Identification of Recoil Proton Tracks for a Neutrino Neutral Current Elastic Scattering Cross-Section Measurement at SciBooNE

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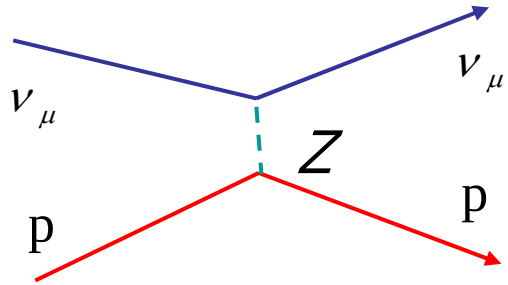
Neutral Current Elastic Scattering at SciBooNE

Neutral Current elastic scattering

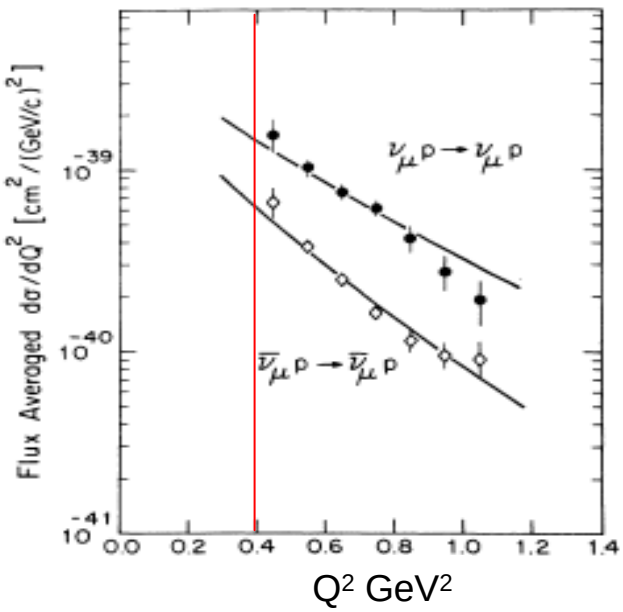
$\nu\, p \rightarrow \nu\, p$



Motivation:

precise measurement of neutral current elastic scattering (NCEL) cross section

- no experimental data of NCEL below Q^2=0.4GeV^2 published, we aim at measurement in smaller Q^2 region

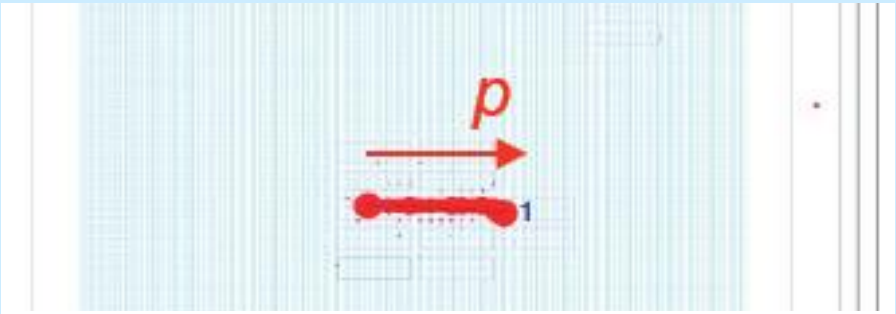


Phys. Rev. D35, 3 (1987)

- access to axial vector form factor of nucleon (Strange component is accessed using $\nu\, p \rightarrow \nu\, p$ events.)

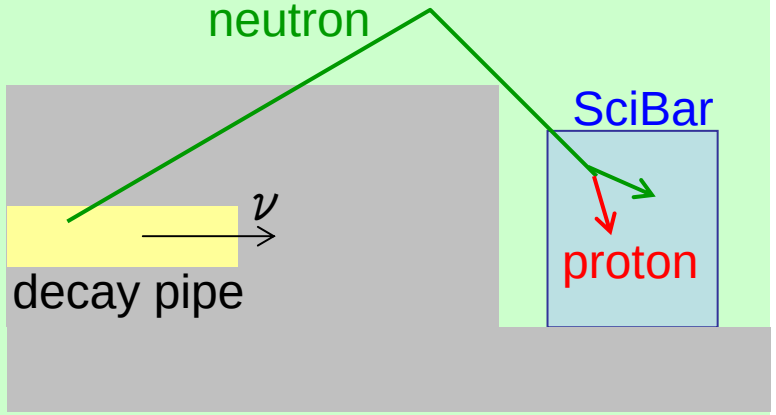
Signals and Backgrounds

Signal : proton



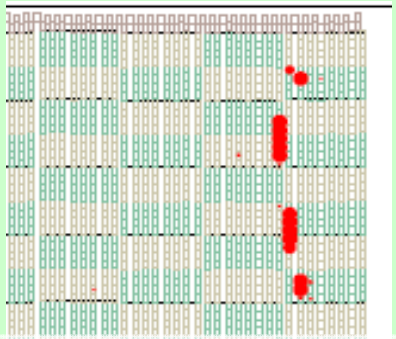
Proton has large energy deposit compared to muon, pion, and electron. dE/dx information is used to identify proton.

Neutron skyshine



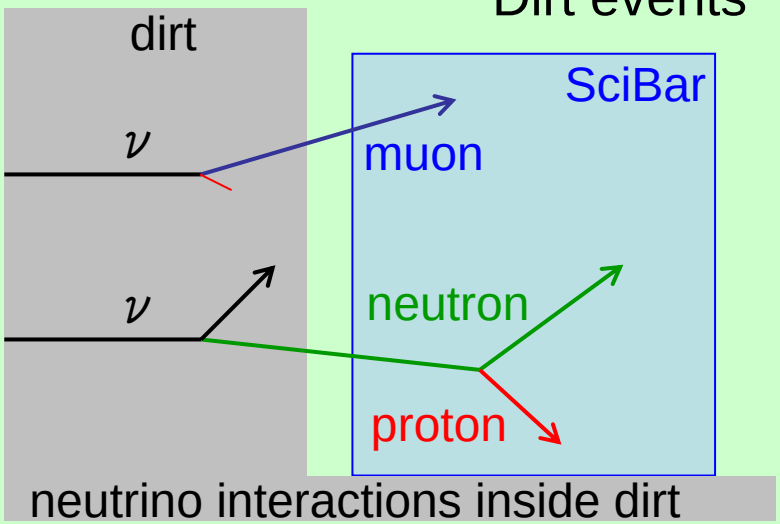
neutron projected into air is scattered toward SciBar

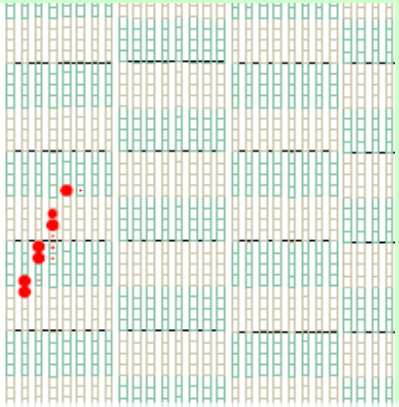
Cosmic muon



cosmic muon without hits out of fiducial volume

Dirt events





dirt muon without hits on 1st layer

Some neutrino events in SciBar and mis-tracking can also be backgrounds.

Proton Selection Criteria

raw data

7.7E19POT data is used

1st reduction

-more than 1 hit in fiducial volume (FV) on each view (top and side)
-one of hits on top or side with >10 p.e.

Data: 1.8E6 events
NCEL efficiency: 80%
non-NCEL efficiency: 93%
(only neutrino events in SciBar)

2nd reduction

-1 track
-edges of track is contained in FV

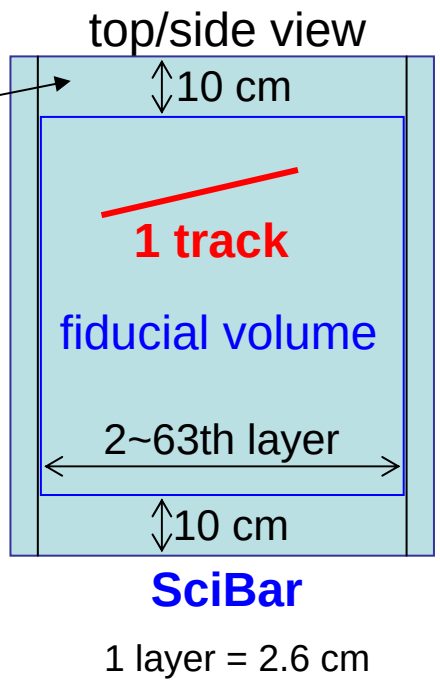
Data: 3.4E5 events
NCEL efficiency: 22%
non-NCEL efficiency: 11%

Proton Filter

-dE/dx cut

Data: 1.8E4 events
NCEL efficiency: 13%
non-NCEL efficiency: 5%

10 cm from upper/lower/ right/left edge

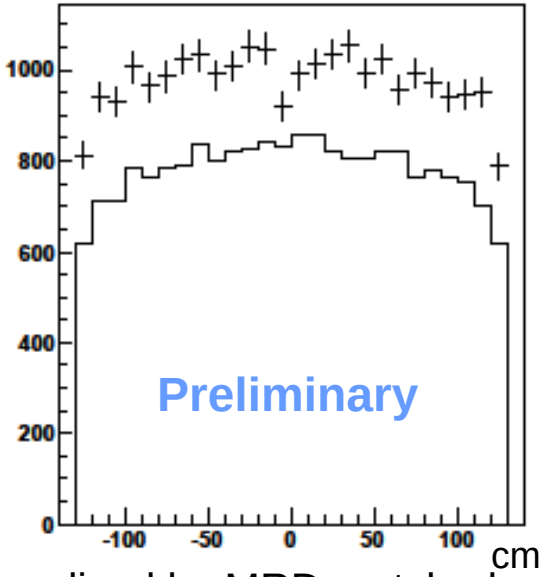


Efficiency is estimated by MC without cosmic, skyshine, and dirt backgrounds.

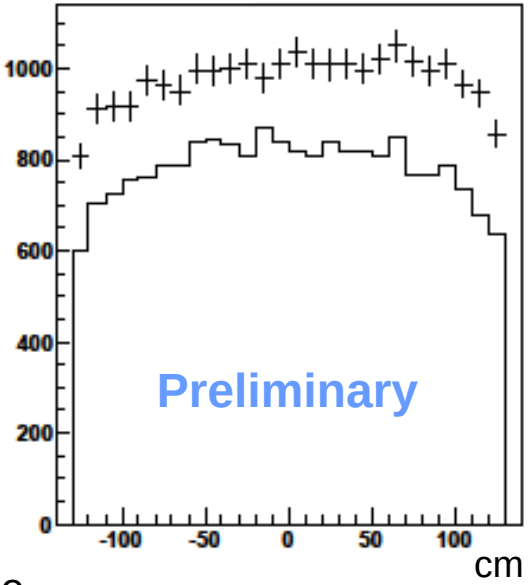
Vertex Distributions (on beam timing)

MC: 4.1E20POT
Data: 7.7E19POT

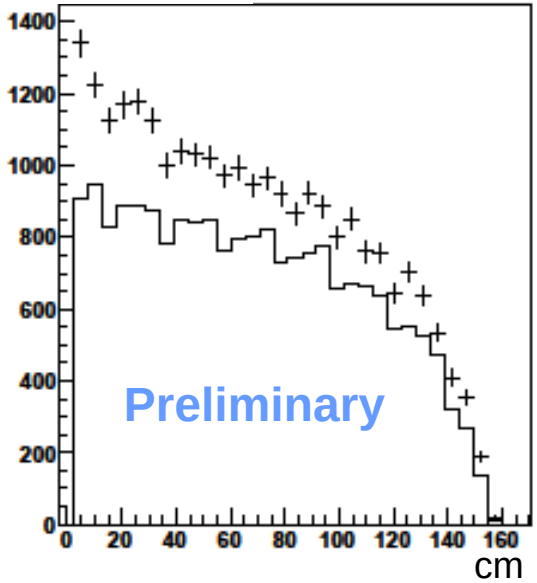
vertex (X)



vertex (Y)

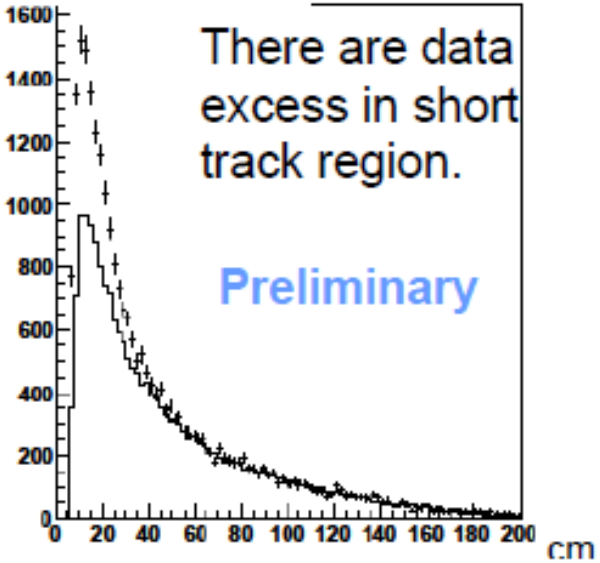


vertex (Z)



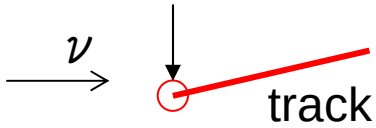
normalized by MRD matched sample

track length



1 track sample

Vertex: upstream edge



Cosmic and skyshine are ~7% of all on beam timing data (estimated from off beam data).

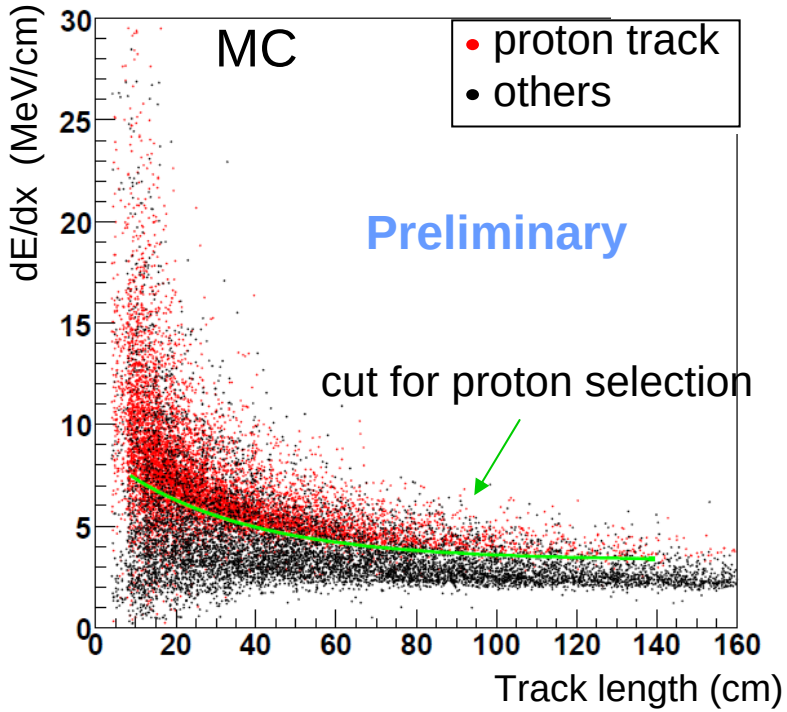
There are data excess in small z and short track region. Dirt events are possible candidate of these events. They are suppressed by veto using most upstream part of SciBar.

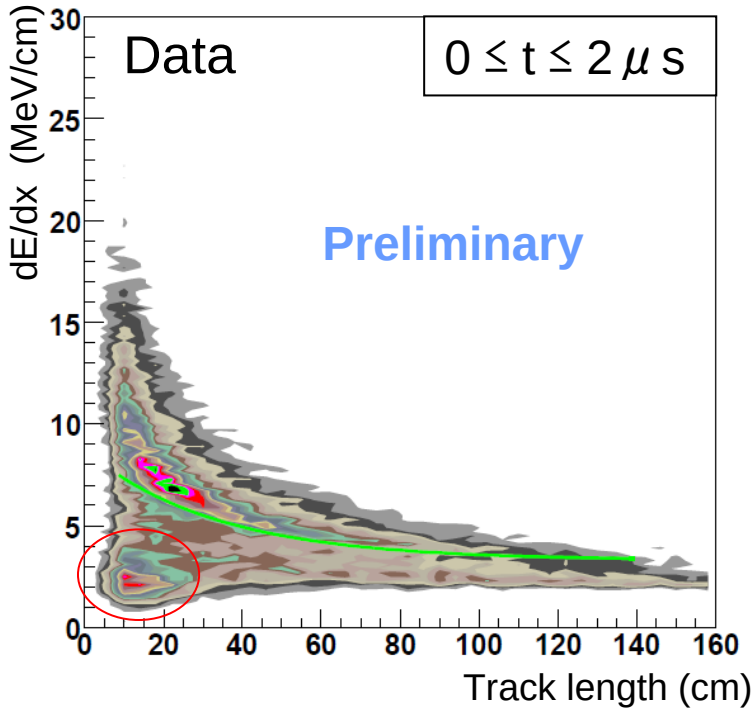
Small asymmetry in Y view comes from cosmic and skyshine.

Length v.s. dE/dx

1 track event sample

MC: 4.1E20POT
Data: 7.7E19POT





83% proton ID efficiency

Proton have large dE/dx.

There is cluster in short length, small energy deposit region due to dirt and cosmic.

These events will be removed after applying proton selection cut.

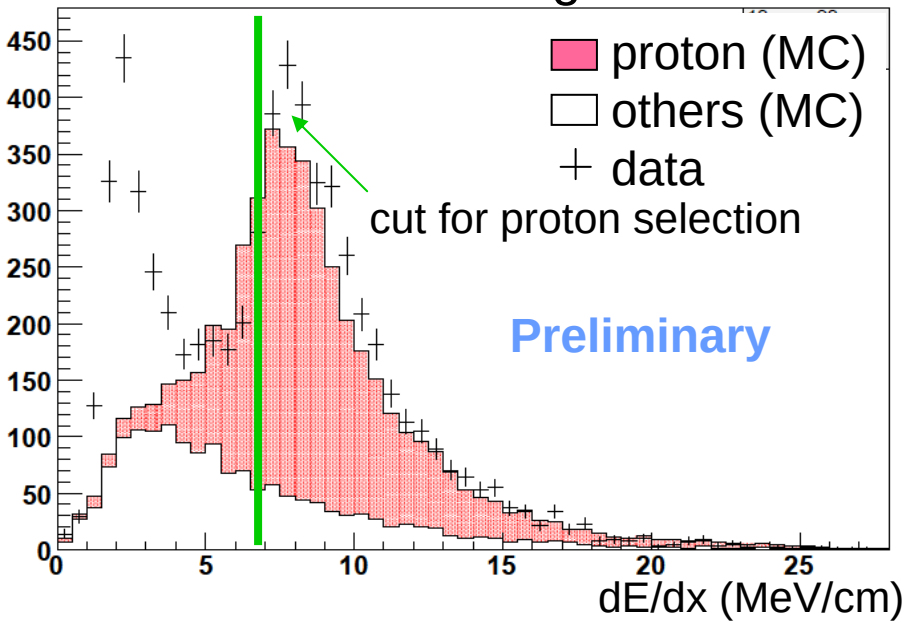
Proton selection cut will be adjusted after applying dirt veto and further selection.

dE/dx Distributions

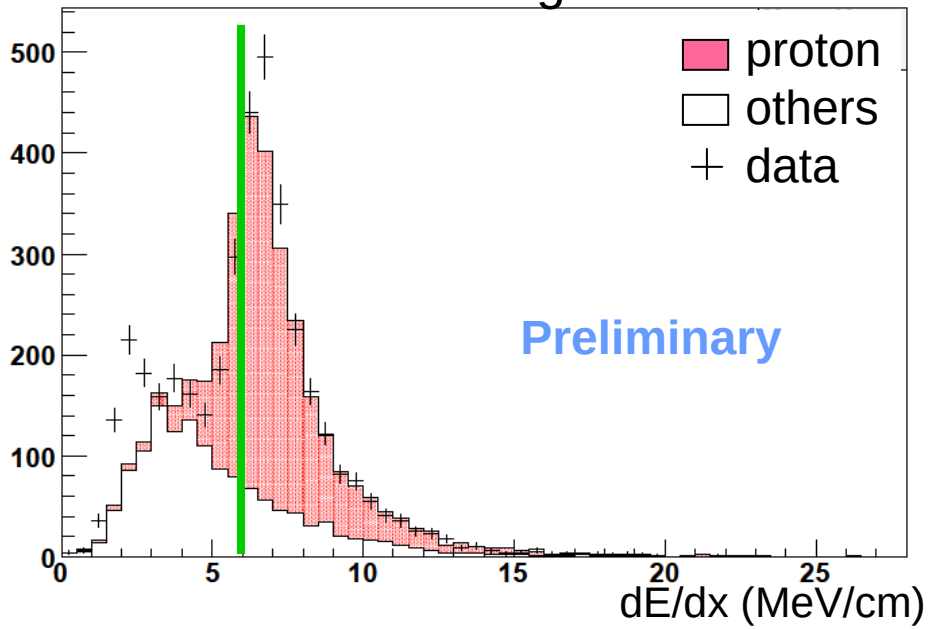
1 track event sample

normalized by MRD matched sample

events with track length 10 – 20 cm



events with track length 20 – 30 cm



Data agrees well with MC for events with dE/dx > 5 MeV/cm for short track length, and all events with long (>20 cm) track.

There is data excess in dE/dx < 5 MeV/cm region of short track events.
Dirt and cosmic events are cause of this discrepancy. They are eliminated bv cut and veto.

Summary

- Proton is signal of neutral current elastic scattering.

- 1 track events were studied. Effect of dirt events can be seen in vertex distribution.
  Cosmic and skyshine events are 7% of all on beam timing events.

- Proton is identified using dE/dx information.

- Dirt and cosmic events are removed by proton selection and veto.

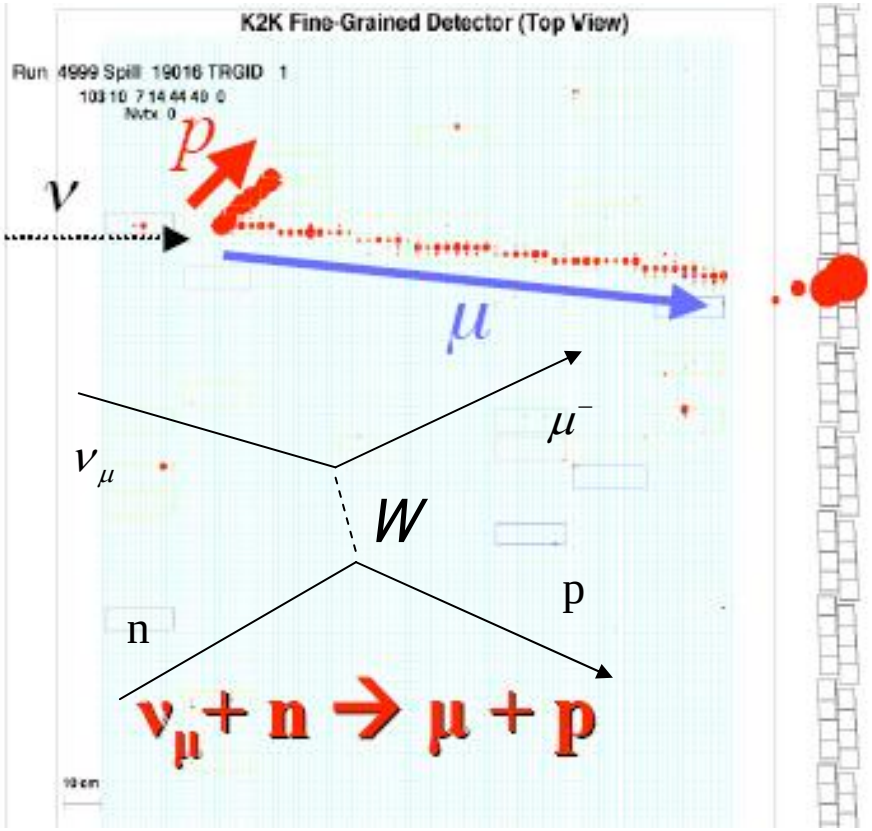
- Neutral current elastic scattering analysis is ongoing.

backup

Neutrino Events

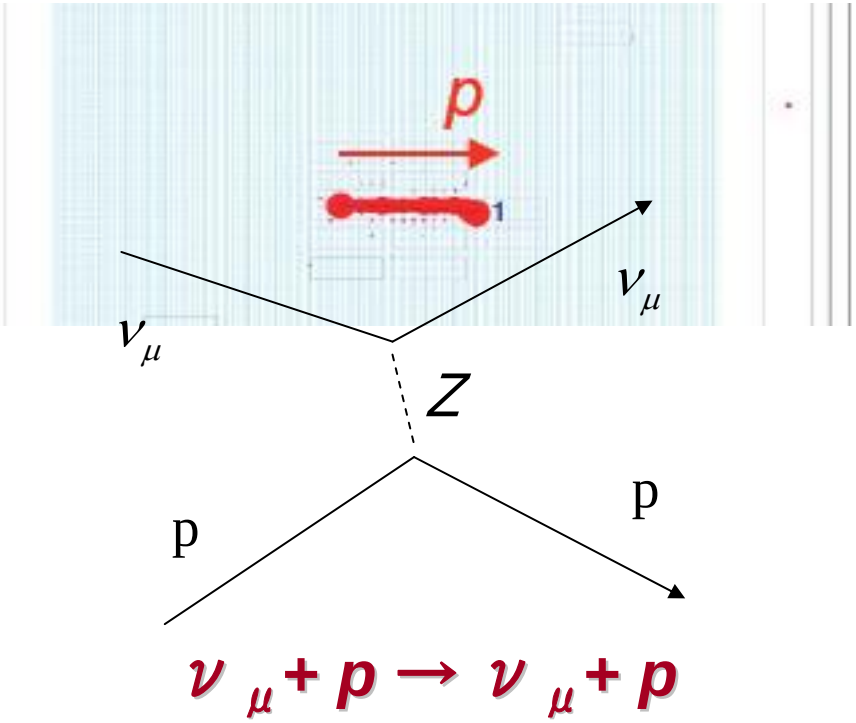
target: carbon, proton

Charged Current (CC) scattering



CC QE （ν +n→ μ +p）
（$\bar{\nu}$ +p→ μ +n）
CC−1pi＋（ν +N→ μ + π +N’）
CC coherent π production

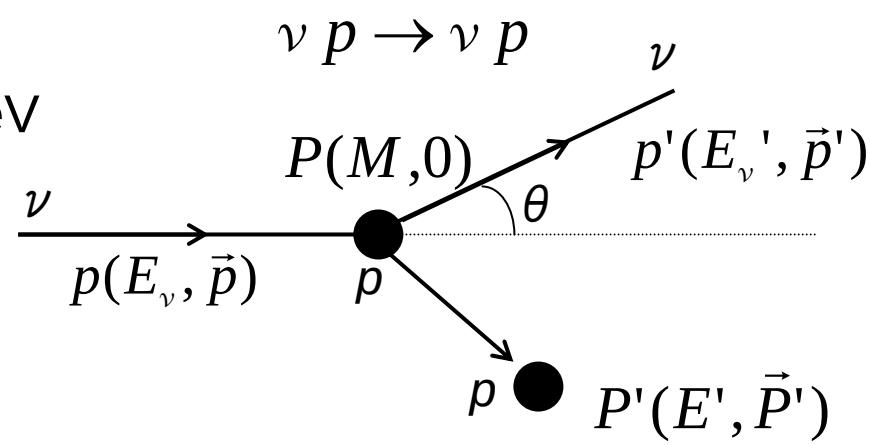
Neutral Current (NC) scattering



NC−1 π^0（ν +p→ ν +p+ π^0）
NC elastic （ν +p→ ν +p）
（$\bar{\nu}$ +p→ $\bar{\nu}$ +p）

Kinematics of Neutral Current Elastic Scattering

E_ν=1.0 GeV



$$Q^2 = -q^2 = -(p - p')^2$$

m_p=938MeV

$$Q^2 = 2m_p E_{kin}$$

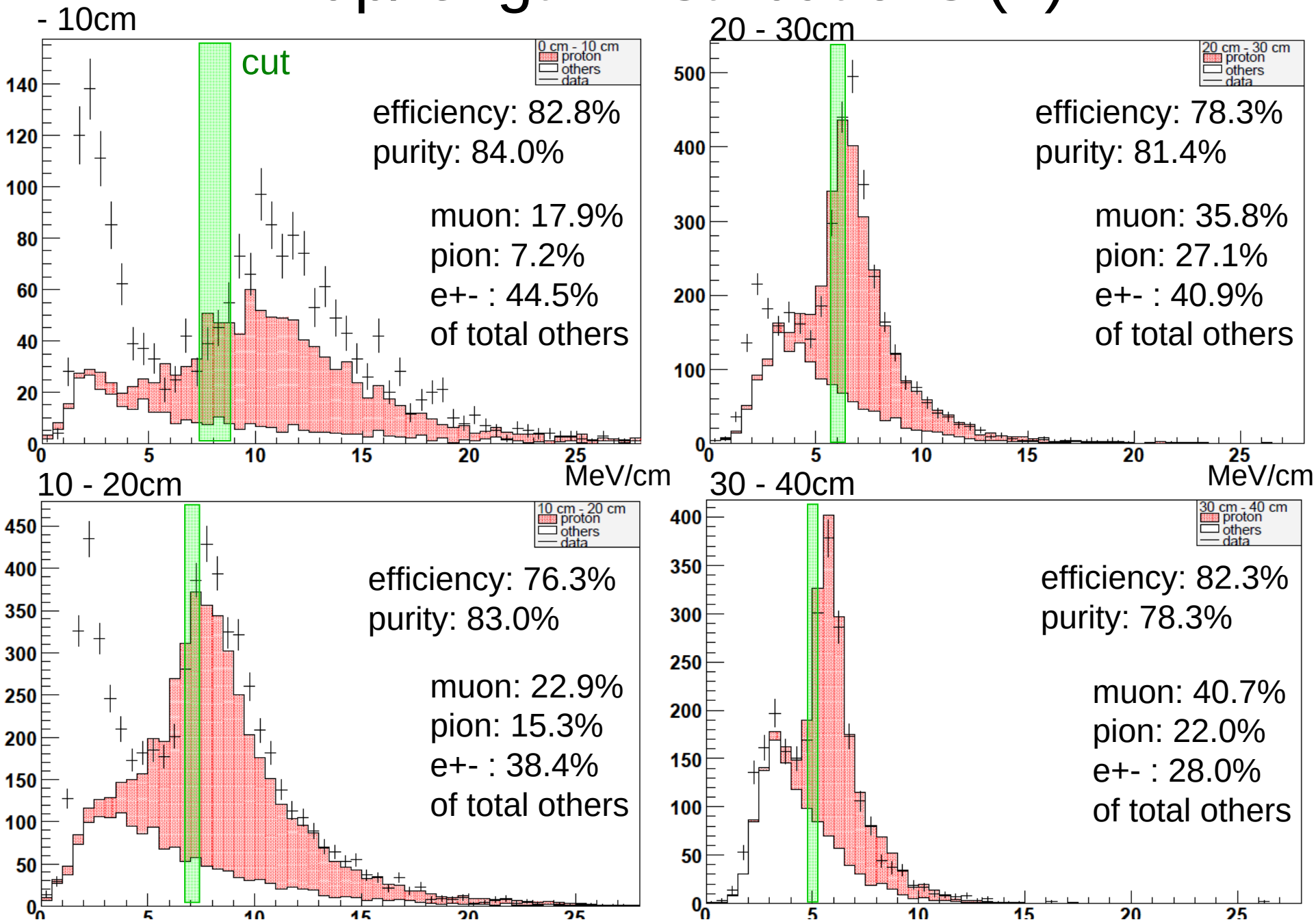
(with no approximation)

E_{kin}: kinetic energy of recoil proton

E_{kin} is reconstructed using energy deposit information in SciBar.

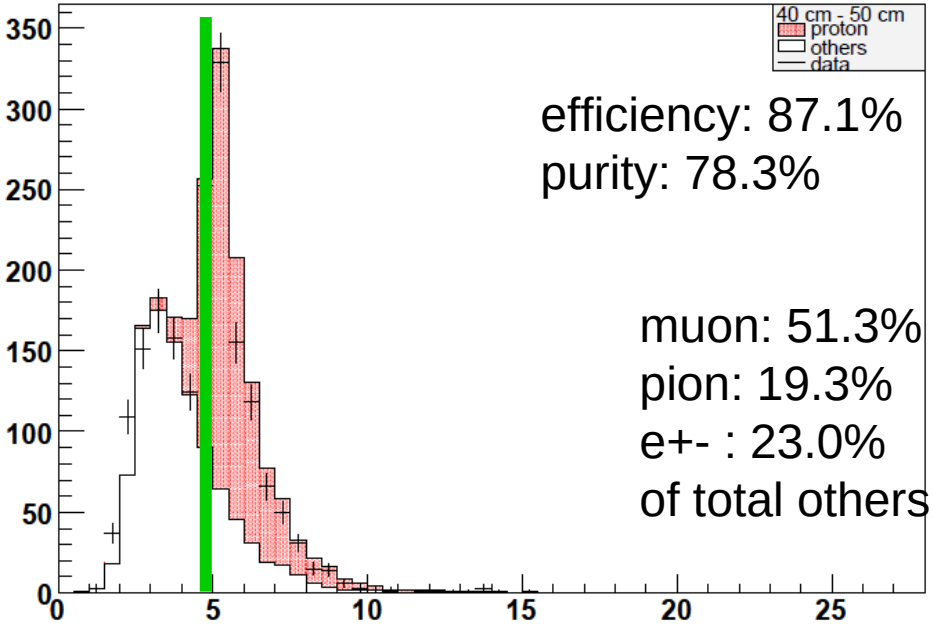
Q^2 can be determined without knowing incident energy nor scattering angle.

Edp/length Distributions (1)



Edp/length Distributions (2)

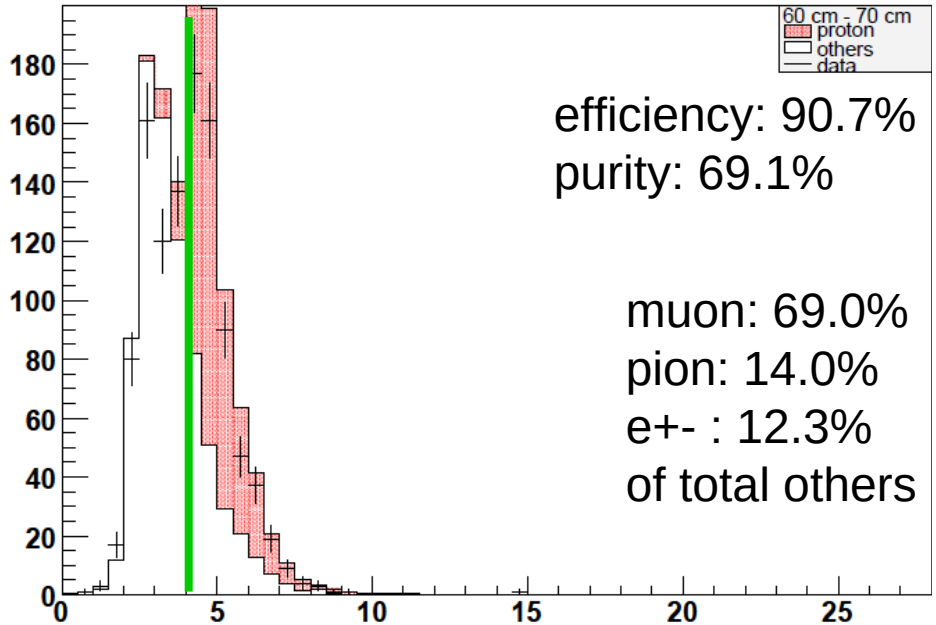
40 - 50cm



efficiency: 87.1%
purity: 78.3%

muon: 51.3%
pion: 19.3%
e+- : 23.0%
of total others

60 - 70cm

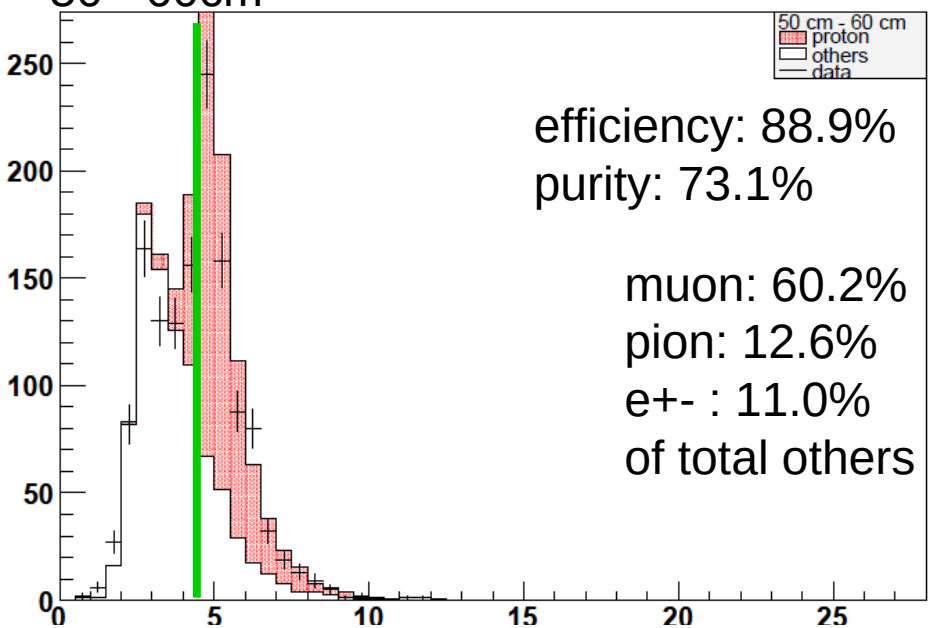


efficiency: 90.7%
purity: 69.1%

muon: 69.0%
pion: 14.0%
e+- : 12.3%
of total others

MeV/cm

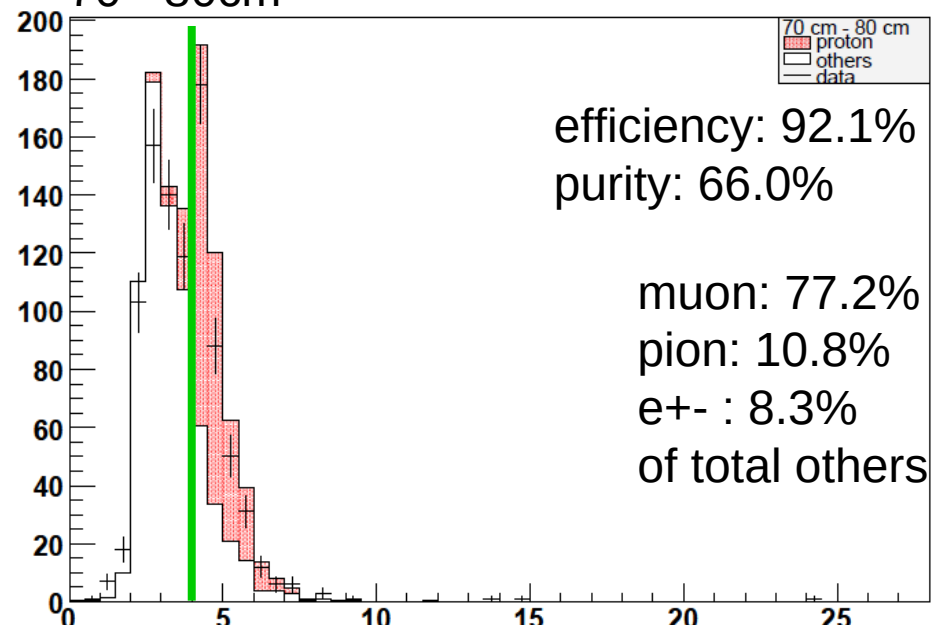
50 - 60cm



efficiency: 88.9%
purity: 73.1%

muon: 60.2%
pion: 12.6%
e+- : 11.0%
of total others

70 - 80cm



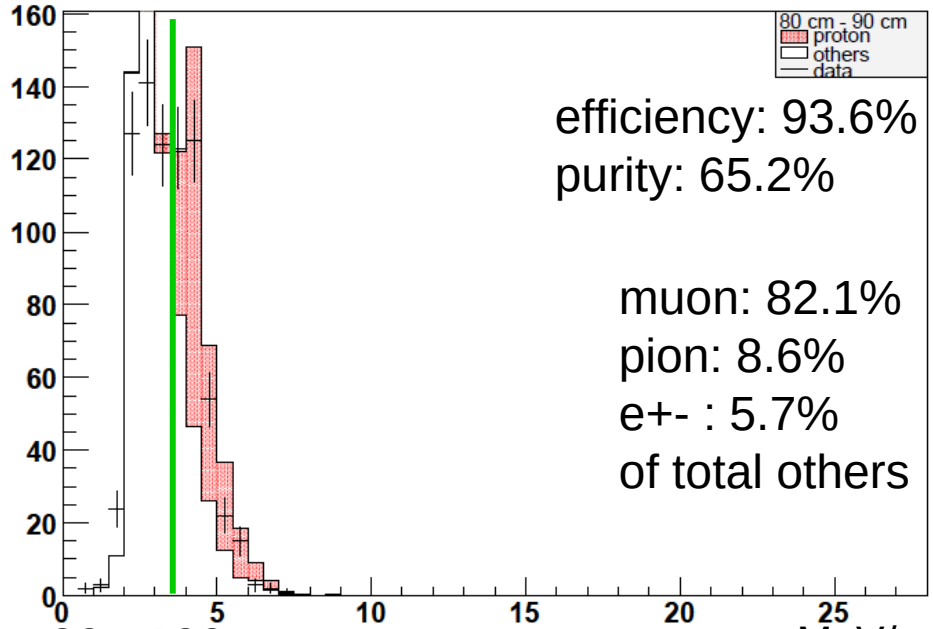
efficiency: 92.1%
purity: 66.0%

muon: 77.2%
pion: 10.8%
e+- : 8.3%
of total others

MeV/cm

Edp/length Distributions (3)

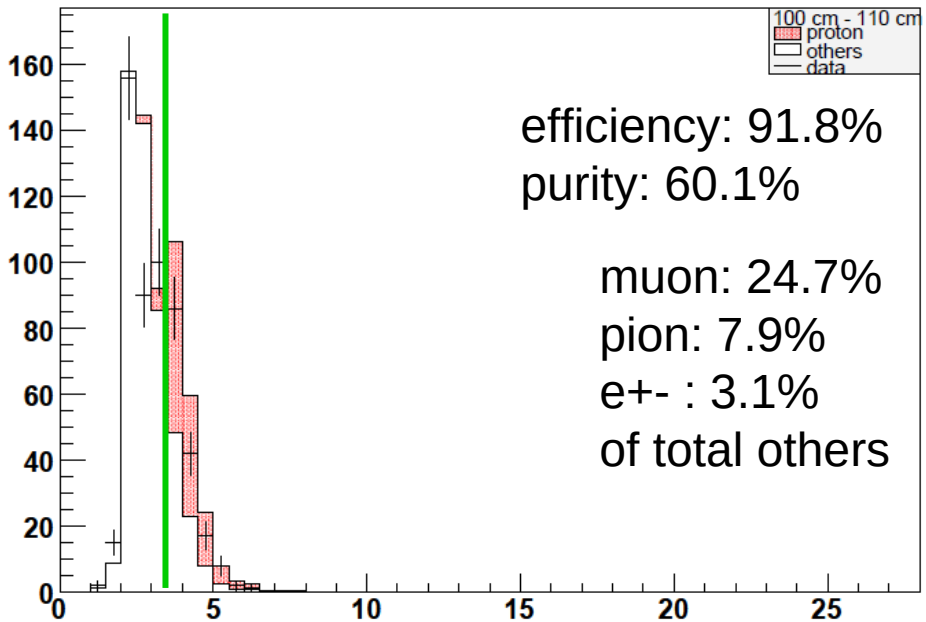
80 - 90cm



efficiency: 93.6%
purity: 65.2%

muon: 82.1%
pion: 8.6%
e+- : 5.7%
of total others

100 - 110cm

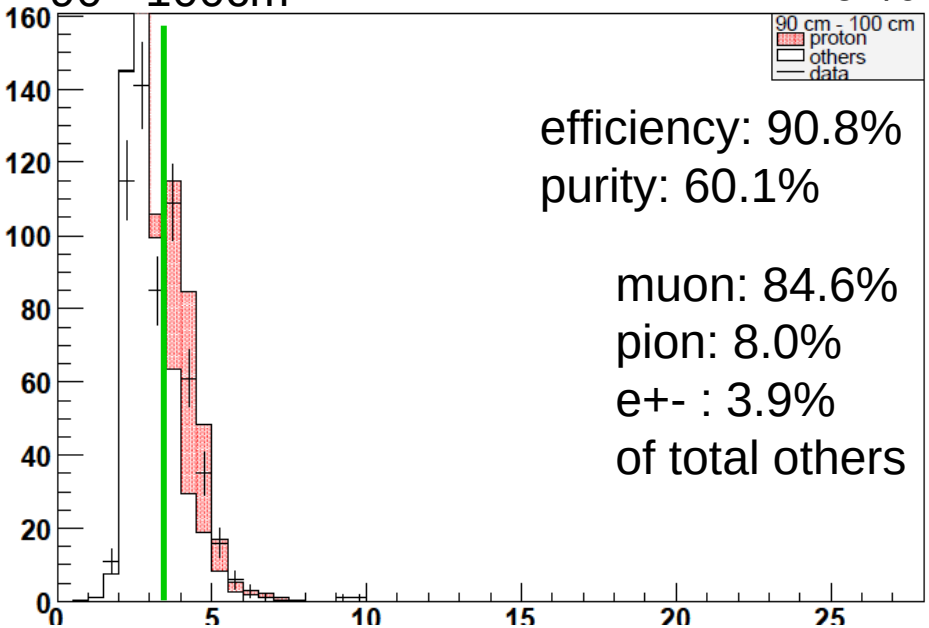


efficiency: 91.8%
purity: 60.1%

muon: 24.7%
pion: 7.9%
e+- : 3.1%
of total others

90 - 100cm

MeV/cm

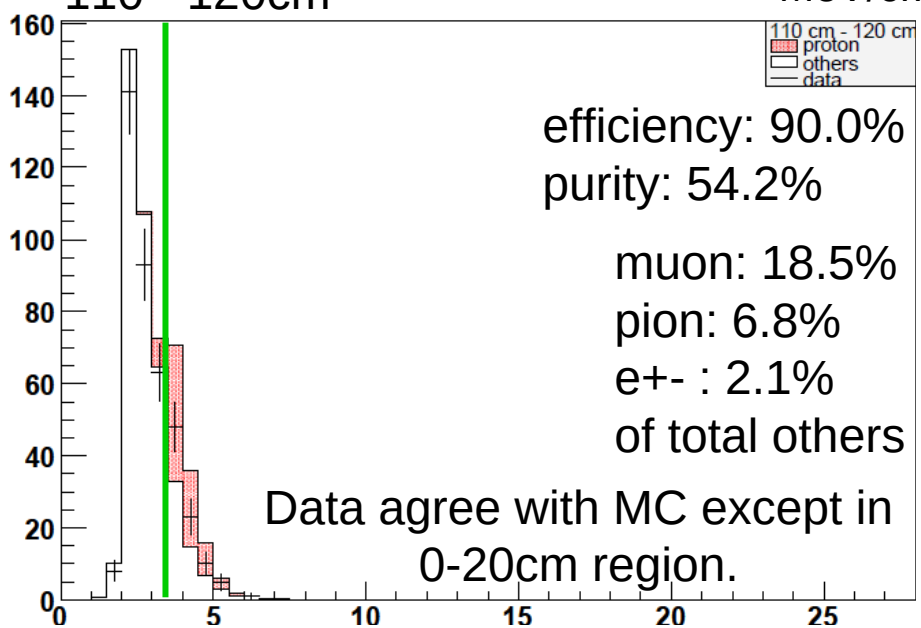


efficiency: 90.8%
purity: 60.1%

muon: 84.6%
pion: 8.0%
e+- : 3.9%
of total others

110 - 120cm

MeV/cm



efficiency: 90.0%
purity: 54.2%

muon: 18.5%
pion: 6.8%
e+- : 2.1%
of total others

Data agree with MC except in 0-20cm region.

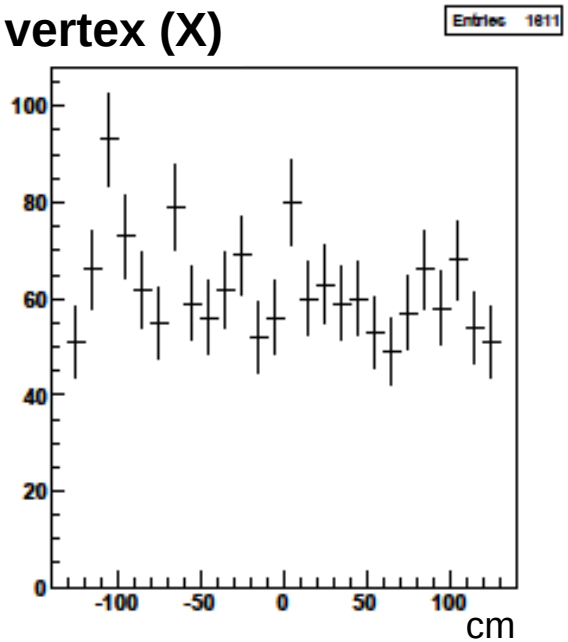
Number of Events

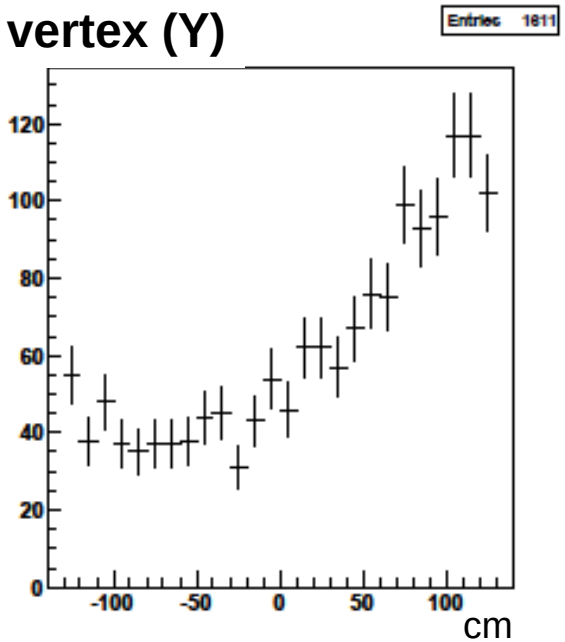
MC
4.1E20POT

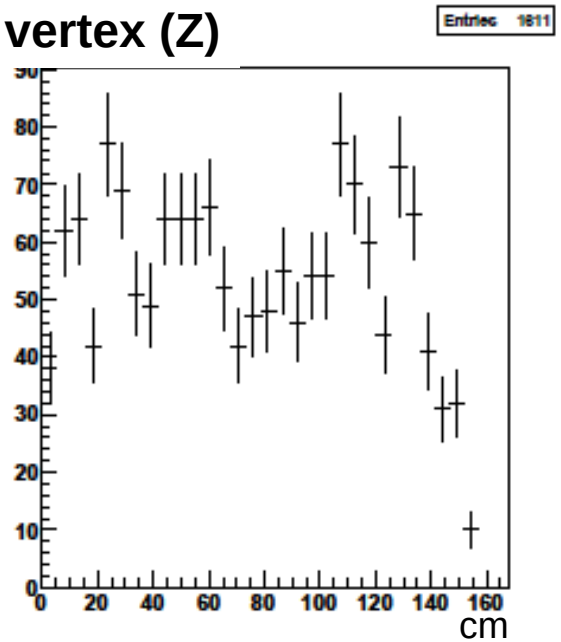
interaction	total	1st reduction	2nd reduction	proton cut
NC(p)	48034	38798 (80.8%)	15625 (32.5%)	9968 (20.7%)
NC(n)	59735	47905 (80.2%)	7658 (12.8%)	4209 (7.0%)
CCQE	255384	237456 (93.0%)	25388 (9.9%)	8078 (3.2%)
CC1pi	152902	144049 (94.2%)	16660 (10.9%)	7328 (4.8%)
NC1pi	47265	42061 (89.0%)	11505 (24.3%)	5102 (10.8%)
CC multi-pi	26600	26239 (98.6%)	2075 (7.8%)	926 (3.5%)
NC multi-pi	8031	7845 (97.7%)	1415 (17.6%)	691 (8.6%)
DIS	4470	4413 (98.7%)	108 (2.4%)	35 (0.8%)
Data 7.7E19POT		1809722	33710	18323

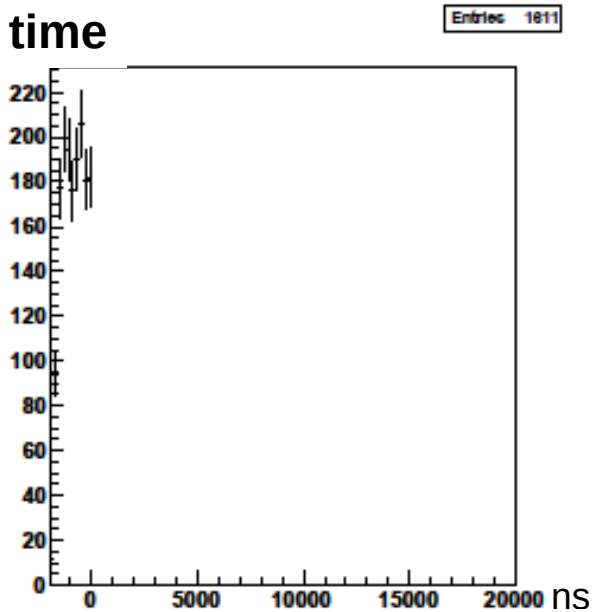
Proton selection cut efficiency for NC(p) is 20.7%,
for NC(p)+NC(n) is 13.2%

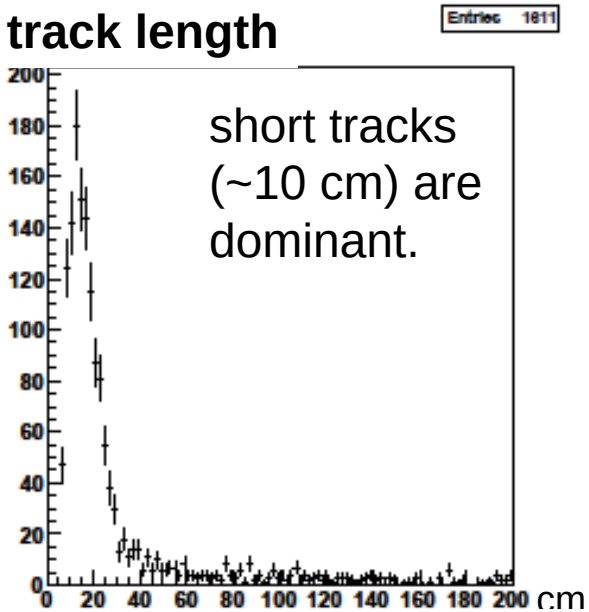
Vertex Distributions (-2000 ≤ t < 0)







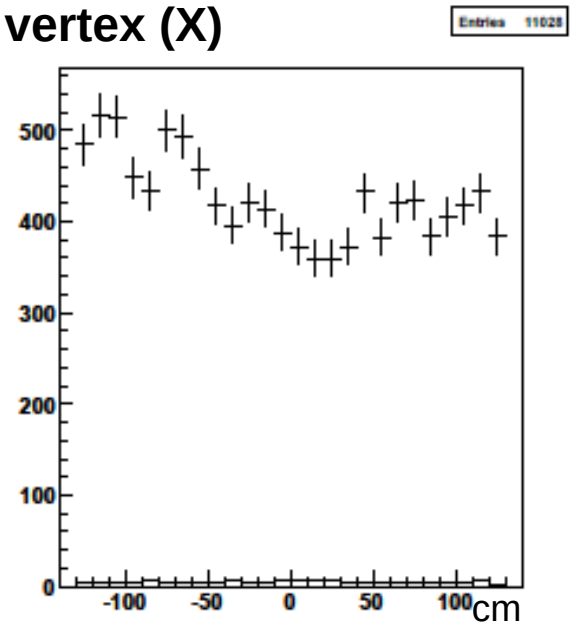


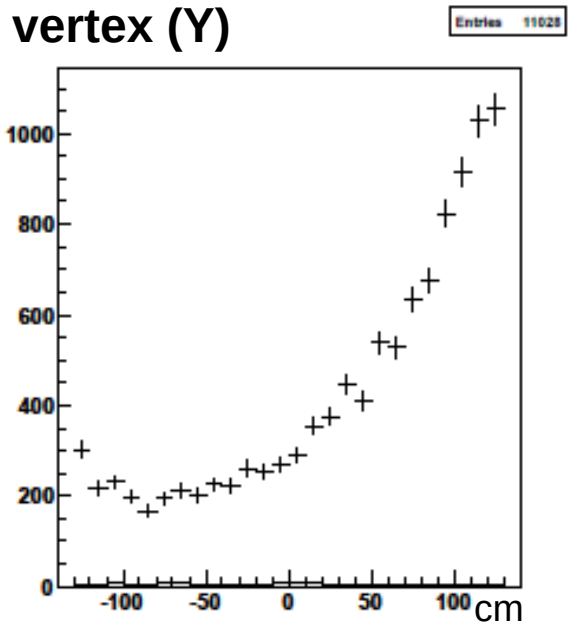


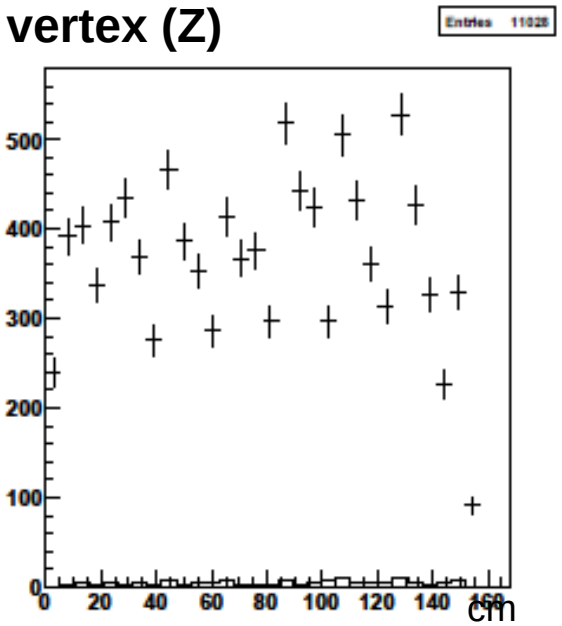
2nd reduction data

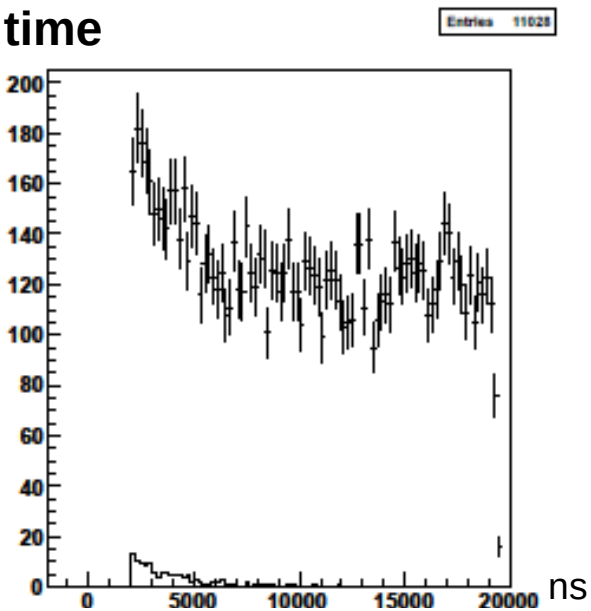
There are large number of events in y>0 region due to cosmic muon.

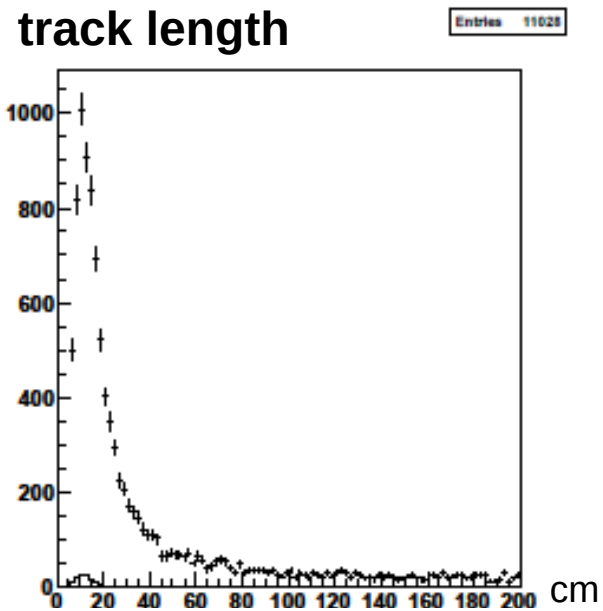
Vertex Distributions (2000 < t ≤ 20000)











2nd reduction data

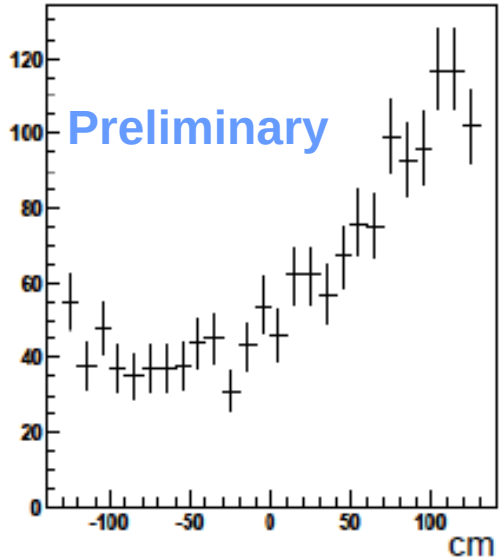
There are large number of events in y>0 region.

Proton selection cut will be applied.

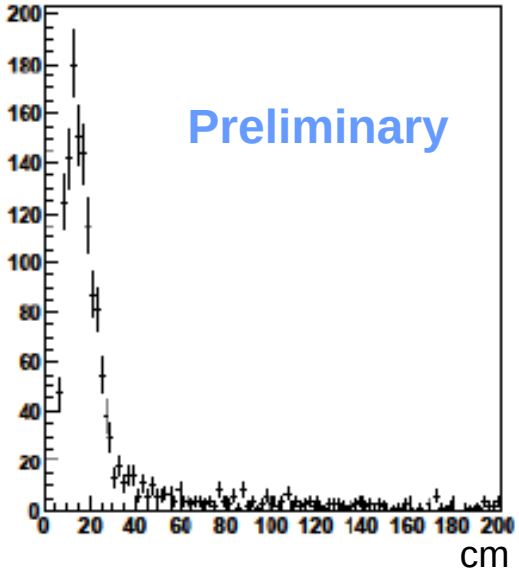
Vertex Distributions (off beam timing)

before beam
$-2 \leq t < 0$ μs

vertex (Y)



track length

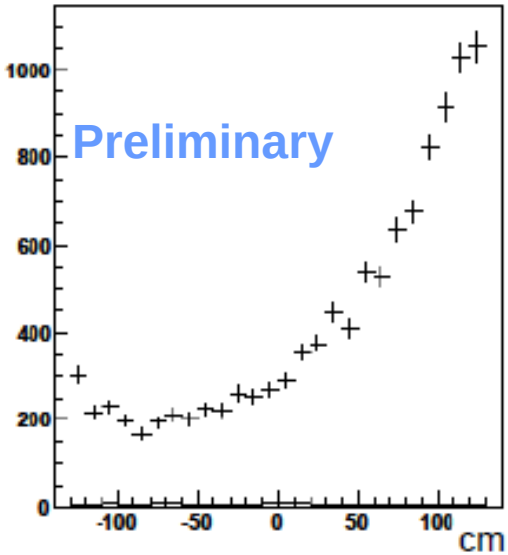


Asymmetry appears in Y distribution due to cosmic.

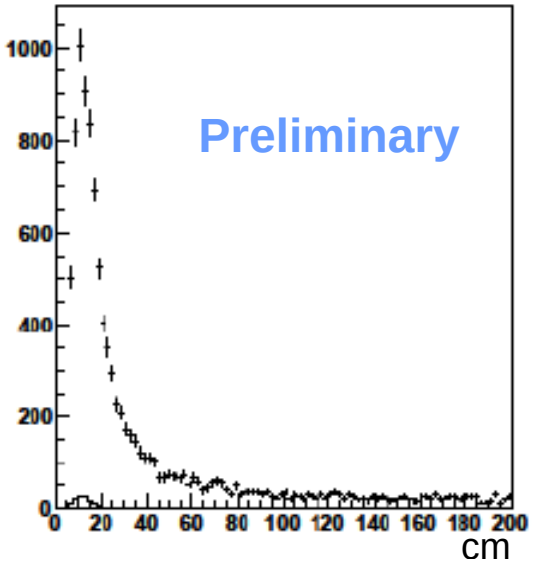
Short tracks (~10cm) are dominant.

after beam
$2 < t \leq 20$ μs

vertex (Y)



track length

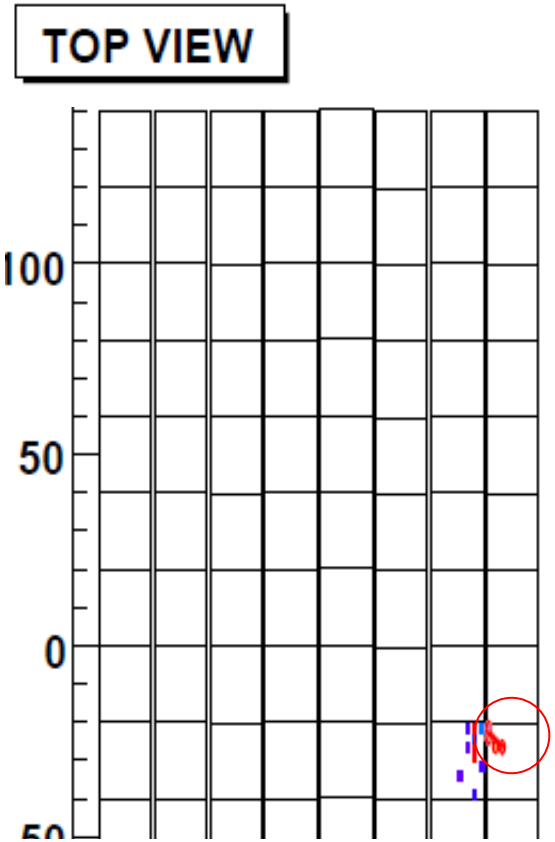


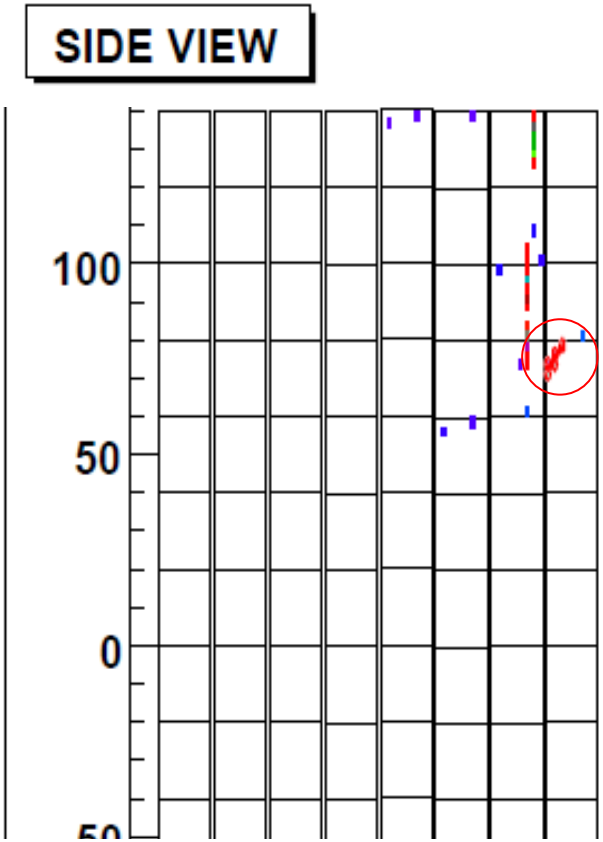
Asymmetry appears in Y distribution due to cosmic and skyshine.

Short tracks (~10cm) are dominant.

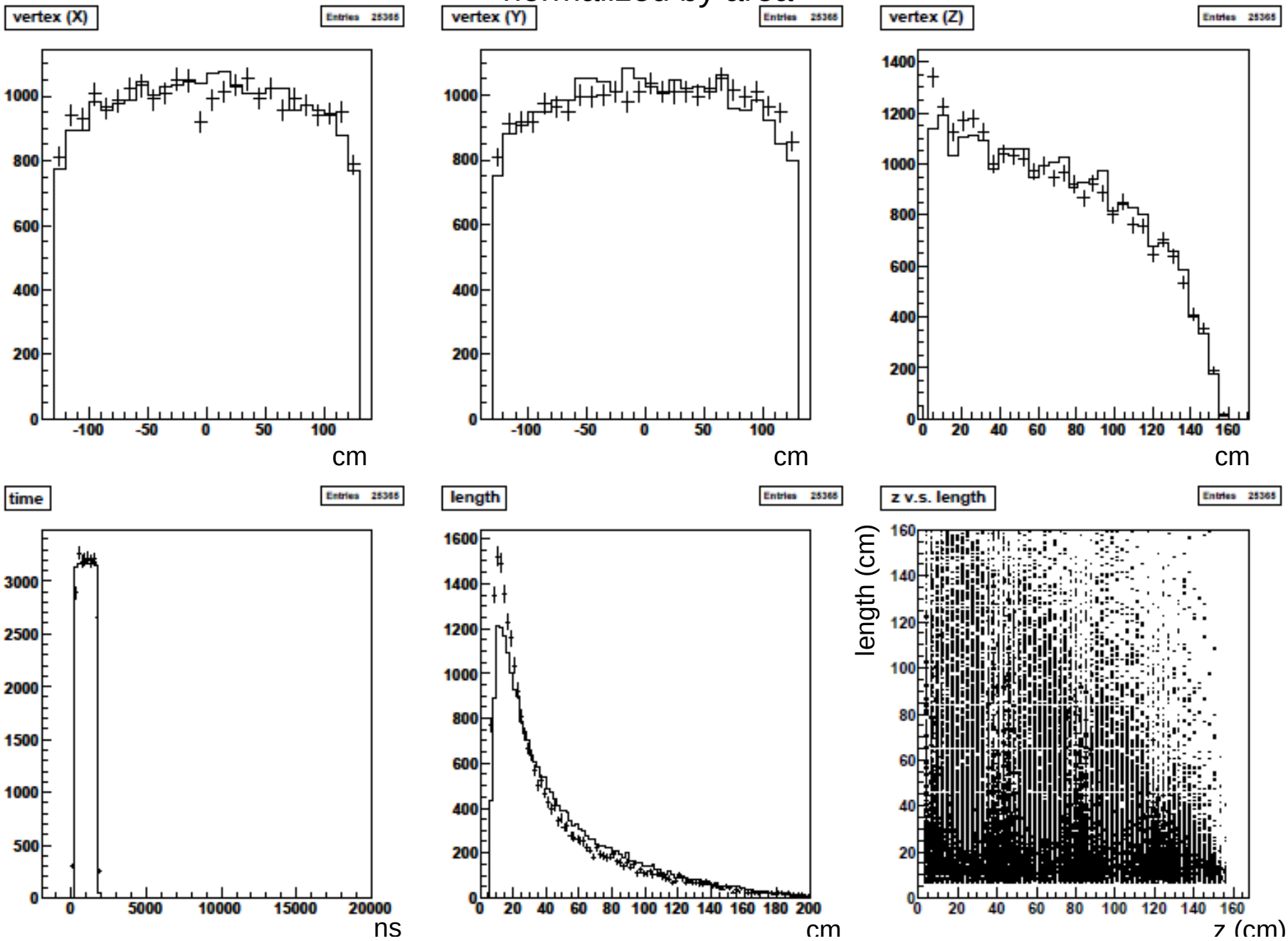
Event Display

possible candidate of Michel decay





This event can pass proton filter due to counting energy deposit of both muon and electron.

Vertex Distributions (on beam timing)

normalized by area