WG1 "close up"

B. Mellado, M. Grazzini, P. Musella, R. Harlander

11th HXSWG General Assembly Meeting

CERN, january 14, 2016

WG1 activities

Mandate: ``to provide recommendations for mainly SM cross-sections and Branching Ratios for the Higgs boson''

SM input parameters for Higgs physics

LHCHXSWG-INT-2015-006

➡ Updated cross sections and distributions to go in the YR4

PDF4LHC recommendations forLHC Run II

arXiv:1510.03865

Both available since mid october '15

Subgroups

Group TWiki	Group Mailing List	Mail to conveners	ATLAS		CMS		THEORY		
BR		Mail	Daniela Rebuzzi (Pavia)		Ivica Puljak (Split)		Ansgar Denner (Würzburg)	Sven Heinemeyer (IFCA)	Alexander Mück (Aachen)
ggF		Mail	Dag Gillberg (CERN)	Chris Hays (Oxford)	Giovanni Petrucciani (CERN)	Andrea Massironi (Northeastern U)	Stefano Forte (Milano)	Achilleas Lazopoulos (ETH Zürich)	Giulia Zanderighi (Oxford)
VBF/VH	Mailing List	Mail	Jason Nielsen (UCSC)	Elisabetta Pianori (Warwick)	Pietro Govoni (Milano-Bicocca)	Luca Perrozzi (ETH)	Stefan Dittmaier (Freiburg)	Barbara Jäger (Tübingen)	Francesco Tramontano (Naples)
ttH/tH	Mailing List	Mail	Stefan Guindon (SUNY)		Christopher Neu (Virginia)		Stefano Pozzorini (Zürich)	Laura Reina (Florida)	
Offshell		Mail	Yanyan Gao (Edinburgh)		Jian Wang (Florida)	Livia Soffi (Cornell)	Fabrizio Caola (CERN)	Nikolas Kauer (Royal Holloway)	

+ cross-groups (not covered here)

BR

SM BRs

Heinemeyer,Mueck

Global picture for YR4:

- setup unchanged for $M_H \sim 125$ GeV
    - Prophecy4f for $H \to 4$ fermions
    - HDECAY for all other channels (now using $\overline{\text{MS}}$ input masses)

- Improvements
    - reduced parametric uncertainties
      (LHCHXSWG-INT-2015-006)
    - improved theory input in HDECAY

$\Rightarrow$ updated central BR values only change well within the YR3 error estimates

$\Rightarrow$ errors shrink considerably

Heinemeyer,Mueck

PU and THU impact on partial width errors:

$M_H = 125$ GeV   YR3 → YR4

Channel	$\Delta\alpha_s$	ΔM_b	ΔM_c	THU
$b\bar{b}$	-2.3% → -1.4% $+2.3\%$ $+1.4\%$	$+3.3\%$ → $+1.7\%$ -3.2% -1.7%	$+0.0\%$ -0.0%	$+2.0\%$ → $+0.5\%$ -2.0% -0.5%
$\tau^+\tau^-$	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+2.0\%$ → $+0.5\%$ -2.0% -0.5%
$\mu^+\mu^-$	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+2.0\%$ → $+0.5\%$ -2.0% -0.5%
$c\bar{c}$	-7.1% → -1.9% $+7.0\%$ $+1.9\%$	-0.0% -0.0%	$+6.2\%$ → $+5.3\%$ -6.1% -5.2%	$+2.0\%$ → $+0.5\%$ -2.0% -0.5%
gg	$+4.2\%$ → $+3.0\%$ -4.1% -3.0%	-0.1% $+0.1\%$	$+0.0\%$ -0.0%	$+3.0\%$ -3.0%
$\gamma\gamma$	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+1.0\%$ -1.0%
$Z\gamma$	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+5.0\%$ -5.0%
WW	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.5\%$ -0.5%
ZZ	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.0\%$ -0.0%	$+0.5\%$ -0.5%

(in YR4 the $\overline{\text{MS}}$ mass $m_c(3$ GeV$)$ is used as input)

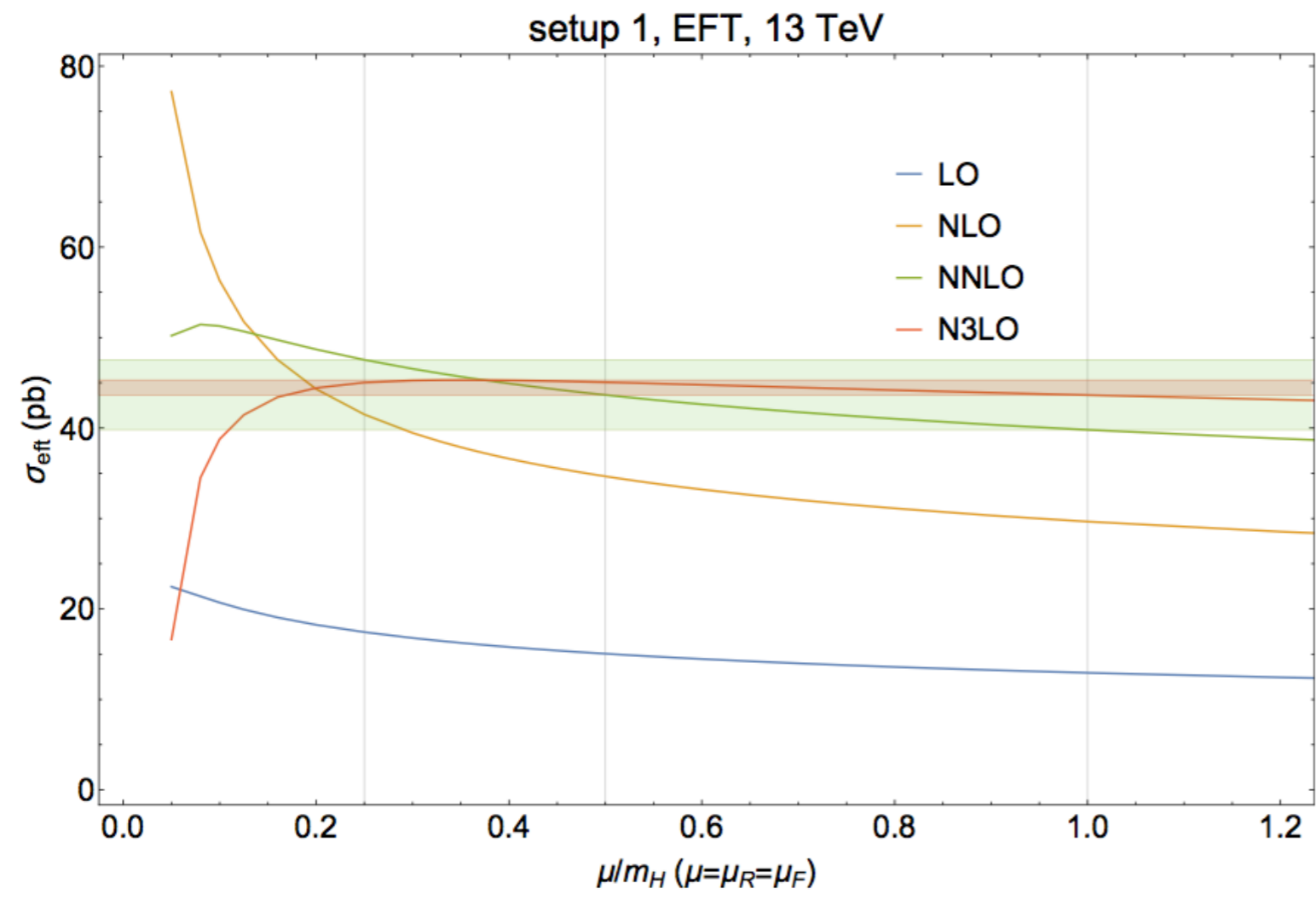(table is starting point if one wants to include error correlations in BR calculations)

ggF

Results on behalf of the N3LO collaboration

C. Anastasiou, C. Duhr, F. Dulat, E. Furlan, T. Gehrmann, F. Herzog, A.L., B. Mistlberger

UNCERTAINTIES: EFT (from scale uncertainty)

setup 1, EFT, 13 TeV

LO
NLO
NNLO
N3LO

σ_{eft} (pb)

μ/m_H ($\mu=\mu_R=\mu_F$)

pure EFT symmetric
LO: ±14.8%
NLO: ±16.6%
NNLO: ± 8.8%
N3LO: ± 1.8%

Lazopoulos

Results on behalf of the N3LO collaboration

C. Anastasiou, C. Duhr, F. Dulat, E. Furlan, T. Gehrmann, F. Herzog, A.L., B. Mistlberger

adding up the theory uncertainties linearly

Higgs XS = 48.57pb

δ(scale) (pb)	δ(trunc) (pb)	δ(PDF-TH) (pb)	δ(EW) (pb)	$\delta(t,b,c)$ (pb)	$\delta(1/m_t)$ (pb)
$^{+0.10}_{-1.15}$	±0.12	±0.56	±0.49	±0.34	±0.49
$^{+0.20\%}_{-2.37\%}$	$\pm0.25\%$	$\pm1.16\%$	$\pm1\%$	$\pm0.7\%$	$\pm1\%$

+4.31%
-6.47%
theory

+3.15%
PDF+as

Lazopoulos

Results on behalf of the N3LO collaboration

C. Anastasiou, C. Duhr, F. Dulat, E. Furlan, T. Gehrmann, F. Herzog, A.L., B. Mistlberger

```
R_LO                    = 1.06274

R_LO * eftlo            = 16.00
R_LO * eftnlo           = 36.84
R_LO * eftnnlo          = 46.40
```

R*eftn3lo = **47.89**

@mh/2

ew rescaled = **2.40**

delta mt exp total = **0.34**

```
exactlo  (t+b+c)        = 14.83
exactnlo (t+b+c)        = 34.78
```

delta QCD = **-2.06**


# Higgs XS = 48.57pb

Lazopoulos

p_T Higgs: comparison
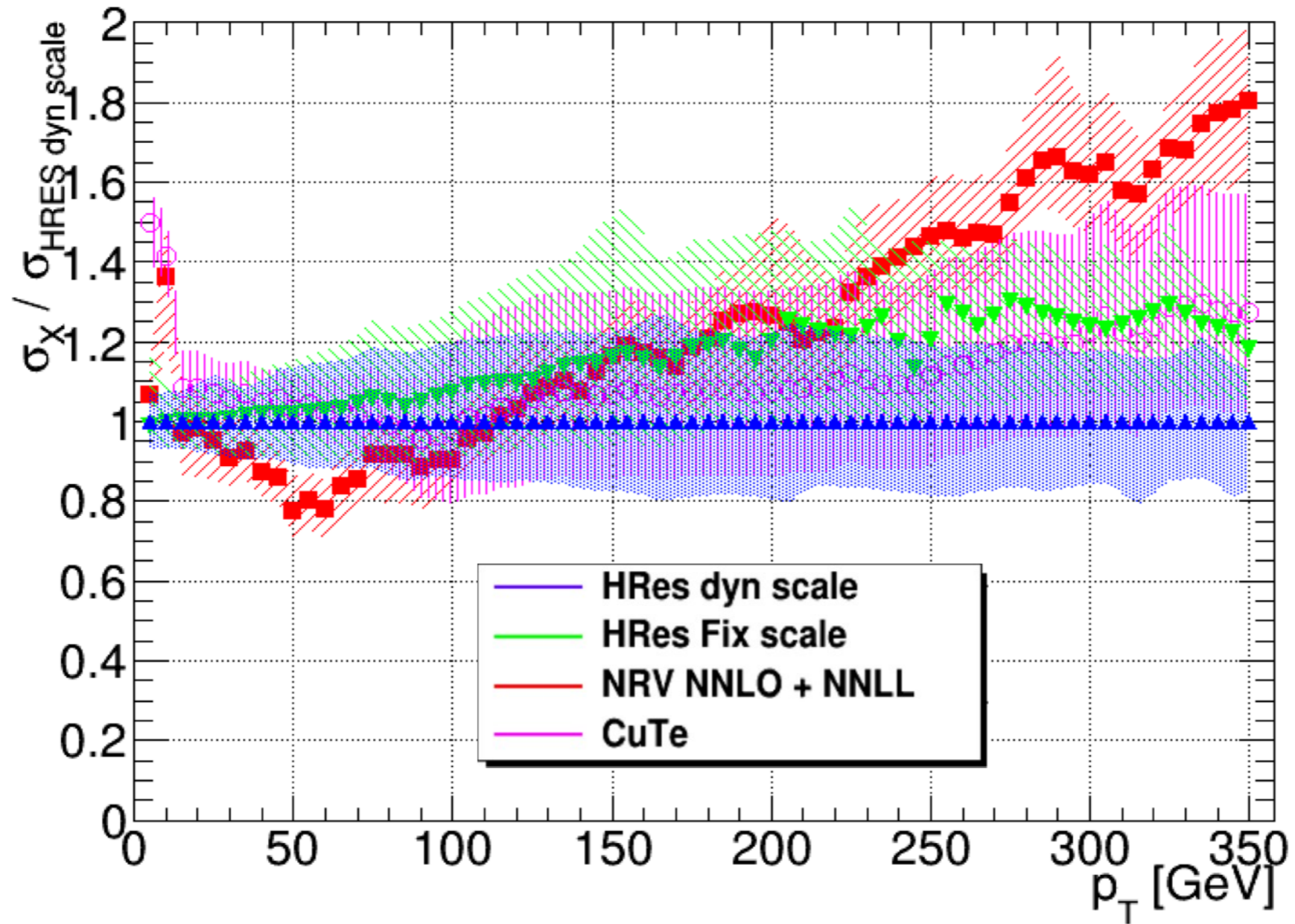
Additional kinematic comparisons

- Additional variables, but no update today w.r.t. Summer meeting

  - 1a) Higgs pT: 40 bins 0-400 GeV
  - 1b) Higgs rapidity, 50 bins from -5 to 5
  - 1c) fraction of events >=0, >=1, >=2, >=3 jets
  - 1d) fraction of events with =0, =1, =2, =3 jets
  - 1e) Higgs pT separately for =0, =1, =2, >=3 jets

    20 bins, 0-400 GeV

  - Jet kinematics
  - 2a) pTj1, pTj2, pTj3: 10 GeV wide bins 0-300
  - 2b) pT(H j1 j2) : 10 GeV wide bins 0-300
  - 2c) yj1, yj2, yj3: 20 bins -5 to 5

  - 2-jet/VBF region :
  - 3a) m_jj: 40 bins 0-1000 GeV
  - 3b) \Delta\y(j1,j2) 40 bins 0-10
  - 3c) \Delta\phi(j1,j2) 20 bins from 0-pi

  - VBF-topology fiducial regions:
  - 4a,b) fractions of events with m(jj) > 400 GeV, Dy(jj) > 2.8 with and without rejecting a third jet
  - 4c,d) fractions of events with m(jj) > 600 GeV, Dy(jj) > 4.0 with and without rejecting a third jet

Massironi

Results

Azimuthal separation of leading and subleading jet
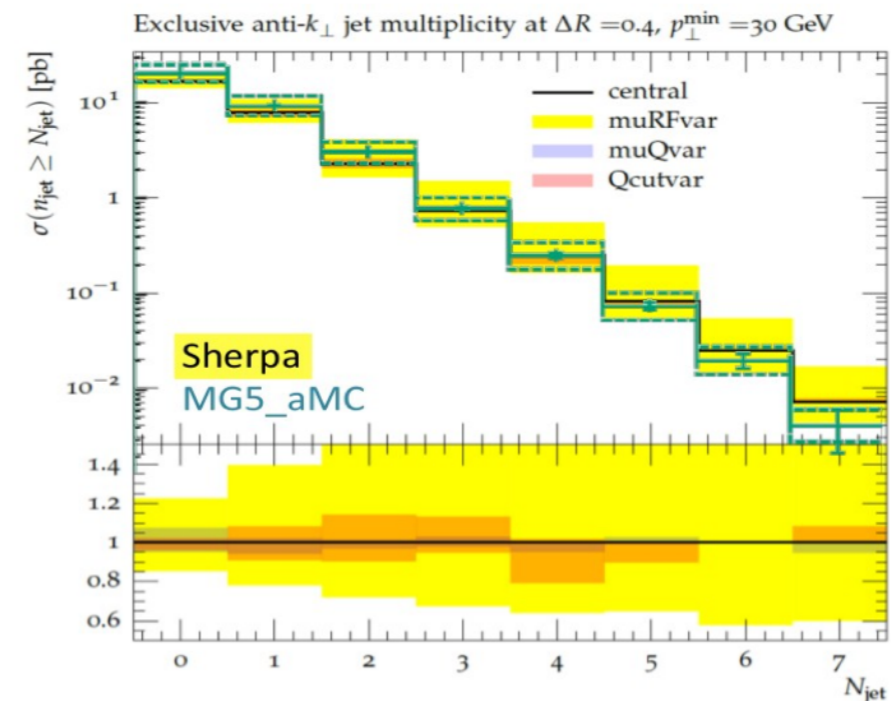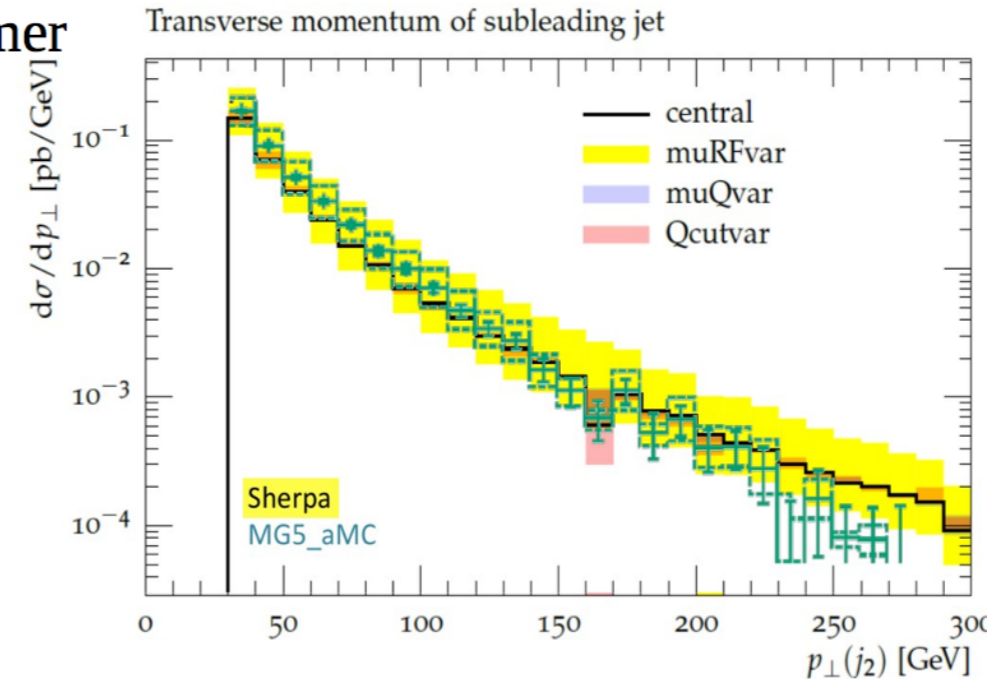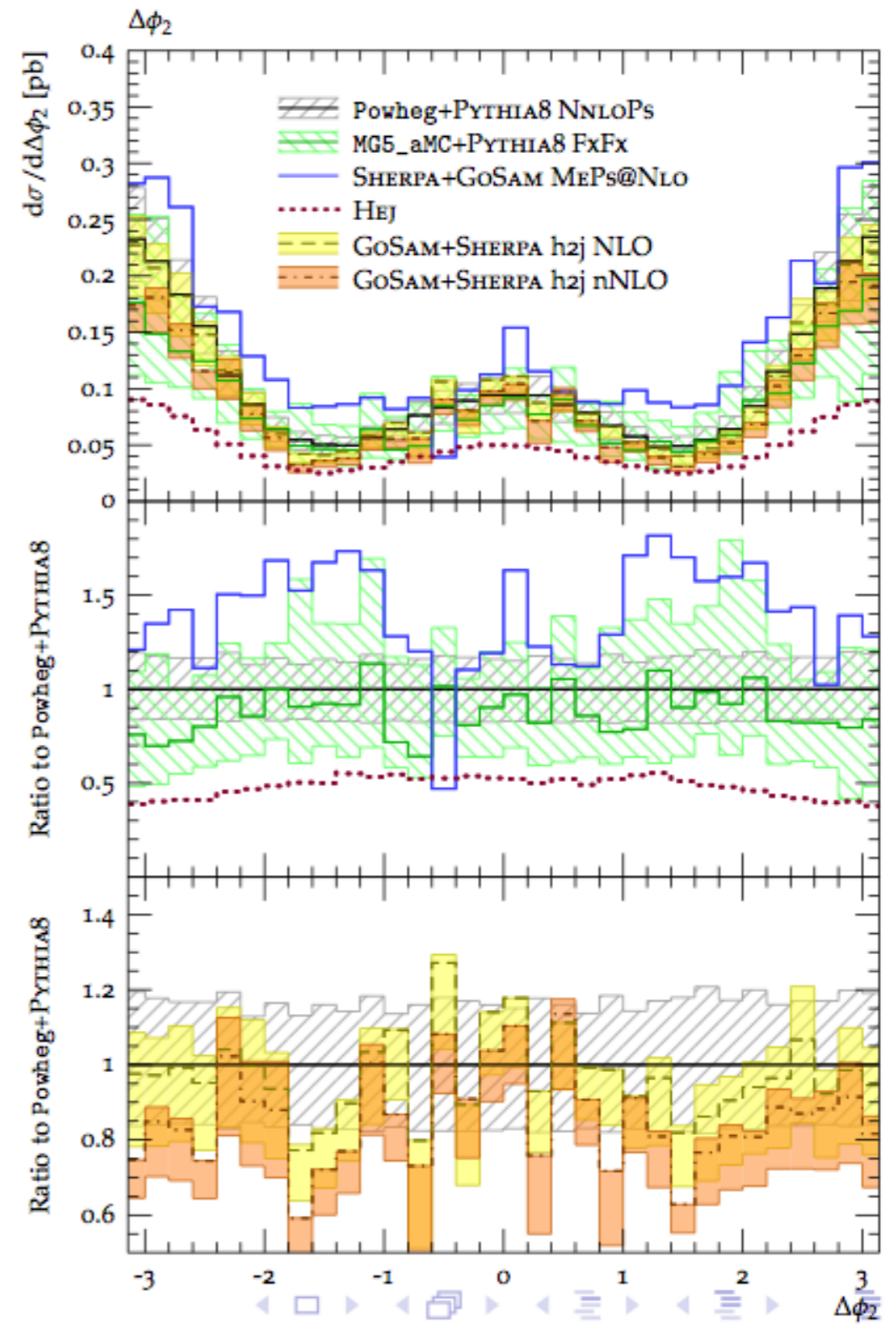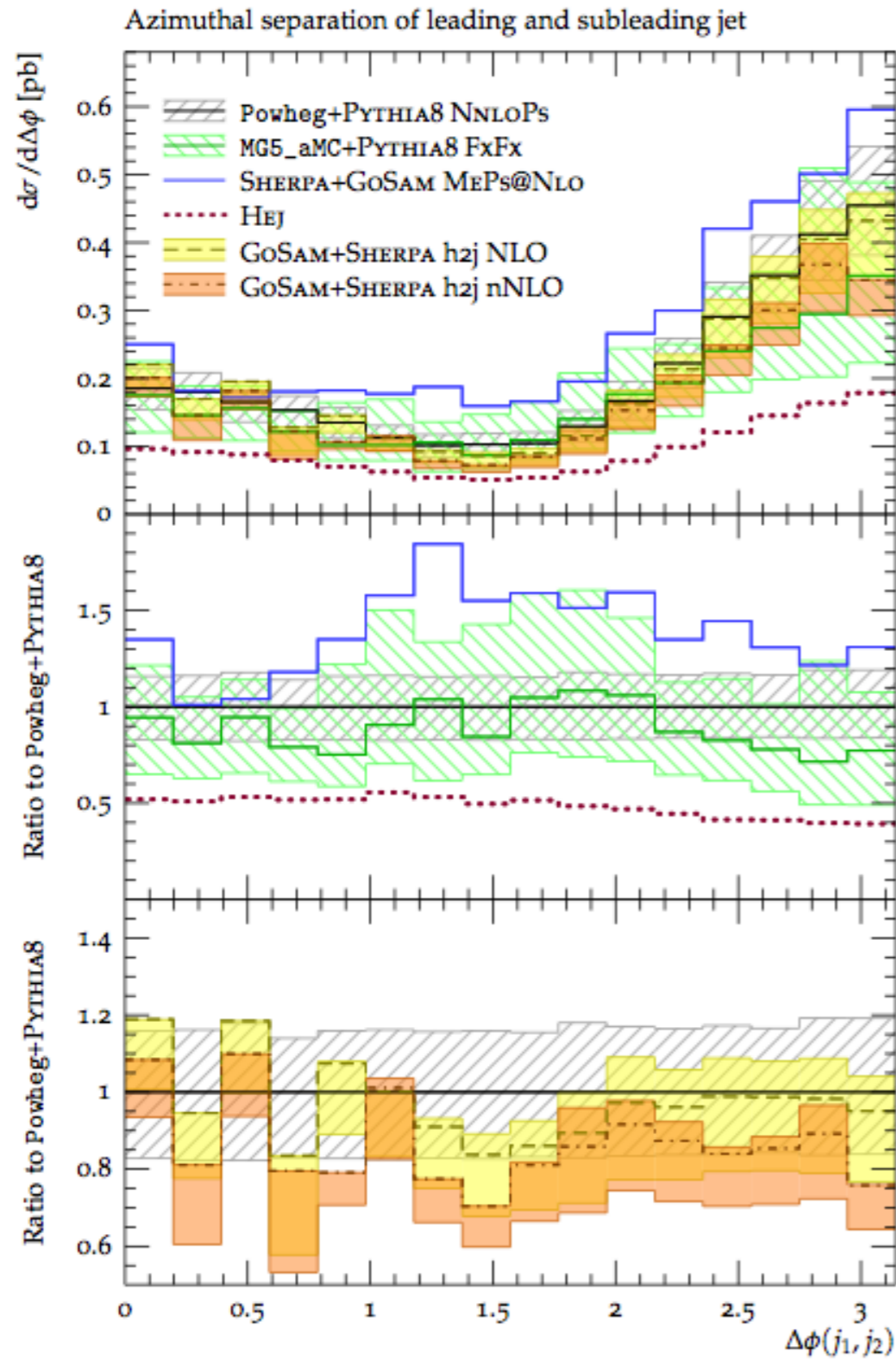
VBF+VH

General plan for the YR4

- Last meeting called on Jan 8th to check the status of the ongoing activities
  https://indico.cern.ch/event/476326/

- VBF
  - H+2j – NNLO QCD total cross section/mass scan
    - Zaro et al. (VBFNNLO)
  - H+2j – NNLO QCD + NLO EWK fiducial/differential cross sections
    - Zanderighi, Cacciari, Salam et al. (QCD), Dittmaier et al. (EWK - HAWK)
  - H+3j – NLO QCD additional jet distributions
    - Jäger et al (POWHEG), Platzer, Figy et al (HERWIG, aka HJets++)
  - ggH+3j – NLO QCD central jet distributions for veto purpose
    - Luisoni et al (GoSAM)
- VH
  - NNLO QCD + NLO EWK total/fiducial/differential cross sections
    - Tramontano et al. + Harlander et al. (QCD – HV@NNLO), Dittmaier et al (EWK – HAWK)
  - NNLO QCD differential cross sections
    - Campbell, Ellis, Williams
  - NLO QCD differential cross sections
    - Frixione et al (aMC@NLO), Luisoni et al (POWHEG), ATLAS+CMS (aMC@NLO+POWHEG)
  - ggZH differential cross sections
    - Vryonidou et al. (Madgraph), ATLAS+CMS (aMC@NLO+POWHEG)
  - NNLOPS differential cross sections
    - Re, Zanderighi et al (POWHEG)

Perrozzi

VBF: SM cross sections at NNLO QCD + NLO EW

The plan:

Update of total and fiducial state-of-the-art SM cross sections

for $\sqrt{s} = 7, 8, 13, 14\,\text{TeV}$ and $M_\text{H} = 120.0, 120.1, ... 125.0, 125.09, ... 130.0\,\text{GeV}$ for SM

Cuts for the fiducial XS:

$$p_{\text{T},j} > 20\,\text{GeV}, \quad |y_j| > 20\,\text{GeV}, \quad |y_{j_1} - y_{j_2}| > 3, \quad m_{jj} > 130\,\text{GeV}$$

Note: Cut on m_{jj} quite loose to maximize available phase space

↪ effects of harder cuts can be read from distributions

Scale choice: $\mu_\text{R} = \mu_\text{F} = M_\text{W}$ (dyn. scale better?)

State-of-the-art XS:

$$\sigma^{\text{VBF}} = \sigma^{\text{DIS}}_{\text{NNLOQCD}} (1 + \delta_{\text{EW}}) + \sigma_\gamma$$

$\sigma^{\text{DIS}}_{\text{NNLOQCD}}$:   based on Cacciari et al., arXiv:1506.02660

(+ Bolzoni et al., arXiv:1003.4451 for total XS)

Perrozzi

VH: SM cross sections at NNLO QCD + NLO EW

The plan:

Update of total and fiducial state-of-the-art SM cross sections with W/Z decays for $\sqrt{s} = 7, 8, 13, 14\,\text{TeV}$ and $M_\text{H} = 120.0, 120.1, ...125.0, 125.09, ...130.0\,\text{GeV}$

Cuts for the fiducial XS:

$$p_{\text{T},\ell} > 15\,\text{GeV}, \quad |y_\ell| < 2.5, \qquad \text{for } Z \to \ell\ell: \quad 75\,\text{GeV} < M_{\ell\ell} < 105\,\text{GeV}$$

State-of-the-art XS:

$$\sigma^\text{VH} = \sigma^\text{DY}_\text{NNLOQCD}(1 + \delta_\text{EW}) + \sigma^\text{non-DY}_\text{NNLOQCD} + \sigma_\text{gg} + \sigma_\gamma$$

$\sigma^{\ddot{}}_\text{NNLOQCD}$: total XS: `vh@nnlo` (Harlander et al.)

diff. XS: Ferrera et al., arXiv:1107.1164, arXiv:1405.4827,

MCFM (Campbell et al.), arXiv:1601.00658

σ_gg: total NLO XS: Altenkamp et al., arXiv:1211.5015,

diff. XS: NLO unknown , LO available from POWHEG and Madgraph

(recipe: K-factor from total XS, but keep LO relative uncertainties)

Perrozzi

ttH+tH

1. NLO QCD+EW predictions for $t\bar{t}H$ production

2. Comparison of NLO QCD+PS simulations of $t\bar{t}H$ production

3. Off-shell effects in $t\bar{t}H$ production and decay

4. $t\bar{t}H$ production beyond NLO QCD

5. $tH + \bar{t}H$ production at NLO QCD

6. $t\bar{t}V(V)$ production at NLO QCD+EW

   } Backgrounds

7. NLO+PS simulations of $t\bar{t}b\bar{b}$ production

Pozzorini

Off-shell

Summary

- YR4 write-up will be finished by end of January

- A lot of work done on Hgg interference section already in a good shape

  → Additional studies to be added from ATLAS after internal approval

- Possibile improvements:

  1 → Study interference effects and mass shift varying the width of the Higgs

  2 → Look at VBF production (to discuss with Sherpa Authors)

External theory contributions are complete and included in YR4
Please have a look at the YR4 draft on SVN

Kauer,Soffi

Status

Higgs Production		SM Higgs-boson production 125GeV						BSM Higgs-boson production with NWA			
		Mass scan MH=[120,130]GeV (38 points)				Ecm scan: √s = [6,15] TeV		MH=[10,3000] GeV (115 points)			
	Comments	7 TeV	8 TeV	13 TeV	14 TeV	(19 points)		7 TeV	8 TeV	13 TeV	14 TeV
ggF	N3LO (by the end of Feb.?)	-	-	-	-	-		-	-	-	-
	NNLO+NNLL	OK	OK	OK	OK	OK		OK	OK	OK	OK
VBF	NNLO QCD + NLO EW	OK	OK	OK	OK	- [1]		-	-	-	-
WH (also W+H and W-H)		OK	OK	OK	OK	OK		OK	OK	OK	OK
ZH (also gg→ZH)		OK	OK	OK	OK	OK		OK	OK	OK	OK
ttH		OK	OK	OK	OK	OK		OK	OK	OK	OK
tH		OK	OK	OK	OK	OK		OK	OK	OK	OK
bbH	5FS ready	-	-	-	-	-		-	-	-	-
		MH=[124.5, 125.0, 125.09, 125.5] GeV (4 points)									
ccH	(XS is 1/6 of bbH)	OK	OK	OK	OK						
HH		OK	OK	OK	OK						
ttHH		OK	OK	OK	OK						
qqHH		OK	OK	OK	OK						
tjHH		OK	OK	OK	OK						
VHH (V=W,Z)	nnlo soon, have nlo										
VVHH	No plans to do this one										
HHH		OK	OK	OK	OK						
VVH (V=γ,W,Z)	Who?	-	-	-	-						

Higgs Decays		Mass scan MH=[120,130]GeV (38 points)			
	SM Higgs boson decays	h->ff	h->VV	h->4f	
		-	-	-	
	Rare decays	MH=[124.5, 125.0, 125.09, 125.5] GeV (4 points)			
		h->J/psi+gamm	-		
		h->W/Z+meson	-		
		...			

courtesy of Reisaburo

Future

For WG1 the future looks clear:

- update theoretical predictions as soon as new results become available

- support experimental groups in the use of the tools and in the assessment of uncertainties

If a reorganisation of the HXSWG is foreseen, we should probably go for a simpler structure

3-layered structure (subgroups - WG1 - SC) maybe not the most effective ?