Advantages of beam polarisation for electroweak precision

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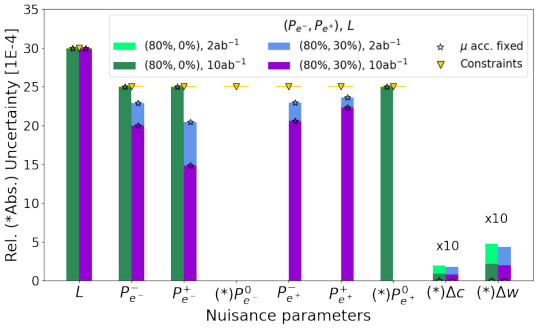
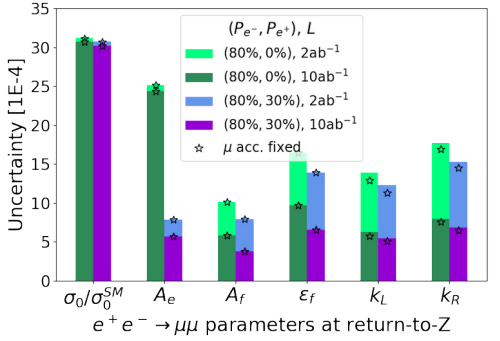
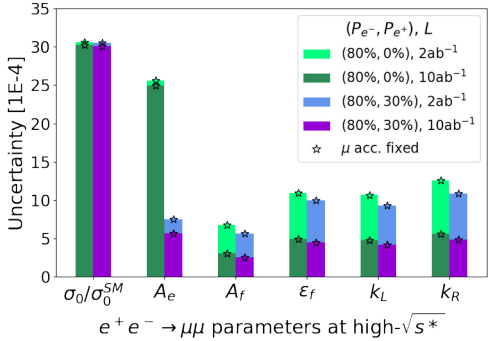
08.06.2021







DESY.

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

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CLUSTER OF EXCELLENCE
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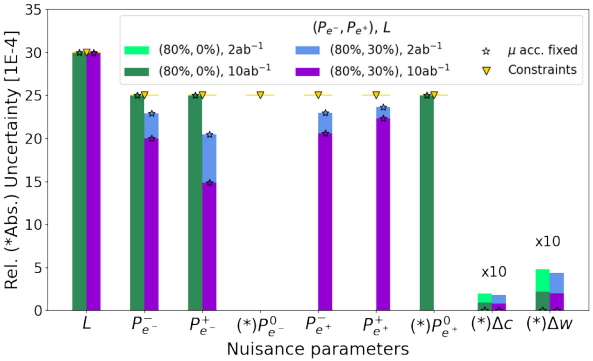
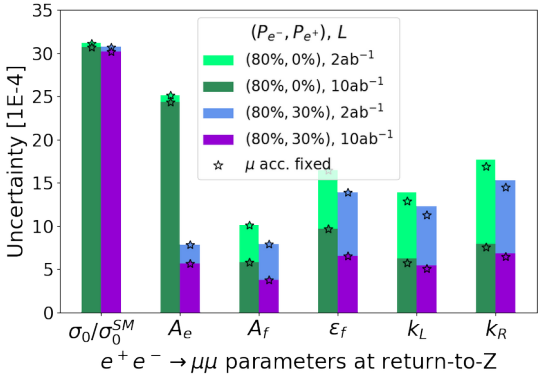
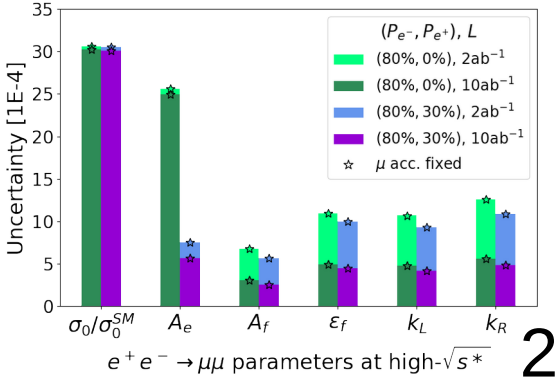
Advantages of beam polarisation

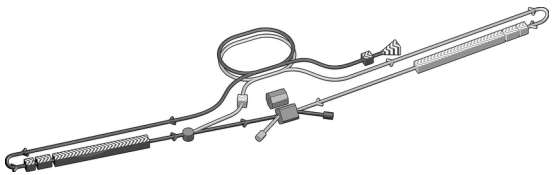
- **direct access to chiral interactions**
  - shown for future colliders
- isolating systematic effects
  - remains somewhat open question

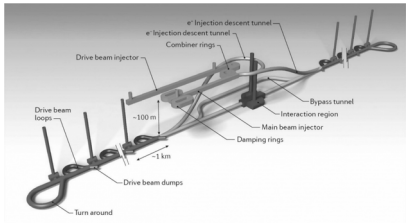


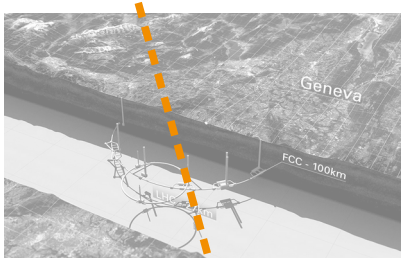




250GeV test scenarios





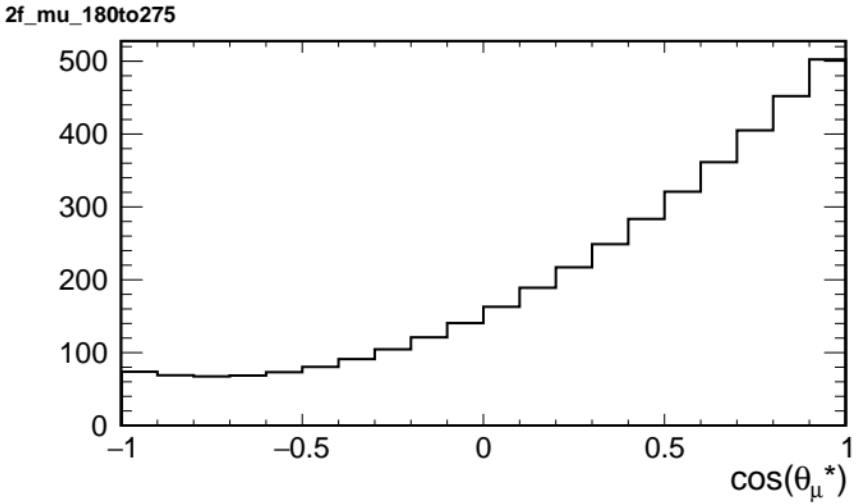


Pol.:	**(80%,30%)**	**(80%,0%)**	(0%,0%)
Sharing:	+- : -+ : ++ : --	+0 : -0	00
	45 : 45 : 5 : 5	50 : 50	

Needs special attention

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

[arXiv:1304.4082] [arXiv:0902.3221]



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

Split into two categories:

- return-to-Z
- high √s*

Polarisation-weighted distributions

Toy fluctuated distributions

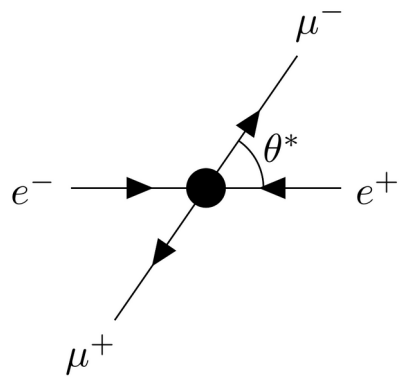
Combined Fit: Log-Likelihood maximisation

Experimental $f\bar{f}$ parametrisation

6 parameters: LEP/SLC parameters

σ_0^f ... total chiral cross section sum

$A_{e/f}$ ... initial / final fermion chiral asymmetry



$$\frac{d\sigma^f_{LR}}{d\cos\theta} = \frac{3}{8}\sigma_0^f \frac{1+A_e}{2}\left[(1+k_L)+(\epsilon_f+2A_f)\cos\theta+(1-3k_L)\cos^2\theta\right]$$

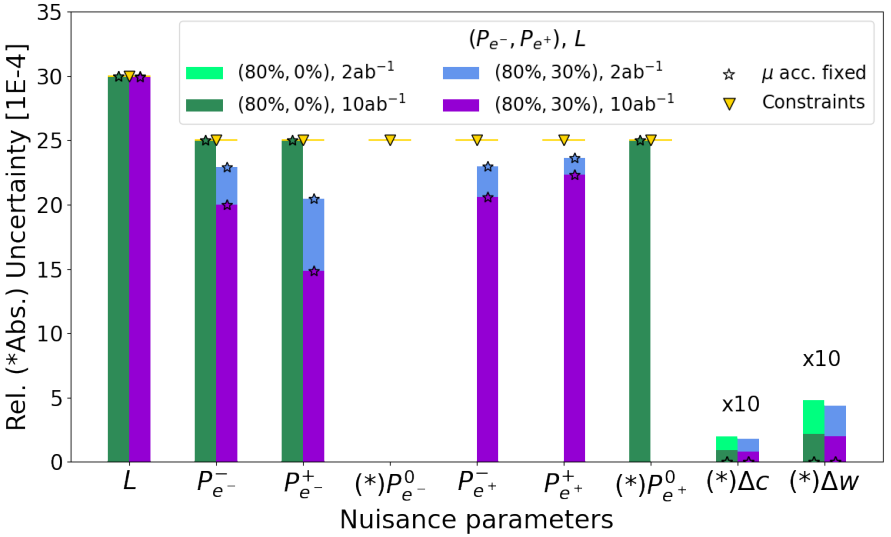
$$\frac{d\sigma^f_{RL}}{d\cos\theta} = \frac{3}{8}\sigma_0^f \frac{1-A_e}{2}\left[(1+k_R)+(\epsilon_f-2A_f)\cos\theta+(1-3k_R)\cos^2\theta\right]$$

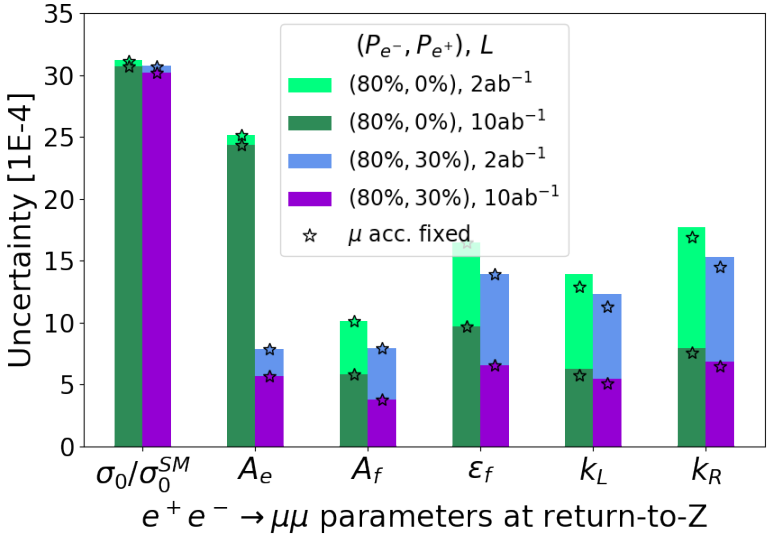
Correction parameters

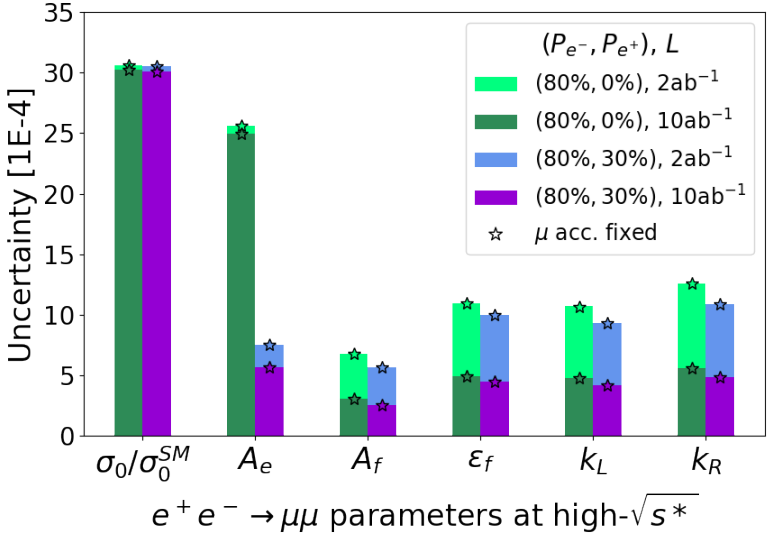
ε_f ... Z/γ interference correction

$k_{L/R}$ ... radiative correction factors

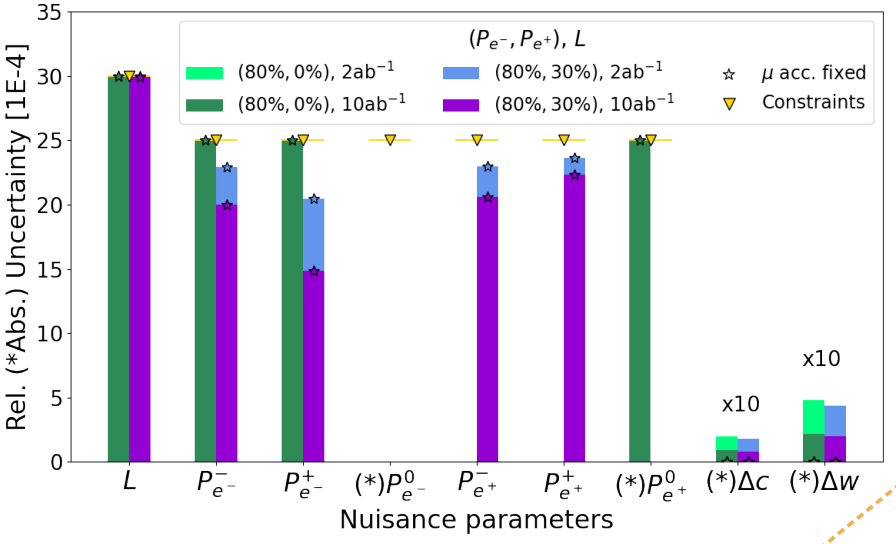
First $\mu\bar{\mu}$ results

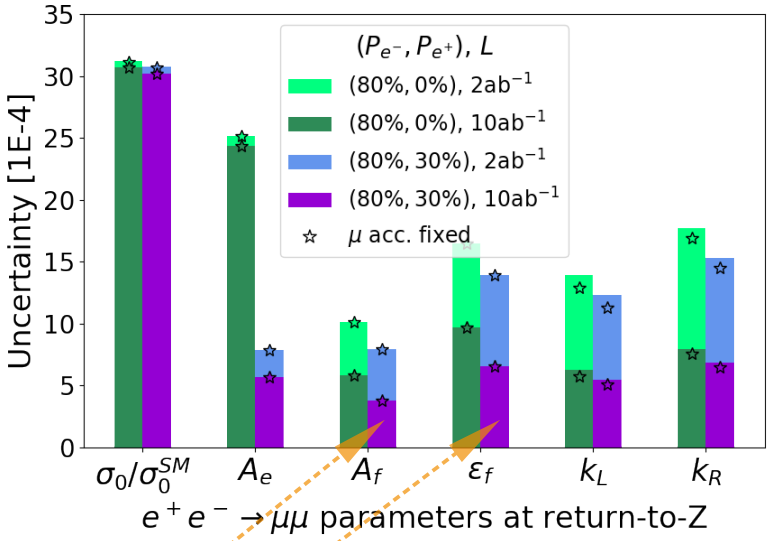


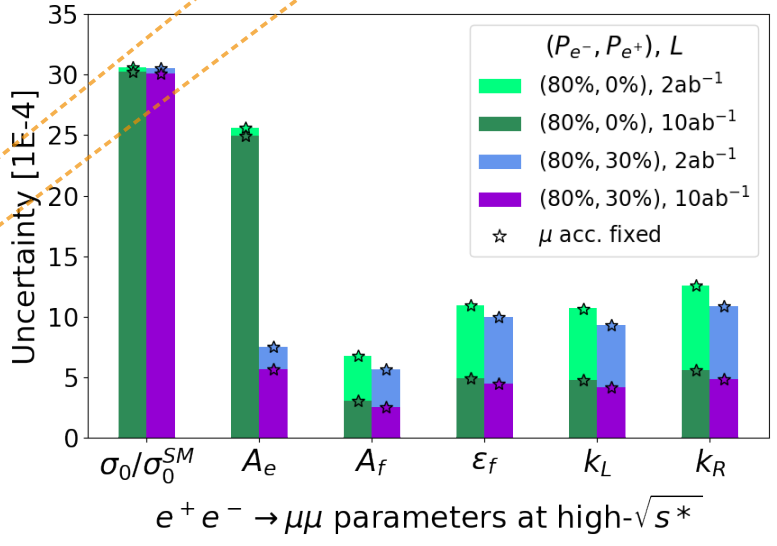




First $\mu\bar{\mu}$ results

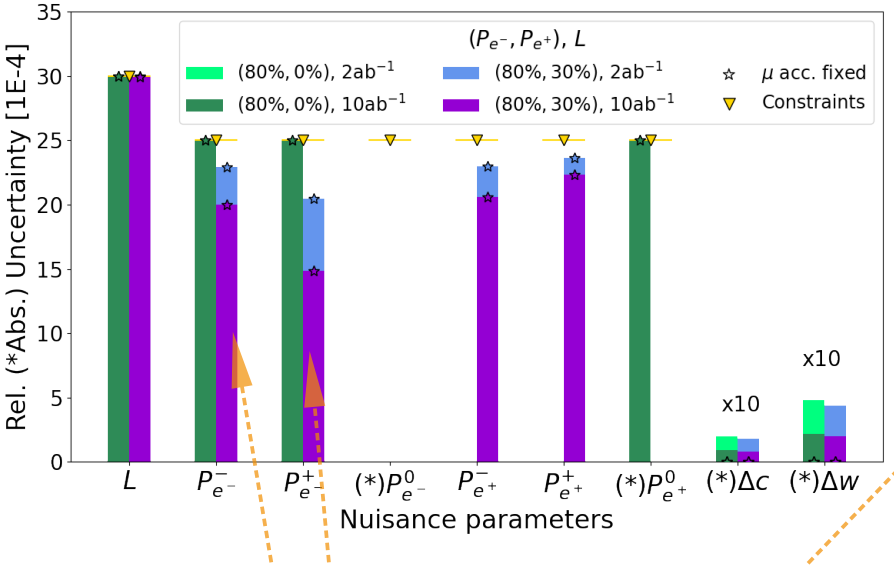


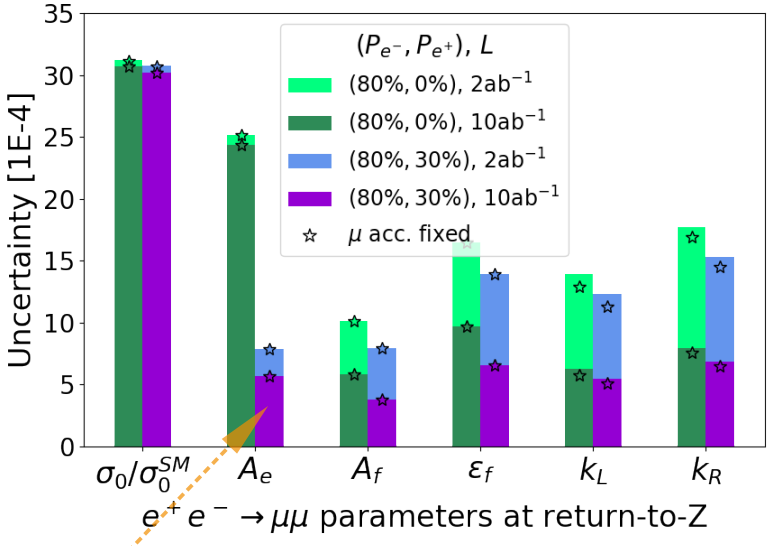


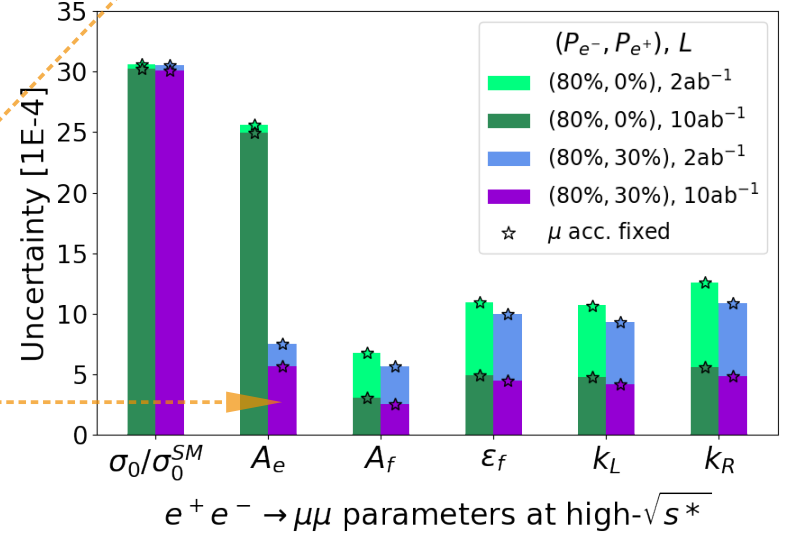


Reflects known e^+ polarisation advantages

First $\mu\bar{\mu}$ results



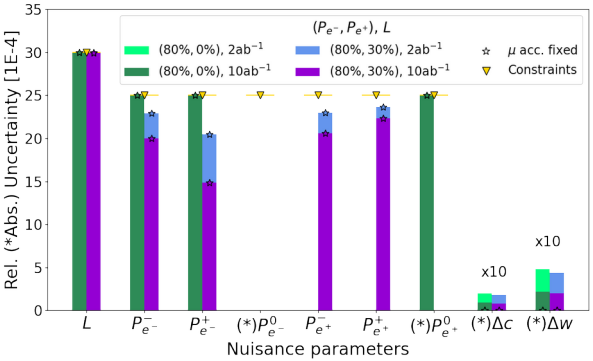


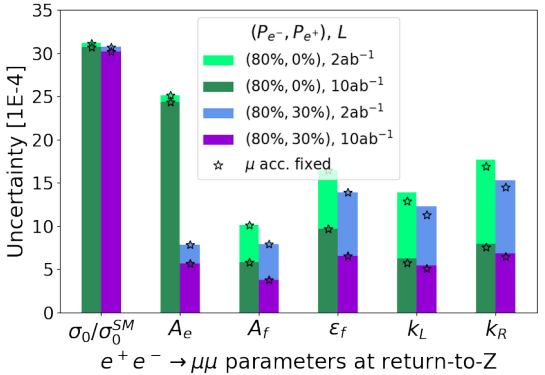


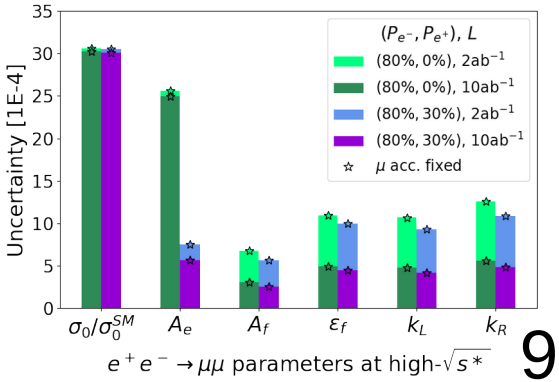
Shows advantage of redundant polarised dataset

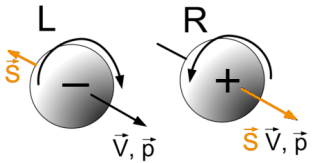
Advantages of beam polarisation

- direct access to chiral interactions
  - shown for future colliders
- **isolating systematic effects**
  - remains somewhat open question



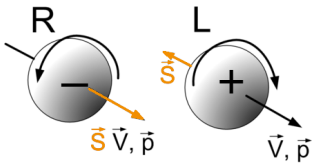


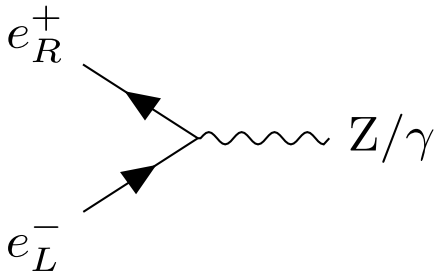




Flipped

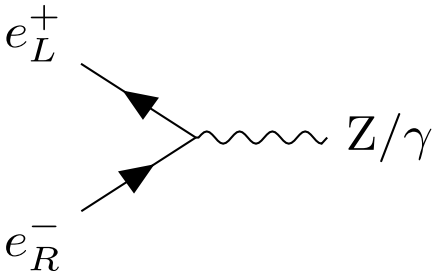
Polarisation

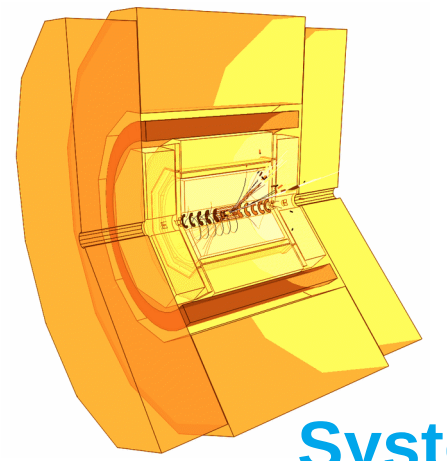




Different

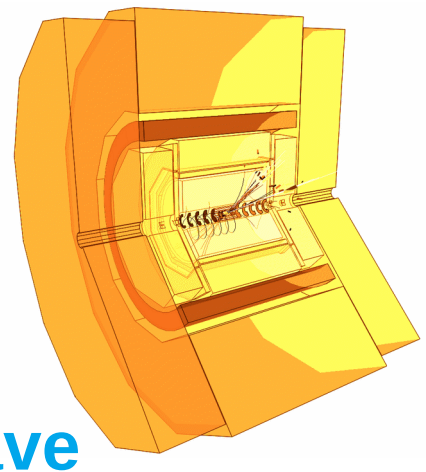
Physics





Same

Detector



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

Which systematic for $\mu\bar{\mu}$?

ALEPH

Table 13. Exclusive $\mu^+\mu^-$ selection: examples of relative systematic uncertainties (in %) for the 1994 (1995) peak points

Source	$\Delta\sigma/\sigma$ (%)
Acceptance	0.05
Momentum calibration	0.006 (0.009)
Momentum resolution	0.005
Photon energy	0.05
Radiative events	0.05
Muon identification	$\simeq$ 0.001 (0.02)
Monte Carlo statistics	0.06
Total	0.10 (0.11)

L3

Table 8. Contributions to the systematic uncertainty on the cross section $e^+e^- \to \mu^+\mu^-(\gamma)$. Except for the contribution from Monte Carlo statistics, all errors are fully correlated among the data sets yielding a correlated scale error of $\delta^{cor} = 3.1^0/_{00}$ for 1993–94 data. For the 1995 data this error is estimated to be $3.6^0/_{00}$ and it is taken to be fully correlated with the other years

Source		1993	1994	1995
Monte Carlo statistics	$[^0/_{00}]$	0.9 – 1.5	0.4	1.7 – 2.4
Acceptance	$[^0/_{00}]$	2.7	2.7	3.2
Selection cuts	$[^0/_{00}]$	1.3	1.3	1.4 – 2.2
Trigger	$[^0/_{00}]$	0.6	0.6	0.5 – 0.7
Resonant background	$[^0/_{00}]$	0.3	0.3	0.3
Total scale	$[^0/_{00}]$	3.2 – 3.4	3.1	3.9 – 4.6
$e^+e^- \to e^+e^-\,\mu^+\mu^-$	[pb]	–	–	0.1
Cosmic rays	[pb]	0.3	0.3	0.3
Total absolute	[pb]	0.3	0.3	0.3

OPAL

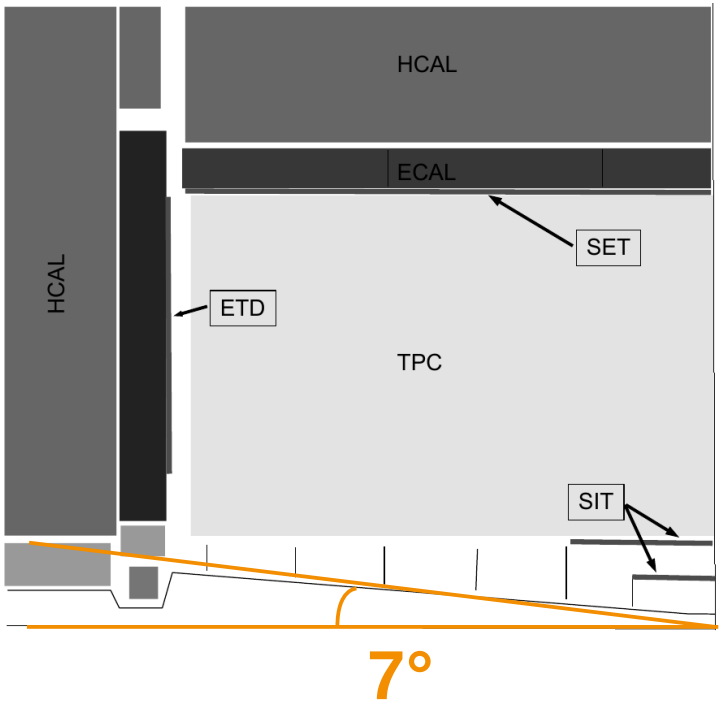
	1993						1994		1995					
	peak−2		peak		peak+2		peak		peak−2		peak		peak+2	
	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)	f	$\Delta f/f$ (%)
Monte Carlo														
$e^+e^- \to \mu^+\mu^-$ Monte Carlo	1.0995	0.10	1.0955	0.07	1.0986	0.10	1.0948	0.04	1.1032	0.12	1.0970	0.05	1.1001	0.10
s' cut correction	0.9971	–	0.9990	–	0.9980	–	0.9990	–	0.9971	–	0.9990	–	0.9980	–
Initial/final state interference	1.0003	–	1.0002	–	1.0001	–	1.0002	–	1.0003	–	1.0002	–	1.0001	–
Acceptance Correction														
Tracking losses	1.0046	0.06	1.0046	0.06	1.0046	0.06	1.0042	0.04	1.0043	0.06	1.0043	0.06	1.0043	0.06
Track multiplicity cuts	0.9999	0.05	1.0007	0.04	1.0000	0.04	1.0004	0.02	1.0007	0.09	1.0010	0.04	1.0013	0.08
Muon identification	1.0000	0.05	1.0000	0.05	1.0000	0.05	1.0015	0.04	1.0000	0.06	1.0000	0.06	1.0000	0.06
Acceptance definition	1.0000	0.10	1.0000	0.10	1.0000	0.10	1.0000	0.05	1.0000	0.05	1.0000	0.05	1.0000	0.05
Other Corrections														
Trigger efficiency	1.0006	0.02	1.0006	0.02	1.0006	0.02	1.0005	0.02	1.0002	0.02	1.0002	0.02	1.0002	0.02
Four-fermion events	1.0009	0.01	1.0011	0.01	1.0011	0.01	1.0011	0.01	1.0009	0.01	1.0011	0.01	1.0011	0.01
Signal Correction	1.1032	0.17	1.1022	0.15	1.1034	0.17	1.1024	0.09	1.1071	0.18	1.1034	0.12	1.1056	0.16
Backgrounds														
$e^+e^- \to \tau^+\tau^-$	0.9914	0.02	0.9914	0.02	0.9914	0.02	0.9903	0.04	0.9905	0.02	0.9905	0.02	0.9905	0.02
$e^+e^- \to e^+e^-\mu^+\mu^-$	0.9988	0.01	0.9995	0.01	0.9991	0.01	0.9996	0.01	0.9987	0.01	0.9995	0.01	0.9990	0.01
Cosmic rays	0.9998	0.02	0.9998	0.02	0.9998	0.02	0.9998	0.02	0.9997	0.02	0.9997	0.02	0.9997	0.02
Background Correction	0.9900	0.03	0.9907	0.03	0.9903	0.03	0.9897	0.05	0.9889	0.03	0.9897	0.03	0.9892	0.03
Total Correction Factor	1.0922	0.17	1.0920	0.16	1.0927	0.17	1.0910	0.10	1.0948	0.18	1.0920	0.12	1.0937	0.17

Table 6: Summary of the correction factors, f, and their relative systematic errors, $\Delta f/f$, for the $e^+e^- \to \mu^+\mu^-$ cross-section measurements. These numbers, when multiplied by the number of events actually selected, give the number of signal events which would have been observed in the ideal acceptance described in Table 2. The effects tracking losses, track multiplicity cuts and muon identification were, in principle, simulated by the Monte Carlo. The quoted corrections were introduced to take into account the observed discrepancies between the data and Monte Carlo for these effects. The error correlation matrix is given in Table 19.

→ First test of systematic effect: **μ acceptance**

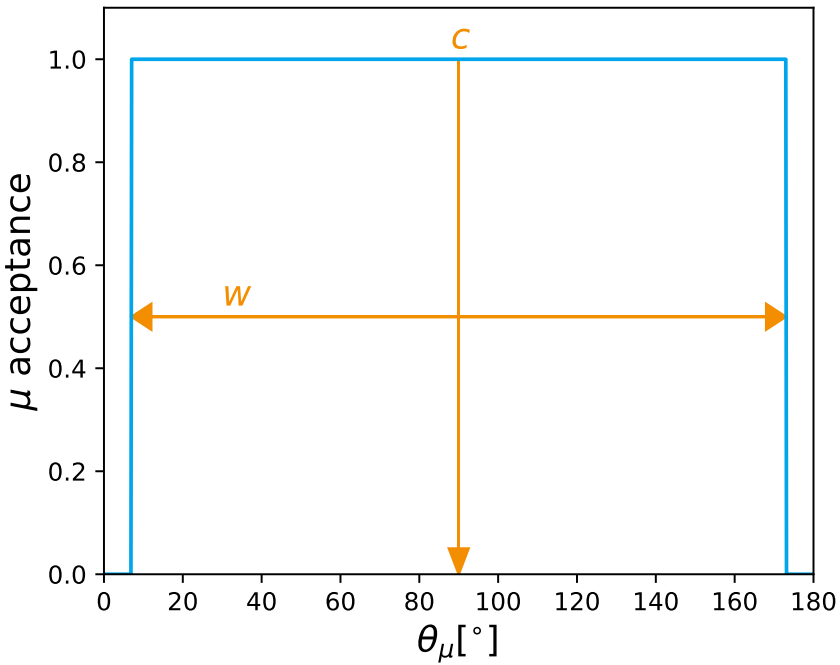
μ acceptance

ILD tracking down to:

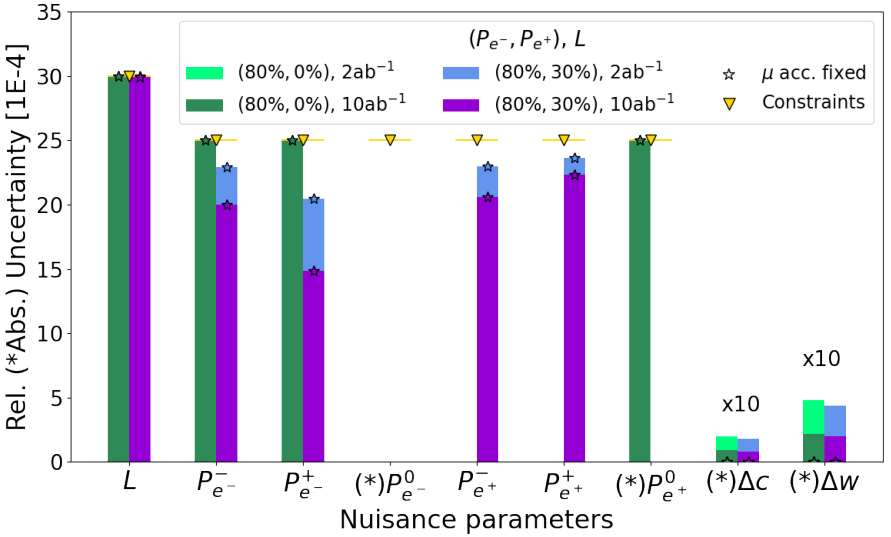


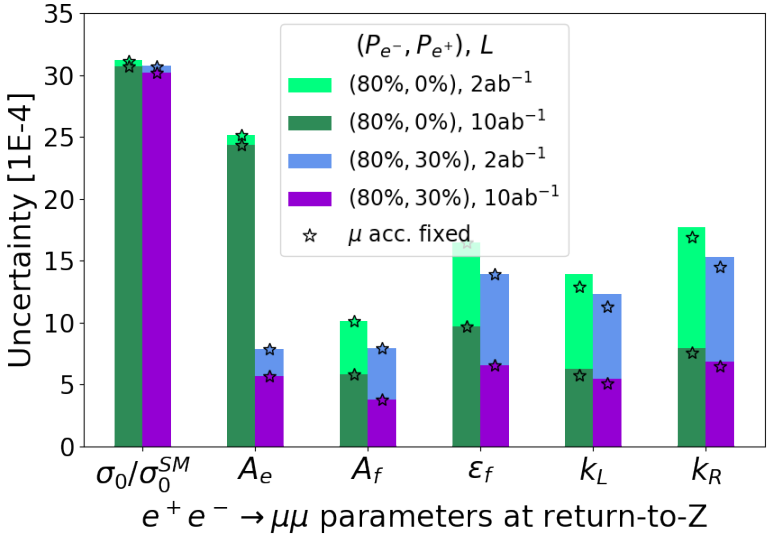
Simplified μ acceptance

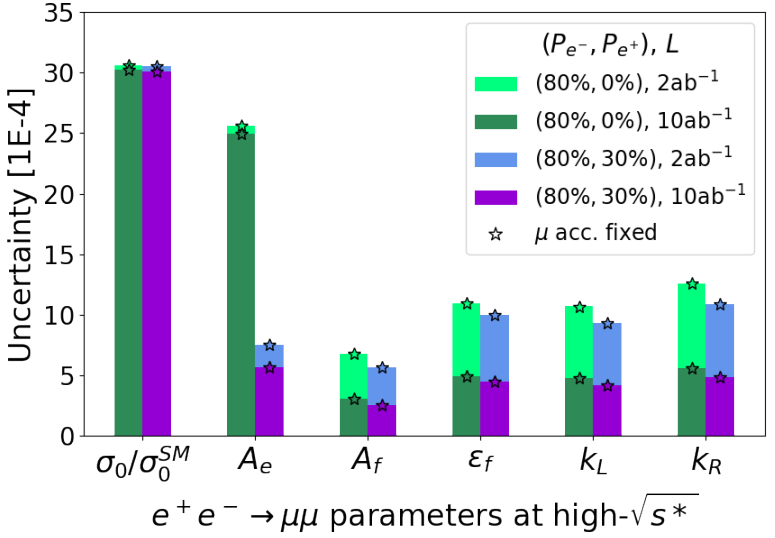
→ 2 Parameters: Δc, Δw



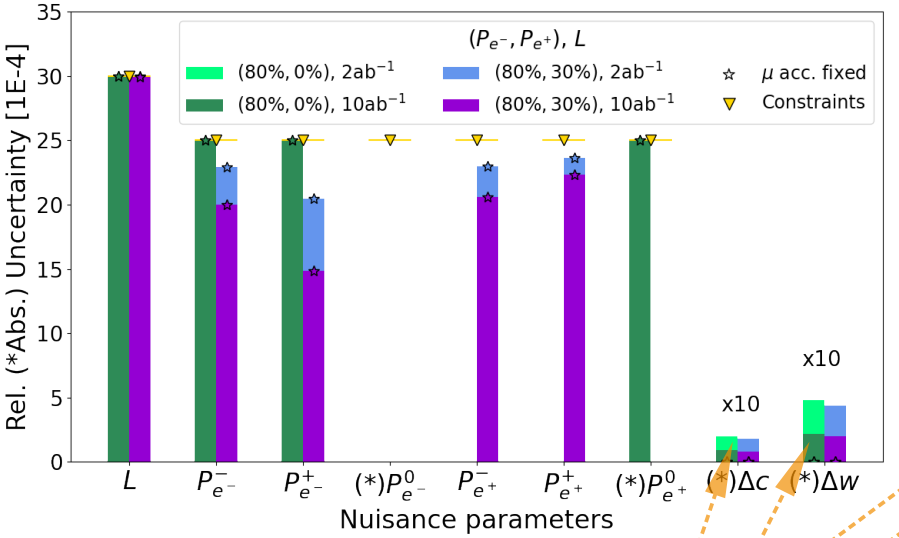
First $\mu\bar{\mu}$ results

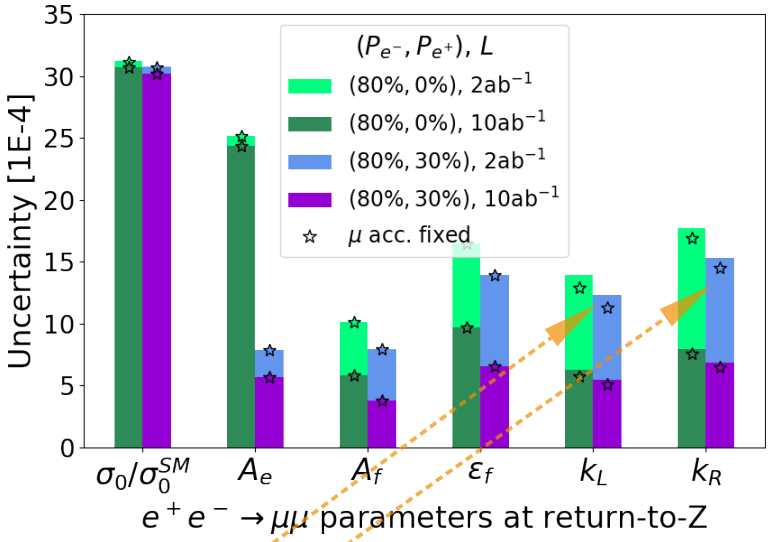


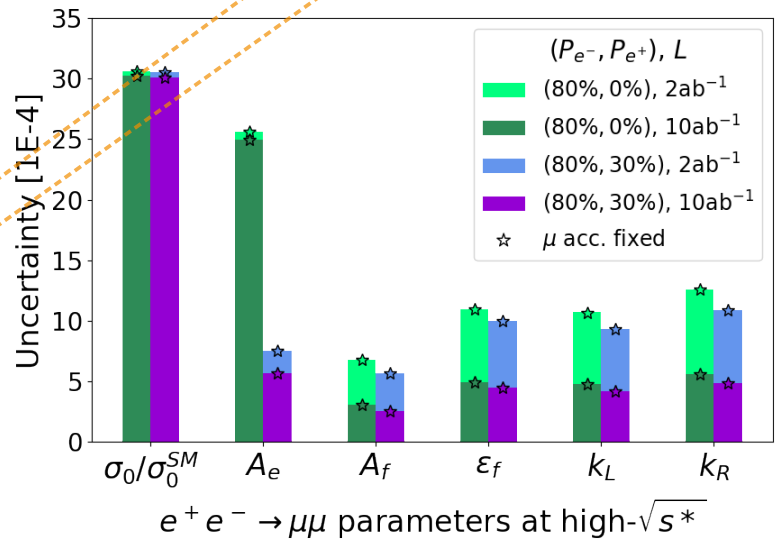




First $\mu\bar{\mu}$ results



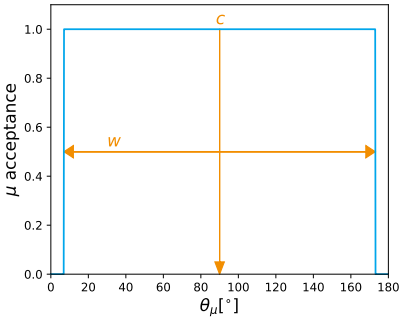




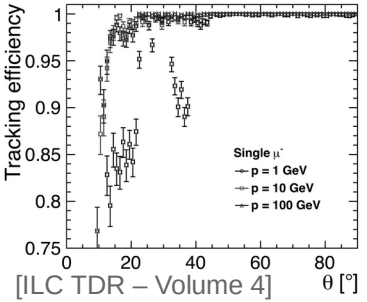
μ acceptance well determined, no add. advantage from e^+ pol.

Why no additional advantage?

(Too?) simplified model

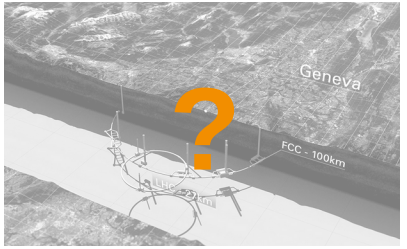


vs



[ILC TDR – Volume 4]

Unpolarised not yet included

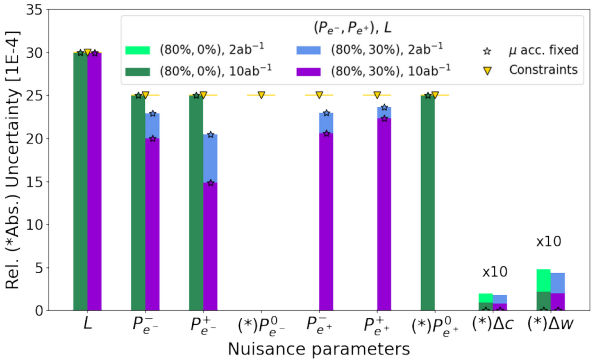


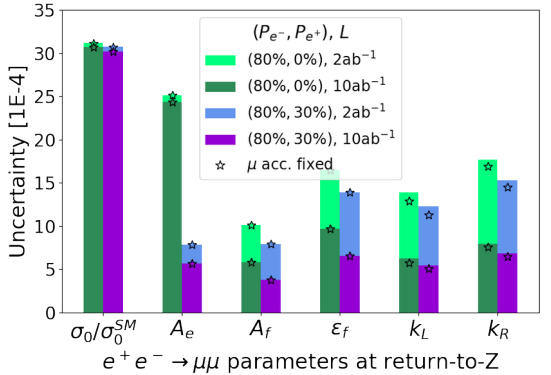
μ acceptance may not be limiting systematic effect
→ Lumimeter / Polarimeter constraints dominating

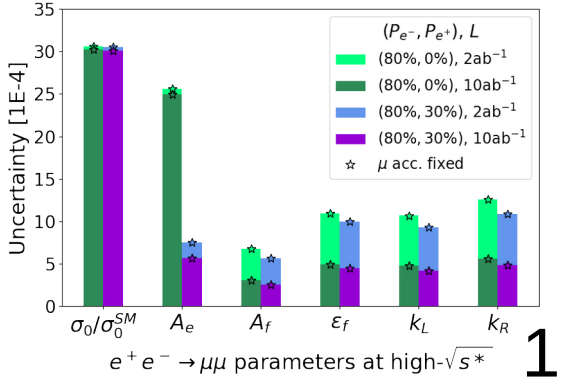
μ acceptance well determined,
no add. advantage from e^+ pol.

Advantages of beam polarisation

- **direct access to chiral interactions**
  - shown for future colliders
- **isolating systematic effects**
  - remains somewhat open question

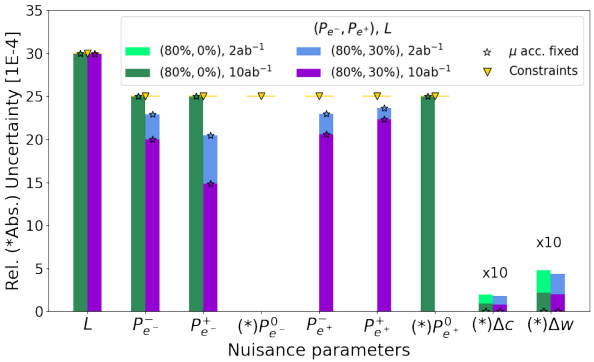


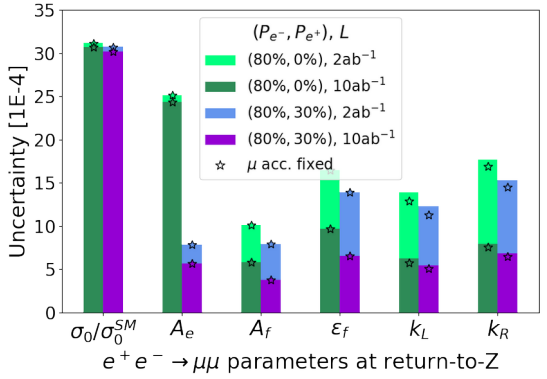


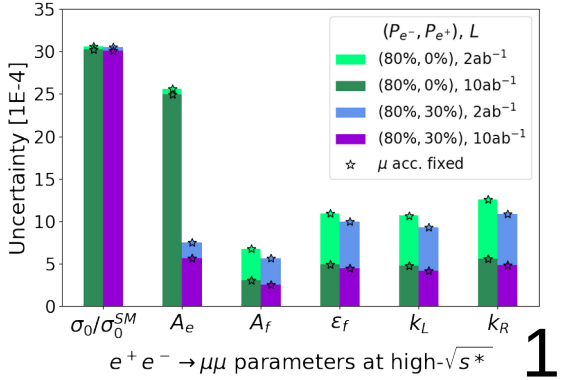


Advantages of beam polarisation

The <u>direct</u> access to the chiral part of interactions makes electroweak measurements much easier, by decoupling them from other physical or systematic effects.

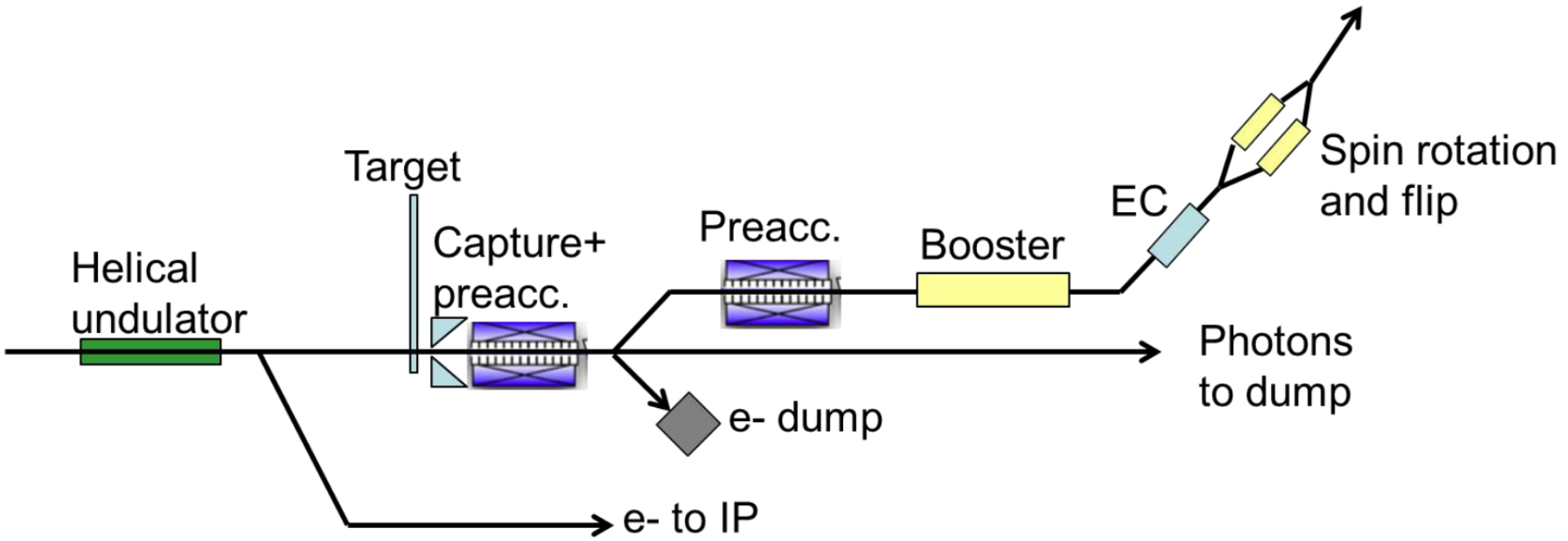




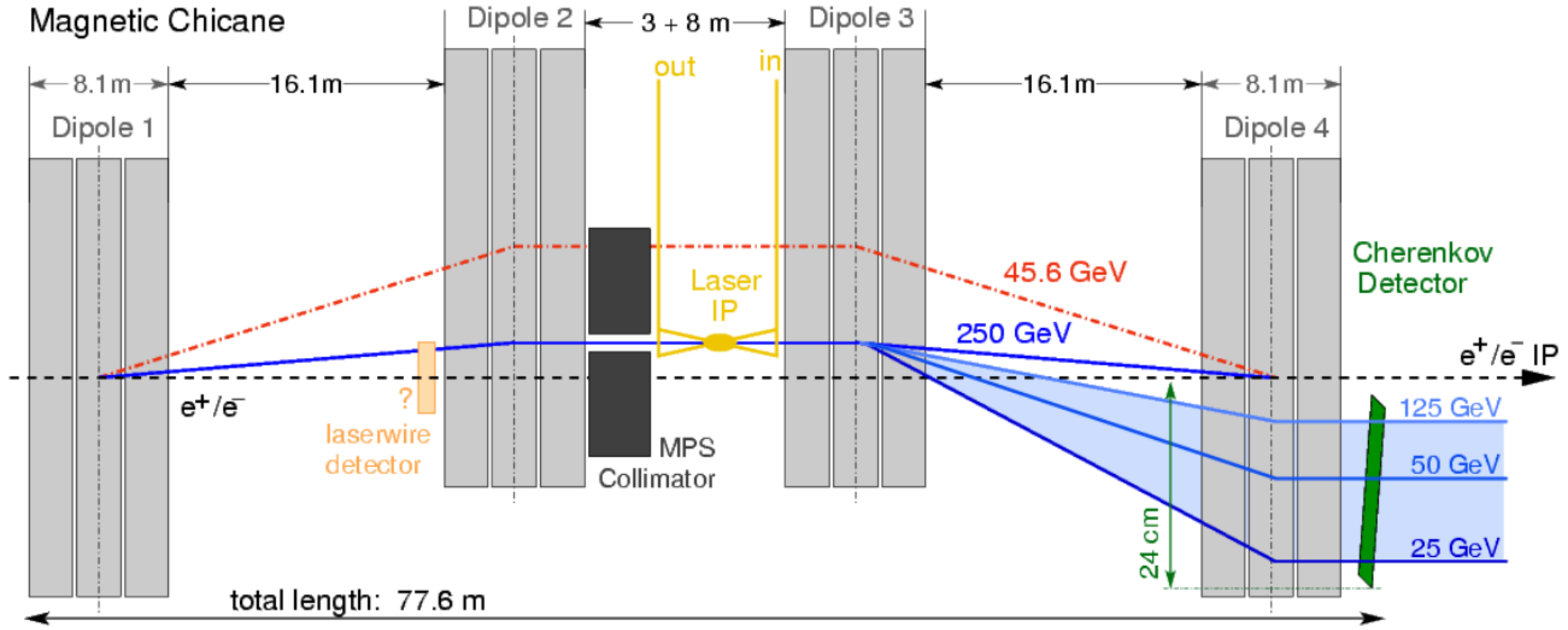


BACKUP

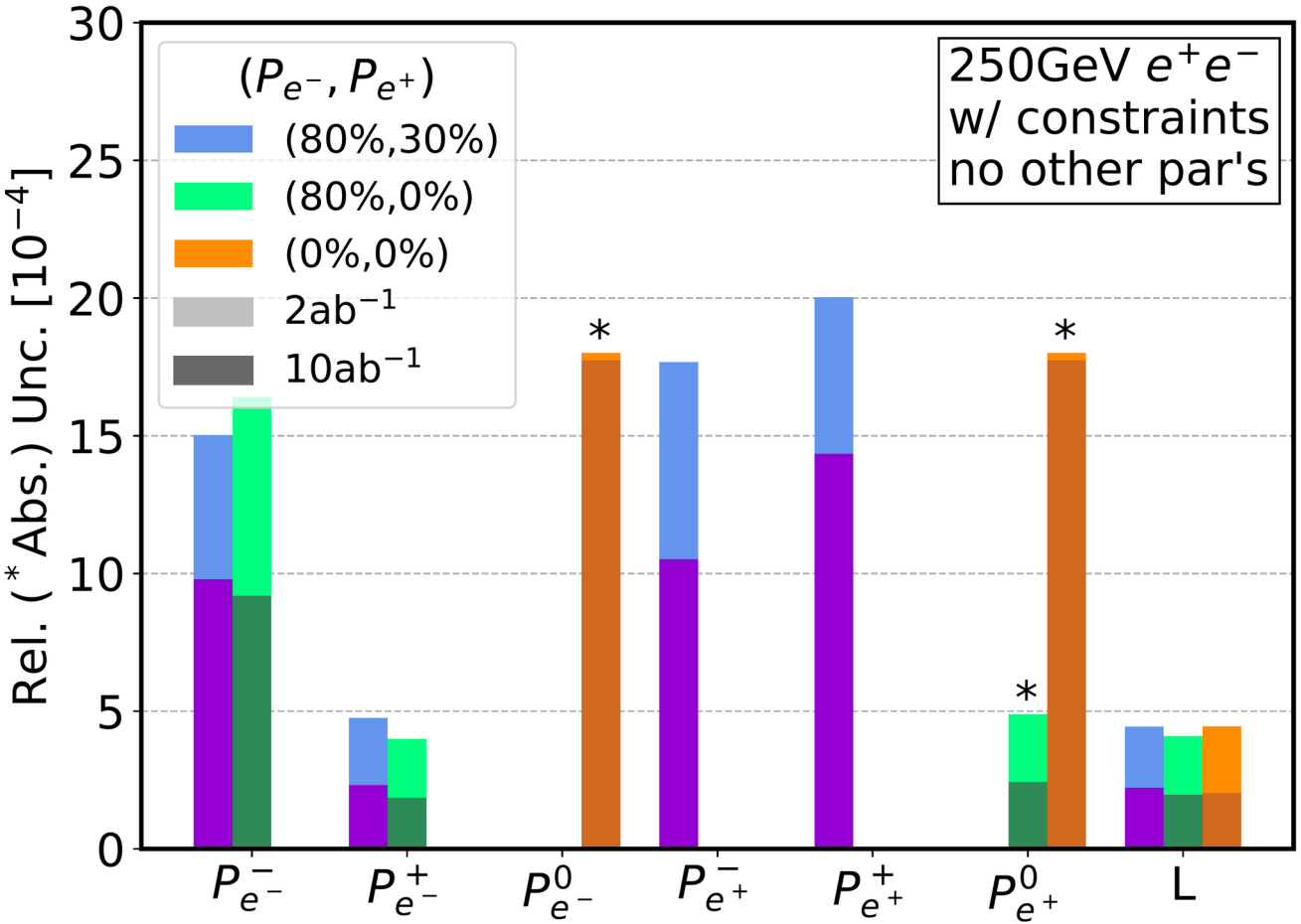
Polarised positron source:



External polarisation measurement



Can test P-&L-dependence of uncertainties

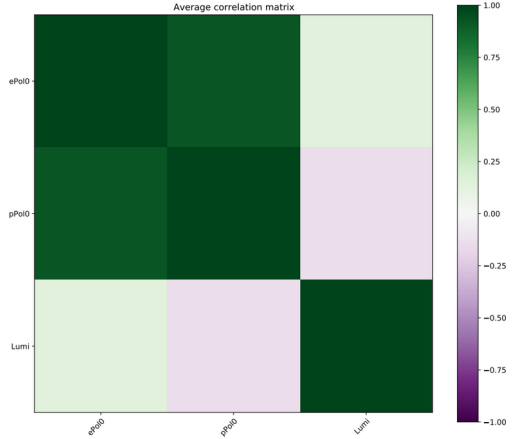


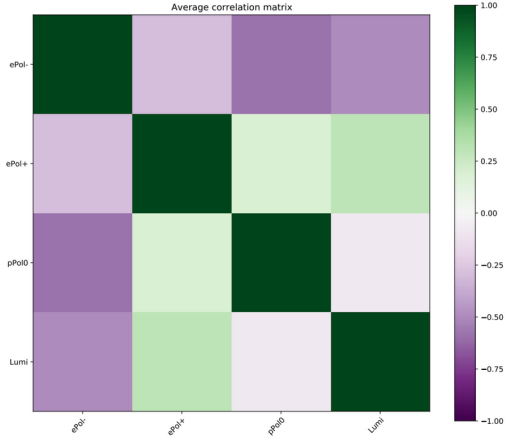
Purely for testing!

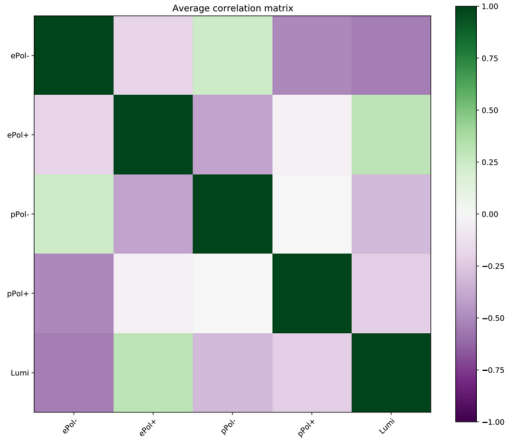
- no other parameters
- cross sections fixed

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

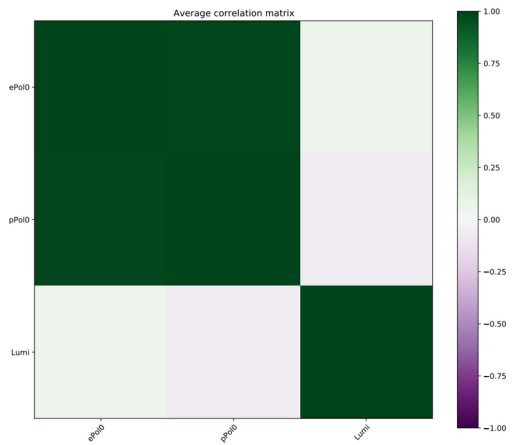
2ab^{-1}

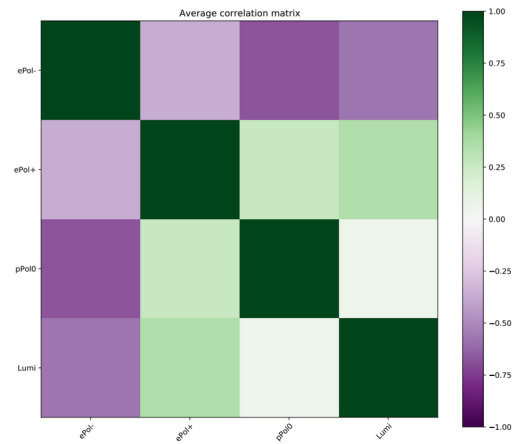


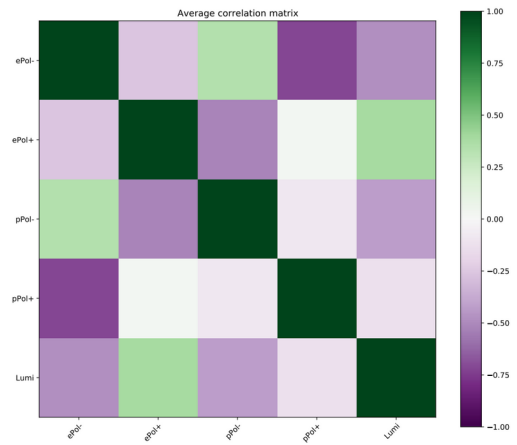




10ab^{-1}

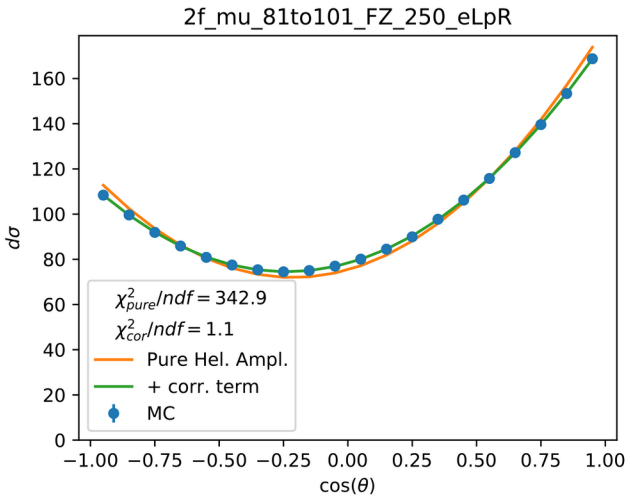


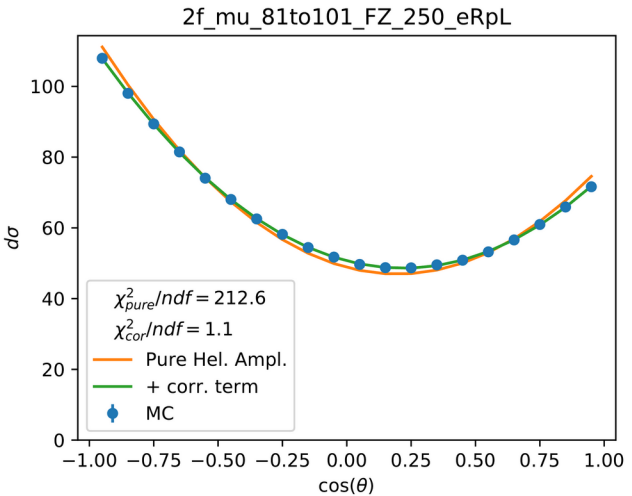




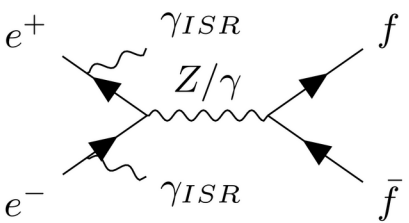
Can test P-&L-dependence of correlations

Helicity amplitude approach @ return-to-Z

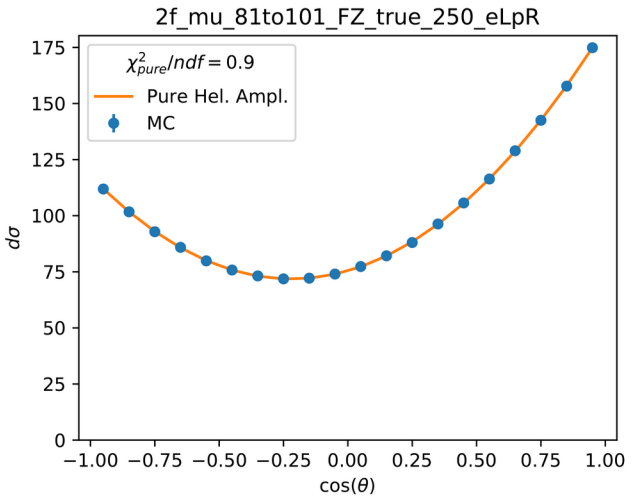


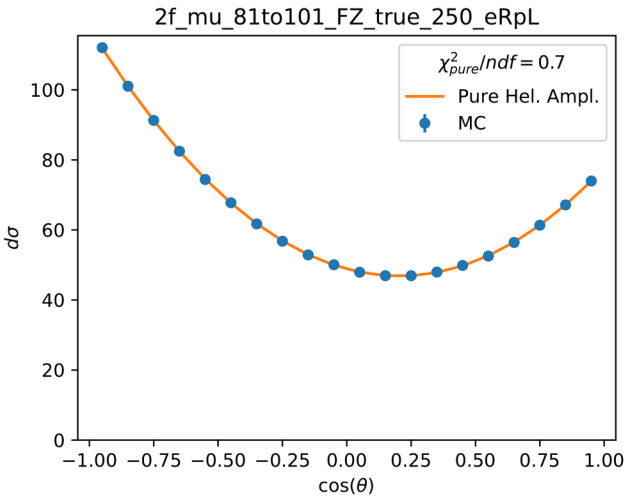


Hypothesis: correction needed because of unknown z∗-axis direction due to ISR

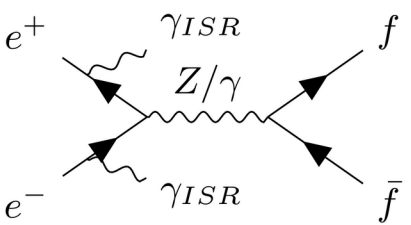


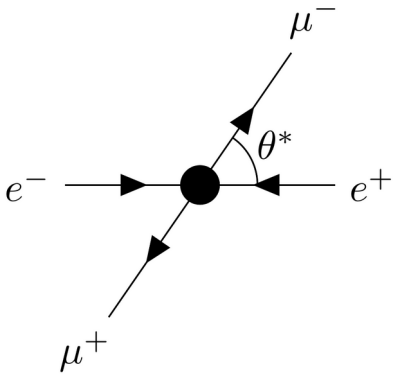
Cheating test: angle after ISR





$\Longrightarrow$ **Hypothesis correct, correction needed because of ISR**

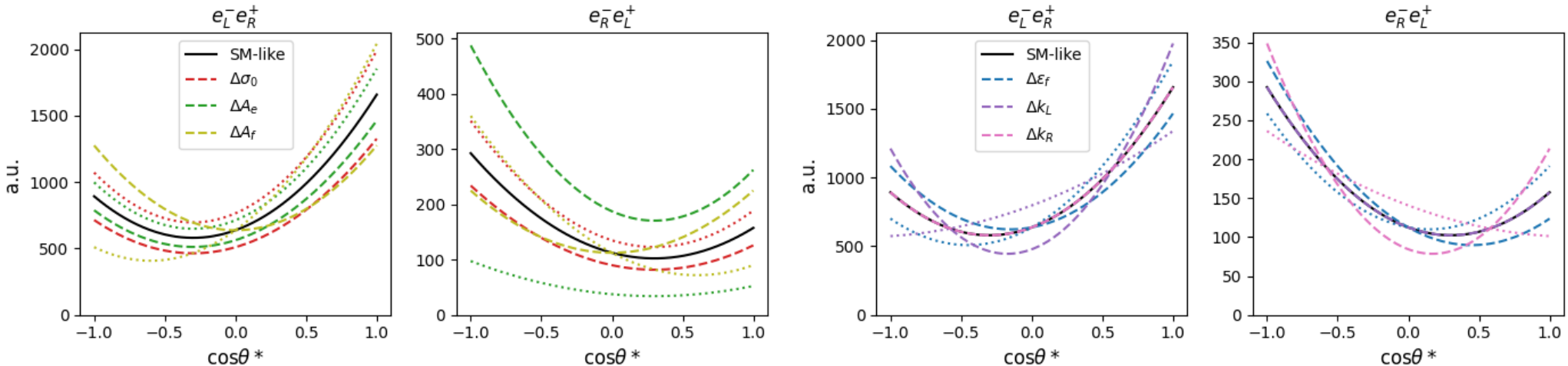




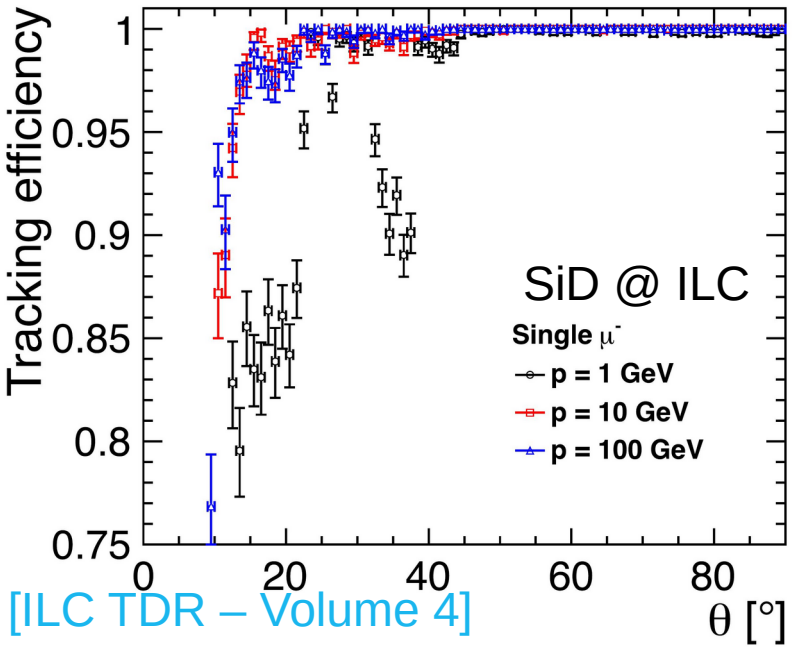
$$\frac{d\sigma^f_{LR}}{d\cos\theta} = \frac{3}{8}\sigma_0^f \frac{1+A_e}{2}\left[(1+k_L)+(\epsilon_f+2A_f)\cos\theta+(1-3k_L)\cos^2\theta\right]$$

$$\frac{d\sigma^f_{RL}}{d\cos\theta} = \frac{3}{8}\sigma_0^f \frac{1-A_e}{2}\left[(1+k_R)+(\epsilon_f-2A_f)\cos\theta+(1-3k_R)\cos^2\theta\right]$$

Example with meaningless values / deviations

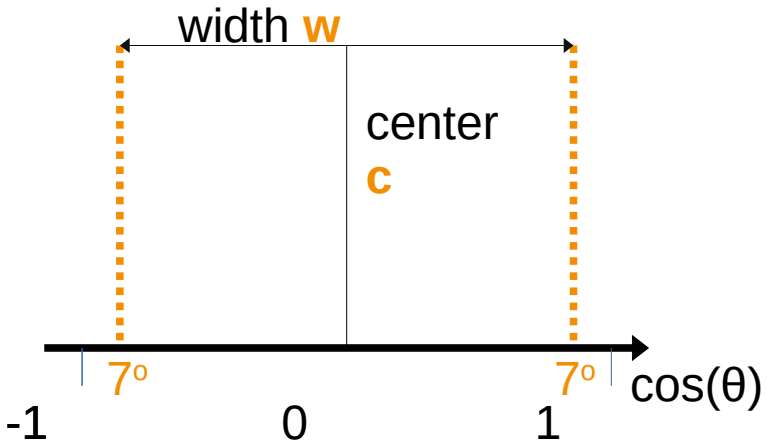


Implementing μ acceptance



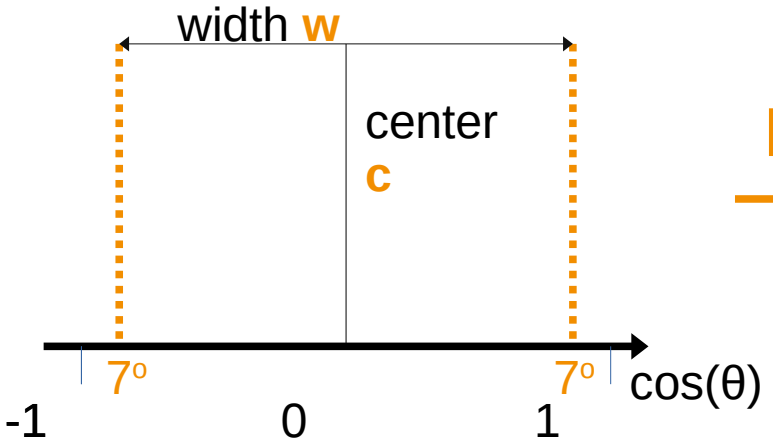
[ILC TDR – Volume 4]

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

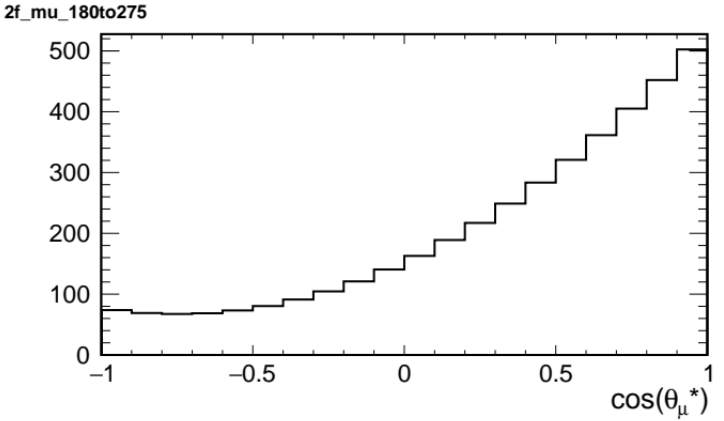


Fit parameters: Δc, Δw

Parametrising μ acceptance



Effect on



?

Parametrisation (per bin):

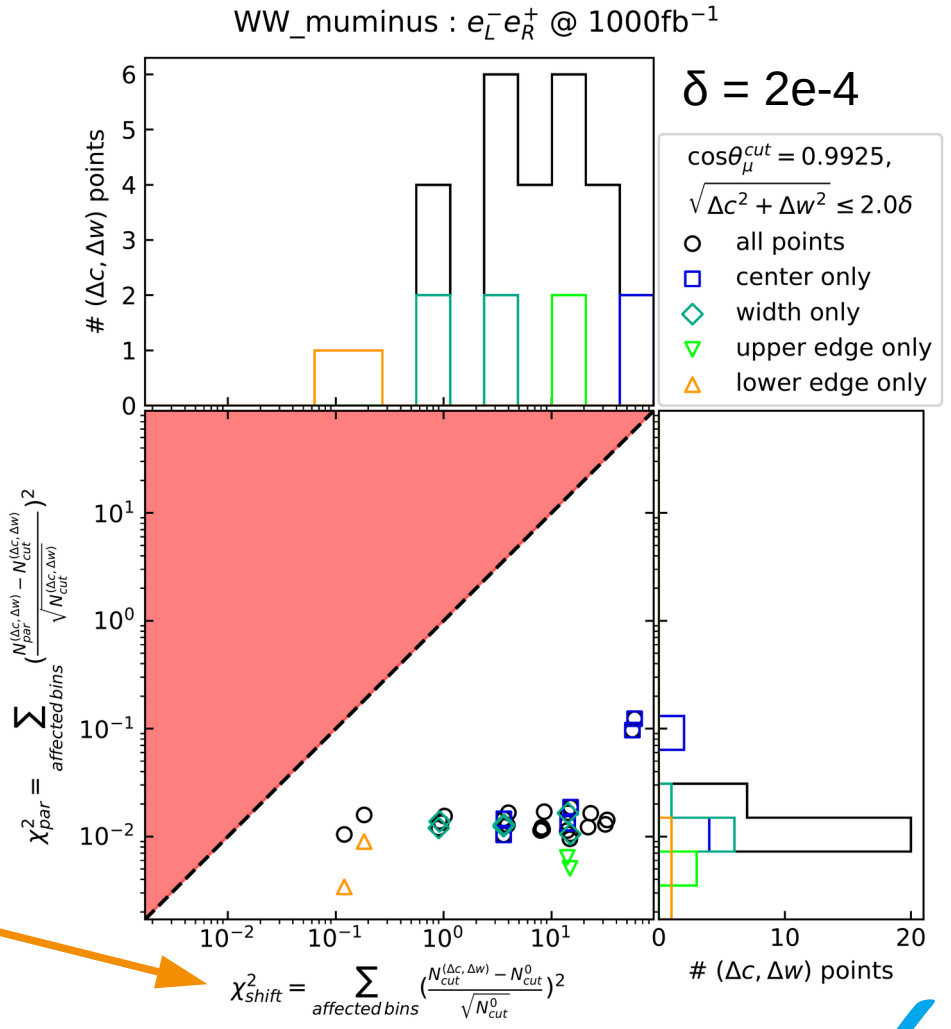
$d\sigma/\sigma = k_0 + k_c\,\Delta c + k_w\,\Delta w + k_{c2}\,\Delta c^2 + k_{w2}\,\Delta w^2 + k_{cw}\,\Delta c\,\Delta w$

...

Test (c±δ,w±δ) values on MC

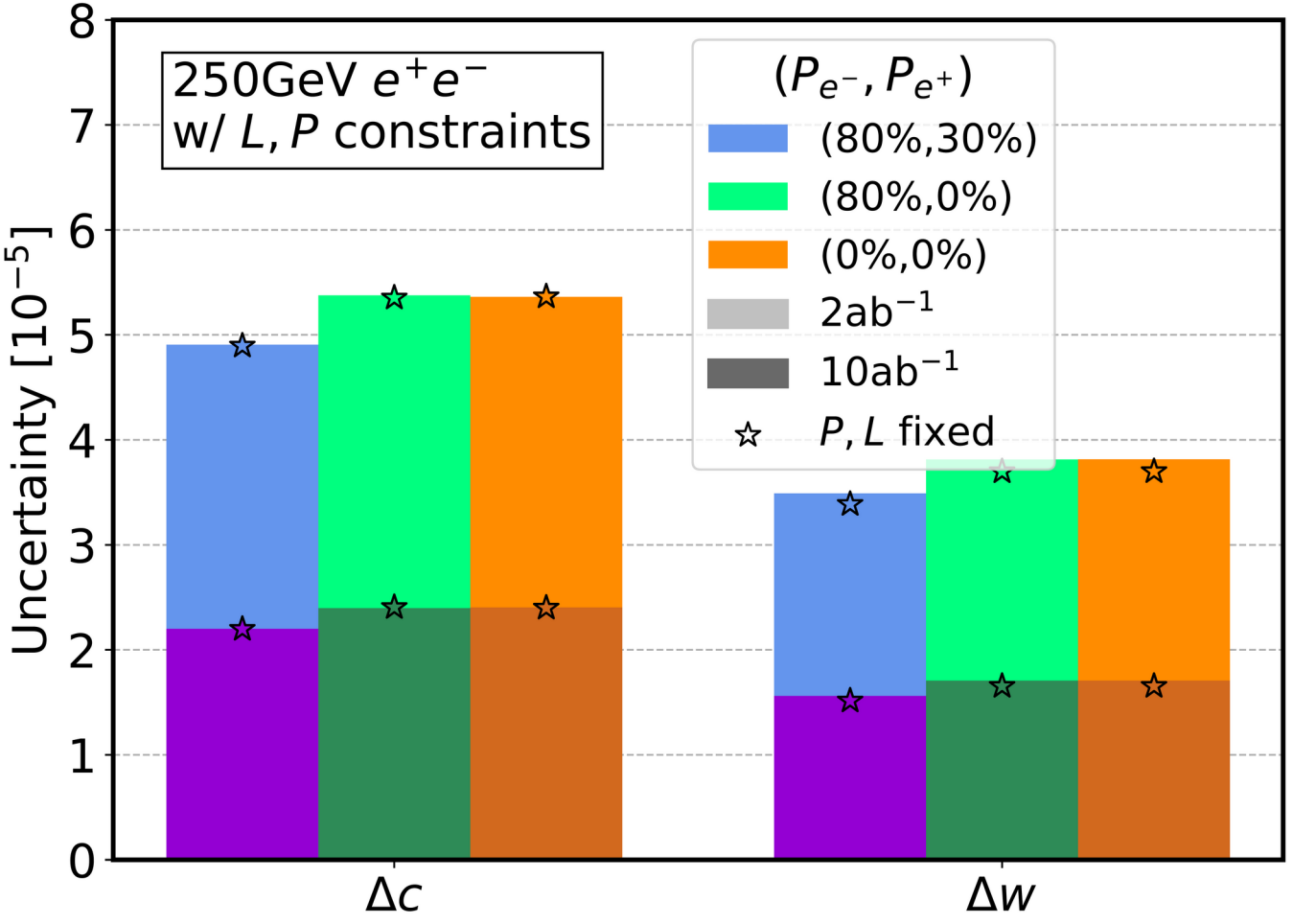
Validation of the parametrisation:

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



Safe to use ✓

First tests: Statistical influence of collider setups



Purely for testing!

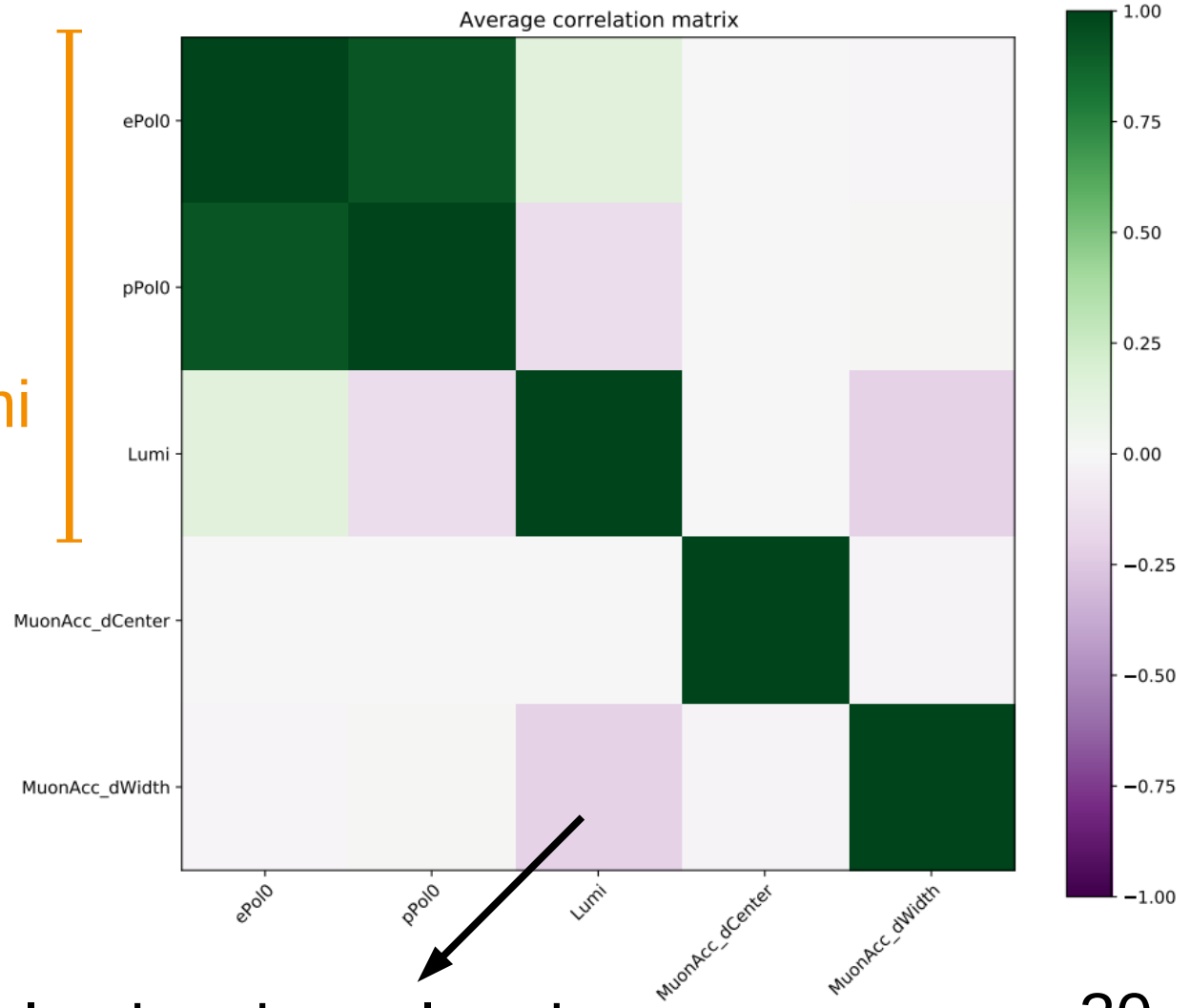
- else only: L,P's
- cross sections fixed

Example:
2ab^{-1} unpolarised

Free parameters:

Polarisations & Lumi
(w/ constraints)

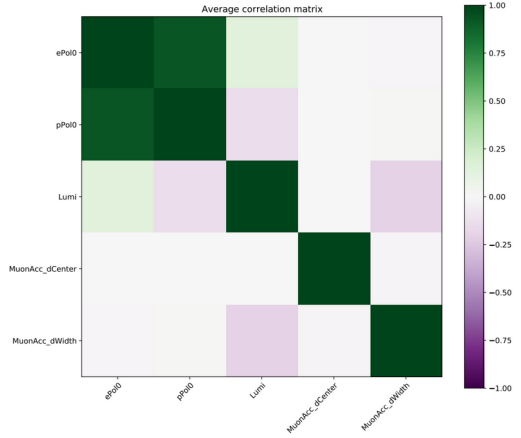
μ acceptance parameters

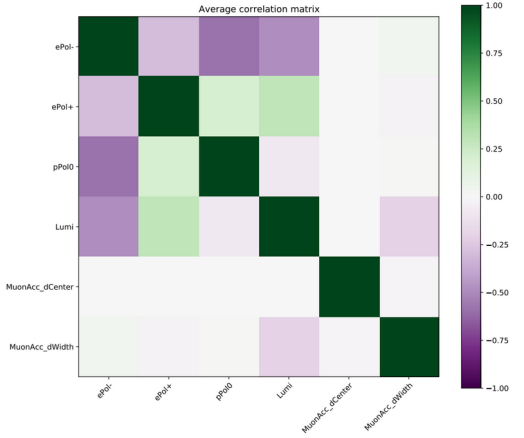


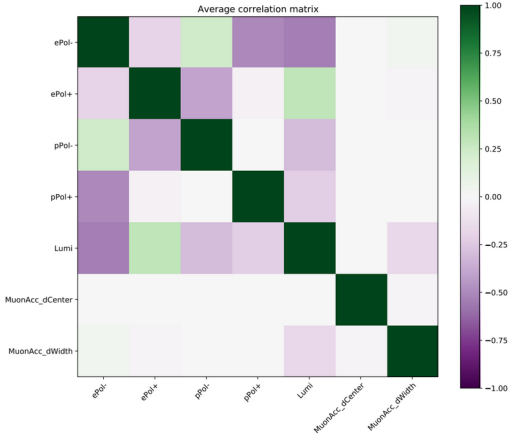
accept. width & lumi anticorrelated

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

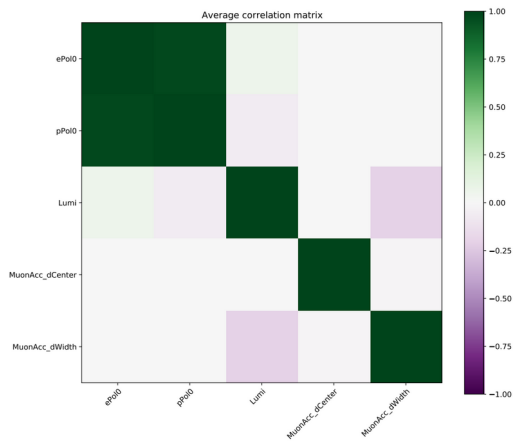
2ab^{-1}

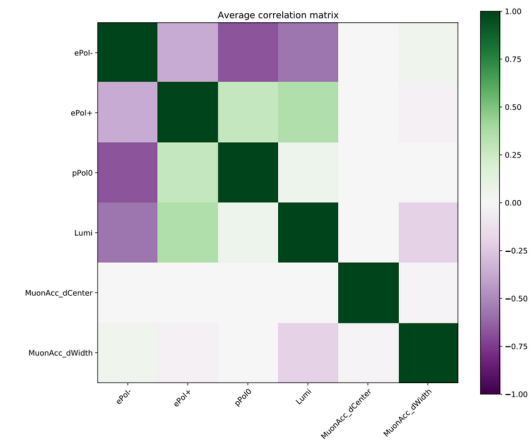


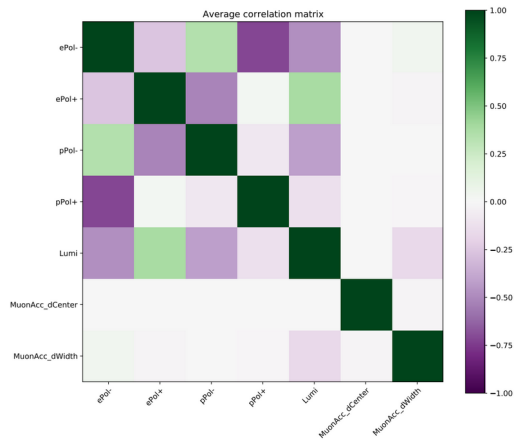




10ab^{-1}







Systematic effect *alone* unaffected by polarisation