Search For Displaced Top Quark

In the CMS experiment

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Search for hints of new physics through exotic signatures.

Combining the expertises of the CMS team @ Strasbourg :

- Top physics
- Tracker/tracking development
- Phenomenology

Models under study :

1. Minimal SuperSymmetric Model with R-parity violation where neutralino is the long-lived particle
2. Gauge-Mediated Supersymmetry Breaking where stop is the long-lived particle
3. Split SUSY where gluino is the long-lived particle

Goal :

Identifying the most sensible way to reconstruct a displaced top

Several possible options :

- Displaced tracks
- Displaced vertices
- Displaced jets
- A combination of them

Iterative Tracking in CMS:

12 iterations targeting different kinds of tracks, allows the trajectories of charged particles to be reconstructed with great precision while keeping the combinatorics under control[1]

For each step :

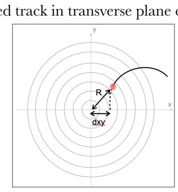
Seeding ⟶ Track building (pattern recognition) ⟶ Track fitting ⟶ Track classification

Long-lived particle:

Travels for some distance before decaying

If decays into SM particles: expecting tracks far from the primary vertex (high R and Z) & not pointing to the primary vertex (high impact parameter values dxy and dz)

Displaced track in transverse plane of tracker



Development of a new tracking iteration :

DisplacedGeneralStep

(Integrated to the official release of CMS-software)

Strategy :

- Using only strip hits for seed building
- Combining the different partitions of the strip tracker (TIB+TID+TOB+TEC ring5-7)
- Larger tracking region (max dxy and dz for seed) than PixelLess and TobTec

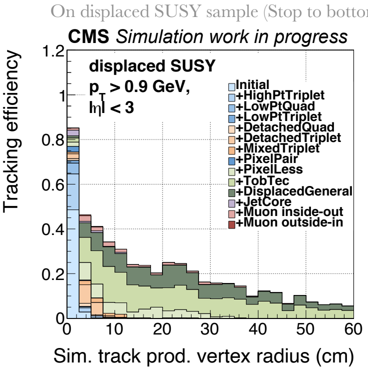
Challenges :

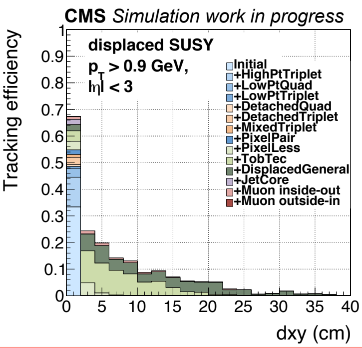
- Additional reco timing
- Increase of fake rate

Tracking efficiency as a function of the transverse impact parameter

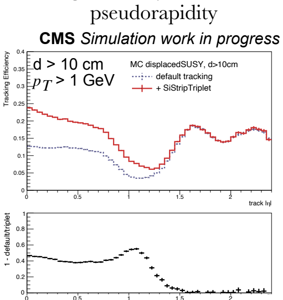
Tracking efficiency as a function of the transverse vertex position

On displaced SUSY sample (Stop to bottom, ctau = 50 cm, Run 3 conditions, <PU>=65)



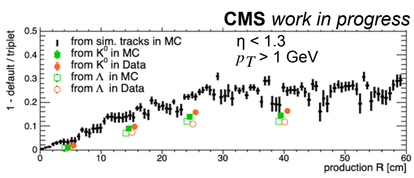


Tracking efficiency as a function of pseudorapidity



Recovery of the efficiency in the barrel region (up to 50% more)

Efficiency gain : comparison between data (UL17) and MC (ttbar) using K_0^S and Λ mass peak



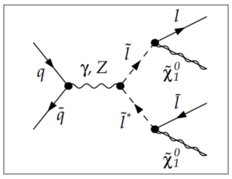
Data-driven estimation gives similar results for K_0^S and Λ when applied on data or MC

Zoom on RPV-SUSY model :

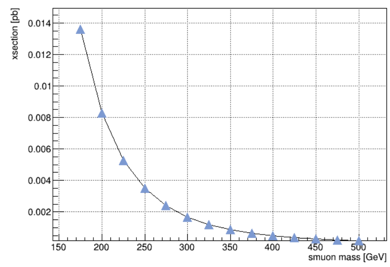
Superpotential function[2]:

$$V = \epsilon_i(H_u \cdot L_i) + \frac{1}{2}\lambda_{ijk}(L_i \cdot L_j)E^c_k + \underbrace{\lambda'_{ijk}}_{\tilde t \to d\mu}(L_i \cdot Q_j)D^c_k + \frac{1}{2}\underbrace{\lambda''_{ijk}}_{\tilde t \to ds} U^c_i D^c_j D^c_k$$

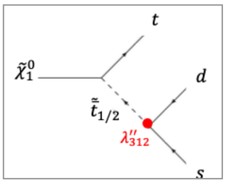
Neutralino production via slepton



Cross section of slepton production



Neutralino (llp) decay



$\tilde\chi_1^0 \to \bar t \bar d \bar s$

$\tilde\chi_1^0 \to tds$

$\lambda''_{312} = -\lambda''_{321}$

Free parameters:

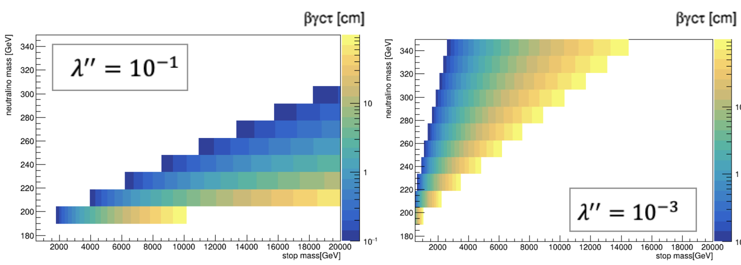
- Smuon (50% right, 50% left) mass
- Neutralino (Bino) mass
- Stop (50% right, 50% left) mass
- λ''

Preliminary results for a future study :

Search for long lived particles decaying into a top quark inside the CMS tracker volume

Scan on stop (off-shell) and neutralino mass for benchmarks definition

Flight distance (w/ relativistic correction) for two values of λ''



- Interesting parameter space allowing for signal with a displaced top quark coming from a long-lived neutralino
- Same procedure has been used for UDD (λ'') and LQD (λ') couplings
- Same procedure has been used for GMSB and Split SUSY study
- Phenomenology paper and MC production (Run 3 conditions) in CMSSW under preparation

[1] The CMS Collaboration, Description and performance of track and primary-vertex reconstruction with the CMS tracker

[2] R. Barbier and al, R-parity violating supersymmetry, Phys.Rept.420:1-202,2005, arXiv:0406039 [hep-ph]

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