HPS JLAB Collaboration Meeting

(*Early Stage of*) SVT Track - ECAL Cluster Matching Studies

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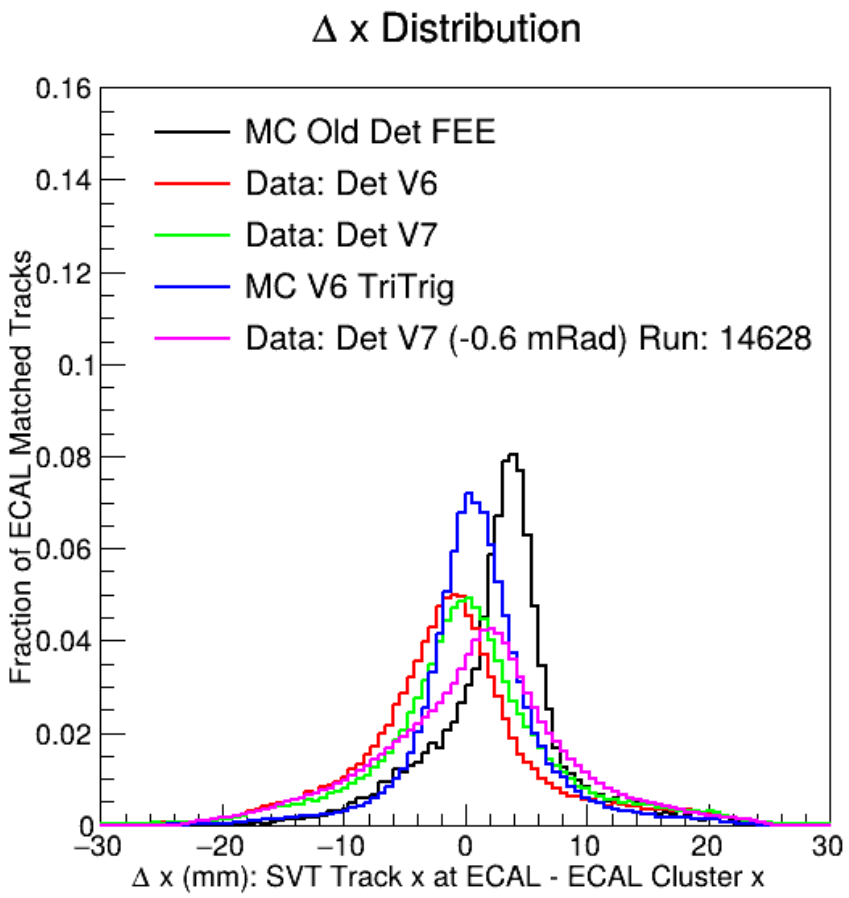
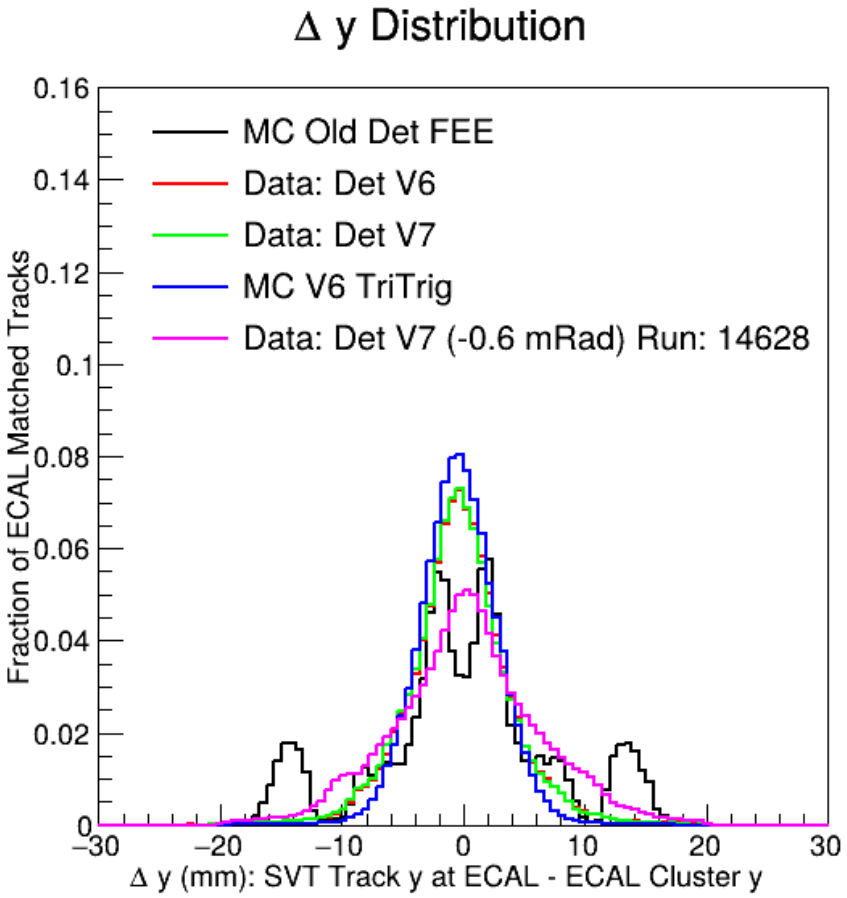
Motivation: Track-Cluster Matching

- Improve charged track matching performance to the ECAL
- Improve electron/positron track measurement
- Assist Global alignment study
- Apply to ECAL cluster energy Calibration
- Potential particle identification with hadron tracks
  - Track-Cluster E/p comparison with e, π, K, and p
  - Potentially contribute to $\phi \rightarrow K^{+}K^{-}$ studies

Previous Studies

- I began a quick look at SVT track cluster matching with the v7 detector back in

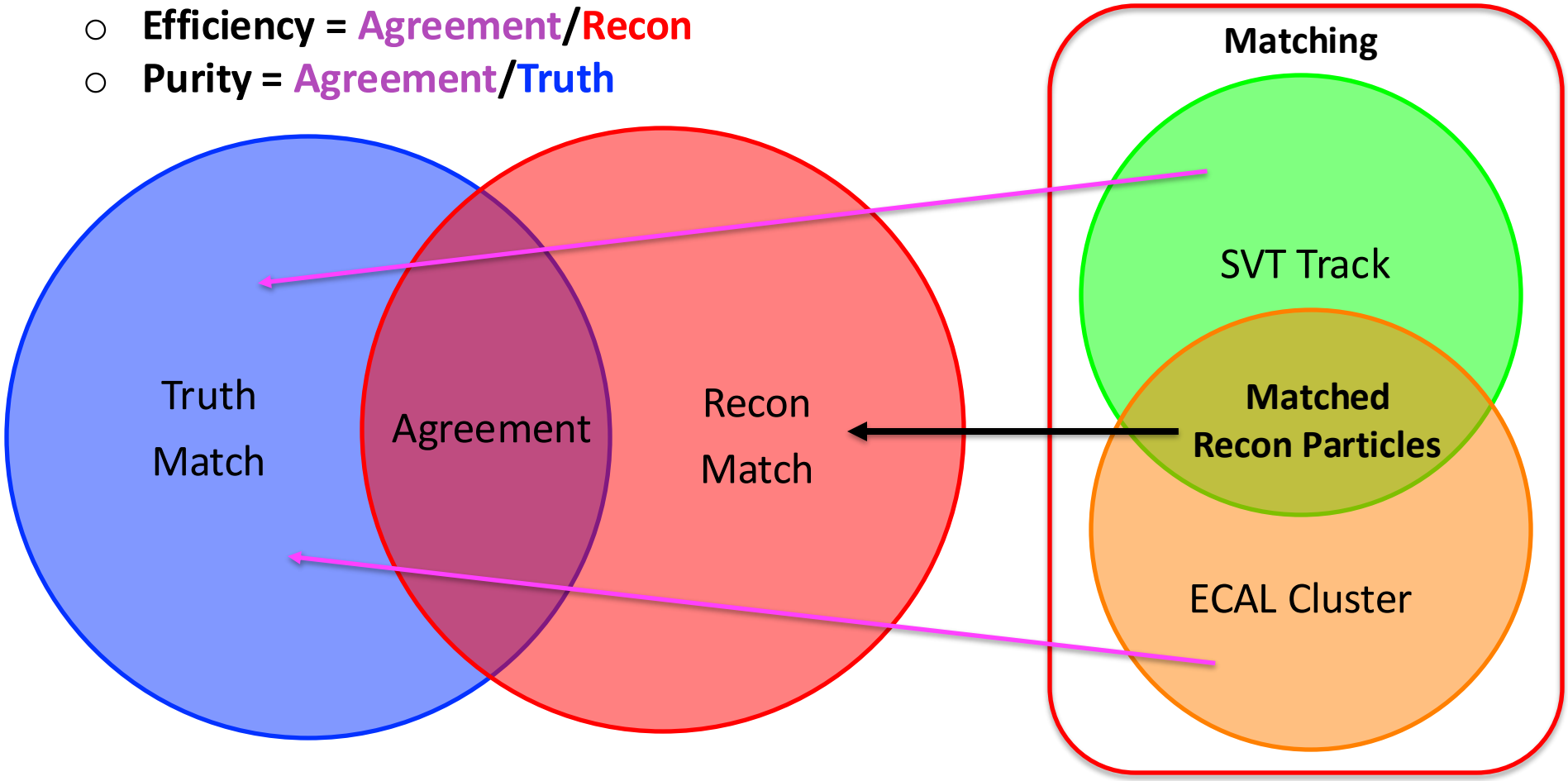




- The matching generally yields good results
  - More differential studies like energy, charge, and ECAL position
  - In terms of both purity and efficiency

General Philosophy

- Focus on performance in the metric of **efficiency and purity**
  - **Efficiency = Agreement/Recon**
  - **Purity = Agreement/Truth**



- **Black arrow:** the matched one from recon that actually agrees with the truth
- **Pink arrows:** the unmatched one falls into the truth, which means they should have matched but did not actually match in recon
- Ideally, all matched one are true and all unmatched are fake

Analysis Strategies

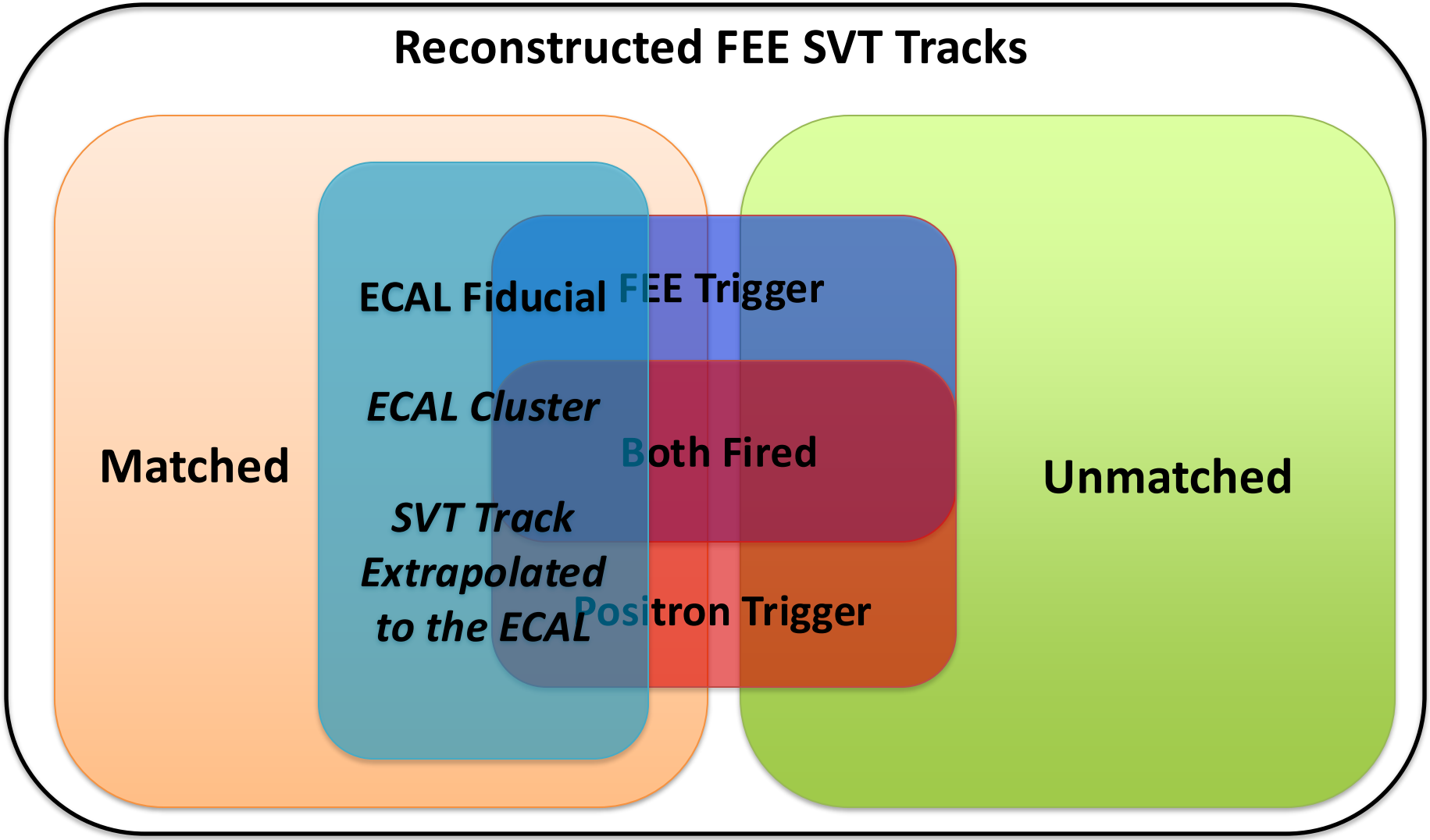
- With some experience in FEE studies and data production, I choose to investigate the ECAL matching performance focusing on **FEE events**
  - FEE (full energy electron) should have the energy of the incident beam electron as name suggests and follows the Rutherford scattering (elastic) cross section since no energy losing to the target
  - FEE tracks should be able to make to the ECAL region (certainly may not leave hits to the ECAL due to the ECAL hole)
  - Features: peak signature with a finite width in data near the beam energy
  - Method: look at how many identified FEE tracks through momentum peak can match to a cluster using the metric of E/p

- Originally, I looked at Run 14180 with latest v7 detector
  - Original intention is to look at SVT alignment effect in a physics run
  - Complexity in triggers

- Start to look at dedicated FEE runs
  - Data process for full Run 14168 (a dedicated FEE run)

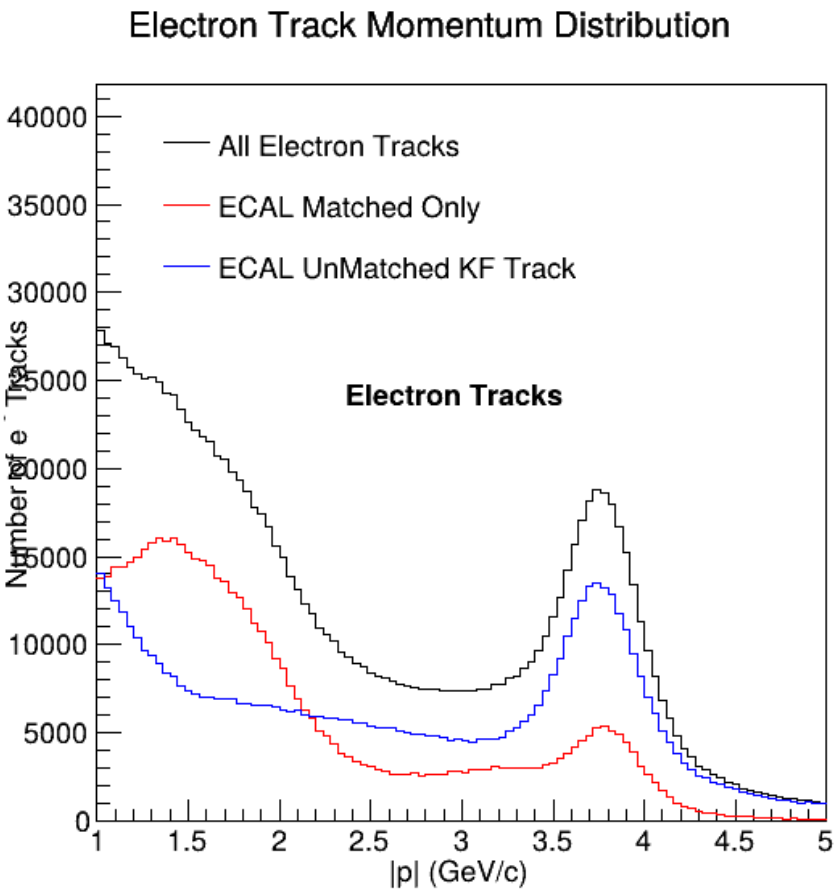
- Potentially run the single electron MC simulation to quantify the performance

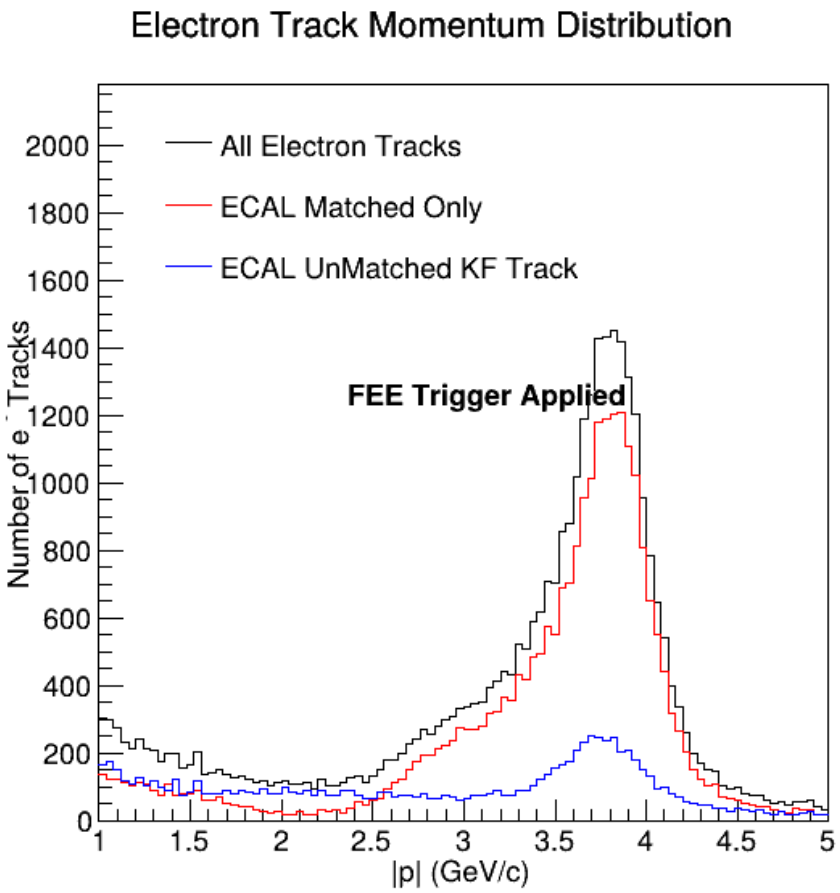
Category Definition in My Data Structure



- Explore different cases with this data structure for applying selections
- Methodology: two peaks to look at in data - peak and the E/p peak

First Glance of Track-Cluster Energy

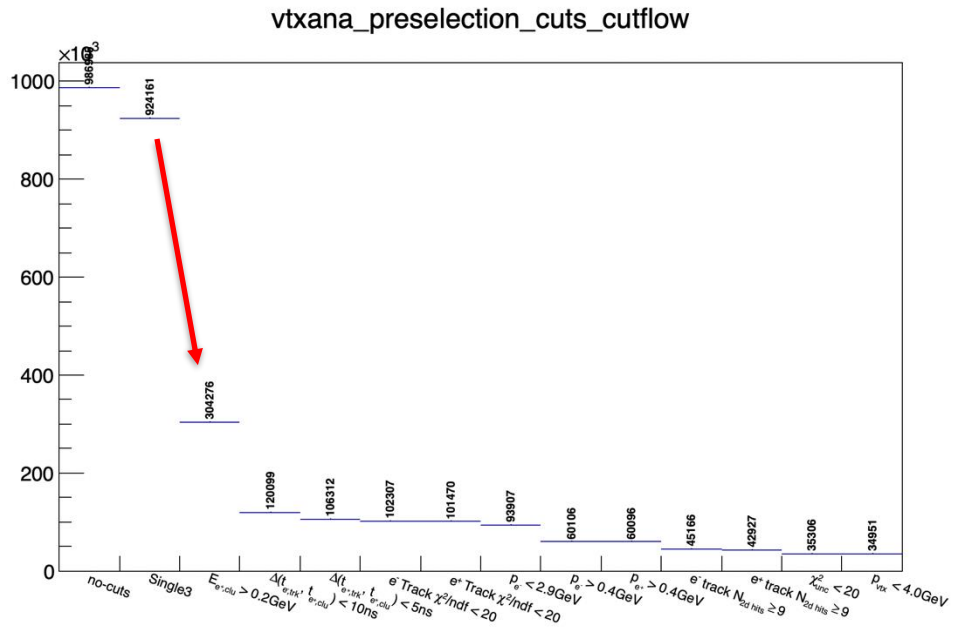




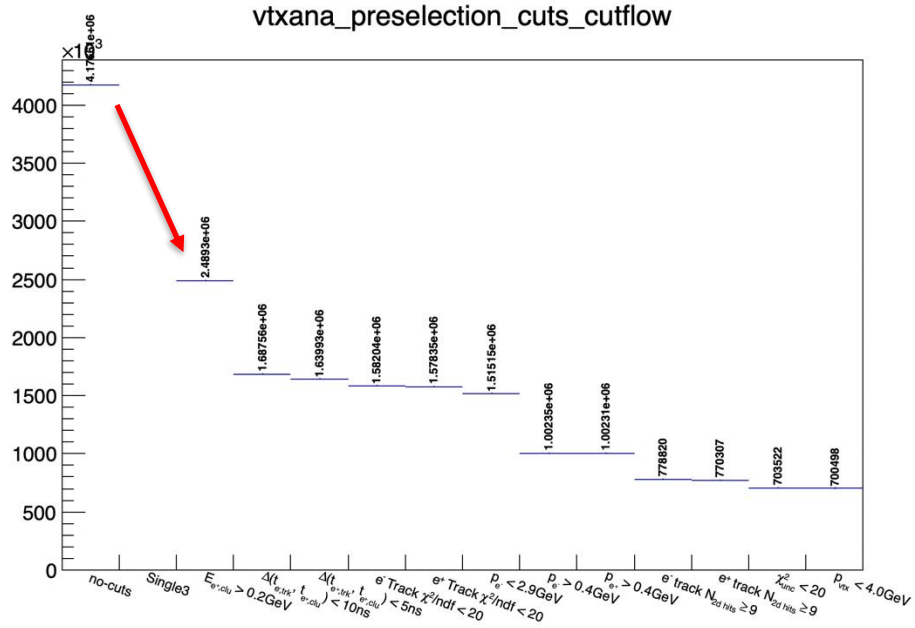
- Core idea: we do see FEE trigger having good match but how about FEE tracks without an FEE trigger
- Caveat: find the right data sample with the right trigger fired for the studies

Sarah's Vertex Preselection Studies

Data



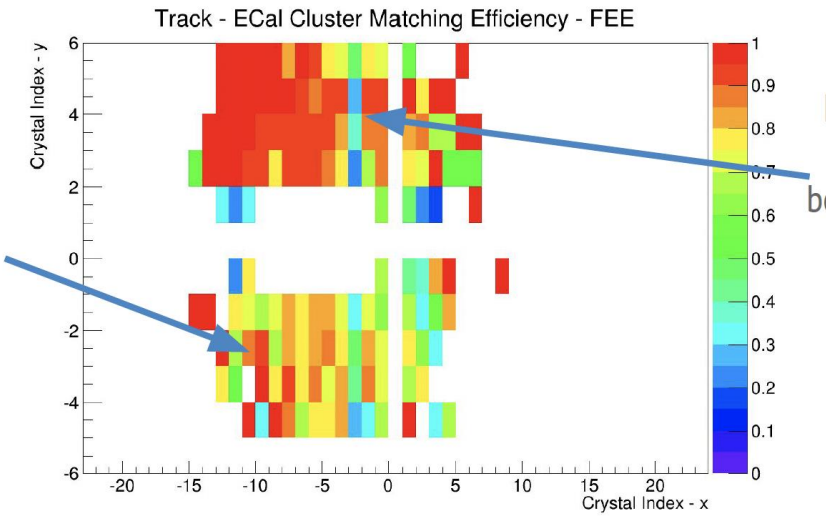
MC



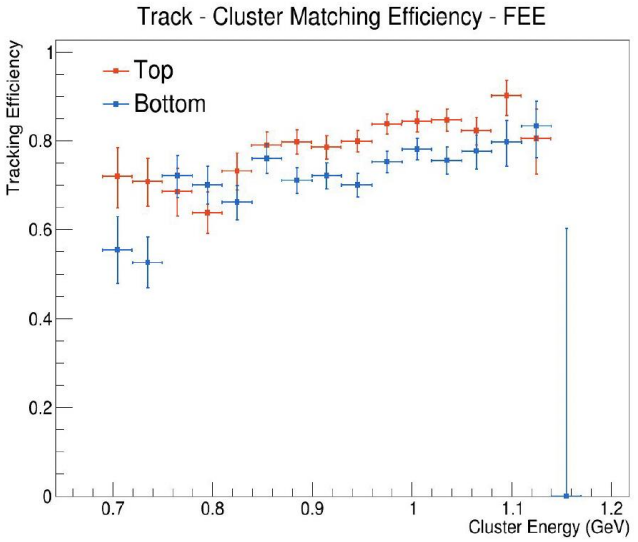
- Thanks a lot for Sarah sharing input from the perspective preselection
- Puzzles for positron trigger (single3): significant drop in data and MC with ECAL matching cuts for positron trigger events
  - Potential ECAL matching issue related to positron cluster
  - Worth looking deeper into why

Matt Gignac Reference to Omar's Studies

lower track-cluster matching efficiency



Low efficiency due to gap between layer 4-6 sensors



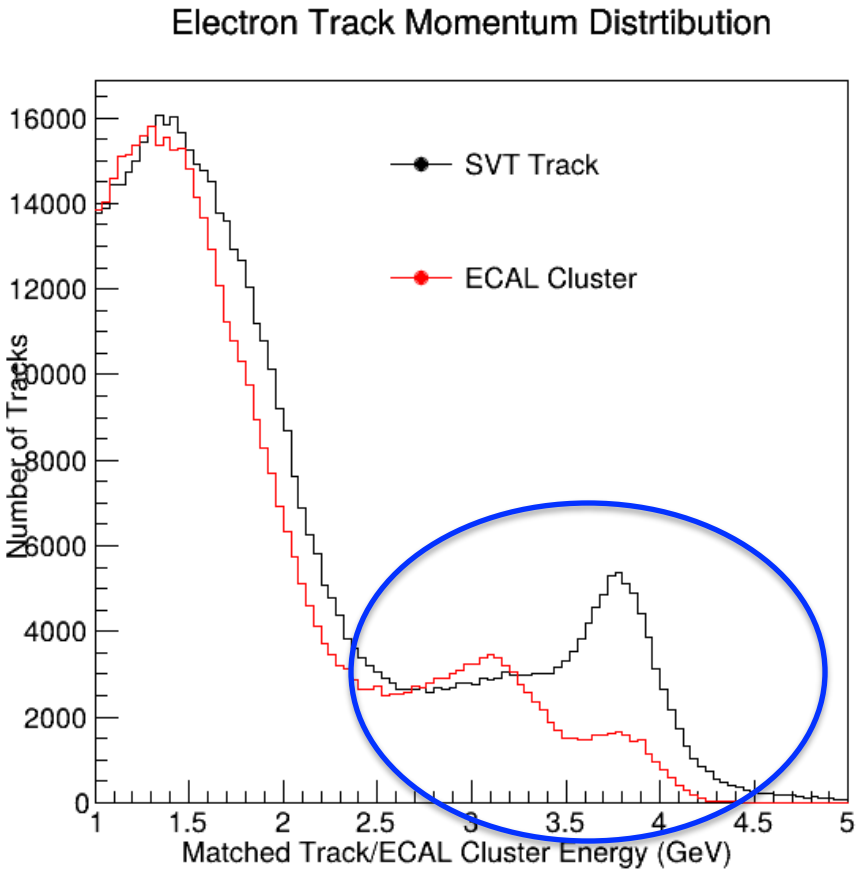
- Thanks Matt a lot for sharing Omar's studies on track-to-cluster matching
  - The beam energy is 1.1 GeV
  - Efficiency in terms as a function of ECAL cluster position and energy using FEE events to study the matching efficiency
  - Preselection on ECAL cluster energy and SVT (GBL) tracks
  - Lots of focus SVT tracking side
- Potential improvement from ECAL clustering side and track-cluster matching to potential improved efficiency

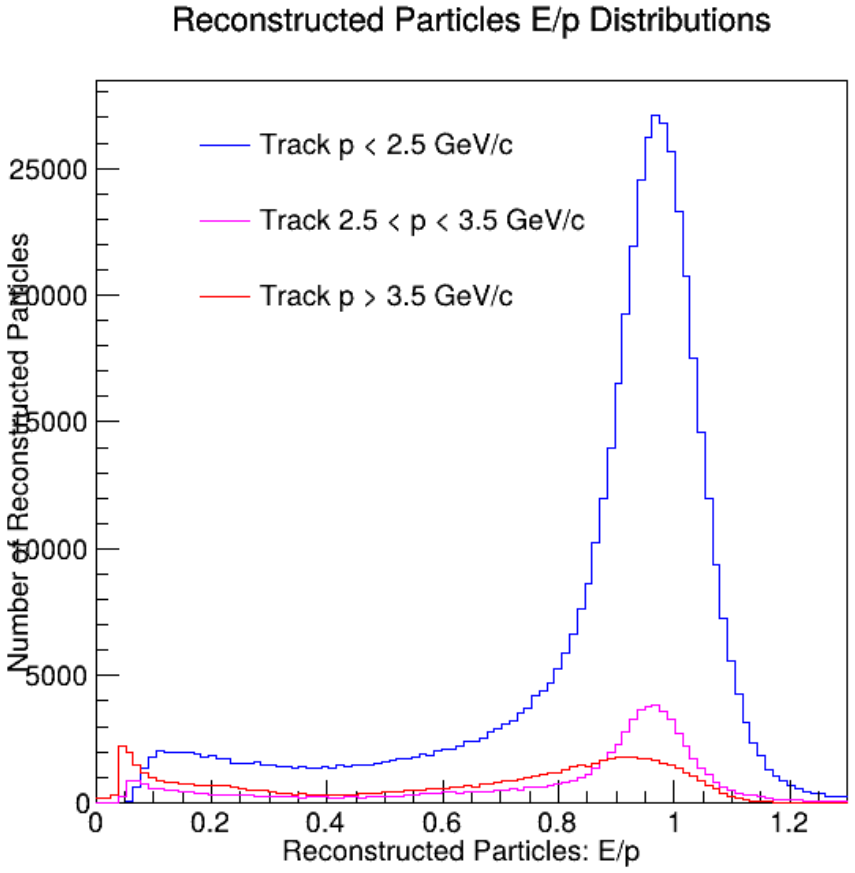
Trigger Definition

```
using TriggerBits_t  = struct{  // Trigger structure for the 2019 data set.
   bool Single_0_Top: 1; //  0   ( 150-8191) MeV (-31,31)   Low energy cluster
   bool Single_1_Top: 1; //  1   ( 300-3000) MeV (  5,31)   e+
   bool Single_2_Top: 1; //  2   ( 300-3000) MeV (  5,31)   e+ : Position dependent energy cut
   bool Single_3_Top: 1; //  3   ( 300-3000) MeV (  5,31)   e+ : HODO L1*L2  Match with cluster
   bool Single_0_Bot: 1; //  4   ( 150-8191) MeV (-31,31)   Low energy cluster
   bool Single_1_Bot: 1; //  5   ( 300-3000) MeV (  5,31)   e+
   bool Single_2_Bot: 1; //  6   ( 300-3000) MeV (  5,31)   e+ : Position dependent energy cut
   bool Single_3_Bot: 1; //  7   ( 300-3000) MeV (  5,31)   e+ : HODO L1*L2  Match with cluster
   bool Pair_0      : 1; //  8    A-prime
   bool Pair_1      : 1; //  9    Moller
   bool Pair_2      : 1; // 10    pi0
   bool Pair_3      : 1; // 11    -
   bool LED         : 1; // 12    LED
   bool Cosmic      : 1; // 13    Cosmic
   bool Hodoscope   : 1; // 14    Hodoscope
   bool Pulser      : 1; // 15    Pulser
   bool Mult_0      : 1; // 16    Multiplicity-0 2 Cluster Trigger
   bool Mult_1      : 1; // 17    Multiplicity-1 3 Cluster trigger
   bool FEE_Top     : 1; // 18    FEE Top       ( 2600-5200)
   bool FEE_Bot     : 1; // 19    FEE Bot       ( 2600-5200)
   unsigned int NA  :12; // 20-31 Not used
};
```

- Since I used MiniDST, in my analysis, I use the following definition for trigger
  - FEE trigger is 18 or 19
  - Positron trigger is 0 – 7

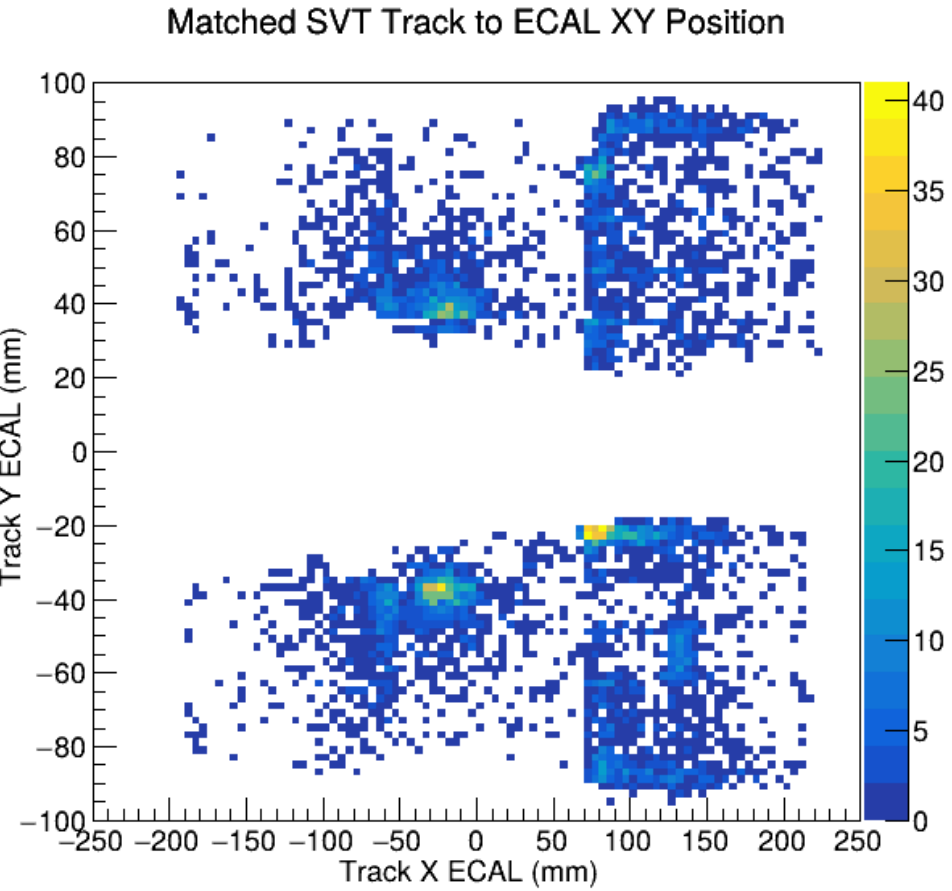
Matched SVT Track-ECAL Cluster Distribution

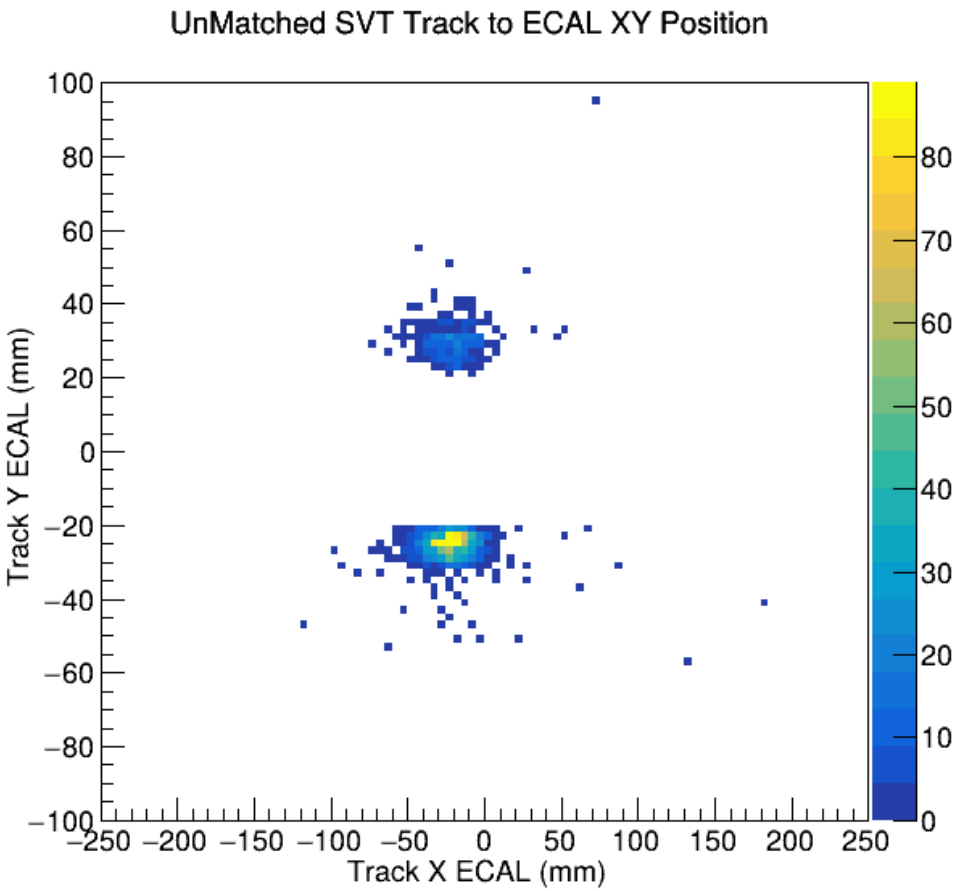




- Things work well until about 2.5 GeV
- Issue: both FEE peak and E/p gets poor for the ECAL at high energy
- Potential explanation to this issue above 2.5 GeV
  - Events contaminated with positron triggers
  - Cluster mismatching
  - Cluster energy leakage due to ECAL geometry

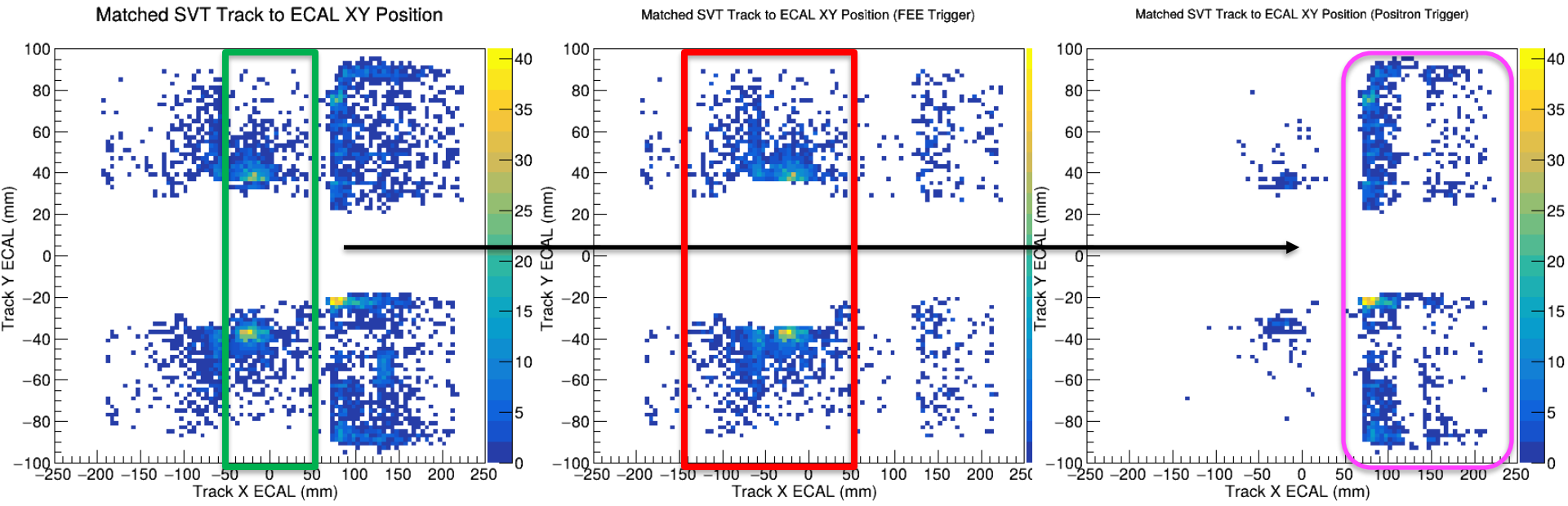
KF Track XY Distribution for the Matched and UnMatched





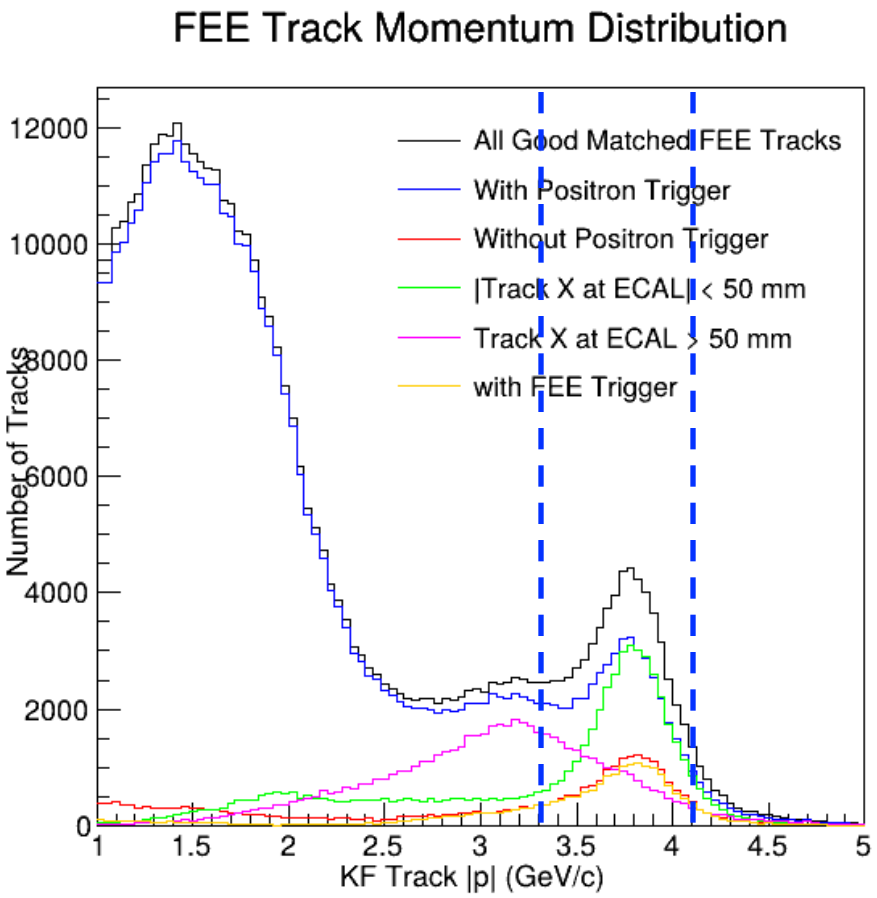
- Exactly 1 track with 1 cluster within the FEE region $|p - 3.7| < 0.4$ GeV/c and Good FEE tracks are required
- Is there a hard y limit where the matching will breakdown?
  - Compare this y limit to the fiducial region of the ECAL
  - Can we extend this y limit?

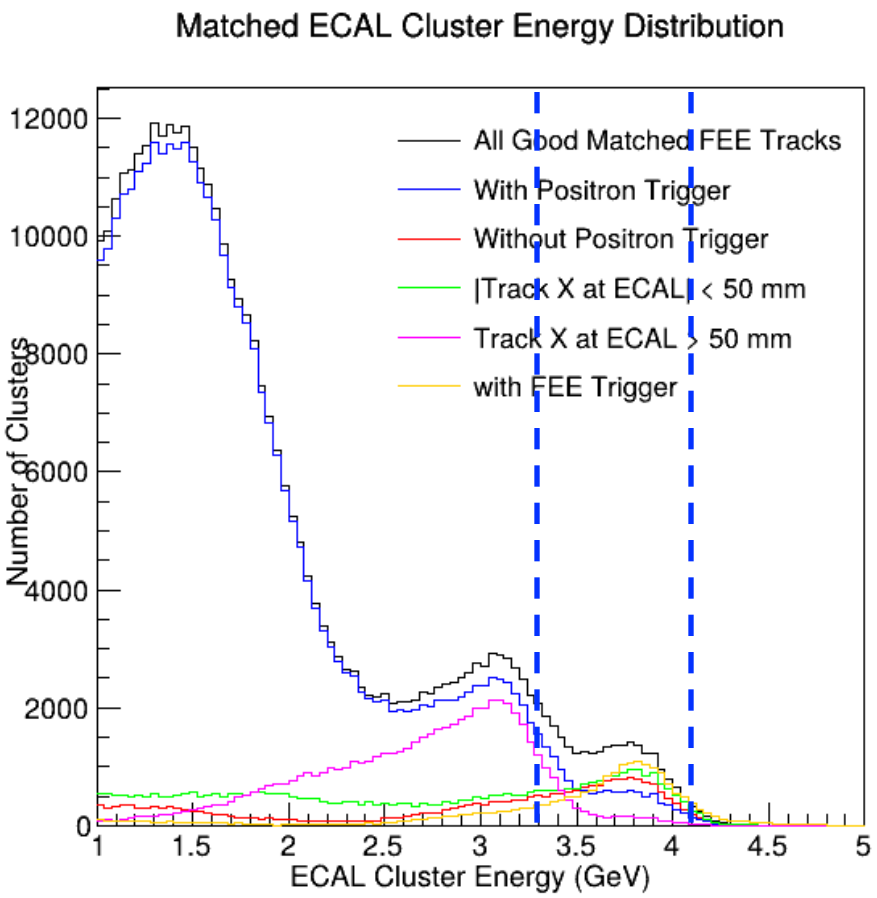
Track XY Distribution for the Matched



- For simplicity, exactly reconstructed 1 cluster and 1 track in each event
- Matched Tracks with FEE trigger only has a hard cuts on the Y, requiring fiducial region
- General matched tracks does not have the cut
- Can we improve the matching in the area where we have a lot of unmatched SVT tracks?

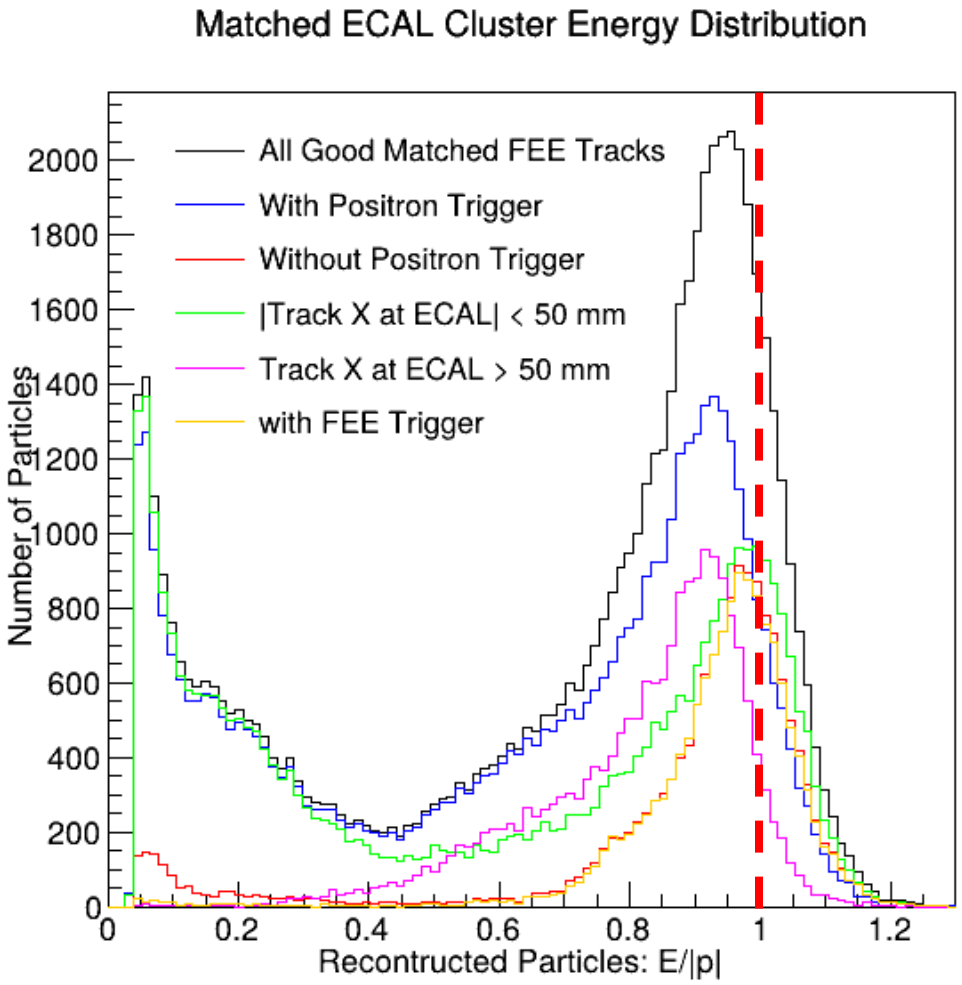
Different Selections on Matched Tracks and Clusters





- Positron trigger does not significant affect the FEE peak but only affect the low energy events
- Requiring **a cut of |track X at ECAL| < 50 mm** of the ECAL origin significant best improving FEE track and ECAL cluster signal
- But the ECAL signal does not improve significantly

E/p near the FEE region



- Not only the FEE peak signal has improved but also the E/p has improved
- Can we improve the other low energy side?

Summary

- Investigation of Track-Cluster Matching Performance
  - Using Physics Run 14180 with also a focus on the FEE tracks
  - Focusing on FEE and E/p peaks as indication for FEE tracks matched to ECAL with the fact that matching algorithm priority already in Δx and Δy

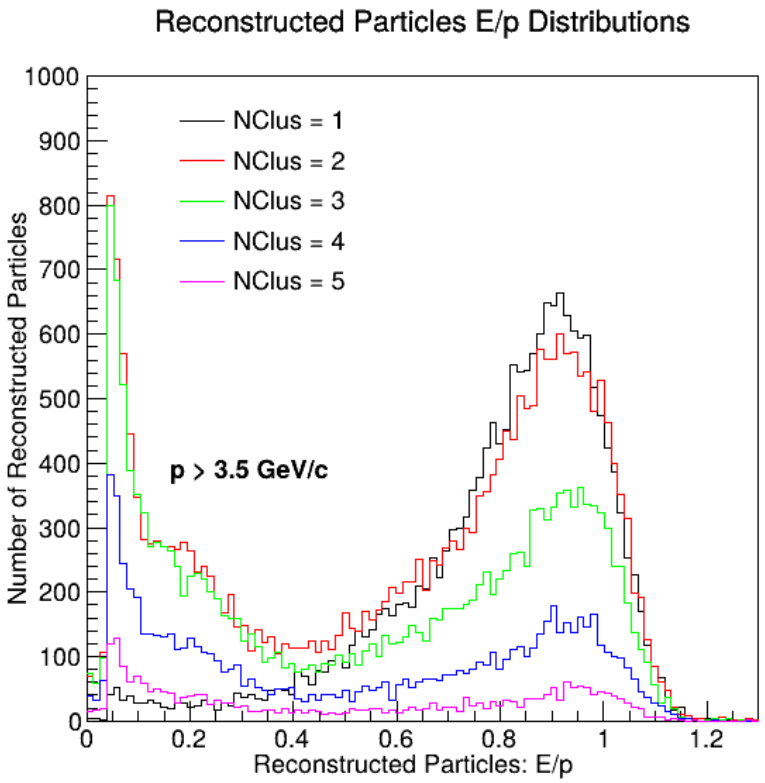
- Improvement of FEE signal and E/p by selection of |track_X_at_ecal| < 50 mm
  - Need validation in MC

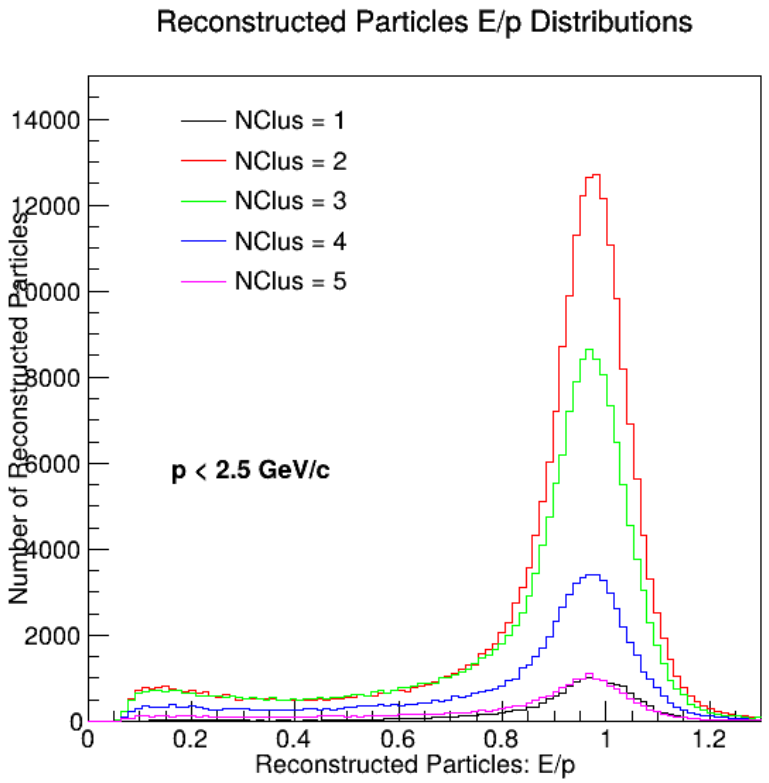
Next Steps

- Define/Derive the ECAL fiducial and non-fiducial region in terms of x and y instead of ix and iy
- Extend matching for unmatched FEE tracks by prioritizing the E/p rather than Δx and Δy in the non-fiducial region
- Look into positron trigger events (low matching efficiency issue reported by Sarah)
- Compare different SVT alignment detector versions
- Switch to the dedicated FEE run 14168
- Better understand the FEE and positron trigger
- Generate and perform MC studies to further validate my results
  - Need support from the MC team

Back Up

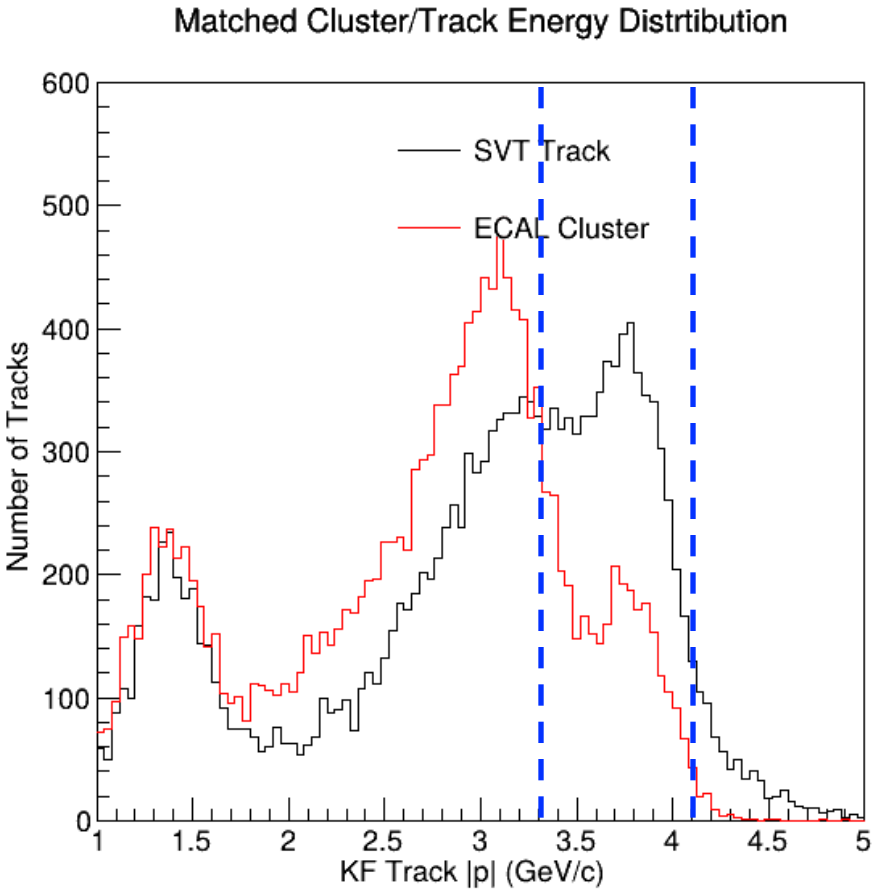
E/p vs NClus

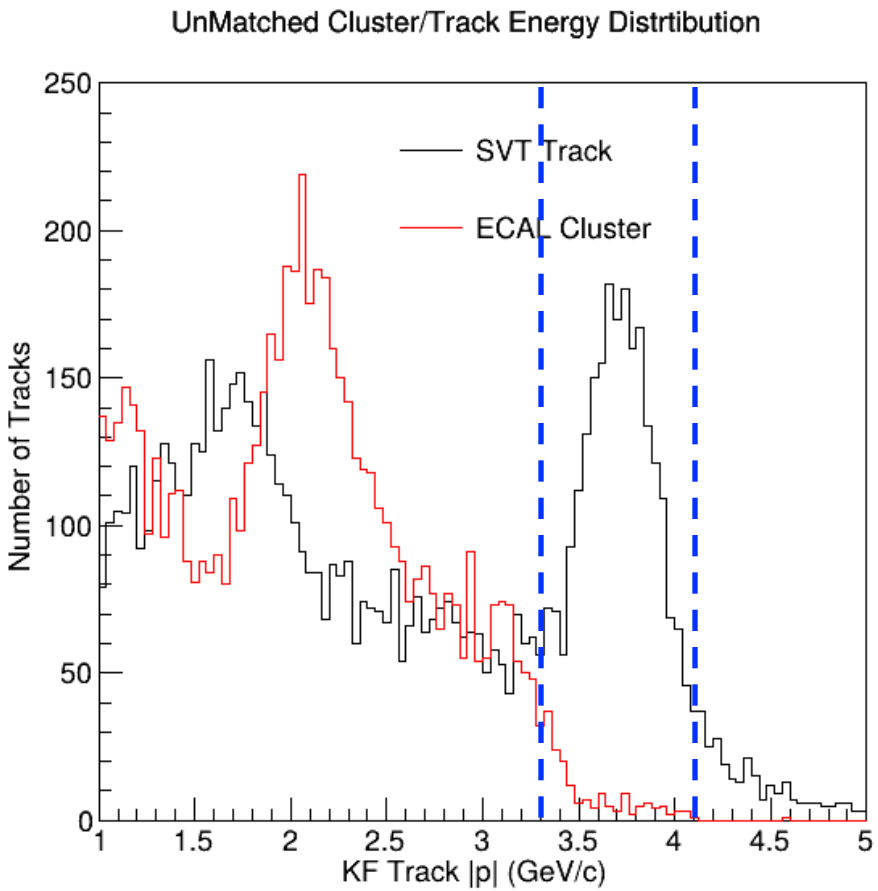




- Track-matching appear to breakdown when we have multiple ECAL clusters at high energy but not low energy
  - Matched ones may not be great
  - Unmatched are not necessarily bad
- Should we improve the ECAL shower clustering to improve the matching efficiency at high energy?
- Look for position dependence since it might help alignment studies

Tighter Selections





- Require good FEE track cut and exactly 1 electron track in 1 ECAL cluster in each event
- For matched one, the FEE peak is not very obvious
  - ECAL Energy looks about fine
- Unmatched tracks have a clear FEE peak but does not match to ECAL
  - ECAL Energy is clearly low (turns out it is due to the leakage)
- Need to cross check more details in MC

Detailed Event UnMatched Investigation

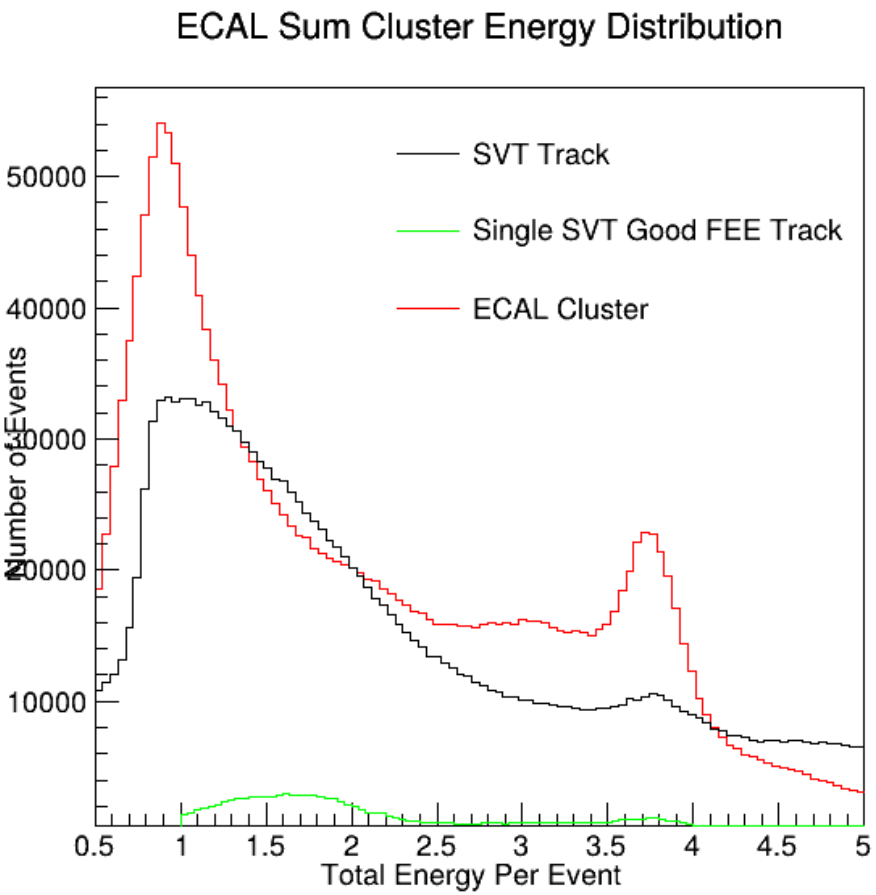
Event ID: 838

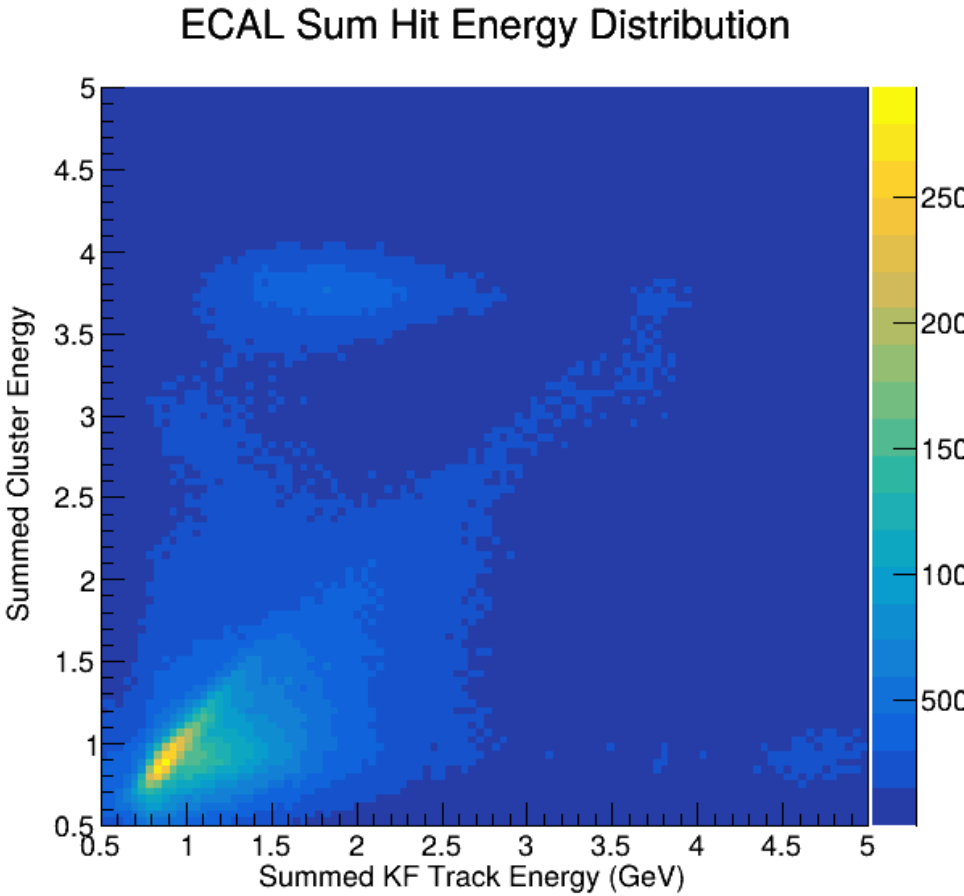
- 1 likely FEE electron track at 3.56 GeV ($\chi^2 = 8.2$)
  - Tanλ = -0.0154 (Bottom Track)
  - Extrapolation to ECAL X = -22.9 mm and Y = -33.8 mm (bottom ECAL)
- 1 ECAL cluster at 0.561 GeV
  - 7 ECAL hits at very different locations (beam background?)
  - Location of the single cluster is at X = 356 mm and Y = 28.4 mm (Top ECAL)
  - Not a fiducial region
- So it is a top FEE track with bottom ECAL clusters in the same event. It is clear that they will not match.
- But why we have such events and how to interpret it

		Energy	X (mm)	Y (mm)
Row	Instance	ecal_hit_	ecal_hit_	ecal_hit_
838	0	0.3638109	384.09863	29.974739
838	1	0.0574582	368.32818	29.974739
838	2	0.0296911	65.058029	29.974739
838	3	0.0281355	65.058029	29.974739
838	4	0.0220045	50.204952	29.974739
838	5	0.0090493	139.49688	-89.14270
838	6	0.0686229	-205.2944	-74.10837

- Double check with MC single pure FEE electron events if possible

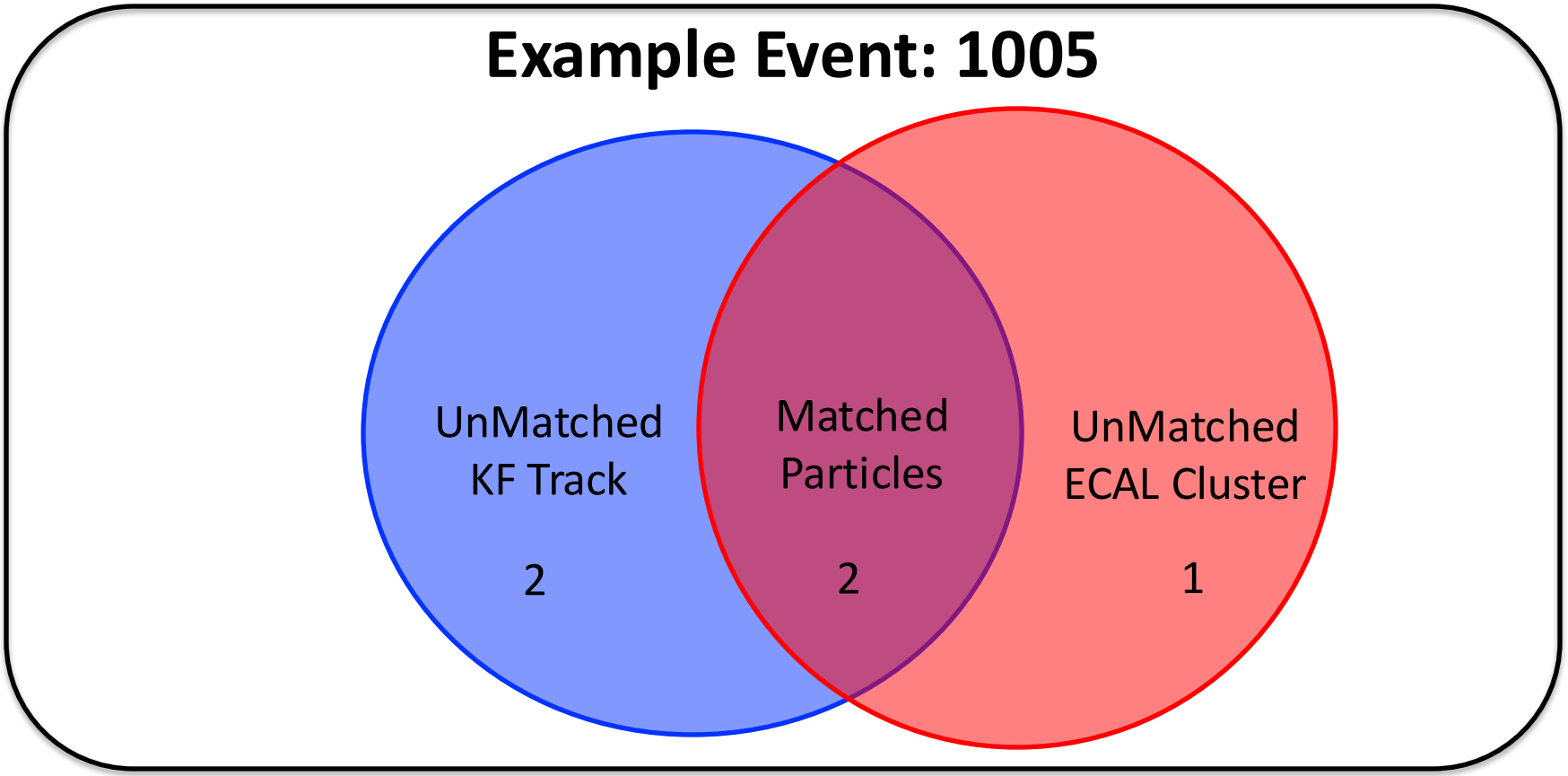
Global Event Level





- Good FEE track selection: first hit layer = 1, last hit layer = 14, and NHits > 9
- All peaks seen at around 3.7 GeV
  - Summed SVT Track $\mu = (3.682 \pm 0.005)$ GeV and $\sigma = (0.354 \pm 0.011)$ GeV
  - Good SVT Track $\mu = (3.750 \pm 0.005)$ GeV and $\sigma = (0.164 \pm 0.005)$ GeV
  - ECAL Cluster $\mu = (3.729 \pm 0.001)$ GeV and $\sigma = (0.197 \pm 0.008)$ GeV
- Strong correlation between total energy in SVT and ECAL

General Event Reconstructed Object Structure



- Five Subcatagories: Reconed but not ECAL matched KF SVT Tracks (2), ECAL-matched KF SVT tracks (2), reconed but not SVT track matched ECAL clusters, and Unreconed ECAL Cluster (1)
  - No reuse tracks/ecal in the matching
- We will focus on studying FEE events

Reconstruction Logic Train

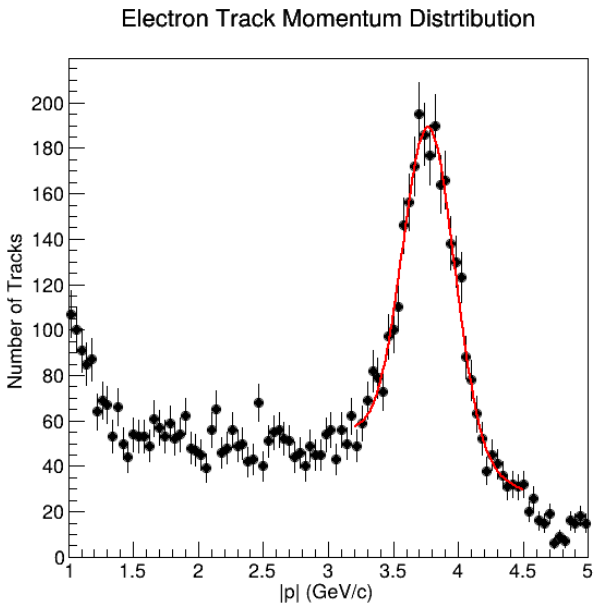
SVT Hits → KF Track

ECAL Hit → ECAL Cluster

KF Track, ECAL Cluster → Particle → Matching

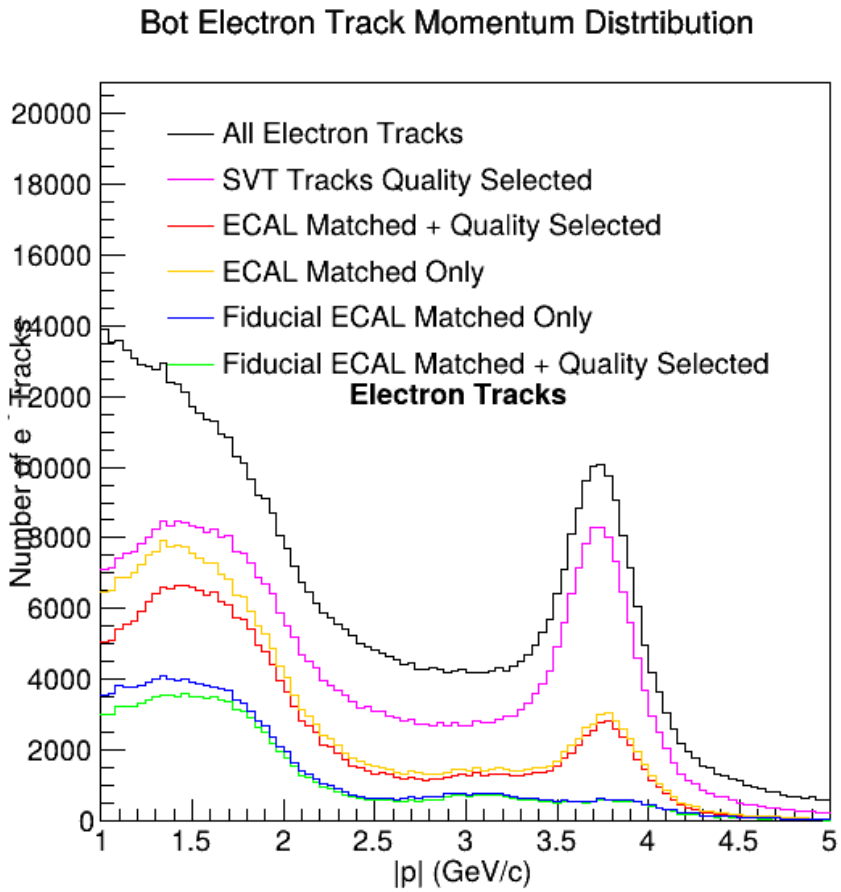
At least 1 track and 1 ECAL cluster to construct a particle

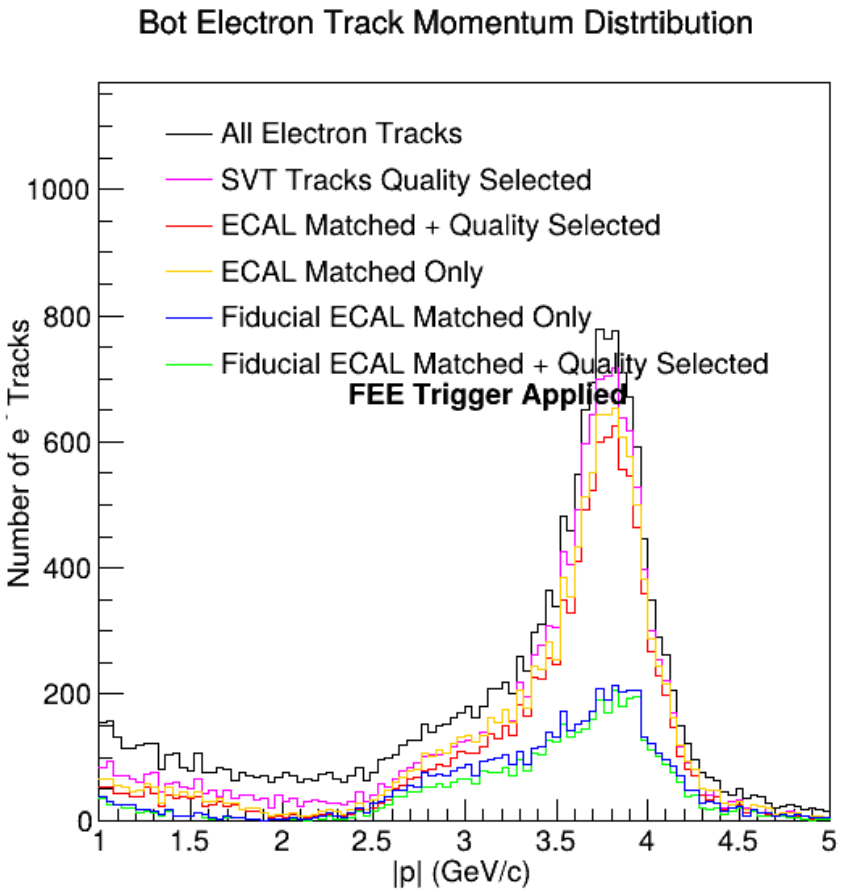
NECAL Hit > 0
NECAL Cluster = 0



ECAL Hits do not guarantee ECAL Cluster
(What is the selection criteria?)

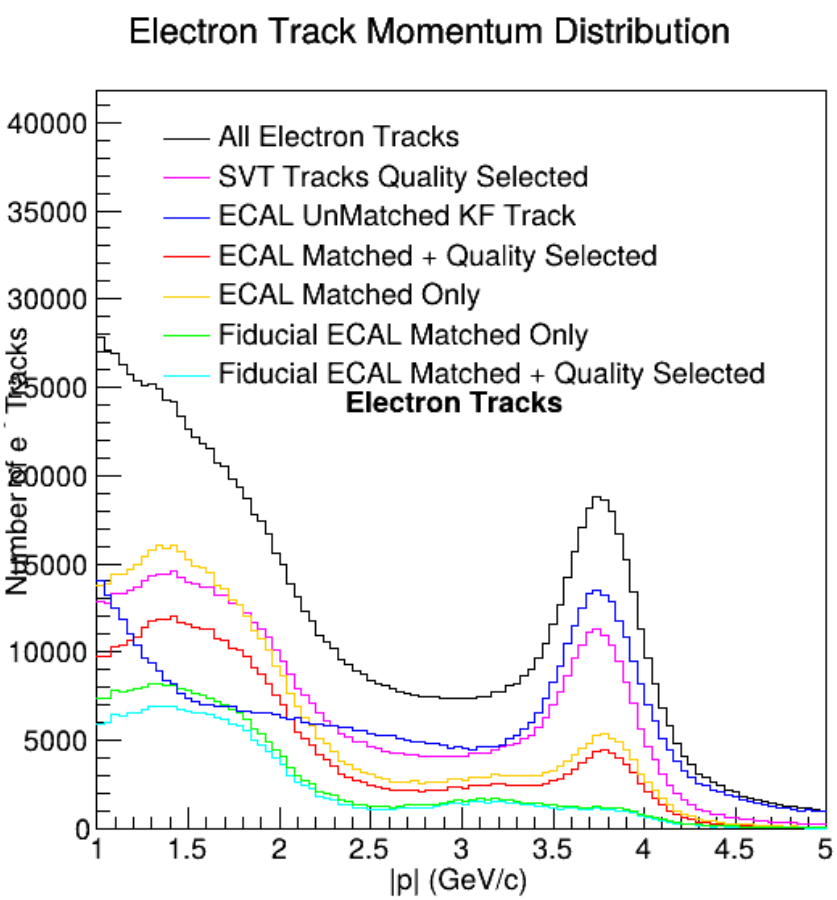
Bottom SVT Track-ECAL Matching

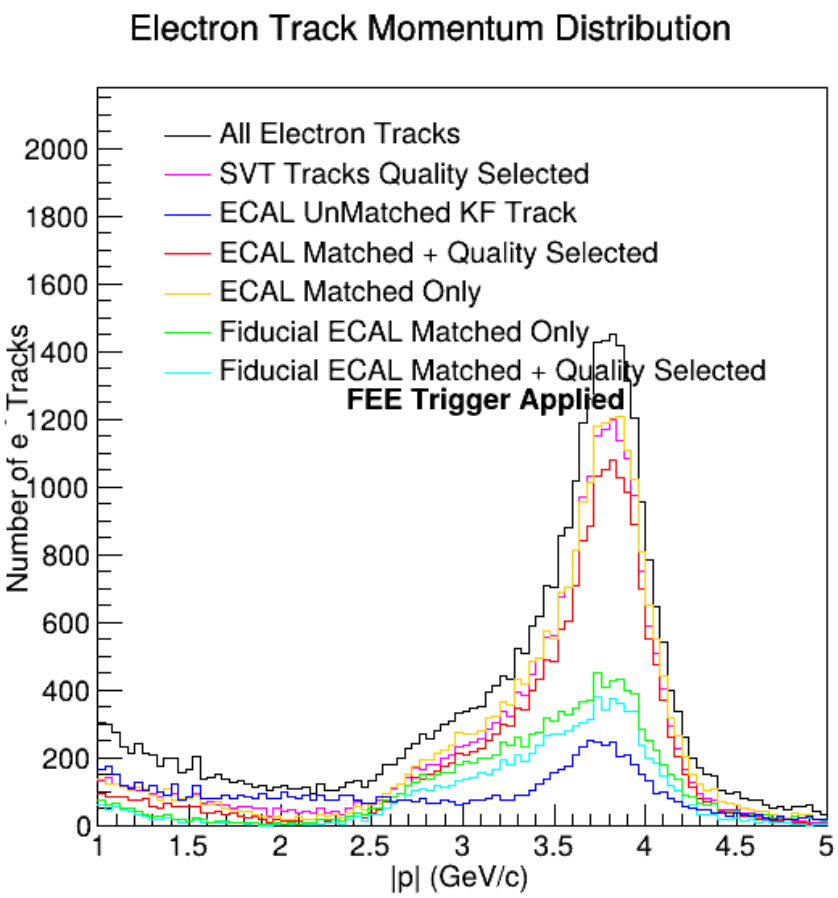




- Quality cut: last SVT layer $\geq$ 12, first SVT layer = 1, and nhit $\geq$ 10
- It looks like matching does not

SVT Track-ECAL Matching





- Quality cut: last SVT layer $\geq$ 12, first SVT layer = 1, and nhit $\geq$ 10
- It looks like matching does not function at the
- Should we reduce the unused/unmatched tracks and clusters for better performance in matching as quite a lot of them are useful
- Investigate with single pure FEE events in MC to understanding matching

Top and Bottom SVT Track-ECAL Matching