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

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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

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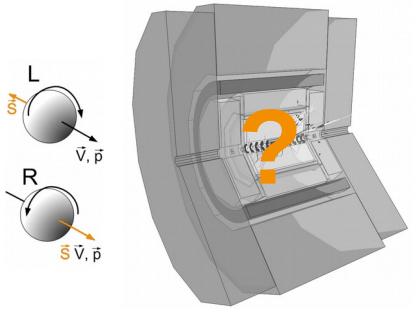
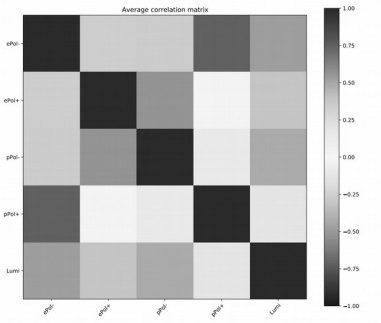
CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

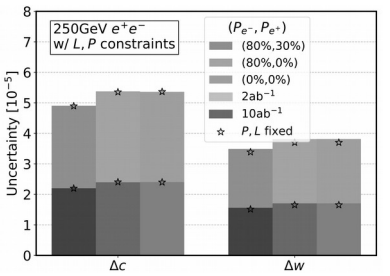
- **Beam polarisation & systematic effects**



- Framework for combined fit



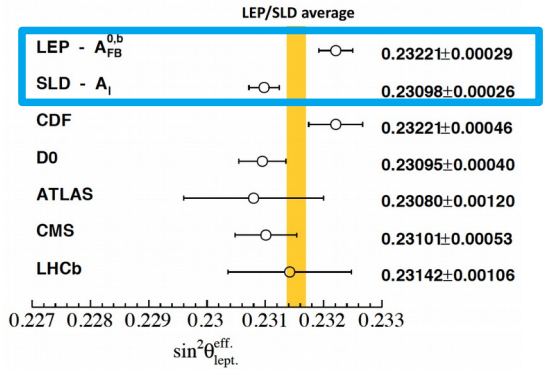
- Systematic effect in fit: μ acceptance



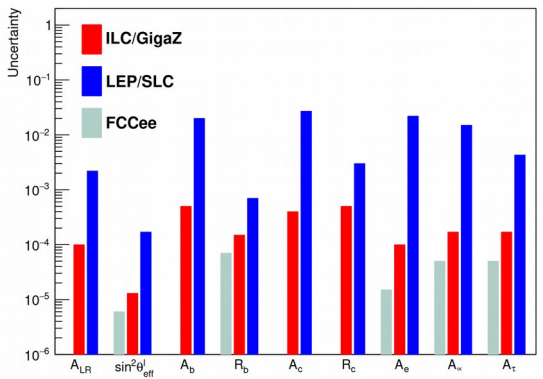
Impact of beam polarisation

Physics ✓

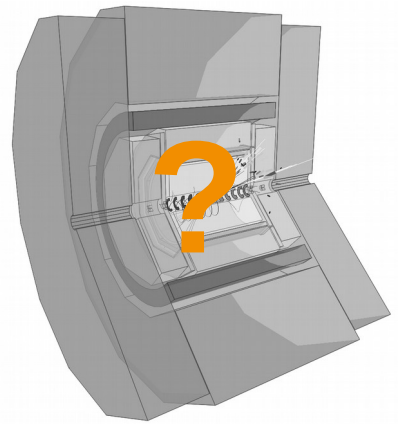
[William J. Barter]



[arXiv:1908.11299]



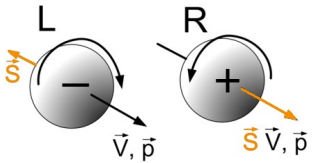
Systematics ?



So far:

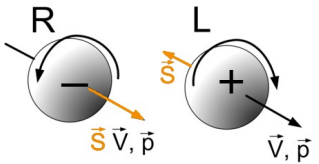
$$\sigma_{final} = \sqrt{\sigma^2_{stat} + \sigma^2_{syst}}$$

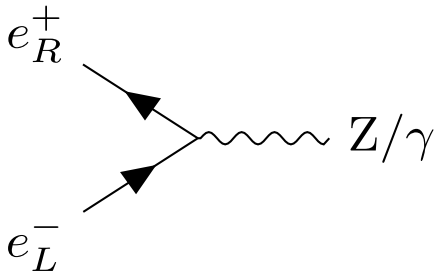
External estimation



Flipped

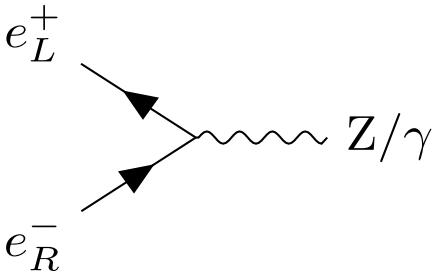
Polarisation

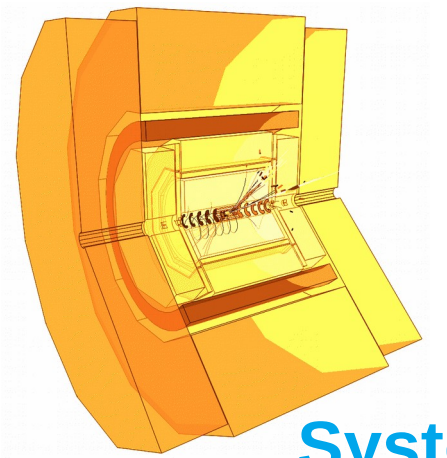




Different

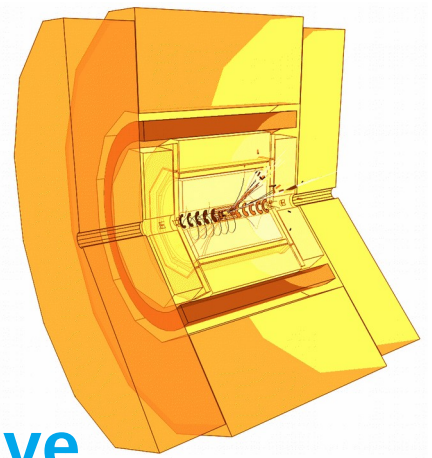
Physics





Same

Detector



Systematic effects will have uniquely global signatures if included in combined fit!

$$\sigma_{final} = \sqrt{\sigma^2_{stat} + \sigma^2_{syst}}$$

External estimation

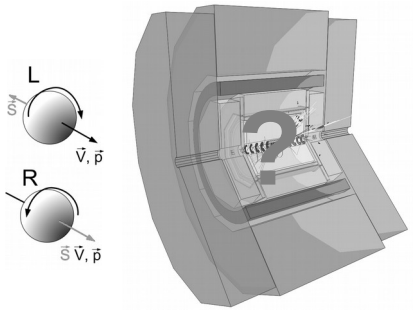
New approach

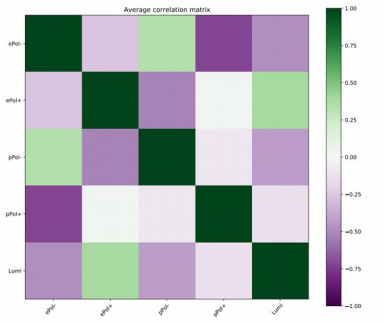
Polarised datasets → **Combined fit** ← Final states

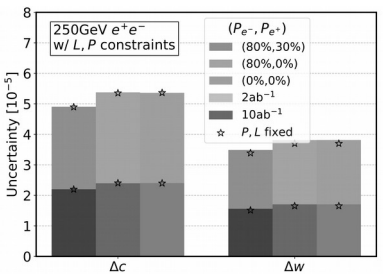
Hypothesis

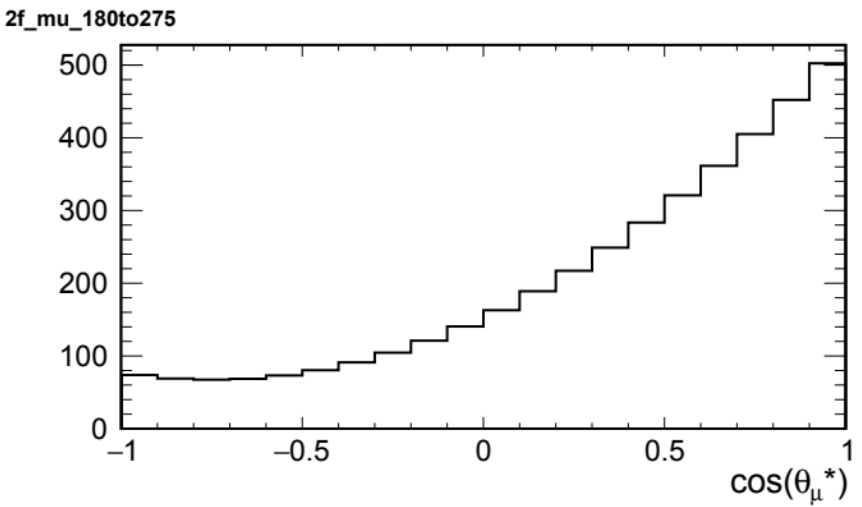
Disentangle systematic from physical effects by fitting them simultaneously!

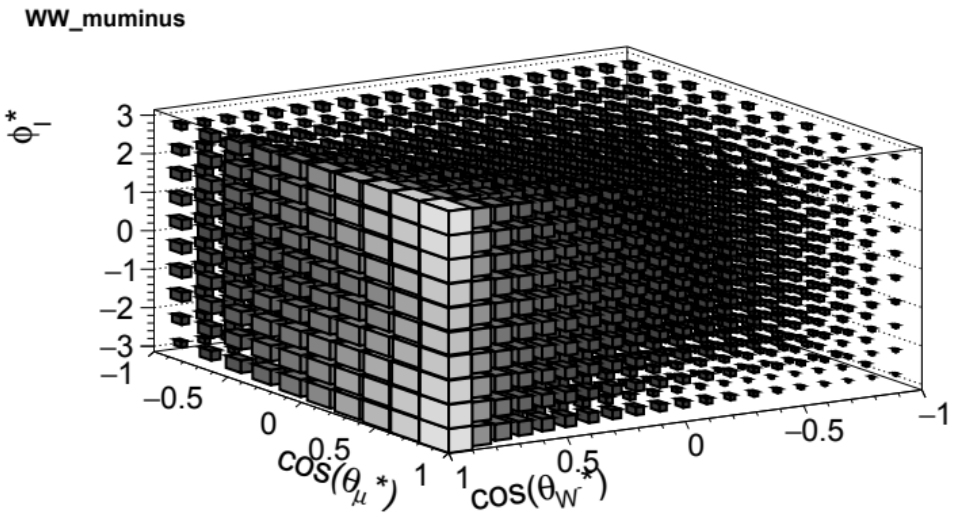
- Beam polarisation & systematic effects
- **Framework for combined fit**
- Systematic effect in fit: μ acceptance











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

return-to-Z separately from high-Q^2

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

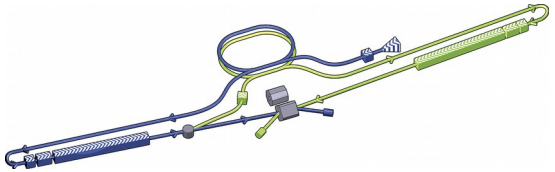
μ^+ and μ^- separatey

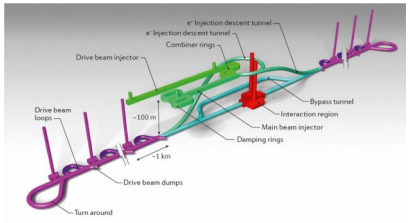
Polarised distributions

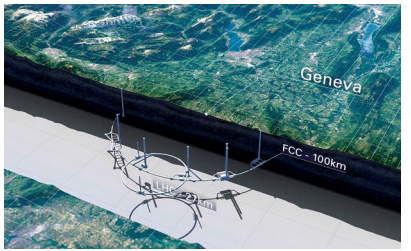
Toy fluctuated distributions

Combined Fit: Log-Likelihood maximisation

250GeV test scenarios







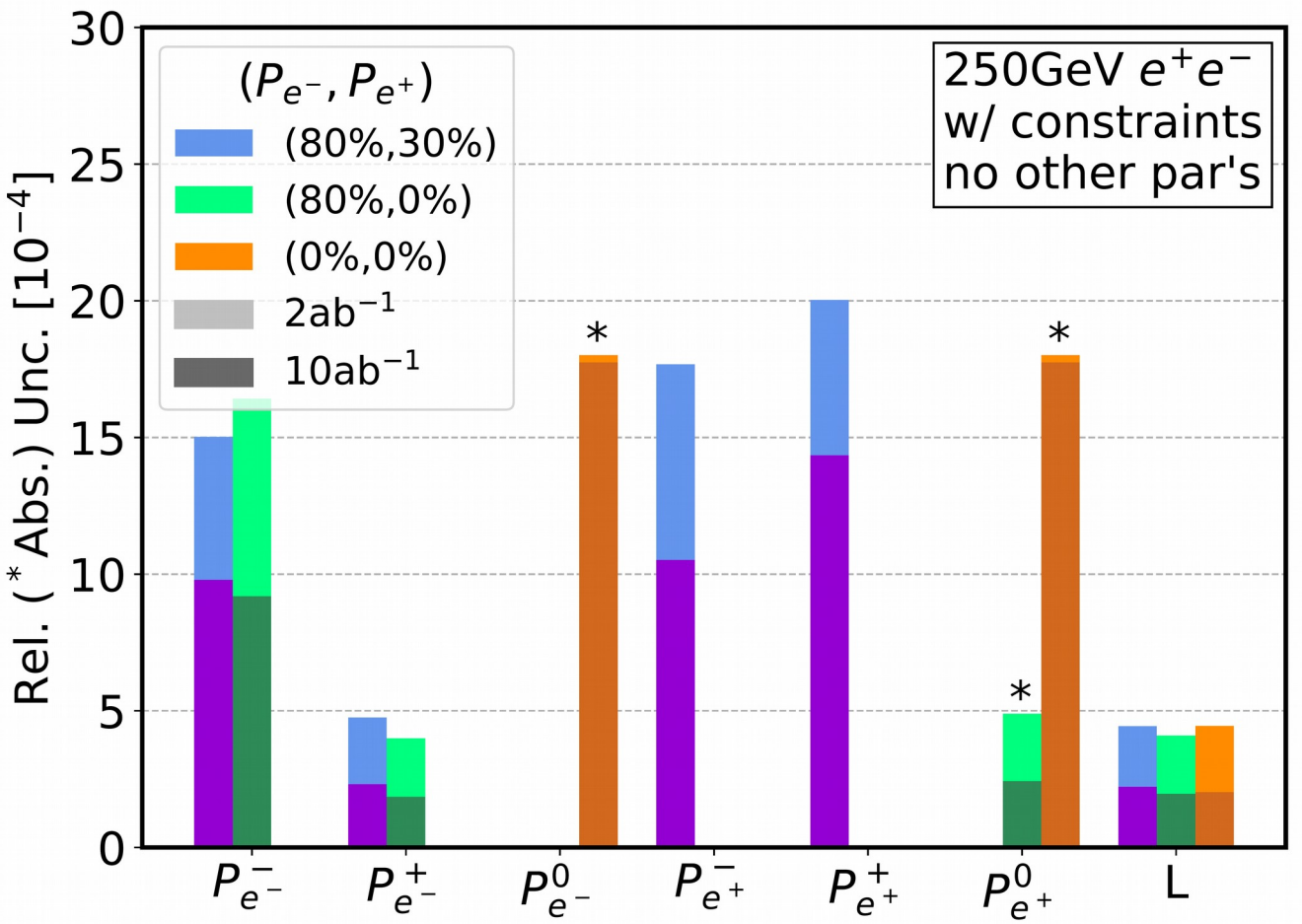
Pol.: (80%,30%) (80%,0%) (0%,0%)

Sharing: +- : -+ : ++ : -- +0 : -0 00

45 : 45 : 5 : 5 50 : 50

- **L**: 2ab^{-1} , 10ab^{-1}
- **Constraints**: $\Delta L/L = 3e\text{-}3$, $\Delta P/P = 2.5e\text{-}3$ (= ΔP_0) [arXiv:1304.4082] [arXiv:0902.3221]

Can test P-&L-dependence of uncertainties

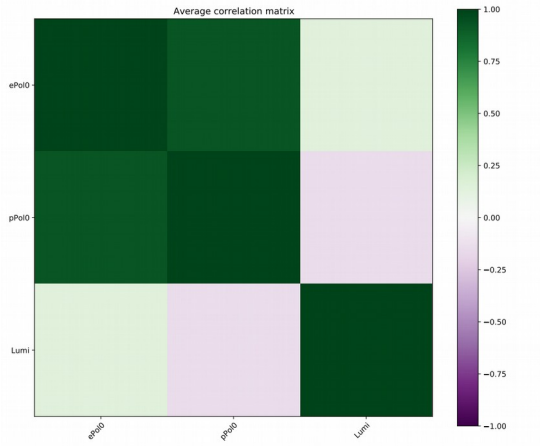


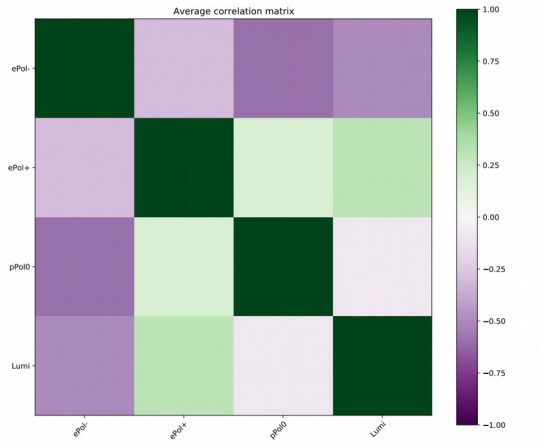
Purely for testing!

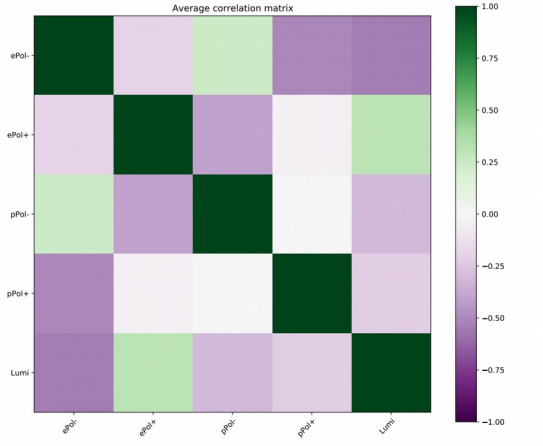
- no other parameters
- cross sections fixed

(0%,0%) (80%,0%) (80%,30%)

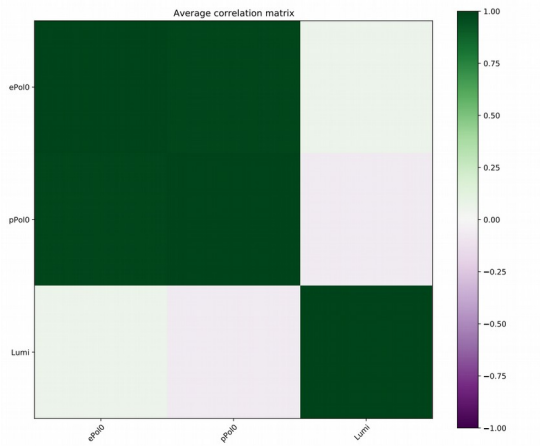
2ab^{-1}

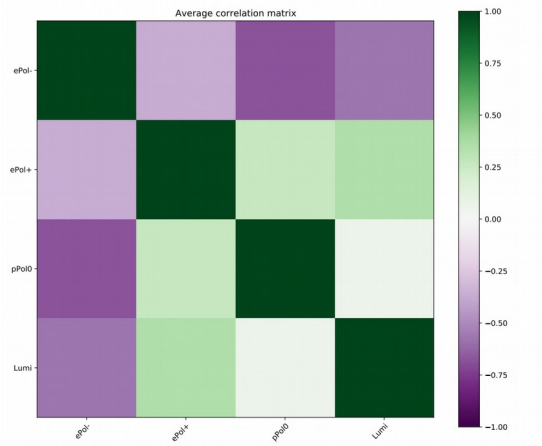


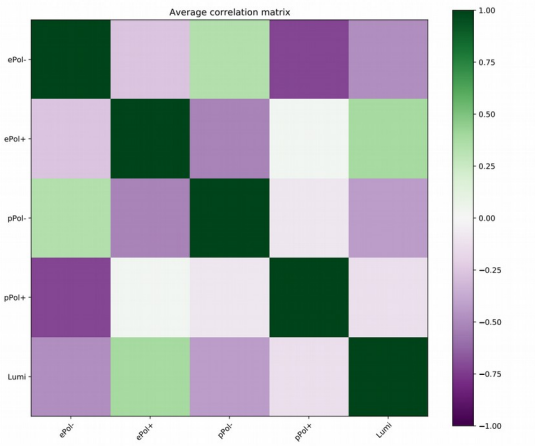




10ab^{-1}

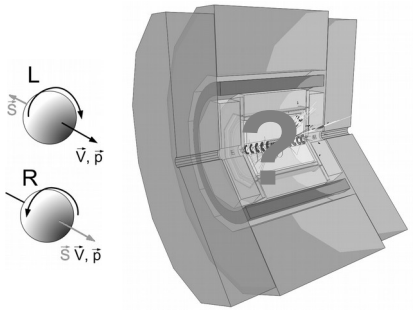


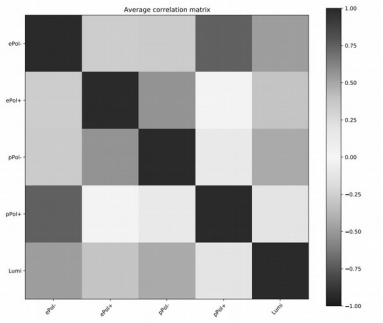


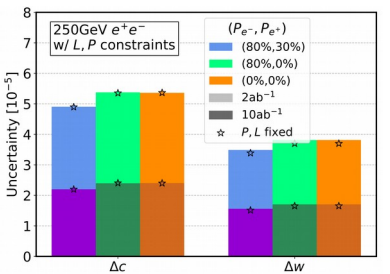


Can test P-&L-dependence of correlations

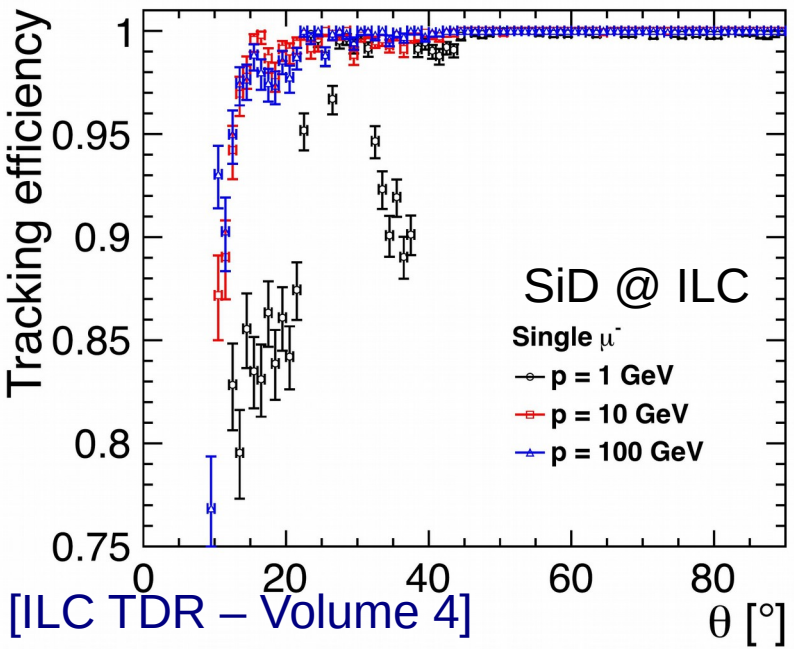
- Beam polarisation & systematic effects
- Framework for combined fit
- **Systematic effect in fit: μ acceptance**





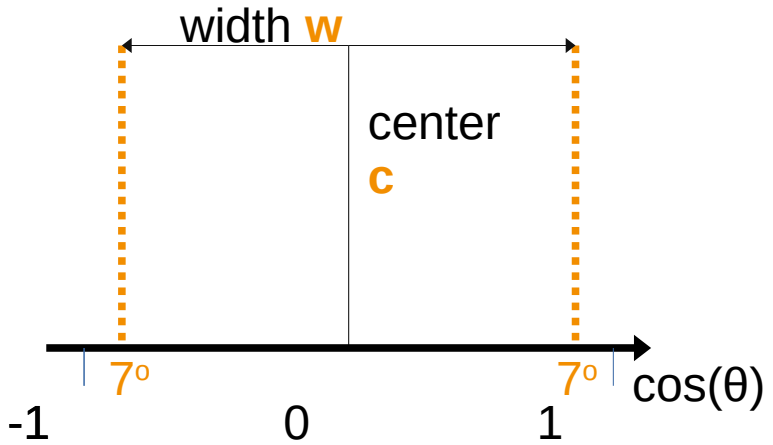


Implementing μ acceptance



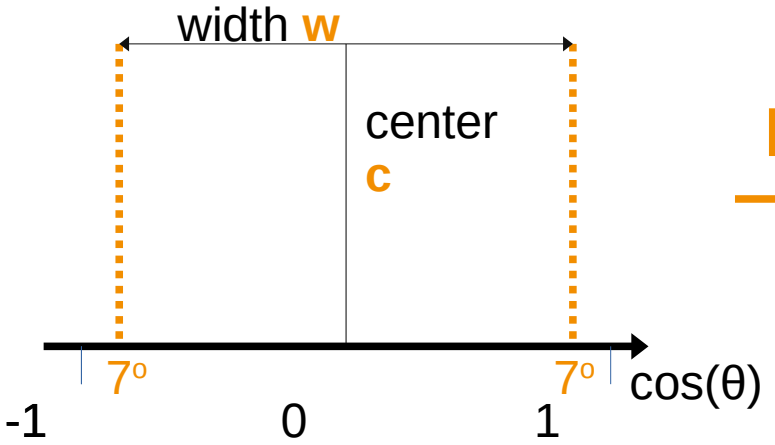
[ILC TDR – Volume 4]

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



Fit parameters: Δc, Δw

Parametrising μ acceptance



Effect on

?

Parametrisation (per bin):

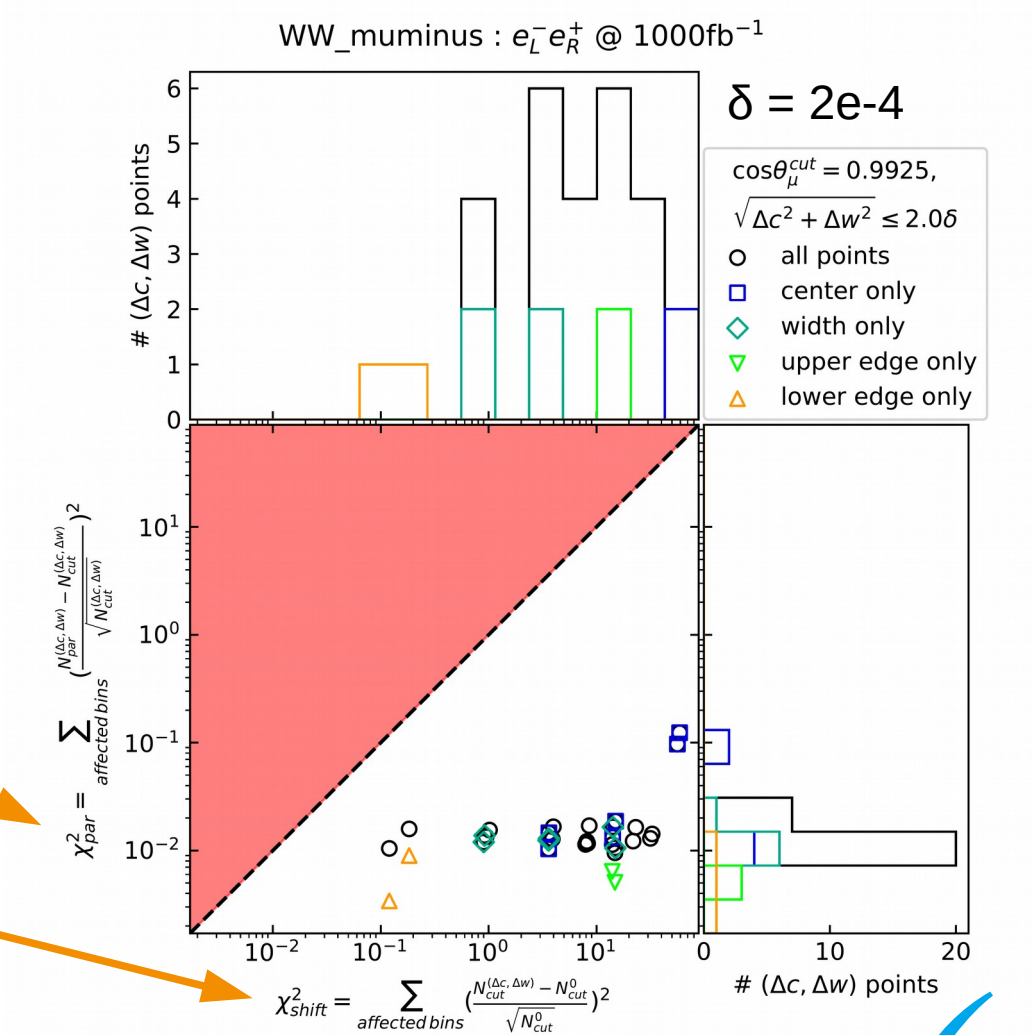
$d\sigma/\sigma = k_0 + k_c\,\Delta c + k_w\,\Delta w + k_{c2}\,\Delta c^2 + k_{w2}\,\Delta w^2 + k_{cw}\,\Delta c\,\Delta w$

...

Test (c±δ,w±δ) values on MC

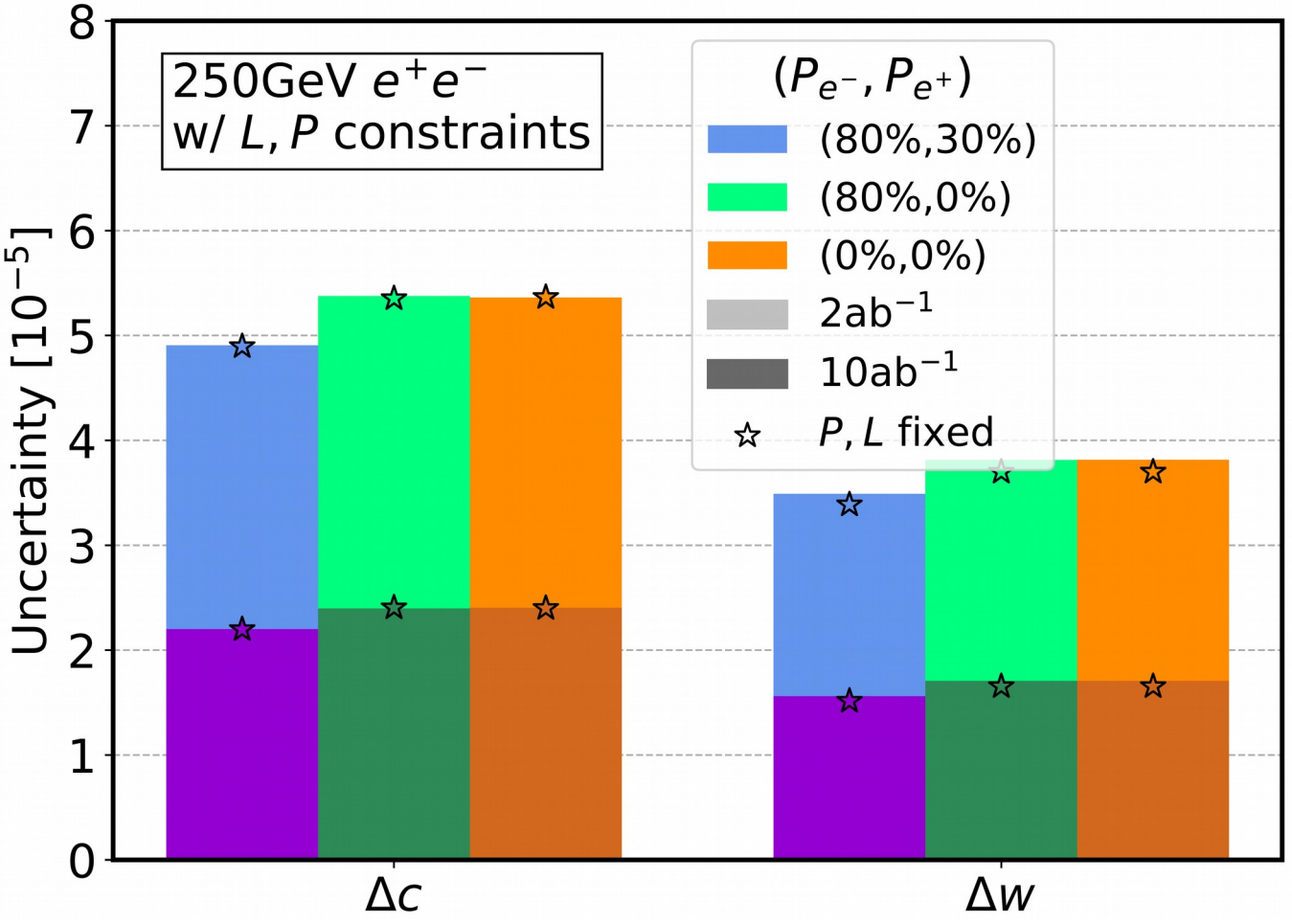
Validation of the parametrisation:

How relevant is:
- **mistake made by parametrisation**
vs.
- **effect of deviation** ?



Safe to use ✓

First tests: Statistical influence of collider setups



Purely for testing!

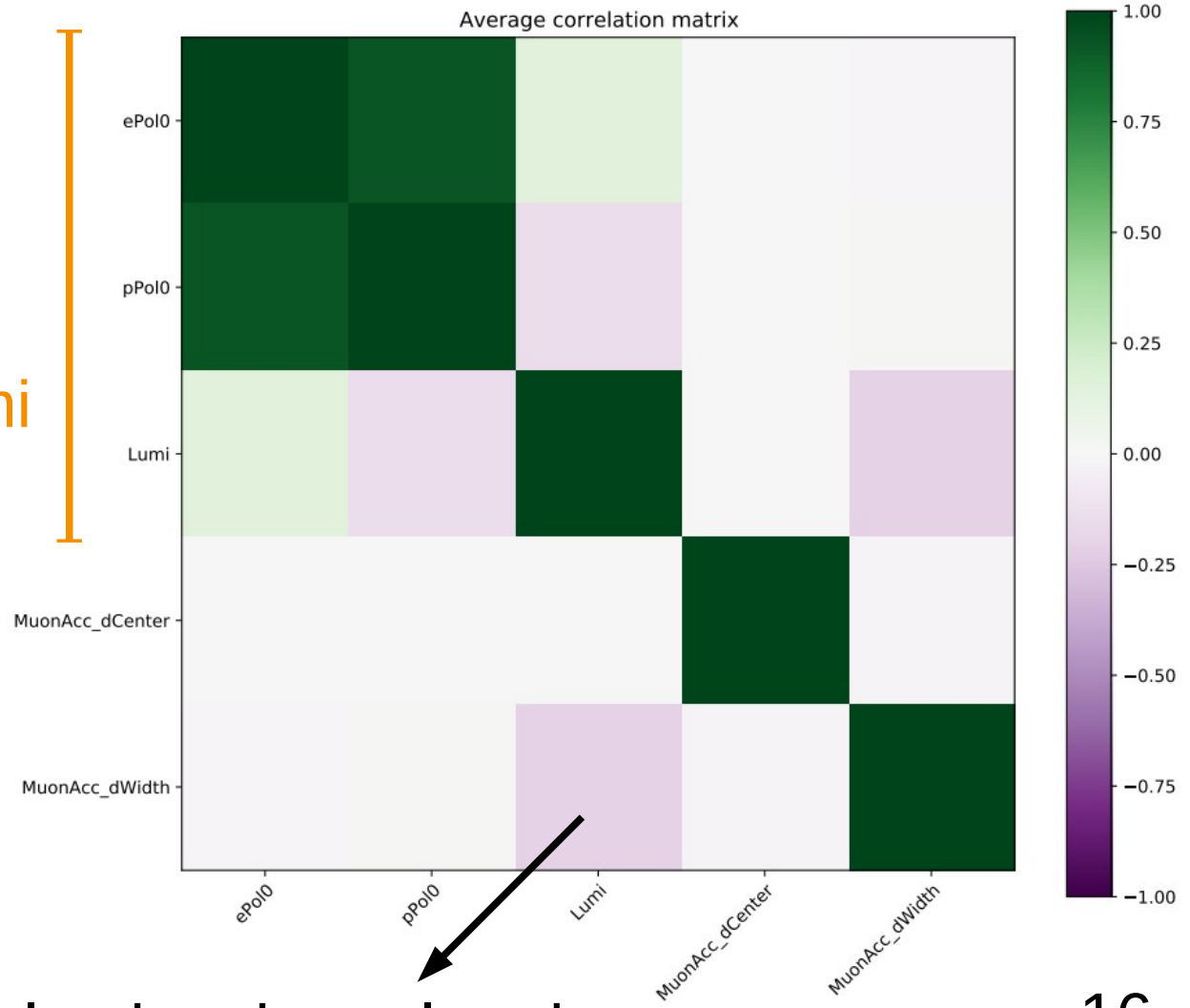
- else only: L,P's
- cross sections fixed

Example:
2ab^{-1} unpolarised

Free parameters:

Polarisations & Lumi
(w/ constraints)

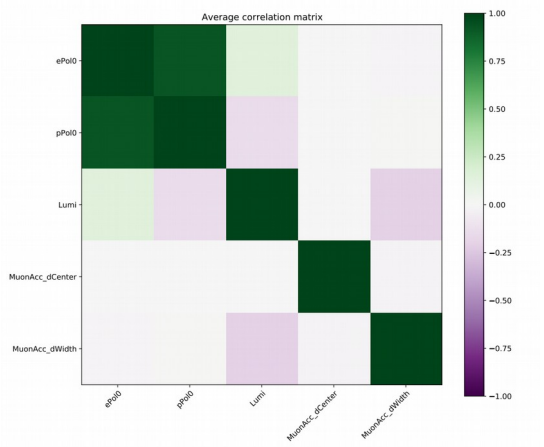
μ acceptance parameters

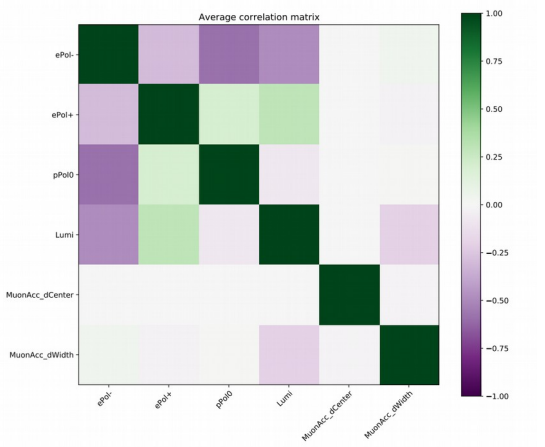


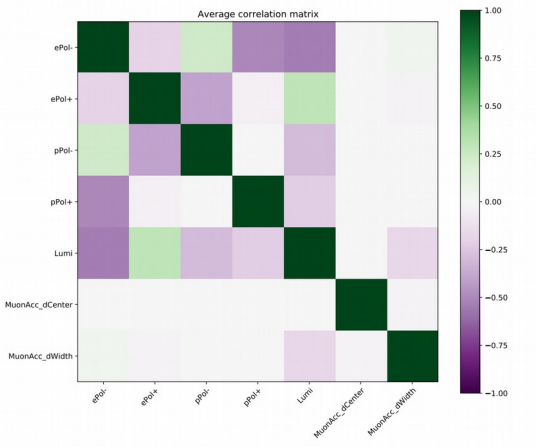
accept. width & lumi anticorrelated

(0%,0%) (80%,0%) (80%,30%)

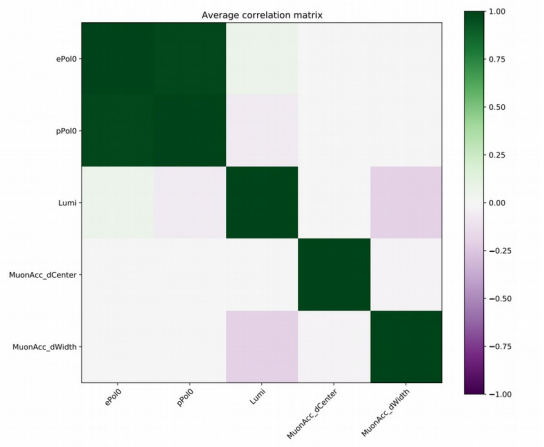
2ab^{-1}

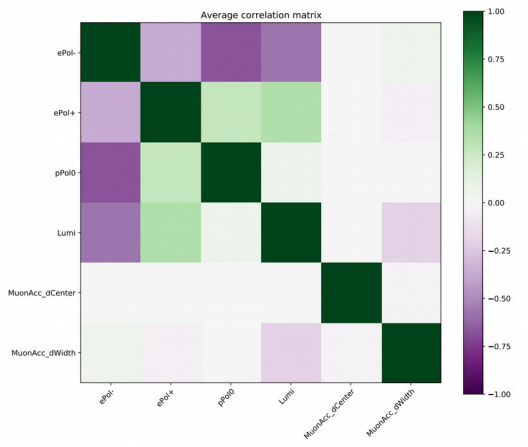


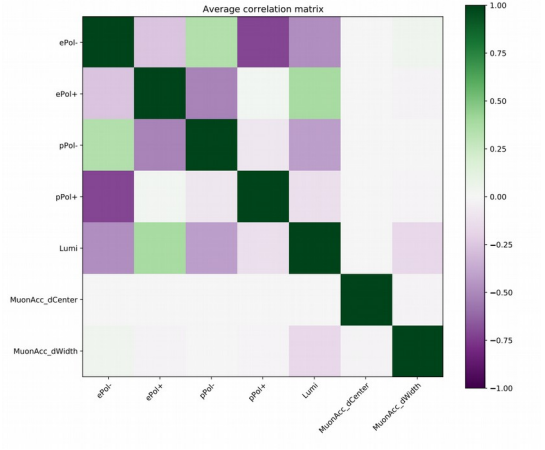




10ab^{-1}

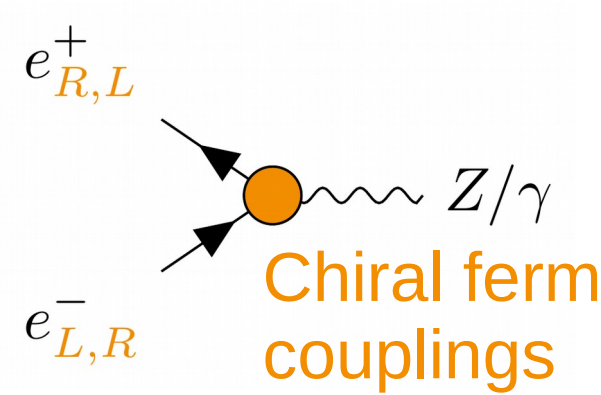




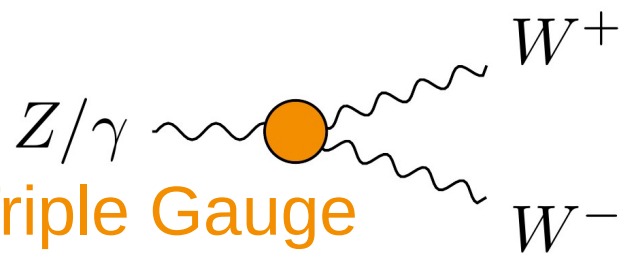


Systematic effect *alone* unaffected by polarisation

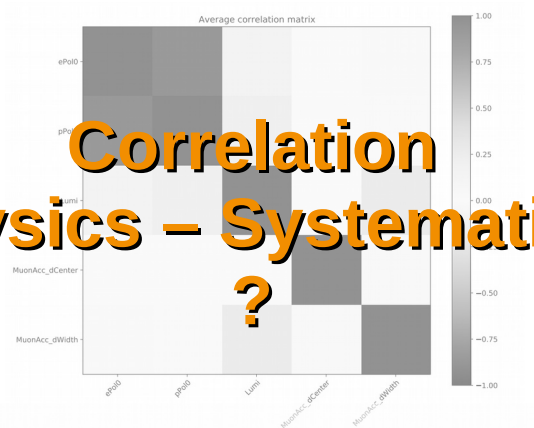
Next step: physical effects



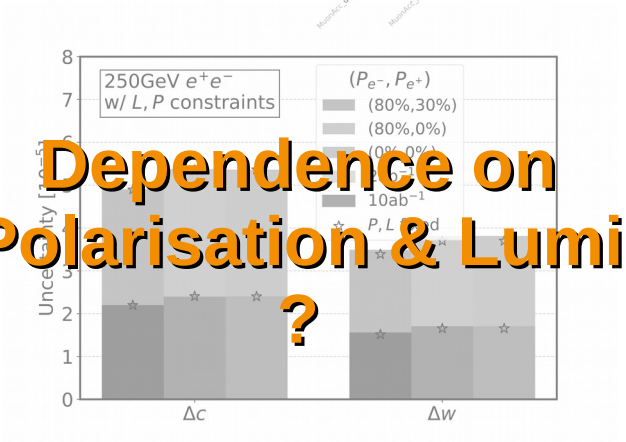
Chiral fermion couplings



Triple Gauge Couplings



Correlation Physics – Systematics ?



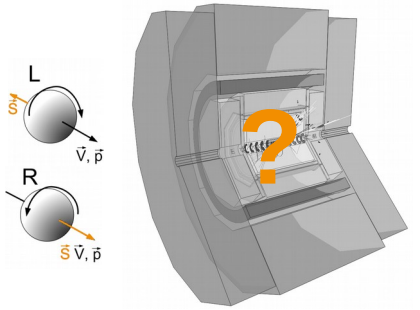
Dependence on Polarisation & Lumi ?

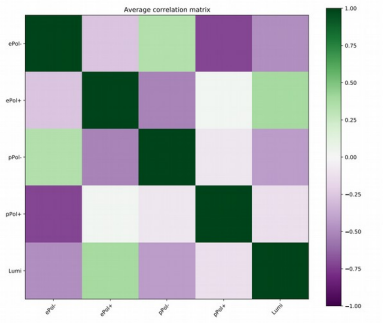
Impact of beam polarisation:

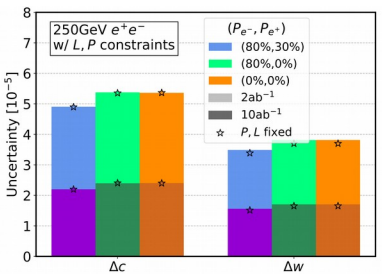
- Physics ✓
- Systematics ?

Your analysis?

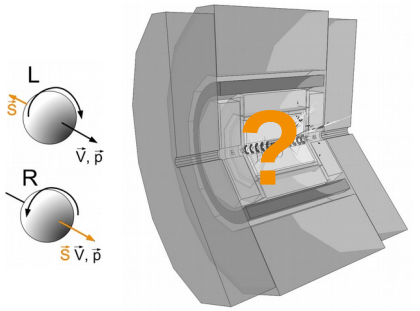
The full impact of beam polarisation has yet to be determined and could significantly change the achieved precisions.



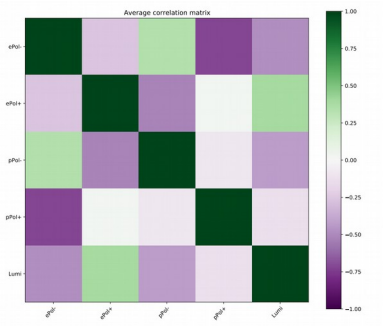




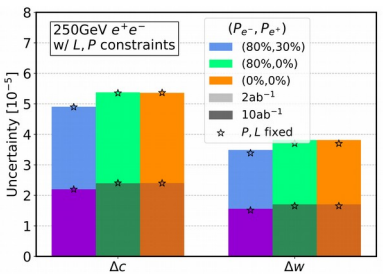
- Beam polarisation hypothesised to help separate physical and systematic effects



- Set up framework for combined fit



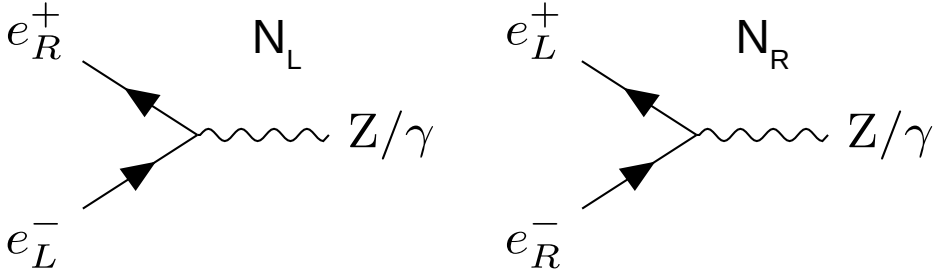
- Implemented first systematic:
  μ acceptance

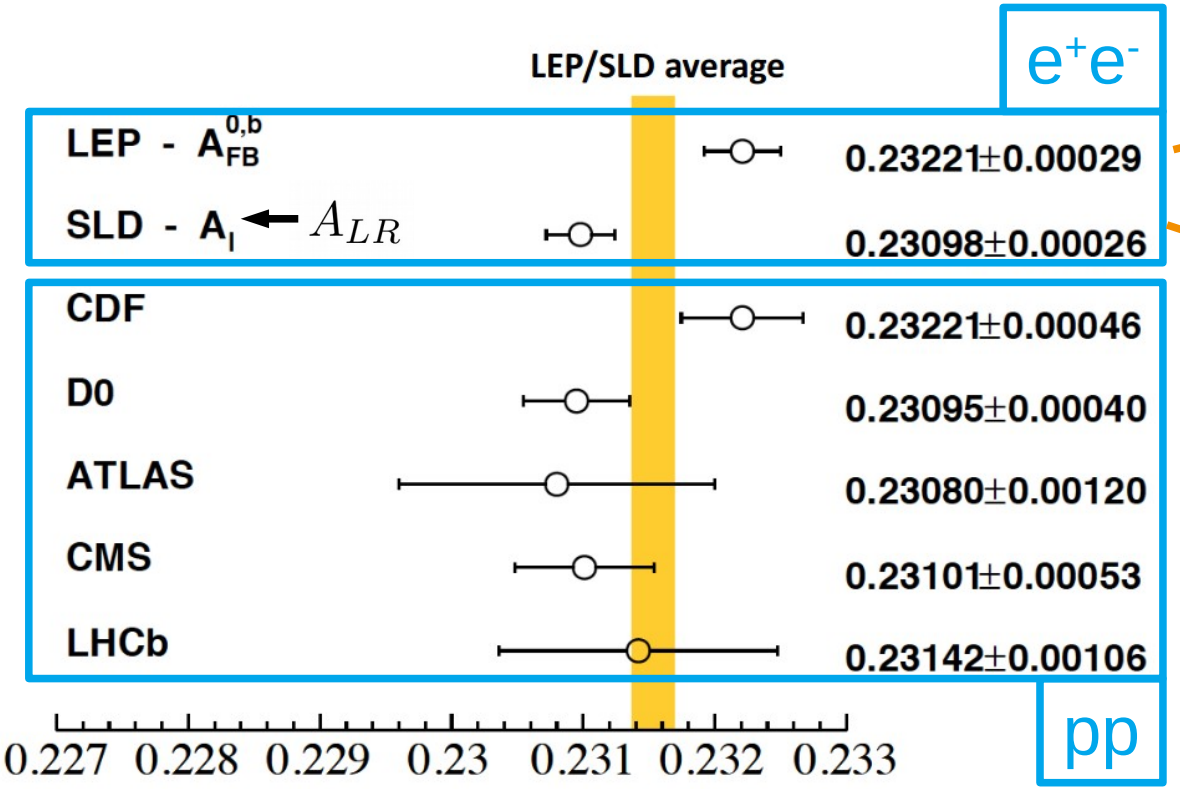


- Next: implement physics to test hypothesis

BACKUP

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





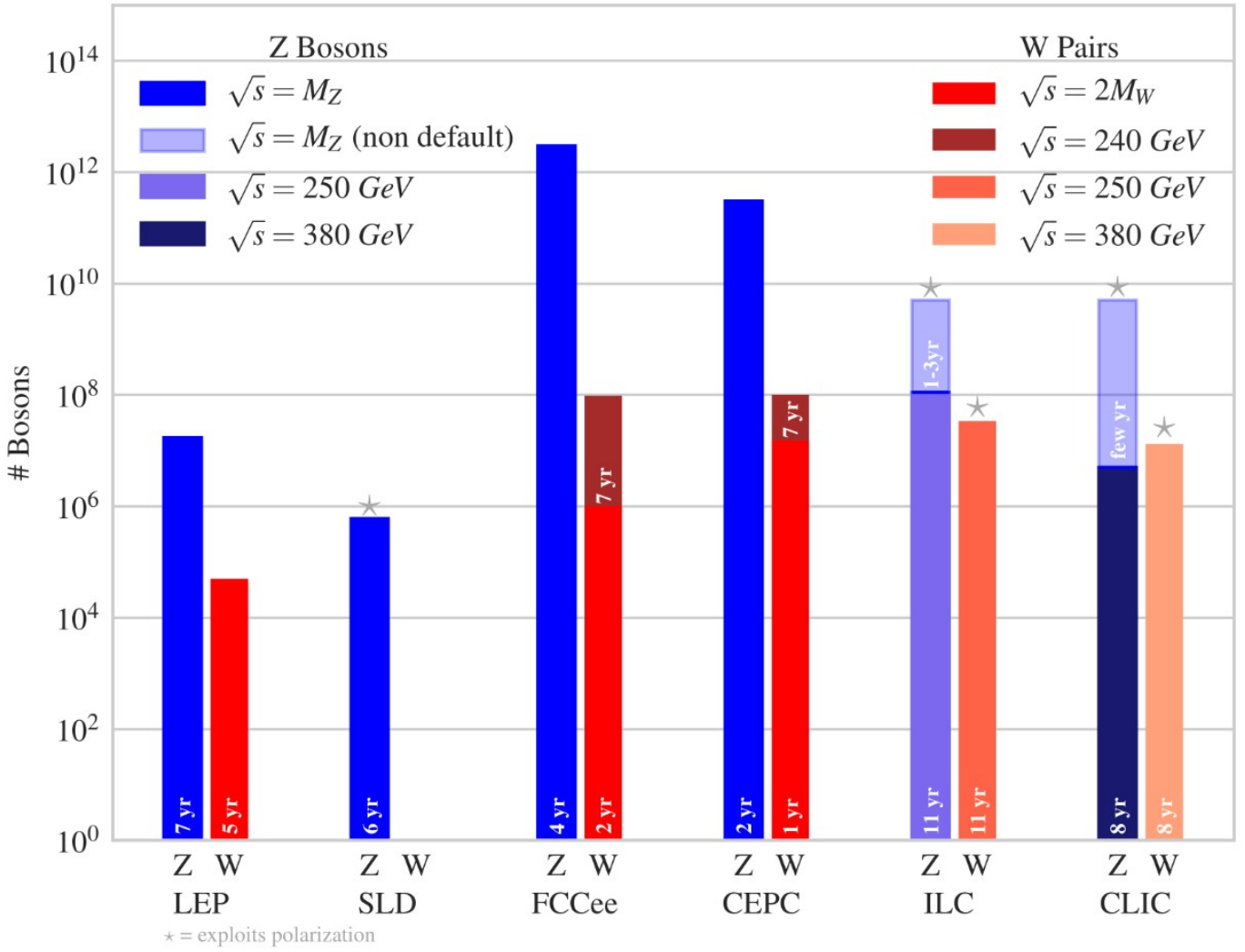
~ 300 x more events

e- polarisation

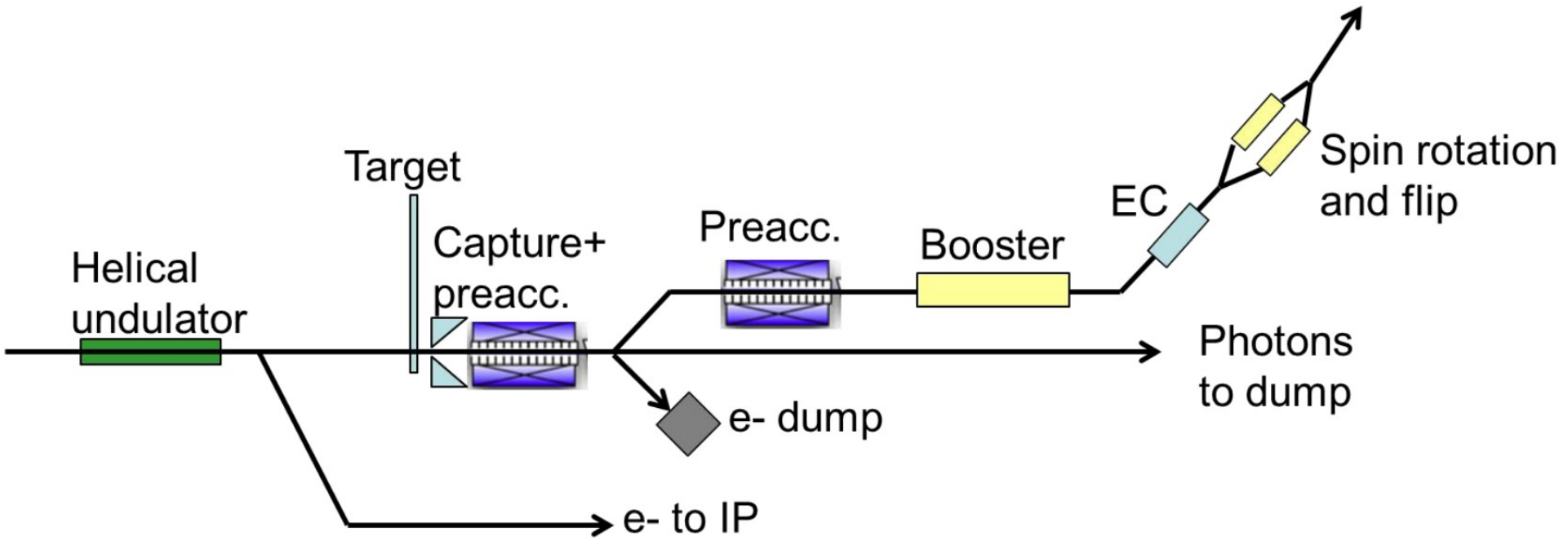
[William J. Barter]

	√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

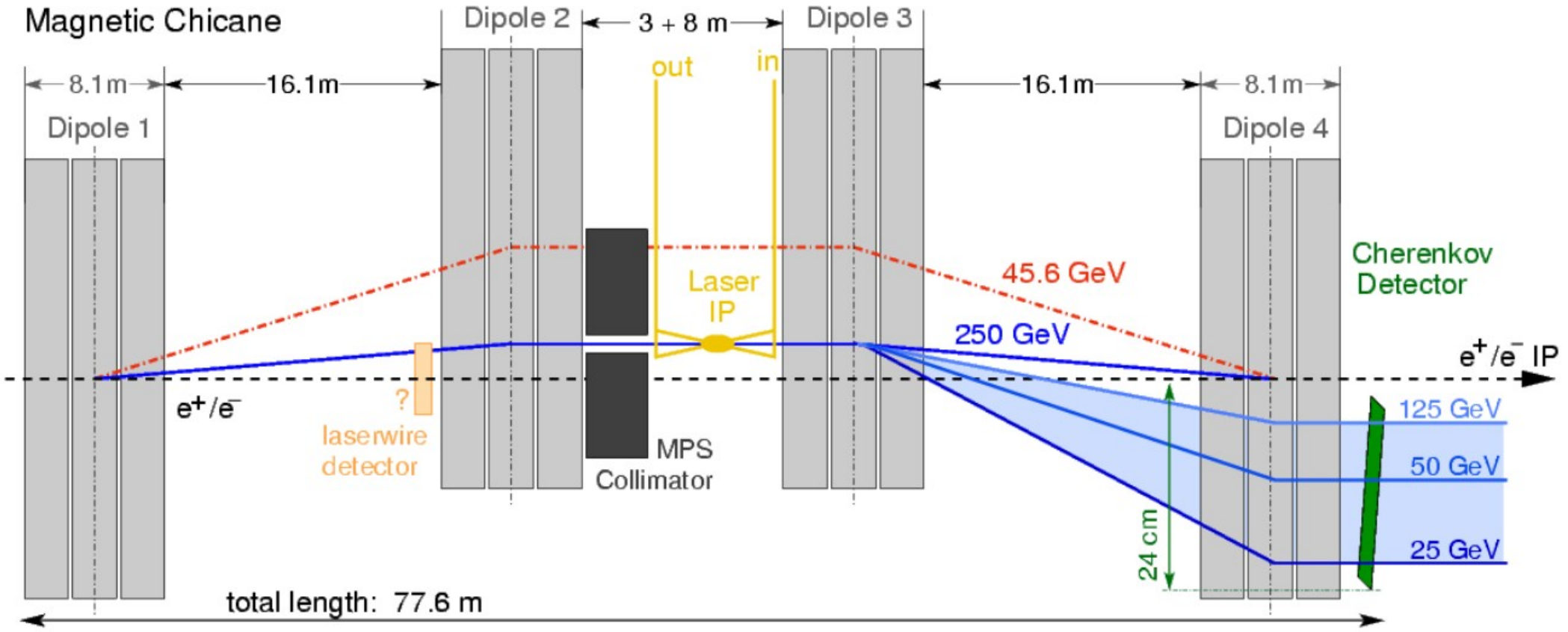
[EPPSU20 Physics Briefing Book]



Polarised positron source:



External polarisation measurement



Fit details

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