Photon physics at CMS

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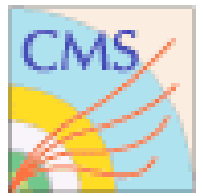
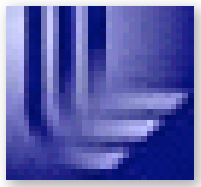
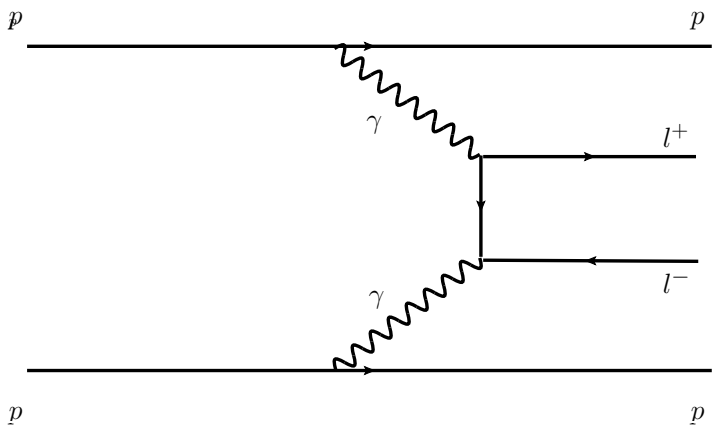




$\gamma\gamma \rightarrow l^+l^-$ interactions

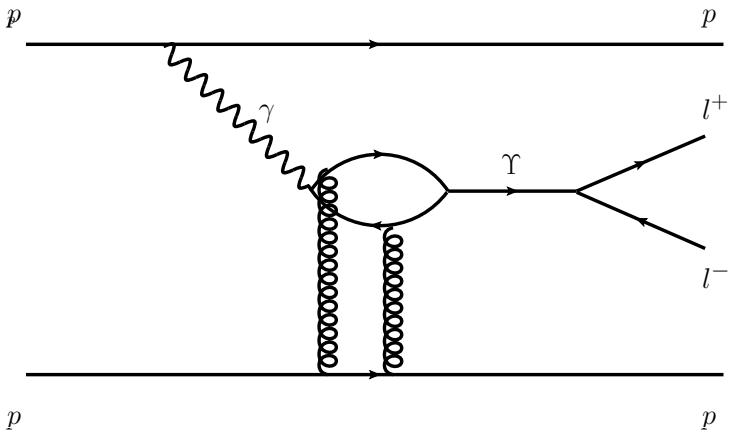
- QED process - elastic (protons stay intact) cross-section is known to ~1%
- Theoretically less clean inelastic (proton-dissociation) events are treated as background



- At startup/low-luminosity
  - Candidate for aboslute luminosity normalization
  - Low p_T lepton ID studies
  - Reference for other "exclusive" analyses

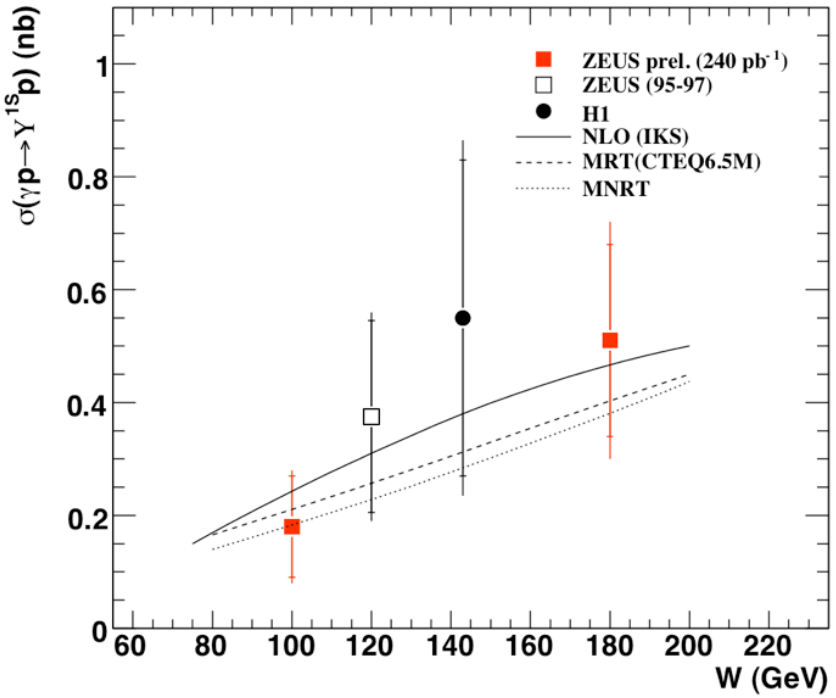
- At high-luminosity
  - Alignment sample for forward proton detectors (FP420 etc.)
  - "Standard candle" for BSM searches in very high energy $\gamma\gamma$ interactions: ($\gamma\gamma \rightarrow \tilde{l}^+\tilde{l}^-$, $\gamma\gamma \rightarrow H^{++}H^{--}$, $\gamma\gamma \rightarrow W^+W^-$ couplings, $\gamma\gamma \rightarrow M\bar{M}$, $\gamma\gamma \rightarrow G \rightarrow l^+l^-$, $\gamma\gamma \rightarrow \gamma\gamma$, etc.)

Vector-meson photoproduction



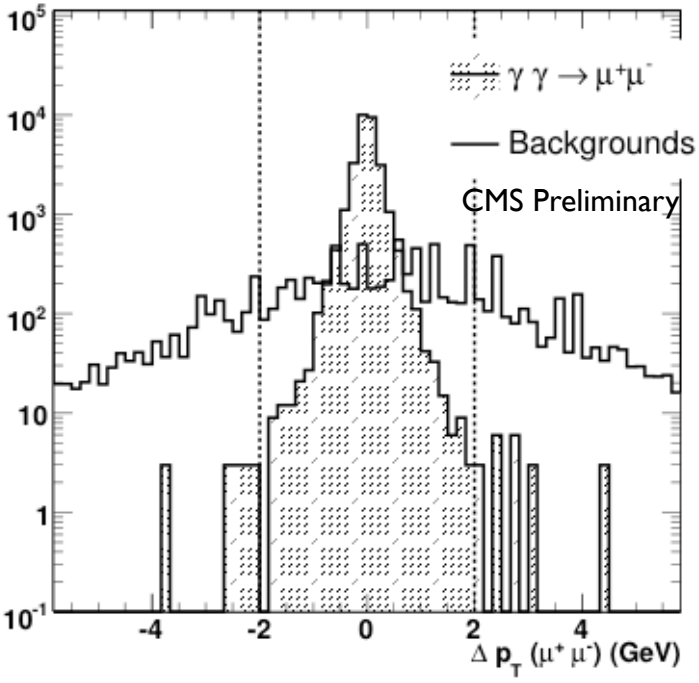
- At CMS, low-mass mesons are difficult to trigger on, but ϒ is accessible in the dilepton channel
  - Probe of generalized parton distributions

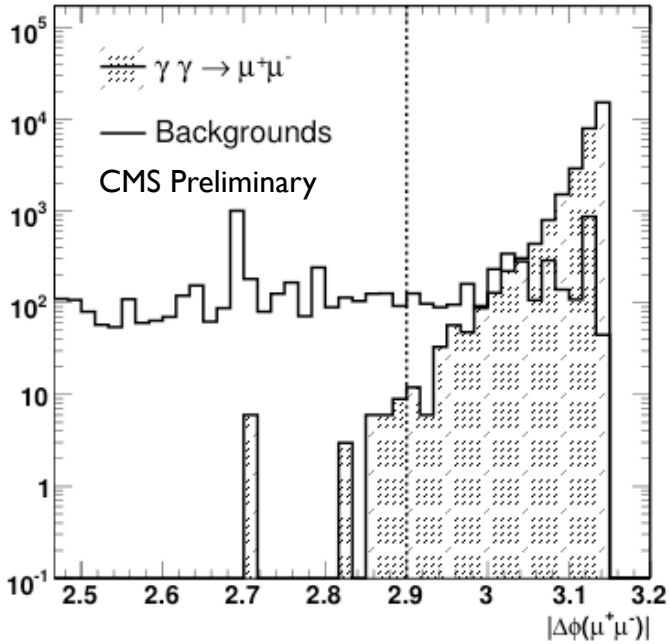
- Cross-sections have been measured at HERA with W_{vis}~100-200GeV
  - At CMS, W_{vis}~550GeV (14TeV)
- Also possible to study Upsilon "t" and η distributions



W_{vis} (γp CM energy)

Samples and l^+l^- selection



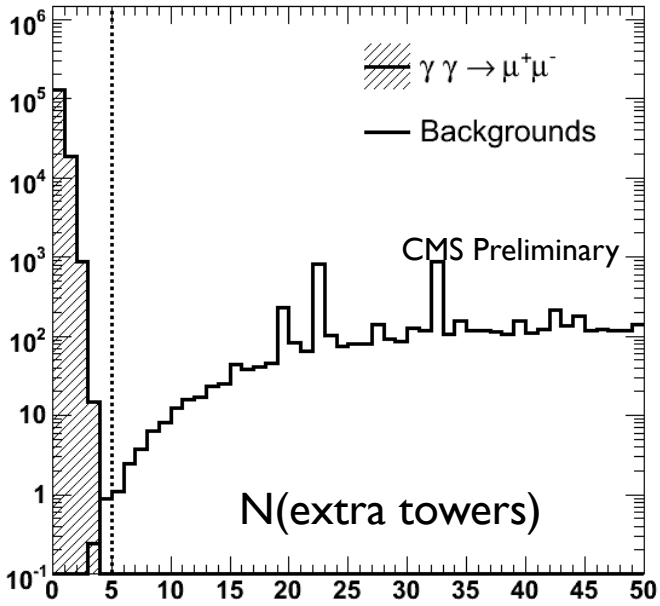


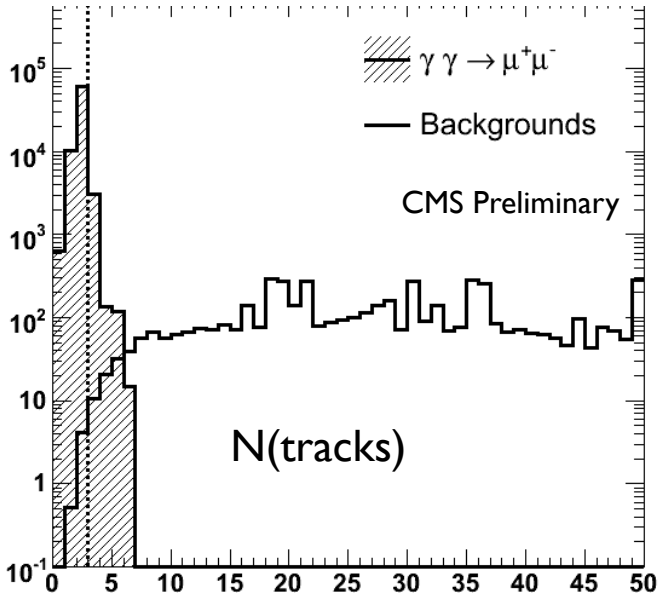
Arbitrary normalization

- Full simulation study for $\sqrt{s}$=14 TeV *pp* collisions using LPAIR and STARLIGHT (J. Nystrand) for signal, Pythia for backgrounds
  - Standard startup 3 GeV dimuon trigger, 6 GeV dielectron trigger
  - Offline analysis: require leptons be back-to-back ($|\Delta\phi| > 2.9$ rad) and balanced in p_T ($|\Delta p_T| < 2.0$ GeV)

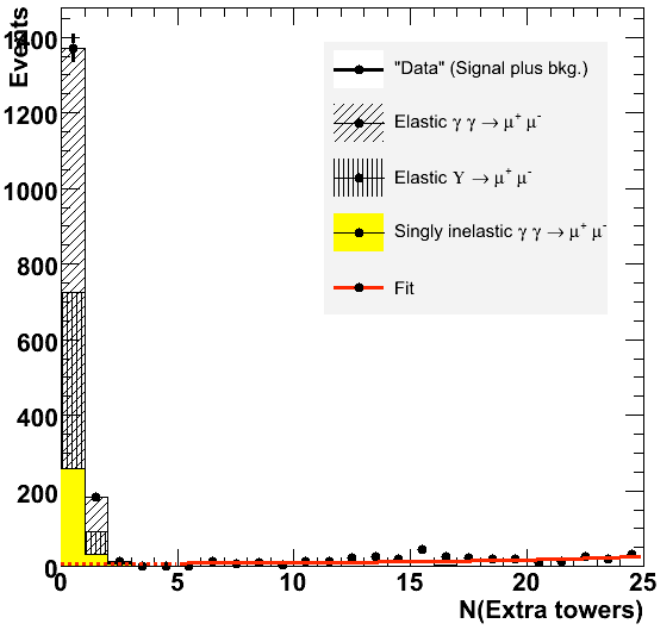
"Exclusivity" selection

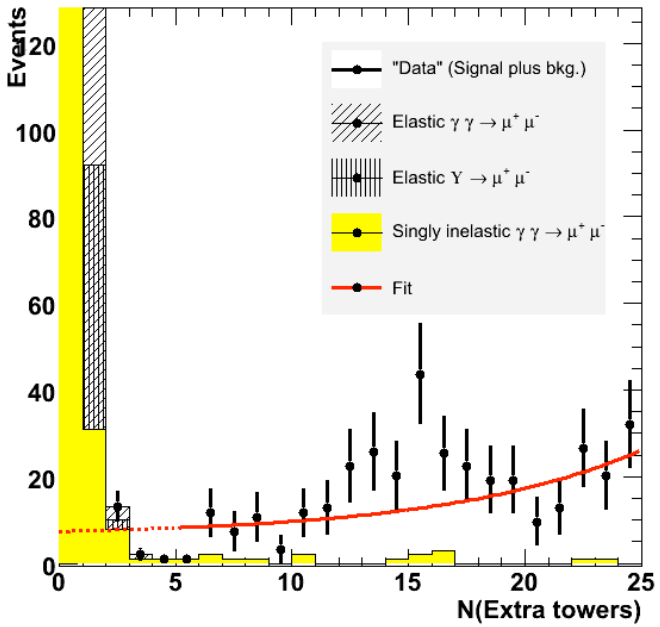
- With low pileup/beam backgrounds, signal events are "exclusive"
- Require no significant extra activity in calorimeter/tracker volume
  - < 5 extra towers with E > 5 GeV in the hadronic calorimeter ($|\eta| < 5$)
  - < 3 tracks in the event ($|\eta| < 2.4$)
- Vetoes on activity in the forward CASTOR ($5.2 < \eta < 6.6$) and Zero Degree Calorimeter ($|\eta| > 8.1$) detectors to further suppress the inelastic backgrounds





Background estimation



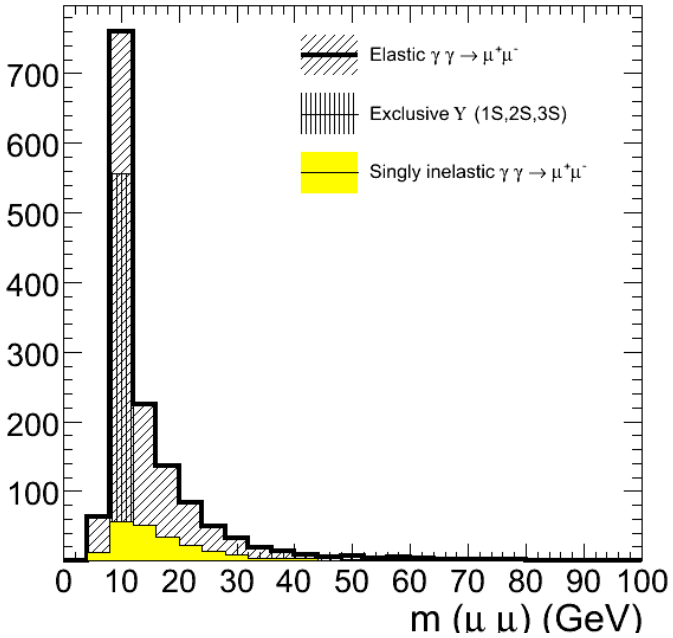


Magnified sideband region

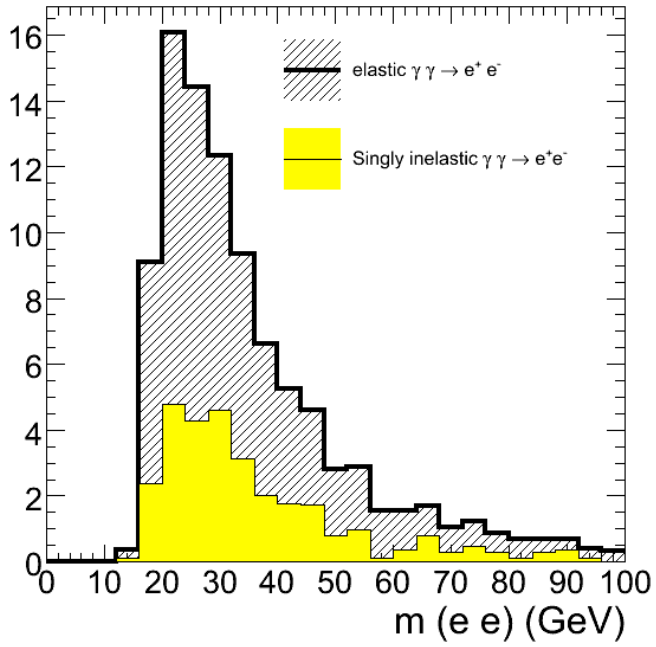
- Residual inclusive backgrounds can be estimated from data
  - Apply all selections except the N (towers) cut, and extrapolate from the sideband into the signal region
- In MC, this gives an estimate of ~40 events
  - Factor of ~5 smaller than the inelastic background

Final samples

- For 100pb^{-1}, expect ~700 elastic $\gamma\gamma \rightarrow \mu\mu$ events, over a background of ~200 inelastic events (~600 without CASTOR/ZDC vetos)
- Several hundred $\gamma p \rightarrow \Upsilon \rightarrow \mu\mu$ events

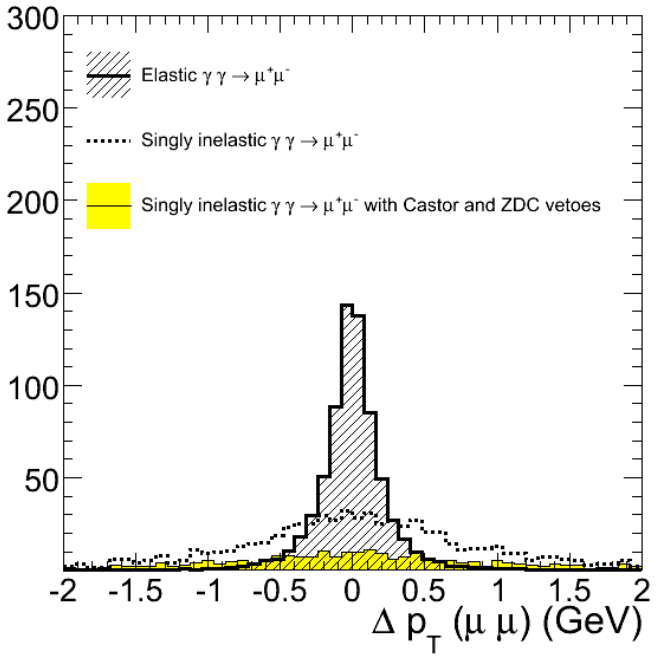


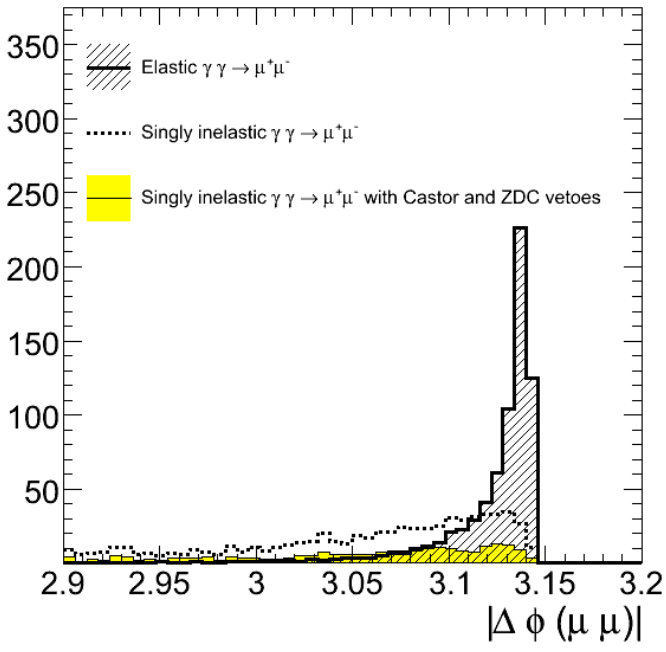
- ~70 elastic $\gamma\gamma \rightarrow e^+e^-$ events with inelastic background of ~30 (~80 without CASTOR/ZDC)
- Without improvements to electron triggers, no sensitivity to the $\Upsilon \rightarrow ee$ mass region



Luminosity prospects

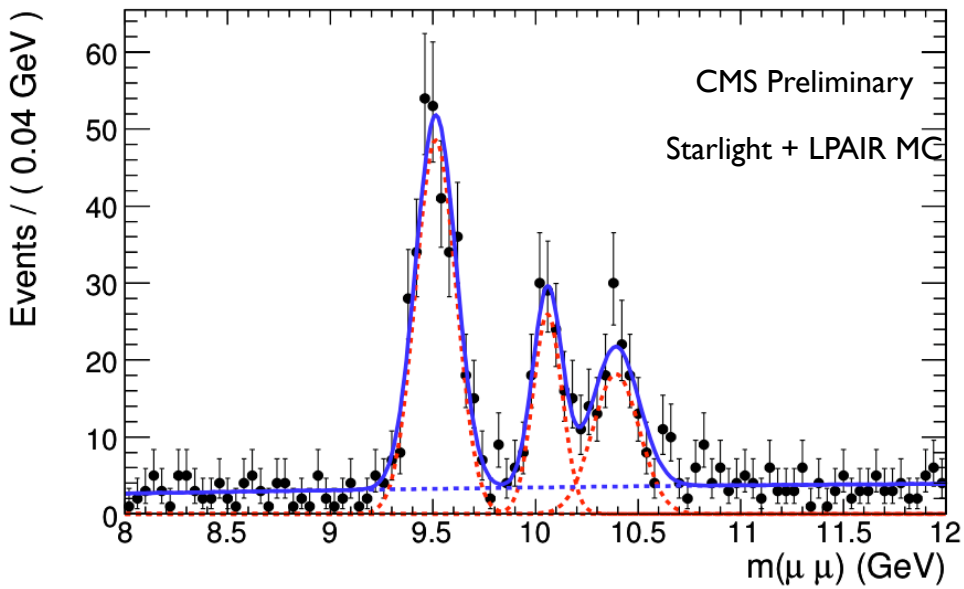
- Theory uncertainties on the elastic $\gamma\gamma \rightarrow \mu\mu$ cross-section are ≈1%
- For 100pb^{-1} at 14TeV, $\sqrt{N}/N \approx 4\%$ after all cuts
  - Non-zero background, but signal can still be statistically separated using $\Delta\phi$ and Δp_T shapes
- Depends on controlling experimental systematics (trigger efficiency, background subtraction, etc.)
- For comparison of luminosity measurements at the LHC, see **arXiv:0903.3861**

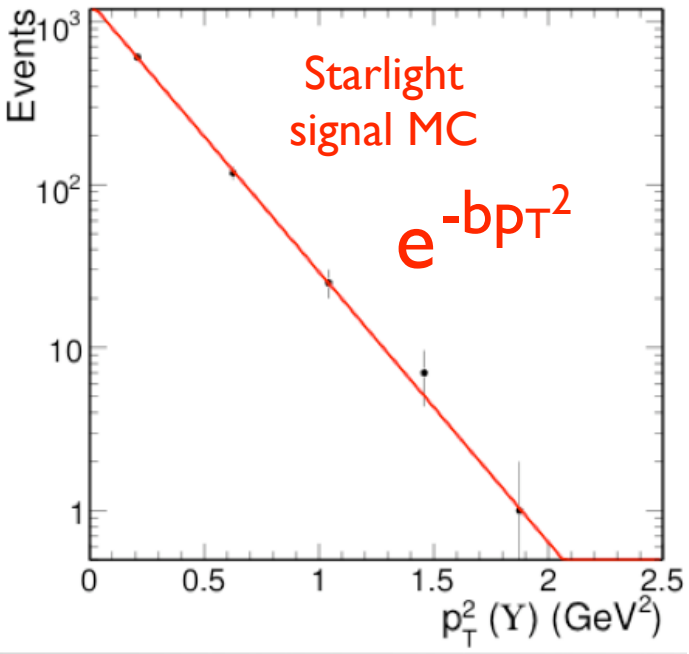




Upsilon region

- After all selections, fit the invariant mass spectrum in the region 8-12 GeV
- First 3 Upsilon resonances should be clearly visible above QED continuum
  - Not included here: $X_b \rightarrow \Upsilon\gamma$



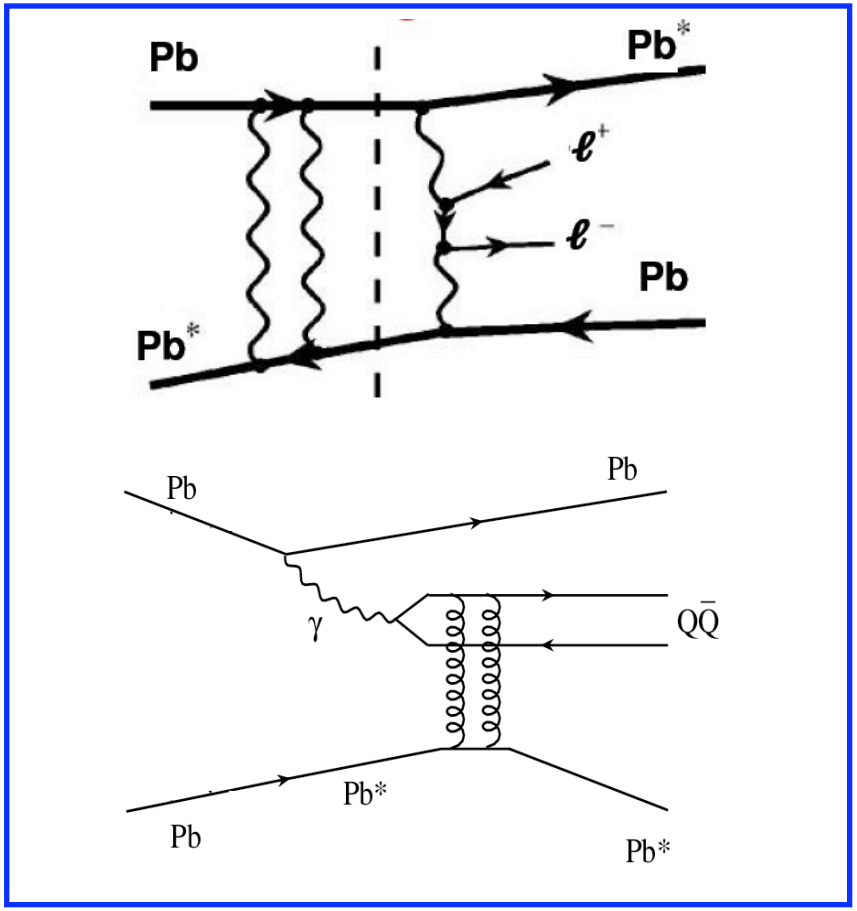


- Sufficient statistics to study the "t" distribution - approximated by the measured p_T^2 of the Upsilon

b(reco p_T^2) = 3.82 ± 0.17 GeV^2
b(true t) = 4.03 ± 0.04 GeV^2

Heavy Ions

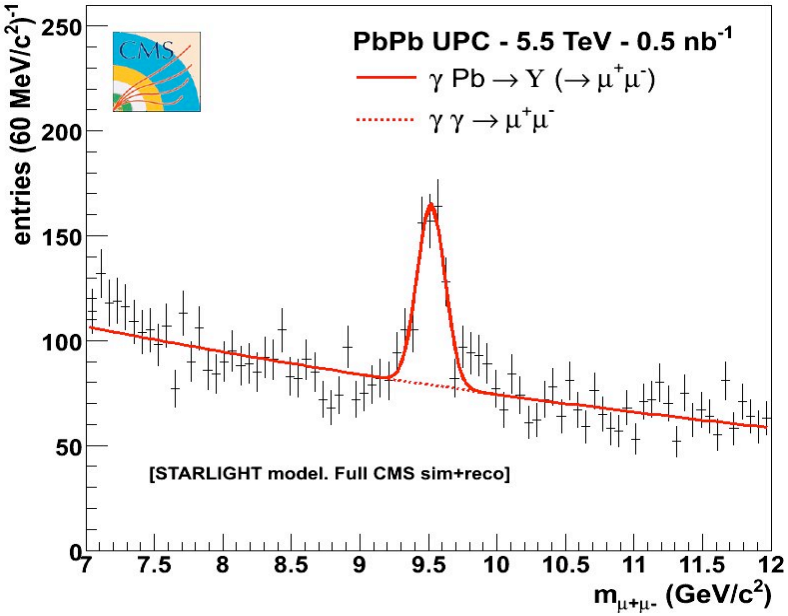
- "Ultraperipheral" γγ and γ*A* interactions are a major part of the heavy ion physics program in CMS
- Lower energy than *pp* collisions, but much larger cross-sections (Z^4 enhancement for γγ, Z^2 enhancement for γ*A*)
  - e^+e^- channel accessible due to low instantaneous luminosity and relatively "open" triggers

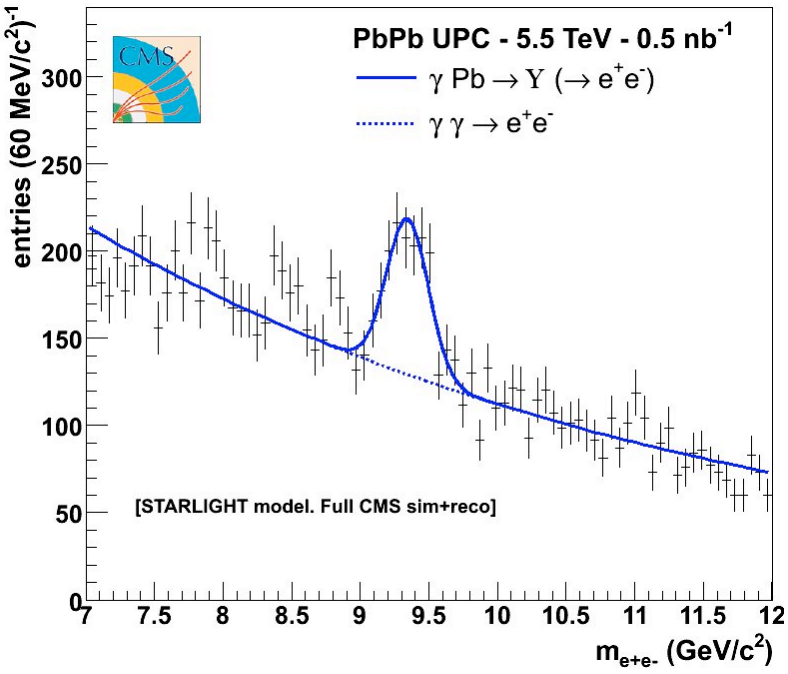


- γ*A*: Upsilon photoproduction (study of nuclear PDF's)
- γγ: Test of higher-order QED effects ($Z\alpha \approx 0.6$)

Heavy Ion (PbPb) results

- Full simulation study for $\sqrt{s}$=5.5 TeV *PbPb* collisions, using STARLIGHT Monte Carlo
- Trigger on events with a $\mu^+\mu^-$ or e^+e^- pair identified in CMS, no activity in the forward hadronic calorimeter ($3<|\eta|<5$), and a neutron detected in the ZDC
- For 0.5nb^{-1}, expect ~180 $\gamma Pb \rightarrow \Upsilon \rightarrow \mu\mu$ events, ~220 $\gamma Pb \rightarrow \Upsilon \rightarrow ee$ events (STARLIGHT cross-sections)
- Continuum background subtracted using like-sign dilepton sample



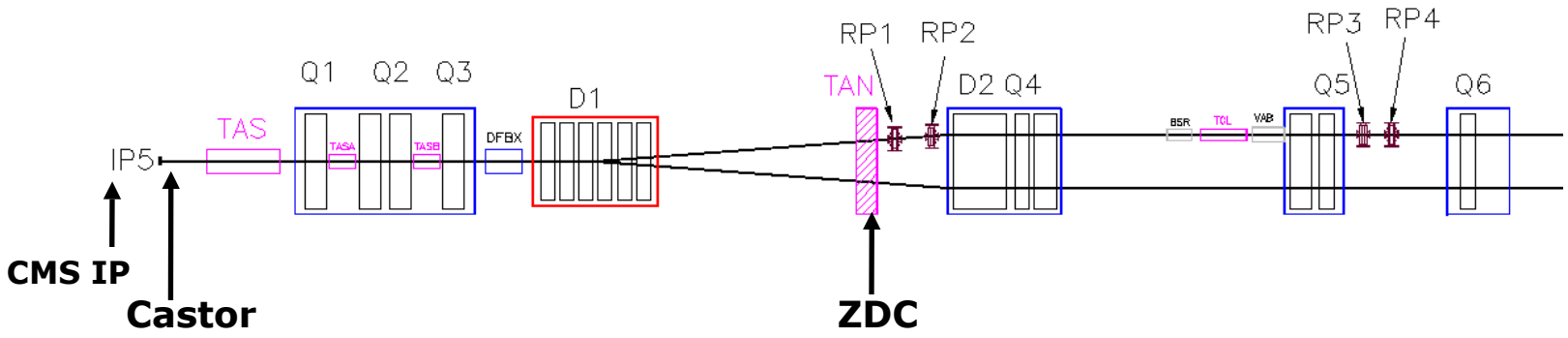


Conclusions

- With 100pb^{-1} of *pp* collisions at at 14 TeV, CMS expects to trigger on and reconstruct several hundred elastic $\gamma\gamma \rightarrow \mu\mu$ and $\gamma p \rightarrow \Upsilon p \rightarrow \mu\mu p$ events
  - Plus a sample of $\gamma\gamma \rightarrow ee$ events
  - With minimal pileup, these can be cleanly separated from the dominant inelastic backgrounds
- With < 1nb^{-1} of *PbPb* collisions at 5.5 TeV, CMS can trigger and reconstruct several hundred $\gamma Pb \rightarrow \Upsilon \rightarrow \mu\mu$ and $\gamma Pb \rightarrow \Upsilon \rightarrow ee$ events
- $\gamma\gamma$ and γp interactions will play a major role in any future forward detector projects in CMS - both for alignment and BSM searches (see talk by K. Piotrzkowski Tuesday)

Backup

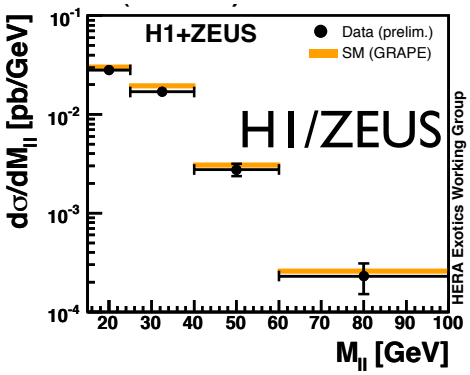
CMS forward calorimeters

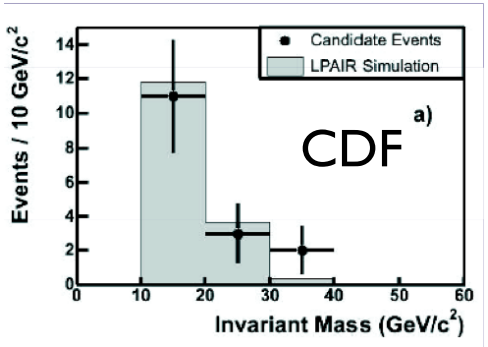


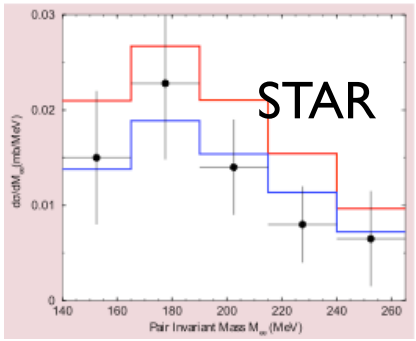
- "Baseline" CMS forward hadronic calorimeter (HF) extends to $|\eta| < 5$
- Castor: quartz-tungsten sampling calorimeter
  - ~14 m from IP, covers $5.2 < |\eta| < 6.6$ (one side only at startup)
- ZDC: quartz-tungsten sampling calorimeter
  - ~140 m from IP

Recent γγ and γp results

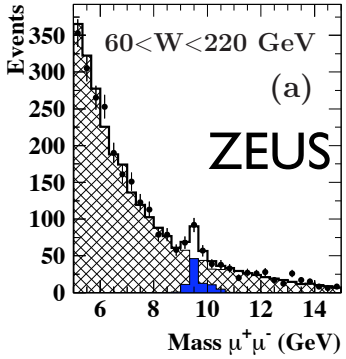
QED

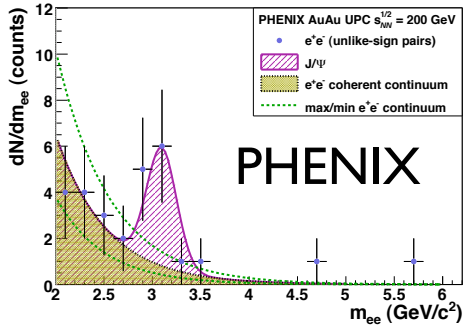


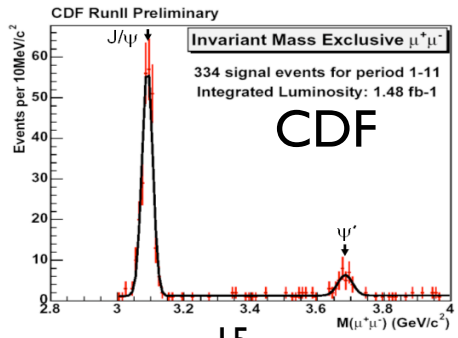




Vector-meson photoproduction







BSM/high pT