Search for long-lived massive particles at CMS

Jie Chen

Florida State University

for the CMS Collaboration

Outline

- Introduction
- Searches for Heavy Stable Charged Particles at CMS
  - stopped gluino/stop
  - slowly moving gluino/stop/stau
- Conclusions

Introduction

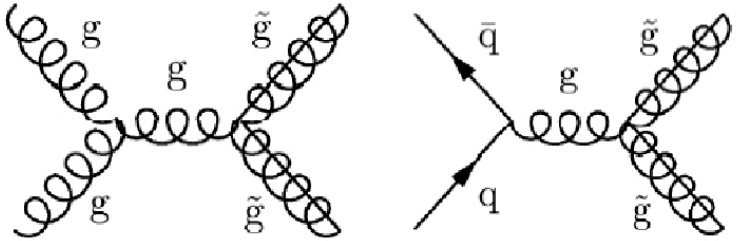
Long-lived massive particle

Long-lived Massive Particles: charged or neutral

- ~cm < cτ < detector scale: non-prompt decay inside detector
- cτ > detector scale: decay outside detector or readout time window. If charged → Heavy Stable Charged Particle (HSCP)

HSCP Production Mechanism:

- Pair production
- Cascade decay



- Lepton-like HSCP
  - GMSB stau
- R-hadron (strongly produced HSCPs hadronize with SM gluon/quarks)
  - Split Supersymmetry → gluino (hadronize to gluinoball, R-meson,R-baryon)
  - Baryogenesis motivated Minimal Supersymmetric Standard Model → stop

HSCP interactions in detector

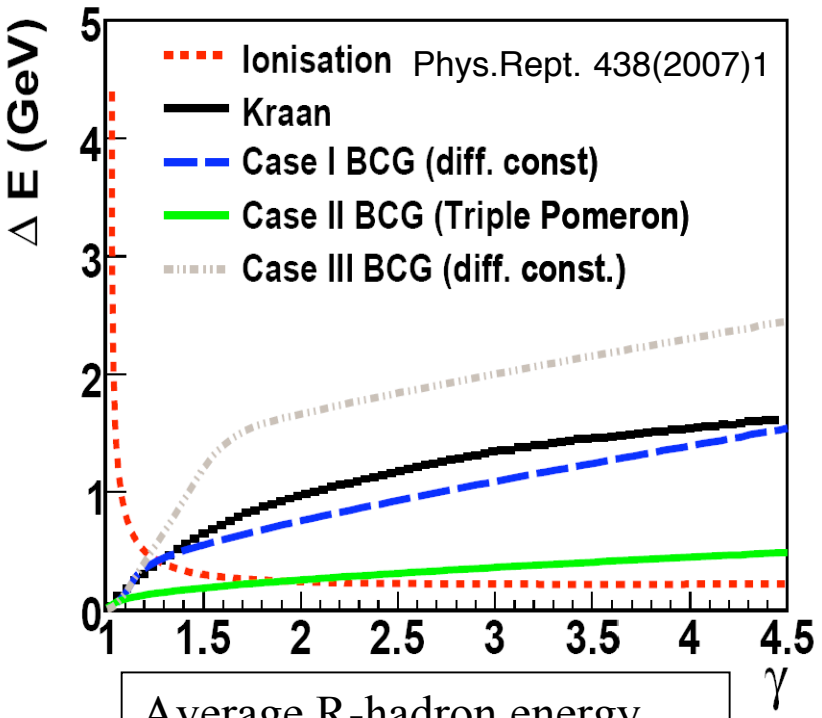
Longer time of flight

- Non-relativistic → $\beta<1$

Higher energy loss inside detector

- Lepton-like HSCPs behave like (heavy) muons with large ionization energy loss

- R-Hadron, also has hadronic interactions
  - Few GeV per interaction → no showering in calorimeters
  - heavy parton acts as spectator, conversion to a different R-hadron species possible
  - Cloud model: most R-hadrons end up charged after several interactions. Eur. Phys. J. C50 (2007) 353
  - Neutral R-baryon interaction model: all R-baryons become neutral after a typical calorimeter. Eur. Phys. J. C66 (2010) 493



Average R-hadron energy loss per hadronic interaction

HSCP detection

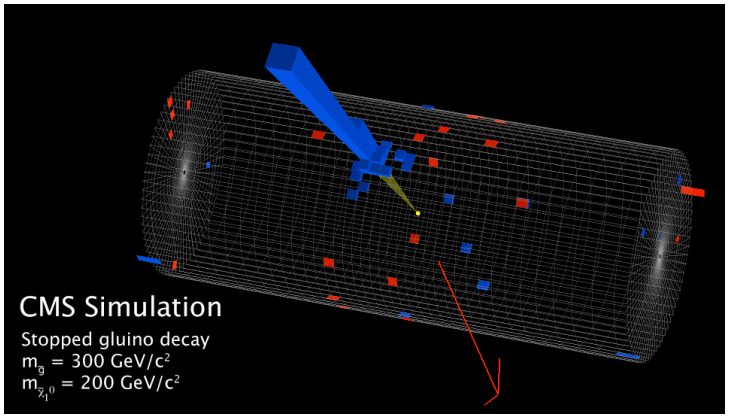
HSCPs can possibly stop inside (β<0.3) or slowly escape (0.4<β<0.9) detector

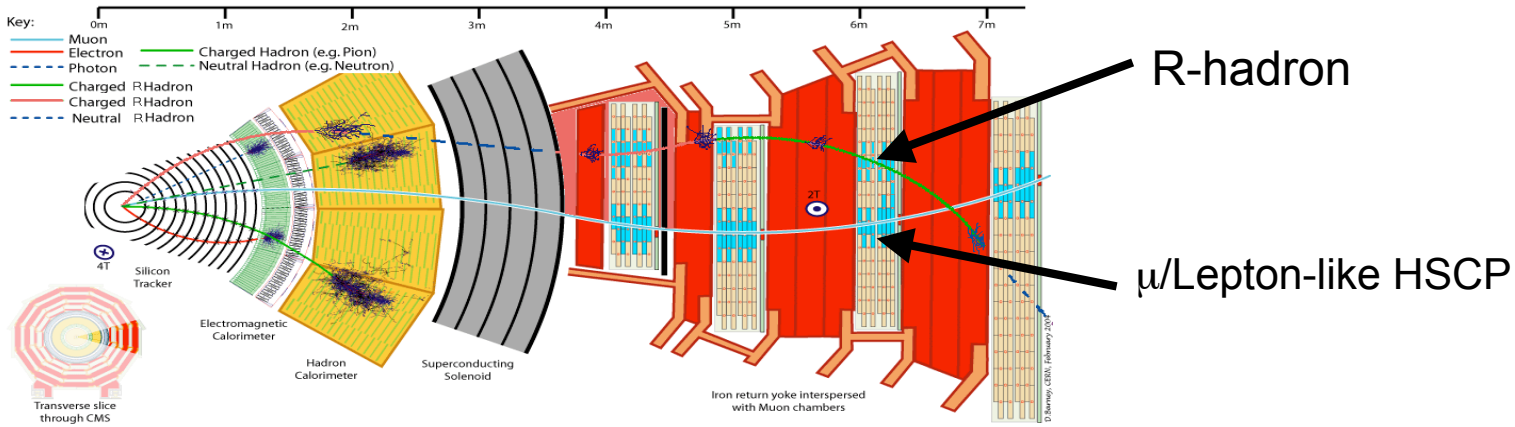
Stopped HSCP: look for energetic hadronic jet from HSCPs decaying when beam off or during beams collisions intervals

Slowly moving HSCP: measure β from delayed time of flight (T.O.F) and tracker dE/dx (ionization energy loss per path length)

- Can measure mass from p/(βγc)

Two searches are complimentary and can confirm each other





Stopped HSCP Search

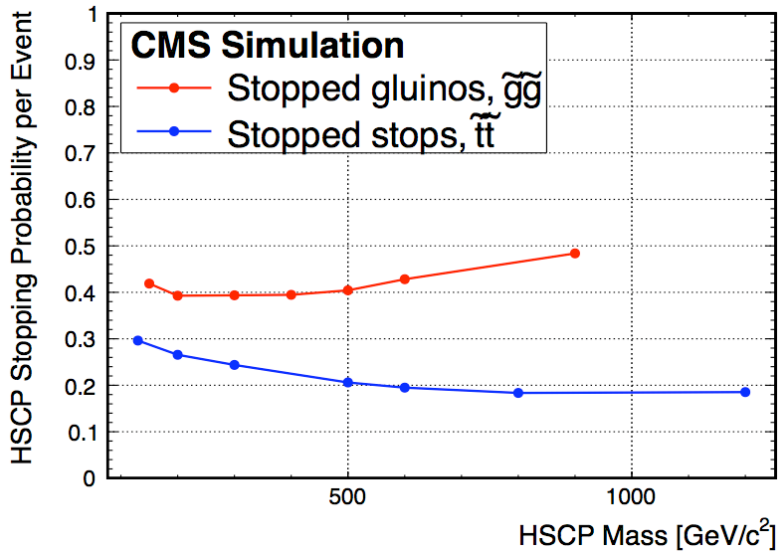
Stopped HSCP

Data Samples:

- 168 hours of trigger live-time LHC fills, peak luminosity up to 10^{33} cm^{-2} s^{-1}
- 2010 data with peak luminosity of 10^{28}~10^{32} cm^{-2} s^{-1}, as background control sample

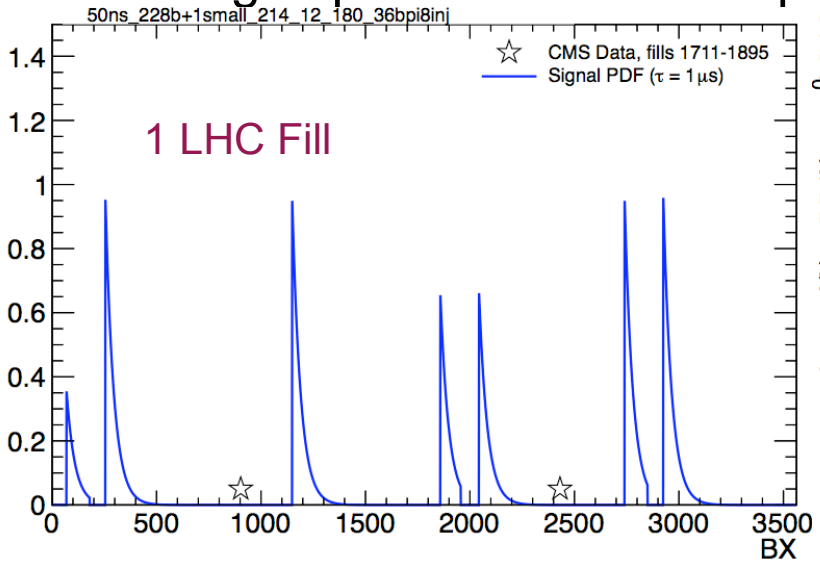
Selection:

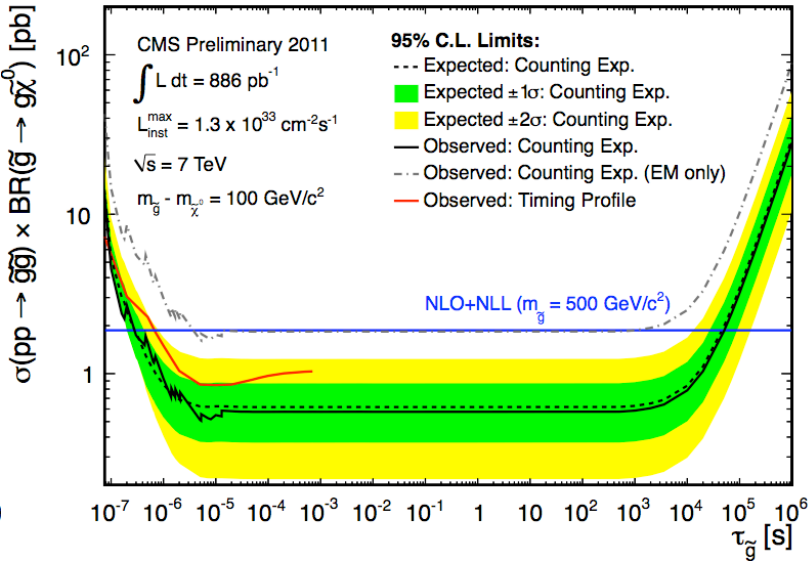
- dedicated 50 GeV jet trigger with no signals from beam position and timing (BPTX) monitors in a window of ±1 Bunch Crossing (BX)
- 70 GeV jet energy requirement, beam-related, cosmic and instrumental background rejection



Stopped HSCP

Counting experiment and time-profile analysis are performed



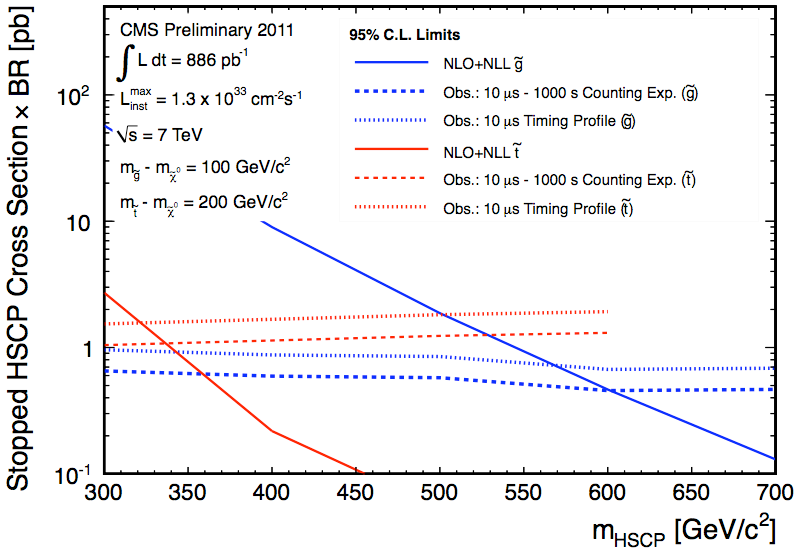


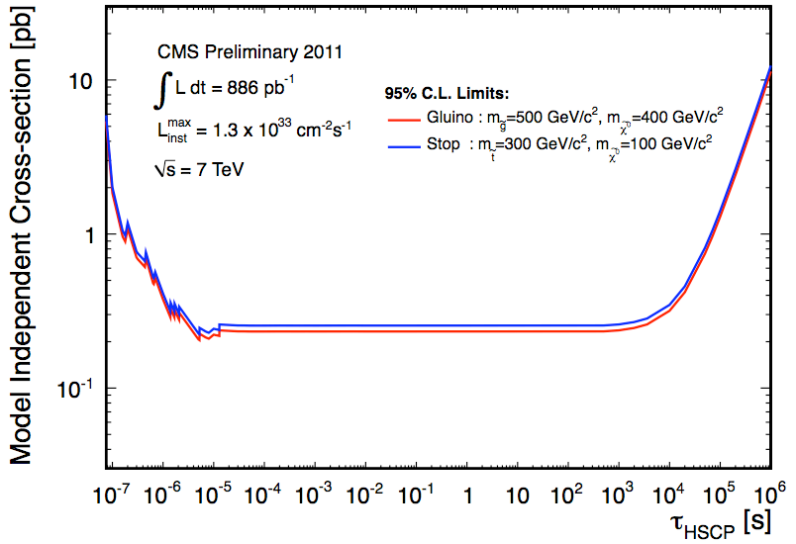
Lifetime	$L_{eff}(pb^{-1})$	Expected Bg	Observed
75 ns	4.3	0.11 ± 0.05	0
100 ns	12.5	0.35 ± 0.14	0
1 μs	139	3.3 ± 1.3	4
10 μs	352	10.1 ± 4.1	9
30 μs - 10^3 s	360	10.4 ± 4.2	10
10^4 s	268	10.4 ± 4.2	10
10^5 s	65	10.4 ± 4.2	10
10^6 s	7.5	10.4 ± 4.2	10

Counting Exp.

Stopped HSCP

- Gluino
  - $M_{gluino} - M_{neutralino} > 100$ GeV, Br(gluino → g + neutralino) =100%, $m_{gluino} < 601$ GeV are excluded @95% C.L. for lifetimes from 10 μs to 1000 s
- Stop ← NEW Addition
  - For $M_{stop} - M_{neutralino} > 200$ GeV, Br(stop → top + neutralino) =100%, $m_{stop} < 337$ GeV are excluded @95% C.L. for lifetimes from 10 μs to 1000 s
- Substantially extends our previous gluino limit (PRL 106 (2011) 011801) of 370 GeV
- 95% C.L. limits are also set for cross-section X BR X stopping efficiency to be interaction model independent



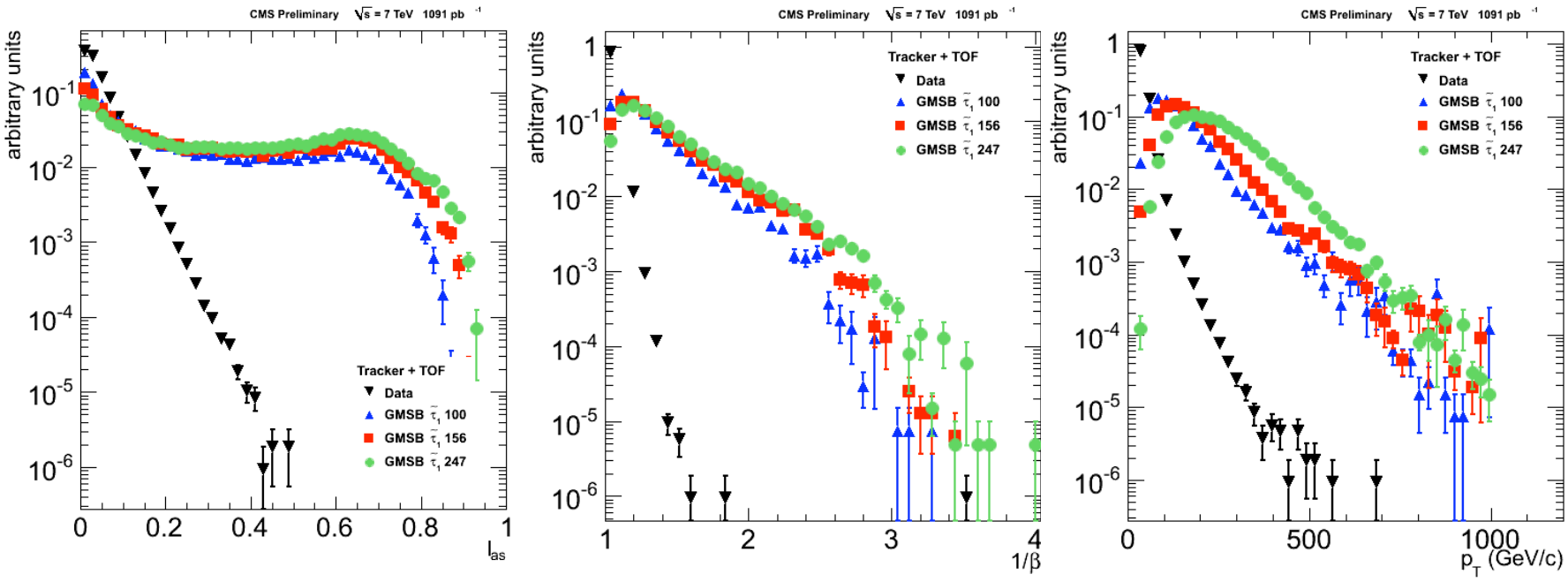


Slowly Moving HSCPs

Slowly Moving HSCP

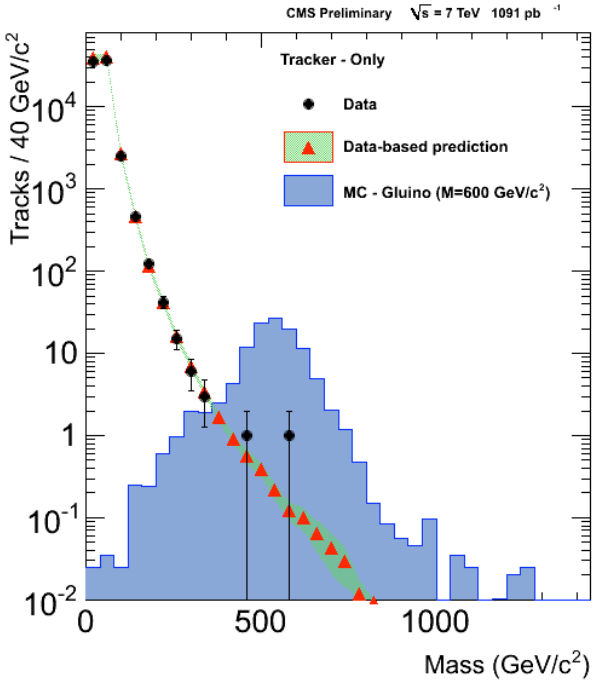
1091 pb^{-1} data used with Muon and MET trigger

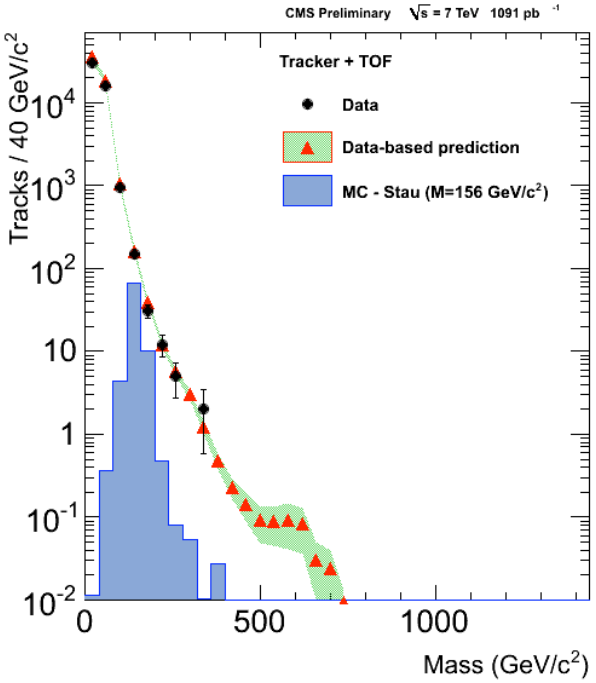
- Two analysis methods
  - ✓ Tracker-only (discriminator I_{as} from tracker dE/dx measument)
  - ✓ Tracker+TOF (β^{-1} measurement from muon system in addition)
- Look for enhancement in high I_{as}, high β^{-1} and high p_T region.



Slowly Moving HSCP

- Data-driven way to estimate background, utilizing the non-correlation between I_{as}, and β^{-1} and p_T
- Mass prediction made from pseudo-exp, using p, I_h, and β^{-1} PDF obtained from non-signal region
- Counting experiment in mass window [$M_{reco} - 2\sigma_{Mreco}$, 2 TeV] is performed with optimized I_{as}, β^{-1} and p_T selection to get the best expected limit for each model mass point considered



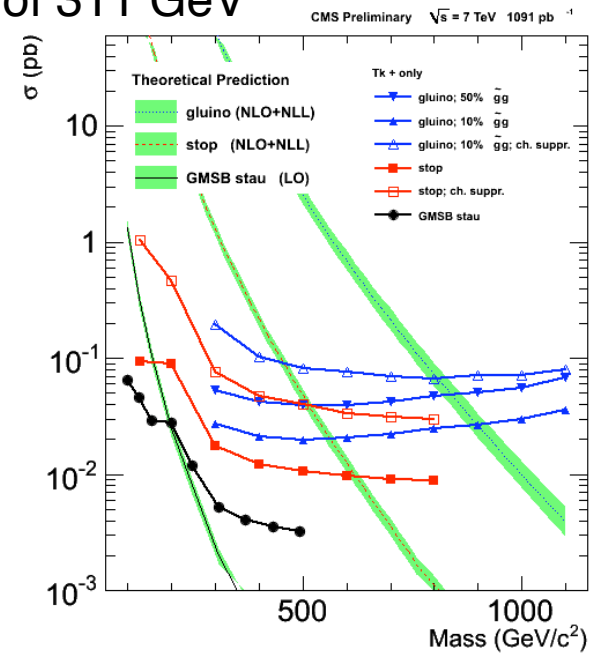


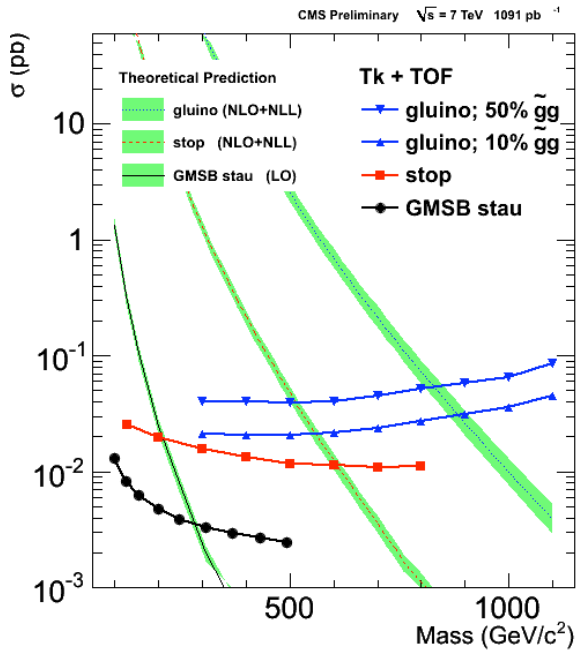
Slowly Moving HSCP

95% C.L. mass limits are set for

- Cloud model interaction scenario
  - Gluino (10% ~gg): 899 GeV, Gluino (50% ~gg): 839 GeV
  - Stop: 620 GeV GMSB Stau:293 GeV ← NEW Addition
- Charge suppression interaction scenario
  - Gluino(10% ~gg): 808 GeV, Stop: 515 GeV

Significant improvement over our previous gluino limit (JHEP 03 (2011) 024) of 311 GeV





Summary

- With ~1 fb^{-1} integrated luminosity, CMS searched both stopped and slow moving HSCPs
  - No significant excess observed
- 95% C.L. mass limits are set on
  - Gluino: 601 GeV, Stop: 337 GeV (stopped HSCP analysis)
  - Gluino: 899 GeV, Stop: 620 GeV, GMSB Stau: 293 GeV (slowly moving HSCP analysis)
  - Significant improvement over our 2010 data limits
- Results shown will be available https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

Stay tuned for more exciting exotica searches

Back Up