FACULTY OF SCIENCES

DEPARTMENT OF PHYSICS AND ASTRONOMY
RESEARCH GROUP ELEMENTARY PARTICLE PHYSICS AND GRAVITY

Measuring spin correlations in diboson systems with CMS

Gill Jacobs, 21/11/2024

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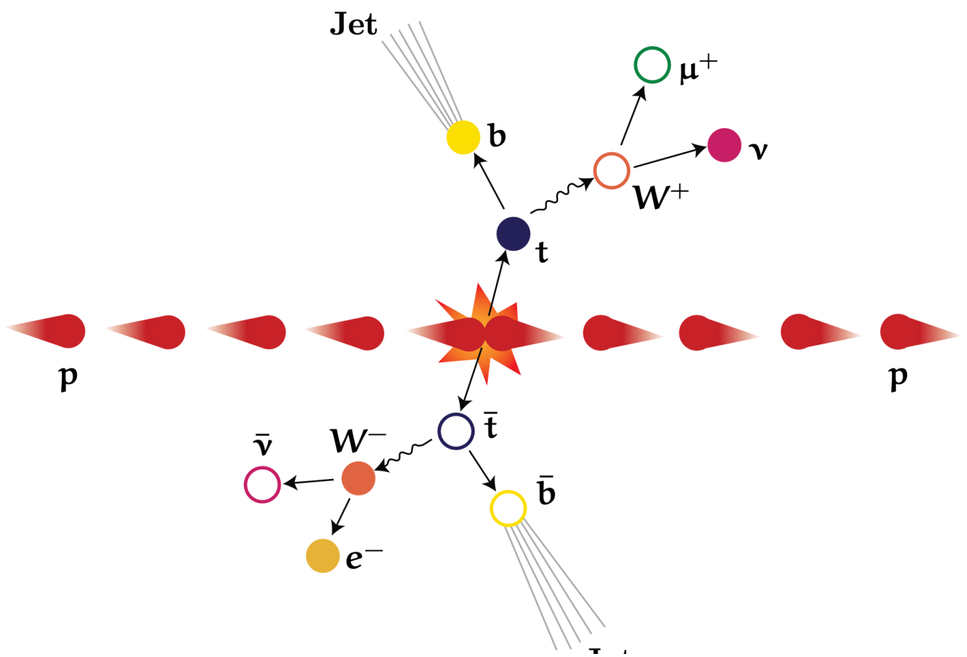
Particle physics and entanglement



entangled state e.g.: $|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow,\downarrow\rangle - |\downarrow,\uparrow\rangle\right)$

probe **polarization** and **spin correlations** in angular distribution of decay products:

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega_+\mathrm{d}\Omega_-} \sim \left(1 + B^+\cdot\hat{\ell}^+ + B^-\cdot\hat{\ell}^- - \hat{\ell}^+\cdot C\cdot\hat{\ell}^-\right)$$

sufficient condition for **entanglement**: $\mathrm{tr}[C] < -1$

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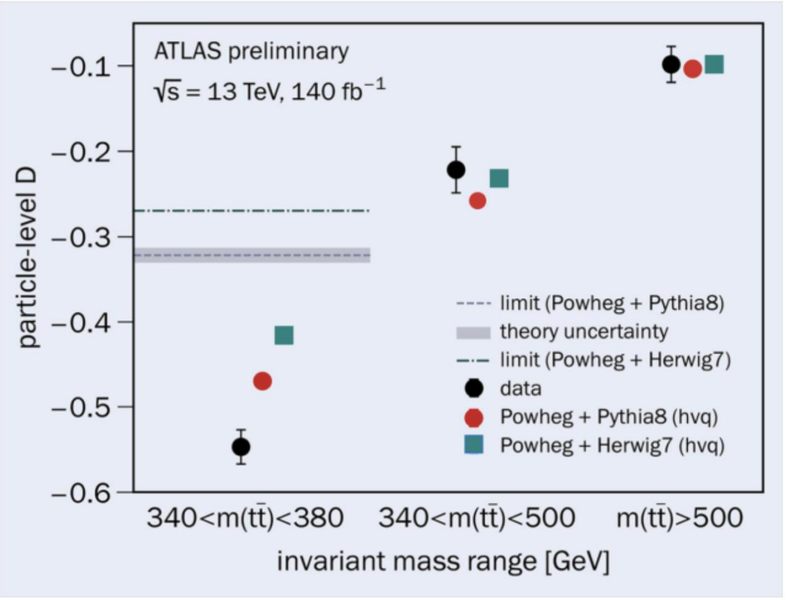
STRONG INTERACTIONS | NEWS

Highest-energy observation of quantum entanglement

29 September 2023

A report from the ATLAS experiment.

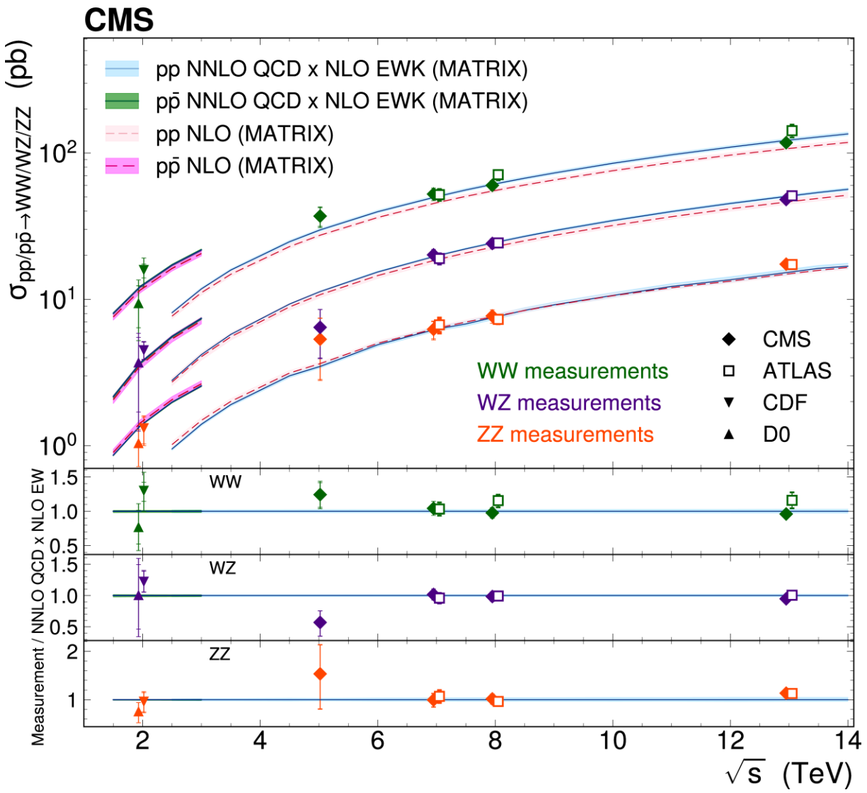


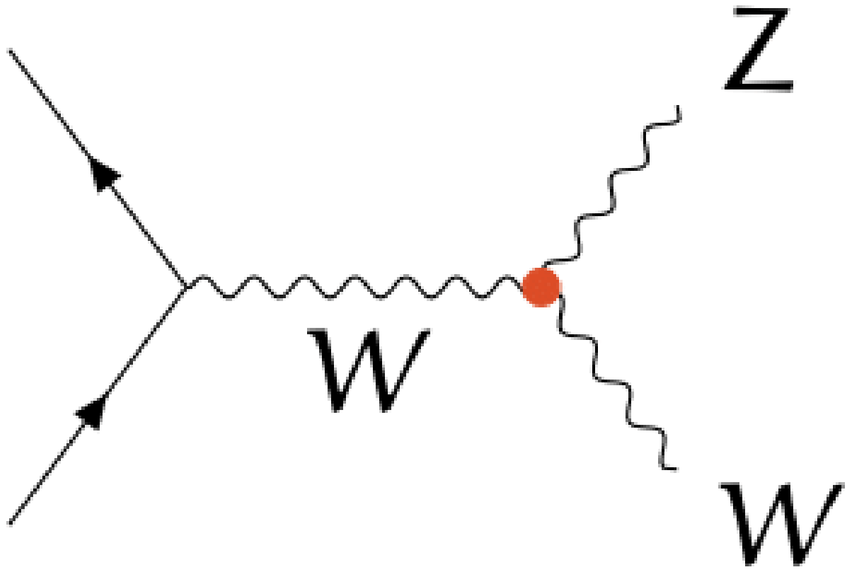
Qubits and qutrits

Photons:
- Massless spin-1 particle
- Two states:
  - Left-handed
  - Right-handed

Top quarks:
- Massive spin-1/2 particle
- Two states:
  - Spin-up
  - Spin-down
- "Qubits"

W and Z boson:
- Massive spin-1 particles
- Three states:
  - Left-handed polarization
  - Right-handed polarization
  - Longitudinal polarization
- "Qutrits"





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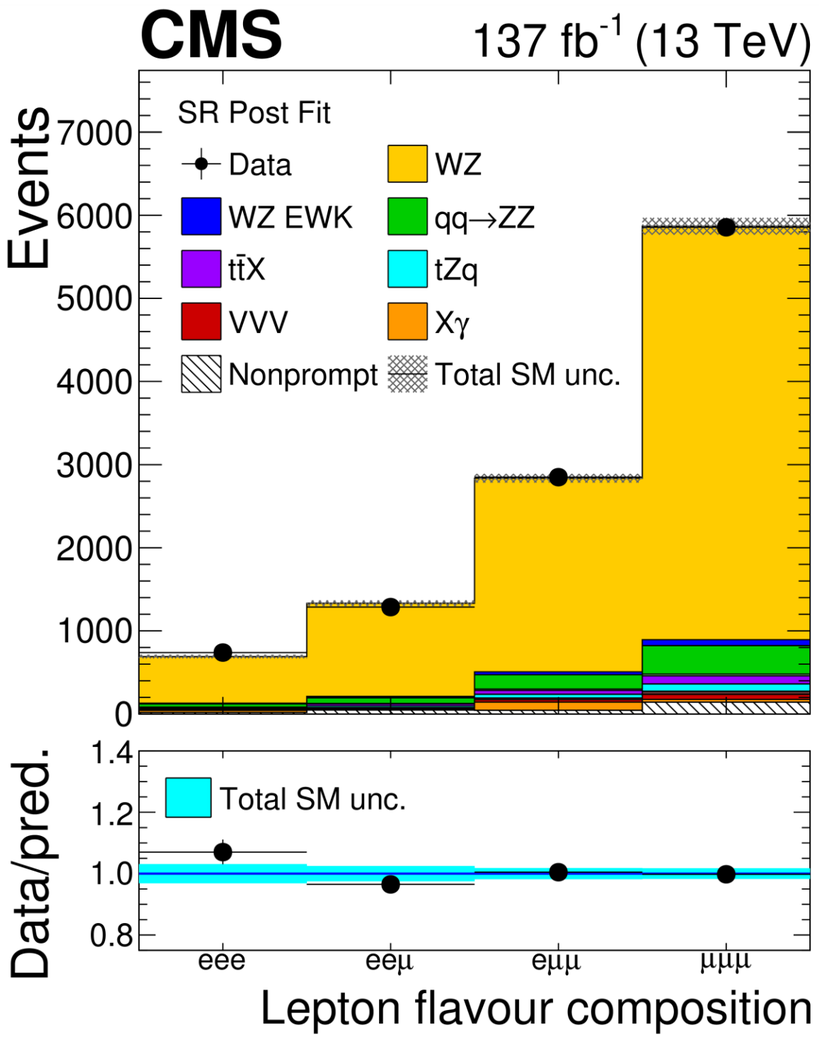
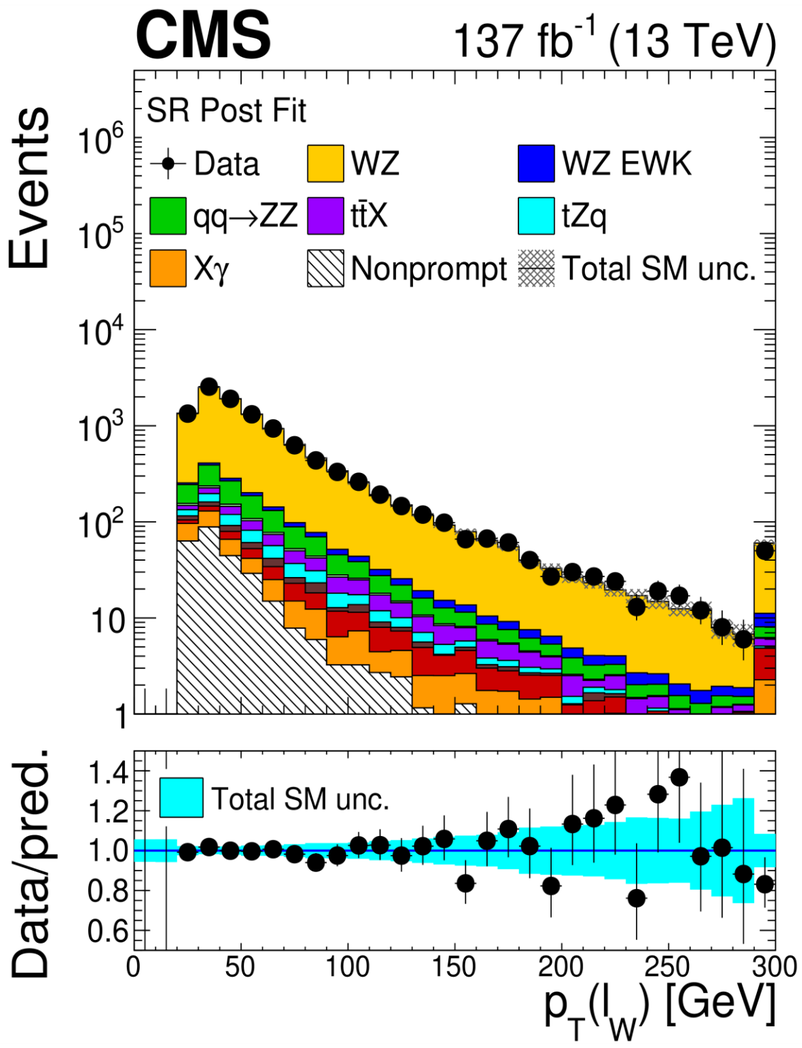
How to measure WZ events

We select the following events:

- Exactly 3 leptons (electrons or muons)
- Exactly 1 opposite-sign pair of same-flavour leptons with invariant mass M(ℓℓ) ~ M(Z)
- p_T^{miss} > 30 GeV





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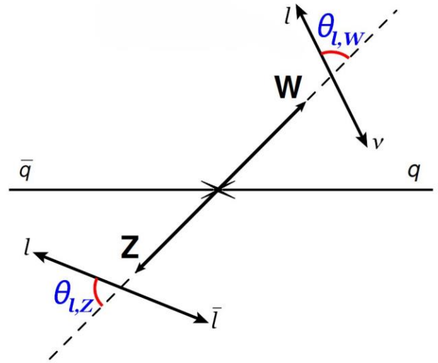
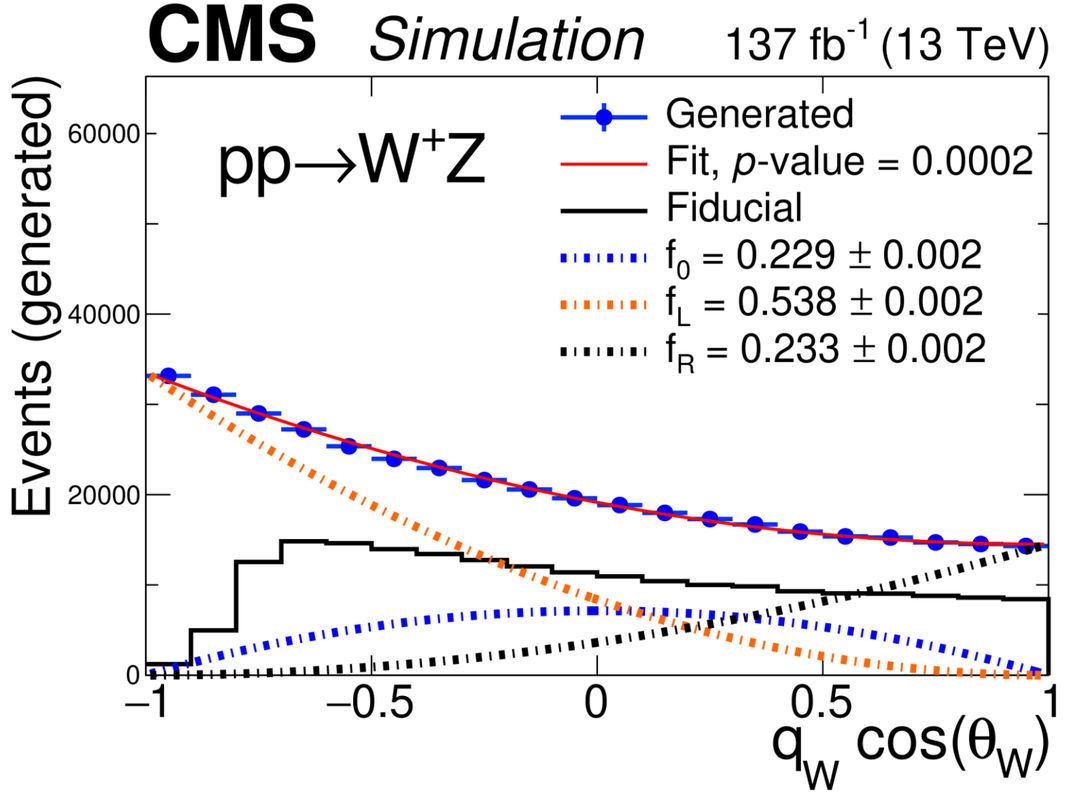
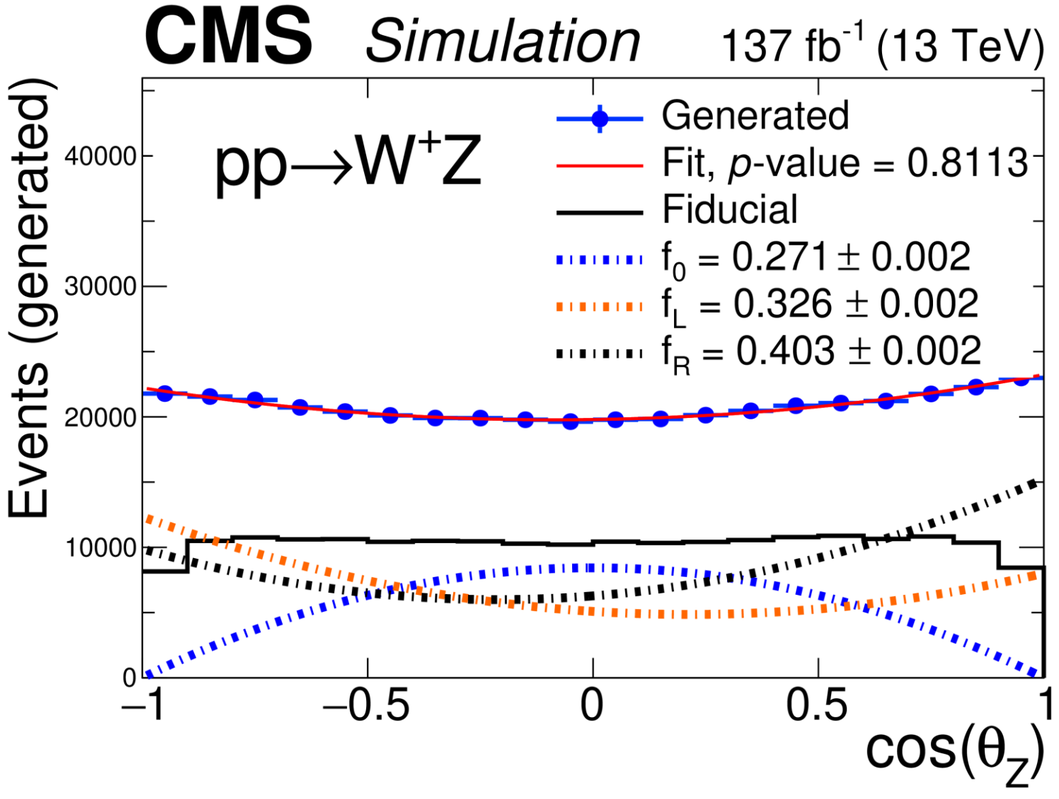
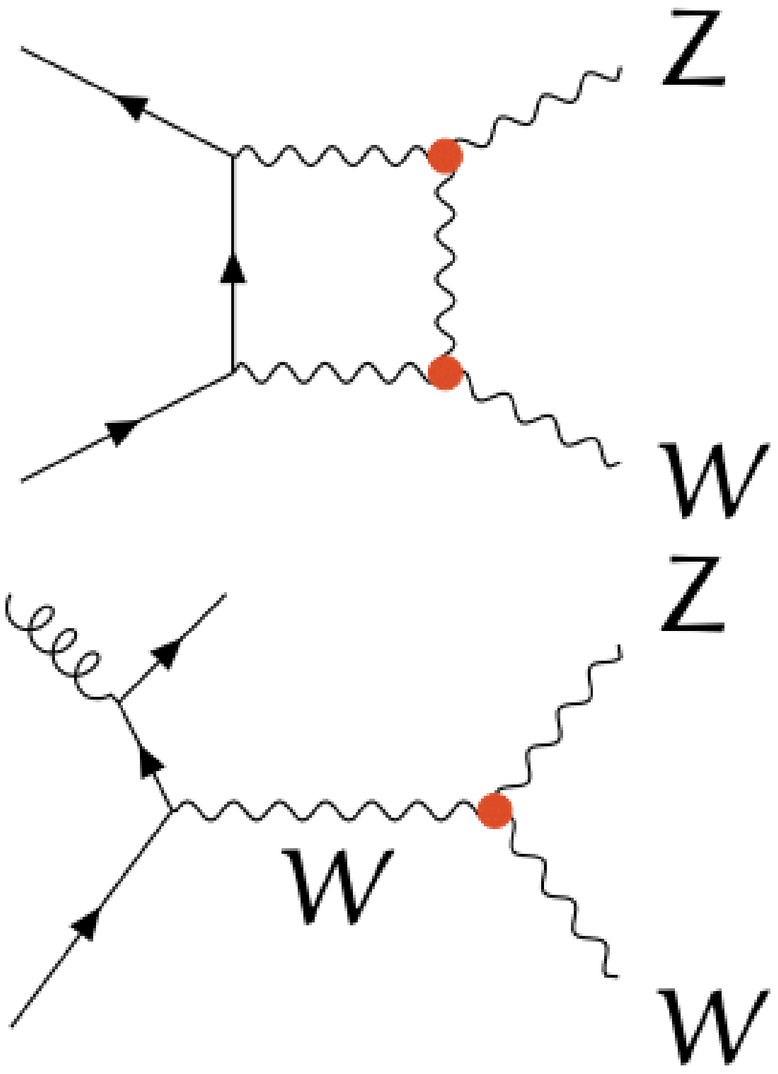
Previous CMS results: polarization fractions

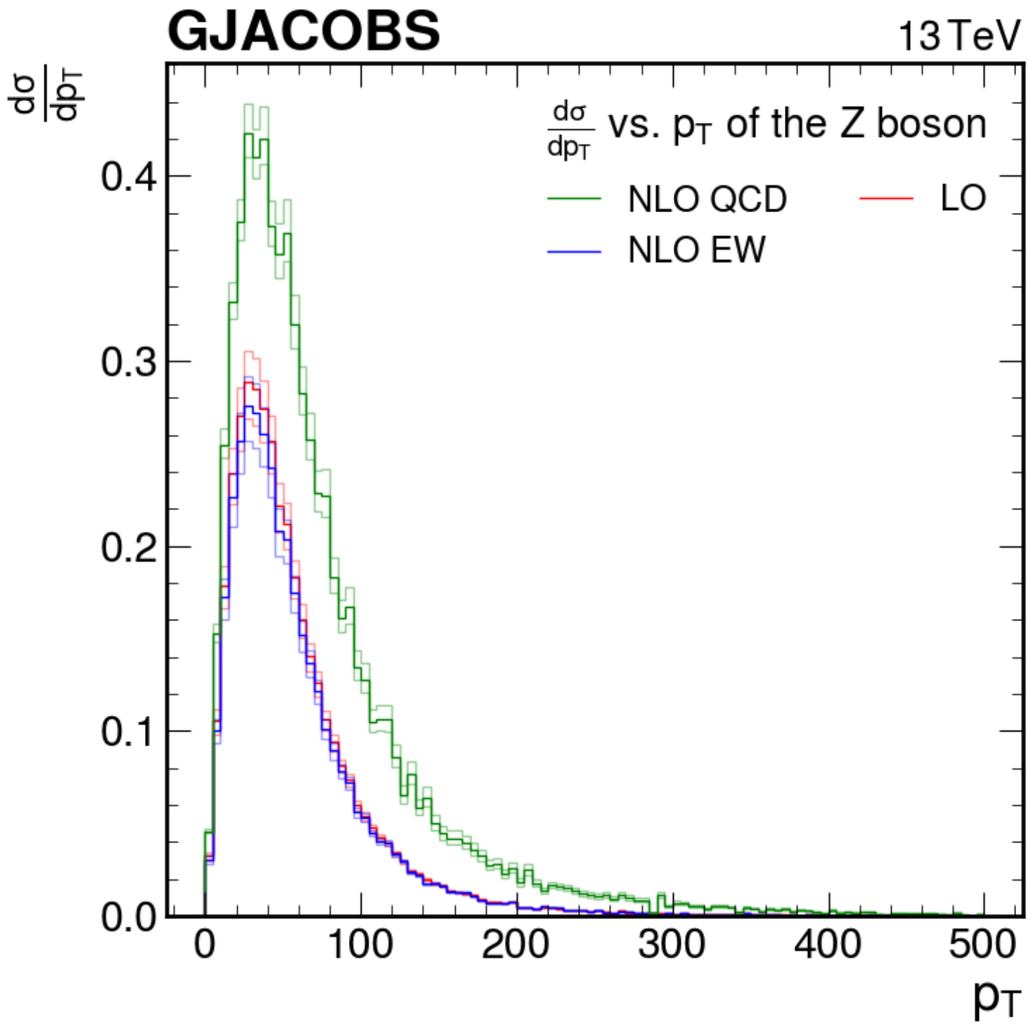






MATRIX





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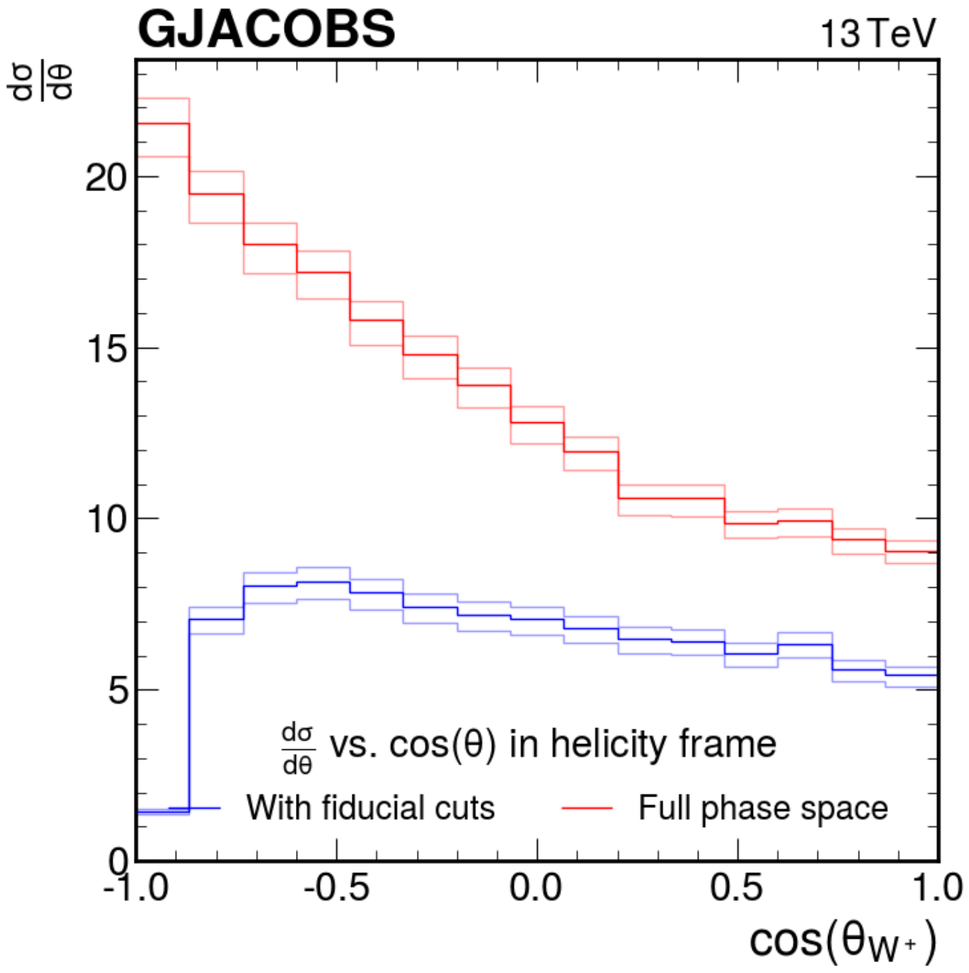
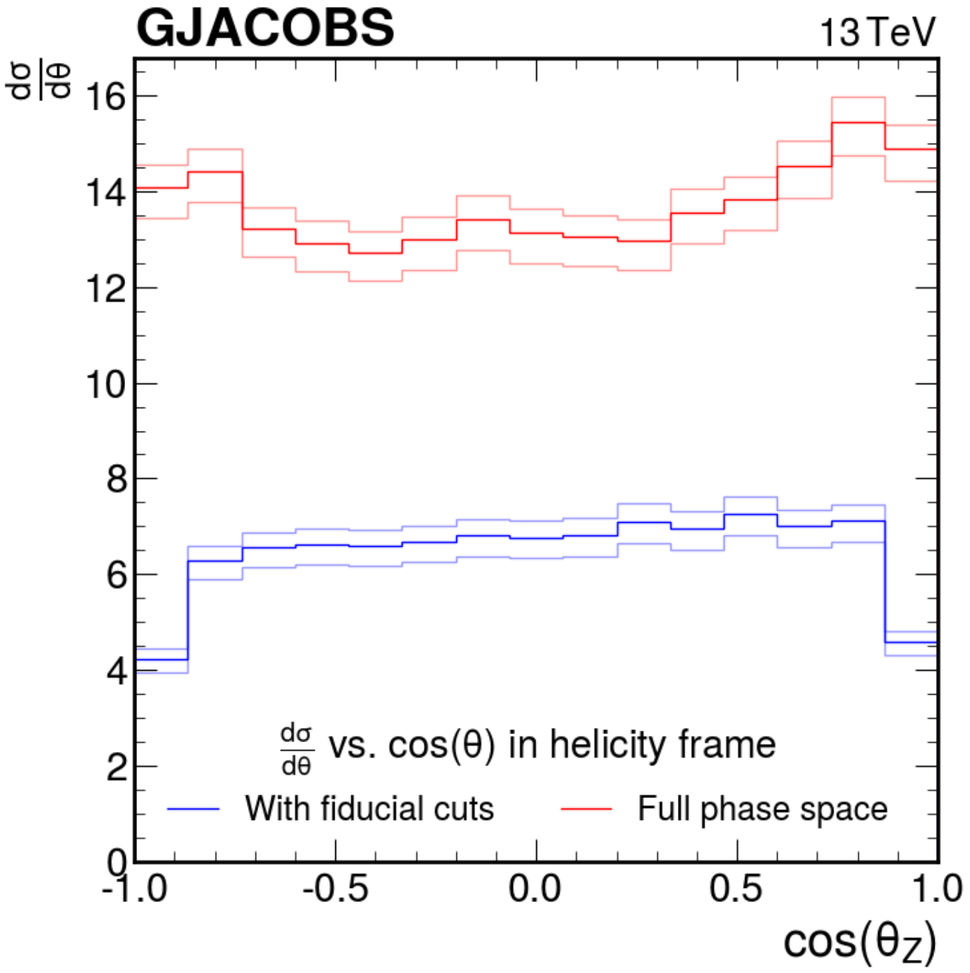
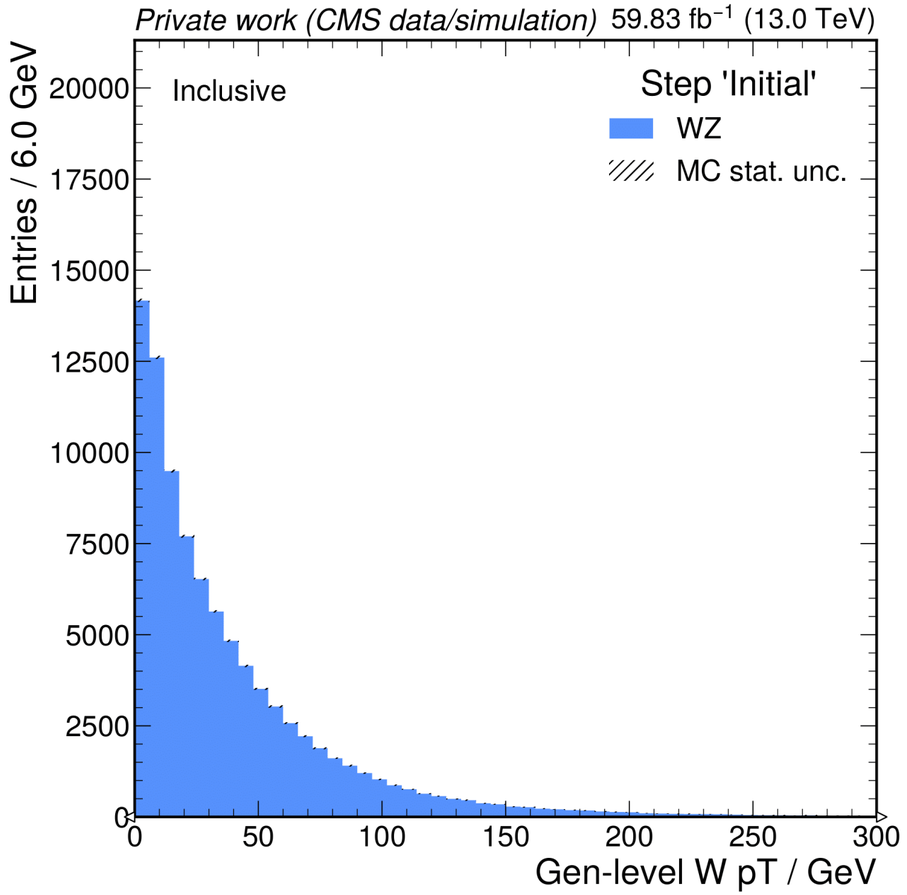
Generated results

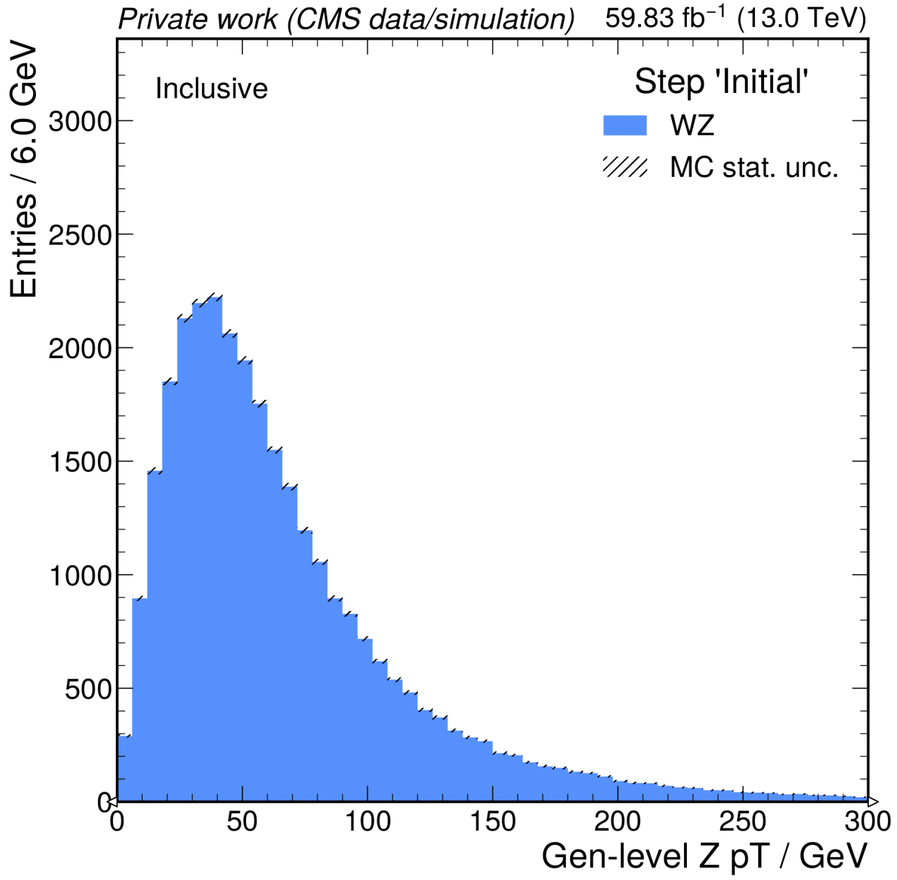
$$pp \rightarrow \mu^+ \nu_\mu e^+ e^-$$





Monte Carlo setup for the near future





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Summary and outlook

Summary

- Implemented polarization fractions for W and Z bosons -> 4 out of 80 parameters
- Ran LO and some NLO calculations with MATRIX
- Started setting up MC sample analysis

Outlook

- Implement all 80 observables (polarizations and spin correlations)
- Calculate differential cross section in five ways: MATRIX LO, NLO, NNLO; PowHeg NLO and MadGraph NLO
- Develop analysis strategy for measurement in data

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Gill Jacobs

Master Student

Elementary Particle Physics and Gravity

E Gill.Jacobs@ugent.be

M +32 489 00 58 05

www.ugent.be

Universiteit Gent

@ugent

@ugent

Ghent University

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