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Search for Heavy Stable Charged Particles at CMS

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Summary. — Some supersymmetric and/or extra dimensions models predict the existence of "Heavy Stable Charged Particles" (HSCP) which could be produced at LHC. In pp collisions at $\sqrt{s} = 7\,\text{TeV}$, the observation of tracks with $\beta = v/c < 1$ would constitute a distinctive sign of HSCP production. At CMS, β can be measured in the tracker, from the specific ionization $\mathrm{d}E/\mathrm{d}x$, and/or in the muon system, by evaluating the time of flight (TOF). With the first $3.1\,\text{pb}^{-1}$ at $7\,\text{TeV}$, limits have been posed on the mass of some types of HSCP, using only the specific ionization. The CMS search for HSCP production with the 2010 data sample will be presented.

PACS 14.80.Ly – Supersymmetric partners of known particles.
PACS 14.80.Pq – R-hadrons.

1. – Heavy Stable Charged Particles, beyond the Standard Model

Several models of physics beyond the Standard Model (SM), including some versions of Supersymmetry (SUSY), predict the existence of new long-lived charged particles with masses of the order of several hundreds GeV/c^2 (Heavy Stable Charged Particles HSCP). Besides a massive dark matter candidate, *i.e.* the lightest supersymmetric particle (LSP), one or more higher-massive metastable charged states are predicted, with characteristics dependent on the parameters of the model.

The Minimal Supersymmetric extension of the Standard Model (MSSM) poses the neutralino as the LSP. The stop $\tilde{t}$, partner of the top quark, would be long lived because of the small mass difference with respect to the neutralino. It carries both electric and color charge and can have a cross section up to $\sim 10\,\text{pb}$.

The SplitSUSY scenario predicts the scalar partners of SM fermions to have very large masses (of the order of several TeV/c^2) while the gauginos and higgsinos, partners of the vector and Higgs bosons of the SM, would be lighter, with masses under the TeV/c^2 scale. This theory sees the gluino $\tilde{g}$ as a color charged HSCP; it would have long life because it could only decay into a neutralino emitting a virtual supermassive squark. Cross sections up to a nb are expected for low masses of the gluino.

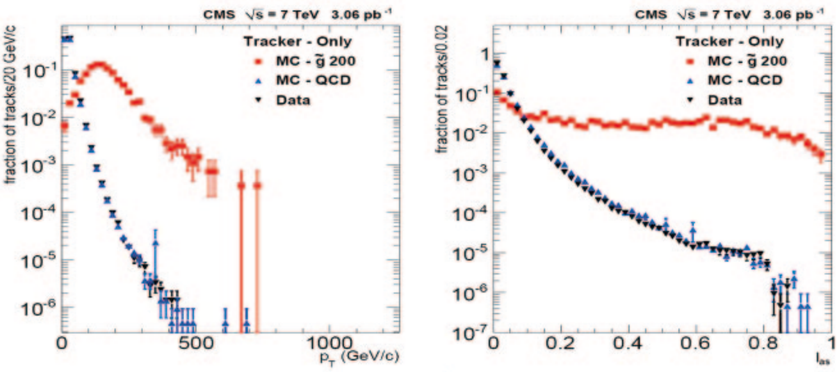

Fig. 1. – Distributions of p_T and I_{as} for data, background and a simulated signal ($\tilde{g}$ 200 GeV/c^2).

Electrically charged HSCPs are expected in other SUSY or extra-dimension scenarios: *e.g.* the stau $\tilde{\tau}$ or the Kaluza Klein tau τ^{kk}. The predicted cross sections for these HSCP are significantly smaller ($<$ pb).

2. – Search for HSCPs at CMS

The Compact Muon Solenoid (CMS) at the Large Hadron Collider (LHC) is a multi purpose experiment designed to explore the TeV energy scale. In CMS, the 3.8 Tesla solenoid magnet is the core of a very compact detection structure: from inside out we encounter the silicon tracker, the electromagnetic and hadronic calorimeters and, outside the magnetic coil, and the muon system.

At LHC, HSCPs can be produced directly in pairs or as consequence of the decay of heavier exotic particles. Since they are charged, they interact directly with the matter. Their behavior strongly depends on the type of charge they carry. HSCPs with electrical charge only are muon-like, *i.e.* they cross the whole detector leaving ionization tracks. Colored ones, like gluino and stop, hadronize combining to quarks or gluons to form the so-called R-hadrons: R-baryons $\tilde{g}qqq$, R-mesons $\tilde{g}qq$ or gluonballs $\tilde{g}g$. There are free parameters of the hadronization model (like the fraction of gluonballs f): depending on these, the HSCPs can reach the muon system or stop in the detector before decaying. The unique signature of HSCPs is $\beta < 1$ even at large momenta; simultaneous measurements of β and momentum permit to evaluate the mass of the particle: $m = p\sqrt{\frac{1}{\beta^2} - 1}$.

β can be measured in the inner tracker from specific ionization. HSCPs are expected to produce higher ionization with respect to a MIP in the silicon strips of the tracker: the ionization scale was calibrated with low energy hadrons.

An independent measurement of β is possible for muon-like particles from their time-of-flight to the muon system.

3. – First search for HSCPs with $3.1\,\mathrm{pb}^{-1}$

The first $3.1\,\mathrm{pb}^{-1}$ of CMS data were used to search for HSCPs, during 2010 [1]. A counting experiment was set-up, the discrimination signal-background relied on the p_T of tracks and their associated specific ionization (I_{as}), as measured in the inner tracker. The distributions of p_T and I_{as} for the background, a simulated signal and the data are shown in fig. 1. Cuts were tuned to reject the background but to maintain sensitivity for

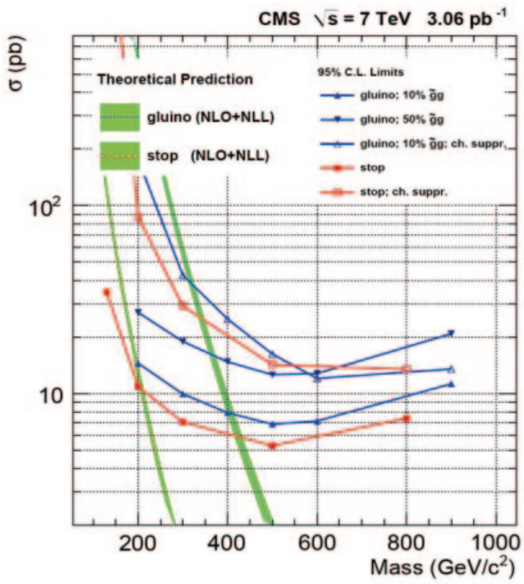

Fig. 2. – 95% CL cross section upper limits for $\tilde{g}$ and $\tilde{t}$ as functions of mass.

TABLE I. – 95% *CL mass lower limits for gluino and stop (f is the fraction of gluonballs, a free parameter of the model).*

Particle	Lower limit on mass
Gluino ($f = 0.1$)	398 GeV/c^2
Gluino ($f = 0.5$)	357 GeV/c^2
Stop	202 GeV/c^2

HSCP discovery and/or exclusion. No events were observed with an expected background of less than 0.1 events.

Since no events were observed, 95% CL upper limits on the production cross sections for gluino and stop were computed. These limits depend on the model assumed for R-hadron interaction with matter. Cross section limits are shown in fig. 2 as a function of the mass. Intersecting the theoretical cross section with the experimental limits, lower limits on masses of gluino and stop were put, dependent on free parameters (see table I).

REFERENCES

[1] THE CMS COLLABORATION, *JHEP*, **03** (2011) 024.