Two-photon and photon-hadron interactions at the LHC

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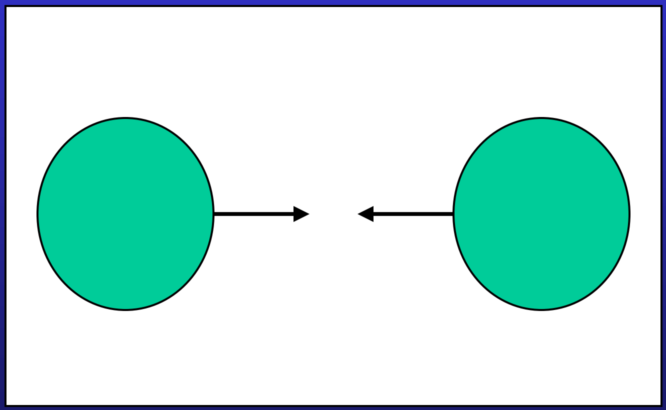
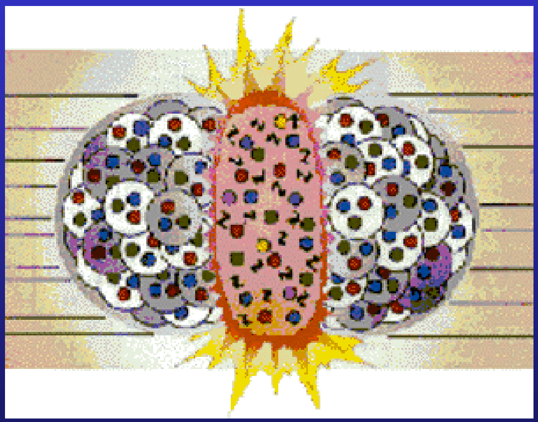
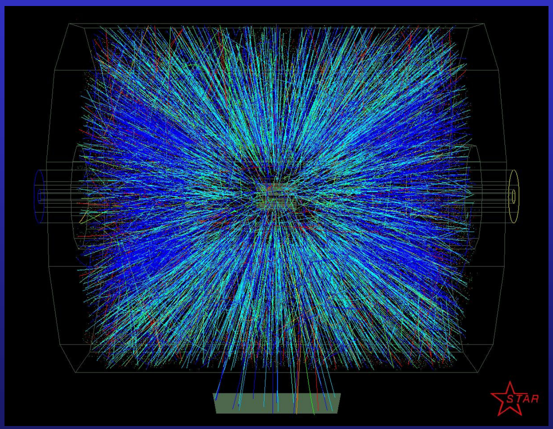
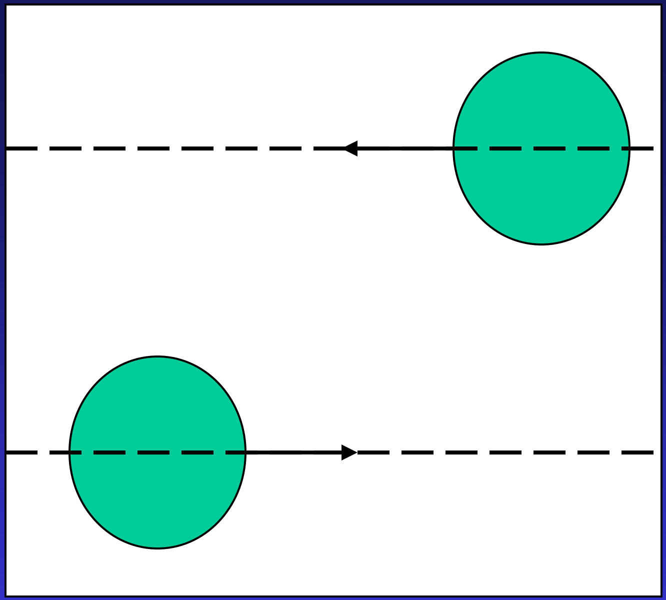
Central vs. Ultra-peripheral Collisions









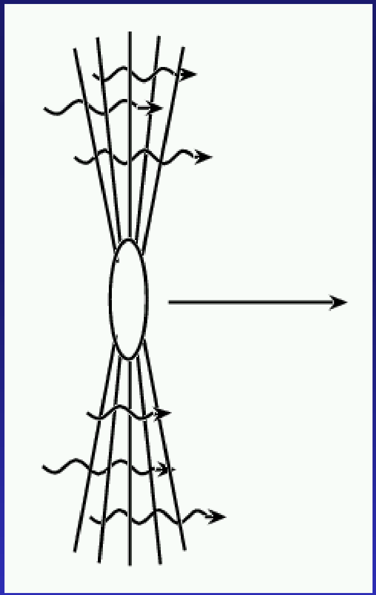
This talk:

b > or >> 2R $\Rightarrow$

Electromagnetic interactions

Electromagnetic Field of a Relativistic Charged Particle

Fermi 1924: *The effect of the electromagnetig field of a relativistic particle is equivalent to a flux of photons with a continous energy spectrum.* (hep-th/0205086)

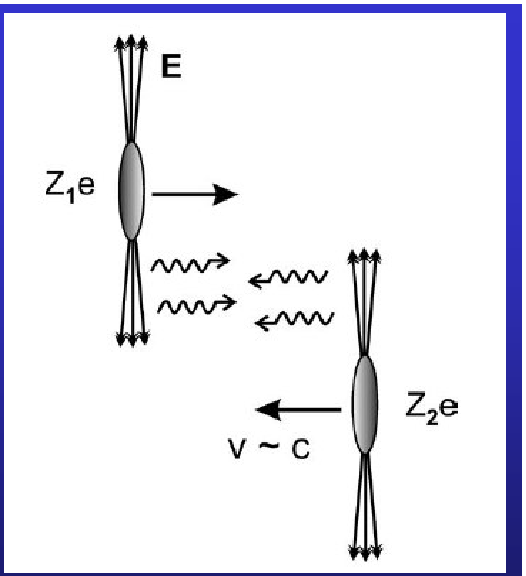


Pulse width b/γc $\leftrightarrow$ the spectrum contains photons w/ $\hbar\omega < \gamma\hbar c/b$

Quantum Mechanical derivation 1935 by Weizsäcker,Williams. $\Rightarrow$ *Weizsäcker-Williams method*

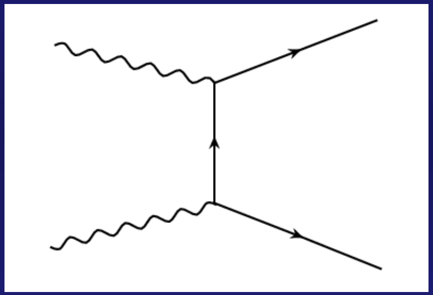
We can calculate n(ω) through a Fourier transform.

Ultra-peripheral collisions

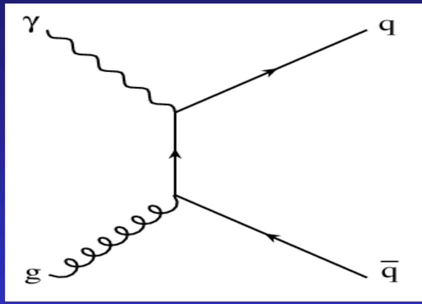


The photons and nuclei can interact in several ways

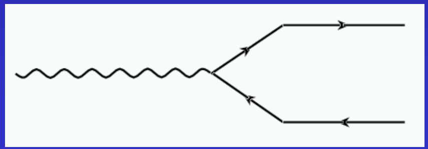
1. Electromagnetic interaction, two-photon



2. Direct photonuclear interaction, gamma+parton (γ+g→qq, γ+q→jet+jet)



3. Resolved photonuclear interaction (VMD), elastic or inelastic



Electromagnetic Interactions in p+p and A+A vs. in e+p(A) and e+e Collisions

Traditionally, photon-induced interactions have been studied with electron beams:

Two-photon interactions at PEP, Petra, LEP.

Photon-proton interactions at HERA and in fixed target expts w/ electron beams.

Why study them at hadron colliders?

- Higher photon energies than at any existing accelerator (LHC).
- An opportunity to study strong electromagnetic fields (coupling $Z\sqrt{\alpha}$ rather than $\sqrt{\alpha}$ in heavy-ion collisions).
- Interference between the photon-emitter and target.
- An opportunity to search for the Odderon.

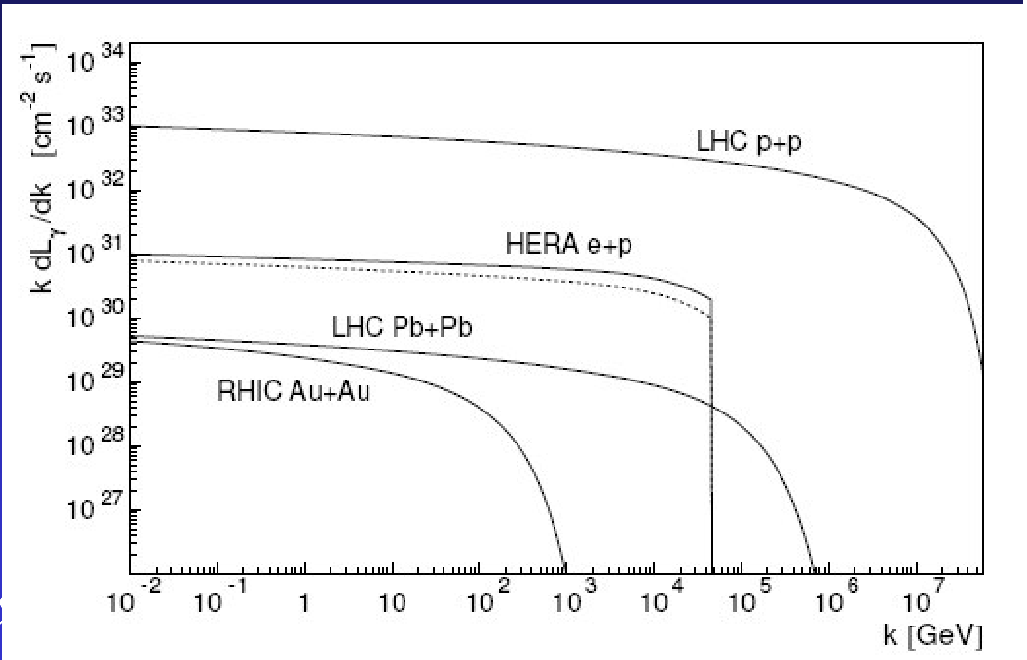
The Equivalent Photon Luminosity

The spectrum of photons with energy $E_\gamma = x \cdot E_{beam}$ and virtuality Q^2 is given by

$$x\frac{dn_\gamma}{dx dQ^2} = \frac{\alpha Z^2}{\pi}\left(1 - x + 1/2x^2\right)\frac{Q^2 - Q^2_{min}}{Q^4}$$

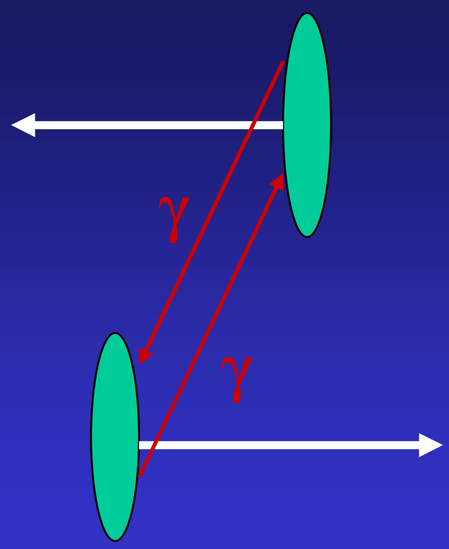
Q^2_{min} is constrained by x and the mass of the projectile. For hadron beams, the maximum of Q^2 is given by a form factor. In configuration space, this corresponds to $Q^2_{max} = (1/R)^2$.

Integrating over all virtualities gives the following equivalent photon spectrum (energy in the rest frame of the target).

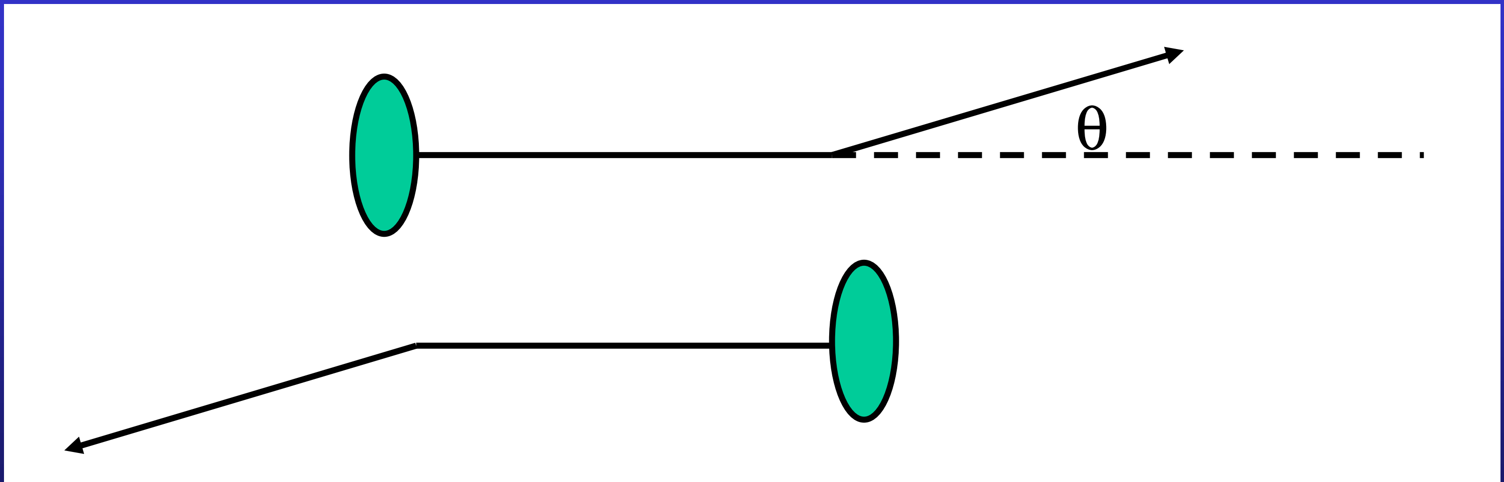


Electromagnetic interactions in heavy-ion interactions vs. in e^+e^- and ep (eA)

- Directional symmetry. Both beams (nuclei) and can act as photon emitter or target.
- Away from y=0, the different photon emitter/target combinations give different contributions.
- Strong fields lead to high probability for emission of multiple photons.



No tagging of the nuclei



The coherence requirement limits the angular deflection to

$$\theta \sim 0.175 / (\gamma \cdot A^{4/3})$$

At RHIC

Au	A=197	$\theta \sim 1$ μrad
Si	A=28	$\theta \sim 17$ μrad

At LHC

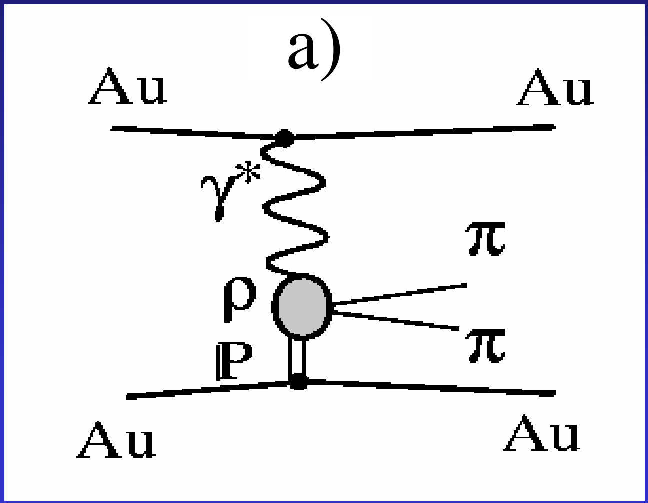
Pb	A=208	$\theta \sim 0.05$ μrad
Ar	A=40	$\theta \sim 0.3$ μrad

$\Rightarrow$Not possible to tag the outgoing nuclei. Might be possible with protons.

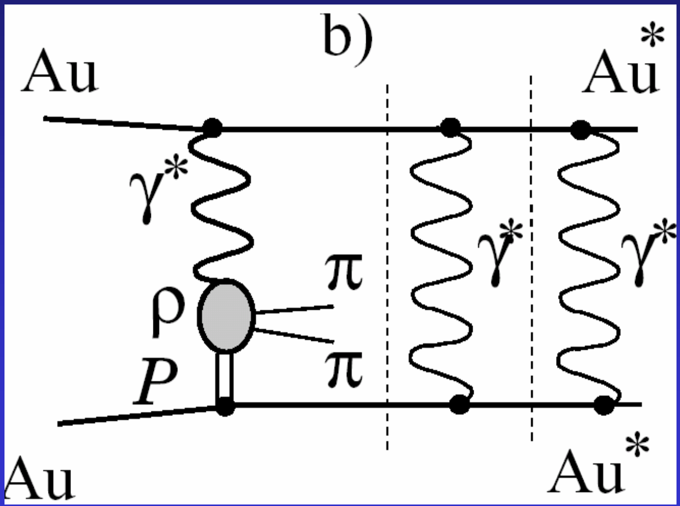
Experimental method: Rapidity gaps, reconstruct the entire event, signal of coherence from low p_T.

Particle production with Coulomb break-up

- Very high probability for emitting one soft photon, which can excite the target to a Giant Dipole Resonance.
- P ≈ 35-50 % in grazing Au+Au/Pb+Pb collisions at RHIC-LHC.
- ≈10 – 50% of exclusive events are accompanied by break-up of one or both nuclei.
- Excitation to GDR leads to emission of neutrons which can be detected in ZDC calorimeters. ⇒ Useful as trigger



vs.



Example I: Production of Heavy Quarks

Consider the production of heavy quarks in a high-energy nucleus-nucleus collision. 3 production modes can be identified:

1. Hadronic production, dominated by $gg \to Q\overline{Q}$.
2. Photonuclear production, dominated by $\gamma g \to Q\overline{Q}$.
3. Electromagnetic production, $\gamma\gamma \to Q\overline{Q}$.

Estimated cross sections for these processes in Pb+Pb interactions at the LHC:

	hadroproduction	photoproduction	two-photon production
	$\sigma(Pb + Pb \to QQ + X)$	$\sigma(Pb + Pb \to Pb + QQ + X)$	$\sigma(Pb + Pb \to Pb + Pb + QQ)$
cc	252 b*	1.2 b	1.1 mb
bb	8.1 b*	4.9 mb	0.9 μb
	1	$\sim 10^{-3}$	$\sim 10^{-6}$

Hadroproduction dominates, but the cross sections for photoproduction and two-photon production are not small in absolute terms.

* Scaled pp cross sections from R.Vogt, Int. J. Mod. Phys. E 12 (2003) 211.
$> \sigma_{tot}$ because of production of multiple pairs in a single event.

Example II: Exclusive Production of di-lepton pairs

$A+A \rightarrow A+A + e^+e^- / \mu^+\mu^-$ or
$p+p \rightarrow p+p + e^+e^- / \mu^+\mu^-$ (the nuclei/protons remain intact).

A strong contribution from exclusively produced vector mesons (γ+Pomeron), followed by $V \rightarrow e^+e^- / \mu^+\mu^-$.

Reaction		Colliding system
$\gamma+\gamma$	$\rightarrow e^+e^- / \mu^+\mu^-$	ee, ep, pp/AA
γ+Pomeron	$\rightarrow V \rightarrow e^+e^- / \mu^+\mu^-$	ep, pp/AA
Odderon+Pomeron	$\rightarrow V \rightarrow e^+e^- / \mu^+\mu^-$	pp/AA

$\Rightarrow$ If the $\gamma+\gamma$ and γ+Pomeron contributions are well understood, pp (and AA) interactions can be used to search for the Odderon.
[A. Schäfer, L. Mankiewicz, O. Nachtmann, Phys. Lett. B 272 (1991) 419 and A. Bzdak, L. Motyka, L. Szymanowski, J.-R. Cudell hep-ph/0702134]

Trigger and Analysis Techniques

Special techniques are required to separate the signal from background.

- Low multiplicity.

- Rapidity gap between photon-emitting nucleus and the produced particles, suppression for a gap Δy: $\exp(-\langle dn/dy\rangle \cdot \Delta y)$
With $\langle dn/dy\rangle \approx 2.5\text{-}3.5$ in pp at the LHC and $\Delta y=2 \Rightarrow \sim 10^{-2}$–$10^{-3}$ reduction.

- Coherence requirement for exclusive production in nucleus-nucleus collisions. If all produced particles are reconstructed, the total (summed) p_T is determined by the nuclear form factor, $p_T < \approx 50$ MeV/c, much smaller than the typical p_T for hadronic events, ≈ 350 MeV/c.

Background sources: Cosmic rays (triggering), beam-gas, low-multiplicity hadronic events.

Exclusive Vector Meson Production

$$A + A \rightarrow A + A + V \quad \text{or} \quad p + p \rightarrow p + p + V$$

- No accompanying hadronic interactions.

- Cross section factor ≈100 larger than for two-photon production of mesons with similar mass.

- Electromagnetic excitation through exchange of additional photons, e.g. to a Giant Dipole Resonance, possible (in heavy-ion collisions).

The Vector Mesons are produced in a γ+Pomeron interaction. For the heavy states (J/Ψ, Ψ', ϒ), the cross section, $\sigma(\gamma A \rightarrow VA)$ can be calculated from QCD (2-gluon exchange):

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

For V → e+e-, there is a background from $\gamma\gamma \rightarrow$e+e-.

The cross section is thus a probe of the nucleon and nuclear gluon distribution function. High sensitivity because of $g^2(x,Q^2)$.

$$\frac{\frac{d\sigma(\gamma A \rightarrow VA)}{dt}\big|_{t=0}}{\frac{d\sigma(\gamma N \rightarrow VN)}{dt}\big|_{t=0}} = \left[\frac{G_A(x, M_V^2/4)}{G_N(x, M_V^2/4)}\right]^2$$

The A+A or p+p cross section is calculated from a convolution of the photonuclear/photon-proton cross section with the photon spectrum.

$$\sigma(A + A \rightarrow A + A + V) = 2\int n(\omega)\sigma_{\gamma p \rightarrow Vp}(\omega)d\omega$$

An early calculation (S.R.Klein, J.Nystrand, Phys. Rev. C 60(1999) 014903) found high cross sections for A+A.

- Weizsäcker-Williams photon spectrum.
- Scaling of $\sigma(\gamma p \rightarrow Vp)$ to $\sigma(\gamma A \rightarrow VA)$ using a Glauber-like model.

Meson	**Au+Au, RHIC σ [mb]**	**Pb+Pb, LHC σ [mb]**
ρ^0	590	5200
ω	59	490
φ	39	460
J/Ψ	0.29	32

More calculations have followed, using slightly different approaches, including gluon shadowing, a full Glauber model for the absorption, the color dipole model etc.

[KN] S. Klein and J. Nystrand, Phys. Rev. C 60 (1999) 014903.
[GM] V. P. Goncalves and M. V. T. Machado, J. Phys. G 32 (2006) 295.
[IKS] Yu. P. Ivanov, B. Z. Kopeliovich and I. Schmidt, arXiv:0706.1532 [hep-ph].
[FSZ] M. Strikman, M. Tverskoy and M. Zhalov, Phys. Lett. B 626 (2005) 72;
L. Frankfurt, M. Strikman, and M. Zhalov, Phys. Lett. B 540 (2002) 220; Phys. Lett. B 537 (2002) 51.

Pb+Pb $\rightarrow$ Pb+Pb+V at the LHC

Model	ρ^0 [b]	J/Ψ [mb]
KN	5.2	32
GM	10.1	41.5
IKS	4.0, 4.4	26.7, 26.3
FSZ	9.5	14, 85

Calculations have also been done for p+p $\rightarrow$ p+p+V and p+$\bar{p}$ $\rightarrow$ p+$\bar{p}$+V (S.R.Klein, J.Nystrand PRL 92(2004)142003).

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

Energy ($\sqrt{s}$)	J/Ψ [nb]	Ψ' [nb]	Υ(1S) [nb]
1.96 TeV	19.6	3.2	0.12
14 TeV	76	12	3.5

See also V.Khoze, A.D.Martin, M.G.Ryskin, EPJ 24(2002)459.

The VM rapidity distribution is given by

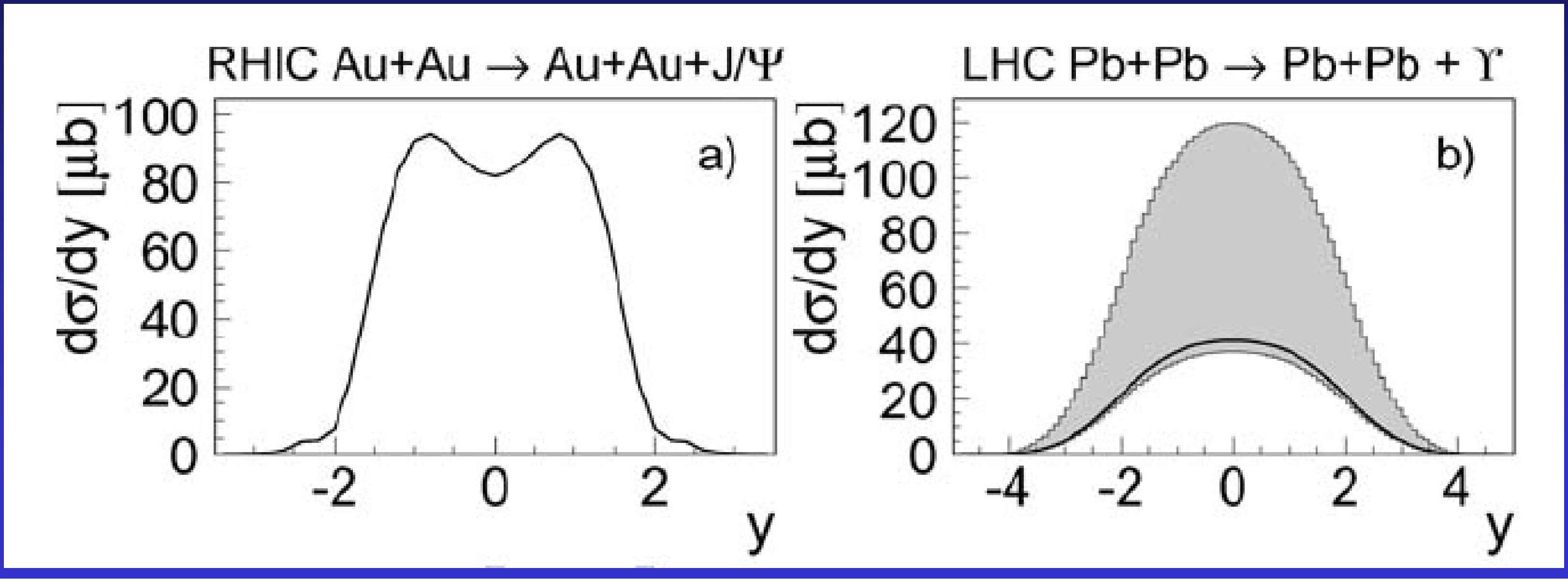
$$\frac{d\sigma}{dy} = k_1 \frac{dn_\gamma}{dk_1} \sigma_{\gamma p \to Vp}(k_1) + k_2 \frac{dn_\gamma}{dk_2} \sigma_{\gamma p \to Vp}(k_2)$$

where

$$k_{1,2} = \frac{1}{2} M_V e^{\pm y}$$

Away from y=0, there is a two-fold ambiguity in the photon energy (k) and consequently in x.

Production is centered around mid-rapidity



Probing the nuclear structure functions

For a final state with invariant mass m_{inv} , the equivalent photon-proton center-of-mass energy is

$$W_{\gamma p}^{2} = 2 \cdot m_{inv} \cdot E_p$$

and the corresponding Bjorken x is

$$x = m_{inv}^{2} / W_{\gamma p}^{2}$$

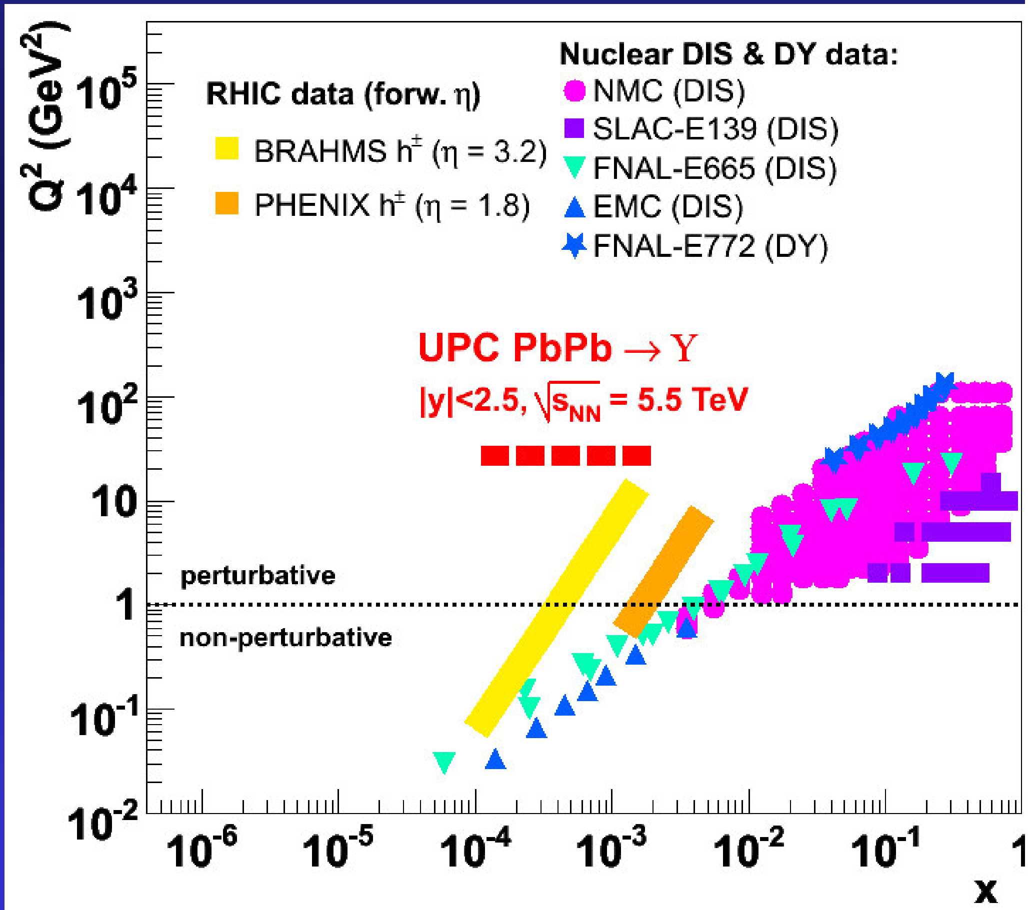
From D. d'Enterria, J. Phys. G 30 (2004)S767.

Examples of x–ranges probed at mid-rapidity at the LHC (exclusive vector meson production):

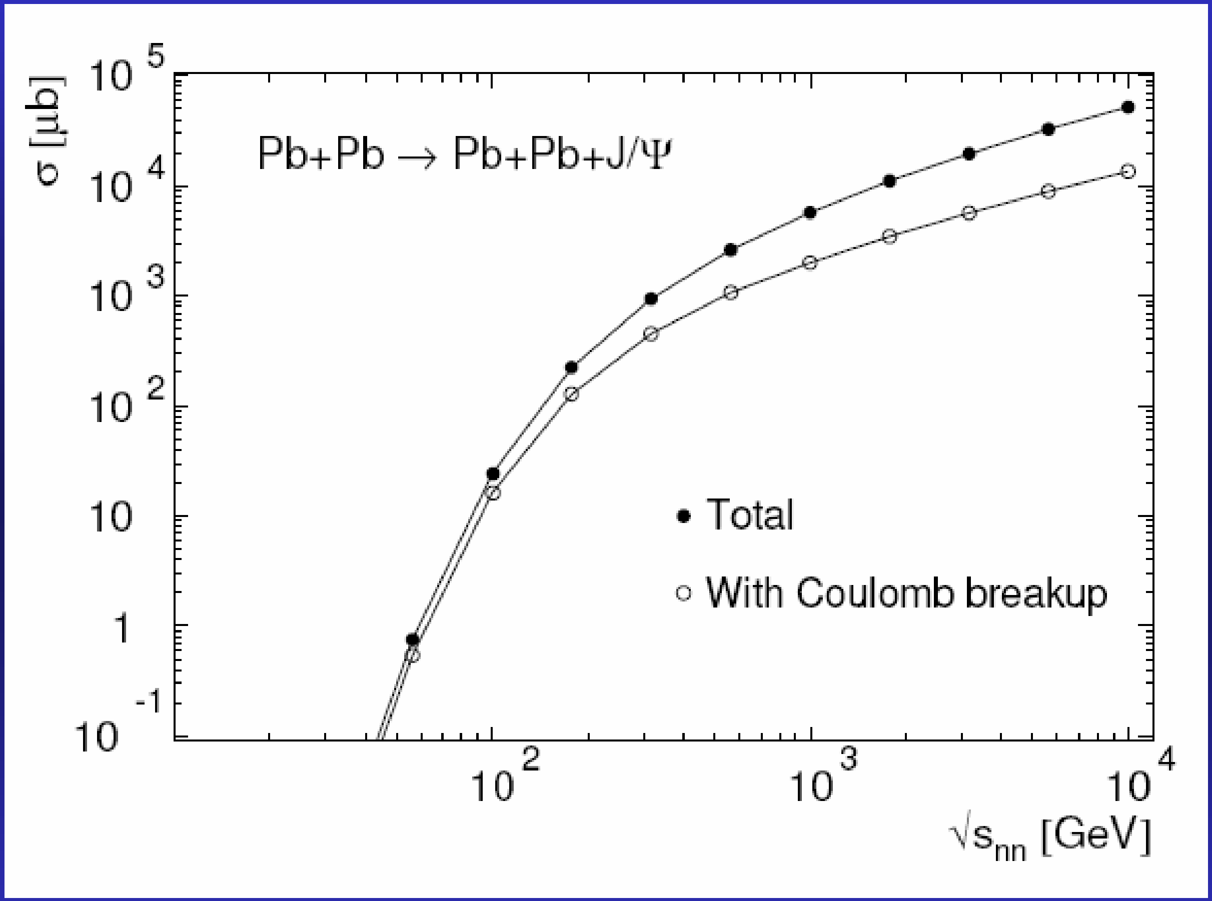
	J/ψ
LHC pp	$x \approx 2 \cdot 10^{-4}$
LHC PbPb	$x \approx 6 \cdot 10^{-4}$

	Υ
LHC pp	$x \approx 6 \cdot 10^{-4}$
LHC PbPb	$x \approx 2 \cdot 10^{-3}$

For $y \neq 0$, $x = (m_{inv}^{2}/W_{\gamma p}^{2})\exp(\pm y)$



Energy dependence of J/Ψ production
Pb+Pb→Pb+Pb+J/Ψ



J/ψ RHIC 0.3 mb → LHC 32mb factor 100

Experimental Results on Ultra-Peripheral Collisions
The Hadron Colliders RHIC, Tevatron and LHC

RHIC (1st collisions 2000):

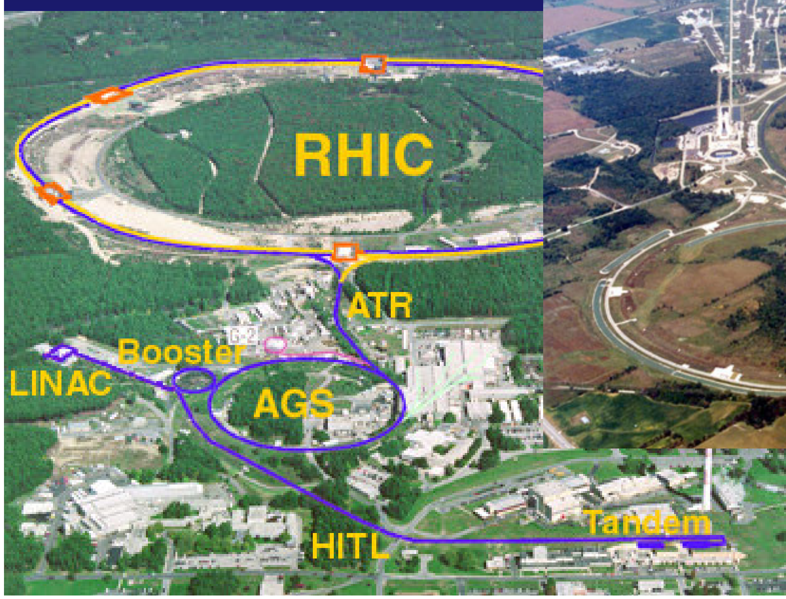
Au+Au at $\sqrt{s_{nn}}$ = 200 GeV; p+p at $\sqrt{s}$ = 200 and 500 GeV.

Tevatron (1st collisions 1987):

p+p at $\sqrt{s}$ = 1.8 and 1.96 TeV

LHC (1st collisions expected in 2008):

Pb+Pb at $\sqrt{s_{nn}}$ = 5.5 TeV; p+p at $\sqrt{s}$ = 14 TeV.



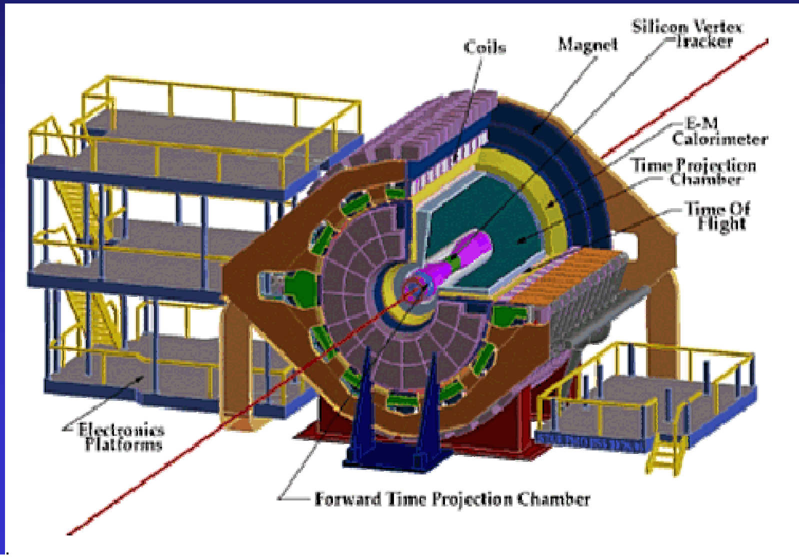
Ultra-Peripheral Collisions at RHIC

Experimental UPC results from RHIC so far:

1) ρ^0-production, Au+Au$\rightarrow$Au+Au+ρ^0 STAR Collaboration (C. Adler et al. PRL 89(2002)272302; B.I. Abelev et al. arXiv:0712.3320).

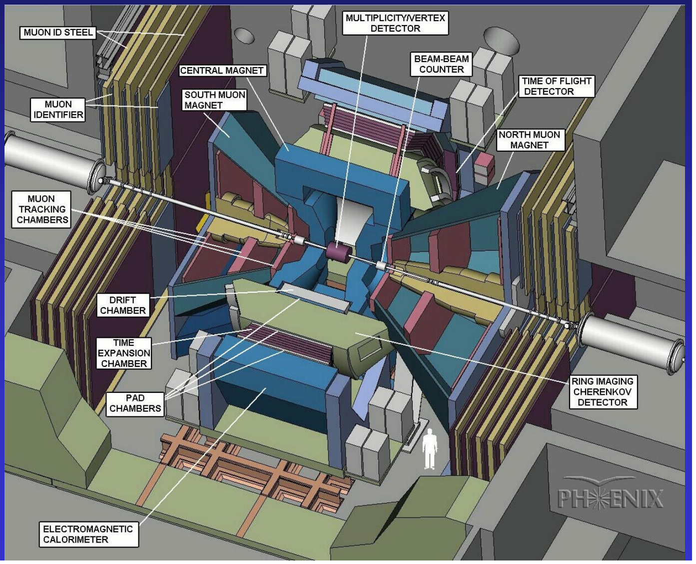
2) e^+e^--pair production, STAR Collaboration, (J.Adams et al., Phys.Rev. C70(2004)031902).

3) J/Ψ and high-mass e^+e^--pair production (D. d'Enterria et al. nucl-ex/0601001).



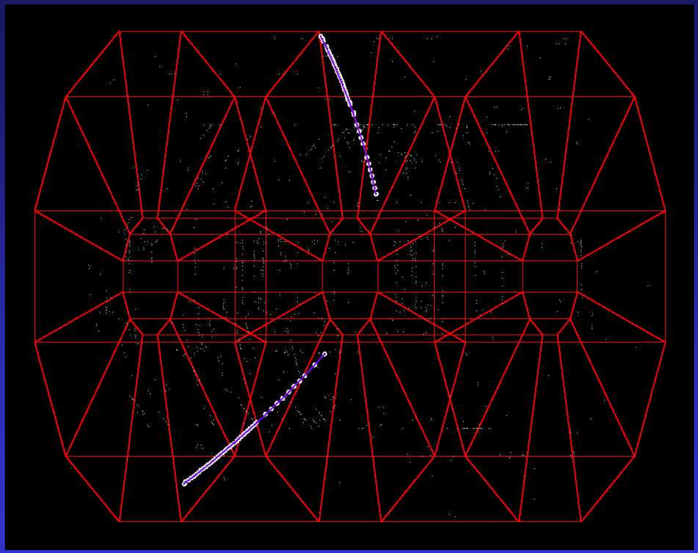
← STAR

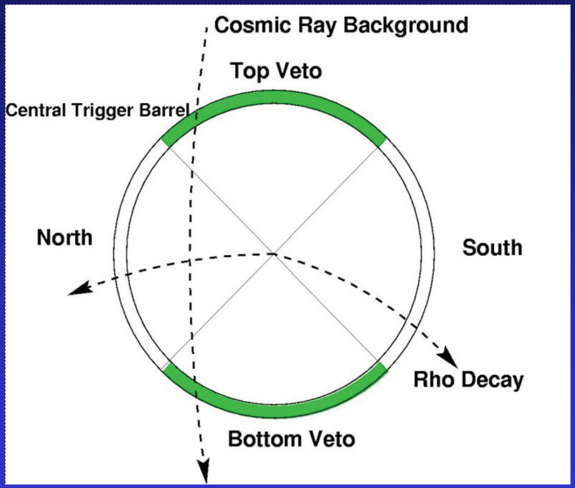
PHENIX →



Ultra-Peripheral Collisions in STAR

Two UPC trigger classes:
1) Topology trigger: Based on hits in Central Trigger Barrel, with a “topology” cut to remove cosmic rays.
2) Min. Bias trigger: At least one neutron in each ZDC (Coulomb break-up). Low mult. in Central Trigger Barrel.



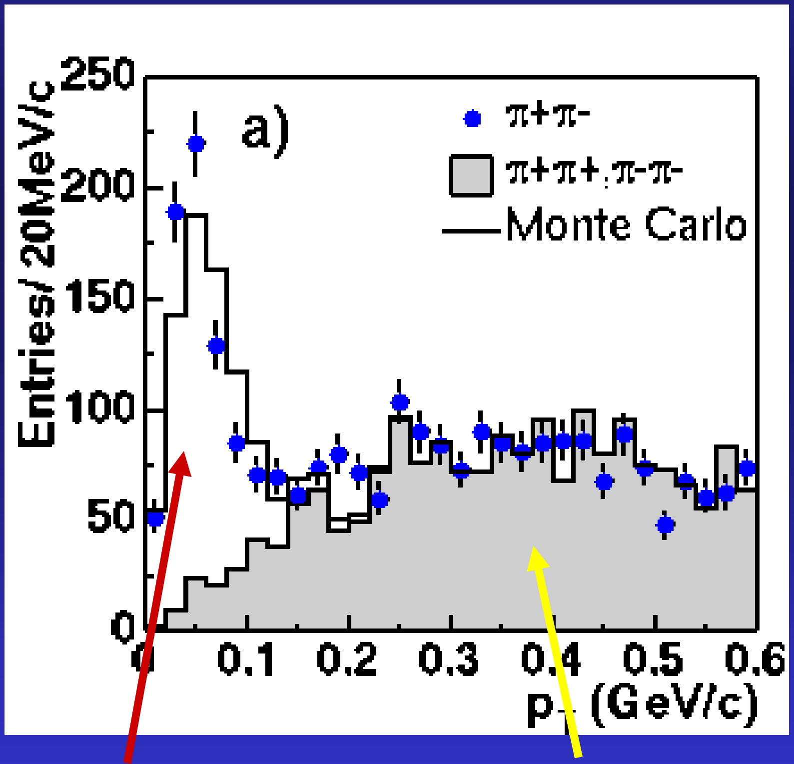


Ultra-Peripheral Collisions in STAR at RHIC

Exclusive ρ^0-production, Au+Au→Au+Au+ρ^0

(C. Adler et al. PRL 89(2002)272302, B.I. Abelev et al. arXiv: 0712.3320).

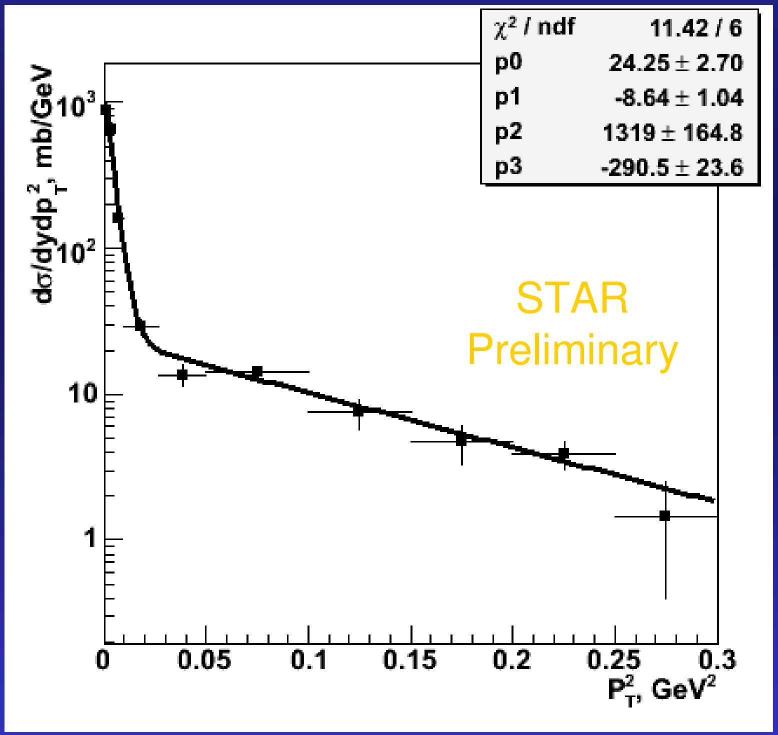
Run 1 $\sqrt{s_{NN}}$ = 130 GeV – Identification of coherent ρ^0.



Signal+background, unlike-sign pairs

background, like-sign pairs

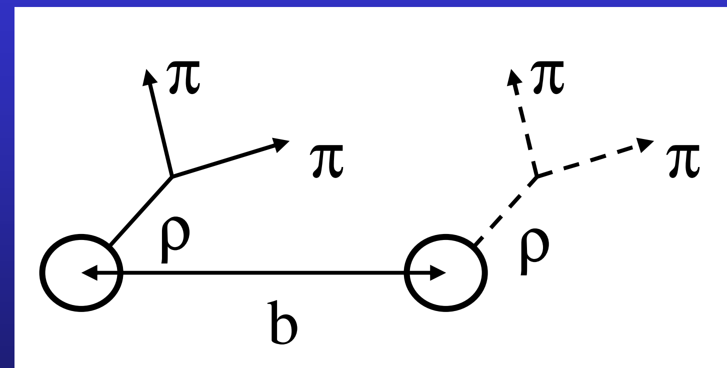
Run 4 $\sqrt{s_{NN}}$ = 200 GeV – Measurement of coherent and incoherent ρ^0.



Interference in ρ^0 Production

The production amplitudes will interfer (at y=0 $|A_1|=|A_2|$),
$|A_1+A_2|^2 = 2\,|A_1|^2\,[1 - \cos(\mathbf{p}\cdot\mathbf{b})]$

The interference is destructive because of the (–) parity of the photon.

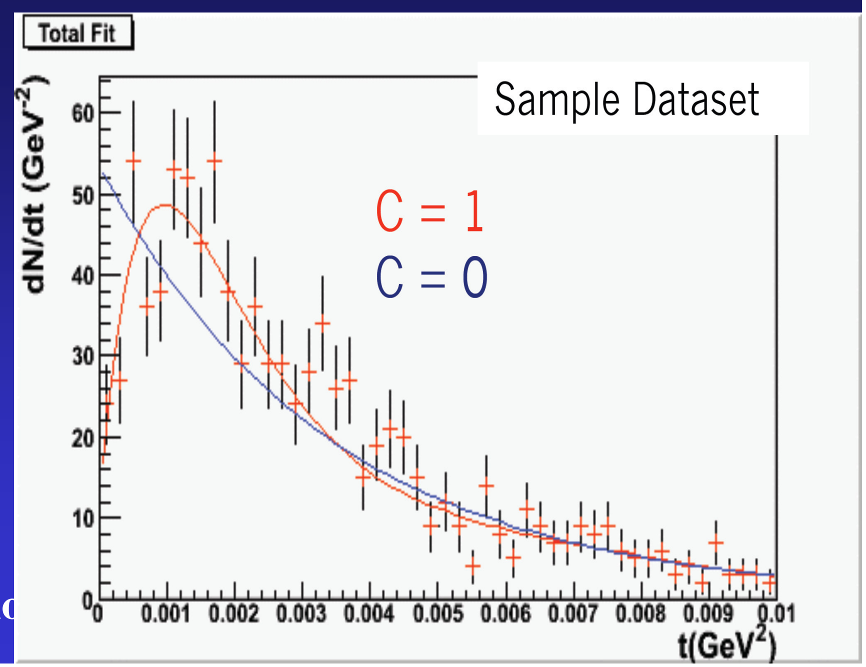


Transverse plane

See S.R. Klein, J. Nystrand PRL 84(2000)2330; PLA 308(2003)323.

Fit the observed t distribution (with $t=p_T^2$) to a function

$$\frac{dN}{dt} = Ae^{-kt}\left(1 + C\left[R(t) - 1\right]\right)$$



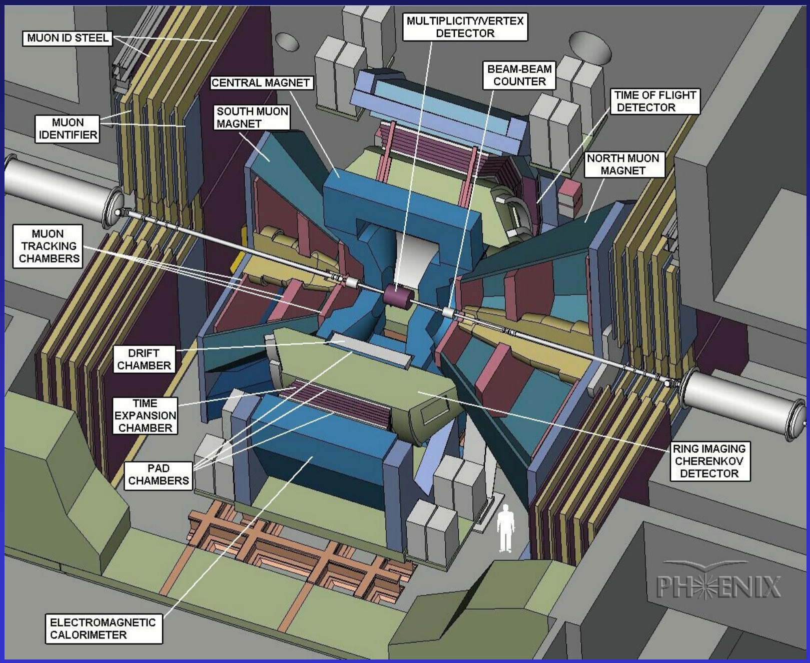
C = 0 ↔ no interference
C = 1 ↔ interference

Ultra-Peripheral Collisions in PHENIX

D. d'Enterria, Quark Matter 2005, nucl-ex/0601001; D. Silvermyr, Workshop on Photoproduction at Collider Energies: ECT* Trento, 15 – 19 January, 2007, http://www.ect.it/.

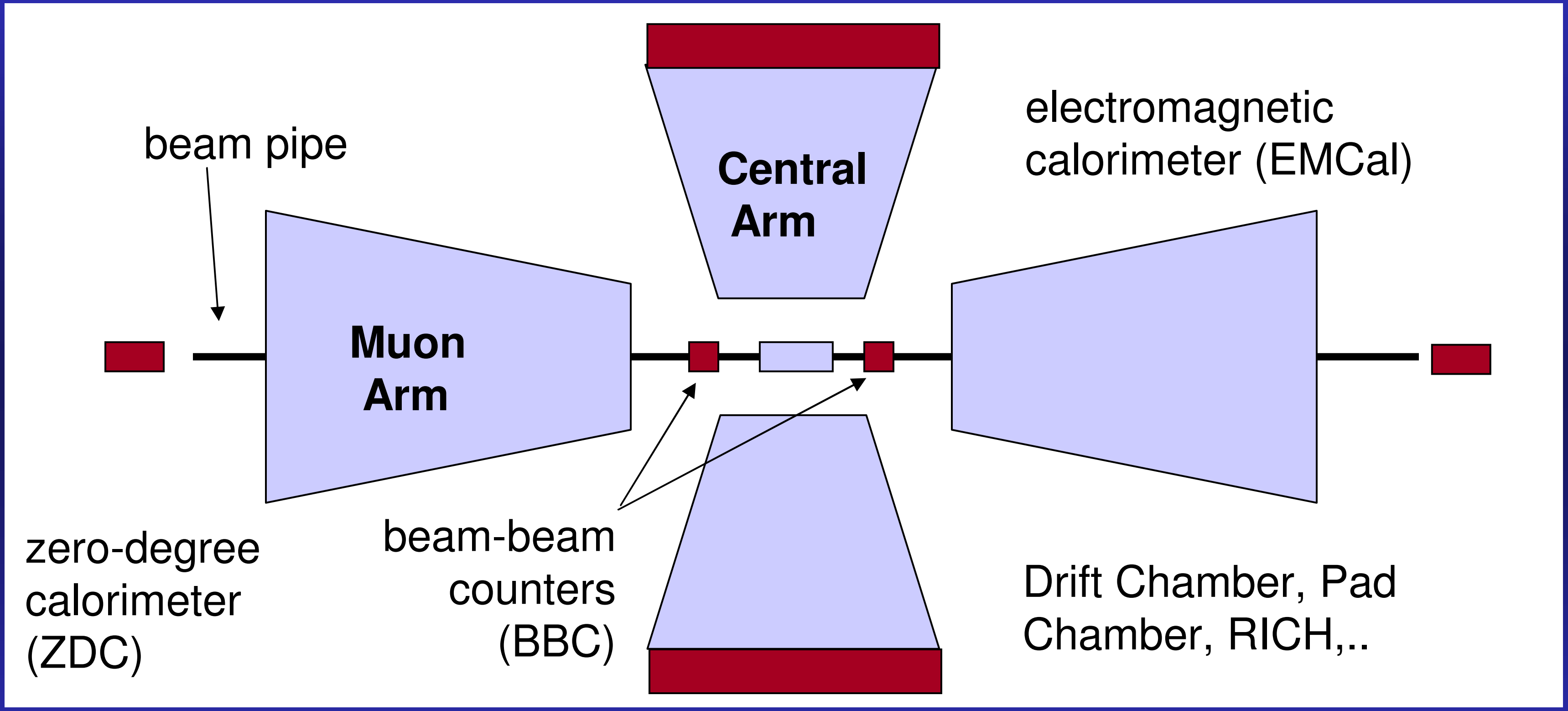
The goal was to search for the process γ+Au $\rightarrow$ J/Ψ+Au in reactions Au+Au $\rightarrow$ Au + Au + e^+e^-. There was also a contribution from $\gamma+\gamma\rightarrow e^+e^-$.

The electrons were identified in the central tracking arm ($|\eta| \leq 0.35$, $\Delta\varphi = 2\times90°$).



Ultra-Peripheral Collisions in PHENIX

PHENIX (bird's eye view)



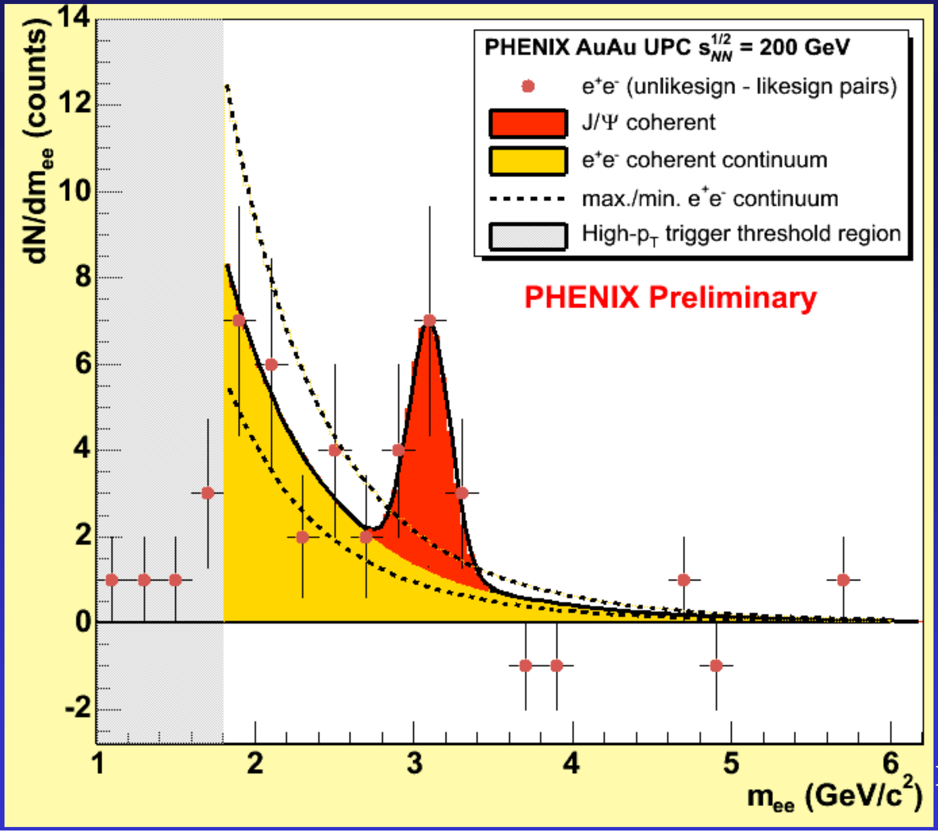
Level 1 Ultra-Peripheral Trigger:

Veto on coincident BBC $|\eta| \sim 3 - 4$, Neutron(s) in at least on ZDC ($E > 30$ GeV), Large Energy ($E > 0.8$ GeV) cluster in EmCal.

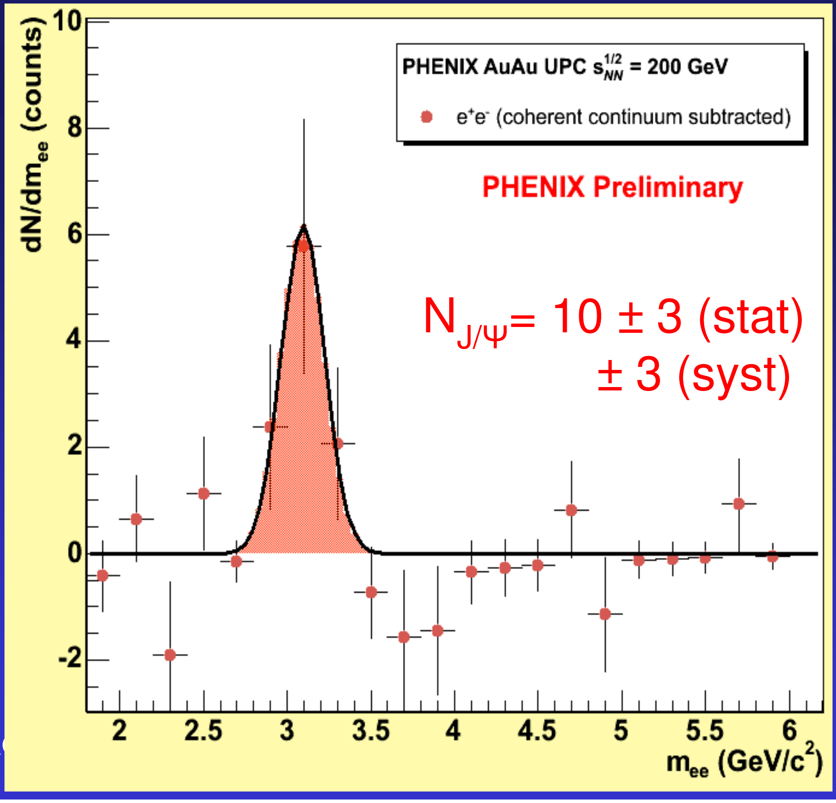
Ultra-Peripheral Collisions in PHENIX

D. d'Enterria, Quark Matter 2005, nucl-ex/0601001; D. Silvermyr, Workshop on Photoproduction at Collider Energies: ECT* Trento, 15 – 19 January, 2007, http://www.ect.it/.

dN/dminv (backgd subtracted) & with 2 fits of expected e+e- continuum shape (normalized at m_{ee} = 1.8 – 2.2 GeV/c2)



dN/dm_{inv} after e^+e^- continuum subtraction

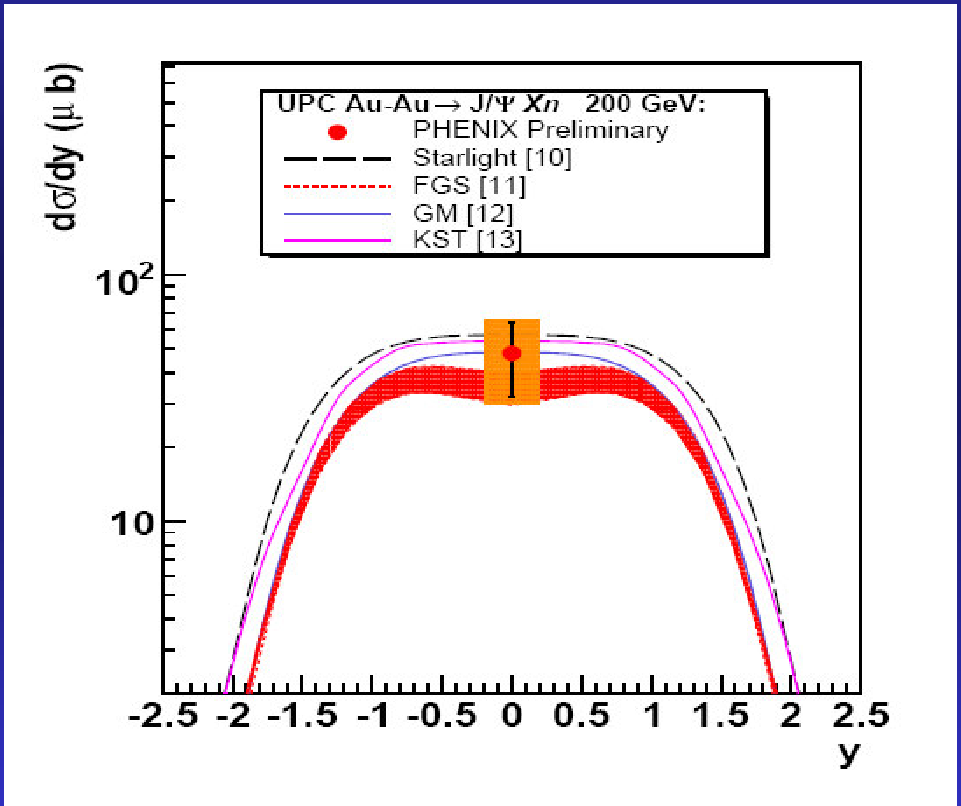


Preliminary J/Ψ cross section

$$d\sigma_{J/\Psi}/dy|_{y=0} = 1/BR \times 1/(Acc|_{y=0}\cdot\varepsilon) \times 1/\varepsilon_{trig} \times 1/L_{int} \times N_{J/\Psi}/\Delta y =$$

$$= 1/(5.9\%)\times 1/(5.7\%\cdot 56.4\%)\times 1/(90\%)\times 1/120\ \mu b^{-1}\times(10 \pm 3 \pm 3) =$$

$$= 48. \pm 16.\ (stat) \pm 18.\ (syst)\ \mu b$$

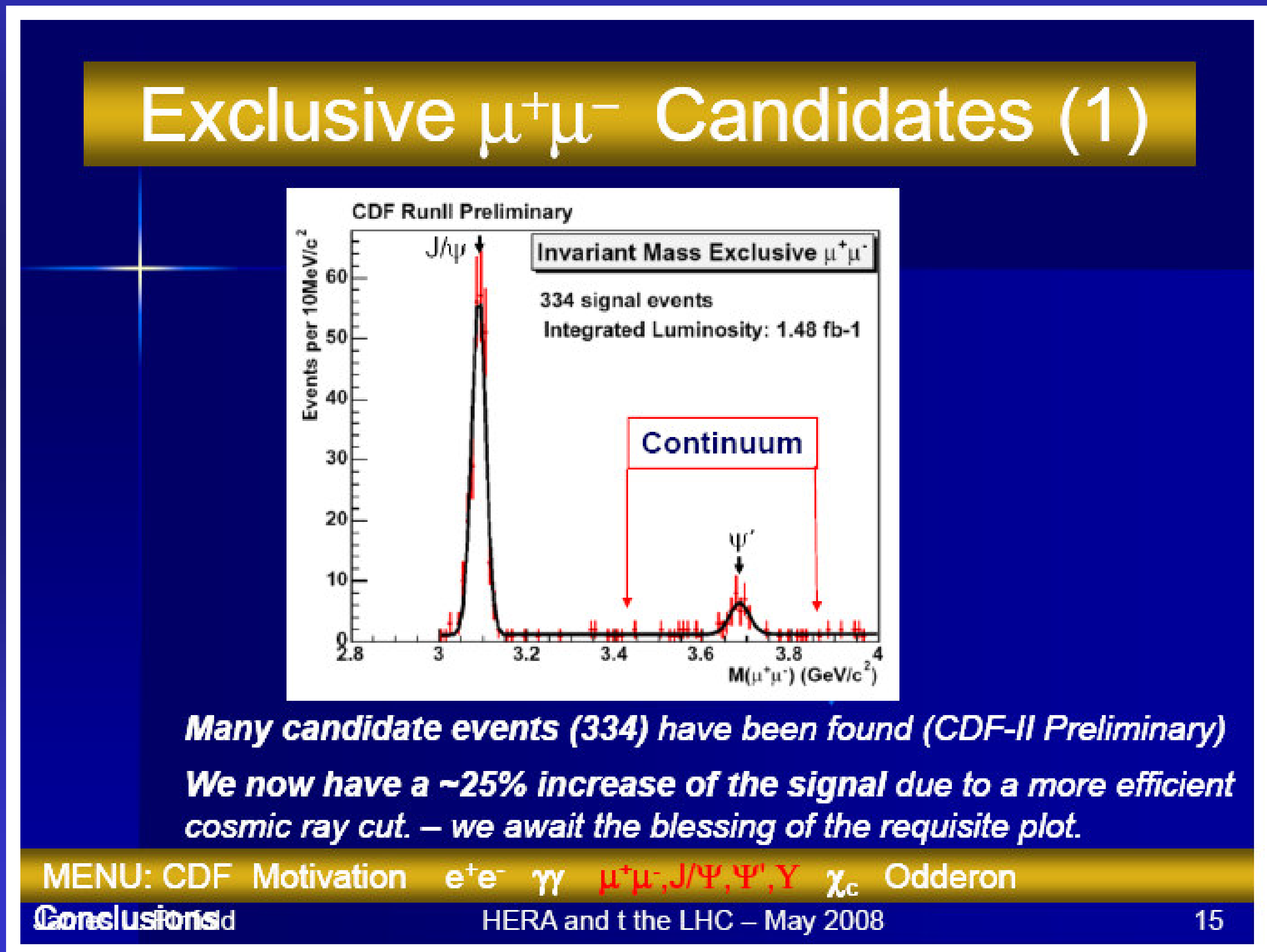


- Measured J/Ψ yield at y=0 consistent w/ theoret. calcs. [1,2]
- Syst. uncertainty: coherent e^+e^- continuum under J/Ψ (*work in progress*).
- Reduction of stat. errors need larger luminosity.
- Current uncertainties preclude yet detailed study of crucial model ingredients: $G_A(x,Q^2)$, σ(J/Ψ absorption).

[10] Starlight: S.R. Klein, J.Nystrand PRC 60(1999)014903, NPA 752(2005)470.
[11] M. Strikman, M. Tverskoy, M. Zhalov, PLB 626(2005)72.
[12] V. P. Goncalves and M. V. T. Machado,arXiv:0706.2810 (2007).
[13] Yu. P. Ivanov, B. Z. Kopeliovich and I. Schmidt, arXiv:0706.1532 (2007).

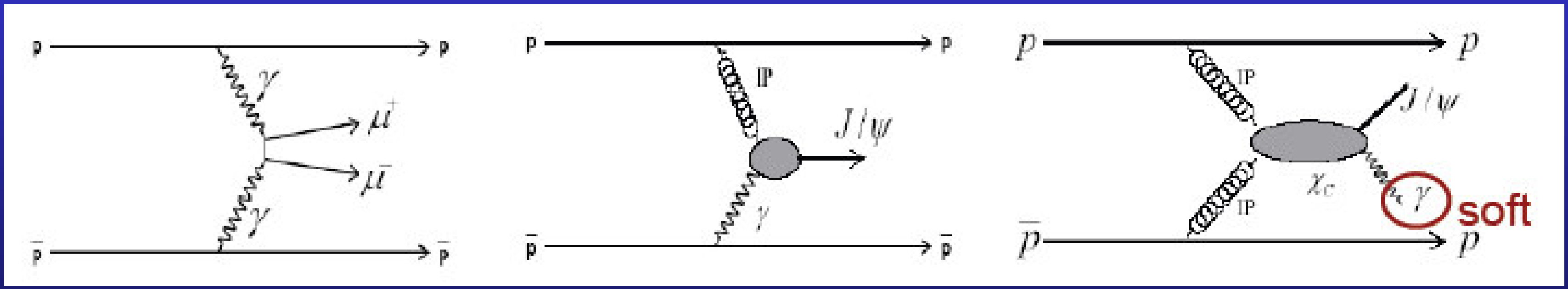
”Ultra-peripheral” Collisions at the Tevatron

Exclusive production of e^+e^- and $\mu^+\mu^-$ pairs. See yesterday’s talk by James Pinfold.



"Ultra-peripheral" Collisions at the Tevatron

Three possible contributions to the process $p+\bar{p}\rightarrow p+\bar{p}+\mu^+\mu^-$:

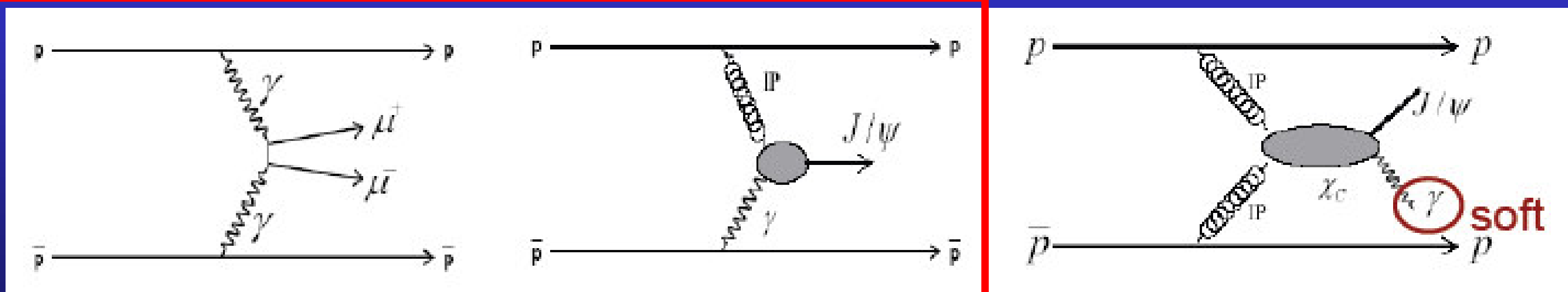


Note: no feed down from χ_c to Ψ'.

A contribution from Odderon+Pomeron also possible.

"Ultra-peripheral" Collisions at the Tevatron

Calculations for the first two ($\gamma\gamma$ and γP):



$\sigma(pp \rightarrow pp + J/\Psi(1S))$: 19.6 nb $\quad$ $\sigma \cdot Br(\mu\mu)$: 1.16 nb

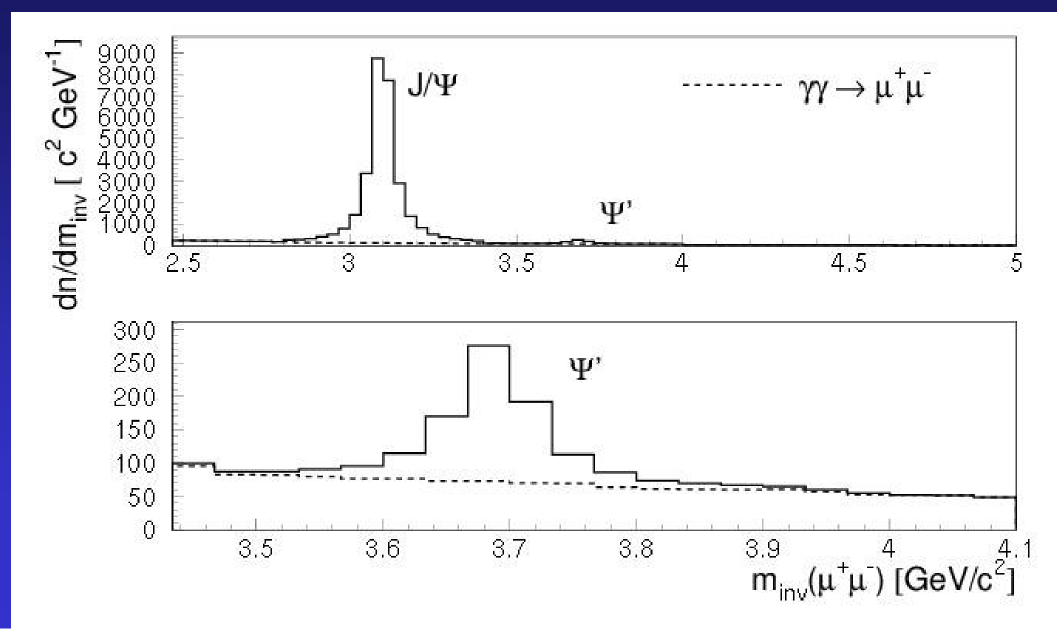
$\sigma(pp \rightarrow pp + \Psi'(2S))$: 3.2 nb $\quad$ $\sigma \cdot Br(\mu\mu)$: 23 pb

$\sigma(pp \rightarrow pp + \mu\mu)$: 2.4 nb ($m_{inv} > 1.5$ GeV/c^2)

Applying cuts on the $\mu^+\mu^-$:

$p_T > 0.5$ GeV/c

$|\eta| < 2.0$ $\quad \Rightarrow$



Yield(Ψ')/Yield(J/Ψ) ≈ 1:50

S.R.Klein, J.Nystrand, PRL 92 (2004) 142003 (J/Ψ only).

”Ultra-peripheral” Collisions at the Tevatron Uncertainties and limits on the cross sections

$$\frac{d\sigma}{dy} = k_1 \frac{dn_\gamma}{dk_1} \sigma_{\gamma p \to Vp}(k_1) + k_2 \frac{dn_\gamma}{dk_2} \sigma_{\gamma p \to Vp}(k_2)$$

Two ingredients:

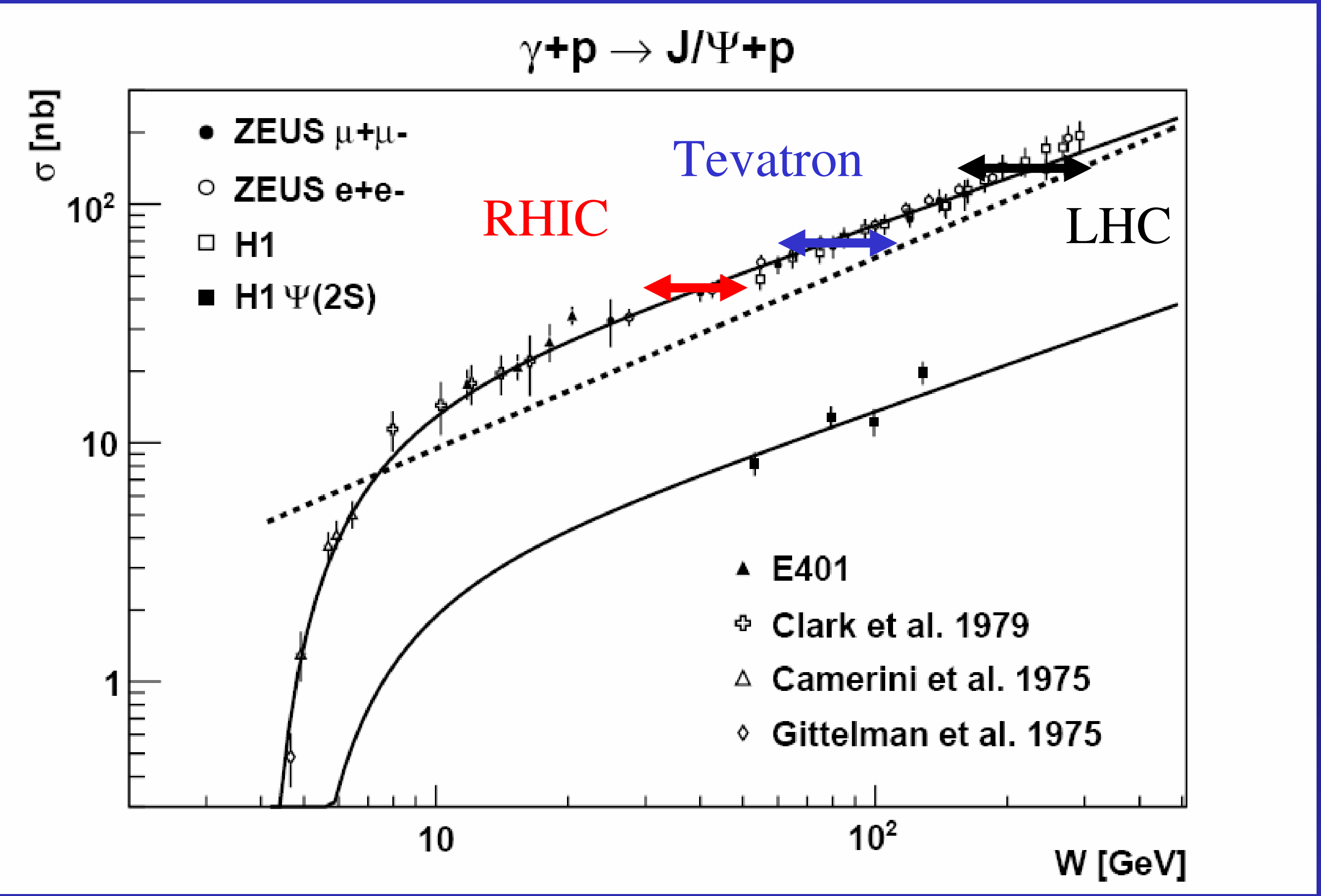
1) The photoproduction cross section, $\sigma(\gamma p \to Vp)$

$\Rightarrow$ Has been measured at HERA

$\Rightarrow$ A J/Ψ within $|y| < 0.5$ at the Tevatron corresponds to $60 \leq W_{\gamma p} \leq 100$ GeV.

2) The photon spectrum, dn/dk, has to be calculated.

"Ultra-peripheral" Collisions at the Tevatron
Measurements at HERA and at lower energies

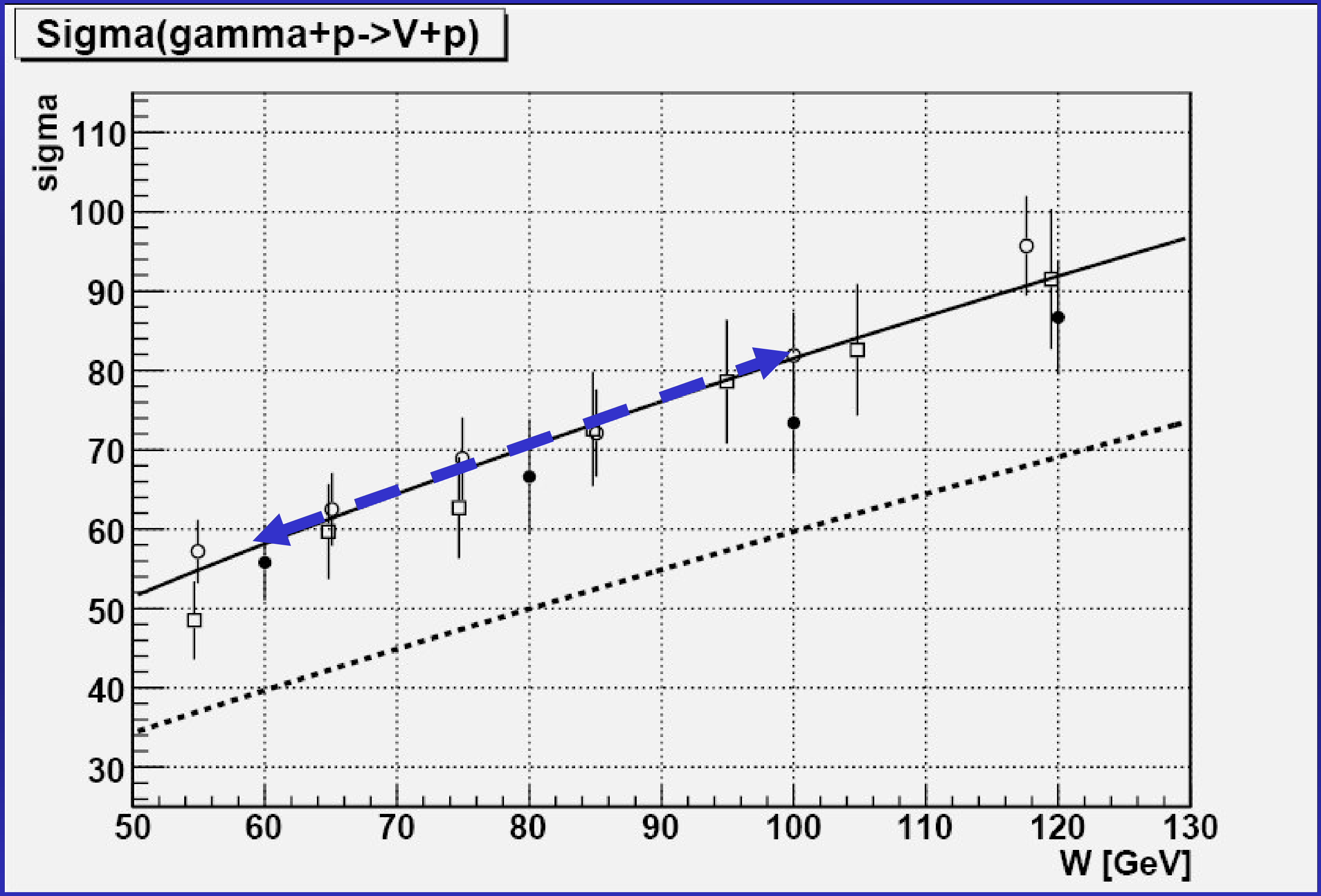


For a J/Ψ within $|y| \leq 0.5$

Data well described by
($\sigma_0 = 4.1 \pm 0.4$ nb)

$$\sigma(\gamma p \to J/\psi p) = \left[1 - \frac{(m_p + m_{J/\psi})^2}{W_{\gamma p}^2}\right]^2 \cdot \sigma_0 \cdot W^{0.65}$$

”Ultra-peripheral” Collisions at the Tevatron
Measurements at HERA and at lower energies



The region $60 \leq W_{\gamma p} \leq 100$ GeV well covered by H1 and ZEUS measurements. Systematic error in σ: 6 – 9%.

”Ultra-peripheral” Collisions at the Tevatron
The photon spectrum

The photon spectrum of a single proton – calculable from the Form Factor

$$\frac{dn}{dk} = \int \frac{dn}{dkdQ^2} |F(Q^2)|^2 \, dQ^2$$

In a pp collision, to exclude strong interactions, the calculations can be done in impact parameter space

$$\frac{dn}{dk} = \int \frac{dn}{dkdb^2} |1 - \Gamma(s, \vec{b})|^2 \, db^2$$

Where Γ(s,b) is the Fourier transform of the pp elastic scattering Amplitude (Frankfurt, Hyde, Strikman, Weiss, Phys. Rev. D 75 (2007) 054009). This is roughly equivalent to setting a min. impact parameter b > 1.4 fm.

”Ultra-peripheral” Collisions at the Tevatron
Uncertainties and limits on the cross sections

Taking into account the error on $\sigma(\gamma p \rightarrow Vp)$ (9%), and using the photon spectrum calculated from the Form Factor as a conservative upper limit gives

J/Ψ: $\sigma(pp \rightarrow ppJ/\psi) = 19.6^{+4.7}_{-1.8}\,\mathrm{nb}$ $\quad \dfrac{d\sigma(y=0)}{dy} = 2.7^{+0.6}_{-0.2}\,\mathrm{nb}$

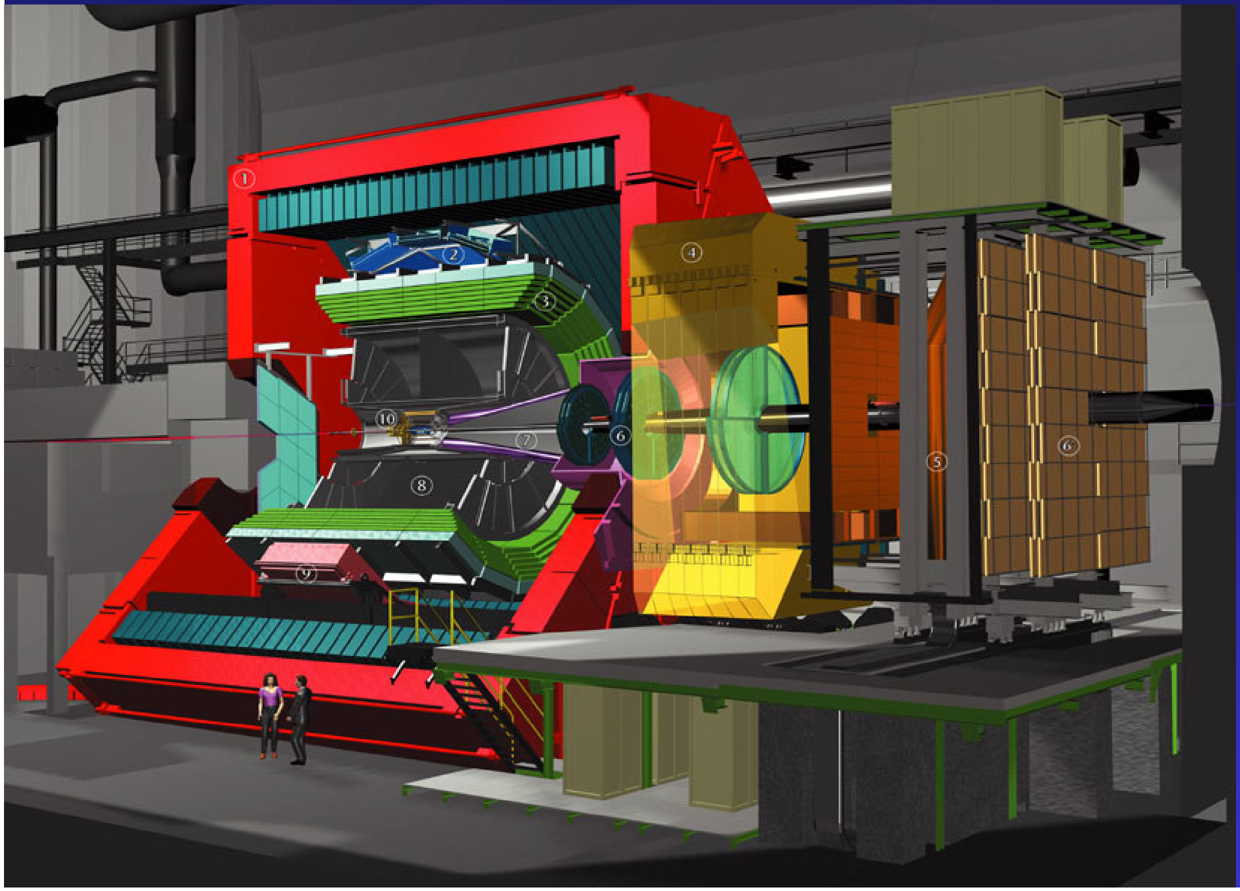
Ψ’: $\sigma(pp \rightarrow pp\psi') = 3.2^{+0.8}_{-0.3}\,\mathrm{nb}$ $\quad \dfrac{d\sigma(y=0)}{dy} = 0.46^{+0.11}_{-0.04}\,\mathrm{nb}$

Eagerly awaiting the final results from CDF on the measured cross sections …

Ultra-peripheral Collisions in ALICE

(from the ALICE PPR, B. Alessandro et al., J. Phys. G 32 (2006) 1295)

ALICE (= A Large Ion Collider Experiment) –
The dedicated Heavy-Ion Experiment at the LHC
Located at IP 2 (former L3) and uses the L3 Magnet



See talk by Rainer Schicker on Thursday

Ultra-peripheral Collisions in ALICE

(from the ALICE PPR, B. Alessandro et al., J. Phys. G 32 (2006) 1295)

Ideas to study exclusive vector meson production, in particular J/Ψ and Υ.

Mid-rapidity $V \rightarrow e^+e^-$.
Trigger: Level 0 multiplicity from SiPixel, ToF in anti-coincidence w/ t0 and v0 detectors ($\approx 2 < |\eta| < 5$).
Electron Id: Transition Radiation Detector (also in Level 1 Trigger).

Forward region ($2.2 \leq \eta \leq 4.0$) $V \rightarrow \mu^+\mu^-$.
Trigger: Muon arm trigger in anti-coincidence w/ central arm detectors (SiPixel, ToF).

Expected rates – Vector Mesons

Pb+Pb ; <L> = $5\cdot10^{26}$ cm^{-2}s^{-1} ; ALICE year 10^6 s

	Prod. Rate	Decay	Br.Ratio	Geo Acc.*	Detection Rate
ρ	$2.6\cdot10^9$	$\pi\pi$	100%	0.079	$2.0\cdot10^8$
J/ψ	$1.6\cdot10^7$	e^+e^-	5.93%	0.101	$1\cdot10^5$
Υ	$\sim1\cdot10^5$	e^+e^-	2.38%	0.141	≈ 400

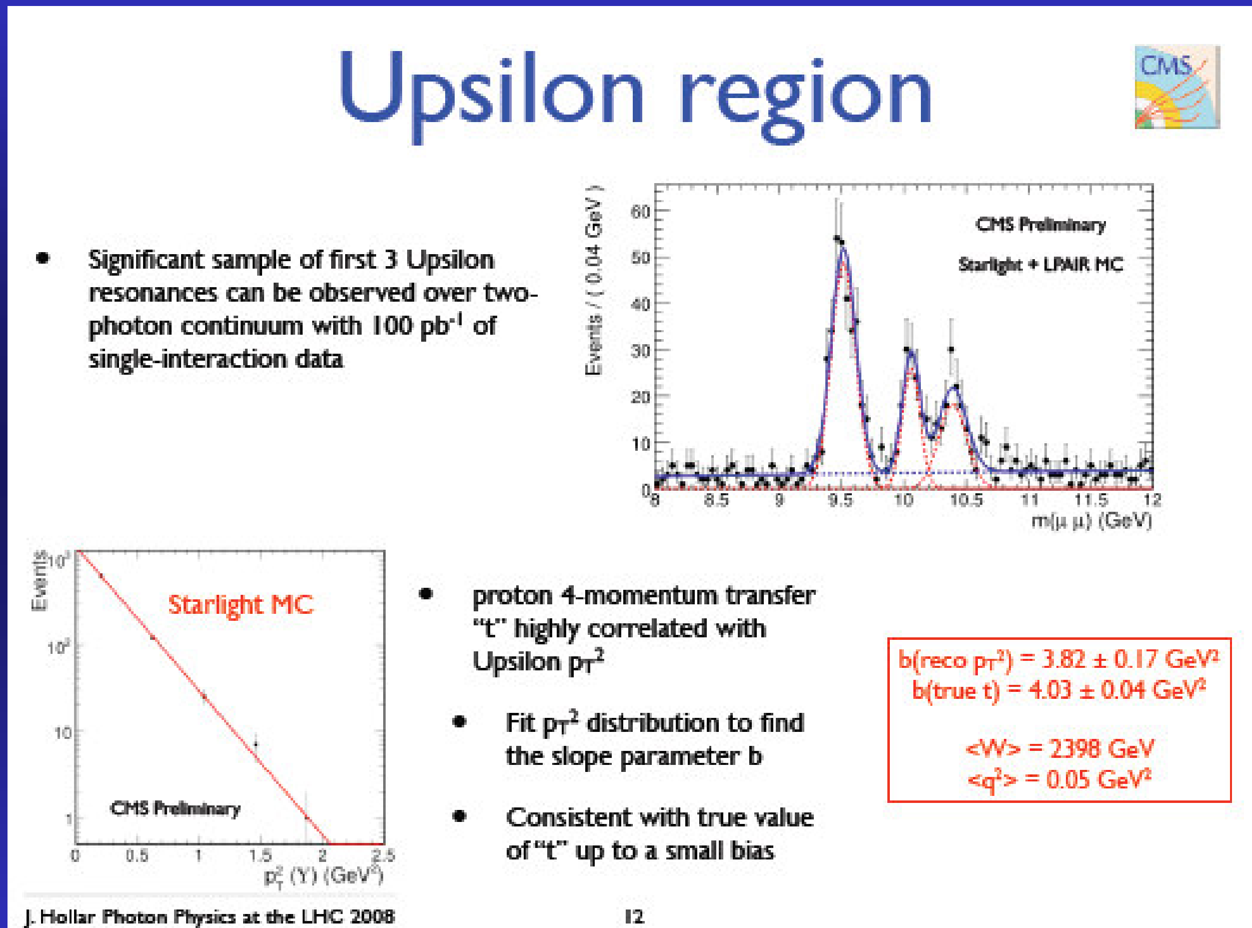
Geo Acc: $|\eta|<0.9$, $p_T>0.15$ GeV/c

The numbers have been confirmed from aliroot (the ALICE off-line analysis tool) simulations. The exact value of the acceptance will depend on the final track selection and the exact status of the detector when the data were taken.

A bug in the MC was found and that is the reason for the lower J/Ψ and Υ acceptances compared with the ALICE Physics Performance Report (J.Phys.G 32(2006)1295).

Ultra-peripheral Collisions in CMS

Exclusive production of Υ in pp and PbPb



From Jonathan Hollar, Presentation at Workshop on High Energy Photon Collisions at the LHC, CERN, 22-25 April, 2008. Also talking here on Thursday.

Two-photon production of Higgs at the LHC

For a standard model Higgs with M=120 GeV, calculations give for two-photon production

$\sigma(pp \rightarrow pp+H) \approx 0.1$ fb and $\sigma(PbPb \rightarrow PbPb+H) \approx 10$ pb

With integrated luminosities of (1 year $10^7/10^6$ seconds)

10^5 pb^{-1} and 1 nb^{-1}

this gives

$\approx$10 events/year and $\approx$0.01 events/year

G.Baur et. al. Eur. Phys. J C32 (2003) s69;
L.I. Sarycheva, presentation at Workshop on High Energy Photon Collisions at the LHC, CERN, 22-25 April, 2008.

Conclusions and Outlook

- Studying photon-induced interactions at hadron colliders is an opportunity that should not be missed.
- The feasibility has been proven at RHIC and the Tevatron.
- Much focus on Vector Mesons in this talk, but there is a rich variety of topics that can be studied:
    * direct γ+p and γ+A interactions, e.g. $\gamma+p\rightarrow jet+jet+X$, $\gamma+p\rightarrow Q+\bar{Q}+X$;
    * two-photon interactions, $\gamma\gamma\rightarrow WW$, $\gamma\gamma\rightarrow e+e-$ from strong fields in Pb+Pb collisions.
    * etc. etc.