East-West cosmic muon flux asymmetry in the Far Detector of NOvA

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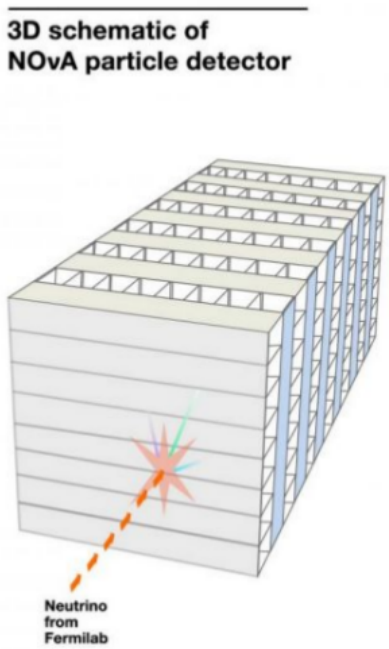
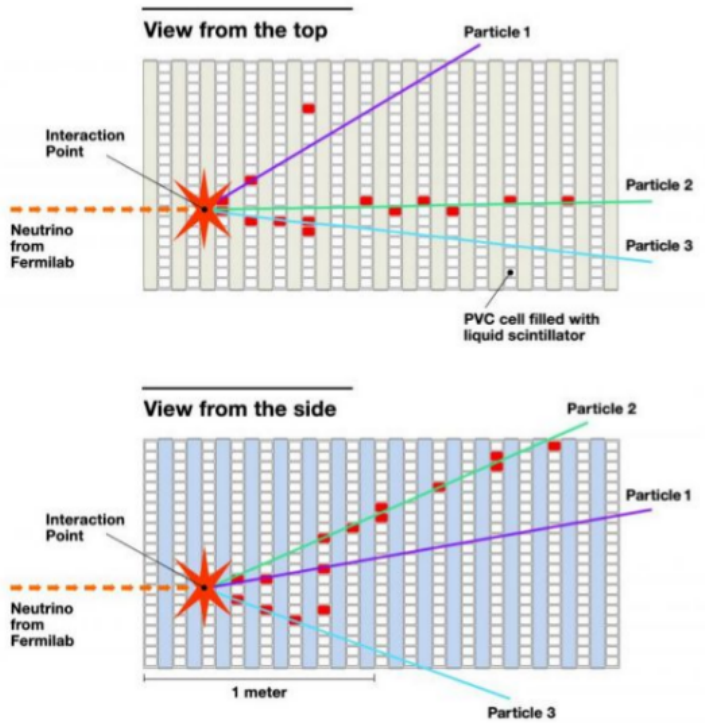
AYSS-2017

2–6 October 2017

NOvA experiment

NOvA is a long-baseline accelerator neutrino oscillation experiment.

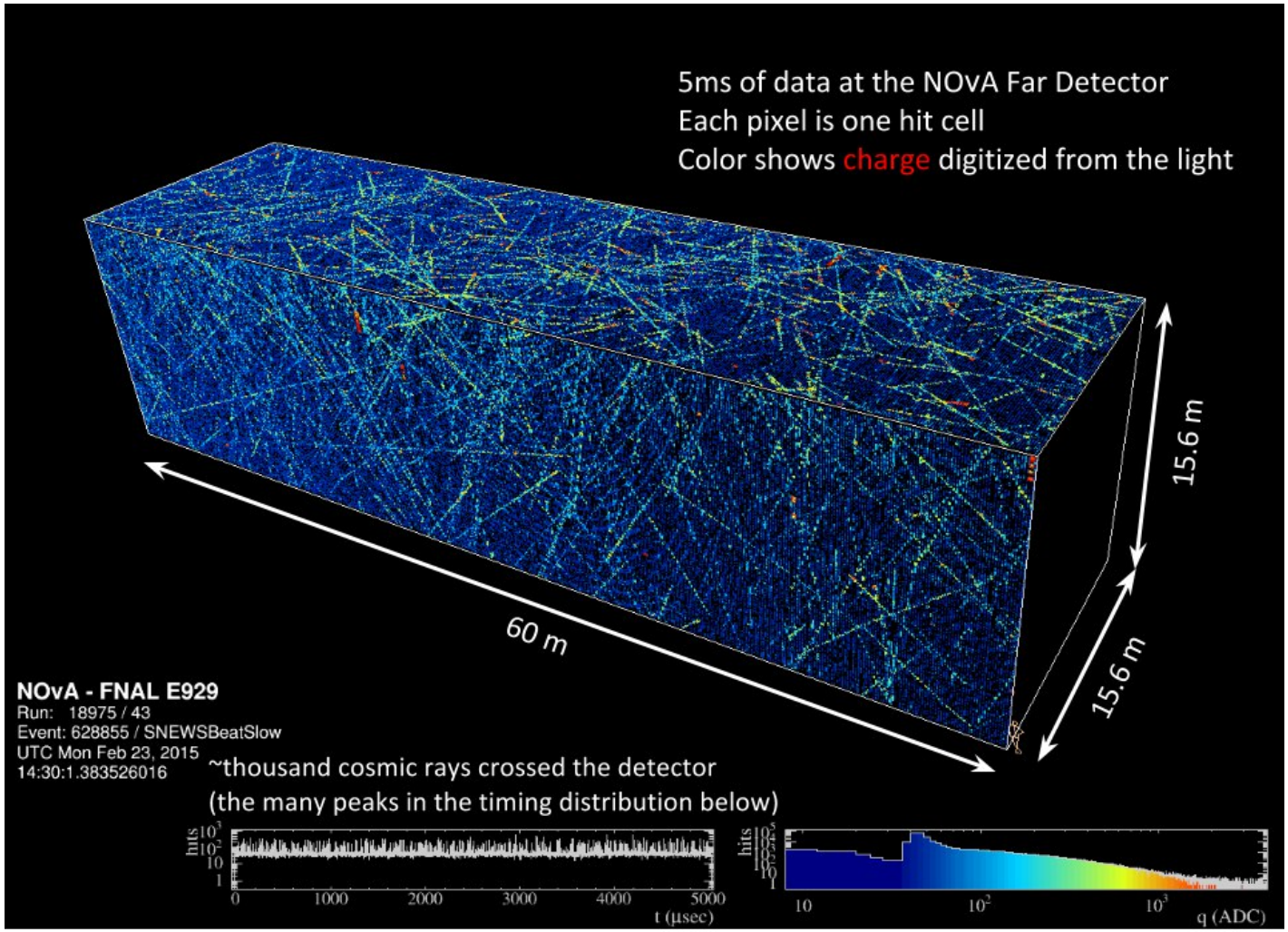




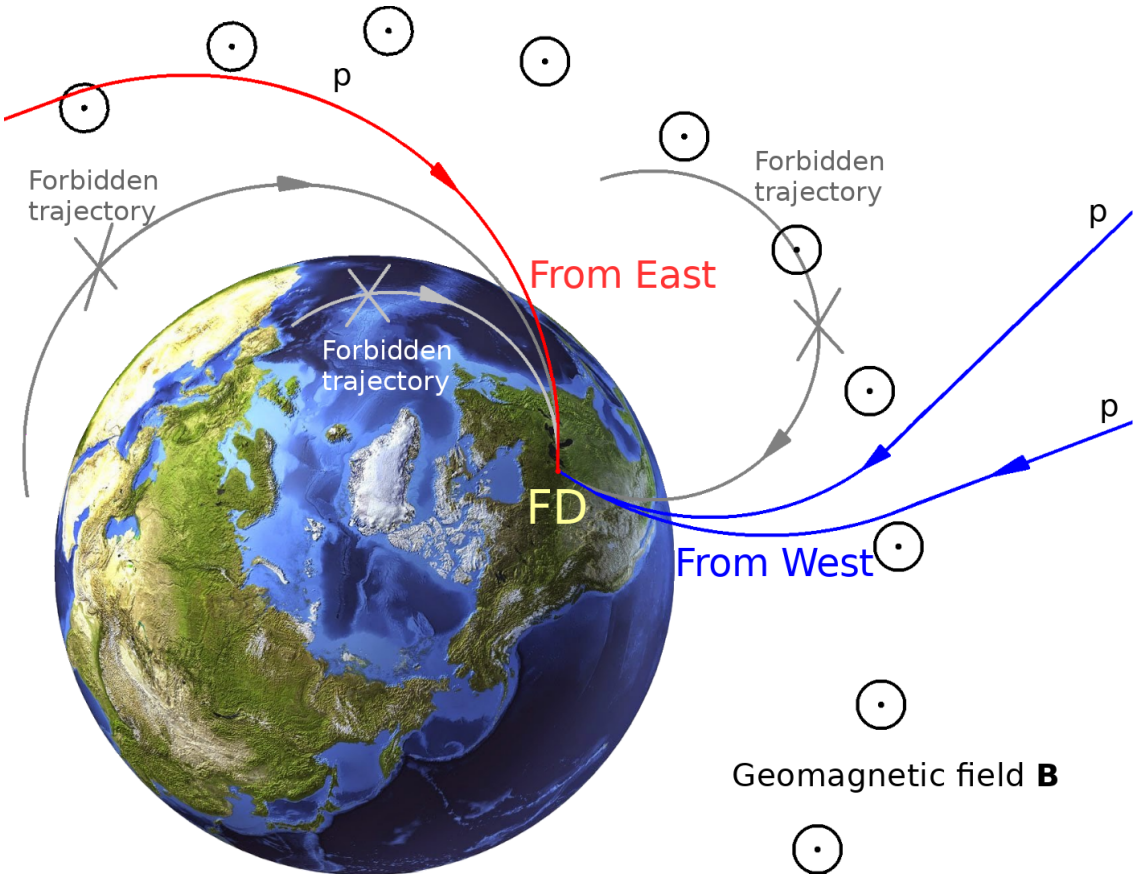
Liquid-scintillator detectors have segmented structure.

NOvA Far Detector

Far Detector is located on the surface and it is huge (14 kt), so rate of cosmic rays is very high.

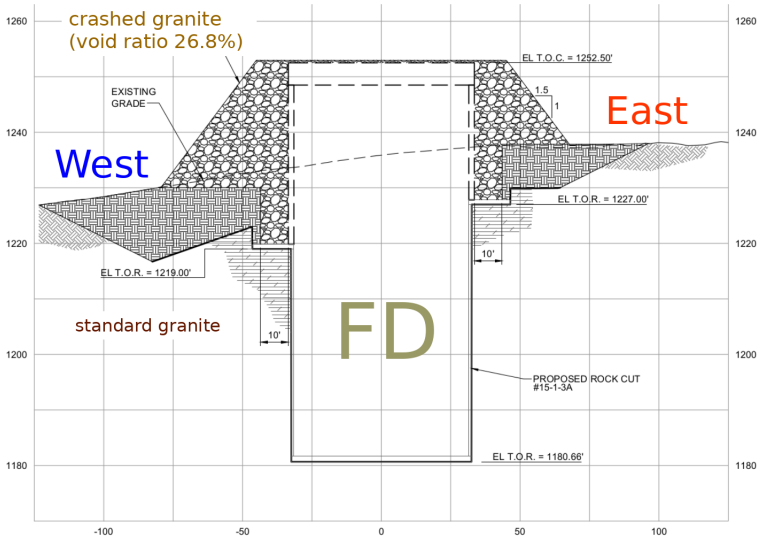


East-West Asymmetry



Asymmetry:

$$A = \frac{\Phi_W - \Phi_E}{\Phi_W + \Phi_E}$$



What result we expect

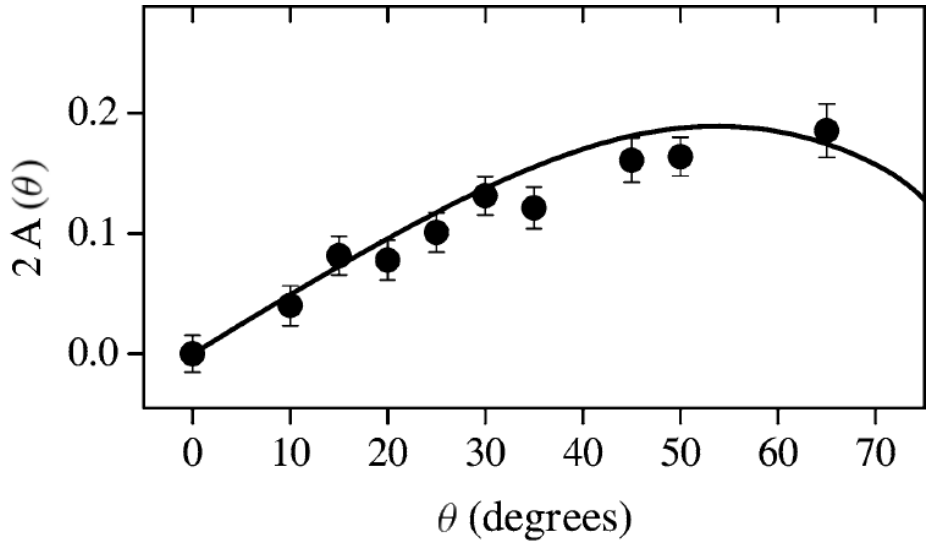


Figure: P.N. Diep *et al.* Measurement of the east-west asymmetry of the cosmic muon flux in Hanoi [$21^\circ 01' 42.5''$ N, geomagnetic cut-off 17 GV] (2003)

(NOvA FD is located at $48^\circ 22' 46''$ N, geomagnetic cut-off is about 1-2 GV.)

What result we expect

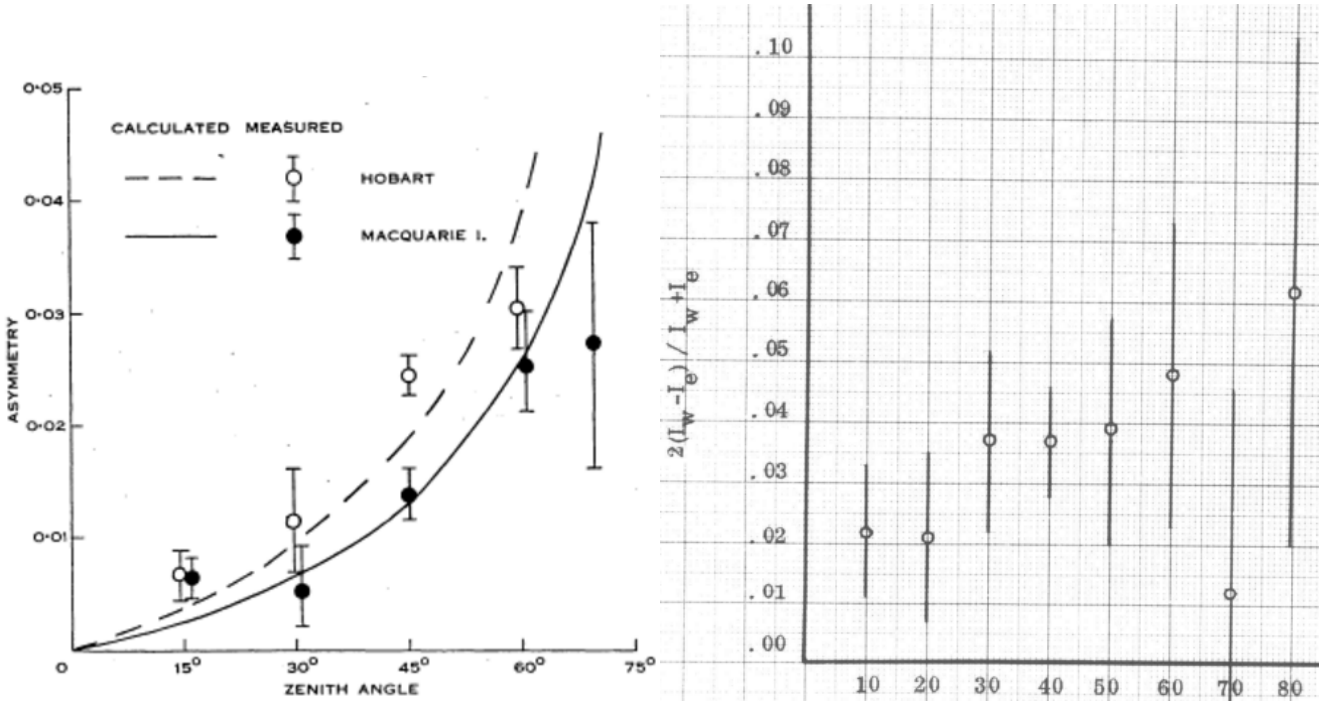


Figure: Left: D.W.P. Burbury, K.B. Fenton. The High Latitude East-West Asymmetry of Cosmic Rays (1951). Hobart [$42°53'00''$ S, 3 GV]. Right: L.L. Nichols. The East-West cosmic ray effect at Corvallis [$44°34'15''$ N, 2 GV], Oregon (1961).

(NOvA FD is located at $48°22'46''$ N, geomagnetic cut-off is about 1-2 GV.)

East-West asymmetry in NOvA (PRELIMINARY)

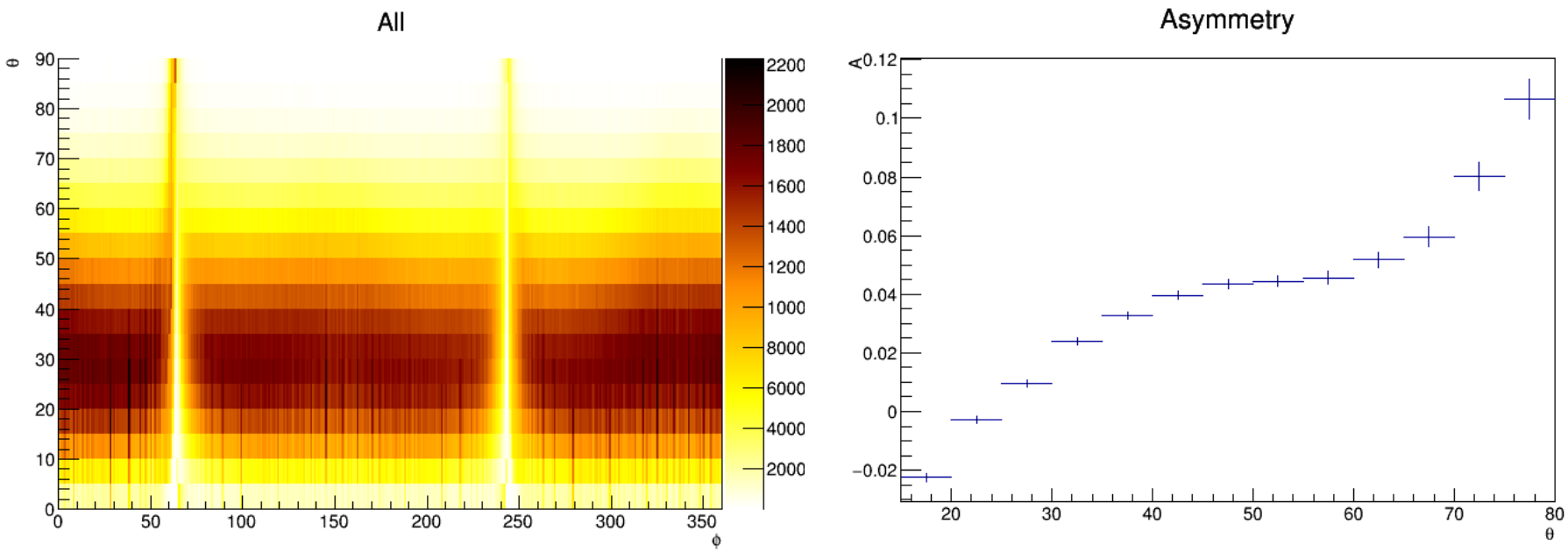


Figure: Cosmic muon flux and EW-asymmetry in the NOvA Far Detector without any correction to the matter of the surrounding hill

Correction to overburden-induced asymmetry

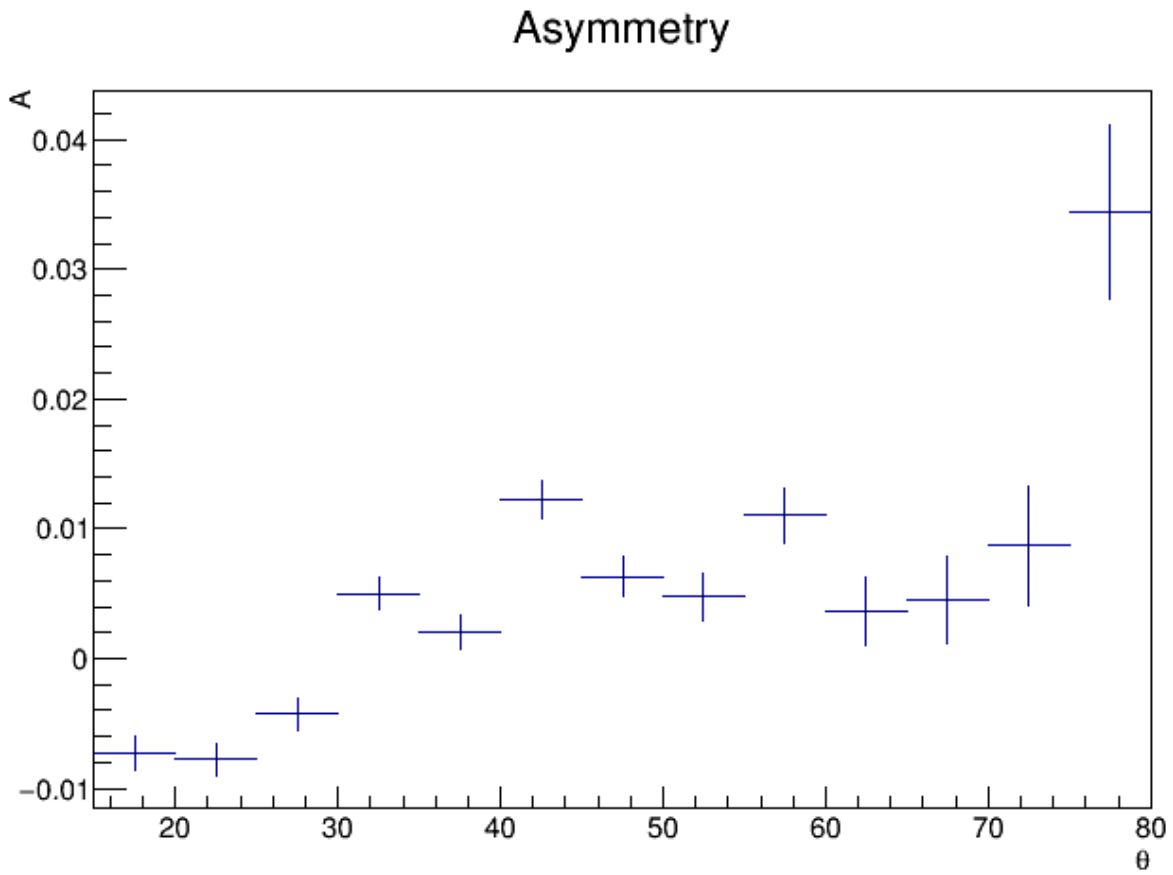


Figure: Roughly corrected EW-asymmetry:
for each bin Φ_E^{data} is multiplied by the factor $\Phi_W^{\text{MC}}/\Phi_E^{\text{MC}}$

Further plans

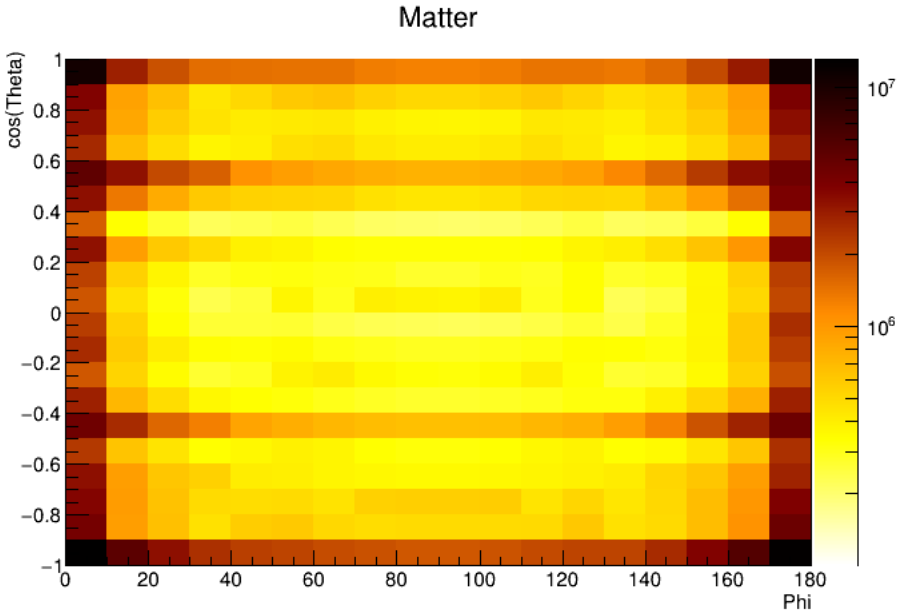
In order to take geometry-induced asymmetry more accurate, we can correct flux with an attenuation factor.

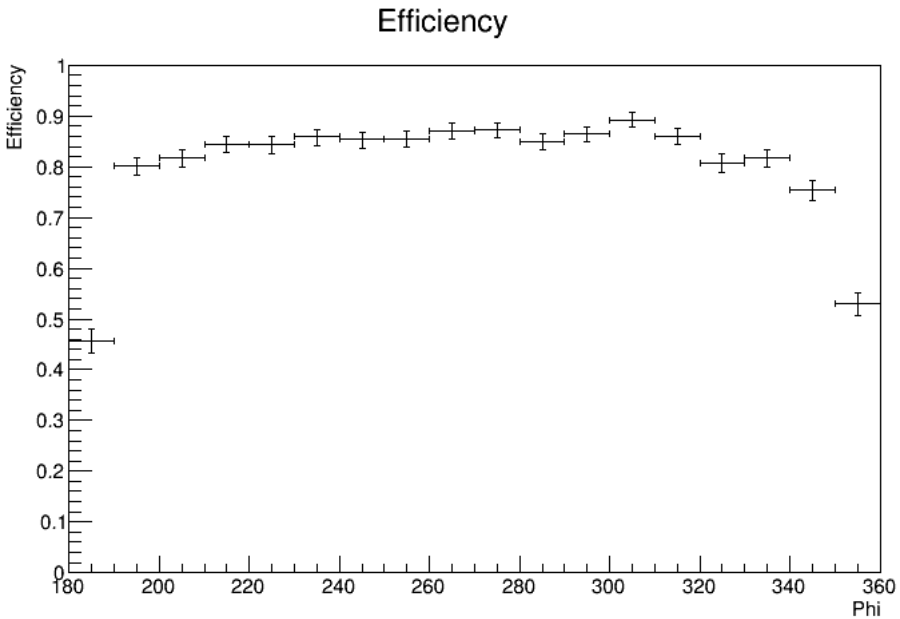
- To calculate EW-asymmetry we need to know 'real', not deformed cosmic muon fluxes from East and West.
  $\Phi(E, \theta, \phi)$ – real muon flux on the surface
  $N(\theta, \phi, \vec{r})$ – muon flux, detected in FD.
- We can calculate an 'attenuation' factor

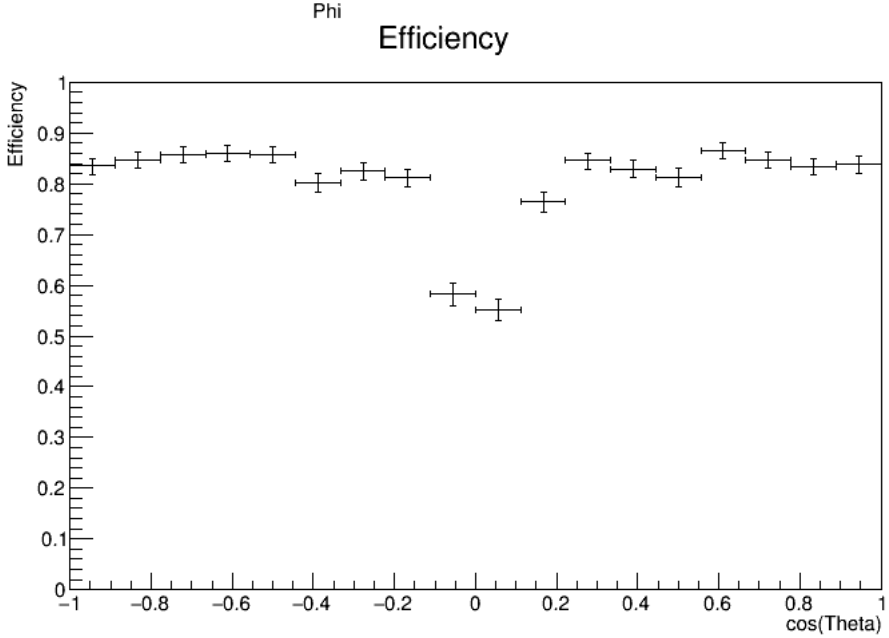
$$d = \frac{N}{\Phi} = \frac{\int \epsilon(\xi') \int \Phi(E, \theta, \phi) P_{\xi \to \xi'}(\xi) d\xi d\xi'}{\int \epsilon(\xi) \Phi(E, \theta, \phi) d\xi},$$

  where ξ accumulate $E, \theta, \phi, \vec{r}$ ($\vec{r}$ characterizes track position (stopping point, for example)), $P_{\xi \to \xi'}$ characterizes muon 'attenuation' in matter, $\epsilon(\xi)$ is a reconstruction efficiency.
- $P \sim \int \rho(l) dl$

Overburden effect and efficiency (detector angle notation)







Work on the East-West asymmetry of cosmic rays in NOvA is in progress.

Thank you!