Exclusive dileptons at CMS

($\gamma\gamma \to l^+l^-$ and $\gamma p \to \Upsilon p \to l^+l^- p$)

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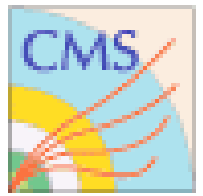
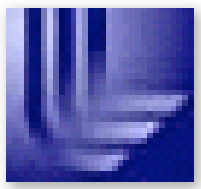
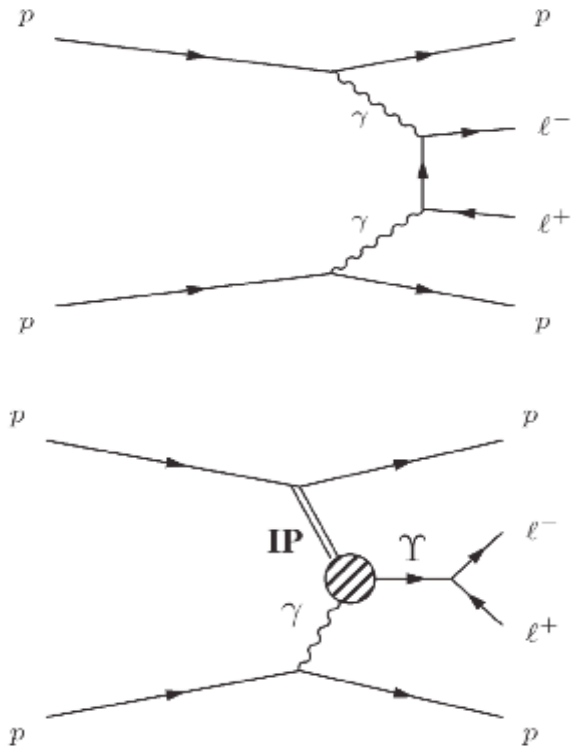




Signal processes

- Excusive dileptons
  - Two leptons, back to back in ϕ, balanced in p_T
  - "Elastic" interactions: protons remain intact & escape down beamline - no other activity in detector (in limit of zero pileup - assumed here for startup)

- Two processes relevant for CMS - identical selection used for both:
  - Two-photon production - non-resonant lepton pairs from $\gamma\gamma \rightarrow l^+l^-$
  - Photoproduction - lepton pairs through Upsilon resonances via $\gamma p \rightarrow \Upsilon \rightarrow l^+l^-$



Two-photon physics

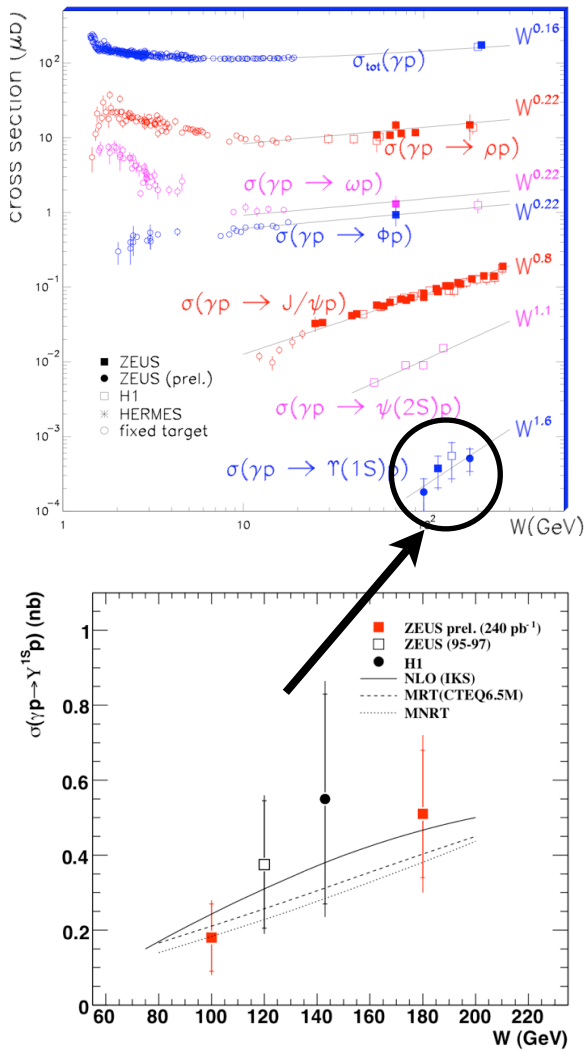
- QED process - minimal uncertainties on the cross-section, highly constrained 4-body final state

- Startup applications - candidate for:
  - Luminosity calibration
  - Low p_T lepton ID studies

- High-luminosity applications
  - Alignment sample for forward proton taggers
  - "Standard candle" for BSM physics in high energy $\gamma\gamma$ interactions: $\gamma\gamma \to \tilde{l}^+\tilde{l}^-$, $\gamma\gamma \to H^{++}H^{--}$, $\gamma\gamma \to \gamma\gamma$, $\gamma\gamma \to W^+W^-$ couplings, etc. (see talks tomorrow)

Upsilon photoproduction

- Narrow resonance, two ~5 GeV muons
  - cross-check low p_T muon reconstruction
- QCD/diffractive physics (a la HERA)
  - cross-section, t-distribution (momentum transfer at p-vertex) depend on generalized parton distributions/correlations within the proton
  - W-dependence of cross-section well measured for light-quark mesons at lower energies
  - Heavy flavor ($b\bar{b}$) mesons studied up to HERA energies, LHC extends energy by ~1 order of magnitude



X CMS

W (γp CM energy)

MC and trigger

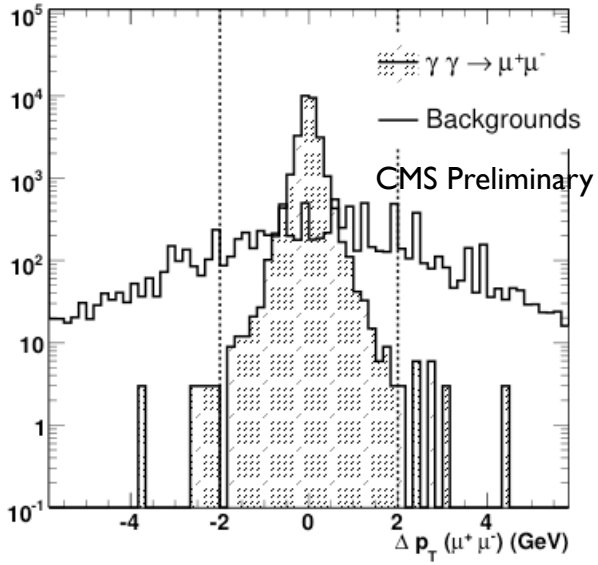
- Full simulation, reconstruction, & trigger emulation applied to all samples
  - Two-photon (elastic + inelastic): LPAIR
  - Upsilon photoproduction:
    - STARLIGHT ($\sigma \times B(\Upsilon(1S) \rightarrow \mu\mu) = 39.0$ pb)
    - Also compared to PHITI - σ lower by a factor of 3
    - (Thanks to J. Nystrand, J de Favreau)
- Signal is mostly very soft leptons - use lowest possible trigger thresholds
  - Standard CMS startup dimuon trigger ($p_T > 3$ GeV)
  - Dedicated dielectron trigger ($E_T > 6$ GeV)

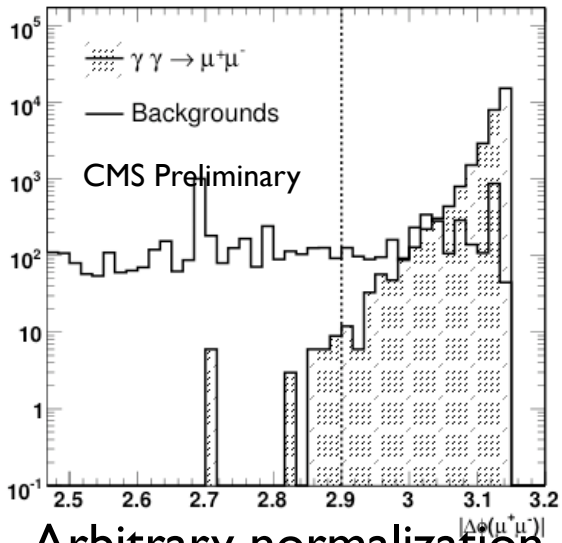
Dilepton selections

- Offline analysis selection: require exactly 2 reconstructed opposite-sign muons or electrons
- Signal is sharply peaked at $|\Delta\phi| = \pi$ and $\Delta p_T = 0$

Select events with:
Δp_T (μμ) < 2.0 GeV
$|\Delta\phi(\mu\mu)| > 2.9$

ΔE_T (ee) < 5.0 GeV
$|\Delta\phi(ee)| > 2.7$

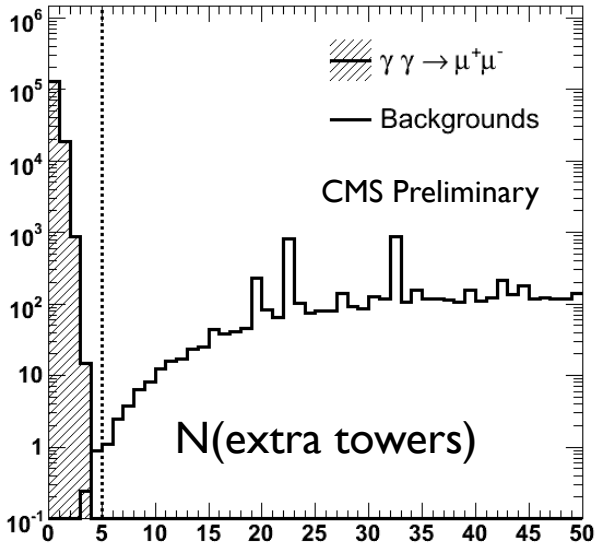




Arbitrary normalization

Exclusivity

- Calorimeter exclusivity: backgrounds contain "extra" calorimeter tower and/or charged tracks
  - "Extra" towers: E > 5 GeV, isolated from either of the lepton candidates by R > 0.3 in the η-ϕ plane
- Tracker coverage in central region (|η| < 2.5)

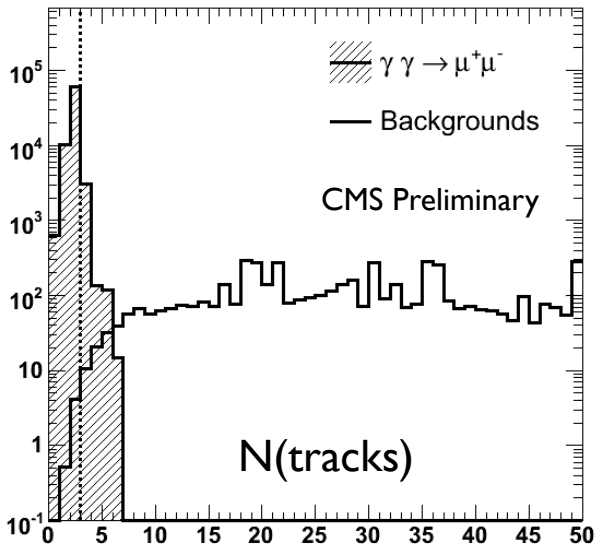


Select events with:

N(extra towers) < 5

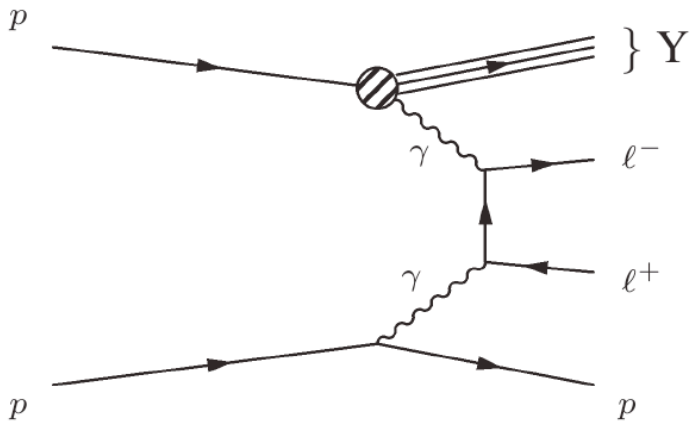
N(tracks) < 3

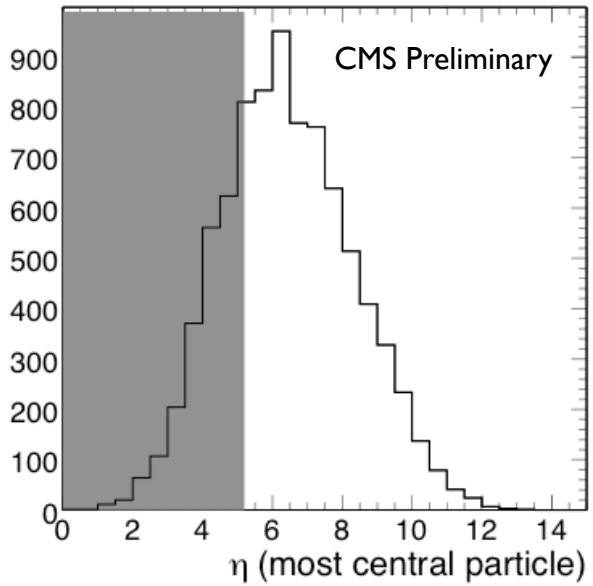
(same for electrons & muons)



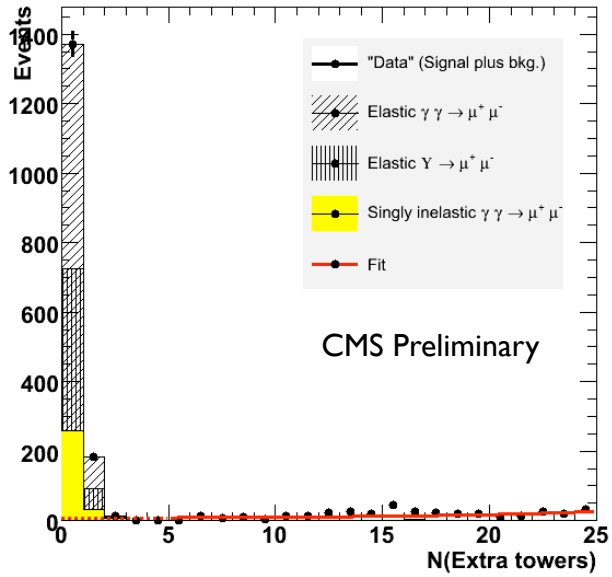
Inelastic backgrounds

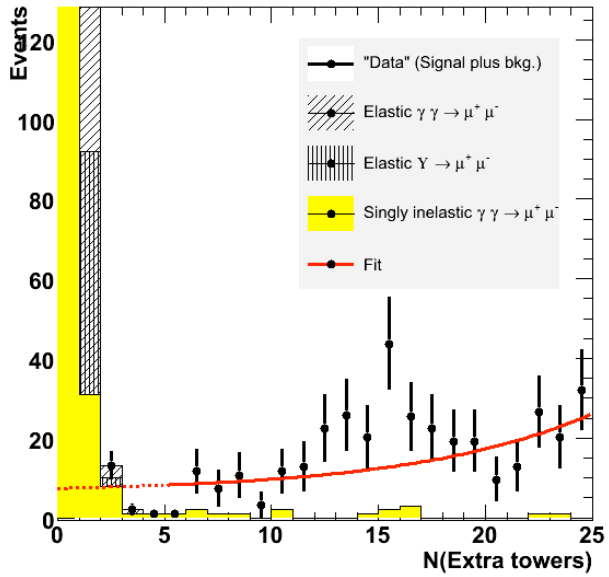
- Irreducible background from inelastic photon-exchange events
  - Cross-section similar to elastic signal, theoretically less clean
  - In 75% of these events, expect no activity within CMS forward hadron calorimeter (HF) acceptance
- Reduce by vetoing with far-forward calorimeters
  - ZDC (Zero Degree Calorimeter): Detection of neutrals in the range $|\eta| > 8.6$
  - Castor: Detection of charged/neutral activity in the range $5.2 < |\eta| < 6.6$
  - Based on acceptance, 2/3 of remaining inelastic events can be rejected using ZDC (2 directions) + Castor (1 direction)





Backgrounds/systematics





Magnified sideband region

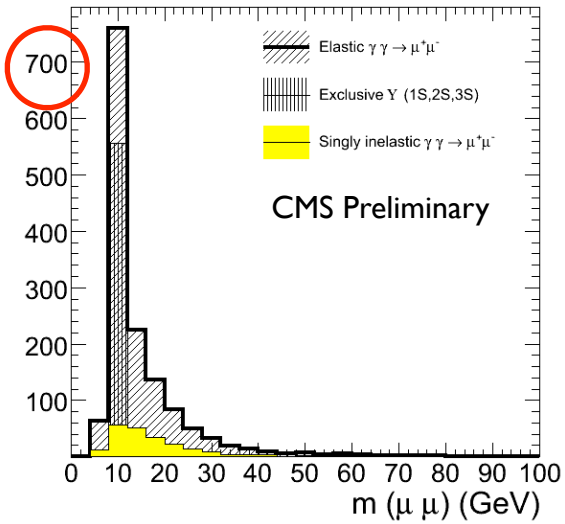
- Remaining non-inelastic backgrounds will be estimated from data by fitting sidebands of calorimeter tower multiplicity distribution
  - In MC, this contribution is smaller than the inelastic background by a factor of 5
- Systematics
  - Inelastic background: assume 19% uncertainty based on CDF study
  - Calo noise: Studied, small effect after cleanup of hot/dead channels

Final samples (100 pb^{-1})

- In MC, several hundred two-photon and Upsilon events pass the final selection in the dimuon channel

709 ± 27 (stat) elastic events
223 ± 15 (stat) ± 42 (model) singly inelastic events

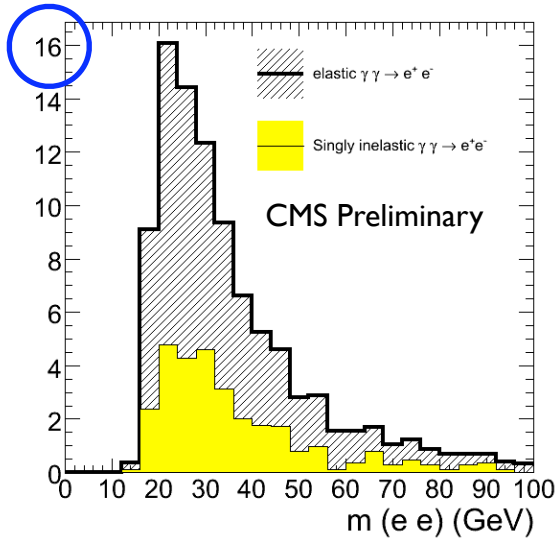
636 ± 25 (stat) ± 121 (model) singly inelastic events, no ZDC/Castor



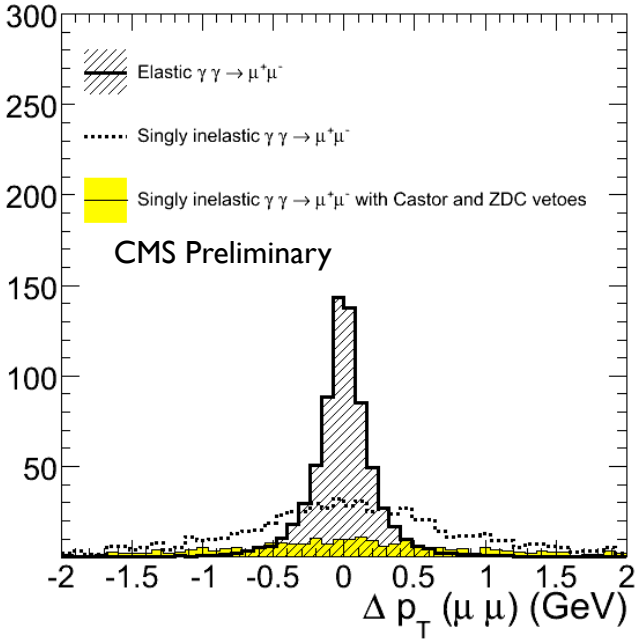
- Electron sample a factor of ~10 smaller due to higher trigger threshold, efficiency for low E_T electron reconstruction
  - No sensitivity to Upsilon region

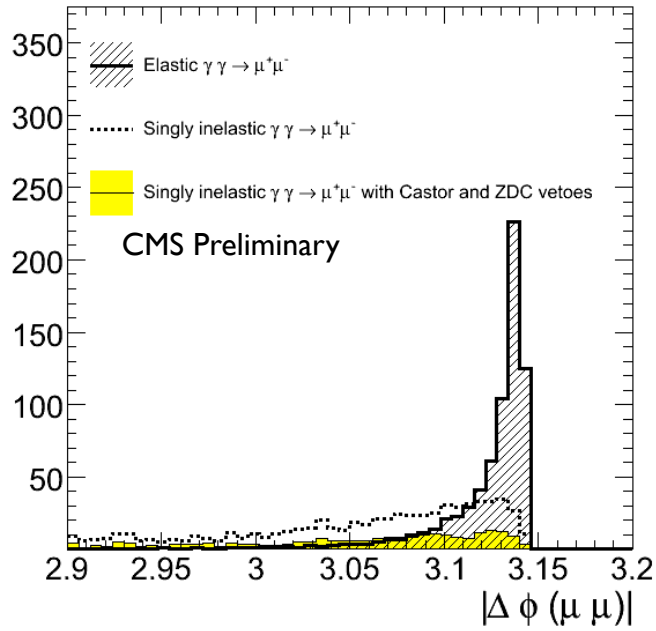
67 ± 8 (stat) elastic events
31 ± 6 (stat) ± 6 (model) singly inelastic events

82 ± 9 (stat) ± 15 (model) singly inelastic events, no ZDC/Castor



Luminosity prospects

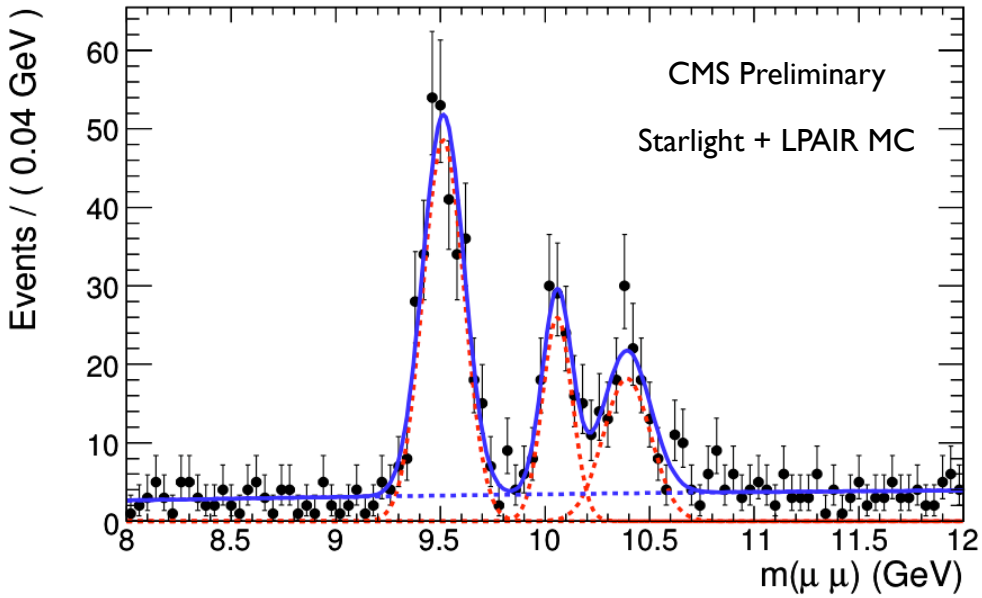


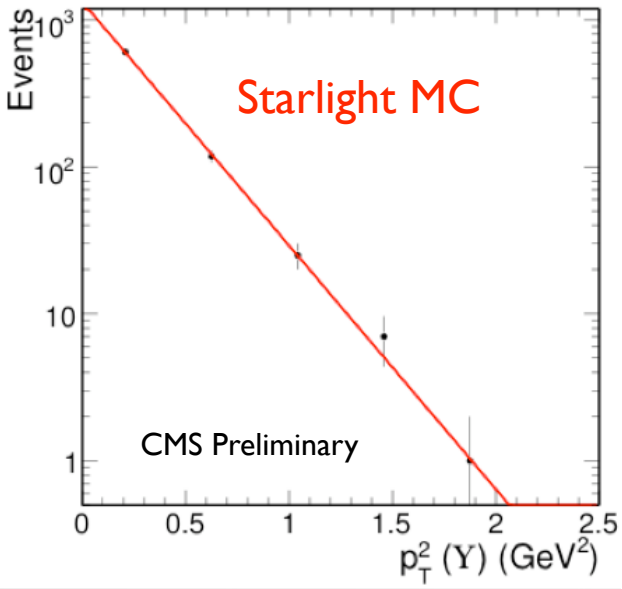


- Elastic events can't be separated event-by-event due to inelastic background
- Can be done statistically using differences in shapes of $\Delta\phi$ and Δp_T distributions within signal region
  - Precision would be improved with forward Castor/ZDC vetos

Upsilon region

- Significant sample of first 3 Upsilon resonances can be observed over two-photon continuum with 100 pb^{-1} of single-interaction data





- proton 4-momentum transfer "t" highly correlated with Upsilon p_T^2
  - Fit p_T^2 distribution to find the slope parameter b
  - Consistent with true value of "t" up to a small bias

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

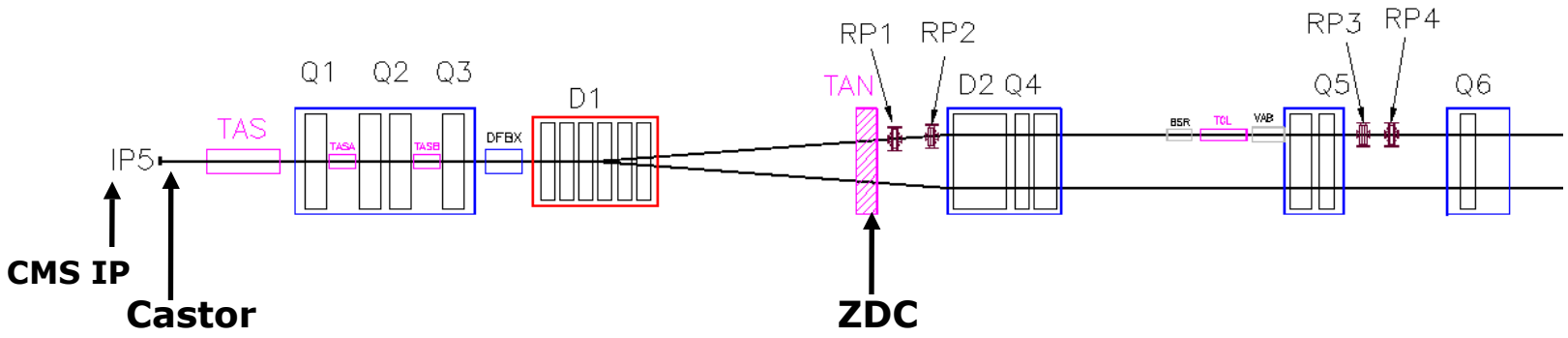
<W> = 2398 GeV
<q^2> = 0.05 GeV^2

Conclusions

- A significant sample of exclusive dimuons from can be triggered on and reconstructed in CMS, with 100 pb^{-1} and minimal pileup
  - Plus a smaller sample of dielectrons
- Other backgrounds should be small compared to inelastics and signal
- Several photon-physics and calibration studies are possible with this sample, using early data from the LHC
  - High-energy Upsilon photoproduction measurements
  - Luminosity normalization
  - Lepton ID studies

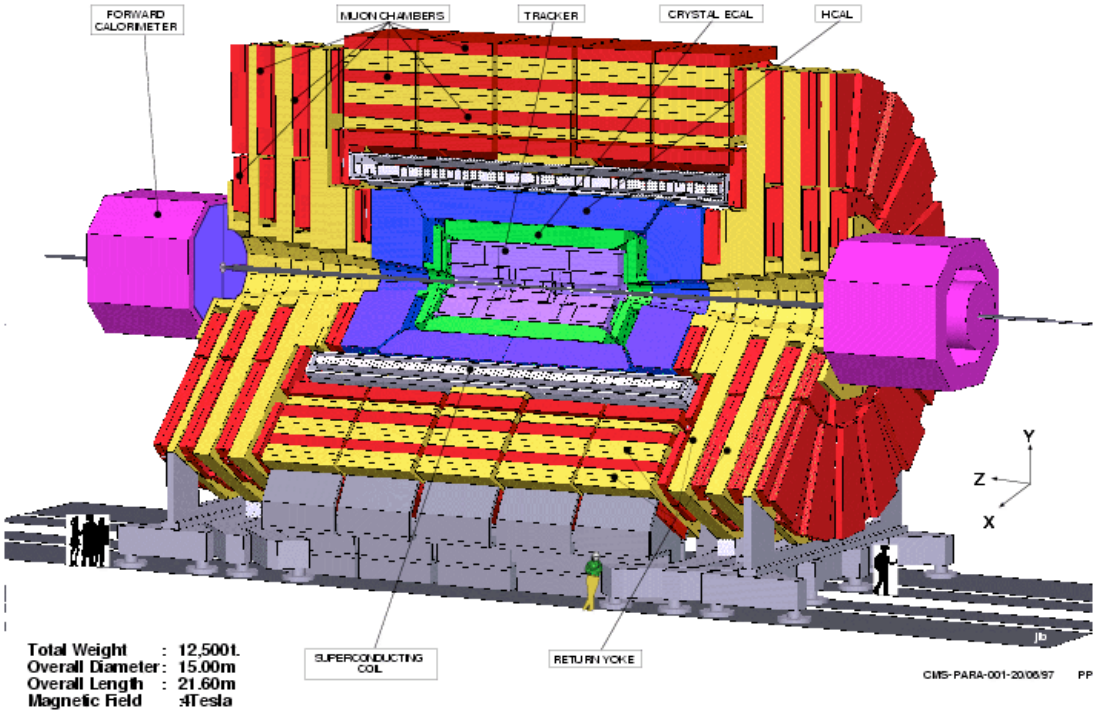
Extra slides

CMS forward calorimeters



- "Baseline" CMS forward hadronic calorimeter (HF) extends to $|\eta| < 5$
- Castor: quartz-tungsten sampling calorimeter
  - ~14 m from IP, covers $5.2 < |\eta| < 6.6$
- ZDC: quartz-tungsten sampling calorimeter
  - ~140 m from IP, covers $|\eta| > 8.6$

CMS



Toal weight	**12500 t**
Overall diameter	**15 m**
Overall length	**21.6 m**

Silicon tracker

micro strips (10M ch)
pixel (40M ch)
(5.4m long, 2.4m Φ: |η| <2.4)

Central calorimeter

ECAL: PbWO4 crystal
HCAL: brass+scinti.
(|η| <3.0)

in 4 Tesla solenoid

(12.5m long, 6m Φ in)

muon system

DT+RPC (barrel)
CSC+RPC (endcap)
(in iron yoke: |η| <2.4)

Fast cerenkov forward calorimeter

quartz fiber
(3<|η|<5)