Hunting for wide resonances in the dijet mass spectrum at CMS

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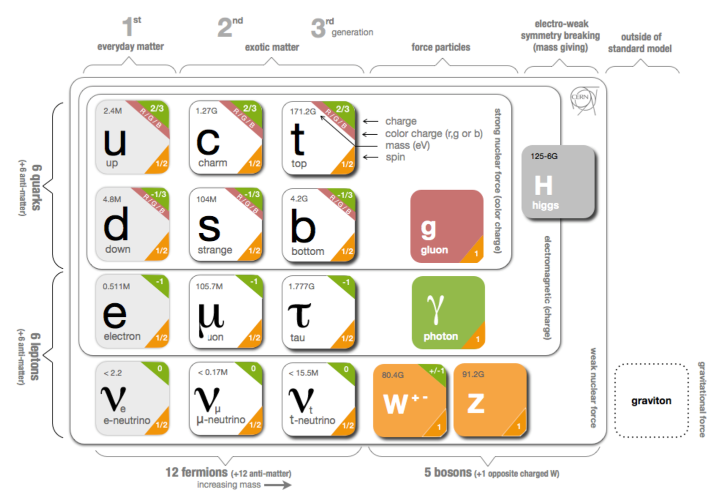
The Standard Model & Beyond

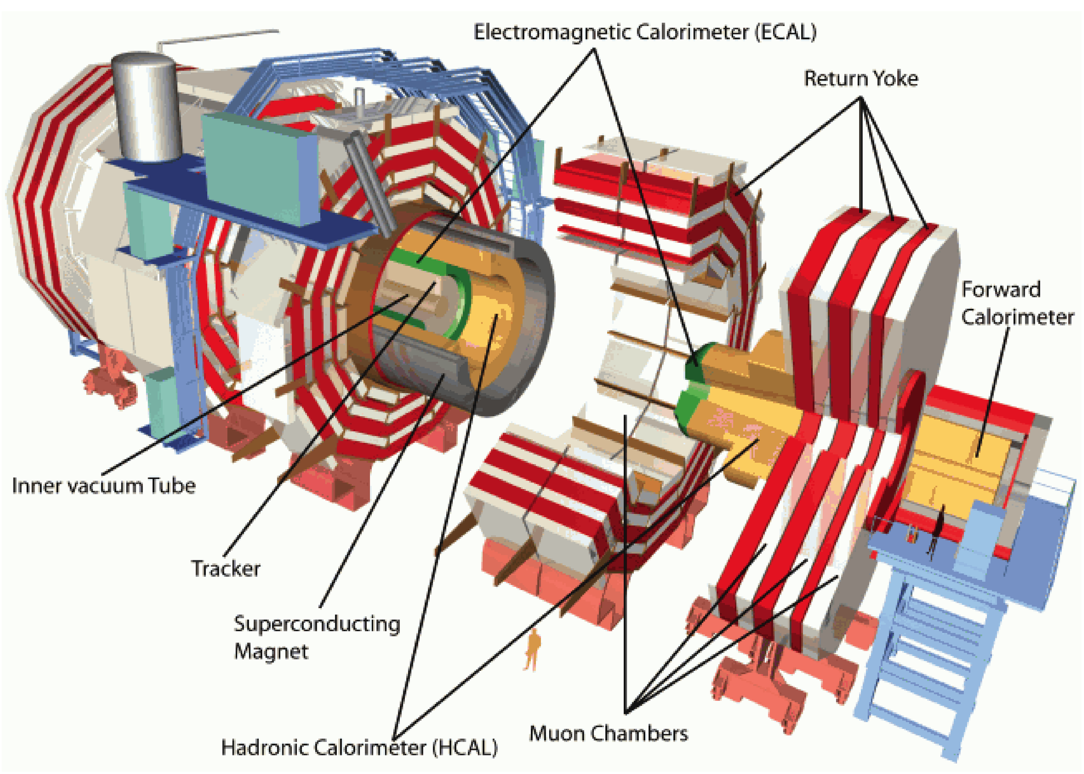


- Experimental observations that cannot be explained with the Standard Model:
  - Matter-antimatter asymmetry
  - Nature of dark matter, dark energy
  - Neutrino oscillations, etc.
- Theoretical motivations that would lead to physics Beyond the Standard Model:
  - Quark Compositeness
  - Hierarchy problem
  - Expansion of QCD's symmetry group.
  - Number of flavors
  - QFT and General Relativity incompatibility

The LHC

- The Large Hadron Collider (LHC) is is the world's largest and most powerful particle accelerator.
- It is a two-ring superconducting proton-proton collider designed to provide collisions with high luminocity and a centre-of-mass energy of 13 TeV.
- The two beams intersect in four collision points – the locations of the four distinct detectors, one of which is the CMS Detector.

The CMS Experiment



Pixels
$\sigma/p_T \sim 1.5 \cdot 10\text{-}4 p_T(\text{GeV}) \oplus 0.005$

Electromagnetic Calorimeter
$\sigma(E)/E \approx 2.9\%/\sqrt{E(\text{GeV})} \oplus 0.5\% \oplus 0.13\text{GeV}$

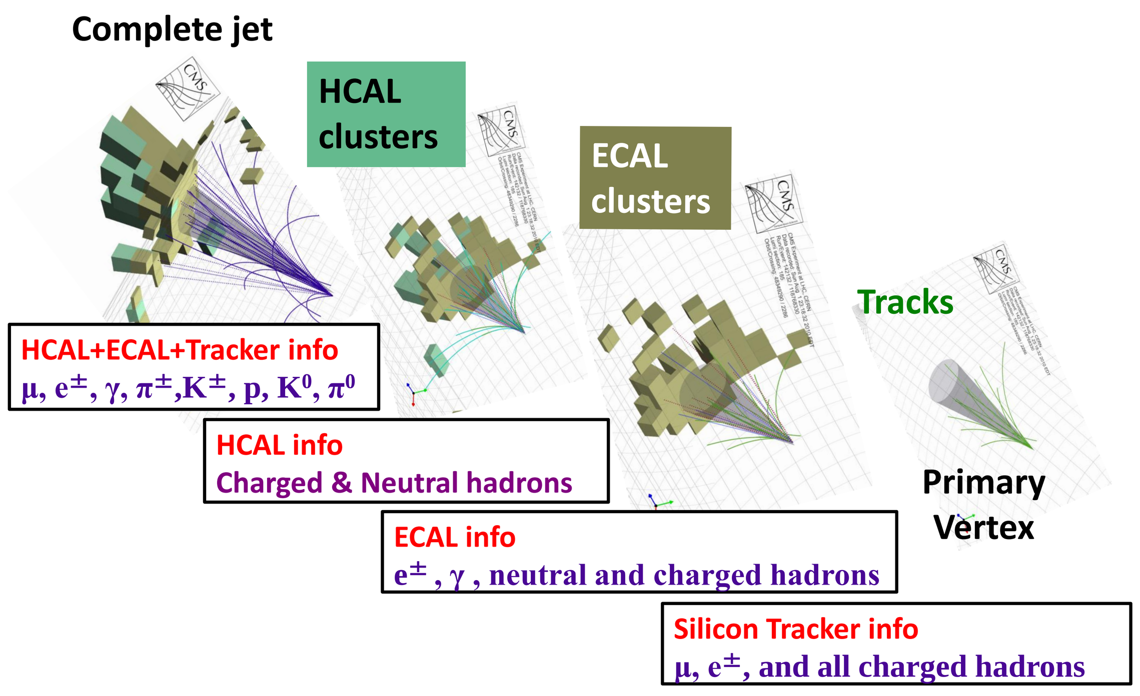
Hadronic Calorimeter
$\sigma(E)/E \approx 120\%/\sqrt{E(\text{GeV})} \oplus 6.9\%$

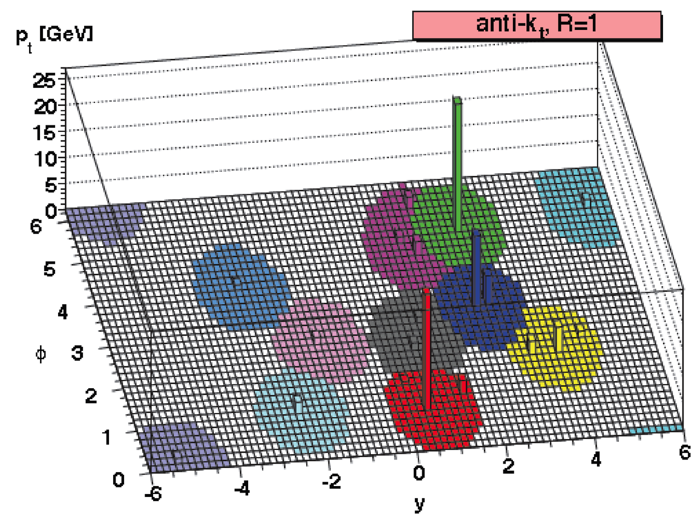
Muon Spectrometer
$\sigma(p_T)/p_T \approx 1\%$ for low p_T muons
$\sigma(p_T)/p_T \approx 5\%$ for 1 TeV muons

Solenoid Magnet
Magnetic field ≈ 3.8 T

Jet Reconstruction

- Particle Flow Algorithm combines all information from several sub-detector systems
- Individual particles are reconstructed with Particle Flow Algorithm and then clustered into jets.

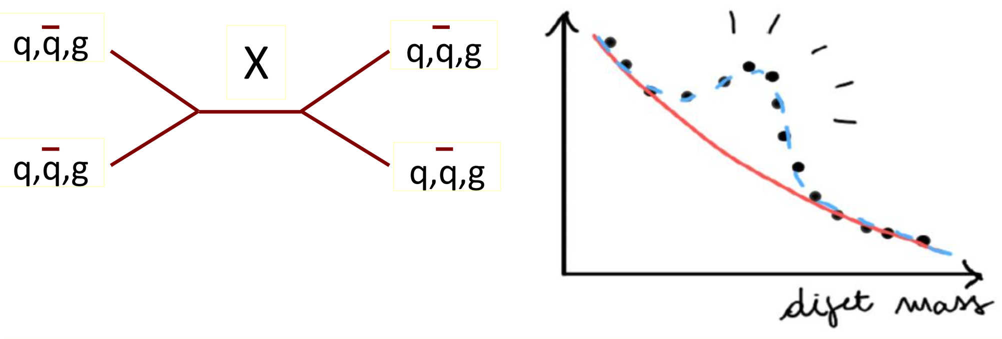




- Anti-k_T clustering algorithm with R = 0.4 and 0.8 for CMS.
- It is infrared and collinear safe, geometrically well defined, and tends to cluster around the hard energy deposits.

Signal Dijet Events

Many new physics models predict the existence of unstable particles that decay (via the *s*-channel) in partons resulting in a resonance in the dijet mass spectrum (signal events).

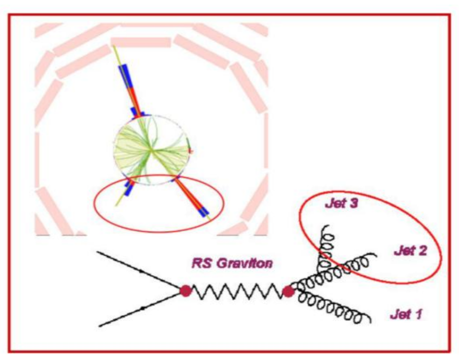


Search for wide resonances (Γ/M > experimental resolution) from:
- *String theory*
- *Excited quarks from theories of quark compositeness*
- *Gravitons from the Randall-Sundrum model of extra dimensions*
- *Dark Matter mediators from simplified (leptophobic) dark matter models*

Reconstruction and Selection

- For recovering the final state radiation use "Wide Jet" (gives better sensitivity than AK4) :
- The clustering starts with the two leading jets which have to satisfy jet criteria. All other jets are added to the closest leading jet if they are within **ΔR=1.1 and have pT > 30 GeV.**

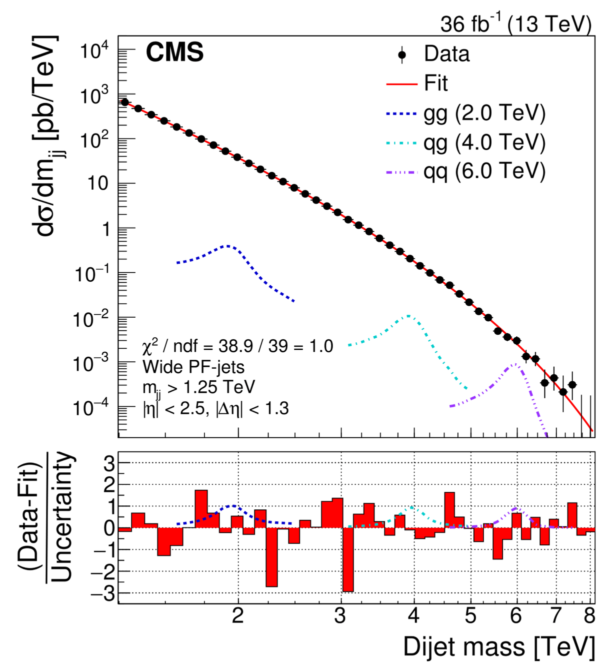
Wide Jet Reconstruction



Dijet Event Selection:
- $|\Delta\eta| < 1.3$ suppresses QCD (mainly *t*-channel) and enhances signal (*s*-channel)
- Dijet Mass > Trigger cut for full efficiency

Analysis Methodology

- **Dijet Mass Distribution**: Fit the data spectrum in the signal region with a smooth empirical parametrization to describe QCD background, use MC templates for the signal models.

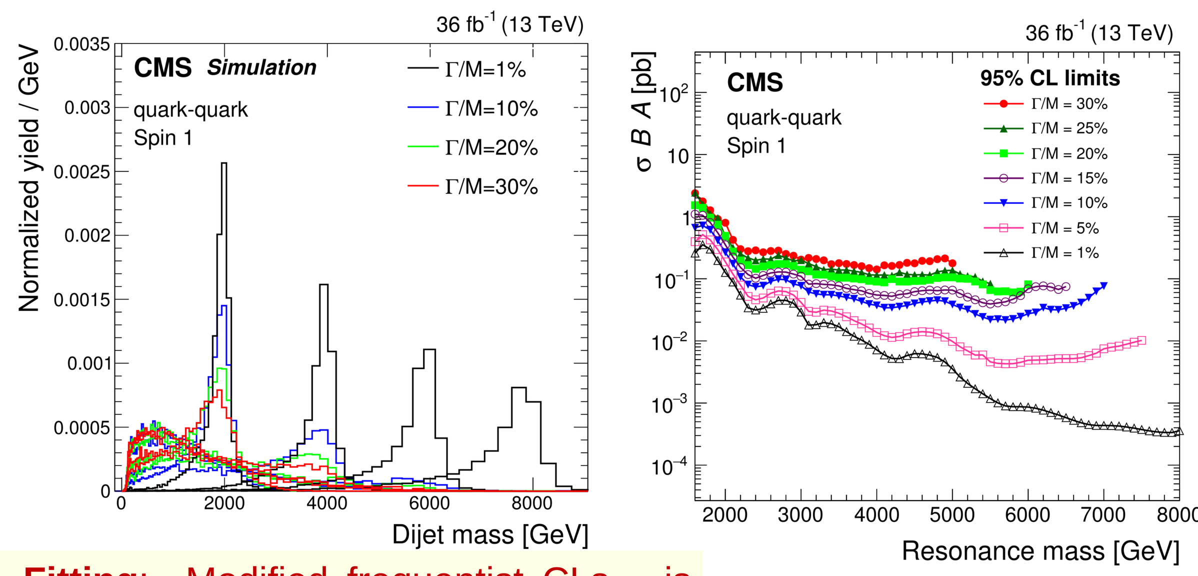


Data is fit with a four parameter function:

$$\frac{d\sigma}{dm_{jj}} = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3 \ln x}}$$

Cross section limits

Spin 1 Resonances



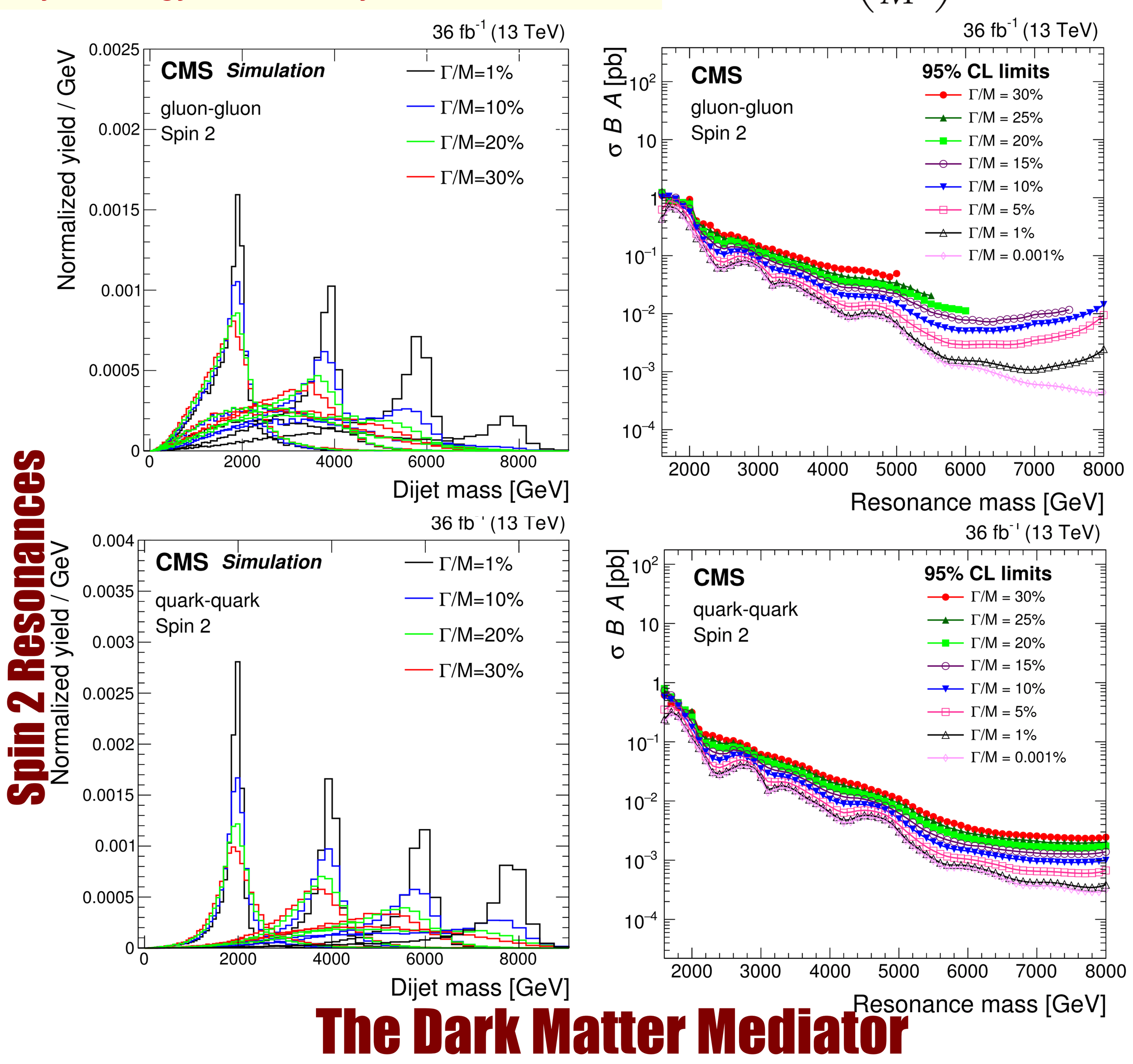
- **Fitting**: Modified frequentist CLs is used for limit setting, performing a binned fit with a background and signal template.
- **Systematic uncertainties**: Only related to signal modeling, luminosity, jet energy scale and jet resolution.

$$\Gamma M \to \left(\frac{m^4}{M^4}\right)\Gamma M$$

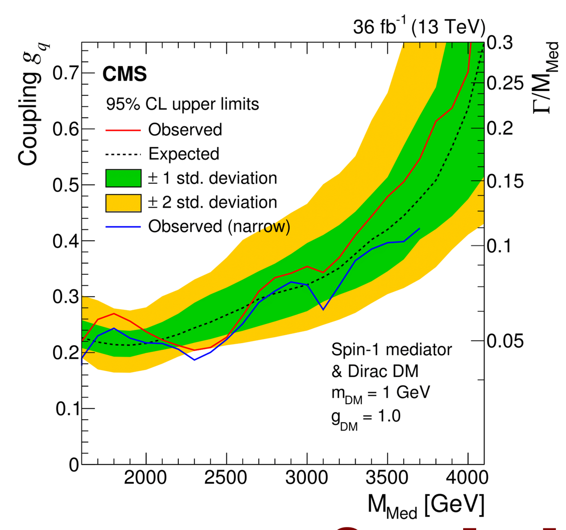
$$\hat{\sigma} \propto \frac{\pi}{m^2}\frac{[\Gamma^{(i)}M]\,[\Gamma^{(f)}M]}{(m^2-M^2)^2+[\Gamma M]^2}$$

$$\Gamma M \to \left(\frac{m^2}{M^2}\right)\Gamma M$$

Spin 2 Resonances



The Dark Matter Mediator



- Limits on the coupling strength of a Z' dark matter mediator.
- Limits probe up to a coupling of 0.76, corresponding to a larger natural width of 30%, for a vector dark matter mediator up to a higher mass of 4.1 TeV.

Conclusions & Outlook

- No sign of a new resonance yet.
- Improving analysis methods especially for wider resonances.
- Using b-tagging.
- Planning new analyses to extend reach to lower resonance masses.

Reference: arXiv1806.00843