Reconstruction of displaced objects in CMS

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EOS solstice meeting

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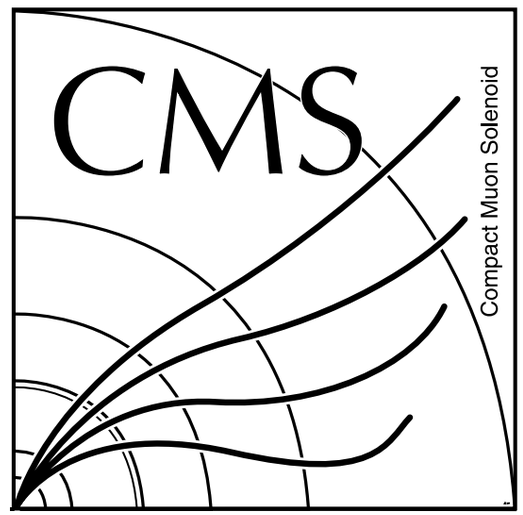


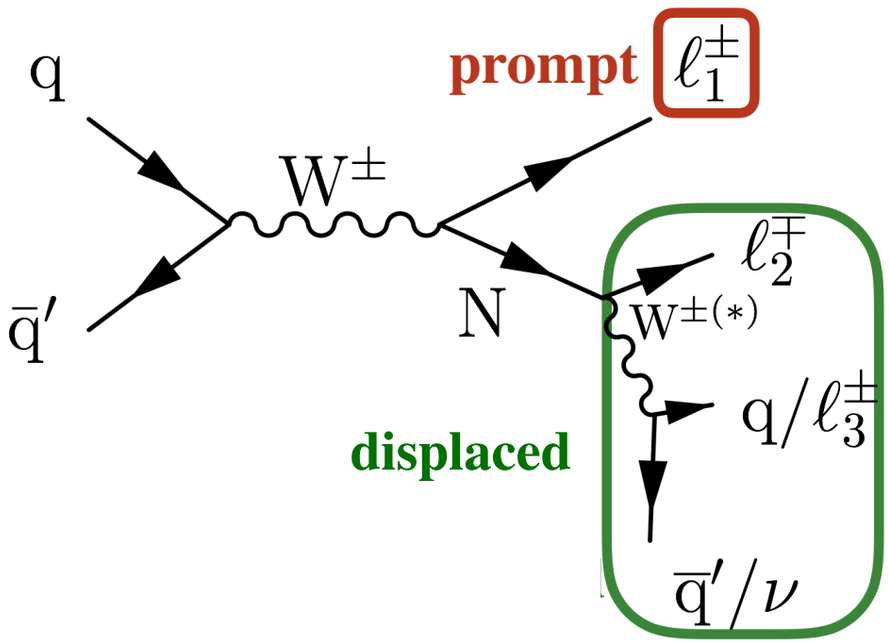
Introduction and outline

- Objective: reconstruction of displaced decays

- Motivations:

HNL searches

Dark Z in dileptons



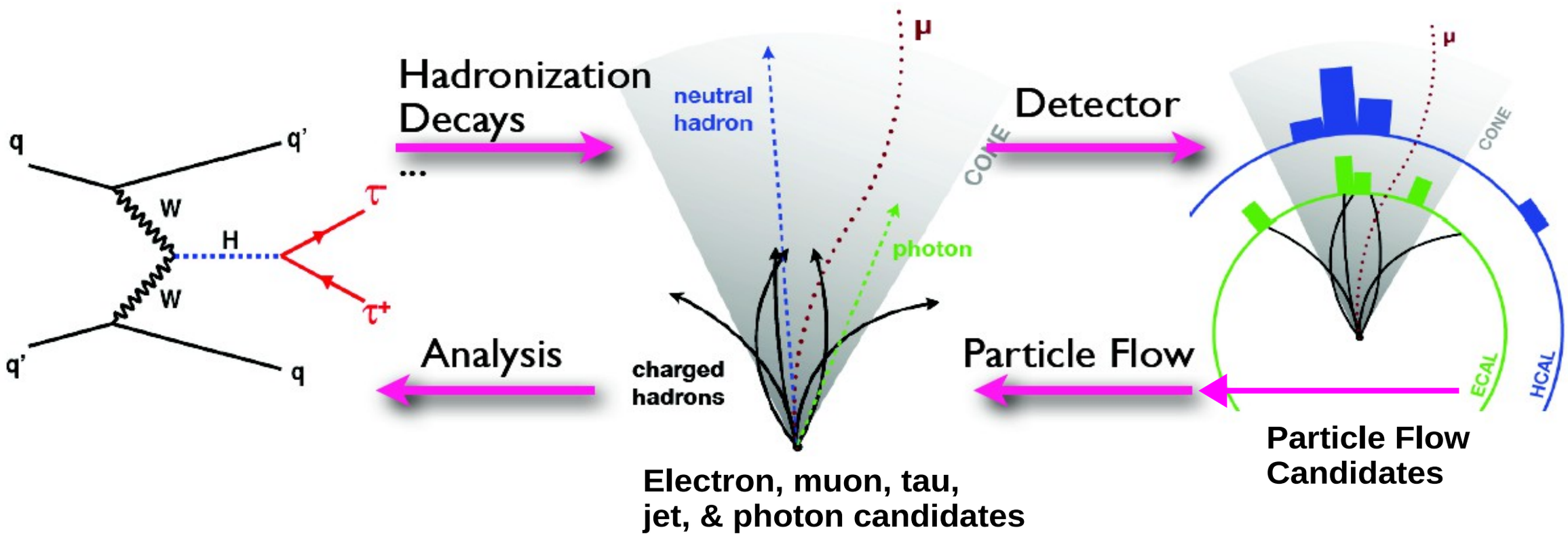
Hadrons from a Hidden Sector

Introduction and outline

- Where are we standing today?
  - Particle flow in CMS
  - Jet reconstruction and classification
  - Hadronic τ reconstruction

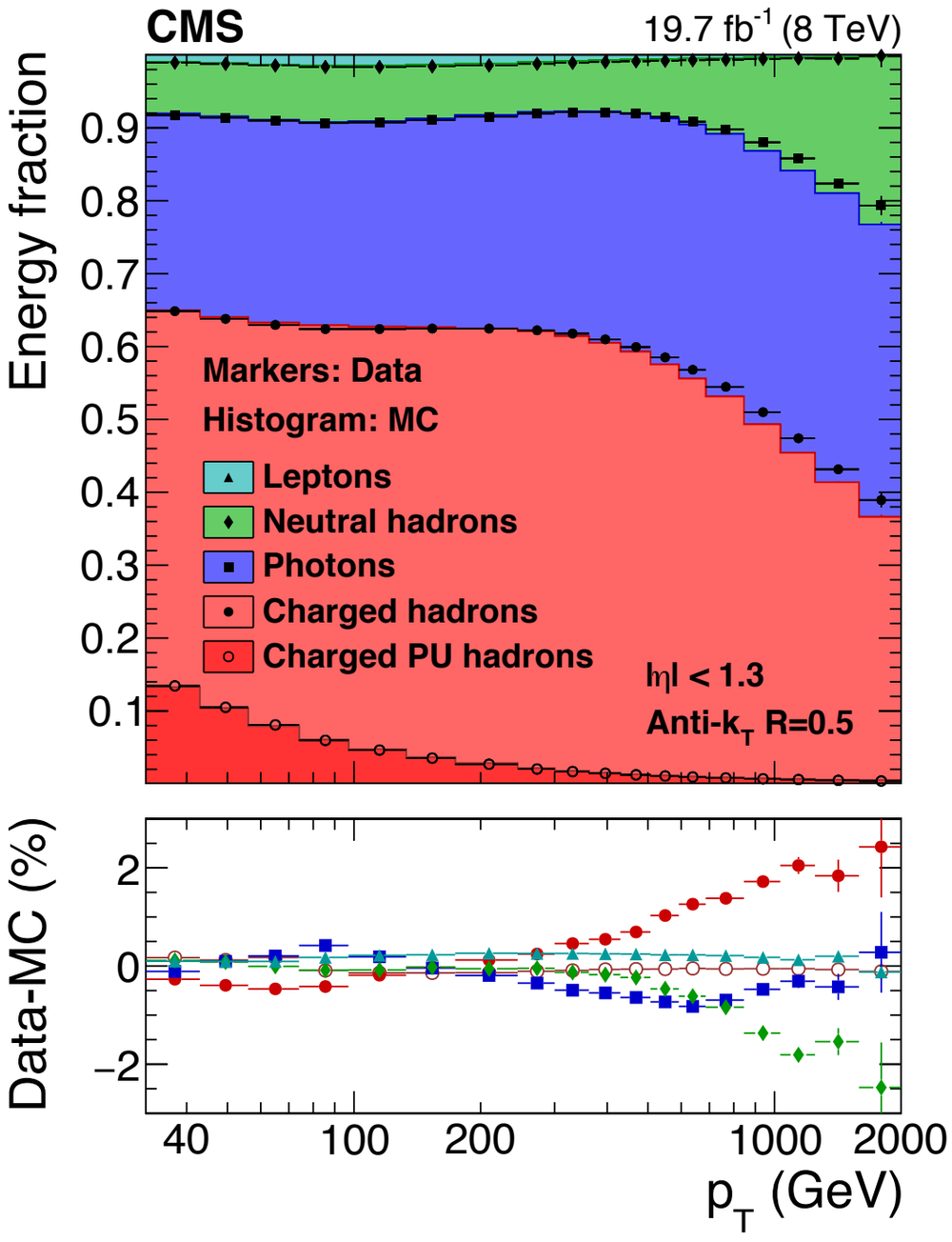
- First steps towards displaced vertex reconstruction:
  - Tagger for displaced jets
  - Reconstruction of displaced object in specific analyses
  - Proper description of nuclear interaction

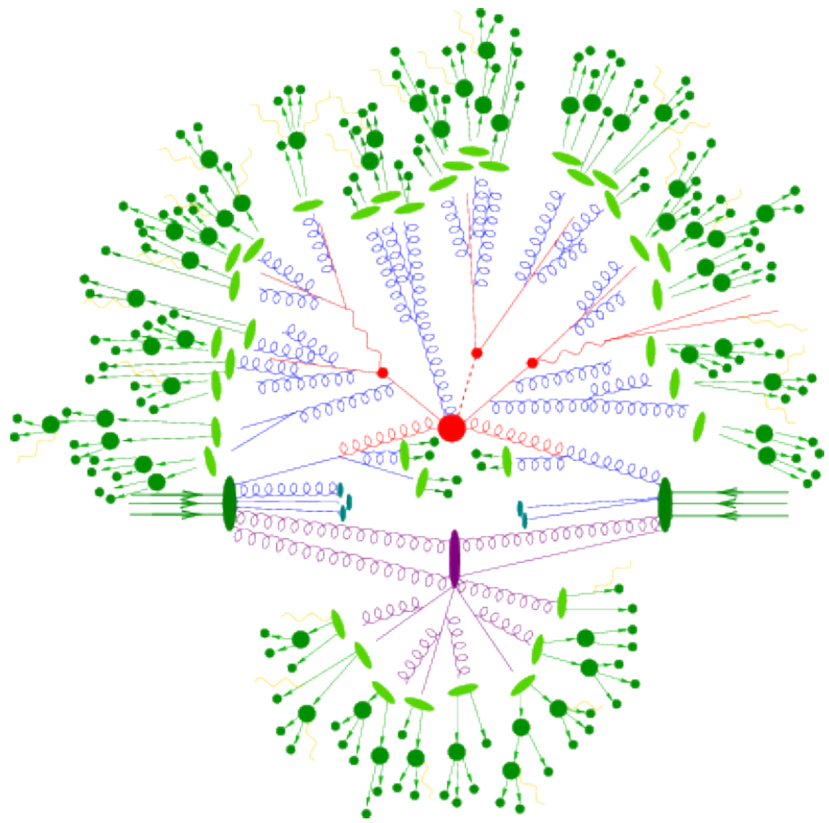
Particle Flow



- Combines infos from all the sub-detectors
- Reconstruct five classes of particles: muons, electrons, photons, charged and neutral hadrons
- Jet and hadronic τ reconstruction/identification

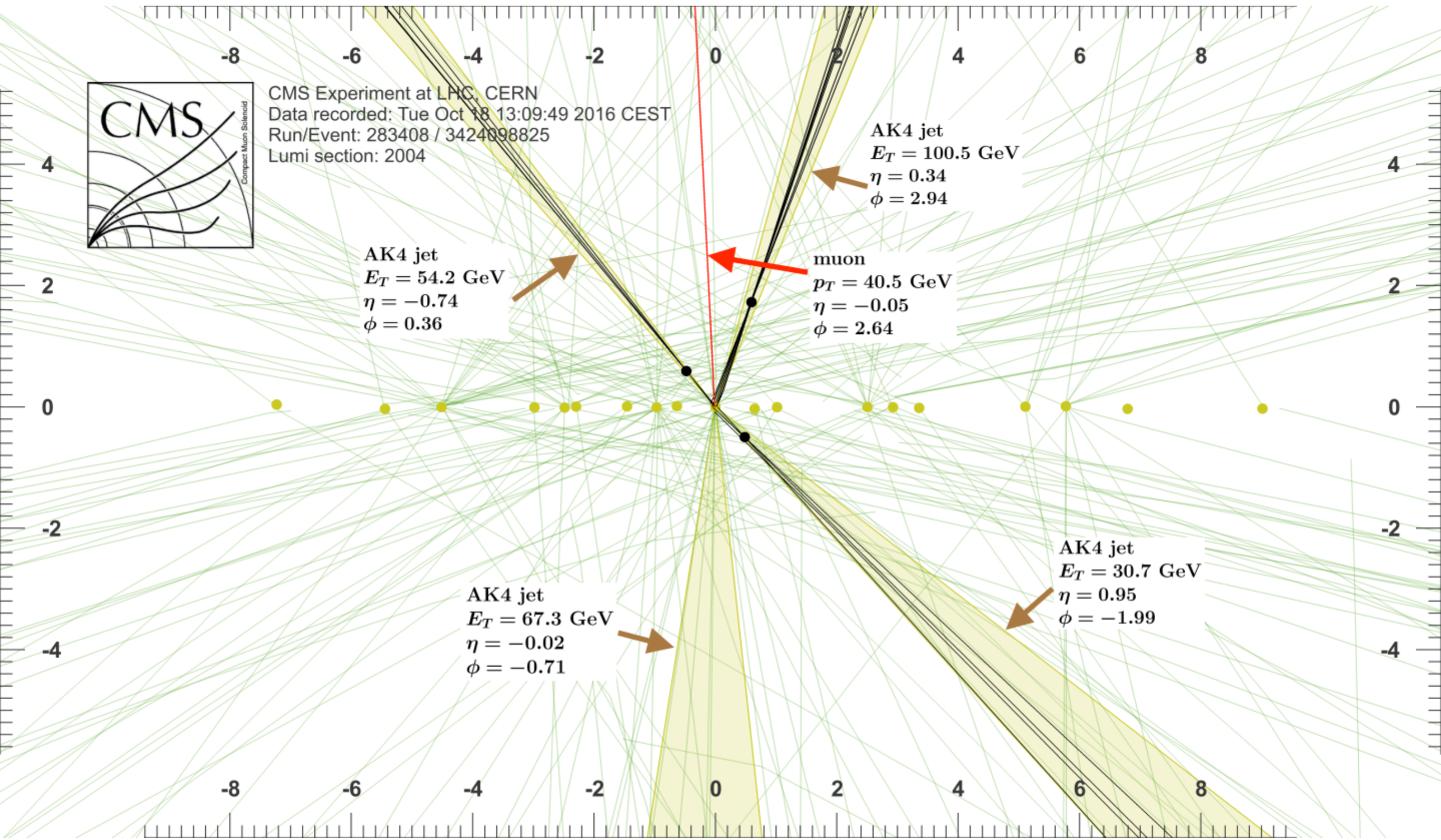
Jet reconstruction



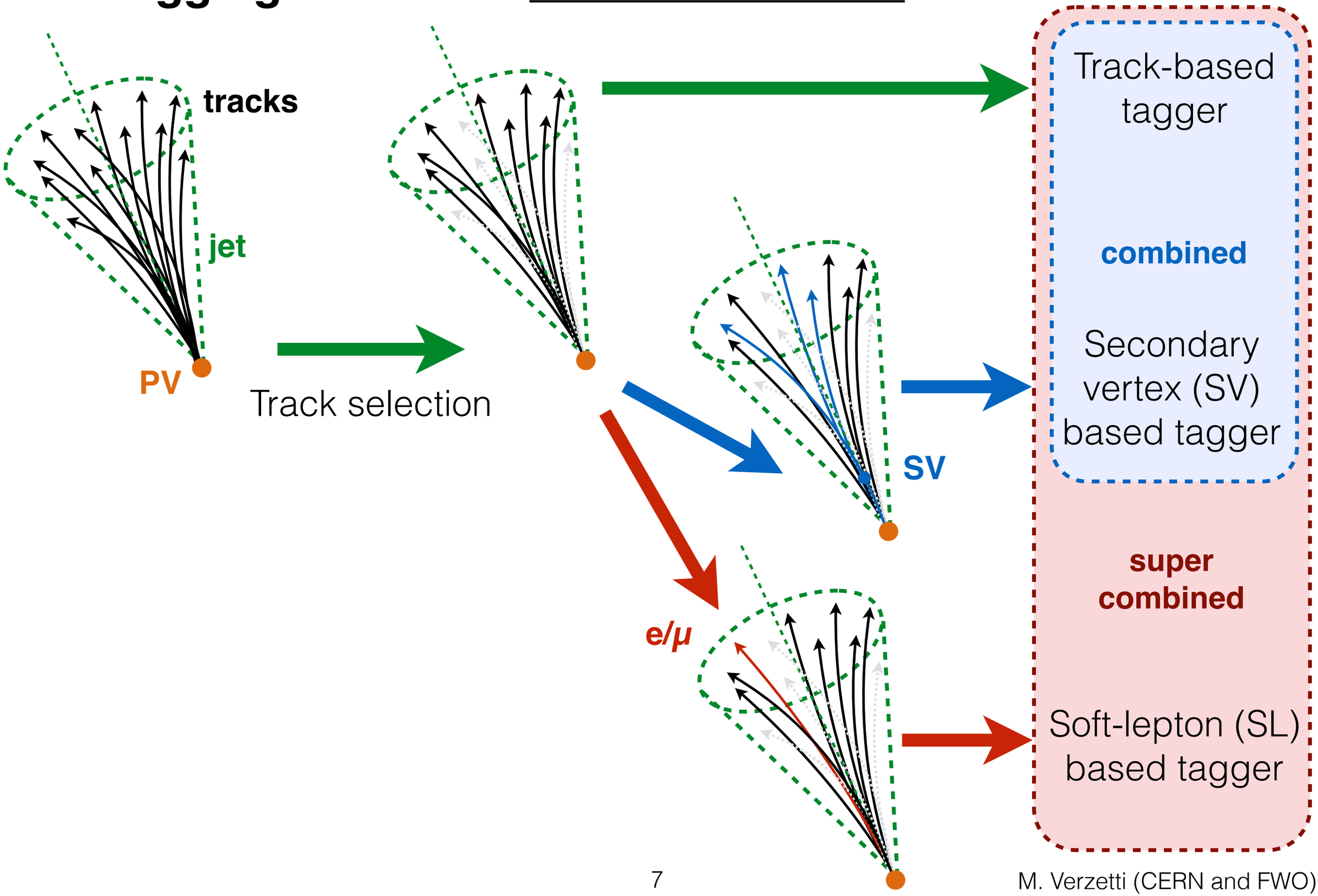


- Jets: highly collimated hadrons and photons
- Produced by the fragmentation of an highly energetic coloured particle
- Reconstructed with the anti-k_T algorithm

How does it look like?



HF tagging @ CMS — arXiv:1712.07158



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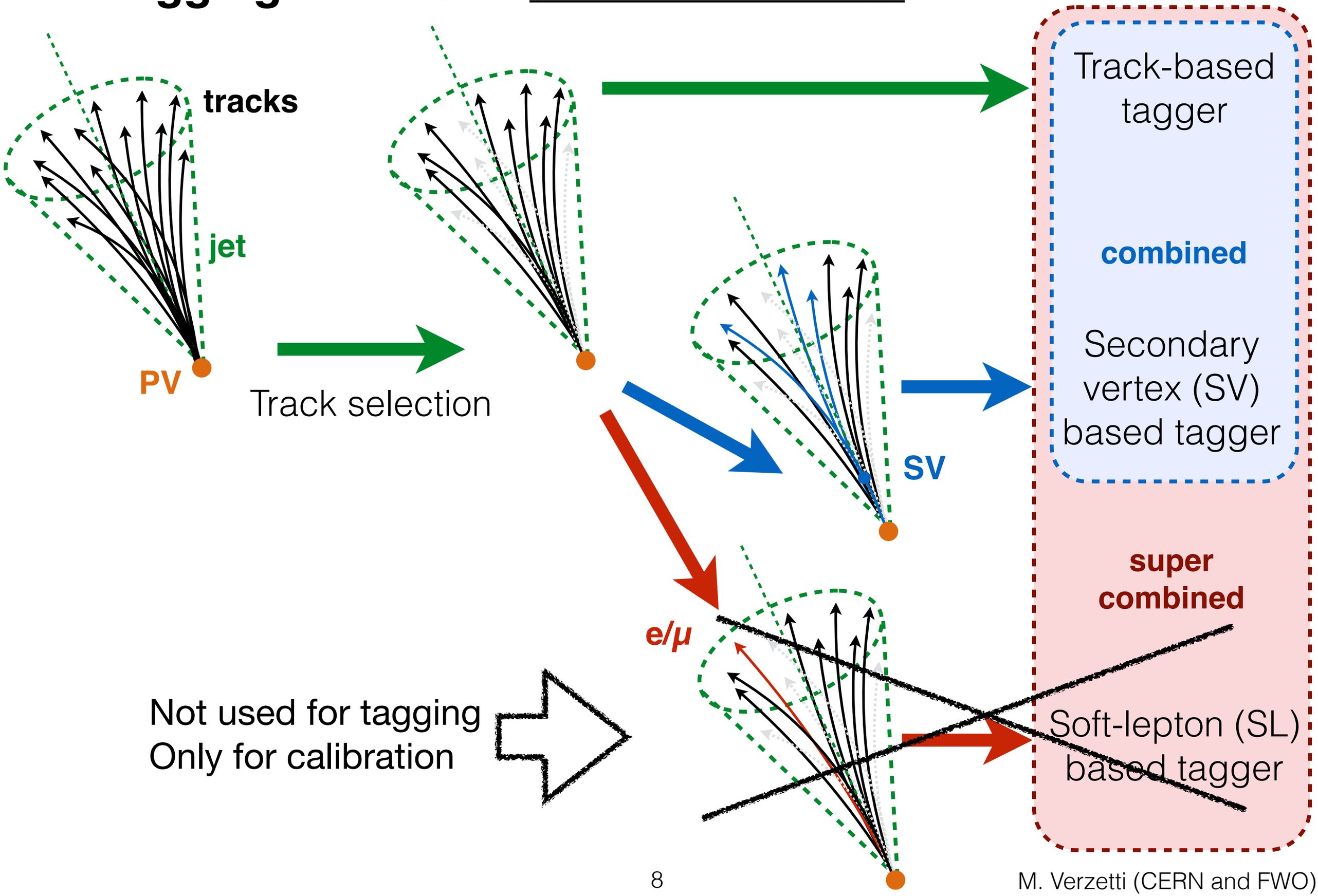
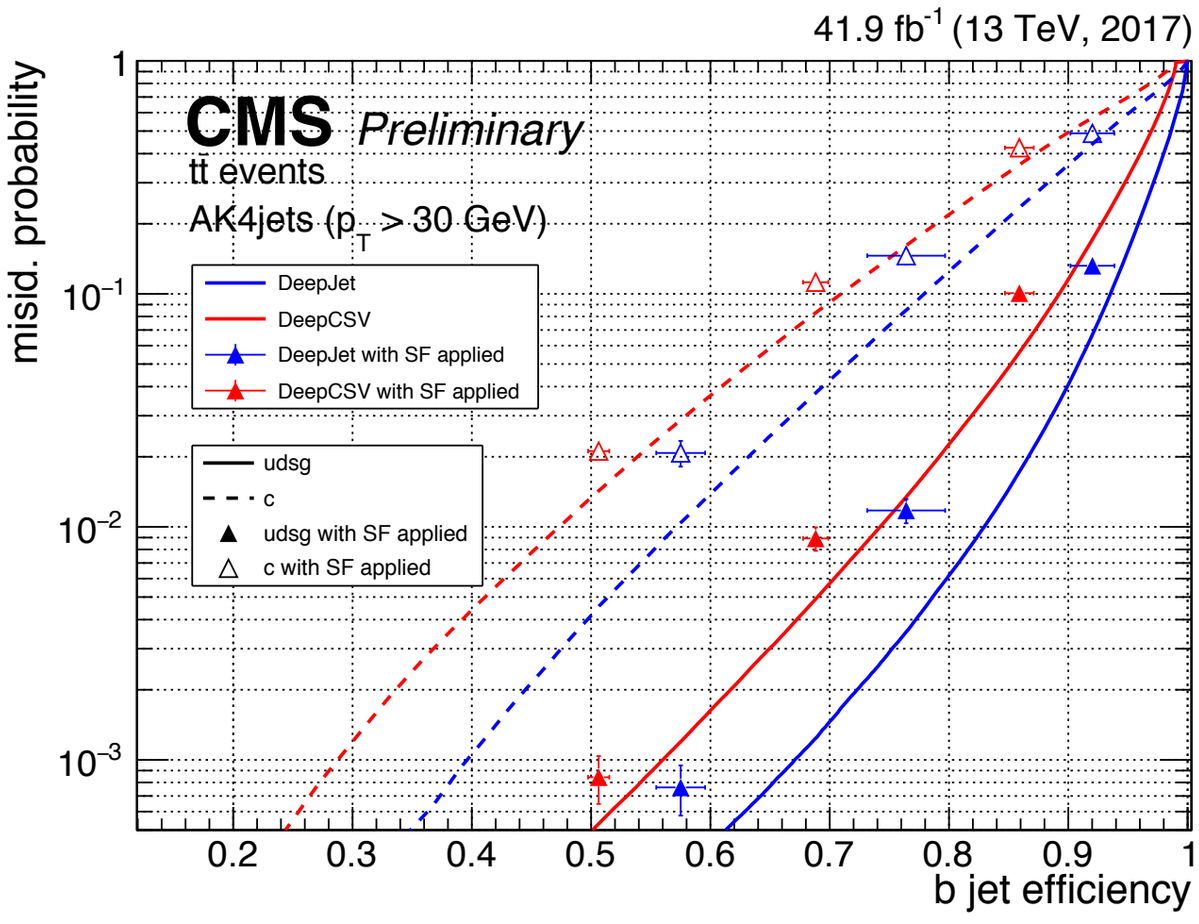
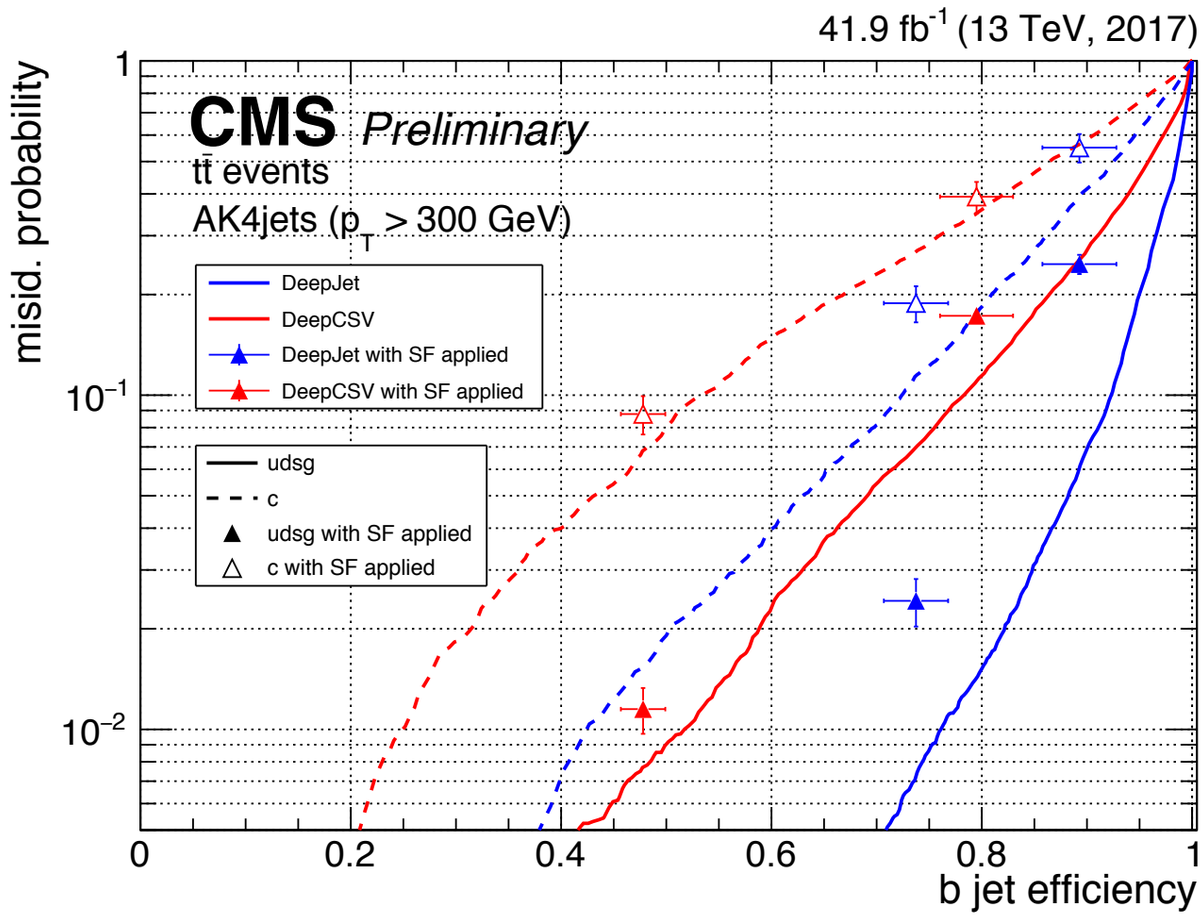


Jet tagging - DeepJet

Two taggers currently supported in CMS:

- DeepCSV
- DeepJet: convolutional networks, significantly outperforms DeepCSV





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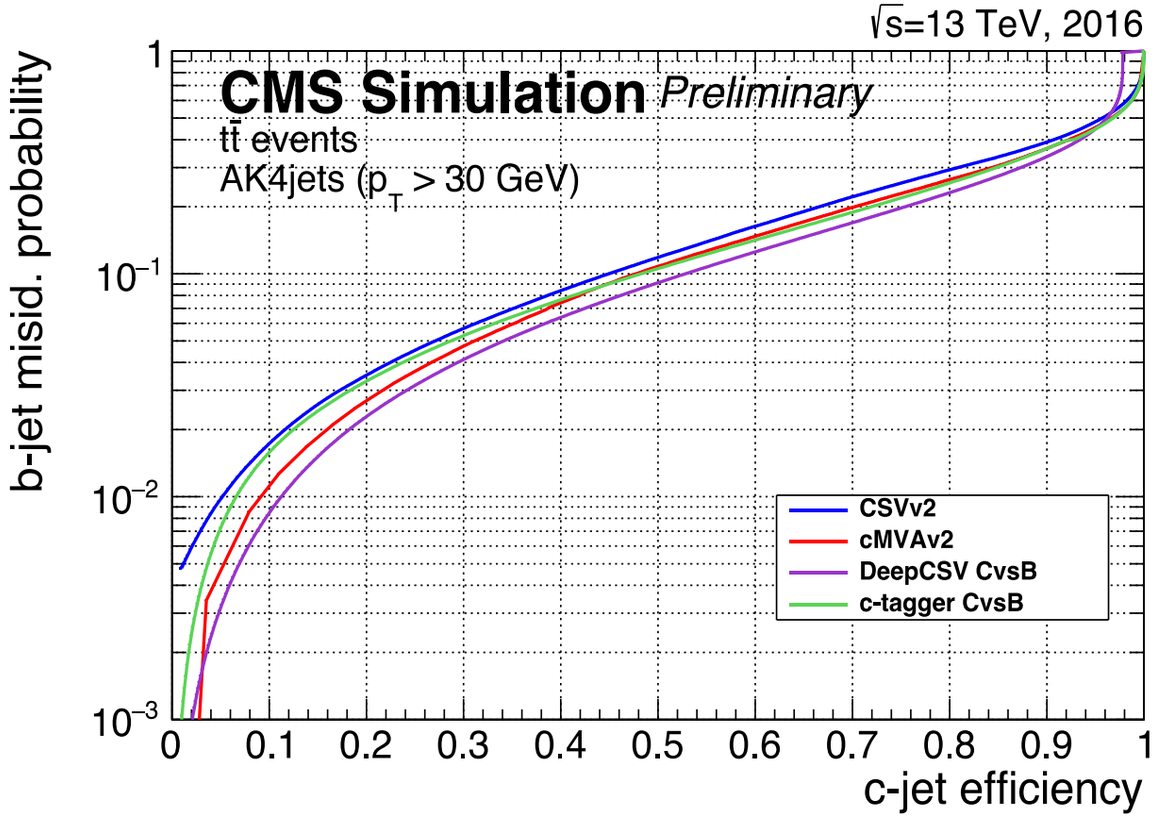
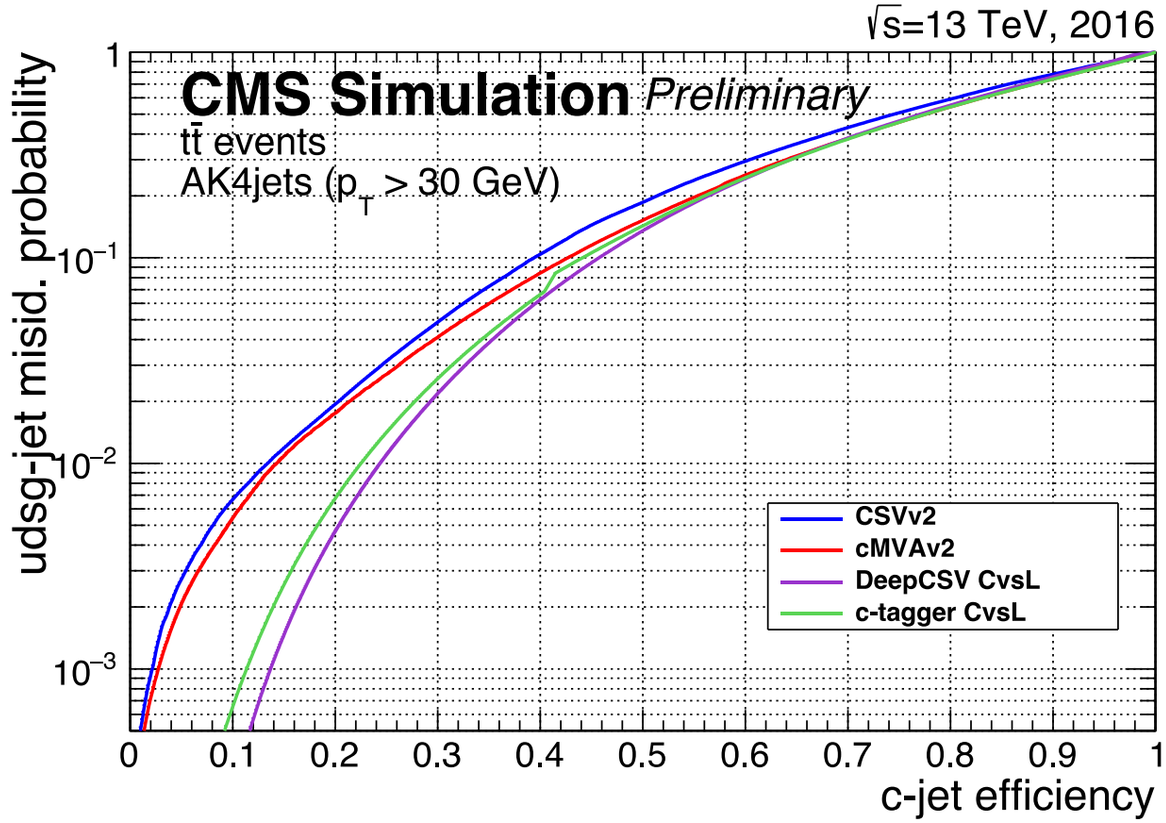
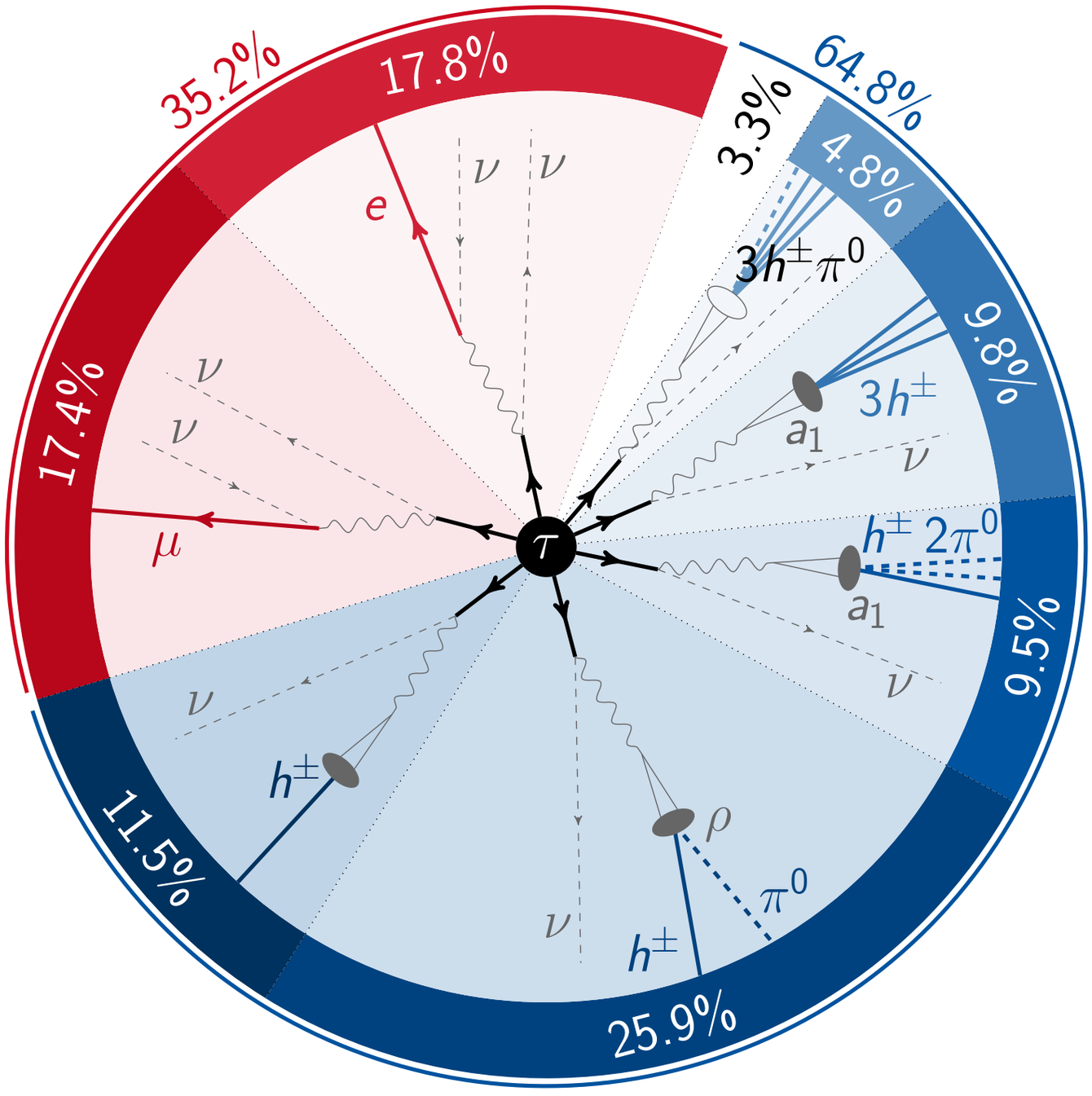




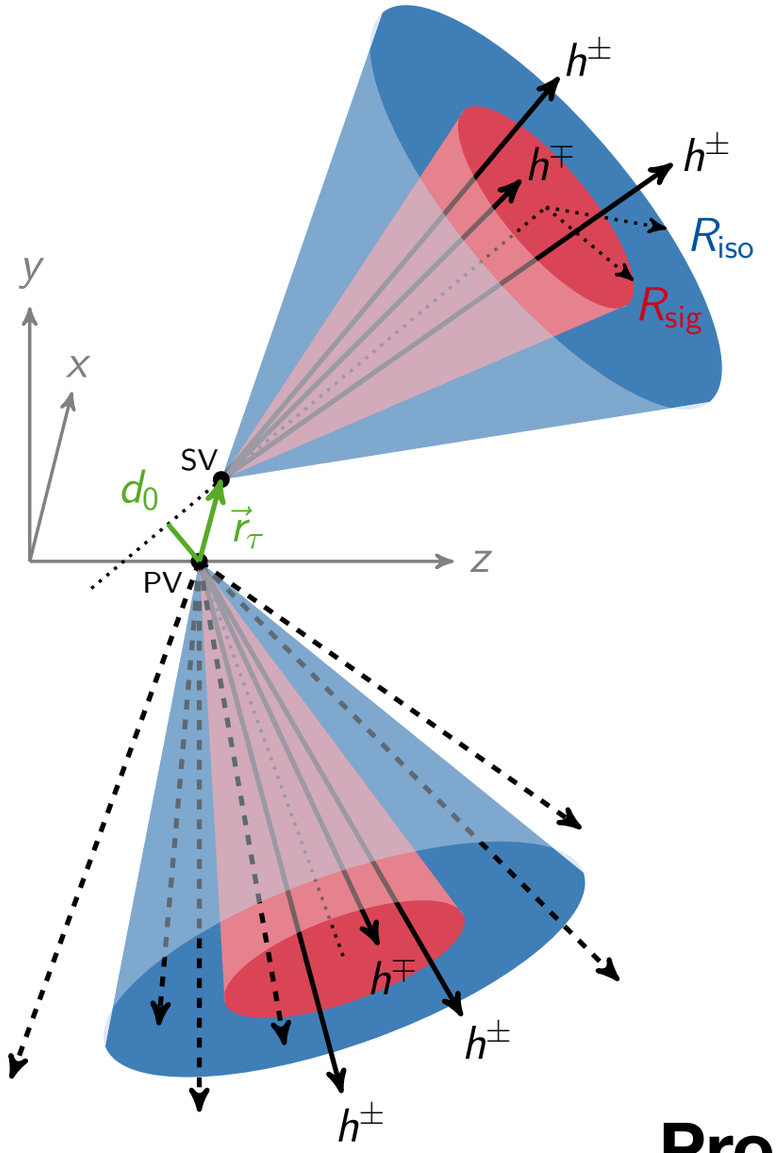
Tau reconstruction

- Standard e/μ reconstruction for leptonic decays



- 5 hadronic τ decay mode considered
- Low particle multiplicity compared to QCD jets

Tau reconstruction



Hadron Plus Strip algorithm

- Inputs: **PF candidates in AK4 jet**
- Consider all the possible decay modes:

  $\tau^{\pm} \rightarrow [1,3]h^{\pm} + [0–2]\pi^0 + \nu_\tau$

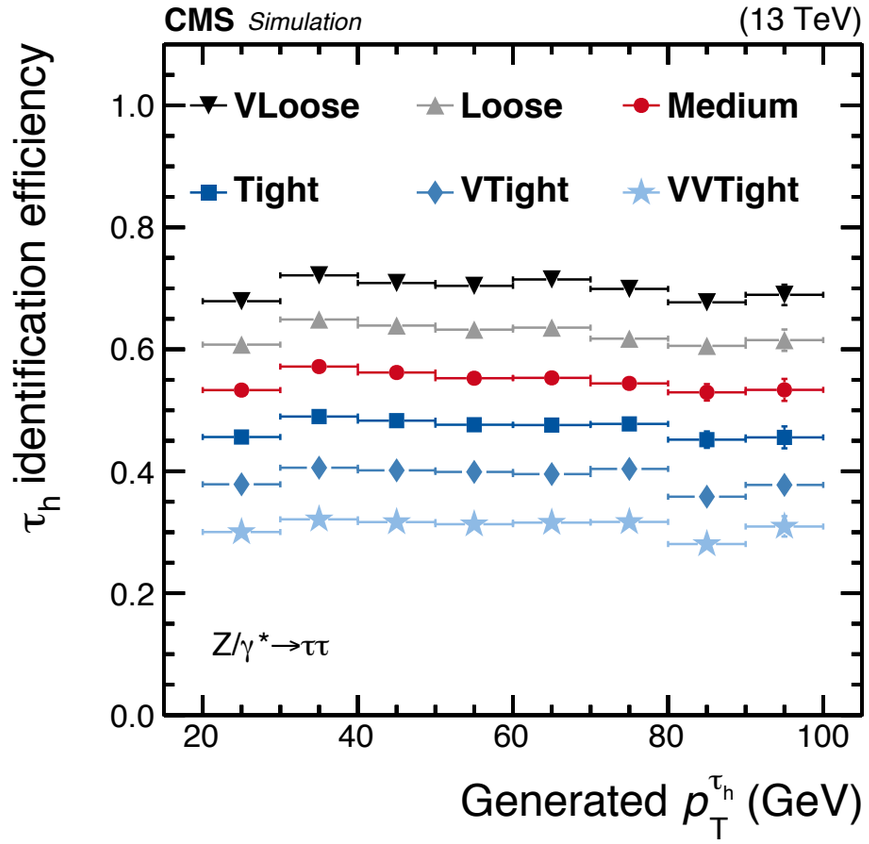
- Search for ρ(770) and $a_1(1260)$ intermediate resonances
- Highest p_T candidate taken

Properties of τ decay:

- Decays isolated from hadronic activity
- Long lifetime : Displaced tracks and decay vertices
- Low particle multiplicity (m_τ = 1.778 GeV)

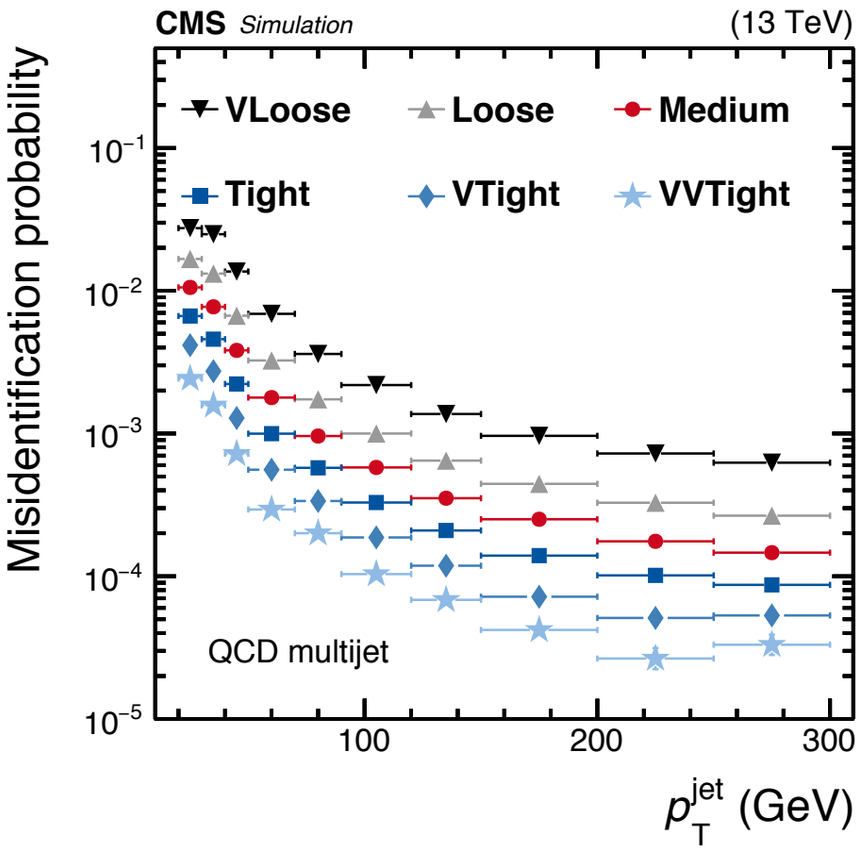
Tau identification

- BDT to discriminate taus from jets.
  Based on :
  - Lifetime
  - Decay mode
  - Particle multiplicity
  - Charged/neutral isolation sum

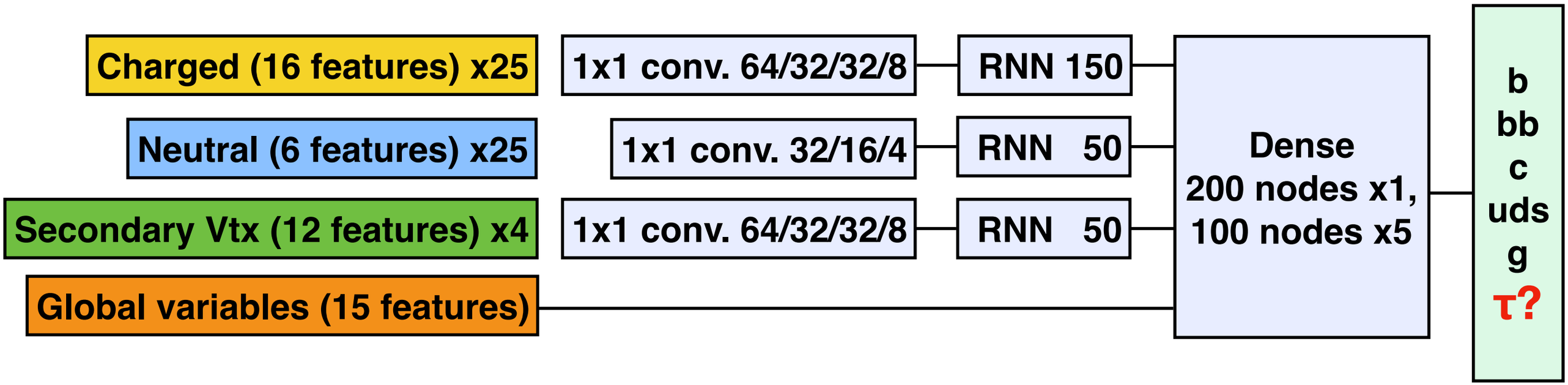


- Cut-based discriminator agains muon:
  - misidentification probability < 0.5%

- BDT discriminator agains electrons



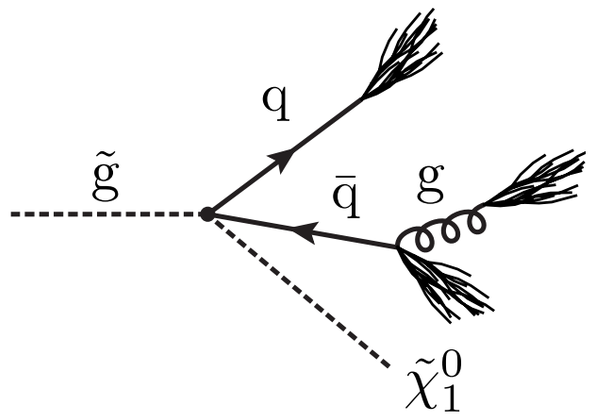
Global tagger with τ ?



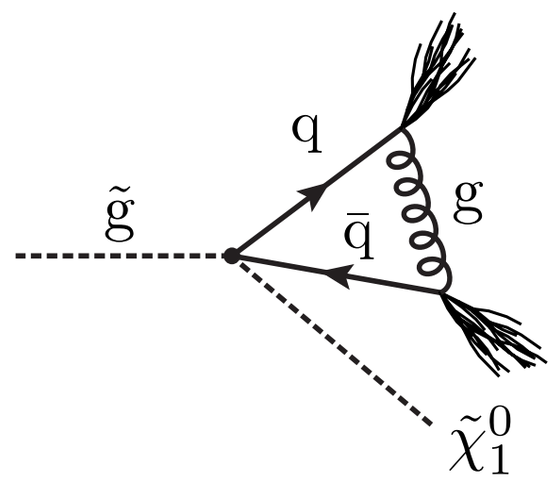
Feasible, but..

- larger number of features to include
- larger dataset needed
- How to calibrate?
- Interplay among classes to be studied

Displaced jets



Displaced jet tagger developed for displaced jets search analysis



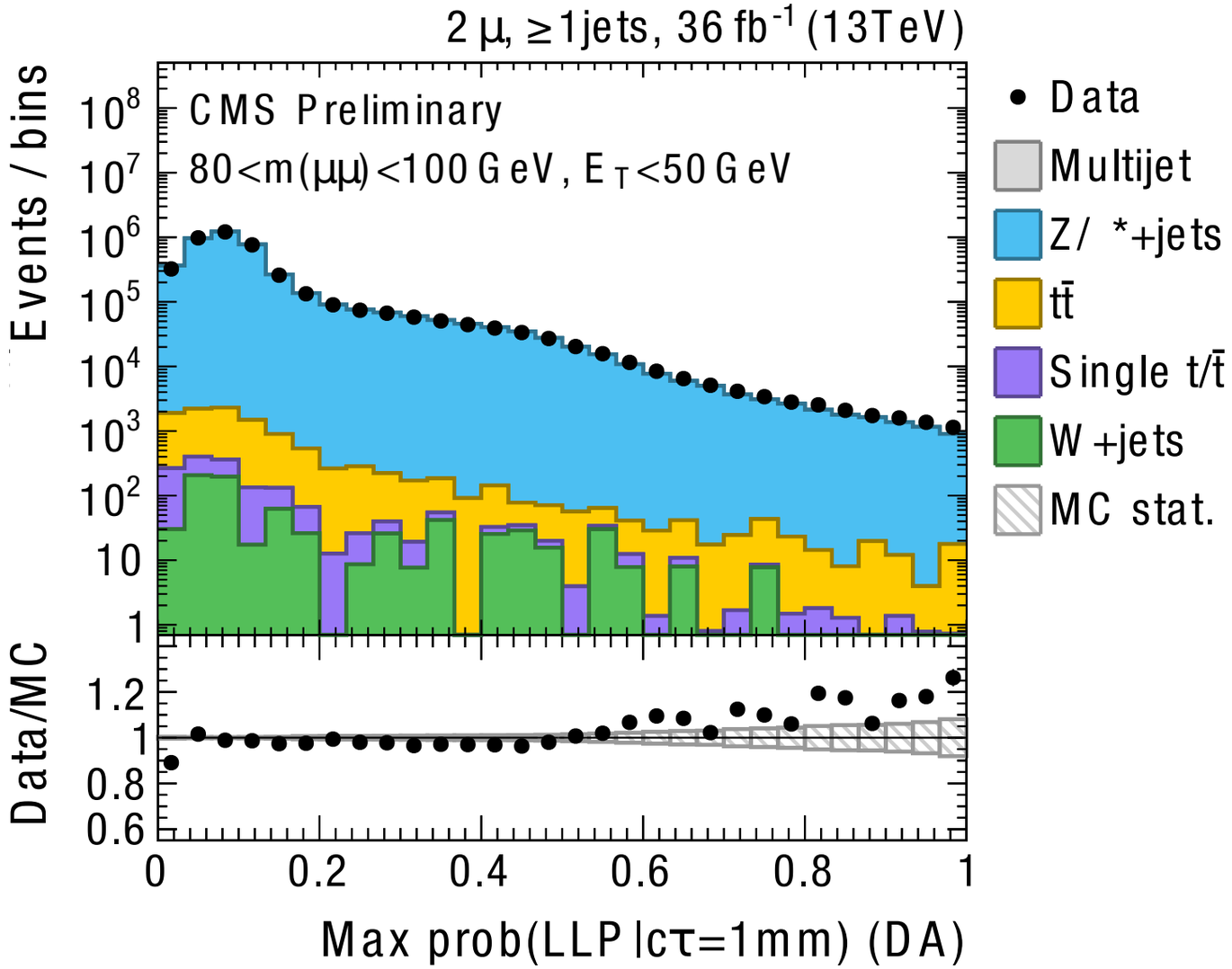
- Relies on PF objects

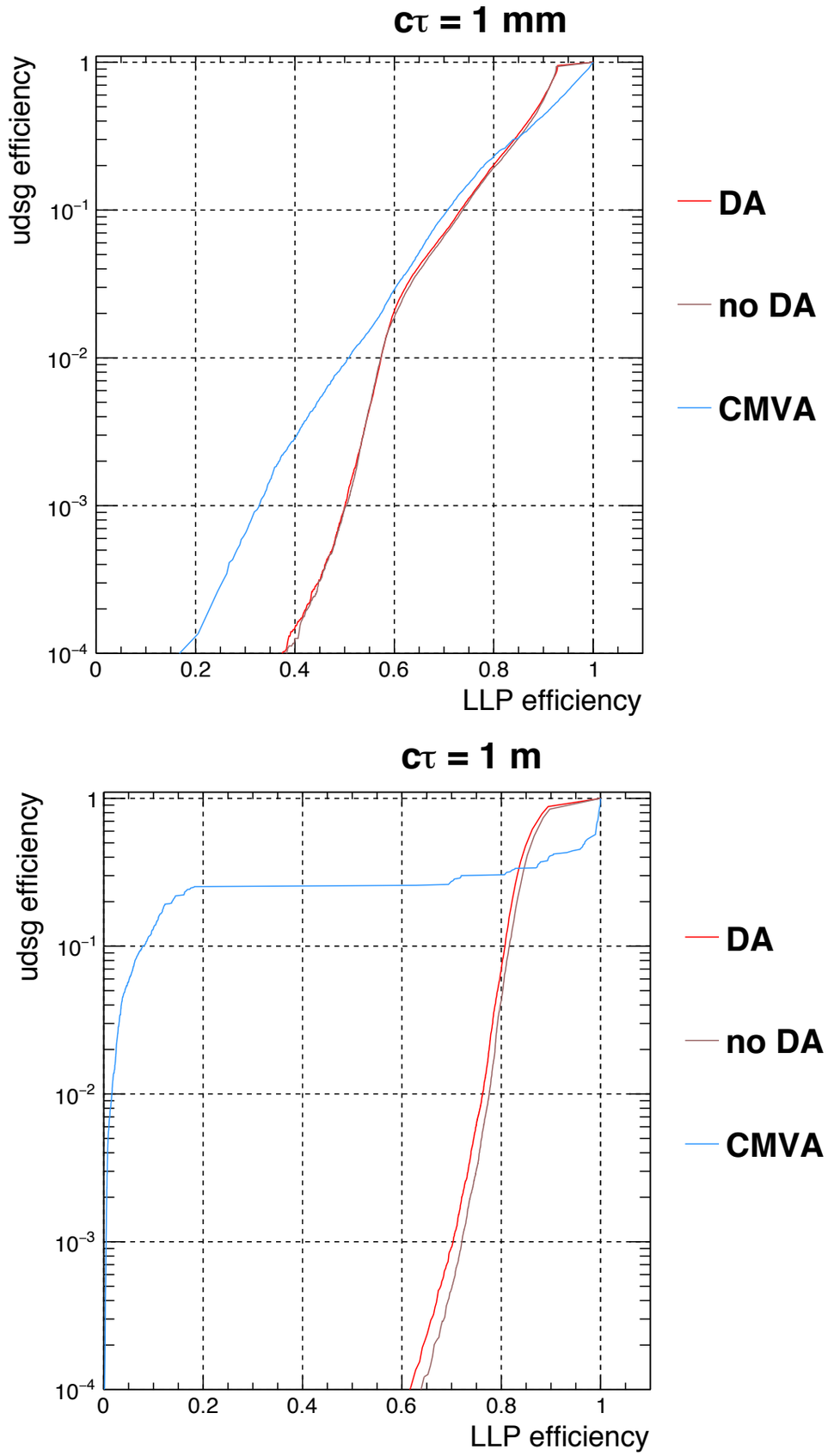
Non-pointing jets

- Based on DeepJet, additional class for LLP objects:
  - Final jets may be non-pointing in the direction of the gluino
  - Ghost tagging cannot be used
  - Tag jets as displaced if most of their p stems from a LLP decay vertex
  - Jet $p_T > 30$ GeV

(From Imperial College Group)

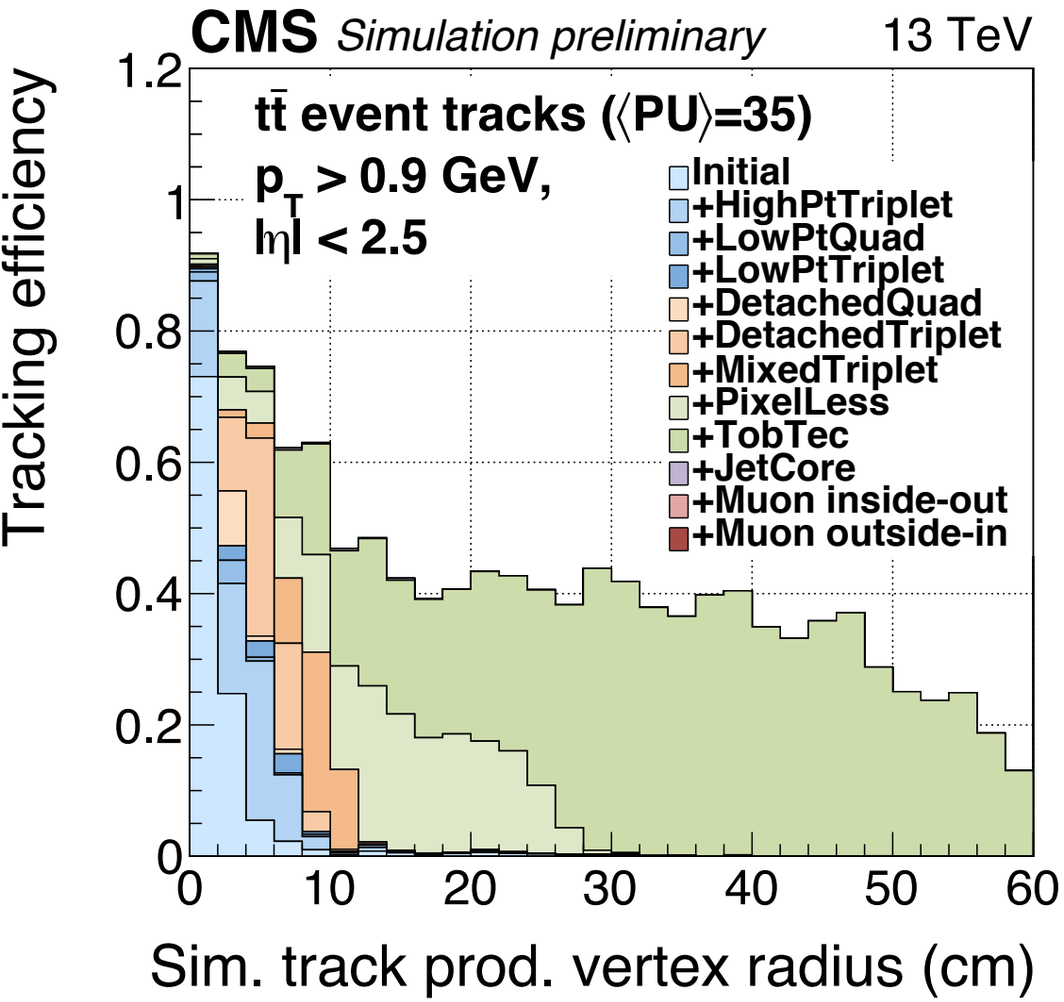
Displaced jets



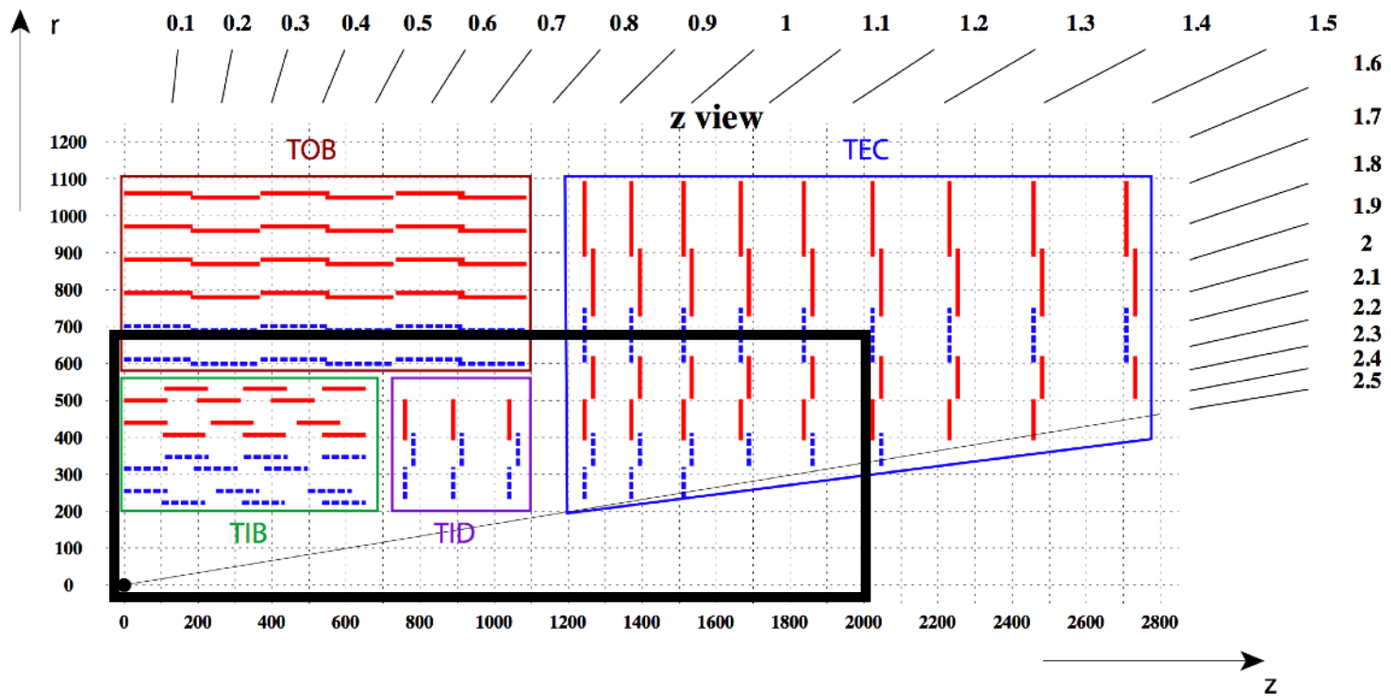


(From Imperial College Group)

Tracking efficiency



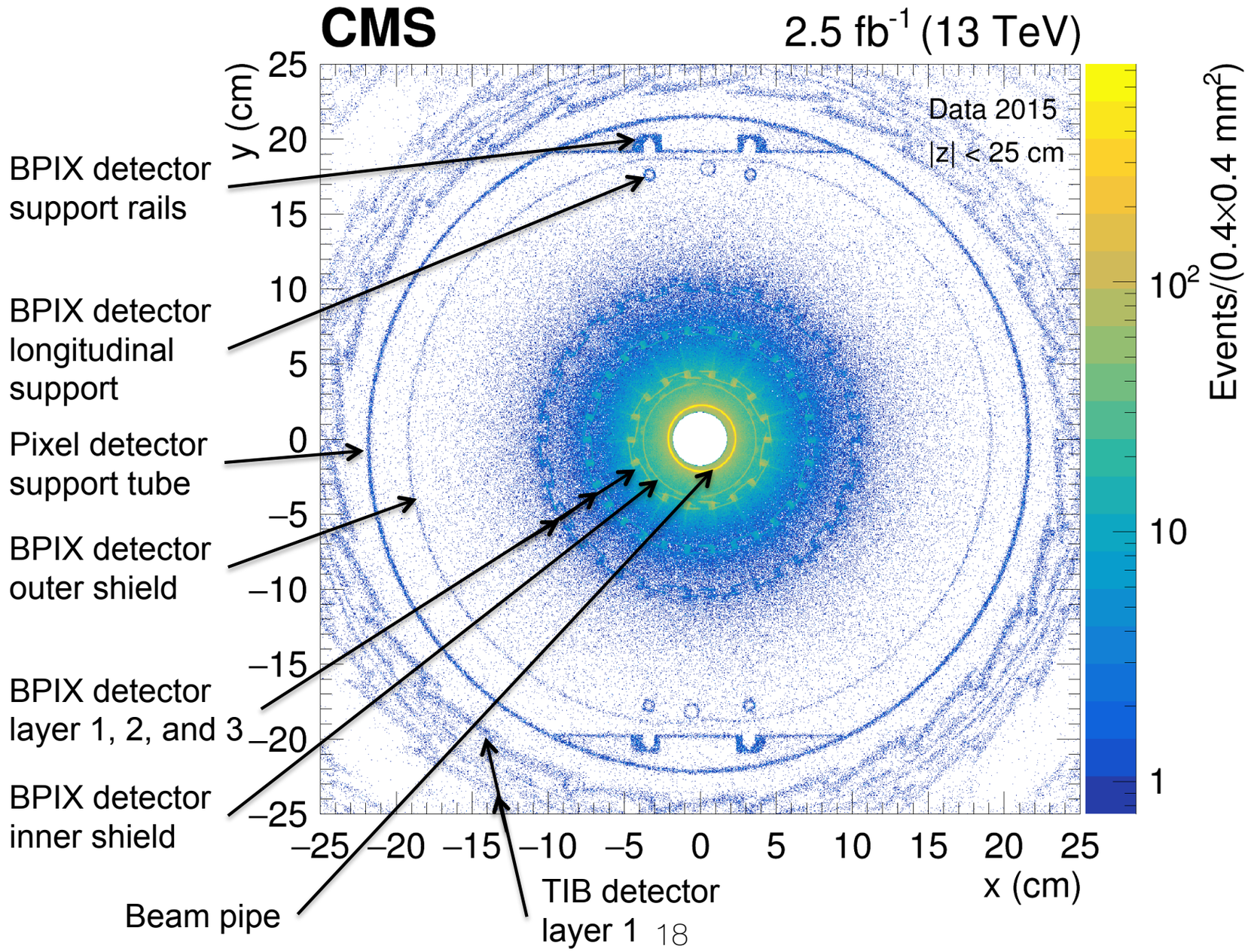
- Displaced charged hadrons have necessary to decay in the tracker
- Muon displaced have specific reconstruction algorithms with no requirements in the tracker
- No dedicated algorithm for electron displaced



Nuclear interaction

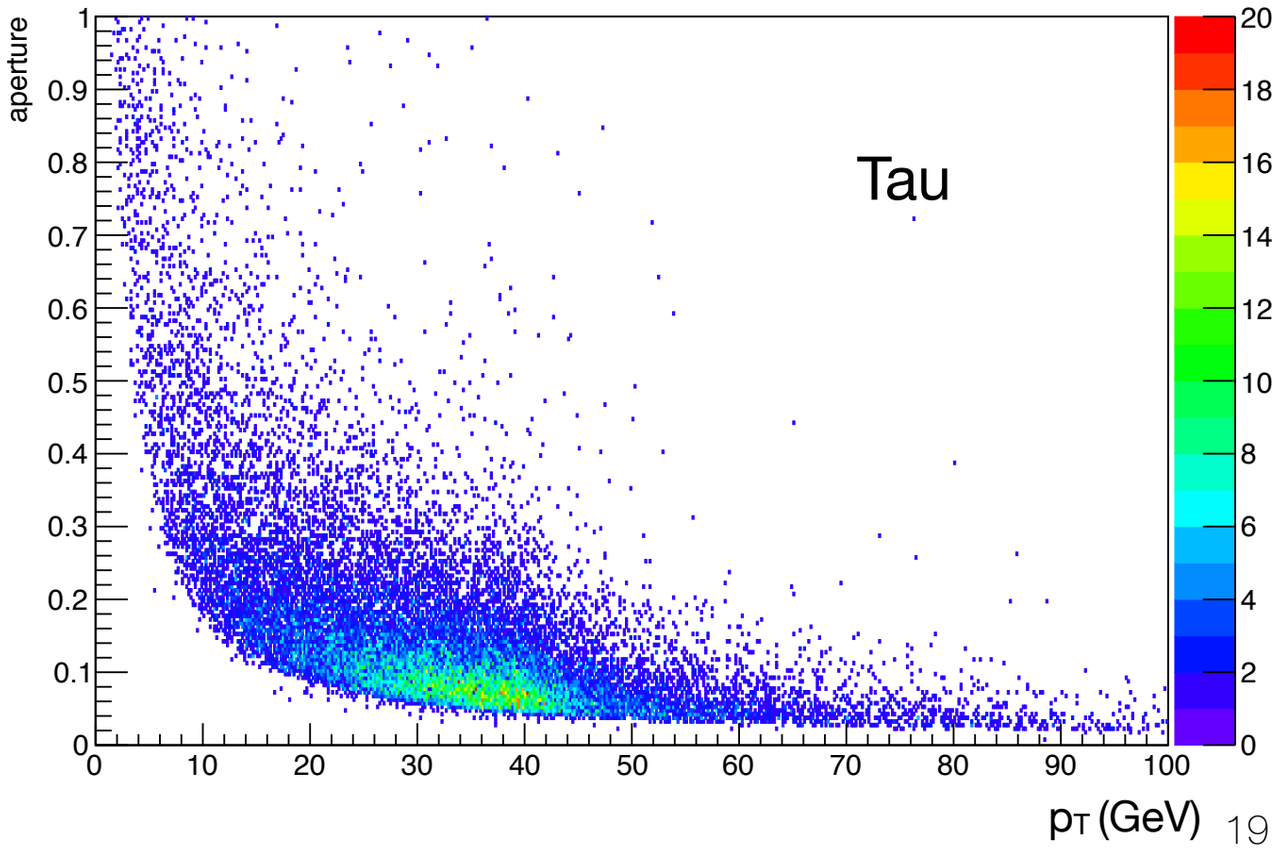
2018 JINST 13 P10034

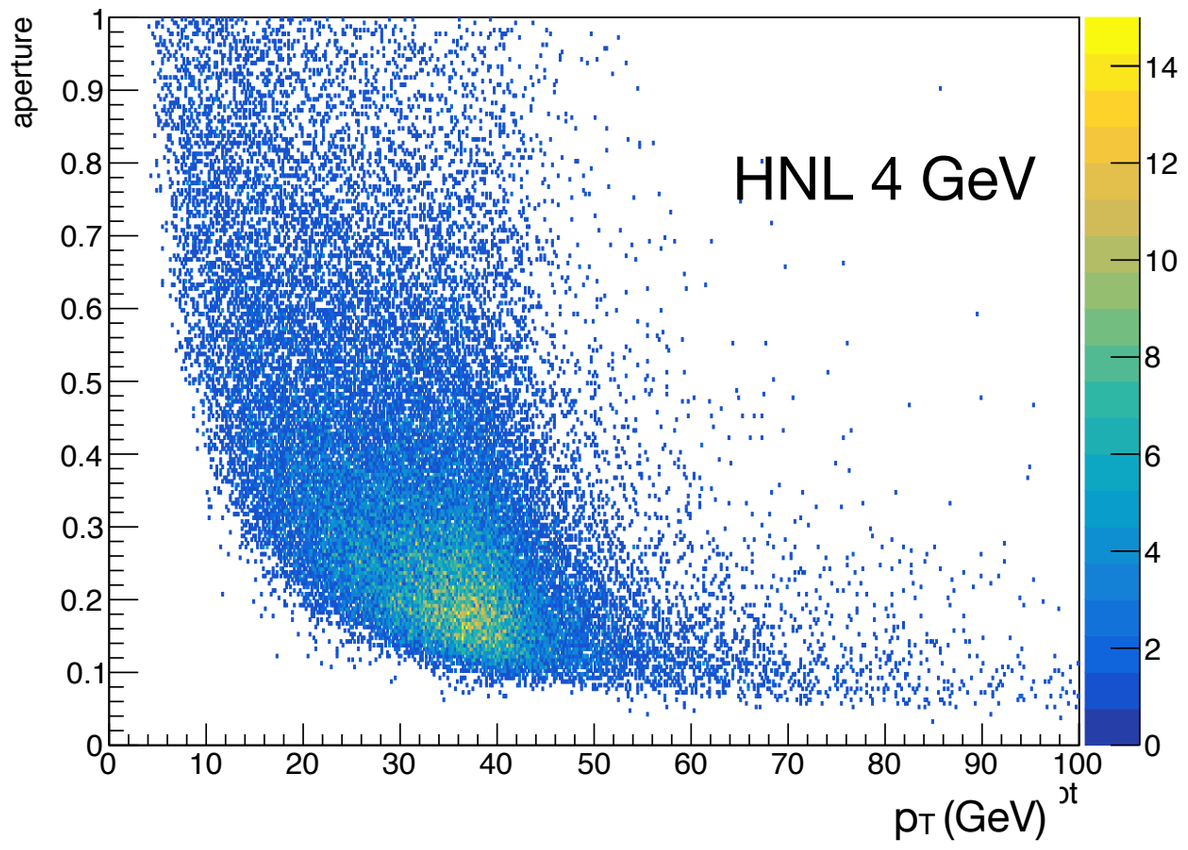
- Nuclear interaction provides a source of displaced vertices
- Precise map of the detector material needed



Is this the right direction?

- Displaced object decay products may decay in larger cone than the usual CMS jet
- Alternative vertex reconstruction algorithm might be more efficient
- Jets can be used to recover part of neutrals





Summary

- Reconstruction in CMS is not optimised for displaced object

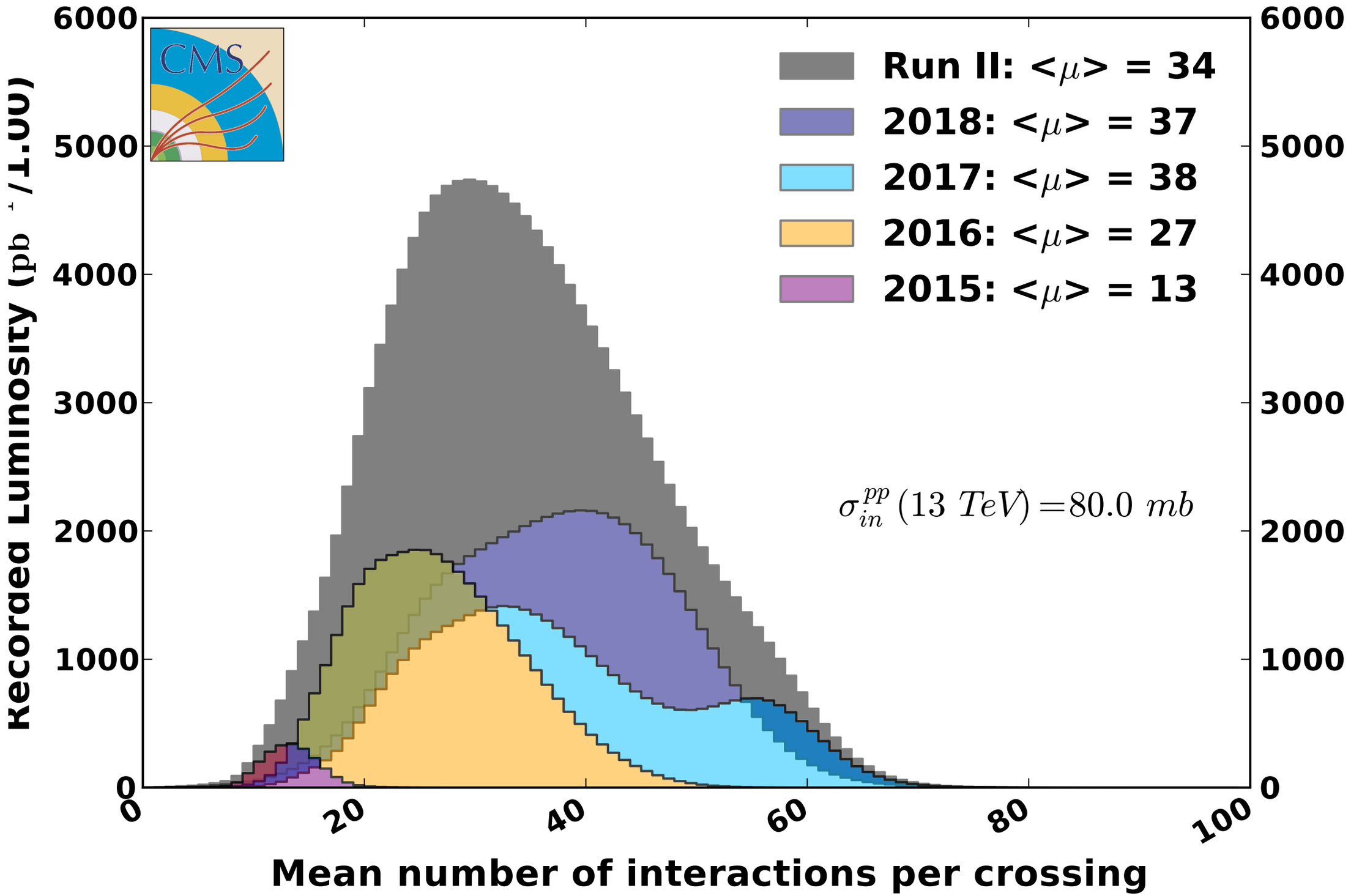
- Two directions to investigate:

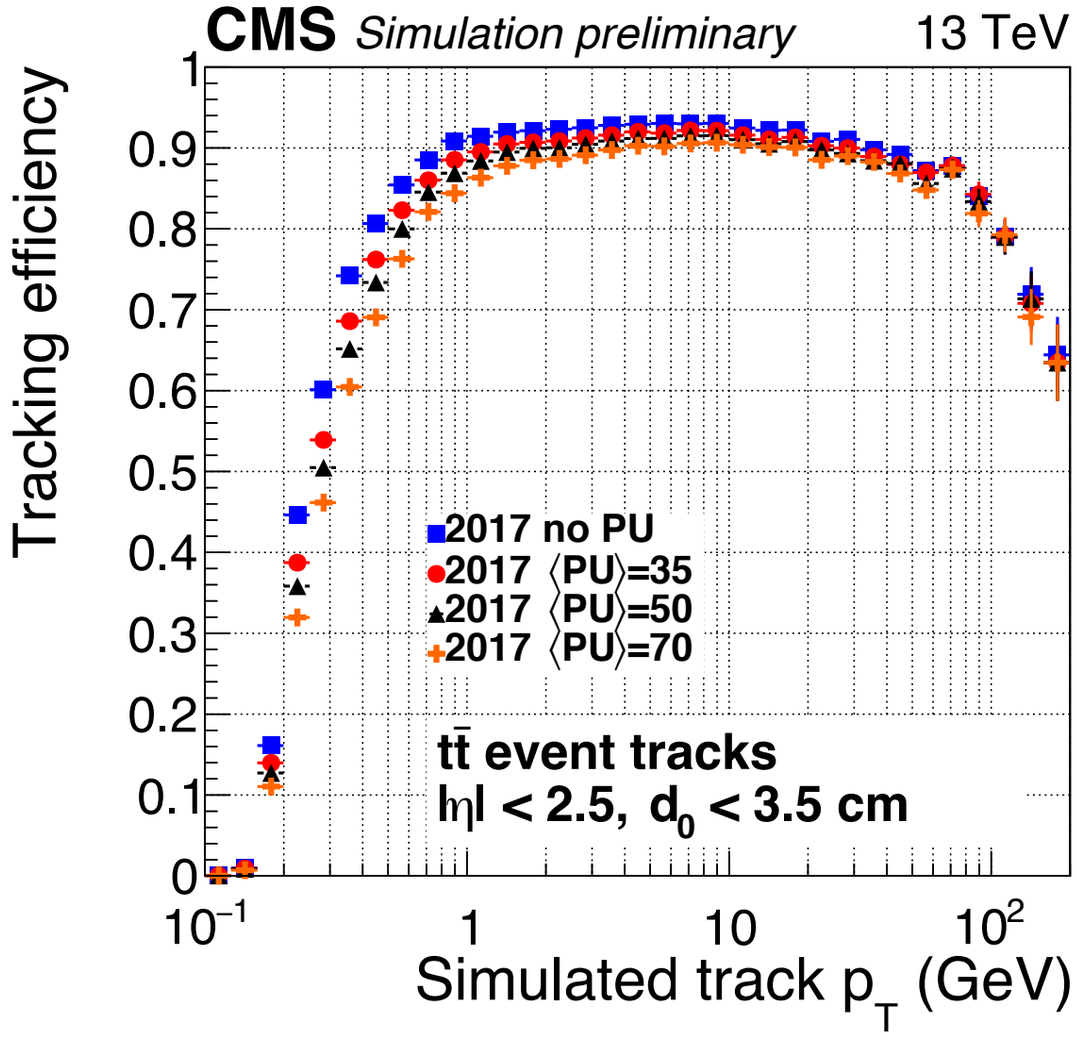
  - develop of reconstruction algorithm dedicated to long lived particles

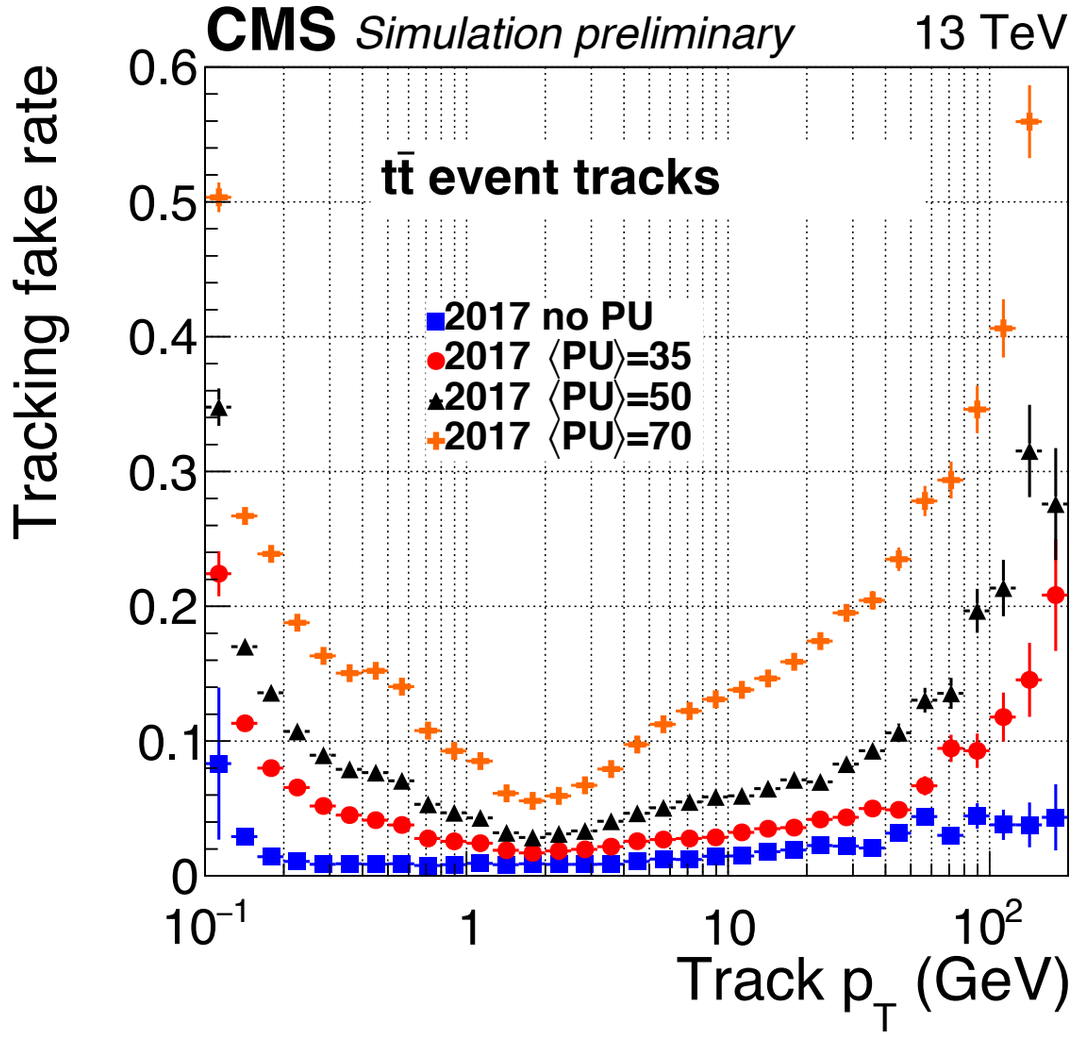
  - good understanding and modelling of background sources

Backup

CMS Average Pileup (pp, $\sqrt{s}$=13 TeV)




CMS Simulation preliminary
13 TeV
Tracking efficiency
2017 no PU
2017 ⟨PU⟩=35
2017 ⟨PU⟩=50
2017 ⟨PU⟩=70
tt̄ event tracks
|η| < 2.5, d0 < 3.5 cm
Simulated track pT (GeV)


CMS Simulation preliminary
13 TeV
Tracking fake rate
tt̄ event tracks
2017 no PU
2017 ⟨PU⟩=35
2017 ⟨PU⟩=50
2017 ⟨PU⟩=70
Track pT (GeV)