Overview of exclusive processes in CMS

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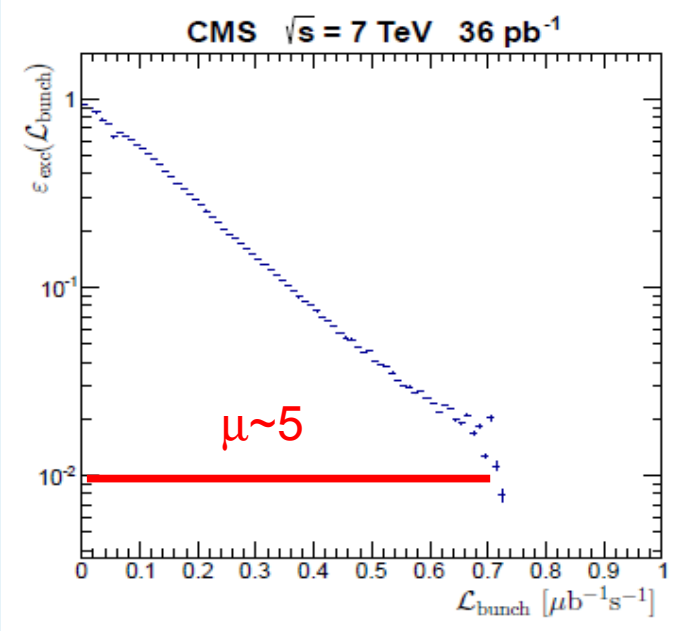
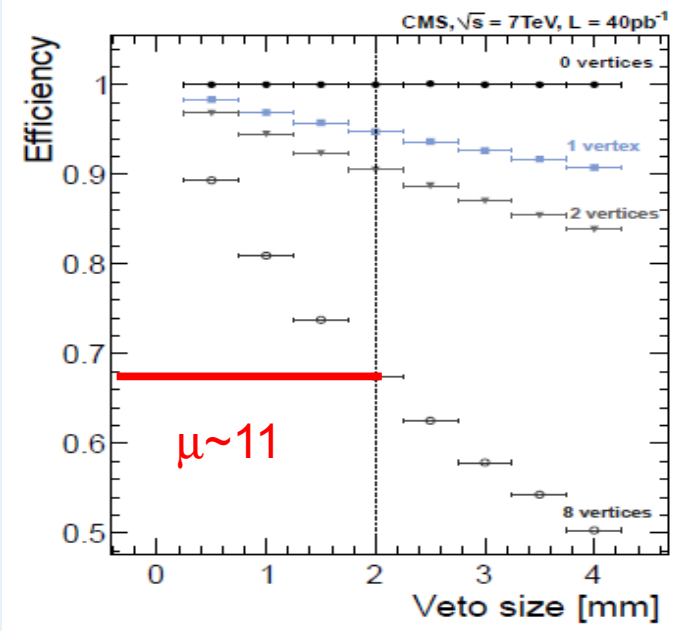
Introduction

- Topics I was asked to cover
  - Overview of public analyses that have been done so far in CMS
  - Which measurements are interesting to repeat at 13/14 TeV
  - Best luminosity/pileup scenarios for different channels
  - What MC's have been used

- Measurements to date in CMS have been done without detecting forward protons
    - Sensitive to the sum of fully exclusive/elastic ($pp \rightarrow pXp$) production and proton-dissociation ($pp \rightarrow p^{(*)}Xp^{(*)}$)
  - (measuring scattered protons would obviously be an improvement...)

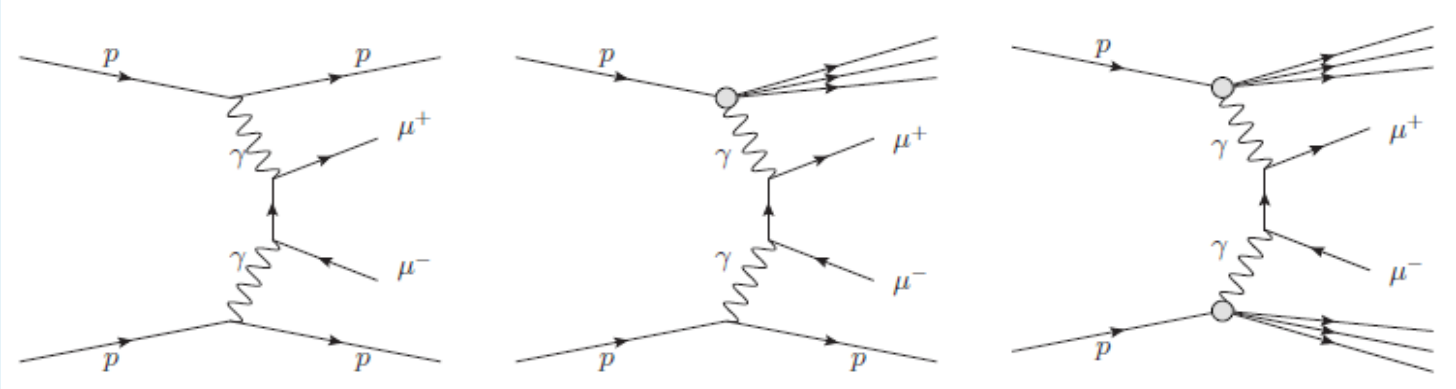
Pileup, and methods used in CMS analyses





- Calorimeter-based (no additional calorimeter or track activity above threshold)
  - Experimentally cleanest, but efficiency drops to 0 with pileup
  - Used for channels with higher backgrounds, low-pT/trigger challenges, complex final states
- Track/vertex-based (counting # of extra tracks on a vertex)
  - Efficient with some pileup, at the cost of larger backgrounds, proton-dissociation
  - Useful for clean channels with high-pT/low backgrounds (only leptons so far)

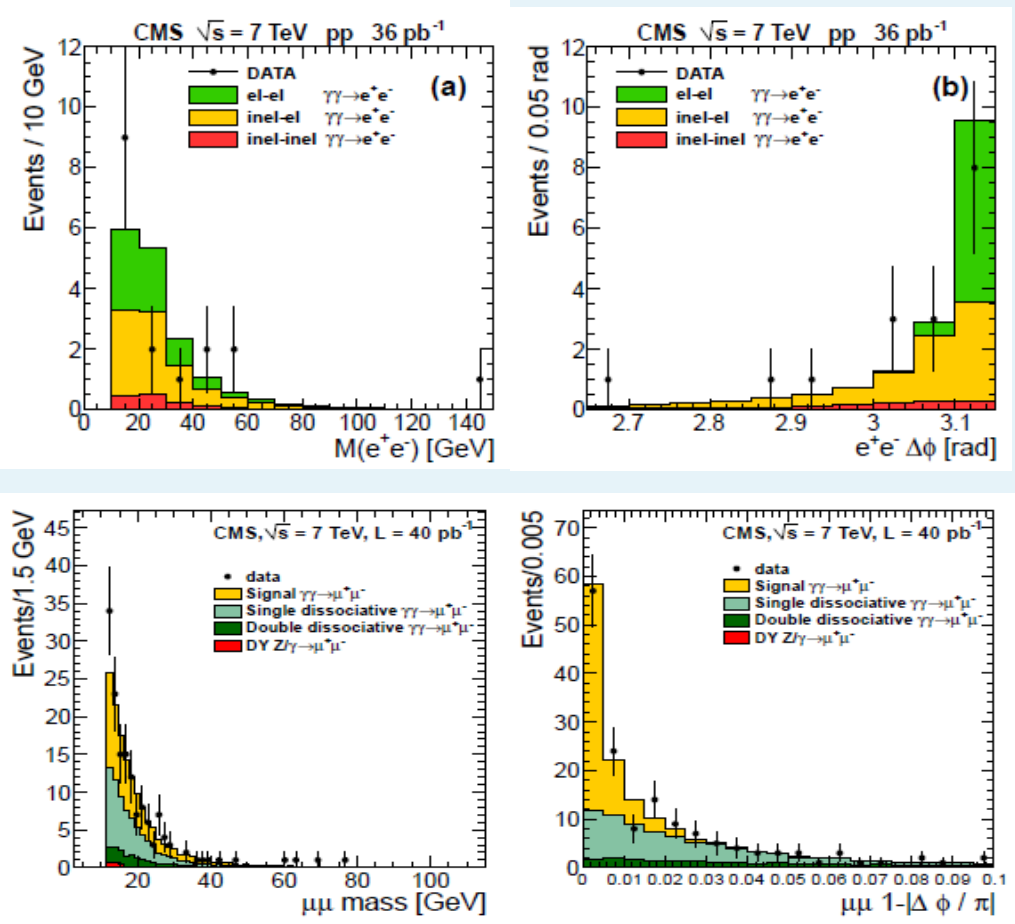
$\gamma\gamma^{23}_{11}$ II



- Measured in 2010 and 2011 data, both with low and (relatively) high luminosity
  - So far only in the “non-resonant” region (m > ~11 GeV), above the expected contribution from VM photoproduction $\gamma p \rightarrow Yp$
- Useful to repeat as a “standard candle” to validate selections for other exclusive processes in any new energy/pileup conditions
  - Theory uncertainties on the fully exclusive/elastic process ~1%
- MC's used: LPAIR (elastic + p-dissociation)

$\gamma\gamma \rightarrow ll$

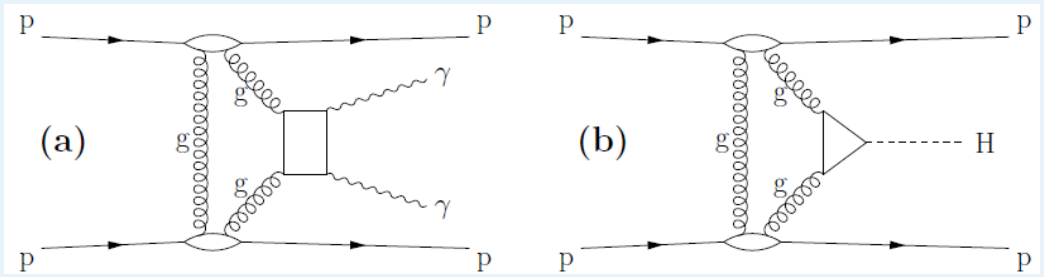
- Different approaches used for the two channels
  - $\gamma\gamma \rightarrow ee$ with full calorimeter-based selection in 2010 data
    - Used as control channel for CEP $\gamma\gamma$ search
  - $\gamma\gamma \rightarrow \mu\mu$ with track/vertex-based selection in 2010 data
- Reasonable agreement with LPAIR expectation for yields, kinematic distributions ($\Delta\phi$, ΔpT, invariant mass...)



JHEP 1201 (2012) 052
JHEP 1211 (2012) 080

Exclusive $\gamma\gamma$

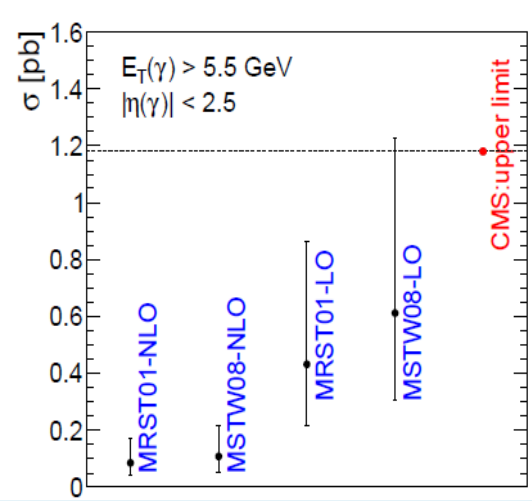
- At low pT, dominated by strong (~gluon-gluon in pQCD) CEP
  - Test of exclusive Higgs predictions



- Analysis done with 2010 data
  - 36pb^{-1}, with "effective" single-interactions luminosity of only 5pb^{-1} (estimated from ZeroBias data)
  - 0 candidates observed with 1.8 background expected

- MC's used: Exhume, SuperCHIC (elastic only)

Exclusive $\gamma\gamma$



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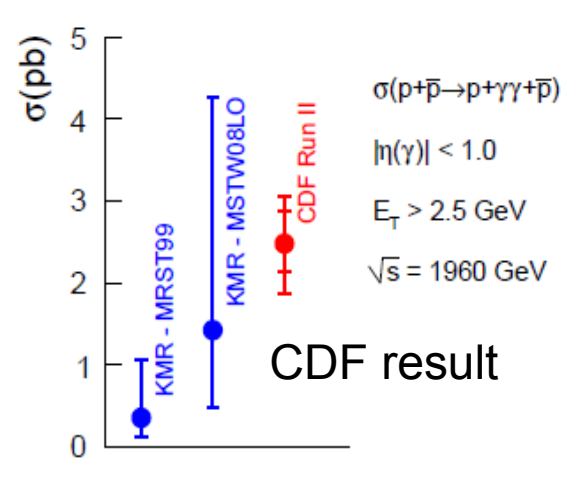
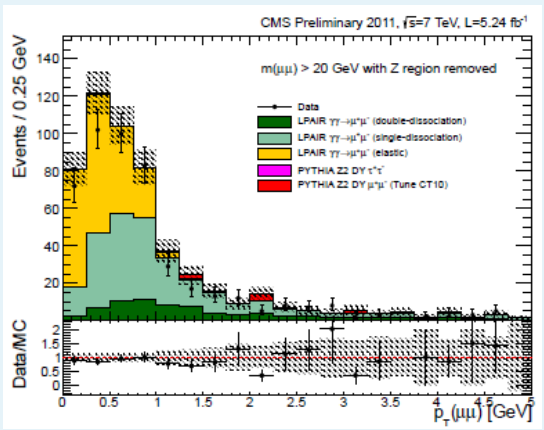


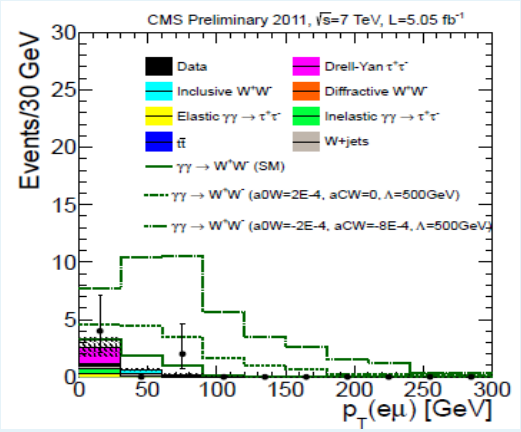
- CMS limits with 2010 data near the upper end of predictions + PDF uncertainties, CDF (with different acceptance & energy) observes a signal near the upper end of predictions
  - Interesting to repeat with higher energy + more data
  - Needs low-pileup, with relatively large effective luminosity of single interactions (>10's of pb^{-1} to cover range of predictions)

$\gamma\gamma \rightarrow WW$

- Search for $\gamma\gamma \rightarrow WW \rightarrow e\mu$ (+neutrinos) in 5fb-1 of 2011 data
- Track/vertex selection due to pileup (μ~9 in 2011)



$\gamma\gamma_{11}^{23}$ $\mu\mu$ control sample, Elastic-enriched selection

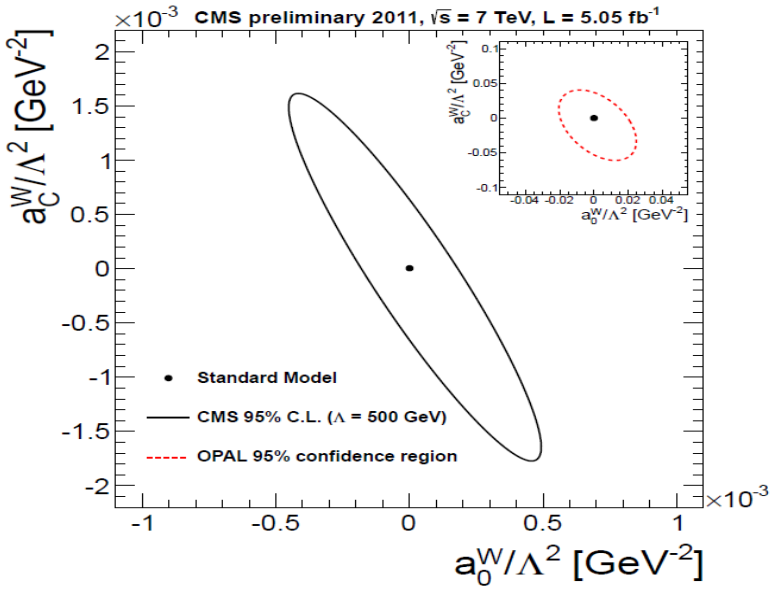


$\gamma\gamma_{11}^{23}$ WW_{11}^{23} $e\mu$ signal selection

- Use $\gamma\gamma \rightarrow \mu\mu$ control samples to validate efficiency with pileup, derive "data-driven" estimate of p-dissociation
- Largest systematics are due to the p-dissociation, pileup (but currently dominated by statistical errors)
- MC's used: CalcHEP (elastic, via EPA)

CMS PAS FSQ-12-010

$\gamma\gamma^{23}_{11}WW$



- SM signal region: observe 2 events with 2.2 signal, 0.84 background expected
- Set limits on anomalous quartic $\gamma\gamma WW$ couplings below recent D0 limits, and a factor ~100 beyond LEP limits

- Interesting to repeat with higher energy – need high luminosity (10's of fb^{-1}) to hope for a significant measurement of a SM-like signal
  - Proof of principle analysis with pileup ~9 in 2011 data, feasibility TBD with 2012 data with >2x pileup
  - 25ns much better than 50ns (at least for untagged analysis) - no major issue for tracking expected from OOT pileup

CMS PAS FSQ-12-010

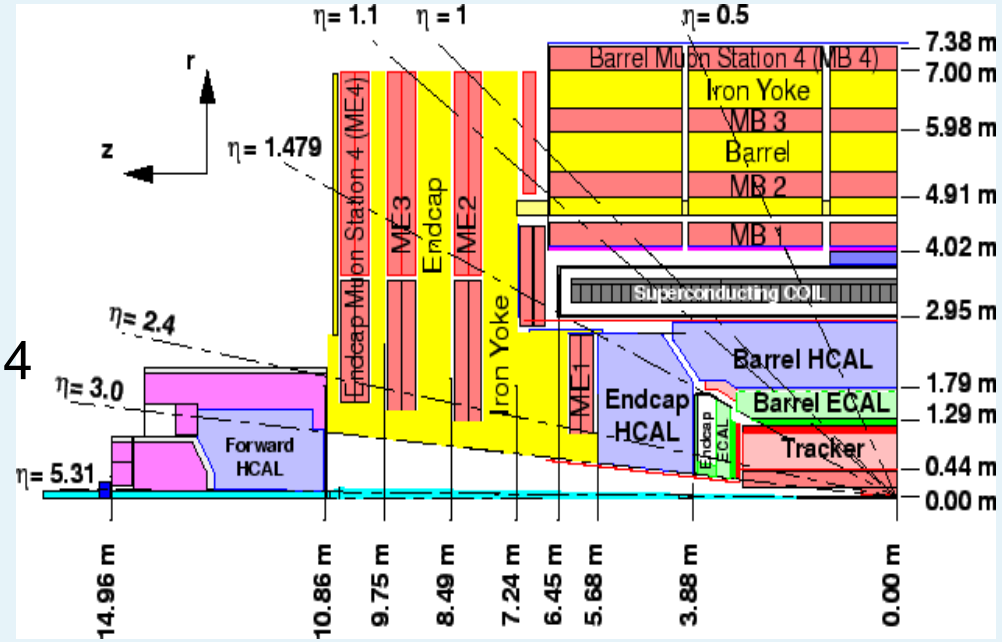
Summary

- Essentially all exclusive analyses worth repeating at 13/14TeV
  - An example needing low pileup data: CEP $\gamma\gamma$
  - An example needing high luminosity: $\gamma\gamma \rightarrow WW$
  - In all conditions: $\gamma\gamma \rightarrow ll$ as a “standard candle” process
  - + many other channels not done in CMS (CEP dijets, $\pi\pi/KK$, $\gamma\gamma \rightarrow ZZ$, $\gamma p \rightarrow Zp$, exclusive charmonium/bottomonium...)
- MC's
  - For $\gamma\gamma \rightarrow ll$: LPAIR is fairly complete apart from rescattering effects, non-trivial to maintain/use (vintage ~1990 Fortran)
  - For other processes: Several options looked at in CMS for fully exclusive production (SuperCHIC, Exhume, STARLIGHT, FPMC, Madgraph/CalcHEP...), not many options for proton-dissociation(?)
    - Anyway try to avoid relying on MC for this...

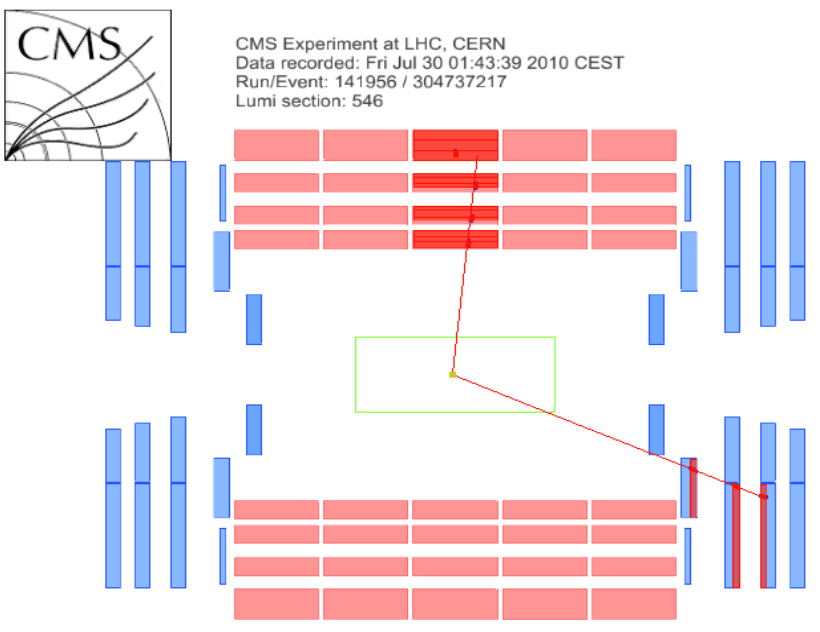
Extra

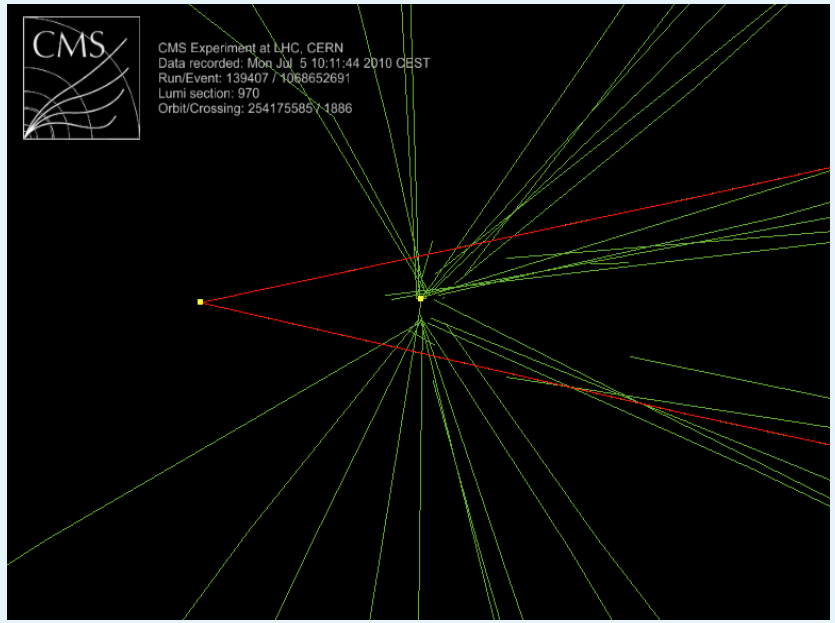
Detector coverage

- Approximate CMS central detector coverage
  - HF |eta| < 5
  - ECAL |eta| < 3
  - Tracking, muons |eta| < 2.4
- Forward region
  - CASTOR (-5.2 < |eta| < -6.6), in for pp runs in 2010, 2012 2.76 TeV reference run
  - ZDC (|eta| > 8.2), in for pp runs in 2010, 2012 2.76 TeV pp reference run
  - FSC (|eta| = ~6-8), installed for 2012 low pileup runs
- + Common triggers with Totem in 2012 low pileup runs



Pileup, and methods used in CMS analyses





- Ideal case – 1 interaction/crossing
  - Exclusive system and “nothing else” in the detector
- In practice
  - Most of the luminosity collected at the LHC comes with extra (“pileup”) interactions

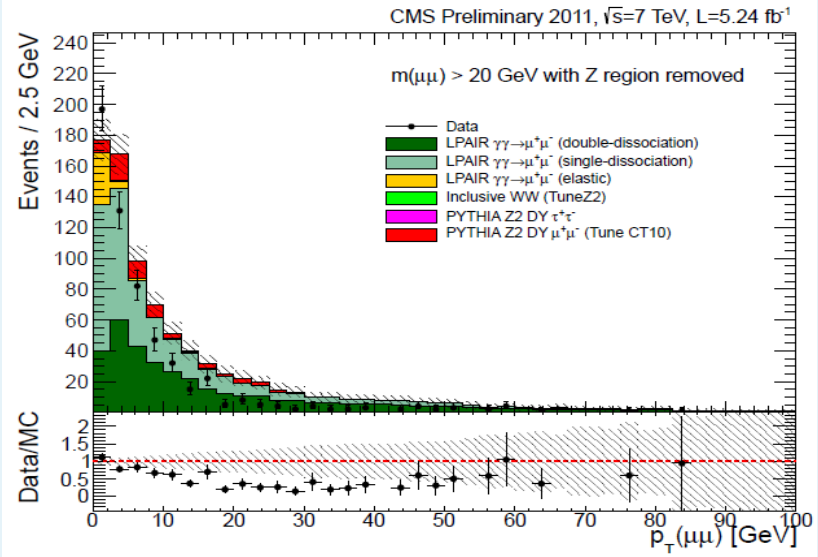
CMS DP 2010/035

p-dissociation, rescattering, etc.

- Frequent comment: LPAIR doesn't include rescattering corrections, for proton-dissociation this could give a large suppression of the observed cross section (c.f. Eur.Phys.J. C72 (2012) 2110)

- In dissociation-enriched $\gamma\gamma_{11}^{23}\,\mu\mu$ control samples, we do observe a deficit in data, particularly at high pT($\mu\mu$)

- Use the high-mass $\gamma\gamma_{11}^{23}\,\mu\mu$ data to estimate the p-dissociation contribution to $\gamma\gamma_{11}^{23}\,WW$



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