The Cosmics Test of The DSECal of The T2K Near Detector

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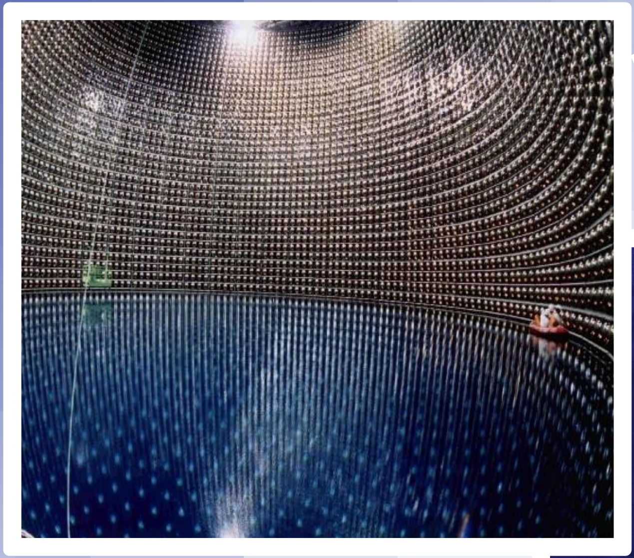
IOP High Energy Particle Physics Conference
6th - 8th April 2009

Queen Mary
University of London

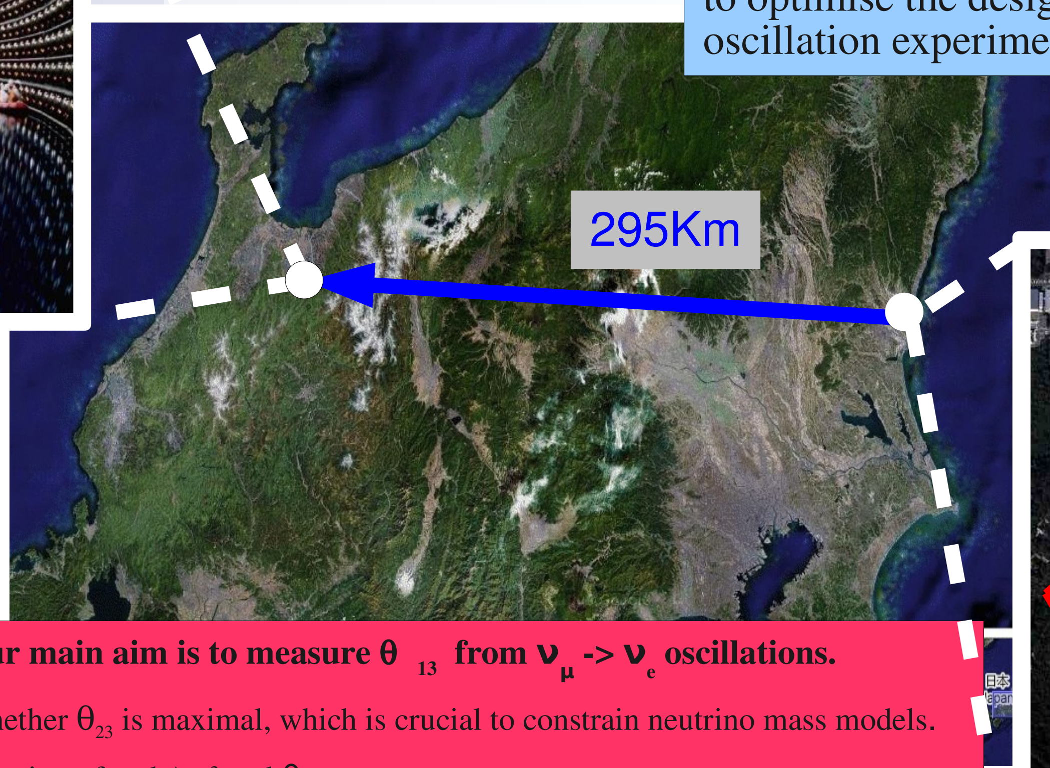
T2K UK

T2K - Tokai To Kamioka

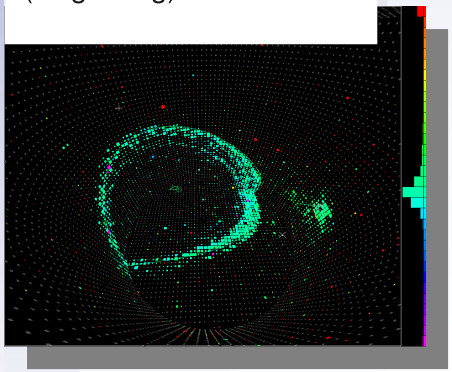


❖The ν_e appearance measurement is sensitive to θ_{13}.

❖ν_μ disappearance will be measured and used to calculate Δm_{23}^2 and θ_{23} and to optimise the design of future oscillation experiments.



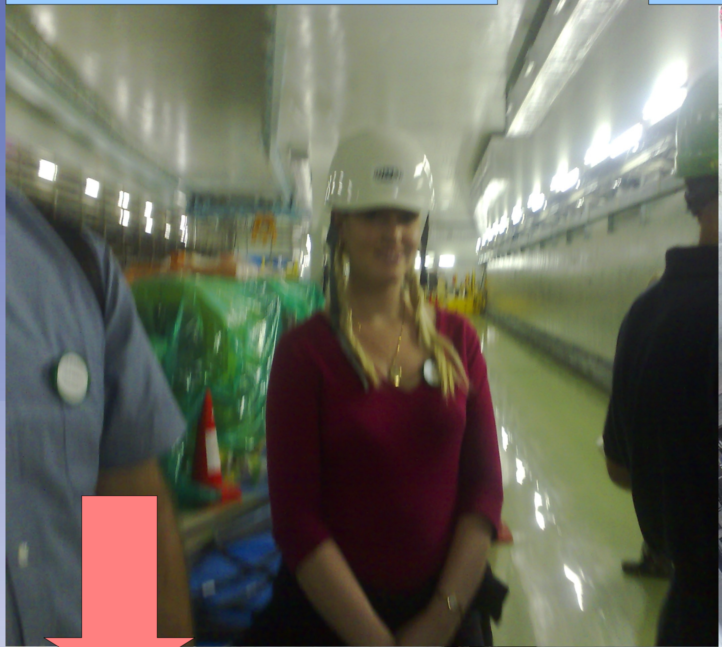
Super Kamiokande muon (single ring) event



- **Our main aim is to measure θ_{13} from $\nu_\mu \rightarrow \nu_e$ oscillations.**
- Whether θ_{23} is maximal, which is crucial to constrain neutrino mass models.
- The sign of and Δm^2 and θ_{23}.
- The mixing angle $\sin^2 2\theta_{23}$.
- The Δm^2_{23} to an accuracy of 3%.
- The sensitivity to the mixing angle $\sin^2 2\theta_{13}$ to $\delta \sin^2 2\theta_{13}$ <0.01.
- If $\delta \neq 0$ CP violation will be shown to occur.

J-PARC and The nd280 Site

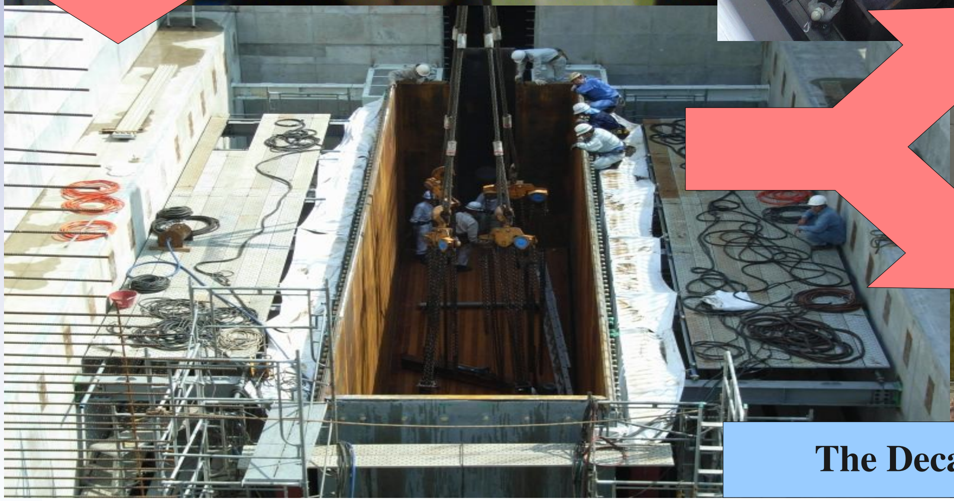
The proton synchrotron



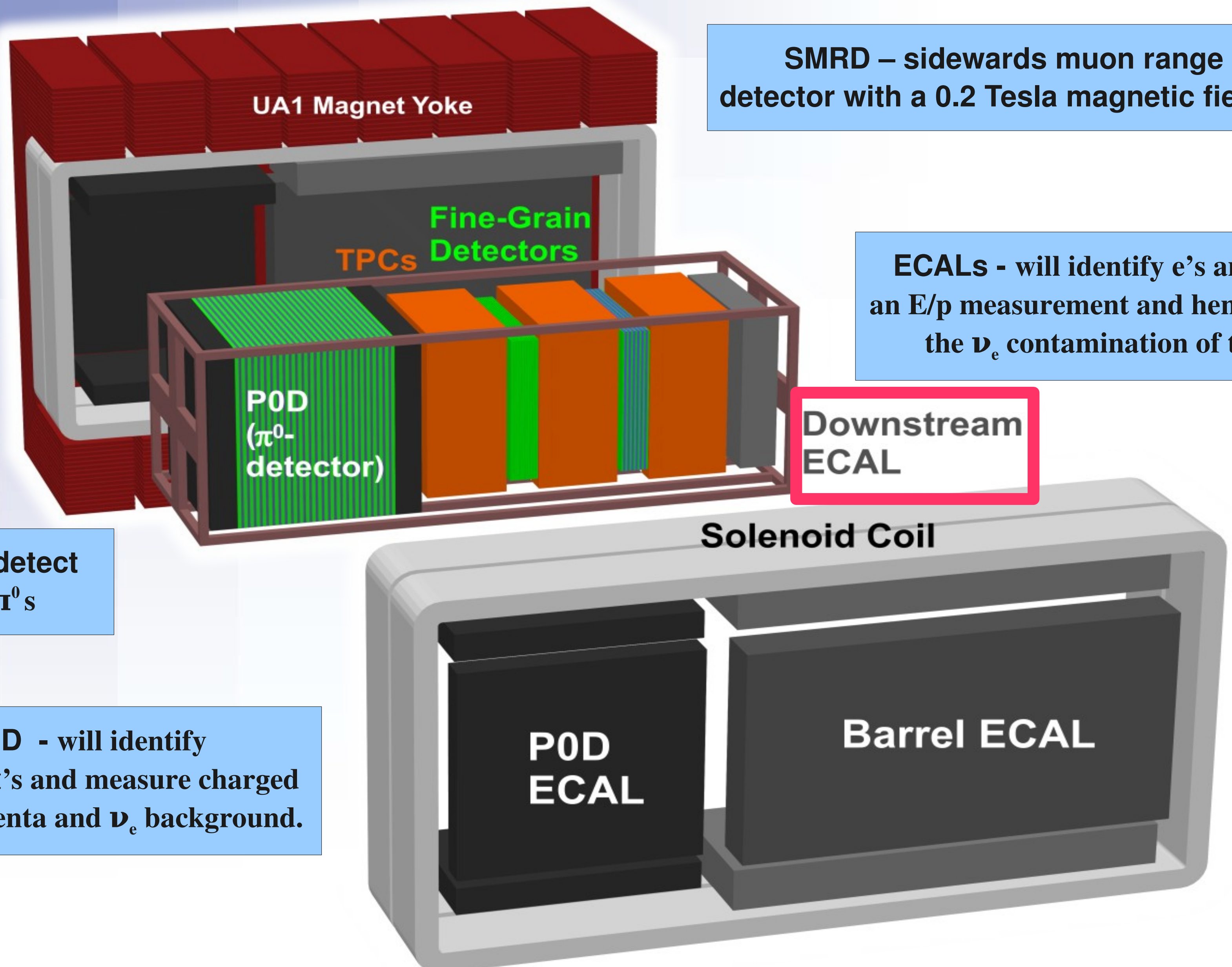
The Beam Dump

The making of the nd280 Pit

The Decay Volume



The Off Axis Near Detector - nd280



SMRD – sidewards muon range detector with a 0.2 Tesla magnetic field

ECALs - will identify e's and μ's from an E/p measurement and hence determine the ν_e contamination of the beam.

P0d – Will detect mainly π^0 s

TPC and FGD - will identify e's, μ's and π's and measure charged particle momenta and ν_e background.

The DSECal
Down Stream Electromagnetic Calorimeter

- Coarse grained detector.
- Made up of 34 layers of 40mm x 10mm x 2000mm bars of plastic scintillator, each layer of 50 bars is separated by a 1mm thick lead sheet.
- 90° rotation between the bars of subsequent layers.
- Wavelength shifting fibres running through the centre of each bar.
- Read out by 3400, Hamamatsu Multi-Pixel Photon

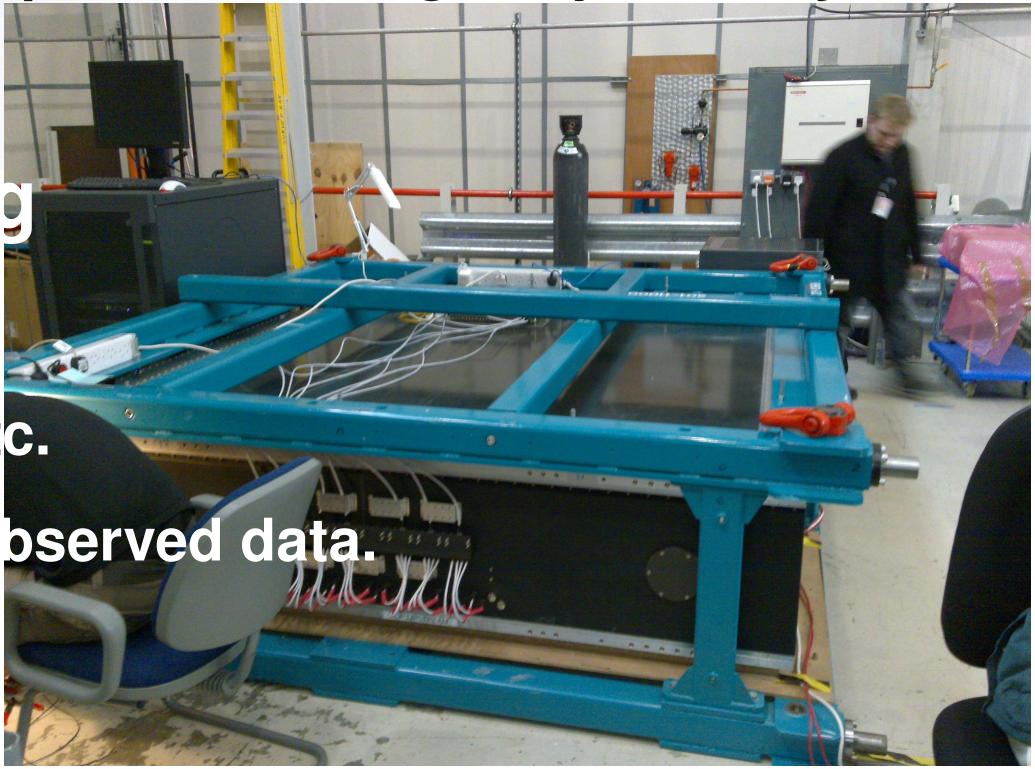
Counters - MPPCs, 667 pixels per device.

- Will identify e's and μ's from an E/p measurement.

The Cosmics Test

There are 4 Main Aims :-

- **Hardware Commissioning**
  - Commissioning of the data acquisition and light injection systems.
  - Tuning the cosmic trigger.
- **Software Commissioning**
  - Tuning the cosmic trigger.
  - Tuning Reconstruction, PID etc.
  - First physics analysis using observed data.
- **Calibration**
- **Background –** We can understand the detector response to cosmic muons now, so that when the DSECal is on site in Japan we can take another cosmic run and eliminate any background we may see.



The Cosmics Test

	Dec '08	Jan '09	Feb '09	Mar '09	Apr '09	May '09	Jun '09	Jul '09
ship DSECal to RAL	■							
Commissioning & cosmics test		■	■	■				
Decommission & ship to CERN					■			
Commissioning					■			
Test beam & cosmics test						■	■	
Decommission							■	
Ship to Japan								■

The Analyses For The Cosmics Test

- **Production of a simulated cosmic flux for use in MC studies.**
- **Calibration of photosensors and TFBs, time, charge, channel mapping etc.**
- **Attenuation in bars.**
- **Reconstruction – position, PID, tracks, efficiency.**
- **Bar and layer efficiency.**
- **MC flux – data comparison.**
- **Data monitoring and quality analysis.**

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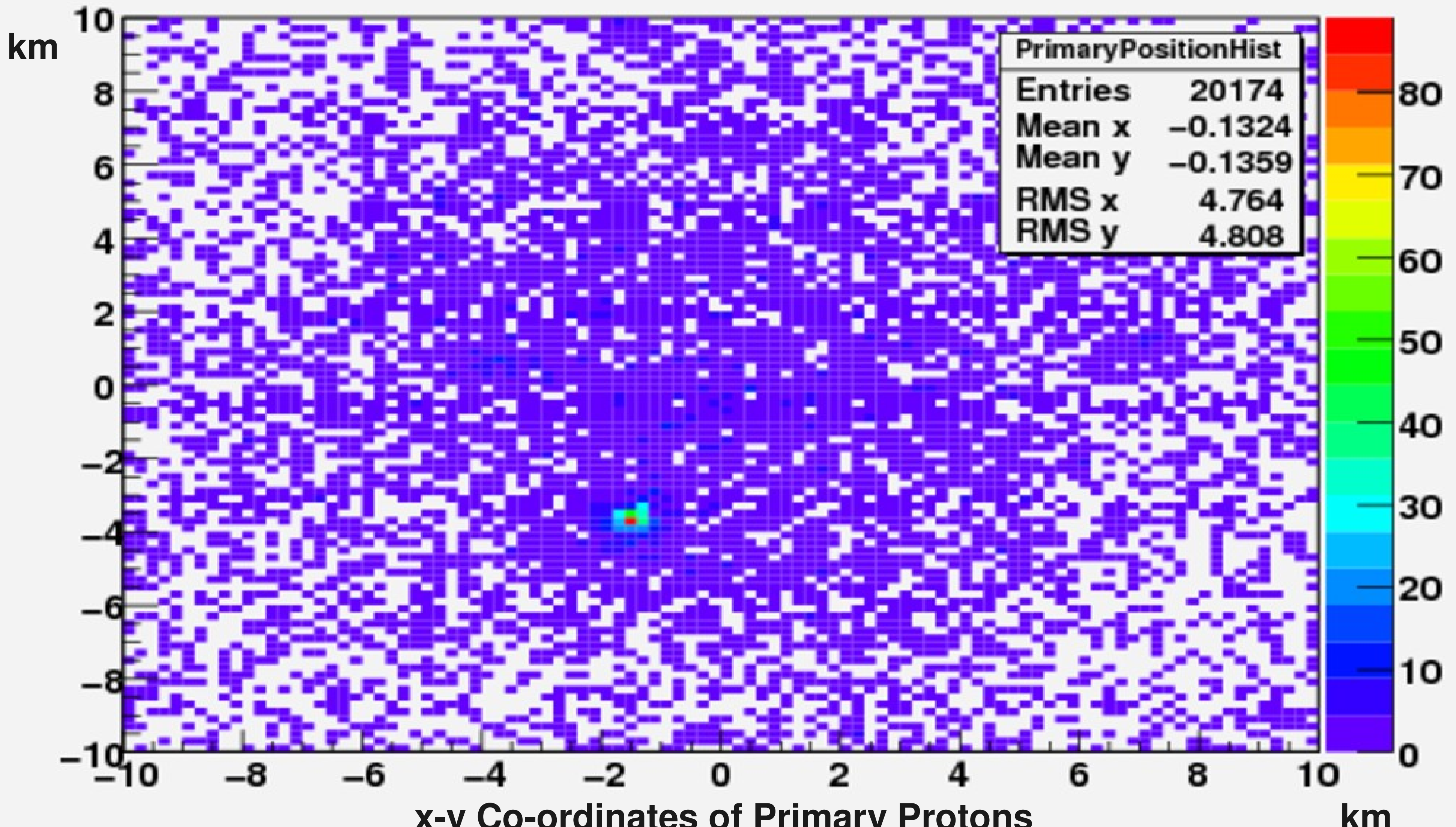
Simulated Cosmic Flux Production

- **Will be used as the standard nd280 Cosmic flux for T2K.**
- **Produced for 4 locations (RAL, CERN, TRIUMF and Tokai) according to sub-detector testing locations and the nd280 detector *in situ*.**
- **Produced using Corsika** *[ref: D. Heck, T. Pierog and J. Knapp Report FZKA 6019 (1998), Forschungszentrum Karlsruhe; http://wwwik.fzk.de/corsika/physics description/corsika phys.html]*
  - **Extensive air shower simulation package.**
  - **Initially developed for use in Kascade exp, and more recently Pierre Auger, continually updated.**
- **High energy hadronic interaction model – QGSJET (Quark Gluon String Model With Jets).**
- **Low energy hadronic interaction model - FLUKA (Fluctuating Cascade).**

Position distribution of the starting vertices of those primary protons that produce muons hitting our detector (detector situated at origin). Made using a flat Earth approximation.



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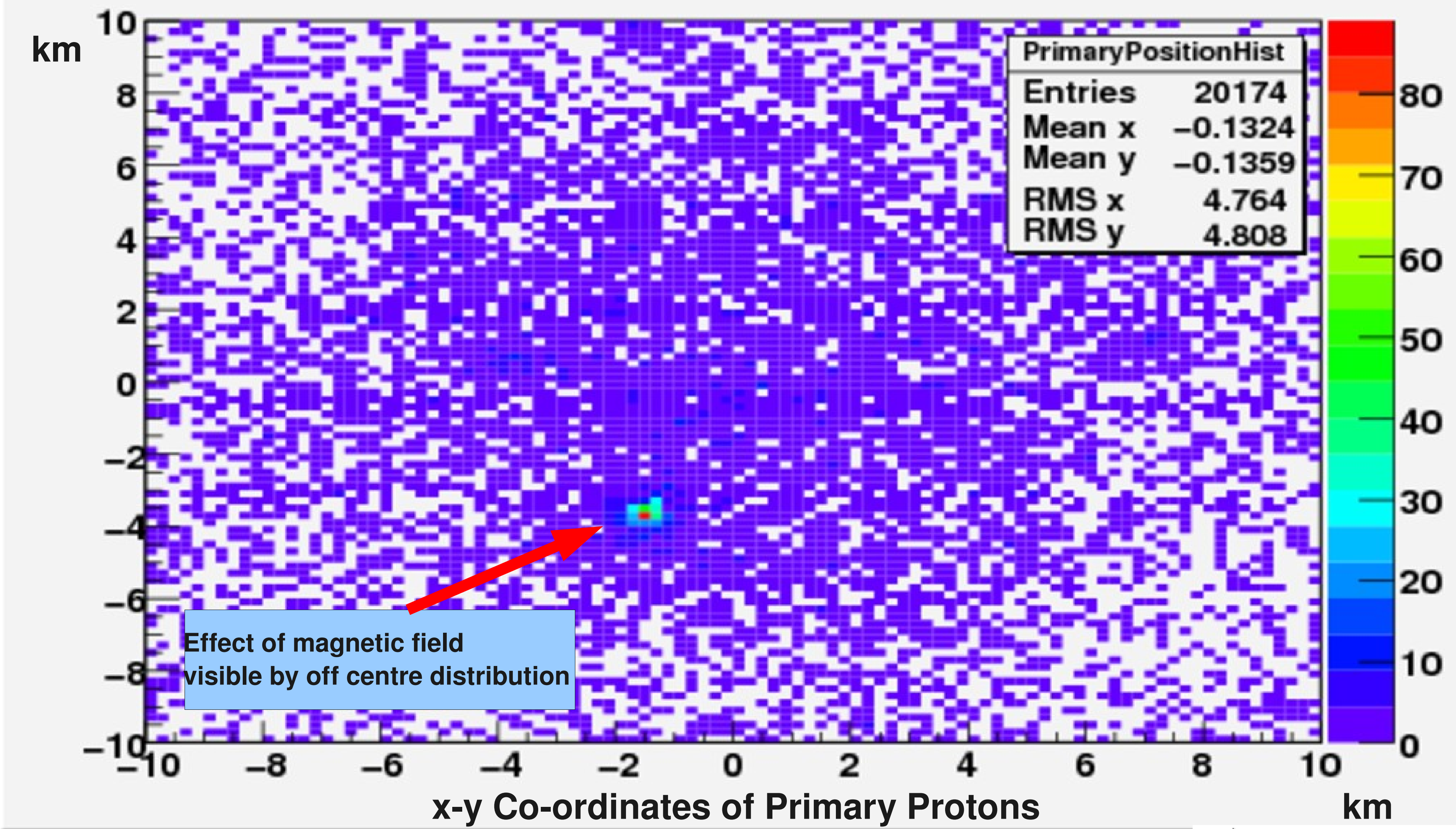
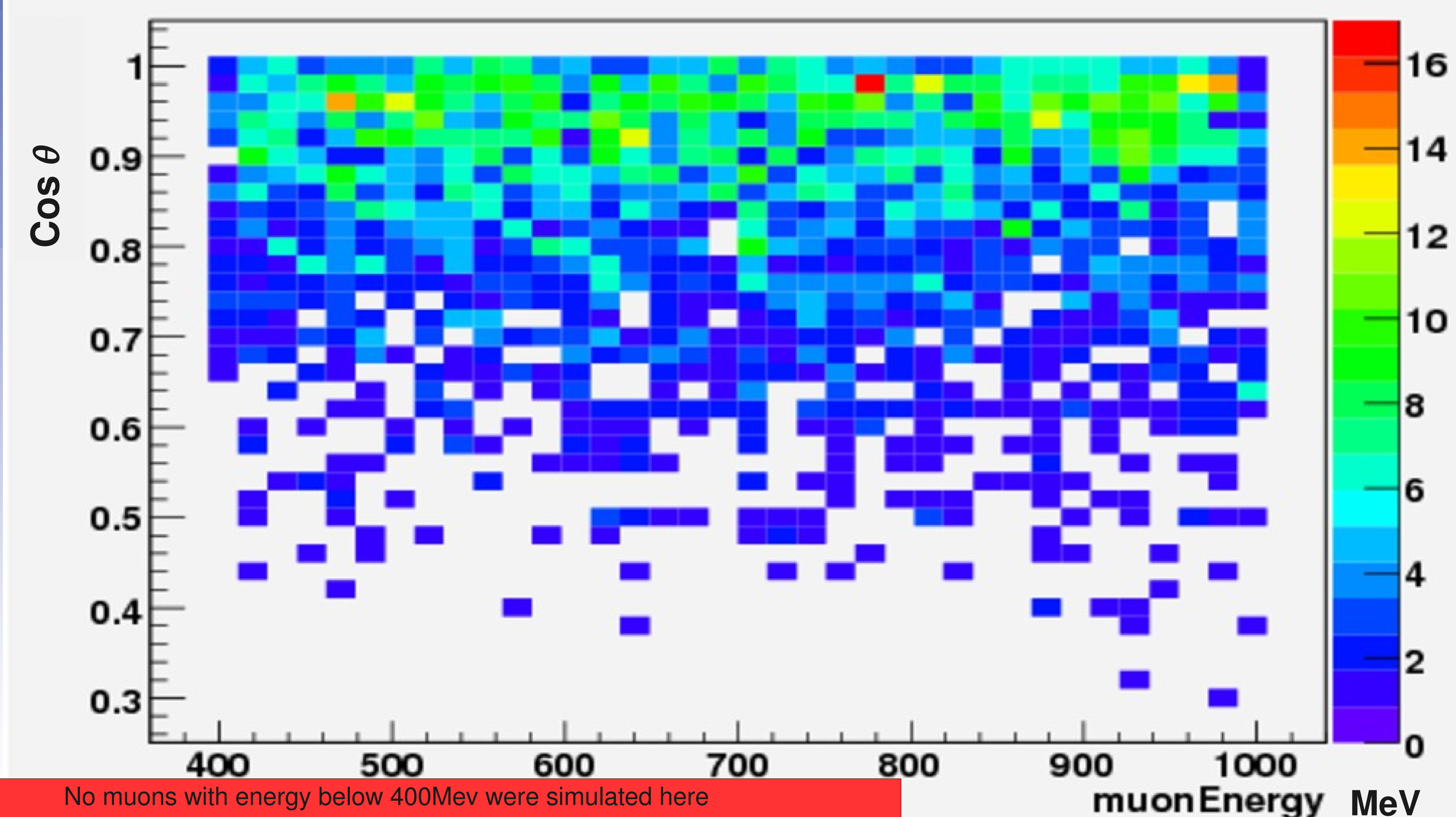


Simulated Cosmic Flux Production

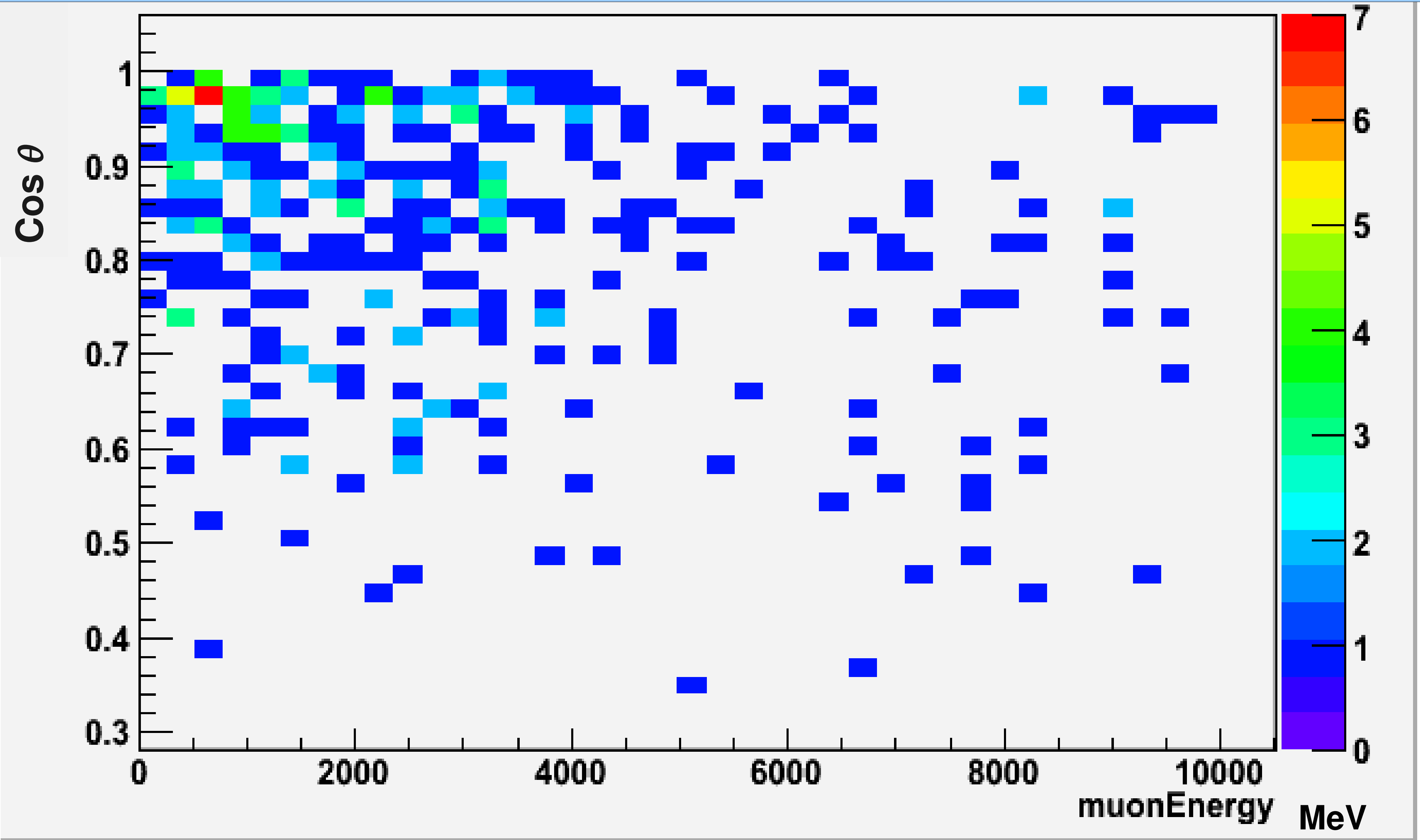
Cos θ where θ = zenith angle vs Energy (MeV) for muons < 1GeV at detector level



No muons with energy below 400Mev were simulated here
Coriska inputs adapted to include all energies of detector level muons

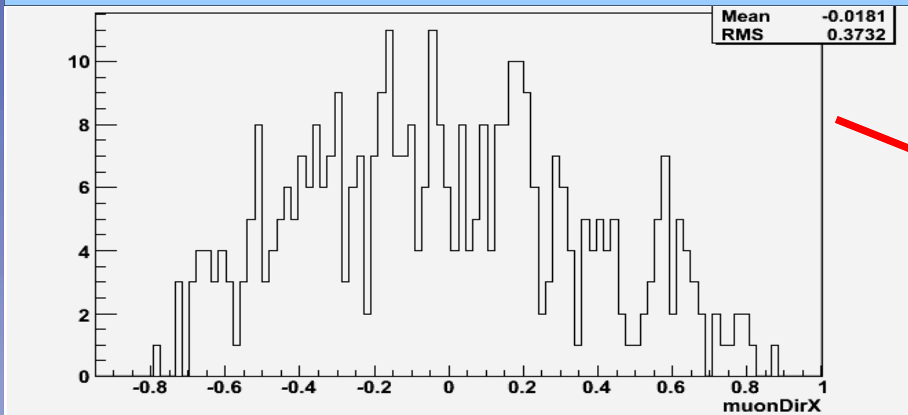
Simulated Cosmic Flux Production

Cos θ where θ = zenith angle vs Energy (MeV) for muons < 10GeV at detector level

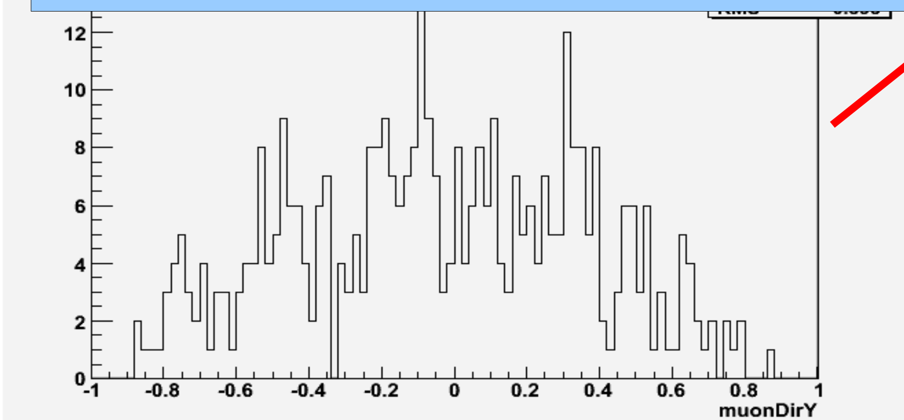


Simulated Cosmic Flux

Azimuthal Distribution of μ in $x=\cos\phi\sin\theta$

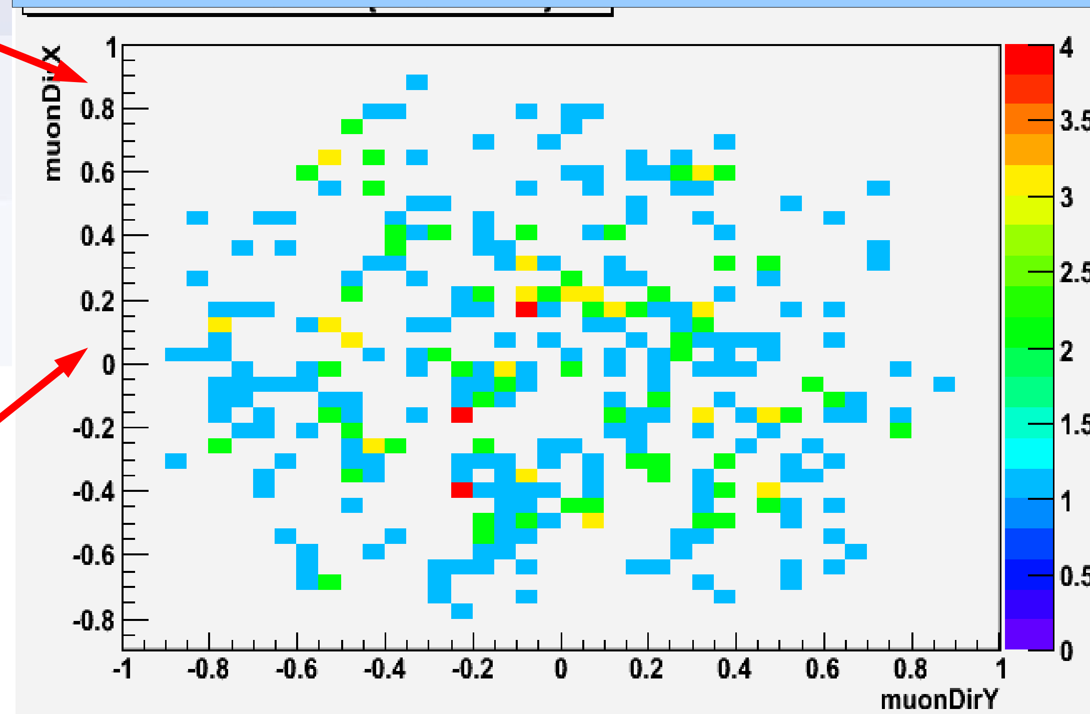


Azimuthal Distribution of μ in $y=\sin\phi\cos\theta$



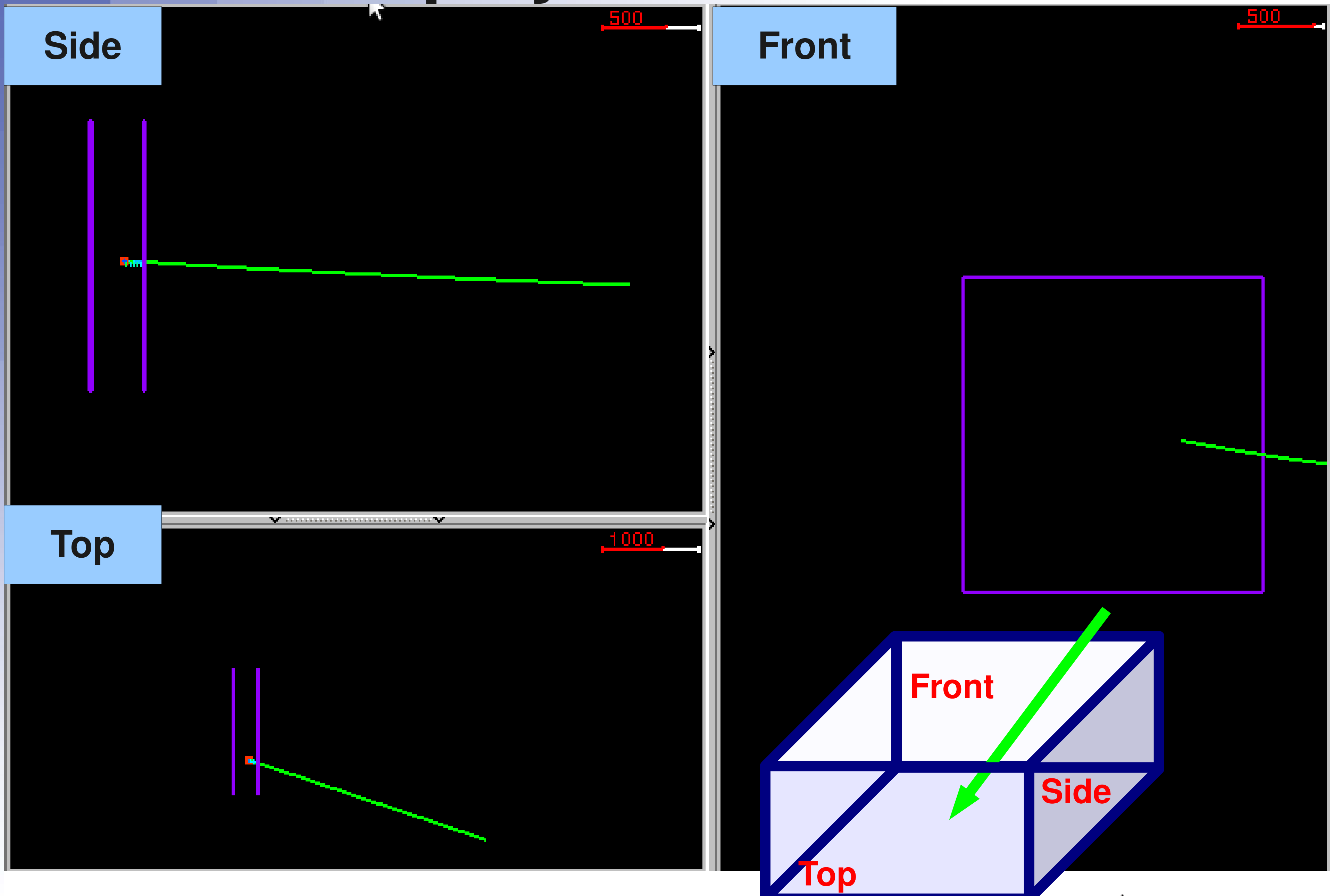
Azimuthal Distribution of Muons in x and y

$x=\cos\phi\sin\theta$ $y=\sin\phi\cos\theta$

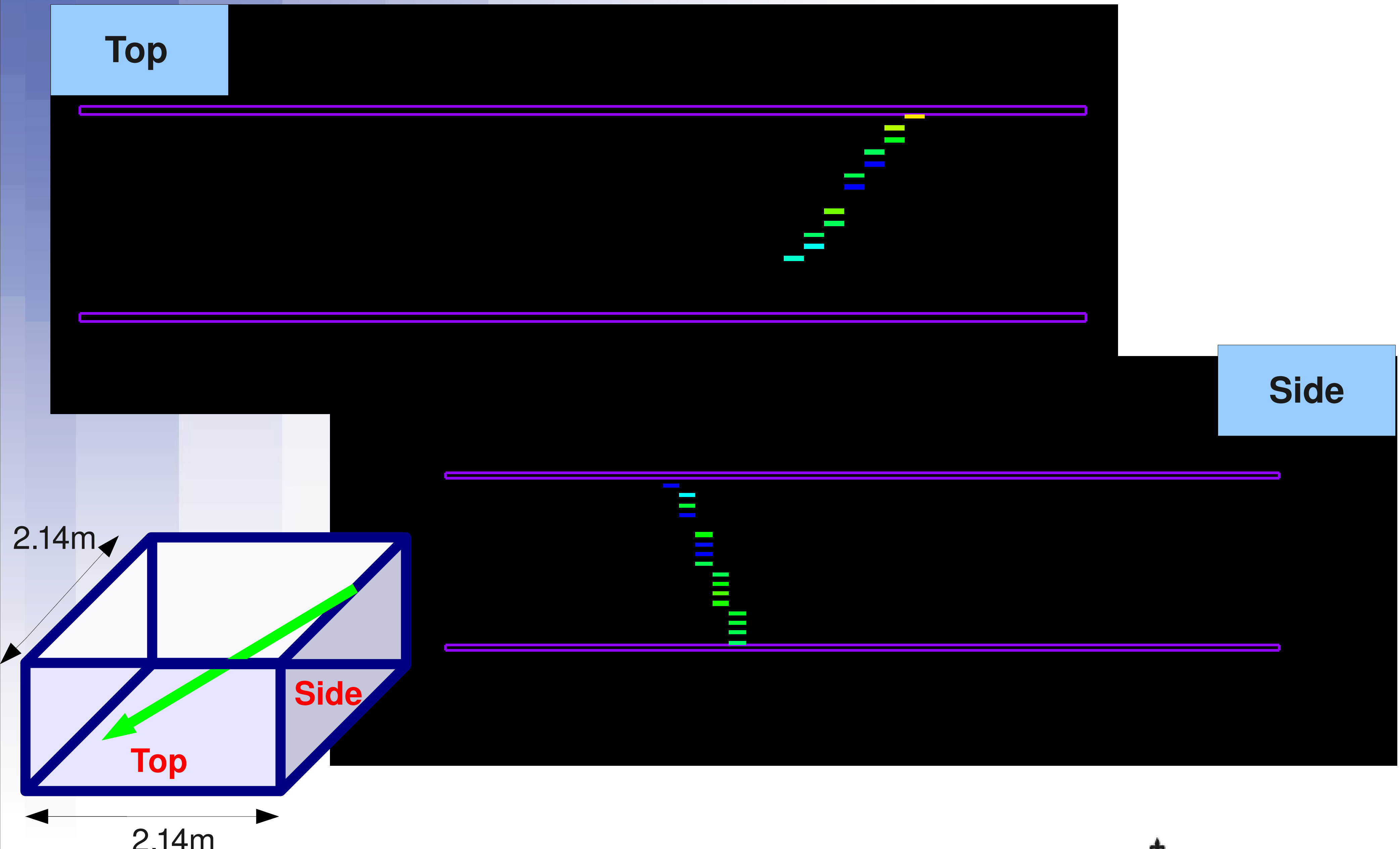


- Ratio mu+/mu- = 1.26
- $0.99999 \leqq \sqrt{x^2+y^2+z^2} \leqq 1$

Event Display of Simulated Muon



First Observed Cosmic Muon Event



Summary

- The cosmic test is an opportunity to commission, calibrate and understand the detector.
- Reliable cosmic flux and Monte Carlo is essential to test and tune the detector hardware and software prior to beam data.
- A cosmic flux has been produced for the near detector in 4 locations; RAL, CERN, TRIUMF and J-PARC.
- The DSECal of the nd280 detector of T2K will have three cosmic tests at RAL, CERN and Tokai.
- There are many steps that must be followed to have a successful cosmic test.

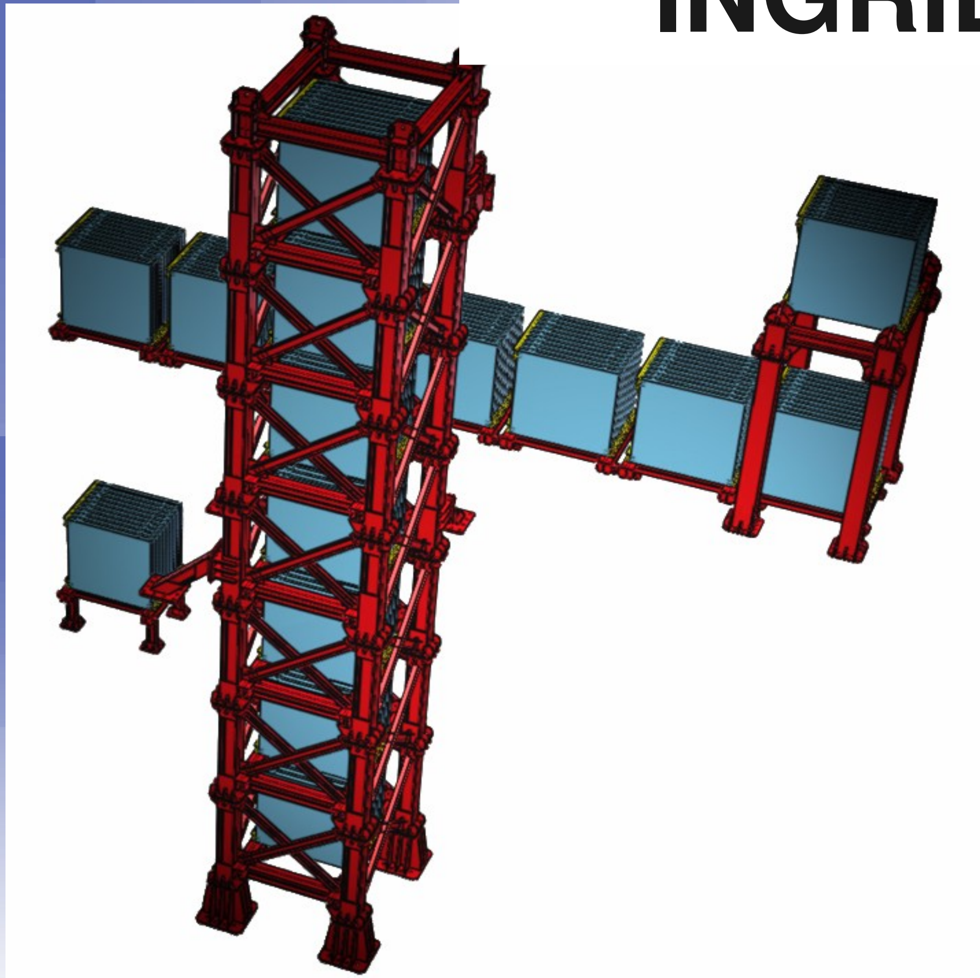
Cosmics Analysis - Attenuation

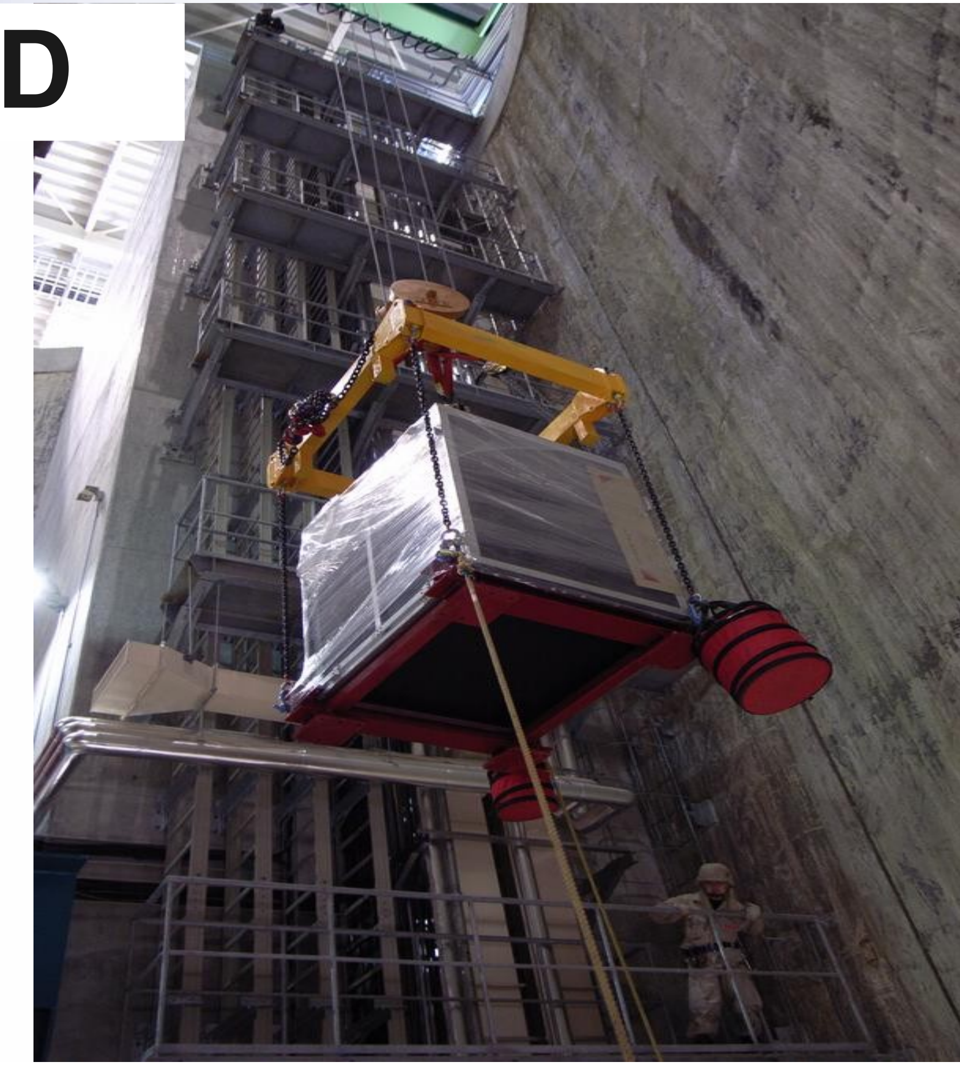
- Looking at clusters in the DSECal that have been through the electronics simulation but prior to reconstruction.
- Tuned on MC.
- Track muons through the detector in terms of photons received at the end of the bar.
- Use track length, angle of track, no. of bars hit, photons received and time of hit recorded at each end of bar, to produce attenuation distribution.

Bar and Layer Efficiency Studies

- Efficiencies expected to be very near 100% but must still be studied.
- Study after attenuation and reconstruction.
- Look at bars and layers that are consecutive but 1.
- If both receive a hit for a given track then the bar/layer in between should also see a hit.
- Are any inefficiencies an artefact of the reconstruction or an effect of that particular bar or layer?
- Measured efficiencies of bars and layers stored in database.

INGRID





- **Measure -beam direction and profile with 1 milli-rad precision on daily basis**
- **Iron - scintillator tracking stacks 16 units(each unit 1⁄4 10 ton total mass: 160 tons)**

T2K's Timeline

	Jan 2007	Apr 2008	Jun 2008	Sep 2008	Mar 2009	Apr 2009	May 2009	Autumn 2009	Winter 2009
T2K first discussed									
J-PARC accelerator commissioning	■	■	■	■	■				
Magnet installed in the nd280 pit		■	■						
T2K funding approved in all countries			■						
INGRID installation				■	■				
FGD and TPC testbeams at TRIUMF				■	■				
First T2K Neutrinos						■			
DS ECAL test beam							■		
Installation of nd280 detector								■	
Start of full T2K running									■

MNS Matrix

$$U = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{bmatrix} \begin{bmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{bmatrix} \begin{bmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{bmatrix} \begin{bmatrix} e^{i\alpha_1/2} & 0 & 0 \\ 0 & e^{i\alpha_2/2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where cij = cosθij and sij = sinθij. The T2K experiment aims to determine whether the phase factor δ ≠ 0 in which case neutrino oscillations are CP violating. The phase factors α1 and α2 are non-zero only if neutrinos are Majorana particles (whether or not they are is unknown), and do not enter into oscillation phenomena regardless. If neutrino-less double beta decay occurs, these factors influence its rate.