FORWARD PHYSICS AT CMS:
Exclusive and Diffractive Physics

Dilson de Jesus Damião
(Universidade do Estado do Rio de Janeiro)
on behalf of the CMS Collaboration

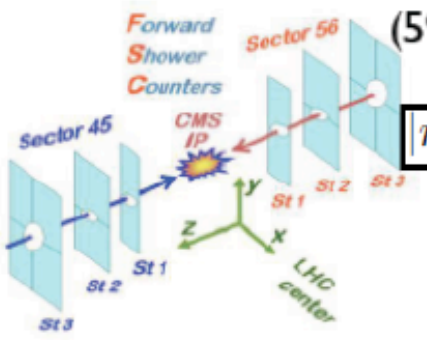
Outline

- CMS detector at forward rapidities
- Dijet production with a large rapidity gap (PAS FSQ-12-001)
- Exclusive WW and limits on Anomalous Quartic Coupling (FSQ-13-008)

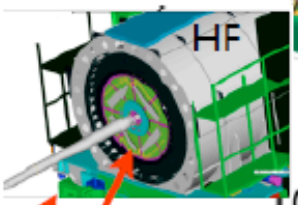
CMS detector at forward rapidities

Forward Shower Counters
(59-114m)

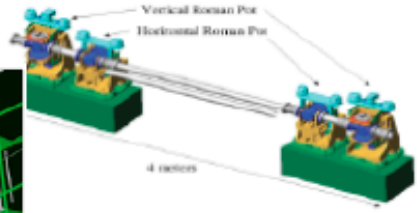
$|\eta| \approx 6 - 8$



HF: $3.0 < |\eta| < 5.0$



BSC*



TOTEM RPs
(147, 220m)

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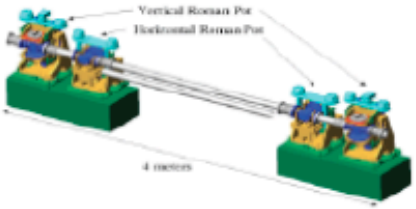
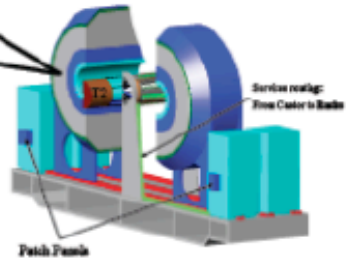
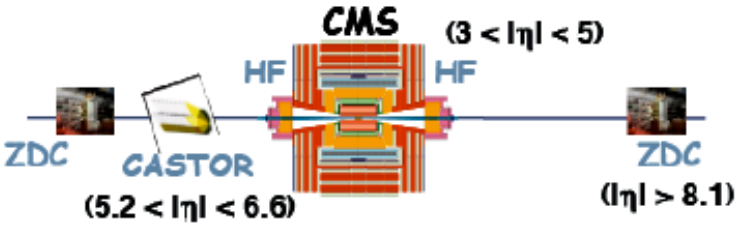




TOTEM T2
(In front of
CASTOR position)

Common data taking during low-PU runs in 2012



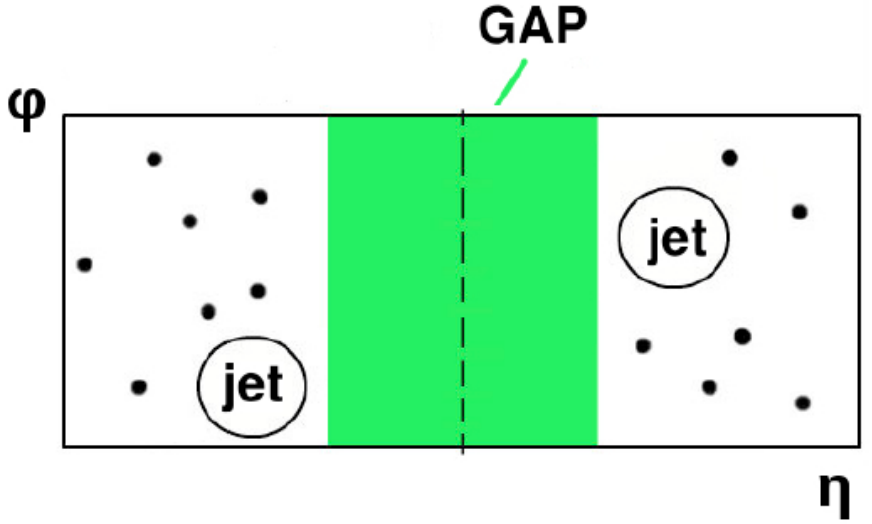
BSC*: Beam Scintillator Counters
(in front of HF) $3.2 < |\eta| < 4.7$

Dijet production with a large rapidity gap

(PAS FSQ-12-001)

- Jet-gap-jet event is characterized by a parton scattering (2→2) through an hard color singlet exchange*
- The fraction of the color singlet exchange is

$$f_{CSE}(p_T^{jet2}, \Delta\eta) = \frac{N_{events\_with\_gap}}{N_{all\_dijet\_events}}$$

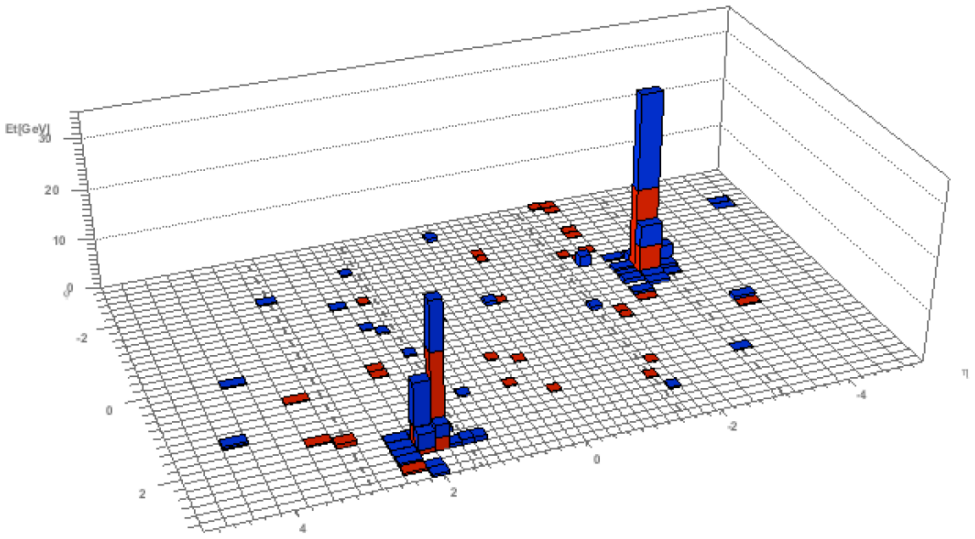


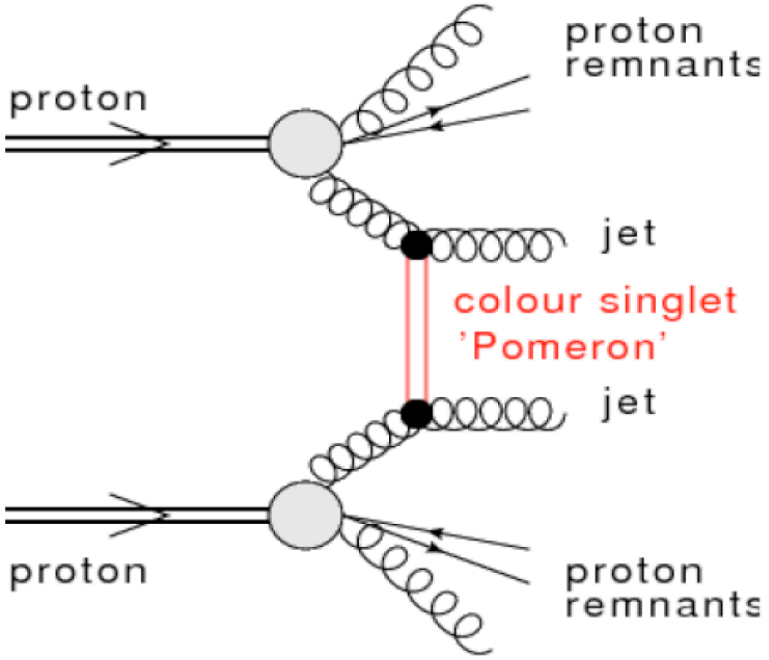
*A. Mueller, W. Tang, Phys. Lett. B284 (1992)

Dijet production with a large rapidity gap

(PAS FSQ-12-001)

- Event signature:
  - two high p_T jets, separated by a large rapidity gap
  - the four-momentum squared transfer is much larger than in a standard diffractive event



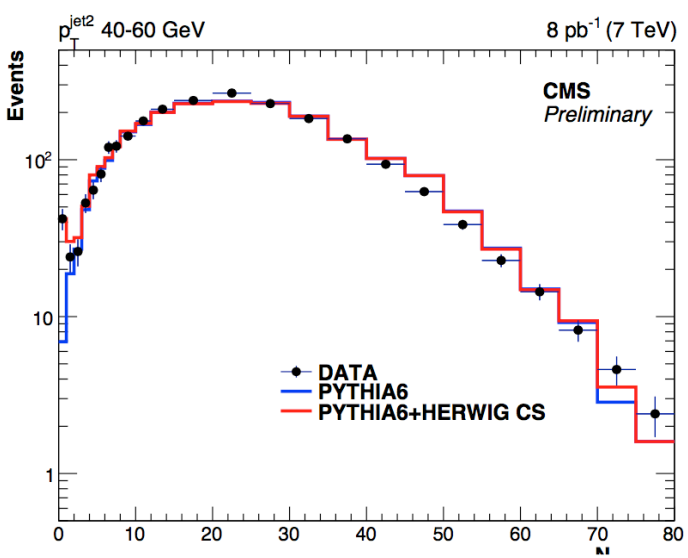


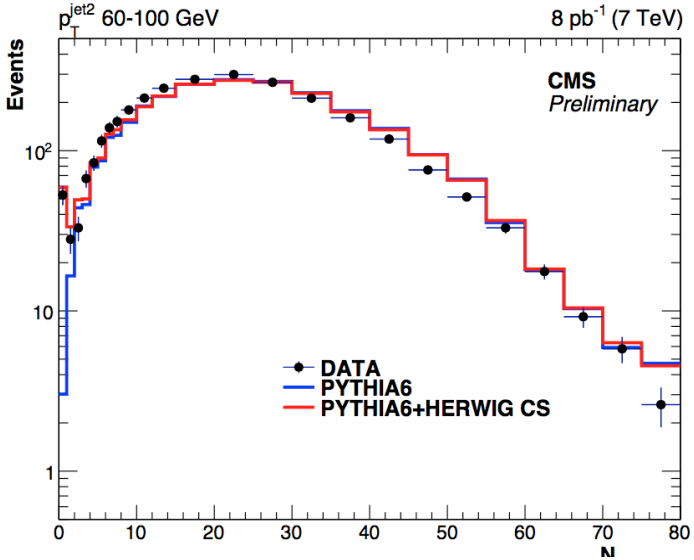
Dijet production with a large rapidity gap

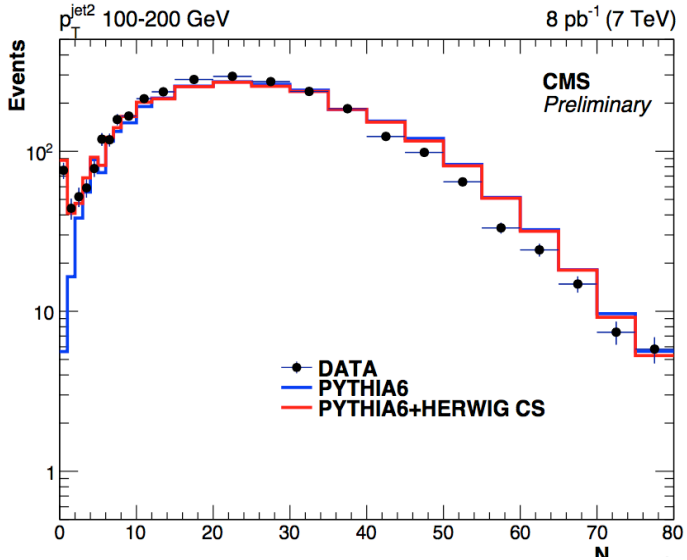
(PAS FSQ-12-001)

- Excess of events in the lowest track multiplicity bins, indication of CSE
  - No satisfactorily described by the Pythia6 (QCD background)
  - Addition of HERWIG color singlet MC (LL BFKL)

    → reasonable agreement







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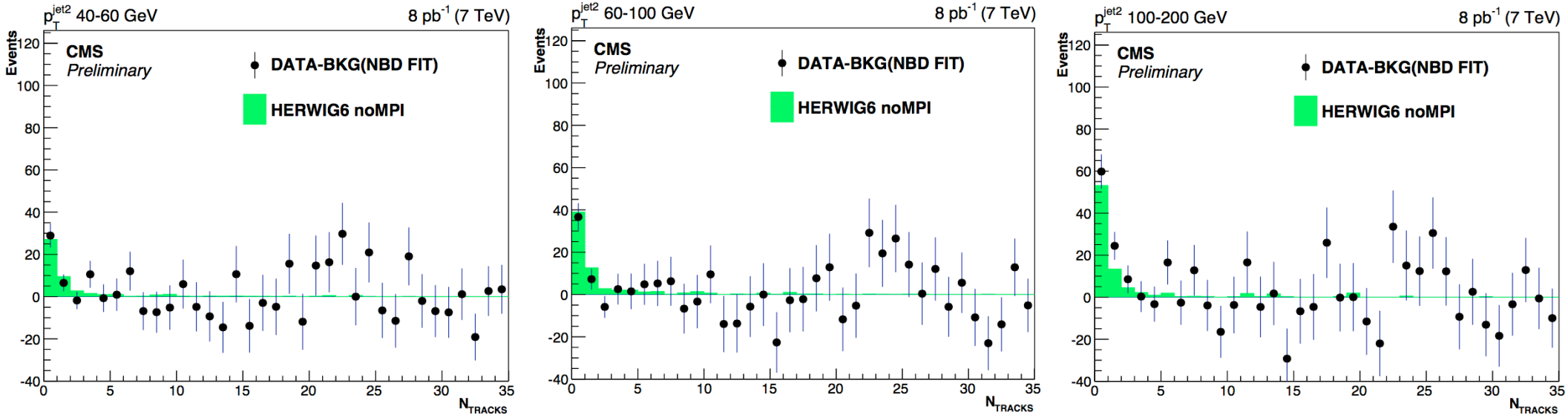
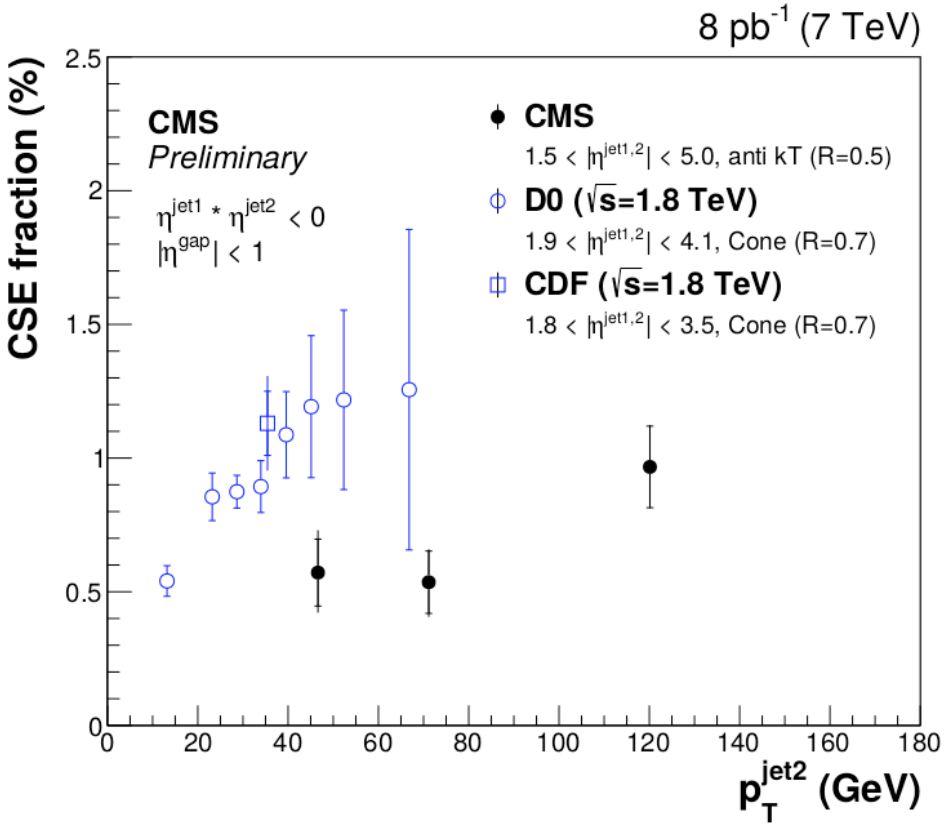


f_{SCE}: ratio of event yields in the first bins after background subtraction to total yield

Dijet production with a large rapidity gap

(PAS FSQ-12-001)

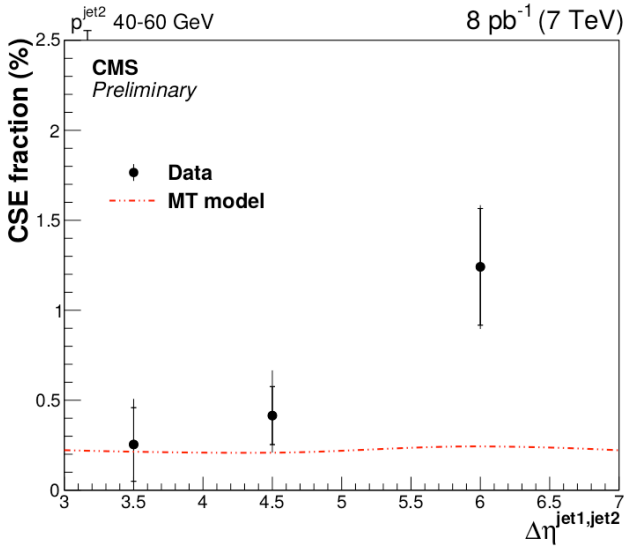
- f_{CSE} vs p_T
  - A suppression of the CSE fraction measured at $\sqrt{s}$ = 7 TeV is observed with respect to those at lower energies
  - The observation reported by DØ and CDF are in agreement with the increase of CSE

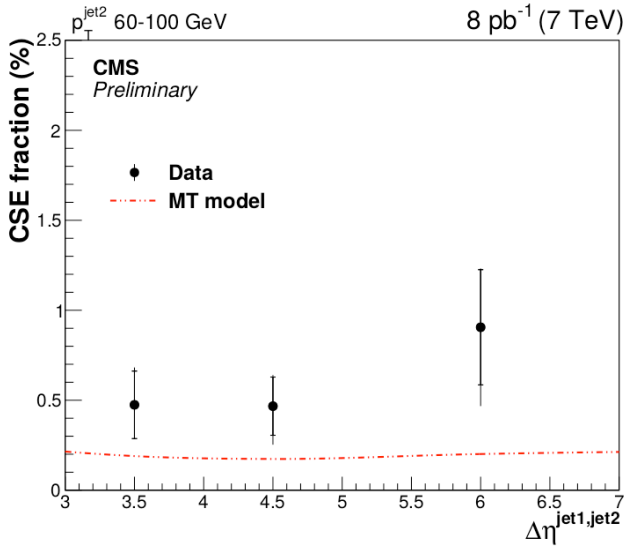


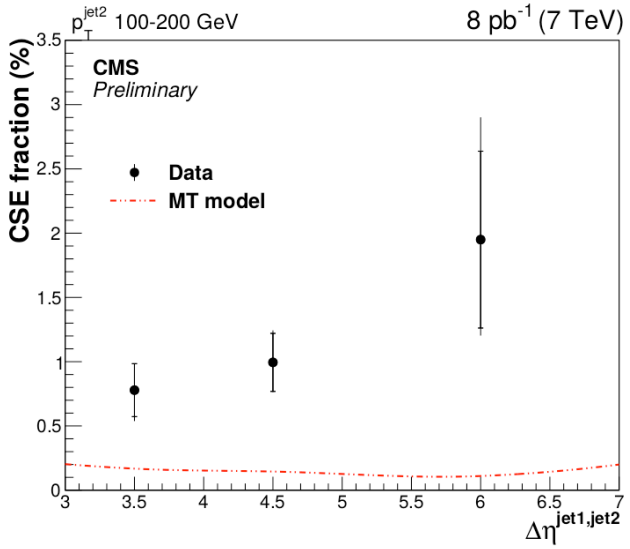
Dijet production with a large rapidity gap

(PAS FSQ-12-001)

- f_{CSE} vs $\Delta\eta^{jet1,jet2}$
  - The gap fraction increases with $\Delta\eta^{jet1,jet2}$, although uncertainties are large at high values
  - Mueller and Tang model (MT), based on simplified BFKL calculations, does not reproduce the growth of f_{CSE} with $\Delta\eta^{jet1,jet2}$, and underestimates the measured gap fractions



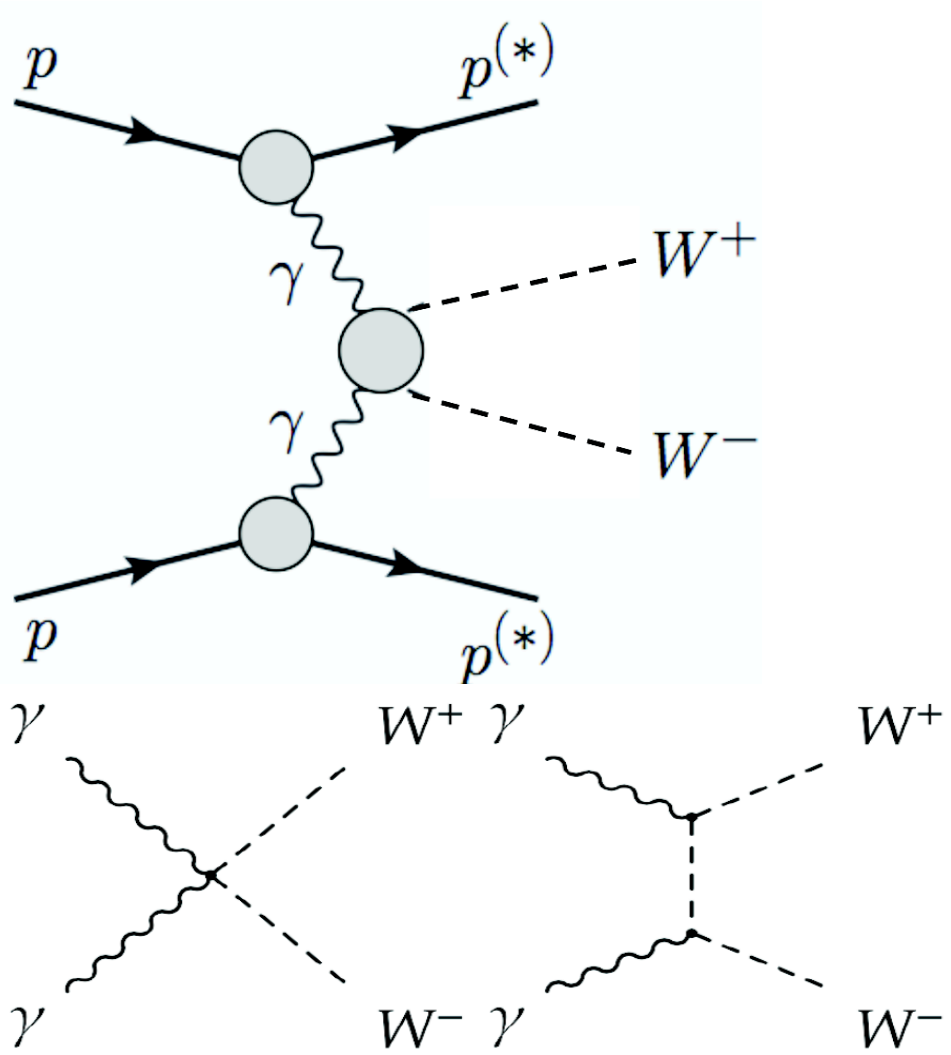




Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

- $pp \rightarrow p^{(*)}W^+W^-p^{(*)}$
  - *: proton may remain intact or dissociate into invisible products
- clean final states, no hadronic activity
- $\gamma\gamma \rightarrow W^+W^-$
  - not observed before LHC
  - measure SM cross section
  - search for Anomalous Quartic Gauge Couplings (AQGC)

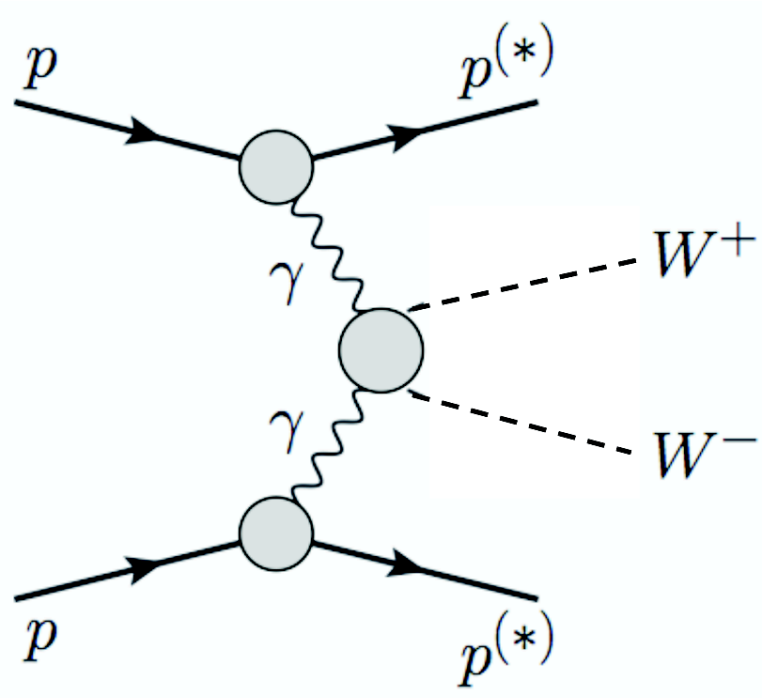


Quartic and t-channel diagrams contributing to LO process in the SM

Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

- *Looking for two W bosons* $pp \rightarrow p^{(*)}W^+W^-p^{(*)}$



Exclusive WW and limits on AQGC

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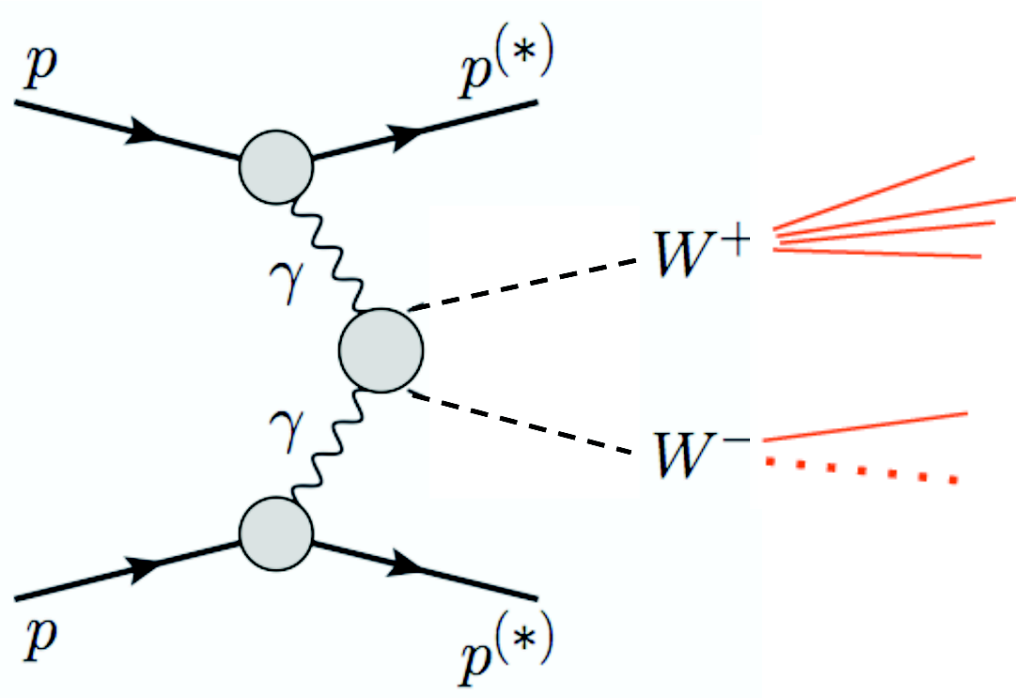
      - Too much QCD background



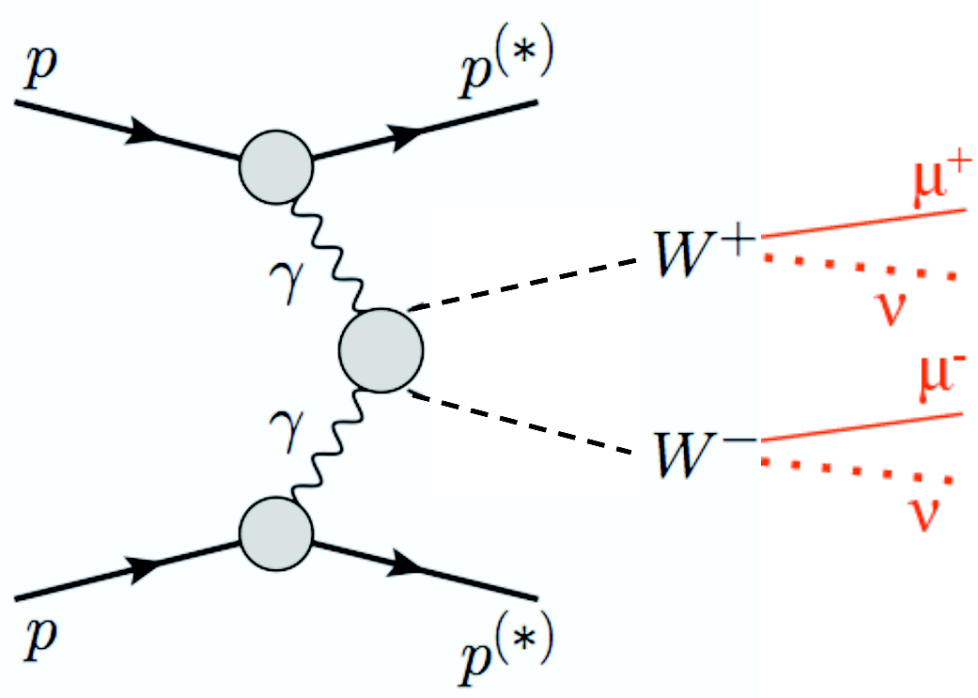
Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

- *Looking for two W bosons pp → p(*)W+W-p(*)*
  - hadronic W decays:
    - at least one W decays hadronically
      - Too much QCD background
  - Leptonic W decays:

$$W^+W^- \to \mu^+\nu\mu^-\nu \qquad W^+W^- \to e^+\nu e^-\nu$$

      - *Too much background from Drell-Yan and direct γγ → l+l-*



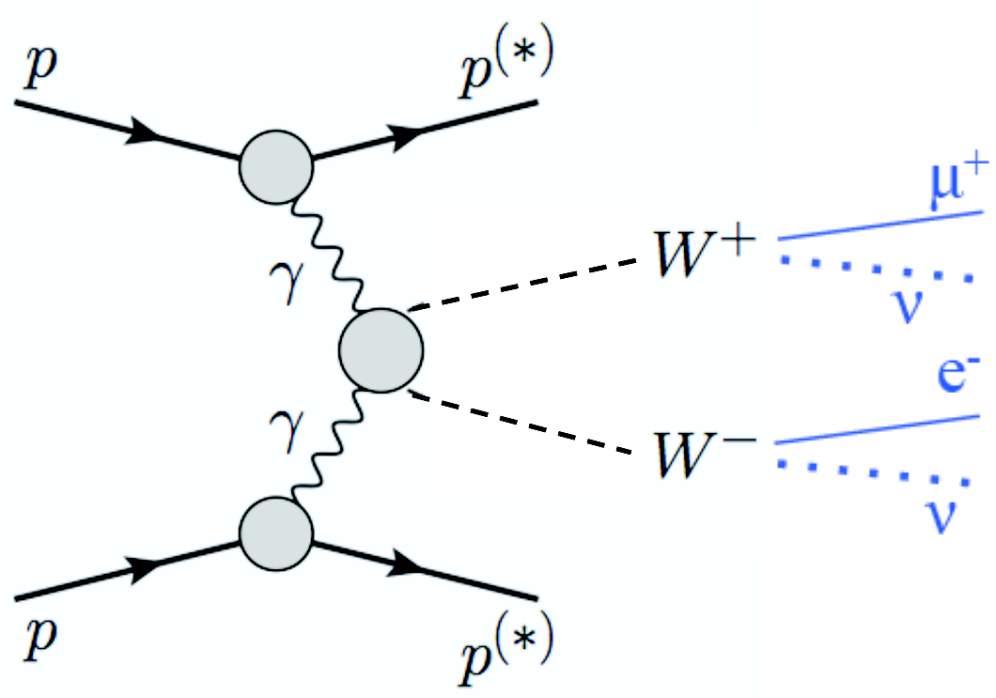
Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

- *Looking for two W bosons*

  $pp \rightarrow p^{(*)} W^+ W^- p^{(*)}$

  - only μ^+e^- and μ^-e^+
    - $W^+W^- \rightarrow \mu^{\pm}\nu\ e^{\mp}\nu$
    - *common vertex*



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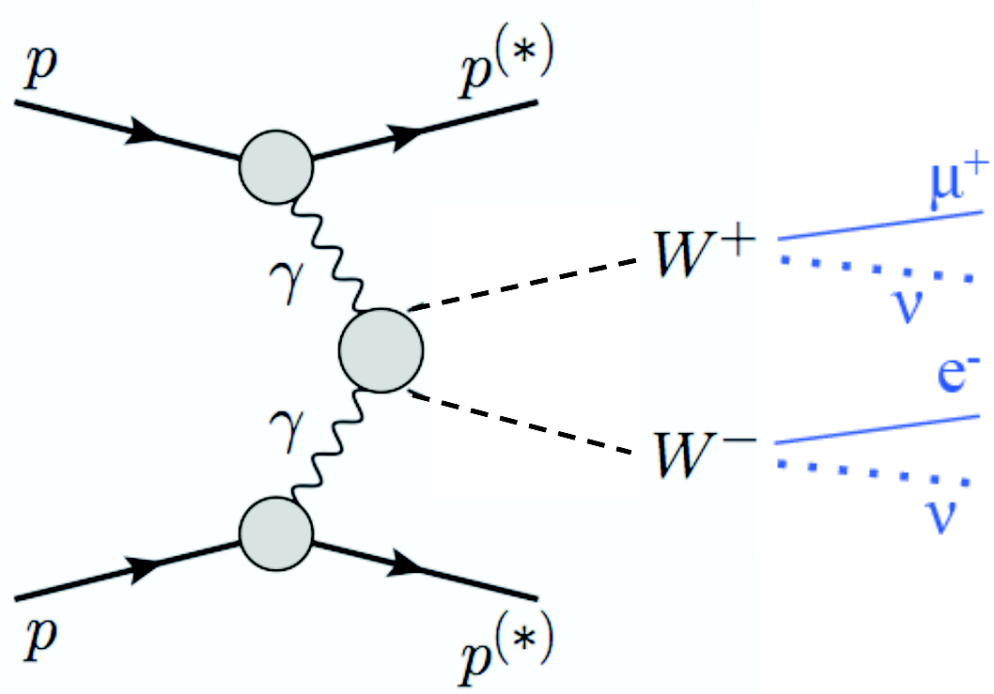


- Veto on additional charged tracks at dilepton vertex
  - Inclusive production almost always accompanied by extra tracks
- Require high p_T (μe) to suppress background

Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

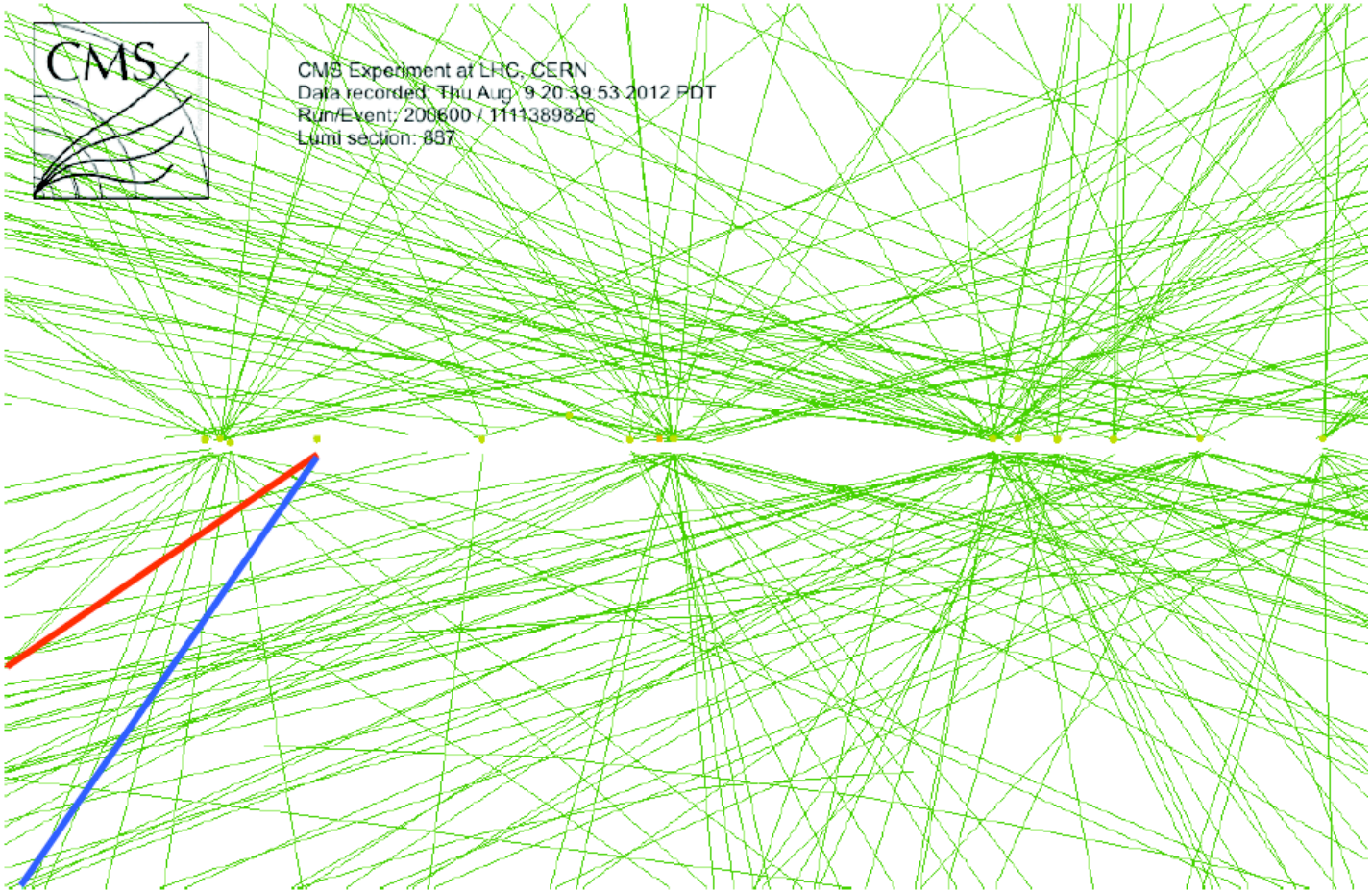
Event display of a signal candidate

only μe and other tracks from pile-up

$$W^+W^- \rightarrow \mu^{\pm}\nu\ e^{\mp}\nu$$

Selection

- opposite-sign μe pair @ the same vertex
- no extra tracks @ μe vertex
- each lepton with
- $p_T > 30$ GeV
- $|\eta| < 2.4$

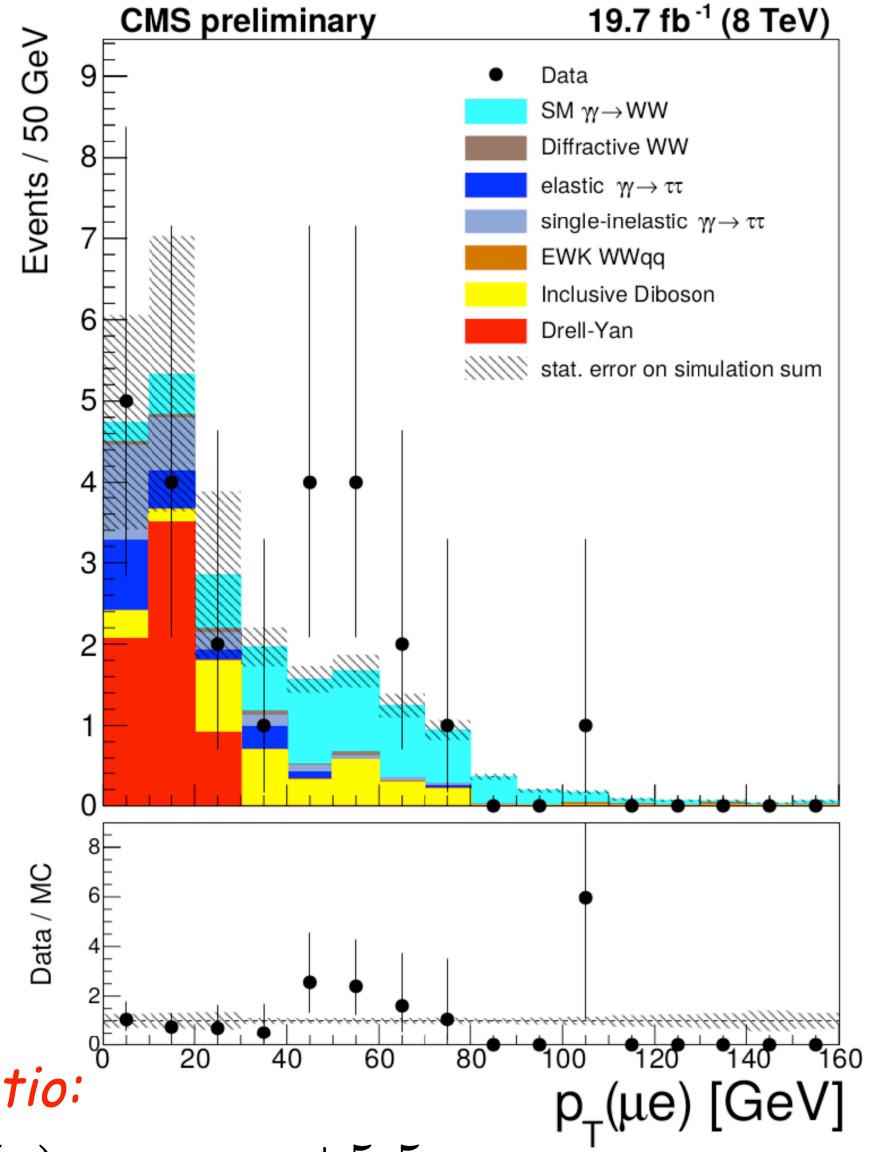


Exclusive WW and limits on AQGC

(PAS FSQ-13-008)

Results

- 13 data events in the signal region
- 3.5 ± 0.5 events were expected in the background
- SM prediction: 6.9 ± 0.6 fb
  - gives a observed significance above background only hypothesis of 3.6σ

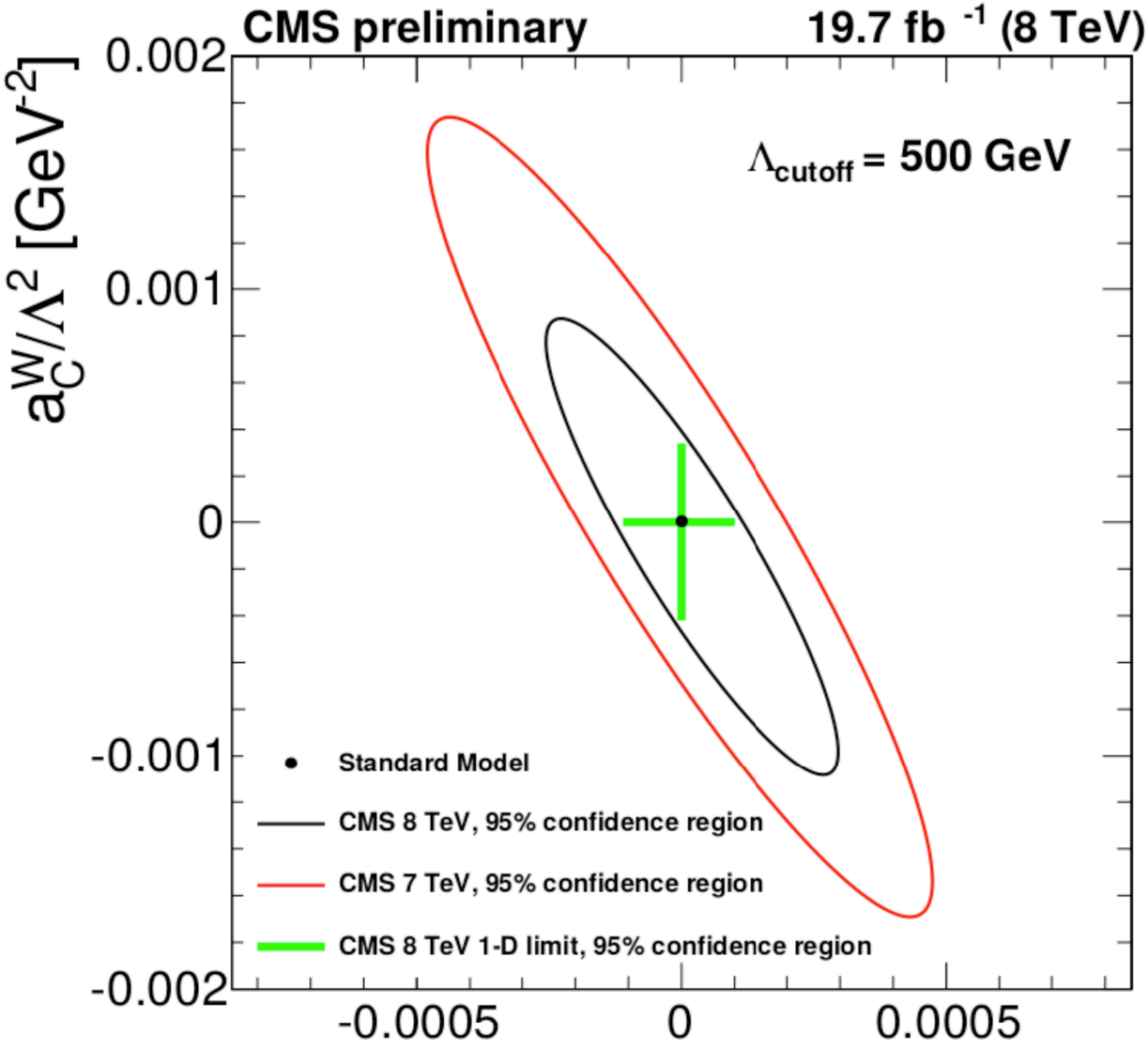


Total cross section measured times branching ratio:

$$\sigma(pp \to p^{(*)}W^+W^-p^{(*)} \to p^{(*)}\mu^{\pm}\mp p^{(*)}) = 123^{+5.5}_{-4.4} fb$$

Exclusive WW and limits on AQGC

- The p_T was used as a discriminating variable to extract limits on AQGC.
- The resulting upper limits are compared to predictions assuming AQGC.



$$-1.1 \times 10^{-4} < a_0^W/\Lambda^2 < 1.0 \times 10^{-4}\,\text{GeV}^{-2} \quad (a_C^W/\Lambda^2 = 0, \Lambda_{\text{cutoff}} = 500\,\text{GeV})$$

$$-4.2 \times 10^{-4} < a_C^W/\Lambda^2 < 3.4 \times 10^{-4}\,\text{GeV}^{-2} \quad (a_0^W/\Lambda^2 = 0, \Lambda_{\text{cutoff}} = 500\,\text{GeV})$$

(PAS FSQ-13-008)

Summary

- CMS has a rich forward physics program with measurements of SM physics:
  - Diffraction
  - Exclusive production
  - Leading charged particles and jets at low p_T
- A suppression of the CSE fraction measured at LHC is observed with respect to those at lower energies (CDF and D∅)
- Provide unique sensitivity to anomalous quartic couplings of the gauge bosons (aQCG)
- More results to come for 13 TeV, with the CT-PPS detector