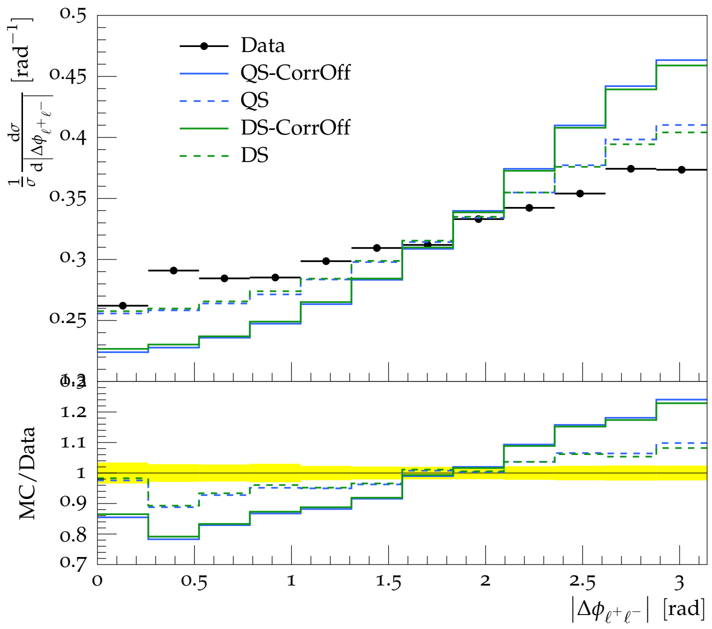
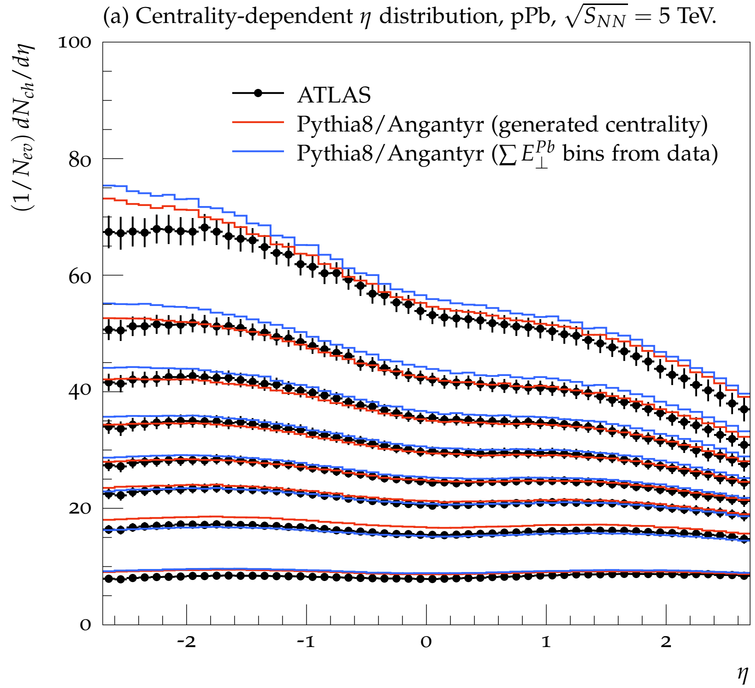
Tools & Monte Carlos in Les Houches 2019

(Emanuele Re, Vitaliano Ciulli, Stefan Prestel)

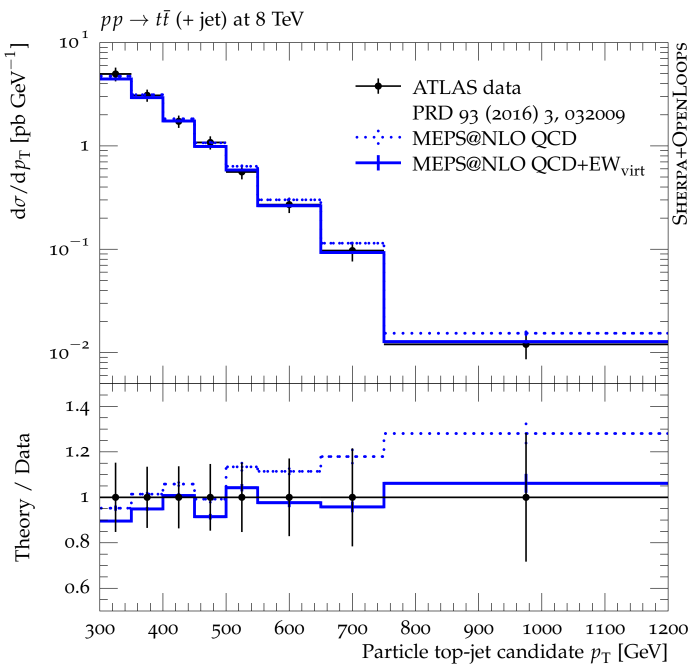
Last two years in General-Purpose MC



Color, spin, higher orders – and theoretical concerns



Heavy ions, collective effects & the ridge



Electroweak matching, multi-jets, resonance-aware generators

Summary of ideas for possible projects

Precision modelling in GPMCs

Mismodeling of top pt? Uncertainties for Higgs, top, VBF?

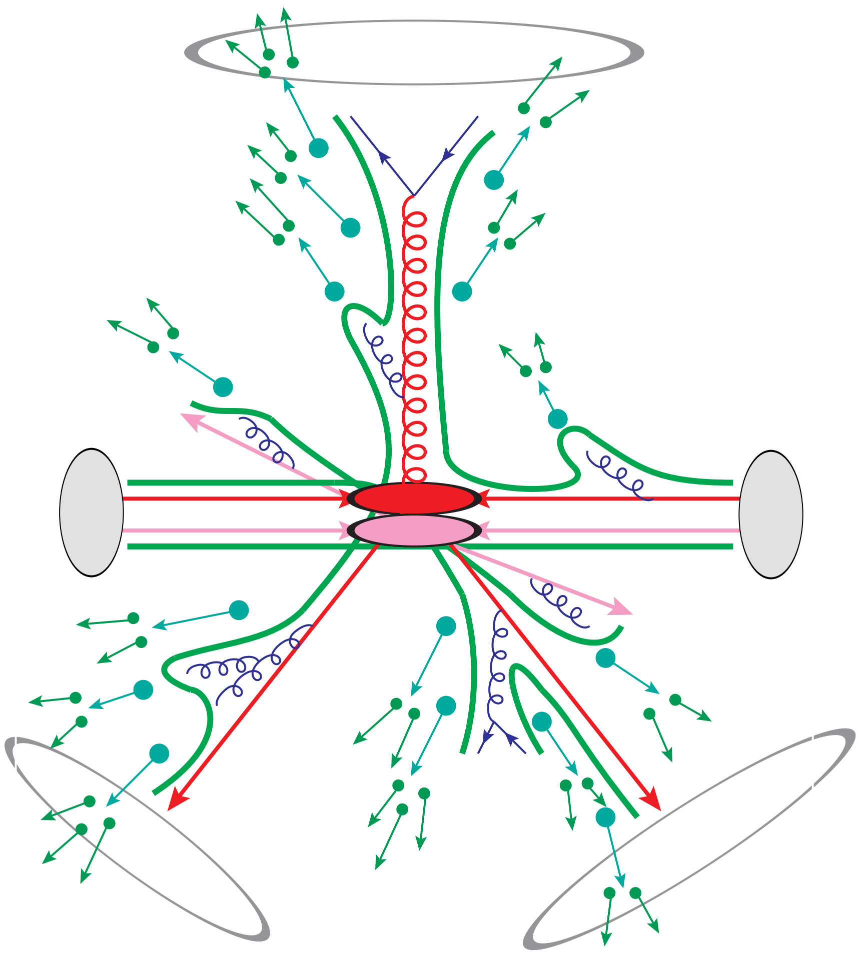
Vector-bosons fusion in GPMCs

Continue study of NLO programs? Impact of matching on crucial distributions? Impact of recoil strategy?

Computing and formats

LH as platform to study negative weights, and suggest ideas to minimize "bad" behavior? Improvements of time-honored LHA?

General-Purpose event generators cover many different phenomena through different models for



hard scattering

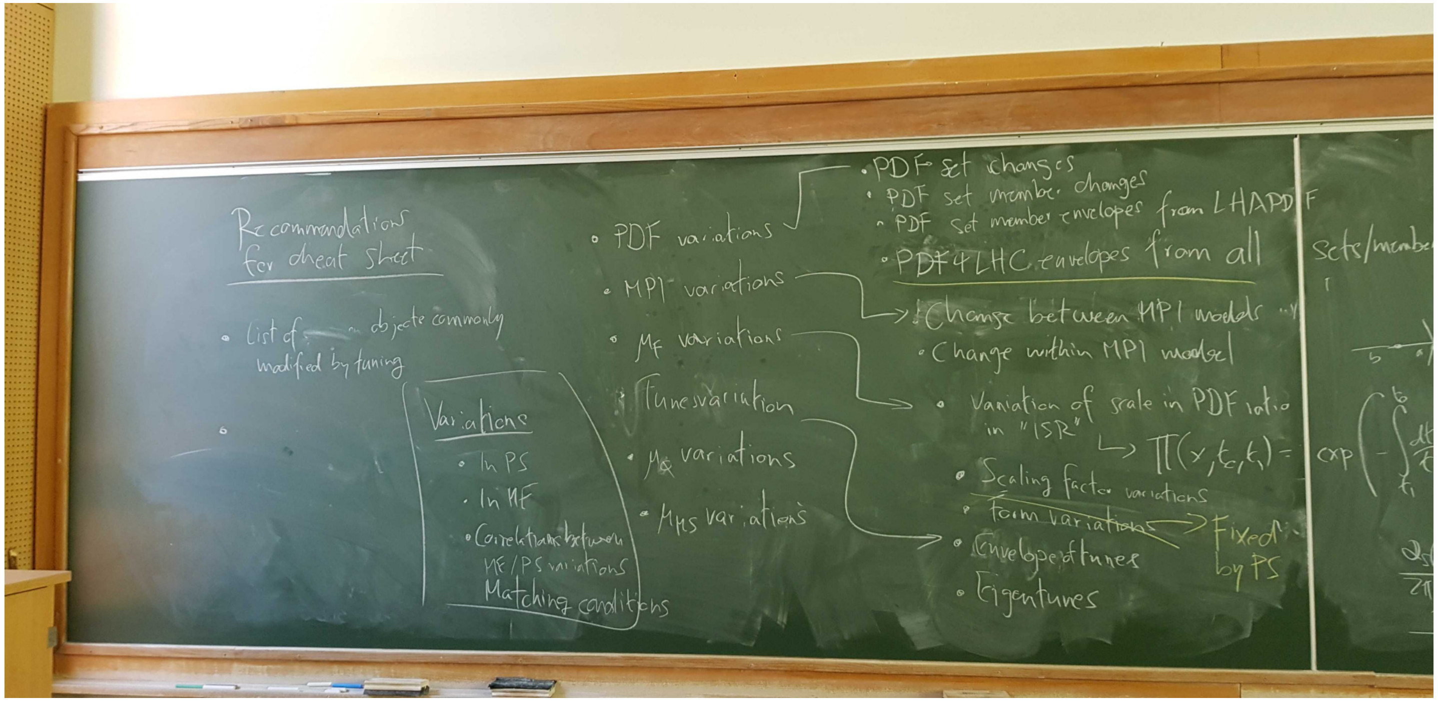
radiation cascade

multiparton interactions

hadronization and decay

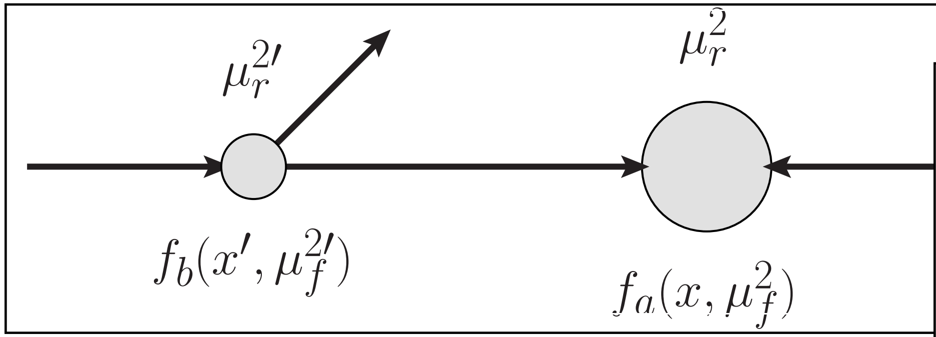
Each model contains parameters & smooth matching introduces more.

Some (inter)dependences studied already... but we're far from there yet.



Problem: Event-generator predictions depend on many different phenomena with many parameters.
First step: Give names to categories of parameters, then describe their interpretation in MCs & give examples where which variations have a dominant impact.
Project: Pedagogical introduction, definition of names for variations, generates "intuition" for variations. Build on arXiv:1101.2599 & coordinate with MCnet.

Study of self-consistency of initial-state showers



LC+ approximation, so that we have diagonal operators in the color space and we can deal the corresponding eigenvalues. Typically, parton shower algorithms replace $\mathcal{V}(\mu^2)$ by 1. This gives

$$\mathcal{F}^{-1}(\mu_2^2)\,\mathcal{N}(\mu_2^2,\mu_1^2)\,\mathcal{F}(\mu_1^2) \sim \mathcal{N}_{\rm pert}(\mu_2^2,\mu_1^2)\,. \quad (4.2)$$

However, $\mathcal{V}(\mu^2) \neq 1$, so this relation is not exact. To find out how much of an approximation this is, we could evaluate the left hand side numerically in a parton shower program that lacks $\mathcal{V}(\mu^2)$ and perform two tests:

1. Is the eigenvalue of $\mathcal{F}^{-1}(\mu_2^2)\,\mathcal{N}(\mu_2^2,\mu_1^2)\,\mathcal{F}(\mu_1^2)$ independent of $\eta_{\rm a}$ and $\eta_{\rm b}$ in the sense defined above?
2. Does the eigenvalue of $\mathcal{F}^{-1}(\mu_2^2)\,\mathcal{N}(\mu_2^2,\mu_1^2)\,\mathcal{F}(\mu_1^2)$ depend on parton distribution functions?

Before doing PDF or μ_f variations, we should understand the baseline behavior. The self-consistency of ISR backward evolution requires relations like

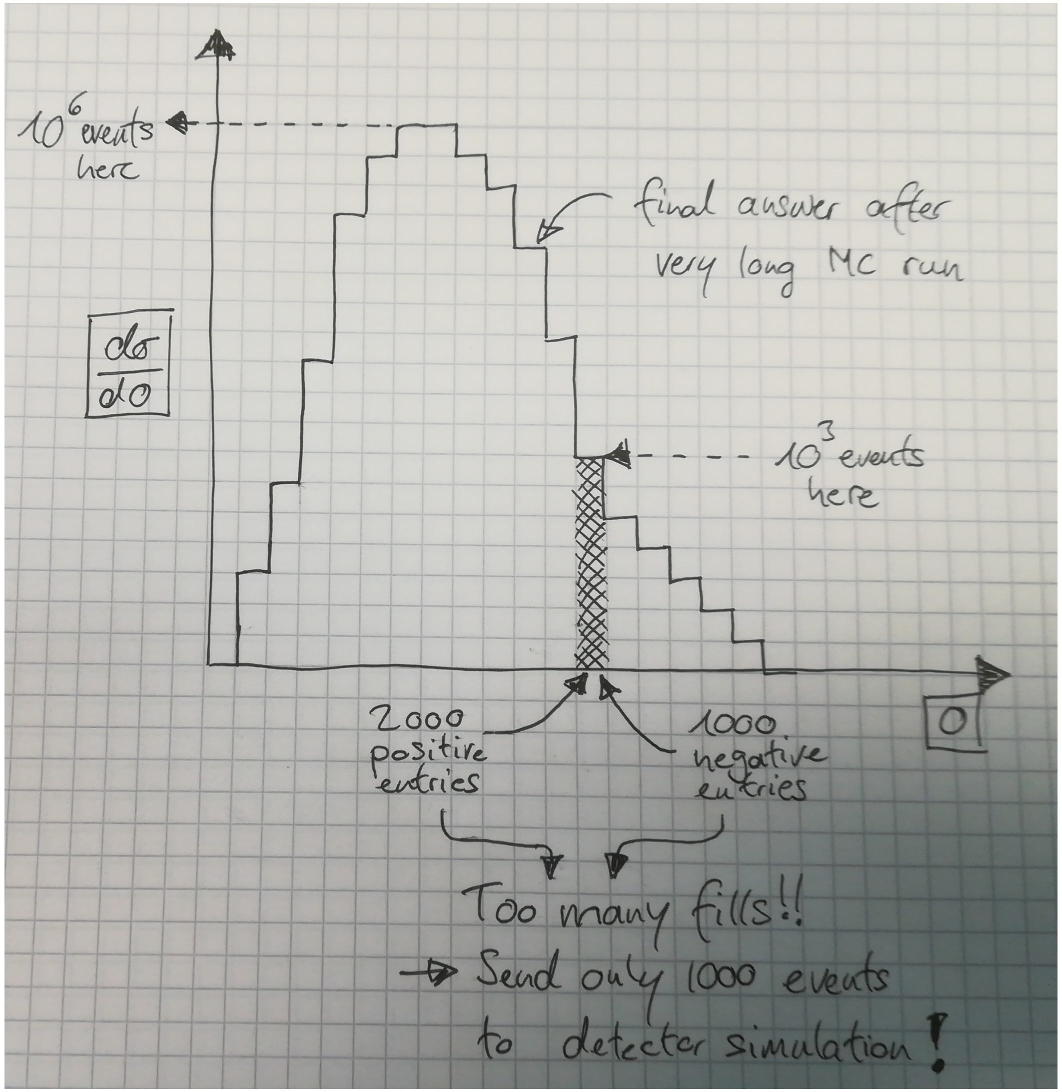
$$\Delta(t_0,t_1) = \frac{f(x,t_0)}{f(x,t_1)}\Pi(x,t_0,t_1)$$

where $\Delta(t_0,t_1)$ is PDF-independent. How accurate do such relations hold?
$\Rightarrow$ Use toy PDFs with different parametrization and and check

$$\mathcal{R}(x,m_D^2,t_0,t_1) = \frac{\Pi(x,,m_D^2,t_0,t_1)}{f(x,t_1)/f(x,t_0)}$$

- ... for independence from PDF set, for different showers, phase-space mappings, starting/stopping scales $t_{0,1}$, ($\propto m_D^2$)...
- ... Check x-(in)dependence of $\mathcal{R}(x,m_D^2,t_0,t_1)$

Negative weights and a-posteriori importance sampling



Weighted evts are indispensable development tool.

Fluctuating or negative wgts complicate MC stats assessment & require more resources.

→ Discussed how to improve situation & concluded to check "a-posteriori importance sampling":

Pass only subset of events to detector simulation. Choose this sample based on binned (multi-dimensional, maybe unphysical) distribution, keeping statistical power.

Les Houches Event Format has allowed to decouple ME generators and GPMCs. Some calculations may need more cross-talk.

It was argued this year that there will not be an updated accord due to limited person power.

Some necessary “private agreements” between Powheg-Box and Pythia were discussed, e.g. multiple scales:

```
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 21   1   0   0  101  103  0.0000000000E+00  0.0000000000E+00  3.0163058970E+02  3.0163058
 21   1   0   0  103  102  0.0000000000E+00  0.0000000000E+00 -2.9643457592E+02  2.9643457
  6   1   1   2  101    0 -1.3588865269E+02 -1.6715922432E+02  1.1286978960E+02  3.0000050
 -6   1   1   2    0  102  1.3588865269E+02  1.6715922432E+02 -1.0767377581E+02  2.9806466
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<scale pos="1 2" stype="pystart" etype="21 1 2 3 4 -1 -2 -3 -4"> 200.0 </scale>
<scale pos="1 3" stype="pystart" etype="21 1 2 3 4 -1 -2 -3 -4"> 100.0 </scale>
</scales>
</event>
```
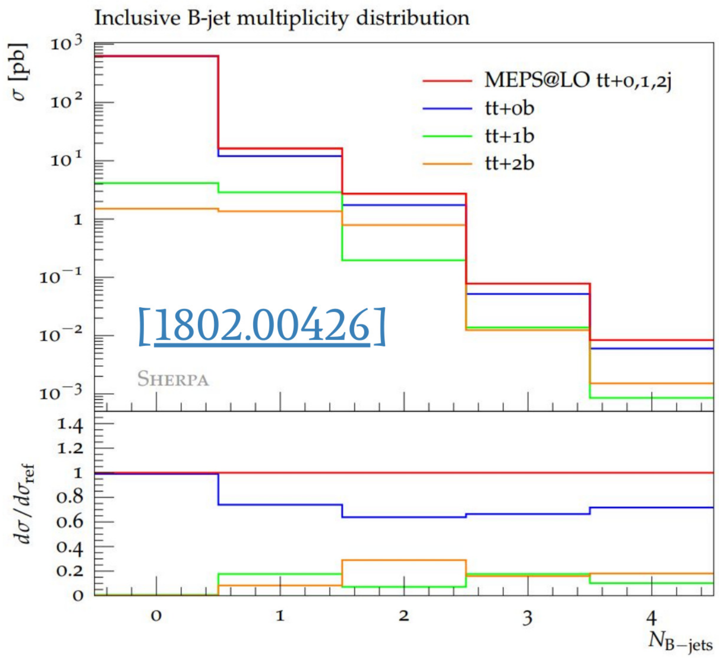

$t\bar{t}b\bar{b}$ and $g \to b\bar{b}$

- $t\bar{t}b\bar{b}$ at NLO+PS: non-negligible spread among predictions in the $N_{bj} = 2$ region
- one interesting question is:

  how large is the contamination of this region due to more than 2 b-quarks in the final state?

  This has been studied for lower multiplicity bins: important motivation to have NLO+PS generators for $t\bar{t}b\bar{b}$.

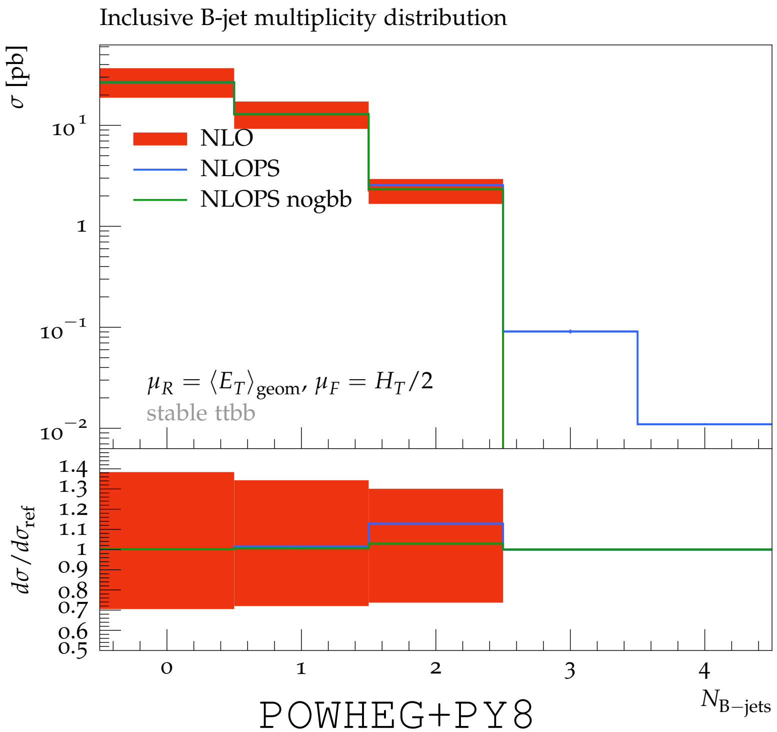


- here: first reproduce HXSWG, then check what happens in the $N_{bj} = 2$ region by comparing against a LO+PS merged sample (up to $t\bar{t}b\bar{b}b\bar{b}$)
- what can be learnt:
  - migration effects from events with more than 2 b-quarks
  - typical hardness of these “secondary” splittings vs. other typical scales (e.g. $\sqrt{\hat{s}}$, ISR)

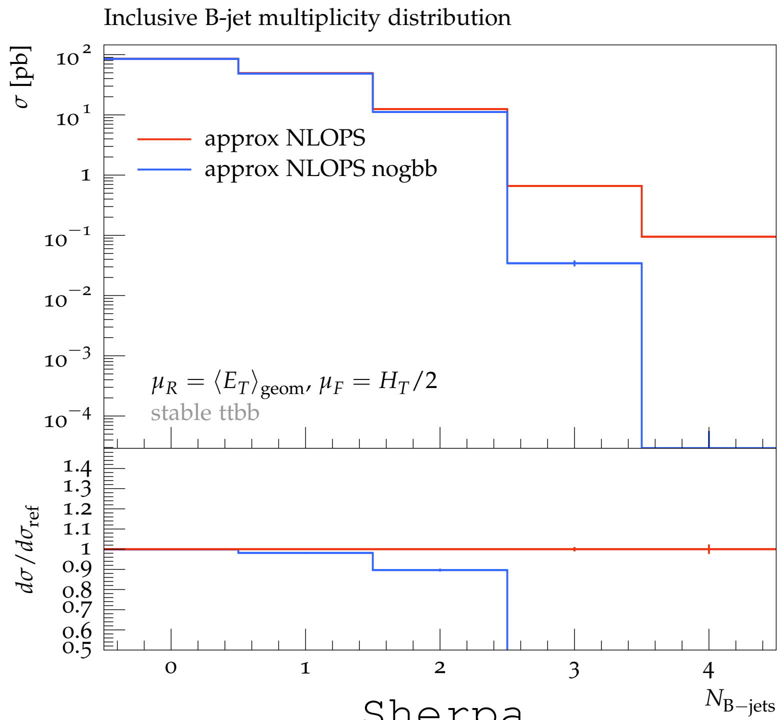
$t\bar{t}b\bar{b}$ and $g \to b\bar{b}$

- so far: reproduced results from studies similar to those in previous papers and HXSWG activities

thanks to Tomas and Davide



POWHEG+PY8

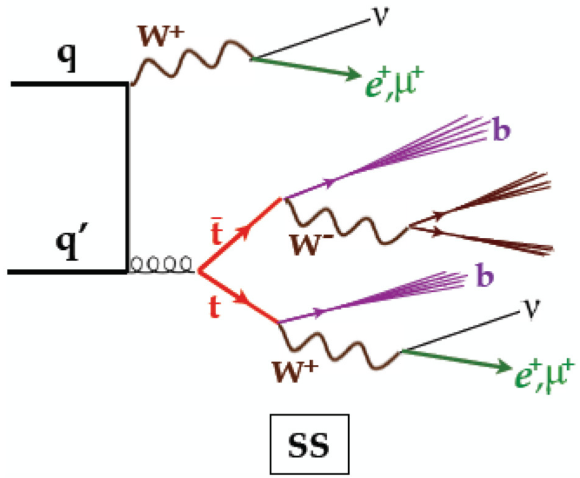


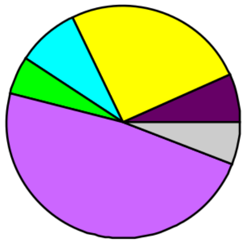
Sherpa

- Merged sample generated too: conclusions not yet clear...
- We'll also look at more differential distributions (possibly with other generators too)

modeling of ttW

- ttW: background for ttH with leptonic signature

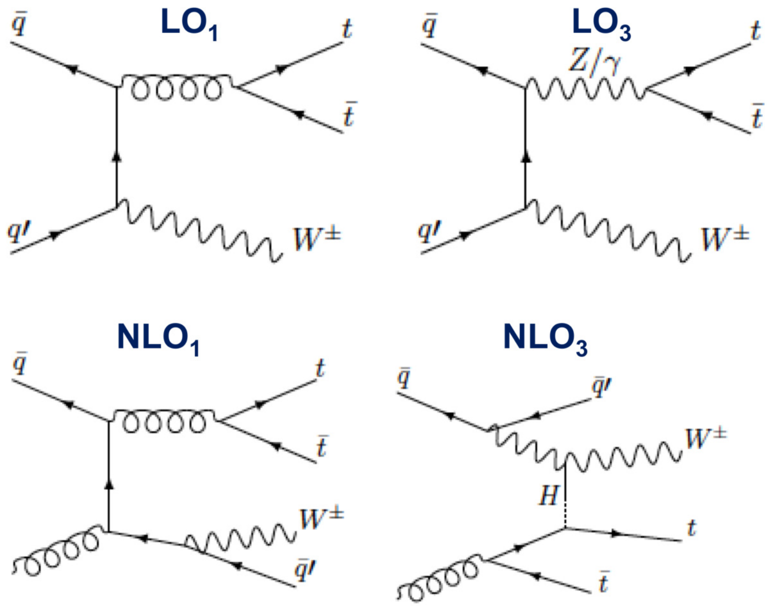




Process	$\sqrt{s}$	$\sigma^{\rm NLO}_{\rm QCD}$	$\sigma^{\rm NLO}_{\rm QCD+EW}$
$t\bar{t}Z$	13	841.3(1.6)	839.3(1.6)
$t\bar{t}W^+$	13	412.0(0.32)	397.6(0.32)
$t\bar{t}W^-$	13	208.6(0.16)	203.2(0.16)
$t\bar{t}W^- + t\bar{t}W^+$	13	620.6(0.36)	600.8(0.36)

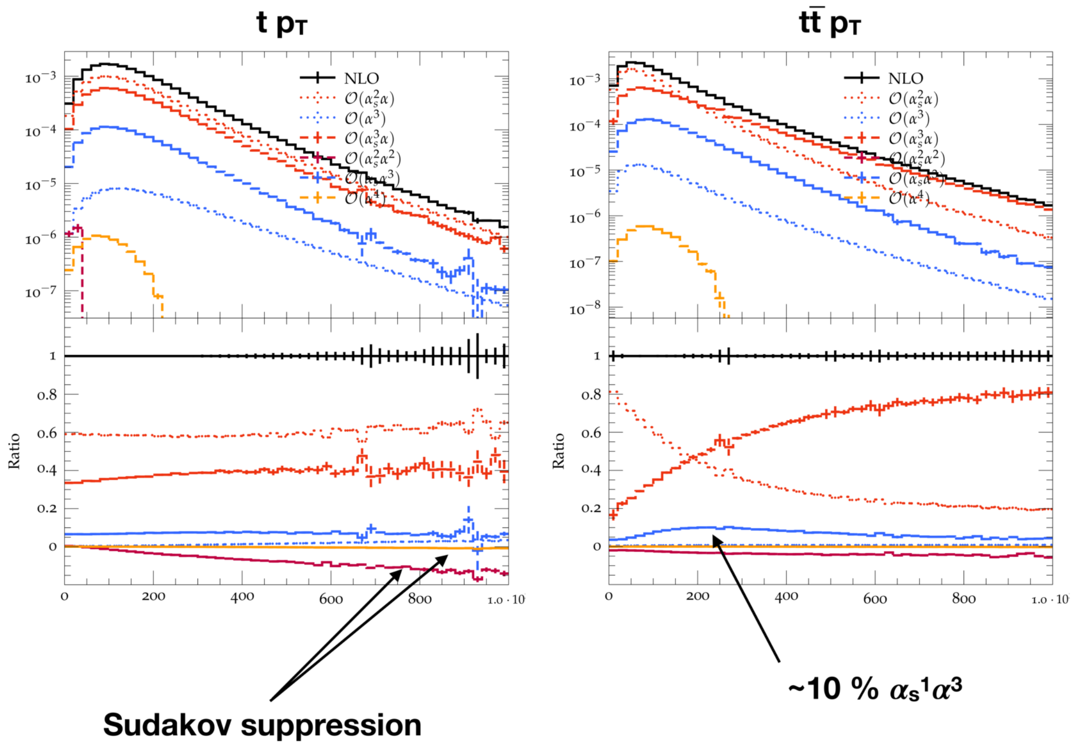
- "complete NLO" corrections are large (due to tW scattering): not included in MC generators, nor in YR reference numbers

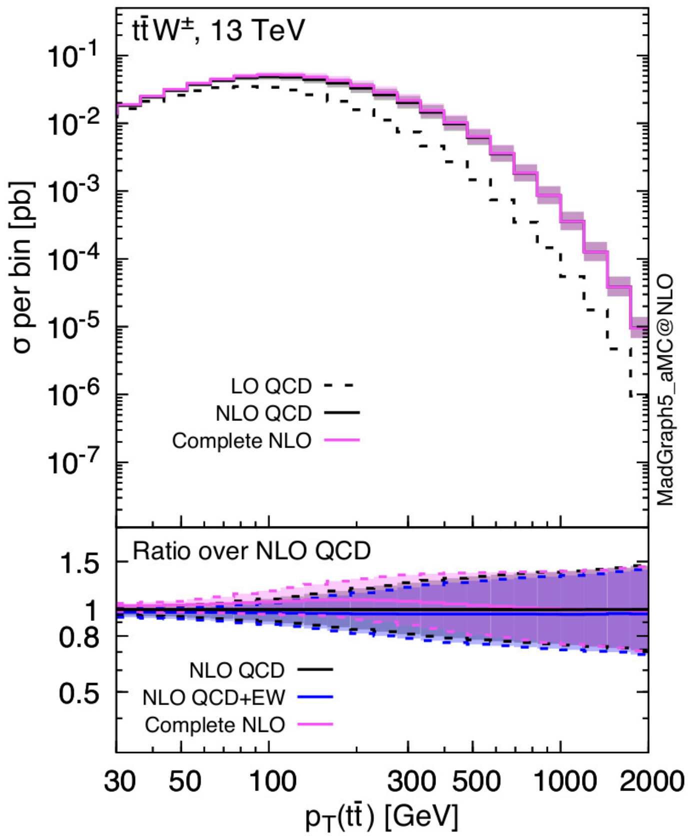
$\delta[\%]$	$\mu = H_T/2$
$\rm LO_2$	-
$\rm LO_3$	0.9
$\rm NLO_1$	50.0 (25.7)
$\rm NLO_2$	−4.2 (−4.6)
$\rm NLO_3$	12.2 (9.1
$\rm NLO_4$	0.04 (−0.02)



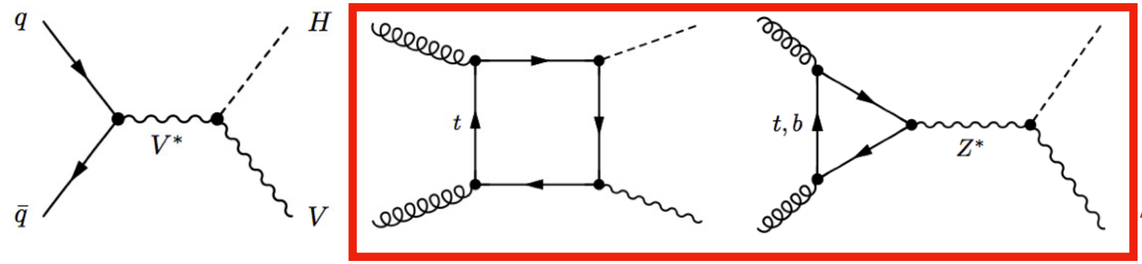
modeling of ttW

- in leptonic ttH, final state kinematics (including jet properties) is important for signal measurement:
    - a study impact of “complete NLO” corrections in these regions
    - b if relevant, what approximations can be made to improve MC tools
- at least a will be studied, with `Sherpa`, `MG5_aMC@NLO`,...

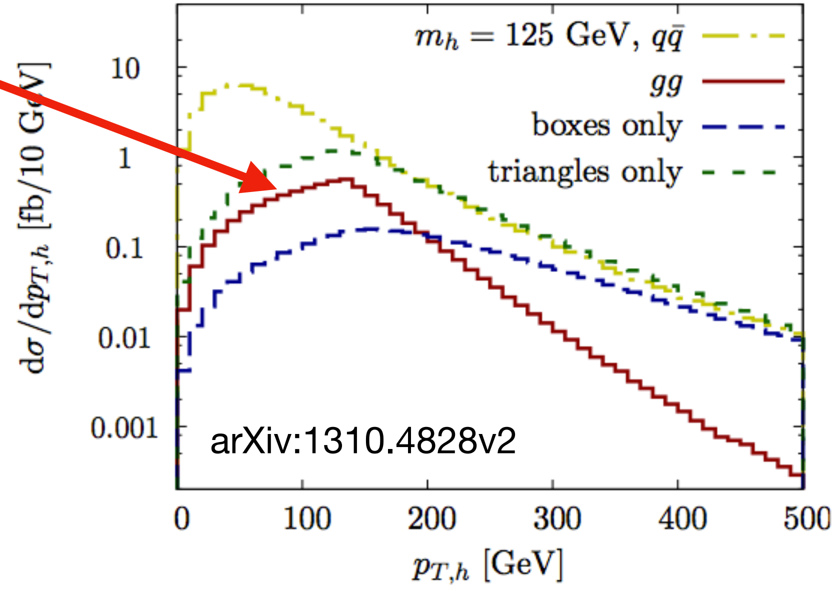




thanks to Enrico and Marek
+ discussion with MG5 authors



XS(gg→ZH) O(14%) of total XS(pp→ZH)
enhanced contribution at medium-high p_T^V

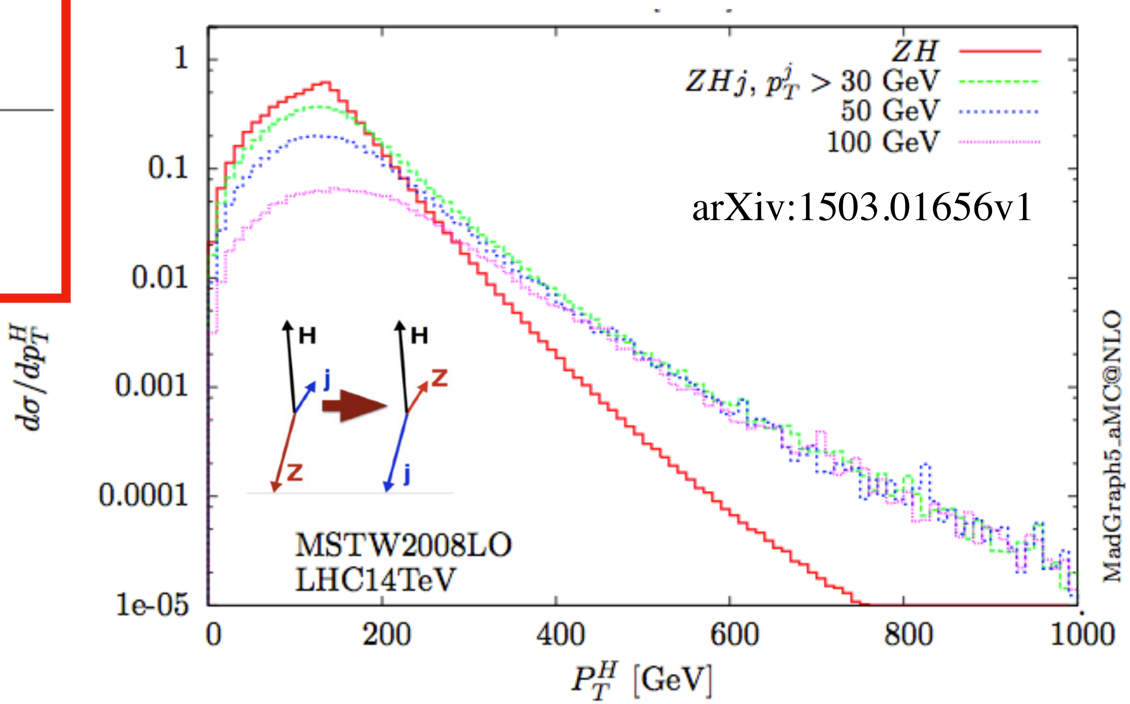


- **loop-induced gg→ZH**: **NLO**(approx)**+NLL[QCD]** kNLO~2 from (mtop→∞) calculation
- **large theory uncertainty** (scale unc. ~25%)

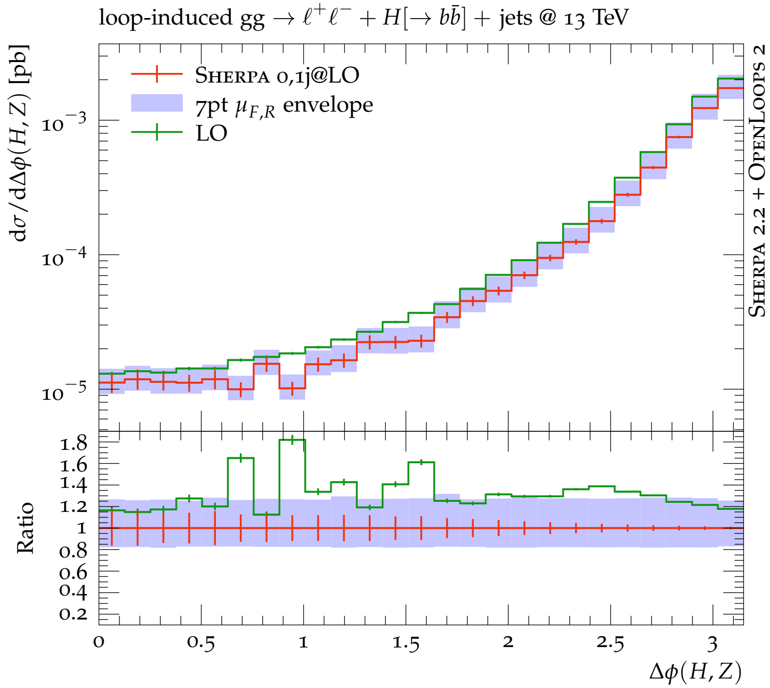
process	p_T^V boundaries [GeV]	Cross Section [fb]	QCD unc [%]
WH	[0, 75[	216.4	3.0
WH	[75, 150[	135.0	3.4
WH	[150, 250[	41.24	3.6
WH	[250, ∞[	12.16	3.9
ZH	[0, 75[	112.4	6.7
ZH	[75, 150[	87.0	7.8
ZH	[150, 250[	32.3	12
ZH	[250, ∞[	8.33	10
$gg \to ZH$	[0, 75[	6.7	100
$gg \to ZH$	[75, 150[	17.0	37
$gg \to ZH$	[150, 250[	10.2	38
$gg \to ZH$	[250, ∞[	1.94	41

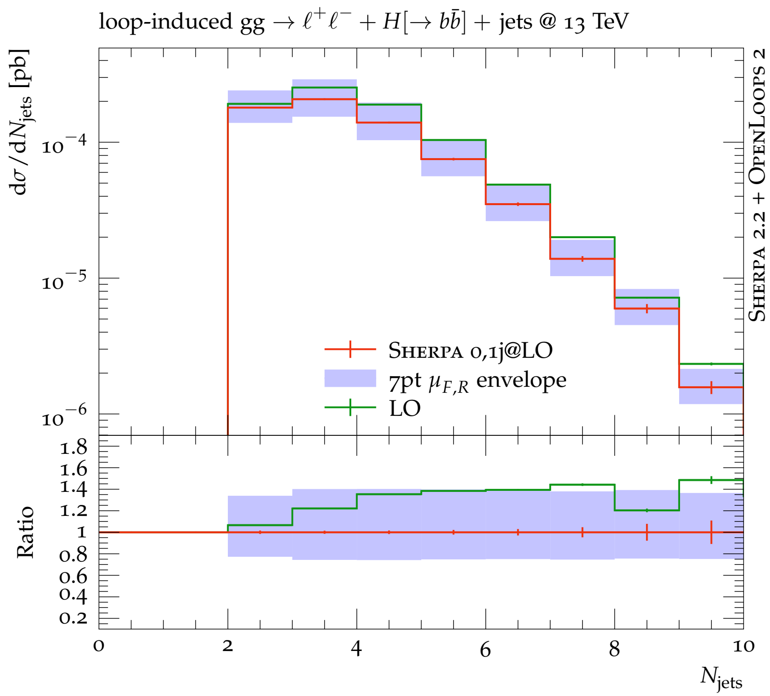
No full NLO calculation and/or MC+PS available
From mg5_aMC@NLO, Sherpa:
gg→ZH+1jet multileg prediction

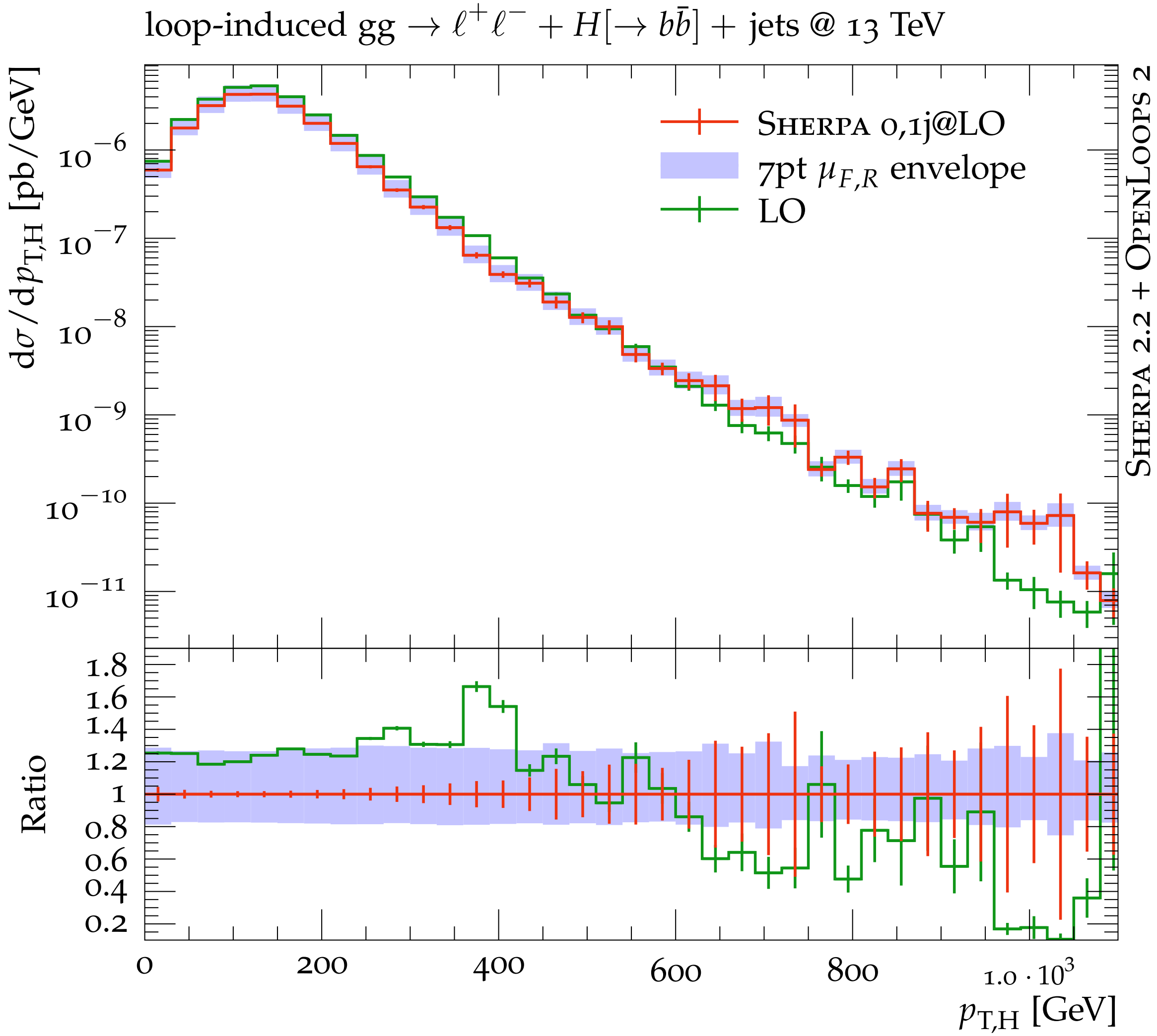
Improved modeling, effect on the QCD uncertainty across STXS selection?



Goals: compare modeling for multileg 0+1jet@LO setup vs inclusive LO (and ATLAS/CMS MC)
Estimate improvement in QCD uncertainties across STXS bin categorization







First plots from **Sherpa** (thanks to Enrico!)
mg5_aMC@NLO+Pythia8 setup almost ready
(thanks to Eleni for the feedback)

Planning

- We'll put/port all the relevant information to the wiki
- We'll keep the slack channel alive for communication.
- Some topics will also be discussed with the larger General-Purpose MC community at the next MCnet meeting.
- Continue working!