Cosmic Ray Issues for Large Liquid Argon Detectors on surface:

- Burden on Data Acquisition
- Inefficiencies (obscuring good events)
- Burden on Reconstruction/Analysis
- Physics Backgrounds (generating fake events)

Beam-spill only:

Argon Drift time : 2 milliseconds (3 meters at 500 V/cm)

In progress

thanks to L. Mualem of U.Minn/NOvA - NOvA note with rates and references
reference: Grieder, P.K.F. Cosmic Rays at Earth. Elsevier Science, 2001
detailed fluxes: http://lartpc-docdb.fnal.gov/cgi-bin/ShowDocument?docid=160.

Burden on Data Acquisition – applies to all backgrounds:

Data Acquisition starts from continuous wave-form recorder on each wire. System design (5 GB/s) can record every digitization during drift-time during inter-spill time.

DAQ has 5 GB/s bandwidth.

Run Mode - > Readout Mode	Continuous (bytes/s)	Spill Only* (bytes/s)
Every digitiz-ation	~~10^{12}~~	2×10^9 OK
Data above threshold	~~4×10^{10}~~	8×10^7 OK
Full hit processing	4×10^9 OK	8×10^6 OK

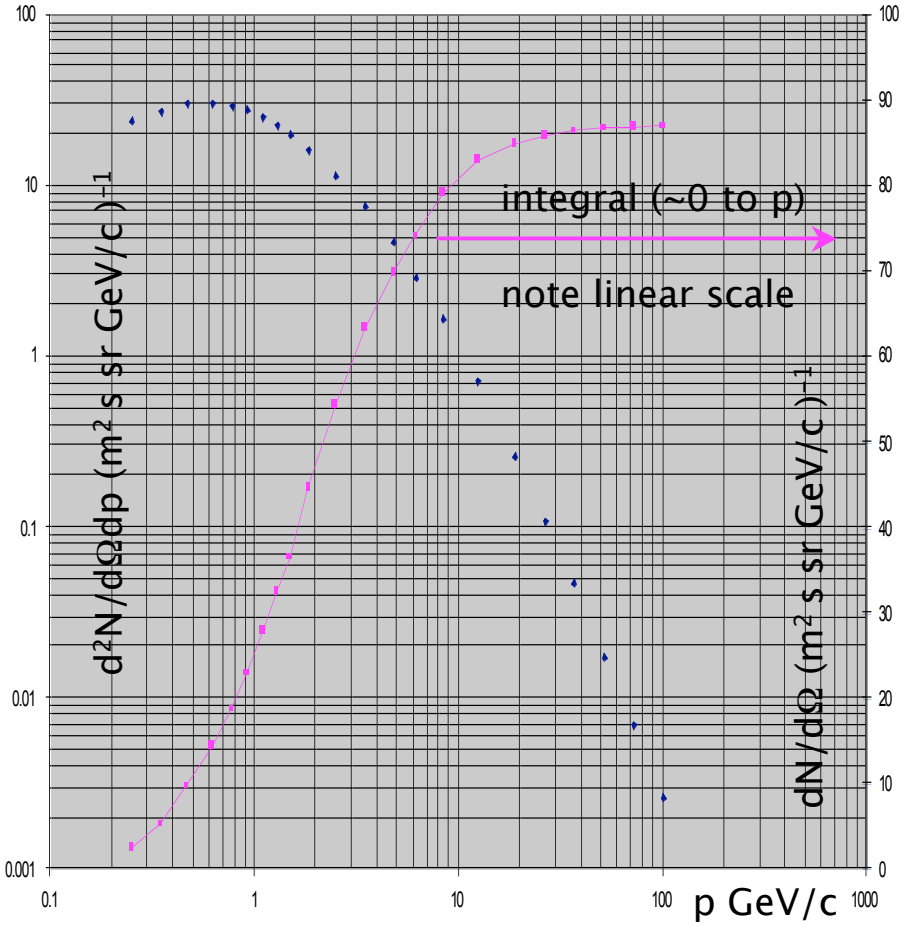
exceeds DAQ bandwidth

(see lartpc-docdb document 81 – flare0051.ppt)

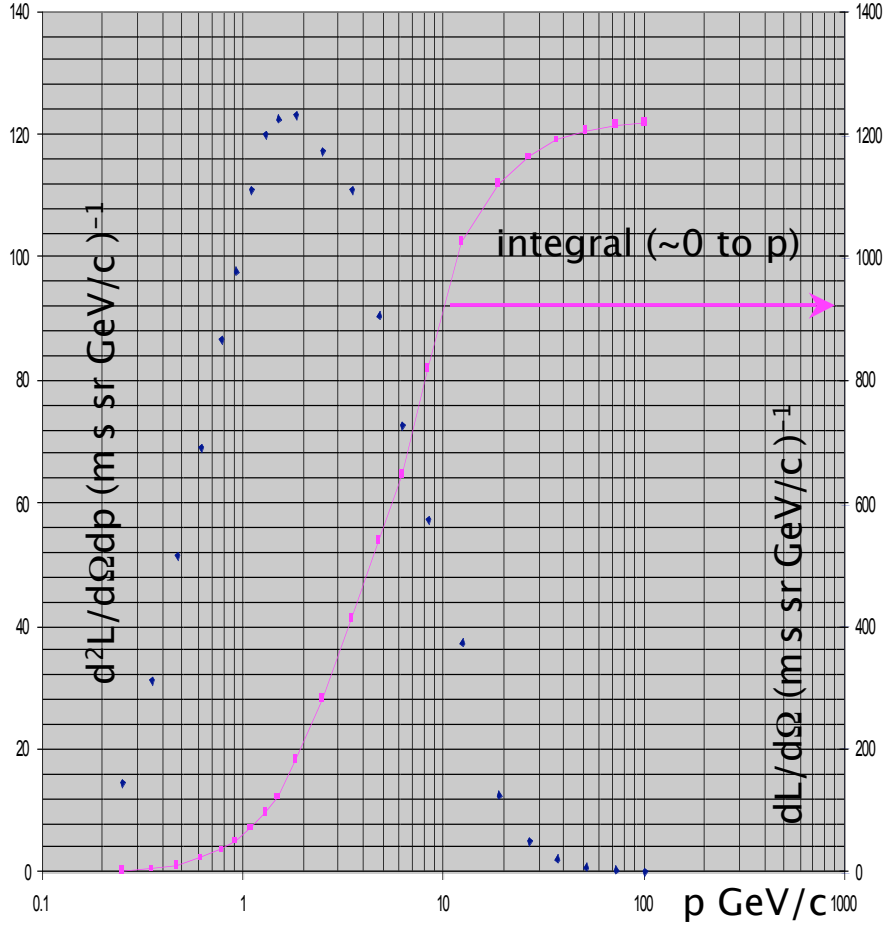
=> Data Acquisition can cope with beam running

Cosmic Muons

flux vs momentum



(path length x flux) vs momentum



Muon Rates are latitude and height dependent:
Above 1 GeV/c, $dN/d\Omega \sim 70 \cos^2(\theta)/(m^2\ s\ sr)$; $dL/d\Omega \sim 1300 \cos^2(\theta)/(m\ s\ sr)$

Muon rate on 50 kton(ne) detector ~ 250 kHz (sides are 1/2 of total)

Number in sensitive time (2 milliseconds) ~ 500

Each muon crosses 3000 wires on average..so there are
~ 7 signals/wire (1.5 x 10^6 hits/225,000 wires) from cosmic rays.

Do these rays blind the detector?

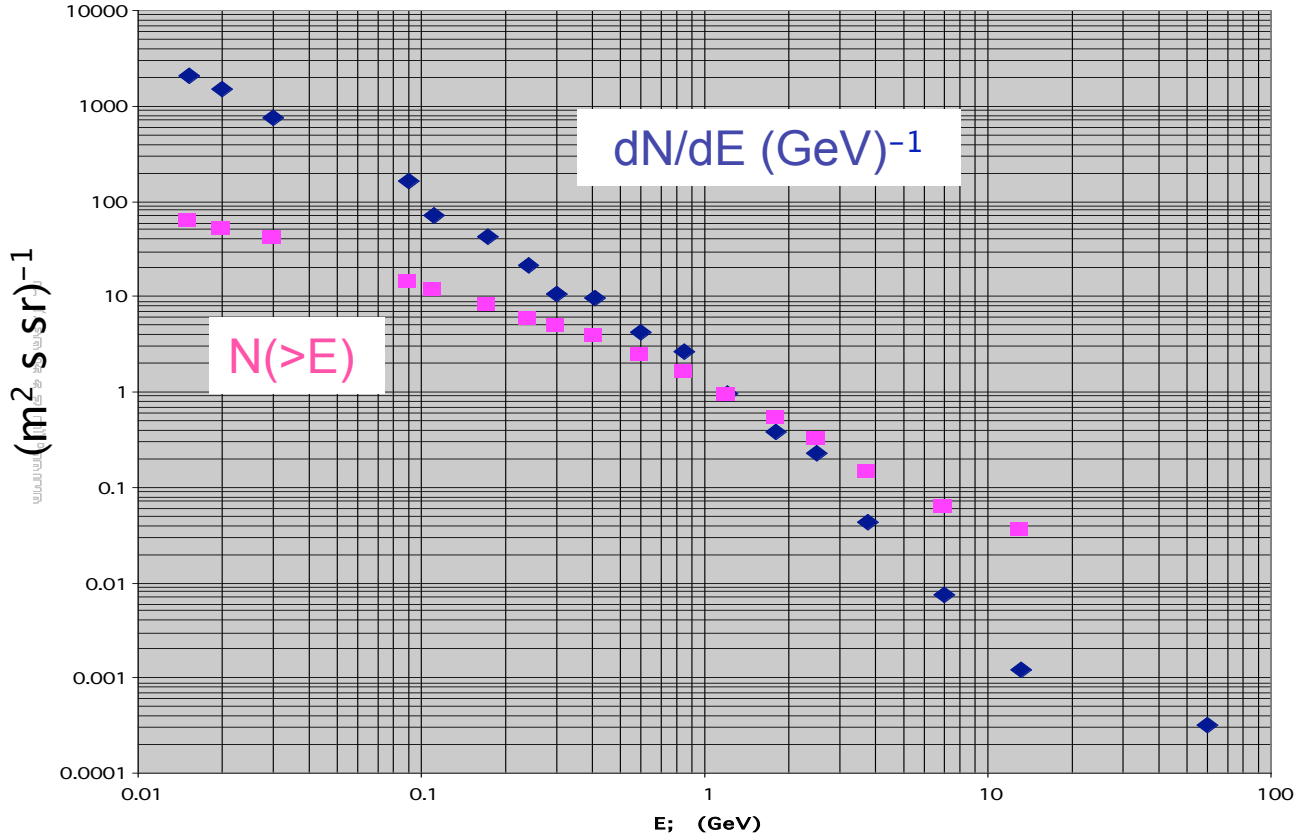
Take a 1 cm diameter (full signal width) tube around each ray =>
loss of 500 cm^2 out of 1000 m^2 < 1 part in 10^3 => small inefficiency

Rejecting/ignoring these hits *is* a major issue for the reconstruction & analysis -> affects (eg) the raw data structures & the pattern recognition approach.

Do muon interactions (hadronic or wide-angle bremsstrahlung where the photon travels a distance from the parent muon) give background events? Follow the muon - but
$3x10^{20}$ NuMI protons @ $3x10^{13}$ proton/spill =>$5x10^9$ muons =>
need rejection of > 10^8.

Cosmic Photons:

photon flux (differential and integral)



Rates are atmospheric depth dependent ($\Lambda \sim 160$ gm/cm^2)

Data used here (Beuermann & Wibberenz – Can.J. Phys., 46, 1968) were taken at 760 gm/cm^2 and extrapolated to 990 gm/cm^2.

Above 1.0 GeV, $dN/d\Omega \sim 1.2/(m^2\ s\ sr)$ ~ 2% of muon rate.

Angular distribution as $e^{-8(1/\cos(\theta)\ -\ 1)}$ (from attenuation with depth)

Photon Issues: (~% of Muon rate)
Steel and Argon outside active volume (~ 1 meter) ~ 6 attenuation lengths = reduction of 400 => not a major burden on reconstruction/analysis.

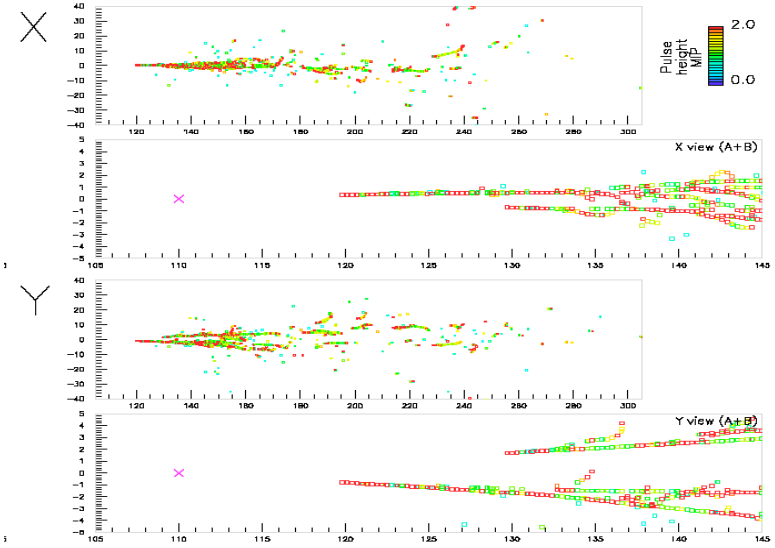
Need (further) rejection of 10^4 for physics backgrounds.

Rejection factors available in LArTPC:

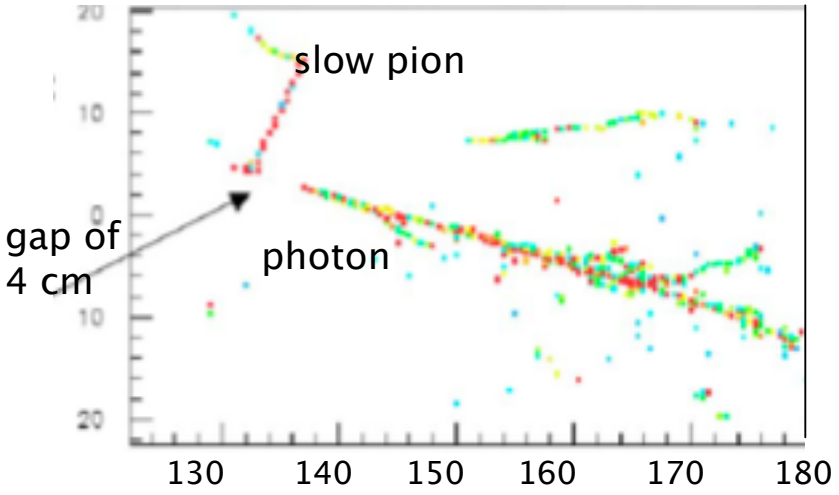
Require hadronic activity;
Require one track that starts from vertex as minimum ionizing for >2 cms and produces a shower; (in present efficiency numbers)
Require event pointing back to Fermilab;

Study starting

photons from π^0 s – note clean vertices



ν_e NC interaction – note activity at vertex



Shielding notions – if shielding is needed:

Photon rate can be reduced by shielding – 3 meters of earth gives a reduction of 100.

Incident muons can be identified immediately by signals on wires at the sides/top of the detector (if, for example, there are horizontal wires at the top)