Analyses for Minneapolis Collaboration Meeting

- ***Analysis of Neutrino Interactions for 396 events***
- ***Analysis of Short candidate 3356_17099***
- ***Total background estimates in 396 events***

Neutrino Interaction Types

1. Extract number of ν_μ events

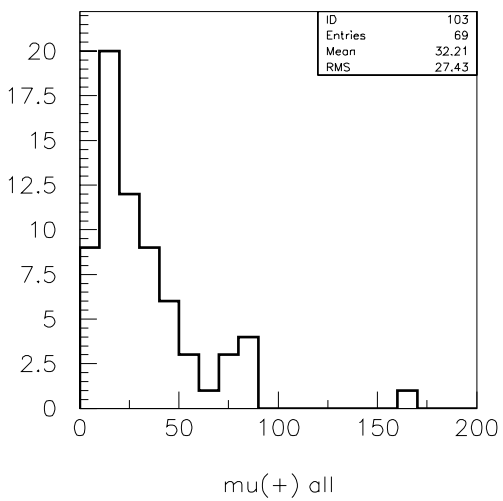
2. Estimate number of ν_e events

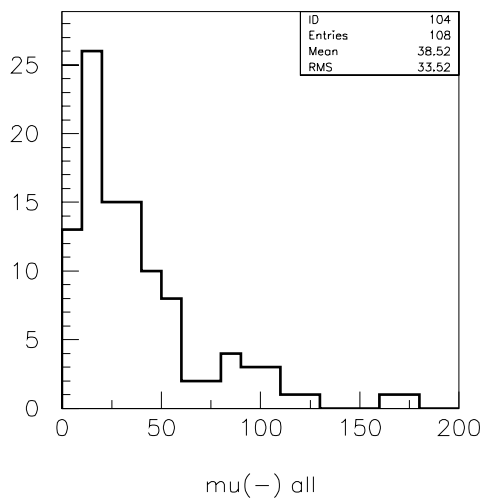
3. Compare to calculations

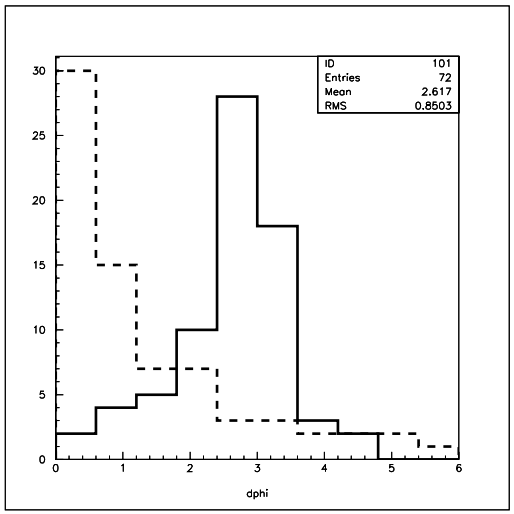
1. Extract number of ν_μ events

Straightforward analysis, already done by Gina

161 of 396 identified as ν_μ CC interactions







$\Delta\phi$

ratio +/- 1.57±0.24 (1.75 expected)

2. Estimate number of ν_e events

Simple analysis based on:

2.1 the fraction of the electron/photon energy is very different in ν_e CC events compared to ν_μ CC and NC events

2.2 the NC e/γ energy distribution is the same as in ν_μ CC events

Algorithm has the following elements:

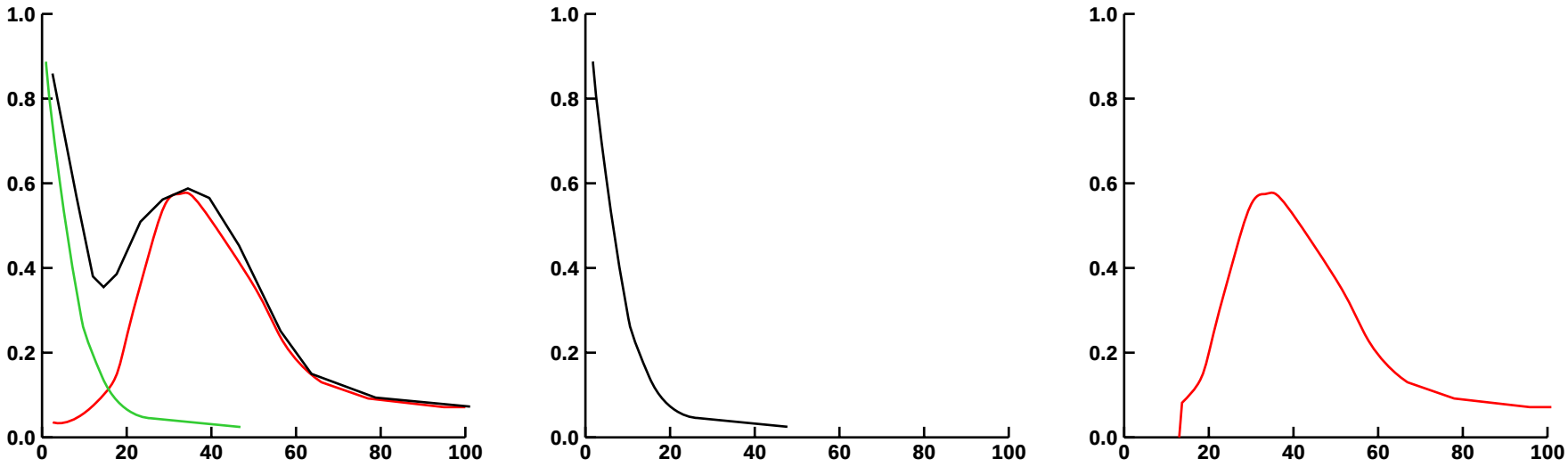
2.3 divide the event sample into ν_μ CC events ($S(\mu)$) and all else ($S(\bar{\mu})$), separate by station

2.4 find the calorimeter energy (sum of clusters > 0.3 GeV) for each event and determine the distribution of energy for all subsets in (2.3)

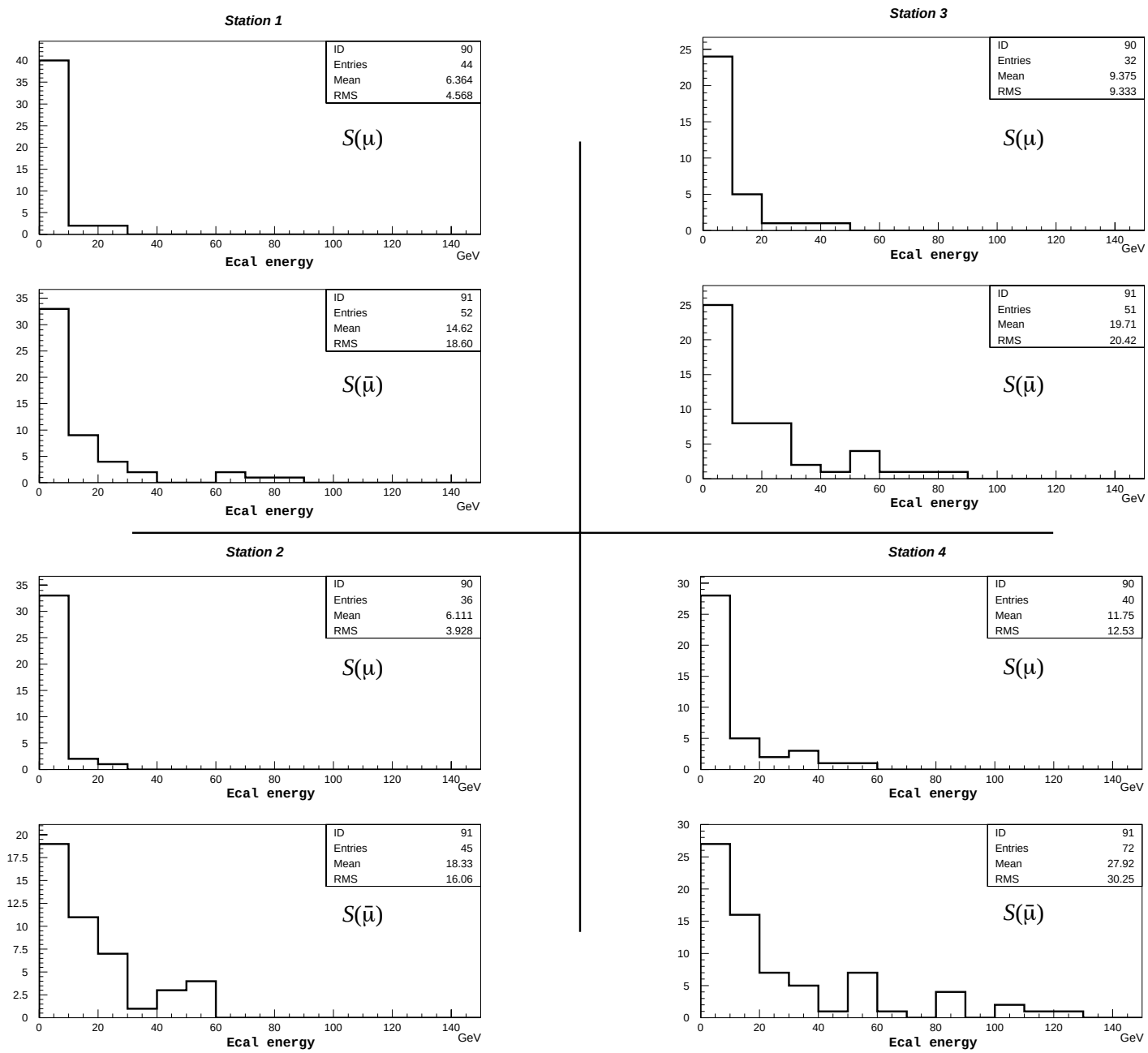
2.5 determine the NC-like fraction by normalizing to the number of entries for $E_{cal} < 10$ GeV and subtract : $S(\bar{\mu})$ - $(n_{\bar{\mu}}(1)/n_\mu(1))\ S(\mu)$

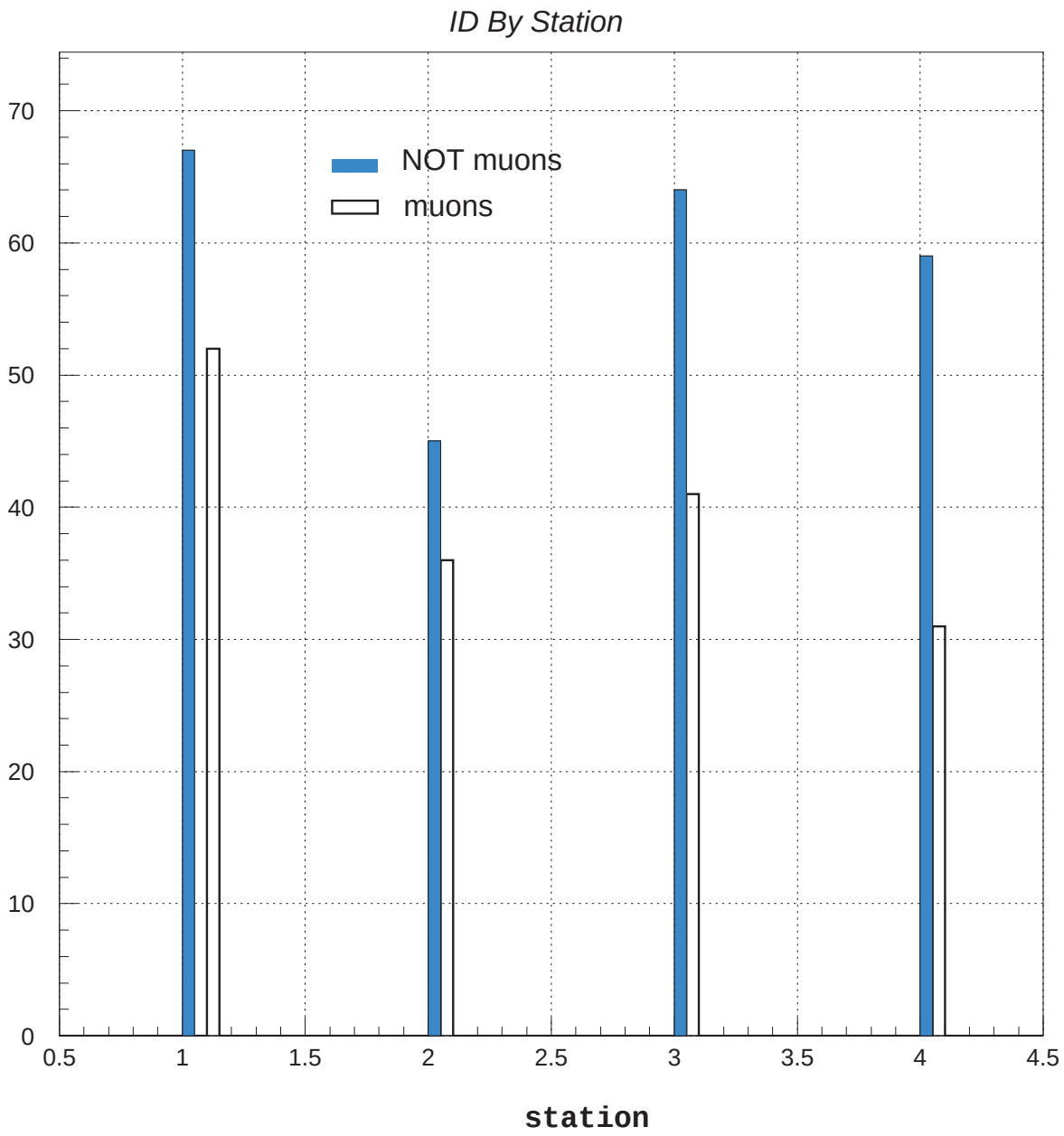
2.6 make corrections for absorption by station

Method

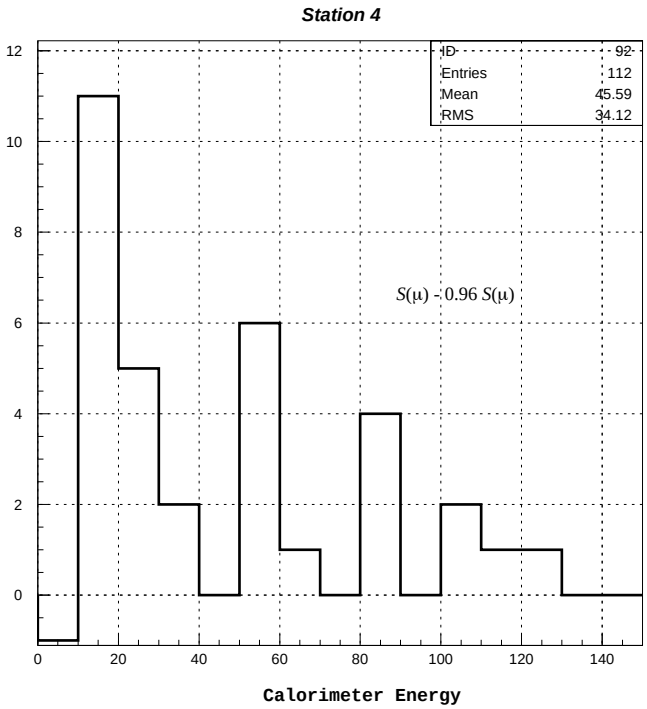


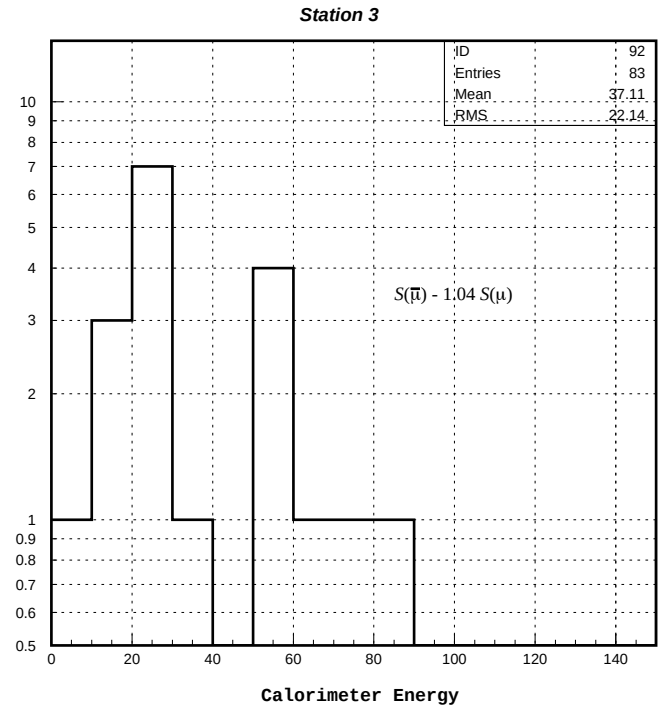
$S(\bar{\mu})$ — $f \times S(\mu)$ = $S(e)$


Station 1
ID 90
Entries 44
Mean 6.364
RMS 4.568
S(μ)
Ecal energy
GeV
ID 91
Entries 52
Mean 14.62
RMS 18.60
S(μ̄)
Ecal energy
GeV
Station 3
ID 90
Entries 32
Mean 9.375
RMS 9.333
S(μ)
Ecal energy
GeV
ID 91
Entries 51
Mean 19.71
RMS 20.42
S(μ̄)
Ecal energy
GeV
Station 2
ID 90
Entries 36
Mean 6.111
RMS 3.928
S(μ)
Ecal energy
GeV
ID 91
Entries 45
Mean 18.33
RMS 16.06
S(μ̄)
Ecal energy
GeV
Station 4
ID 90
Entries 40
Mean 11.75
RMS 12.53
S(μ)
Ecal energy
GeV
ID 91
Entries 72
Mean 27.92
RMS 30.25
S(μ̄)
Ecal energy
GeV


ID By Station
NOT muons
muons
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
station

Results 1:





32 event excess

33 (corrected)

18 event excess

22 (corrected)

Results 2:

	μ	e	NC	τ	no ID
prompt	0.56	1.00	0.78	1.00	
non-prompt	0.43	0.0	0.22	0.0	
A production	1.79	1.00	1.01	0.09	
B trigger ε	0.98	0.98	0.84	0.97	
C ID ε	0.74	0.95	-	0.50	
C NOT. ID ε	0.26	0.05	-	0.50	
Π (A.B.C)	1.30	0.93	0.85	0.04	0.55
fraction	0.35	0.25	0.23	0.013	0.15
	0.35	0.64			
Data	0.41	0.58			
Station 1	0.44				
Station 2	0.46				
Station 3	0.40	0.21	0.28 ±0.04		
Station 4	0.34	0.36			

Analysis of Short candidate 3356_17099

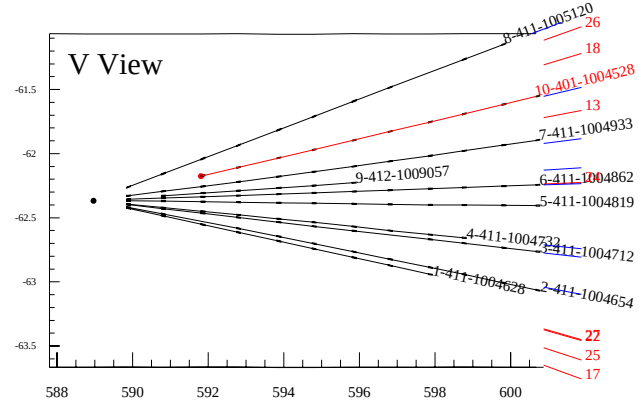
- **This event was not included as τ candidate in the 203 events set because a primary emulsion track was linked to 3 hits in the MuID system**
- **The short track found in the decay analysis *is* linked to SFT hits**
- **The main task is to determine the probability of a muon in the event**
- **Also estimate probability of hypotheses:**

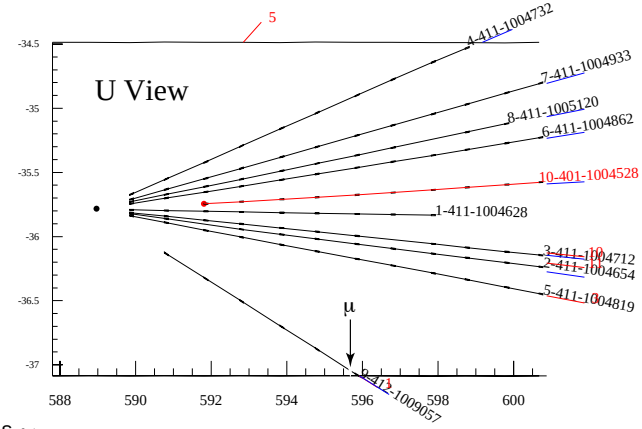
A) ν_τ CC event .AND. (π decay .OR. random)

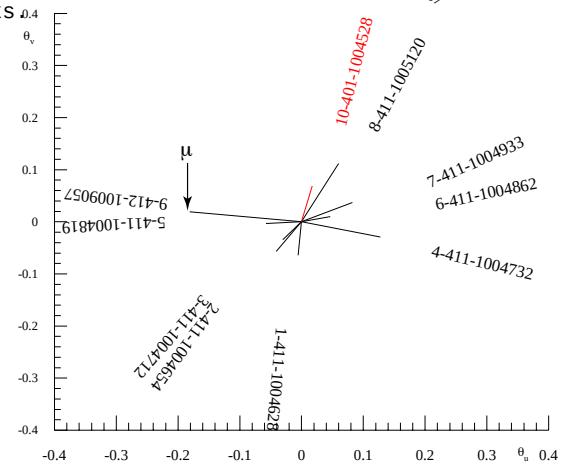
B) ν_μ CC event .AND. (S background .OR. charm)

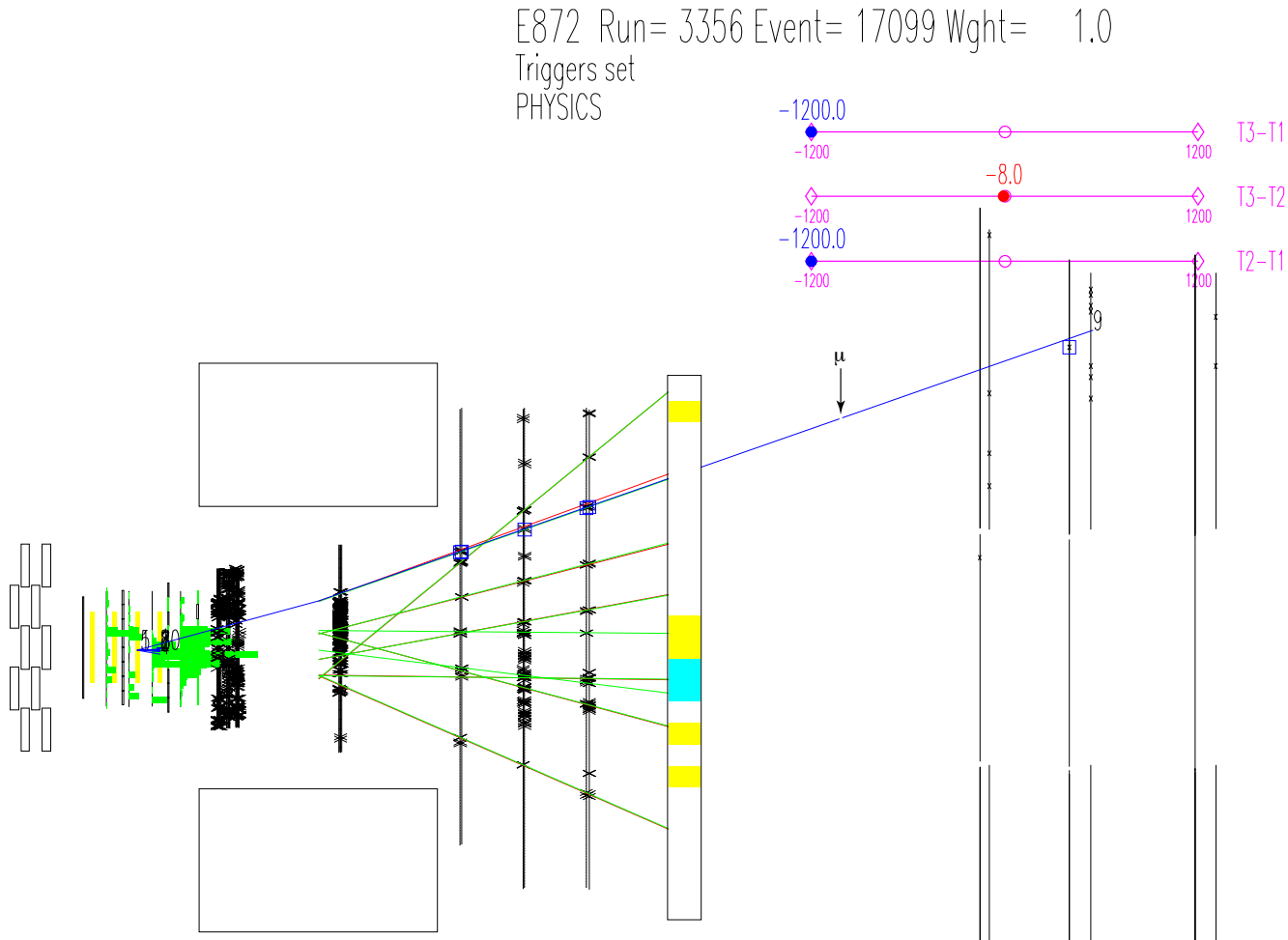
C) (S background) .AND. (π decay .OR. random)

```
>>>>>>>>>>>>> RDTDECAY results 3356_17099<<<<<<<<<<<<<<
Run period 4 Module type E/B3. Vtx in SFT station 3, emulsion module 7
Primary vertex @   -35783.5  -62366.5  588965.2 micron
       primary trk     nseg  eplt  flag     ip   theta   mom
       1-411-1004628     9   371     0    3.08  0.065   0.0
       2-411-1004654    11   362     1    2.27  0.070   0.0
       3-411-1004712    11   362     1    2.84  0.046   0.0
       4-411-1004732    10   372     2    3.46  0.131   0.0
       5-411-1004819    12   362     1    2.97  0.058   0.0
       6-411-1004862    12   362     1    2.68  0.048   0.0
       7-411-1004933    12   362     1    4.05  0.090   0.0
       8-411-1005120    10   361     2    3.47  0.127   0.0
       9-412-1009057     6   381     2    6.47  0.187   0.0
Short decay (code=1) IP cut= 200. microns. Angle cut= 0.200
Long decay  (code=2) IP cut=   5. microns. Angle cut= 0.250
 Code + 10 -> track in SFT. Min seg cut= 2
 code ptk  2ndry trk     nseg  eplt  flag   flght     ip    theta   mom   Gnt ID
   1   0   0-411-1004844    12   401     1    875.    20.0   0.023   0.0
  11   0  10-401-1004528    10   372     1   2851.    10.9   0.004   0.0
   1   0   0-412-1011650     3   401     2   1909.   131.2   0.076   0.0
   1   0   0-401-1005170     2   412     0   2935.   188.1   0.068   0.0
   1   0   0-401-1004026     2   412     0   2852.   101.9   0.036   0.0
   1   0   0-412-1007924     2   401     2   1864.   127.7   0.071   0.0
   1   0   0-401-1003492     2   401     0   2919.    66.8   0.023   0.0
   1   0   0-401-1005092     2   401     0   2902.   157.1   0.056   0.0
   1   0   0-401-1004190     2   411     2   2955.   128.7   0.046   0.0
   1   0   0-411-1005479     2   411     0    911.    42.4   0.049   0.0
   1   0   0-411-1004837     2   411     0    877.   125.6   0.146   0.0
   1   0   0-411-1005215     2     0     0    891.    72.9   0.084   0.0
  >>>>>>>>>>>>>>>>>>>>> CHK2NDRY <<<<<<<<<<<<<<<<<<<<<
Emul tracks within   6. microns and  10. mrad which stop upstream of 2ndry tracks
     trk     nseg   dplt    dr      dsl     U/S trk
                           [um]    [mrad]
 CHK2NDRY: Search for more 2ndry vertex tracks
******** Vtx  2 -35744.9 -62175.1 591810.0 microns **************
  emtrk    nseg     IP      dplt to vtx
```

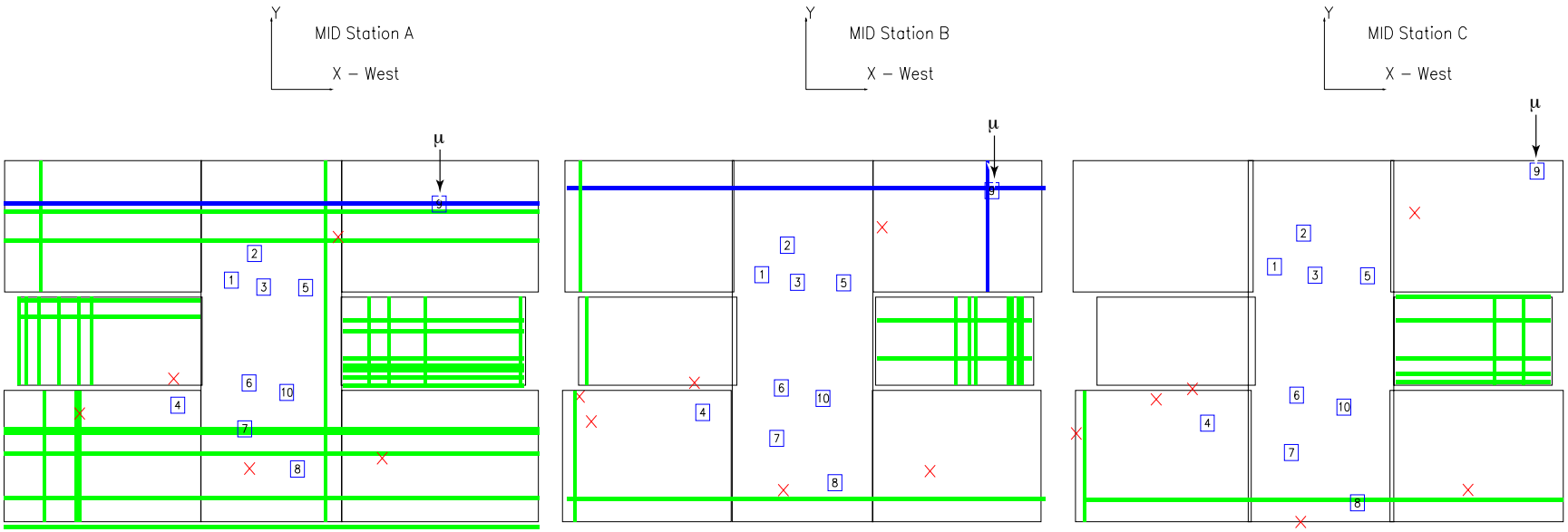


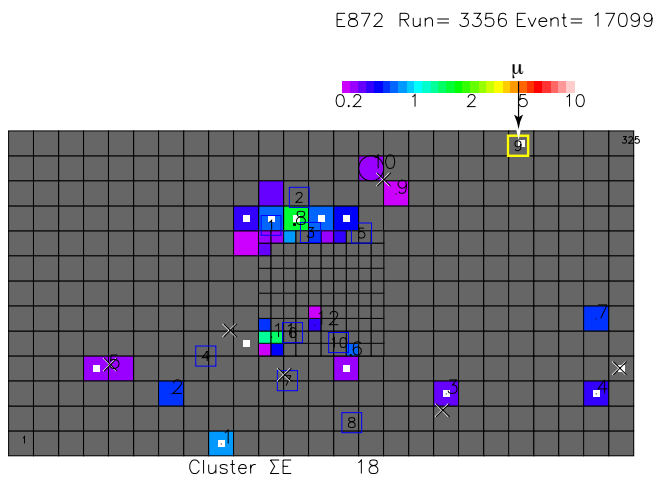






Trk	Mom	Chi	nht	Emul	Vtx
1	0.0	0.0	0	4111004628	1
2	0.0	0.7	9	4111004654	1
3	0.0	0.6	9	4111004712	1
4	0.0	0.2	9	4111004732	1
5	0.0	0.0	0	4111004819	1
6	0.0	0.8	9	4111004862	1
7	0.0	0.8	8	4111004933	1
8	0.0	2.2	8	4111005120	1
9	-5.0	0.9	8	4121009057	1
10	0.0	2.7	8	4011004528	2





1	0.8	9	0.2
2	0.6	10	0.3
3	0.3	11	5.0
4	0.4	12	0.4
5	0.5		
6	0.9		
7	0.5		
8	7.6		

y View

Reasonable hypothesis:

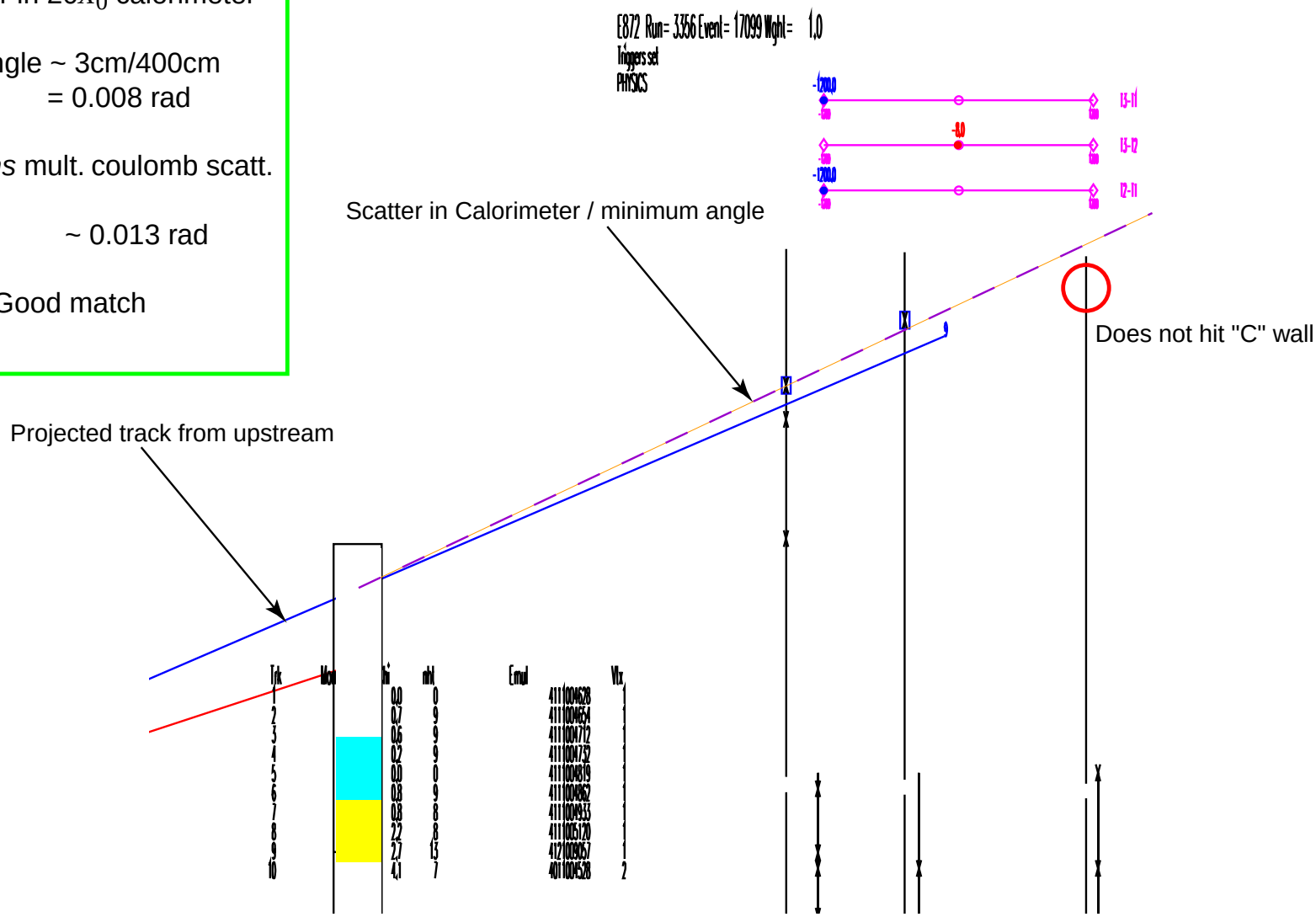
Scatter in 20X_0 calorimeter

Min angle ~ 3cm/400cm
= 0.008 rad

Est *rms* mult. coulomb scatt.

~ 0.013 rad

Good match



Summary of 3356_17099

- Short candidate track SFT match $(\Delta u, \Delta v) = (0.008, -0.018)$
- Emulsion momentum estimate 3.2 GeV/c
  $\Rightarrow$ scattering consistent with match

- Track 9 ("muon") matches hits in KSx,y / DC / Ecal
- Spectrometer momentum -5.0 GeV/c
- Range through A wall : 0.9 GeV
  B wall : 2.0 GeV
  C wall : 3.0 GeV
  $\Rightarrow$ expect penetration to C wall

- random hits in 20cm window ~ $(\overline{Ax})(Ay)(Bx)(By)$
  $(0.4)(0.9)(0.03)(0.09)$
  $= 1.0\times10^{-3}$

- There are 2.5 $\pi^{\pm}$ / event ; avg. energy ~ 6 GeV
  $\gamma c\tau \sim 280$m ; decay space ~7.5m $\Rightarrow$ 0.027 $\pi^{\pm}$ decay probability

Hypotheses for 3356_17099 "muon track":

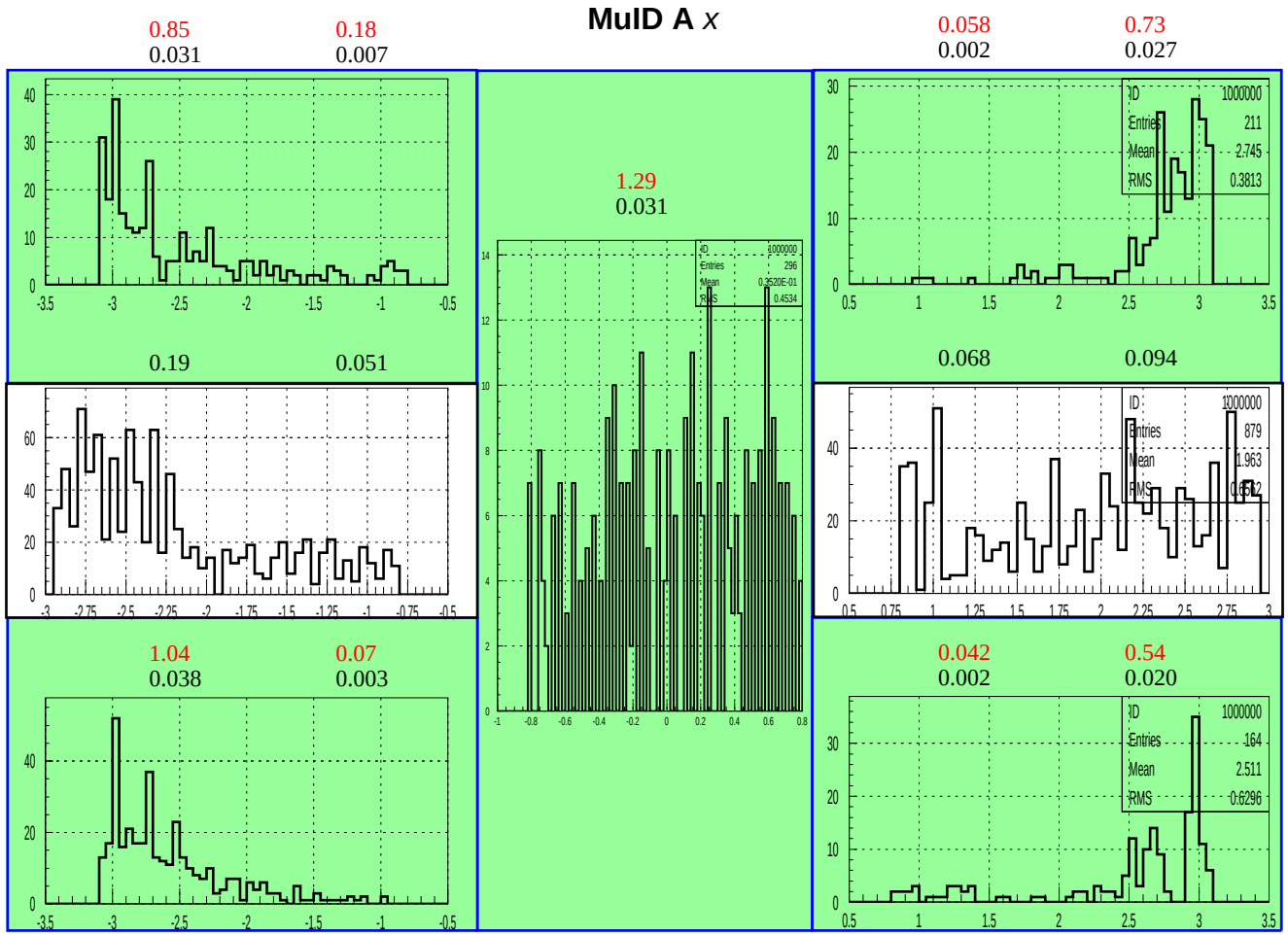
A) Random coincidence of hits in MuID system

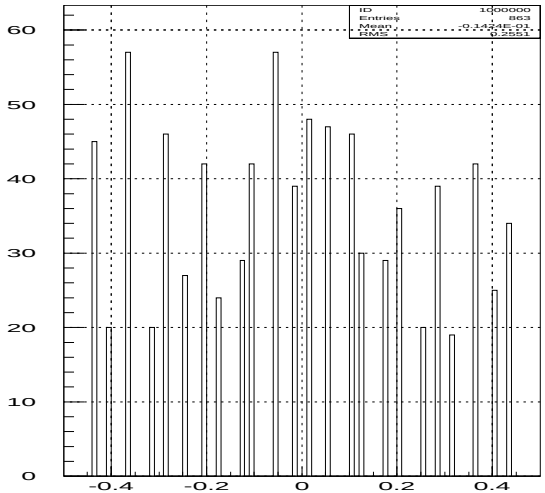
Prob ~ 0.001

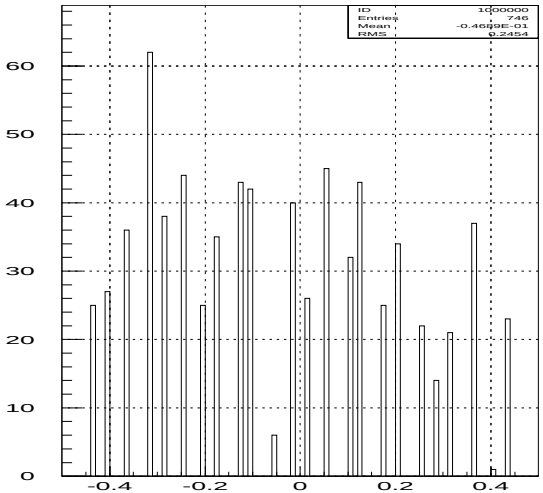
B) π decay-in-flight; scatters out of C-wall

Prob ~ (0.027)(6)(0.06) = 0.010

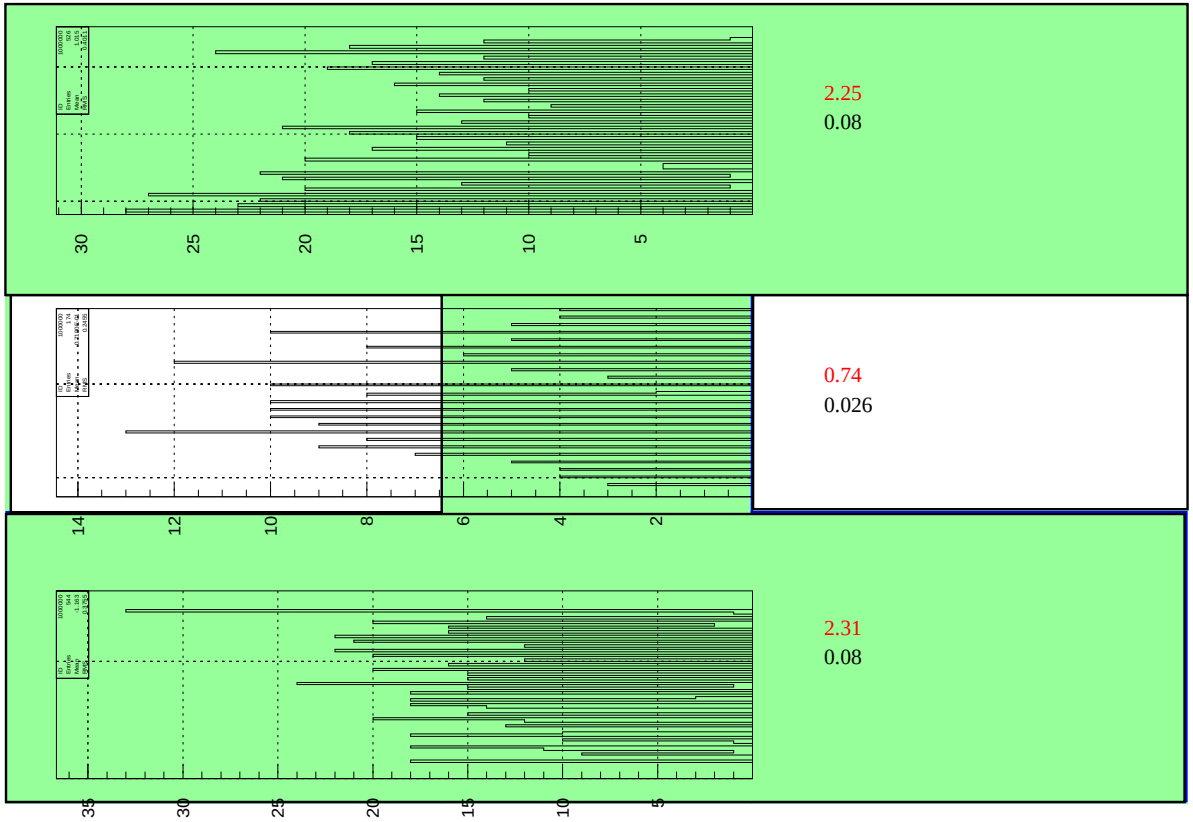
π decay no. π 3 of 4 hits

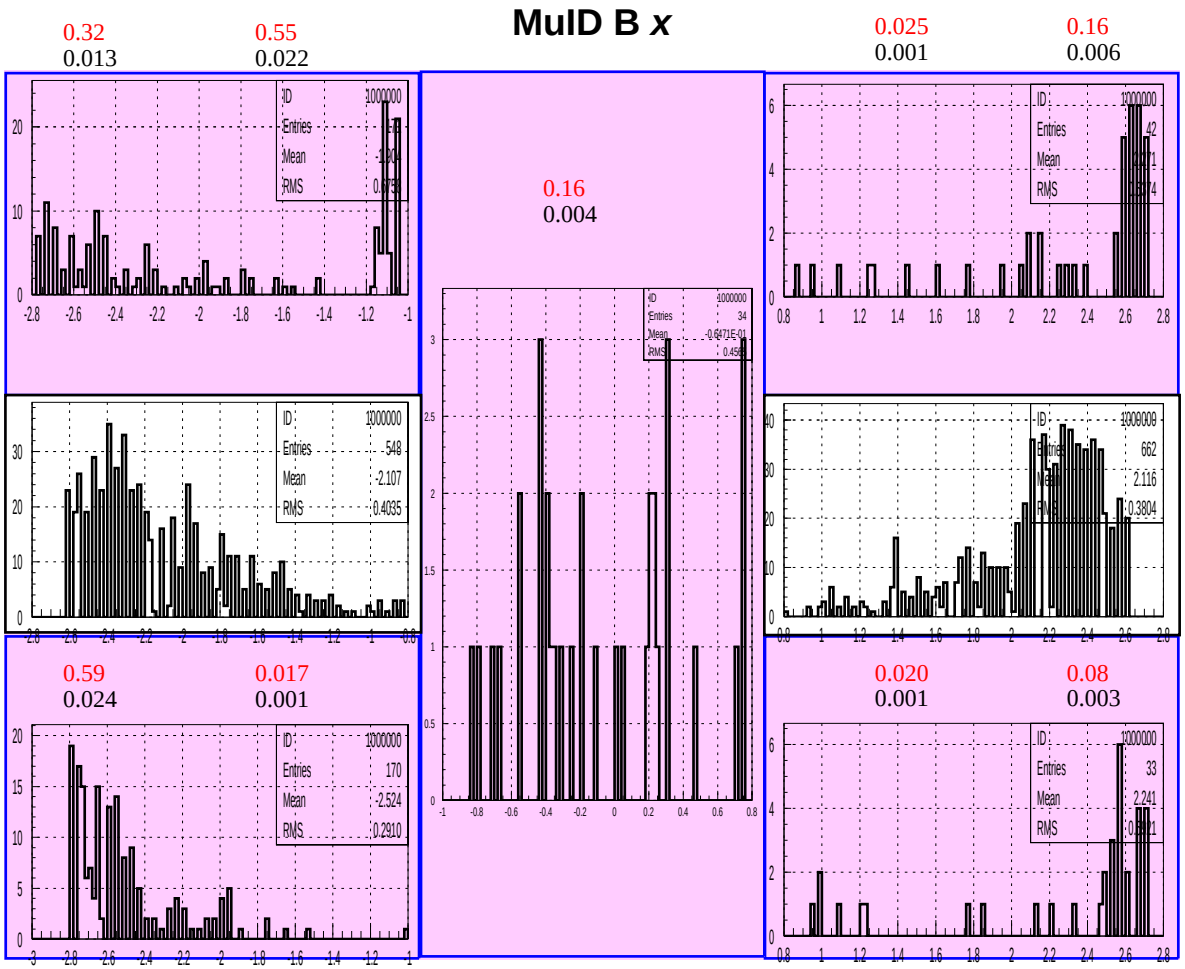

MuID A x
0.85
0.031
0.18
0.007
0.058
0.002
0.73
0.027
1.29
0.031
0.19
0.051
0.068
0.094
1.04
0.038
0.07
0.003
0.042
0.002
0.54
0.020
ID 1000000
Entries 211
Mean 2.745
RMS 0.3813
ID 1000000
Entries 296
Mean 0.3520E-01
RMS 0.4534
ID 1000000
Entries 879
Mean 1.963
ID 1000000
Entries 164
Mean 2.511
RMS 0.6296


ID 1000000
Entries 863
Mean -0.1142E-01
RMS 0.2551

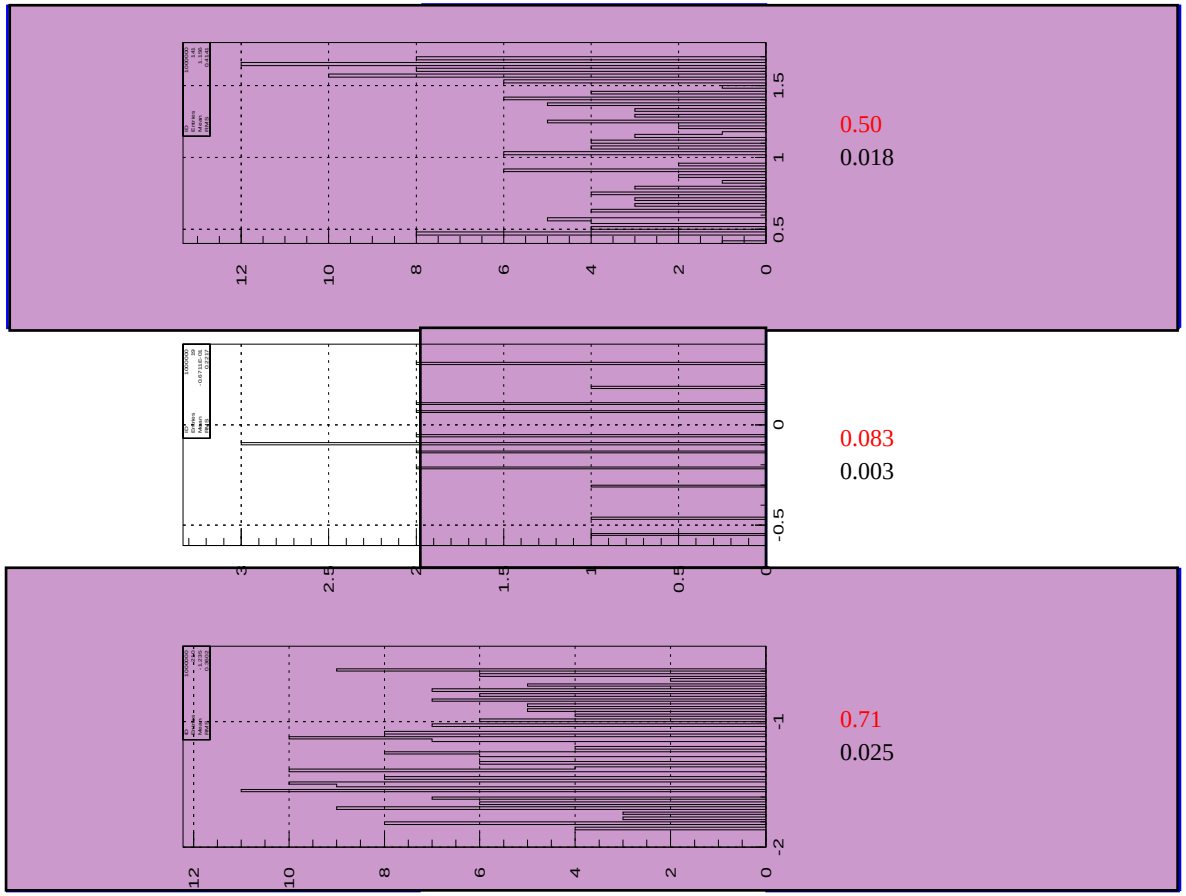

ID 1000000
Entries 746
Mean -0.4690E-01
RMS 0.2454

MuID A *y*


2.25
0.08
0.74
0.026
2.31
0.08


MuID B *x*
0.32
0.013
0.55
0.022
0.025
0.001
0.16
0.006
0.16
0.004
0.59
0.024
0.017
0.001
0.020
0.001
0.08
0.003

MulD B *y*



Total background estimates for 396 events

Preliminary estimates for the following processes:

- ***charm*** single-prong
- ***charm*** trident
- ***interaction*** single-prong
- ***interaction*** trident

Propose additional cut for trident background reduction

- Σ **IP** cut

C1 - charm single-prong

$$\Pi_c(1V) = (\nu N \rightarrow cX)\ (CC)\ (charged)\ (1\text{-prong})\ (1-\varepsilon_{ID})\ (\varepsilon_{1V})$$

$$= (0.07)\ (0.60)\ (0.40)\ (0.38)\ (0.25)\ (0.66)$$

$$= 1.0\times10^{-3}$$

Apply 0.25 GeV/c p_T cut $(0.81)\ (1.0\times10^{-3}) = \boxed{8.1\times10^{-4}}$

C3 - charm trident

$$\Pi_c(3V) = (\nu N \rightarrow cX)\ (CC)\ (charged)\ (3\text{-prong})\ (1-\varepsilon_{ID})\ (\varepsilon_{3V})$$

$$= (0.07)\ (0.60)\ (0.40)\ (0.54)\ (0.25)\ (0.70)$$

$$= \boxed{1.6\times10^{-3}}$$

S1 - Interaction single-prong

$$\Pi_s(\mathbf{C1}) = (\pi N \rightarrow 1)\,(\overline{\mathbf{CC}})\,(L\ mm)\,(\varepsilon_{\mathbf{C1}})$$

$$= (0.0069)\,(0.40)\,(6.2)\,(0.75)$$

$$= 1.3\times10^{-2}$$

Apply 0.25 GeV/c p_T cut $(0.096)\,(1.3\times10^{-2}) = \boxed{1.2\times10^{-3}}$

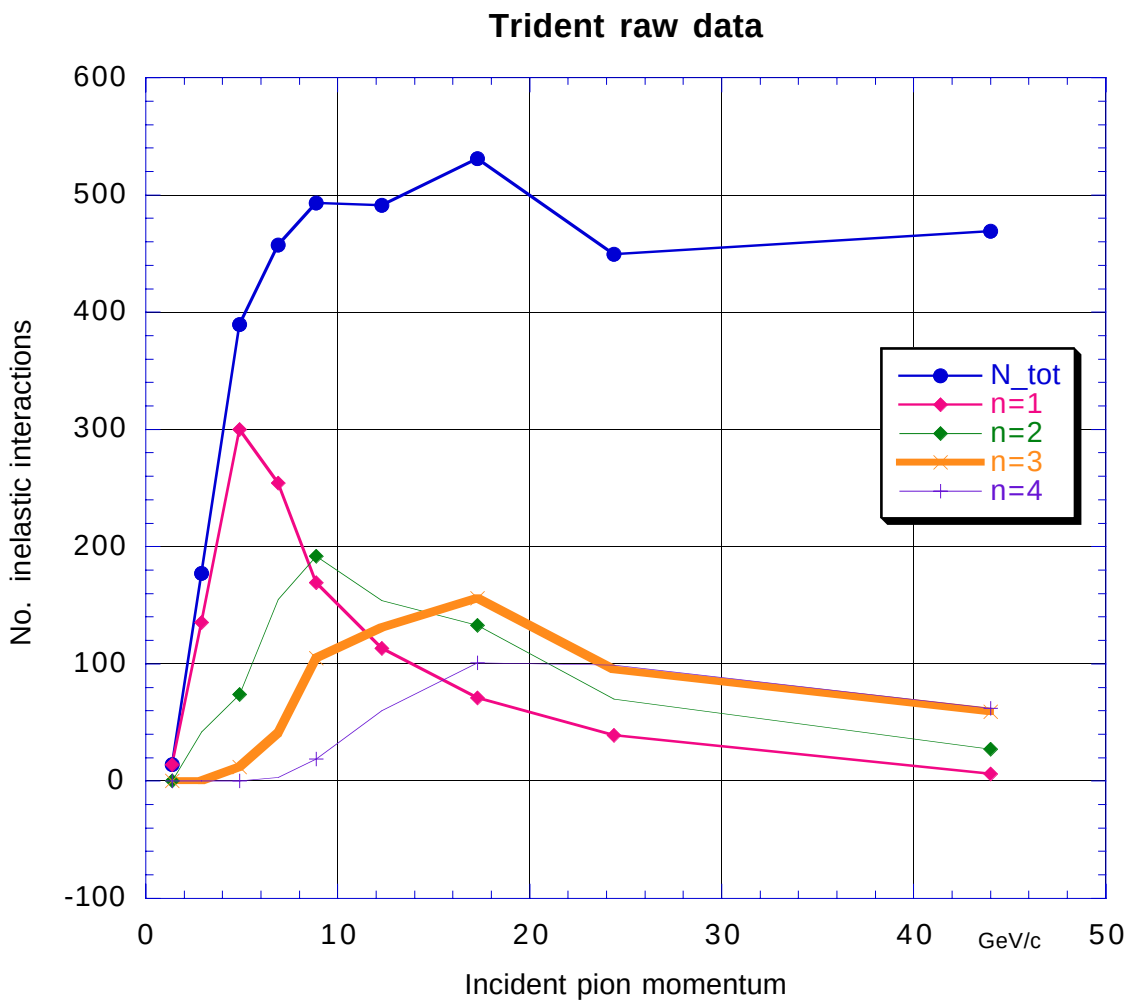
S3 - Interaction trident

$$\Pi_s(\mathbf{C3}) = (\pi N \rightarrow 3)\,(\overline{\mathbf{CC}})\,(L\ mm)\,(\varepsilon_{\mathbf{C3}})$$

$$= (0.0011)\,(0.40)\,(6.2)\,(0.75)$$

$$= \boxed{2.0\times10^{-3}}$$

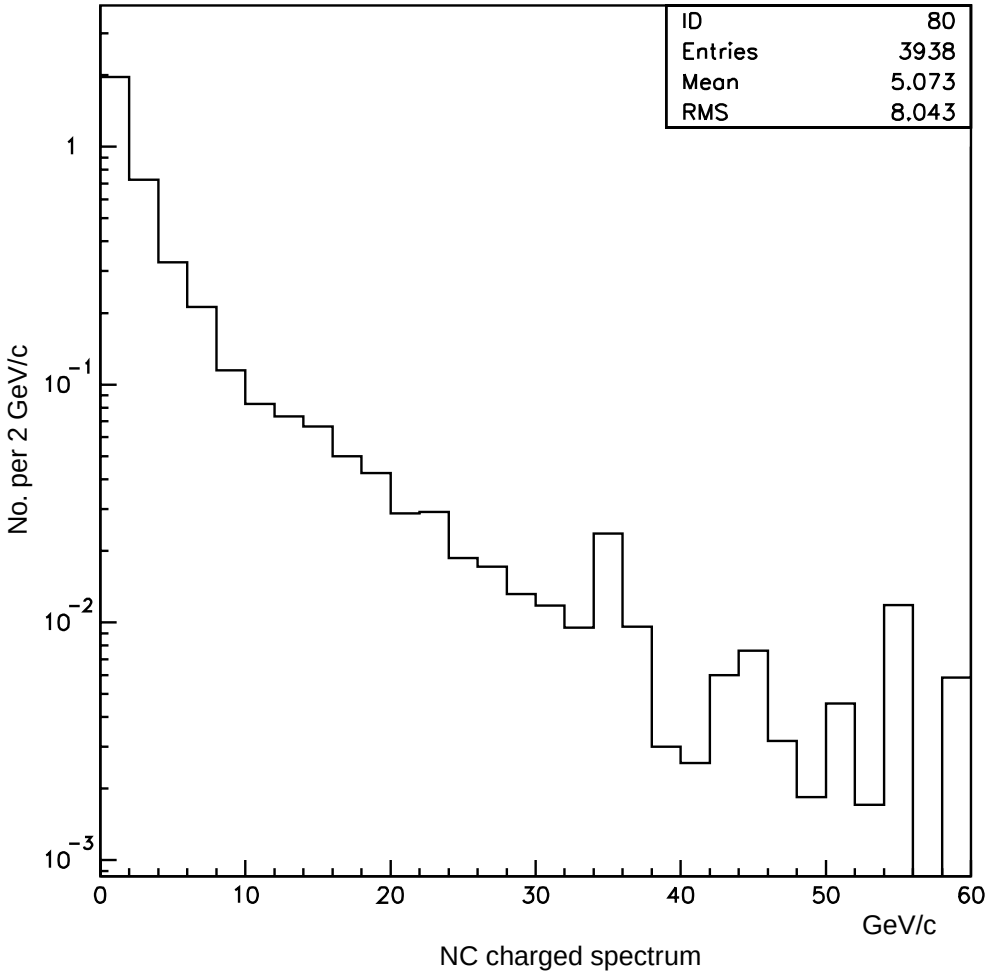
Inelastic interactions as a function of incident momentum.
Cuts: $|\theta_{2ry}| < 0.25$; $p_{2ry} > 1$ GeV/c ;



Each momentum bin contains 10^4 events, on a 1mm Fe plate of density 87 g cm^{-3}, equivalent to 10^5 events

The expected rate of interactions is 625 w/o cuts

Note that only the *n*=3 data are background



The spectrum of charged secondary particles in NC interactions

This spectrum is used to weight the individual mometum bins in the next plot

Assume CC events with mis-identified lepton is the same as NC

Sum of charm and interaction backgrounds:

	rate	for 396 events
C1	8.1×10^{-4}	**0.32**
C3	1.6×10^{-3}	**0.63**
S1	1.2×10^{-3}	**0.48**
S3	2.0×10^{-3}	**0.79**
Σ	5.6×10^{-3}	**2.22**

64% of the background is from tridents (C3 + S3)

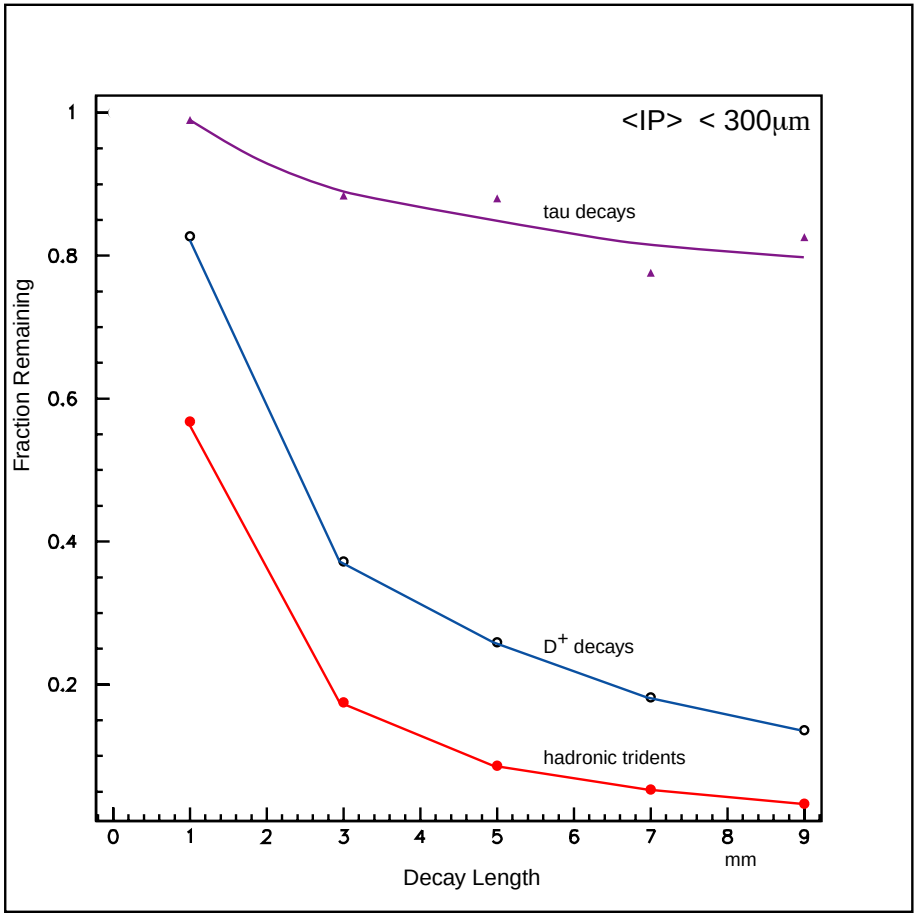
This can be reduced by a simple cut based on decay kinematics...

The proposed cut is based on the fact that the average IP for decays (like τ and charm) approaches the lifetime ($c\tau$) as the charged multiplicity becomes large.

$$\langle IP \rangle \cong \frac{1}{n} \sum_{i}^{n} b_i$$

In other words, the decay topology changes with decay length so that long decays have small opening angles, on the average.

The topology of interaction is invariant with respect to length.



Z (mm)	N_{int}	f_{int}	N_{charm}	f_{charm}	N_{τ}	f_{τ}
0-2	344/606	0.57	840/1016	0.83	7254/7330	0.99
2-4	106/606	0.18	165/444	0.37	1138/1288	0.88
4-6	52/606	0.086	72/278	0.26	439/499	0.88
6-8	32/606	0.053	28/154	0.18	194/250	0.78
8-10	20/606	0.033	14/103	0.14	95/115	0.83
Σ		0.18		0.56		0.96

The cut used :
<IP> < 300μm

The fraction of events remaining in a sample of MC hadronic interactions, tau and charm decays in ECC 800 steel plates.

Cuts:
θ_{inc} < 300 mrad
θ_{2ry} < 250 mrad
p_{2ry} > 1 GeV/*c*
No leptons

Integrated fraction remaining of interactions:
0.18