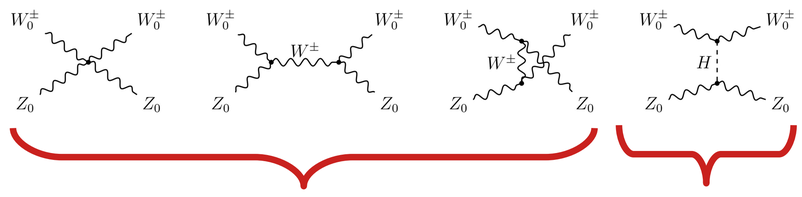
Precision Predictions for Polarized Electroweak Bosons

Rene Poncelet
IFJ PAN Krakow
ICHEP 2024 Praha

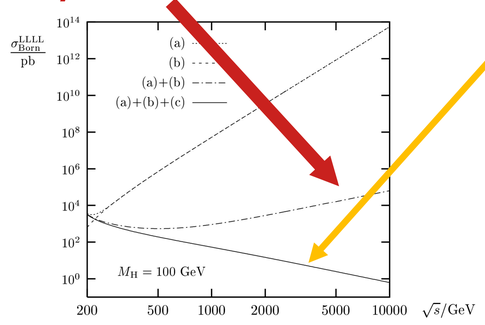
COMETA
Funded by the European Union
PAN POLISH ACADEMY of SCIENCES

Motivation

Study **E**lectro**W**eak **S**ymmetry **B**reaking (EWSB)



Unitarity violation $\sim E^2$ $\sim -E^2$

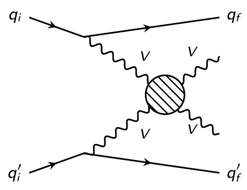


Radiative corrections to W+ W- → W+ W- in the electroweak standard model
A. Denner, T. Hahn hep-ph/9711302

Polarized vector boson scattering (VBS) or production probes:

- EWSB mechanism
- Higgs and gauge sector
- New physics models

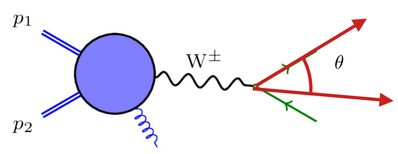
At hadron colliders:



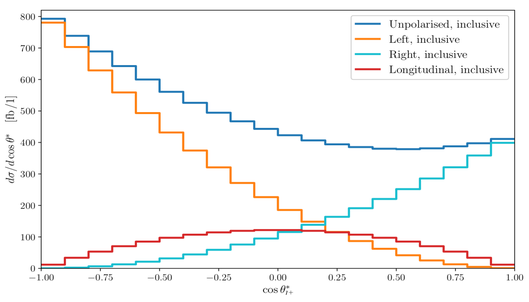
VBS topology

- Rare process, but observed
- Needs small statistical & systematic unc.
  → requires good theory modelling!

How to measure polarized EW bosons



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



For on-shell bosons:

$$\left(-g^{\mu\nu} + \frac{k^\mu k^\nu}{k^2}\right) \to \sum_\lambda \epsilon_\lambda^{*\mu} \epsilon_\lambda^\nu$$

Matrix elements:

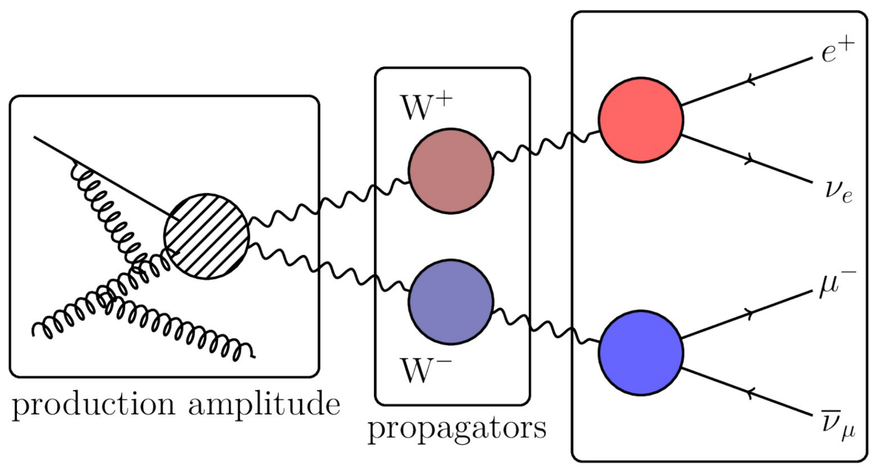
$$|M|^2 = \underbrace{\sum_\lambda |M_\lambda|^2}_{\text{Polarised}} + \underbrace{\sum_{\lambda \neq \lambda'} M_\lambda^* M_{\lambda'}}_{\text{Interferences}}$$

Separate cross sections of fixed polarisation:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}X} = f_L \frac{\mathrm{d}\sigma_L}{\mathrm{d}X} + f_R \frac{\mathrm{d}\sigma_R}{\mathrm{d}X} + f_0 \frac{\mathrm{d}\sigma_0}{\mathrm{d}X} \left(+ f_{int.} \frac{\mathrm{d}\sigma_{int.}}{\mathrm{d}X}\right)$$

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

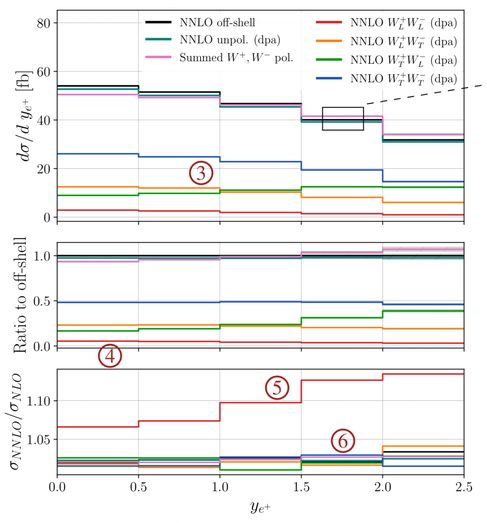
Polarized boson pair production
Example: pp → W+W- → leptons



Radiative QCD Corrections

Virtual corrections and real-emissions modify polarization fractions!

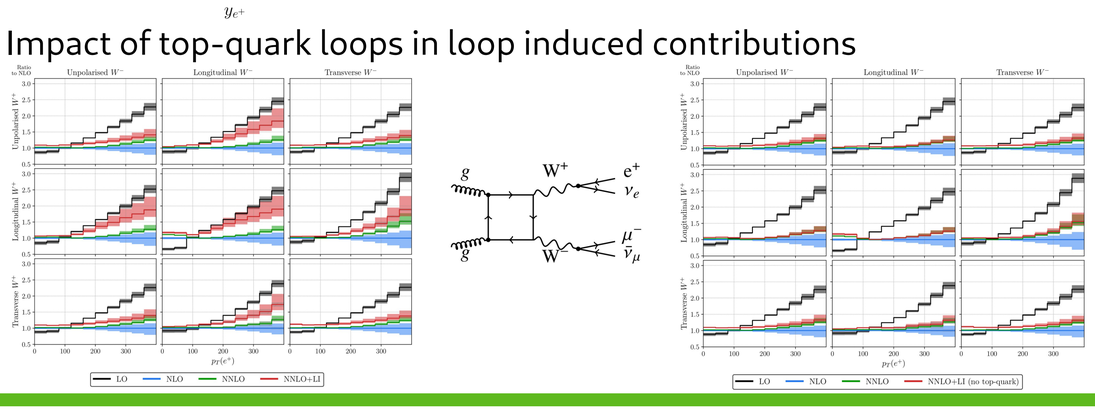
NNLO QCD study of polarised W+W- production at the LHC,
Poncelet, Popescu 2102.13583



Positron rapidity features:

① polarisation interference
② non-resonant background
③ "Monte-Carlo true" polarisation distributions
④ $W_L^+W_L^-$ contribution is small, $W_T^+W_T^-$ dominates
⑤ distinct and large NNLO corrections for $W_L^+W_L^-$
⑥ mild NNLO corrections for other setups

Impact of top-quark loops in loop induced contributions

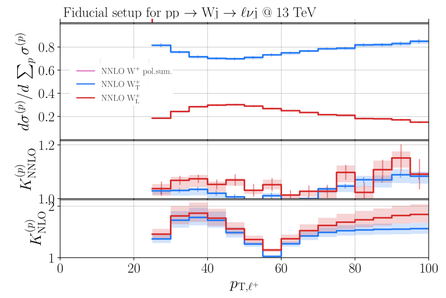


Polarization fractions

Example: $pp \to W^\pm(\to l\nu)j$

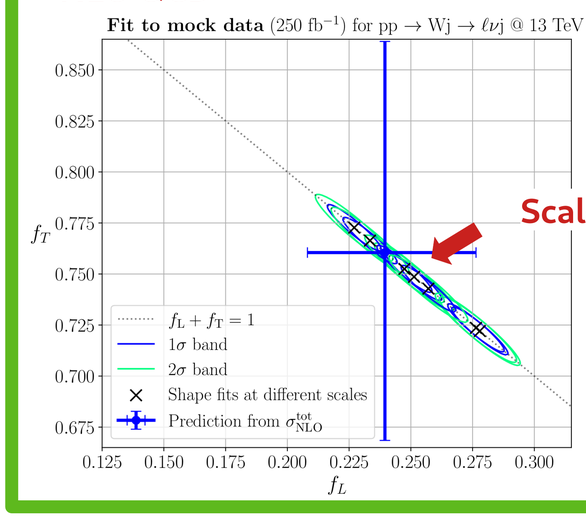
Polarised W+j production at the LHC: a study at NNLO QCD accuracy,
Pellen, Poncelet, Popescu 2109.14336

Impact of NLO and NNLO QCD effects:

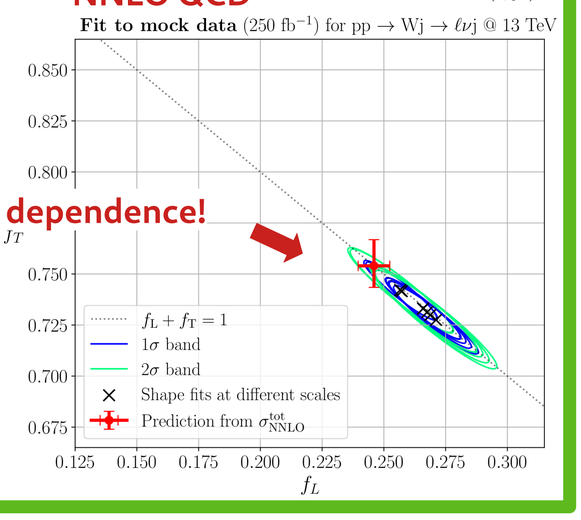


Fit to mock-data (based on NNLO QCD and 250 fb^{-1} stats):
→ extreme case to see effect of scale dependence reduction

NLO QCD



NNLO QCD Observable: $\cos(\ell, j_1)$



Do you like to try it yourself? → Try using HighTEA?

Run your own polarization fraction measurement in W+W- on your phone!

- Including NLO QCD corrections (NNLO QCD on the way)
- Study impact of scale and PDF choices
- Develop your own observables

high tea