Measuring fast neutrons with large liquid scintillator for ultra-low background experiments

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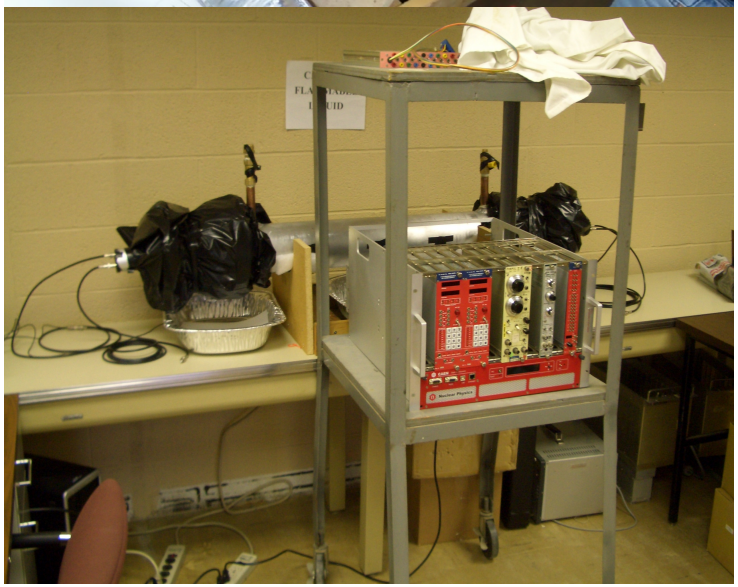
Outline

1. Fabrication of Big scintillation neutron detector at USD.
2. Energy & position calibration, n/γ discrimination.
3. Surface neutron measurement.
4. Soudan mine underground neutron measurement.

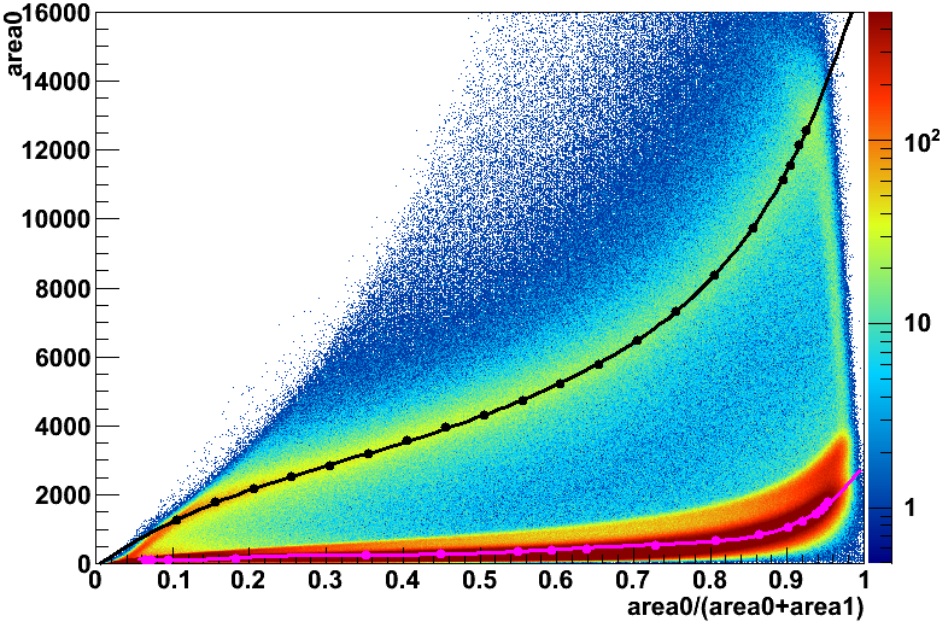
Large Liquid Scintillation Neutron Detector

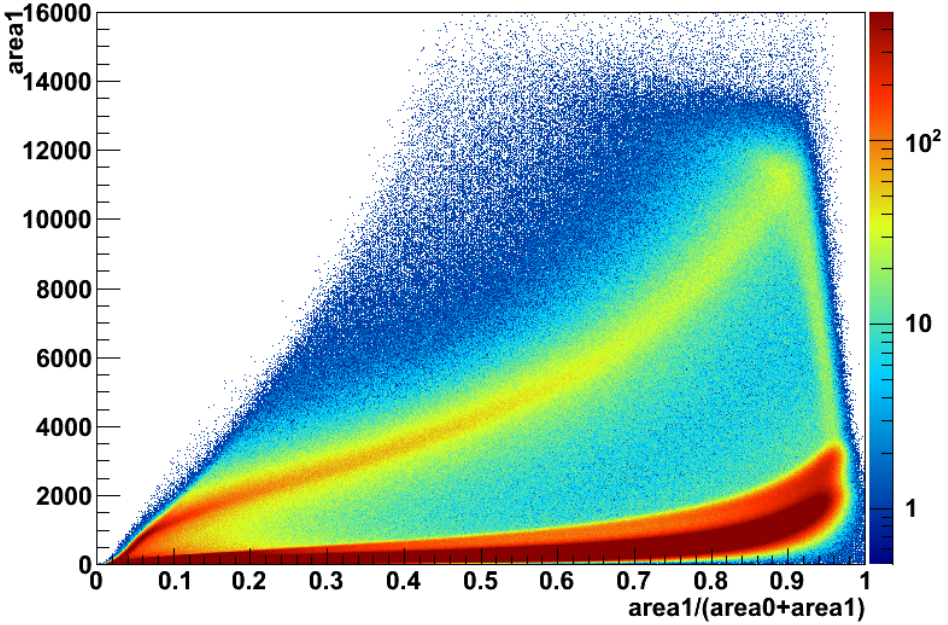


Detector Design

- 1m long LS neutron detector filled with 12 liters LS EJ301.
- Internally covered with diffusive paint EJ520.
- 2 Hamamtsu 5” PMTs(R4144) attached to the detector through Pyrex glass windows.

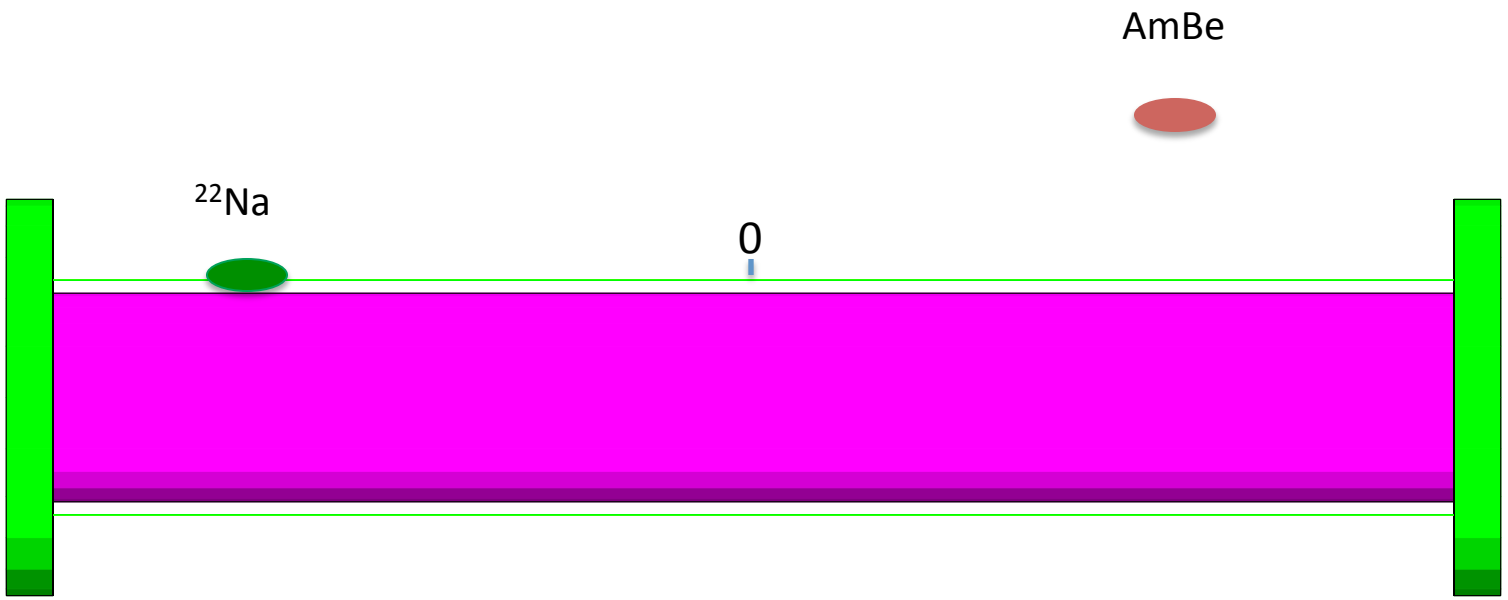
Detector Response





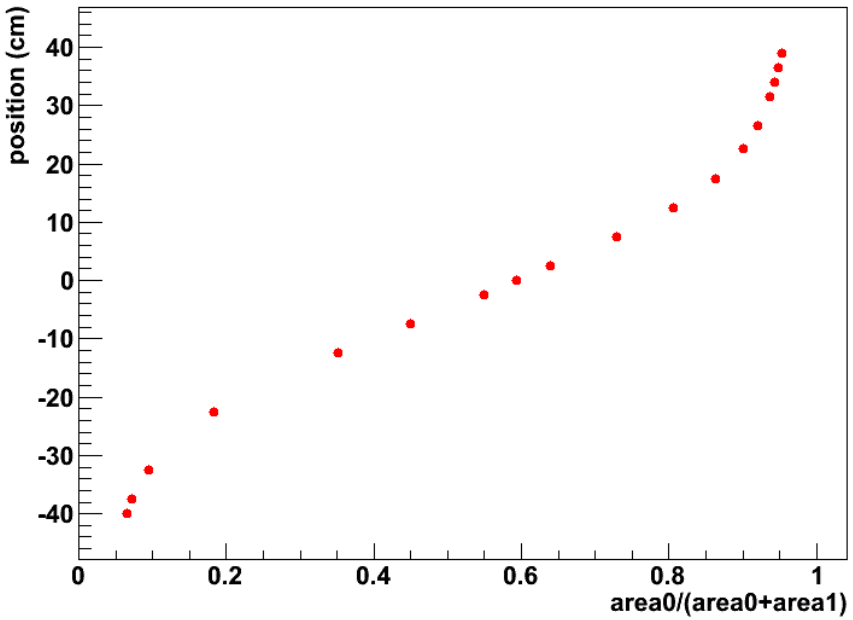
- Working High Voltage: Ch0 2000V, Ch1 2000V, attenuator 23dB applied for Both.
- Time coincidence within 30ns(peak time) are required for two PMTs. Detector response to the room background signal are shown above(Ch0 left, Ch1 right).
- Muon minimum ionization peak and the response to 22Na source along with the Tube are marked in the left figure.

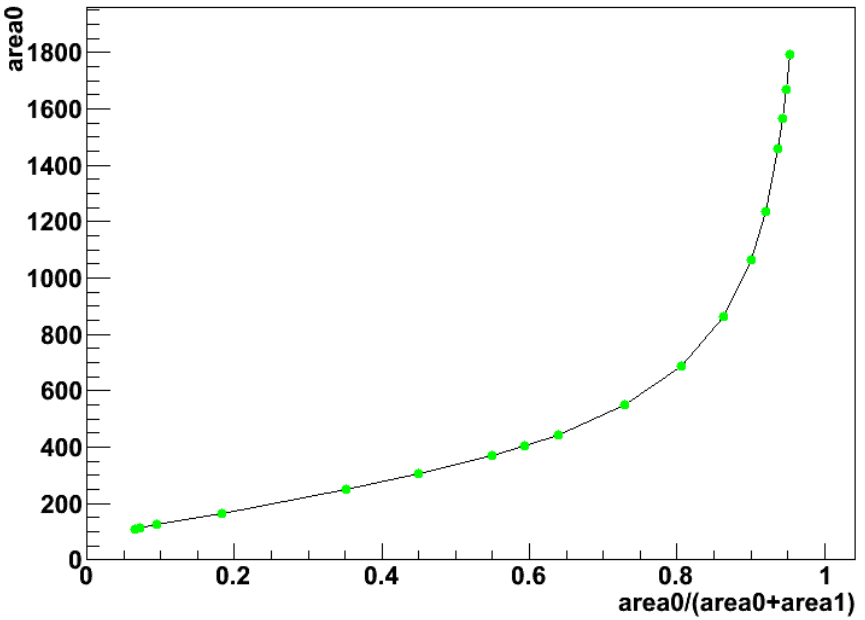
Energy Calibration



^{22}Na: 1.0μCi. Placed at each 2.5 cm along with the tube.
AmBe: 3.33MBq. Placed at the fixed position above the detector.

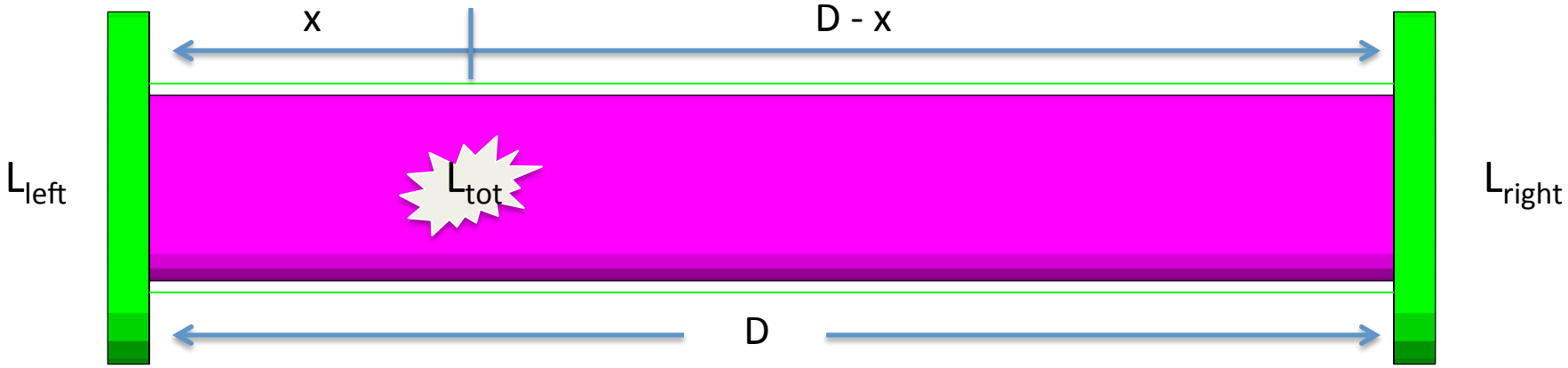
Response to ^{22}Na source





- Actual position VS charge ratio response to ^{22}Na source(Left).
- Total charge (Ch0) VS charge ratio response to 22Na source(Right)

Energy – Position independent?

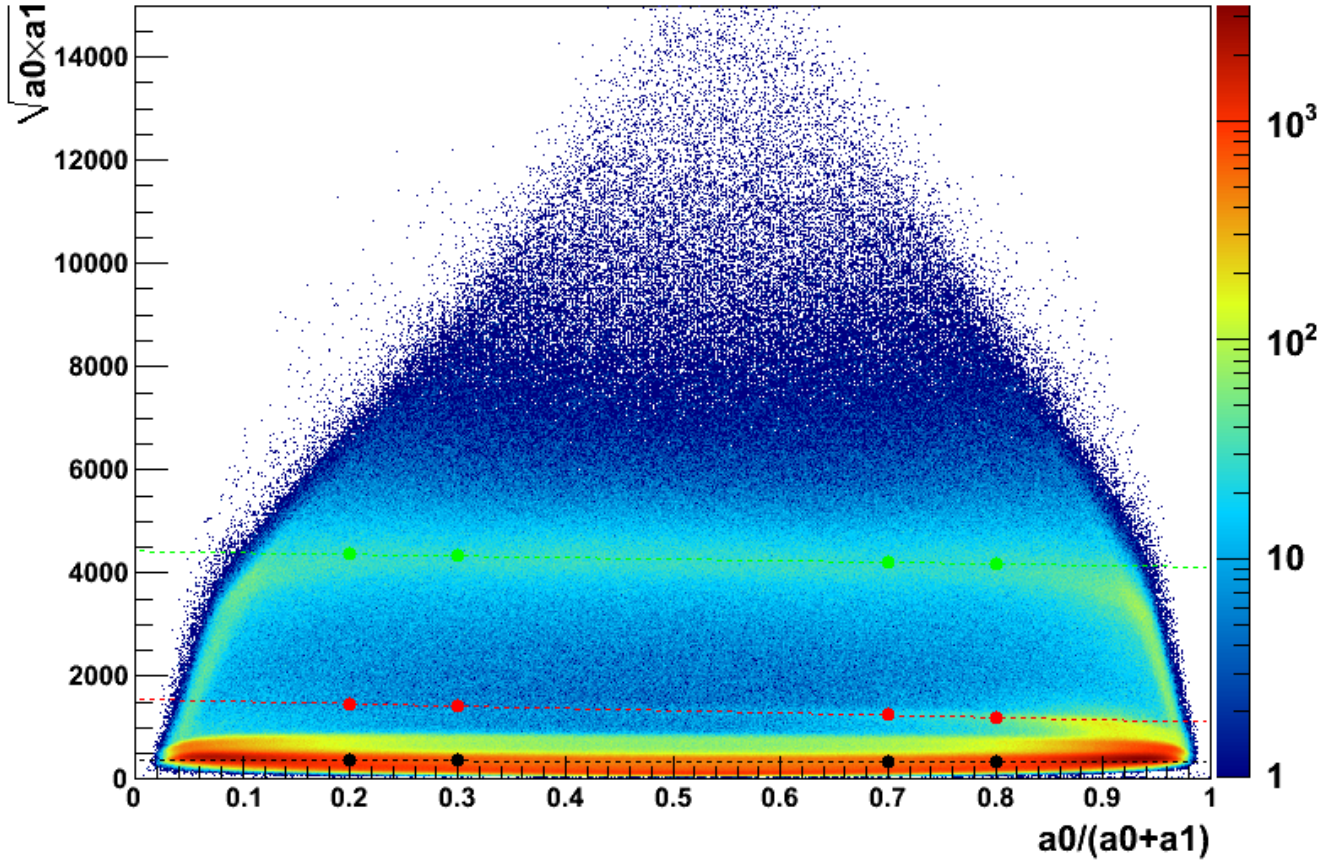


$$L_{left} = 0.5 L_{tot} e^{-x/l}$$

$$L_{right} = 0.5 L_{tot} e^{-(D-x)/l}$$

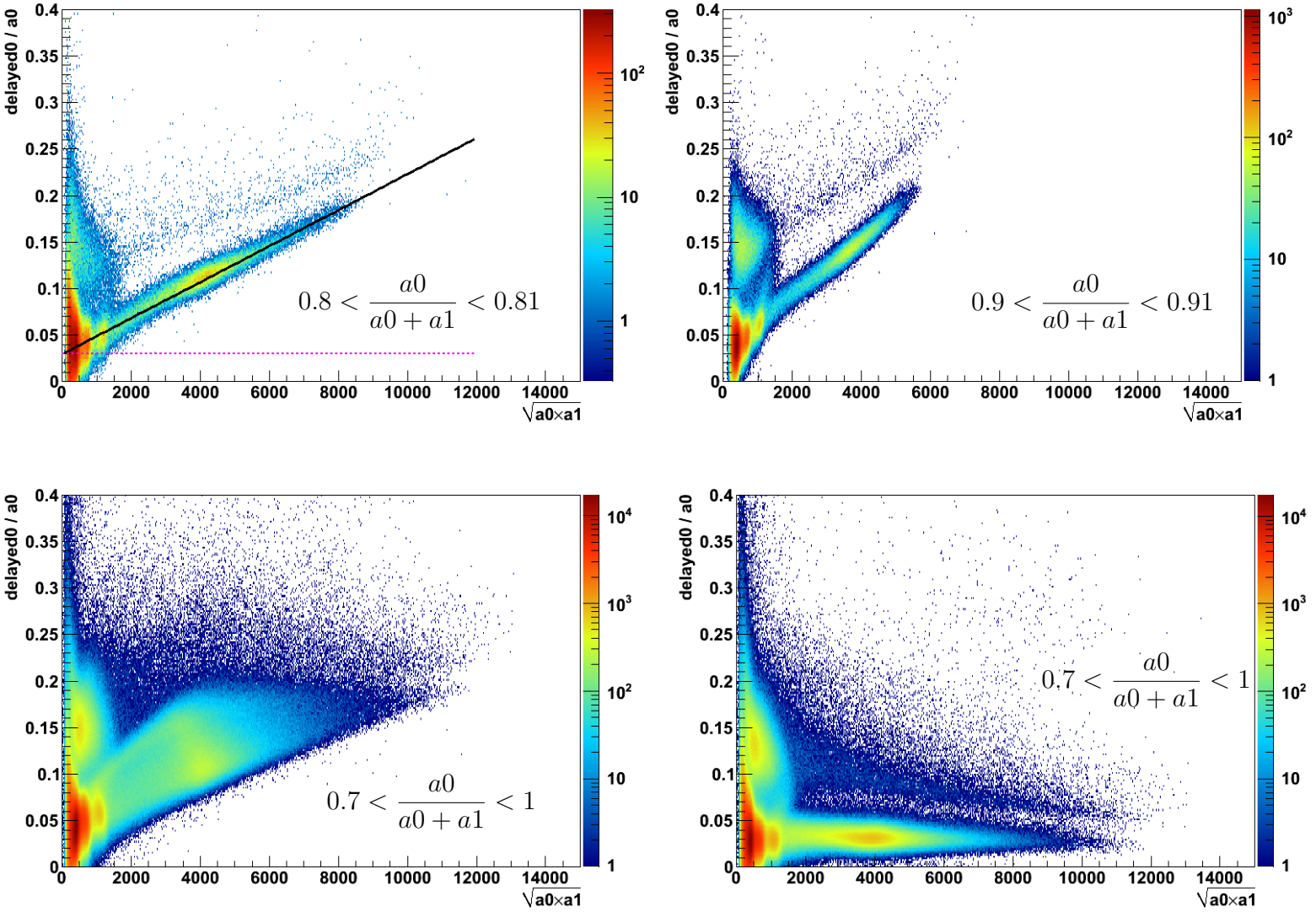
$$\sqrt{L_{left} L_{right}} = 0.5 L_{tot} e^{-D/2l} \sim E_{tot}$$

Energy - Position Independence



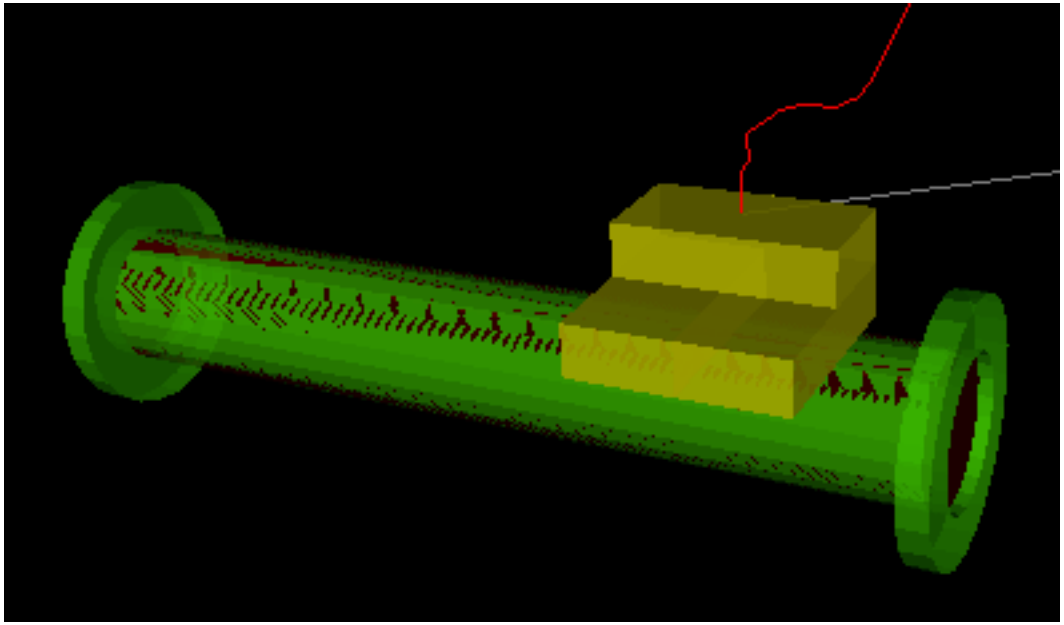
Three calibration source energy: Na22(1.27MeV), AmBe (4.4MeV) and muon minimum ionization peak(~20MeV)

n/g Discrimination

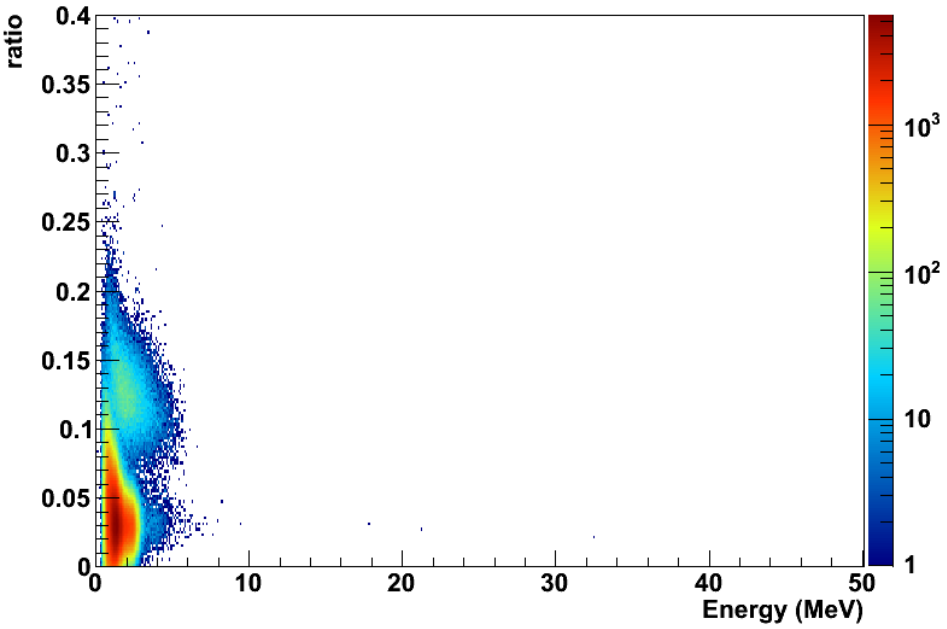


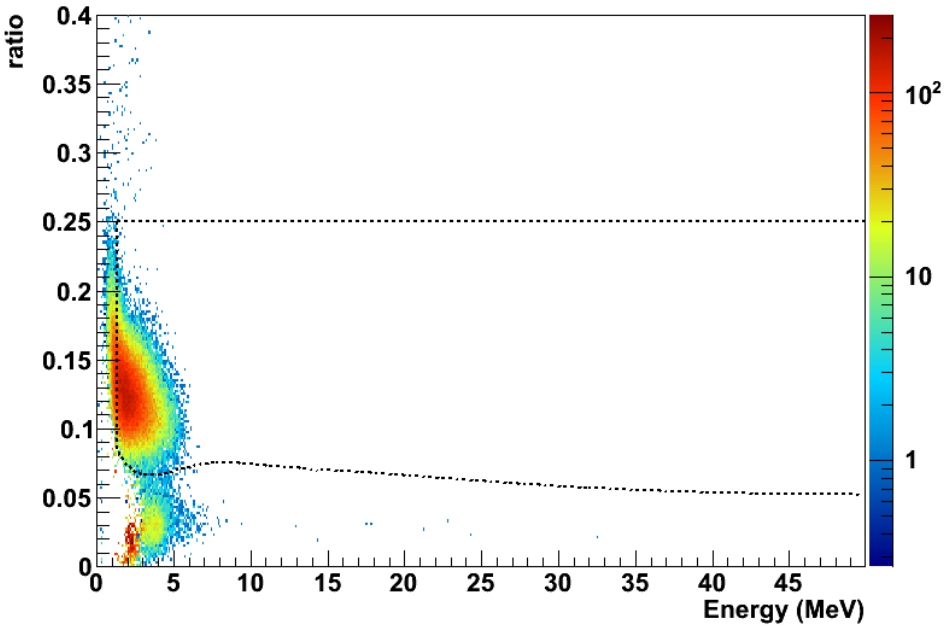
- AmBe source at surface about 68 hours data.
- n/g can only be separated in narrow slices along the tube(top two plots) otherwise they will be buried (left-bottom plot). All slices could be folded to the horizontal then summed up(right-bottom plot).

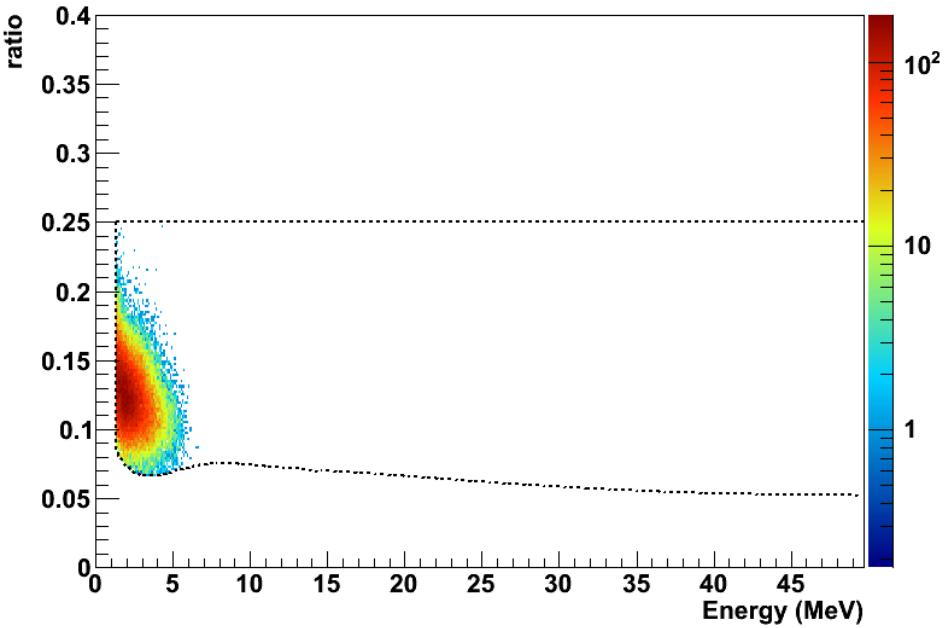
AmBe Calibration at Soudan Mine

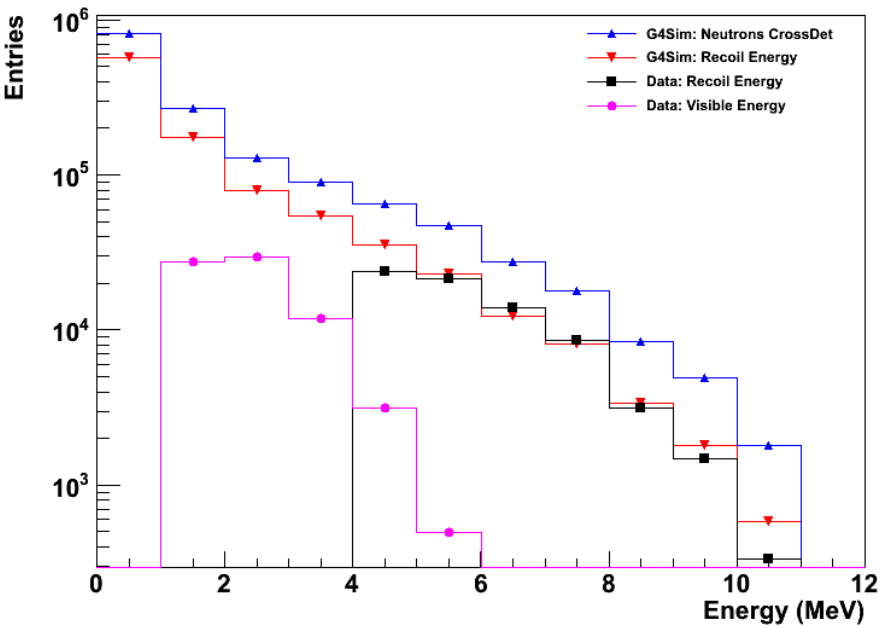


- In order to remove the effect of gamma ray contamination, two layer of lead bricks(4'' total) is place right above the tube and the AmBe source located on the top of it.
- We took about two days Ambe data and three days background data w/wo the source.

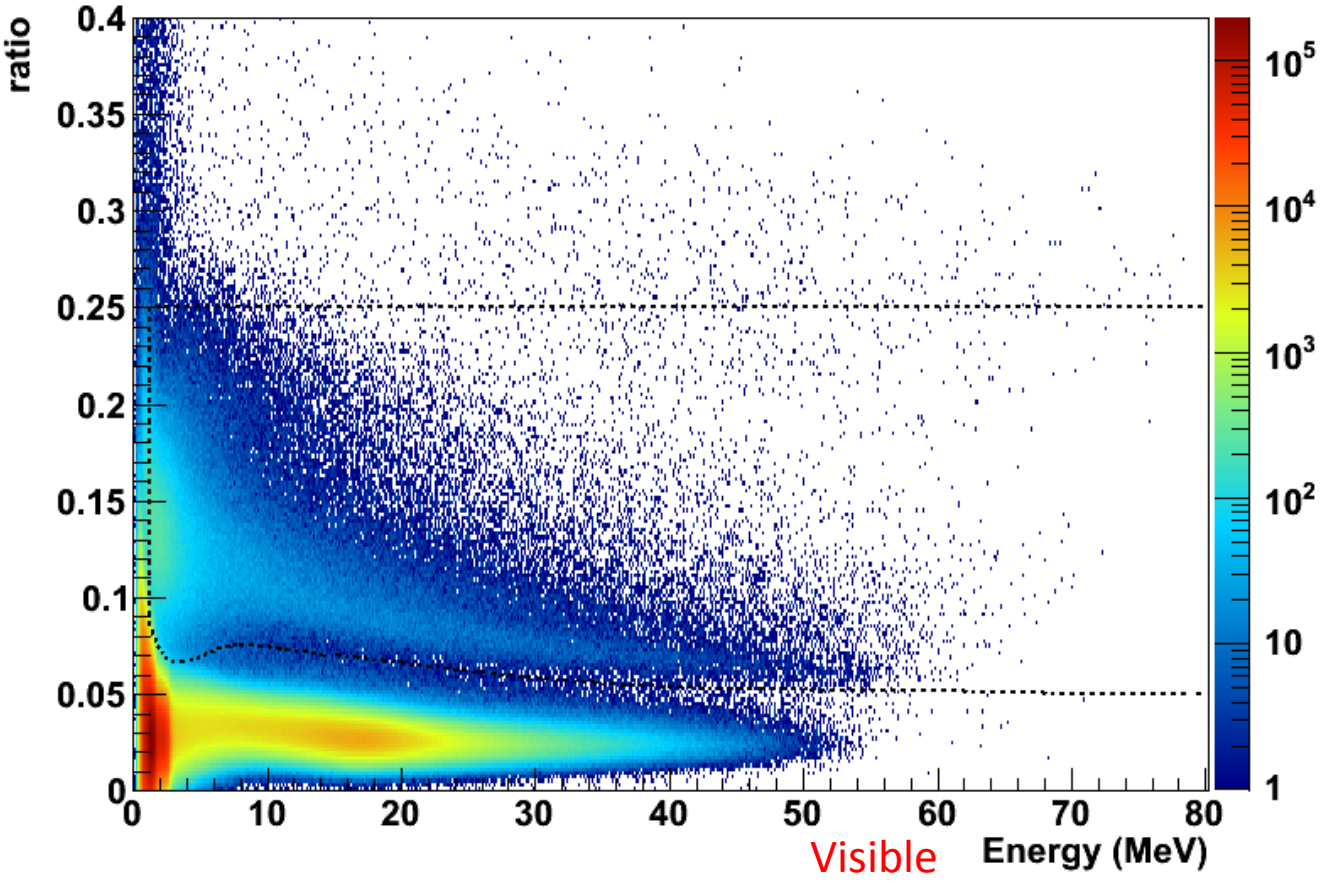

ratio
Energy (MeV)


ratio
Energy (MeV)


ratio
Energy (MeV)


Entries
G4Sim: Neutrons CrossDet
G4Sim: Recoil Energy
Data: Recoil Energy
Data: Visible Energy
Energy (MeV)

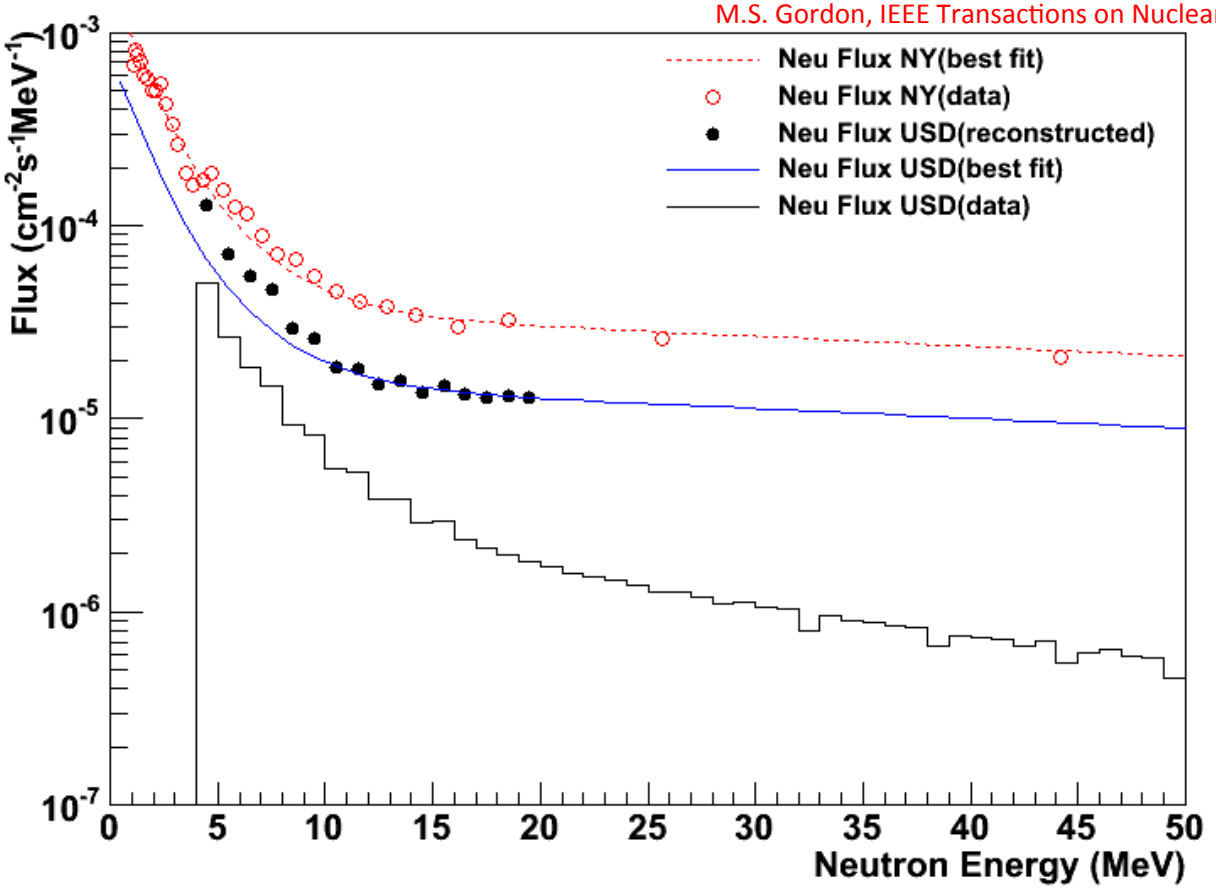
Surface Data



Surface run with live time about 19 days.

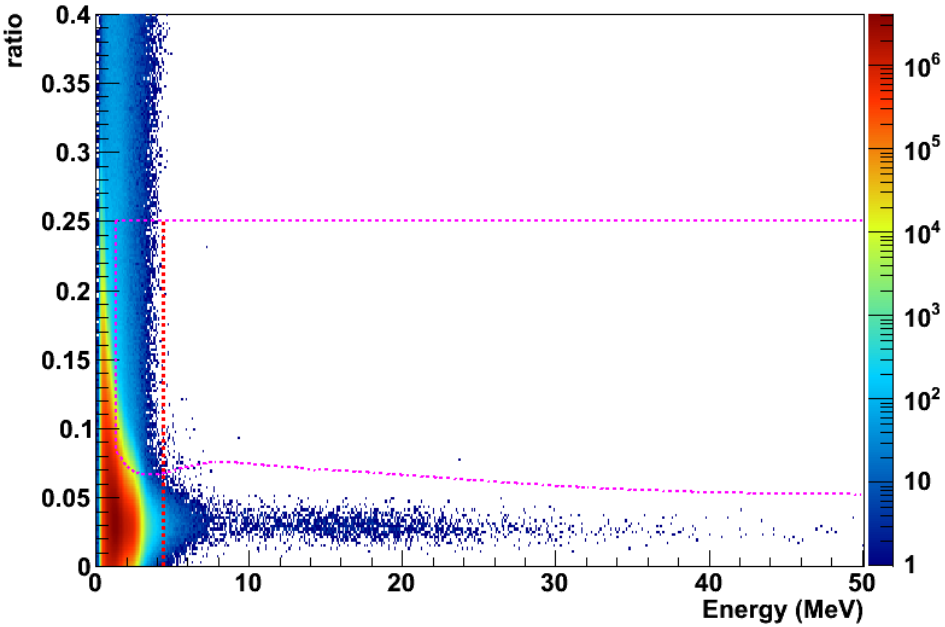
Surface Data

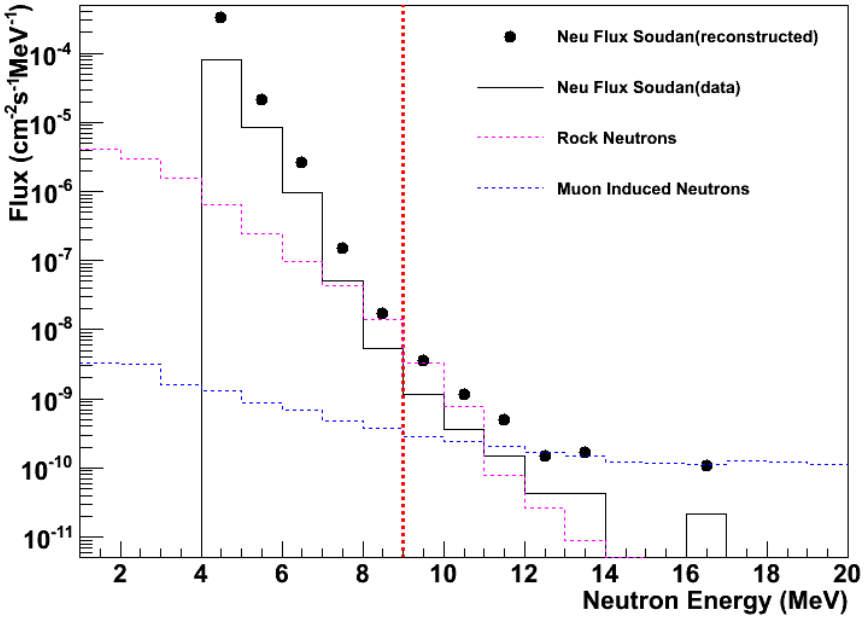
M.S. Gordon, IEEE Transactions on Nuclear Science, V51, No. 6, 2004



- New York data is the result on the roof of a building while USD data is measured at the first floor of a three-storey building(~1 m.w.e). So a factor of 2 difference is expected in terms of flux.
- The accidental coincidence for two PMTs (30ns coincidence) is on a few $\times 10^{-5}$/s/cm2 level.

Neutrons at Soudan Mine



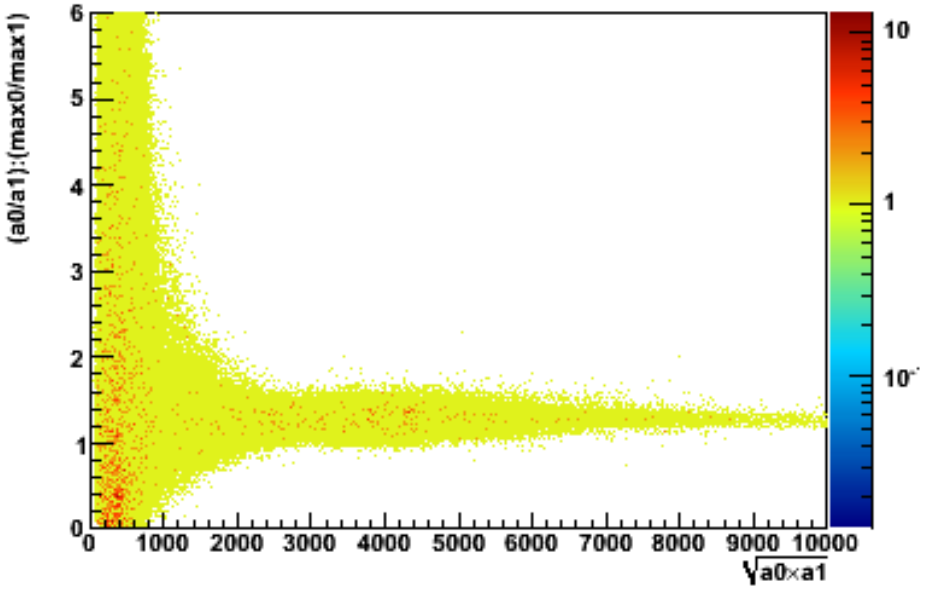


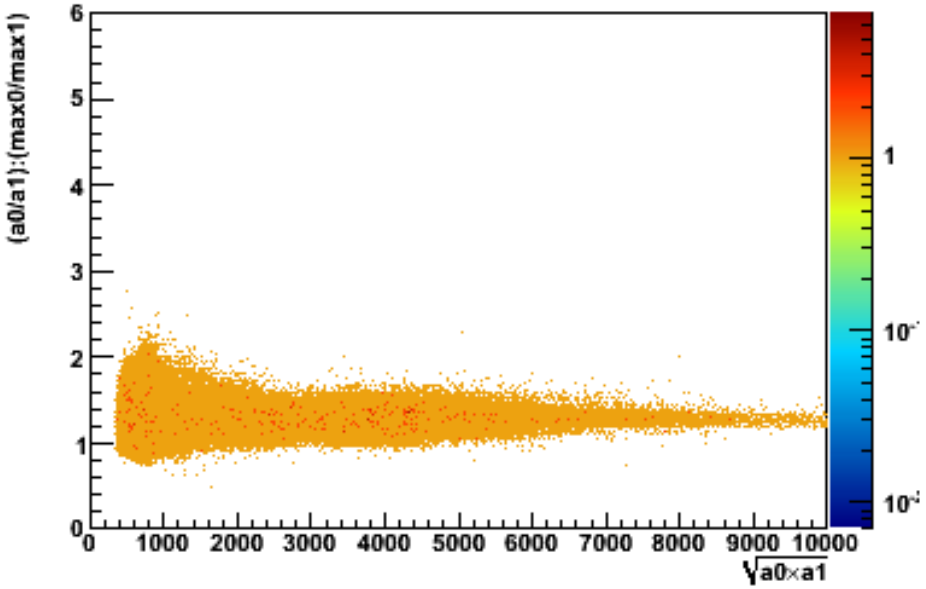
- Soudan run about 354 days data.
- E_{vis}<4.5MeV in left-hand plot (E_{recoil}<9MeV in right plot) are dominated by noise.

Current Status

- Only half of analyzed data(one PMT signal) have been used. More than factor of two statistics can be achieved if we fully analyze all the data we have now.
- It seems that we are suffering high rate of accidental coincidence at lower energy range for Soudan run which limited our sensitivity up to ~9MeV. But there might be a workaround to lower it by raise the energy threshold for both of PMTs.
- We are planning to terminate the running by January sometime then bring it back to campus for further tuning up.

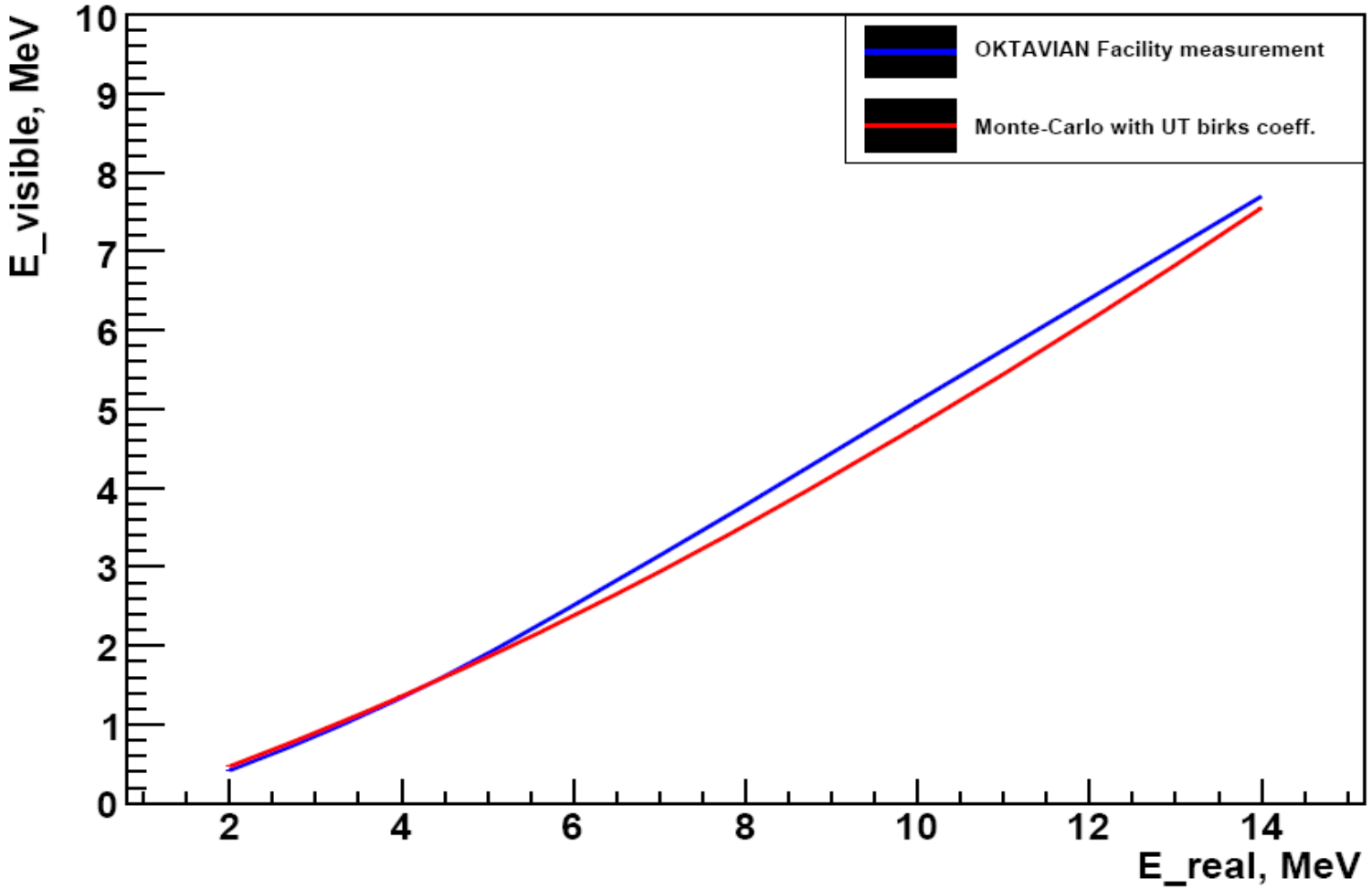
Backup I: raise energy threshold





- Maximum sample as well as the integral area can both present the energy of a event independently. Therefore (a0/a1) : (max0/max1) is supposed to be energy independent if both PMTs are triggered by same event.
- Left plot shows clearly accidental coincidence is dominant for lower energy range. By raising the threshold to both PMTs, it can be reduced dramatically(right plot).

Backup I: Quenching factor(KamLand)



E_visible=E_real*0.5806*(1-exp(-0.2072*E_real-0.00335))