ICHEP2012 Melbourne

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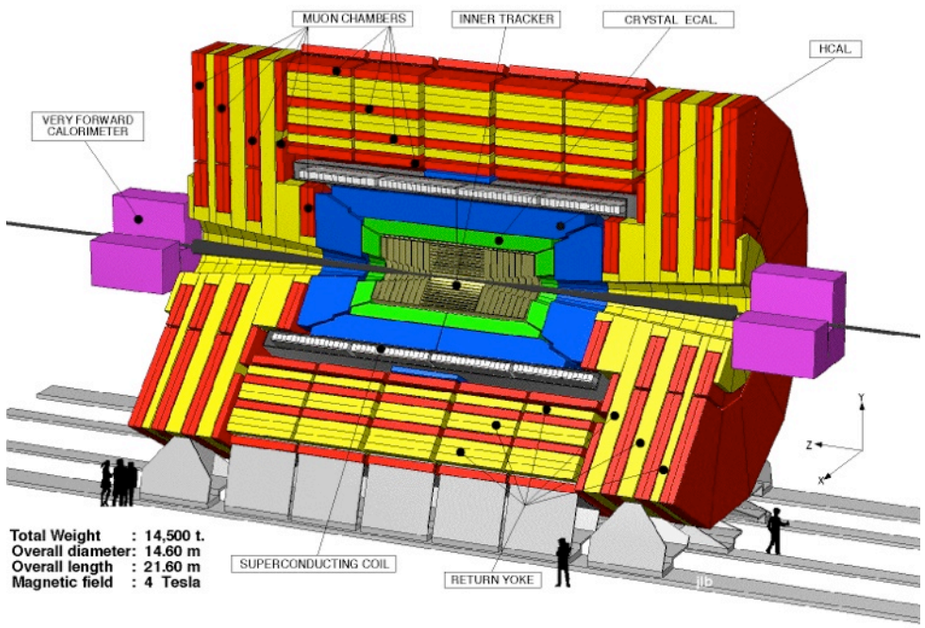
Melbourne Convention and Exhibition Centre



Search for New Massive Stable Particles at CMS

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on behalf of the CMS Collaboration

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CMS Compact Muon Solenoid

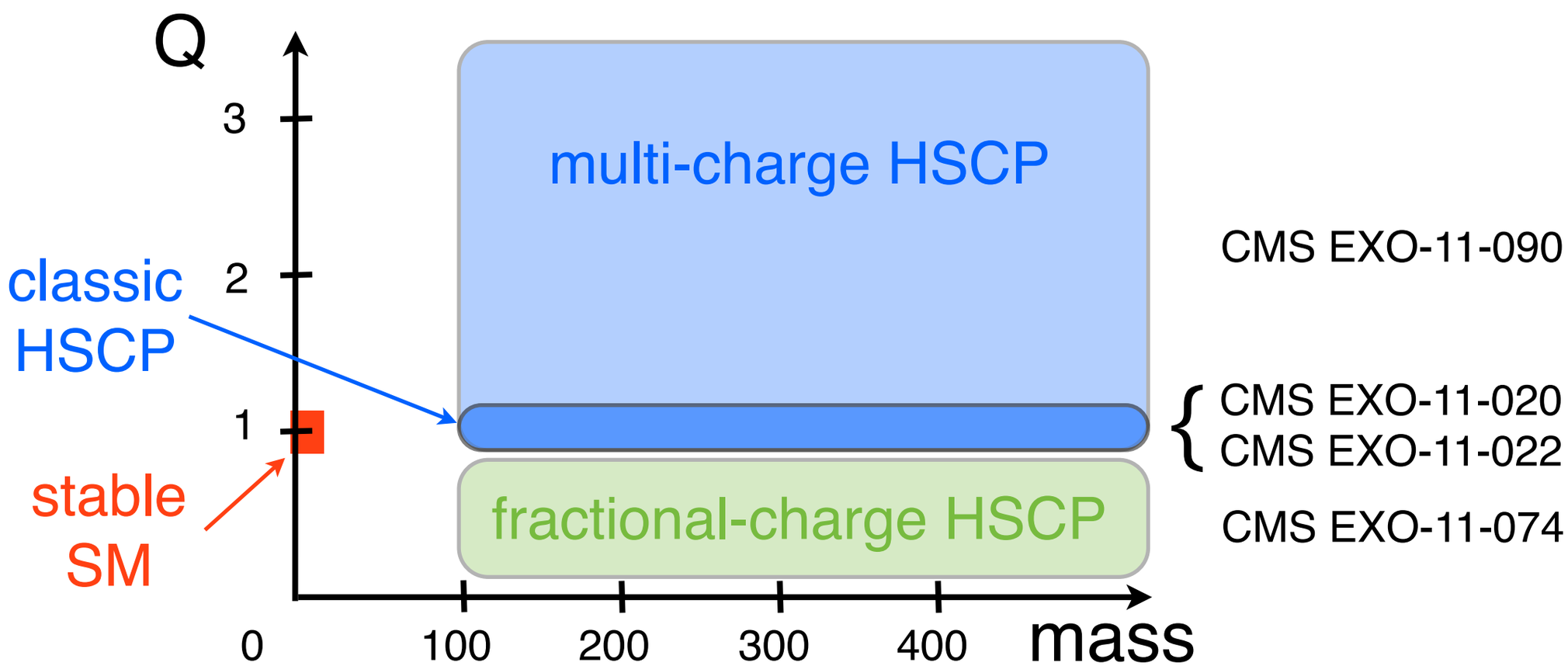
Motivation

- Some SUSY flavors predict long living gluino, stop, stau...
  - hidden valley models, certain GUTs
- Lifetimes $10^2..10^3$ s are of particular interest by cosmology
  - may explain $_7$Li and $_6$Li abundance discrepancy between measurement and conventional nucleosynthesis
- Extension to more exotic predictions
  - long-living particles with fractional charge
    - e.g. heavy (s)quarks
  - long-living particles with multiple charge
    - e.g. AC-fermions, Q-balls etc.

Scope: HSCP a.k.a. CHAMP, LLP, ...

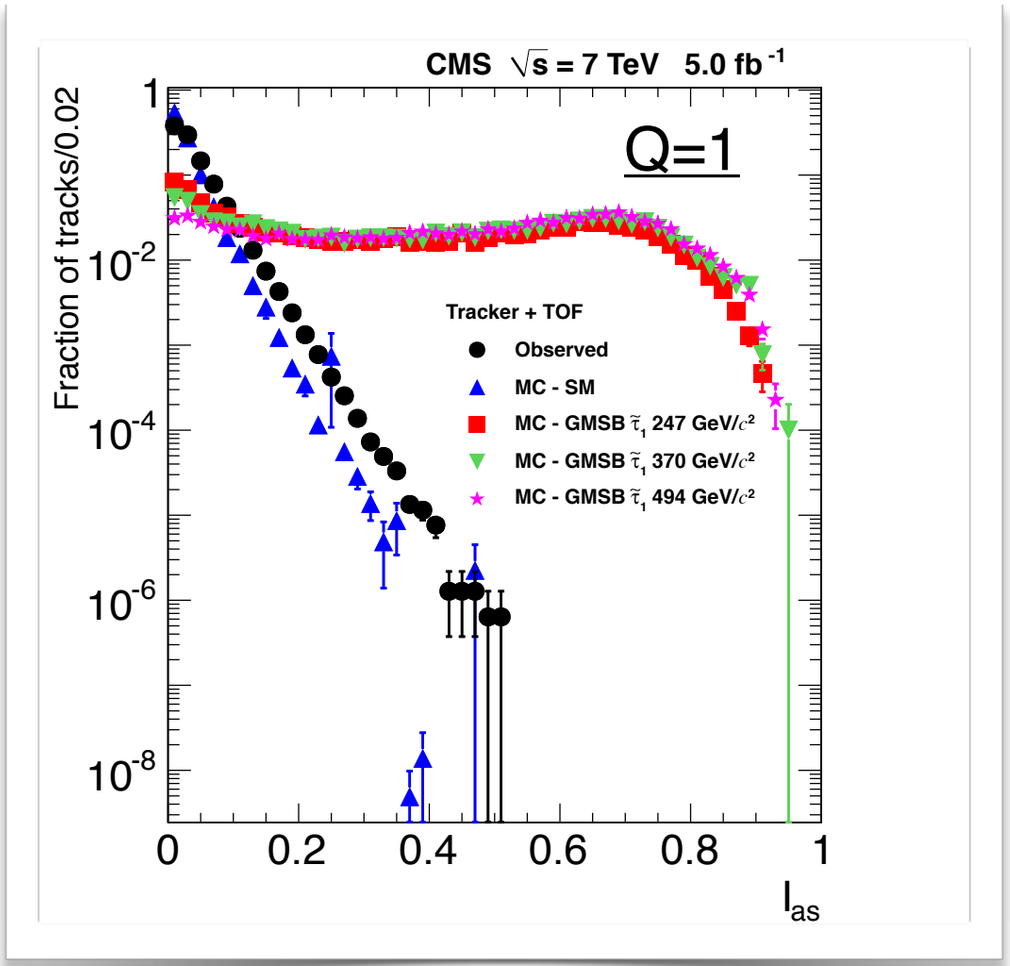
Heavy	mass > 100 GeV/c^2 (TOF signature)
Stable	τ > 30ns (10m ~CMS size)
Charged	Q > 0 (dE/dx signature)
Particles	

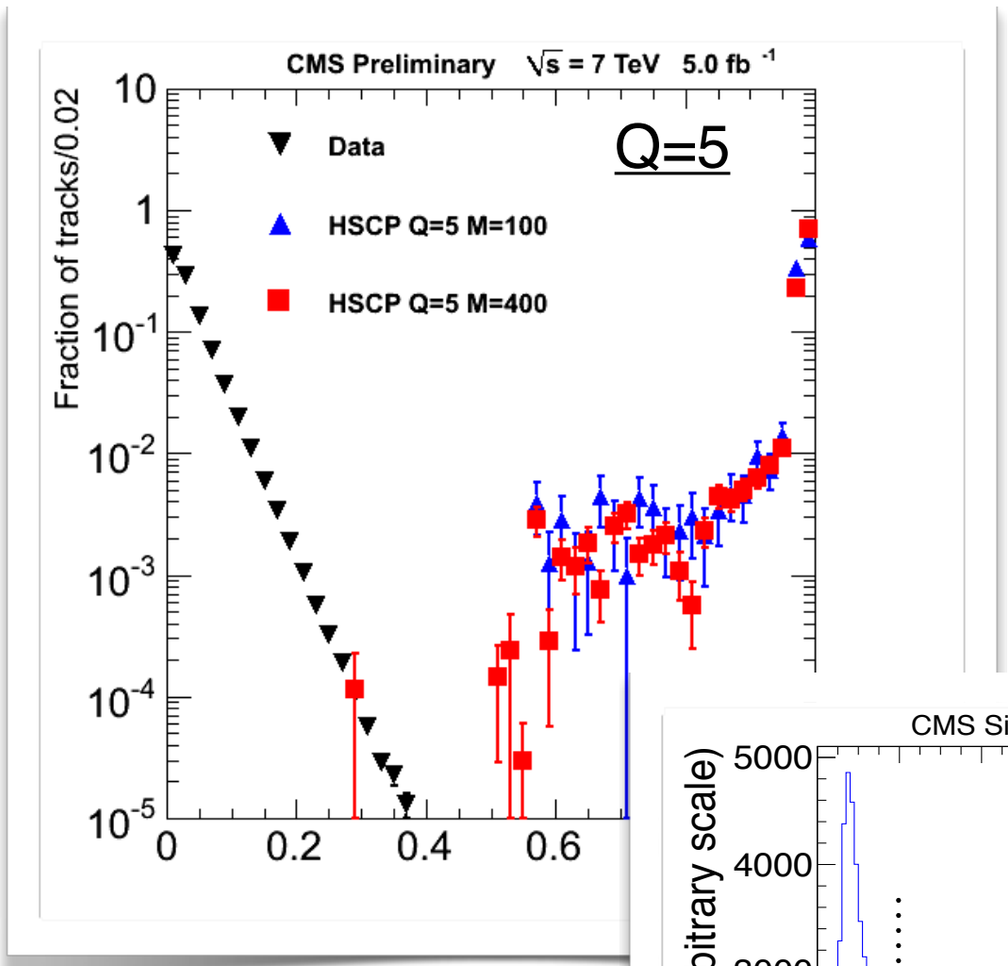
4 complimentary CMS analyses

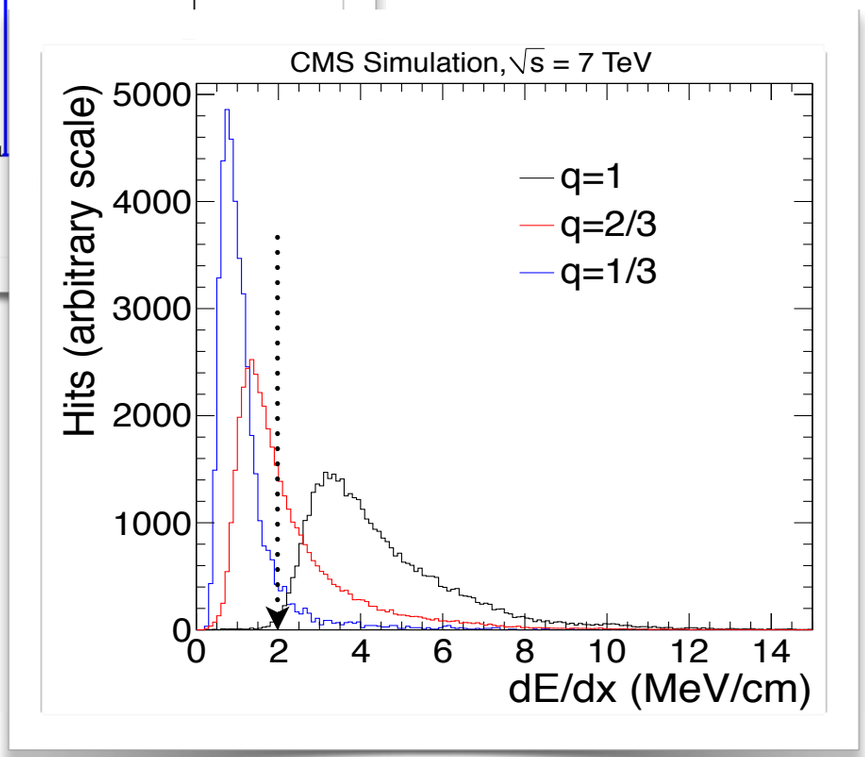


dE/dx Based Analyses

Q>=1: discriminator based on comparing all charges produced by the track in every Si detector with charge expected from MIP



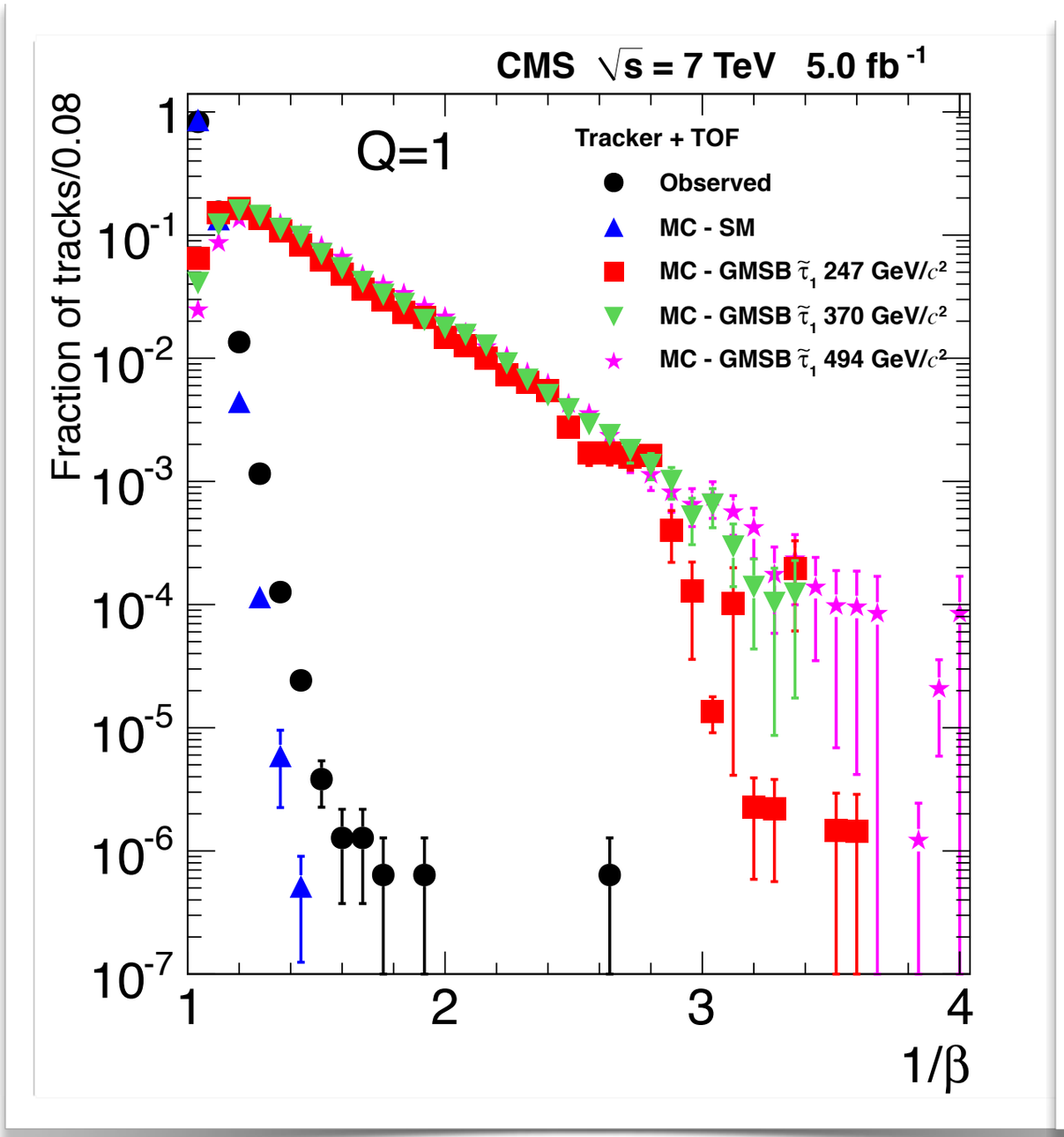


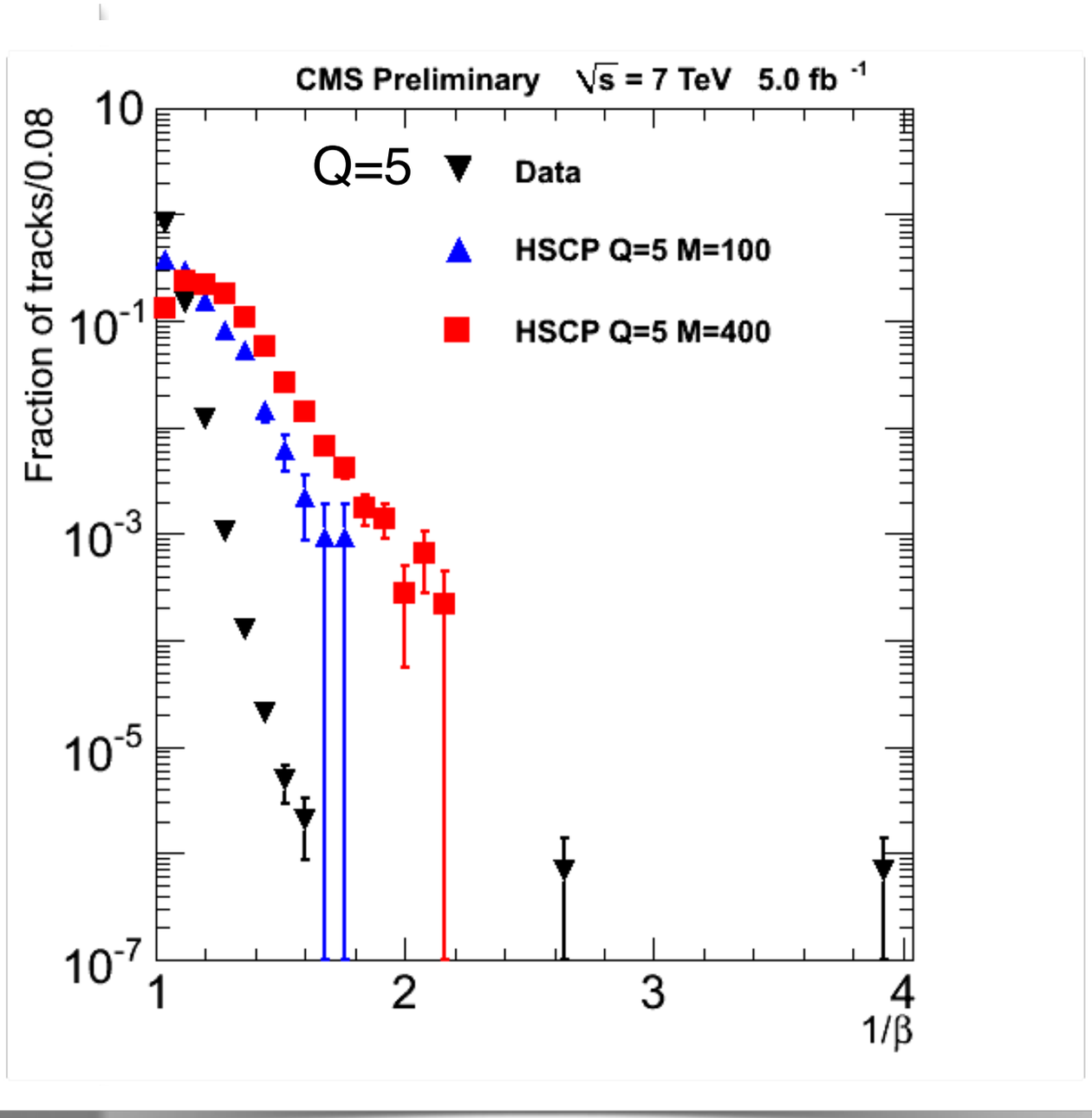


Q<1: discriminator based on counting hits with low dE/dx (<2MeV/cm)

TOF in Muon System

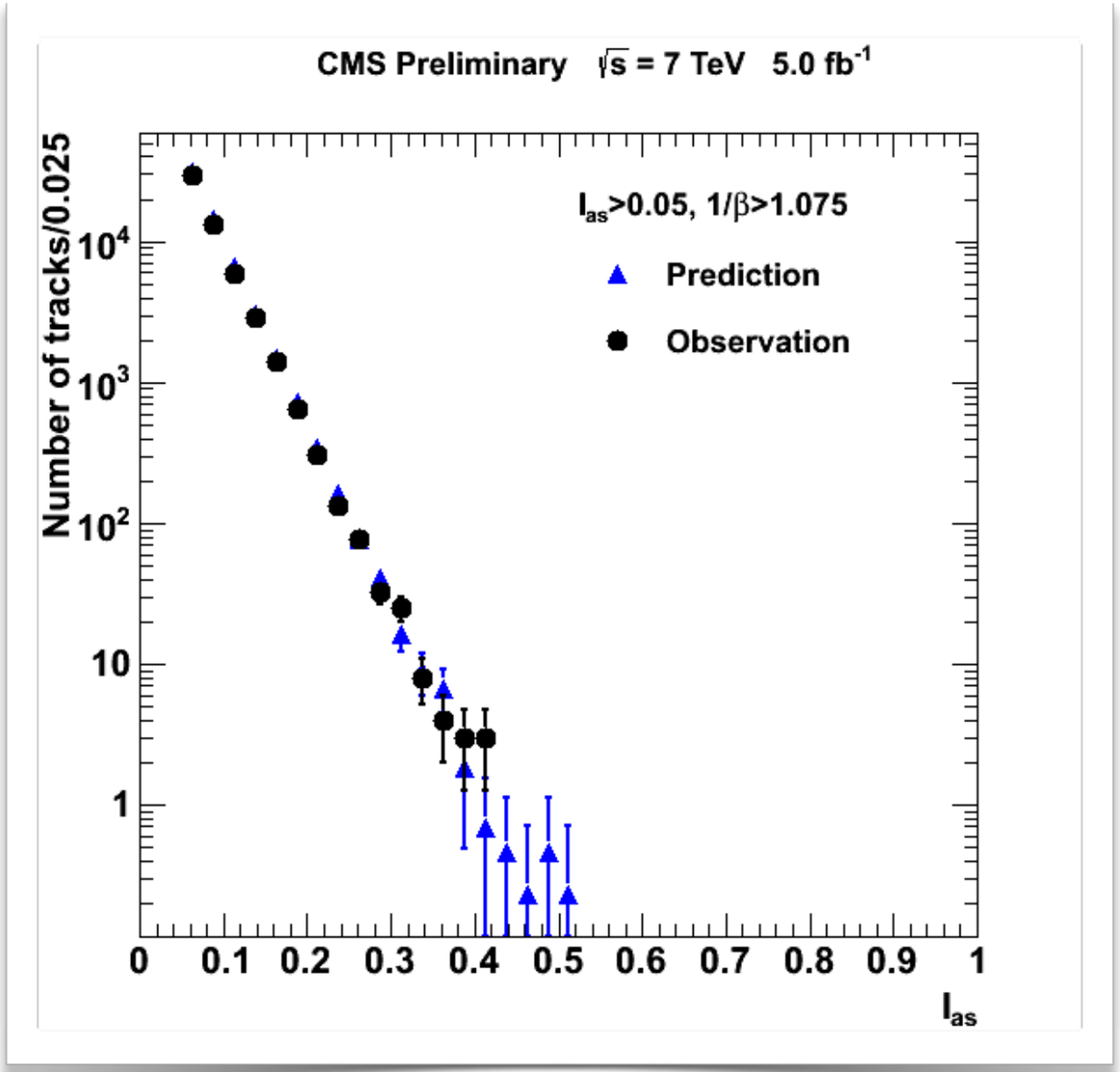
- 1/β is reconstructed using time information of muon (DT, CSC) hits





Data Driven Background Estimations

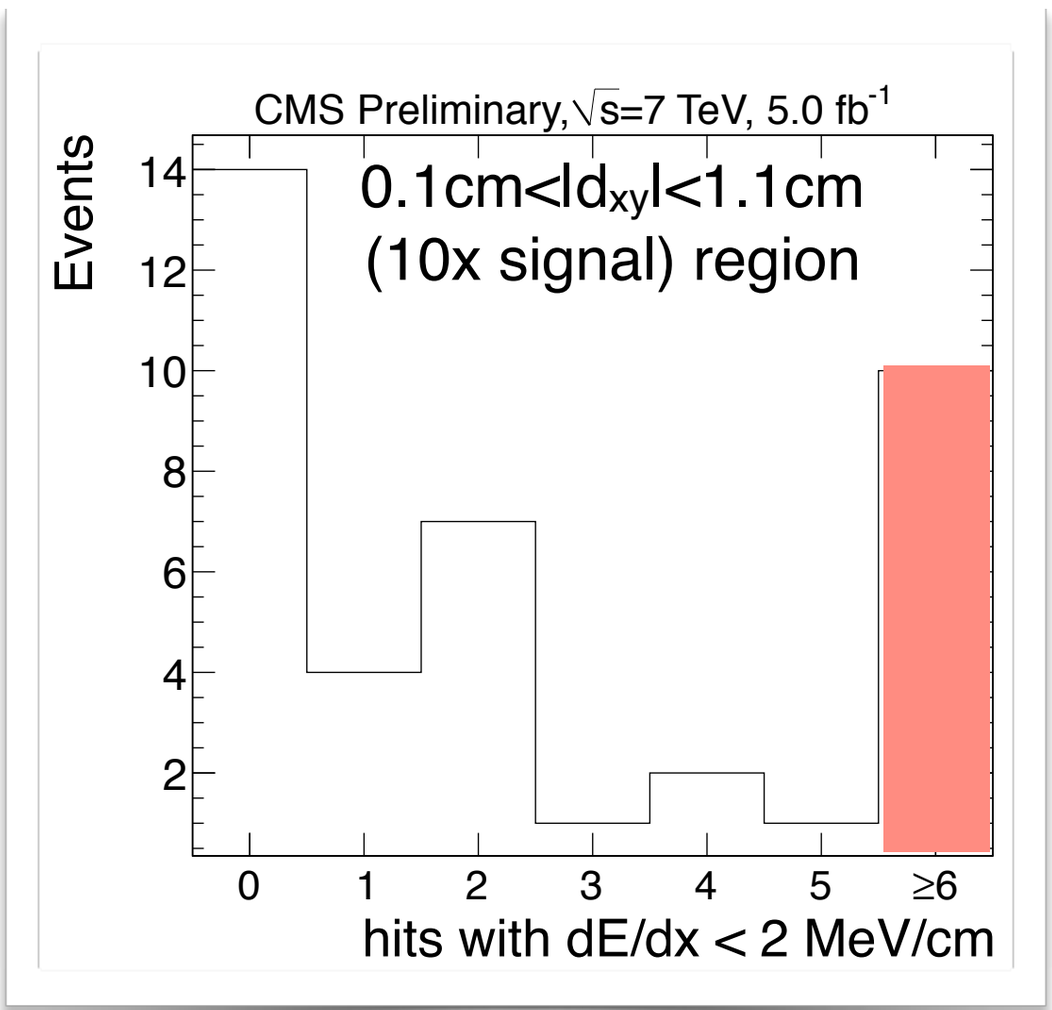
- Multiple charge HSCP
  - ABCD in uncorrelated variables Ias : 1/β
    - loose selection demonstrates agreement between predictions and observations
  - optimize discriminators for the best reach for each model and mass hypothesis under consideration



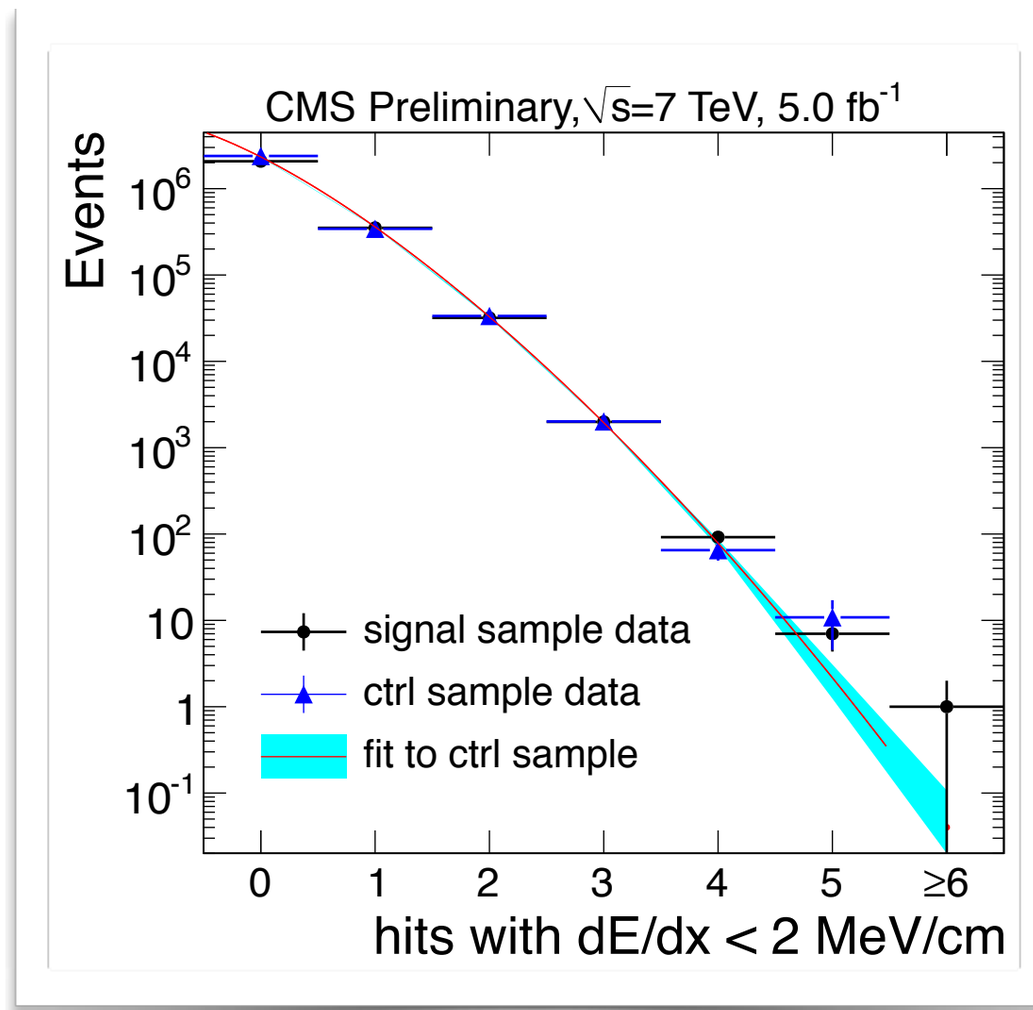
Data Driven Background Estimations

Fractional-charge HSCP

- cosmics
  - estimated from d_{xy} sidebands



- pp background
  - use muons from $Z \rightarrow \mu\mu$
  - propagate fraction of tracks from $N_{hits}^{low\ dE/dx}=0...5 \rightarrow N_{hits}^{low\ dE/dx} \geq 6$



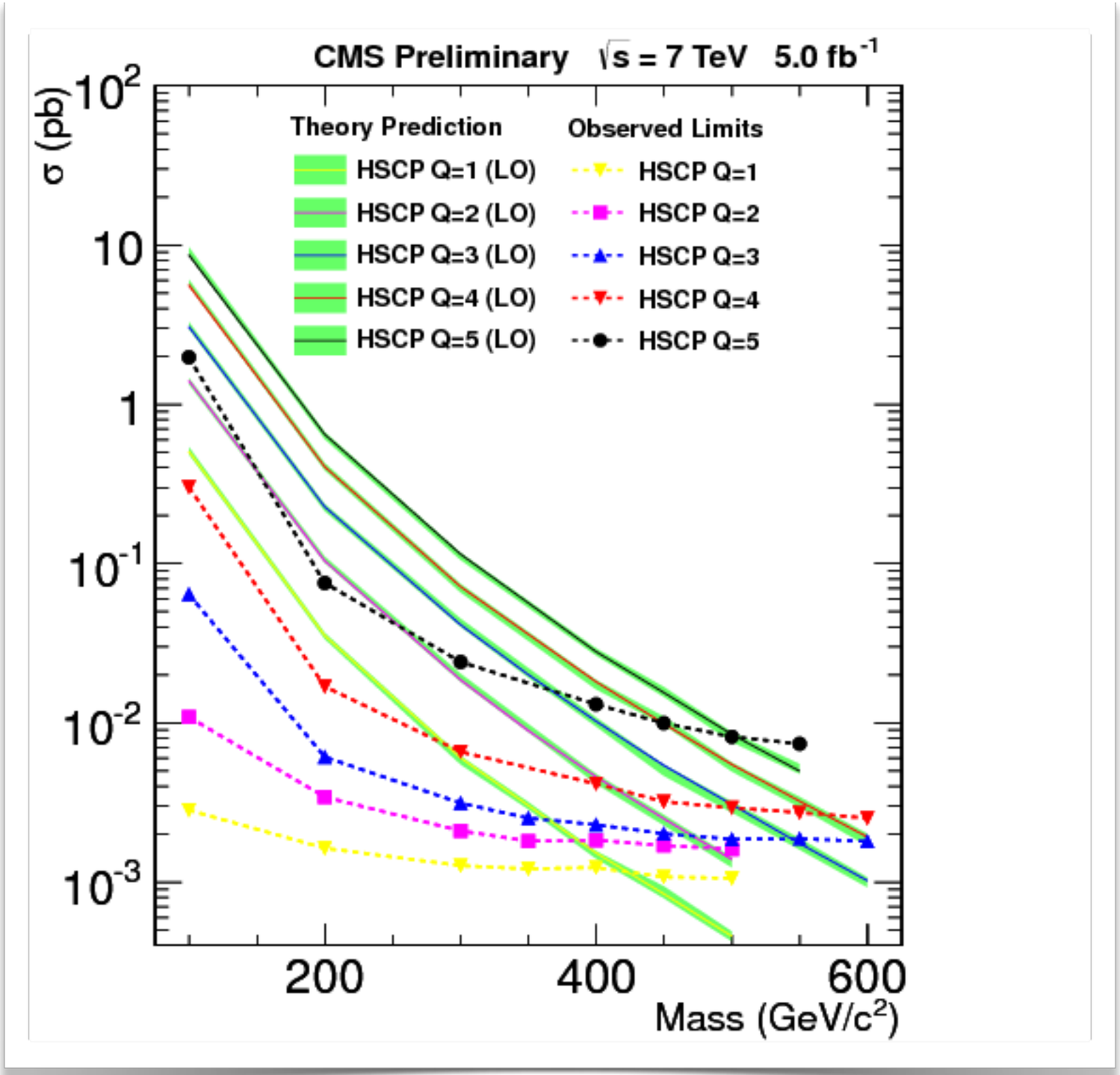
Observations

- No excess is found in any channel
  - no events is observed in most channels
- convert observations into 95% CL upper limit for particular models

Limits for Multiple-charge HSCP

CMS EXO-11-090

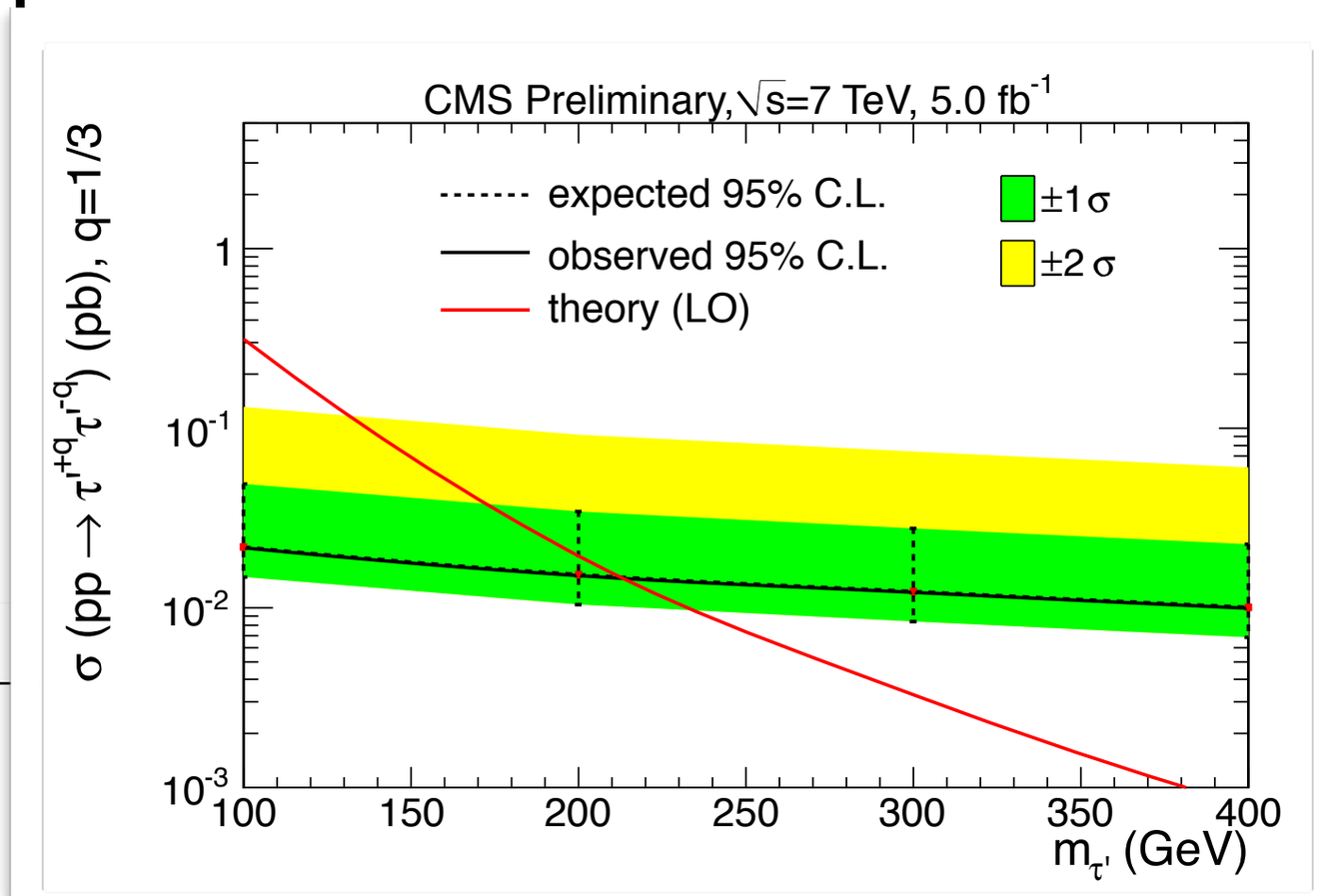
- Lepton-like spin=1/2 HSCP
  - Masses excluded:
    - Q=1: m > 427 GeV
    - Q=2: m > 489 GeV
    - Q=3: m > 545 GeV
    - Q=4: m > 572 GeV
    - Q=5: m > 504 GeV

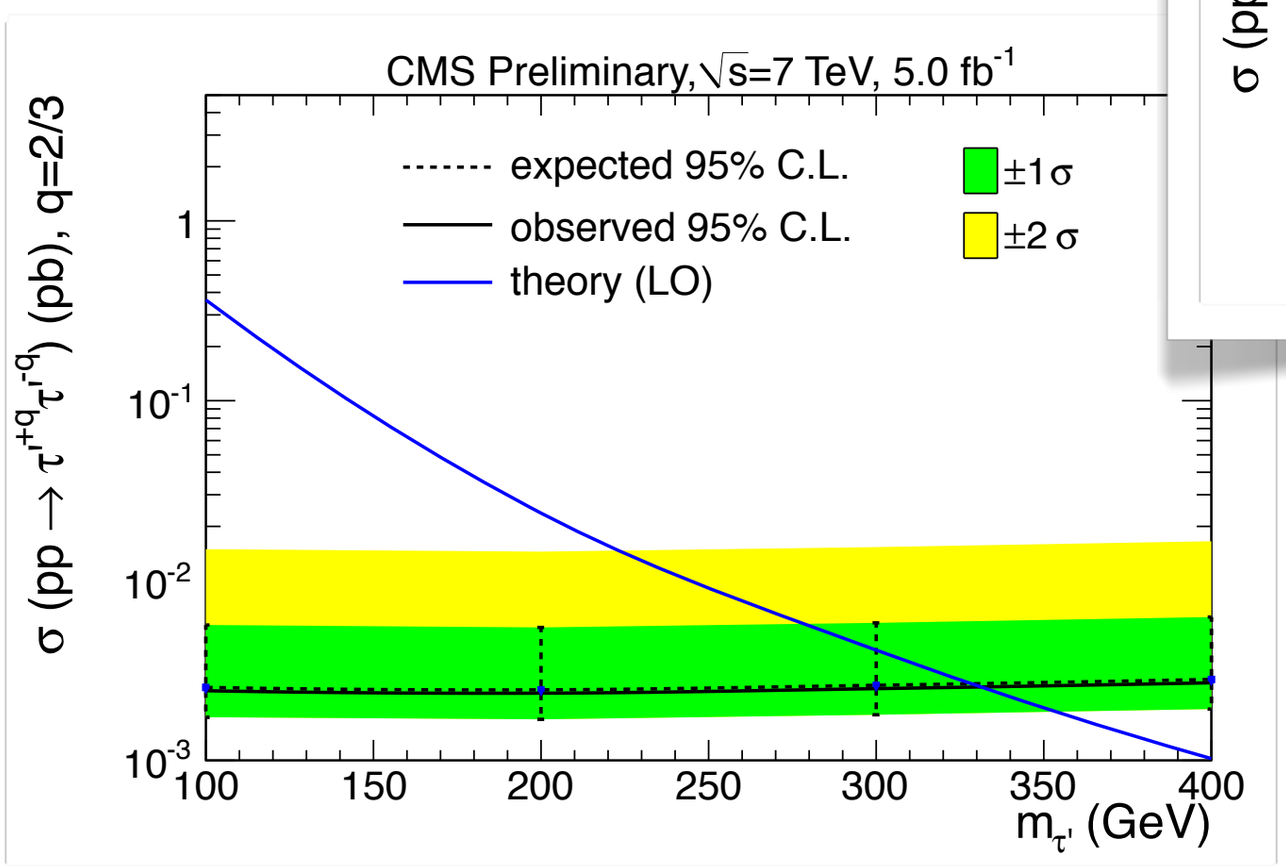


Limits for Fractional-charge HSCP

CMS EXO-11-074

- Lepton-like spin=1/2 HSCP
  - Masses excluded :
    - Q=⅓: m > 210 GeV
    - Q=⅔: m > 330 GeV





Search for Stopped HSCP

CMS EXO-11-020

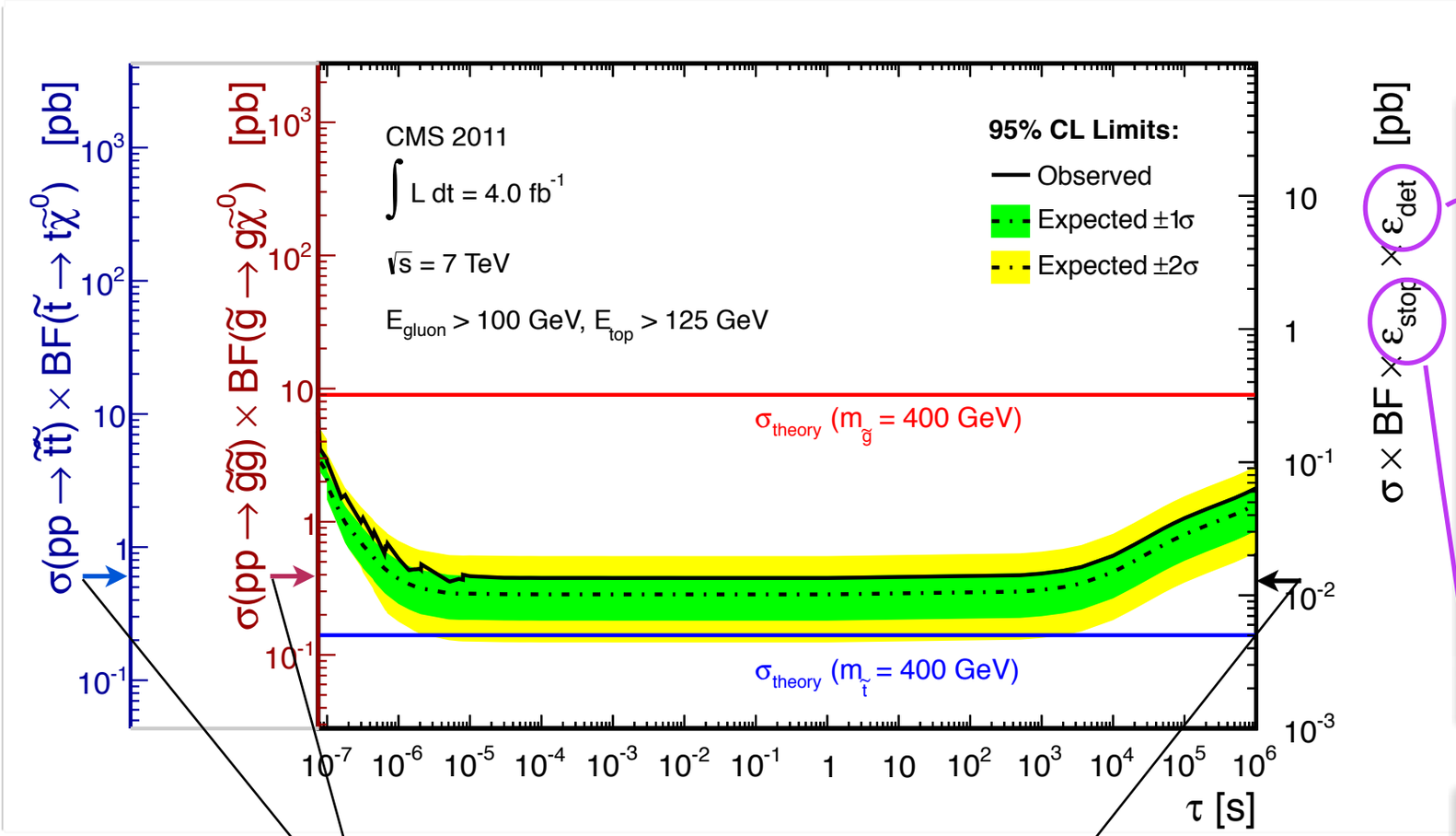
- Slow HSCP may stop in detector material
  - ... and decay later after $\Delta t>25$ns
    - ... i.e. beyond the collision BX
- Look for such decays later when no collisions is expected
  - i.e. in gaps in LHC beam structure
- Selections:
  - trigger: Jet $E_T>32$ & EMPTY_BX
  - HCAL jet $E>70$ GeV, $|\eta|<1$
  - instrumental noise cleanup
    - good HCAL pulse shape: both time and spacial
  - cosmics cleanup
    - no muons, no close muon DT and/or RPC hits
  - beam-halo cleanup

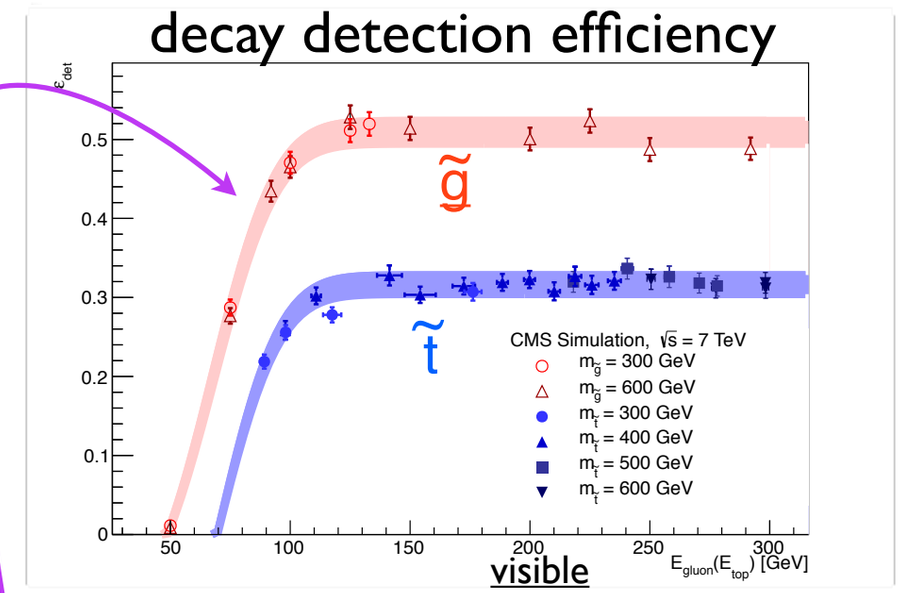
Backgrounds

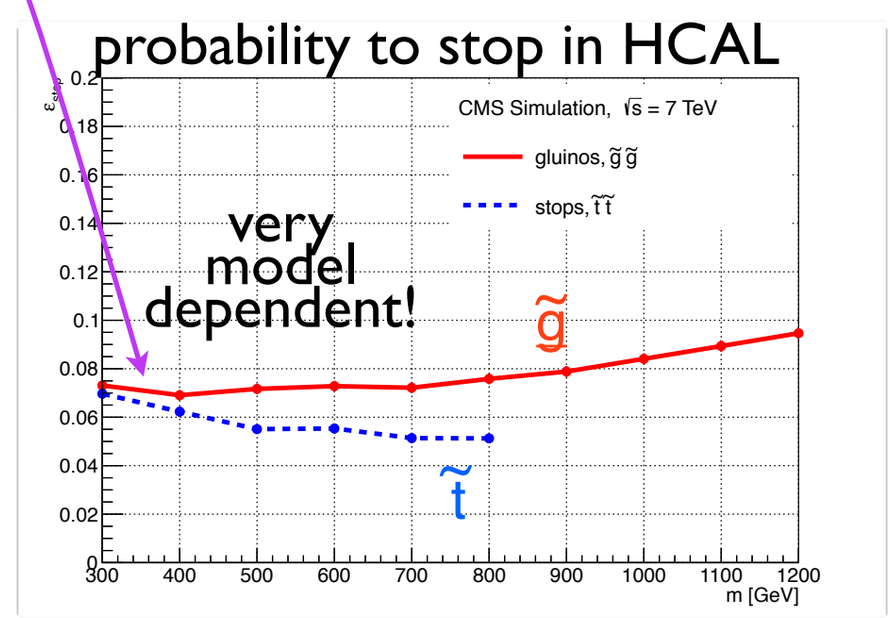
- unidentified cosmics
  - geometrical effect - propagate from rate of identified cosmics
- instrumental noise
  - estimate from low luminosity 2010 run
- unidentified beam-halo
  - estimate from identified beam-halo using tag&probe in opposite endcaps

Cosmic rays	Beam-halo	Noise	Total
5.71 ± 0.62	1.50 ± 0.70	1.4 ± 2.2	8.6 ± 2.4

Stopped HSCP Exclusions







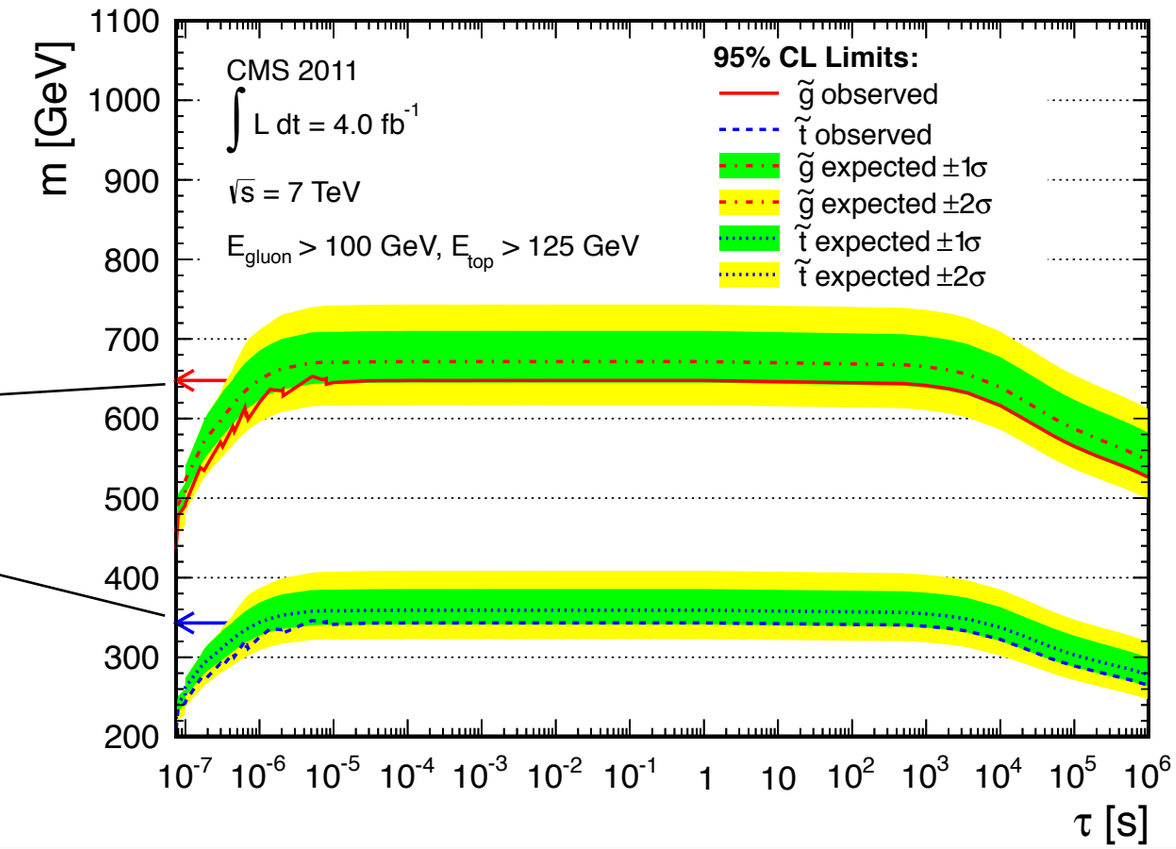
model dependent limits

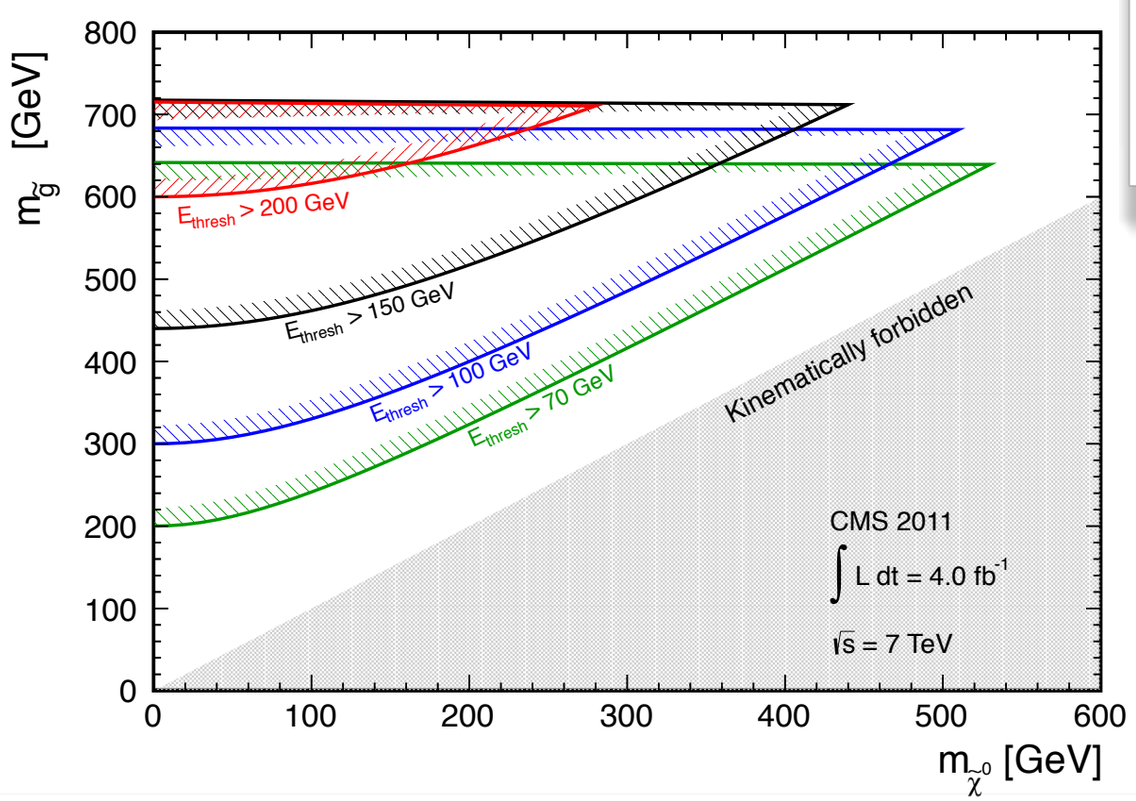
model independent limit

maximum sensitivity for 1μs < τ < 3h

Mass Exclusions

- Extract mass limits
  - use pp→gluino gluino and pp→sTop sTop NLL cross sections
  - gluino: m > 640 GeV
  - sTop: m > 340 GeV
    - for 10μs < τ < 1h

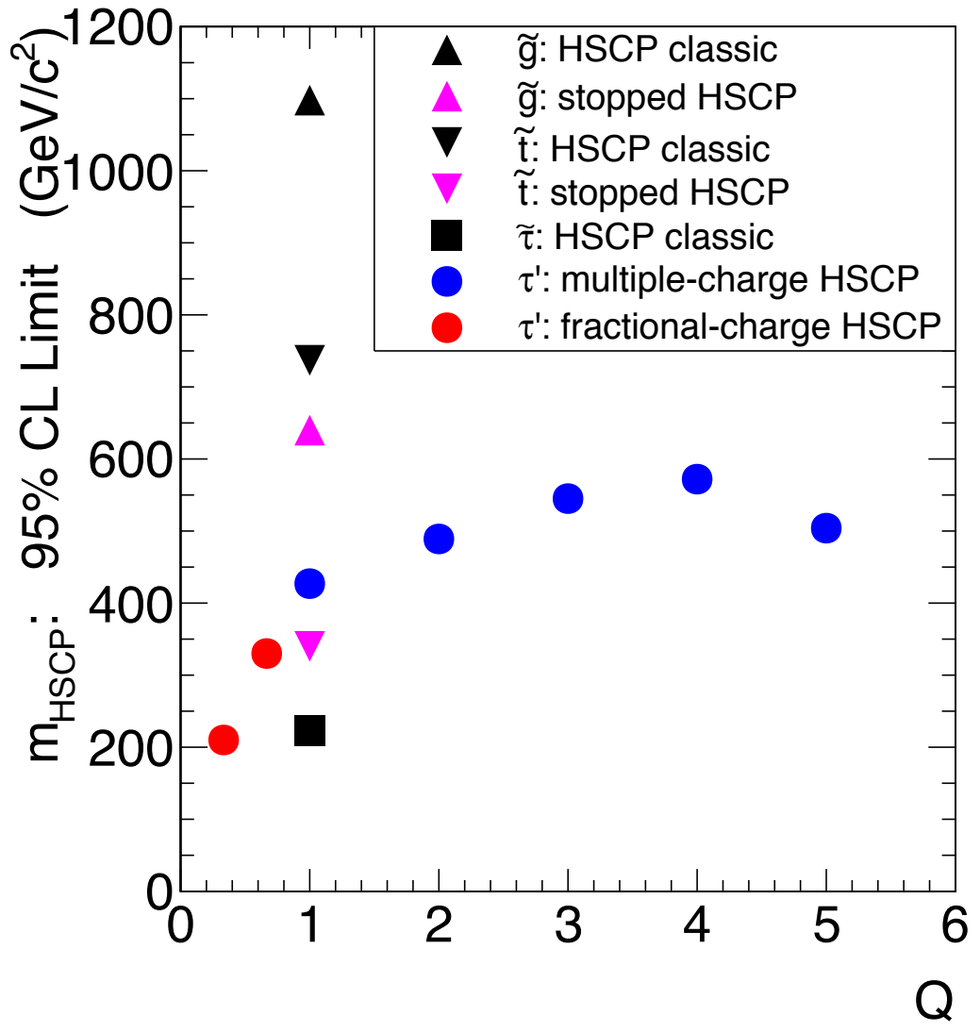




- Get more reach by increasing energy threshold?
  - energy threshold limits HSCP mass
  - can not get much far beyond e.g. 700 GeV for gluino

Summary

- CMS has completed four complimentary HSCP analyses using 2011 data
  - scan different charge hypothesis
  - covers both high-β (using dE/dx) and low-β (using delayed decays) phase spaces



- Observations are consistent with SM background expectations
  - interpret result in variety of different models

Backup

Multiple-Charge HSCP Observation Summary

Mass (GeV/c^2)	I_{as} Cut	$1/\beta$ Cut	Prediction	Data
$Q = 1e$				
100	0.325	1.250	0.09 ± 0.02	0
200	0.300	1.275	0.09 ± 0.02	0
300	0.300	1.275	0.09 ± 0.02	0
350	0.325	1.250	0.09 ± 0.02	0
400	0.300	1.275	0.09 ± 0.02	0
450	0.300	1.275	0.09 ± 0.02	0
500	0.325	1.250	0.09 ± 0.02	0
$Q = 2e$				
100	0.350	1.200	0.22 ± 0.05	0
200	0.350	1.225	0.11 ± 0.03	0
300	0.350	1.225	0.11 ± 0.03	0
350	0.350	1.225	0.11 ± 0.03	0
400	0.350	1.225	0.11 ± 0.03	0
450	0.350	1.225	0.11 ± 0.03	0
500	0.350	1.225	0.11 ± 0.03	0
$Q = 3e$				
100	0.350	1.125	2.25 ± 0.55	3
200	0.350	1.225	0.11 ± 0.03	0
300	0.350	1.225	0.11 ± 0.03	0
350	0.350	1.225	0.11 ± 0.03	0
400	0.350	1.225	0.11 ± 0.03	0
450	0.350	1.225	0.11 ± 0.03	0
500	0.350	1.225	0.11 ± 0.03	0
550	0.350	1.225	0.11 ± 0.03	0
600	0.350	1.225	0.11 ± 0.03	0

Mass (GeV/c^2)	I_{as} Cut	$1/\beta$ Cut	Prediction	Data
$Q = 4e$				
100	0.350	1.100	4.96 ± 1.21	5
200	0.350	1.225	0.11 ± 0.03	0
300	0.350	1.225	0.11 ± 0.03	0
400	0.350	1.225	0.11 ± 0.03	0
450	0.350	1.225	0.11 ± 0.03	0
500	0.350	1.225	0.11 ± 0.03	0
550	0.350	1.225	0.11 ± 0.03	0
600	0.350	1.225	0.11 ± 0.03	0
$Q = 5e$				
100	0.350	1.075	10.40 ± 2.60	10
200	0.350	1.200	0.22 ± 0.05	0
300	0.350	1.200	0.22 ± 0.05	0
400	0.350	1.225	0.11 ± 0.03	0
450	0.350	1.225	0.11 ± 0.03	0
500	0.350	1.225	0.11 ± 0.03	0
550	0.350	1.225	0.11 ± 0.03	0

- I_{as} and $1/\beta$ cuts are optimized for every charge/mass hypothesis

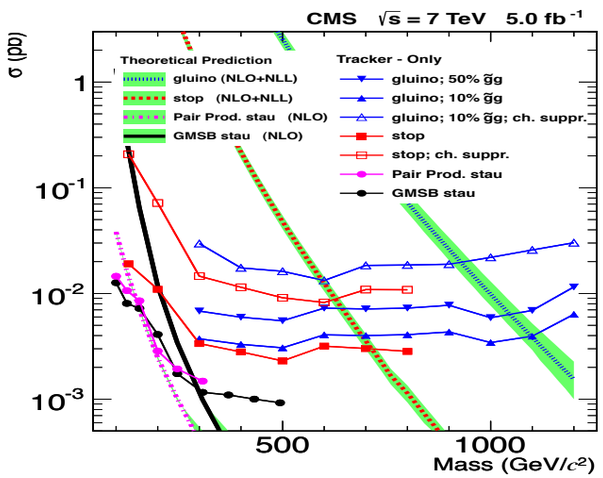
Fractional-Charge HSCP Observation Results

cosmic ray background estimate	1.0 ± 0.32
pp collisions uncorrelated background estimate	0.04 ± 0.07
pp collisions correlated background estimate	$0^{+4.6}_{-0}$
observed events in signal sample data	1

mass (GeV/c^2)	q	signal eff.	exp. limit (pb)	obs. limit (pb)
100	2/3	0.357 ± 0.045	0.0025	0.0024
200	2/3	0.368 ± 0.046	0.0025	0.0024
300	2/3	0.347 ± 0.043	0.0026	0.0025
400	2/3	0.322 ± 0.040	0.0028	0.0027
100	1/3	0.043 ± 0.008	0.0218	0.0216
200	1/3	0.061 ± 0.011	0.0153	0.0151
300	1/3	0.076 ± 0.014	0.0123	0.0122
400	1/3	0.093 ± 0.017	0.0101	0.0099

Four Complimentary Analyses

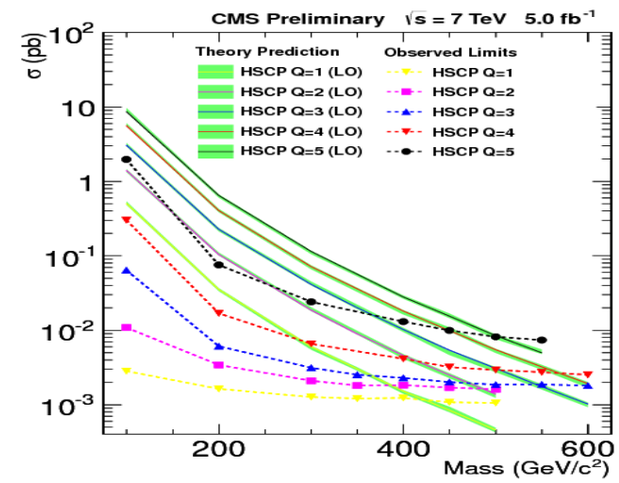
HSCP Classic



arXiv:1205.0272

dE/dx
TOF

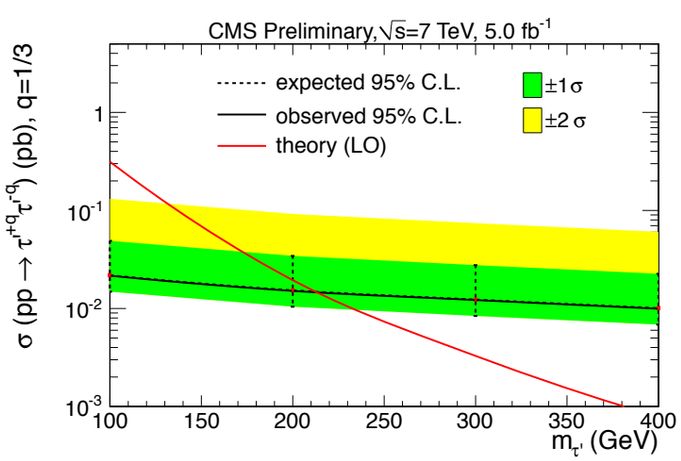
multi-charge HSCP



CMS EXO-11-090

dE/dx
TOF

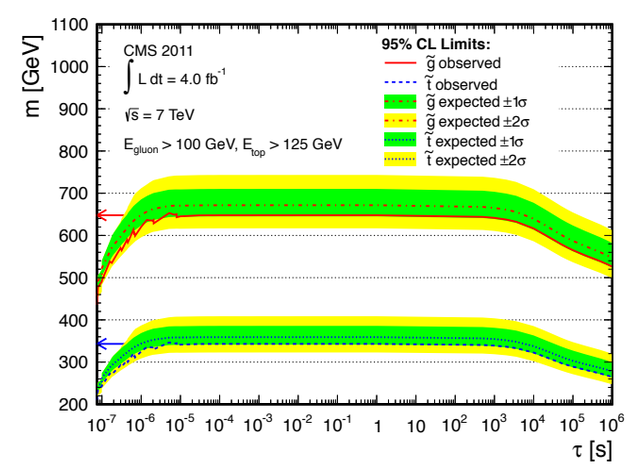
fractional-charge HSCP



CMS EXO-11-074

dE/dx

Stopped HSCP



arXiv:1207.0106

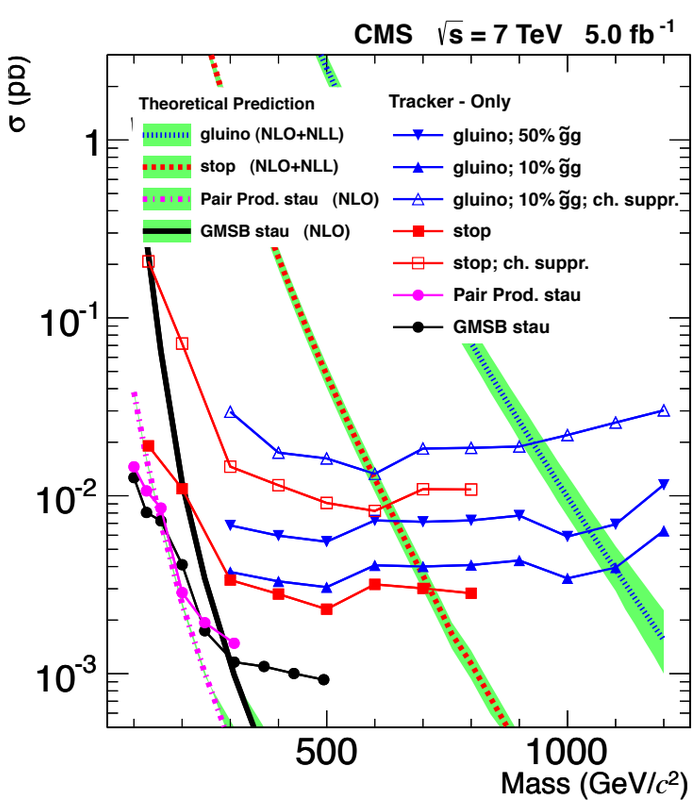
delayed
decay
in HCAL

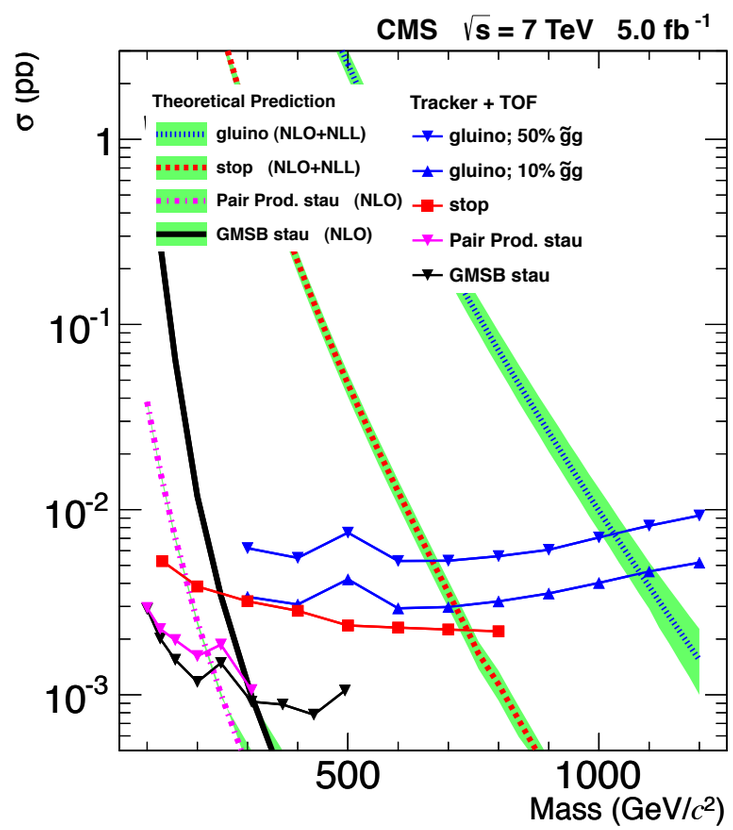
Further Discriminators

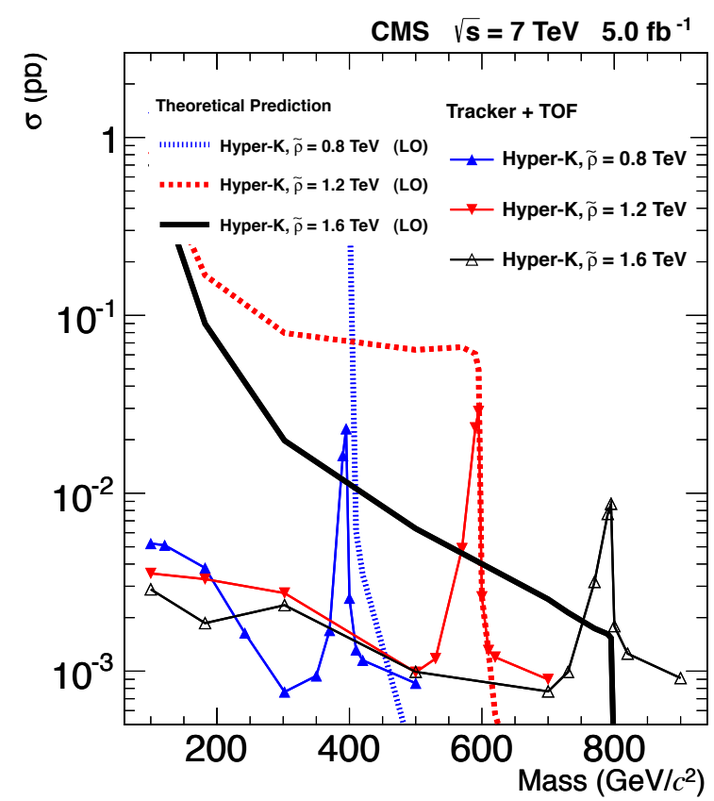
- visible track $p_T > 45$ GeV/c,
- track pointing to the good vertex
- relative track isolation $Iso_{0.3}^{track} < 0.1$
- HSCP classic
  - further p_T discrimination to optimize sensitivity
  - $|\eta| < 1.5$
  - relative calorimeter isolation $Iso_{0.3}^{ECAL+HCAL} < 0.3\text{-}0.6$
- multi-charge HSCP
  - $|\eta| < 2.1$
- fractional-charge HSCP
  - ≥6 hits with low dE/dx
  - $|\eta| < 1.5$
  - calorimeter isolation $Iso_{0.3}^{ECAL+HCAL} < 5$GeV
  - cosmics cleanup: in-out TOF > -5ns (β=1)

Limits for HSCP Classic

- Lepton-like HSCP
  - Stau:
    - GMSB(SP7): m>314 GeV
    - pair produced: m>223 GeV
  - hyper-K with $m_{hyper\text{-}\rho}$=800/1200/1600GeV: m>484/602/747 GeV
- Hadron-like HSCP
  - gluino: m>1098/1046 GeV depending from gluinoball production
  - sTop: m>737 GeV



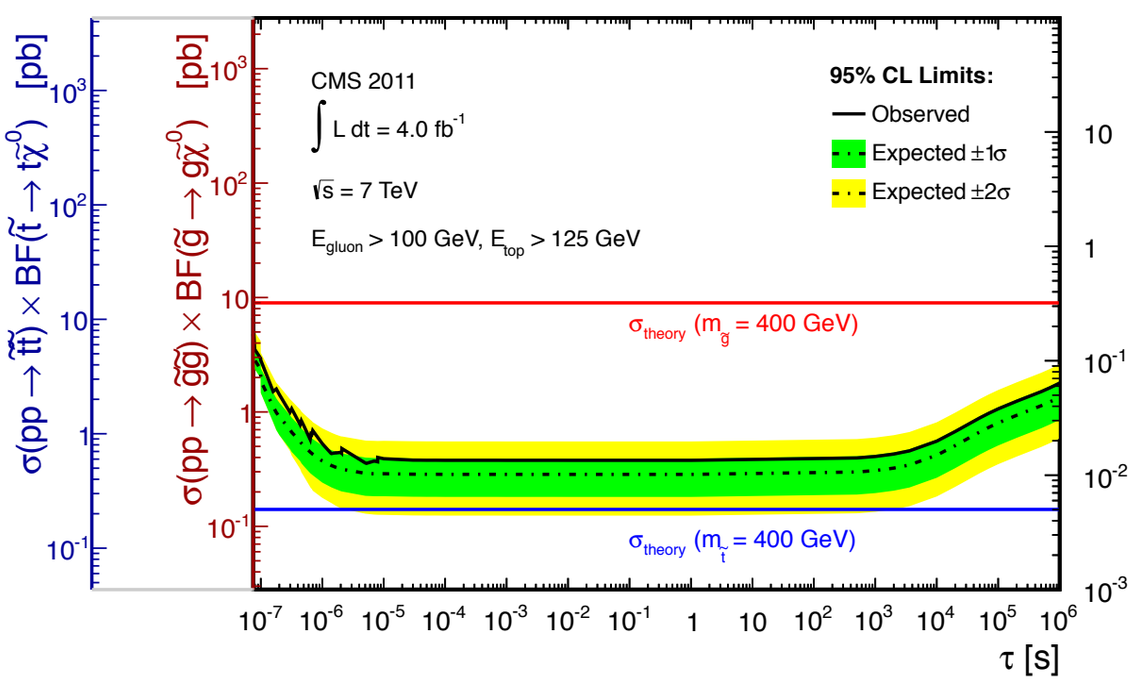




Results

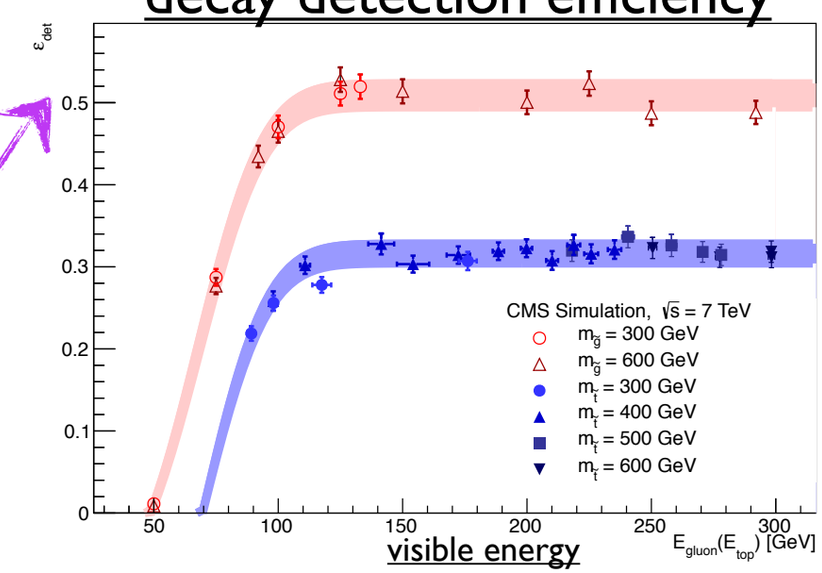
- $\tau < T_{\text{LHC orbit}}$ → optimize registration time

τ	L_{eff} (pb^{-1})	Live time (s)	N_{exp}	N_{obs}
75 ns	19.6	2.06×10^4	0.200 ± 0.056	1
100 ns	57.8	6.17×10^4	0.60 ± 0.17	2
1 μs	508	4.41×10^5	4.3 ± 1.2	7
10 μs	913	8.67×10^5	8.5 ± 2.4	12
100 μs	935	8.86×10^5	8.6 ± 2.4	12
10^3 s	866	8.86×10^5	8.6 ± 2.4	12
10^4 s	636	8.86×10^5	8.6 ± 2.4	12
10^5 s	332	8.86×10^5	8.6 ± 2.4	12
10^6 s	198	8.86×10^5	8.6 ± 2.4	12

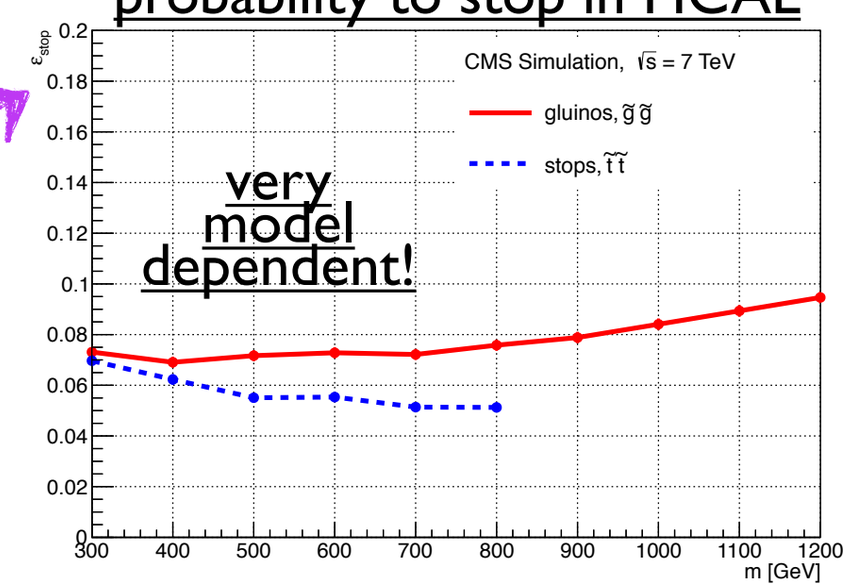


$\sigma \times BF \times \varepsilon_{stop} \times \varepsilon_{det}$ [pb]

decay detection efficiency



probability to stop in HCAL



very model dependent!