Ultraperipheral Heavy-Ion Collisions with CMS

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For the CMS Collaboration

International Workshop on Diffraction in High-Energy Physics

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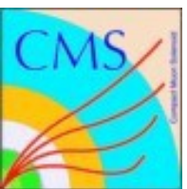


KU

Overview of Ultraperipheral Collisions with CMS

UPC Physics

- Introduction to UPC
- Probing nPDFs

CMS Detector

PbPb 2011

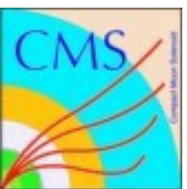
- Trigger for PbPb
- UPC J/ψ

pPb 2013

- Trigger for pPb
- $\gamma\gamma$ to $\mu\mu$

PbPb 2015

- UPC Υ
- UPC jets



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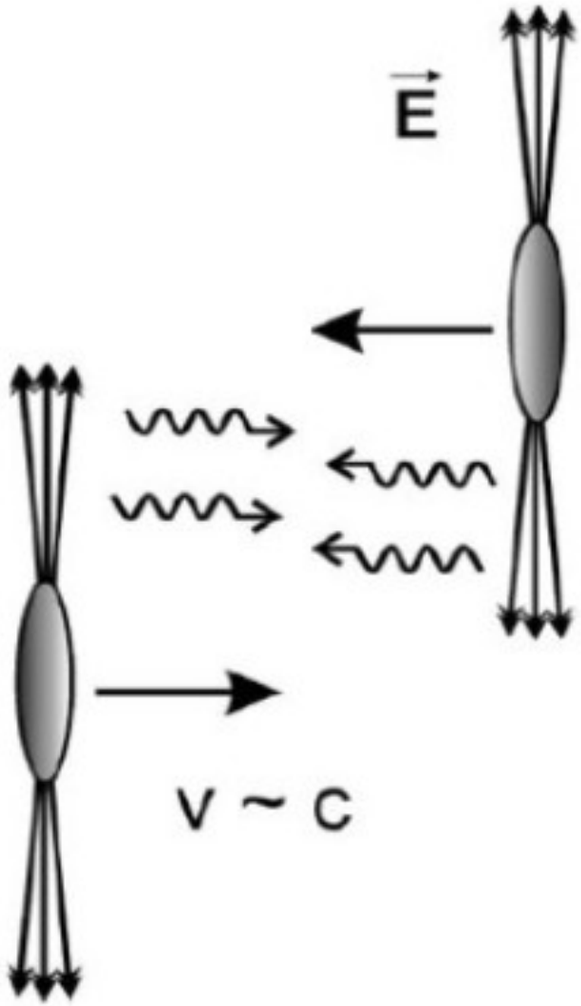
Physics Processes in Ultraperipheral Collisions



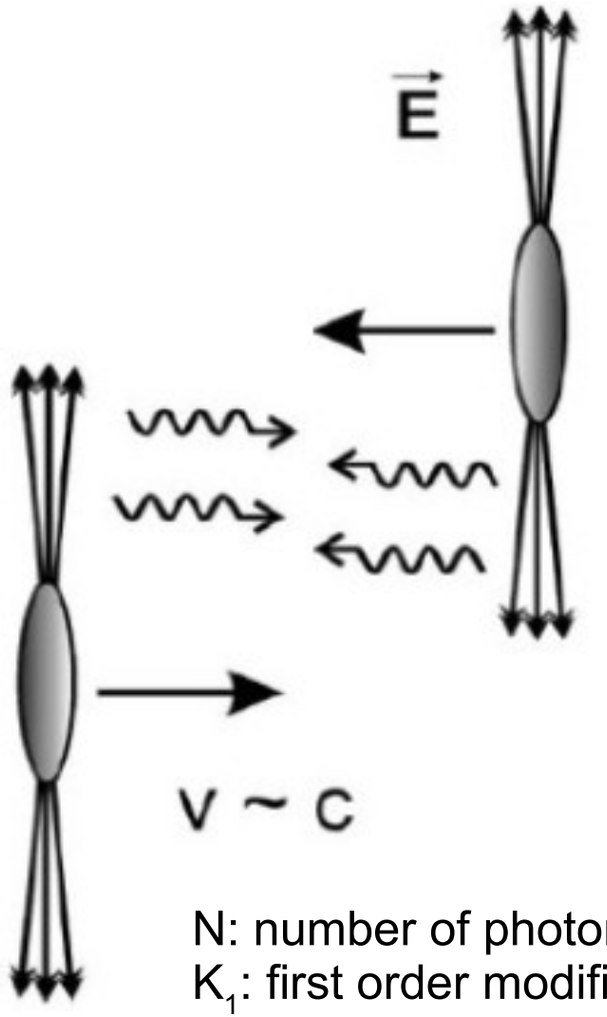
Coherent photoproduction: the photon couples to the nucleus as a whole

Incoherent photoproduction: the photon couples to the nucleons inside

Photon-photon interaction: photons from the two nuclei can interact with each other producing a lepton pair

Photonuclear dissociation: neutrons can be ejected from the nucleus by photon induced nuclear break-up

Weizäcker-Williams

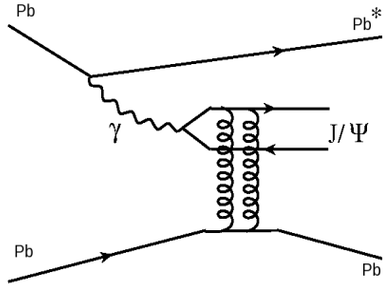


- Boost a point charge to an ultra relativistic frame
  - The transverse electric field is enhanced relative to the longitudinal electric field
  - The electro-magnetic fields resemble that of a plane wave
- Calculate the temporal Fourier transform of the Poynting vector
- Exploit Einstein's equation for the energy of a photon to calculate a photon flux from the Fourier mode

$$\frac{d^3N}{d\omega d^2b} = \frac{\alpha}{\omega b^2}\left(\frac{cZ}{\pi v}\right)^2\left(\frac{\omega b}{\gamma v}\right)^2 K_1^2\left(\frac{\omega b}{\gamma v}\right)$$

N: number of photons
K_1: first order modified Bessel function
b: collision impact parameter
Z: number of protons in projectile nucleus

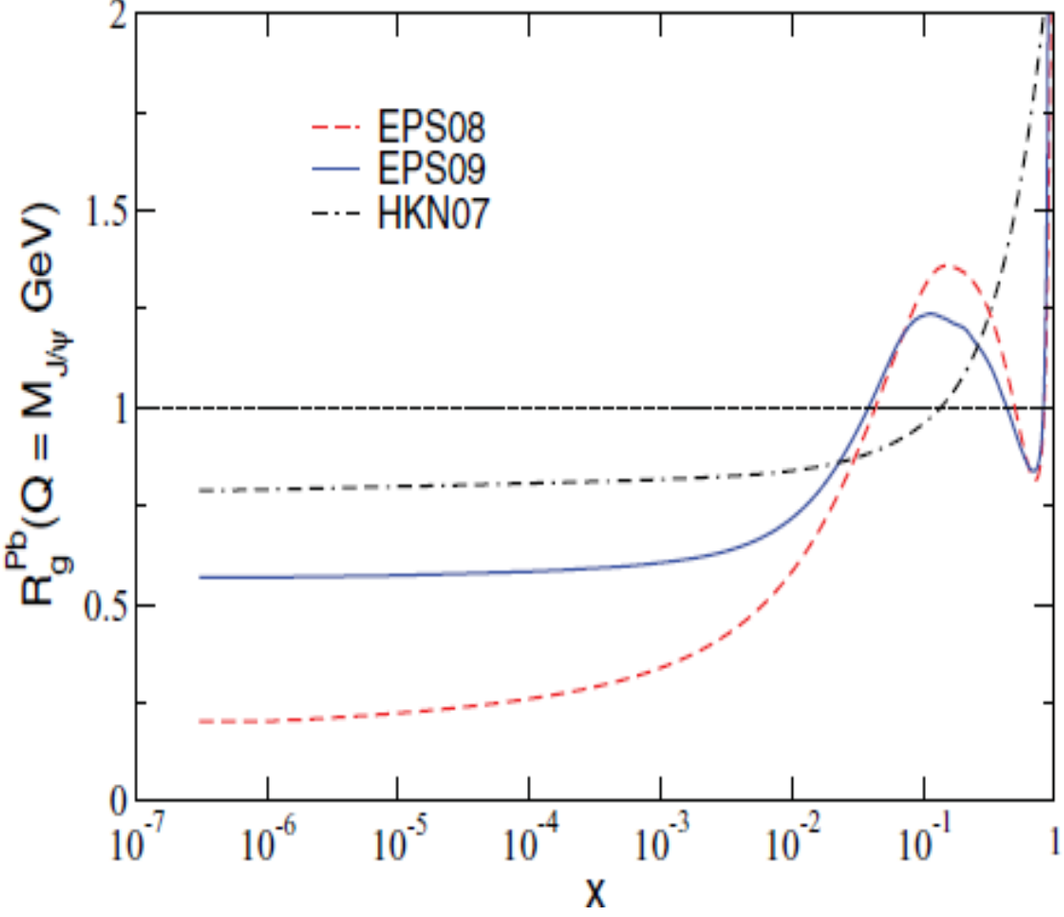
UPC Quarkonia Probes Nuclear Glue



$$\left.\frac{d\sigma_{\gamma A\to J/\Psi A}}{dt}\right|_{t=0} = \xi_{J/\Psi}\left(\frac{16\pi^3\alpha_s^2\Gamma_{l^+l^-}}{3\alpha M_{J/\Psi}^5}\right.$$

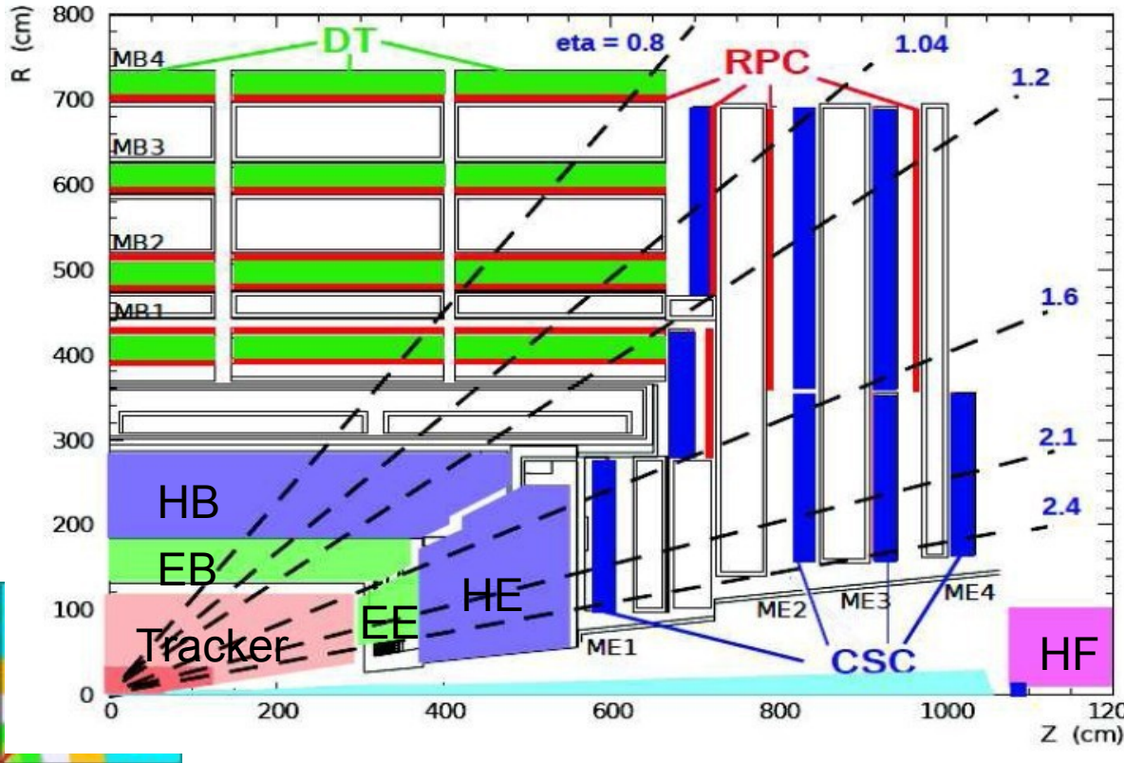
$$\left.[xG_A(x,\mu^2)]^2\right.$$

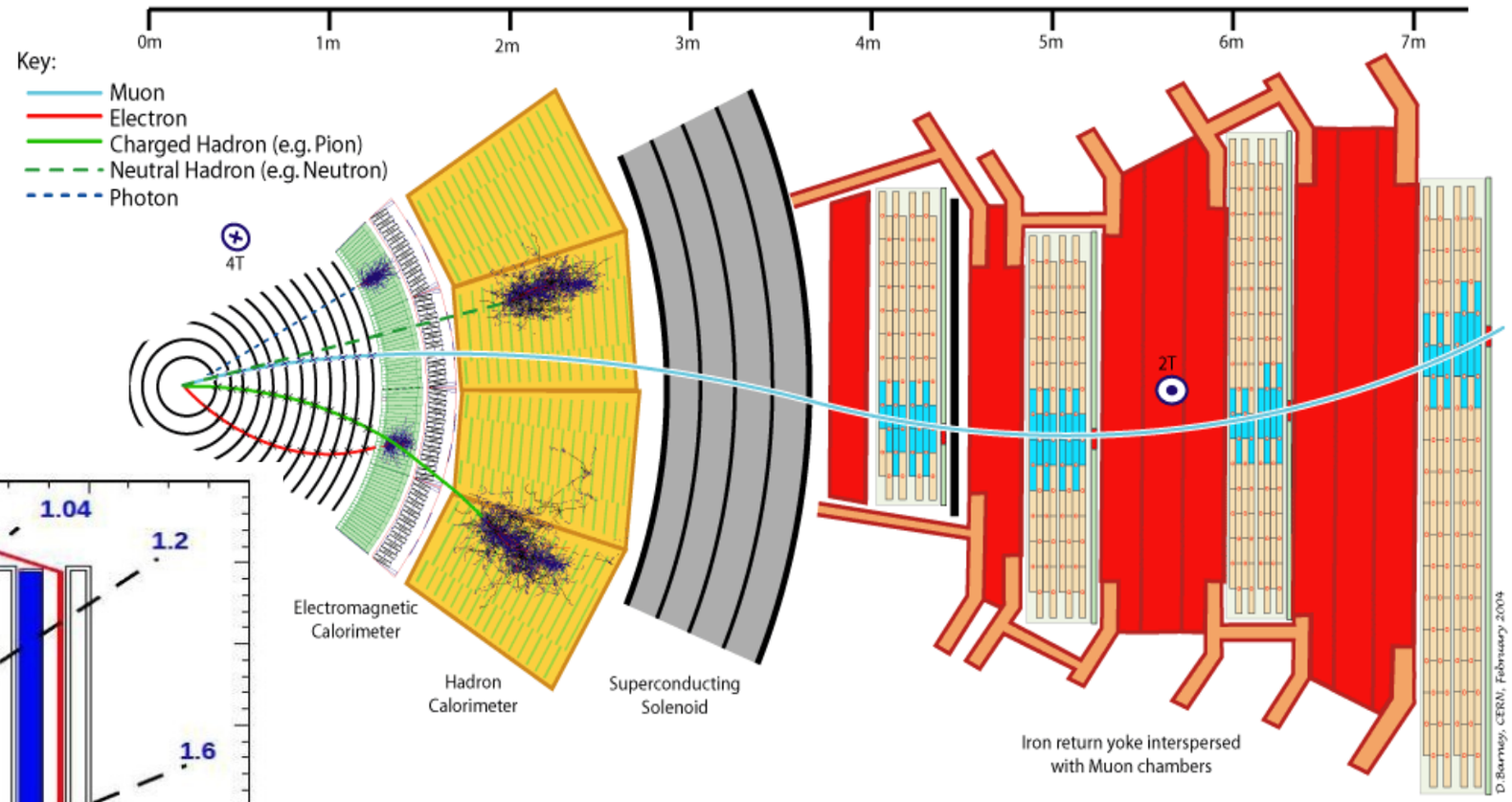
The ultraperipheral J/ψ photoproduction cross section depends on the **nuclear gluon density squared**



The Compact Muon Soleniod

- Efficient triggering
- Good resolution for high p_T tracks
- Good muon triggering and ID

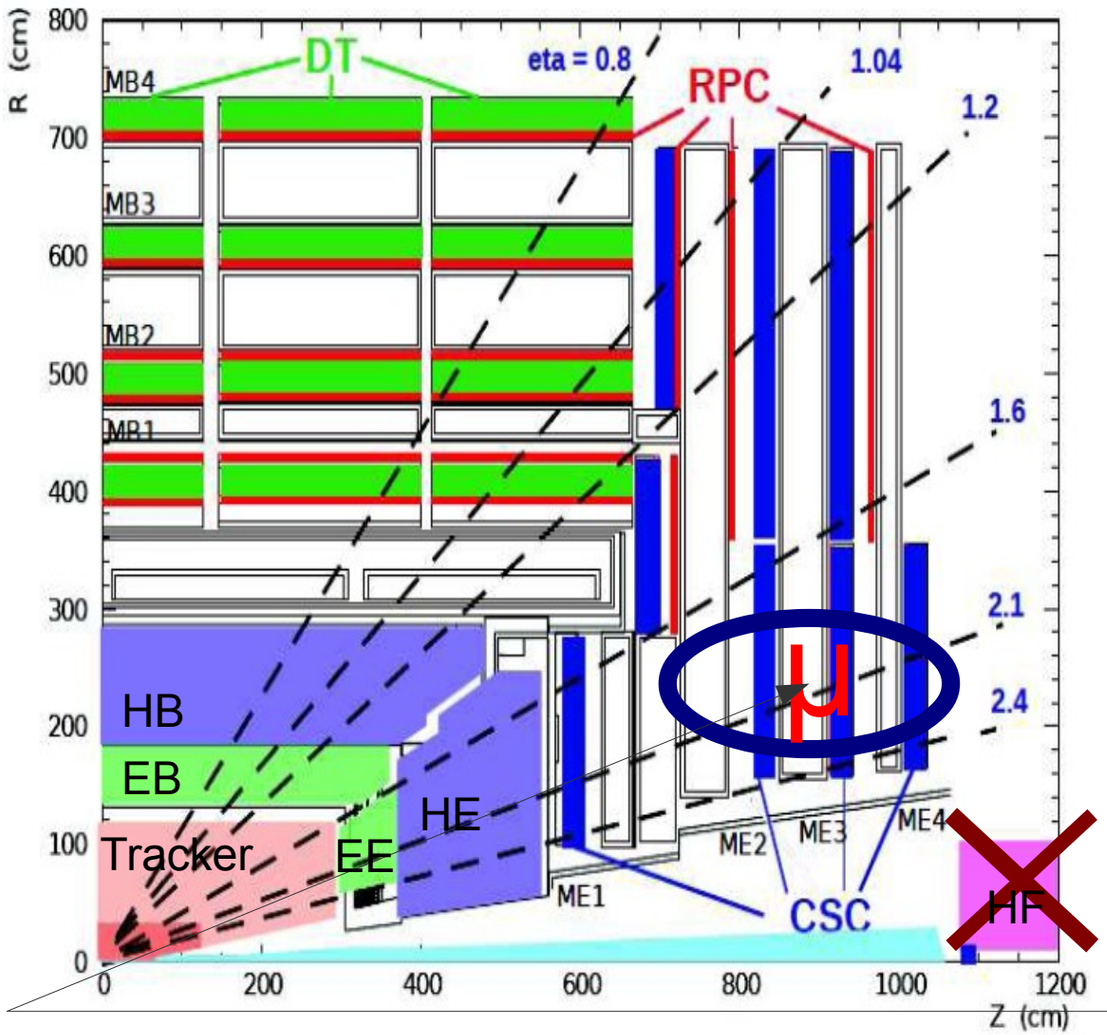




Well suited for rare high p_T objects, but low p_T UPC events can also be studied

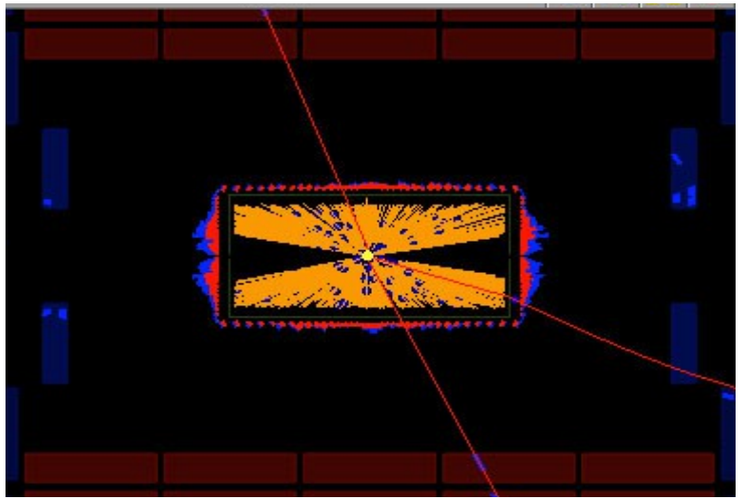
ZDC

UPC Triggers for 2011 PbPb



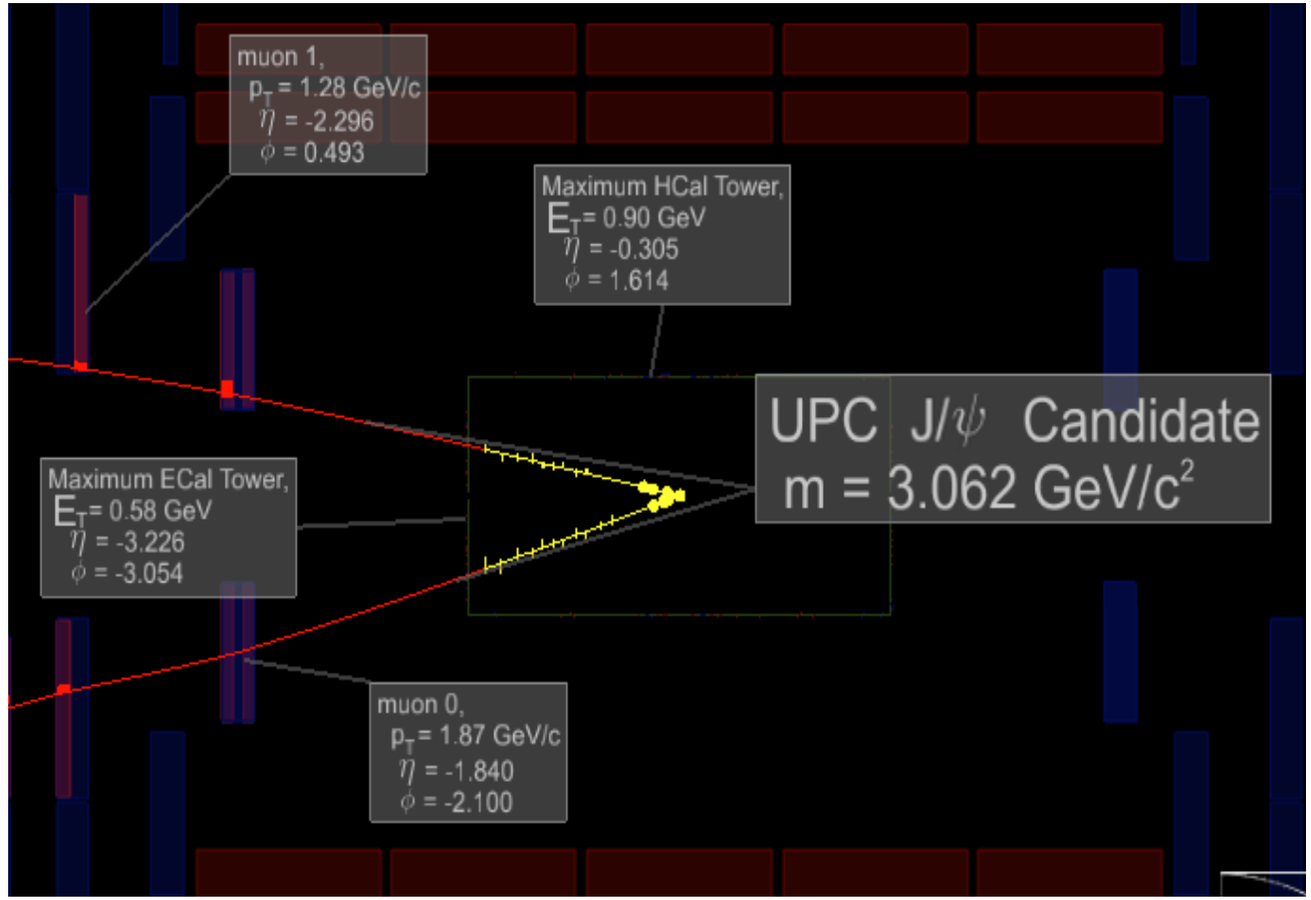
- L1: hardware trigger system from calorimeters and muon systems only
  - Loosest muon trigger and electromagnetic calorimeter trigger
  - At least one ZDC above threshold
  - No activity on both sides of the interaction point in the BSC detectors, $3 < |\eta| < 5$
- HLT: software trigger system using the full detector
  - Require reconstruction of at least on pixel track

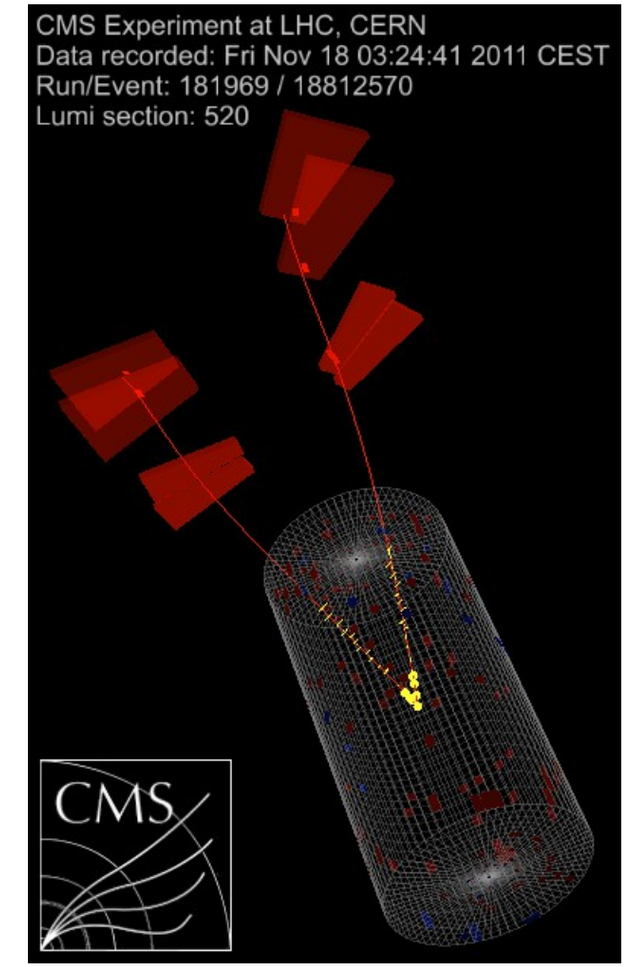
UPC J/ψ from PbPb 2011



Z to μμ in embedded in PbPb minimum bias

- Events from UPC triggers
- Only two muons in the events

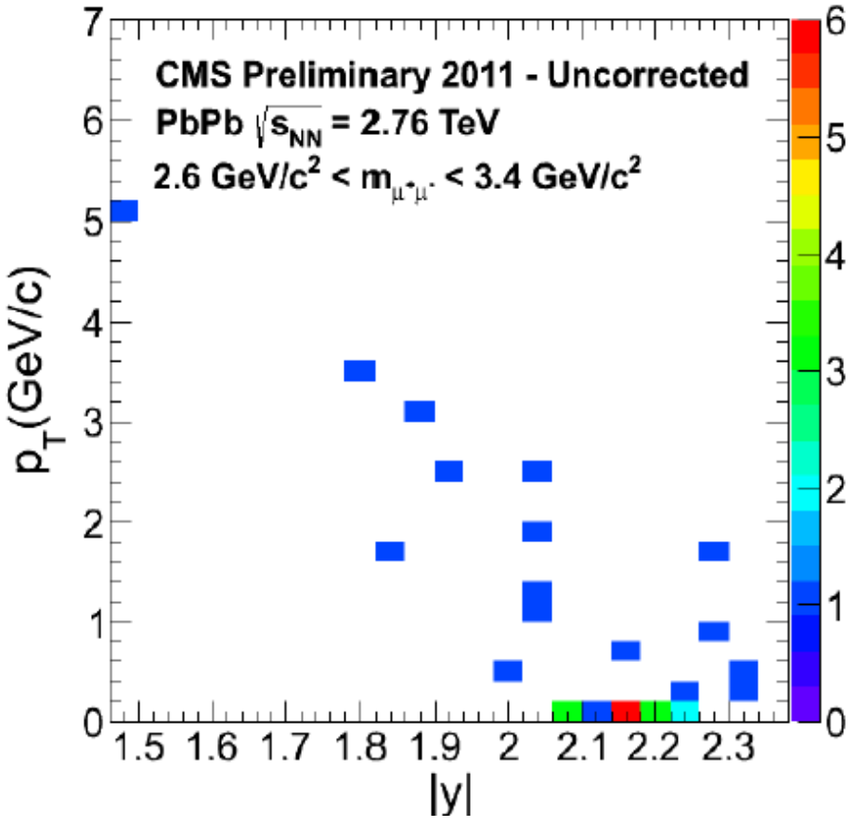


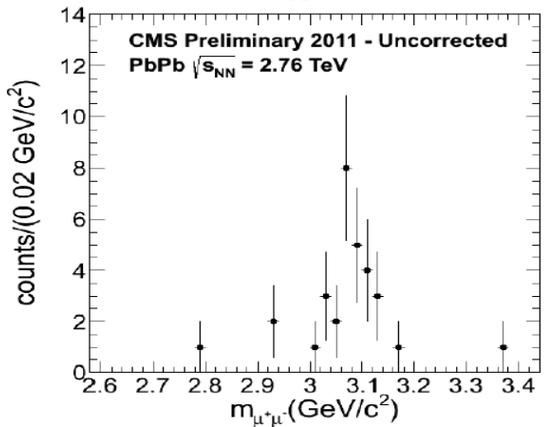


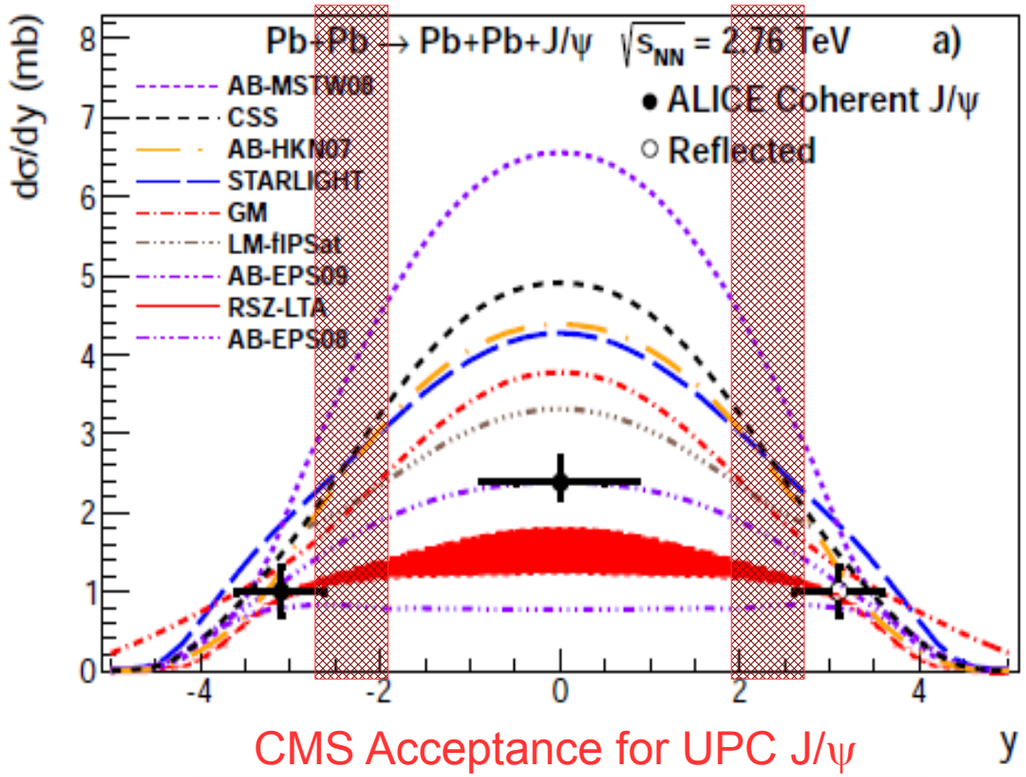
- All calorimeters consistent with noise

CMS DP Note 2012-017

Contribution from CMS to UPC J/ψ in PbPb





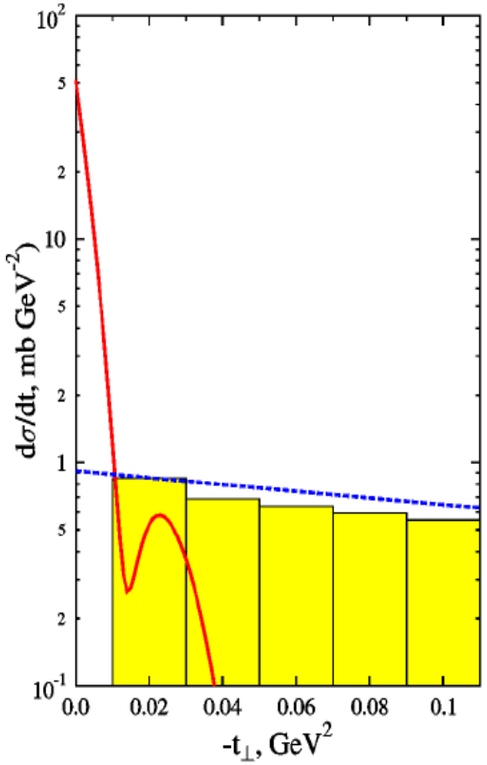


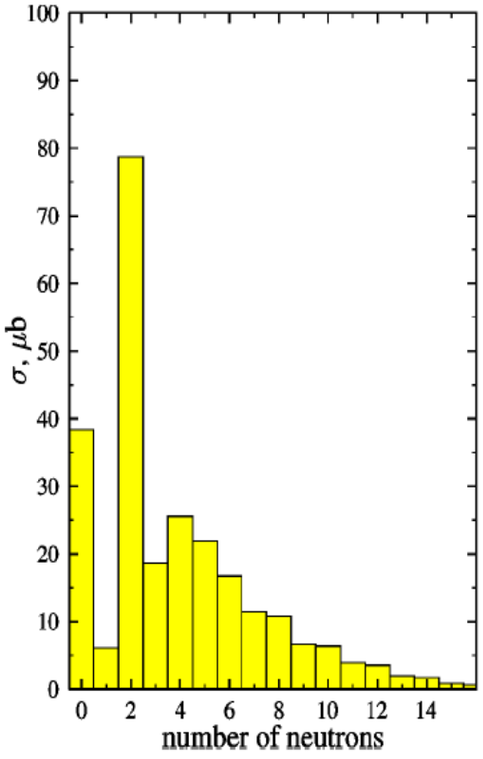
CMS Acceptance for UPC J/ψ

Phys.Lett. B718 (2013) 1273-1283

UPC J/ψ from PbPb 2011 from CMS will complement the ALICE measurements providing coverage of the region ~ 2 < |y| < 2.2

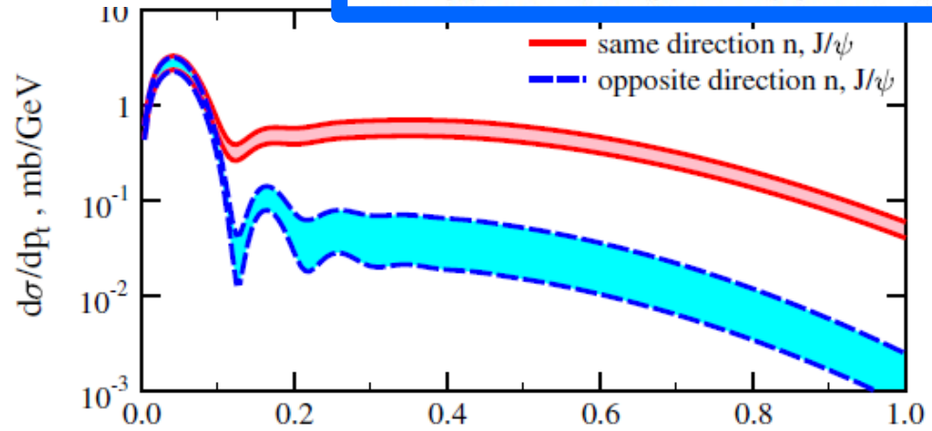
Incoherent UPC J/ψ from PbPb 2011



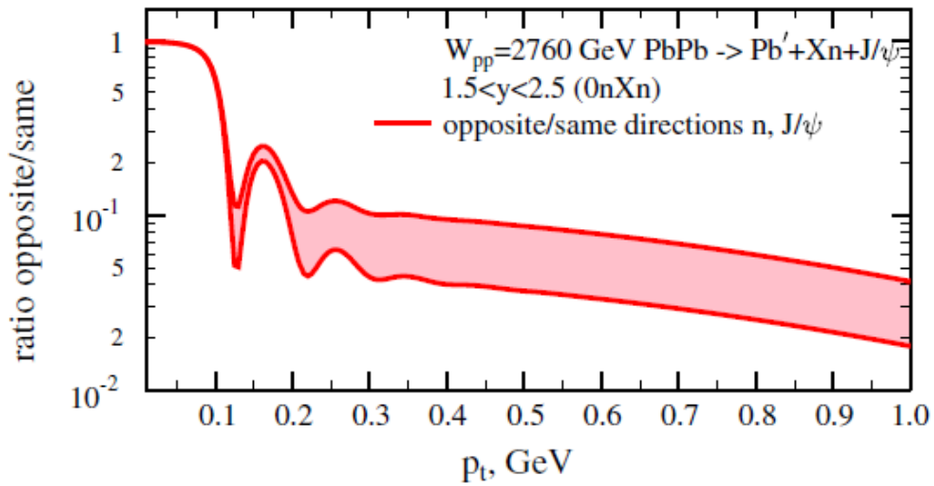


Phys. Lett. B626 (2005) 72–79

$$\frac{d\sigma_{AA\to AA'J/\psi}(y)}{dy} = N_{\gamma/A}(y)\sigma_{\gamma A\to J/\psi A'}(y) + N_{\gamma/A}(-y)\sigma_{\gamma A\to J/\psi A'}(-y)$$



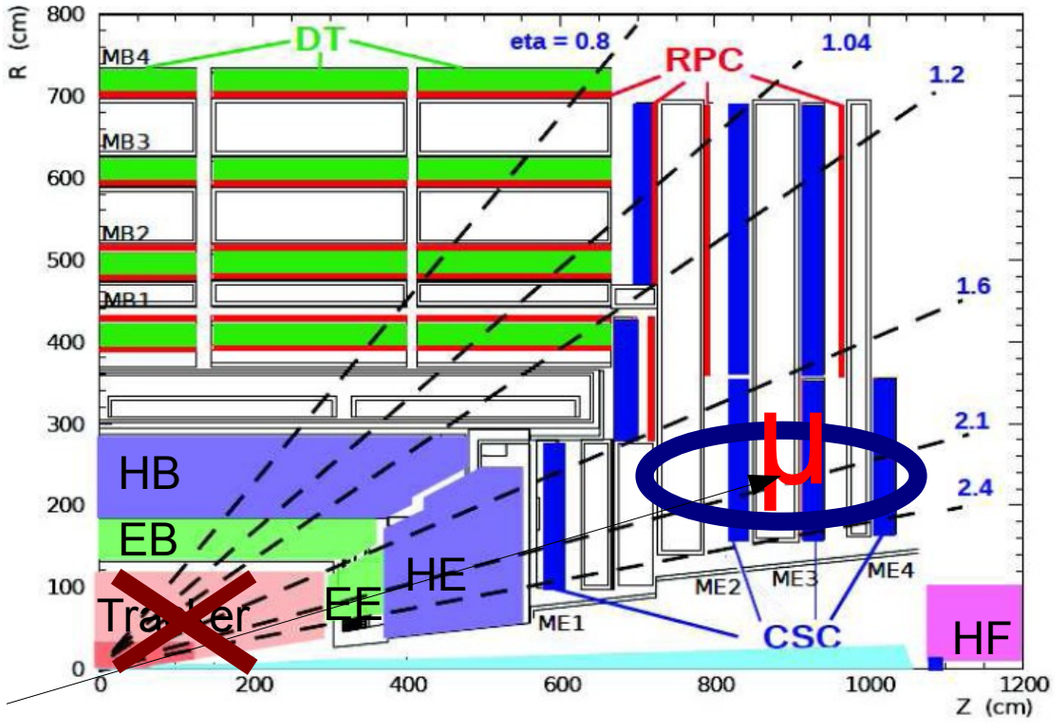
Eur. Phys. J. C (2014) 74:2942



- ZDC trigger requirement enhances incoherent contribution
- Higher p_T compared to coherent production

UPC Triggers for 2013 pPb

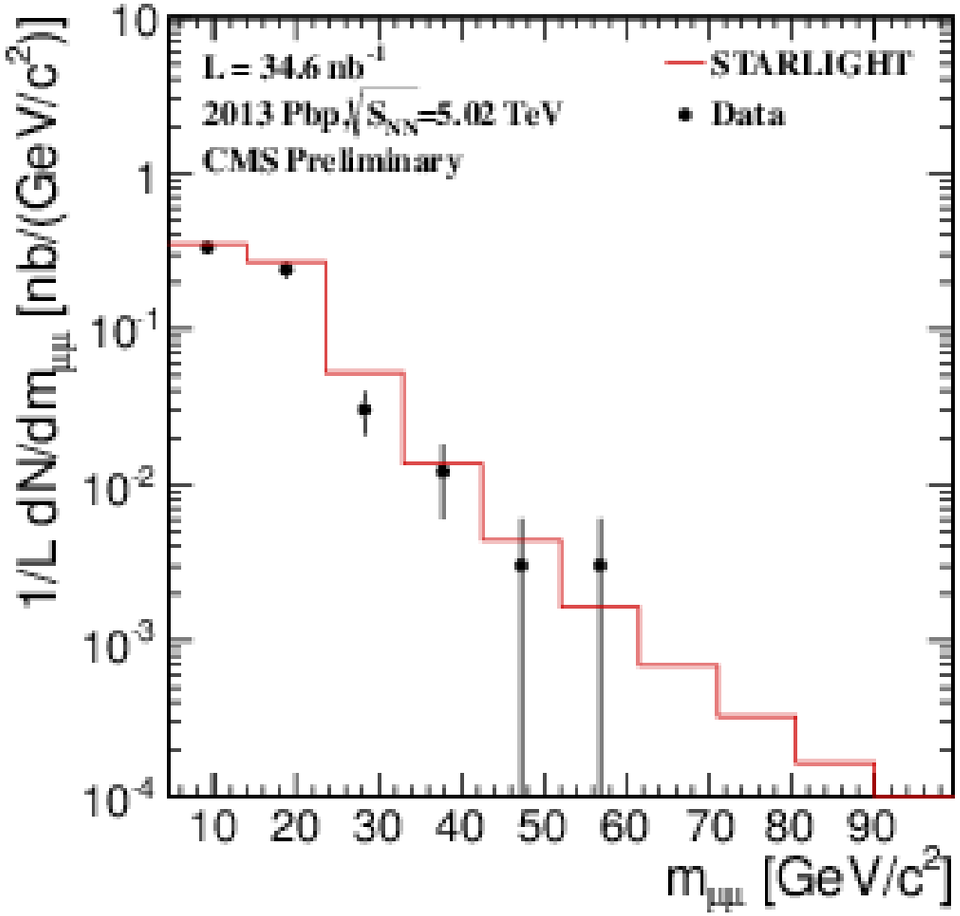
- L1 required loosest muon or electromagnetic calorimeter triggers only
- More sophisticated HLT

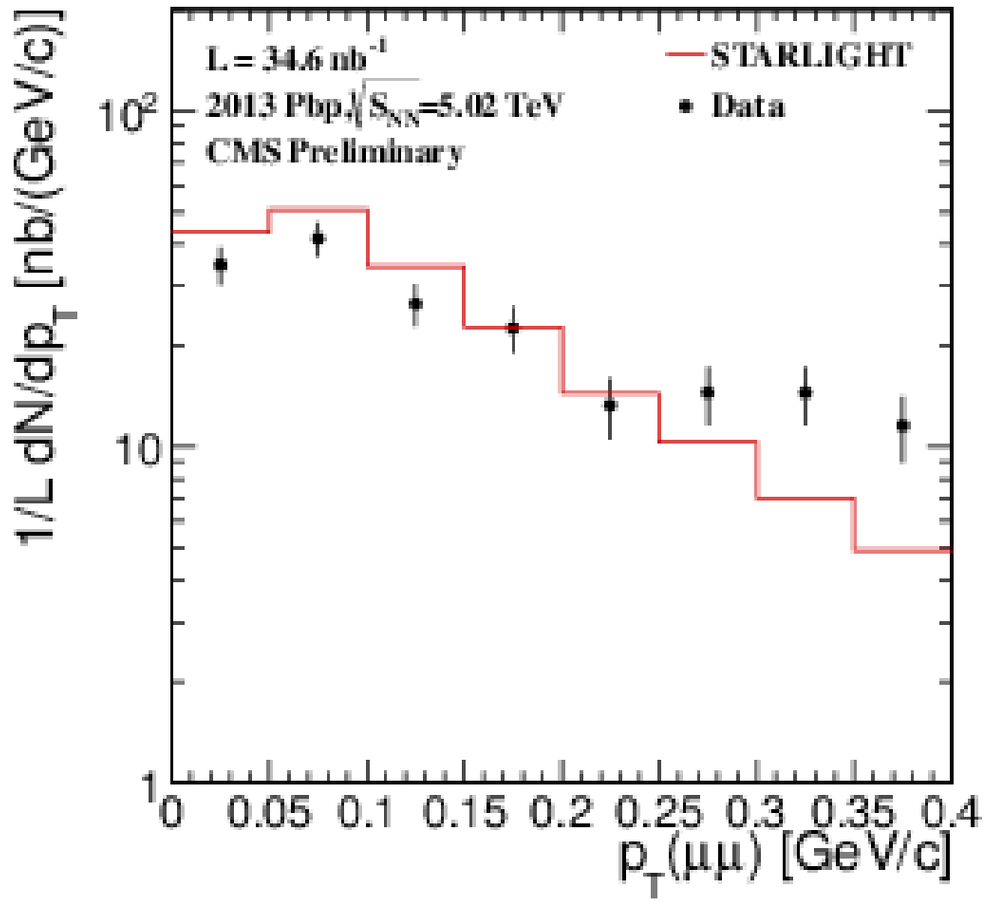


- Higher available L1 bandwidth
  - Removed veto on BSC and requirement of ZDC from the the L1 trigger
- Restrict multiplicity to < 7 tracks in the HLT
- HLT Triggers
  - Require at least one fully reconstruction of dimuon candidate
  - Require < 10 pixel tracks in monitoring path

γγ to μμ in pPb

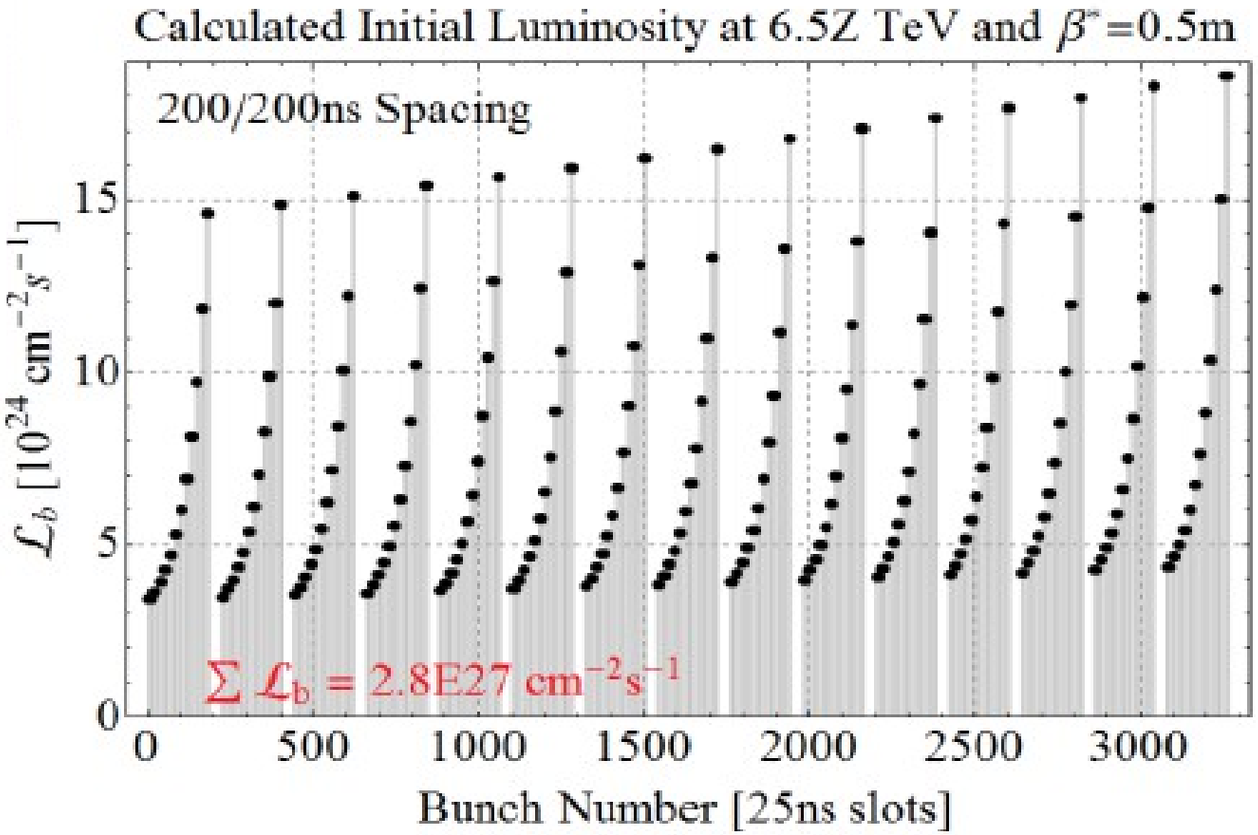
https://twiki.cern.ch/twiki/bin/view/CMSPublic/CMSExclusiveGGMMHighmass





- CMS can explore high dimuon masses in UPC pPb events
- Preliminary results qualitatively agree with STARLIGHT
- Background from other process are not considered

UPC PbPb 2015

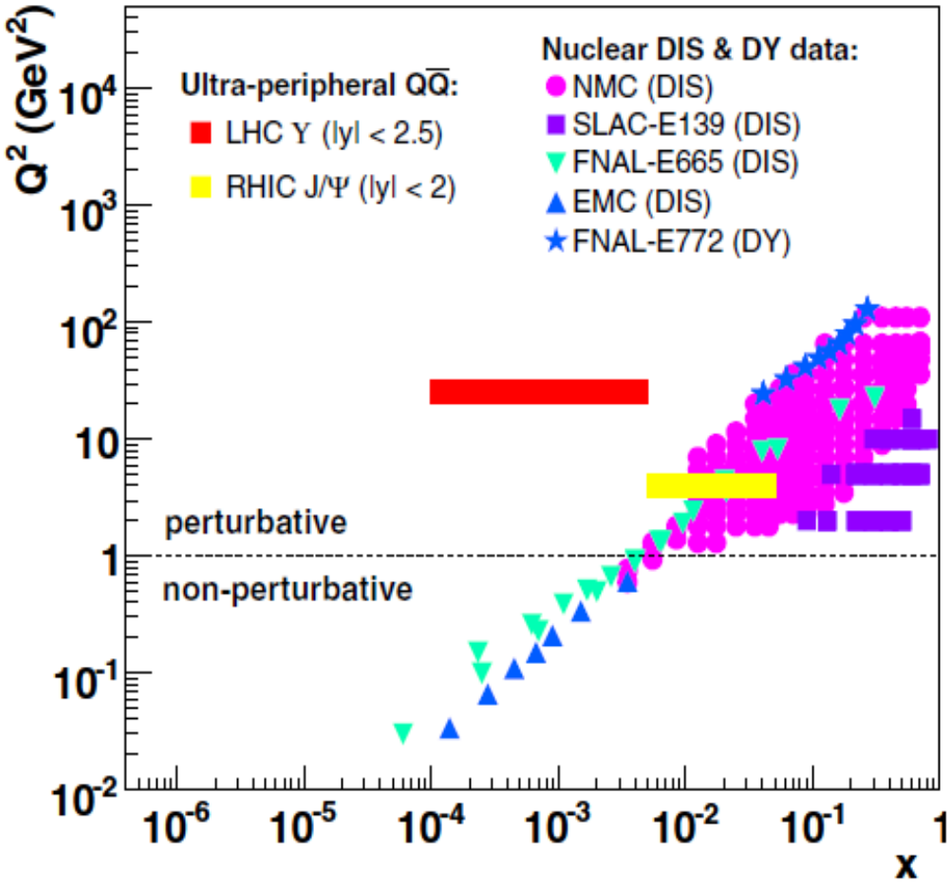


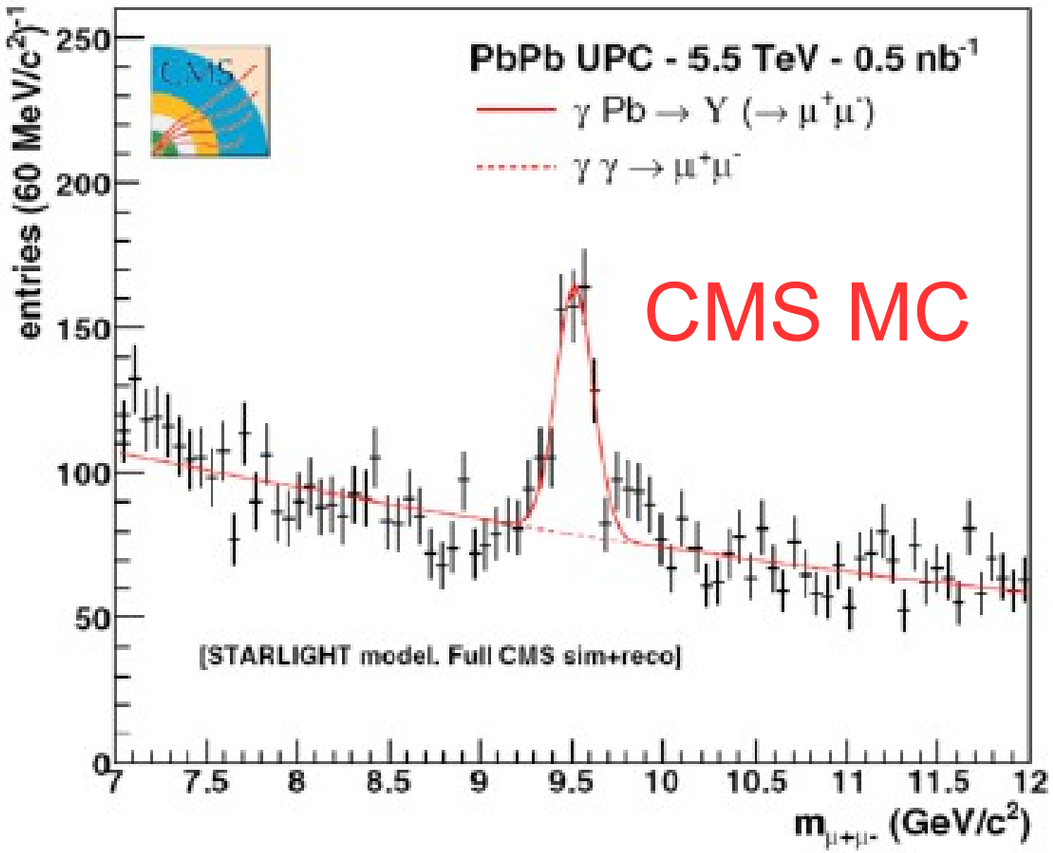
2011: 150 μb^{-1}
at $\sqrt{s_{NN}}$ = 2.76 TeV

2015: 0.5-1.5 nb^{-1}
at $\sqrt{s_{NN}}$ = 5.1 TeV

- About a factor of 5-10 increase in luminosity from 2011 PbPb
- Energy increase by about a factor of 2

UPC Υ in PbPb 2015





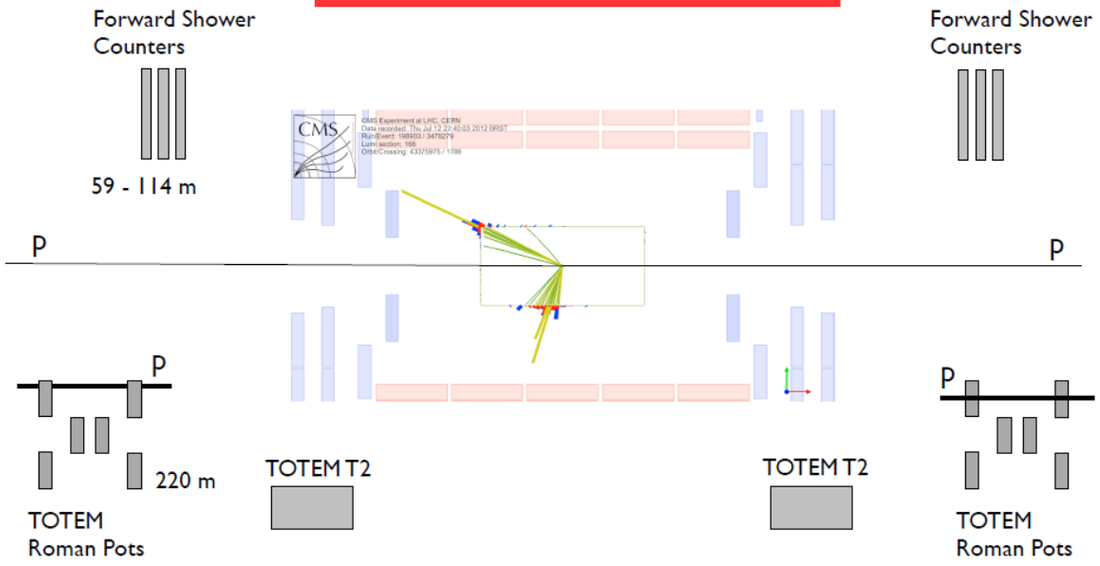
- Increase energy increase the cross section by factor of 4
- Increase rate will improved statistics

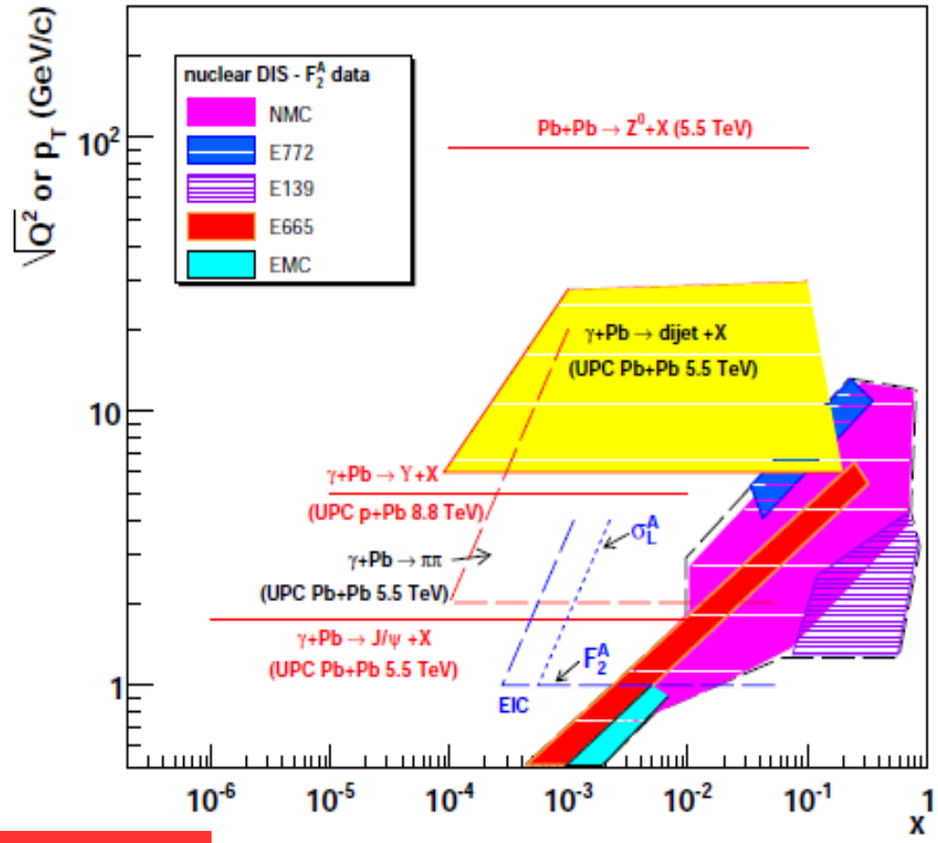
Nuclear Physics B 179–180 (2008) 150–155

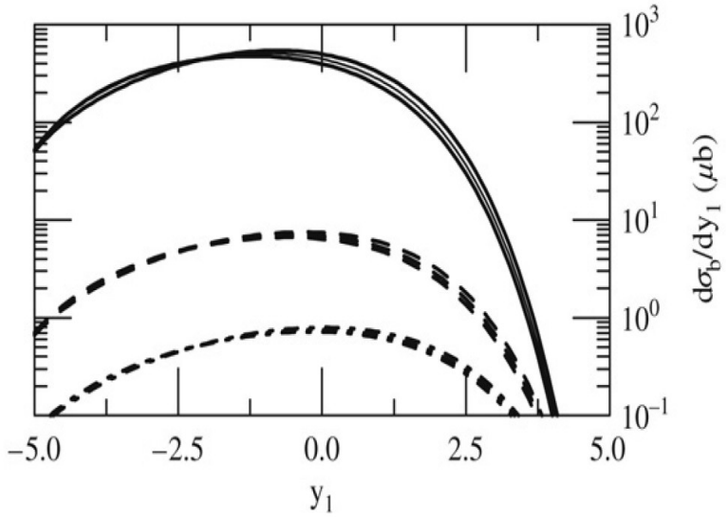
- Triggering without break-up requirement from ZDC will increase the statistics as well
- Expect 200-1000 depending on the delivered luminosity and trigger scheme

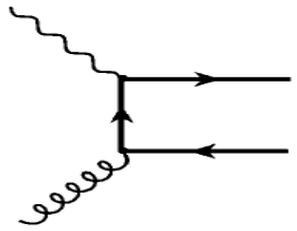
UPC dijets and Heavy Flavor

CMS DP Note 2013-006









Physics Letters B 626 (2005) 72–79

- UPC dijets can be measured in 2015
- Trigger and event selection development needed

Summary

- UPC data from 2011 PbPb and 2013 pPb already on tape
- Ability to measure coherent UPC J/ψ has been shown and the measurement from PbPb will be out soon
- Incoherent production is well suited to the 2011 trigger offering the opportunity to look at rapidity correlations between the J/ψ and neutrons
- Lepton pair production demonstrated in pPb and studies of UPC J/ψ and Υ are underway
- 2015 offers a clear opportunity to look at UPC dijets and Υ