Sensitivity to Longitudinal VBS at 100 TeV

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Introduction

- Aim: Study the sensitivity to longitudinal Vector Boson Scattering (VBS) at a 100 TeV hadron collider
  - ➤ An important medium to test electroweak symmetry breaking (Higgs contribution cancels divergences)
  - ➤ Search for anomalous quartic gauge couplings

- We will explore the fully leptonic $W^\pm W^\pm$jj channel
  - ➤ offers the largest electroweak to strong production cross-section ratio among VBS processes
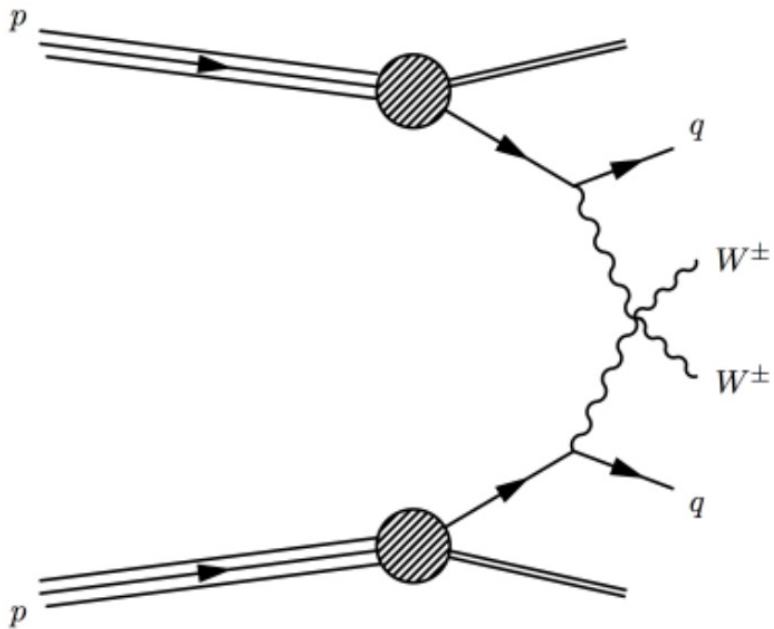
Signature

➤ 2 same-sign leptons, large MET, 2 forward jets

Backgrounds

➤ Diboson processes (WZ, $W^\pm W^\mp$, ….)

➤ Z+jets and W+jets processes

➤ ttbar and single top processes

➤ Triboson processes

➤ Z+gamma and W+gamma processes

Status and plans

- Our primary goal is the sensitivity measurement

  ➤ Studies such as anomalous couplings will depend on availability of person power

- Production of signal sample is in progress

  ➤ So far, we have generated some test samples and performed some basic generator level validation (more on next slides)

  ➤ Setup for the final production is being prepared (including interface to Delphes)

- For background processes, we will use the centrally generated samples

  ➤ We might have to generate a WZ electroweak sample and also a QCD induced WZ sample

  ➤ Efforts to help with validation of central samples are underway (more on next slides)

- For analysis, we plan to use a BNL framework (also used for the yellow report study at HL-LHC)

  ➤ Entire analysis chain (including cross-section measurement) is in place but needs some tweaking

  ➤ Currently just working with rivet for our validation studies

Production of signal sample

Sample details

- Generator used: MADGRAPH5 3.1.0+PYTHIA8 with dipole recoil ON

- Generated processes:
  - generate pp > j j $W^+ W^+$ QCD = 0 QED = 4, $W^+ \to l^+ \, v_l$
  - generate pp > j j $W^+\{0\} \, W^+\{0\}$ QCD = 0 QED = 4, $W^+ \to l^+ \, v_l$
  - generate pp > j j $W^+\{0\} \, W^+\{T\}$ QCD = 0 QED = 4, $W^+ \to l^+ \, v_l$
    - add process pp > j j $W^+\{0\} \, W^+\{T\}$ QCD = 0 QED = 4, $W^+ \to l^+ \, v_l, W^+ \to ta^+ \, v_l$
    - add process pp > j j $W^+\{0\} \, W^+\{T\}$ QCD = 0 QED = 4, $W^+ \to ta^+ \, v_l, W^+ \to l^+ \, v_l$
    - add process pp > j j $W^+\{0\} \, W^+\{T\}$ QCD = 0 QED = 4, $W^+ \to ta^+ \, v_l$
  - generate pp > j j $W^+\{T\} \, W^+\{T\}$ QCD = 0 QED = 4, $W^+ \to l^+ \, v_l$

- This is repeated for the $W^- W^-$ case

- Note: decay to taus has to be added separately for the mixed polarizations. see launchpad

  - taus are also not included in the particle definition. E.g we use "define l+ = e+ mu+"

- PDF set: NNPDF3.0 LO

- Number of events generated: 10000 per sample
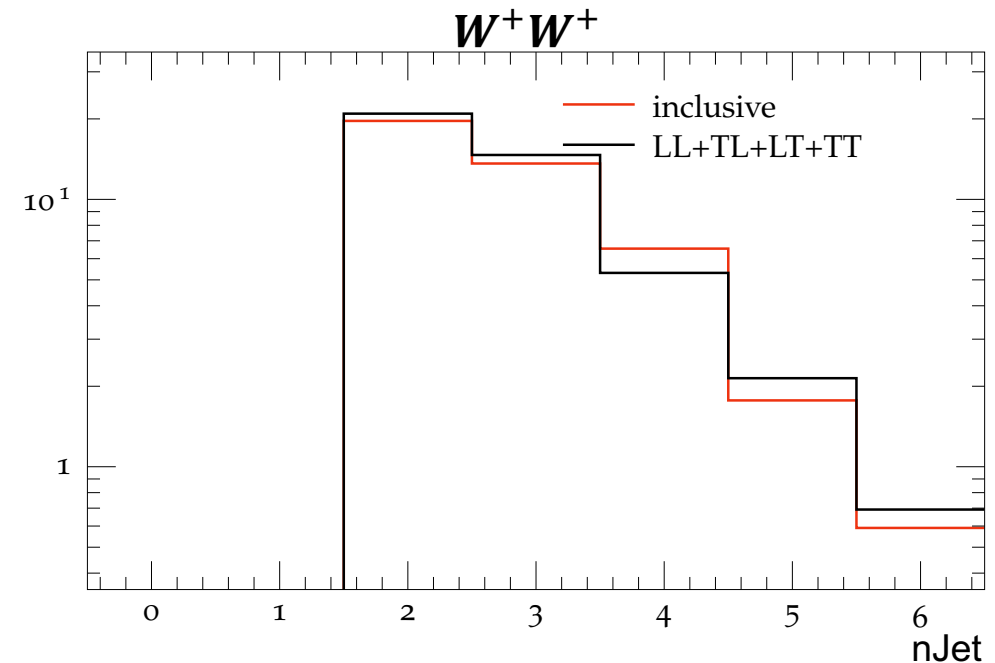
- C.M energy: 100 TeV

Sample Cross-sections

Generator cuts

- Lepton p_T > 10 GeV

- Jet p_T > 10 GeV

- Jet eta $\leq$ 6.5

- Lepton eta $\leq$ 5.0

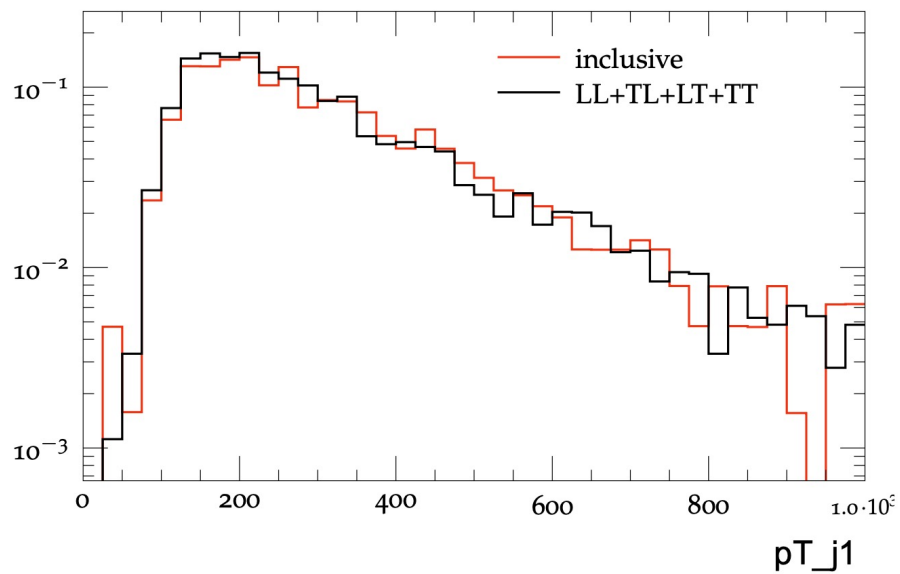|	W^+W^+	W^-W^-
Inclusive	**0.399 pb**	**0.222 pb**
LL	0.023 pb	0.013 pb
LT+TL	0.139 pb	0.077 pb
TT	0.236 pb	0.131 pb
LL+LT+TL+TT	**0.398 pb**	**0.221 pb**

Cuts applied in same-sign WW rivet routine

- 2 same-sign leptons, p_T^l > 20 GeV

- nJets $\geq$ 2, p_T^j > 30 GeV, $|\eta_j|$ < 4.5

- m_{jj} > 200 GeV

- Min ΔR_{ll} > 0.3

- MET > 40 GeV

W^+W^+

W^-W^-
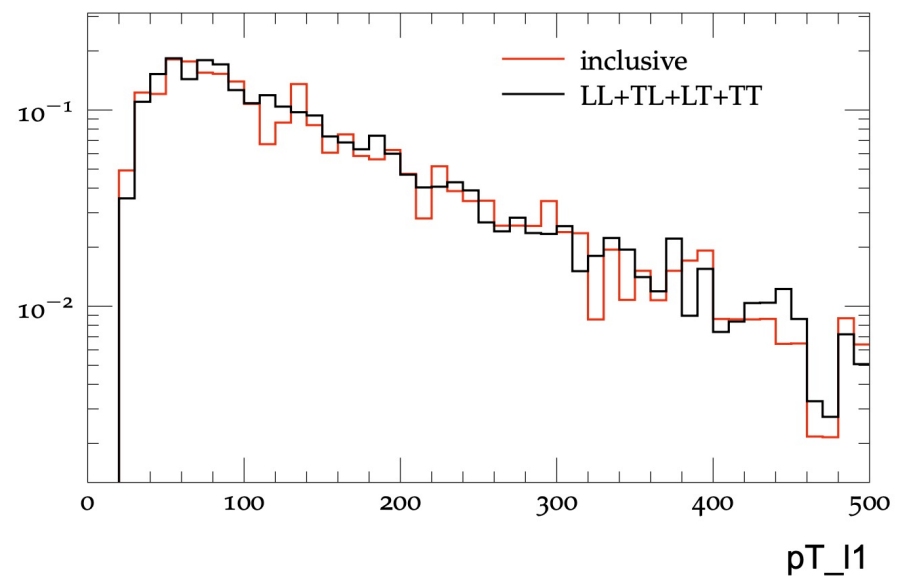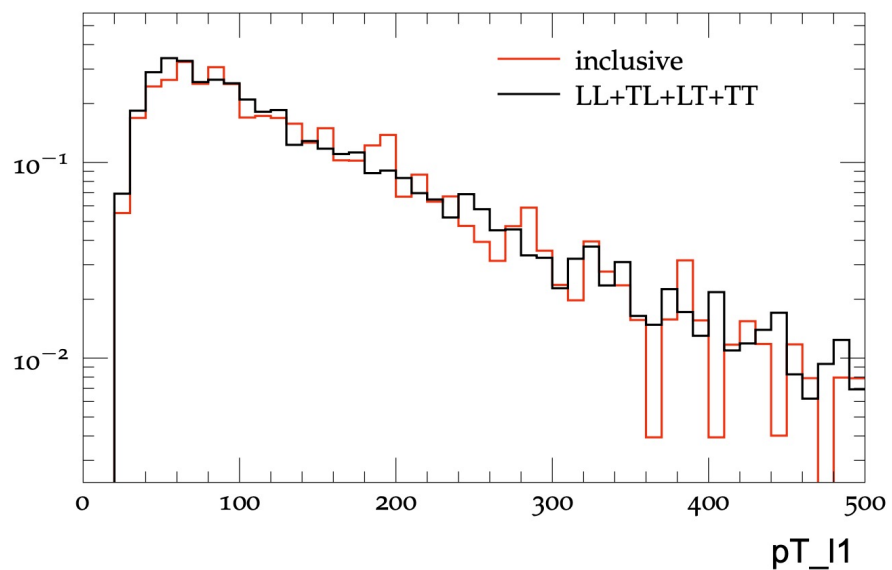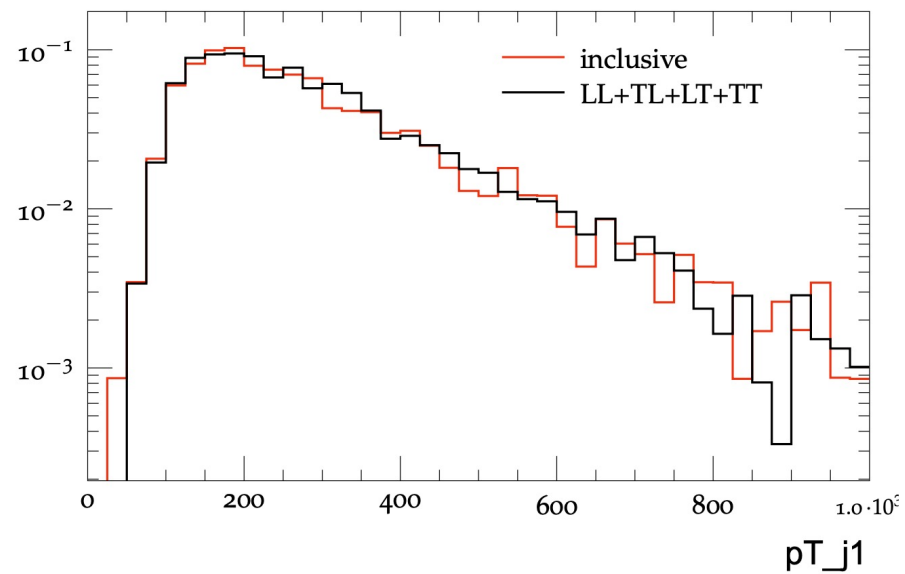
Validation of Background Samples

Validation Procedure

❖ Validation involves comparing snowmass (MCProd) samples to fcc-hh samples at truth level

- Example: **ttbar sample**
- Number of events: 10,000

- fcc-hh: /eos/experiment/fcc/hh/generation/lhe/mg_pp_tt012j_5f/events_022118229.lhe.gz
  - ➢ eos is not mounted on the snowmass cluster
  - ➢ Sample is thus copied to BNL cluster and converted to hepmc
  - ➢ Run through some generic and same-sign WW rivet routines

- MCProd: /collab/project/snowmass21/data/smmc/v0.1/r1/100TeV_tt.tar.gz/mgstep/out_5423_13.lhe.gz
  - ➢ Converted to hepmc on the snowmass machine and copied to BNL cluster
  - ➢ Run through some generic and same-sign WW rivet routines

Validation results
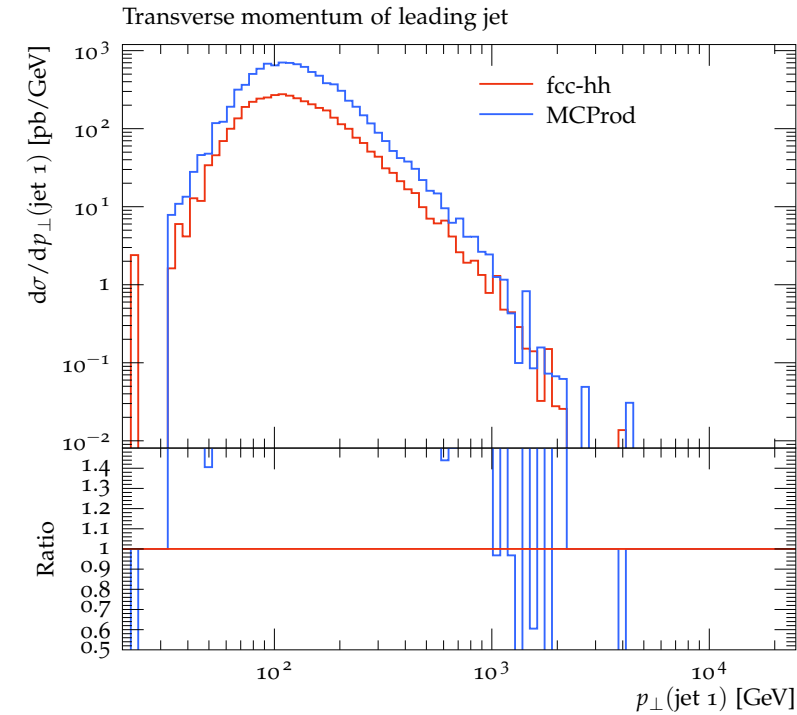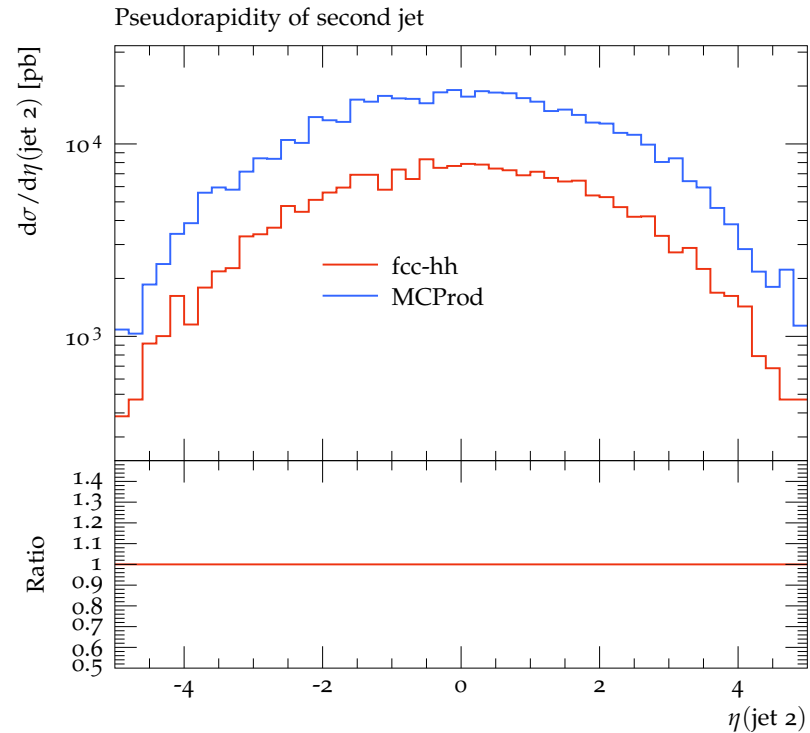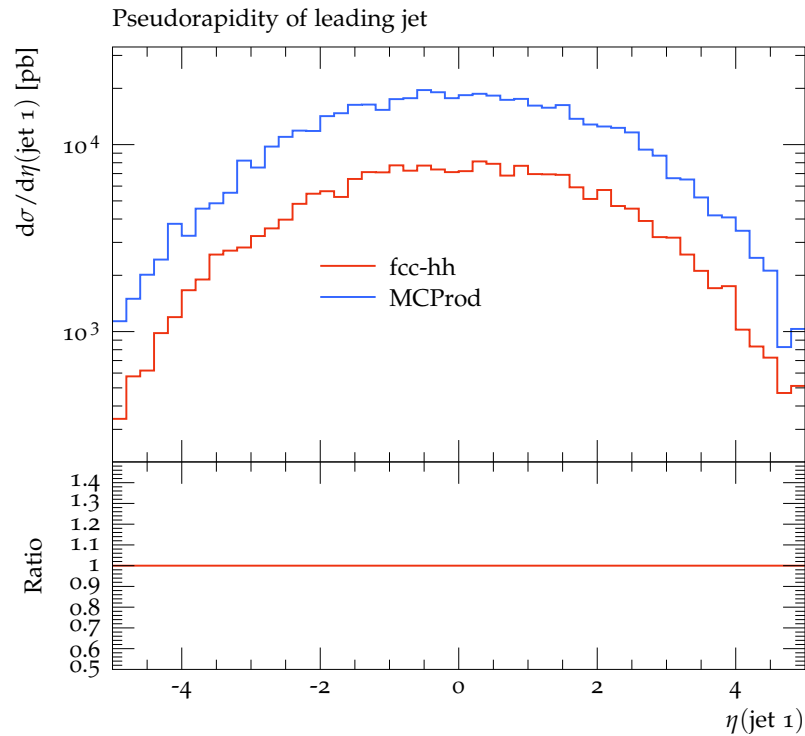
❖ The MC_JETS rivet routine is used for these plots

❖ Disagreement between the two samples is quite obvious

Differences between fcc-hh and Mcprod samples

Fcc-hh sample	MC prod sample
MG v2.5.4	MG v3.1.1
Jet pT > 5 GeV	Jet pT > 20 GeV
Lepton pT > 5 GeV	-
Jet eta < 8	Jet eta < 5
Lepton eta < 8	-
Mll > 20 GeV	-
Cross-section: 0.40×10^5 pb	Cross-section: 1.03×10^5 pb

- ❖ The fcc-hh sample is a dilepton sample whereas the Mcprod sample is inclusive
- ❖ We might need to carefully define a dilepton phase space in order to compare them properly
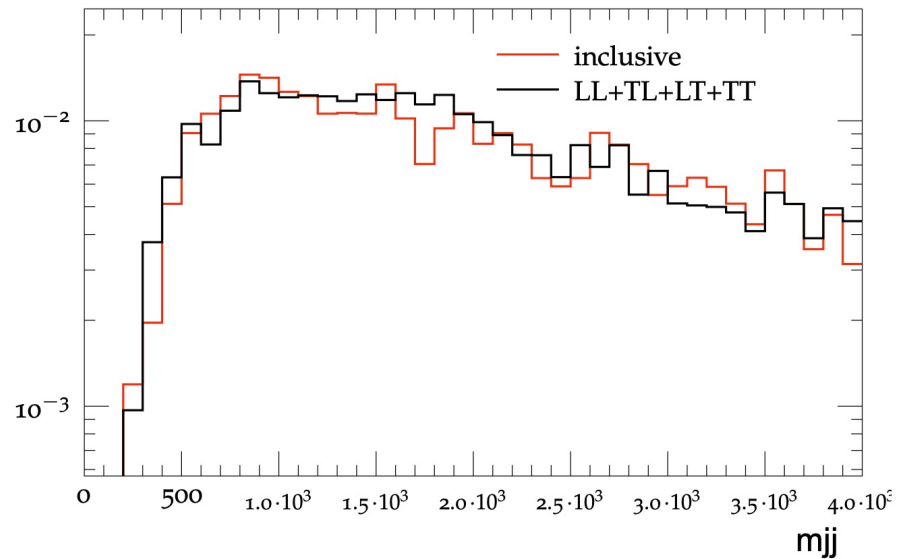- ❖ We'll follow-up with the MC production team

Summary

✓ We have exercised and validated the setup for signal sample production

✓ Preparation for the full signal sample production is progressing well

✓ We have started looking at the validation of some background samples (ttbar)

✓ Comparison to fcc-hh samples is not yet well understood

✓ Only relying on rivet for analysis at the moment

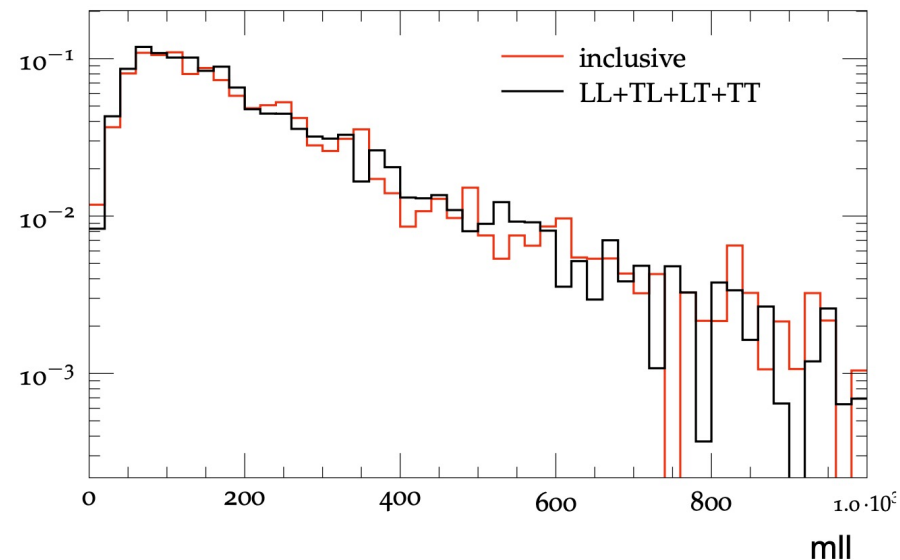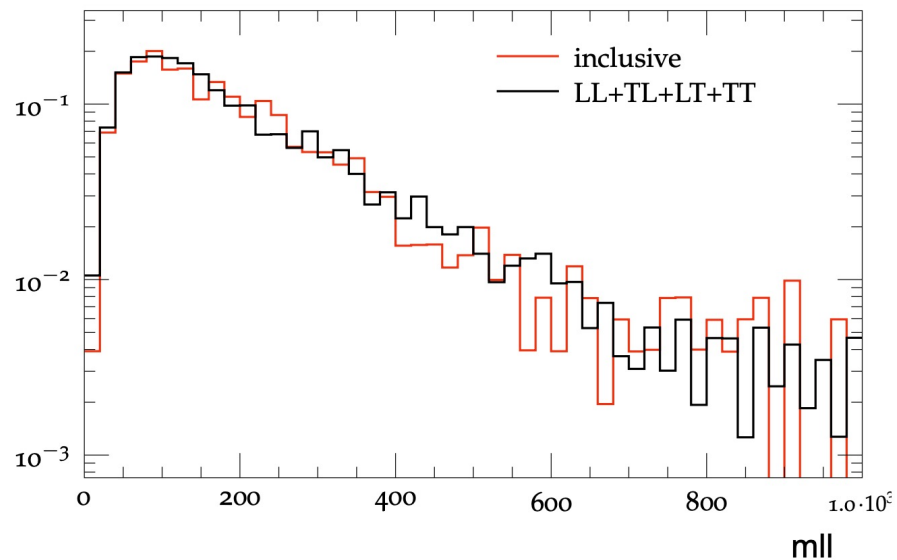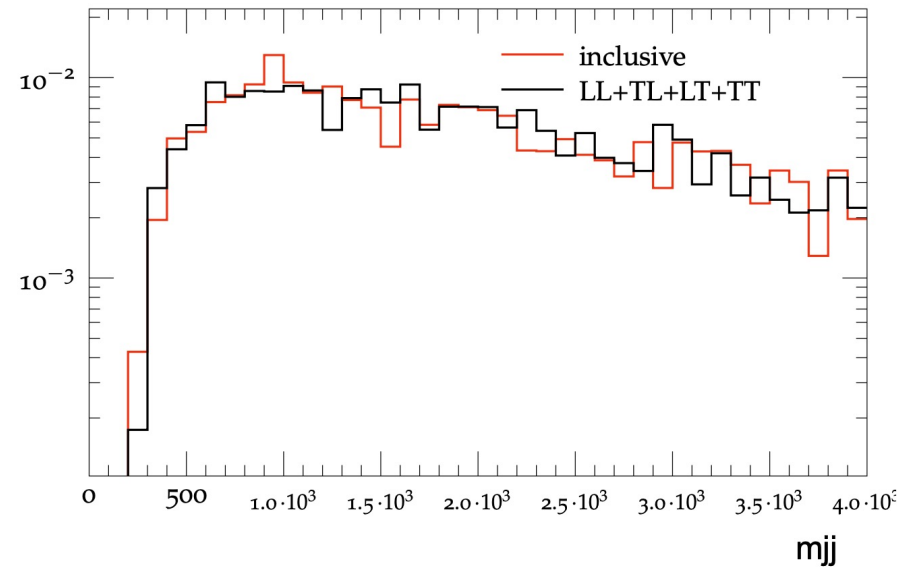✓ Analysis framework is in place but needs some adjustments

Back-up

W^+W^+

W^-W^-

Leading lepton transverse momentum in lab frame

Subleading lepton transverse momentum in lab frame

Dijet invariant mass spectrum
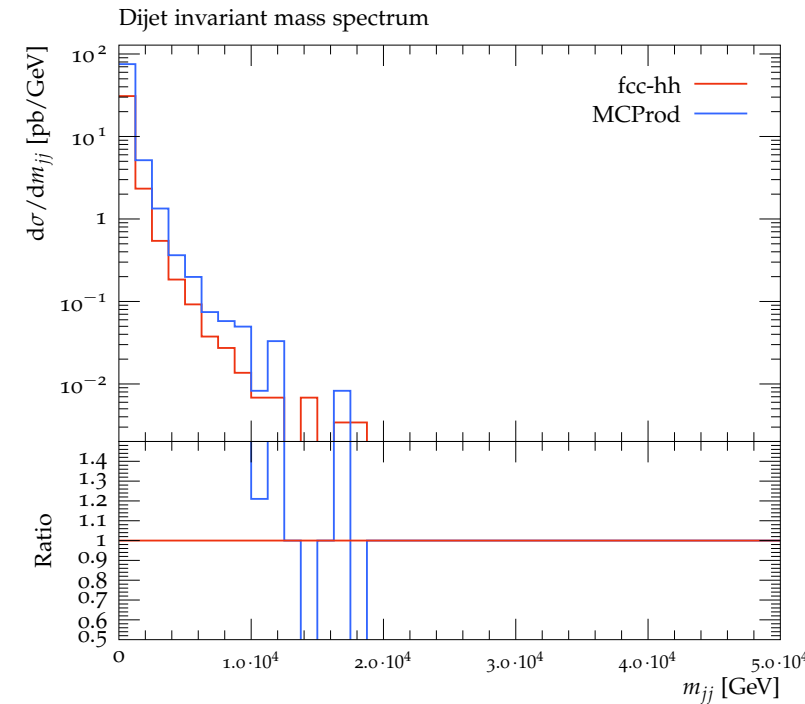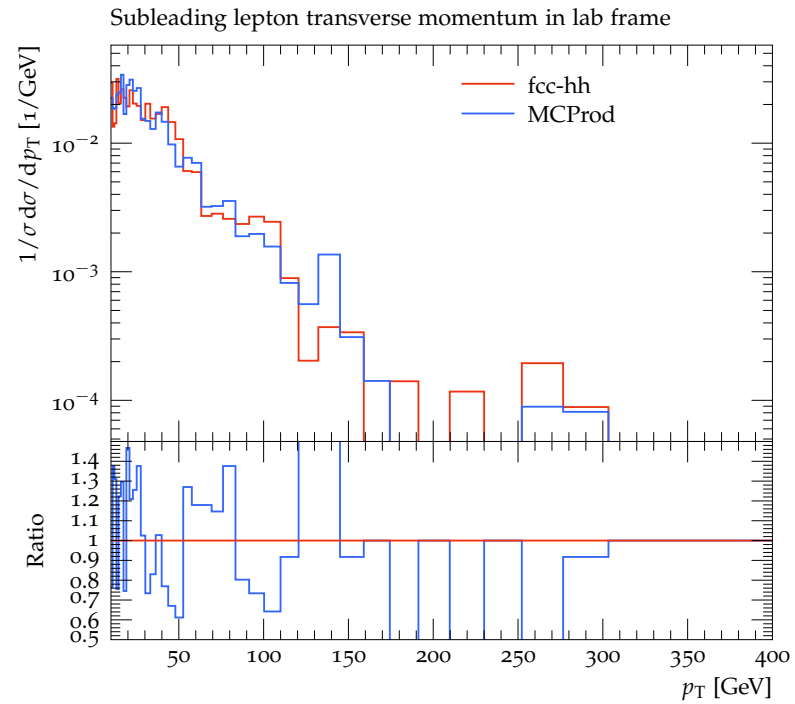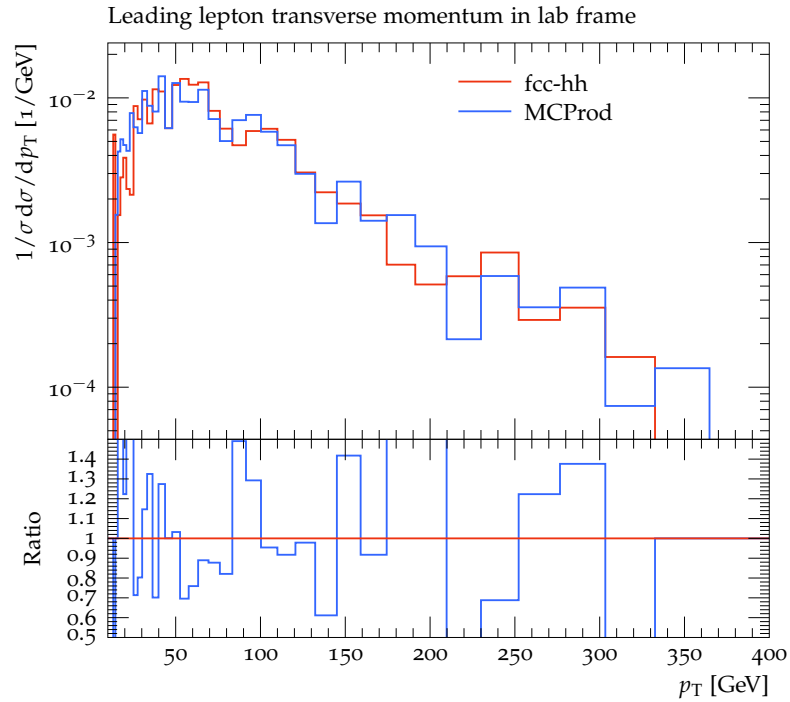
Dataset name	Physics process
Bj-4p	γ or on-shell W, Z
Bjj-vbf-4p	γ or off-shell W, Z, H in VBF topology
BB-4p	Diboson (γ, W, Z) processes
BBB-4p	Tri-boson (γ, W, Z) processes including BH
LL-4p	Non-resonant dileptons (including neutrinos)
LLB-4p	Non-resonant dileptons with an on-shell boson
H-4p	Higgs
tj-4p	Single top (s- and t-channel)
tB-4p	Single top associated with a boson
tt-4p	$t\bar{t}$ pair production
ttB-4p	$t\bar{t}$ associated with γ, W, Z, H