Isolating systematic effects with beam polarisation at e+e− colliders

Jakob Beyer

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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

Universität Hamburg
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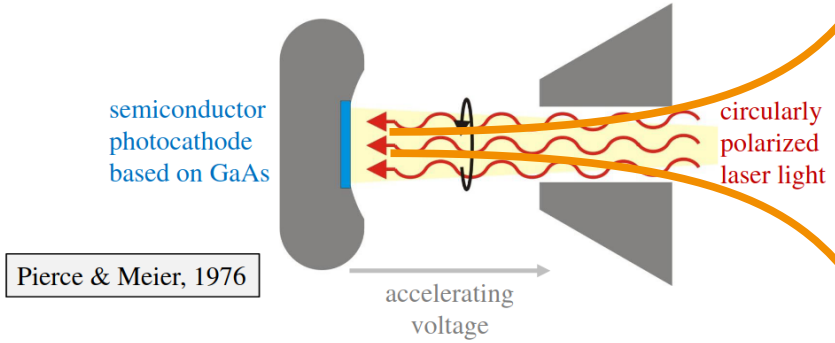
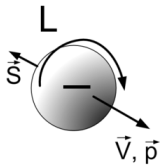
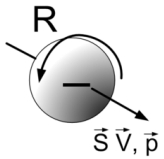
CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

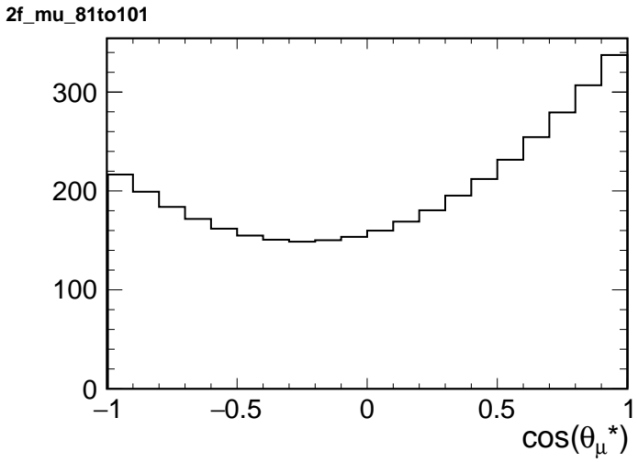
Beam polarisation: Defined spin direction

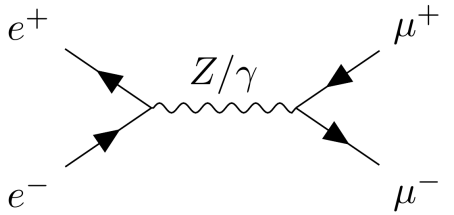


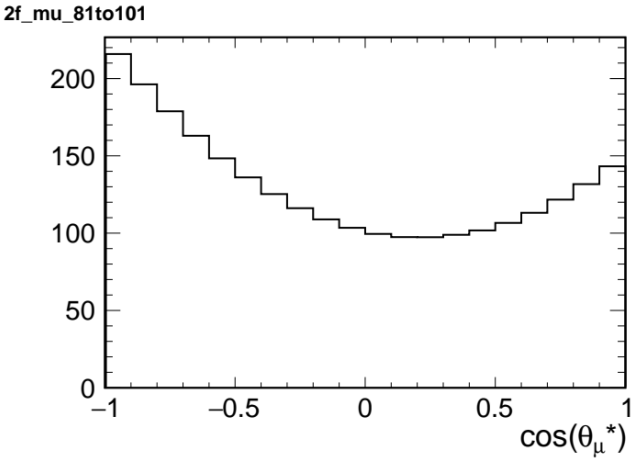
Pierce & Meier, 1976



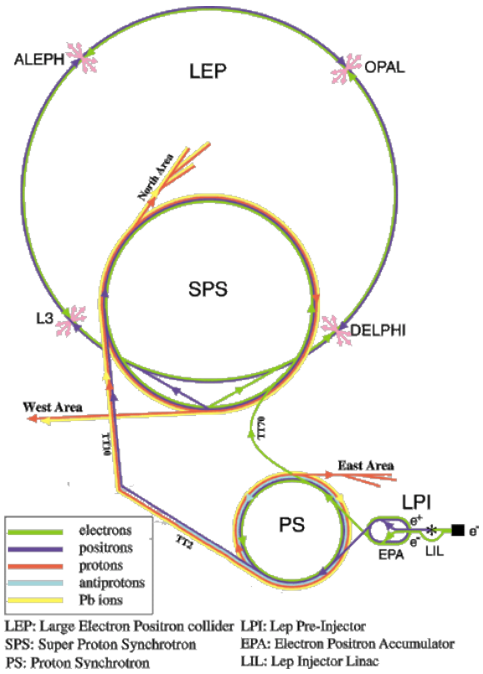


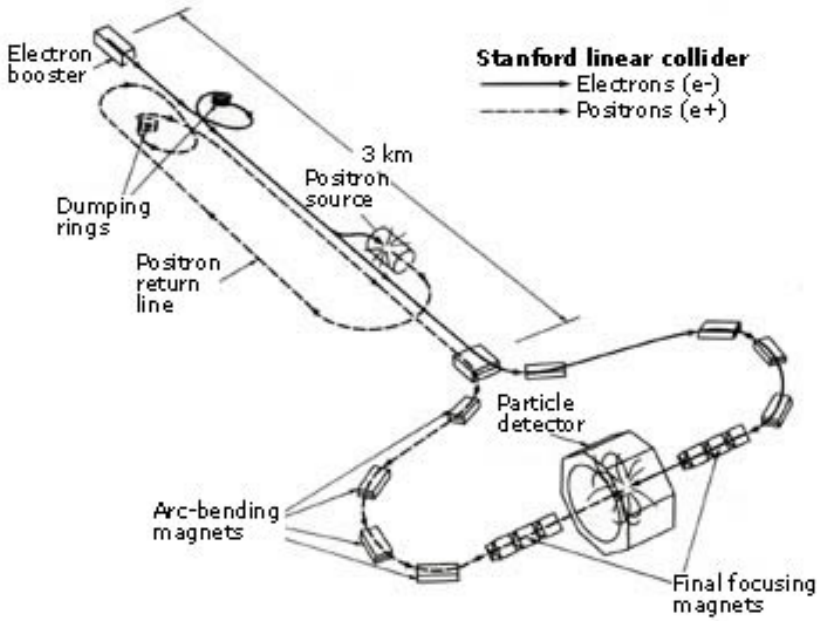






DESY.





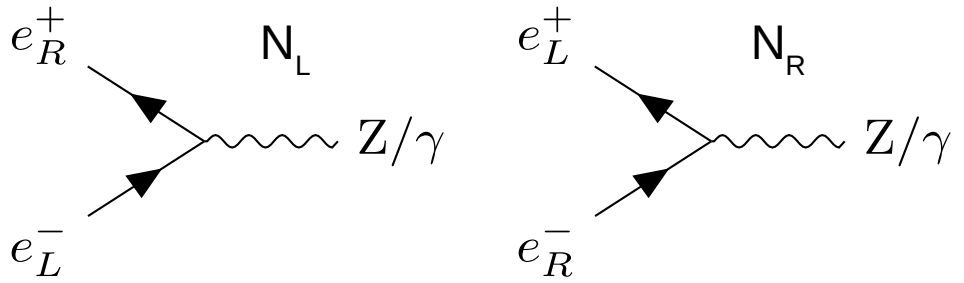
LEP

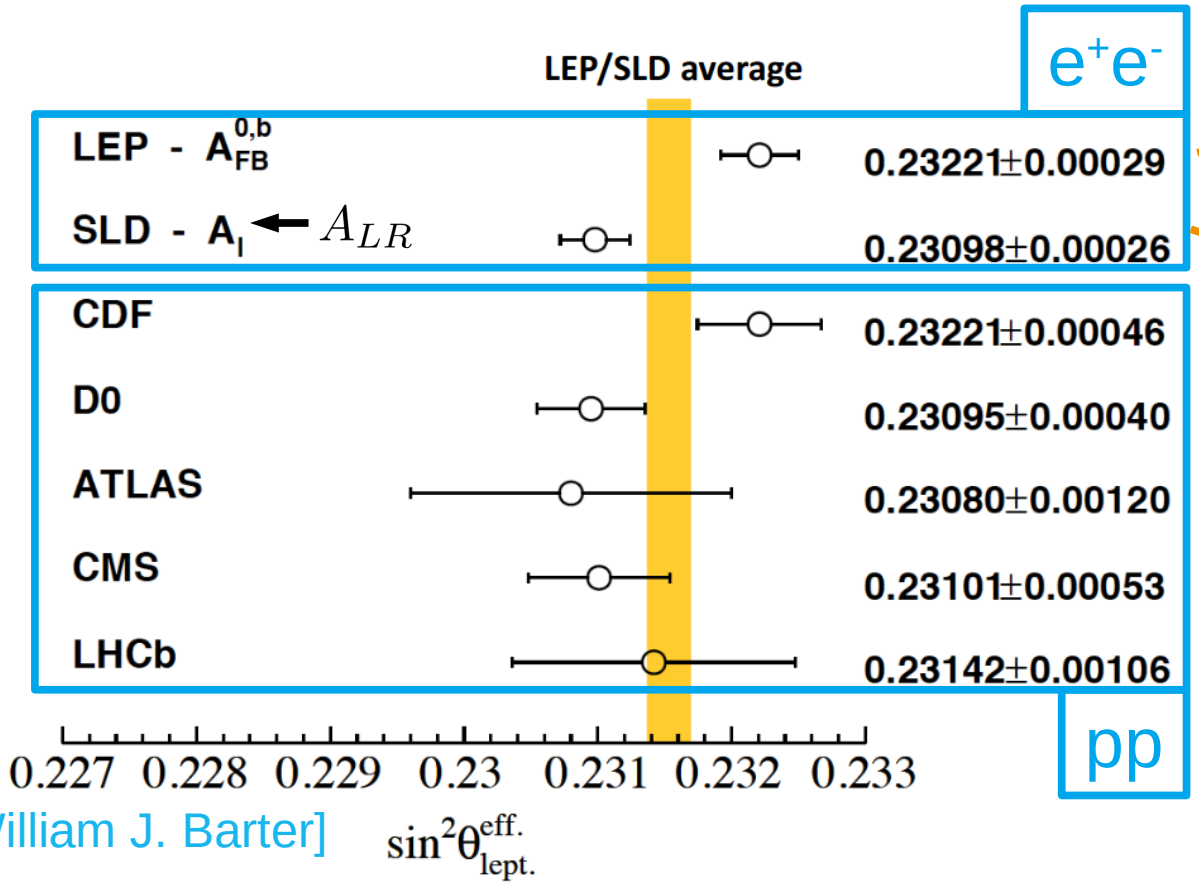
- Unpolarised
- > 15M Z events

SLC

- e^- beam polarised
- ~ 50k Z events

$$A_{LR} = \frac{N_L - N_R}{N_L + N_R} \sim \sin^2\theta_W$$



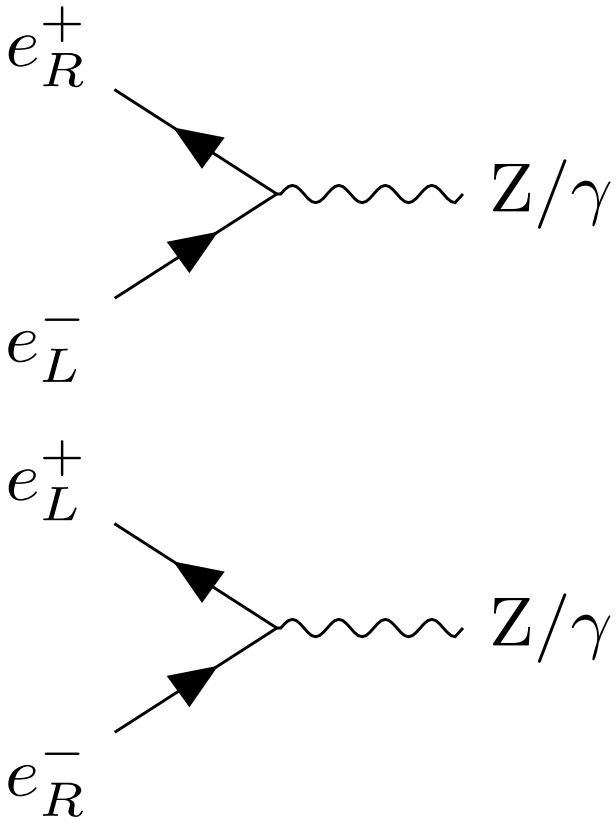


[William J. Barter]

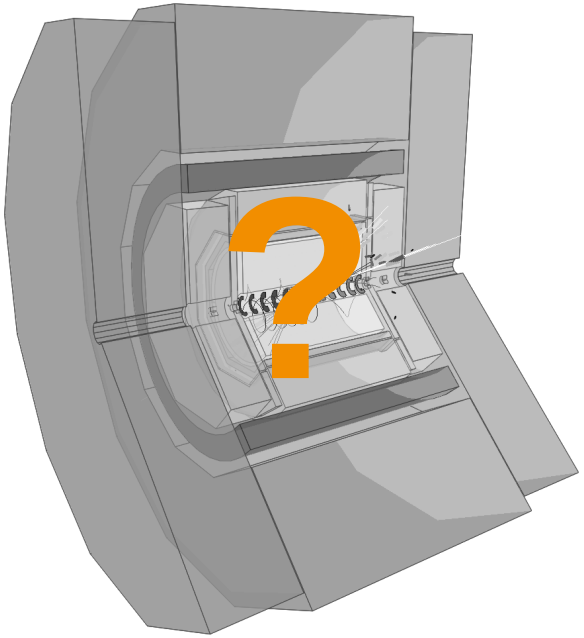
~ 300 x more events

e- polarisation

Physics ✓



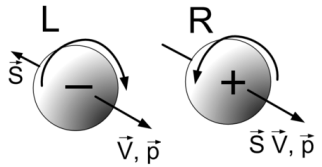
Systematics ?



So far:

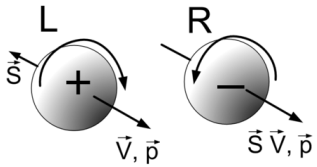
$$\Delta\mathcal{O}_{final} = \sqrt{\Delta\mathcal{O}_{stat}^2 + \Delta\mathcal{O}_{syst}^2}$$

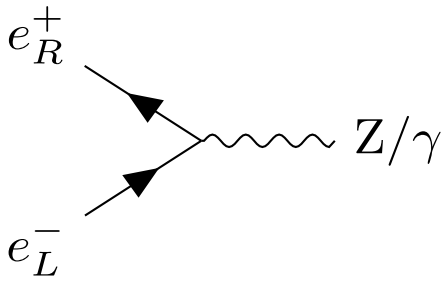
External estimation



Flipped

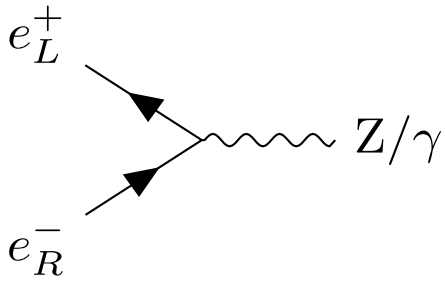
Polarisation

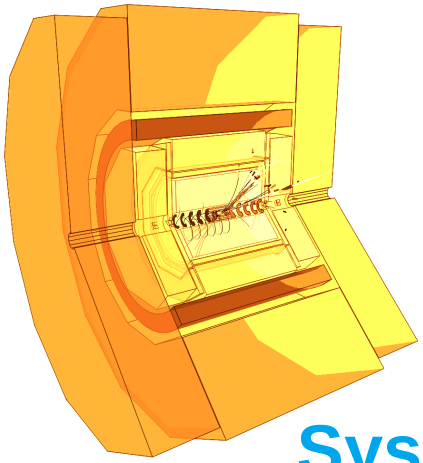




Different

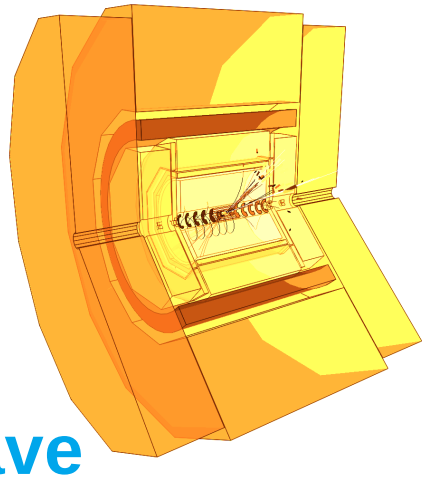
Physics



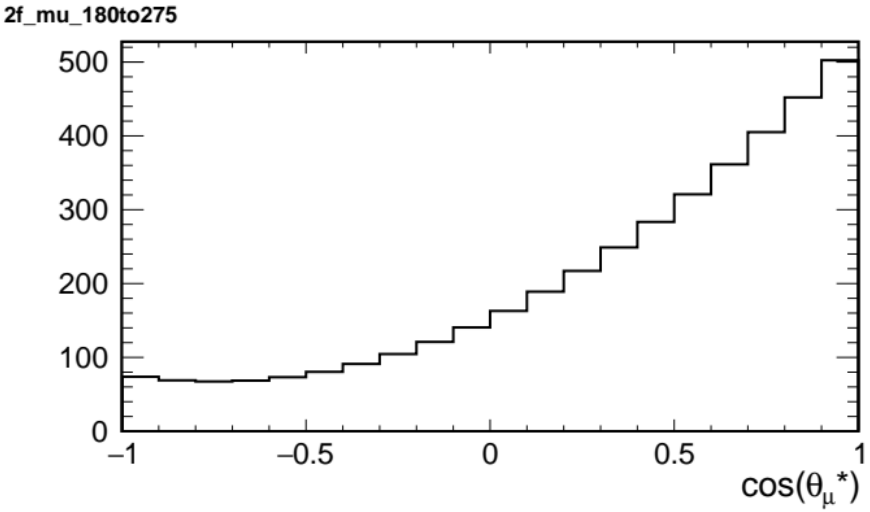


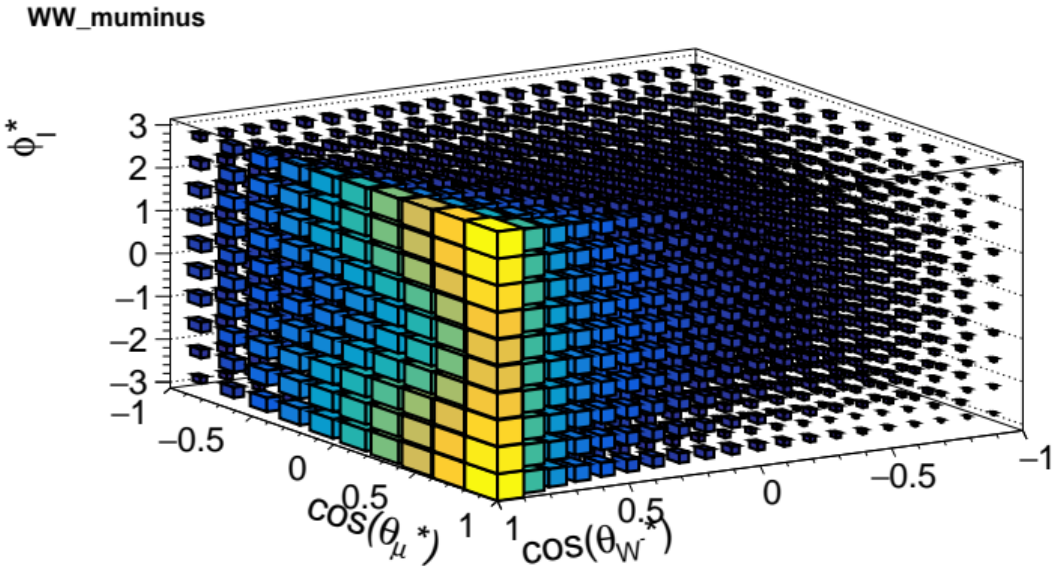
Same

Detector



Systematic effects will have uniquely global signatures if directly included in measurement!





$e^+e^- \to Z/\gamma \to \mu^+\mu^-$

Separated into
strong / weak ISR

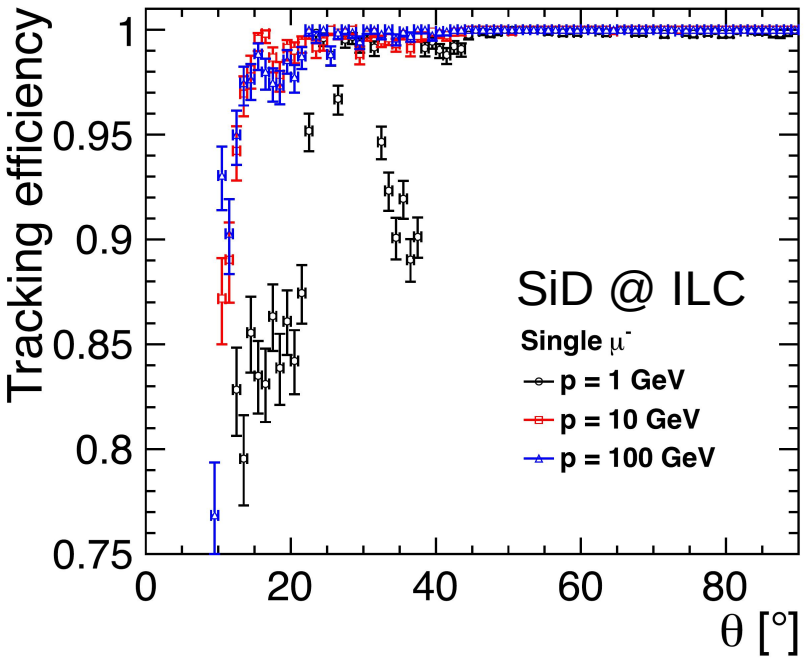
$e^+e^- \to W^+W^- \to qq\mu\nu$

Separated into
muon / anti-muon

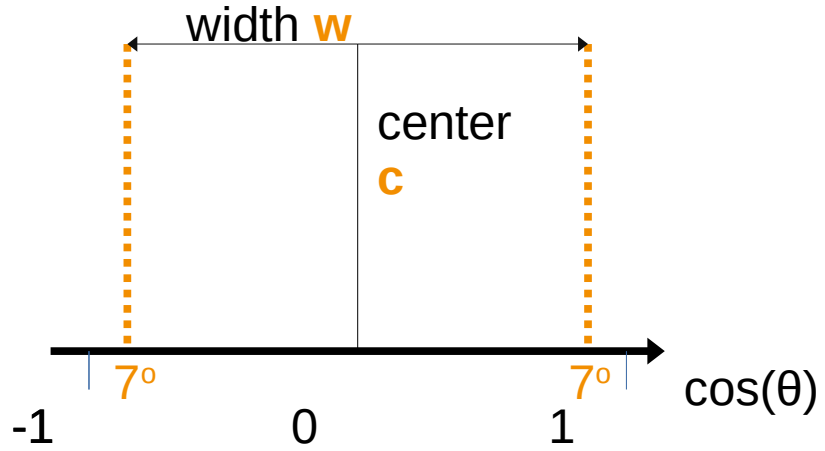
Polarised distributions

Toy fluctuated distributions
→ **Fit:** Log-Likelihood maximisation

Parametrising μ acceptance



Simplified picture:
Event passes if all μ's inside box



Each bin in fit:

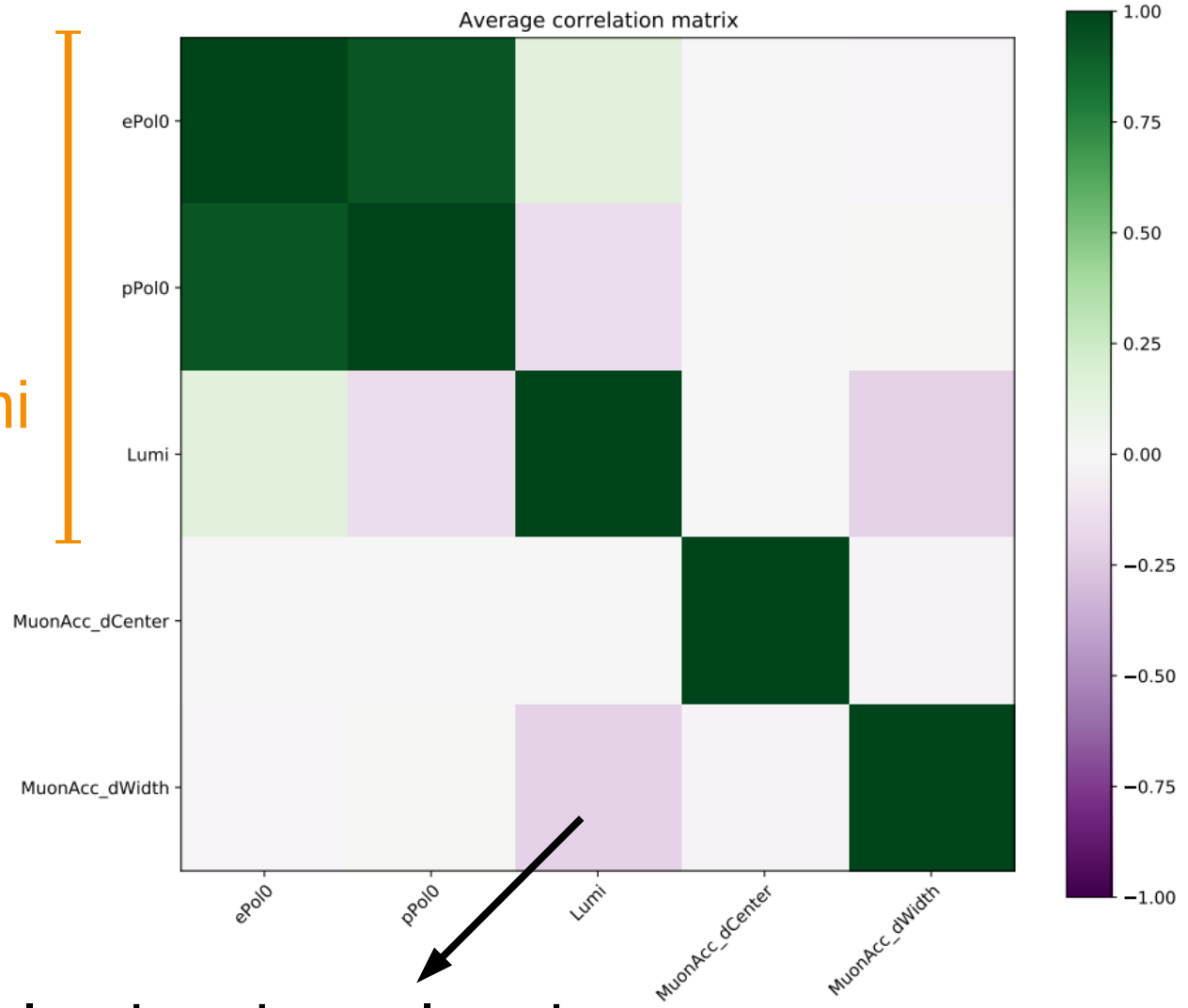
$$d\sigma/\sigma = k_0 + k_c\,\Delta c + k_w\,\Delta w + k_{c2}\,\Delta c^2 + k_{w2}\,\Delta w^2 + k_{cw}\,\Delta c\,\Delta w$$

Example:
2ab^{-1} unpolarised

Free parameters:

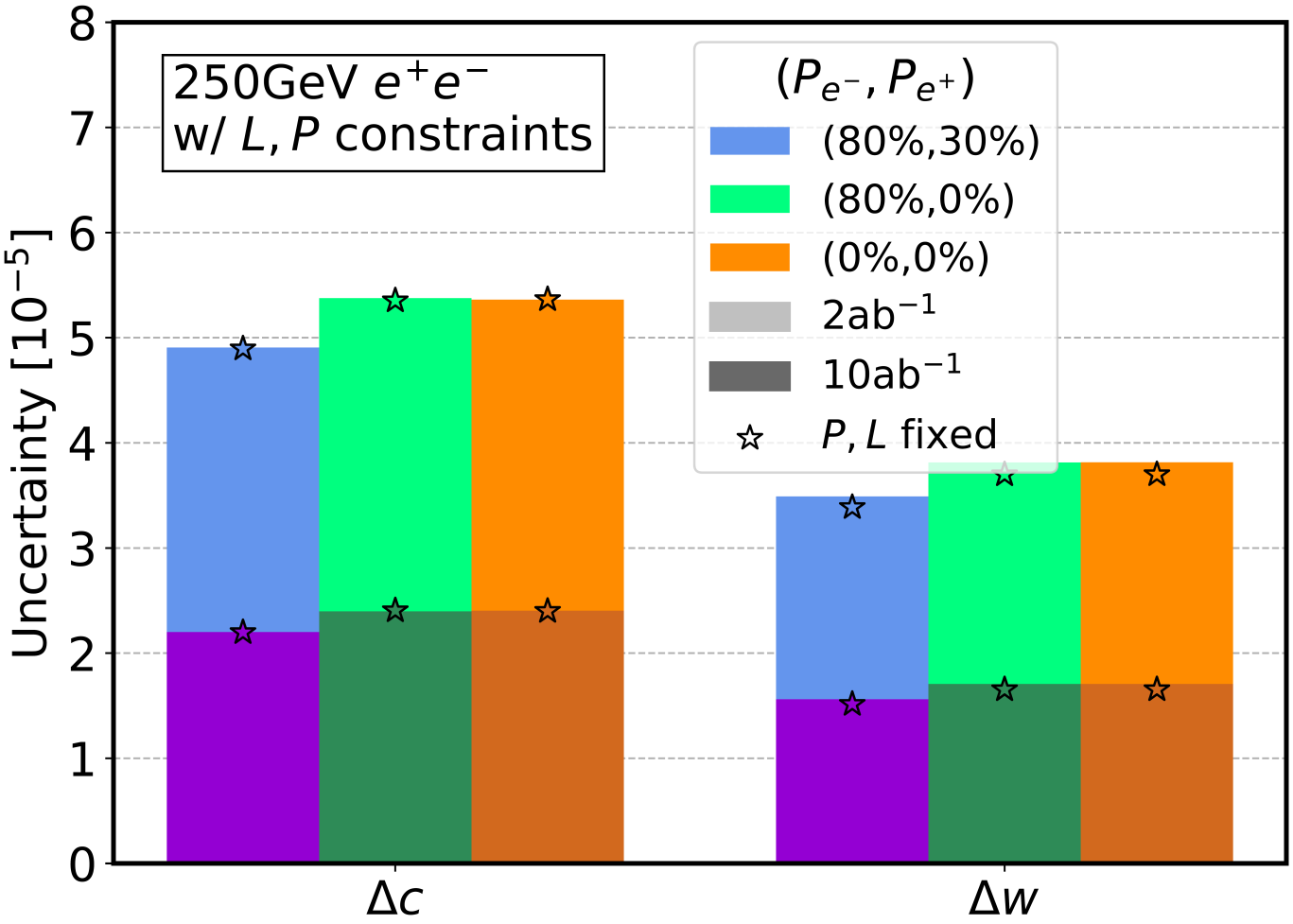
Polarisations & Lumi
(w/ constraints)

μ acceptance parameters



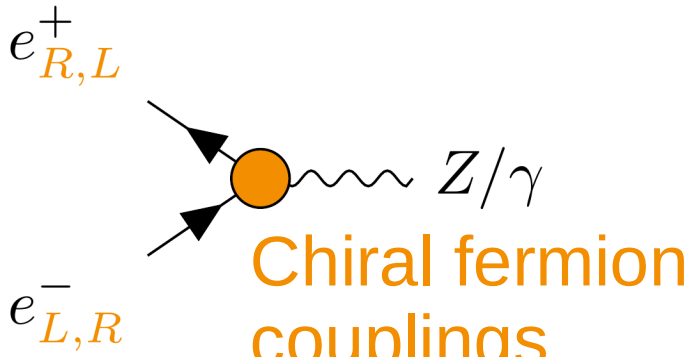
accept. width & lumi anticorrelated

First tests: Statistical influence of collider setups

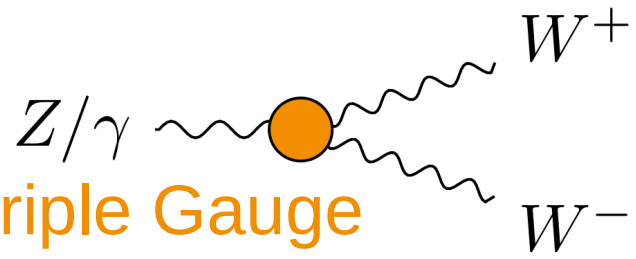


* so far not fitting any SM or BSM physics

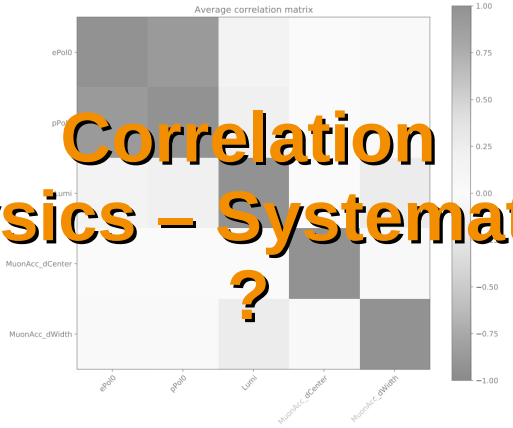
Next step: physical effects



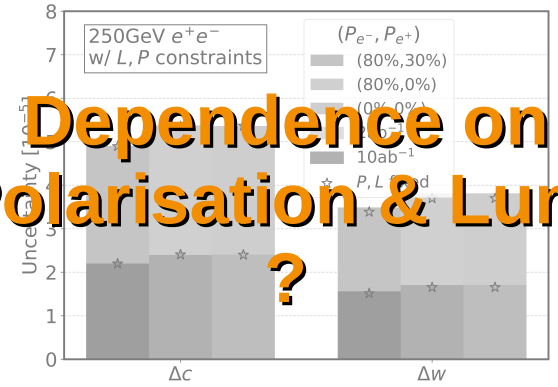
Chiral fermion couplings



Triple Gauge Couplings



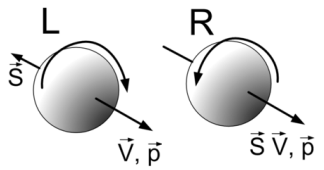
Correlation Physics – Systematics ?

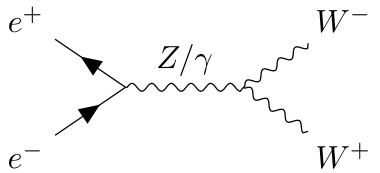


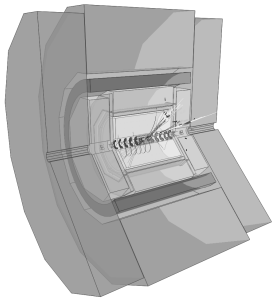
Dependence on Polarisation & Lumi ?

Impact of beam polarisation:

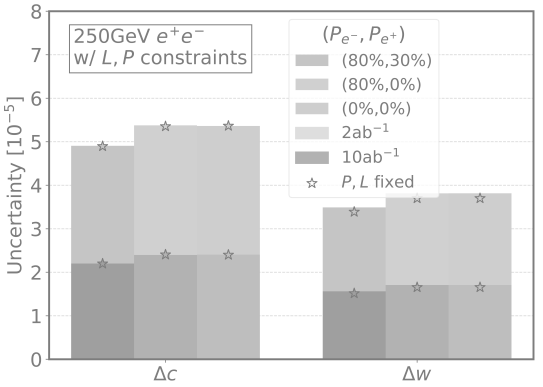
- Physics ✓
- Systematics ?



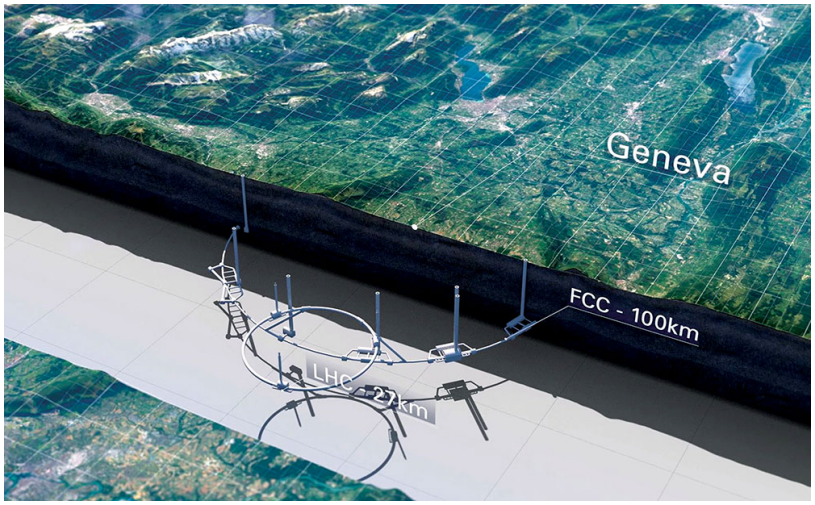


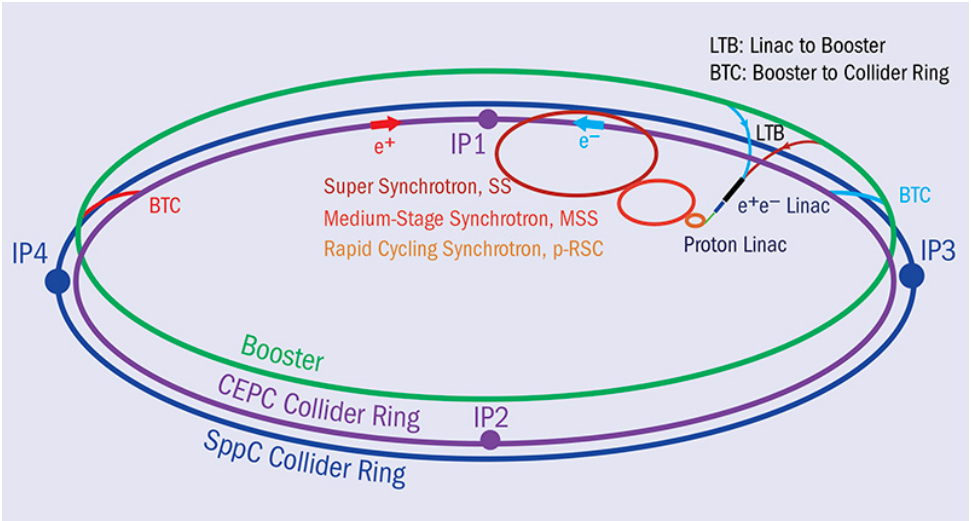


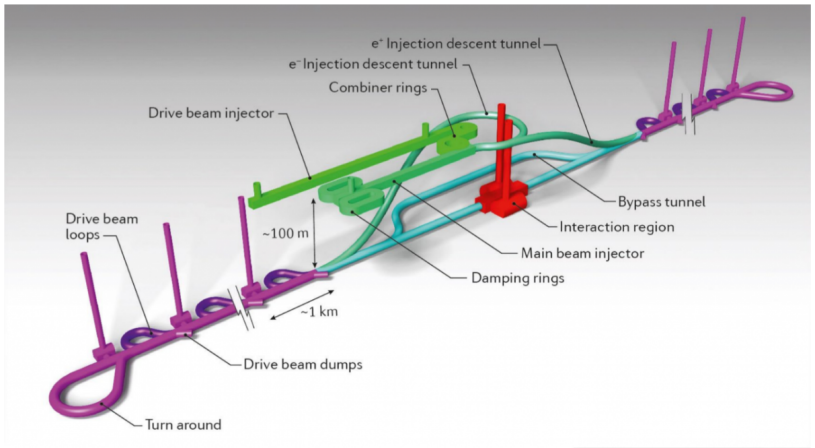
The full impact of beam polarisation has yet to be determined and could significantly change the achieved precisions.

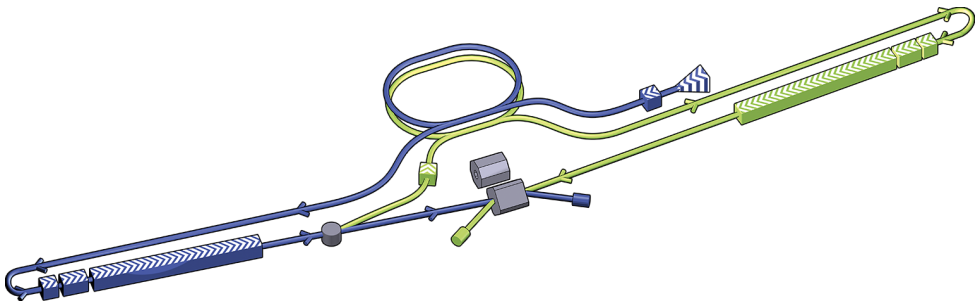


BACKUP

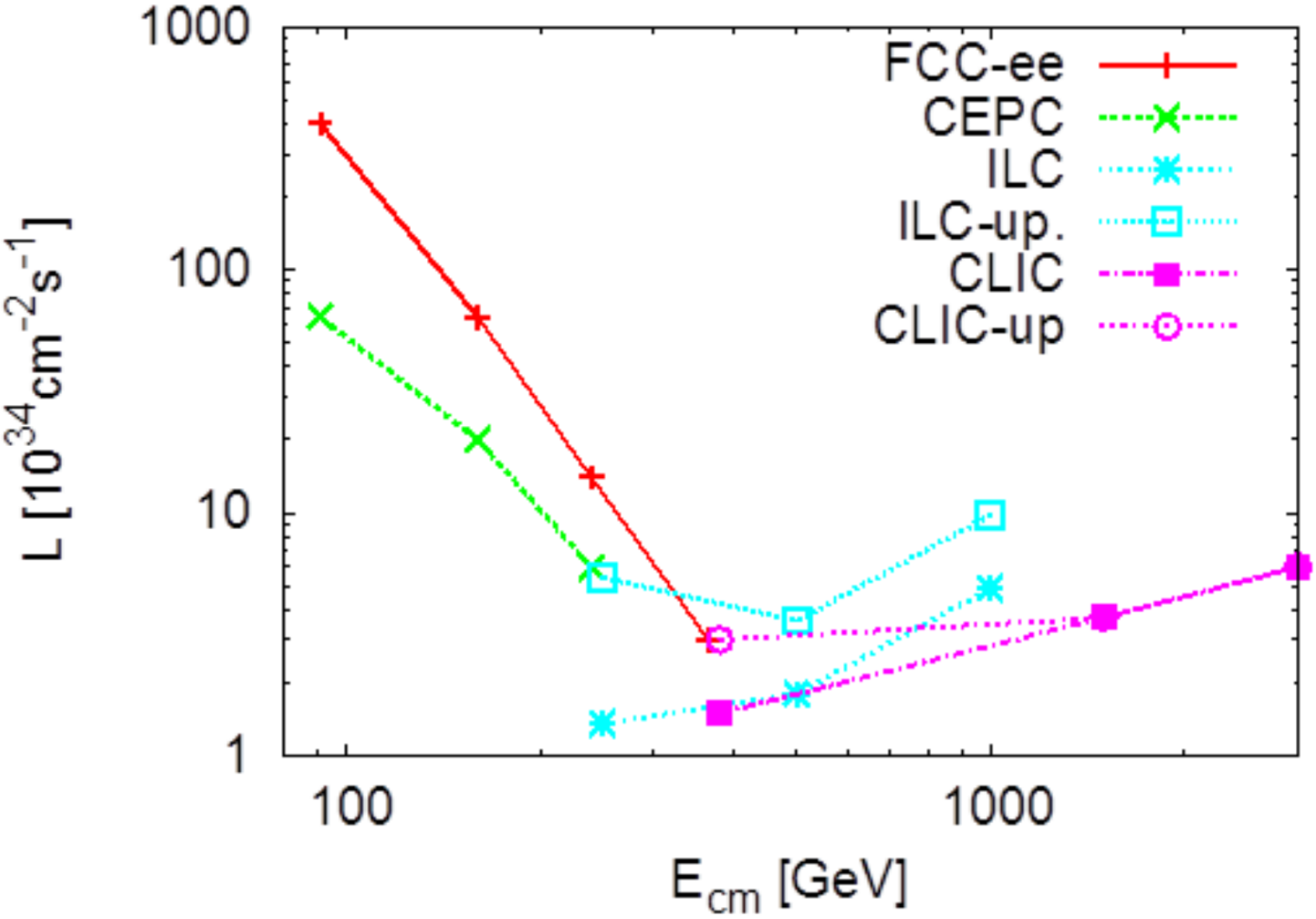

Geneva
FCC - 100km
LHC - 27km


LTB: Linac to Booster
BTC: Booster to Collider Ring
e+
IP1
e−
LTB
BTC
Super Synchrotron, SS
Medium-Stage Synchrotron, MSS
Rapid Cycling Synchrotron, p-RSC
e+e− Linac
Proton Linac
BTC
IP4
IP3
Booster
CEPC Collider Ring
IP2
SppC Collider Ring


e+ Injection descent tunnel
e− Injection descent tunnel
Combiner rings
Drive beam injector
Bypass tunnel
Interaction region
Drive beam loops
~100 m
Main beam injector
Damping rings
~1 km
Drive beam dumps
Turn around

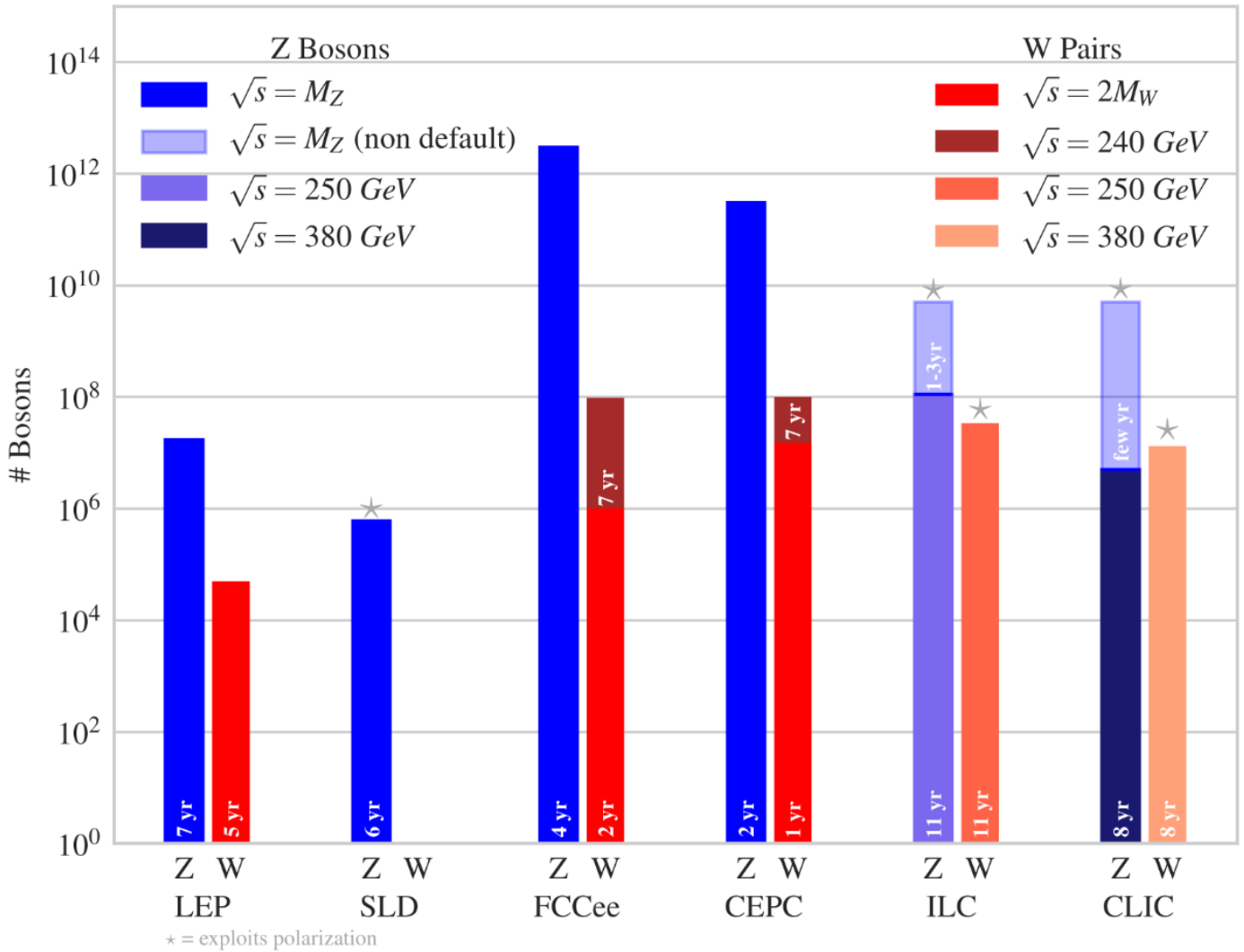


[EPPSU20 Physics Briefing Book]

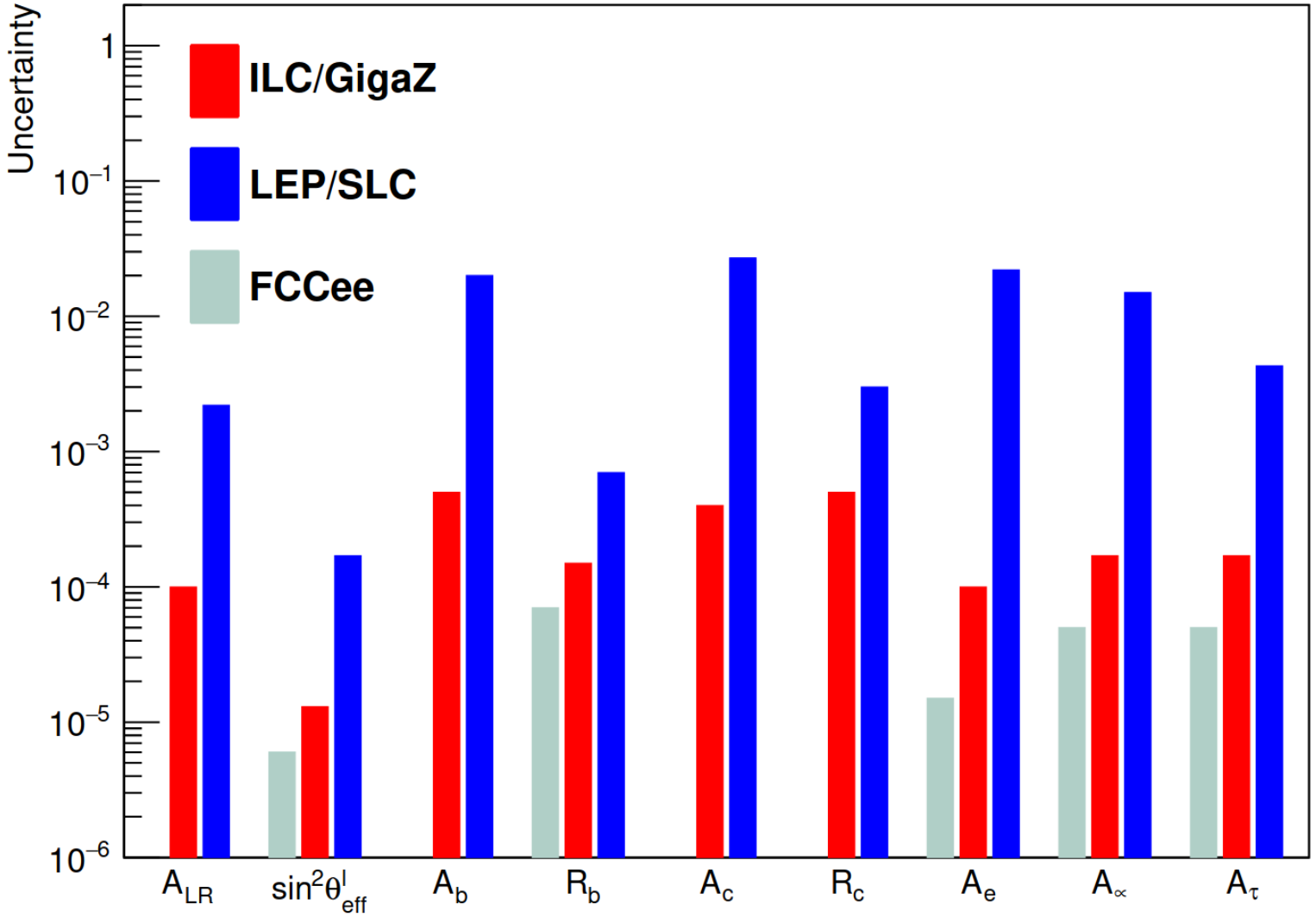


	√s	beam polarisation	∫Ldt (baseline)	R&D phase
ILC	0.1 - 1 TeV	e-: 80% e+: 30% (20%)	2 ab^{-1} @ 250 GeV 0.2 ab^{-1} @ 350 GeV 4 ab-1 @ 500 GeV 8 ab-1 @ 1 TeV	TDR 2013
CLIC	0.35 - 3 TeV	e-: (80%) e+: 0%	1 ab^{-1} @ 380 GeV 2.5 ab^{-1} @ 1.5 TeV 5 ab^{-1} @ 3 TeV	CDR 2012
CEPC	90 - 240 GeV	e-: 0% e+: 0%	5.6 ab^{-1} @ 250 GeV 16 ab^{-1} @ M_Z 2.6 ab^{-1} @ $2M_W$	CDR 2018
FCC-ee	90 - 350 GeV	e-: 0% e+: 0%	150 ab^{-1} @ M_Z 10 ab^{-1} @ $2M_W$ 5 ab^{-1} @ 250 GeV 1.7 ab^{-1} @ 365 GeV	CDR 2018

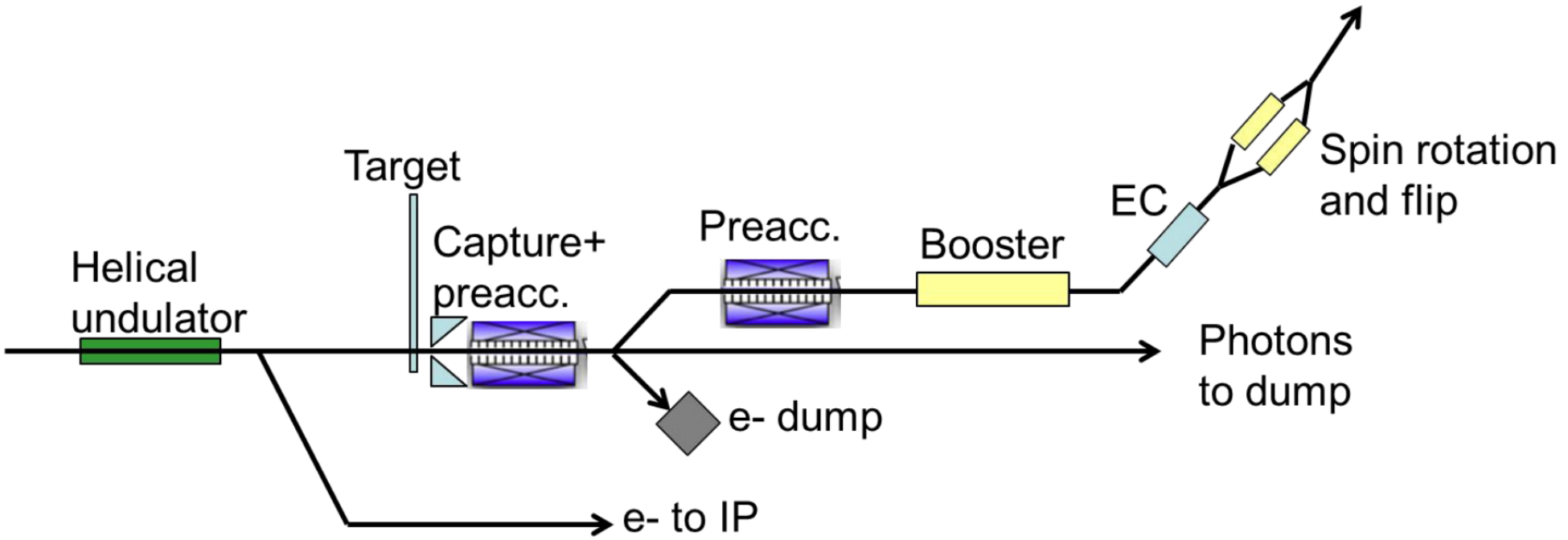
[EPPSU20 Physics Briefing Book]



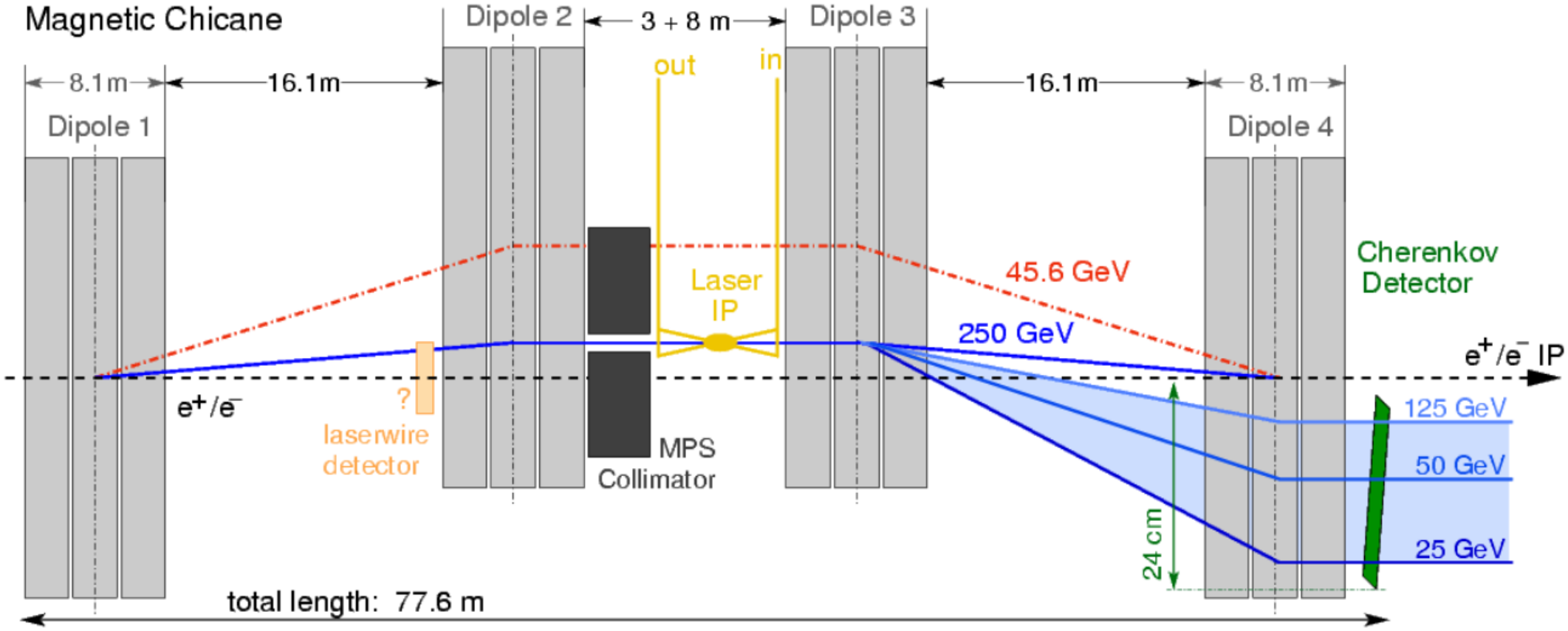
[arXiv:1908.11299]



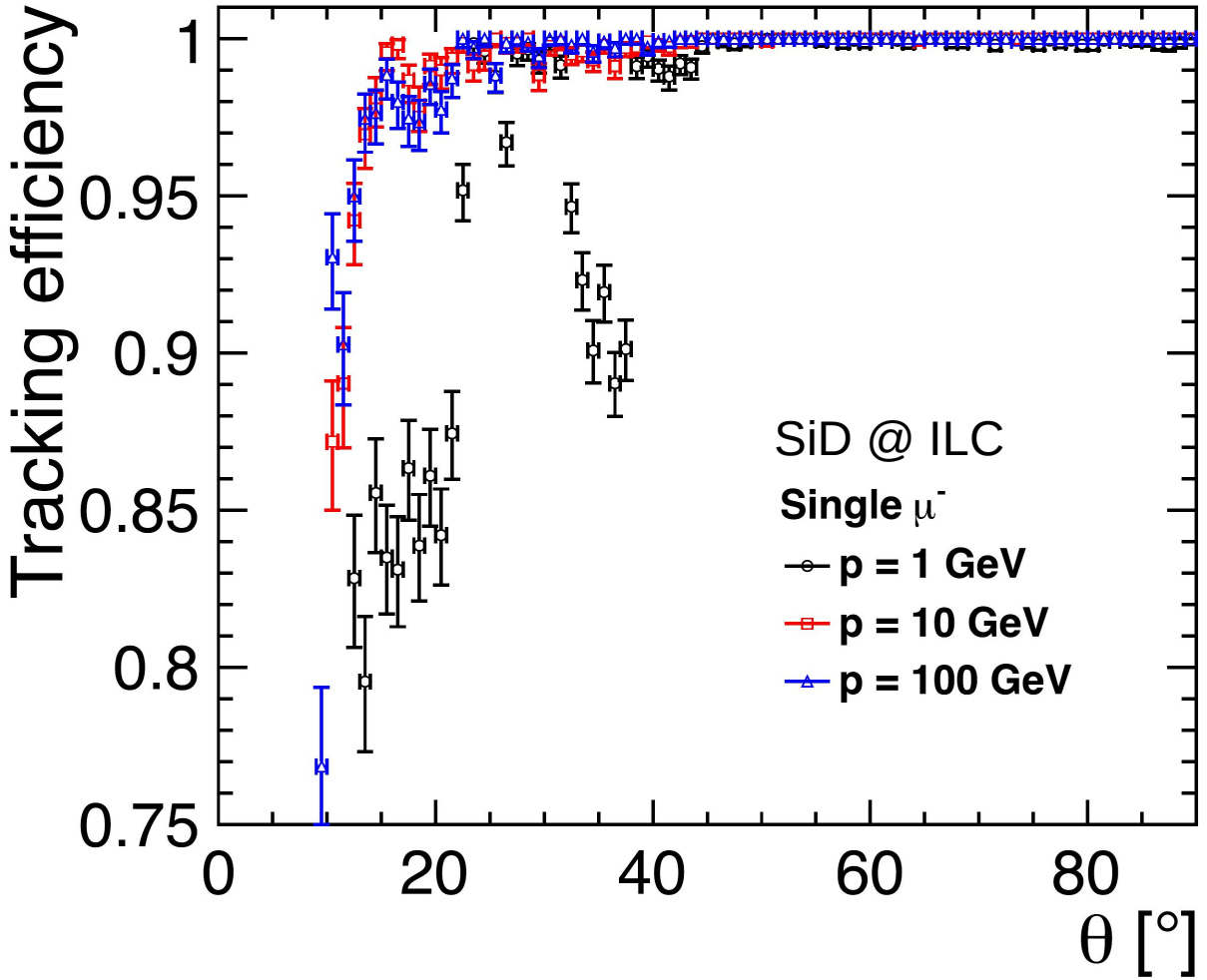
Polarised positron source:



External polarisation measurement



Realistic muon efficiency:



[ILC TDR – Volume 4]

Fit details

- External Lumi & Pol constraints:
  - $\Delta L/L$ = 3e-3
  - For P = 0: ΔP = 2.5e-3, else: $\Delta P/P$ = 2.5e-3
- Polarisation sharings for (P_{e-},P_{e+}):
  - (80%,30%): -+ 45%, +- 45%, ++ 5%, -- 5%
  - (80%,0%): -0 50%, +0 50%