Search for $K_L \rightarrow \pi^0\mu\mu$ in 1999 Data

- Outline
  - Issues from last meeting
    - $KL \rightarrow \pi^0\mu\mu$ analysis
      - Backgrounds: $KL \rightarrow \pi^+\pi^-\pi^0$ MC
        - $KL \rightarrow \pi^+\pi^-\pi^0$ MC - No selection at generator level
      - Backgrounds: $KL \rightarrow \pi\mu\nu$ MC
        - $KL \rightarrow \pi\mu\nu$ MC - No selection at generator level
  - Current Issues
  - Plans

$K_L \rightarrow \pi^+\pi^-\pi^0$ and $K_L \rightarrow \pi\mu\nu$ MC

- For $K_L \rightarrow \pi^+\pi^-\pi^0$: 6 distinct classes of events
  1. 1 Decay + Accidental
  2. No decay or punch-thru
  3. 1 Punch-thru + Accidental
  4. 1 Decay + 1 Punch-thru
  5. 2 Decays
  6. 2 Punch-thrus
- For $K_L \rightarrow \pi\mu\nu$: 3 distinct classes of events
  1. 1 Decay + Accidental photons
  2. No decay or punch-thru + Accidental photons
  3. 1 Punch-thru + Accidental photons
- Run MC with no selection
  - Let KTEVMC $K_L \rightarrow \pi^+\pi^-\pi^0$ and $K_L \rightarrow \pi\mu\nu$ run normally
  - Select Trigger 5 Events ($K_L \rightarrow \pi^0\mu^+\mu^-$, $K_L \rightarrow \mu\mu\gamma\gamma$)
    - 2V * DC12 * 2MU3_LOOSE * PHVBAR1 * 2HCY_LOOSE * HCC_GE2

"Non-selected" $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

	Output of MC	After all cuts except pt2&Mass	After all cuts except Mass
No Decay or Punch	23%	4%	10%
1 Punch	> 1 %	> 1%	> 1%
1 Decay	49%	20%	28%
1 Punch + 1 Decay	> 1%	> 1%	> 1%
2 Decays	28%	76%	62%
2 Punch	0%	0%	0%

“Non-selected” $K_L \rightarrow \pi\mu\nu$ MC

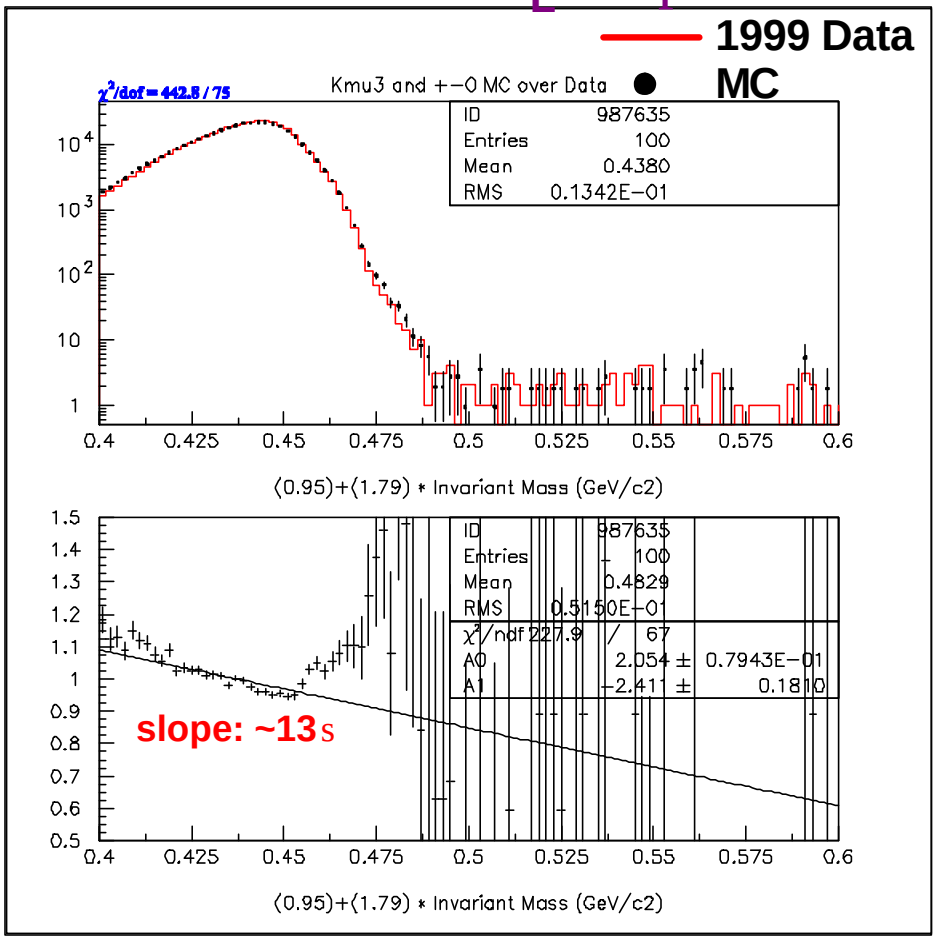
	Output of MC	After all cuts except pt2&Mass	After all cuts except Mass
No Decay or Punch	81%	58%	36%
1 Punch	>0.6%	-	-
1 Decay	19%	42%	64%

1999 Data/$K_L \rightarrow \pi^+\pi^-\pi^0$ + $K_L \rightarrow \pi\mu\nu$ MC

- Fit 1999 Data with "Non-Selected" $K_L \rightarrow \pi^+\pi^-\pi^0$ and $K_L \rightarrow \pi\mu\nu$ MC, where I have not selected off events with pion decays or punch through
  - No higher level cuts applied
    - No cuts on K3pi inv mass cut, 2trk inv mass, MM0KINE, Pt2, no extra cluster/hit-pairs cut to reject accidentals
  - Floated MC in fit
    - $K_L \rightarrow \pi^+\pi^-\pi^0$ - generated ~1.31x 1999 data set. Normalization from fit ~1.06x.
    - $K_L \rightarrow \pi\mu\nu$ - generated ~68% 1999 data set. Normalization from fit ~56%.

  (~20% lower than expected)

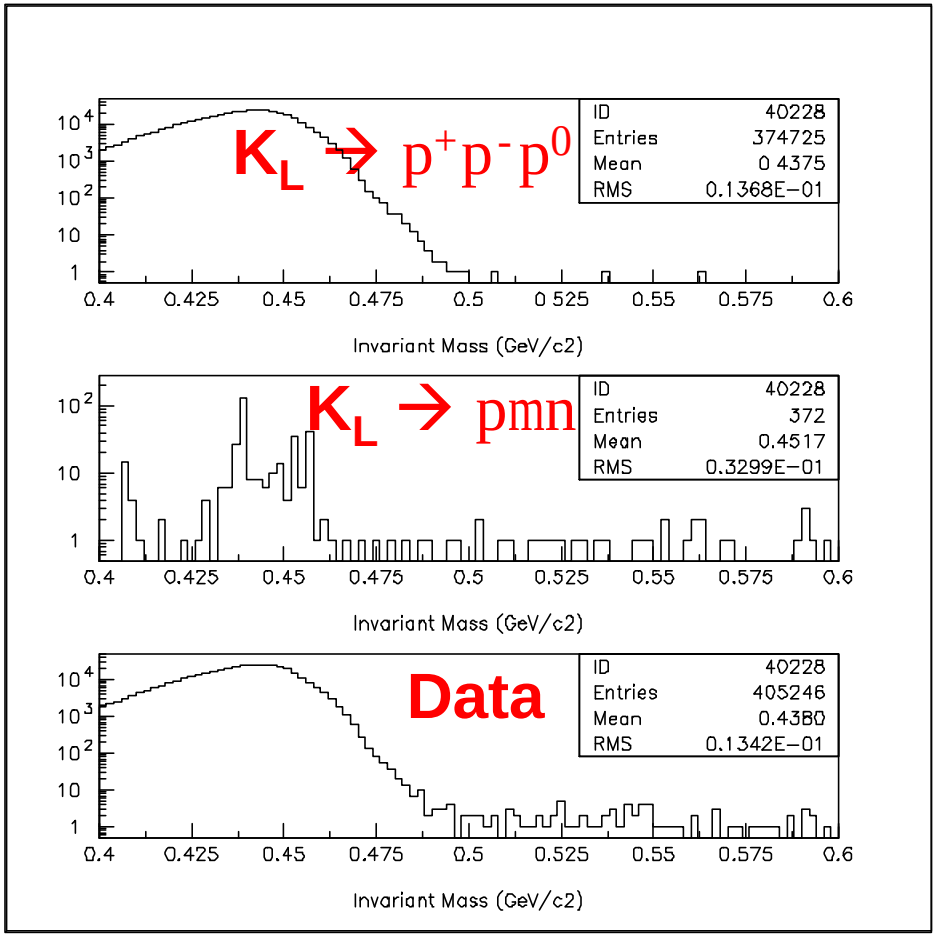
Invariant Mass: Reconstruct as $K_L \rightarrow p^0 mm$



Data/ $K_L \rightarrow \pi^+\pi^-\pi^0 + K_L \rightarrow \pi\mu\nu$ MC

- Quick check of the number of events in the high mass region
  - Integrate from 0.5→0.6 GeV/c^2
  - Kmu3 - 31 events x 1.79 = 56 evts
  - K3pi - 3 events x 0.95 = 3 evts
  - Total MC = 59 evts
  - Data - 68pts

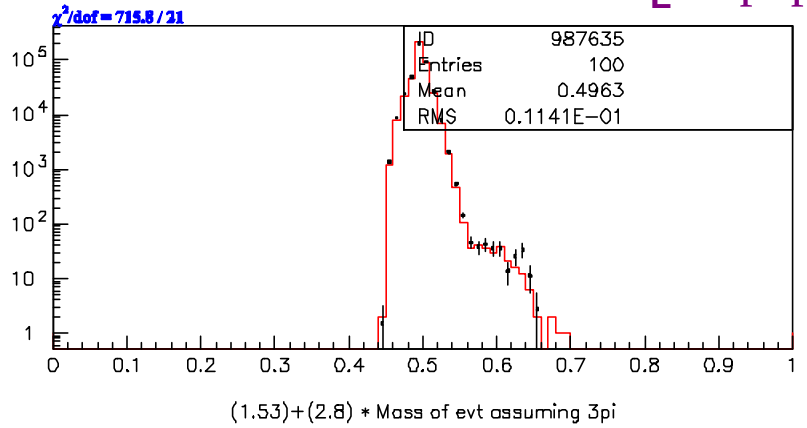
Invariant Mass: Reconstruct as $K_L \rightarrow p^0 mm$

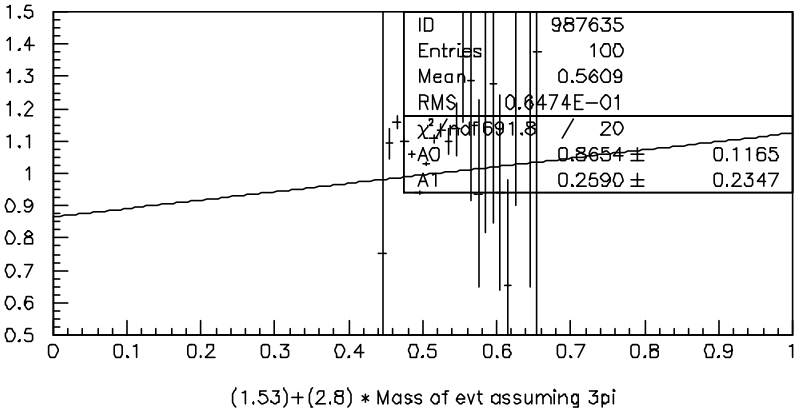


$K_L \rightarrow \pi^+\pi^-\pi^0$ and $K_L \rightarrow \pi\mu\nu$ MC

$(K_L \rightarrow \pi^+\pi^-\pi^0 + K_L \rightarrow \pi\mu\nu)$ MC

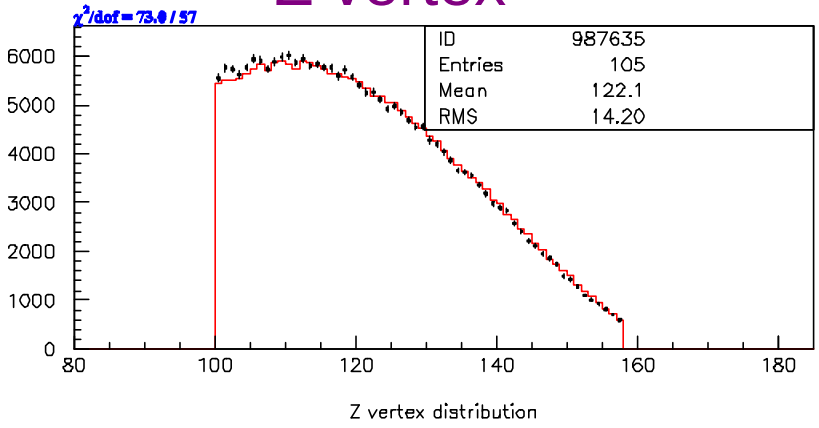
Inv Mass:Reconstruct as $K_L \rightarrow p^+p^-p^0$

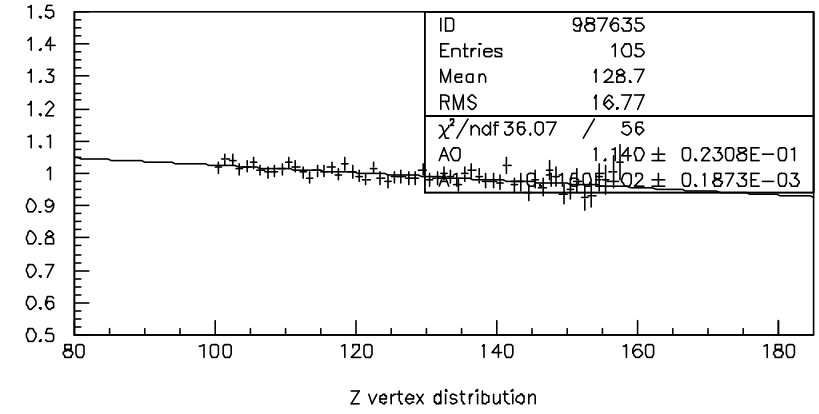




$K_L \rightarrow \pi^+\pi^-\pi^0$ MC

Z vertex

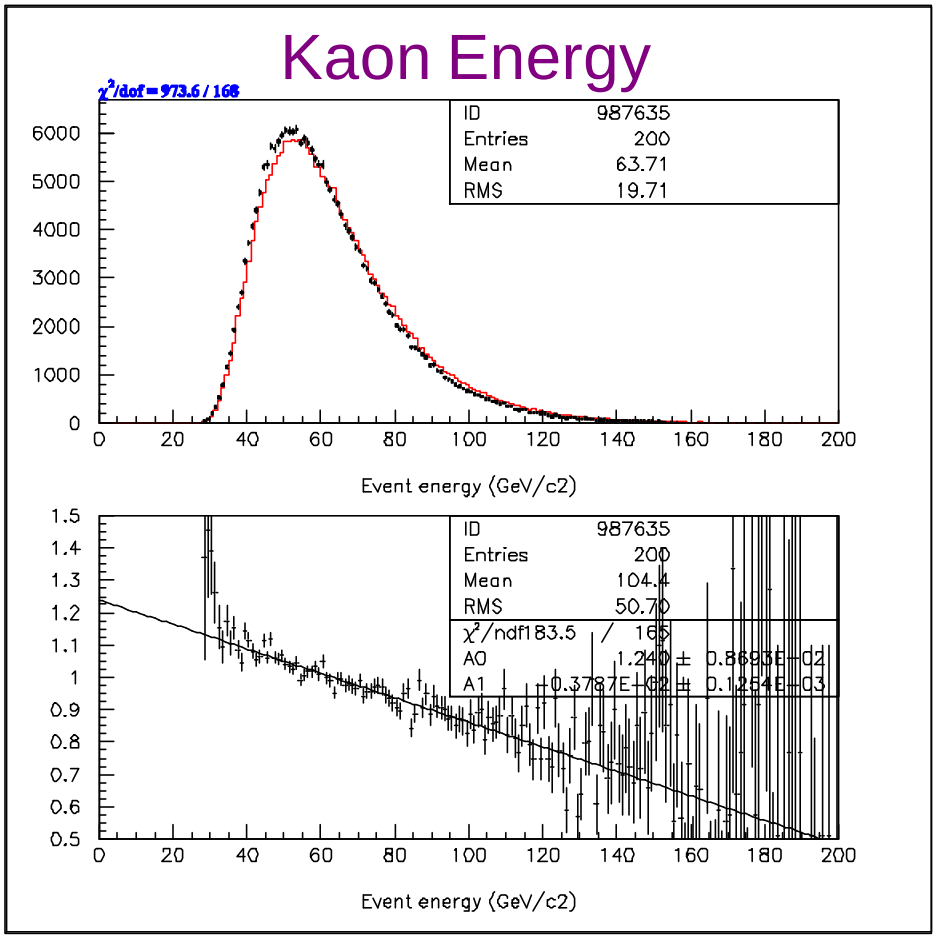


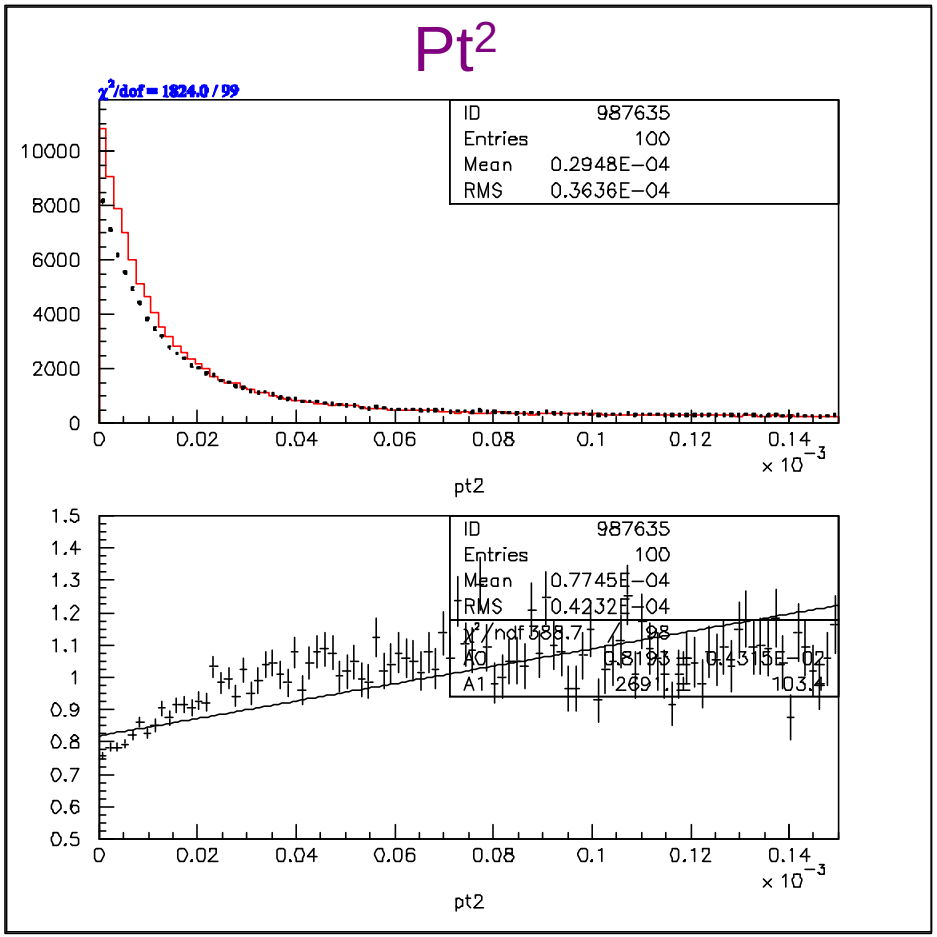


1999 Data
MC

Problems with $K_L \rightarrow \pi^+\pi^-\pi^0$ MC

$K_L \rightarrow \pi^+\pi^-\pi^0$ MC





1999 Data

MC

$K_L \rightarrow \pi\mu\nu$ MC

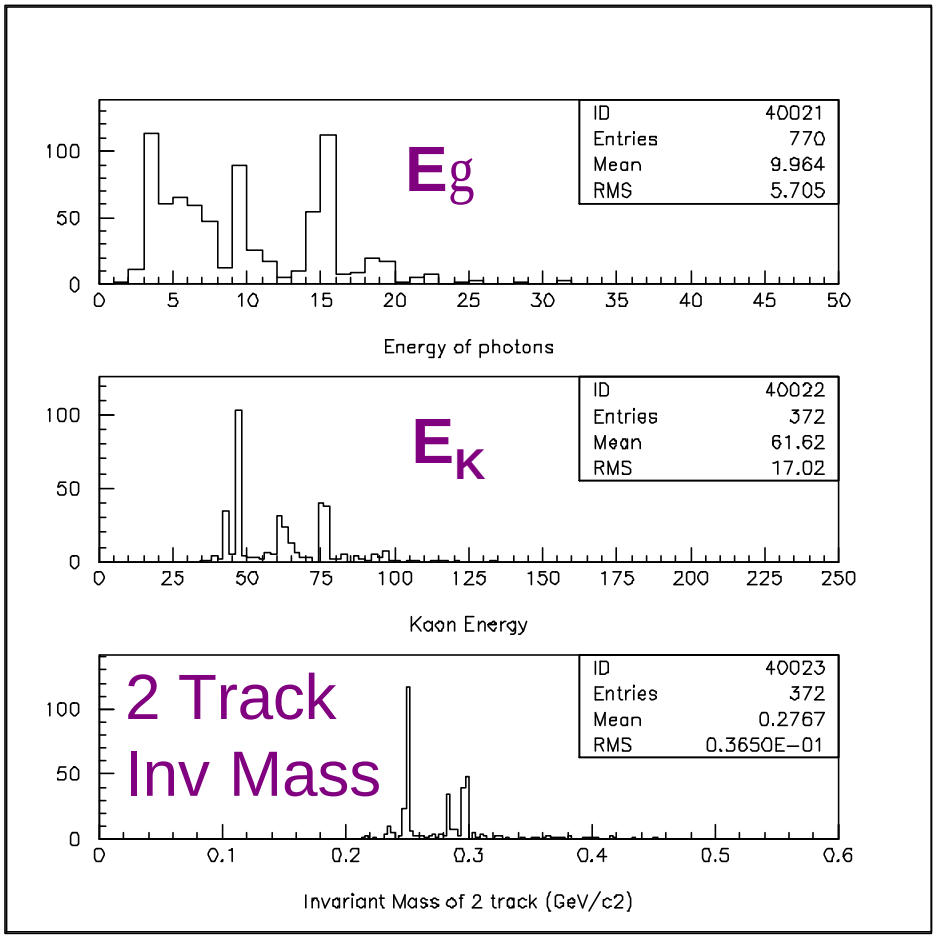
- For $K_L \rightarrow \pi\mu\nu$ to pass B05 trigger
  - = 2 HCC
  - (= 1 hit in Mu3X .AND. = 2 hit in Mu3Y) .OR.
    (= 1 hit in Mu3Y .AND. = 2 hit in Mu3X)
- Offline cuts
  - Require exactly 2 HCC from photons
  - Require = 2 hits in MU3X .AND. = 2 hits in MU3Y

→ Muons: π decay, π punch-through, accidental muon

→ HCC clusters: 2 accidental photons, π with satellite shower

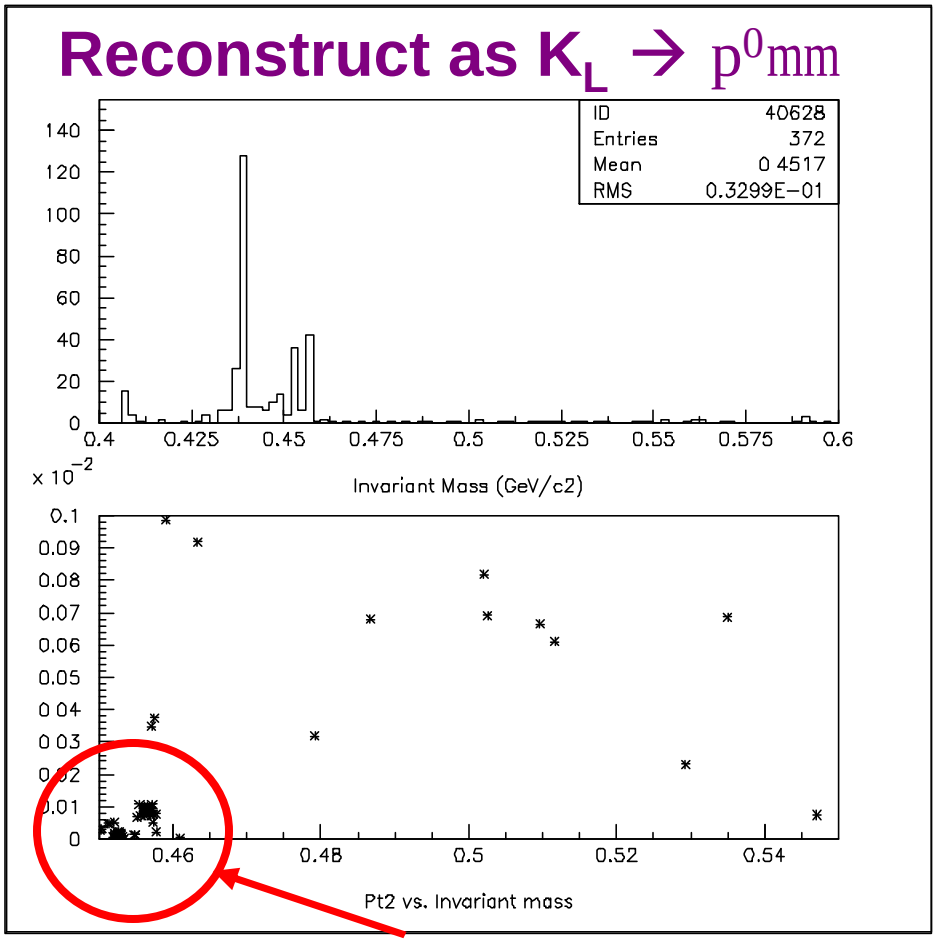
- Not very many accidentals with 2 HCC clusters
  - Spikes in invariant mass plot are at low Pt^2
  - Scan of Monte Carlo shows that these events are coming from the same run/spill → Accidental events are being used multiple times.

Spikes in $K_L \rightarrow \pi\mu\nu$ MC



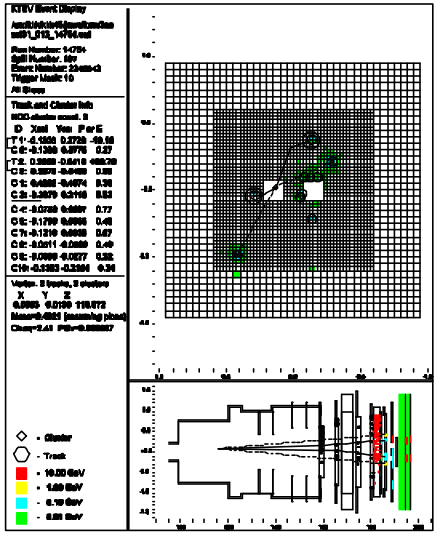
Inv Mass:

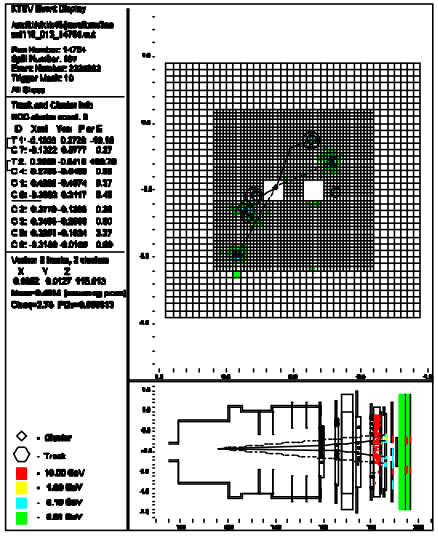
Reconstruct as $K_L \rightarrow p^0 mm$

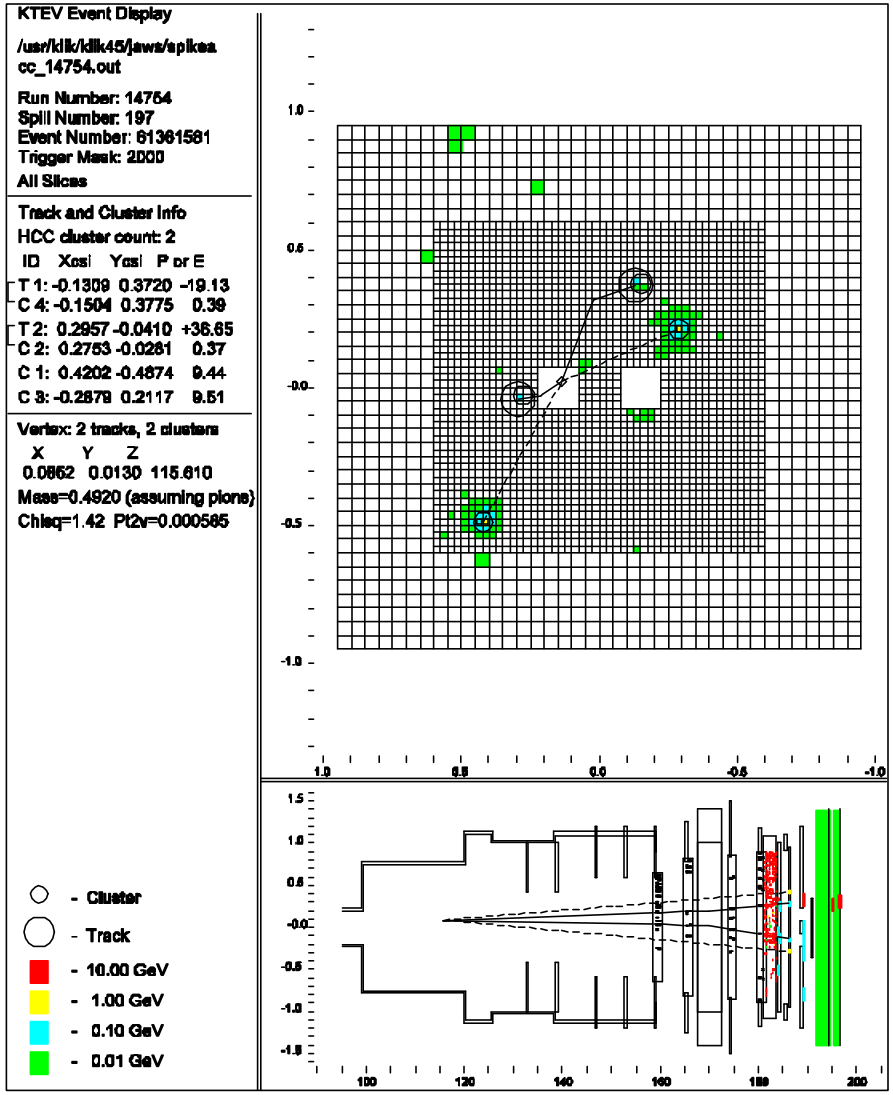


Spikes in Inv Mass Plot

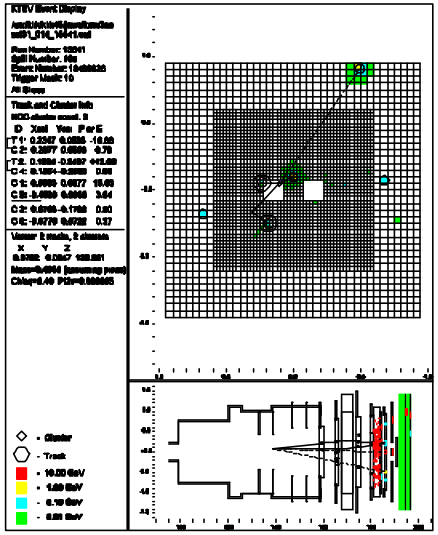
Duplicate Accidental Events

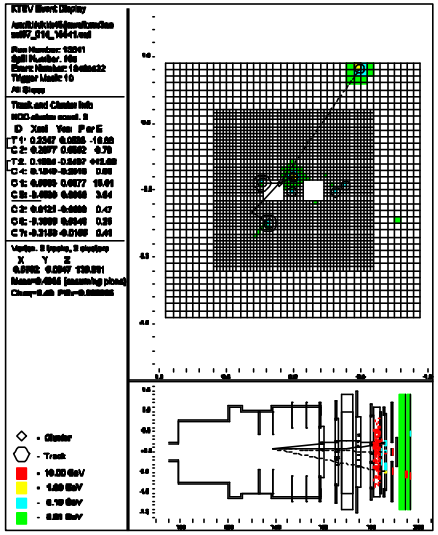


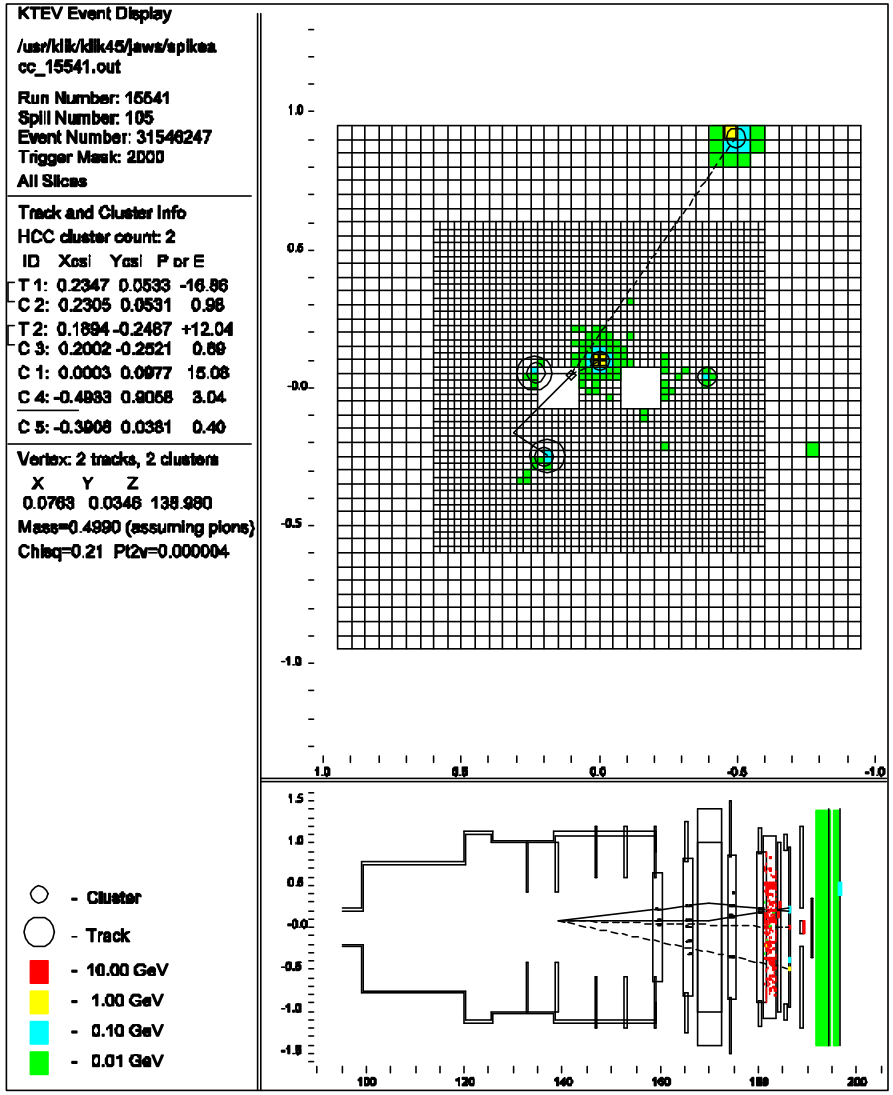




Duplicate Accidental Events







Spikes in $K_L \rightarrow \pi\mu\nu$ MC

- Events are real $K_L \rightarrow \pi^+\pi^-\pi^0$ accidental events
- At least some background coming from $K_L \rightarrow \pi^+\pi^-\pi^0 + K_L \rightarrow \pi\mu\nu$ double decays
- Need to estimate this effect when calculating event statistics from background MC

Improvements to $K_L \rightarrow \pi\mu\nu$ MC

- Increase Accidental sets used on farm (standard: 1/3 total)
- Add PHOTOS to $K_L \rightarrow \pi\mu\nu$ generation in the MC (Thanks to Sasha)
  - Discovered that L1SRC trigger bits not set for runs 15520,15521,15270-15322, but L1 trigger checked at stage 20 → vetoes from accidentals never cause L1 rejection
    - Added fix to v6.00 MC and my analysis code
  - MCPIPUNCH applied at Stage 35 to MIP pions, but L1 trigger is examined after stage 30 → punch through muons never cause L1 trigger accept
    - Put MCPIPUNCH at stage 20 for all pions
- Try to generate $K_L \rightarrow \pi^+\pi^-\pi^0 + K_L \rightarrow \pi\mu\nu$ double decay to understand backgrounds
  - Avoid the statistical problem of having limited accidental events

Current Issues

- $K_L \rightarrow \pi^+\pi^-\pi^0$ MC
  - Bad mismatches in data/MC overlays
  - If there is a problem with the "mix" of the different event types, (π decay/π punch-thru/no decay or punch) → Float various distributions
- $K_L \rightarrow \pi\mu\nu$ MC
  - PHOTOS and 3X standard accidental data set
    - Improve the problem of reusing accidental events
  - Study $K_L \rightarrow \pi\mu\nu$ + $K_L \rightarrow \pi^+\pi^-\pi^0$ double decay
  - Otherwise, I need to understand the statistical impact of the "spikes"

Plans

- Keep generating MC on farm – “No-selection” MC
  - $K_L \rightarrow \pi^+\pi^-\pi^0$ – Understand data/MC mismatches
  - $K_L \rightarrow \pi\mu\nu$ – Generate PHOTOS MC for study
  - $K_L \rightarrow \pi\mu\nu + K_L \rightarrow \pi^+\pi^-\pi^0$ – Generate double decays
- Reduce background near box with additional cuts
  - Now that I have a relatively large MC data set, use it to study cuts
    - Extra DC hits from accidentals?
    - Neutral v. charged vertex cut?
    - Upstream/downstream track-angle cut?
    - Kinematic fit?