The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2146-33

Gribov-80 Memorial Workshop on Quantum Chromodynamics and Beyond'

26 - 28 May 2010

The photon-jet angular distribution in pp collisions at \sqrt{S} = 1.96 TeV

Zouina Belghobsi
University of Jijel
Algeria

Strada Costiera 11, 34151 Trieste, Italy - Tel.+39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it

The photon-jet angular distribution in $p\bar{p}$ Collisions at $\sqrt{S} = 1.96$ TeV

Zouina Belghobsi

Laboratoire de Physique Théorique (LPTh)

University of Jijel,

Algeria

Collaborators: E. Pilon, J.-Ph. Guillet, M. Werlen, (LAPTH), M.Fontannaz (LPT,orsay), G. Heinrich (IPPP, Durham)

Outline

- *Introduction*
- *Motivations.*
- *Photon−Jet angular distribution.*
- *Summary.*
- *Conclusions.*

Introduction

· At the LHC, photon + jet final states will be important for jet calibration and parton distribution function (pdf) studies. An accurate knowledge of the photon+jet rate is required to estimate and control the reducible background to the Higgs boson search in diphoton channel.

· In addition, highly energetic photons are important signatures for various scenarios of physics beyond the SM.

Motivations

- The production of prompt photon in hadronic collisions may be schematically seen from two mechanisms.

- ⁕The first may be called "direct" (D),

The photon behaves as a high p_T colorless parton.

- ⁕The other one may be called "fragmentation" (F),

- The photon behaves hadronlike.

- So, it results from the collinear fragmentation of a colored high p_T parton , possibly accompagnied by hadrons.

Motivations

- The (F) component grows with the center-of-mass energy of the collision. It becomes dominant at collider energies.
- At these energies, the inclusive prompt photon signal would be swamped by a large background of secondary photons.
- These experiments impose isolation criteria on the hadronic final state of photon candidate events
- Cuts suppress the background, and also substantially reduce the (F) component.
- Yet a fraction of (F) may survive and affect shapes of various tails of distribution, $\longrightarrow$ correlation observables

Photon-Jet angular distribution

- ***An observable expected to receive a distinctive contribution from the (F) component is the photon-jet angular distribution which has measured by the CDF Collaboration [1].***

- ***At LO,*** $\longrightarrow$ ***to*** 2 $\longrightarrow$ 2 kinematics, $\cos\theta^*$ is the cosine of angle between the photon direction and the beam axis in the center-of-mass system of the partonic subprocess.

$$\cos\theta^* = \tanh y^*$$

$$y^* = (y_\gamma - y_{jet})/2$$

This angular distribution is expected to receive a dominant contribution from the (F) component when $\cos\theta^* \longrightarrow 1$.

----

[1]: F. Abe et al. (CDF Collaboration), Phys. Rev. Lett. 71, 679 (1993).

- The (D) component proceeds via a t-channel quark exchange $\longrightarrow$ behavior ~ $1/(1-\cos\theta^*)$, whereas the (F) component involves gluon exchange in t-channel $\longrightarrow$ behavior ~ $1/(1-\cos\theta^*)^2$.
- On this ground, one thus expects (F) to take over for $\cos\theta^*$ values close enough to 1.

- Focusing on the direct (D) contributions, and parametrizing the LO phase space as

$$d(p_T^\gamma)^2\, dy_\gamma\, dy_{\rm jet} = \frac{1}{2}\, d(p^*)^2\, dy_B\, d\cos\theta^*$$

$$y_B = (y_\gamma + y_{jet})/2$$

$$p^* = p^\gamma_T \cosh y^*$$

The LO distribution in $\cos\theta^*$ reads

$$\frac{d\,\sigma}{d\cos\theta^*} = \sum_{i,j}\int dy_B\, dp^*\, G_{i/P}(x_i)\, G_{j/\bar{P}}(x_j)\frac{d\,\sigma_{ij}}{d\cos\theta^*\, dy_B\, dp^*}$$

with

$$x_{i,j} = \frac{2p^*}{\sqrt{S}}\, e^{\pm y_B}$$

· *Beyond LO the definition of* $\cos\theta^*$ *has to be extended. Here we take:*

$$\cos\theta^* = \tanh y^*$$

$$y^* = \frac{1}{2}\left(y_\gamma - y_{\mathrm{leading\,jet}}\right) ,$$

· *Leading jet is the jet of highest transverse energy.*

· *The higher order contributions to the angular distribution involve an extra convolution smearing over kinematical configurations, the interpretation of this distribution beyond LO is less transparent.*

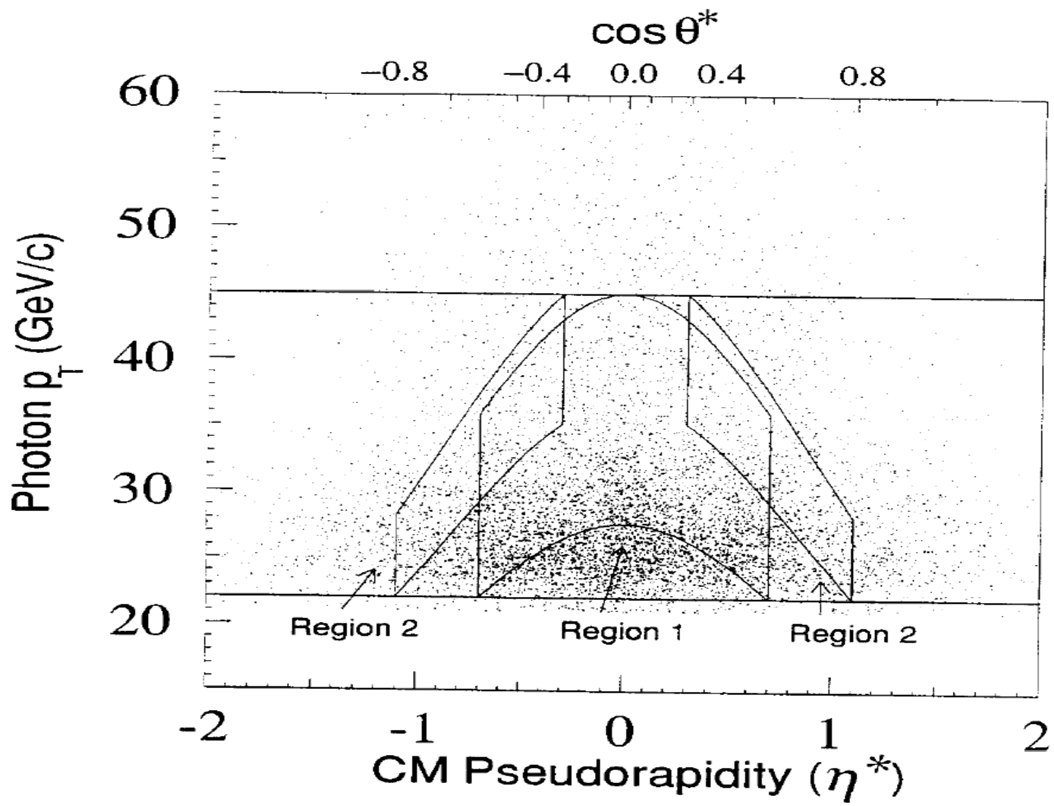
• CDF Collaboration analysis

• *In a preliminary study* **(J.I Lamoureux, AIP Conf. Proc. 357, 548 (1996))**

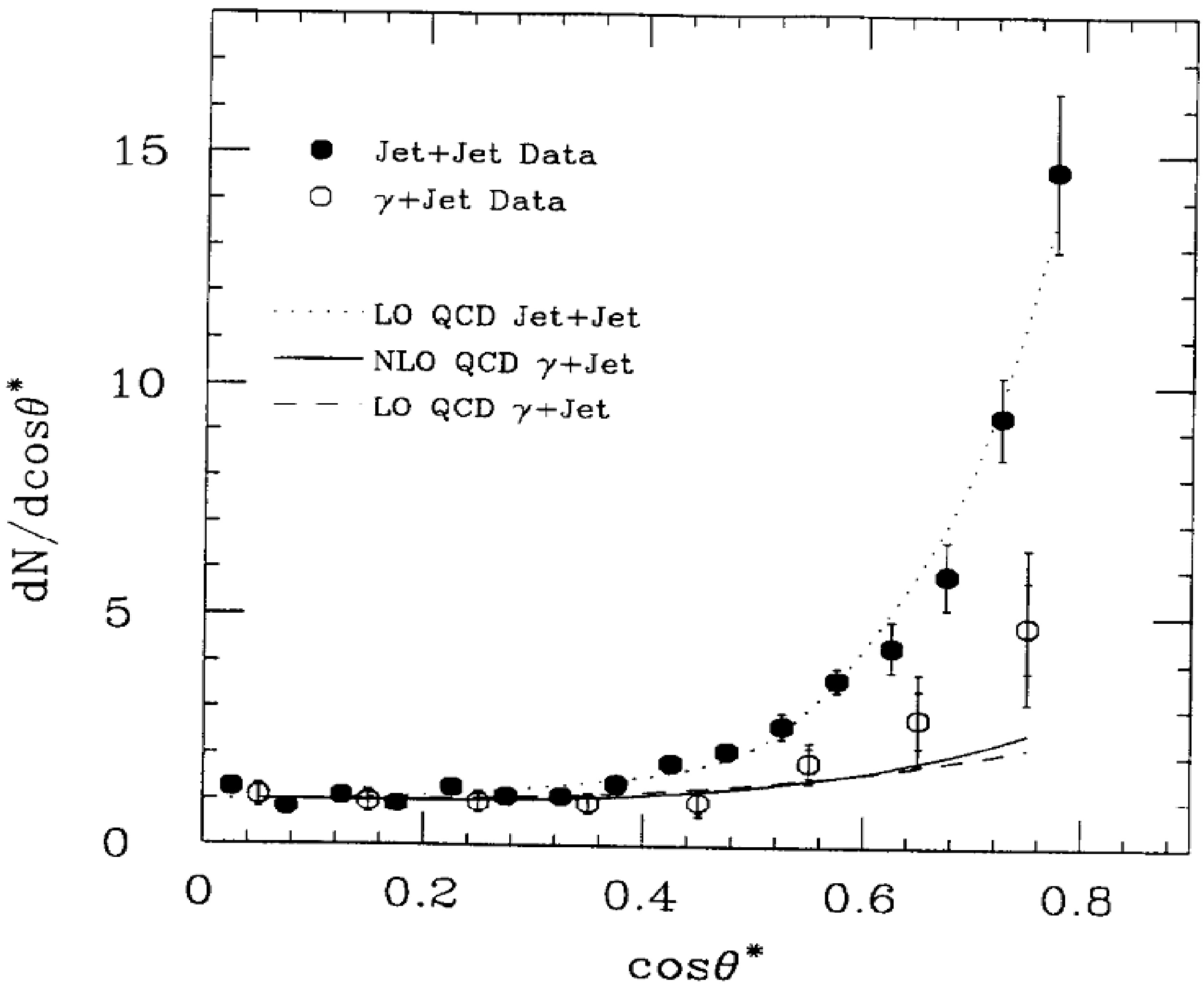
• *The CDF Collaboration found a discrepancy between the measured* $\cos\theta^*$ *distribution and the theoretical prediction. This CDF analysis concluded that extra dijetlike contributions involving t−channel gluon exchange would be necessary to bridge the gap.*

•. *These extra contributions might come NLO contributions to the (F) component.*

• *The CDF Coll. adopted a procedure to patch together the contributions from data* $\longrightarrow$ *to two regions distinct in* p^* *and* y_B *though overlapping in* $\cos\theta^*$ *in order to maximize the range in* $\cos\theta^*$



The vertical lines delineate the regions in η^* ($\cosh\theta^*$) and the curves are contours of constant p^*. The points within the curves are regions of flat acceptance in p^* and η^*.



Prompt photon dN/dcos θ^* after background subtraction. The photon data (open circles) are compared to LO-QCD (dashes) and NLO-QCD (solid) shown are previously published dijet data (solid circles) and theory curves for LO dijet tree level diagram (dots). The data and theory curves are normalized to an area of 3.0 in the region $|\cos\theta^*| < 0.3$.

We understand this approximate procedure but we did not follow it in our study for several reasons:

- *First, the normalization to 1 in the bin farthest from aims at getting rid of the numerical factor coming from the integration of partonic luminosity. However, in the present case, the distribution is*

$$\frac{d\sigma}{d\cos\theta^*} = \sum_s \mathcal{L}^{(s)} \frac{d\hat{\sigma}^{(s)}}{d\cos\theta^*}$$

.

In particular, considering (D) only, $gq\ (\mathrm{or}\ g\bar{q})$ *initiated &* $q\bar{q}$ *initiated processes which contribute at LO have distinct functional dependences on* $\cos\theta^*$

- *Second,* $\mathcal{L}^{(s)}$ *depends also on the integration regions in phase space*

⇒ *The relative weights of the subprocesses from (D) and (F) thus differ* in the two regions defined by CDF as "1" and "2".

.The normalization enforced by the matching procedure of CDF is not harmless on the impact of the NLO correction to (F) contribution, might reduce impact of this correction.

. Our study has been made for

$$\sqrt{S} = 1.96 \text{ TeV}$$

$$|y_\gamma| \leq 0.9, \quad p_T \geq 30 \text{ GeV}, \quad p_T^{\text{leading jet}} \geq 25 \text{ GeV}$$

$$R_c = 0.7$$

The photon isolation required that in a cone of aperture $R = 0.4$ in rapidity and azimuthal angle around the photon direction

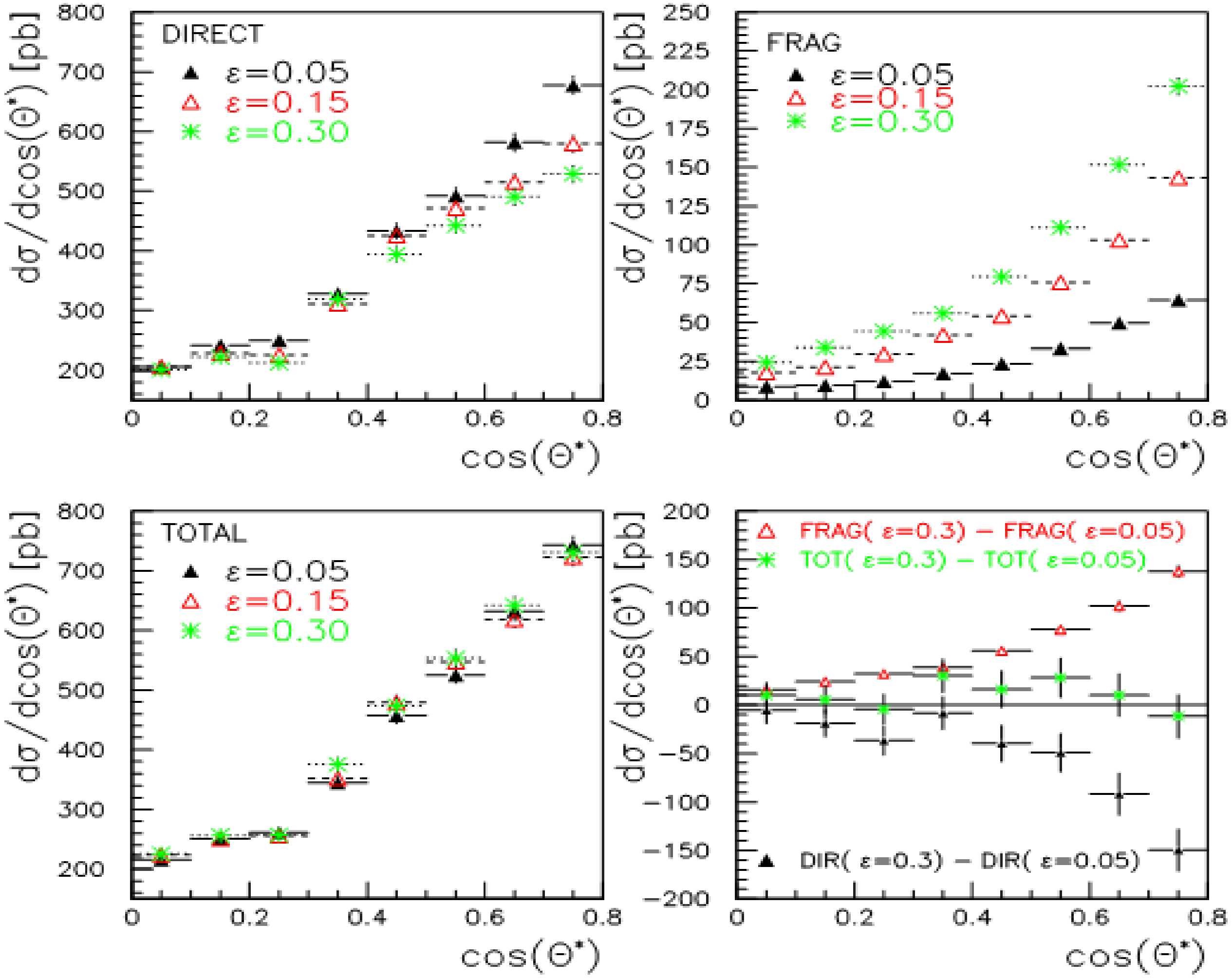
$$45 \text{ GeV} \leq p^* \leq 55 \text{ GeV}$$

We have considered three ingredients which may affect the size of the contribution of (F) component:

- *One is the account for the NLO corrections to many subprocesses.*

- *An other one concerns the uncertaintity on the FFs.*

- *Yet another one deals with a possible mismatch between the implementation of isolation at partonic level vs hadronic one.*



Sensitivity of the distribution of $\cos\theta^*$ in photon + jet at NLO to the isolation parameter $\epsilon = E_{t\,max}/p_T^{\gamma}$. Top left: Direct (D) contribution only. Top right: Fragmentation (F) contribution only. Bottom left: total (D) + (F) contribution. Bottom right: differences in (D), (F) and total (D)+(F) between $\epsilon = 0.3$ and 0.05.

- *Is it possible to increase the (F) contribution by modifying the FFs?*

- *When a stringent isolation cut is required on the photon candidate as in the CDF experiment, the (F) contribution involves the photon FF at* $z \geq z_c$

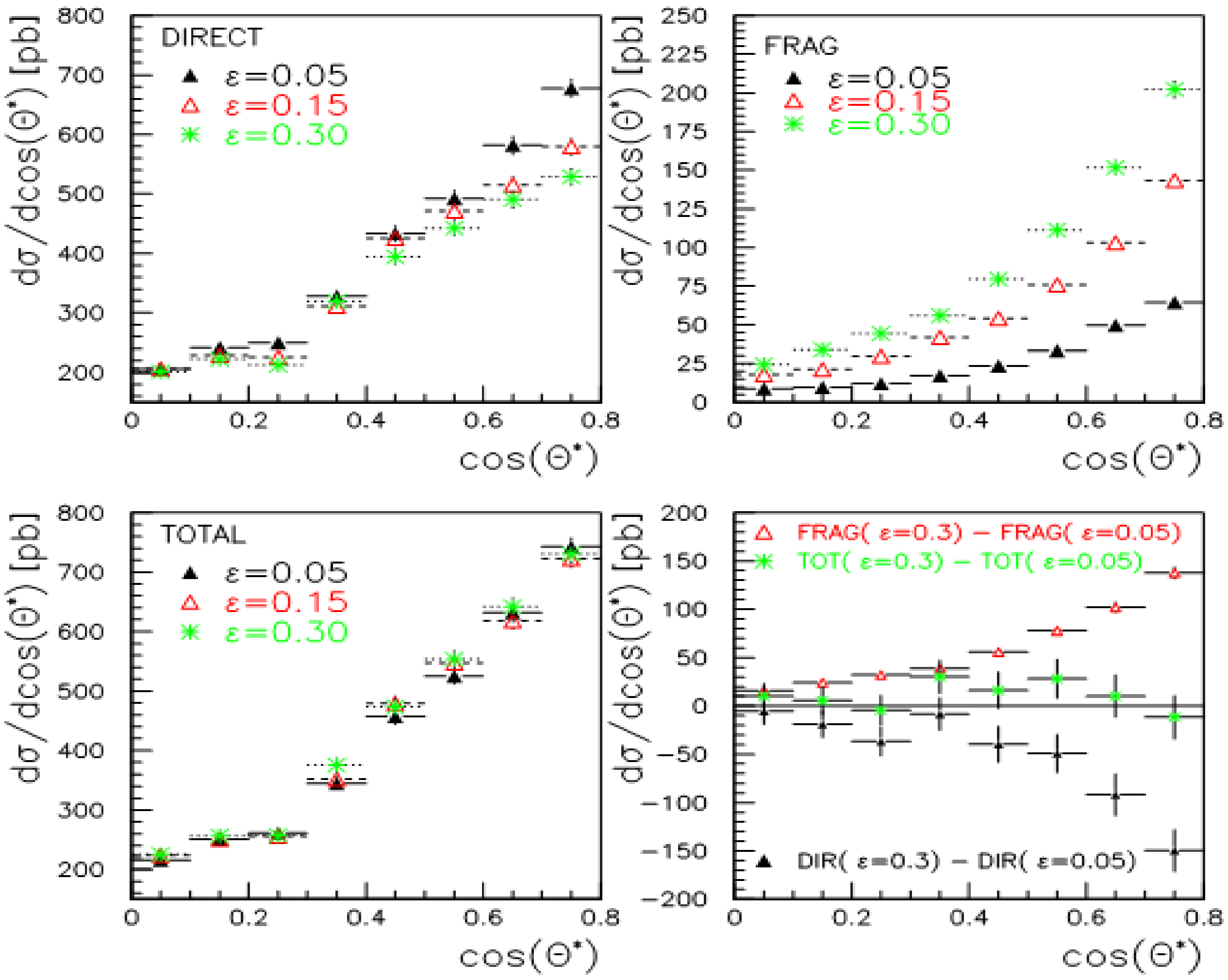
- *FFs are dominated by anomalous parts (predicted by pQCD).*
- *Nonperturbative parts (which would be adjustable ingredients) play no role:*

⇨ *The (F) contributions to the* $\cos\theta^*$ *distribution is rather tightly constrainted*

- *We have tackled the issue of the account of isolation at the partonic vs hadronic level by varying the isolation parameter*

$$\varepsilon = E_t/p^{\gamma}_T$$

from : 0.05 to 0.3



Sensitivity of the distribution of $\cos\theta^*$ in photon + jet at NLO to the isolation parameter $\epsilon = E_{t\,max}/p_T^{\gamma}$. Top left: Direct (D) contribution only. Top right: Fragmentation (F) contribution only. Bottom left: total (D) + (F) contribution. Bottom right: differences in (D), (F) and total (D)+(F) between $\epsilon = 0.3$ and 0.05.

Summary

To summarize, the results of our calculations show that the idea of playing with the (F) component as suggested in the CDF analysis turns out to be ineffective in conditions which we have considered.

It would be worthwhile to perform a quantitative analysis of the much larger statistics data set gathered in Run II, without relying on the questionable matching procedure used in the CDF Run I analysis.

On the other hand, the *very small* fraction of hadronic events which pass the isolation cuts corresponds to the tail of fragmentation at large z which is not constrained by the data. These background events yield namely dijet-type contributions involving t-channel gluon exchange, which might explain part of the discrepancy observed, and the distribution in $\cos\theta^*$ at $\cos\theta^* \to 1$ might provide an enhanced sensitivity to this contamination w.r.t. other prompt photon observables.

Conclusions

- We have studied photon-jet correlations in hadronic collisions based on the NLO program JETPHOX, which is a Monte Carlo program of partonic event generator type which incorporates NLO corrections to both direct photons and photons from fragmentation. The program is flexible to account for user-defined kinematic cuts and photon isolation parameters.

It is available at the web site: http://lappweb.in2p3.fr/lapth/PHOX_FAMILY/main.html

- Correlation observables offer in general a larger sensitivity to the short distance dynamics than one particle inclusive observables. We studied the photon-jet angular distribution $\cos\theta^*$ and the jet rapidity distribution (which is not mentionned in this talk) in view of possible constraints on the parton distribution functions (PDFs) in the proton, in particular, the gluon.

Thank You

Thank You