Low Energy Positron Polarimetry for the ILC

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Outline

Low Energy Polarimeter - Purpose, Environment

Available Processes -> Polarimeter Options

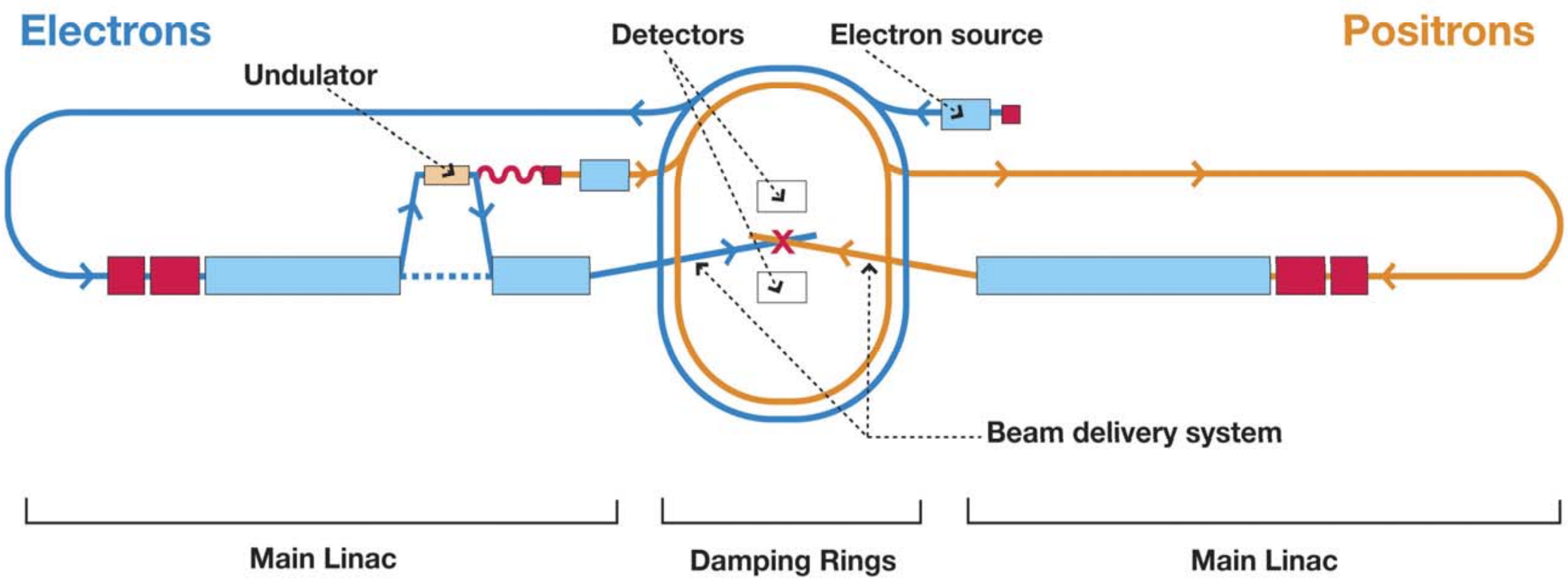
Bhabha Polarimeter
(Compton Transmission Polarimeter)

Summary

The International Linear Collider (ILC)

- Center of mass energy: 500 GeV
- Luminosity: $L = 2\cdot10^{34}\ cm^{-2}s^{-1}$
- Length: ~ 31 km
- Polarized beams: $P(e^-) > 80\%$, $P(e^+) \sim 30\%(60\%^\dagger)$ †upgrade
- Polarization of both beams is advantageous f. SM- and non-SM-physics (eff. luminosity, signal/background in SM processes …)

→ http://www.ippp.dur.ac.uk/~gudrid/source/

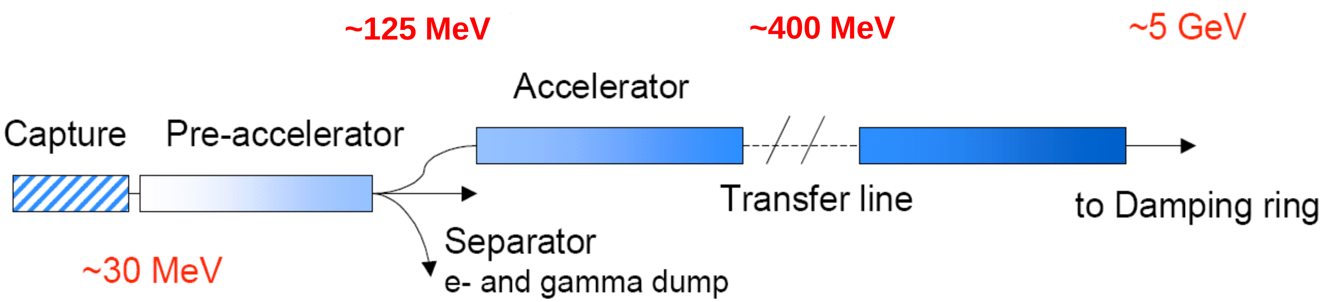


Low Energy Positron Polarimeter

- Measurement of positron polarization at the source
  - -> Optimization of the positron beam polarization/intensity
  - -> Control of polarization transport

- Beam Parameters

e^+ / bunch N_{e+}	$2 \cdot 10^{10}$
bunches / pulse	2820
Rep. Rate R	5 Hz
Energy E	30 – 5000 MeV
Energy spread $\Delta E/E$	10 %
Normalized emittance ε^*	~ 3.6 cm rad
Beam size $\sigma_{x,y}$	~ 1 cm



The challenges

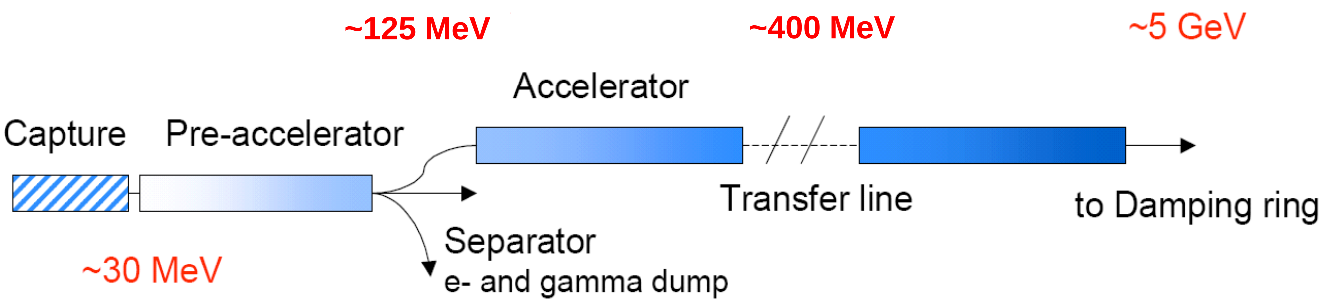
Polarization measurement -> measure Asymmetries !

Find for the low energy range a process with

- **sensitivity** to **longitudinal polarization** of positrons (electrons)
- good **signal/background** ratio
- significant **asymmetry**
- accuracy at percent level

Desired:

- non-destructive
- good reliability
- easy to handle
- fast (short measuring time)

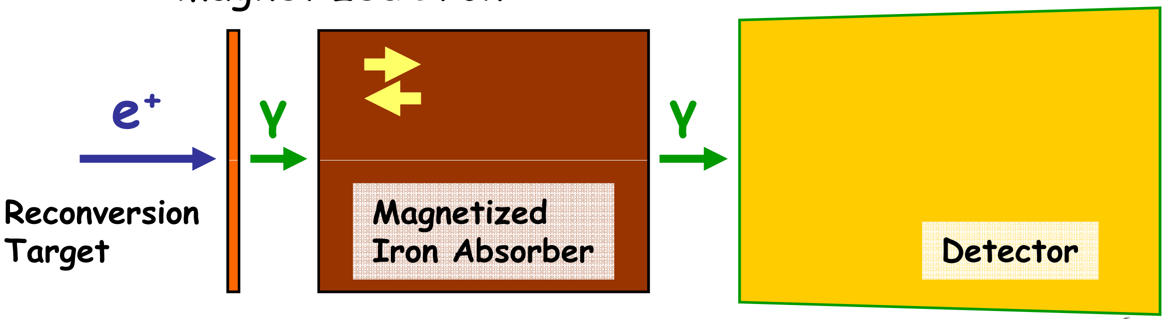


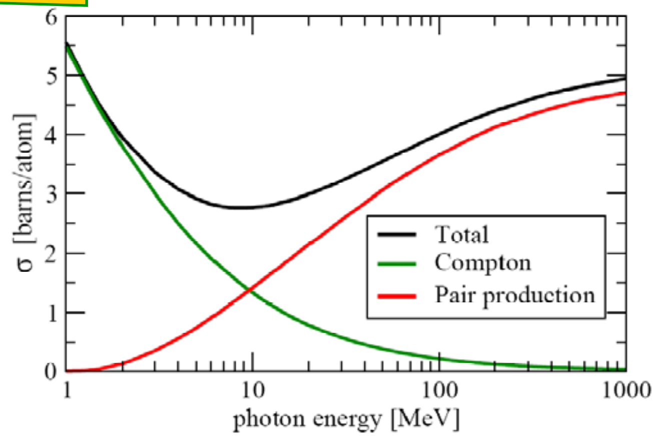
Available Processes

- **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
- Polarization dependent transmission due to Compton scattering in magnetized Iron





- Working point: E_{e^+} < 100 MeV
  ideal after capture section O(~30 MeV)

{ Dimensions O(1m)
  Experiences from E166 }

{ Thick Target (1 to 3 X_0)
  with high energy deposition O(~KW)
  Small asymmetries O(<1%) }

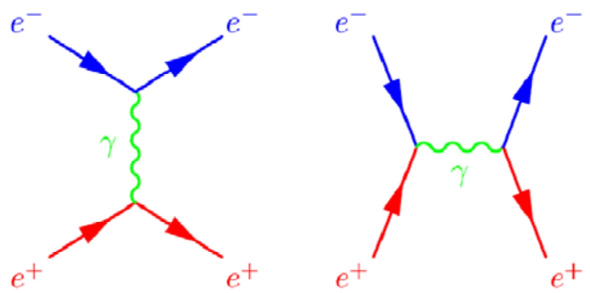
Example: E_{beam} 30 MeV, P_{e-}=7.92%, Target: $2X_0$ W, Absorber 15cm Fe
-> $A(P_{e+}=30\%) \sim 0.4\%$
$A(P_{e+}=60\%) \sim 0.8\%$

Bhabha Polarimetry

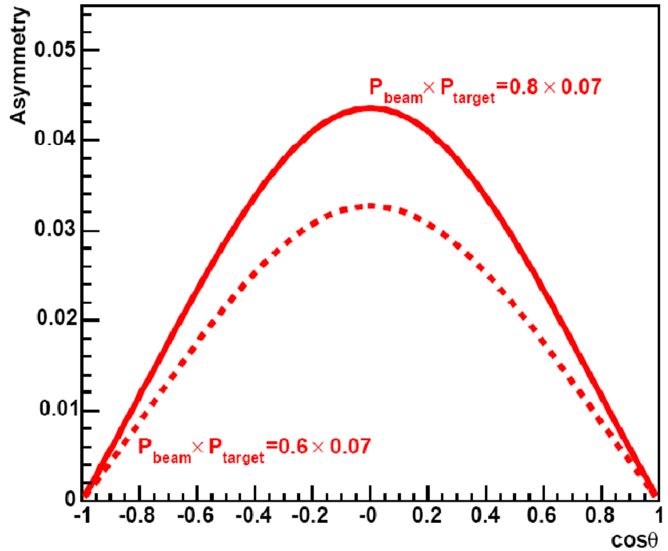
- As Møller Polarimeter already used (SLAC, VEPP-3)
- Non-destructive !
- Working point:
  - After pre-acceleration 125 MeV – 400 MeV
  - First design studies done for 200 MeV / 400 MeV
- Cross section:

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

- Theor. maximal asymmetry at 90°(CMS) ~ 7/9 ≈ 78 %

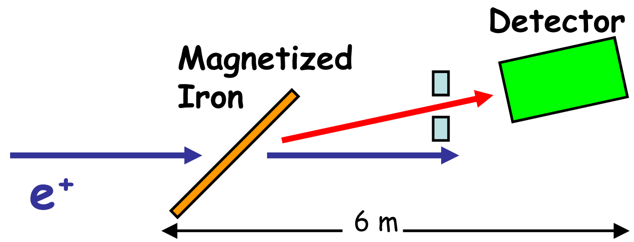


- Example: P_{e+}= 80%, P_{e-}= 7% A_{max} ~ 4.4

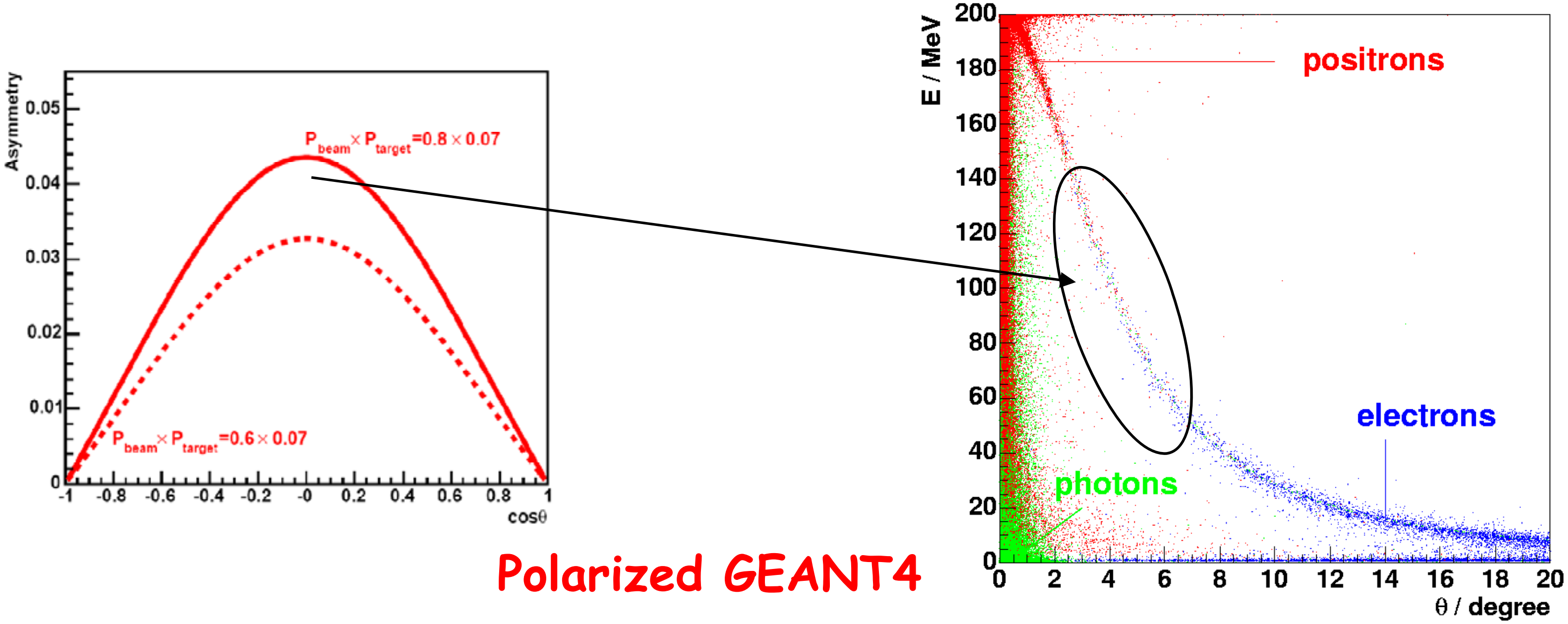


Bhabha Polarimeter

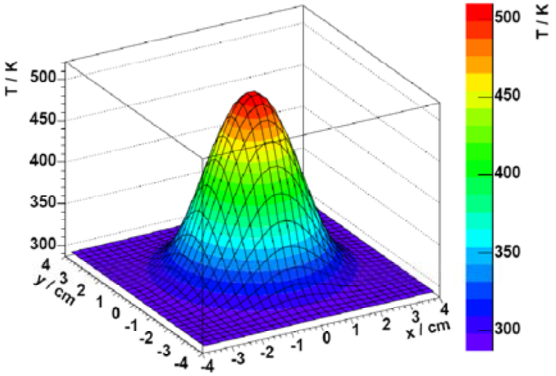
- Measures Asymmetry of scattered particles (e^+,e^-,(γ)) of two magnetization states of the target

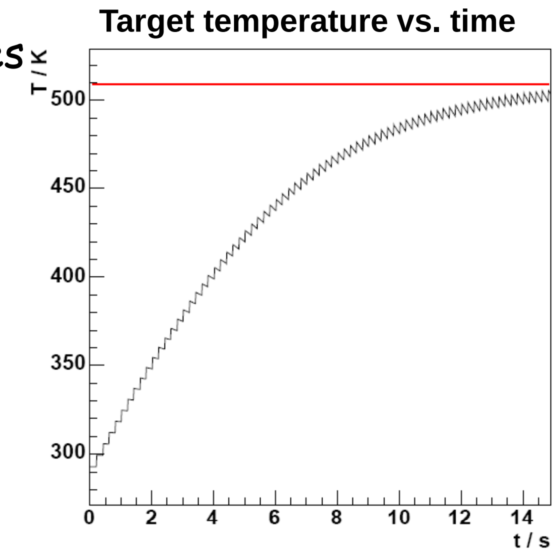


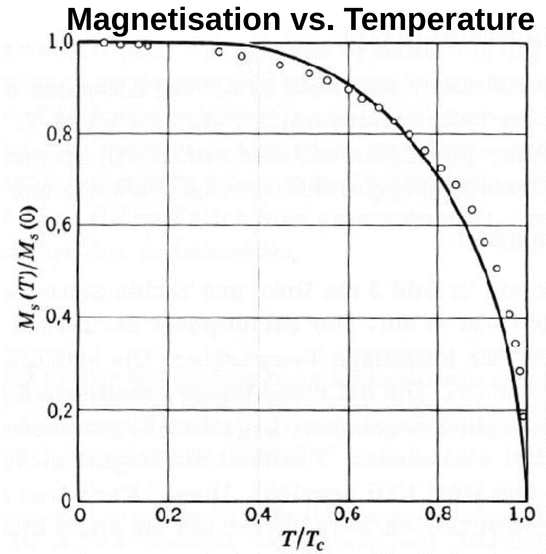
- Mask or shielding selects angular range with max. asymmetry
- Spectrometer -> particle separation, energy selection



- Magnetized thin IronTarget
- Heating of the target -> Magnetization decreases
  - Simulation for 30 μm
  - Cooling by radiation
  - T_C (Fe) = 1039 K; melting point 1808 K



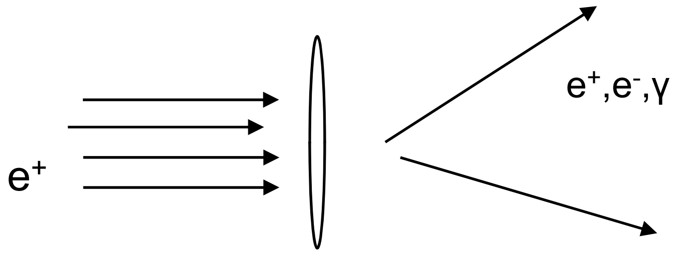




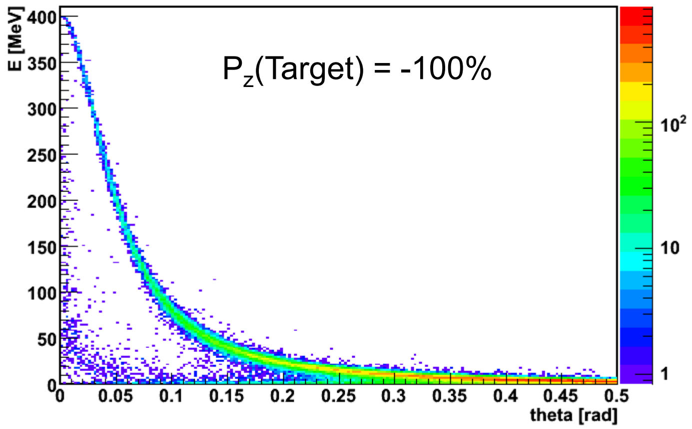
- Ongoing considerations on target layout
  - ΔT -> ΔM -> ΔP -> ΔA
  - Magnetic field (tilted or not)
  - Cooling in real
  - Monitoring of magnetization

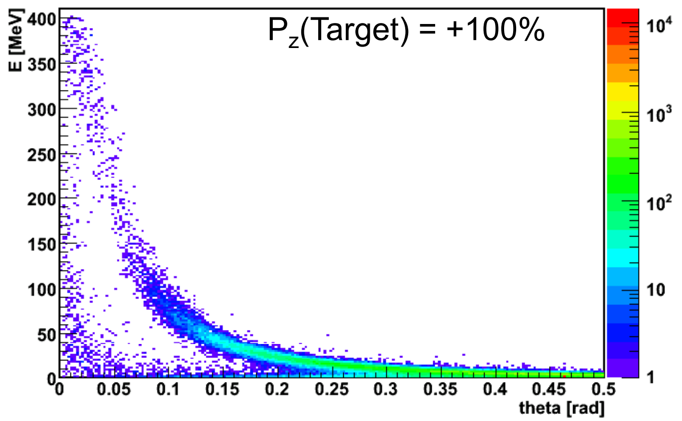
Example: e^- distribution and e^- asymmetry

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

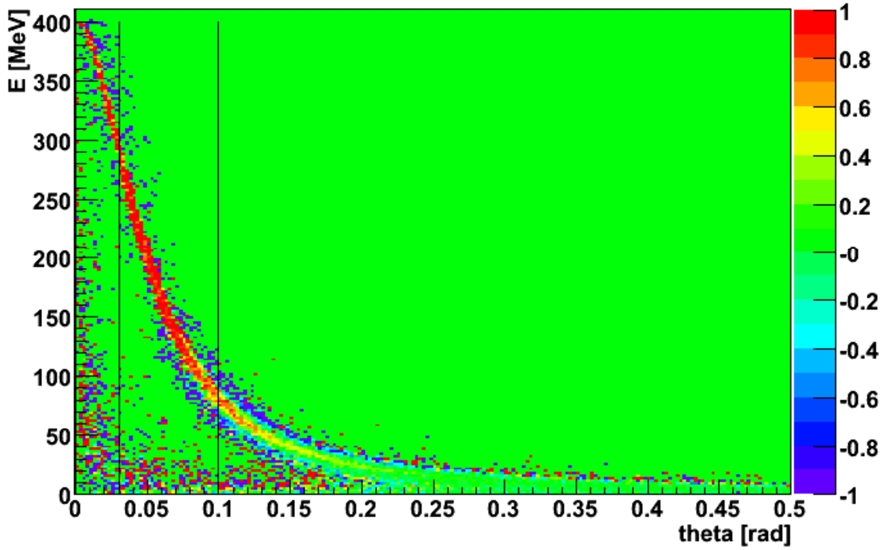


e^- distribution



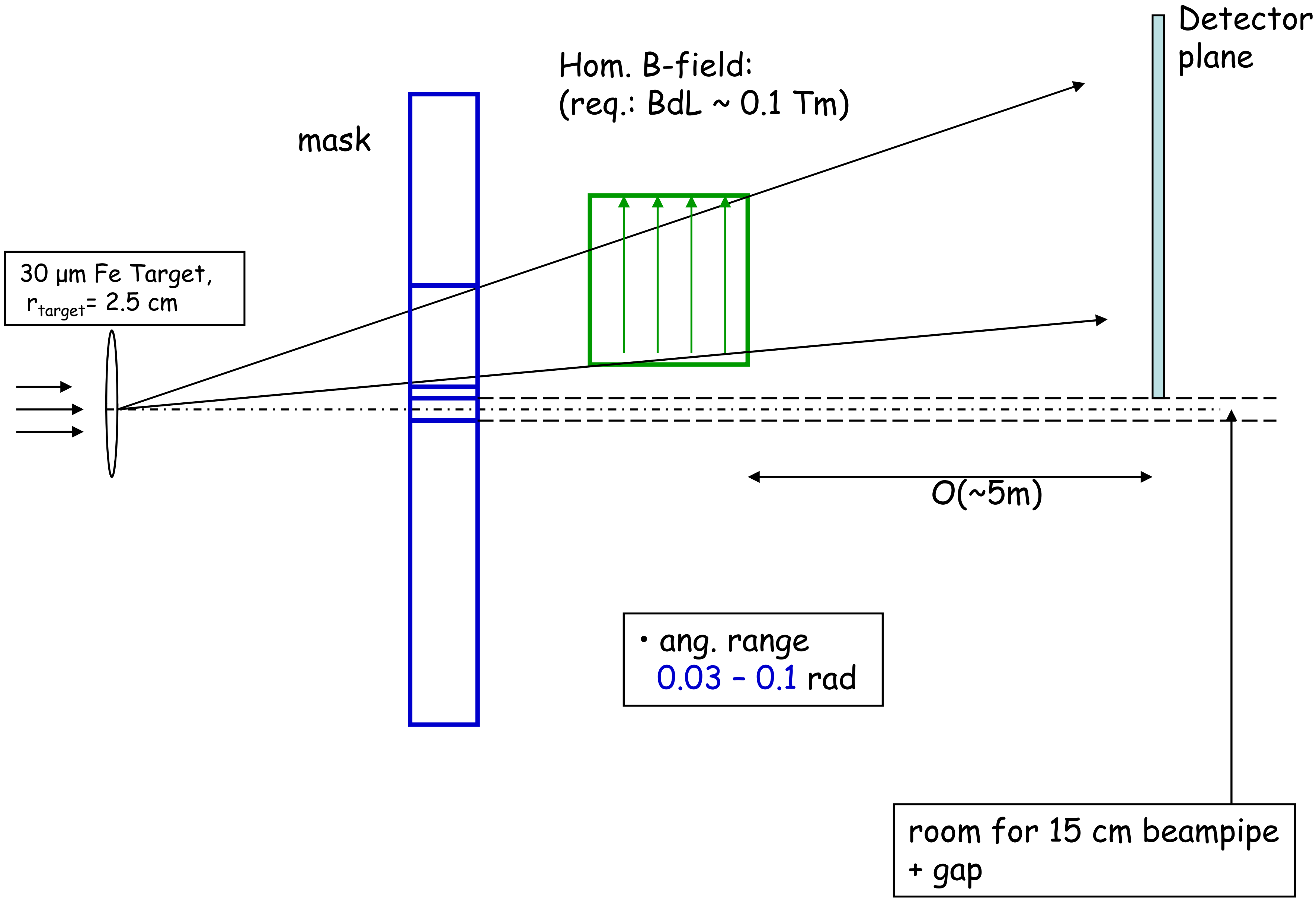


asymmetry (analyzing power)

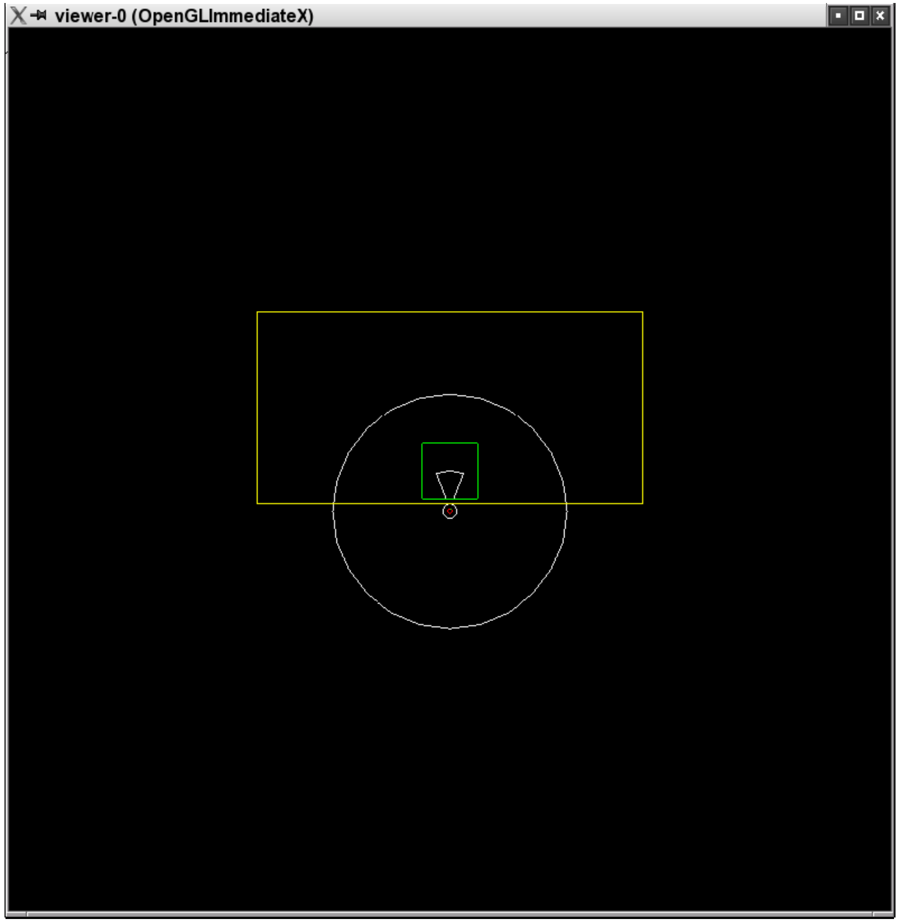


ang. range of interest: 0.03 – 0.1 rad
-> Asymmetry in the ang. range: A_{e-} ~50 %
(A_{e+} ~5%, A_γ ~-15%)

Geometry


Detector plane
Hom. B-field:
(req.: BdL ~ 0.1 Tm)
mask
30 μm Fe Target,
r_target= 2.5 cm
O(~5m)
• ang. range
0.03 – 0.1 rad
room for 15 cm beampipe
+ gap

Towards a Geometry for a LEPOL

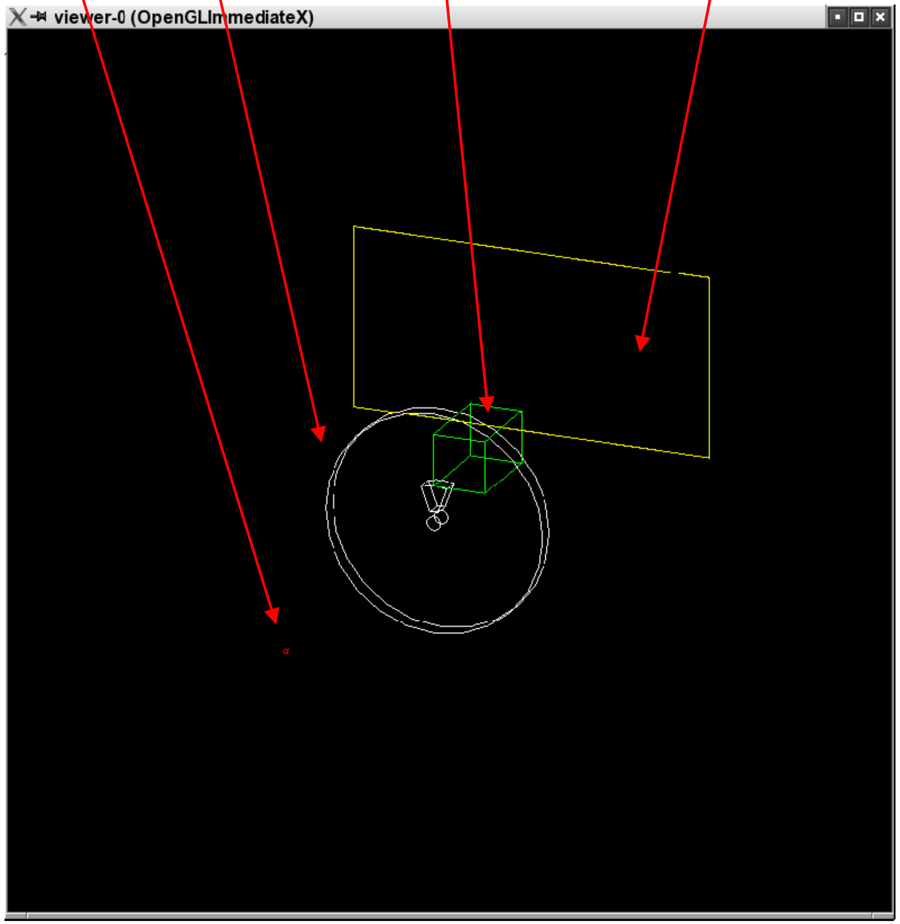


Mask

Detector plane

Mag. field

Target

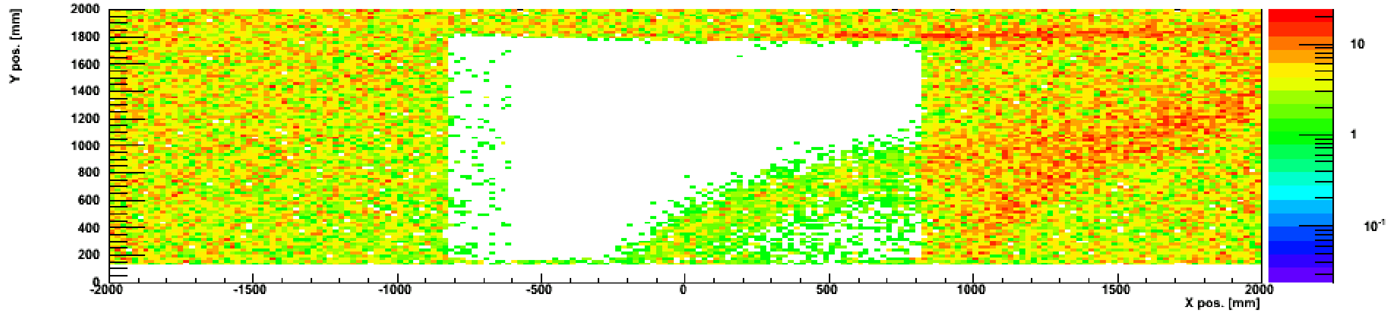


Questions to answer:

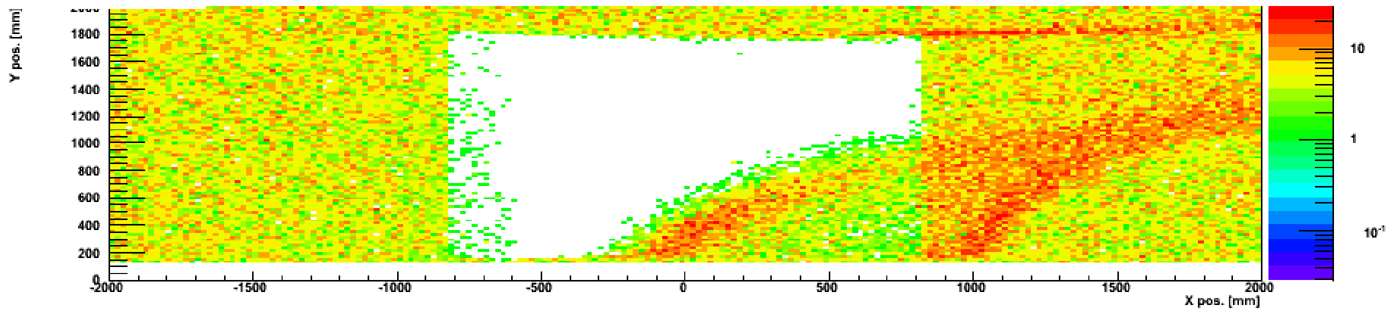
- detector area with best significance ?
- detector type ?
- mask dimensions, material ?
- magnet dimensions ?

Detector plane, int. B-field 0.1 Tm

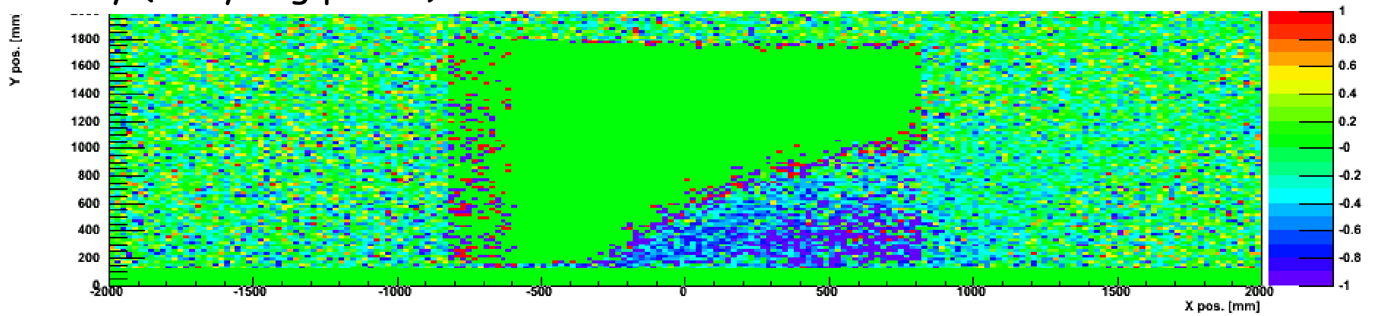
e⁻ distribution



e⁻ distribution



asymmetry (analyzing power)



(beam: $1*10^9$ e^+, E: 400 MeV (10 % spread), ang spread: 0.5º

Summary

- Present ongoing work:
  - Detailed design studies for **Bhabha polarimeter**:
    - Layout
    - Target
    - Implementation into beam line
  - Compton transmission performance studies
  - Simulation studies of Laser Compton Method (Minsk, TelAviv)

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