# Level 0 Control Trigger Strategy and Selecting a $K^+ \to \pi^+\pi^0$ Sample

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NA62 Collaboration Meeting, Ferrara

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# Outline

1. Control Sample L0 Trigger Strategy
   - 6 main $K^+$ decay modes in the beam
   - Trigger Primitives
   - 2 minimum bias triggers and downscaling
   - Summary

2. Testing Detector Efficiencies
   - Aims from control samples
   - $K^+ \to \pi^+\pi^0$ **early in the run**
   - $K^+ \to \pi^+\pi^0$ sample uses
   - Summary

# 6 Main Decay Modes

6 largest $K^+$ decay modes are:

$$K^+ \to \mu^+\nu \ (K\mu 2),$$
$$K^+ \to \pi^+\pi^0,$$
$$K^+ \to \pi^+\pi^+\pi^-,$$
$$K^+ \to \pi^0\mu^+\nu \ (K\mu 3),$$
$$K^+ \to \pi^0 e^+\nu \ (Ke3),$$
$$K^+ \to \pi^+\pi^0\pi^0.$$

3 other major components of the beam are:

**Beam Pions** - Pions in the beam and their subsequent decay products,
**Beam Protons** - Protons in the beam,
**Muons Upstream** - Muons originating upstream of GigaTracker 3 (Muon Halo)

# 6 Main Decay Modes

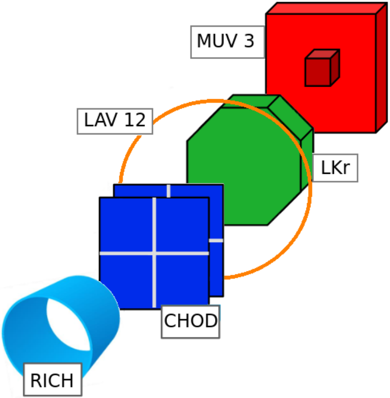
- 750 MHz beam particles
- 45 MHz of $K^+$
- 9 MHz of $K^+$ decays

| | $K\mu 2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu 3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Rate (MHz) | 5.7 | 1.9 | 0.5 | 0.5 | 0.3 | 0.2 | 526 | 173 | 135 | 879 |

- No higher level trigger available for control channels
- Significant downscaling to get $\sim$O(10kHz)
- Downscaling will change with beam intensity during the run

# Available Trigger Primitives

**Triggers Primitives available in 2014**




- **CHOD - Coincidence of hits in two layers of plastic scintillator ($Q_1$ represents 1 coincidence)**
- **LKr** - Energy deposited in a group of liquid krypton cells known as clusters
- RICH - Number of PMTs above threshold
- **MUV3 - Hits above threshold in PMTs**
- LAV12 - Hits above threshold in PMTs

# Trigger Primitives Used

Control Channel triggers must be:

- Minimum bias
- Collect a good sample of 6 main $K^+$ decay modes
- Implemented in the October 2014 run

All 6 decay modes posses at least 1 charged track.

1 track trigger $\rightarrow$ CHOD, Q1 primitive.

Remove events with muons,

No muon trigger $\rightarrow$ MUV3, !MUV3 primitive.

# Simulation Outline

For the 6 main decays + Beam Pions + Beam Protons used Monte Carlo files available on castor.
Simulated the Muons Upstream sample.

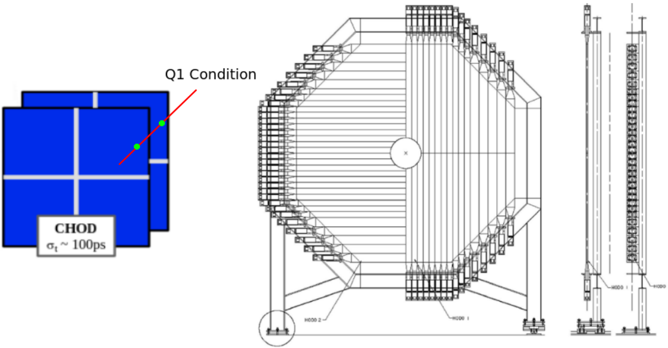
$K^+ \to \mu^+\nu$ ($K\mu2$) - 100,000
$K^+ \to \pi^+\pi^0$ - 10,000
$K^+ \to \pi^+\pi^+\pi^+$ - 10,000
$K^+ \to \pi^0\mu^+\nu$ ($K\mu3$) - 10,000
$K^+ \to \pi^0 e^+\nu$ ($Ke3$) - 10,000
$K^+ \to \pi^+\pi^0\pi^0$ - 10,000

**Beam Pions** - 1 Million
**Beam Protons** - 1 Million
**Muons Upstream** - 135,342

NA62MC version 304
NA62Reconstruction version 309

# CHOD Q1 Primitive

Q1 Primitive allows us to trigger on at least 1 charged track




Coincidence of hits in the same quadrant in the front and back planes is the Q1 condition

Require at least 1 Q1 condition to trigger on the event. **1 track condition**

# Q1 Trigger Rate

| | $K\mu2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Rate (MHz) | 5.7 | 1.9 | 0.5 | 0.5 | 0.3 | 0.2 | 526 | 173 | 135 | 879 |
| Q1 (KHz) | 4153 | 1766 | 466 | 271 | 408 | 156 | 3629 | 692 | 3335 | 14877 |

Left with a total rate of $\sim$ 15,000 KHz.

To achieve 5 KHz downscaling of 3000.

How many $K^+ \to \pi^+\pi^0$ decays can we hope to collect in 1 day of data taking?

# Q1 Trigger Rate

What rate of decays are in detector acceptances (In Acc)?

- Charged Particles are within acceptance of 4 straw planes
- Photons from $\pi^0$ are within LKr Acceptance

| | $K\mu2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
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| In Acc | 1933 | 528 | 72 | 70 | 84 | 18 | | | | 2707 |

# Q1 Trigger Downscaling

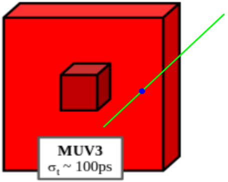
- 528 KHz of $K^+ \to \pi^+\pi^0$ decays in detector acceptance
- Downscaling of 3000

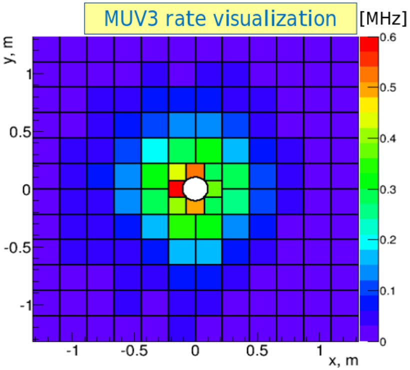
- 0.2 KHz of potentially usable $K^+ \to \pi^+\pi^0$ decays
- Assuming data taking 30% of the time
- 5 Million decays collected per day

# !MUV3 Primitive

Q1 trigger rates dominated by decays containing muons (*Kmu*2, Muons Upstream, Beam Pions)

!MUV3 primitive asks for **NO hits above threshold** in the MUV3 PMTs.



# Q1 and !MUV3 Trigger Rate

| | $K\mu 2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu 3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
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| Q1 (KHz) | 4153 | 1766 | 466 | 271 | 408 | 156 | 3629 | 692 | 3335 | 14877 |
| Q1 x !MUV3 (KHz) | 43 | 1603 | 372 | 43 | 392 | 139 | 1052 | 657 | 176 | 4505 |

Left with a total rate of $\sim$ 4,500 KHz.

To achieve 5 KHz downscaling of 900.

How many $K^+ \rightarrow \pi^+\pi^0$ decays can we hope to collect in 1 day of data taking?

# Q1 and !MUV3 Trigger Rate

Applying the same definition for acceptance as previously, i.e charged particles within straw acceptance $\pi^0$ photons within LKr acceptance.

| | $K\mu2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Rate (MHz) | 5.7 | 1.9 | 0.5 | 0.5 | 0.3 | 0.2 | 526 | 173 | 135 | 879 |
| Q1 (KHz) | 4153 | 1766 | 466 | 271 | 408 | 156 | 3629 | 692 | 3335 | 14877 |
| Q1 x !MUV3 (KHz) | 43 | 1603 | 372 | 43 | 392 | 139 | 1052 | 657 | 176 | 4505 |
| In Acc | 7 | 486 | 54 | 7 | 84 | 7 | | | | 670 |

# Q1 x !MUV3 Trigger Downscaling

- 486 KHz of $K^+ \to \pi^+\pi^0$ decays in detector acceptance
- Downscaling of 900

- 0.5 KHz of potentially usable $K^+ \to \pi^+\pi^0$ decays
- Assuming data taking 30% of the time
- 13 Million decays collected per day

# Summary of Trigger Studies

- **2 Minimum bias triggers for October 2014 run, Q1 and (Q1 x !MUV3)**

| | $K\mu 2$ | $\pi^+\pi^0$ | $\pi^+\pi^+\pi^-$ | $K\mu 3$ | $Ke3$ | $\pi^+\pi^0\pi^0$ | Pions | Protons | Muons | Total |
|---|---|---|---|---|---|---|---|---|---|---|
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| Q1 x !MUV3 (KHz) | 43 | 1603 | 372 | 43 | 392 | 139 | 1052 | 657 | 176 | 4505 |

- Significant downscaling is required due to no higher level triggers
- Can write data to the pc farm at a rate of $\sim$ 10 KHz
- $K^+ \rightarrow \pi^+\pi^0$ per day (within detector acceptances):
  - 1 Million $\rightarrow$ Q1 trigger
  - 3 Million $\rightarrow$ (Q1 x !MUV3) trigger

# Outline

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2. **Testing Detector Efficiencies**
   - Aims from control samples
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# Aims of control sample data

Want to analyse any data obtained from the control samples.

- Efficiency measurements of sub-detectors
- Time resoloution of sub-detectors
- Time correlation between sub detectors

Want to do this analysis during the 2014 run.

**CHOD - one control sample trigger (Q1)**

**LKr - reconstruct the $K^+ \to \pi^+\pi^0$ decay**

# Aims of control sample data

**Aim**

- **Reconstruct a sample of $K^+ \to \pi^+\pi^0$ using only LKr**
- **Demonstrate the sample contains $< 1\%$ Background**
- **Reconstructed $\pi^+$ can be used for detector commissioning**

# Reconstructing $K^+ \to \pi^+\pi^0$ using the LKr

The following selection cuts are based on a previous study of $K^+ \to \pi^+\pi^0$ done using 2012 TR data. **G.Ruggiero Physics Working Group Meeting June 2013**

Based on a sample of 6,466 $K^+ \to \pi^+\pi^0$ events (Q1 trigger on 10,000 events)

Selection can be sub-divided as follows

- **Identifying Photon candidates from LKr clusters**
- **Reconstructing the $\pi^0$ from the photon candidates**
- **Reconstructing the $\pi^+$ assuming a nominal $K^+$ beam**

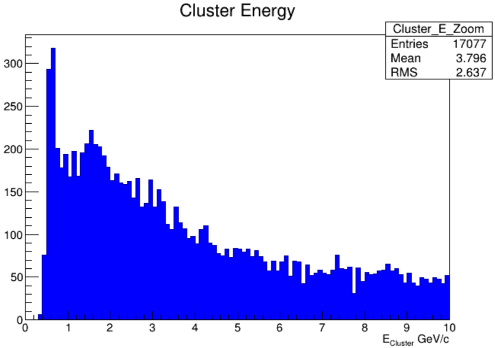
# Identifying Photon candidates from LKr clusters

Apply the following selection cuts

- **Cluster energy $>$ 3 Gev**
- Cuts on the energy distribution within the cluster
- Distance from any dead cell $>$ 2cm
- At least two clusters within $\pm$ 1.5 ns
- Distance between clusters $>$ 20cm

# Cluster energy > 3 Gev

- Place a 3 GeV cut on the energy of cluster deposits
- Rejects MIPs at 0.5 Gev/c




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| >= 2 Clusters | 5479 | 17077 |
| $E > 3$ | 4475 | 11396 |

# Identifying Photon candidates from LKr clusters

Apply the following selection cuts

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- **Cuts on the energy distribution within the cluster**
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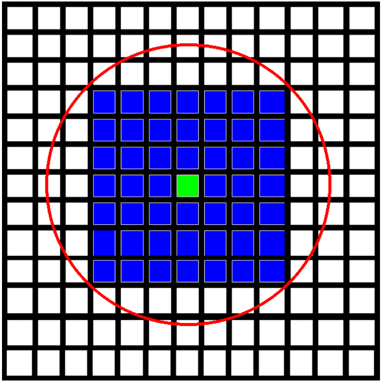
# Cuts on the energy distribution within the cluster



**Cell size $\sim$ 2cm x 2cm**

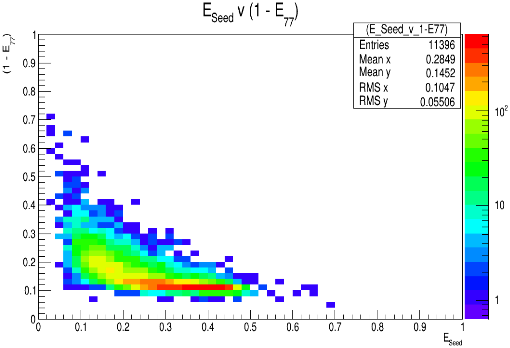
- $E_{Cluster}$ is the energy contained within the full cluster of **radius 11cm**
- $E_{Seed}$ is the energy contained within the cell at the centre of the cluster
- $E_{77}$ is the energy contained in the 49 central cells

# Cuts on the energy distribution within the cluster

- Identify clusters as 'photon like' by placing the following cuts on $E_{seed}$ and $1 - E_{77}$

$$\mathbf{0.2} < E_{seed} < \mathbf{0.45}$$

$$\mathbf{0.03} < 1 - E_{77} < \mathbf{0.14}$$

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| *E Cuts* | 2348 | 5074 |

# Identifying Photon candidates from LKr clusters

Apply the following selection cuts

- Cluster energy $>$ 3 Gevt
- **Distance from any dead cell $>$ 2cm**

  Rejects poorly reconstructed clusters
- At least two clusters within $\pm$ 1.5 ns
- Distance between clusters $>$ 20cm

# Identifying Photon candidates from LKr clusters

Apply the following selection cuts

- Cluster energy $>$ 3 Gev
- Cuts on the energy distribution within the cluster
- Distance from any dead cell $>$ 2cm
- **At least two clusters within $\pm$ 1.5 ns**

  No meaningful effect in MC
- Distance between clusters $>$ 20cm

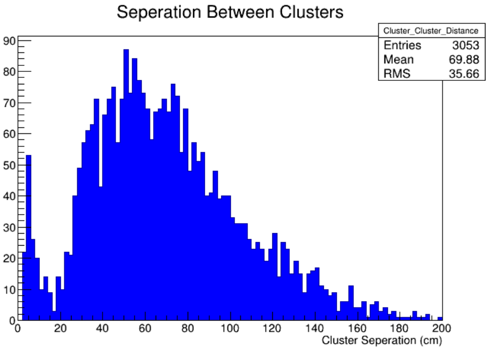
# Identifying Photon candidates from LKr clusters

Apply the following selection cuts

- Cluster energy $>$ 3 Gev
- Cuts on the energy distribution within the cluster
- Distance from any dead cell $>$ 2cm
- At least two clusters within $\pm$ 1.5 ns
- **Distance between clusters $>$ 20cm**

# Distance between clusters > 20cm

- Require that any cluster center is > 20cm from any other cluster center

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| $E > 3$ | 4475 | 11396 |
| $E$ *Cuts* | 2348 | 5074 |
| Dead Cell | 2272 | 4910 |
| Cluster Time | 2272 | 4908 |
| **Cluster Seperation** | **2144** | **4535** |

# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- **Calculated Z vertex must satisfy 105 $<$ Z $<$ 180m**

$$Z_{Vertex} = Z_{LKr} - \frac{\sqrt{E_1 E_2 d_{12}^2}}{m_{\pi^0}}$$

- X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X
- Calculate Photon momentum using Vertex position and cluster energy deposition
- $\pi^0$ 4-momentum calculated by summing the photon 4-momenta
- Events with only 1 candidate $\pi^0$ with 10 $<$ E $<$ 65 GeV/c considered

# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- Calculated Z vertex must satisfy $105 < Z < 180$m
- **X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X**

  No deflection in y
  1.2mrad deflection in x from TRIM5

- Calculate candidate photon momentum using Vertex position and cluster energy deposition
- $\pi^0$ 4-momentum calculated by summing the photon 4-momenta
- Events with only 1 candidate $\pi^0$ with $10 < E < 65$ GeV/c considered

# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- Calculated Z vertex must satisfy $105 < Z < 180$m
- X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X
- **Calculate candidate photon momentum using Vertex position and cluster energy deposition**

$$|P_\gamma| = E_\gamma = E_{Cluster}$$

$\overrightarrow{P}$ set from $Cluster_{XYZ}$ - $Vertex_{XYZ}$

- $\pi^0$ 4-momentum calculated by summing the photon 4-momenta
- Events with only 1 candidate $\pi^0$ with $10 < E < 65$ GeV/c considered

# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- Calculated Z vertex must satisfy $105 < Z < 180$m
- X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X
- Calculate Photon momentum using Vertex position and cluster energy deposition
- $\pi^0$ **4-momentum calculated by summing the photon 4-momenta**

$$P_{\pi^0} = P_{\gamma 1} + P_{\gamma 2}$$

- Events with only 1 candidate $\pi^0$ with $10 < E < 65$ GeV/c considered

# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- Calculated Z vertex must satisfy $105 < Z < 180$m
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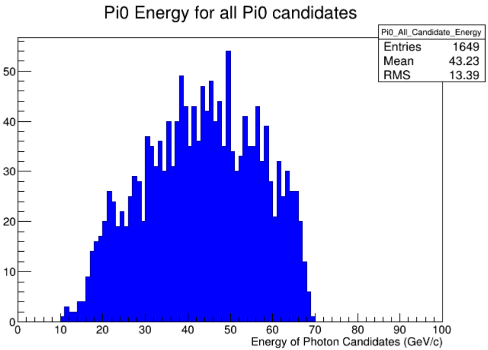
- **10** $< E_{\pi^0} <$ **65 GeV/c**
- Events with only 1 $\pi^0$ candidate considered

# $10 < E_{\pi^0} < 65$ GeV/c

- $10 < E_{\pi^0} < 65$ GeV/c




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| >= 2 Clusters | 5479 | 17077 |
| **LKr Selection** | **2144** | **4535** |
| | Events | $\pi^0$ Candidates |
| Z Vertex | 1476 | 1649 |
| Energy | 1411 | 1584 |

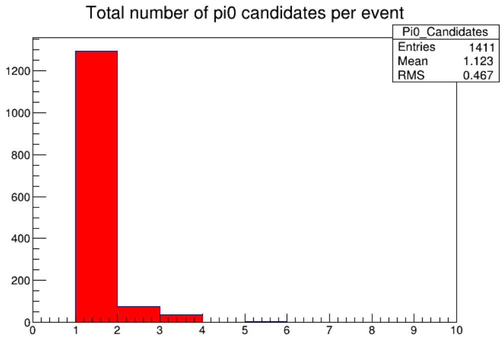
# Reconstructing the $\pi^0$ from photon candidates

Reconstruct the $\pi^0$ requiring

- Calculated Z vertex must satisfy $105 < Z < 180$m
- X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X
- Calculate Photon momentum using Vertex position and cluster energy deposition
- $\pi^0$ 4-momentum calculated by summing the photon 4-momenta
- $10 < E_{\pi^0} < 65$ GeV/c
- **Events with only 1 $\pi^0$ candidate considered**

# Events with only 1 $\pi^0$ candidate considered

- Require exactly 1 $\pi^0$ candidate per event

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| Z Vertex | 1476 | 1649 |
| Energy | 1411 | 1584 |
| 1 $\pi^0$ | 1294 | 1294 |

# Reconstructing the $\pi^+$

Reconstruct the $\pi^+$ requiring

- **Assume nominal parameters for the $K^+$**

  $$|P_{K^+}| = 75\ \text{GeV}/c^2$$

  $\overrightarrow{P_{K^+}}$ Mainly along z with small component in x

- $P_{\pi^+} = P_{K^+} - P_{\pi^0}$
- $\pi^+$ must be in CHOD and LKr acceptance
- Plot $P^2_{\pi^+}$

# Reconstructing the $\pi^+$

Reconstruct the $\pi^+$ requiring

- Assume nominal parameters for the $K^+$
- $P_{\pi^+} = P_{K^+} - P_{\pi^0}$
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# Reconstructing the $\pi^+$

Reconstruct the $\pi^+$ requiring

- Assume nominal parameters for the $K^+$
- $P_{\pi^+} = P_{K^+} - P_{\pi^0}$
- $\pi^+$ **must be in CHOD and LKr acceptance**

  Pre Acceptance 1294 events

  Post Acceptance 1074 events
- Plot $P^2_{\pi^+}$

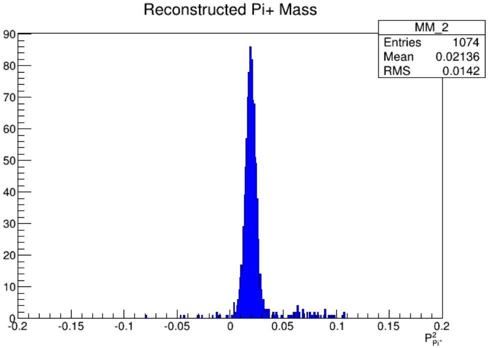
# Reconstructing the $\pi^+$

Reconstruct the $\pi^+$ requiring

- Assume nominal parameters for the $K^+$
- $P_{\pi^+} = P_{K^+} - P_{\pi^0}$
- $\pi^+$ must be in CHOD and LKr acceptance
- **Plot** $P^2_{\pi^+}$

# Plot $P^2_{\pi^+}$

- Result of $P^2_{\pi^+}$ should be $m^2_{\pi^+} = 0.0195$ Gev$/c^2$

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| | Events | $\pi^0$ Candidates |
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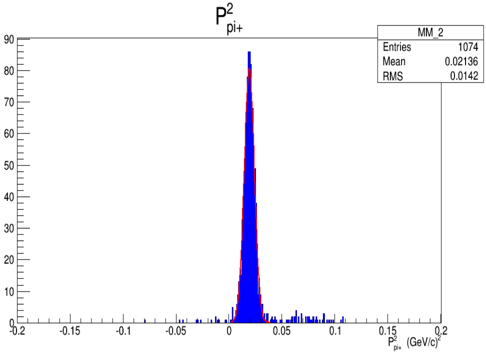
| Z Vertex | 1476 | 1649 |
| Energy | 1411 | 1584 |
| 1 $\pi^0$ | 1294 | |
| 1 $\pi^0$ In Acc | 1074 | |

# Plot $P^2_{\pi^+}$

- $m^2_{\pi^+} = 0.0195\ (GeV/c^2)^2$
- Define a signal region $0 < P^2_{\pi^+} < 0.04\ (GeV/c^2)^2$



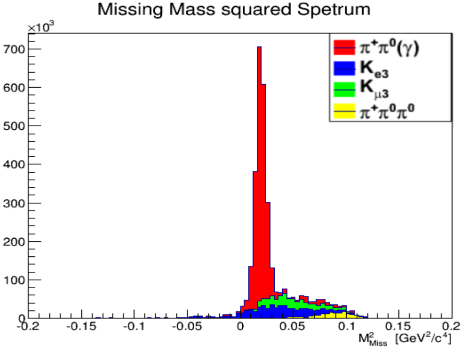

**Fit results - signal region**

$m^2_{\pi^+} = \mathbf{(0.0191 \pm 0.0002)}$

$\sigma(m^2_{\pi^+}) = \mathbf{(0.0048 \pm 0.0001)}$

# Plot $P^2_{\pi^+}$

- $m^2_{\pi^+} = 0.0195\ (GeV/c^2)^2$
- Define a signal region $0 < P^2_{\pi^+} < 0.04\ (GeV/c^2)^2$




Background in signal region $\sim$ 16%

$Ke3 \rightarrow \sim 10\%$

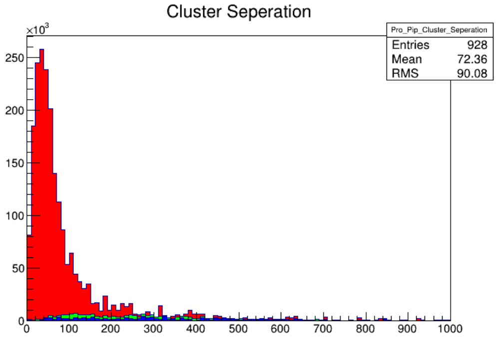
$K\mu3 \rightarrow \sim 5\%$

$\pi^+\pi^0\pi^0 \rightarrow \sim <1\%$

# Reducing the Backgrounds

Around 70% of the time $\pi^+$ will leave a cluster in LKr

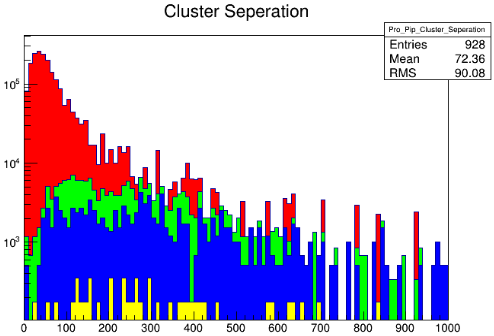
Propagate reconstructed $\pi^+$ up to LKr and look for matching clusters
(Separation $<$ 150mm)



# Reducing the Backgrounds

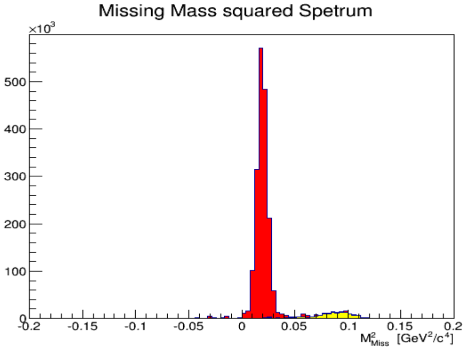
Around 70% of the time $\pi^+$ will leave a cluster in LKr

Propagate reconstructed $\pi^+$ up to LKr and look for matching clusters (Separation $< 150$m)



# Plot $P^2_{\pi^+}$

- $m^2_{\pi^+} = 0.0195\ (GeV/c^2)^2$
- Define a signal region $0 < P^2_{\pi^+} < 0.04\ (GeV/c^2)^2$
- **Ask for $\pi^+$ to have a matching LKr cluster** ($< 150$mm)



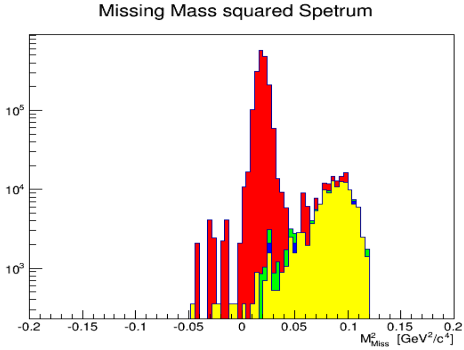

Background in signal region $\sim$ 0.5%

$Ke3 \rightarrow \sim 0.03\%$
$K\mu3 \rightarrow \sim 0.17\%$
$\pi^+\pi^0\pi^0 \rightarrow \sim 0.35\%$

Loss of signal $\sim$ 15%

# Plot $P^2_{\pi^+}$

- $m^2_{\pi^+} = 0.0195\ (GeV/c^2)^2$
- Define a signal region $0 < P^2_{\pi^+} < 0.04\ (GeV/c^2)^2$
- **Ask for $\pi^+$ to have a matching LKr cluster** ($< 150$mm)




Background in signal region $\sim$ 0.5%

$Ke3 \rightarrow \sim 0.03\%$
$K\mu3 \rightarrow \sim 0.17\%$
$\pi^+\pi^0\pi^0 \rightarrow \sim 0.35\%$

Loss of signal $\sim$ 15%

# Reconstructed $K^+ \to \pi^+\pi^0$ Selection Summary

- **Able to select a $K^+ \to \pi^+\pi^0$ sample using only LKr**
- **$<$1% background in signal region**
- **Procedure for doing selection during 2014 run**

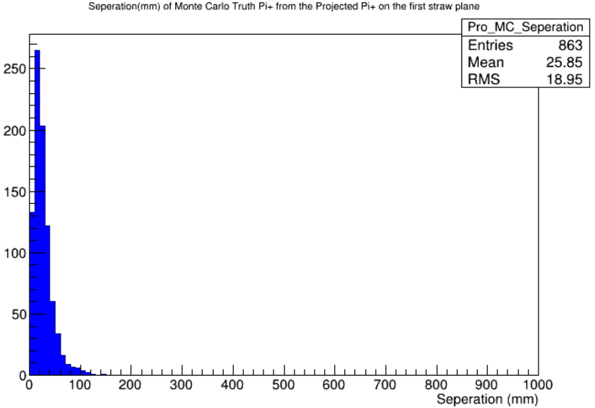
**How large a $K^+ \to \pi^+\pi^0$ sample can we hope to collect in 1 day?**

1. 6,466 pass the Q1 trigger
2. 1,007 (15.6%) pass the Selection cuts

3. Q1 trigger $\to$ expect to collect $\sim$1 Million per day
4. $\sim$ **150,000 $K^+ \to \pi^+\pi^0$ passing the selection per day**

# Using the $K^+ \rightarrow \pi^+\pi^0$ Sample

- **Now have a reconstructed sample of $\pi^+$**
- **Use the reconstructed $\pi^+$ can test sub-detector efficiencies and timings**
- **Example: Resolution of reconstructed $\pi^+$ at the first straw plane**



# Using the $K^+ \to \pi^+\pi^0$ Sample

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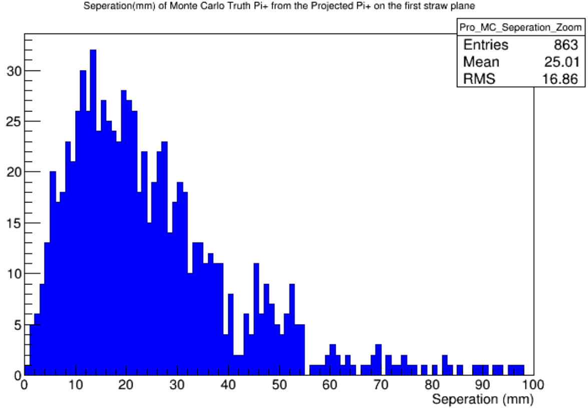


# Summary and Next Steps

- **2 Level 0 Control Triggers have been identified**
- $K^+ \to \pi^+\pi^0$ **Selection using only LKr has been investigated**
- Use $K^+ \to \pi^+\pi^0$ sample **during the run** to aid detector commissioning

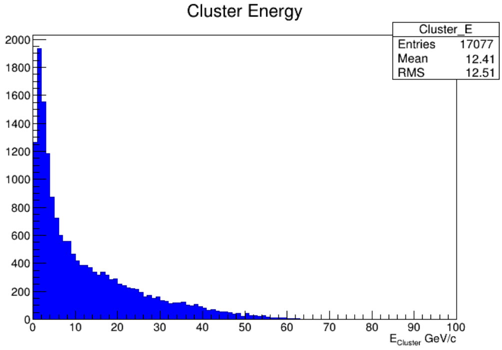
**Next Steps**

- Incorporate magnetic fields into the Vertex calculations
- **Prepare routines for efficiency and timing measurements**
- Look at what other channels will be useful during the 2014 run

# Spares

# Cluster energy > 3 Gev

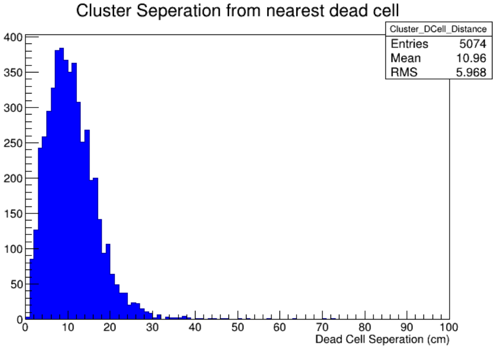
- Place a 3 GeV cut on the energy of cluster deposits.




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| >= 2 Clusters | 5479 | 17077 |
| $E > 3$ | 4475 | 11396 |

# Distance from any dead cell $> 2$cm

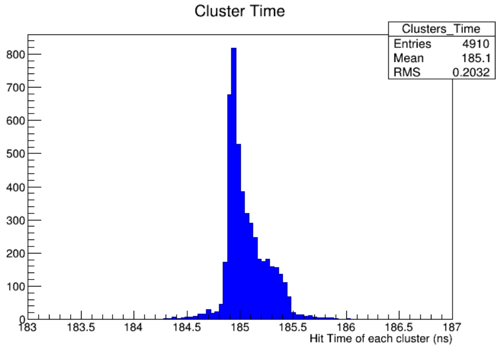
- Require that any cluster center is $>$ 2cm from any dead cell




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| $>=$ 2 Clusters | 5479 | 17077 |
| $E > 3$ | 4475 | 11396 |
| $E$ *Cuts* | 2348 | 5074 |
| Dead Cell | 2272 | 4910 |

# At least two clusters within $\pm$ 1.5 ns

- Must be two clusters within a 1.5ns window




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| $>=$ 2 Clusters | 5479 | 17077 |
| $E > 3$ | 4475 | 11396 |
| $E$ $Cuts$ | 2348 | 5074 |
| Dead Cell | 2272 | 4910 |
| Cluster Time | 2272 | 4908 |

# Calculated Z vertex must satisfy 105 < Z < 180m

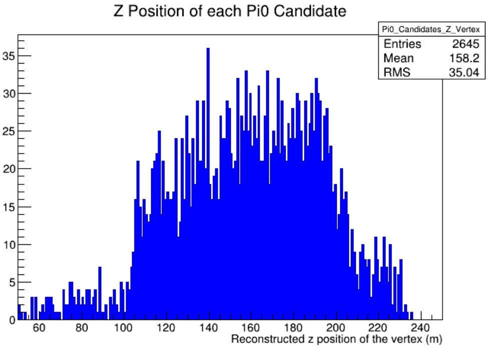
The Z vertex is calculated by assuming the two clusters come from a $\pi^0$ decay.

Also that the decay point of the $\pi^0$ is the decay point of the parent $K^+$

$$Z_{Vertex} = Z_{LKr} - \frac{\sqrt{E_1 E_2 d_{12}^2}}{m_{\pi^0}}$$

# Calculated Z vertex must satisfy 105 $<$ Z $<$ 180m

- Reject $\pi^0$ candidates which are not in the decay volume




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| $>=$ 2 Clusters | 5479 | 17077 |
| **LKr Selection** | **2144** | **4535** |
| | Events | $\pi^0$ Candidates |
| **Z Vertex** | **1476** | **1649** |

# X,Y Vertex co-ordinates assuming 1.2 mrad deflection along X

Ideal beam therefore $K^+$ receives no deflection in Y.

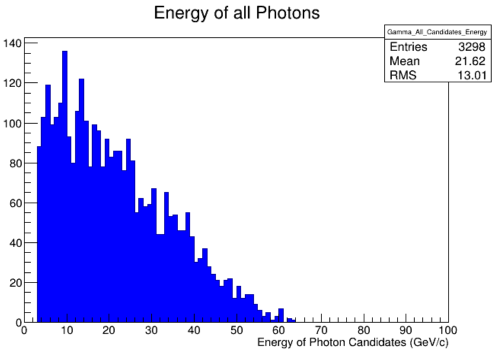
$$Y_{Vertex} = 0$$

$K^+$ receives 1.2mrad deflection along X from the Trim 5 magnet.

$$X_{Vertex} = (Z_{Vertex} - Z_{Trim5}) tan(0.0012)$$

# Calculate Photon momentum using Vertex position and cluster energy deposition

- Photon Momentum direction set by $Cluster_{xyz}$ - $Vertex_{xyz}$
- Photon $|P|$ and E set by cluster energy



## Assume nominal parameters for the $K^+$

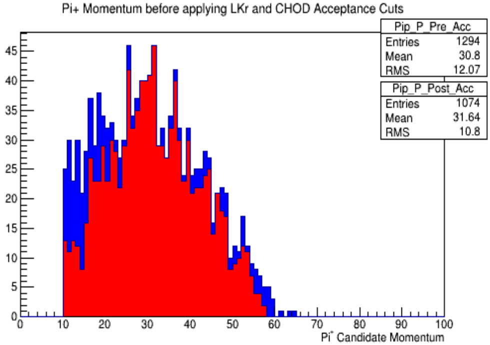
Assume a $|P| = 75$ Gev/c $K^+$.

Momentum is mainly in z direction with an x component corresponding to a 1.2mrad deflection

$$p_k = \begin{pmatrix} \sqrt{75^2 + m_{\pi^+}^2} \\ \\ 75tan(0.0012) \\ \\ 0 \\ \\ 75(1 - tan(0.0012)) \end{pmatrix}$$

# $\pi^+$ must be in CHOD and LKr acceptance

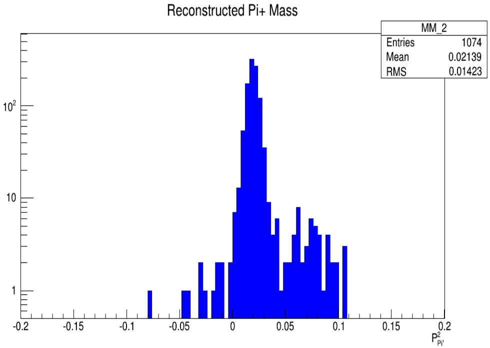
- Require $\pi^+$ is within the CHOD and LKr acceptance
- Important for reconstruction later




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| $>=$ 2 Clusters | 5479 | 17077 |
| **LKr Selection** | **2144** | **4535** |
| | Events | $\pi^0$ Candidates |
| Z Vertex | 1476 | 1649 |
| Energy | 1411 | 1584 |
| 1 $\pi^0$ | 1294 | |
| 1 $\pi^0$ In Acc | 1074 | |

# Plot $P^2_{\pi^+}$

- $m^2_{\pi^+} = 0.0192$ Gev/c




| | Events | Clusters |
|---|---|---|
| Total Events | 6466 | 17854 |
| >= 2 Clusters | 5479 | 17077 |
| **LKr Selection** | **2144** | **4535** |

| | Events | $\pi^0$ Candidates |
|---|---|---|
| Z Vertex | 1476 | 1649 |
| Energy | 1411 | 1584 |
| 1 $\pi^+$ | 1294 | |
| 1 $\pi^+$ In Acc | 1074 | |

# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Began with 6466 Events, end up with 1074 events after the selection (16.6%)

**Issue**

The $m^2_{\pi^+}$ distribution has a 'shoulder'

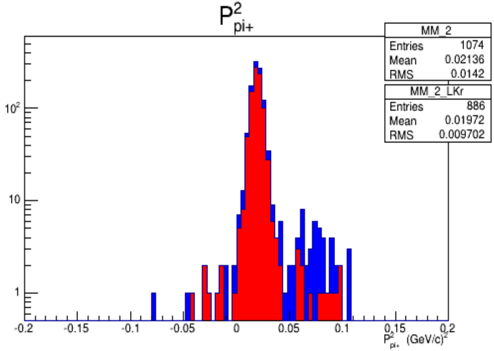
Suspect this is due to a cluster from a $\pi^+$ being incorrectly identified as a $\pi^0$ cluster

**Solution**

Propagate the reconstructed $\pi^+$ up to the Lkr and look for matching clusters

Attempt to match the $\pi^+$ projection to a cluster in the Lkr

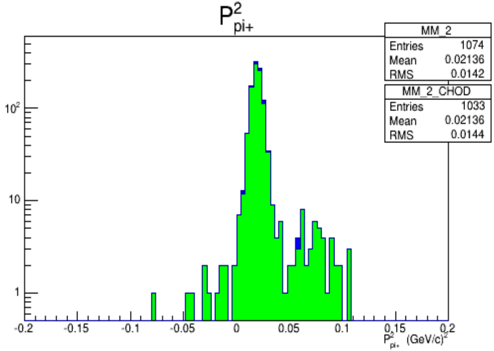
# Understanding the $K^+ \to \pi^+\pi^0$ Selection




Why do 188 events (17.5%) of $\pi^+$ not leave a cluster deposit?
Try Matching the $\pi^+$ to a Q1 condition (More efficient at detecting $\pi^+$)

# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Using Q1 CHOD Matching for the $\pi^+$




Only 41 (3.8%) of events do not have a matching CHOD condition.
Does not seem to remove 'shoulder'

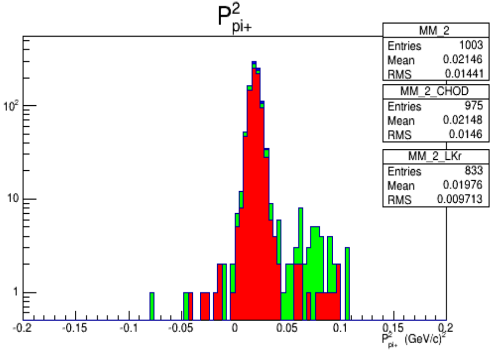
# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Possible Origins of the loss of event when requiring Lkr Cluster (Q1) matching for the $\pi^+$

- **Remove events with muons**
- $\pi^+$ does not reach the LKr(CHOD)
- $\pi^+$ near edges of detector acceptance
- $\pi^+$ undergoes large scattering before the LKr(CHOD)
- The vertex and 4-momentum of the $\pi^+$ is not accurate

# Remove events with muons

Remove events which have any hits above threshold in the MUV3




| | Events | CHOD | LKr |
|---|---|---|---|
| Selection | 1074 | 1033 | 886 |
| !MUV3 | 1003 | 975 | 833 |

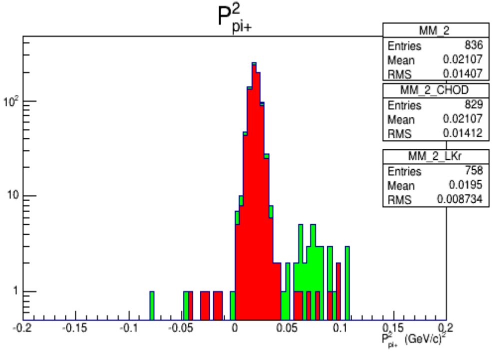
# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Possible Origins of the loss of event when requiring Lkr Cluster (Q1) matching for the $\pi^+$

- Remove events with muons
- $\pi^+$ **does not reach the LKr(CHOD)**
- $\pi^+$ near edges of detector acceptance
- $\pi^+$ undergoes large scattering before the LKr(CHOD)
- The vertex and 4-momentum of the $\pi^+$ is not accurate

# $\pi^+$ does not reach the LKr(CHOD)

Remove events were the $pi^+$ ends before LKr, from MC.




| | Events | CHOD | LKr |
|---|---|---|---|
| Selection | 1074 | 1033 | 886 |
| !MUV3 | 1003 | 975 | 833 |
| $Z > Z_{LKr}$ | 836 | 829 | 758 |

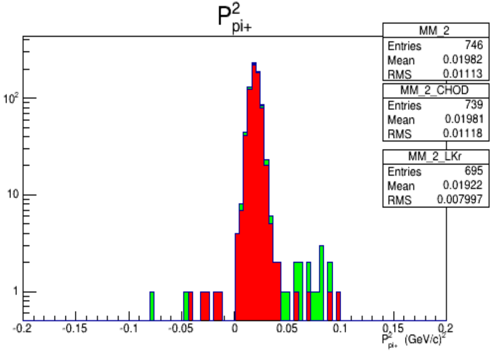
# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Possible Origins of the loss of event when requiring Lkr Cluster (Q1) matching for the $\pi^+$

- Remove events with muons
- $\pi^+$ does not reach the LKr(CHOD)
- $\pi^+$ **near edges of detector acceptance**
- $\pi^+$ undergoes large scattering before the LKr(CHOD)
- The vertex and 4-momentum of the $\pi^+$ is not accurate

# $\pi^+$ near edges of detector acceptance

Reduce the detector acceptance by 10cm on the inner and outer edges of the LKr and CHOD.




| | Events | CHOD | LKr |
|---|---|---|---|
| Selection | 1074 | 1033 | 886 |
| !MUV3 | 1003 | 975 | 833 |
| $Z > Z_{LKr}$ | 836 | 829 | 758 |
| Det Acc | 746 | 739 | 695 |

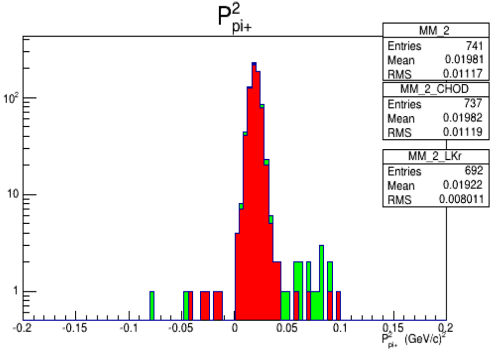
# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Possible Origins of the loss of event when requiring Lkr Cluster (Q1) matching for the $\pi^+$

- Remove events with muons
- $\pi^+$ does not reach the LKr(CHOD)
- $\pi^+$ near edges of detector acceptance
- $\pi^+$ **undergoes large scattering before the LKr(CHOD)**
- The vertex and 4-momentum of the $\pi^+$ is not accurate

# $\pi^+$ undergoes large scattering before the LKr(CHOD)

Remove $\pi^+$ which undergo large scattering.




| | Events | CHOD | LKr |
|---|---|---|---|
| Selection | 1074 | 1033 | 886 |
| !MUV3 | 1003 | 975 | 833 |
| $Z > Z_{LKr}$ | 836 | 829 | 758 |
| Det Acc | 746 | 739 | 695 |
| Scatter | 741 | 737 | 692 |

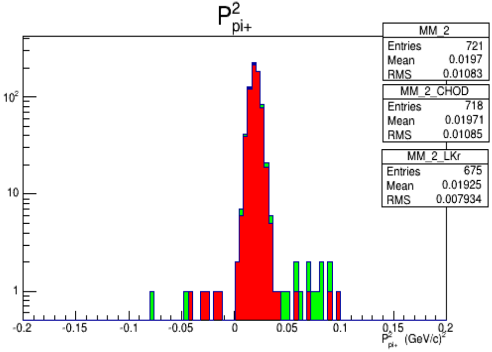
# Understanding the $K^+ \to \pi^+\pi^0$ Selection

Possible Origins of the loss of event when requiring Lkr Cluster (Q1) matching for the $\pi^+$

- Remove events with muons
- $\pi^+$ does not reach the LKr(CHOD)
- $\pi^+$ near edges of detector acceptance
- $\pi^+$ undergoes large scattering before the LKr(CHOD)
- **The vertex and 4-momentum of the $\pi^+$ is not accurate**

# The vertex and 4-momentum of the $\pi^+$ is not accurate

Use the MC Vertex and Momentum for propagating $\pi^+$.




| | Events | CHOD | LKr |
|---|---|---|---|
| Selection | 1074 | 1033 | 886 |
| !MUV3 | 1003 | 975 | 833 |
| $Z > Z_{LKr}$ | 836 | 829 | 758 |
| Det Acc | 746 | 739 | 695 |
| Scatter | 741 | 737 | 692 |
| MC | 721 | 718 | 675 |