LHAASO-ENDA 研制进展

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主要内容

1、热中子探测器原理

2、单元探测器模拟程序建立

3、LHAASO-ENDA-HNU阵列运行情况

4、阵列标相对标定

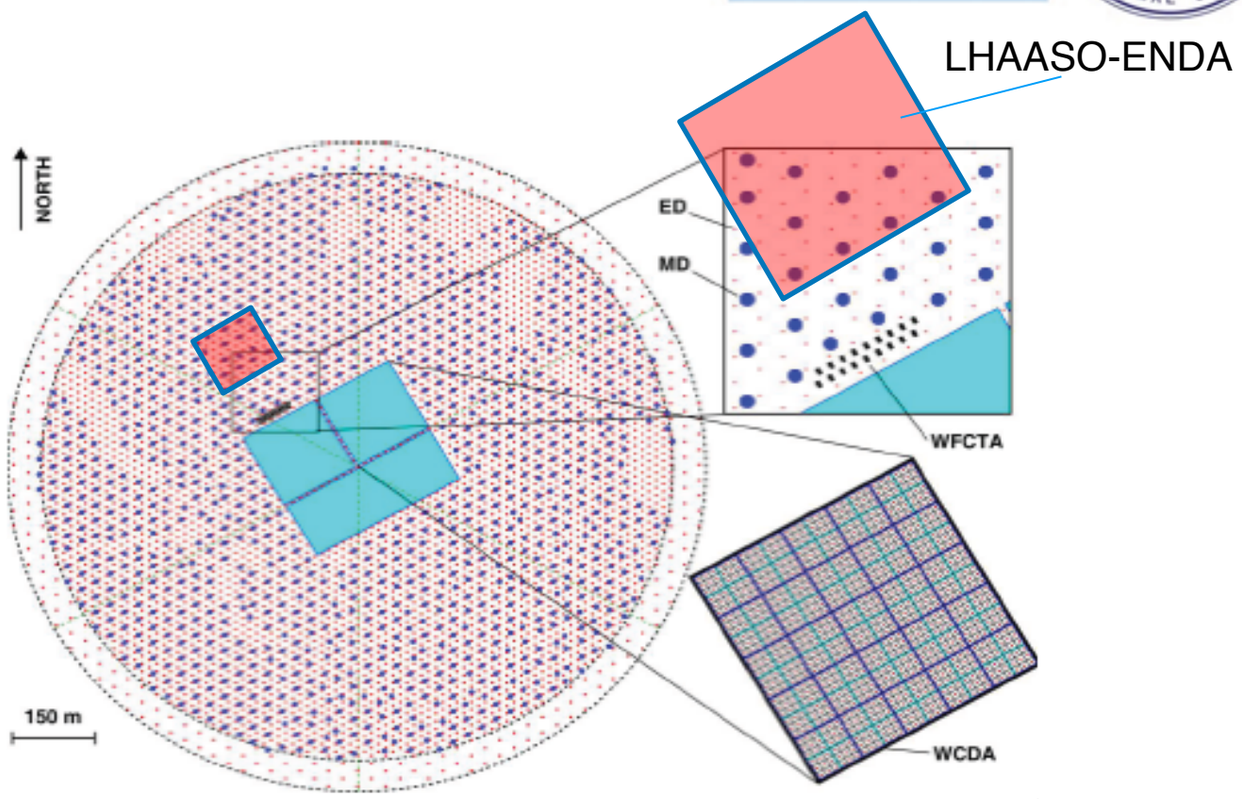
5、小结

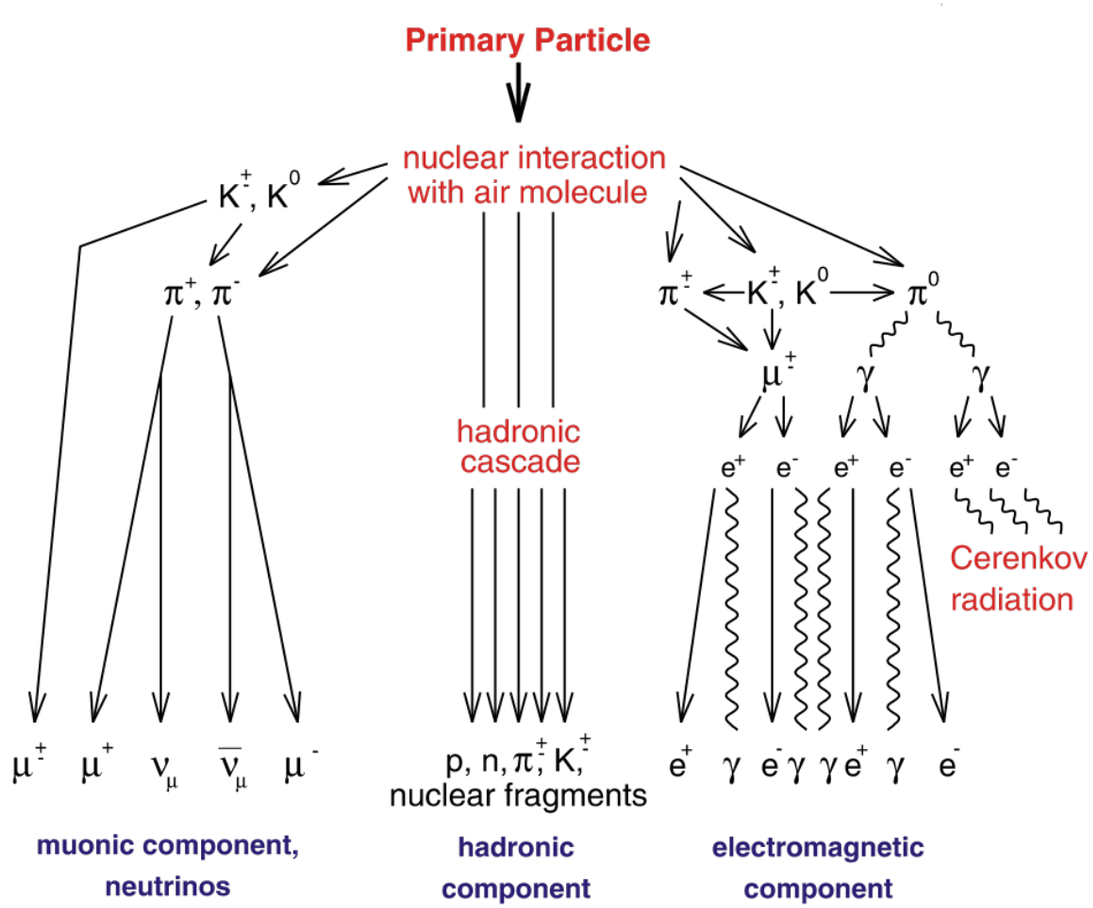
热中子探测器原理

强子是簇射的骨架对宇宙线成分很敏感，因此研究EAS中的强子信息是很有必要的。

热中子探测技术用于探测宇宙线簇射中强子产生的大量热中子，

热中子数量比强子高2-3数量级。热中子的放大效应有很强的成分区分能力，对膝区探测来说是一个新的独特的技术手段，将显著加强LHAASO在膝区物理方面的研究能力





LHAASO与俄罗斯科学院核研究所签署合作备忘录，建设400台EN探测器组成的阵列

LHAASO-ENDA-400，作为LHAASO的组成部分，用于测量膝区宇宙线分成份能谱

MEMORANDUM OF UNDERSTANDING

between

The LHAASO Collaboration

and

Institute for Nuclear Research of the Russian Academy of Sciences

Preamble

Within the LHAASO collaboration, the groups signing the present MoU designed and much progressed with the construction of the en-detector (electron-neutron detector) array (ENDA). The array will be composed of 400 en-detectors in the Large High-Altitude Air Shower Observatory (LHAASO) located at Mt. Haizi (4400 m a.s.l., 29° 21′ 31″N, 100° 8′ 15″E) in the Sichuan Province, China. The ENDA will be devoted to the hybrid detection of ultra-high energy cosmic rays above 100 TeV energies.

The en-detector, based on alloy of inorganic scintillator ZnS(Ag) with B_2O_3, capable of recording both thermal neutrons and charged particles, was developed in the frames of PRISMA project by the Scientific Group lead by Prof. Yuri Stenkin at the Institute for Nuclear Research of the Russian Academy of Sciences (INR RAS).

The present MoU formalizes the collaboration between the INR RAS and the LHAASO Collaboration.

Article 1

The Memorandum of Understanding is signed between:

Institute for Nuclear Research of the Russian Academy of Sciences (the Russian Partner)
represented by Director,
Prof. L.V. Kravchuk
and
the LHAASO Collaboration

represented by *IHEP of Chinese Academy of Science,*
LHAASO Spokesperson
Prof. Zhen Cao

Article 2

Representative

Institute of High Energy Physics (IHEP) – Chinese Academy of Science (indicated as the Chinese Partner) as the institution representing the LHAASO Collaboration in the further proceedings of the present project.

Article 3

Purpose

Any amendments of this MoU must be done in a written form signed by all Parties. A change of the appendixes to this agreement is not considered as the change of the MoU.

Article 9

Signatories and Language

This Memorandum of Understanding is prepared in English only. It has been prepared and signed in two copies, one for each Party.

For the Russian Partner	*For the Chinese Partner*
Prof. L.V. Kravchuk	*Prof. Zhen Cao*
Institute for Nuclear Research of Russian Academy of Sciences	*IHEP Chinese Academy of Science*
Director	*LHAASO Spokesperson*
Jan. 17 2019	*May 25 2019*

探测器结构

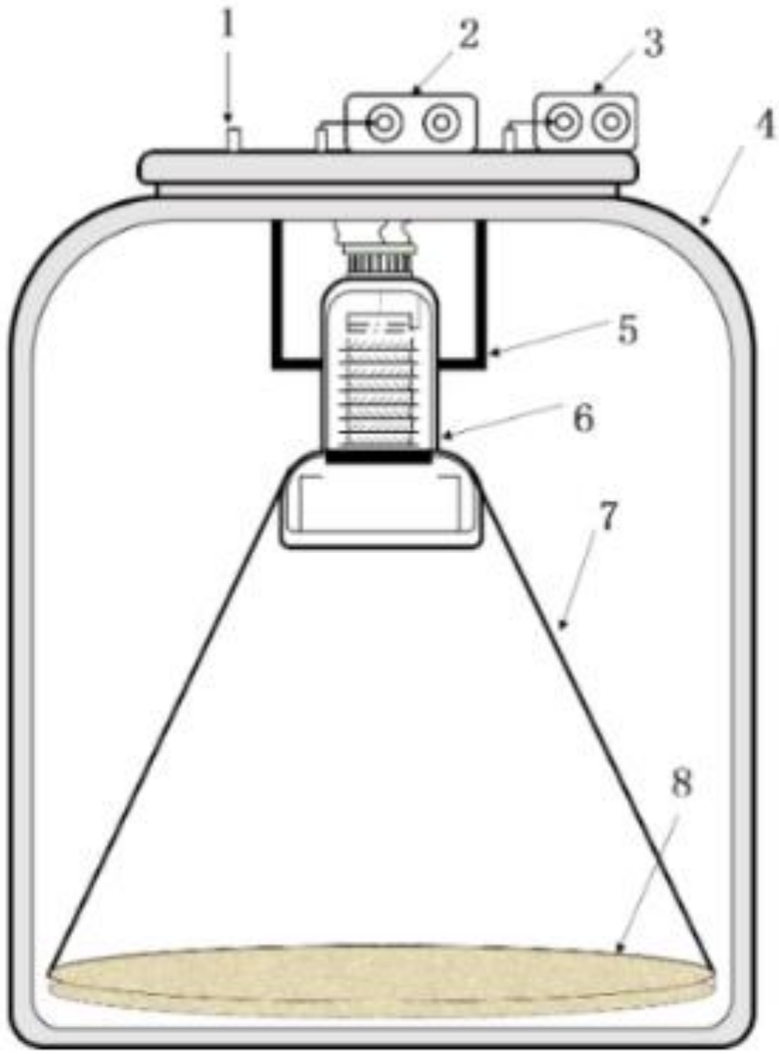
新型EAS热中子探测器（EN-detector）是一种无机闪烁体探测器。闪烁体主要成分是掺B的ZnS(Ag)。

$^{10}B+n \rightarrow {}^{7}Li^{*}+\alpha \rightarrow {}^{7}Li+\alpha+0.48MeV\gamma+2.3MeV(93\%)$

$\rightarrow {}^{7}Li+\alpha+2.8MeV(7\%)$

探测器主体结构由闪烁体、PMT、光反射层、遮光桶组成。

由于 ZnS(Ag)闪烁体本身对原子核敏感而对μ子、γ射线和电子不敏感，所以探测器对热中子有较好的探测效率，可以把热中子从较强的背景辐射中识别出来。



1—高压输入端；2—d8前放；3—d5前放；4—遮光桶；5—PMT固定架；6—PMT；7—光反射层；8—闪烁体屏ZnS(Ag)+B_2O_3

单元探测器模拟程序建立

使用**Geant4**对探测器进行模拟

初步进展，主要是对闪烁体、**PMT**、光反射层和遮光桶进行建模

结构	形状	内外径	高 (mm)
PMT	**Tubs**	**0~50**	**20**
Scintillator	**Tubs**	**0~380**	**6**
Reflection	**Cons**	**0~380**	
		0~54	**296**
Tank	**Tubs**	**0~400**	**580**

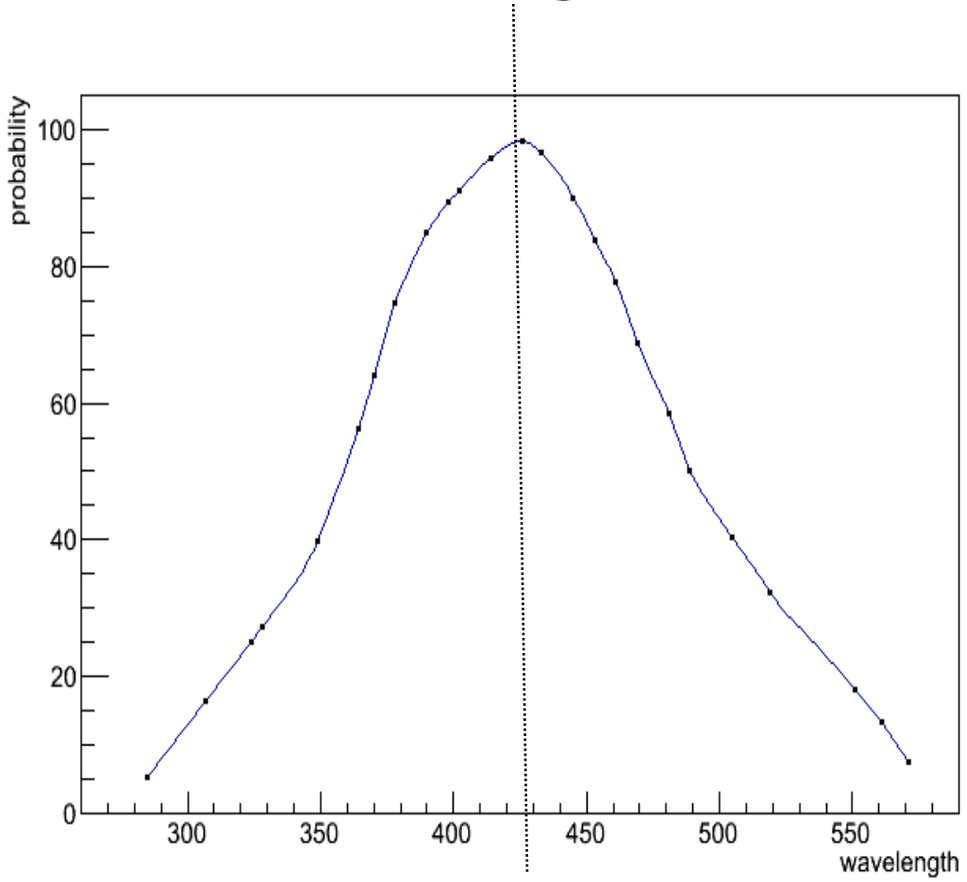
材料性质的初始设置

1. 闪烁体（**ZnS(Ag)+B_2O_3**）的密度**3.747g/cm³**，折射率**1.78**，光衰减长度**1m**，光产额为**80000/MeV**；

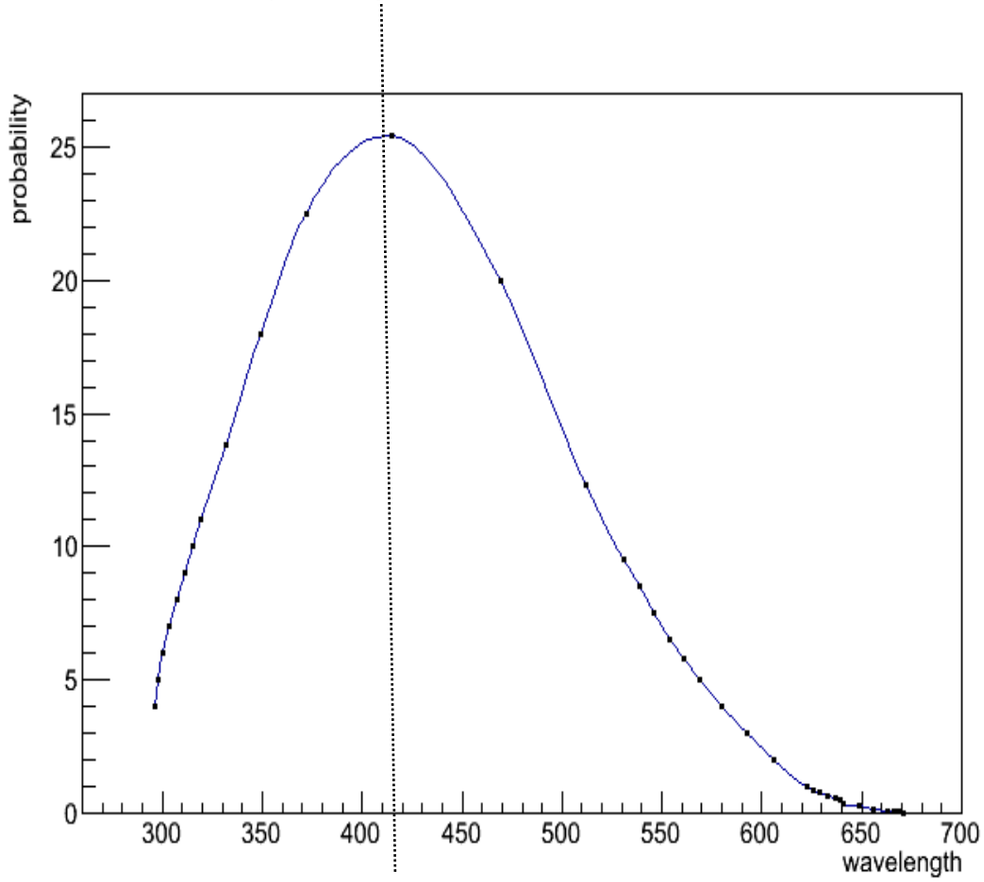
2. PMT玻璃的密度**1.032g/cm³**，折射率**1.54**，光衰减长度**4.2m**；

3. Tank密度**1.03g/cm³**，折射率**1.54**，光衰减长度**0.0m**；

4. Air的密度**0.001205g/cm³**，折射率**1.000277**，光衰减长度**50.0m**；

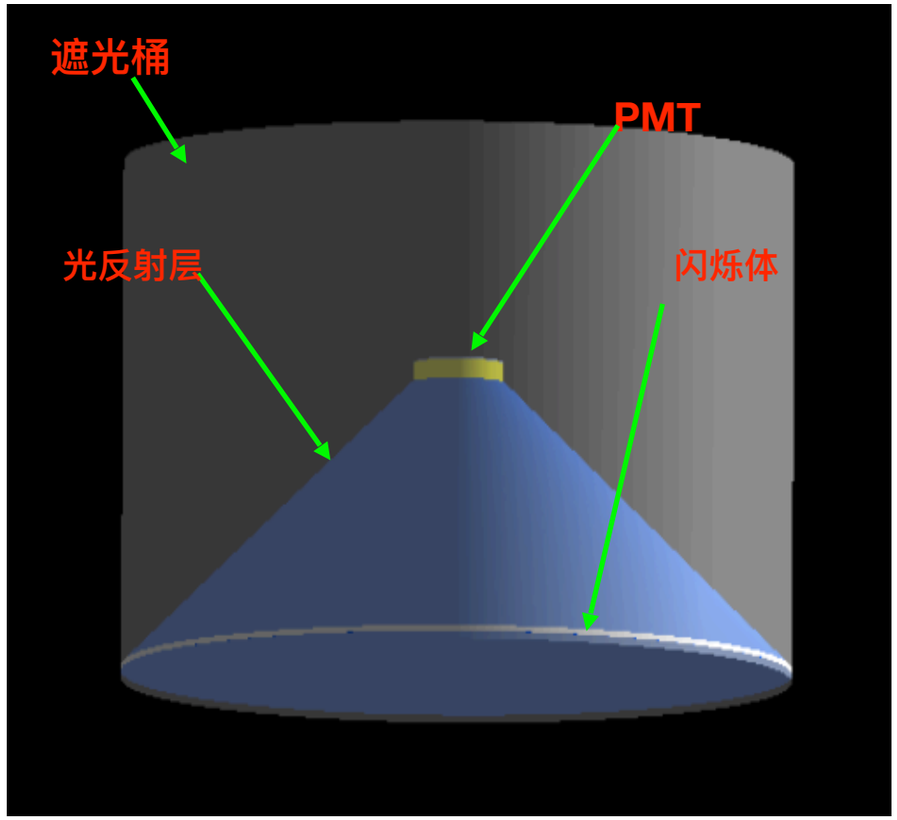


闪烁体发光概率

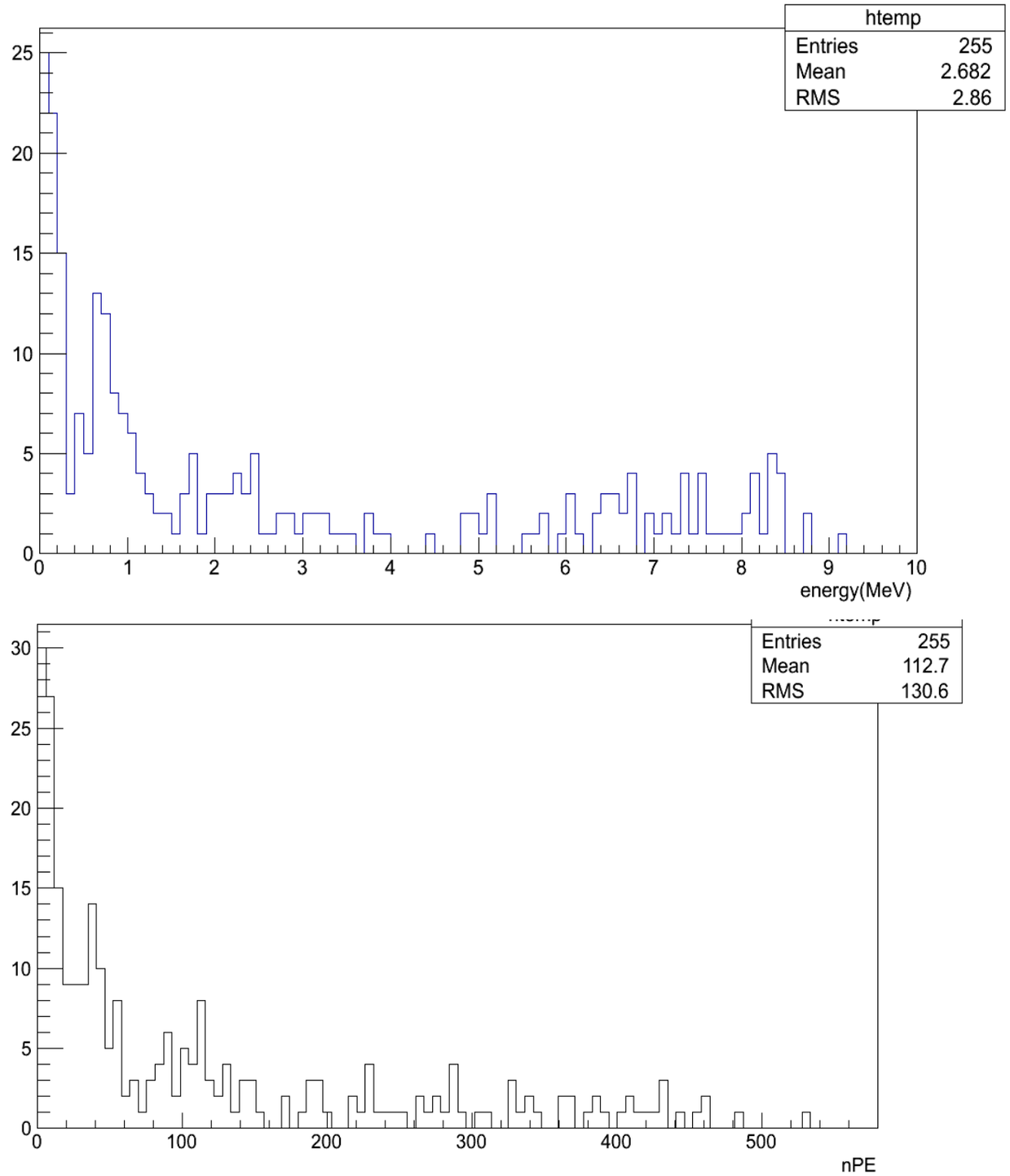


PMT量子效率

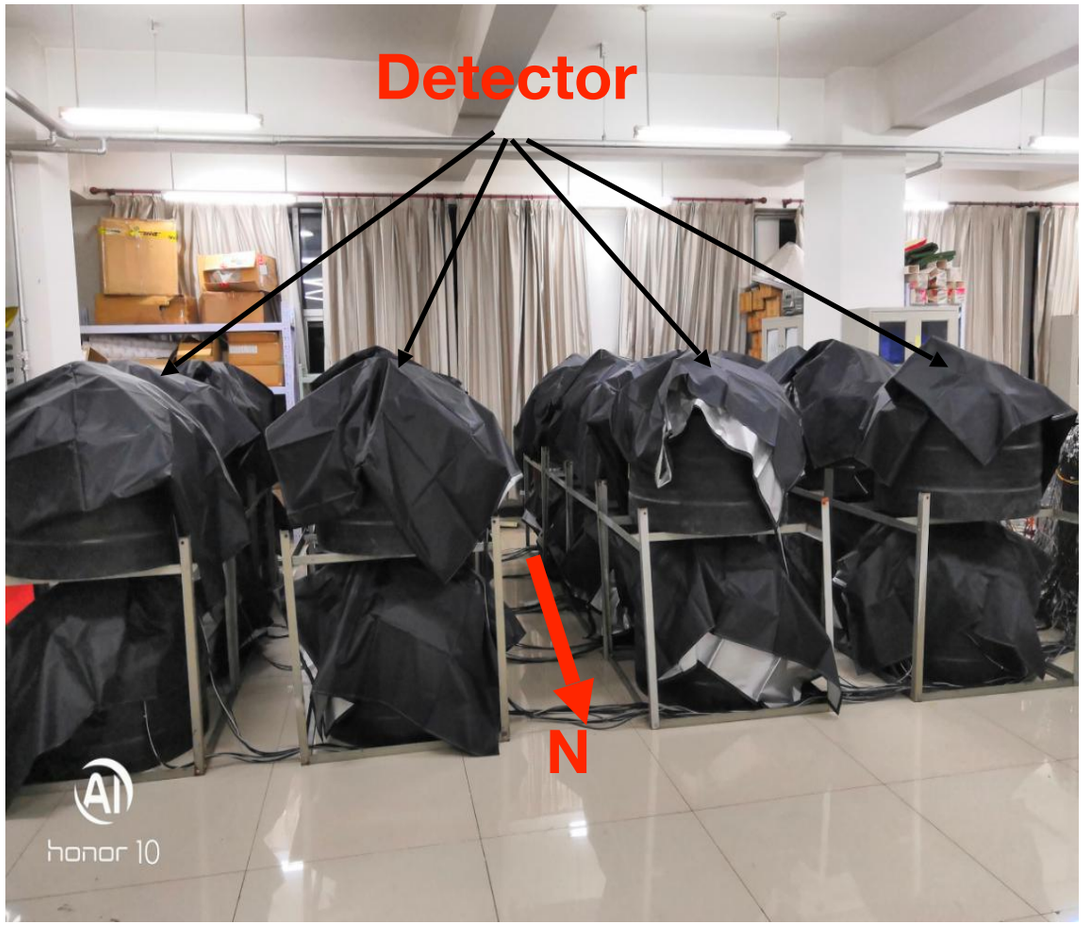
初步结果，对闪烁体、PMT、光反射层和遮光桶的模型建立

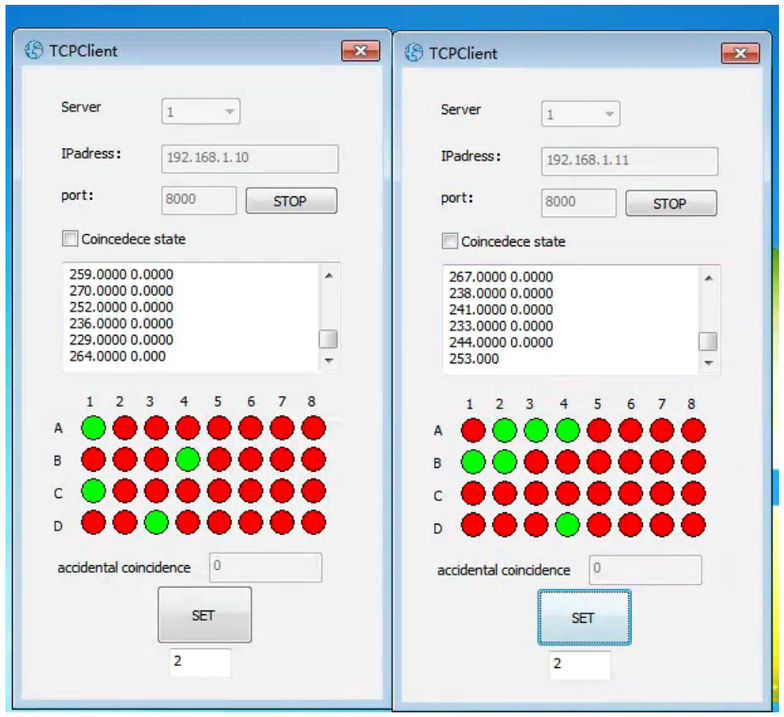


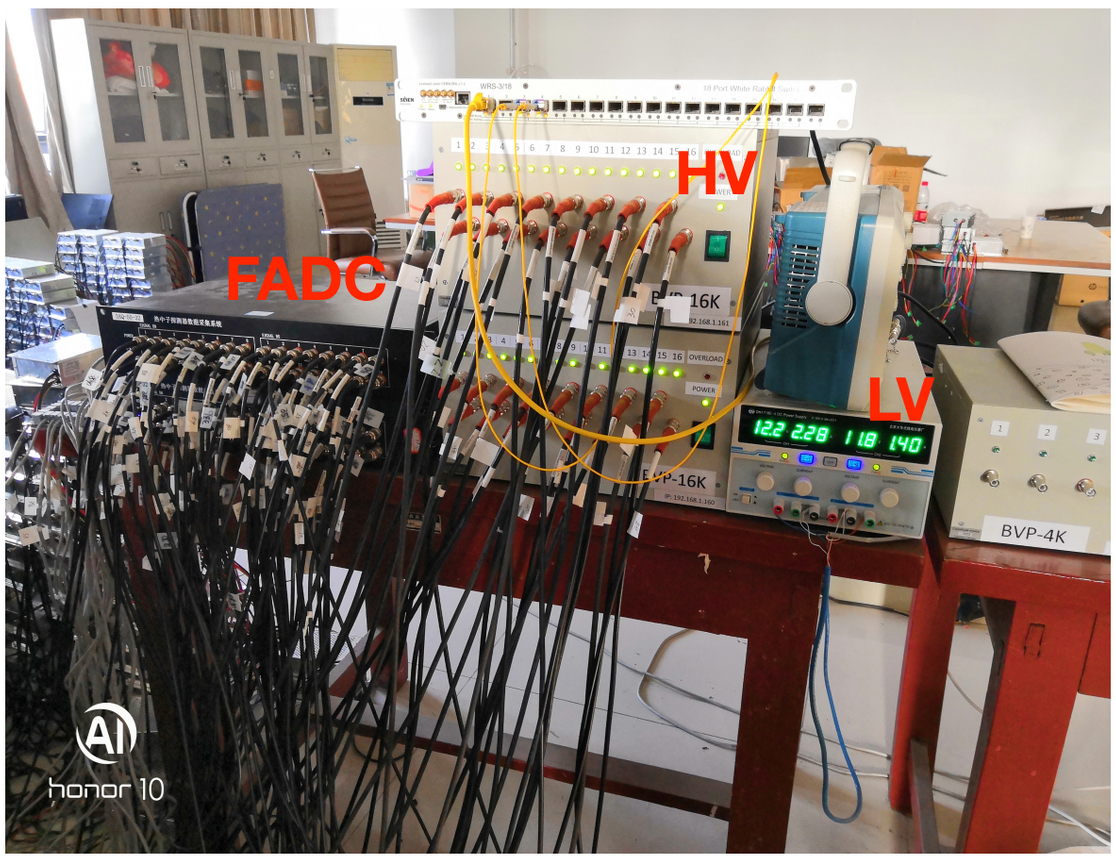
模拟探测器对中子的俘获，上图为中子在闪烁体中能量沉积，下图为PMT的光电子分布，初步计算探测器的中子俘获效率约为25%



LHAASO-ENDA-HNU阵列



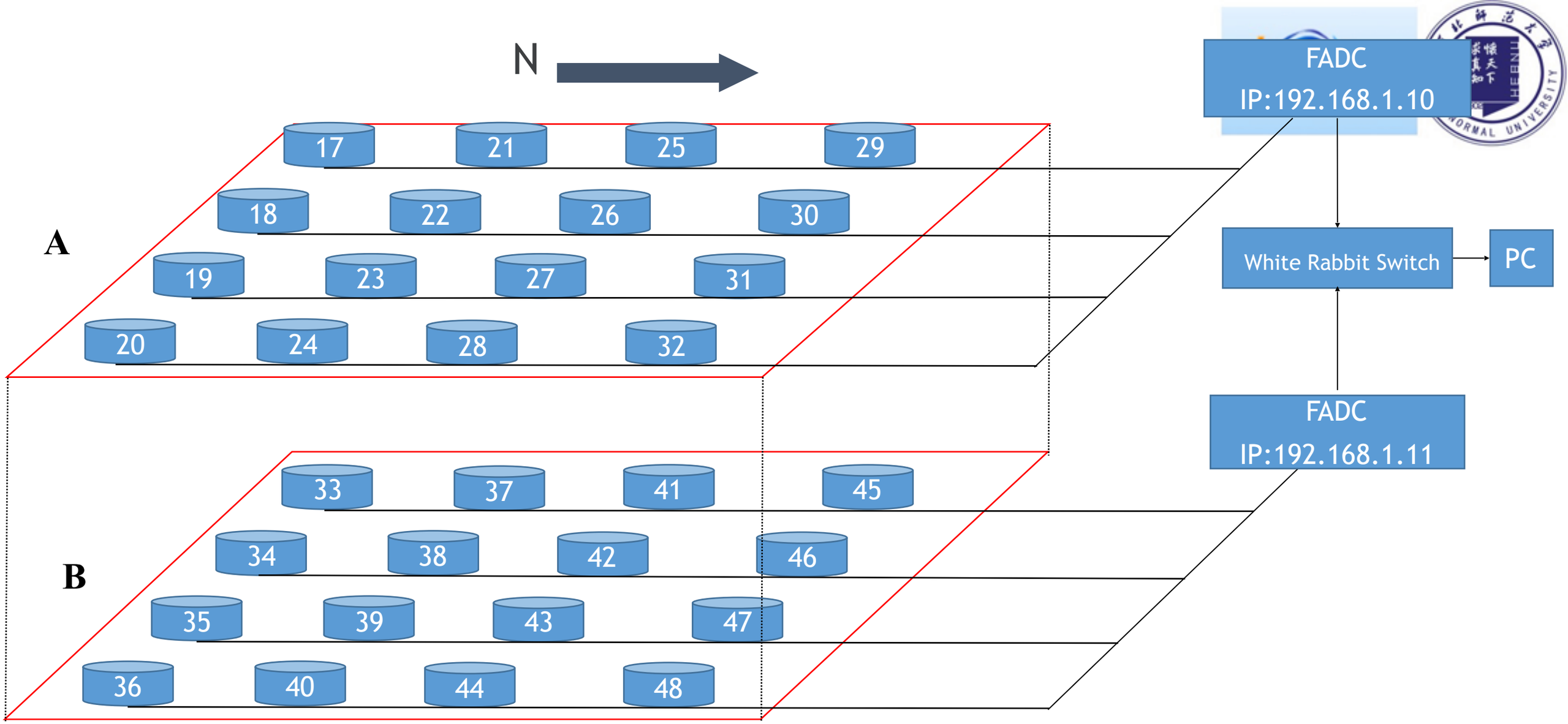




2019年1月-2月，由河北师大、高能所、西藏大学、四川大学、俄罗斯科学院核研究所合作，在河北师范大学实验室扩建了3个cluster（50台探测器，其中2台探测器做备份）其中2个cluster已经开始调试运行；

探测器采用低增益和高增益双打拿级（d5和d8）结构输出信号；

阵列运行模式为符合探测模式，设定为至少2台探测器的符合。



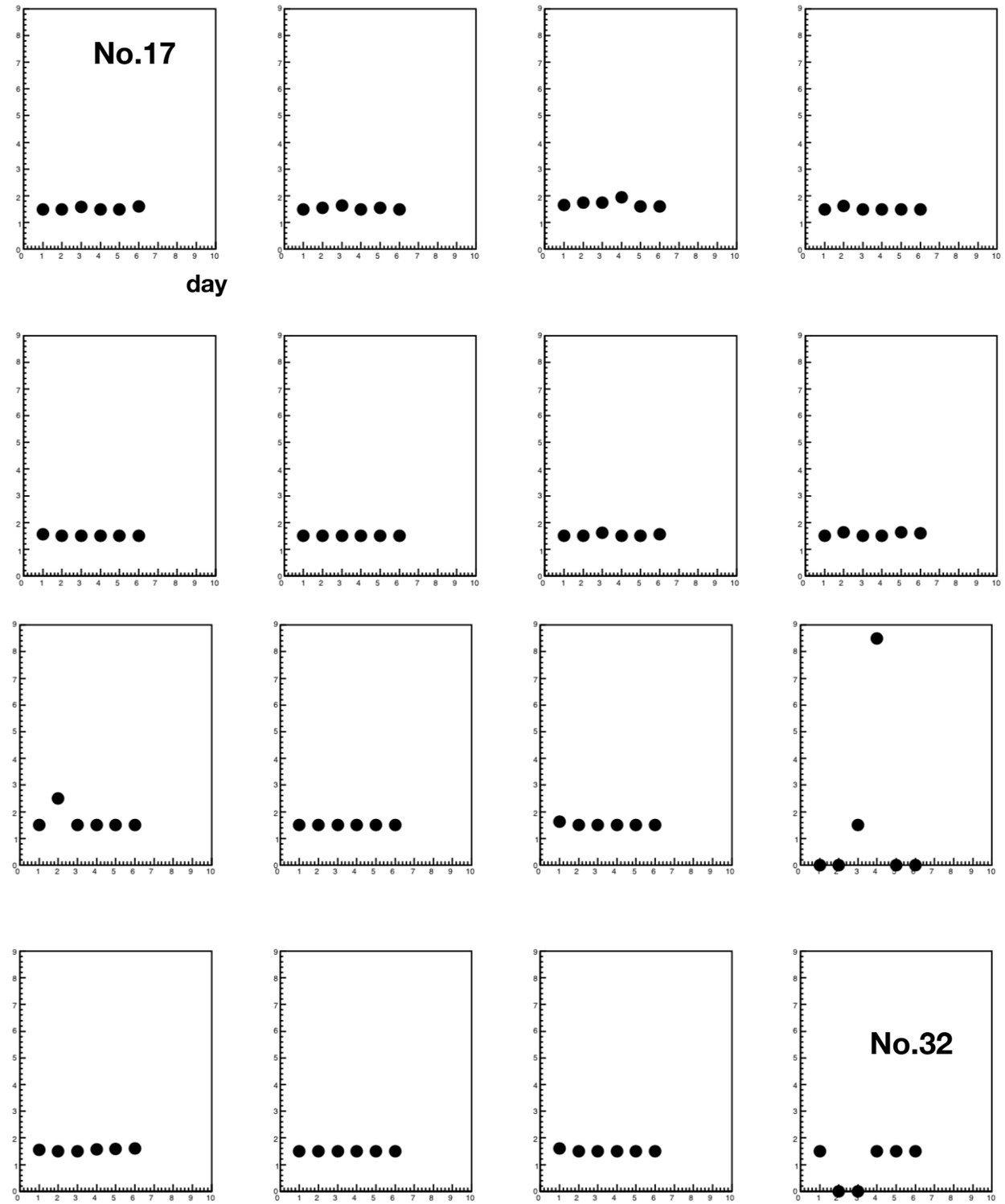
由于实验室面积有限，探测器间距大约0.5m，上（A）下（B）两层排列；继羊八井16台探测器之后编号为，A：No.17—No.32 B：No.33—No.48，

No.49和Mo.50作为备用探测器，每个cluster使用一个FADC进行数据采集；

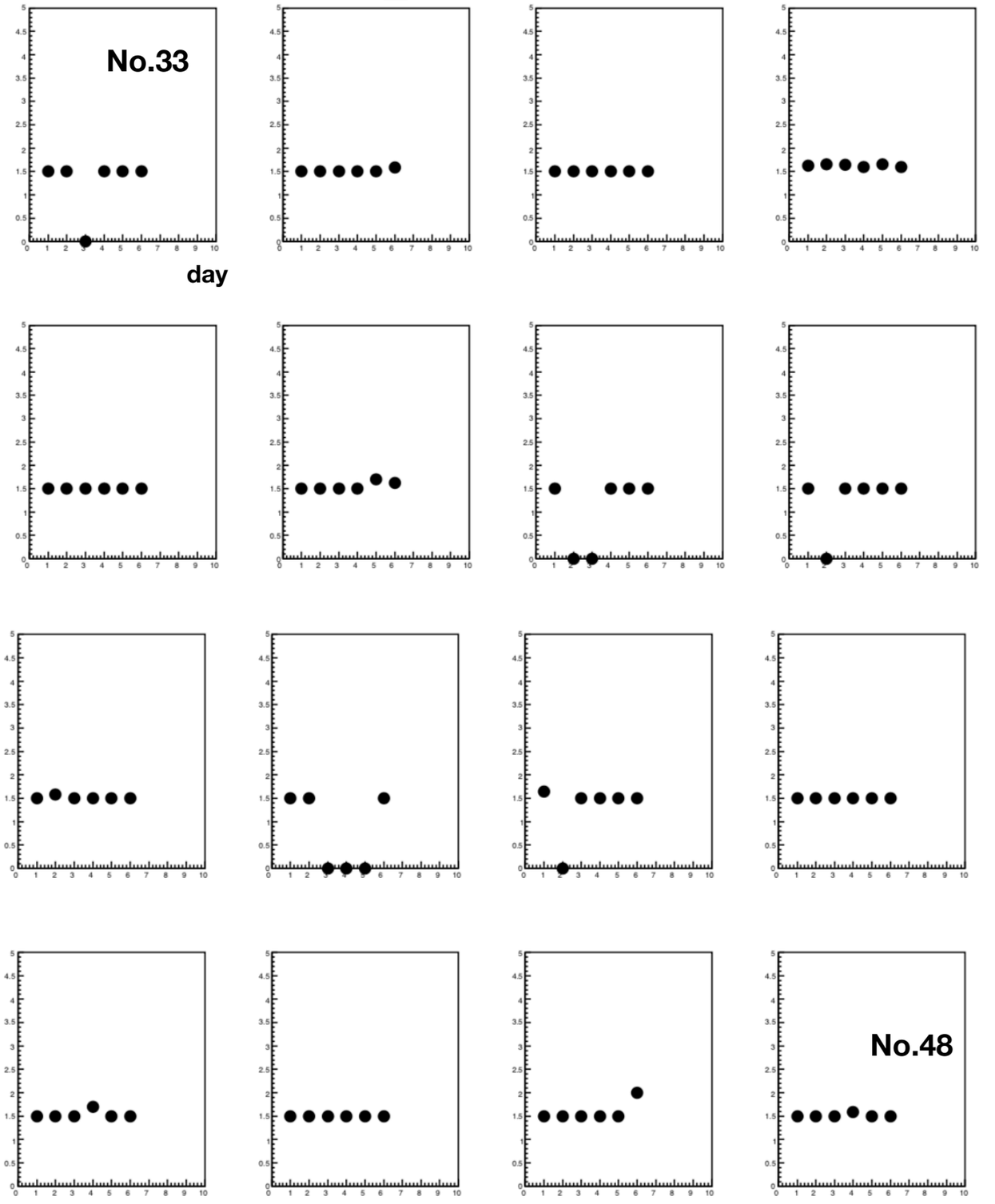
主要作用检验FADC和各个部分运行情况，上下符合检验电磁成分和中子数的测量。

中子数统计（mean value）
2019/04/1-2019/04/06

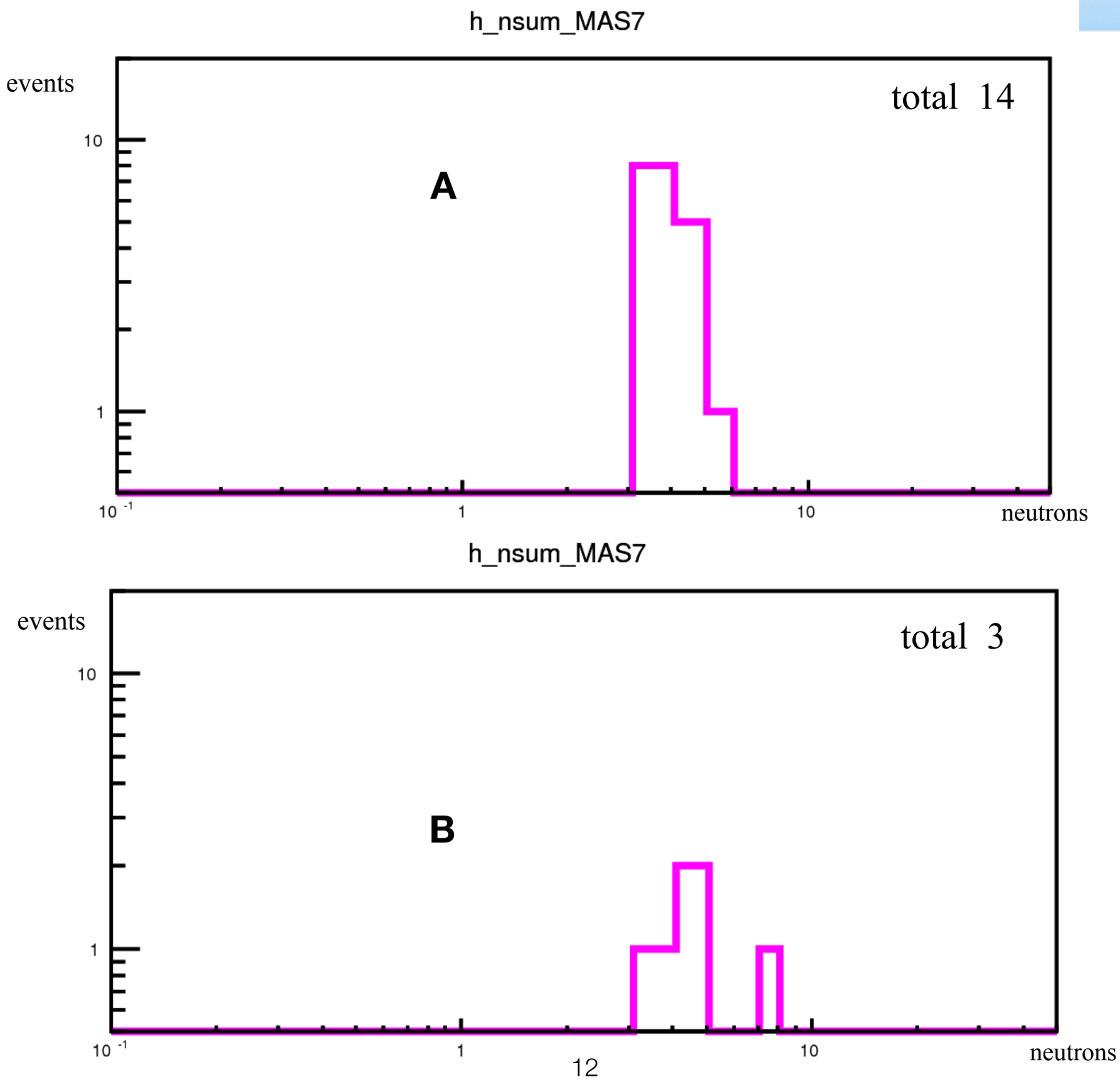
A



B



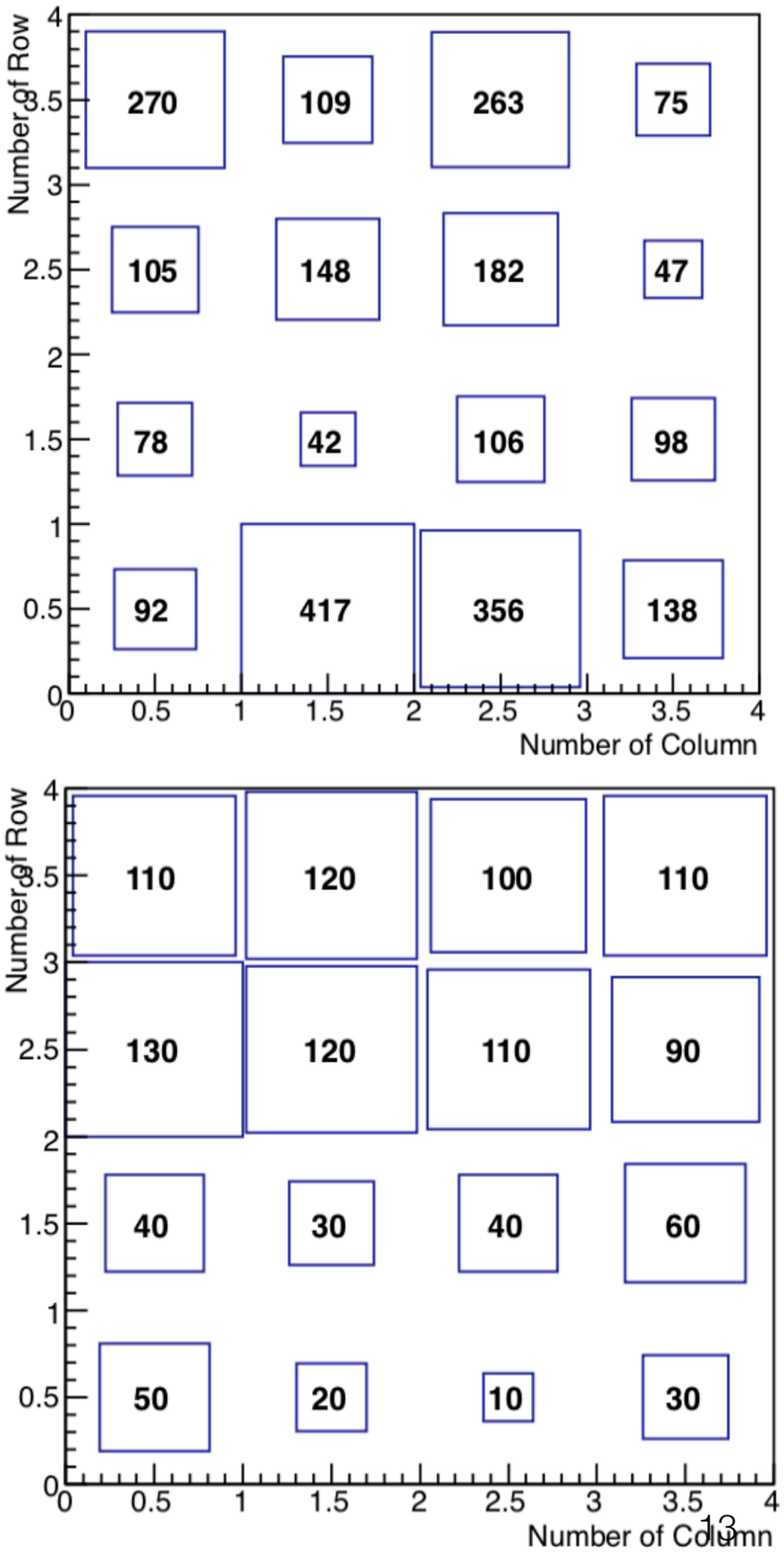
EAS事例中子数分布


h_nsum_MAS7
events
total 14
10
A
1
10 -1
1
10
neutrons
h_nsum_MAS7
events
total 3
10
B
1
10 -1
1
10
neutrons

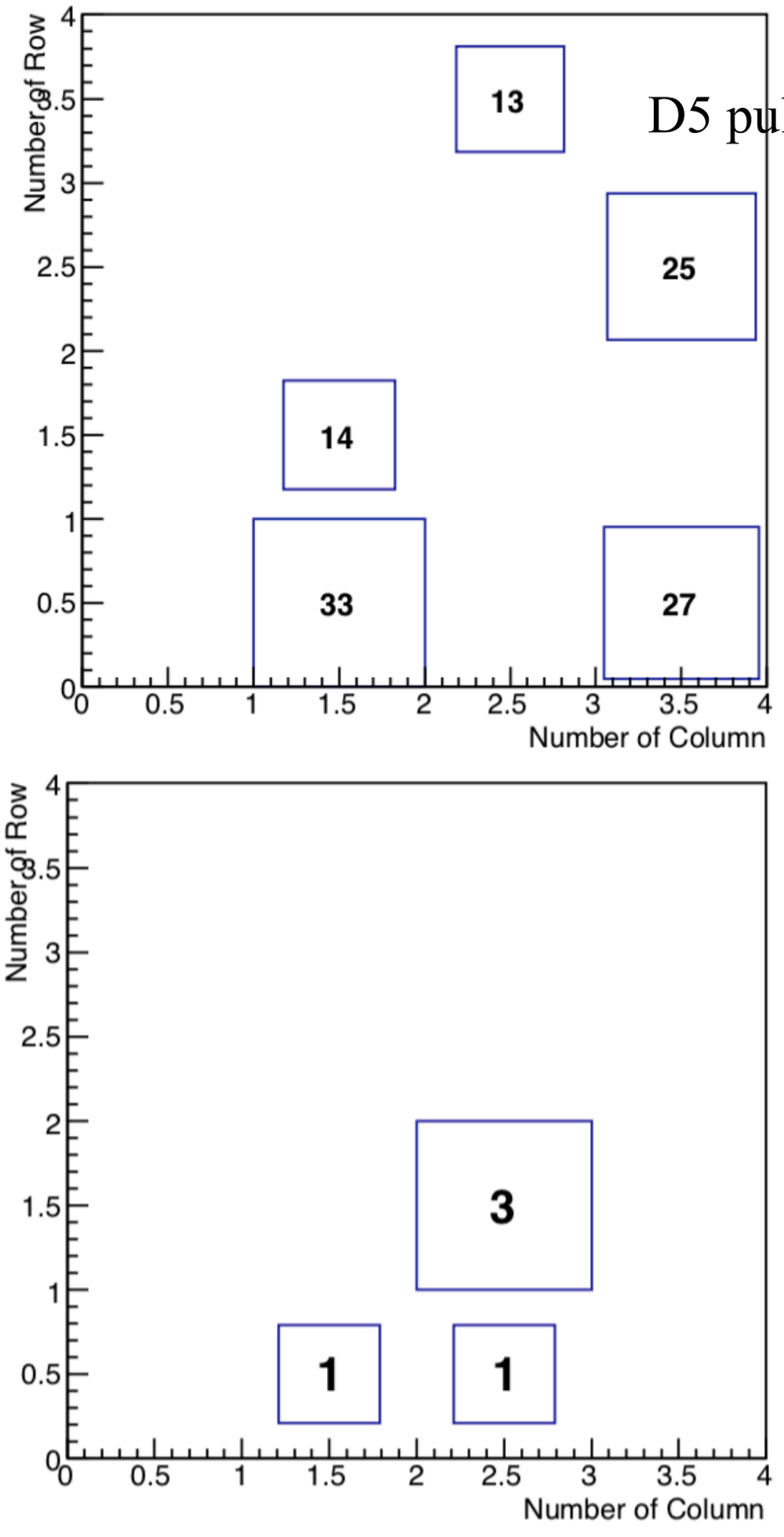
阵列探测到一个EAS事例

20190401
Event890

D8 pulse(mV)



D5 pulse(mV)



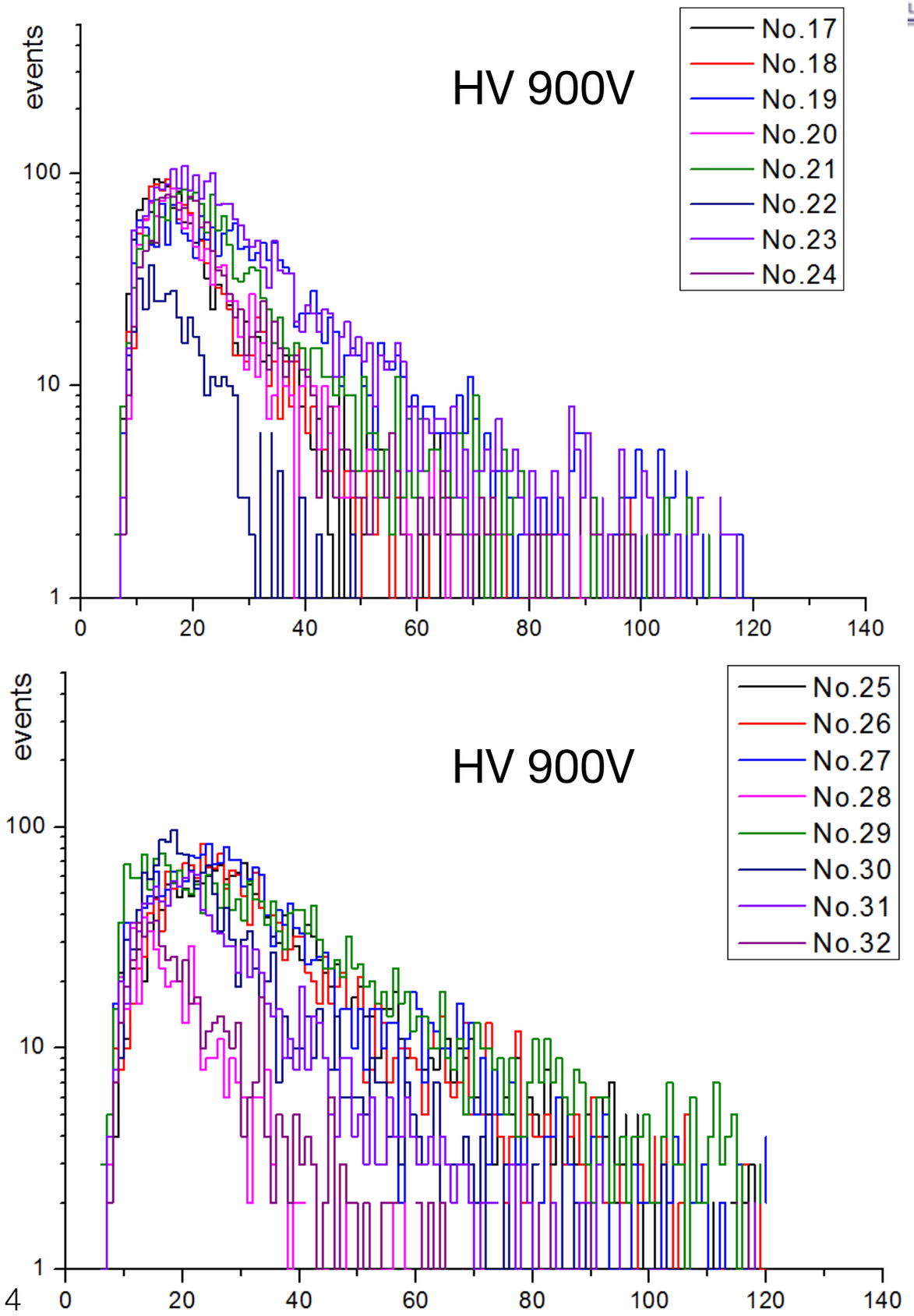
time(ns)

neutrons

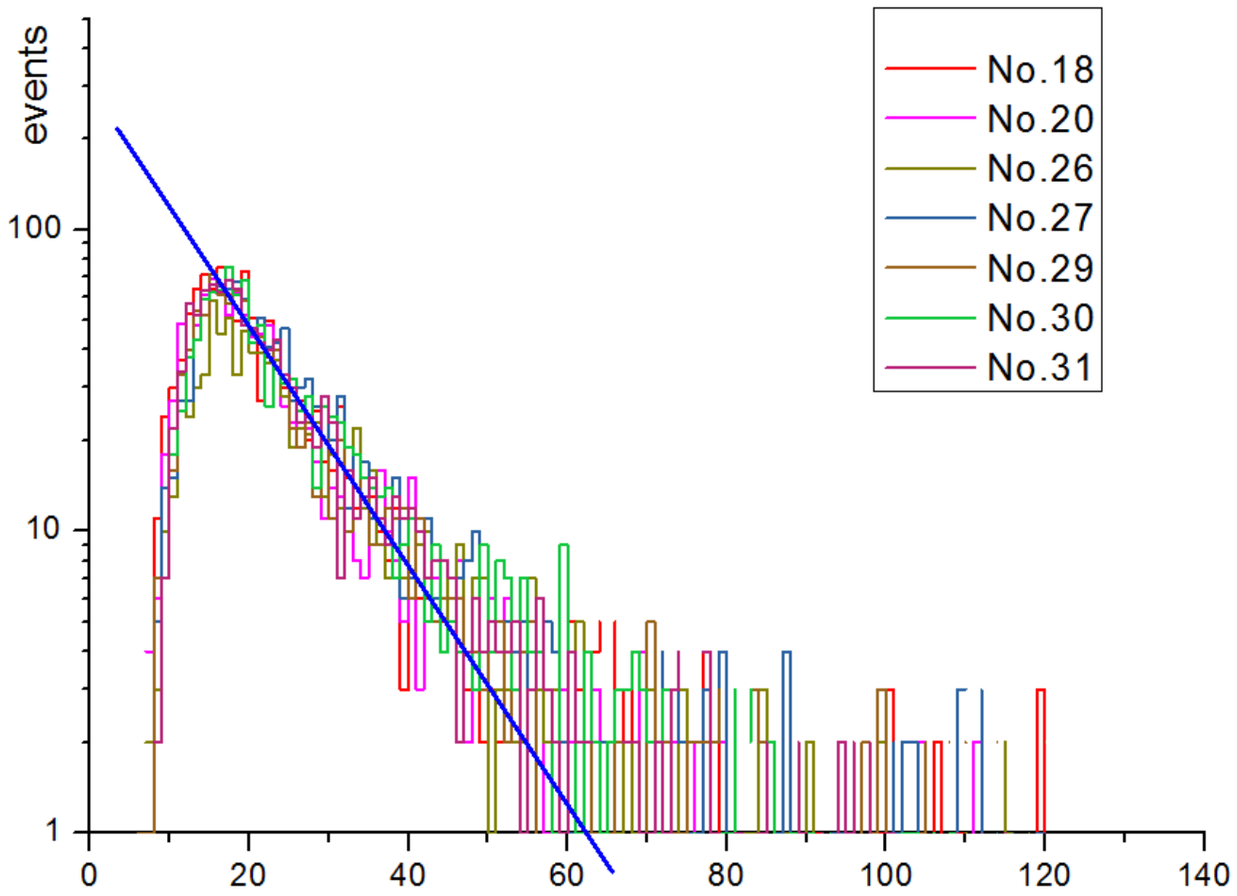
阵列的相对标定

探测器响应存在差异，对探测器做标定，使得单中子幅度谱达到相对一致

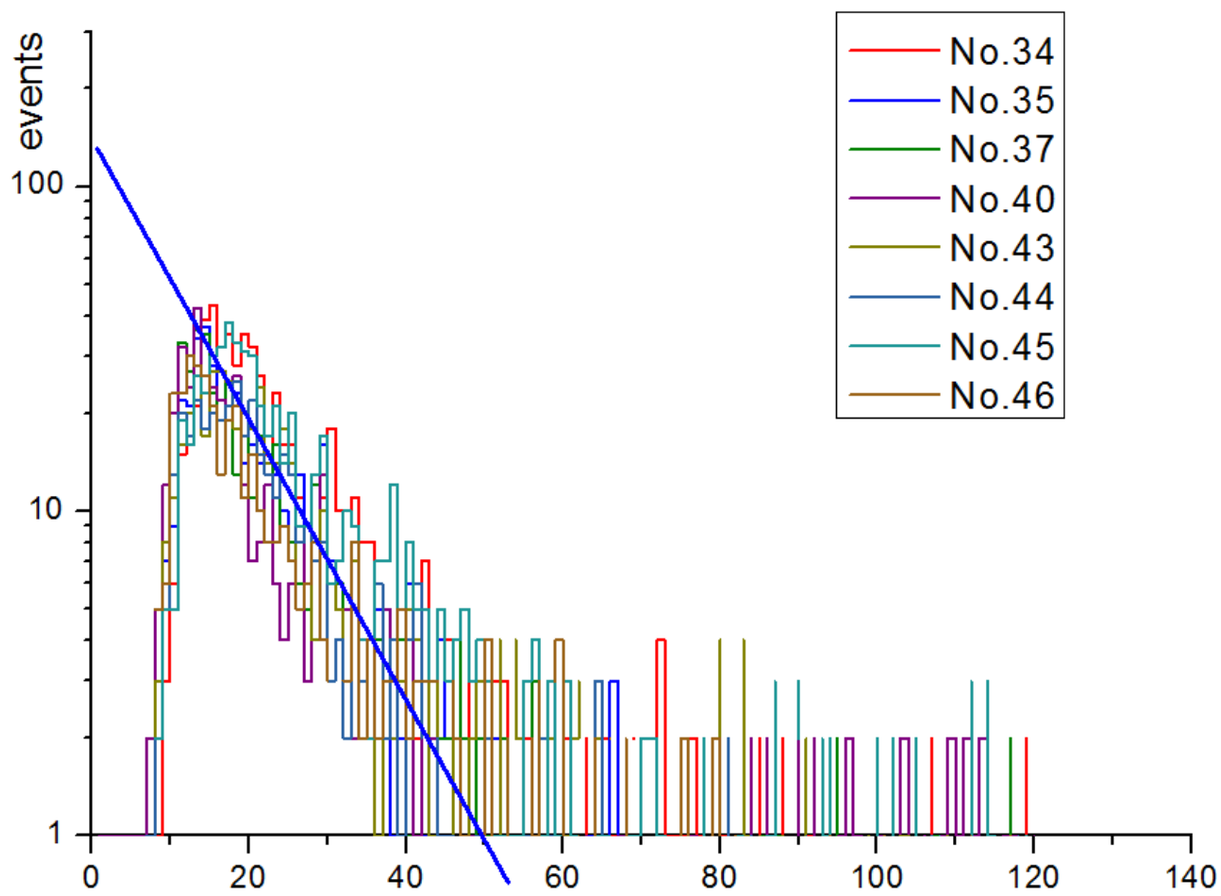
在海平面符合事例少，需要采集六天左右的Sp数据进行标定



主要调节PMT的高压与前放阈值，使用6天左右的数据进行相对标定，由于时间原因，标定工作正在进行中。



A 层



B 层

小结

1. 单元探测器模拟工作有一定进展，还需要和探测器运行相比对；

2. 河北师大实验室探测器装配和调试工作顺利进行。光电倍增管测试和探测器标定工作正在进行；

3. 下一步，完成LHAASO-ENDA阵列模拟和重建工作，研究和优化阵列性能，为LHAASO-ENDA全阵列的建设打好基础。

谢 谢