"First Look at Fully Reconstructed

$p \rightarrow l^+\rho^0$ & $p \rightarrow \mu^+K^0$ events"

NORMAN MARTINEZ/HECTOR MENDEZ
UNIVERSITY OF PUERTO RICO
(JULY 20, 2016)

Outline

i.- $p \rightarrow \mu^+\rho^0$ and $p \rightarrow e^+\rho^0$ and $p \rightarrow \mu^+K^0$

ii.- Generation (GENIE) & Reconstruction (DUNE 10KT) (LArSoft_v05_14_01)

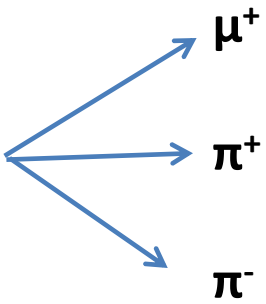
DEEP UNDERGROUND NEUTRINO EXPERIMENT

$p \rightarrow \mu^+ \rho^0(770)$

Main decay mode: $\pi^+\pi^-$ $(\sim 100\%)$

Natural width: $\Gamma_{\rho^0} = 149\ MeV$

Very wide ! and Prompt decay (just 1 vertex)

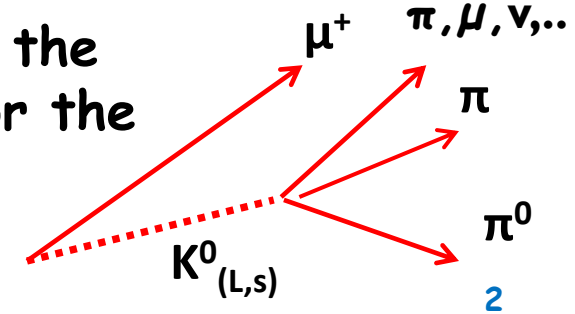


Lifetime Limit: $\tau_p > 0.16 \times 10^{33}$ years (1 candidate [SK-2012])

$p \rightarrow e^+ \rho^0$

Lifetime Limit: $\tau_p > 0.71 \times 10^{33}$ years (0 candidates [SK-2012])

The final state of this mode is very similar to the exclusive p decay mode $p \rightarrow l^+ K^0$ except for the displaced K^0 decay vertex.



Generation and Reconstruction Steps

Generated 1000 events in GENIE in the standalone mode and passed them to DUNE 10 kT through Geant.

- gen [P^{μ}](GENIE):

```
gevgen_ndcy -g 1000180400 -m 4 -n 1000 -o p2murho.root
gevdump -f p2murho.1000.ghep.root > p2murho.out
```

ρ^0 decay in GENIE, in the nucleus, so the pions go to geant..
K^0 decay in Geant (not in GENIE)

- gen → LArSoft

```
lar -c prodndkGolden.fcl -n 1000 -o p2murho_2.root
```

- geant-4 (Energy Deposition)

```
lar -c standard_g4_dune10kt_1x2x6.fcl
```

- detsim (Digitalization/hits)

```
lar -c standard_detsim_dune10kt_1x2x6.fcl
```

This step take too long !

- reco (Reconstruction)

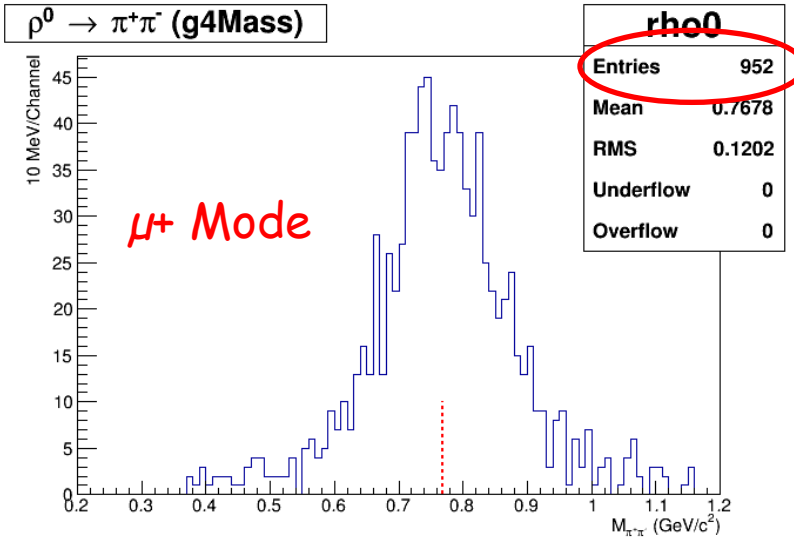
```
lar -c standard_reco_dune10kt_1x2x6.fcl
```

- anal (produce an n-tuple from module NueAna_module.cc)

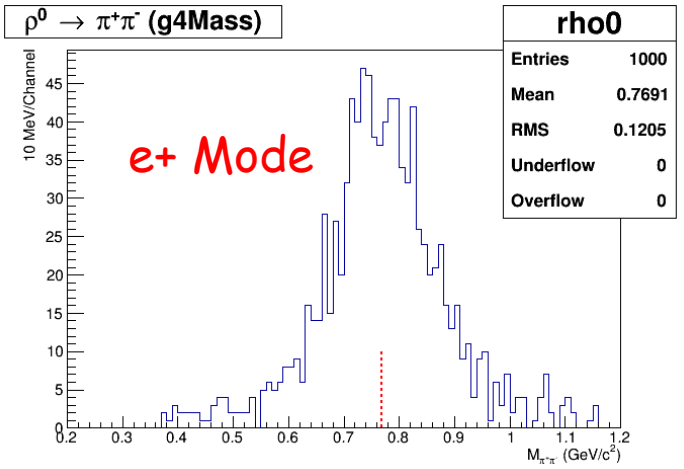
```
lar -c standard_ana_dune10kt_1x2x6.fcl
```

ρ^0 Mode

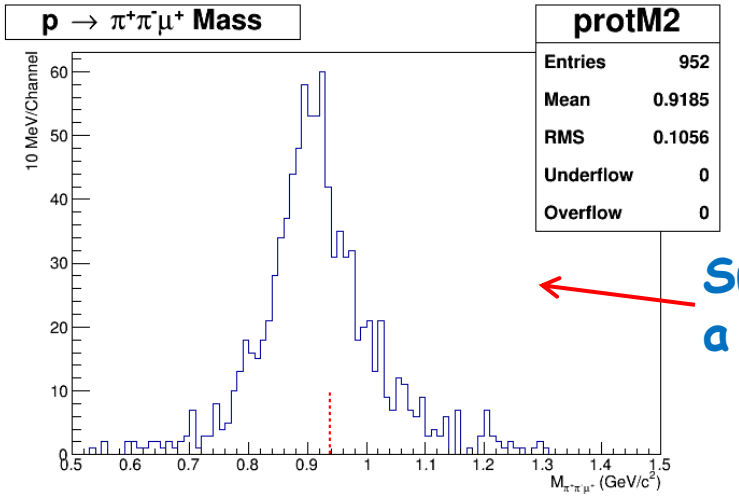
~5% missing (48 evts with no proton decay in GENIE)



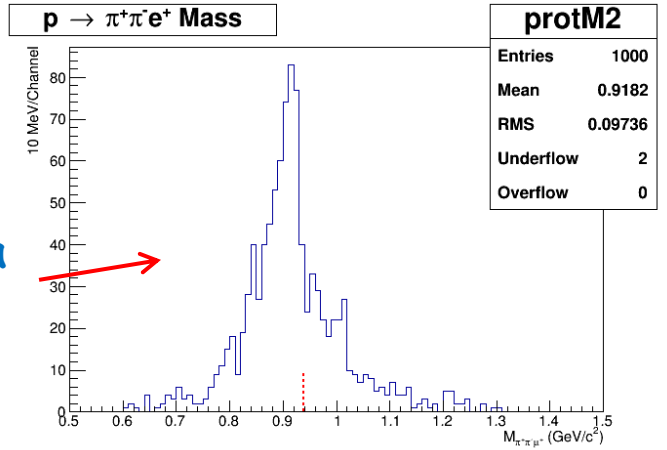
μ+ Mode



e+ Mode



Supposed to be a a narrow peak !



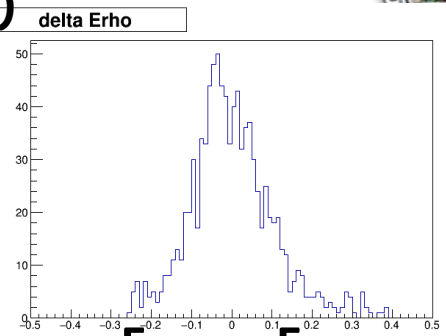
Soon to be fixed
(reported already to GENIE's group)

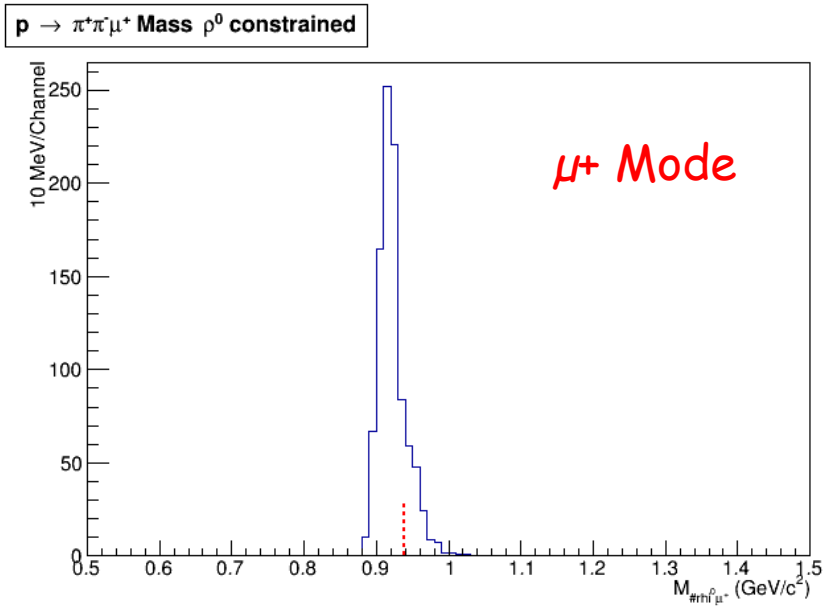
ρ^0 mass Constraint

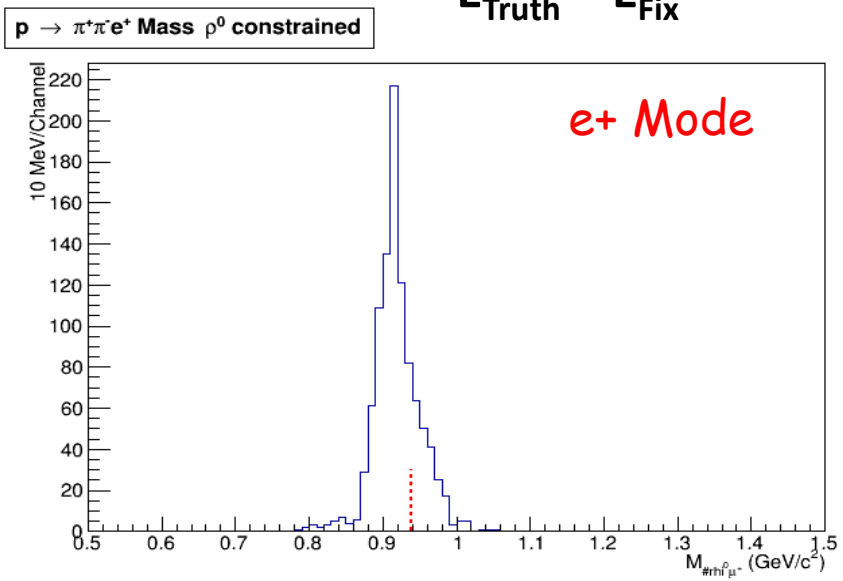
(to increase the p mass resolution)

$$E^2_{\rho 0} = M^2_{\rho 0} + P^2_{\rho 0}$$

0.77 GeV (pdg mass)





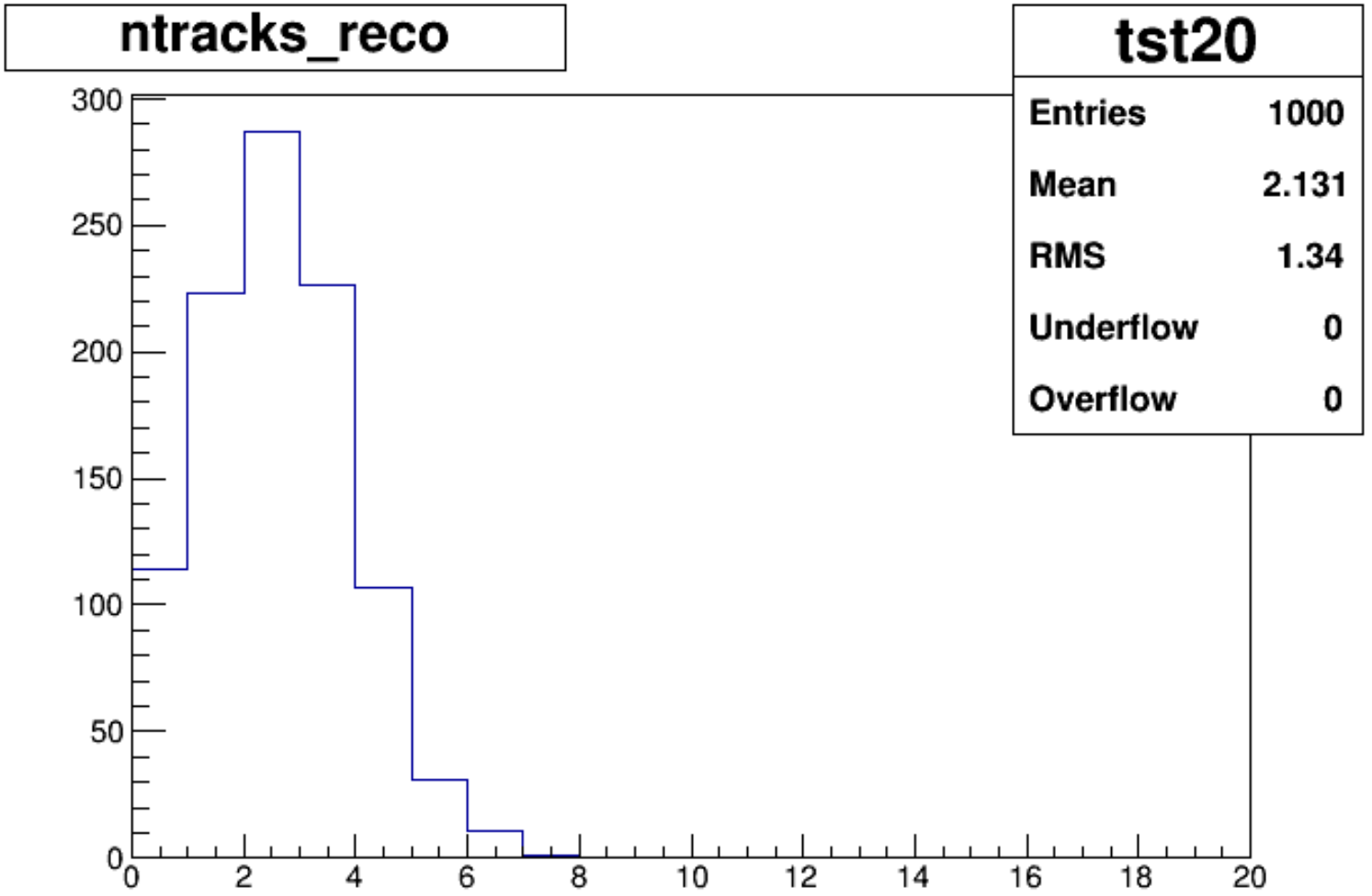


μ^+ almost always decay here

$$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$$

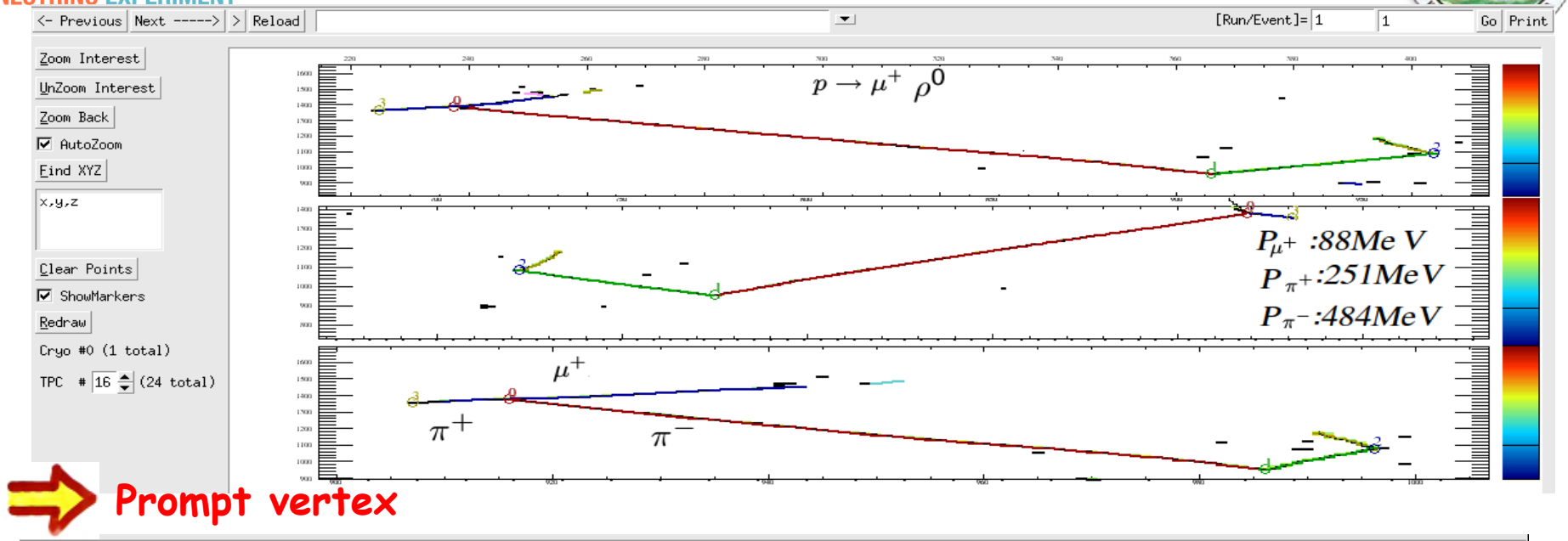
(expect reconstruct fewer μ+ (slide 8))

Track Reconstruction

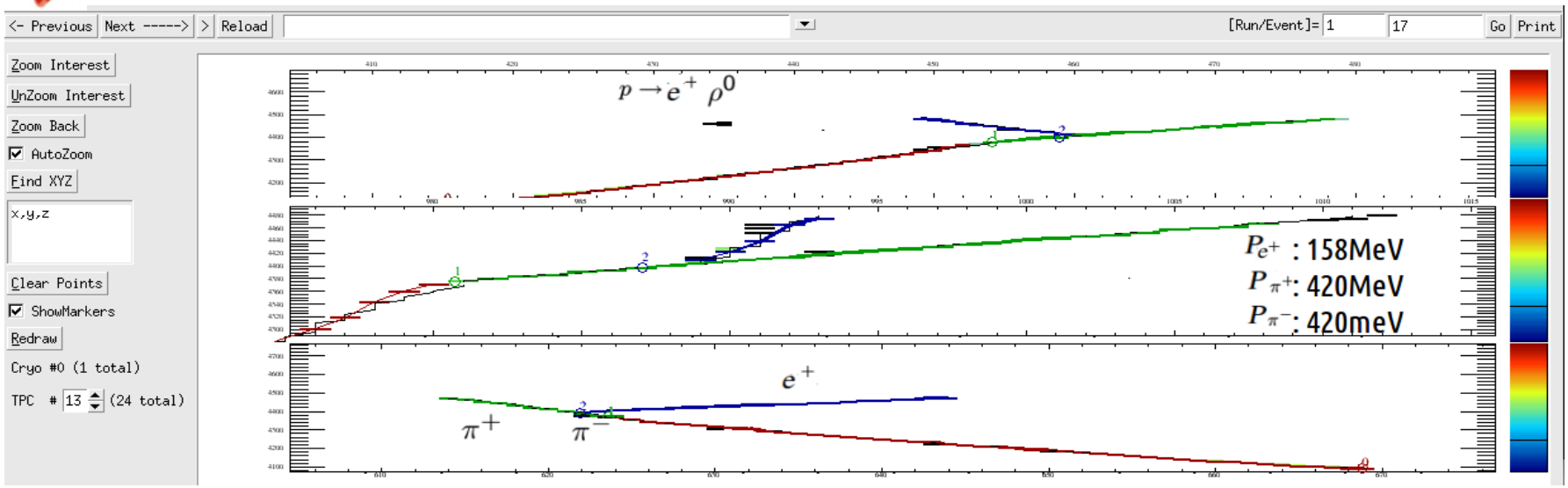


Almost same track multiplicity in both mode.

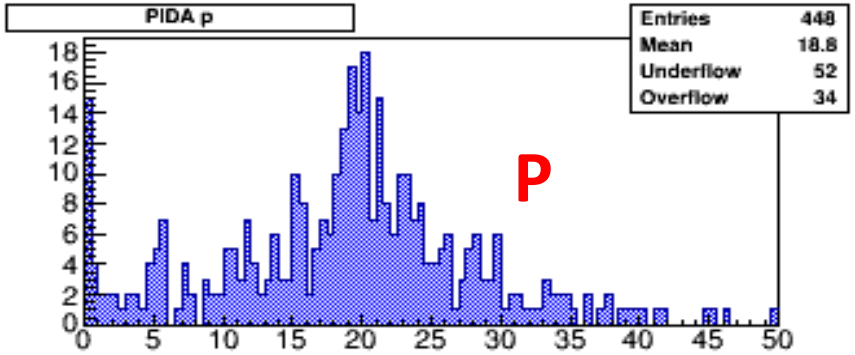
Event Display

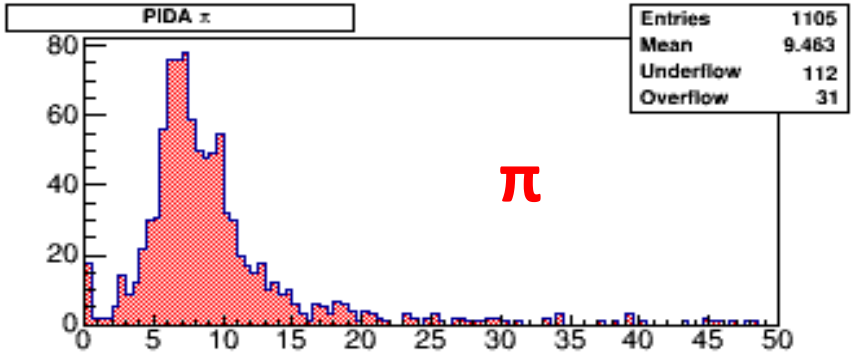


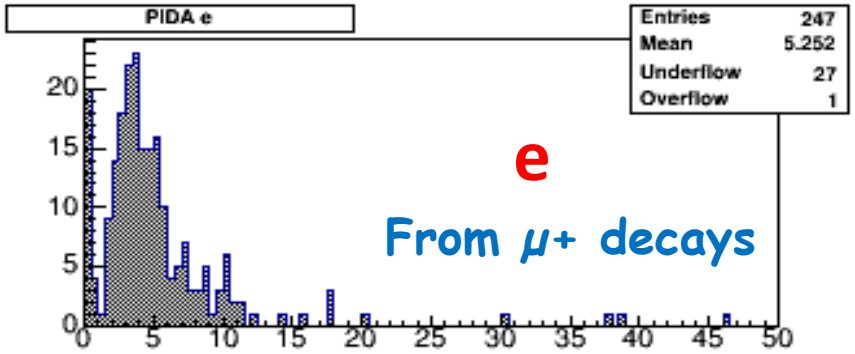
Prompt vertex

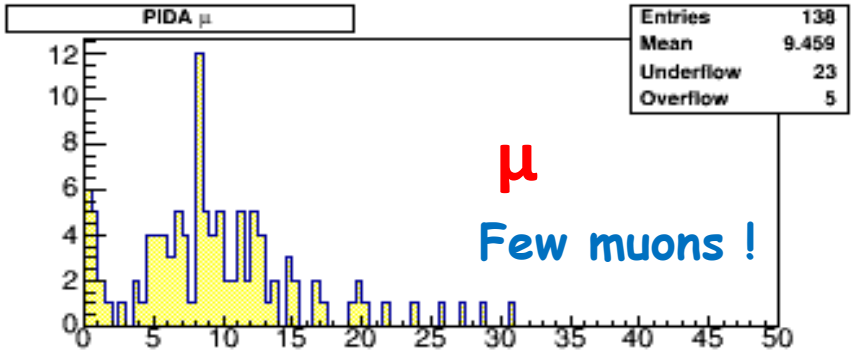


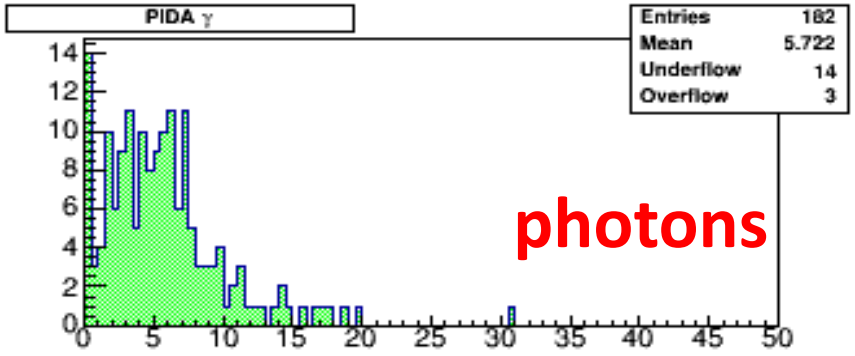
PIDA distributions (as expected)





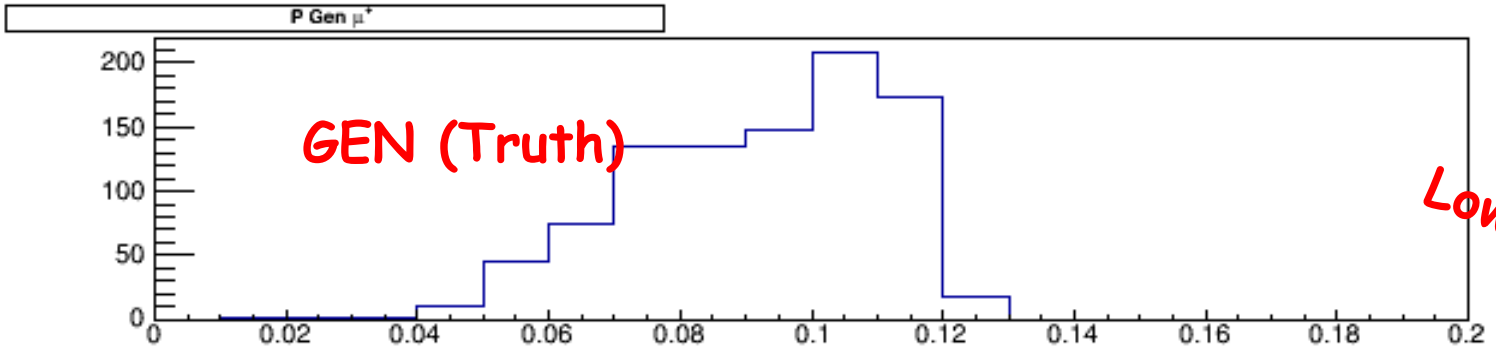




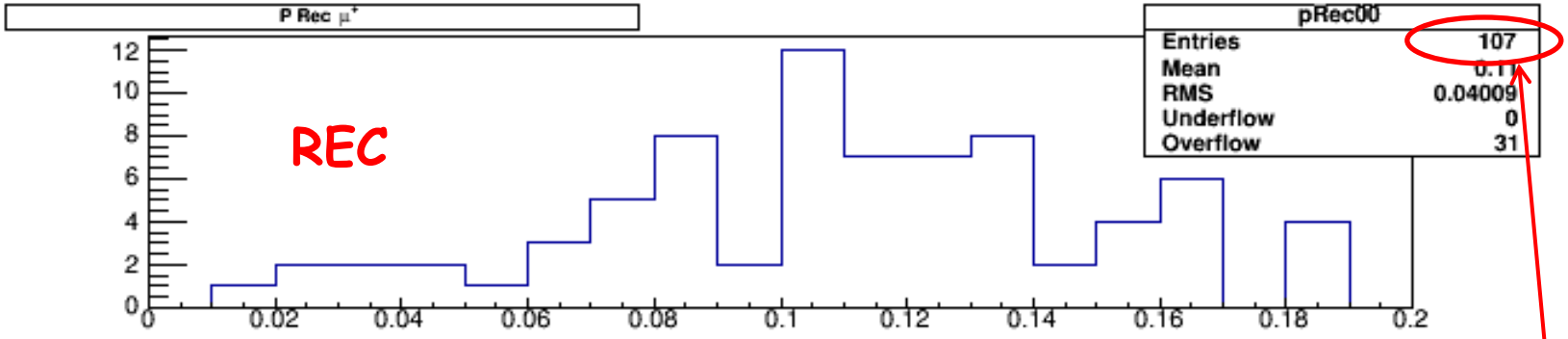


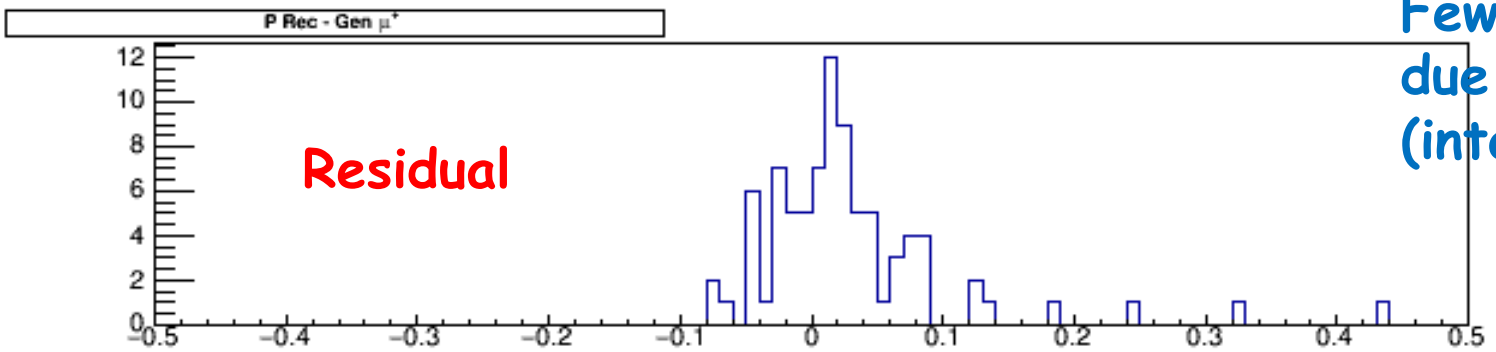
$$\text{PIDA} = \frac{dE}{dx}\, r^{0.42} \quad for\ each\ track$$

Momentum Comparison



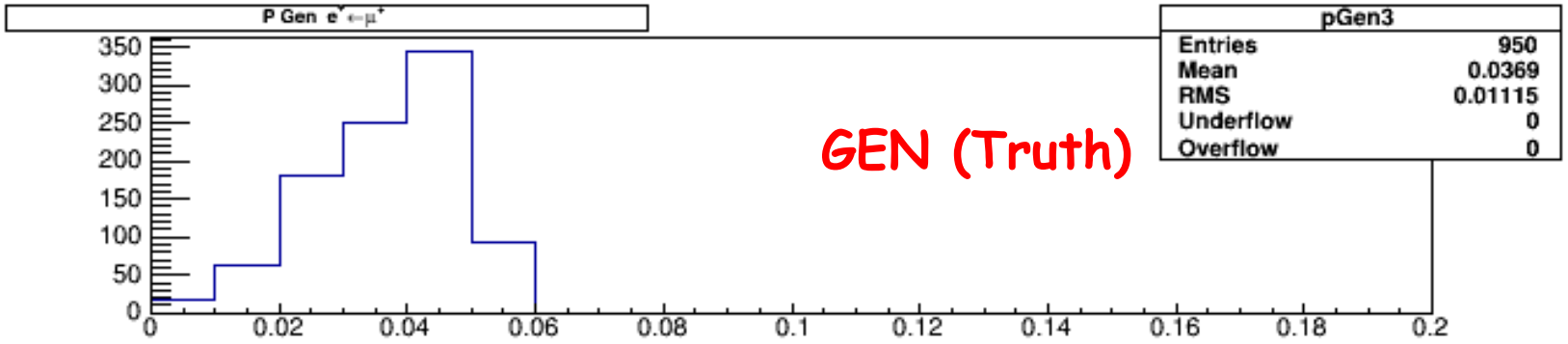
Low Momentum

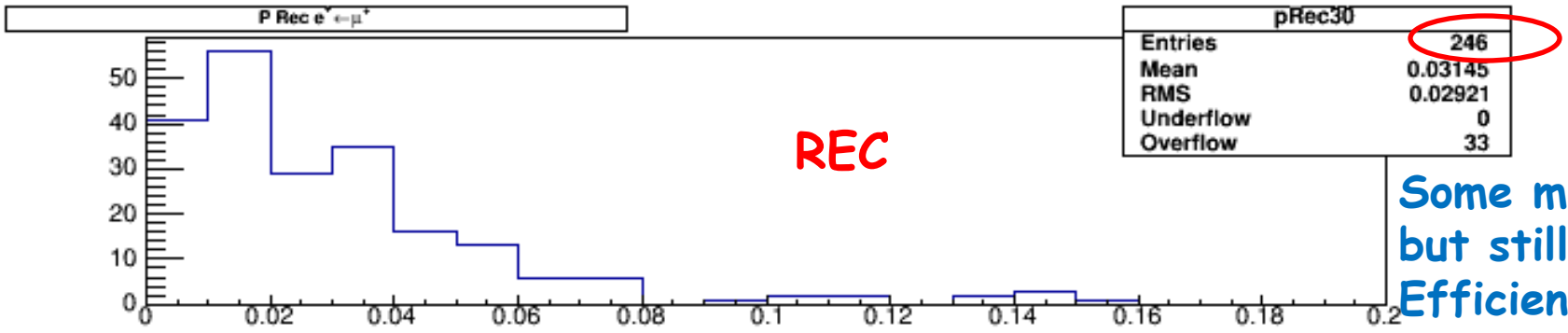




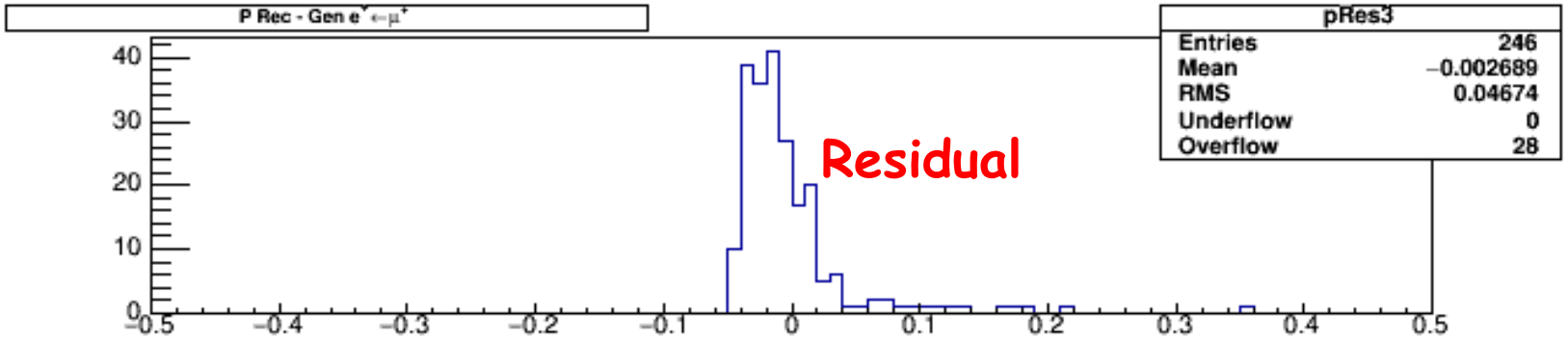
Few entries due to μ+ decays (into e+)

e^+ from μ^+





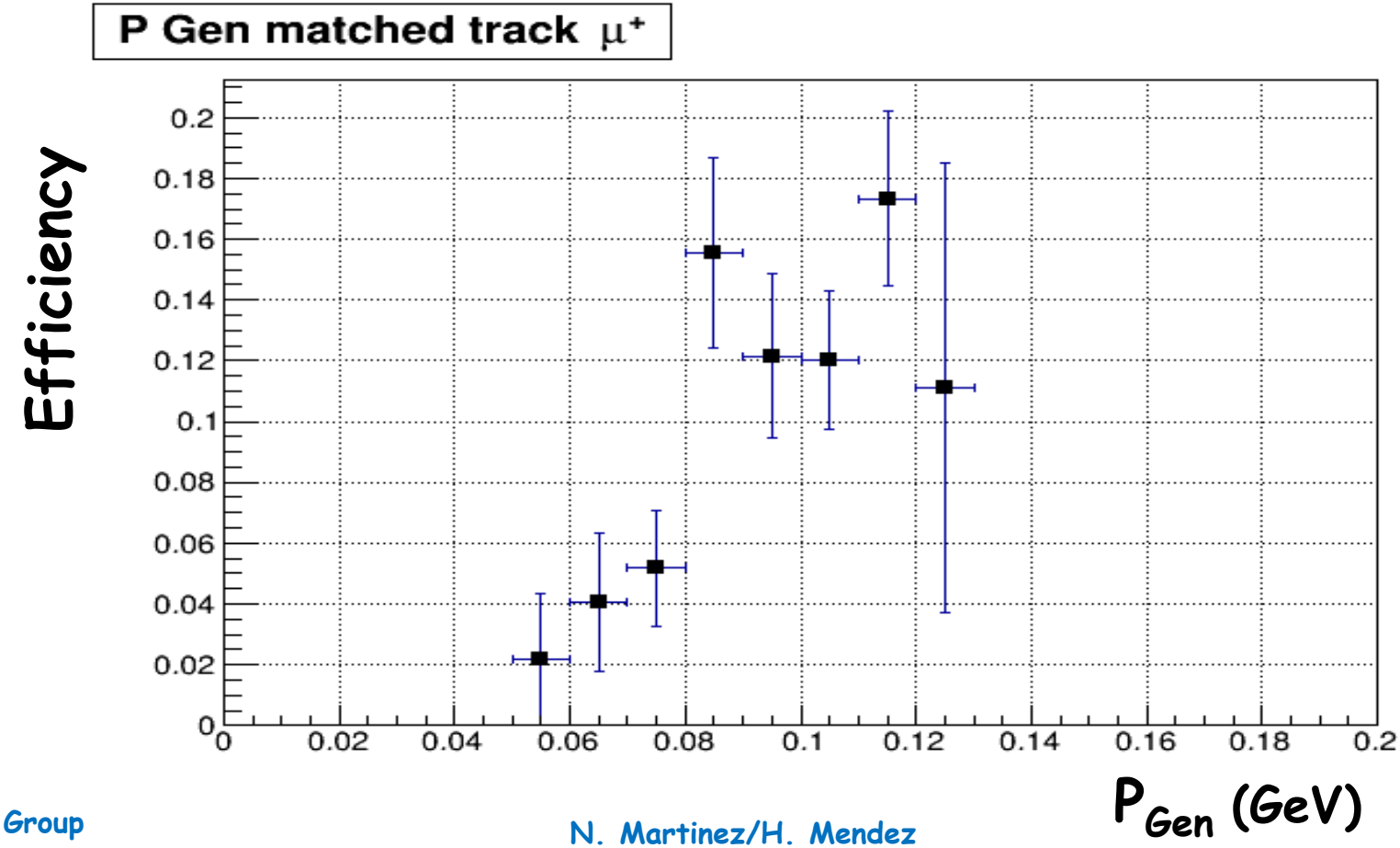
Some more but still low Efficiency.



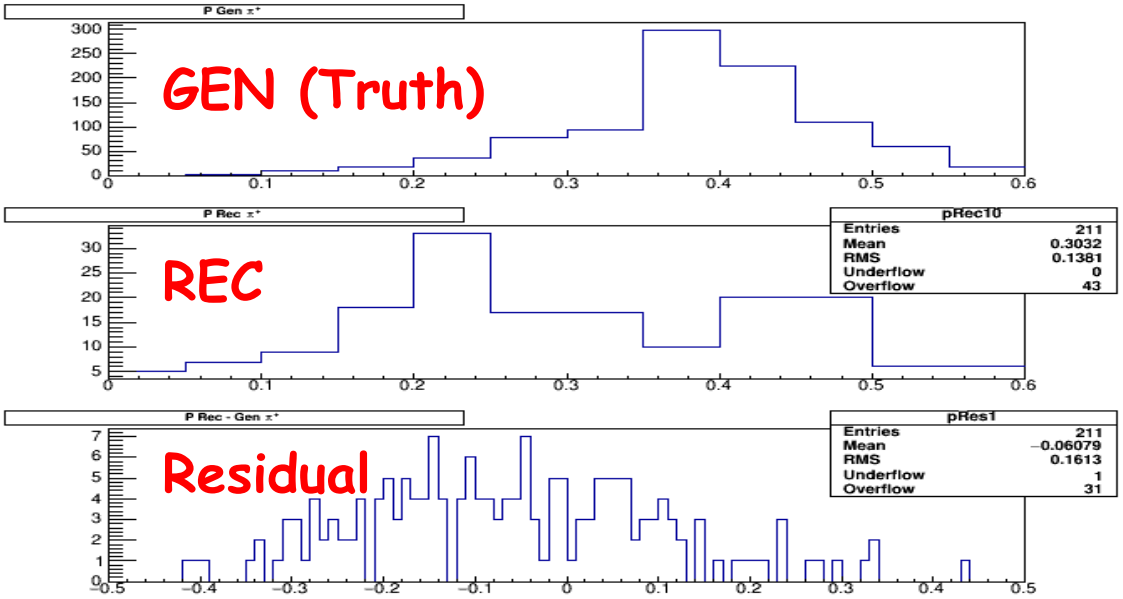
μ^+ Reconstruction Efficiency

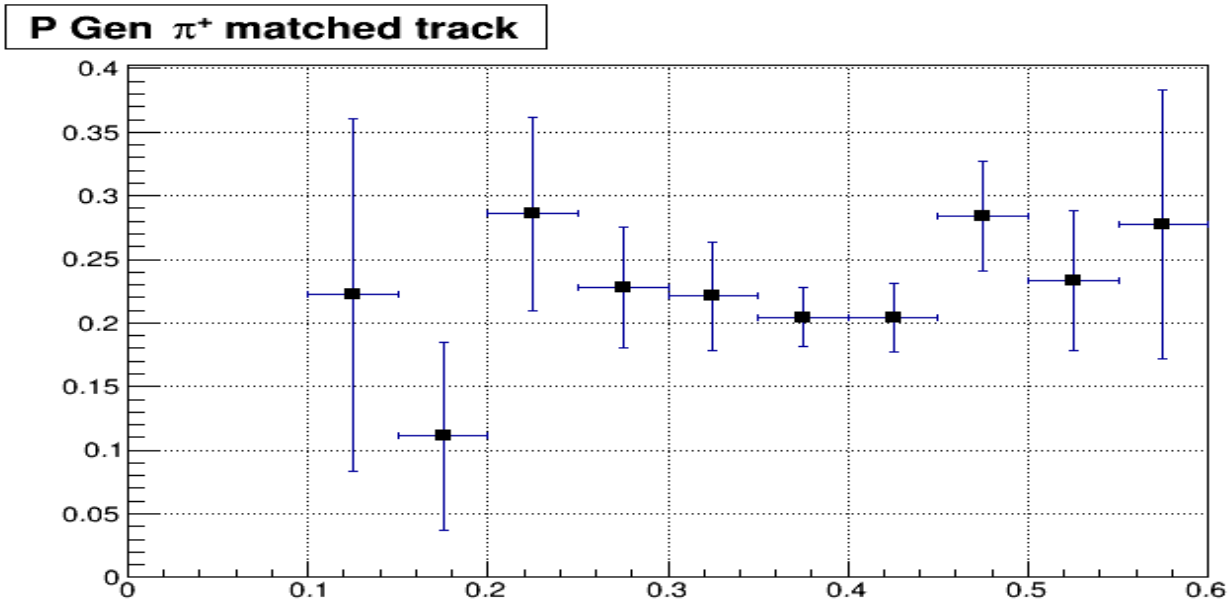
This is an attemp to measure the rec Efficiency
(very very preliminary and low statistics)

Eff = $N^{Rec}_{\mu^+}$ (trkg4pdg==-13 and trkg4id==1) / $N^{Gen}_{\mu^+ \leftarrow p}$

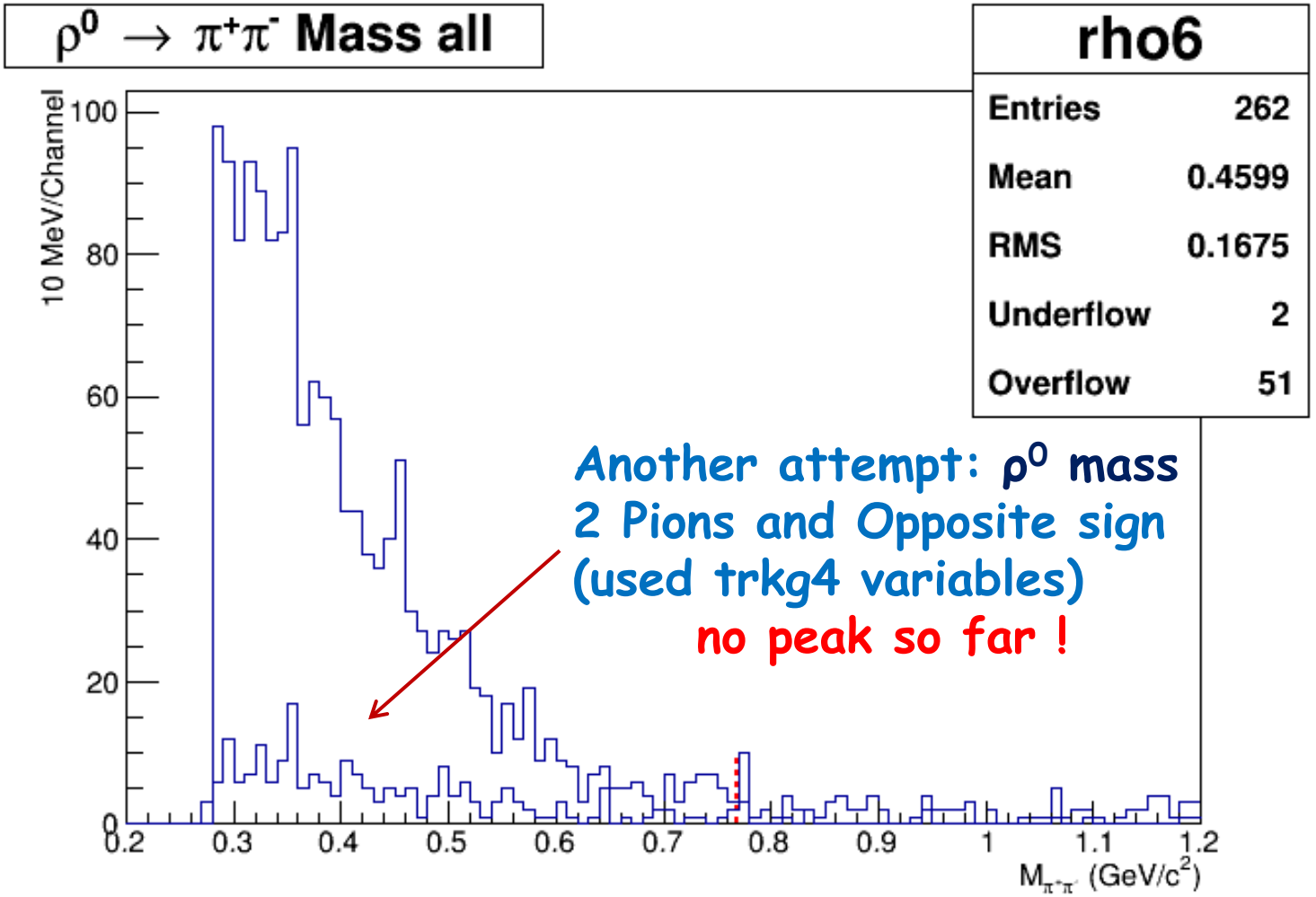


π^+ Reconstruction Efficiency





π+π- Rec Invariant Mass



$p \rightarrow \mu^+ K^0$ (497)

- Main decay mode: 50% K^0_L and 50% K^0_s

not see here

- GEANT. Gen: 1000 K^0 events decayed by GEANT
  Observed: K^0_s: 495 K^0_s/K^0: (49.5 +/- 2.72034)% [~50%]
  K^0_L: 505 K^0_L/K^0: (50.5 +/- 2.75686)% [~50%]

- Lifetime:
  K^0_L = 5100 X 10^{-11} s (too long to decay in DUNE)
  K^0_s = 1 X 10^{-11} s (Displaced Vertex in DUNE)

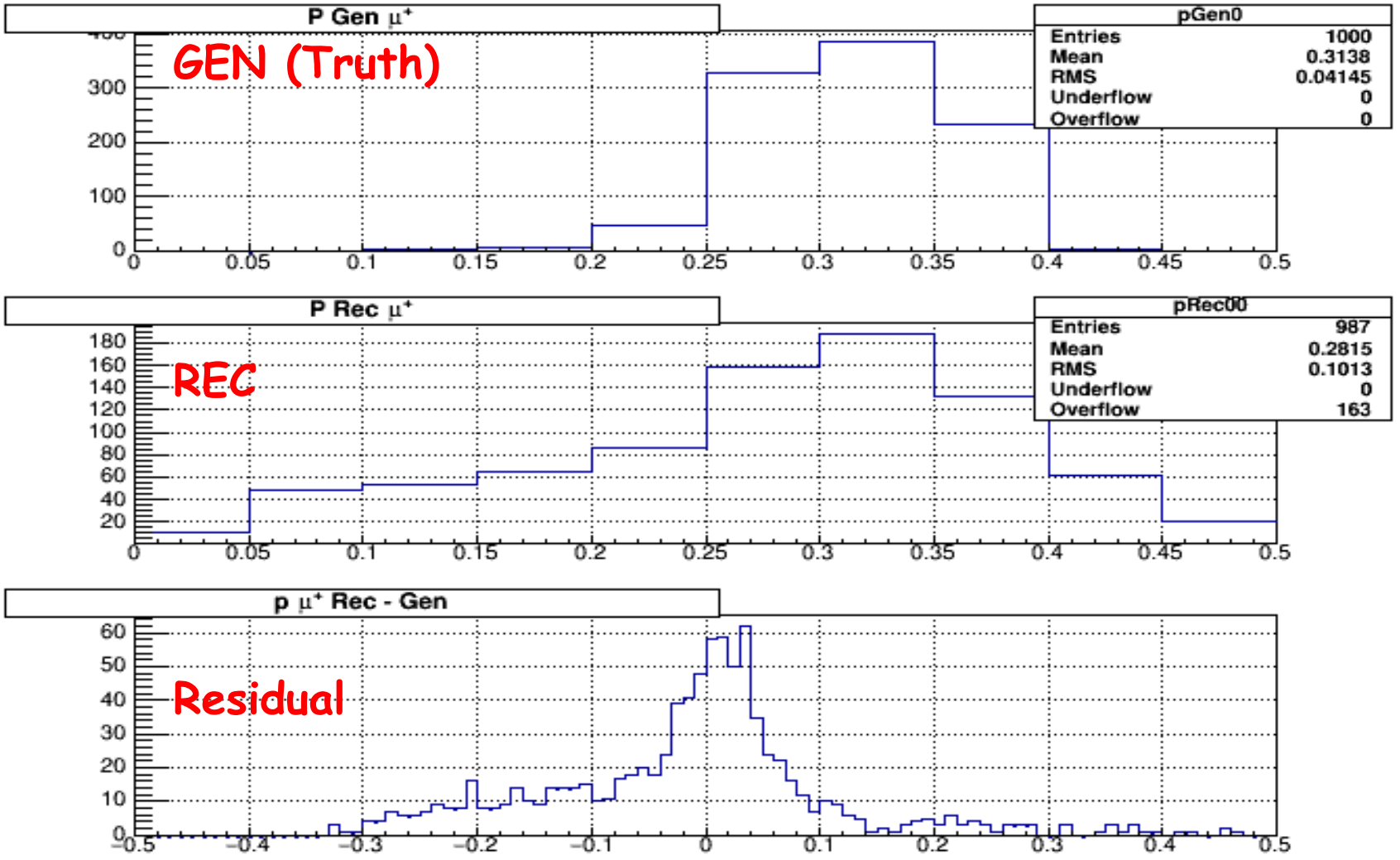
- "Golden" Decay mode:

	PDG	Observed Rates
$K^0_L \rightarrow \pi^+ e^- \bar{\nu}_e$	[~41%]	(11 evts): 2.17822%
$\rightarrow \pi^+ \mu^- \bar{\nu}_\mu$	[~27%]	(8 evts): 1.58416%
$\rightarrow \pi^0\pi^0\pi^0$	[~20%]	(4 evts): 0.792079%
$\rightarrow \pi 0 \pi + \pi -$	[~13%]	(4 evts): 0.792079%
$K^0_s \rightarrow \pi^+\pi^-$	[~70%]	(324 evts): (65.4545 +/- 4.67742)%
$\rightarrow \pi^0\pi^0$	[~31%]	(162 evts): (32.7273 +/- 2.96232)%

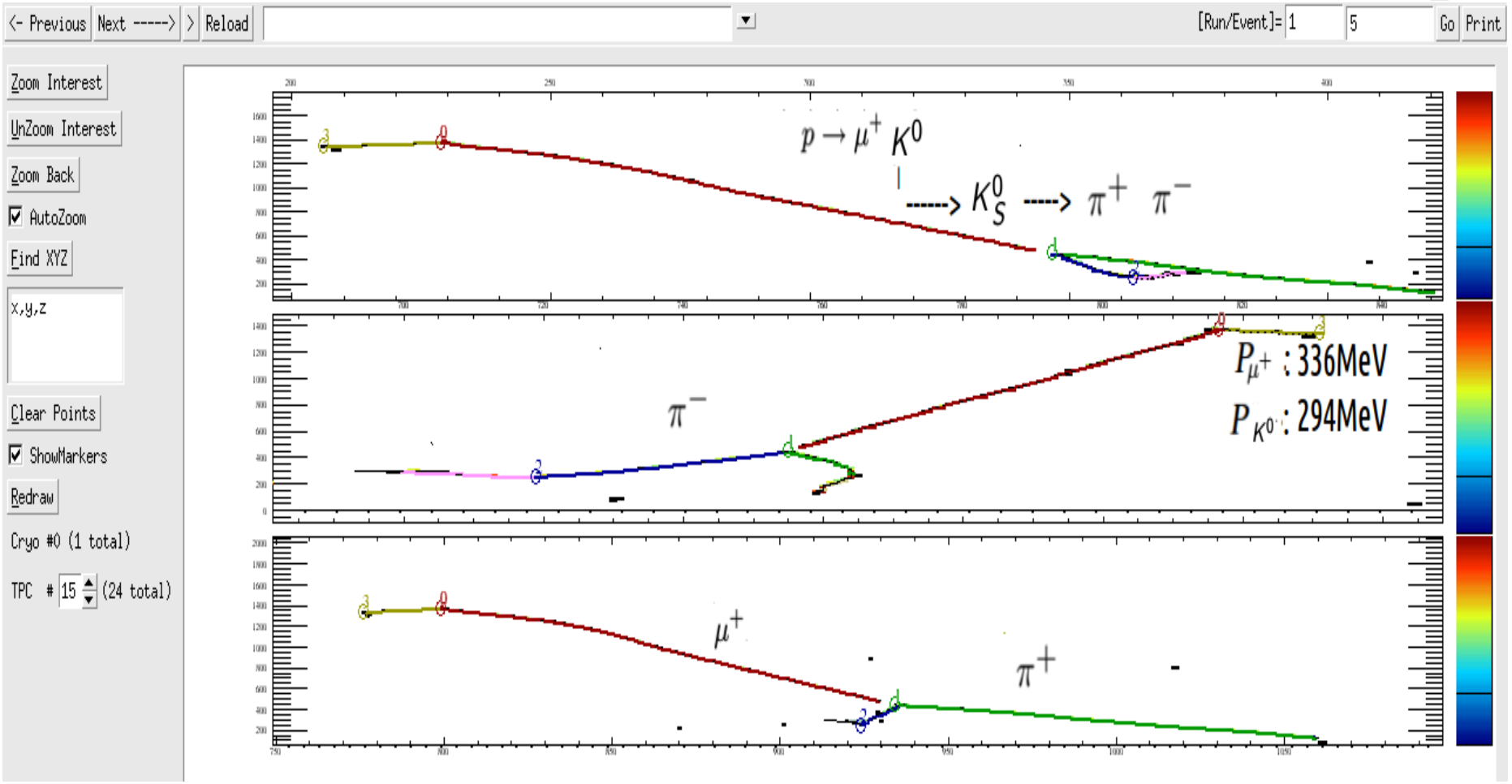
K^0_L not seen here

μ^+ Momentum Comparison

(Higher muon momentun and efficiency in this mode)



Event Display

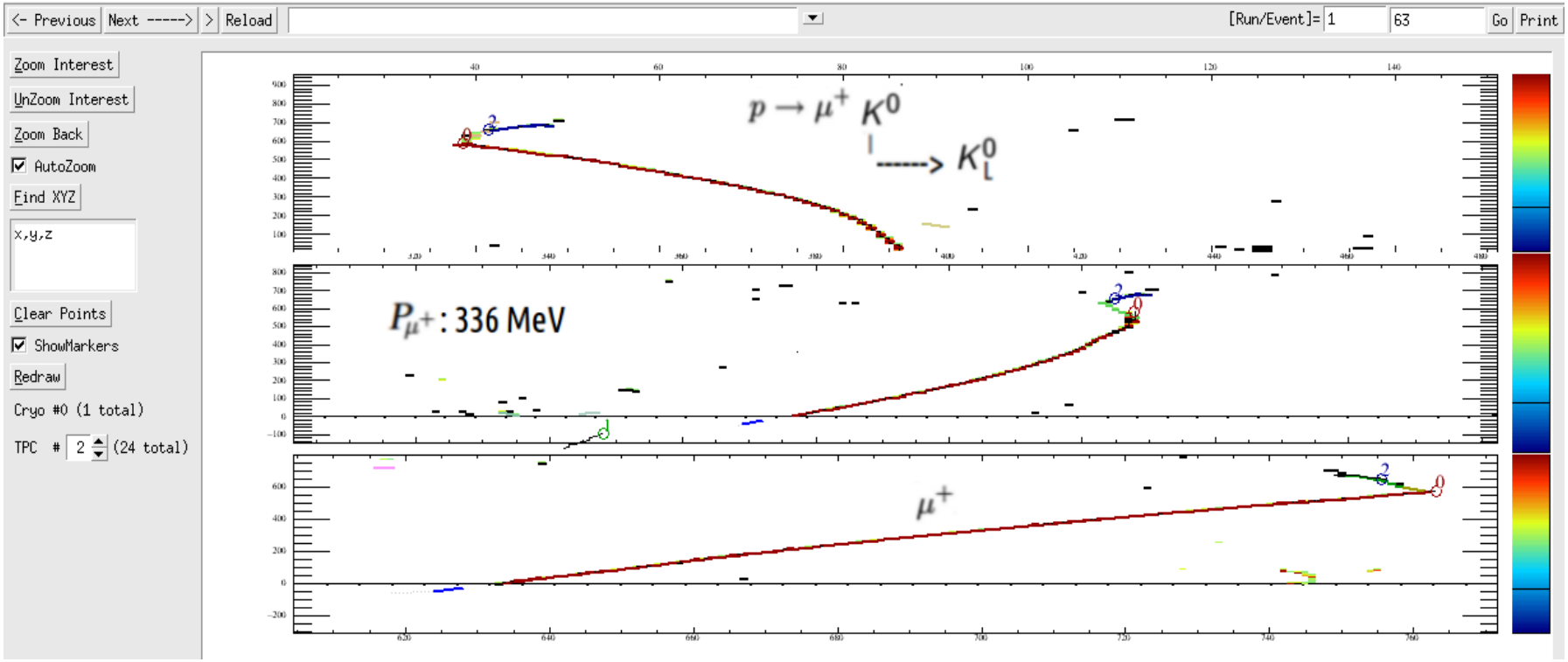


Displaced K^0_s vertex

Generation : (no decay but an interaction)

$p \rightarrow \mu^+ K^0$

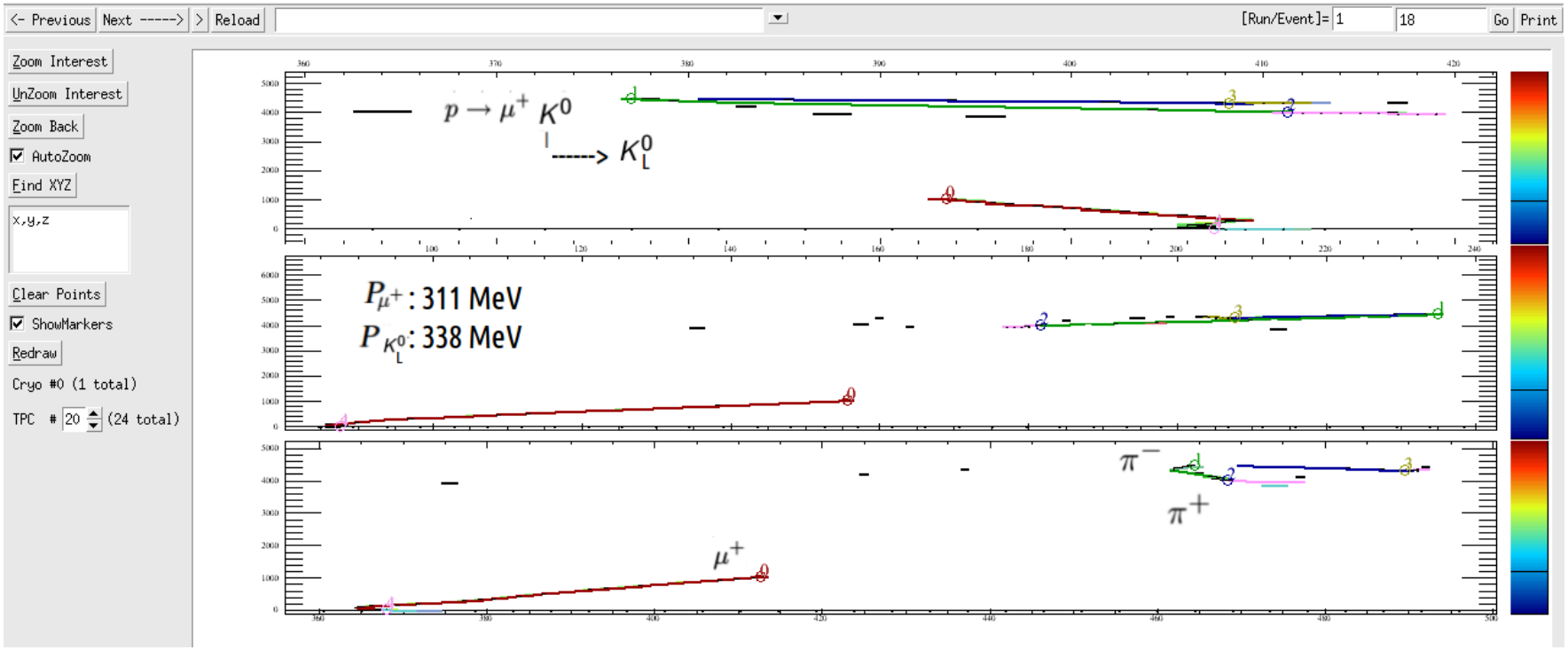
$\hookrightarrow K^0_L \rightarrow K^0_L$ n (3-photons) Ar-39



Generation : (no decay but an interaction)

$p \rightarrow \mu^+ K^0$

$\hookrightarrow K^0_L \rightarrow$ Ar-40 K^0_s (2-photons) Ar-40



Need to be done:

- Run more statistics (grid)
- check efficiency as a function of "range"
- Reconstruct the full Energy

A lot of help from:

- Tingjun Yang
- Tom Junk
- Kevin Wood
- Michel Sorel
- Gabriel Santucci

THANKS TO ALL