Exotica searches in CMS

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on behalf of the CMS collaboration

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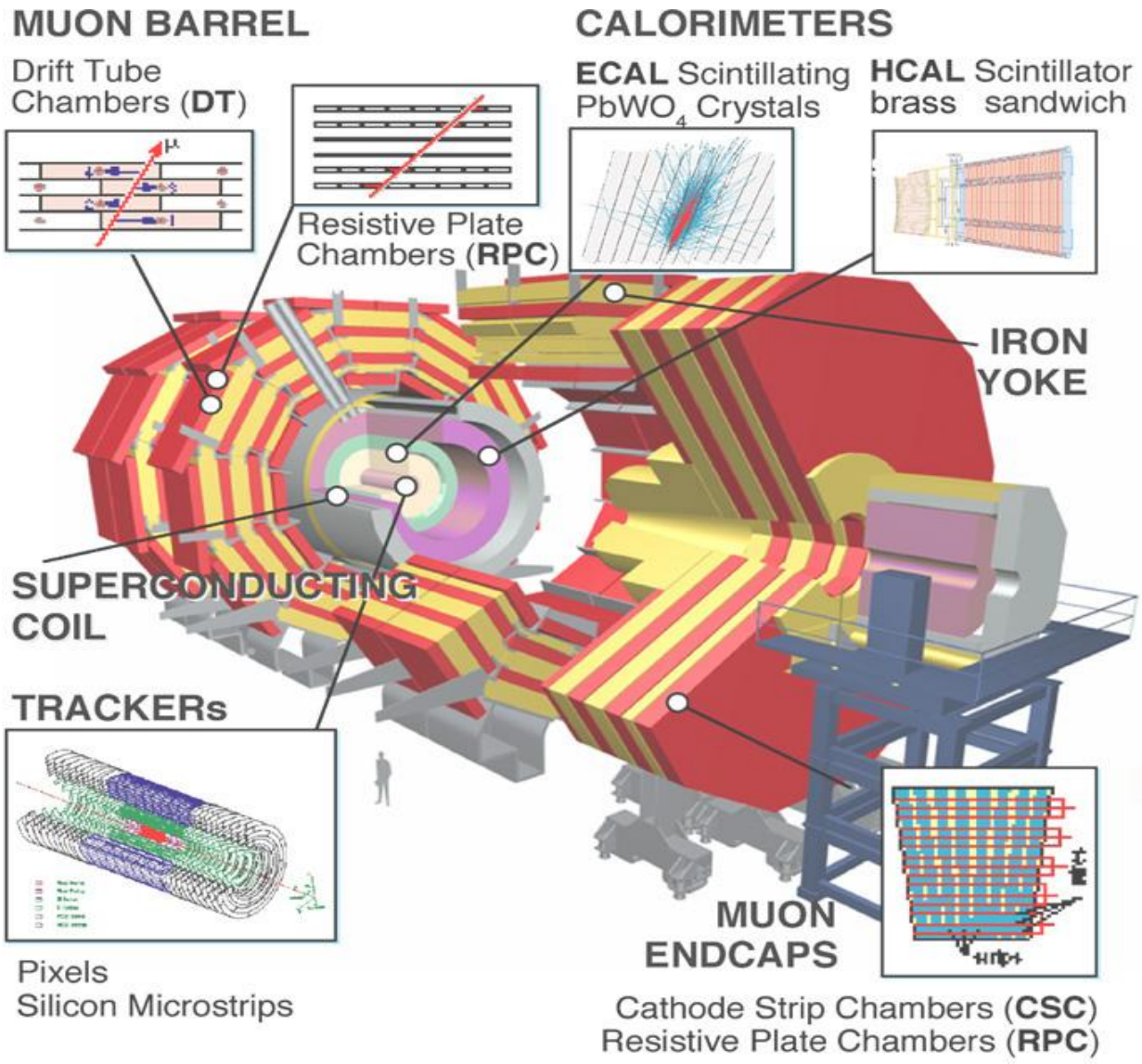
Outline :

- CMS detector and data taking
- Exotica program: extra-dimensions, compositeness, new gauge bosons, microscopic black holes … everything beyond SM but SUSY

The CMS detector



Some performances* :

Tracking :
$\sigma_{pT}/p_T \approx 1.5 \cdot 10^{-4}\ p_T(GeV) \oplus 0.5\%$

ECAL energy deposit :
$\sigma_E/E \approx 2.9\%/\sqrt{E(GeV)} \oplus 0.5\%$

HCAL energy deposit :
$\sigma_E/E \approx 120\%/\sqrt{E(GeV)} \oplus 6.9\%$

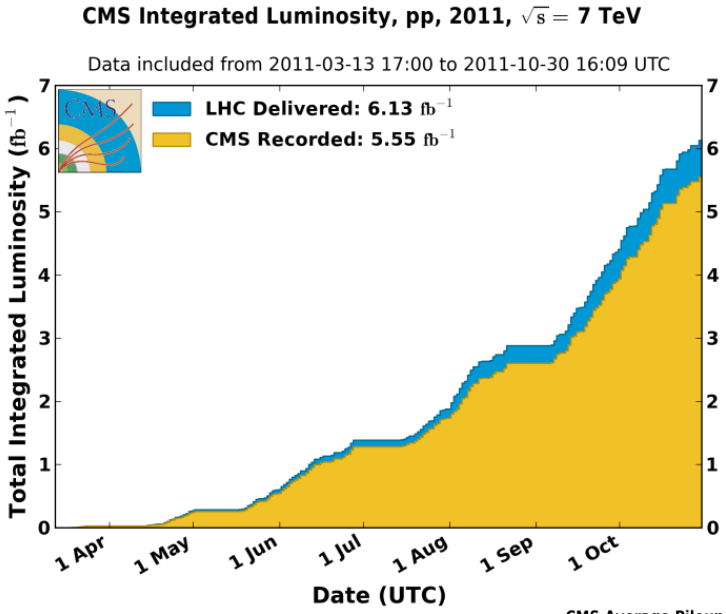
Muons (tracker + muon system) :
$\sigma_{pT}/p_T \approx 5\%$ for 1 TeV muons

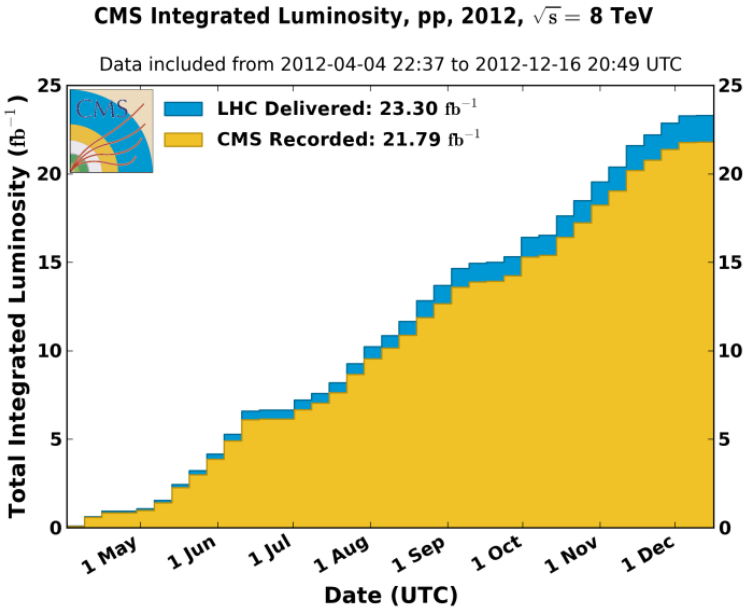
* ref.: The CMS experiment at the CERN LHC, JINST 3:S08004 (2008)

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

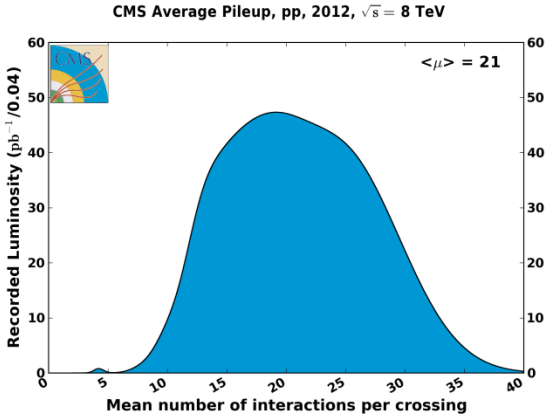
Data taking

- Data taking @7 and 8 TeV : ∫Ldt and pile-up





∫Ldt good for physics @7 TeV : 5 /fb



∫Ldt good for physics @8 TeV : 20 /fb

<PU> @8 TeV around 20
Max. PU @8 TeV around 40

Exotica searches

Exotica searches

- The Exotica program covers the beyond Standard Model searches but SUSY:
  - do we have additional heavy gauge bosons (W', Z') ?
  - are there extra-dimensions (large or warped) ?
  - is there any compositeness ?
  - any hint of dark matter ?
  - new phenomena generic searches are also performed (dijet mass spectrum analysis or looking for anomalous $t\bar{t}$ production)
  - any other new phenomena (microscopic black holes, heavy stable charged particles, unparticles …) ?

Exotica searches

- The Exotica program covers the beyond Standard Model searches but SUSY:

Typical topologies :

high P_T e, μ, γ

- do we have additional heavy gauge bosons (W', Z') ?
- are there extra-dimensions (large or warped) ?
- is there any compositeness ?

high P_T jets

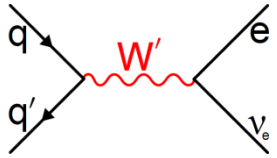
- any hint of dark matter ?
- new phenomena generic searches are also performed (dijet mass spectrum analysis or looking for anomalous $t\bar{t}$ production)

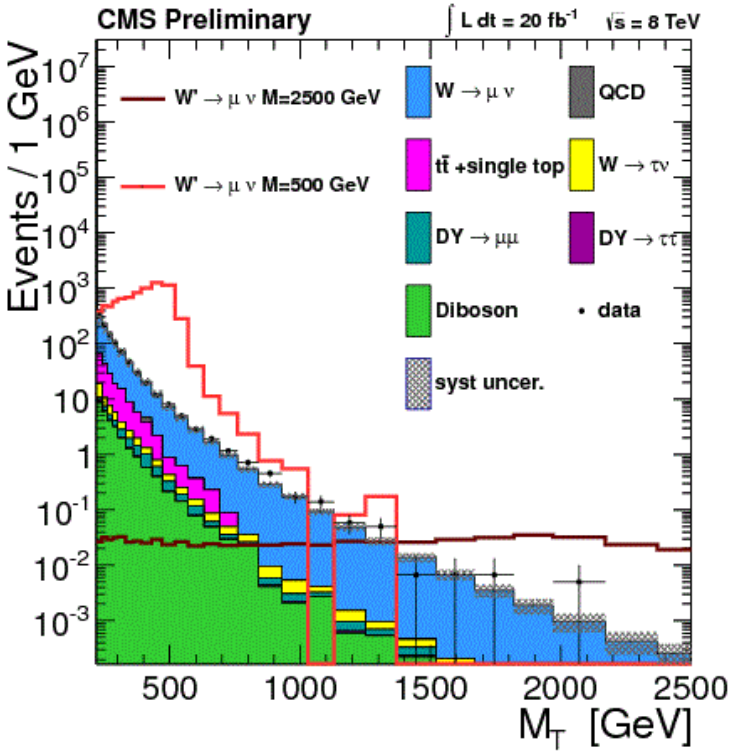
> 3l, long decays

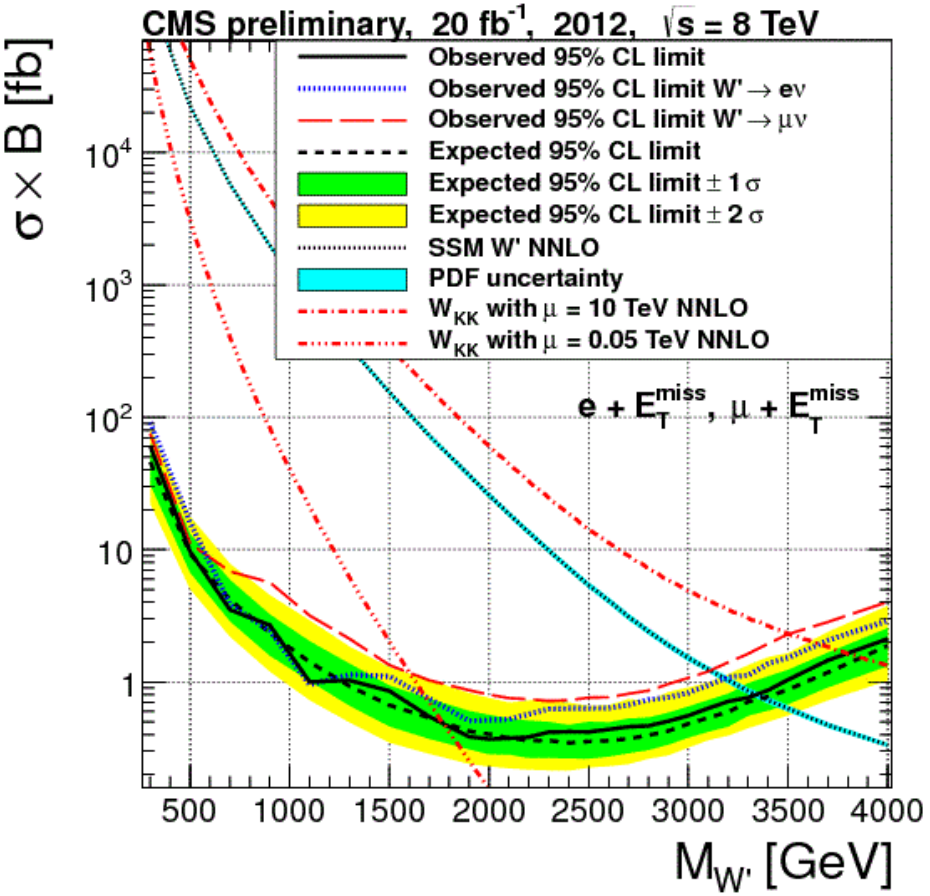
- any other new phenomena (microscopic black holes, heavy stable charged particles, unparticles …) ?

Exotica searches

- Heavy gauge bosons: W′ searches in the sequential SM







$$M_{\mathrm{T}} = \sqrt{2E_{\mathrm{T}}^{\mathrm{miss}} p_{\mathrm{T}}^{l} (1 - \cos\Delta\phi_{l,E_{\mathrm{T}}^{\mathrm{miss}}})}$$

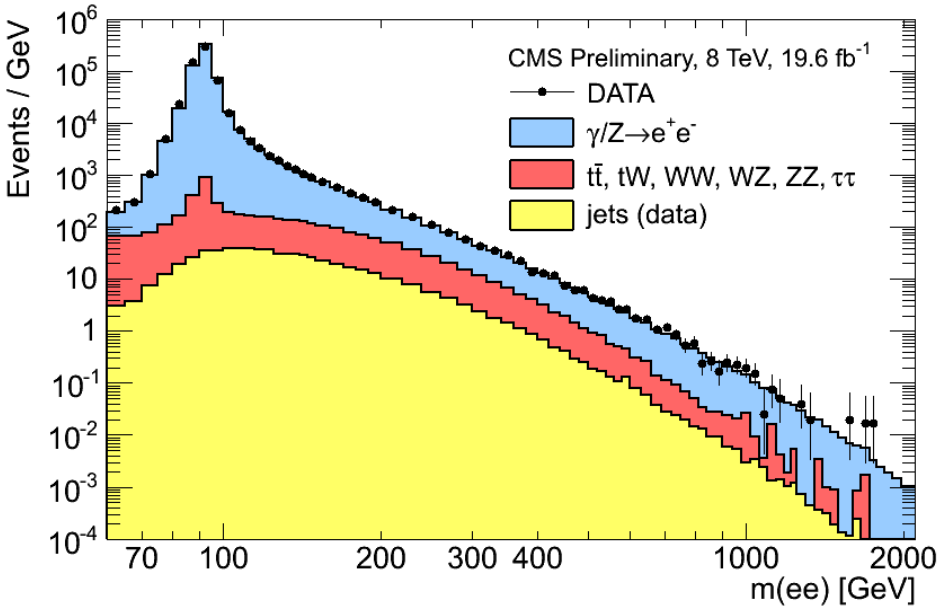
Both electron/muon channels are combined

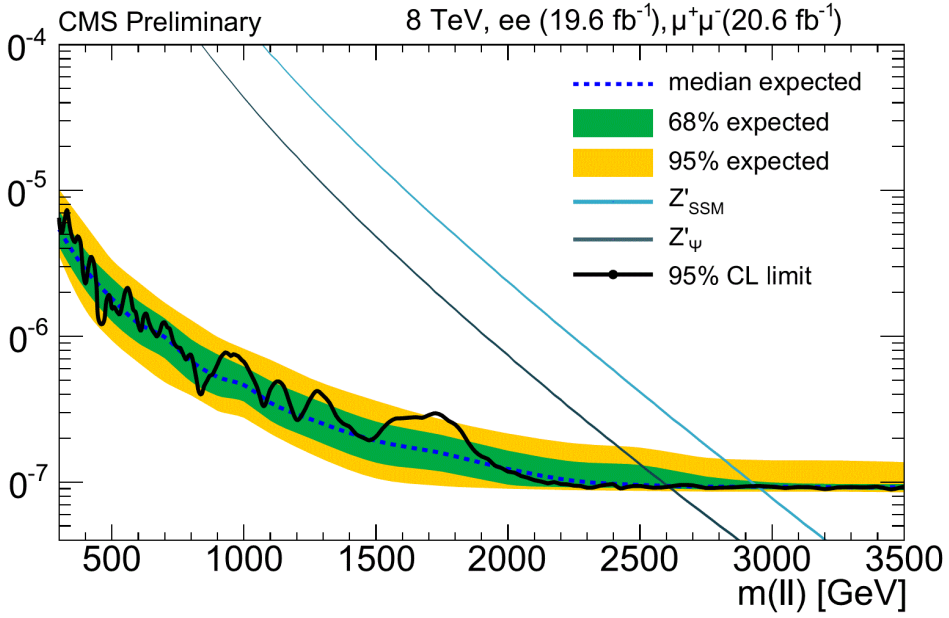
CMS limit in the sequential SM : 3.3 TeV (CMS-PAS-EXO-12-060)

Exotica searches

- High-mass dilepton resonances: Z′ searches

High-mass resonances can decay into e or μ pairs, using the sequential SM as benchmark model (same coupling to fermions as the Z boson)





Both electron/muon channels are combined

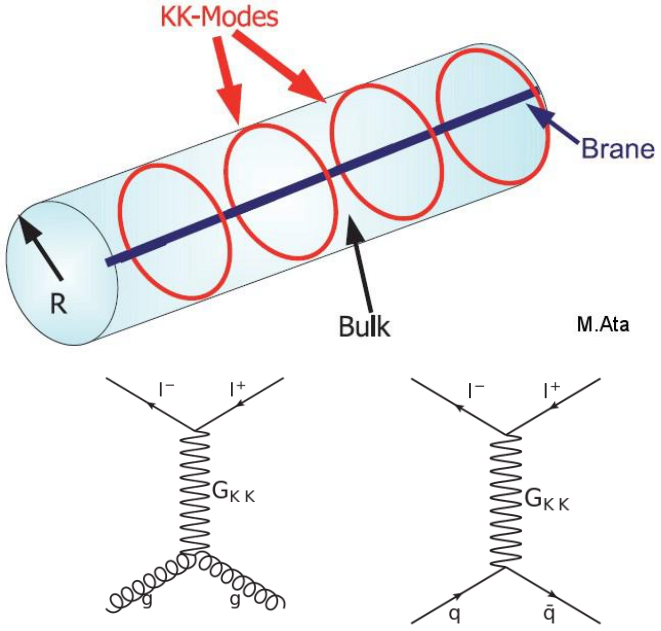
CMS limit in the sequential SM : 2.96 TeV (CMS-PAS-EXO-12-061)

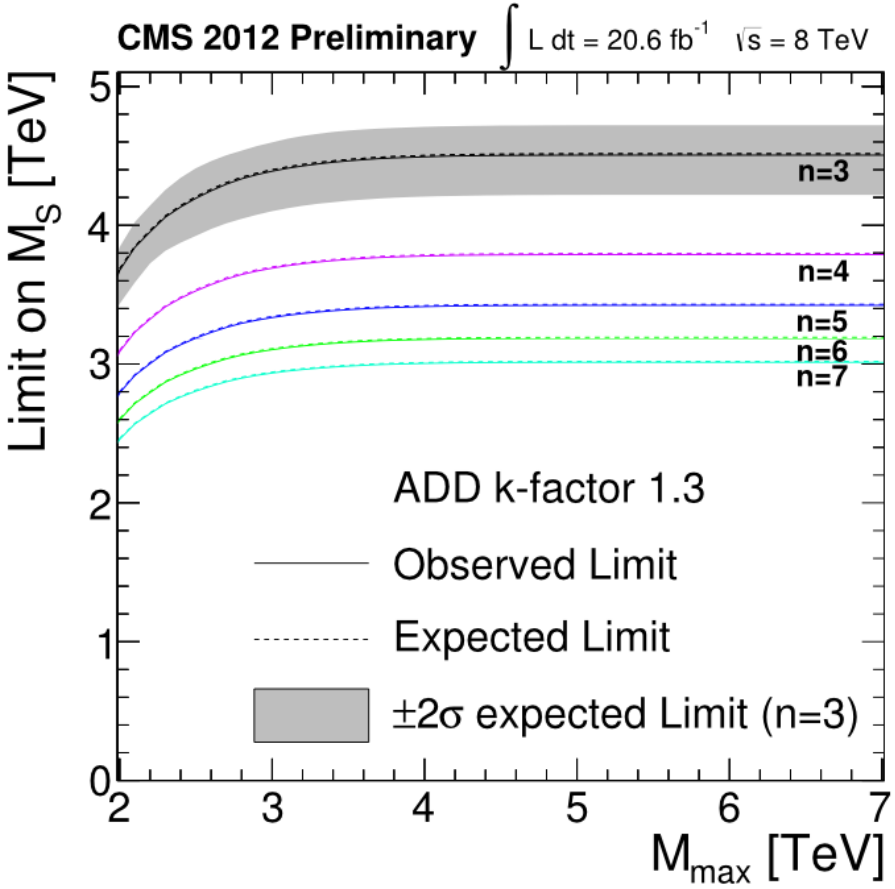
Exotica searches

- Search for extra-dimensions in the di-lepton final state:

Extra dimensions proposed as a solution to the hierarchy problem in the SM

ADD (Arkani-Hamed, Dimopoulos, and Dvali) model postulates compactified extra dimensions:





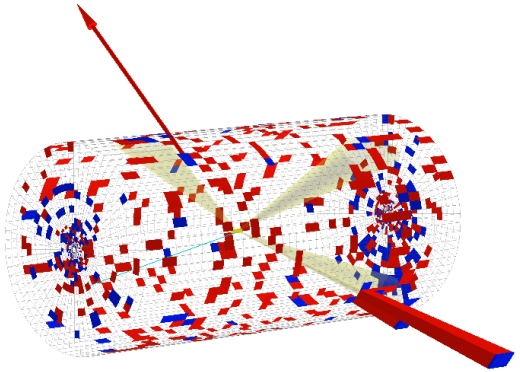
Looking for a pair of TeV electrons or muons in the final state

Probe the mass scale up to ~ 3 TeV (CMS-PAS-EXO-12-027 and CMS-PAS-EXO-12-031)

Exotica searches

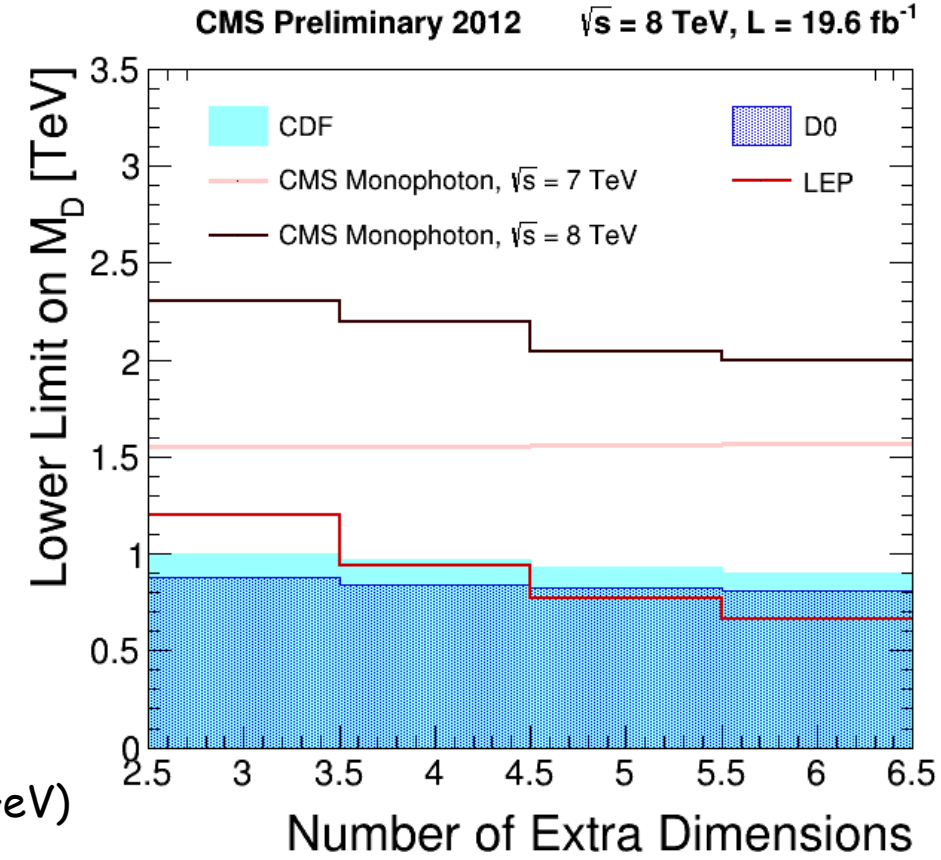
- Search for extra-dimensions in the monophoton final state:

ADD, Branon large extra dimensions or dark matter pair production can be searched in the final state photon plus missing transverse energy



CMS Experiment at LHC, CERN
Data recorded: Sat Nov 17 17:23:56 2012 IST
Run/Event: 207454 / 1095163126
Lumi section: 771

Highest photon p_T candidate event (p_T=653 GeV)



Looking for a photon and high missing transverse momentum in the final state

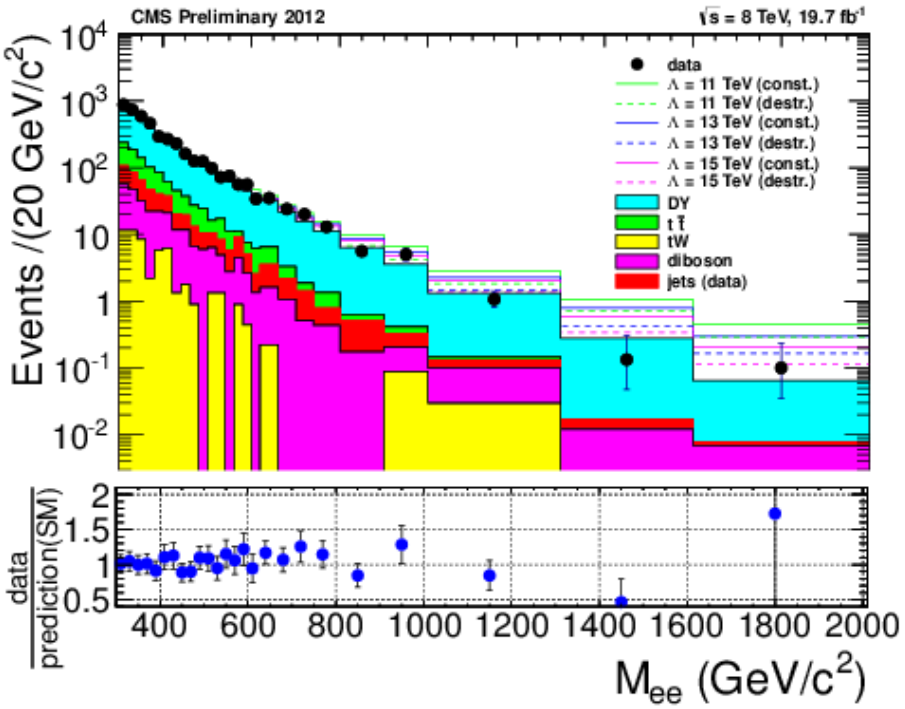
Probe the multi-dimensional Planck scale up to ~ 2.3 TeV (CMS-PAS-EXO-12-047)

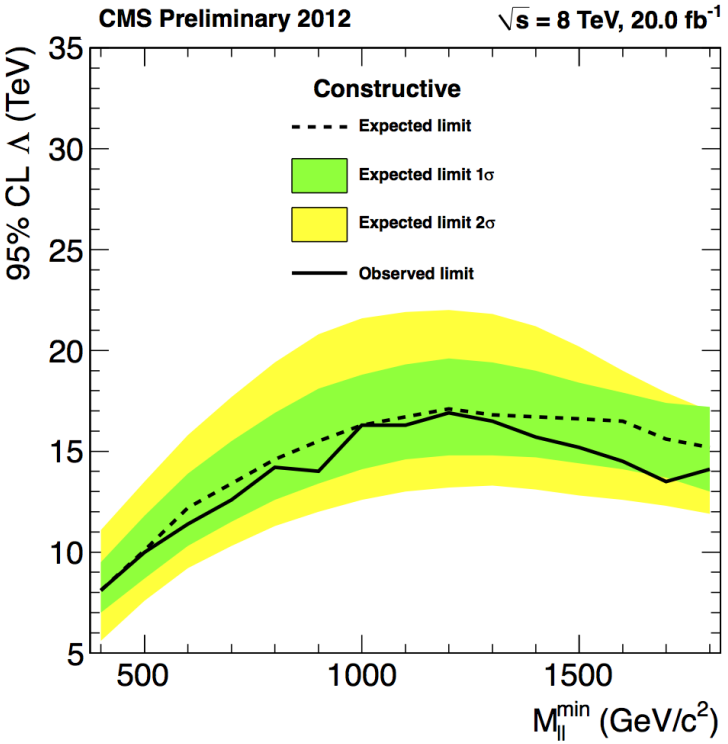
Exotica searches

- Excited electrons/muons (compositeness):

Excited states would be the consequence of fermions substructure

Excited leptons to be produced via four-fermion contact interactions, decaying to a lepton and a gauge boson or a lepton and a pair of fermions



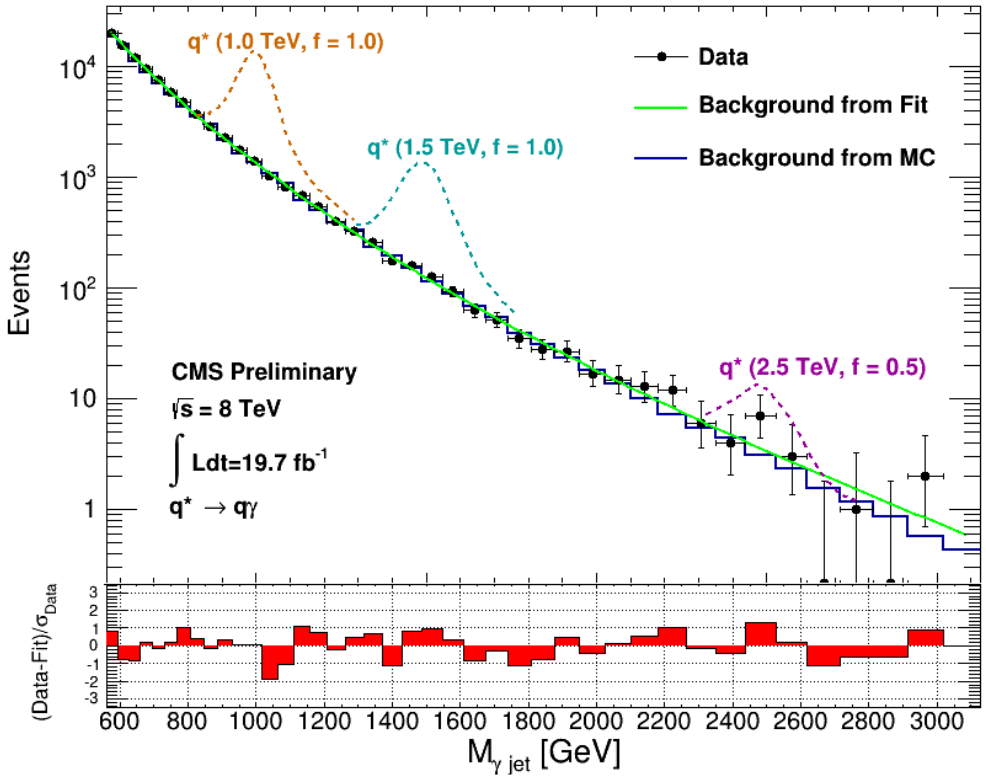


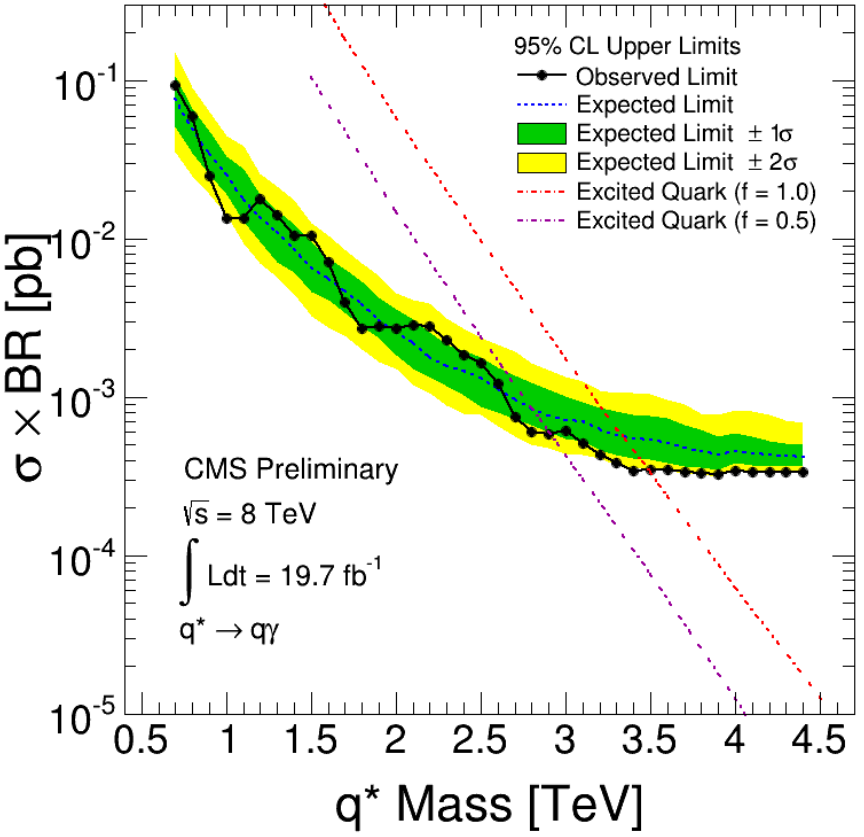
CMS lower limit on Λ (energy scale parameter for the contact interaction): up to 15.2 TeV (18.3 TeV) in the dimuon (dielectron) channel (CMS-PAS-EXO-12-020)

Exotica searches

- Search for excited quarks (compositeness):

Excited quarks q* decay to a photon plus jet final state



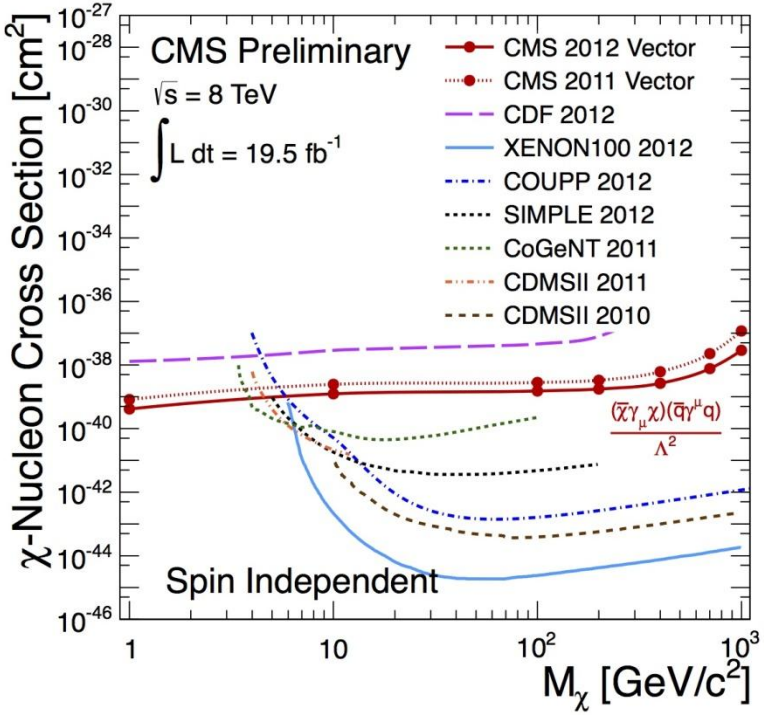


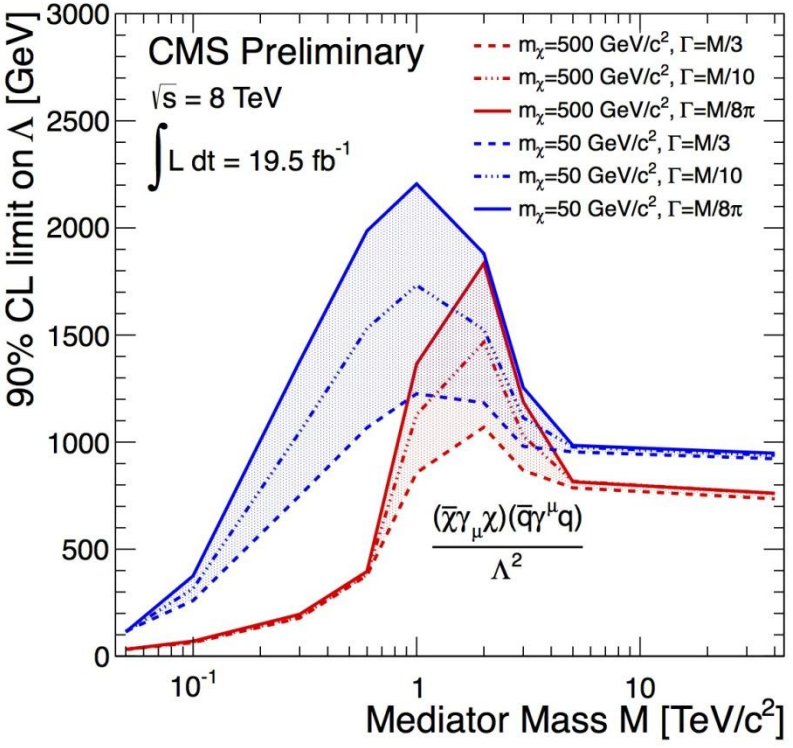
CMS limit for SM couplings: 0.7 < Mq* < 3.5 TeV (CMS-PAS-EXO-13-003)

Exotica searches

- Generic searches of new physics using monojet events:

The dark matter-nucleon scattering cross-section can be constrained in both spin-independent and spin-dependent interaction models, and also the ADD M_D model parameter in an extra dimensions scenario



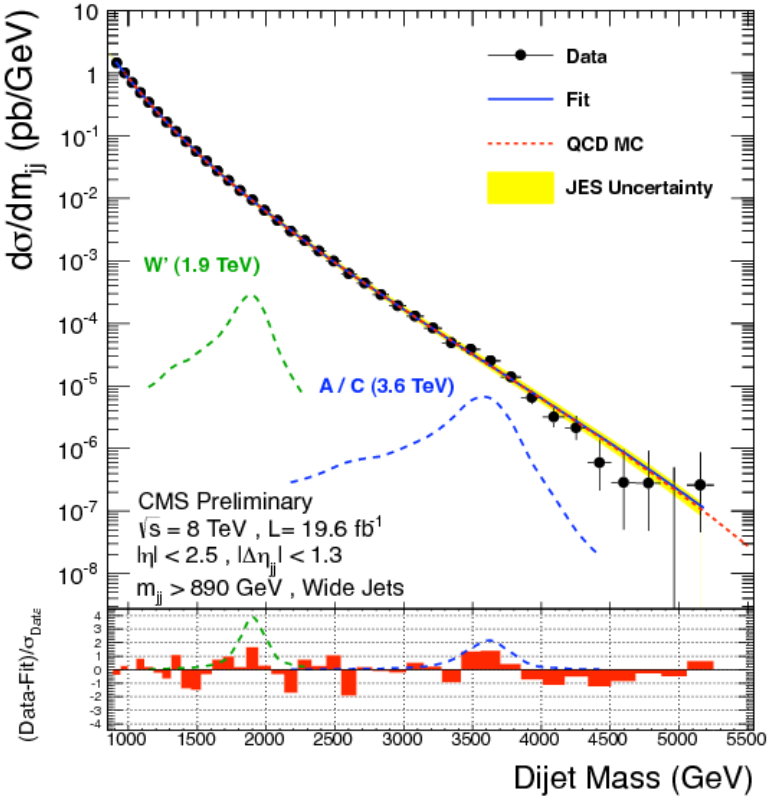


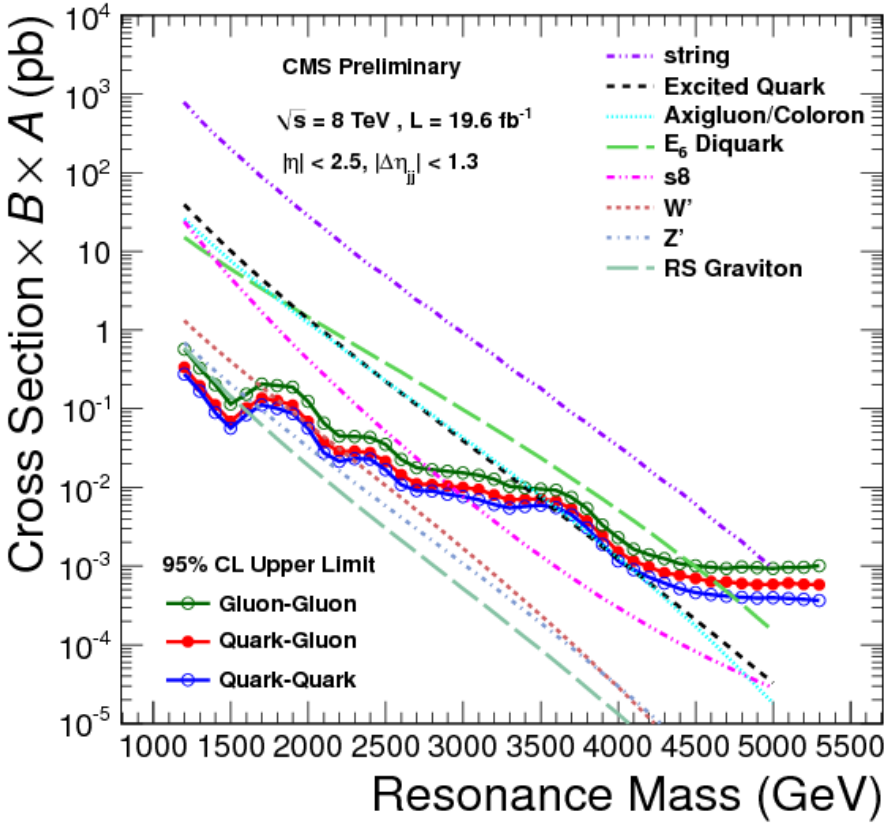
Dark matter searches are also compared to CDF, XENON100, CoGeNT, CDMSII …

CMS ADD M_D lower limit : 2.9 to 5.1 TeV (CMS-PAS-EXO-12-048)

Exotica searches

- Generic searches of new physics using the dijet mass spectrum:





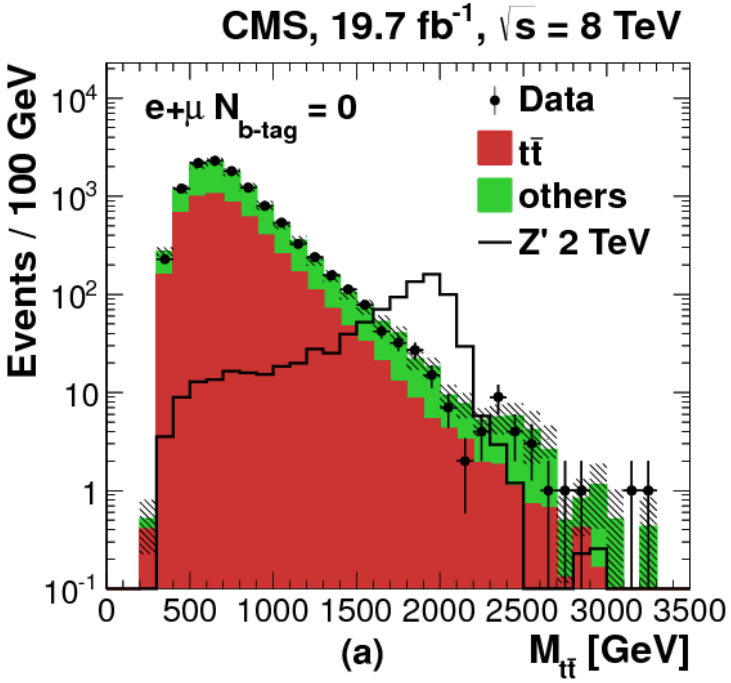
Several exotica searches (string resonances, excited quarks, axigluons, colorons …) can be searched as narrow resonances in the dijet mass spectrum

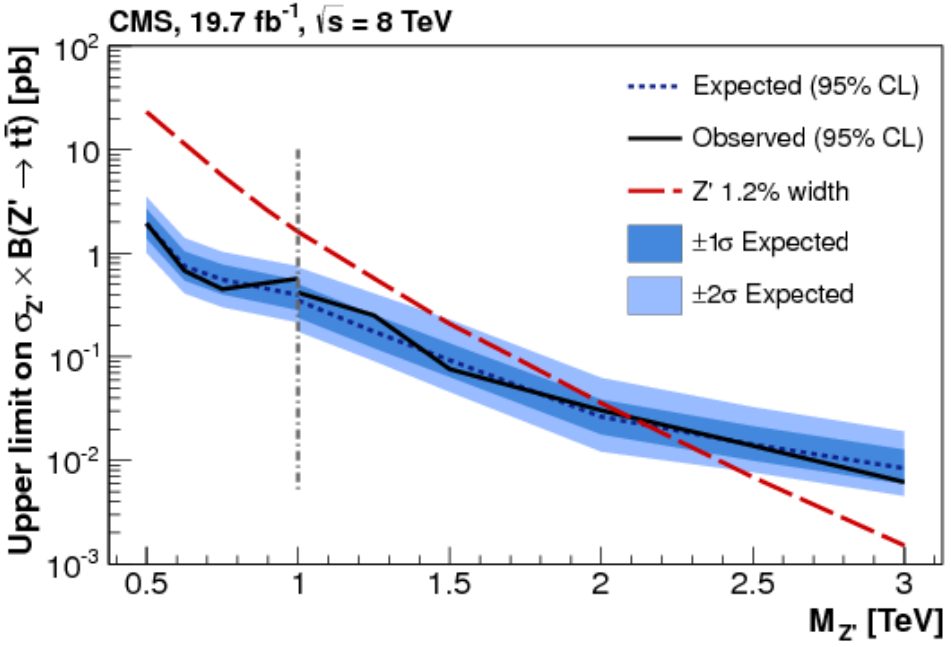
CMS lower mass limits reach up to 5.1 TeV (CMS-PAS-EXO-12-059)

Exotica searches

- Searches for anomalous $t\bar{t}$ production:

Kaluza-Klein excitations of gluons/gravitons (extra dimensions models) as well as new gauge bosons Z' could have enhanced couplings to $t\bar{t}$ pairs:





Several limits given depending on the ratio width/mass

CMS limit on Z' mass (for $\Gamma_{Z'}/M_{Z'}$ = 1.2%) : 2.1 TeV

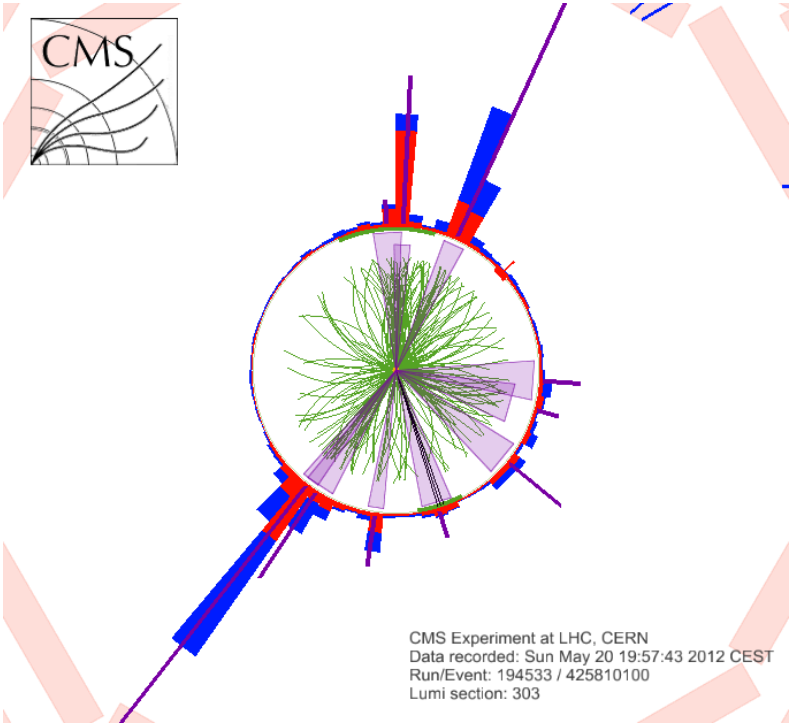
CMS limit on Randall-Sundrum KK gluons : 2.5 TeV

(CMS-PAS-B2G-13-001/hep-ex:1309.2030)

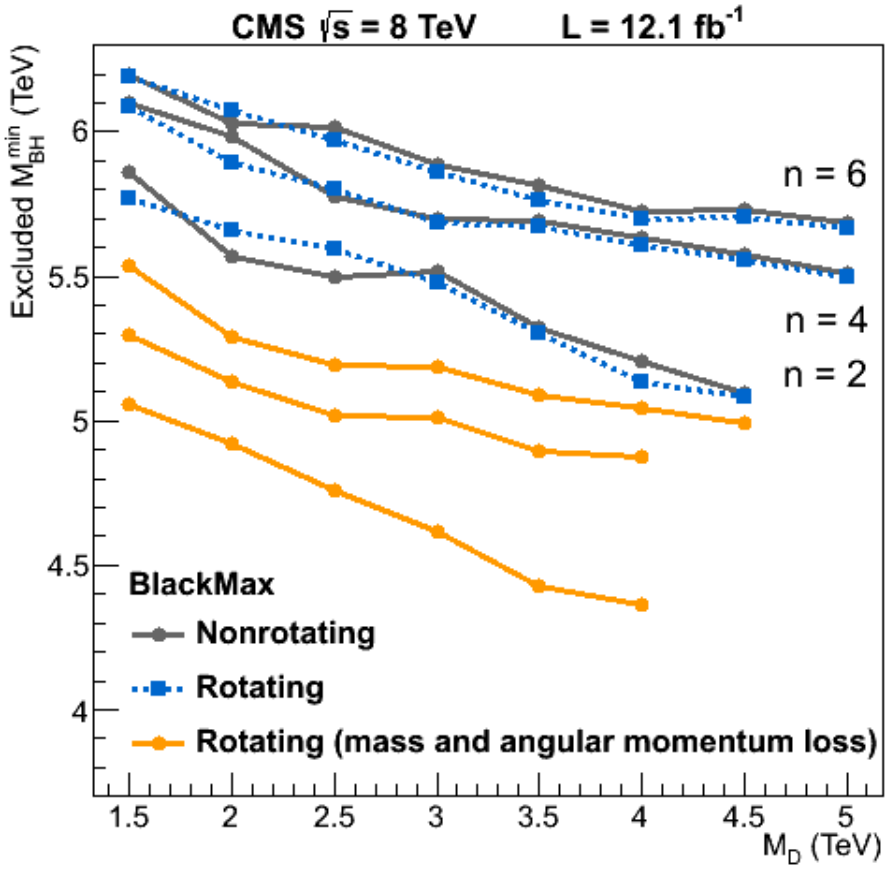
Exotica searches

- Search for microscopic Black Holes:

Typical signature of evaporating black holes: multiple energetic jets, leptons and photons



BH candidate event with 10 high P_T jets

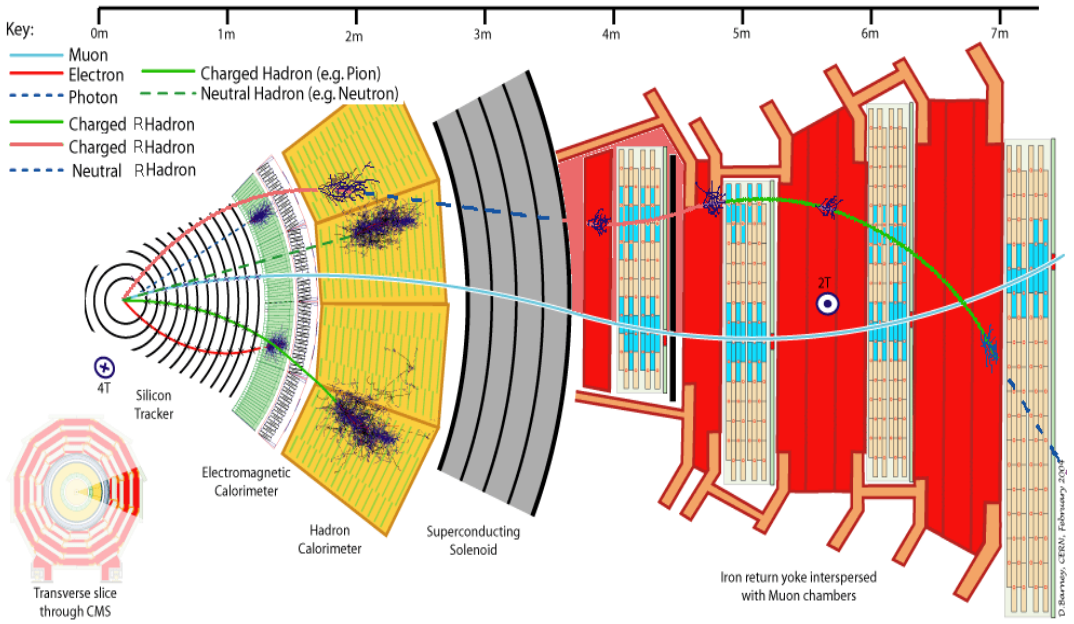


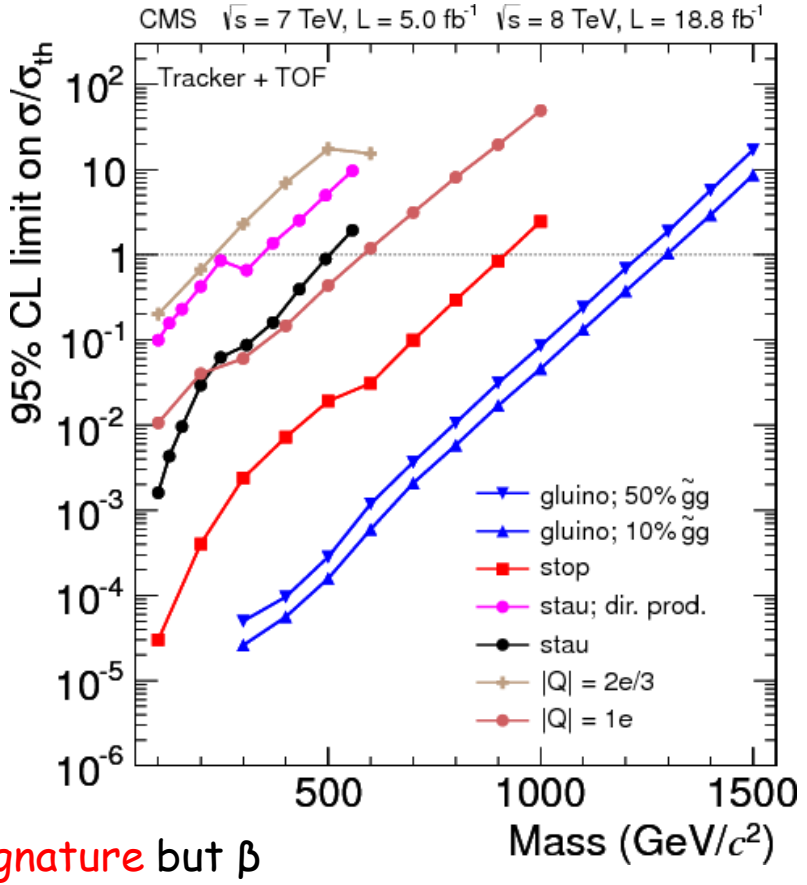
CMS limit on BH mass for several specific models : 4.3 to 6.2 TeV (JHEP 07 (2013) 178)

Exotica searches

- Search for long-lived charged particles:

Several models in MSSM framework predict quasi-stable sleptons, a long-lived gluino or a long-lived stop





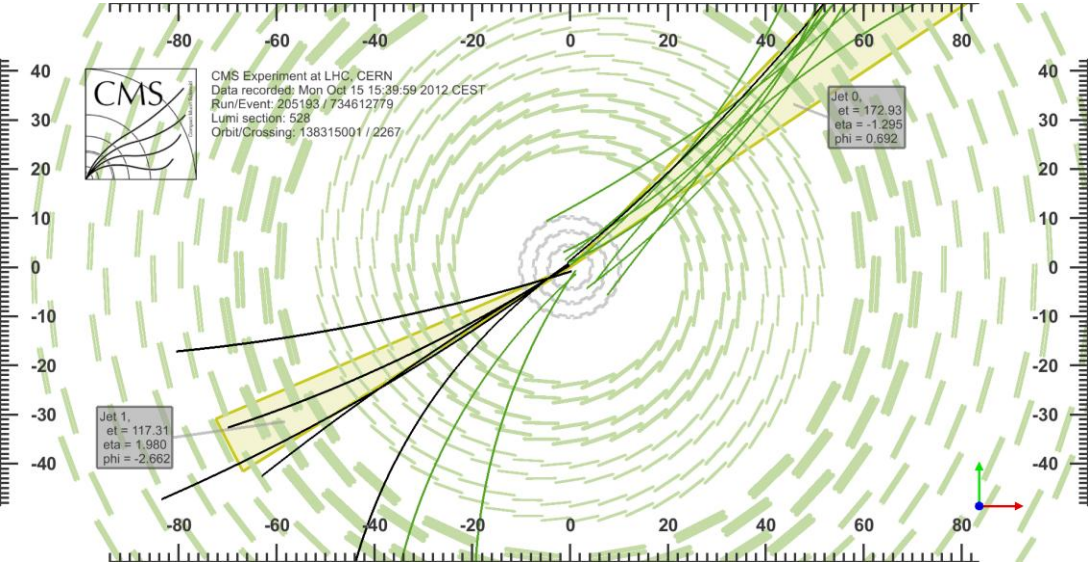
g̃ and t̃ hadronize to form R-hadrons : muon-like signature but β lower than high relativistic muons and possible charge flipping

CMS limit for long-lived gluino : 1.32 TeV (CMS-PAS-EXO-12-026)

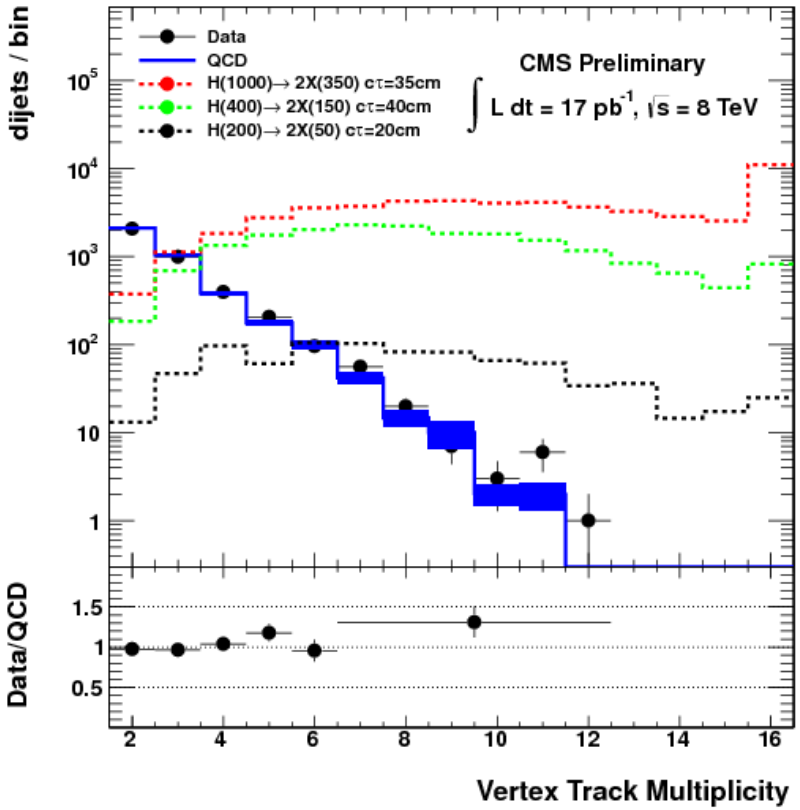
Exotica searches

- Search for long-lived massive neutral particles decaying to dijets:

Distinctive topology: pair of jets originating at a secondary vertex

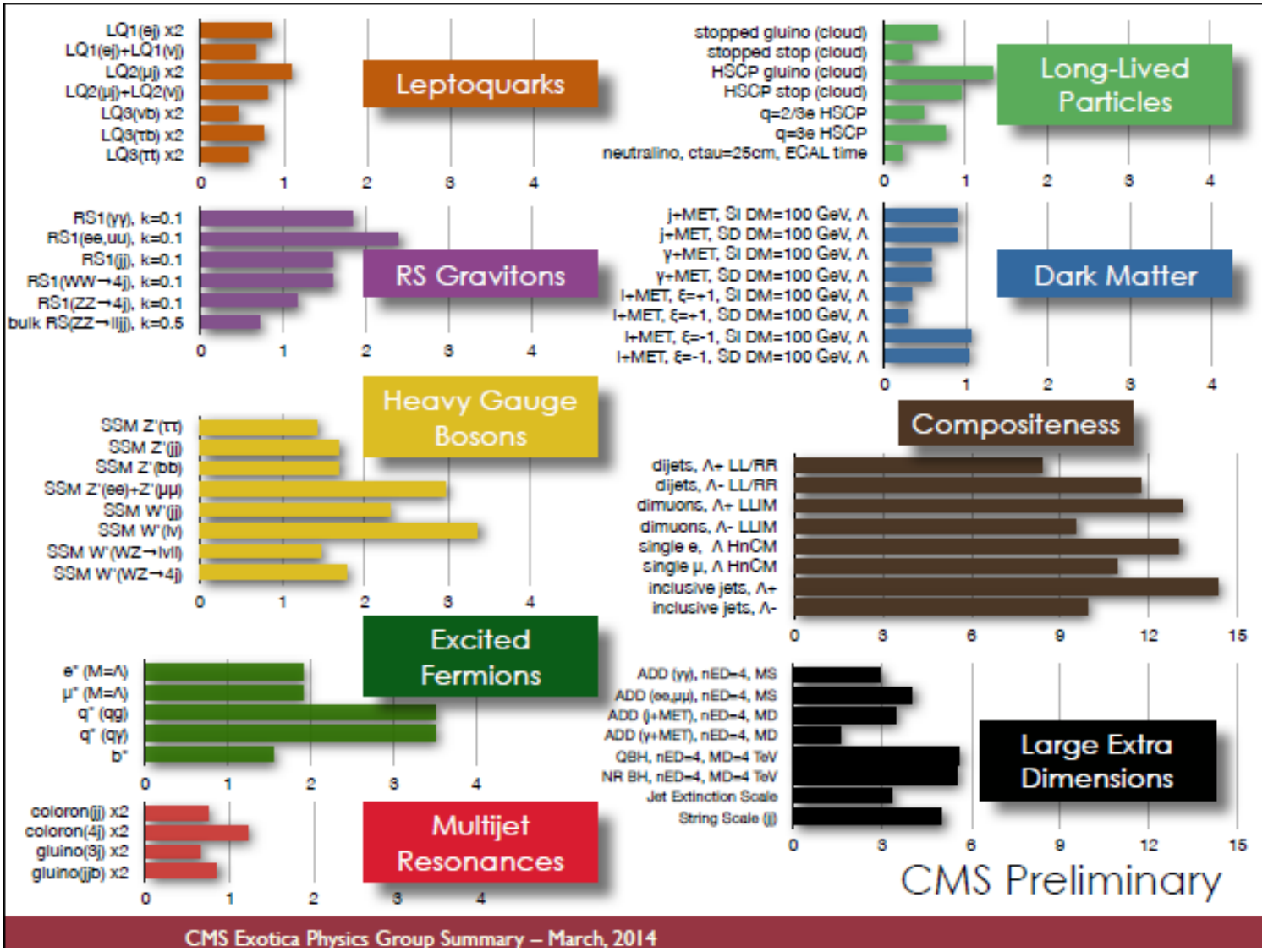


The secondary vertex (black tracks) contains 6 tracks and is transversely displaced by 5cm from the event primary vertex. The invariant mass of the dijet system is 770GeV.



CMS upper limit in this example for a heavy scalar H0 (1 TeV) decaying to a pair of long-lived neutral X0 (350 GeV) : 0.3-300 fb (CMS-PAS-EXO-12-038)

Exotica searches



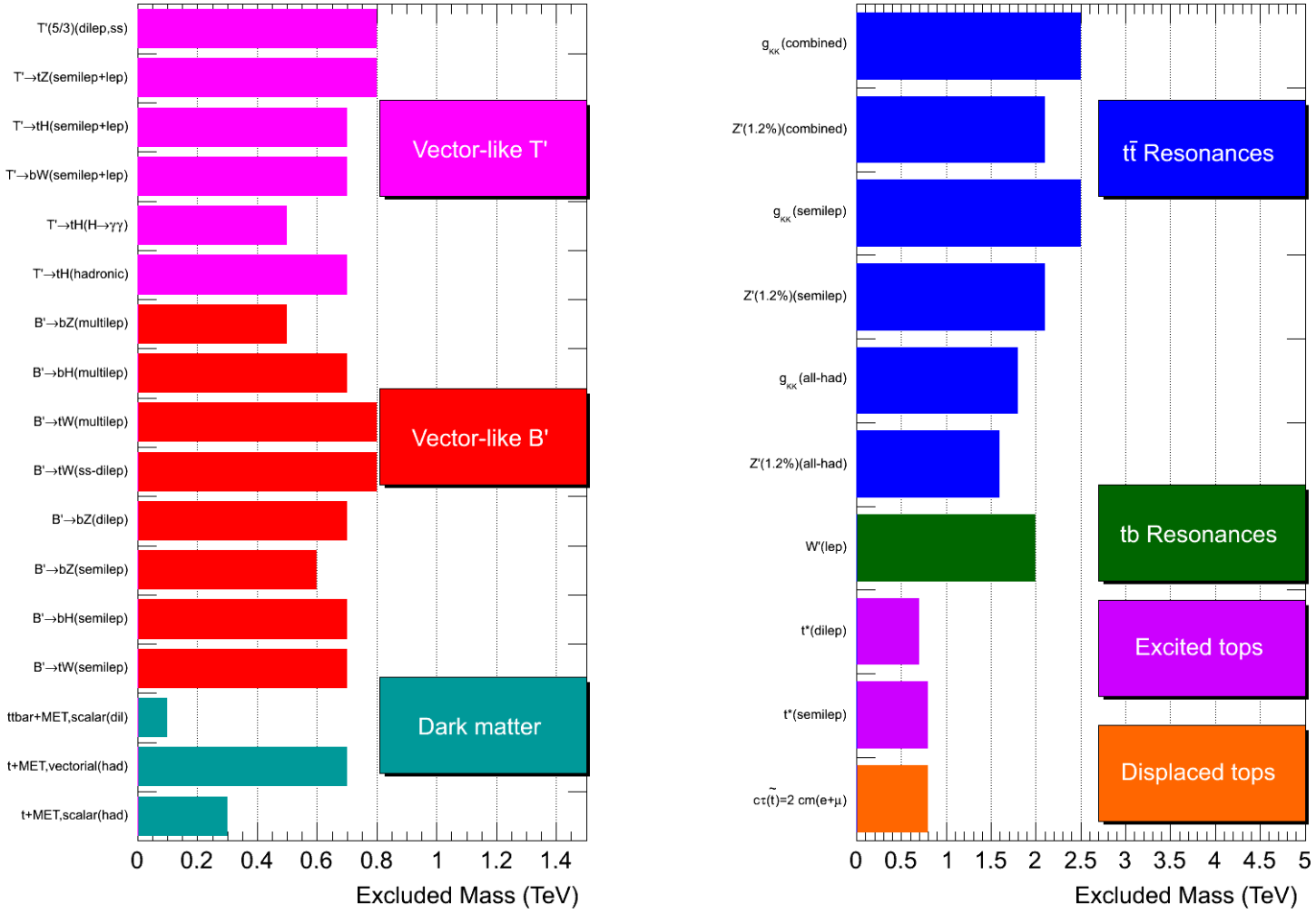
Conclusion

- No hints of new physics beyond SM
- The exotica program allowed to push the limits on the mass scale in a large variety of scenarios : W' (3.3 TeV), Z' (2.9 TeV), extra-dimensions (~3 TeV) …
- Exotica searches will benefit from the higher center-of-mass energy starting in beginning 2015 (13 TeV then 14 TeV)
- The expected integrated luminosity up to the end of the LHC program (~300 /fb in 2022) and the HL-LHC (~3000 /fb in 2030) will largely increase the sensitivity of exotica searches

Backup

CMS Searches for New Physics Beyond Two Generations (B2G)

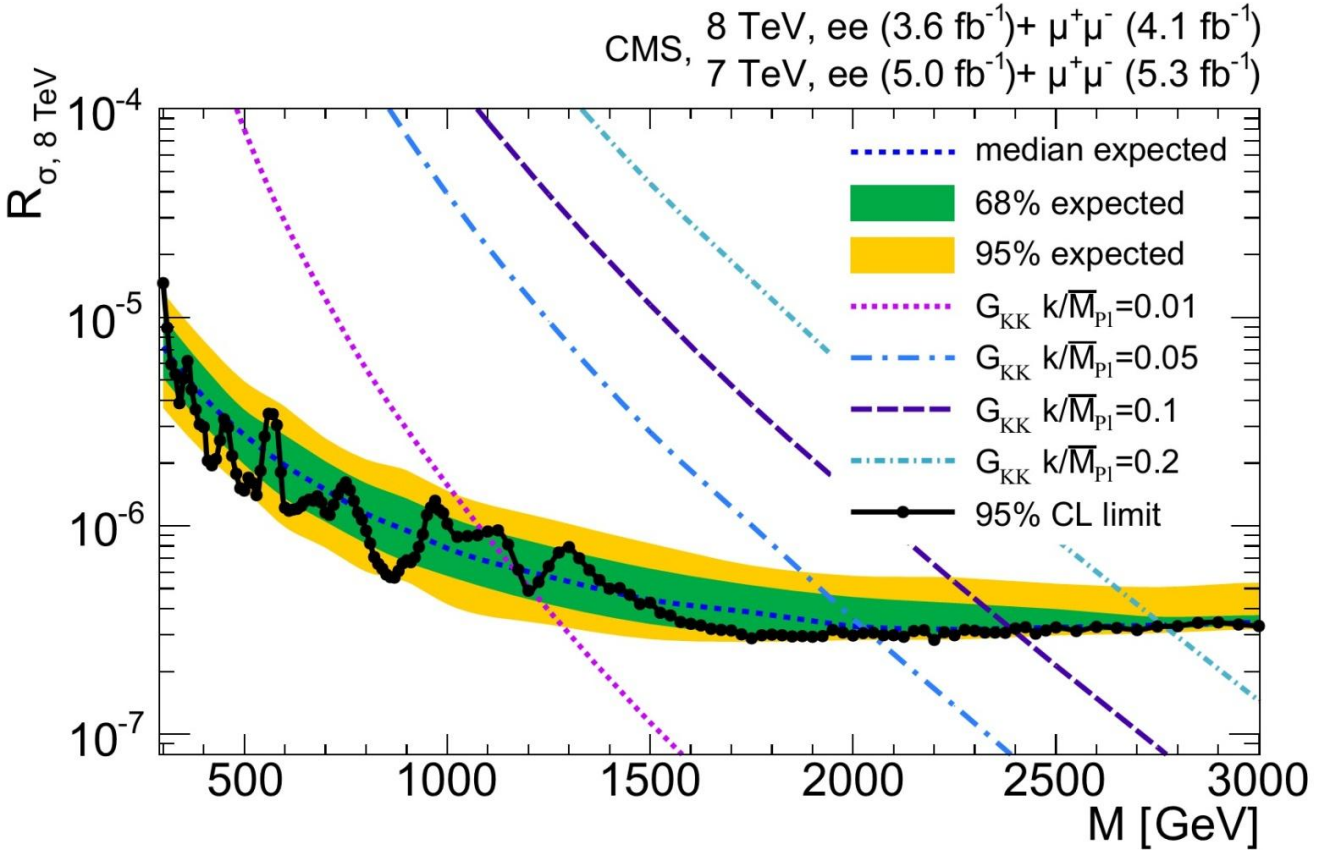
95% CL Exclusions (TeV)



Exotica searches

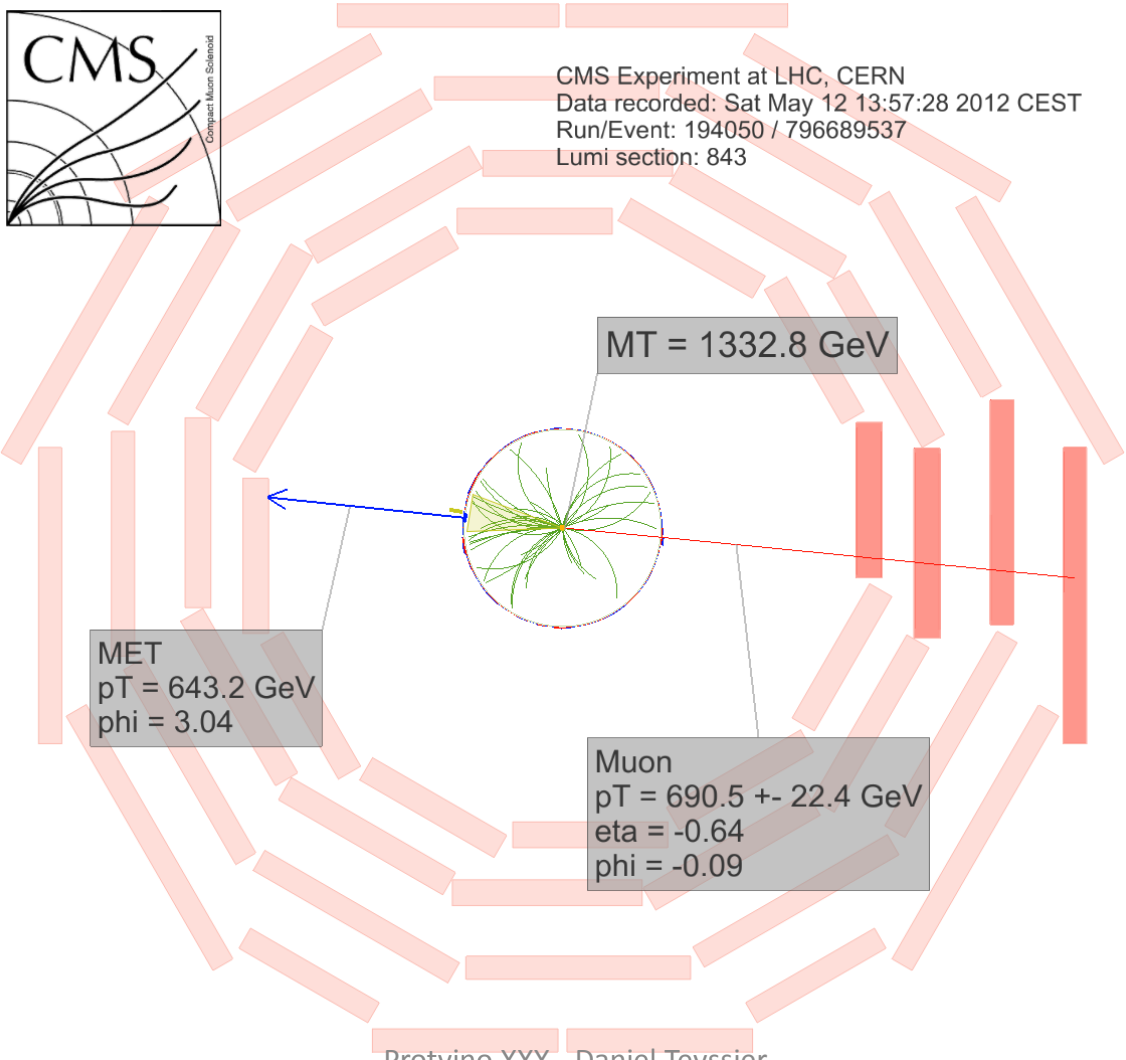
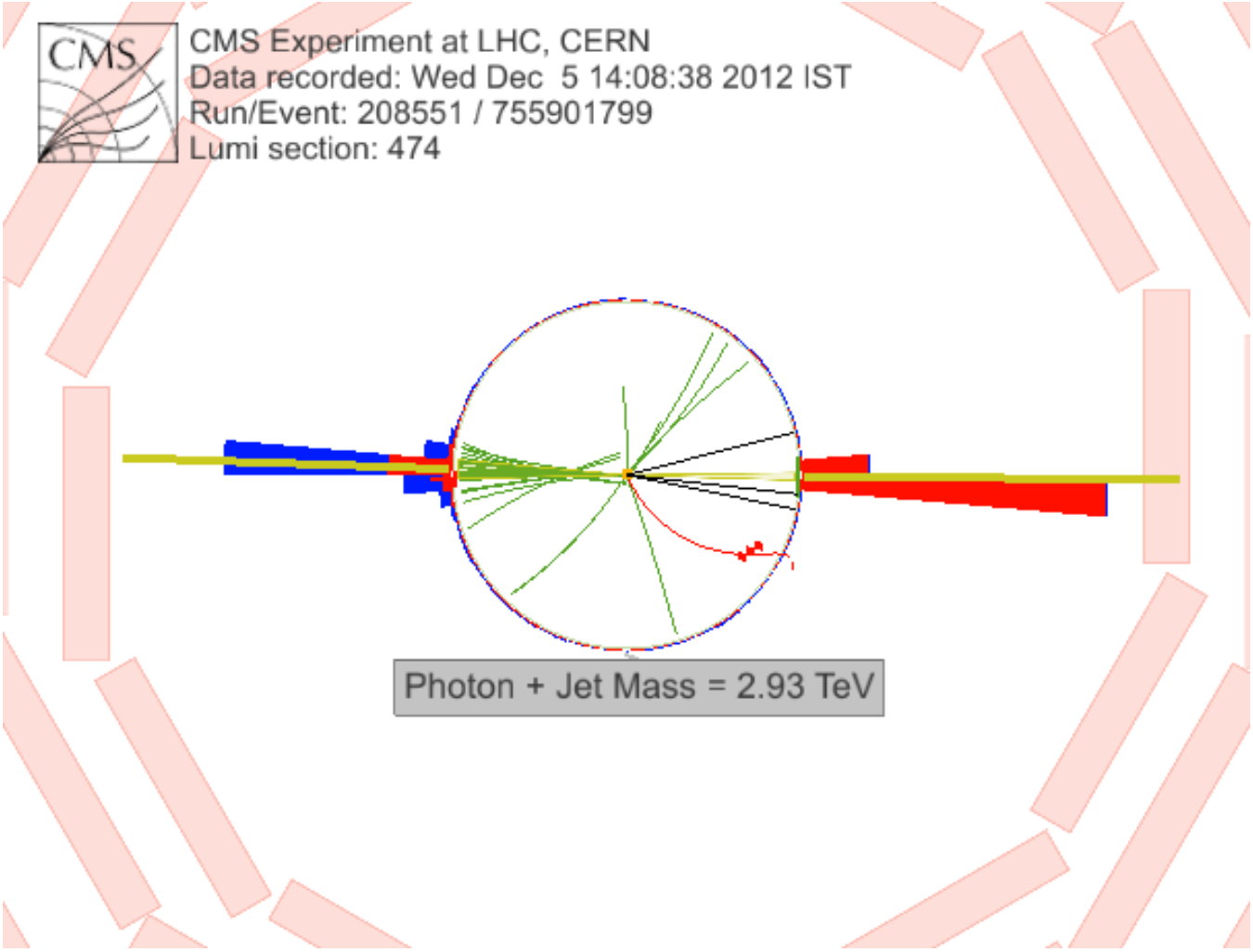
- High-mass dilepton resonances: RS gravitons searches

Hierarchy problem can be addressed by Randall-Sundrum model with an extra-dimension, the excited Kaluza-Klein modes of the graviton decaying into a pair of leptons



CMS limit for a 0.1 coupling parameter k/M_{Pl}: 2.4 TeV (CMS-PAS-EXO-12-015)

- Highest tranverse mass muon event in the W' search:



- Photon plus jet candidate (excited quarks search) :