News from Les Houches

V. Ciulli, University and INFN of Florence

VBSCan Mid-Term Scientific Meeting

July 3rd, 2019

Piri Reis University, Istanbul

The Les Houches Workshop

The PhysTeV workshop takes place every two years

- This year celebrated 20 years!
- Two sessions, 10 days each: one SM and one BSM
- About 70 people (both experimentalists and theorists) gathered together at Les Houches Physics School
- No formal talk or agenda prepared in advance

- All discussions are very informal, brainstorming-like
- Collaboration on projects starts at the meeting and continue through the year till the publications of the proceedings
- Even people not present in LH can contribute!

Topics of discussion

SM session is organised in 3 working groups, with some overlap:

- Loops/Multilegs/Jets
- Higgs
- Monte Carlo and Tools

Ideas, initially collected by the conveners, are updated during the workshop based on the interests of partecipants

A wiki is used to keep track of the status of different projects

I will give an overview of what might be interesting for VBSCan

It is my (biased) selection

Have a look at the workshop wiki pages for more

Les Houches 2019 Tools and Monte-Carlo Working Group

- **List of Participants** (Accessible only to registered participants)
  - Present in Les Houches in session 1
  - Present in Les Houches in session 2
  - The Global List including all registered participants for Tools and MC

Session 1

- intro talk: PDF
- ideas before LH
- summary TH: final_th_merged.pdf

Project pages

- Jet activity in VBF Z and VBF W events
- MC variation ("compendium")
- MC variation ("case study")
- ttbar+bbar (2 Nb jets)
- gg -> HZ pheno study
- self consistency of ISR in showers
- dealing with negative weights
- differential EW corrections for ttW

Jet activity in VBF Z and W production

Physics motivation:

- Standard candle for VBF H and VBS
- New measurements are becoming available
- New Theory/MC developments trying to improve the description of these kind of processes

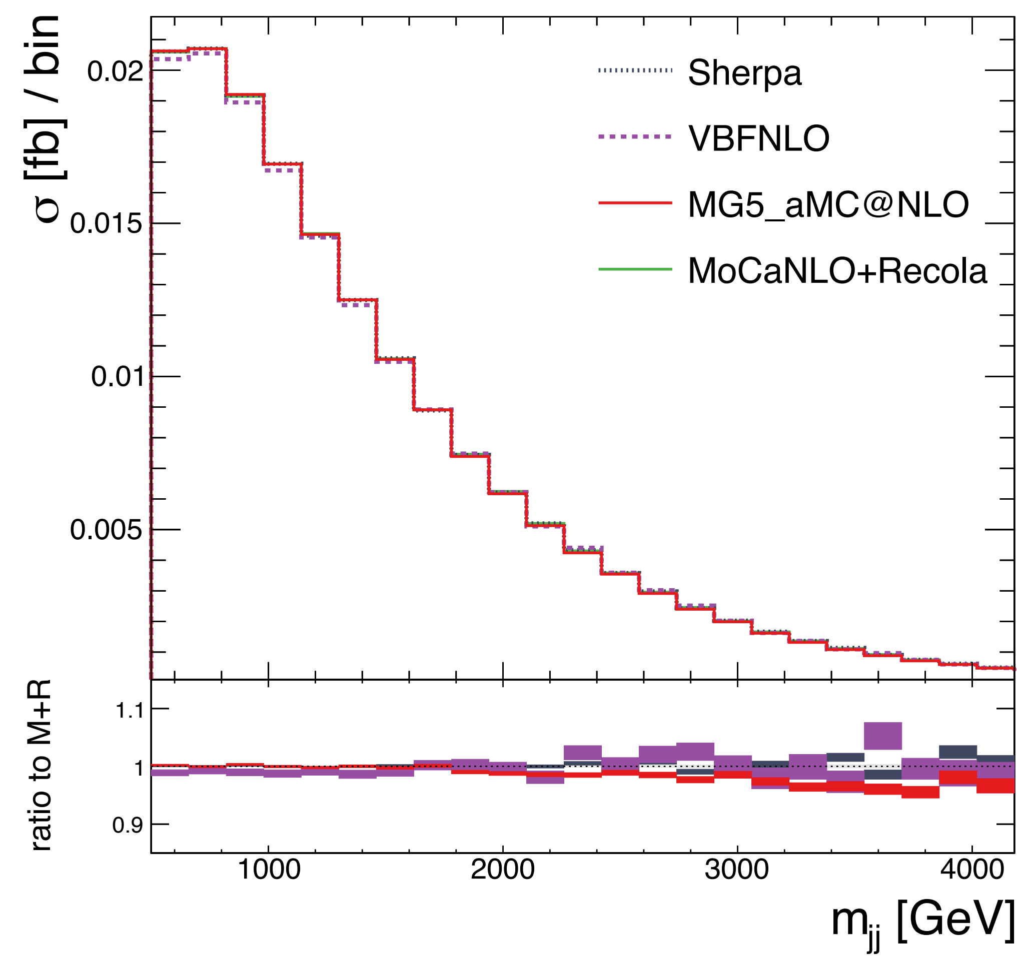
Ideally a continuation of the study

on VBS WZ at LH 2017

K.Long, M.Pellen *et al.* arXiv:1803.07977

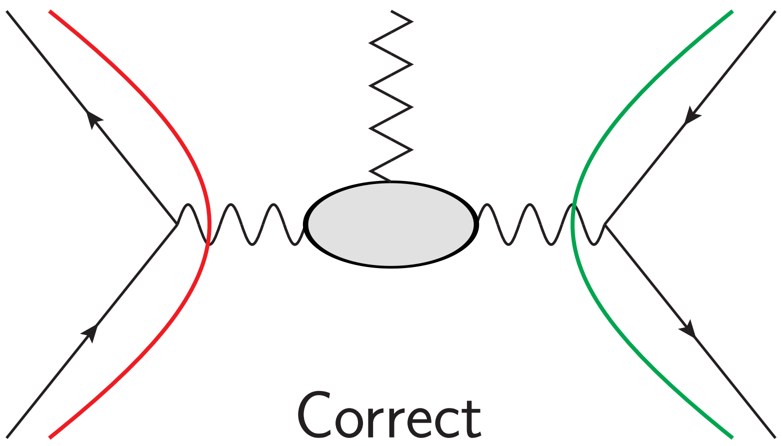
VBF Z and W are a proxy to VBS,

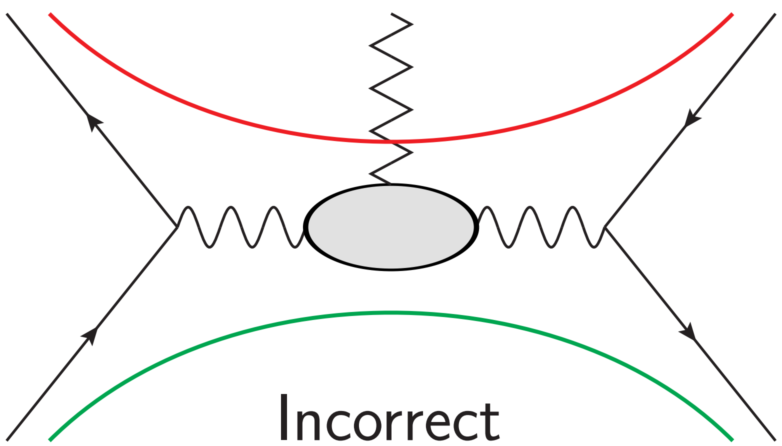
with much more data!



Third jet and Parton Shower

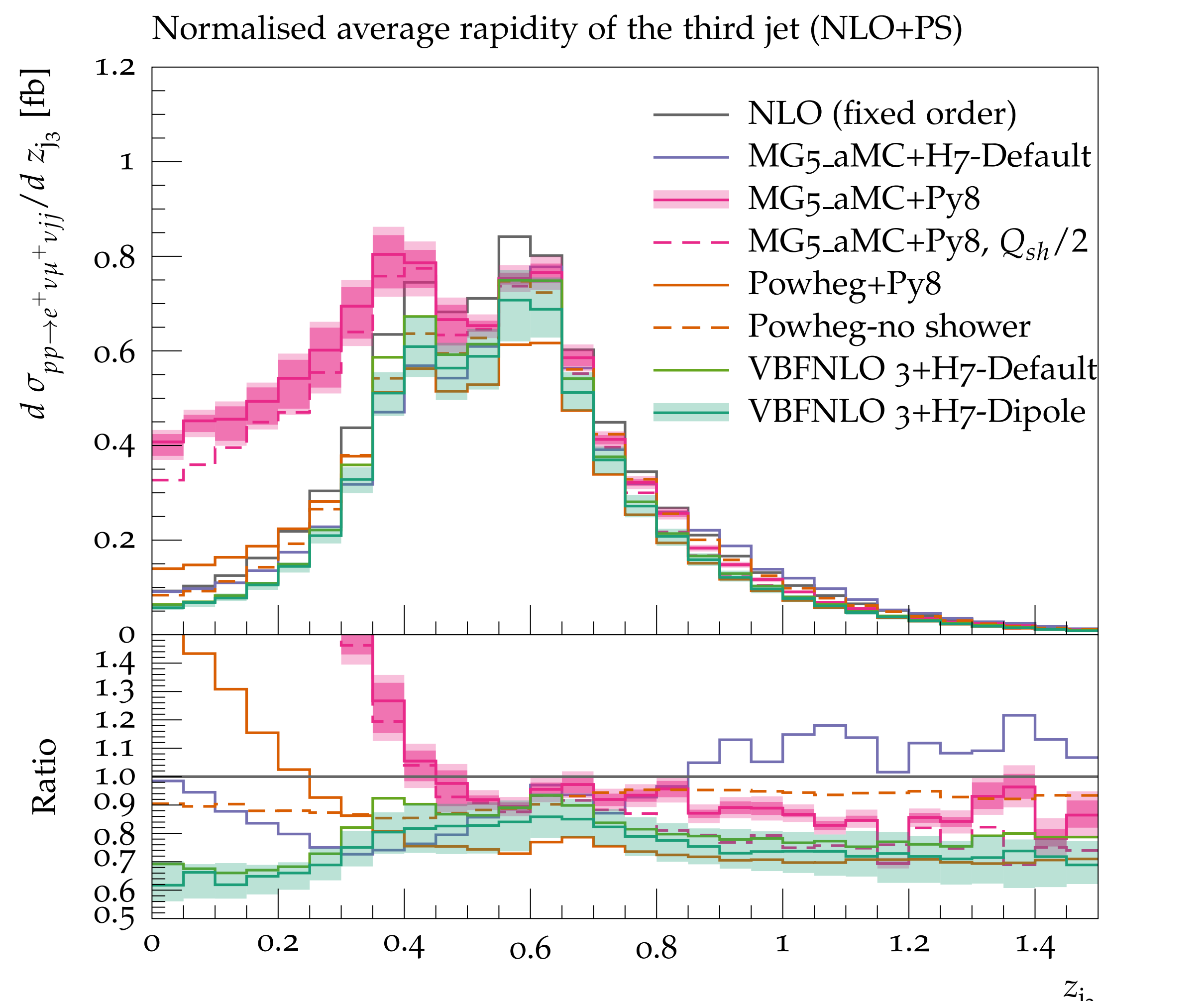
Possible issue with color flow in VBF-like topology:





Several studies of W+W+ showing disagreement on the third jet, even at NLO

e.g. VBSCan study, A. Ballestrero et al., arXiv:1803.07943



arXiv:1803.07943

Third jet and Parton Shower

Both Pythia and Sherpa recently provided a “fix” for the color flow

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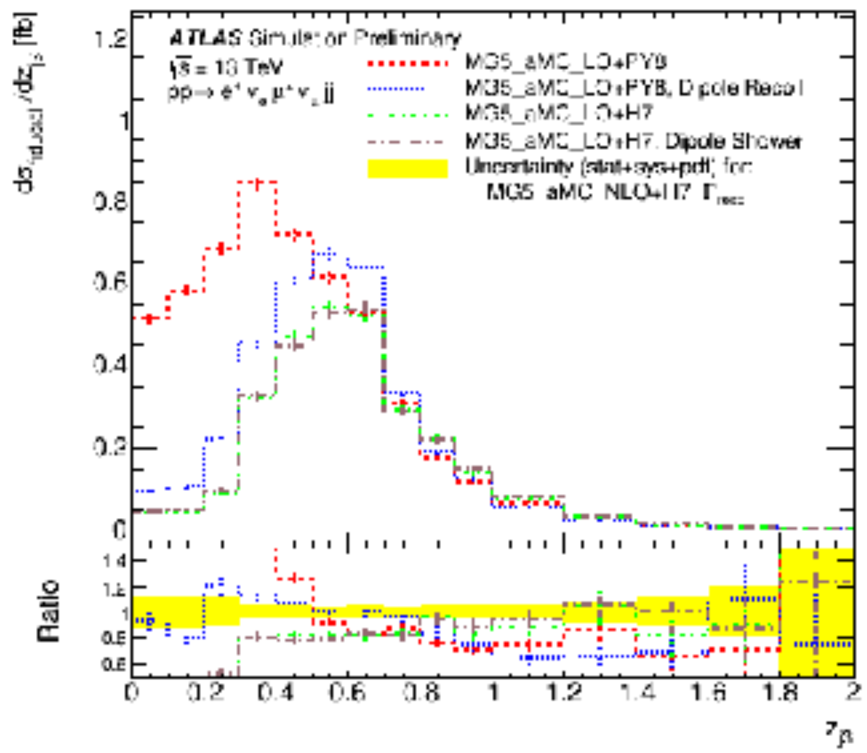
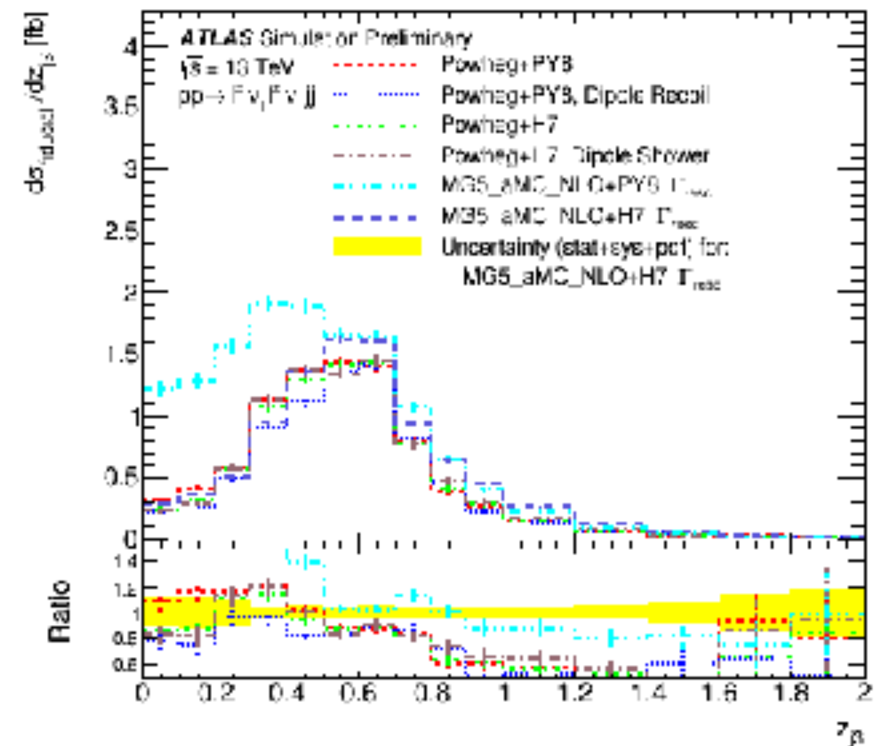
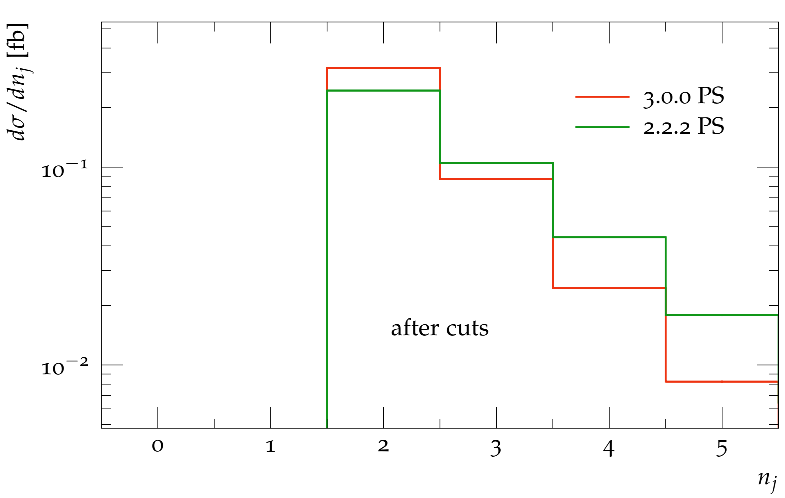
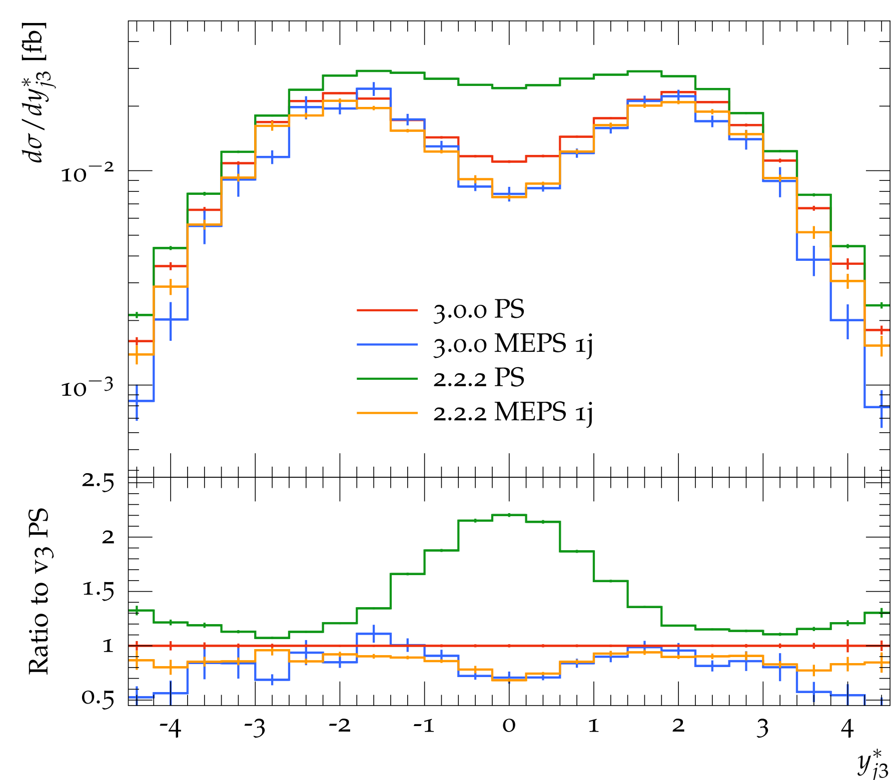






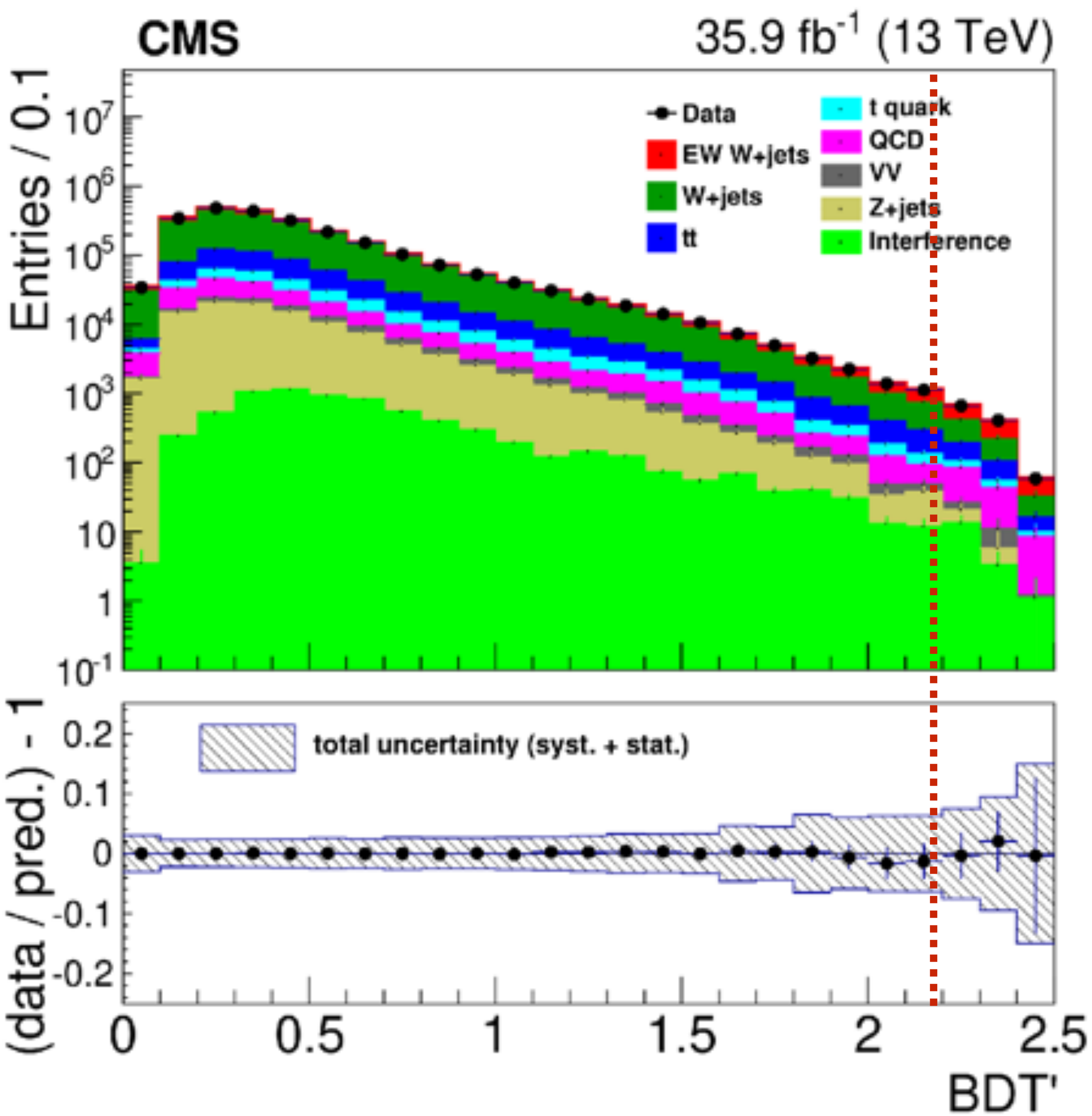


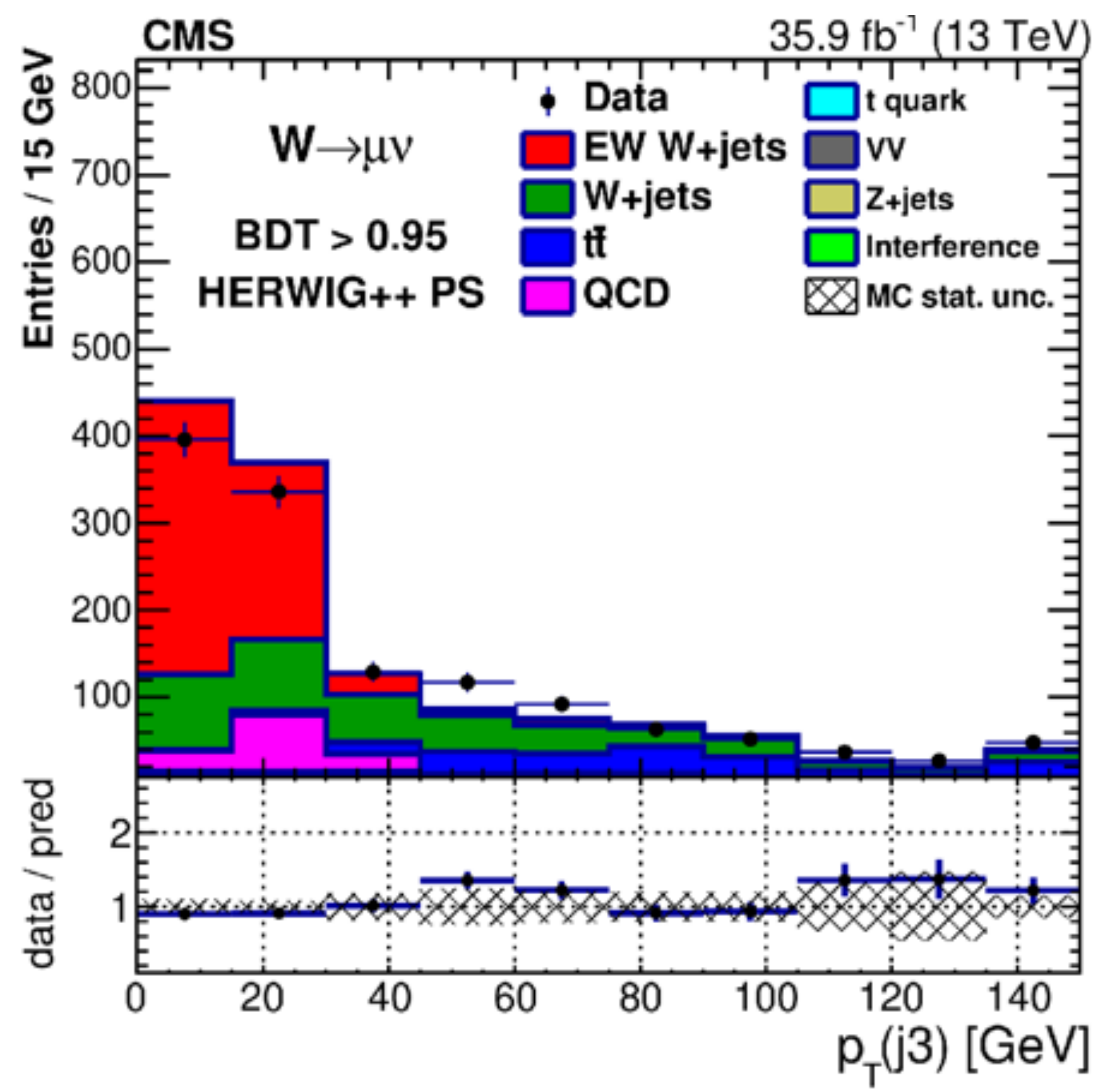
Sherpa 3.0.0 vs 2.2.2
S. Höche, MBI Workshop, Ann Arbor, 2018

Jet activity in VBF W

CMS measured the jet activity in the rapidity gap in a signal region selected with a BDT

- in the signal region about same amount of EWK and QCD Zjj or Wjj
- the BDT is based on mjj, Δηjj, z*, quark/gluon likelihood (QGL)



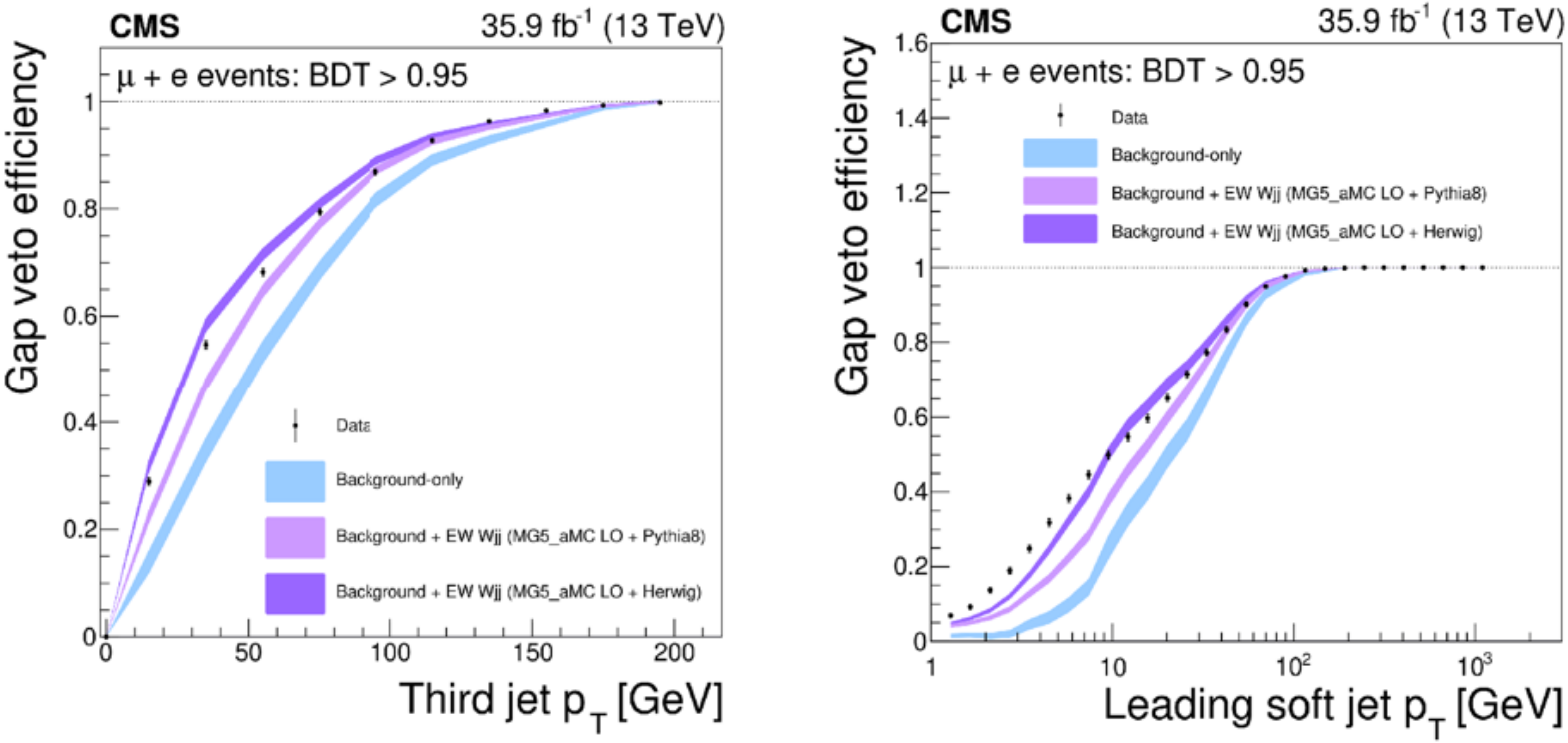


arXiv:1903.04040

Jet veto efficiency

Clear disagreement between MG+Pythia and data

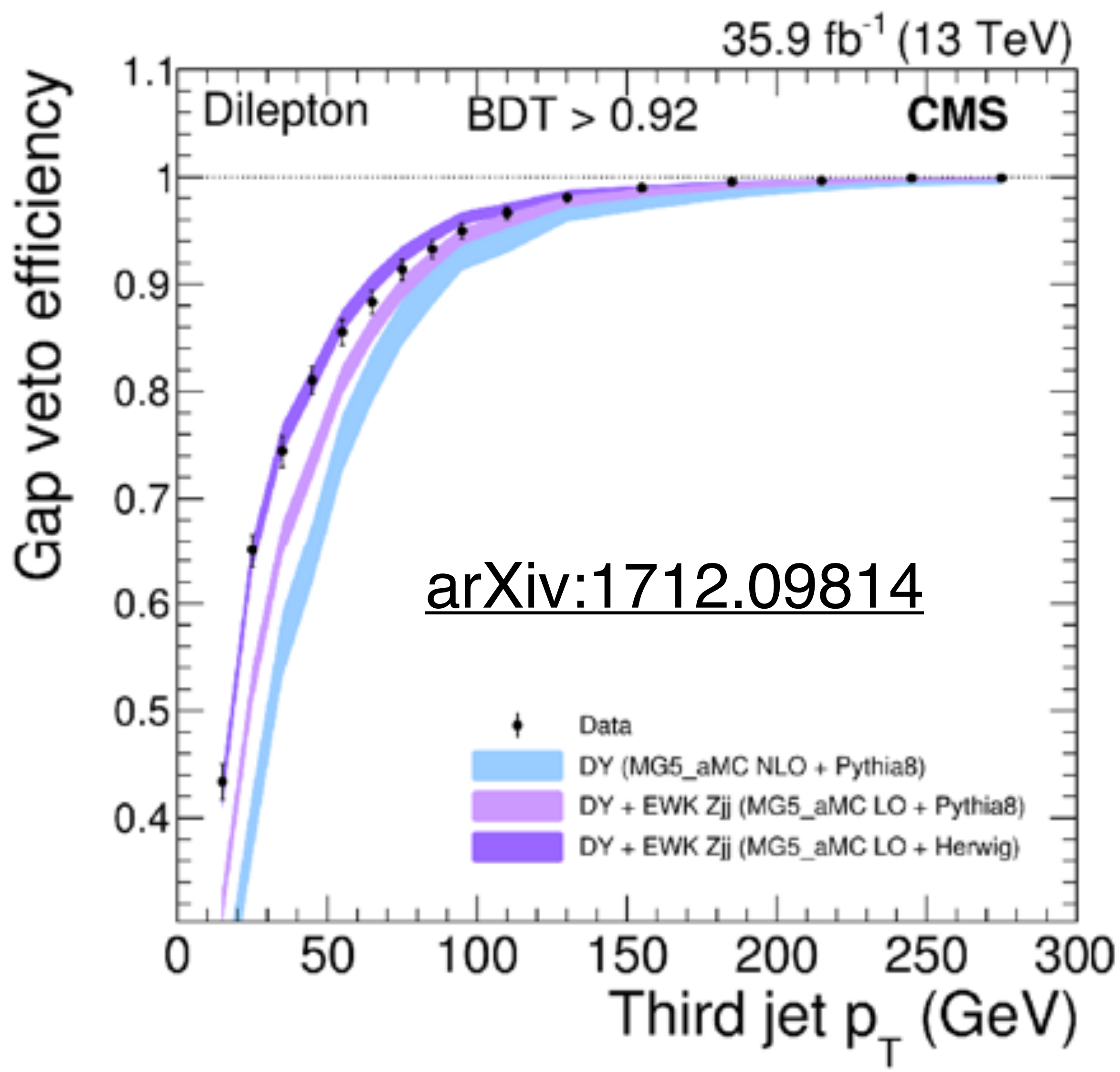
MG+HW ok down to jet p_T ~ 10 GeV

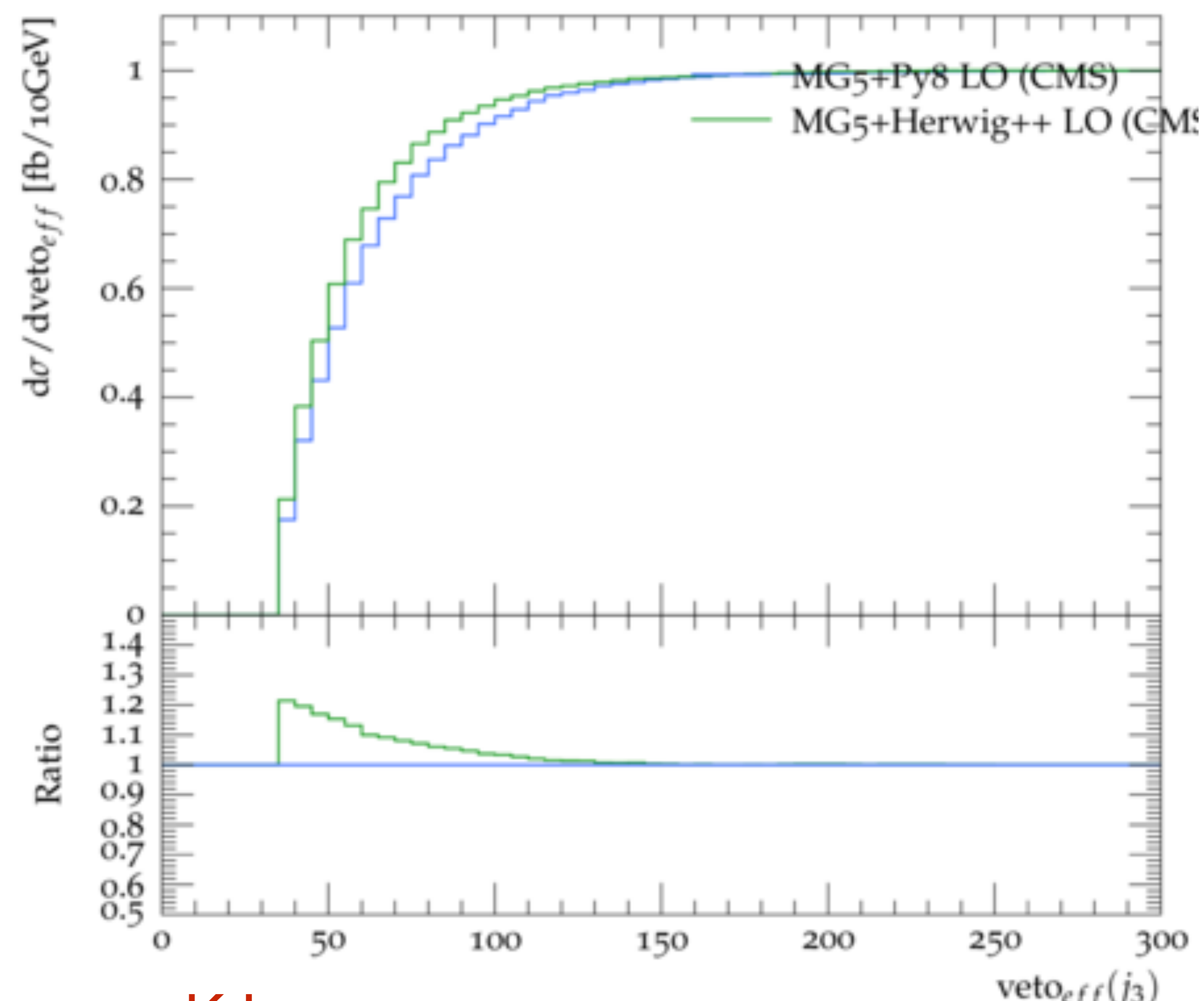


VBF Z measurement

Similar analysis for VBF Z, which also uses a BDT

Preliminary Rivet which selects signal events with mjj > 500 and Δηjj > 2.5





K.Long

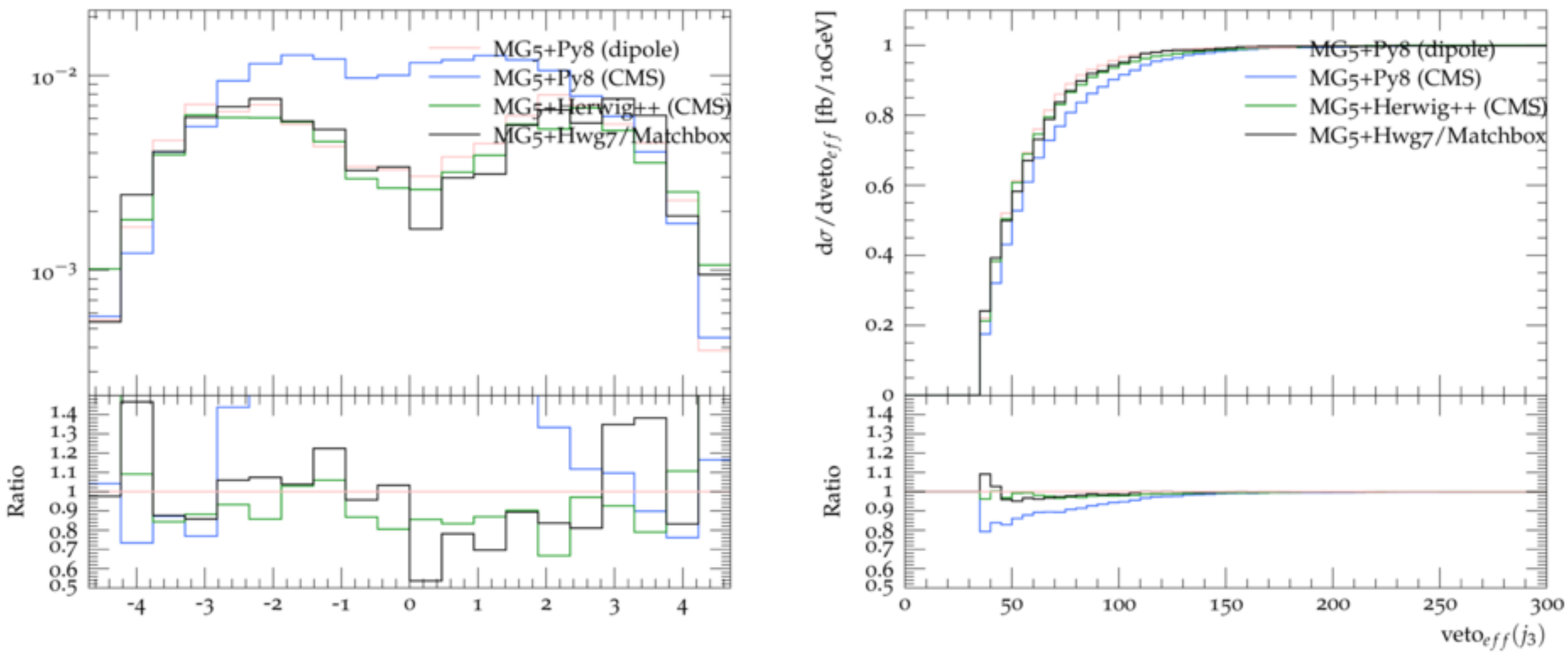
Same qualitative behaviour

Even without a fully unfolded measurement, MG+HW can be used as a "proxy" to the data

VBF Z measurement

More predictions from the Rivet plugin for MG LO

- the effect of “dipole recoil” in Pythia can be clearly seen



K.Long, L. Gellersen, C. Reuschle

- We plan to run a full set of comparisons: LO (fixed order), LO+PS, NLO (fixed order), NLO+PS

Unfolding BDT selection

An (ambitious) experimental project is to provide a “fast folding” for the Rivet analysis

The problem with BDT is that it uses measured observables as input: mjj, $\Delta\eta$jj, z*, quark/gluon likelihood

However we can train another BDT_{gen} on particle level inputs, (mjj_{true}, z^*_{true}, quark/gluon jet) to the output of the selection BDT:

- events with a BDT > 0.95 are tagged as signal
- events with a BDT < 0.95 are tagged as background

If able to tag them with good efficiency, we can obtain a sample as that in the data!

Not sure it will work, but worth trying…

For practical reason this is easier for VBF W analysis, so we agreed to focus on that for the proceedings instead of VBF Z

Jets

Very active group (theory + ATLAS) on jet substructures

Quark-gluon tagging was the main focus

Possible applications to VBF H, VBF Z/W and VBS

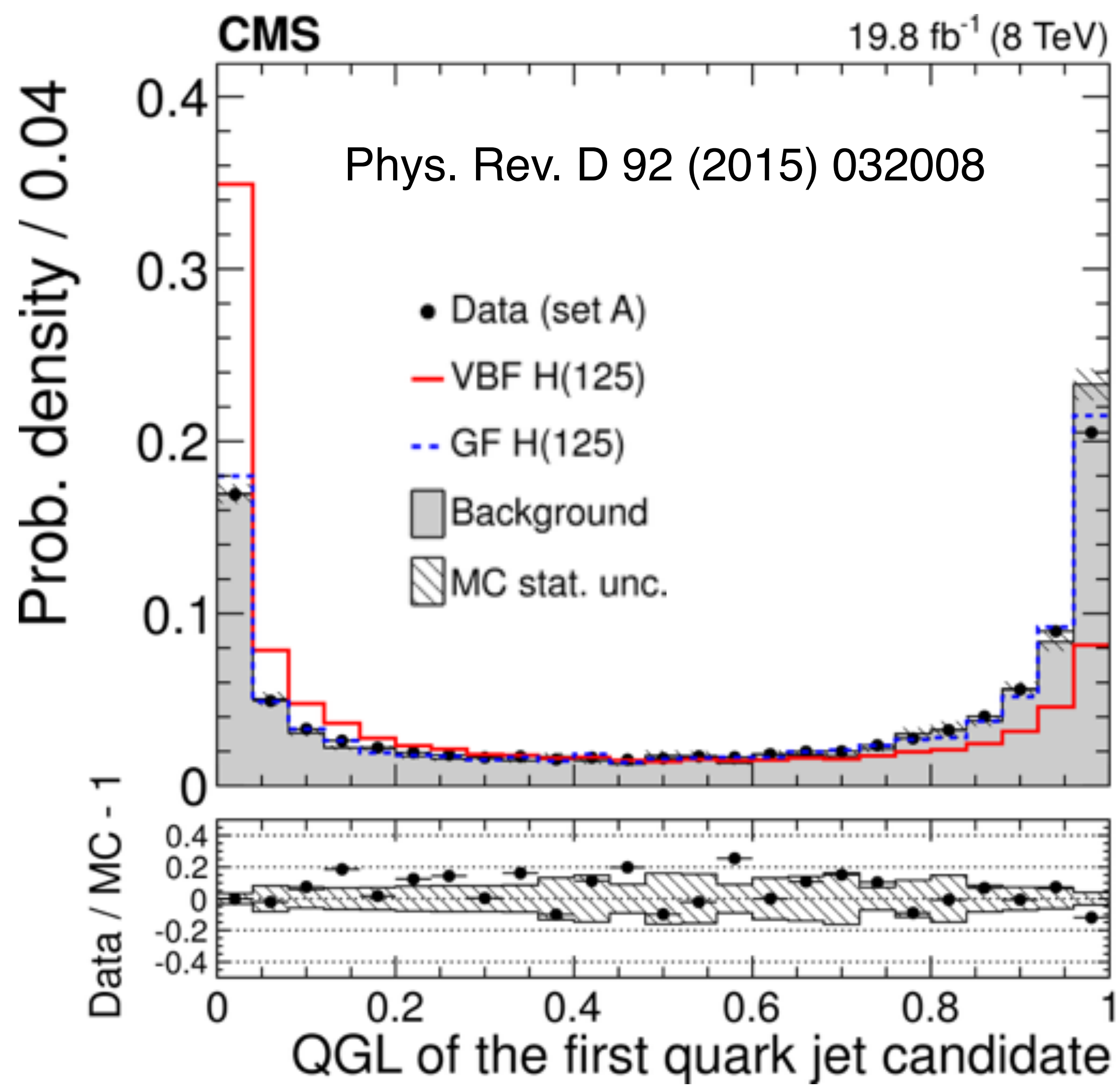
Our study has two components:

Signal versus background.

How useful is q/g tagging & how well is it modeled?

Signal versus signal

Can q/g tagging be used to disentangle VBF from VH/ggH?

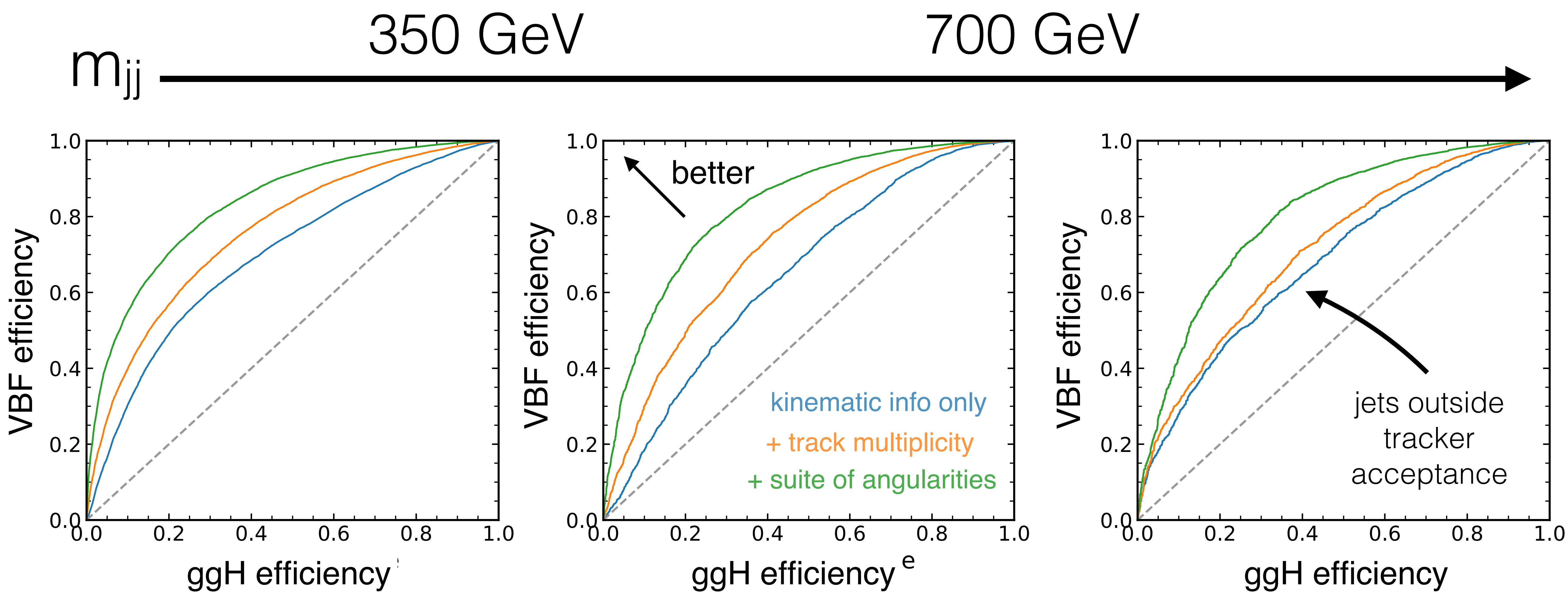


B. Nachmann

q/g discrimination in VBF

Case study: can q/g tagging help disentangle VBF from ggH?

At high m_{jj}, jets from ggH are also quark-like - biggest gains expected at lower mass.



Non-trivial gains seem possible!

…for the **proceedings**: signal versus background, modeling, etc.

B. Nachmann

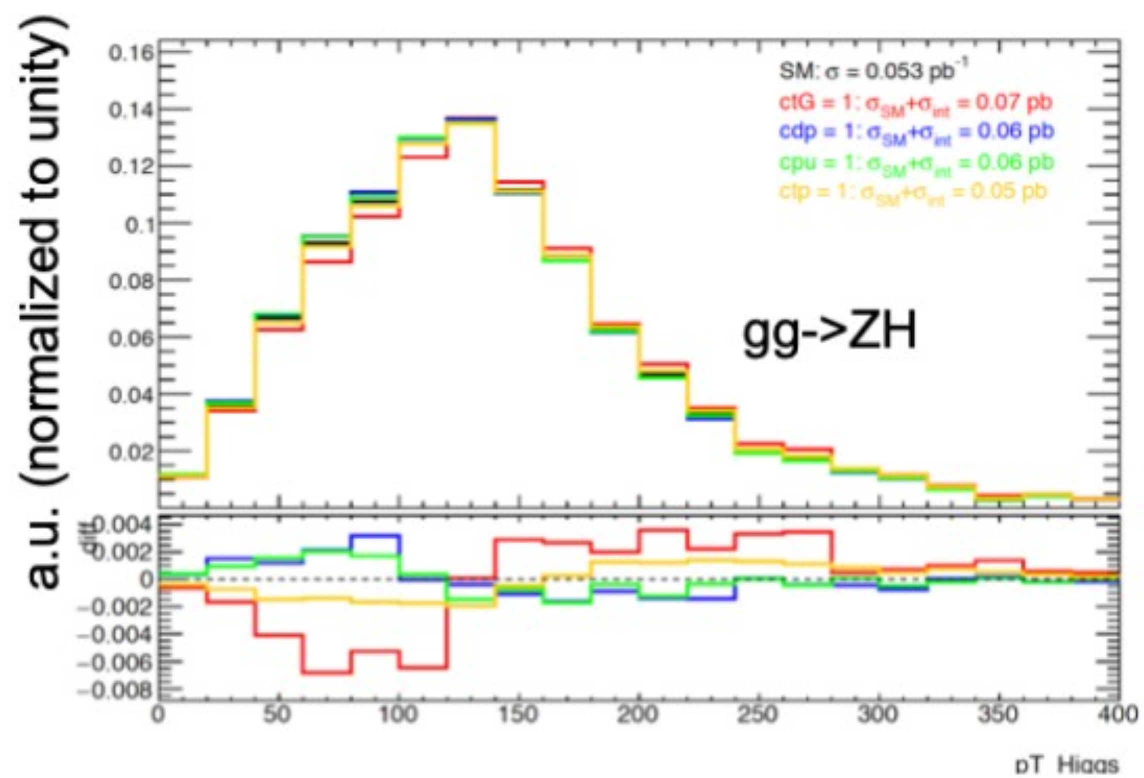
EFT interpretations of Higgs meas.

- Start discussing about EFT interpretations of Higgs measurements
  - Trend to move from anomalous couplings to EFT

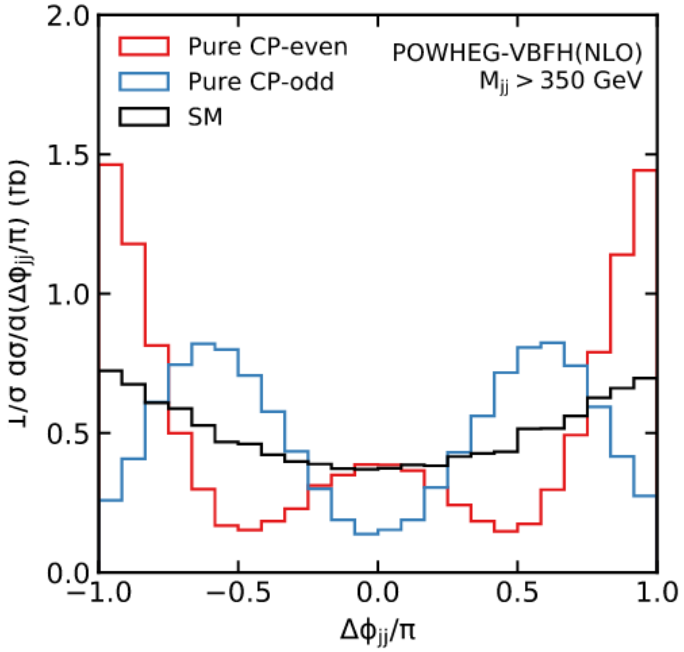
- Use Warsaw basis $$\mathcal{L}_{\mathrm{Eff}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{C_i^{(6)} O_i^{(6)}}{\Lambda^2} + \mathcal{O}(\Lambda^{-4})$$

- Available tools:
  - SMEFTsim → LO tool containing all EFT operators but no loops
  - SMEFT@NLO → automated calculation at NLO within MadGraph including loops but not complete

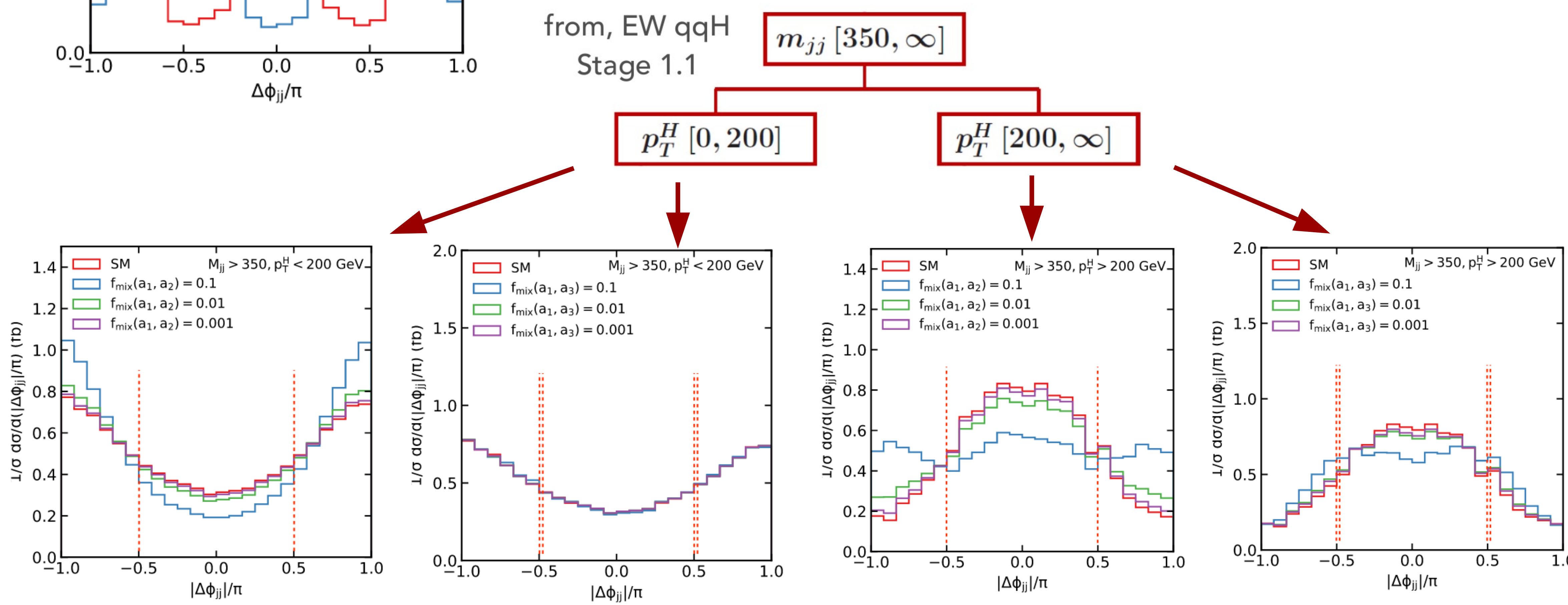
- Ongoing studies:
  - Study ggH and ggZH at NLO EFT
  - Provide STXS parameterization
  - Study EFT for HH production (details here)



Δφ distribution in VBF Higgs



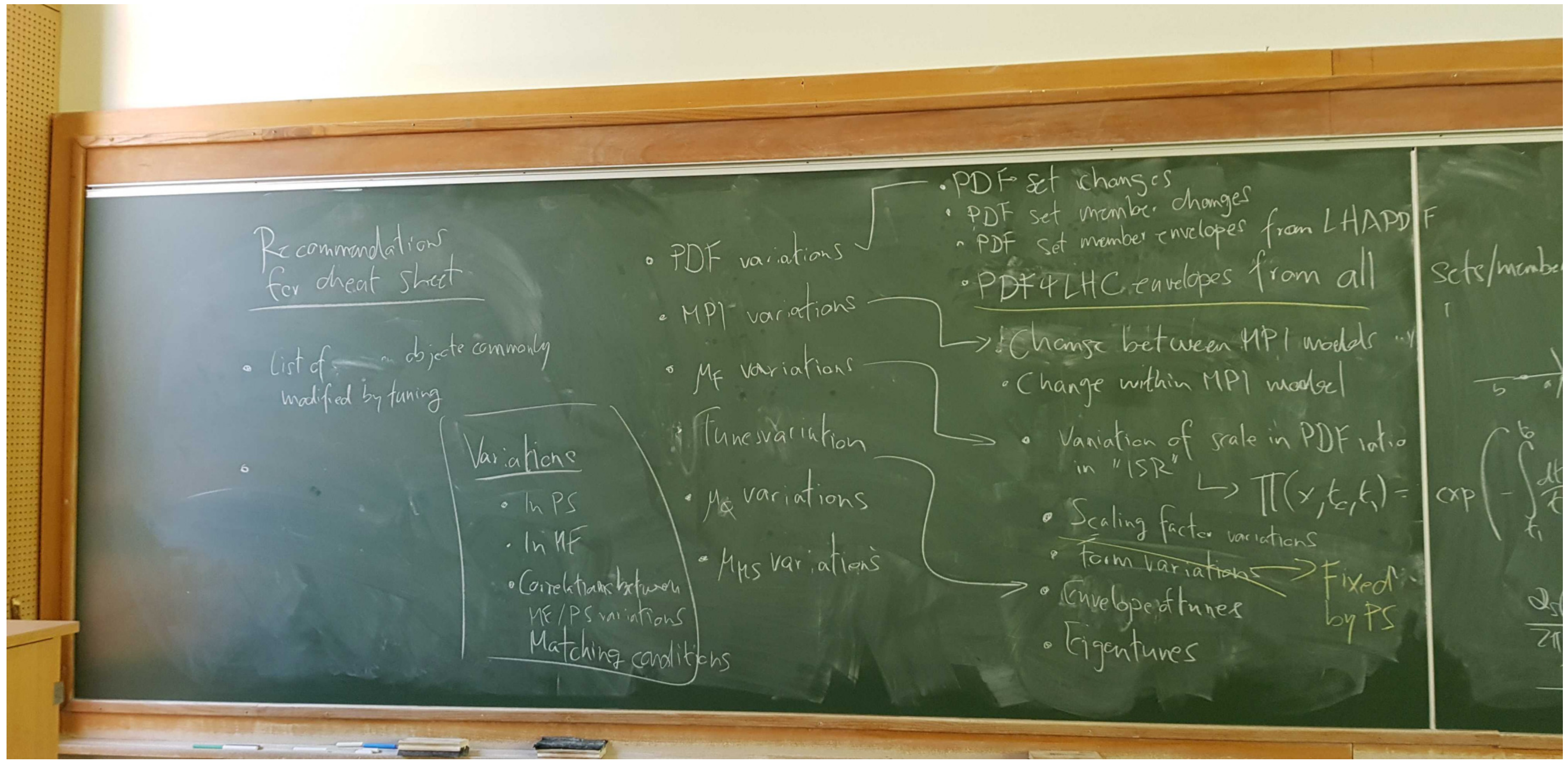
- In VBF the signed Δφ between the 2 tagging jets can be used to probe the HVV vertex tensor structure
  - Check Δφjj distributions in VBF STXS bins using a mixture of SM and CP-odd/even
  - 3 values of fmix = 0.1%, 1%, 10%



a2 CP-even | a3 CP-odd | a2 CP-even | a3 CP-odd

Y. Haddad

MC variations "compendium"



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.

5 / 8

S. Prestel

MC variations "case study"

Several possible "case studies" considered for an exercise on MC variations

ttH most interesting:

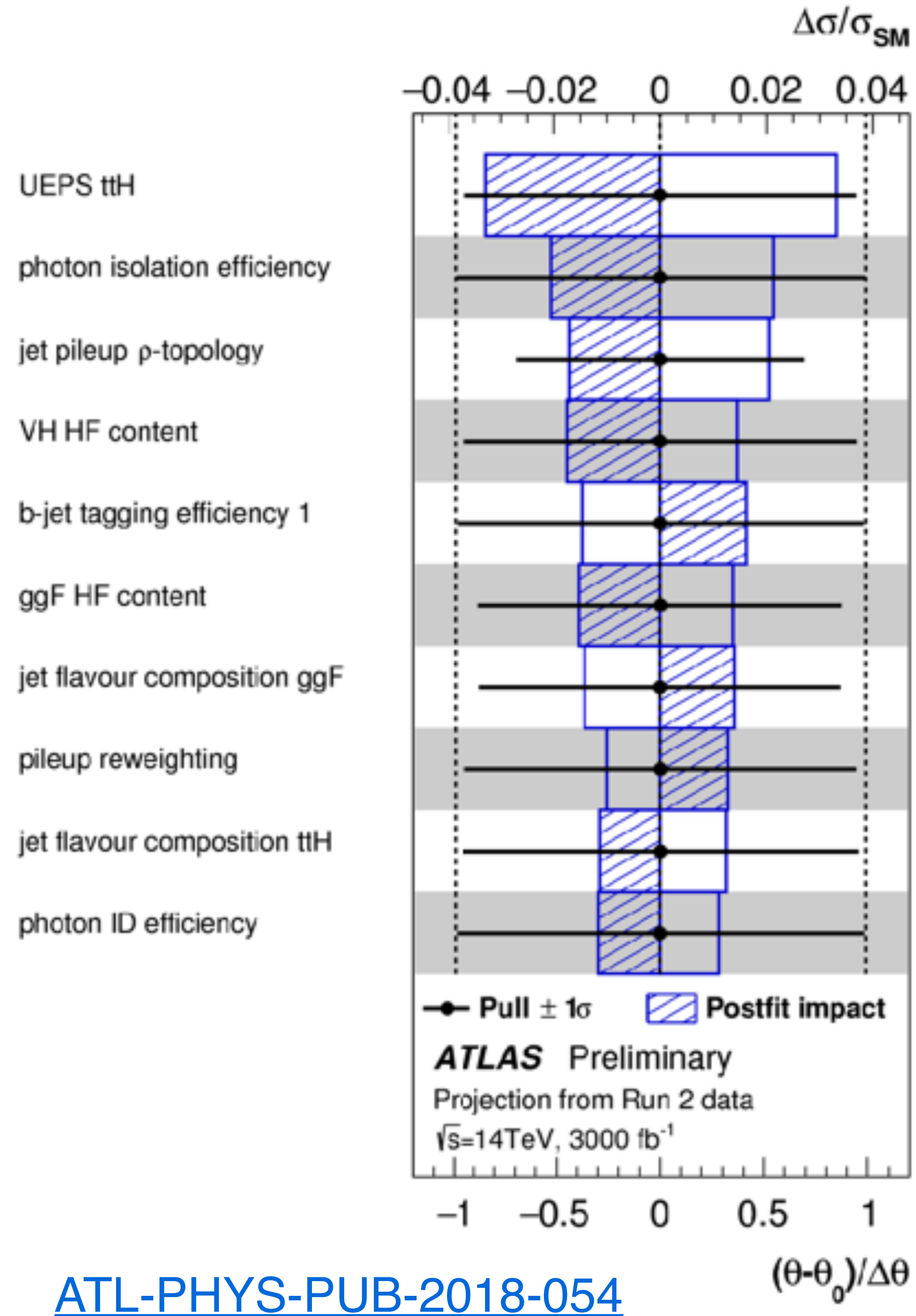
- largest uncertainty at HL-LHC expected to come from UEPS (actually difference between PYTHIA and HERWIG…)
- but **ttH** too difficult to start with

tt is a good proxy to it**:**

- standard candle with many available measurements
- background to many channels

Plan:

- runs NLO+PS and select 2-3 obs.
- produce envelope varying matching, PS model, NP models
- check that envelops for different setups overlaps



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Experimental treatment of theory uncertainty

Example: Extrapolating from Z to W.

$$\underbrace{\frac{\mathrm{d}\sigma(W)}{\mathrm{d}p_T}}_{\text{needed}} = \underbrace{\left[\frac{\mathrm{d}\sigma(Z)}{\mathrm{d}p_T}\right]_{\text{measured}}}_{\text{measure precisely}} \times \underbrace{\left[\frac{\mathrm{d}\sigma(W)/\mathrm{d}p_T}{\mathrm{d}\sigma(Z)/\mathrm{d}p_T}\right]_{\text{theory}}}_{\substack{\text{calculate precisely} \\ \text{theory uncertainties cancel}}}$$

- Ratio is just a proxy
  - More generally: Combined fit to both processes
  - Tuning Pythia on Z and using it to predict W is one example of this
- Crucial Caveat: Cancellation fundamentally relies on theory correlations
  - Take 10% theory uncertainty on $\mathrm{d}\sigma(W)$ and $\mathrm{d}\sigma(Z)$
    - → 99.5% correlation yields 1% uncertainty on their ratio
    - → 98.0% correlation yields 2% uncertainty on their ratio – 2× larger!
- One of many examples, this happens whenever experiments extrapolate from some control region or process to the signal region

F. Tackmann

Scale uncertainties and correlations

Correlations only come from common sources of uncertainties

- ✓ "Straightforward" for unc. due to input parameters ($\alpha_s(m_Z)$,)

Scale variations are inherently ill-suited for correlations

- ✗ Scales are not physical parameters with an uncertainty that can be propagated
  - ✗ They are not the underlying source of uncertainty
  - ✗ Scale variation reduces at higher order not because the scales become better known but because the cross section becomes less dependent on them
- ✗ A priori, scale variations do not imply true correlations between different kinematic regions or different processes
- ✗ Taking an envelope is not a linear operation and so does not propagate

⇒ In my mind, trying to decide how to (un)correlate scale variations in the end only treats a symptom, but not the actual problem

F. Tackmann

Theory Nuisance Parameters

The general structure of higher order corrections it is known for resummation

→ Each resummation order only depends on a few semi-universal parameters

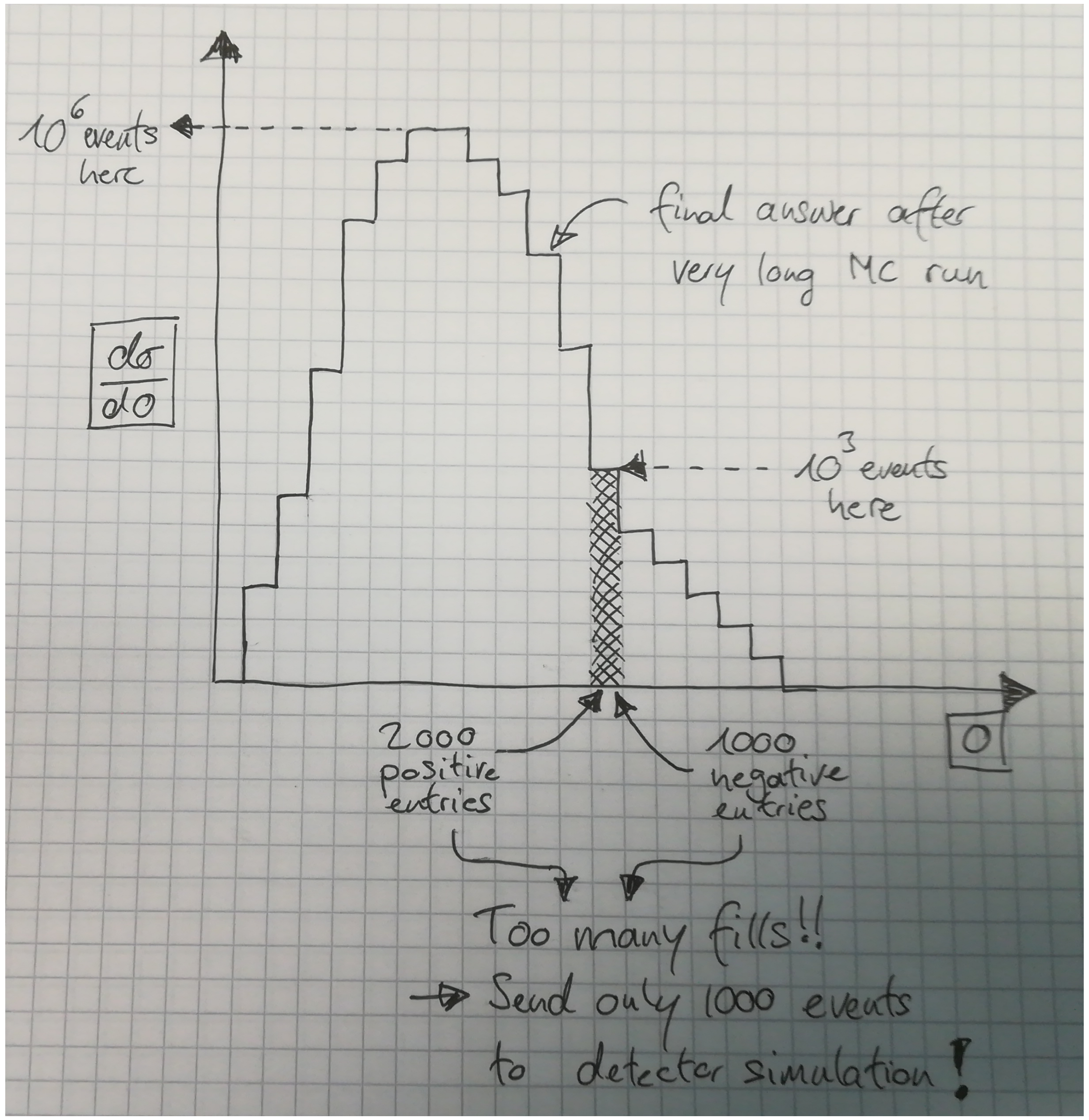
→ Unknown parameters at higher orders are the actual sources of perturbative theory uncertainty

	boundary conditions			anomalous dimensions			
order	h_n	s_n	b_n	γ_n^h	γ_n^s	Γ_n	β_n
LL	h_0	s_0	b_0	–	–	Γ_0	β_0
NLL′	h_1	s_1	b_1	γ_0^h	γ_0^s	Γ_1	β_1
NNLL′	h_2	s_2	b_2	γ_1^h	γ_1^s	Γ_2	β_2
N^{3}LL′	h_3	s_3	b_3	γ_2^h	γ_2^s	Γ_3	β_3
N^{4}LL′	h_4	s_4	b_4	γ_3^h	γ_3^s	Γ_4	β_4

- Basic Idea: Use them as theory nuisance parameters
  - ✓ Vary them independently to estimate the theory uncertainties
  - ✓ Impact of each independent nuisance parameter is fully correlated across all kinematic regions and processes
  - ✓ Impact of different nuisance parameters is fully uncorrelated
- Price to Pay: Calculation becomes quite a bit more complex

F. Tackmann

Negative weights and 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.

S. Prestel 7 / 8

Not sure if it will work, but good that MC experts started to discuss it!

Conclusions(?)

The work has just started!

Many other projects discussed for the proceedings: most of them are just getting going

Some, I believe, are interesting for VBSCan action

Have a look at Les Houches wiki pages and feel free to join if you are interested!

Results/conclusions to come in about a year…