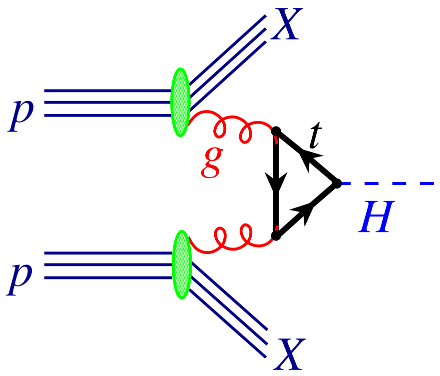
Higgs production at the LHC
– Theory Status –

Robert Harlander

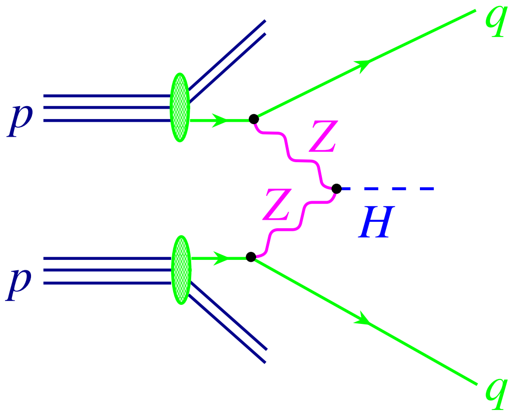
`CERN, July 8, 2003`

- Introduction
- Gluon fusion
- Weak Boson Fusion
- Higgs Strahlung
- $t\bar{t}H$ & $b\bar{b}H$
- Conclusions and Goals

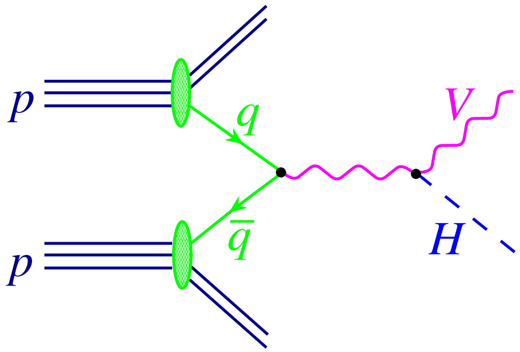
Production Modes



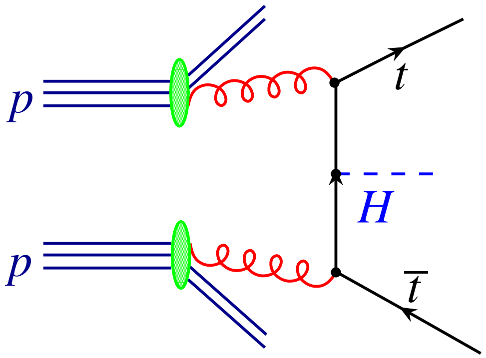
Gluon fusion



Weak Boson Fusion

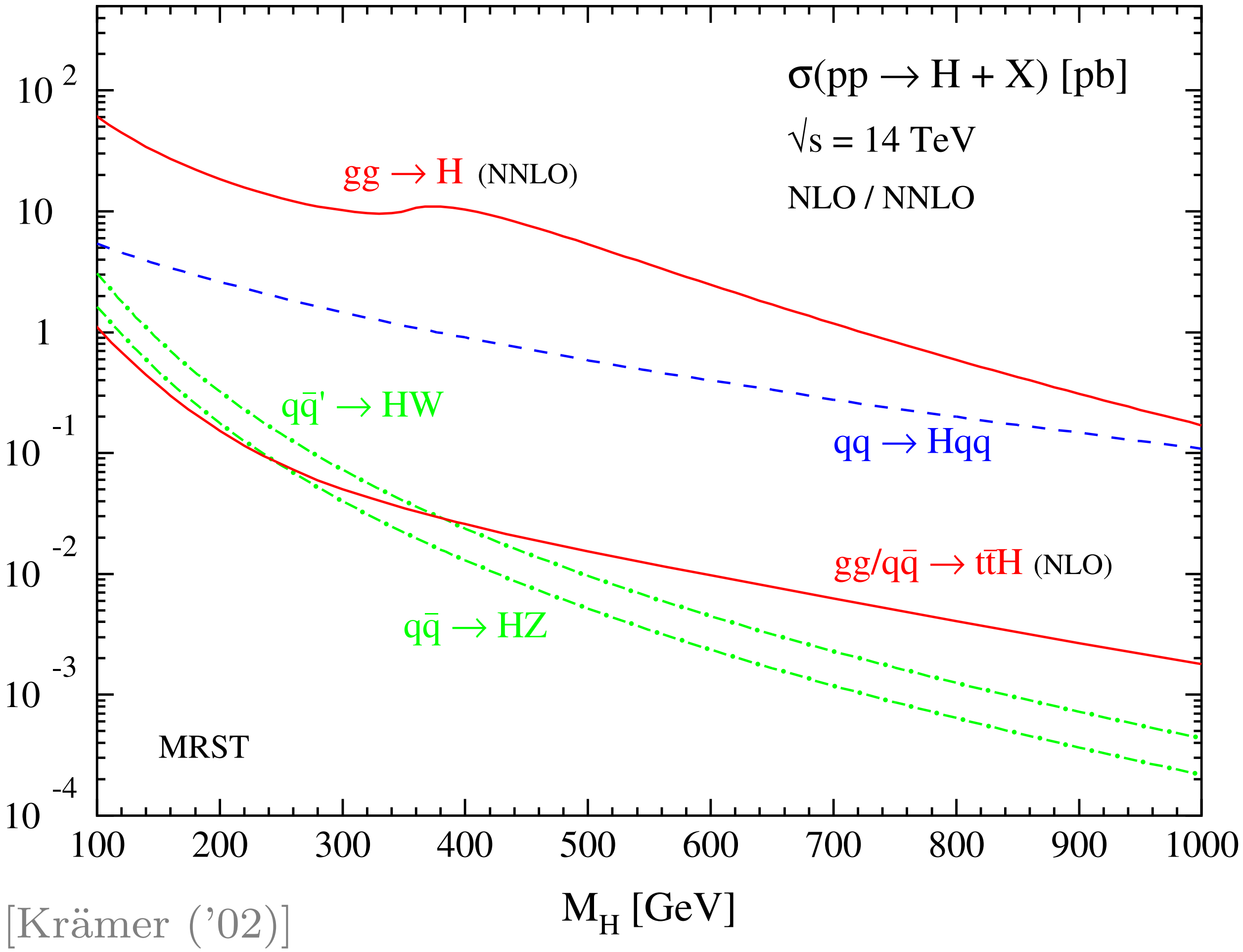


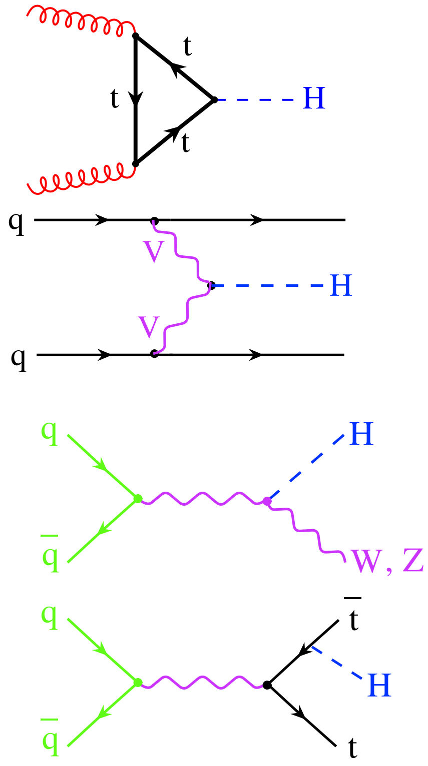
Higgs Strahlung



$t\bar{t}H$

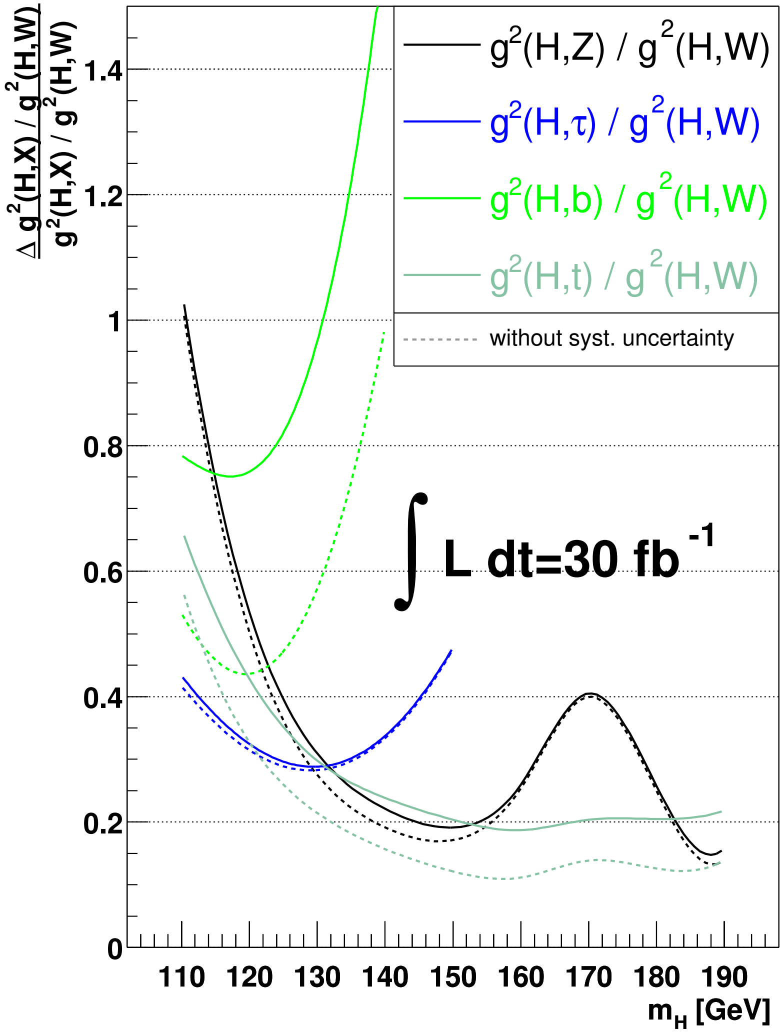
Cross sections at the LHC





[Krämer ('02)]

Combination: Couplings

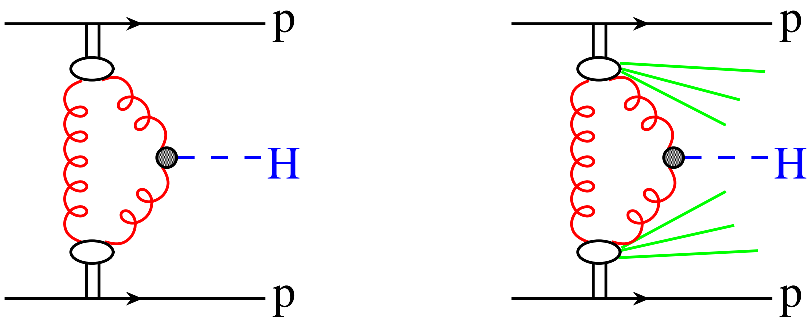


[Duehrssen, Jakobs]

→ talk by D. Zeppenfeld

Thu, 9.00am, Higgs session, Council Chamber

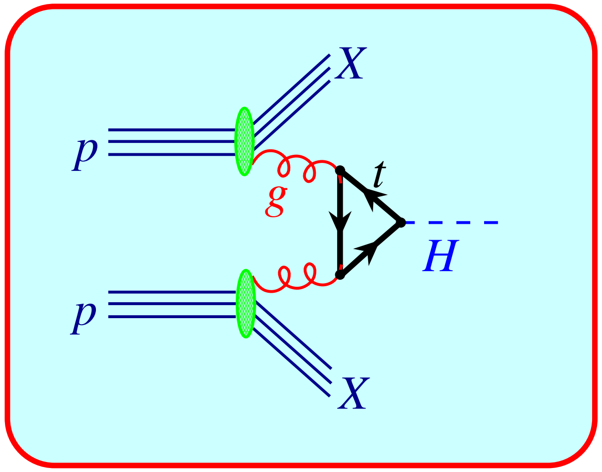
Diffractive Higgs Production



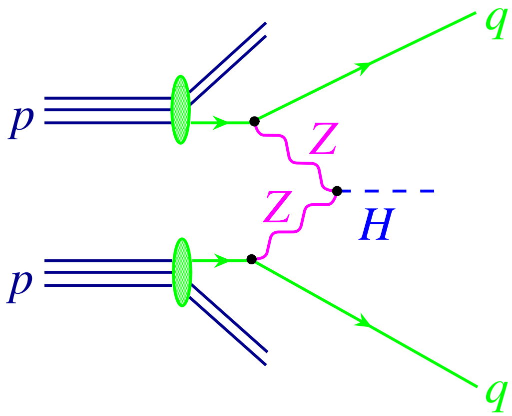
- protons detected in roman pot detectors
- first investigations ('90):
  [Bialas, Landshoff, Szeremeta, Janik, Nachtmann, Schäfer, Schöpf, ...]
- recent activity: → talk by A. de Roeck

  Wed 13.45, Higgs Session, Council Chamber

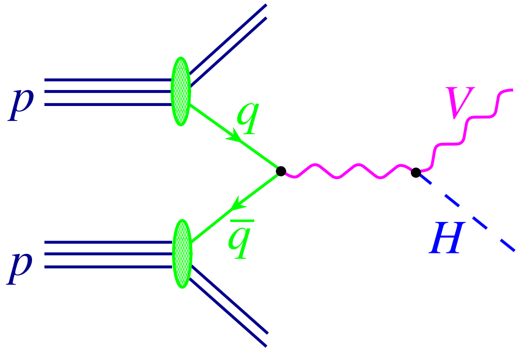
Production Modes



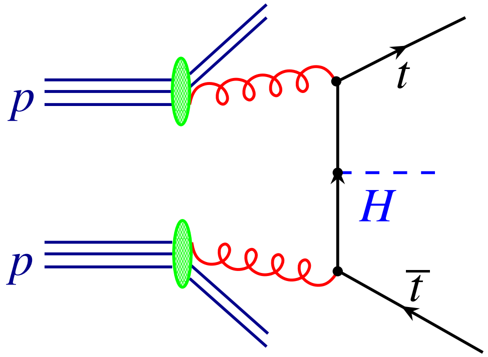
Gluon fusion



Weak Boson Fusion

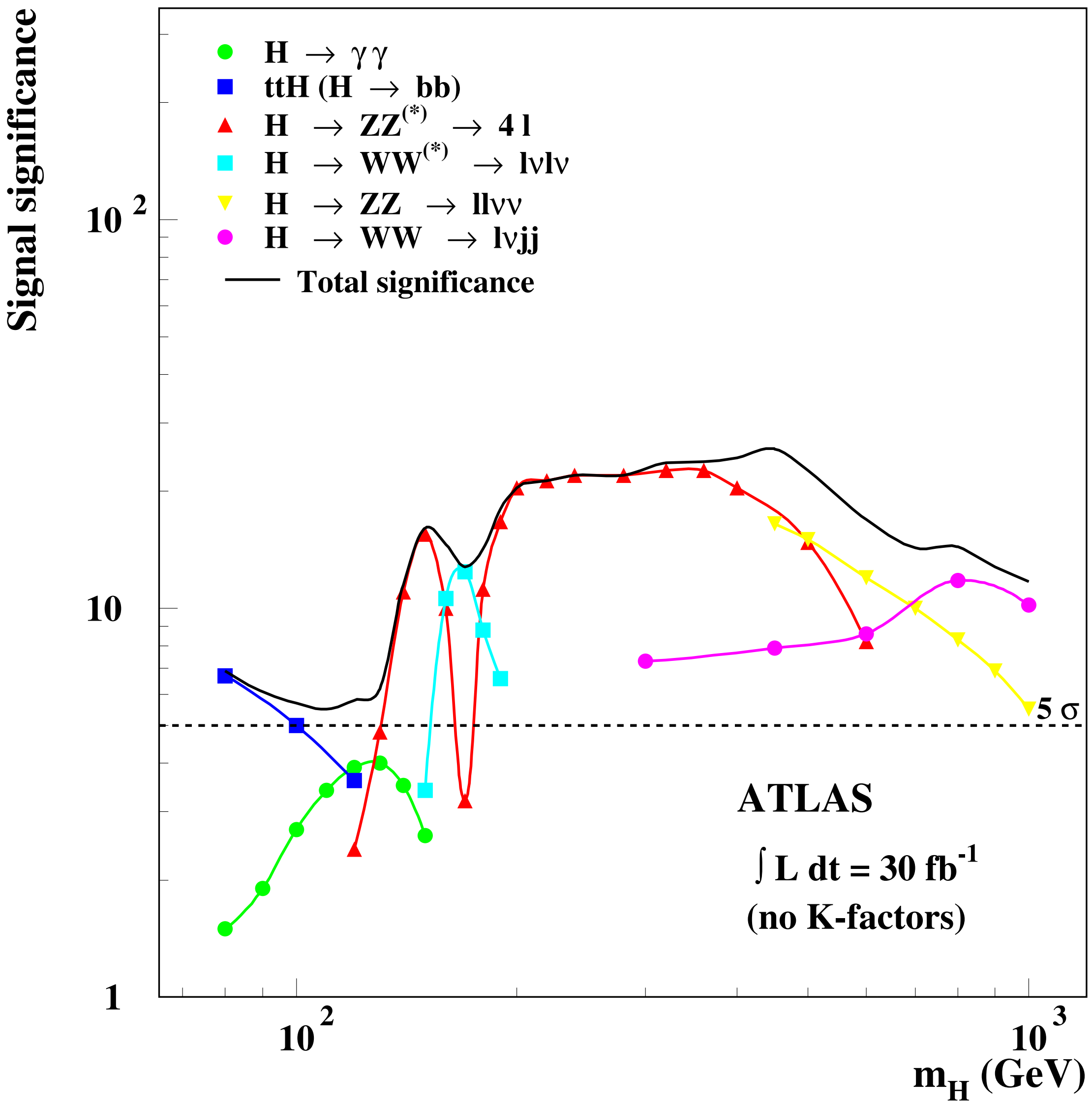


Higgs Strahlung

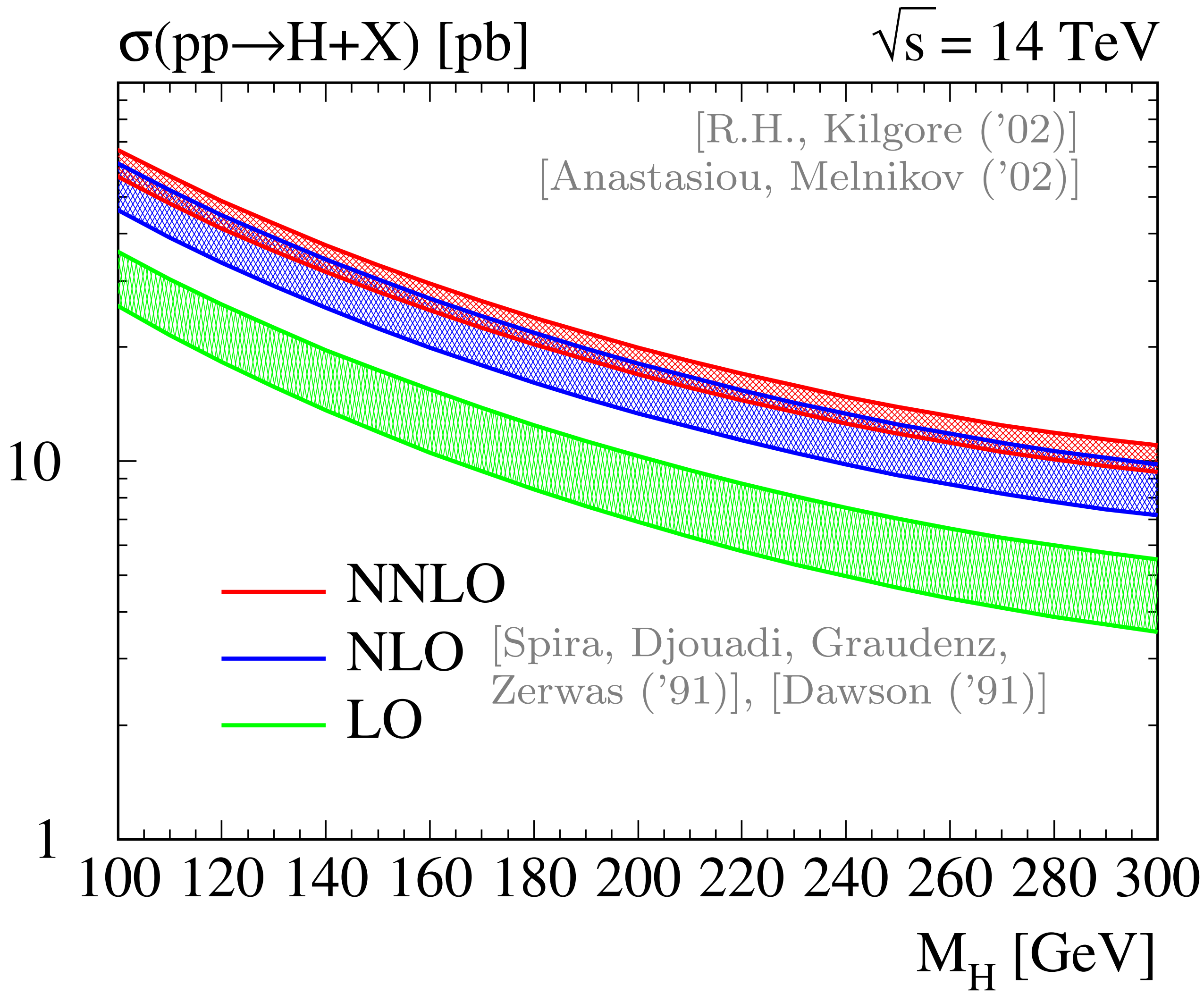


$t\bar{t}H$

Higgs discovery potential



Total cross section for $gg \to H + X$



- see also [Ravindran, Smith, v.Neerven ('03)]
- soft gluon resummation: +6% [Catani, de Florian, Grazzini, Nason]

Distributions

- Higgs Rapidity and Transverse Momentum at NLO:

$$\frac{d^2\sigma}{dp_T\,dy}\,, \qquad \frac{d\sigma}{dp_T}\,, \qquad \frac{d\sigma}{dy}$$

[de Florian, Grazzini, Kunszt ('99)]
[Glosser, Schmidt ('02)]
[Ravindran, Smith, v.Neerven ('02)]
[Bozzi, Catani, de Florian, Grazzini ('03)]
[Anastasiou, Dixon, Melnikov ('03)]

$\longrightarrow$ talk by M. Grazzini

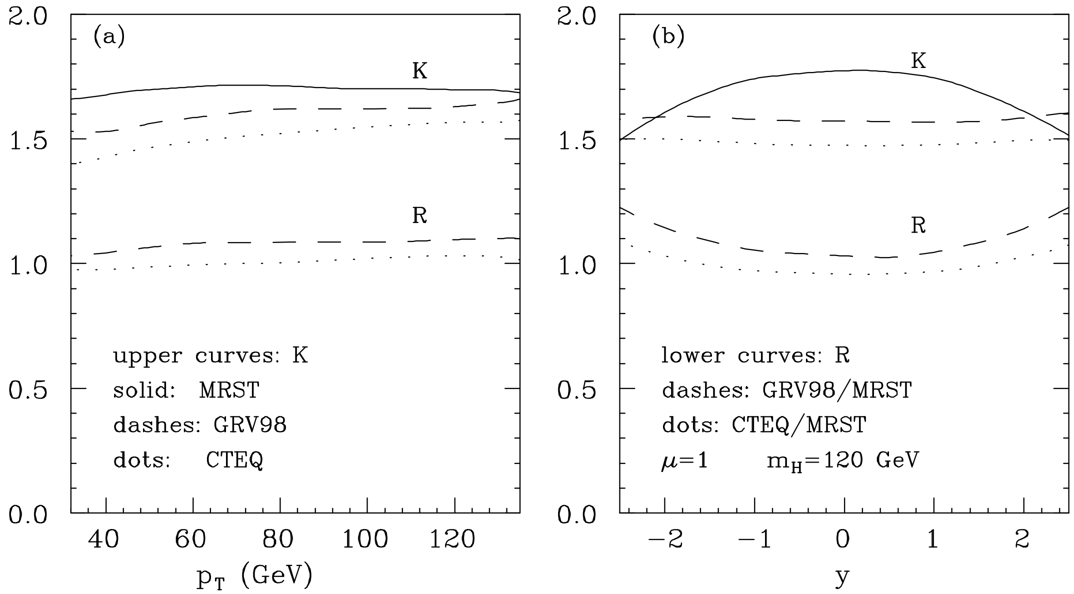
Wed, 2.10pm, Higgs session, Council Chamber

$gg \to H$: Open questions

- effective Lagrangian valid at NNLO?
- NNLO parton densities?
- Tools? NNLO Monte Carlo?
- K-factors in experimental analyses?

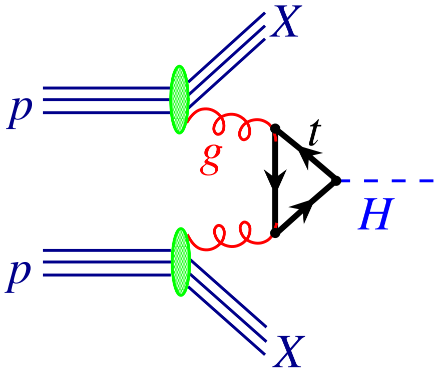
$\longrightarrow$ talk by B. Mellado
Wed, 16.45, Higgs Session, Council Chamber

- K-factors for distributions:

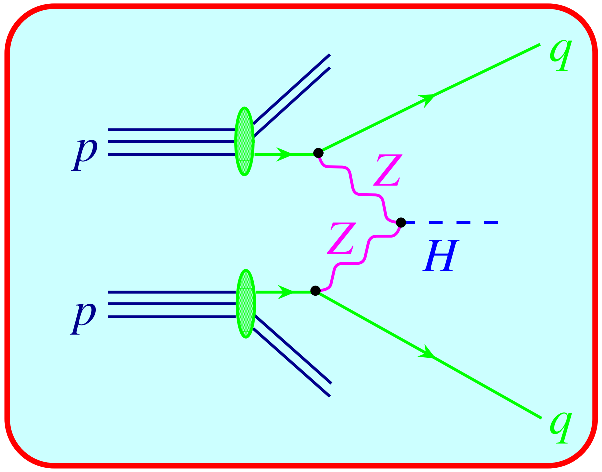


[de Florian, Grazzini, Kunszt ('99)]

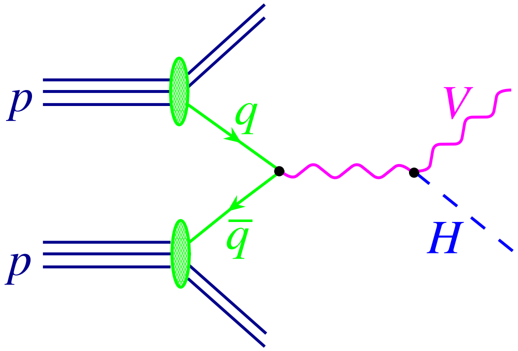
Production Modes



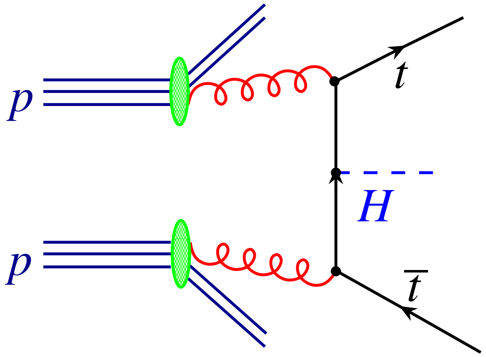
Gluon fusion



Weak Boson Fusion

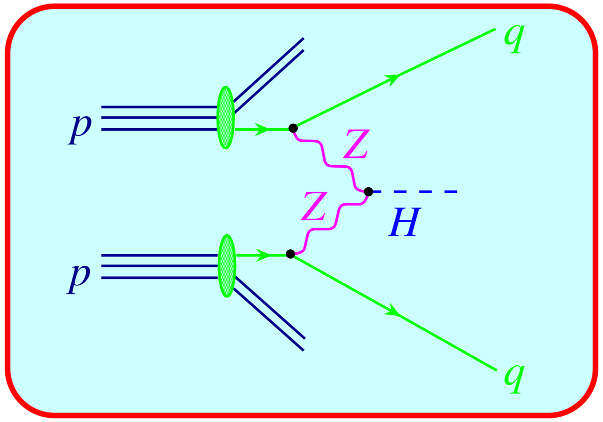


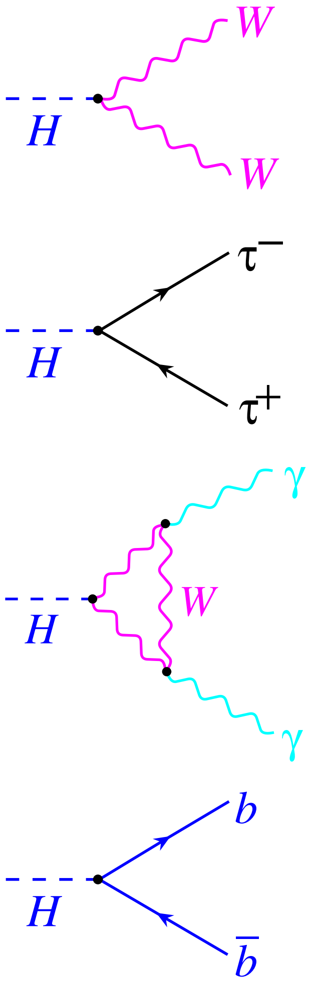
Higgs Strahlung



$t\bar{t}H$

Weak Boson Fusion

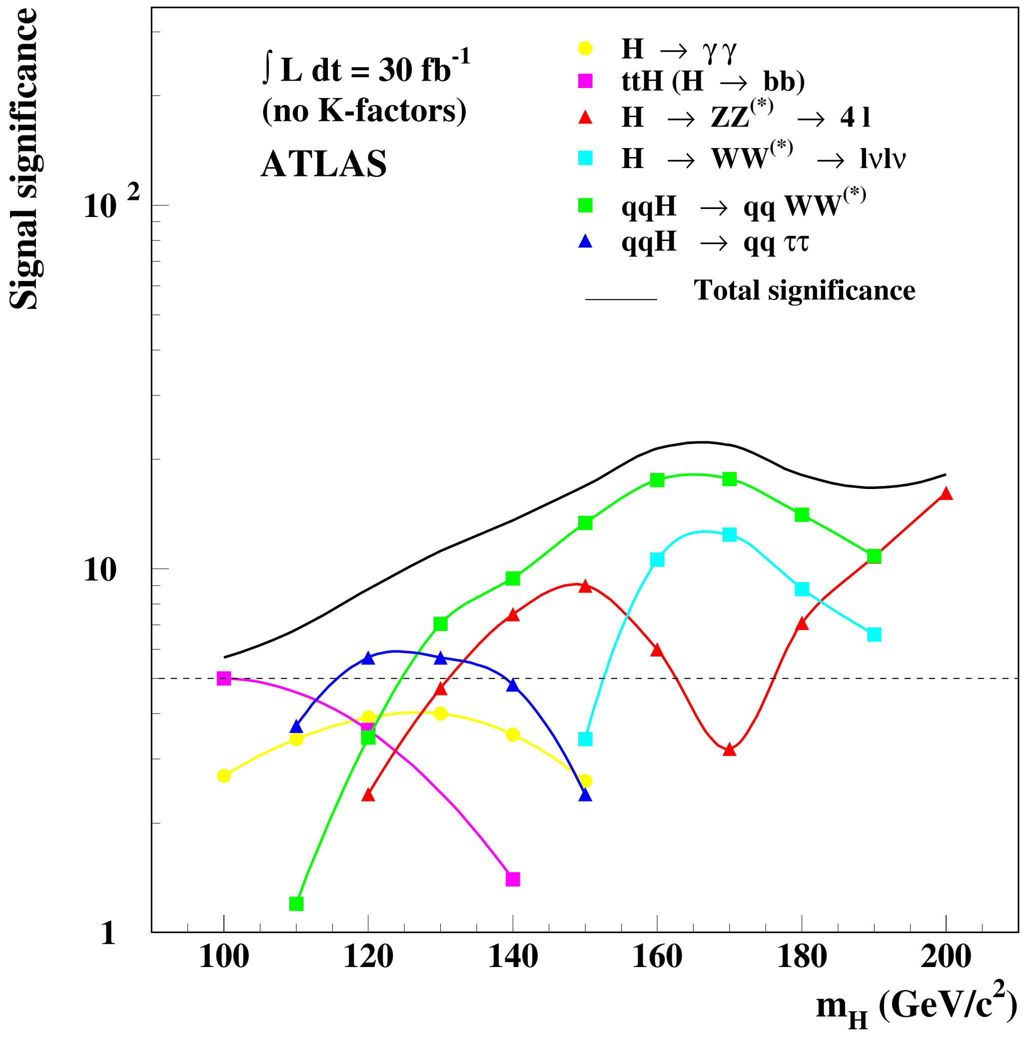




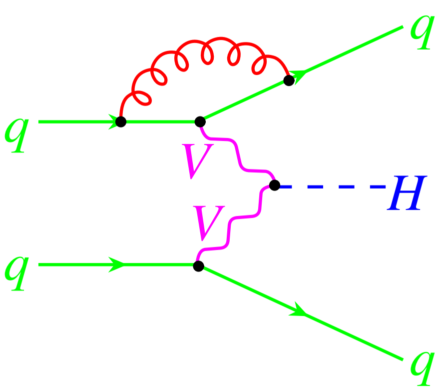
- [Rainwater, Zeppenfeld, Plehn, Kauer, Hagiwara, Eboli,. . .]
- two forward jets
- helpful for $M_H < 140\,\mathrm{GeV}$
- couplings, CP, . . .

[Mangano, Moretti, Piccinini, Pittau, Polosa ('03)]

Higgs discovery potential



Weak Boson Fusion at NLO



$\sim$ Deep inelastic scattering!

[Han, Valencia, Willenbrock ('92)]

$\approx +10\%$

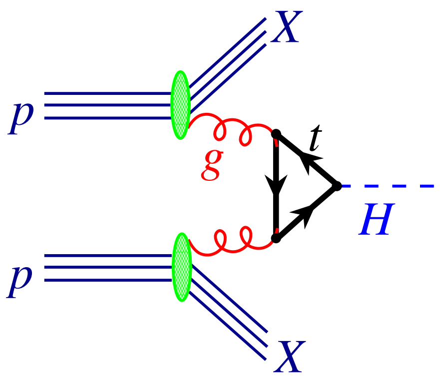
jet distributions [Figy, Oleari, Zeppenfeld ('03)]

$\longrightarrow$ Tools?

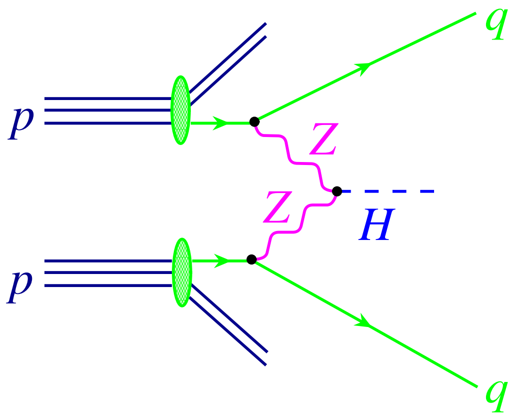
$\longrightarrow$ talk by C. Oleari

Wed, 14.35, Higgs Session, Council Chamber

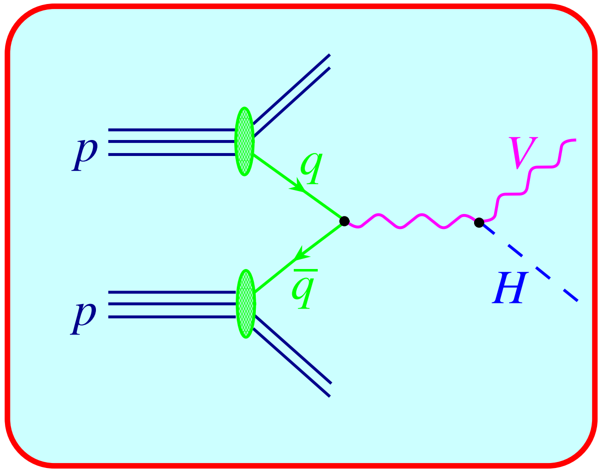
Production Modes



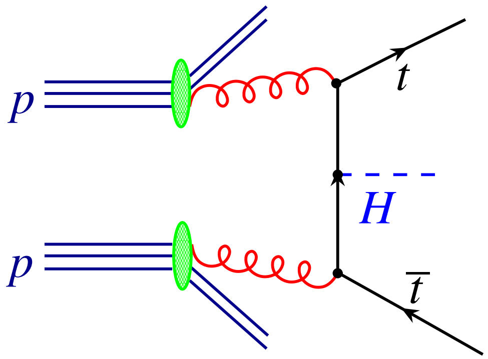
Gluon fusion



Weak Boson Fusion

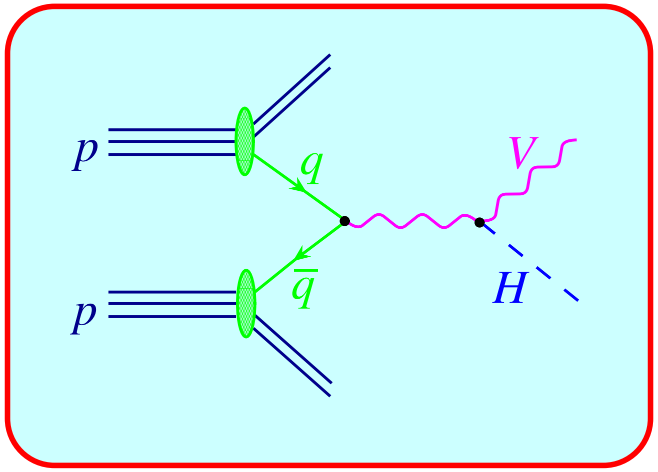


Higgs Strahlung

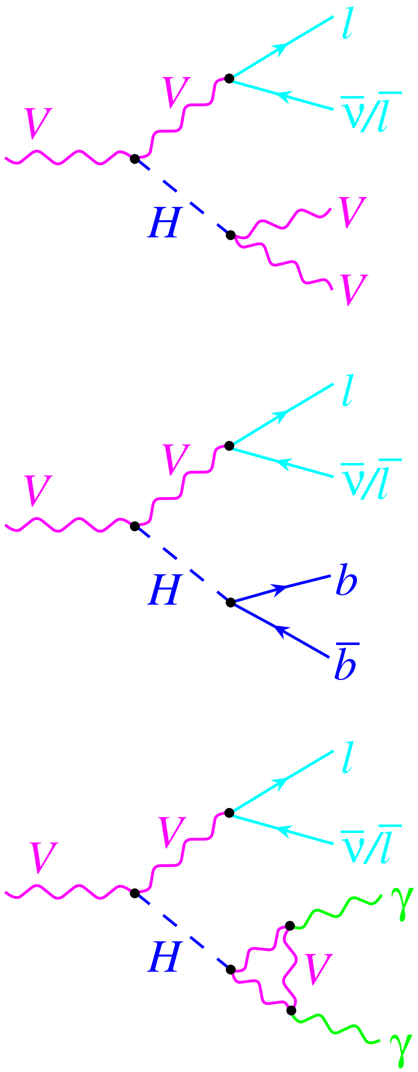


$t\bar{t}H$

Higgs Strahlung

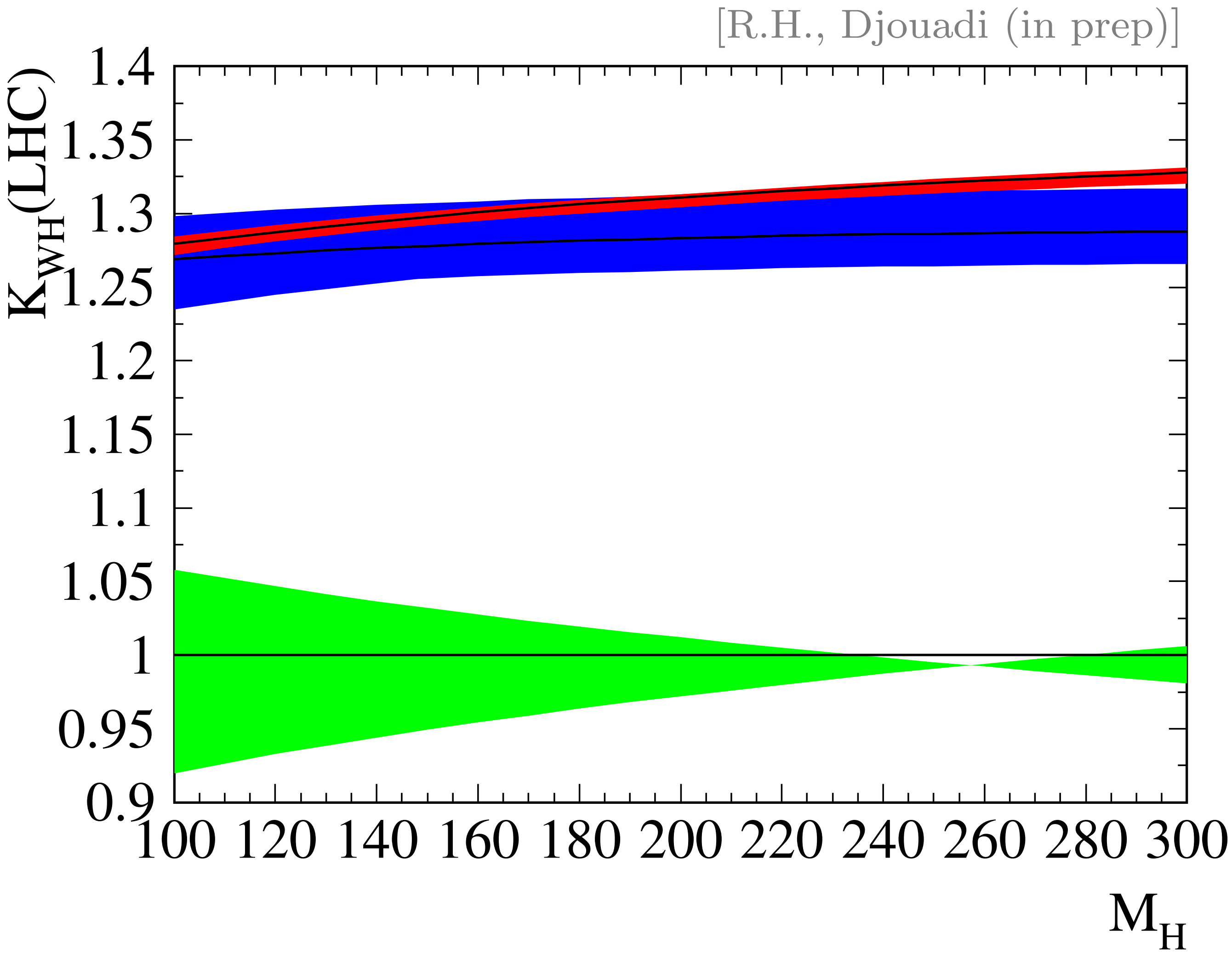


- most important for Tevatron
- relevance for LHC?

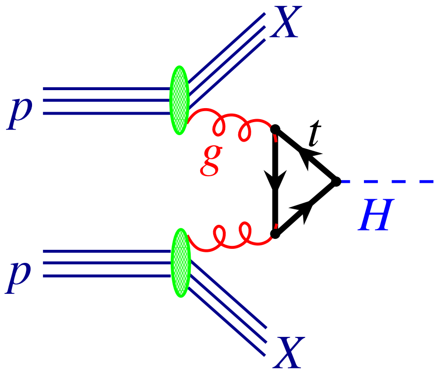


?

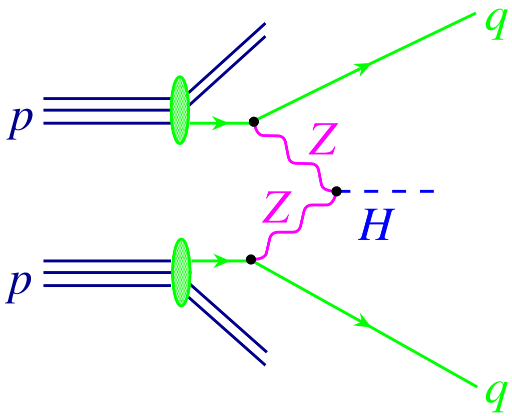
Higgs Strahlung at NNLO



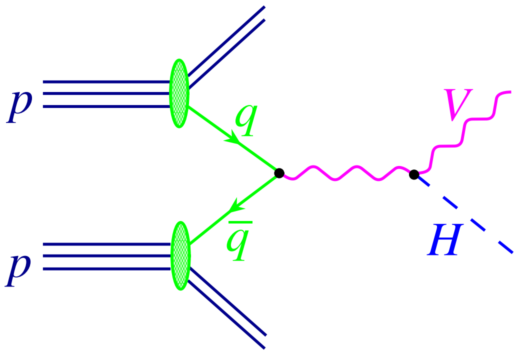
Production Modes



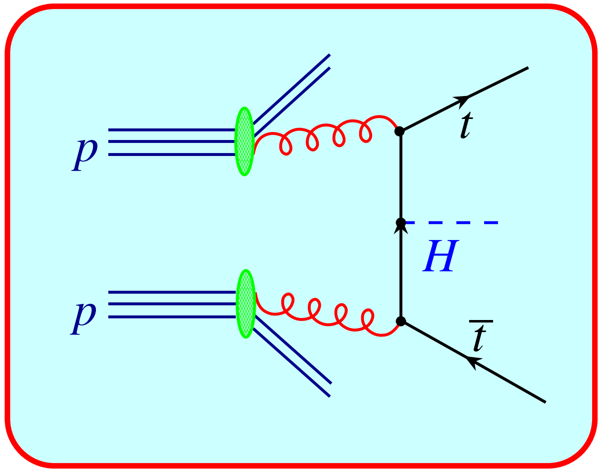
Gluon fusion



Weak Boson Fusion

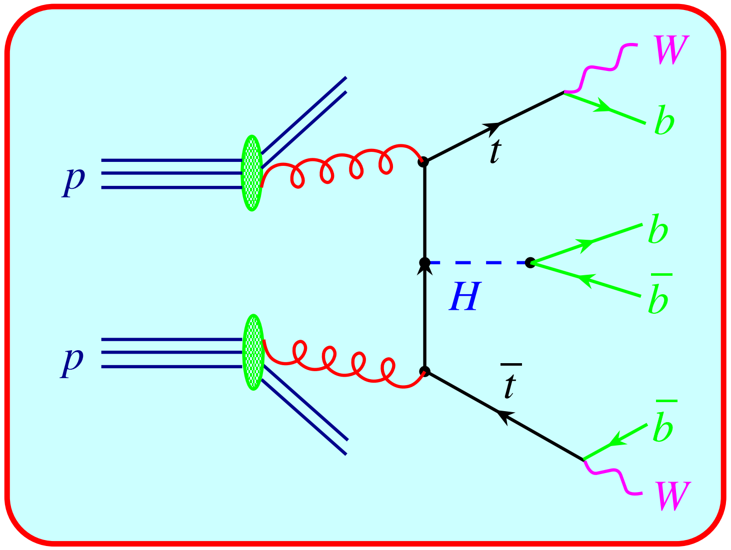


Higgs Strahlung



$t\bar{t}H$

Associated $t\bar{t}H$

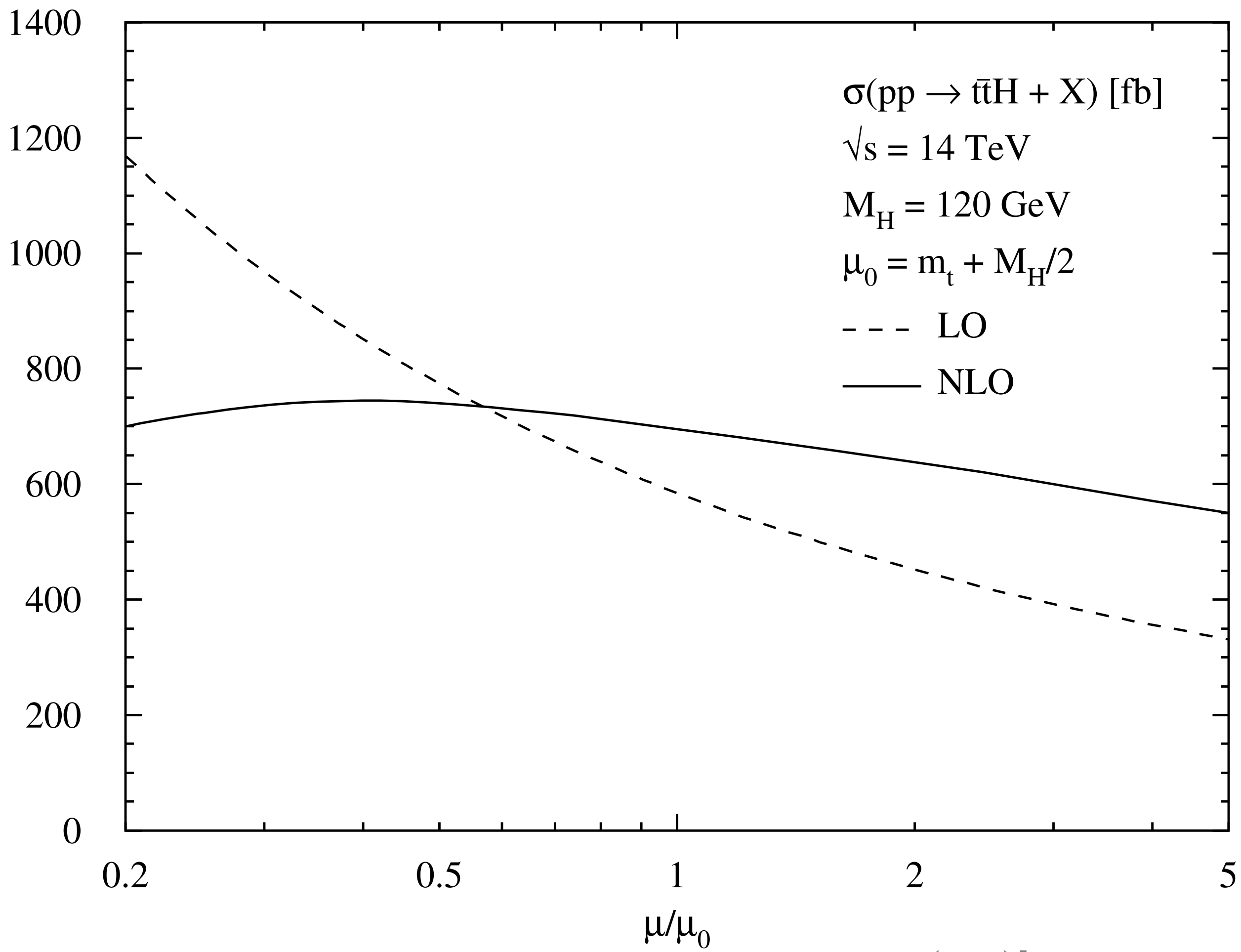


- small rate but clear signature
- top Yukawa coupling
- NLO prediction very stable
- Tools? Also useful for $b\bar{b}H$?

  $\rightarrow$ talk by M. Spira

  Wed, 3.15pm, Higgs Session, Council Chamber

$t\bar{t}H$: LHC



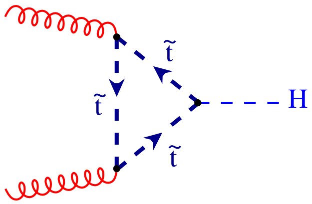
[Beenakker, Dittmaier, Krämer, Plümper, Spira, Zerwas ('01)]
[Dawson, Reina, Wackeroth, Orr, Jackson ('03)]

Supersymmetry

- charged Higgs: $\longrightarrow$ talk by T. Plehn
  Wed, 3.00pm, Higgs Session, Council Chamber

- pseudo-scalar Higgs:
  NNLO cross section [R.H., Kilgore ('02)], [Anastasiou, Melnikov ('02)] [Ravindran, Smith, v.Neerven ('03)]
  NLO distributions [Field, Smith, Tejeda-Yeomans, v.Neerven]

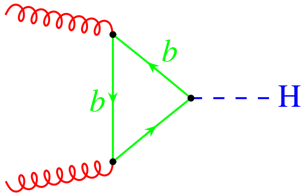
- squark loops: suppressed by $\dfrac{m_t^2}{\tilde{m}_t^2}$



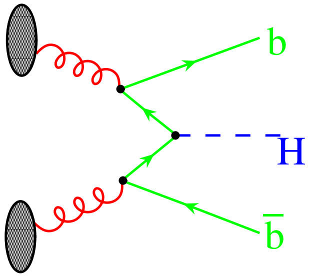
  NLO: [Dawson, Djouadi, Spira ('96)]

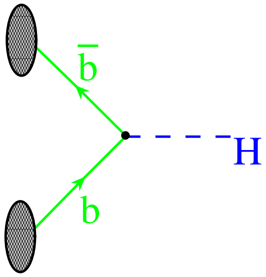
Supersymmetry: Bottom quarks

$$\frac{\lambda_b}{\lambda_t} = \frac{m_b}{m_t} \cdot \frac{v_u}{v_d} = \frac{m_b}{m_t} \cdot \tan\beta$$

(a) 

NLO: [Spira, Djouadi, Graudenz, Zerwas ('95)]

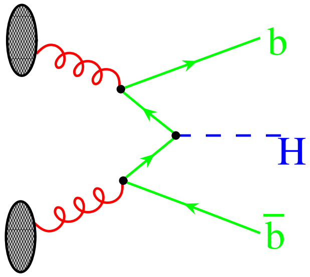
(b) 

$\longrightarrow$ 

+ higher orders

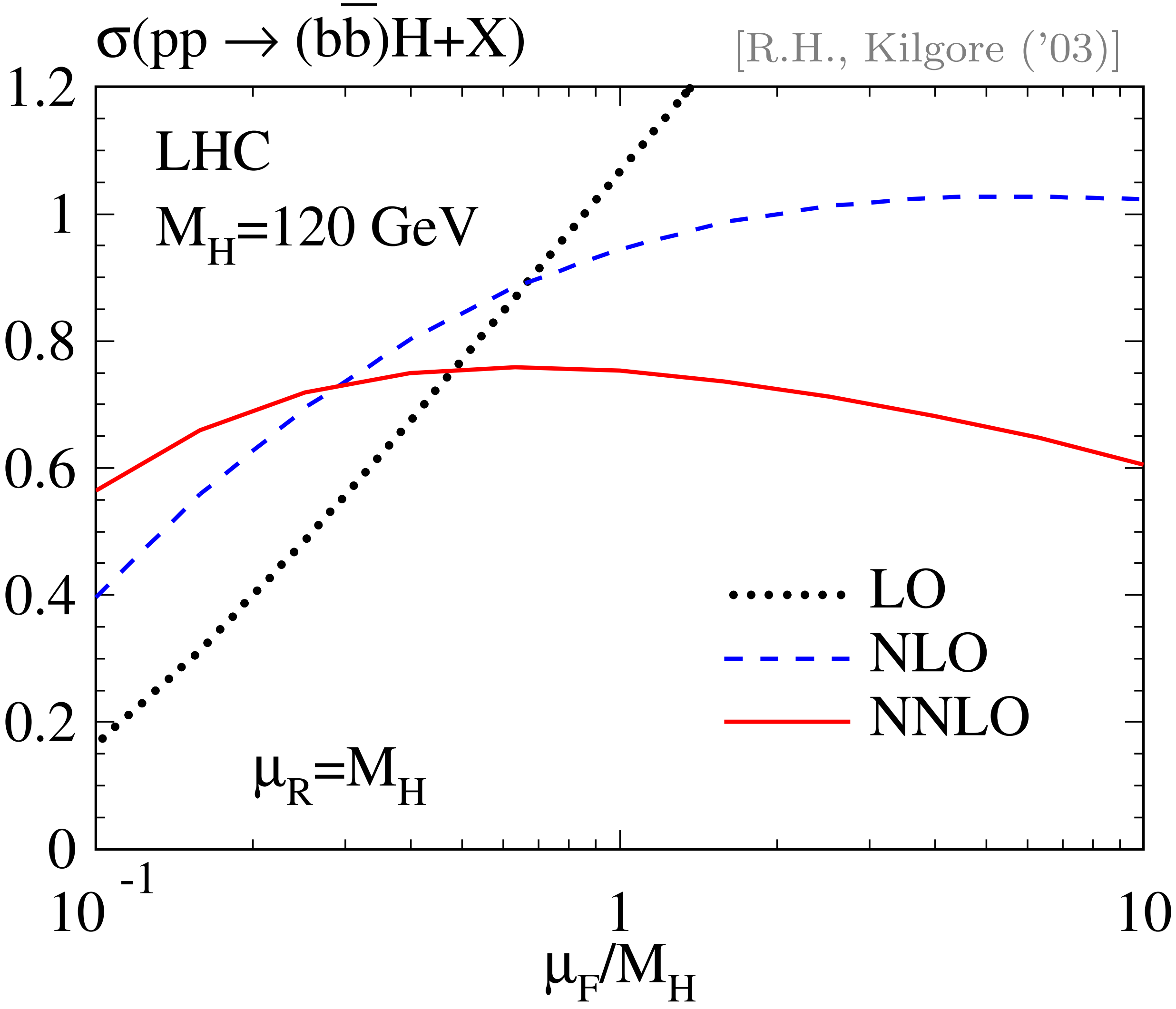
NLO:
[Maltoni, Sullivan, Willenbrock ('03)]

at NNLO:
[R.H., Kilgore ('03)]



− collinear terms

$b\bar{b} \longrightarrow H$ at NNLO



Backgrounds

- which tools available?

  beyond LO: `MCFM` [Ellis, Campbell]

  `DIPHOX` [Binoth, Giullet, Pilon, Werlen]

- where do we need higher orders?
- use NNLO signal with NLO background?
- Goal: collection/qualification of existing tools for BG's

$\longrightarrow$ talk by T. Binoth

Wed, 17.15, Higgs session, Council Chamber

Summary and Conclusions

- LHC challenges $\longrightarrow$ scientific progress!
  NNLO calculations, Monte Carlos, ...
- Standard Higgs:
  all signal and most important background processes under good control
- SUSY Higgs: on the way

Goals of Higgs Session:

- Specify open issues for signals/backgrounds
- Qualify existing and identify missing TOOLS
  $\longrightarrow$ talks by E. Richter-Was, M. Spira, ...
  Thu, 9.00am, Higgs Session, Council Chamber