Low Energy Polarimetry

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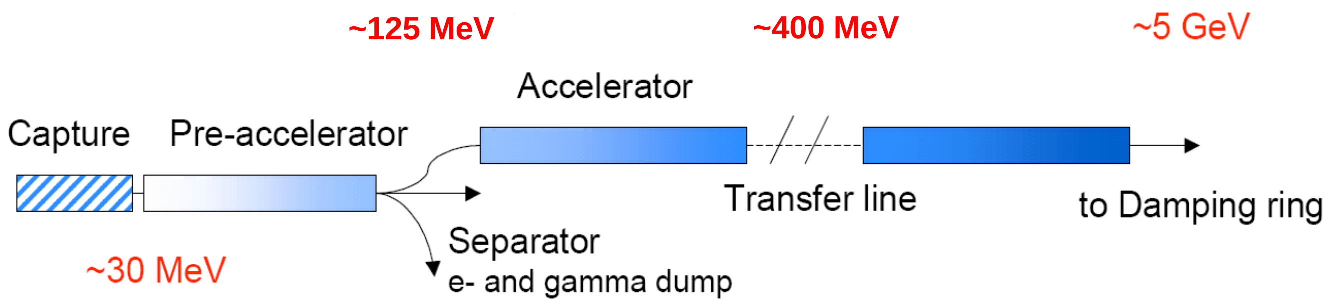
for the
LEPOL
Collaboration

Low Energy Polarimeter

- Optimization of the positron beam polarization/intensity at the source, commissioning
- Control of polarization transport

Criteria: (in spite of rather poor beam quality at the source)

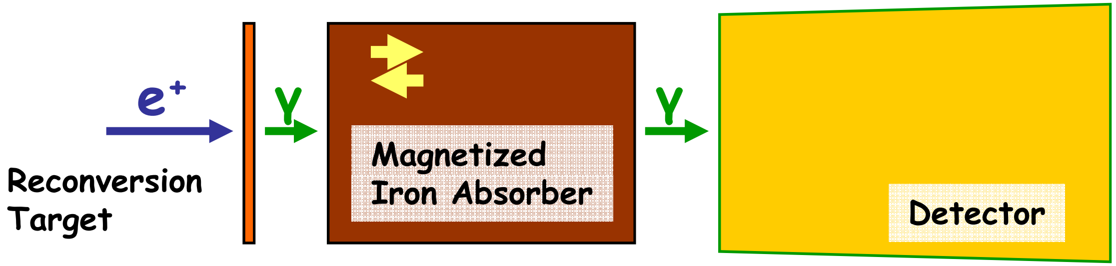
- minimum influence on the positron beam
- Reasonable sensitivity to longitudinal Polarization
- Reliability
- Accuracy - few percent



Available Processes

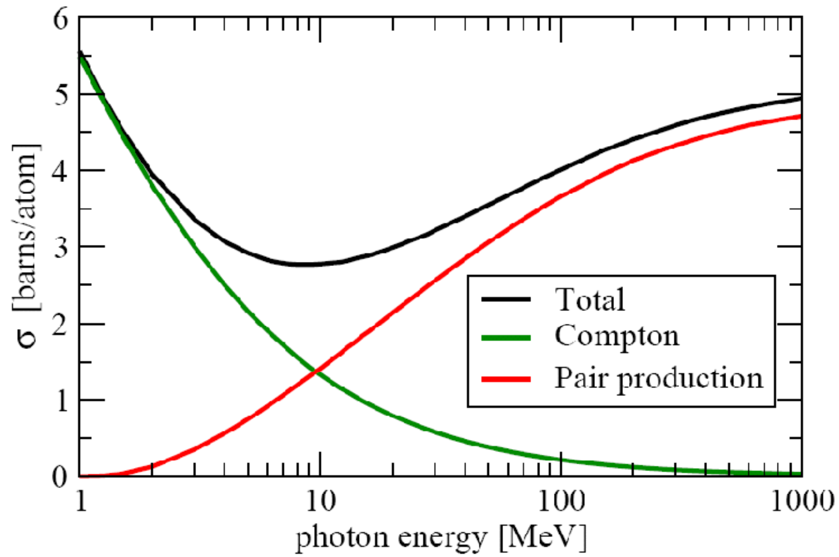
- **Laser Compton Scattering** (ex.: SLC, HERA)
  - High intensity Laser on low emittance beam
  - Only after Damping Rings (Intensity, Energy)
  - High precision
- **Bhabha/Møller** (ex: SLAC, JLAB, VEPP-3)
  - Thin magnetized Target
  - Suitable for desired energy range
- **Compton Transmission** (ex.: E166, KEK-ATF Pol. Experiment)
  - Beam absorbed in thick target
  - Very low energy ($<$ 100 MeV)
- **Mott**
  - Transverse polarized positrons, high background
- **Synchrotron radiation** (ex.: VEPP-4 storage ring)
  - Transverse polarization
  - Near/in damping ring ?
  - Low signal – Asymmetry $< 10^{-3}$

Compton Transmission Method



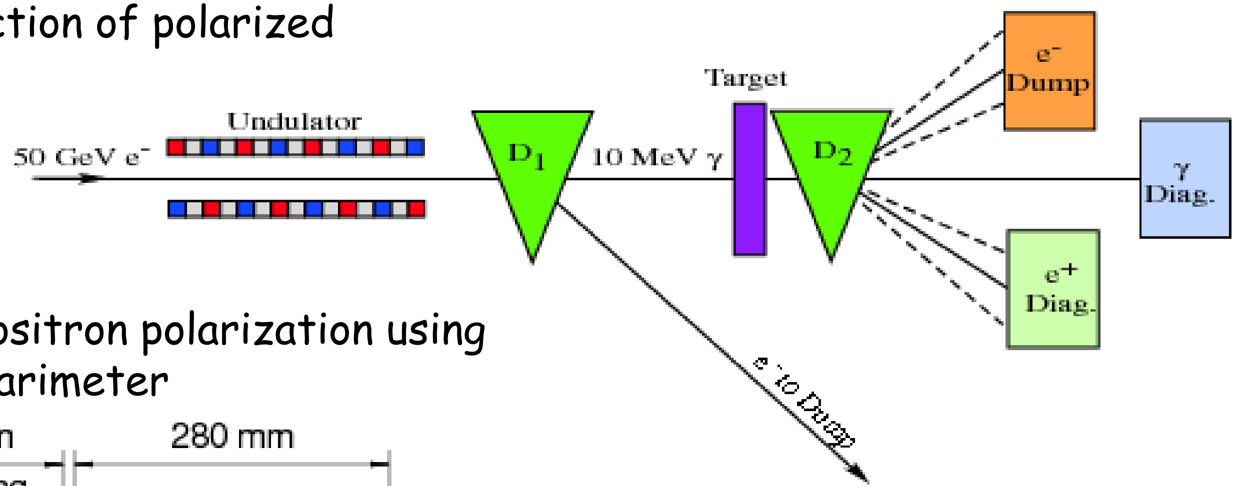
- Destructive !
- Polarized positrons reconverted into polarized gammas in rel. thick target (1 to 3 X_0)
- Polarization dependent transmission due to Compton scattering in magnetized Iron
- Working point: E_{e^+} < 100 MeV ideal after capture section O(~30 MeV)
- Compact O(1m)

- The E166 experiment used this method we participated from the beginning during the experimental phase and did a major part of the data analysis
- Gained much experience !

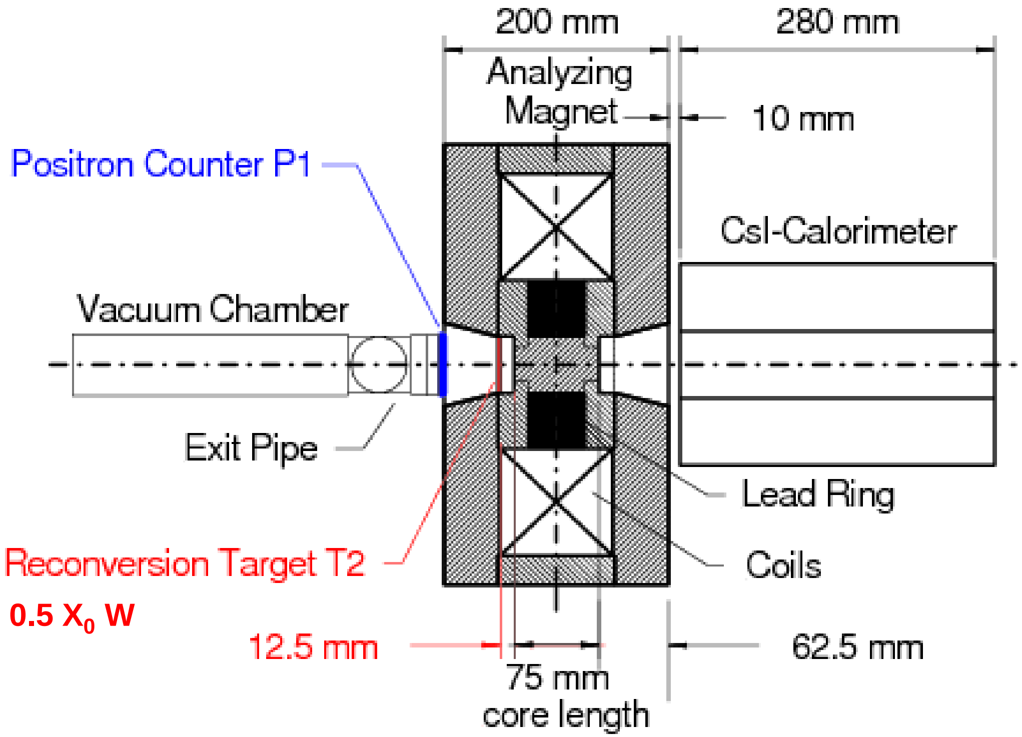


E166

E166 – proof of principle experiment to demonstrate the undulator based Production of polarized positrons for the ILC



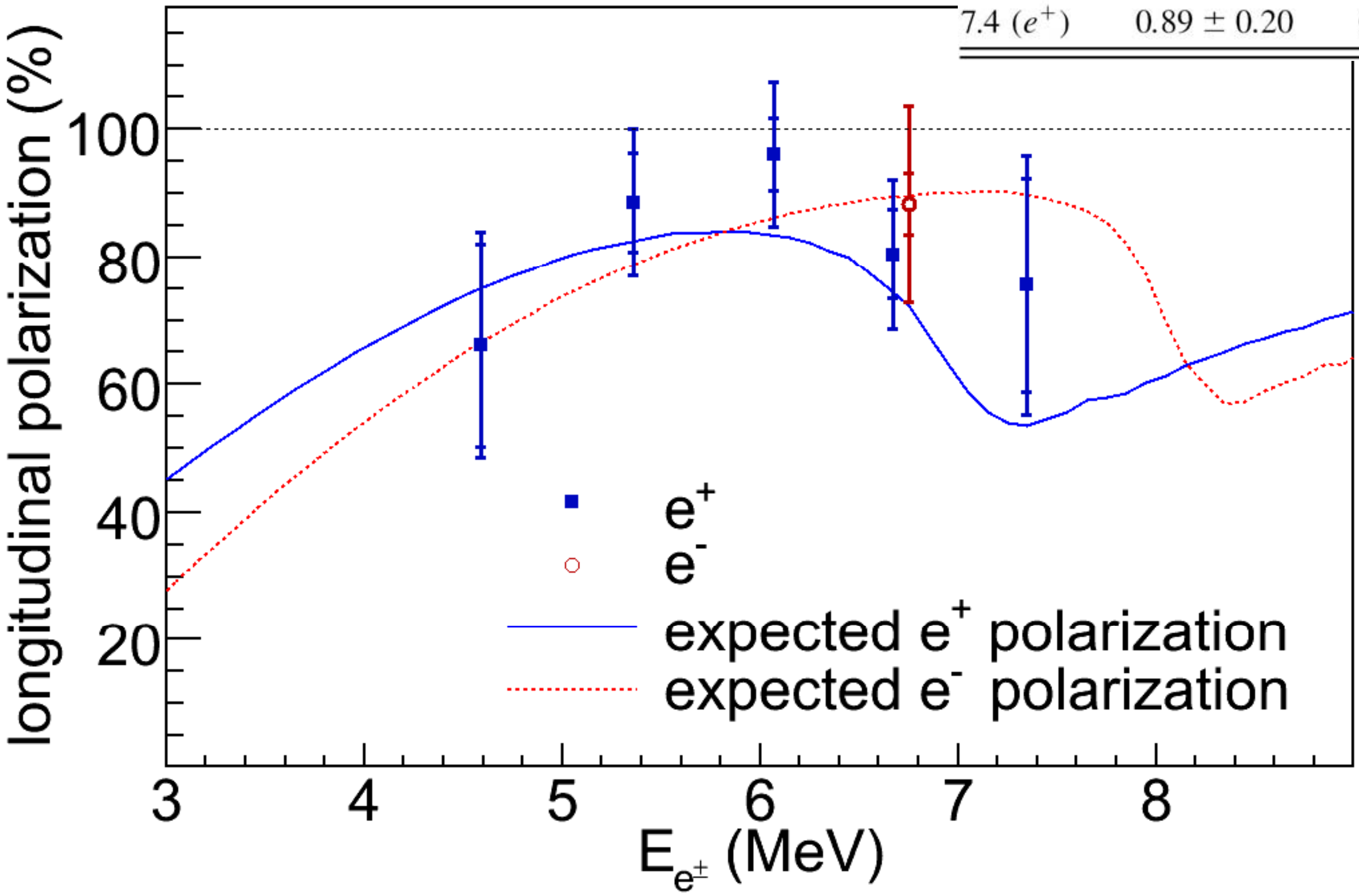
succesfully measured the positron polarization using a Compton transmission polarimeter



E166 results

$E_{e^\pm}$	$\delta \pm \sigma_\delta$(stat)	A	$P \pm \sigma_P$(stat) $\pm \sigma_P$(syst)
4.6 (e^+)	0.69 ± 0.17	0.150	66 ± 16 ± 8
5.4 (e^+)	0.96 ± 0.08	0.156	89 ± 8 ± 9
6.1 (e^+)	1.08 ± 0.06	0.162	96 ± 6 ± 10
6.7 (e^+)	0.92 ± 0.08	0.165	80 ± 7 ± 9
6.7 (e^-)	0.94 ± 0.05	0.153	88 ± 5 ± 15
7.4 (e^+)	0.89 ± 0.20	0.169	76 ± 17 ± 12

Phys. Rev. Lett. **100**, 210801 (2008)



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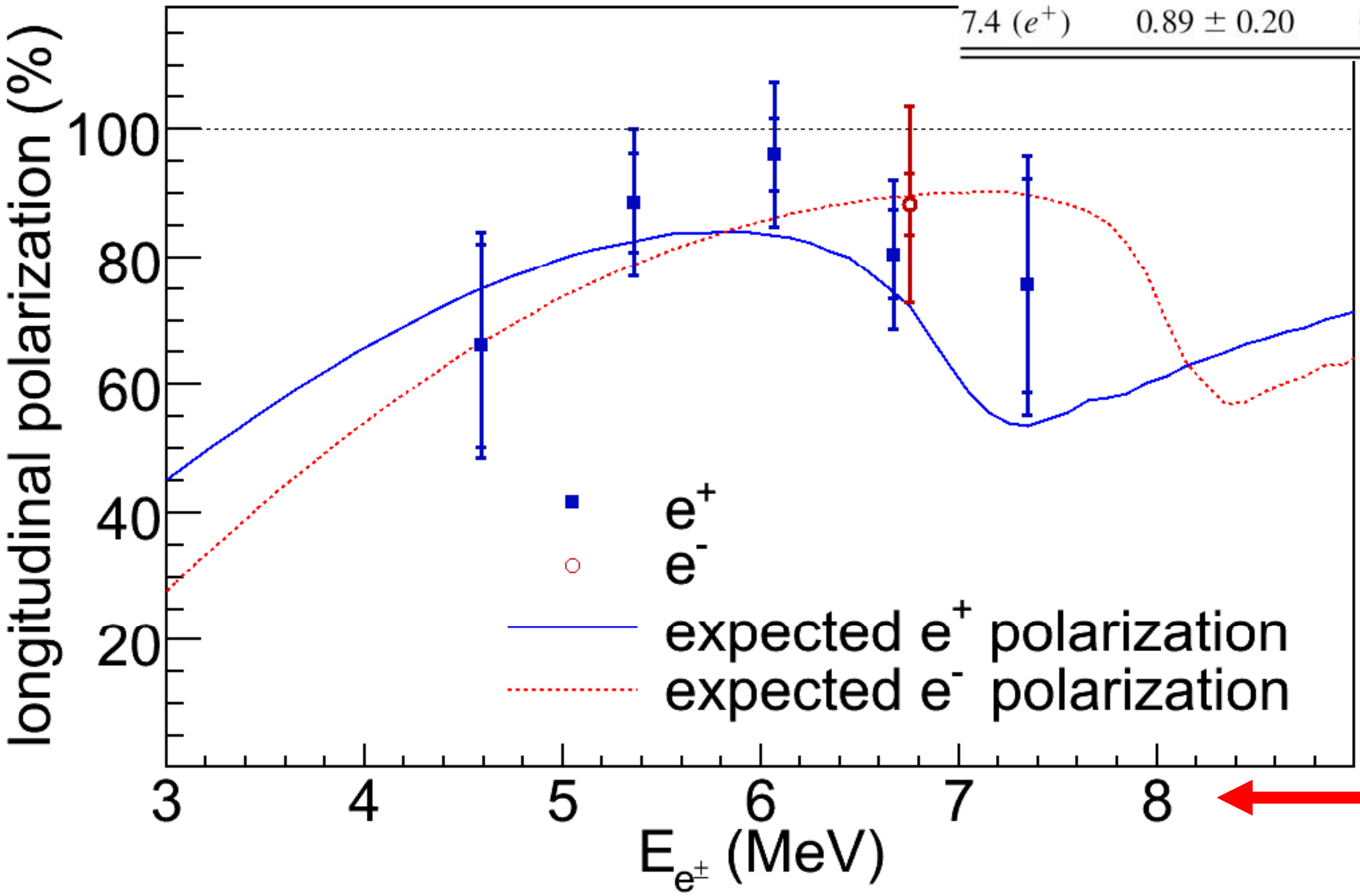


not possible at These energies at PPS

Compton Transmission Method at PPS

Simulation of application at PPS

- $1*10^6$ positrons on reconversion target (per polarization state)
- reconversion target directly in front of the polarized absorber
- reconversion target: Tungsten (P_{e^-} 7%)
- Absorber: Iron cylinder surrounded by a lead ring

$2\ X_0$ (7 mm)		
Beam energy	30 MeV	125 MeV
Absorber length [mm]	150	150
analyzing power	16.7	19.0
Measured asymmetry P_{e^+} 30% / 60 %	0.4% / 0.8%	0.5% / 1%

Energy deposition in the target:
$2X_0$ (30 MeV): 17.3 MeV/e^+
$2X_0$ (125 MeV): 33.2 MeV/e^+

Energy deposition in the absorber:
100 mm: ($1X_0$ T., 30 MeV): 9 MeV/e^+
100 mm: ($1X_0$ T., 125 MeV): 56.2 MeV/e^+

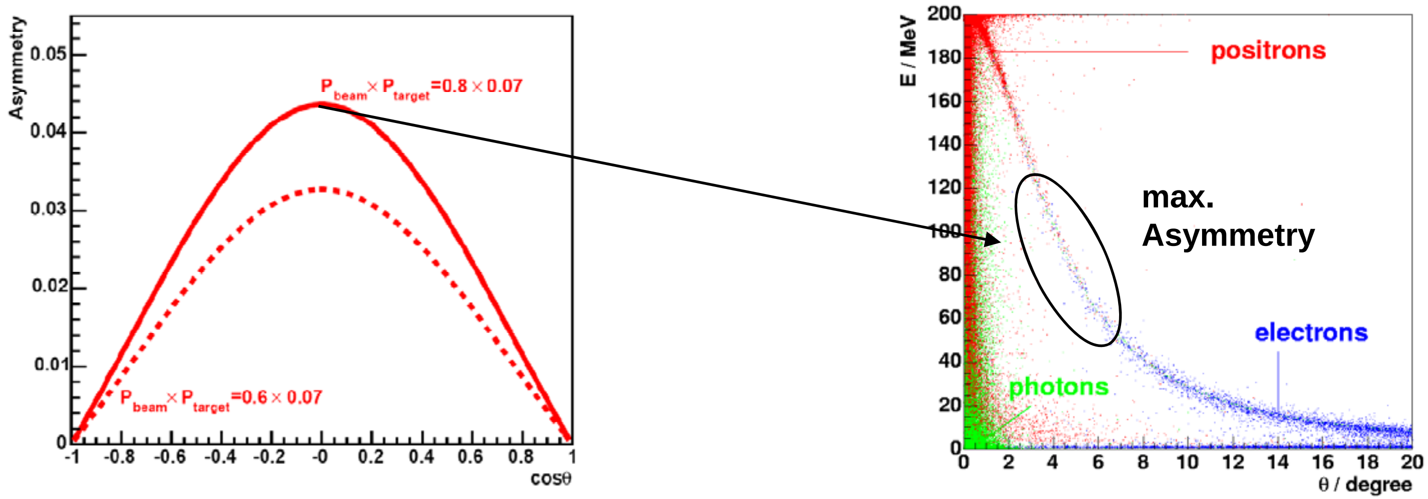
Only a fraction of the positron beam can be used for polarimetry
-> kicker and parallel polarimeter beam line needed

Bhabha-Polarimeter

- E_{beam}: after pre acceleration ~ 400 MeV
- diff. cross section:

$$\frac{d\sigma}{d\Omega} = r_0^2 \frac{(1+\cos\theta)^2}{16\gamma^2 \sin^4\theta} \left\{ \left(9 + 6\cos^2\theta + \cos^4\theta\right) - P_{e^+} P_{e^-} \left(7 - 6\cos^2\theta - \cos^4\theta\right) \right\}$$

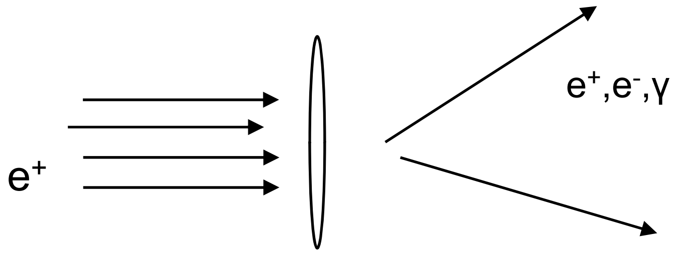
- theor. max. asymmetry bei 90°(CMS) ~ 7/9 ≈ 78 %
- example: P_{e+}= 80%, P_{e-}= 7% A_{max} ~ 4.4 %



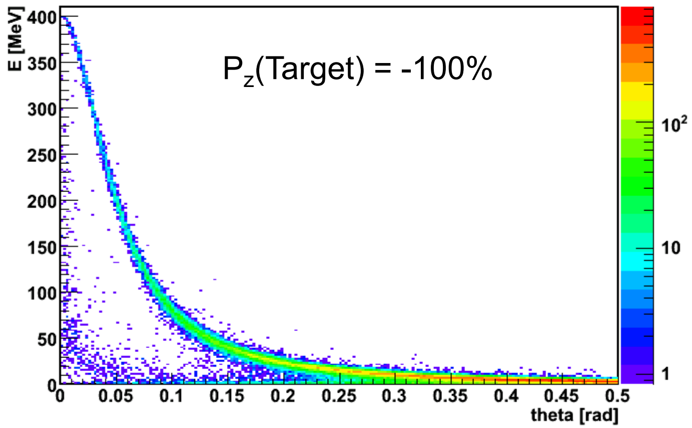
For the simulation studies polarization extensions for GEANT4 necessary (available since release 4.8.2)

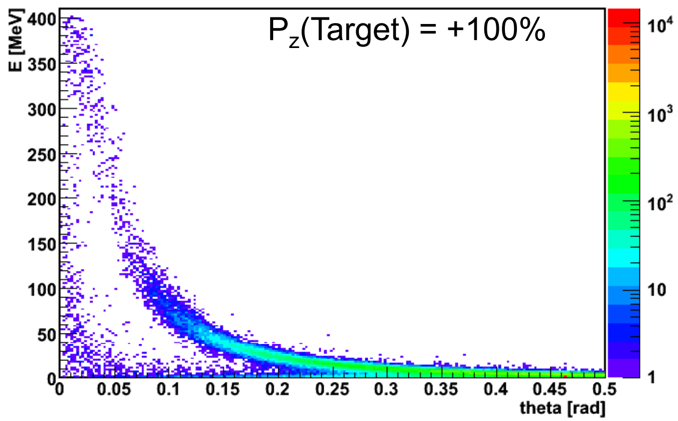
Principles

- 30 µm magnetized Fe-Foil (-> polarized)
- E_{beam} : 400 MeV (10 % spread)
- Ang. Spread : 0.5°

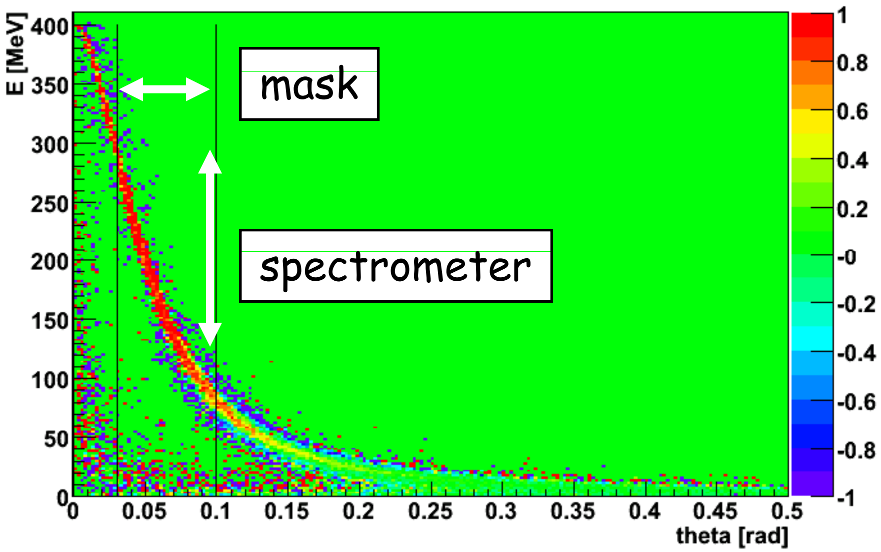


e^- distribution





asymmetry (analyzing power)

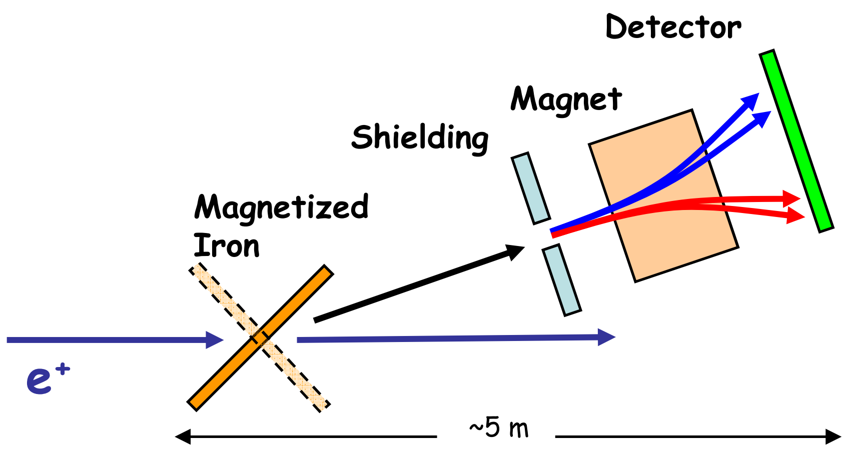


ang. range of interest: 0.03 – 0.1 rad
-> Asymmetry in the ang. range: A_{e-} ~50 %
(A_{e+} ~5%, A_{γ} ~-15%)

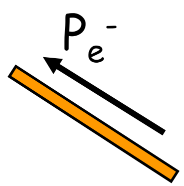
Bhabha-Polarimeter

- Mask/shielding: selection of angular range with max. asymmetry
- Spectrometer: charge, energy
- Polarization measurements

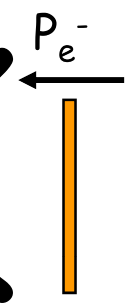
  -> Asymmetry measurements of opposite polarization states of the target (and/or the incident beam)



Target: thin magnetized Iron foil (~ 30 μm)

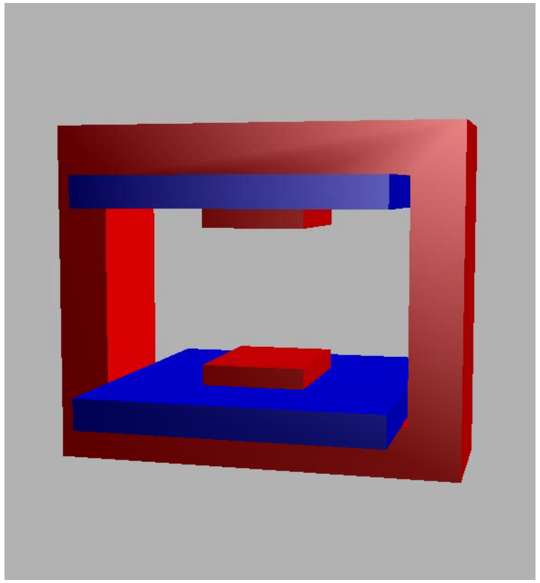


Magetization with Helmholtz coils (O(0.01T))



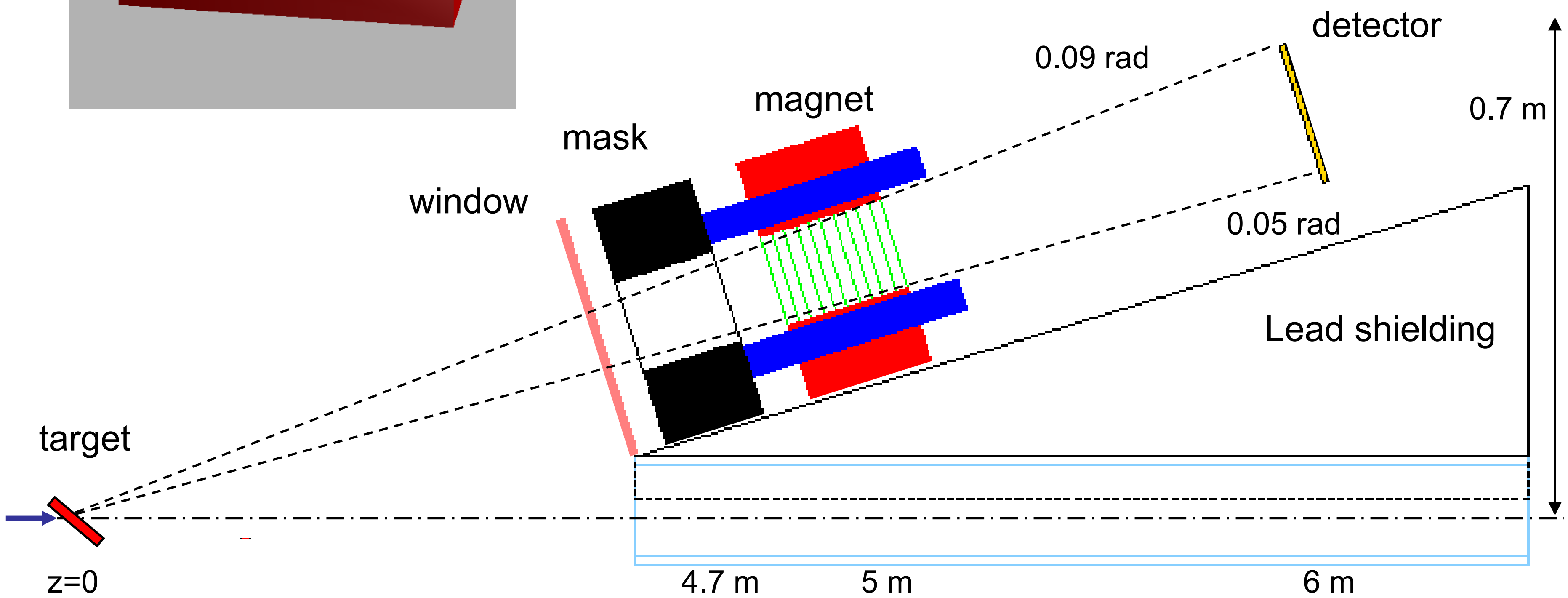
(Magnetized in a high B-field (O(4T)) (But no option for LEPOL))

Geometry

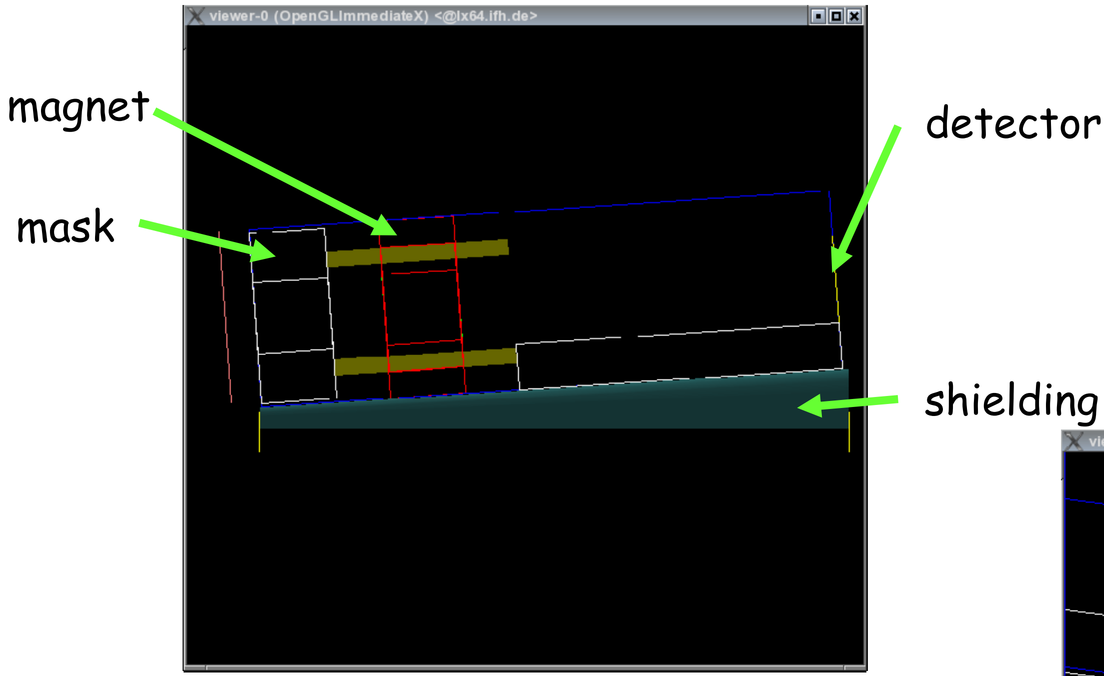


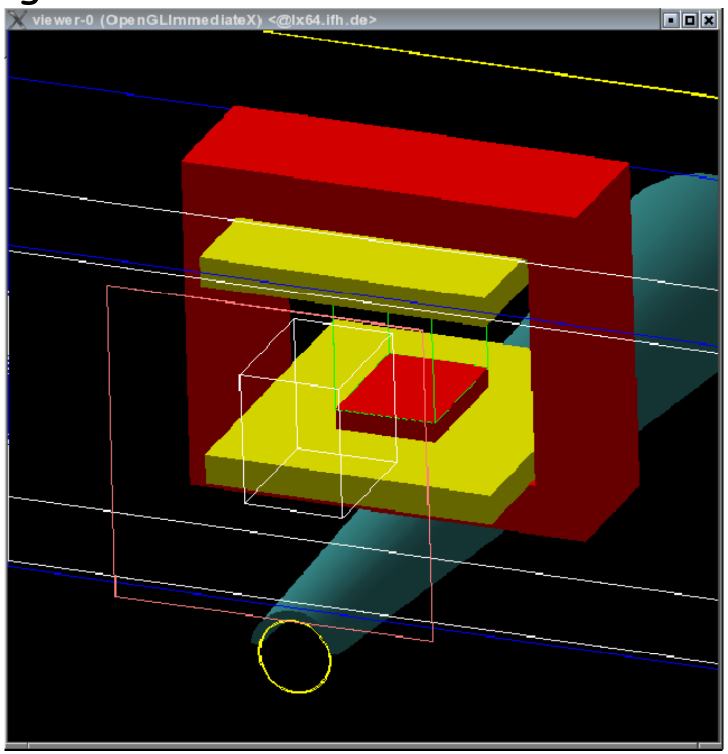
Magnet:
- BdL: 0.1 Tm
- gap: 20 cm
- length in z 20 cm
- yoke thickn.: 7.5 cm
- coil: ~ 80 000 Amp turns

(-> ~2·100 turns w. 400 A, curr. density ~6.3/mm², water cooling assumed…)



Geometry in G4





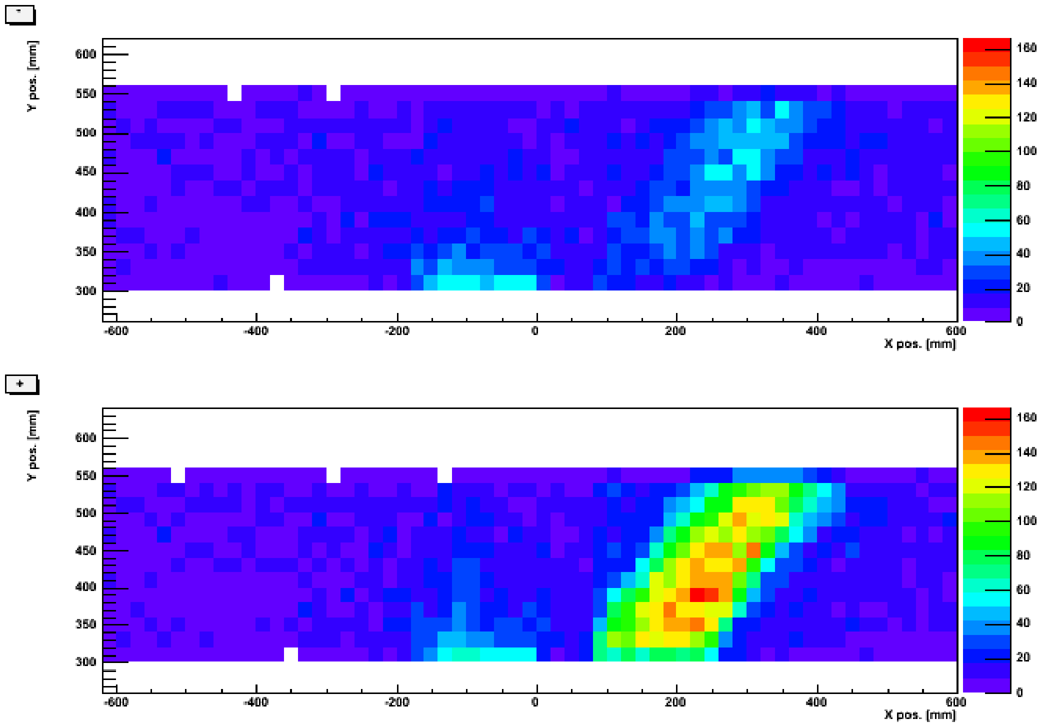
Bhabha results

Beam parameters: (from source simulation!)

E [MeV]	400 (± 3.5 %)
σ_x ,σ_y [mm]	5.78, 5.76
ε_x ,ε_y [mm mrad]	5.67,5.65
P(beam)	-100%

- Target: 30 μm Fe
  P ±100%
- Spectrometer: BdL 0.1 Tm
- Detector charge sensitive
  2x2 cm pads
- 2 x 10^{10} positrons on target
  (per polarization state)

Example:
distribution of scattered Bhabha electrons for opposite polarization states of the target:



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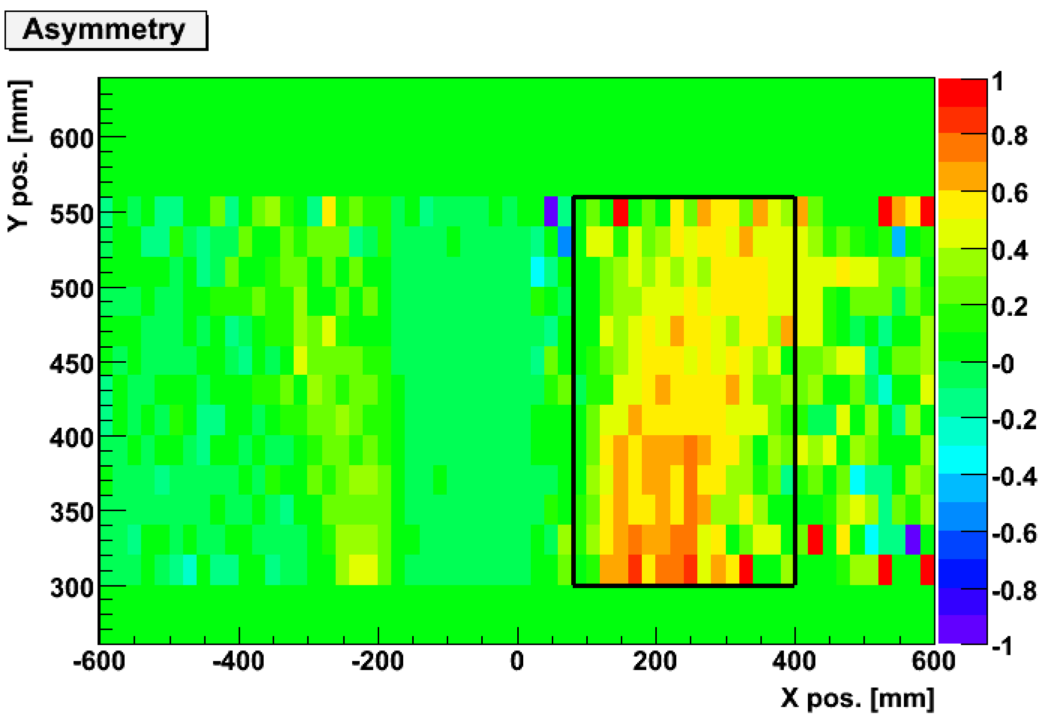
Example:
Asymmetry of the **e^-+e^+** distribution for opposite polarization states of the target:



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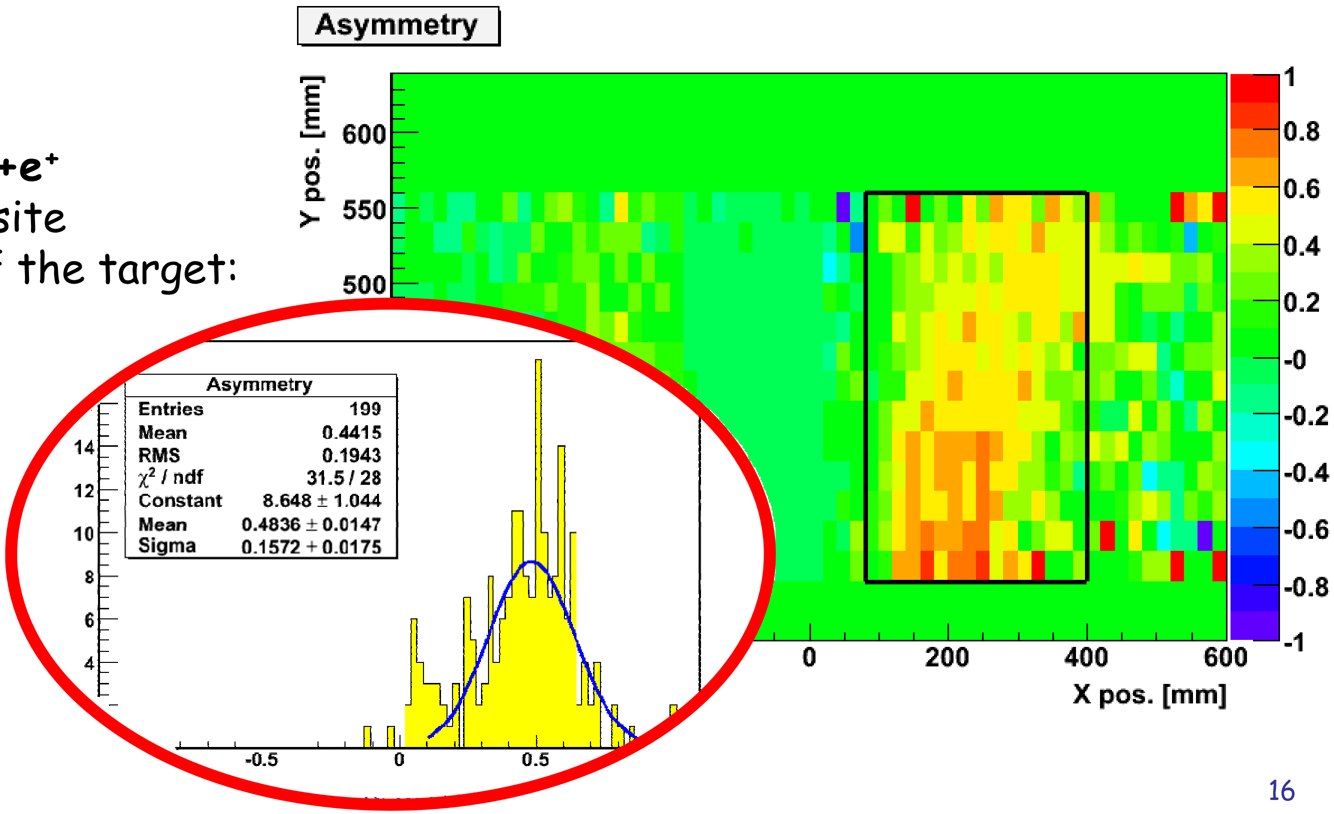
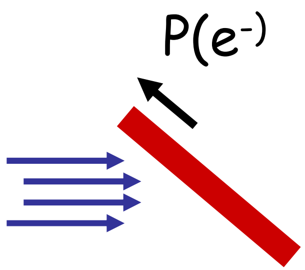


Bhabha polarimeter –Analyzing power

Target inkl. w.r. to the beam, $P(e^-)$ in target direction:



E_{cut} [MeV]	Analyzing Power [%]	exp. Asymmetry [%]	
		P_{beam}30%	P_{beam}60%
0	26(1.4)	0.39	0.77
10	30(1.2)	0.45	0.89
20	32(1.2)	0.48	0.95
30	35(1)	0.52	1.04

(Knowledge of eff. target polarization !)

eff. long. foil polarization: 4.95%

Measurimg time for 5% acuracy – O(few min)
Energy deposition in the target: 29.2 keV / e^+ (30 µm)
(beam energy: 400 MeV) 1.25 MeV / e^+ (1 mm)
(G4)

Target heating → O(20%) decrease of polarization

Summary

- Studied possibility of Compton Transmission Polarimeter and Bhabha Polarimeter as LEPOL at the positron source
- Compton transmission polarimeter
  - Polarisation measurements succesfully demonstrated with the E166 transmission polarimeter
  - Robust, compact
  - Energy low, only a fraction of the beam must be used
- Bhabha polarimeter
  - Less material in the beam, less energy deposition
  - Higher analyzing power even with inclined target (and polarization)
  - faster
- Lepol layout, energy, dimension depends on final positron source design
- Spin flip before the polarimeter would be advantagous to cancel systematic effects (as we learned from E166)

The LEPOL Collaboration:
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Pavel Starovoitov, Minsk
Gideon Alexander, TelAviv