## Higgs p<sub>T</sub> treatment in ATLAS

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#### Why is the Higgs $p_{\tau}$ important for us ?

First of all, changing the Higgs  $p_T$  distribution can affect the acceptance.

 $H \rightarrow ZZ^* \rightarrow 4l$ 

- Studying the possibility of using Higgs p<sub>T</sub> to help in discrimination against ZZ background, and to better separate VBF and ggF.

 $H \longrightarrow \tau\tau$ 

- Use Higgs  $p_T$  to categorize events into "boosted" and "non-boosted".
- Would also like to include it in the BDT.

 $H \rightarrow \gamma \gamma$ 

- Categorization of events using  $p_{\mathsf{T}}^{\mathsf{thrust}}$
- Measurement of differential cross section needs to be compared to the proper central value and uncertainty

 $H \to WW^* \to lv lv$ 

- Sensitive through the impact of Higgs  $p_T$  on the jet multiplicity (analysis categorized in jet bins).
- ⇒ Need reliable systematic uncertainties

 $\Rightarrow$  Best central value ?

### ATLAS $gg \rightarrow H$ sample is Powheg+Pythia8 (CT10)

 $\rightarrow$  Powheg with fixed  $\mu_{ref} = m_H$ , and hfact = m\_H/1.2 (to match HqT in range [10 GeV, m\_H])

#### **Best central value**

• Re-weight Powheg to HRes ? (Study in  $H \rightarrow \gamma\gamma$ )

### Systematic uncertainties

• PDFs  $\rightarrow$  PDF Error set

Differences with other PDF sets (negligible)

- Higher-order corrections  $\rightarrow$  scales  $\mu_F$ ,  $\mu_R$ ,  $\mu_{Res}$  variations in HRes
- ME-PS matching
  Heavy quark mass effect ?
  Powheg vs MC@NLO
- Parton shower → Powheg+Pythia vs Powheg+Herwig ?
- Hadronisation, UE
- ...

# PDF4LHC

**Best central value** 







Large discrepancies at low  $p_T$ .

### **Proposition for a Powheg re-weighting to HRes (??)**

(study in HSG1)

• Differences between PoWHEG + Pythia8 and HRes:

- ► HRes: NNLO+NNLL (soft gluon); Infinite top mass
- PoWHEG + Pythia8: NLO+PS; Heavy Quarks (HQ) mass effect (hfact = mH/1.2)
  - We propose the following strategy:

$$P_{weighted} = \frac{H}{P} \times \left( \frac{P_{with (FSR, MPI, had.)}}{P_{without (FSR, MPI, had.)}} \times \frac{P_{with top}}{P_{without top}} \right) \times P$$
$$= R \times R' \times R'' \times P$$

Effect is very small (<2%) => neglected wrt other effects



This lead to the question if this re-weighting improves over the current prescription.

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Systematic uncertainties

### **PDF error set**

PDF re-weighting used to run over the CT10 error set.

Error set decomposed in the eigenvector space of the correlation matrix.  $\rightarrow$  The eigenvalues furnish the uncorrelated error for each element of the set.

Error evaluated in different  $p_T$  bins using the CTEQ Master formula:

$$\Delta X^+_{max} = \sqrt{\sum_{i=1}^N [max(X^+_i - X_0, X^-_i - X_0, 0)]^2}$$

$$\Delta X_{max}^{-} = \sqrt{\sum_{i=1}^{N} [max(X_0 - X_i^+, X_0 - X_i^-, 0)]^2}$$

Impact using different PDF (MSTW2008, NNPDF23) small.



Shape comparison (integral normalized to 1). Higgs  $p_T$  after PS.

< 2% effect for  $p_T(H)$  < 150 GeV

2 – 8 % in 150 GeV < p<sub>⊤</sub>(H) < 350 GeV

### **Scale variations** R. Di Nardo, K. Nikolopoulos et al.

3 scales in HRes: factorization ( $\mu_F = m_H$ ), renormalization ( $\mu_R = m_H$ ), resummation ( $\mu_{Res} = m_H/2$ )

Evaluate the uncertainties by varying the scales by factors 0.5 and 2.





• 10% - 20% for p<sub>T</sub>>100GeV

### Powheg vs MC@NLO

Powheg and MC@NLO use different (equally valid) approaches for ME and PS matching.

(Could be the reason of the different heavy quark mass effects on  $p_{\tau}(H)$ ).

=> Propose to include the difference as an uncertainty.

Both generators should be compared at the same scale.

Powheg uses fixed scale ( $m_H$ ), MC@NLO uses running scale ( $m_T$ (H)). Consensus seems to be that running scale should be used (at least in MC@NLO).



### Powheg vs MC@NLO

We didn't produce the P+HW sample (with running scale) up to reco level.

But we do have a P+HW sample (with fixed scale) up to reco level.

- => Decided to re-weight the P+HW sample (fixed scale) at truth level with ratio
- R = P+HW(running scale) / P+HW(fixed scale). Then compare to MC@NLO.

When re-weighting Powheg from fixed to running scale, the change in the total cross section is taken into account as predicted by Powheg, but this effect is < 1%.



Plots after applying a preselection at reco level (see backup for details)

### Powheg vs MC@NLO

So far we assigned only a normalization uncertainty, obtained from comparing the total yields between MC@NLO and Powheg in the different analysis categories.

The table below presents the yields obtained in each category. Both samples were normalized to the same integrated luminosity and using the same (NNLO) cross section.

	MC@NLO	P+ HERWIG	MC@NLO/POWHEG
VBF	8.6	11.1	0.77
Boost	28.3	40.0	0.70
1 Jet	221.9	235.1	0.94
0 Jet	594.8	466.6	1.27

In last meeting it was said that it is not good idea to compare Powheg vs MC@NLO in VBF category... Shouldn't we include then the uncertainty in the VBF category ?



## **Backup slides**

### **Preselection applied in plots from slide 12**

This is the  $H \rightarrow \tau \tau$  channel with one hadronic-tau decay and one leptonic tau decay.

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Hadronic tau with p_T > 25 GeV, |\eta| < 2.5
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One electron (or muon) with some p_{\scriptscriptstyle T} cut > 15 (10) GeV and |\eta| < 2.5
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### HRes vs Powheg+Pythia8 (with HQ mass effect)

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Good agreement between HRes and Powheg+Pythia8 before PS (status 22), but not that good agreement after PS (status 62).

=> Re-weighting is proposed after PS (study in HSG1).



## Effect of MPI+FSR+hadronisation (R')

Run Pythia8 from PoWHEG output used to produce the ATLAS ggh125 official sample turning off MPI, FSR and hadronisation



Cross check with inputs from Roberto:

## Top mass effect (R'')

From YR2 p62



Effect of order  $\sim$  10%.

## Summary of weights

• PoWHEG: official ggH125 production • HRes:  $\mu_R = \mu_F = 2Q = m_H = 125 \text{ GeV}$ , CT10



• 15 to 20% difference in the high  $p_T$  region;

HQ mass effect contribute to a small fraction of the difference btw PoWHEG and HRes.

## Effect of Pythia6 VS Pythia8

Pythia6 using Perugia tune (CT6) - Normalized to 1



See larger bottom plot on next slide.

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pT in PoWHEG and HRes

## Effect of Pythia6 VS Pythia8

Pythia6 using Perugia tune (CT6) - Normalized to 1



HQ mass effect not changed by Pythia8 wrt Pythia6
Difference at low p<sub>T</sub> between Pythia6 and Pythia8.

### Effect of acceptance cuts on the weight

- Compare HRes and PoWHEG distributions before and after acceptance cuts
  - $|\eta^{\gamma}| < 2.37$
  - $\blacktriangleright p_T^{max} > 40 ~GeV$  and  $p_T^{min} > 30 ~GeV$
- Compute the ratio H/P before and after acceptance cuts.



Weight seems globally independent of the acceptance cut (small discrepancy at low  $p_T$ , but low statistics...)

 $p_T$  in PoWHEG and HRes

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### Comparison HqT and HRes

http://xxx.lanl.gov/pdf/1203.6321v1.pdf (M. Grazzini et al.)

