Hard QCD results with photons at the LHC

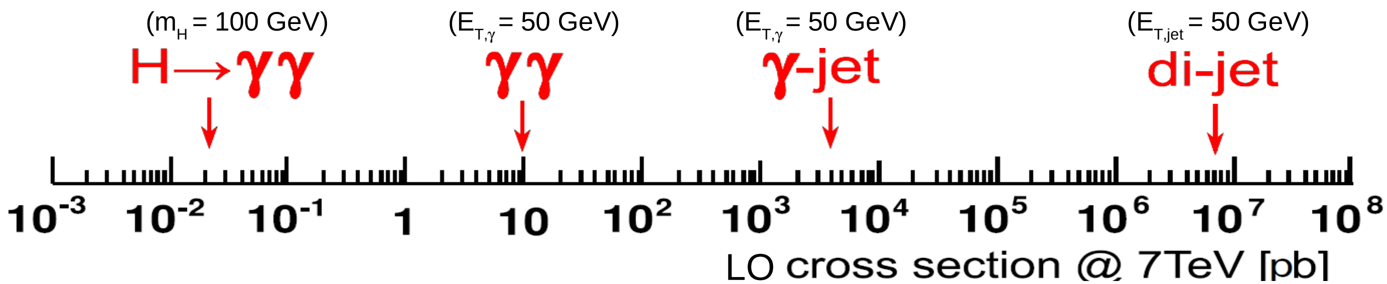
HCP 2011

Paris, 17th Nov 2011

David d'Enterria
CERN

Outline

- Introduction:
  - Test pQCD: collinear- & k_T-factorization, resummations (soft, collinear, threshold)
  - Constrain gluon PDF
  - Irreducible backgd. for searches: Higgs, SUSY, extra-dims (UED, RS), ...



- ATLAS & CMS photon measurements:
  - ECAL reconstruction, identification, isolation, backgd subtraction, uncertainties

- Isolated-γ in p-p @ 7 TeV (36 pb^{-1}) & p-p,Pb-Pb @ 2.76 TeV (~0.25 pb^{-1}):
  - $d\sigma_\gamma/dp_T$ spectra vs NLO

ATLAS: PRD 83 (2011) 052005
arXiv:1108.0253

CMS: PRL 106 (2011) 082001
PRD84 (2011) 052011
PAS-HIN-11-002 (Pb-Pb)

- Diphotons in p-p @ 7 TeV (36 pb^{-1}):
  - $d\sigma/dm_{\gamma\gamma}$, $d\sigma/dp_{T,\gamma\gamma}$, $d\sigma/d\Delta\varphi_{\gamma\gamma}$ vs NLO/NNLL

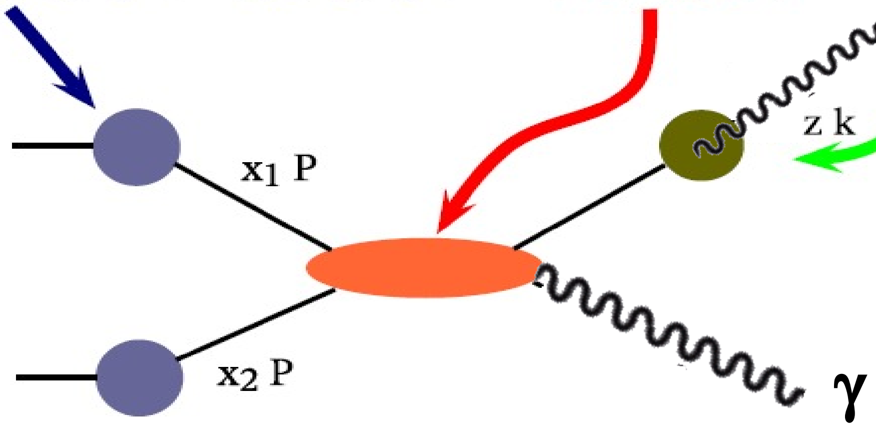
ATLAS: arXiv:1107.0581

CMS: arXiv:1110.6461

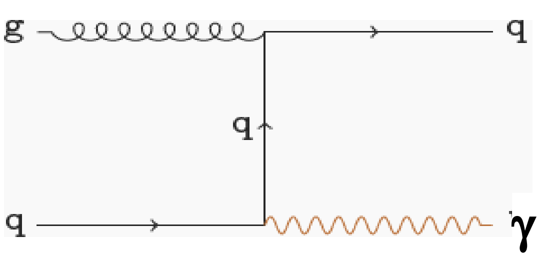
pQCD with prompt photons

- Factorization theorem:

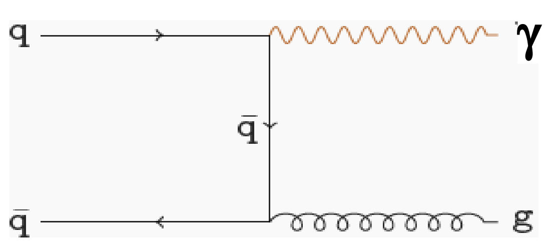
$$\sigma^{pp\to\gamma X} = \underbrace{f_p(x_1,Q^2)\otimes f_p(x_2,Q^2)}_{\text{PDFs}} \otimes \underbrace{\sigma(x_1,x_2,Q^2)}_{\text{partonic x-sections}} \otimes \underbrace{D(z,Q^2)}_{\text{FFs}}$$



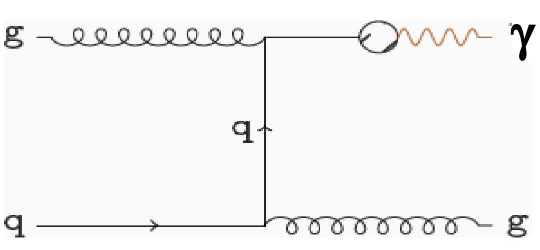
- Prompt QCD photons (LO):



q-g Compton



q-q̄ annihilation



fragmentation

pQCD with prompt <u>isolated</u> photons

- Factorization theorem:

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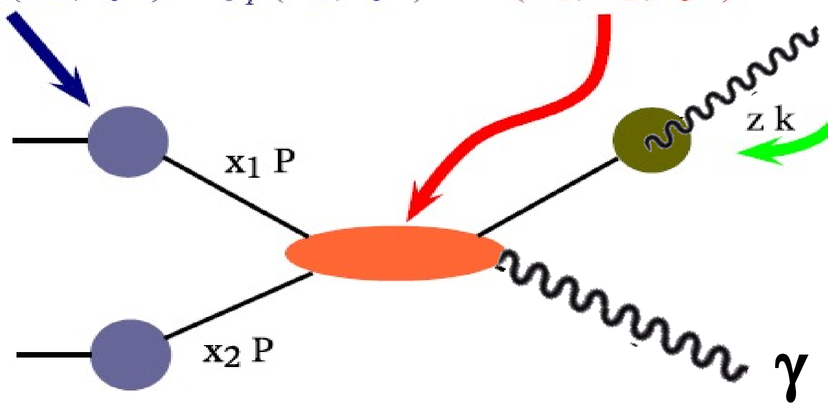
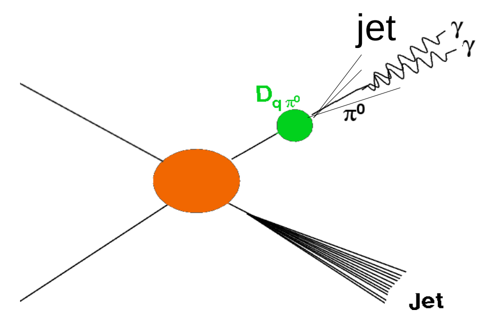


Isolation needed to remove experimental decay-γ backgrounds:



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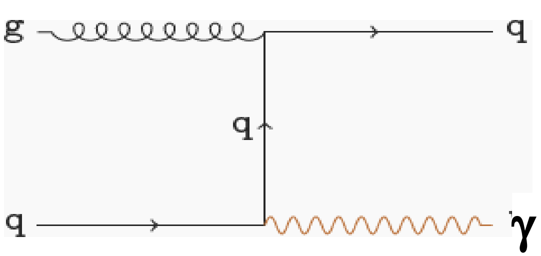

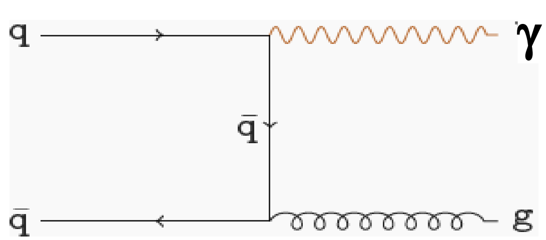

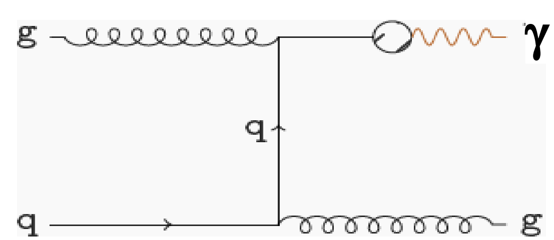

q-g Compton **q-q̄ annihilation** **fragmentation**

pQCD with prompt isolated photons

- Factorization theorem:

PDFs — partonic x-sections — FFs

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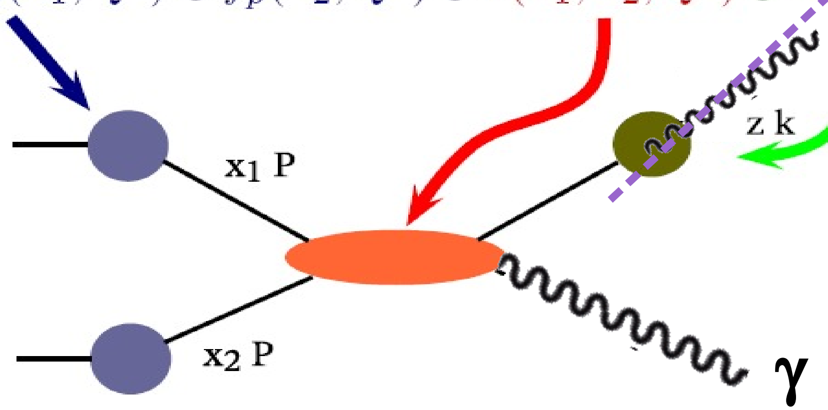

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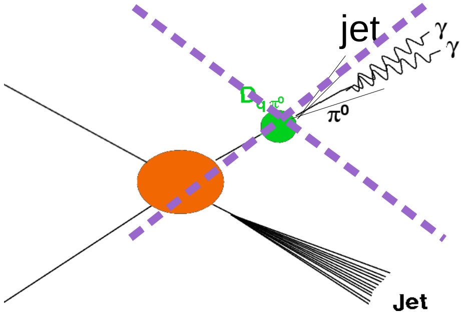

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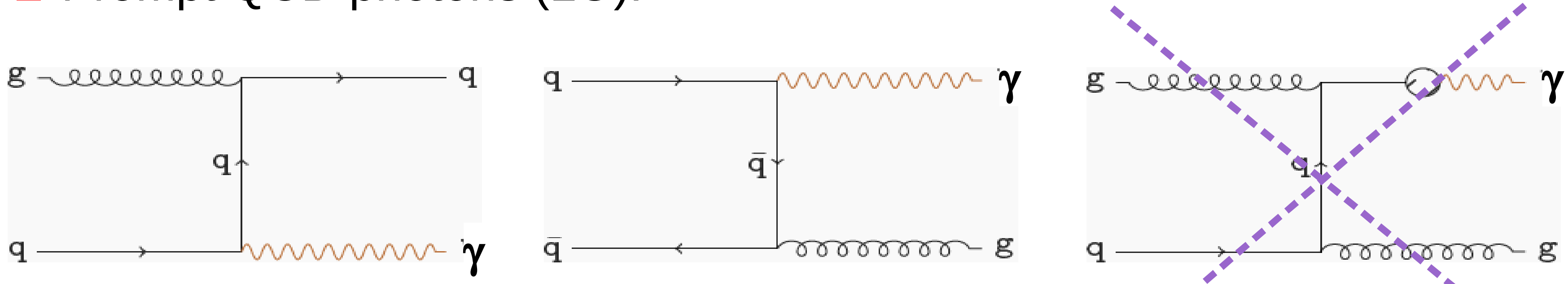

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pQCD with prompt diphotons

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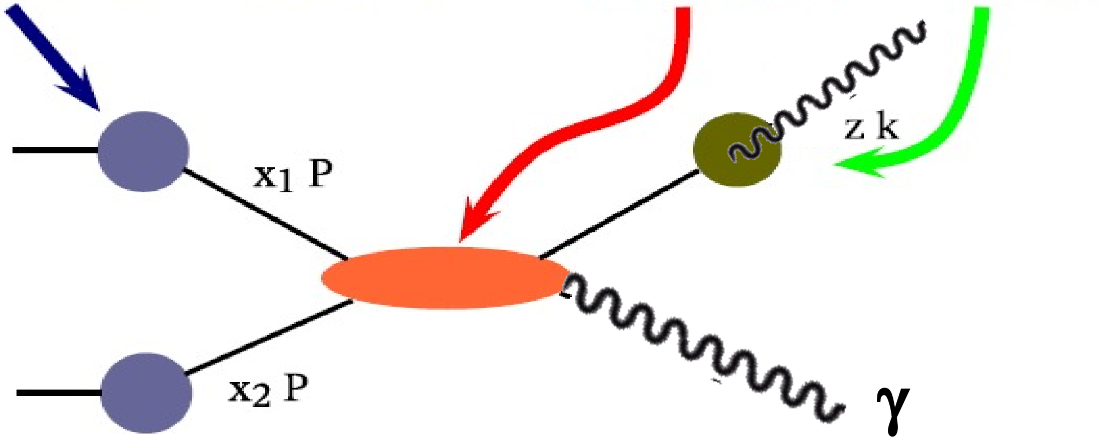
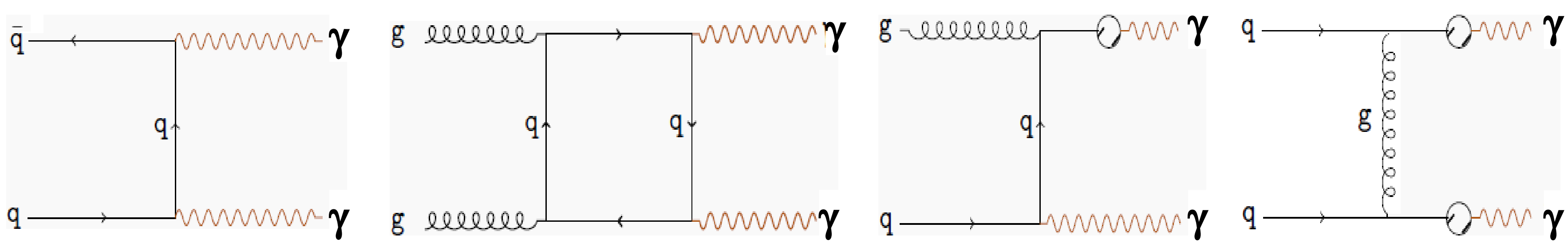


- Prompt QCD diphotons (“LO”):



q-q̄ annihilation **g-g box** **1-frag** **2-frag**

pQCD with prompt isolated diphotons

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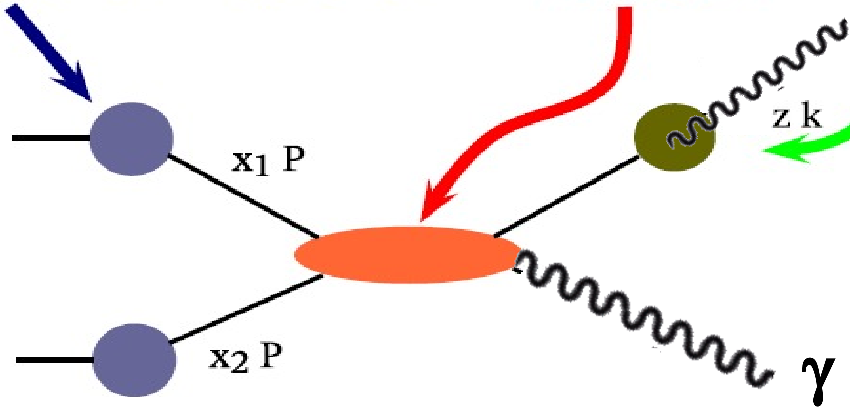

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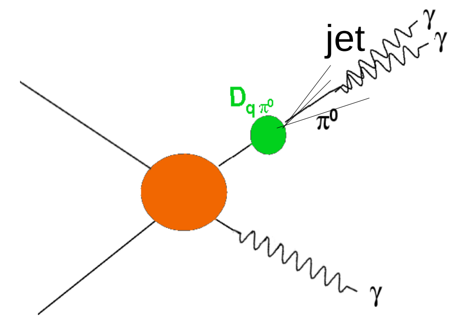

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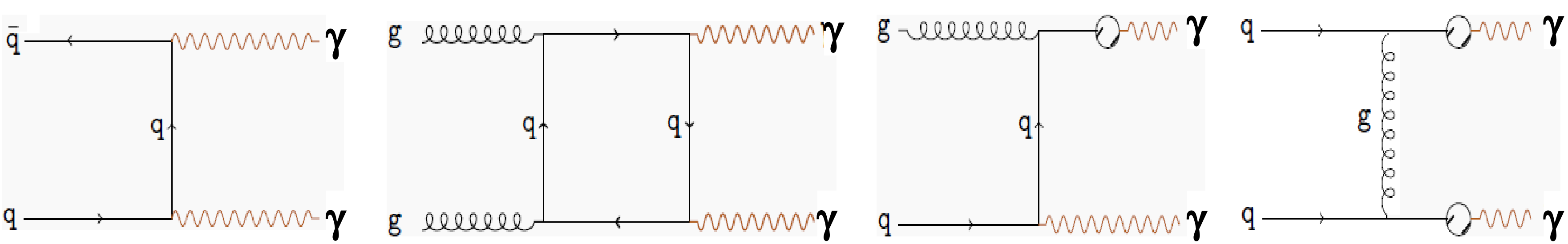

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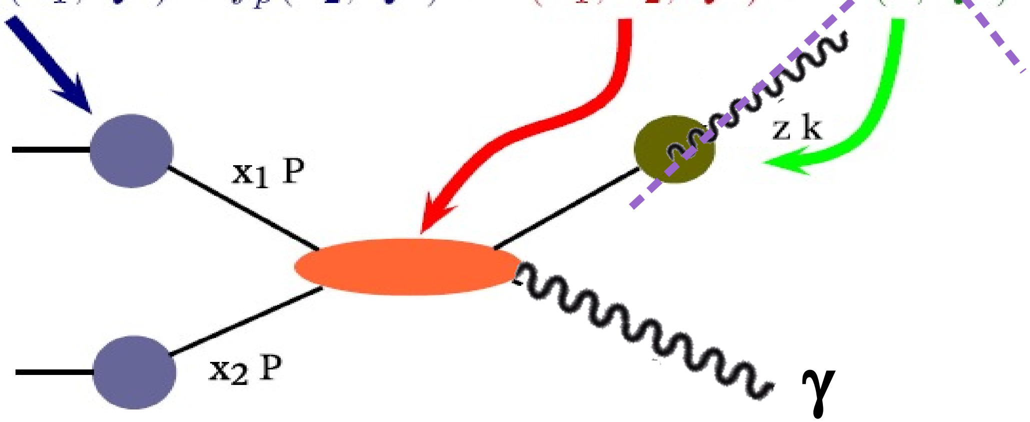

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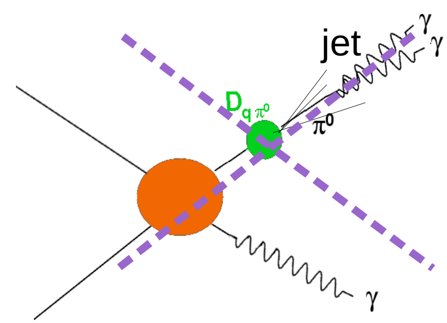

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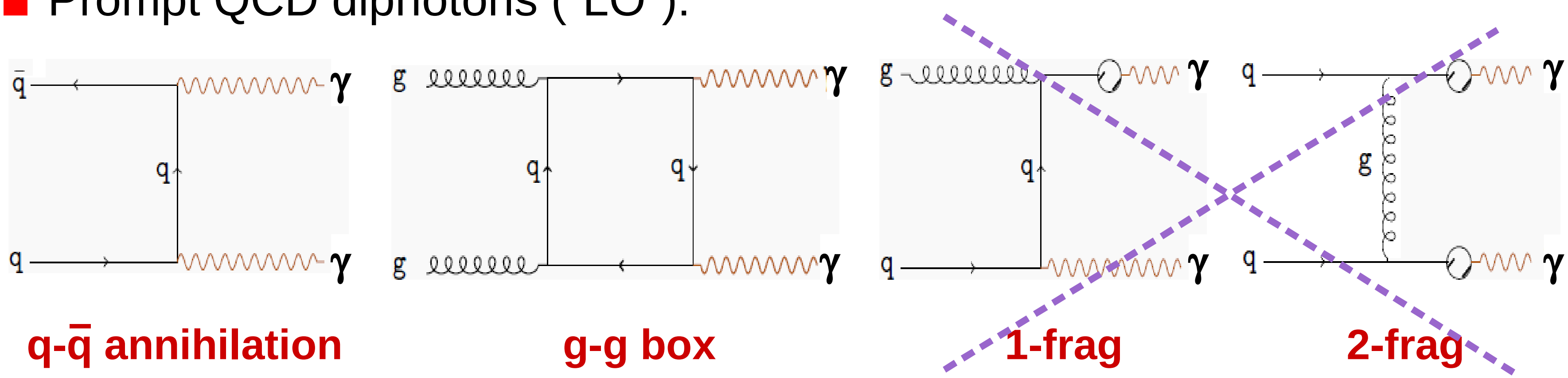


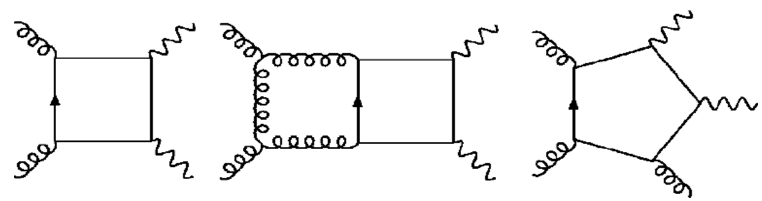
q-q̄ annihilation **g-g box** **1-frag** **2-frag**

pQCD (di)photon theoretical x-sections

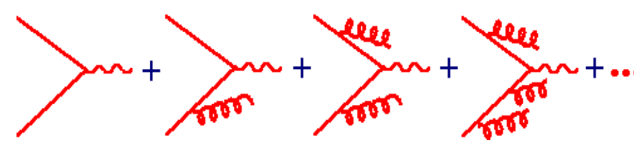
- JETPHOX / DIPHOX: [Guillet-Aurenche-Werlen et al. '00]
  - NLO processes: q-g, q-$\bar{q}$, parton-parton (1γ-frag & 2γ-frag)
  - PDFs interfaced via LHAPDF: CTEQ6.6/CT10, MSTW08, NNPDF2.1

    PDF4LHC uncertainties: Combined (68% CL eigenvalues $\oplus$ α_s) enveloppes from 3 global-fit PDFs (400 PDFs !): → **±(10 – 2)%**
  - FFs: BFG-II parton-to-photon (suppressed by isol. cuts). Identical results for BFG-I.
  - Theoretical scales default: $\mu_R = \mu_F = \mu_{FF} = E_T^{\gamma}, m_{\gamma\gamma}$

    Uncertainty: (μ_R,μ_F) =(1,1),(1/2,1),(1,1/2),(1/2,1/2),(2,1),(1,2),(2,2)×$E_{T,\gamma}, m_{\gamma\gamma}$ → **±(20 – 7)%**
- gamma2MC: [Bern-Dixon-Schmidt '02]
  - gluon-gluon diphoton box at 'NNLO':



- 2γNNLO: [deFlorian et al. '11]
  - All direct (but not frag) components at NNLO
- ResBos: [Nadolsky-Yuan-Balasz-Berger '00]
  - (N)LO+NNLL soft-gluon resummation:



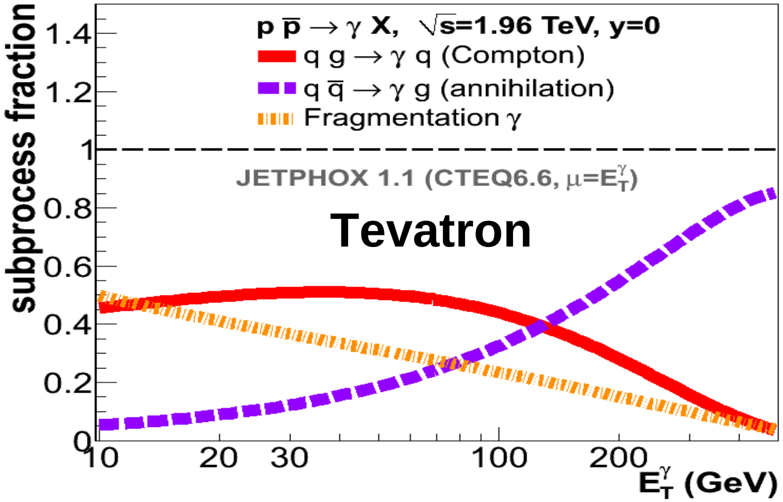
$$\left.\frac{d\sigma}{dq_T^2 dy}\right|_{q_T\to 0} \sim \frac{1}{q_T^2}\sum_{n=1}^{\infty}\sum_{m=0}^{2n-1}\alpha_S^n \ln^m\left(\frac{Q^2}{q_T^2}\right)\cdot C_m^n$$

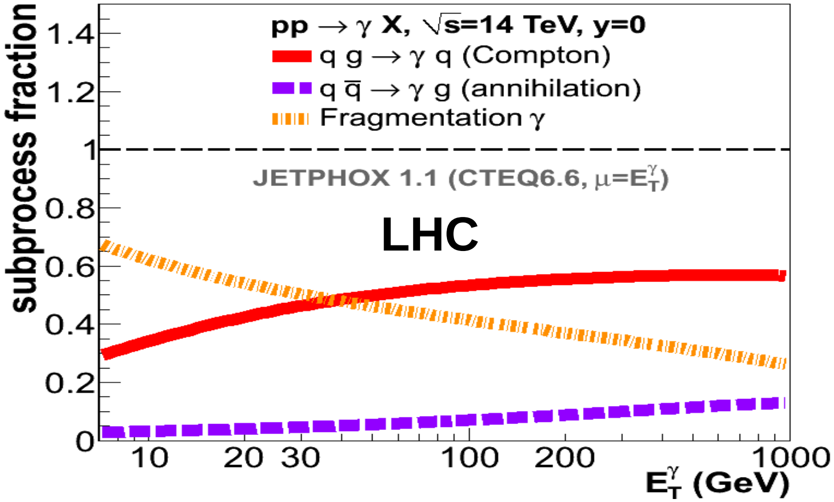
- PYTHIA / HERWIG:
  - UE & hadronization corrections needed for parton-level calculations → **0.95 – 0.97**

NLO photon partonic subprocesses

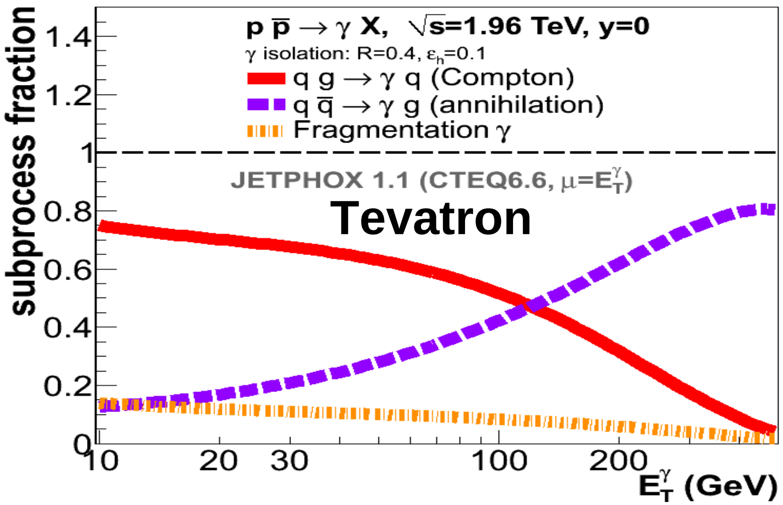
[R.Ichou & D.d'E, PRD82 (2010) 014015]

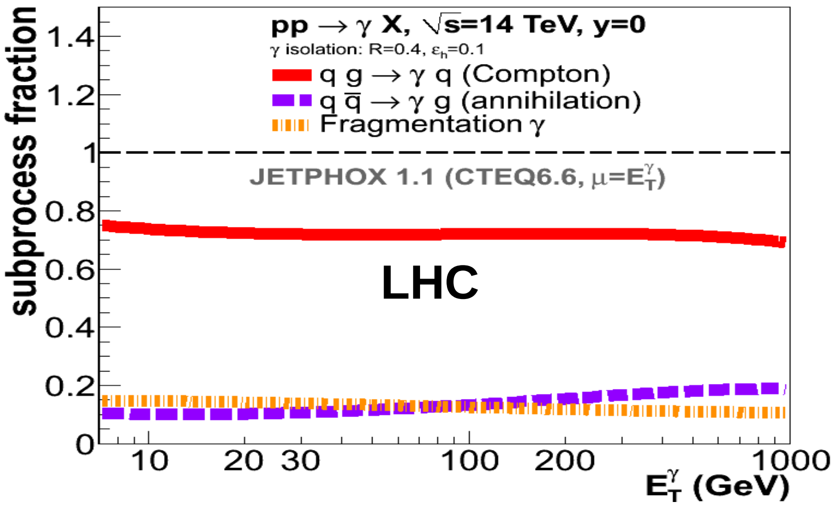
- Prompt photons: fragmentation important below p_T~50 GeV/c





- Isolated photons (R=0.4, $E_{T,had}$<5 GeV): q-g Compton ~80% at LHC

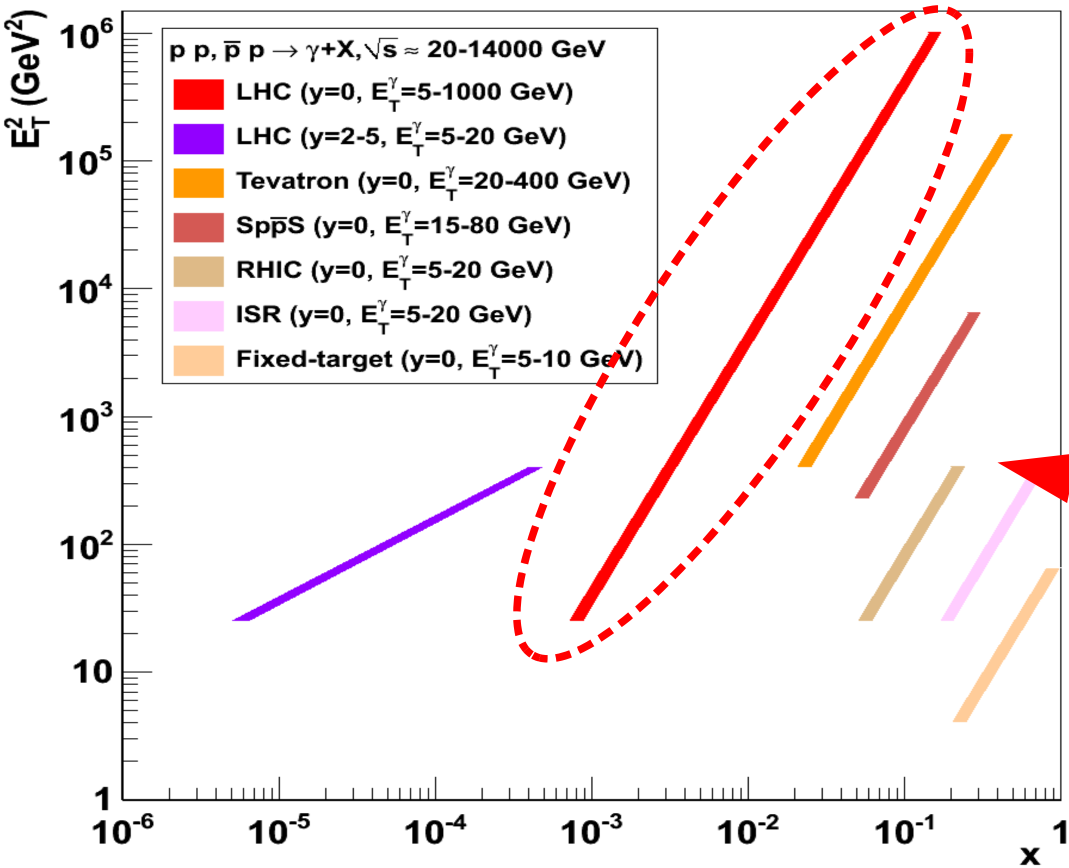


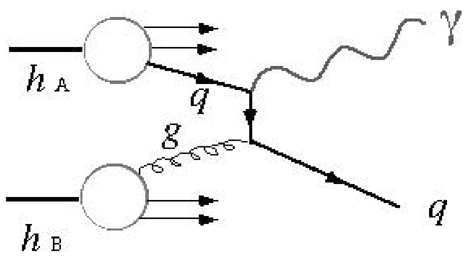


(x,Q^2) map of collider isolated- γ data-sets

[R.Ichou & D.d'E, PRD82 (2010) 014015]

- Kinematical range of LHC, Tevatron, $Sp\bar{p}S$ & RHIC γ_{isol} data:



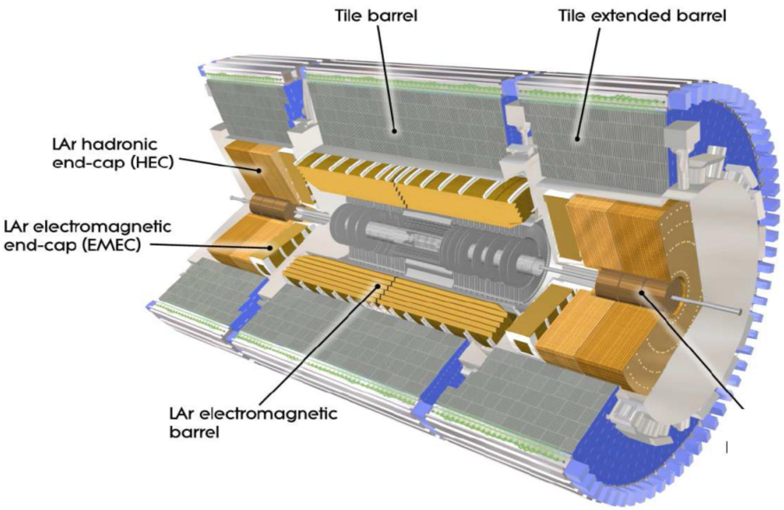


- Direct sensitivity to gluon PDF over wide (x,Q^2) domain

[$xG(x,Q^2)$ is only constrained indirectly by DIS & directly by p-p jets at high-x]

Experimental photon measurements at the LHC

(0) EM calorimetry: ATLAS vs CMS



|η| < 1.5 (barrel)

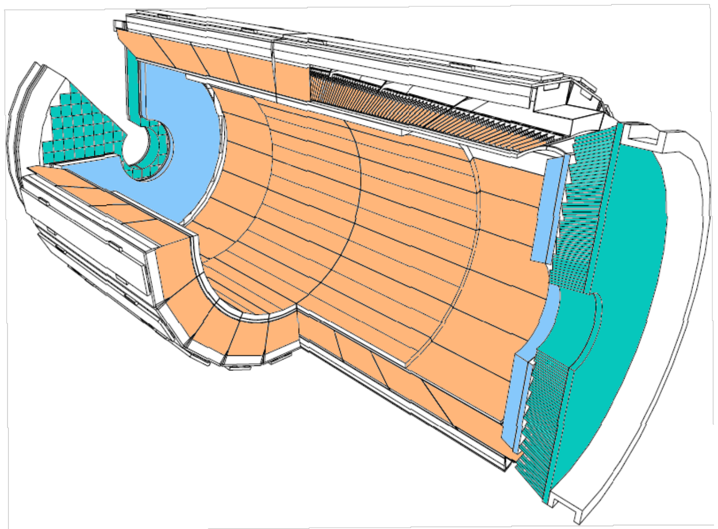
1.5 < |η| < 3 (endcap)

ATLAS:

Liquid(Ar)-Pb sampling calo (accordion geom):

- Longitudinal segmentation (3 layers): $\Delta\eta\times\Delta\varphi$: (0.003-0.006); (0.025×0.025); (0.050×0.025)
- Presampler for $|\eta|<1.8$: $\Delta\eta x \Delta\varphi \sim (0.025x0.1)$
- $\sigma(E)/E$ = (10 – 17%) (η) / √E (GeV) ⊕ 0.7%

Strength: Good π^0-γ separation



CMS:

$PbW0_4$ calorimeter (75848 crystals,~$25.8X_0$):

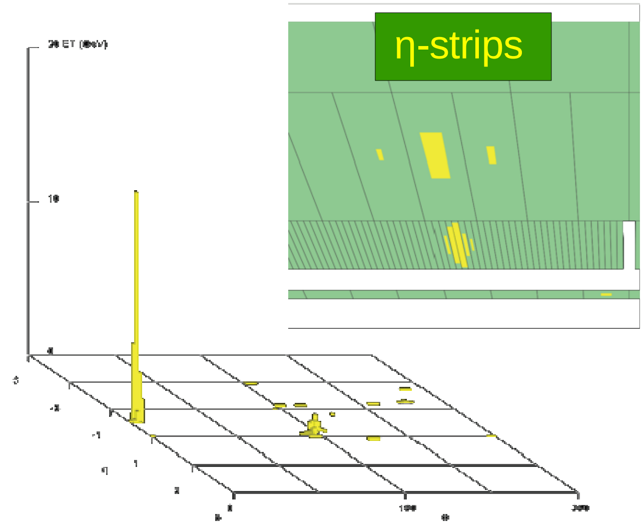
- $\Delta\eta\times\Delta\varphi$: (0.0175×0.0175, barrel); (0.05×0.05, endcap)
- Preshower for $|\eta|$=1.6-2.6
- $\sigma(E)/E$ = (2.5 – 7%) (η) / √E (GeV) ⊕ 0.3%

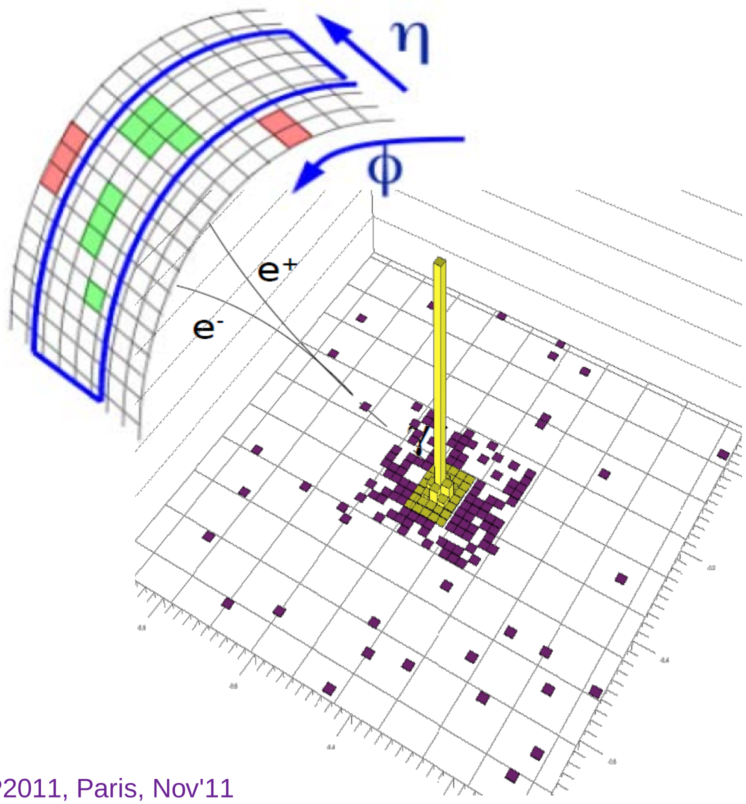
Strength: Excellent energy resolution

(1) γ reconstruction: ATLAS vs CMS

ATLAS:

- ECAL cluster = 2nd layer 3×5 cells & E >2.5 GeV
- Unconverted-γ (3×5): no matched track
- Converted-γ (3×7): matched track(s) in inner det.





CMS:

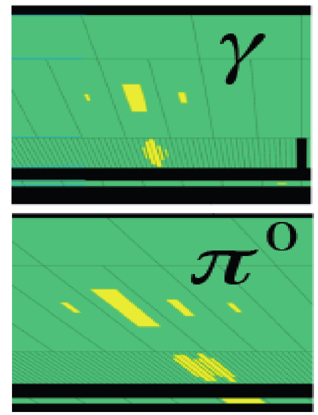
- ECAL cluster = 5×5 – 5×35 cells :
  - Material in front of ECAL converts γ's (~50%) into e^+e^- pairs.
  - Solenoidal B-field spreads energy along φ
- Prompt $e^{\pm}$ rejected: veto on pixel detector.
- Photon conversion method:
  ECAL clusters matched to tracks with E/p_T ~1

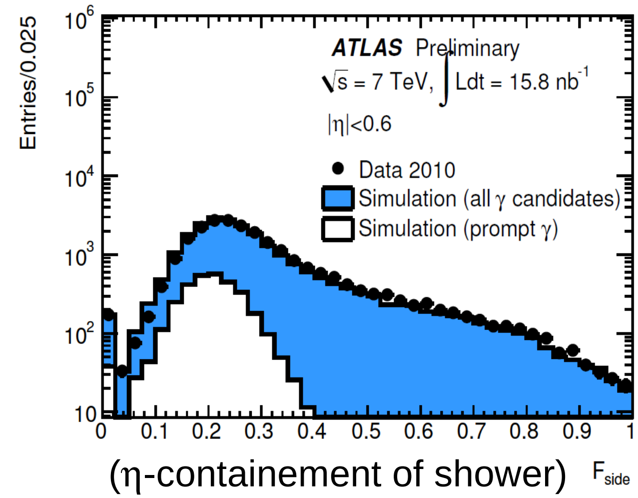
(2) γ identification: ATLAS vs CMS

ATLAS:

- Cuts on longitudinal & transverse shower-shape variables:
  - 'loose': R_{had}, R_η, w_2
  - 'tight': w_{s3}, w_{stot}, F_{side}, ΔE, E_{ratio}

(MC & data-driven)





(η-containement of shower)

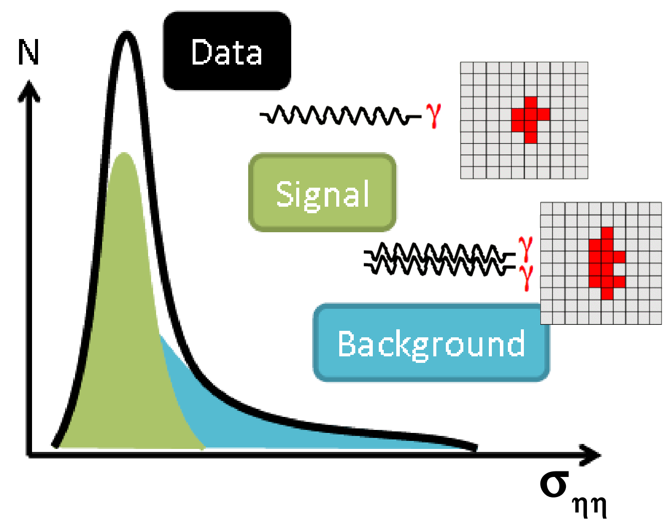
CMS:

- Cut on 2nd moment of energy distribution about mean η position:

$$\sigma_{i\eta i\eta}{}^2 = \frac{\sum (\eta_i - \bar{\eta})^2 w_i}{\sum w_i}, \quad \bar{\eta} = \frac{\sum \eta_i w_i}{\sum w_i}$$

$$w_i = \max\left(0, 4.7 + \log(E_i / E_{5\times5})\right)$$

- Signal (identified $e^\pm$) & bckgd (inverted cuts) templates obtained in data-driven way



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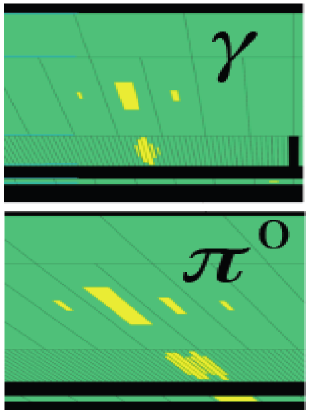

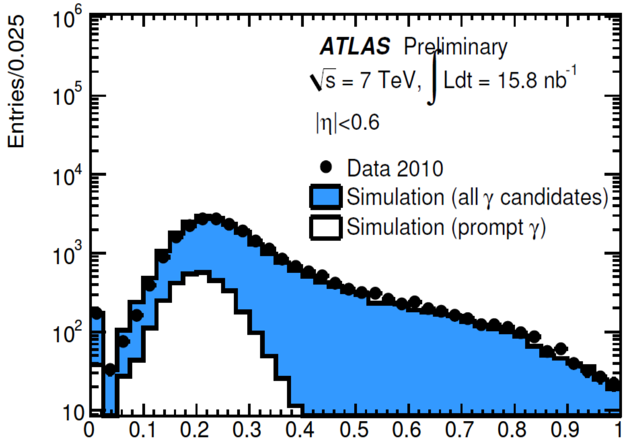

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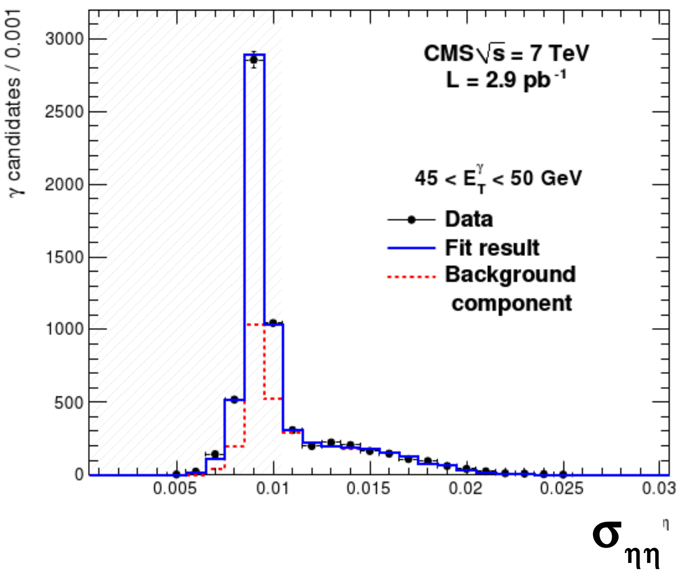
$$w_i = \max\left(0, 4.7 + \log(E_i / E_{5\times5})\right)$$

$\sigma_{\eta\eta}$(barrel) < 0.01

$\sigma_{\eta\eta}$(endcap) < 0.03

- Signal (identified e±) & bckgd (inverted cuts) templates obtained in data-driven way



(3) γ isolation: ATLAS vs CMS

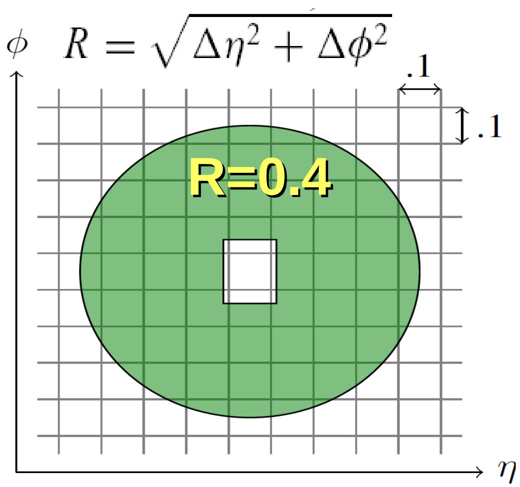
- ATLAS & CMS parton-level-equivalent isolation: R=0.4, $\sum E_{T,had} < 4{,}5$ GeV

ATLAS:

- Calorimeter-based isolation:

  ∑[Energy in cone R=0.4, except 5x7 hollow] < 3 GeV

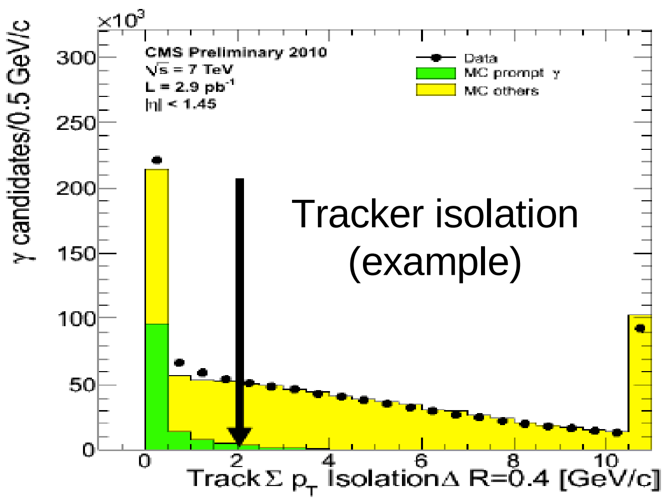
- Corrections for non perturbative effects (UE, pileup): evt-by-evt ambient density from median jet energy (k_T-algo with $p_T \rightarrow 0$): ~0.55GeV+0.2GeV/pileup-evt



CMS:

- Combined multi-isolation in cones R=0.4 + "zero" leakage in HCAL:

Variable	Selection
$\mathrm{Iso}_{\mathrm{TRK}}$	$< 2.0\,\mathrm{GeV} + 0.001 \cdot E_T^{\gamma}$
$\mathrm{Iso}_{\mathrm{ECAL}}$	$< 4.2\,\mathrm{GeV} + 0.003 \cdot E_T^{\gamma}$
$\mathrm{Iso}_{\mathrm{HCAL}}$	$< 2.2\,\mathrm{GeV} + 0.001 \cdot E_T^{\gamma}$
H/E	< 0.05



- Corrections due to UE,hadronization isolation losses with diff. PYTHIA tunes

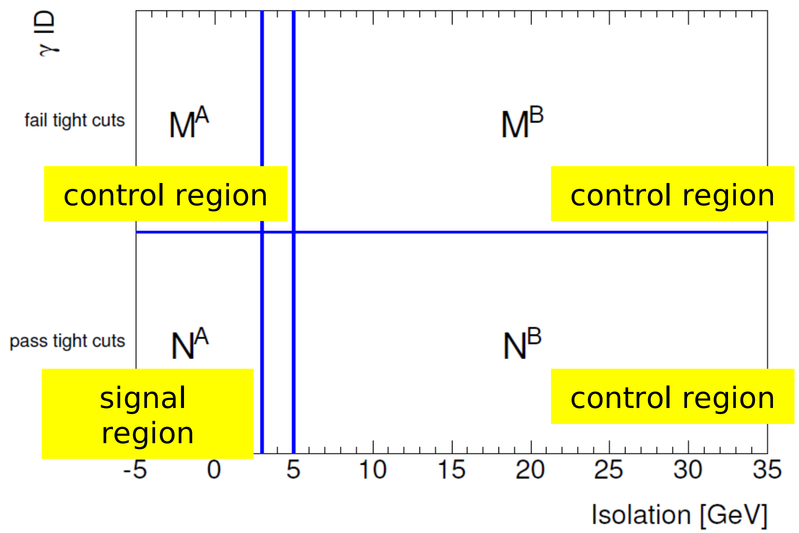
(4) γ backgd subtraction: ATLAS vs CMS

ATLAS:

- 'ABCD method': Data-driven 2-D histo with PID vs. ISO variables:

Signal yield: $N^A_{sig} = N^A - N^B \frac{M^A}{M^B}$

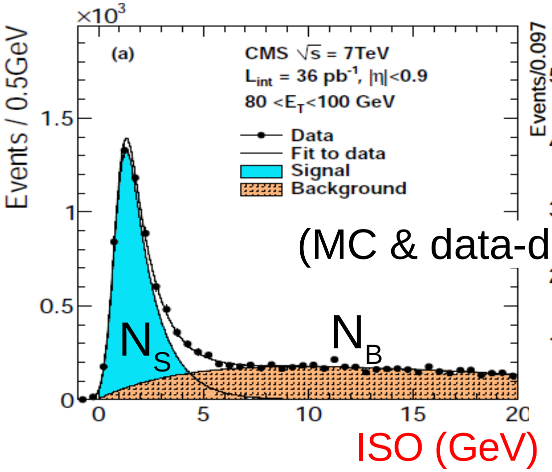
[Purity: 65% (p_T~20 GeV) – 95% (p_T>60 GeV)]

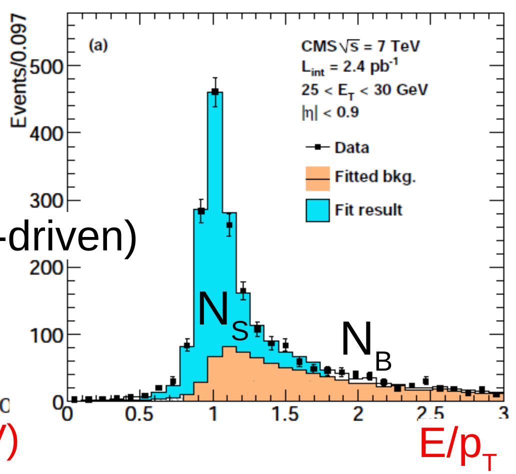


CMS:

- Discriminant templates for :
  - ISO (unconverted-γ):
    ISO =∑Trk Iso +∑ECAL Iso+∑HCAL Iso
  - E/p_T (conversion method).
  - ECALiso (diphotons).

(MC & data-driven)





- 2-component (binned) extended maximum likelihood fits for signal & background:

$$\mathcal{L} = -\ln L = -(N_S + N_B) + \sum_{i=1}^{n} N_i \ln(N_S \mathcal{S}_i + N_B \mathcal{B}_i)$$

(5) x-section corrections & syst. uncertainties

$$\frac{d^2\sigma_{isol}}{d\eta\, d p_T} = \frac{\Delta N_S(p_T,\eta)}{L \cdot \Delta p_T \Delta\eta \cdot U \cdot \epsilon}$$

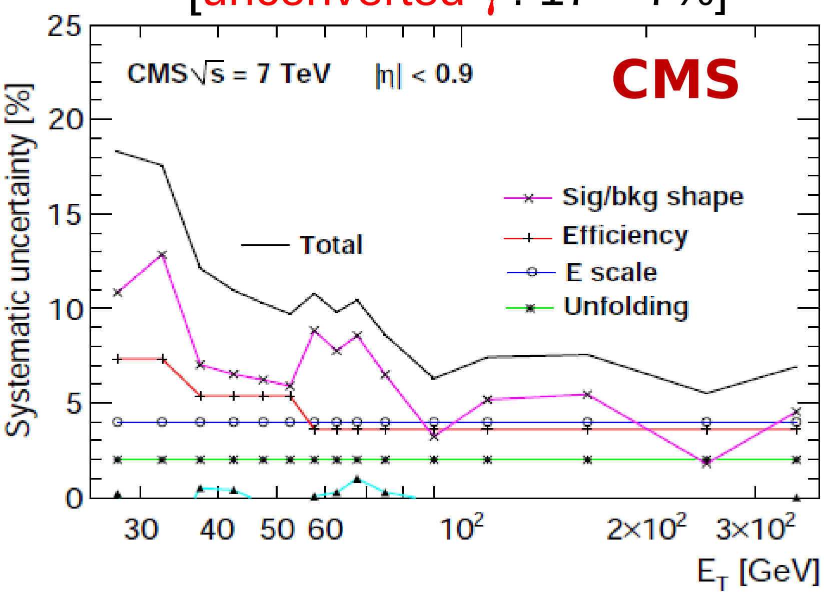
- Number of signals
- Luminosity
- Efficiency
- Unfolding

■ Typical correction factors (ATLAS):

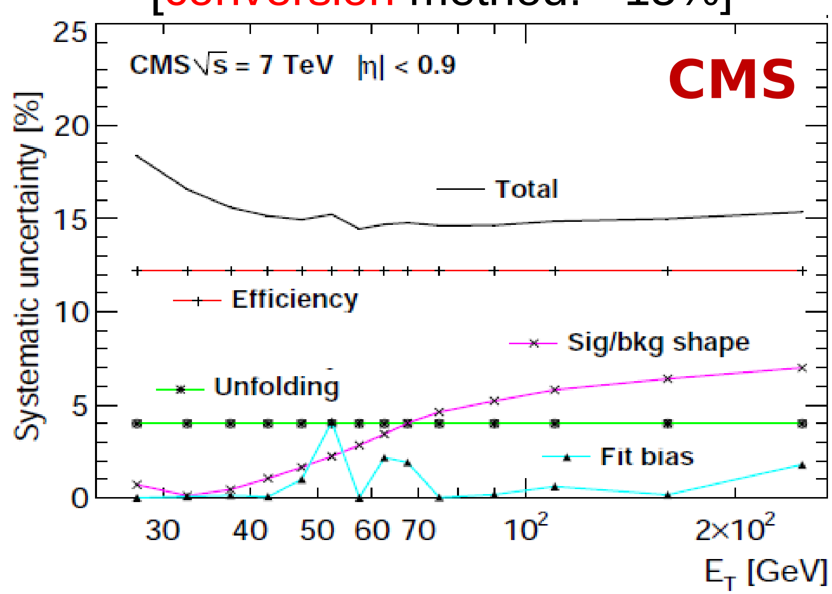
- Efficiencies: ~100% trigger, ~85% reco-barrel, ~75% reco-endcap, ~(60 – 90)% identification & isolation
- Unfolding (bin migrations): ~95%

■ Typical syst. uncertainties (CMS): 17 – 7% + luminosity (~4%)

[unconverted γ: 17 – 7%]

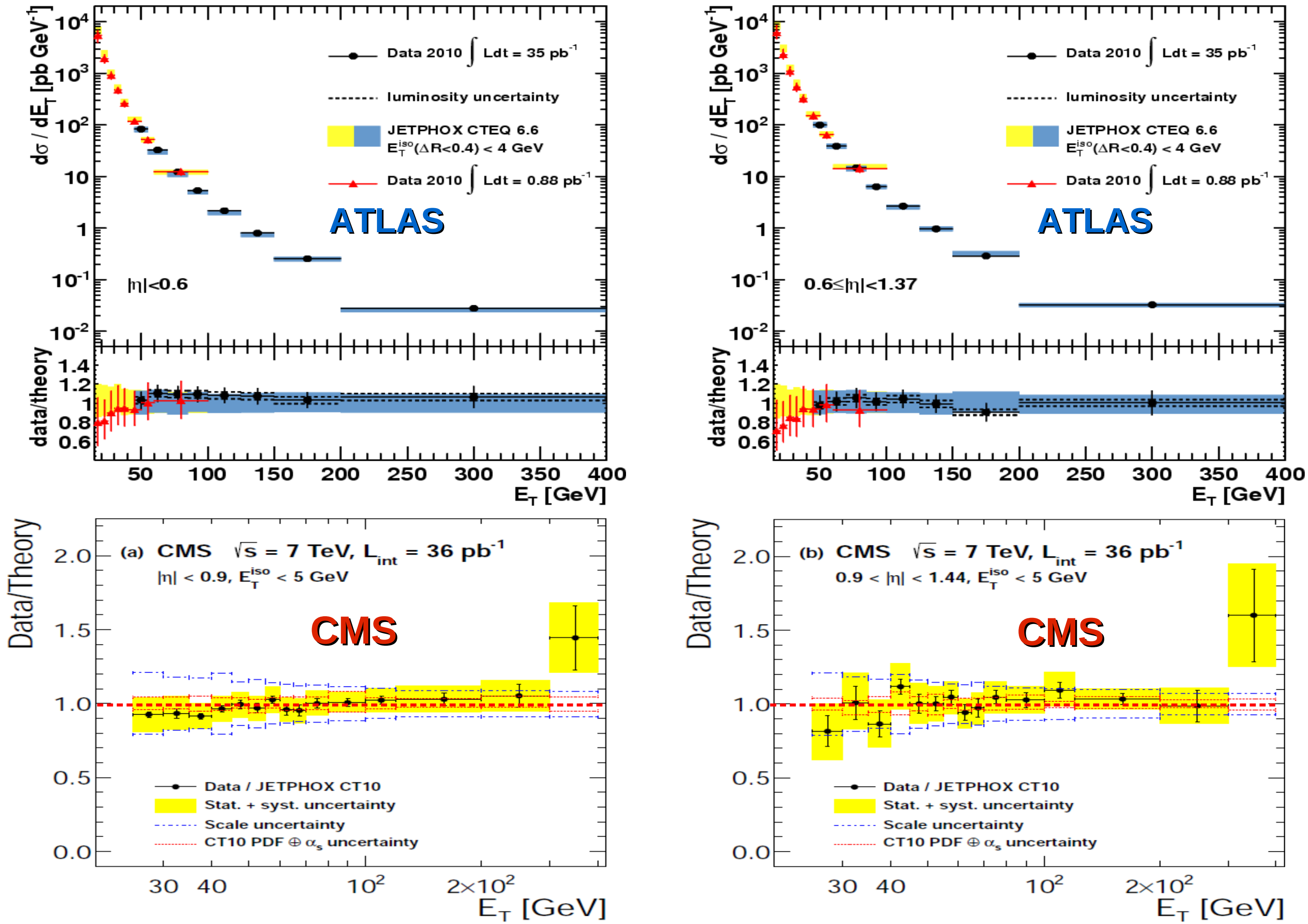


[conversion method: ~15%]



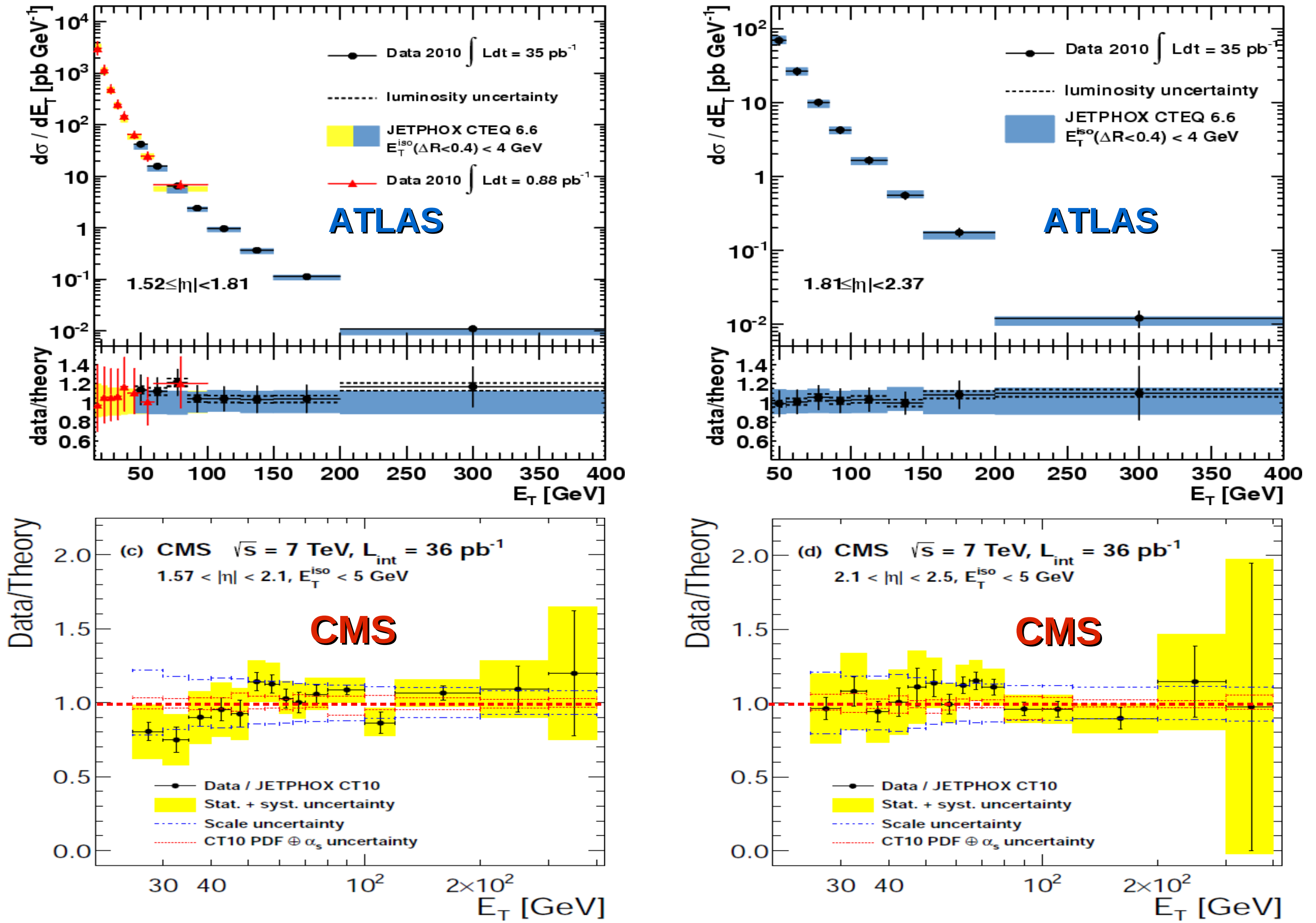
Isolated photon results at the LHC

pp → γ_{iso}+X at 7 TeV (barrel) vs NLO



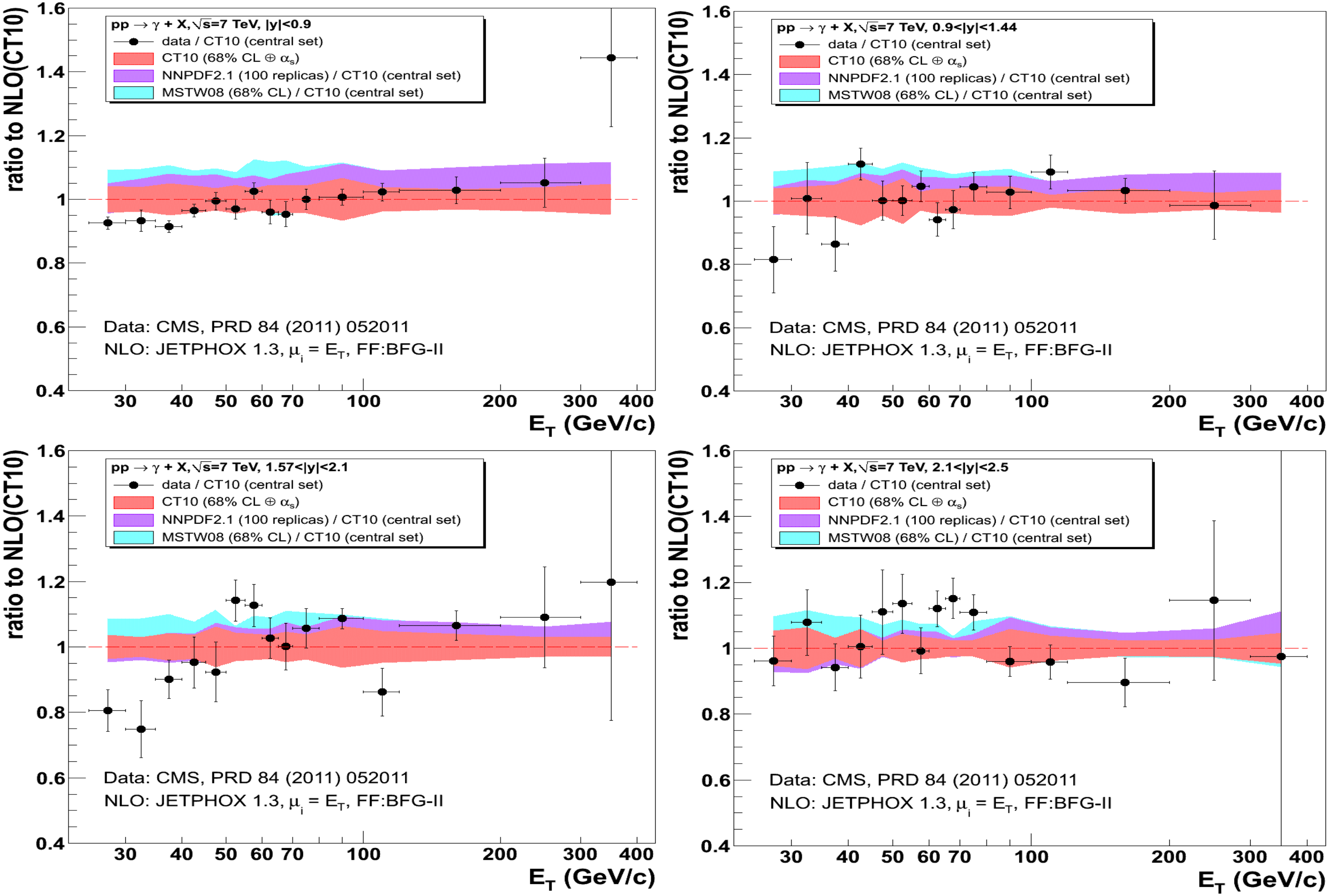
- Very good agreement data-NLO (slight overprediction at E_T<50 GeV/c ?)

pp → γ_{iso}+X at 7 TeV (endcap) vs NLO



- Very good agreement data-NLO at more forward rapidities

pp → γ_{iso}+X at 7 TeV vs NLO (3 PDFs)

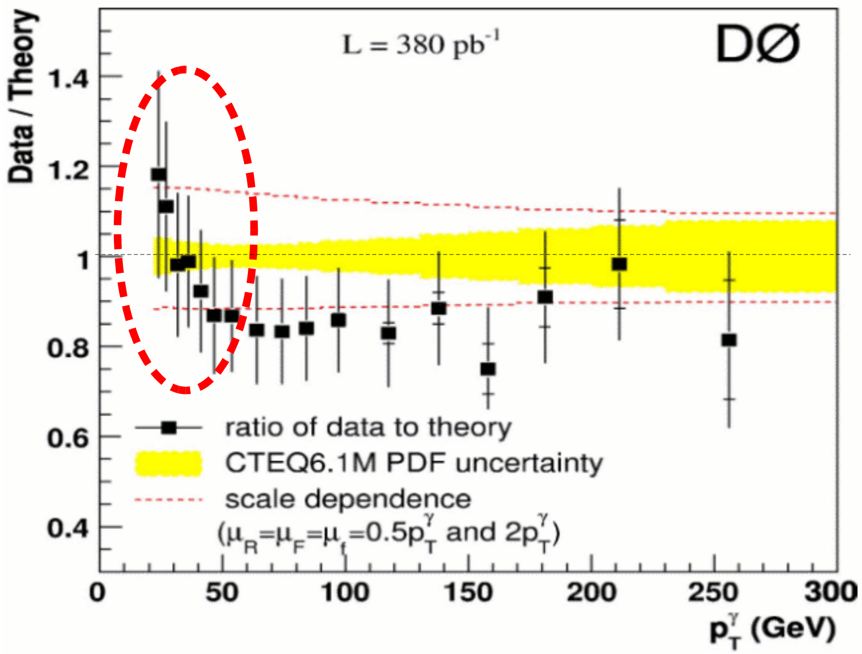


Compare to ... pp → γ_{iso}+X at 1.96 TeV vs NLO

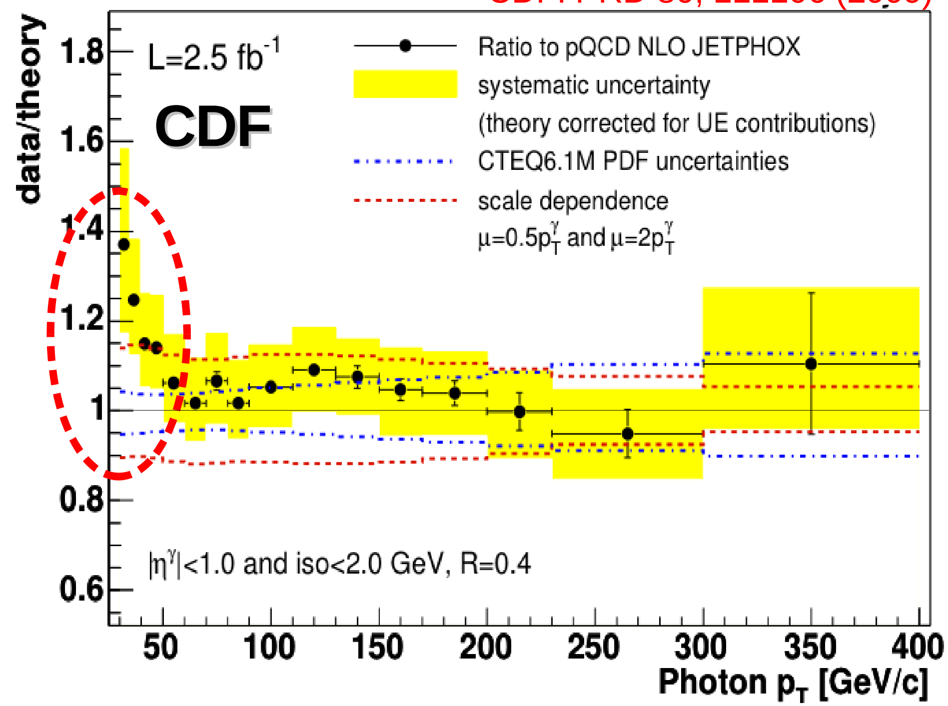
- D0 syst. uncertainty: ~20%
- CDF syst. uncertainty: 15 – 10%

(Tevatron uncertainties dominated by photon energy scale)

DZERO: PLB 639 (2006) 151; 658 (2008) 285(E)



CDF: PRD 80, 111106 (2009)



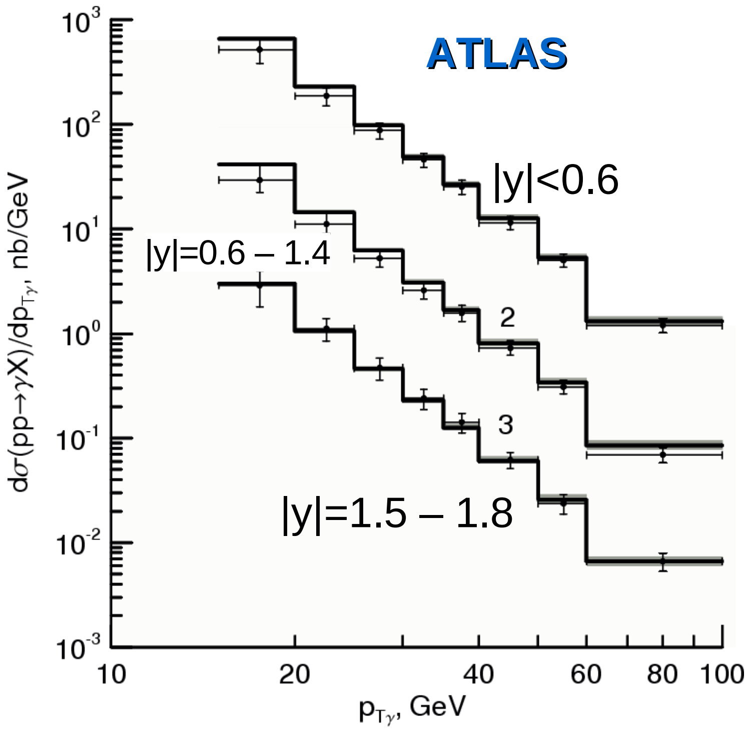
- NLO tends to underpredict data at p_T < 50 GeV/c (still OK within errors)
  - Theory scale uncertainty: 15 – 10%
  - Theory PDF uncertainty: 5 – 10%

[See also R.Ichou & D.d'E, PRD82 (2010) 014015]

pp → γ_{iso}+X at 7 TeV vs k_T-factorization

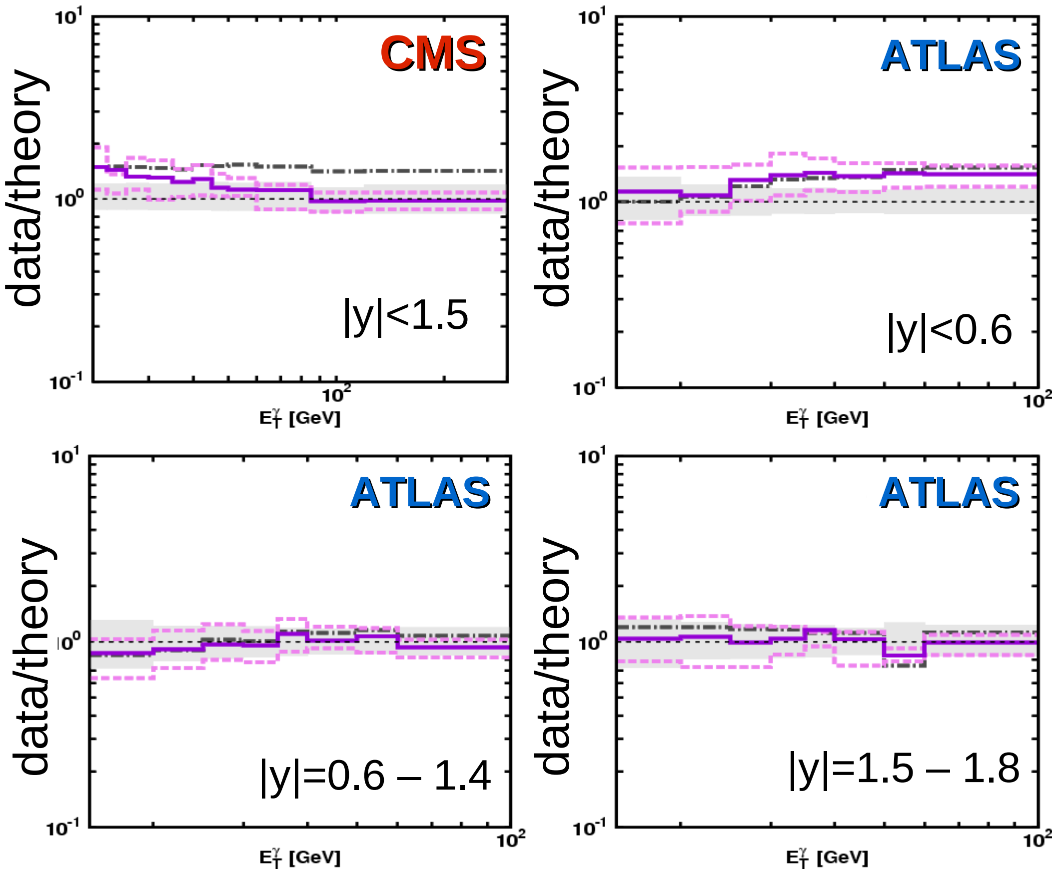
- Good data – theory agreement also for models including BFKL (or CCFM) evolution:

— KMR unintegrated PDFs



B.Kniehl et al. PRD 84 (2011) 074017

----- KMR unintegrated PDFs
-·-·- Set-A uPDFs + CCFM

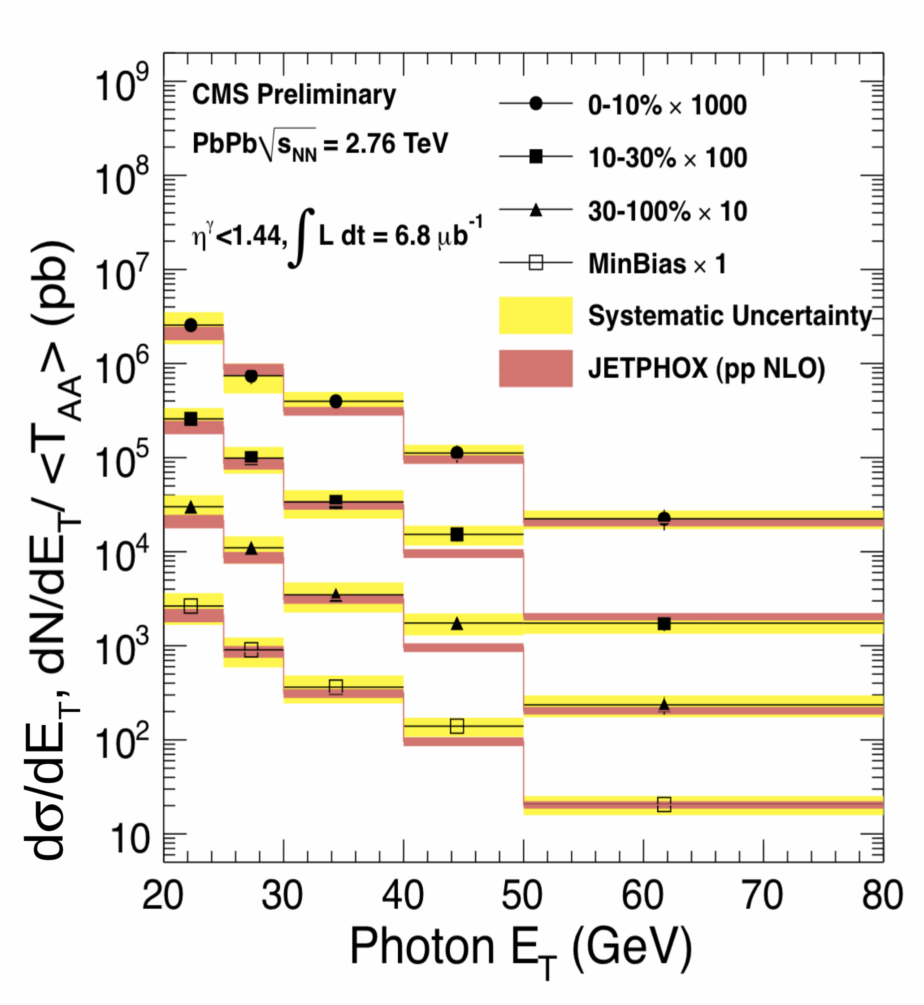


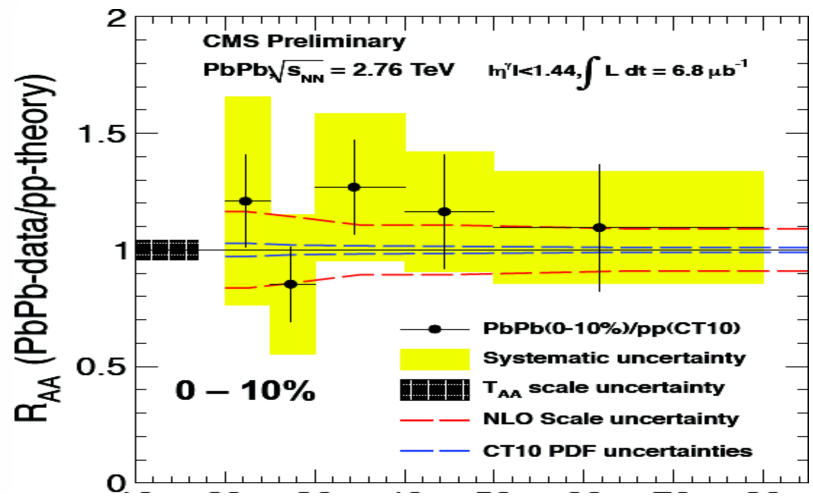
A.V. Lipatov et al. PLB 699 (2011)93

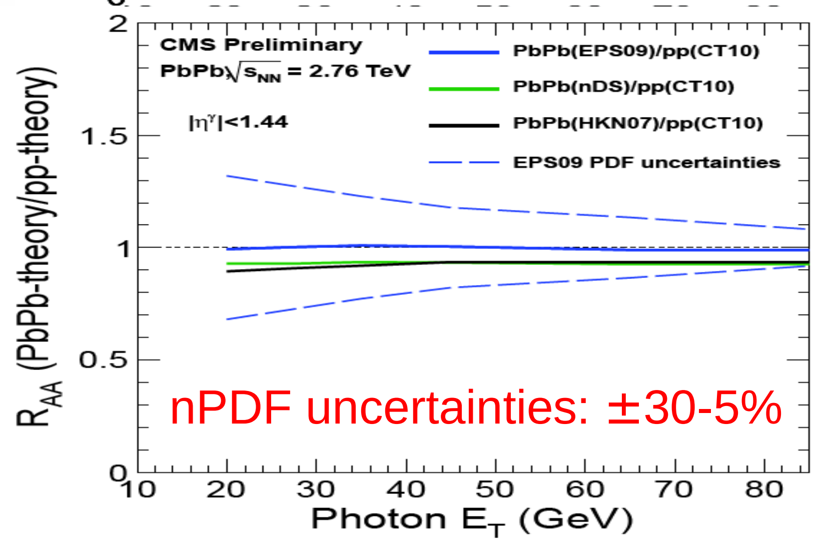
PbPb,pp → γ_{iso}+X at 2.76 TeV (barrel) vs NLO

[cf. L.Benhabib HCP'11 talk]
CMS-PAS-HIN-11-002

- Good agreement data – NLO for both systems
- R_{AA}=Pb-Pb/p-p~1 ⇒ small nuclear PDF modifications in probed x,Q^2





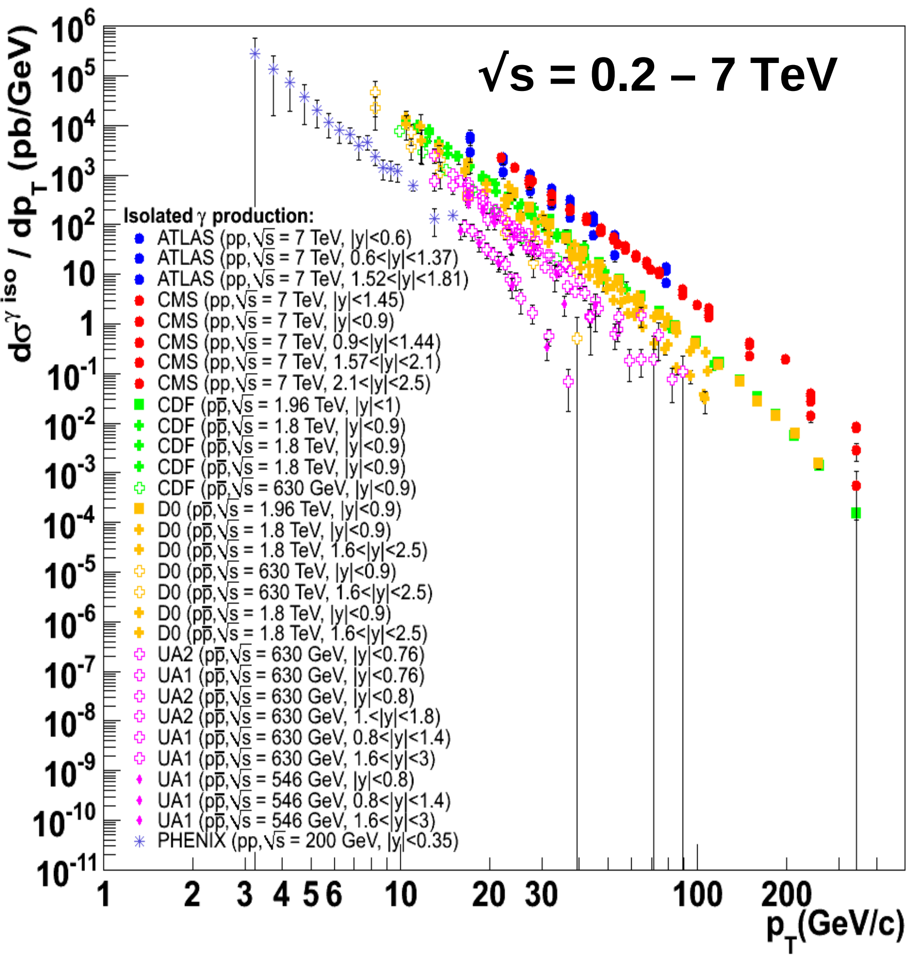


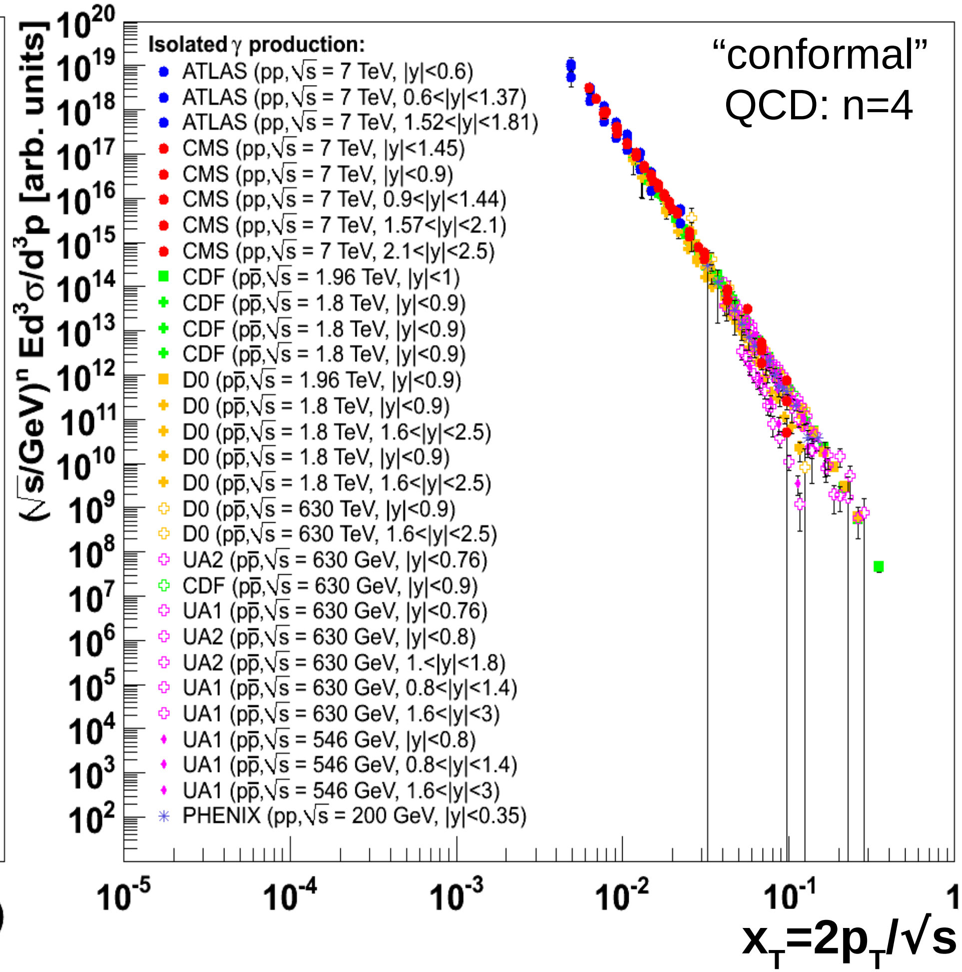
Isolated-γ collider world-data

[D.d'E & R.Ichou, HEP-EPS'11 Proceeds.]

- LHC/Tevatron/Sp$\bar{p}$S/RHIC
  power-law p_T spectra
  within ~4 – 400 GeV/c

- x_T-scaled cross sections:
  power slope n=4.5
  (pQCD tell-tale behaviour)





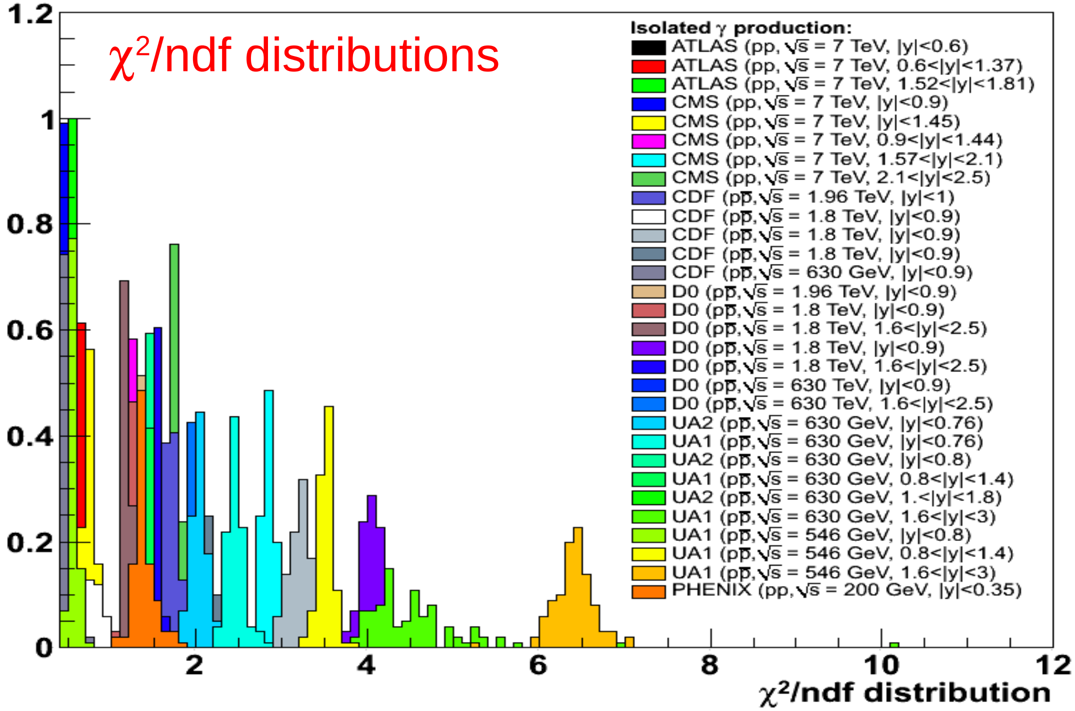
PDF constraints via JETPHOX + NNPDF2.1

[D.d'E & J.Rojo in preparation]

- NNPDF "reweighting technique":

(1) JETPHOX $d\sigma_{NLO}/dp_T$ for 100 replicas (NNPDF21_100.LHgrid)

(2) χ^2 analysis $d\sigma_{EXP}/dp_T$ vs $d\sigma_{NLO}/dp_T$ for each replica:



~2/3 of measurements have all replicas with $\chi^2/ndf<2$

Rest of measurements have all replicas with $\chi^2/ndf\sim 2-4$

(3) Obtain associated "weight" for each replica:

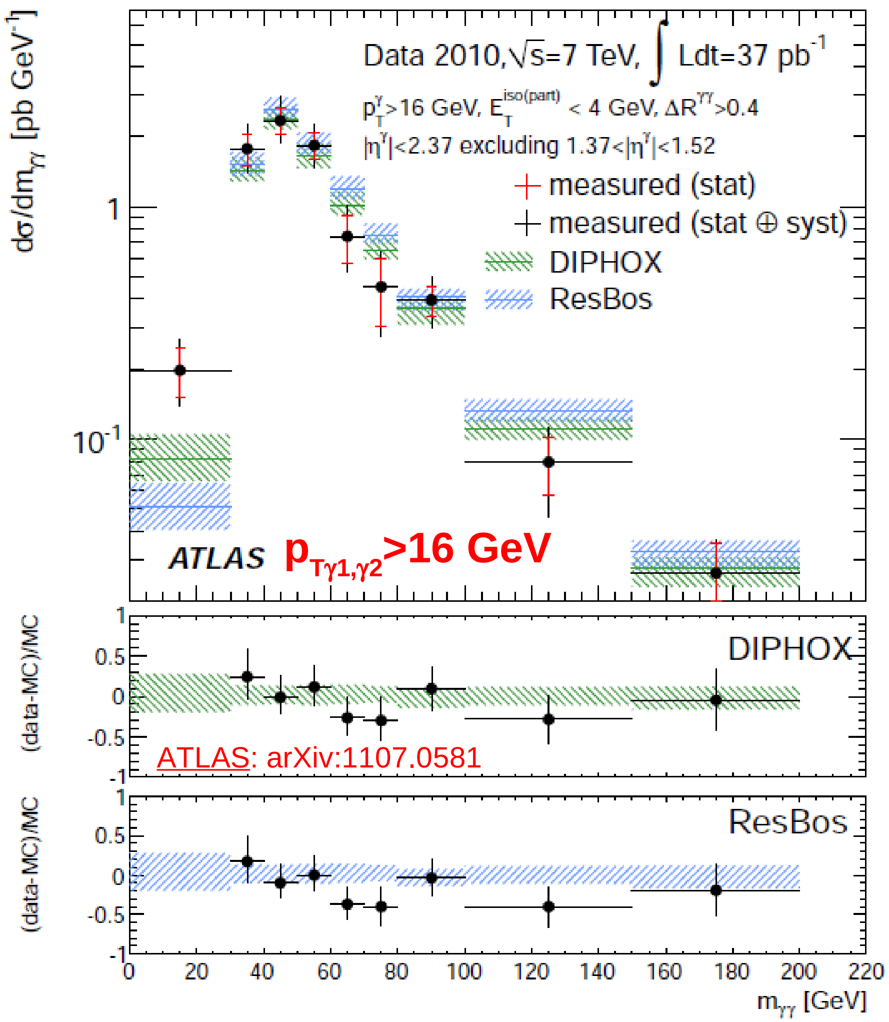
$$w_k = \frac{(\chi_k^2)^{n/2-1} e^{-\frac{1}{2}\chi_k^2}}{\frac{1}{N}\sum_{k=1}^{N}(\chi_k^2)^{n/2-1} e^{-\frac{1}{2}\chi_k^2}}.$$

(4) Obtain reweighted PDF replicas: $\langle \mathcal{O} \rangle_{\rm new} = \frac{1}{N}\sum_{k=1}^{N} w_k \mathcal{O}[f_k]$

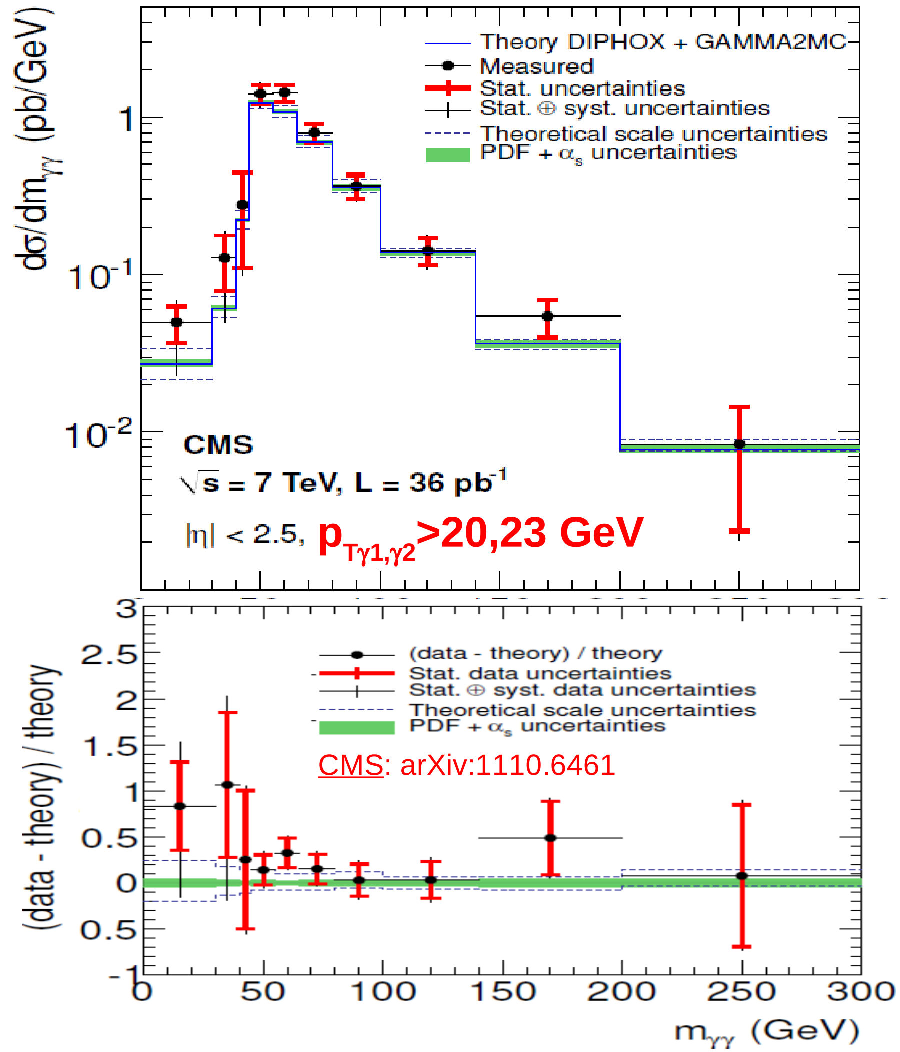
Isolated di-photon results at the LHC

pp → γ γ +X at 7 TeV vs theory: $m_{\gamma\gamma}$

Theory: DIPHOX, RESBOS



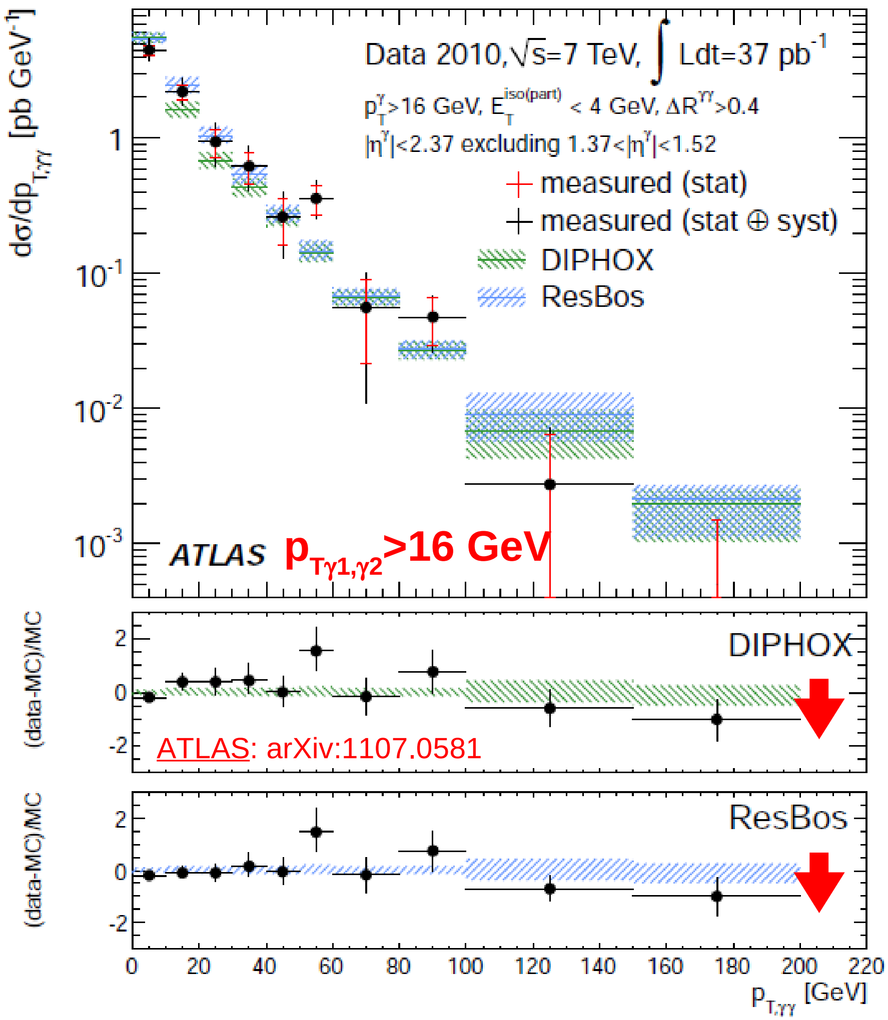
Theory: DIPHOX+gamma2MC



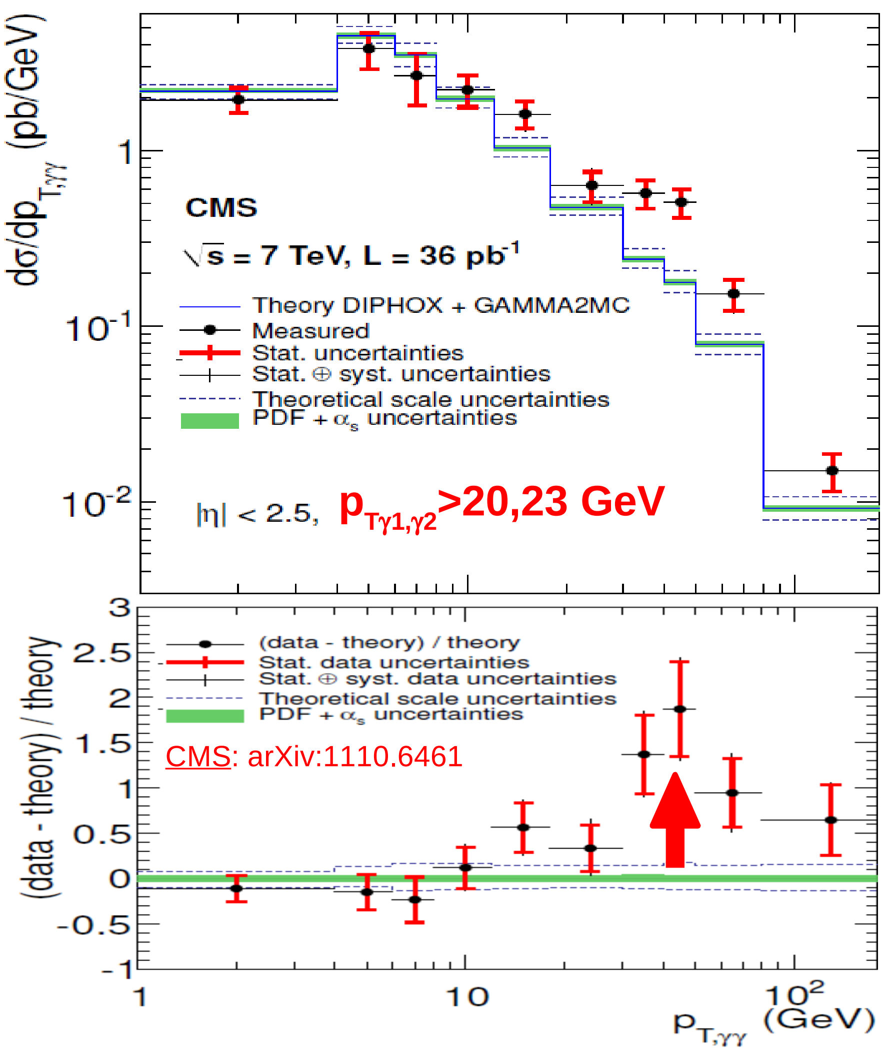
- Overall agreement data-NLO/NNLL for diphoton mass distributions (not bad news for H→ γγ ...). Note: K(NNLO/NLO)~1.3 [D.deFlorian et al, arXiv:1110.2375]

pp → γ γ +X at 7 TeV vs theory: $p_{T,\gamma\gamma}$

Theory: DIPHOX, RESBOS



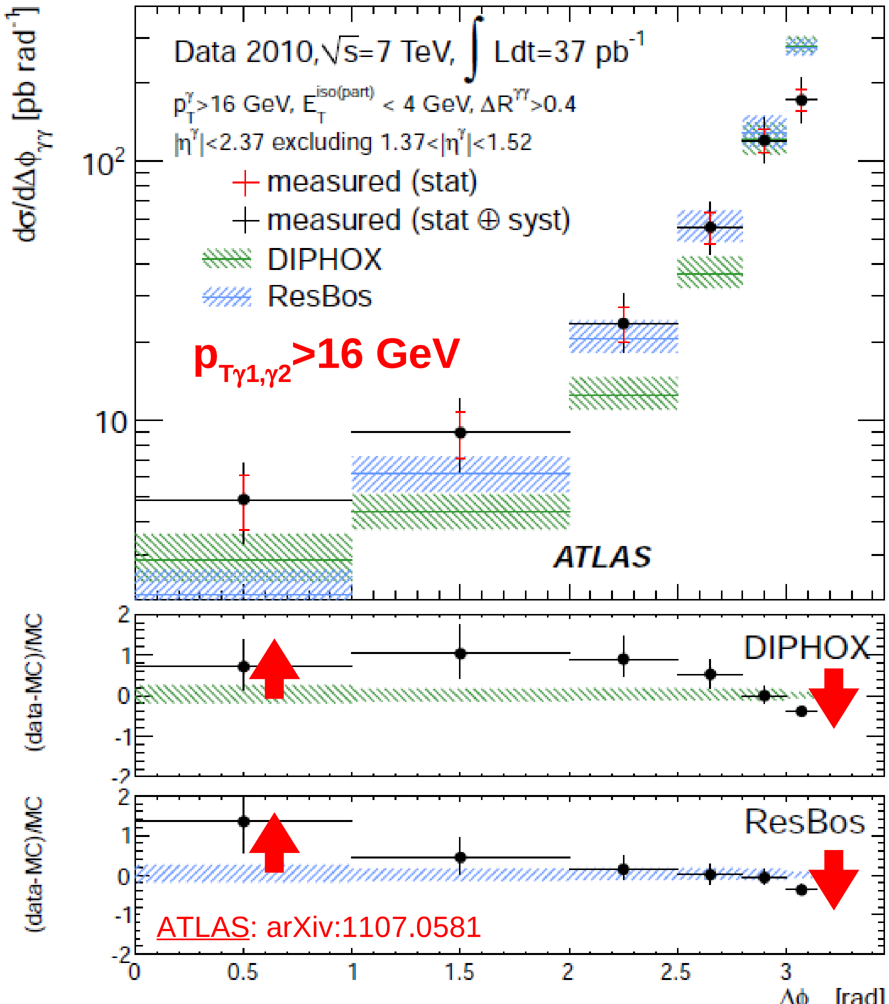
Theory: DIPHOX+gamma2MC



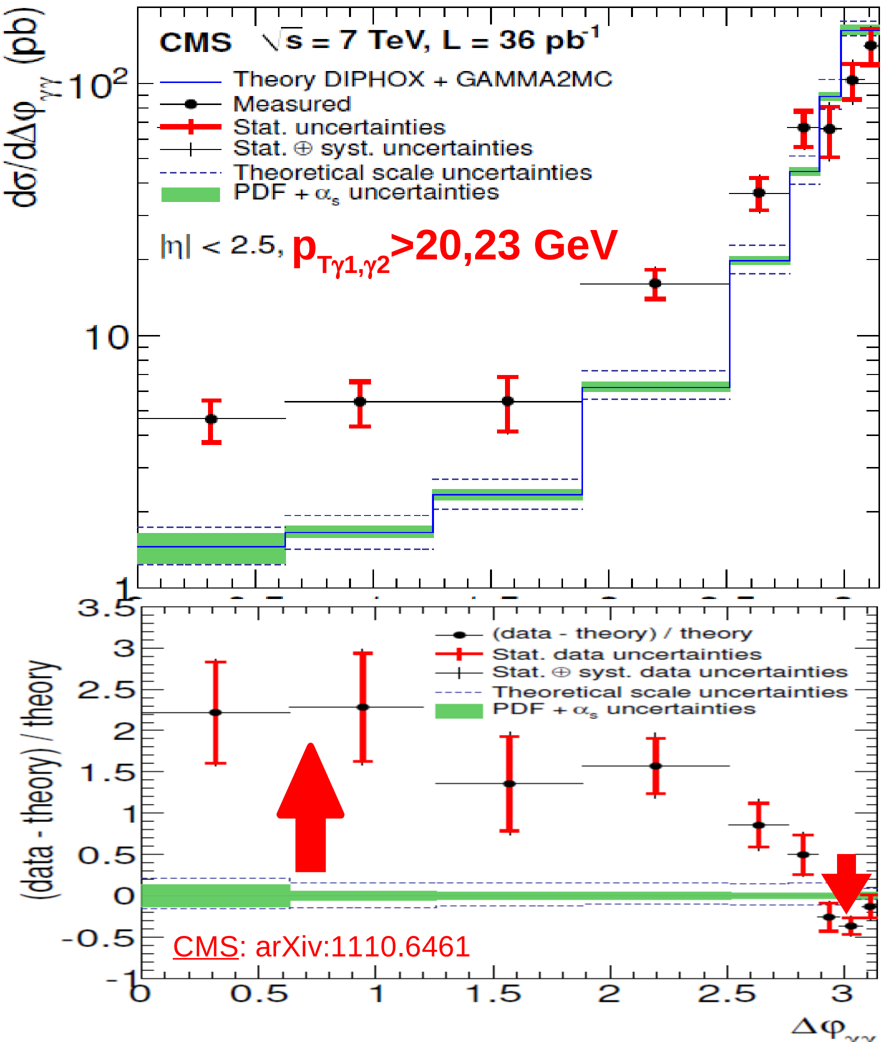
- NLO/NNLL reproduces diphoton pair p_T below ~30 GeV. Above, unclear...

pp → γ γ +X at 7 TeV vs theory: $\Delta\varphi_{\gamma\gamma}$

Theory: DIPHOX, RESBOS



Theory: DIPHOX+gamma2MC

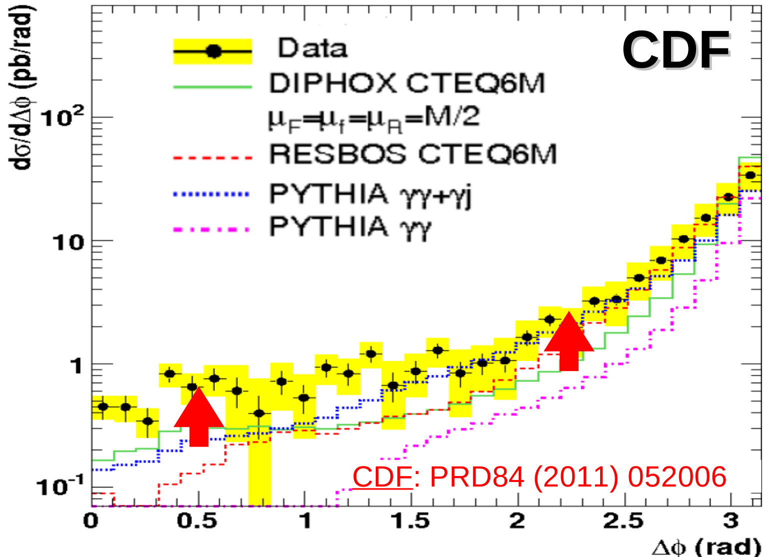


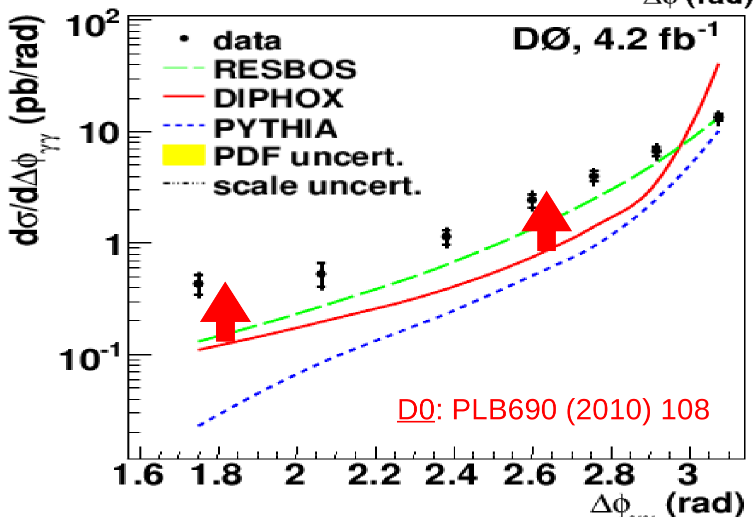
- Large NLO under-estimation for $\Delta\varphi<2.5$ (partially cured by NNLL)

  Large over-estimation at $\Delta\varphi=\pi$. NLO is effectively LO in large $\Delta\varphi$ regions !

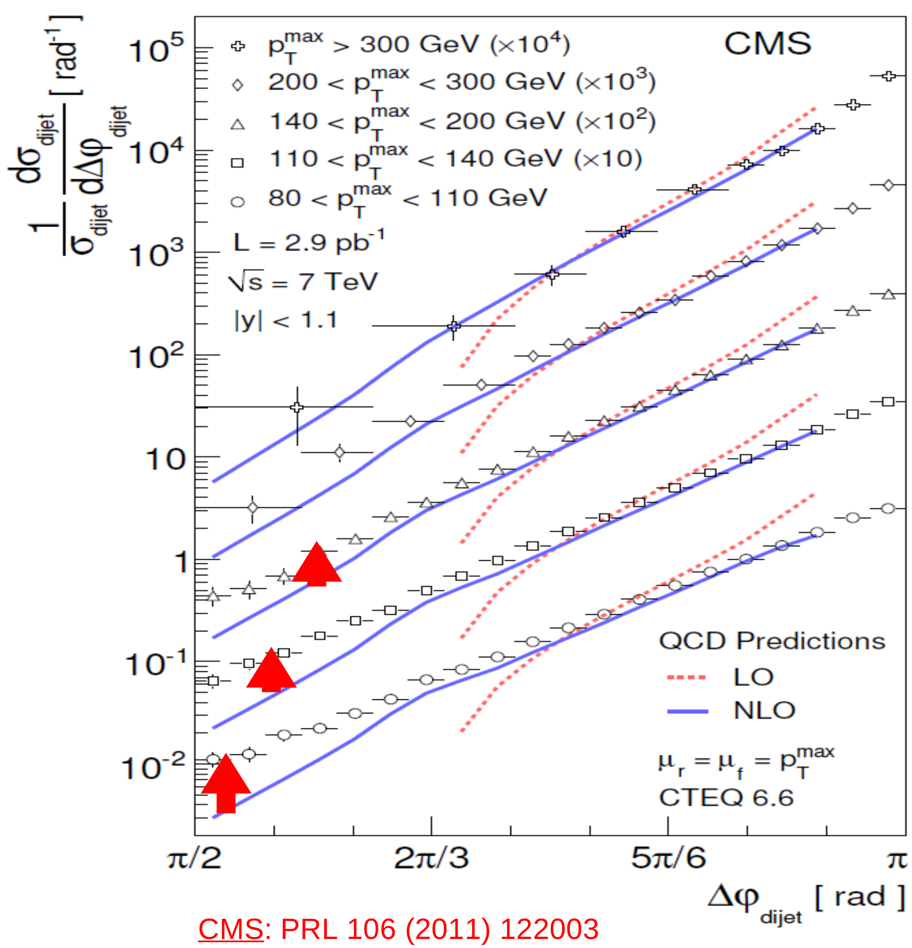
$pp \rightarrow \gamma\gamma + X$ at 7 TeV vs theory: $\Delta\varphi_{\gamma\gamma}$

- Clear NLO underestimation below $\Delta\varphi \sim 2.5$ also seen in $\gamma\gamma$ at Tevatron:





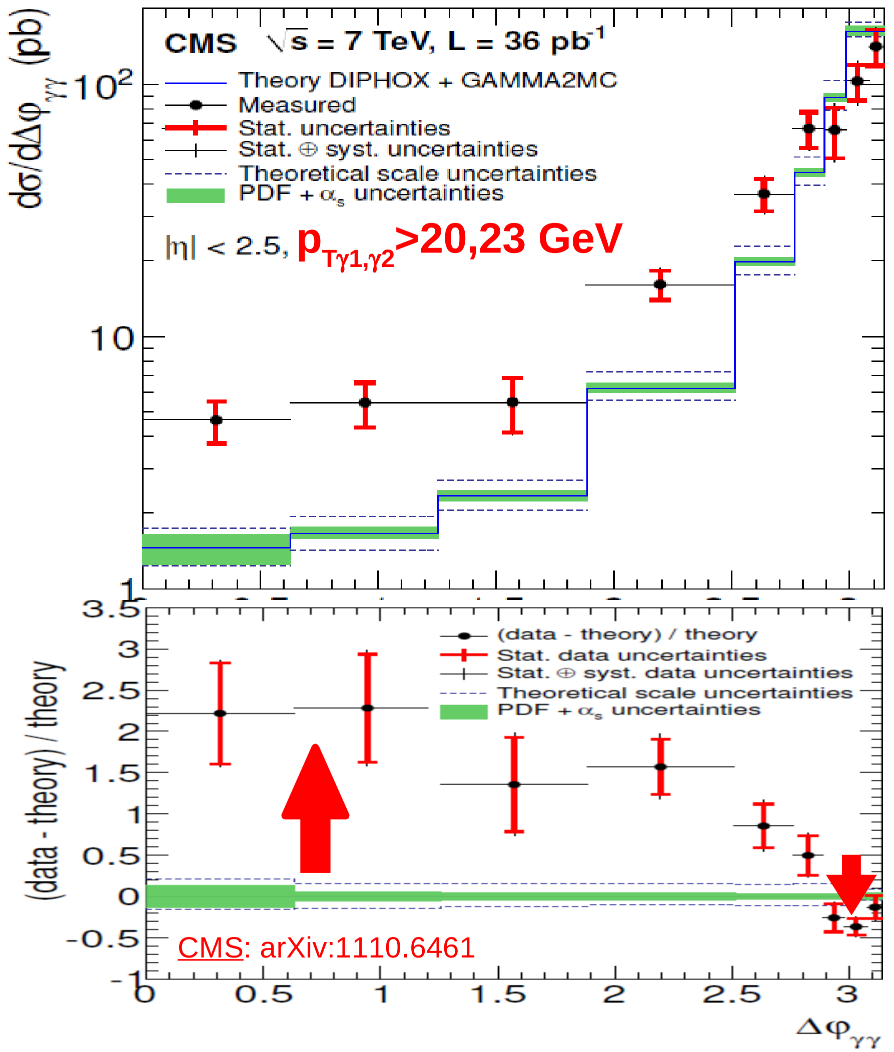
- Similar NLO behaviour observed also in dijet $\Delta\varphi$ correlations ....



pp → γ γ +X at 7 TeV vs theory: $\Delta\varphi_{\gamma\gamma}$

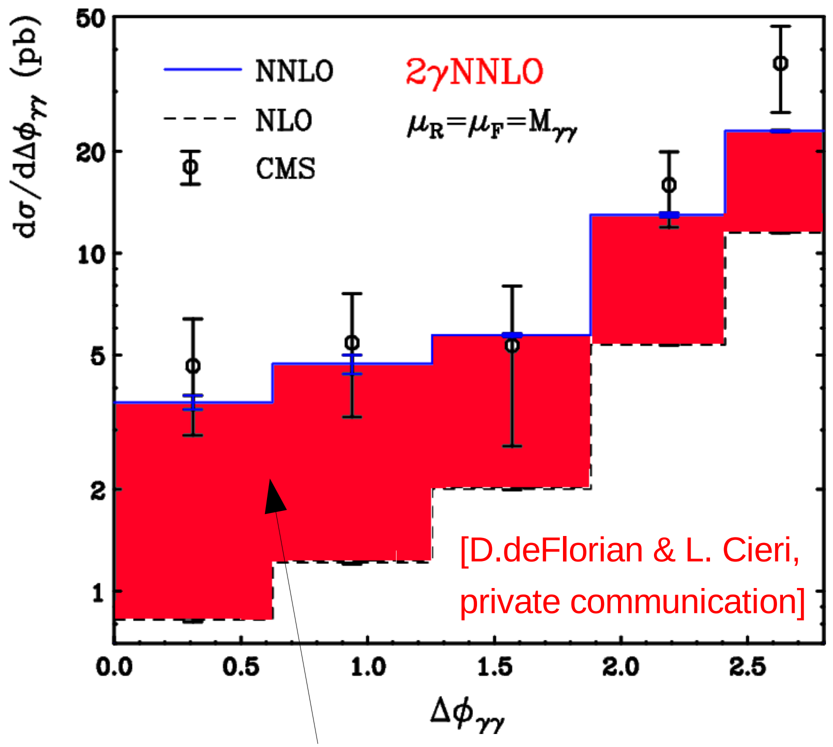
- Large NLO under-estimation for $\Delta\varphi<2.5$ & over-estimation at $\Delta\varphi=\pi$ ....

NLO: DIPHOX+gamma2MC



- Cured by latest state-of-the-art NNLO diphoton calculations:

[D.deFlorian, L. Cieri et al, arXiv:1110.2375]



Enhanced NNLO production of collinear γ's in region where NLO is ~1st order !

Conclusion

- High-p_T (di)photons confirmed as "clean" pQCD probes in p-p and Pb-Pb collisions at the LHC.

- <u>Isolated photons</u>:
  - Quark-gluon Compton dominates LHC x-sections (frag. γ much reduced).
  - World data follow "x_T scaling" with quasi-conformal n~4 power-law.
  - Good data – NLO (and k_T-factorization) agreement within uncertainties:

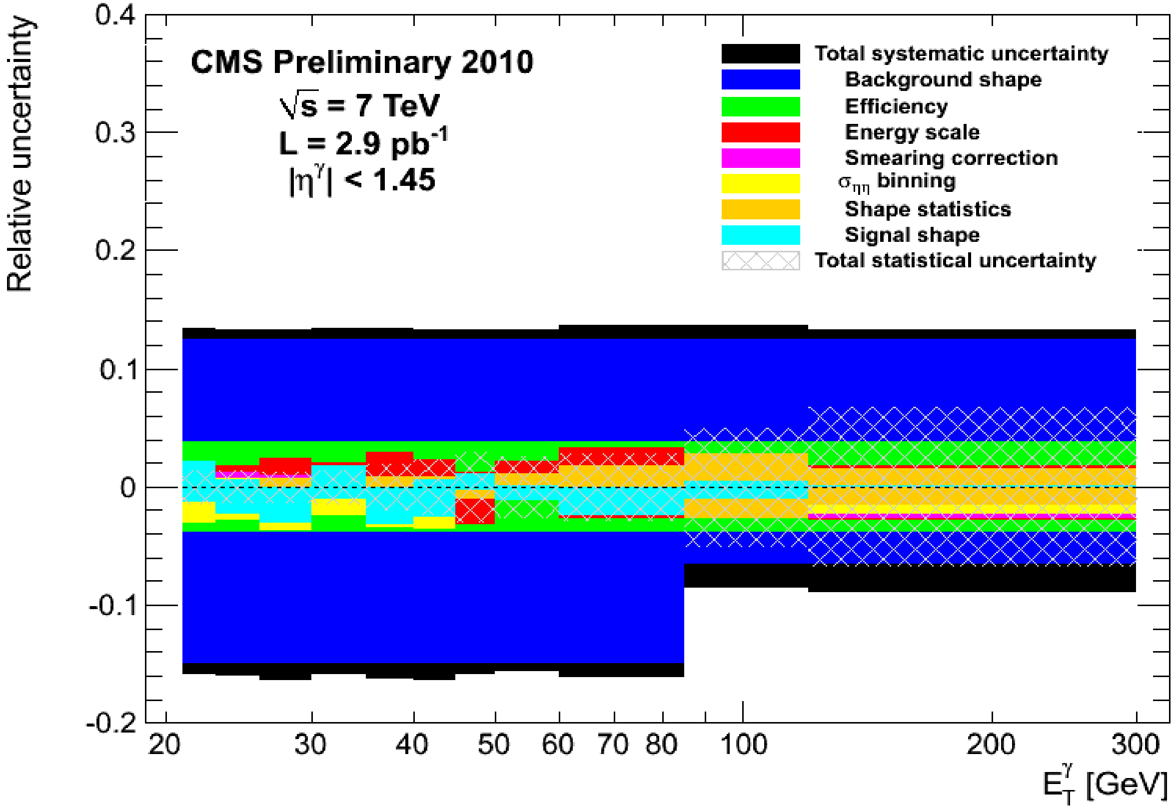
    EXP systematics: 7 – 15% (dominated by background shape)
    TH PDF+α_s : 10 – 2%
    TH scales : 20 – 7%

  - Existing 350 (plus ~100 new LHC) data-points useable for direct constraints of the gluon PDF (NNPDF "reweighting").

- <u>Isolated di-photons</u>:
  - Useful testbed for higher-order (NNLO) & resummation (NNLL) calculations.
  - Decent data – NLO agreement within uncertainties for pair-mass & pair-p_T
  - NLO large underprediction of diphoton azimuthal correlation for $\Delta\varphi$<2.5 (not cured by NNLL, but by NNLO ...).

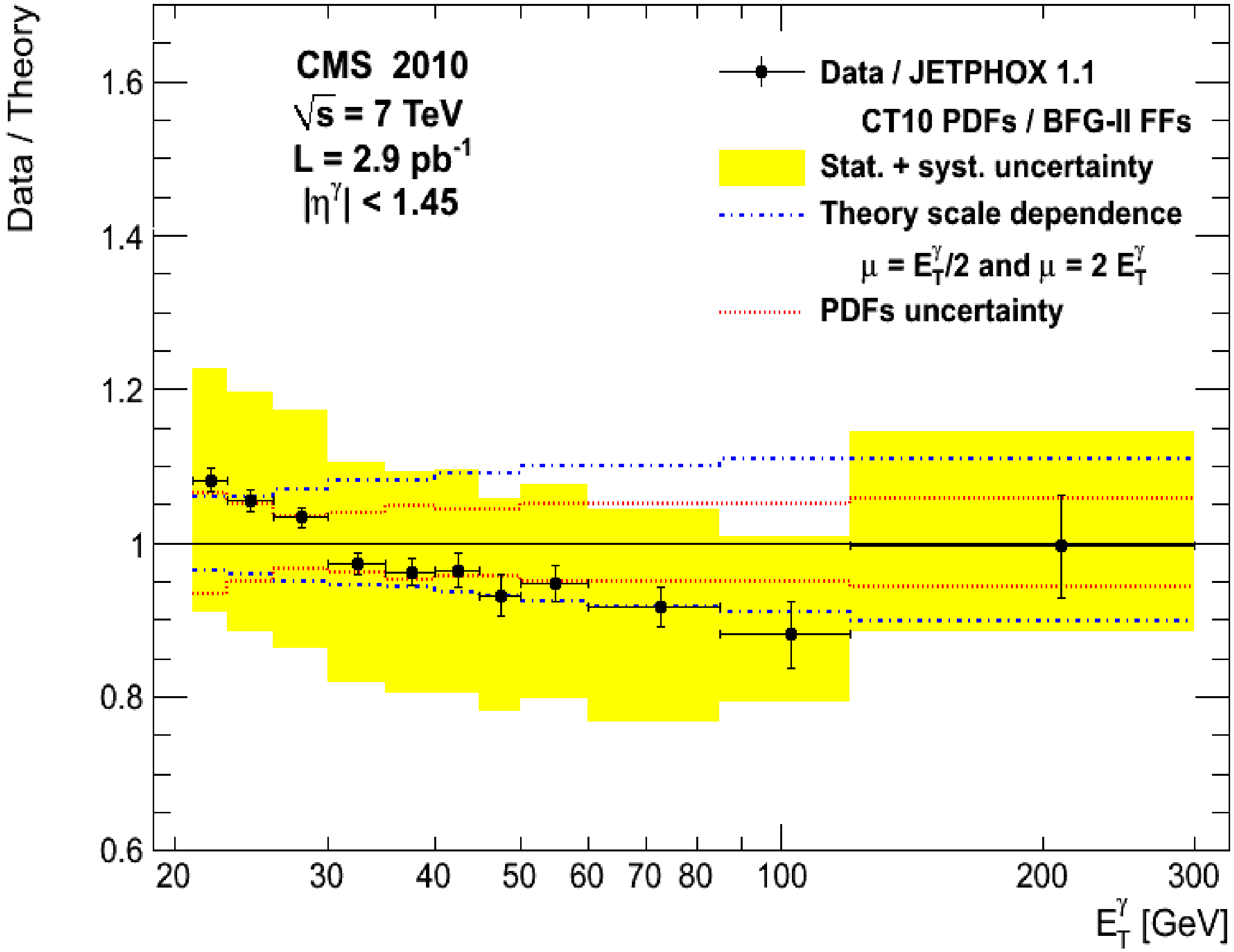
Backup slides

(6) γ syst. uncertainties: ATLAS vs CMS



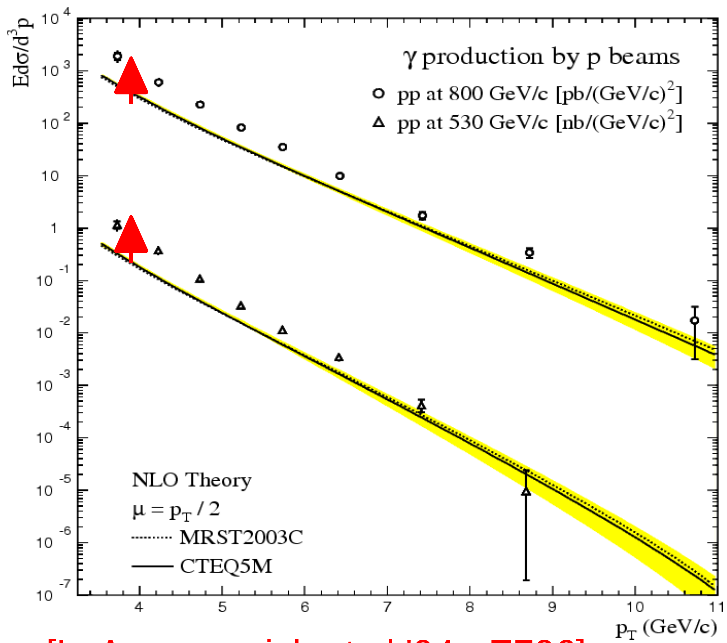
pp → γ_{iso}+X at 7 TeV (barrel) vs NLO

CMS: PRL 106 (2011) 082001

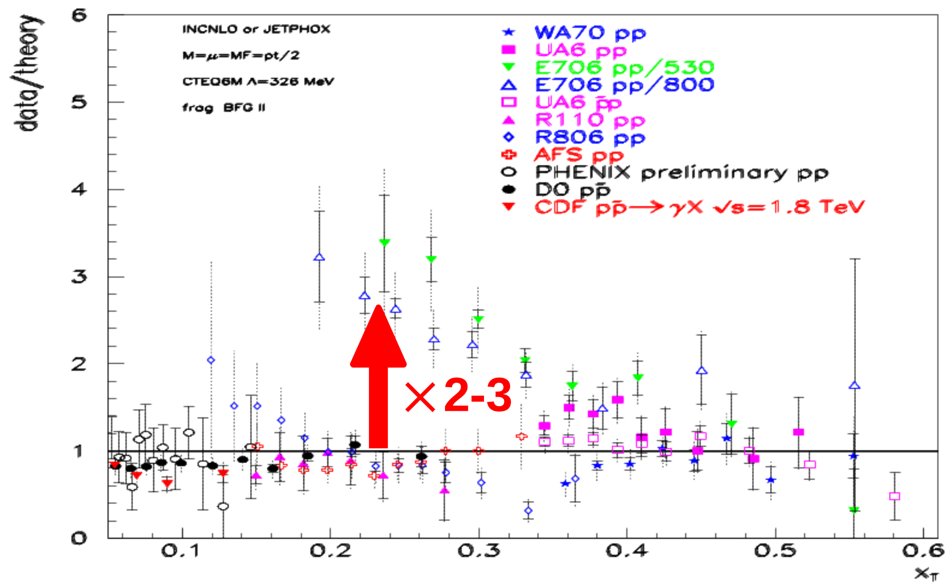


Prompt γ production in hadronic collisions

- Long-standing disagreement between NLO pQCD & fixed-target inclusive photon data (p-p, p-A @ √s~20-40 GeV):



[L. Apanasevich et al.'04 - E706]



[P.Aurenche et al.'06]
[Also Owens, Vogelsang, ...]

- Not solved by (N)NNL soft-gluon threshold & recoil resummations ...
  low p_T dominated by intrinsic-k_T ? parton-to-γ FF ? nuclear target effects ?

- "Conclusion": Photons removed from global PDF fits (used to constrain high-x gluon) since MRST99 !

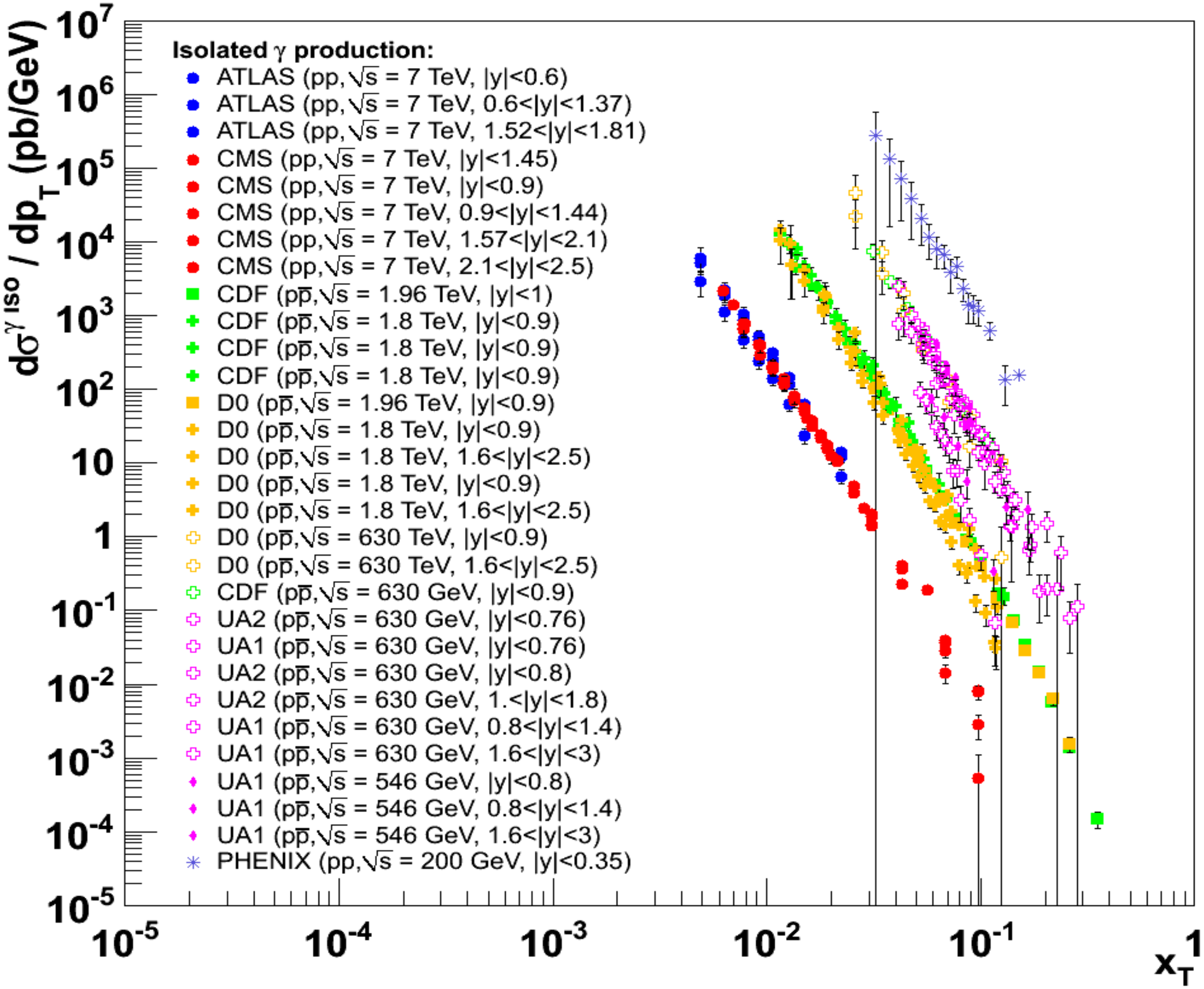
Collider isolated- γ world-data

- 30 meas. (350 data points) at LHC/Tevatron/SppS/RHIC & increasing ...

System	Collab./Exp. (collider)	$\sqrt{s}$ (GeV)	Ref.	y (c.m.)	p_T range (GeV/c)	Number of points	Isolation
p-$p \to \gamma_{isol} + X$	ATLAS (LHC)	7000.	(Aad *et al.*, 2010) [3]	-0.6 – 0.6	15. – 100.	8	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	ATLAS (LHC)	7000.	(Aad *et al.*, 2010) [3]	0.6 – 1.37	15. – 100.	8	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	ATLAS (LHC)	7000.	(Aad *et al.*, 2010) [3]	1.52 – 1.81	15. – 100.	8	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	CMS (LHC)	7000.	(Khatrchyan *et al.*, 2010) [1]	-1.45 – 1.45	21. – 300.	11	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	CMS (LHC)	7000.	(Khatrchyan *et al.*, 2011) [2]	-0.9 – 0.9	25. – 400.	15	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	CMS (LHC)	7000.	(Khatrchyan *et al.*, 2011) [2]	0.9 – 1.44	25. – 400.	15	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	CMS (LHC)	7000.	(Khatrchyan *et al.*, 2011) [2]	1.57 – 2.1	25. – 400.	15	$R = 0.4$, $E_h < 5$ GeV
p-$p \to \gamma_{isol} + X$	CMS (LHC)	7000.	(Khatrchyan *et al.*, 2011) [2]	2.1 – 2.5	25. – 400.	15	$R = 0.4$, $E_h < 5$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	CDF (Tevatron)	1960.	(Aaltonen *et al.*, 2009) [4]	-1.0 – 1.0	30. – 400.	16	$R = 0.4$, $\varepsilon_h = 0.1$
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	1960.	(Abazov *et al.*, 2005) [5]	-0.9 – 0.9	23. – 300.	17	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	CDF (Tevatron)	1800.	(Abe *et al.*, 1994) [6]	-0.9 – 0.9	8. – 132.	16	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	CDF (Tevatron)	1800	(Acosta *et al.*, 2002) [7]	-0.9 – 0.9	11. – 132.	17	$R = 0.4$, $E_h < 4$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	CDF (Tevatron)	1800	(Acosta *et al.*, 2004) [8]	-0.9 – 0.9	10. – 65.	17	$R = 0.4$, $E_h < 1$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	1800.	(Abachi *et al.*, 1996) [9]	-0.9 – 0.9	9.0 – 126.	23	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	1800.	(Abachi *et al.*, 1996) [9]	1.6 – 2.5	9.0 – 126.	23	$R = 0.4$ $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	1800.	(Abbott *et al.*, 1999) [10]	-0.9 – 0.9	10. – 140.	9	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	1800.	(Abbott *et al.*, 1999) [10]	1.6 – 2.5	10. – 140.	9	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	CDF (Tevatron)	630	(Acosta *et al.*, 2002) [7]	-0.9 – 0.9	8. – 38.	7	$R = 0.4$, $E_h < 4$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	630	(Abazov *et al.*, 2001) [11]	-0.9 – 0.9	7.0 – 50.	7	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	D0 (Tevatron)	630	(Abazov *et al.*, 2001) [11]	1.6 – 2.5	7.0 – 50.	7	$R = 0.4$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	630.	(Albajar *et al.*, 1988) [12]	-0.8 – 0.8	16. – 100.	16	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	630.	(Albajar *et al.*, 1988) [12]	0.8 – 1.4	16. – 70.	10	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	630.	(Albajar *et al.*, 1988) [12]	1.6 – 3.	16. – 70.	13	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA2 (Sp$\bar{p}$S)	630.	(Alitti *et al.*, 1992) [14]	-0.76 – 0.76	14. – 92.	13	$R = 0.265$, $\varepsilon_h = 0.25$
p-$\bar{p} \to \gamma_{isol} + X$	UA2 (Sp$\bar{p}$S)	630.	(Ansari *et al.*, 1988) [13]	-0.76 – 0.76	12. – 83.0	14	$R = 0.25$, $E_h < 0.1$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA2 (Sp$\bar{p}$S)	630.	(Ansari *et al.*, 1988) [13]	1.0 – 1.8	12. – 51.	8	$R = 0.53$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	546.	(Albajar *et al.*, 1988) [12]	-0.8 – 0.8	16. – 51.	6	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	546.	(Albajar *et al.*, 1988) [12]	0.8 – 1.4	16. – 46.	5	$R = 0.7$, $E_h < 2$ GeV
p-$\bar{p} \to \gamma_{isol} + X$	UA1 (Sp$\bar{p}$S)	546.	(Albajar *et al.*, 1988) [12]	1.6 – 3.	16. – 38.	5	$R = 0.7$, $E_h < 2$ GeV
p-$p \to \gamma_{isol} + X$	PHENIX (RHIC)	200.	(Adler *et al.*, 2006) [15]	-0.35 – 0.35	3.0 – 16.0	17	$R = 0.5$, $\varepsilon_h = 0.1$

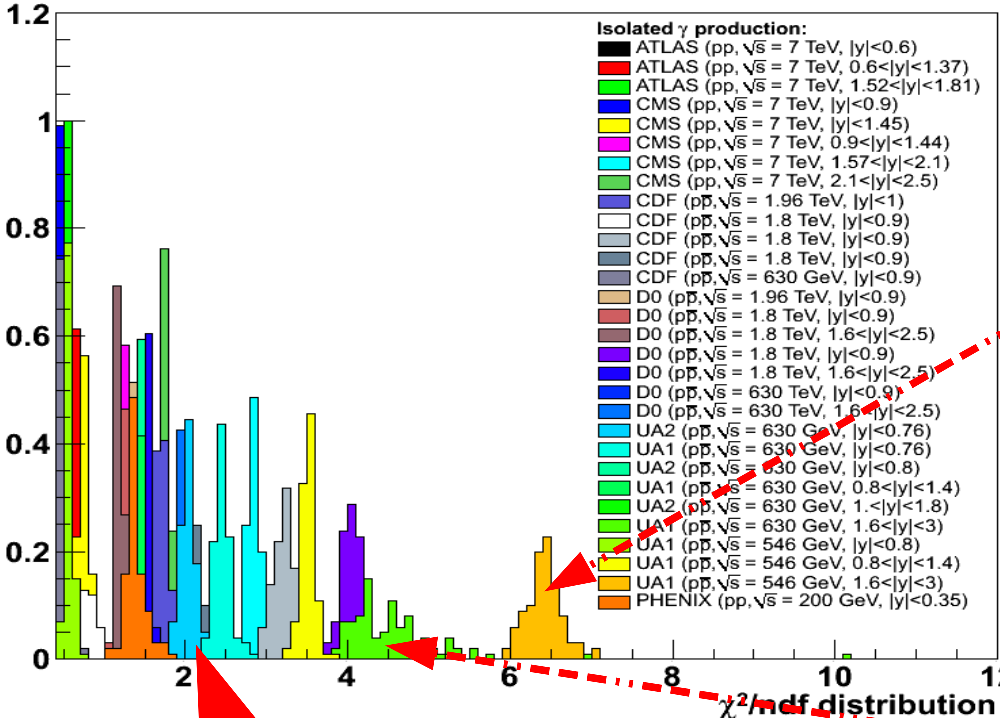
Collider isolated- γ world-data

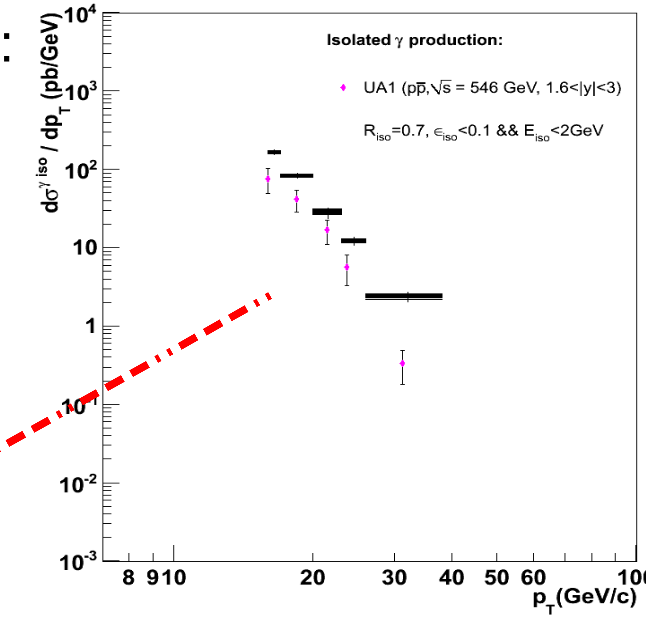
- LHC/Tevatron/SppS/RHIC power-law $x_T = 2p_T/\sqrt{s}$~10^{-3}-0.4 spectra:

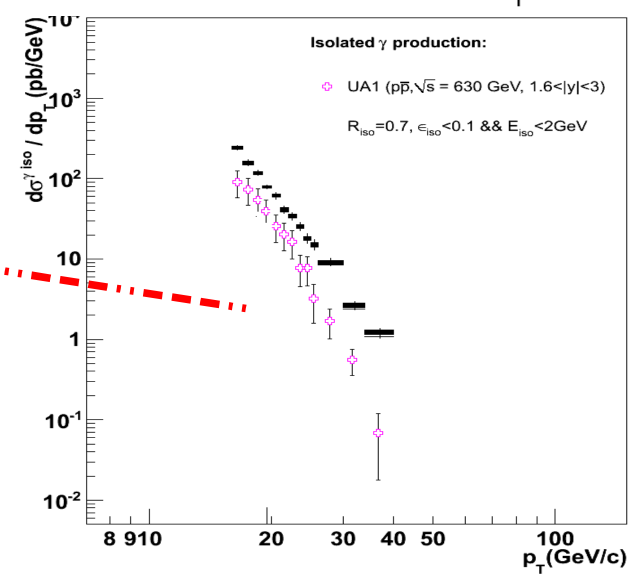


World γ_{isol} data vs NNPDF replicas

- A few outliers from Sp$\bar{p}$S at fwd rapidities (likely not “physics”. To be rechecked ...):

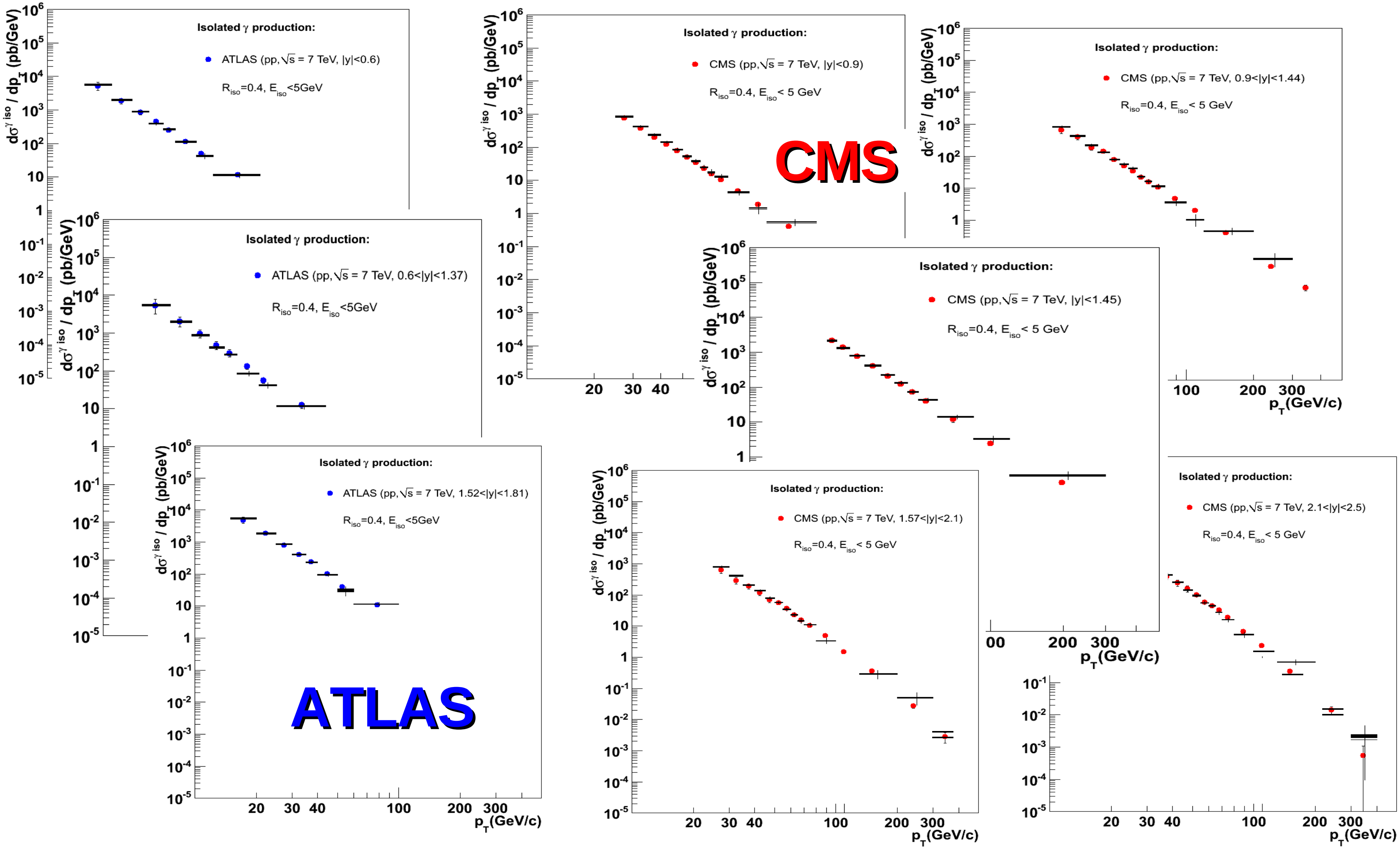






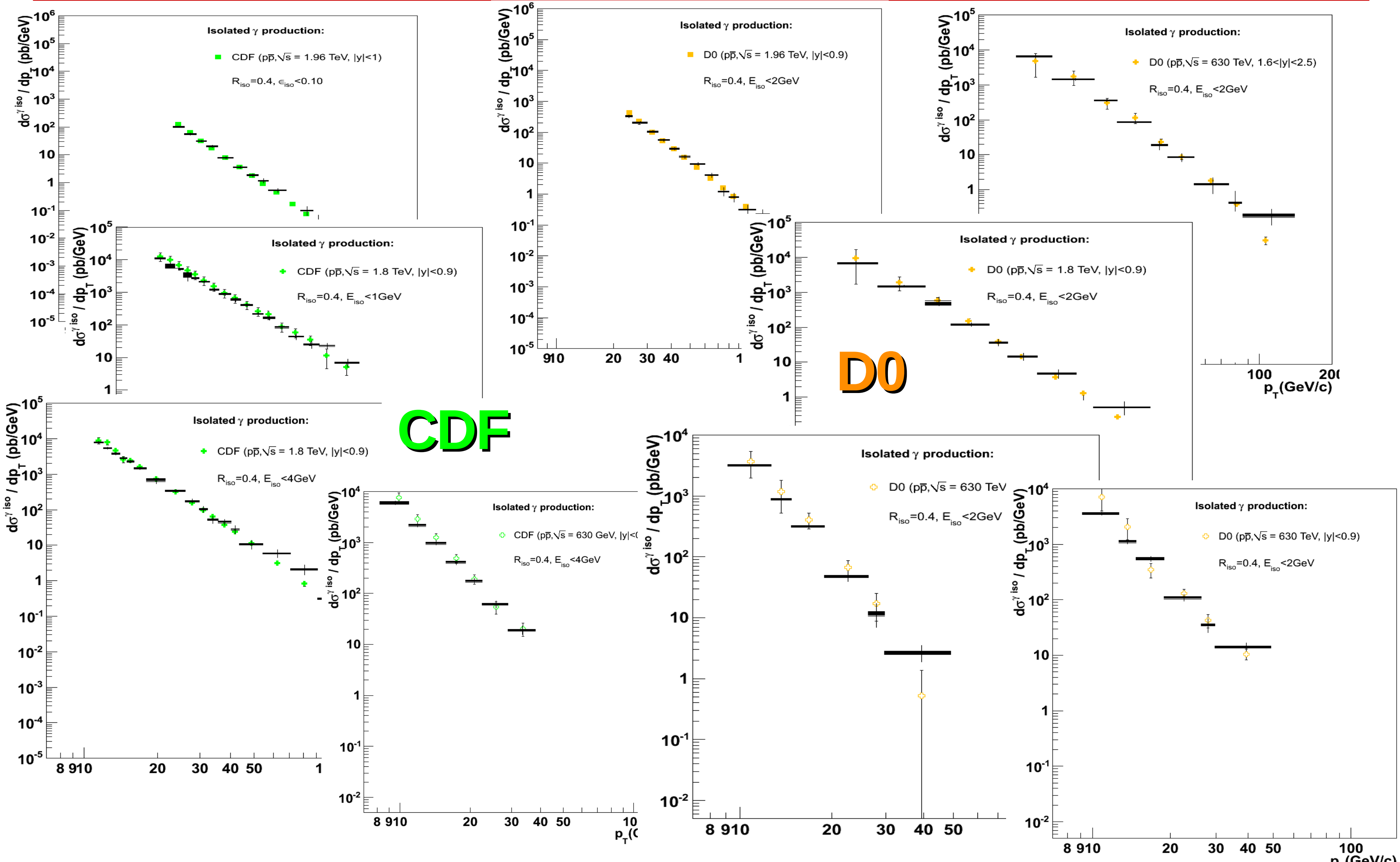
- Other measurements with χ^2/ndf~2-4 may have some impact on global PDF fits

Preliminary: LHC vs JETPHOX-NNPDF



■ p-p 7-TeV spectra well bracketed by 100 replicas at all p_T, y ranges

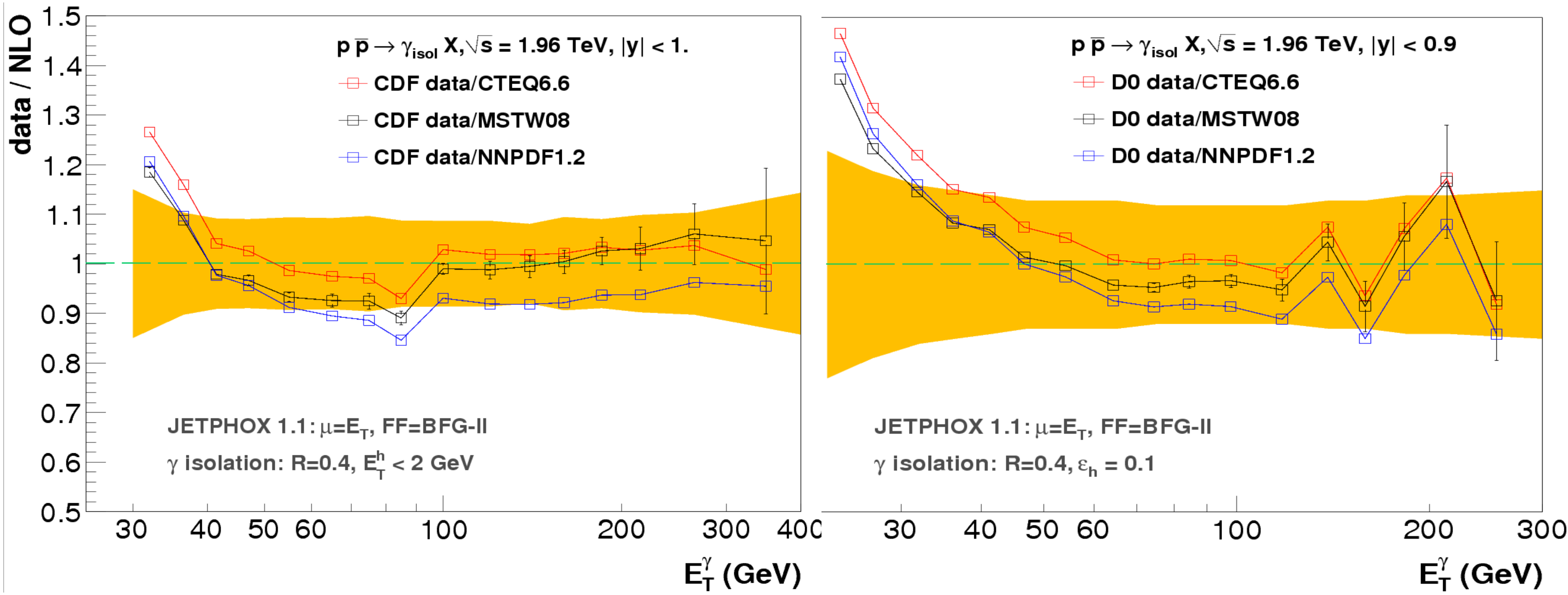
Preliminary: Tevatron vs JETPHOX-NNPDF



- 0.63,1.8,1.96-TeV γ_{isol} data overall bracketed (some excess at lowest p_T)

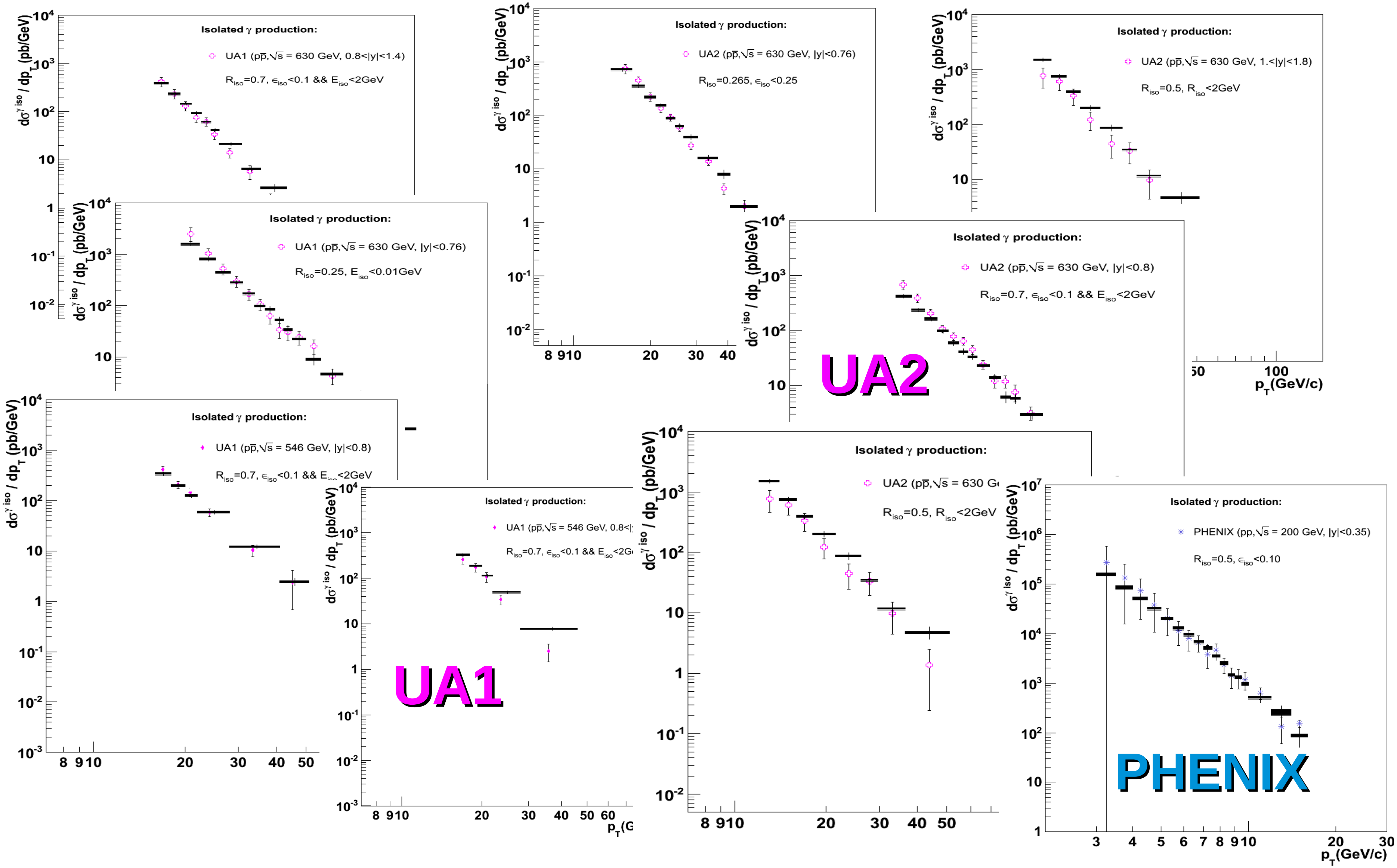
Tevatron isolated-γ vs JETPHOX

[R.Ichou & D.d'E, PRD82 (2010) 014015]



- Good overall agreement data-NLO in pp → γ_{isol}+X at 1.96 TeV.
- Excess at p_T<30 GeV/c (still within exp. uncertainties):
  physics ? Instrumental ?

Preliminary: SppS/RHIC vs JETPHOX-NNPDF



■ 200,546,640-GeV γ_{isol} data overall bracketed (larger errors, some exceptions)