T-CHANNEL MODELING UNCERTAINTIES AND FURTHER QUESTIONS TO TH AND NEW FIDUCIAL MEASUREMENTS

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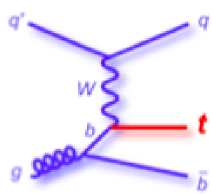
SINGLE TOP PRODUCTION

LO Single Top Production Modes

s-Channel

t-Channel



Wt-Channel

LO $t\bar{t}$ Production Modes

At LHC gg fusion dominant (~87% @ √s = 8 TeV)

Backgrounds

Types

W+jets

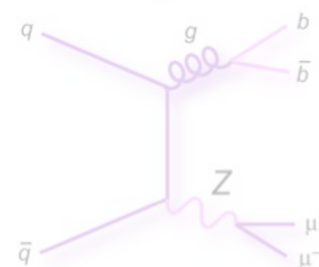
QCD multijet

mainly for t- and s-channels

top pair production

for all three channels

Z+jets



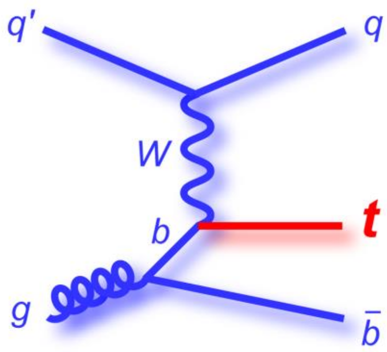
mainly for tW associated production

GENERATORS

4 Flavour (2 ⟶ 3) NLO

- *aMC@NLO* { Herwig++/Herwig; Pythia8
- ***Powheg*** { Herwig++/Herwig; Pythia8 / **Pythia6 ⟶ ATLAS Default**

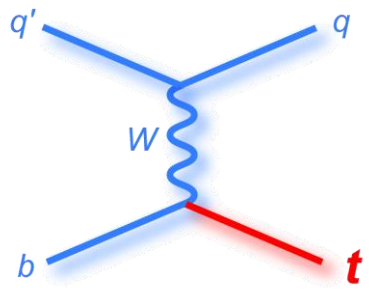
** ATLAS : being commissioned*



- Matched samples for 2 ⟶ 2 (LO) and 2 ⟶ 3 (LO) process
  - Matching using p_T of second b (*Comphep+Pythia6*)
  - ACOT method **(*AcerMC+Pythia6*) ⟶ ATLAS Previous Default**

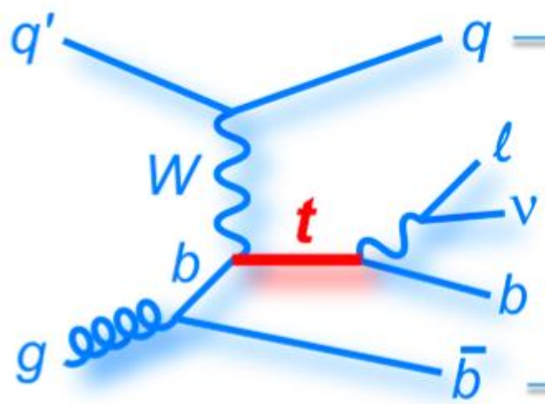
5 Flavour (2 ⟶ 2) NLO

- *aMC@NLO* { Herwig++; Pythia8
- ***Powheg*** { Herwig++; Pythia8 / **Pythia6 ⟶ CMS Default**



FIDUCIAL MEASUREMENT

T-CHANNEL : PRE-SELECTION



"light" jet with high pseudo-rapidity (η)

Isolated high p_T lepton

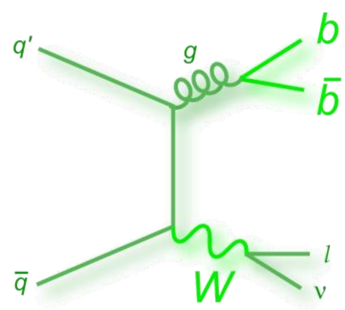
missing energy (E_T^{miss})

b-jet central with large momentum

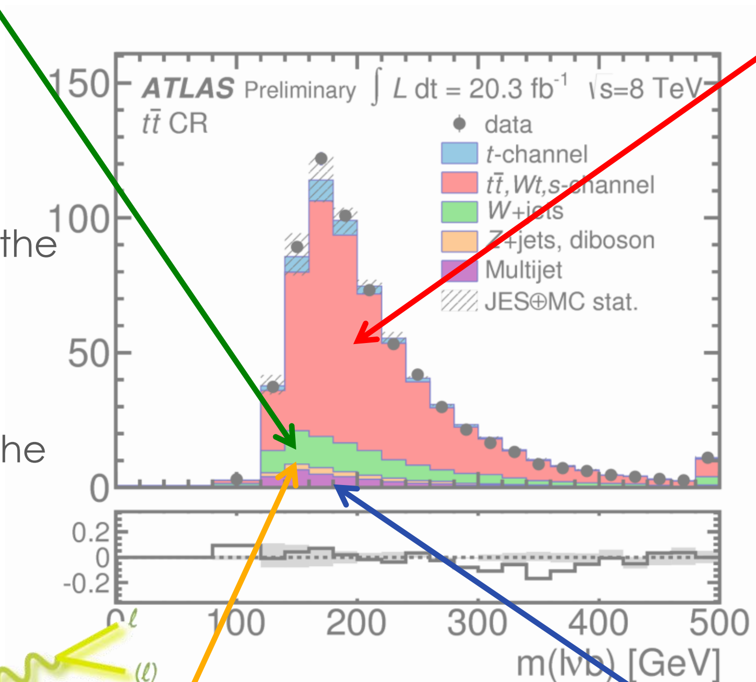
Second b-jet with lower p_T

	Cuts
1 muon or electron	$p_T > 25$ GeV (|η| < 2.5)
2 jets 1 b-tagged	$p_T > 30$ (|η| < 4.5) / $p_T > 35$ GeV (2.75 < |η| < 3.5)
additional cuts	$E_T^{miss} > 30$ GeV, $m_T^W > 50$ GeV, $p_T(l) > 40\,GeV\left(1 - \frac{\pi - \lvert\Delta\phi(j_1, l)\rvert}{\pi - 1}\right)$

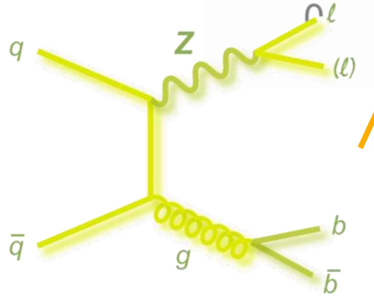
BACKGROUNDS

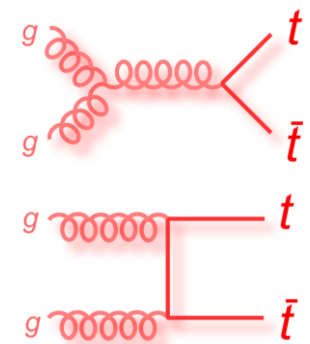


W+jets (W+bb) : One of the largest backgrounds.



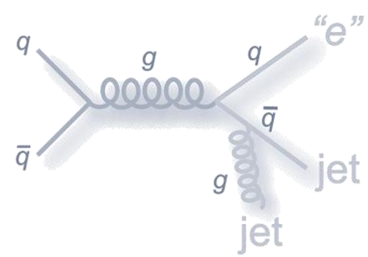
Z+jets (Z+bb) : One of the leptons is missed





top-pairs : background for single top channels

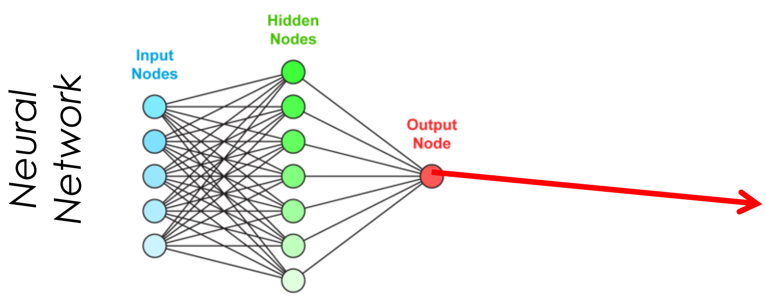
Multijet : large cross-section process. One of the jets is miss-identified as a lepton.

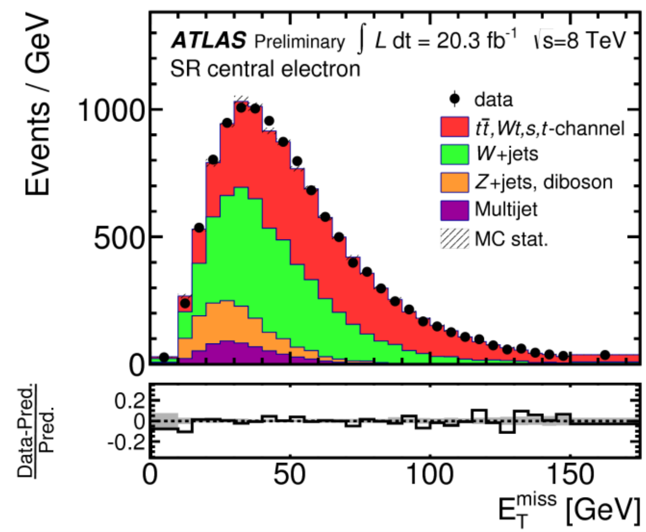


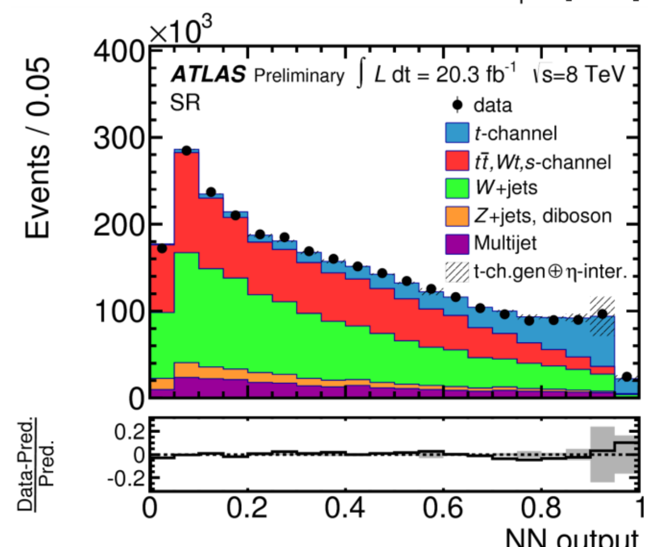
Signal:
- After event selection the signal over background ratio is 15%

Backgrounds:
- Larges contributions coming from top pairs and W+jets

Multivariate analysis :
t-channel discrimination by combining 14 kinematic variables in a neural network
.







Maximum Likelihood Fit to the output of the NN to obtain the contributions from the different processes. Fit result,v expected number of single top t-channel candidates.

T-CHANNEL : **FIDUCIAL** MEASUREMENT

Aim – Measure a cross-section **less dependent** of the signal generator :

- Minimize uncertainties from MC modeling
- Minimize the dependency on MC signal
- Disentangle theoretical and experimental uncertanty

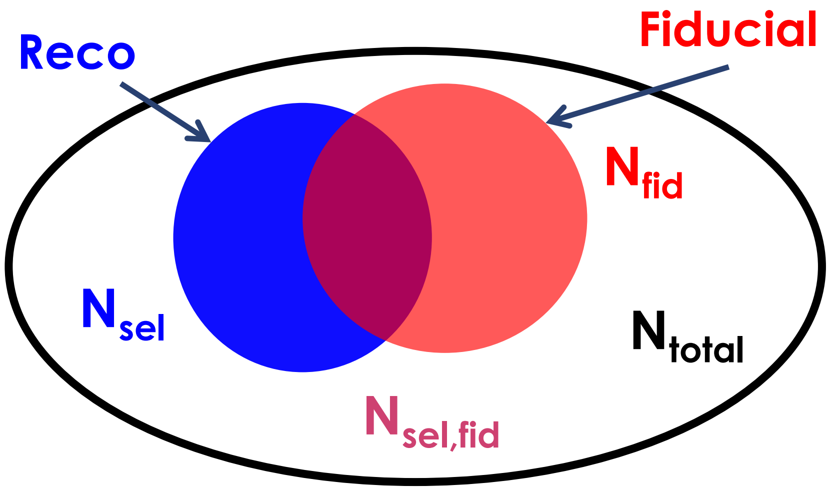
How – Definition of **a truth (fiducial) phase space** close to the phase space of the reconstructed and selected data events.

- Truth objects (leptons, jets,…) defined as close as possible to reconstructed ones using final state particles.

T-CHANNEL : FIDUCIAL MEASUREMENT

Fiducial cross-section :

$$\sigma_{\text{fid}} = \frac{\epsilon_{\text{corr,sel}}}{\epsilon_{\text{corr,fid}}} \cdot \frac{\hat{\nu}}{\mathcal{L}}$$

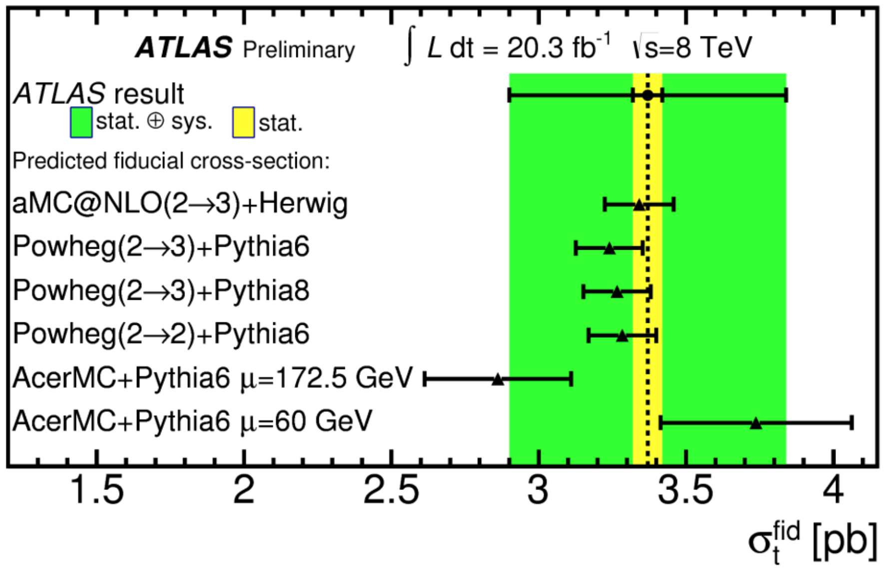


ν number of single top candidates and :

$$\epsilon_{\text{fid}} = \frac{N_{\text{fid}}}{N_{\text{total}}} \qquad \epsilon_{\text{corr,fid}} = \frac{N_{\text{sel,fid}}}{N_{\text{fid}}} \qquad \epsilon_{\text{corr,sel}} = \frac{N_{\text{sel,fid}}}{N_{\text{sel}}}$$

$\varepsilon_{corr,sel}$ = Fraction of selected events in fiducial from all selected events
$\varepsilon_{corr,fid}$ = Fraction of selected events in fiducial from events in fiducial region

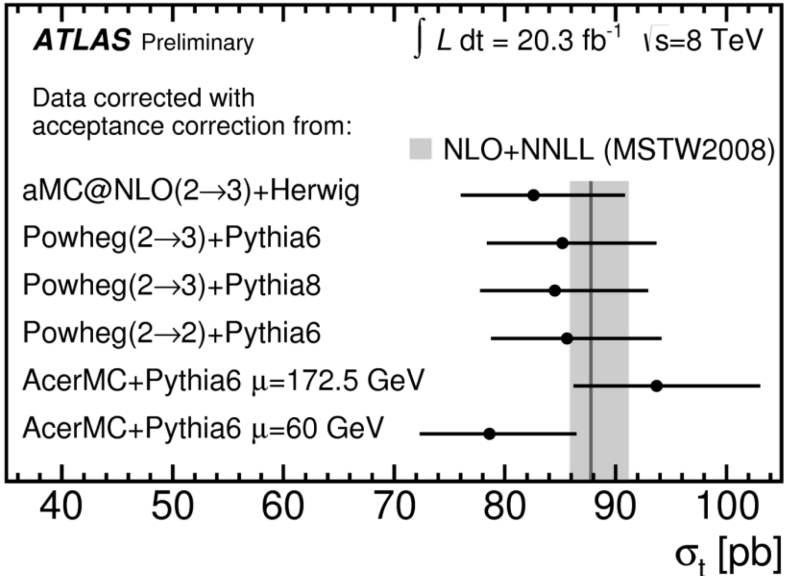
T-CHANNEL : CROSS – SECTION FIDUCIAL



$$\sigma_{\mathrm{fid}} = 3.37 \pm 0.05\,(\mathrm{stat}) \pm 0.47\,(\mathrm{syst.}) \pm 0.09\,(\mathrm{lumi.})\,\mathrm{pb}$$

- Uncertainties **smaller** compared to inclusive measurement :
  - Total uncertainty is ±14% (17% direct)
  - **Signal generator** uncertainty reduced from **13%** to **8%**
  - **PDF** from **4%** to **1%**

T-CHANNEL : CROSS – SECTION FULL PHASE SPACE

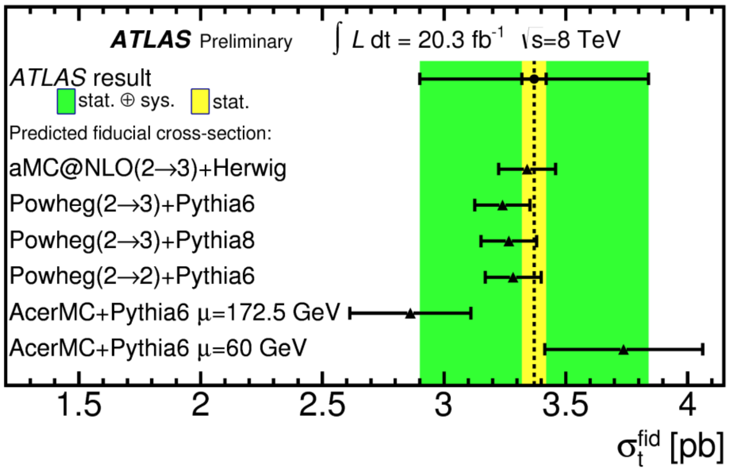


$\sigma = \frac{1}{\epsilon_{\mathrm{fid}}}\sigma_{\mathrm{fid}}$ with ϵ_{fid} correction to full phase space

$$\sigma_t = 82.6 \pm 1.2\,(\mathrm{stat.}) \pm 11.4\,(\mathrm{syst.}) \pm 3.1\,(\mathrm{PDF}) \pm 2.3\,(\mathrm{lumi.})\,\mathrm{pb}$$

- Acceptance difference between generators as large as theory uncertainties
- Additional PDF systematics added at the extrapolation (around 4%)
- Large differences between generators included in the measurement

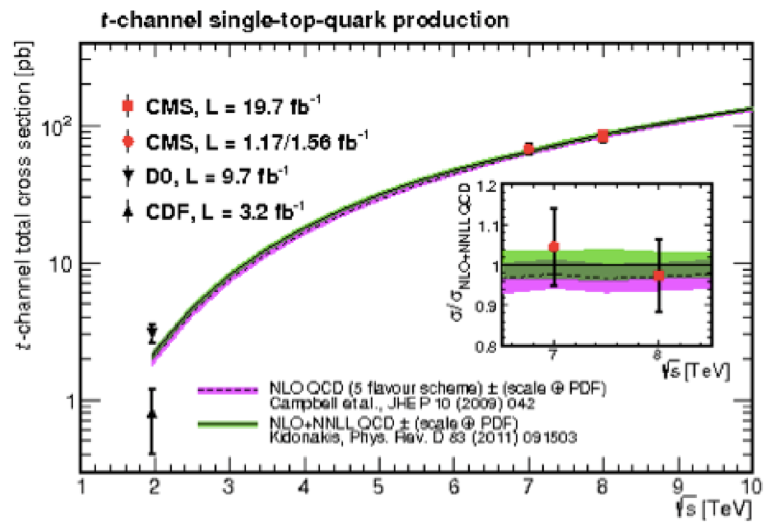
T-CHANNEL : CROSS – SECTION



Multivariate analysis

$$\sigma_{\text{fid}} = 3.37 \pm 0.05(\text{stat.}) \pm 0.47(\text{syst.}) \pm 0.09(\text{lumi.})\ \text{pb}$$

Main systematics : signal generator (ACERMC vs aMC@NLO) and Jet Energy Scale (JES)



Template analysis |$\eta_{j'}$|

$$\sigma = 83.6 \pm 2.3\,(\text{stat.}) \pm 7.4\,(\text{syst.})\ \text{pb}$$

Main systematics : signal generator (Powheg vs CompHEP) and Jet Energy Scale (JES)

T-CHANNEL MODELING

MODELING – PREVIOUSLY

Default Sample :
- AcerMC+Pythia6

Systematics :
- AcerMC+Pythia6 vs aMC@NLO+fHerwig
- PDF (PDF4LHC) reweighting of AcerMC
- Any generator comparison possible for acceptance

Default Sample :
- Powheg (2 ⟶ 2) + Pythia6

Systematics :
- Renormalization and factorization scales ME and shower? Independent?
- Powheg (2 ⟶ 2) + Pythia6 vs Comphep+Pythia6 (half of difference)
- PDF (PDF4LHC) reweighting of Powheg

INPUT FROM THEORY - PROPOSAL

For observables that have NLO precision, the theory/generator uncertainties can be estimated by :

1. *Independent renormalisation and factorisation scale variations*
2. *PDF error sets (preferably following the PDF4LHC agreement)*
3. *Matching an NLO computation to at least 2 different parton showers*
4. *These PDF and scale variations can be obtained via reweighting in MG5_aMC@NLO and POWHEG, not yet possible in Sherpa.*

For observables that do not have NLO precision, further uncertainties are coming from the shower starting scale ("Power" or "Wimpy" shower). Currently these cannot be approximated with the (a)MC@NLO program, but not really relevant because why use an NLO+PS computation for these observables in the first place? They can be estimated more correctly in the NLO Sherpa program.

Rikkert Frederix

Last TOPLHC Meeting

MODELING – UPDATED

Default Sample :

- Powheg (2 ⟶ 3) +Pythia6*

Systematics :

- Powheg (2 ⟶ 3) +Pythia6 vs Powheg(2 ⟶ 3) + fHerwig
- PDF (PDF4LHC) reweighting of aMC@NLO

Recently Updated Scenario

**See Dominic's talk*

Default Sample :

- Powheg (2 ⟶ 2) + Pythia6

Systematics :

- Renormalisation and factorisation scales ME and shower? Independent?
- Powheg (2 ⟶ 2) + Pythia6 vs Comphep+Pythia6 (half of difference)
- PDF (PDF4LHC) reweighting of Powheg

GENERATORS : SCALES

Powheg (2 ⟶ 2) renormalization and factorization scale x0.5 / x2 simultaneously. Consistent shower variations for radLo μ_R=2

Powheg (2 ⟶ 3) Independent restricted scale variations and consistent scale variations in shower – **RECENTLY MODIFIED**

SUGGESTION

μ_F	μ_R	*SHOWER*
0.5	0.5	radHi
1.0	0.5	radHi
0.5	1.0	default
1.0	1.0	default
2.0	1.0	default
1.0	2.0	radHi
2.0	2.0	radHi

Independent renormalization and factorization scale variations

what about **hdamp?**

Liza's talk

GENERATORS : PDFs

PDF4LHC : Reweighting Powheg + Pythia6

PDF4LHC : Reweighting with aMC@NLO – **RECENTLY MODIFIED**

Caveat: External reweighting with Powheg does not work correctly because it has only x_1, x_2 according to 2 ⟶ 2 kinematics

- **SUGGESTION :** Internal reweighting of Powheg (preferred) or LO generators (second preferred solution)

PDF error sets (preferably following the PDF4LHC agreement)

GENERATORS : PARTON SHOWERS

Not Applied

Powheg (2 ⟶ 3) + Pythia6 **vs** Powheg (2 ⟶ 3) + Herwig – **RECENTLY MODIFIED**

- **SUGGESTION :**
  - Compare Powheg (2 ⟶ 3) + Pythia6 vs Powheg (2 ⟶ 3) + Herwig(++)
  - **or :**
    ① Powheg (2 ⟶ 2) + Pythia6 vs Powheg (2 ⟶ 2) + Herwig++
    ② aMC@NLO + Pythia8 vs aMC@NLO + Herwig++

Matching an NLO computation to at least 2 different parton showers

GENERATORS : NLO + PARTON SHOWERS

Not Applied

Powheg (2 ⟶ 3) + Pythia6 **vs** aMC@NLO + Herwig – **RECENTLY MODIFIED**

- **SUGGESTION :**
  ① Powheg (2 ⟶ 3) + Herwig(++) vs aMC@NLO + Herwig(++)
  ② Powheg (2 ⟶ 2) + Herwig++ vs aMC@NLO + Herwig++

  - **or :**
    Powheg (2 ⟶ 2) + Pythia8 vs aMC@NLO + Pythia8

Caveats : aMC@NLO + Pythia6 or Powheg (2 ⟶ 2) + Herwig not possible

Comparing different NLO calculations and matching schemes to the same PS

OUTLOOK

- Different approaches by both experiments that need harmonization to make them comparable and allow combination of results.

- Suggestion is to follow the recipe from Rikkert for :
  - Scale Variation
  - Parton Shower
  - PDF uncertainty
  - NLO subtraction method
  - Need some suggestion about $2 \longrightarrow 2$ **vs** $2 \longrightarrow 3$
    - additional systematics/comparison?
- Follow suggestion from Paolo Nason for the scale/hdamp variation in Powheg