

# Experimental Study of $K_{\mu 3\gamma}$ (BNL-E787)

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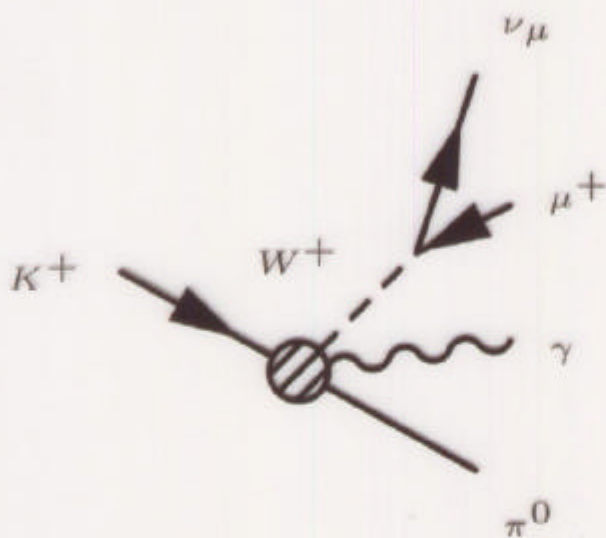
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# Physics motivations

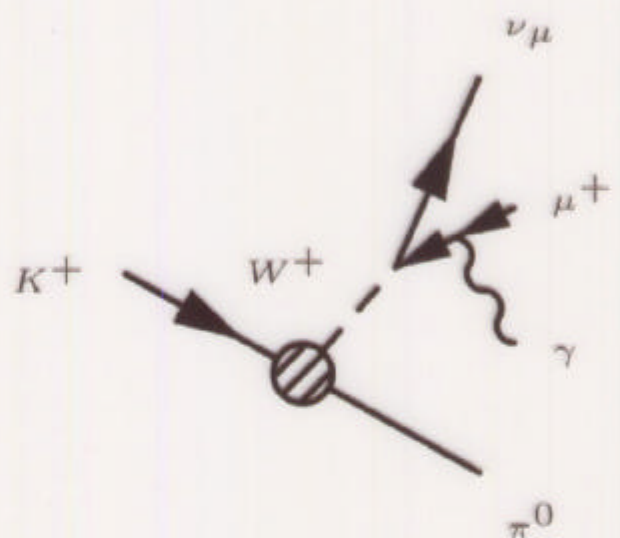
- Chiral Perturbation Theory

QCD effective theory in low energy region  
quark field  $\rightarrow$  pseudoscalar meson field  
(using Only Chiral Symmetry)

Branching ratio is predicted as  $\sim 2.0 \times 10^{-5}$   
( $E_\gamma > 30 \text{ MeV}, \theta_{\mu\gamma} > 20^\circ$ )



Structure Dependent



Internal Bremsstrahlung

- T-violation

asymmetry of  $P_\pi \cdot (P_\mu \times P_\gamma)$

# Experimental Status

Previous exp. @ Argonne National Laboratory  
(PR D8 1307(1973))

No events were observed. :

$$BR < 6.1 \times 10^{-5} (CL = 90\%)$$

**No observation yet!**

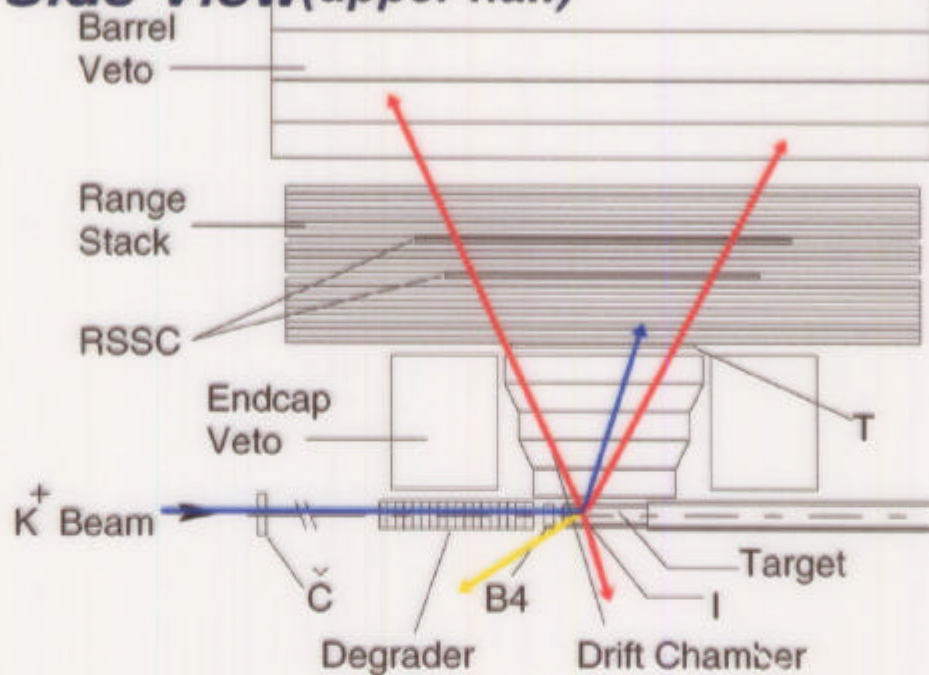
Other  $K_{l3\gamma}$  decays are already measured...

- $K_{e3\gamma}^+$  ...  $(2.62 \pm 0.20) \times 10^{-4}$
- $K_{e3\gamma}^0$  ...  $(3.62^{+0.26}_{-0.21}) \times 10^{-3}$
- $K_{\mu3\gamma}^0$  ...  $(5.7^{+0.6}_{-0.7}) \times 10^{-4}$

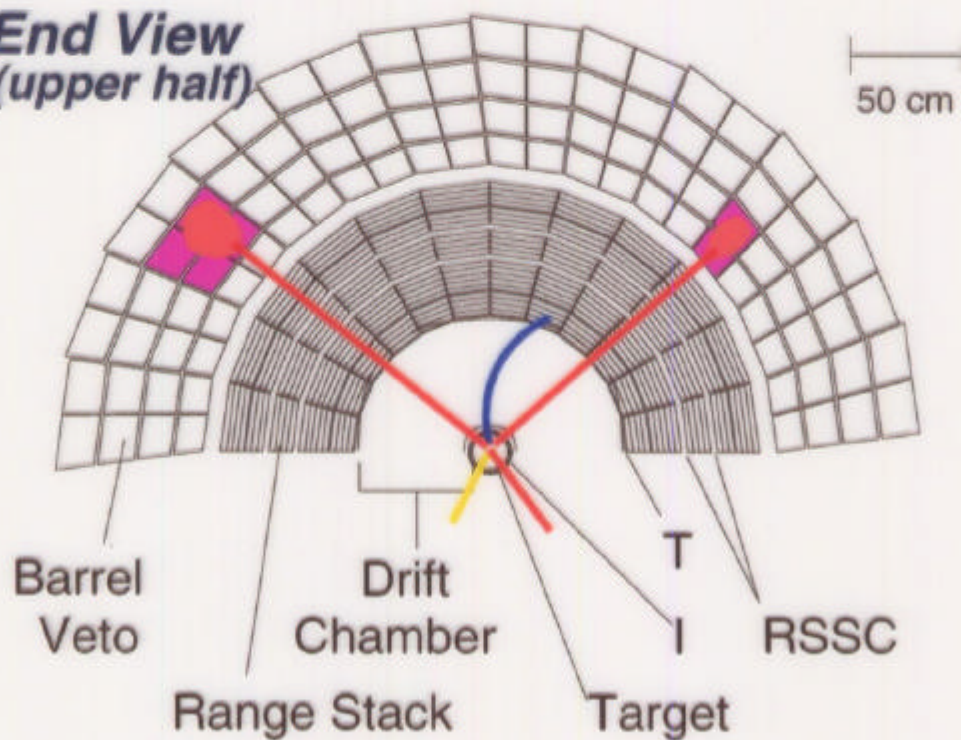
**Structure Dependent Term: NOT MEASURED!**

# Detection Method

## Side View (upper half)



## End View (upper half)



# Trigger

'98 3gamma trigger  $\equiv$

$$\frac{KB \cdot DC \cdot T\bullet 2 \cdot (3_{ct} + 4_{ct}) \cdot \overline{(7_{ct} + 8_{ct})}}{(9 + \dots + 21) \cdot \overline{EC} \cdot HEX \cdot NG3}$$

- KB ... Kaon Beam
- DC ... Delayed Coincidence
- T•2 ... charged track from stopped  $K^+$
- $n$  ... hit in Range Stack
- $n_{ct}$  ... charged track hit in Range Stack
- EC ... Endcap Veto
- HEX ... RangeStack Photon veto
- NG3 ... # of clusters in Barrel-Veto  $\geq 3$

## Features:

**Inner Layer of RS  $\Rightarrow$  Low momentum**

**$\gamma$  detector  $\Leftarrow$  BV only**

# 98-Gamma3 PASS1 Summary

- Data Set: DLT \* 35
- Number of KB\_LIVE:  $2.001 \times 10^{12}$   
(1.4 times larger than that of '95)
- Data Reduction:  
1TB  $\rightarrow$  368GB(36.4%)(DLT\*13)

| Cuts   | —       | reduction |
|--------|---------|-----------|
| INPUT  | 9625377 | —         |
| TRBIT  | 9625375 | 1.0000    |
| RD_TRK | 9624906 | 1.0000    |
| TRKTIM | 9531784 | 1.0098    |
| UTC    | 8396973 | 1.1351    |
| RDUTM  | 8229728 | 1.0203    |
| PDC    | 7671854 | 1.0727    |
| LAY14  | 7671599 | 1.0000    |
| TOTAL  | 7671599 | 1.2547    |

# MC

- UMC(EGS-based MC customized for E787)
- customized for  $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma$

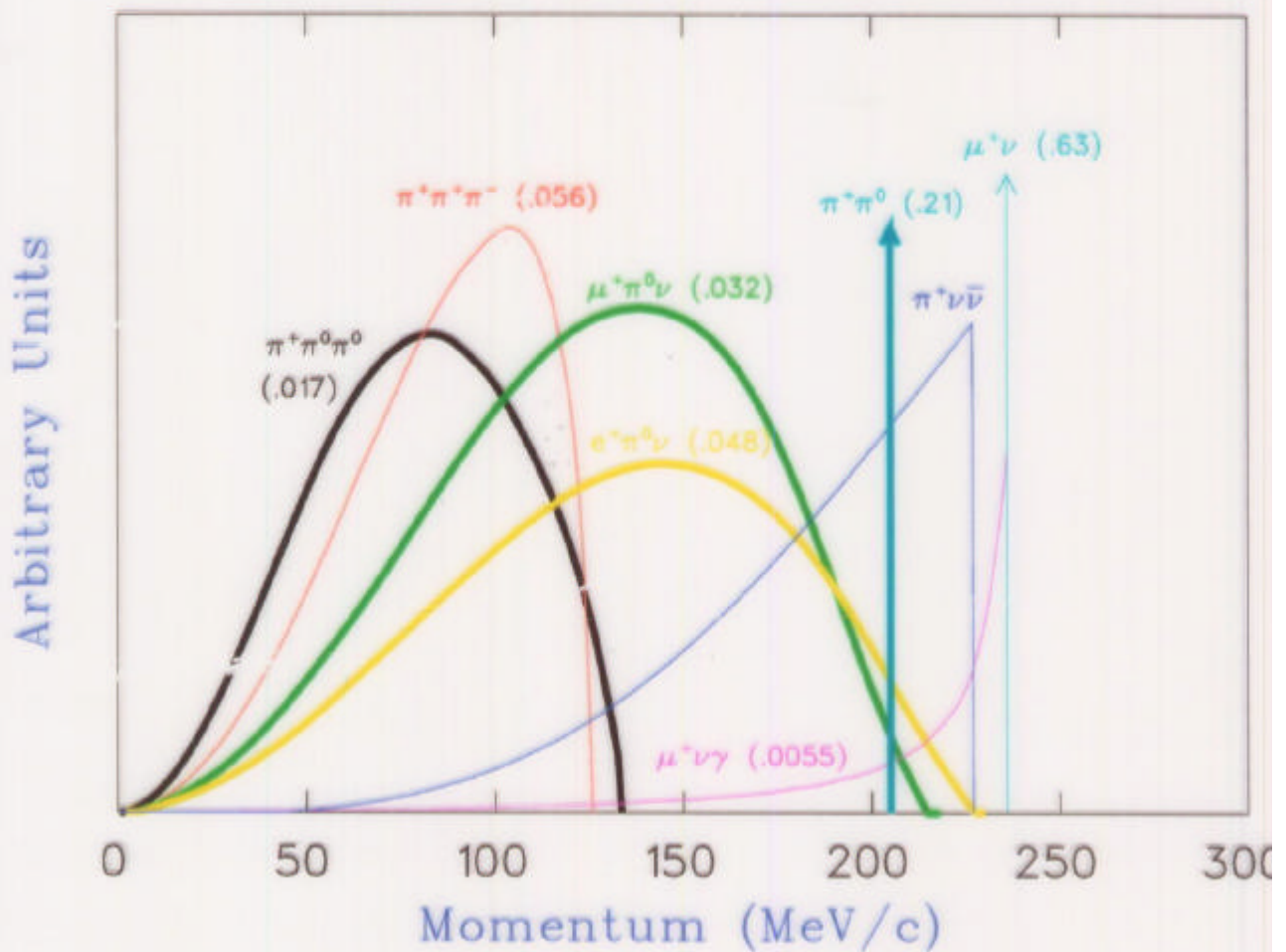
| $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma$ |        |                 |
|--|--------|-----------------|
| Trigger                                      | Events | total reduction |
| KB   | 599945 | —               |
| TDOT2  | 172734 | 0.28792         |
| DC   | 172734 | 0.28792         |
| $3_{ct} + 4_{ct}$                            | 152631 | 0.25441         |
| $7_{ct} + 8_{ct}$                            | 83336  | 0.13891         |
| $9 + \dots + 21$                             | 15184  | 0.02531         |
| Endcap Veto                                  | 4675   | 0.00779         |
| Hextant Veto                                 | 4260   | 0.00710         |
| NG3  | 318    | 0.00053         |

## Expected signal

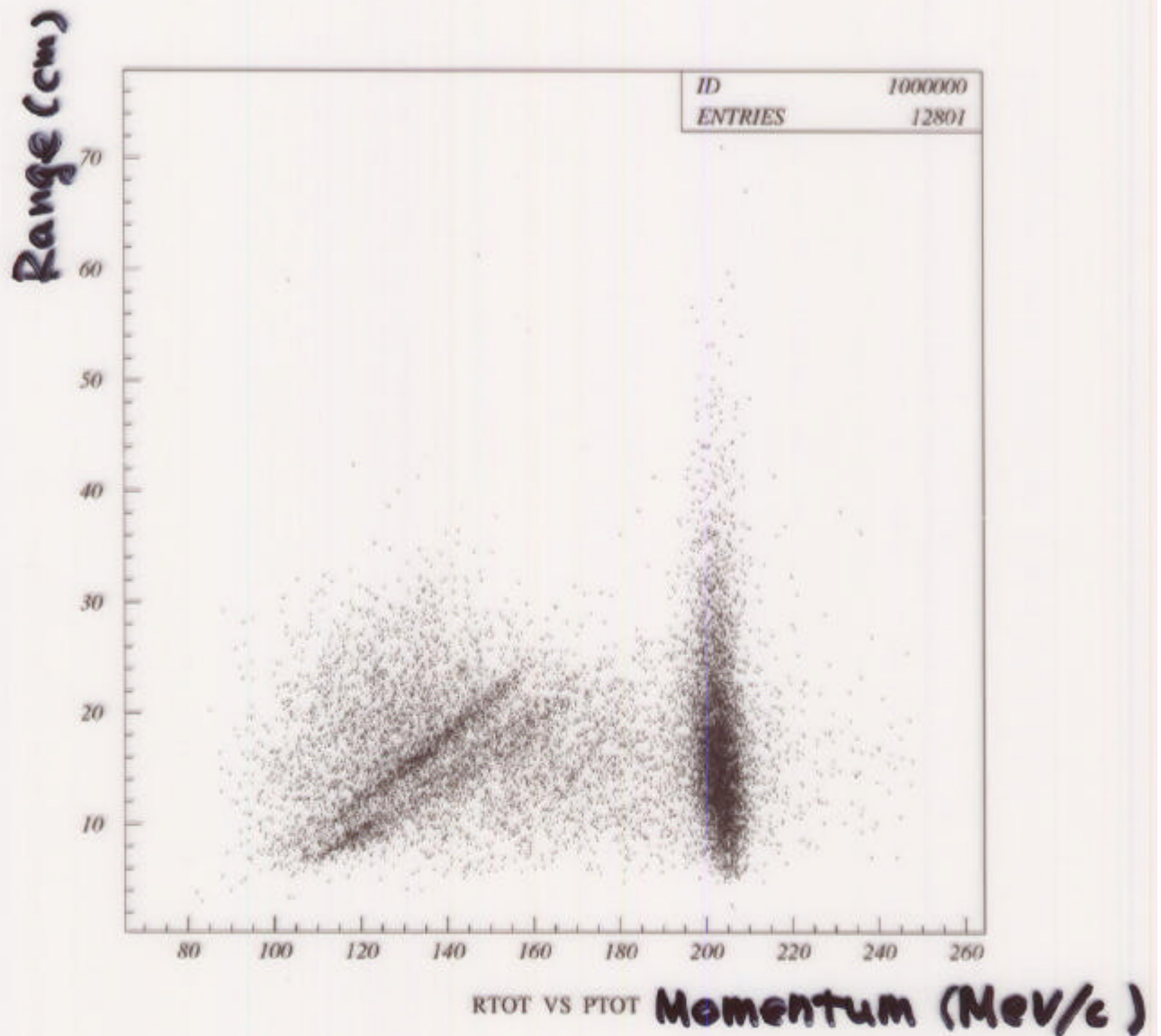
$KB \cdot Prescale(1/5) \cdot BR \cdot Acceptance \sim \underline{4K \text{ events}}$

# Backgrounds

- $\pi^0 \mu^+ \nu_\mu$  +accidental
- $\pi^0 e^+ \nu_e$  +accidental
- $\pi^+ \pi^0 \pi^0$  +missing/overlapping photon
- $\pi^+ \pi^0$  +accidental



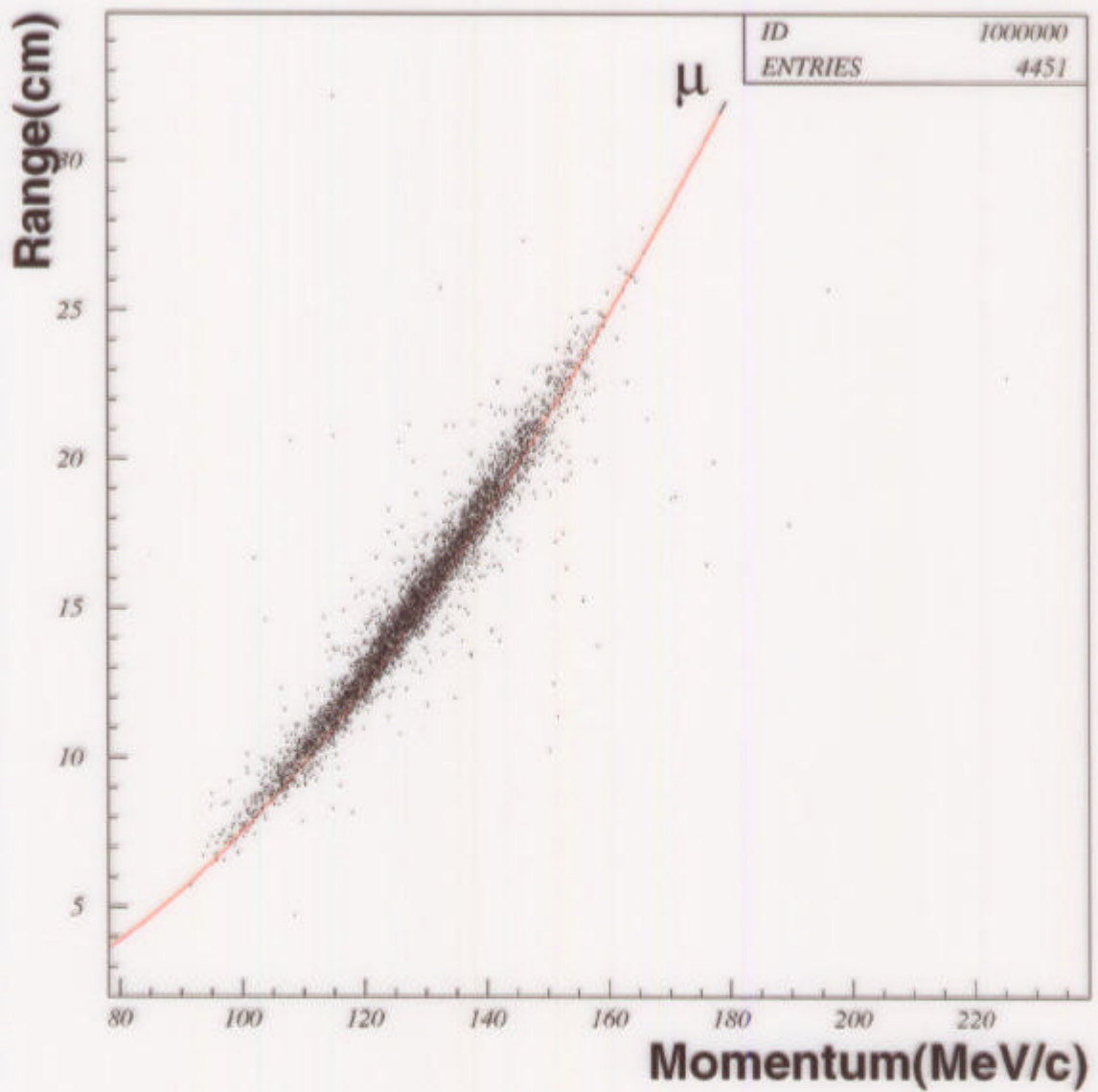
# Event Sample



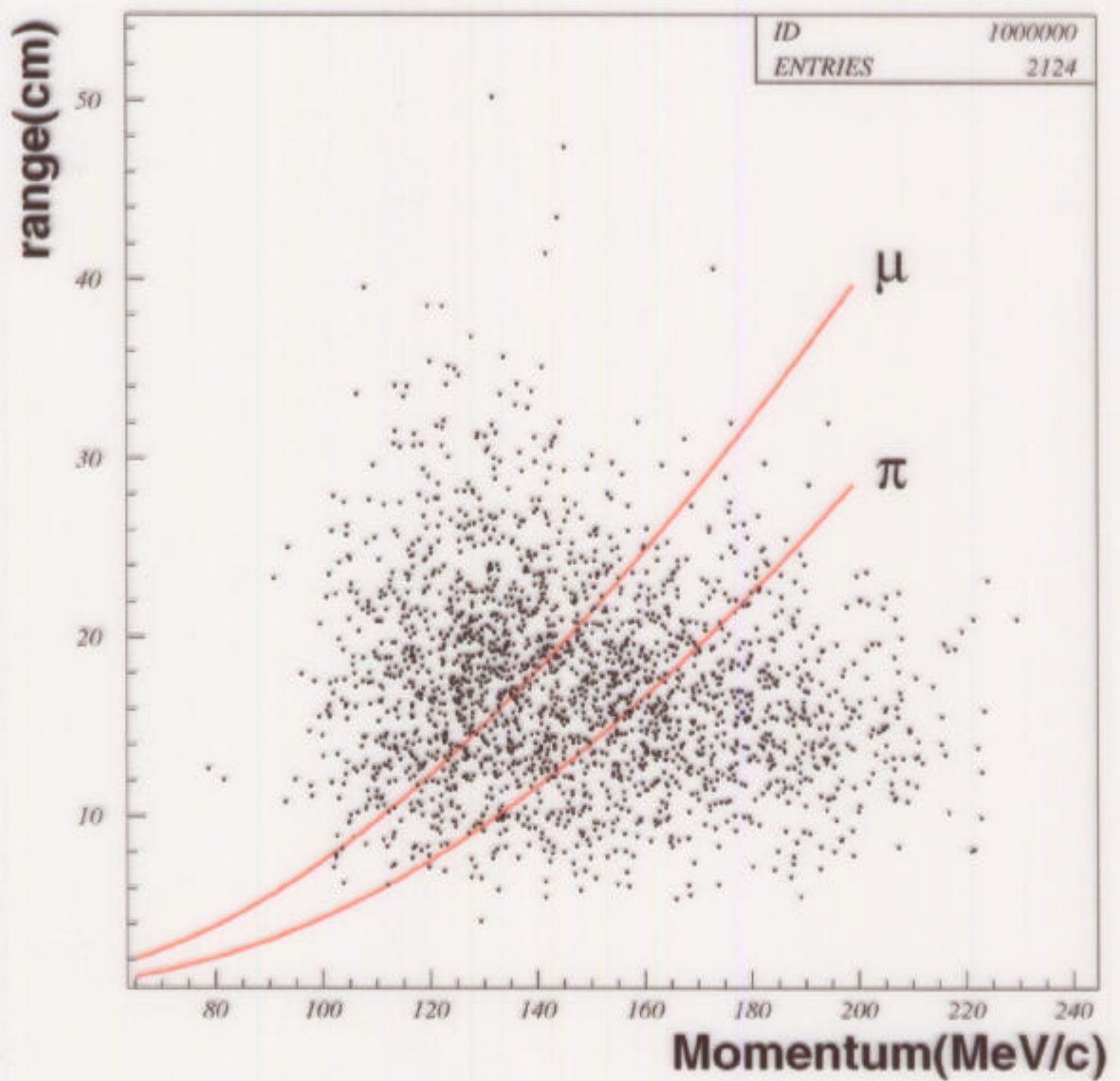
clearly seen

- $\mu$  band
- $\pi$  band
- $K_{\pi 2}$

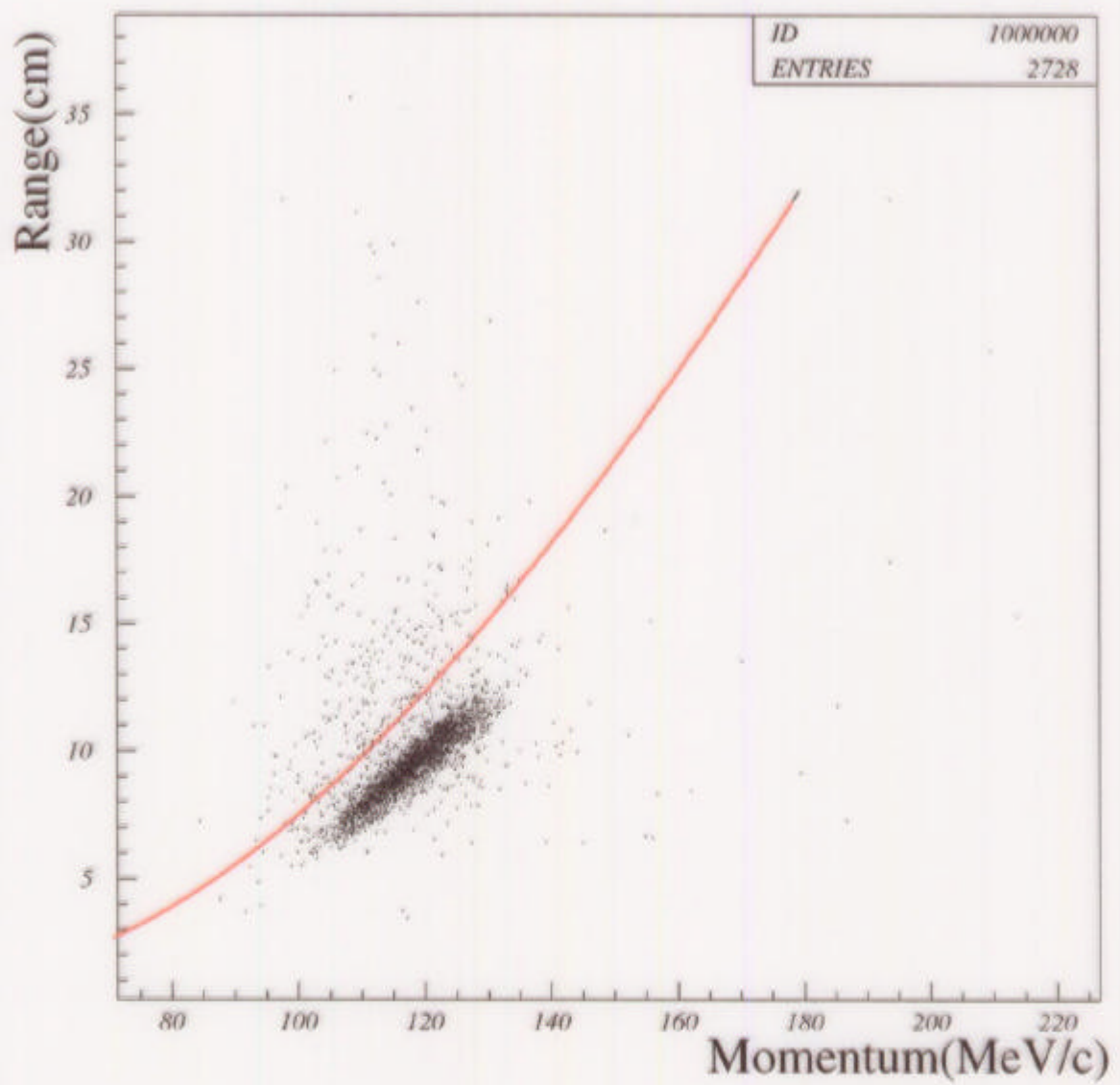
Signal:  $K_{\mu 3\gamma}$



# Background: $K_{e3}$ (MC)



# Background: $K_{\pi 3}$



# Kinematic Fitting

## 13 Measured variables:

- $\mu \dots P_\mu, \theta_\mu, \phi_\mu, T_\mu$
- $\gamma_1 \dots E_{\gamma_1}, \theta_{\gamma_1}, \phi_{\gamma_1}$
- $\gamma_2 \dots E_{\gamma_2}, \theta_{\gamma_2}, \phi_{\gamma_2}$
- $\gamma_3 \dots E_{\gamma_3}, \theta_{\gamma_3}, \phi_{\gamma_3}$

## 3 Unmeasured variables:

- $\nu \dots E_\nu, \theta_\nu, \phi_\nu$

## 6 Constraints:

- energy-momentum balance
- $\mu$ -track consistency ( $\mu$  mass)
- $\pi^0$  invariant mass

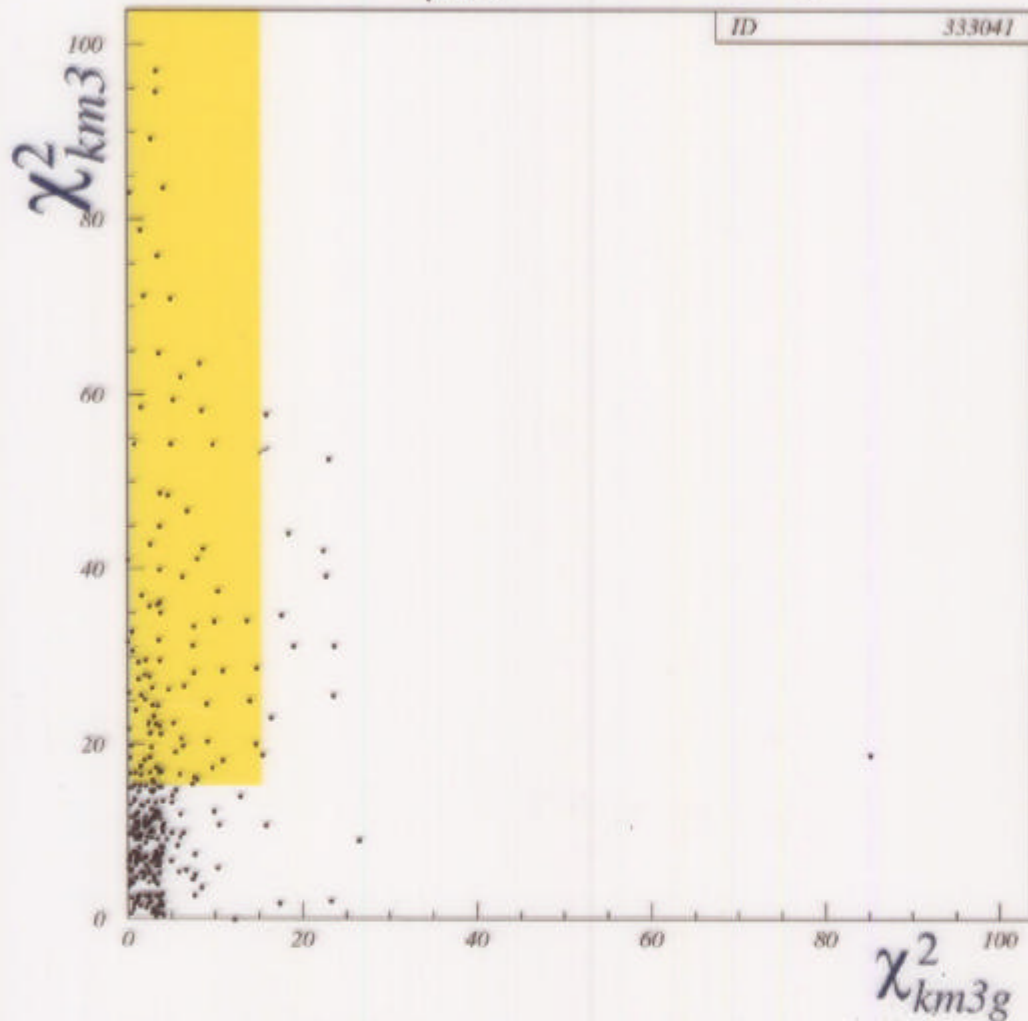
$\pi^0$  *paring* ...

- highest  $\chi^2$  probability

Least-Square Minimization with Lagrange-Multipliers Method

# Chisquare( $\chi^2$ ) Cut

Radiative  $K_{\mu 3}$ (MC Events)



$K_{\mu 3}$  will be effectively removed by  $\chi^2$ -cut  
e.x.

- $K_{\mu 3}$  rejection  $\sim 1000$
- $K_{\mu 3\gamma}$  acceptance  $\sim 25\%$

# Summary & Future Plan

- Check the Prospects for  $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma$   
 $\sim$  4K events
- Study possible background sources

## TODO

### 1. PASS2

- $\pi/\mu$  sample separation
  - $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma$
  - $K^+ \rightarrow \pi^0 \pi^+ \gamma$
- extra cut

### 2. Precise Background Estimation

- Bifurcation Method
- Tune Kinematic Fitting

### 3. Physics Results