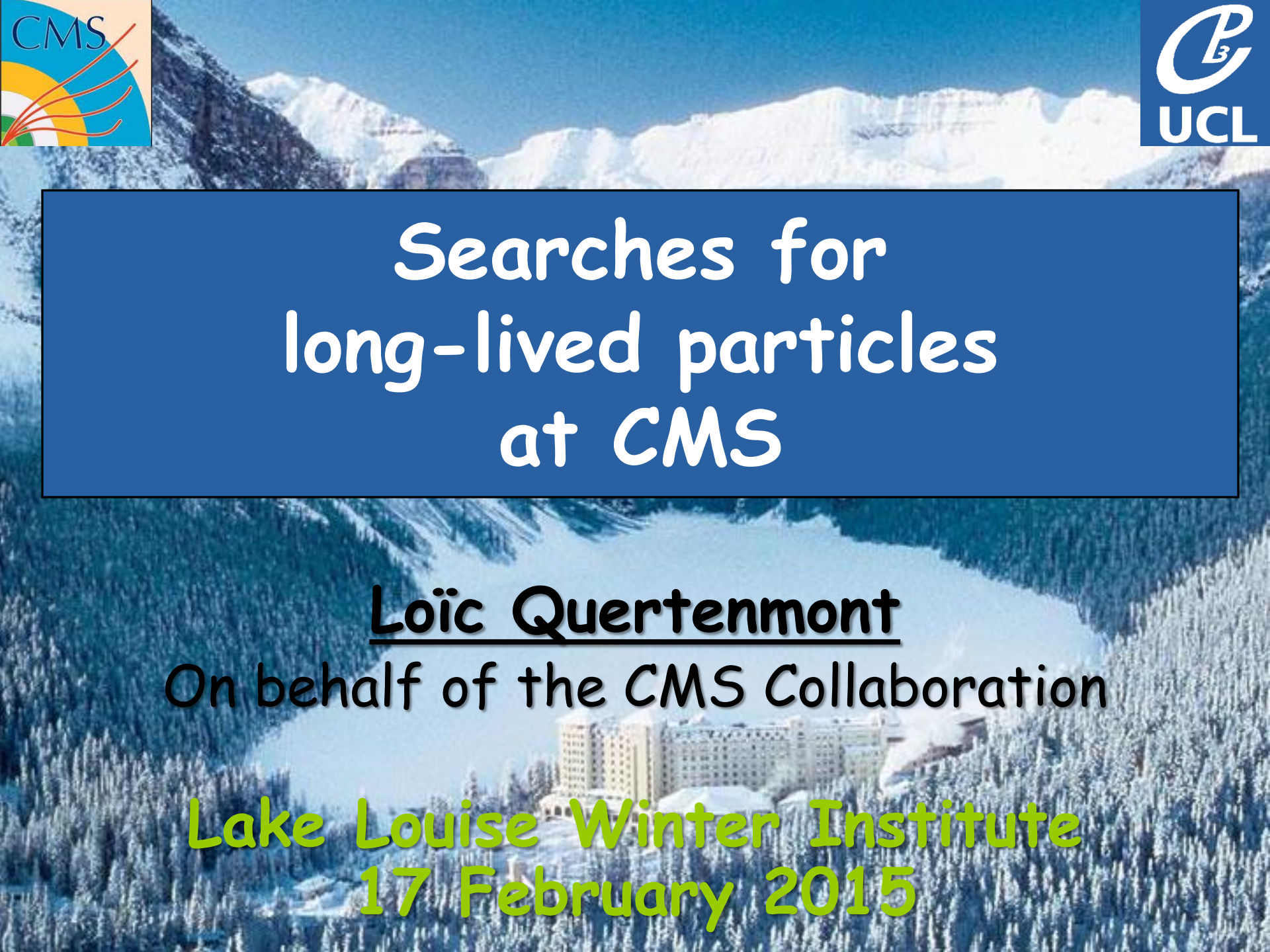


Searches for long-lived particles at CMS

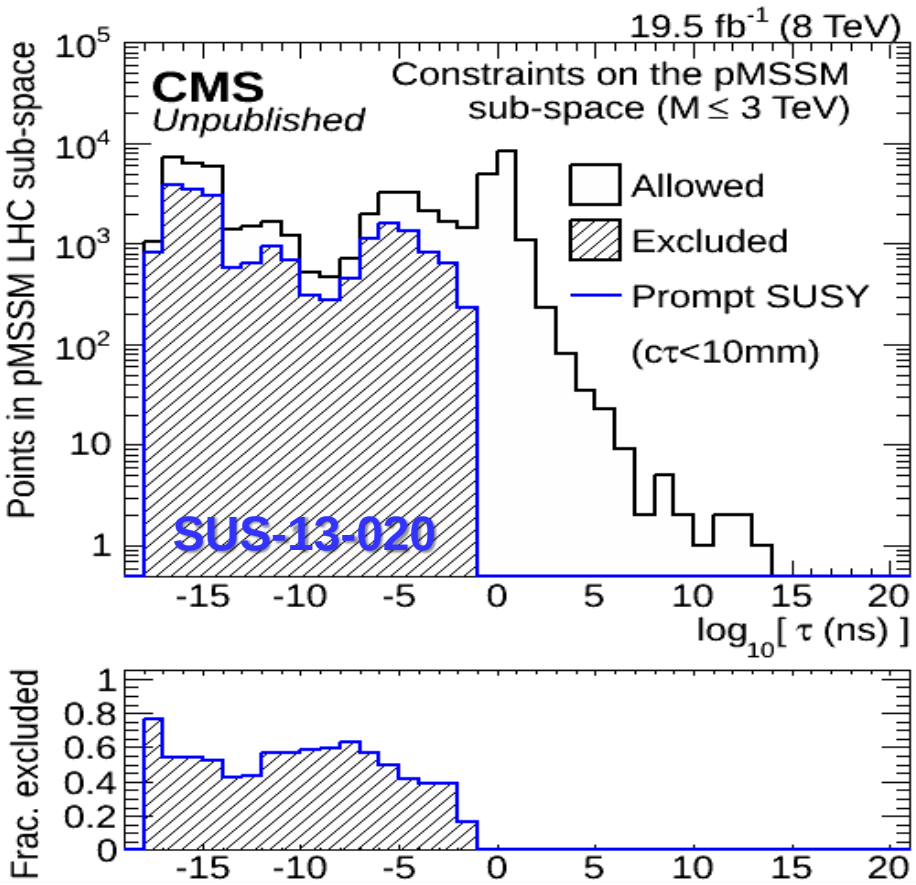
Loïc Quertenmont

On behalf of the CMS Collaboration

Lake Louise Winter Institute
17 February 2015

Why ?

- **Why searching for Long-Lived particles ?**
  - Predicted by many BSM models:
    - Split SUSY, GMSB, AMSB, pMSSM, Hidden Valley, RPV SUSY, UED, …
    - Long lifetime because of a new symmetry conservation or small decay phase space
  - Escape all constrained from prompt particles searches
    - May explain why SUSY was not yet discovered at the LHC ☺
  - Who knows what BSM looks like
    - Model independent searches



- **Example with the pMSSM**

  27% of pMSSM points have the NLSP with cτ>1cm...
  Completely unconstrained by prompt searches

Each entry correspond to a point in the 19D pMSSM parameter space → each point is a model

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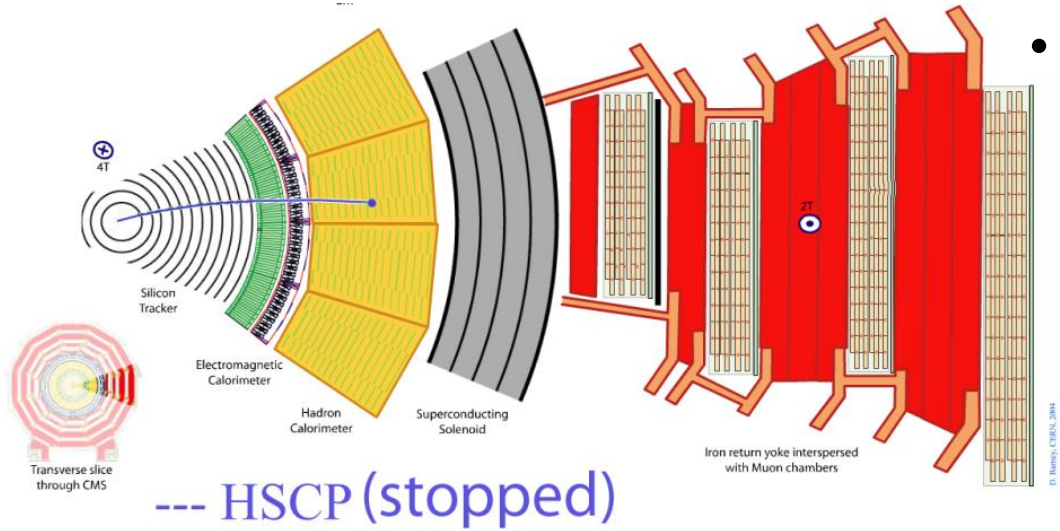
Long-Lived particle searches@CMS

- **Stable or Long lifetime ($c\tau > \sim 1m$)**
  - Stopped particles **New** — arXiv:1501.05603
  - Long-Lived charged particles (HSCP) **New** — JHEP 07 (2013) 122 + arXiv:1502.02522
- **Short lifetime ($c\tau < \sim 1m$)**
  - Disappearing Tracks **New** — arXiv:1411.6006
  - Displaced Leptons **New** — arXiv:1411.6977
  - Displaced Photons *Not shown here* — j.physletb.2013.04.027
  - Displaced Jets **New** — arXiv:1411.6530
  - Two Displaced e/μ leptons **New** — arXiv:1409.4789

Many new results… but only 15' to described them…
I won't go into the details of the analyses but just flash the results

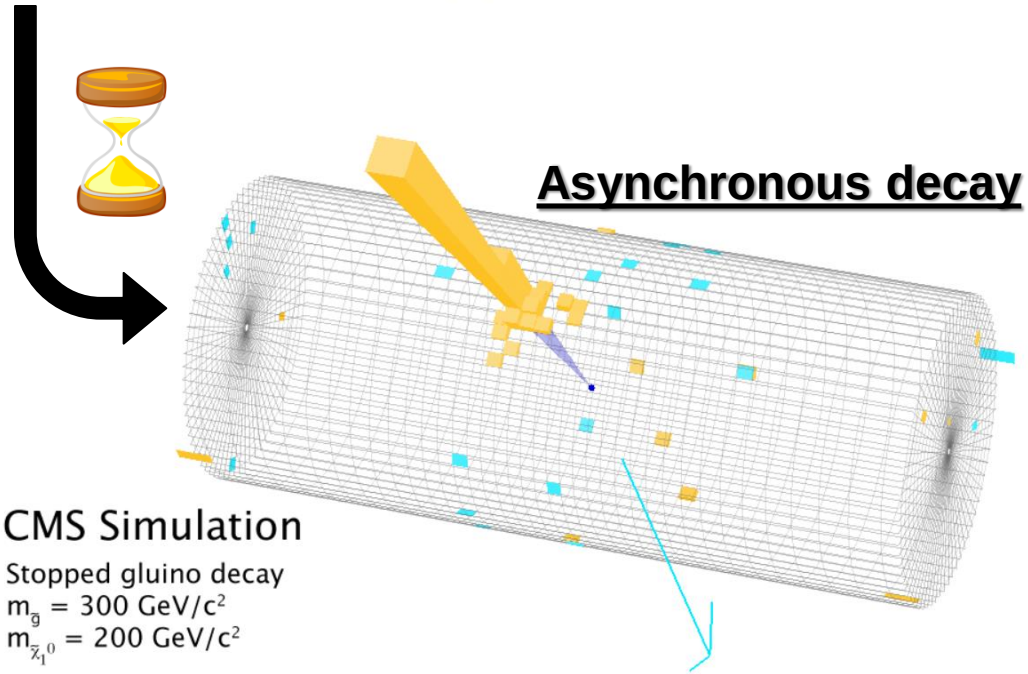
Search for stopped particles

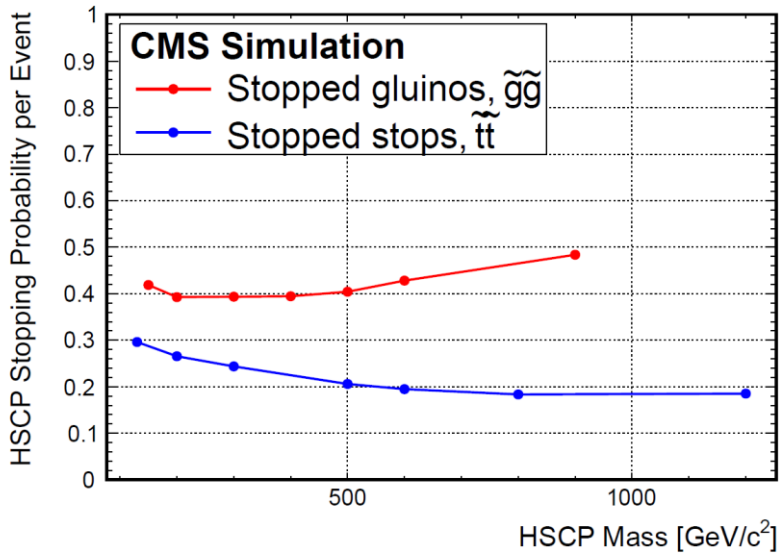


- Stopped HSCP Signature
  - Energetic cluster in calorimeter coming from the decay of a stopped particle

$$\tilde{g} \rightarrow g\tilde{\chi}_1^0 \text{ or } \tilde{t} \rightarrow t\tilde{\chi}_1^0$$

  - Assynchronous
    → No p-p collisions produced
  - Backgrounds: cosmics, beam halo instrumental (noise) backgrounds





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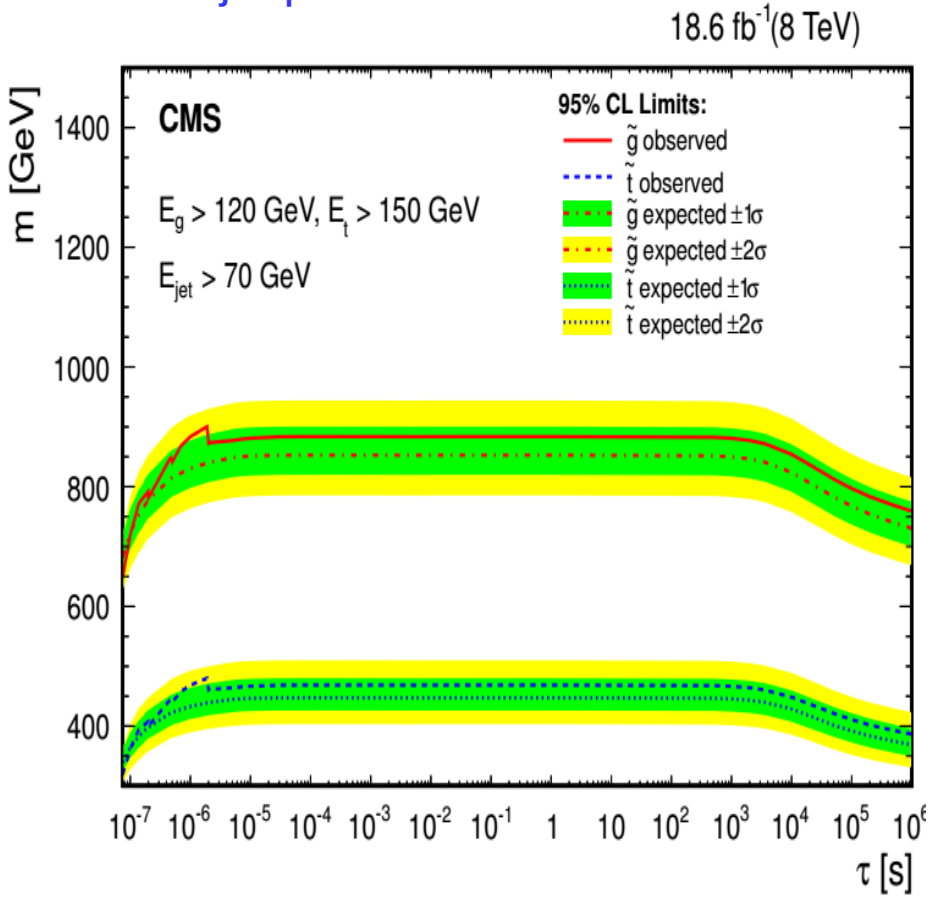
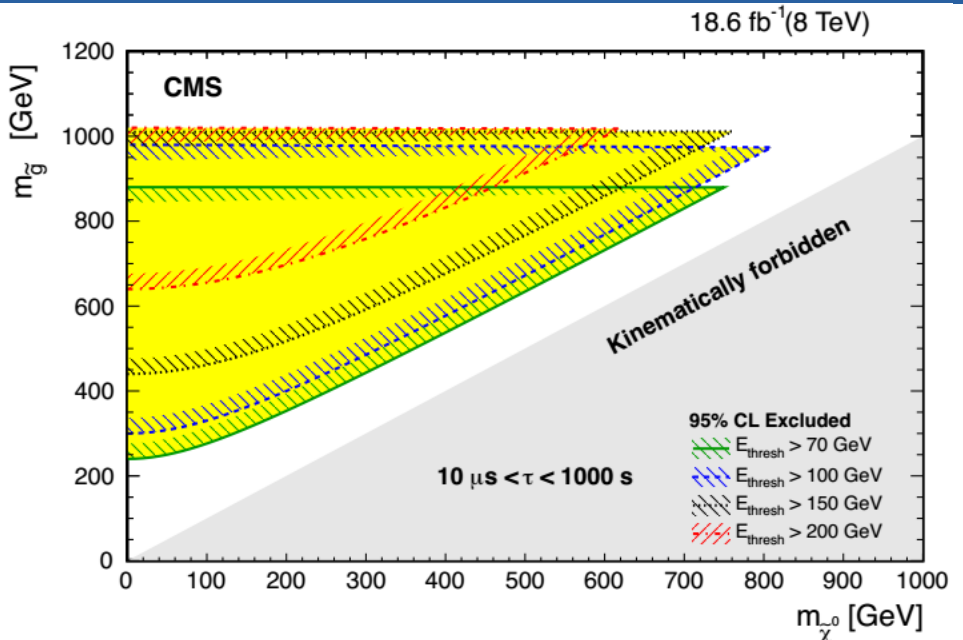
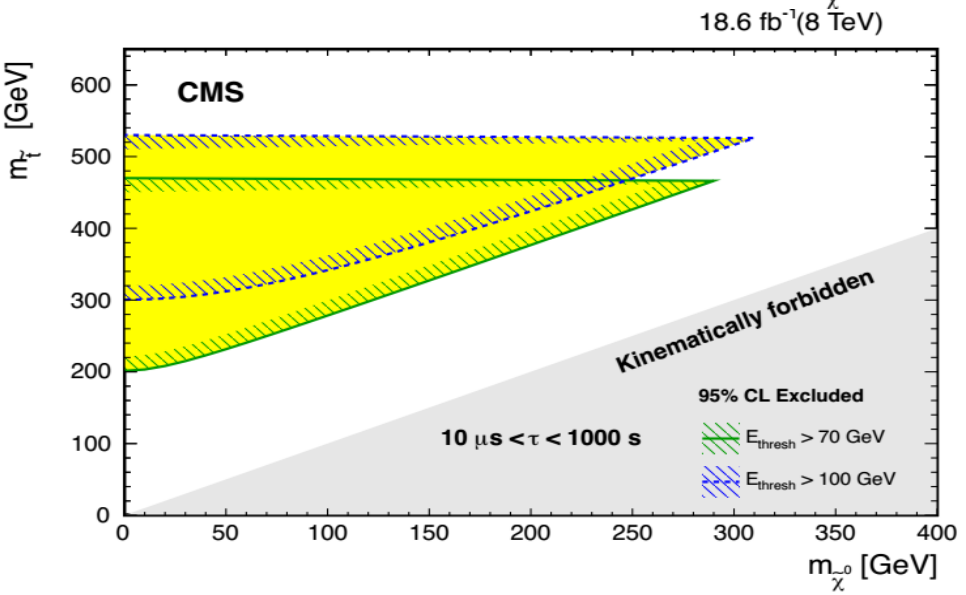
Results

Constaints are set on stops/gluinos over 13 order of magnitudes in the lifetime

Model independent limits provided for different jet pT thresholds.







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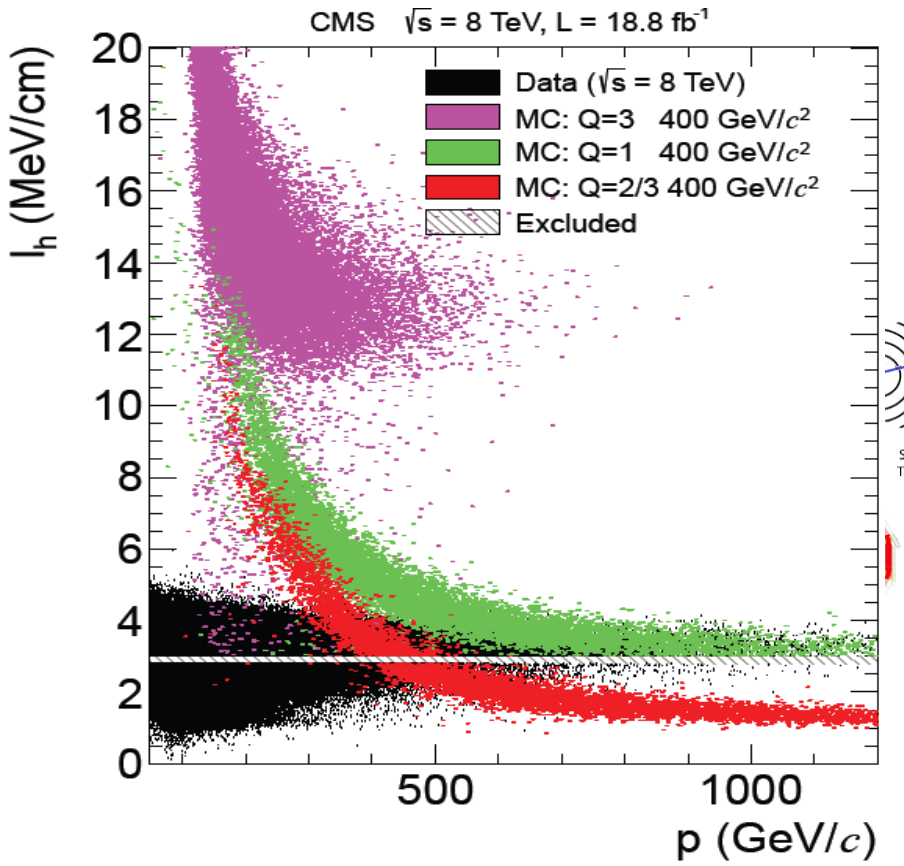
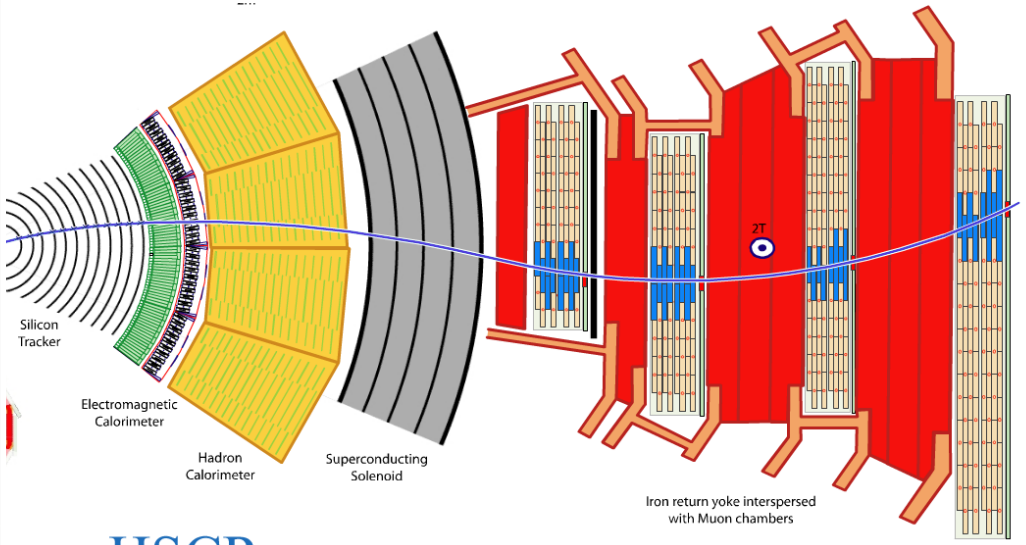
Search for LL charged particles

High pT Track with low velocity

- **Signature : Muon or Tracker track with high pT and high dE/dx and long TOF**
- **Sensitivity : long-lived ($c\tau$>~1m) particles with e/3<|Q|<8e**
  - **Stops, Gluinos, Staus, Charginos, other species of leptons**





--- HSCP

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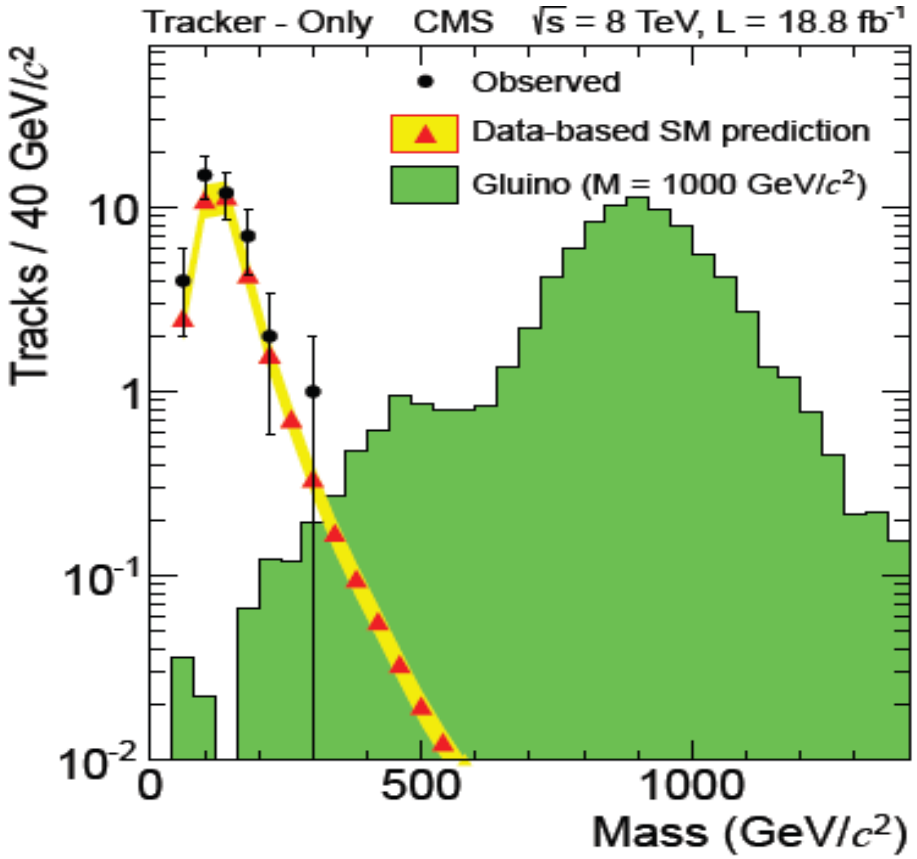
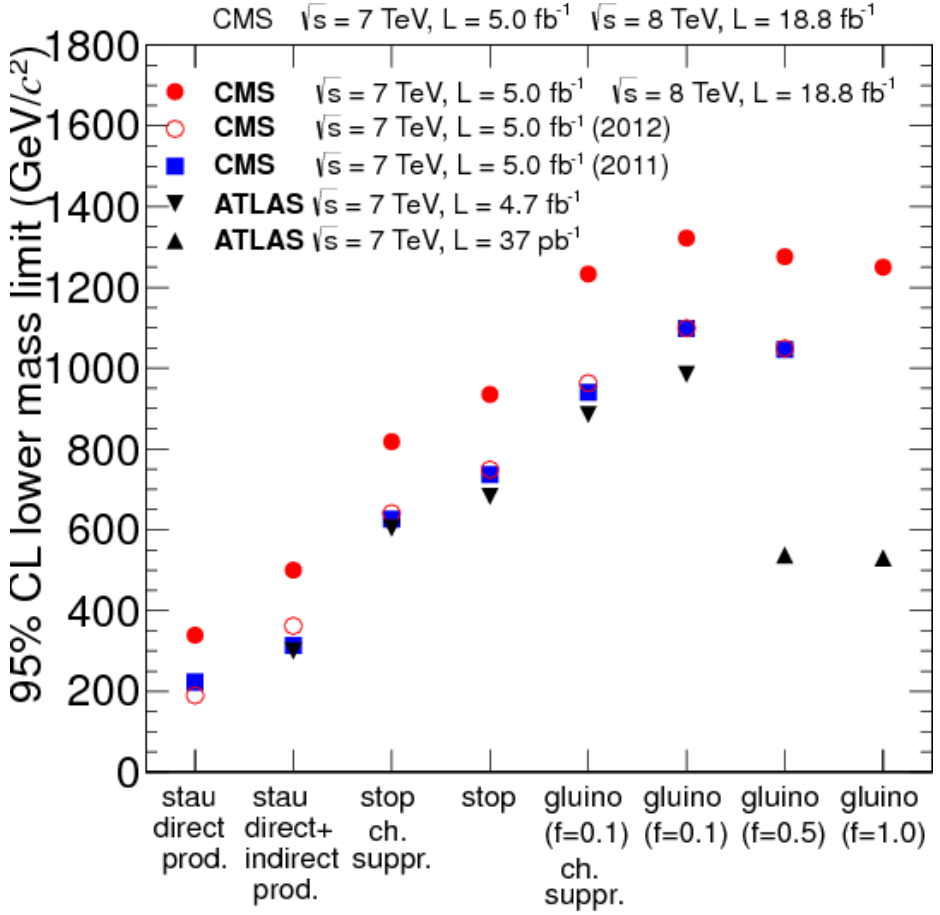
Results





- Best limits to date on several long-lived particle classes
- $M_{Gluino} > 1322GeV$, $M_{Stop} > 935GeV$
- First CMS limits on gluino fully hadronizing into gluino balls (f=100%).
- Many more results in arXiv: 1305.0491

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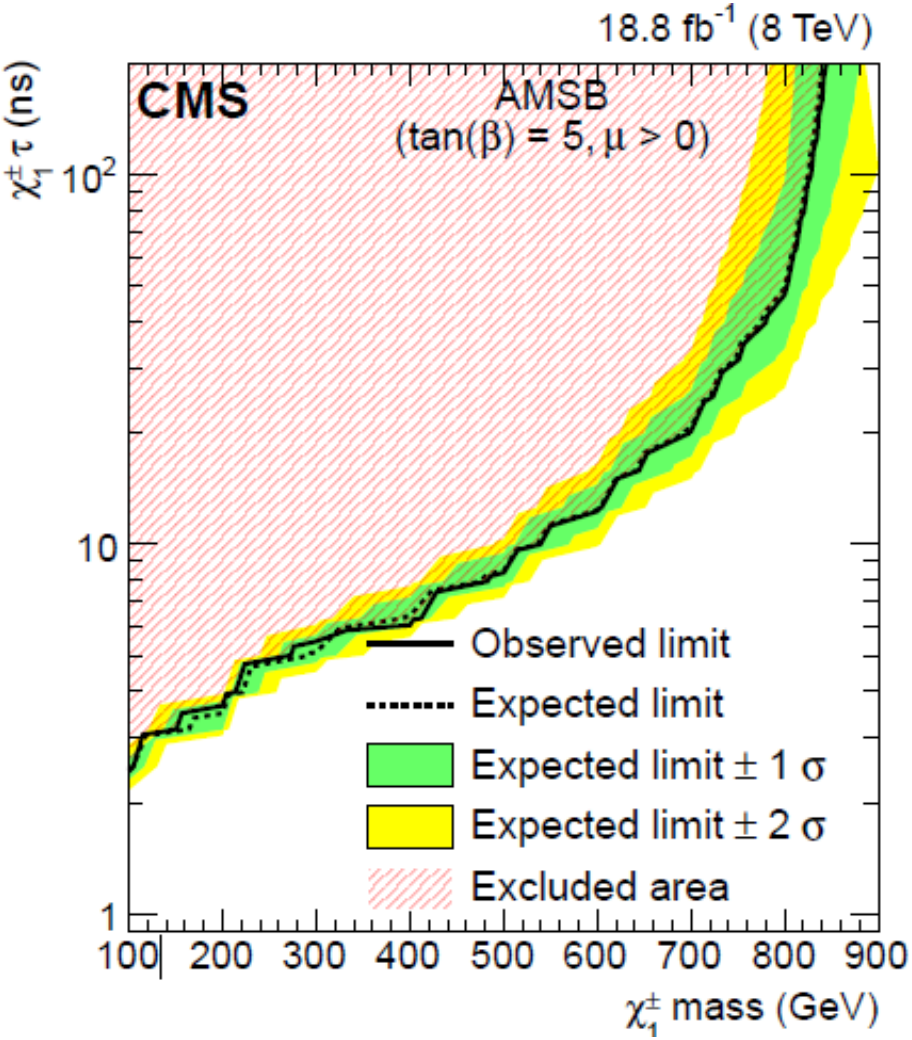
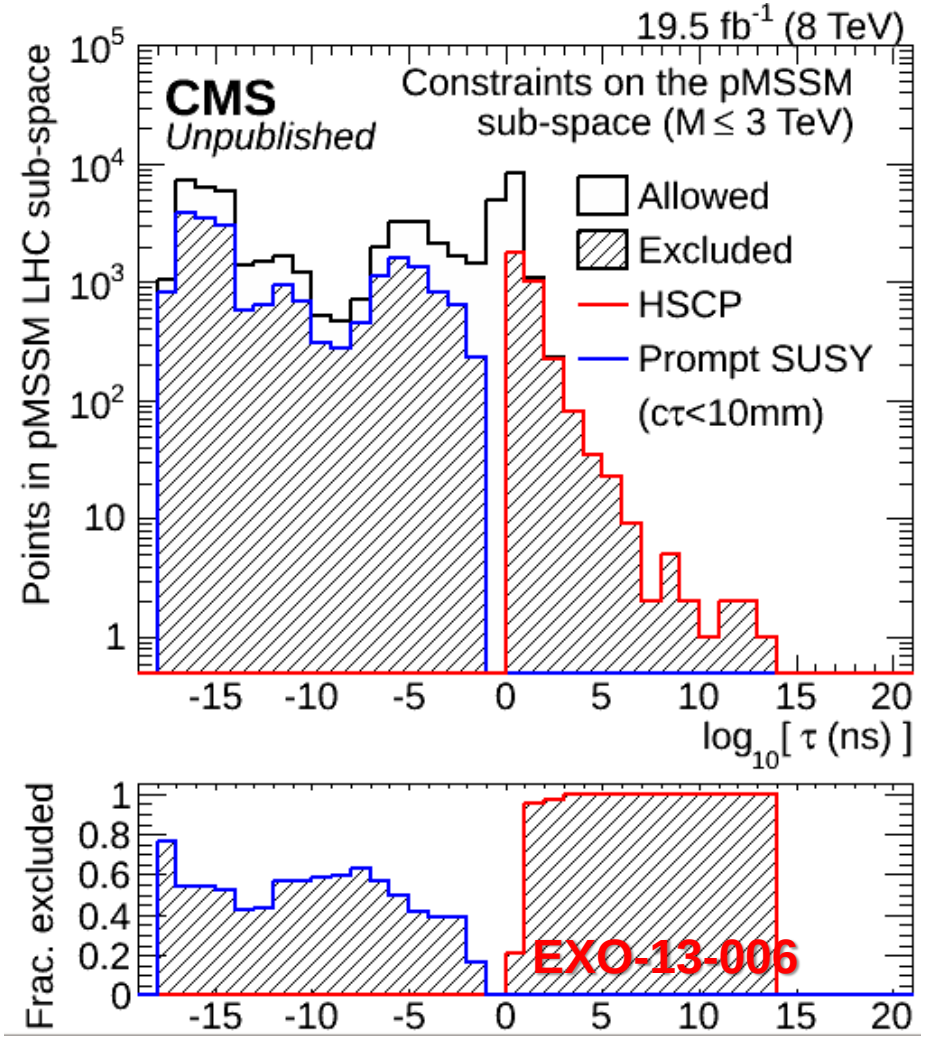
Constraining other BSM models

- A fast technique to estimate the CMS sensitivity to LL particles in other BSM models was developped and used to constrained AMSB and pMSSM models
  96% of pMSSM points with τ >10ns are excluded



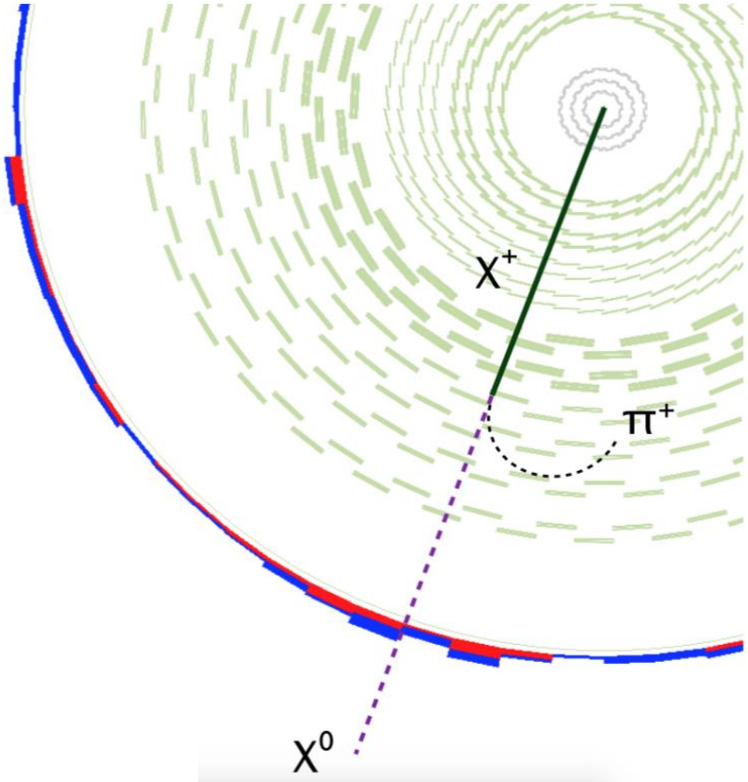


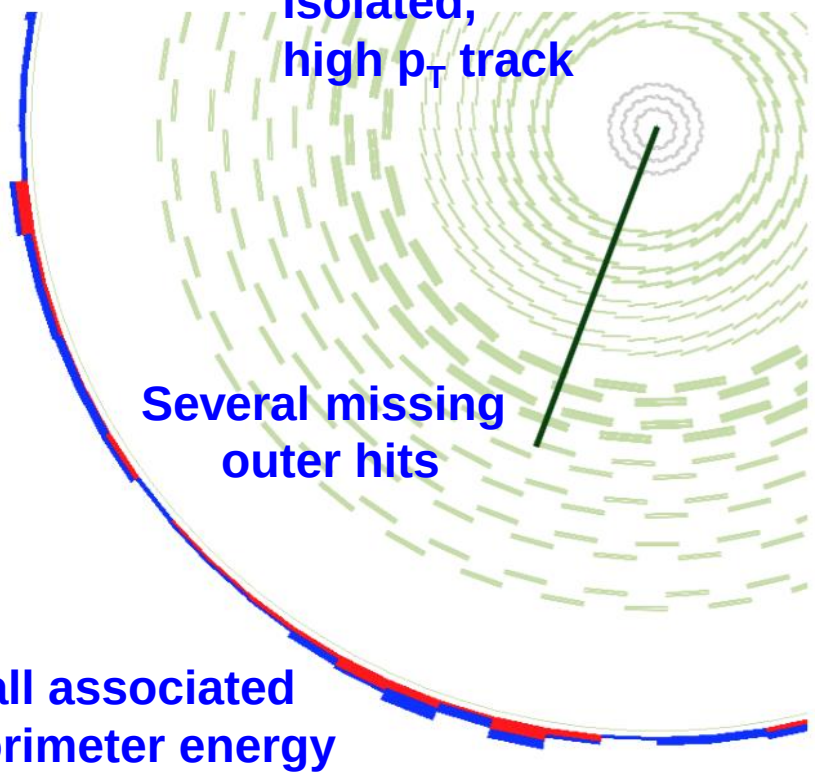
Search for disappearing tracks

AMSB SUSY predicts nearly degenerate neutralino and chargino: $\Delta M \approx 100\text{-}200$ MeV
→ Chargino is long-lived and decays to neutralino and a very soft pion

Disappearing High pT Track

- **Signature : tracker track with high pT and missing outer hits and small E_{calo}**
- **Backgrounds : fake tracks, kinked tracks (bremsstrahlung and nucl. int)**





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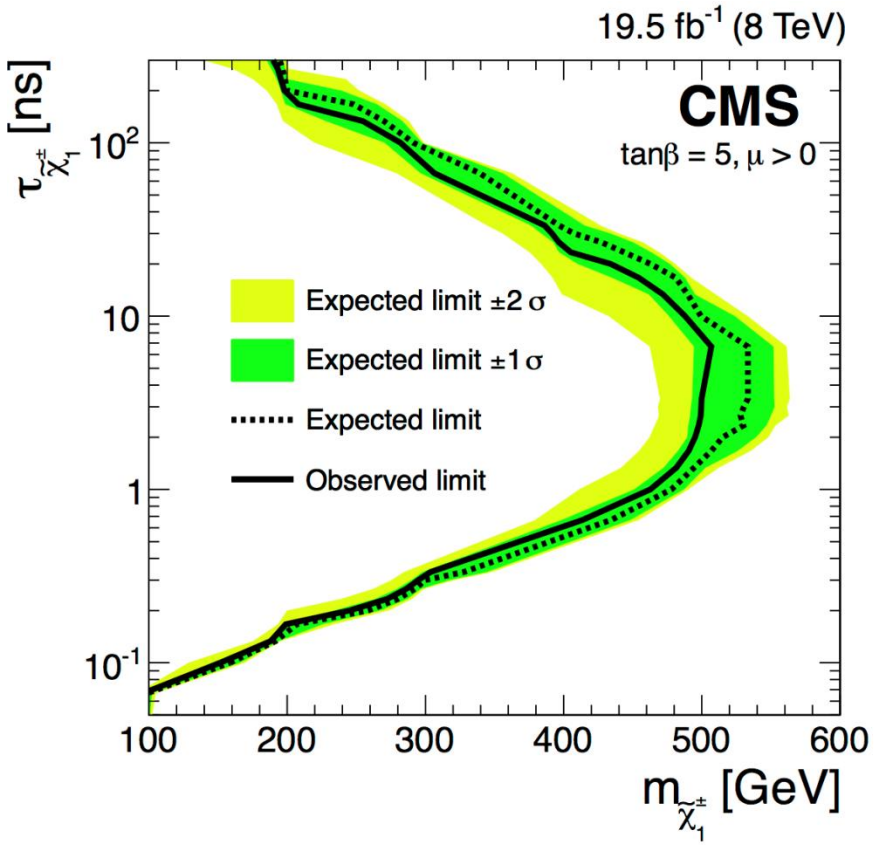
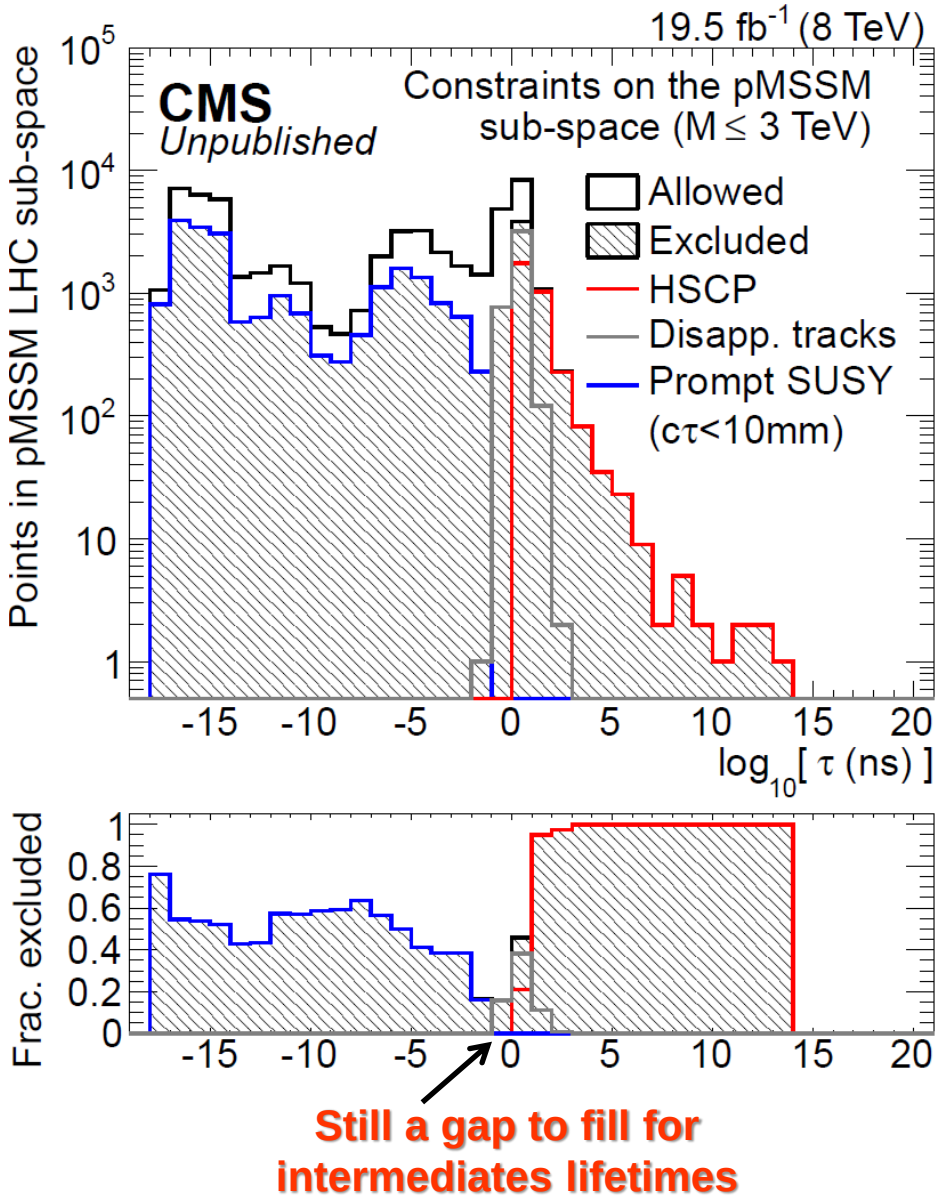
Results

AMSB models with a chargino mass less than 260 GeV, corresponding to a mean proper lifetime of 0.2 ns are excluded

Start filling the gap in pMSSM too





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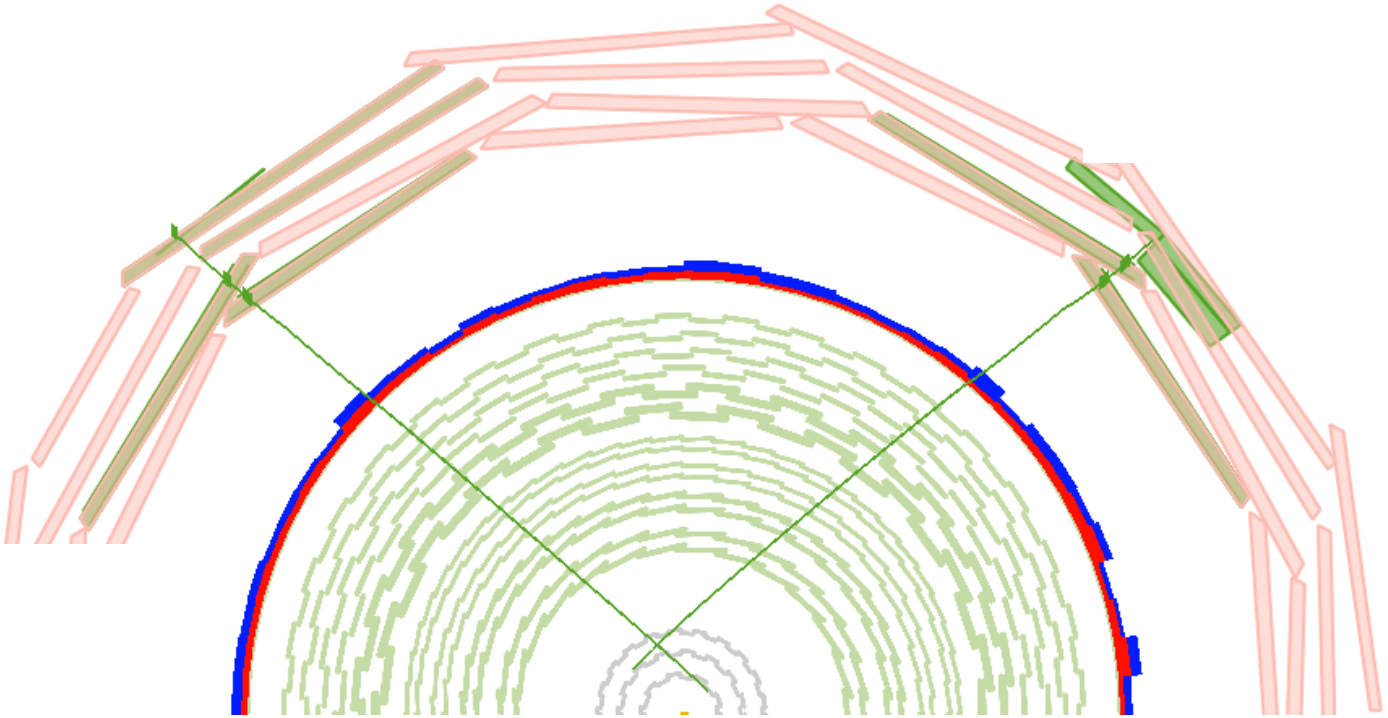
Search for displaced di-lepton pairs

Displaced pair of leptons (ee or μμ)

- **Signature : Displaced vertex → use the significance of the displacement**
- **Backgrounds : fake tracks, nuclear interactions, …**
- **Signal benchmark :** **RPV SUSY:** $\tilde{q} \rightarrow (q)\tilde{\chi}^0 \rightarrow \ell\ell\nu$

  and **h or H→XX, X→ll where X is long-lived**

  (this totally espaces limits from BR(H→Invisible))



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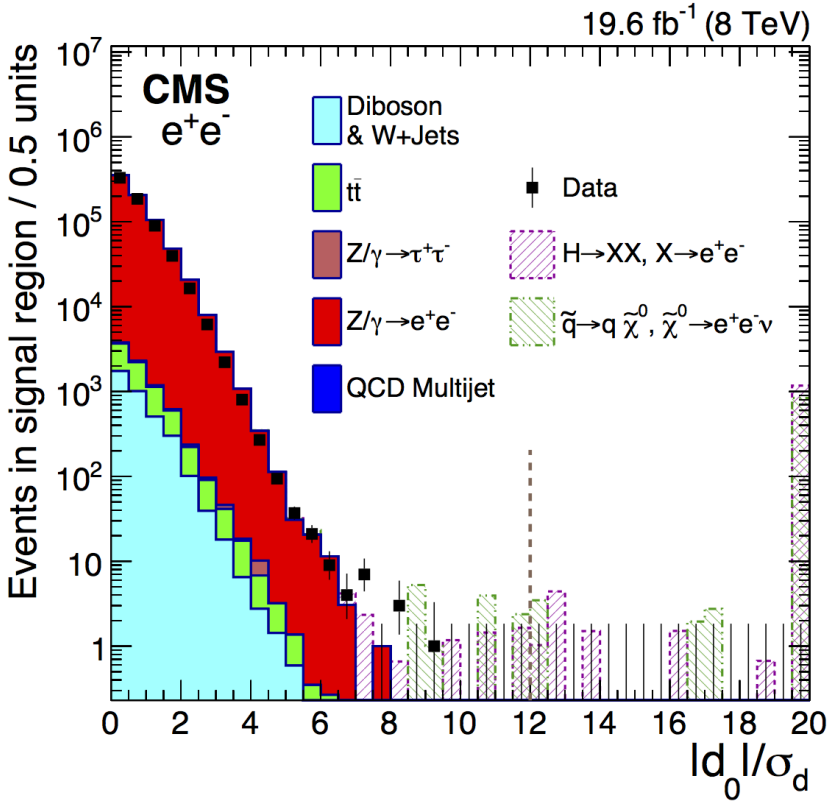
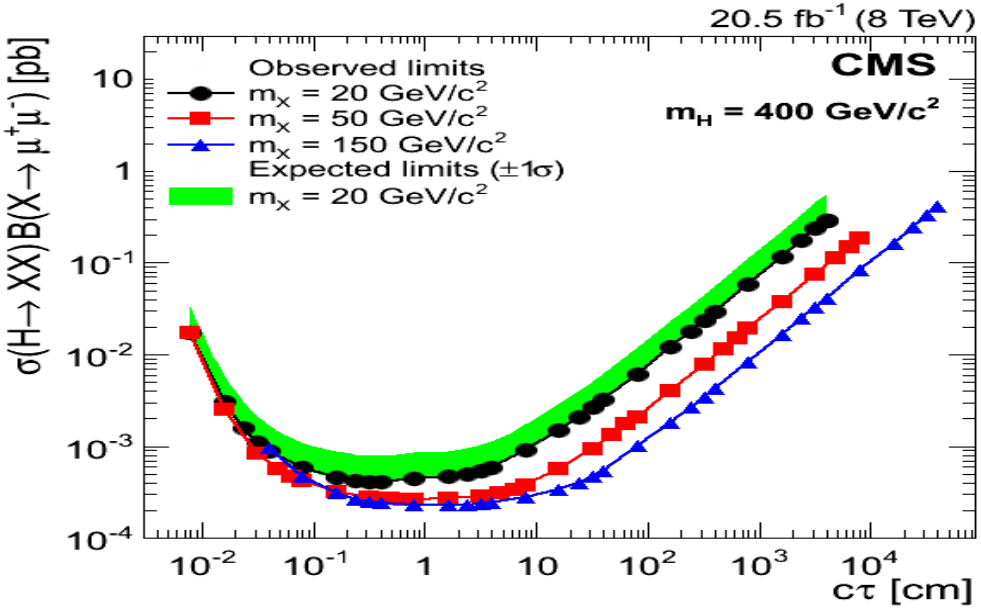
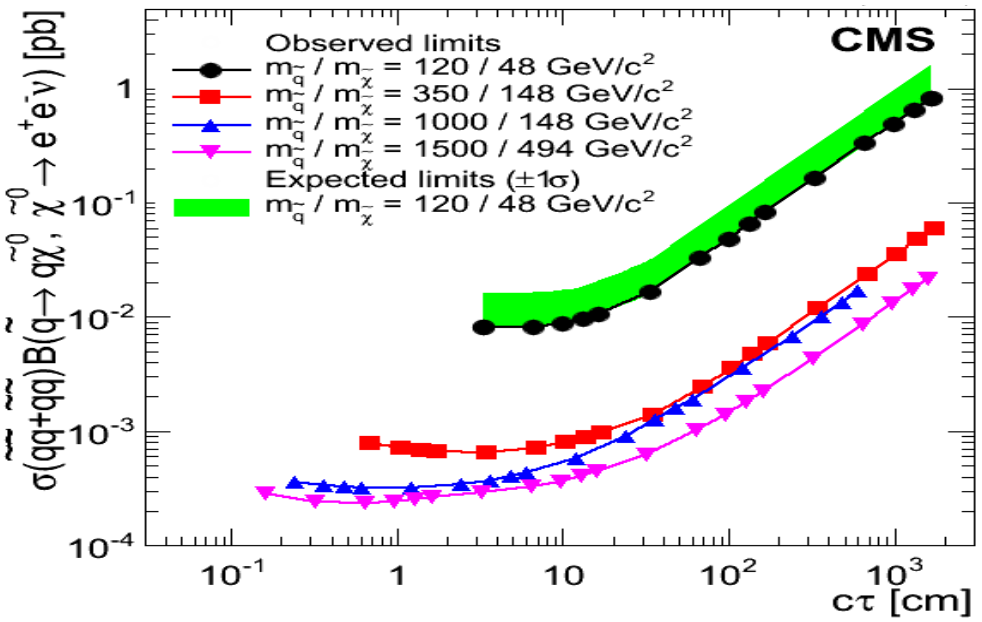
Results

Limits are presented for mH in [125,1000] GeV.
Parametrization of the acceptance is provided for possible reinterpretation!

As model independent as possible…



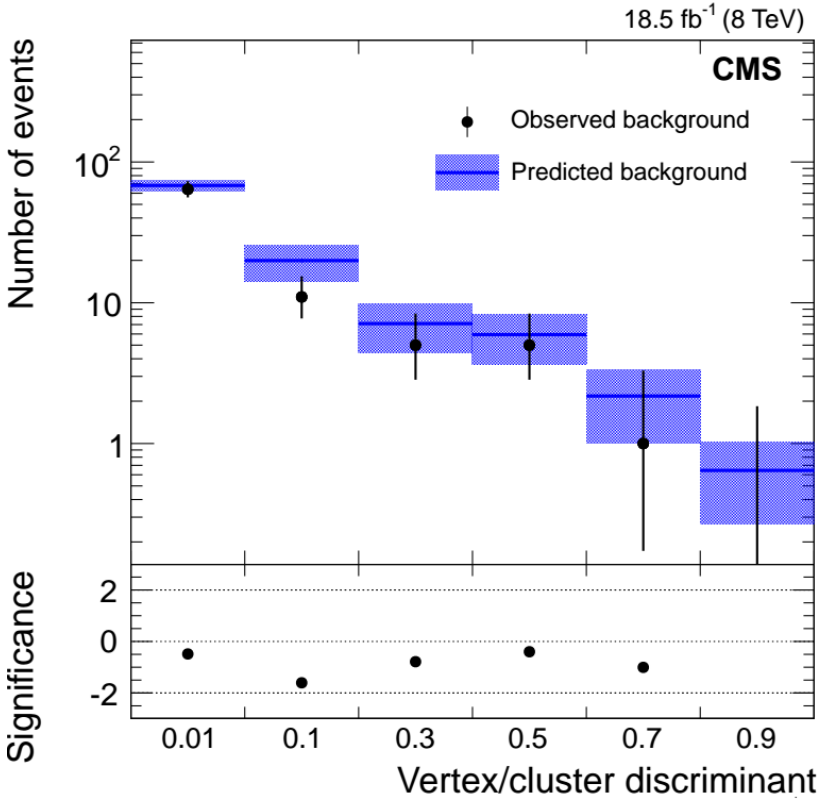


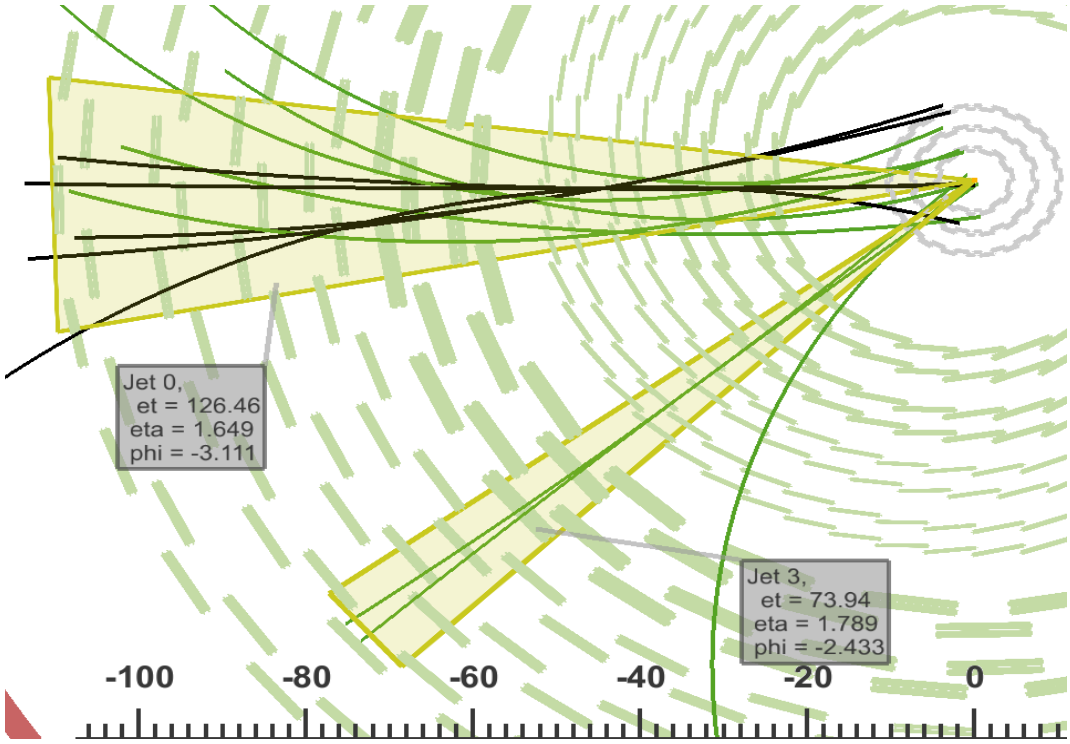


Search for displaced di-jet pairs

Displaced pair of jets

- **Signature : Displaced vertex → use a vertex discriminant for S/B separation**
- **Signal benchmark : RPV SUSY: neutralino → u d v**
  and H→XX, X→qq where X is long-lived





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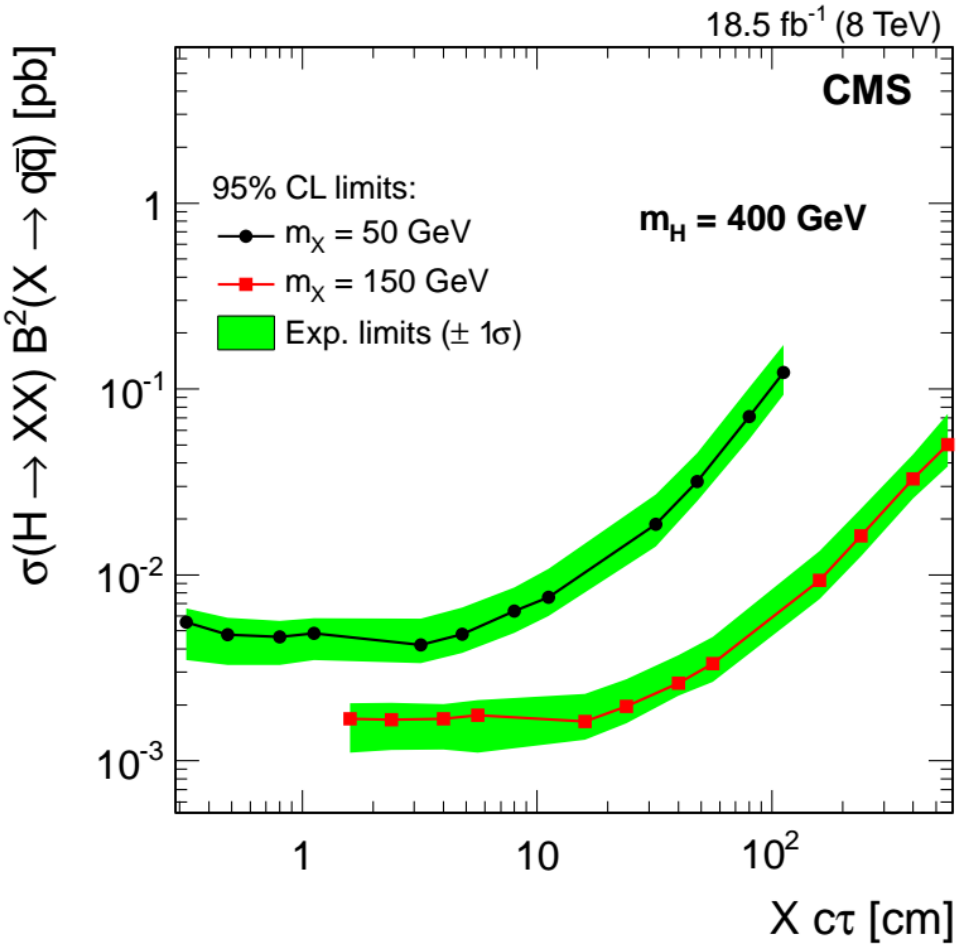

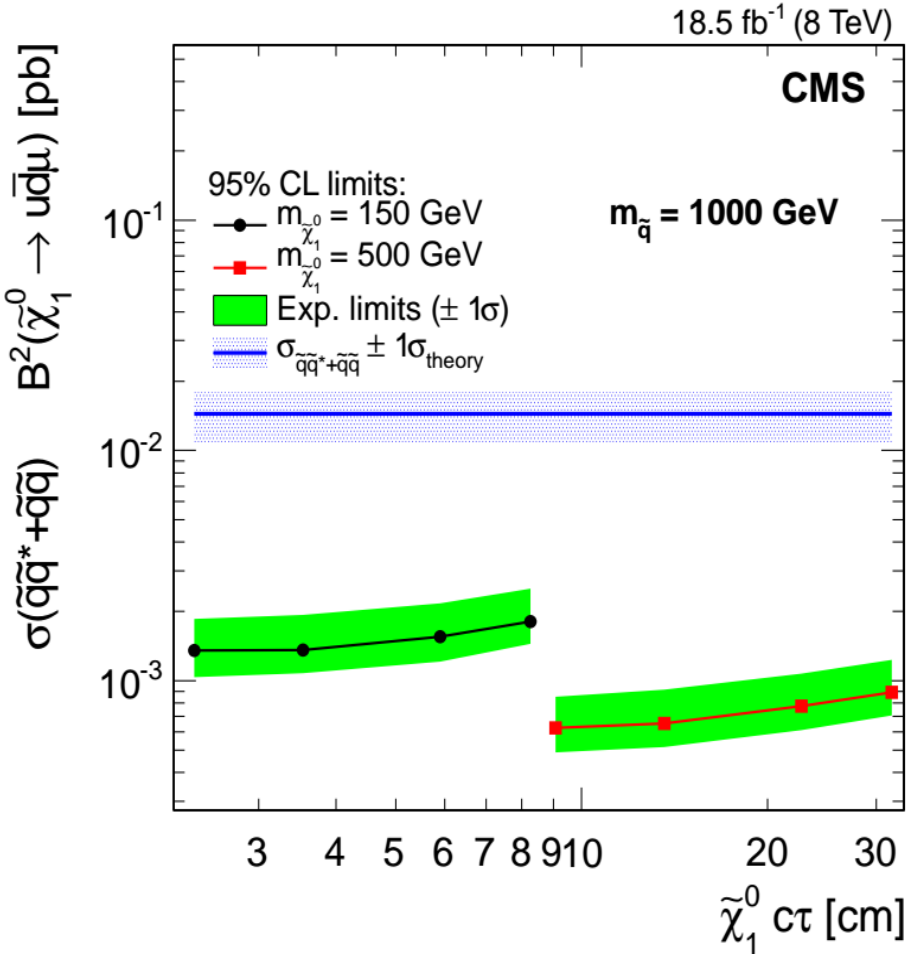

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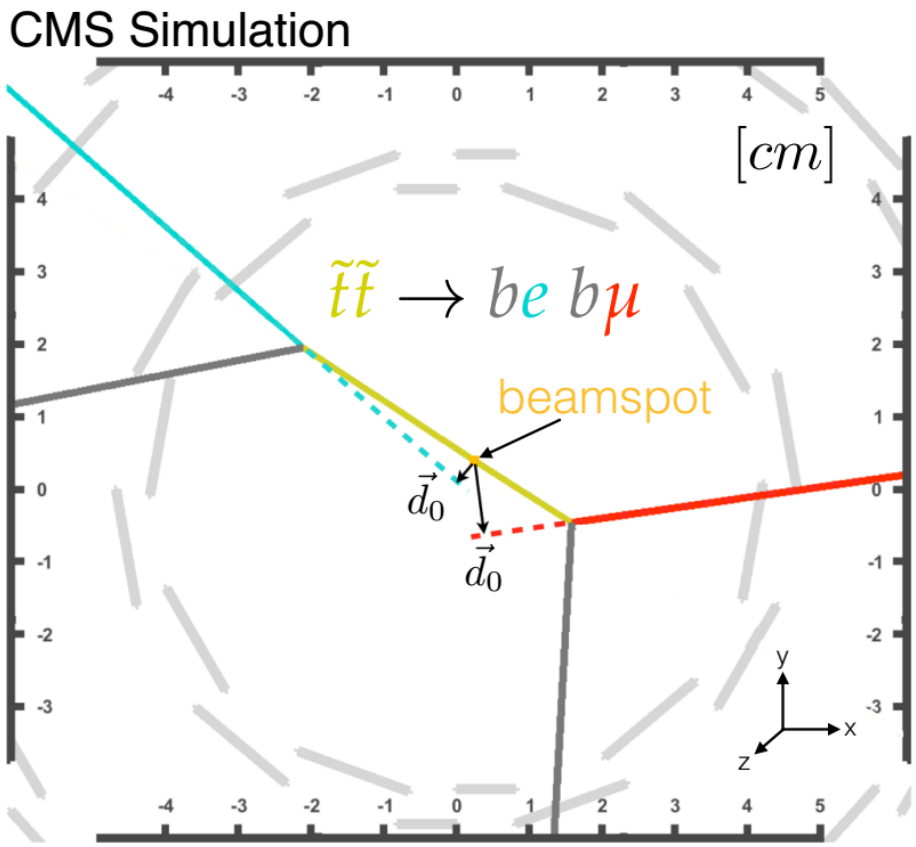
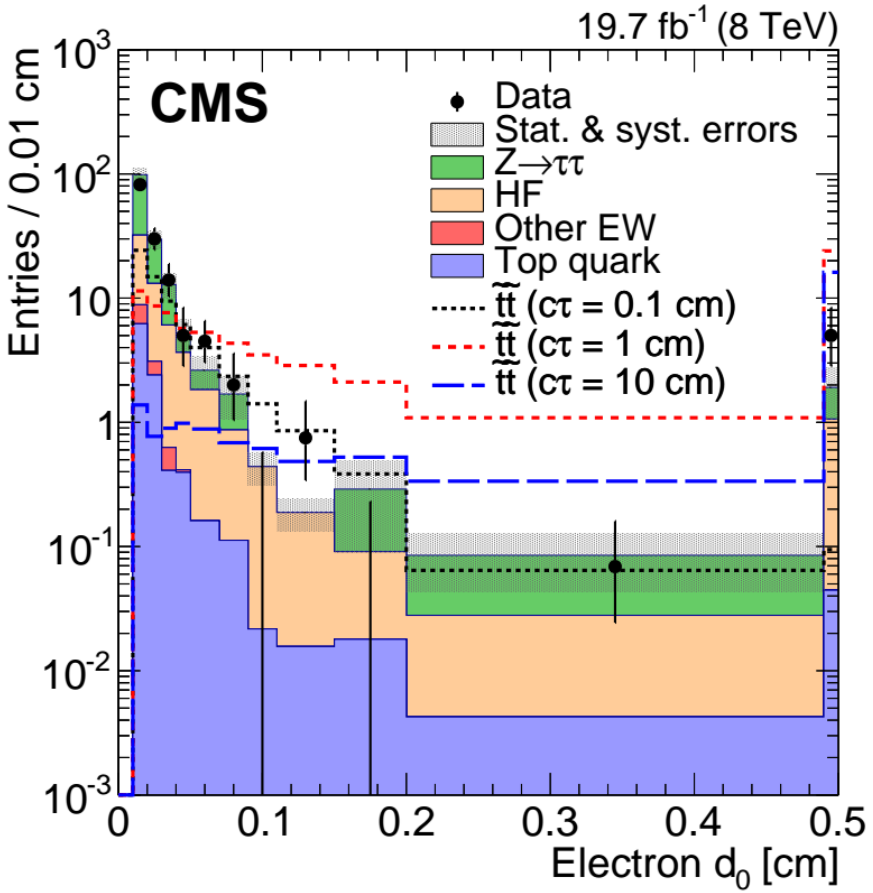
Search for displaced e+μ leptons

- **Signature : electron and muons originating from two displaced vertex focus on displacement from 200μm to 2 cm**
- **Signal benchmark : stop stop → eb μb**
- **Backgrounds: tau leptons and Heavy flavor quaks (b/c)**





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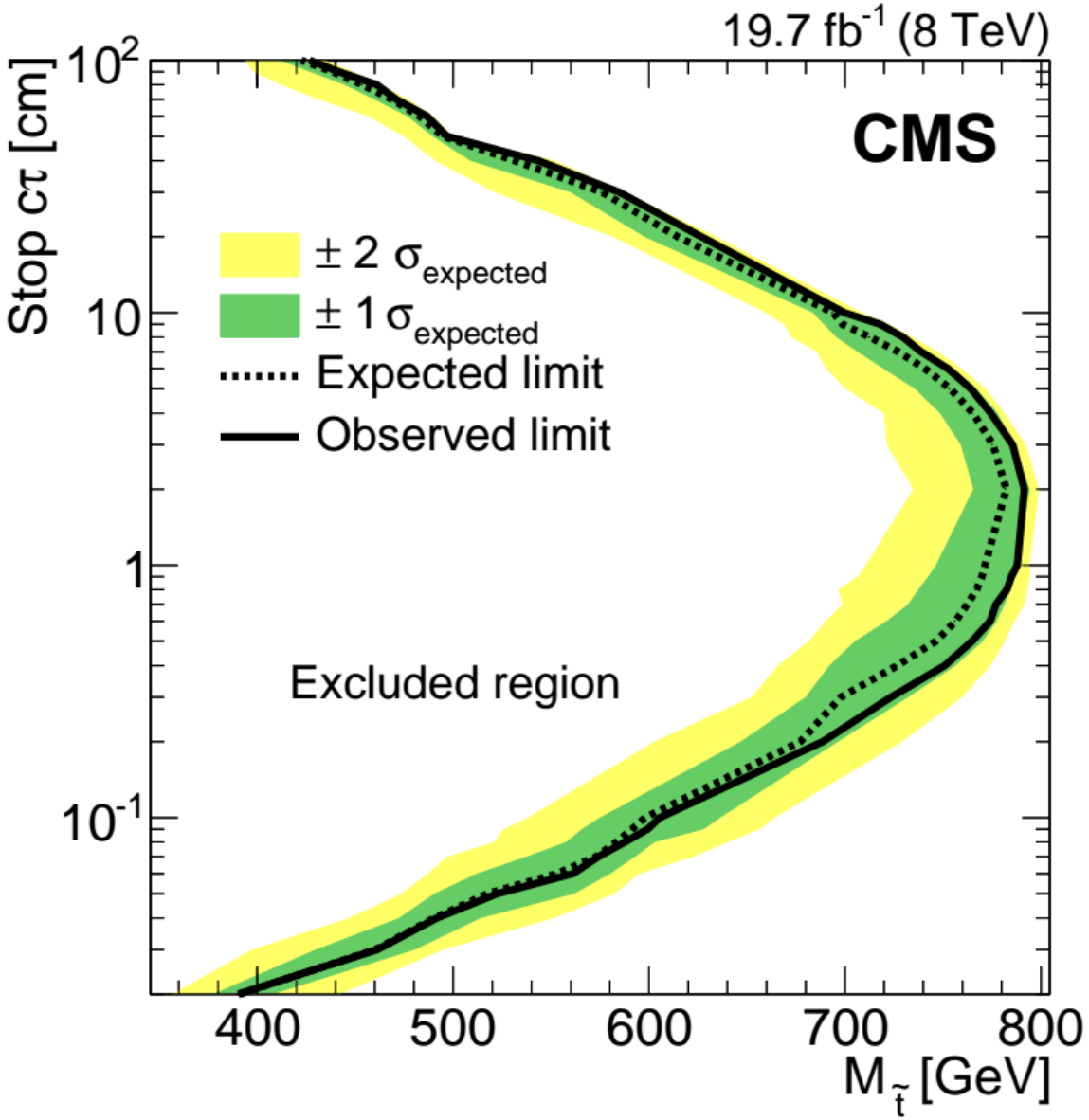
Results



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Summary

- **CMS has a strong research program for Long-lived particles**
- **A large variety of signatures have been used,**
  - **Stopped objects (in calorimeters)**
  - **Special tracks (dE/dx, TOF, missing hits)**
  - **Displaced objects (photons, leptons and jets)**
- **Constrains set on a large variety of models**
  - **Split SUSY, GMSB, AMSB, pMSSM, Hidden Valey, RPV SUSY, etc…**
- **Model independent results**
  - **For most case, we provide techniques to evaluate the acceptance of the CMS analyses to other BSM models**
- **More details, plots and results on**

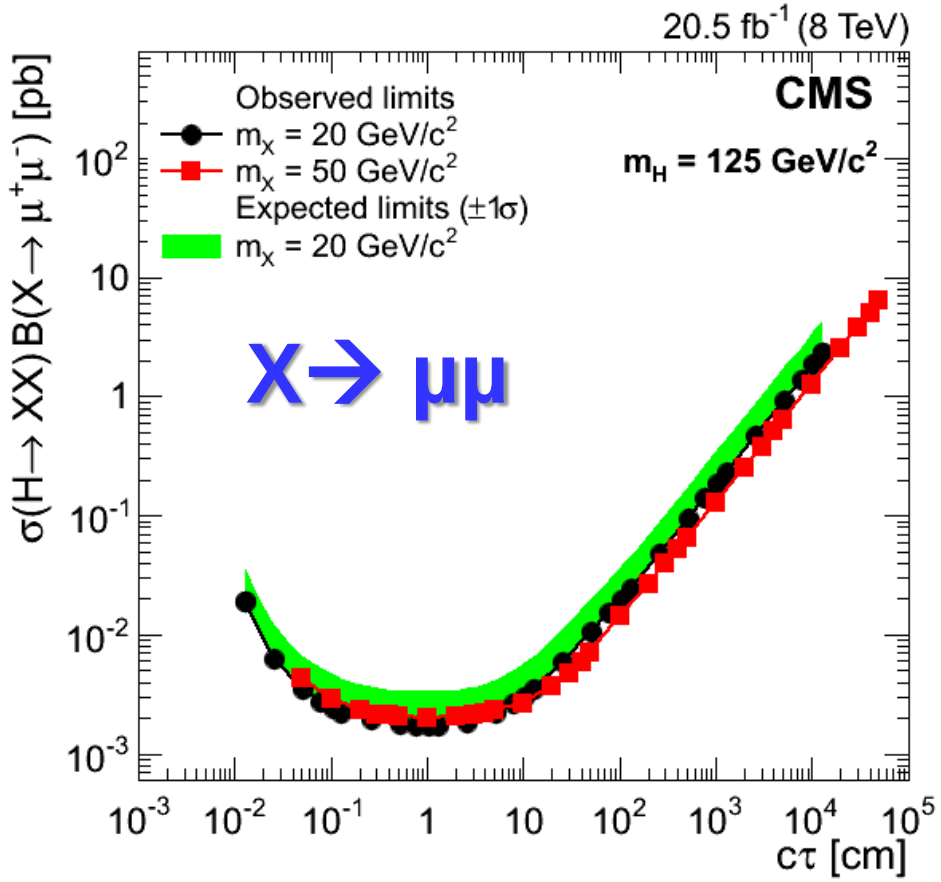
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

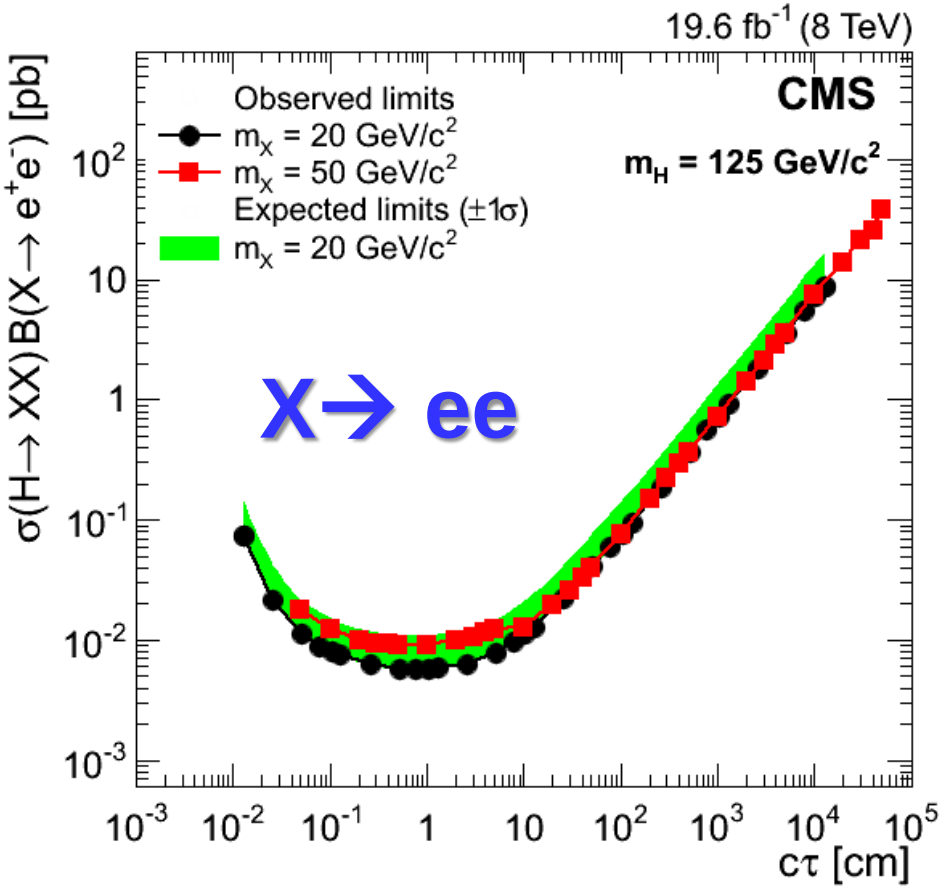
Time may drastically change the scene….

Thank you….

Backups

125GeV Higgs → XX, X→ll





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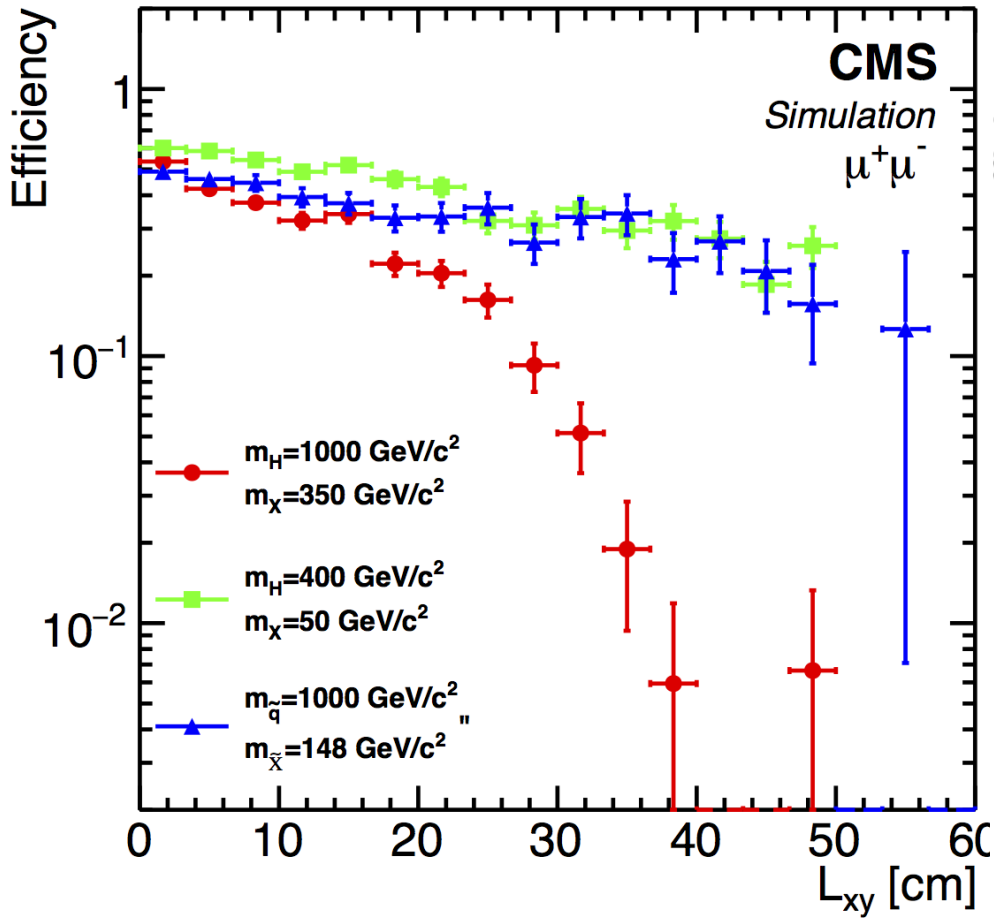
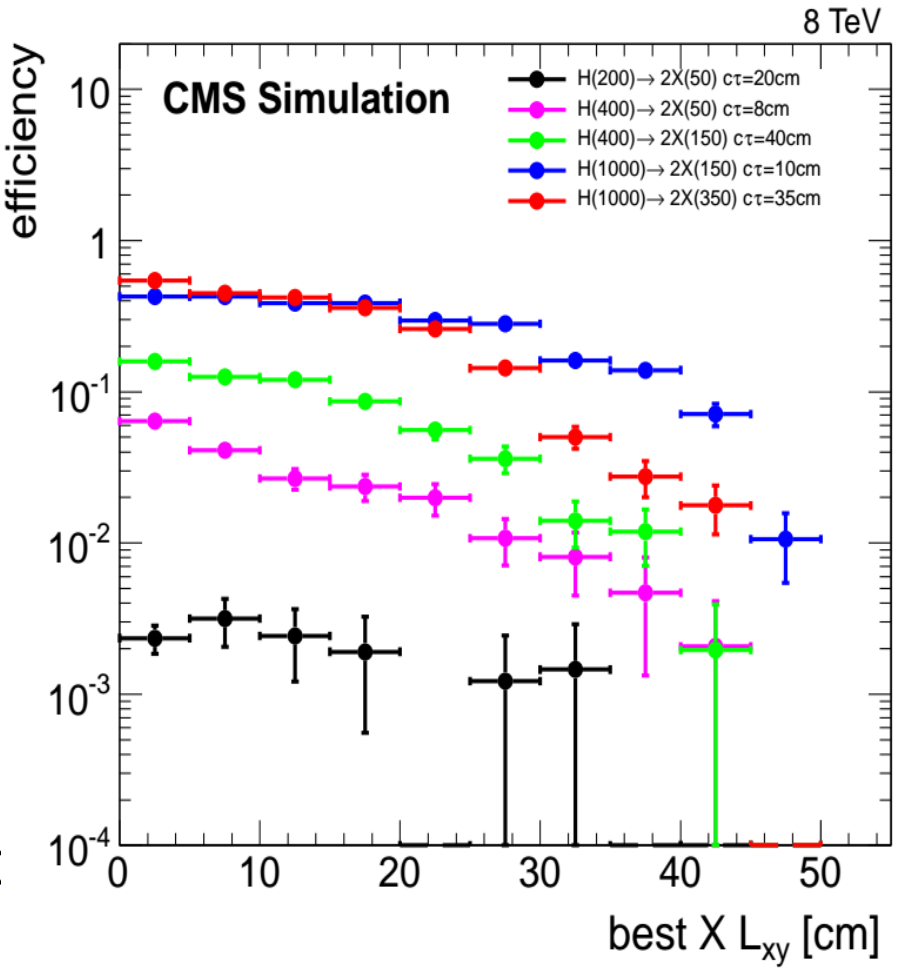
Reconstruction efficiency vs Lxy





X→ μμ

X→ qq

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