Measurement of W-width in high mass charged current Drell-Yan process

Pedro Henrique de Almeida Mascarenhas
Advisor - Dr. Marco Aurélio Lisboa Leite
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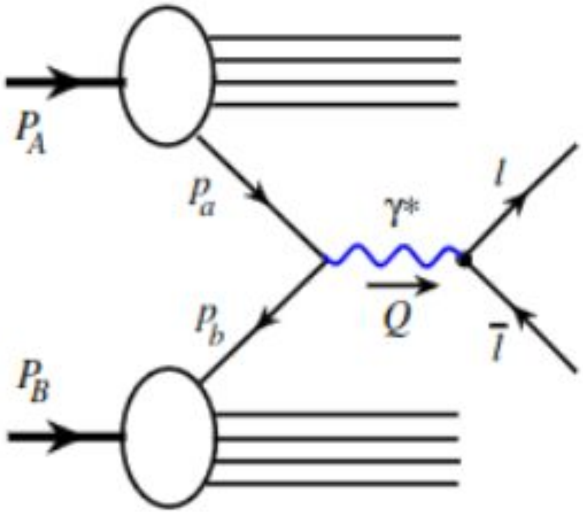
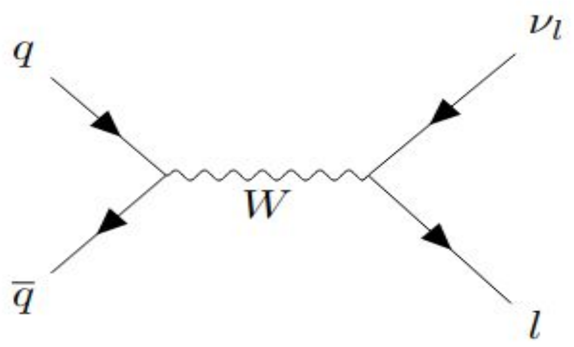
Drell-Yan process

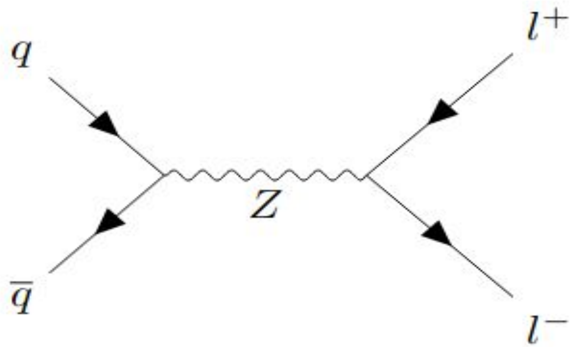
- Drell-Yan process was formulated as a electromagnetic process.
- A quark-antiquark interaction in hadrons annihilation generates a lepton pair.
  - Photon mediated.
- Later it was discovered that Higgs, Z and W bosons also can mediate.
  - Neutral or charged process.
- Lepton pair formation was important to discover quarkonia states, Higgs, Z and W bosons.
- Now, it is important in the search of New Physics.



The weak force

- Standard Model is the most successful theory to describe the interaction of fundamental particles.
- Precise measurements is important to test the consistency of SM.
  - Deviations can indicate the possibility of New Physics.
- W and Z bosons mediates the weak force.
- Precise measurements of W boson are more complicated than Z boson.
  - Formation of 1 neutrino.





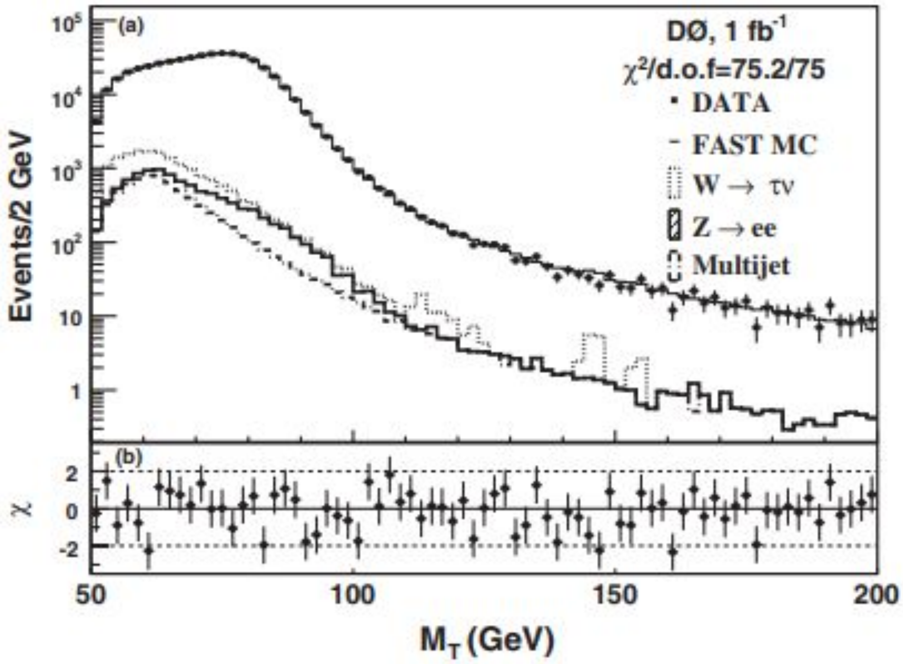
Motivation

- Decay width (Γ) is related with particle decay time.
- Electroweak predicts W width decay Γ_{W}, = 2088 ± 1 MeV.
- Particles candidates that have masses smaller than W boson and couple with it, would alter Γ_{W}, as result of new W decay channel.
- Knowing Γ_{W} hadronic decay ratio with precision can determine α_{S} from QCD.
- Γ_{W} and m_{W} are related by G_{F} constant.
    - m_{W} is constraint with m_{t} and m_{H}.
    - m_{W} are related to weak mixing angle.

W boson width direct measurement in Tevatron

Fermilab Tevatron

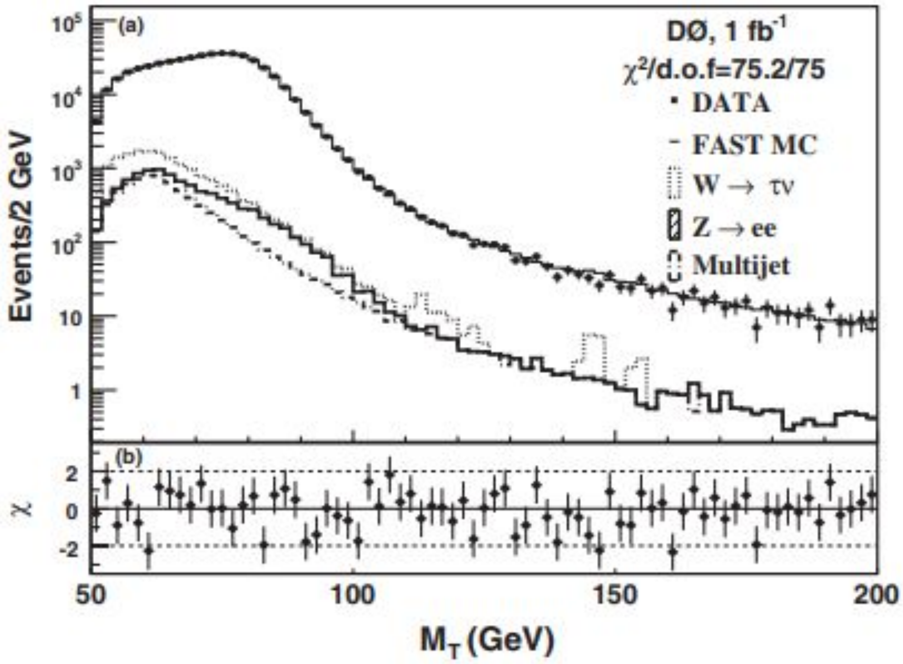
- Using D0 detector Γ_W was measured directly by proton - antiproton collisions, at 1.96 TeV center-of-mass.
  - 1 fb^{-1} integrated luminosity.
- Electron with p_t > 25 GeV. Neutrino p_t was inferred using MET.
- W → eν channel.
- Background events:
  - Z → ee
  - W → $\tau\nu$
  - Multijet were 1 jet was identified as electron.



ABAZOV, V. M. et al. Direct measurement of the W boson width. **Physical review letters**, v. 103, n. 23, p. 231802, 2009.

Fermilab Tevatron

- Γ_W was retrieved by comparing transverse mass distribution with MC simulations generated with different widths.
- Maximum likelihood method was used to retrieve Γ_W.
- $\Gamma_W = 2.202 \pm 0.072$ GeV.
    - Consistent with SM.



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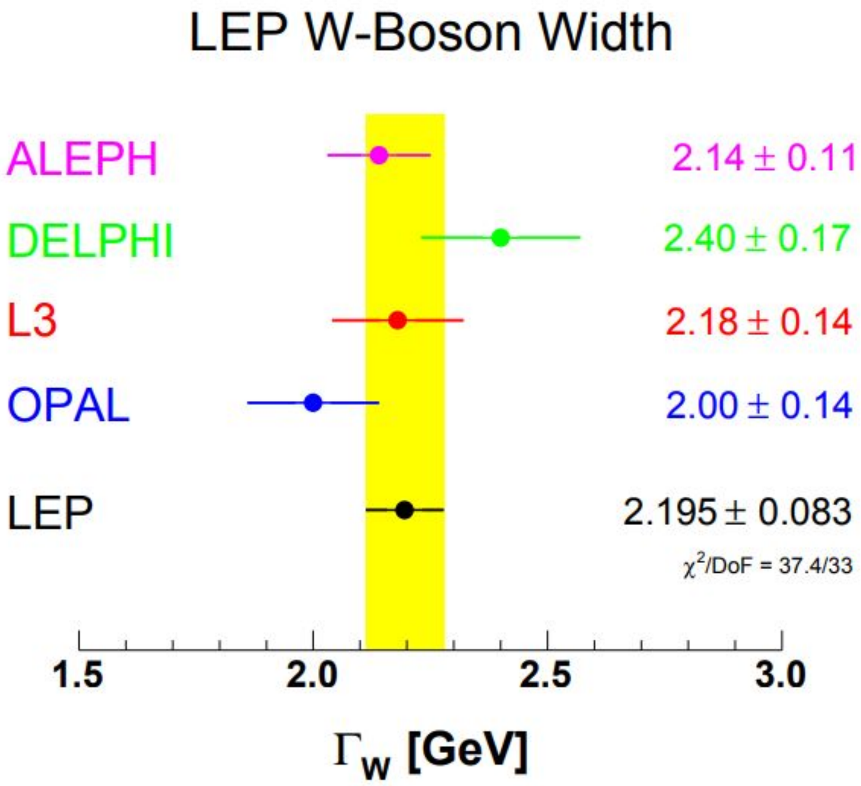
W boson width direct measurement in LEP collaboration

LEP collaboration

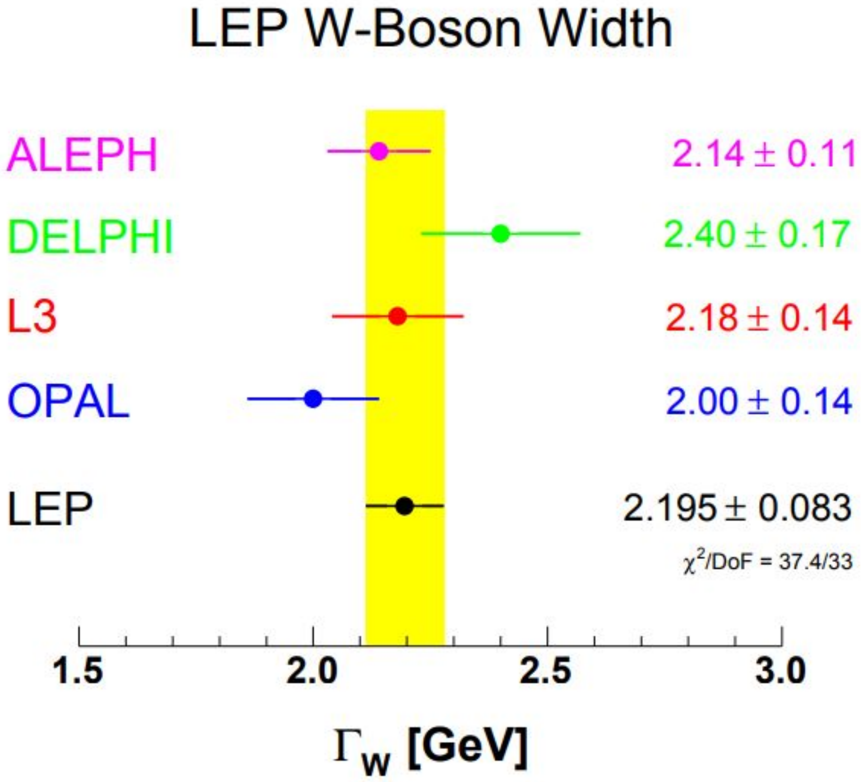
- m_W and Γ_W were determined in process that yielded two W bosons.
  - Mostly in hadronic or semi-leptonic channels.
- Data are compared with MC samples with known values of m_W and Γ_W, which had the best model for the data.
  - MC simulations in 161 GeV center-of-mass energy was used.
    - Has the most sensitive m_W cross-section.
  - 172 - 183 GeV center-of-mass energy was used too.



ALEPH COLLABORATION et al. Electroweak measurements in electron–positron collisions at W-boson-pair energies at LEP. **Physics reports**, v. 532, n. 4, p. 119-244, 2013.

LEP collaboration

- Maximum likelihood was used to determine m_W and Γ_W.
- $m_W = 80.376 \pm 0.025_{stat} \pm 0.022_{syst}$ GeV.
- **$\Gamma_W = 2.195 \pm 0.063_{stat} \pm 0.055_{syst}$ GeV**

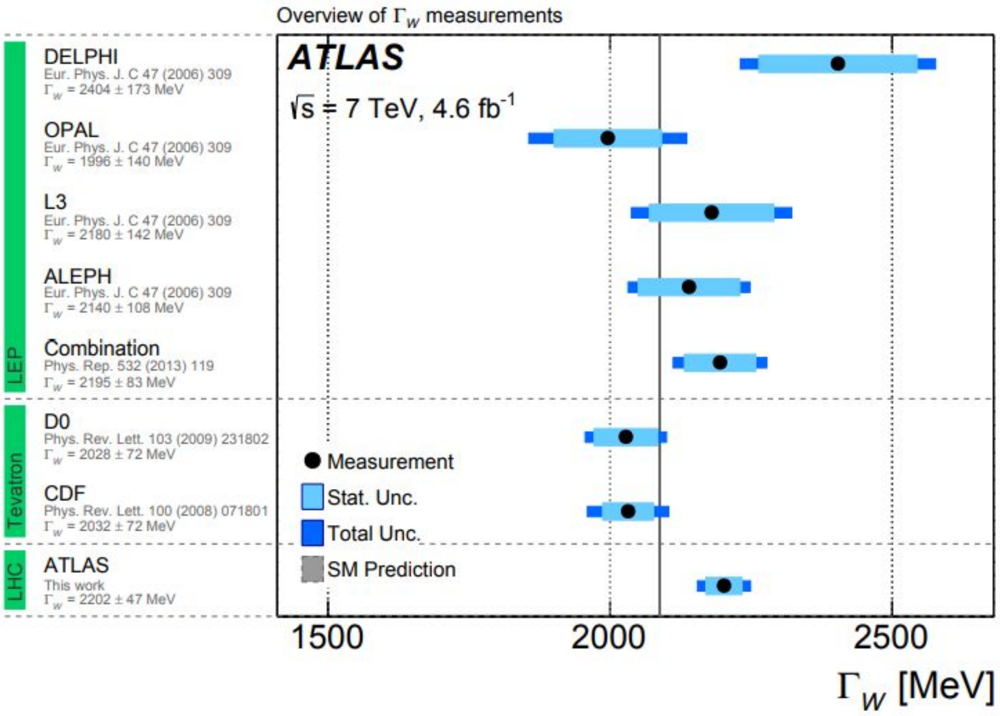


ALEPH COLLABORATION et al. Electroweak measurements in electron–positron collisions at W-boson-pair energies at LEP. **Physics reports**, v. 532, n. 4, p. 119-244, 2013.

W boson width direct measurement in ATLAS

ATLAS collaboration

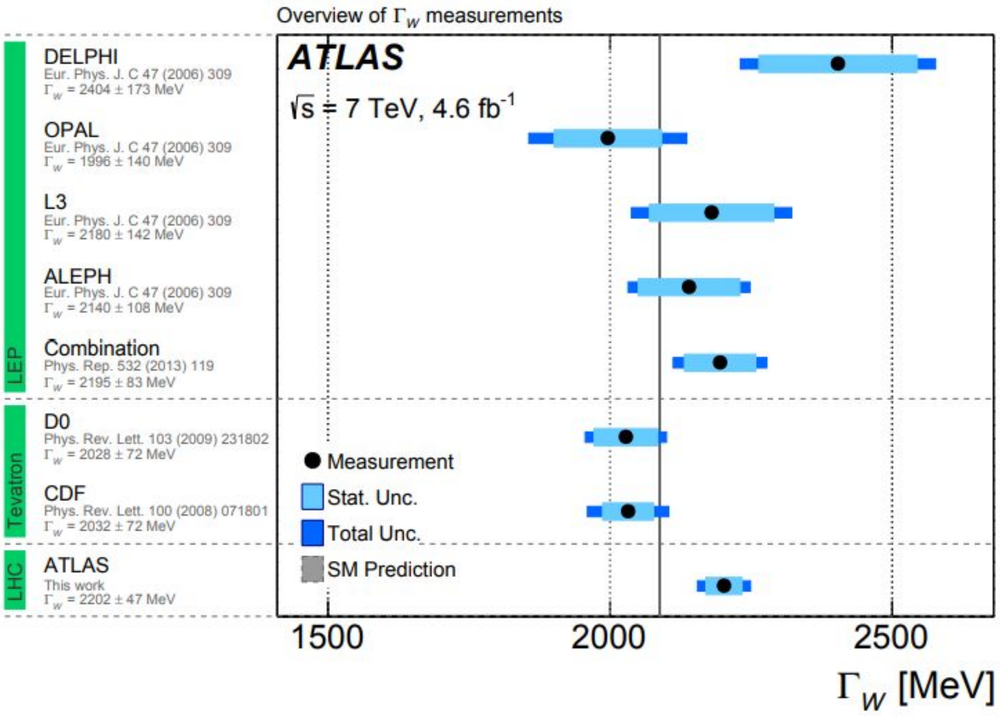
- First Γ_W direct measure in LHC, with 7 TeV center-of-mass energy.
  - Low luminosity.
- m_W also was measured.
- $W \rightarrow l\nu$, (l = e, μ).
- Leptonic decaying Z, boson pair, $W \rightarrow \tau\nu$ and top-quark backgrounds was treated with MC simulations.
- Maximum likelihood was used to determine m_W and Γ_W.



ATLAS COLLABORATION et al. Measurement of the W-boson mass and width with the ATLAS detector using proton-proton collisions at $\sqrt {s} $= 7 TeV. **arXiv preprint arXiv:2403.15085**, 2024.

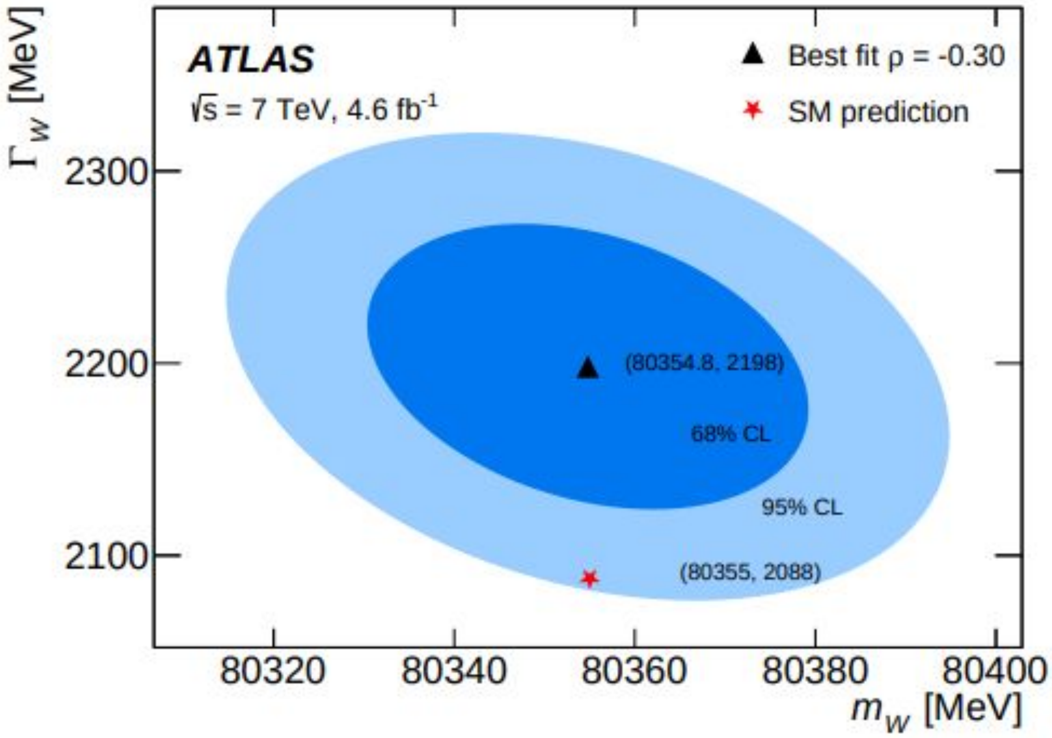
ATLAS collaboration

- The results were:
- m_W = 80.366 ± 15.9 MeV.
- Γ_W = 2202 ± 47 MeV.
    - Most precise measurement.
- Both measurements were in agreement with SM prediction.
    - Γ_W in 2.4σ.
- Ongoing analysis at high luminosity.



ATLAS COLLABORATION et al. Measurement of the W-boson mass and width with the ATLAS detector using proton-proton collisions at $\sqrt {s} $= 7 TeV. **arXiv preprint arXiv:2403.15085**, 2024.

ATLAS collaboration - Γ_W and m_W constraint

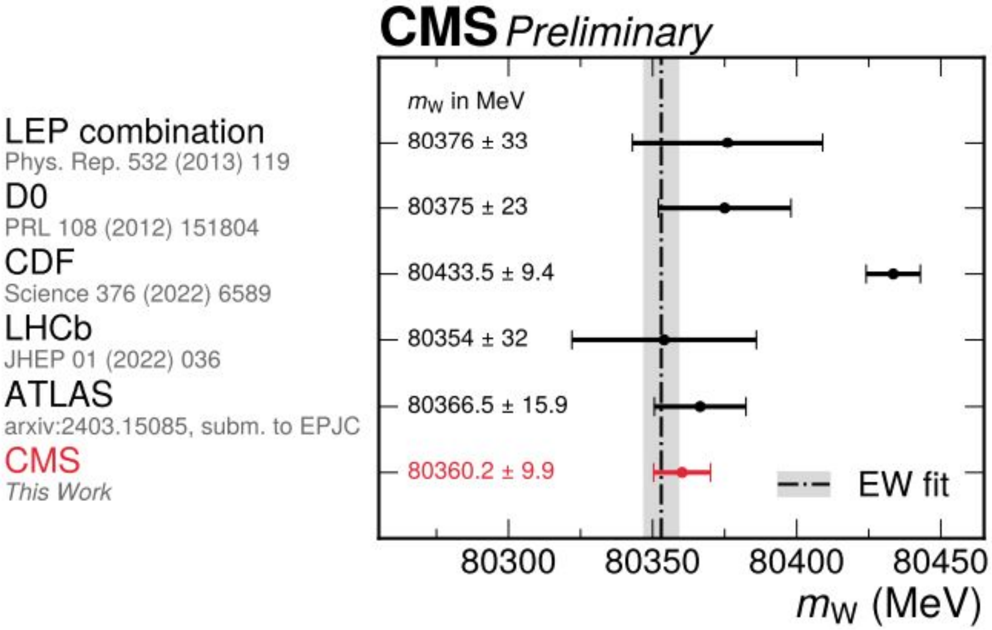


ATLAS COLLABORATION et al. Measurement of the W-boson mass and width with the ATLAS detector using proton-proton collisions at $\sqrt {s} $= 7 TeV. **arXiv preprint arXiv:2403.15085**, 2024.

W boson mass measurement in CMS

CMS collaboration

- First measurement in CMS collaboration.
- 13 TeV center-of-mass energy.
- $W \rightarrow \mu\nu$ channel.
- Most precise measure of m_W
  - Consistent with SM prediction.
- Background events:
  - μ from QCD jets
  - $W \rightarrow \tau\nu$ and $Z \rightarrow \tau\tau$ were treated with MC simulations.
- Maximum likelihood was used to determine m_W.

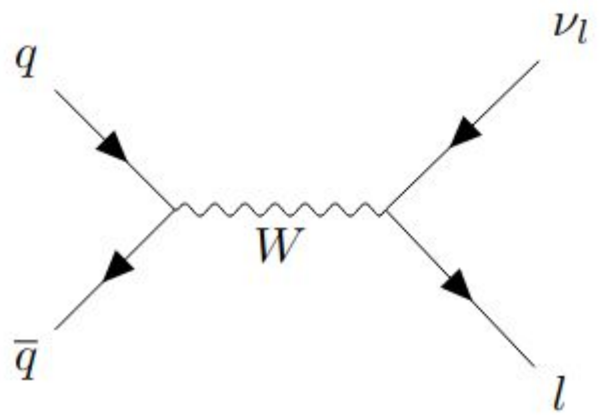


CMS COLLABORATION et al. Measurement of the W boson mass in proton-proton collisions at √s= 13 TeV, 2024.

Methodology

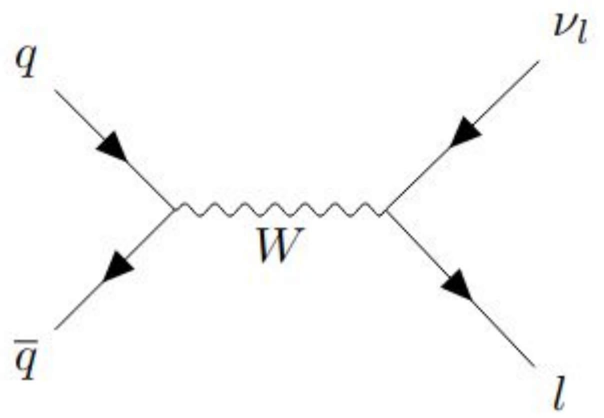
Methodology

- MC generator validation - Sherpa 2.2.14 at 13 TeV center-of-mass energy.
    - High-mass.
    - High-luminosity.
    - Comparison with Sherpa 2.2.14 simulation and unfolded data.
        - Unfolding: Infer the true distribution of an observable, using reconstructed data.
- Γ_W from $W \to l\nu$, (l = e, μ) channel.
- Rivet 3.1.7 software (ATLAS implementation).
    - C++ based-software.
    - High-Energy Physics research.
    - SM and BSM analysis.
    - It has an extent analysis codes repository.



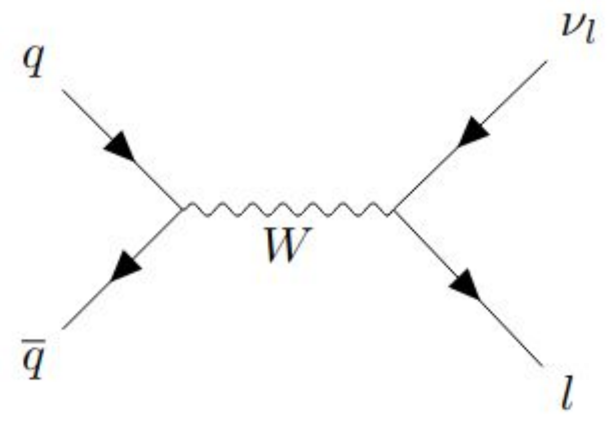
Methodology

- Cuts:
  - 1 Lepton of either electric charge.
  - Leptons with $p_T > 26$ GeV.
  - $|\eta| < 2.47$
  - MET < 25 GeV.
- Initial samples:
  - BFilter; CFilterBVeto; CVetoBVeto.
  - 10^5 events.
  - Sherpa 2.2.11 at 13 TeV center-of-mass energy.
    - MC16
  - Sherpa 2.2.14 at 13.6 TeV center-of-mass energy.
    - MC23
- Rivet 3.1.7 software.



Methodology

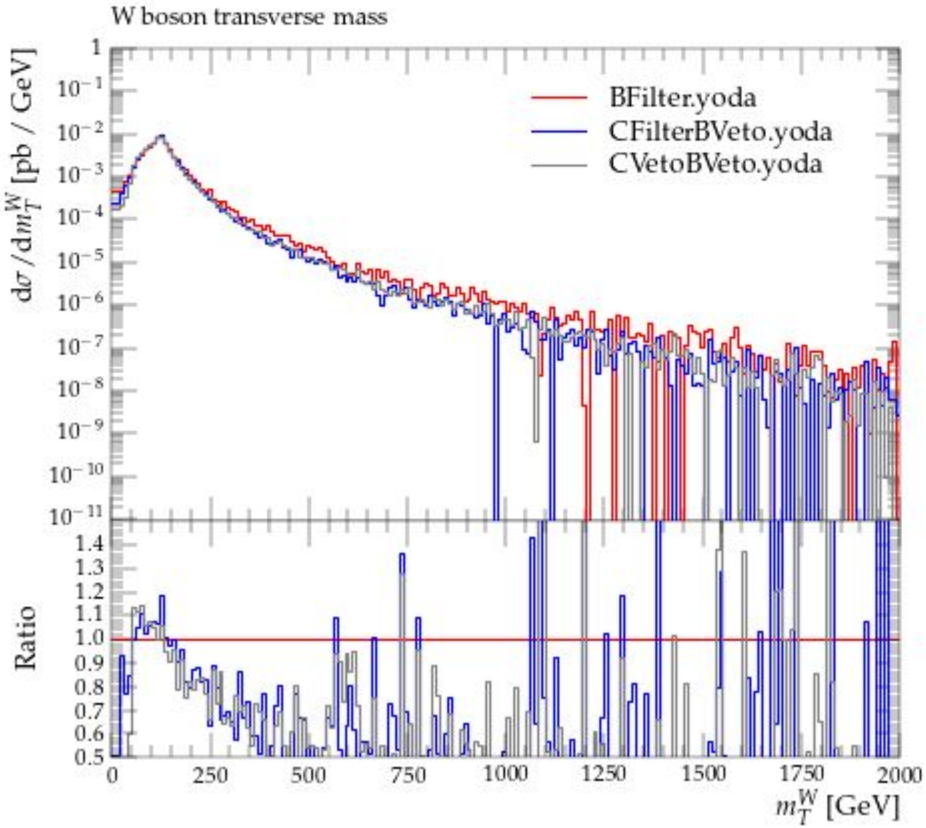
- W boson kinematic distributions:
  - Transverse mass
  - Mass
  - Transverse momentum
  - Rapidity
  - Pseudorapidity
  - Azimuthal angle
- Lepton kinematic distributions:
  - Transverse momentum
  - Pseudorapidity
  - Azimuthal angle
- W boson - lepton distributions:
  - Azimuthal separation.
  - Pseudorapidity separation.
  - Angular distance separation.



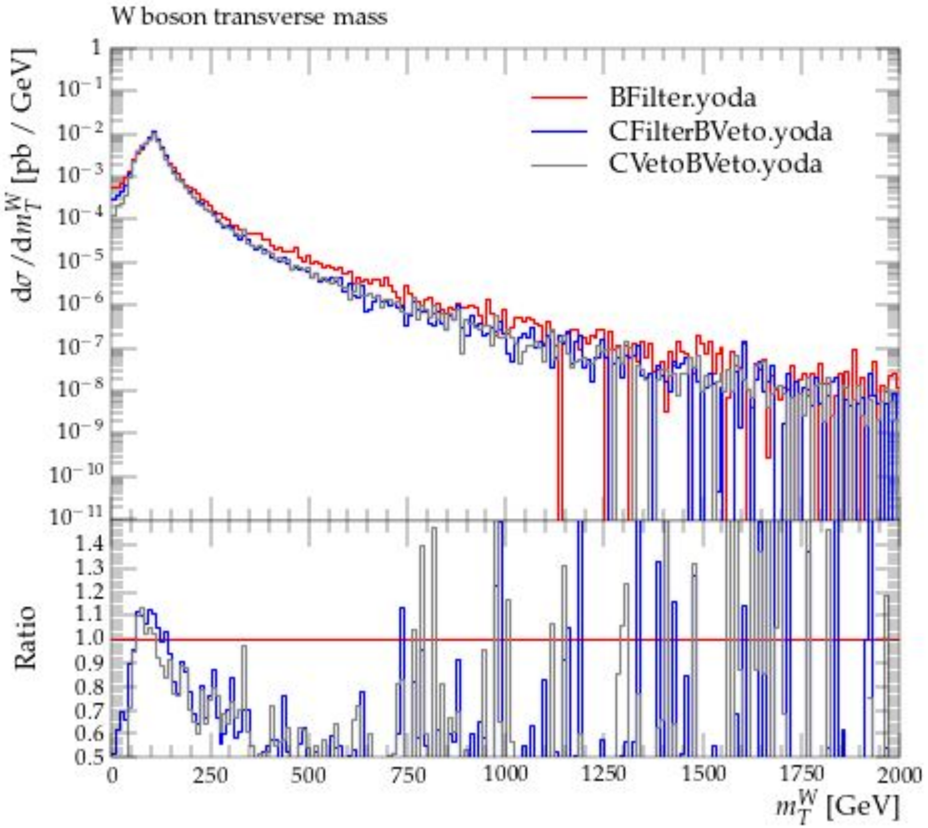
Results
W $\rightarrow$ eν process

W transverse mass

Sherpa 2.2.11

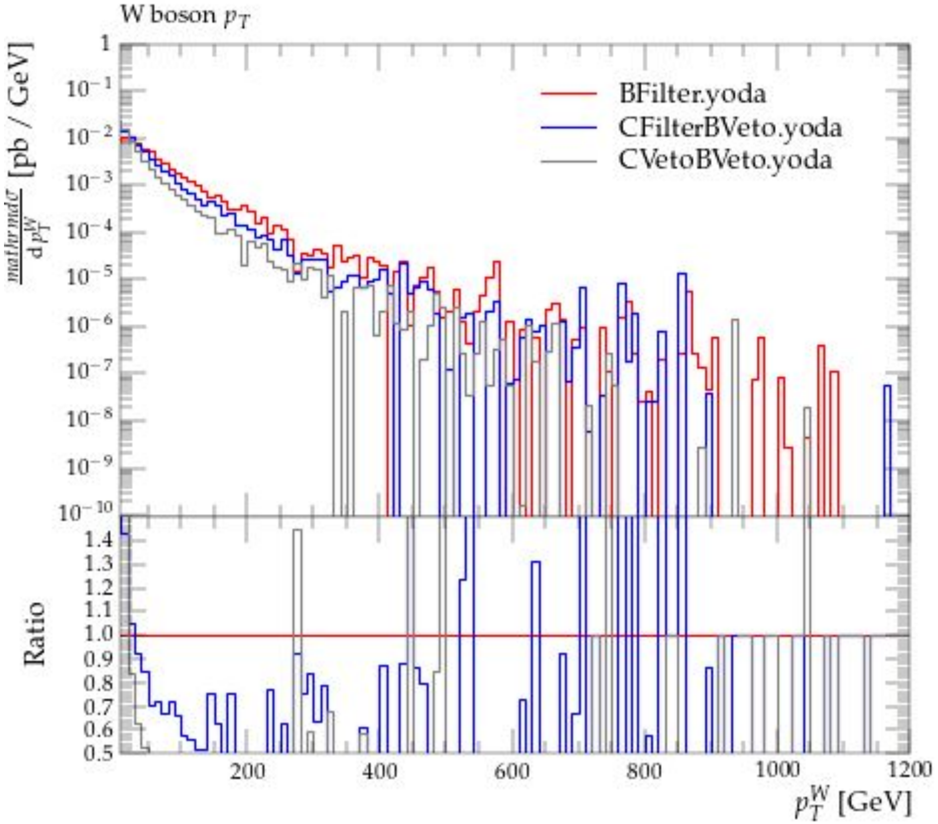


Sherpa 2.2.14



W transverse momentum

Sherpa 2.2.11



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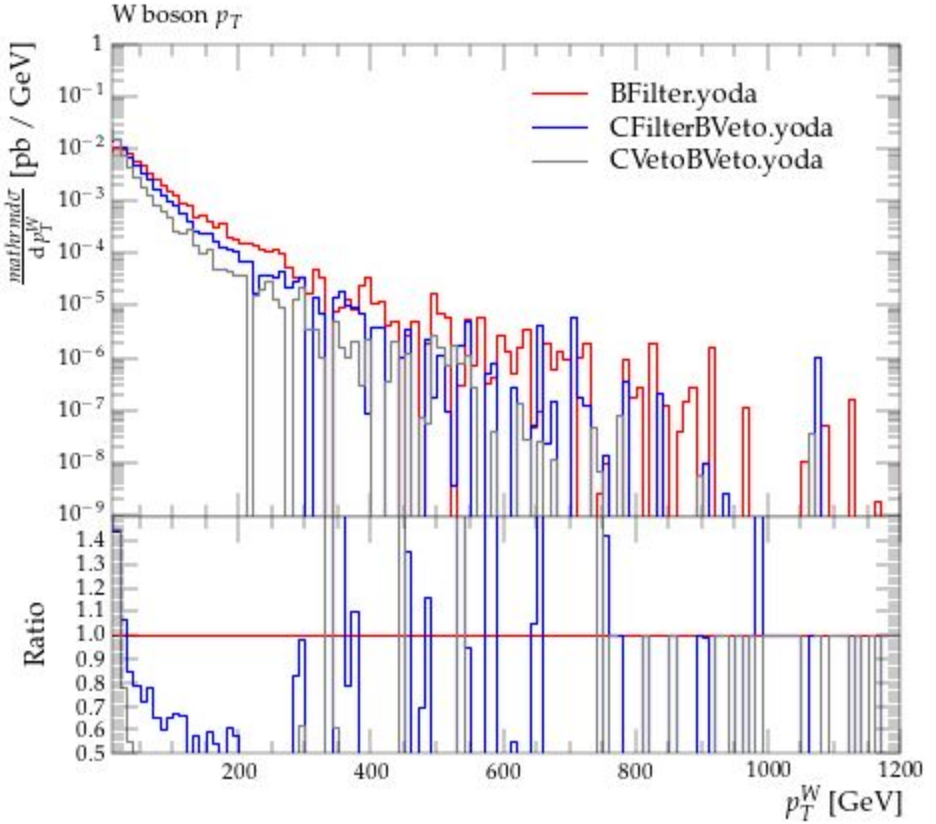
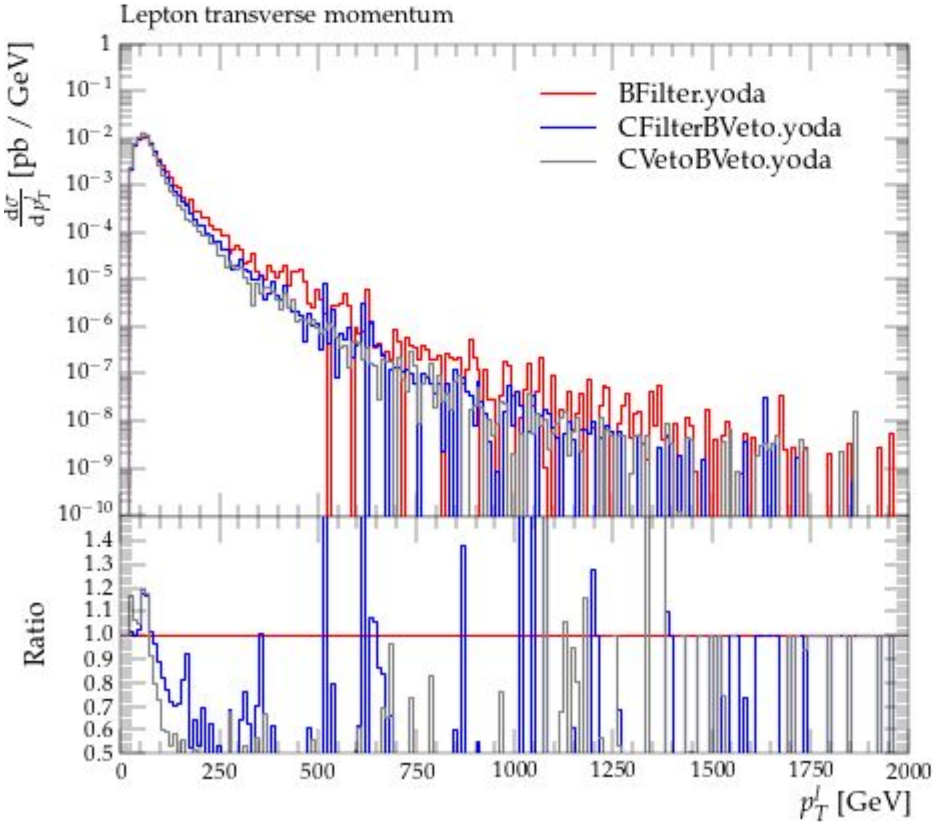
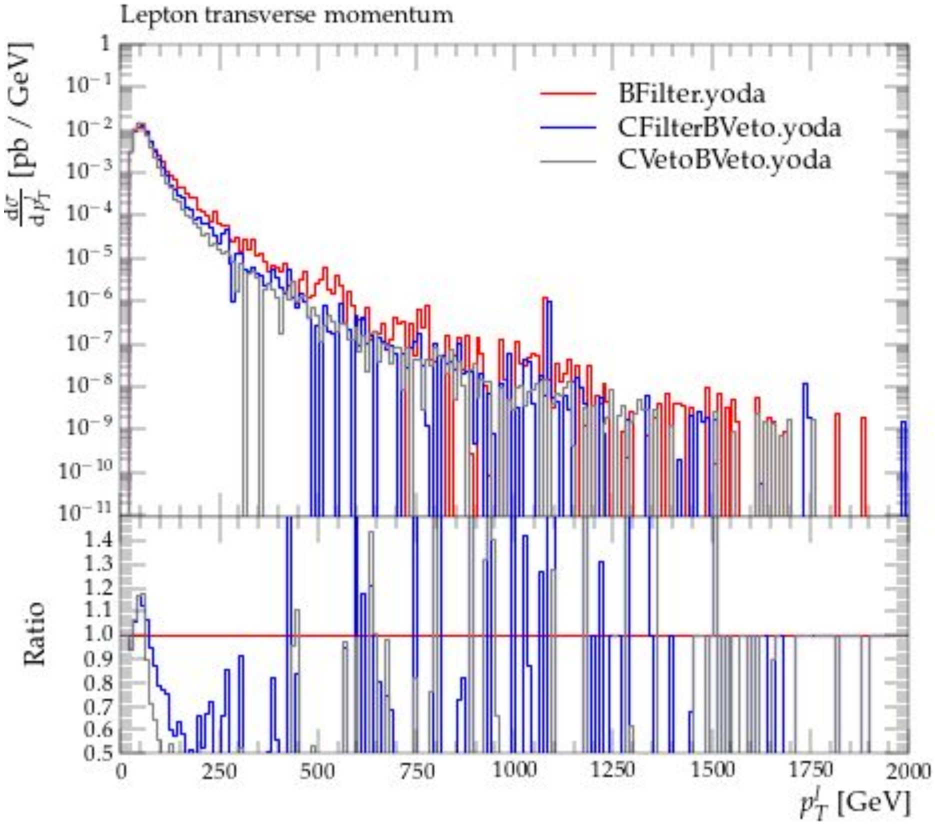


Leptonic transverse momentum

Sherpa 2.2.11

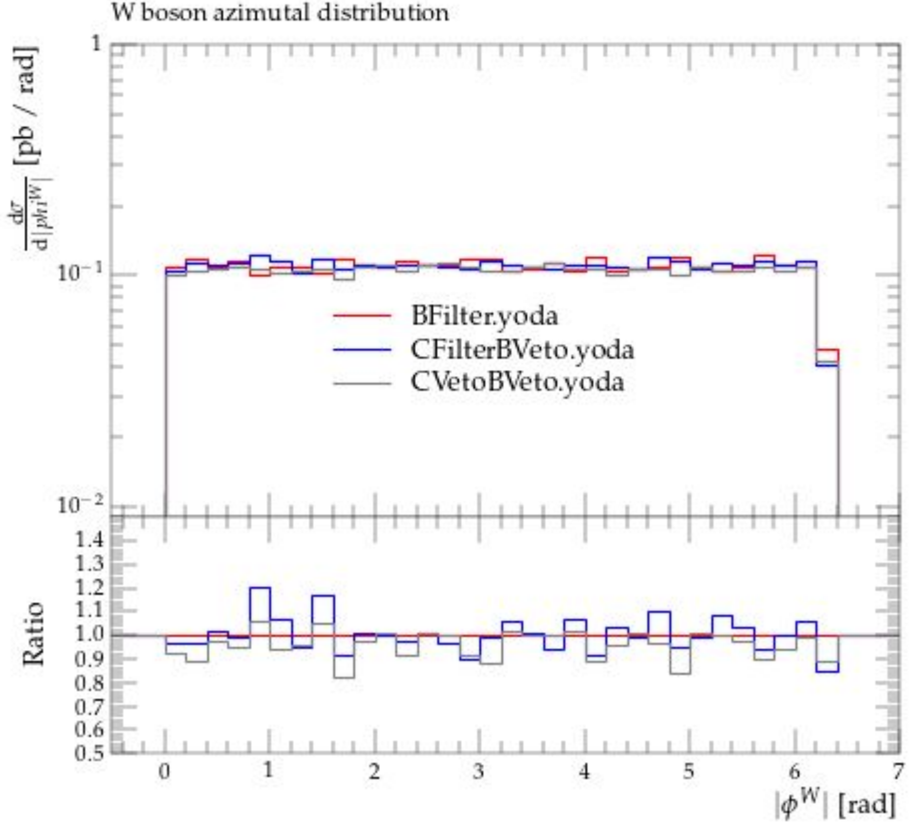


Sherpa 2.2.14

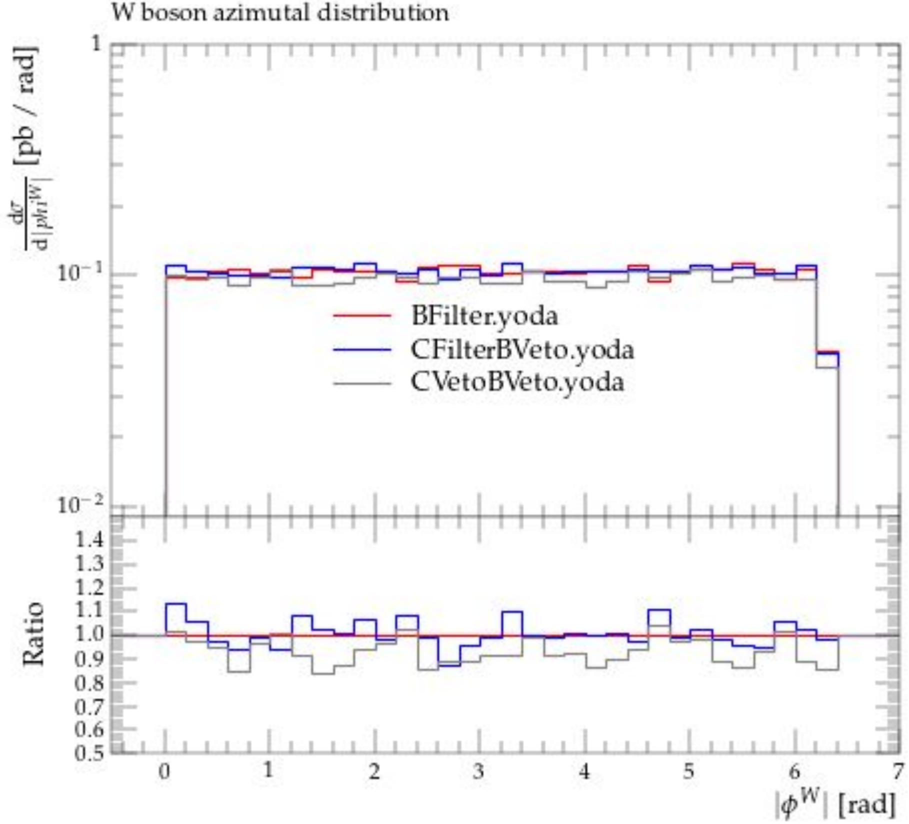


W boson azimuthal distribution

Sherpa 2.2.11

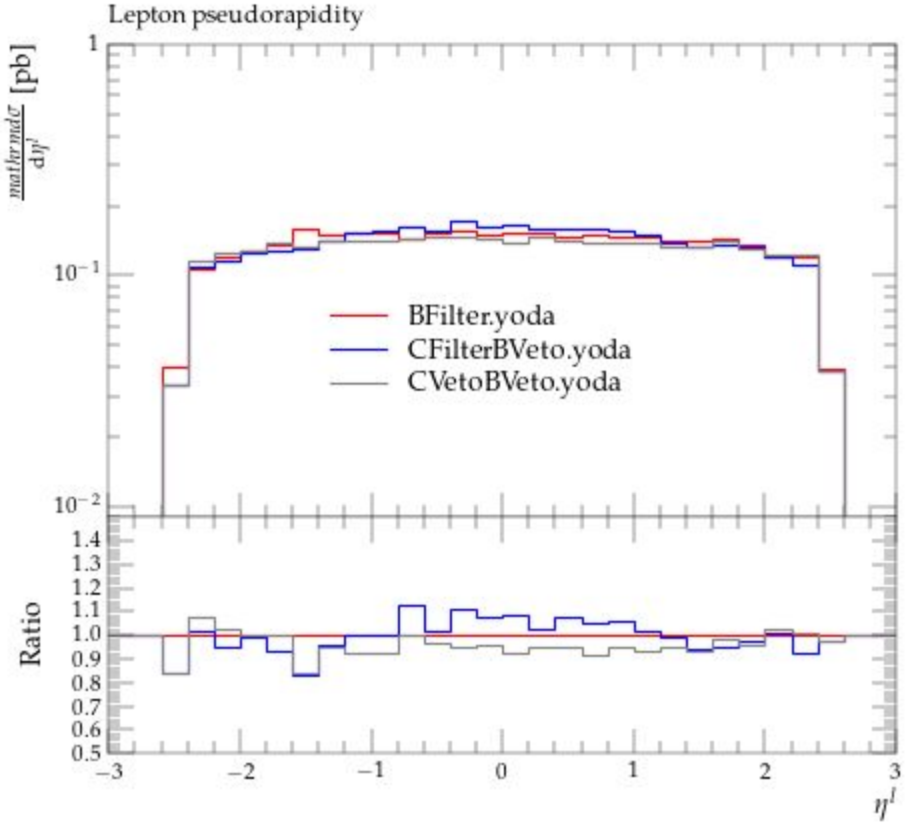


Sherpa 2.2.14

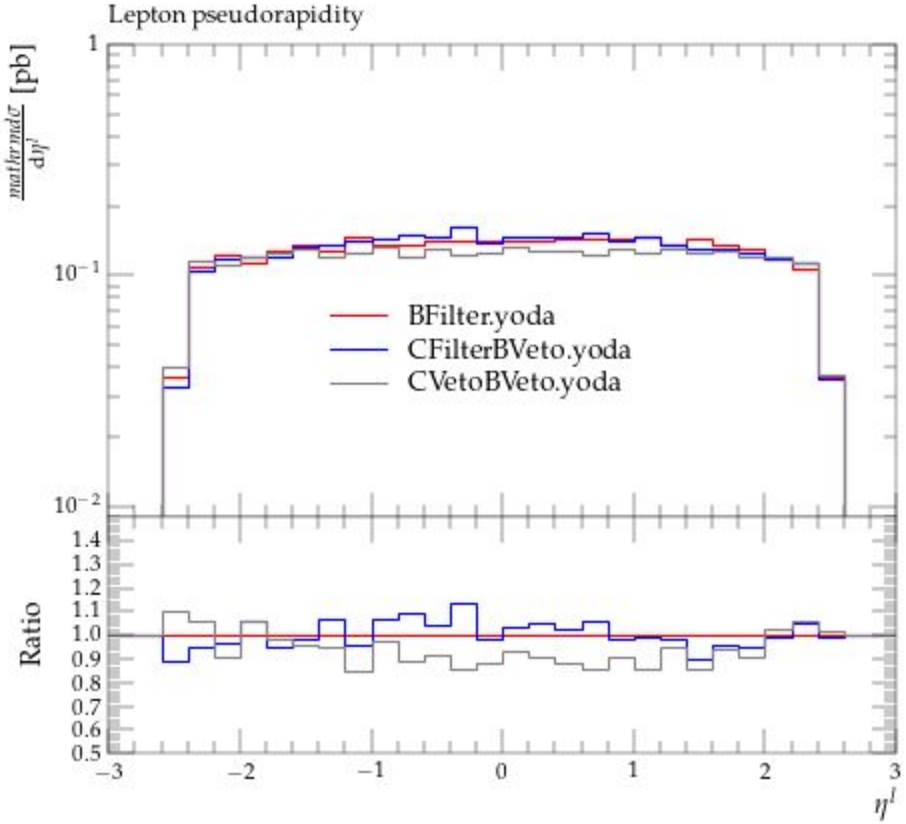


Lepton pseudorapidity

Sherpa 2.2.11



Sherpa 2.2.14



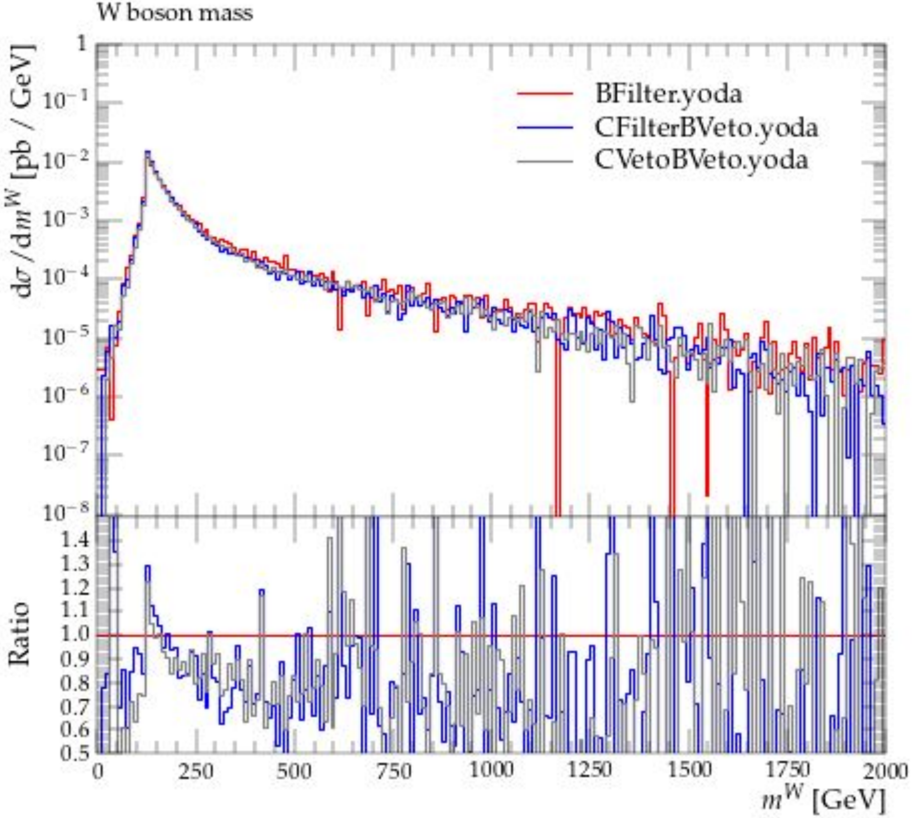
Next steps…

- Implementation of unfolded data to HmTW MC simulations.
- Generate Sherpa 2.2.14 at 13 TeV center-of-mass energy MC samples, with different Γ_W values.

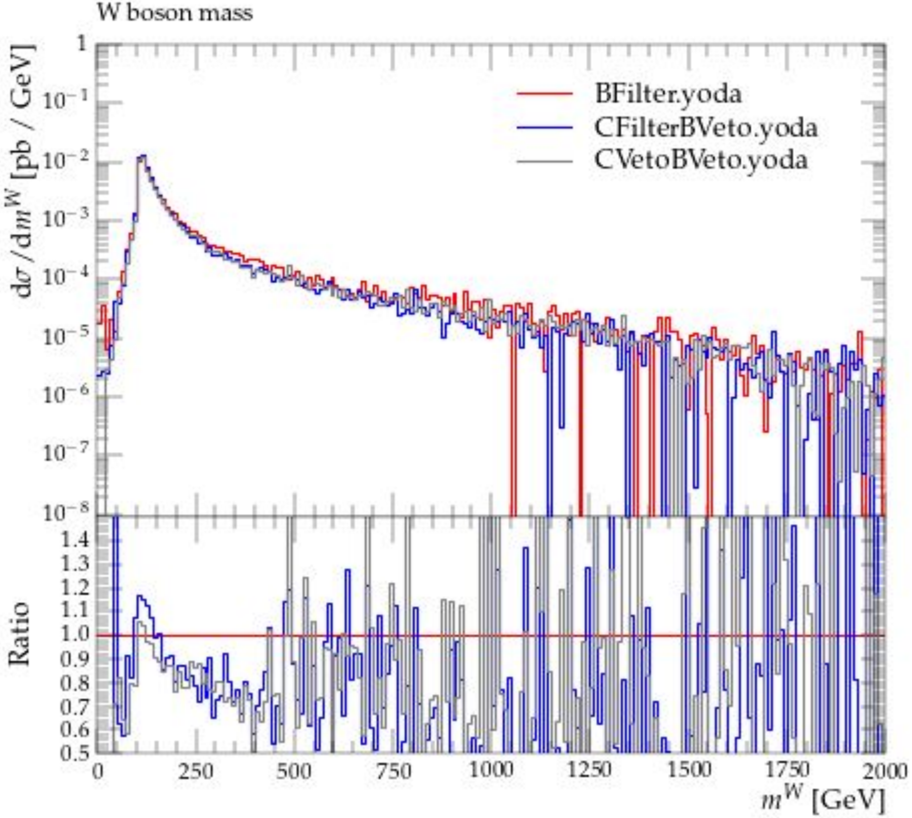
Appendix - Another kinematic distributions

W mass

Sherpa 2.2.11

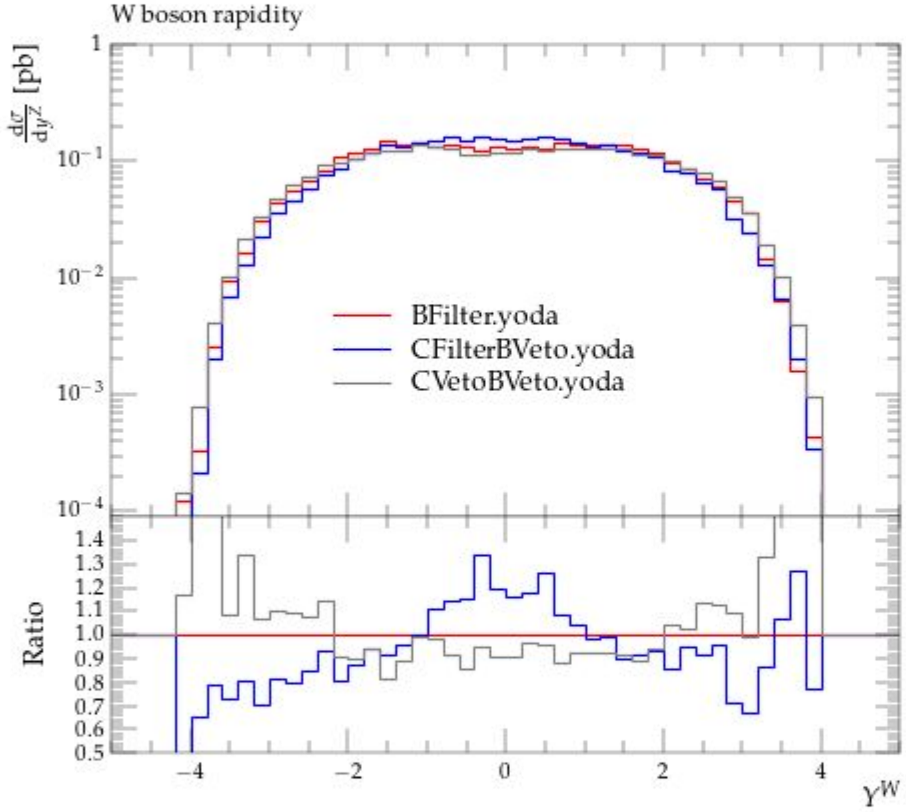


Sherpa 2.2.14

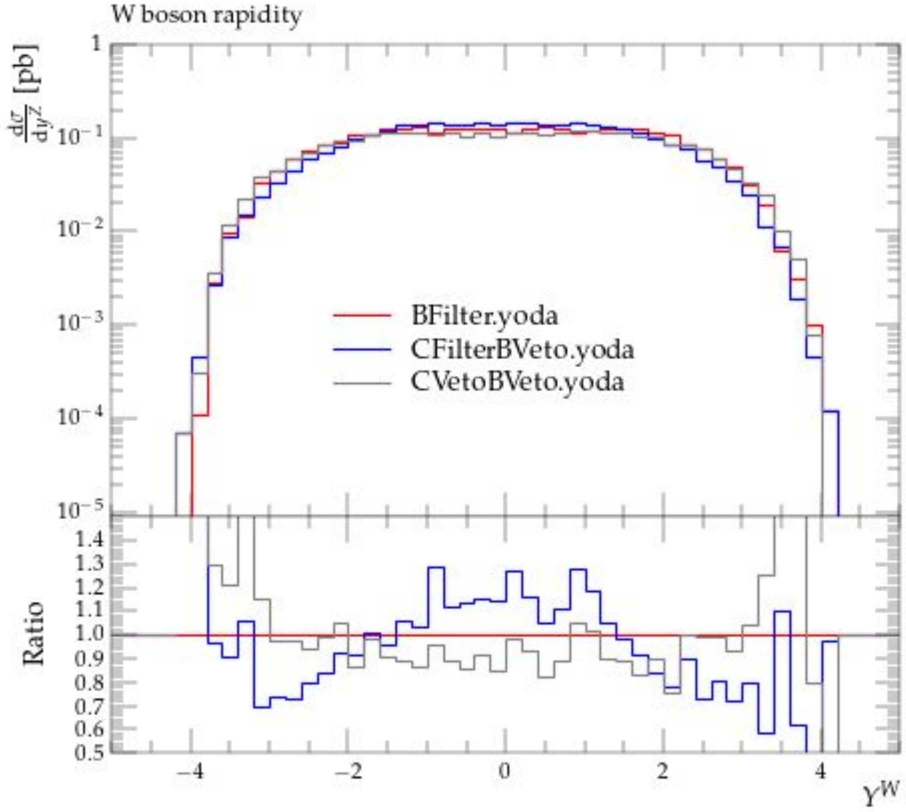


W boson rapidity

Sherpa 2.2.11

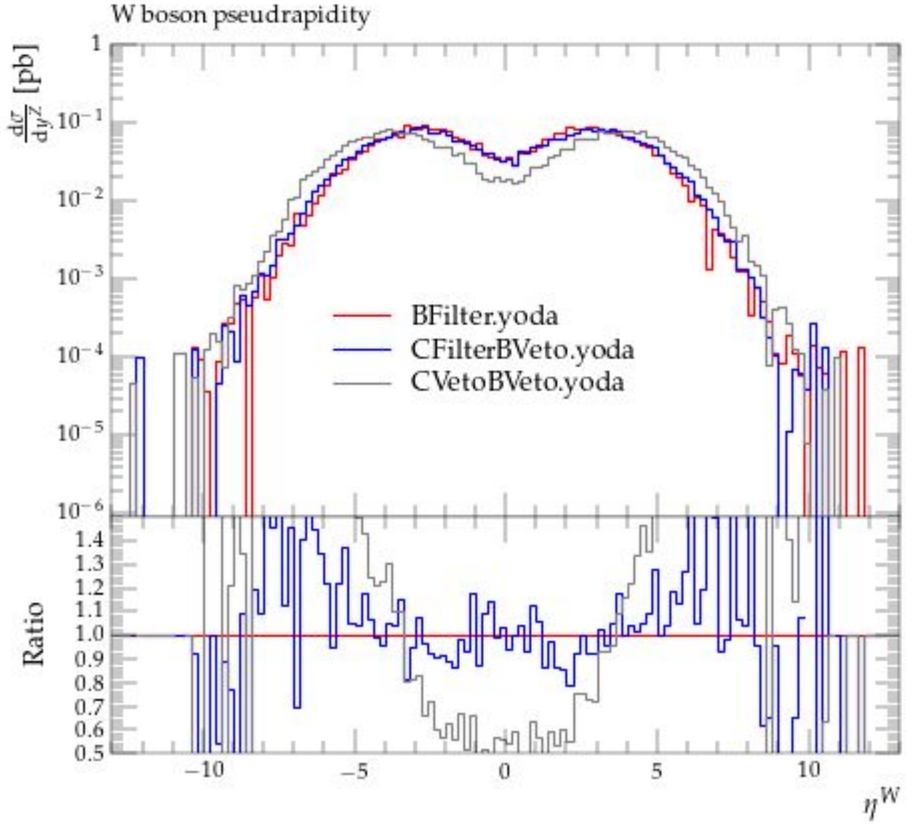


Sherpa 2.2.14

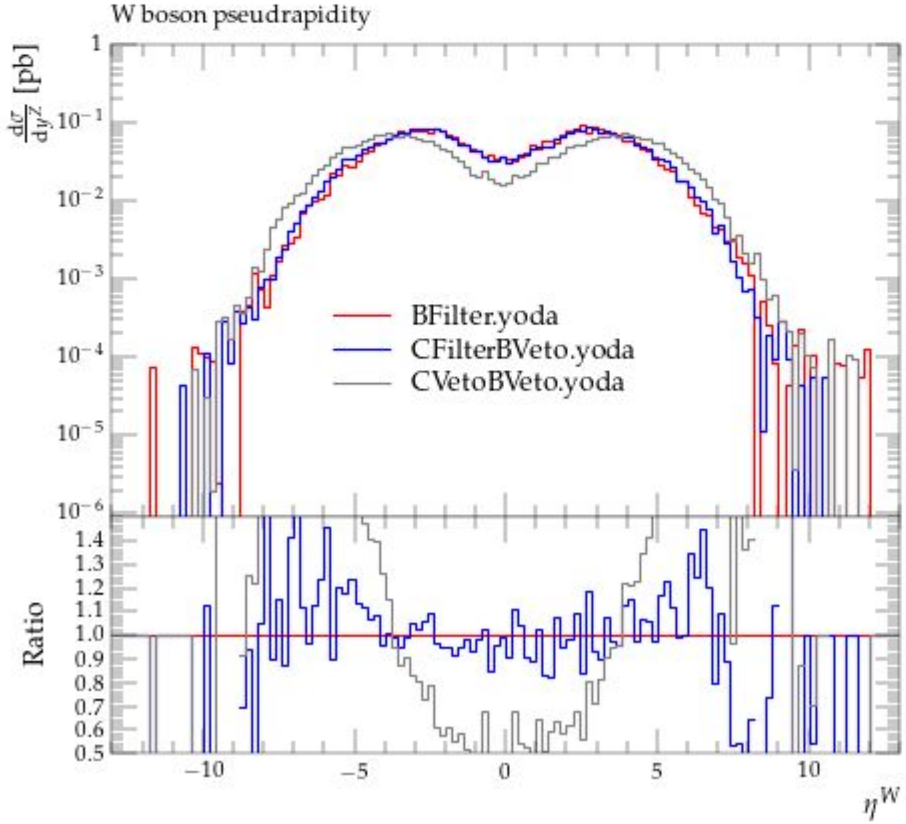


W boson pseudorapidity

Sherpa 2.2.11

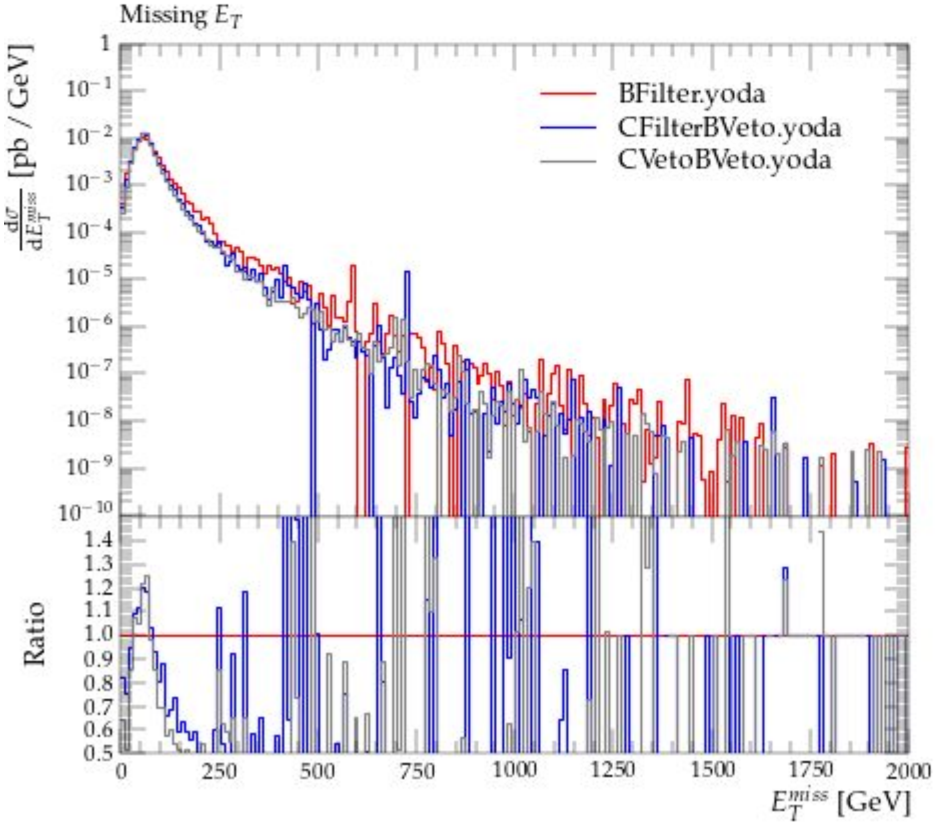


Sherpa 2.2.14

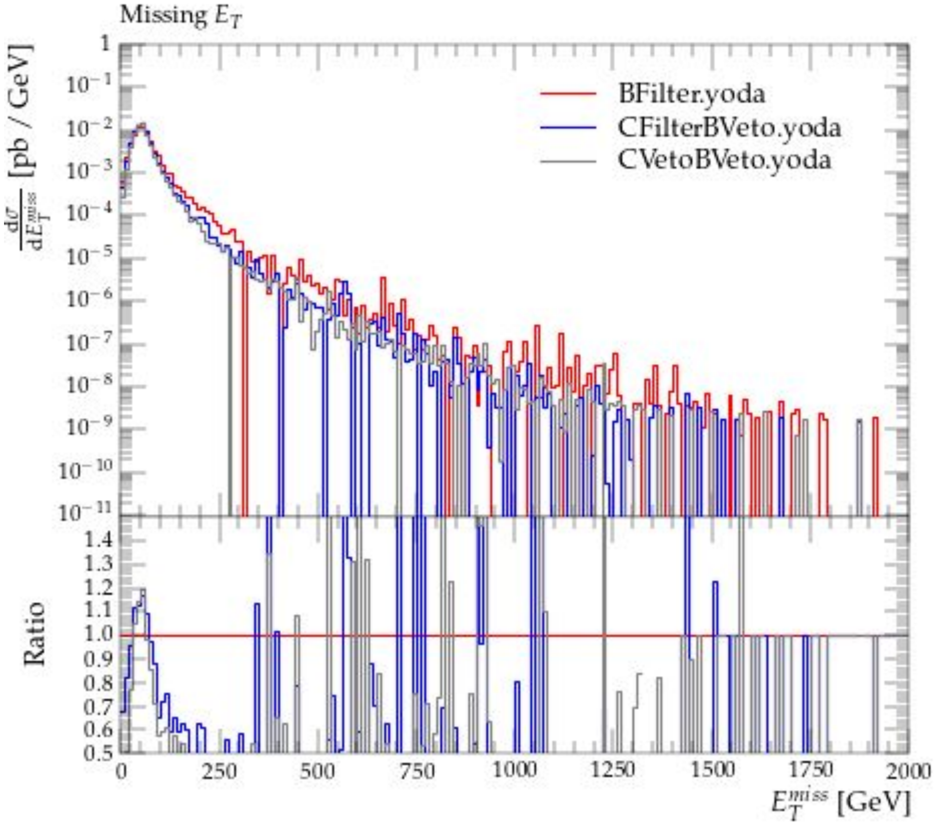


Missing transverse energy

Sherpa 2.2.11

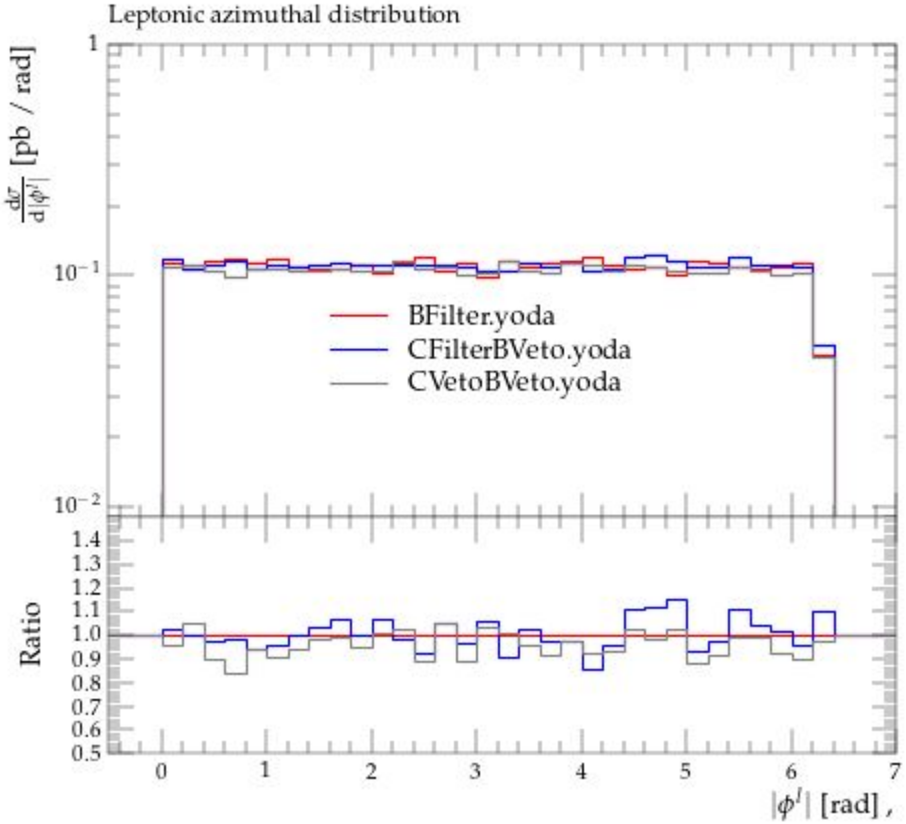


Sherpa 2.2.14

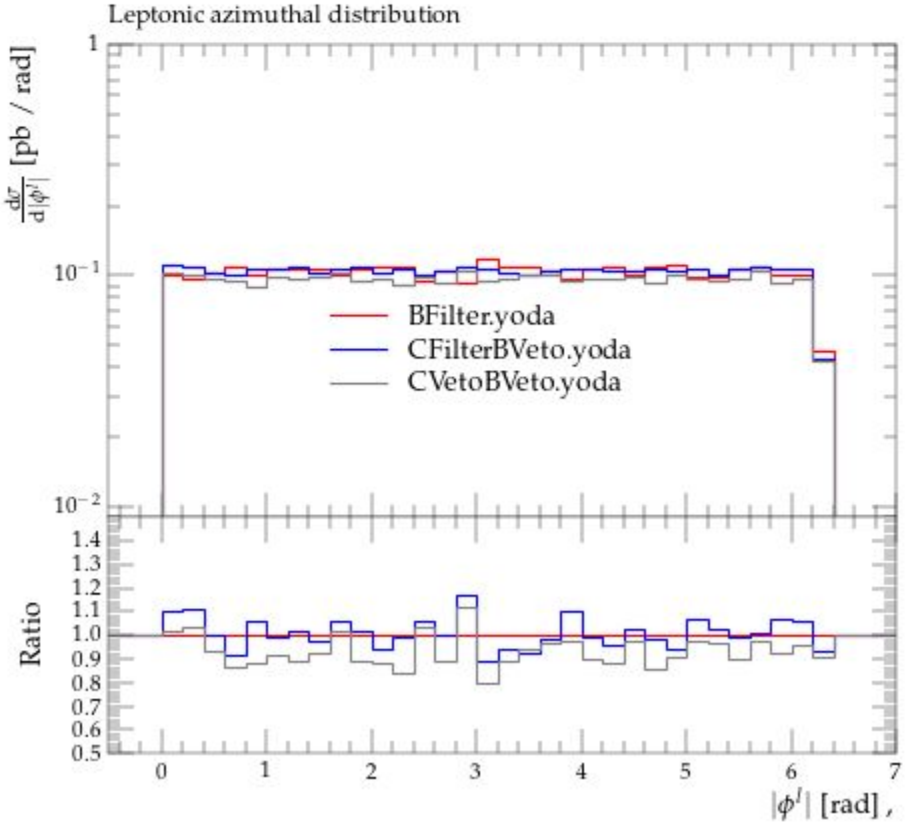


Leptonic azimuthal distribution

Sherpa 2.2.11

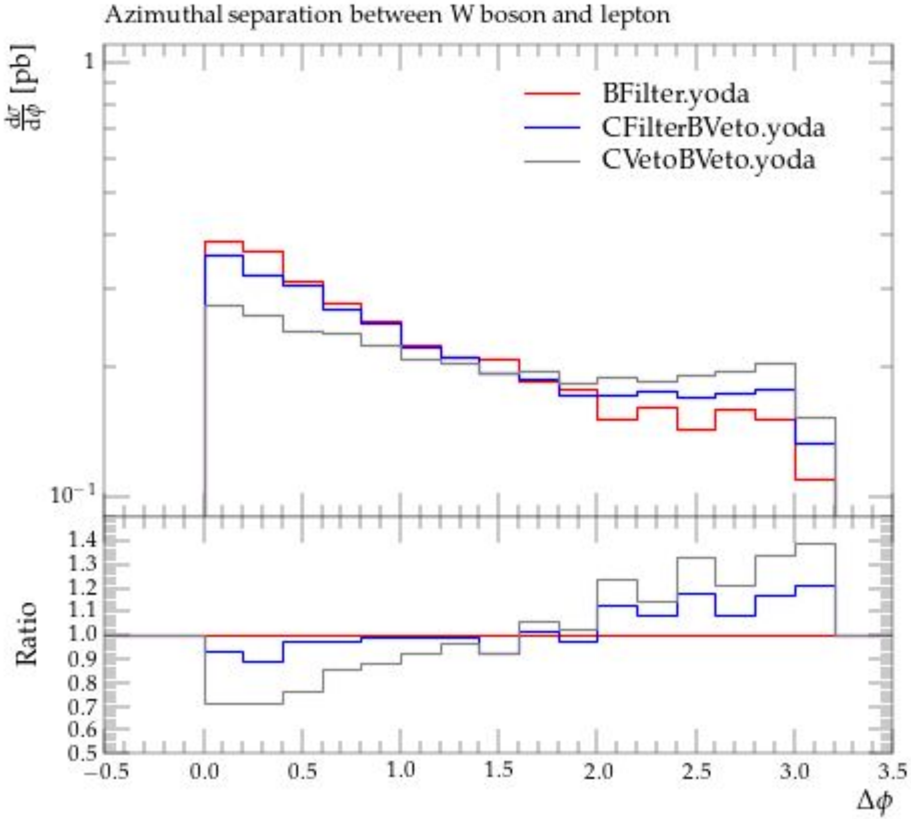


Sherpa 2.2.14

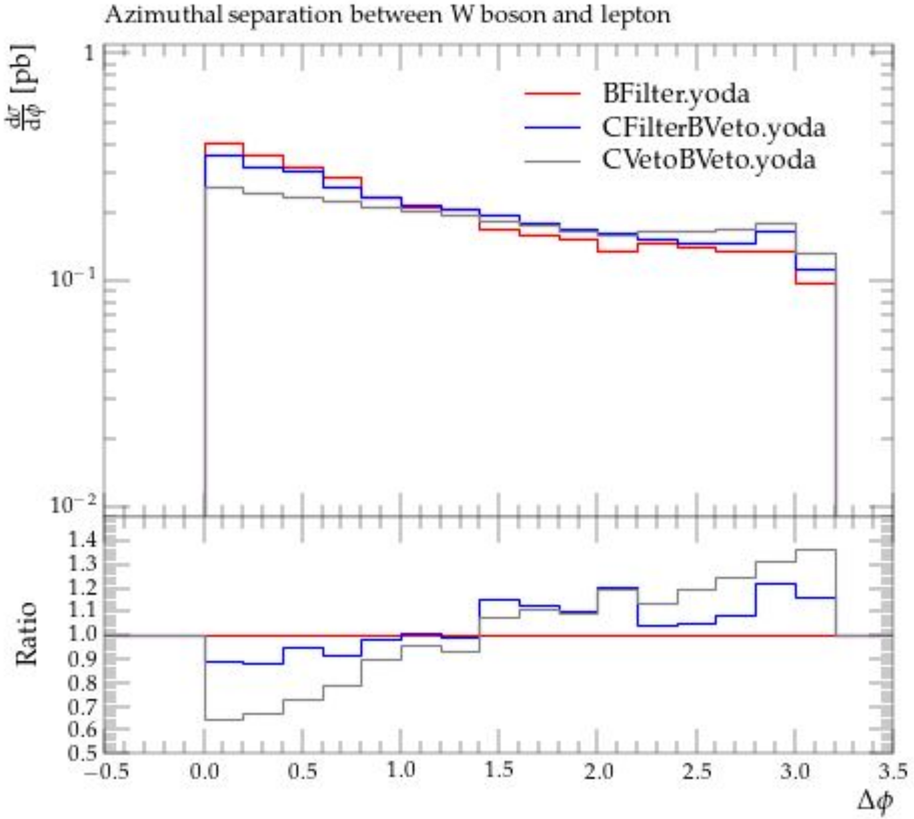


Azimuthal separation between W boson and lepton

Sherpa 2.2.11

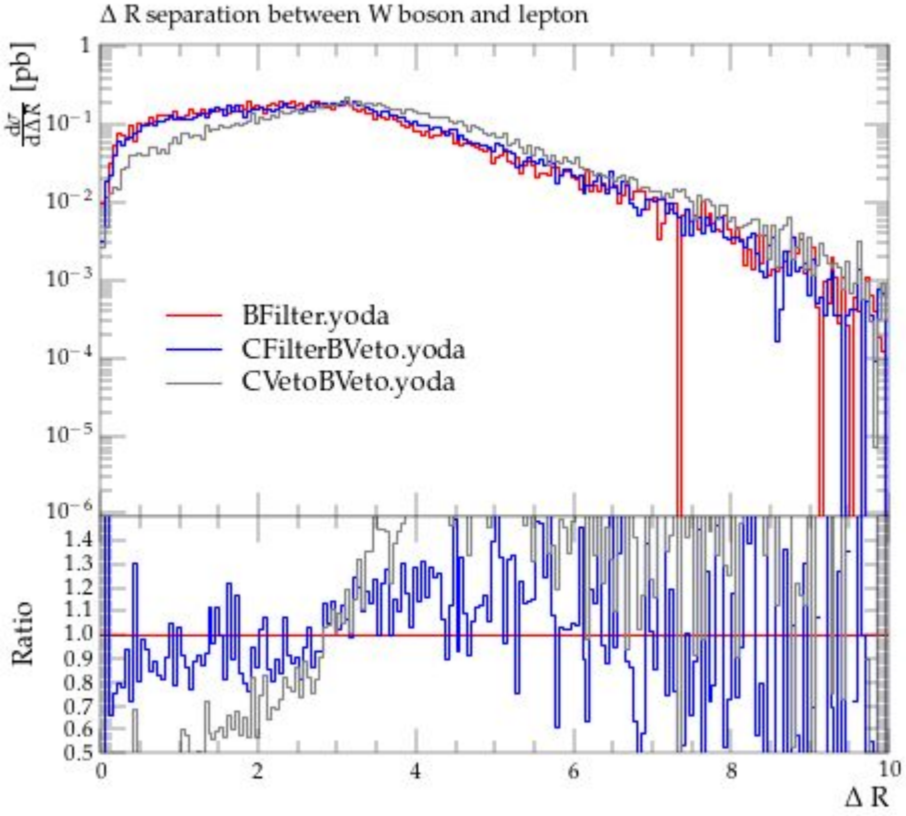


Sherpa 2.2.14

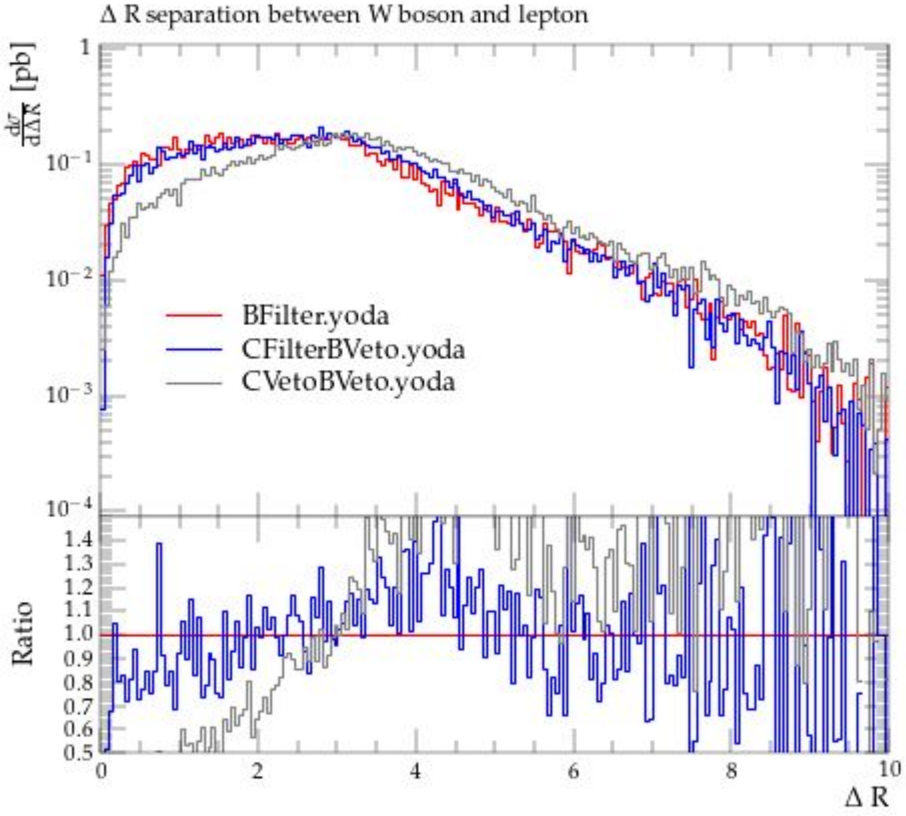


Angular separation between W boson and lepton

Sherpa 2.2.11

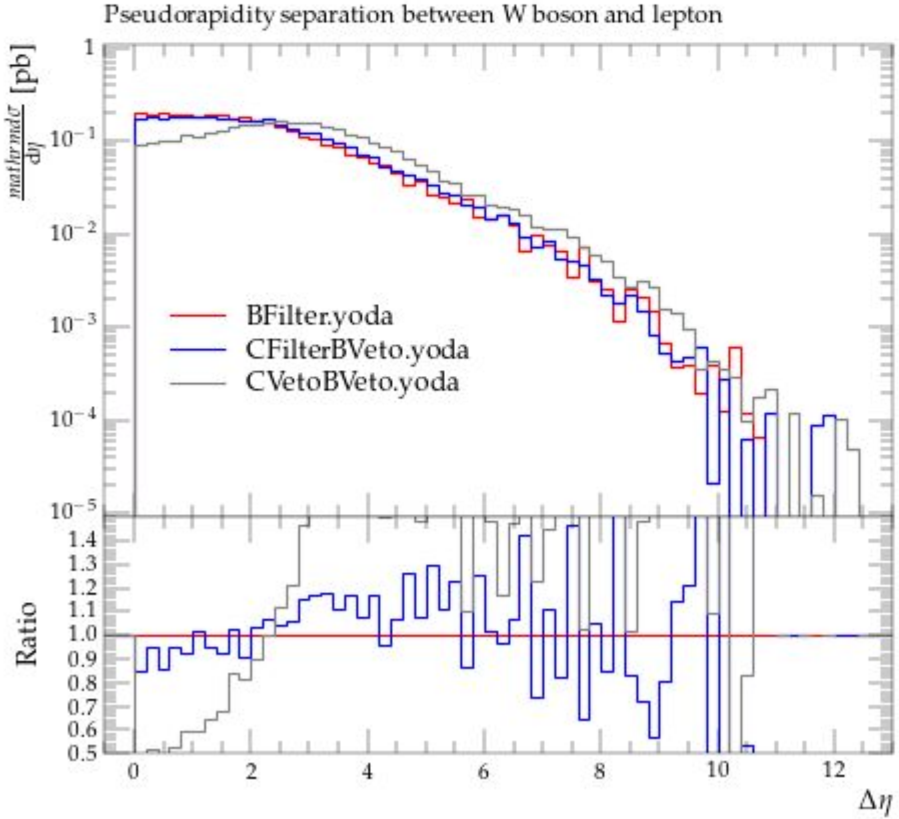


Sherpa 2.2.14



Pseudorapidity separation between W boson and lepton

Sherpa 2.2.11



Sherpa 2.2.14