Neutron Detector Study

Peng Hu,Zhigang Wang
IHEP,CAS

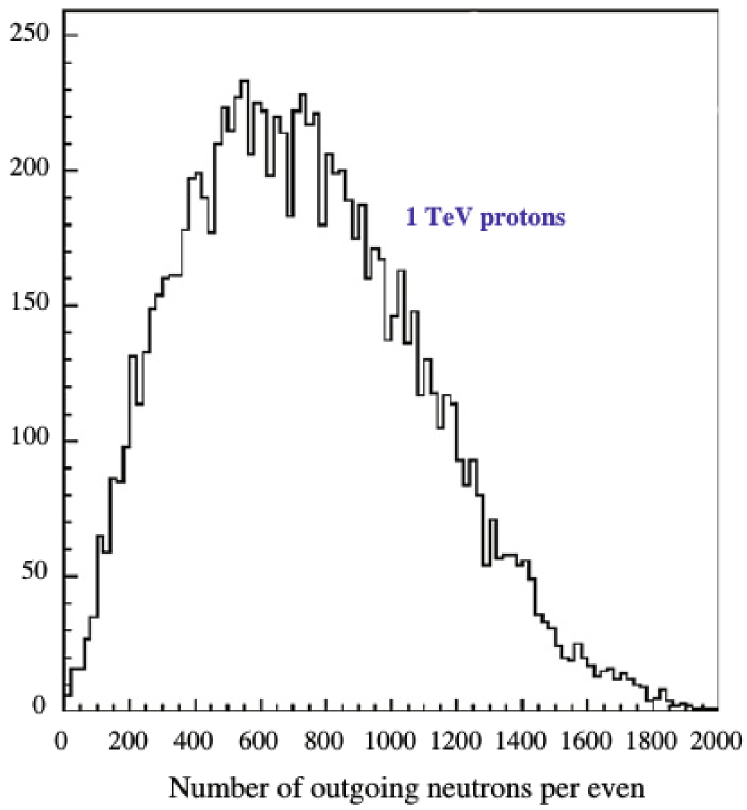
7th HERD WorkShop @ CERN 6th November 2018

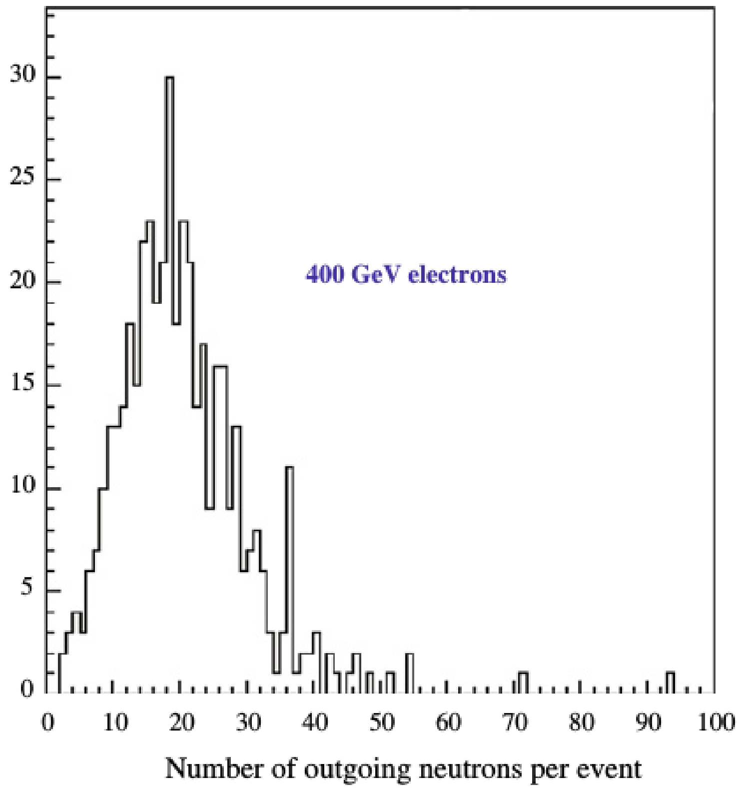
Outline

- **Simulation of neutron emission and moderation**
  - neutron component of electromagnetic and hadron showers
  - optimization of moderator thickness
  - count and time distribution of thermal neutron
- **Lab and beam test of neutron detector**
  - Energy calibration
  - Comparison of Beam test with lab test

Introduction

NEUCAL's study with BGO Calo of CALET





The neutron component of electromagnetic and hadron showers has a significant difference

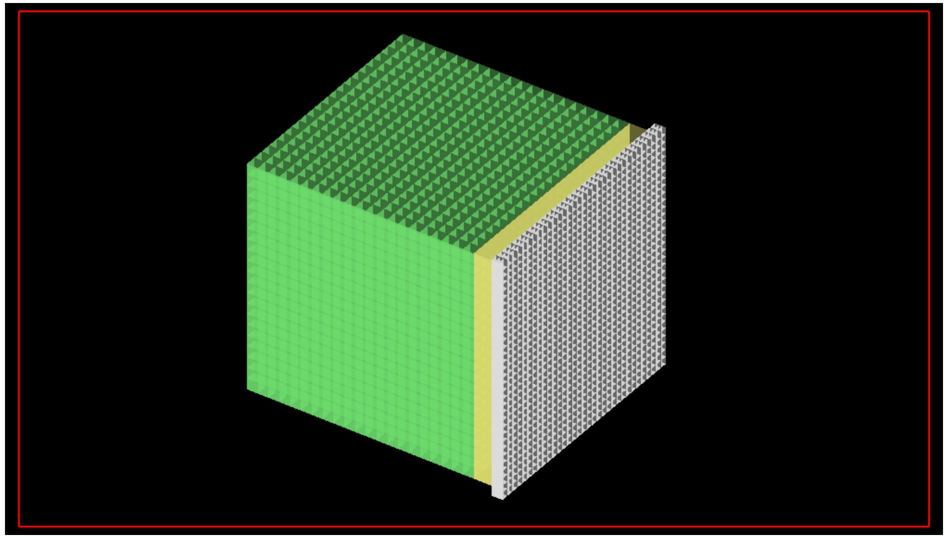
It's possible to enhance calorimeter discrimination by measuring the neutron component

Reference:S. Bottai et al.,Nucl. Instr. & Meth., A617, 464-466 (2010)

HERD Calo ?

Simulation Setup

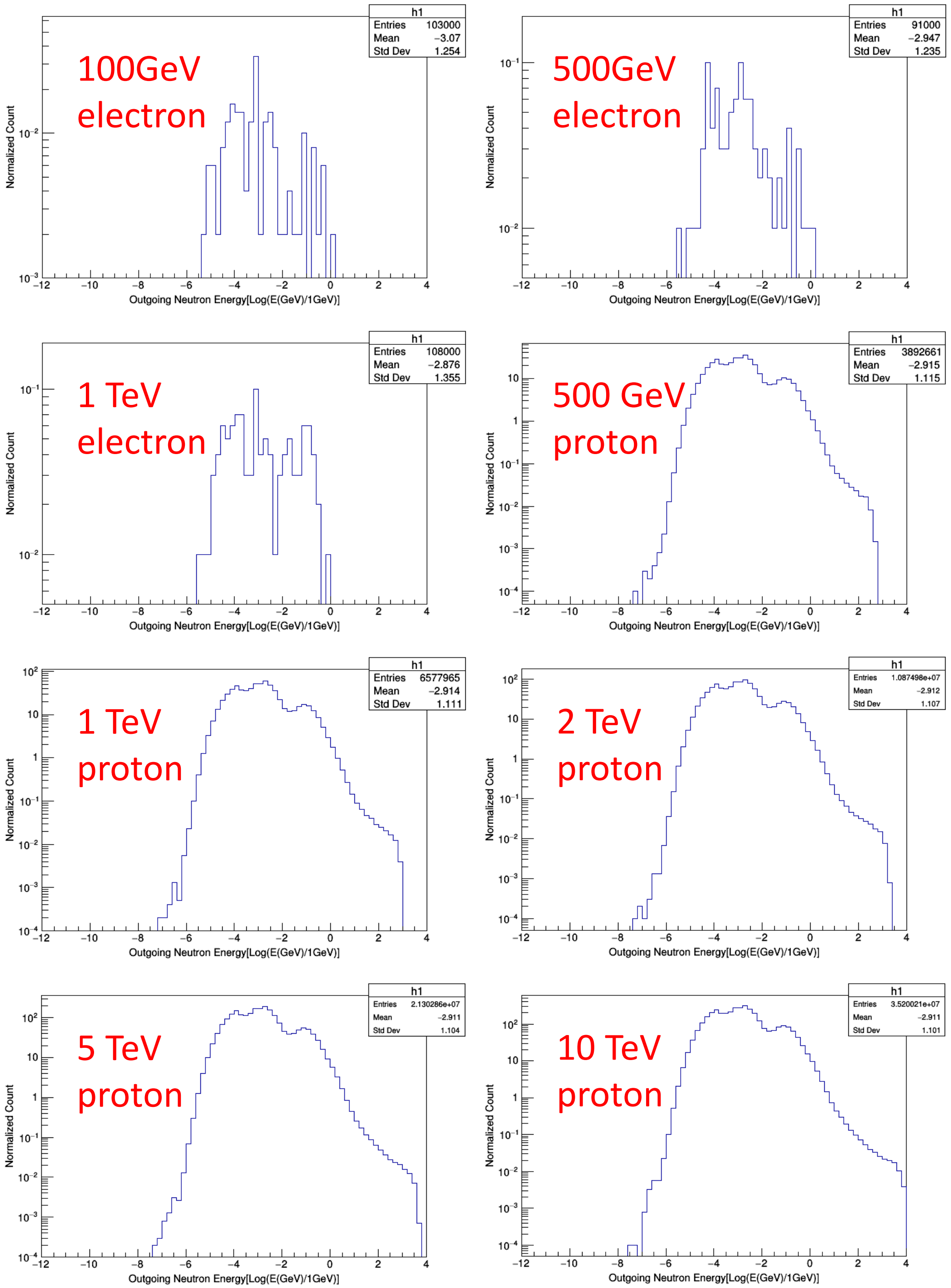
- Calo
  - 21 layers in z direction (63*63*3 cm3/ layer)
- Moderator
  - Paraffin Cube
  - Next to Calo with same cross section
  - Optimized thickness
- ND
  - 3 layers in z direction (66*66*1 cm3/ layer)
  - 2cm*2cm*1cm cell



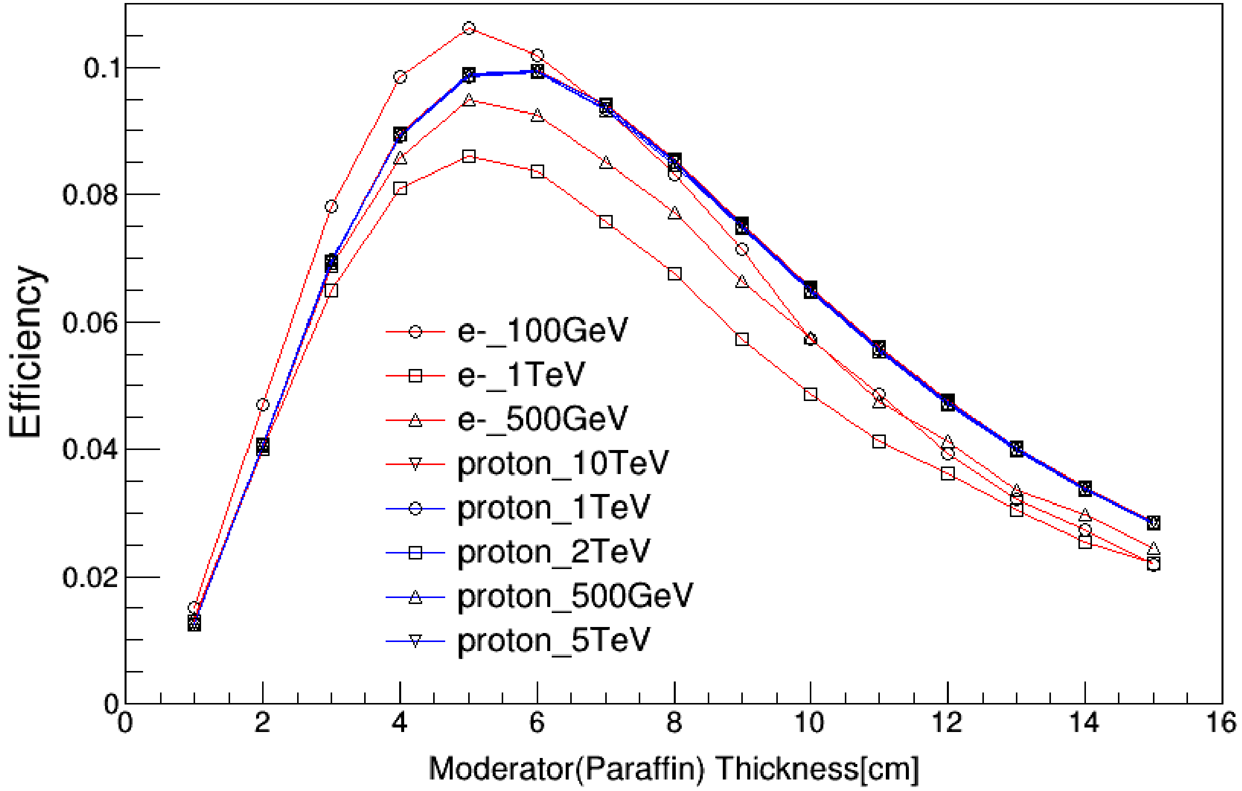
Physics List

FTFP_BERT_HP

Input Particle include
electron(100,500,1000Gev)
proton(powerlaw with index -1,From 500GeV to 10TeV
total 1 million events)

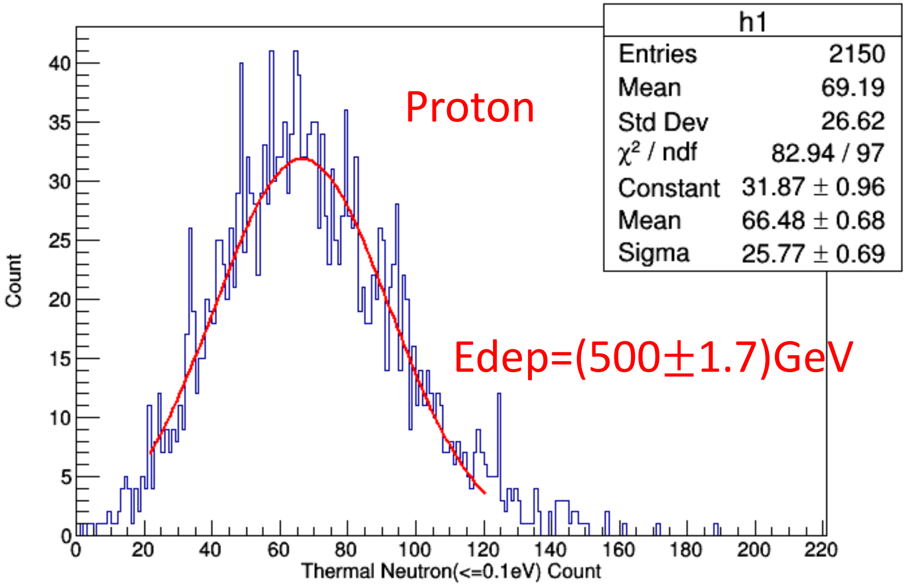


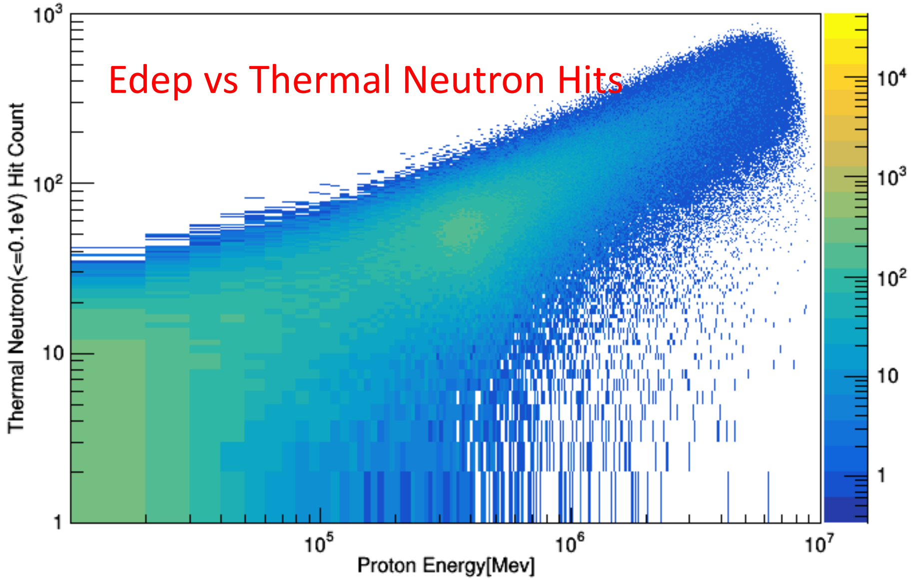
Moderation Efficiency vs Thickness

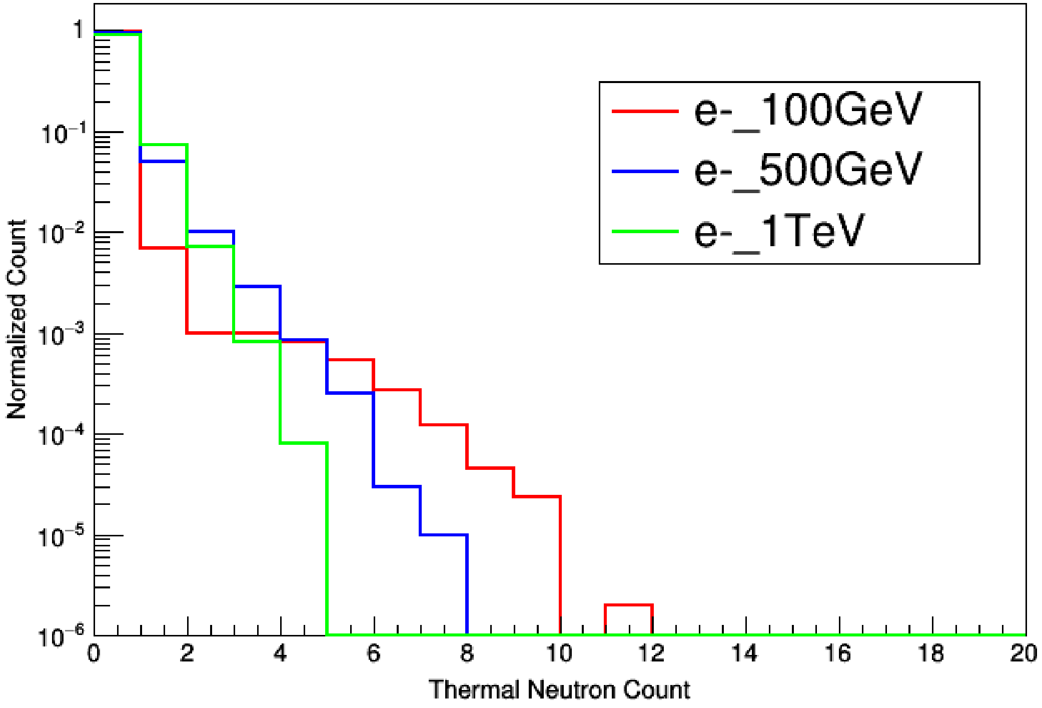


- Moderation efficiency： thermal neutron from bottom of Moderator(<=0.1eV)/all incidental neutron into moderator
- Optimized thickness @ 6cm， Efficiency ~10%

Hits Count(Proton & electron)

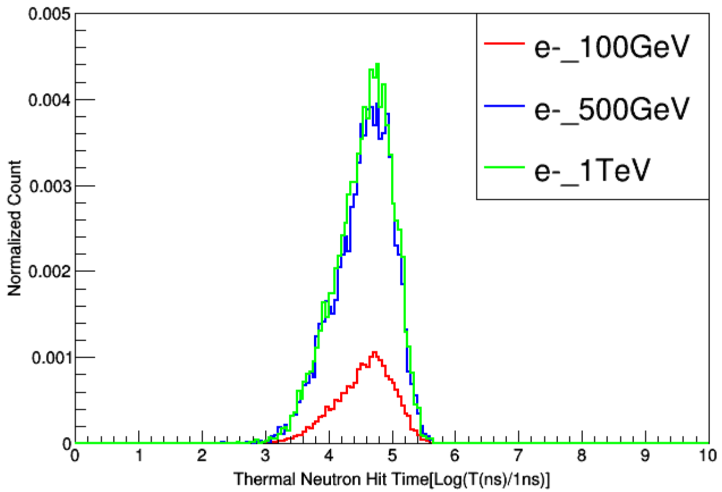


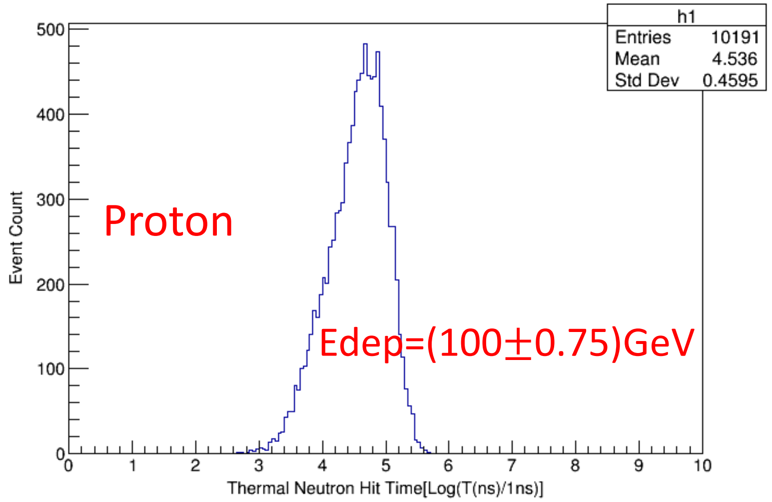


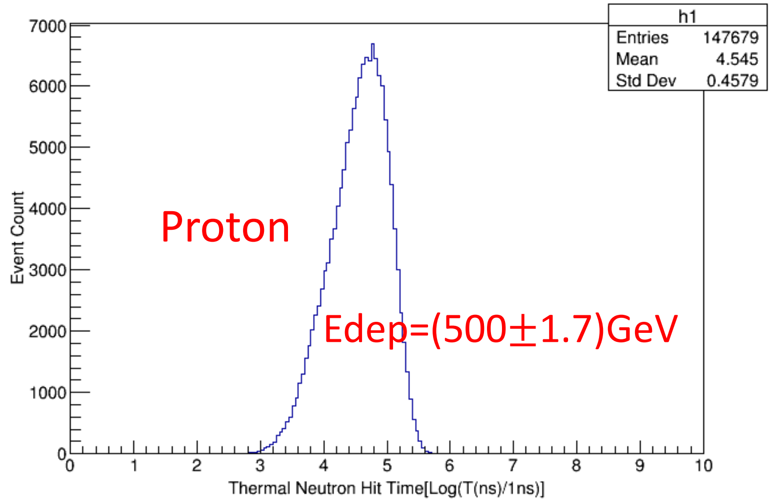


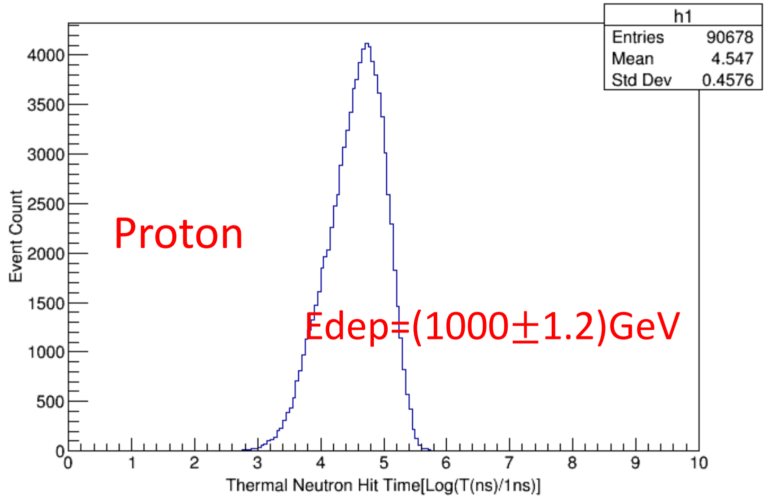
- The thermal neutron hits of hadron shower are approximately in proportion to proton energy deposition in Calo
- There is almost no thermal neutron in electromagnetic shower

Time Distribution



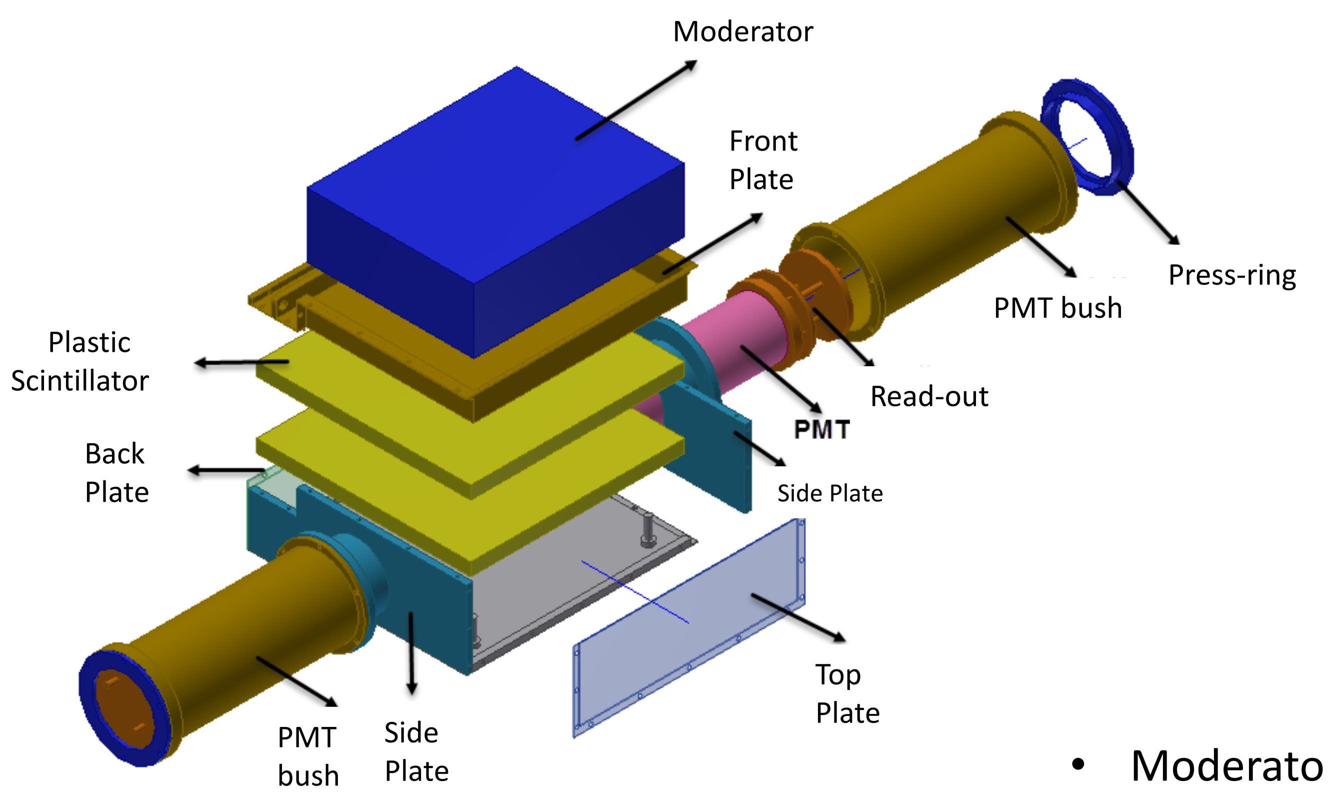


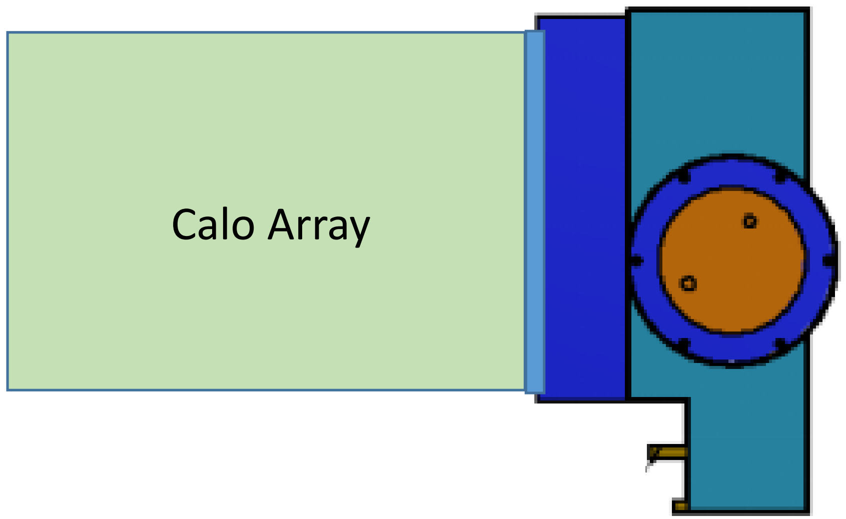




- Time distribution of thermal neutron hits on detector is almost same
- Time window is from 1 microsecond to about 400 microseconds

Preliminary Design of ND





- Plastic Scintillator: EJ254(5% natural B)
  20cm*20cm*1cm

- Moderator: HDPE,16cm*16cm*6cm
- PMT: XP2020
- Read-out: (Beam)HERD DAQ System, Waveform information ~100μs
  (Lab) DT5751, self trigger

Characteristic of EJ254

PROPERTIES	EJ-254-5%	EJ-254-2.5%	EJ-254-1%
Light Output (% Anthracene)	48	56	60
Scintillation Efficiency (photons/1 MeV e^-)	7,500	8,600	9,200
Wavelength of Maximum Emission (nm)	425	425	425
Rise Time (ns)	0.85	0.85	0.85
Decay Time (ns)	1.51	1.51	1.51
Pulse Width, FWHM (ns)	2.24	2.24	2.24
No. of H Atoms per cm^3 ($x10^{22}$)	5.18	5.17	5.16
No. of C Atoms per cm^3 ($x10^{22}$)	4.44	4.55	4.62
No. of ^{10}B Atoms per cm^3 ($x10^{20}$)	5.68	2.83	1.14
No. of Electrons per cm^3 ($x10^{23}$)	3.33	3.33	3.33
Density (g/cc)	1.026	1.023	1.021
Polymer Base	Polyvinyltoluene		
Refractive Index	1.58		
Softening Point	75°C		
Vapor Pressure	Vacuum-compatible		
Coefficient of Linear Expansion	7.8×10^{-5} below 67°C		
Light Output vs. Temperature	At 60°C, L.O. = 95% of that at 20°C No change from 20°C to -60°C		
Temperature Range	-20°C to 60°C		

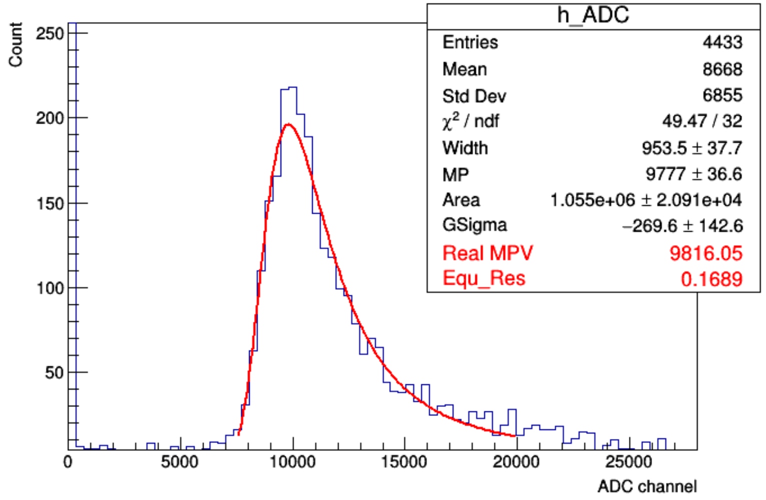
The neutron capture reaction on the boron 10B(n,αγ)7Li has a Q value of 2.78 MeV of which 2.34 MeV is shared by the alpha and lithium particles

Because of quenching effect,This energy is fully captured in the plastic to produce a scintillation signal approximately equivalent in amplitude to that of a 76 keV electron

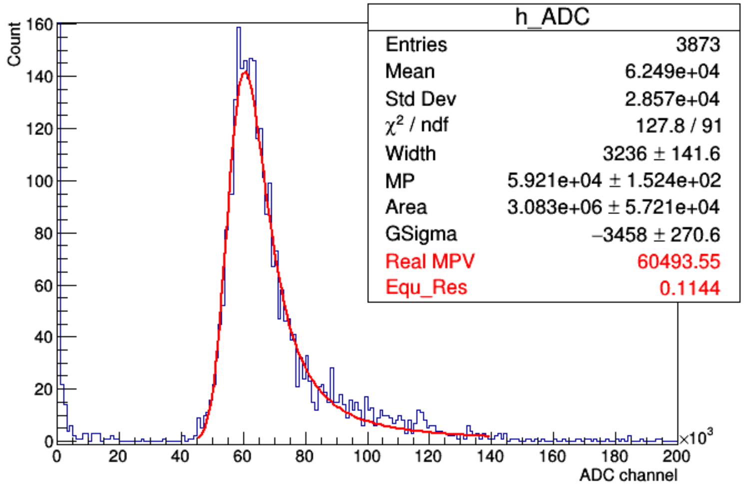
Reference:https://eljentechnology.com/products/plastic-scintillators/ej-254

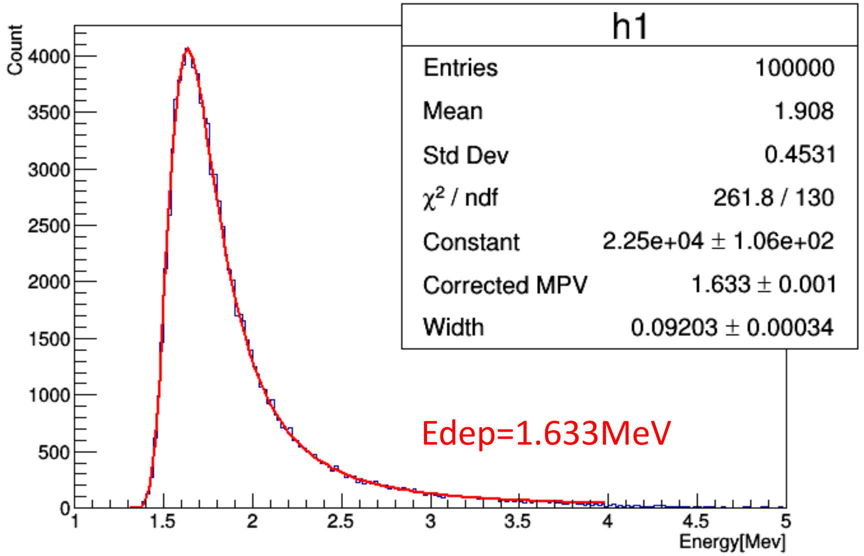
Energy calibration with CR

Lab Test



Beam Test





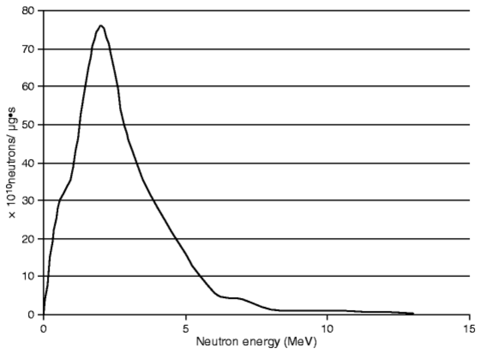
Edep Simulation of CR

- We can convert the ADC channel into corresponding energy

Thermal Neutron Lab Test

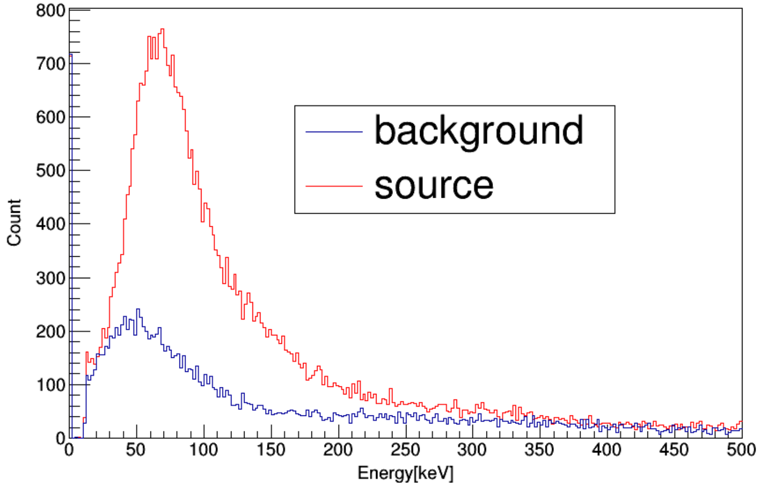
HDPE

Source： Cf252

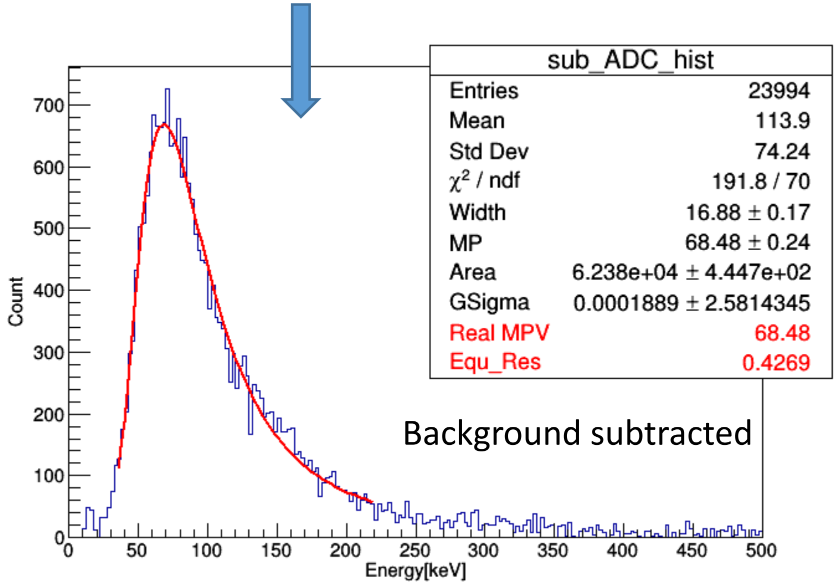


neutron energy spectrum

Lead shielding room(thickness ~10cm)

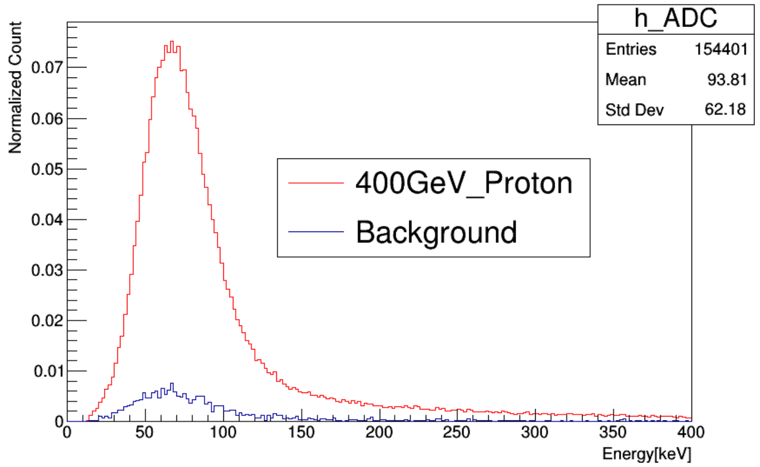


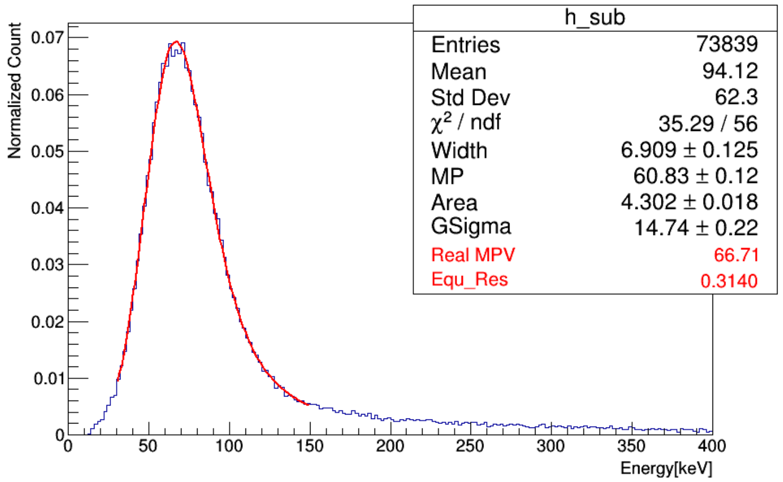
Event acquisition time is same for background and source

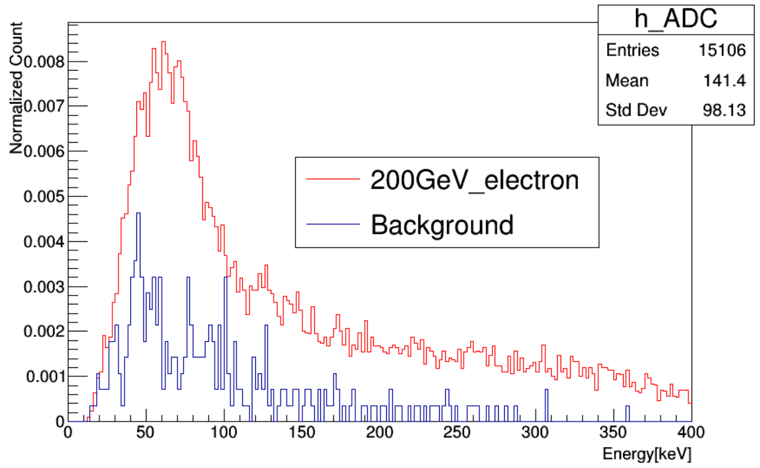


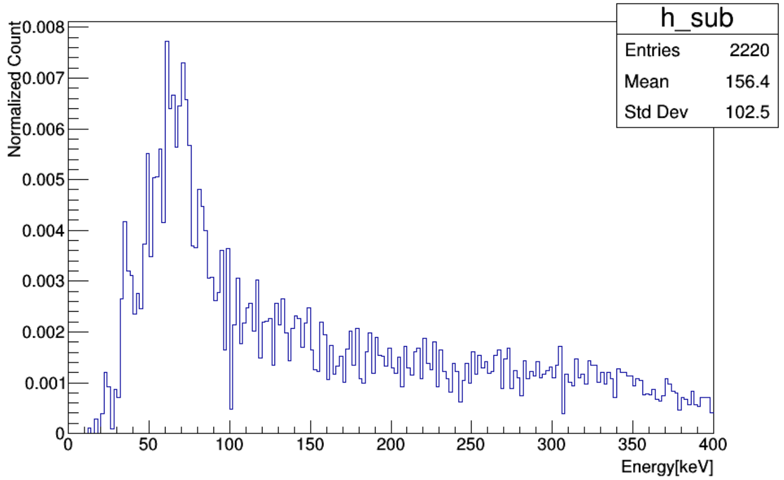
Background subtracted

Beam Test Result





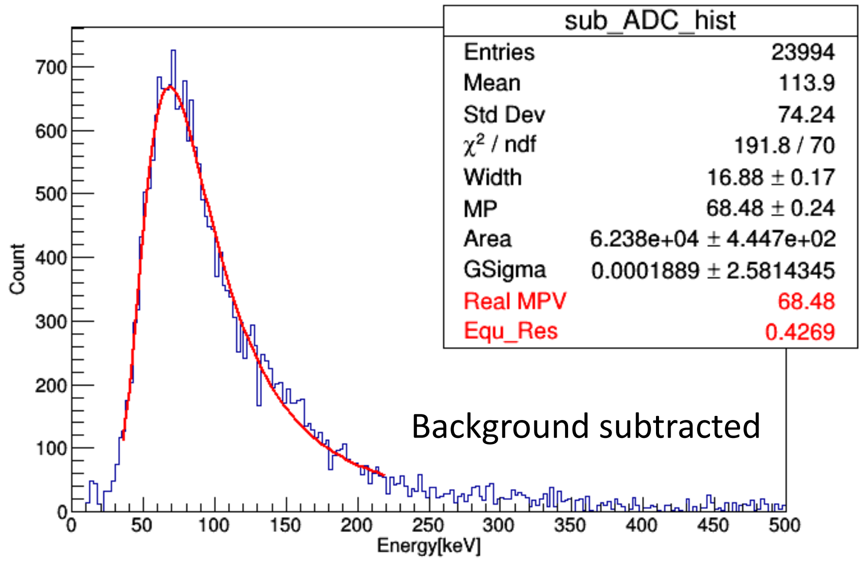




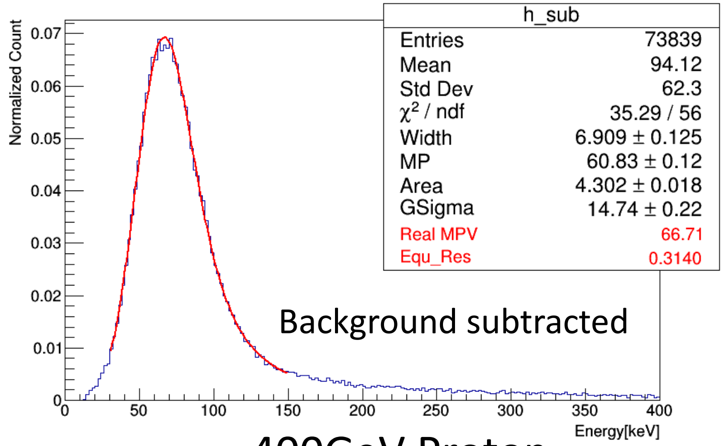
- The background spectrum and source spectrum of ND
- The source spectrum with background subtracted

Comparison

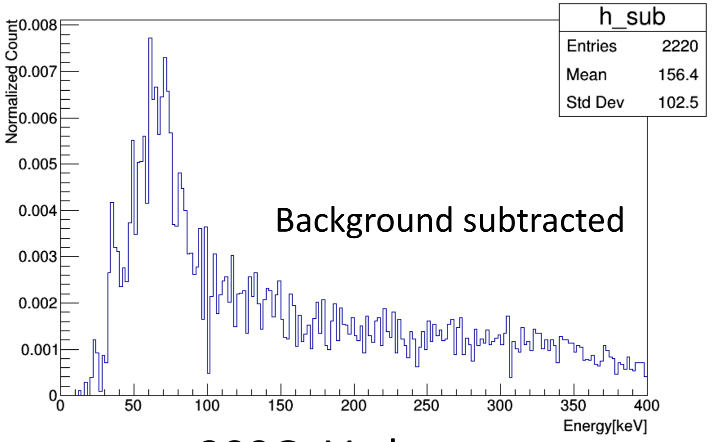
Lab Test



Beam Test



400GeV Proton



200GeV electron

- By comparison of lab test and beam test, we can confirm that we have detected the thermal neutron signal from electromagnetic and hadron shower.
- The thermal neutron producing probability of 200GeV electron shower is about an order of magnitude lower than that of 400GeV proton shower

Summary

1. A prelimary simulation of neutron emission from the bottom of HERD CALO has been made， it shows a significant difference in thermal neutron count between electromagnetic and hadron shower;

2. With the help of MC,the Optimized thickness of moderator should be 6 cm;

3.Preliminary result shows that we have detected the thermal neutron signal from shower of 400GeV proton and 200GeV electron, the thermal neutron producing probability of 200GeV electron shower is about an order of magnitude lower than that of 400GeV proton shower.

4.We need more test and more accurate simulation to confirm its contribution to particle discrimination, the design of detector structure need to be updated.