Compton transmission polarimetry of LPA-accelerated electron beams

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FTX

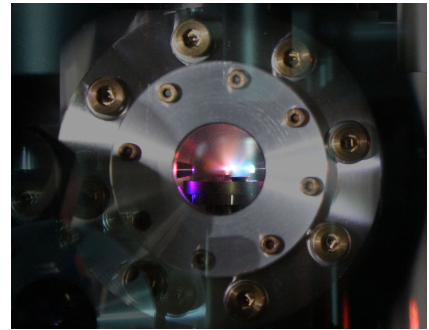
DESY.

Compact polarized electron sources with PAs

- no RF-breakdown for plasma accelerators:
  - high acceleration gradients [1]
  - compact sources

- So far only theoretically explored what happens to polarisation during PA [2]

  ⇒ LEAP: proof-of-principle experiment for a polarised electron beam from laser plasma acceleration

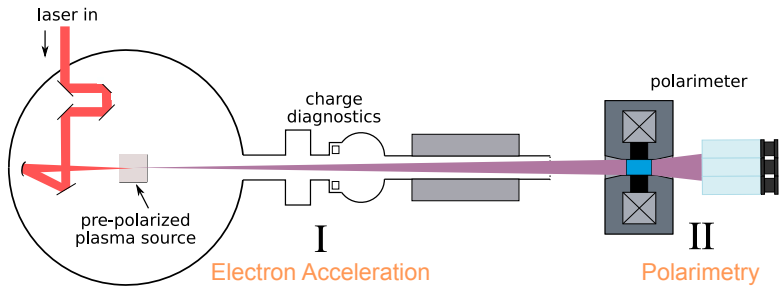


[1] E. Esaray, C. Schroeder and W. Leemans, Rev. Mod. Phys.81(3),1229-1285(2009)
[2] J. Viera et al., Phys Rev. ST Acell. Beams 14, 071303 (2011)

The LEAP project at DESY

Proof of principle experiment for spin-polarised electrons from LPA

- Existing high-stability LPA [3]
- Introduce polarisation via a pre-polarised plasma target [4]
- Compton transmission polarimeter



[3] Bohlen, S et al., Phys. Rev. Accel. Beams 25 no 3, 031301 (2022), [4] Spiliotis, A et al., Light Sci. Appl.10 no35 (2021)

Current status on the accelerator side

Expected beam parameters

- preparation of prepolarised plasma source ongoing
- with the laser system currently in place we expect:

Expected Parameters

- energy : 30-80 MeV
- charge : 3 pC
- polarisation: 10 %

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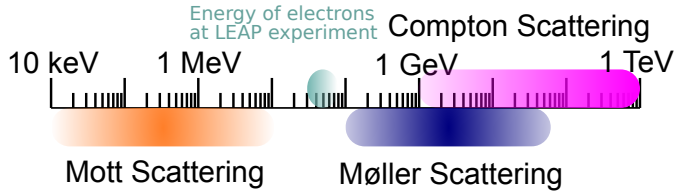
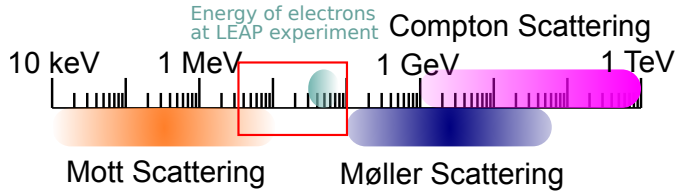
- **Important Note**
  - LEAP $\neq$ what's possible
    - > 90 % Polarization
    - tens of pC charge
  - For more info look at:
    Bohlen, S. et al., arXiv:2304.02922 [physics.acc-ph] (2023)

How to measure the polarisation?



How to measure the polarisation?

Transmission Polarimetry



> at expected energy range **transmission polarimetry** is the best option

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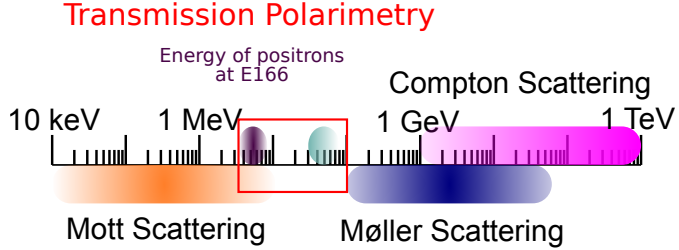

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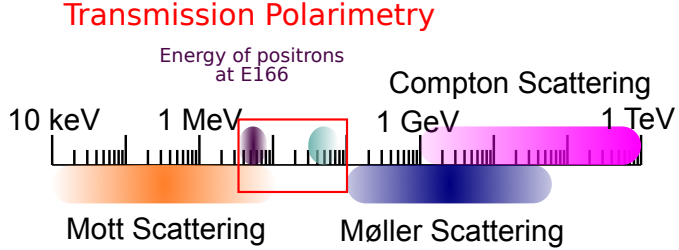
> demonstrated for positron polarimetry
at the E166 Experiment [5]

- E_{e^+} between 4-8 MeV
- polarization about 80 %
- rel. meas. error about 10-15%

[5] G. Alexander et al., Nucl. Instrum. Methods Phys. Res. A, vol 610, no 2, 451-487 (2009)

How to measure the polarisation?



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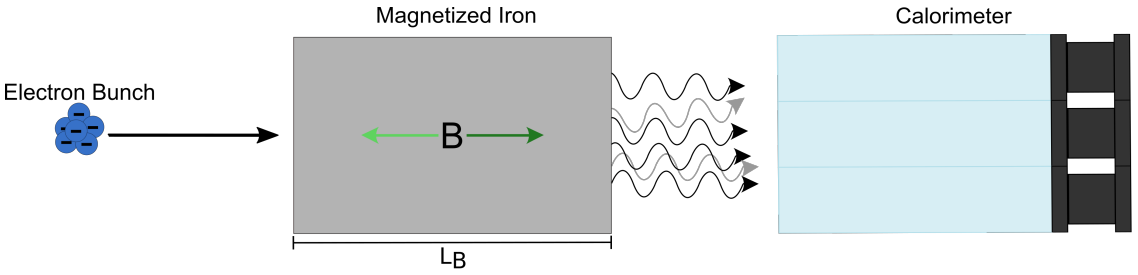
> challenges for LEAP polarimetry:
- expected E_{e^-} of tens of MeV
- polarization of initial beam $\approx$10%
- what asymmetries can we achieve?

[5] G. Alexander et al., Nucl. Instrum. Methods Phys. Res. A, vol 610, no 2, 451-487 (2009)

Compton transmission polarimetry



I

creation of circularly **polarised** photons via **Bremsstrahlung**

II

Polarisation dependent transmission through magnetised iron absorber

$$T \propto exp(-nL_B\sigma_{pol}P_\gamma P_{Fe})$$

III

Photon detection

LEAP: Lead glass crystals + PMTs

The measurement principle

Transmission Asymmetry

$$\delta = \frac{E_{AP} - E_P}{E_{AP} + E_P}$$

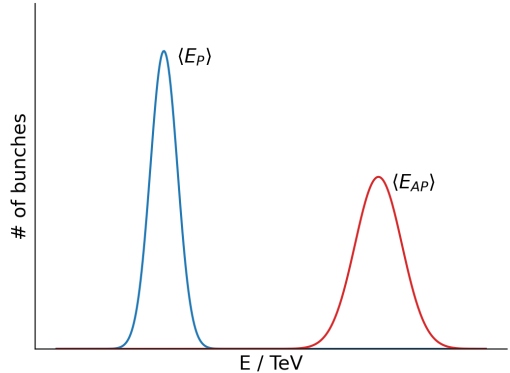
Simulate analyzing power

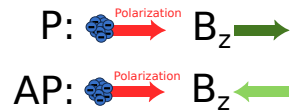
$$\mathcal{A} = \delta(P_{e^-} = 1, P_{Fe} = 1)$$

Measure $E_{AP/P}$

calculate δ_m

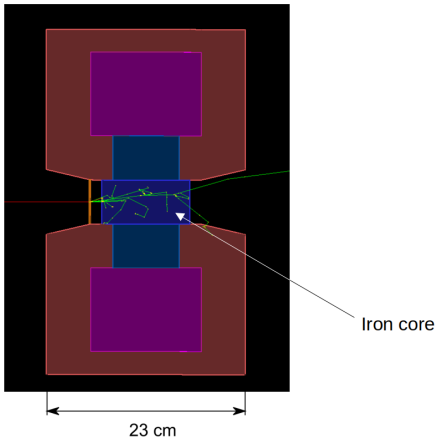
$$P_{e-} = \frac{\delta_m}{P_{Fe}\mathcal{A}}$$





Parameter study (1/2)

Set up and specifics of GEANT4 simulations

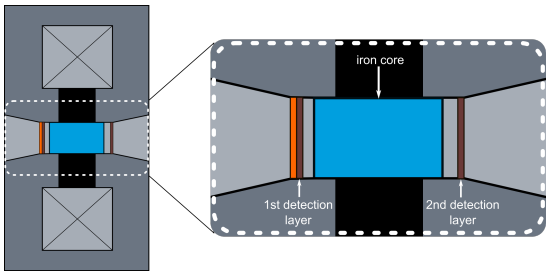


- Monte-Carlo type simulations with GEANT4 [6]
- mono-energetic point-source
- e-/iron core polarization of +/- 1
- GEANT4 physicslist including polarized em physics [7]

[6] S. Agostinelli et al., Nucl. Instrum. Meth. A 506 (2003) 250-303
[7] A.Schälicke,K. Laihem,P. Starovoltov, arXiv:0712.2336 (2007)

Parameter study (2/2)

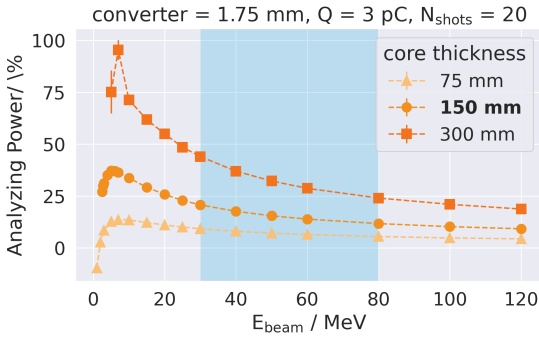
Set up and specifics of GEANT4 simulations



- simulated 1k bunches per polarisation configuration
- for calculation of analysing power mean E extracted from virtual volume

Analyzing Power

Results of Design Study



- $\mathcal{A}$ decreases with E_{beam}, less dependent on exact E_{beam} at higher values

Analyzing Power

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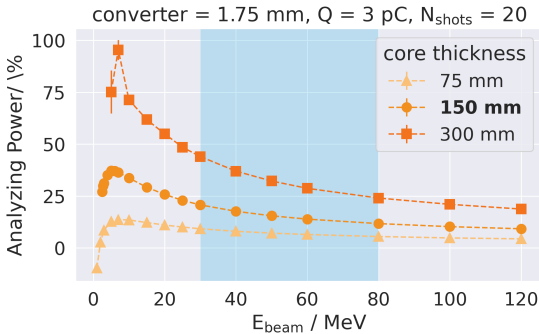
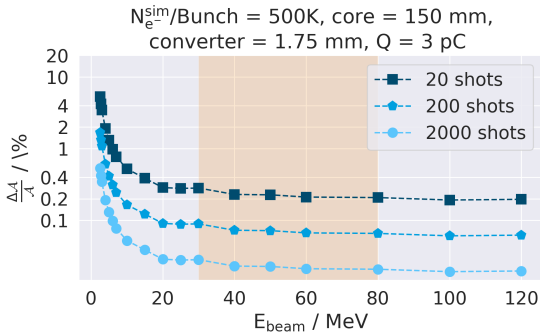


- $\mathcal{A}$ decreases with E_{beam}, less dependent on exact E_{beam} at higher values
- $\mathcal{A}$ increases with core thickness L_B, so does the statistical error

Statistical Uncertainty

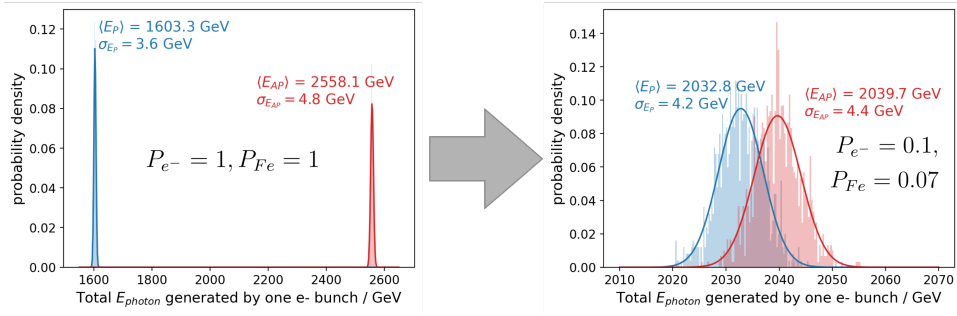
Results of Design Study



> With $E_{\text{beam}} = 30\,\text{MeV}$ and $L_B = 150\,\text{mm}$, 20 shots would suffice to achieve a statistical error below 1 %

Estimate of the expected Asymmetries

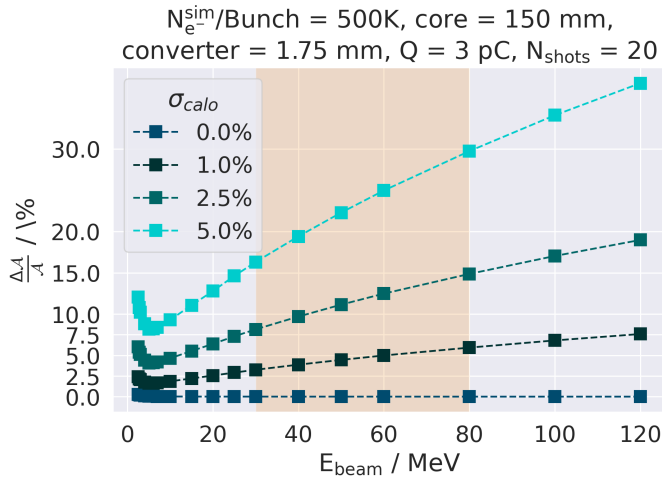
E_{beam} = 30 MeV, core = 150 mm,
toy MC data, full bunch charge



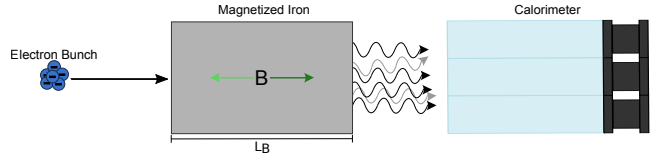
- $\delta_m = \mathcal{A} \times P_{e^-} \times P_{Fe} = 22.95\% \times 10\% \times 7\% = 0.17\%$ in example on top
- Simulations with realistic beam conditions in progress
- What does this mean for the calorimeter ?

Calorimeter requirements

- 19M e^- (3 pC) with ~30 MeV each
  $\rightarrow N_\gamma$ ~550K
  $\rightarrow$~ 2 TeV deposited energy
- essential to reach resolution as close to 1% as possible
  $\Rightarrow$crystal calorimeter

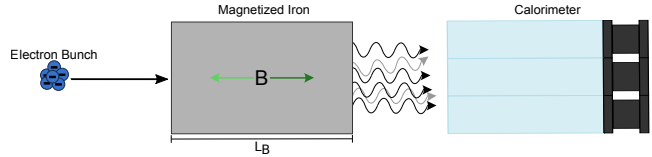


The LEAP polarimeter

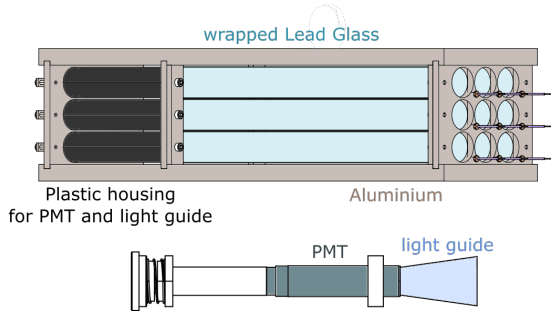


> Solenoid with $L_B = 150$ mm

The LEAP polarimeter

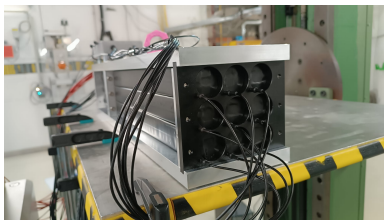


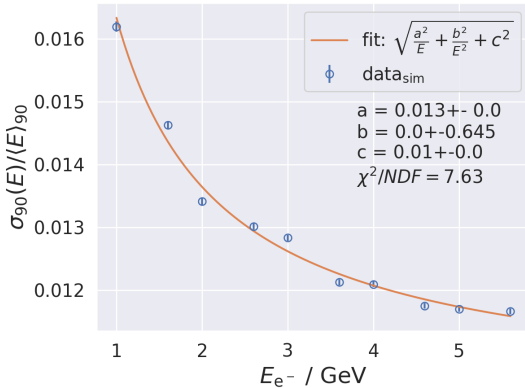
- Solenoid with $L_B = 150$ mm
- Calorimeter of 3x3 lead glass crystals
  ⇒because we need such a high energy resolution



Calorimeter tested in DESY II testbeam

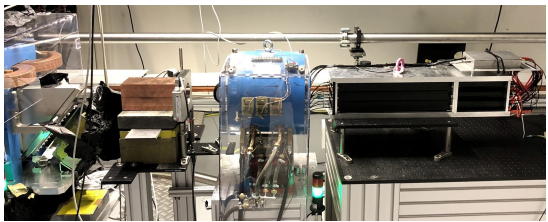
- single electrons from 1.6 - 6 GeV
- Analysis ongoing
- simulations show constant term of 1%

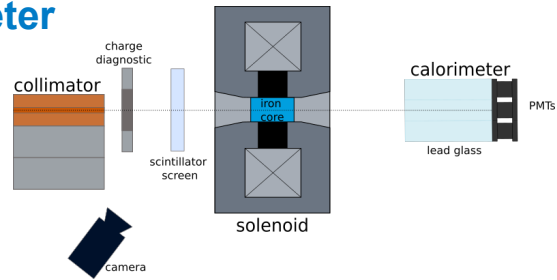


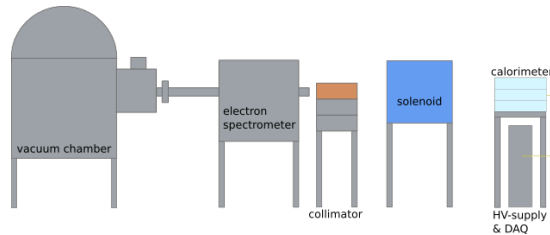


Current Status of the Polarimeter

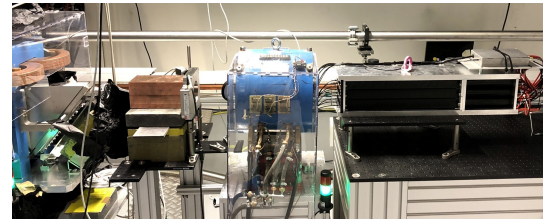
- full setup ready and tested in beam area
- zero polarisation measurement planned in 2 weeks







Summary



- LEAP aims to demonstrate the creation of spin-polarised electron beams from LPA
- current setup: ~10% polarisation expected for 3pC bunches at 30 MeV, ultimately up to 100% possible
- few tens of MeV ⇒Compton transmission polarimetry
- expect ~TeV transmitted photon energy with 0.2% observable asymmetry
- with 20 bunches expect relative statistical precision of 5-10% on observable $\mathcal{A}$ for calorimeter resolution of 1-2.5%
- setup incl. crystal calorimeter in place & tested
- first $P_{e^-} = 0$ measurements in October

Thank you!

Contact

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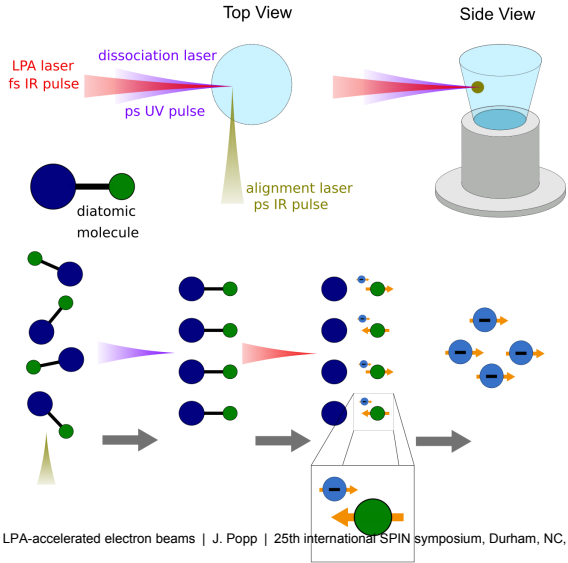
Back Up

LEAP


Top View
Side View
LPA laser
fs IR pulse
dissociation laser
ps UV pulse
alignment laser
ps IR pulse
diatomic
molecule

Converter target