Surface Performance of a Big Liquid Scintillation Detector for Measuring Neutrons

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The role of neutrons in underground low background experiments

Fatal background

- behave the same way as signals
- Cosmogenic production caused radioactivities

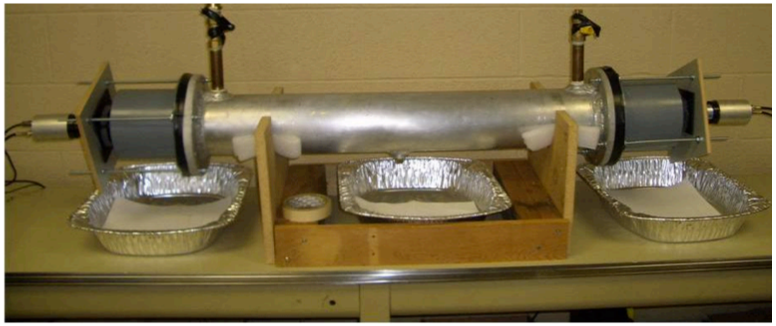
✧ Two categories

✓ radioactive activation - (a, n), fission decay

✓ spallation & capture neutrons

Related to the local rock composition, radioactivity, and the geometries – a library is need to understand its intensity.

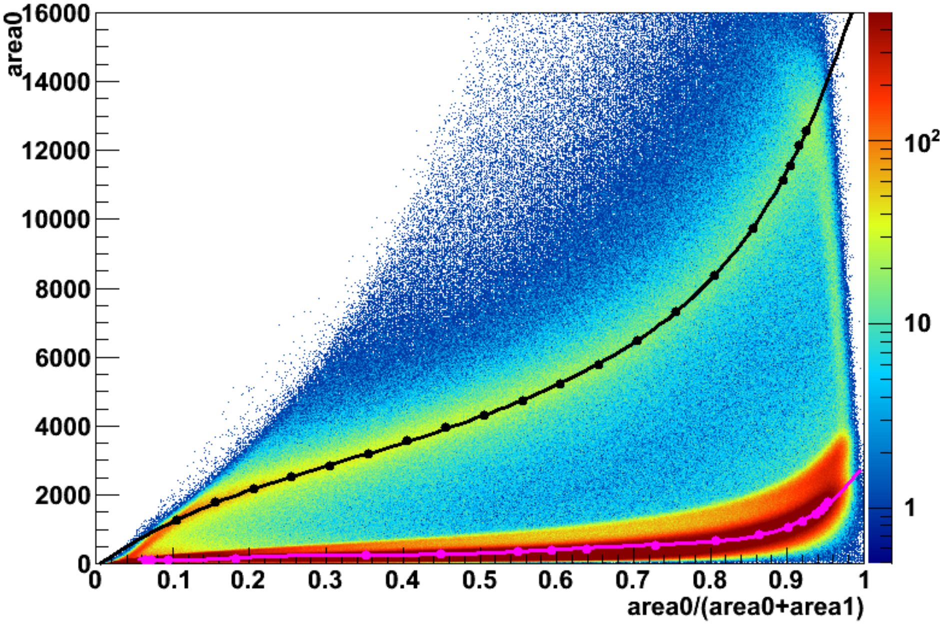
Large Liquid Scintillation Neutron Detector

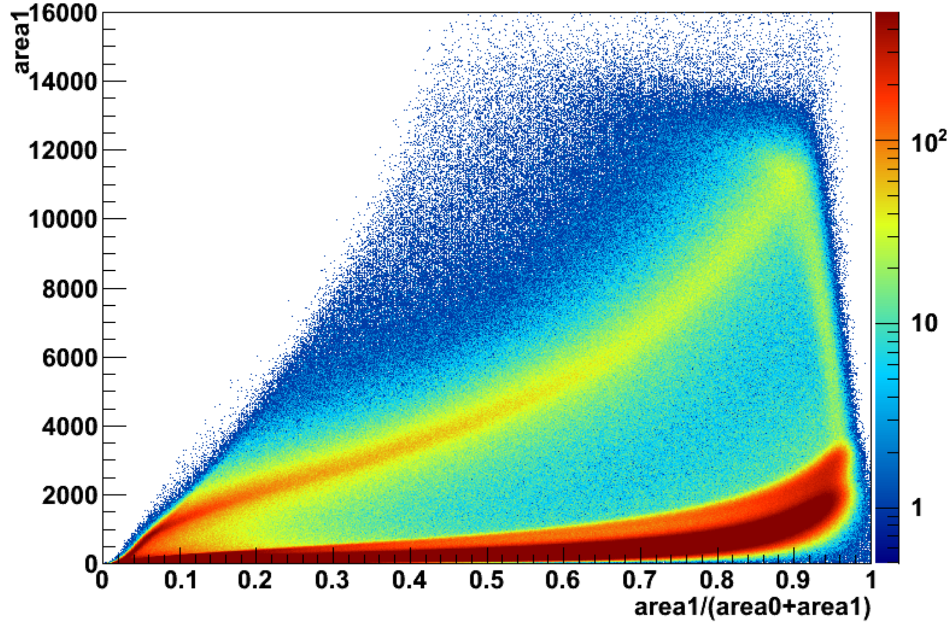


Detector Design

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

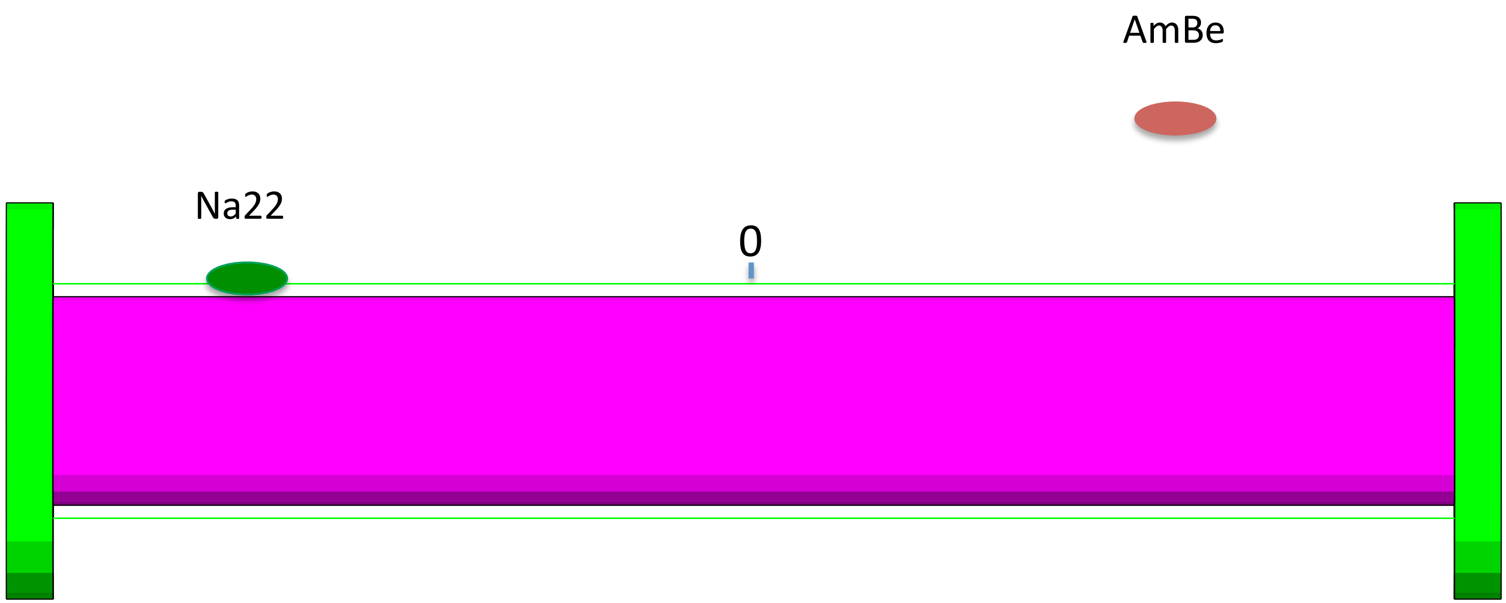
Detector Response





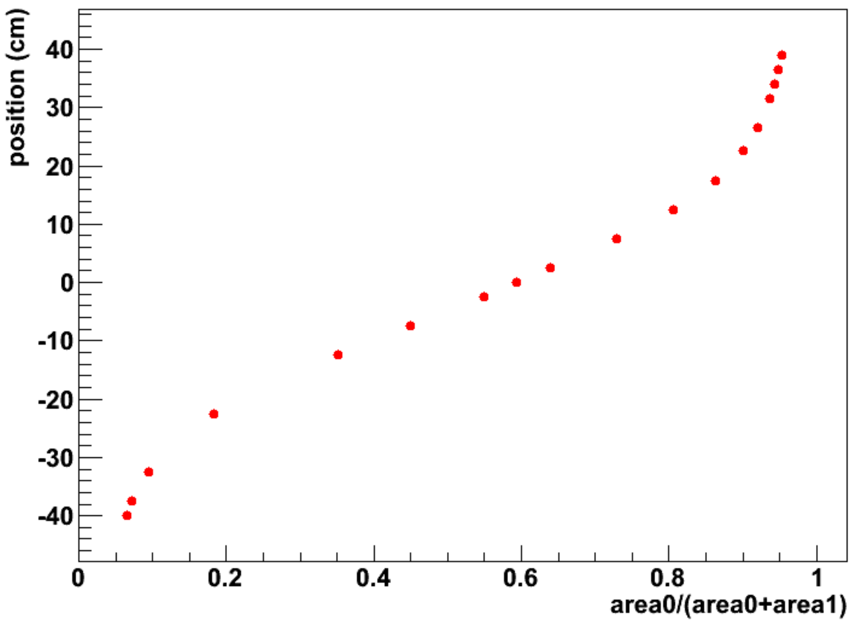
- Working High Voltage: Ch0 2000V, Ch1 2000V, attenuator 23dB applied for Both.
- Time coincidence within 30ns(peak time) are required for two PMTs. Detector response to the room background signal are shown above(Ch0 left, Ch1 right).
- Muon minimum ionization peak and the response to 22Na source along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

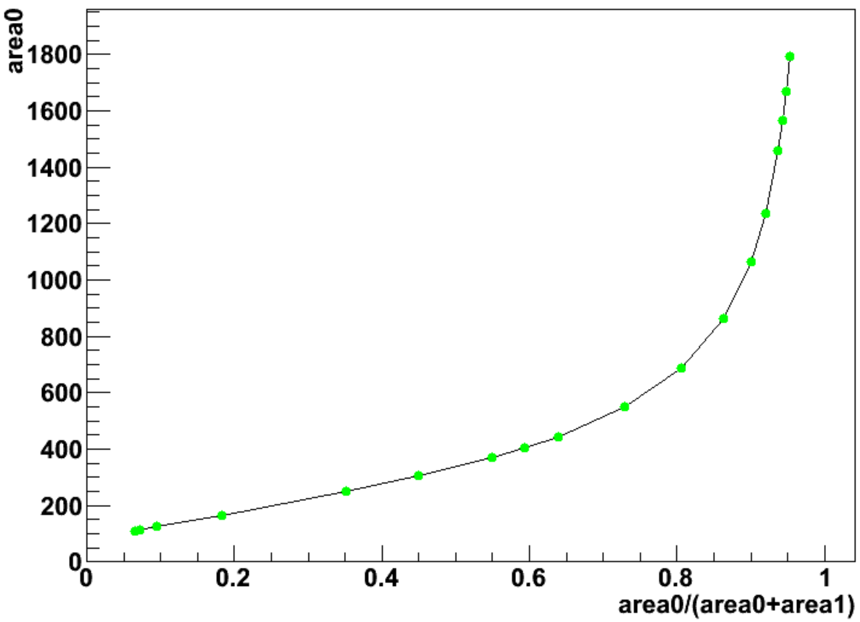
Calibration



Na22: 1.0µCi. Placed at each 2.5 cm along with the tube.
AmBe: 3.33MBq. Placed at the fixed position above the detector.

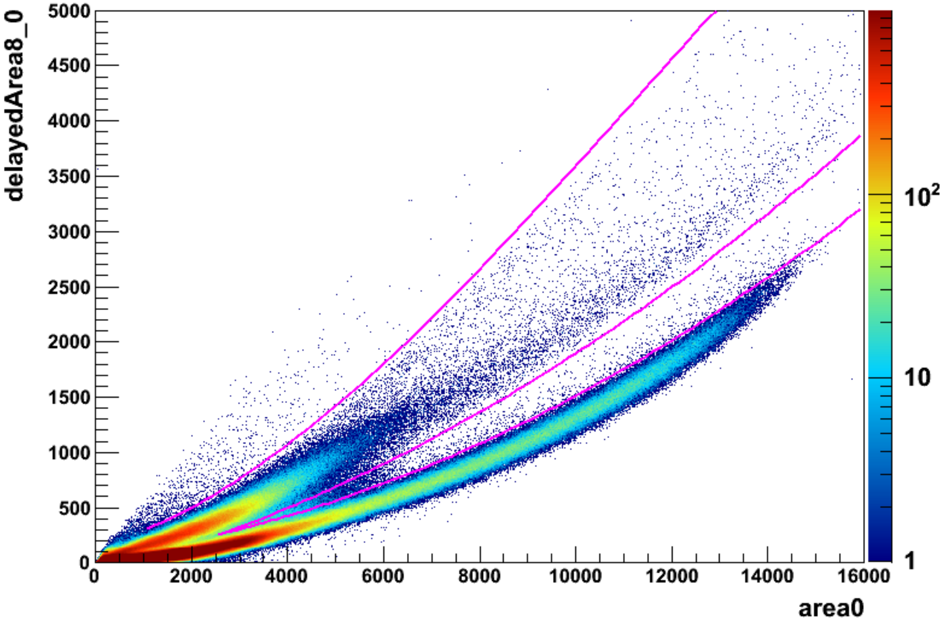
Response to 22Na source

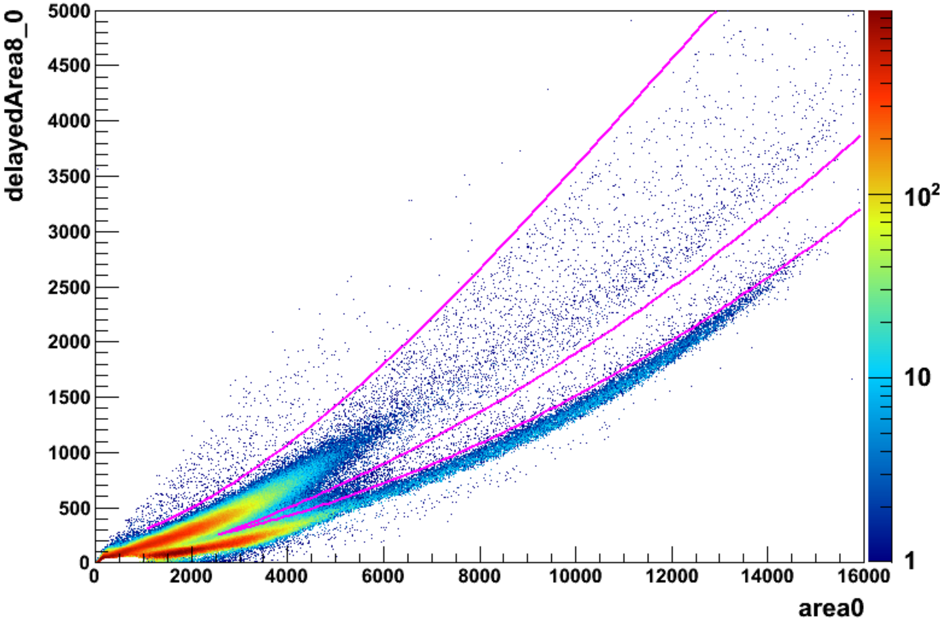




- Actual position VS charge ratio response to 22Na source(Left).
- Total charge (Ch0) VS charge ratio response to 22Na source(Right)

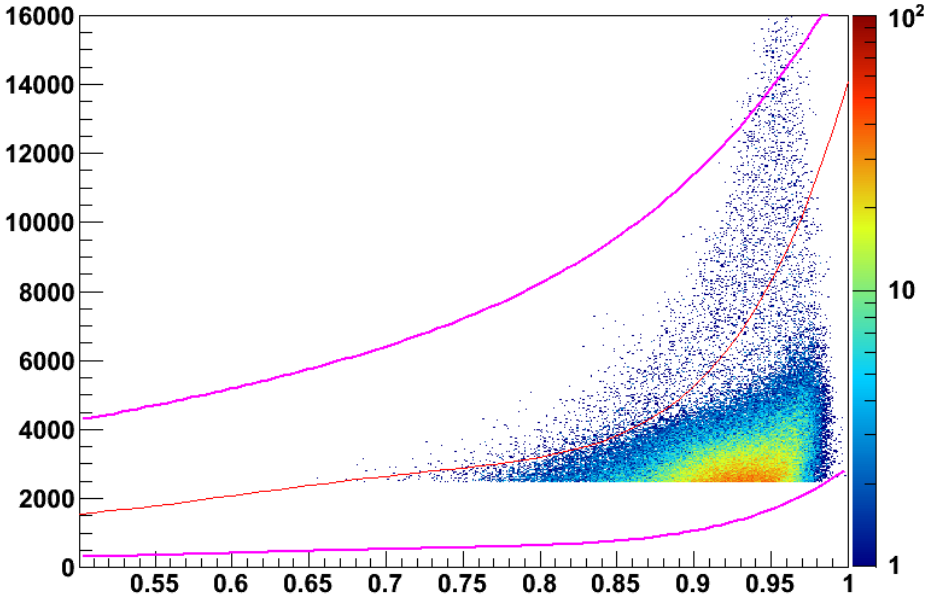
AmBe Source

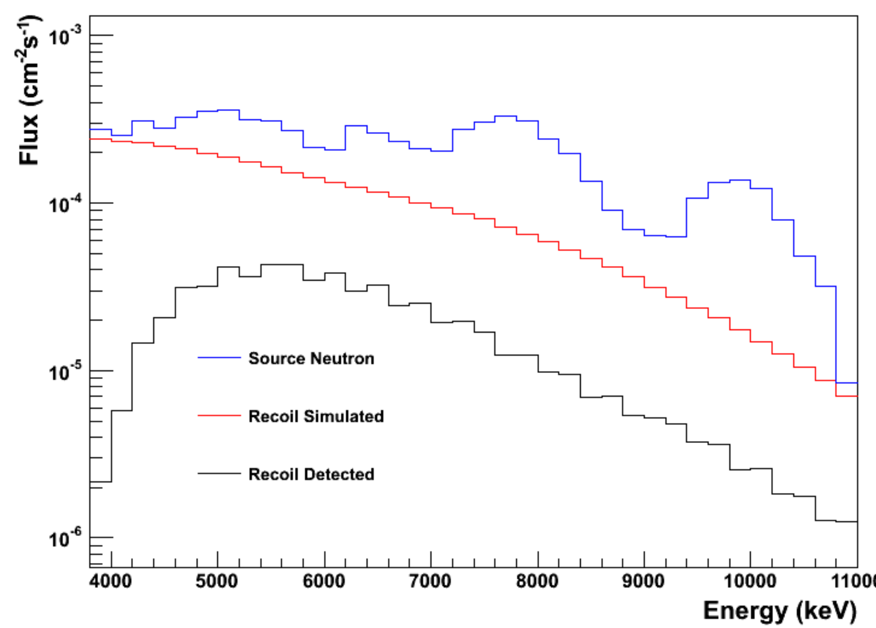




- AmBe: about 68.3 hours data(left) and the one with background subtracted(right)
- The AmBe source(3.33MBq) is placed at 6.5cm above the detector, close to Ch0 end about 15cm and to Ch1 end about 60cm.

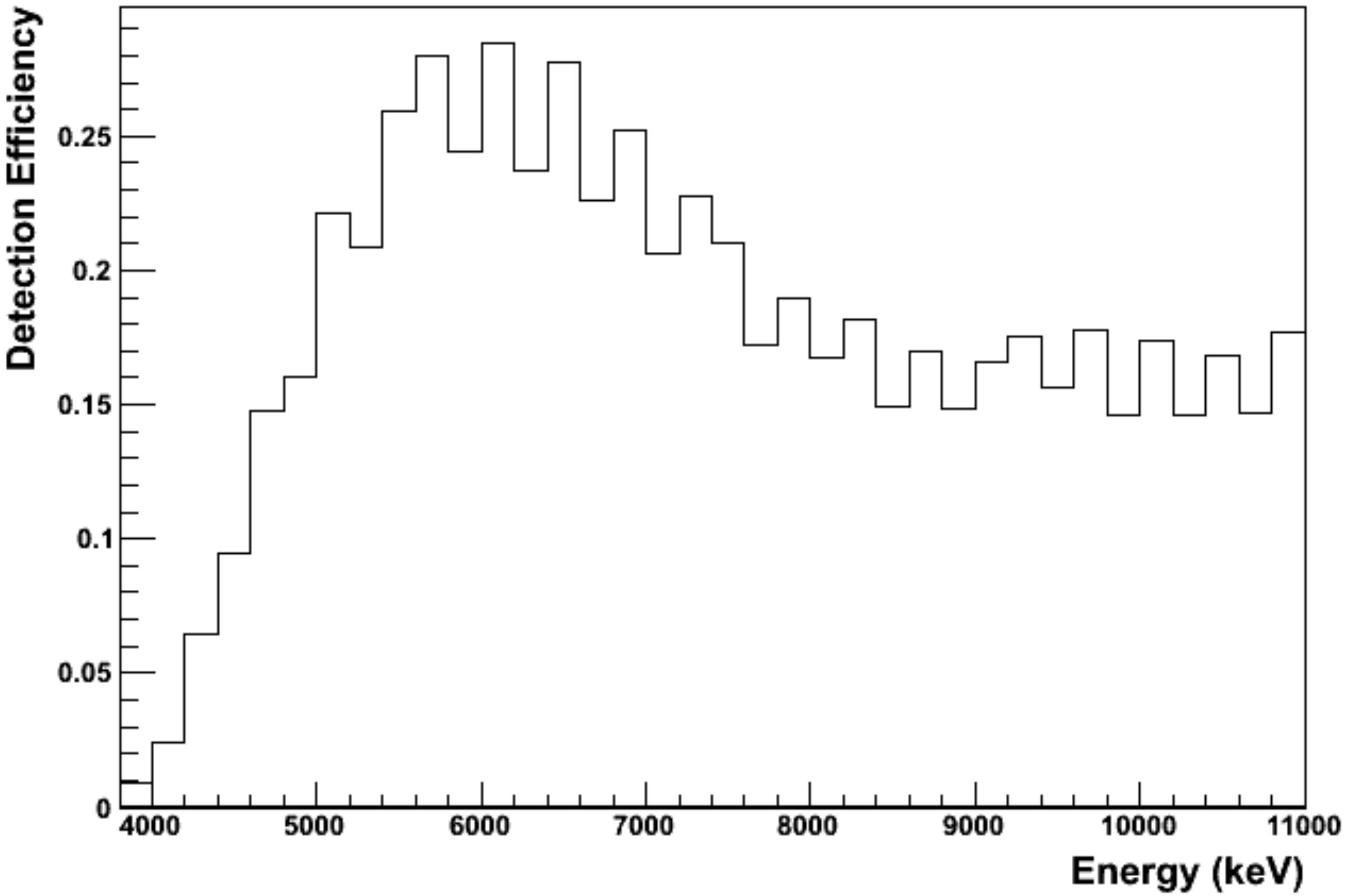
Energy Reconstruction



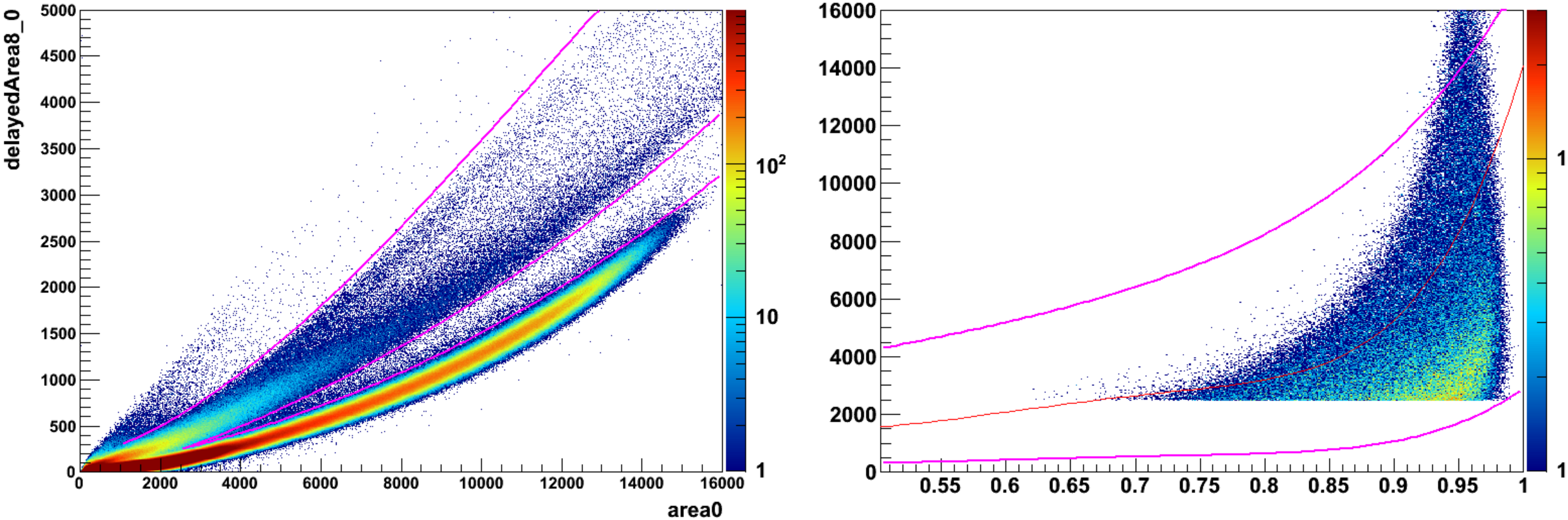


- AmBe neutrons with cut area0>2500 (Left). Red curve indicates 11 MeV real energy.
- Energy spectrum comparison between the simulated AmBe neutron by assuming 100% detection efficiency and the reconstructed neutron data (Right).
- Quenching factor is applied to convert visible energy to recoil energy.

Detection Efficiency

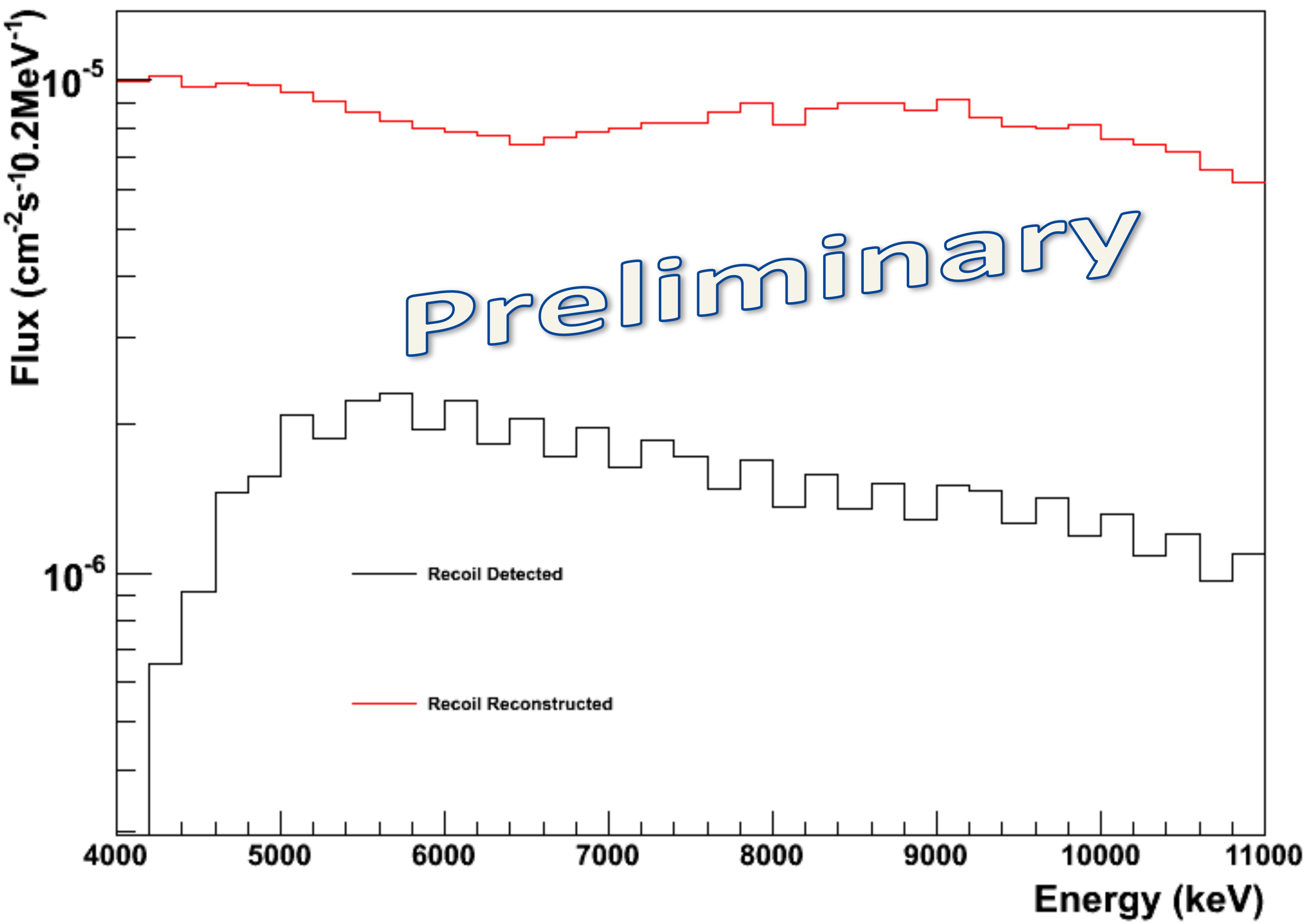


Room Background Data



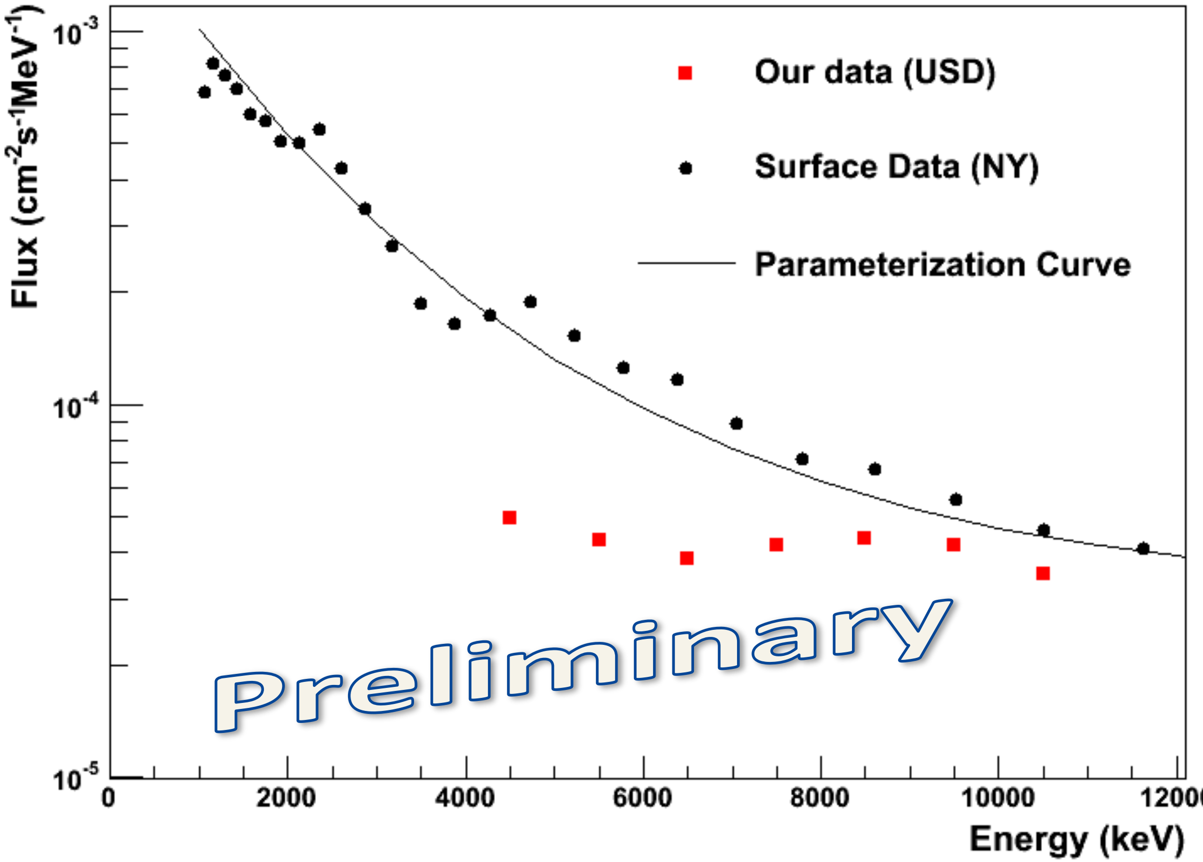
- Room Background about 19 days data.

Room Neutron Spectrum



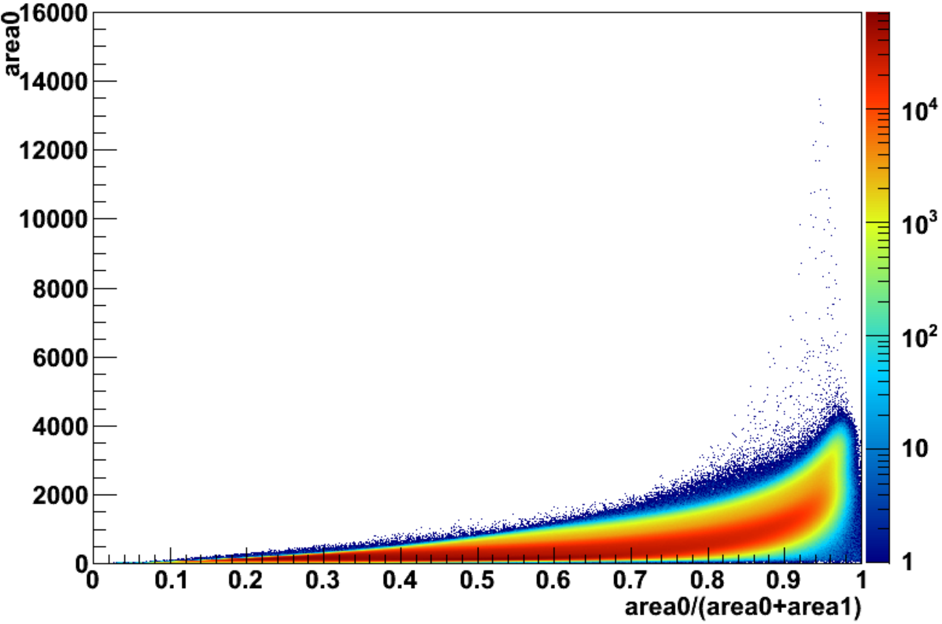
Comparison with Others

M.S. Gordon et. al, IEEE, Vol.51, No.6, P3427

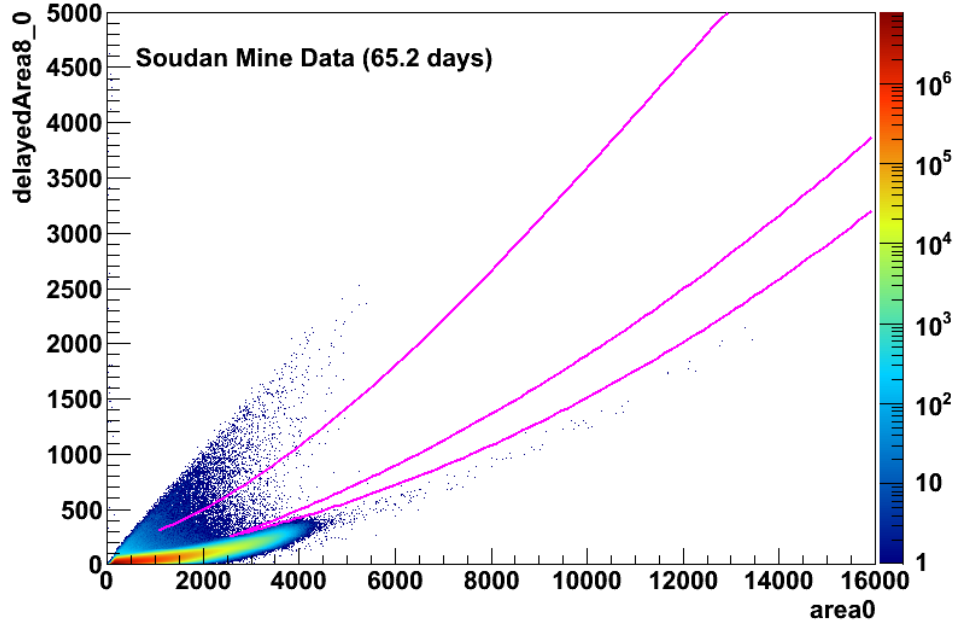


- On the roof of a building, NY.
- In the first floor of Patterson Hall, USD

Soudan Data

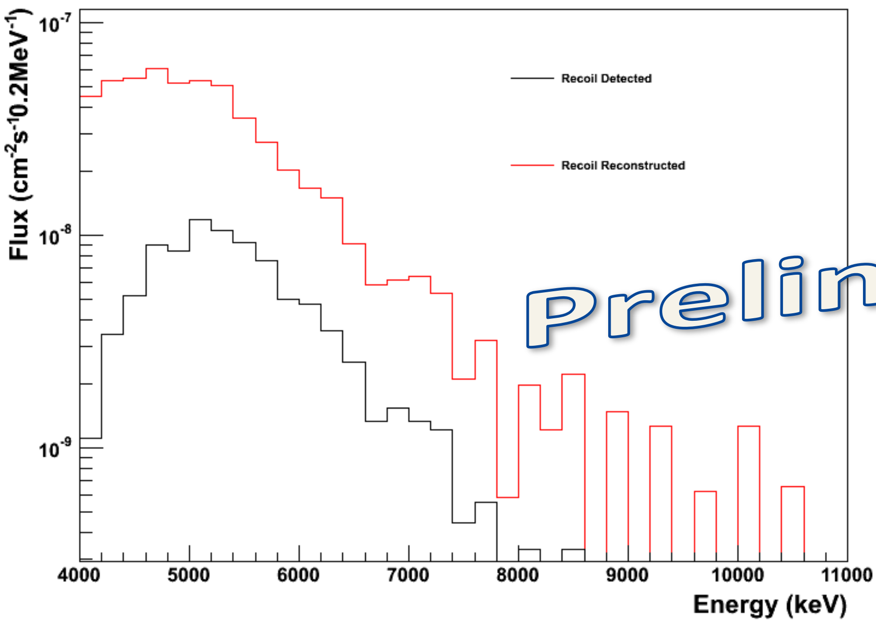


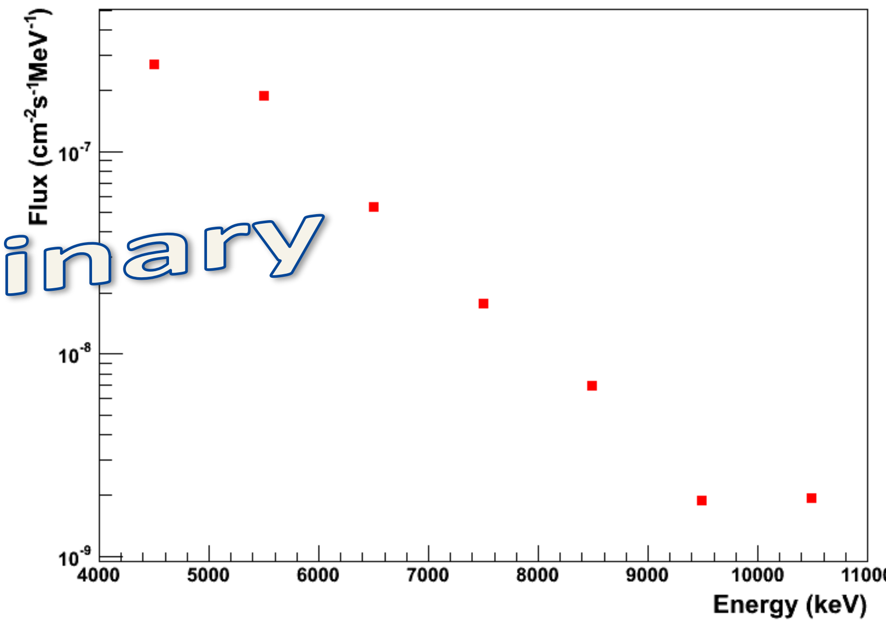
area0
16000
14000
12000
10000
8000
6000
4000
2000
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
area0/(area0+area1)
10^4
10^3
10^2
10
1



Soudan Mine Data (65.2 days)
delayedArea8_0
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2000 4000 6000 8000 10000 12000 14000 16000
area0
10^6
10^5
10^4
10^3
10^2
10
1

Soudan Data





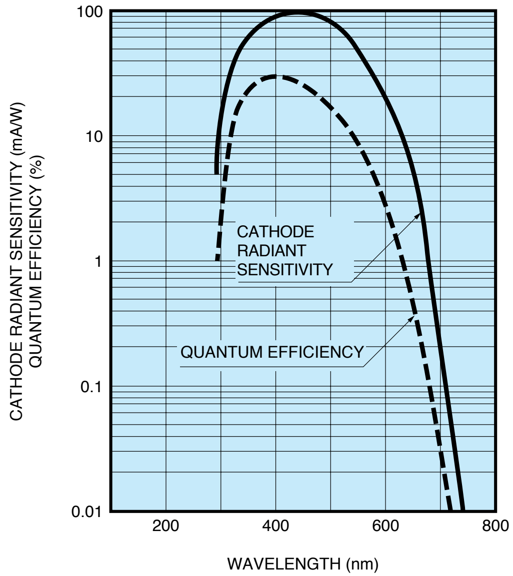
Soudan mine 65.2 days data

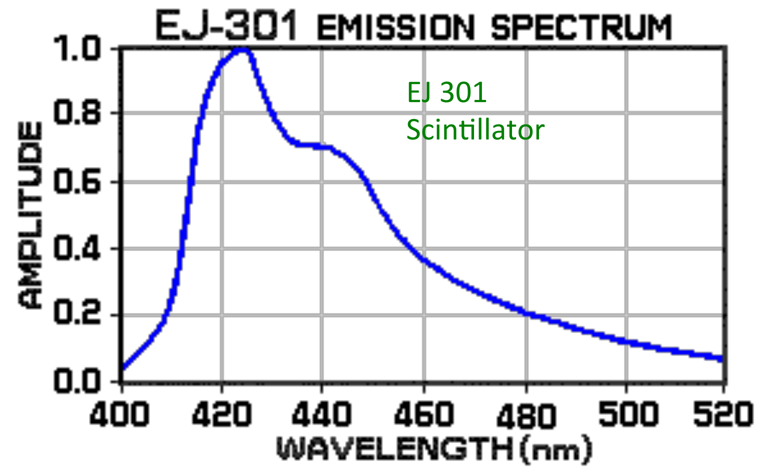
Current Status

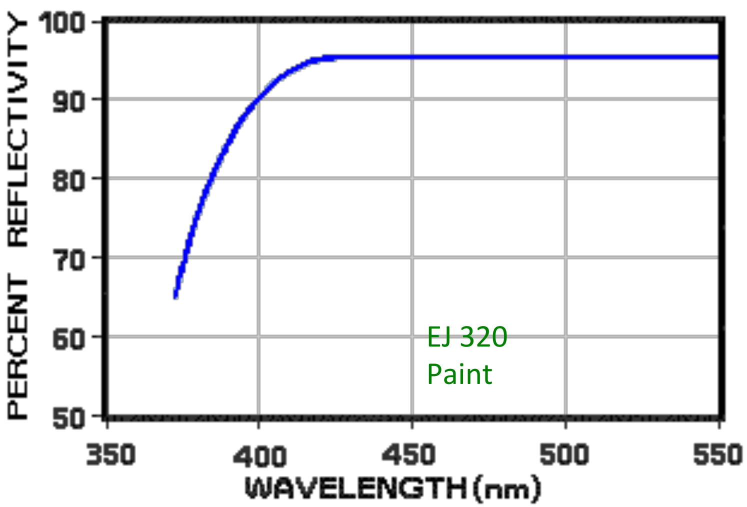
- Detector is working stable at 2000V high voltage with good n/g PSD.
- Muon minimum ionization peak is present with 23dB signal attenuation applied to both PMTs. Together with 22Na source, position and energy relations are well understood.
- By using AmBe source, the detection efficiency for neutrons with energy below 11MeV is calibrated.
- About three weeks surface room background data were accumulated. The detector has been running at Soudan mine for a few months.

Backup I: Optical properties

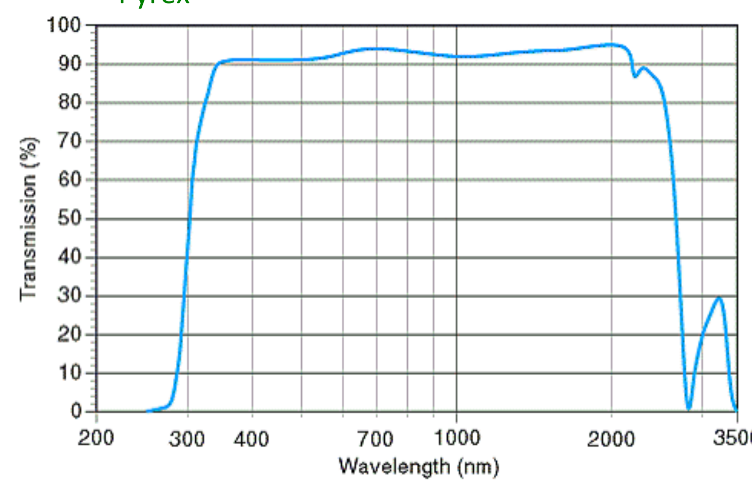
PMT R4144
Spectral Response







Pyrex



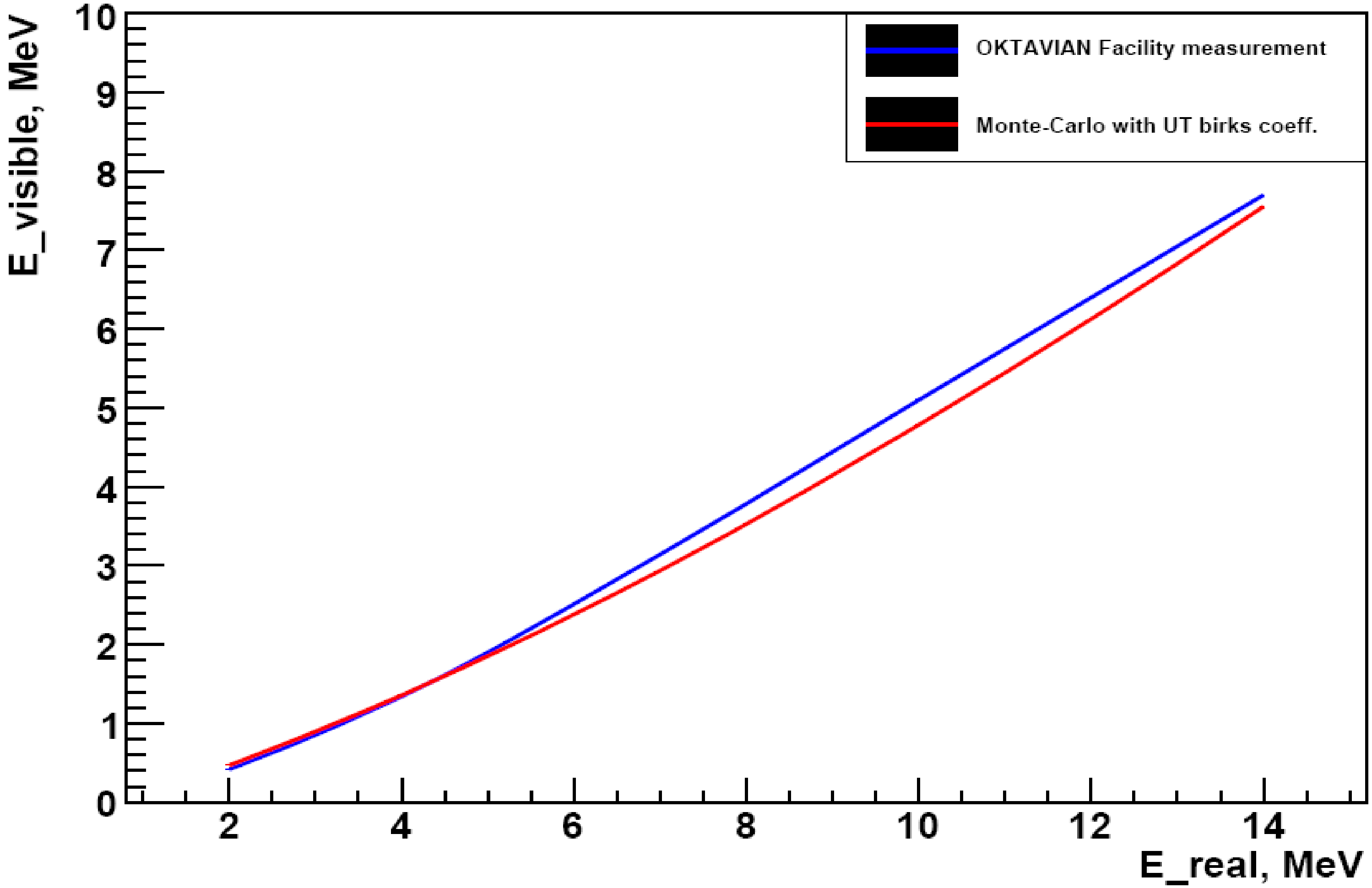
Backup II: R4144 PMT & EJ301

Part Number	R4144
Type	Head on
Size	127mm
ActiveDia/L	120mm
Min λ	300μm
Max λ	650μm
Peak Sens.	420μm
Cathode Radiant Sensitivity	72mA/W
Window	Borosilicate
Cathode Type	Bialkali
Cathode Luminous Sensitivity	70μA/lm
Cathode Blue Sensitivity Index	9
Anode Luminous Sensitivity	100A/lm
Gain	1.4E+06
Dark Current after 30 min.	10nA
ENI	10
Rise Time	1.5ns
Transit Time	35ns
Transit Time Spread	0.7ns
Number of Dynodes	8
Applied Voltage	3000V
Multi Anode	N
Socket Bare	E678-20B

Q.E. ~ 20%

L. Y. ~ 12000pe/MeV

Backup III: Quenching factor



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