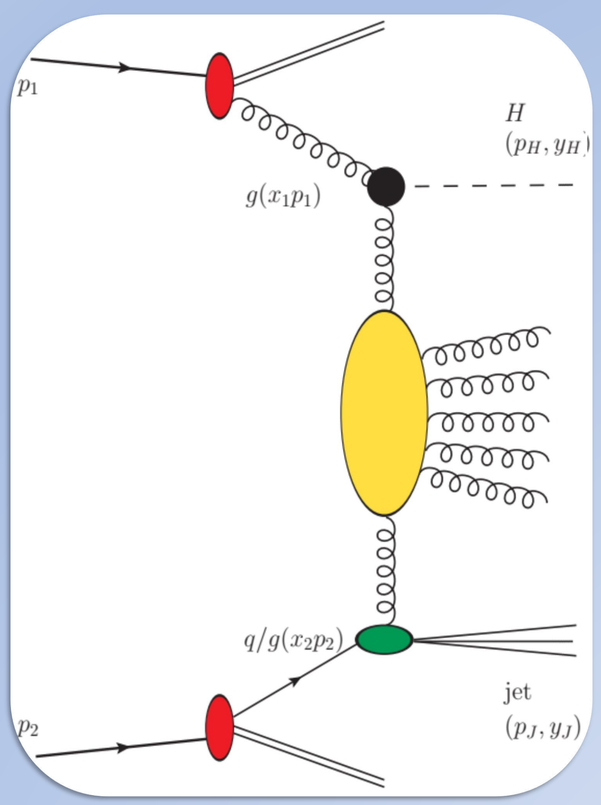
The real corrections to the Next-to-Leading Order Higgs Impact Factor at Physical Top Quark Mass

Francesco Giovanni Celiberto [a], Luigi Delle Rose [b,c], Michael Fucilla [d], Gabriele Gatto [b,c], Alessandro Papa [b,c]

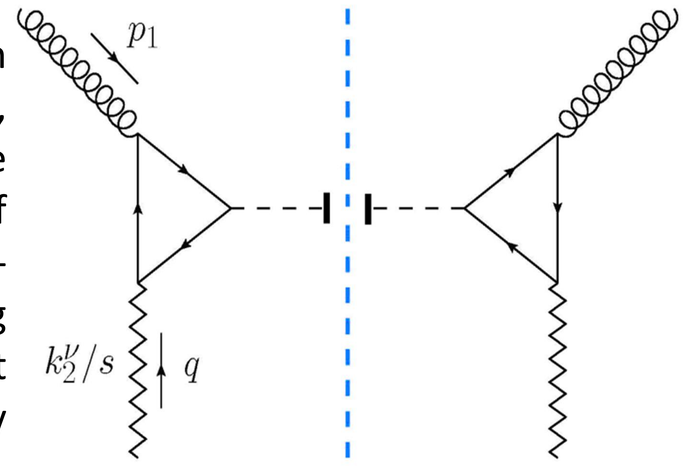
Diffraction and Low-x – September 8-14, 2024



Overview

We calculate **real corrections** to the **forward Higgs boson impact factor** with full top-mass dependence. It will enable new predictions for high-energy processes such as: inclusive forward Higgs production, inclusive production of a forward Higgs with a backward object (jet or hadron) at the LHC and future hadron colliders.

The impact factor is a function that describes the transition between the initial and final state of a particle in its fragmentation region, capturing the specific dynamics of the interaction process. In the **BFKL approach**, differential cross sections take the peculiar form of a convolution, in transverse-momenta space, of two process-dependent *impact factors*, describing the transition of each colliding particle to a definite state, and a universal, process-independent *Green's function*, which encodes the resummation of energy logarithms.

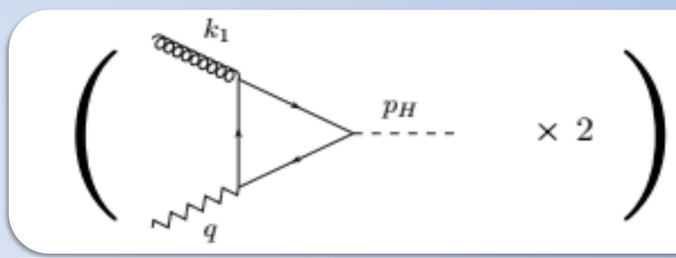


LO Computation

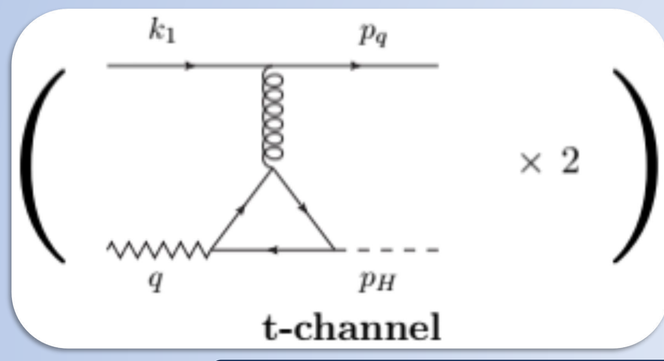
The proton-initiated impact factor reads

$$\frac{d\Phi_{PP}^{\{H\}(0)}(\vec{q})}{dx_H d^2\vec{p}_H} = \int_{x_H}^{1} \frac{dz_H}{z_H} f_g\left(\frac{x_H}{z_H}\right) \frac{d\Phi_{gg}^{\{H\}(0)}(\vec{q})}{dz_H d^2\vec{p}_H} = \frac{\left|F_T(0,-\vec{q}^2,m_H^2)\right|^2 \vec{q}^2 f_g(x_H)}{8(1-\epsilon)\sqrt{N^2-1}} \delta^{(2)}(\vec{q}-\vec{p}_H),$$

where $f_g(x_H)$ is the gluon parton distribution function.



The two triangular-like diagrams contributing to the Higgs impact factor at the LO.



The two triangular-like diagrams contributing to the quark-initiated contribution to the Higgs impact factor at the NLO.

NLO Computation

The Next-to-Leading Order computation analyzes the impact factor for Higgs boson production with full top-mass dependence, addressing infrared, collinear, and rapidity divergences.

Infrared Structure and Gauge Invariance

Analysis of infrared and collinear singularities in real impact factor corrections.

- *Collinear Singularity*: appears when $\vec{p}_g = \vec{q} - \vec{p}_H \to 0$
- *Soft Singularity*: occurs when $z_H \to 1$, indicating gluon energy loss

The complete result for the infrared limit of the impact factor is

$$\frac{d\Phi_{gg}^{\{Hg\}}(z_H,\vec{p}_H,\vec{q};s_0)}{dz_H d^2\vec{p}_H} \xrightarrow{\vec{q}\sim\vec{p}_H} \frac{g^2\left|F_T(0,-\vec{p}_H^2,m_H^2)\right|^2 N}{4(1-\epsilon)\sqrt{N^2-1}(2\pi)^{D-1}} \left(\frac{\vec{p}_H^2}{(\vec{q}-\vec{p}_H)^2}\frac{z_H}{1-z_H}\theta(s_\Lambda - s_{gR}) + \frac{1}{(\vec{q}-\vec{p}_H)^2}\left[z_H(1-z_H)\vec{p}_H^2 + 2(1-\epsilon)\frac{1-z_H}{z_H}\frac{(\vec{p}_H\cdot(\vec{q}-\vec{p}_H))^2}{(\vec{q}-\vec{p}_H)^2}\right]\right).$$

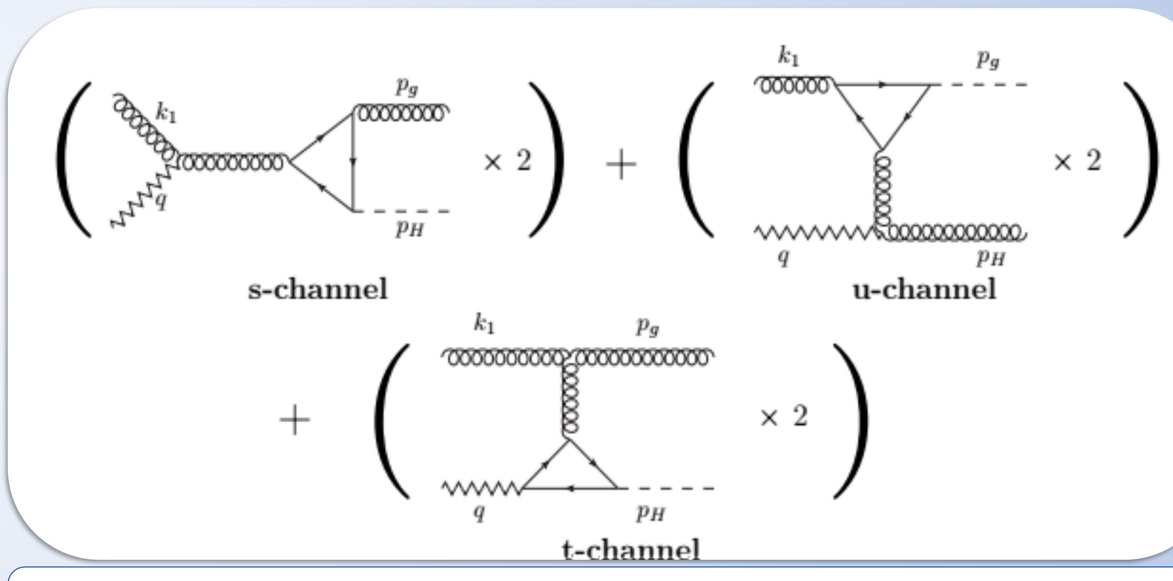
This is the proper structure of divergences and moreover the full impact factor vanishes when the transverse momentum of the Reggeon approaches zero, in agreement with the gauge invariance.

Rapidity Divergence within the BFKL factorization framework

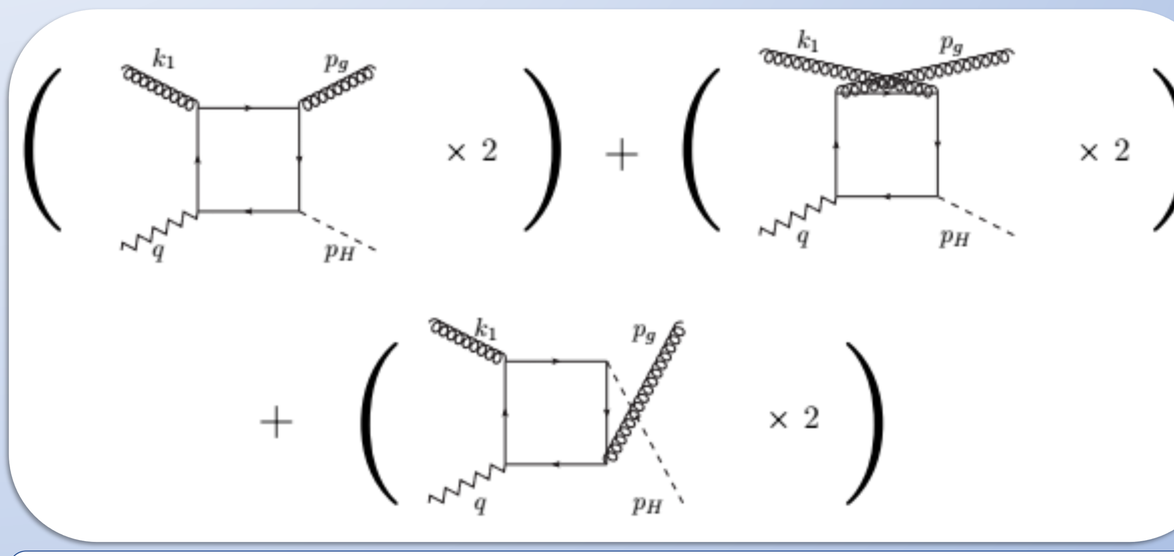
The high-rapidity limit of the impact factor is

$$\left.\frac{d\Phi_{gg}^{\{Hg\}}(z_H,\vec{p}_H,\vec{q};s_0)}{dz_H d^2\vec{p}_H}\right|_{z_H\to 1} = \frac{g^2\left|F_T(0,-\vec{p}_H^2,m_H^2)\right|^2 N}{4(1-\epsilon)\sqrt{N^2-1}(2\pi)^{D-1}} \frac{\vec{q}^2}{(\vec{q}-\vec{p}_H)^2}\frac{1}{(1-z_H)}\theta\left(s_\Lambda - \frac{(\vec{q}-\vec{p}_H)^2}{1-z_H}\right).$$

The rapidity divergence is cancelled through the BFKL counter-term, aligning with theoretical predictions.



The six triangular-like diagrams contributing to the gluon-initiated contribution to the Higgs impact factor at the NLO.



The six box-like diagrams contributing to the gluon initiated contribution to the Higgs impact factor at the NLO.

Further information

[a] Universidad de Alcalá (UAH), Departamento de Física y Matemáticas, Campus Universitario, Alcalá de Henares, E-28805, Madrid, Spain
[b] Dipartimento di Fisica, Università della Calabria, Arcavacata di Rende, I-87036, Cosenza, Italy
[c] INFN, Gruppo Collegato di Cosenza, Arcavacata di Rende, I-87036, Cosenza, Italy
[d] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405, Orsay, France
francesco.celiberto@uah.es, luigi.dellerose@unical.it, michael.fucilla@ijclab.in2p3.fr, gabriele.gatto@unical.it, alessandro.papa@fis.unical.it