Data Scouting and Data Parking with the CMS High level Trigger

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Huge amount of data from LHC. Need to filter out online. Filters based on theory/pheno bias. Store events with high $p_T$ objects. **Low** or **zero** sensitivity to new physics with low-mass.

**Huge reduction in rate. We might be losing good events**

Reconstruction in:

**L1 trigger**: hardware based, read-out of detector with coarse granularity, **VERY FAST**.

**High Level Trigger (HLT)**: software based, full readout of detector with full granularity, **FAST**.

**Offline**: software based, no time constraint.
ONE WAY OUT FOR LOW MASS SEARCHES: SCOUTING

Trigger Bandwidth = \[\text{Event Rate} \times \text{Event Size}\]

- Event Rate \approx 1 \text{ kHz}
- Event Size \approx 1 \text{ MB}

If we want to increase rate, we need to decrease event size.

This is the idea of data scouting.

No offline reconstruction, use HLT reconstructed objects.

Practical (so far) only for specific topologies.
Data Scouting: technicalities in a nutshell

Scouting:
- no offline reconstruction
- no RAW data saved

Scouting being used in CMS since 2011

Di-jet resonance search: first successful application of scouting

1 kHz*1MB=1 GB/sec

5 kHz*2 kB=10 MB/sec
What do we gain? From **HEAVY** to **LIGHT**

\[ 200 < M_{jjj} < 700 \text{ GeV} \]
accessible by \( H_T \) particle flow scouting

\[ 600 < M_{jj} < 1600 \text{ GeV} \]
accessible by \( H_T \) calo scouting

**tri-jet search**

Searches involving jet substructure techniques seems promising with PF scouting.

**di-jet search**

27 fb\(^{-1}\) & 36 fb\(^{-1}\) (13 TeV)

RS Graviton mass [TeV]
Going beyond hadronic scouting: Di-muon scouting trigger

Di-muon scouting trigger designed in 2015, improved in 2017

In 2017-onward version, very loose HLT requirement:

At least 2 muons with $p_T > 3$ (1) GeV in 2017 (2018). **No cut on invariant mass.**

Muon tracks should have

>0 hit in pixel and overall >4 hits in tracker

Hits in muon chamber

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**Targeting endcap muons**

Small excess $\sim 330$ MeV corresponds to $\phi \rightarrow K^+K^-$ decays where Kaons are misidentified as prompt muons.

Un-prescaled trigger

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Diagram showing di-muon mass with scouting data.
Di-muon scouting trigger

~90 fb⁻¹ data collected using di-muon scouting trigger in 2017 and 2018

https://twiki.cern.ch/twiki/bin/view/CMSPublic/HLTDiMuon2017and2018
Search for dark photons (A’) in dimuon channel.
For small mixing (\(\epsilon\)), A’ can be long-lived \(\rightarrow\) displaced muon-pair

Scouting data can be used to test other models also.
Theoretical motivation for di-muon scouting

Standard Model \[ U(1)_y \times U(1)_b \]

Dark Sector

\[ \epsilon e A'_\mu J^{\mu}_{EM} \]

cross section is suppressed by \( \epsilon^2 \)

Scouting data can be used to test other models also

Search for dark photons (A’) in dimuon channel.

For small mixing (\( \epsilon \)), A’ can be long-lived \( \rightarrow \) displaced muon-pair

BABAR / LHCb already put constrains in M(A’)-\( \epsilon \) plane

90% CL exclusion regions on \([m(A’), \epsilon^2]\)

LHCb

Phys. Rev. Lett. 120, 061801
Theoretical motivation for di-muon scouting

Search for dark photons (A') in dimuon channel. For small mixing (\(\epsilon\)), A' can be long-lived \(\rightarrow\) displaced muon-pair

CMS prompt dark-photon search in di-muon channel is in progress

CMS is searching in this region. Might go even lower in mass.
Theoretical motivation for di-muon scouting

Search for dark photons ($A'$) in dimuon channel.
For small mixing ($\epsilon$), $A'$ can be long-lived $\rightarrow$ displaced muon-pair

CMS prompt dark-photon search in di-muon channel is in progress
Published papers / public PAS using scouting data


Search for narrow resonances in dijet final states at 8 TeV with the novel CMS technique of data scouting, arxiv1604.08907, PRL 117, 031802 (2016)

Search for dijet resonances in proton-proton collisions at 13 TeV and constraints on dark matter and other models, arxiv1611.03568, PLB 769 (2017) 520

Search for narrow and broad dijet resonances in proton-proton collisions at 13 TeV and constraints on dark matter mediators and other new particles, arxiv1806.00843, JHEP 08 (2018) 130


Scouting is well established strategy in CMS. Being used consistently in new physics searches since 2011
A drawback of Scouting & the idea of Parking

- Full event information not available in scouting
- Difficult to fully characterize a potential signal (if seen)
- Way out: Parking of the full RAW data
  - NO offline reconstruction immediately
  - Reconstruct later (during technical stop / long shutdown) according to need

2016(Full), 2017 (partial) scouting data was parked

Data parking **not necessarily** only for scouting trigger. Eg. in 2018, CMS invested major effort and resource in B-physics parking.
**B parking in CMS**

**Motivation**: Study B anomalies observed by other experiments. Can be useful for other searches also, eg. Long-lived exotic new particle searches.

**Data sample**: Collected large unbiased sample of B (~$10^{10}$ events)

**Strategy**: Triggered on muon from B (tag), to collect unbiased B on the other side (probe). Rates up to 5 kHz.

Plots taken from J. Prisciandaro’s talk in https://agenda.irmp.ucl.ac.be/event/3186/
Summary

• Reach so-far-unexplored territory with the help of scouting & parking.

• Successful ‘prompt’ searches using scouting technique motivate more challenging attempts.

• Scouting and parking strategies for Run III under discussion. Possibility to expand to other final states.

• Investing efforts to optimally use the B parking dataset

• Leave no stone unturned. Do the best that can be done with CMS.

More searches to come.

Stay tuned!