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Search for Heavy Stable Charged Particles in CMS

Krzysztof Nawrocki*
Soltan Institute for Nuclear Studies
E-mail: nawrocki@fuw.edu.pl

The CMS detector can be used to search for Heavy Stable Charged Particles (HSCPs) which might signal physics beyond the Standard Model. Such particles can be distinguished from Standard Model particles by exploiting their unique signature: a low velocity, β, associated with a high momentum of order a few hundred GeV/c. Two techniques to measure β of such particles using the Silicon Tracker and the Barrel Muon Drift Tube detectors are reviewed and perspectives for HSCP searches in CMS are shown.

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*Speaker.

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1. Motivation for HSCP searches

HSCPs arise in models in which one or more new states exist and which carry a new conserved, or almost conserved, global quantum number. Supersymmetry with R-parity and extra dimensions with KK-parity provide examples of such models. A full review of models with HSCPs can be found in [1]. The lightest of the new states will be stable, due to the conservation of this new parity and depending on quantum numbers, mass spectra, and interaction strengths, one or more higher-lying states may also be stable or metastable.

HSCPs could be produced by the Large Hadron Collider (LHC) as a result of direct pair-production processes or as final products of the decay chain of heavier exotic particles. HSCPs with colour charge will hadronize and form mesons, baryons or glueballs. These hadronized states are generically called R-hadrons.

2. Methods of the detection

The identification of a HSCP relies on the fact that it can be slow ($v < c$), but with a high momentum ($p \gtrsim 100$ GeV). Since mass, velocity and momentum are related by

$$P = \beta\gamma m \quad , \quad m = P\sqrt{\frac{1}{\beta^2} - 1}. \tag{2.1}$$

it is possible to measure the mass if both β and the momentum are measured. In this section we describe how a measurement of β can be made with the CMS [2] detector.
Two approaches have been followed, one based on time-of-flight (TOF) measured with the Drift Tube detector and one based on specific ionization in the Tracker.

2.1 TOF from DT

In each wheel of the barrel of CMS there are four muon stations. Each station except the outermost contains three super-layers (SL), each composed of four DT layers. Two of the SLs measure the $r-\phi$ coordinate and one measures the z coordinate. There are only two SLs in the outermost station, with no z SL.

1D rec-hits associated with a local track element (2D rec-hit) form a zig-zag pattern which can be aligned by an appropriate $t0$ correction. This correction has 3 main ingredients: (i) time of flight from the Interaction Point (IP) to the rec-hit $t_c = l/(\beta c)$, where l is the distance from the IP, (ii) signal propagation time along the sensitive wire t_w, (iii) off-time correction δ_t. The expected value $\langle\delta_t\rangle$ for muons originating at the primary vertex of the correct bunch crossing (BX) should be equal to zero by construction, but it will differ from zero for off-time particles. In particular, for HSCP particles which travel with velocity $\beta < 1$, the average value $\langle\delta_t\rangle > 0$.

A group of 1D rec-hits forming a local track element (2D rec-hit) in a given SL allows the determination of $\langle\delta_t\rangle_{SL}$ if the coarse position along the drift tubes is known sufficiently well to estimate $t_c + t_w$.

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2.2 dE/dx from tracker

A reconstructed track in CMS has associated the *RecHits* which are the measurement points of the track in the various layers of silicon tracker. Each RecHit has associated the position and the cluster charge, i.e. the sum of the heights of the signals on the strips that form the cluster. This signal is proportional to the amount of energy released by the charged particle crossing the silicon module. Since the energy release depends on the β of the particle with a β^{-2} dependence in the region $0.1 < \beta < 0.8 \div 0.9$, we measure β from $\frac{dE}{dX}$. It is possible to compute the $\frac{dE}{dX}$ from the collected signals once the normalization factors are properly computed as explained in [3]. The main effects to be taken into account are the geometrical effective path length of the track crossing the detector and the readout channel gain factor.

3. Simulation studies

Several strategies can be followed to select events according to the expected signal signature. We expect three slightly different Heavy Stable Charged Particle signatures: a lepton-like massive charged particle (stau, KK-tau), a charge-flipping massive particle (stop, gluino), a charge-flipping massive particle always produced as neutral (i.e. a gluino if it is produced as gluon-gluino ball).

To maximize the S/B ratio, we can combine the two β measurements described in section 2 and reduce the background to a negligible level without significant loss of the signal. The first step of the selection process is to associate the candidate HSCP measured in the muon system with that measured in the tracker. All the muon tracks reconstructed in the muon system with $p_T > 30$ GeV are considered as HSCP candidates, while for the tracker candidates a preselection requires some additional quality criteria on the reconstructed track in the inner tracker and muon system. The two collections are associated by geometric and momentum compatibility. Figure 1 shows the distribution of β_{Dt}^{-1} vs β_{Tk}^{-1} for background and signal events after matching. For signal events, the two measurements are clearly correlated. There is no correlation between the measurements in the background case. Finally it is required that both β measurements are smaller than 0.8 and that the average of the mass measured with the two techniques is greater than 100 GeV/c^2. No background events are observed to pass the above selection.

Finally we can compute the luminosity needed to discover the models discussed in this note. The left plot on Figure 2 shows the required luminosity to select three events for the different signal samples. The error bars correspond to the systematic uncertainty of about 50%, which in this study is dominated by the muon trigger efficiency. The right plot on Figure 2 shows the reconstructed mass distribution with 1fb^{-1} for two of the lowest cross section samples (300 GeV/c^2 KK tau and 800 GeV/c^2 stop).

4. Conclusions

In this note we report the status of the work to define a search strategy for Heavy Stable Charged Particles. We show that HSCPs can be discovered with early data for different models and in different mass regions.

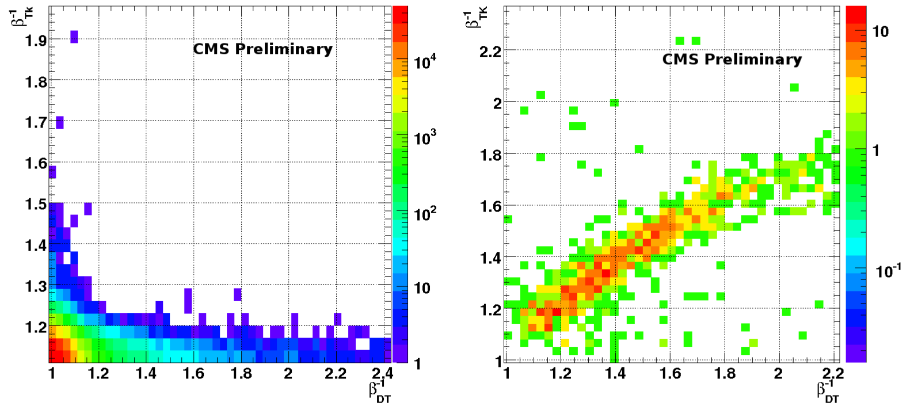

Figure 1: Distribution of β_{Dt}^{-1} as a function of β_{Tk}^{-1} for muon background (left) and for a signal sample (right).

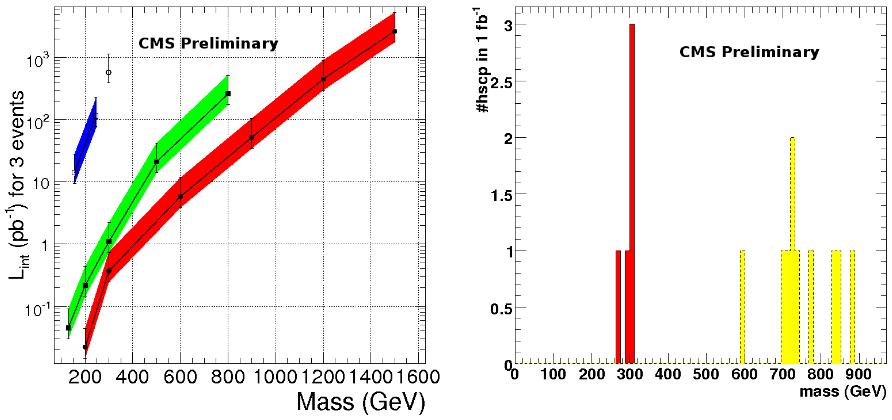

Figure 2: The left plot shows the integrated luminosity (pb^{-1}) needed for 3 events, for the four signal models (gluino full circles, stop full squares, KK tau empty circles, stau empty squares) as a function of HSCP mass. The right plot shows the mass distribution with 1 fb^{-1} for two of the lowest cross section samples (300 GeV KK tau and 800 GeV stop).

References

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[2] CMS Collaboration, *Technical proposal*, CERN/LHCC 94-038.

[3] A. Giammanco, *Particle Identification with Energy Loss in the CMS Silicon Strip Tracker*, CMS AN-2007/008.