MINOS Near Detector

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On behalf of…

C. James & J.Thron	*Near Detector Installation*
P. Shanahan	*Near Detector Electronics*
D. Harris & H. Montgomery	*Near Detector Analysis Group*
J. Hylen, S.Kopp, M.Messier	*Beam Systematics Analysis Group*
P.Anderson, A.Cabrera, G.Drake, A.Erwin, M. Kordosky, K.Lang, D.Petyt, H.Ping, D. Reyna, P.Shanahan, N.Tagg, J.Thomas, T.Vahle, A.Weber	*Calibration Detector*
J. Morfin	*A Possible New Near Detector*

First Role of Near Detector

- Non-ideal focusing requires knowledge of acceptances and pion production in x_F, p_T
- Hadron production variations lead to ~20% variations of predictions in flux.

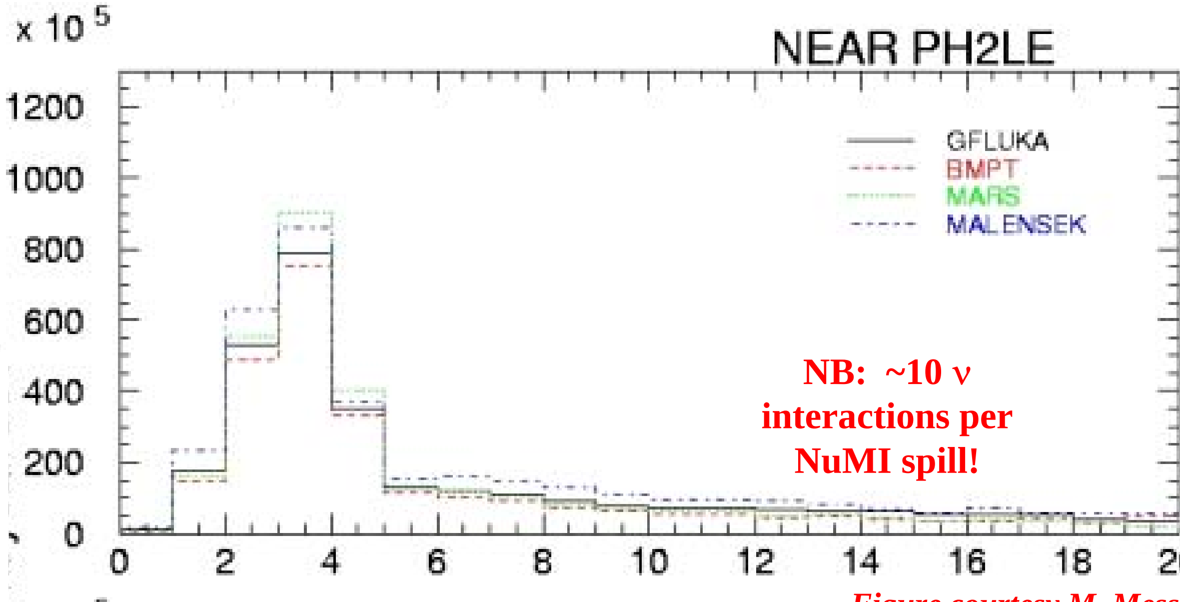


Figure courtesy M. Messier

- This is seen in the flux measured by near detector
- This is the ND's *raison d'être* -- to measure the flux directly and thereby predict far flux

- Pion production data modeled by
  - Fluka
  - Geant/Fluka
  - MARS
  - BMPT
  - Malensek
  - Sanford/Wang

Differences in Spectra

- The near detector, however, does not exactly reproduce the spectrum at the far detector

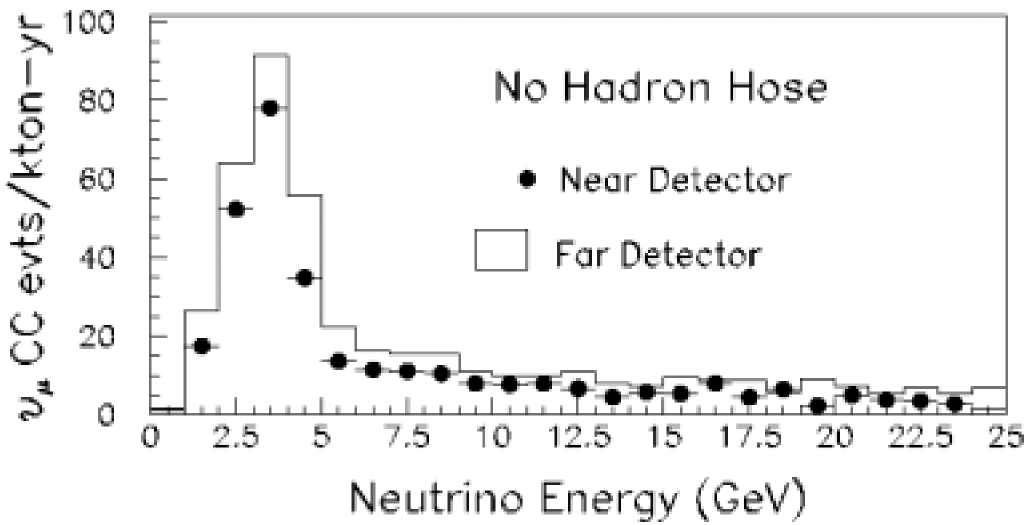
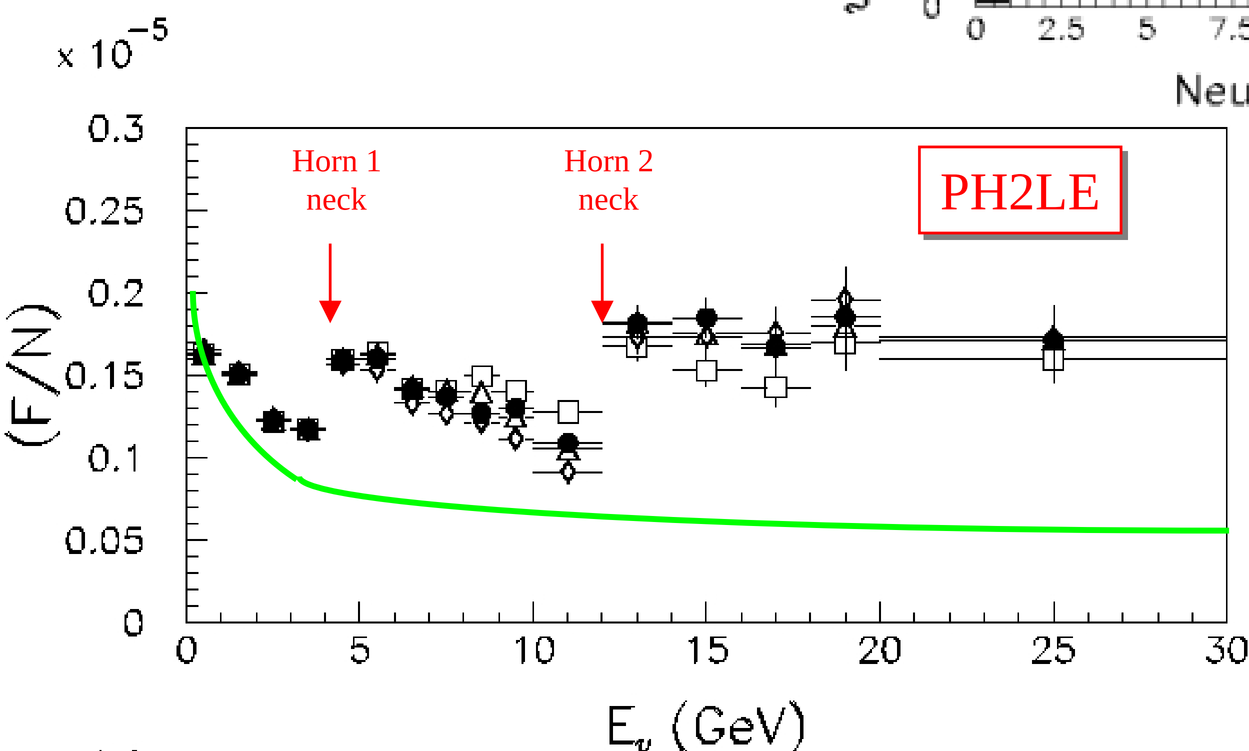


Figure courtesy M. Kostin

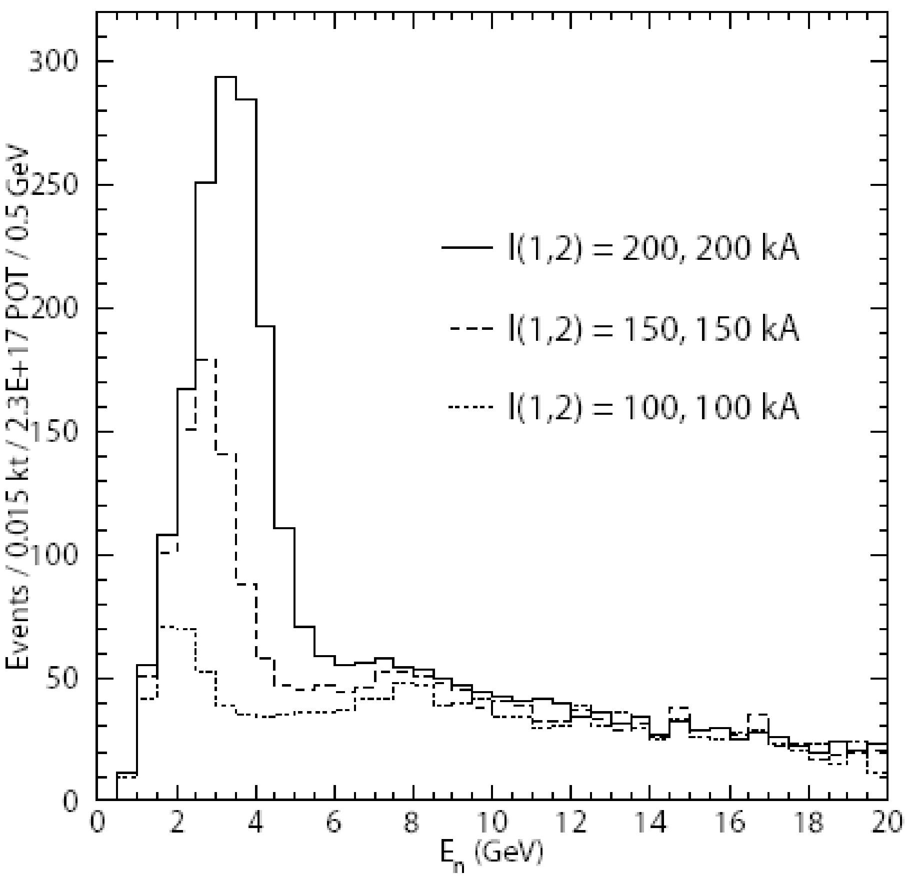


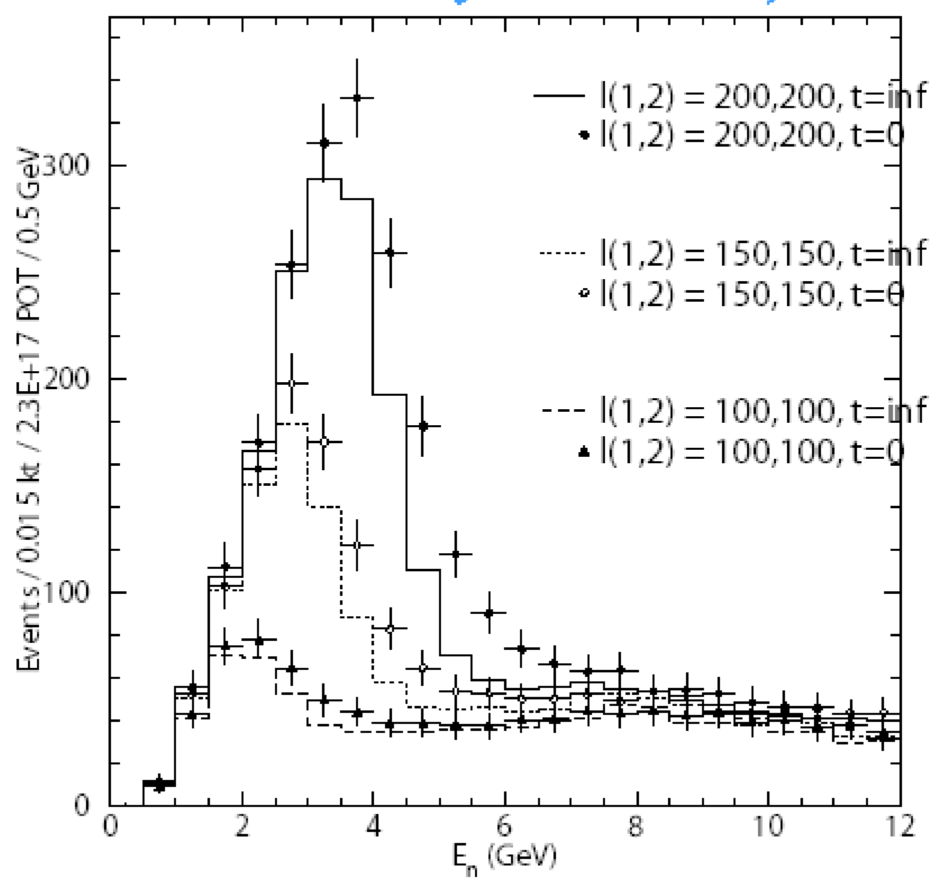
2nd Role: Commissioning

Can we convince ourselves that we understand our beam during commissioning?

(stat. errors for ~1 day of Near Detector)

Vary horn currents together

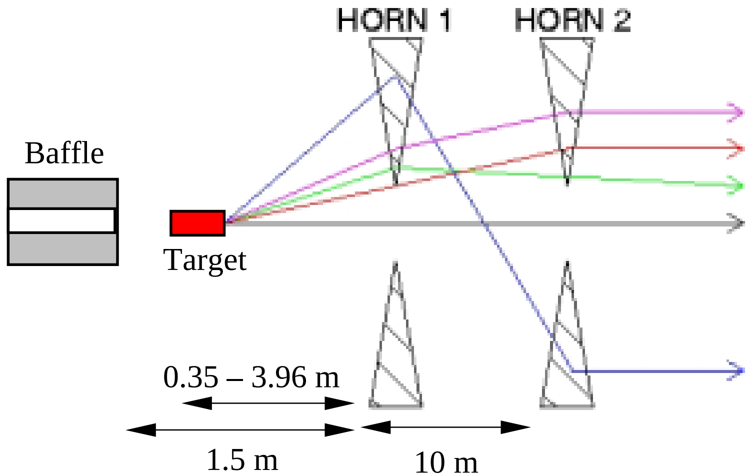


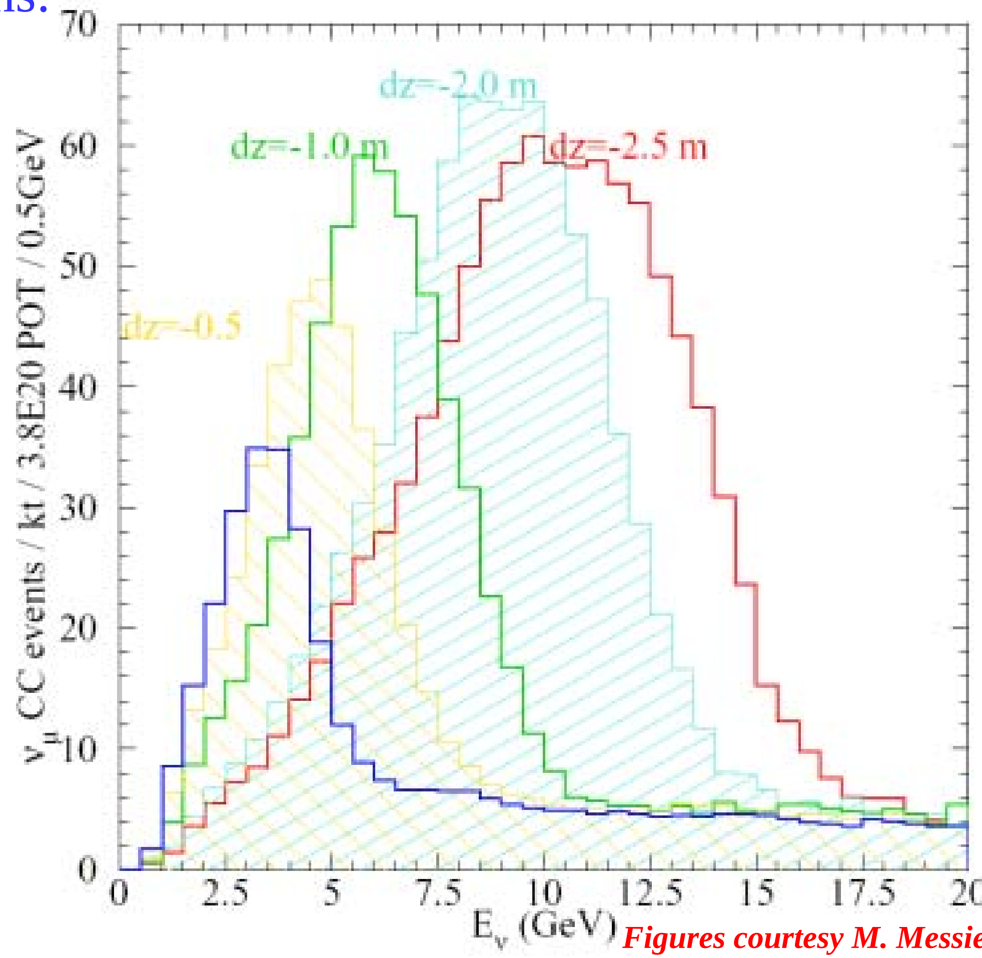


Figures courtesy M. Messier

3rd Role: ν Monitor

- Low E_ν beam flat, hard to monitor relevant parent particles.
- Best way to focus higher energy pions: focus smaller angles.
- Place target on rail system for remote motion capability.
- Horn focusing systematics remain constant ⇒ can monitor with this variable beam

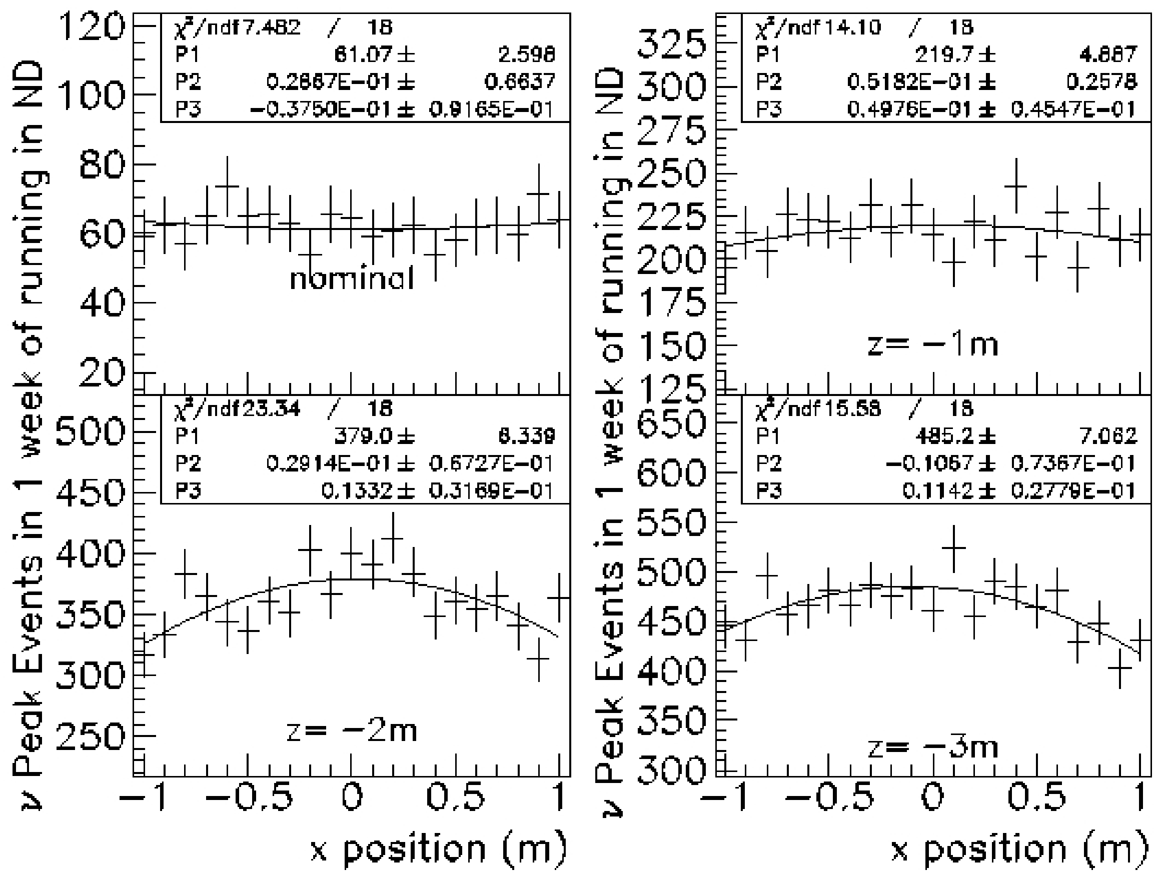




Figures courtesy M. Messier

Variable Energy Beam Seen by MINOS Near Detector

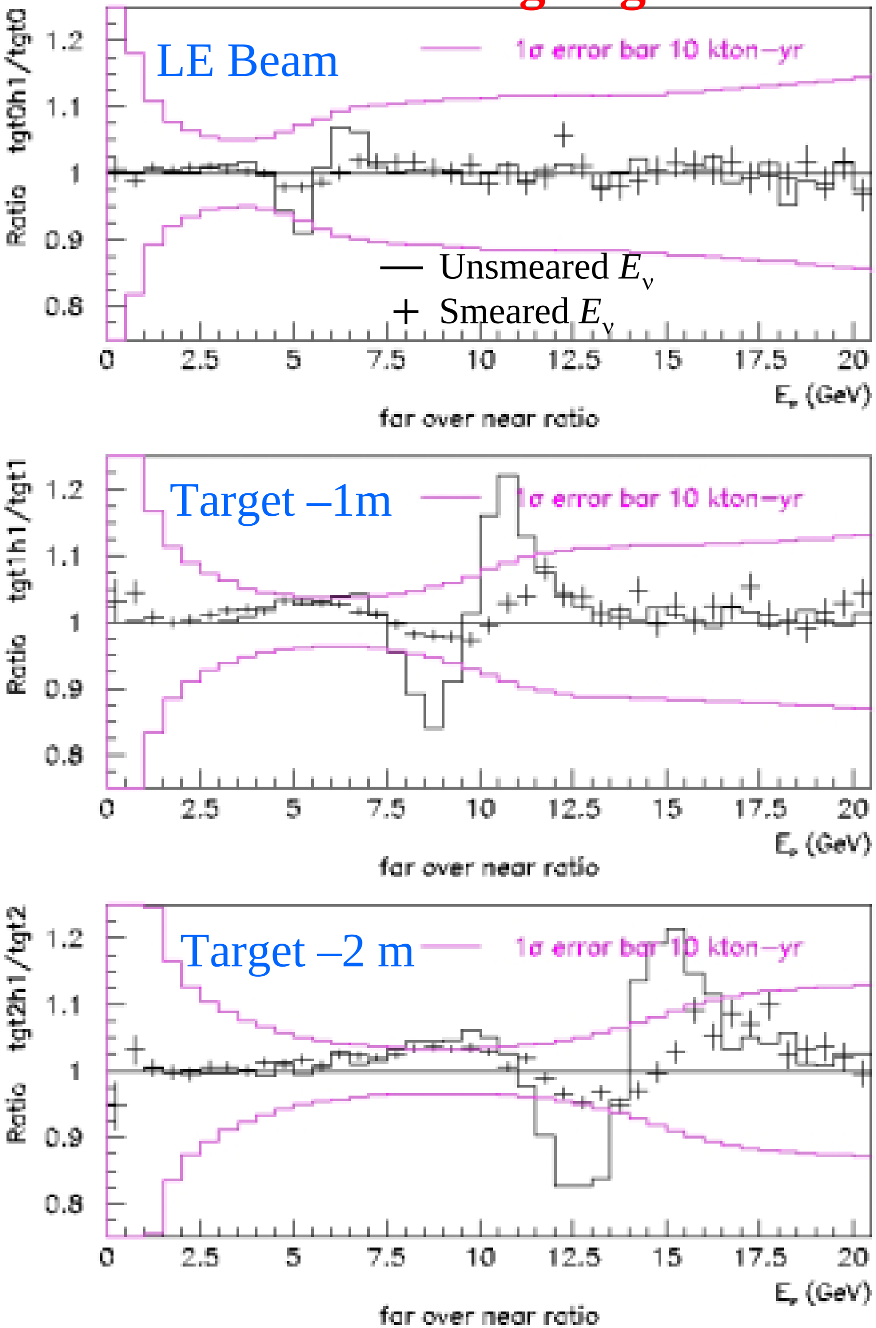
- Also locates neutrino beam
- Lever arm ~ 1040 m
- Neutrino beam center to ~ 10 cm (1 week's data)
- Align ν beam to 10 μrad
- Requires
  - Special ME/HE run
  - 1 week's data
- See also R.Zwaska's talk on μMonitors



Figures courtesy D. Harris

Occasional Monitoring

Effect of Misaligning Horn 1



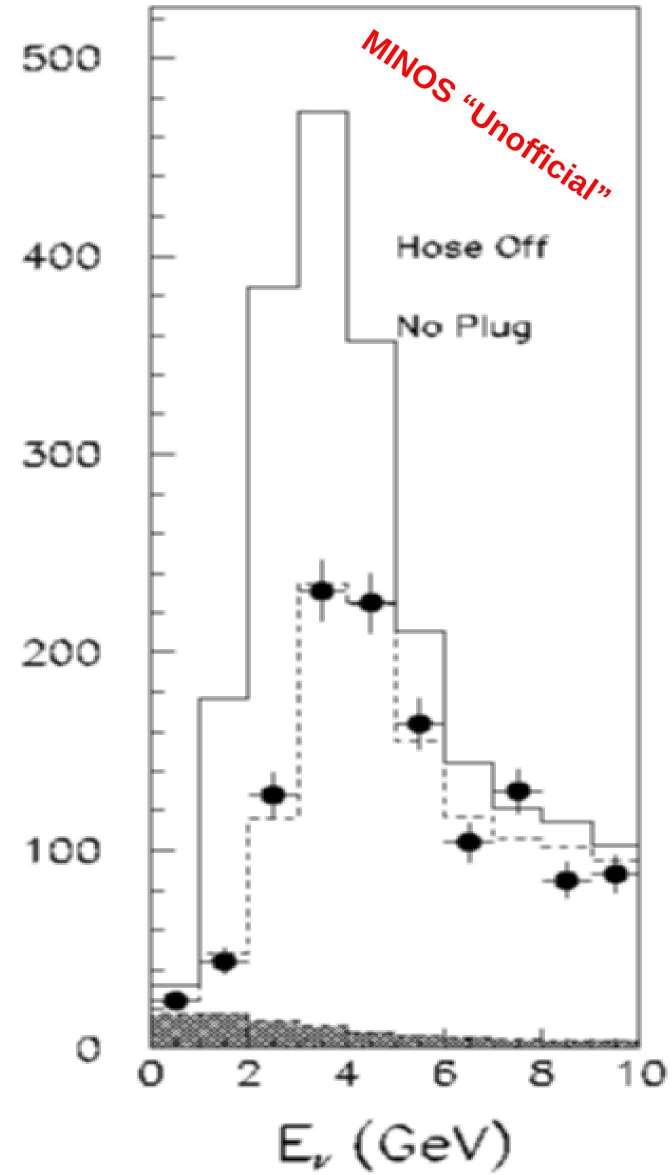
Figures courtesy D. Harris

- NuMI low energy beam is *broad*!
  - μMon acceptance small at DV end
  - Investigated instrumenting upstream concrete around DV
- Some systematics barely show up
  - Bad: hard to see in monitors
  - Good: not as important for near-to-far extrapolation
- Therefore, some monitoring not as important to do spill-to-spill
  - Periodic monitoring runs sufficient

4th Role: Study ν Interactions

- Hypothetical MINOS 'experiment'
- Far detector Expect (Δm^2=0.003 eV^2)
- Far detector Expectation (no oscillations)
- Expected NC Background

- Major goal of MINOS is demonstration of dip at E_ν~1.8GeV and *rise* below this point.
- Neutral currents which mimic CC interactions unfortanately contaminate the low E_ν region.
- Would like to be able to study level of expected NC contamination.



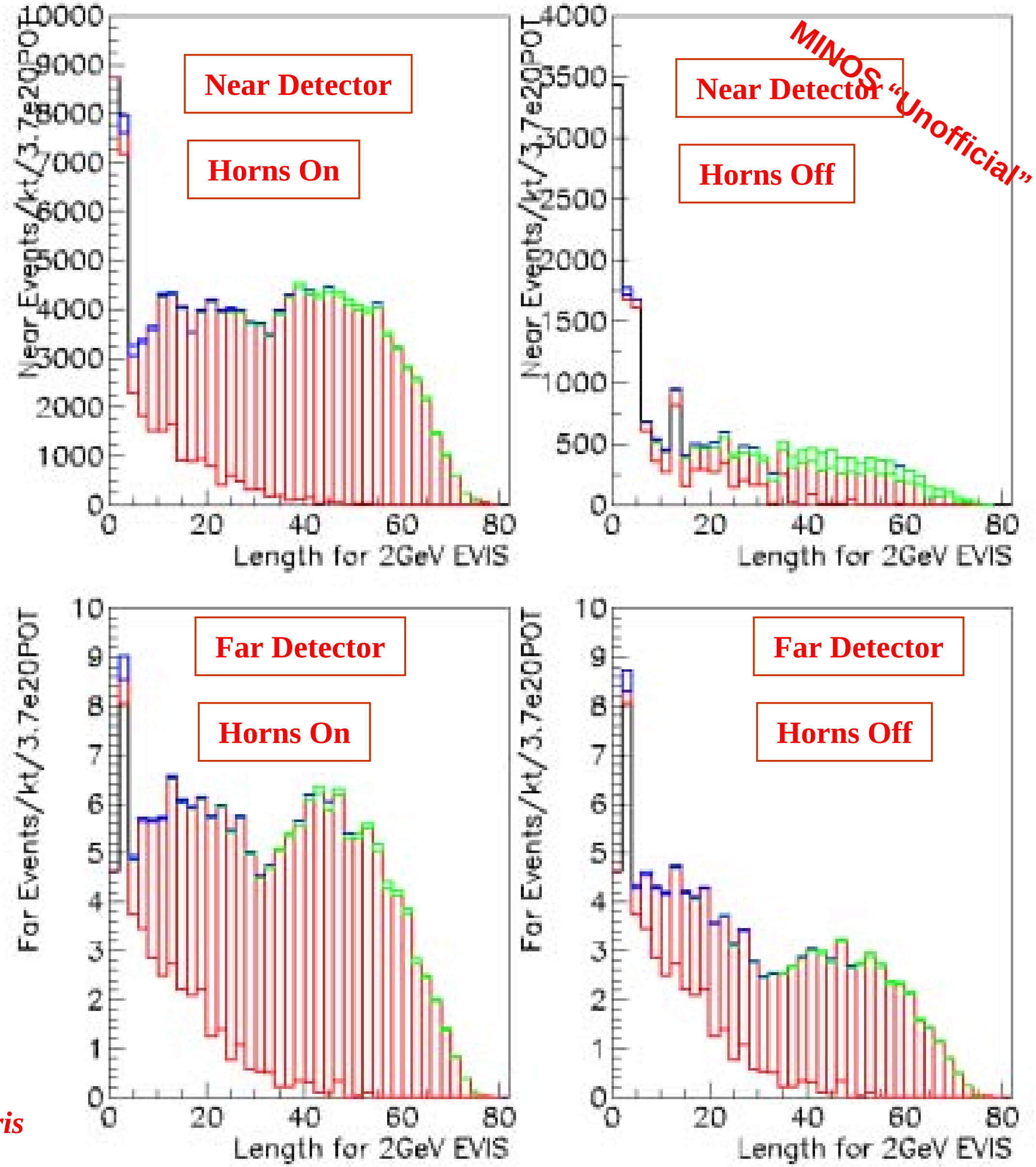
Studying ν Interactions (*cont'd*)

Apparent CC events at E_{vis} = 2 GeV

NC events

CC events

- Possibility of disentangling NC background from real CC events during dedicated running
- Turning off horns removes focusing for pions ⇒ less CC events

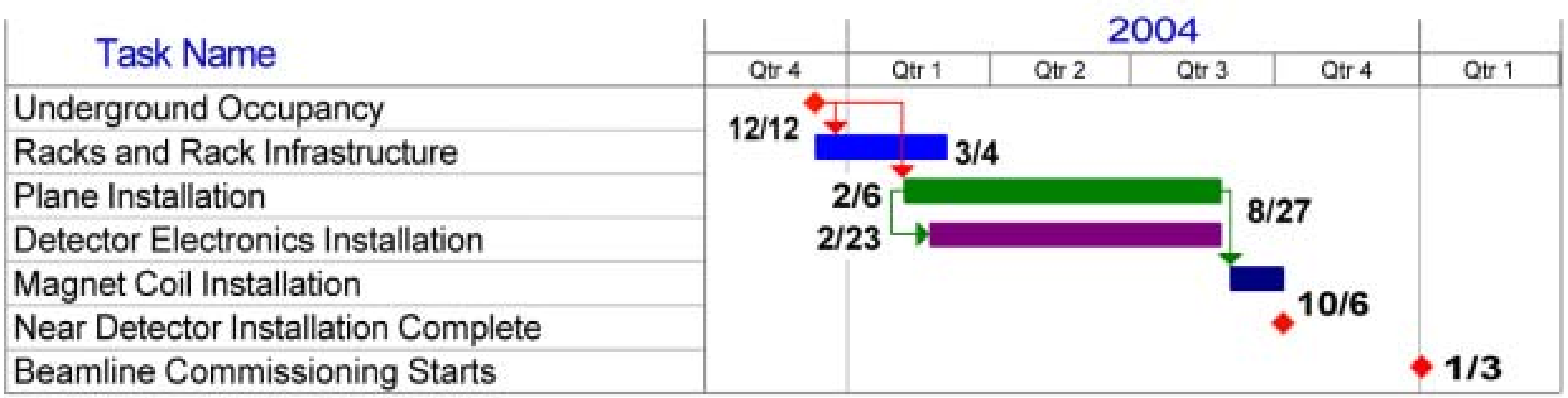


Figures courtesy D. Harris

Status of Civil Construction

Near hall

Overview of Installation



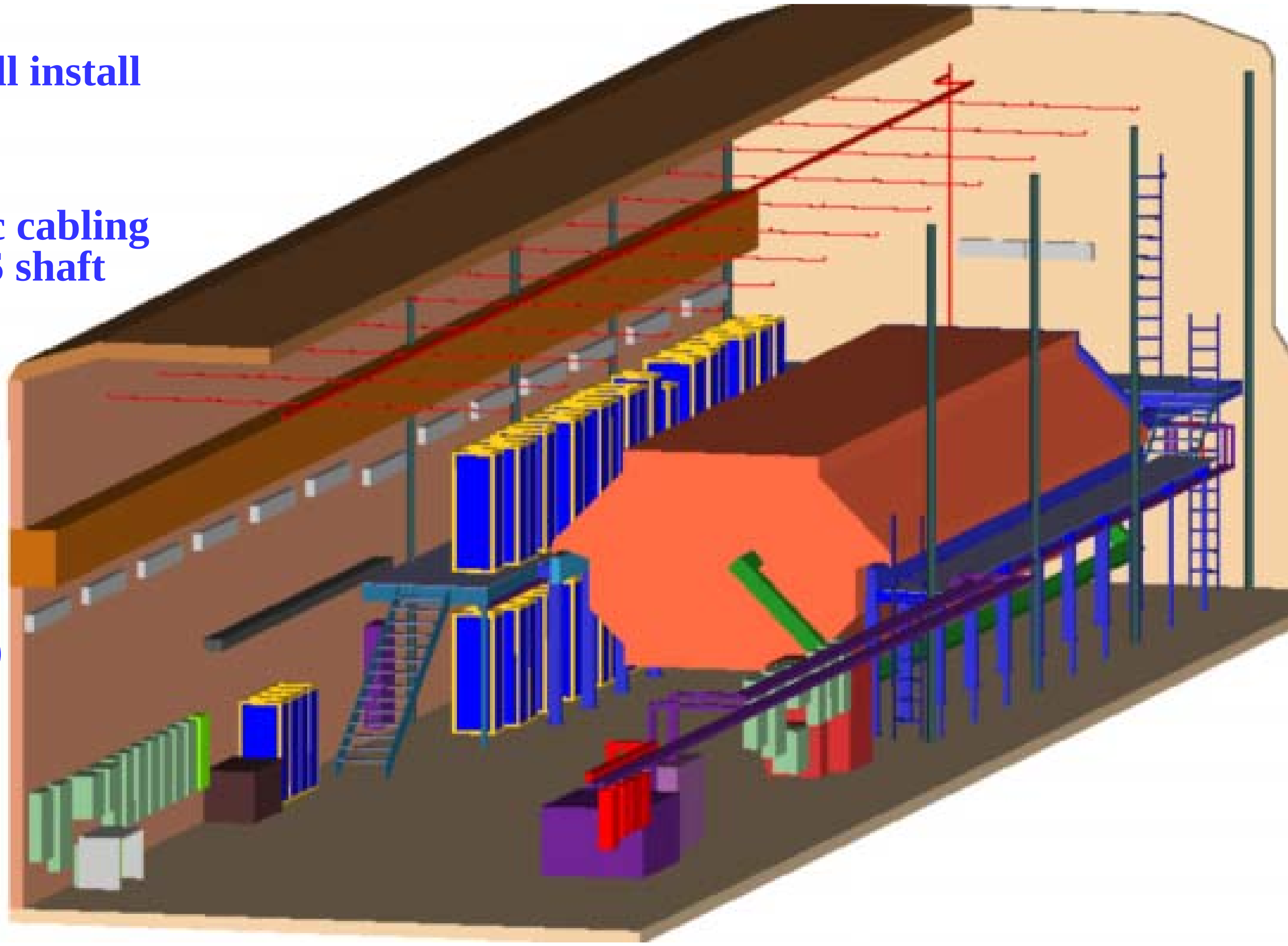
- A few months of rack and other infrastructure installation
- Plane installation begins once the electrical portion of the infrastructure is completed
- Electronics cabling and checkout proceeds in parallel with plane installation
- Magnet Coil installation is done after all planes are installed

Infrastructure Installation

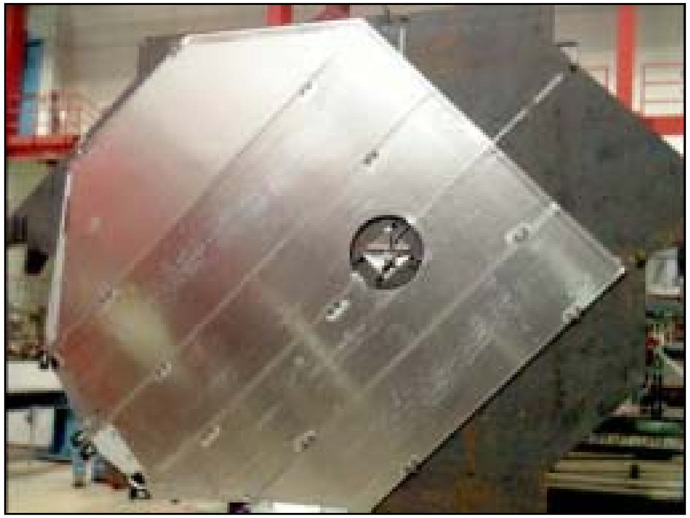
Civil Contractor will install

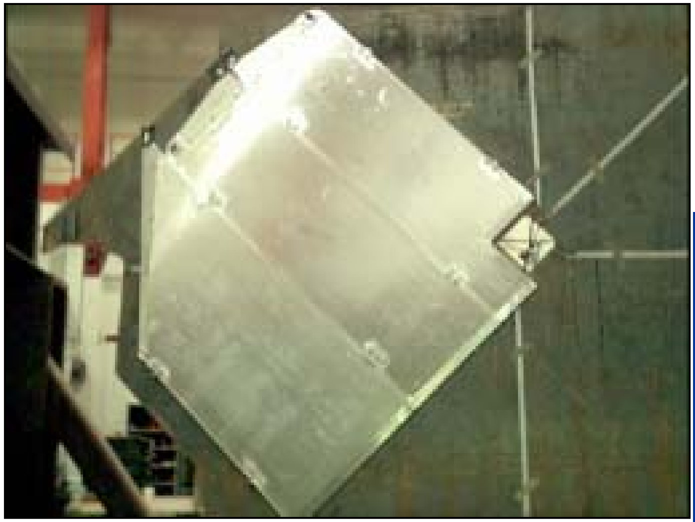
- **Water delivery**
- **Electrical power**
- **Signal, fiber optic cabling down the MINOS shaft**

- **After Beneficial Occupancy of the MINOS hall, we install…**
- **Hall LAN**
- **ACNET (FNAL accelerator controls)**
- **Power supply for magnet coil**
- **Water cooling for electronics**



NearDet construction





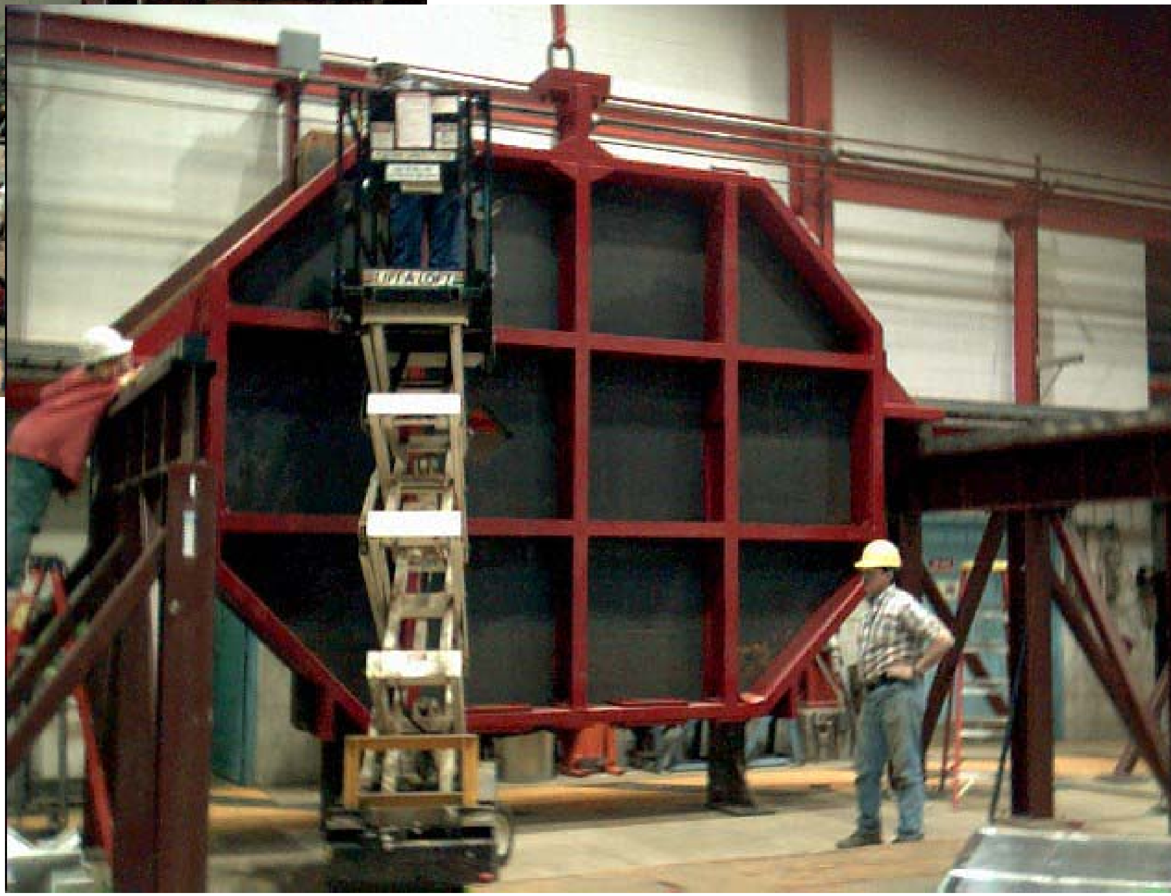
Status as of October , 2003

- **All planes assembled and "shelved"**
- **Beneficial occupancy of the Near Hall in Dec'03**
- **Near detector will be ready late summer 2004**

Steel Plane Assembly

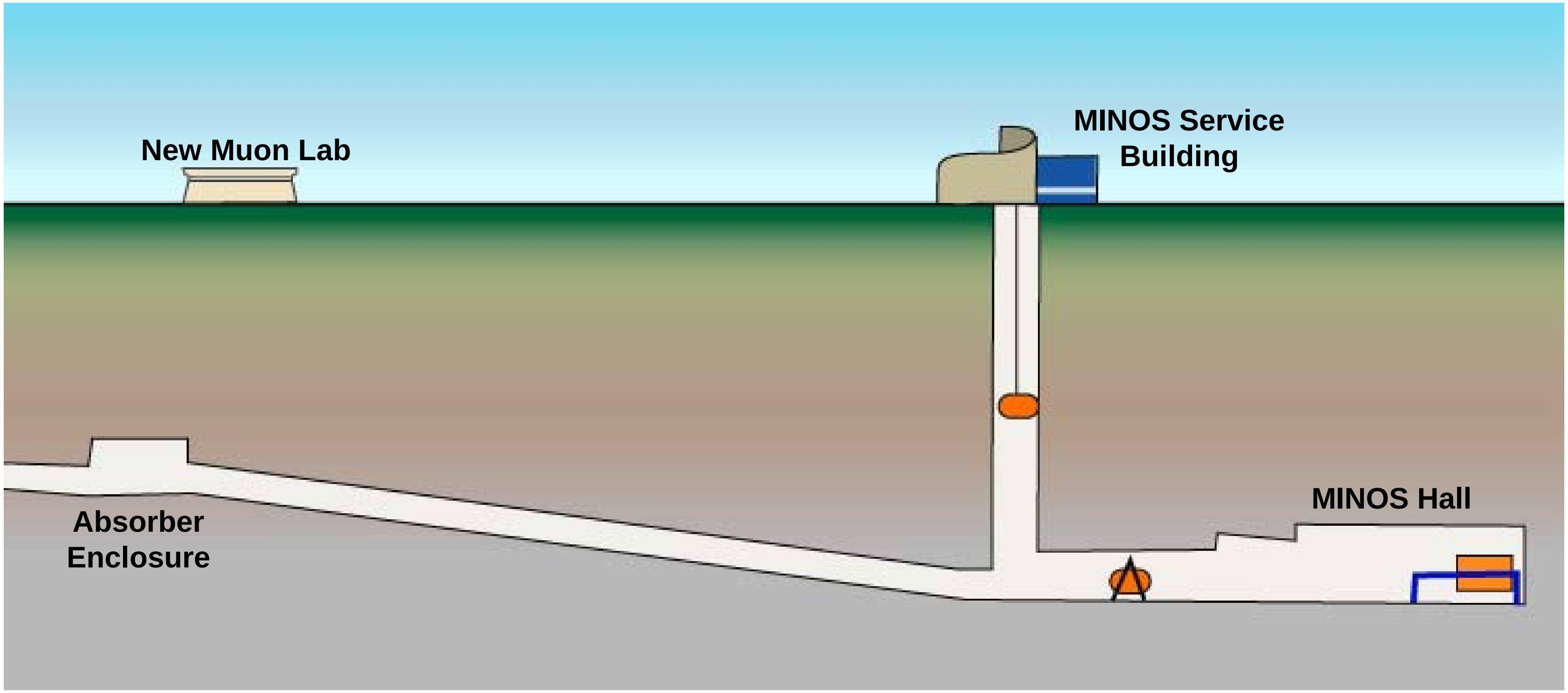
Scintillator Installation

Plane Rigging



Plane Installation

- **All planes sit in storage at New Muon**
- **Install planes one-at-a-time, moving from New Muon, to MINOS Service Building, to Underground, to detector support structure in the MINOS Hall**



Move planes

From New Muon to MINOS Service Building

Strongbacks loaded onto truck (shown here without detector planes). Two fit on the Lab's longer flatbed trailer.

Underground Transfer

At the base of the MINOS shaft, a detector plane is transferred from the strongback to a similar fixture on a cart. The strongback never leaves the shaft crane hook.

Mount Planes in Hall

The cart is rolled into the MINOS Hall, and the plane lifted onto the detector support structure.

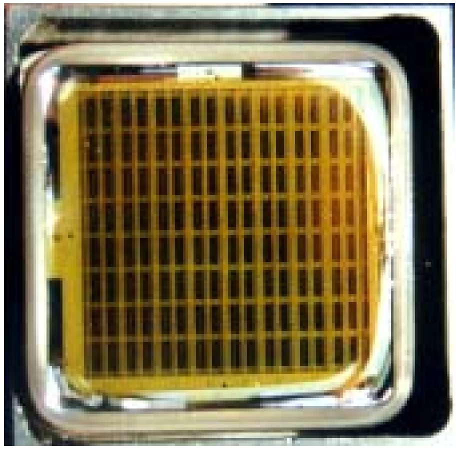
M16s and M64s

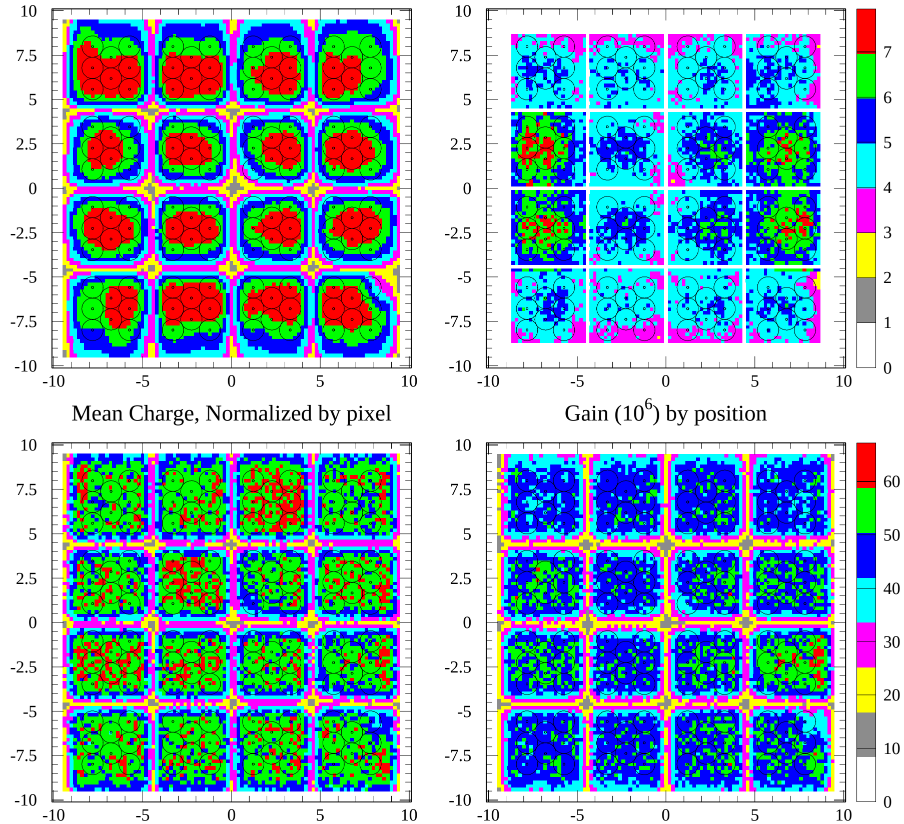
Far

- 8-fold muxing
- 128 fibers per PMT
- 1452 PMTs

Near

- No muxing
- 64 fibers per PMT
- 210 PMTs





The Eyes of MINOS

Detector Cabling Mock-up

Set up platform alongside one of the Plane storage stands. Install cabling systems on 2-racks worth of planes.

Tests of Near Det at CERN (CalDet)

- **MINOS calibration challenge:**
  - **Near/Far relative calibration to 2%**
  - **absolute calibration of 5%**

- **Main ingredients:**
  - **cosmic ray muons**
    - **energy scale calibration**
    - **strip-to-strip response**
    - **muon energy unit (MEU)**
  - **light injection system**
    - **PMT gain drifts**
    - **PMT/electronics linearity**
  - **calibration detector (CalDet)**
    - **define MEU**
    - **topology and pattern recognition**

CalDet modules in T7

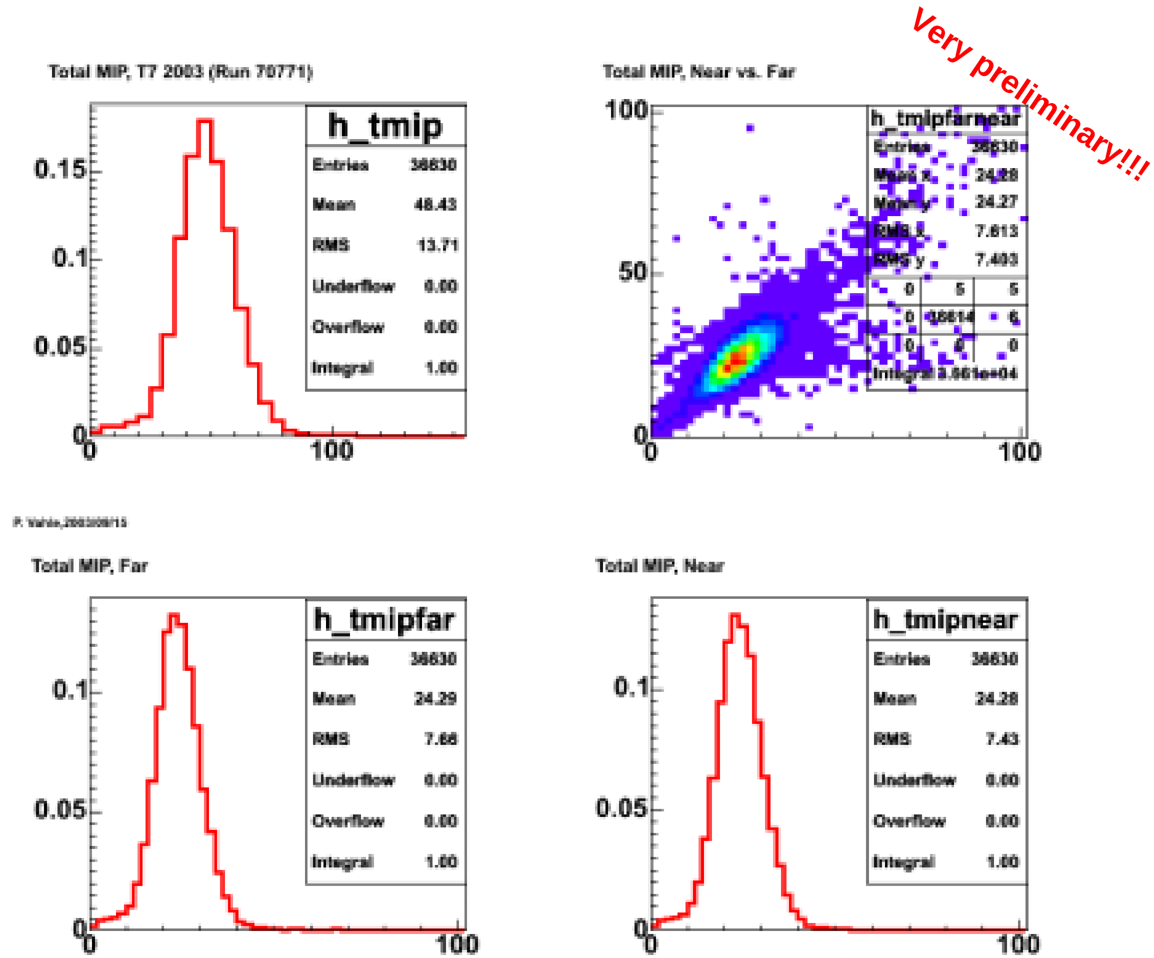
On the move… (2003)

2001-2003: Moved in/out beamlines ~10 times

One reason why everyone loves the CalDet

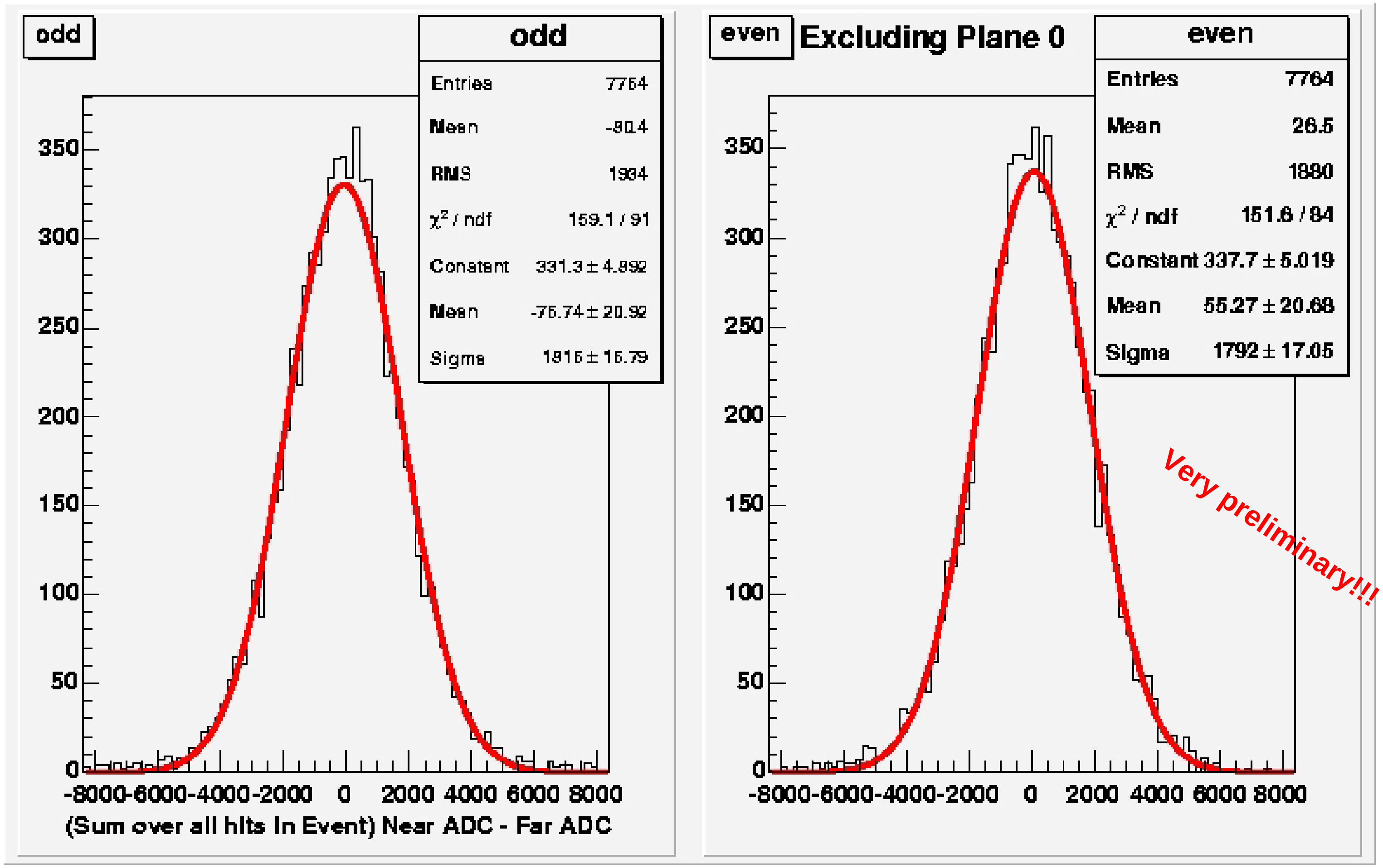
Front-end electronics comparison: NearDet vs FarDet in CalDet

- **In order to have NearDet and FarDet respond similarily they have to be … different.**
- **This is due to scales of the detectors and event rates difference by ~10^5**
- **VA + M16 (8x multiplexed)**
- **QIE + M64 (not multiplexed)**
- **In 2003 run, each scintillator strip read out on one end by FD electronics, other by ND electronics.**
- **Compare electronics on same physics hits!**



Figures courtesy T.Vahle

Near vs Far MIPs

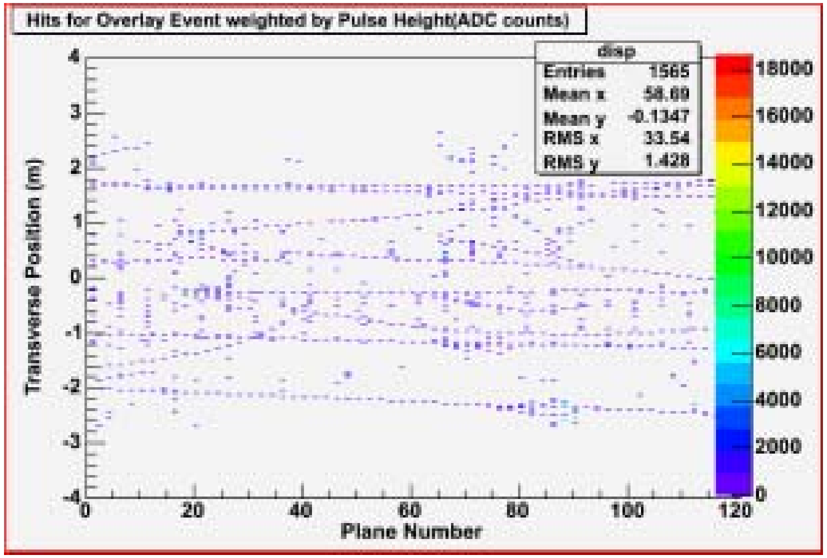


Figures courtesy L.Mualem

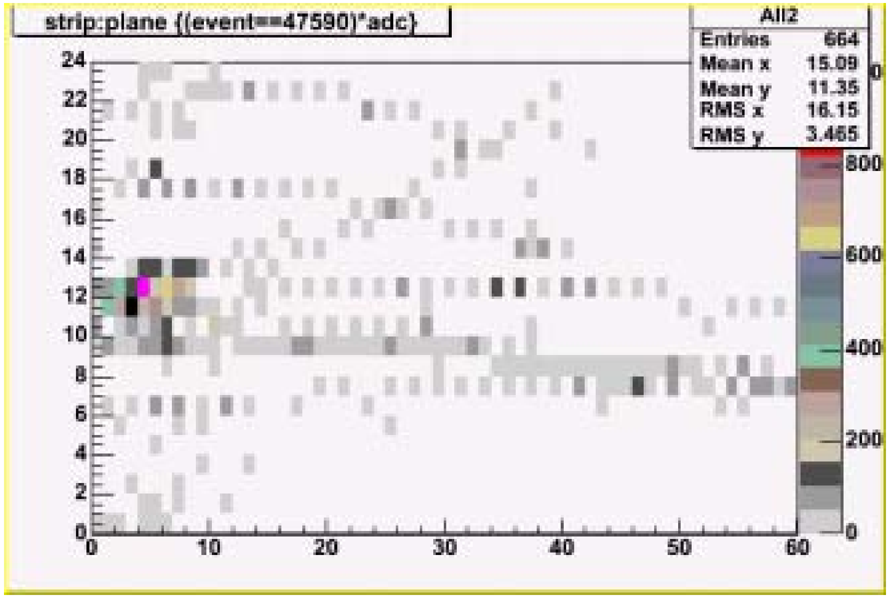
Disentangling Multiple Interaction Spills

- **Near detector will see ~10 neutrino interactions per NuMI spill (Far <<1).**
- **To disentangle the multiple interactions/spill, near detector employs fast "QIE" electronics developed for KTeV for fast digitization**
- **Possible to turn up event rate at Caldet to test electronics**

Near Detector in NuMI

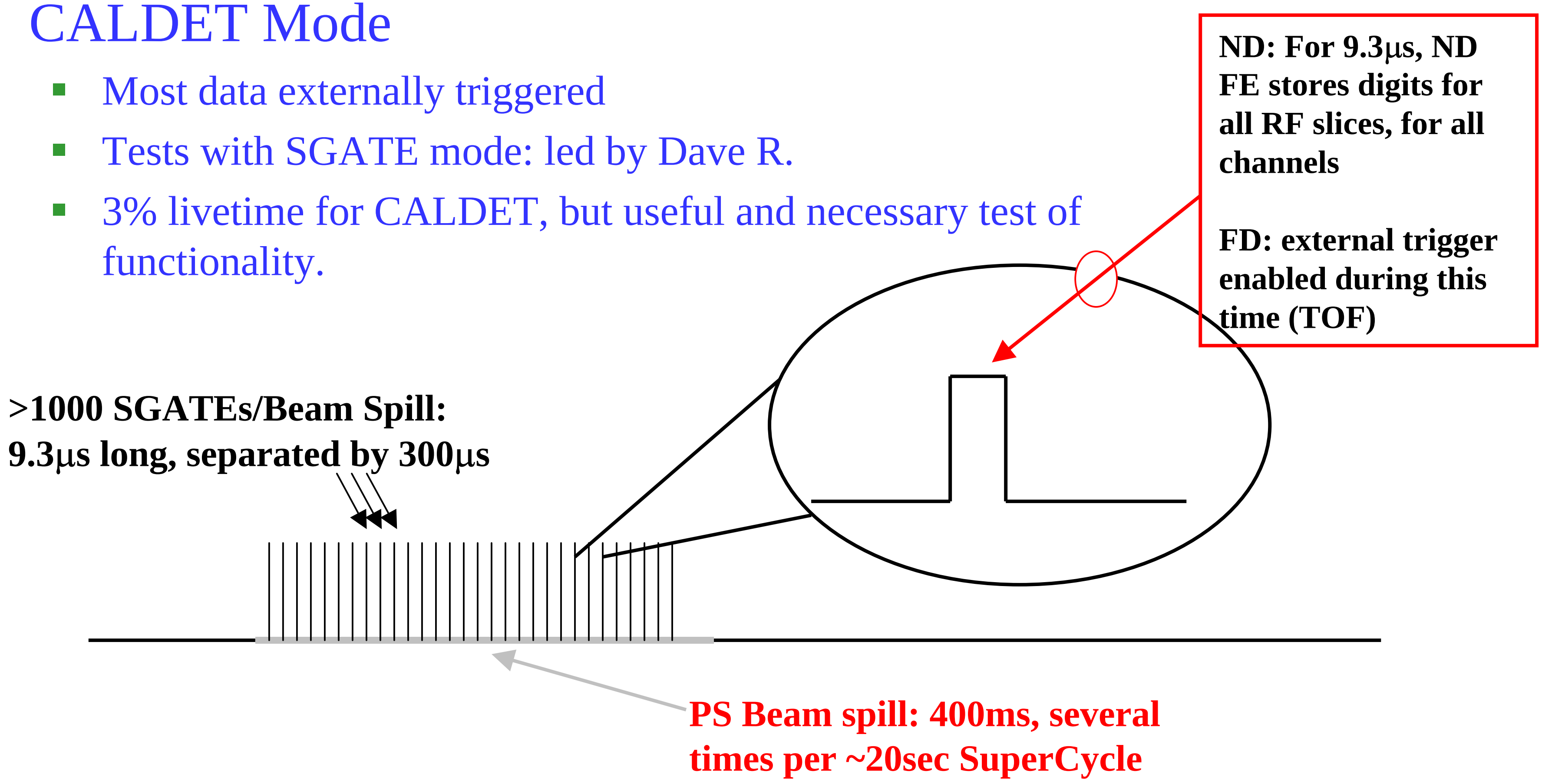


CalDet at CERN



S-GATE Running

- ND mode for fast spill
  - 10μs of continuous data stored in MENU FIFOs
  - Read out after end of spill
- CALDET Mode
  - Most data externally triggered
  - Tests with SGATE mode: led by Dave R.
  - 3% livetime for CALDET, but useful and necessary test of functionality.



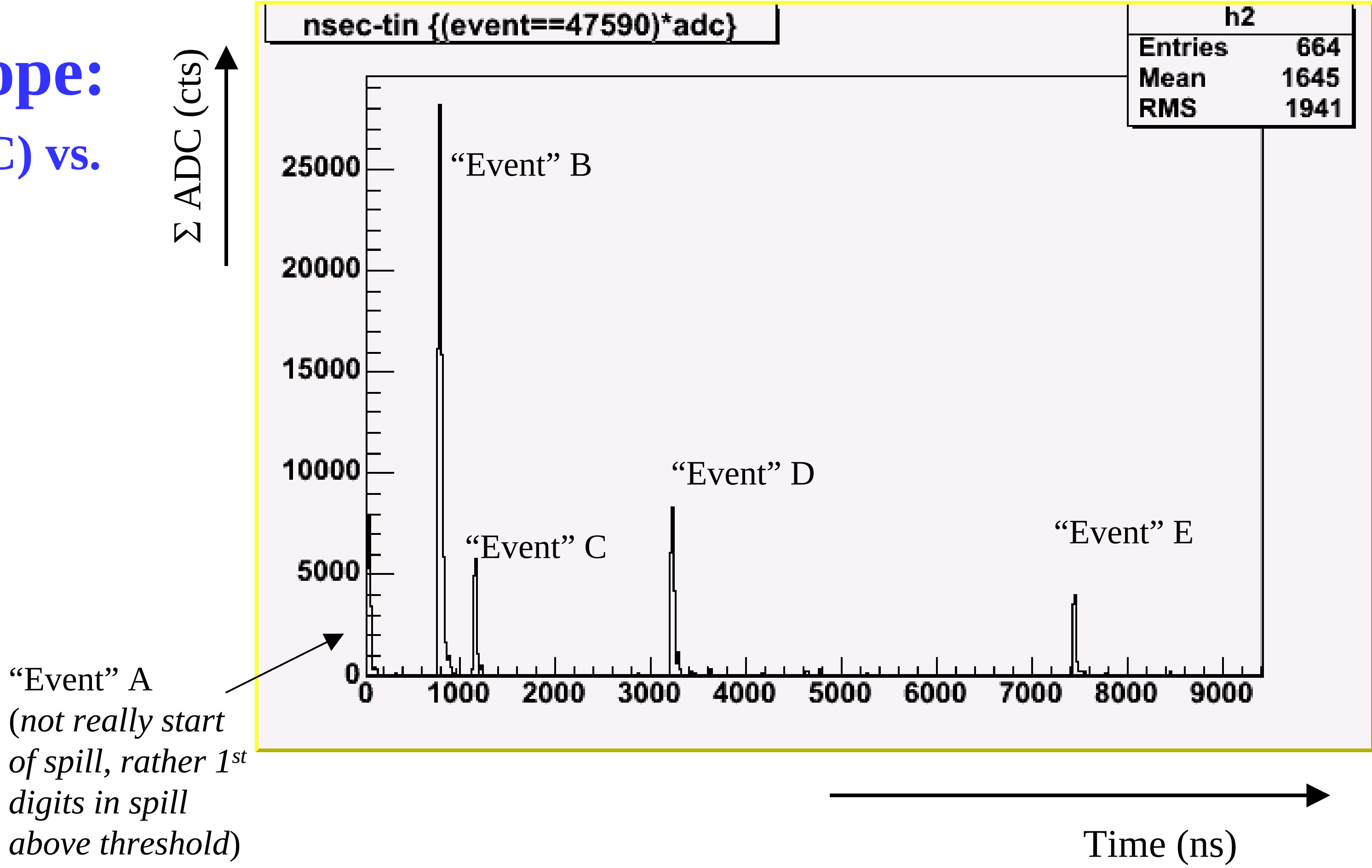
S-GATE DATA

-5 GeV

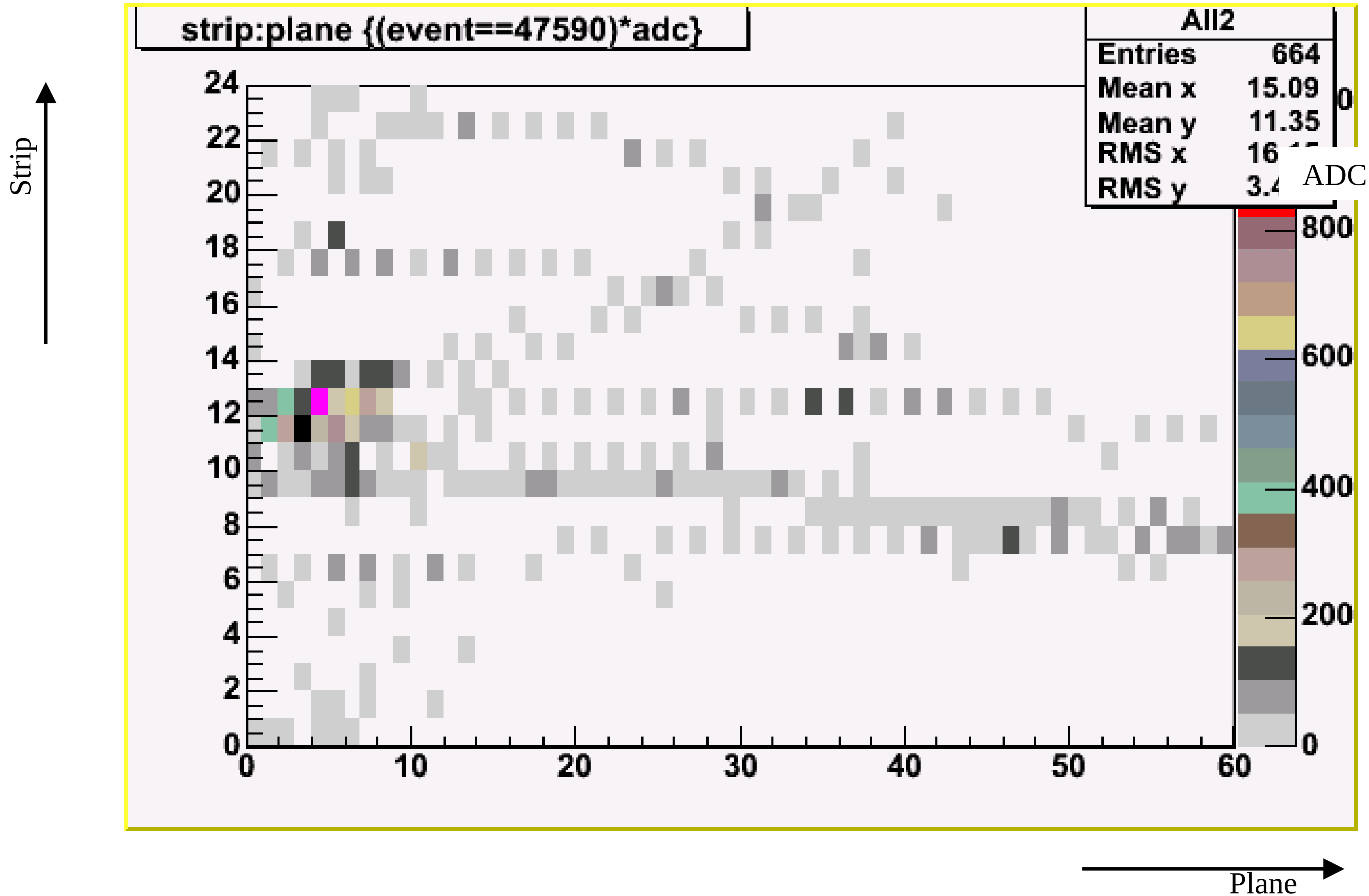
- **Near Detector *cum* Oscilloscope:**
  - **Sum(ADC) vs. Time in SGATE**

One SGATE 9.3 μs long

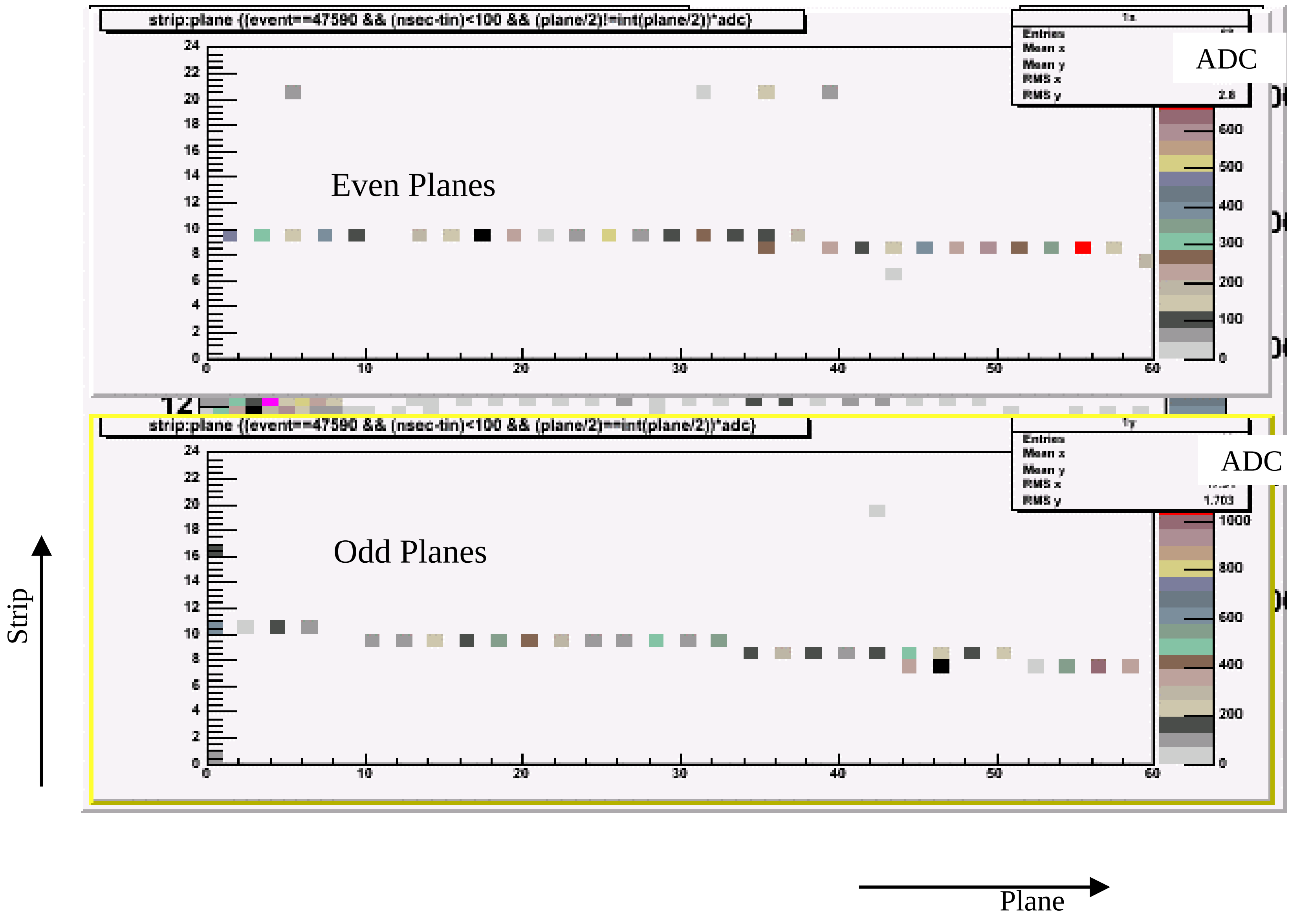
Each x-bin is 1 RF slice



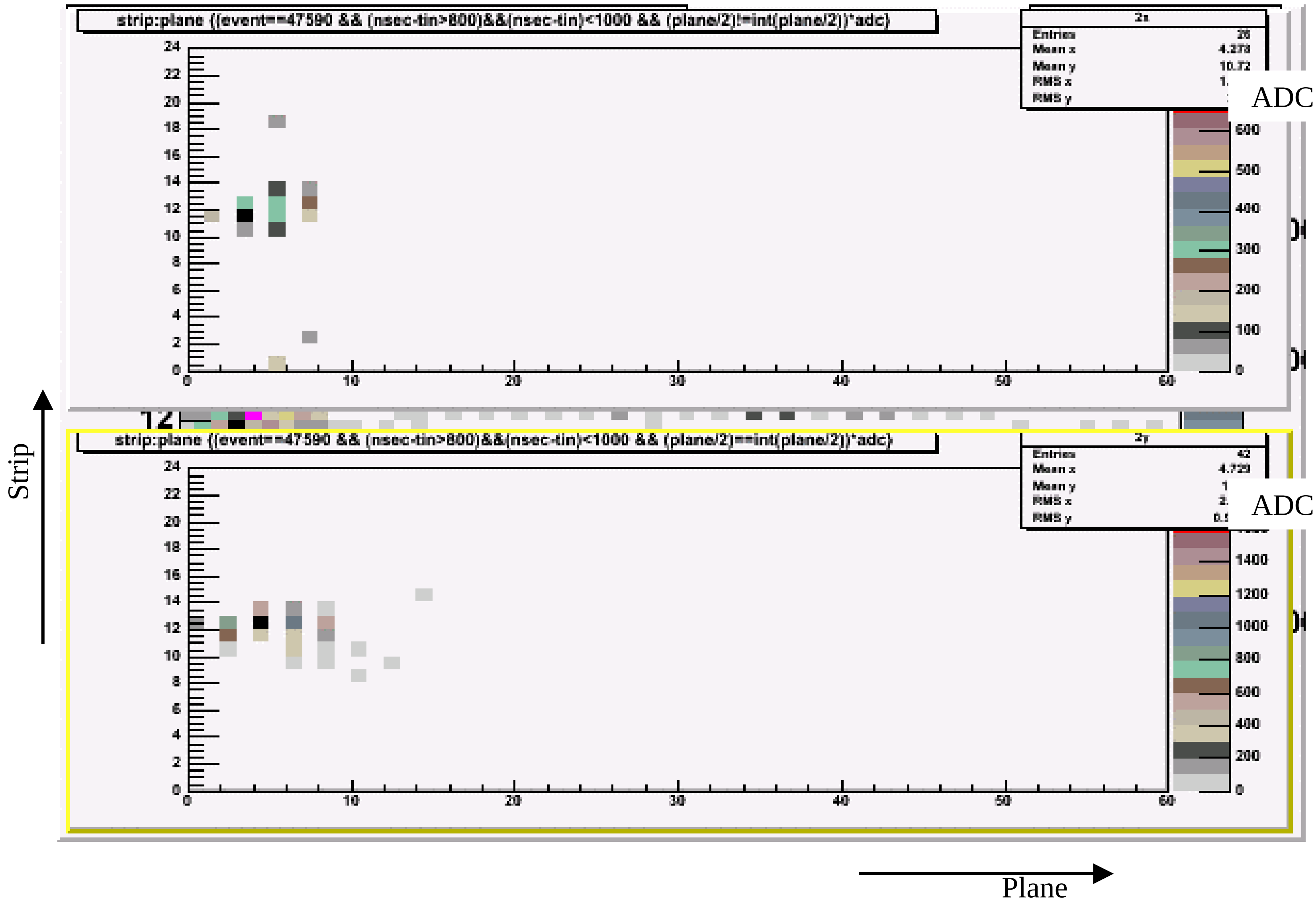
Snarl 47590


strip:plane {(event==47590)*adc}
All2
Entries 664
Mean x 15.09
Mean y 11.35
Strip
Plane
ADC
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24
200
400
600
800

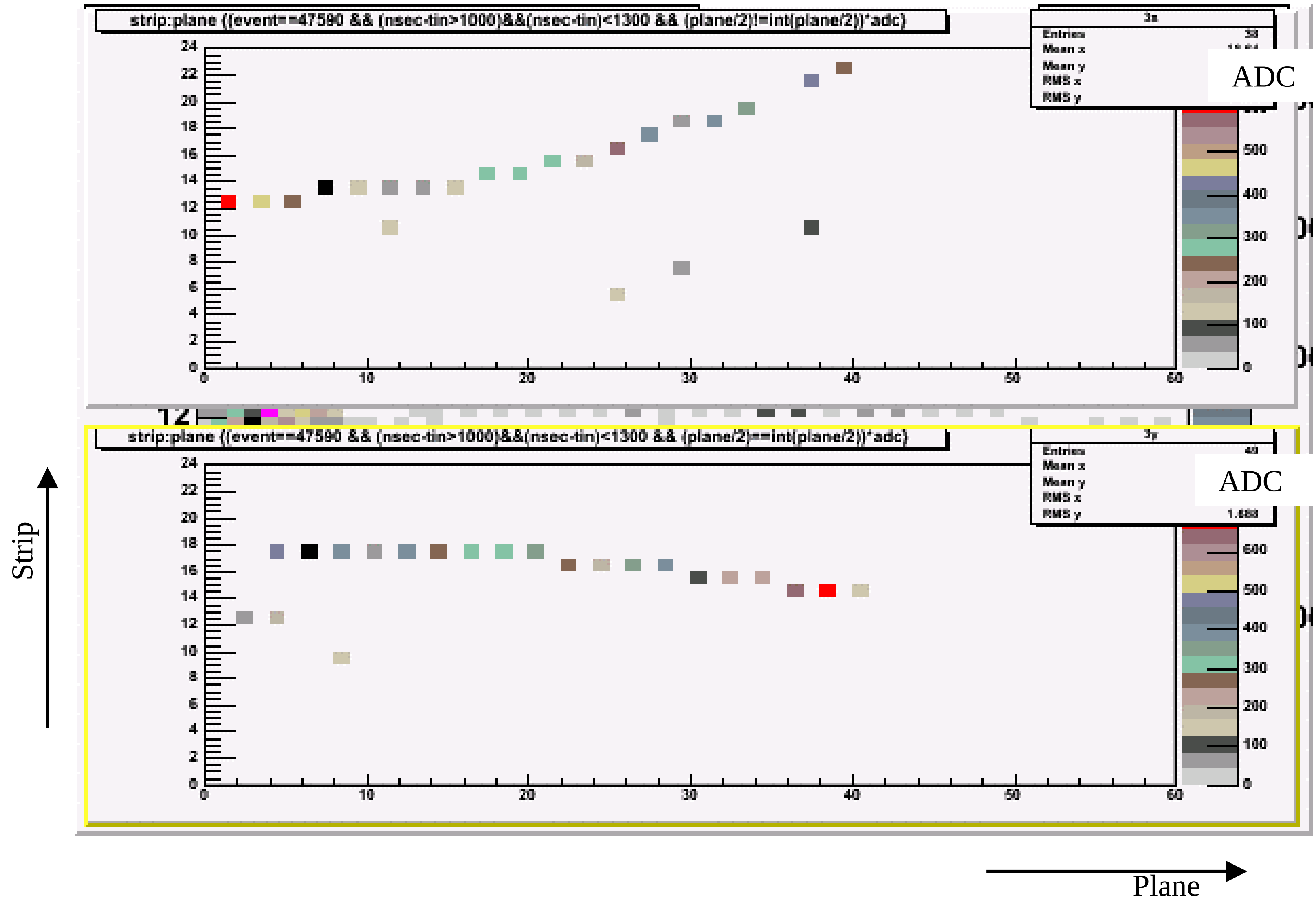
Event A


strip:plane {(event==47590 && (nsec-tin)<100 && (plane/2)!=int(plane/2))*adc}
Even Planes
ADC
Entries
Mean x
Mean y
RMS x
RMS y
strip:plane {(event==47590 && (nsec-tin)<100 && (plane/2)==int(plane/2))*adc}
Odd Planes
ADC
Strip
Plane

Event B

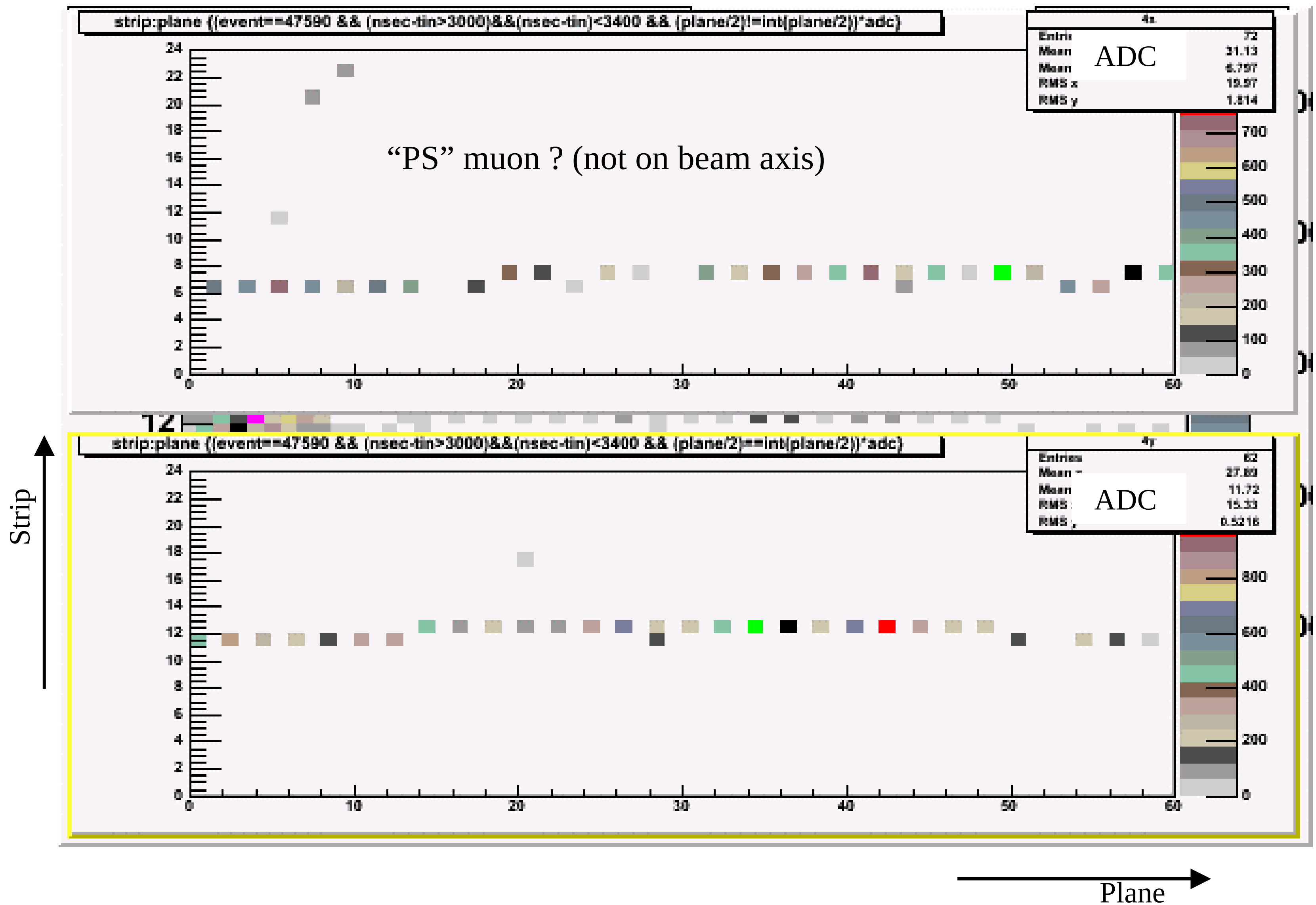

strip:plane ((event==47590 && (nsec-tin>800)&&(nsec-tin)<1000 && (plane/2)!=int(plane/2))*adc)
Entries 28
Mean x 4.278
Mean y 10.72
ADC
strip:plane ((event==47590 && (nsec-tin>800)&&(nsec-tin)<1000 && (plane/2)==int(plane/2))*adc)
Entries 42
Mean x 4.729
ADC
Strip
Plane

Event C

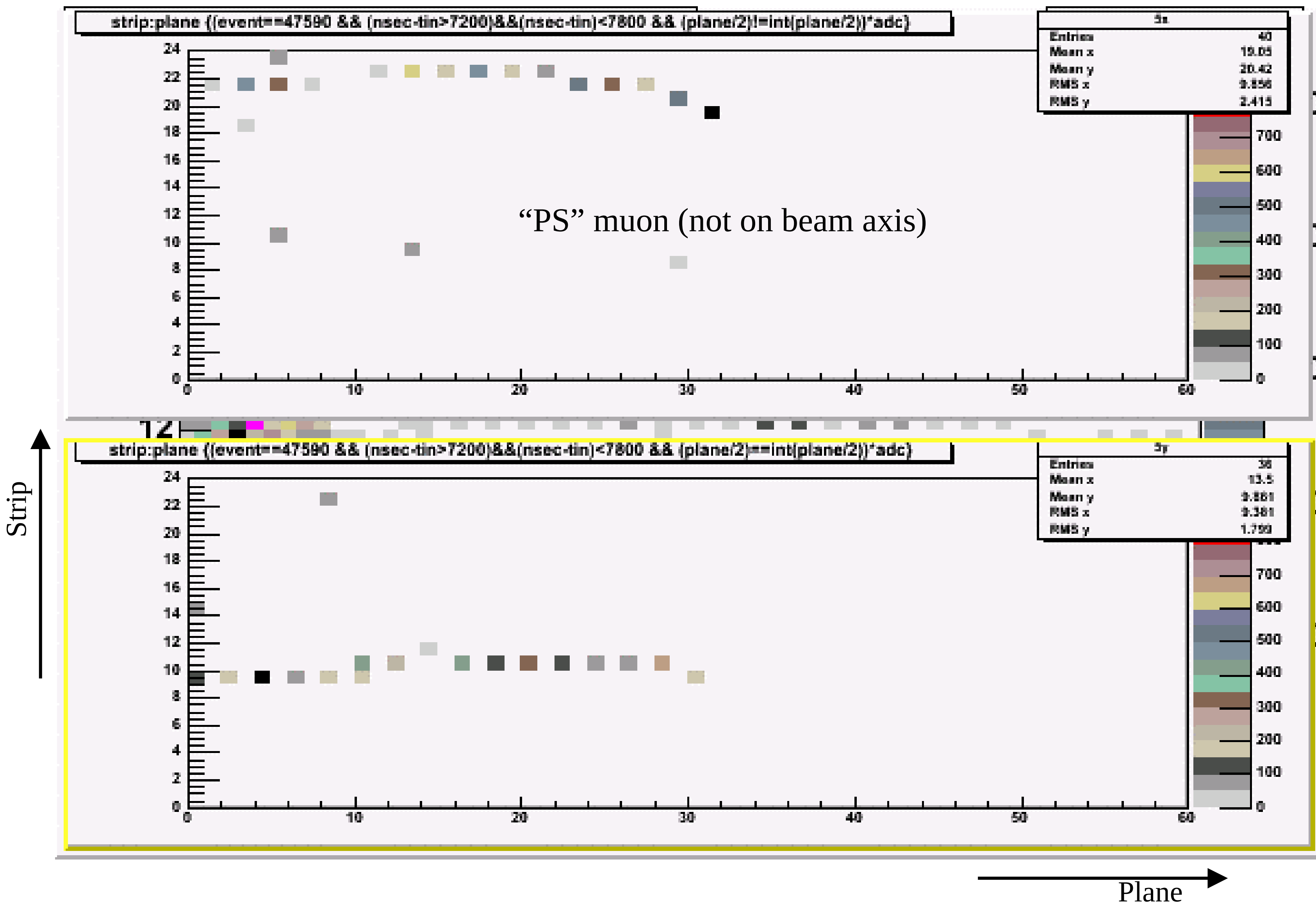

strip:plane ((event==47590 && (nsec-tin>1000)&&(nsec-tin)<1300 && (plane/2)!=int(plane/2))*adc)
strip:plane ((event==47590 && (nsec-tin>1000)&&(nsec-tin)<1300 && (plane/2)==int(plane/2))*adc)
ADC
ADC
Entries
Mean x
Mean y
RMS x
RMS y
Strip
Plane

S.Kopp -- UTAustin
NBI2003, Tsukuba

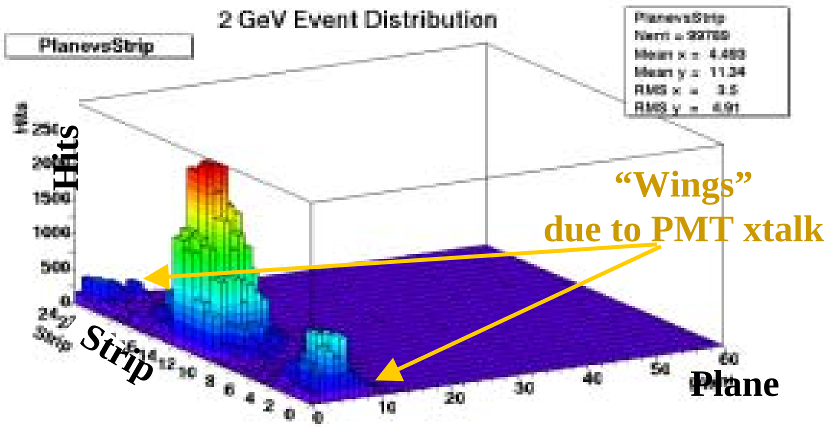
Event D



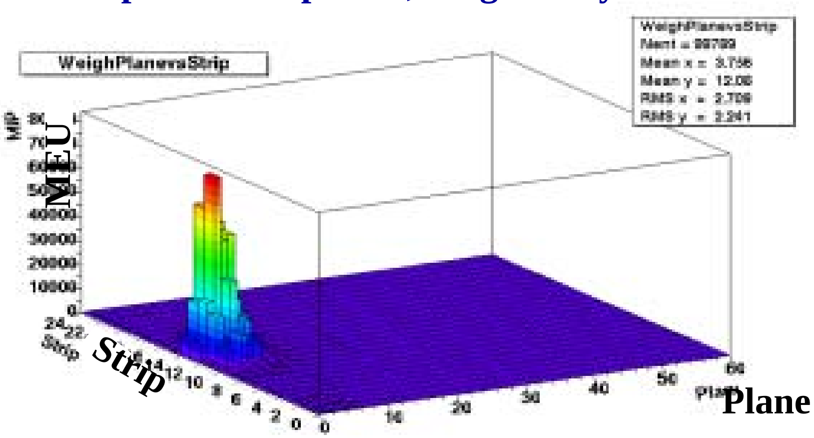
Event E


strip:plane {(event==47590 && (nsec-tin>7200)&&(nsec-tin)<7800 && (plane/2)!=int(plane/2))*adc}
"PS" muon (not on beam axis)
strip:plane {(event==47590 && (nsec-tin>7200)&&(nsec-tin)<7800 && (plane/2)==int(plane/2))*adc}
Strip
Plane

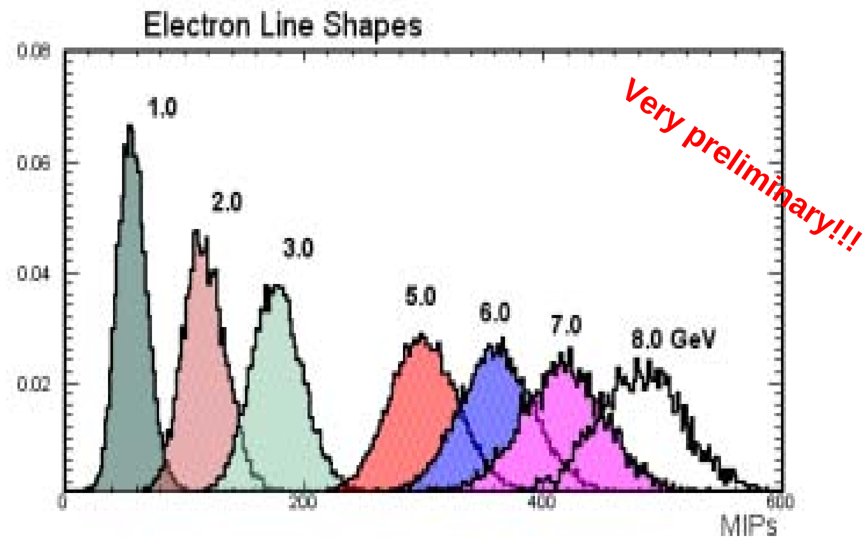
CalDet: electrons

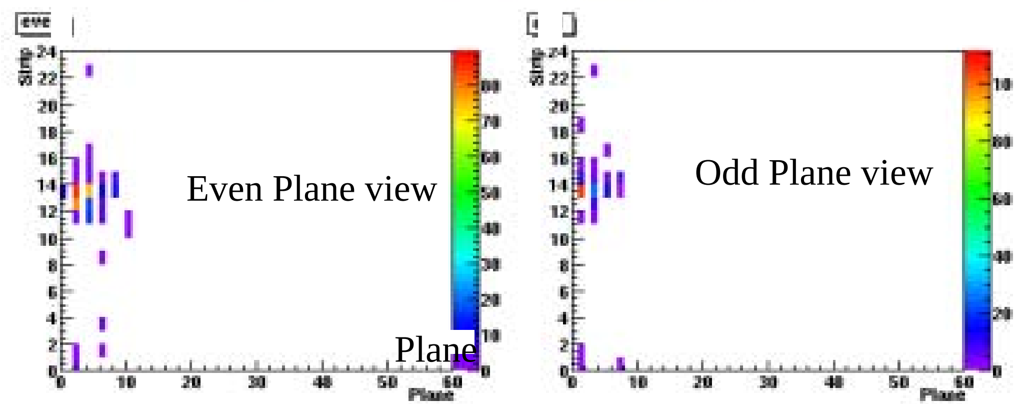


Strip vs. Plane profile, weighted by number of hits



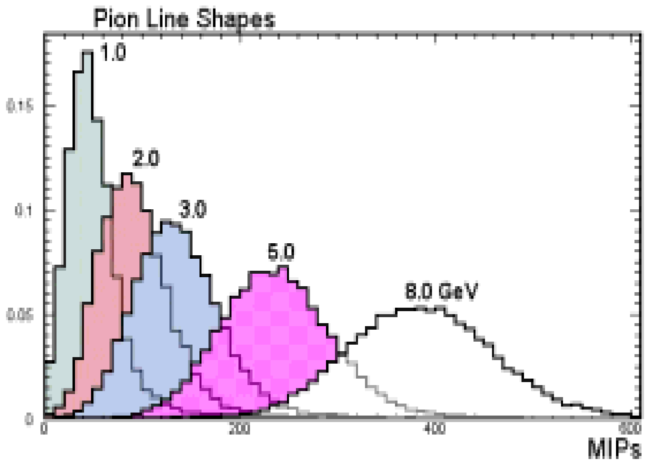
Strip vs. Plane profile, weighted by MEU deposited

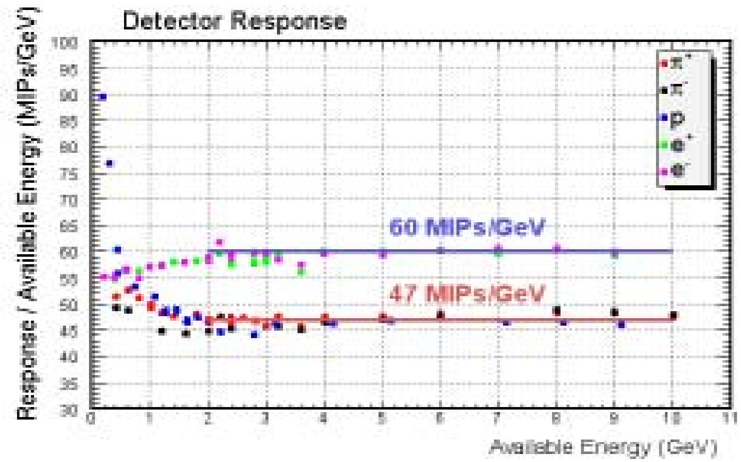


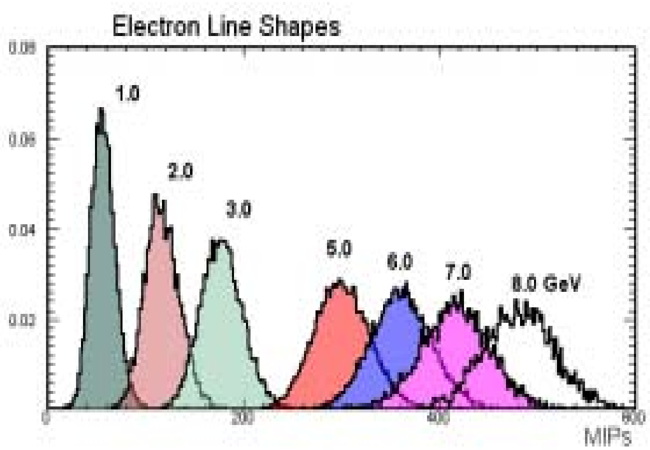


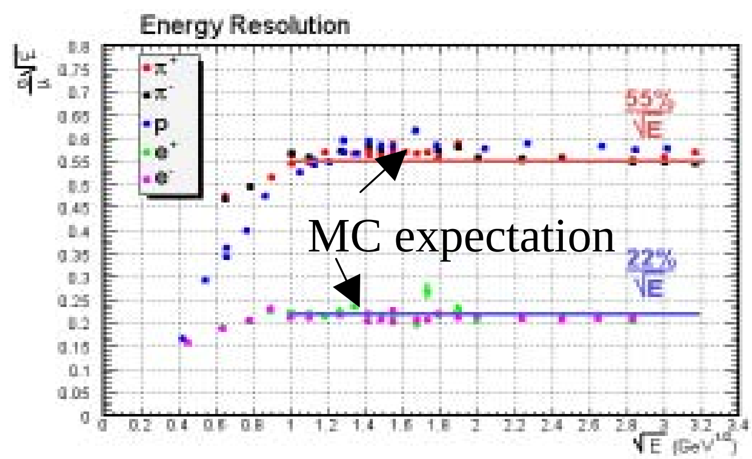
Sample Event (2GeV e^+)

Particle response (preliminary)

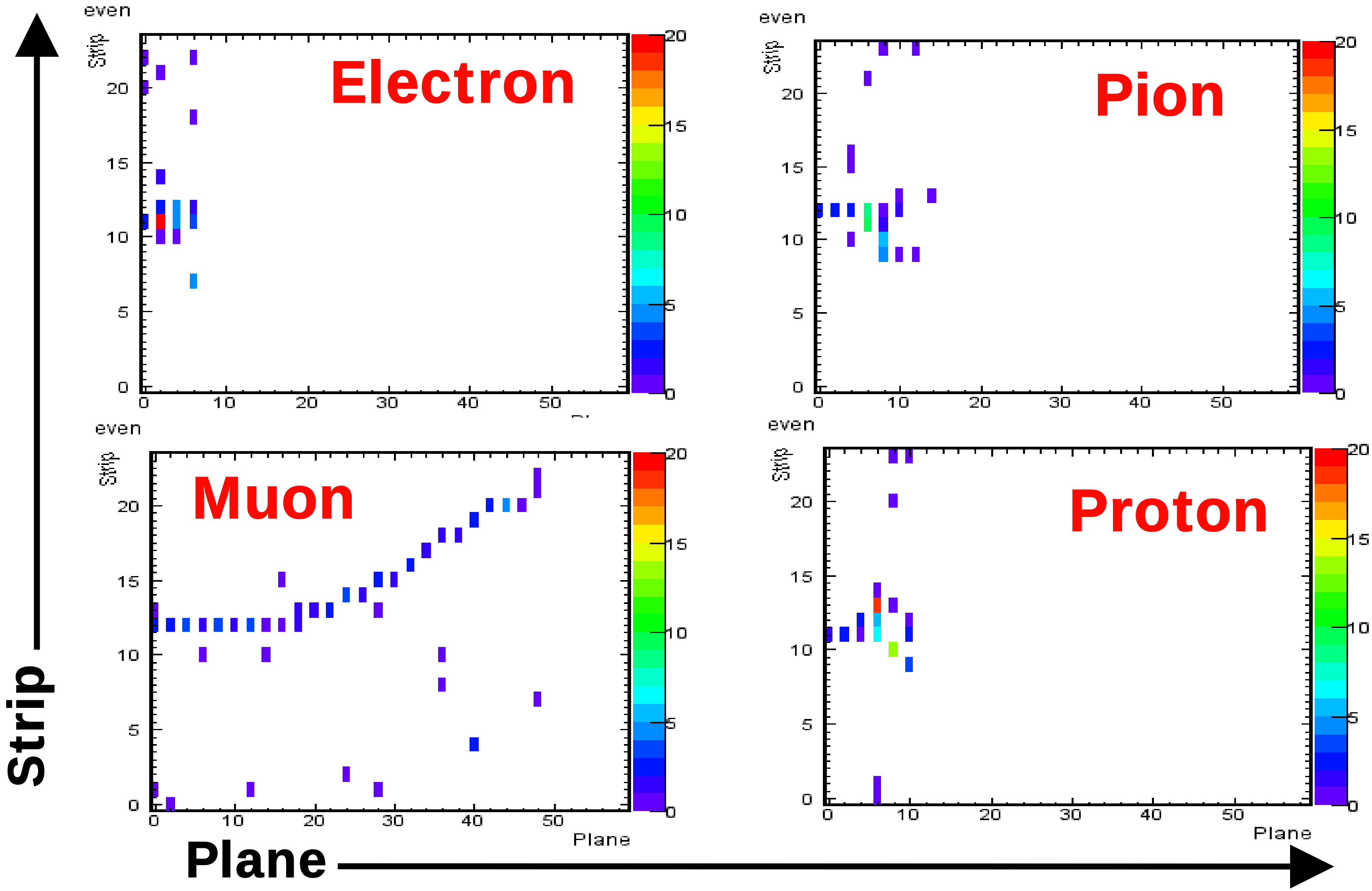








CalDet – 2 GeV events



Additional proposed detector in Near NuMI hall?

Expression of Interest submitted to FNAL PAC

To Perform a High-Statistics (On-Axis) Neutrino Scattering Experiment using a Fine-grained Detector in the NuMI Beam

40 Collaborators from

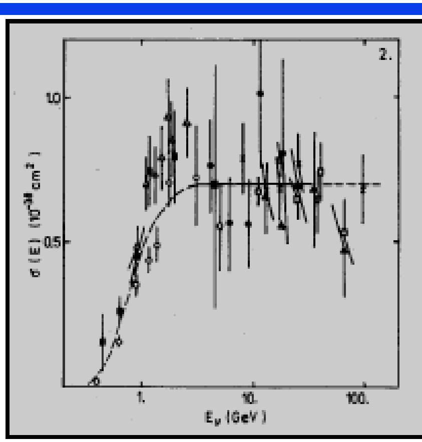
Argonne - Athens - California/Irvine - Colorado - Duke - Fermilab - Hampton - I I T - James Madison - Jefferson Lab - M I T - Minnesota - Pittsburgh - Rutgers - South Carolina - Tufts

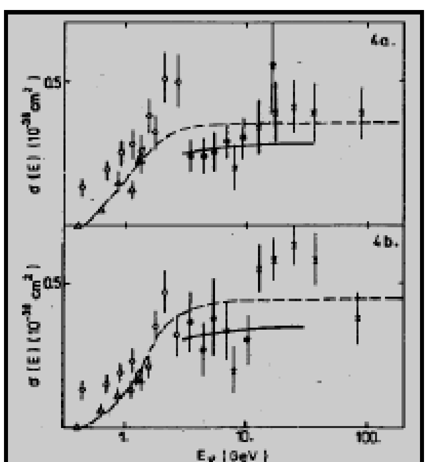
16 Groups: Red = HEP, Blue = NP

Jorge G. Morfín - Fermilab

Survey (pre-K2K) of world's data:

Motivation: Exclusive Cross-sections at Low Energies (1-Pion and Strange Particle): Status - DISMAL





CC

$\nu p \to \mu^- p \pi^+$

$\nu n \to \mu^- p \pi^0$

$\nu n \to \mu^- n \pi^+$

World's sample of NC 1-π

- ANL
  - $\nu\ p \to \nu\ n\ \pi^+$ (7 events)
  - $\nu\ n \to \nu\ n\ \pi^0$ (7 events)
- Gargamelle
  - $\nu\ p \to \nu\ p\ \pi^0$ (178 evts)
  - $\nu\ n \to \nu\ n\ \pi^0$ (139 evts)
- K2K
  - Starting a careful analysis of single π^0 production.

Strange Particle Production

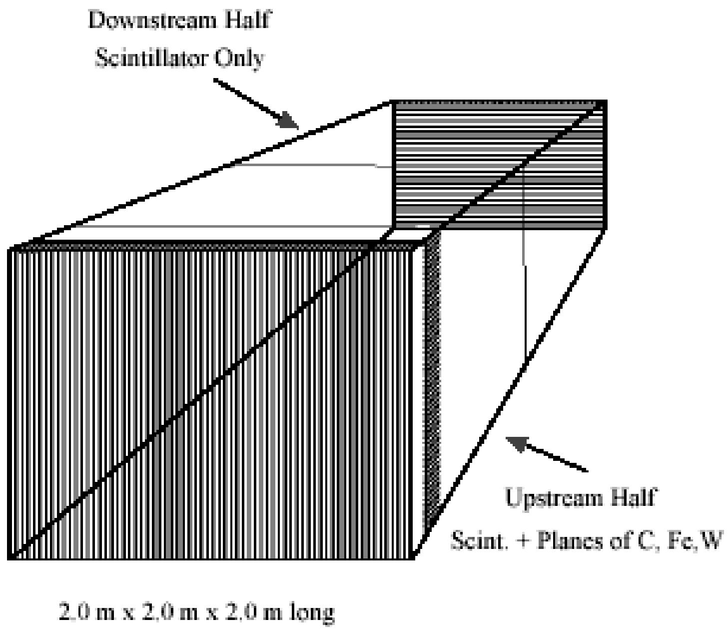
- Gargamelle-PS - **15** Λ events.
- FNAL 15' $\approx$ 100 events
- ZGS - 7 events
- BNL - 8 events

A Phased (Installation) High-resolution ν Detector: Basic Conceptual Design

- 2m x 2 cm x 2cm scintillator (CH) strips with fiber readout. (λ_{int} = 80 cm, X_0 = 44 cm)
- Fiducial volume: (r = .8m L = 1.5 m): 3.1 tons

  R = 1.5 m - p: μ =.45 GeV, π = 51, K = .86, P = 1.2

  R = .75 m - p: μ =.29 GeV, π = 32, K = .62, P = .93
- Also 2 cm thick planes of C, Fe and Pb.
  - 11 planes C = 1.0 ton (+Scintillator)
  - 3 planes Fe = 1.0 ton (+MINOS)
  - 2 planes Pb = 1.0 ton
- Readout: Current concept is VLPC. (How about PMT or CCD + Image Intensifier?)
- Use MINOS near detector as forward μ identifier / spectrometer.
- Considering the use of side μ-ID detectors for low-energy μ identification.



UNOFFICIAL Response of the Fermilab PAC to EOI

- Only unofficial summary is currently available! Official letter due in a week or two.
- We seem to be "encouraged" to continue developing the physics, detector and collaboration in order to submit a formal Proposal. How "encouraged" will have to wait for the official letter.
- An indication (quantitative) of how these results would aid neutrino oscillation experiments would be welcome.
- **A combined R&D program (multiple EOIs) for detector + readout technology is encouraged.**

Summary

- Near Detector planes are constructed
- Installation schedule now fully developed
  - Begin installation January 2004
  - Complete installation October 2004
- Utility of detector for MINOS is still under study
  - Beam Commissioning
  - Online monitor
  - Neutrino Flux
  - Neutrino reconstruction systematics
- Exciting opportunities to add an additional detector(s) for greater physics reach
  - Collaborators welcome!

- Thanks to Tanaka-san and all for great workshop!