Data Scouting: A New Trigger Paradigm (#172)

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Data Scouting Overview

- With improving LHC performance and limited bandwidth, trigger algorithms must become more selective to keep the total trigger rate under control.
- For difficult signatures (e.g. hadronically decaying resonances), this implies a loss of sensitivity at low mass.
- To combat this limitation, CMS introduced novel "data scouting" technique:
  - Physics objects are reconstructed online at the High Level Trigger (HLT).
  - The HLT objects are saved in a minimal format, and the events are not reconstructed offline.
  - Events can be written at a high rate, compensated by the much smaller event size.

Trigger **Bandwidth** = Event Rate × Event Size

~1 kHz ↑ × ~1 MB ↓ ≈1 GB/sec for normal trigger paths in total

Increase Reduction

General Strategy

- **Calo Scouting**:
  - Save jets reconstructed from calorimeter deposits. Also save basic event information.
  - Perform low-mass dijet resonance search.
- **PF Scouting**:
  - Run Particle Flow (PF) reconstruction online. Save four-momenta of PF candidates + auxiliary information.
  - Enough information saved to perform a large spectrum of analyses, and to move beyond fully hadronic final states.
- **Parking**:
  - Save raw events with full event information.
  - Events stored on tape, to be reconstructed in case a hint of new physics is seen in PF scouting.

Size and content of scouting event

Normal event size in CMS is ≈1 MB

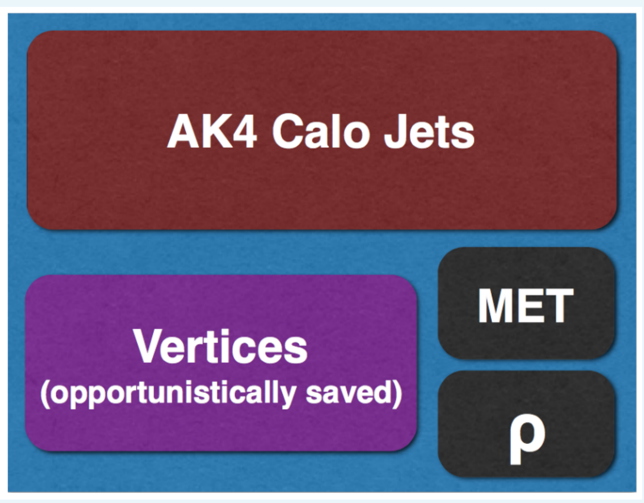


Figure 1: Calo Scouting. Event size ≈1.5 kB

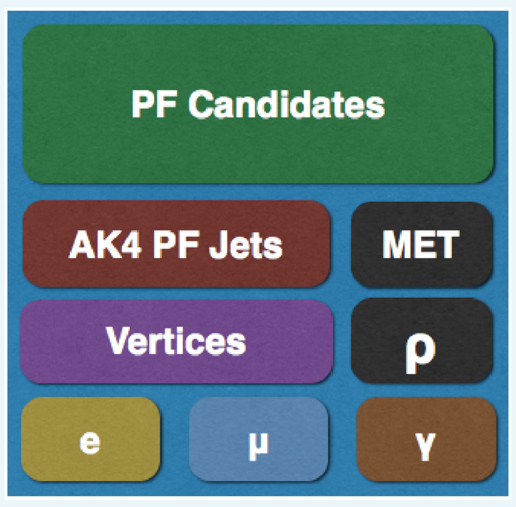


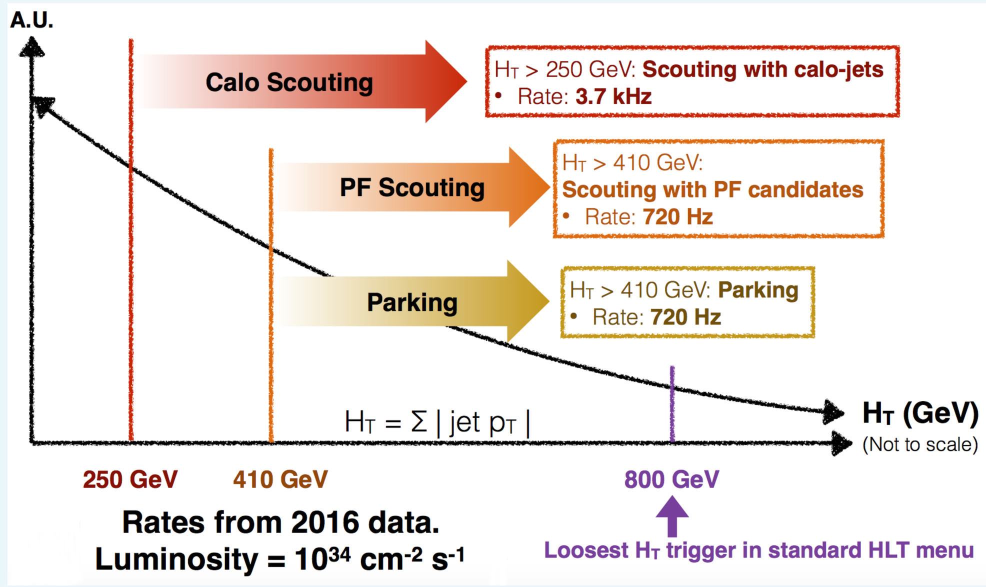
Figure 2: PF Scouting. Event size ≈10 kB

Scouting trigger algorithms in 2016

- **Hadronic Triggers:**
  - Collect events based on the value of $H_T = \sum_j p_T^j$, scalar sum of jet transverse momenta.
- **Double-Muon Trigger:**
  - Collect events with a pair of muons having invariant mass > **10** GeV.
- **Commissioning Triggers:**
  - Looser prescaled triggers to measure the HLT selection efficiency and the L1 trigger turn-on.
- A dedicated monitoring stream reconstructs a small fraction of the scouting events offline, enabling detailed online-offline comparisons of physics objects.

Scouting trigger paths	Rate[Hz] @10^{34} cm^{-2} s^{-1}	Bandwidth[MB/sec]
Calo Scouting H_T	3700	11
PF Scouting H_T	720	9
PF Scouting DiMuon	480	6
Commissioning	30	<1
Monitoring	26	23

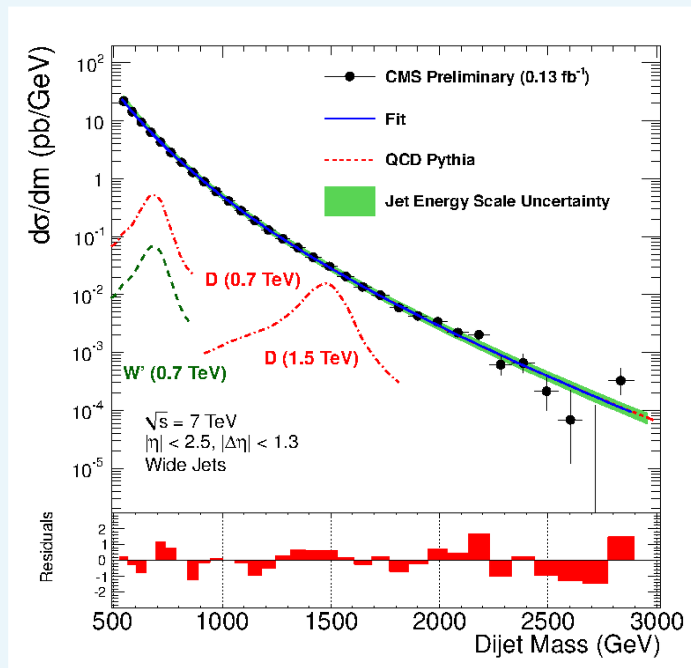
Scouting Trigger Strategy



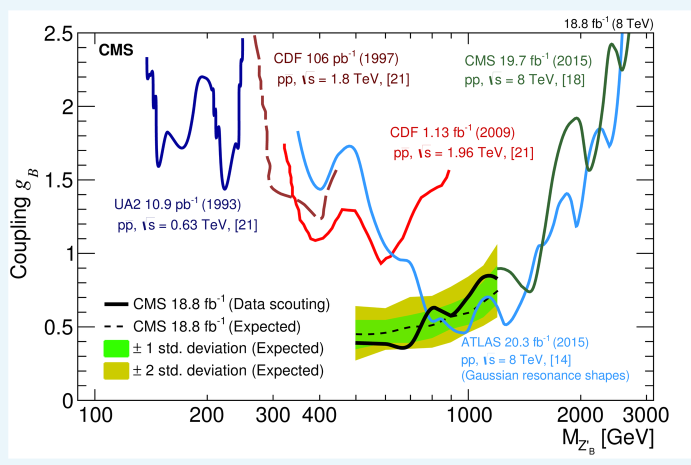
- **H_T scouting in 2016**
  - Scouting with calo-jets for H_T > **250** GeV.
  - Scouting with PF candidates for HT > **450** GeV. Rate is limited by the CPU resources needed to run PF reconstruction online.
  - The H_T > **450** GeV events are also parked (full raw-event sent to tape without further reconstruction).
- **Double-muon scouting in 2016**
  - Use the double-muon PF scouting trigger to look for new resonances above 10 GeV with small production cross section.
  - Online resolution is good enough to see known resonances by eye.

Physics results with scouting

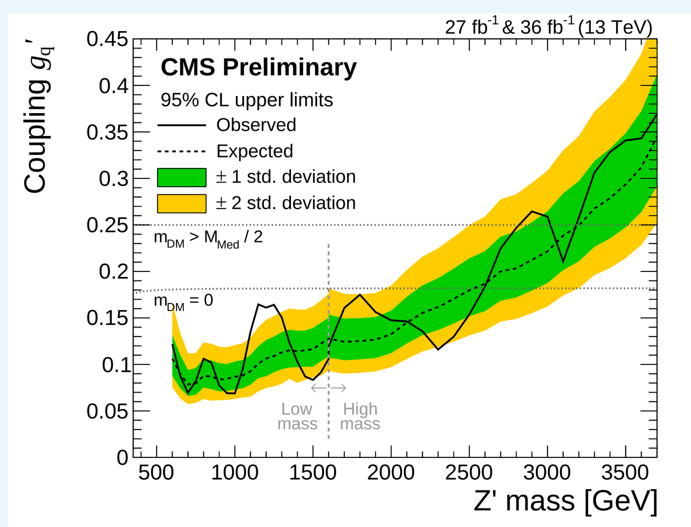
- **$\sqrt{s}$ = 7 TeV (2011 data)** [1]
  - Dijet resonance search performed with 0.13 fb^{-1} of scouting data.
  - Events with H_T > **250** GeV were recorded. Normal trigger: H_T > **600** GeV.
  - Sensitivity in M_{jj} < **900** GeV by scouting technique.



- **$\sqrt{s}$ = 8 TeV (2012 data)** [2]
  - Dijet resonance search performed with 18.8 fb^{-1} of scouting data.
  - The result is used to set limits on the coupling of a massive Z'_B as a function of its mass.
  - Most stringent limits in Run 1 between 500 and 800 GeV.



- **$\sqrt{s}$ = 13 TeV (2016 data)** [3]
  - Dijet resonance search performed with 27 fb^{-1} of scouting data.
  - Sensitivity in M_{jj} < **1.6** TeV by scouting technique.



Conclusion

- Reach so-far-unexplored territory with the help of novel data scouting technique.
- Successful scouting searches in LHC Run I motivate a more comprehensive strategy for Run II.
- Leave no stone unturned. Do the best that can be done with CMS.
- More scouting searches to come. Stay tuned !

References

1. "Search for Narrow Resonances using the Dijet Mass Spectrum in pp Collisions at $sqrts = 7$ TeV", CMS Collaboration, CMS-PAS-EXO-11-094
2. "Search for narrow resonances in dijet final states at $\sqrt{(s)} = 8$ TeV with the novel CMS technique of data scouting", Phys.Rev.Lett. 117 (2016) no.3, 031802
3. "Searches for dijet resonances in pp collisions at $sqrts = 13$ TeV using data collected in 2016", CMS Collaboration, CMS-PAS-EXO-16-056