Diffractive Higgs production in Peripheral Collisions

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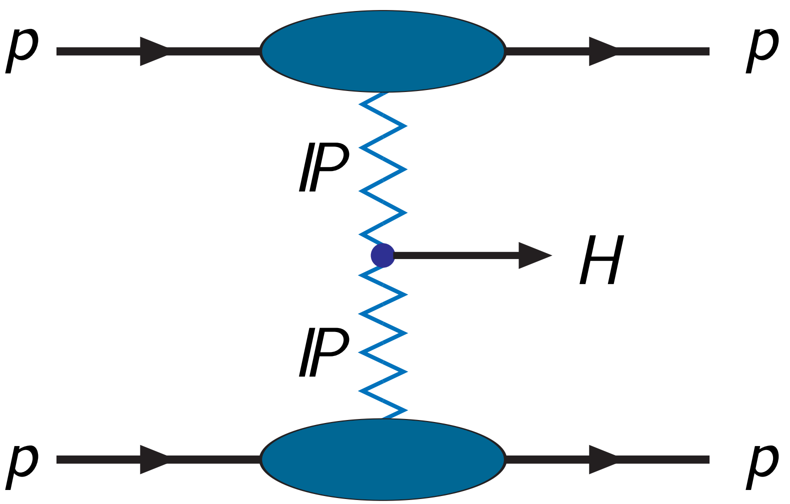
work with M.B. Gay Ducati [PRD **78** (2008) 113005]

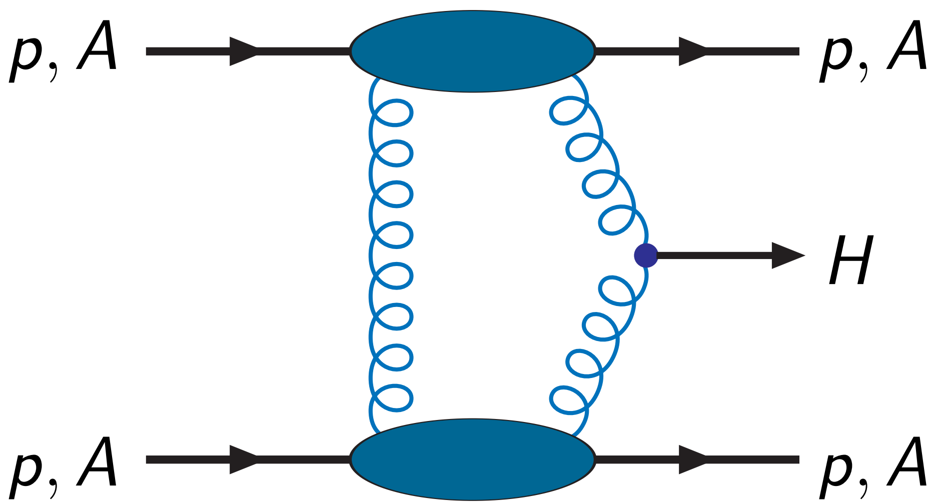
Motivations

- The Large Hadron Collider will allow to study a new kinematic regime never reached
  - CM energy: $E_{pp} = 14$ TeV, $E_{pA} = 8.8$ TeV, $E_{AA} = 5.5$ TeV
  - Bjorken-x: $x \lesssim 10^{-4} - 10^{-5}$
  - Rapidity (CMS): $|\eta_{jets}| < 6.6$, $|\eta_{\gamma,e^{\pm}}| < 3$ and $|\eta_{\mu}| < 2.5$.
  - Higgs physics: the pp collisions would be able to produce the Higgs boson at LHC.
- Collisions will occur with **no** strong interaction in LHC
  - The Peripheral Collisions are a new way to study the Higgs boson production in pp and AA collisions.
- DPE allows to study the diffractive Higgs production at low-x
  - DPE enables the Higgs boson production by the leading ggH vertex mainly in the mass range $M_H = 100 - 200$ GeV.

Diffractive Higgs production in *pp* and *AA* collisions

- **1991**: Bialas and Landshoff — PLB **256** (1991) 540
  - Regge Theory → **non-perturbative gluons**
- **1997**: Khoze, Martin and Ryskin — PLB **401** (1997) 330
  2007: Levin and Miller — arXiv:0801.3593[hep-ph]
  - QCD Pomeron → **hard-gluon exchange**





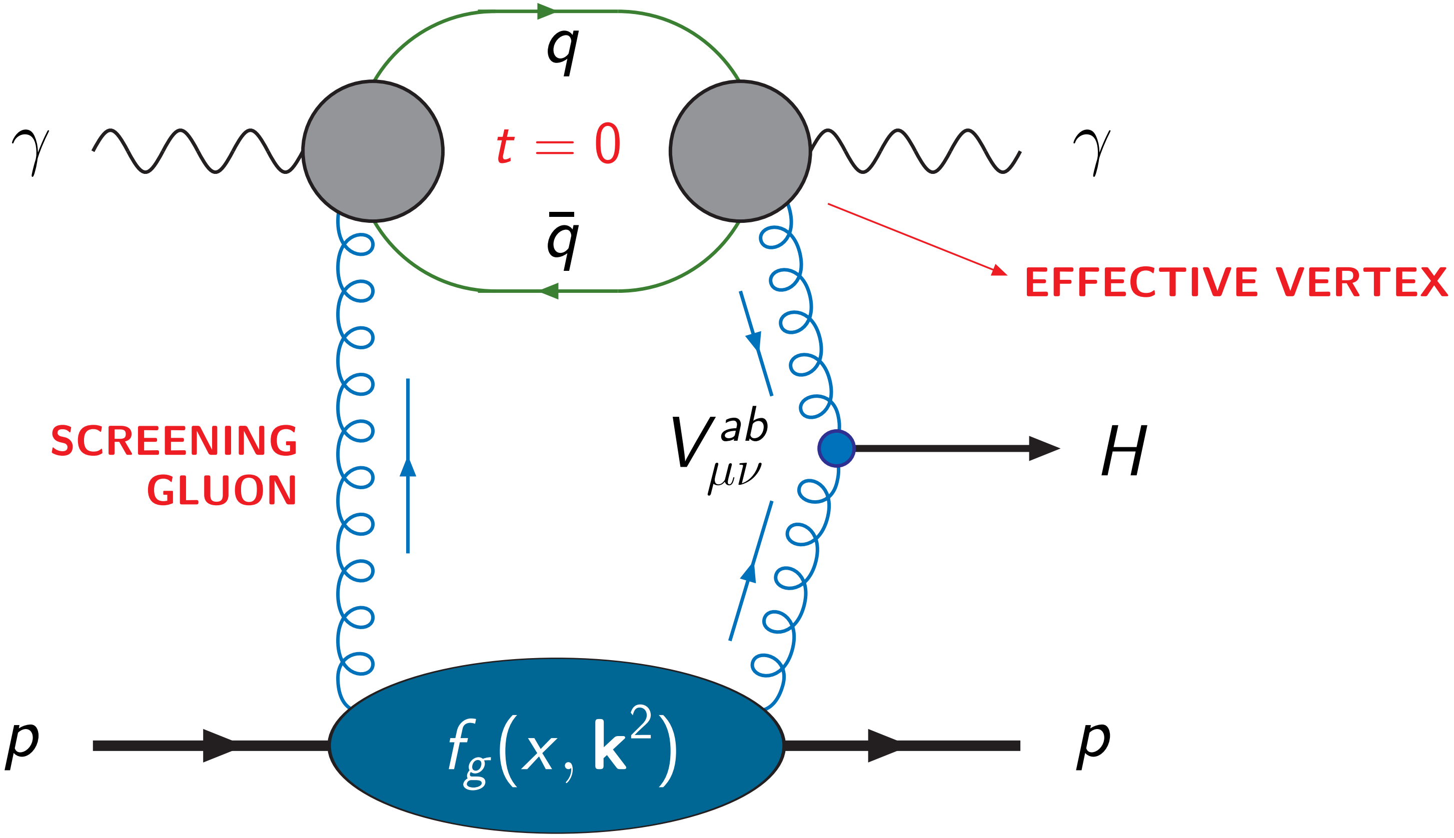
$M_H = 150$ GeV, $\sqrt{s} = 16$ TeV $\left\{\ \textbf{BL} : \sigma_{pp} = 0.1 \text{ pb}\right.$

$M_H = 120$ GeV

$$\sqrt{s} = \begin{cases} 14 \text{ TeV} \\ 5.5\ (8.8) \text{ TeV/A} \end{cases} \quad \begin{cases} \textbf{KMR} : \sigma_{pp}^{\text{exc/inc}} \sim \mathbf{1\ fb}/300 \text{ fb} \\ \textbf{LM} : \sigma_{pA(AA)} = 100\ (3.9) \text{ pb} \end{cases}$$

Diffractive Higgs photoproduction

- **Proposal**: Apply the **DPE** to the **DVCS** in *pp* collision.

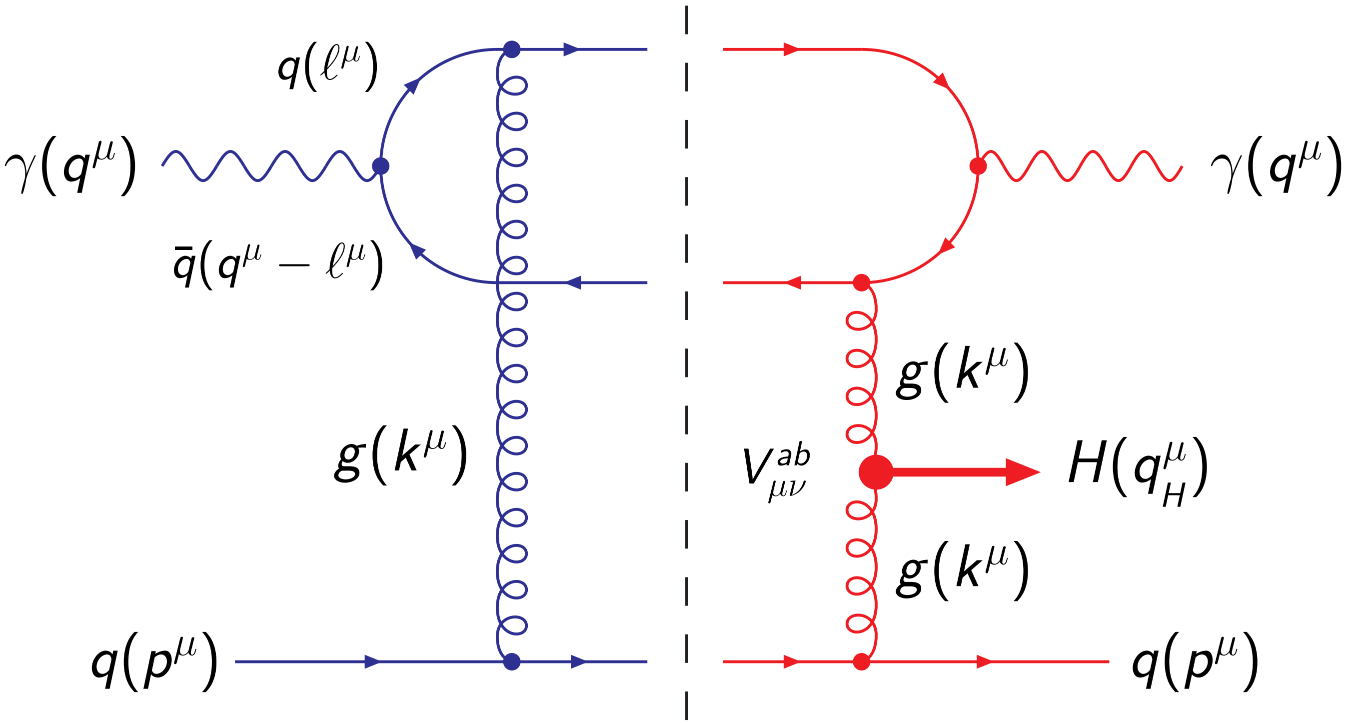


- For a **not too heavy Higgs** ($M_H \lesssim 200$ GeV), the *ggH* vertex reads

$$V^{ab}_{\mu\nu} \approx \frac{2}{3} \frac{M_H^2 \alpha_s}{4\pi v} \left(g_{\mu\nu} - \frac{k_{2\mu} k_{1\nu}}{k_1 \cdot k_2} \right) \delta^{ab}$$

Scattering amplitude

- **Partonic process**: $\gamma q \to \gamma + H + q$



- The scattering amplitude is obtained by the **Cutkosky rules**

$$\mathrm{Im}\,\mathcal{A} = \frac{1}{2}\int d(PS)_3\, \mathcal{A}_{(left)}\, \mathcal{A}_{(right)} = \frac{20 M_H^2}{9}\, \frac{\alpha_s^2 \alpha s}{N_c v} \sum_q e_q^2 \underbrace{\left(\frac{\alpha_s\, C_F}{\pi}\right)}_{*} \int \frac{d\vec{k}^2}{\vec{k}^6}\, \mathcal{X}(\mathbf{k}^2, Q^2)$$

Cross section for central rapidity

- The cross section is calculated for central production ($y_H = 0$)

$$\left.\frac{d\sigma}{dy_H\, dt}\right|_{y_H,t=0} = \frac{S^2_{gap}}{2\pi B}\left(\frac{\alpha_s^2 \alpha M_H^2}{3N_c \pi v}\right)^2 \left(\sum_q e_q^2\right)^2 \left[\int_{\mathbf{k}_0^2}^{\infty} \frac{d\mathbf{k}^2}{\mathbf{k}^6}\, e^{-S(\mathbf{k}^2, M_H^2)}\, f_g(x,\mathbf{k}^2)\, \mathcal{X}(\mathbf{k}^2, Q^2)\right]^2$$

- * Quark contribution[1]: $\alpha_s C_F/\pi \quad \rightarrow \quad f_g(x,\mathbf{k}^2) = \mathcal{K}\, \partial_{(\ell n\, \mathbf{k}^2)}\, xg(x,\mathbf{k}^2)$
- Gap Survival Probability[2]: $S^2_{gap} \quad \rightarrow \quad 3\%$ (5%) for LHC (Tevatron)
- Gluon radiation suppression[3]: **Sudakov factor** $S(\mathbf{k}^2, M_H^2) \sim \ell n^2\left(M_H^2/4\mathbf{k}^2\right)$
- Cutoff $\mathbf{k}_0^2$: In order to avoid **infrared divergencies** :: $\mathbf{k}_0^2 = 1$ GeV^2.
- Electroweak vacuum expectation value: $v = 246$ GeV
- Slope of the gluon-proton form factor: $B = 5.5$ GeV^{-2}

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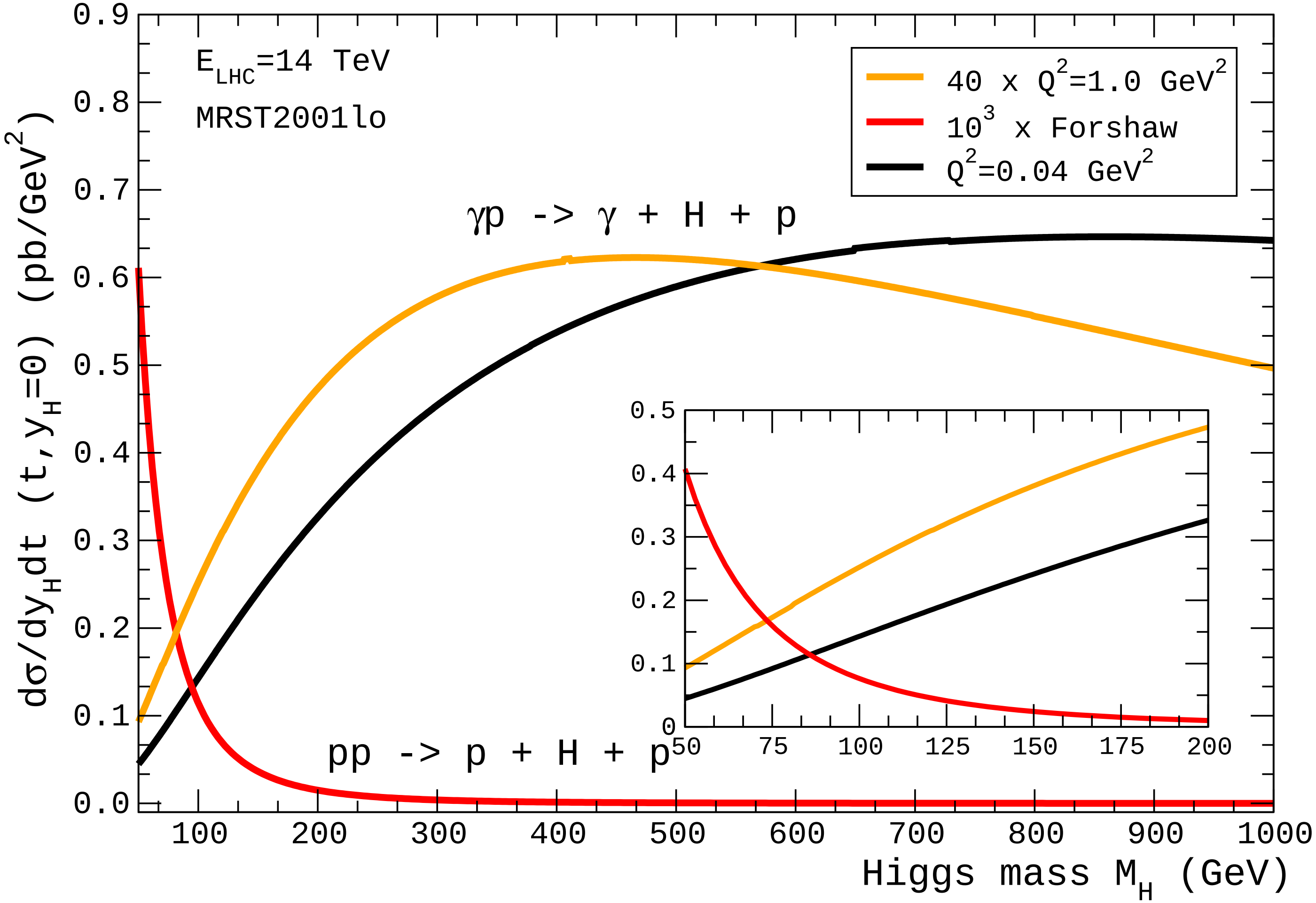
[1] Khoze, Martin, Ryskin, EJPC **14** (2000) 525

[2] Khoze, Martin, Ryskin, EJPC **18** (2000) 167

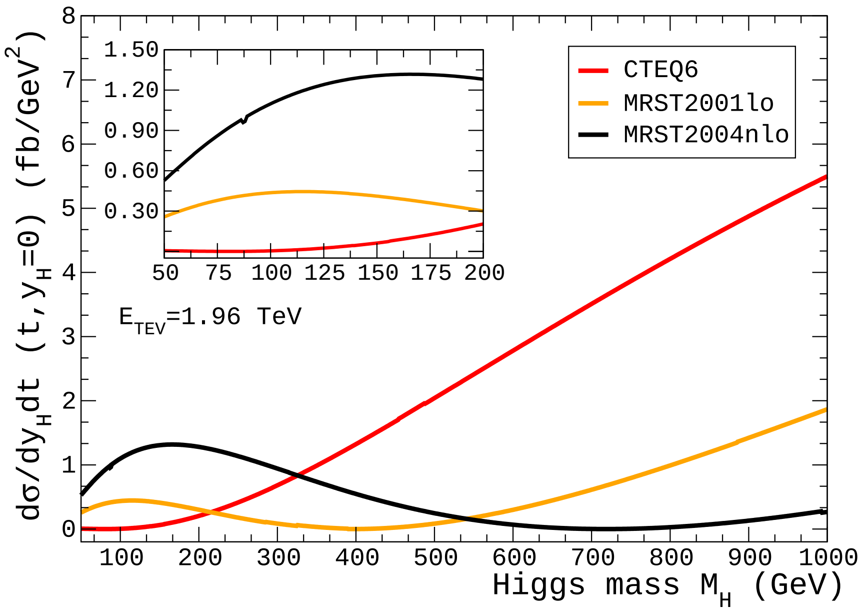
[3] Forshaw, hep-ph/0508274

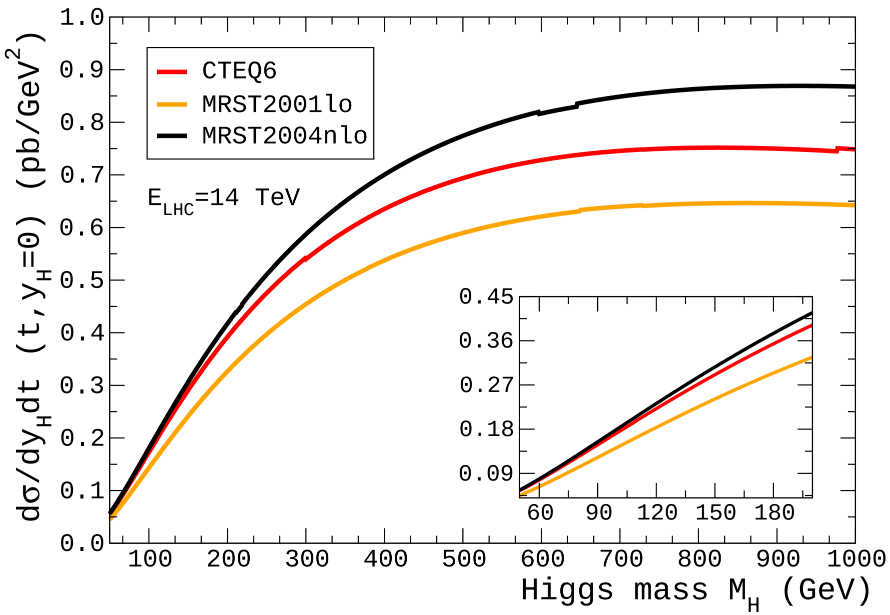
Results: pp vs. γp process

- **Higher** rate in the **mass region** expected for Higgs detection.



Results: Gluon distribution functions

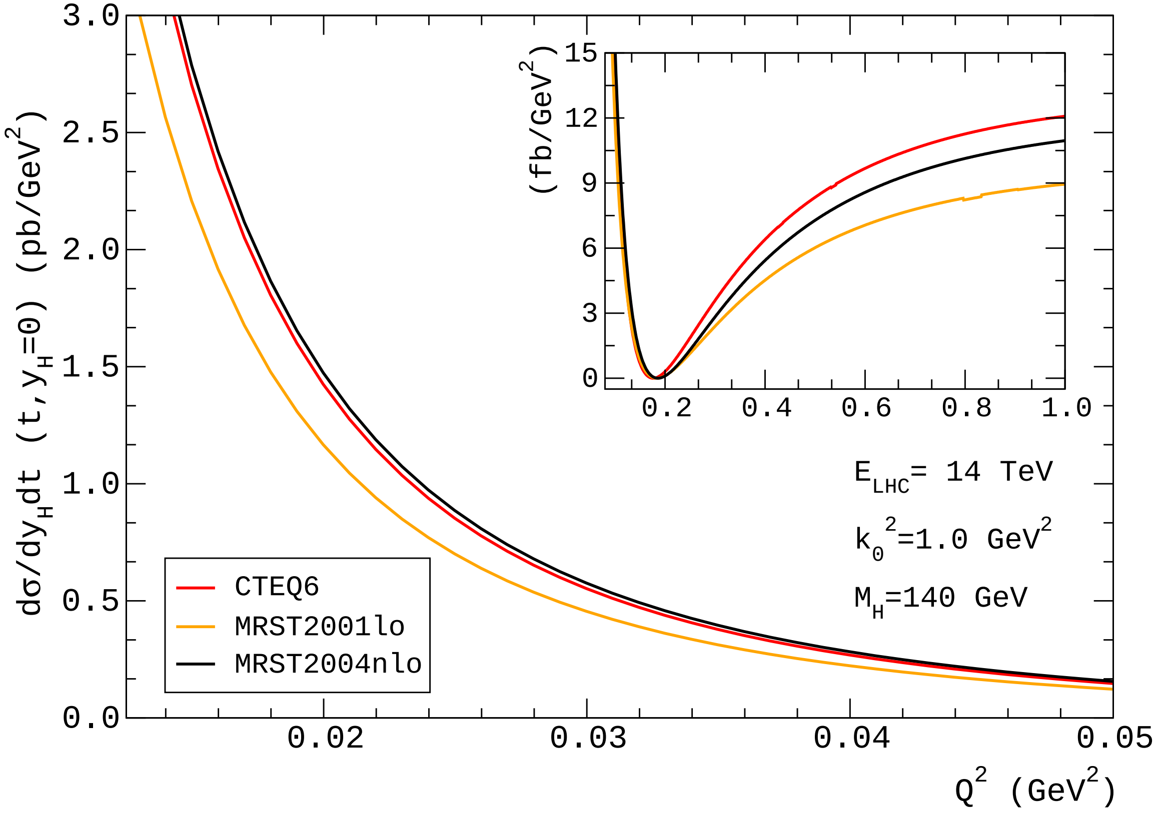




- **Tevatron**: **Distinct** behaviors for the **LO** and **NLO** distributions;
  - Leading contribution $\begin{cases} \textbf{NLO} \rightarrow & M_H \lesssim 200 \text{ GeV} \\ \textbf{LO} \rightarrow & M_H \gtrsim 400 \text{ GeV} \end{cases}$
- **LHC**: NLO distributions show a **higher** contribution than the LO ones.

Results: Q^2-dependence

- Peripheral Collisions: photon limit of $Q^2 = 0.04$ GeV^2
  - **Divergent region**: highest cross section for Higgs production
- Perturbative region: $Q^2 \sim 1$ GeV^2 KMR, hep-ph/0605189
  - **Smaller event rate**: range expected to its detection $\sigma_{\rm exc} \sim 3$ fb.



The photoproduction in Peripheral Collisions

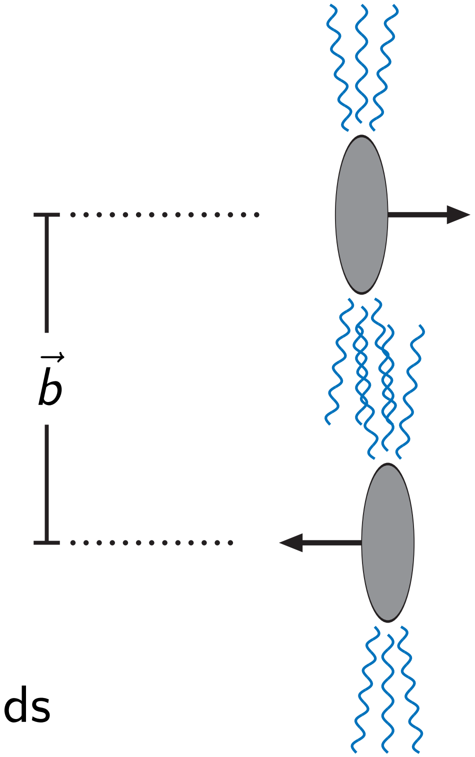
- The γp process is a subprocess of **Peripheral *pp* Collisions**

- **Large impact parameter** $|\vec{b}| \gtrsim 2R_p$

  NO STRONG INTERACTION OCCURS !

- The hadronic cross section is given by

$$\sigma^{pp} = 2 \int dk \, \frac{dn}{dk} \, \sigma^{\gamma p}$$

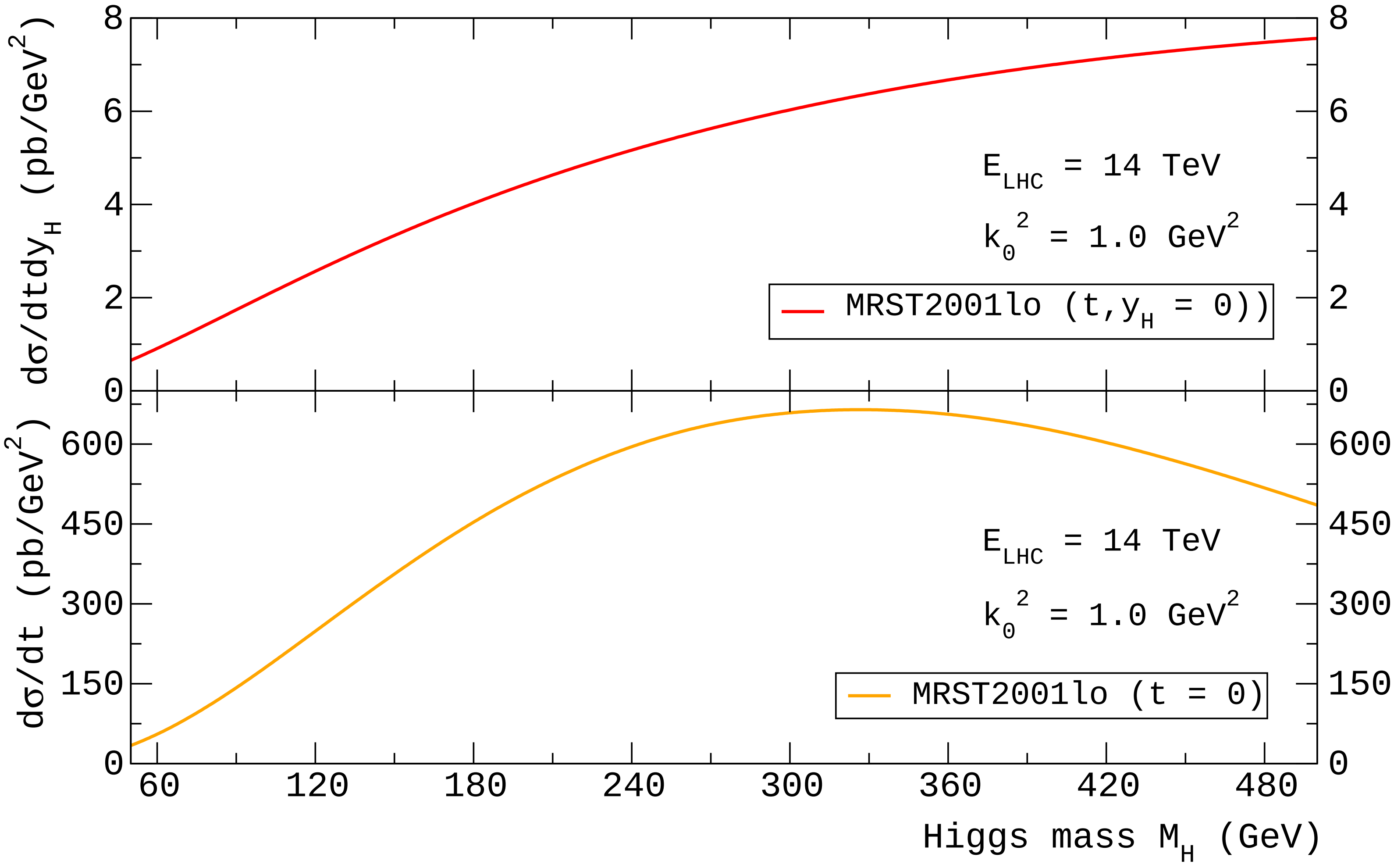


and the **photon flux** in Peripheral *pp* Collisions reads

$$\frac{dn}{dk} = \frac{\alpha_{em}}{2\pi k} \left[1 + \left(1 - \frac{2k}{\sqrt{s}} \right)^2 \right] \left(\ln A - \frac{11}{6} + \frac{3}{A} - \frac{3}{2A^2} + \frac{1}{3A^2} \right)$$

where $A = 1 + (0.71 \text{ GeV}^2)/Q^2_{min}$ and $Q^2_{min} \simeq k^2/\gamma_L^2$.

Results: *pp* cross section



- *pp* **collisions**: The results have the **same** shape as the γp ones.

Summary

- We compute the event rate for **Higgs boson production** in γp and pp processes in Peripheral Collisions at LHC.
- In the LHC kinematical regime, the results with NLO distributions are **15%** higher than the LO ones.
  - It assigns the importance of the **gluon recombination effects** (if the non-perturbative effects are small).
- These results are **three times** less sensitive to the integration cuts if compared to the KMR approach.
  - The next step is to produce a comprehensive phenomenological analysis of the pp collision.
- The pp results show the robustness of this approach, which predicts an **enhanced signal** for the Higgs detection in LHC.