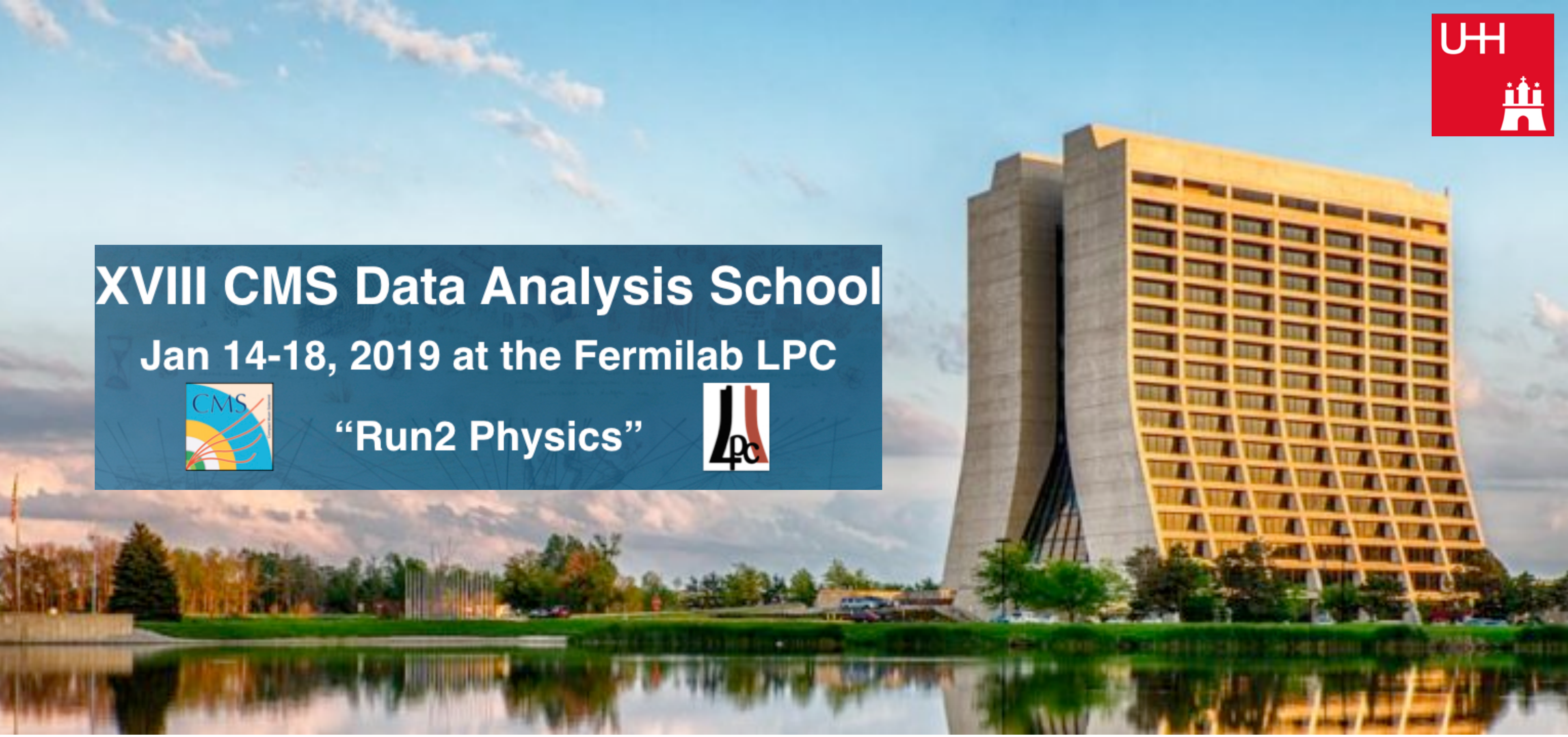


Long Exercise: Search for SUSY with disappearing tracks

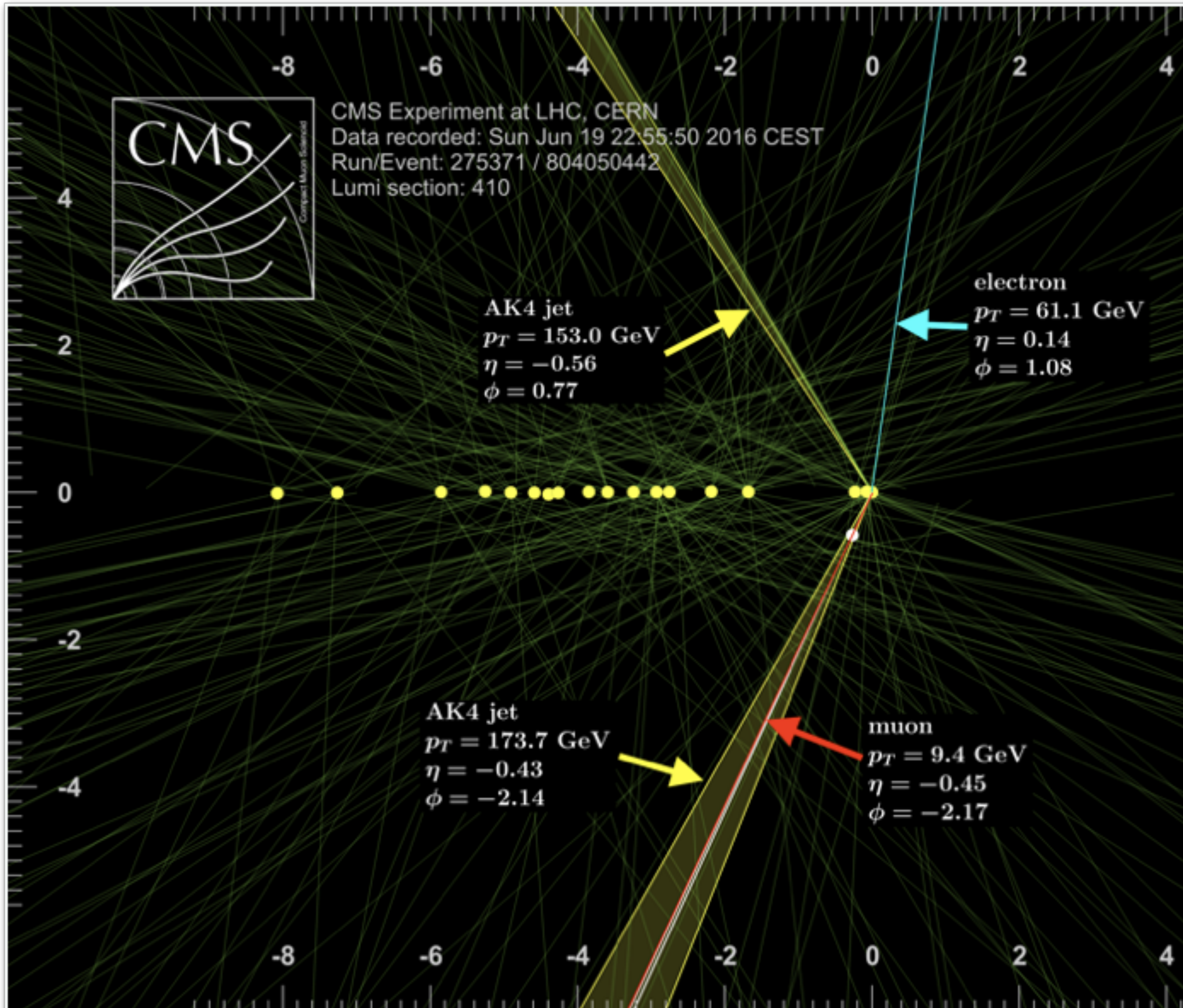
Jan 16 2019

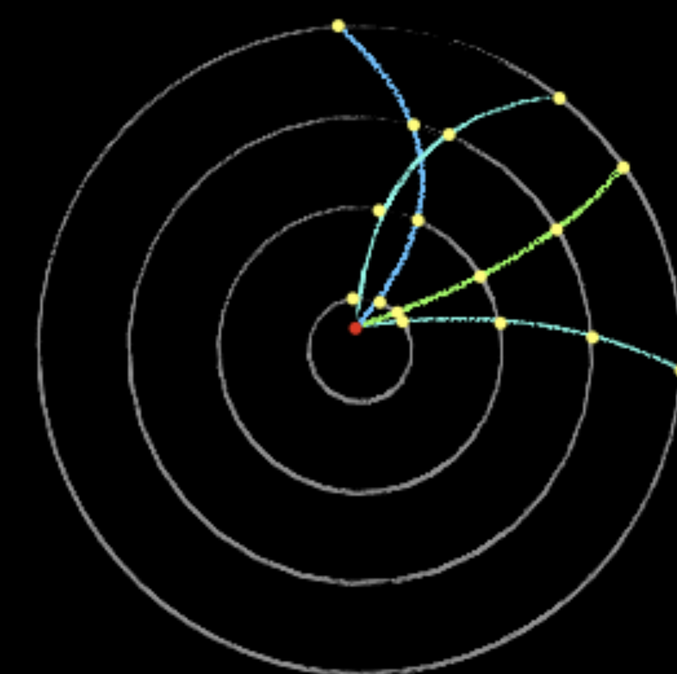
Sam Bein, Viktor Kutzner, Sezen Sekmen, Loukas Gouskos, Colin Fallon, Caleb Smith, Zhenbin Wu

Structure

1. **Introduction to tracking**
2. Search for disappearing tracks
    1. track tag
    2. signal region selection
    3. prompt background estimation
    4. non-prompt background estimation
    5. limit estimation

Tracking at CMS





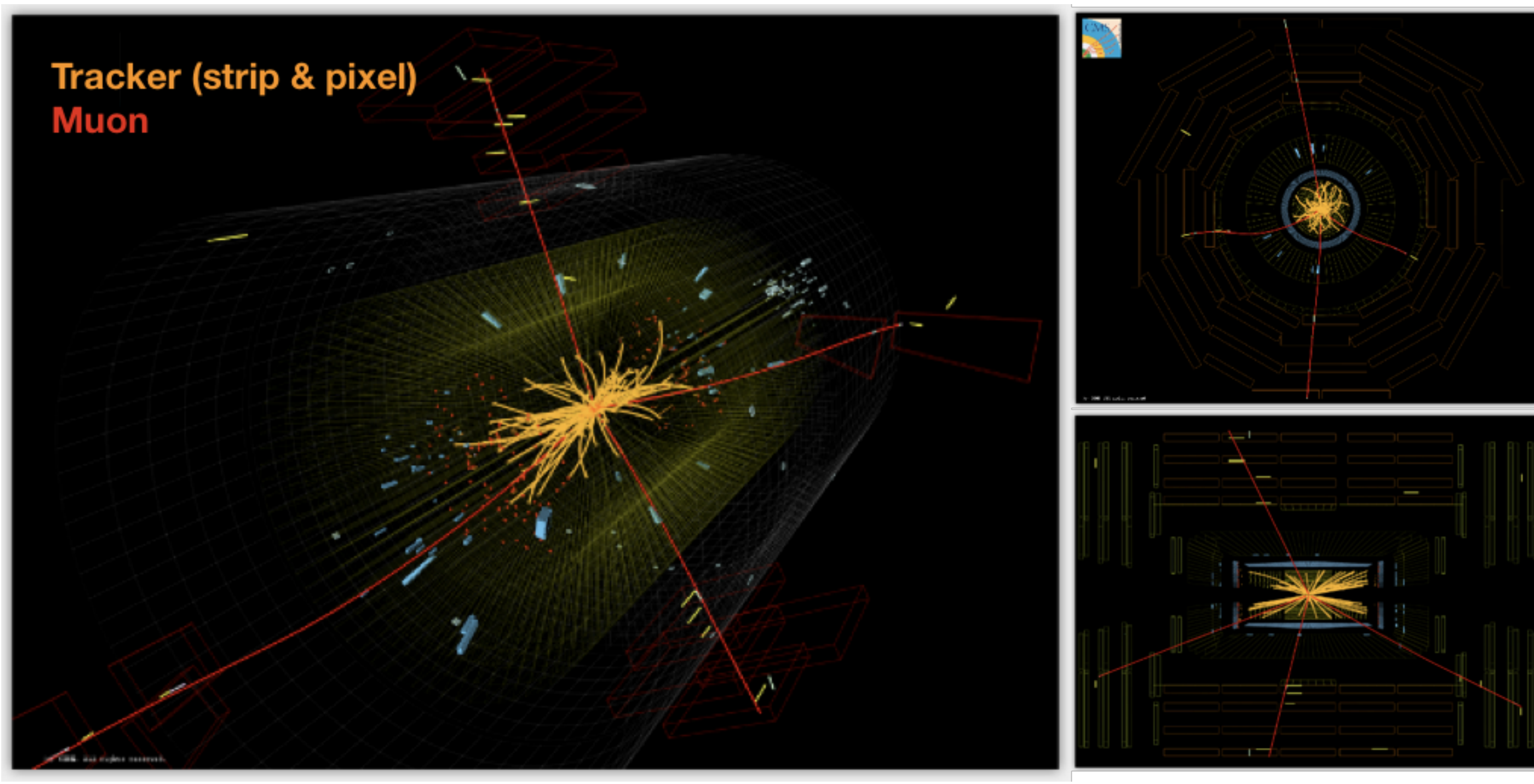
Measure hits

Reconstruct tracks

- Find single particles
- Measure momenta
- Identify particles

Reconstruct vertices

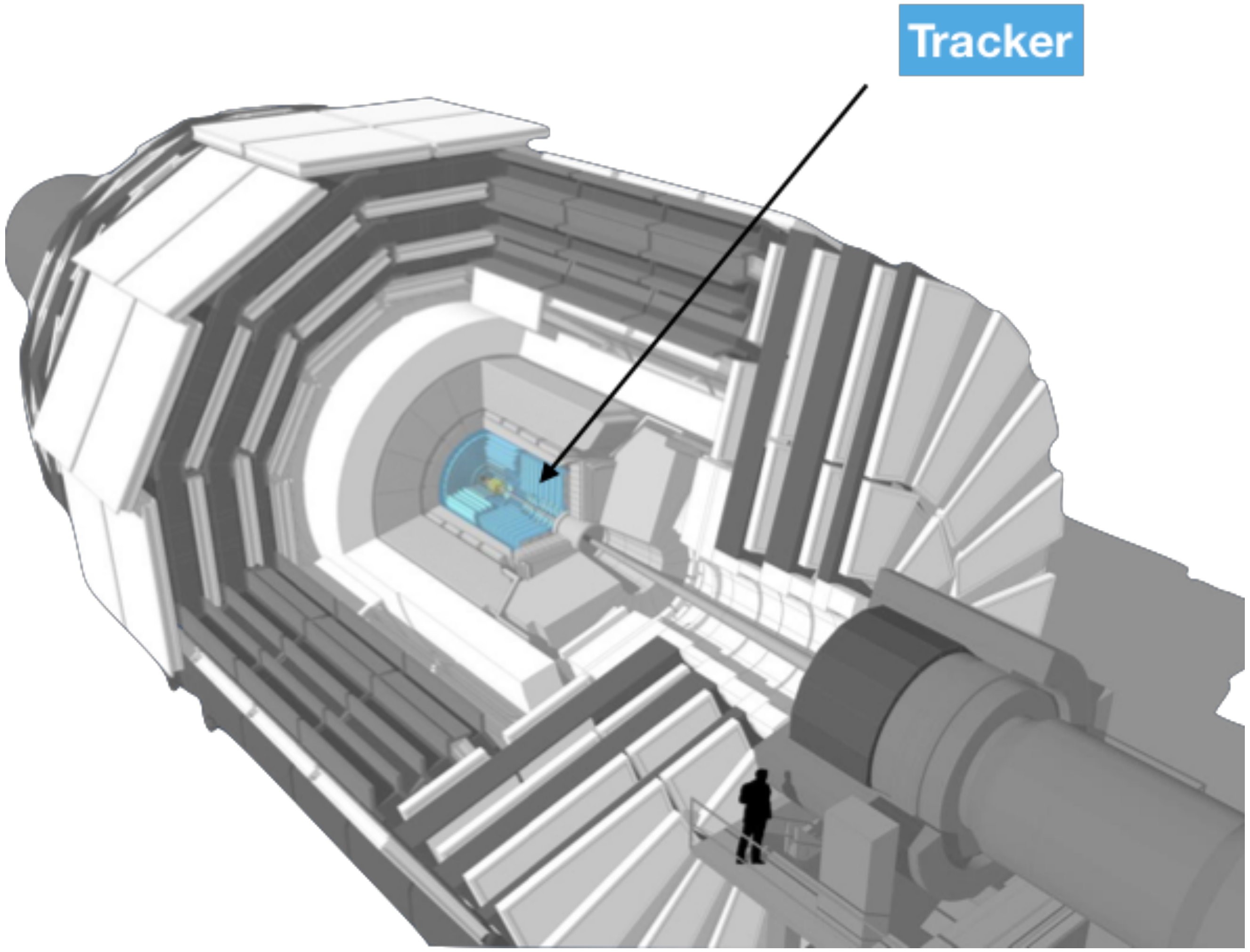
Tracking components



CMS tracker

Position information from finely segmented silicon sensors:

- record the path of charged particles
- measure momentum from bending radius in a magnetic field
- reconstruct primary and secondary vertices



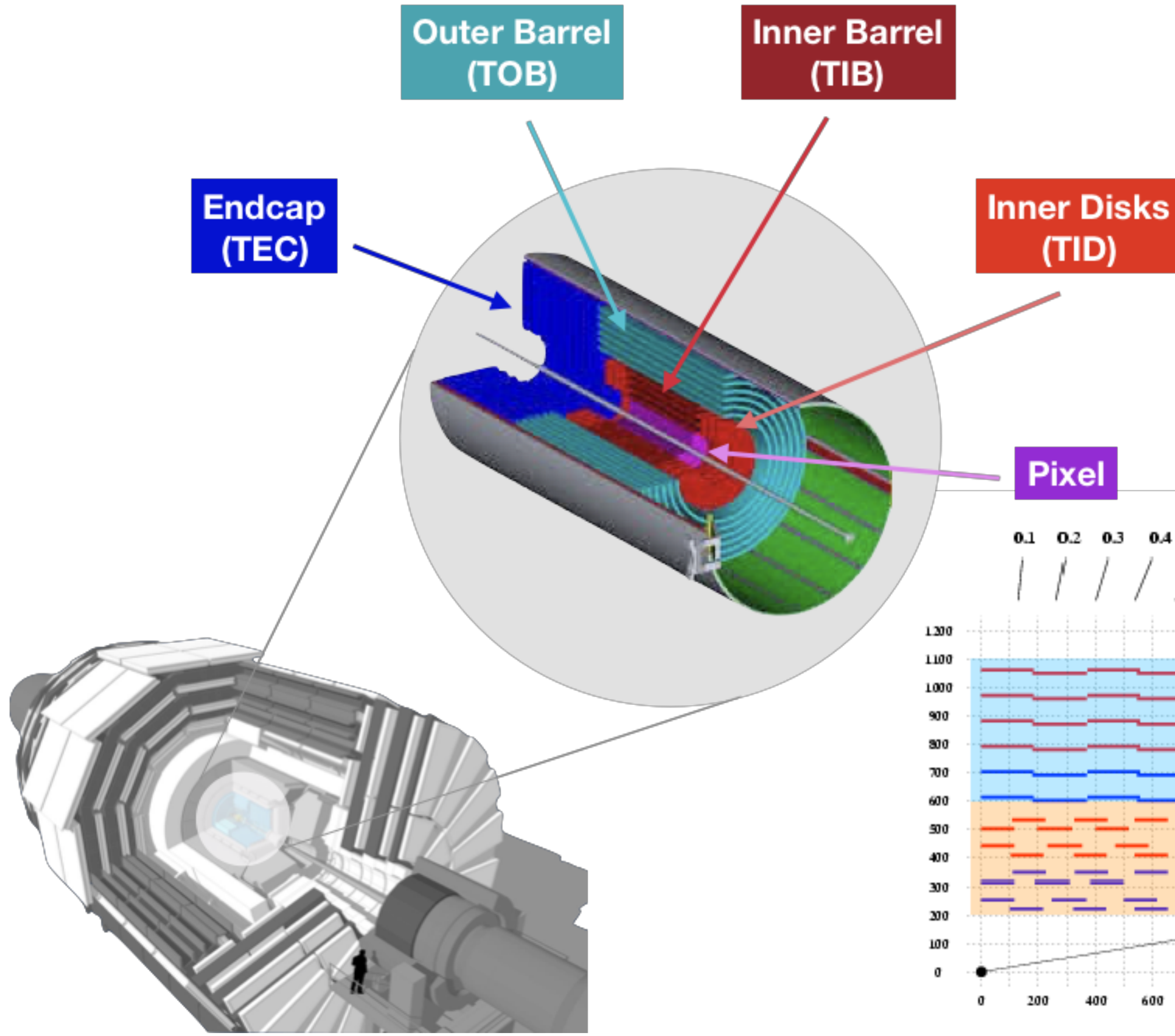
Requirements:

- High resolution & low occupancy: Resolve and isolate individual tracks, reconstruct vertices. Finer granularity is needed closer to the IP: High particle density, small tracking volume
- High rate capability: Fast charge collection time and read-out electronics to keep up with the expected event rates
- Low material budget: Minimal multiple scattering
- Radiation hardness: Innermost subdetectors, receive highest particle fluence

CMS tracker: Silicon strips

10 million strips

8 - 14 hits per track



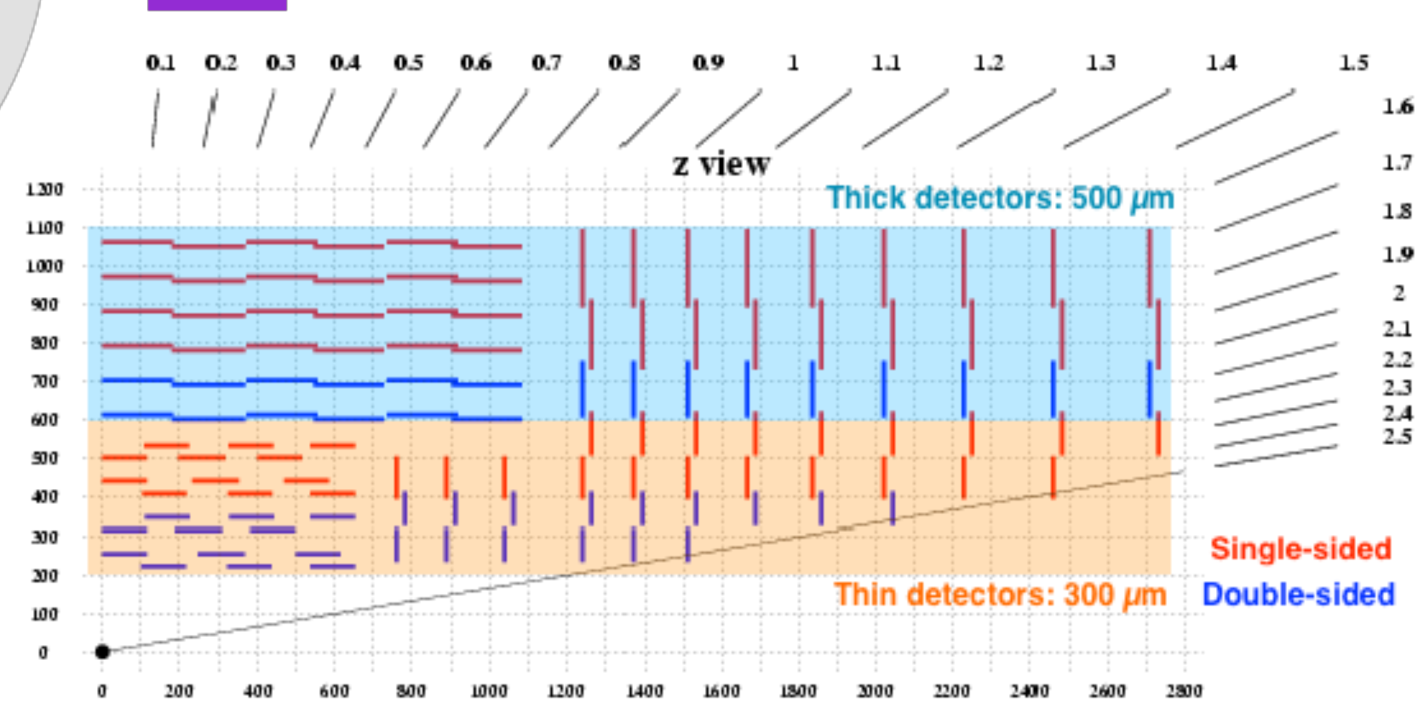
Layers:

- inner Barrel (TIB): 4
- inner Disks (TID): 3
- outer Barrel (TOB): 6
- endcap (TEC): 9

Many layers: Redundancy

Occupancy: 1 - 3%

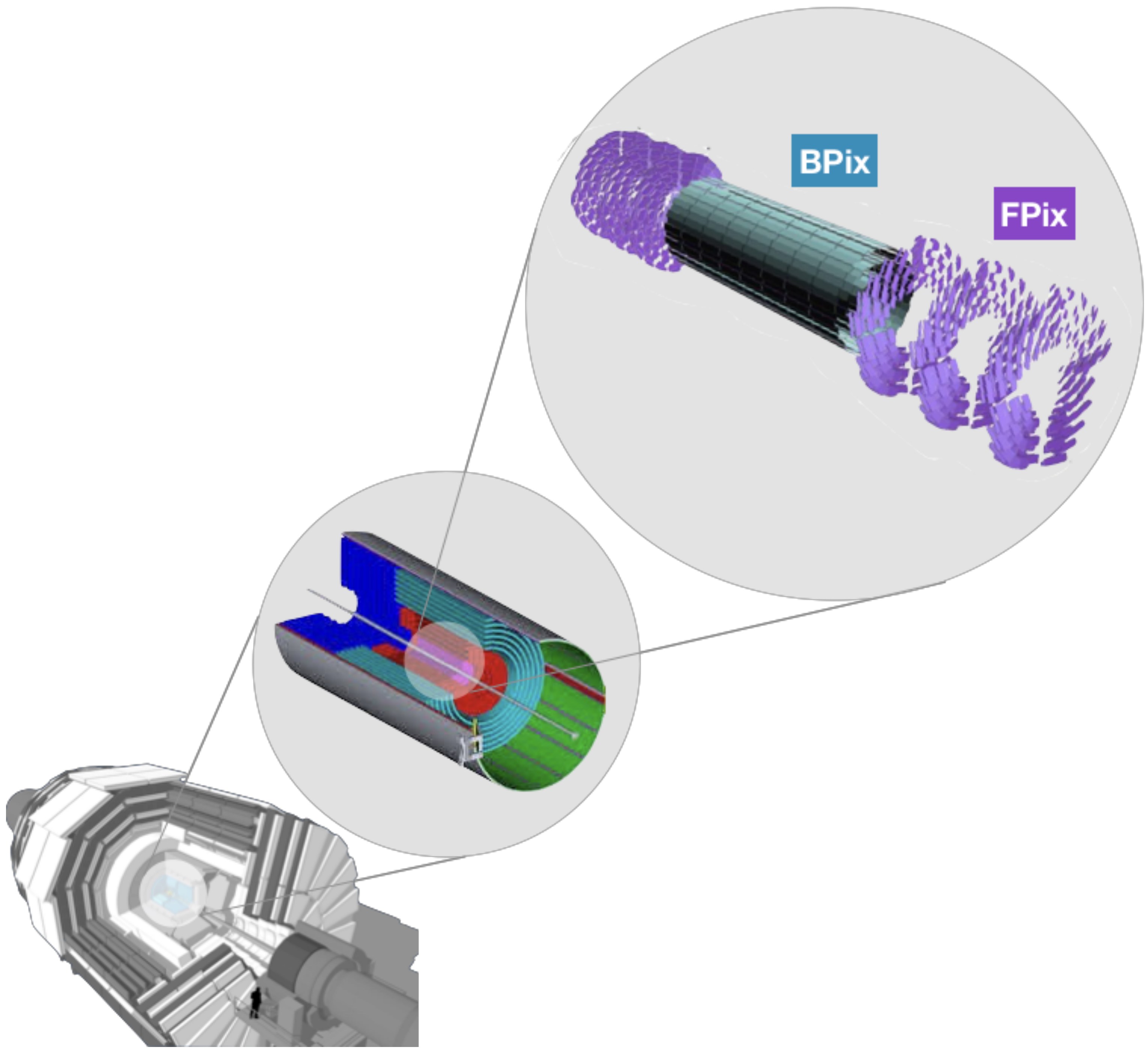
Resolve and isolate tracks



CMS tracker: Silicon pixel

127 million pixels, 100 x 150 μm^2 in size

4-hit coverage up to $|\eta| = 2.5$



Layer position [cm]:

- BPix: 2.9, 6.8, 10.9, 16.0
- FPix: 29.1, 39.6, 51.6

Low occupancy: 10^{-3}

High segmentation:

- High quality seeds for offline tracking (>95% efficiency)

Fast online tracking (HLT):

- vertex reconstruction
- e / γ identification
- muon reconstruction
- tau identification
- b-tagging

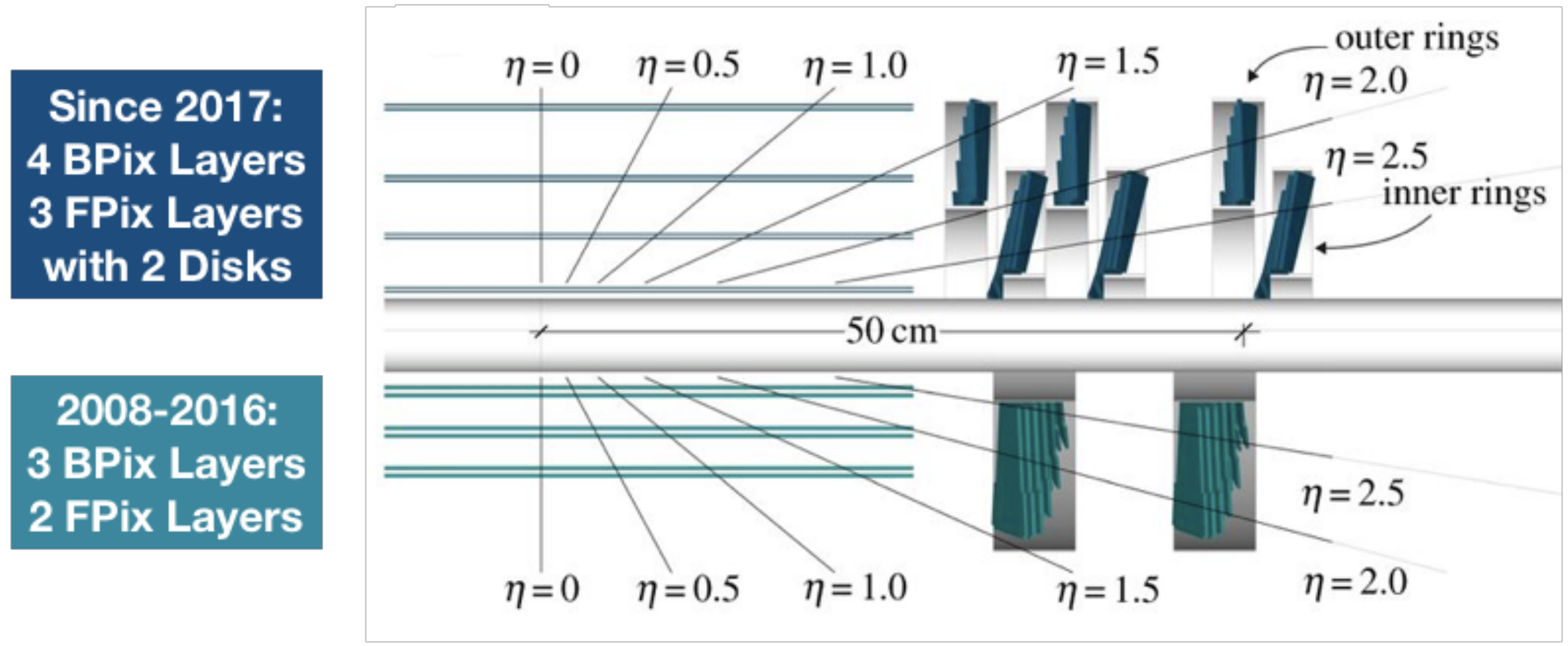
CMS tracker: pixel upgrade

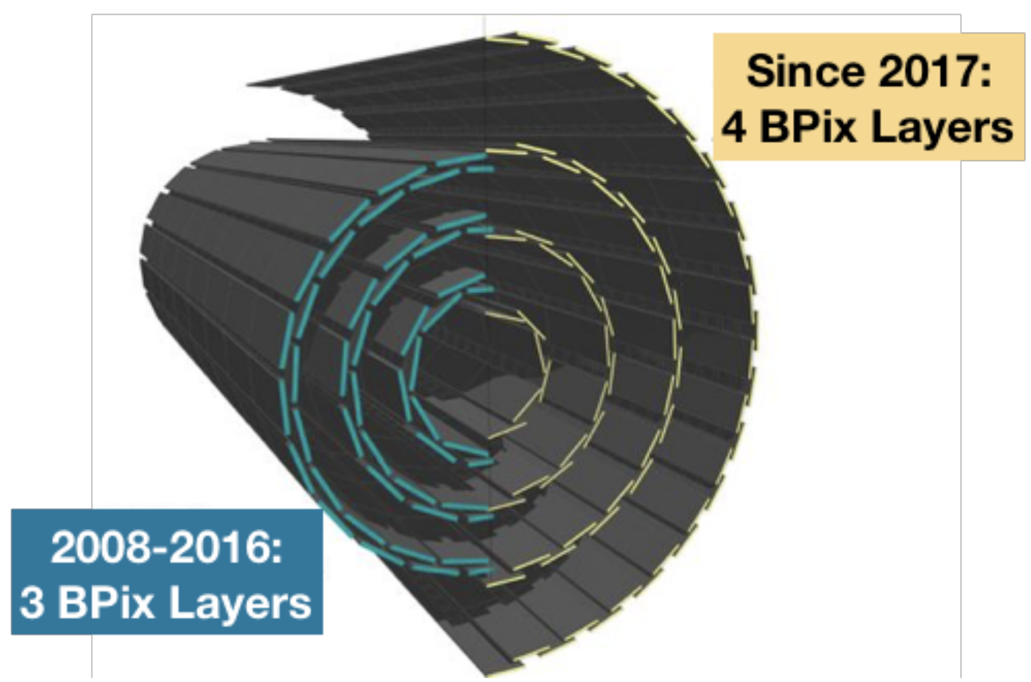
one additional tracking point, in both barrel and forward regions:
⇒ 4-hit seeds

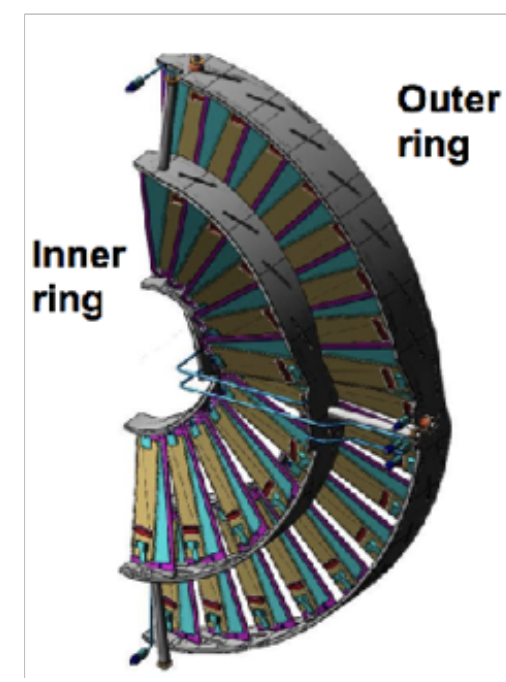
⇒ lower fake rate!

smaller radius of the innermost pixel layer
⇒ closer to the interaction region
⇒ Improved track reconstruction

reduced material budget
⇒ reduce multiple scattering





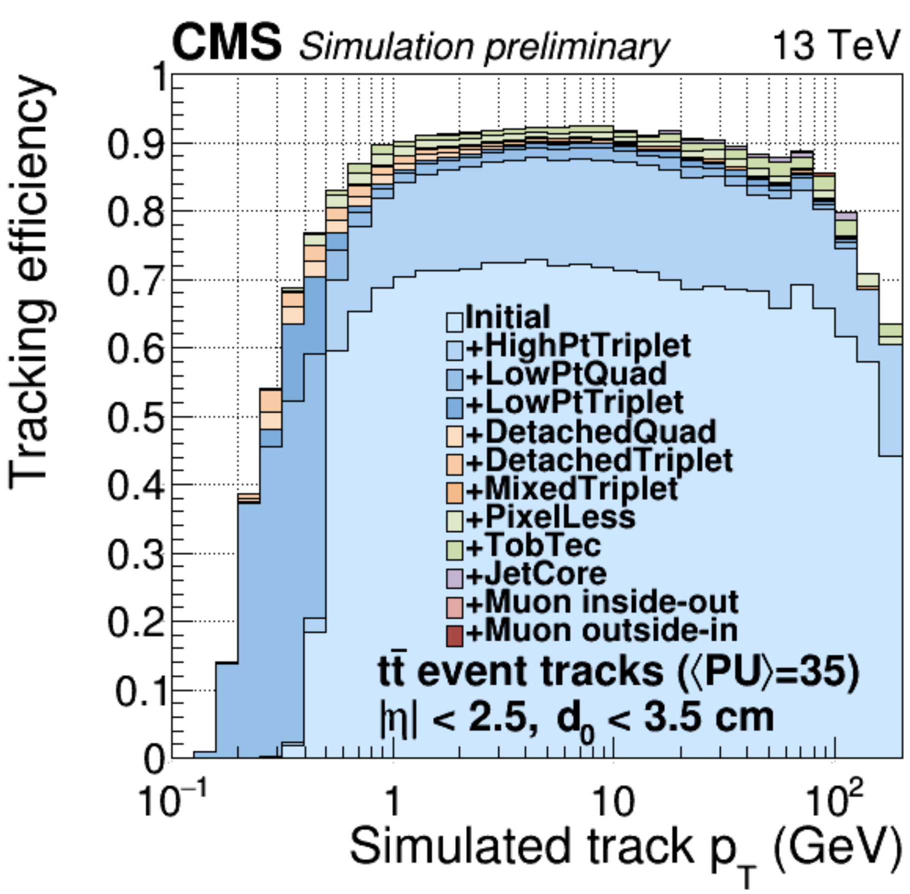


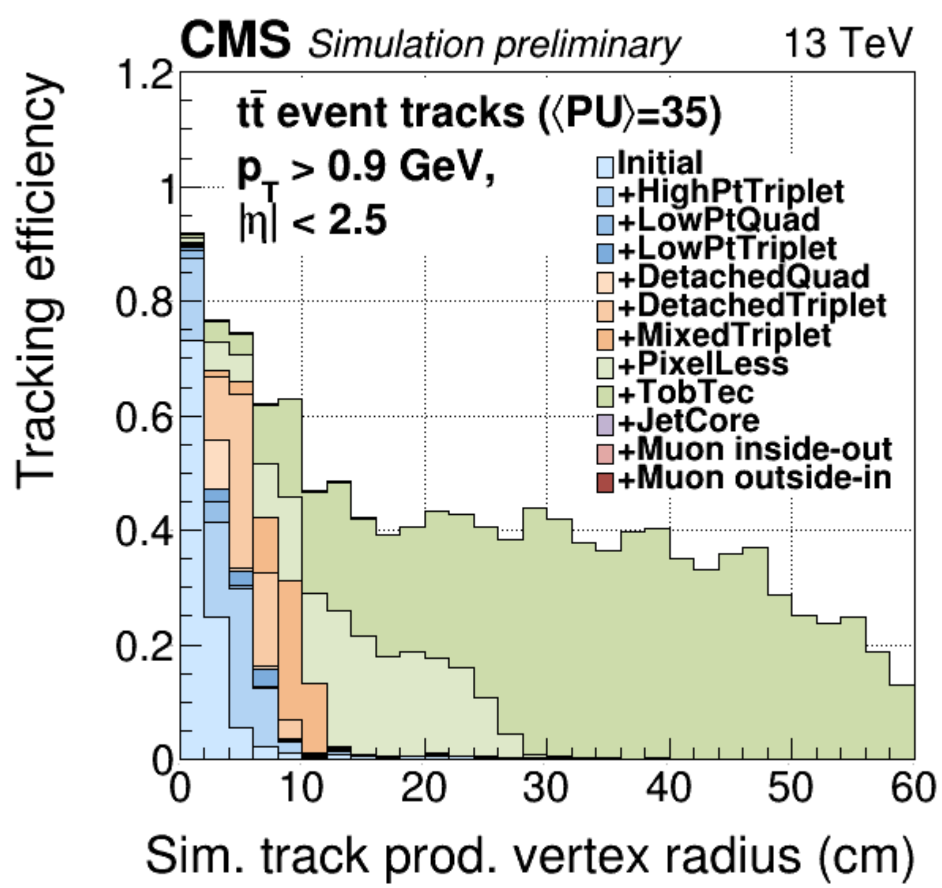
Iterative tracking

In CMS, tracks reconstruction is an iterative procedure: High-quality tracks are reconstructed, their hits are removed, and other tracks are reconstructed from the remaining hits.

In the InitialStep, high-p_T quadruplets coming from the beam spot region are used.

Subsequent steps use triplets, or improve the acceptance either in p_T or displacement.



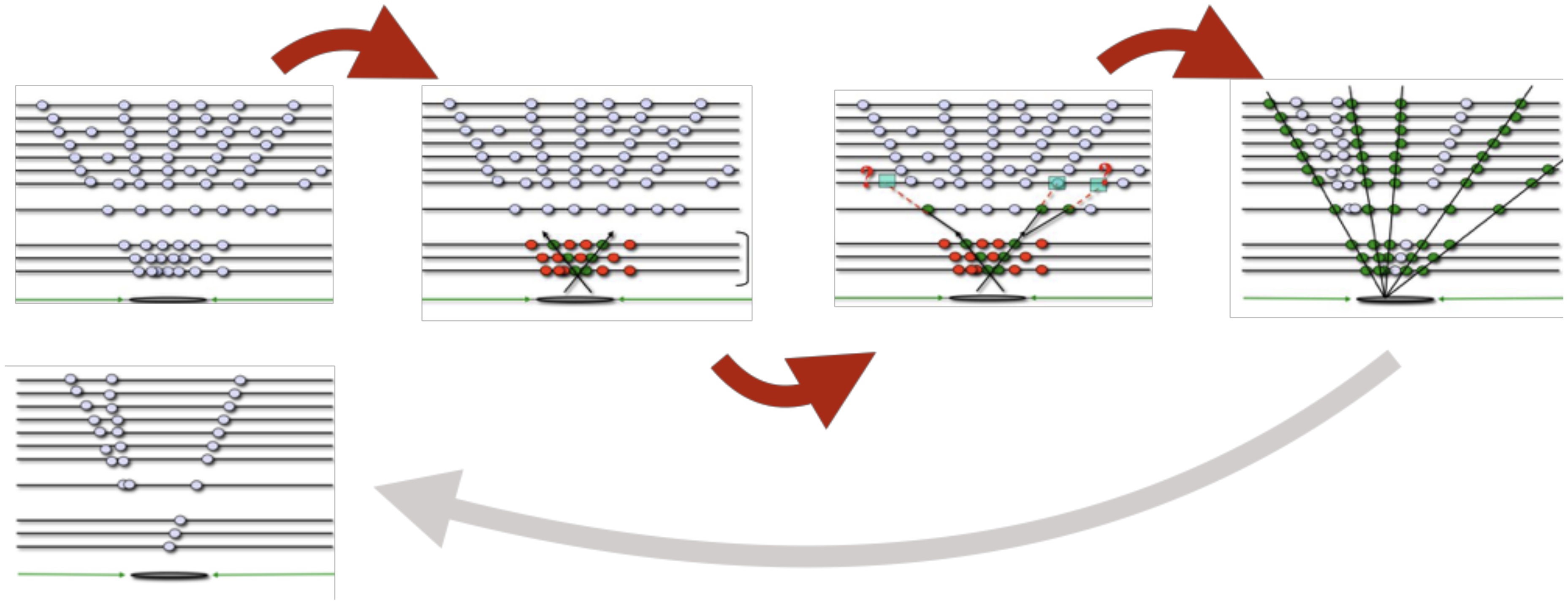


The later steps use seeds with hits from the strip detector to find detached tracks, e.g. from LLPs.

Tracking at CMS

In each iteration, tracks are reconstructed in four steps:

1. **Seeding:** Provides track candidates, with an initial estimate of the trajectory parameters and their uncertainties.
2. **Pattern recognition:** Track candidates are propagated to find new compatible hits. Track parameters are updated.
3. **Final fitting:** Provides the best estimate of the parameters of each smooth trajectory, after combining all associated hits.
4. **Selection:** Sets quality flags based on the fit χ^2 and the track compatibility with interaction region. Aims to reject fake tracks.



Tracking at CMS

First part of the exercise:

- extract basic track parameters
- reconstruct invariant masses from tracks

Structure

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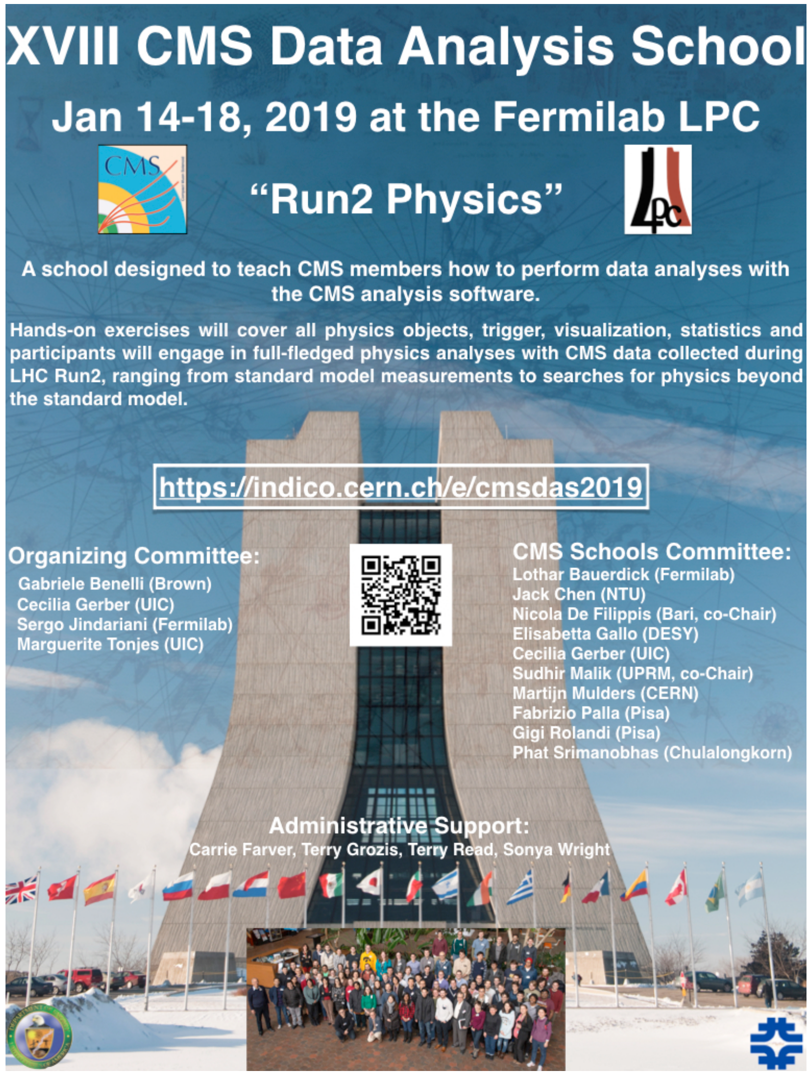
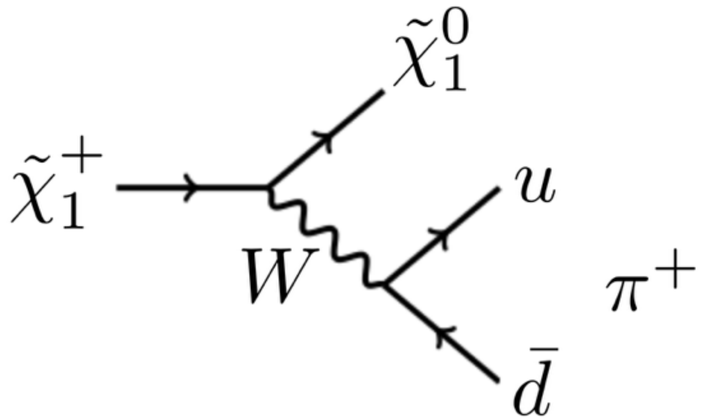


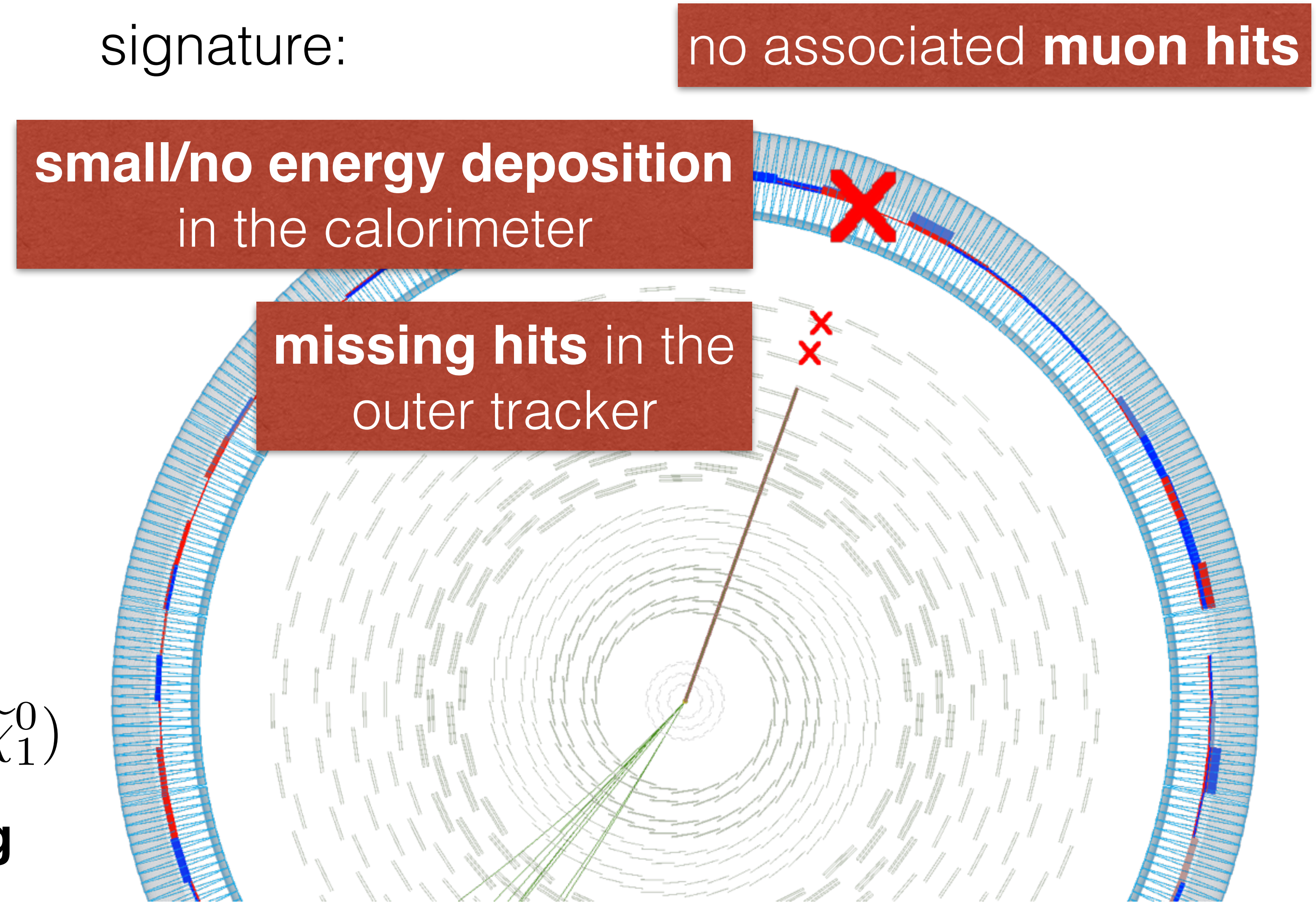
Search strategy



- pion: too soft to be reconstructed

mass splitting: $\Delta m = m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)$

- $m_\pi < \Delta m \lessapprox 200$ MeV: **disappearing track visible in tracker**
- $\Delta m \gtrapprox 200$ MeV: decay before first tracking layer

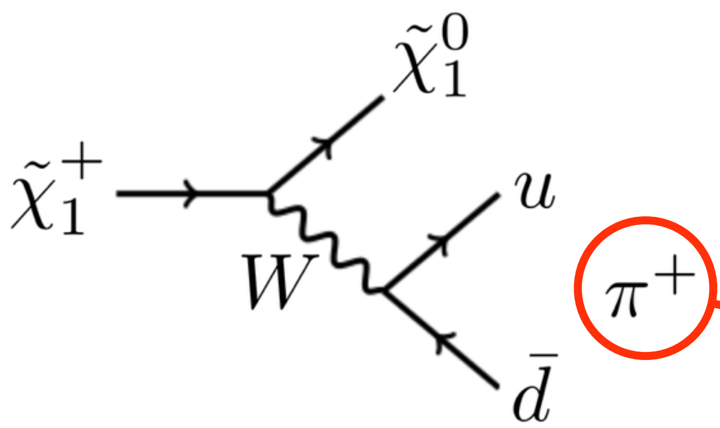


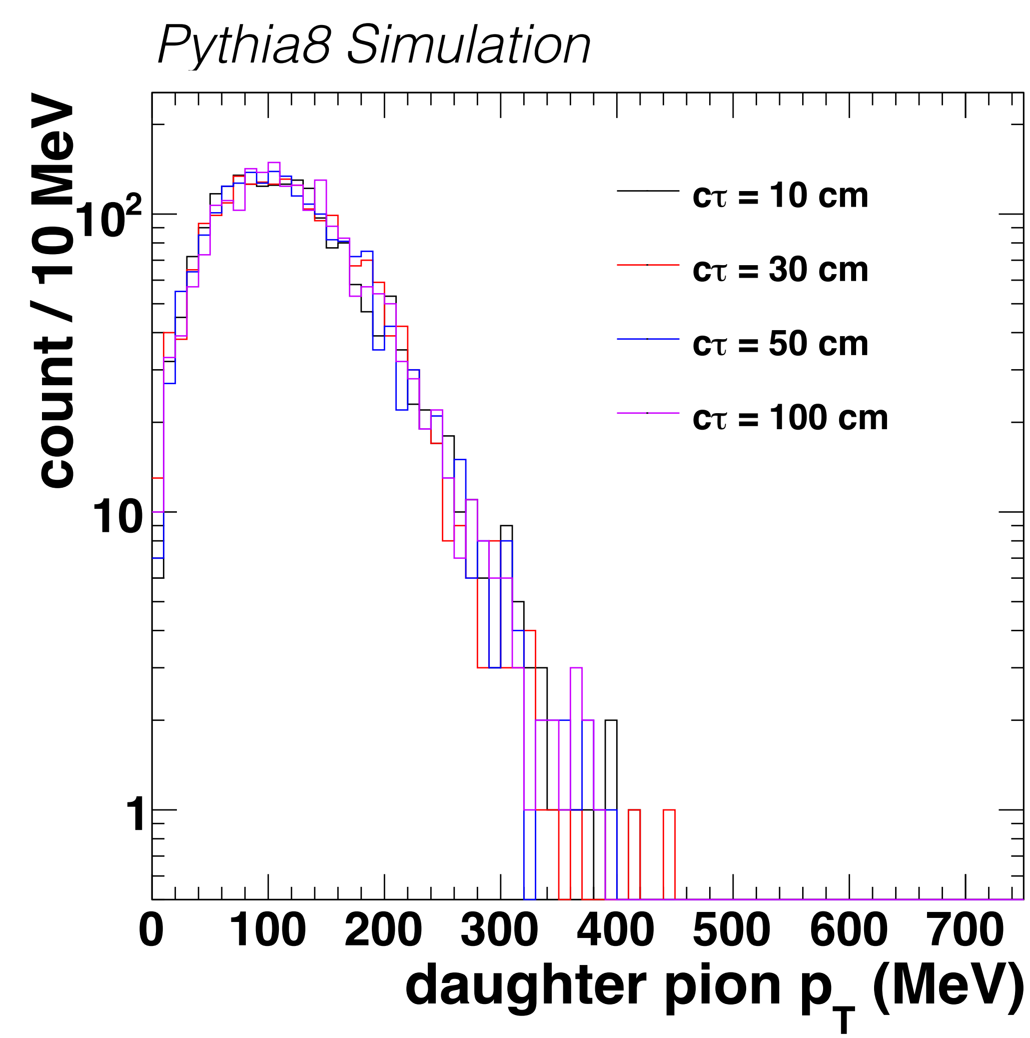
need to suppress background from

- fake tracks
- tracks from failed lepton reconstruction

Illustration: Andrew Hart et al. (OSU)

Search strategy





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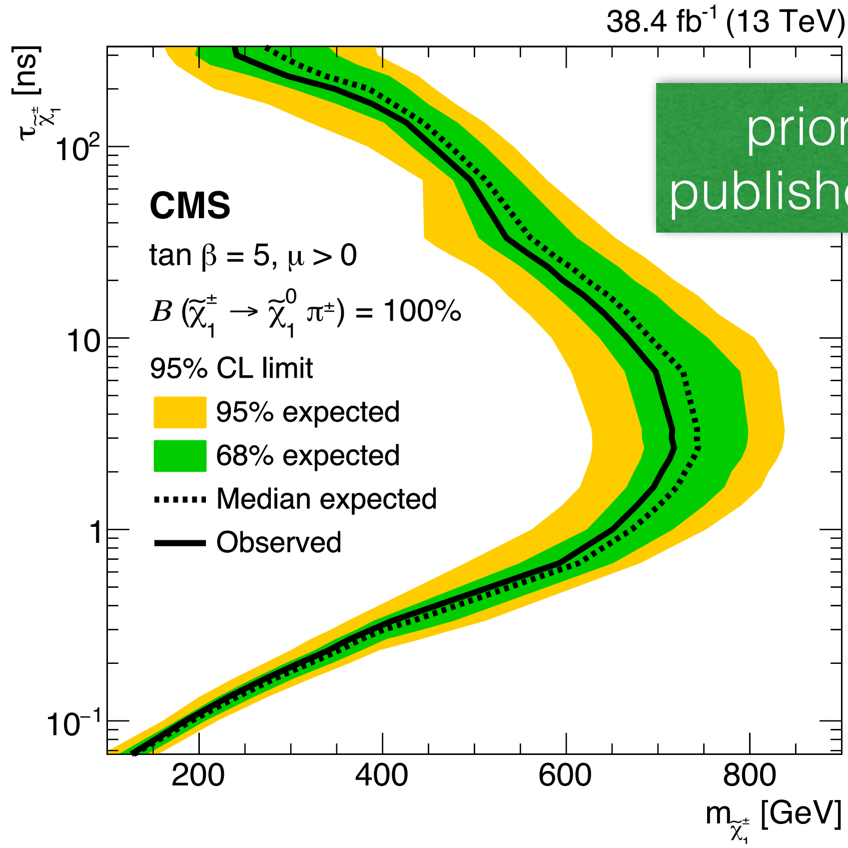
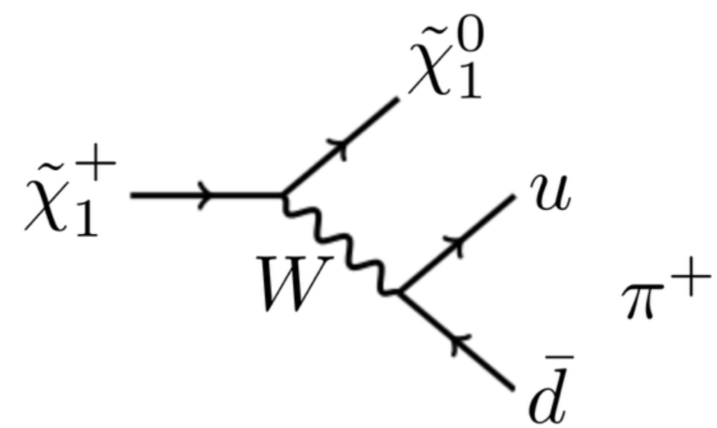
Disappearing track signal

JHEP



prior search published in JHEP

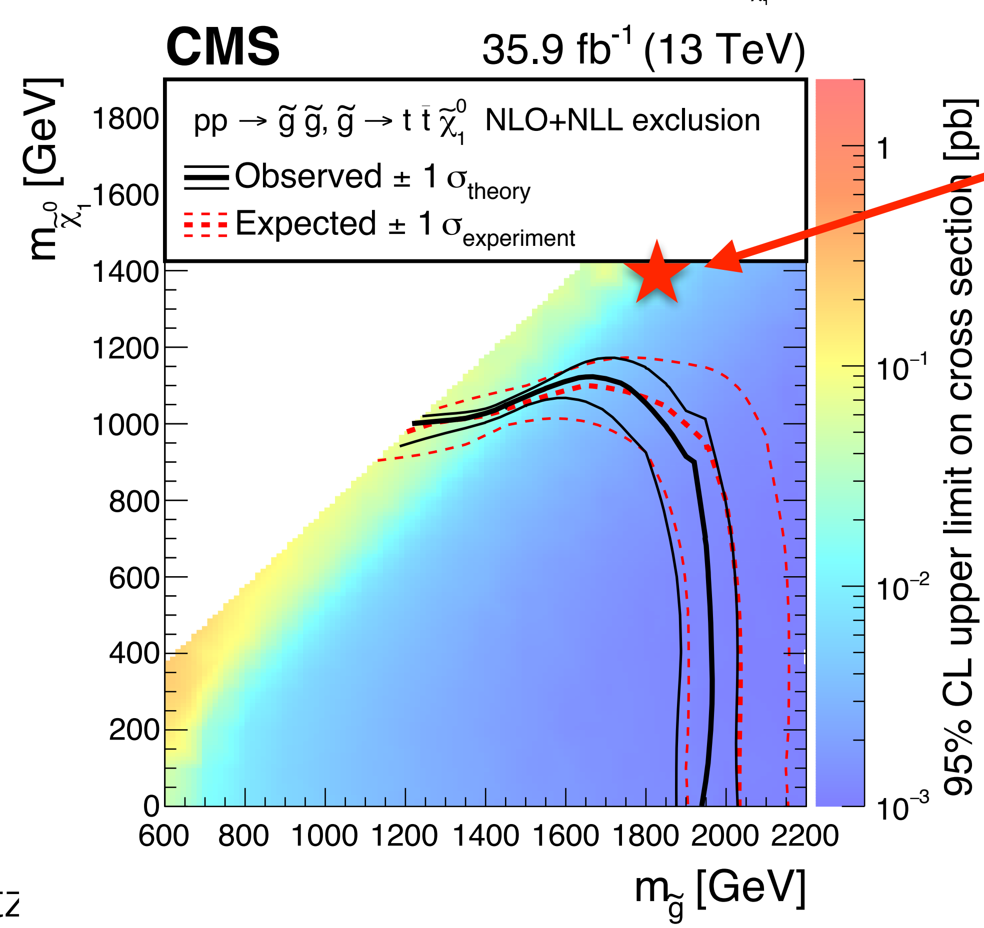


signal generation with Pythia8: strong chargino production through $gg \rightarrow \tilde{g}\tilde{g}$

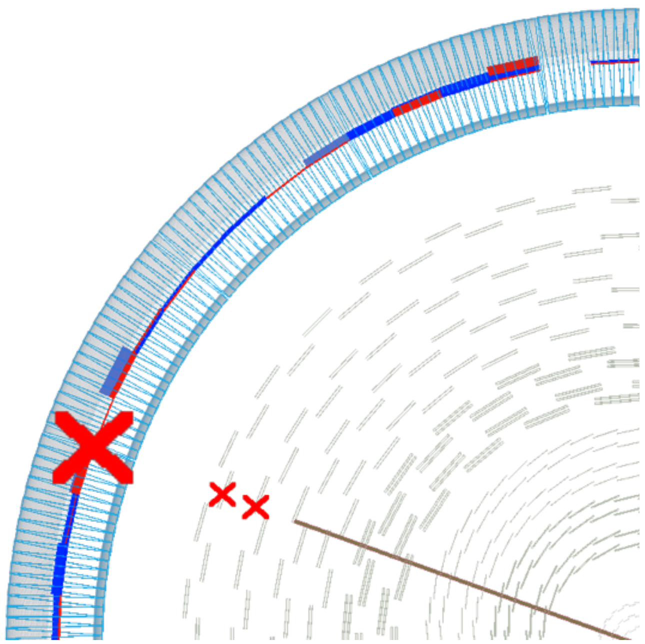
- m($\tilde{g}$) = 1800 GeV
- m(chargino) = 1400 GeV
- Δm = 180 MeV
- cτ = 10, 30, 50, 100 cm

include models from pMSSM scan for event selection

Phys.Rev. D



Tagging disappearing tracks



relevant track properties:

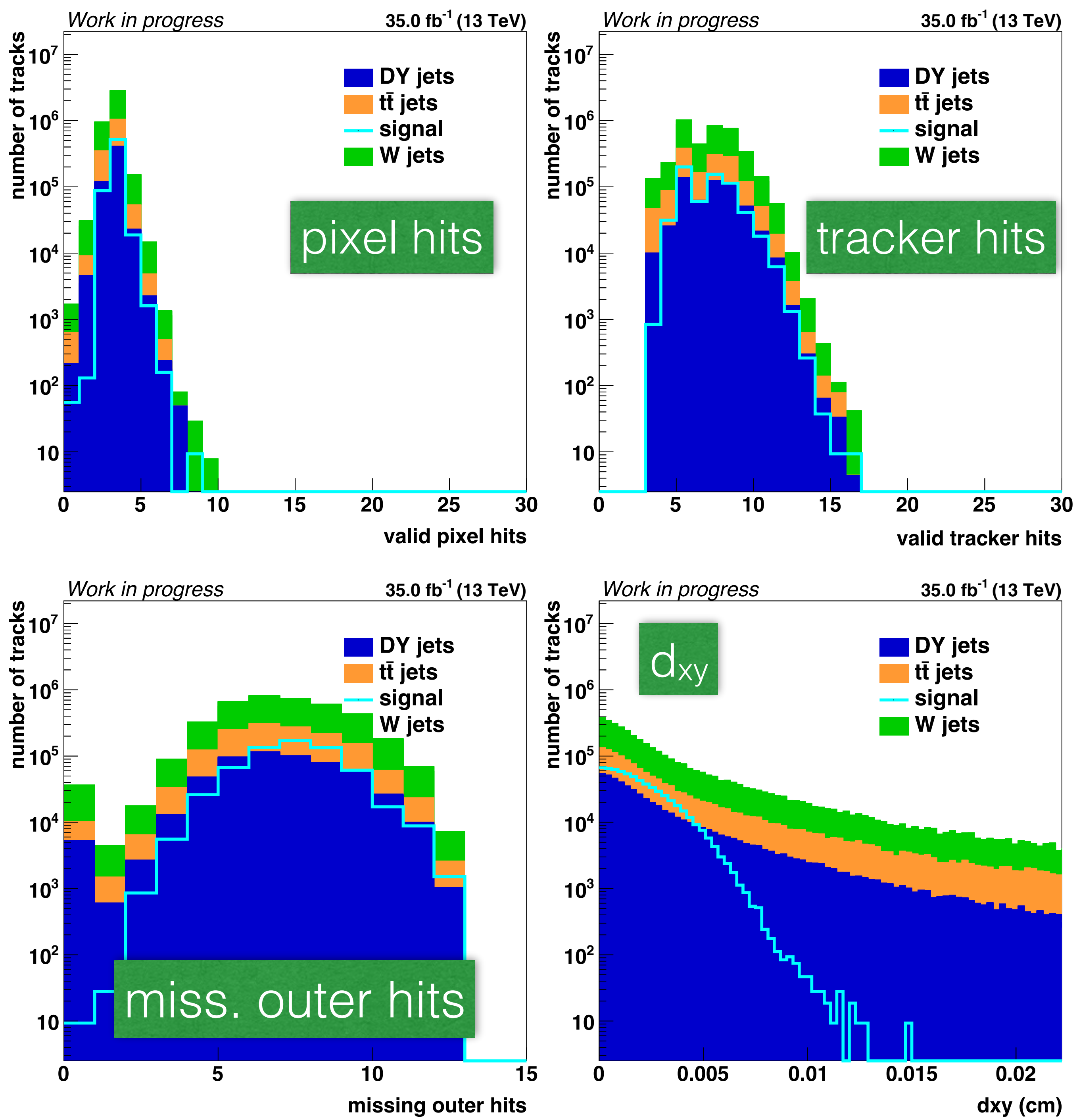
- number of pixel / tracker hits
- missing inner / middle / outer hits
- distance to primary vertex (d_{xy}, d_z)
- χ^2 / ndof
- $\Delta p_T / p_T^2$
- high purity track quality
- deposited energy in calorimeter within cone of $\Delta R < 0.5$

- avoid **model dependence** by too tight cuts on p_T, η, or isolation

(Some) tracking variables

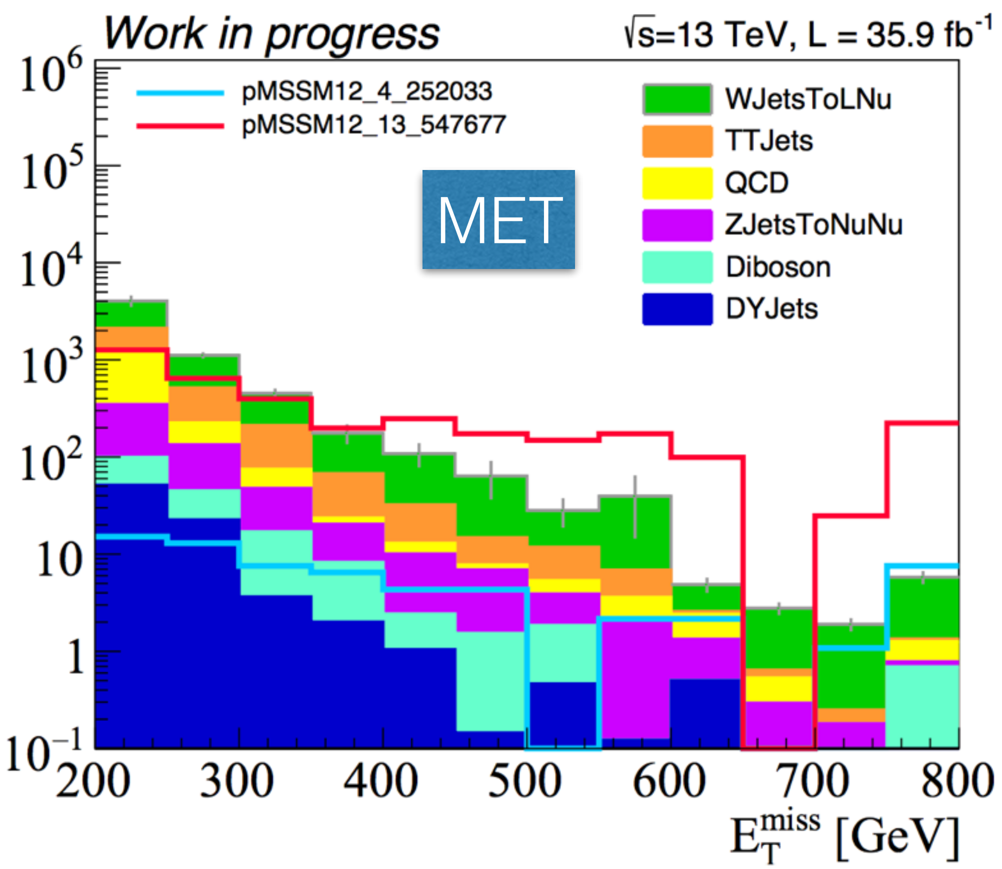
track variables after applying a basic preselection including a **reconstructed lepton veto & no missing inner hits**:

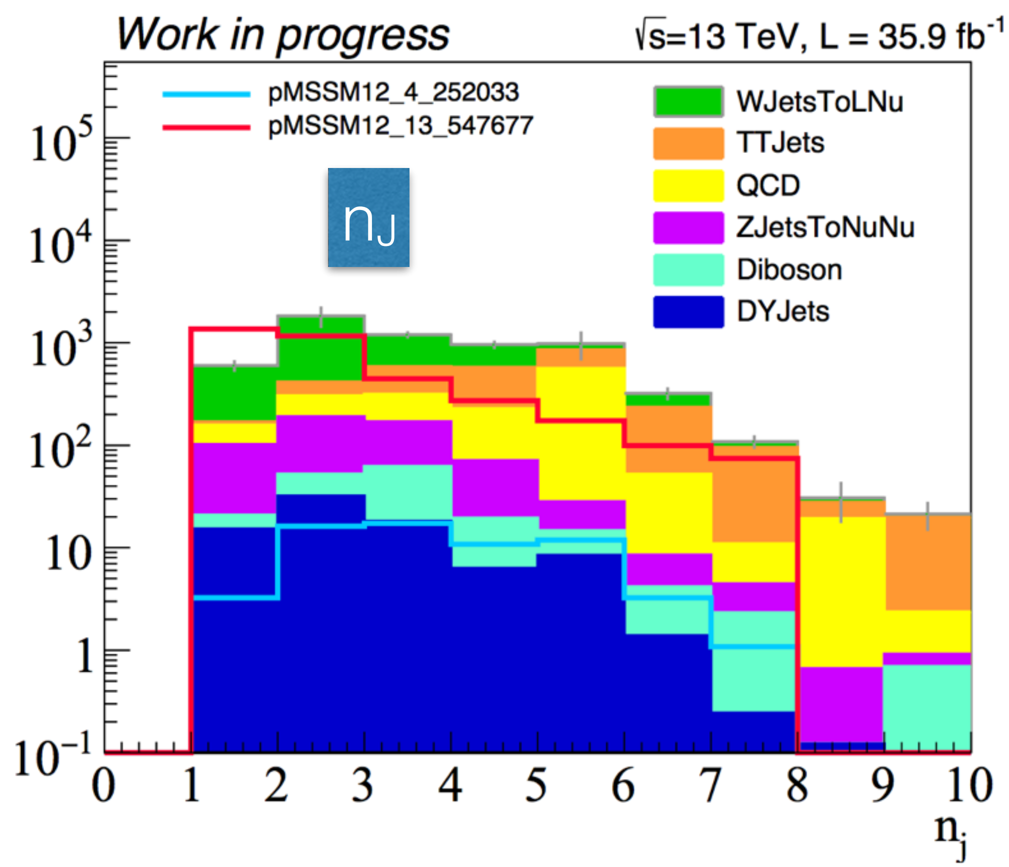
medium tracks,
signal scaled to 100 pb



Event topology

- use **disappearing track tag** for event selection
- look at **event topology** variables

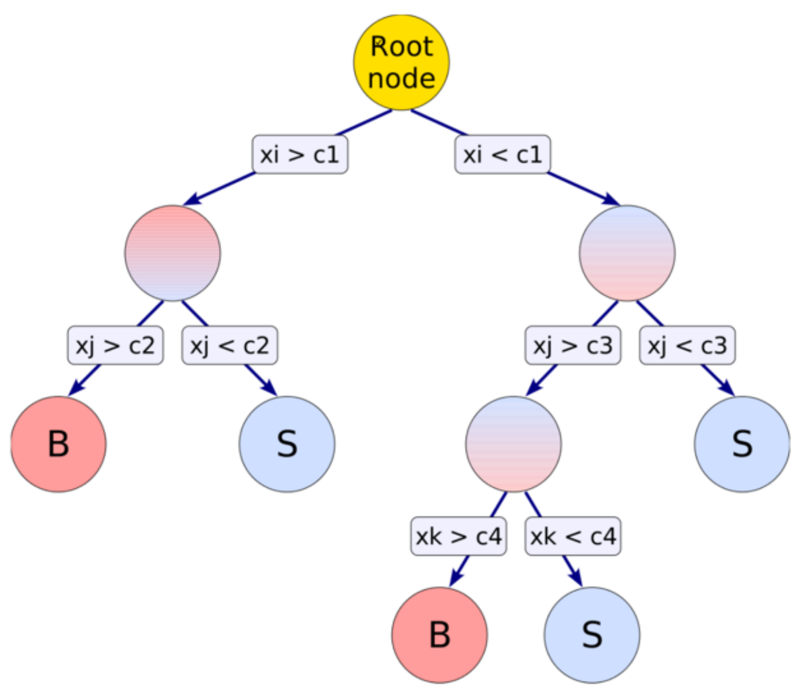




Optimization methods

- **random grid search (RGS)**: find optimal cuts via importance sampling, focus on signal-like regions rather than entire phase space
- **boosted decision tree (BDT)** using TMVA

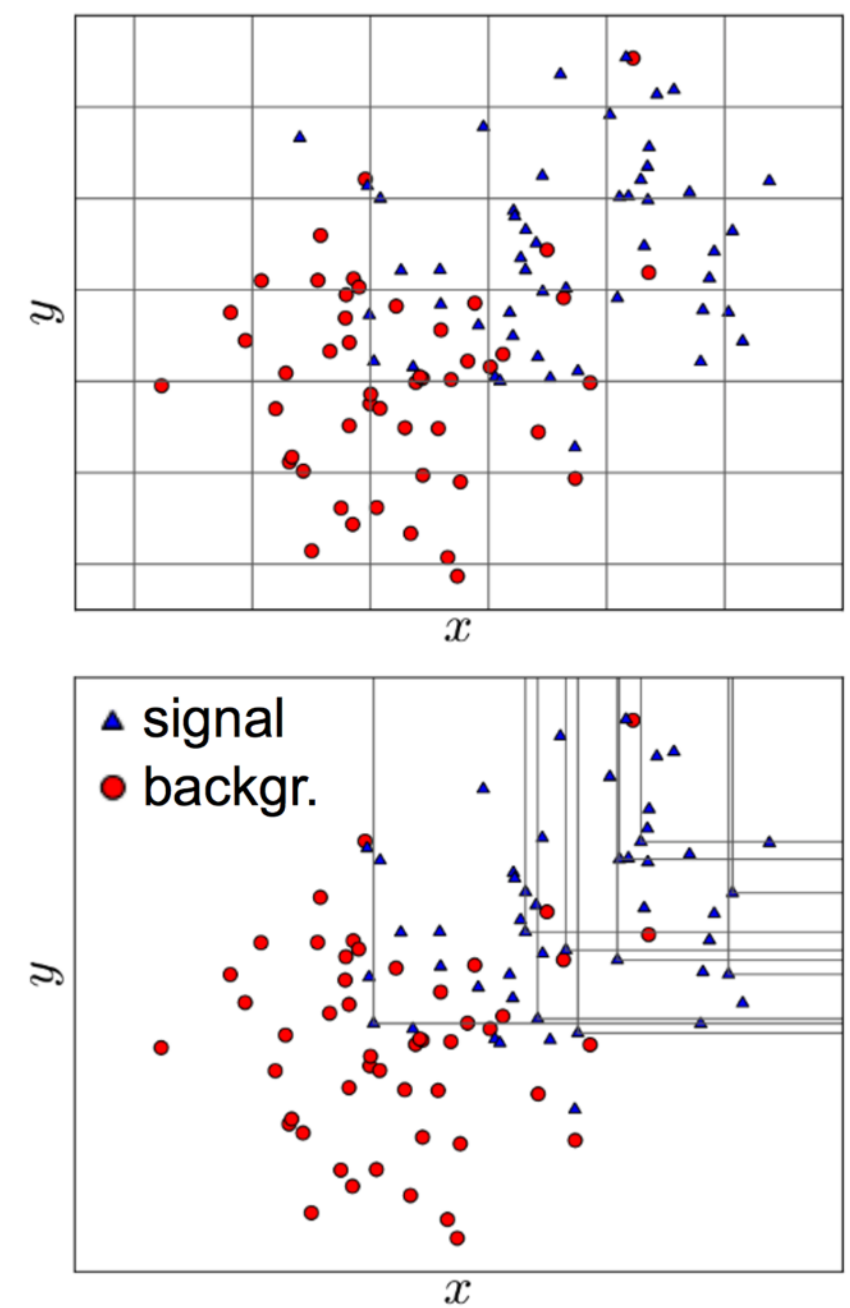
BDT



both methods:

select best cuts by maximizing significance $s/\sqrt{s+b}$

random grid search



arxiv: 1706.09907

BDT illustration by Böser, Fink, Röcker (KIT)

Today’s exercise

today:

- introduction to tracking in CMS
- construct disappearing track tag using a BDT
- define signal regions with RGS for event selection

tomorrow:

- background estimation methods for
    - prompt background
    - fake track background
- systematic uncertainties, derivation of excepted limit

Today’s exercise

- start here: **https://github.com/ShortTrackSusy/cmsdas**