Resummation of a Higgs Boson Produced in Association with a Bottom Quark

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Outline

- Higgs and Bottom Quarks
- Differential Resummation Formalism
- Higgs Resummation
- Process:
  - b g → b H
  - Resum soft gluons to resolve instabilities
- Results
- Conclusions

Bottom Quarks

- In SM, bottom contribution is quite small
- In MSSM, large tan(β) means bottom quarks become important

	H_{SM}	h^0	H^0	A^0
Up-type quarks	1	$\frac{\cos(\alpha)}{\sin(\beta)}$	$\frac{\sin(\alpha)}{\sin(\beta)}$	$\frac{1}{\tan(\beta)}$
Down-type quarks	1	$-\frac{\sin(\alpha)}{\cos(\beta)}$	$\frac{\cos(\alpha)}{\cos(\beta)}$	$\tan(\beta)$

- Higgs + b-jet is great channel for bottom quark properties

Resummation Justification

- Potentially large logarithms appear in pQCD
- The logs can ruin the perturbation

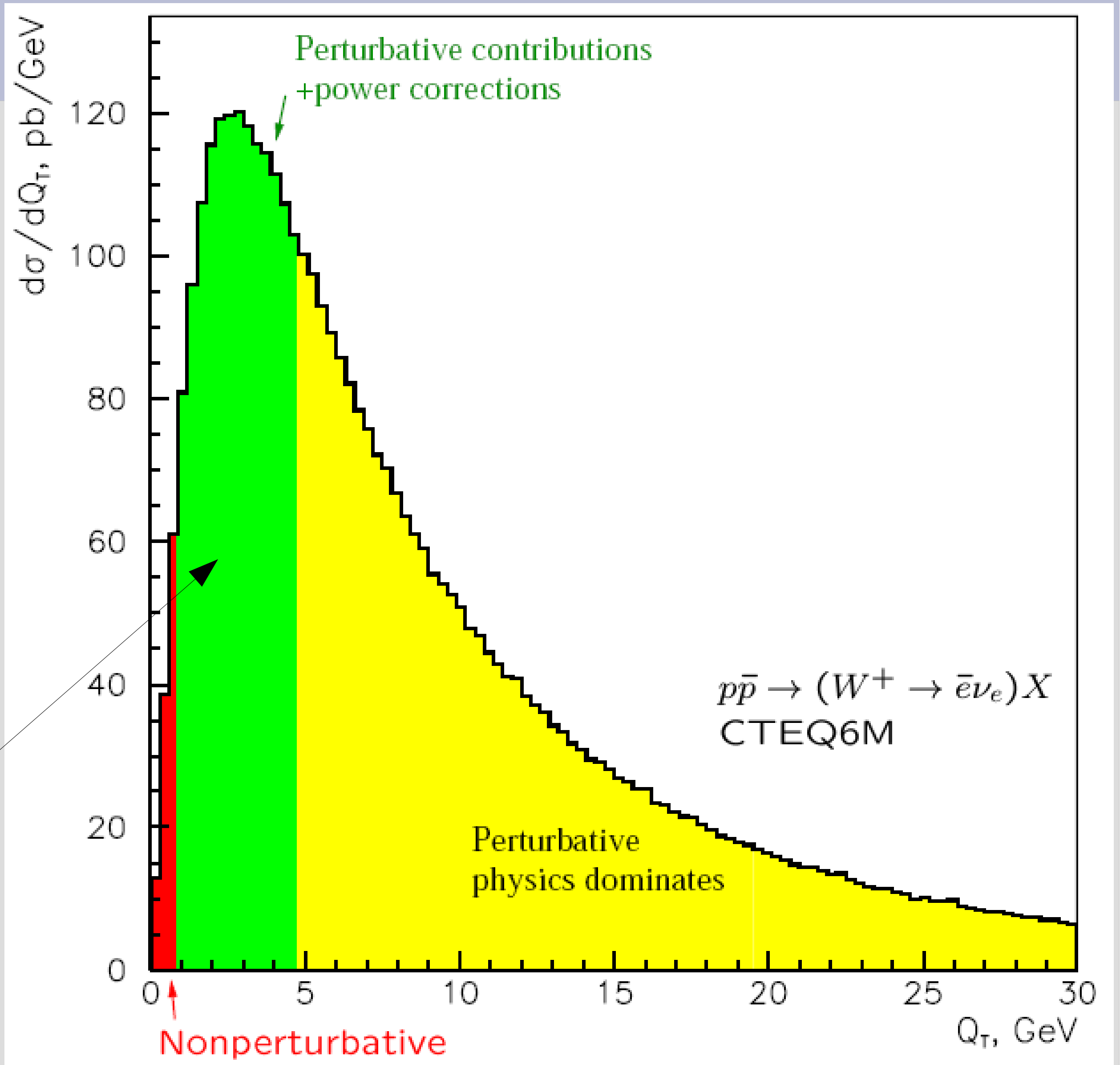
$$\alpha_s \rightarrow \alpha_s \log\left(\frac{\mu^2}{Q^2}\right)$$

- More differential quantities → More mass scales → More logarithms
- pQCD diverges at small p_t like $1/p_t^2$
- Cuts can introduce numeric instabilities

Resummation in Pictures

Different regions
require different
formalisms
to properly
describe dynamics

Interesting region
for Resummation,
Large signal



[Thanks F. Olness]

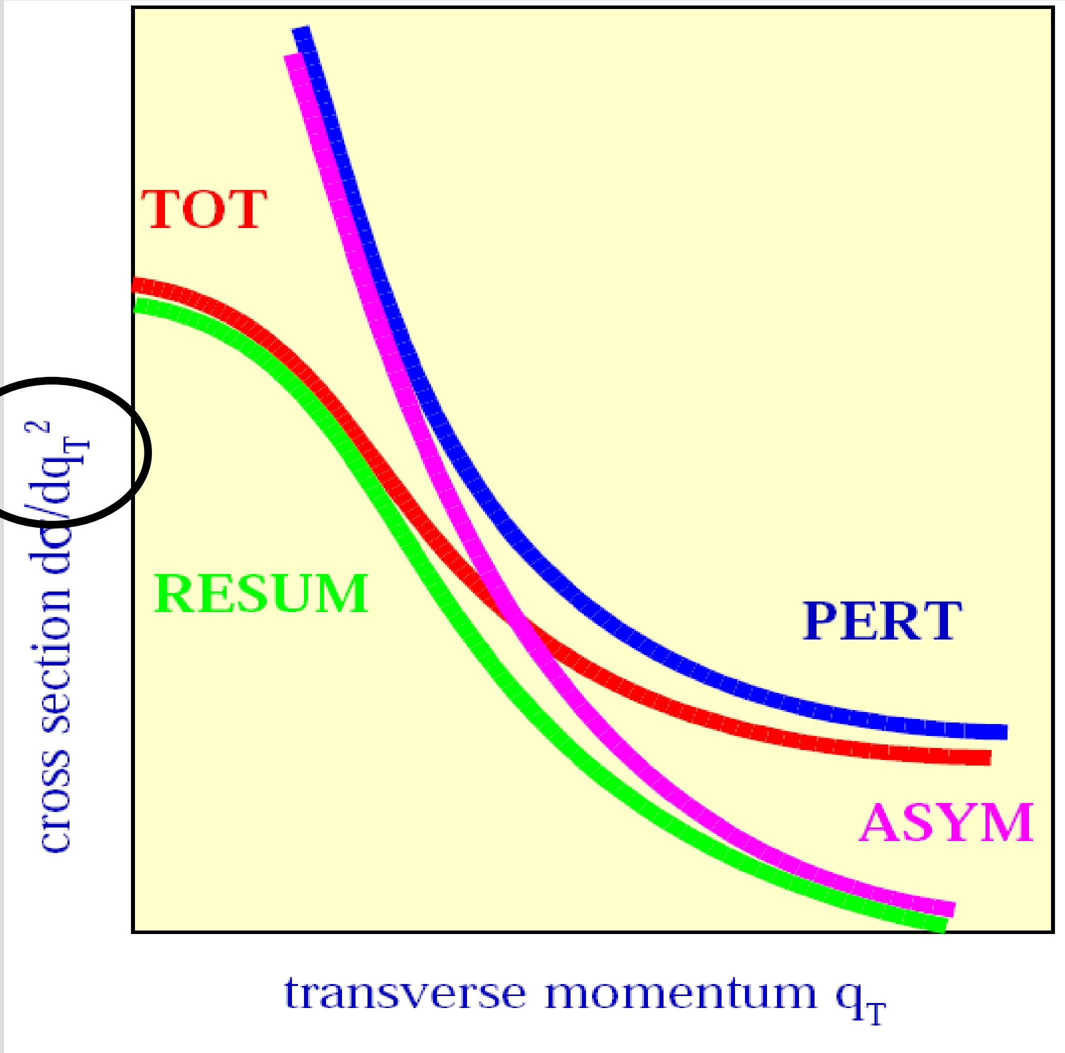
Resummation + pQCD

Total cross-section = Resummed cross-section + perturbative cross-section - asymptotic cross-section

Matching conditions

Non-perturbative inputs (fit to data typically)

$$\sigma_{tot} = \sigma_{resum} + \sigma_{pert} - \sigma_{asym}$$



[Thanks F. Olness]

Resummation Formalism

$$\frac{d\sigma^{res}}{dp_t^2\,dy\,d\phi}=\sum_{a,b}\int_{x_{1,min}}^{1}dx_1\int_{x_{2,min}}^{1}dx_2\int_0^{\infty}db\,\frac{b}{2}J_0(b\,p_t)\,f_{a/h_1}(x_1,b_0/b)\,f_{b/h_2}(x_2,b_0/b)\frac{S}{Q^2}W_{ab}(x_1x_2S;Q,b,\phi)$$

$$W_{ab}(s;Q,b,\phi)=\sum_c\int_0^1 dz_1\int_0^1 dz_2\,\bar{C}_{ca}(\alpha_s(b_0/b),z_1)\,\bar{C}_{cb}(\alpha_s(b_0/b),z_2)\,\delta(Q^2-z_1z_2s)\frac{d\sigma_{c\bar{c}}}{d\phi}S_c(Q,b)$$

$$S_c(Q,b)=\exp\left\{-\int_{b_0^2/b^2}^{Q^2}\frac{dq^2}{q^2}\left[A_c(\alpha_s(q))\ln\left(\frac{Q^2}{q^2}\right)+B_c(\alpha_s(q))\right]\right\}\qquad b_0=2e^{-\gamma_E}$$

$$A_c(\alpha_s)=\sum_{n=1}^{\infty}\left(\frac{\alpha_s}{\pi}\right)^n A_c^{(n)}$$

$$B_c(\alpha_s)=\sum_{n=1}^{\infty}\left(\frac{\alpha_s}{\pi}\right)^n B_c^{(n)}$$

$$\bar{C}_{ab}(\alpha_s,z)=\delta_{ab}\delta(1-z)+\sum_{n=1}^{\infty}\left(\frac{\alpha_s}{\pi}\right)^n\bar{C}_{ab}^{(n)}(z)$$

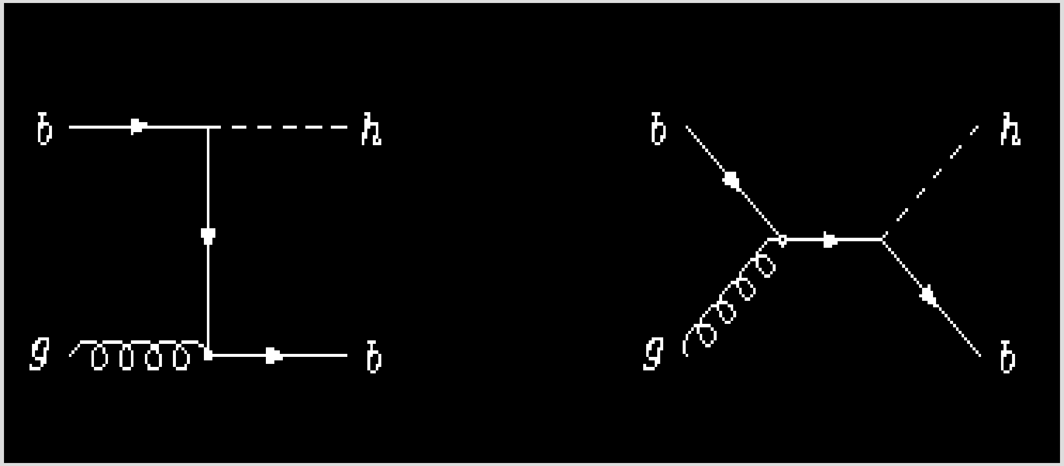
Formalism (II)

$$W_{qg}(s;Q,b,\phi)=\int_0^1 dz_2\int_0^1 dz_2\left(\bar{C}_{gq}\bar{C}_{gg}\,d\sigma_{gg}S_g+\bar{C}_{qq}\bar{C}_{qg}\,d\sigma_{q\bar{q}}S_q\right)\delta\left(Q^2-z_1z_2s\right)+\left\{q\Leftrightarrow\bar{q}\right\}$$

- Resummation coefficients are known
- For b g → b H process, we need all the known coefficients
- $A/B^{(n)}$ for gg and qq initial states
- $C^{(n)}$ for gg, qq, and qg channels

Higgs + B-jet

- Initial state bottom quarks (5FNS)
- Great channel to determine bottom Yukawa coupling → limit tan(β)
- Higgs produced with significant p_t
- Use resummation to resolve instabilities



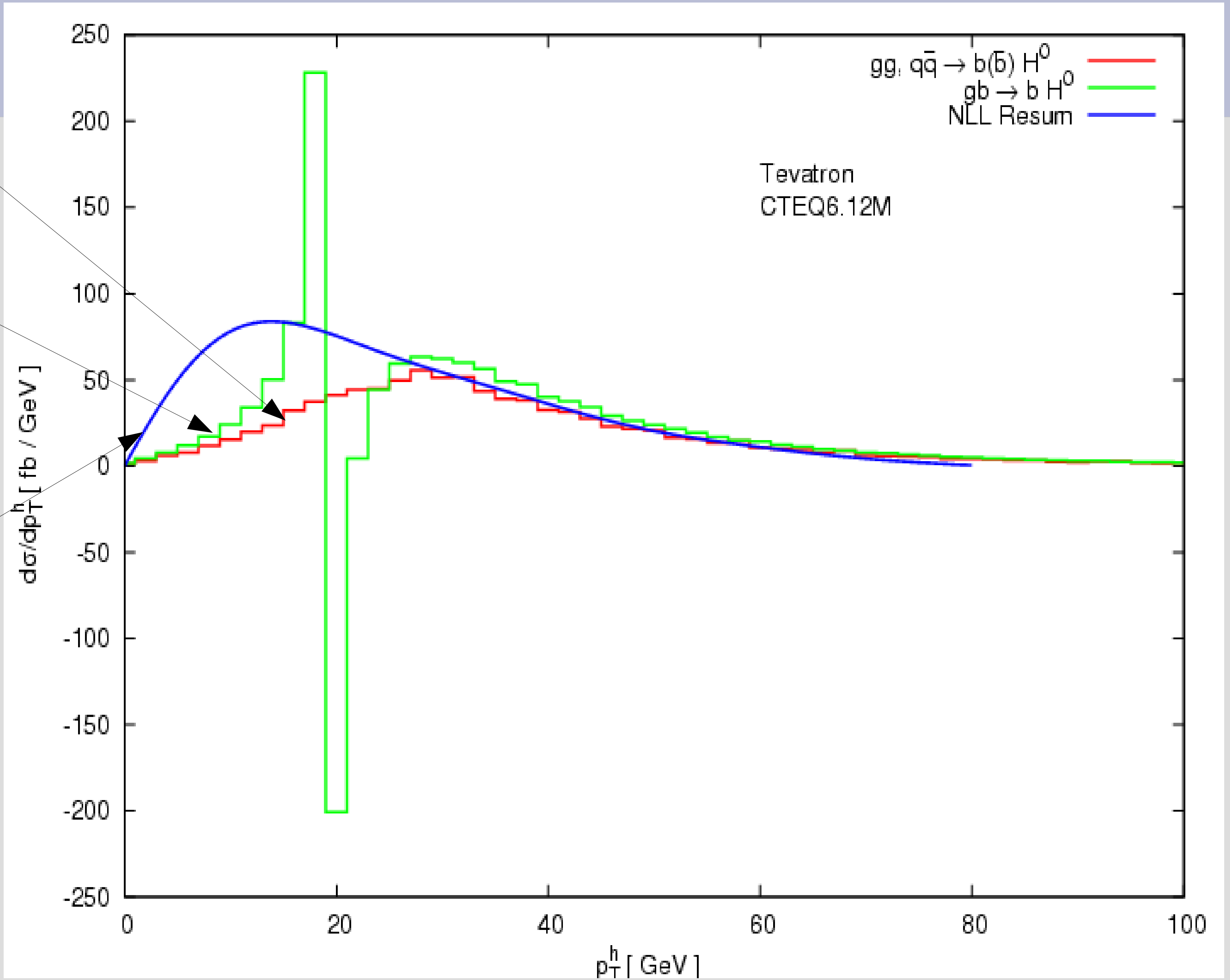
Tevatron

$$\mu=\mu_0/2, \mu_0=(m_b+M_h/2)$$
$$M_h=120\,GeV$$

4FNS

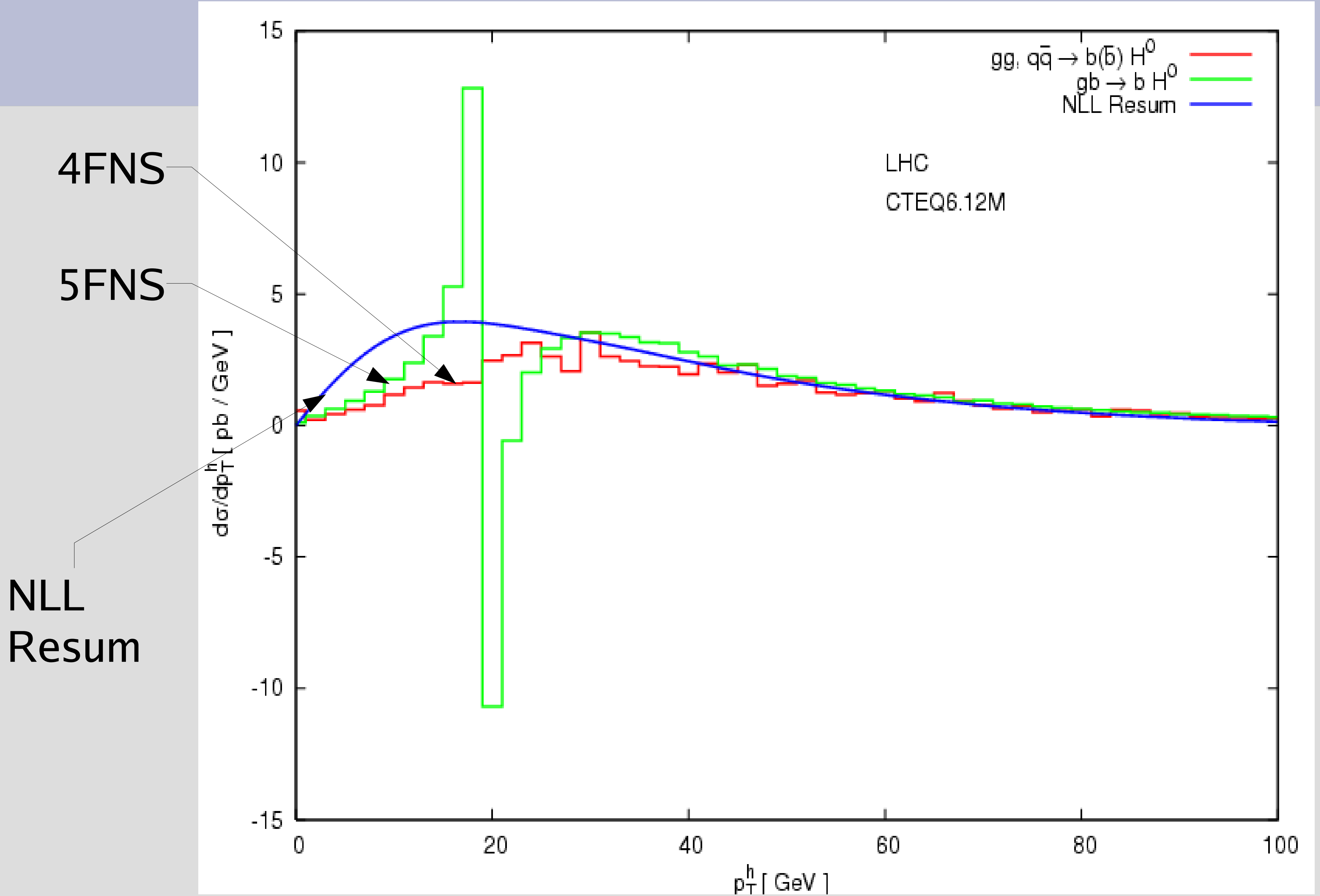
5FNS

NLL
Resum



LHC

$$\mu = \mu_0/2, \mu_0 = (m_b + M_h/2)$$
$$M_h = 120\, GeV$$



Results

- Resummation resolves instabilities in 5FNS
- Consistent results in small p_t region
- 4FNS, 5FNS, and Resummation match very well in moderate to high p_t region
- Find excellent matching at scale $\mu_0/2$ and beyond

Conclusions

- Regions of fixed-order calculation can be unreliable, need to be supplemented
- Resummation addresses this problem
- Better constraints on $\tan(\beta)$ could be achieved
- Future: Write an implementation in mainstream software packages