Isolated γ at fixed-target LHC & large-x parton densities in the proton & nucleus

Meeting on fixed-target projects at CERN

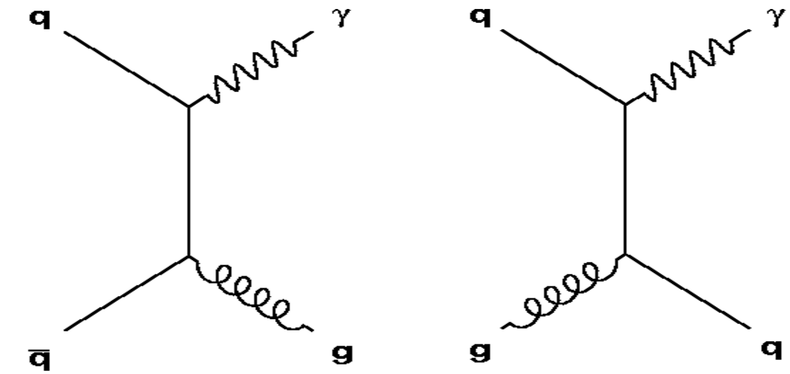
Orsay, 7th July 2011

David d'Enterria

CERN

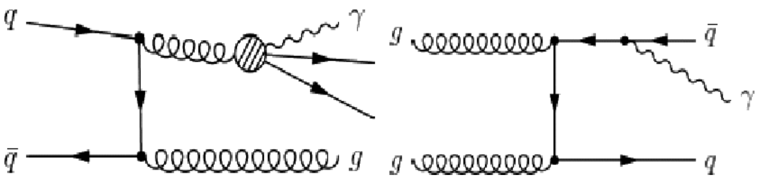
Isolated photons in p-p & parton densities

- Leading parton-parton γ production processes in hadronic collisions:



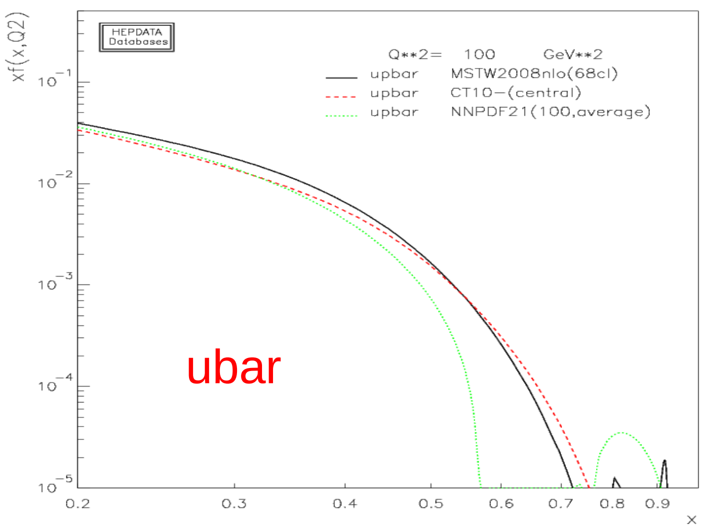
Annihilation Process **Compton Process**

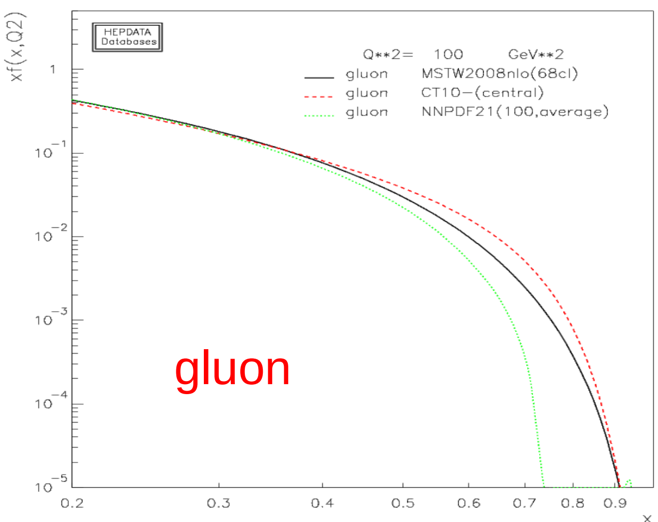
Parton-to-photon fragmentation:



(Suppressed by isolation cuts)

- Isolated-γ at "low"-$\sqrt{s}$ & high-p_T are sentitive to high-x gluons & sea:

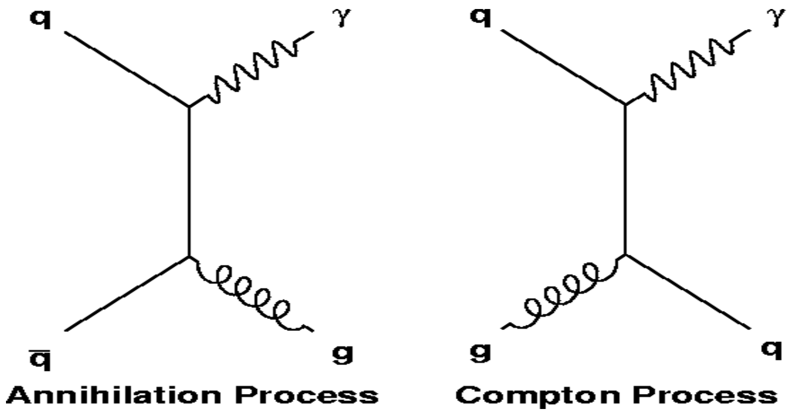




Very large uncertainties above x~0.3. Also at large Q^2 !

Isolated photons in p-p & parton densities

- Leading partonic γ production processes in hadronic collisions:



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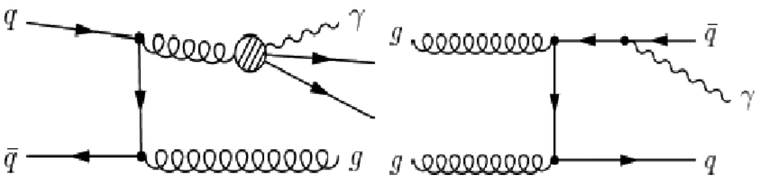

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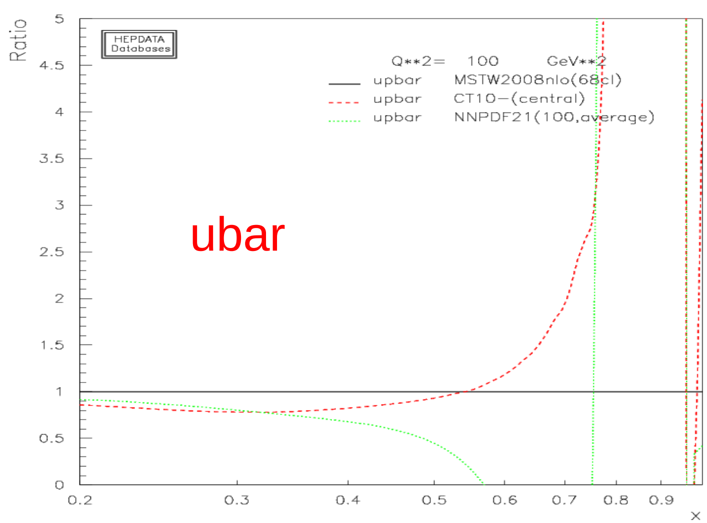
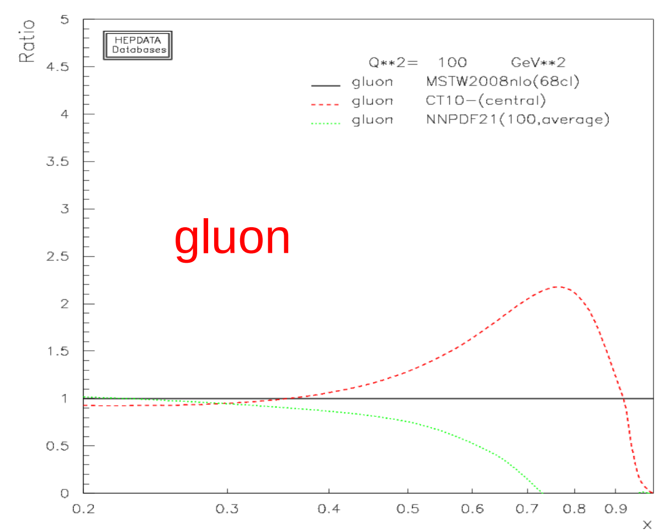
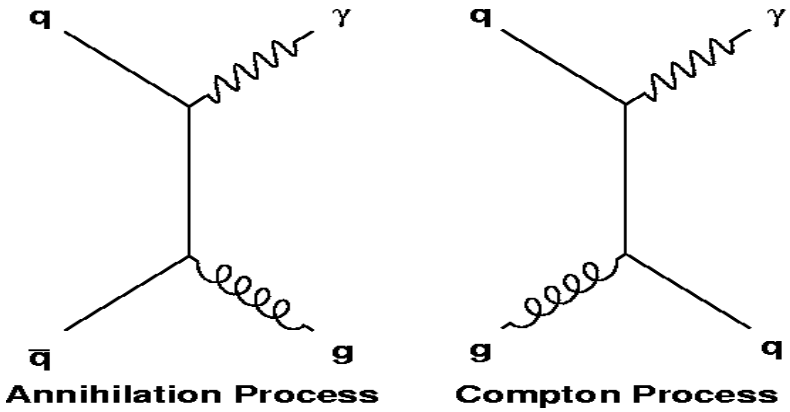




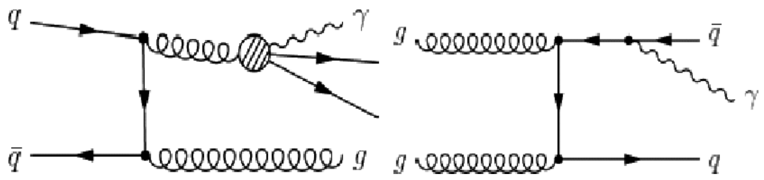
Very large uncertainties above x~0.3. Also at large Q^2 !

Isolated γ in Pb-Pb & nuclear parton densities

- Leading partonic γ production processes in hadronic collisions:



Parton-to-photon fragmentation:



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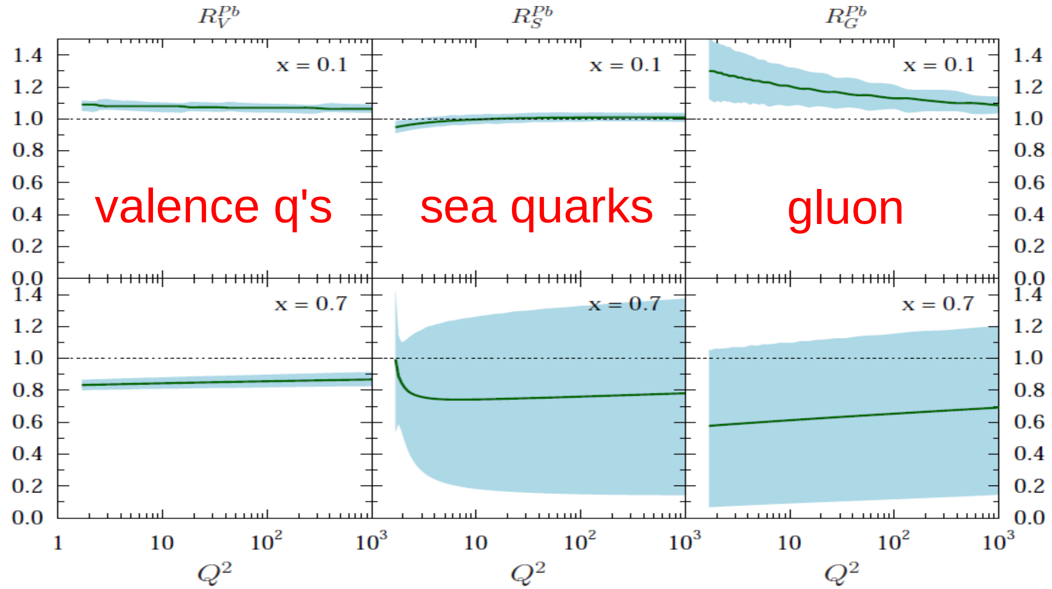


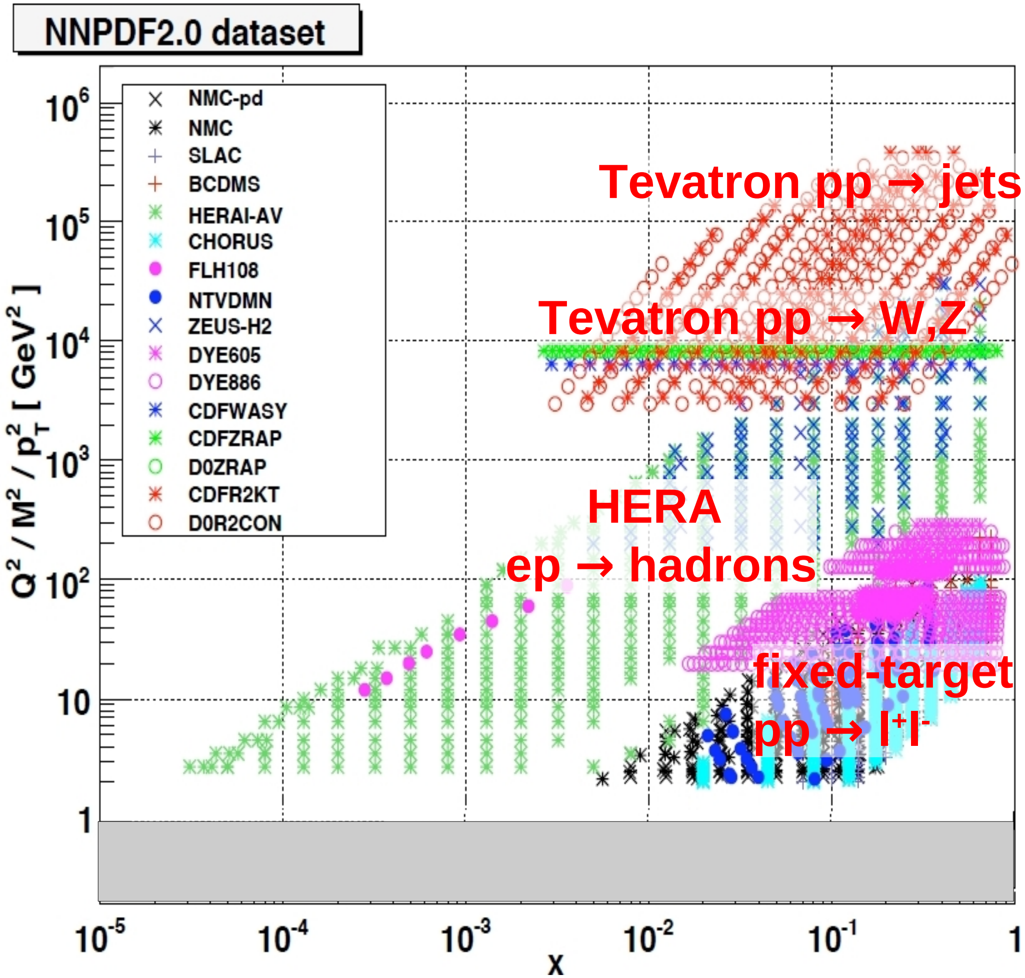
Very large uncertainties in EMC & Fermi regions !

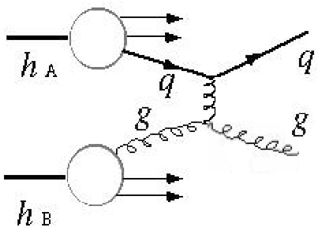
Also at large Q² !

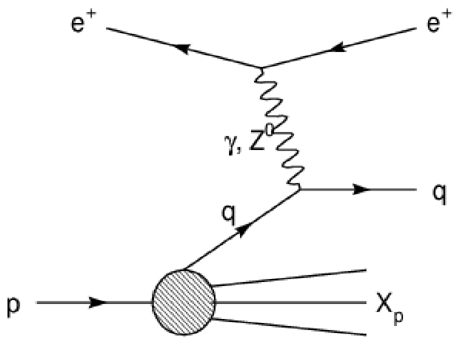
EPS09, arXiv:1011.6534

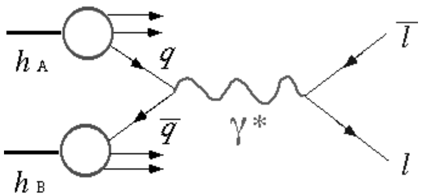
Current data-sets in PDF global fits

- Deep-inelastic-scattering (ep), fixed-target (pp), collider (pp) data:









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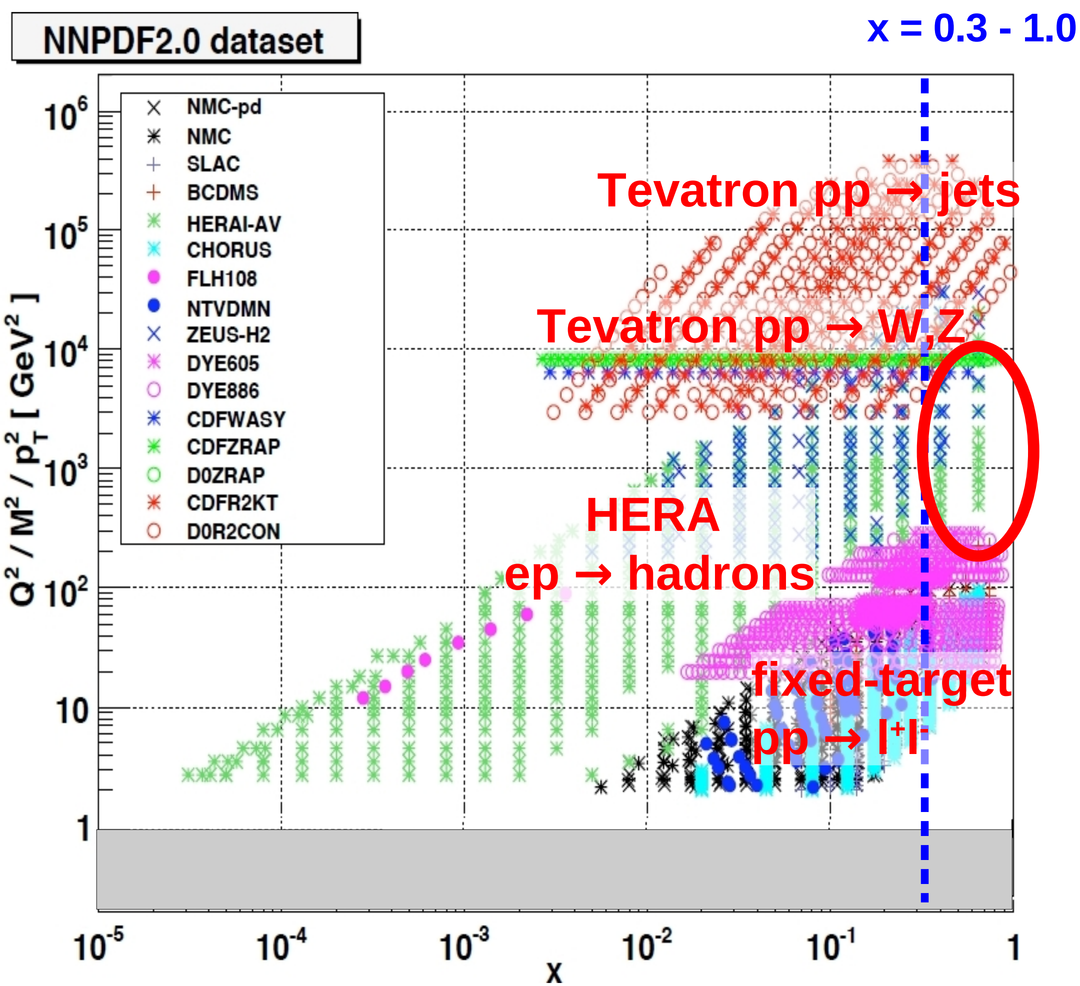
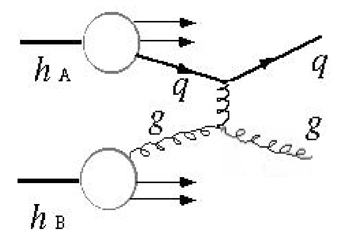
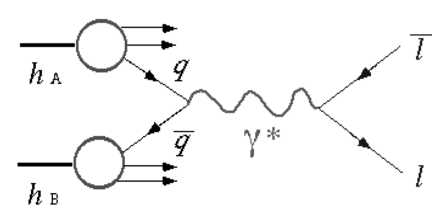




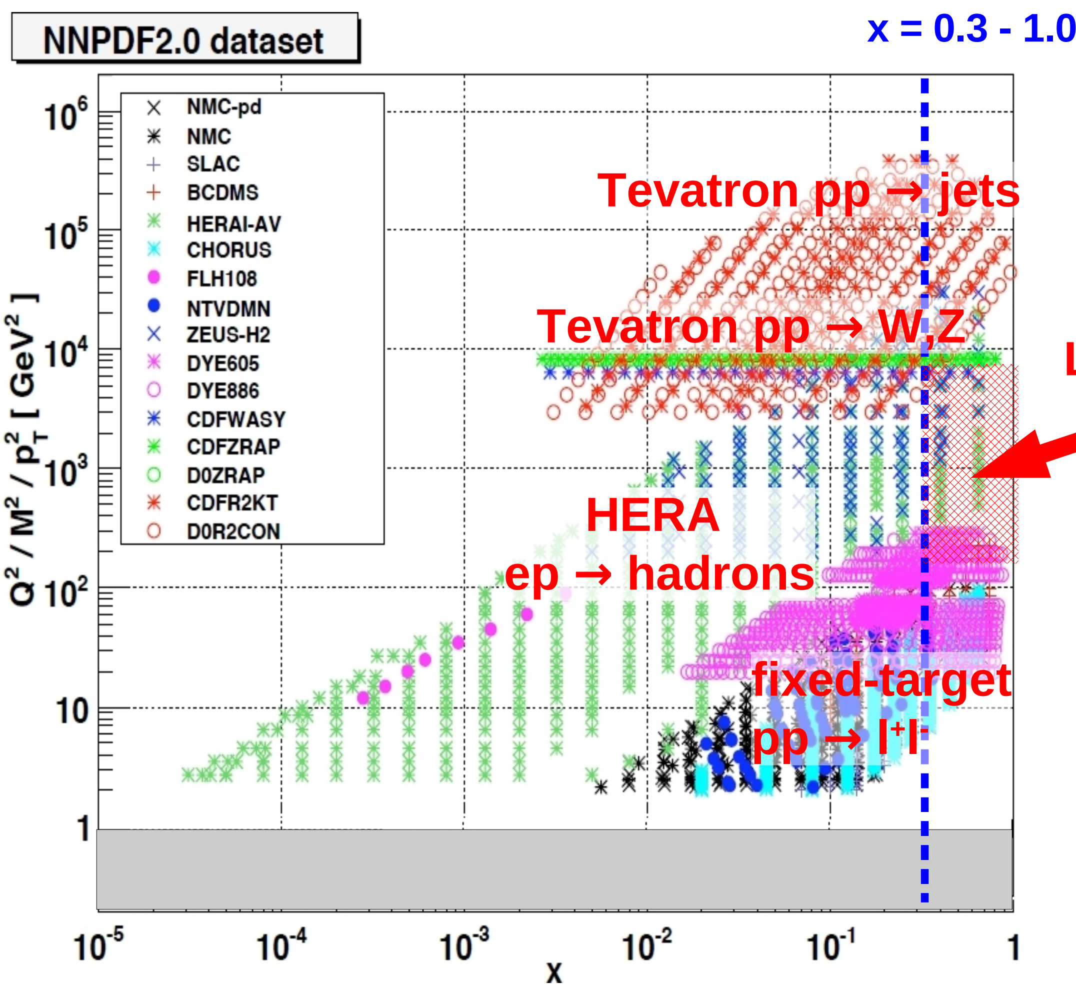
High-x PDFs:
Few data (DIS) available
& mostly sensitive just to
valence-quarks

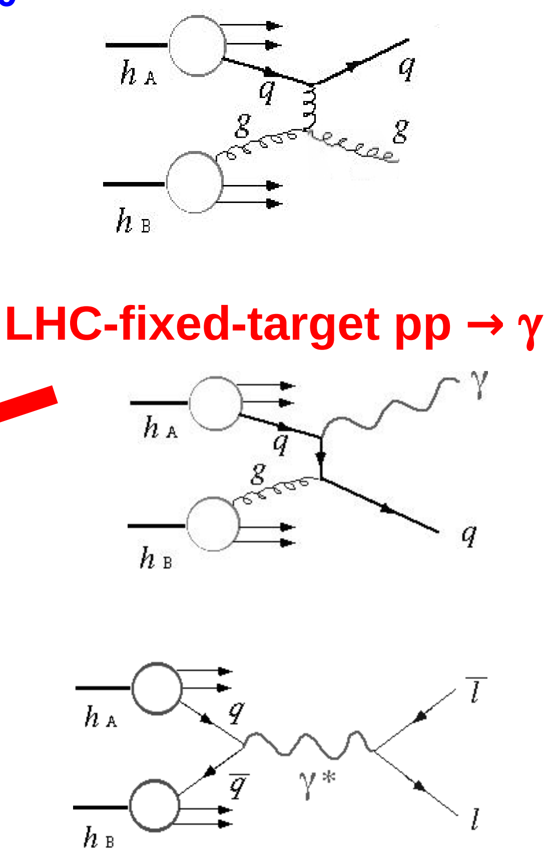


Isolated γ in p(7 TeV)-p(rest): √s ~ 115 GeV

- p-p kinematics at fixed-target LHC:

  To access x > 0.3 one needs isolated-γ with: $p_T = x_T\sqrt{s}/2 > 20$ GeV/c





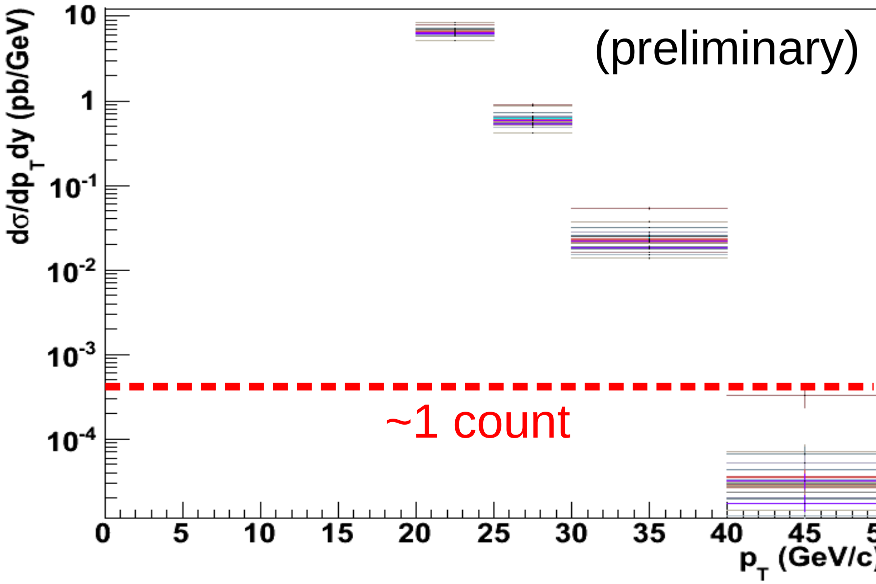
Isolated γ in p(7 TeV)-p(rest): √s ~ 115 GeV

- p-p photon kinematics at fixed-target LHC (central rapidities):
  To access x > 0.3 one needs isolated-γ at: $p_T = x_T\sqrt{s}/2 > 20$ GeV/c

- JETPHOX NLO
  pQCD calculations:

  p-p at √s=115 GeV
  |y|<0.5, p_T>20 GeV/c
  Isolation: R=0.4, E_T^{had}<5 GeV

$\mathcal{L}$(10 cm H_2-target) ~ $2\cdot10^3$ pb^{-1}/year



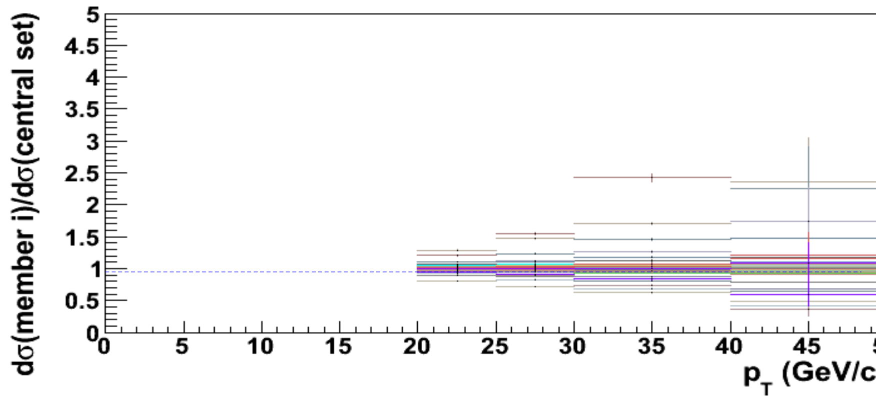
PDF: CT10 52 eigenval. (90% CL)

Scales: $\mu_i = p_T$

FF = BFG-II

x-section uncertainties(*) of ±150%

(*) (68%CL)/(90% CL) ~ 1.65

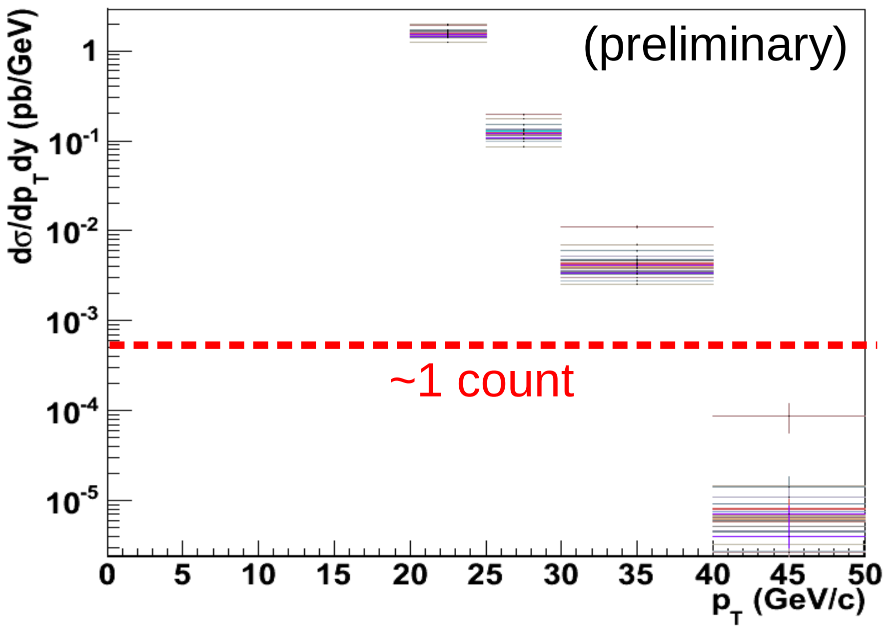


Isolated γ in p(7 TeV)-p(rest): √s ~ 115 GeV

- p-p photon kinematics at fixed-target LHC (backwards rapidities):
  To access x > 0.3 one needs isolated-γ at: $p_T = x_T\sqrt{s}/2e^{-y} > 10$ GeV/c
- JETPHOX NLO
  pQCD calculations:

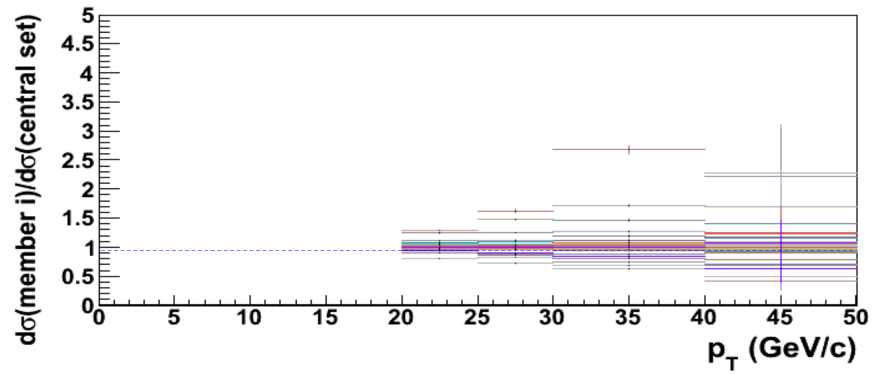
  p-p at √s=115 GeV
  0<y<-3., p_T>20 GeV/c
  Isolation: R=0.4, E_T^{had}<5 GeV

$\mathcal{L}$ (10 cm H_2-target) ~ $2\cdot10^3$ pb^{-1}/year



PDF: CT10 52 eigenval. (90% CL)
Scales: $\mu_i = p_T$
FF = BFG-II
x-section uncertainties(*) of ±170%

(*) (68%CL)/(90% CL) ~ 1.65

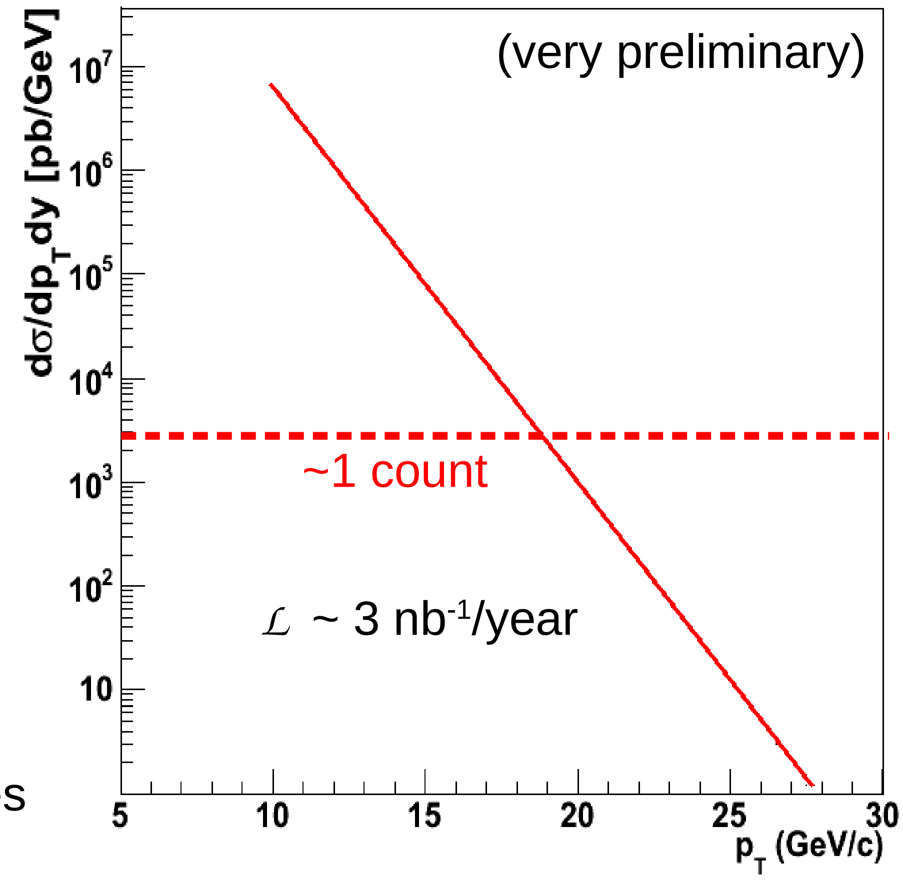


Isolated γ in Pb(2.76 TeV)-Pb(rest): $\sqrt{s_{NN}}$~72 GeV

- Pb-Pb photon kinematics at fixed-target LHC:
  To access x > 0.3 one needs isolated-γ at: $p_T = x_T\sqrt{s}/2 > 10$ GeV/c
- JETPHOX NLO
  pQCD calculations:

  Pb-Pb at $\sqrt{s_{NN}}$=72 GeV
  |y|<0.5, p_T>20 GeV/c
  Isolation: R=0.4, E_T^{had}<5 GeV

  PDF: EPS09
  Scales: $\mu_i = p_T$
  FF = BFG-II

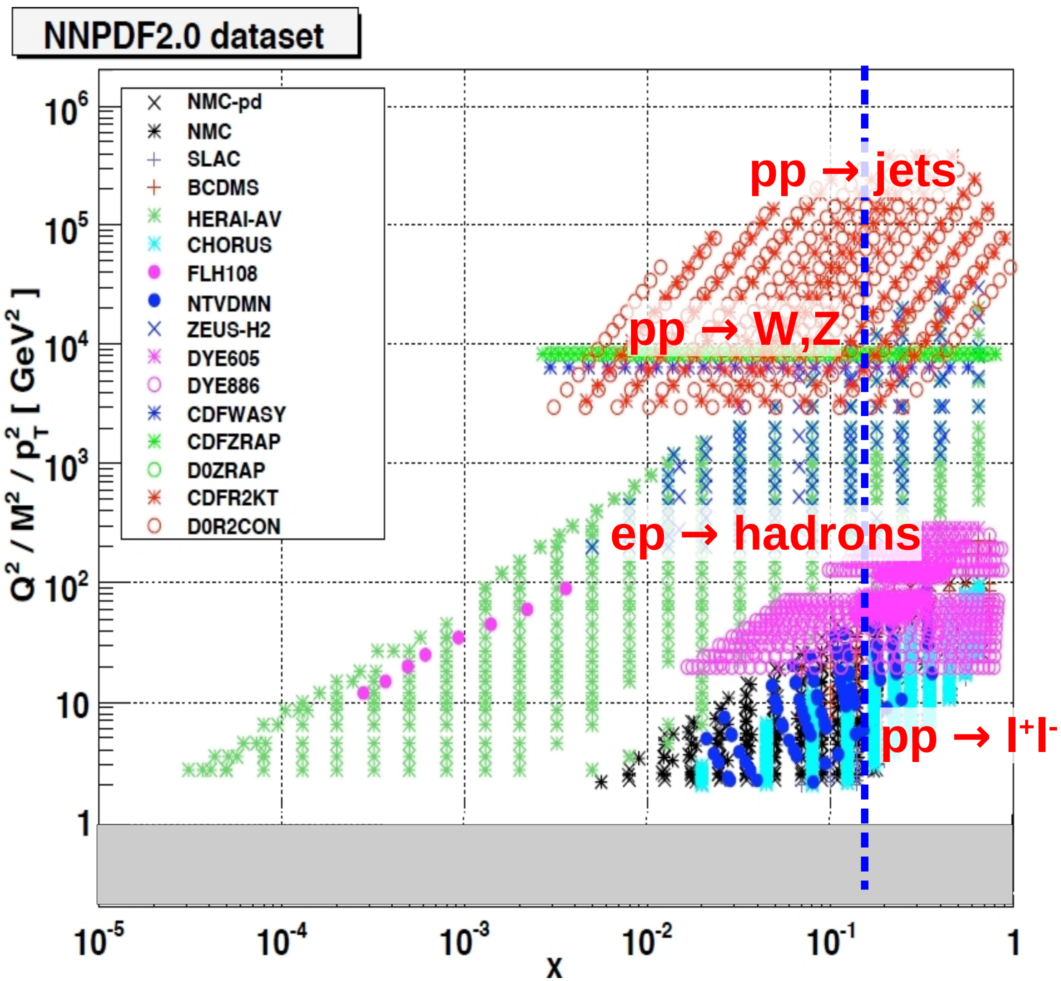


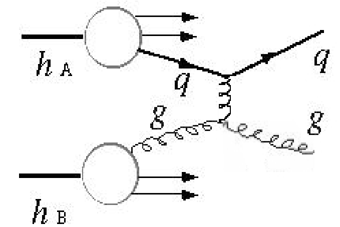
(Ongoing determination of uncertainties with 40 EPS09 eigenvalues ...)

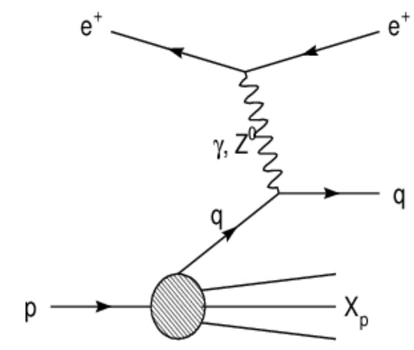
Backup slides

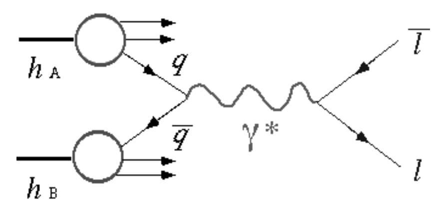
Q² versus Bjorken-x (pre-LHC)

- Deep-inelastic-scattering (ep), fixed-target (pp), collider (pp)



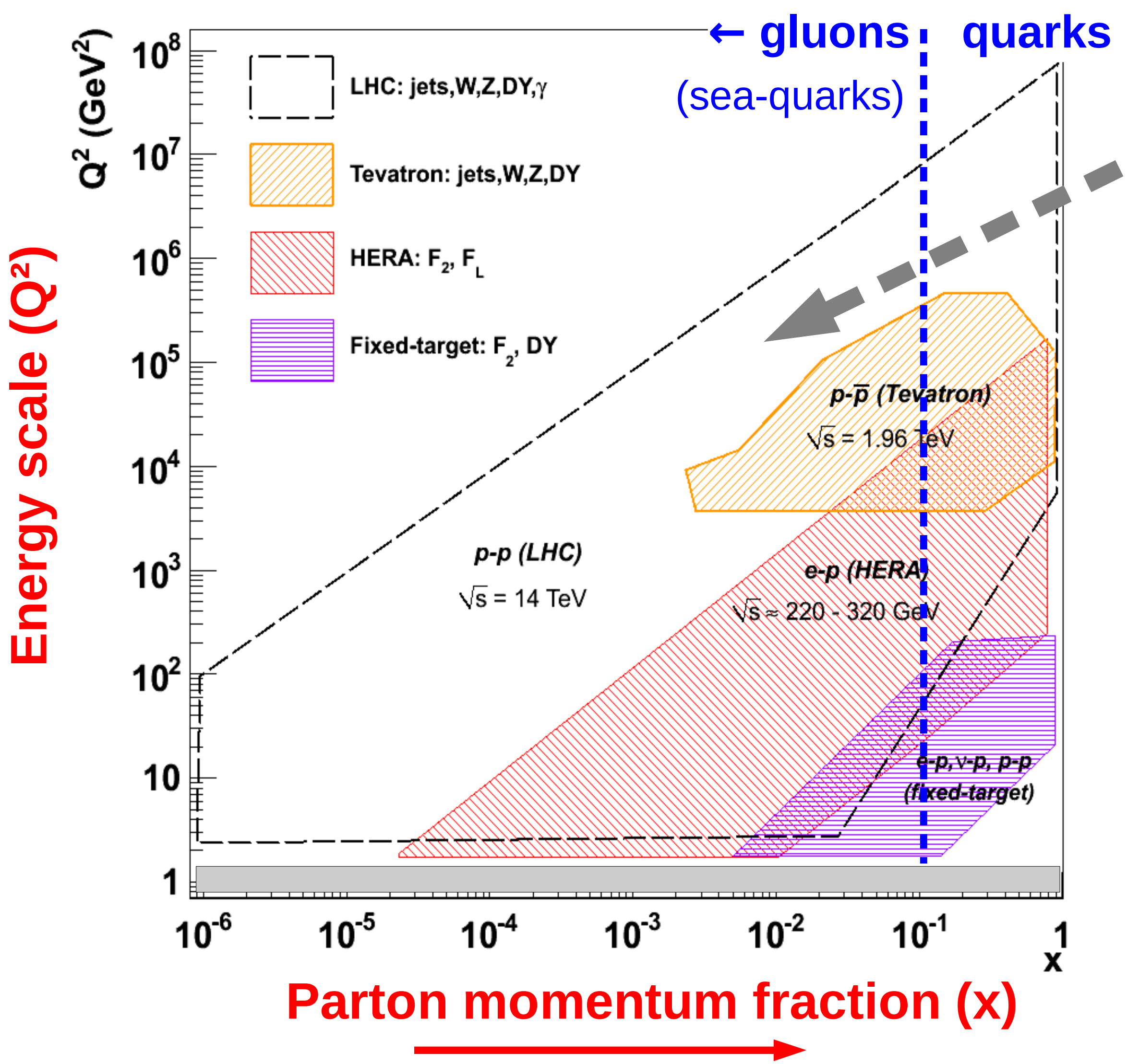


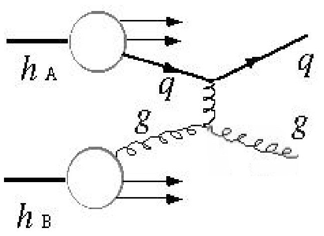




Q² versus Bjorken-x (LHC)

- (x,Q^2) reach increased significantly !





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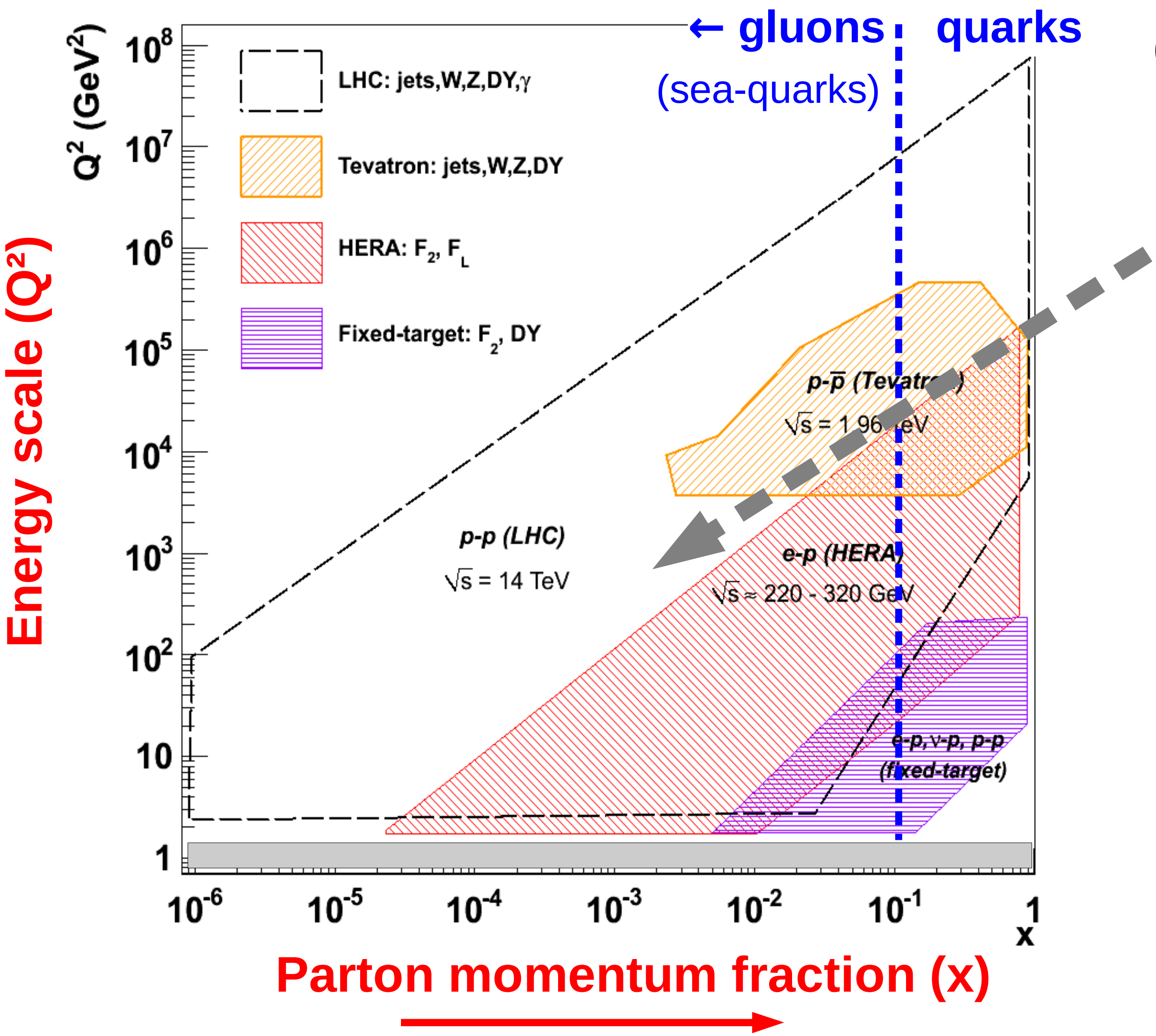
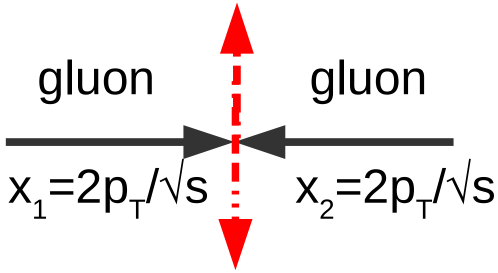


- parton-parton collision:

(mid-rapidity, 90°):



Q² versus Bjorken-x (LHC)

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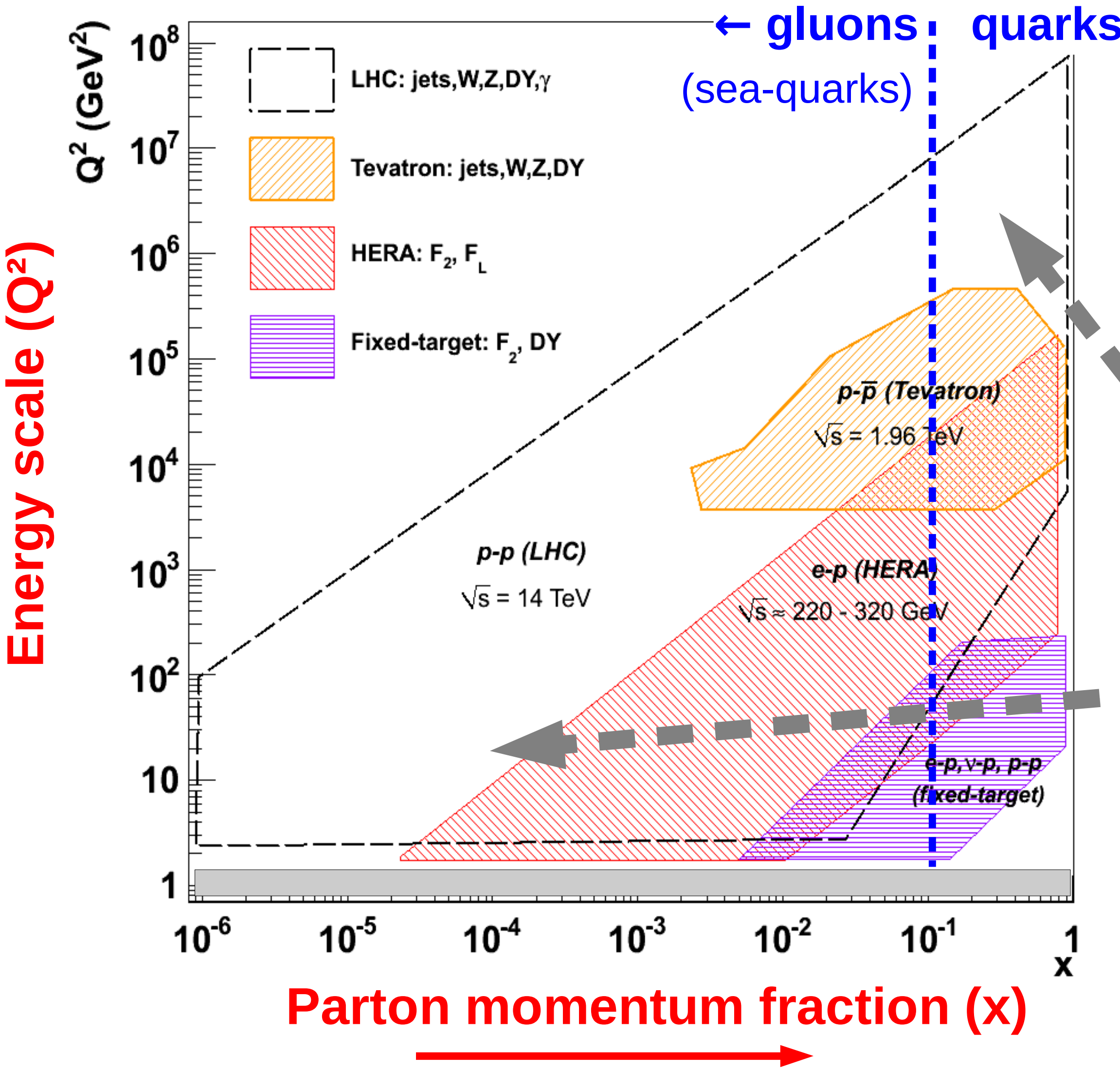
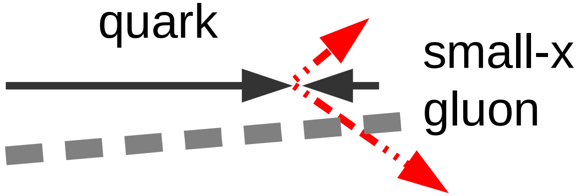


- parton-parton collision:

(forward rapidities):

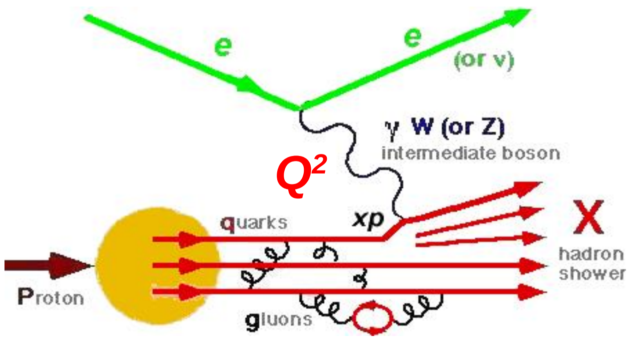


$x_2^{min} \sim p_T/\sqrt{s} \cdot e^{-y} = x_T \cdot e^{-y}$

every 2-units of y x^{min} decreases by ~10

Low-x PDFs

- DIS collisions probe distributions of partons inside hadrons:



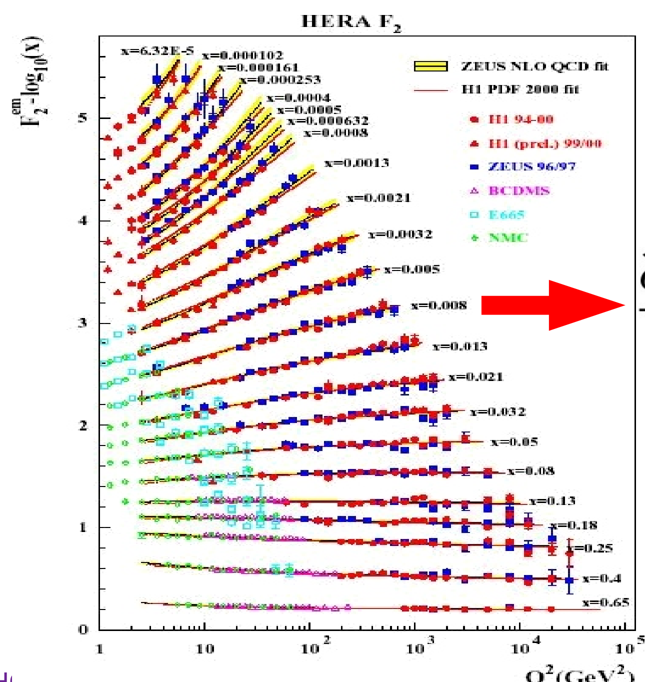
Q^2 = "resolving power"

Bjorken x = momentum fraction carried by parton

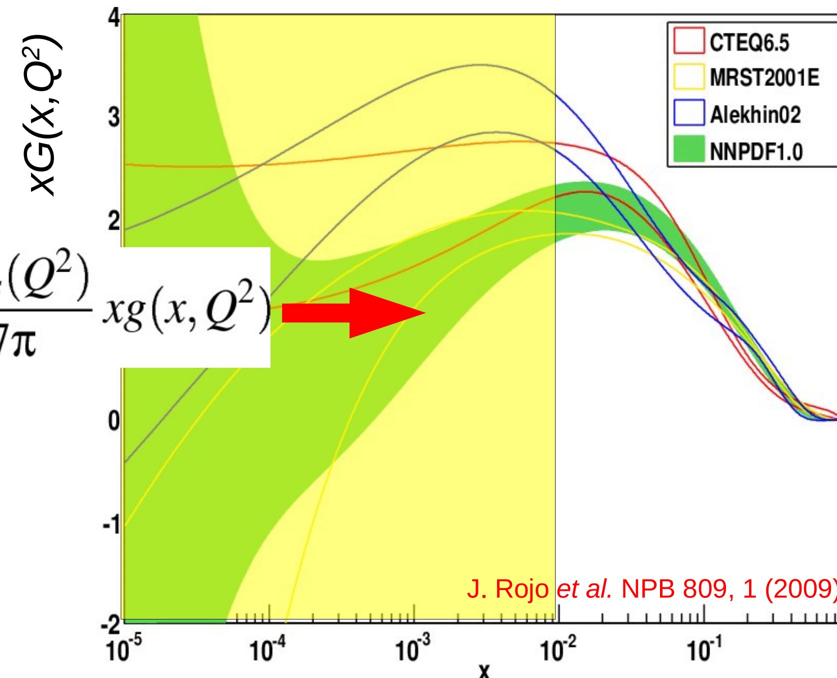
$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ \cdot F_2 \mp Y_- \cdot xF_3 - y^2 \cdot F_L\right]$$

F_2, F_3, F_L = proton structure functions, (y = inelasticity).

- Gluons dominate but only indirectly constrained via F_2 "scaling violations":



$$\frac{\partial F_2(x,Q^2)}{\partial \ln(Q^2)} \approx \frac{10\alpha_s(Q^2)}{27\pi}\, xg(x,Q^2)$$



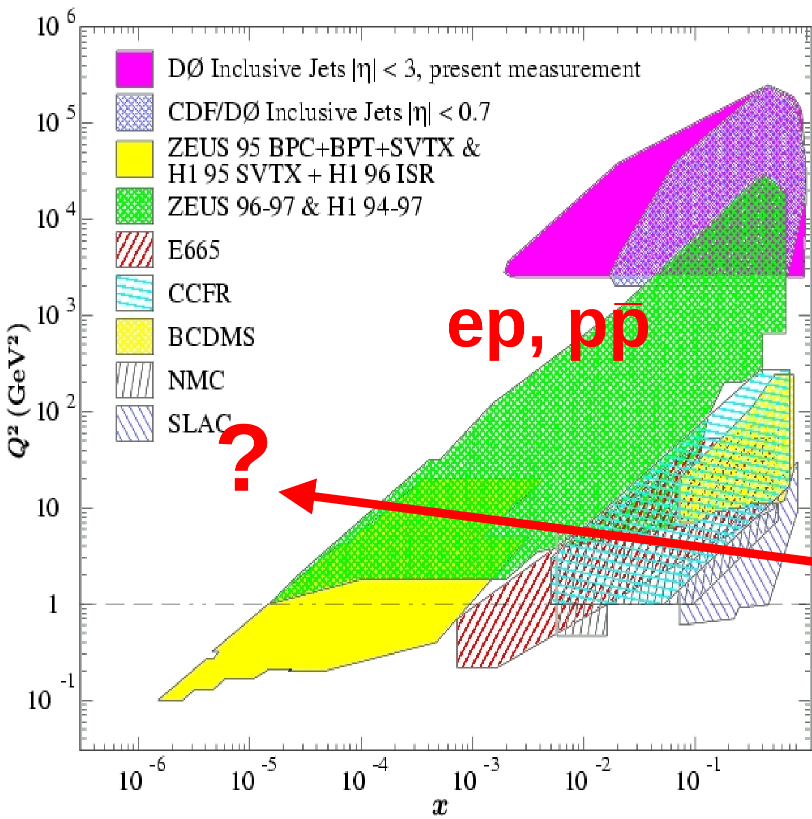
Low-x studies at the LHC: proton

- p-p @ 14 TeV :

(1) At y=0, $x=2p_T/\sqrt{s}\sim10^{-3}$ (domain probed at HERA,Tevatron). Go fwd. for $x<10^{-4}$

(2) Saturation momentum: $Q_s^2\sim$ 1 GeV² (y=0), 3 GeV² (y=5)

(3) Very large perturbative cross-sections:



$$p(p_1)+p(p_2)\to \text{jet}+\gamma+\ \text{X}$$ Prompt γ

$$p(p_1)+p(p_2)\to l\bar{l}+\ \text{X}$$ Drell-Yan

$$p(p_1)+p(p_2)\to \text{jet}_1+\text{jet}_2+\ \text{X}$$ Jets

$$p(p_1)+p(p_2)\to \text{Q}+\bar{\text{Q}}+\ \text{X}$$ Heavy flavour

$$p(p_1)+p(p_2)\to W/Z+\ \text{X}$$ W,Z production

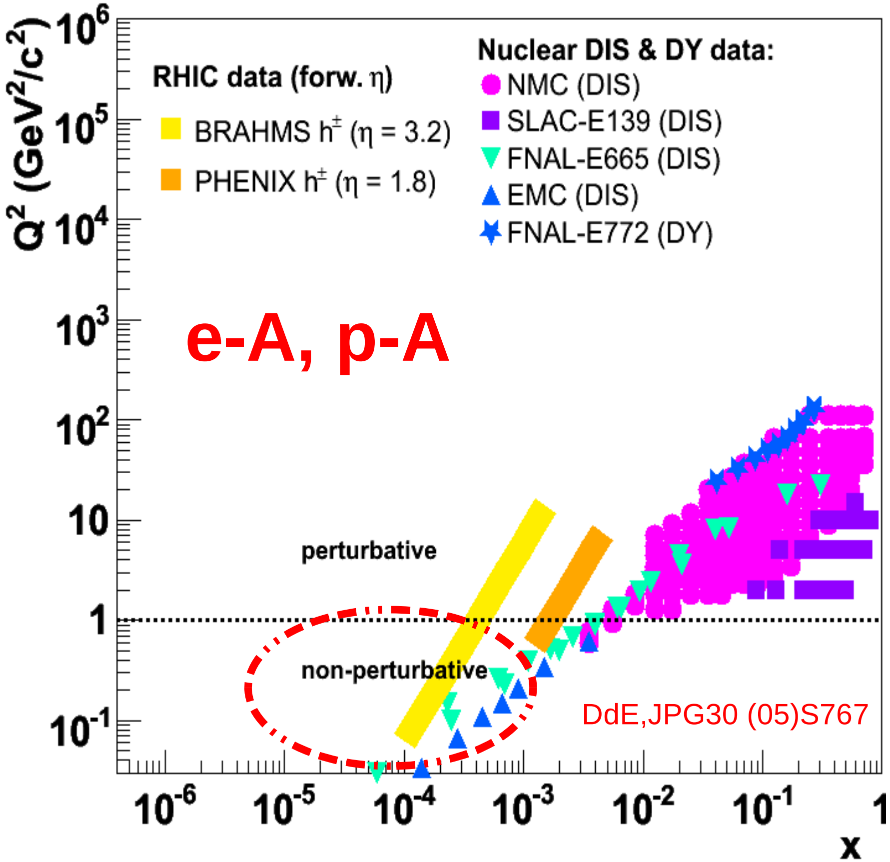
LHC forward rapidities:

e.g. y ~ 6, Q ~ 10 GeV

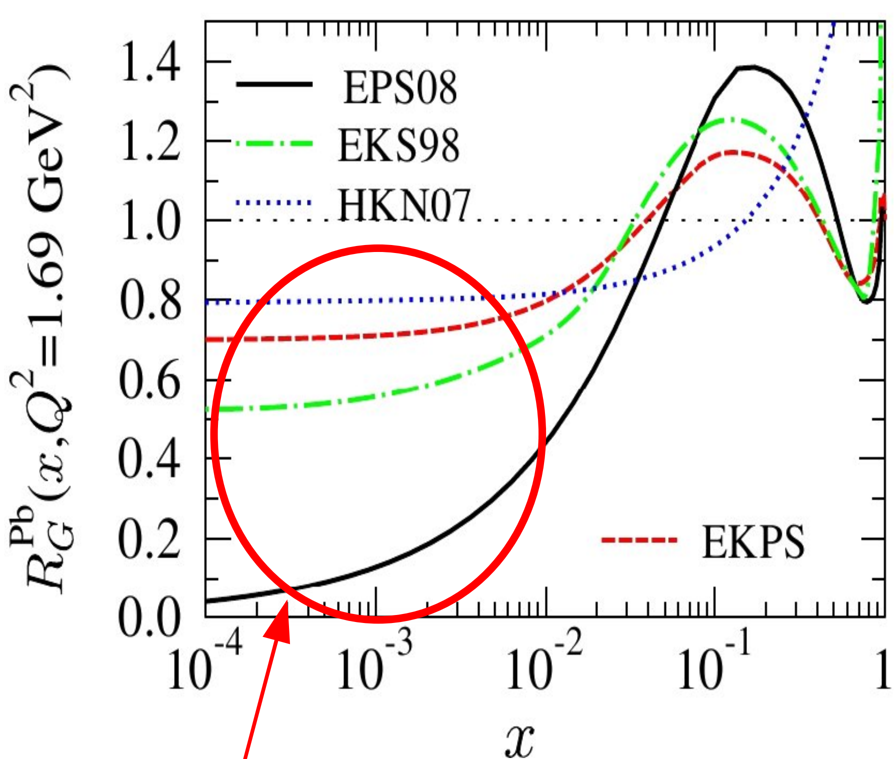
x down to 10^{-6} !

Low-x gluon nuclear densities

- Current knowledge of low-x gluons from:
  F_2 (e-A), Drell-Yan (p-A), high-p_T hadrons (d-Au).
- x<0.01: very few measurements (non-perturbative): huge uncertainties !



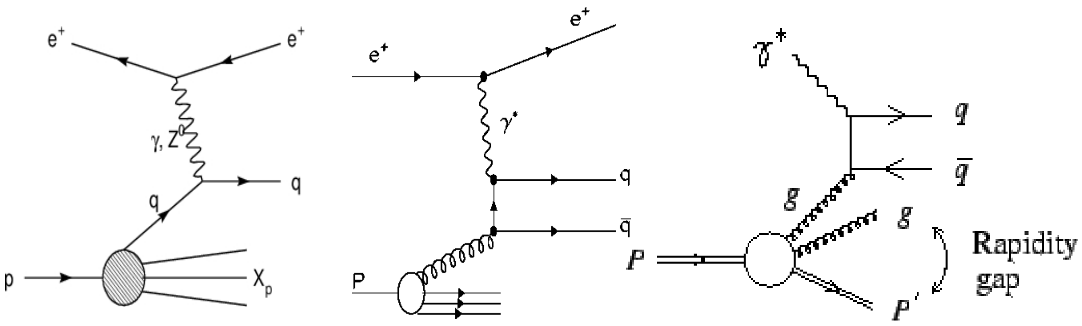
K.Eskola et al. JHEP 0807 (08)102



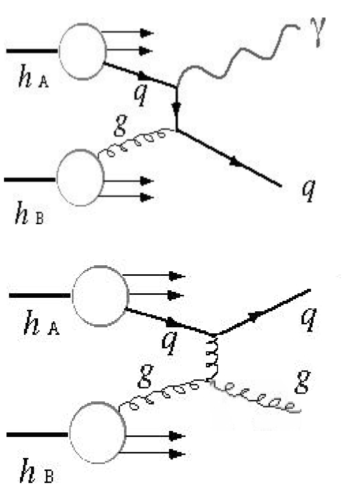
$xG(x,Q^2)$ virtually unknown below x~10^{-2} !

Experimental access to low-x PDFs

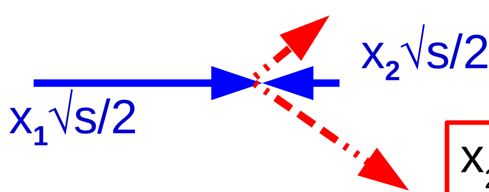
- Perturbative processes:
  - e(γ)-p, e(γ)-A: F_2, F_L, F_2^{charm}, excl. $Q\bar{Q}$, ...



  - p-p, p-A: jets, direct γ, γ* (DY), heavy-Q:



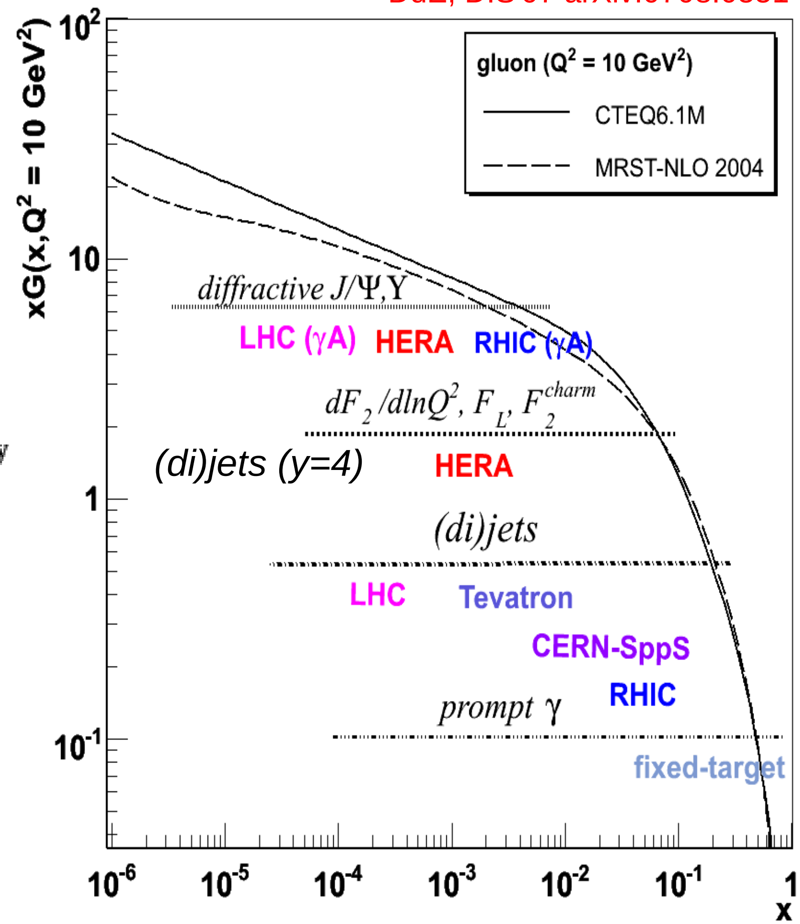
  - Forward production:



$x_2^{min} \sim p_T/\sqrt{s} \cdot e^{-y} = x_T \cdot e^{-y}$

Every 2-units of y, x^{min} decreases by ~10

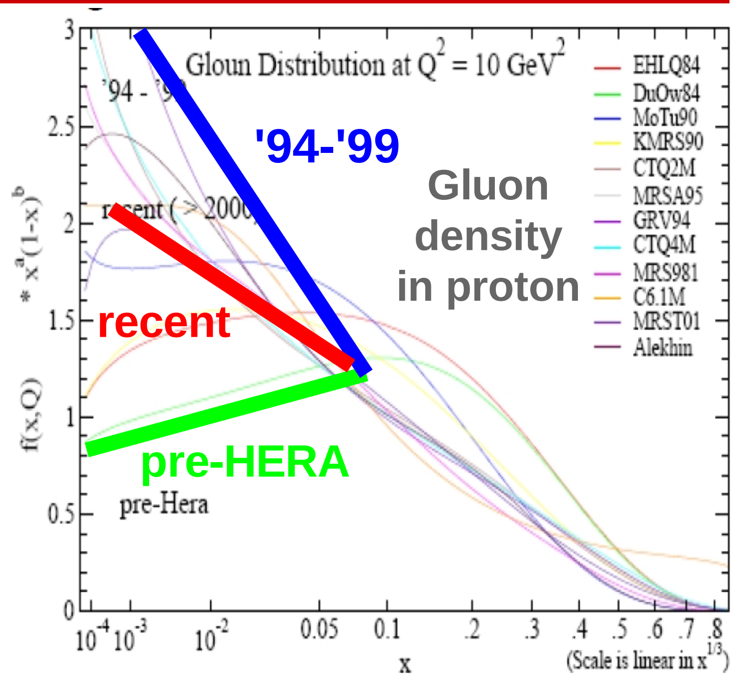
DdE, DIS'07 arXiv:0708.0551



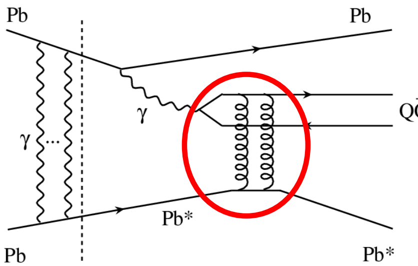
Summary

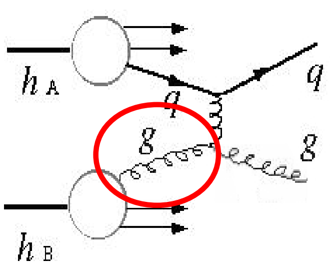
- Current knowledge of low-x nuclear gluon density (& evolution?) is as bad or worst! than for the proton ~15 years ago (pre-HERA).

Large impact on genuine physics (saturation) & on interpretation of QGP data (e.g. J/ψ suppr.).

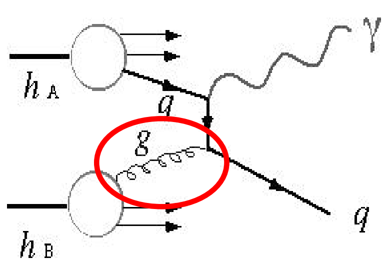


- Likely, in order to reach present-day proton PDF precision we would need a machine like LHeC.





- Hopefully, we can constrain $xG(x,Q^2)$ with coming LHC data:
  - ▷ γ-Pb (Pb-Pb) @ 5.5 TeV
  - ▷ p-Pb @ 8.8 TeV



... in particular thanks to excellent forward detection capabilities