Search for MSSM Higgs into Tau Pairs at CMS

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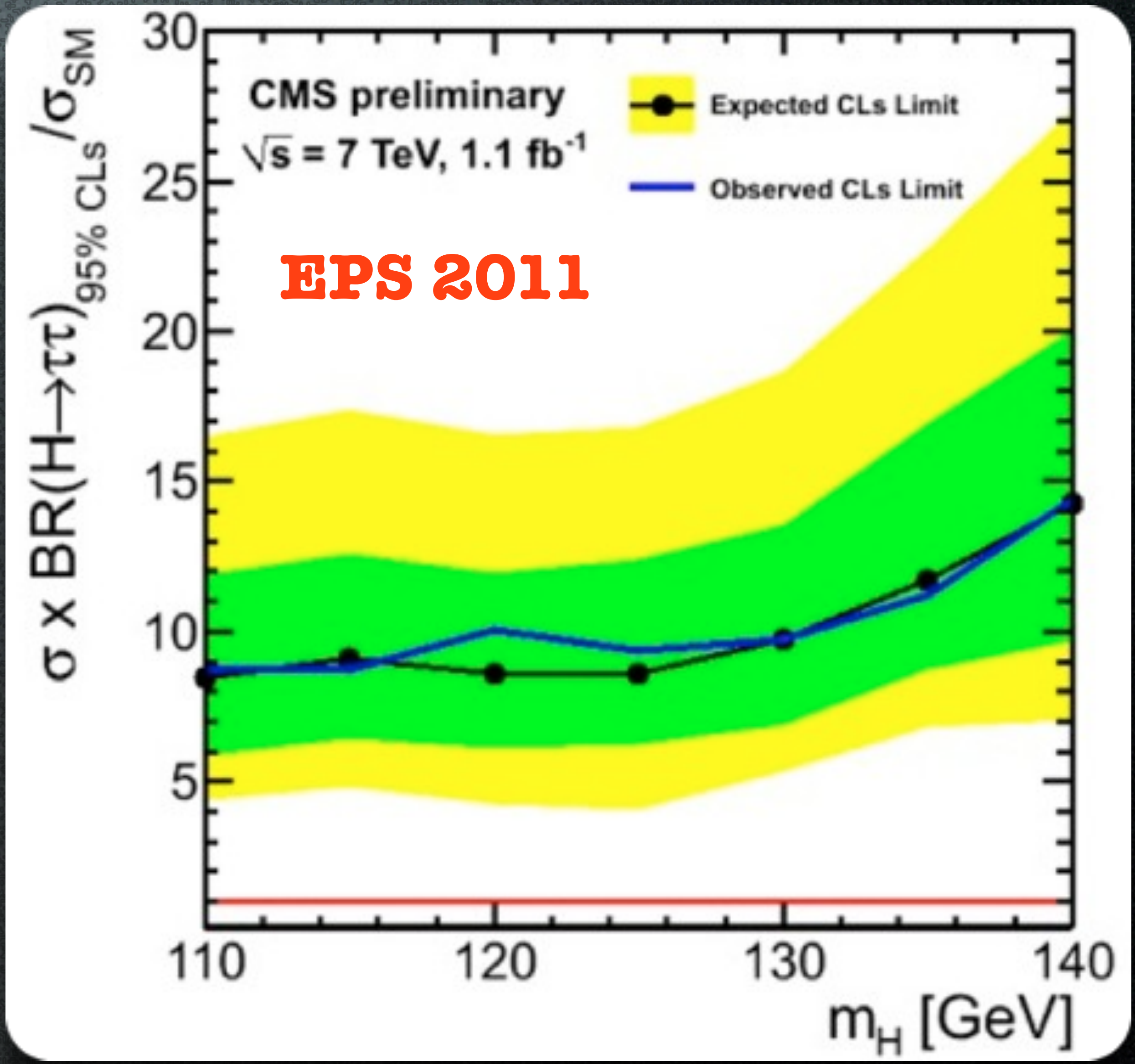
Outline

- Motivations
- Tau identification at CMS
  - Particle Flow
  - Tau decay features
  - Particle Flow Tau: Hadron Plus Strip Algorithm
- Pileup
  - Effects
  - Solutions
- Measurement of Tau identification Efficiency

Motivations

- My plan is to look for MSSM $H \rightarrow \tau\tau$ in 2011-2012 data
- τ pairs are not the best tool to look for SM Higgs boson, but one of the strongest for MSSM
- The τ lepton has the largest S/N ratio in some mass regions
- CMS collaboration already published the results from 2011 search
- Before starting my hunt my task is helping the commissioning of the identification algorithm and measuring the efficiency



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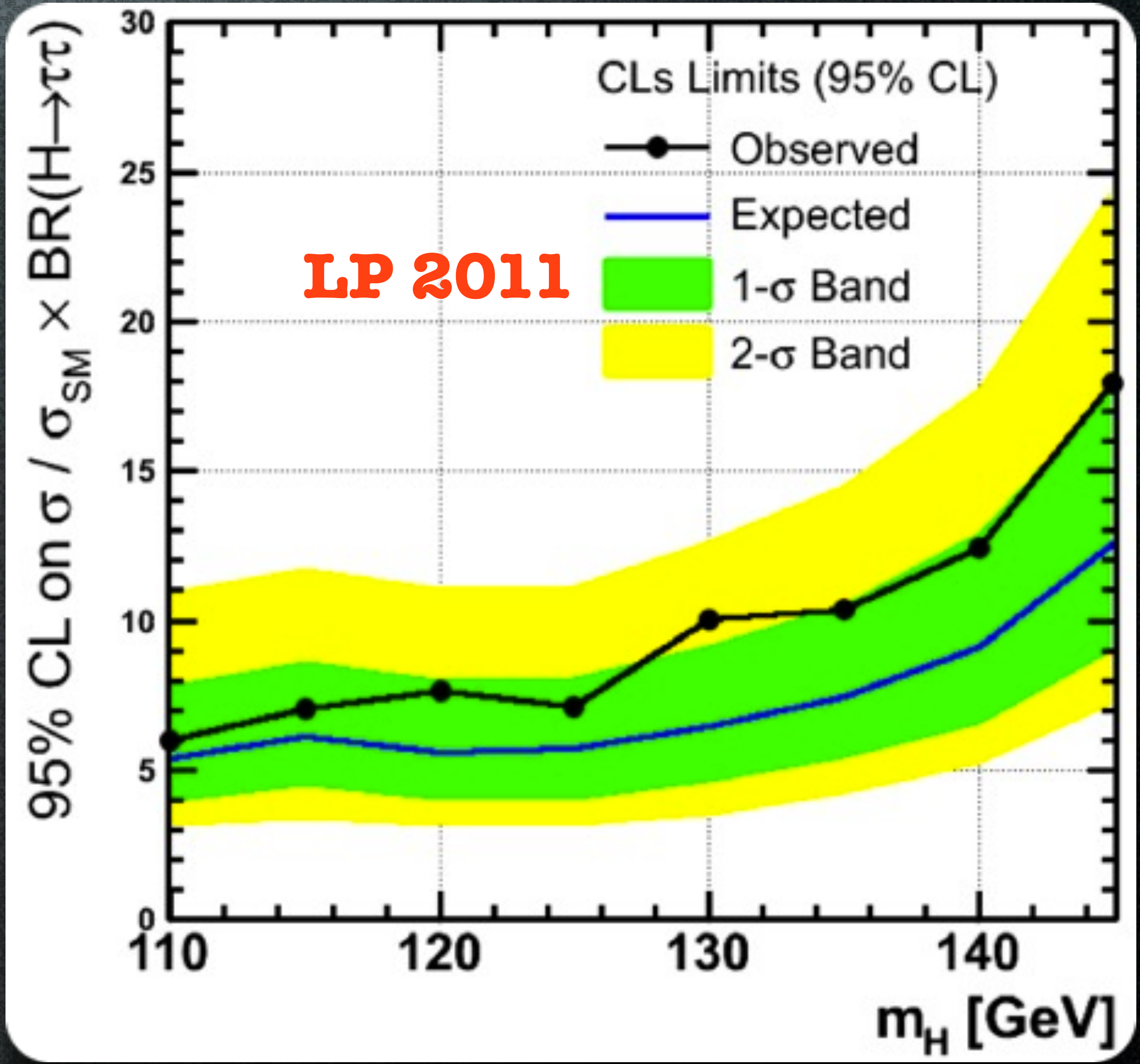

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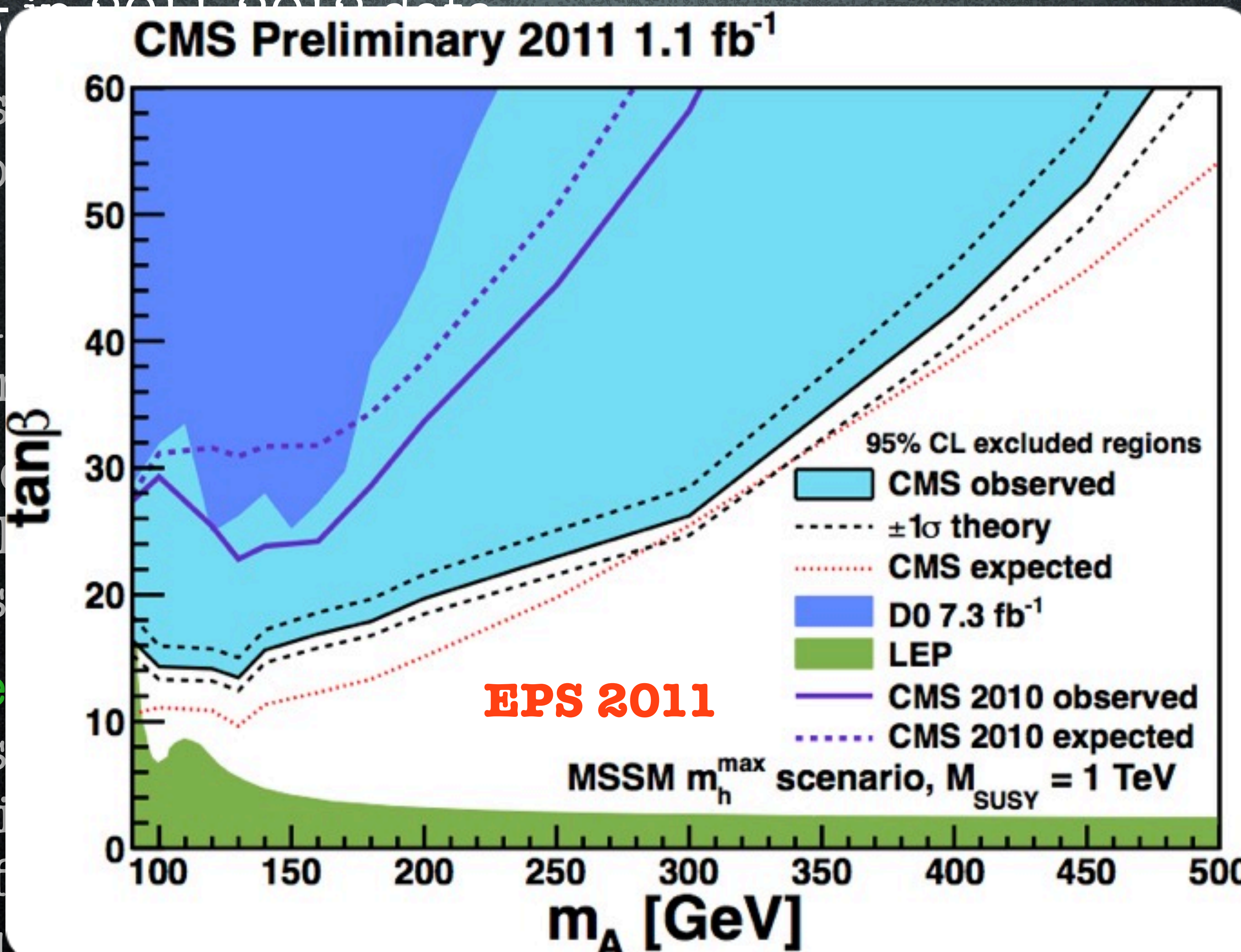

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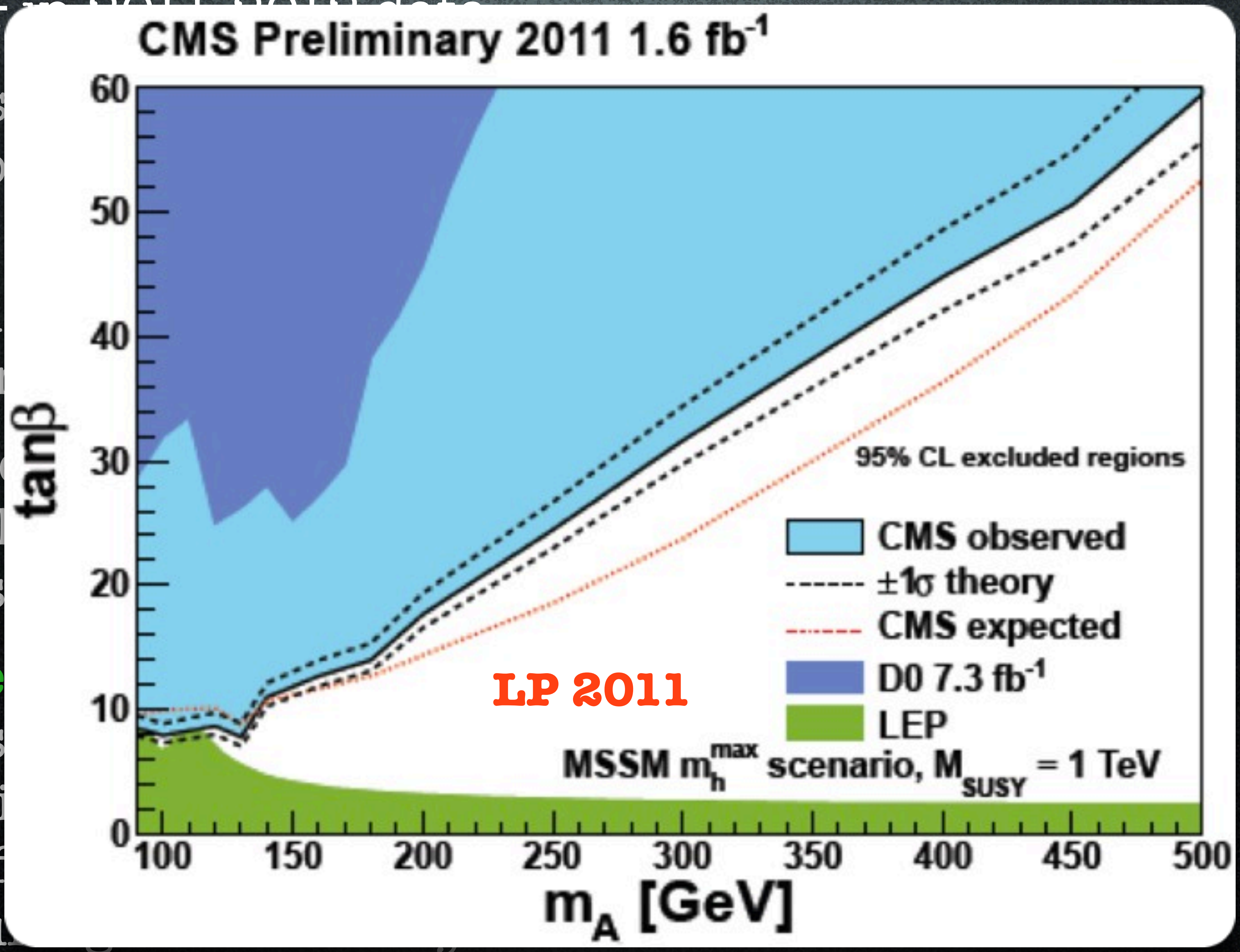
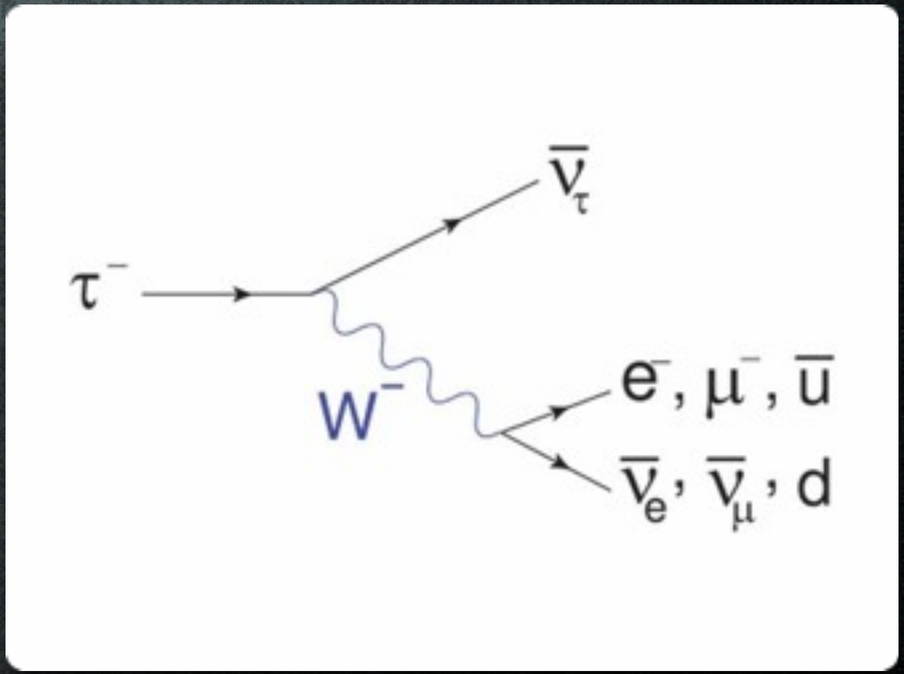


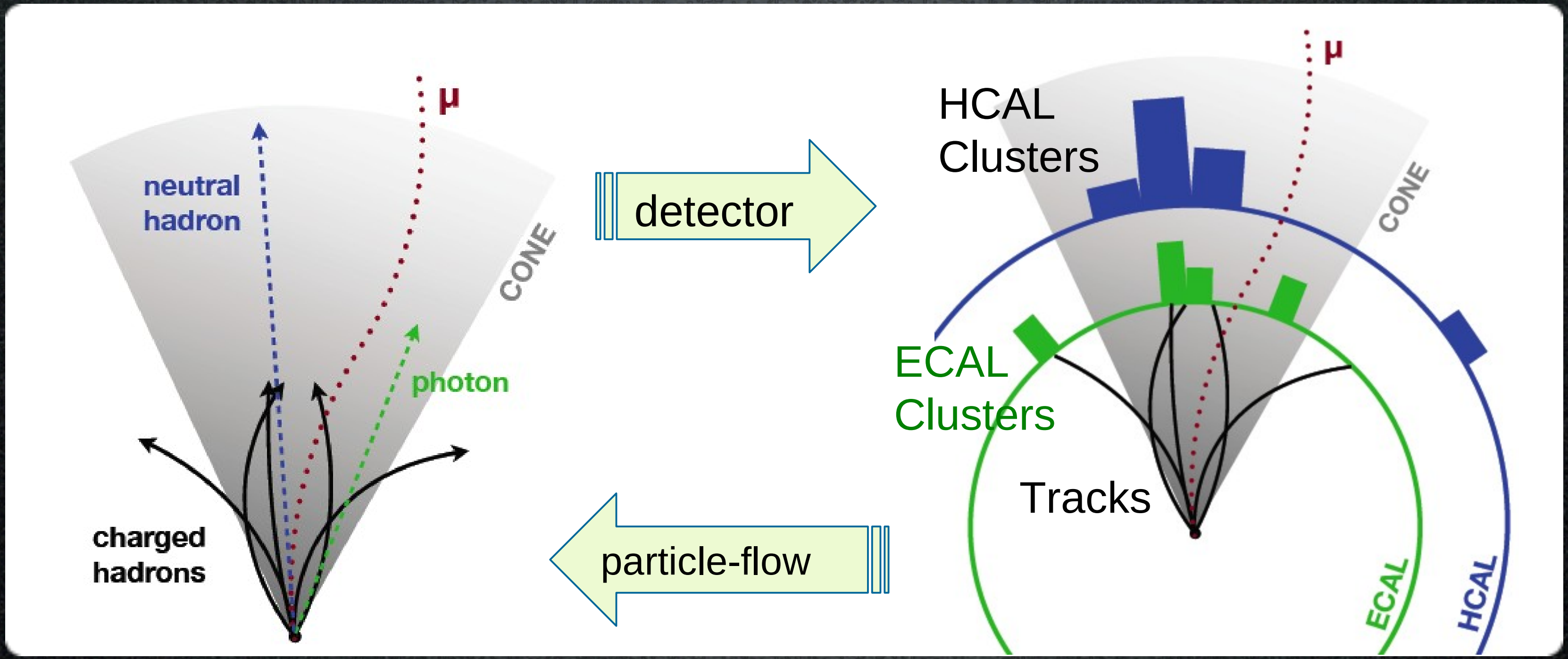
Characteristics of tau decay

- Tau is the heaviest (known) lepton
  - Mass: 1.78 GeV
  - $c\tau$ = 87 μm
- Electroweak decay, with neutrinos
- It decays into other leptons (~17% μ,e)
- It mainly decays into hadrons (usually π's)
- Jets from tau decays are collimated due to large boost.
- Tau jets can be identified due to low detector activity around decay products



Particle Flow

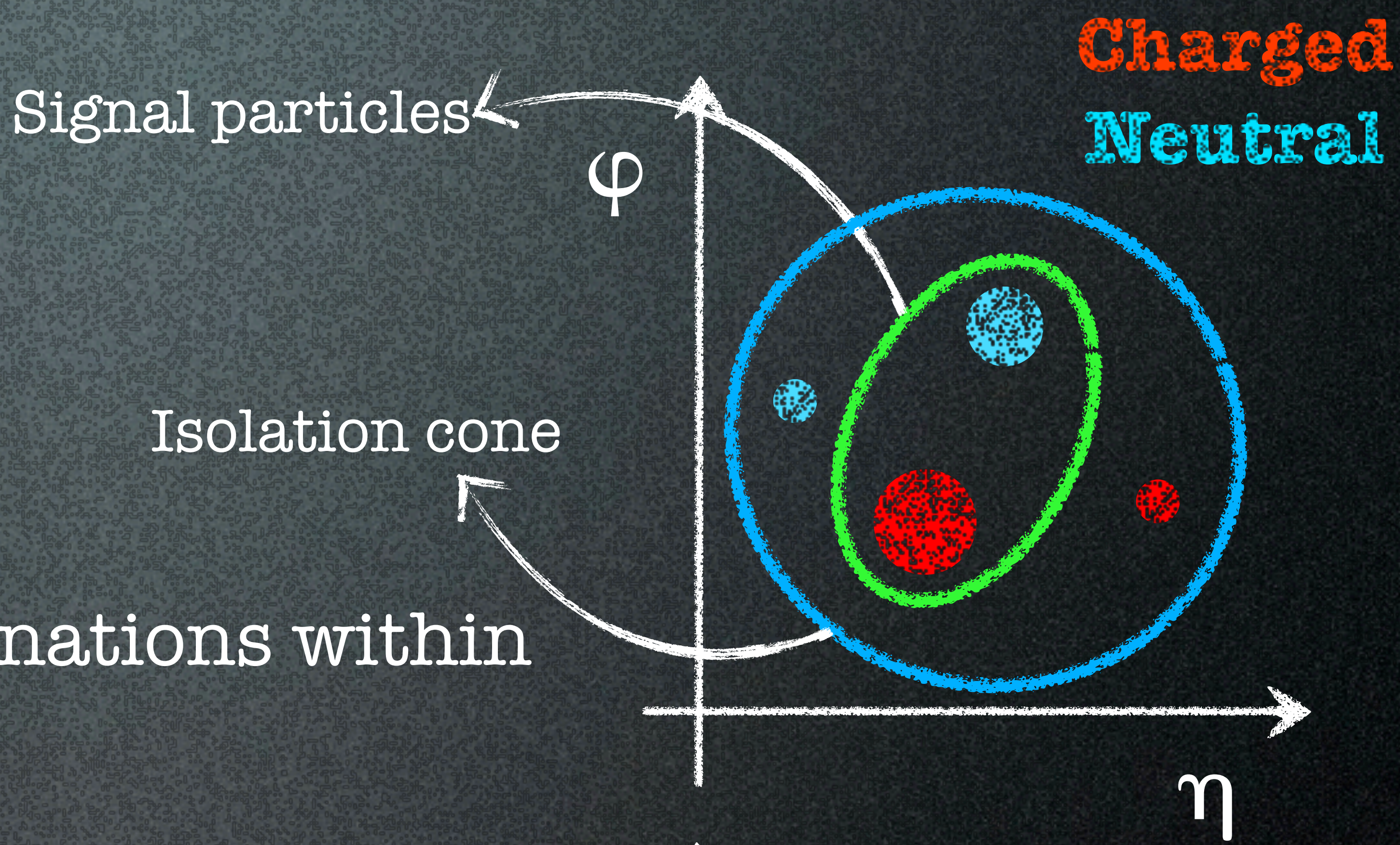
- Particle Flow (PF) is an algorithm that gives a complete description of the event
- Links all the signals from different subdetectors
- produces a list of particle candidate (e, μ, γ, hadron)
- Taus are built from PF objets

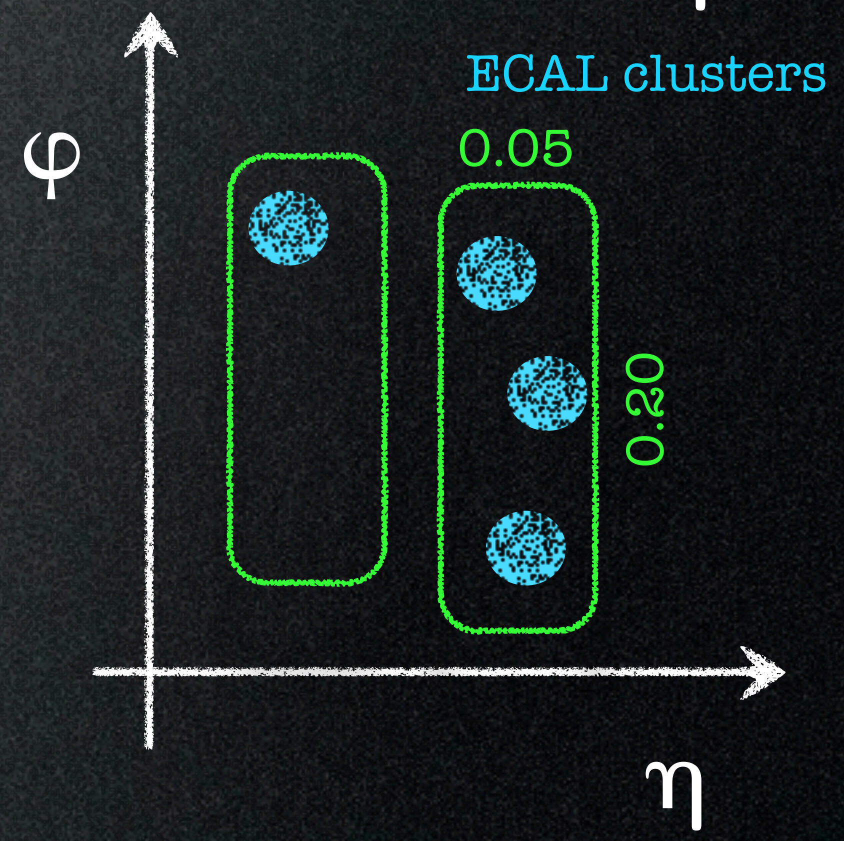


Hadron Plus Strip

Two main features:

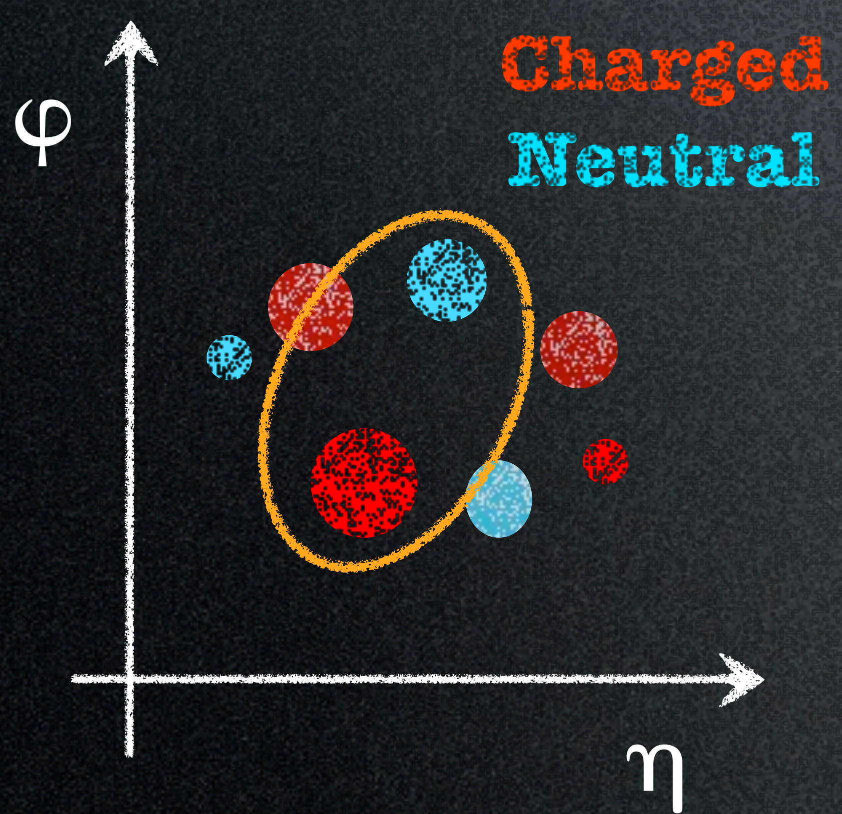
- Decay Mode Finding:
  - Builds all possible combinations within (π,$\pi\pi^0$,$\pi\pi\pi$)
  - Chooses among them the most isolated with compatible visible mass
- π^0's are formed summing clusters in a strip along φ.

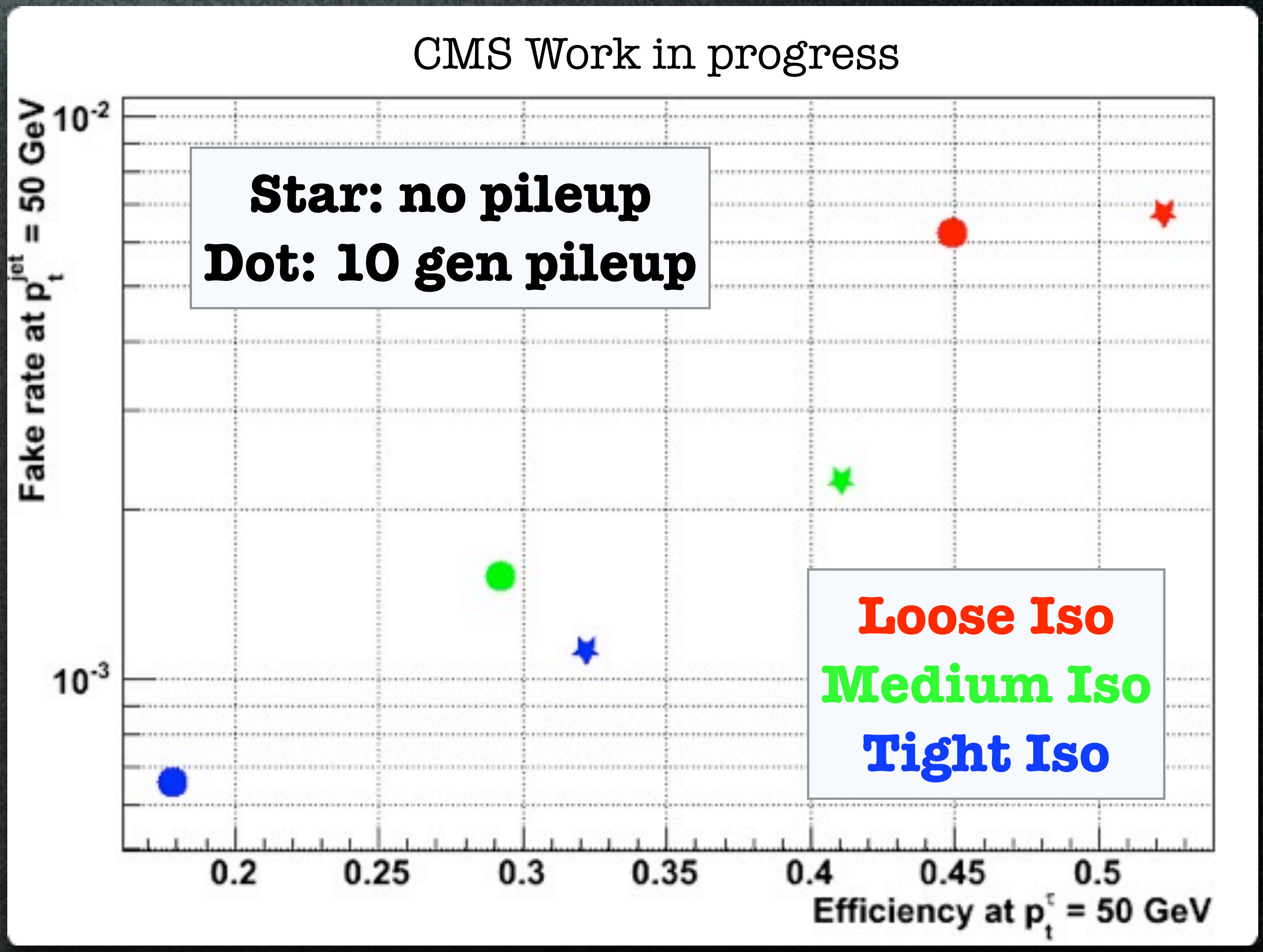




Effects of pileup

- With increasing instantaneous luminosity delivered by LHC we started having more than an interaction per bunch crossing
- In 2010 ~3 interactions, in 2011 (spring) ~6.
- Without a vertex constraint pileup spoils isolation
- We should see a decrease in efficiency and fake rates
- MC simulation confirms this effect



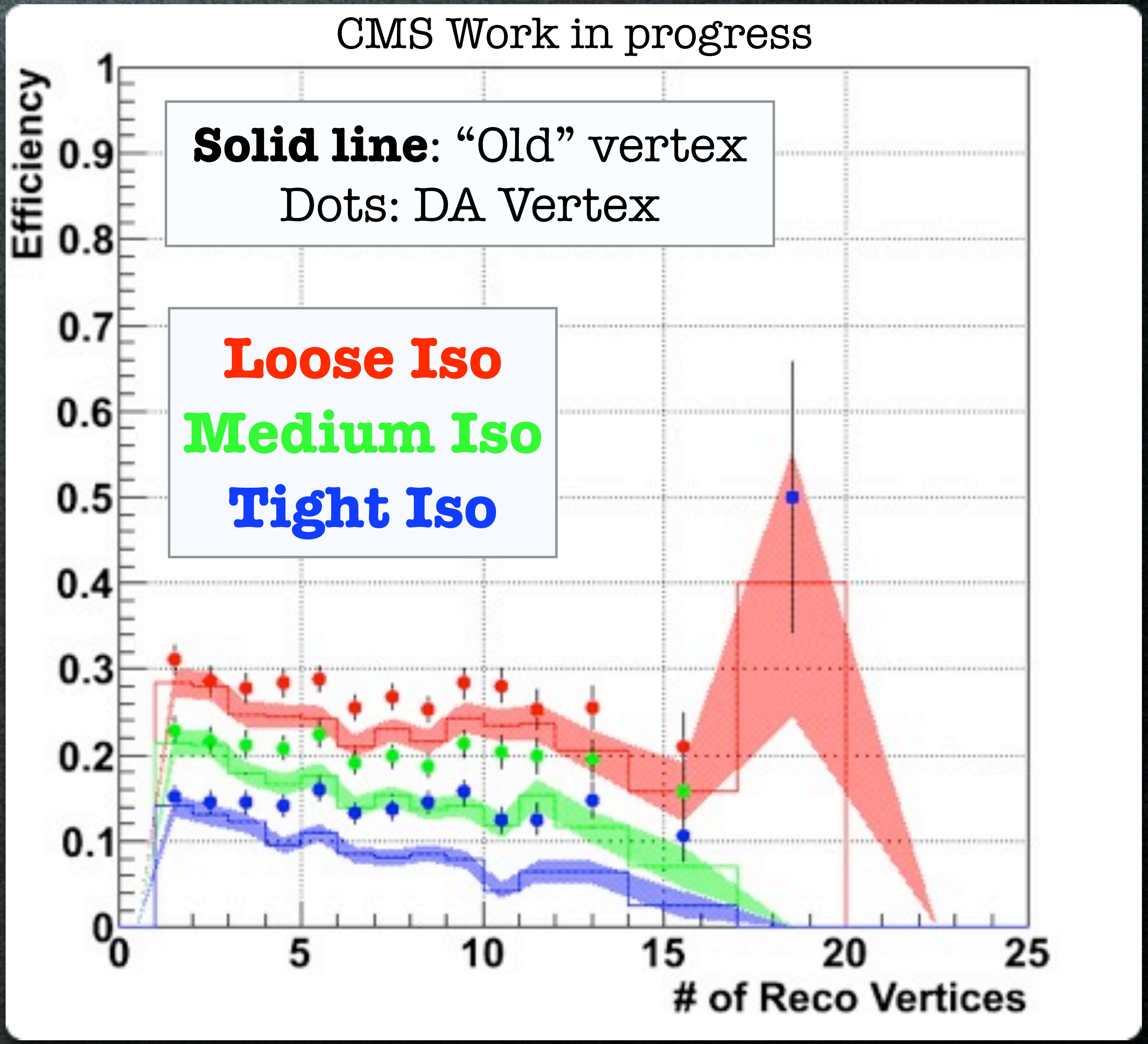


Solutions

Introducing a vertex requirement to the signal/isolation charged particles is not enough. We need a better vertex algorithm.

Deterministic Annealing vertexing: new algorithm the substitutes the traditional vertex algorithm based on gaps.

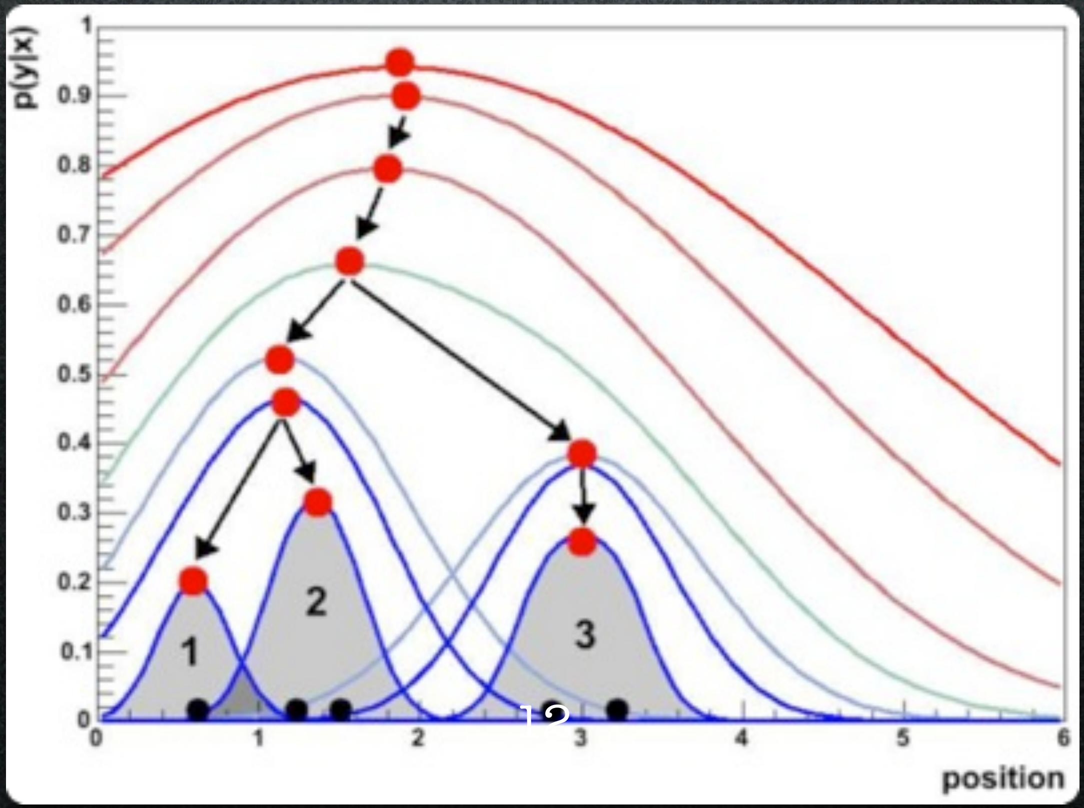
Δβ correction:
derives from the amount pileup tracks the neutral energy deposit due to pileup.
(more about this in next slides)



The final goal: efficiency independent from pileup

DA Vertex

- Recursive algorithm
- Global χ^2 with each track assigned to a vertex
- Tracks assigned with a weight parameter [0,1]
  - Soft assignment: all weights equal
  - Hard assignment: all weights 0, 1
- Softness controlled by a “temperature” parameter
- Iteration by iteration prototype vertices are split / merged and the temperature is decreased



$\Delta\beta$ correction

- Vertex requirement improves isolation vs. charged particles
- No improvement for neutrals (no vertex)
- $\Delta\beta$ correction starts computing the quantity of energy present in the jet due to pileup tracks (exploit vertex)
- Infers the neutral energy deposit due to pileup scaling the charged deposit by a constant factor (tunable)
- Subtracts this deposit to the measured one
  - Jet-by-jet basis
  - relies on averaged quantity

Measuring Tau ID efficiency

Our aim is to prove that both simulations and the algorithm are understood and under control

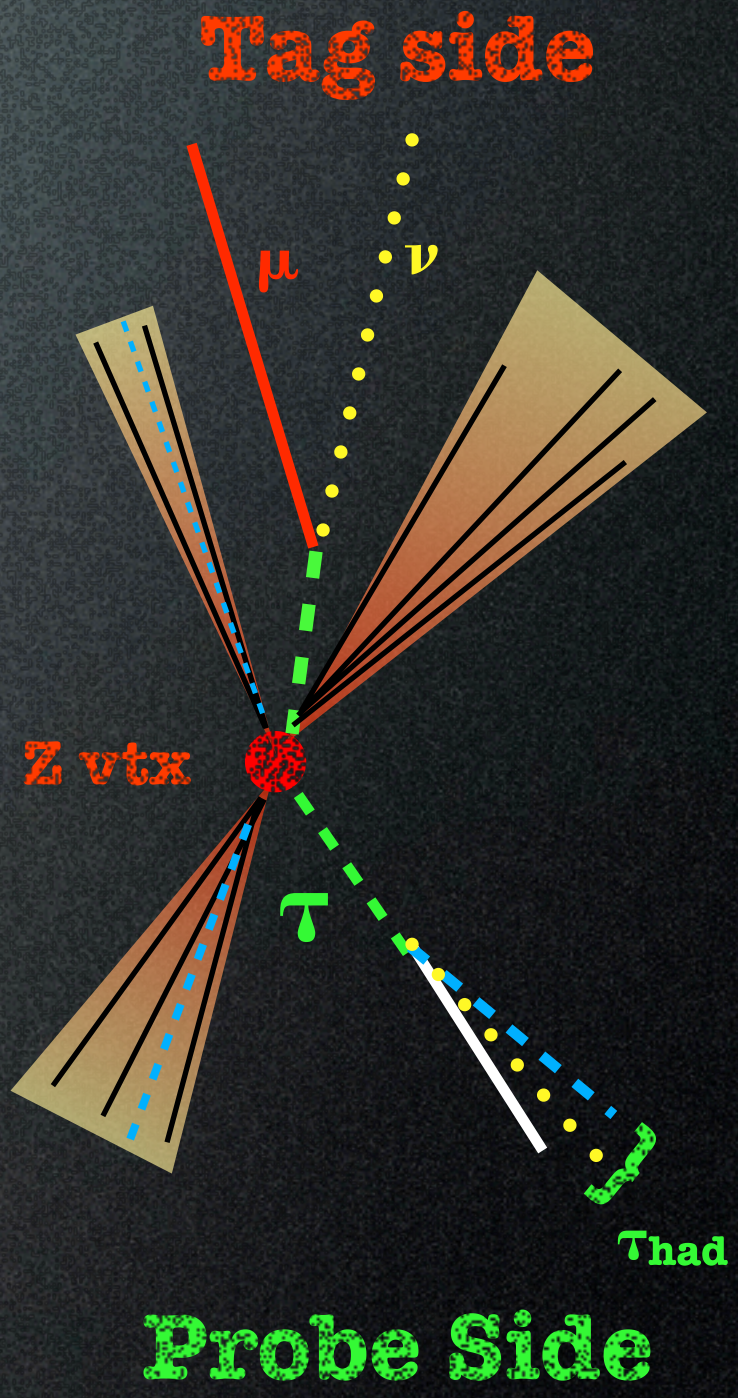
Measuring the efficiency from data without bias is the only way to go

Two methods:

- $Z \to \tau^+\tau^-$ / $Z \to \mu^+\mu^-$ yield (not totally unbiased)
- Tag & probe

Tag & Probe

- Uses Z→ττ→μ + jet
  - $\varepsilon = \frac{N^{fit}_{\tau ID\ passed}}{N^{fit}_{\tau ID\ passed} + N^{fit}_{\tau ID\ failed}}$
- No bias from possible Higgs contaminations in the Z peak
- Event preselection with no Tau ID applied
  - P_t^{jet} > 20GeV
  - Muon and Jet leading track of opposite sign
  - $M_t(\mu+MET)$ < 80GeV
  - P_ζ - 1.5 P_ζ^{vis} > -20 GeV

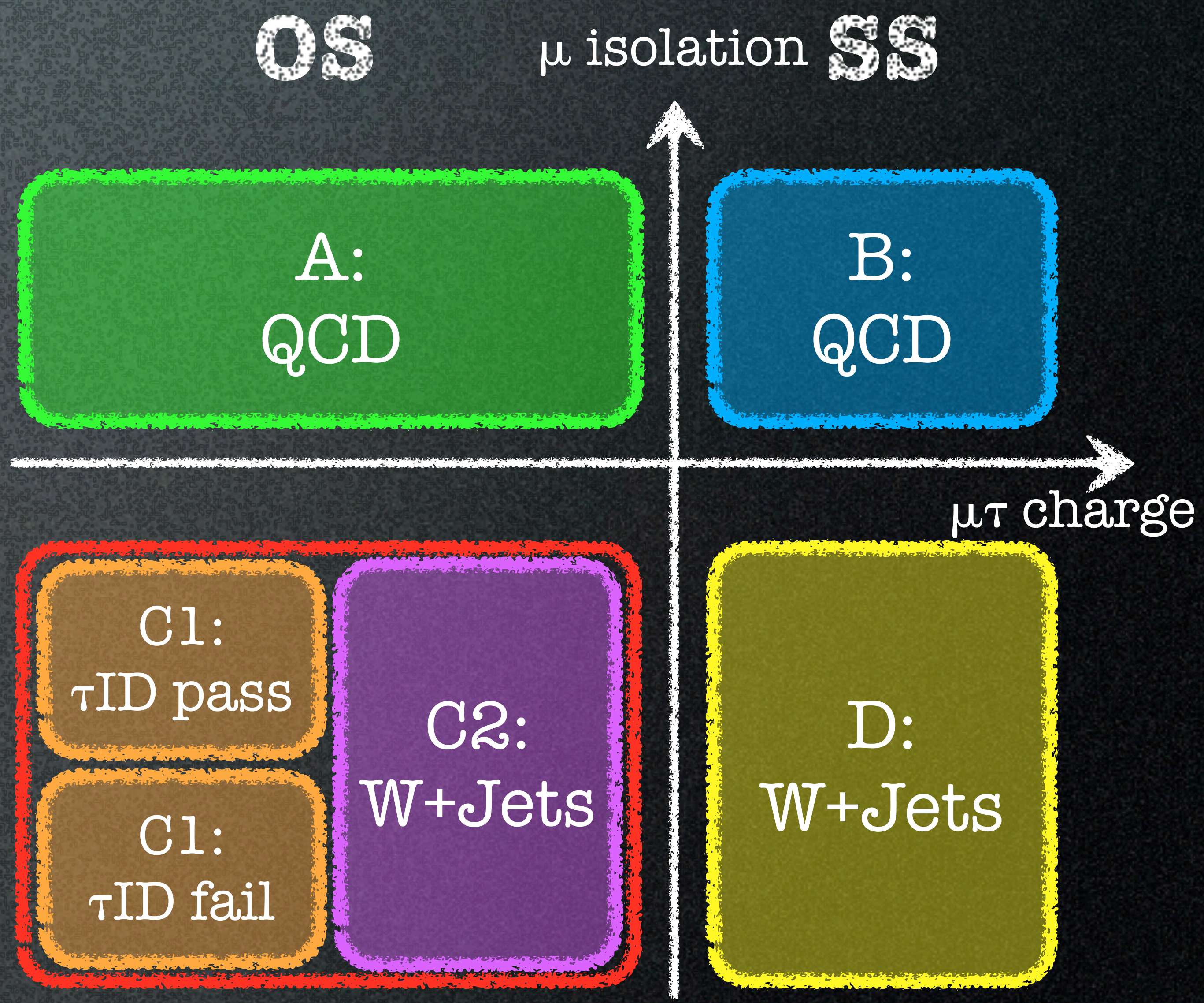


Event Selection

- Events rejected moved to sidebands
- Signal region (C1) purified from W+Jets background requiring $M_t(\mu+MET) < 40$GeV
- Good events are divided into "Tau Passed" and "Tau Failed"

- Signal bands + sidebands are fitted simultaneously using MC templates.
  - $M_{vis}(\mu+jet)$ used for signal region
  - $M_T(\mu+MET)$ for others
- Sidebands used to constrain the backgrounds (ABCD Method)

$$\varepsilon = \frac{N^{fit}_{\tau ID\ passed}}{N^{fit}_{\tau ID\ passed} + N^{fit}_{\tau ID\ failed}}$$

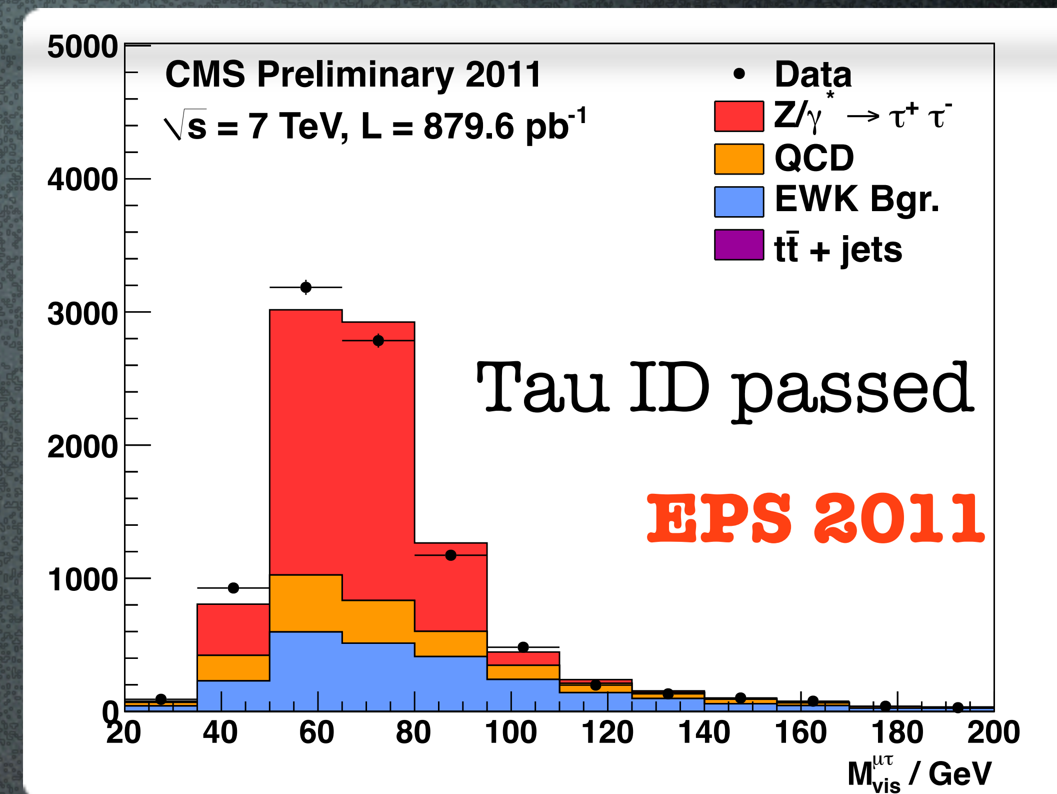


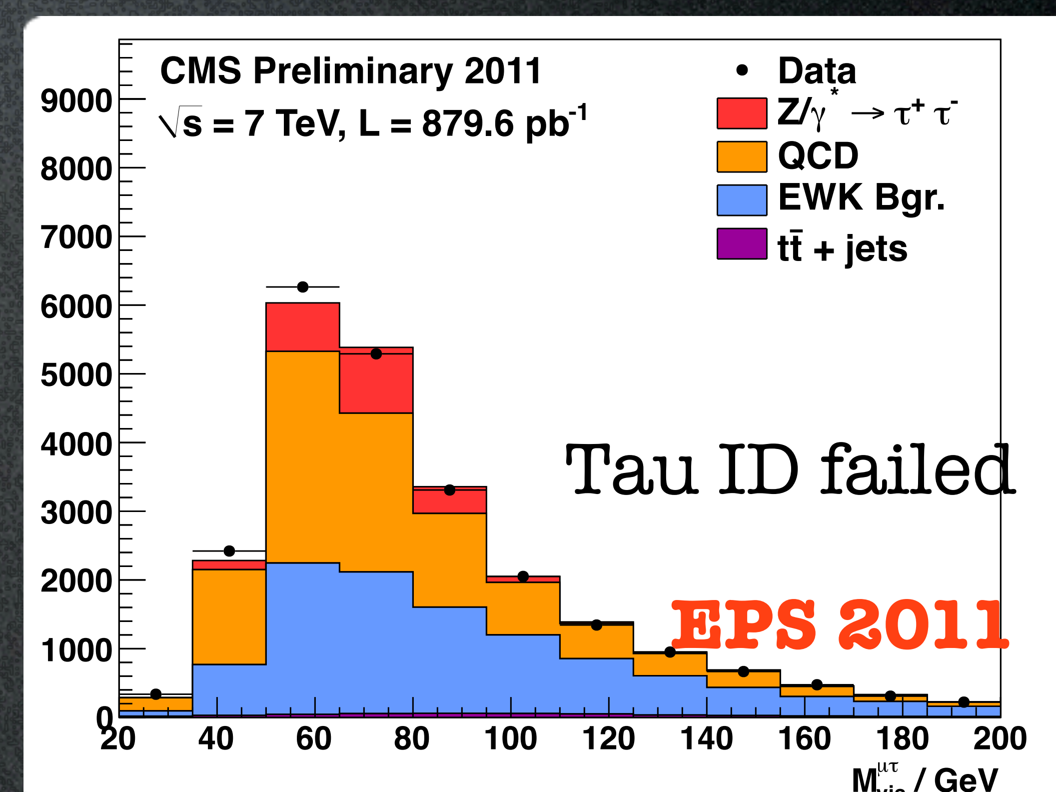
Results

Uncertainty's source	
Muon Momentum Scale	<< 1%
τ-Jet Energy Scale	< 1%
Track Reconstruction	3.9%
Track Momentum Scale	< 1%
Lead. Track P_T Cut	1%
Loose Isolation	2.5%
Jet → τ_{had} Fakes	1.2%
Lead. Track Corr. Factor	1.7%
Loose Iso. Corr. Factor	2.1%
Fit (Statistical Uncertainty)	2.6%
Total uncertainty	6%

Moriond 2011 uncertainty: 23%

HPS Loose: (69.2 ± 1.8)%
MC Scale factor: 1.003 ± 0.060





Summary

- The presence of pileup is a challenge for an isolation based algorithm like the tau ID.
- Commissioning of new tau identification for medium pileup environment completed.
  - Deterministic Annealing vertexing
  - Delta Beta corrections
- Efficiency of tau identification measured with **6%** of total uncertainty
- Final goal: Heavy neutral higgs to tau tau search with 2011-12 data

Back-up

Notation

- $M_t(\mu+MET)$

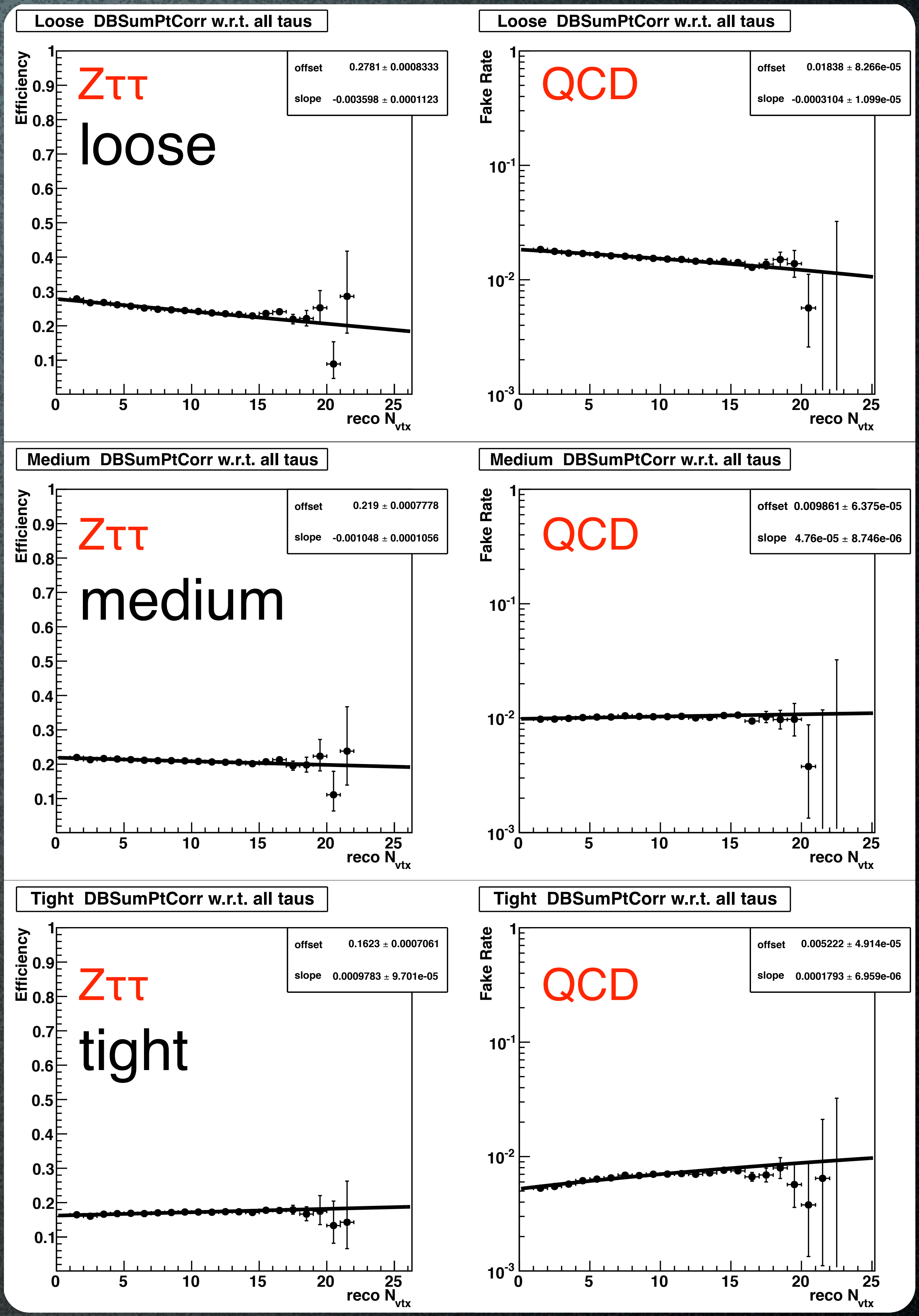
$$\mathbf{M_T^{\mu E_T^{miss}}} = \sqrt{(\mathbf{P_T^{\mu}} + \mathbf{E_T^{miss}})^2 - \left((\mathbf{P_x^{\mu}} + \mathbf{E_x^{miss}})^2 + (\mathbf{P_y^{\mu}} + \mathbf{E_y^{miss}})^2\right)}$$

- P_ζ

$$\mathbf{P}_\zeta = \mathbf{P_T^{vis_1}} + \mathbf{P_T^{vis_2}} + \mathbf{E_T^{miss}} \mathbf{P}_\zeta^{\mathbf{vis}} = \mathbf{P_T^{vis_1}} + \mathbf{P_T^{vis_2}}$$

  - Developed by CDF
  - Rejects events where the MET is not collinear with the tau jet (W + jets)

New Discriminator



Efficiencies and fake rates