Searches for Resonant and Non-resonant Phenomena in CMS

Hwidong Yoo

Seoul National University

On behalf of the CMS Collaboration

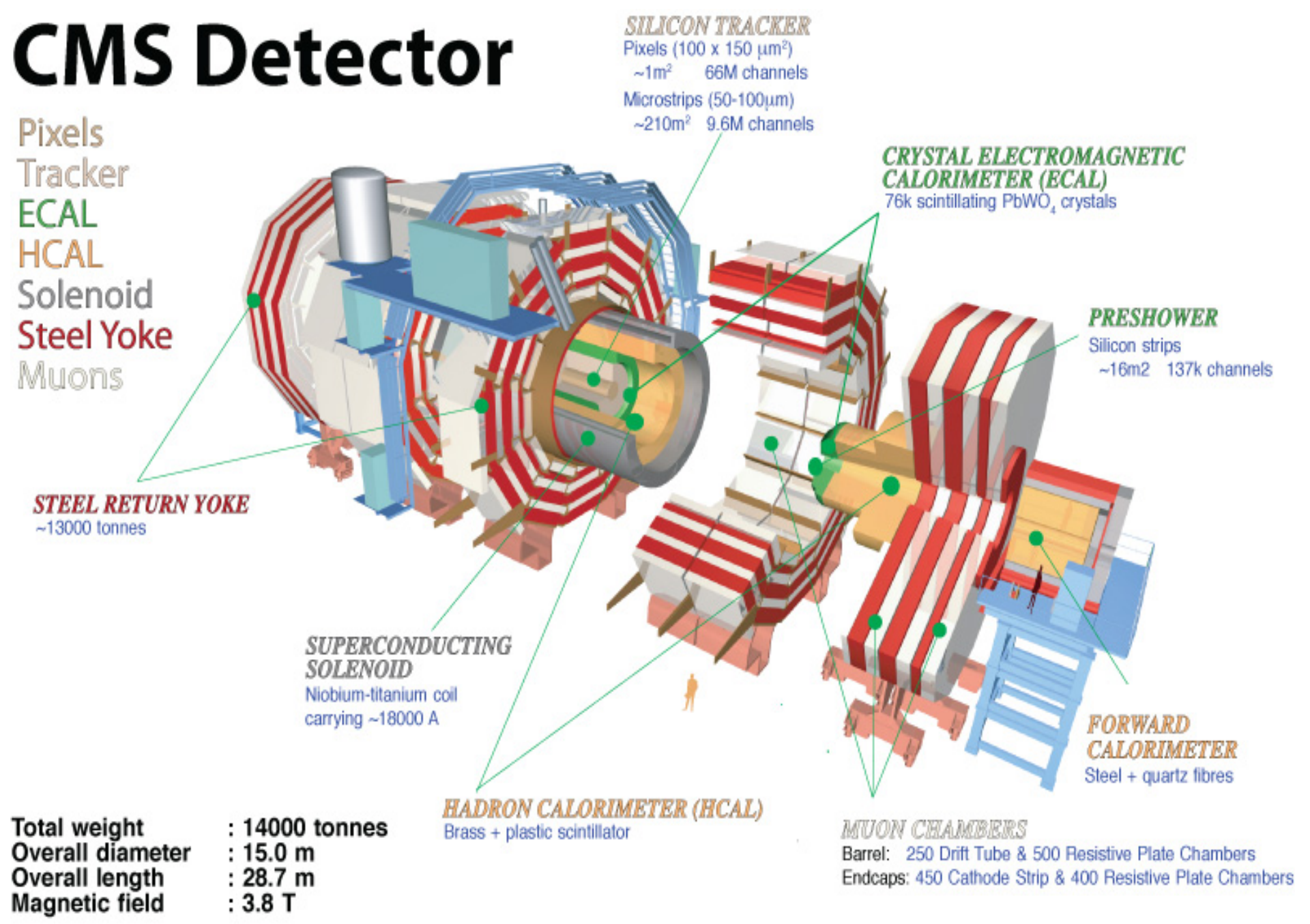
QCD@LHC, September 2nd 2015

Outline

- Leptonic channels at 8 TeV
  - Dilepton (ee, μμ)
  - Multilepton
  - W'
  - Ditau
- Jet channels at 8 TeV
  - Dijet
  - Multijet
- Bosonic channels at 8 TeV
  - Diphoton
  - Diboson
- Preliminary results at 13 TeV data

- Searches for t/b quarks channel will be discussed a talk by F. Margaroli on Wed. in "Heavy Quarks" session

CMS Detector

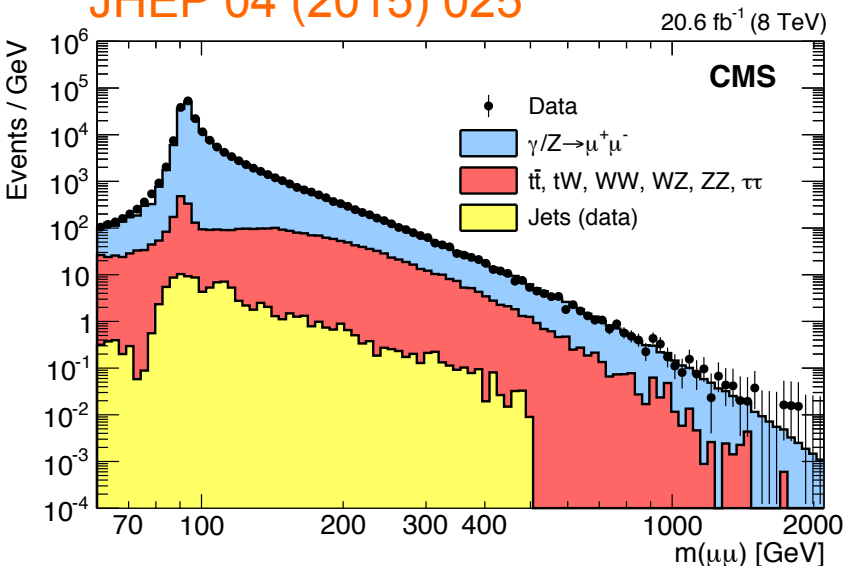


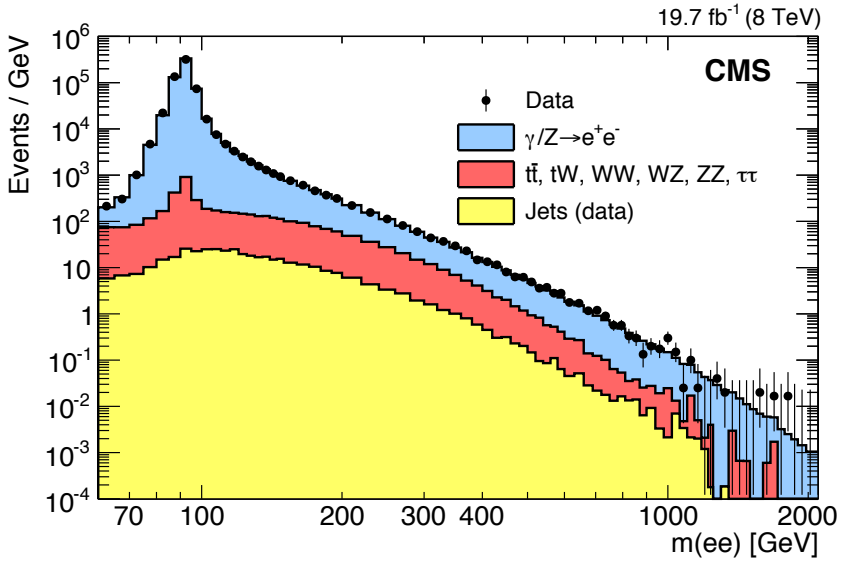
Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**

Dilepton (ee, μμ)

- Model independent shape-based search for a narrow resonance
  - Further interpretations of high mass dilepton
- Standard CMS high pT muon/ electron id and event selection are used
- Dominant background
  - Drell-Yan, ttbar, tW, diboson
  - Jets misidentified as leptons (W+jets, QCD)
- Highest mass event: 1.79 TeV (ee), 1.87 TeV (μμ)

JHEP 04 (2015) 025

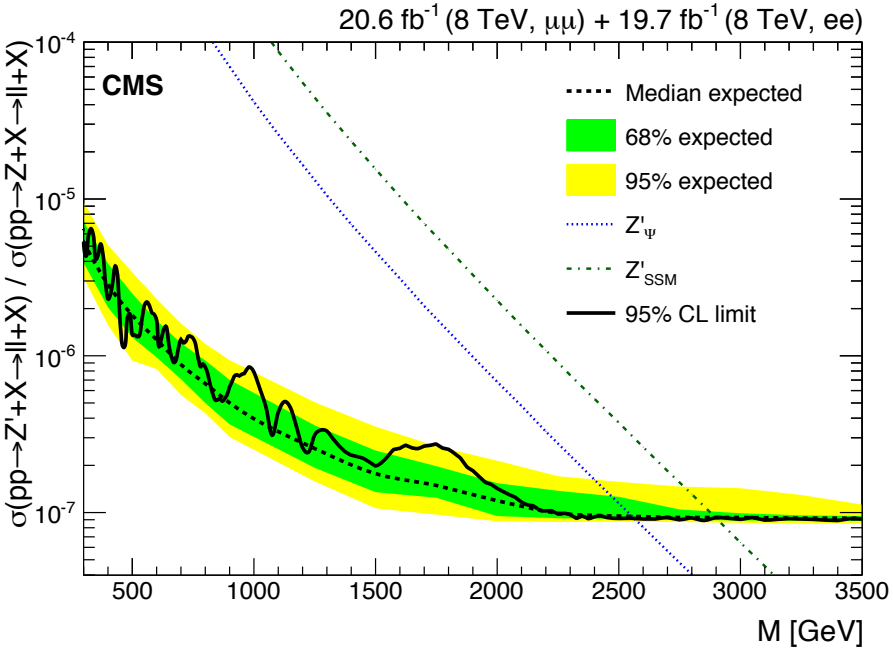


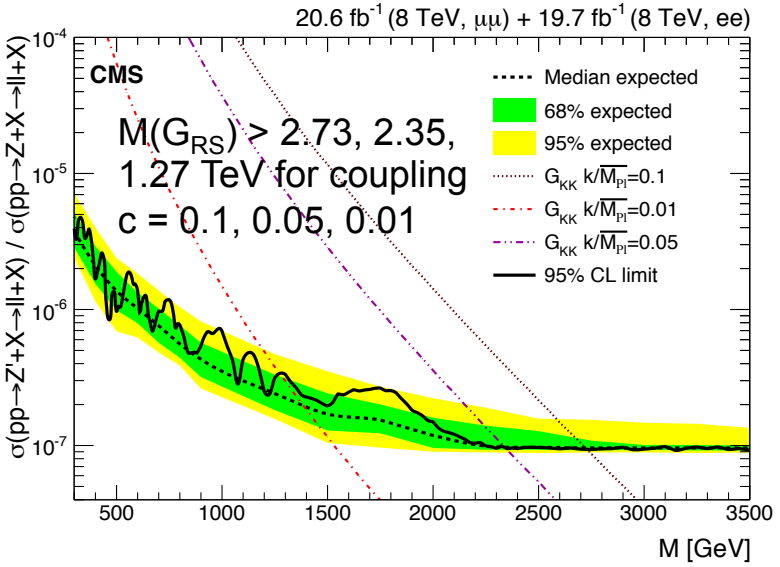


Dilepton (ee, μμ)

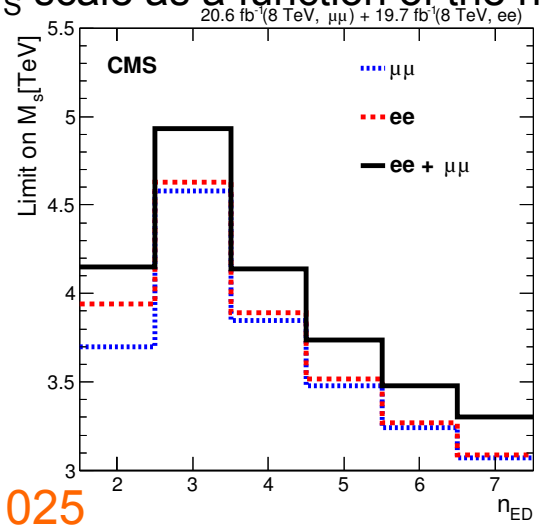
Limit on the resonance mass M

: $M(Z'_{SSM}) > 2.90$ TeV, $M(Z'_{\psi}) > 2.57$ TeV





Limits on M_S scale as a function of the n_{ED}



- Interpretation using 2 non-resonant analyses
  - Large extra dimension
  - Compositeness

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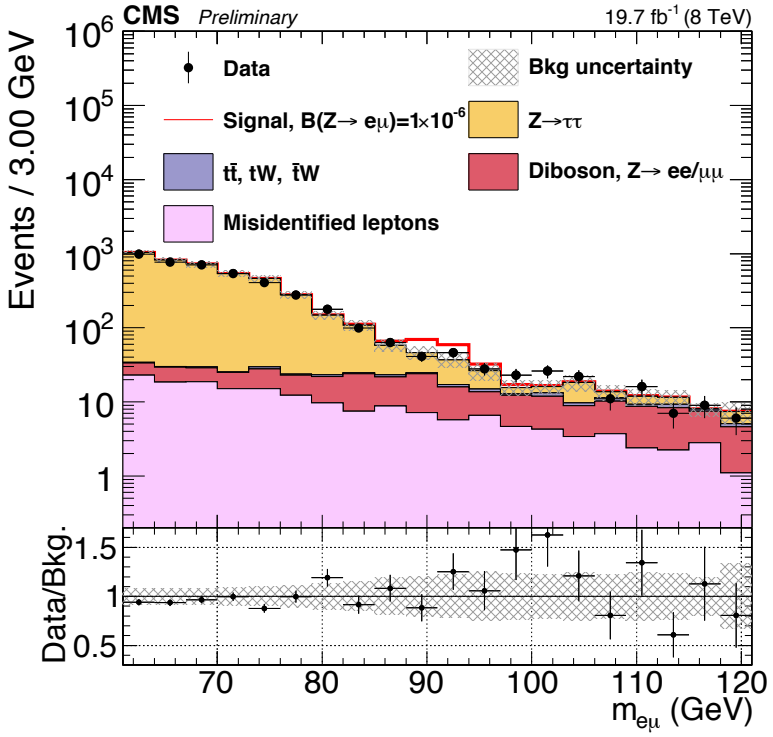
Lepton Flavour Violation

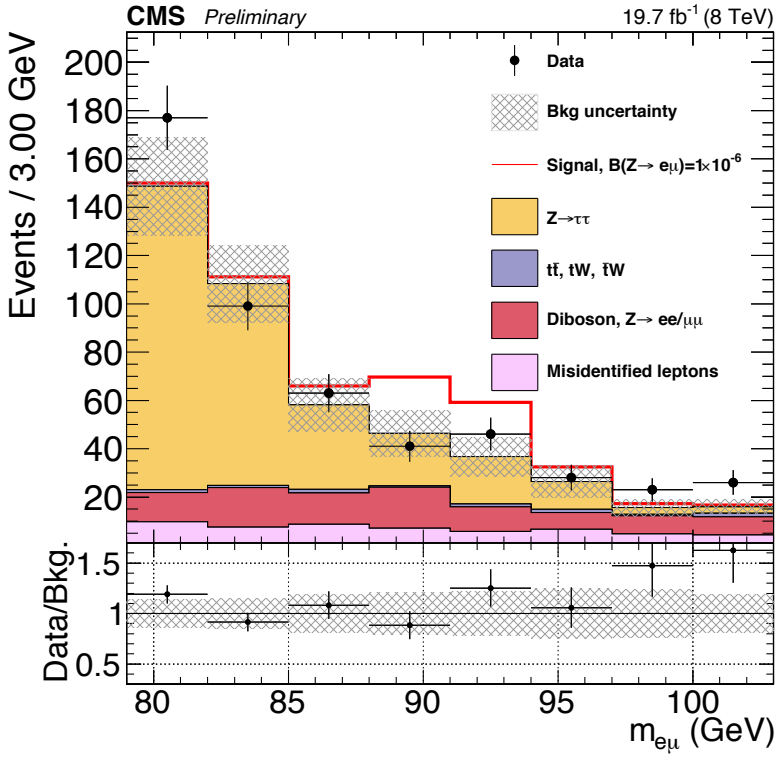
- Decays of Z→eμ

CMS-PAS-EXO-13-005

  - New physics like massive Dirac or Majorana neurinos or R-parity SUSY
- Oppositely charged e and μ
- Dominant background: Z→ττ

$Br(Z \rightarrow e\mu) < 7.3 \times 10^{-7}$

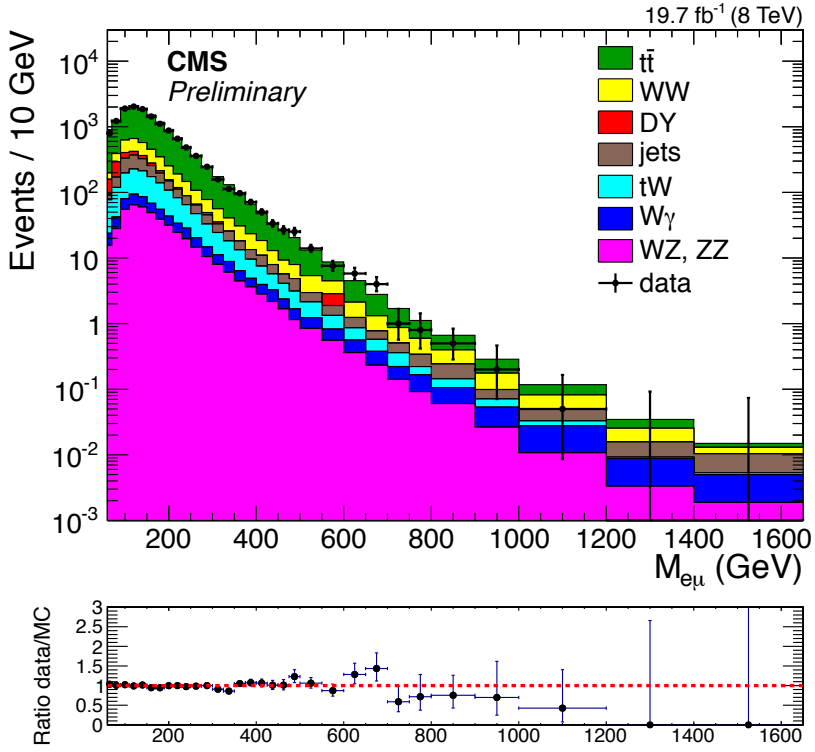


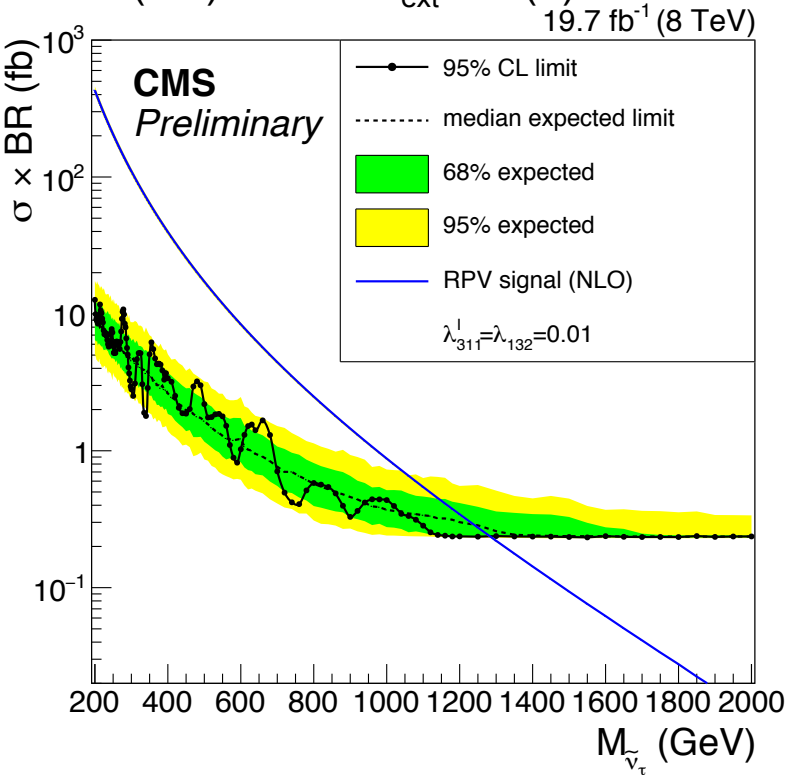


Lepton Flavour Violation

CMS-PAS-EXO-13-002

- Decays of new heavy resonances
  - Resonant $\tilde{\nu}_\tau$ LSP production in RPV SUSY
  - LFV gauge boson (Z'/a') exist and generate tranisitions between families
    - RPV: $M(\nu_\tau) > 1.3$ TeV
    - QBH: $M_{th} > 2.36$ (3.6) TeV for $n_{ext} = 1$ (6)

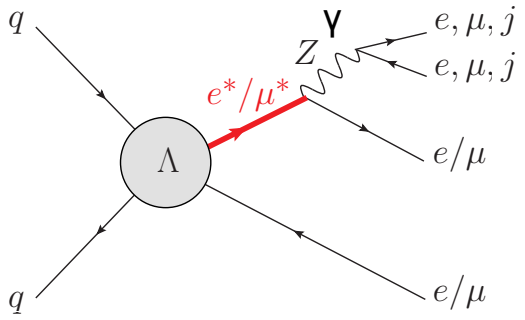


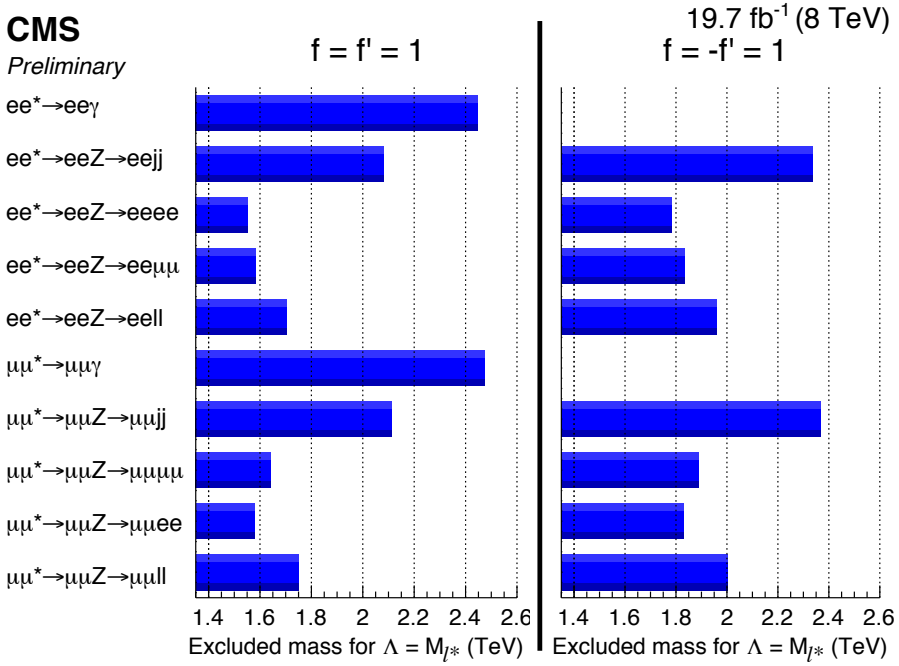


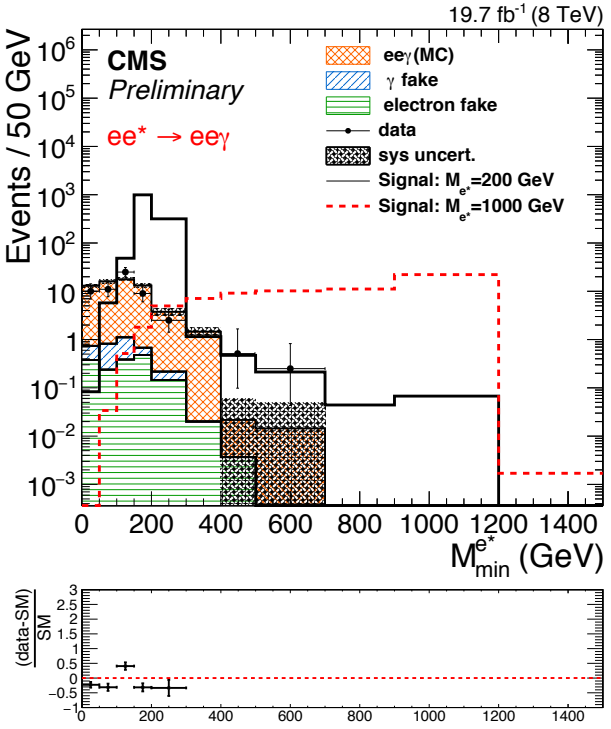
Excited Leptons

- Look for single production of excited lepton
  - Final state with llZ: Z boson is boosted
  - Relaxed isolation is applied
- llγ final state: M(l*) < 2.45 (2.48) TeV for e(μ)
- llZ final state: M(l*) < 2.35 (2.38) TeV for e(μ)

CMS-PAS-EXO-14-015



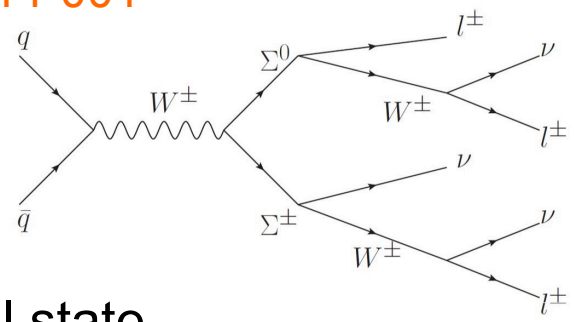


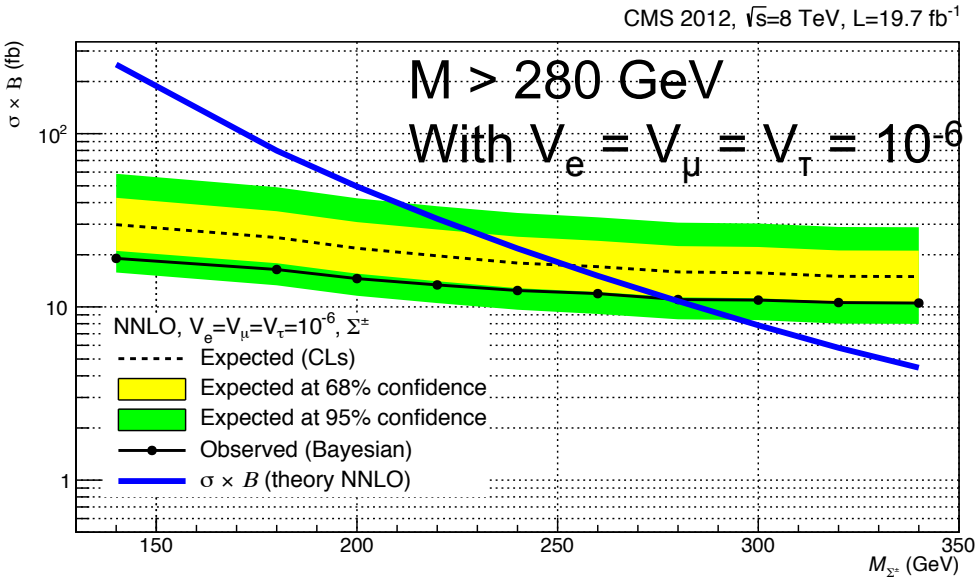


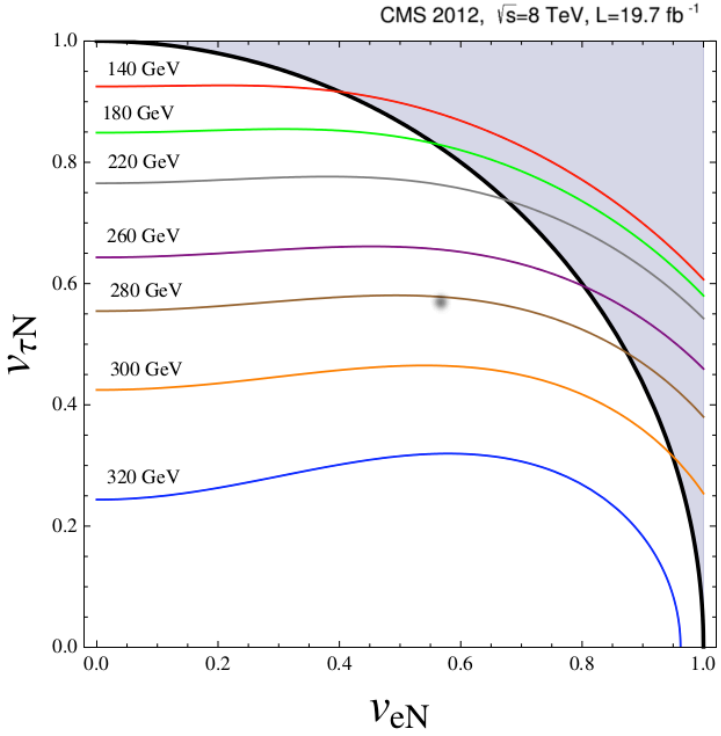
Heavy Lepton Partners of Neutrinos

CMS-PAS-EXO-14-001

- Look for triplet state: Σ^0, $\Sigma^{+/-}$
  - Type III seesaw
  - Can explain why the neutrino has a mass and it is small
  - 3 isolated leptons and large MET in the final state



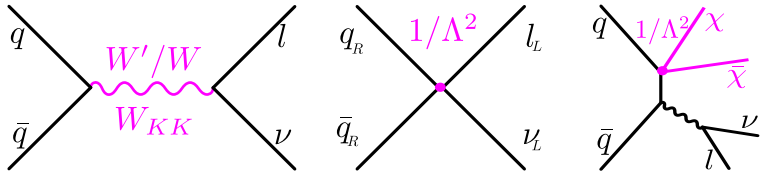




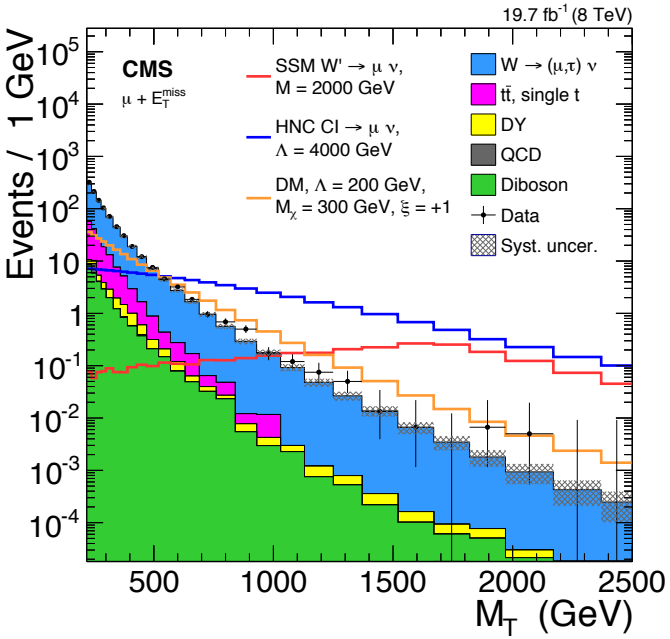
W'→lν (e or μ)

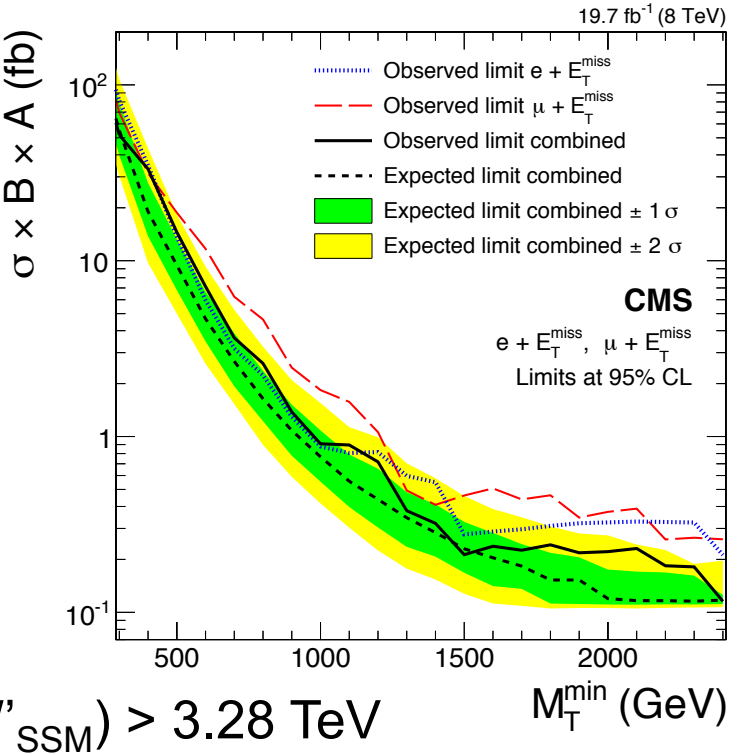
- New heavy gauge bosons can appear in many BSM models
  - SSM, RS gravitons, composite Higgs, etc.
  - Signature based to cover all possible scenarios and interpret in many benchmark signal models

PRD 91 (2015) 092005



- W' couples to fermions as the SM W



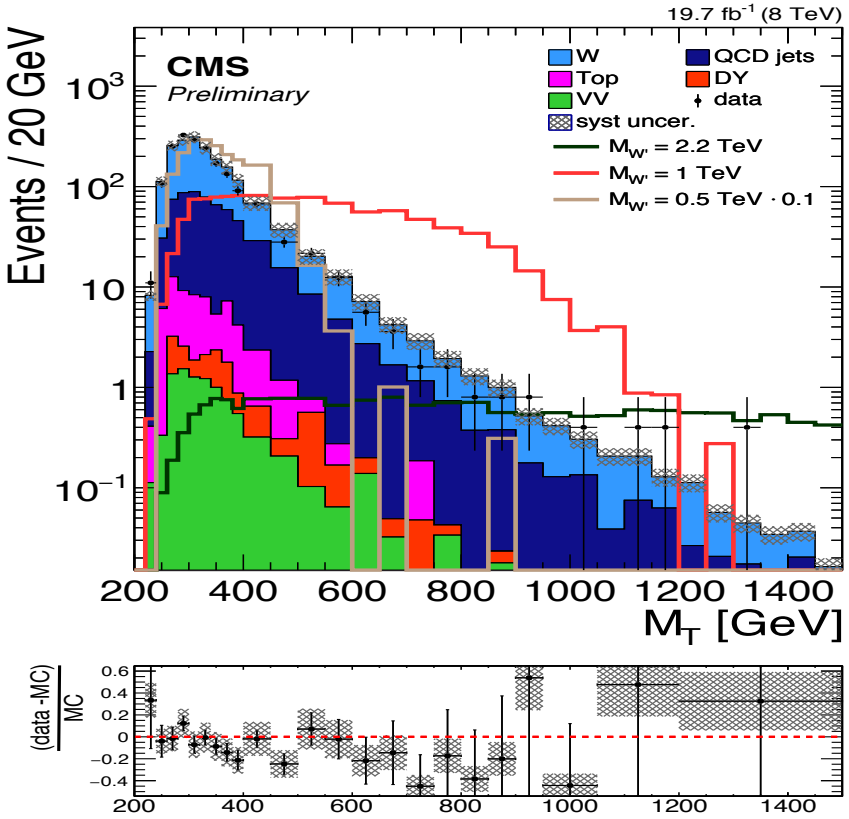


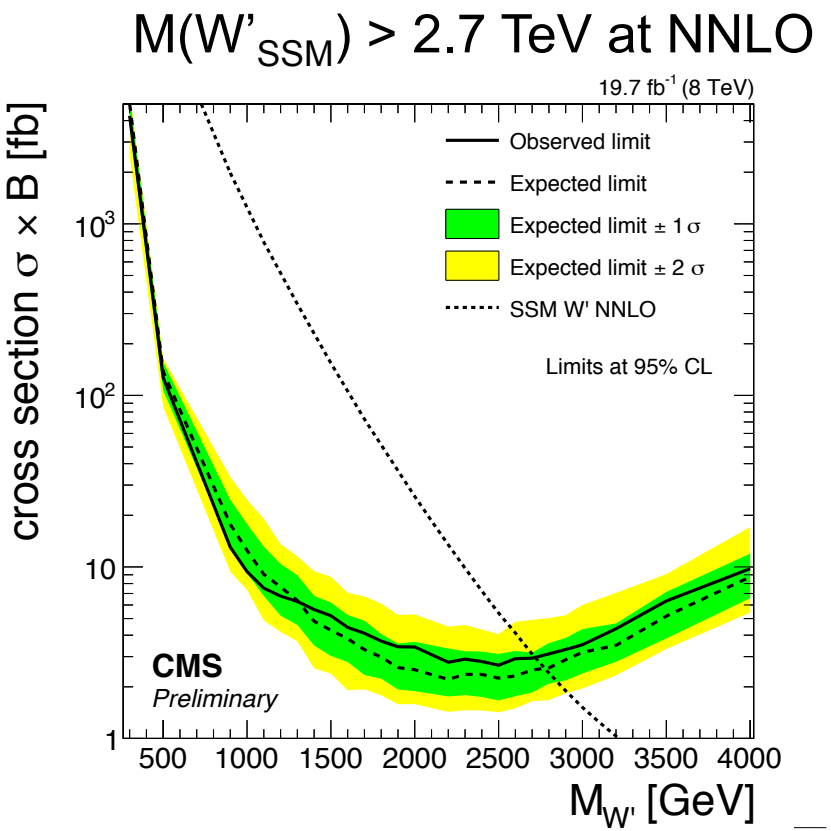
$M(W'_{SSM}) > 3.28$ TeV

W'→τν

- Test a possible non-universal coupling
- Consider hadronic decay of the τ-lepton
- Distribute the M_T variable

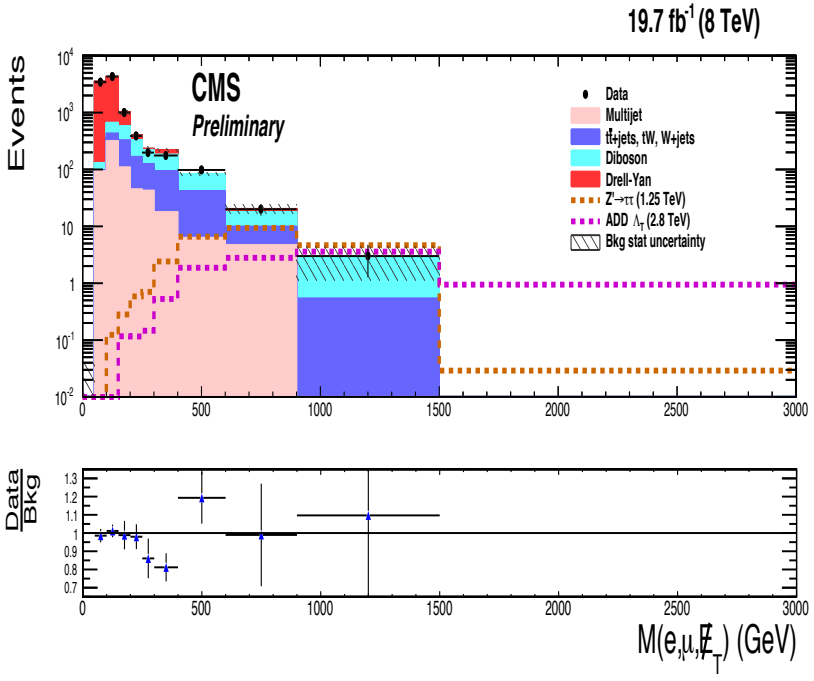
CMS-PAS-EXO-12-011
Submitted to PRL
(arXiv: 1508.04308)



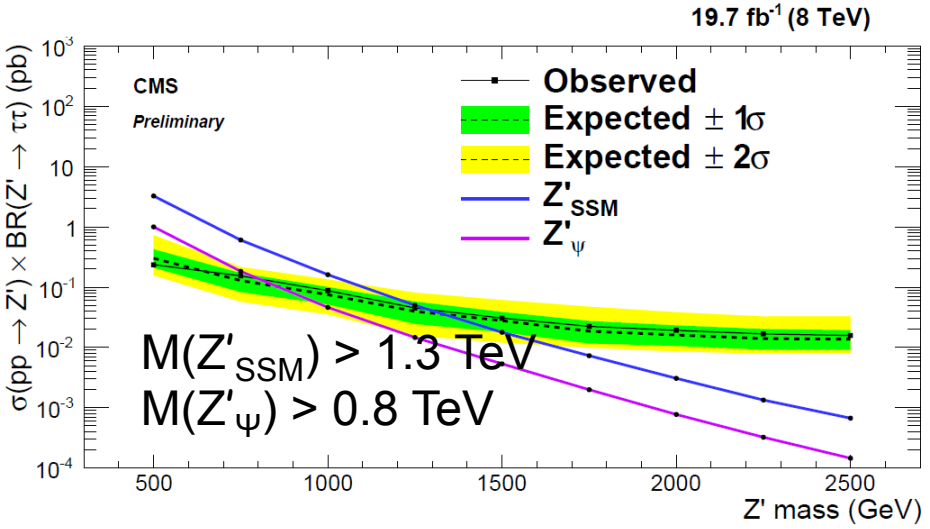


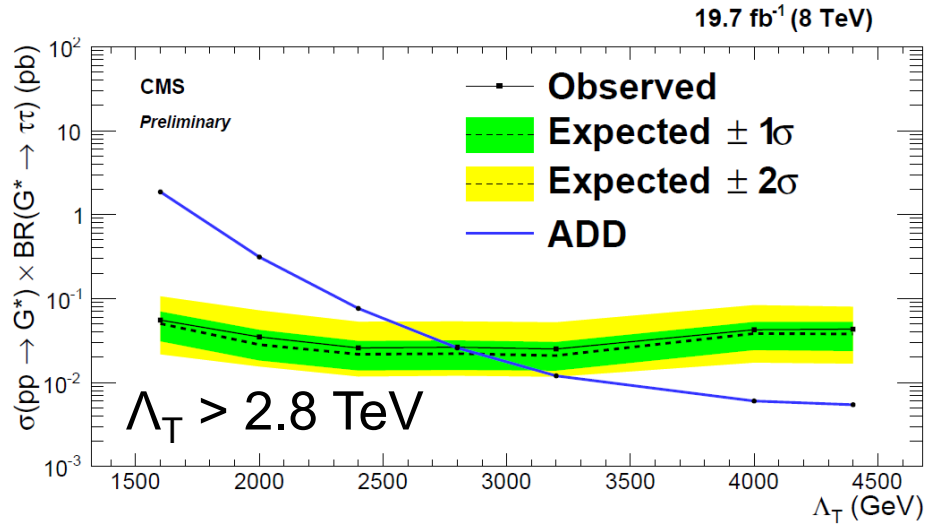
Ditau

- Consider τ_e-τ_μ final states (eμ channel)
- Main backgrounds: ttbar, dibosons, Drell-Yan, multijet from QCD



CMS-PAS-EXO-12-046



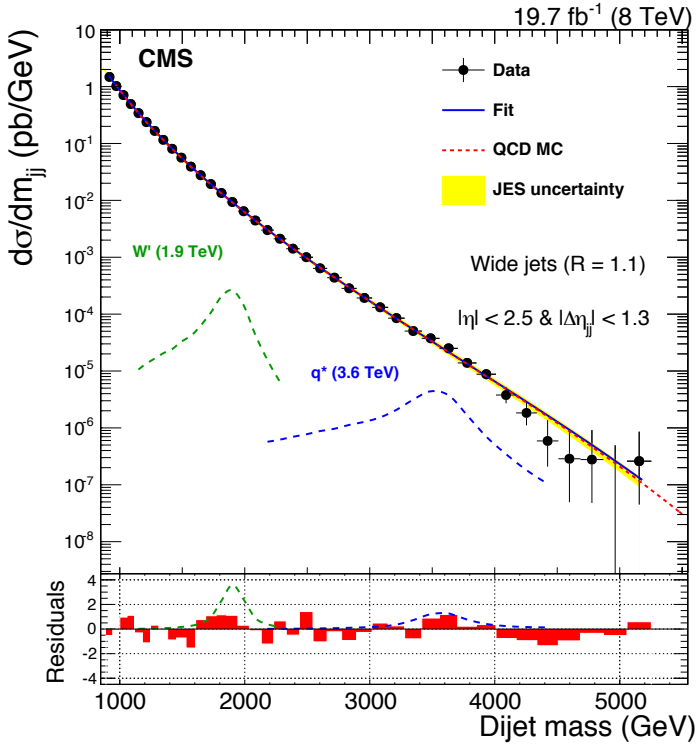


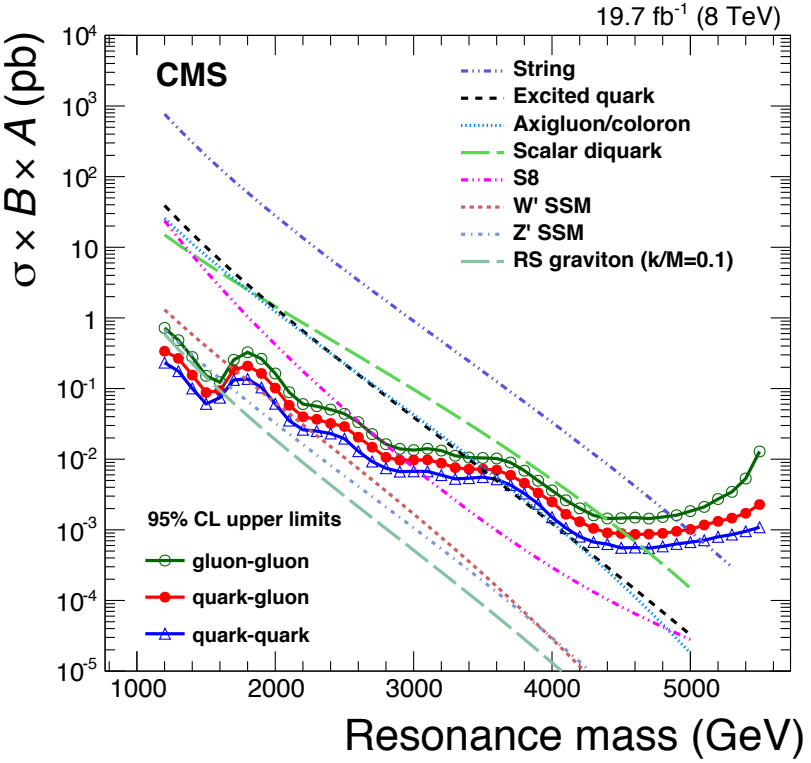
Dijet

- Search for hint of new physics in the dijet mass spectra for narrow/wide resonances
- Geometrically close jets (dR < 1.1) combined into wide jets: use to measure m_{jj}
- Highest dijet mass is at 5.15 TeV

PRD 91 (2015) 052009

String res. < 5.0 TeV
Excited quarks < 3.5 TeV
Scalar diquarks < 4.7 TeV
W' (SSM) < 2.2. TeV
Z' (SSM) < 1.7 TeV
RS(g, c=0.1) < 1.6 TeV





Multijet

- Pair produced resonances decaying to jets: X→YY, Y→jj
  - Exclude top squark masses for decays to light (heavy) jets in range
  - 200 < m(jj) < 350 (385) GeV

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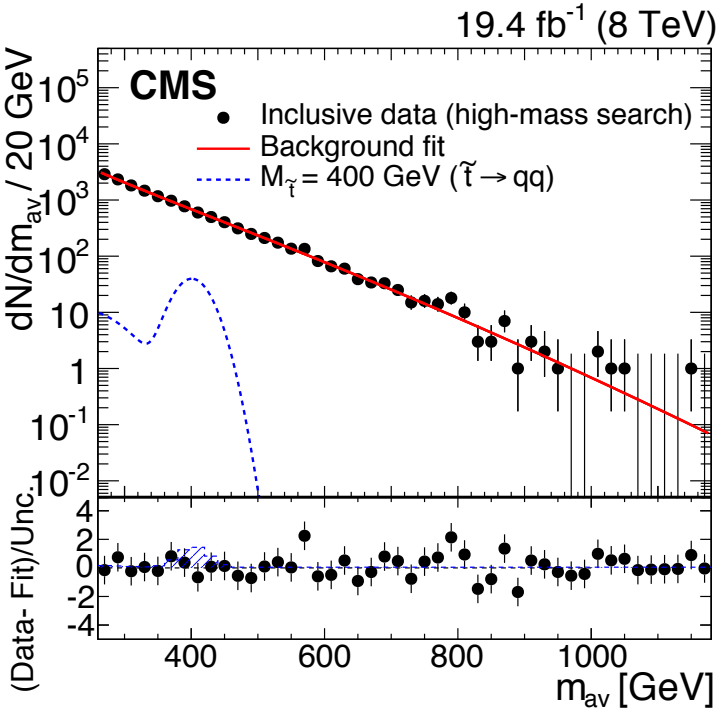
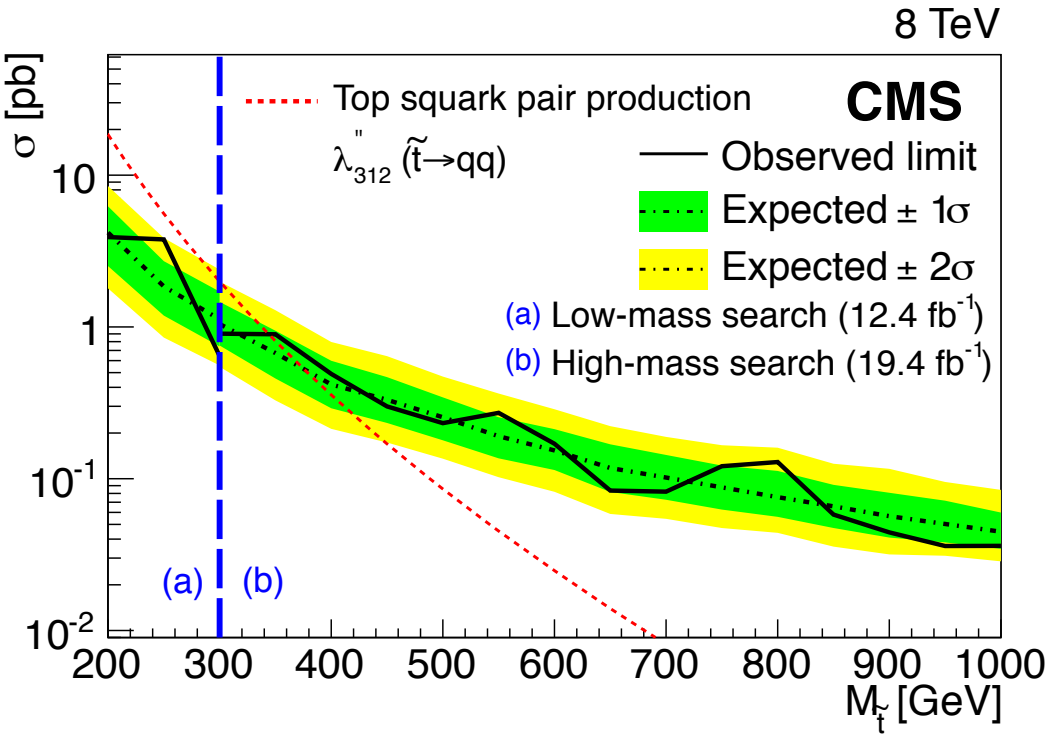
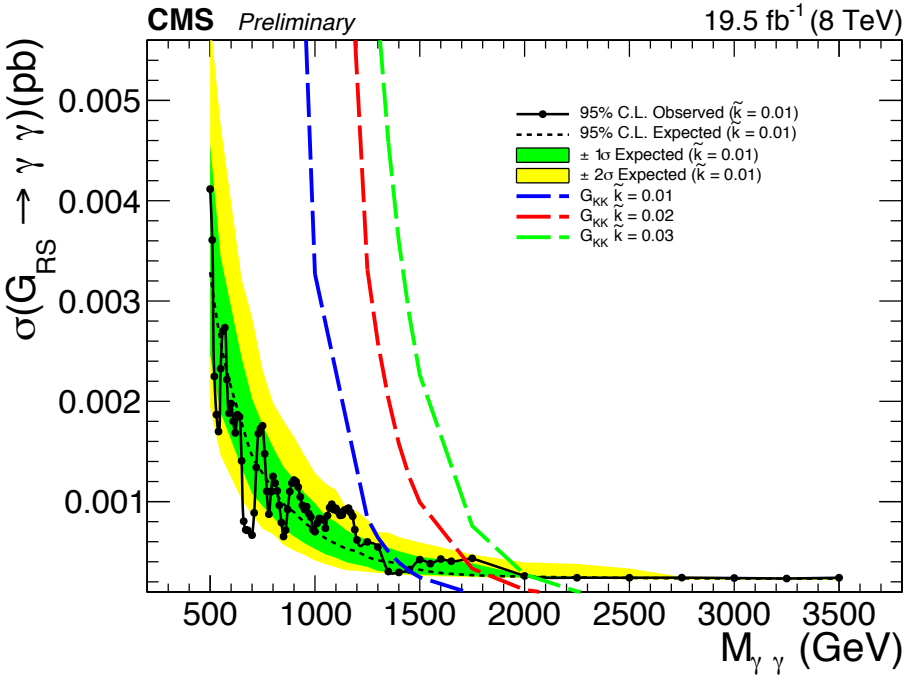


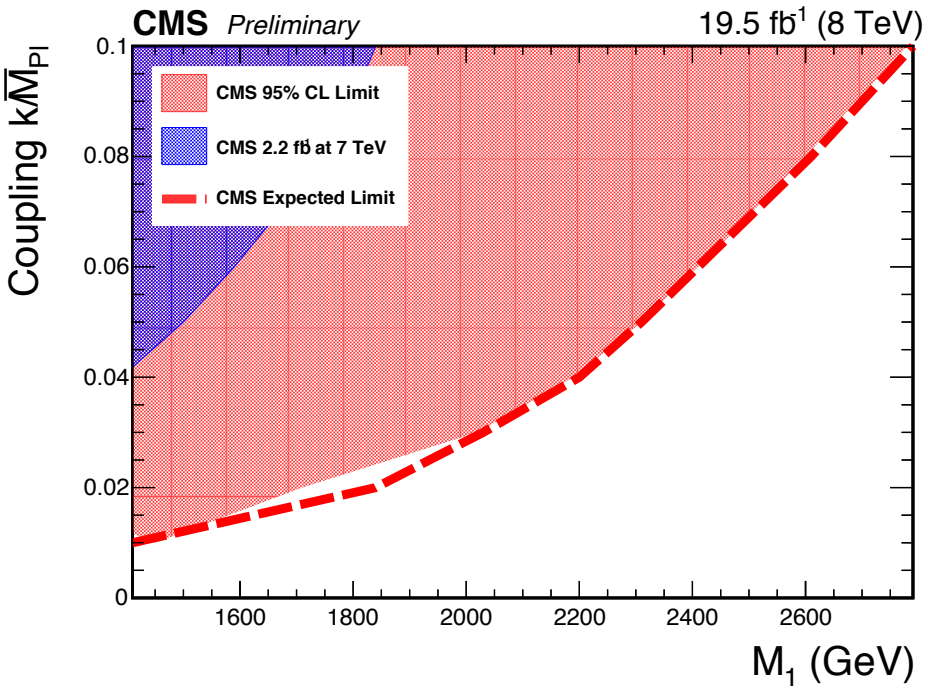


Diphoton

- Look a signature of an excited state of the graviton in the RS model
  Simple final state, large background
- Background: SM diphoton, photon+jet or di-jet processes (jets identified as photons)
- Limits on $M(G_{RS})$: 1.45 – 2.78 TeV for $0.01 < k/M_{Pl} < 0.1$

CMS-PAS-EXO-12-045





Diboson

- Massivie resonances in dijet (multijet) searches with W, Z tagging
  - Used jet-substructure for boosted signature
  - GRS→WW (left), WZ (middle), WH→lvbb (right) resonances

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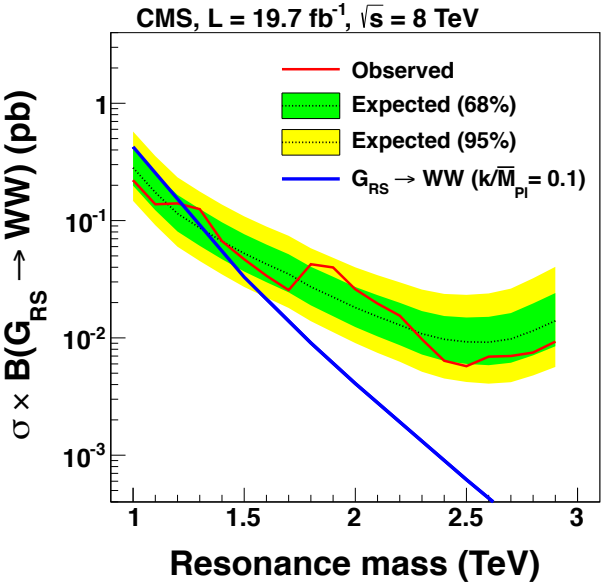
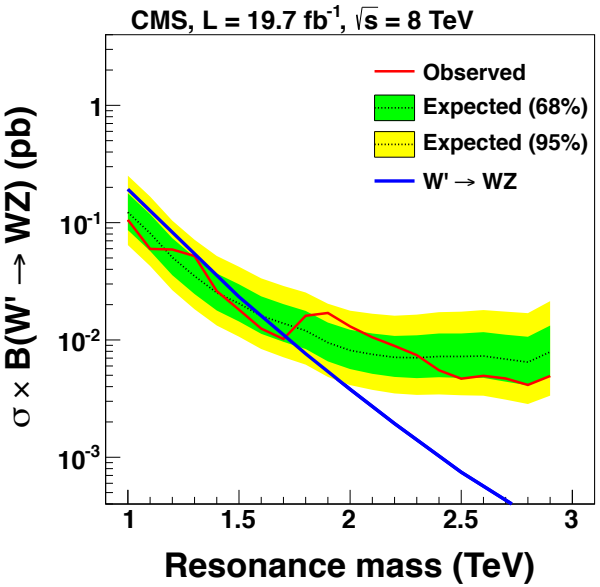
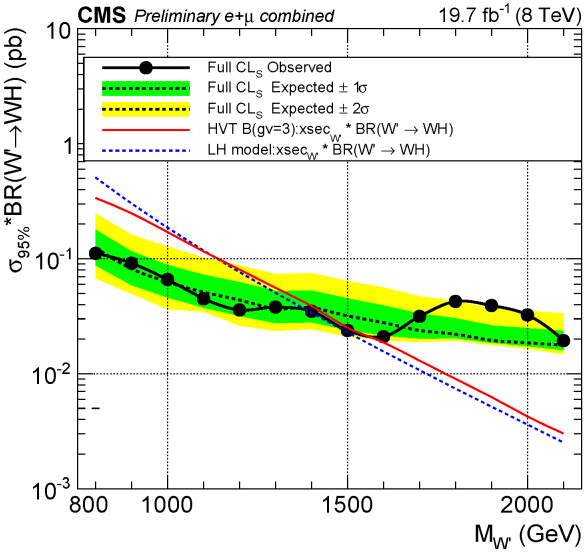




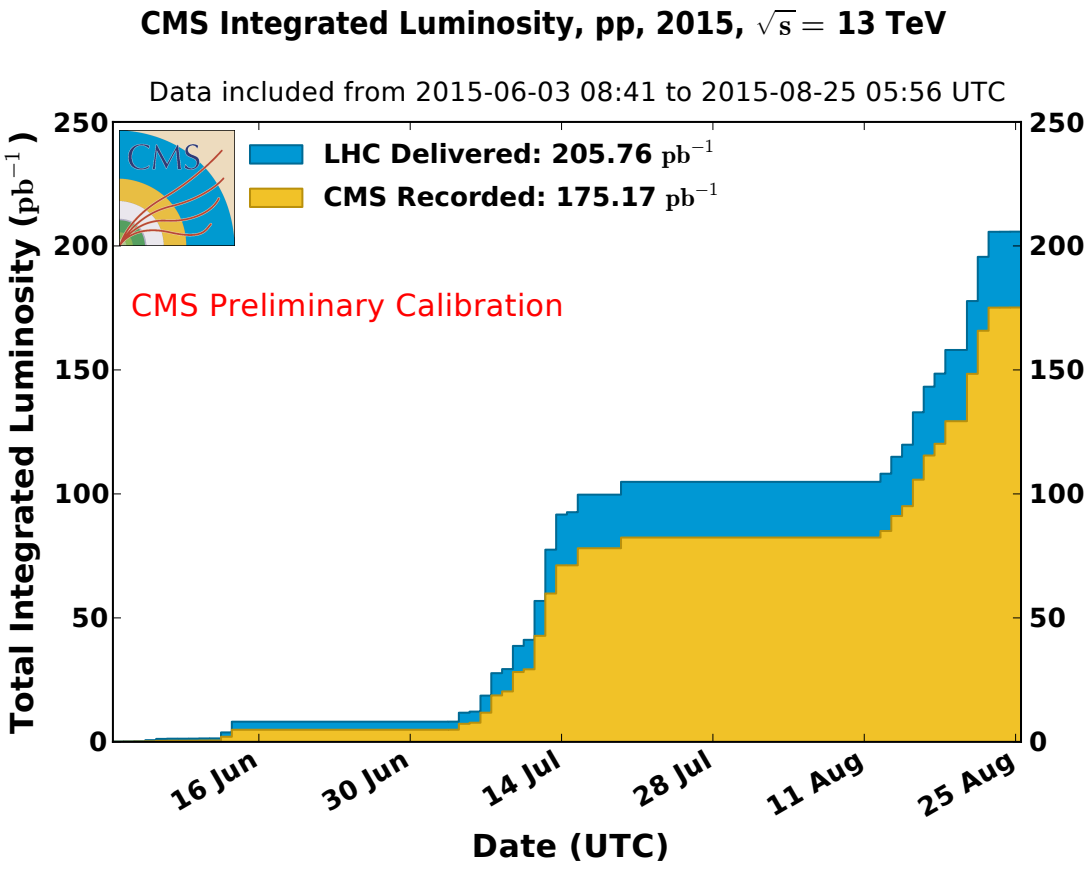
CMS PAS EXO-14-010



- Small excess around 1.8 TeV (1.5σ in VV, ~2.0σ in VH)
  - Enhanced in exclusive decay modes

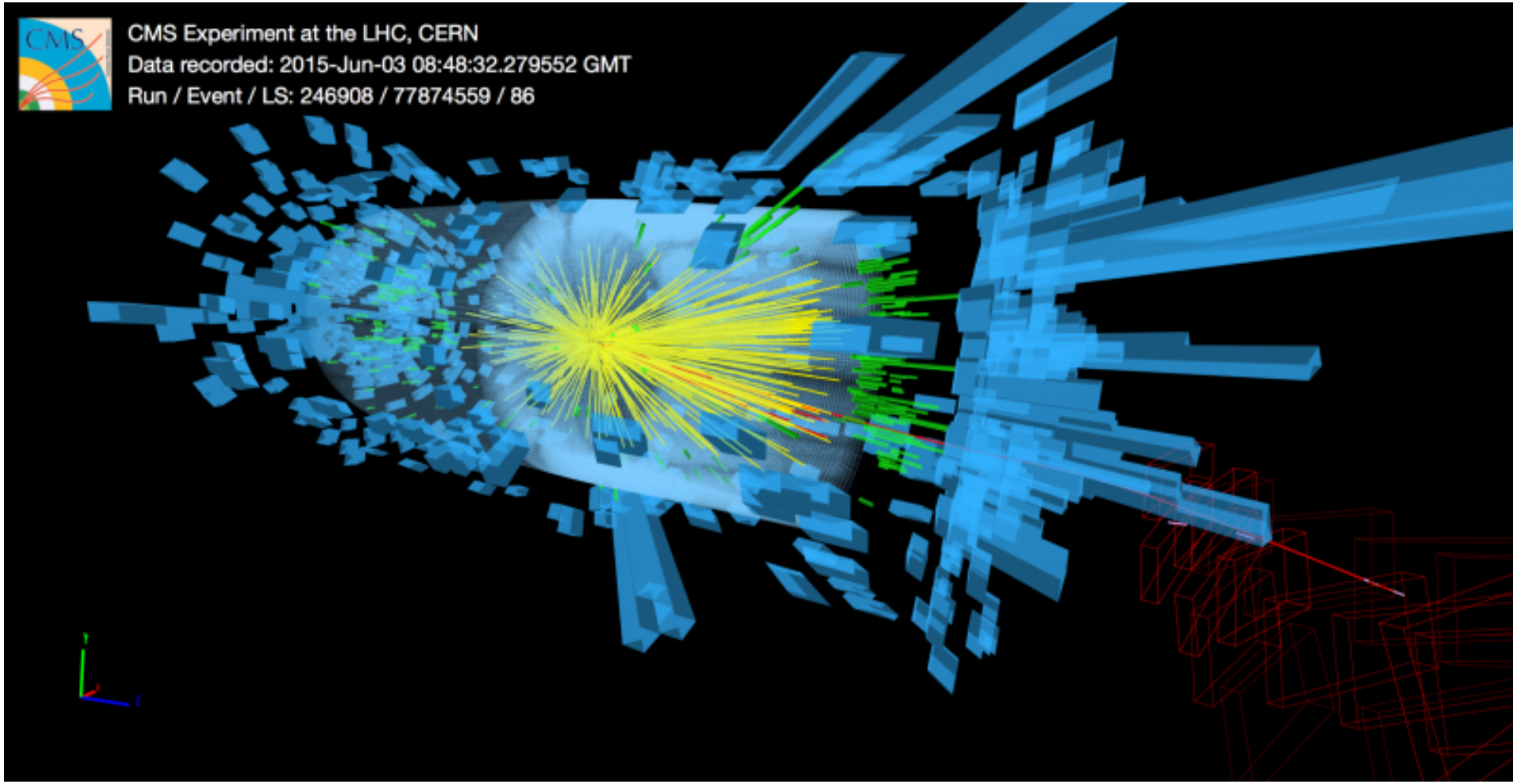
Status of LHC Run II

- Run II operation with 50ns completed successfully
  - Start 25ns operation from August
  - Performance studies are on-going



First 13 TeV Collision!!

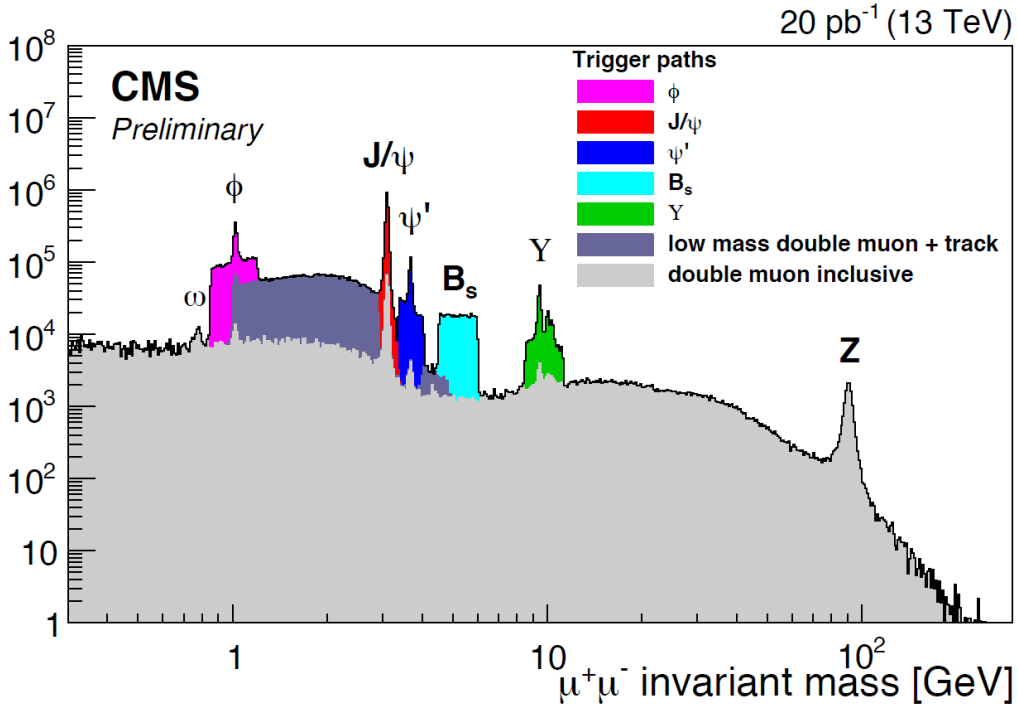
- LHC collides protons at 13 TeV
  - Physics run started from June 3rd!!!



Resonances

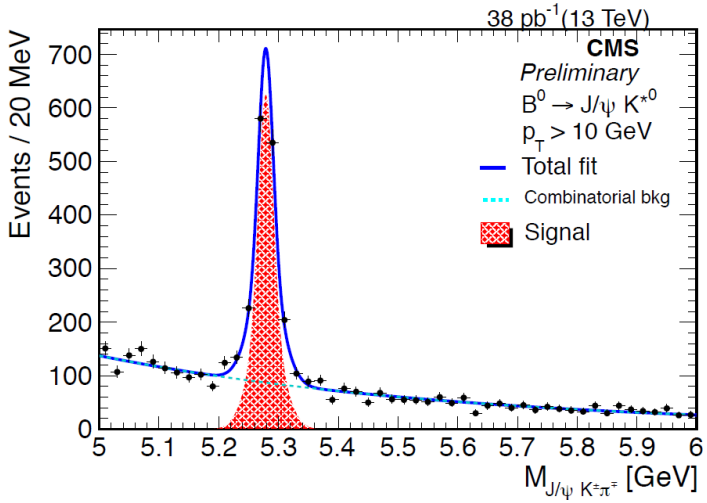
Special Triggers

In certain mass regions
and with different p_T cuts



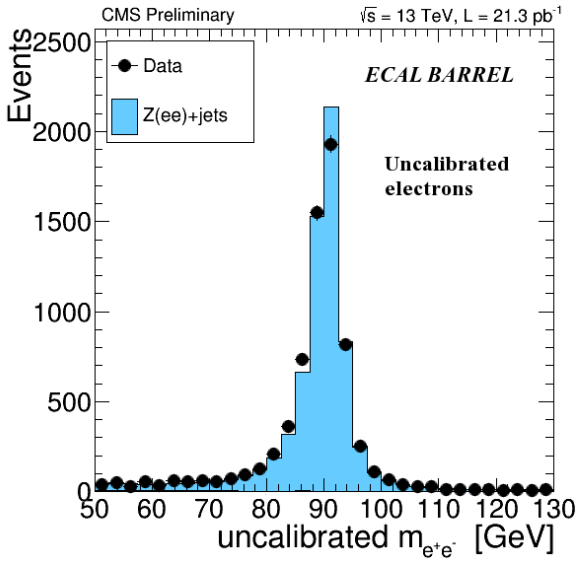
$B^0_s \rightarrow J/\psi\ \varphi$

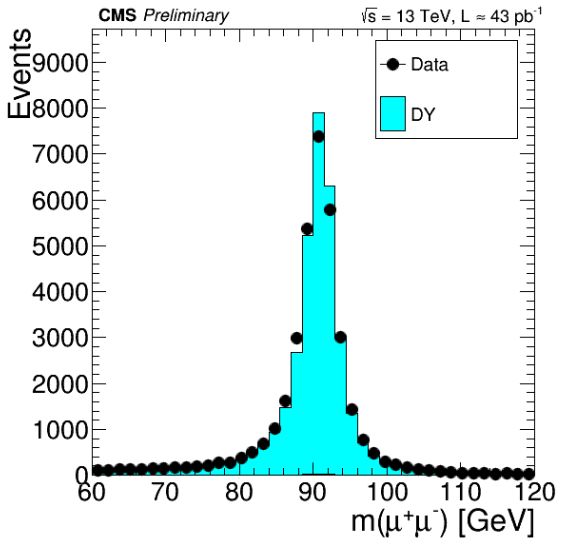
with displaced J/ψ +
track trigger



Mass:
5.369 ± 0.001(stat.) GeV
PDG: 5366.7 ± 0.4 MeV

Z Boson Resonance

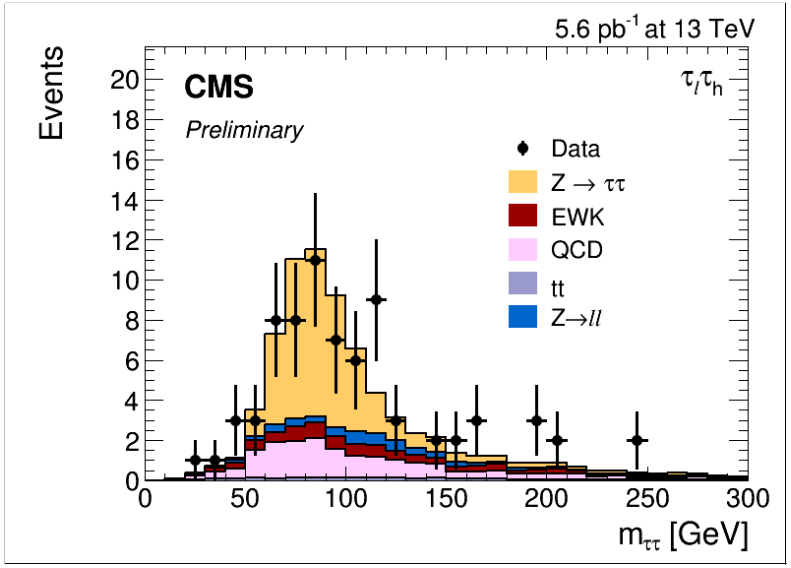




Z → ee

Z → μμ

Z → ττ

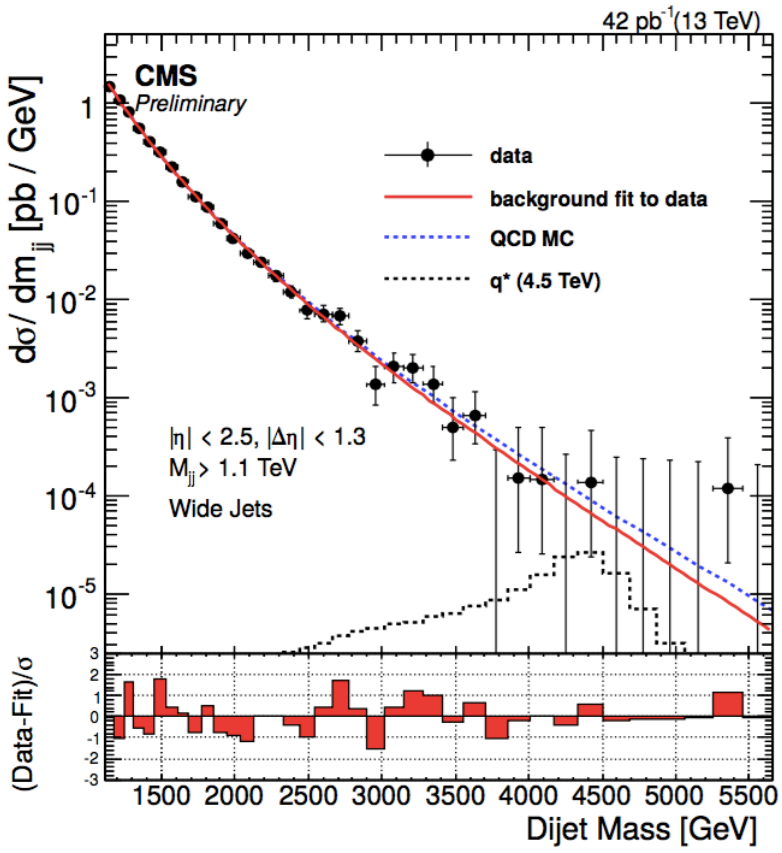


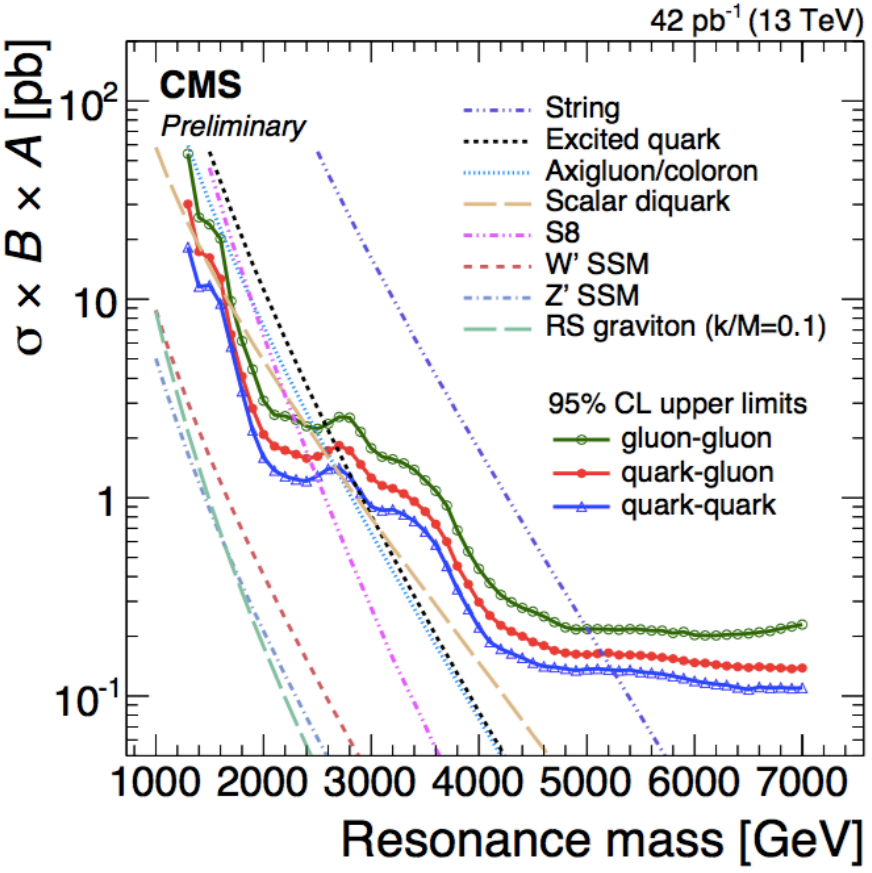
Z – Boson as standard physics candle

Dijet Search at 13 TeV

CMS PAS EXO-15-001

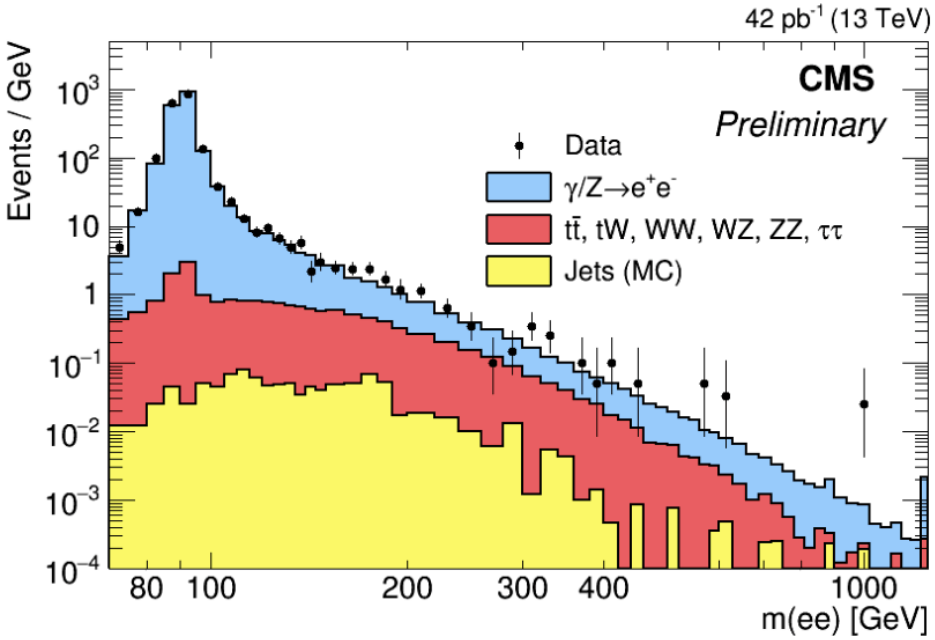
- With 42/pb expect to exceed the sensitivity of 8 TeV analyses only for narrow resonances with masses >≈ 5 TeV
- The dijet mass distribution is fitted using 4-parameter function

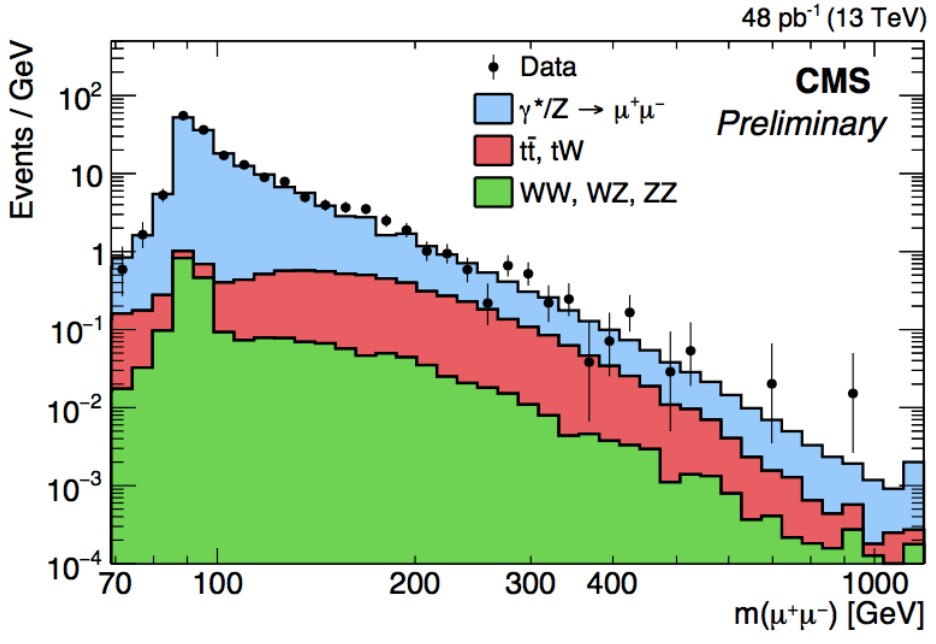




Dilepton Search at 13 TeV

- Two isolated leptons are required
- Highest mass events are observerd at around 1 TeV for dielectron and dimuon channels
- Run 1 sensitivity will be reached after about 2/fb





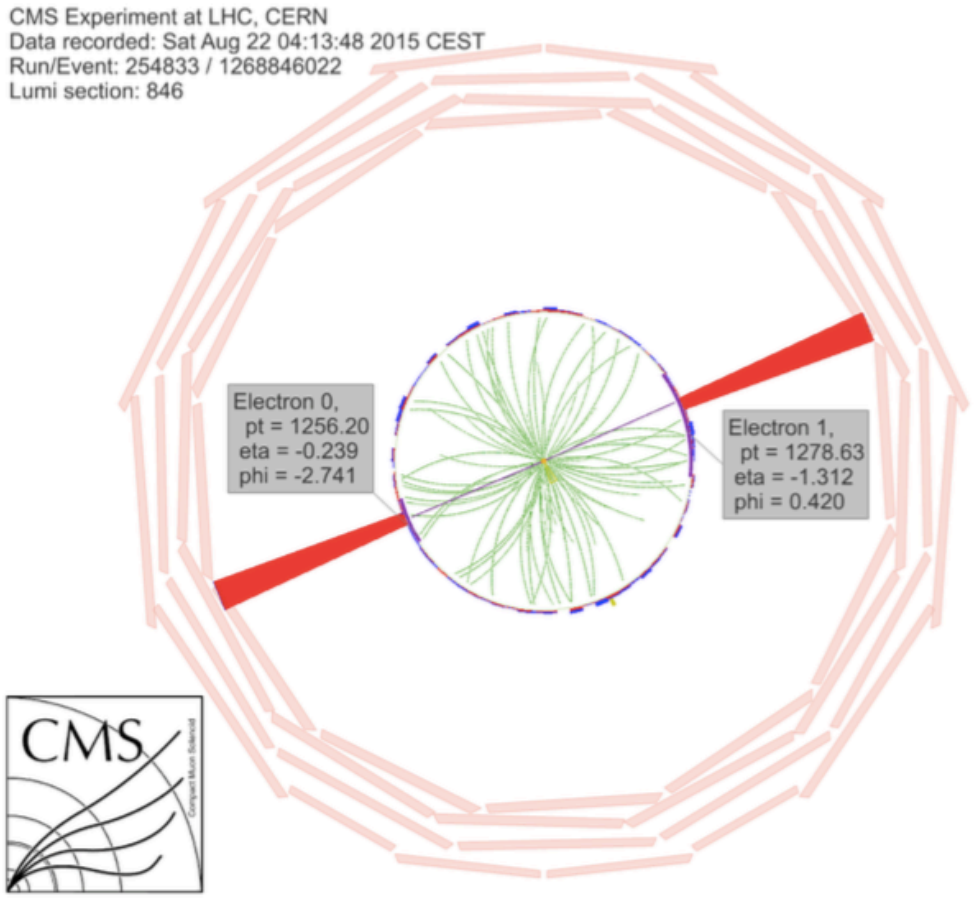
Dielectron Event at ~3 TeV

In the additional 25 pb^{-1} data @13 TeV and 50 ns processed last Wednesday:

An event with a di-electron mass of 2.9 TeV has been observed

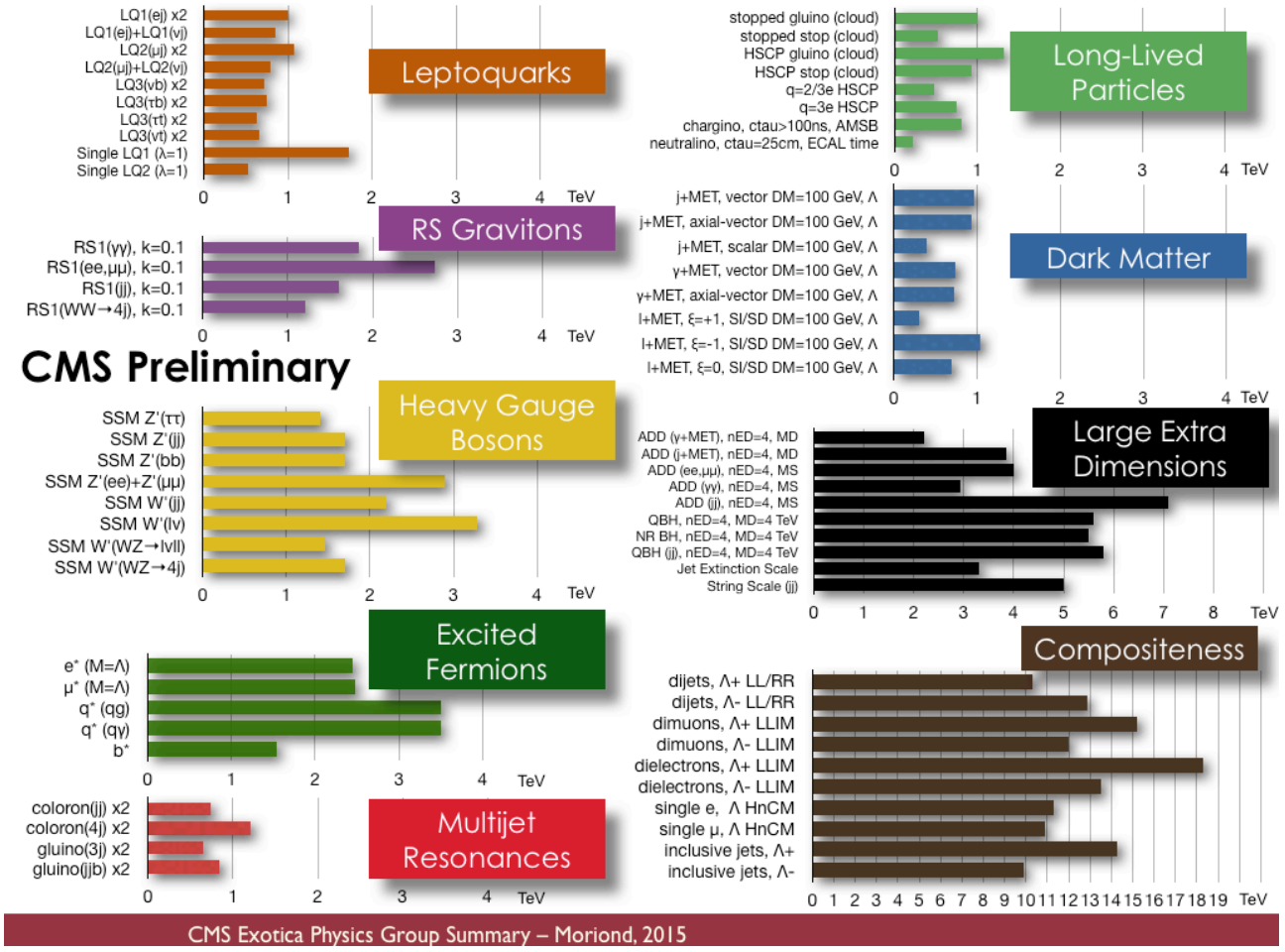
The event consists in two perfectly balanced electrons and no other significant activity

M = 2.9 TeV !!!



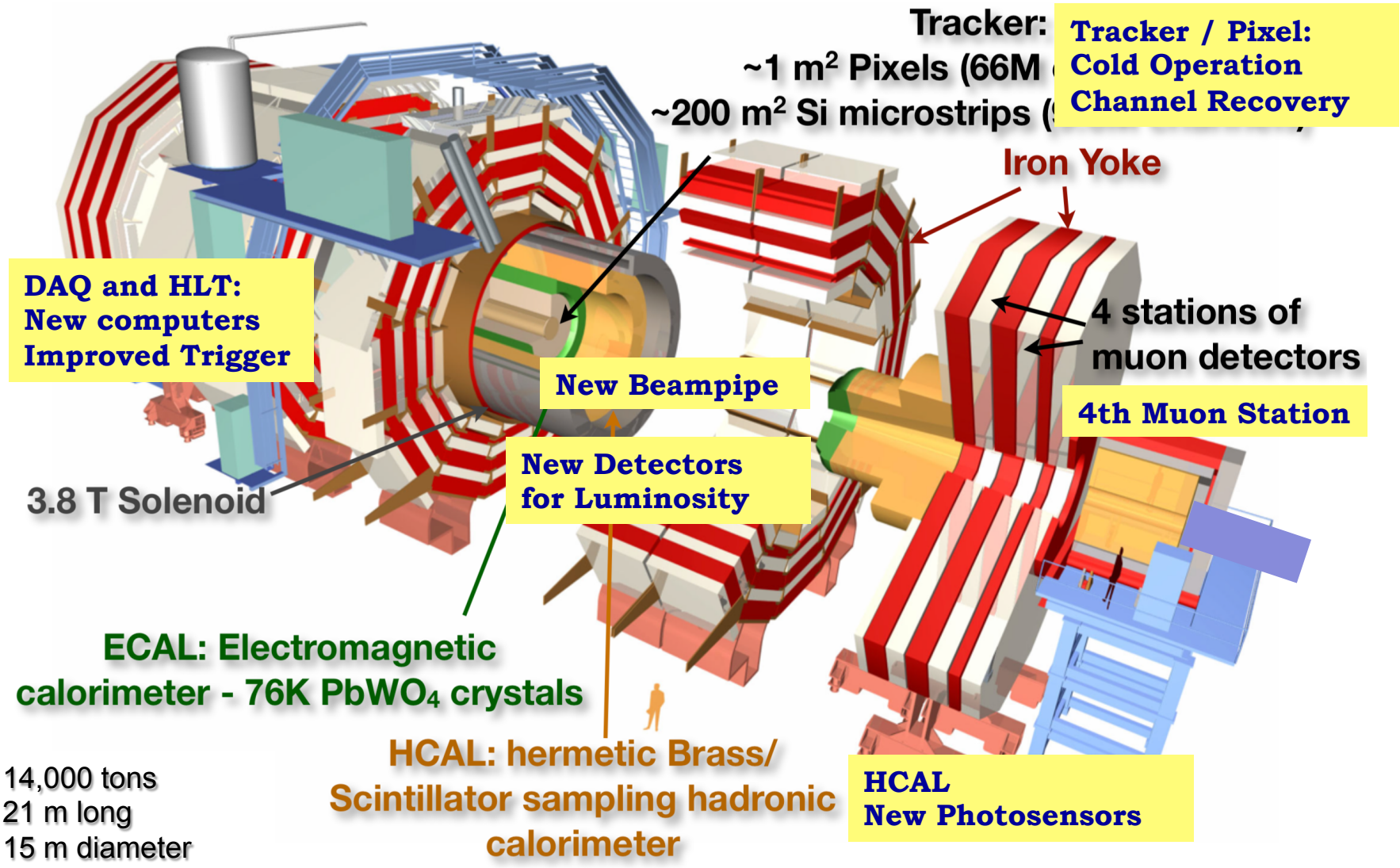
Summary

- Many searches for new physics are delivered with Run I data and stay tuned with new 13 TeV results from CMS



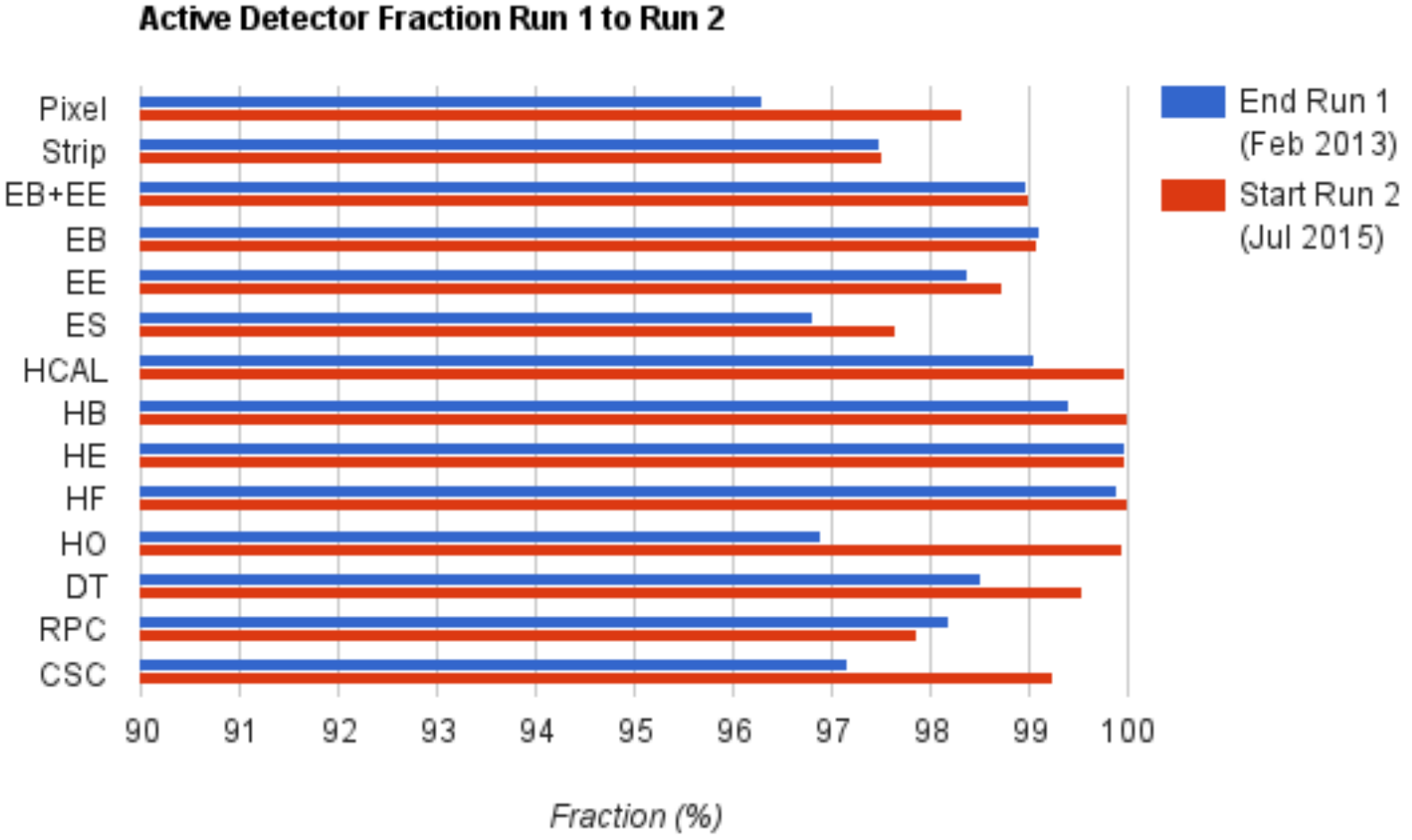
Back Up

CMS After Long Shutdown 1



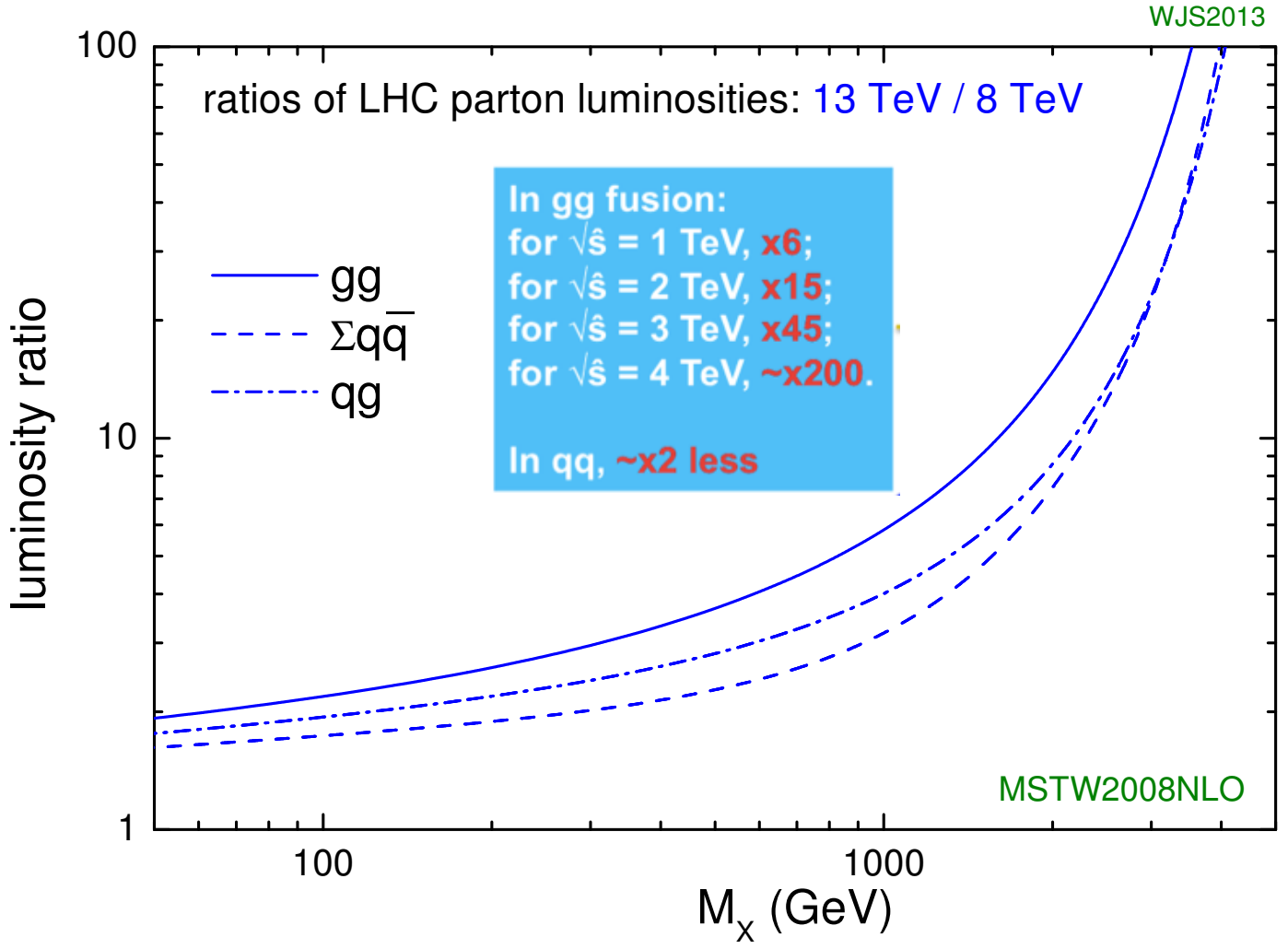
Detector Commissioning

- **All sub-detectors ready for data-taking**
- **Active channel fraction higher than Run 1**

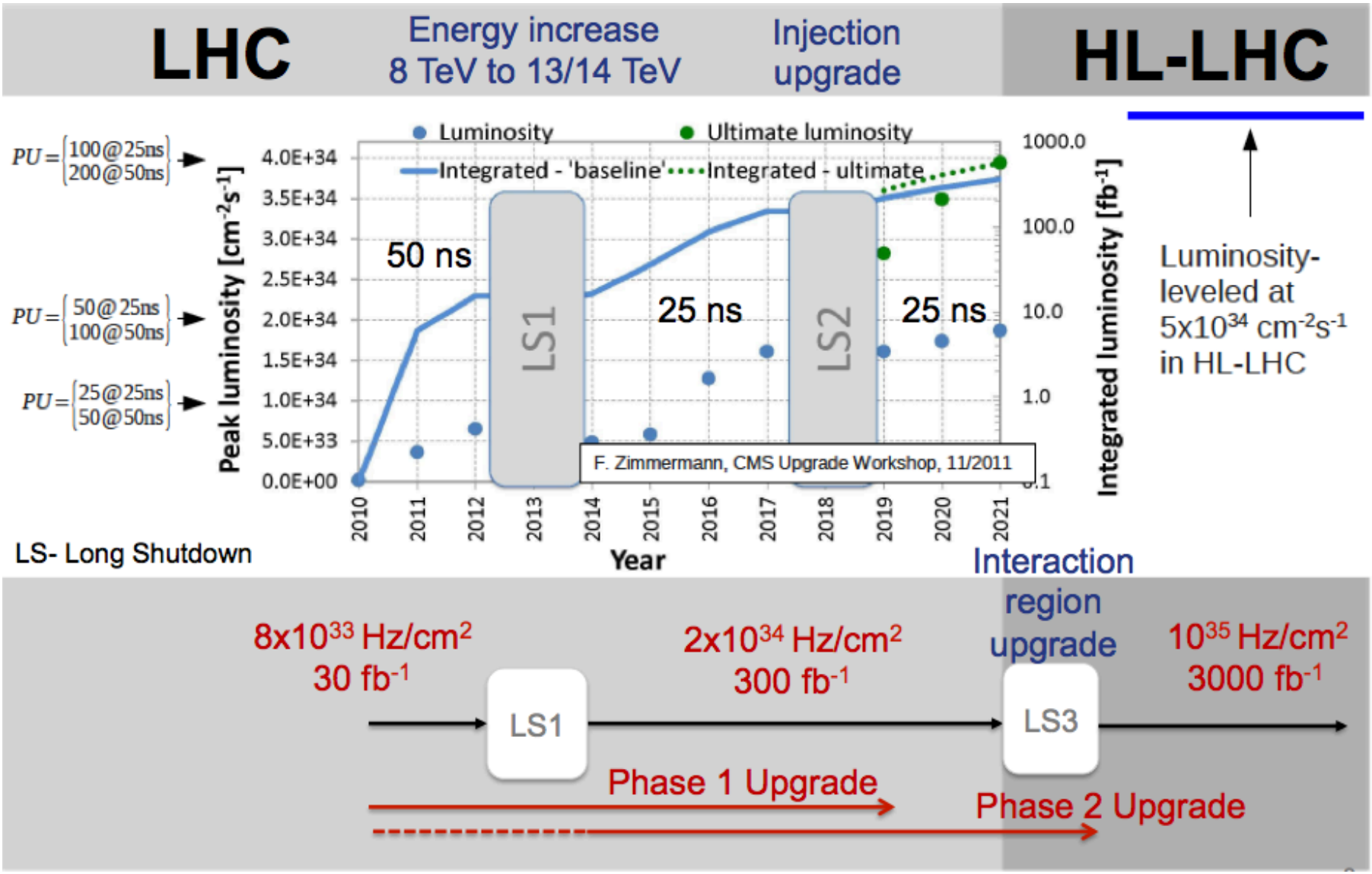


Luminosity Ratio

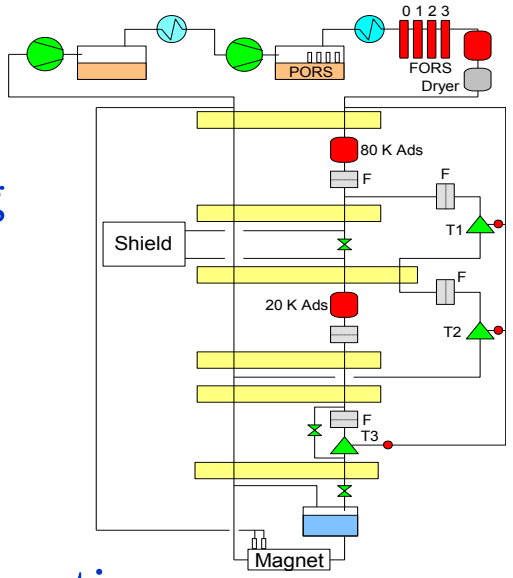
J. Stirling



LHC Operation



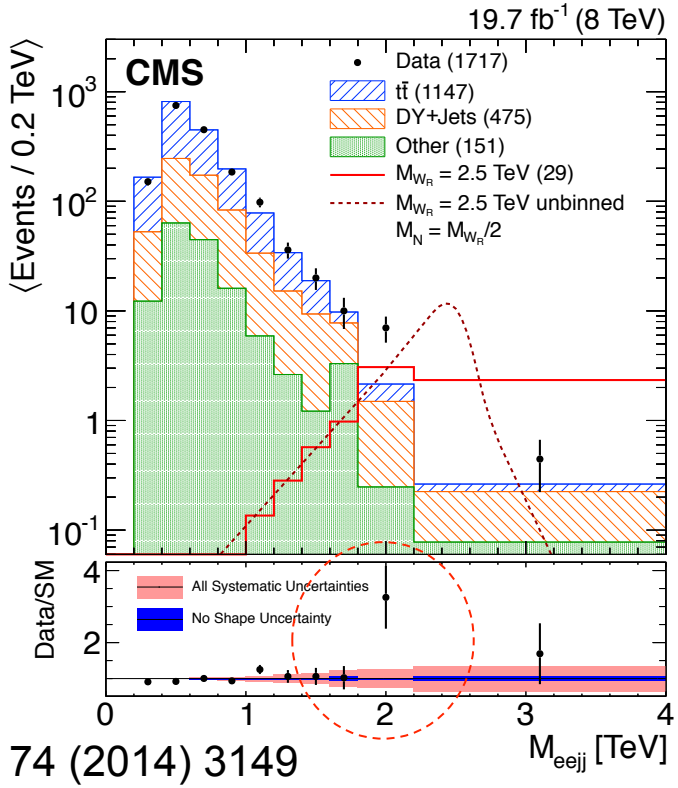
Magnet Cryogenics



- The restart of the CMS magnet after LS1 was more complicated than anticipated due to problems with the cryogenic system in providing liquid Helium.
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system.
- Currently the magnet can be operated, but the continuous up-time is still limited by the performance of the cryogenic system requiring more frequent maintenance than usual.
- A comprehensive program to re-establish its nominal performance is underway. These recovery activities for the cryogenic system will be synchronized with the accelerator schedule in order to run for adequately long periods.
- A consolidation and repair program is being organized for the next short technical stops and the long TS at the end of the year.

Sensitivity at 2 TeV: Electron Excess

- An excess with 2.8σ @ 2.1 TeV visible on the eejj invariant mass in the search for W_R (not observed the excess in mumujj)
- Similar excess (@ 650 GeV) is observed in both eejj and evjj channel in leptoquarks searches (dominated by evjj)



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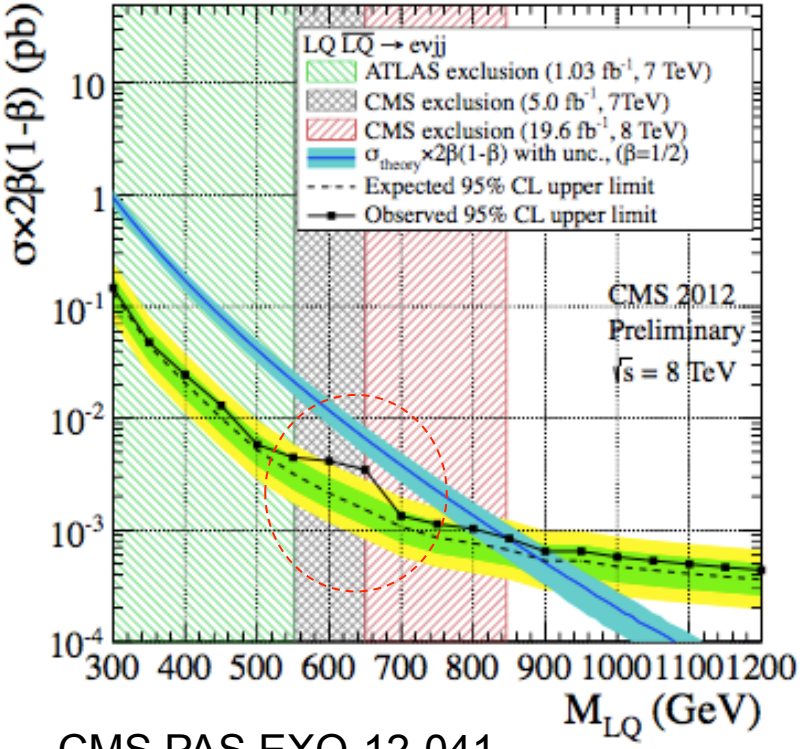
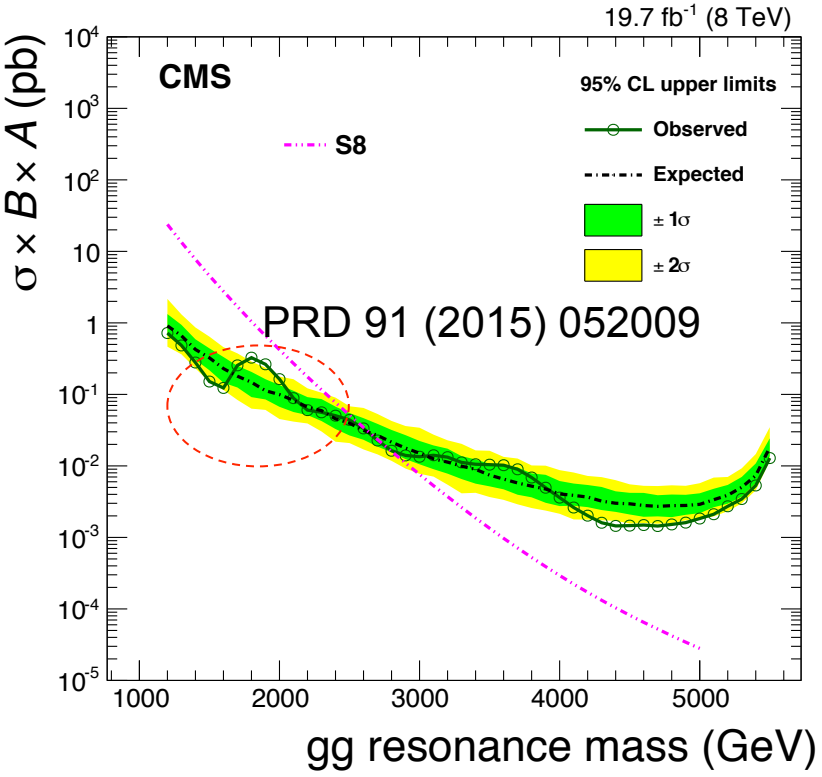
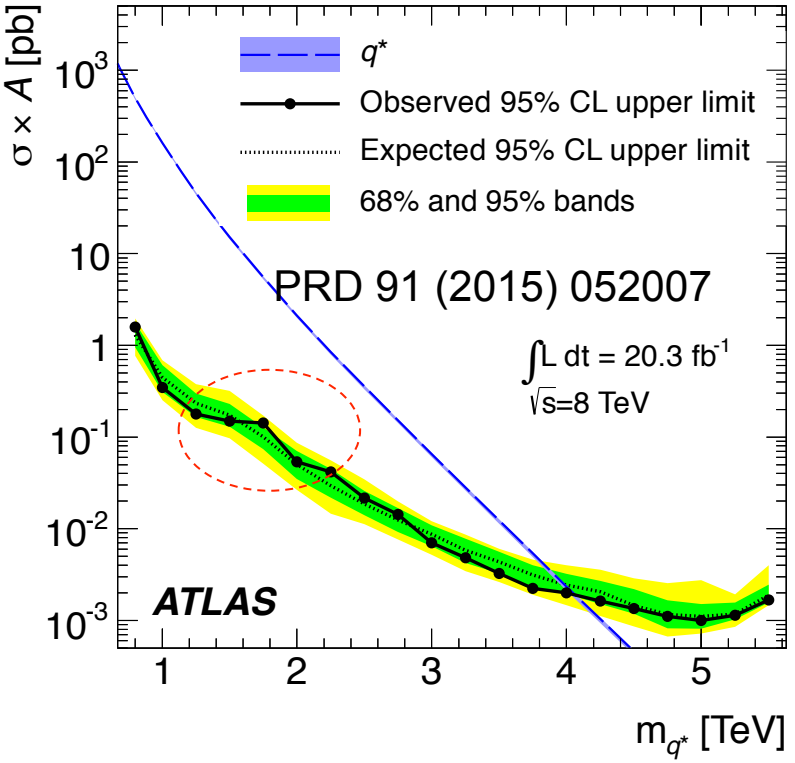


CMS PAS EXO-12-041

Sensitivity at 2 TeV: Dijet

- CMS observed ~2.0σ (local) and ATLAS also did small excess (but not much like CMS)
- This is the ONLY place where both experiments observed with limit > expectation!!





Z′ Projection at 14 TeV

- Projection of discovery reach at 14 TeV with 300, 1000, 3000/fb
- Used in Snowmass white paper
- Studies are based on generator level extrapolations and scaling of 8 TeV results

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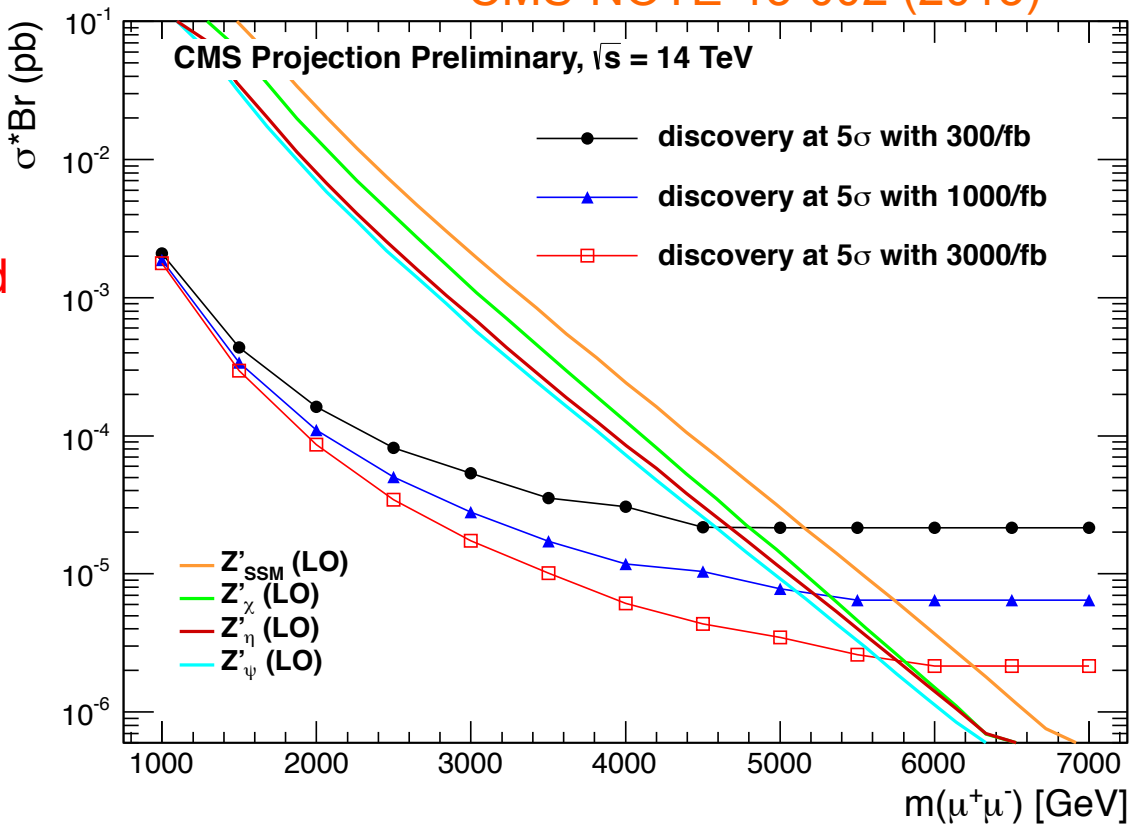

Important to understand the future expectation to decide the detector upgrade plan