# Low Energy Polarimeter

R. Dollan, HU Berlin

# Summary (April meeting) = outline

- Simulation studies for Bhabha polarimeter at 400 MeV are promising …
- … with help of a powerful simulation tool (polarized G4) and the experience from E166

Ongoing simulation studies:

- Bhabha Polarimeter – preferred and only method
  - high statistics studies with ideal setup
  - analyzing power for real. polarization values ($P_{beam}$30(60)% / $P_{e-}$7%)
  - background studies (optimization of shielding, materials, geometry)
  - implementation of real beam properties

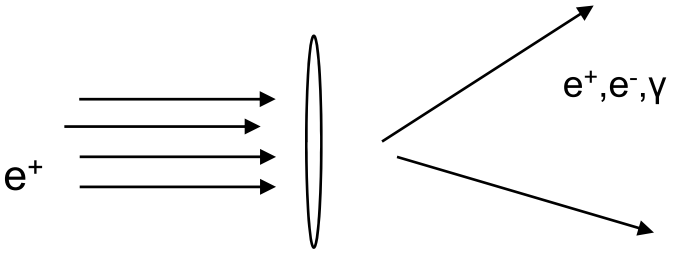
- Compton Transmission Polarimeter
  - high statistics for 35 MeV beam energy and real beam properties

# Bhabha polarimeter - principles

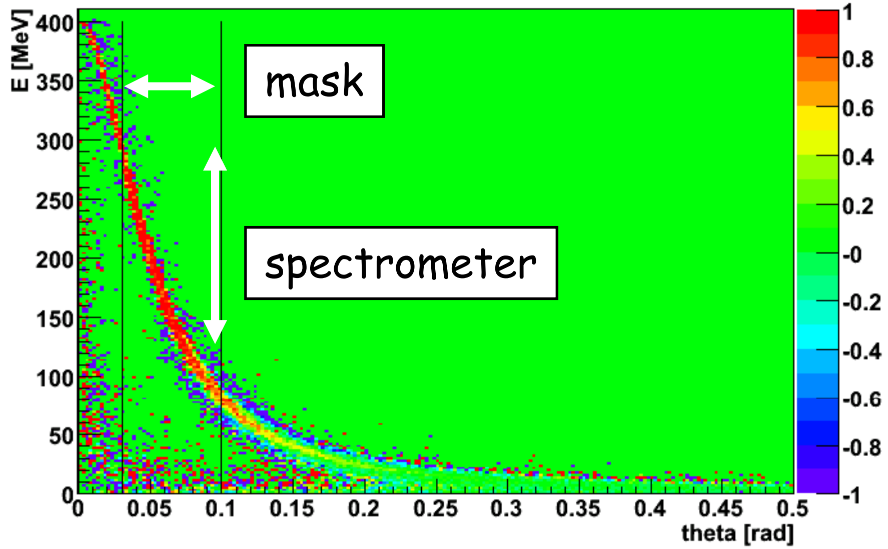
$$\frac{d\sigma}{d\Omega} = r_0^{\,2}\,\frac{(1+\cos\theta)^2}{16\gamma^2\sin^4\theta}\left\{\left(9+6\cos^2\theta+\cos^4\theta\right)-P_{e^+}P_{e^-}\left(7-6\cos^2\theta-\cos^4\theta\right)\right\}$$

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

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




asymmetry (analyzing power)

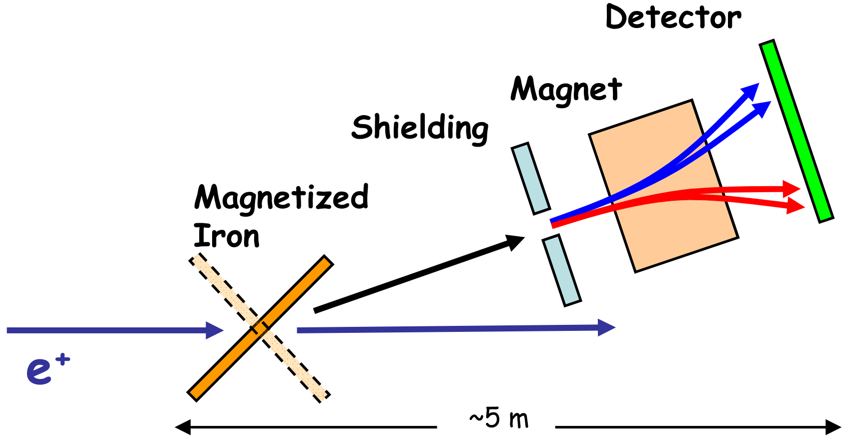



ang. range of interest: 0.03 – 0.1 rad

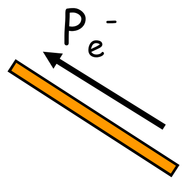
-> Asymmetry in the ang. range: $A_{e-}$ ~50 % ($A_{e+}$ ~5%, $A_\gamma$ ~-15%)

# Bhabha-Polarimeter

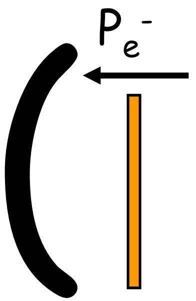
- Mask/shielding: selection of angular range with max. asymmetry
- Spectrometer: charge, energy
- Detector: sensitive to charged particles
- -> Asymmetry measurements of opposite polarization states of the target (and/or the incident beam) by
  - Flipping the target
  - Change the field orientation




Target: thin magnetized Iron foil (~ 30 μm)

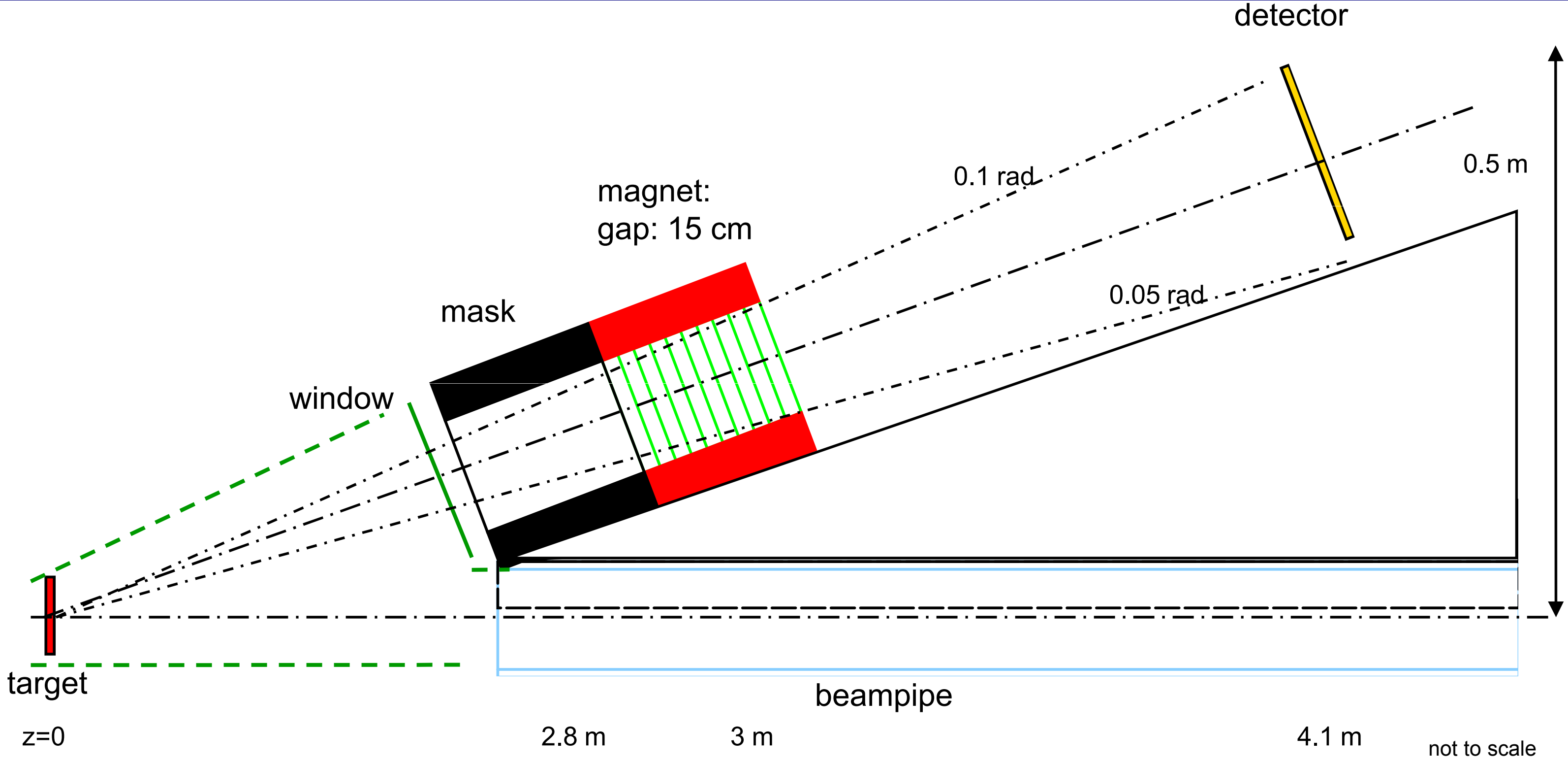



Magetization with Helmholtz coils (O(0.01T))



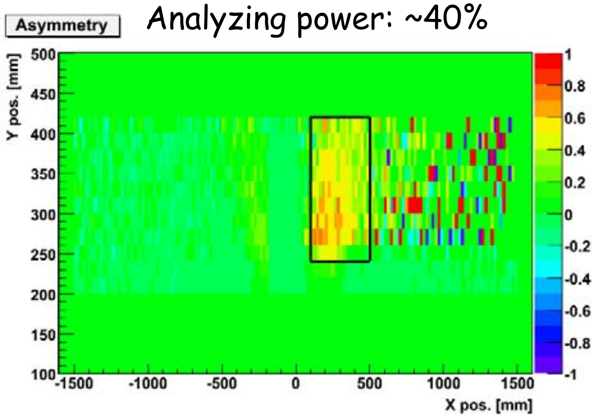

Magnetized in a high B-field (O(4T)) (But no option for LEPOL)

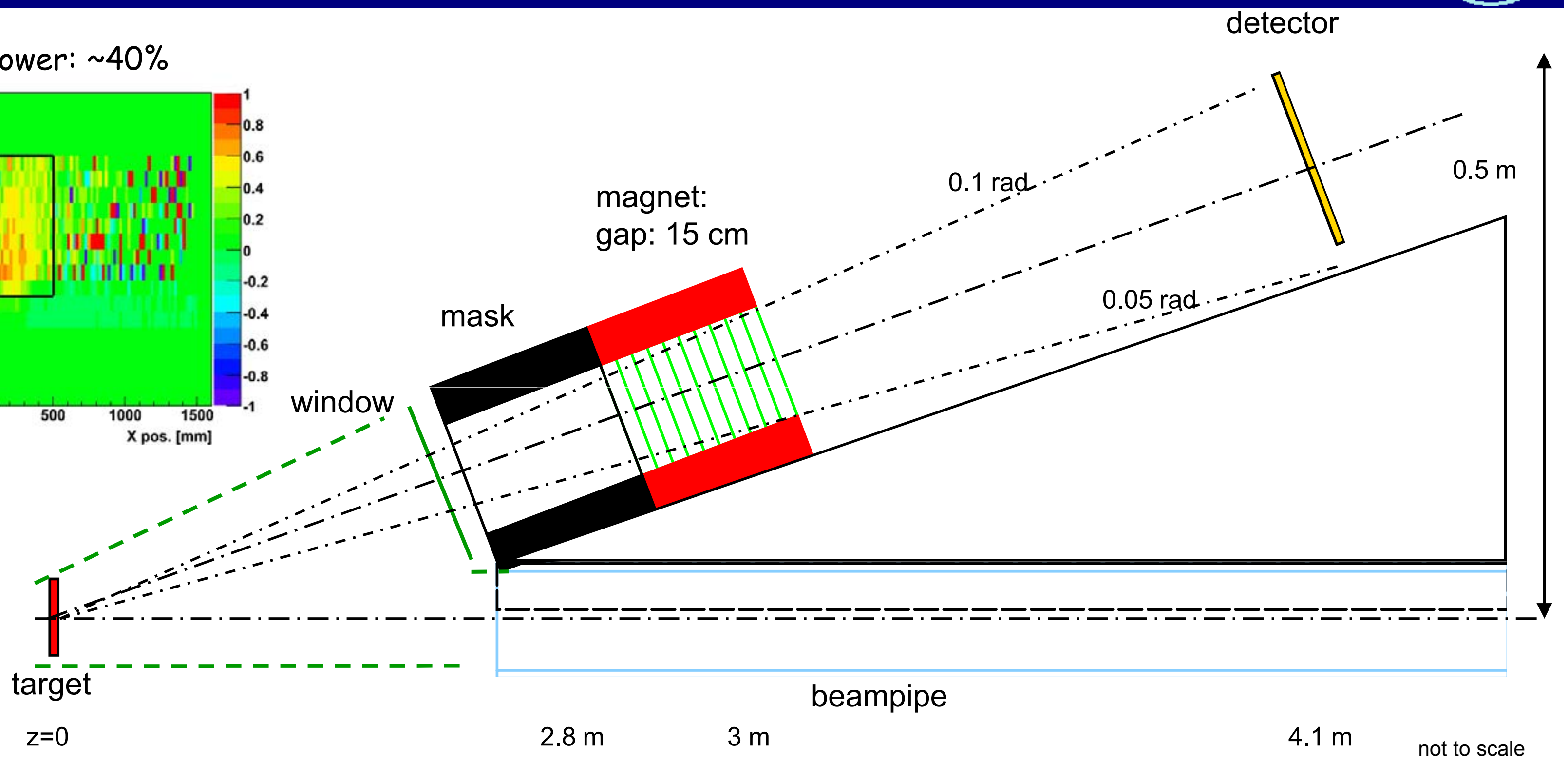
# Geometry (last meeeting)



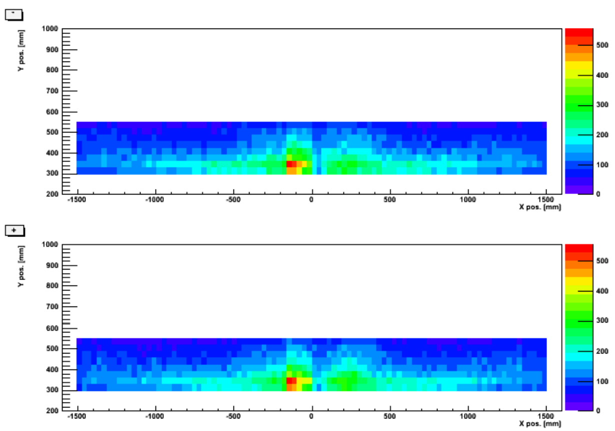
# Geometry (last meeeting)

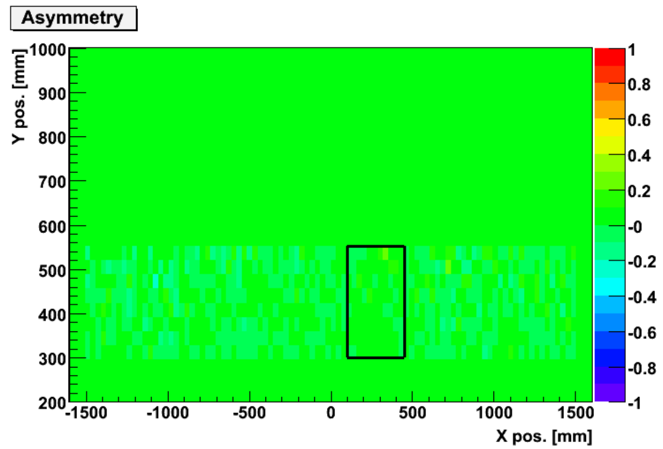
Analyzing power: ~40%



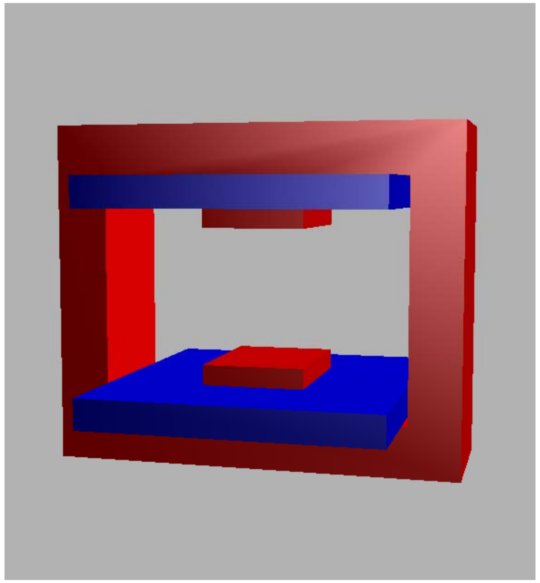




but:
- Background
- geometry not optimized
- no real beam parameters

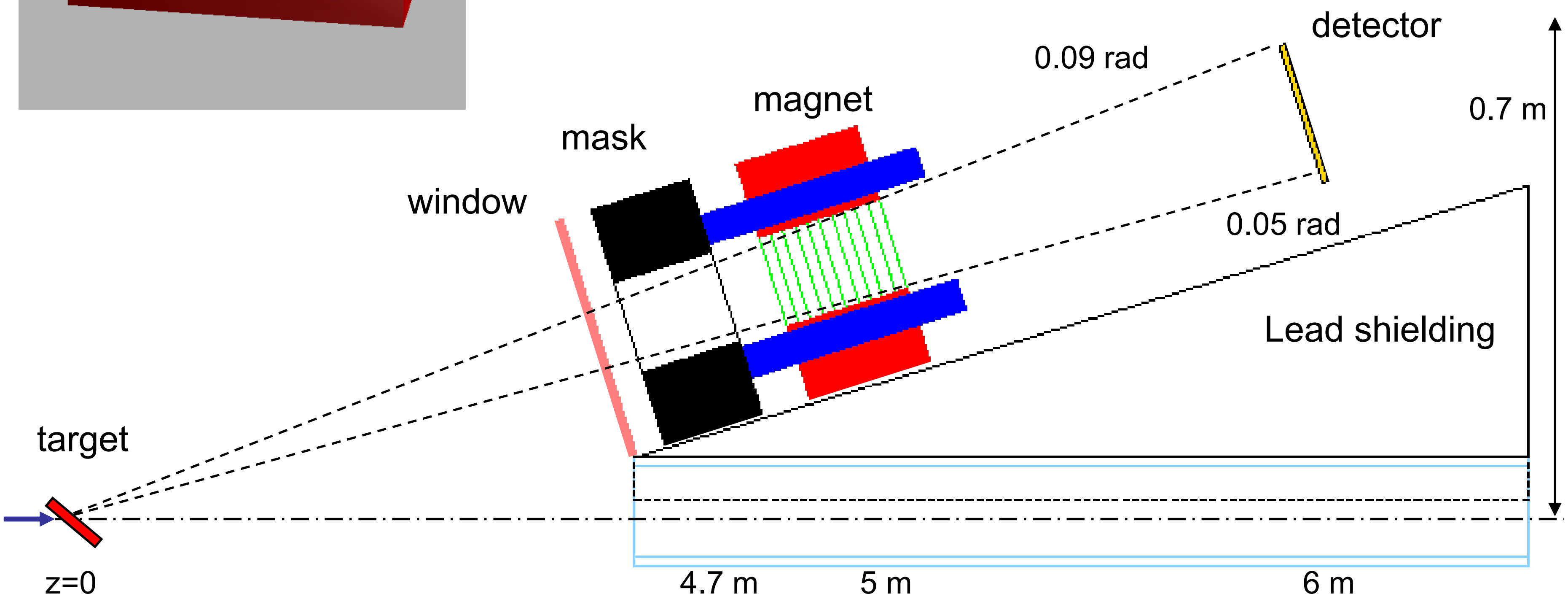




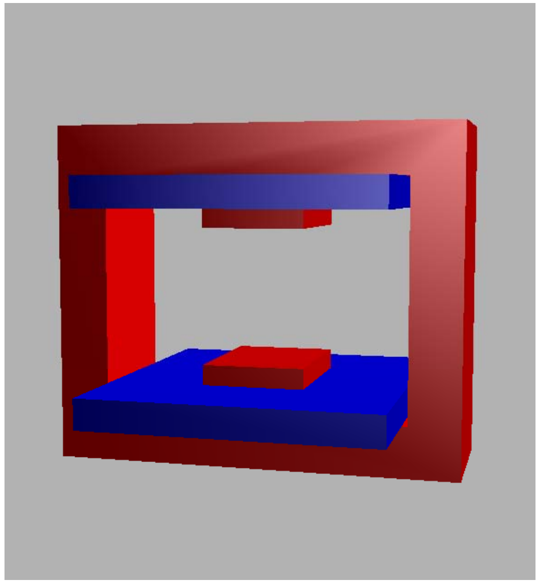
# Geometry improved



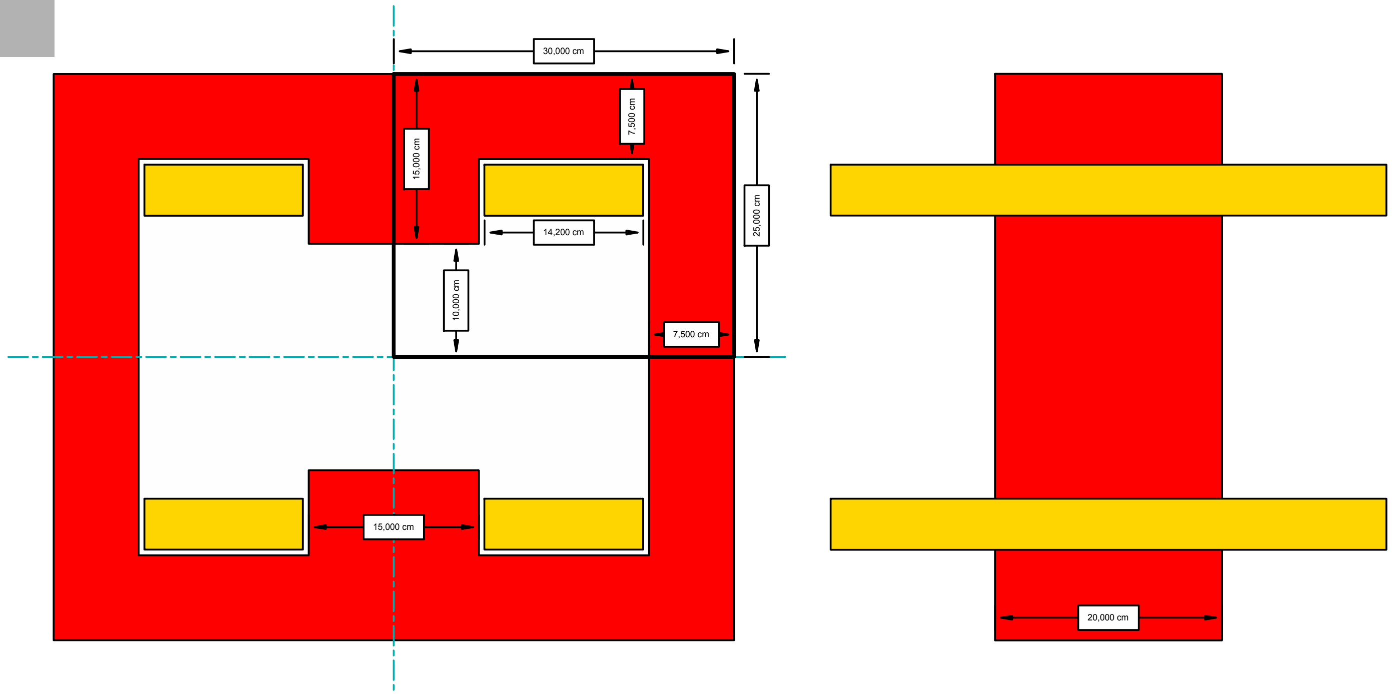
- "realistic" magnet design
- magnetic field inclined
- distances adapted
- target inclination
- eff. Taret Polarization
- improved shielding
- beam parameters from undulator simulation



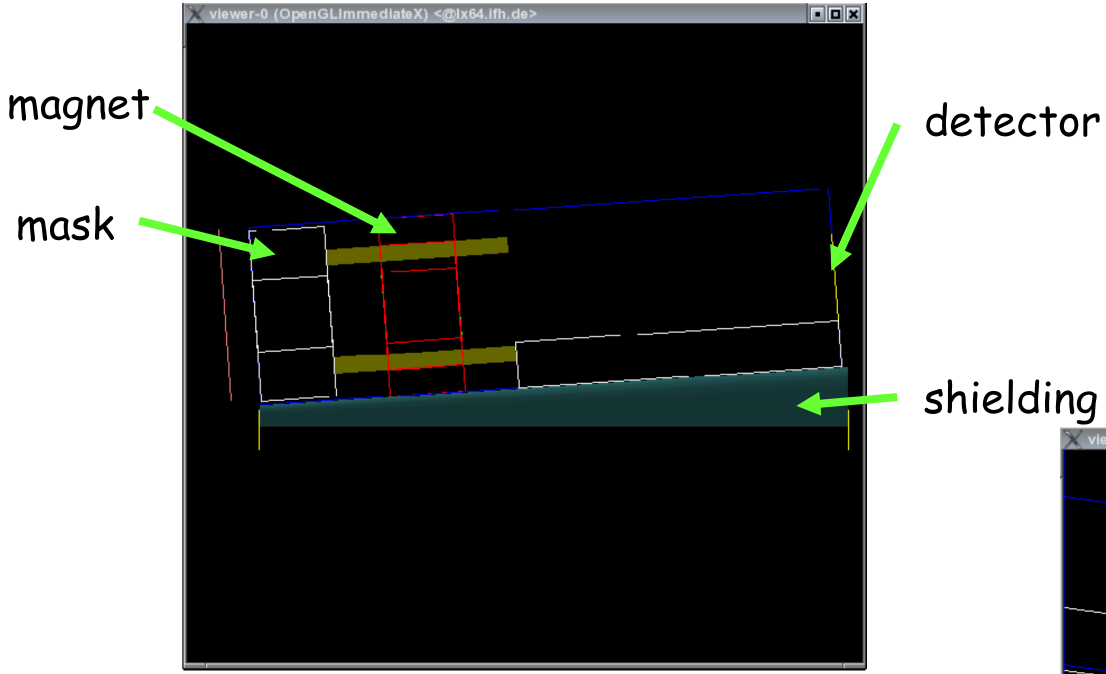
# Magnet

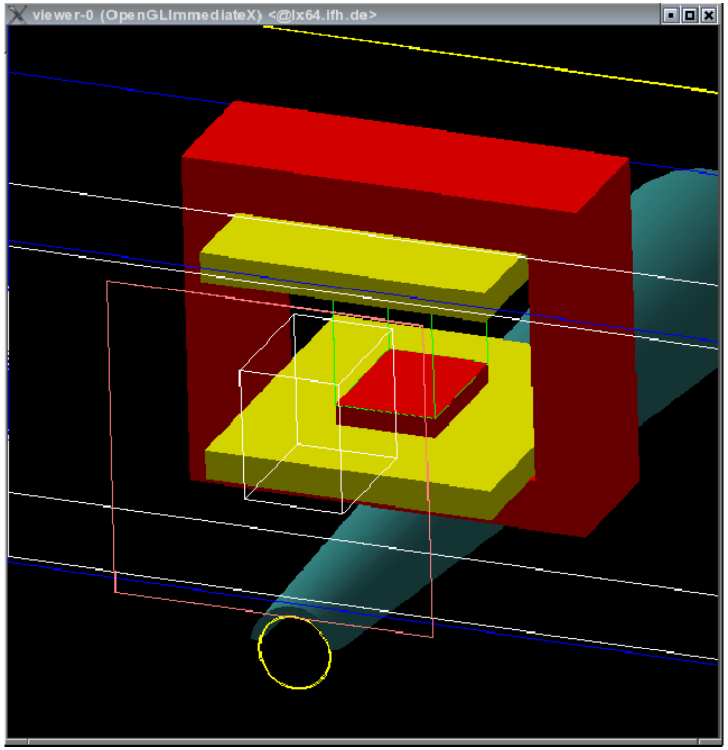


- $B_{gap}$ — 0.5 T
- BdL — 0.1 Tm
- gap — 20 cm
- length in z — 20 cm
- yoke thickness — 7.5 cm
- coil — ~ 80 000 Amp turns in total
  ~ 2·100 turns w. 400 A
- conductor — 8x8 $mm^2$ copper w. 3 mm water channel



# Geometry in G4



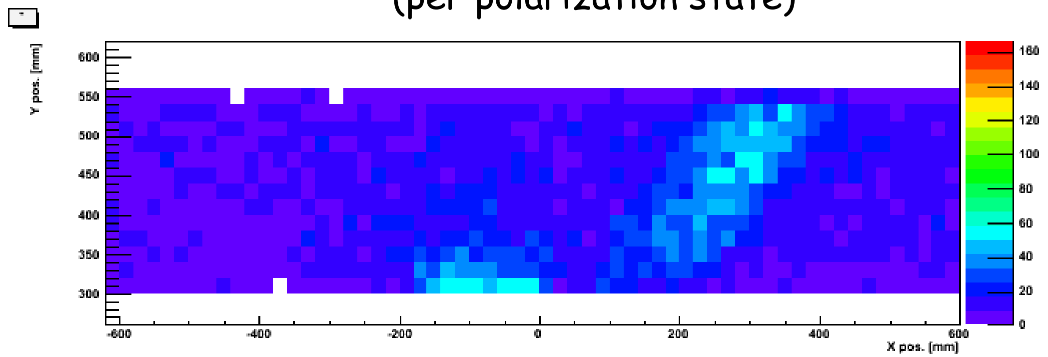
# Bhabha results

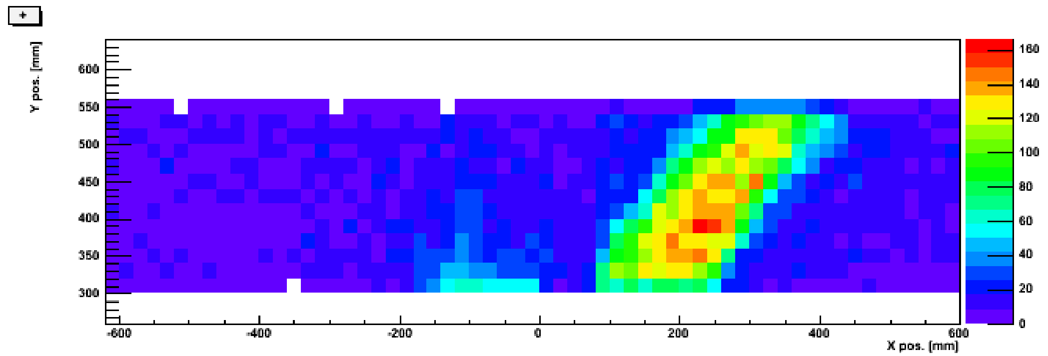
Beam parameters: (from source simulation!)

| | |
|---|---|
| E [MeV] | 400 (± 3.5 %) |
| $\sigma_x$ ,$\sigma_y$ [mm] | 5.78, 5.76 |
| $\varepsilon_x$ ,$\varepsilon_y$ [mm mrad] | 5.67,5.65 |
| P(beam) | -100% |

- Target: 30 $\mu$m Fe
  90°
  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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- Target: 30 μm Fe
  90°
  P ±100%
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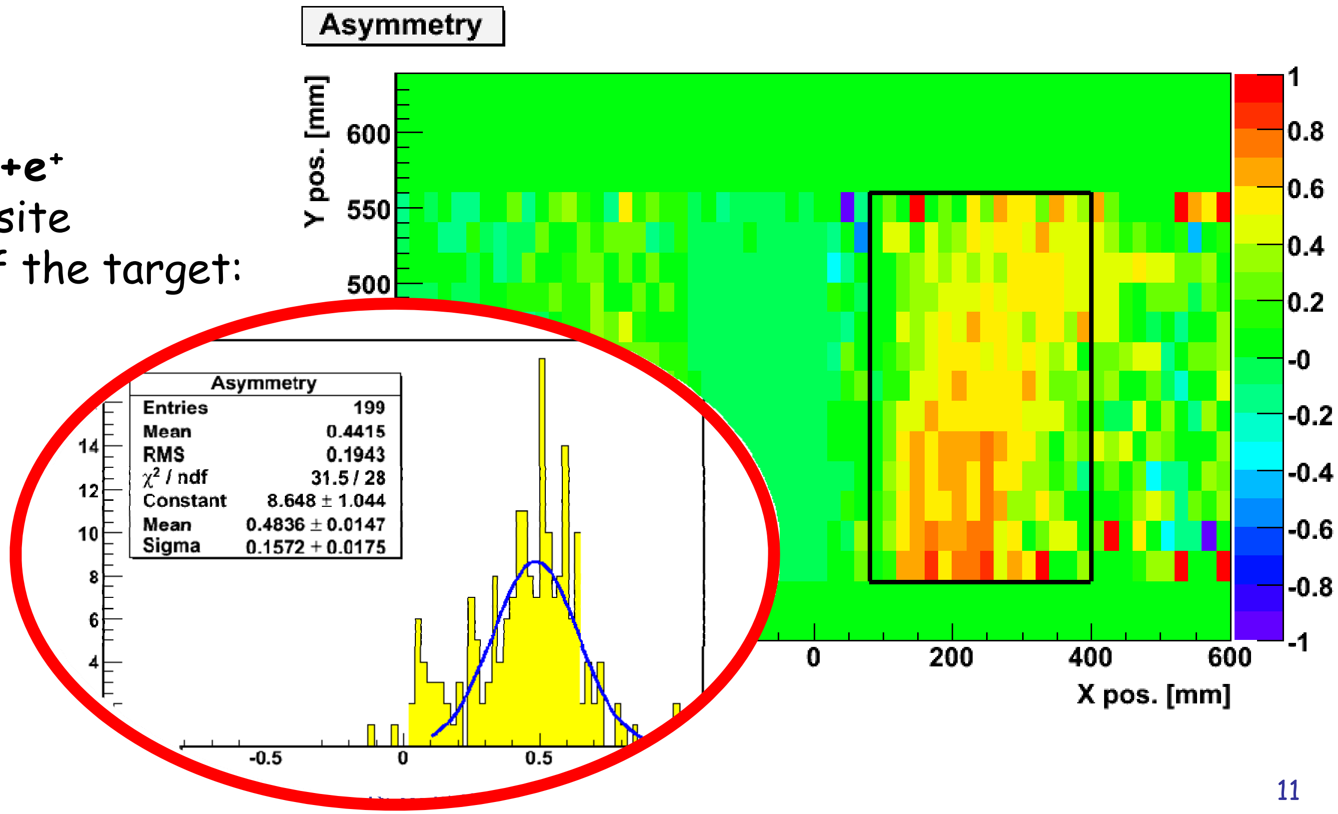
  (per polarization state)

Example:
Asymmetry of the **$e^-$+$e^+$**
distribution for opposite
polarization states of the target:
Ecut: 20 MeV



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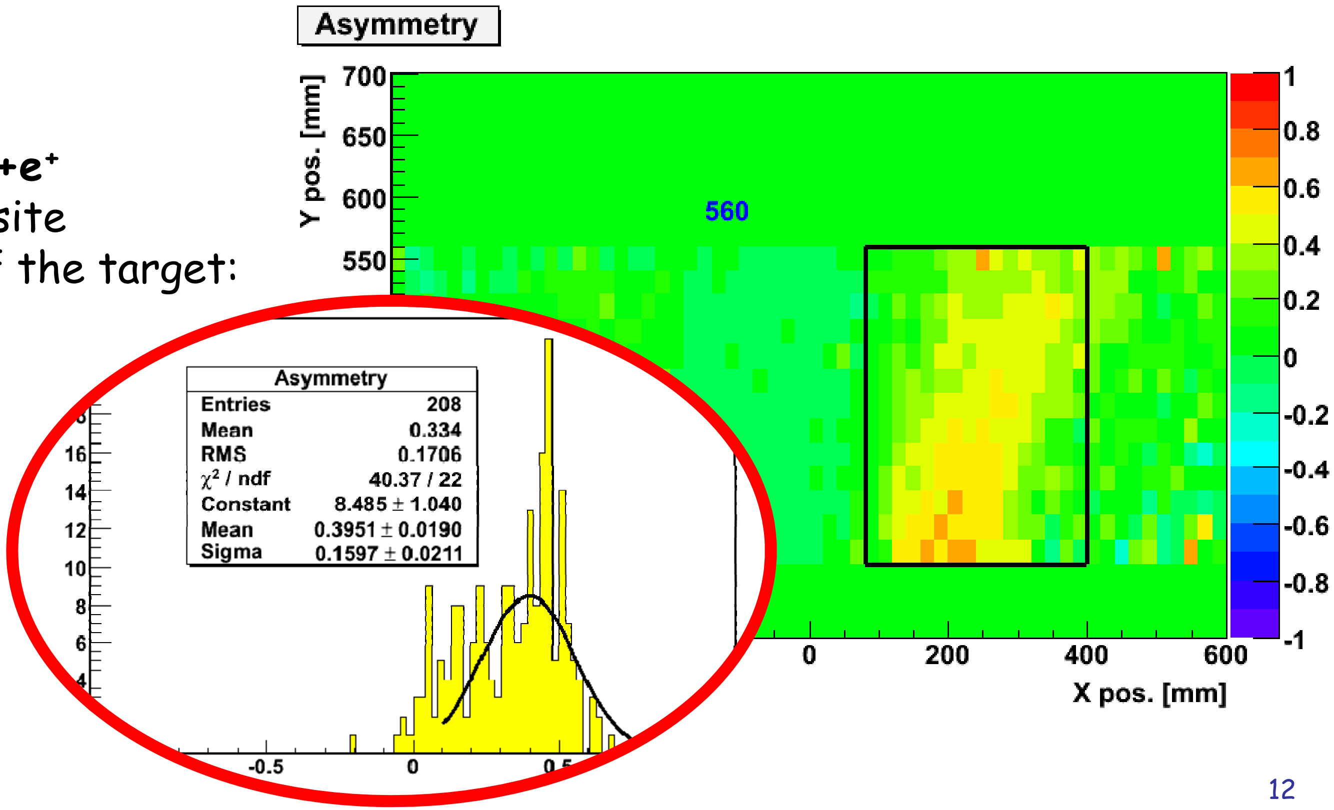
| | |
|---|---|
| E [MeV] | 400 (± 3.5 %) |
| $\sigma_x$ ,$\sigma_y$ [mm] | 5.78, 5.76 |
| $\varepsilon_x$ ,$\varepsilon_y$ [mm mrad] | 5.67,5.65 |
| P(beam) | -100% |

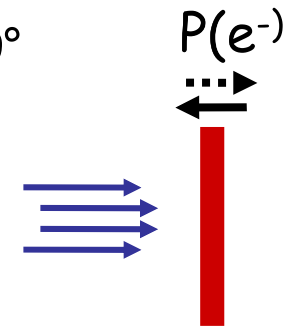
- Target: 30 μm Fe
  21°
  P ±100%
- Spectrometer: BdL 0.1 Tm
- Detector: charge sensitive
  2x2 cm pads
- 2 x $10^{10}$ positrons on target
  (per polarization state)

Example:
Asymmetry of the **$e^-$+$e^+$** distribution for opposite polarization states of the target:
Ecut: 10 MeV



# Bhabha polarimeter –Analyzing power

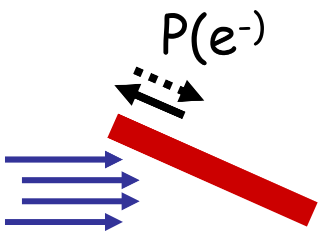
Incl.: 90°




| $E_{cut}$ [MeV] | Analyzing Power [%] | exp. Asymmetry [%] | | | |
|---|---|---|---|---|---|
| | | $P_{beam}$30% | $P_{beam}$60% | $P_{beam}$30% | $P_{beam}$60% |
| | | $P_{eff}$(foil) 7 % | | $P_{eff}$(foil) 5.6 % | |
| 0 | 37(2.0) | 0.78 | 1.55 | 0.62 | 1.24 |
| 10 | 45(1.5) | 0.95 | 1.89 | 0.76 | 1.51 |
| 20 | 48(1.5) | 1.01 | 2.02 | 0.81 | 1.61 |
| 30 | 53(1.2) | 1.11 | 2.23 | 0.89 | 2.23 |

20% depolarization due to target heating

Incl.: 21°

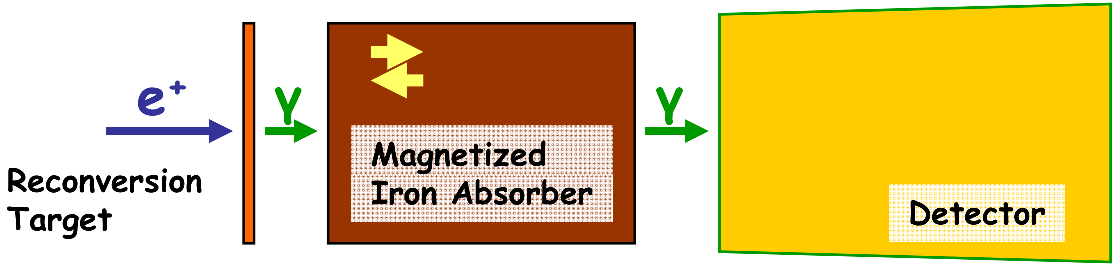



| $E_{cut}$ [MeV] | Analyzing Power [%] | exp. Asymmetry [%] | | | |
|---|---|---|---|---|---|
| | | $P_{beam}$30% | $P_{beam}$60% | $P_{beam}$30% | $P_{beam}$60% |
| | | $P_{eff}$(foil) 6.5 % | | $P_{eff}$(foil) 5.2 % | |
| 0 | 30(2.2) | 0.59 | 1.18 | 0.47 | 0.94 |
| 10 | 40(1.9) | 0.78 | 1.57 | 0.63 | 1.25 |
| 20 | 41(1.4) | 0.80 | 1.61 | 0.64 | 1.29 |
| 30 | 44(1.5) | 0.86 | 1.73 | 0.69 | 1.38 |

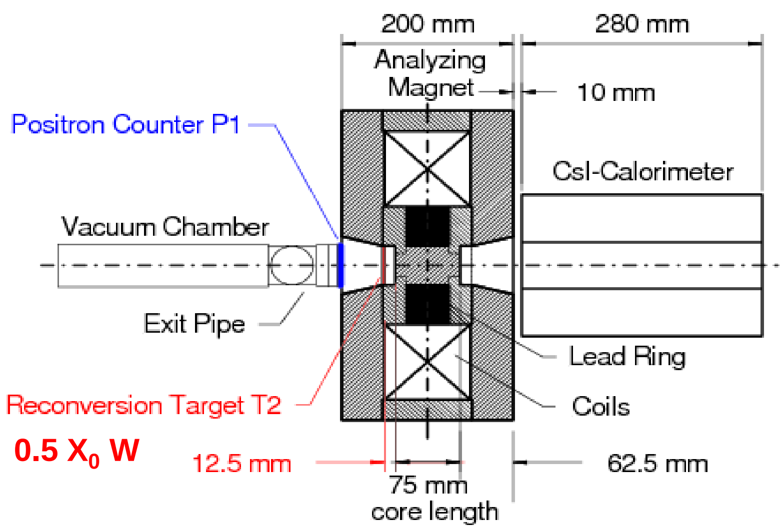
Measurimg time for 5% acuracy – O(few min)

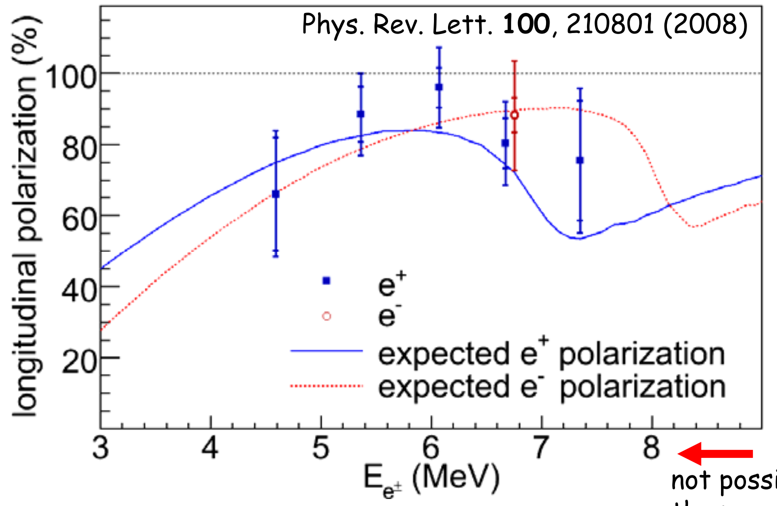
Energy deposition in the target: 29.2 keV / $e^+$ (30 μm)
(beam energy: 400 MeV) 1.25 MeV / $e^+$ (1 mm) (G4)

# Compton Transmission Method




- Destructive !
- Polarized positrons reconverted into polarized gammas in a thick target (1 to 3 $X_0$)
- The E166 experiment used this method -> a lot of experience !




not possible at these energies at PPS

# Compton Transmission Method

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: 2 $X_0$ Tungsten
- Absorber: Iron cylinder surrounded by a lead ring

| $e^+$ energy | 30 MeV | 125 MeV |
|---|---|---|
| Absorber length [mm] | 150 | 150 |
| Analyzing power [%] | 16.7 | 19.0 |
| Measured asymmetry [%]: $P_e^-$(Fe): 7%, $P_e^+$ 30% / 60 % | 0.33 / 0.65 | 0.37 / 0.75 |

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

Energy deposition in absorber:
$E(e^+)$ 30 MeV: 9 MeV/$e^+$
$E(e^+)$ 125 MeV: 56 MeV/$e^+$

# Summary

- Bhabha polarimeter:
  - Geometry has been optimized
  - beam parameters from undulator simulation implemented
  - from the simulation studies reasonable performance expected
- Compton transmission polarimeter:
  - CTP is our second choice
  - Only a fraction of the beam can be used (additional beamline)
- Still much room for optimization
- Lepol layout, energy, dimension depend on final positron source design