Photon production at hadronic colliders

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LAPTH
CNRS/Université de Savoie

Higgs hunting – Jully 2010

Outline

- Inclusive photon production
- Single photon production
- Isolation criterion
- Double photon production
- Conclusion

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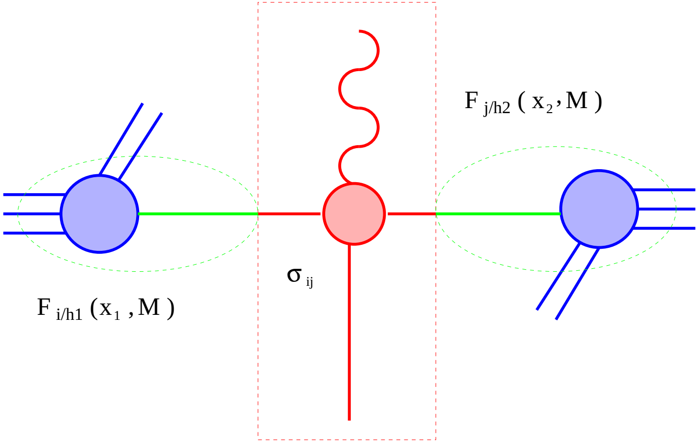
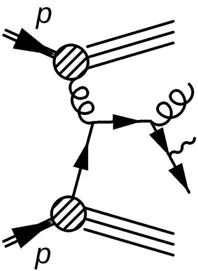
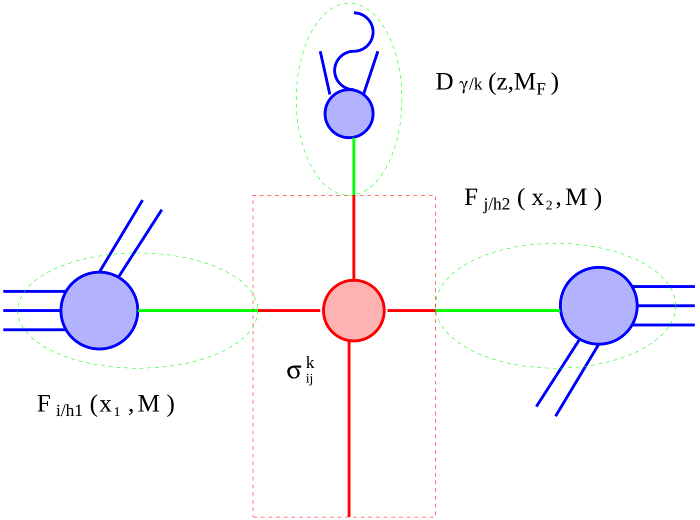
Inclusive photon production
Direct



$O(\alpha_s)$:




D γ/k (z,M_F)
F j/h2 (x2 , M)
σ k ij
F i/h1 (x1 , M)

- Only the sum $\sigma^D + \sigma^F$ is a physical observable
- When $M_F \gg$ hadronic scale $D_{\gamma/k}(z, M_F)$ behaves like $\alpha/\alpha_s(M_F)$

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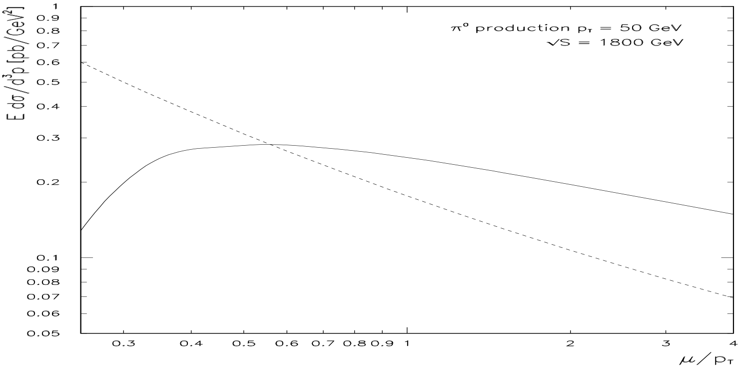
$$\frac{\partial}{\partial \ln(M)} \left(\frac{d\,\sigma}{d\,\vec{P}_{T\,\gamma}\,d\,y_\gamma} \right) = O(\alpha_s^{n+1})$$



- $\hat{\sigma}_{ij}^{(1)}$ contains other logarithmic terms such as $\ln(\hat{x}_T)$, $\ln(1-\hat{x}_T)$, ... where $\hat{x}_T = 2\,P_{T\,\gamma}/\sqrt{\hat{s}}$.
  - when $P_{T\,\gamma}$ is close to $\sqrt{S}/2$, the extra gluons are forced to be soft $\rightarrow$ large logarithms of infra-red origin
  - when $P_{T\,\gamma} \ll \sqrt{S}$, two scale problem, in this regime, the assumptions of the QCD improved parton model may not be valid $\rightarrow$ The Altarelli-Parisi evolution may be not valid.
- assumption that the γ produced is collinear to the parent parton $\rightarrow$ inter jet activity cannot be described by this type of calculation
- the fragmentation functions are extracted from $e^+ e^-$ data in a range $.1 < z < .8$. What are the errors due to FF?

Inclusive photon production

Validity of this type of calculation

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Large domain of energies experimentally studied (it was thought that the photon production gave a clean probe of parton dynamics!!!!!)

Single photon production
NLO codes

	type of code	Direct	Fragmentation
INCNLO (*)	I/FO	NLO	NLO
Vogelsang, Gordon (*)	I/FO	NLO	NLO
Owens et al.	G/FO	NLO	LO
Frixione, Vogelsang	G/FO	NLO	LO
JETPHOX (*)	G/FO	NLO	NLO

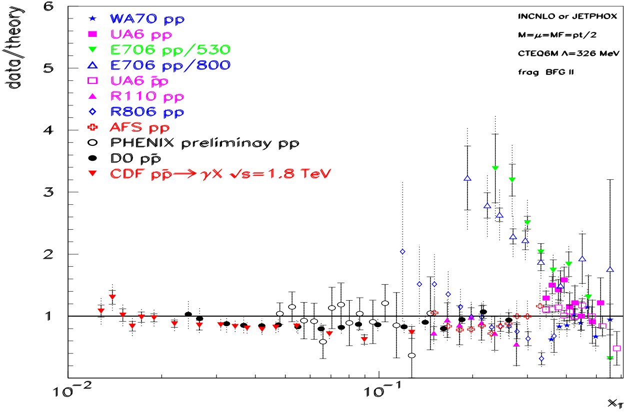
I : Inclusive
G : Generator
FO : Fixed Order

(*) http://wwwlapp.in2p3.fr/lapth/PHOX_FAMILY/main.html

Threshold resummation: (*) Catani et al., Vogelsang, Sterman
(*) Kidonakis, Owens

Disagreement between data and theory

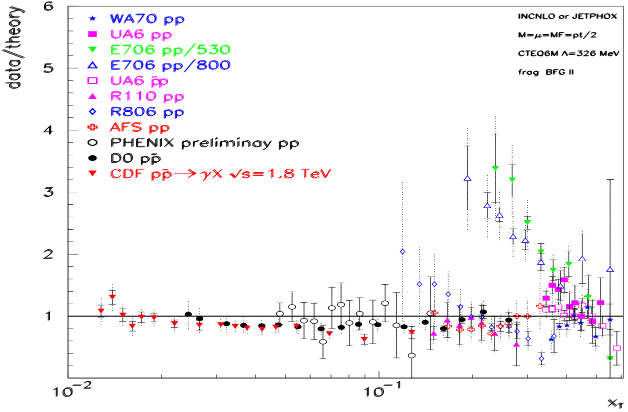
$23 \leq \sqrt{S} \leq 1960$ GeV: fixed target + ISR data + Tevatron data

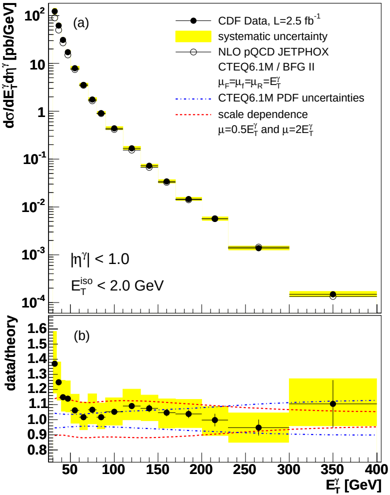


Single photon production
Comparison with existing data

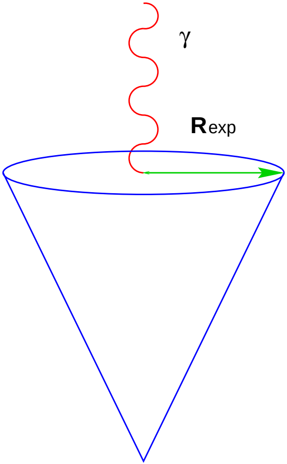
Disagreement between data and theory or disagreement among experimental data???

$23 \leq \sqrt{S} \leq 1960$ GeV: fixed target + ISR data + Tevatron data

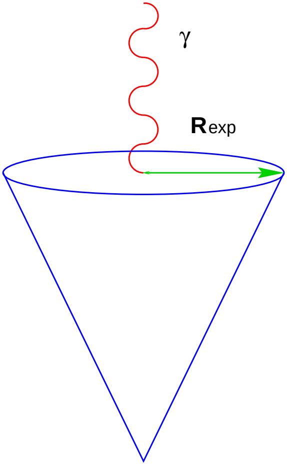




high energy resummation ($P_{T\,\gamma} << \sqrt{S}$) is negligible at Tevatron : G. Diana, J. Rojo and R. D. Ball (arXiv:1006.4250 [hep-ph])

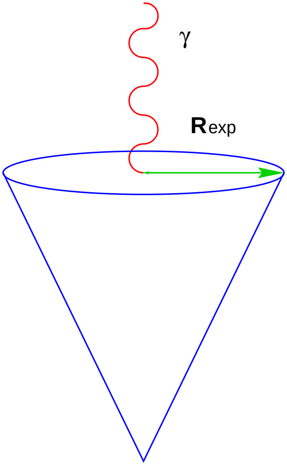


$$E_T^{had} \leq E_{T\,max} \text{ inside}$$
$$(y - y_\gamma)^2 + (\phi - \phi_\gamma)^2 \leq R_{exp}^2$$



$E_T^{had} \leq E_{T\,max}$ inside
$(y - y_\gamma)^2 + (\phi - \phi_\gamma)^2 \leq R_{exp}^2$

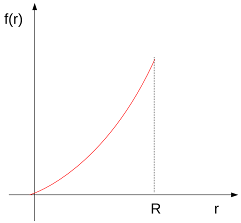
Large Log. when $R_{exp} \rightarrow 0$ and $E_{T\,max} \rightarrow 0$



$E_T^{had} \leq E_{T\,max}$ inside
$(y - y_\gamma)^2 + (\phi - \phi_\gamma)^2 \leq R_{exp}^2$

Large Log. when $R_{exp} \to 0$ and $E_{T\,max} \to 0$

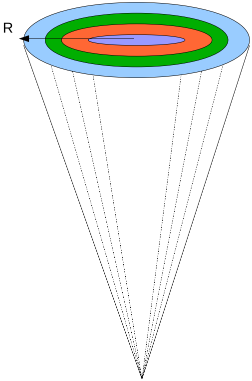
Underlying events, pile up, ...

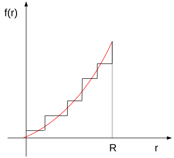


Other isolation criterion (S. Frixione)
where $E_{T\,had} < f(r)$

$f(r) \to 0$ when $r \to 0$ like r^{2n}

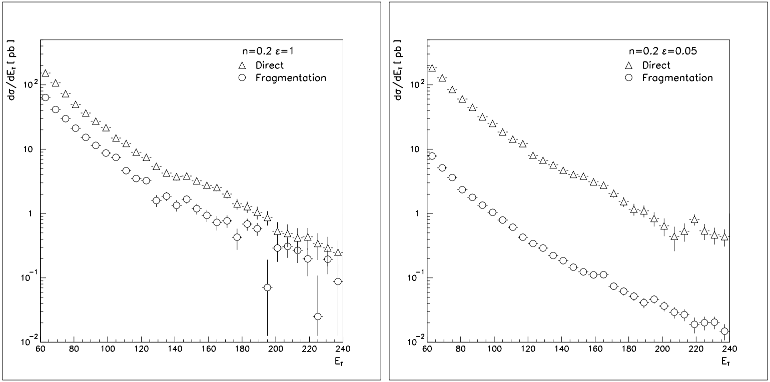
kill the fragmentation contribution





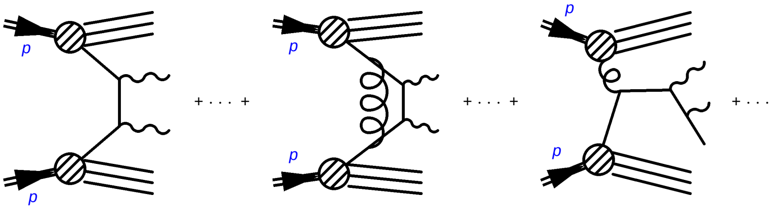
$$E^{j}_{T\,max} = \epsilon P_{T\,\gamma} \left(\frac{1 - \cos(r_j)}{1 - cos(R)} \right)^n$$

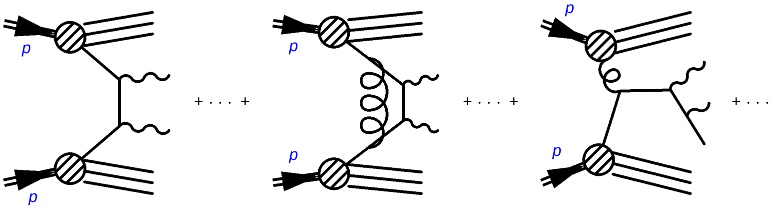
6 nested cones : 0.1, 0.16, 0.22, 0.28, 0.34, 0.4



Higgs search at LHC ($M_{Higgs} \leq 140$ GeV)

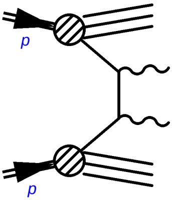
Double photon production
Direct



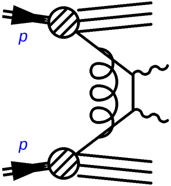


$O(\alpha^2) + O(\alpha^2\ \alpha_s)$

Double photon production
Direct



$+ \cdots +$



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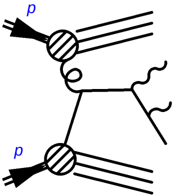
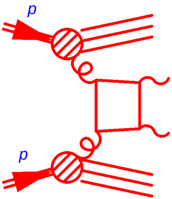


$+ \cdots$

$O(\alpha^2) + O(\alpha^2\ \alpha_s)$



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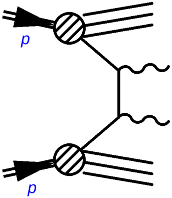
Double photon production

Direct



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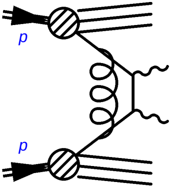

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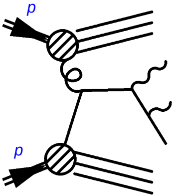

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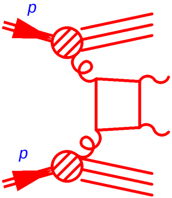
$O(\alpha^2) + O(\alpha^2\ \alpha_s)$



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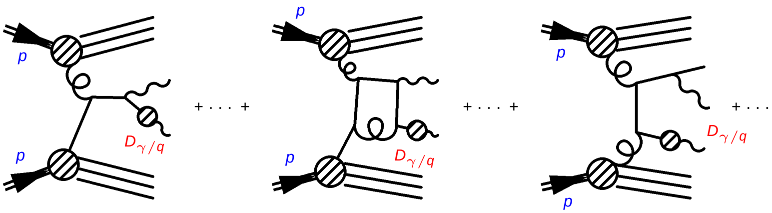
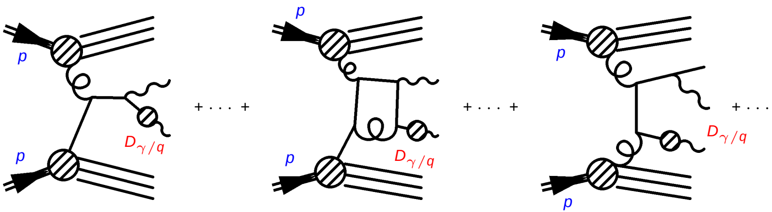
$O(\alpha^2\ \alpha_s^2)$

Double photon production
One Fragmentation



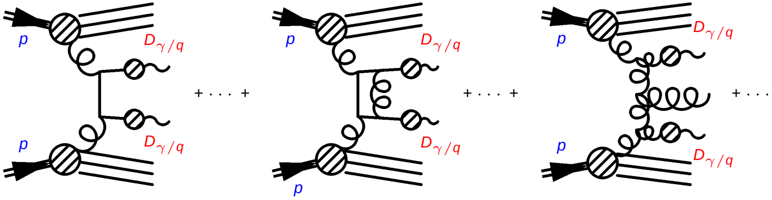
Double photon production
One Fragmentation



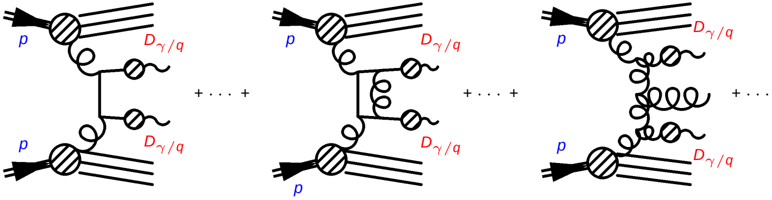
$O(\alpha^2\ \alpha_s) + O(\alpha^2\ \alpha_s^2)$ but $D_{\gamma/q}(z, M_f^2) \simeq 1/\alpha_s(M_f^2)$

Double photon production

Two Fragmentation



Double photon production
Two Fragmentation



$O(\alpha^2\ \alpha_s^2) + O(\alpha^2\ \alpha_s^3)$

	type of code	Direct	One Frag.	Two Frag.
Aurenche et al.	I/FO	NLO	LO	none
Owens et al.	G/FO	NLO	LO	none
DIPHOX (*)	G/FO	NLO	NLO	NLO
RESBOS	G/SGS	NLO	LO	none

I : Inclusive
G : Generator
FO : Fixed Order
SGS: Soft Gluon Summation

(*) http://wwwlapp.in2p3.fr/lapth/PHOX_FAMILY/main.html

Preliminary CDF runII data

$P_{T\gamma_1} > 17$ GeV, $P_{T\gamma_2} > 15$ GeV, $|y_{\gamma_{1,2}}| < 1$

Photon isolation:

$E_T^{had} \leq 2$ GeV in a cone of $R_{exp} = 0.4$

Acollinearity cut between the photons:

$R_{min} : \sqrt{(y_{\gamma_1} - y_{\gamma_2})^2 - (\Phi_{\gamma_1} - \Phi_{\gamma_2})^2} > 0.3$

Scale choice:

μ = M = M$_f$ = $M_{\gamma\,\gamma}/2$

also Data points D0 runII (arXiv:1002.4917 [hep-exp])

$P_{T\gamma_1} > 21$ GeV, $P_{T\gamma_2} > 20$ GeV, $|y_{\gamma_{1,2}}| < 1$

Photon isolation:

$E_T^{had} \leq 2.5$ GeV in a cone of $R_{exp} = 0.4$

Acollinearity cut between the photons:

$R_{min} : \sqrt{(y_{\gamma_1} - y_{\gamma_2})^2 - (\Phi_{\gamma_1} - \Phi_{\gamma_2})^2} > 0.4$

Scale choice:

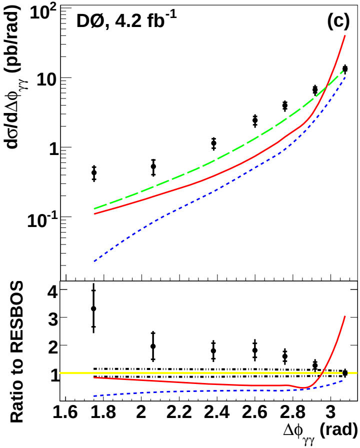
μ = M = M$_f$ = $M_{\gamma\,\gamma}$

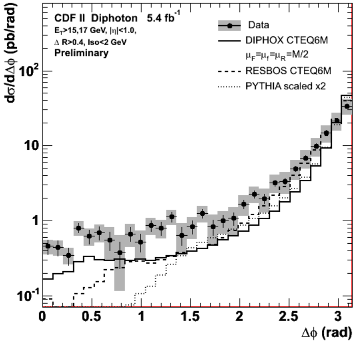
extra cut :

$q_T < M_{\gamma\,\gamma}$

Double photon production

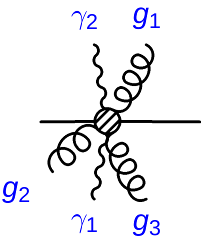
Azymuthal angle distribution



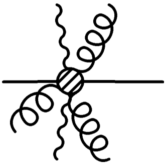


Double photon production

Divergence of IR origin at the end of phase space



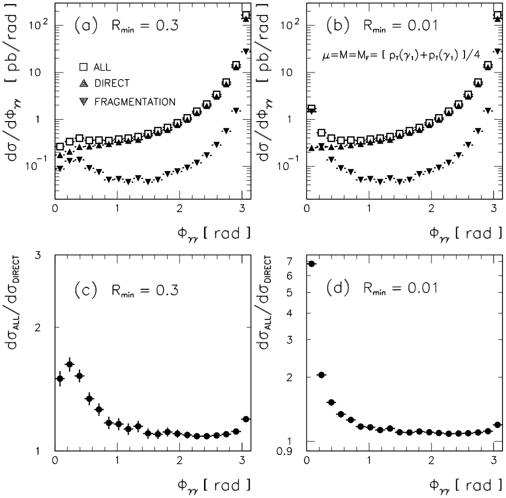
- $\phi_{\gamma\gamma} \simeq \pi$ dominated by config. where the extra gluons are forced to be either soft or collinear to the initial or final state $\rightarrow$ large logarithms of infra-red origin
- $q_T \simeq 0$ dominated by config where the extra gluons are forced to be either soft or collinear to the initial state $\rightarrow$ large logarithms of infra-red origin

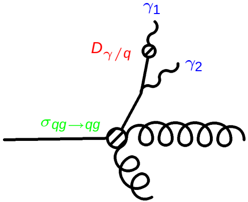


- $\phi_{\gamma\,\gamma} \simeq \pi$ dominated by config. where the extra gluons are forced to be either soft or collinear to the initial or final state $\longrightarrow$ large logarithms of infra-red origin
- $q_T \simeq 0$ dominated by config where the extra gluons are forced to be either soft or collinear to the initial state $\longrightarrow$ large logarithms of infra-red origin

Double photon production

Enhancement at $\phi_{\gamma\gamma} = 0$



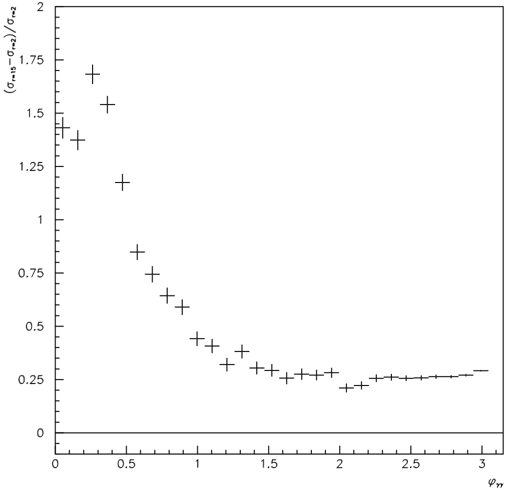


assume difficulties to measure the energy along the photon direction

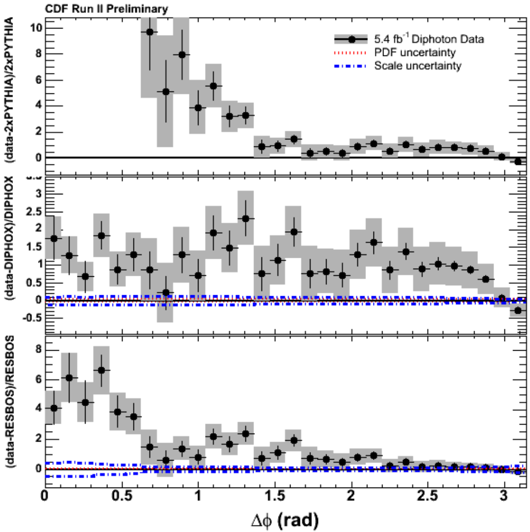
$R_2 = 0.4$ $R_1 = 0.1$
In the inner cone R_1, $E_{T\,max} < 15$ GeV
In the crown $R_2 - R_1$, $E_{T\,max} < 2$ GeV

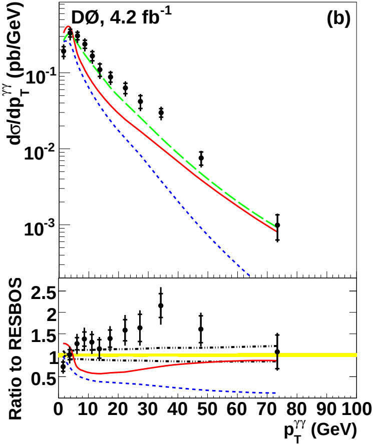
Double photon production

Azymuthal angle distribution th

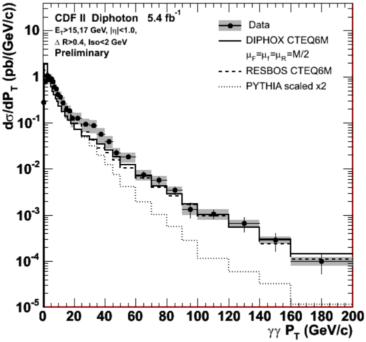


Azymuthal angle distribution CDF



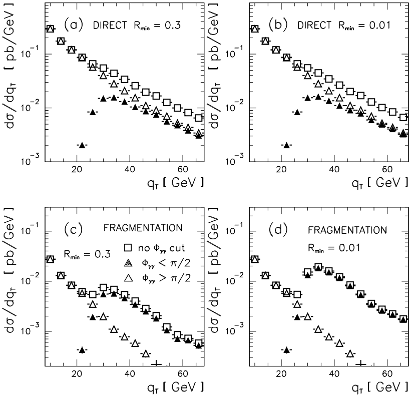


DØ, 4.2 fb^{-1}
(b)
$d\sigma/dp_T^{\gamma\gamma}$ (pb/GeV)
Ratio to RESBOS
$p_T^{\gamma\gamma}$ (GeV)



CDF II Diphoton 5.4 fb^{-1}
E_T>15,17 GeV, |η|<1.0,
Δ R>0.4, Iso<2 GeV
Preliminary
Data
DIPHOX CTEQ6M
$\mu_F=\mu_f=\mu_R=M/2$
RESBOS CTEQ6M
PYTHIA scaled x2
$d\sigma/dP_T$ (pb/(GeV/c))
γγ P_T (GeV/c)

Double photon production
q_T shoulder

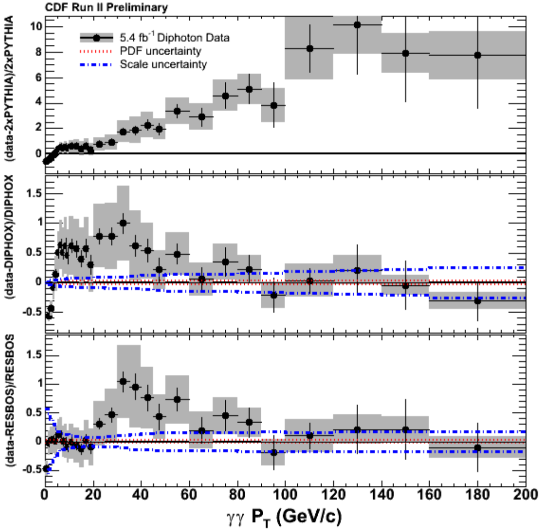


$$q_T^2 = |\vec{P}_{T\,\gamma_1} + \vec{P}_{T\,\gamma_2}|^2$$
$$= P_{T\,\gamma_1}^2 + P_{T\,\gamma_2}^2 + 2\,P_{T\,\gamma_1} P_{T\,\gamma_2} \cos\Phi_{\gamma\gamma}$$

$$q_{T\,min} = \sqrt{P_{T\,\gamma_1\,min}^2 + P_{T\,\gamma_2\,min}^2} \simeq 20.34\ \text{GeV}$$

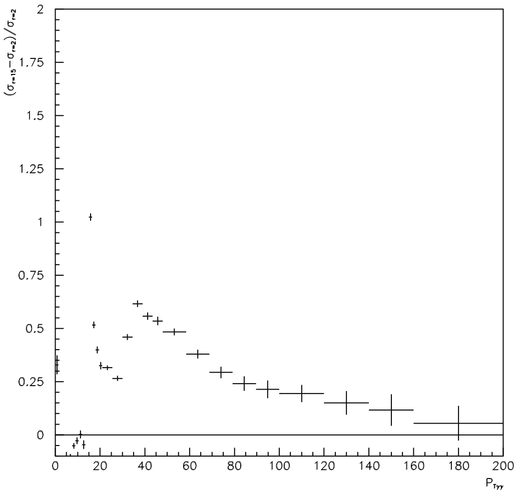
$$q_{T\,lim} = P_{T\,\gamma_1\,min} + P_{T\,\gamma_2\,min} \simeq 28.75\ \text{GeV}$$

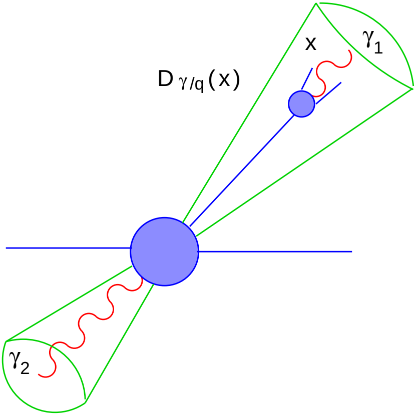
Double photon production
q_T distribution CDF



Double photon production

q_T distribution th





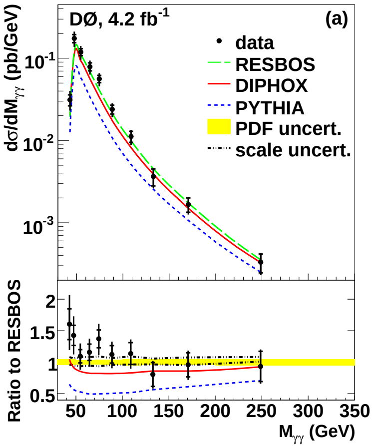
For one fragmentation, at LO:

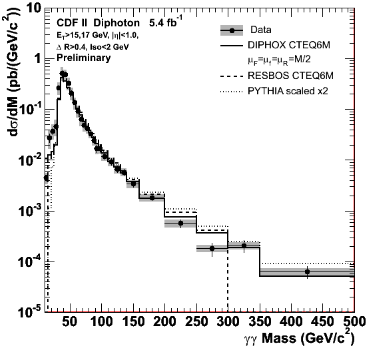
$$q_T = |\vec{P}_{T\gamma_1} + \vec{P}_{T\gamma_2}| = (1 - x)\, P_{T\gamma_2} = E_T^{had}$$

Because of isolation criterion:

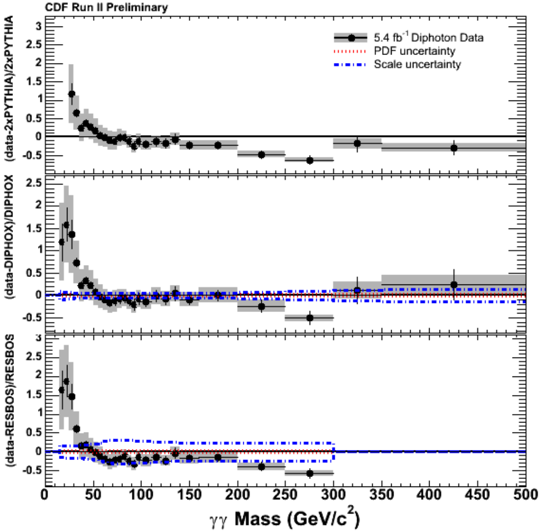
$$\frac{d\sigma^{LO}}{dq_T} \simeq \Theta(E_{T\,max} - q_T)\,\sigma$$

Double photon production
Invariant mass distribution



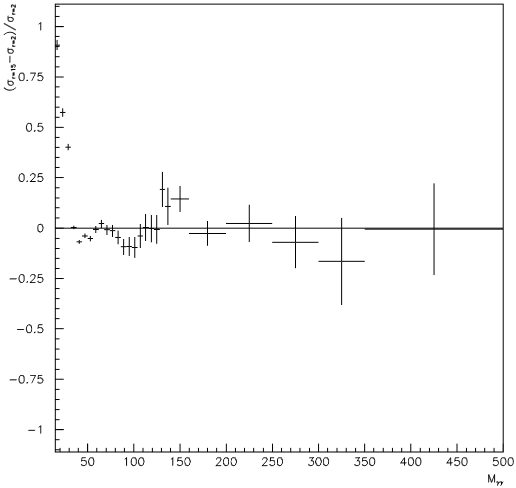


Double photon production
Invariant mass distribution : ratio



Double photon production

Invariant mass distribution : th



Conclusion

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