Higgs production at the Tevatron: theoretical predictions and uncertainties

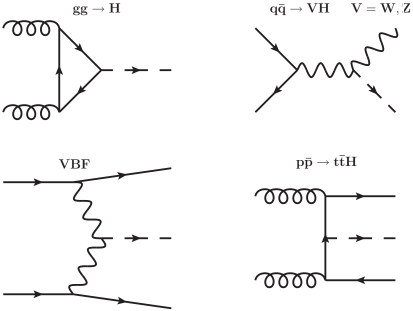
Julien Baglio

Laboratoire de Physique Théorique, Orsay

ICHEP 2010 - July 22nd, 2010

(J.B., A. Djouadi, arXiv:1003.4266 [hep-ph] submitted to JHEP)

Main production channels

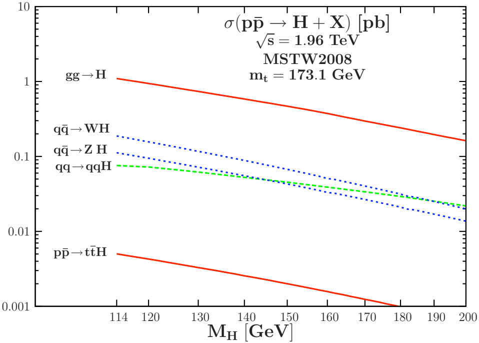


- gluon–gluon fusion and Higgs–strahlung known at NNLO in QCD
- $t\bar{t}H$ known at NLO only
- VBF pushed partly to NNLO in 2010
  (Bolzoni, Maltoni, Moch, Zaro; arXiv:1003.4451)
  but considered in this talk at NLO only ($\sim$ 0.3% difference)

Higgs production at Tevatron

$M_H \gtrsim 150$ GeV, $gg \to H$ channel
Exact at NLO QCD[a], $K_{\rm NLO} \sim 2$
Infinite top mass at NNLO QCD[b], $K_{\rm NNLO} \sim 3$
Exact NLO EW corrections[c],
Effective NNLO mixed QCD-EW[d]: $\simeq \pm$ a few %

$M_H \lesssim 150$ GeV, $p\bar{p} \to HV$ channel
Exact at NNLO QCD[e], $K_{\rm NNLO} \sim 1.5$
Exact NLO EW corrections[f] $\simeq -5\%$
CKM effects included ($\sim -5\%$)



[a] Dawson (EFT, 1991), Djouadi, Spira & Zerwas (EFT, 1991); Spira, Djouadi, Graudenz, Zerwas (1995)
[b] Harlander & Kilgore (2002), Anastasiou & Melnikov(2002), Ravindran, Smith & V. d. Neerven (2003)
[c] Djouadi & Gambino (1994), Aglietti *et al.* (2004), Degrassi & Maltoni (2004), Actis *et al.* (2008)
[d] Anastasiou, Boughezal, Pietriello (2009)
[e] Hamberg, V. d. Neerven & Matsuura (1991), Brein, Djouadi & Harlander (2004)
[f] Ciccolini, Dittmaier, Krämer (2003)

Resummation in the gluon–gluon fusion channel?

Gluon–gluon fusion channel known up to Next-to-Next-to-Leading-Logarithm (NNLL)
(Catani, de Florian, Grazzini & Nason (2003)). But here not included because:

- Experimental analysis still at the NNLO
  $\Rightarrow$ theoretical input should be (for now) at NNLO
- Cross section with cuts (and no resummation) have reduced K–factors
  $\Rightarrow$ should be seen in the NNLO scale uncertainty
- No PDF at the NNLL level until now
  $\Rightarrow$ calculation slightly inconsistant (Corcella & Magnea (2005))

Scale uncertainty

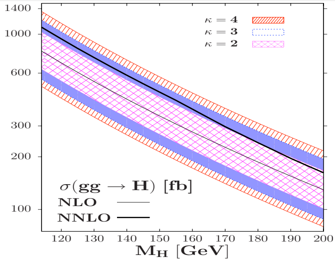
Higher orders (HO) guessed with μ_R, μ_F variation around central $\mu_0 = m_H$

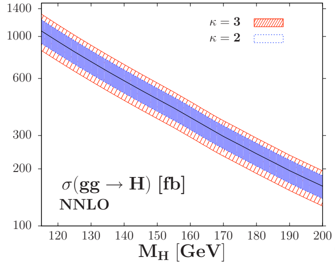
$$\frac{m_H}{\kappa} \leq \mu_R, \mu_F \leq \kappa m_H$$

Small HO $\Rightarrow \kappa = 2$ enough (ex. $q\bar{q} \to HV$)

Large HO in $gg \to H$ ($K_{HO} \simeq 3$)
guess scale domain from $\sigma_{\rm NLO}$:
NLO band catches $\sigma_{\rm NNLO}$
$\Rightarrow \kappa = 3$ needed (at least) according to our criterium
NNLO $gg \to H$: $\simeq$ **20% scale variation**

($\neq$ 10% assumed by CDF/D0)





PDF and $\alpha_s^{\mathrm{exp+th}}$ errors

Different sets of PDFs on the market

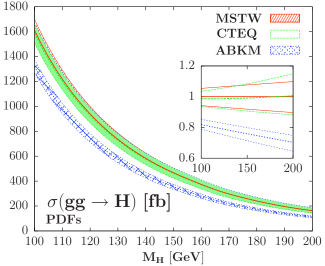
$\Rightarrow$ differents errors on individual PDF

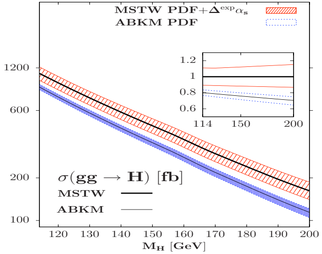
$+$ different central values

All have $\sim 5-7\%$ error, but central ABKM is 25% smaller than MSTW/CTEQ !

Add PDF+α_s^{exp} correlated error (MSTW dedicated set)

$\Rightarrow \alpha_s(M_Z) = 0.1171 \pm 0.0034$ (90%CL) error





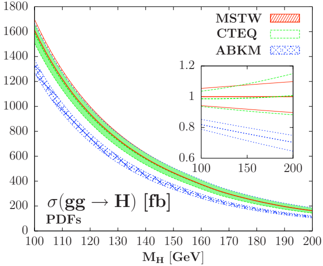
PDF and $\alpha_s^{\text{exp+th}}$ errors

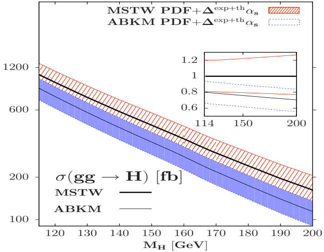
Different sets of PDFs on the market
$\Rightarrow$ differents errors on individual PDF
$+$ different central values
All have $\sim 5-7\%$ error, but central ABKM is 25% smaller than MSTW/CTEQ !

Add PDF+α_s^{exp} correlated error (MSTW dedicated set)
$\Rightarrow \alpha_s(M_Z) = 0.1171 \pm 0.0034$ (90%CL) error

Add $\Delta^{\text{th}}\alpha_s = 0.002$ error with central fixed–α_s MSTW PDF sets
$\Rightarrow$ ABKM is now consistent with MSTW/CTEQ

$\sim$ 20% final error $\gg$ 5% PDF alone





Effective theory at NNLO

NNLO: easier with $M_{\rm loop} \gg M_H$

Good for t–loop (Marzani *et al.* 2008, Harlander *et al.* 2009)
Not for b–loop: $\sim 10\%$ error at NLO

$$\Delta^{\rm b}_{\rm NNLO} = \frac{K_{\rm NLO}}{K_{\rm NNLO}} \times \frac{\sigma^{\rm NLO}_{\rm exact} - \sigma^{\rm NLO}_{\rm EFT}}{\sigma^{\rm NLO}_{\rm exact}}$$

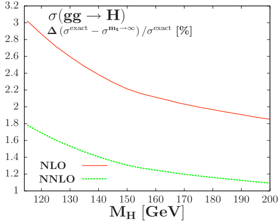
Then add M_b uncertainty (on-shell versus $\overline{\rm MS}$)

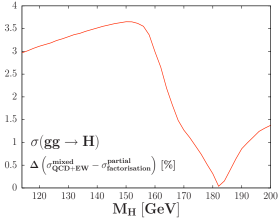
b–loop uncertainty: $\pm 2 - 3\%$

Exact EW corrections at NLO (Actis *et al.* 2008)
Effective theory for NNLO mixed QCD–EW, $M_H \ll M_{W,Z}$ (Anastasiou *et al.* 2009)

$$\Delta^{\rm EW}_{\rm NNLO} = \frac{\sigma_{\rm mixed} - \sigma_{\rm NLO\ EW}}{\sigma_{\rm mixed}}$$

Add at most $\sim \pm 3.5\%$ error





Putting together all the errors

Combining the errors: quadature or linear?

CDF: 10% scale $\oplus$ 5% PDF = 11% total error

D0: 10% total error

Reasonable way: add in quadature

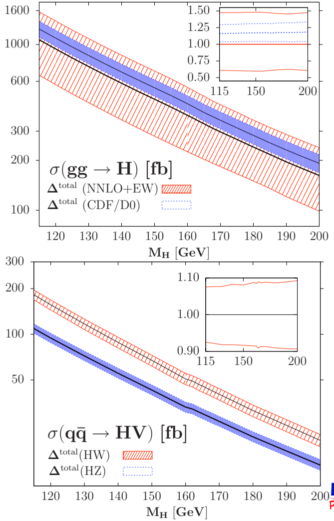
PDF+$\Delta^{\rm exp+th}\alpha_s$ on $^{\rm min}_{\rm max}\sigma(\mu)$

and eventually linearly the small EW and b–loop errors

$gg \to H$: $\sim \pm 40\% \gg \sim 10\%$ CDF/D0

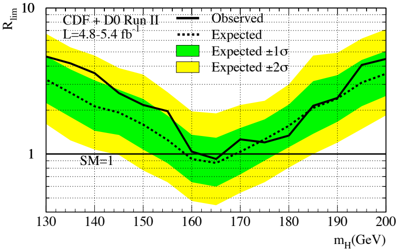
$p\bar{p} \to HV$: $\sim \pm 10\% > \sim 5\%$ CDF/D0

$p\bar{p} \to HV$ much more under control



CDF+D0 exclusion bands?

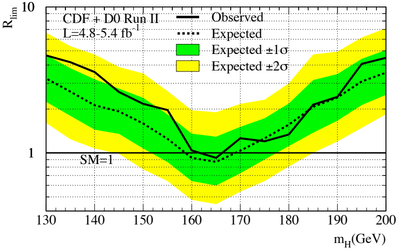
CDF& D0: excluded $M_H \in [162 - 166]$ GeV (Phys. Rev. Lett. 104, 061803 (2010))

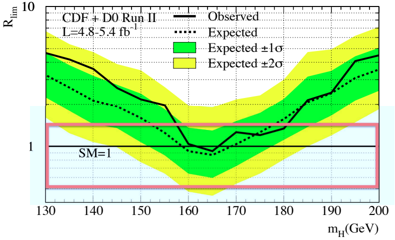


CDF+D0 exclusion bands?

CDF& D0: excluded $M_H \in [162 - 166]$ GeV (Phys. Rev. Lett. 104, 061803 (2010))

But with our errors:





This 95% CL exclusion should therefore be reconsidered

Summary and conclusion

Higgs production at Tevatron

- The two most important channels have been revisited at Tevatron (minor update for the two others)

Summary and conclusion

Higgs production at Tevatron

- The two most important channels have been revisited at Tevatron (minor update for the two others)
- gluon–gluon fusion has been thoroughtly studied with all uncertainties: scale, PDF, $\alpha_s^{\text{exp+th}}$, EFT

Summary and conclusion

Higgs production at Tevatron

- The two most important channels have been revisited at Tevatron (minor update for the two others)
- gluon–gluon fusion has been thoroughtly studied with all uncertainties: scale, PDF, $\alpha_s^{\text{exp+th}}$, EFT
- Higgs–strahlung has been revisited with all major uncertainties: scale, PDF, $\alpha_s^{\text{exp+th}}$

Summary and conclusion

Higgs production at Tevatron

- The two most important channels have been revisited at Tevatron (minor update for the two others)
- gluon–gluon fusion has been thoroughtly studied with all uncertainties: scale, PDF, $\alpha_s^{\text{exp+th}}$, EFT
- Higgs–strahlung has been revisited with all major uncertainties: scale, PDF, $\alpha_s^{\text{exp+th}}$
- **The overall $\simeq 40\%$ error on $gg \to H$ cross section implies that the Tevatron exclusion bands on Higgs mass should be revisited**

Summary and conclusion

Higgs production at Tevatron

- The two most important channels have been revisited at Tevatron (minor update for the two others)
- gluon–gluon fusion has been thoroughtly studied with all uncertainties: scale, PDF, $\alpha_s^{\rm exp+th}$, EFT
- Higgs–strahlung has been revisited with all major uncertainties: scale, PDF, $\alpha_s^{\rm exp+th}$
- **The overall $\simeq 40\%$ error on $gg \to H$ cross section implies that the Tevatron exclusion bands on Higgs mass should be revisited**
- **Same has also been done at ℓHC = LHC@7 TeV and 1 fb^{-1} for gluon–gluon fusion**, MSSM study under way

Backup: $gg \to H$ at the LHC@7 TeV

Combination: same exercice as at Tevatron

Final error in gg → H: $\sim -25\%$, $\sim +30\%$

much more under control than at Tevatron ($\sim -40\%, +50\%$ error).