Search for heavy resonances decaying to long-lived neutral particles

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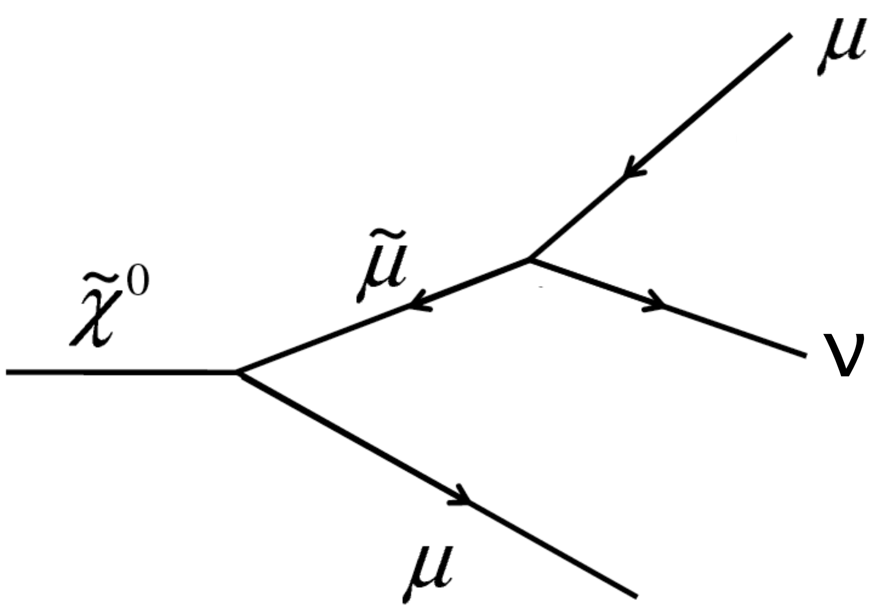
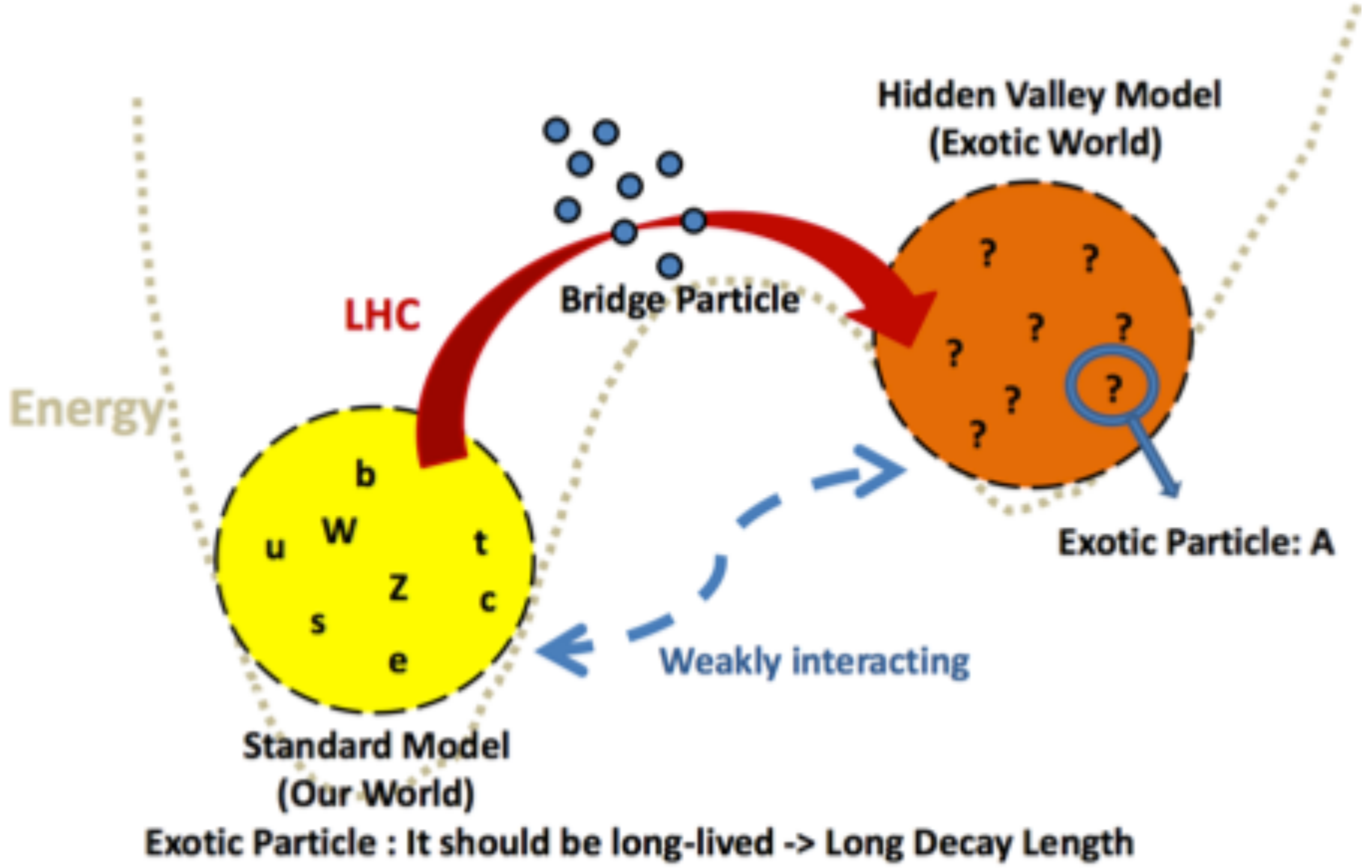
on behalf of the CMS Collaboration

Motivation

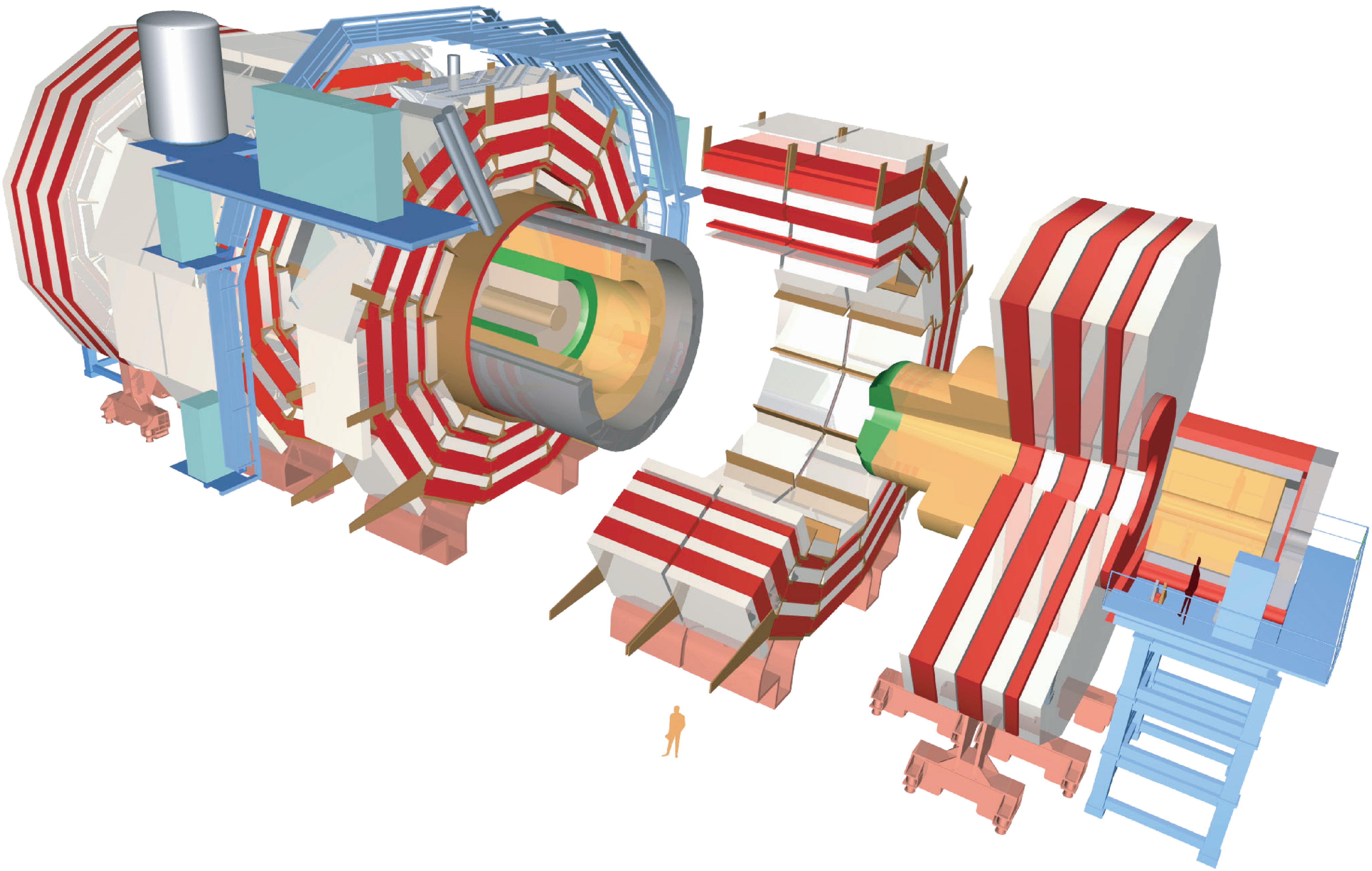
- Many new physics scenarios predict heavy long-lived particles
  - ➡ Weak R-Parity Violating SUSY
  - ➡ Split SUSY
  - ➡ Hidden Valley Scenario
  - ➡ Exotic decays of recently discovered Higgs boson?



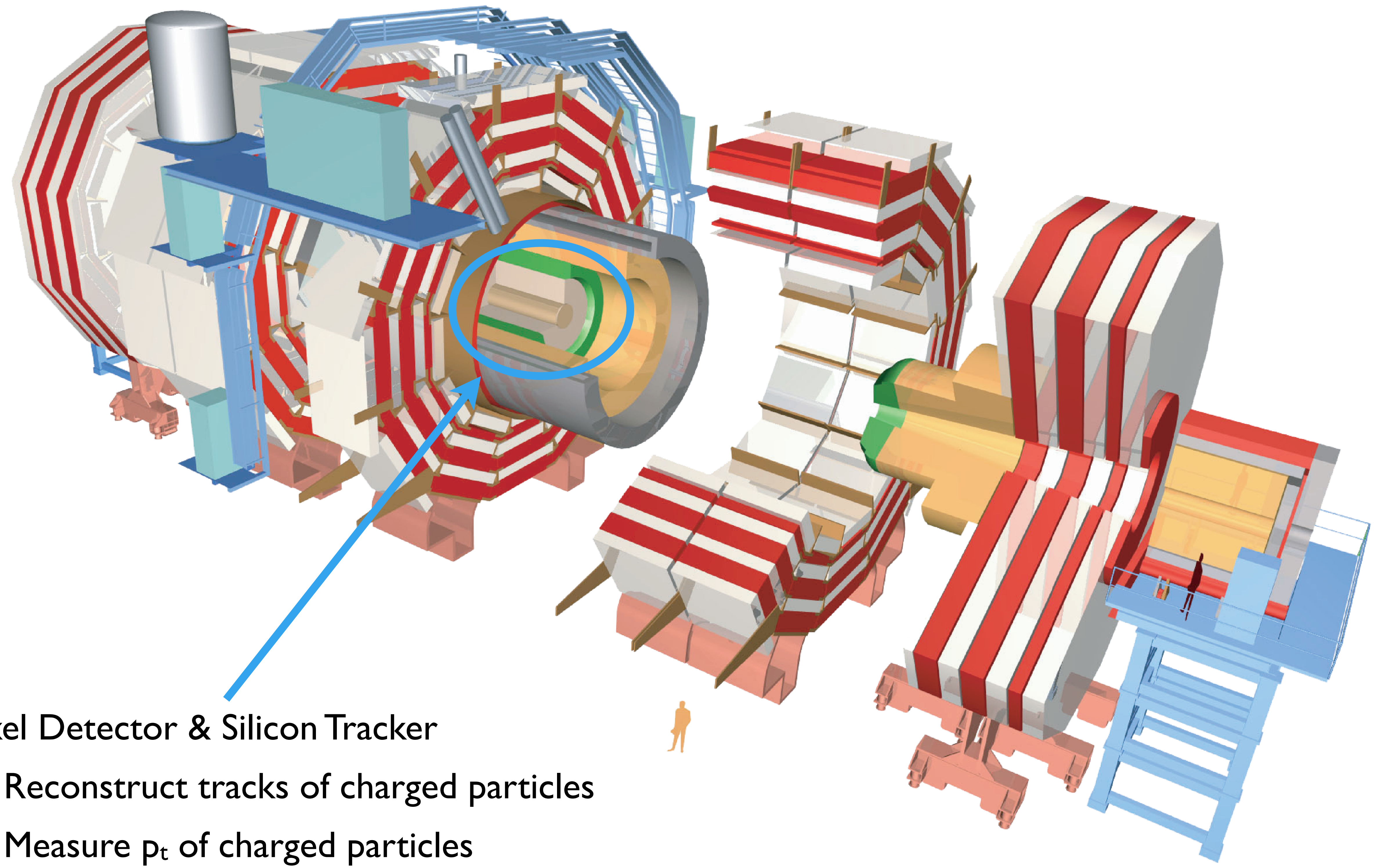
- Search for neutral long-lived particles using CMS
  - ➡ Decay to pairs of displaced electrons or muons
  - ➡ Proton-proton data at $\sqrt{s}$ = 7 TeV
  - ➡ 4.1 - 5.1 fb^{-1} integrated luminosity
  - ➡ Arxiv link to public result



CMS



CMS

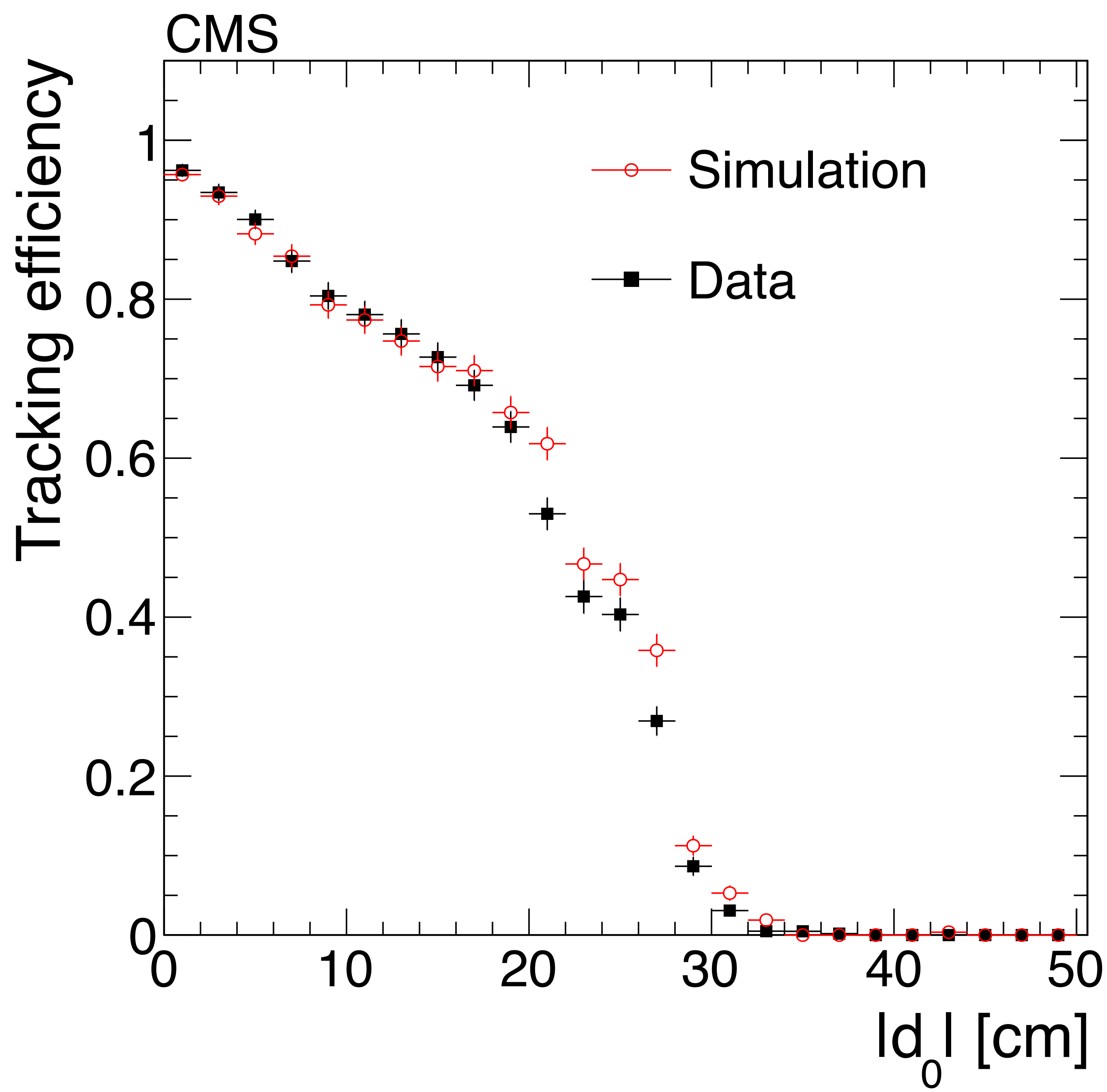


- Pixel Detector & Silicon Tracker
  - ➡ Reconstruct tracks of charged particles
  - ➡ Measure p_t of charged particles

Reconstruction of Displaced Tracks

- CMS exploits an iterative tracking algorithm
  - ➡ First iterations find tracks originating near the primary vertex
  - ➡ Final iterations find displaced tracks

- Can reconstruct displaced leptons with impact parameters (d_0) up to ~ 30 cm
  - ➡ Efficiency to reconstruct track decreases at larger displacements

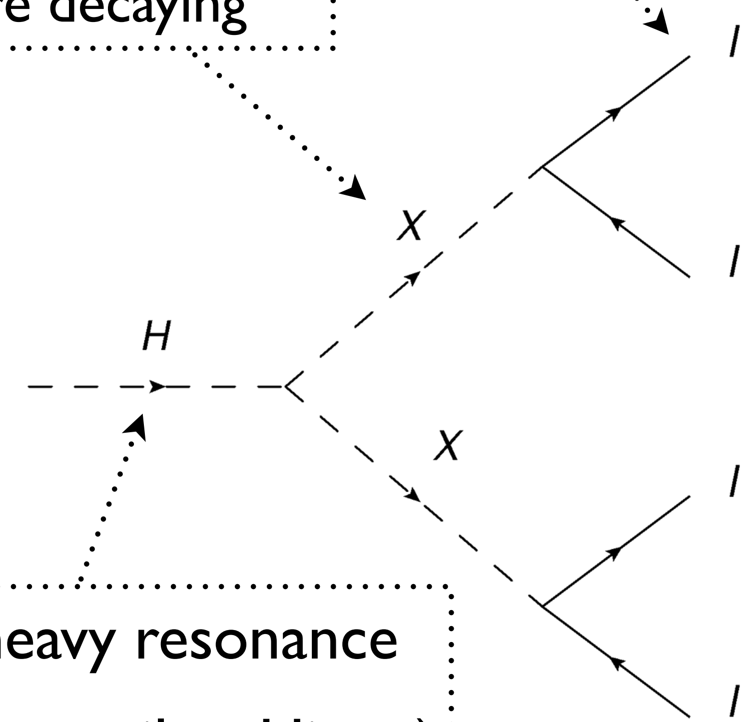


Displaced Vertex Signature

Long-lived particle, X

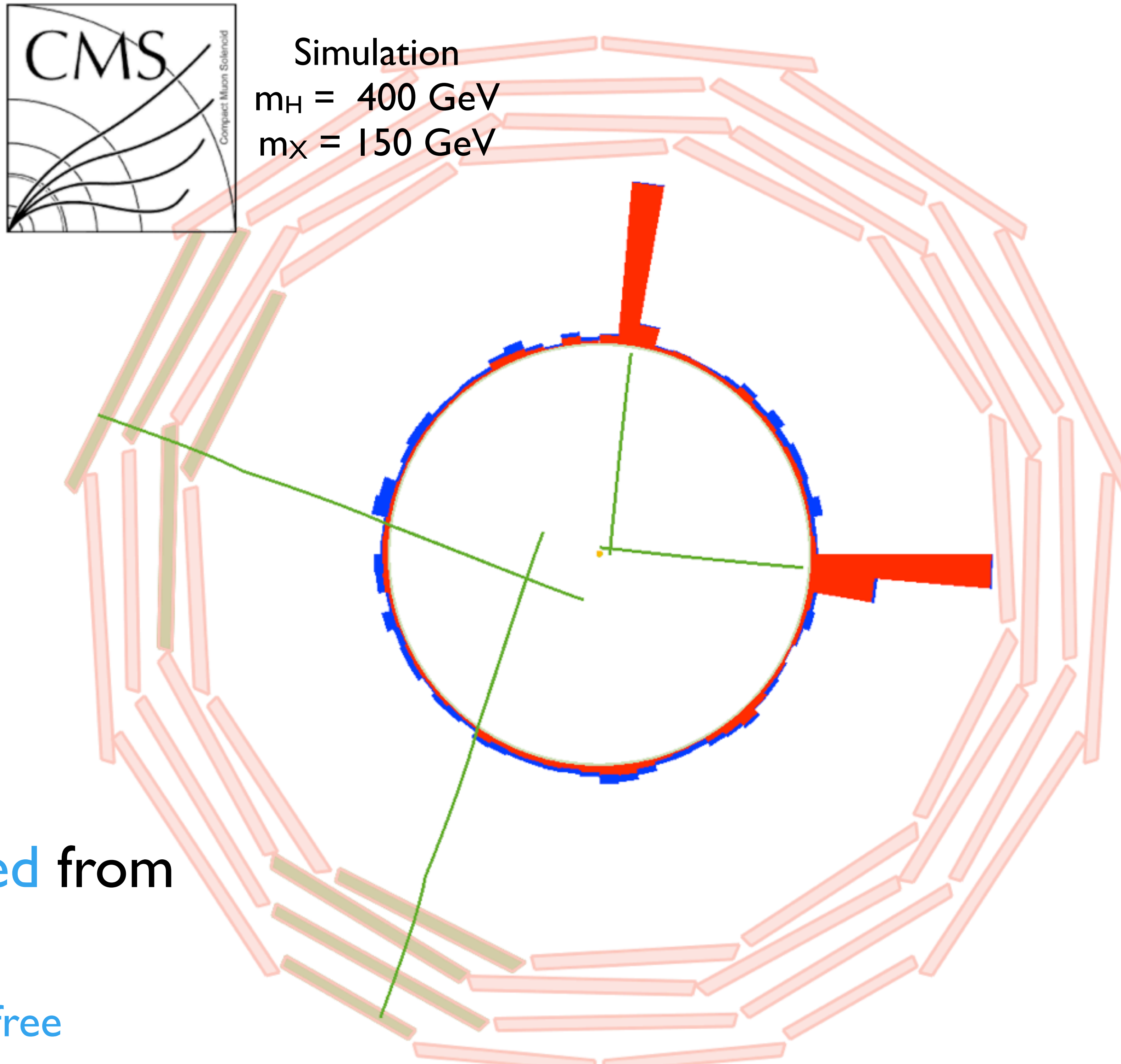
- ➡ Travel ~20cm in transverse plane before decaying

electron or muon pairs



Some heavy resonance

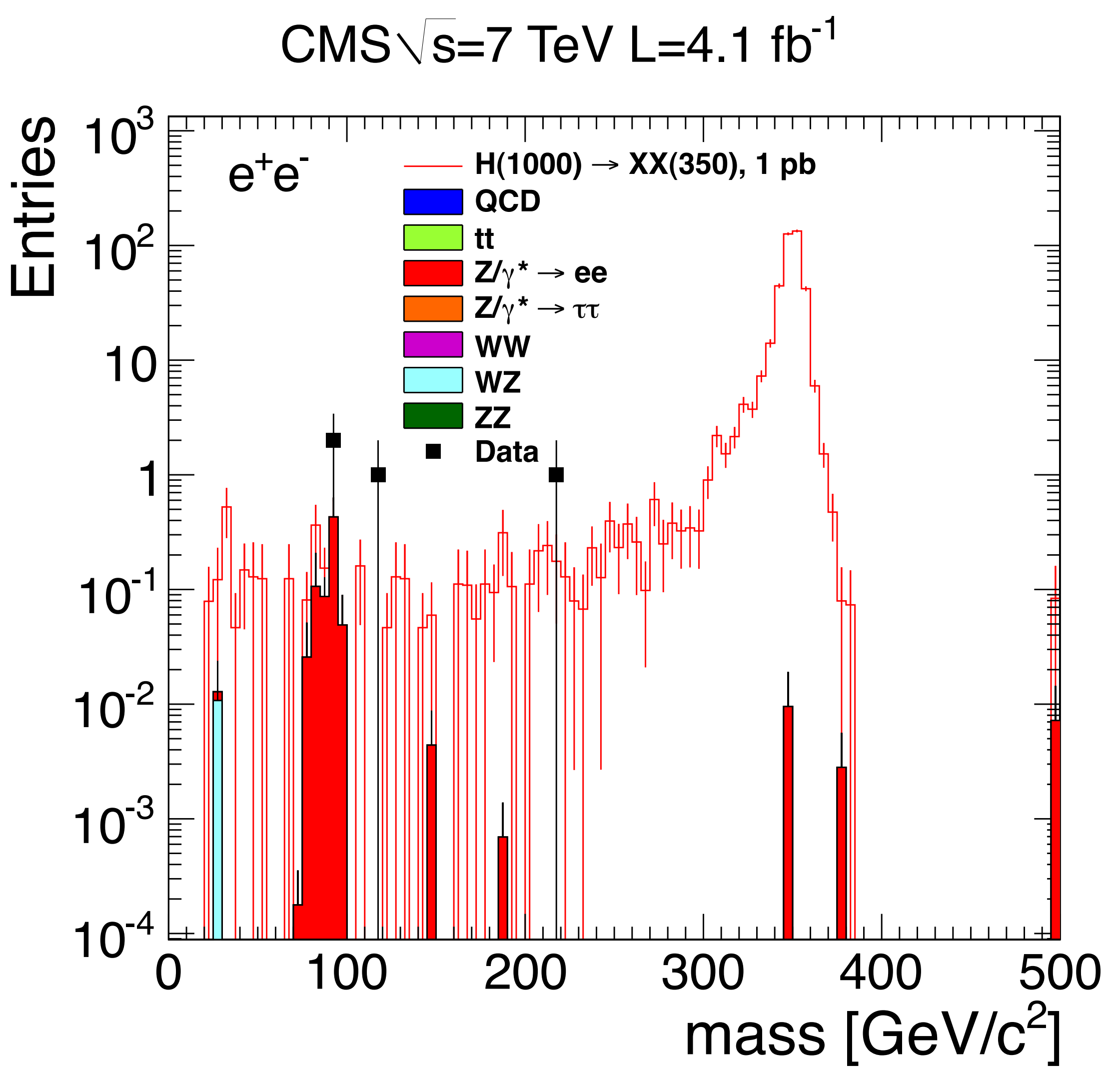
(not necessarily a Higgs)



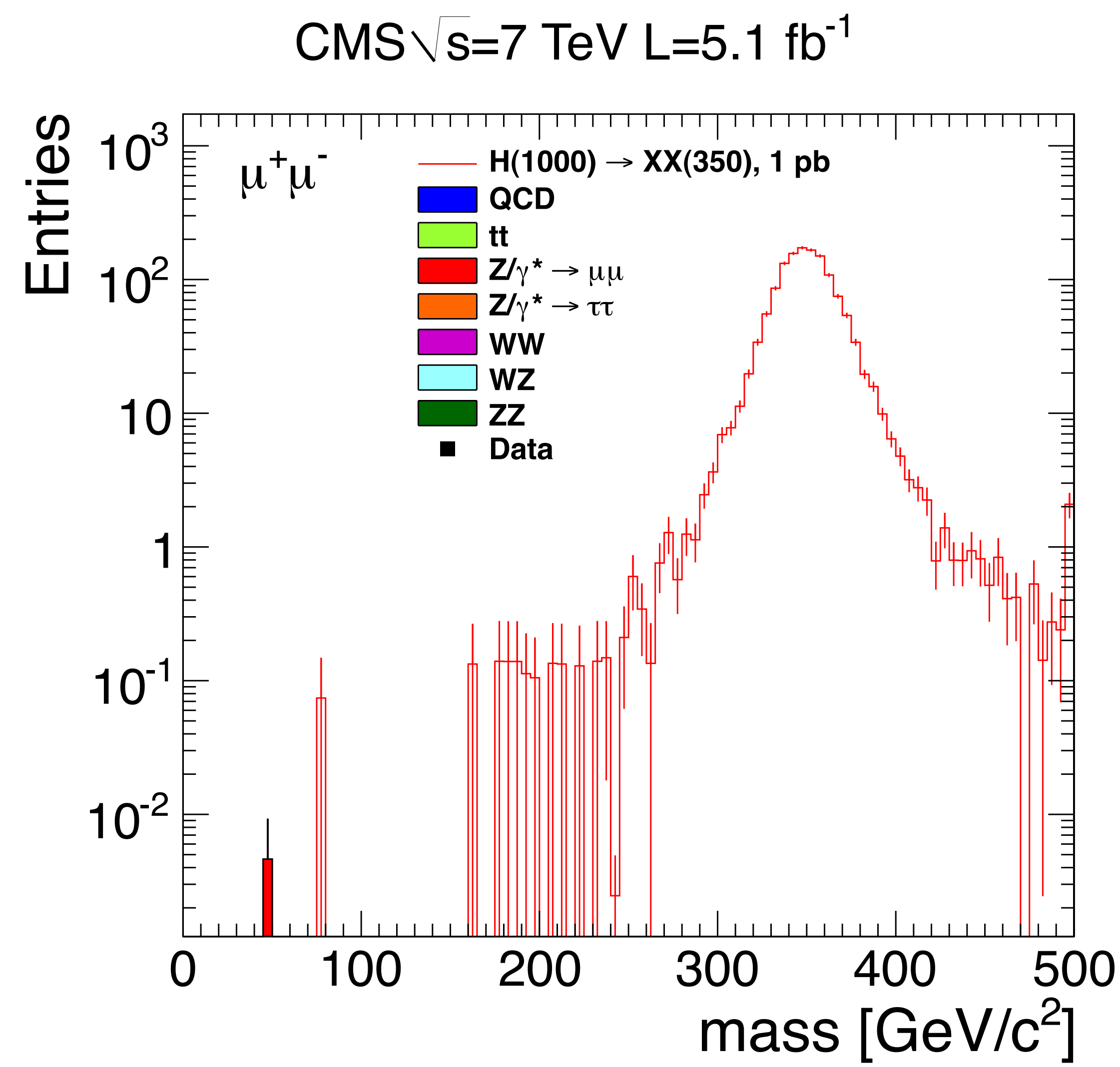
- Tracks and vertex are displaced from centre of CMS
  - ➡ Makes analysis almost background free
  - ➡ Only need to reconstruct one displaced vertex

Dilepton Mass Spectrum

- Look for a narrow resonance in dilepton mass spectrum



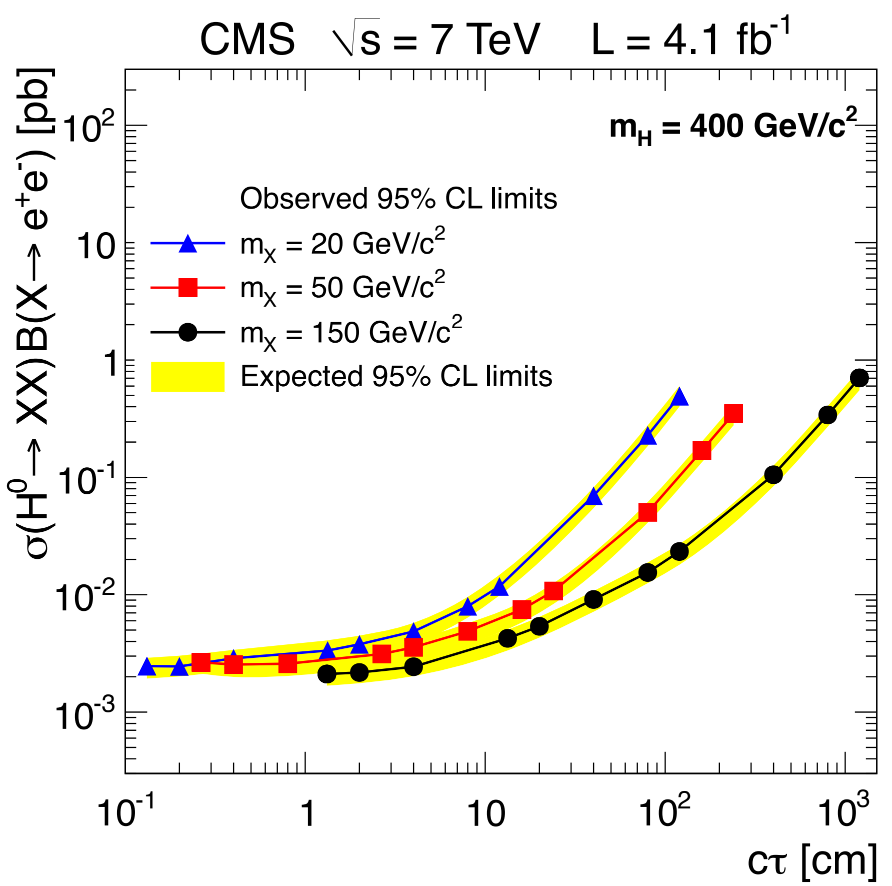
Expected $1.38^{+1.78}_{-1.19}$ background candidates



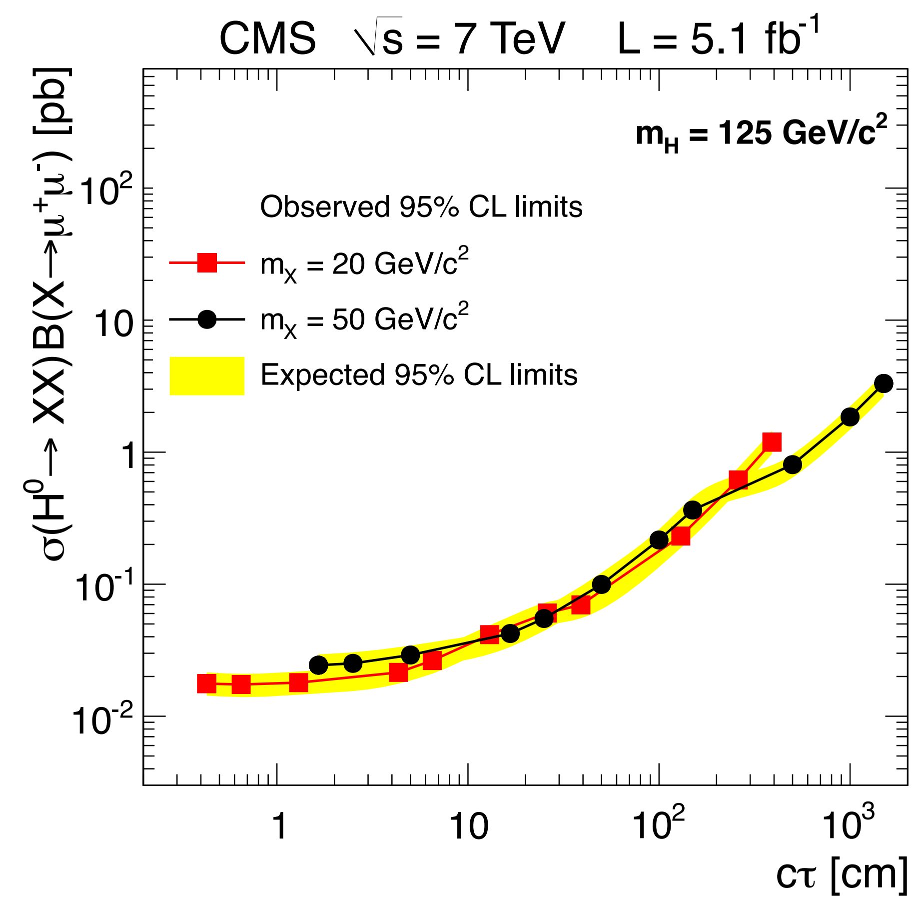
Expected $0.02^{+0.09}_{-0.02}$ background candidates

Results

- See no significant excess
- Set 95% CL upper limit on $\sigma(H \rightarrow XX) \times B(X \rightarrow l^+l^-)$
  - ➡ Range of H and X masses
- Main systematic uncertainty due to displaced tracking efficiency



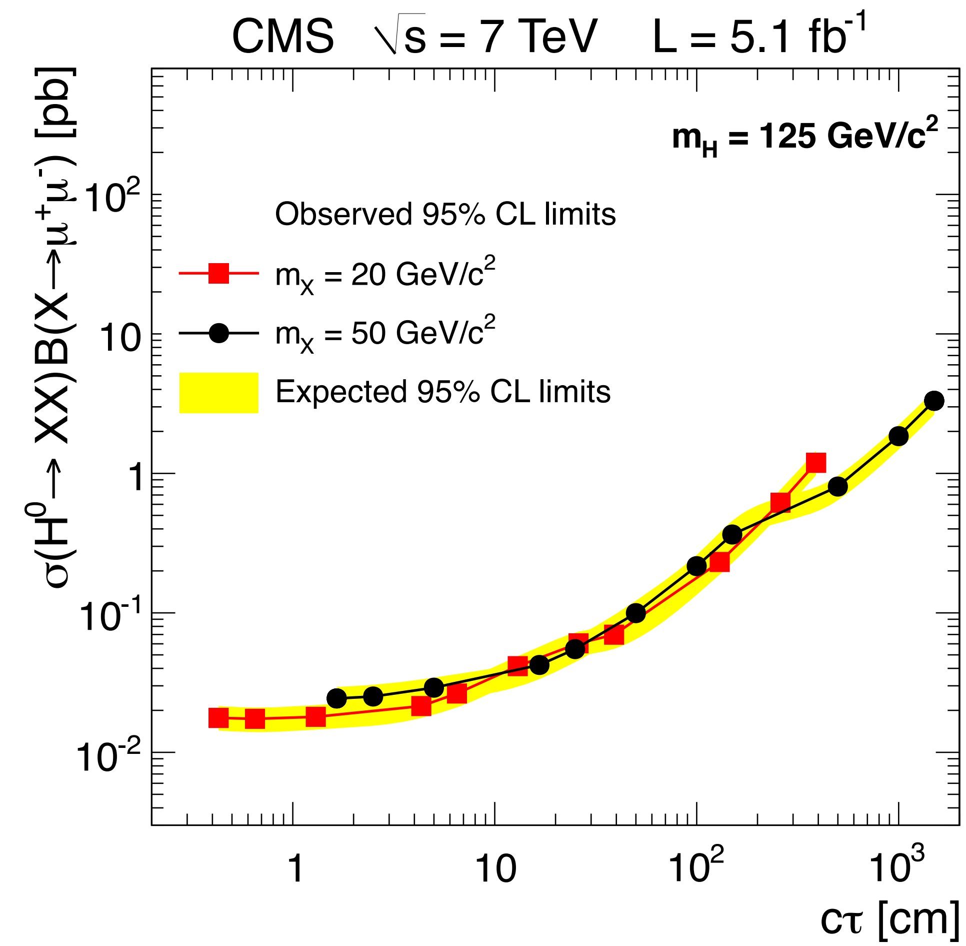
m_H = 400 GeV/c², m_X = 20→150 GeV/c²

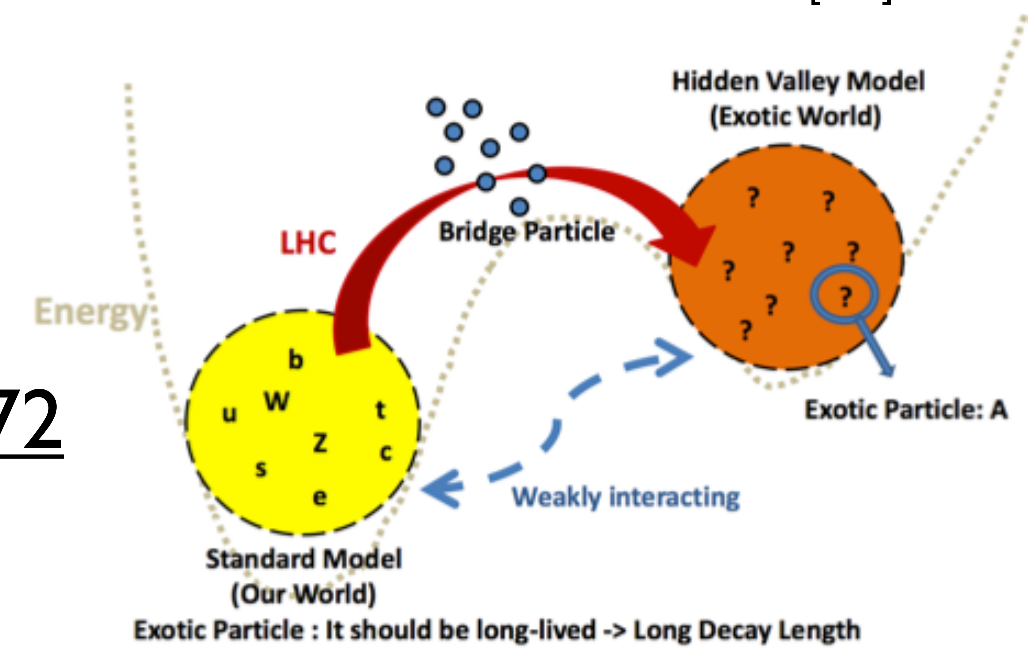


m_H = 125 GeV/c², m_X = 20→50 GeV/c²

Summary

- A search for neutral long-lived particles
  - ➡ Decay to pairs of electrons or muons
- No significant excess seen
  - ➡ Set upper limits
  - ➡ $m_H = 125 \rightarrow 1000$ GeV/c^2
  - ➡ $m_X = 20 \rightarrow 350$ GeV/c^2
- Limits in range 0.7 fb → 100 fb
  - ➡ For X with L_{xy} in laboratory frame of ~2→100cm
- Further information : arxiv.org/abs/1211.2472





Backup

Online Selection

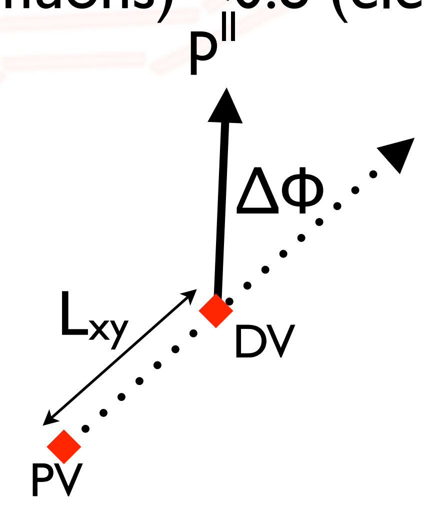
- Muon channel
  - ➡ Two muons reconstructed in muon systems only
  - ➡ No primary vertex constraint
  - ➡ No tracker requirement
  - ➡ p_t>30 GeV/c

- Electron channel
  - ➡ Two clustered energy deposits in the ECAL
  - ➡ E_t>38 GeV
  - ➡ No tracker requirement

Detailed Candidate Selection

- Selection cuts on track/leptons
  - ➡ High purity tracks, 6 valid hits, $|\eta|<2$
  - ➡ p_t of tracks > 33 GeV (muon) > 41 (electron)
  - ➡ d_0/σ of tracks > 2 (muon), > 3 (electron)
  - ➡ Tracker isolation
    - Σp_t < 4 GeV within ΔR < 0.3
- In electron channel, also match track to offline supercluster
- In muon channel, reject back-to-back muons and require ΔR between muons >0.2

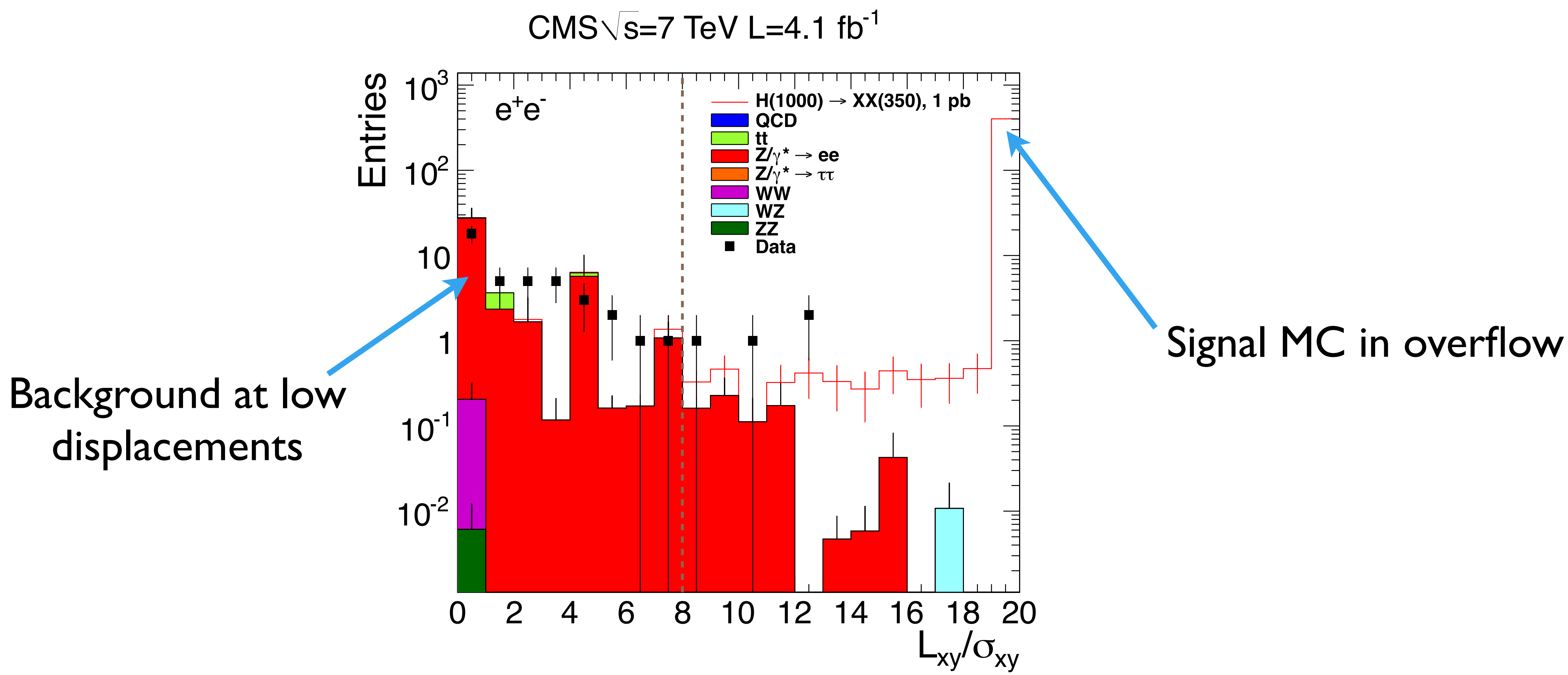
- Selection cuts on dileptons/X candidates
  - ➡ Good vertex fit
    - $\chi^2/NDF < 5$
  - ➡ No more than one tracker hit in front of vertex
  - ➡ Decay length significance (L_{xy}/σ) cut > 5 (muons) > 8 (electrons)
  - ➡ Reconstructed candidate momentum collinear with vertex flight direction
    - $\Delta\Phi$<0.2 (muons) <0.8 (electrons)



Identification of Displaced Vertex

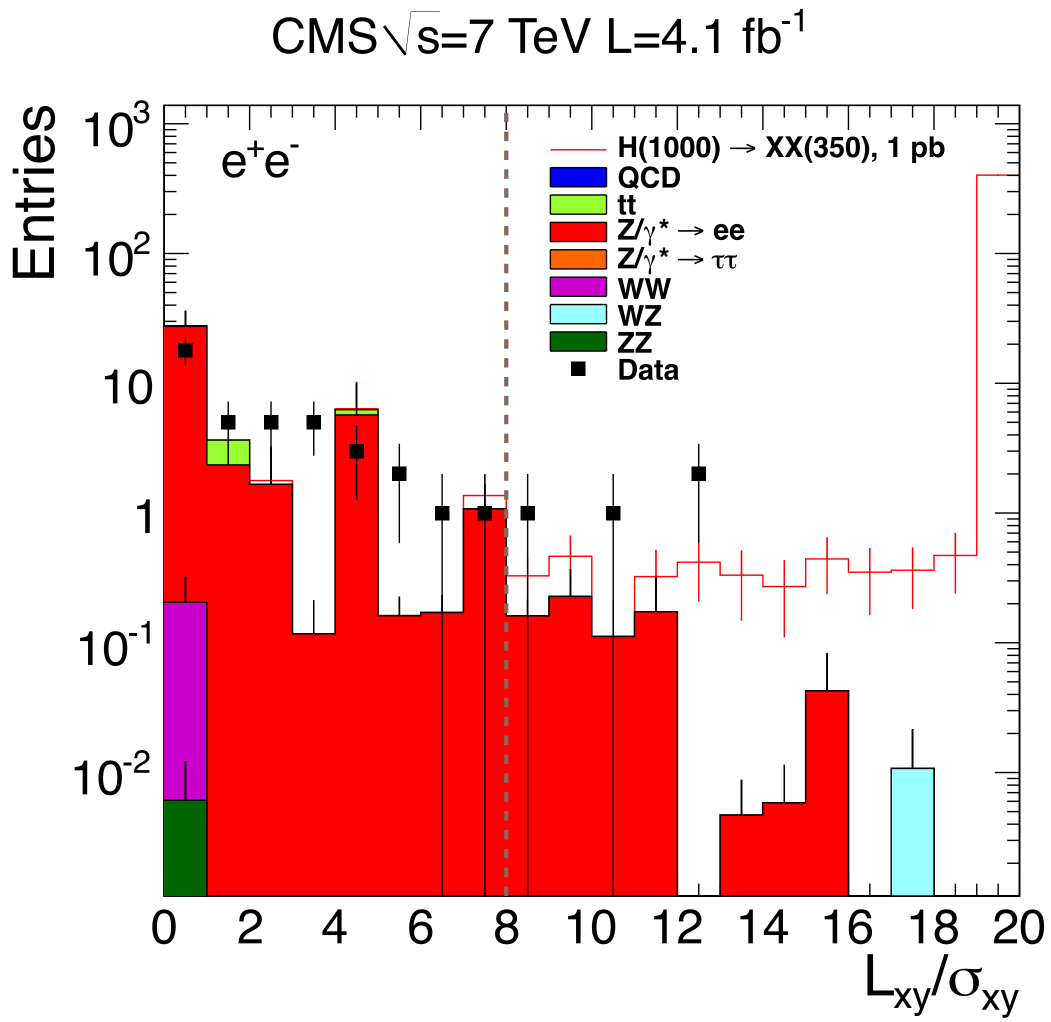
- Select lepton pairs that form a vertex
  - ➡ Our X candidates

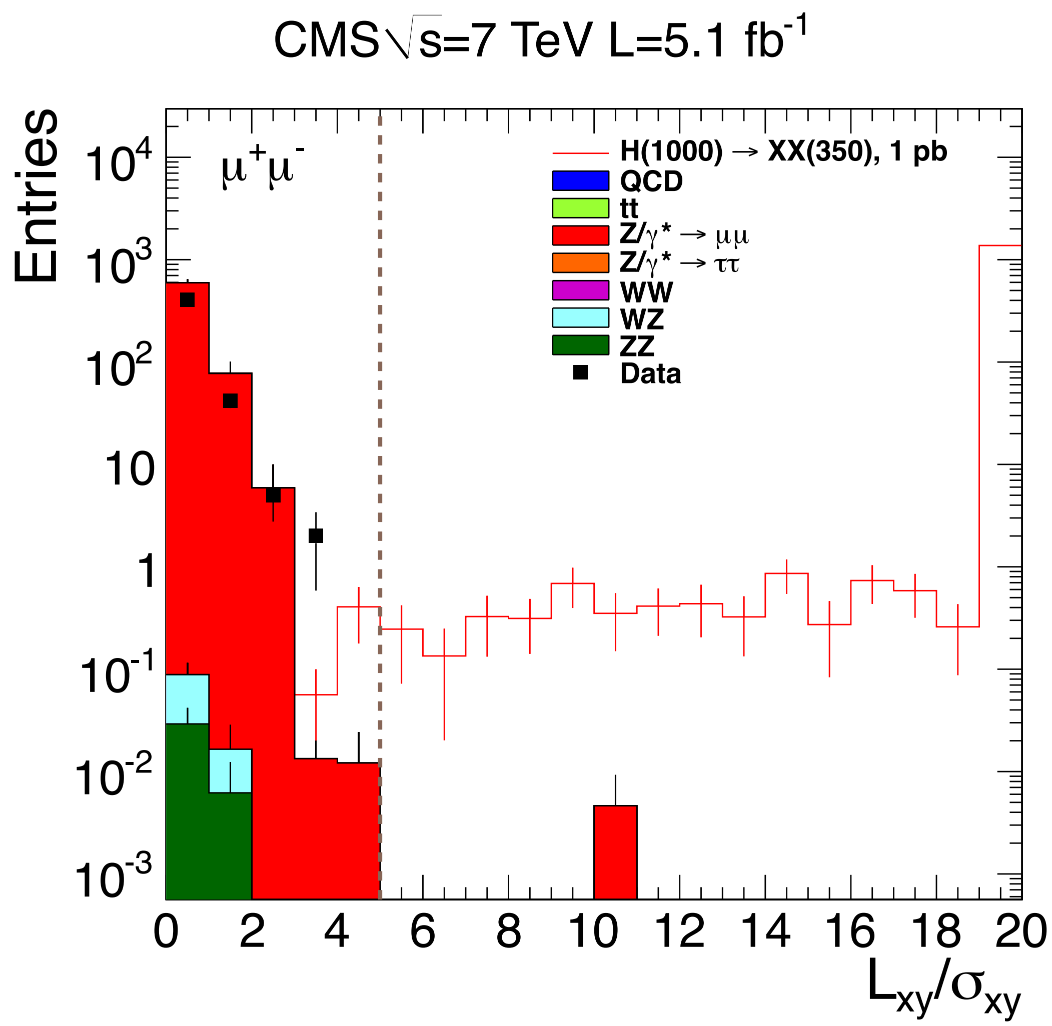
- Require tracks and vertex to be displaced from centre of CMS
  - ➡ Selection makes analysis almost background free



Candidate Selection (II)

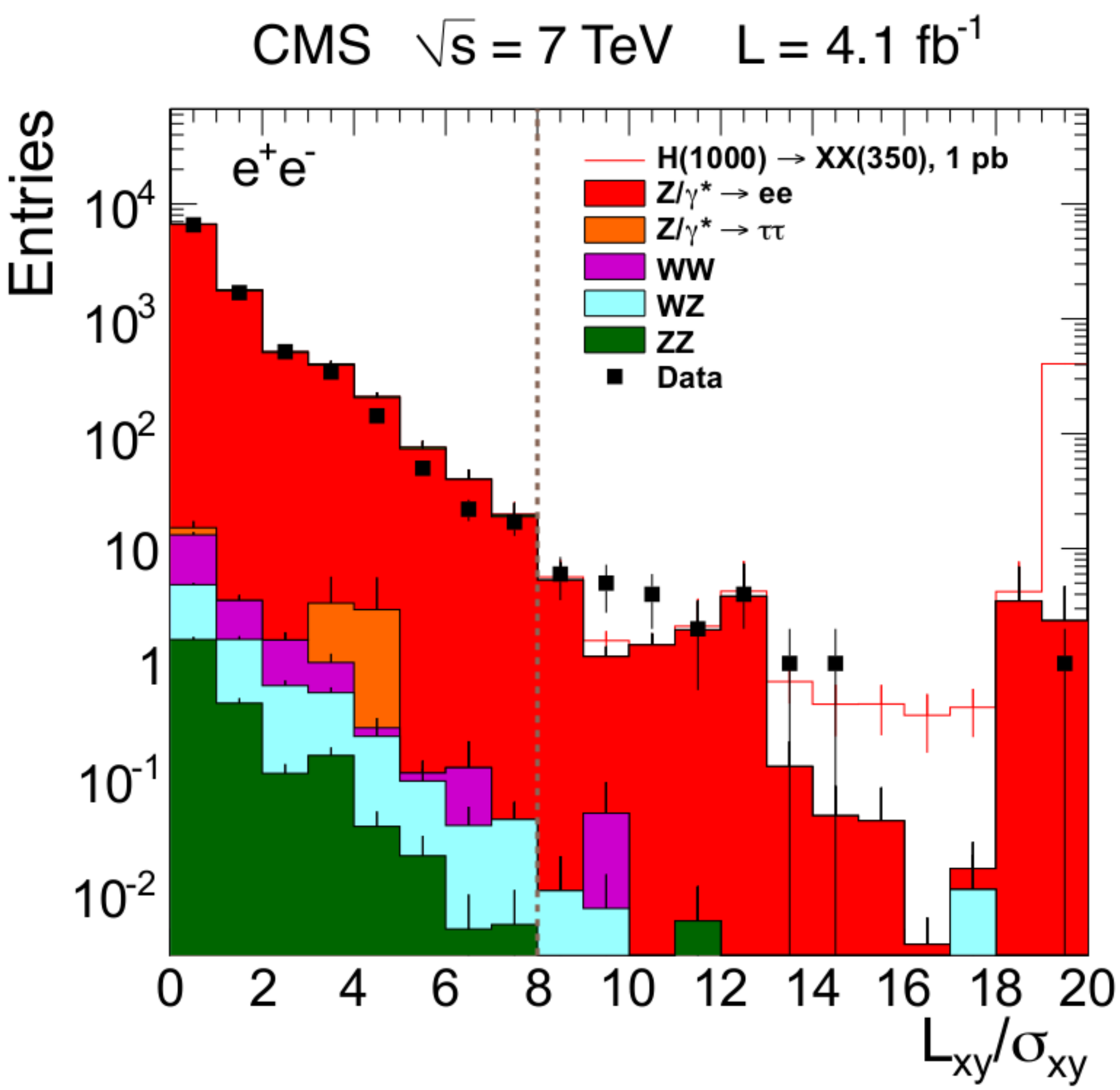
- n-1 selection plot for transverse decay length significance (L_{xy}/sigma)
  - ➡ Good separation of signal from background

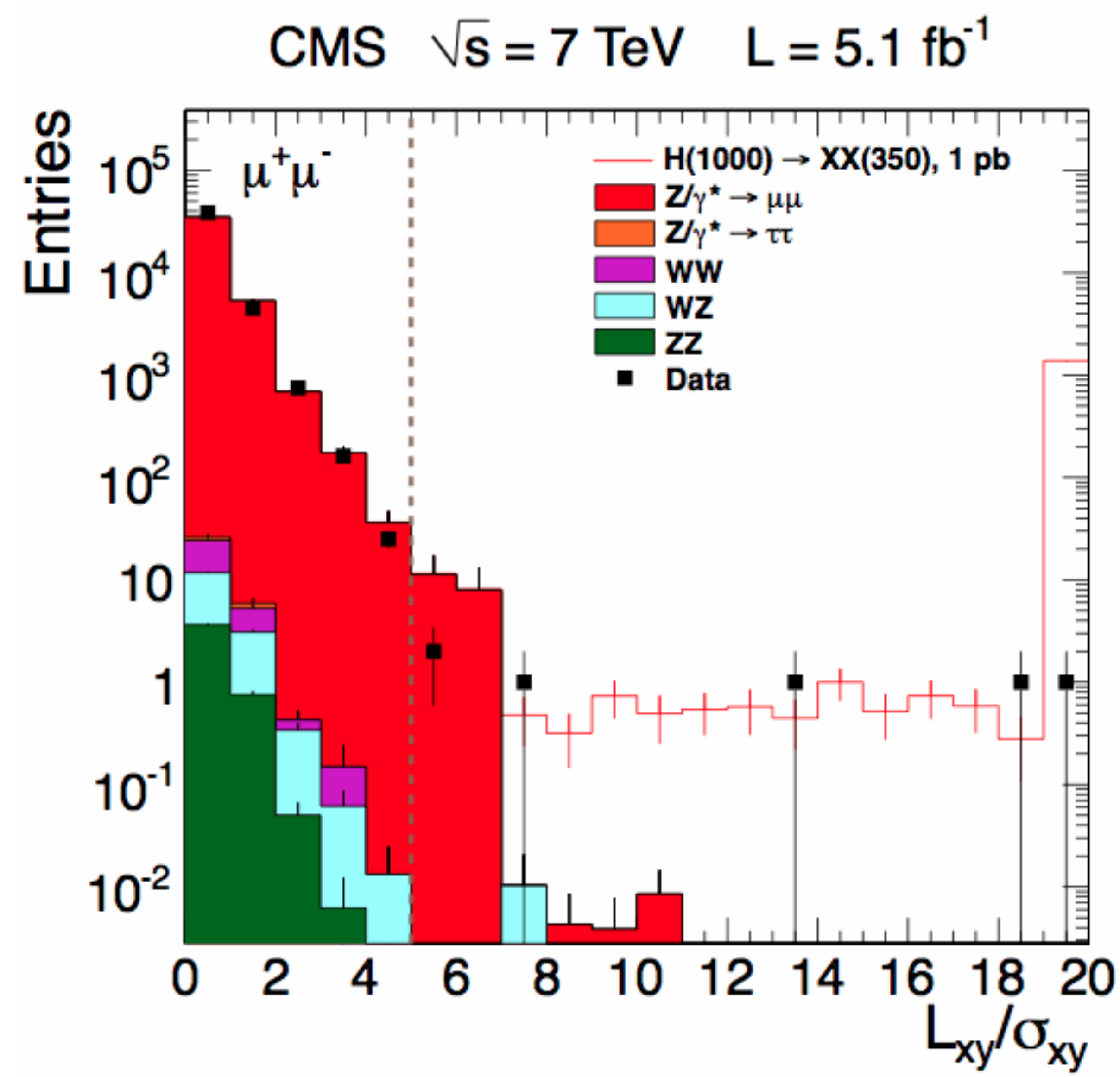




Candidate Selection (III)

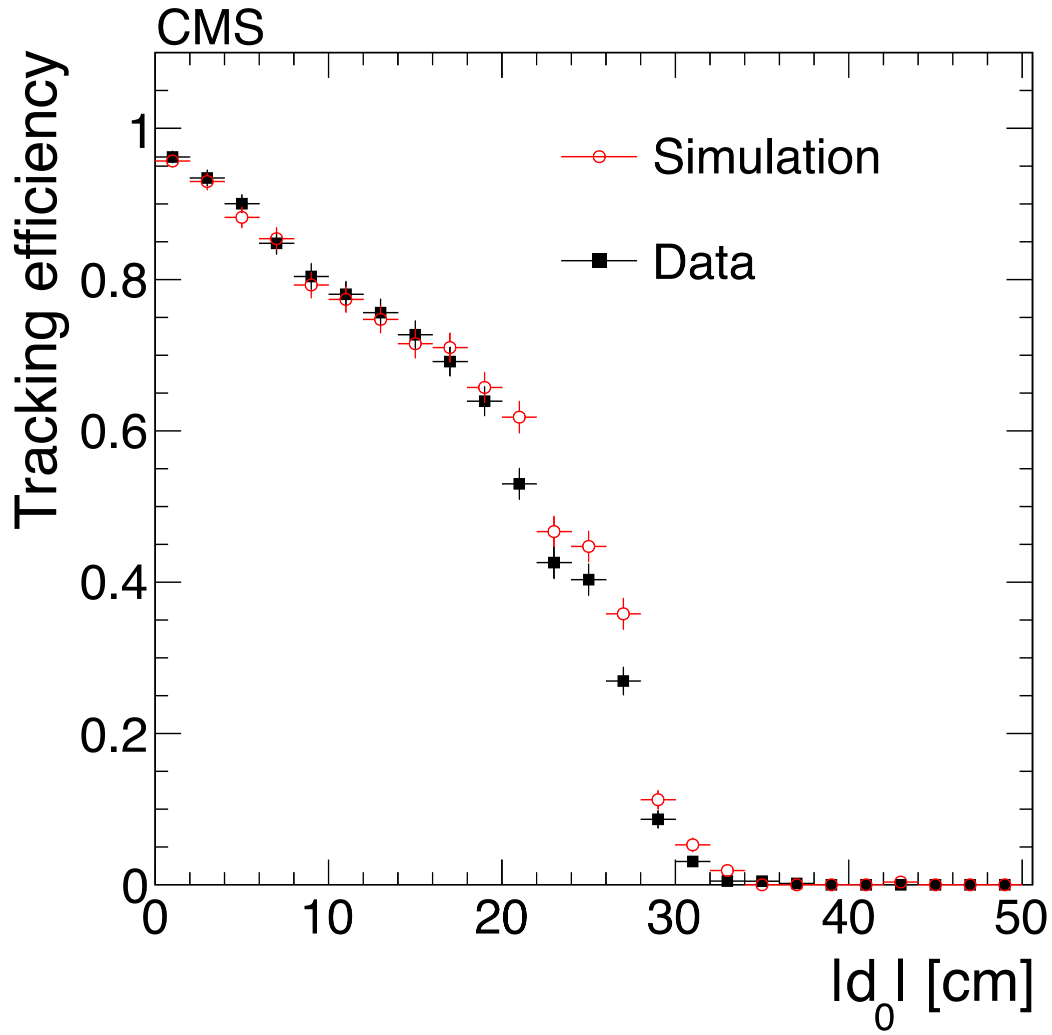
- Can relax some selection to increase statistics
  - ➡ Check agreement between data and background MC





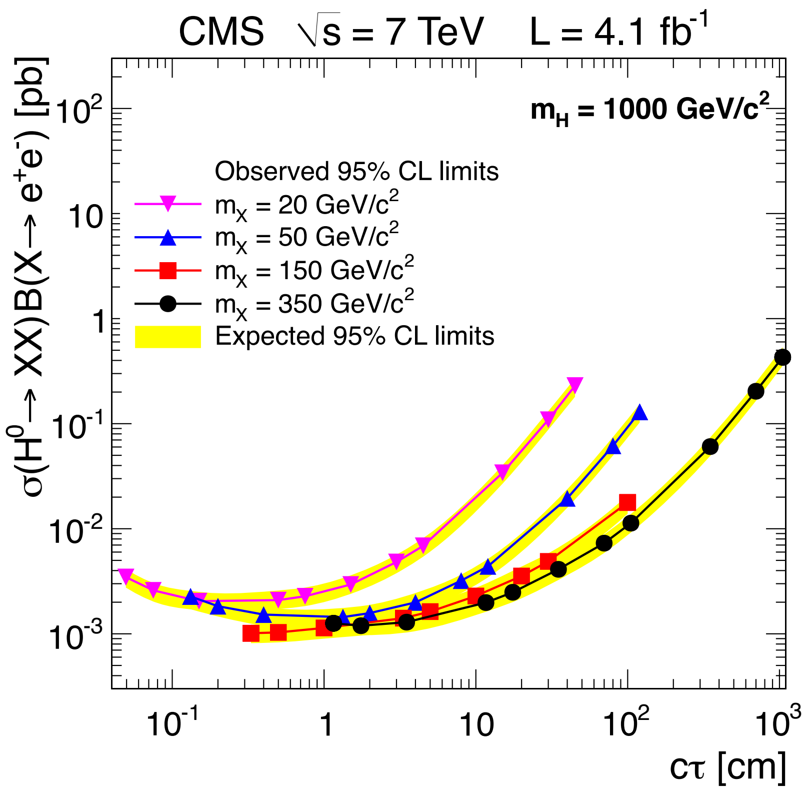
Systematic Uncertainties

- Most crucial systematic uncertainty, how well do we understand tracking efficiency for displaced tracks
  - ➡ Main method to study: use cosmic muons
  - ➡ Cosmic muon leaves a track in the muon systems
  - ➡ Is cosmic also reconstructed in central tracker?
  - ➡ Assign 20% systematic uncertainty to account for disagreement between data and MC

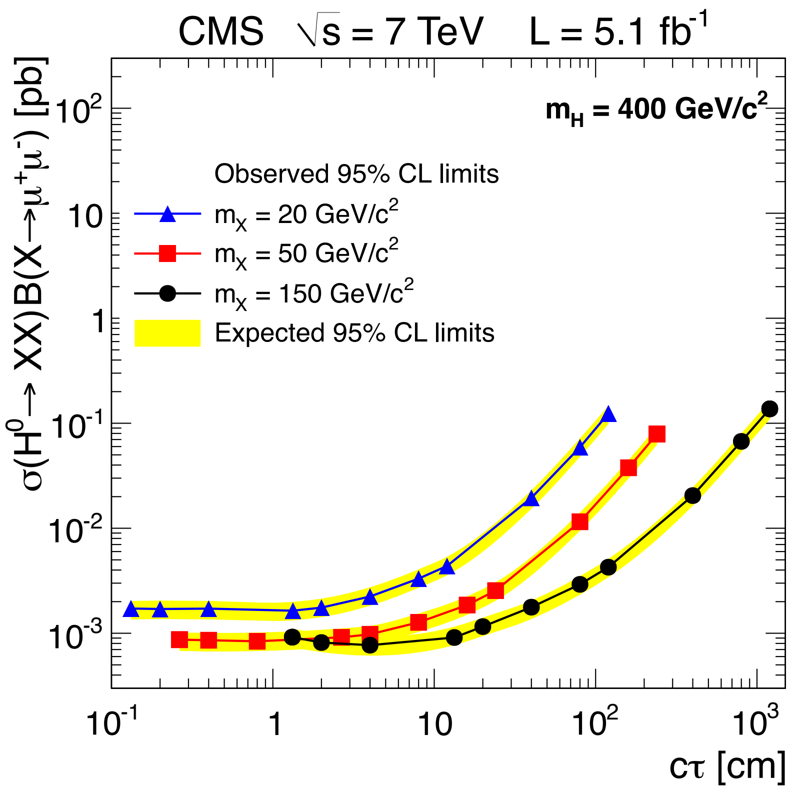


- Trigger Efficiency Uncertainty
  - ➡ Use standard tag & probe
  - ➡ Assign 11% systematic uncertainty in muon channel
  - ➡ Assign 2.6% systematic uncertainty in electron channel

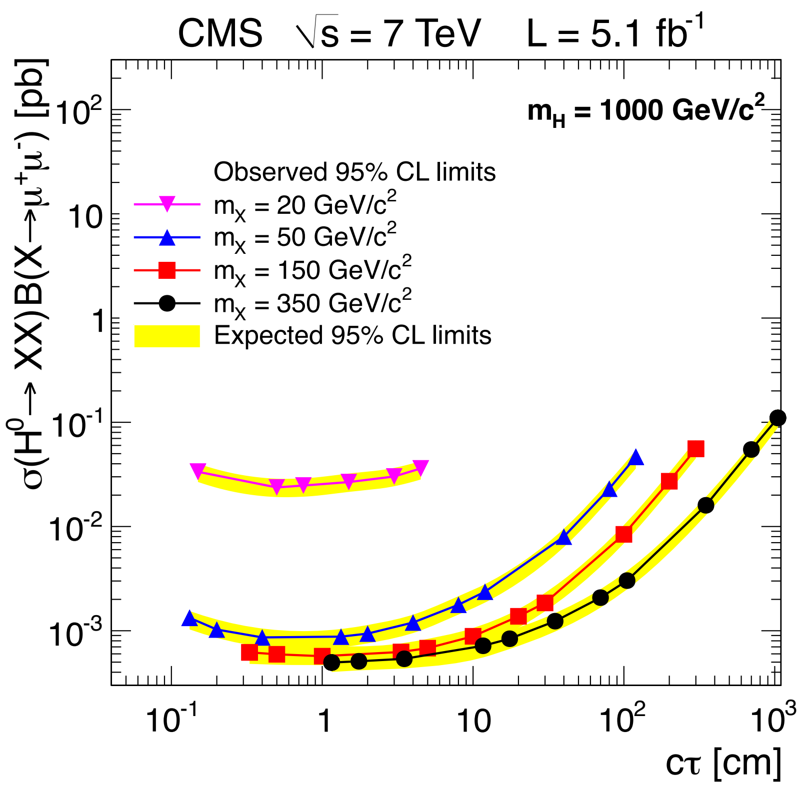
Limits



CMS √s = 7 TeV L = 4.1 fb-1
mH = 1000 GeV/c2
Observed 95% CL limits
mX = 20 GeV/c2
mX = 50 GeV/c2
mX = 150 GeV/c2
mX = 350 GeV/c2
Expected 95% CL limits
σ(H0→ XX)B(X→ e+e-) [pb]
cτ [cm]



CMS √s = 7 TeV L = 5.1 fb-1
mH = 400 GeV/c2
Observed 95% CL limits
mX = 20 GeV/c2
mX = 50 GeV/c2
mX = 150 GeV/c2
Expected 95% CL limits
σ(H0→ XX)B(X→μ+μ-) [pb]
cτ [cm]



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mH = 1000 GeV/c2
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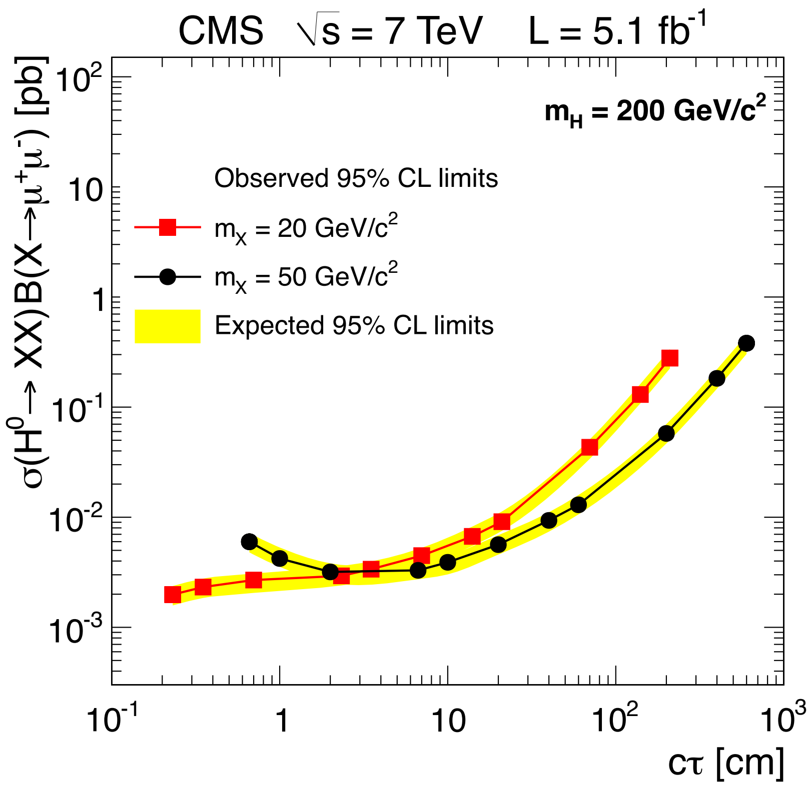

CMS √s = 7 TeV L = 5.1 fb-1
mH = 200 GeV/c2
Observed 95% CL limits
mX = 20 GeV/c2
mX = 50 GeV/c2
Expected 95% CL limits
σ(H0→ XX)B(X→μ+μ-) [pb]
cτ [cm]