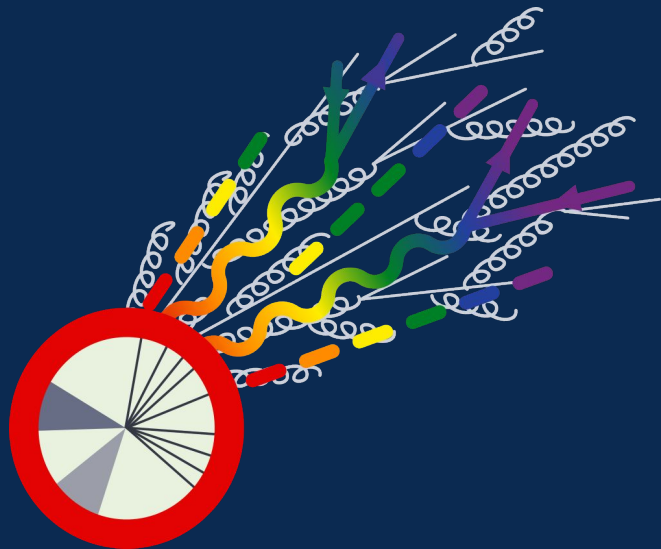
TECHNISCHE UNIVERSITÄT DRESDEN
INSTITUT FÜR KERN- UND TEILCHENPHYSIK

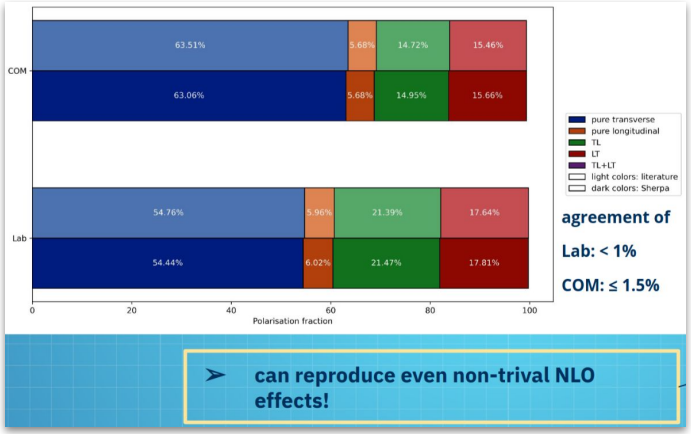
Panel discussion on W and Z polarization

COMETA General Meeting
Izmir 2024



Sensitivity to higher-order corrections

[Mareen]



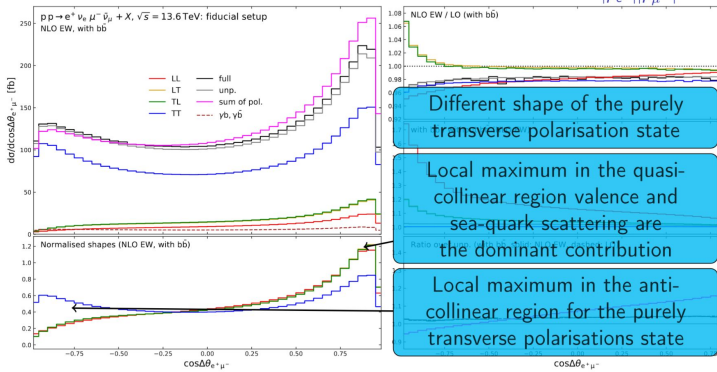
Important [Rene]

Just using some K-factors is not enough

Process	LO	NLO	NLO EW	NNLO	+ PS
pp → WW	X	X	X	X	X
pp → ZZ	X	X	X		X
pp → WZ	X	X	X		X
pp → W/Z	X	X	X	(X)	X
pp → W+j	X	X	(X)	X	
pp → Z+j	X	(X)			
pp → VH	(X)				
pol. VBS	X	X			

[Christoph]

Angular separation positron and muon $\cos(\Delta\vartheta_{e^+\mu^-}) = \frac{\vec{p}_{e^+}\vec{p}_{\mu^-}}{|\vec{p}_{e^+}||\vec{p}_{\mu^-}|}$



How can me make polarised HO calculations usable in experimental analysis? [Mareen, Rene]

- Further systematic tests: **QCD corrections** captured by real emissions?
  - would allow to apply ~automatic approaches (ME+PS, nLO+PS) to complicated processes
- **EW corrections** more difficult... dedicated fixed-order calculations, not included in MC generators
  - similar extensions of automatic methods? EW Sudakovs? EWvirt? [Christoph, Christopher]
- Until then: fudges in the experiment... how to not get them too wrong (**avoid double counting**, ...)
- New HO approaches → **systematic generator comparison paper in COMETA** [needs commitment!!!]

Templates as proxies for measurements

How to measure polarization?

- Parity violation in weak interactions → polarization has effects on the decay products
- Angular variables between the bosons and the decays are typically used to measure the weak bosons polarizations
- Perform fits to data distributions using ***polarized templates***

[Joany]

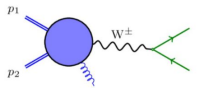
Getting polarised templates is a challenge!

MC simulations + multiple reweighing techniques used to include corrections from fix order calculations

Are fits to theory templates the best approach?

- Can we still call it a measurement?
- More model independent measurement?
  - decomposition into coefficients has similar problems (no lepton cuts, ...)
- With the limited statistics can't do sensitive unfolded measurements :-(
  - (yet...?)

Polarized cross sections [Rene]



On-shell bosons: $\left(-g^{\mu\nu}+\frac{k^\mu k^\nu}{k^2}\right)\rightarrow\sum_\lambda \epsilon_\lambda^{*\mu}\epsilon_\lambda^{\nu}$ (DPA or NWA)

$$M = \mathbf{P}_\mu \cdot \frac{-g_{\mu\nu}+\frac{k^\mu k^\nu}{k^2}}{k^2-M_V^2+iM_V\Gamma_V}\cdot \mathbf{D}_\nu$$

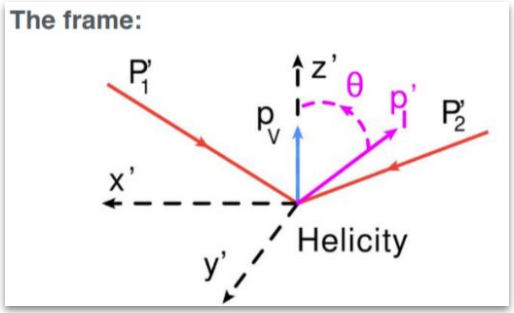
$$|M|^2=\underbrace{\sum_\lambda |M_\lambda|^2}_{\text{polarised x-sections}}+\underbrace{\sum_{\lambda\neq\lambda'} M_\lambda^* M_{\lambda'}}_{\text{Interferences}}$$

Create samples of fixed polarisation: $\frac{d\sigma}{dX}=f_L\frac{d\sigma_L}{dX}+f_R\frac{d\sigma_R}{dX}+f_0\frac{d\sigma_0}{dX}\left(+f_{int.}\frac{d\sigma_{int.}}{dX}\right)$

Template fit f_L, f_R, f_0 to measured $\frac{d\sigma^{exp.}}{dX}$

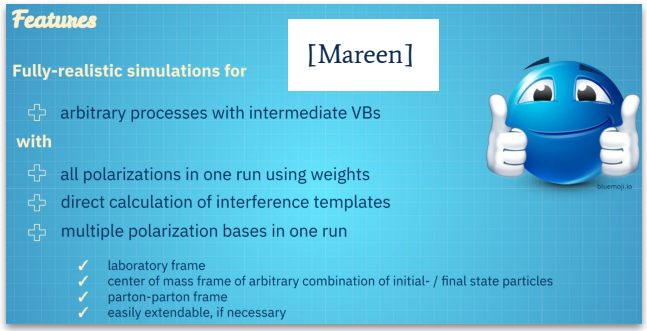
Observables/frames with best separation power?

- Which frame to use?
  - Typically maximising longitudinal component
- Is this optimisation really meaningful?
  - Want to test EWSB, what if we could get to 100%
    → not meaningful?



[Joany]

- Analyses currently relying on MVA for significance
  - Observables to unfold once we have enough statistics?
- Efforts to learn polarisation from fully differential events
  - Can this be exploited for new analysis strategies?



[Mareen]

	NLO	NNLO	K_{NNLO}	LI
off-shell	$220.06(5)^{+1.8\%}_{-2.3\%}$	$225.4(4)^{+0.6\%}_{-0.6\%}$	1.024	$13.8(2)^{+}_{-}$
unpol. (nwa)	$221.85(8)^{+1.8\%}_{-2.3\%}$	$227.3(6)^{+0.6\%}_{-0.6\%}$	1.025	$13.68(3)^{+}_{-}$
unpol. (dpa)	$214.55(7)^{+1.8\%}_{-2.3\%}$	$219.4(4)^{+0.6\%}_{-0.6\%}$	1.023	$13.28(3)^{+}_{-18.7\%}$
W_L^+ (dpa)	$57.48(3)^{+1.9\%}_{-2.6\%}$	$59.3(2)^{+0.7\%}_{-0.7\%}$	1.032	$2.478(6)^{+25.5\%}_{-18.3\%}$	$61.8(2)^{+1.0\%}_{-0.8\%}$
W_L^- (dpa)	$63.69(5)^{+1.9\%}_{-2.6\%}$	$65.4(3)^{+0.8\%}_{-0.8\%}$	1.026	$2.488(6)^{+25.5\%}_{-18.3\%}$	$67.9(3)^{+0.9\%}_{-0.8\%}$
W_T^+ (dpa)	$152.58(9)^{+1.7\%}_{-2.1\%}$	$155.7(6)^{+0.7\%}_{-0.6\%}$	1.020	$11.19(2)^{+25.5\%}_{-18.8\%}$	$166.9(6)^{+1.6\%}_{-1.3\%}$
W_T^- (dpa)	$156.41(7)^{+1.7\%}_{-2.1\%}$	$159.7(6)^{+0.5\%}_{-0.6\%}$	1.021	$11.19(2)^{+25.5\%}_{-18.8\%}$	$170.9(6)^{+1.7\%}_{-1.3\%}$
$W_L^+W_L^-$ (dpa)	$9.064(6)^{+3.0\%}_{-3.0\%}$	$9.88(3)^{+1.3\%}_{-1.3\%}$	1.090	$0.695(2)^{+25.5\%}_{-18.8\%}$	$10.57(3)^{+2.9\%}_{-2.4\%}$
$W_L^+W_T^-$ (dpa)	$48.34(3)^{+1.9\%}_{-2.5\%}$	$49.4(2)^{+0.9\%}_{-0.7\%}$	1.021	$1.790(5)^{+25.5\%}_{-18.3\%}$	$51.2(2)^{+0.6\%}_{-0.8\%}$
$W_T^+W_L^-$ (dpa)	$54.11(5)^{+1.9\%}_{-2.5\%}$	$55.5(4)^{+0.6\%}_{-0.7\%}$	1.025	$1.774(5)^{+25.5\%}_{-18.3\%}$	$57.2(4)^{+0.7\%}_{-0.7\%}$
$W_T^+W_T^-$ (dpa)	$106.26(4)^{+1.6\%}_{-1.9\%}$	$108.3(3)^{+0.5\%}_{-0.5\%}$	1.019	$9.58(2)^{+25.5\%}_{-18.9\%}$	$117.9(3)^{+2.1\%}_{-1.6\%}$

Small LL contribution, with large corrections (→ polarization frame)

[Rene]

Results in the WW reference frame

Significance for LX production at 2.3σ (3.1σ expecte

Process	$\sigma\,\mathcal{B}$ (fb)	Theoretical pr
$W_L^\pm W_L^\pm$	$0.32^{+0.42}_{-0.40}$	0.44 ± 0.05
$W_X^\pm W_T^\pm$	$3.06^{+0.51}_{-0.48}$	3.13 ± 0.35
$W_L^\pm W_X^\pm$	$1.20^{+0.56}_{-0.53}$	1.63 ± 0.18
$W_T^\pm W_T^\pm$	$2.11^{+0.49}_{-0.47}$	1.94 ± 0.21

Results in the incoming parton reference frame

Significance for LX production at 2.6σ (2.9σ expected

Process	$\sigma\,\mathcal{B}$ (fb)	Theoretical pr
$W_L^\pm W_L^\pm$	$0.24^{+0.40}_{-0.37}$	0.28 ± 0.03
$W_X^\pm W_T^\pm$	$3.25^{+0.50}_{-0.48}$	3.32 ± 0.37
$W_L^\pm W_X^\pm$	$1.40^{+0.60}_{-0.57}$	1.71 ± 0.19
$W_T^\pm W_T^\pm$	$2.03^{+0.51}_{-0.50}$	1.89 ± 0.21

BSM

- Not discussed much this week (maybe too early?):
  Any concerted efforts to study BSM sensitivity in polarised analyses?
  - Tools are getting very advanced:
    - » EFT etc. via UFO models in MG5_aMC@NLO & Sherpa
    - » Both can do polarised cross sections

  → Easy to explore sensitivity at LO / nLO+PS / ME+PS
  [Generator experts available in COMETA :-)]

& … ?