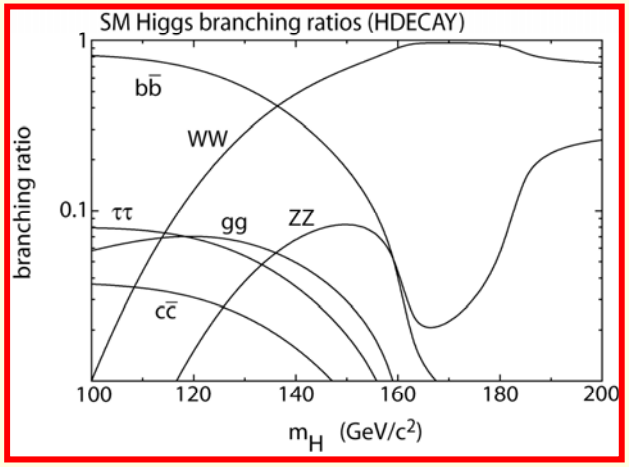
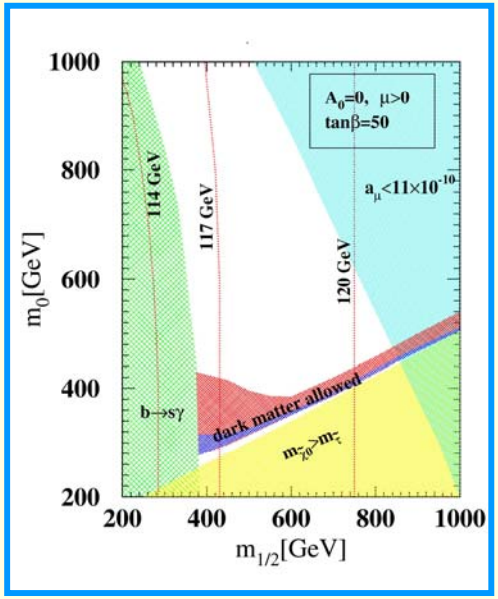
Hadronic Taus at CMS: Goals, Status, and Plans…

Alexei Safonov (Texas A&M)
for the tau people

Motivation for Taus

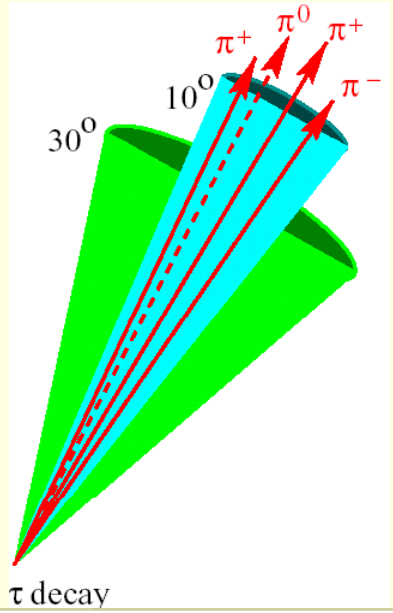
- Light higgs discovery:
  - Taus - second highest BR after b's
    - Cleaner signatures – high sensitivity
  - Understanding higgs:
    - Verifying fundamental $V_{hff} \sim m_f$ SM prediction requires measurements in τ and b channels.
  - If nature chose SUSY, taus are even more important:
    - Co-ahhihilation region: SUSY cascade decays will have lots of taus, easy to confuse with jets
    - Higgs: enhancement in cross-sections, additional heavy higgs bosons can be directly observed (H, H+ or even H++)

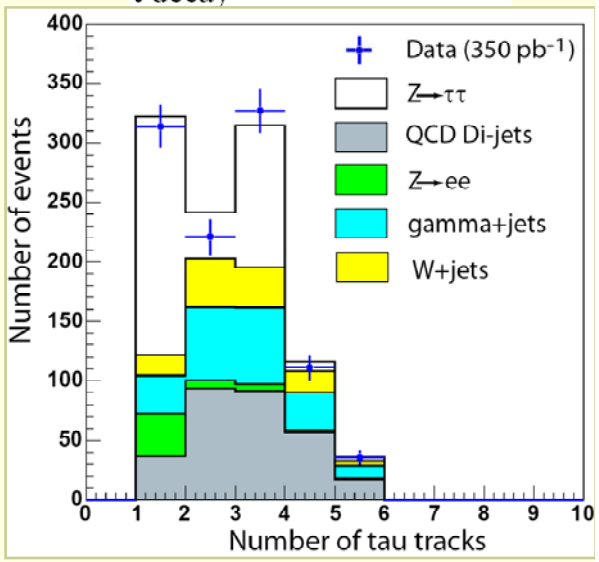




Experimental Challenge

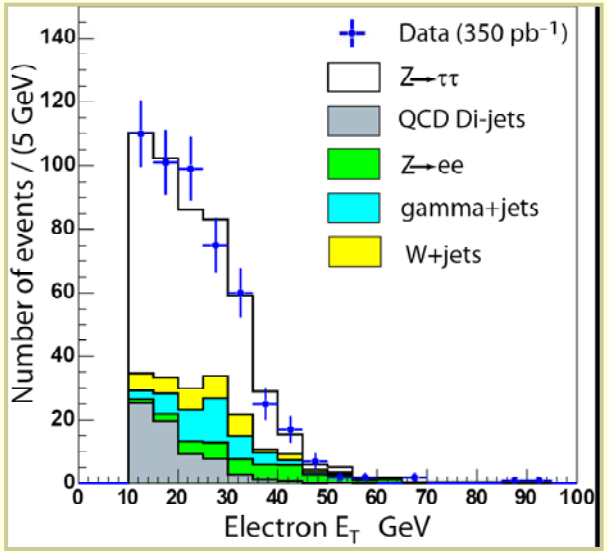
- Visible decay products of taus are very soft due to escaping neutrinos:
  - Requires low thresholds to preserve acceptance
  - True for both light higgs and SUSY searches and also for important calibrations samples (Z's, W's)
- Multi-jet background enormously high:
  - Fake rate is at least an order of magnitude higher than for electrons and muons
- Typical strategies:
  - Look for narrow energetic isolated jets
    - At least one relatively high p_T track, isolation, low multiplicity and narrow shape of the jet core





Goals

- Provide efficient and well understood tau triggers, reconstruction and identification suitable for wide range of physics analyses
  - Higgs (heavy and light, also charged)
  - SUSY
  - Z-prime like resonances
  - … (unexpected)
- Real life puts constraints on what we can do
  - External constraints
    - Can't change trigger hardware
    - Can't remove material from the tracker
- … and how fast we can get there:
  - Lower acceptance and larger backgrounds require more data compared to light leptons



Three Components

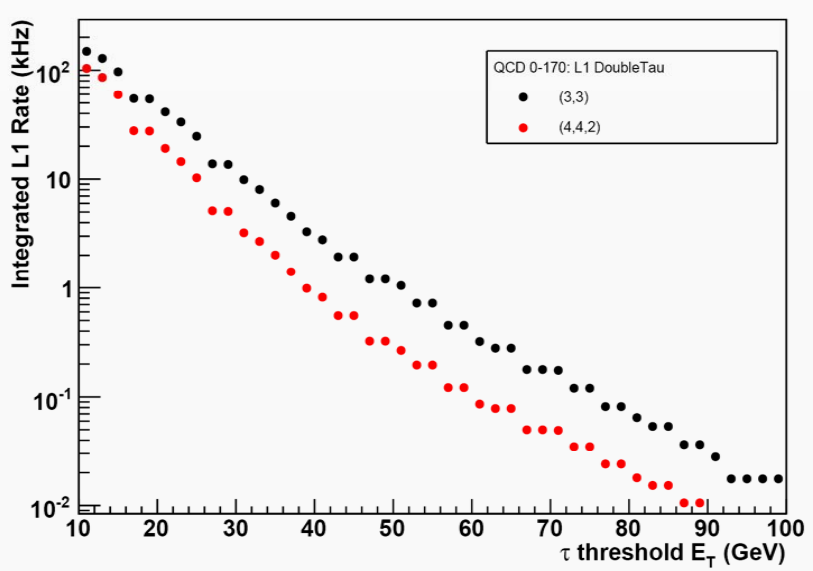
- Successful execution of physics program with taus relies on several inter-related ingredients:
- Triggers:
  - High efficiency at tolerable rate
  - Ability to measure efficiency
- Offline Reconstruction:
  - High efficiency at acceptable fake rate
  - Ability to understand and measure efficiency
- Standard candle proto-analyses:
  - Measurement of efficiencies requires reasonably clean samples
  - Selection of clean samples can only be by advancing standard candle analyses

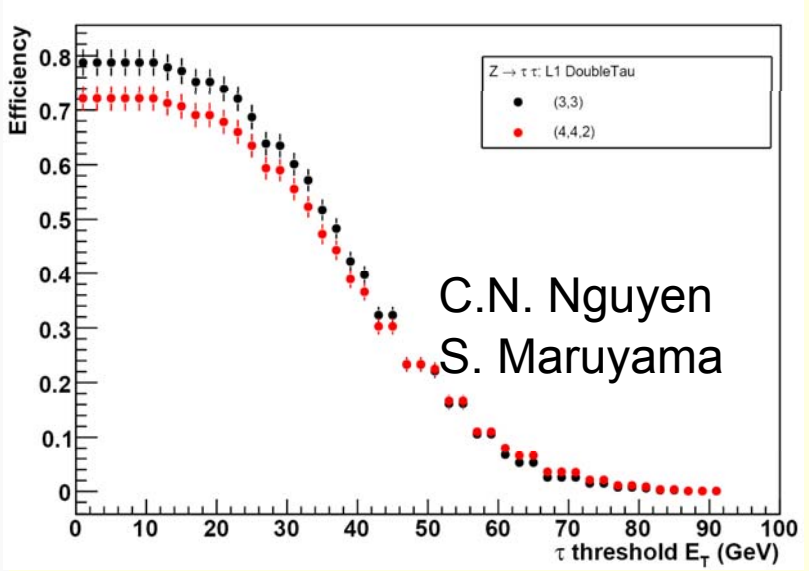
Triggers: Status

- Most critical area, therefore large fraction of our manpower was directed there
  - Main challenge is high rates, also have to watch for HLT timing
  - Simplified and improved the overall setup for easier manageability and maintenance
- Focus on increasing background rejection as early in the trigger chain as possible:
  - Large improvements in L1 and L2 rejection
    - Directly helps timing as less events need to be processed
  - Better path definition to recover efficiency at high E_T
  - Splitting tracking selections between L2.5 (seeding with pixels+SI) and L3 (isolations)

Level 1 Triggers

- A not so recent proposal:
  - L1 tau rates down by a factor of 2 per jet
  - Efficiency nearly intact



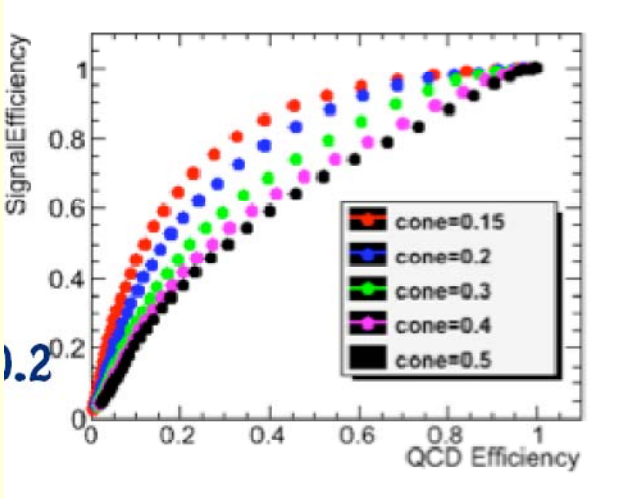


- Approved a year ago, but not implemented yet:
  - Requires firmware modifications, in the queue
  - Not critical for very low luminosity, but needs to get in
- TO DO: study tuning for higher inst. luminosity

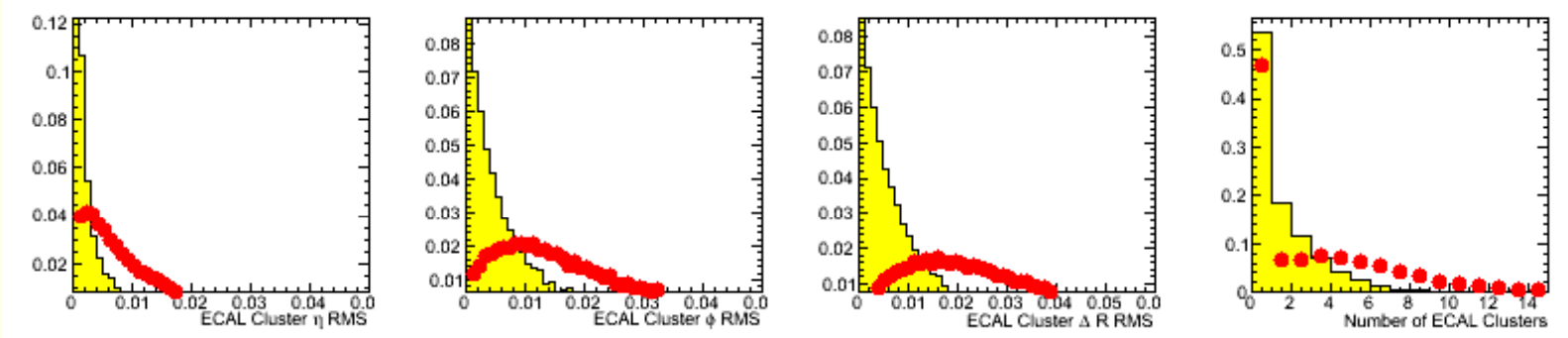
HLT: Level 2

Mike Bachtis (Wisconsin)

- While L1 has many hardware constraints, L2 is the place where we can implement a better calorimeter tau trigger:
  - Jet energy in a small cone:
  - Implement clustering – substantial improvements from any clustering, recently have added PF clusters

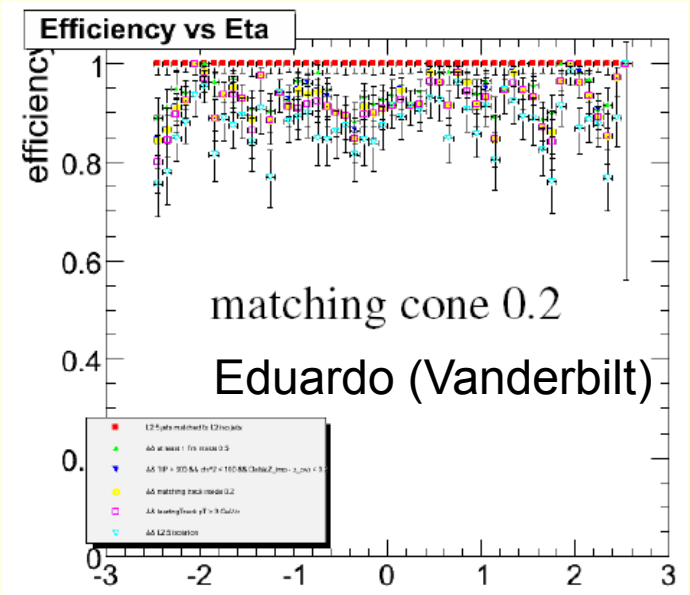


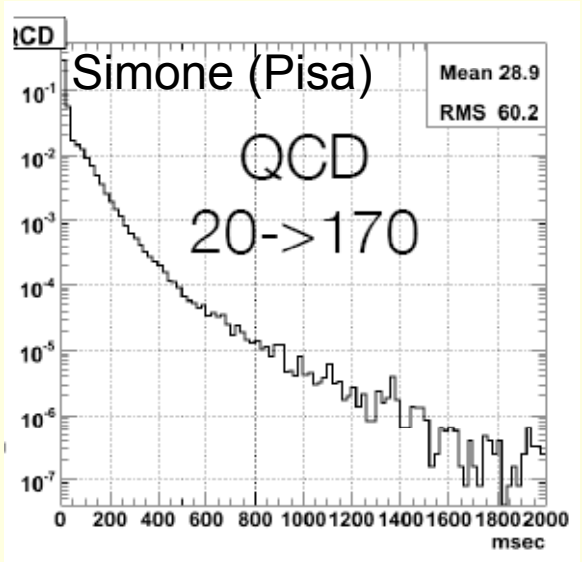
  - Online selections become similar to offline making a better trigger



HLT Level 2.5: Tracking

- Tracking can provide a huge reduction in rates:
  - Require seed track (~5 GeV) and apply isolation (e.g. no tracks above) 1 GeV
- L3 is too slow, need to cut rate already at L2.5
  - Old solution: pixel only tracking
    - But resolution is not great above 3 GeV
  - Even after improvements, pixel only reconstruction has ~10% inefficiency vs offline
- New solution: seed with pixel+SI regional tracking at L2.5
  - Possible due to improved timing
  - Need polishing and tuning
    - E. Brownson (Vanderbilt)



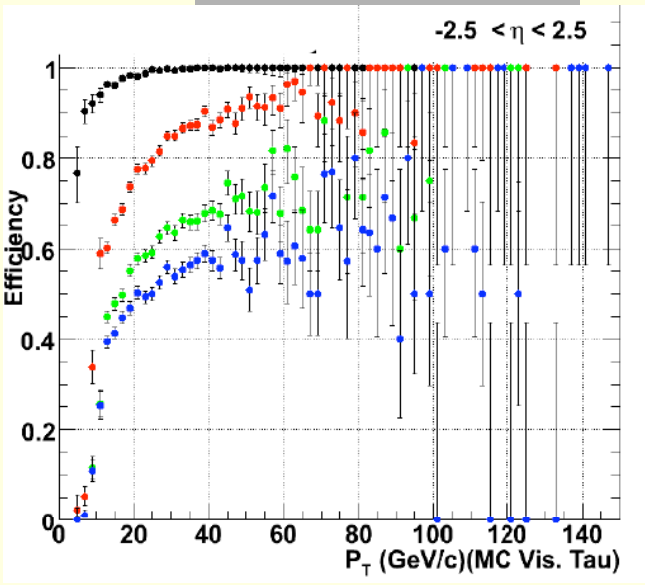


Tau Trigger Line-Up

- Will be a subject of discussions at the upcoming Tau Trigger Review
  - The bottom line we will insist on is that all cross-channel (l+τ) triggers should have thresholds of 10 GeV on lepton side and ~15 GeV on tau side
    - These will be workhorses of all di-tau analyses!
  - Purely tau triggers (single and double) will have somewhat higher thresholds, but not too high
- Come to the review to learn the details!

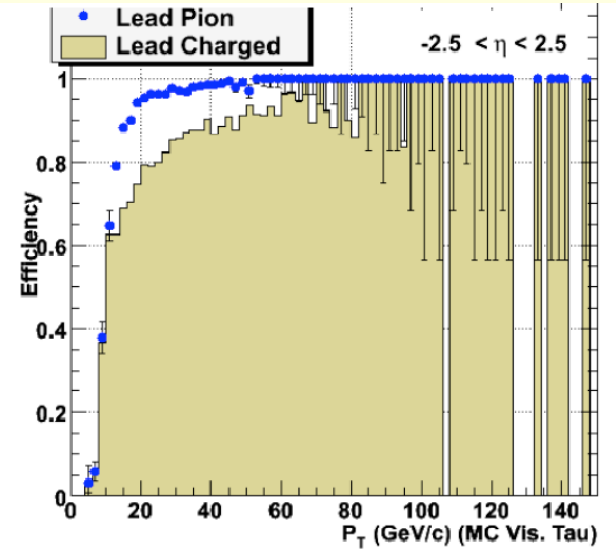
Offline Reconstruction

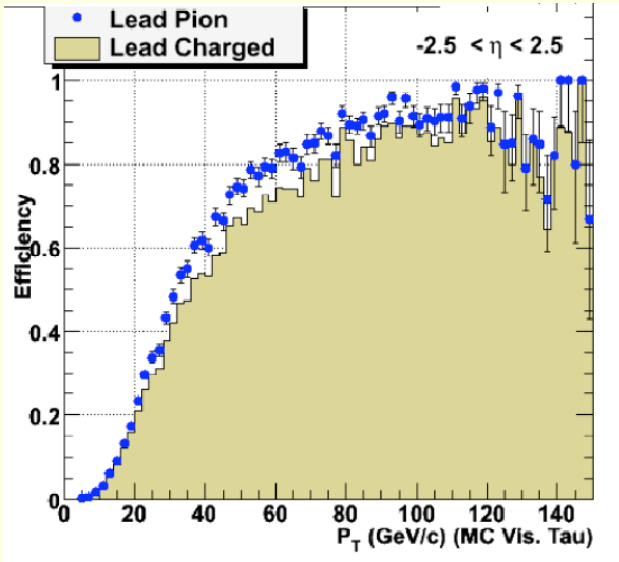
- Deliverable: efficient/robust reconstruction code
  - Implementation of the core PF-based tau has been largely completed a while ago (very similar to e.g. CDF setup)
- Since then large new improvements beyond baseline:
  - Seeding with neutral pions in addition to tracks gives a large boost to efficiency
    - Still needs to be determined how to match in the trigger
  - More intelligent selections (MVA) allow further reduction in backgrounds:
    - Conversion tagging can likely help there a lot, but progress is not as fast as we want
  - I predict that a better treatment and more intelligent use of isolations will give next large improvement in efficiency



Seeding with Neutral or Charged Pion

- Instead of requiring a track above threshold (5 GeV), ask a track or a neutral pion candidate with p_T>5 GeV
  - Recovers a whole class of previously untaggable tau candidates allowing large improvement in efficiency, especially in low E_T region
- Yields a very moderate increase in QCD backgrounds

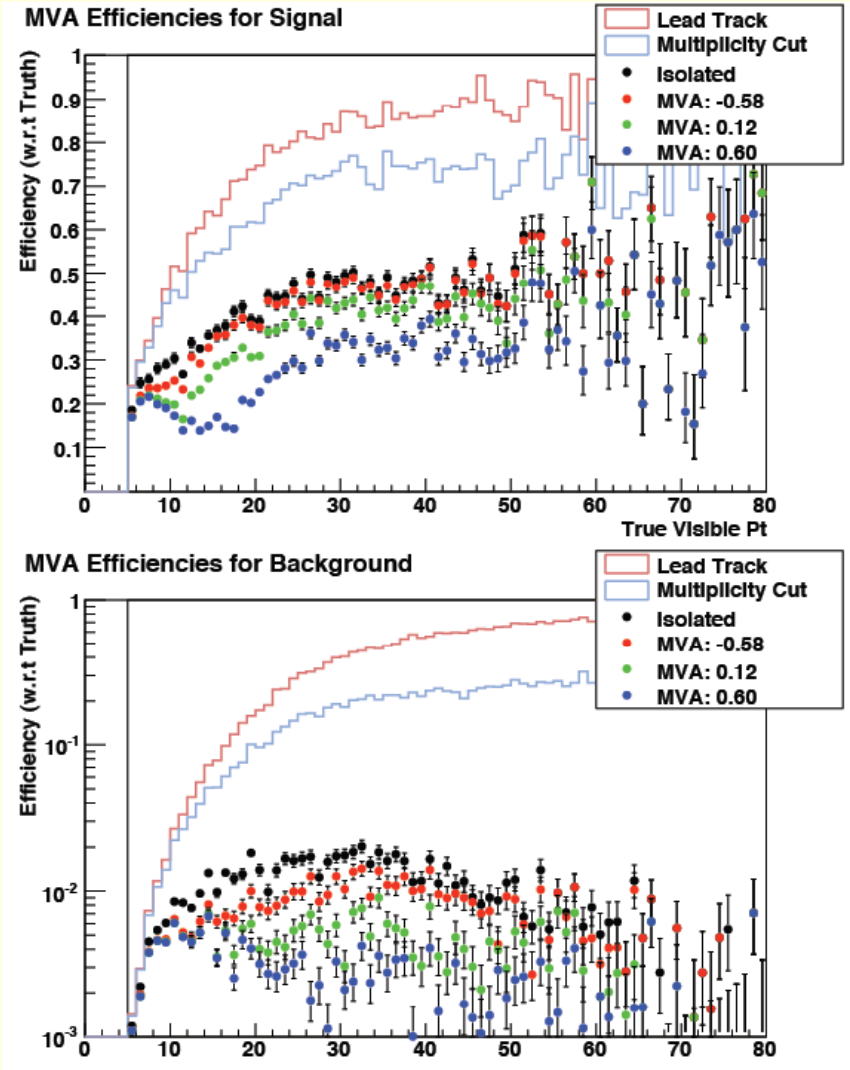




S. Gennai (Pisa)

MVA Based Tau ID Tools

- Two pieces:
  - Categorize different reconstructable tau topologies by the number of charged tracks and neutral pions
  - Apply individual NN to each class
- Very nice work and good progress, very close to final shape:
  - Some interesting observations indicating more sophisticated MVAs can further improve these results
  - Also need underlying improvements to make better defined variables (e.g. conversions are currently smearing the shape difference)



E. Friis (UC Davis)

Towards Physics Measurements

- A must: Tau Reco/ID efficiency measurement
  - Impossible to select a clean sample of unbiased taus due to large backgrounds
    - “Tag and probe” is gone
  - A data/MC scale factor from normalizing to rate of Z’s in light lepton channels is undesirable:
    - Complex shapes of efficiencies of reconstruction steps may hide large problems in MC by cancelling each other
    - Large statistical uncertainty
      - A couple hundred final clean events will give ~10%, which is in addition to anything else (background subtraction etc.)
- Solution: factorization

Example of Factorization

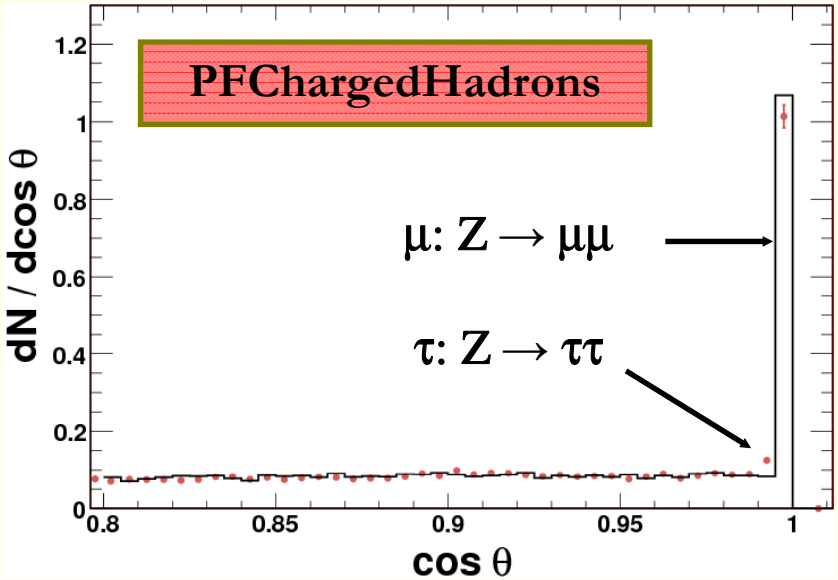
- A trivial trick, but somehow often misunderstood or not appreciated, so consider an example:

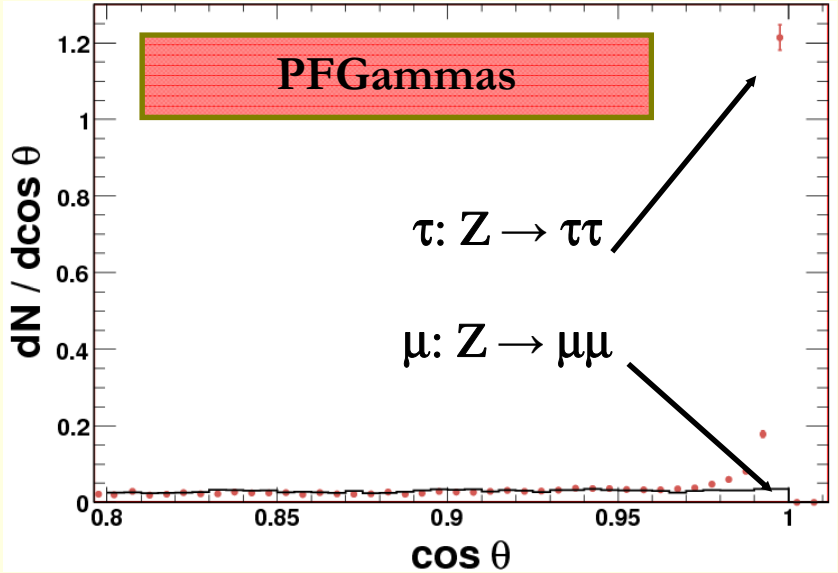
Selection	Events Passing
Acceptance	*200*
Isolations	*80*
All ID cuts	*78*
Efficiency	0.390±0.035

- Straight measurement gives ~10% uncertainty
- However, if isolation efficiency is known precisely from someplace else, e.g. ε(iso)=40.0+/-0.1%:
  - $\varepsilon = \varepsilon(\text{iso}) * \varepsilon_{\text{bin}}(78/80) = (40.0+/-0.1\%) * (97.5+/-1.7\%) \sim 0.390+/-0.007$
  - That's a 1.7% uncertainty !

Factorizing Isolation Out

- Isolation region is dominated by Underlying Event (UE), pile-up (PU) and occasional jets recoiling against Z
- Absolutely the same sources for $Z \rightarrow \tau\tau$ as for $Z \rightarrow \mu\mu$
- Plot flow of particles above given threshold



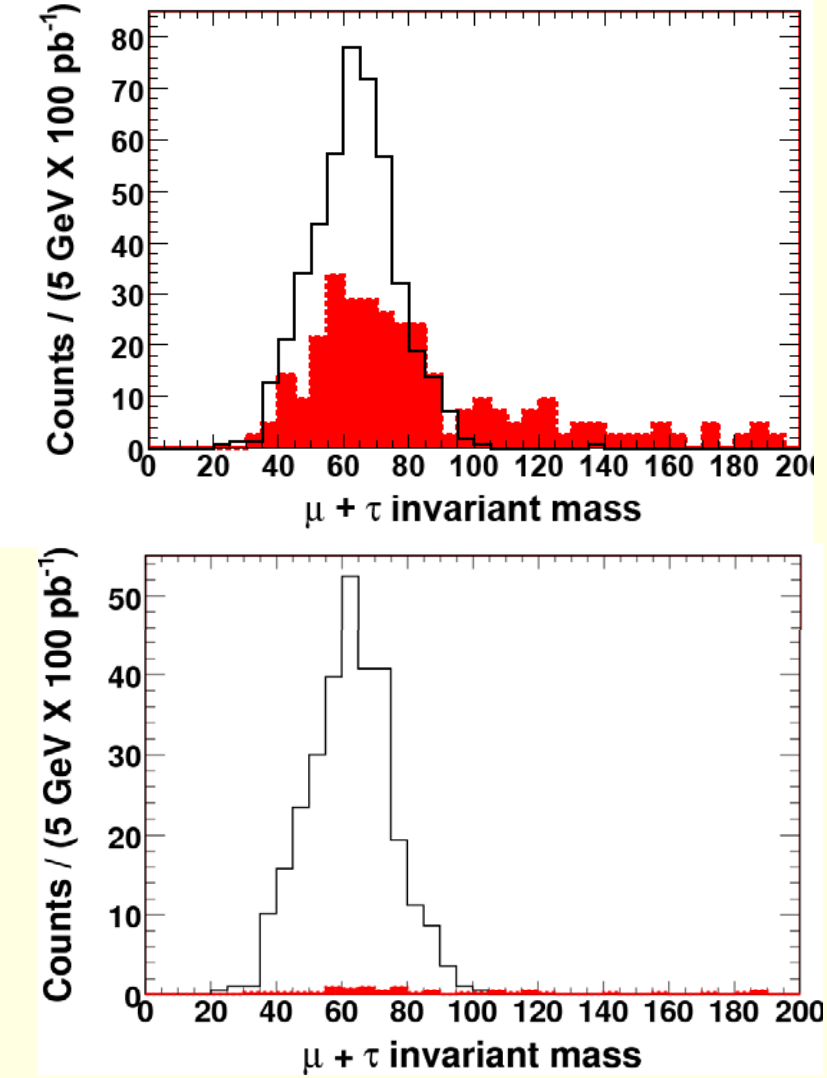


- Can be measured with extreme precision, directly related to isolation efficiencies

A. Gurrola (Texas A&M)

Measuring Other ID Efficiencies

- Except for isolation and track reconstruction efficiency, other efficiencies are going to be very high
  - Early, we won't cut hard on something we do not well understand
- Still needs to be measured in a clean sample
  - The good news is we know isolation efficiencies and so we can apply harsh isolations to select a clean sample
  - Roughly 3 clean events/ipb of data



A. Gurrola (Texas A&M)

Summary

- Tau reconstruction is mature and comparable to existing Tevatron experiments:
  - There are some missing pieces that need to be factored in, e.g. conversions
- New improvements go beyond the baseline:
  - Continuous trigger improvements
  - Photon based seeding for taus
  - MVA-based approaches to further reduce backgrounds
- Work on standard candle analyses is ongoing
  - Finishing those and preparing to be tested with real data is the next large challenge