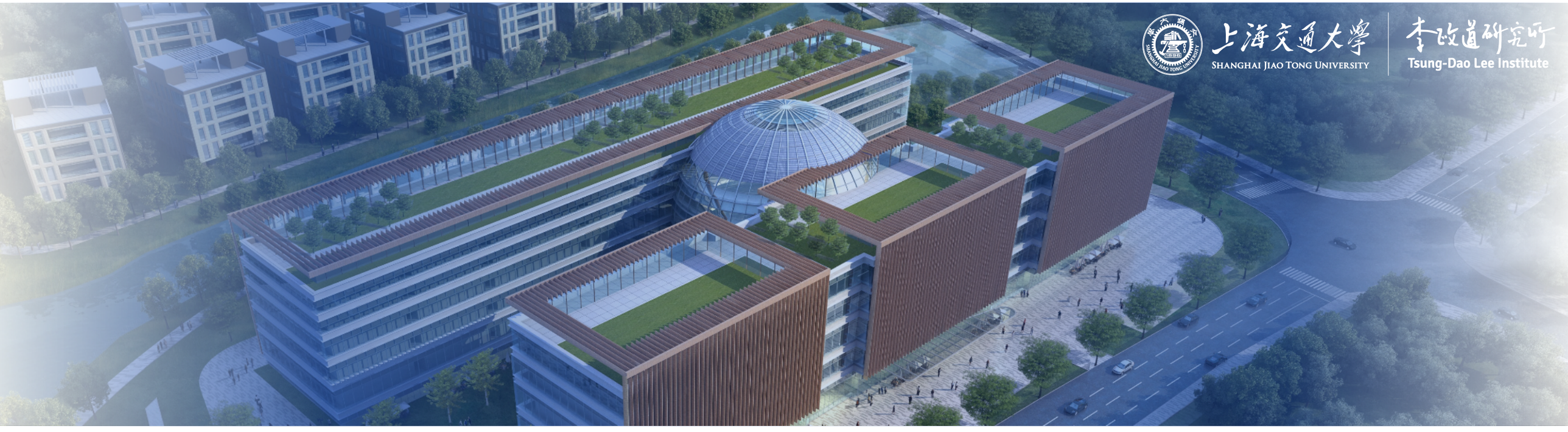

Di-boson Process Modeling with FxFx merging at ATLAS

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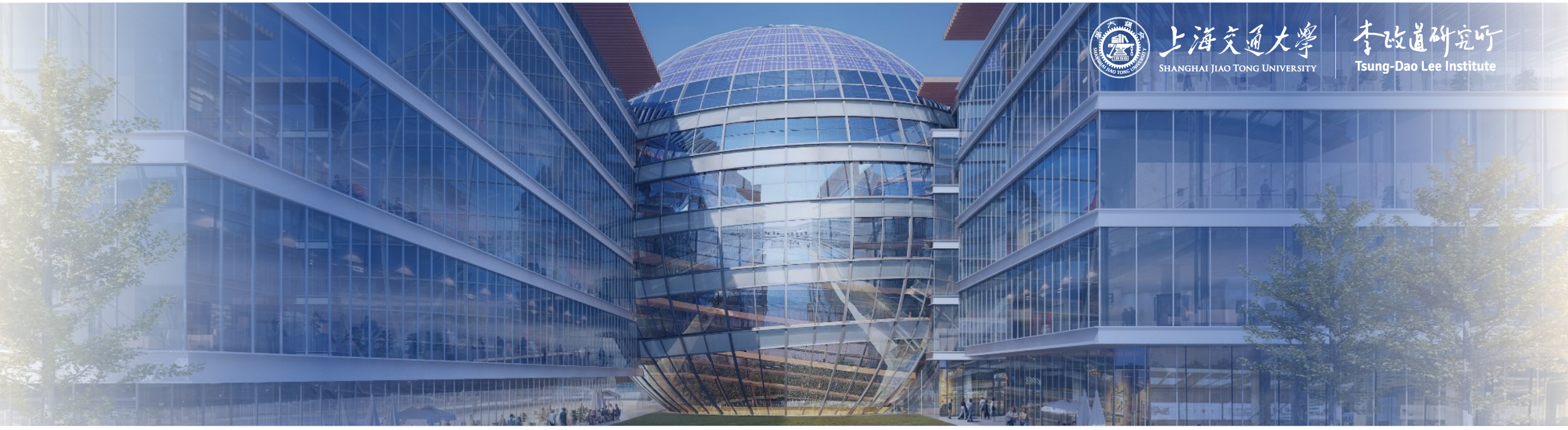
On behalf of ATLAS Collaboration

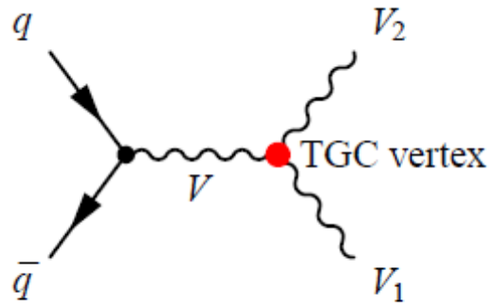
2021.11.25 Nanjing CLHCP



- Introduction to Di-boson Process and FxFx merging algorithm
- Process modeling status and application of FxFx in ATLAS
- Current FxFx merged Di-boson sample readiness in ATLAS
- Summary

Introduction — Di-boson Physics

- Di-boson production ($W\gamma, Z\gamma, WW, WZ, ZZ$)
- The measurement of vector boson pair production at LHC provides an important test of high energy behavior of electroweak interactions
- Di-boson production is an important test of the Standard Model Electroweak Symmetry Breaking (EWSB) and perturbative QCD
- Measurements of Di-boson production cross sections at LHC are important milestones for initial physics program (e.g. ZZ, Zy)
- Di-boson detection will be initially focused on W/Z leptonic decay modes
- Irreducible backgrounds for new physics searches. (e.g. Higgs decay into Di-boson, anomalous couplings : TGCs/ QGCs)



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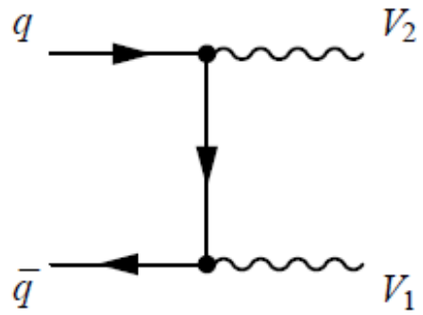

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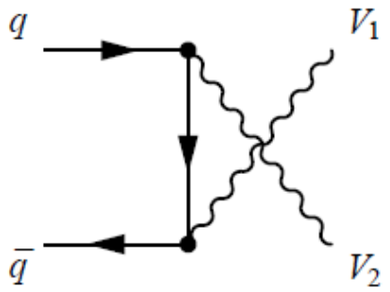
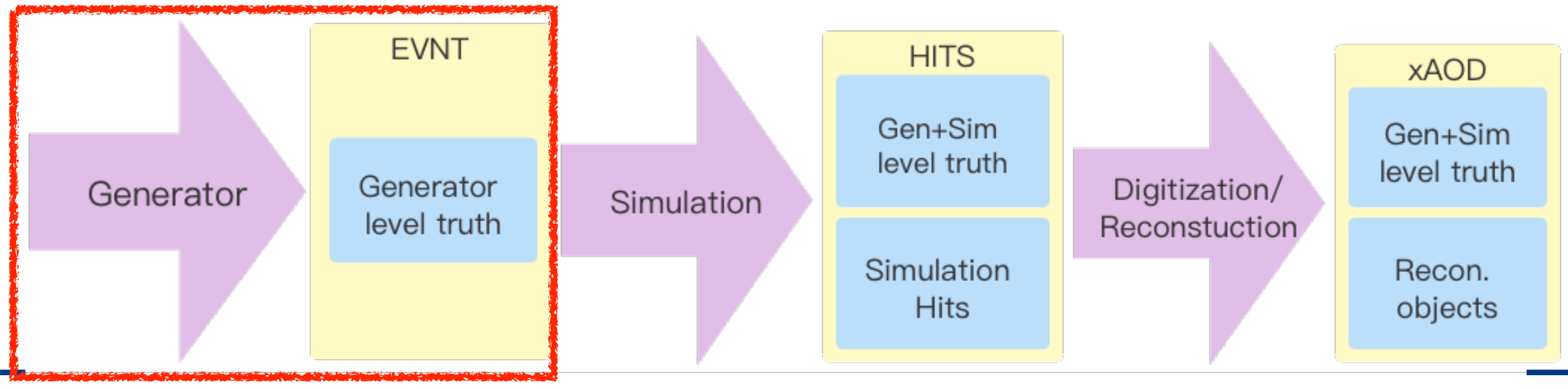


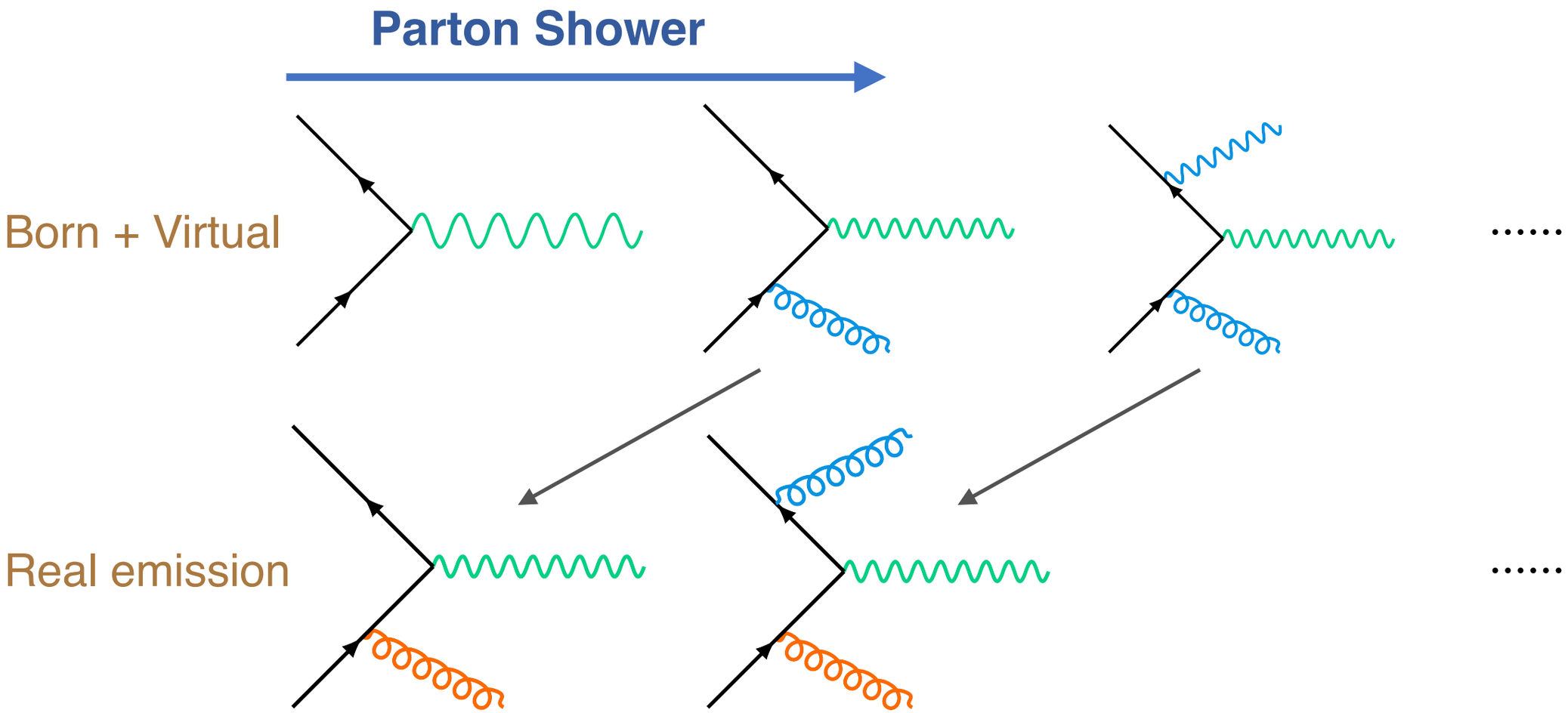
u-channel

Introduction — Di-boson Physics

Process	Generator	JetMerging Algorithm
llll	Sherpa 2.2.2	MEPS@NLO
	PowhegBox + Pythia8	CKKW-L
	MG5_aMC@NLO+Pythia8	FxFx
lvll	Sherpa 2.2.2	MEPS@NLO
	PowhegBox + Pythia8	CKKW-L
	MG5_aMC@NLO+Pythia8	FxFx
lvlv	Sherpa 2.2.2	MEPS@NLO
	PowhegBox+Pythia8	CKKW-L
	MG5_aMC@NL)+Pythia8	FxFx
lvvv	Sherpa 2.2.2	MEPS@NLO
	PowhegBox + Pythia8	CKKW-L
vvvv	Sherpa 2.2.1	MEPS@NLO



Source of double counting[1]



- Double counting between the real emission matrix elements and the Parton shower : the extra radiation can come from the matrix elements or the Parton shower
- Assuming a sample consisting of multiple N-jet calculations at NLO, each individual calculation can already consist of up to N+1 partons at particle level (quarks, gluons)

FxFx Merging

FxFx merging algorithm : allows for **consistent merging** of event files of various multiplicities at NLO accuracy, **without double counting** !

- Monte Carlo sample production at NLO consists of two steps
  - Generation of Parton-level events using matrix element(ME) calculations (MadGraph5_aMcAtNlo)
  - Addition of ISR effects, underlying event to Partion-level results using shower MC generators (Pythia8 / Herwig)

- FxFx merging
  - Parton showering can assign extra radiation to events → double counting
  - FxFx-merging is an attempt to avoid double counting of jets at NLO

Example — lvll process

Use MadGraph5_aMcAtNlo + Pythia8 to generate VV+jets FxFx samples

FxFx algorithm will be executed during the hadronization of production

Process definition

generate $p\ p\ >\ l\ \nu\ l\ l$ [QCD]
add process $p\ p\ >\ l\ \nu\ l\ l\ j$ [QCD]

Final state : lvll + 0, 1 jets @ NLO

Object selection

	Selections
pT_l	10 GeV
pT_j	10 GeV
M_{ll}	10 GeV

Modeling of off-shell lvll process :

- Fully leptonic decay + 0,1 jets @ NLO

Generator version :

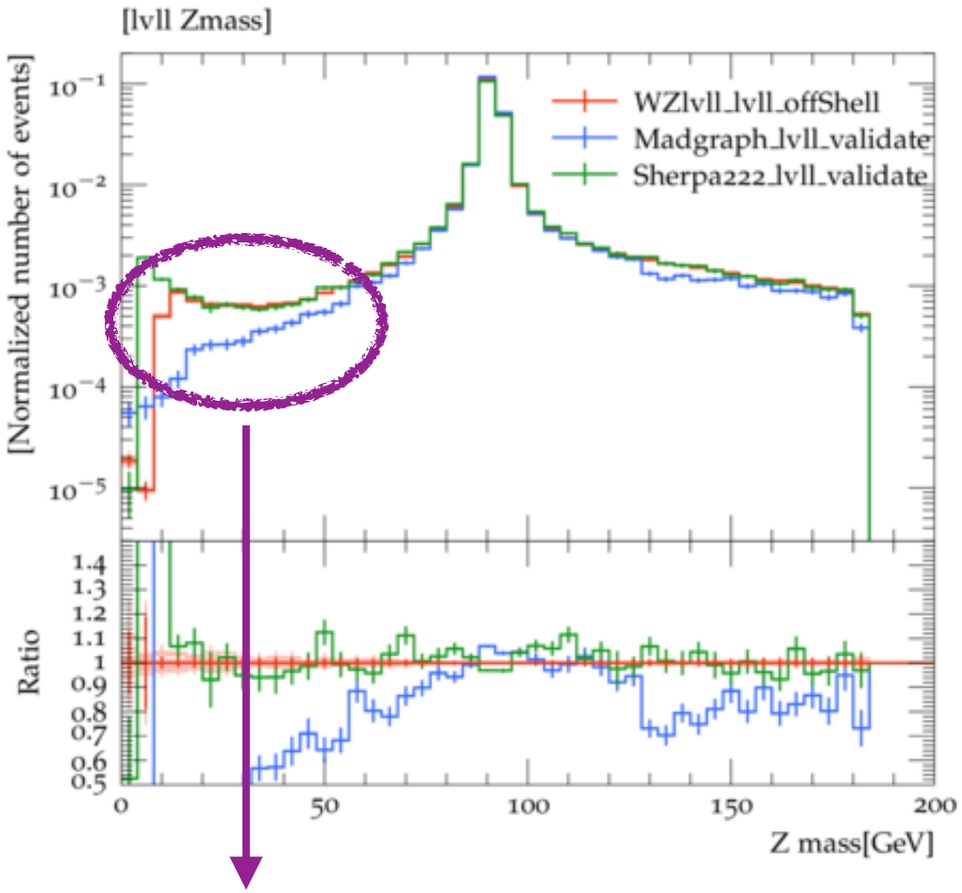
- Madgraph (v2.8.1)
- Pythia (8.244)

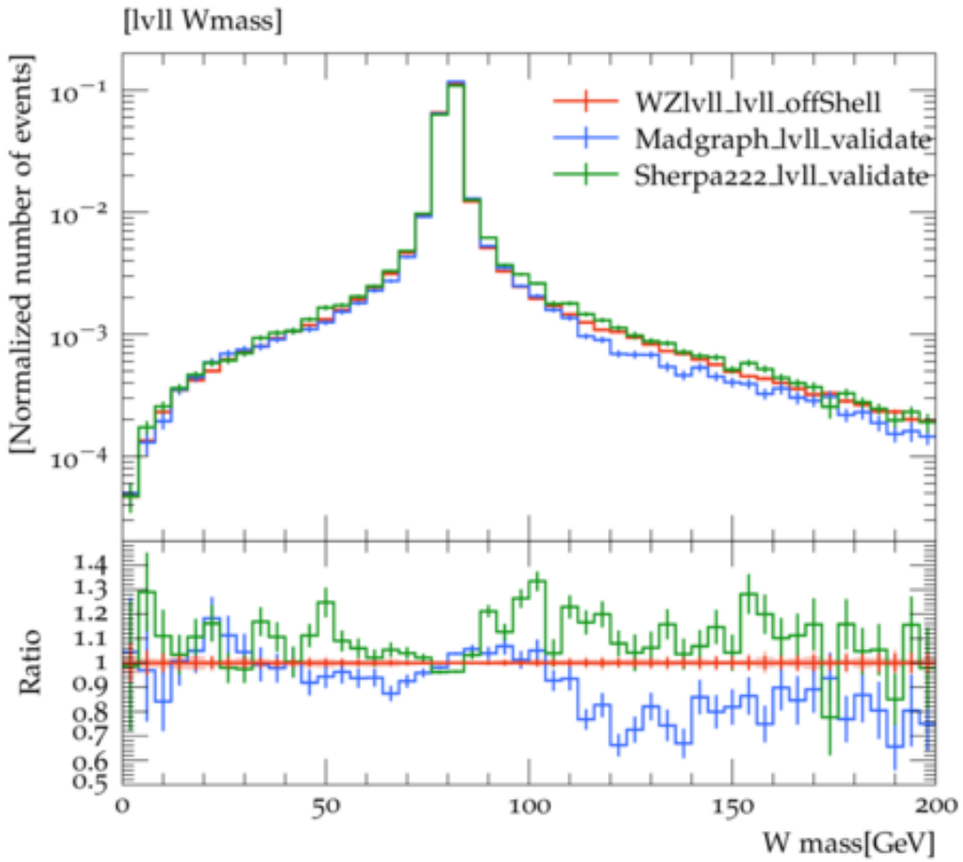
Example — lvll process

Rivet Analysis-Routine

Validation Samples :

1. Madgraph on-shell : DSID-361292
2. Sherpa222 : DSID-364253





Differences :

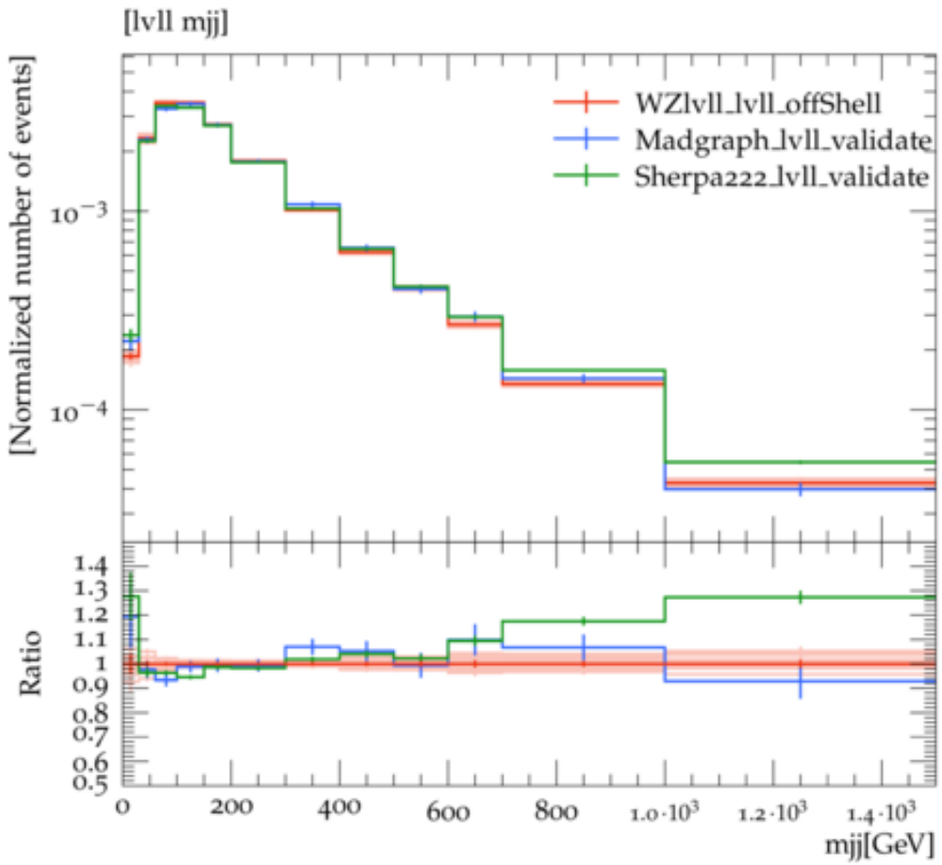
1. Different processes (orange : off-shell process, and blue : on-shell process)
2. Different object selections in JO (orange one has tighter selections than green one)

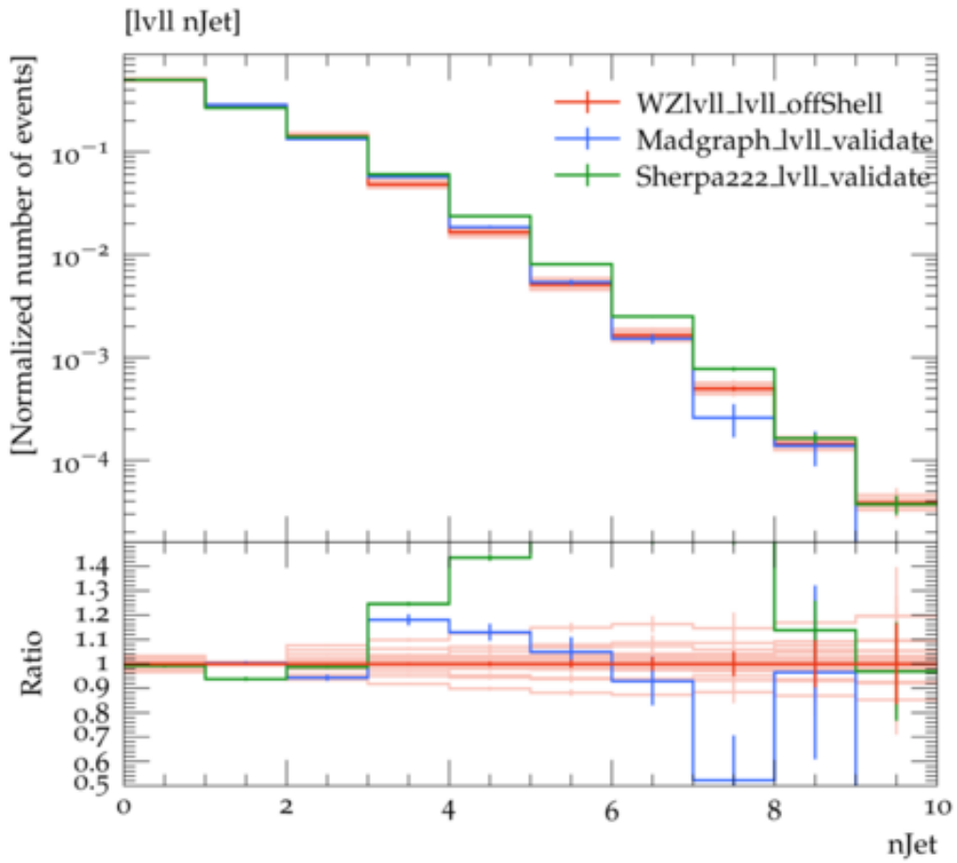
Example — lvll process

Rivet Analysis-Routine

Jet related observables

Pass overlapRemoval with leptons $\Delta R(j, l) > 0.2$





Jet variables

- lvll off-shell FxFx : 0,1 jets @ NLO
- Madgraph lvll on-shell FxFx : 0,1,2 jets @ NLO
- Sherpa222 lvll : 0,1 jets @ NLO + 2,3 jets @ LO

Current Status of Di-boson Modeling task

The preparation of Di-boson FxFx samples

Process	Status
lvll	Finished
lvvv	Finished
vvvv	Finished
llll	Finished

lvll, lvvv, vvvv, llll Di-boson processes are currently modeled by MadGraph5_aMcAtNlo + Pythia8 generators with FxFx jet merging algorithm!

Summary

- The source of double counting and jet merging algorithm has been introduced.
- MadGraph5_aMcAtNlo + Pythia8 generators have been used to prepare VV+jets FxFx samples.
- Rivet Analysis package works as an effective tool, help to analyze the performance of observables on truth level, and also a useful tool to help validate the MC samples.
- Except for lvll process, llll, lvvv, vvvv processes have been prepared and validated, under central production now.
- Performance of lvll process has been documented following up the qualification task, and more Di-boson processes' modeling with FxFx merging are being carefully studied at the moment in preparation for future ATLAS official MC sample production for analysis publication to use.

Thank you!

Backup

Generator Introduction

- MadGraph5_aMcAtNlo
  - A framework that aims at providing all the elements necessary for SM and BSM phenomenology, such as the computations of cross sections, the generation of hard events and their matching with event generators, and the use of a variety of tools relevant to event manipulation and analysis.

- Pythia8
  - A program for the generation of high-energy collision events, i.e. for the description of collisions at high energies between electrons, protons, photons and heavy nuclei.
  - Contains theory and models for a number of physics aspects, including hard and soft interactions, parton distributions, initial and final state Parton showers, multiparty interactions, fragmentation and decay.

Merging Methods

- Both FxFx and MEPS@NLO merging are based on making MC@NLO calculation for jet-multiplicities exclusive in more jets
  - Veto additional radiation; resume dependence on the veto scale (=merging scale)
- Major difference is in the way this exclusivity is applied
  - CKKW-L approach
    - Used in Sherpa's MEPS@NLO
    - Using shower kernels prevents for a direct link with Minlo approach, but prevents issues with mismatch in k_T and shower ordering values
  - Minlo (CKKW) from hard scale down to the scale of the softest jet not affected by veto; MLM-type rejection from there down to merging scale
    - Used in MadGraph5_aMcAtNlo w/Pythia/Herwig:"FxFx merging"
    - Direct link with Minlo, but MLM-type rejection prevents large mismatches in ordering values

Detailed explanation

Rivet

The Rivet toolkit (Robust Independent Validation of Experiment and Theory) is a system of validation of Monte Carlo event generators.

- Provides a large set of experimental analyses useful for MC generator development, validation, and tuning, as well as a convenient infrastructure for adding your own analyses
- A useful tool which can provide an interface to EVNT file (HepMC file), and help to study the performance of MC samples at truth level, also can help to compare with the unfolded data.

Rivet Introduction