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CDEX-200 Background Simulation: Preliminary Results

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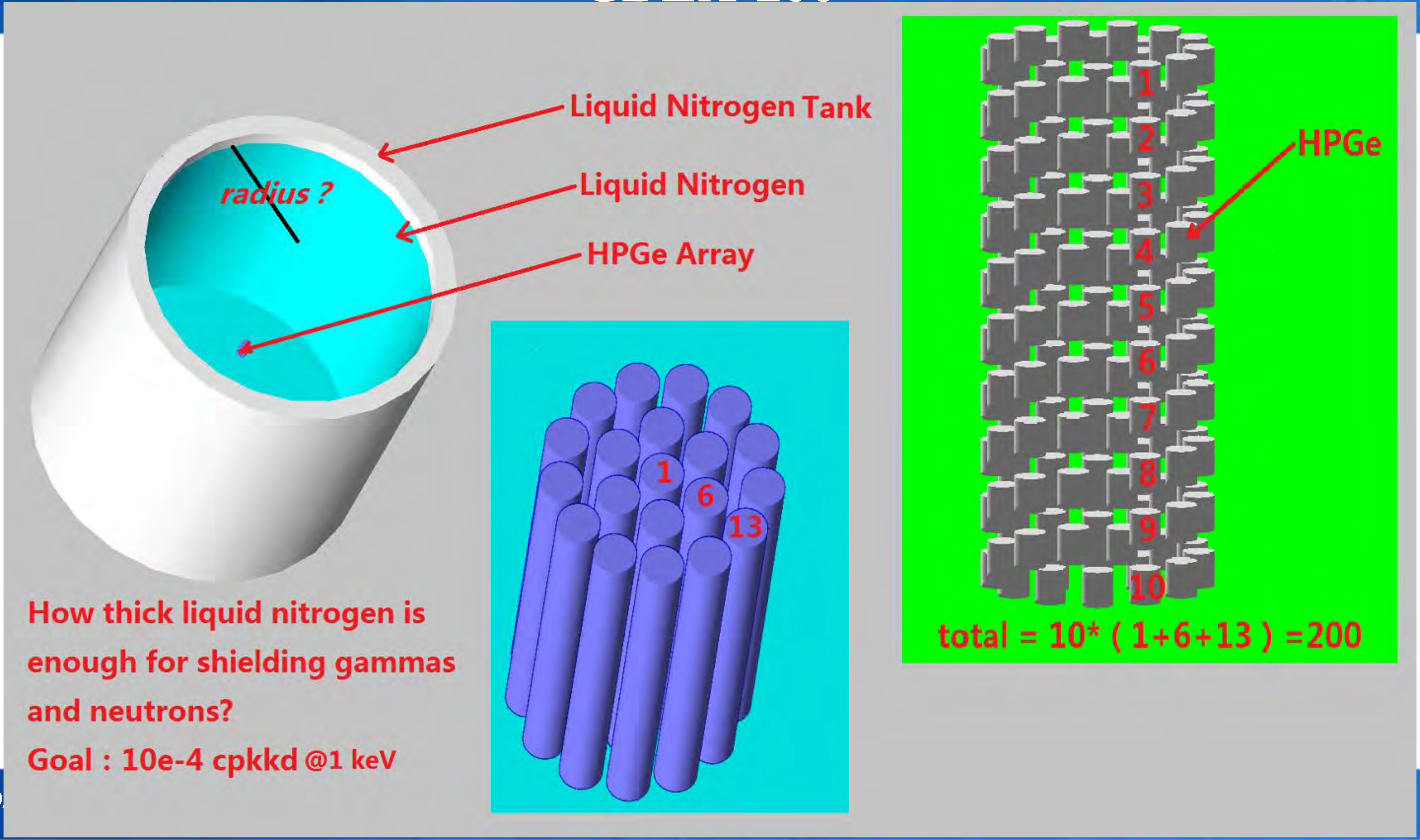
CDEX-200


Liquid Nitrogen Tank
radius ?
Liquid Nitrogen
HPGe Array
1
6
13
HPGe
1
2
3
4
5
6
7
8
9
10
total = 10* (1+6+13) =200
How thick liquid nitrogen is enough for shielding gammas and neutrons?
Goal : 10e-4 cpkkd @1 keV

Background Analysis

We need to know how thick liquid nitrogen is enough to shield gammas and neutrons from rock.

Sources of background :

√ Gammas from rock

√ Neutrons from rock

× Muons from cosmic rays $(2.0\pm0.4)\times10^{-10}\ cm^{-2}s^{-1}$

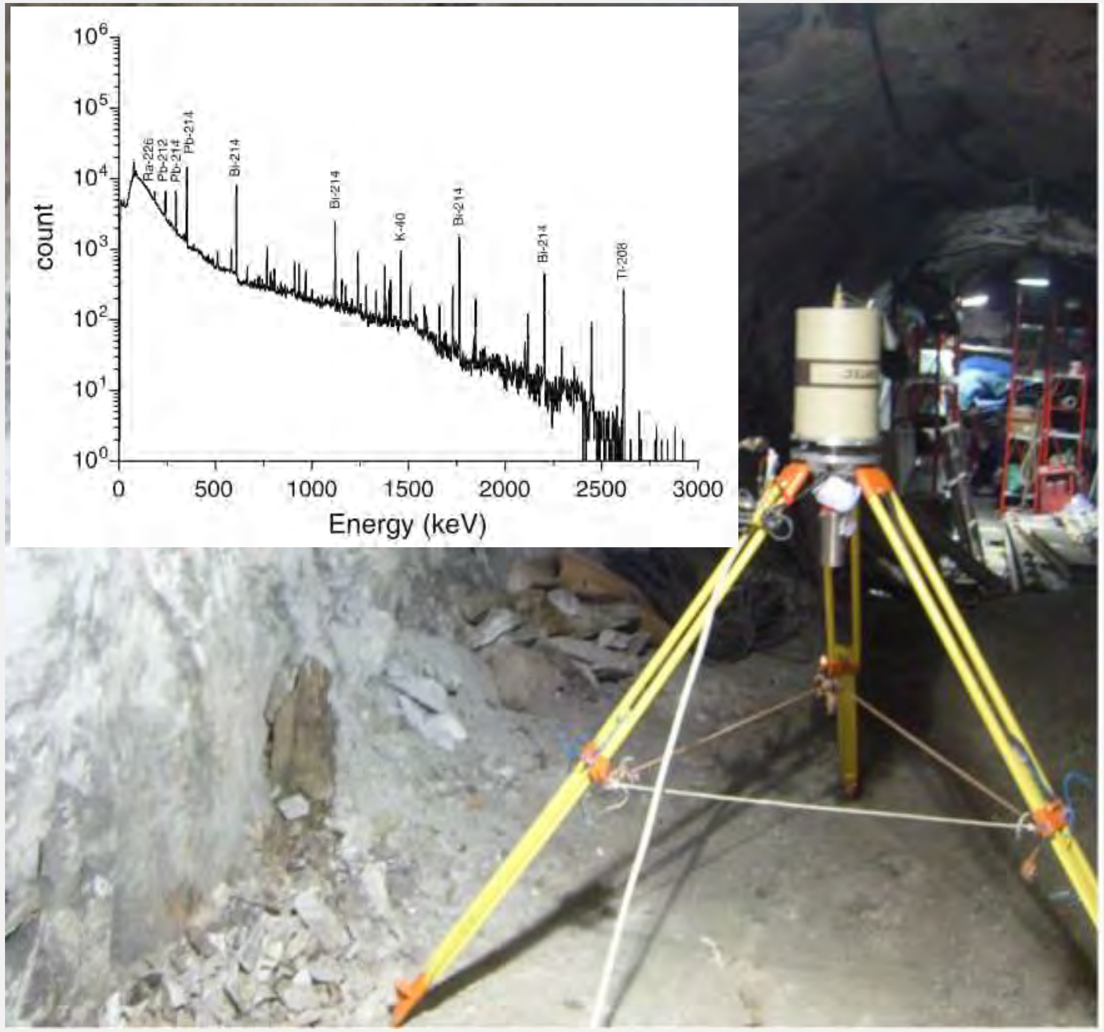
× Cosmogenic Radionuclides in Ge Crystal

× Background from electronic devices

Gamma background from rock

Gamma spectrum @CJPL

We obtained the gamma spectrum in a tunnel cave by in situ gamma spectrometer.



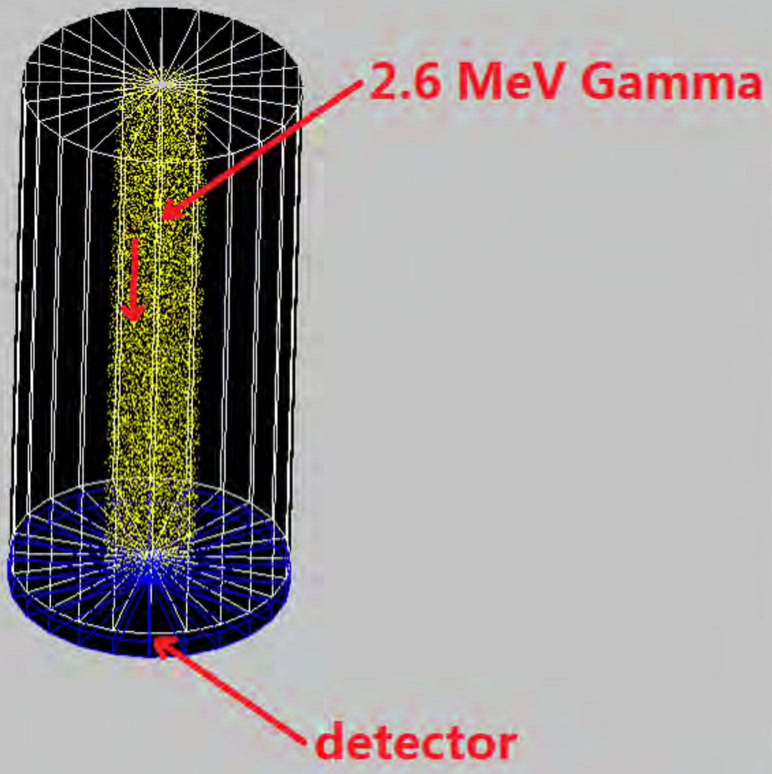
The U/Th/K activity concentrations obtained by in situ gamma spectrum.

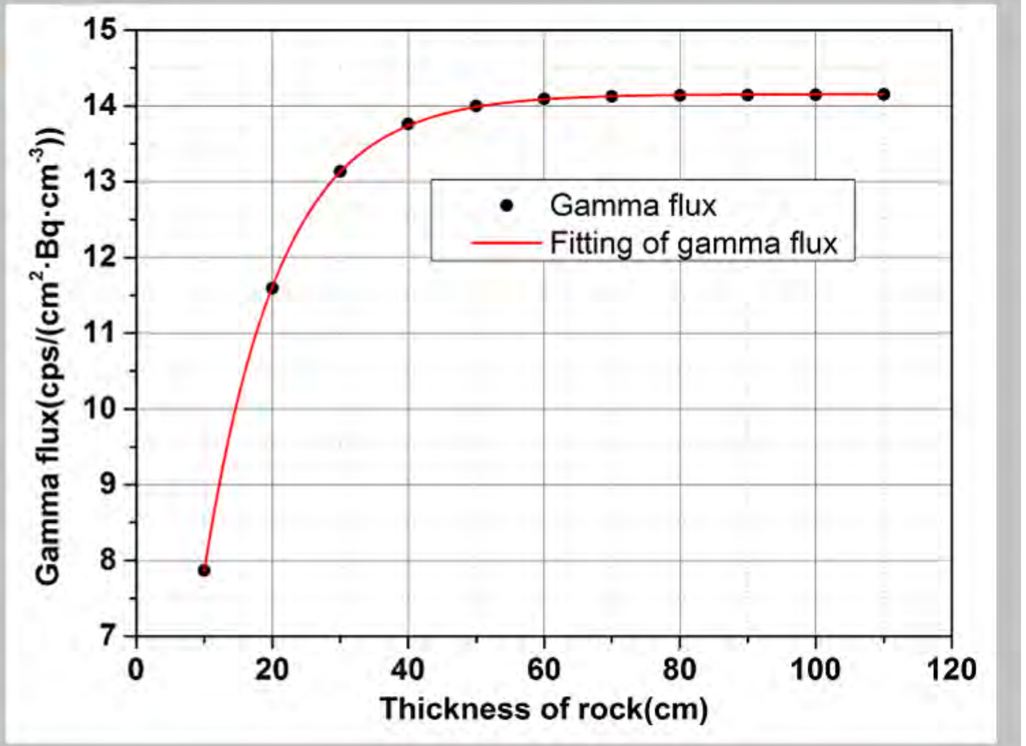
Radionuclides in rock	Activity concentrations (Bq/kg)
U-238	3.69~4.21
Th-232	0.52~0.64
K-40	4.28

Zeng Z, Su J, Ma H, et al. Journal of Radioanalytical and Nuclear Chemistry, 2014, 301(2): 443-450.

Gamma spectrum @CJPL

We need to know the gamma spectrum at the surface of CJPL rock and it is the input spectrum for our shied. But firstly how thick rock is enough to generate gamma?



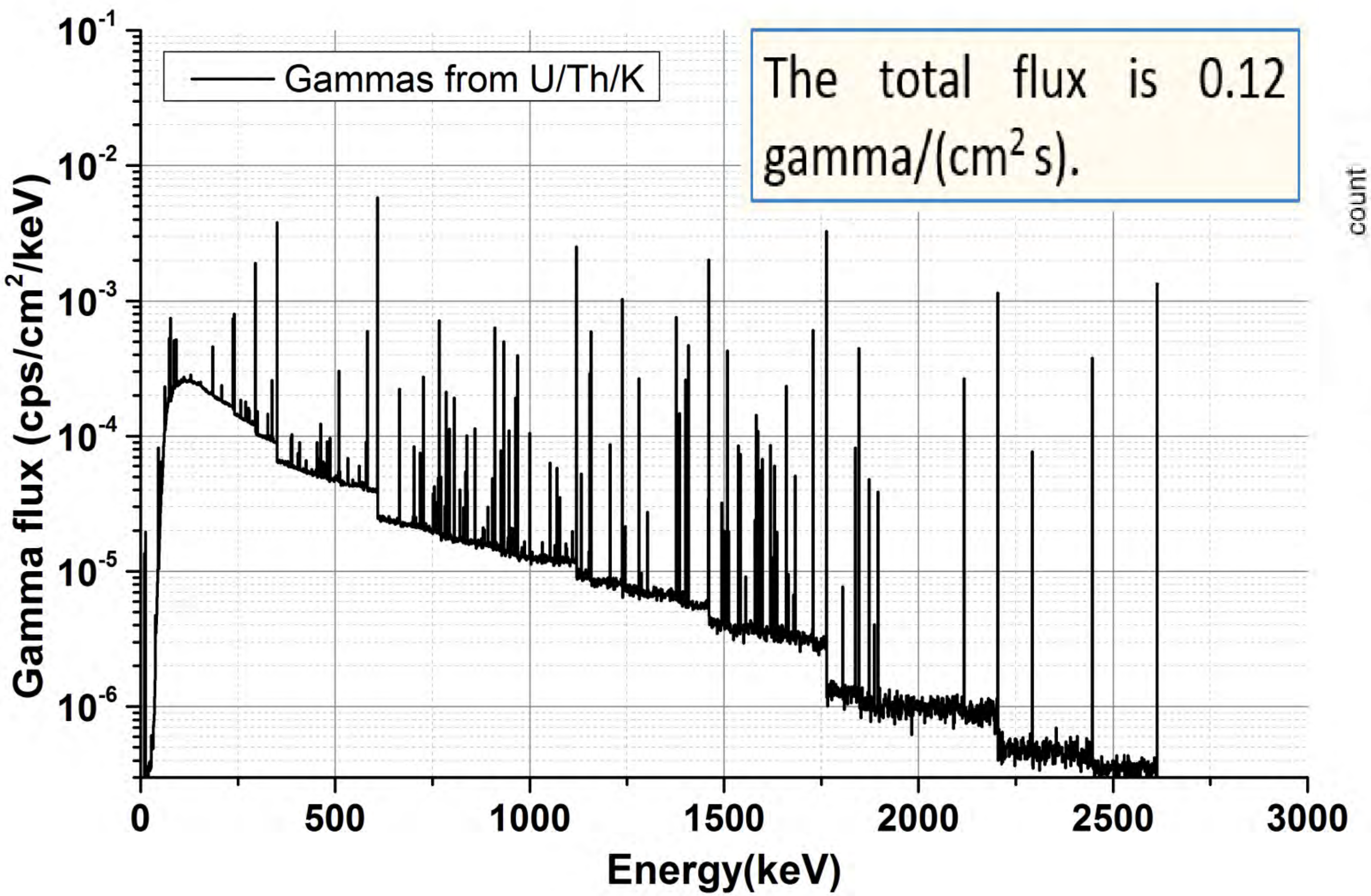


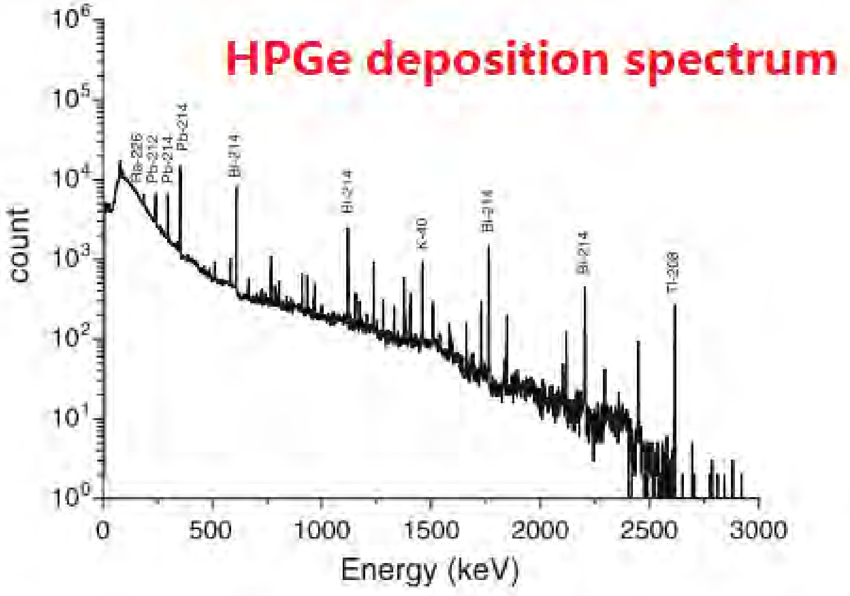
it is enough to generate gammas when the thickness of rock is 60 cm !

Gamma spectrum @CJPL

According to 60 cm thick rock and U/Th/K activity concentrations we get the gamma spectrum at the surface of CJPL rock by MC simulation.

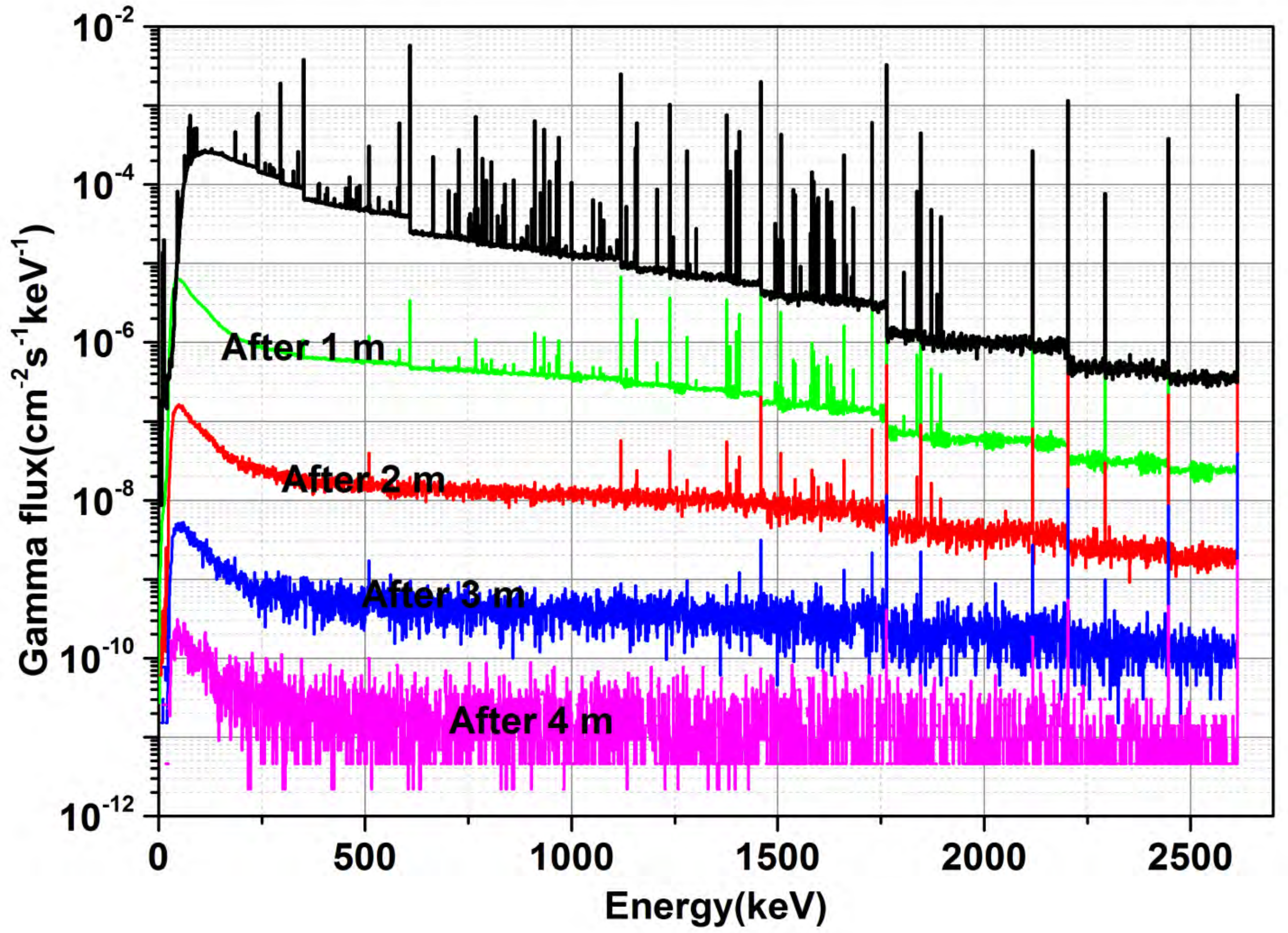
The total flux is 0.12 gamma/(cm^2 s).





Liquid nitrogen shield for gammas

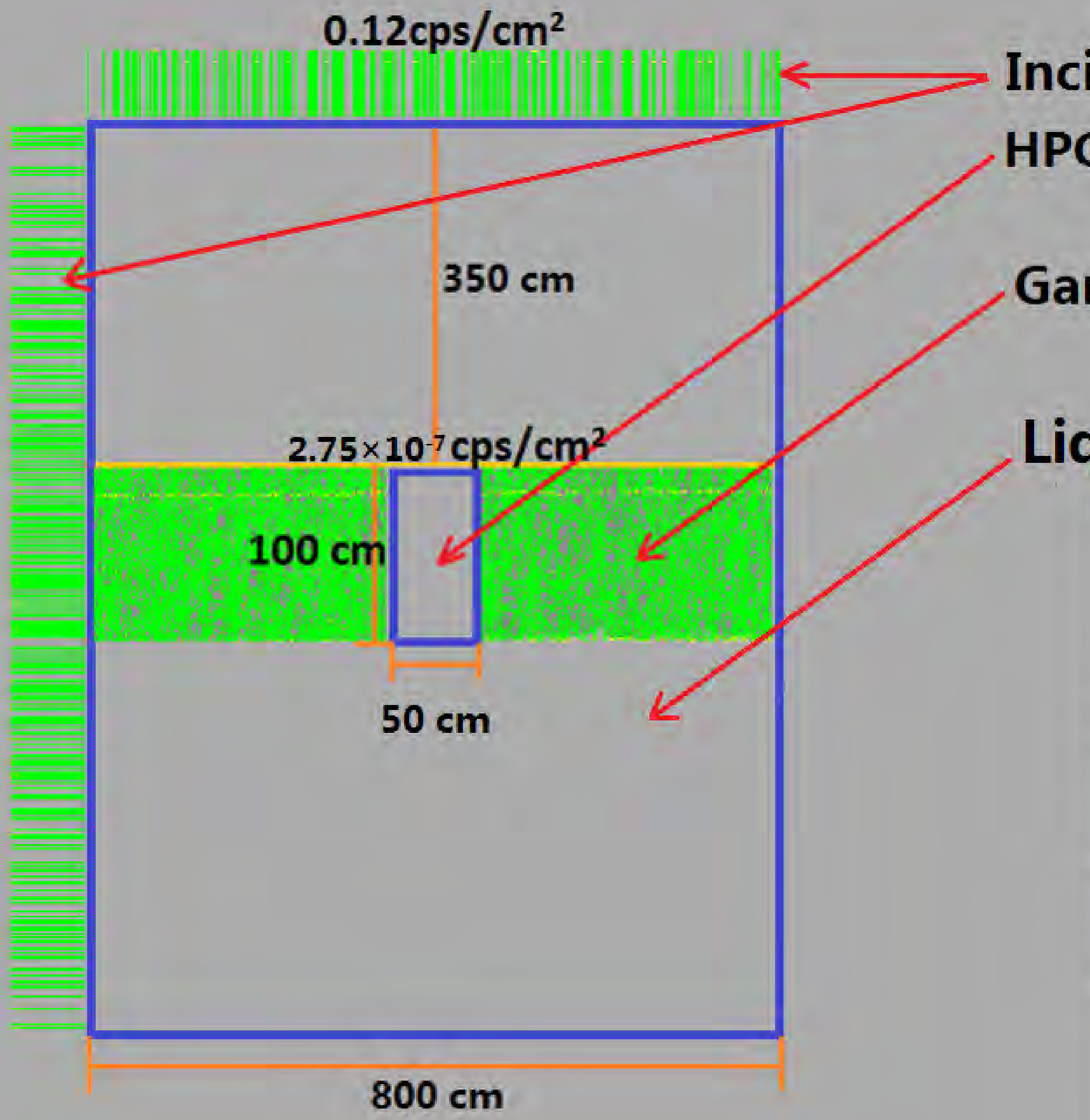
The thick line is the gamma spectrum before the shield while the thin lines are the gamma spectrum after each meter of liquid nitrogen.

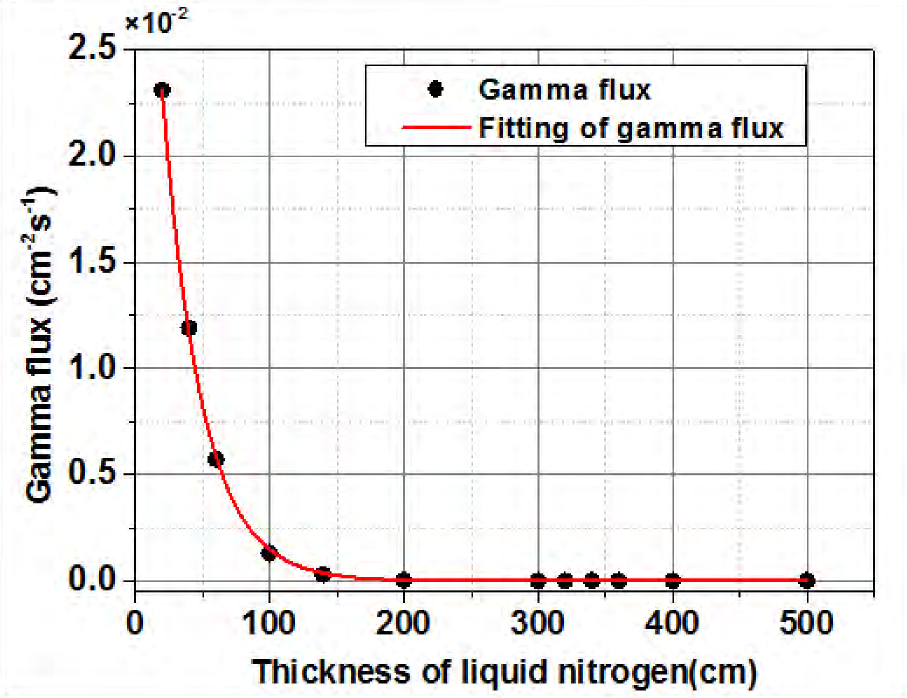


The total gamma flux outside the shield is 0.12 $cm^{-2}s^{-1}$

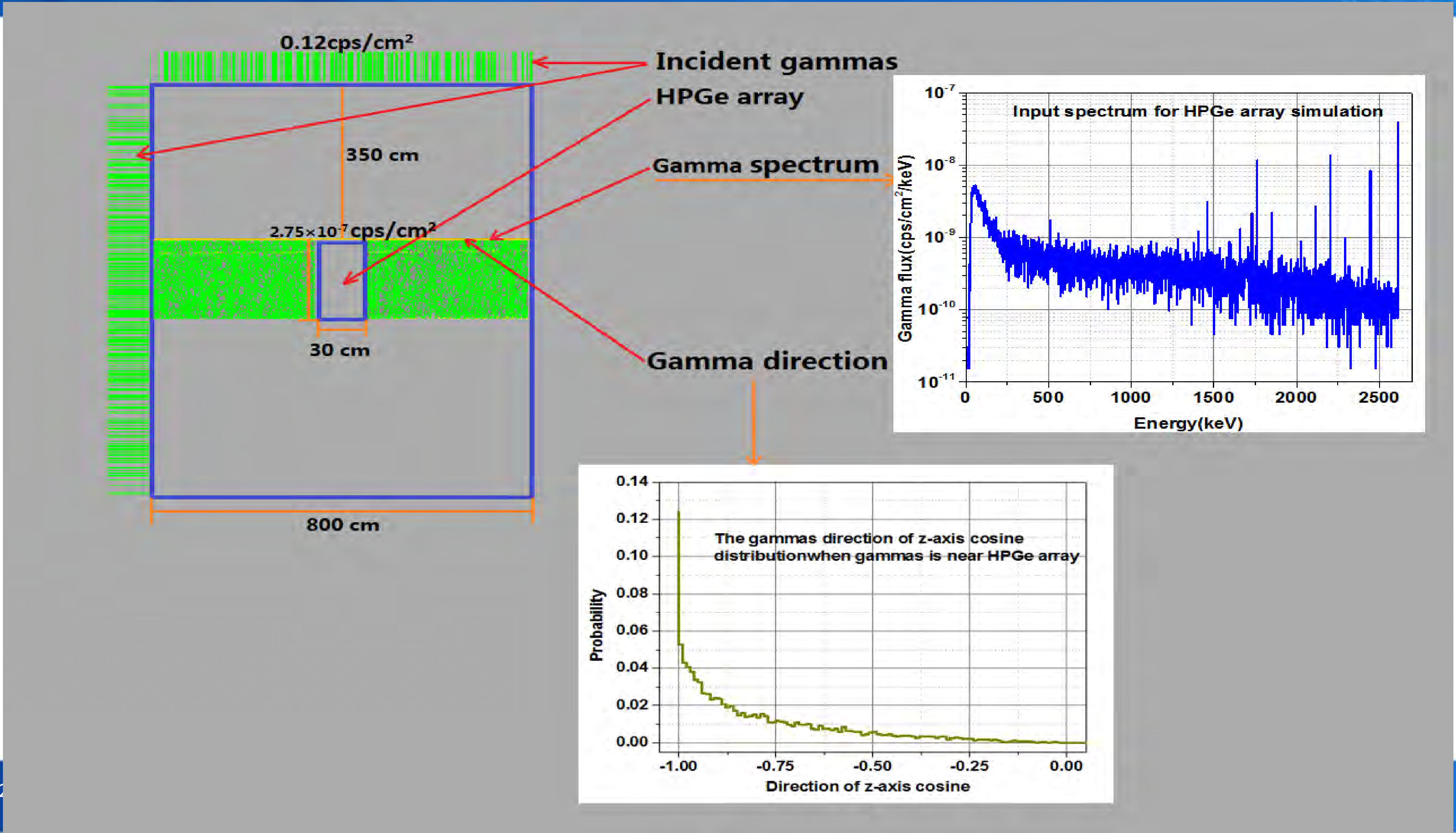
Liquid nitrogen thickness(m)	Gamma flux ($cm^{-2}s^{-1}$)
1	1.30×10^{-3}
2	3.85×10^{-5}
3	1.36×10^{-6}
4	5.48×10^{-8}

Liquid nitrogen shield for gammas



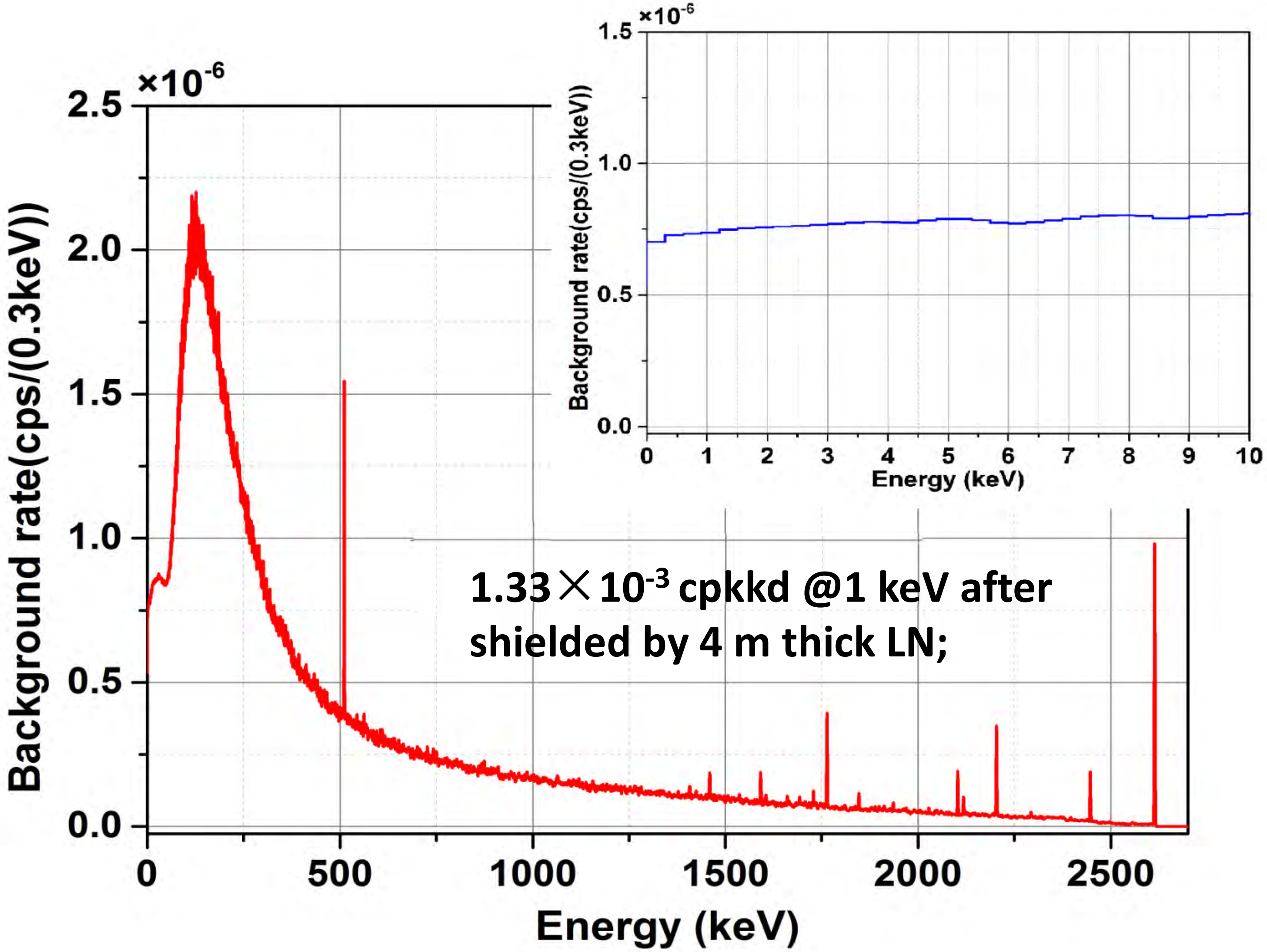


Liquid nitrogen shield 4 m: γ in LN



Liquid nitrogen shield 4 m: γ in LN

The background of HPGe array from gammas after 4 m LN



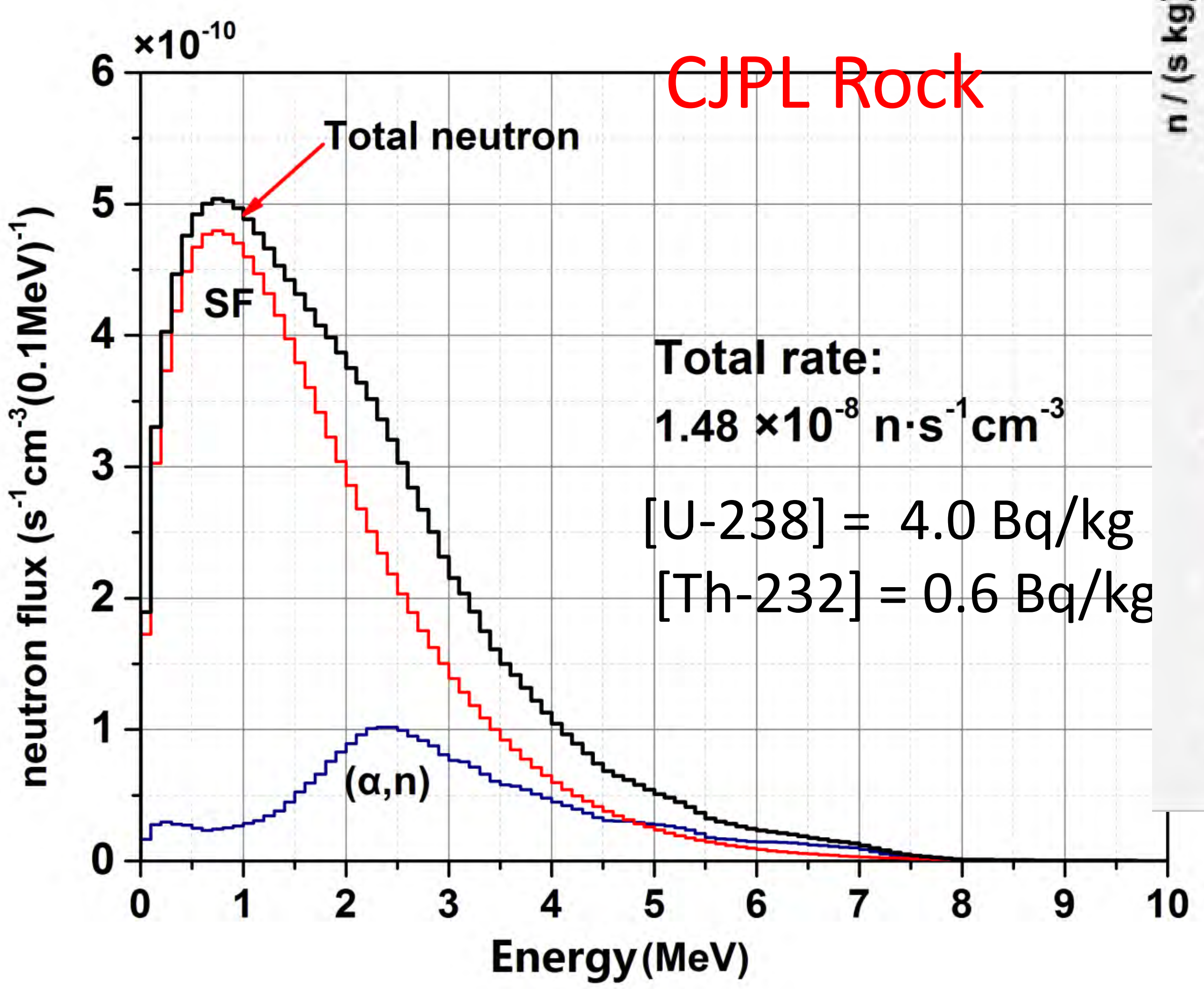
Liquid nitrogen thickness(m)	Gamma background (cpkkd@1keV)
2	1.19
3	3.90×10^{-2}
4	1.33×10^{-3}
5	4.77×10^{-5}

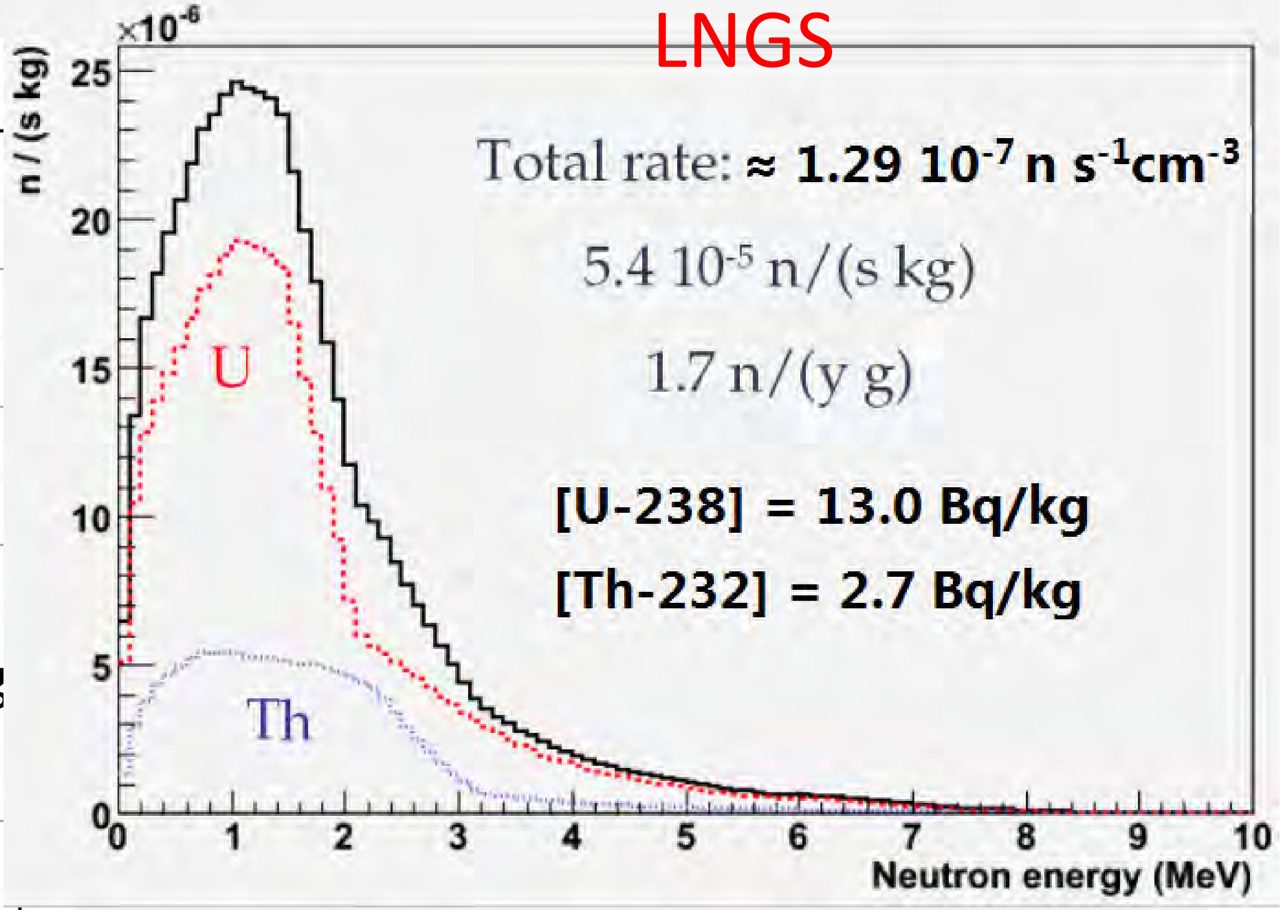
Goal: 10^{-4} cpkkd@1keV;
When LN thickness >4.75 m

Neutron background from rock

Neutrons from fission and (α,n)

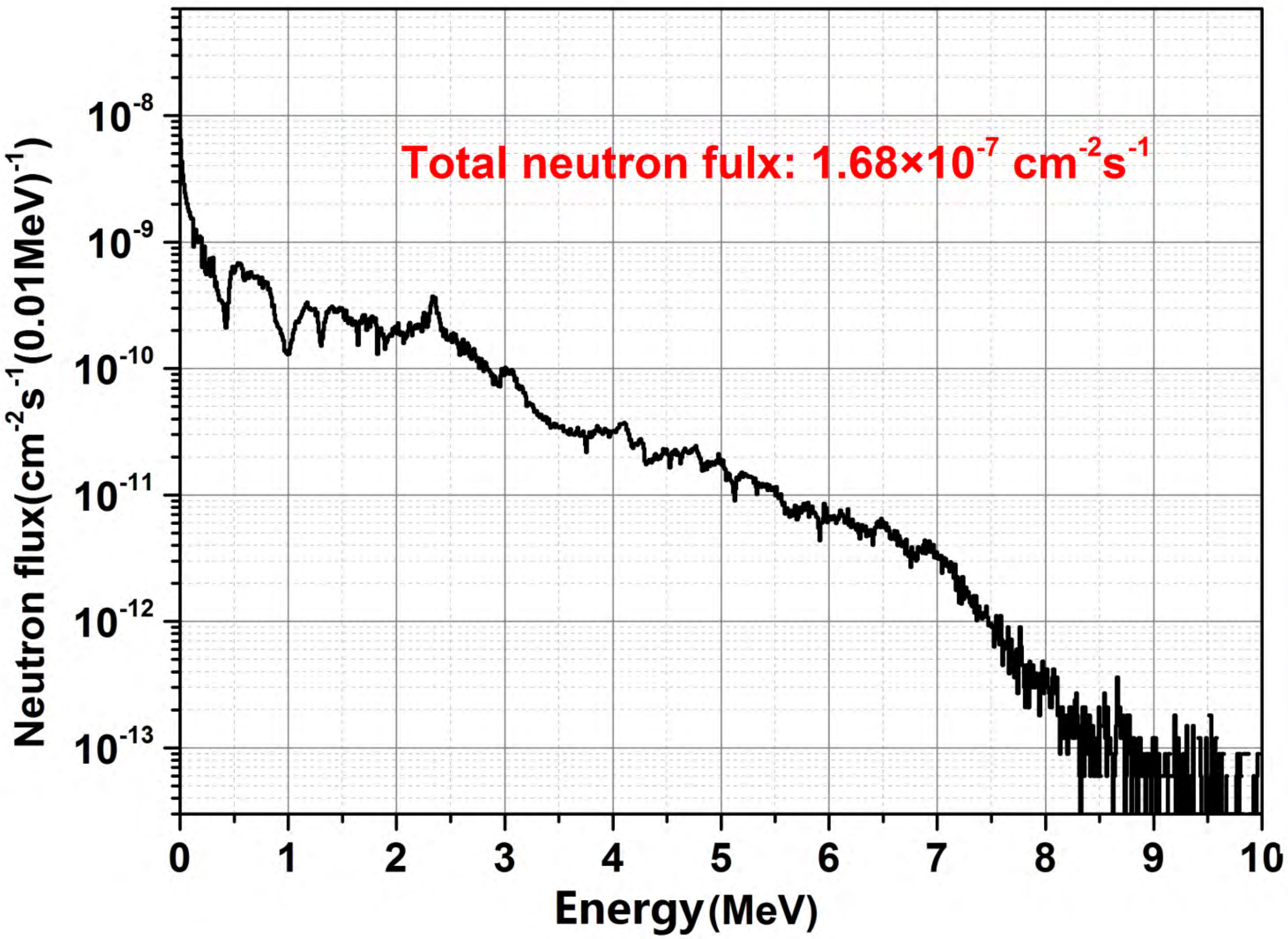
Neutrons from U-238 fission and (α,n) reactions from U/Th decay chains, generated by SOURCES code in rock.

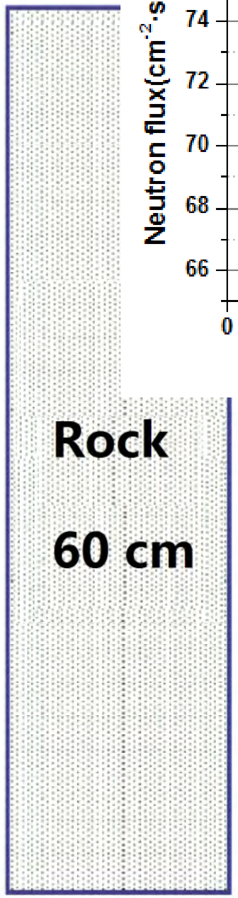


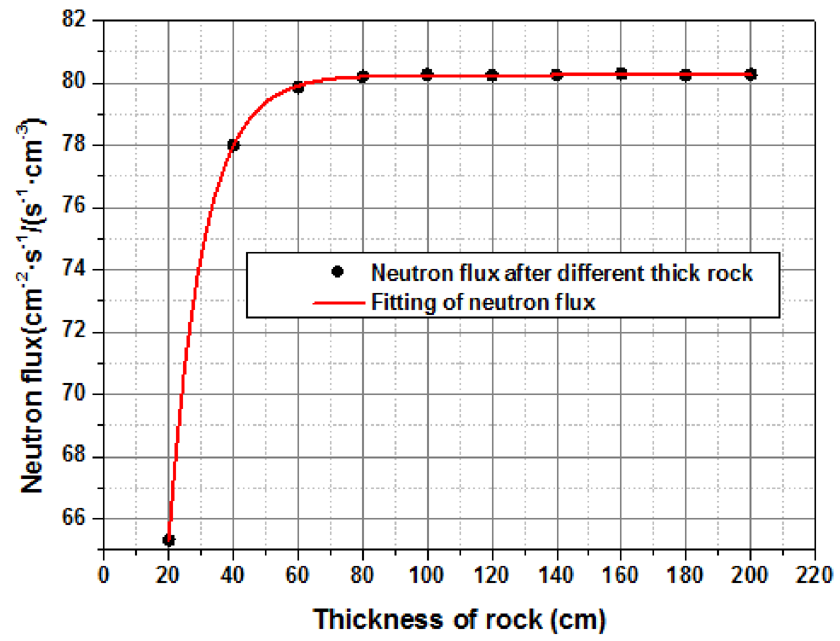


Neutron emitting spectrum

Neutron flux spectrumat the surface of CJPL rock.

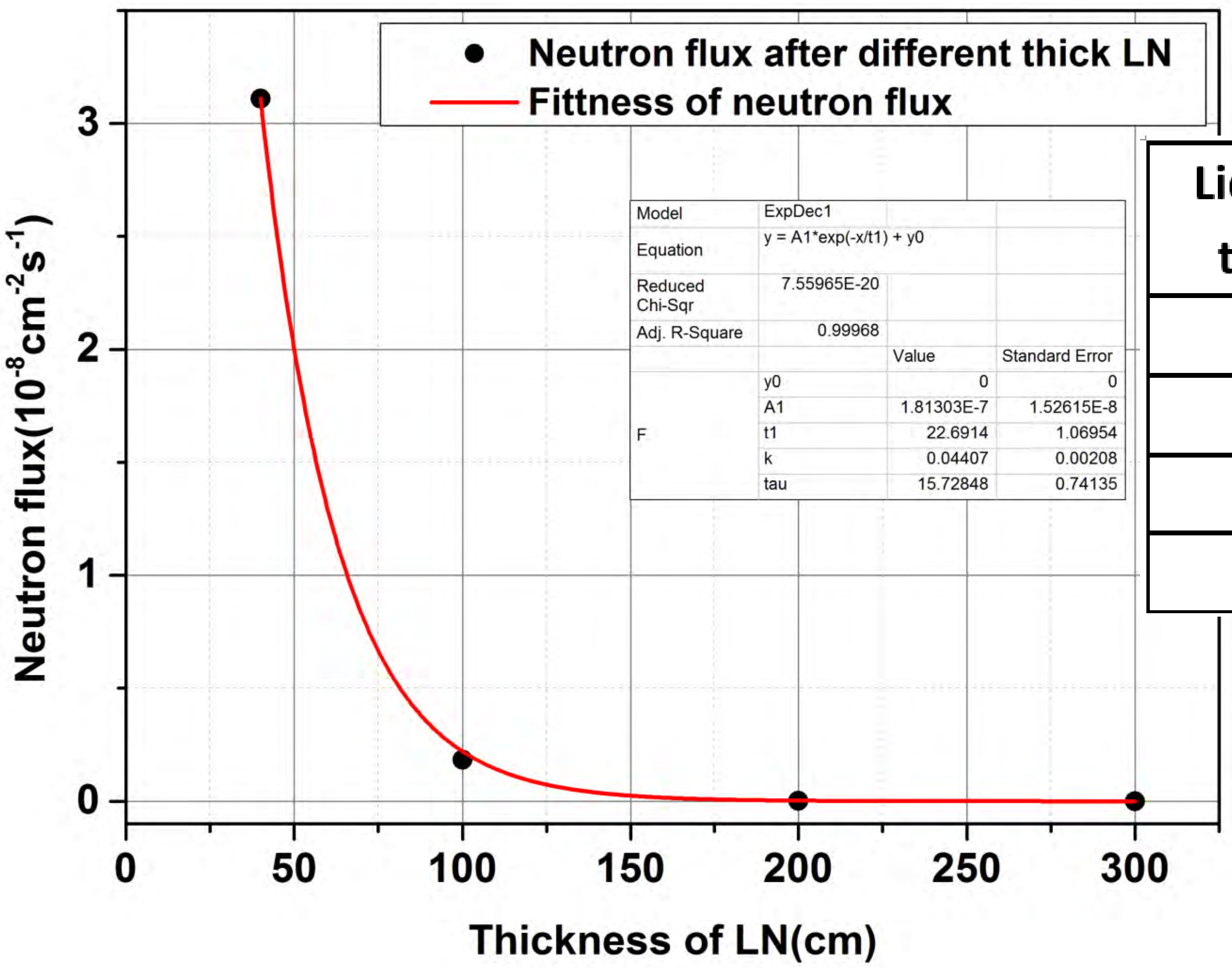






Liquid nitrogen shield for neutrons

Neutron flux is reduced by different thick LN.



Liquid nitrogen thickness(m)	Gamma flux ($cm^{-2}s^{-1}$)	Neutron flux ($cm^{-2}s^{-1}$)
1	1.38×10^{-3}	1.82×10^{-9}
2	3.85×10^{-5}	1.82×10^{-11}
3	1.36×10^{-6}	1.82×10^{-13}
4	5.48×10^{-8}	

Assuming all neutrons can be detected, the neutron background is lower than 7.17×10^{-6} cpkkd when LN thickness > 3m

Summary

Background summary

1. To obtain the background of 10^{-4} cpkkd @1 keV the thickness of LN >4.75 m
2. Neutron background can be negligent when thickness of LN > 3 m

3. Some background need to consider in simualtion in the future

   √ Cosmogenic Radionuclides in Ge Crystals

   √ Background from electronic devices

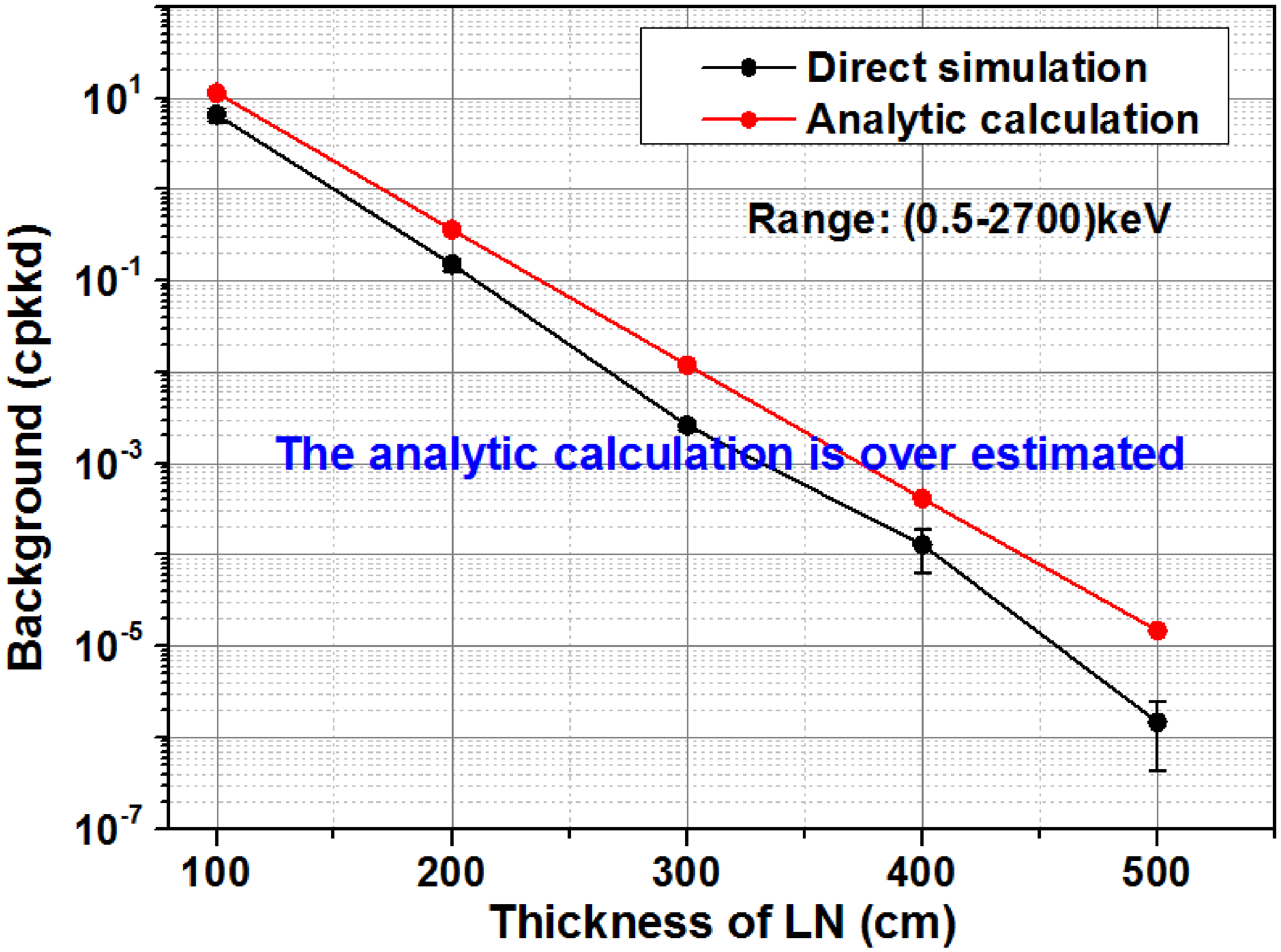
   √ Radon and impurity in liquid nitrogen

Thanks!

Directly simulating by MC

Direct simulation

We model the liquid nitrogen tank and compute the background in HPGe array directly by MC simulation without analytic calculation. But the statistics of count is bad and time consuming even with the help of variance reduction techniques.



(2160-2880) cpu·h per thickness of LN for direct simulation.

Comparing with direct simulation, our analytic calculation is conservative and the thickness of LN is enough!