

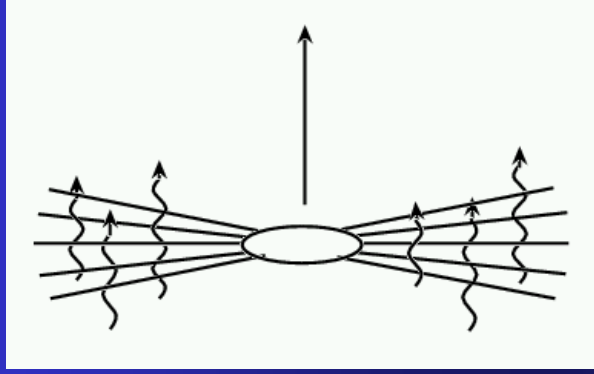
Physics topics in photon-proton and photon-ion interactions at the LHC

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- Photon-nucleon/nucleus interactions will occur at the LHC at energies higher than at any existing accelerator.

- Examples: photoproduction of Vector Mesons, photon+gluon $\rightarrow q\bar{q}$

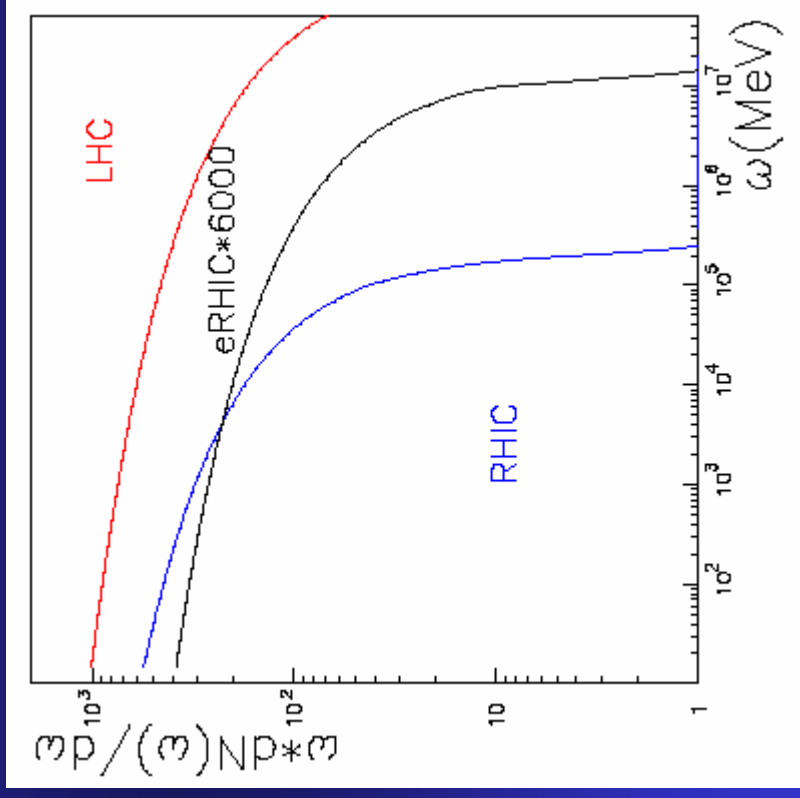
Photon spectrum at Heavy-Ion Colliders



Electromagnetic field \leftrightarrow An equivalent flux of photons.

(Fermi 1924, Weizsäcker-Williams 1935)

Equivalent photon spectrum



The photon spectrum extends to $\sim \gamma/R$
 $\Leftrightarrow W_{\gamma p} \approx 1000$ Gev in Pb+Pb collisions ($Q^2 \approx 0$)

Two examples

”Elastic”

$$\gamma+p \rightarrow V+p$$

or

$$\gamma+A \rightarrow V+A$$

← Studied at RHIC

”Partonic”

$$\gamma+g \rightarrow q+\bar{q}$$

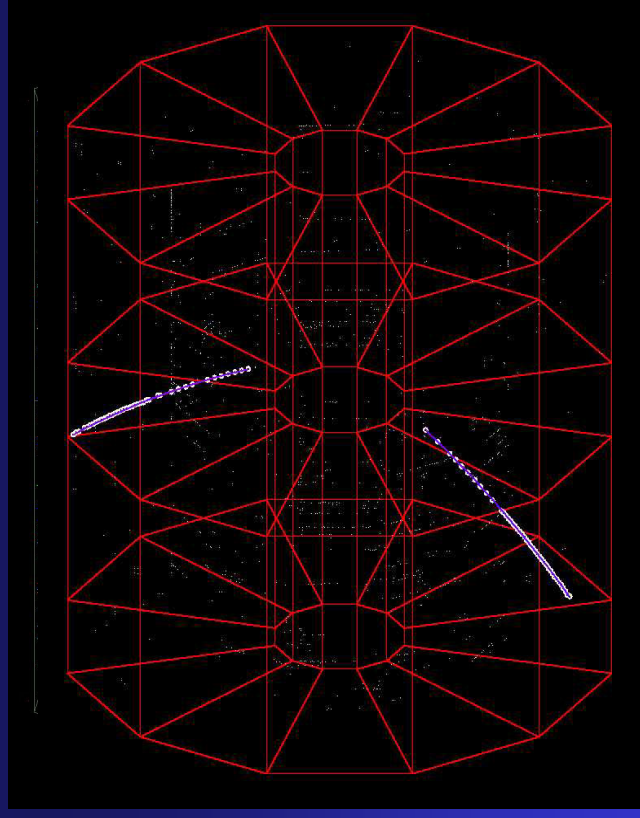
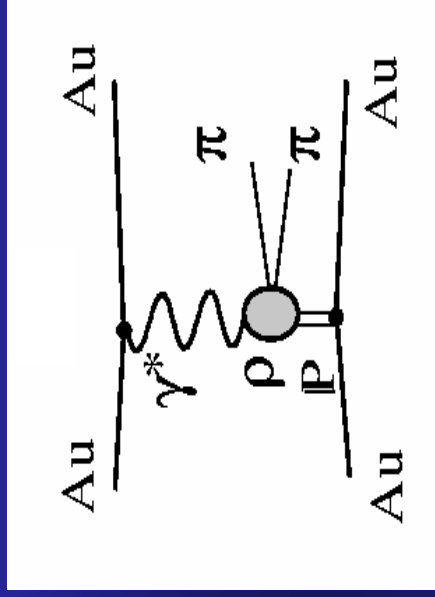
in p+p or A+A

Both processes sensitive to the proton/nucleus gluon density at low x.

Exclusive ρ^0 production - STAR@RHIC

RHIC: Au+Au at $\sqrt{s} = 200$ GeV

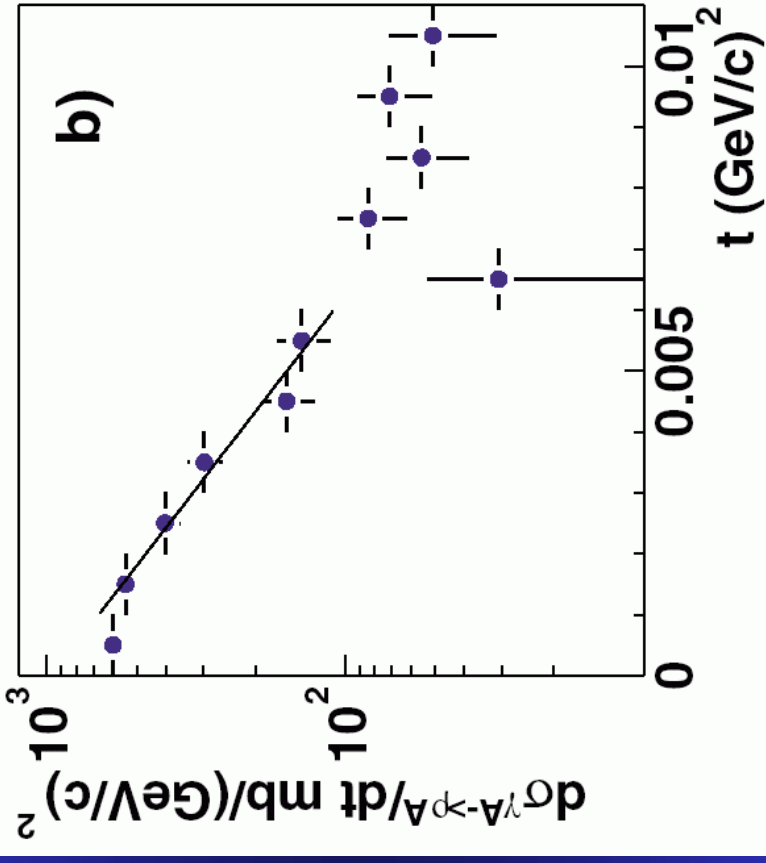
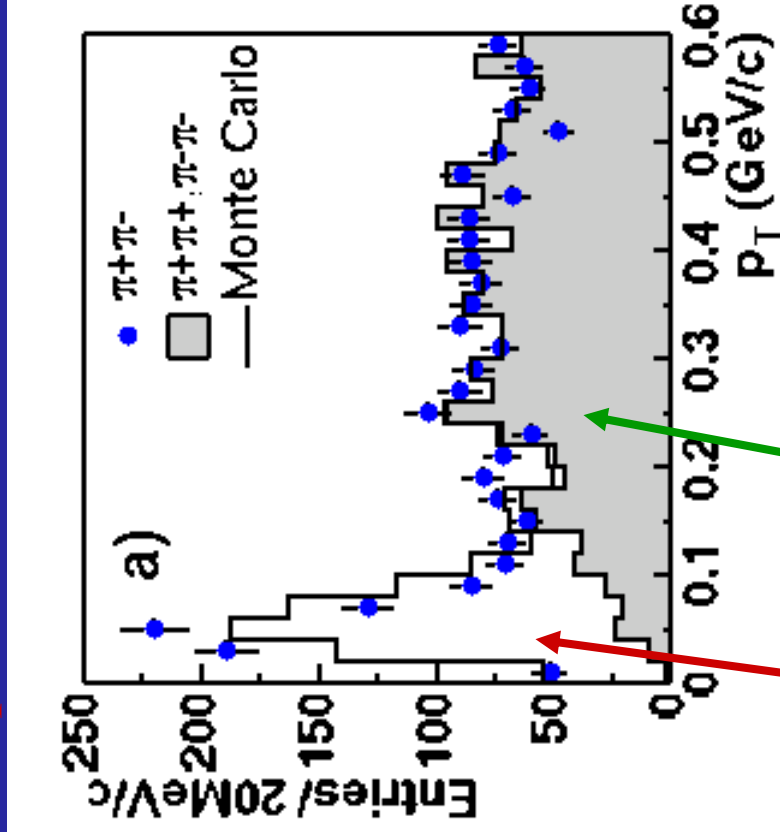
Au+Au \rightarrow Au+Au+ ρ^0



Experimental signature:

Coherent coupling $\Rightarrow p_T \sim \hbar/R$
 \Rightarrow Impossible to tag the outgoing nuclei

p_T spectrum shows clear coherent signal



background, like-sign pairs

Signal+background, unlike-sign pairs

Fit to $\exp(-bt)$:

$b \Leftrightarrow R = 7.5 \pm 2$ fm

First final results from STAR Collaboration at RHIC $\sqrt{s_{\text{m}}} = 130 \text{ GeV}$
(C. Adler et al., Phys. Rev. Lett. 89(2002)272302)

Cross sections in agreement with

Glauber model:

$$\sigma(\text{Au+Au} \rightarrow \text{Au+Au}+\rho^0) \text{ [mb]}$$

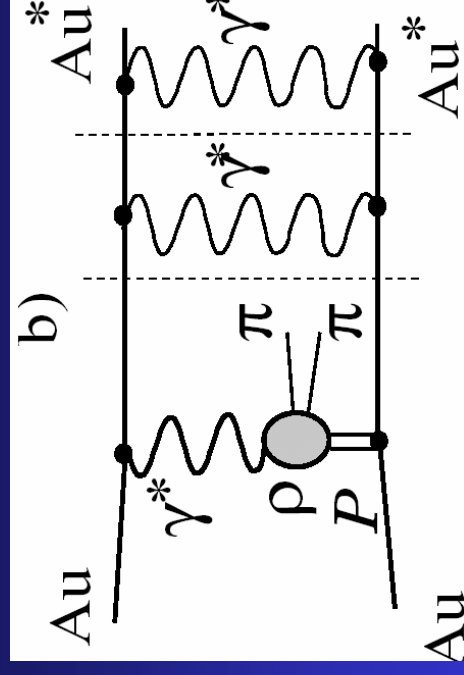
STAR

Theory

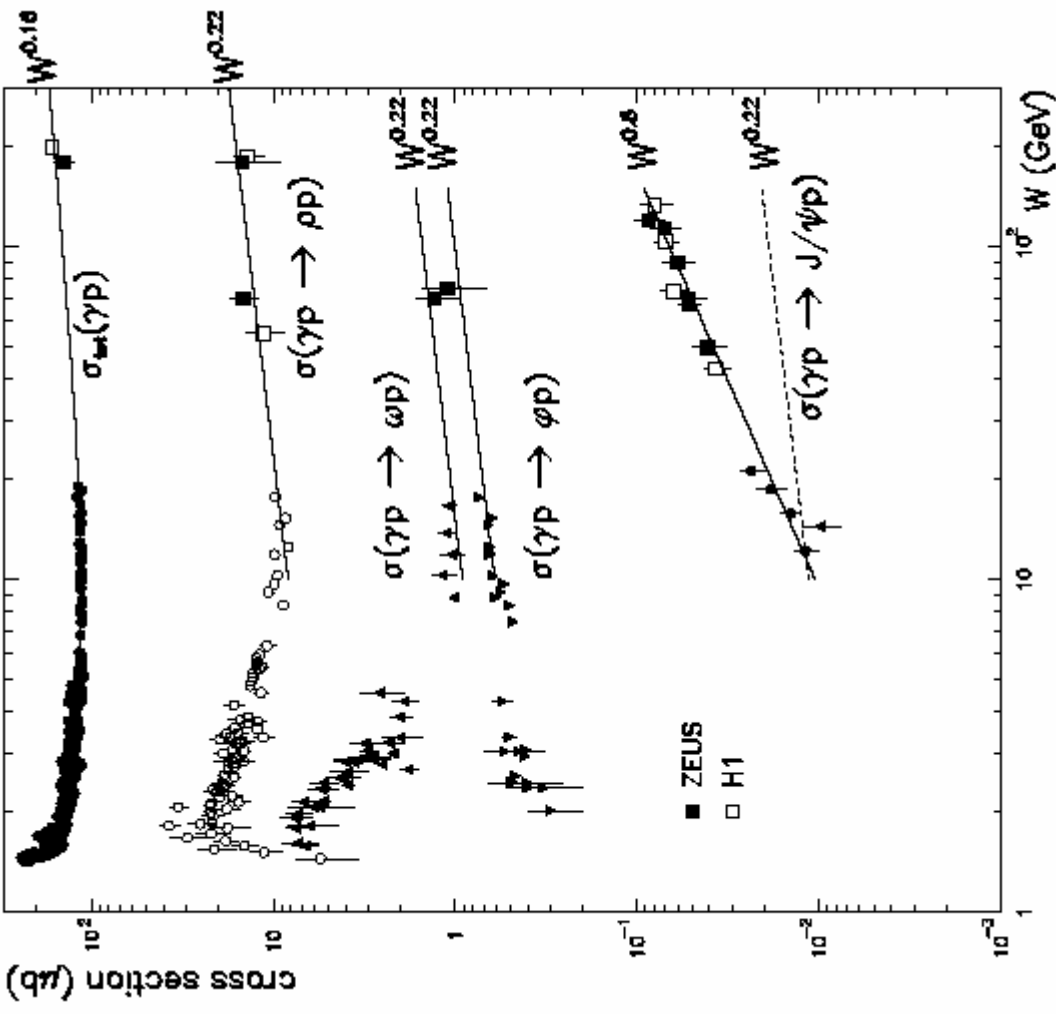
Exclusive: $410 \pm 190 \pm 100$ 350

Possible to have production
in coincidence w/ Coulomb
breakup.

\Rightarrow Easier to trigger on, but
reduces σ by factor 10-100.



Summary of HERA Results



- $W_{\gamma p}$ up to 200 GeV
- Light mesons:
 - $\sigma \propto W_{\gamma p}^{0.22}$
- J/ Ψ :
 - $\sigma \propto W_{\gamma p}^{0.80}$
- a few tens of Υ seen

What can one expect at LHC ?

$$\frac{d\sigma}{dy} = k \frac{dn_\gamma}{dk} \sigma(\gamma p \rightarrow Vp)$$

$y=0$

J/ψ

Υ

LHC PbPb

$$W_{\gamma p} = 130 \text{ GeV} \quad x \approx 5 \cdot 10^{-4}$$

$$W_{\gamma p} = 220 \text{ GeV} \quad x \approx 1 \cdot 10^{-3}$$

LHC pp

$$W_{\gamma p} = 210 \text{ GeV} \quad x \approx 2 \cdot 10^{-4}$$

$$W_{\gamma p} = 350 \text{ GeV} \quad x \approx 6 \cdot 10^{-4}$$

Tevatron

$$W_{\gamma p} = 80 \text{ GeV} \quad x \approx 1 \cdot 10^{-3}$$

$$W_{\gamma p} = 130 \text{ GeV} \quad x \approx 5 \cdot 10^{-3}$$

γp data from HERA

$$J/\Psi: \sigma = 1.5 W_{\gamma p}^{0.80} \quad [\text{nb}, W \text{ in GeV}]$$

\Rightarrow Extrapolate this to LHC energies

Too little data on Υ , QCD predicts (2 gluon exchange)

$$\left. \frac{d\sigma}{dt} \right|_{t=0} = \frac{\alpha_s^2 \Gamma_{ee}}{3\alpha M_V^5} 16\pi^3 \left[xg\left(x, \frac{M_V^2}{4}\right) \right]^2$$

Ryskin 1993

Can be parameterized as

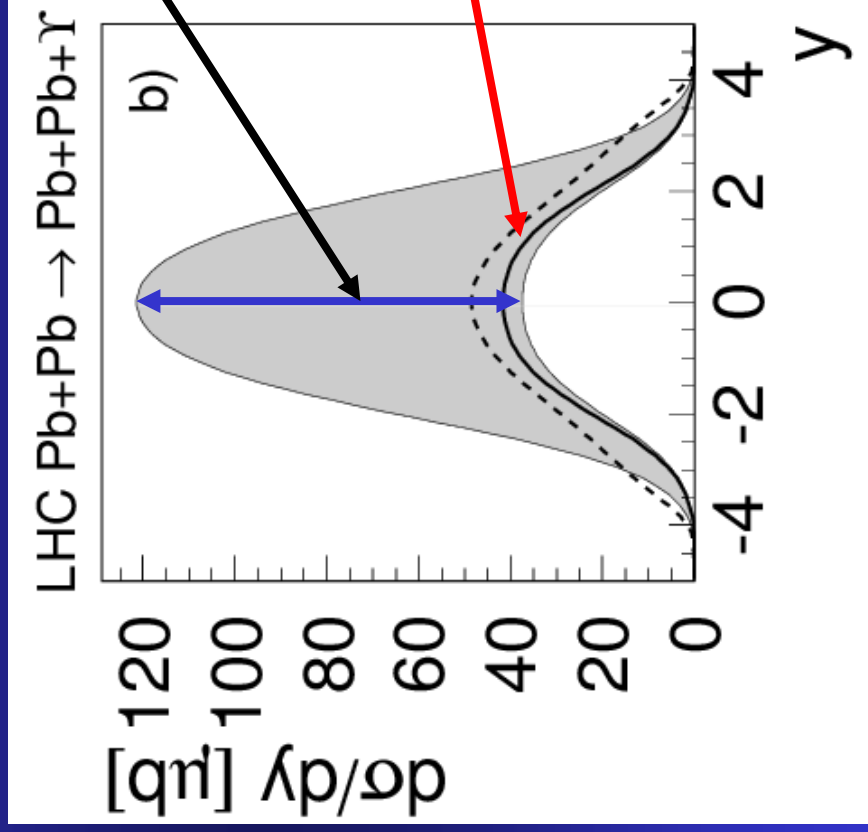
(Martin et al. PLB 454 (1999)339, Frankfurt et al. JHEP 02(1999)002)

$$\Upsilon: \sigma = 0.06 W_{\gamma p}^{1.7} \quad [\text{pb}, W \text{ in GeV}]$$

$$\frac{d\sigma}{dy} = k \frac{dn_\gamma}{dk} \sigma(\gamma p \rightarrow V p)$$

S.R.Klein, J. Nystrand
 hep-ph/0311164, PRL
 in press.

Υ in ultra-peripheral Pb+Pb collisions at the LHC



Uncertainty in measured
 Υ cross section (mainly
 statistics).

A^2 scaling of QCD
 prediction

See also Frankfurt, Guzey,
 Strikman, Zhalog hep-ph/0304218

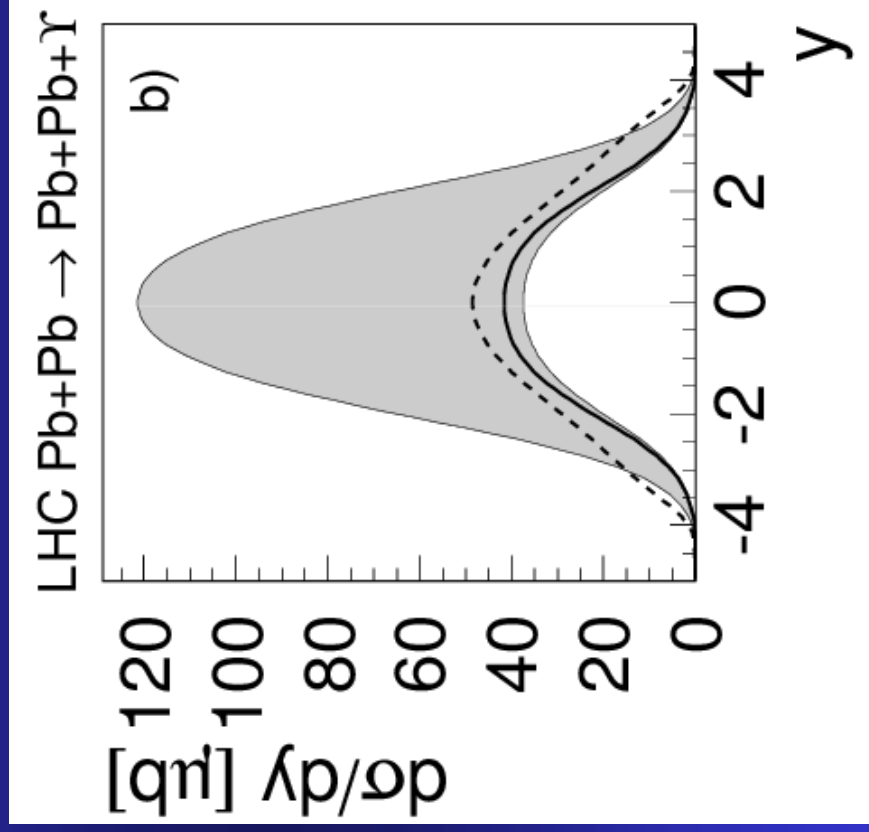
Can we see these events at LHC?

Rates at design Luminosity:

$$J/\psi \rightarrow \mu^+\mu^-, e^+e^- : 0.8 \text{ Hz}$$

$$\Upsilon \rightarrow \mu^+\mu^-, e^+e^- : 8 \text{ events/hour}$$

$$\text{Br.}(J/\psi \rightarrow \mu^+\mu^-, e^+e^-) \approx 5.9\%, \text{ Br.}(\Upsilon \rightarrow \mu^+\mu^-, e^+e^-) \approx 2.4\%$$



- The rates should be sufficient.
- The production is centered around mid-rapidity.
- No other particles in the event.
- The coherence gives a clear experimental signal through reconstruction of the total transverse momentum.

$$\sigma(pp \rightarrow pp+V)$$

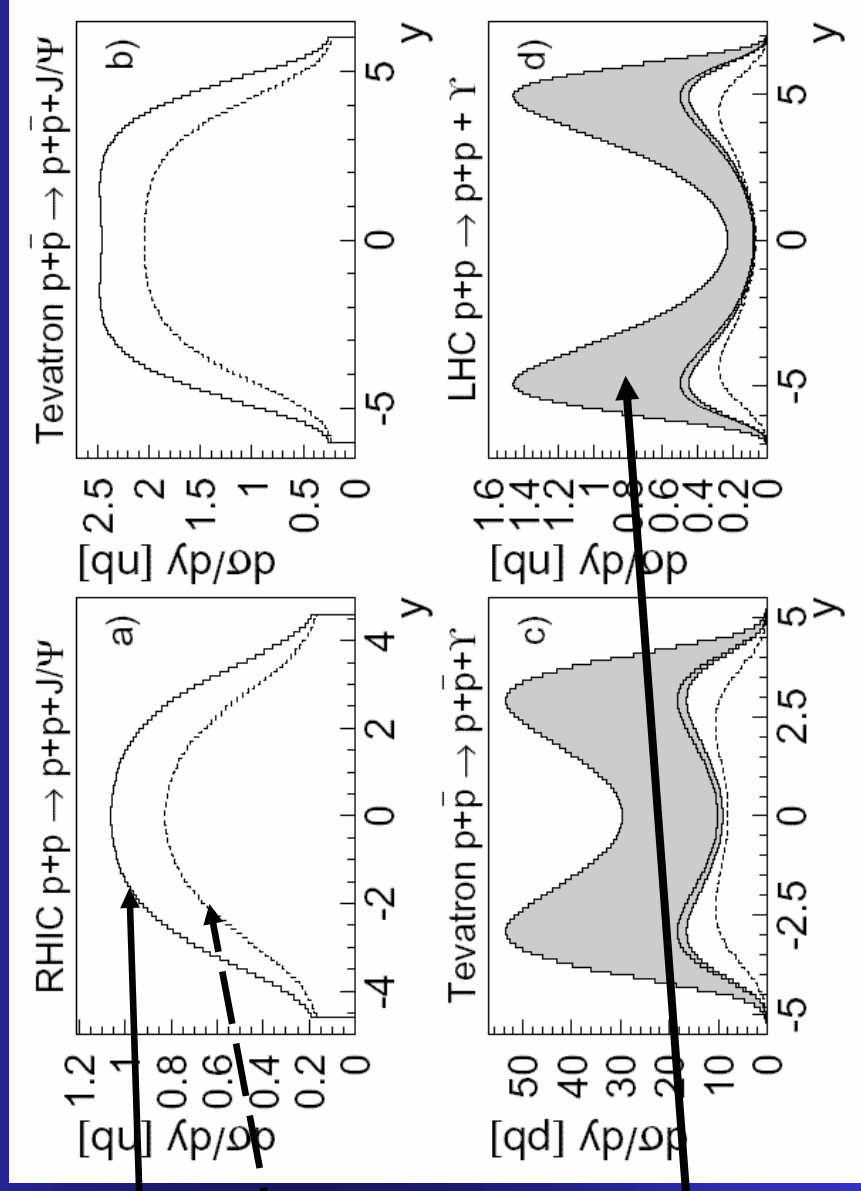
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$$\frac{d\sigma}{dy} = k \frac{dn_\gamma}{dk} \sigma(\mathcal{N} \rightarrow Vp)$$

Drees&Zeppenfeld
 photon spectrum

point charge, $b > 1 \text{ fm}$

Unlike Pb+Pb, production
 not centered at mid-rapidity.



J/Ψ at RHIC, Υ at Tevatron: $\sigma(\text{"photon"}) \approx 10^{-3} \sigma(\text{"hadron"})$
 \Rightarrow Have to reject hadronic background by a factor 10^3

Rapidity gaps:

$\langle dn_{ch}/dy \rangle \approx 4 - 6$ in pp at Tevatron/LHC

Probability of having a gap of width Δy :

$$\approx \exp(- \langle dn_{ch}/dy \rangle \cdot \Delta y)$$

$\Rightarrow \Delta y \approx 2$ will be sufficient

Further rejection from p_T distribution, $p_T < 1 \text{ GeV}/c$

Example 2: γ +gluon $\rightarrow c\bar{c}, b\bar{b}$

S.R.Klein, J.Nystrand,
R.Vogt PRC 66 (2002)
044906.

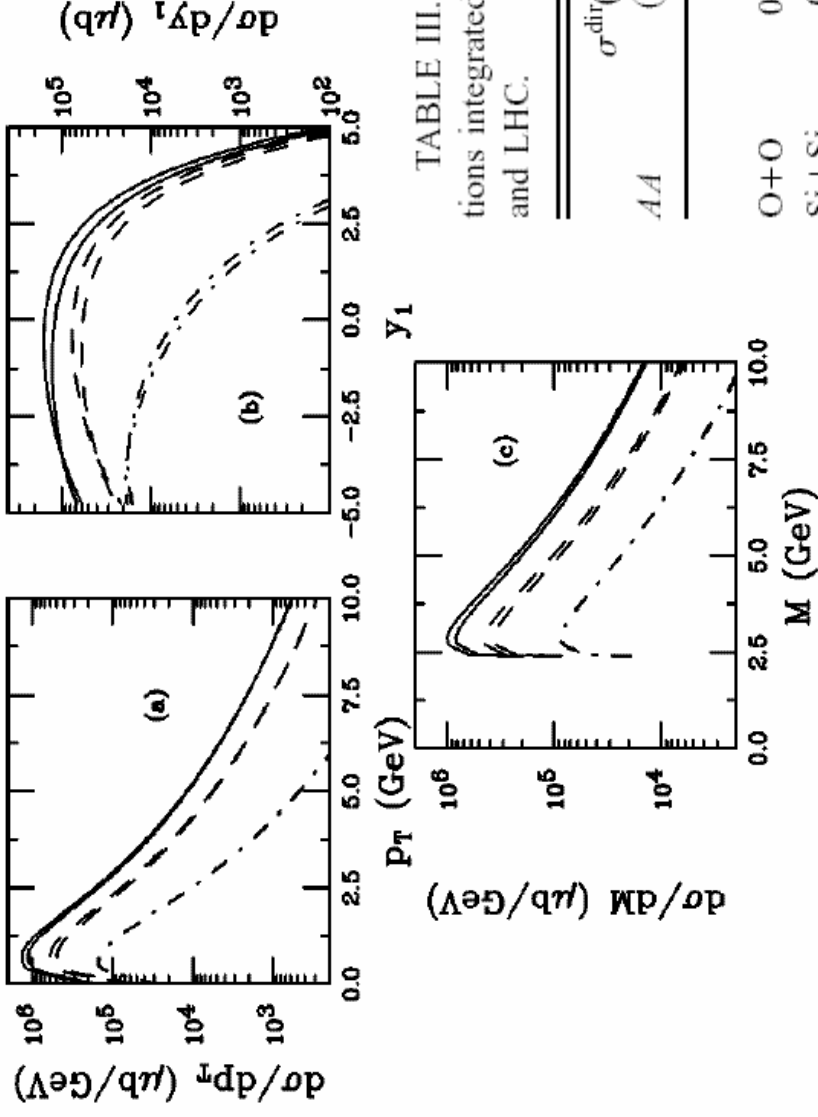


TABLE III. Direct and resolved $c\bar{c}$ photoproduction cross sections integrated over $b > 2R_A$ in peripheral AA collisions at RHIC and LHC.

AA	$\sigma^{\text{dir}}(S^i=1)$ (mb)	$\sigma^{\text{dir}}(\text{EKS98})$ (mb)	$\sigma^{\text{res}}(S^i=1)$ (mb)	$\sigma^{\text{res}}(\text{EKS98})$ (mb)
O+O	0.067	0.068	0.0019	0.0019
Si+Si	0.30	0.31	0.0080	0.0083
I+I	8.96	9.74	0.199	0.206
Au+Au	24.8	27.4	0.530	0.550
			LHC	
O+O	2.35	2.13	0.351	0.346
Ar+Ar	23.3	20.4	3.00	2.93
Pb+Pb	1790	1500	190.0	186.7

Summary

- Photon-proton and photonuclear interactions will occur at the LHC.
- Extends the energy range studied at HERA.
- Large cross section for exclusive production of vector mesons in p+p and Ultra-peripheral Pb+Pb collisions.