Trigger algorithm for HSCP
RPC Phase-II point of view

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Joint P2 Muon Upgrade + P2 L1 Muon Algorithms Workshop

2018.11.30
Introduction

• Many BSM predict Heavy Stable particles (e.g, LSP in SUSY)
• These particles can have nonzero electric charge, Heavy Stable Charged Particles (HSCP)
  • Stable enough (>ns) to travel through the CMS detector
• Signature is similar to a slowly moving muon-like particle
  • High dE/dX, large Time of Flight
• CMS have performed very nice analysis combining both information
  • Based on SingleMuon + MET trigger
  • Note: there was HSCP-dedicated trigger with RPC when bx=50ns
RPC Phase-II upgrade

Two upgrades in Phase-II

• Link system upgrade of present system
  • Same chambers, replace electronics
  • Necessary for the HL-LHC after >10 years of operation until the Run-3
  • Provide timing information (~25ns → 2ns)
    • Extra smearing due to signal propagation along the strip

• iRPC upgrade in the high-|\eta| region
  • Extends to \(|\eta| < 2.4\) in RE3/1 & RE4/1
  • Improved RPC chamber design allows to run at lower threshold
  • New front-end electronics at both ends of the strips
  • Precise timing and 2D measurement (2cm, <1.5ns)
    • Cancel out the smearing due to sig. propagation time
HSCP trigger with RPC

RPC-ToF can be used trigger algorithm for HSCP

- HSCP hits are detected as delayed signals
  (detector clocks are synchronized to muons)
- Finding hit patterns with RPC time/distance > 0
  will provide very good separation of HSCP from muons

We have proposed a L1 trigger algorithm for HSCP
(in the Muon Phase-II TDR)

- At least 3 RPC hits correlated in space (4-6 layers in $|\eta|<1.9$)
- Linear fit to find $\beta$, fit error < 30%, slope > 0
- No bx=0 restriction - increases acceptance in small $\beta$
- Not applicable for forward region with only 2 RPC hits
HSCP trigger performance

RPC-TOF “fitting” algorithm

- At least 3 RPC hits correlated in space (4-6 layers in $|\eta| < 1.9$)
- Linear fit to find $\beta$, fit error < 30%, slope > 0
- No $bx=0$ restriction - increases acceptance in small $\beta$

Recovers slow particles of $\beta < 0.7$

Efficiency drop in $\beta < 0.3$ corresponds to extreme cases which spans >3 BX
We observe efficiency drop at high PU, combinatorial backgrounds affect fit quality and decrease efficiency.
HSCP trigger algorithm for iRPC

High-\(\eta\) region is challenging for HSCP trigger

- High multiplicity: muons, punch-through, pileup, etc
- Fake signals from combinatorial backgrounds
- Small bending angle by B-field
- Only two RPC layers \(\rightarrow\) more information is needed
- Higher \(\beta\): Need better time resolution

- All region
- iRPC region
Proposing a new algorithm

- Assume a HSCP is originated at $b_x=0$
  - $B_x$ assignment should come from different source
  - Track trigger could be the best candidate
- $\beta$ at each stations can be computed,
  \[ \beta_i = \frac{v_i}{L_i} \approx 1 + c_t \frac{\text{RPCHit}}{d_i} \]
- Finally take $\langle \beta \rangle = \frac{\sum \beta_i}{N}$ and error from the RMS
Matching efficiency

There are efficiency drop due to the geometry, ~80% in high-eta region

- ≥ 2hits
- ≥ 3hits

*Introduced additional cuts to reduce combinatorial background, But keep >99% of hits*
$|\eta|$-dependent $\beta$ cuts

- $|\eta| < 1.6$
  - $\beta_{\text{cut}} = 0.85$

- $1.6 \leq |\eta| < 2.1$
  - $\beta_{\text{cut}} = 0.95$

- $2.1 \leq |\eta| < 2.4$
  - $\beta_{\text{cut}} = 0.95$

Optimal cut value depends on $|\eta|

We can increase $\beta$ thanks to be better resolution
Efficiency with new algorithm

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New algorithm works for all region at very high efficiency
Summary

• Trigger algorithms for HSCP are proposed
• Fitting algorithm works for the existing RPCs, as a complement to the regular muon trigger at low beta region
• We show an algorithm to cover the iRPC region
• Constraining at Bx=0 simplifies the algorithm and dramatically improves the efficiency
• Combination with other detector information is necessary for the correct Bx assignment