Prototype for an Undulator-based Source for Polarised Positrons for a Linear Collider: Project E-166 (LC-DET-2003-044)

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1. The experiment E-166
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3. Motivation and Layout of E-166
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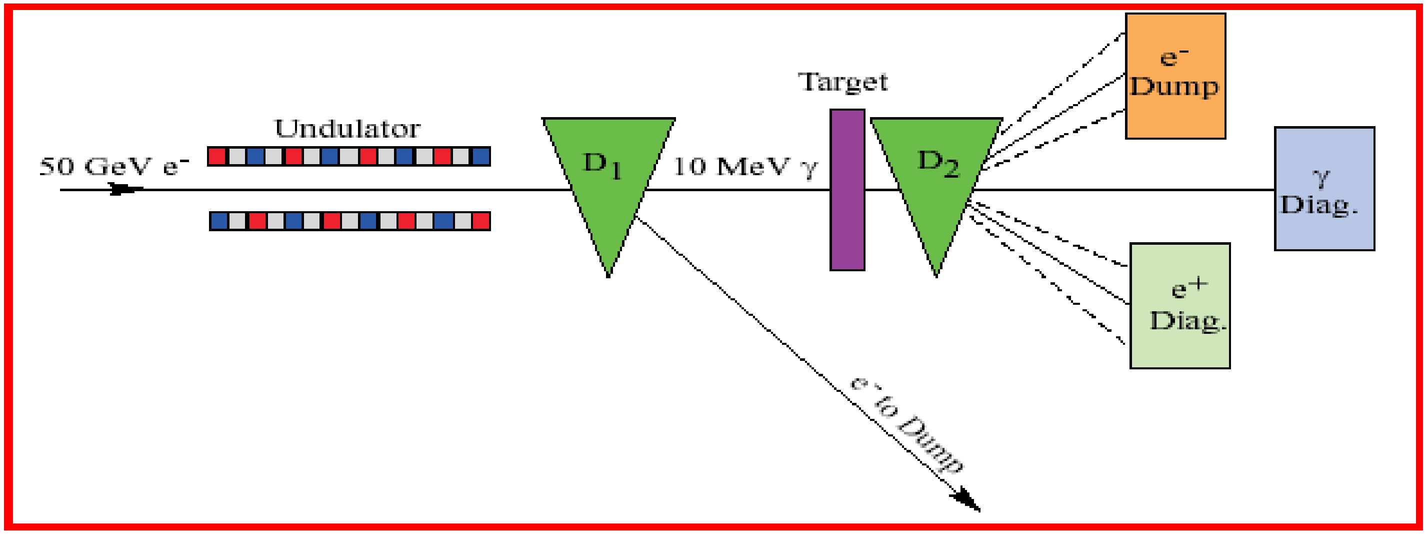
5. Next steps: E-166 and the way ahead towards pol. beams at a LC

E-166 Experiment

E-166 is a demonstration of undulator–based polarised positron production for linear colliders



- E-166 uses the 50 GeV, low emittance FFTB@SLAC in conjunction with a 1 m-long, 2.4 mm period helical undulator ($K = 0.17$) to make polarised photons with 0-10 MeV
- These photons are converted in a ~ 0.5 rad. length thick target into polarised positrons
- The polarisation of the positrons and photons will be measured
- Performance expectations are for positron polarisation of about 60%

Undulator-Based Production of Polarised positrons
E-166 Collaboration

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⇒ 46 Collaborators from 15 Institutions:

Brunel, CERN, Cornell,DESY, Durham,Thomas Jefferson Lab, Humboldt, KEK, Princeton, South Carolina, SLAC, Tel Aviv, Tokyo Metropolitan, Tennessee, Waseda

1. Why do we need Polarised Positrons at a LC?

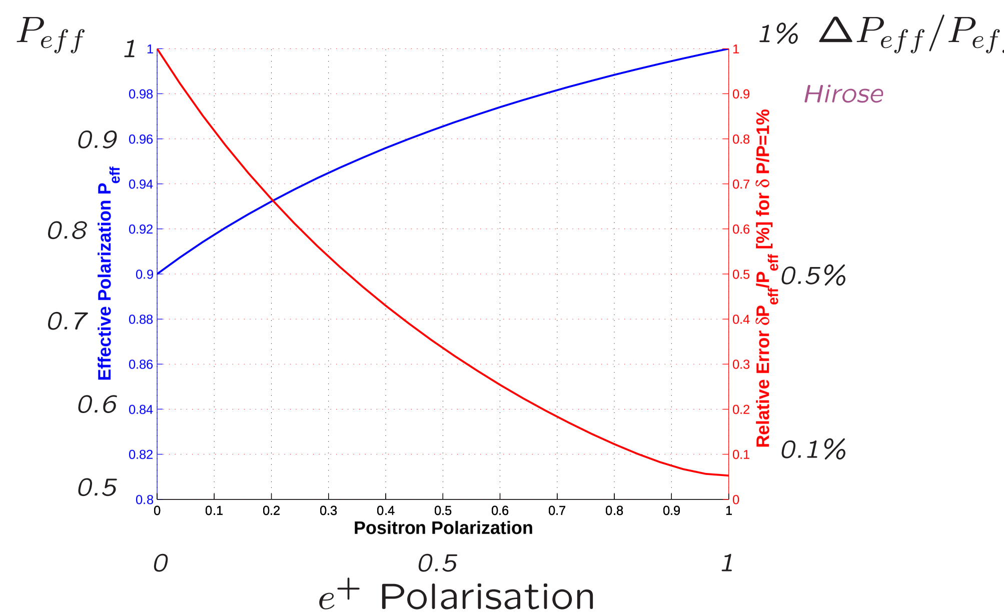
- higher eff. polarisation

  $P_{eff} = (P(e^-) - P(e^+))/(1 - P(e^-)P(e^+))$

  ($\sim$ 95% with [80%, 60%])

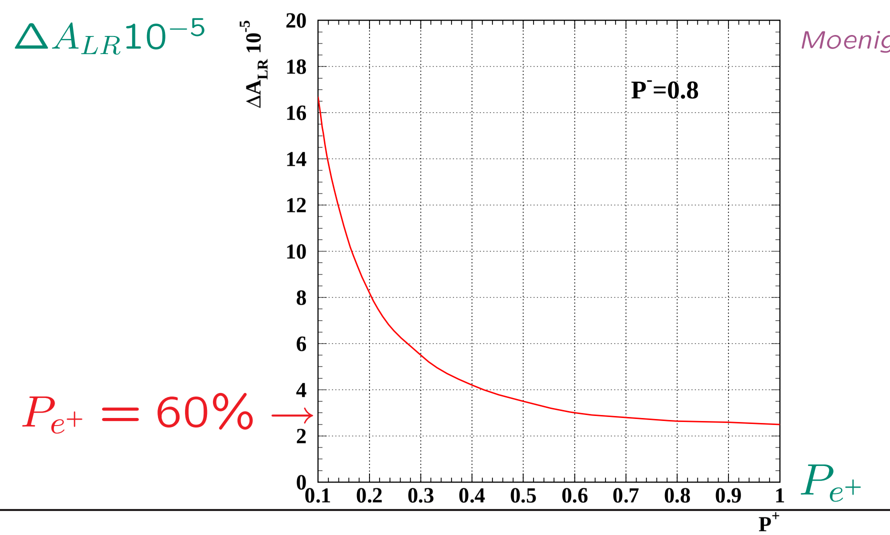
  and background suppression

$P(e^-)$	$P(e^+)$	$e^+e^- \to W^+W^-$
0	0	1.0
−0.8	0	0.2
−0.8	+0.6	0.1



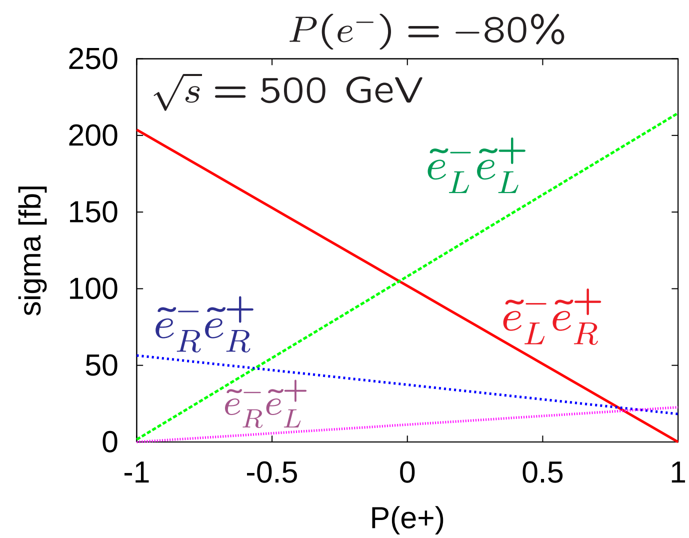
- improved accuracy in measuring polarisation ($\to$ 'Blondel Scheme')

  $\Rightarrow$ needed for high precision measurement of $\sin^2\theta^\ell_{eff}$ in $A_{LR}(e^+e^- \to Z \to f\bar{f})$



Physics Case for Polarised Positrons at a LC

- precise analysis of non–standard couplings



E.g. proof of Susy assumptions

$\Rightarrow e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$

Scalar partners $\leftrightarrow$ chiral quantum numbers!

Example:

$P(e^-) = -80\%$ but $P(e^+) = 0$: no separation!

$P(e^-) = -80\%$ and $P(e^+) = -40\%$: ratio 163 fb/66 fb!

$\Rightarrow$ Separation of $\tilde{e}^-_L \tilde{e}^+_L$ and $\tilde{e}^-_L \tilde{e}^+_R$ not possible with only $P(e^-)$!

Physics Case for Polarised Positrons at a LC

- option of using transversely polarised beams!

Rates are given by:

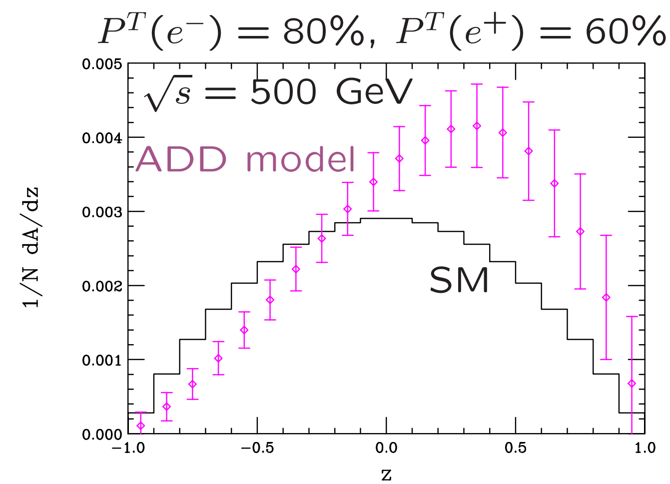
$\sigma = (1 - P_{e^+} P_{e^-}) \sigma_{unp} + (P^L_{e^-} - P^L_{e^+}) \sigma^L_{pol} + P^T_{e^-} P^T_{e^+} \sigma^T_{pol}$

$\Rightarrow$ only possible with both beam polarised!

Example:

Clear separation of different models

of new physics, of e.g. extra dimensions



Rizzo

(→ see also e.g. TESLA TDR, JLC Roadmap, Snowmass '01 Resource Book, Moortgat-Pick '03, etc.)

$\Rightarrow$ Polarised e^+ in addition to polarised e^- needed at a LC

E-166 Vis-a-vis a Polarised Linear Collider Source

⇒ E-166 is the 'proof of principle' for undulator-based positron sources

- Photons are produced in the same energy range and polarisation characteristics as for a linear collider
- The same target thickness and material are used as in the LC

Parameter	Units	TESLA	NLC	E-166
Beam Energy, E_e	GeV	150-250	150	50
N_e/bunch	-	3×10^{10}	8×10^9	1×10^10
N_{bunch}/pulse	-	2820	190	1
Pulses/s	Hz	5	120	30
Undulator Type	-	planar/helical	helical	helical
Und. Parameter, K	-	1	1	0.17
Und. Period, λ_u	cm	1.4	1.0	0.24
Und. Length, L	m	135	132	1
1^{st} Harmonic Cutoff, E_{c10}	MeV	9-25	11	9.6
dN_γ/dL	photons/m/e^-	1	2.6	0.37
Target Material	-	Ti-alloy	Ti-alloy	Ti-alloy, W
Target Thickness	rad. len.	0.4	0.5	0.5

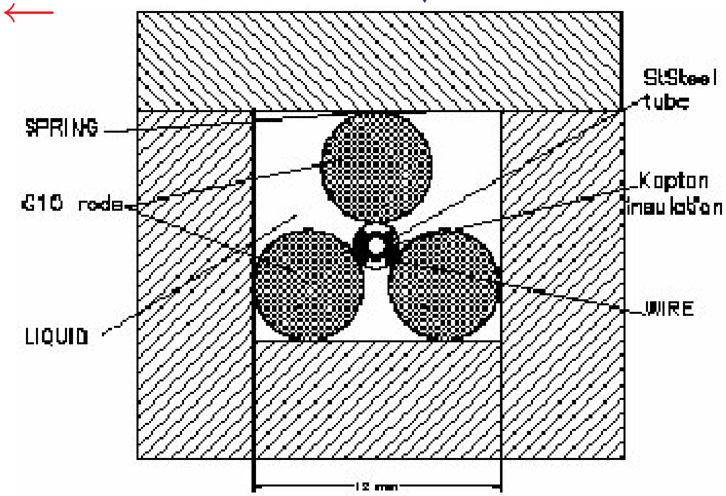
- But: e^+ intensity/pulse lower by a factor 1/2000 compared to e^+ source of a LC

E-166 Helical Undulator Design, $\lambda = 2.4$mm, $K = 0.17$

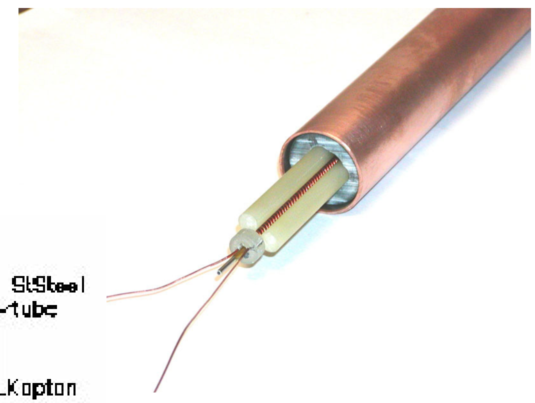
- 'Pulsed Helical Undulator for Test@SLAC the polarised positron production scheme. Basic description', A.A. Mikhailichenko

Parameter	Units	Value
Number of Undulators	-	1
Length	m	1.0
Inner Diameter	mm	0.89
Period	mm	2.4
Field	kG	7.6
Undulator Parameter, K	-	0.17
Current	Amps	2300
Peak Voltage	Volts	540
Pulse Width	μs	30
Inductance	H	0.9x10^{-6}
Wire Type	-	Cu
Wire Diameter	mm	0.6
Resistance	ohms	0.110
Repetition Rate	Hz	30
Power Dissipation	W	260
ΔT/pulse	^{0}C	2.7

cross section ↓



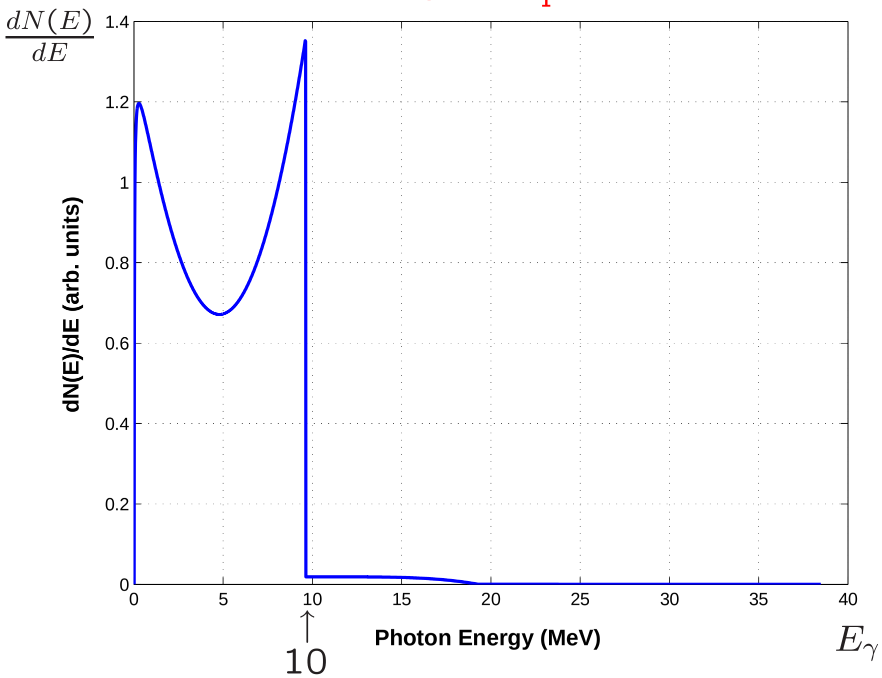
prototype →

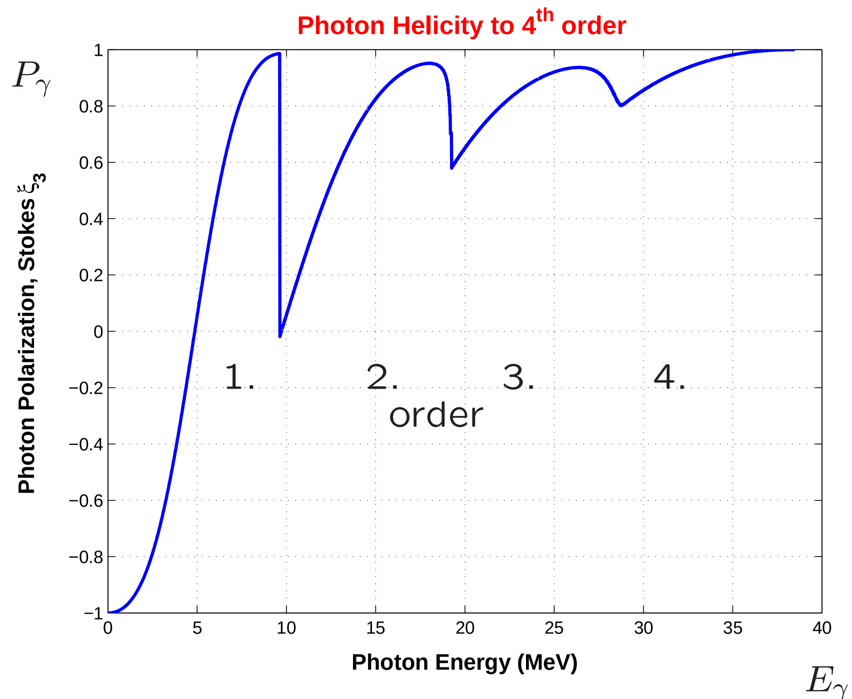


$\Rightarrow$ Undulator Radiation: $\frac{dN_\gamma}{dL} = \frac{30.6}{\lambda_u[\text{mm}]}\frac{K^2}{1+K^2}\text{photons}/m/e^- = 0.37\,\text{photons}/e^-$

$\Rightarrow$ Circ. pol. photons with $E_{c10} = 24[\text{MeV}]\frac{(E_e/50[\text{GeV}])^2}{\lambda_u[\text{mm}](1+K^2)} = 9.6$ MeV

Photon Spectrum and Polarisation of Undulator Radiation

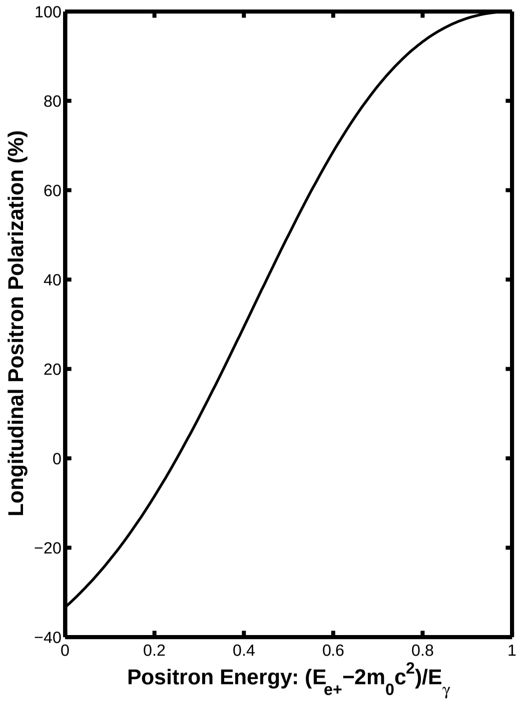


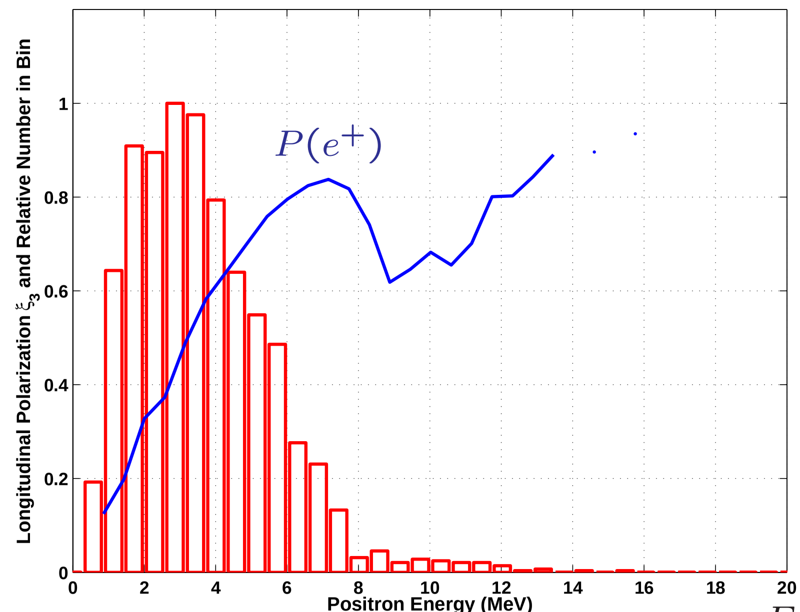


⇒ Photon intensity spectrum of undulator radiation with $E_e = 50$ GeV, $\lambda_u = 2.4$ mm, $K = 0.17$

⇒ First harmonic peak: $E_{c10} = 9.62$ MeV

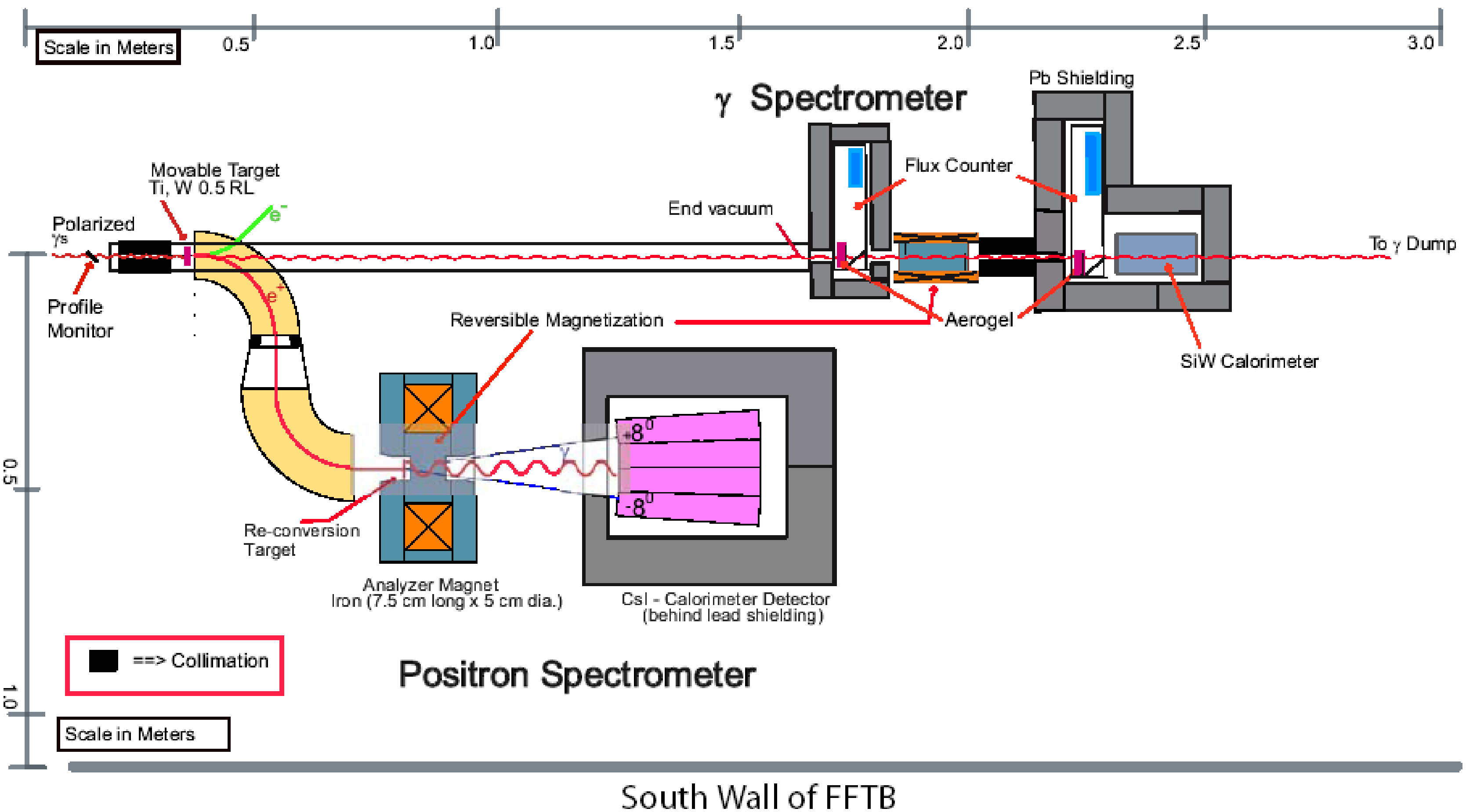
Polarisation Transfer: circular pol. $\gamma \rightarrow$ long. pol. e^+





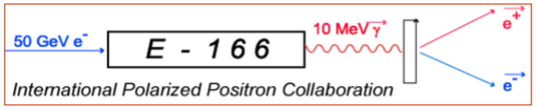
- Long. polarisation of $P(e^+) = 54\%$ averaged over full spectrum

Polarimetry@E-166: Overview



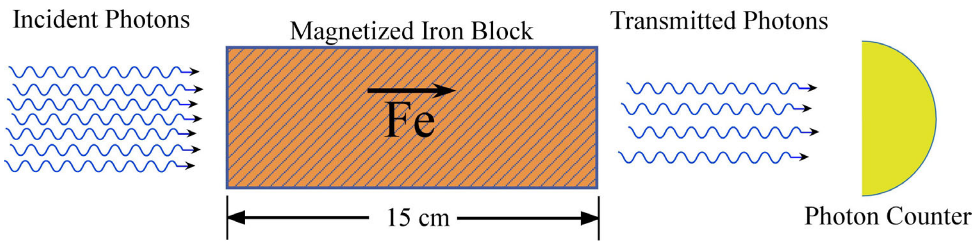
⇒ Polarisation of $P(\gamma)$ and $P(e^+)$ will be measured: $P(e^+) \sim 60\%$ expected

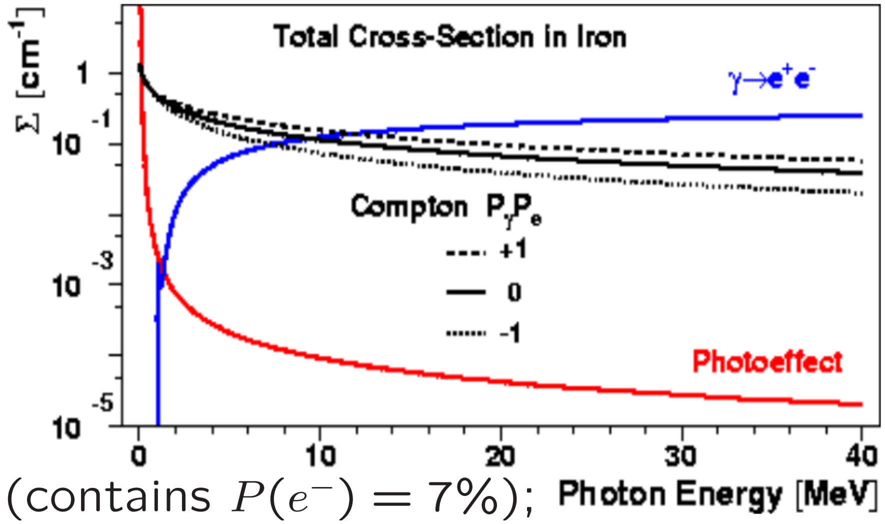
⇒ Polarimetry precision of 5% will be sufficient



Transmission Polarimetry of Photons and Positrons

M Goldhaber, 1957





Transmission method for γ Polarimetry:

- Pass pol. γ through magnetised iron cylinder (contains $P(e^-) = 7\%$); measure trans. γ signal as the direction of magnetisation is modulated by reversing an external magnetic field
- Three physical processes: photo effect, Compton scattering, pair production
- Only Compton scattering has useful spin dependence

Transmission Method for e^+ Polarimetry: 2–step process

- reconversion of $e^+ \to \gamma$
- apply γ transmission polarimetry:
  $\to$ infer e^+ polarisation from measured γ polarisation

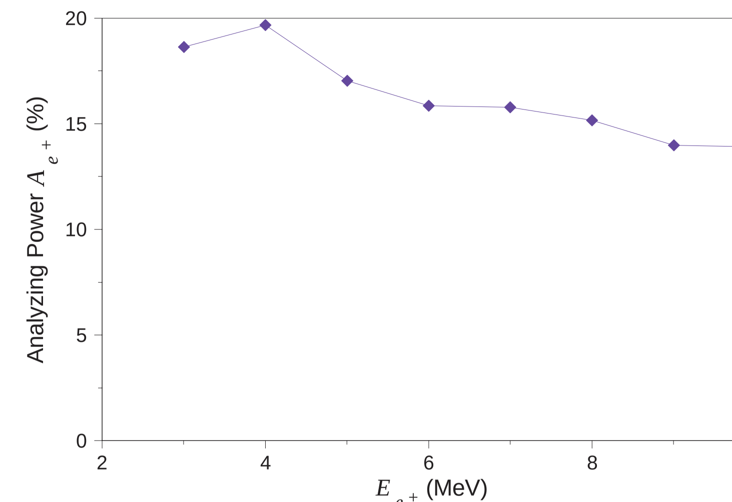
Polarimetry Simulation Results and Expected Errors

Geant simulation: 7.5 cm iron absorber, Cs I cal., $P(e^-) = 7\%$

Positron Energy (MeV)	Positron Pol. P_{e^-} (%)	Positron Transport Eff. ϵ_{e^+} (%)	Photon Transport Eff. ϵ_γ (%)	Photon Asym. δ (%)	Analyzing Power A_{e^-} (%)	N_γ in 15 min	15 min Abs.Error ΔP_{e^-} (%)
3	42	1.5	0.045	0.55	18.6	3.7×10^6	4.0
4	61	1.9	0.078	0.84	19.7	8.0×10^6	2.6
5	69	2.1	0.12	0.82	17.0	1.45×10^7	2.2
6	78	2.3	0.20	0.87	15.9	2.44×10^7	1.8
7	84	1.7	0.28	0.93	15.8	2.59×10^7	1.6
8	77	0.9	0.38	0.82	15.0	1.86×10^7	2.2
9	64	0.4	0.50	0.63	14.0	1.09×10^7	3.1
10	68	0.3	0.64	0.66	13.9	1.04×10^7	3.2

$\delta \uparrow$ $A_e \uparrow$

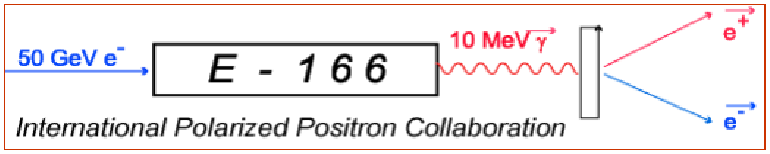
$A_{e^+} = \delta(L)/P(e^-)P(e^+)$



E_{e^+}/MeV

- Transmission polarimetry is well-suited for E-166
- Analysing power is sufficiently large and robust in simulations

$\Rightarrow$ Expected systematic errors of $\Delta(P)/P \sim 5\%$ dominated by eff. magnetisation of iron



Summary

- Physics case for the use of polarised e^+ well motivated!
- E-166 is a 'proof of principle' demonstration of undulator based production of polarised e^+ for a LC
- Polarisation characteristics of γ and e^+ will be measured
- Precision of polarimetry of $\sim 5\%$ with transmission method is sufficient

W. Pauli →

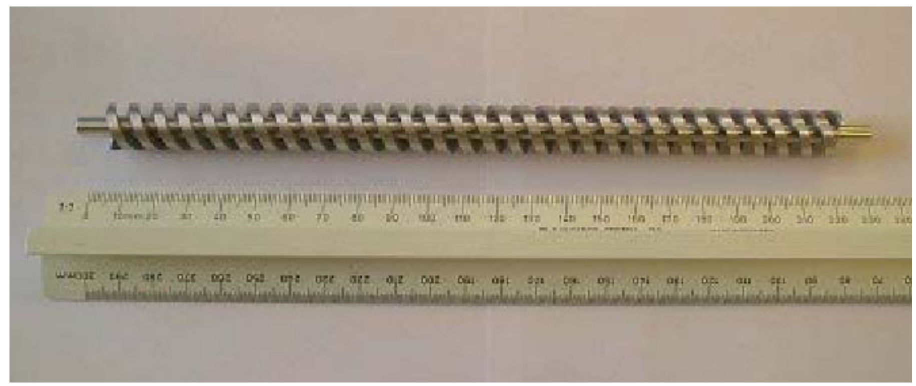
← P. Dirac

Outlook

- Schedule for E-166: 6 weeks of work at FFTB@SLAC in 2004/2005
  → principle approval in June 2003
  a few background questions still open, but do not worry,
  some shielding needed, background studies will be finished in 2003

Other LC Polarisation Activities

- ASTeC@Daresbury: construction of a prototype for a ∼30 cm s.c. helical undulator with 14 mm period, 4 mm aperture, K=1
  → could be tested at TTF2 in 2004



- And last but not least: next POWER meeting in Oct'03@SLAC
  → Further news, please look at: http://www.ippp.dur.ac.uk/˜gudrid/power/

⇒ A lot of interesting LC R&D in the polarisation business, don't miss it!