Taus @ Muon Collider

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Who we are

Ethan

Junior undergrad, Mu2e

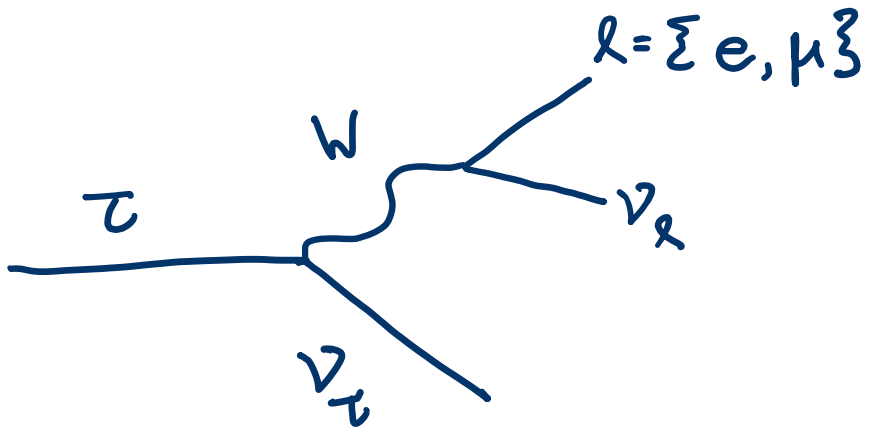
- Developed anti-proton trigger
- Tuned anti-proton reco algorithm
- Trigger effeciency studies

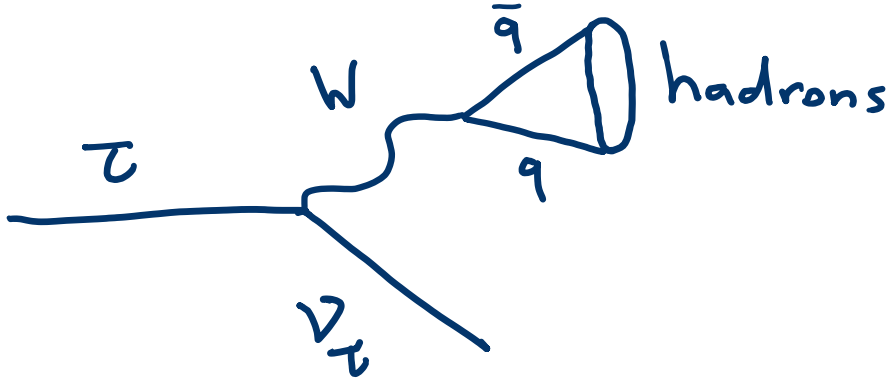
Greg

4th year PhD student, ATLAS

- τ's @ HL-LHC, offline and online (Event Filter tracking)
- $H \to \tau\tau$ differential σ, CP property
- Trigger "contact" for $H \to \tau\tau$ analyses

For Later Reference: Taus





Final State	Branching Fraction
$\tau^- \to e^- \nu_\tau \bar{\nu}_e$	17.8%
$\tau^- \to \mu^- \nu_\tau \bar{\nu}_\mu$	17.4%

(numbers for $h^- = \{\pi^-, K^-\}$)

Final State	Intermediate Meson	Branching Fraction
$\tau^- \to h^- \nu_\tau$	—	11.5%
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770\ \text{MeV})$	25.9%
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260\ \text{MeV})$	9.3%
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260\ \text{MeV})$	9.4%
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$	—	2.8%
Other hadronic		5.9%

Thanks to Rose and Lorenzo Valla for their continued help!

Lorenzo's slides

Lorenzo's results

- Some particular tunings to energy thresholds in charged pion reco

ECAL and HCAL energy cuts

- Standard configuration hits energy thresholds: ECAL = 2 MeV, HCAL = 2 MeV
  - Central region π^+ ID efficiency of ~ **25%** (bad)
  - Forward region π^+ ID efficiency of ~ **20%** (bad)
  - **Few minutes** required to process a single event with BIB (good)

L. Valla

- Low threshold configuration (CLIC): ECAL = 50 keV, HCAL = 250 keV
  - Central region π^+ ID efficiency of ~ **90%** (good)
  - Forward region π^+ ID efficiency of ~ **80%** (good)
  - **Many hours** required to process a single event with BIB (bad)

- Intermediate configuration: ECAL = 2 MeV, HCAL = 250 keV
  - Central region π^+ ID efficiency of ~**75%** (ok)
  - Forward region π^+ ID efficiency of ~ **70%** (ok)
  - **10/15 minutes** required to process a single event with BIB (acceptable)

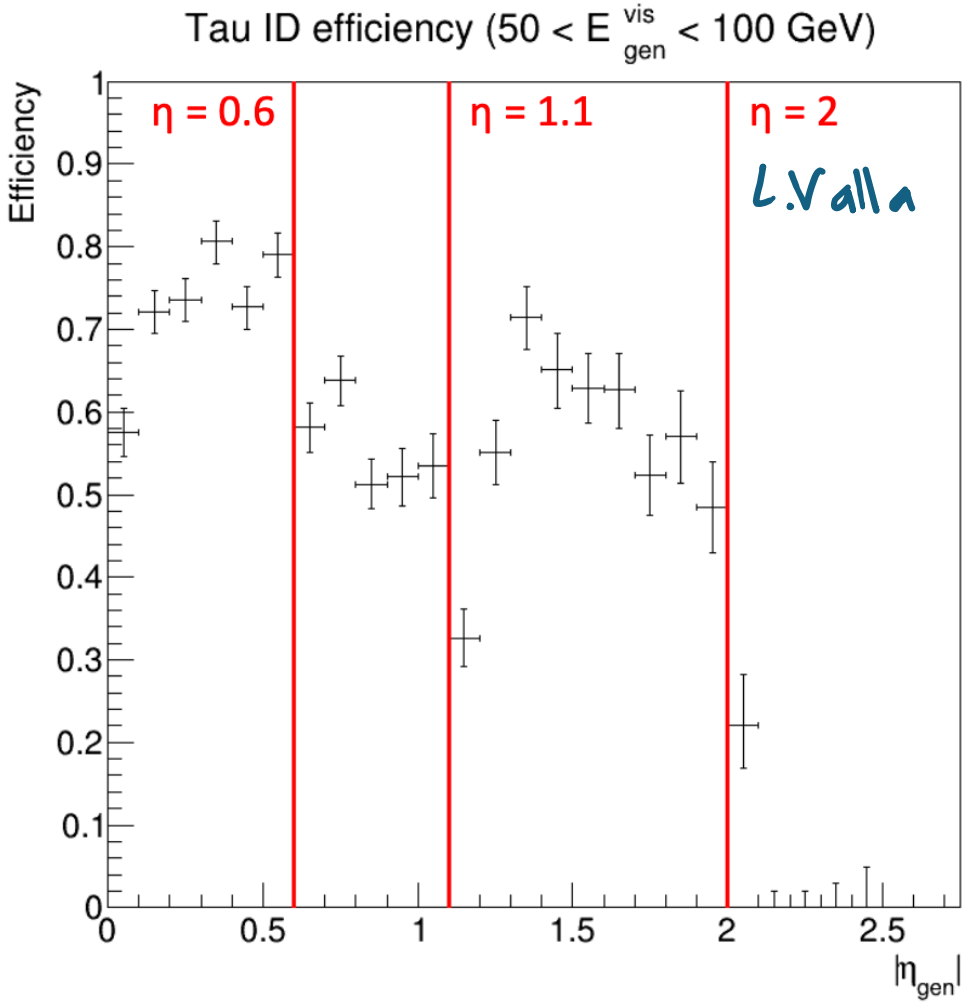
Lorenzo's results

Lorenzo's slides

- Uses TauFinder (backup) as a baseline ID algorithm, tau eff ~ 66%

- **Fixed quality cuts**
  - Number of charged tracks larger than 0 but smaller than 4
  - Total number of charged + neutral particles below 10
- **Reconstruction cuts** (customisable)
  - Total charge equal to +1 or -1
  - For each particle: $p_T > 1$ GeV/c
  - τ seed: $p_T > 5$ GeV/c
  - τ seed: impact parameter 10^{-5} mm < D0 < 0.5 mm
  - Search cone opening angle: 0.05 rad
- **Quality cuts** (customisable)
  - **Isolation cone** around the search cone: + 0.02 rad
  - Most energetic particle in the isolation cone: $p_T^{IC} < 5$ GeV/c

L.Valla



Our strategy

- We'd like to reproduce Lorenzo's results
  - Nominal $\pi^{+/-}$ performance of ~20%, improved by playing with energy thresholds
- Workflow (Ethan's GitHub) (no BiB!):
  1. Begin with tutorial (*we are using MuColl_v1!*)
  2. Add tau gun script (15,000 taus, p_T = 100 GeV)
  3. Run the tutorials' simulation
     1. Check that the tau branching ratios match what we expect
  4. Run the tutorials' digitization and reconstruction
     1. Pandora*, no changes
  5. Add some analysis scripts

*: some level of a black box to us

Ethan's Progress

*: # includes Kaons

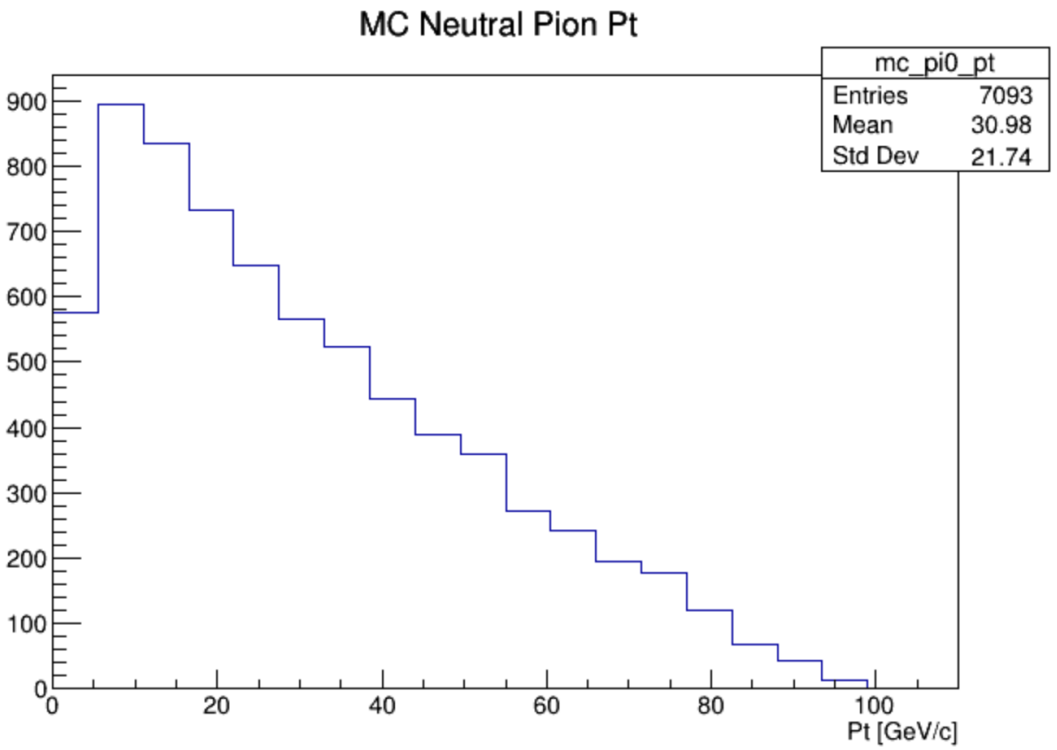
15,000 taus

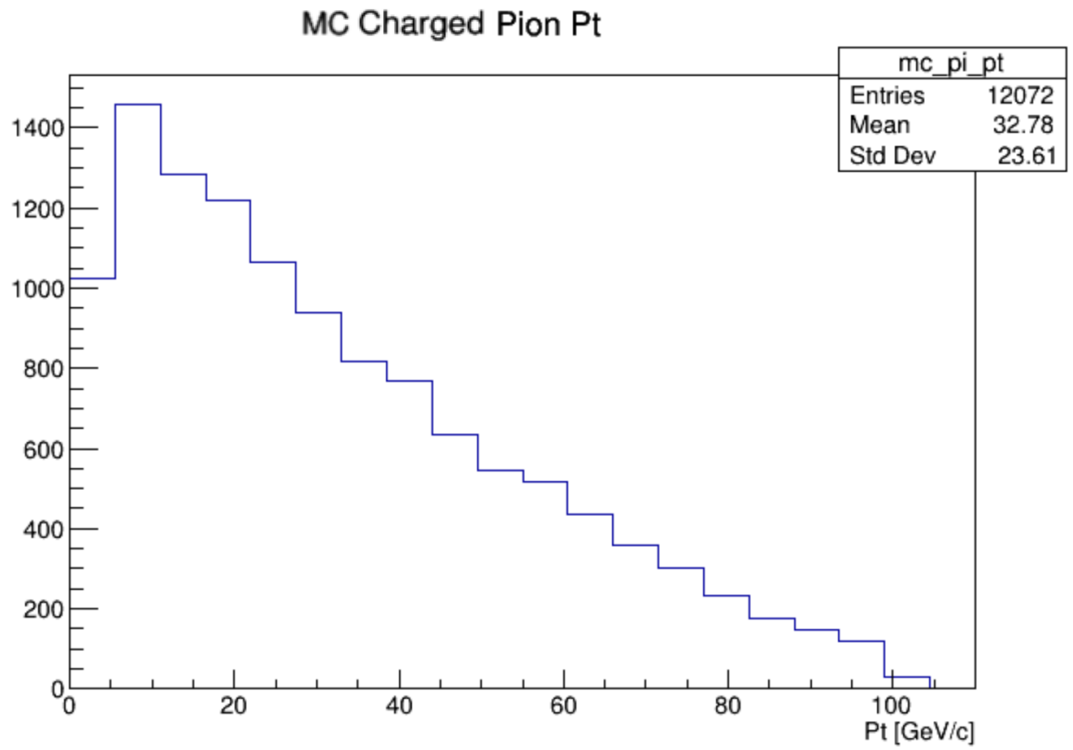
τ decay mode	# generated (%)	# expected (%)
$\tau^- \to e^- \nu_\tau \bar{\nu}_e$	20.2%	17.8%
$\tau^- \to \mu^- \nu_\tau \bar{\nu}_\mu$	19.3%	17.4%
$\tau^- \to \pi^- \nu_\tau$	12.3%	11.5%*
$\tau^- \to \pi^- \pi^0 \nu_\tau$	27.4%	25.9%*
$\tau^- \to \pi^- \pi^0 \pi^0 \nu_\tau$	10.2%	9.3%*
$\tau^- \to \pi^- \pi^+ \pi^- \nu_\tau$	10.7%	9.4%*
others	0%	8.7%

We need to double check: did we only count taus of these decay modes, or are they all that are generated?

Are there Kaons?

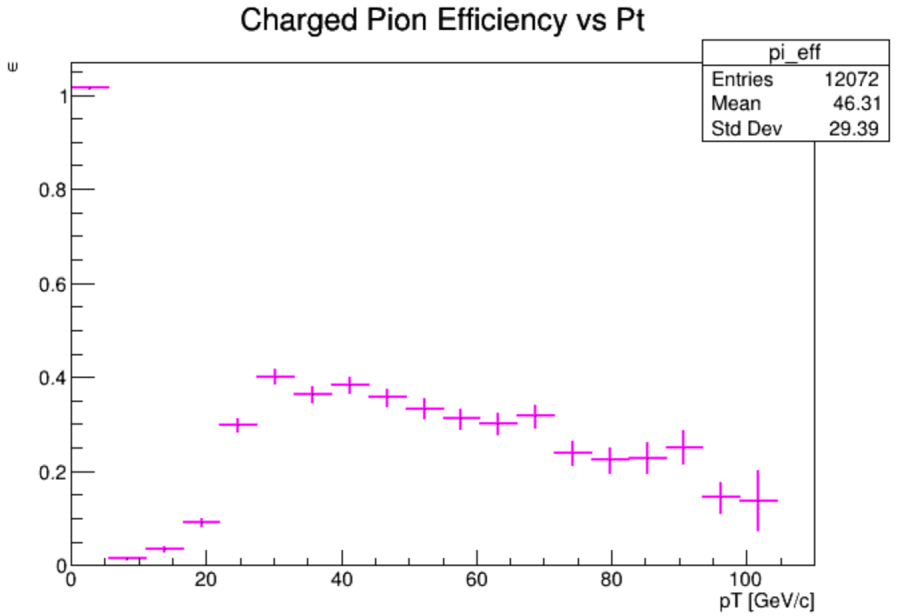
Ethan’s Progress

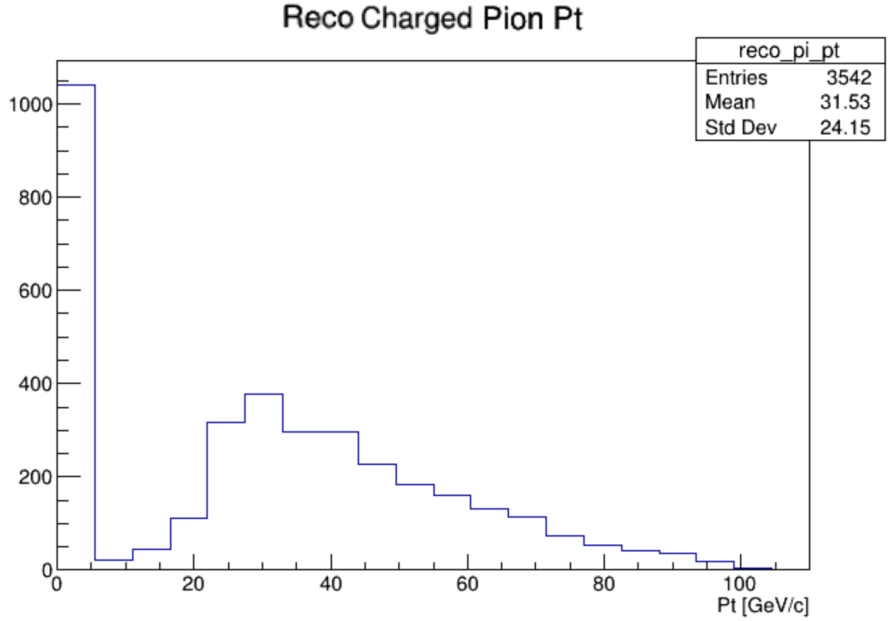


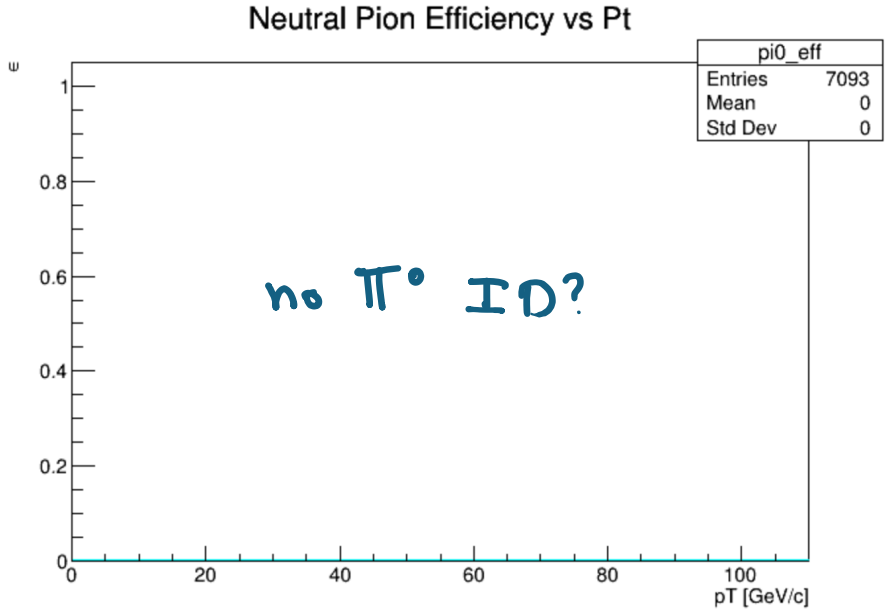


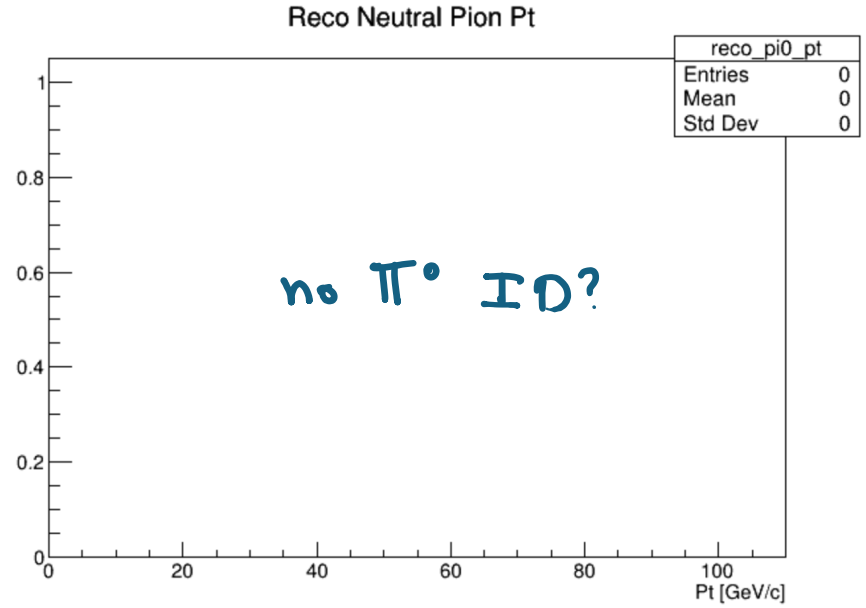
Ethan's Progress

$$\epsilon = \frac{\#\ \text{reconstructed}}{\#\ \text{generated (truth)}}$$









Discussion

- We seem to have replicated the low $\pi^{+/-}$ efficiencies!
  - Known from Lorenzo and Rose's work
- Have others seen the observed missing π^{0}'s?
- Next steps:
  - Inspect reconstructed particle distribution (status in backup)
  - Vary ECAL / HCAL energy hit thresholds as Lorenzo
  - Continue to run tau reco & ID
- But…
- How much more time to put into Pandora? Code up tau reco on our own?
- Do we want to invest more time into MuColl_v1?
  - Move to MAIA immediately?

Thanks!

Tau ID

- *TauFinder:*
  1. Begins with reconstructed charged and neutral particles
  2. Seed taus from charged particle *tracks (!)*
  3. Define a search cone
  4. Add charged particles within search cone to tau seed, recalculating barycenter
  5. Add neutral particles within search cone
  6. Combine into a reconstructed tau
  7. Loop over seeds
  8. Merge taus that are within a search cone of one another
  9. Make some ID cuts!

Ethan's Progress

15,000 taus

Particle (PDG ID)	# reconstructed	# expected (truth)
e (11)	0 (!?)	2670
μ (13)	1205	2610
γ (22)	18925	14190 (depends if combined into π⁰ cand.) ↓ ~7095
π⁰ (111)	0 (!?)	~7095
π⁺/⁻ (211)	3542	~12495
n (2112)	16844 (!?)	0

A lot looking strange!

1. We aren't finding electrons
   - Possibly filtering out secondary particles out incorrectly
2. Finding more photons than expected, and *no* π^0's
   - π^0 reco / ID "broken"?
3. Not enough $\pi^{+/-}$'s, many n's
   - "Broken" track-to-cluster matching?
   - ~30% $\pi^{+/-}$ efficiency
4. More work on our side to make sense of these numbers