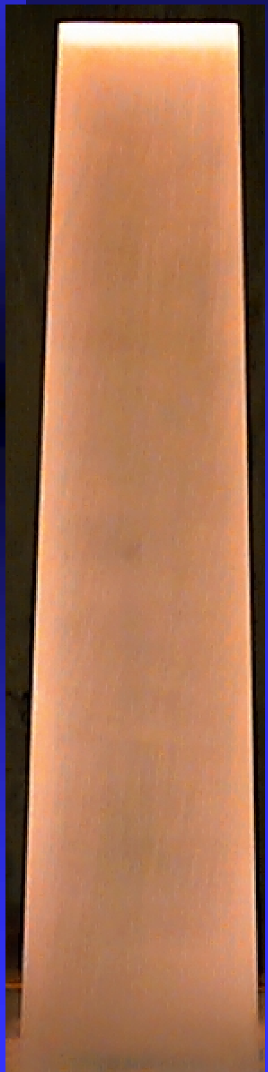
CsI Crystal Property



Properties:

▪ light yield	70.000 ph. / MeV
▪ temp. coeff.	0.1 % / ^{o}C
▪ peak emission	565 nm
▪ decay time	940 nsec
▪ index of reflection	1.79
▪ density	4.51 g/cm^3
▪ radiation length	1.86 cm
▪ Molière radius 3.8 cm	

- ‘soft material’ / slightly hygroscopic

- dimensions: ≈ 5 x 5 x 30 cm^3
- weight: ≈ 4 kg

- doping: Thallium ≈ 100 p.p.m

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

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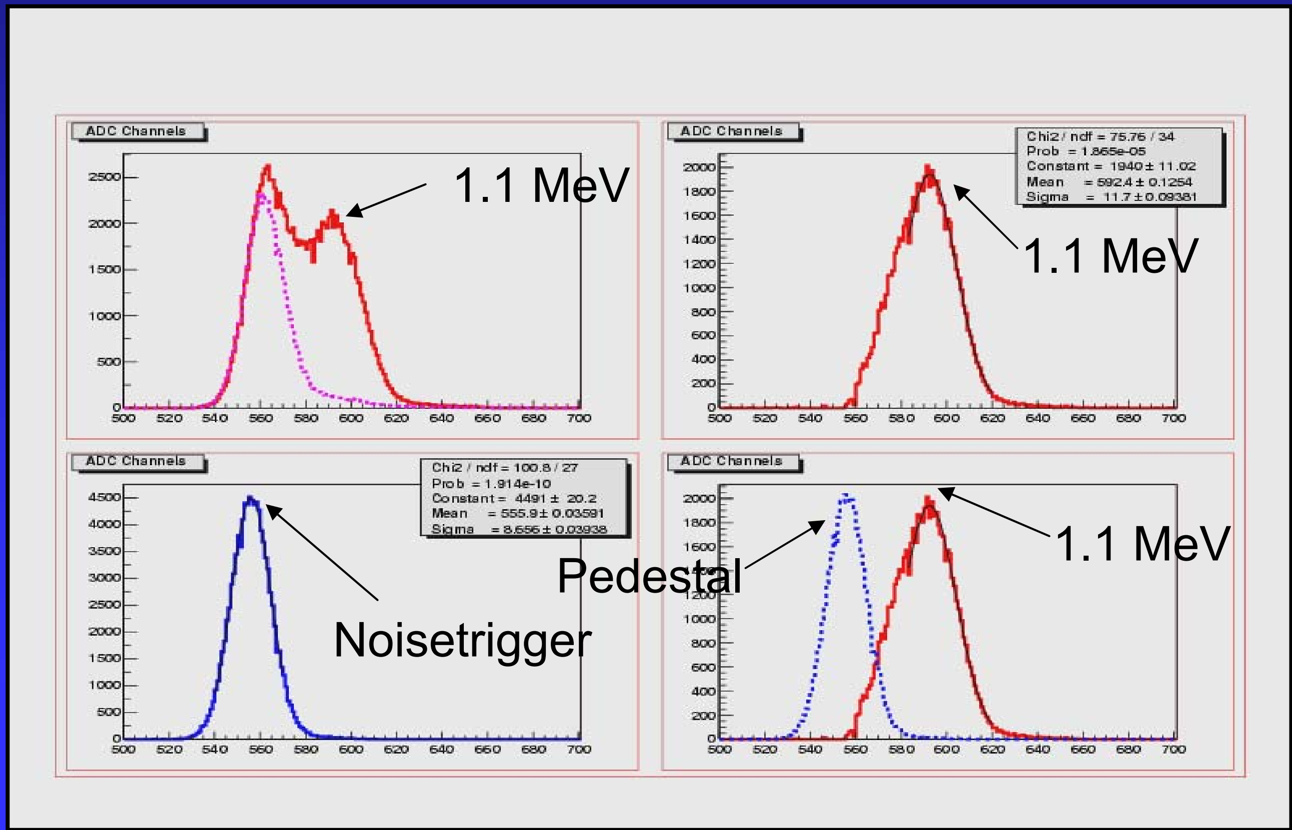
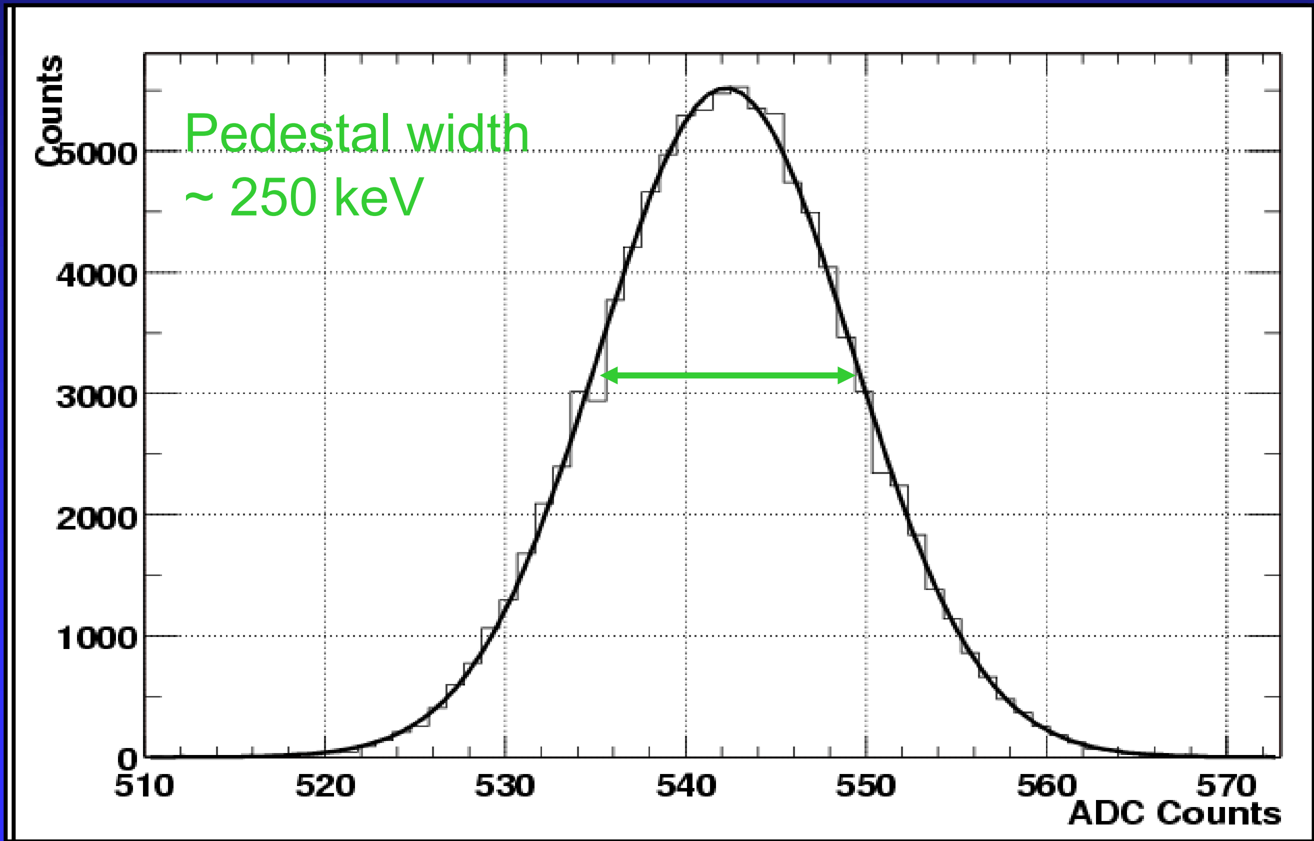
Calibration with Co60

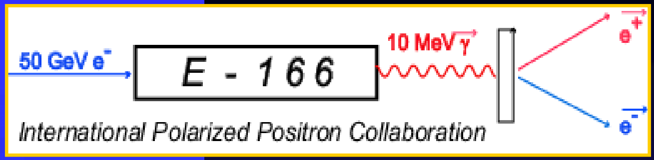
- We resolve signal at 1.1 MeV
- Energy resolution (sigma of pedestal): ~ 250 keV
- At SLAC we probably use Th^{228} ~2.6 MeV gammas



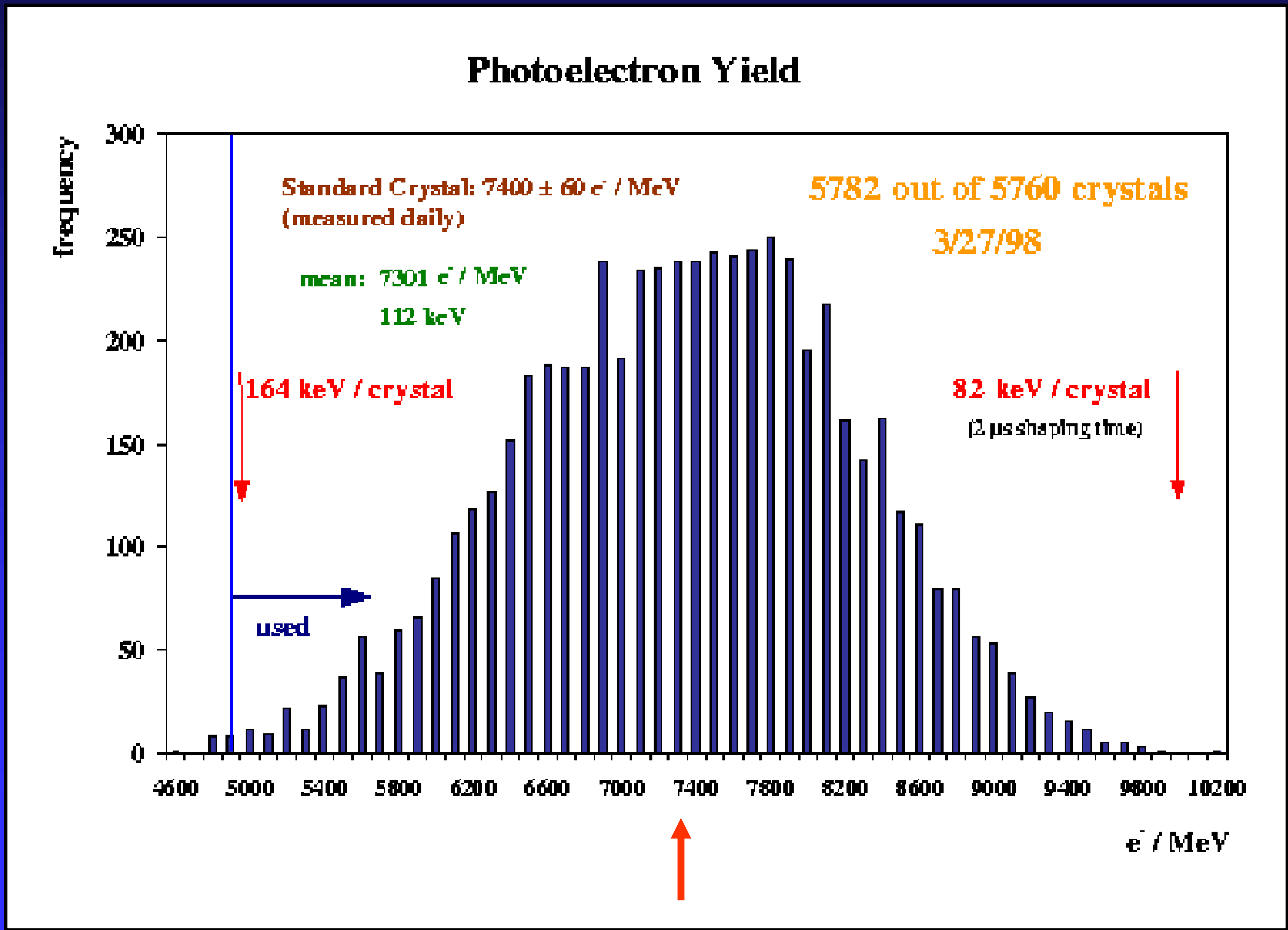
Calibration with cosmics

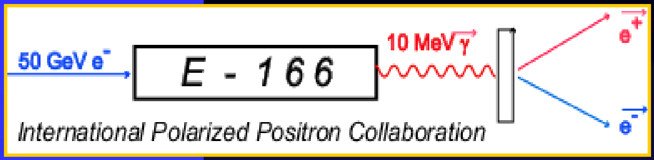
- It is also possible to calibrate with cosmics
- They deposit about 36 MeV in Crystal





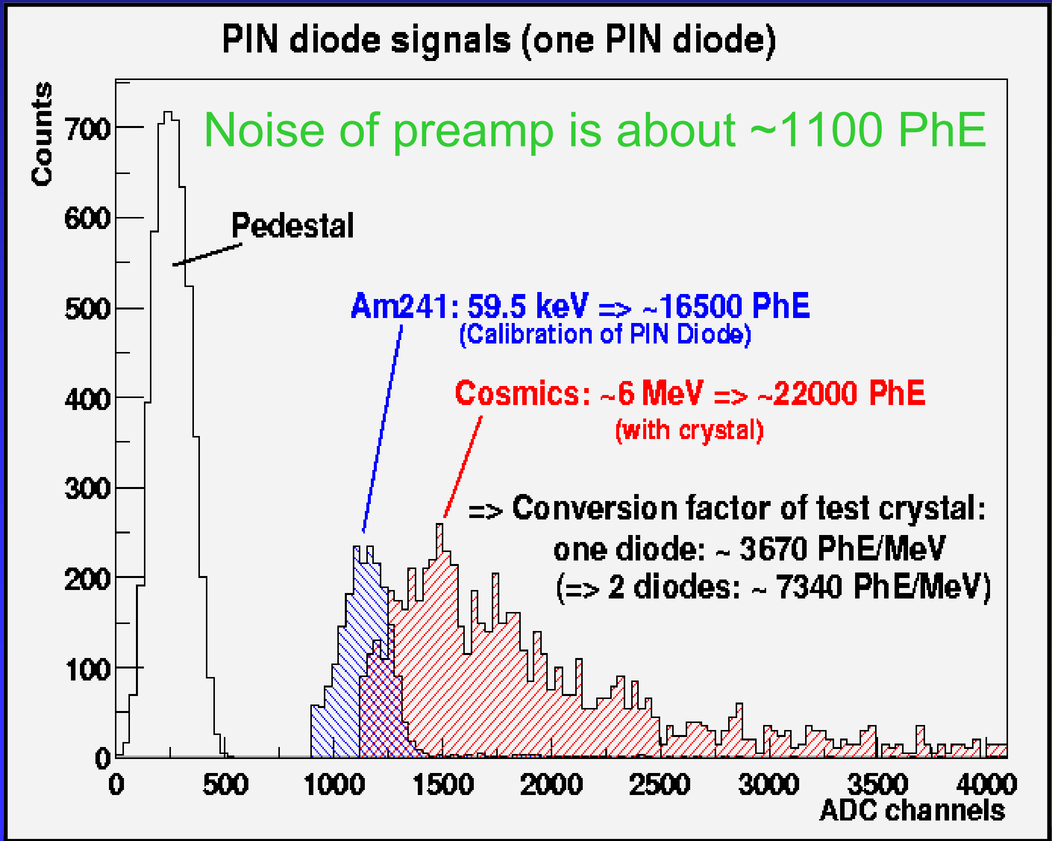
Comparison with BaBar crystals





Electronic Noise of Preamplifier

- Measurement of noise: 59.5 keV gamma from Am 241 source creates signal of ~16500 PhE in PIN diode
  → noise of preamp (pedestal sigma) is about ~ 1100 PhE



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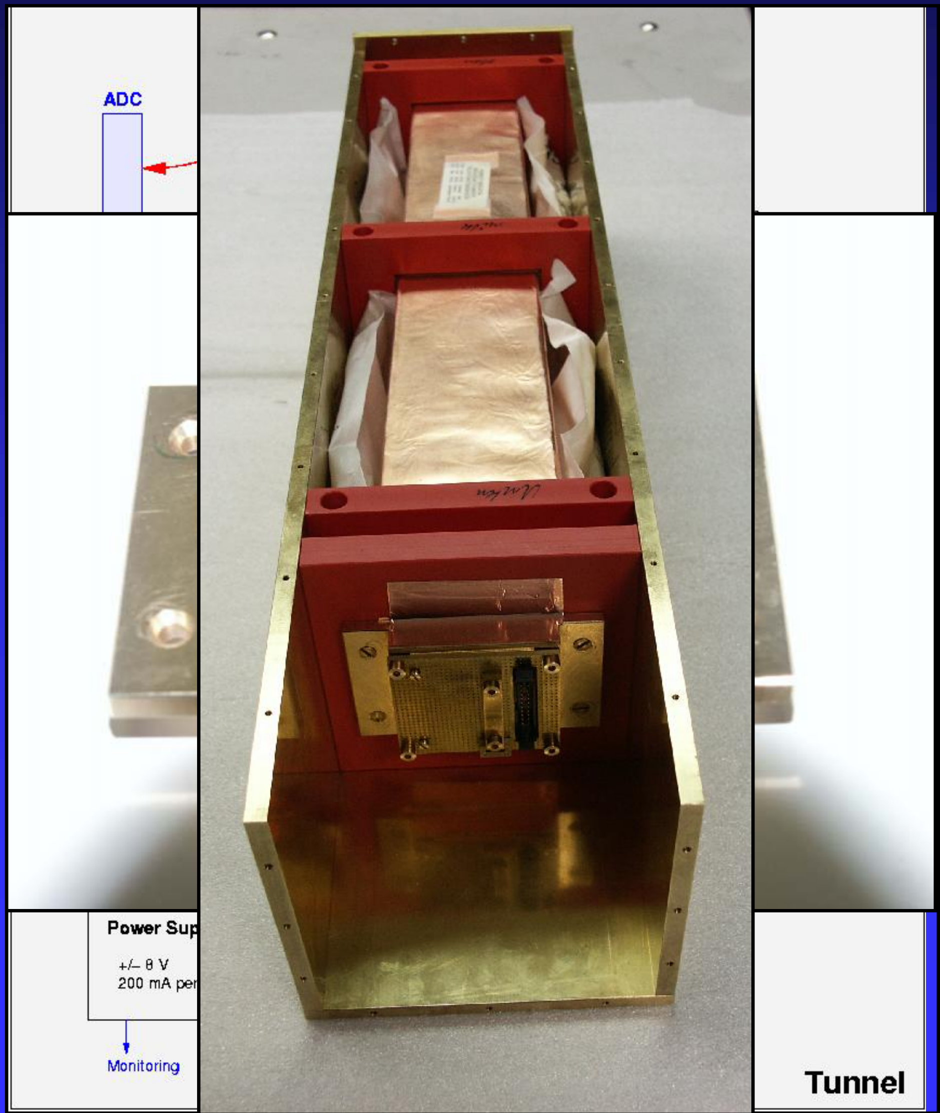
PIN Diode Layout Prototype



- PIN diode preamp has gain 1 and 32
- CAMAC ADC
  - 11 Bit,
  - 5 microsec gate
- Dynamic range
  -> effective 15 bits
  -> ~ 30 000

- PIN diodes from University Dresden
- Preamps from SLAC (BaBar)
- Shaper electronics from University Massachusetts

E - 166

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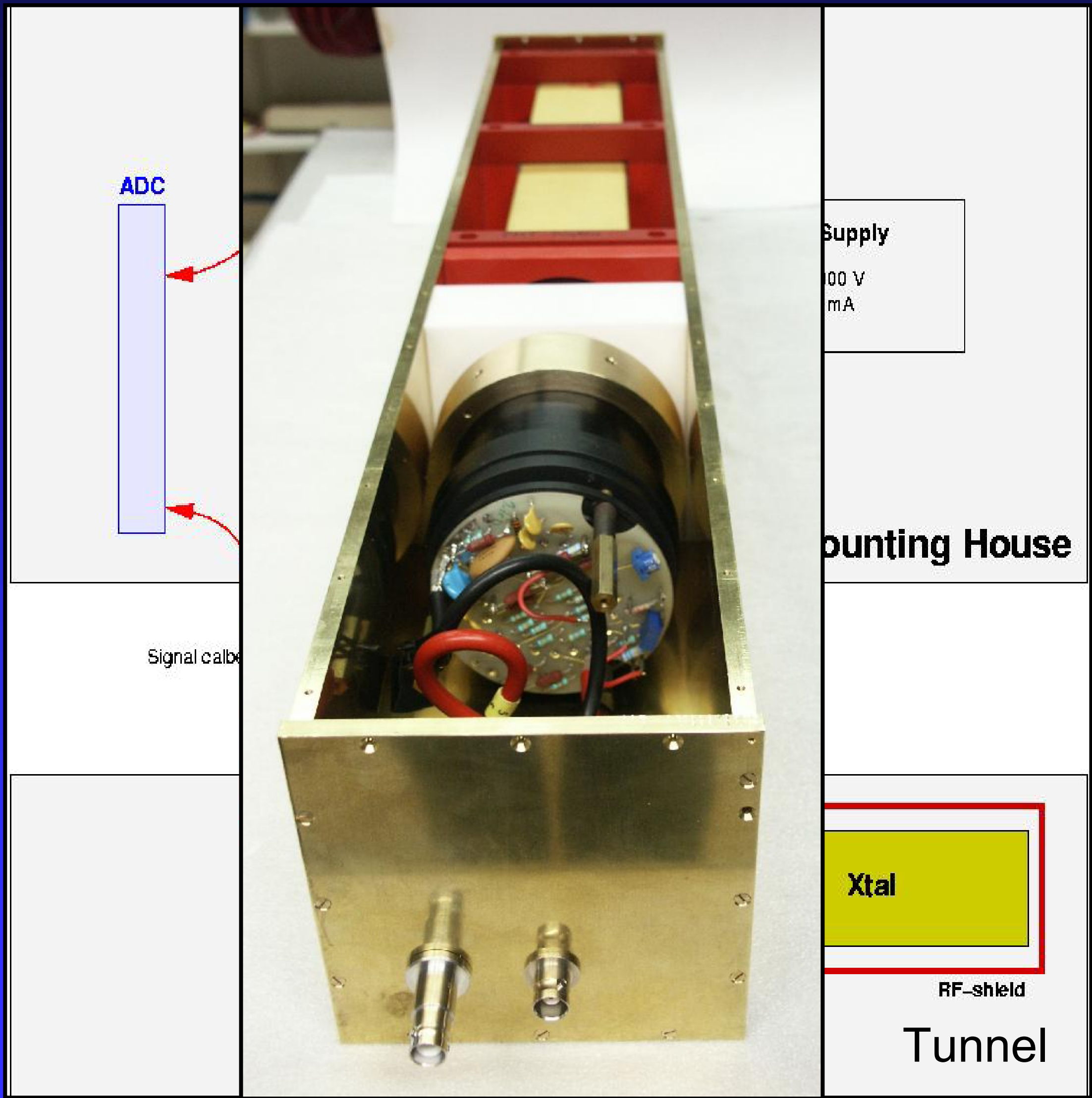
PMT Layout



Boxes made by M.Jablonski (HU Berlin)

ADC's

source calibration x32

typ. energy 1 MeV
min. res. 100 keV/bin

data taking x1

typ. energy 1 GeV
max. energy 5 GeV

5 GeV / 100 keV / 32

→ dynamic range ≈ 2000

→ 11-bit ADC

SLAC: LeCroy 2249 W:

- CAMAC Q-ADC
- 11-bit

Zeuthen: CAEN V265

- VME Q-ADC
- 12-bit resolution
- 15 bit dynamic range

CsI Calorimeter: Crystals

Expected signal:

~1000 Re-converted photons
up to 10 MeV
Total energy: max 5 GeV

- CsI crystals: ~ 6 cm X 6 cm X 30 cm from DESY

- Radiation length: 1.86 cm
- Molière radius: 3.8 cm
- About 80.000 phot / MeV

50 GeV e⁻ E - 166 10 MeV γ e⁺ e⁻
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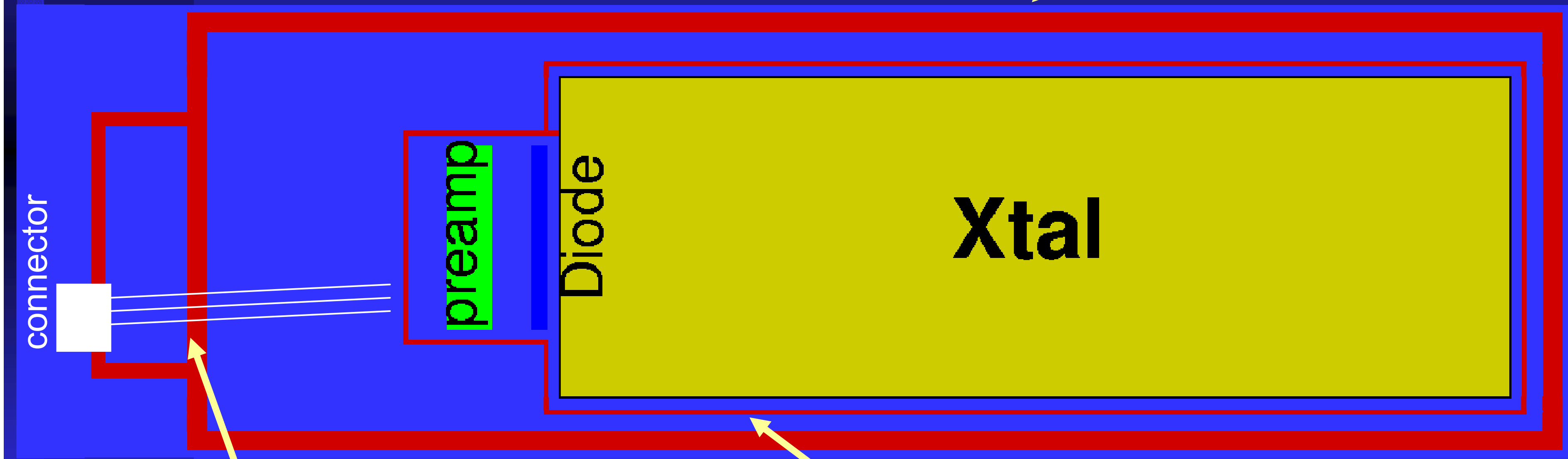
Shields and Grounding

Outer RF-shield:
brass housing



Feed-through
RF-filter on power

Inner RF-shield:
Cu-wrapping + preamp-housing