Status & Plans for 1999 $K_L \rightarrow \pi^0\mu\mu$

- Outline
  - Overview
    - $KL \rightarrow \pi^0\mu\mu$ analysis
      - Higher backgrounds from accidentals
      - Backgrounds estimate issues: Spikes in $KL \rightarrow \pi\mu\nu$ MC distributions
        - Reusing a few $KL \rightarrow \pi^+\pi^-\pi^0$ accidentals in MC
        - Estimate from data?
  - Current issues & Plans for wrapping up the analysis

Analysis Cuts for $K_L \rightarrow \pi^0\mu\mu$

- No extra tracks
- Ptrk > 10 GeV/c
- Etrkclus < 1 GeV
- Offmag < 1mm (x & y)
- 97 < zvtx < 157 *
- Xvtx & yvtx in beam region at CsI
- Vtxchi2 < 10
- Trk to trk cluster position < 3.5cm
- Photon clus to trk clus > 20cm
- Exactly 2 hits in MU3X and MU3Y
- Non-adjacent mu hits in 1 plane
- RC energy < 0.2 GeV
- CA energy < 3.0 GeV
- 20 GeV < E_K < 220 GeV
- No extra HCC clusters
- Fusechi2 < 5

Signal Cuts ($K_L \rightarrow \pi^0\mu\mu$)

- Trigger 5
- Exactly 2 HCC clusters (no trk)
- $0.1315 < M\pi^0 < 0.1385$ GeV/c^2 *
- $M_{2T} < 0.350$
- -0.01 < mm0kine < 0.1
- $Pt^2 < 0.0001$ $(GeV/c)^2$
- $0.490 < M\pi^0\mu\mu < 0.506$ GeV/c^2

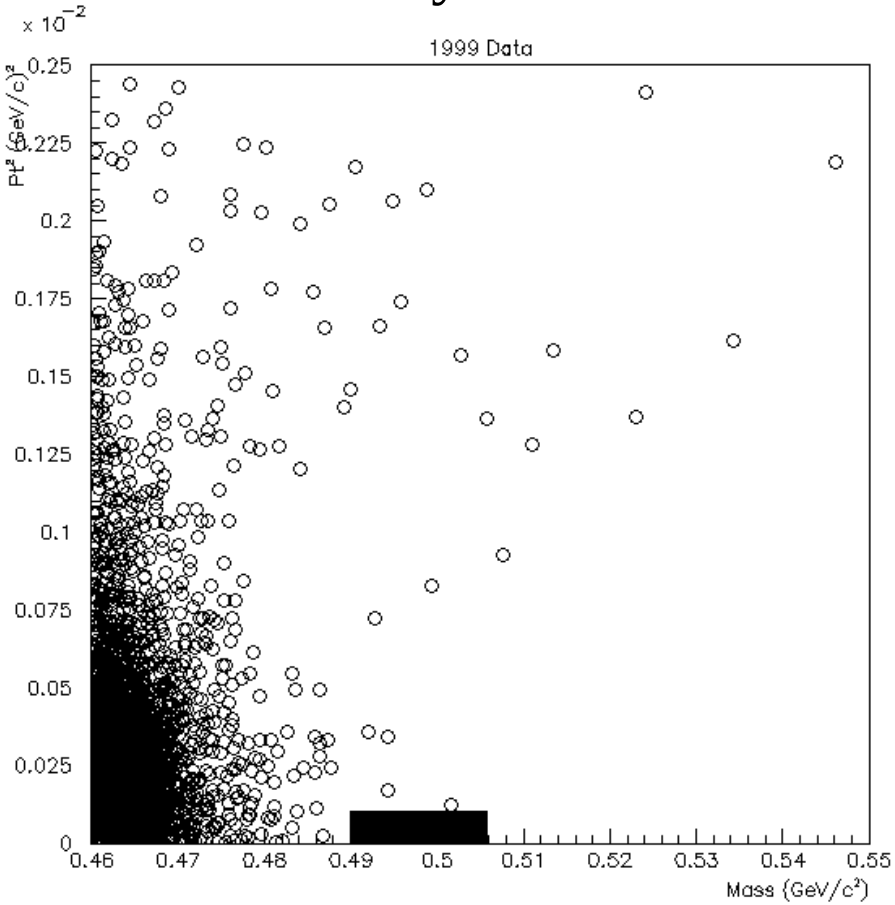
Normalization Cuts ($K_L \rightarrow \mu\mu\gamma$)

- Trigger 6
- Exactly 1 HCC cluster (no trk)
- $E\gamma > 8.0$ GeV
- $Pt^2 < 0.0001$ $(GeV/c)^2$
- $0.490 < M\pi^0\mu\mu < 0.506$ GeV/c^2

1999 Data: $K_L \rightarrow \pi^0\mu\mu$

- 1999 data
  - Signal acceptance = 4%
  - Background level is higher near the box than in 1997
    - More background close to box due to lowered B-field
    - Low mass background is from $K_L \rightarrow \pi^+\pi^-\pi^0$
- Largest background expected comes from $K_L \rightarrow \mu^+\mu^-\gamma\gamma$
  - Dangerous background that peaks at kaon mass

JAWS Analysis: 1999 Data

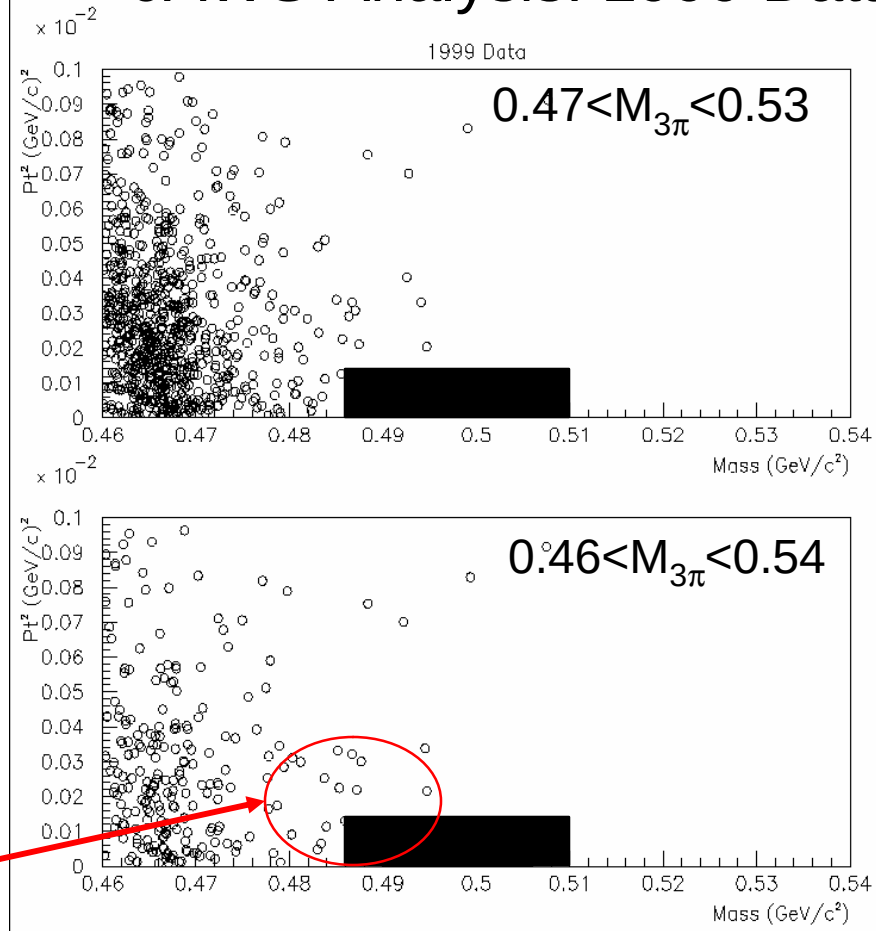


$K_L \rightarrow \pi^0\mu\mu$

$K_L \rightarrow \pi^0\mu\mu$ 1999 Data

- Cut on track inv mass assuming $KL \rightarrow \pi^+\pi^-\pi^0$ event
  - $0.47 < M_{3\pi} < 0.53 \rightarrow$ 45% drop in background near box with no signal loss
  - $0.46 < M_{3\pi} < 0.54 \rightarrow$ 75% drop in background near box with ~10% signal loss
- Backgrounds from K3pi, Kμ3 and μμγγ

JAWS Analysis: 1999 Data



There are still events in this region that I need to deal with

Inceased box size during cut tuning

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

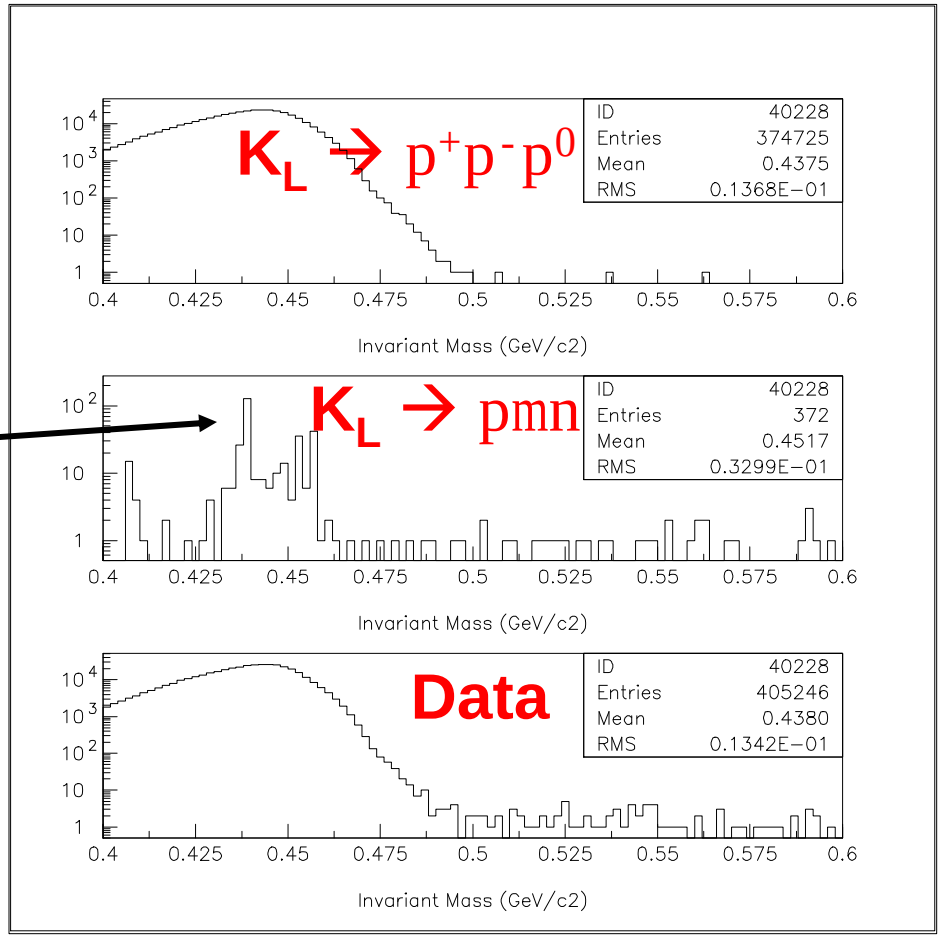
	Output of MC	After all cuts except pt2&Mass	After all cuts except Mass
No Decay or Punch	81%	58%	36%
1 Punch	>0.6%	-	-
1 Decay	19%	42%	64%

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

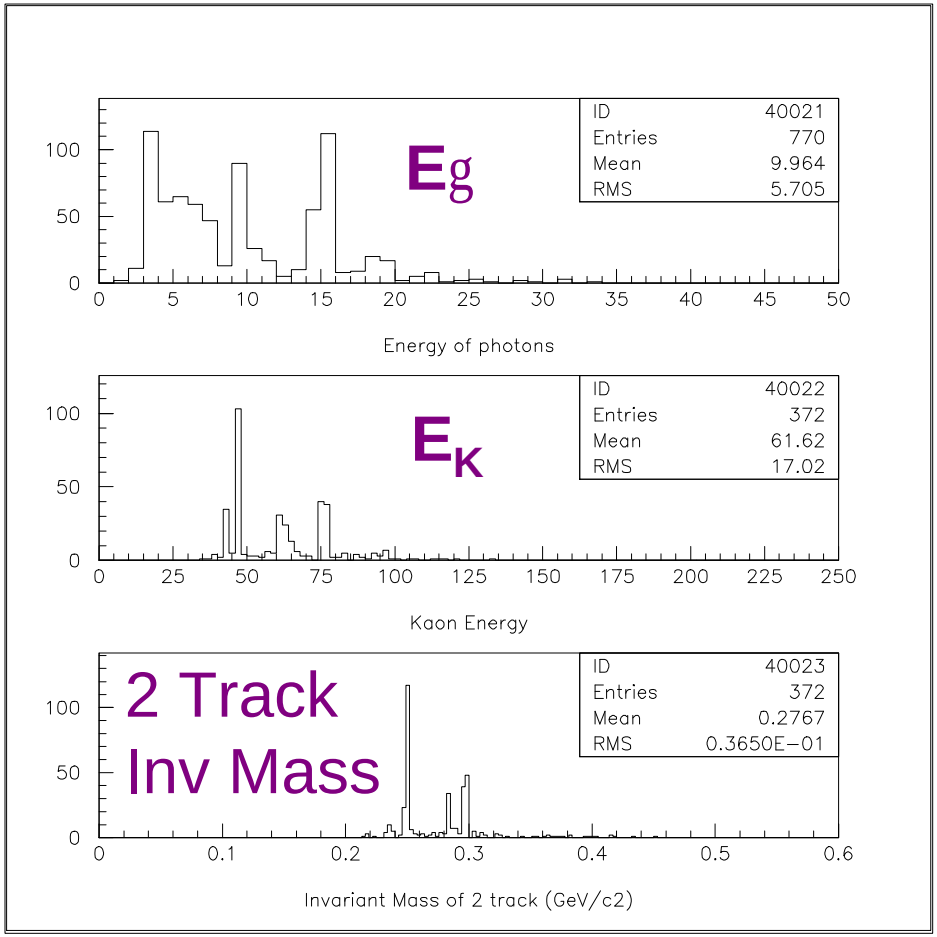
- Quick check of the number of events in the high mass region – loose cuts!
  - Integrate from 0.5→0.6 GeV/c^2
  - Kmu3 - 31 events x 1.79 = 56 evts
  - K3pi - 3 events x 0.95 = 3 evts
  - Total MC = 59 evts
  - Data - 68pts

Spikes

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

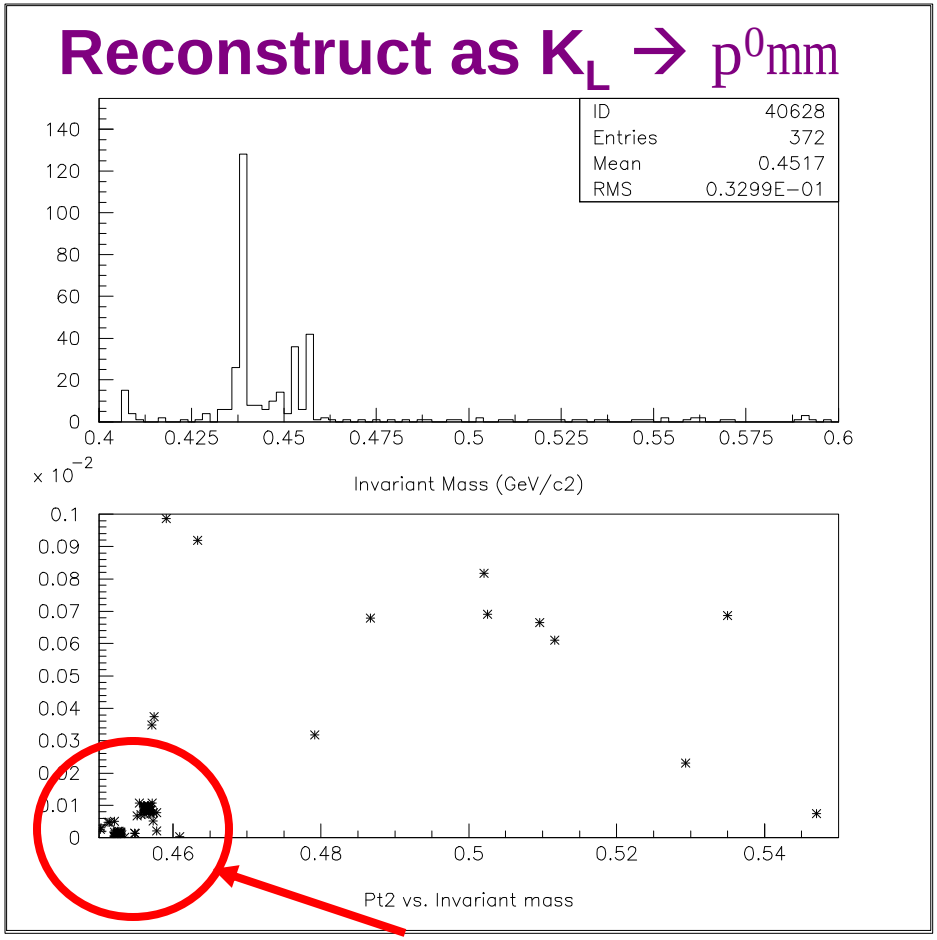


Spikes in $K_L \rightarrow \pi\mu\nu$ MC



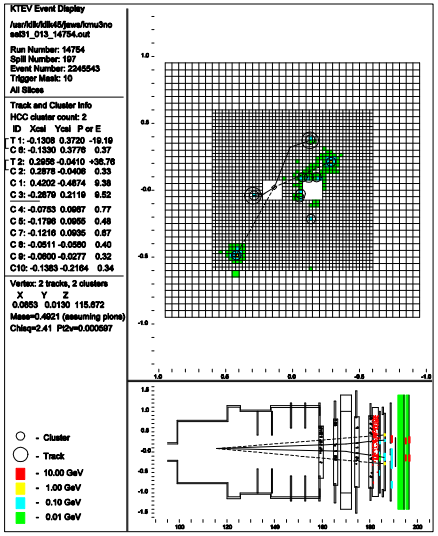
Inv Mass:

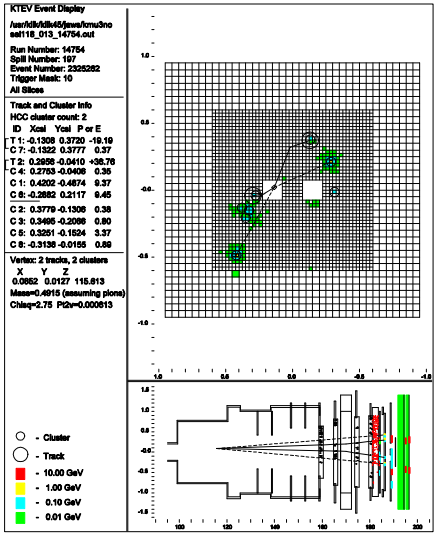
Reconstruct as $K_L \rightarrow p^0 mm$

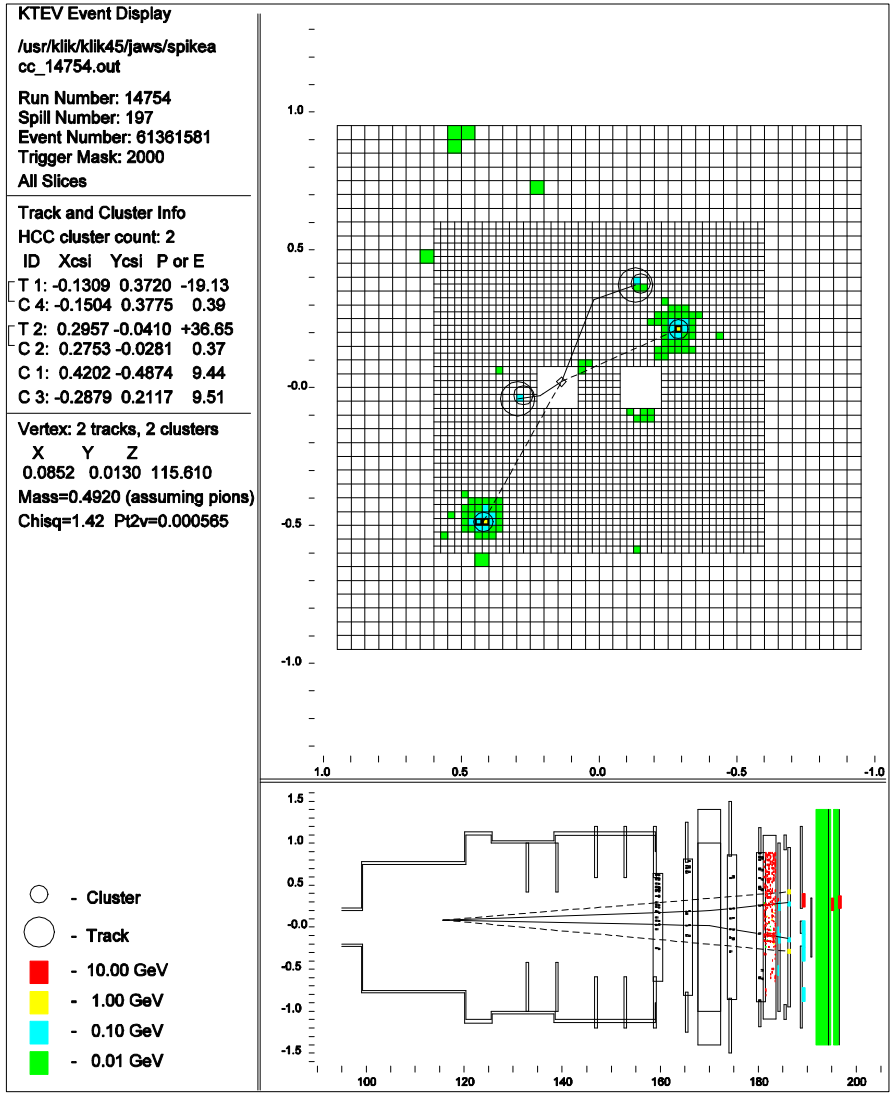


Spikes in Inv Mass Plot

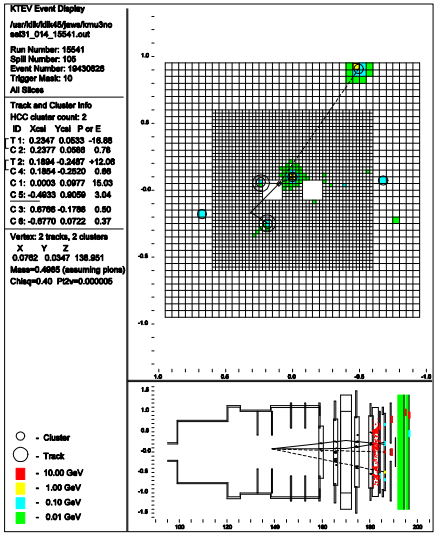
Duplicate Accidental Events

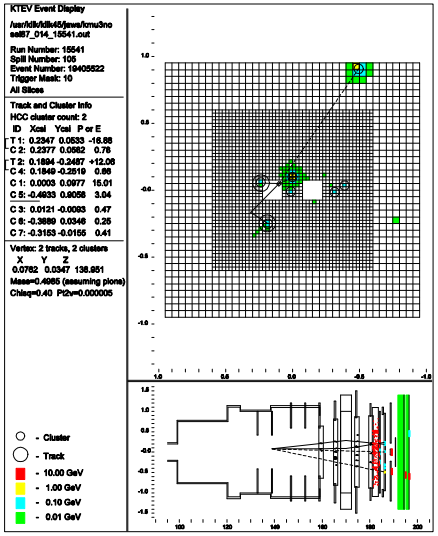


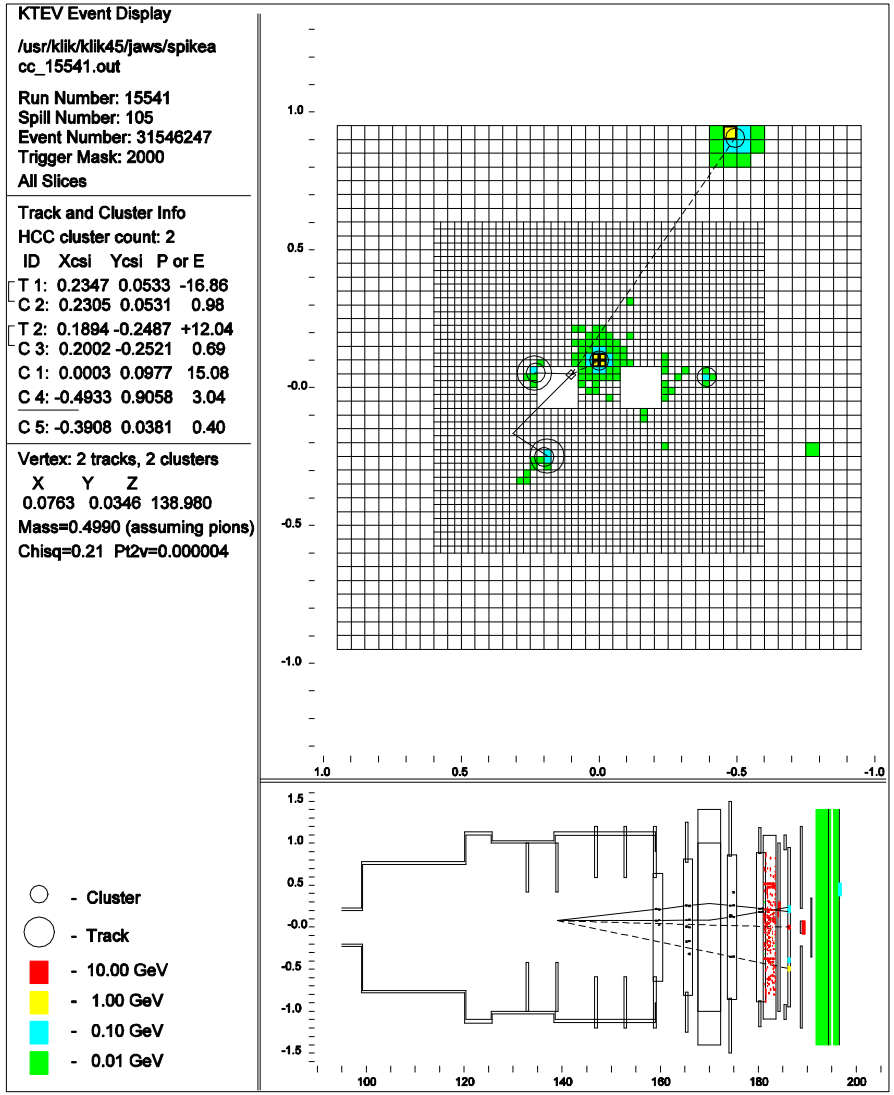




Duplicate Accidental Events





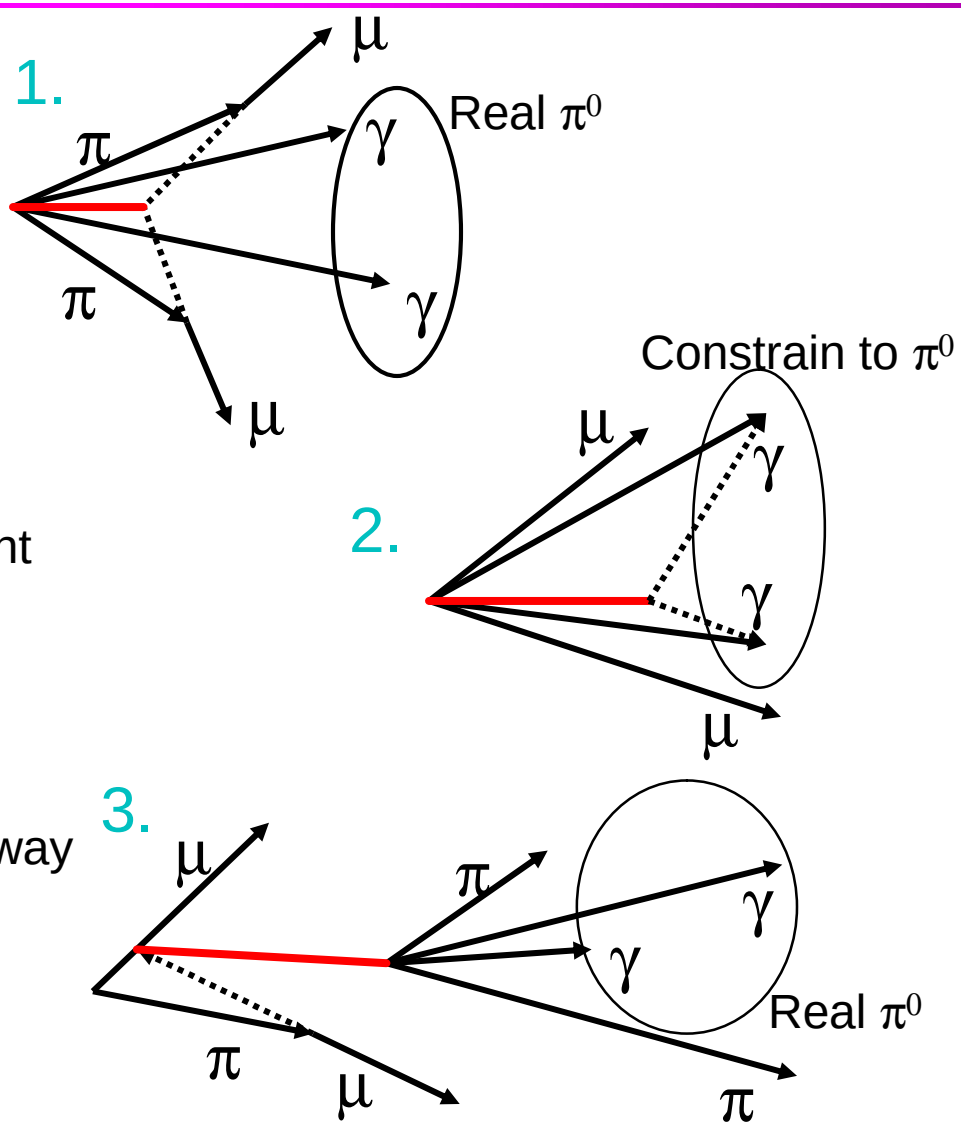


Spikes in $K_L \rightarrow \pi\mu\nu$ MC

- 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

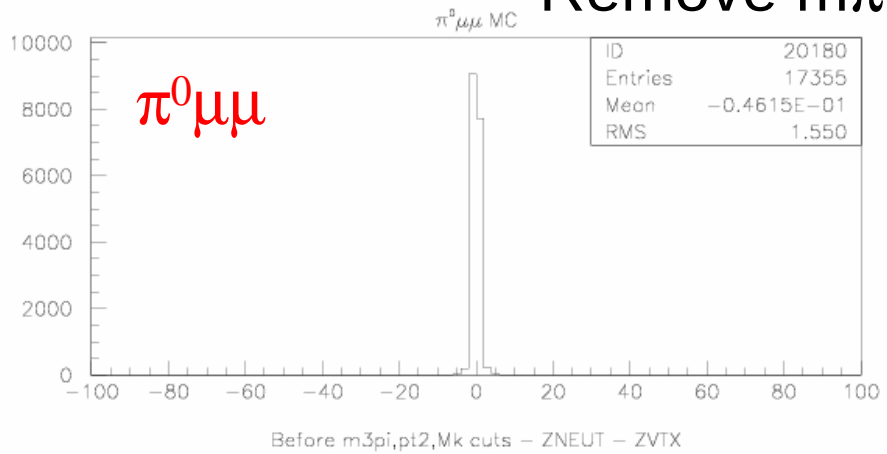
Background Estimate

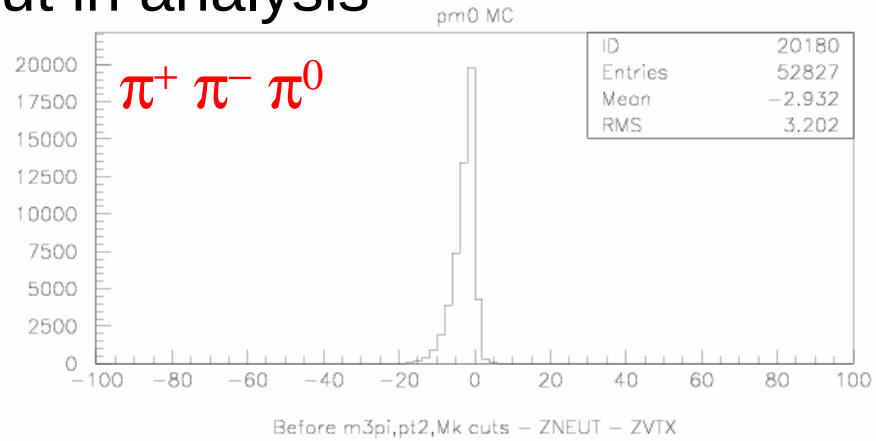
- Possible problem estimating backgrounds due to re-used accidentals in kmu3 MC
  - Signal: $K_L \rightarrow \pi^0 \mu\mu$
  - Backgrounds: kmu3,k3pi,$\mu\mu\gamma\gamma$
- Use (zneut – zchg) distribution in data to estimate background
  1. Charged vertex from decay in flight pion (muon accidental) charged vertex can reconstruct away from neutral vertex (if real π^0)
  2. Neutral vertex from 2 photons not coming from π^0 can reconstruct away from charged vertex
  3. Charged and neutral vertices can come from different kaon decays

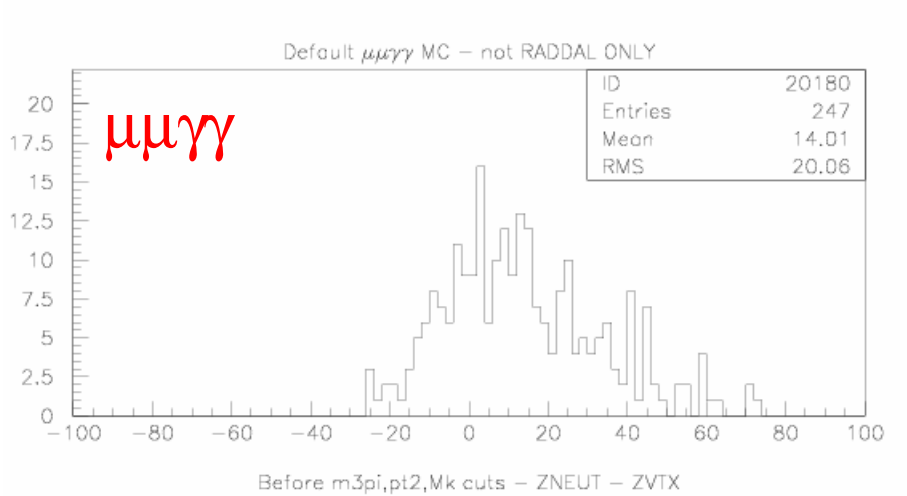


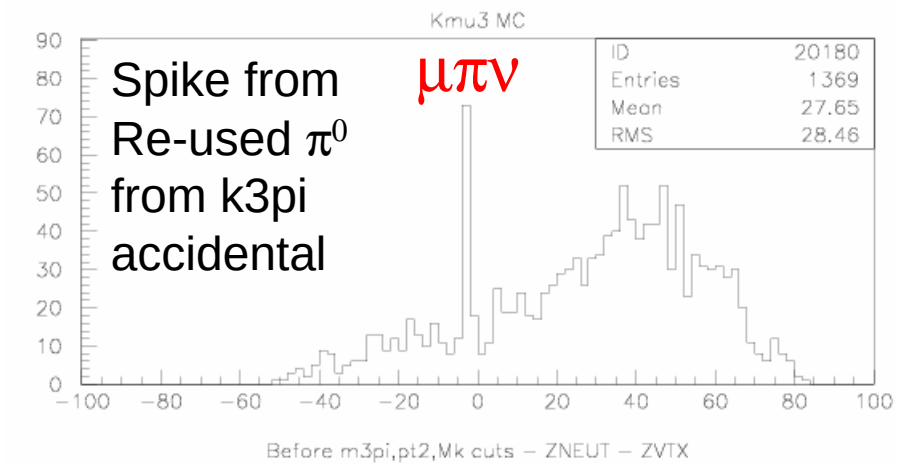
MC zneut-zchg: Before final cuts

Remove $m\pi^0$ cut in analysis



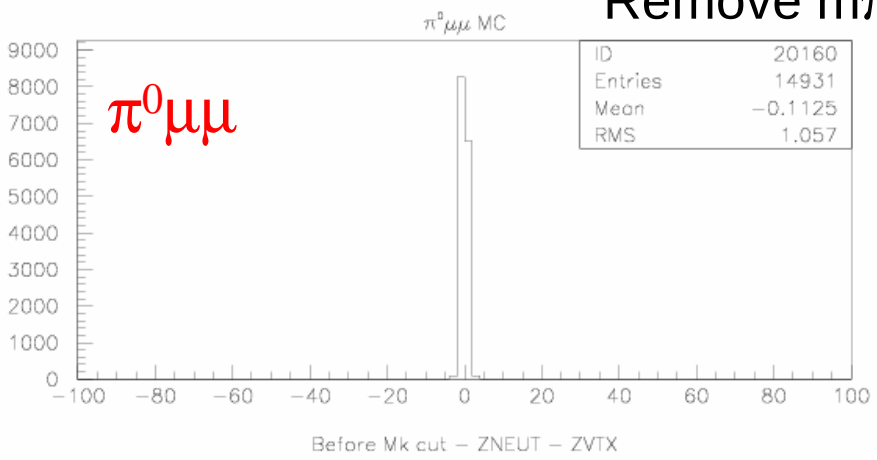


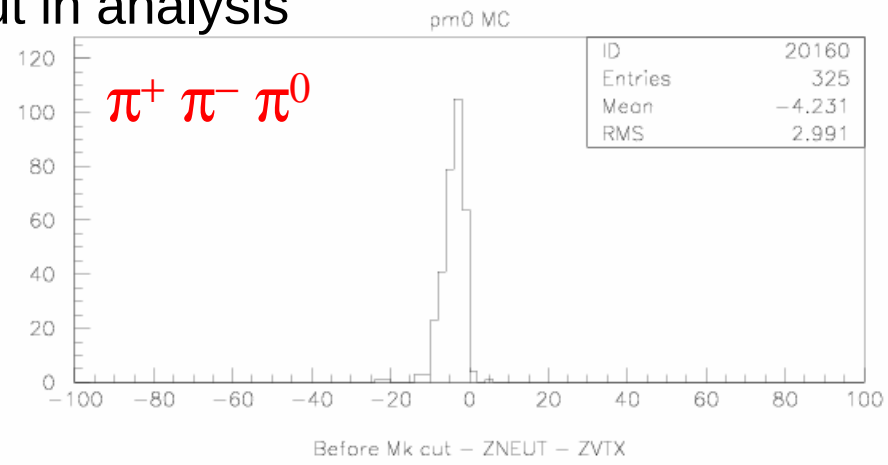


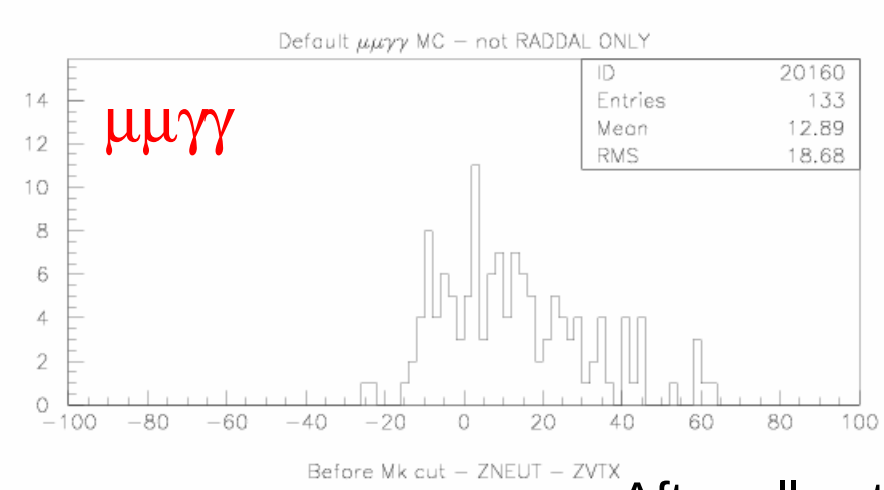


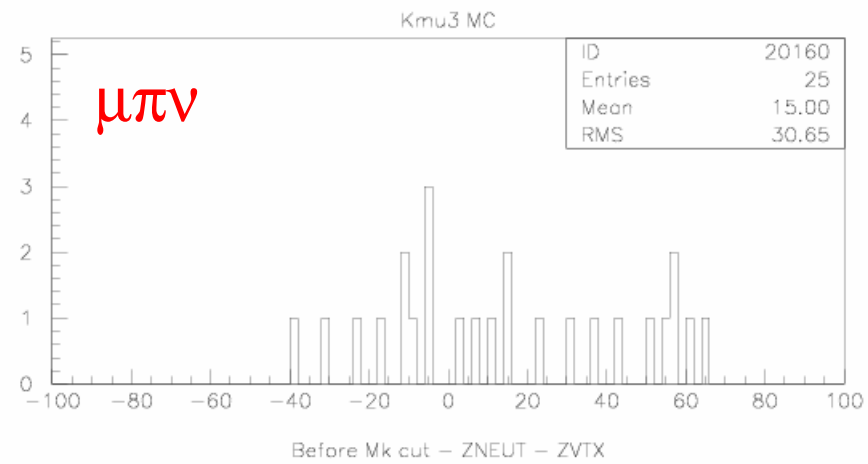
MC zneut-zchg: After all cuts

Remove $m\pi^0$ cut in analysis







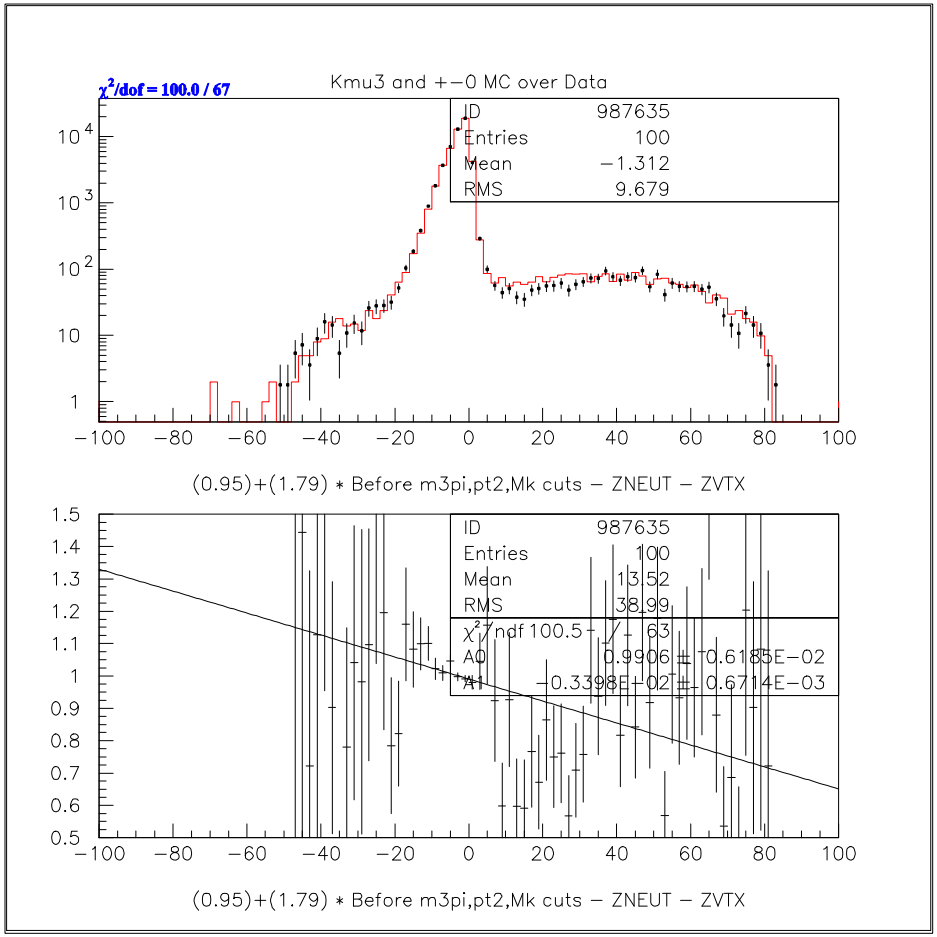


After all cuts except M_K cut

Data/MC Overlay: zneut - zchg

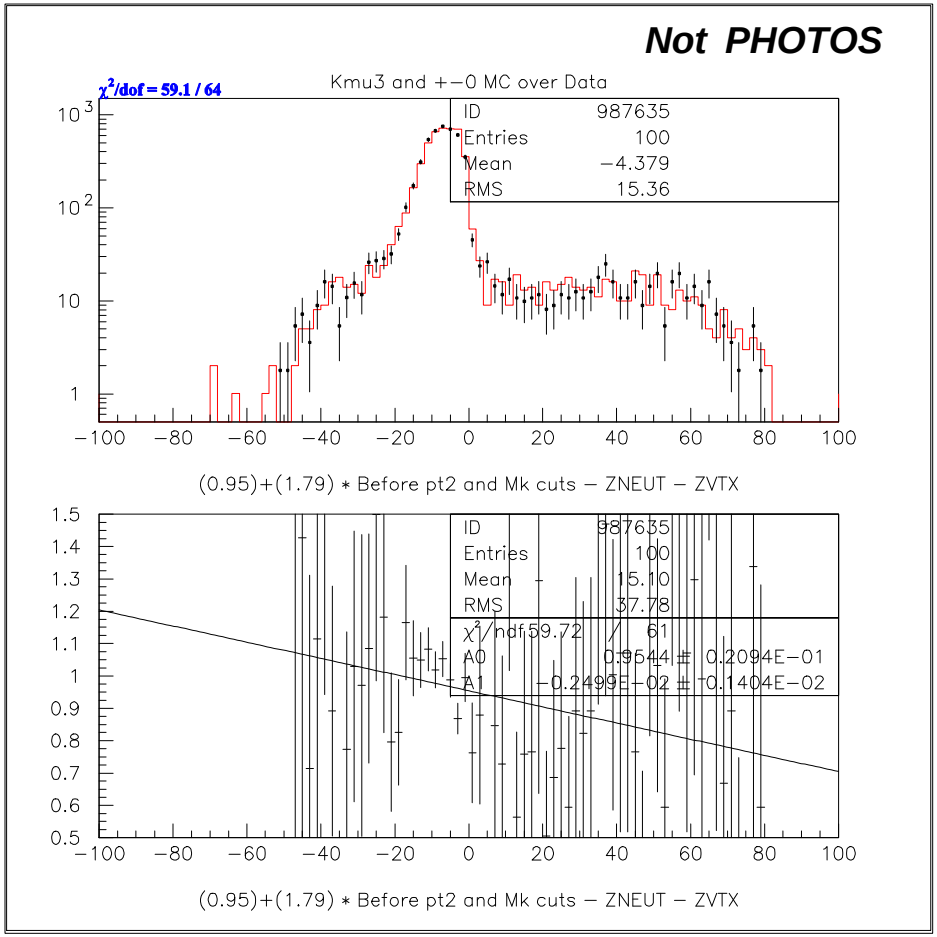
Remove $m\pi^0$ cut in analysis

MC Norm: from inv mass dist



After all cuts except M_{3pi}, pt^2, M_K cut

Not PHOTOS

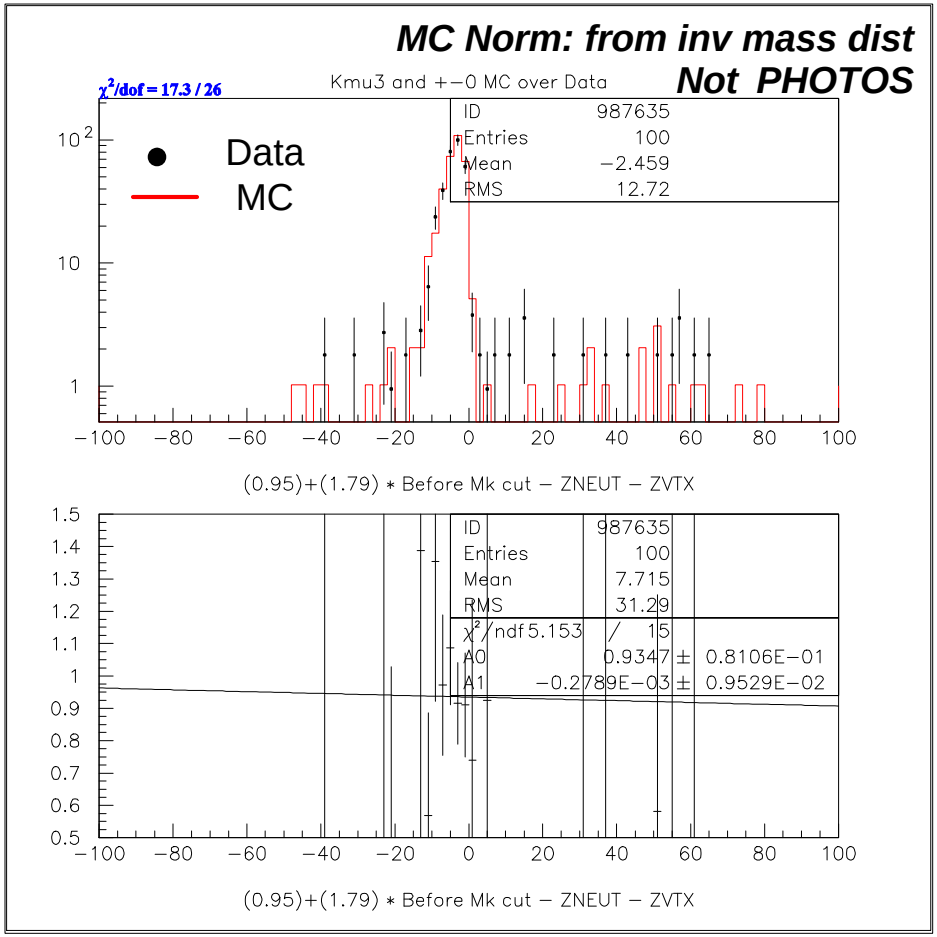


After all cuts except pt^2, M_K cut

Overlay after cuts: zneut - zchg

- Zdiff distribution is well modeled
- Estimate background under peak
  - Estimate background
    - Cut at -2m<zdiff<+2m (+/-2σ signal region)
    - Fit background in asymmetric region (z>10m, z<-20m)
    - Integrate in signal region
  - Need to reduce background
    - Try track quality cuts: dist(zneut – nearest track),
    - Track straightness in y-view
    - Timing X^2 on software clusters

Remove $m\pi^0$ cut in analysis



After all cuts except M_K cut

Plans

- MC reproduces zneut – zchg
- Check shape of MC and data distributions in (zneut – zchg) sidebands
  - pt^2 vs (zneut – zchg)
  - M_K vs (zneut – zchg)
- Binned likelihood in signal box region
- Go through technique to estimate background from data, with MC estimate X-check
  - Currently looks like at least 1-2 events in “box”
  - Would like to reduce background

Current Issues

- Unfortunately, ntuples - did not save fundamental track/CsI info
  - MC Files – kept raw data files
  - MC tally: $\pi^+\pi^-\pi^0$: 2880 files

    kmu3 standard KTeVMC: 3344 files

    kmu3 with PHOTOS: 1424
    - Need to run through ~7650 MC files

    →Copy from enstore and analyze
  - Data Files
    - Reprocess ~60 files – half way through
    - SLOW!
      - Enstore→disk→analyze→copy ntuples to dcache/enstore
      - I've also been having enstore copy problems
    - Would like to store ntuples on dcache, but routines to access files (other than ktev migrated tapes) have not been written