Polarimetry at the LC Source

Which type of polarimetry, at which energies for LC ?

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International Workshop on Linear Colliders 2010, Geneva
October 25-29, 2010

Outline

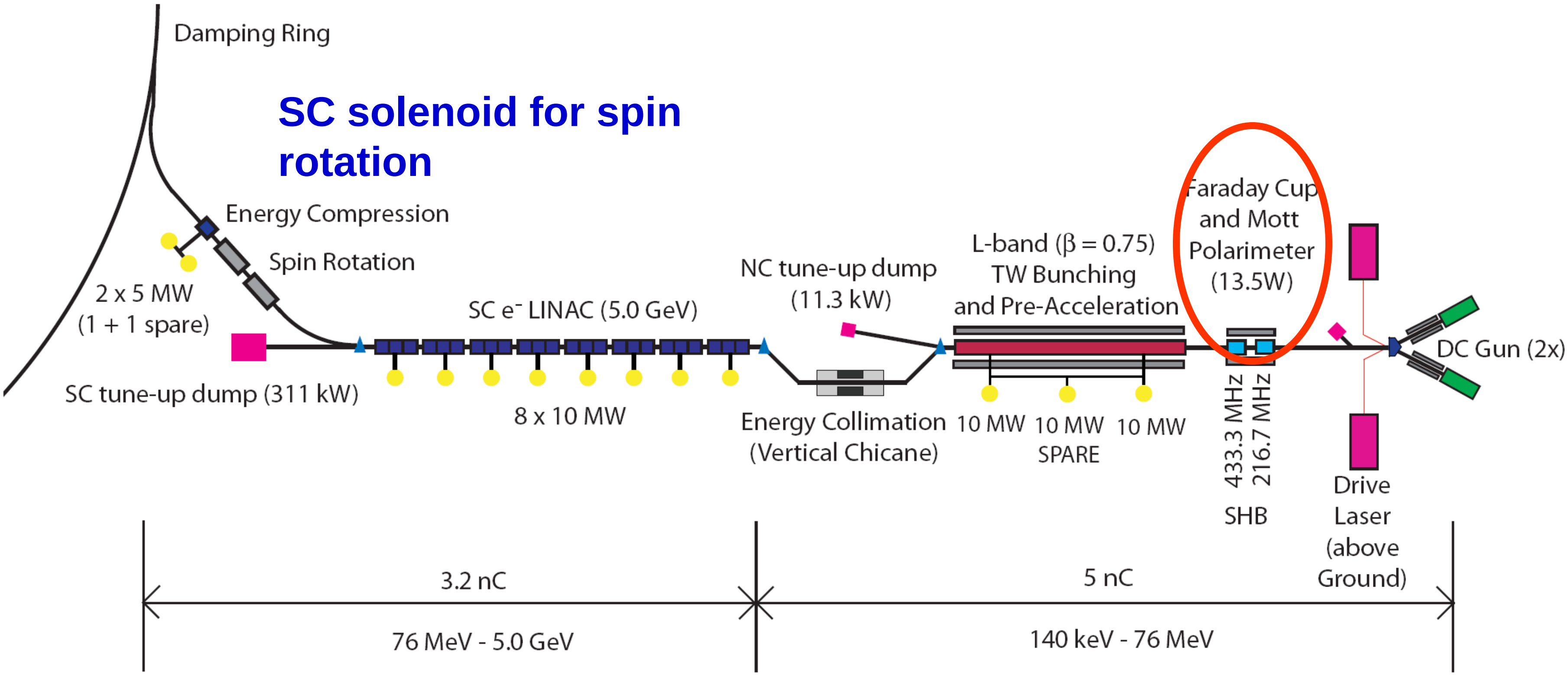
- Sources (CLIC and ILC)
- e+ polarimetry at low energies (LEPOL)
  - Compton transmission polarimeter
  - Bhabha polarimeter studies
  - Compton polarimetry downstream DR
- Spin rotation, fast helicity reversal

Low Energy POLarimeter Group:

DESY/HUB: R. Dollan, T. Lohse, S. Riemann, A. Schälicke, P.Schuler, A. Ushakov

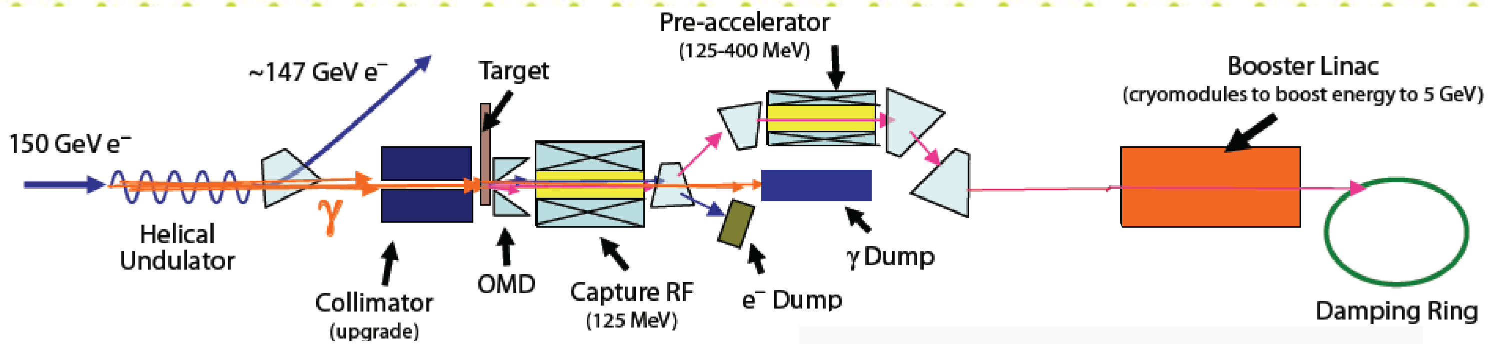
Minsk/CERN: P. Starovoitov, Tel Aviv U: G. Alexander

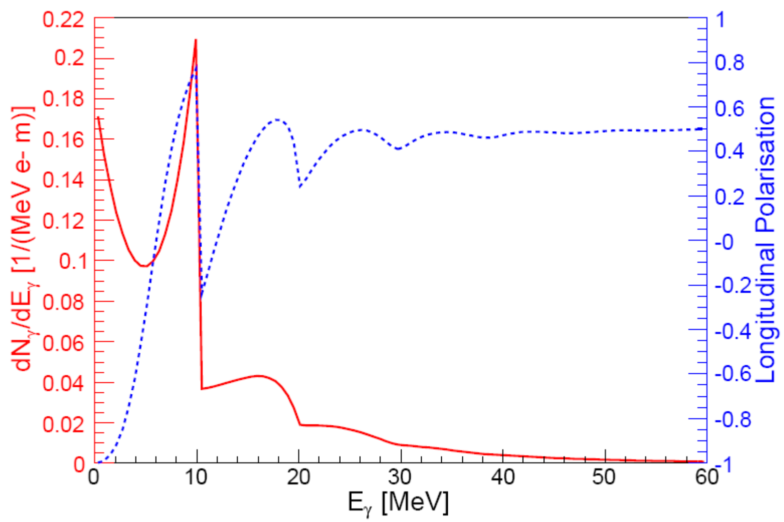
ILC Electron Source System (RDR)

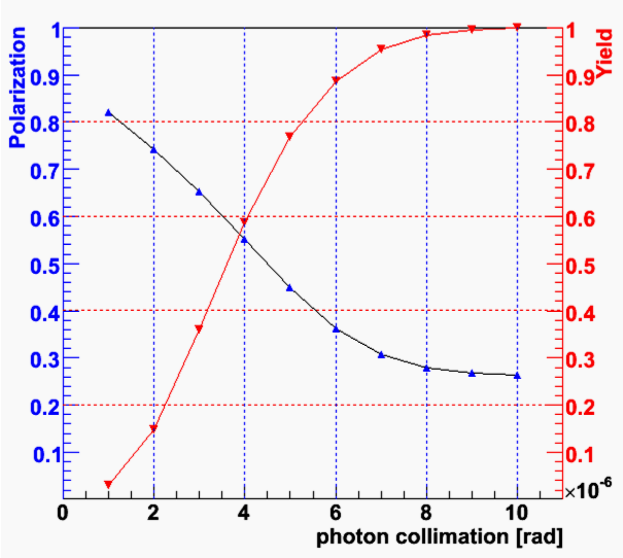


- **Mott polarimeter to measure e- polarization near the gun (ILC, CLIC)**
  - **Mott polarimetry requires transverse polarization of positrons → spin rotation from longit. to horizontal**
- Faraday cup → charge

ILC positron source (RDR)





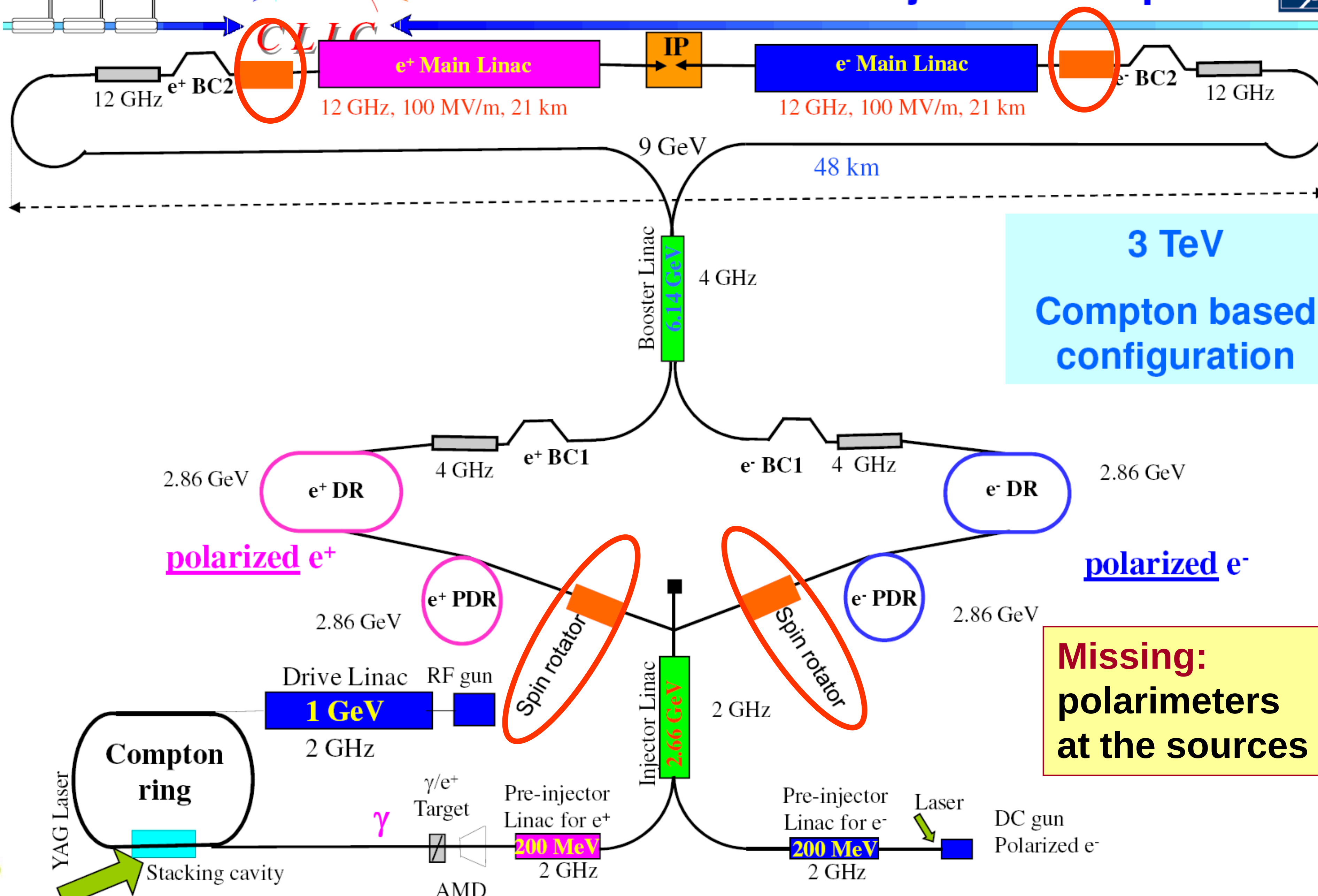


Helical undulator ➔ Average positron polarization **~30%**

Polarimeter at the source:

- commissioning
- Optimization of e+ polarization and e+ intensity at the source

CLIC Main Beam Injector Complex



3 TeV

Compton based configuration

Missing: polarimeters at the sources

Polarimetry at the positron source

Conditions:

- Large beam size [O(cm)]
- Downstream capture section:
  - Energy (ILC): ≥125 MeV

Requirements for the method:

- Suitable for low energy range
- Suitable for large positron beam size
- Suitable for intense beam
- Fast, non-destructive
- Accuracy O(few %)

Laser Compton Scattering

- High intensity Laser on low emittance beam
- High precision
- Only downstream Damping Rings

Bhabha/Møller scattering

- Thin magnetized target
- Suitable for desired energy range

Compton Transmission

- Beam absorbed in thick target
- energy ~few tens MeV

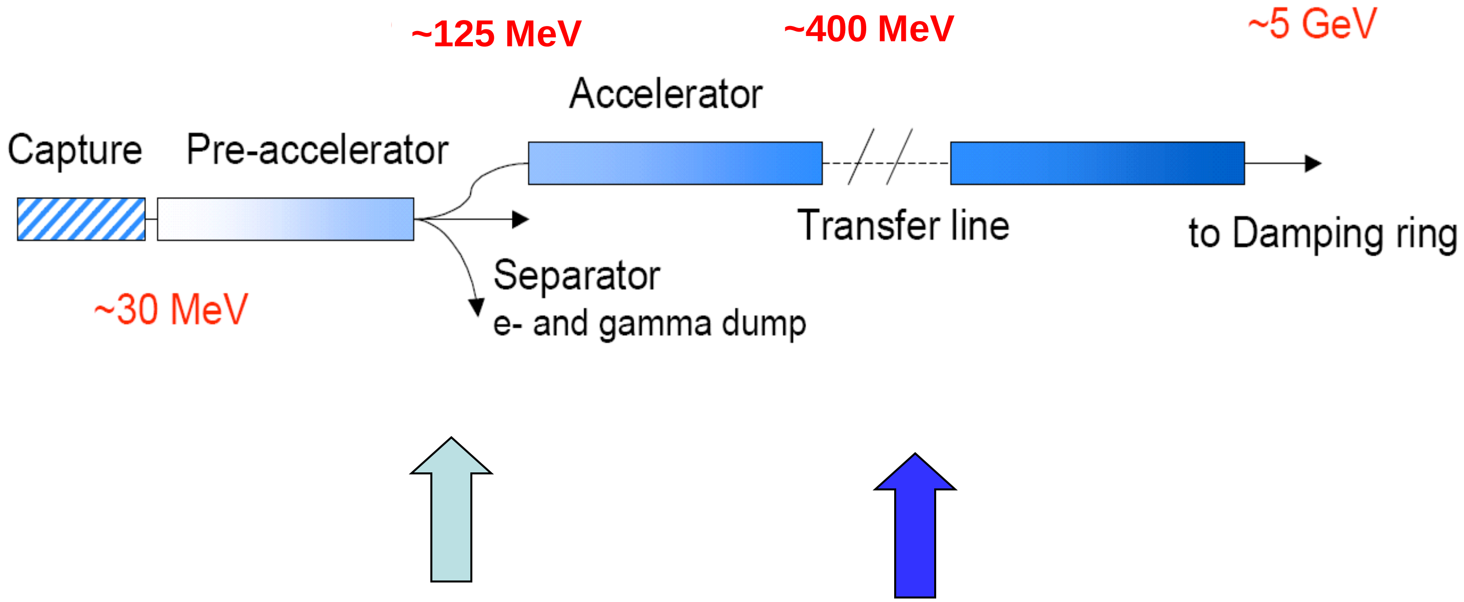
Mott scattering

- Transverse polarized positrons → need spin rotation
- destructive

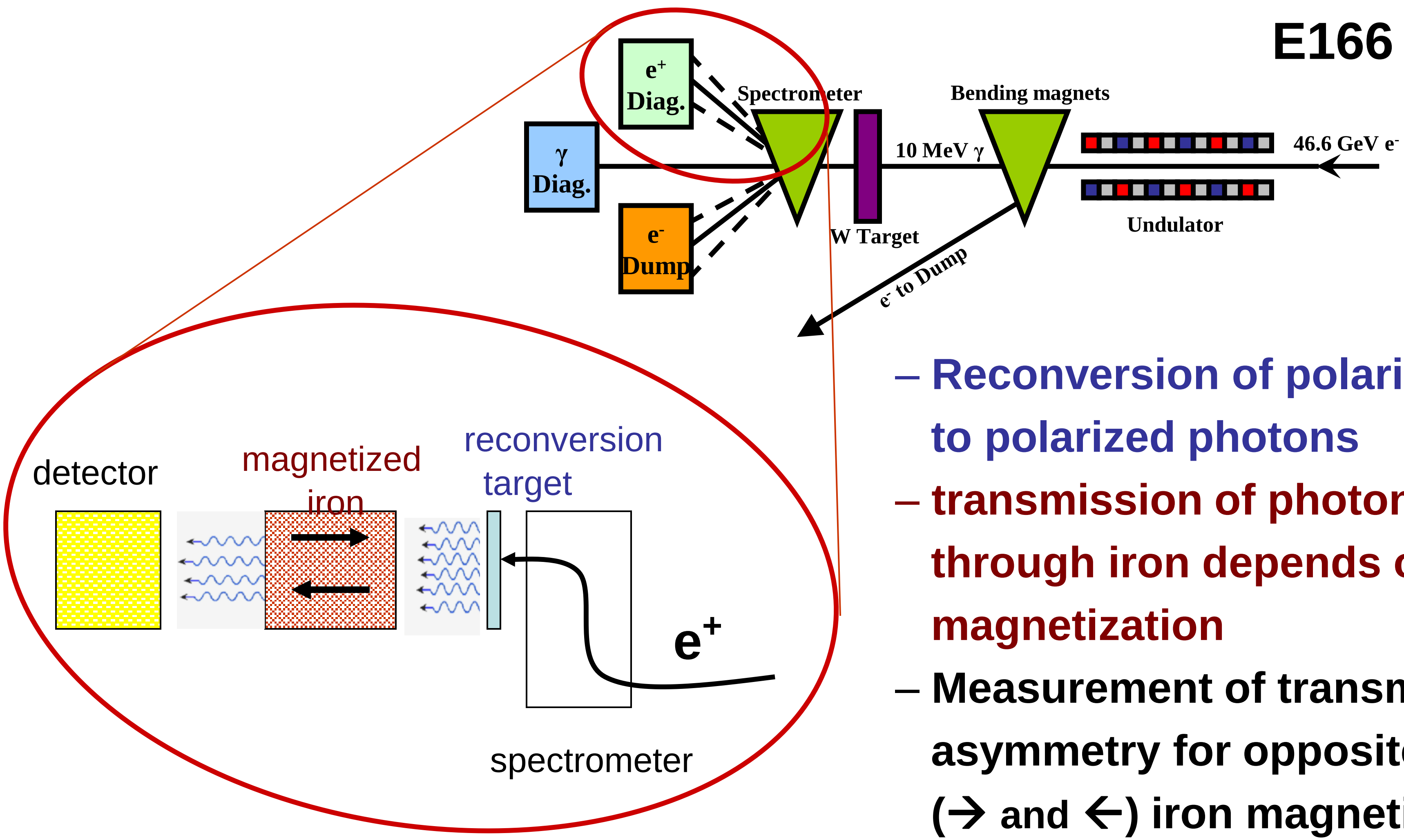
Polarimetry at the e+ source

Considered options for the ILC:

- **Compton transmission (125 MeV)**
- **Bhabha polarimeter (400 MeV)**
- **Compton polarimeter – downstream DR (beamsize!) (5 GeV)**
- **Simulations using Geant4 with polarized processes**



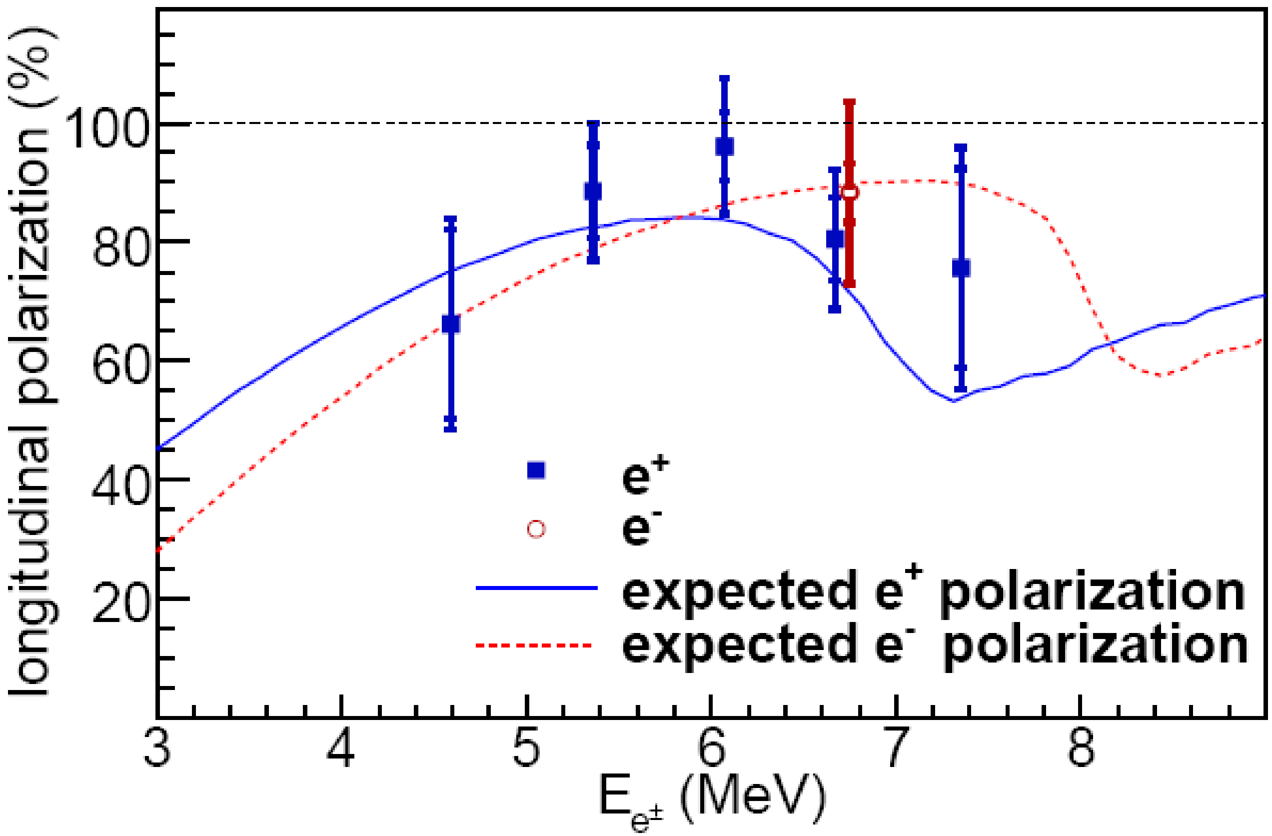
Compton transmission polarimeter



– Reconversion of polarized e+ to polarized photons
– transmission of photons through iron depends on its magnetization
– Measurement of transmission asymmetry for opposite (→ and ←) iron magnetization

Method was used at ATF and E166

E166 results



Good agreement of measurement and prediction

E166 results published in

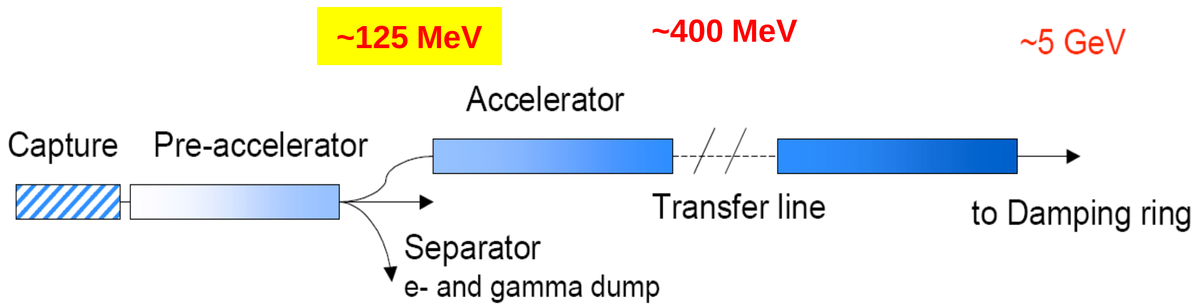
PRL 100:210801,2008 (arXiv:0905.3066 [physics.ins-det])

NIM: http://dx.doi.org/10.1016/j.nima.2009.07.091

CT polarimetry at the e+ source

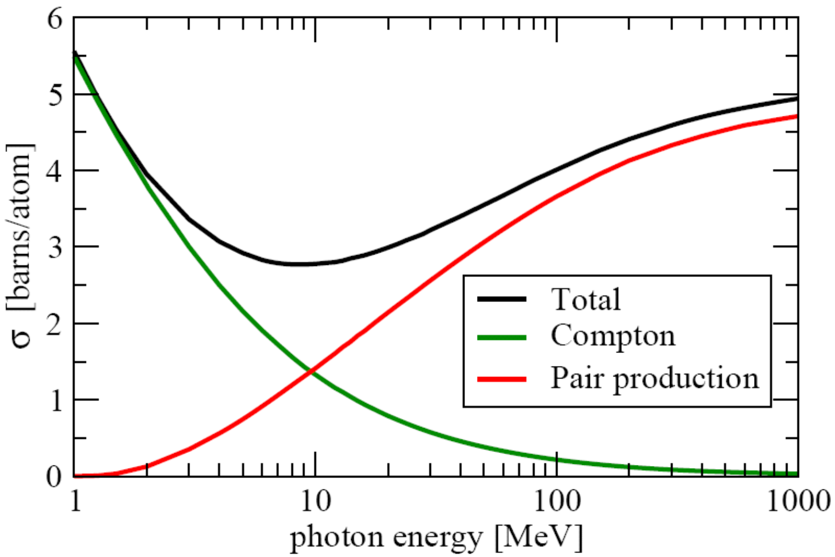
Compton transmission polarimetry at ILC

- E_{e+} = 125 MeV



Disadvantages:

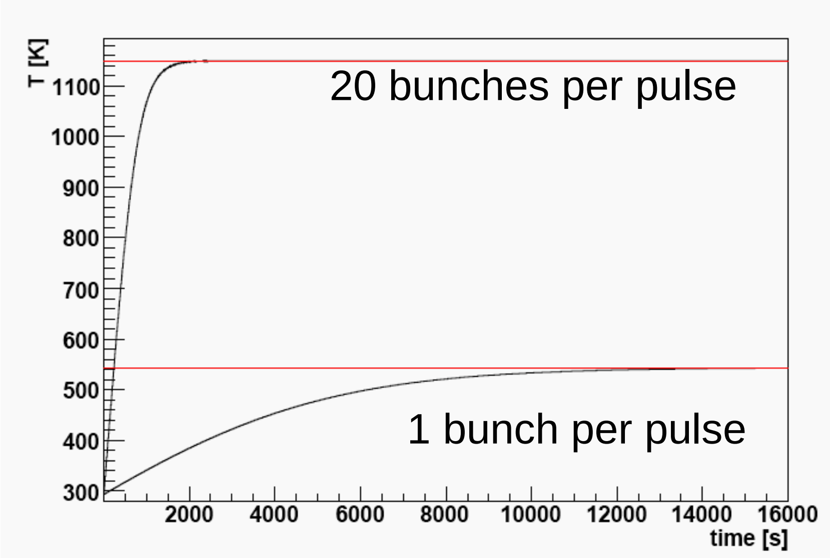
- At 125MeV Compton process is suppressed
- Method is destructive
  → only few bunches/pulse



CT polarimetry at LC

- **Heating of reconversion target:**
  power deposition in target (W, $2X_0$) and iron absorber ➔ only few bunches (1 bunch) for polarization measurement
  → fast kicker needed

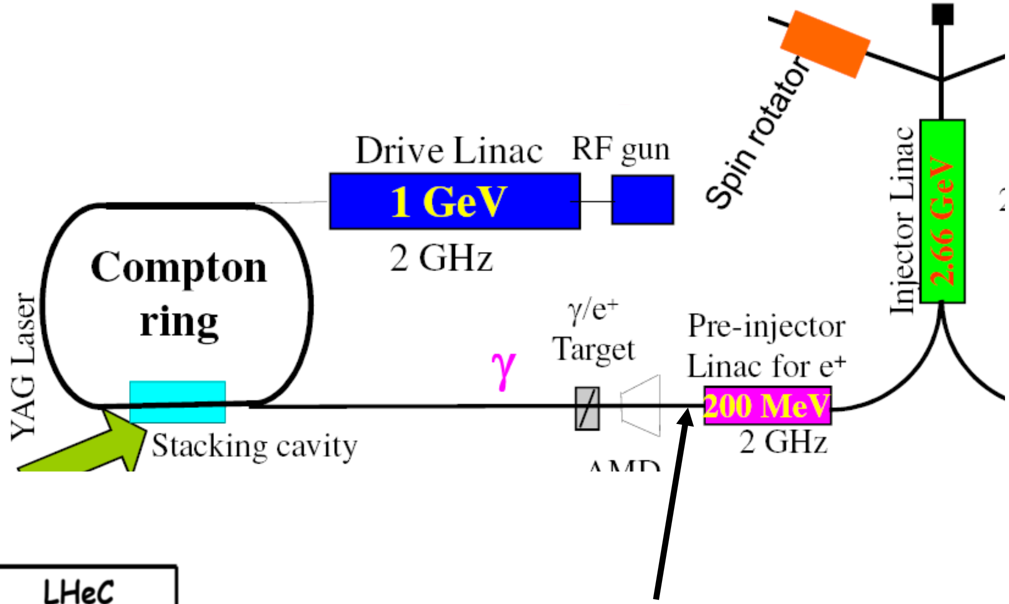
	Positron beam energy [MeV]	material	thickness [X_0 / mm]	E_{dep} per e^+ [MeV/1e^+]
Target	35	W	2.0 / 7.0	22.4
Absorber		Fe	26.7 / 150	6.9
Target	125	W	2.0 / 7.0	38.1
Absorber		Fe	26.7 / 150	61.6



- **Precision:**
  Intense beam → sufficient statistics,
  precision <10% after few pulses

➔ Compton transmission polarimetry is possible, but not the preferred solution

CT polarimetry at CLIC



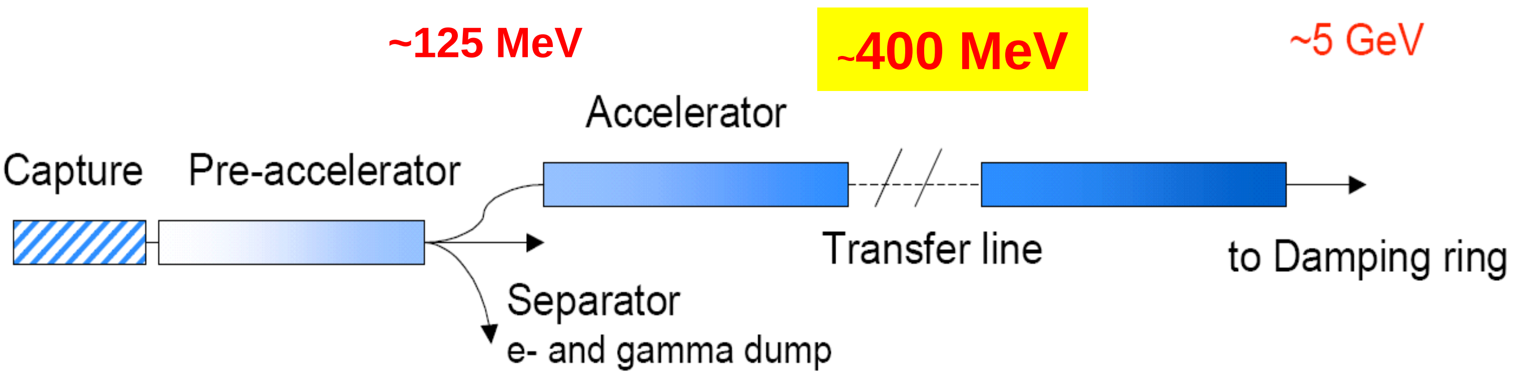
e+ flux (Rinolfi)

	SLC	CLIC	ILC	LHeC
e^+/ bunch	3.5×10^{10}	0.64×10^{10}	2×10^{10}	1.5×10^{10}
Bunches / macropulse	1	312	2625	20833
Macropulse Rep. Rate.	120	50	5	10
e^+ / second	0.042×10^{14}	1×10^{14}	2.6×10^{14}	31×10^{14}

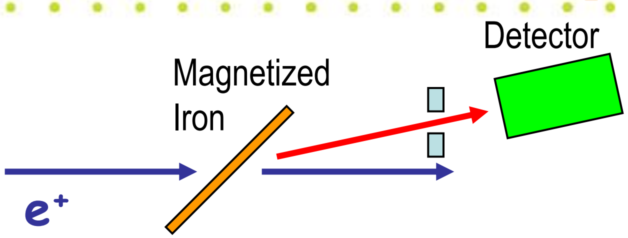
Compton transmission with selected bunches

→ kicker needed

Bhabha Polarimeter



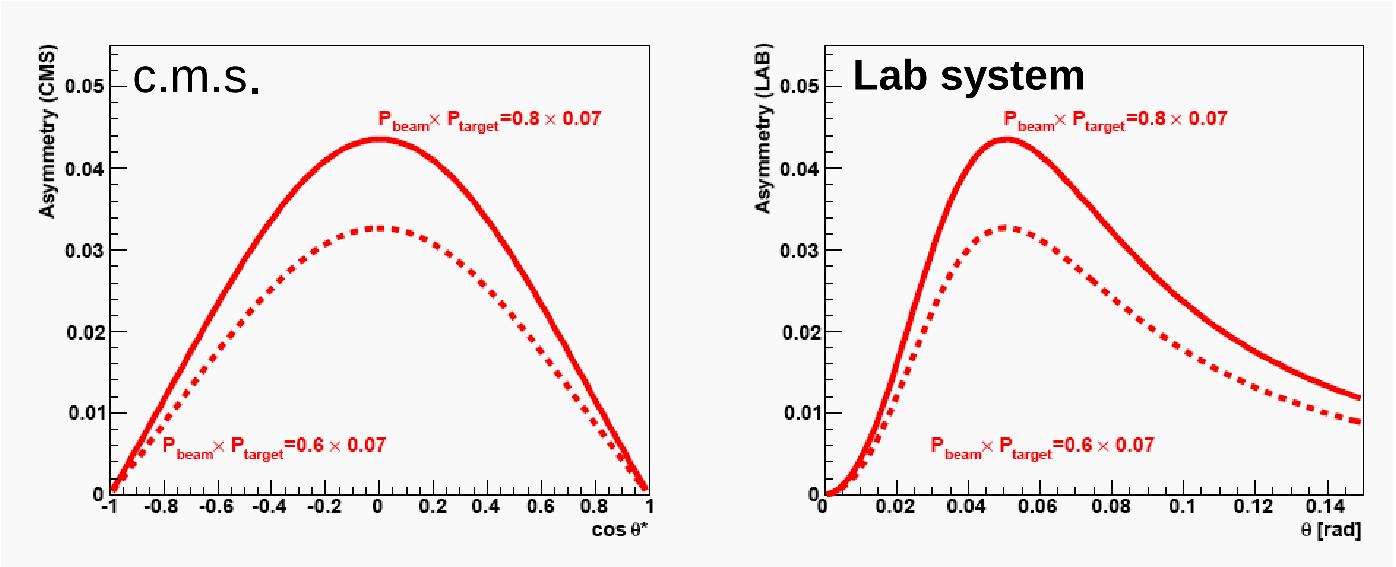
Bhabha Polarimetry



Cross section:

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

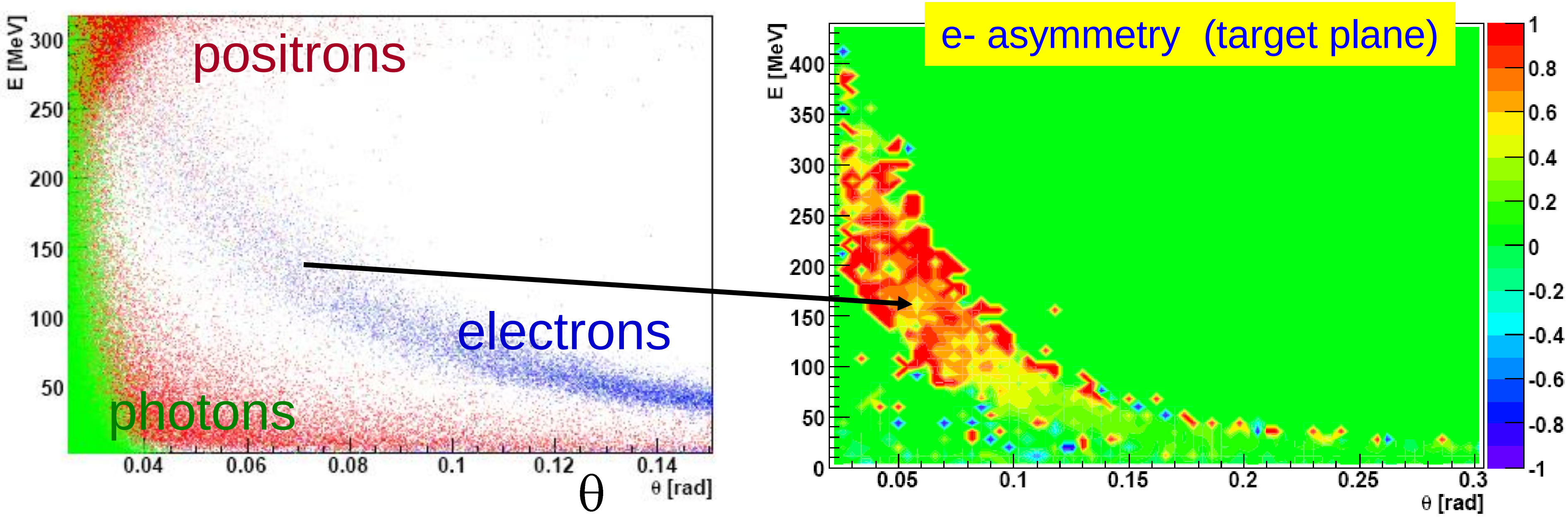
- e+ and e- must be polarized
- maximal asymmetry at 90°(CMS) ~ 7/9 ≈ 78 %



Example:
P_{e+}= 80%,
P_{e-}= 7%

A_{max} ~ 4.4 %

Bhabha Polarimetry@400MeV

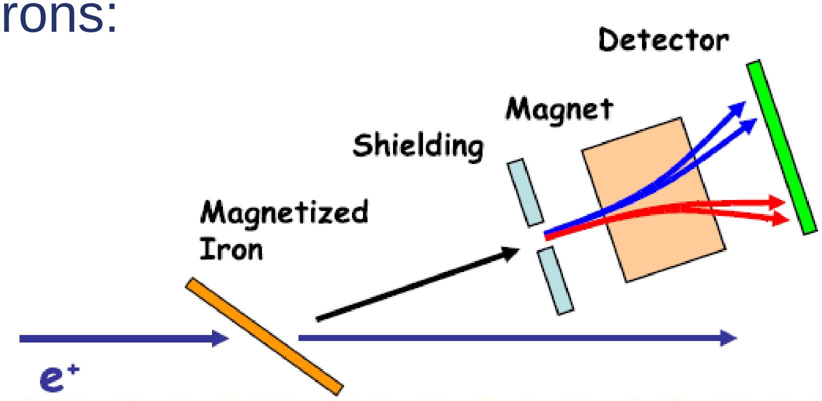


Selection of scattered electrons and positrons:

- $0.05 < \theta < 0.09$rad (mask)
- 100MeV < E < 300 MeV (spectrometer)

Reverse polarization in target foil

→ Asymmetry ~ P(e+)

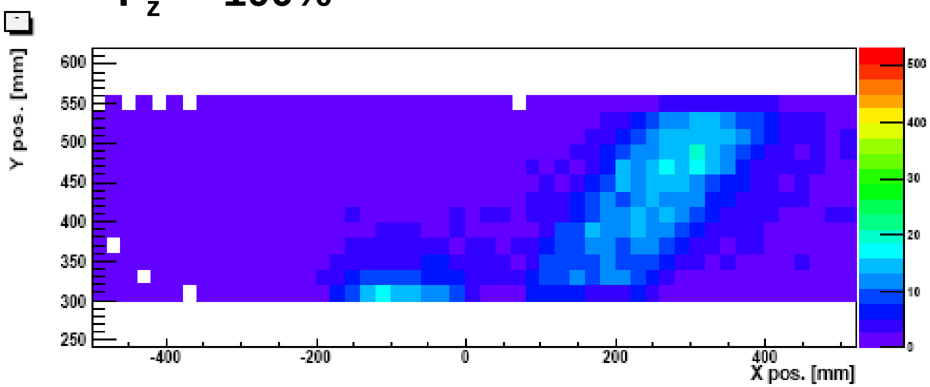


Bhabha Pol.: asymmetry measurement

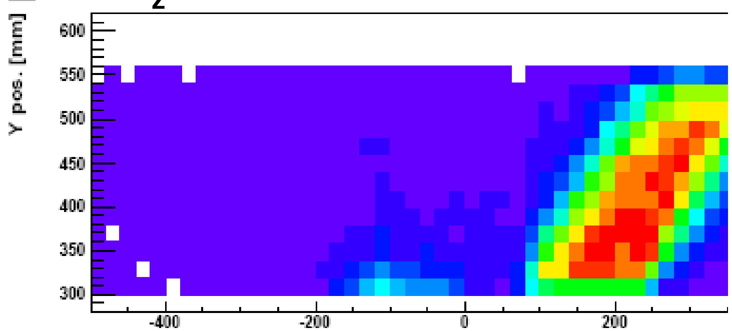
- 30 µm magnetized Fe foil
- E_{beam} = 400 MeV (±3.5%)
- Angular spread: 0.5º
- 100% e+ and e- polarisation

e^- distribution (detector plane)

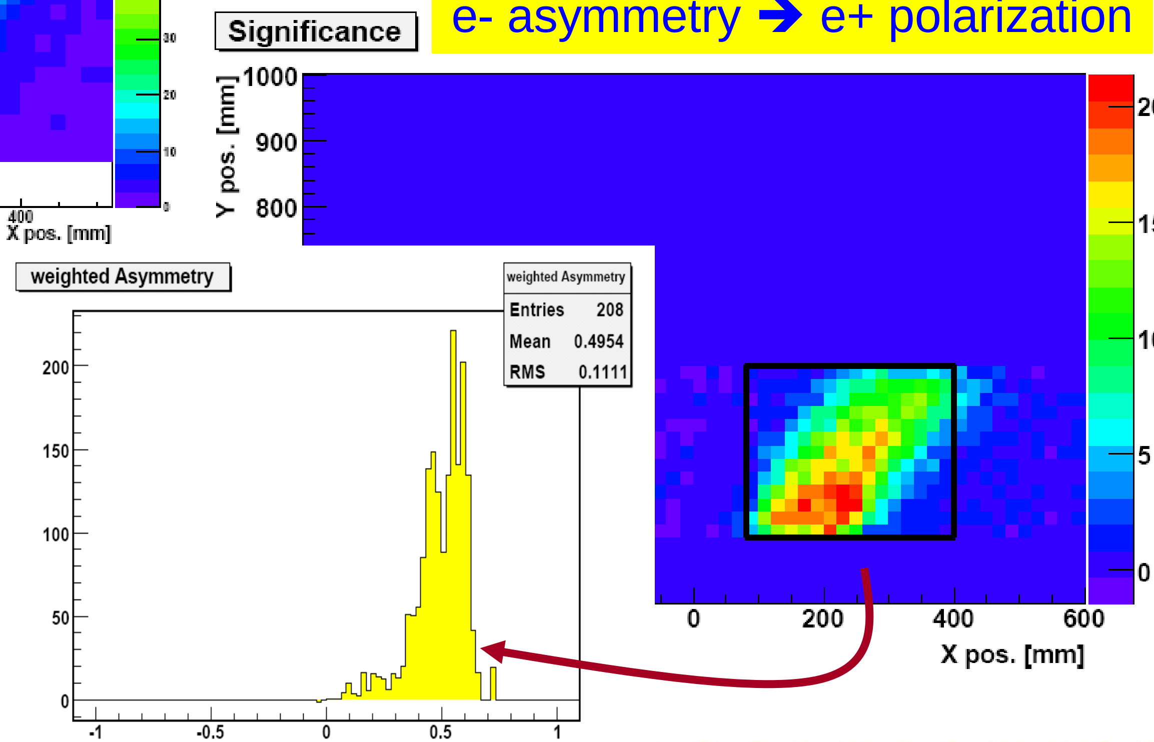
P_z = -100%



P_z = +100%

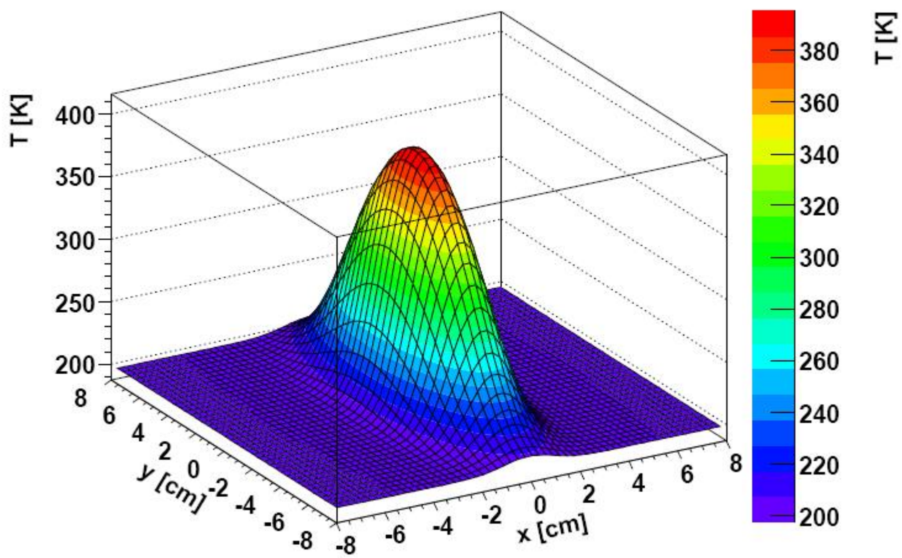


e- asymmetry ➔ e+ polarization

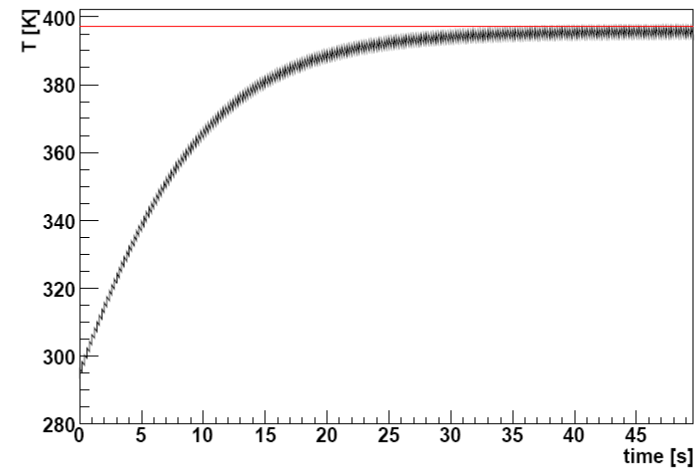


Bhabha target heating

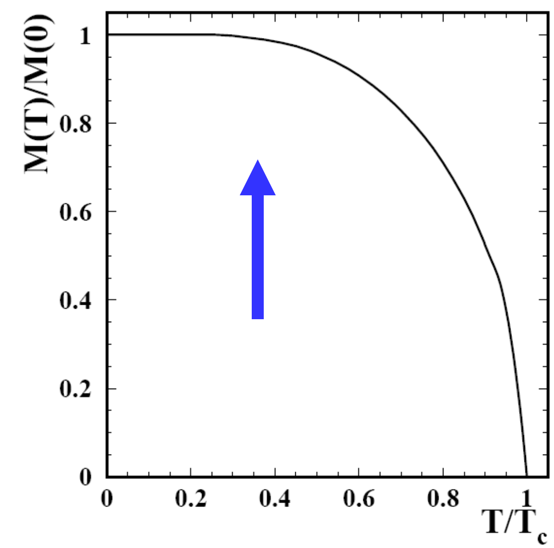
Peak temperature in iron foil (30μm)



time dependence



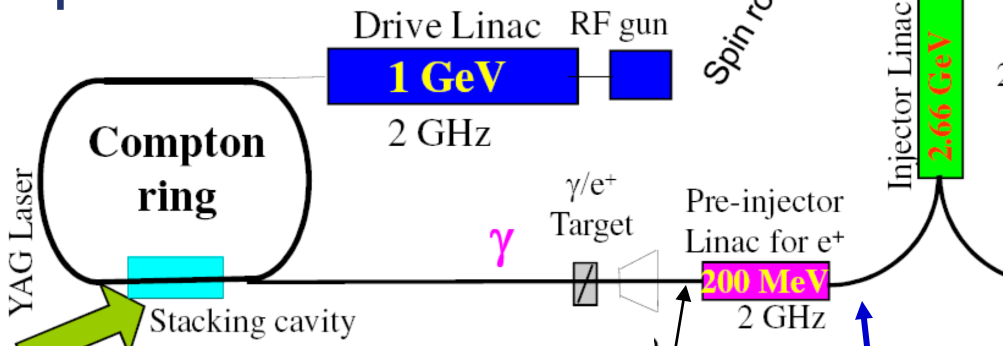
Magnetization of iron foil
depends on temperature
➔ Only small reduction of P_{Fe}



Emittance growth (ILC): 1.3% (σ=1.0cm)
5.2% (σ=0.5cm)

Bhabha polarimeter at CLIC

polarized e+



Compton transmission

with selected bunches

Bhabha polarimeter

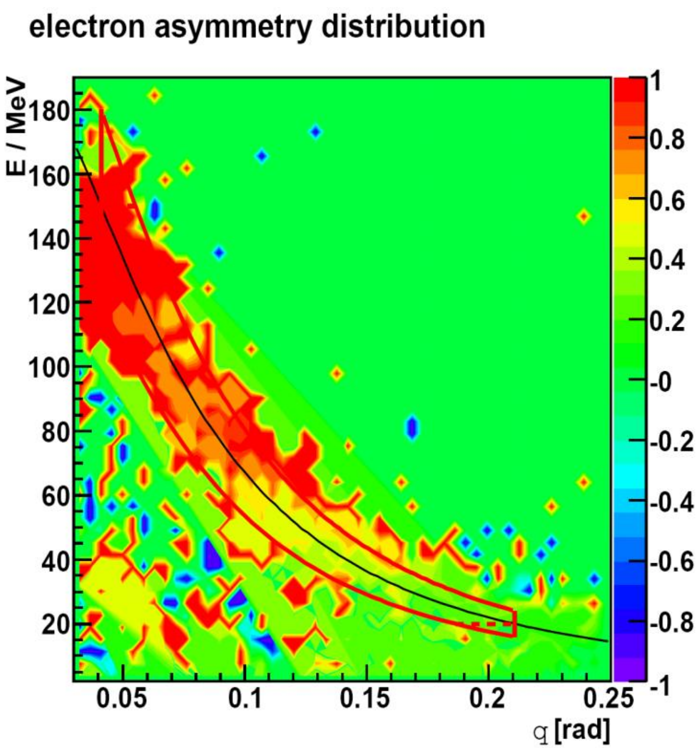
at 200 MeV

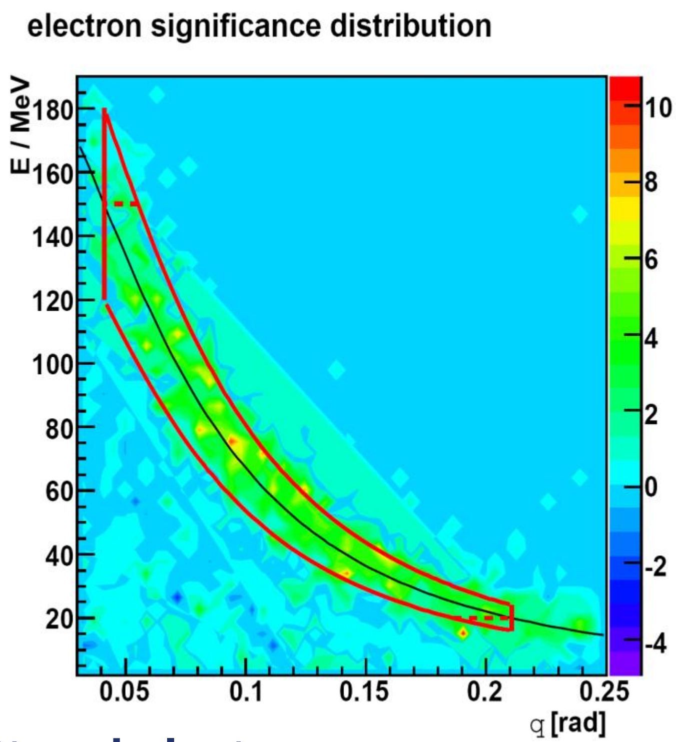
upstream spin rotator

Bhabha Polarimeter @ 200 MeV

- G4 Simulation
  - E_{e+} 200 MeV
  - Target 30 µm Fe

Significance S: $S = \frac{A}{\Delta A}$





asymmetry measurement with scattered electrons

Energy range: 30 – 150 MeV

cosθ: 0.04 ~ 0.2 rad

- Target heating at CLIC less than at ILC (assuming beam sizes as at ILC)

	SLC	CLIC	ILC	LHeC
e^+/ bunch	3.5×10^{10}	0.64×10^{10}	2×10^{10}	1.5×10^{10}
Bunches / macropulse	1	312	2625	20833
Macropulse Rep. Rate.	120	50	5	10
e^+ / second	0.042×10^{14}	1×10^{14}	2.6×10^{14}	31×10^{14}

Bhabha polarimetry at CLIC, 200 MeV, is possible

- reversal of photon beam polarization by switching polarity of laser light

→ Control of systematic effects

S-Dalinac: Moller polarimeter for 50-120MeV electrons

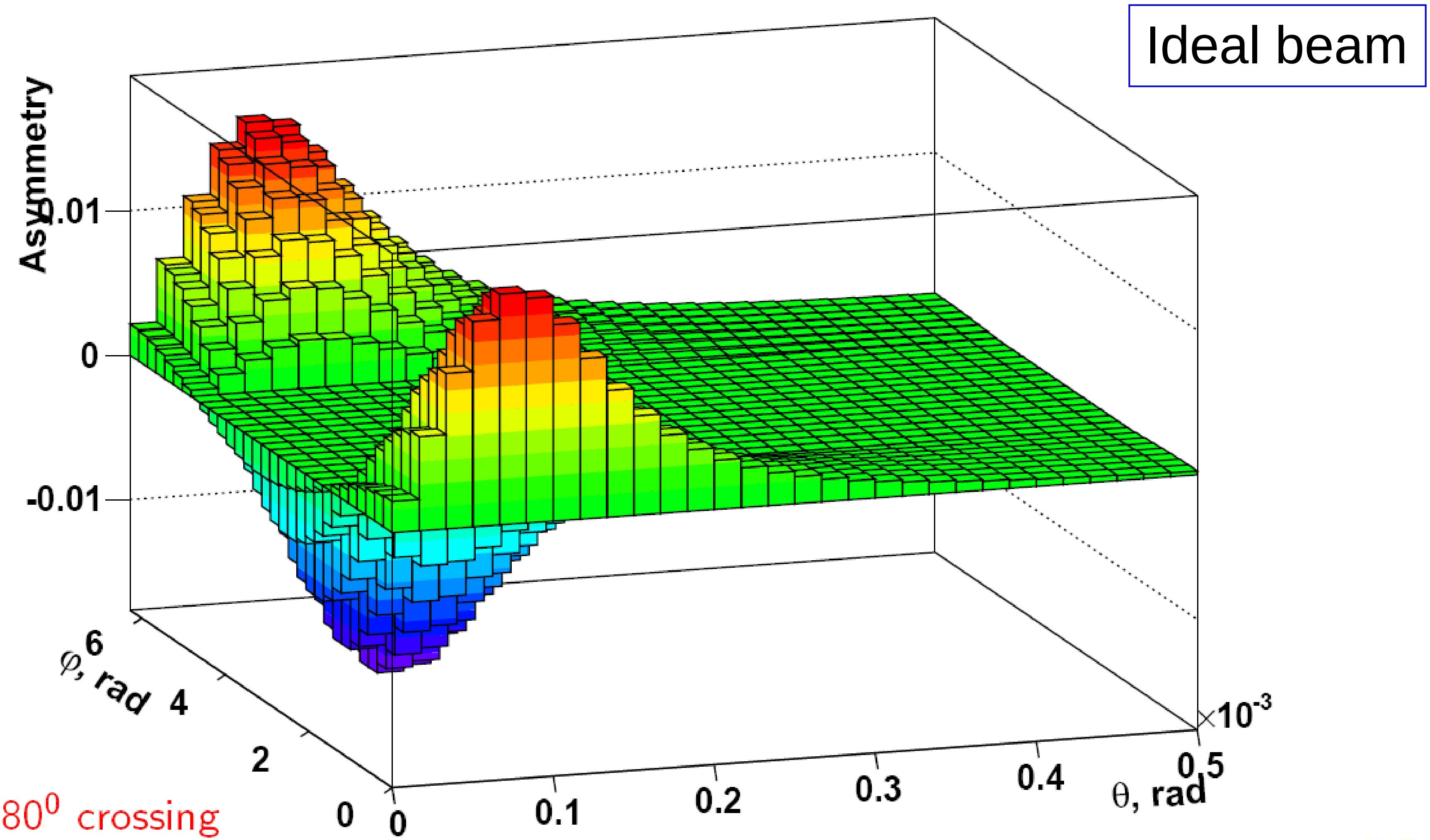
(see Barday et al., EPAC08, TUPD022)

Compton Polarimetry downstream DR

Compton polarimetry is only efficient for small beam sizes → downstream the damping ring

- Considerations for 5 GeV
  - see G. Alexander, P. Starovoitov, LC-M-2007-014
  - **Fast measurement for ~π crossing angle between e and γ**
  - **Combination with laser wire?**
    - e beam size larger than laser beam waist → not a good solution
  - **Measurement of transverse polarization downstream DR**
    - Luminosity and cross section are the same as for longitudinal polarization
    - Very small asymmetry ~ 1-2%
    - Detector has to resolve the φ dependence of asymmetry ⇔ to measure the shift of the center of the backscattered photon spatial distribution
  - **Similar measurements at currently performed at ELSA (E = 1.2-3GeV);** see Hillert, Aurand, Wittschen, "Compton Polarimetry at ELSA", **[AIP Conf. Proc. -- August 4, 2009 -- Volume 1149, pp. 1160-1164 (SPIN2008)]**

Asymmetry due to transverse positron beam polarisation



180^0 crossing

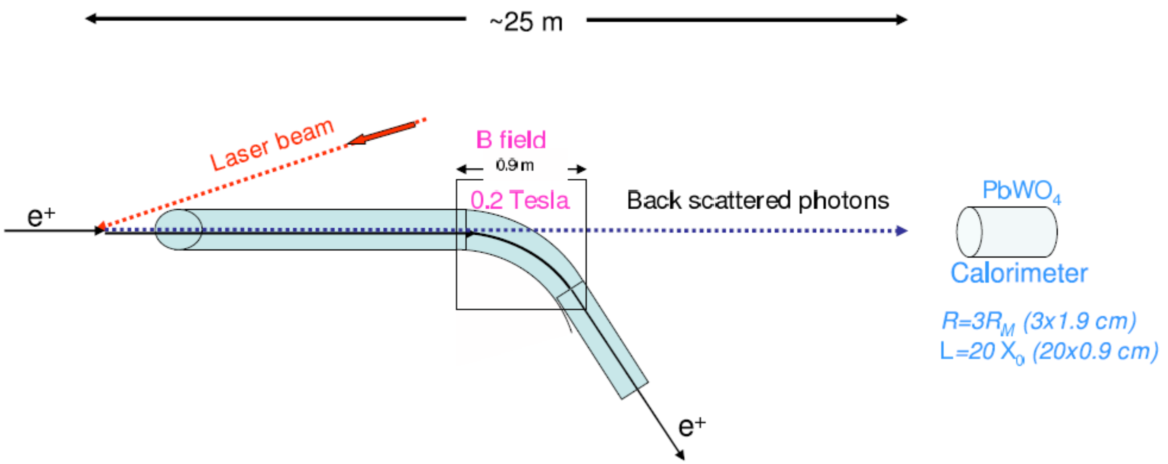
Summary

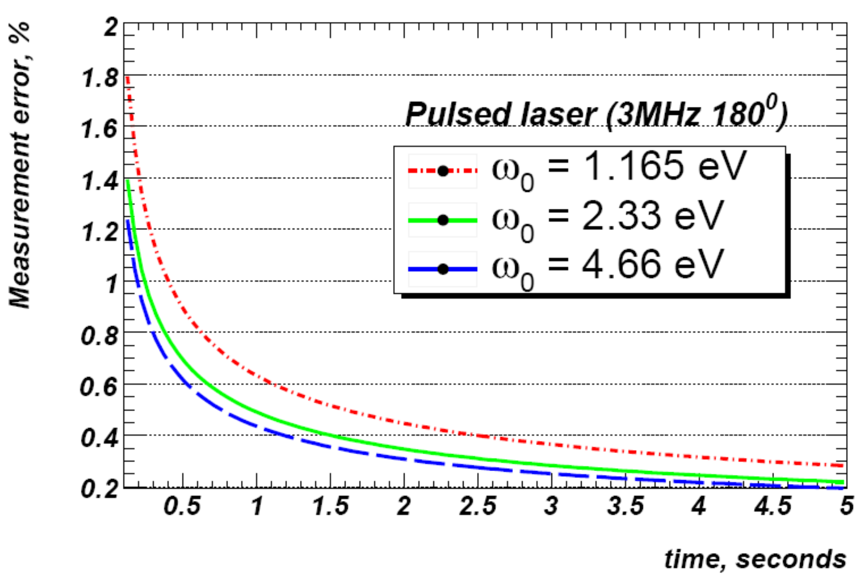
- Polarimetry at e- source: Mott polarimeter
- Polarimetry at e+ source:
  - **Compton transmission (E ~ 125 MeV)**
    - destructive
    - very few bunches can be used for measurement (kicker)
  - **Bhabha (~400 MeV at ILC, 200 MeV for CLIC) ⇔ recommended**
  - **Compton downstream DR**
    - Where is it needed (depolarization) ? Positron spin tracking studies at CLIC to be done
    - It is more difficult to measure the transverse polarization

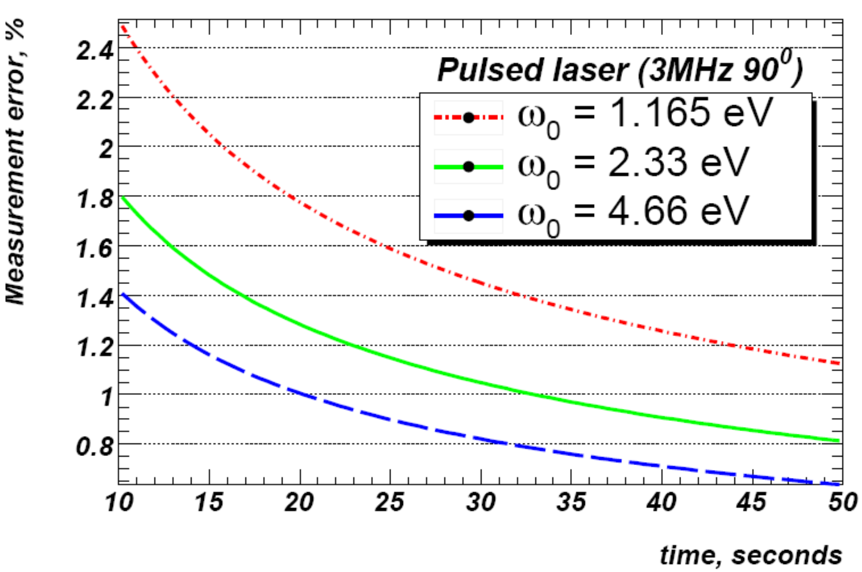
  → Details of e+ polarimeter design will depend on LC design
- Polarimetry at IP: Compton ($\delta P/P$ ~0.25%)
- So far, there is no low energy e+ polarimeter in the LC design

Backup

Compton polarimeter @ 5 GeV







Method	e+ Energy		precision	
Compton transmission	125 MeV	Destructive → use only very few bunches per pulse	Stat: few %; Syst. will dominate	Prototype (E166,) ILC design Simulations
Bhabha	>200 MeV	Almost non-destructive	Stat: few %; Syst. will dominate	ILC design Simulations
Compton	5 GeV (after DR)	Non-destructive	Stat: few %; Syst. will dominate	ILC design simulations