EAS Thermal Neutron Detector Array to Add into LHAASO

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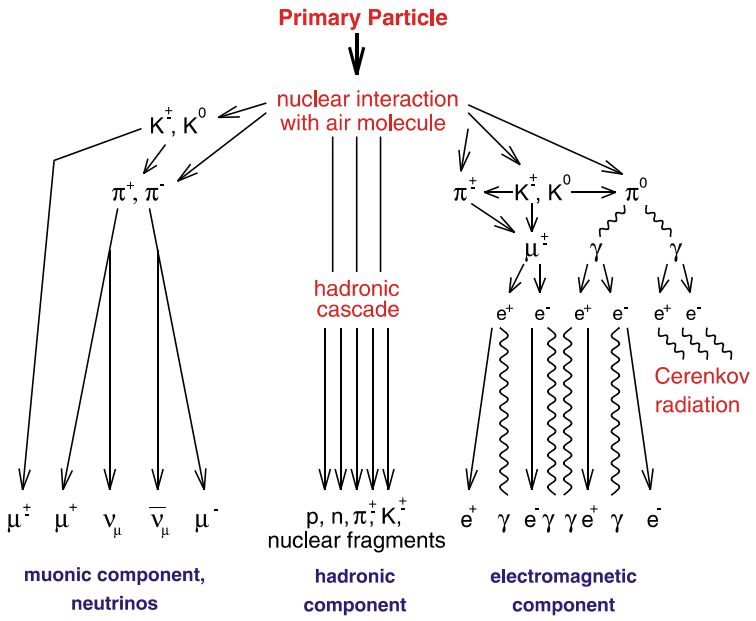
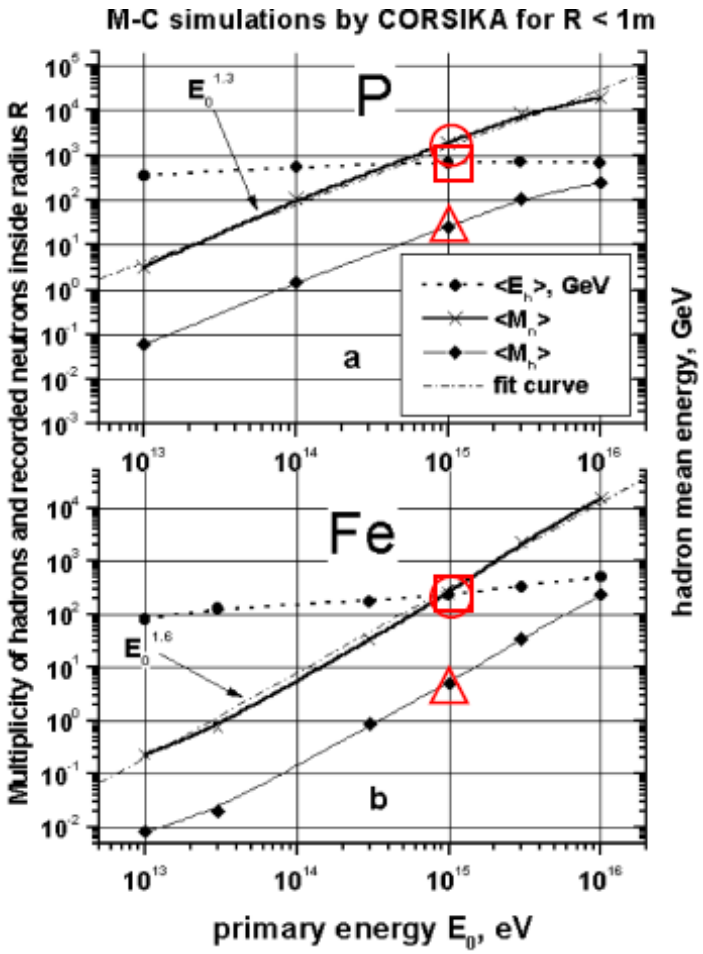
outline

1. **Physical motivation**
2. **EN-detector**
3. **PRISMA-YBJ: early study at high altitude**
4. **ENDA to add into LHAASO**

1. Physical motivation

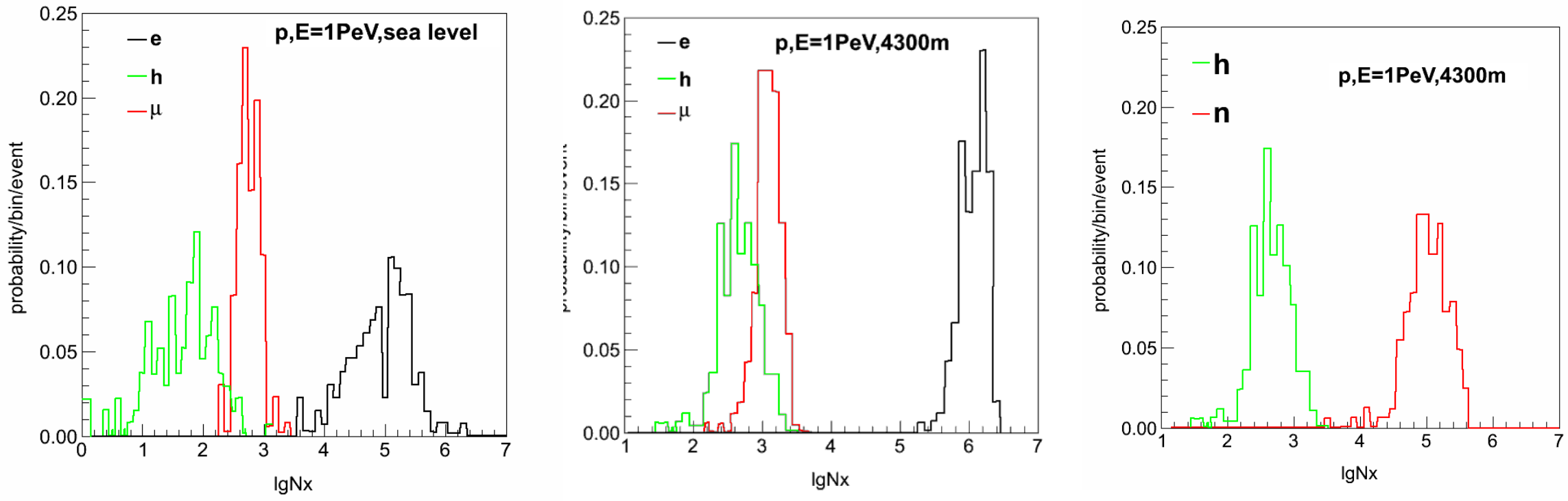


- **Hadrons are the backbone of the shower development, very sensitive to primary composition.**
- **hadrons can generate amount of fast neutrons in ground media (soil, building, etc.). Fast neutrons are moderated to thermal neutrons.**



Modern Physics Letters A, Vol. 17, No. 26 (2002) 1745-1751

At the same primary energy, thermal neutrons generated by light components (such as proton) are one order more than one by heavy components (such as iron). It is very good for primary component separation.



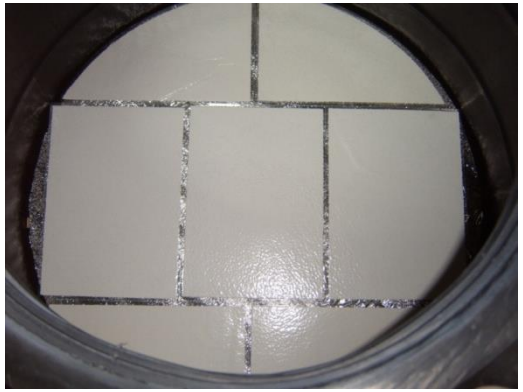
Chinese Physics C Vol. 37, No. 1 (2013) 015001

- Thermal neutrons are 2-3 orders more than hadrons.
- thermal neutrons are 1-2 orders at high altitude more than one at sea level

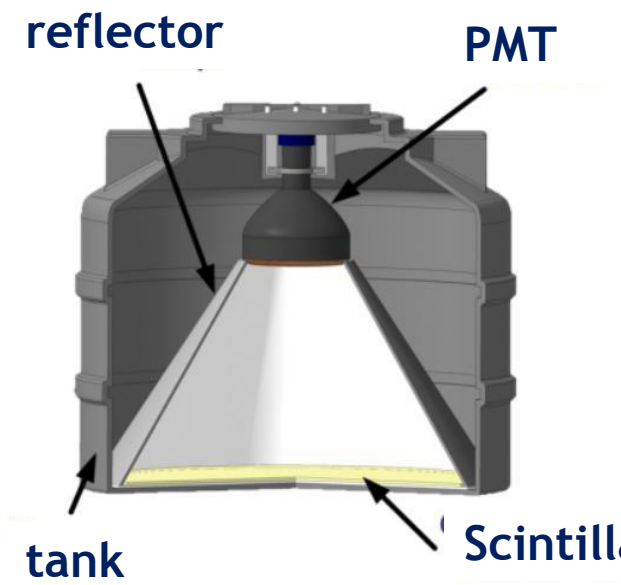
2. EN-detector

EN-detector (electron-neutron detector), developed by Yuri Stenkin et al., can detect both thermal neutrons and "charged" components.

Nuclear Physics B (Proc. Suppl.) 196 (2009) 293–296

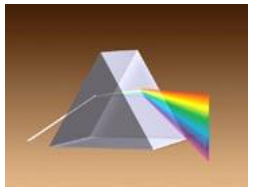


$ZnS(Ag)+^{6}LiF$



Thermal neutron recording efficiency ~20%. Scintillator effective thickness 30 mg/cm^2.

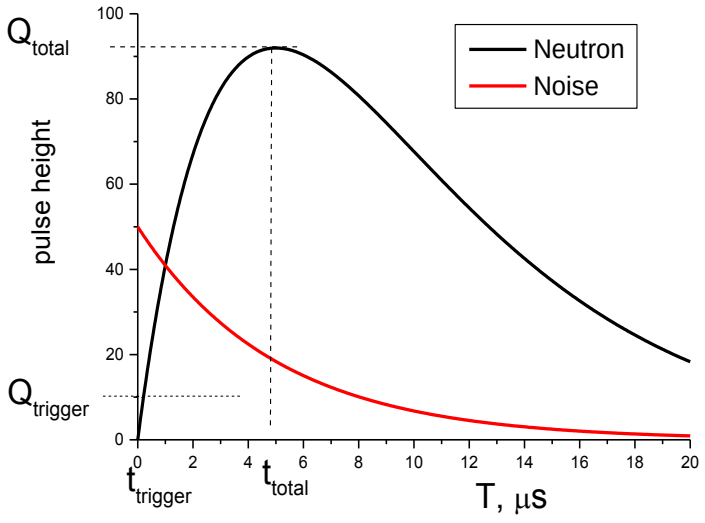
$ZnS(Ag)+^{10}B_2O_3$

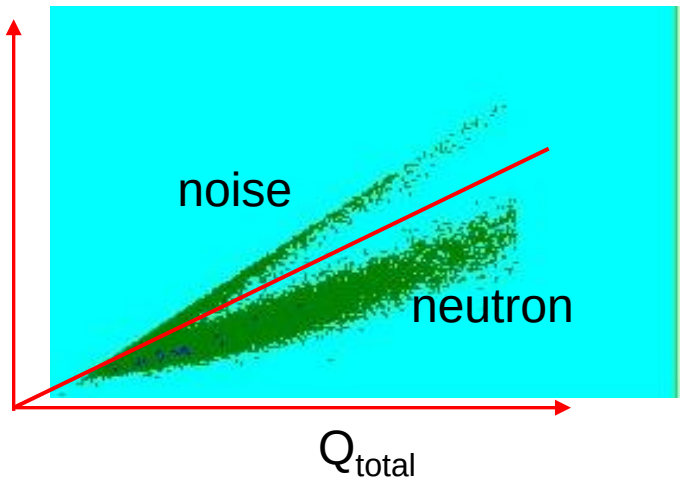


PRISMA(PRImary Spectrum Measurement Array)

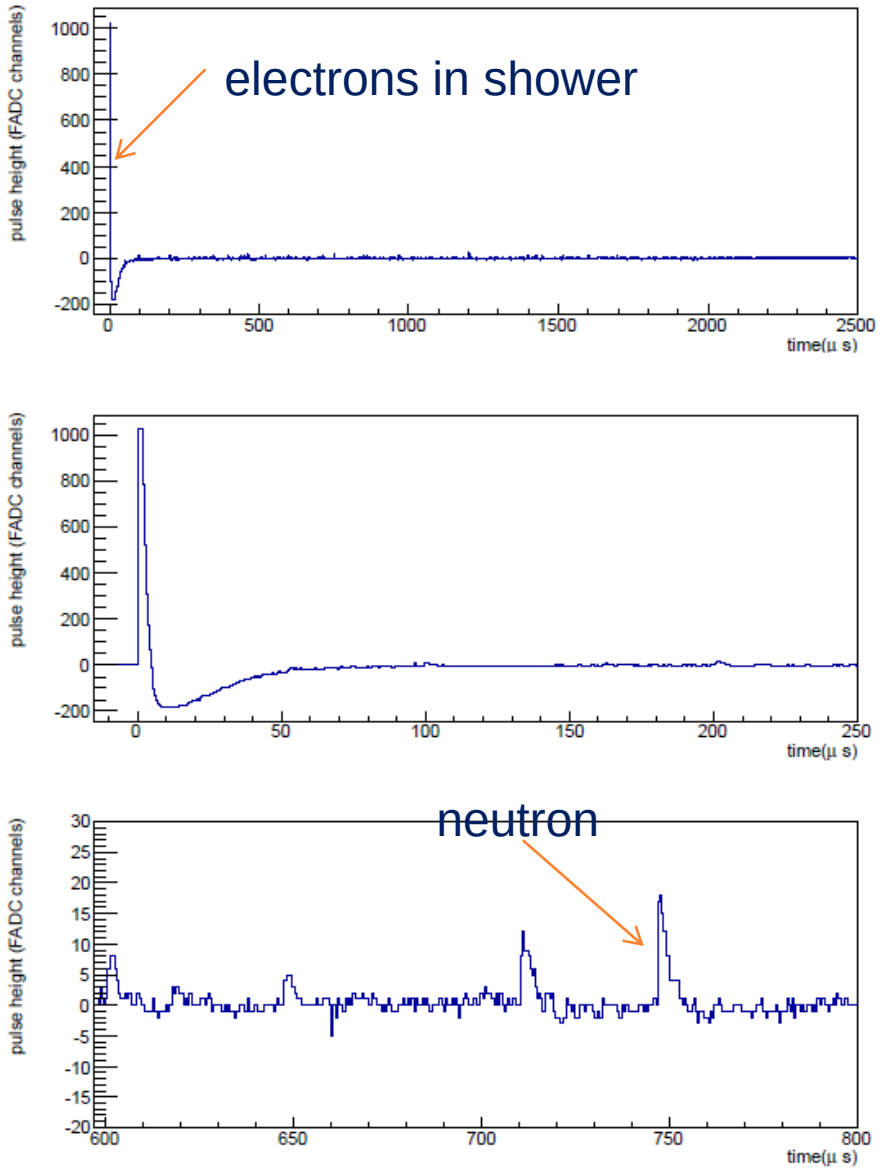
Nucl. Phys. B (Proc. Suppl.), 196, (2009), p. 293-296.

neutron / noise separation



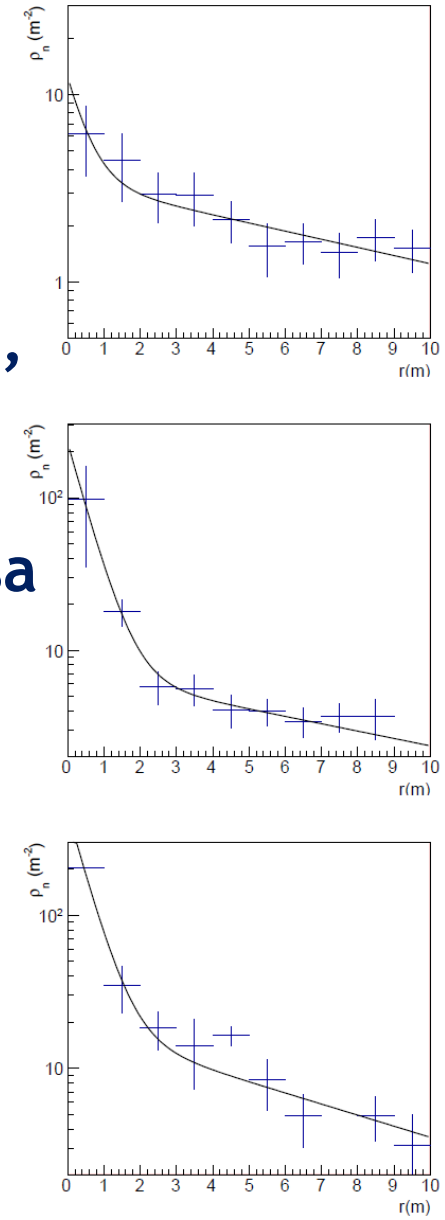


electrons / neutron separation in one shower



3. early study at high altitude

PRISMA-YBJ:
4 EN-detectors
4300m a.s.l.
Yangbajing Tibet, China, from Jan. 2013.
In March 2016 move to Tibet University in Lhasa



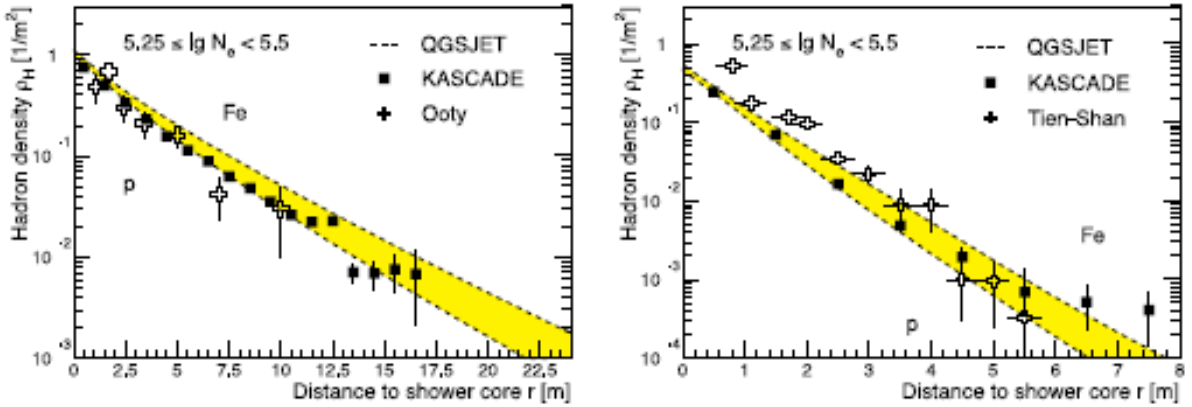
thermal neutron lateral distribution

Astroparticle Physics 81 (2016) 49–60

$$\rho_n(r) = \rho_0 \times e^{-(r/r_0)} + \rho_1 \times e^{-(r/r_1)}$$

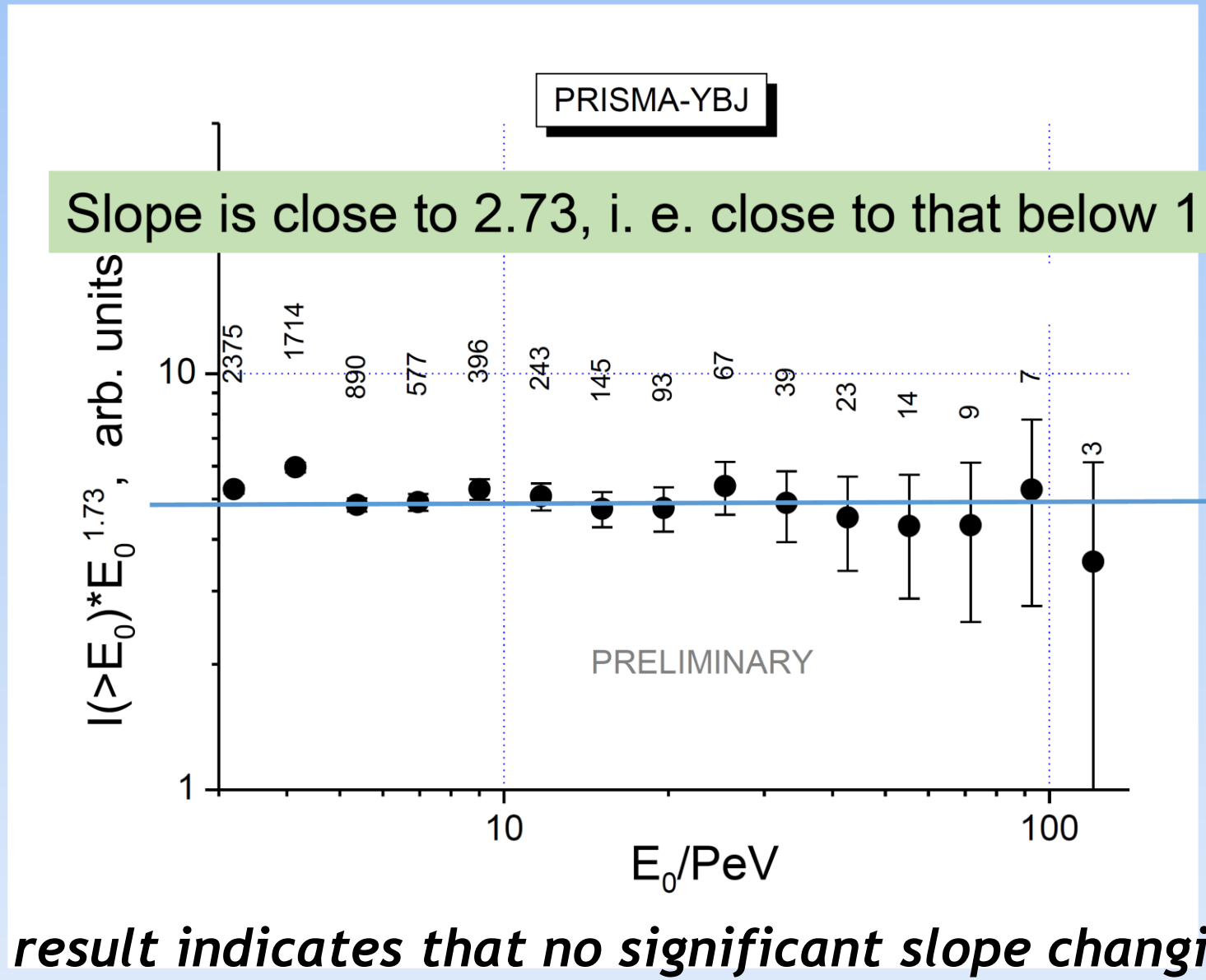
N_{p10} intervals	χ^2/ndf	$\rho_0(m^{-2})$	$\rho_1(m^{-2})$
$\lg(N_{p10}) < 4.8$	2.44/8	9.0 ± 6.8	3.41 ± 0.32
$4.8 < \lg(N_{p10}) < 5.4$	2.69/7	222 ± 65	7.17 ± 0.65
$\lg(N_{p10}) > 5.4$	20.1/7	456 ± 230	18.7 ± 2.3

hadron lateral distribution, KASCADE HCAL, sea level



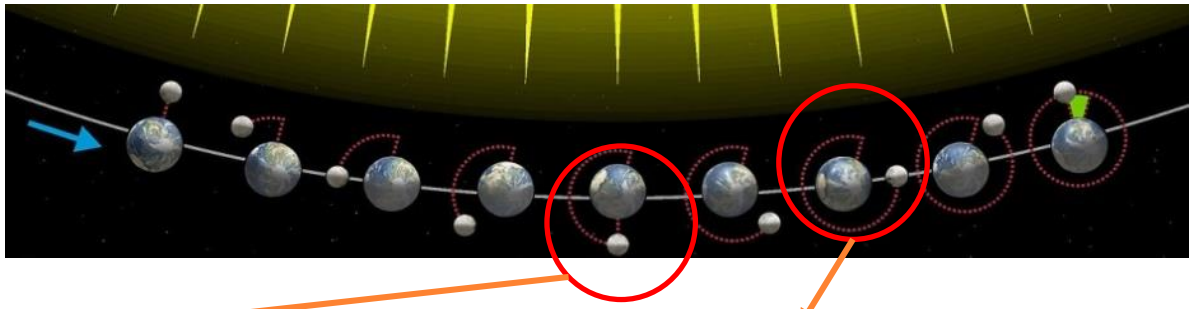
J. Phys. G: Nucl. Part. Phys. 25 (1999) 2161–2175

Result of PRISMA-YBJ from Nn measurement



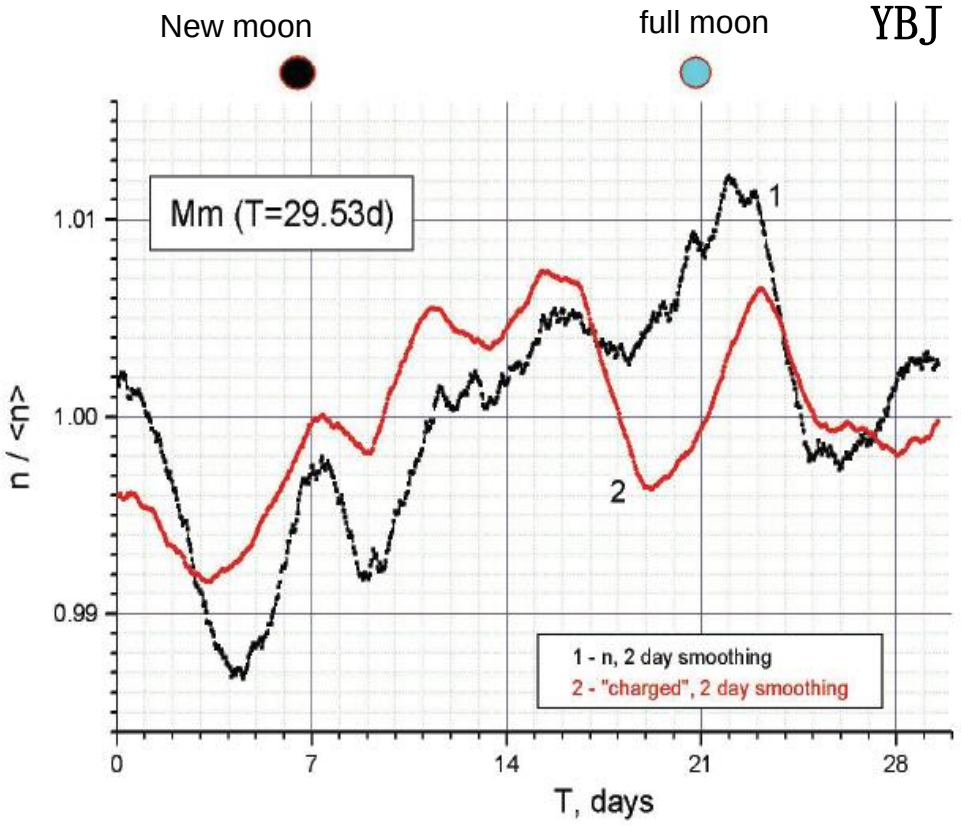
Our preliminary result indicates that no significant slope changing above 3PeV

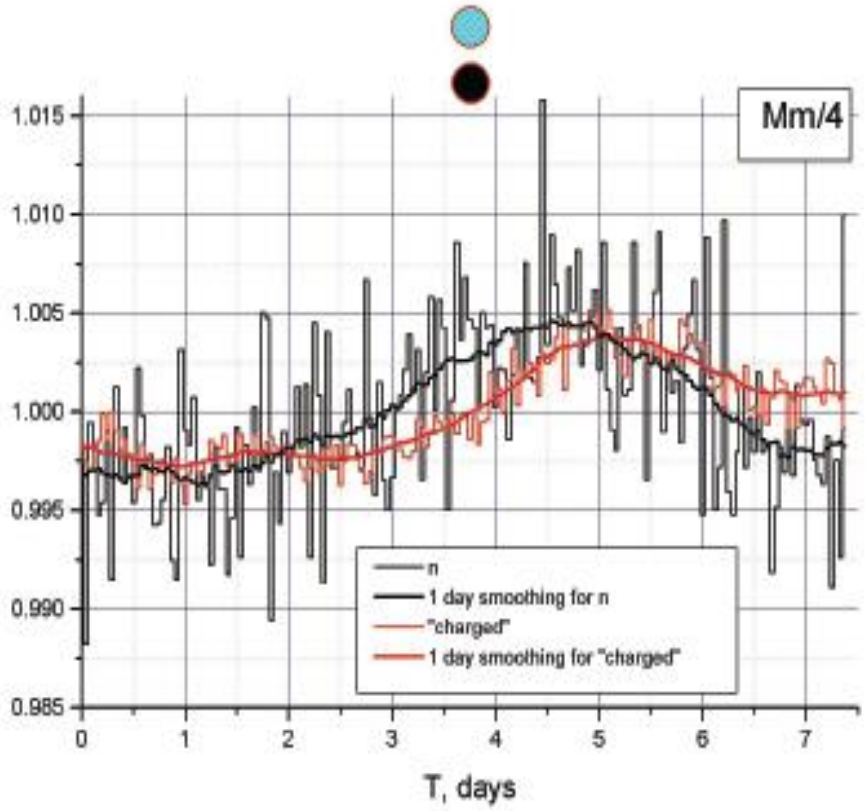
lunar tidal effect



monthly

weekly

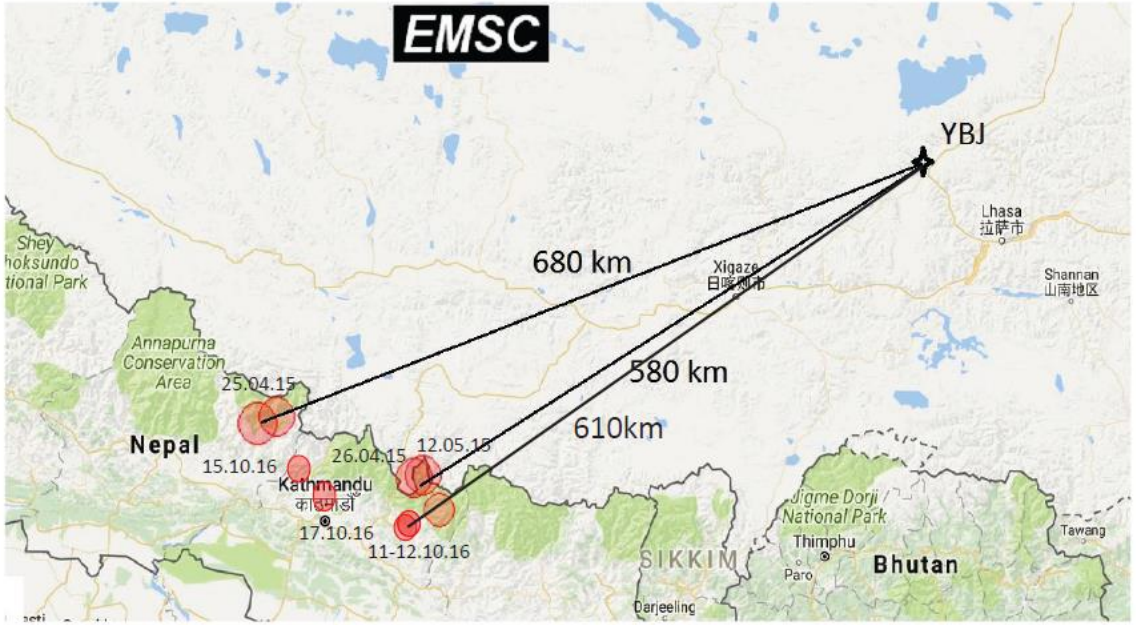


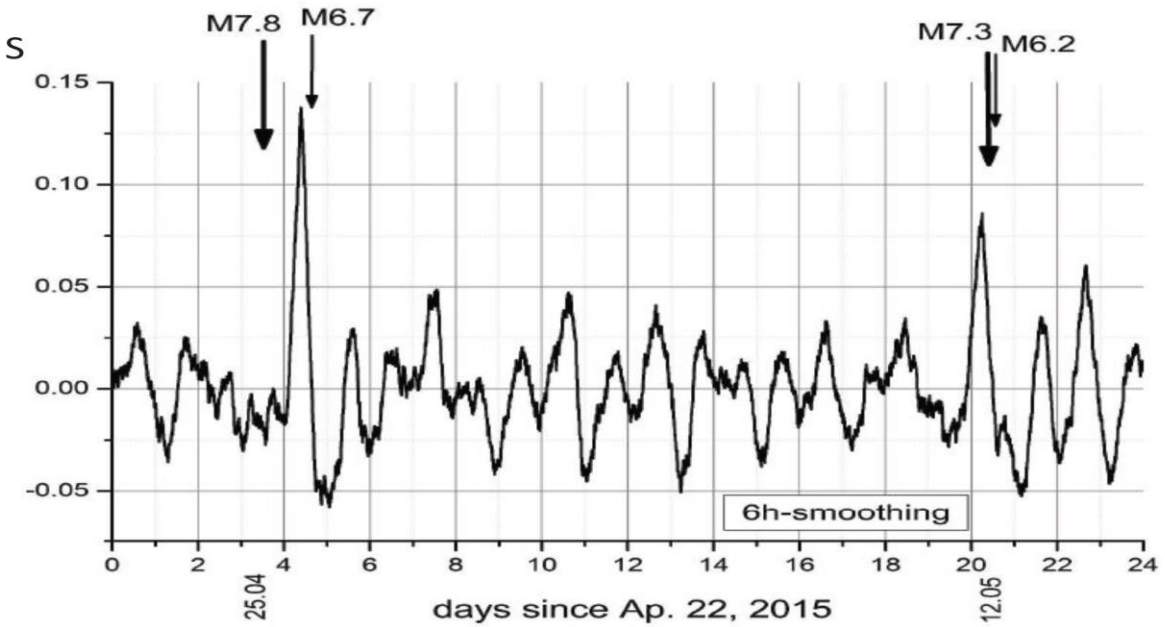


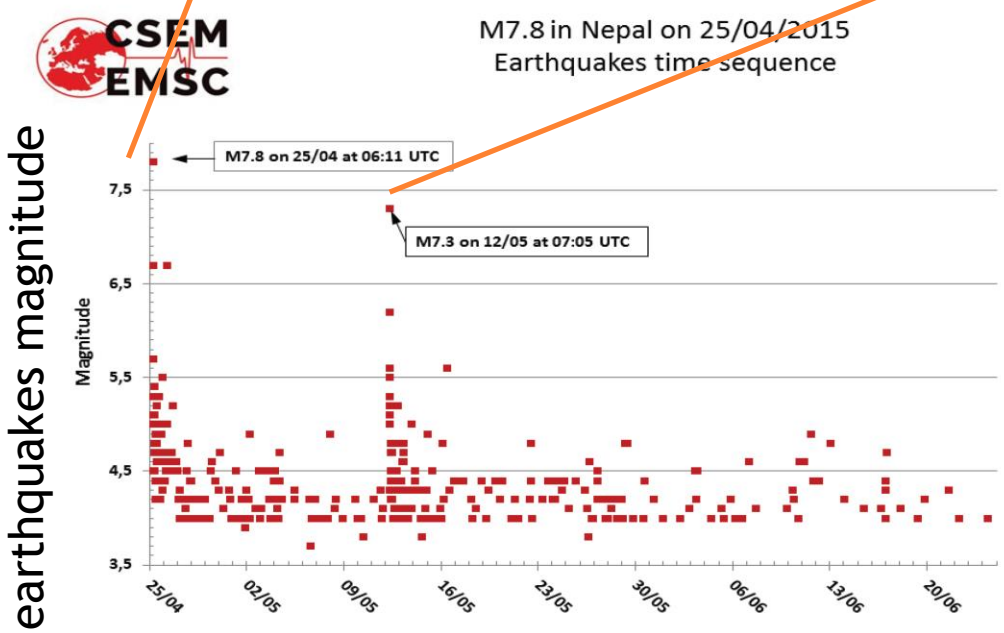
superimposed epoch analysis

Pure And Appl. Geophys. 174 (2017) 2763-2771

Response of PRISMA-YBJ to 2015 Nepal earthquakes



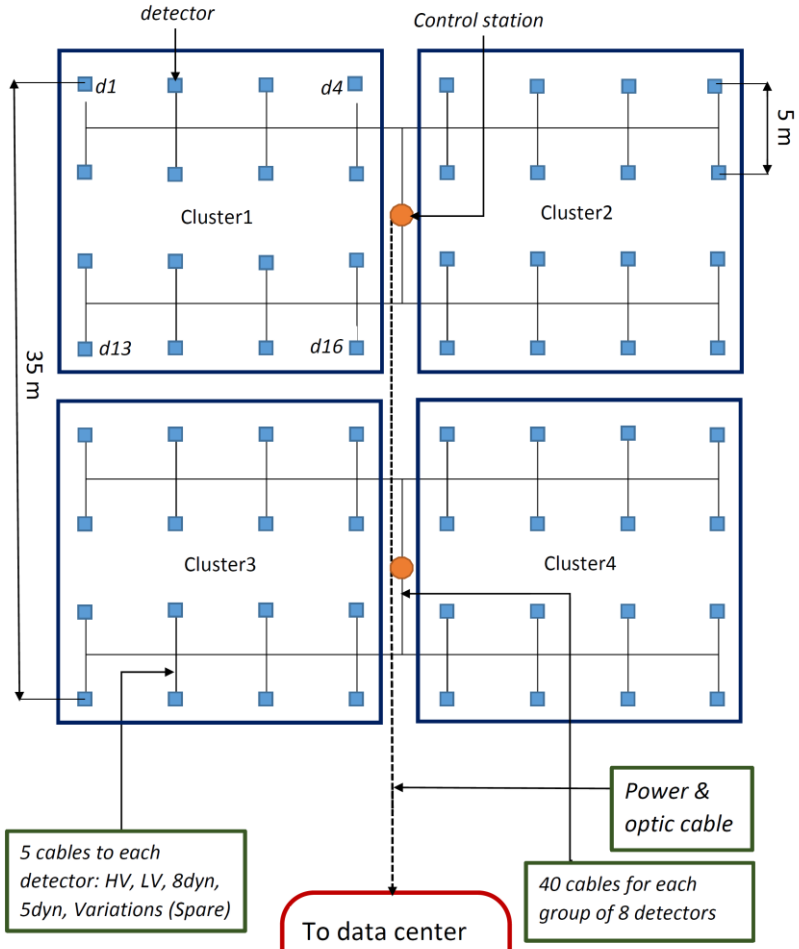




Journal of Environmental Radioactivity 208-209 (2019) 105981

4. ENDA (EN-Detector Array) to add into LHAASO

ENDA-64 (1100m^2)

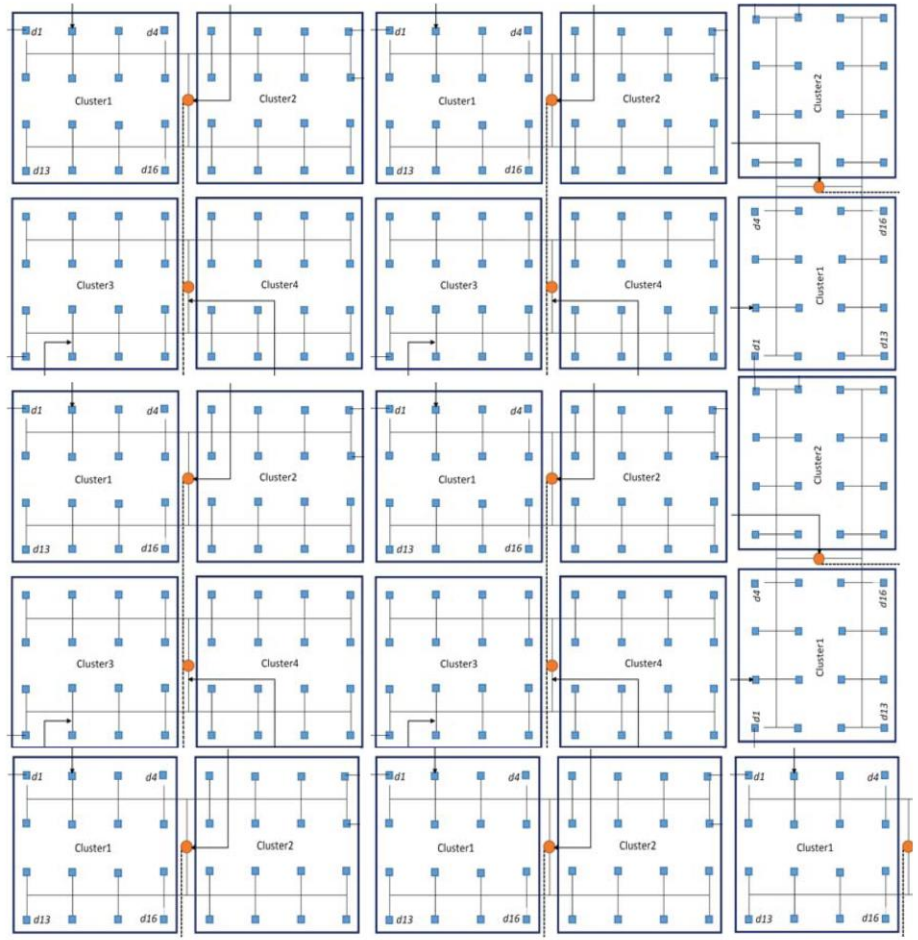


To data center & power supply

Power: ~ 500 Watt
Data: ~50Mb/day

+ White Rabbit clock system

ENDA-400 (10000m^2)



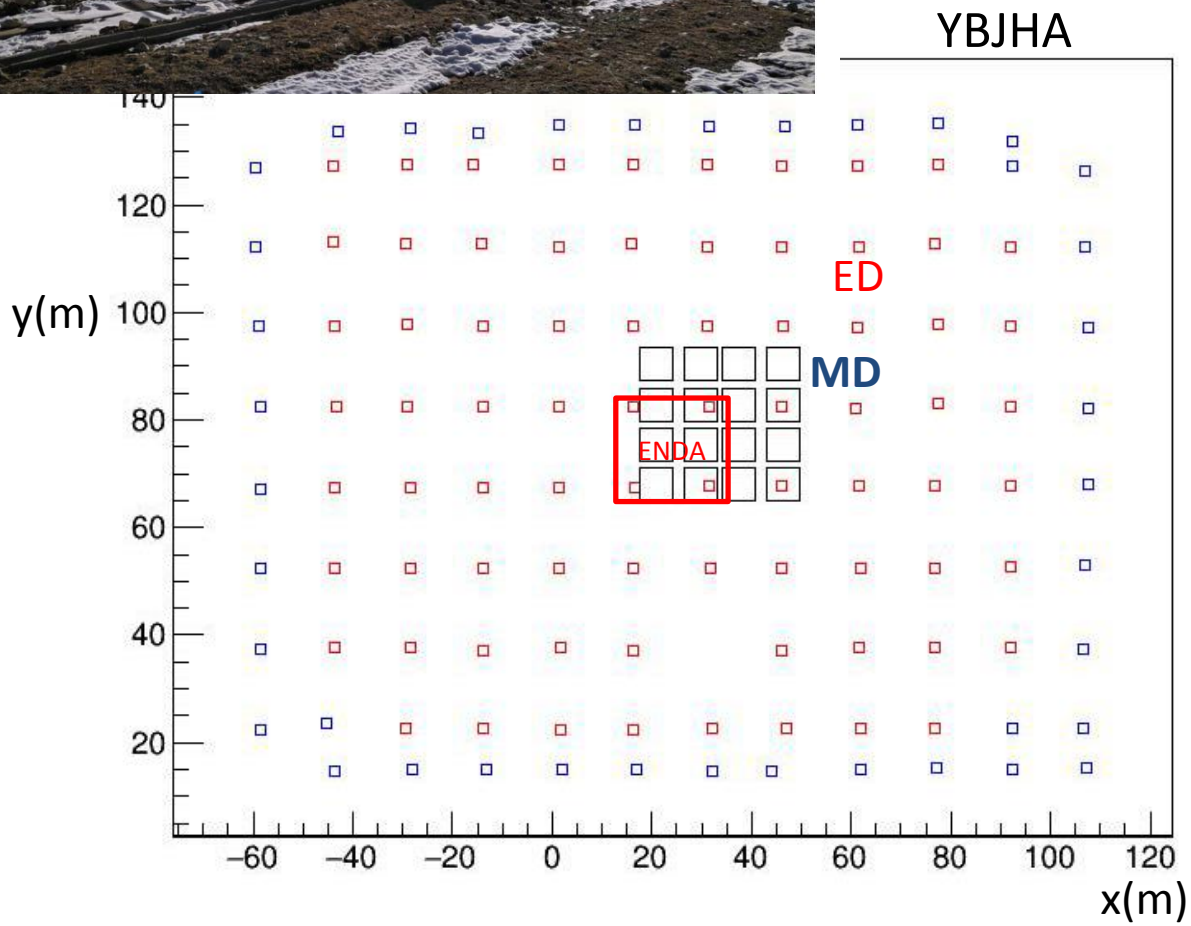
Under supports by Tibet University, Institute for Nuclear Research RAS, Institute of High Energy Physics CAS, Hebei Normal University (HNU) and Sichuan University, ENDA-64 are made and will be added into LHAASO in 2019.

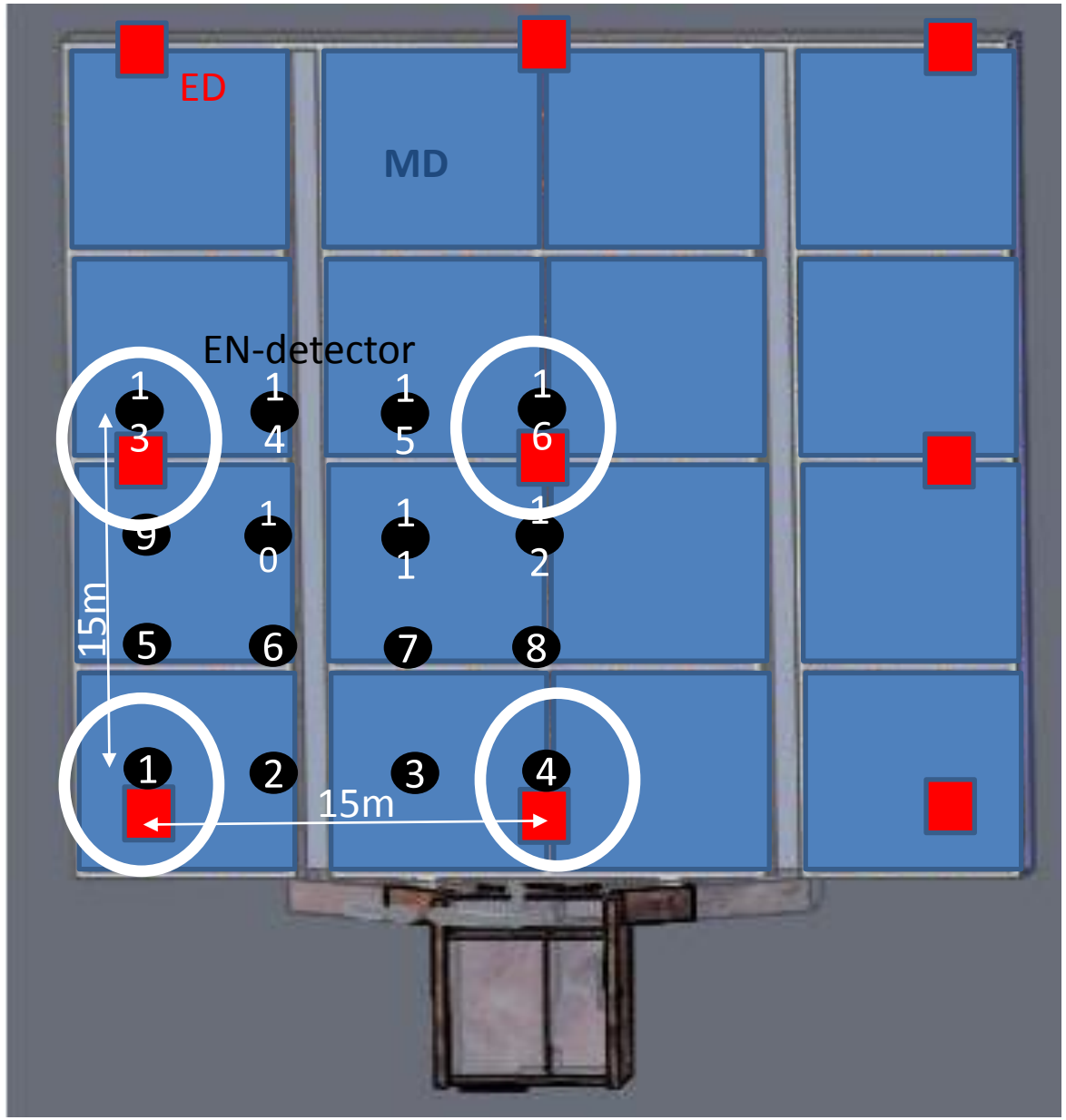
EN-detectors at HNU
FADCs are made by Sichuan University.

ENDA-16 at Tibet University
Mar. 2017-Dec. 2018

2017 JINST 12 P12028

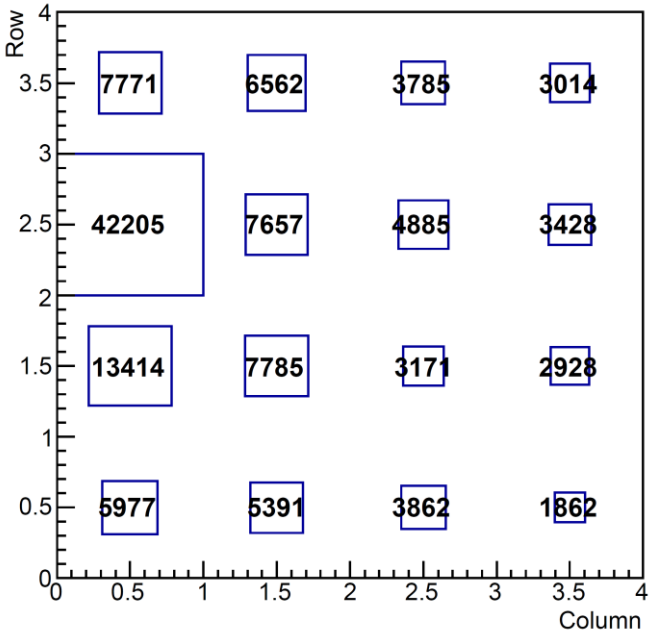

ENDA-16 at Yangbajing
from Dec. 2018


YBJHA
ED
MD
ENDA
y(m)
x(m)
140
120
100
80
60
40
20
−60
−40
−20
0
20
40
60
80
100
120

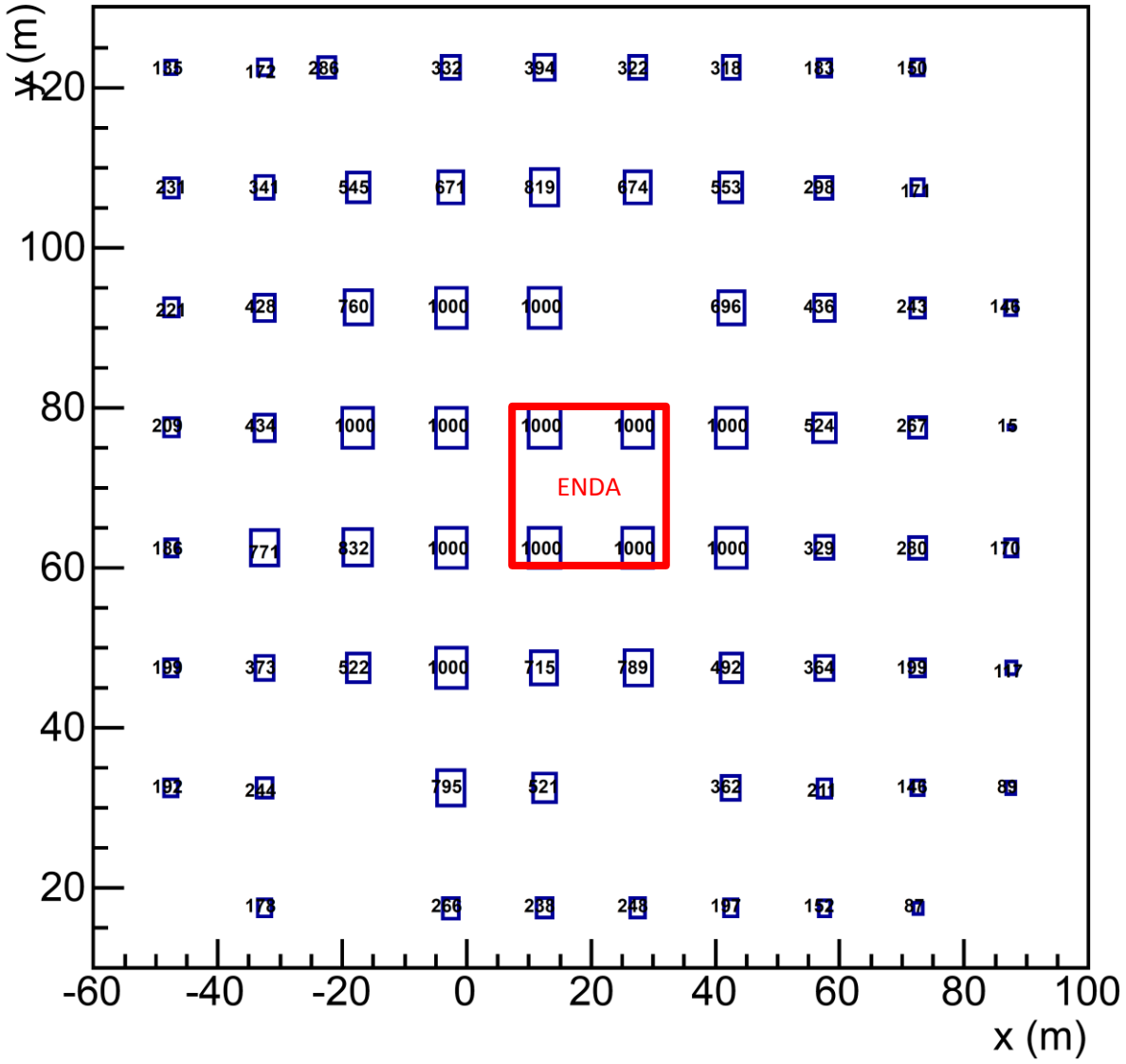

ED
MD
EN-detector
13
14
15
16
9
10
11
12
5
6
7
8
1
2
3
4
15m
15m

One coincident event

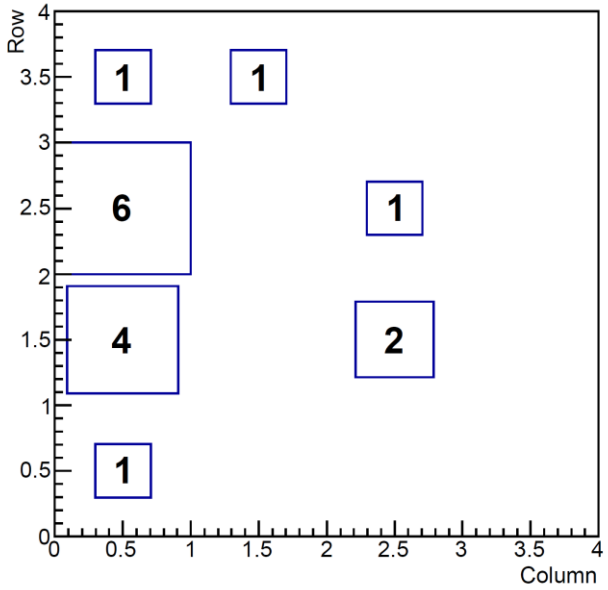
ρ_e (m^{-2}) at ENDA



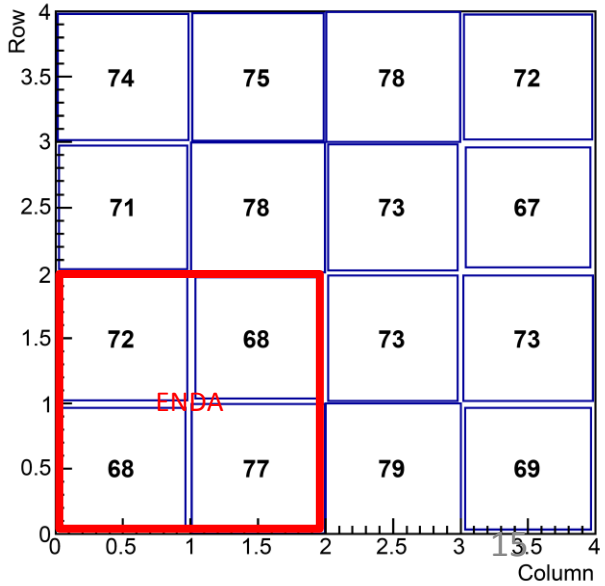
ρ_e (m^{-2}) at YBJHA

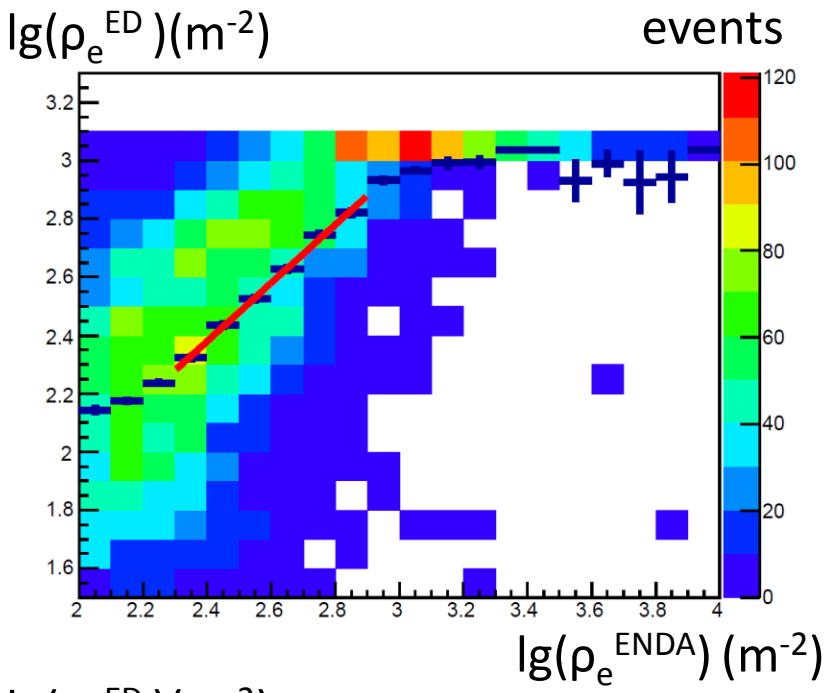


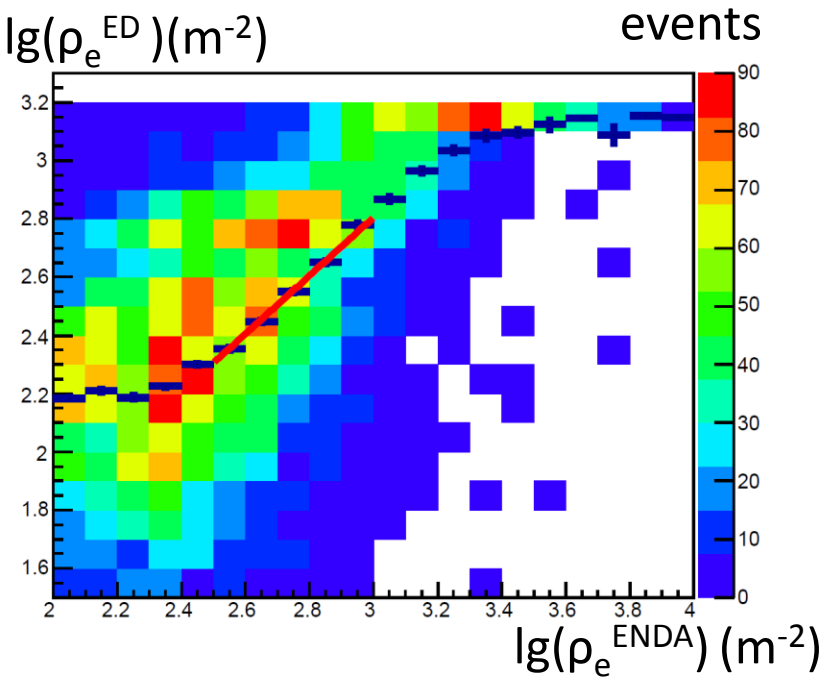
neutrons at ENDA

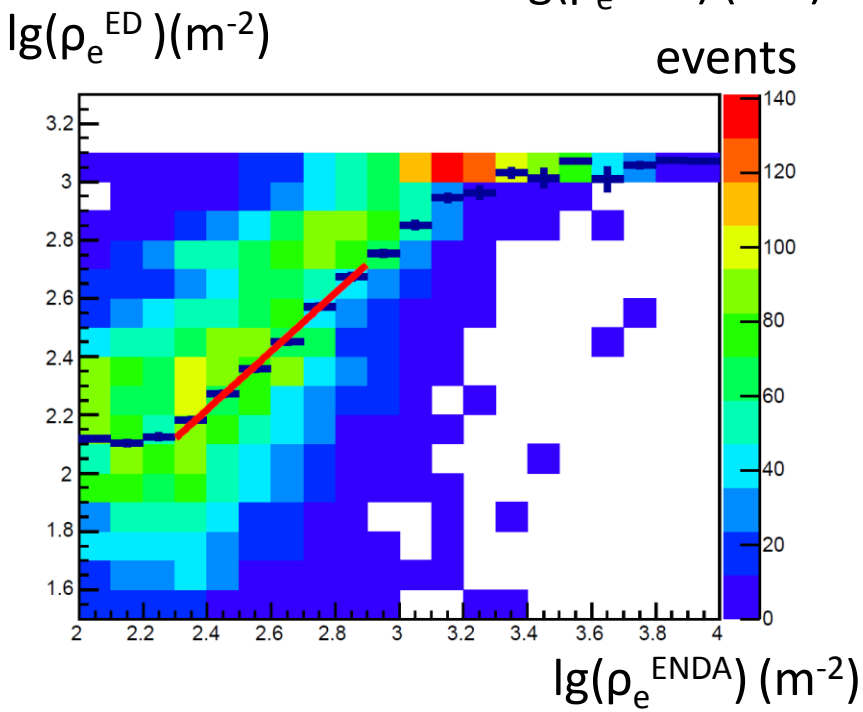


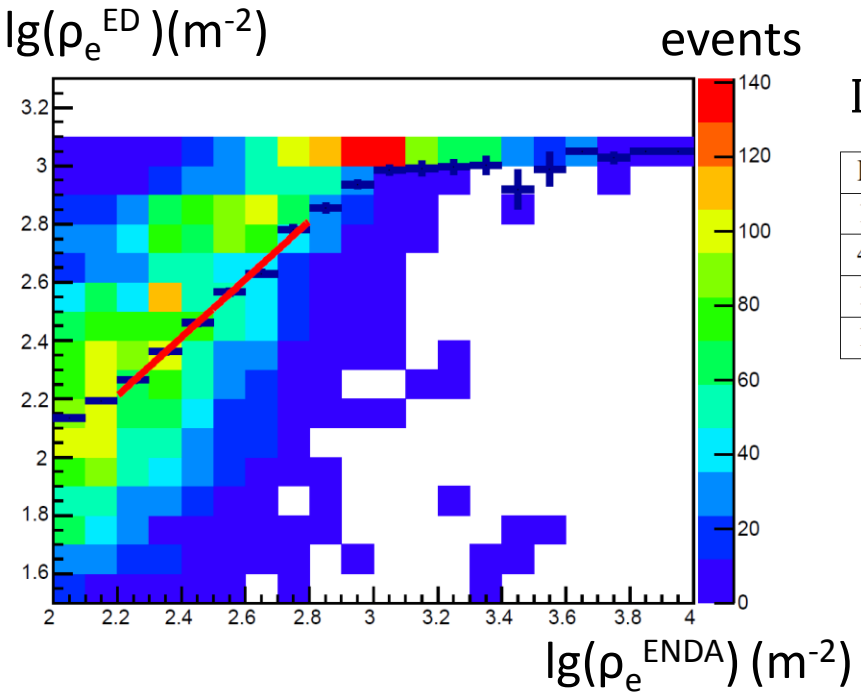
muons at YBJHA





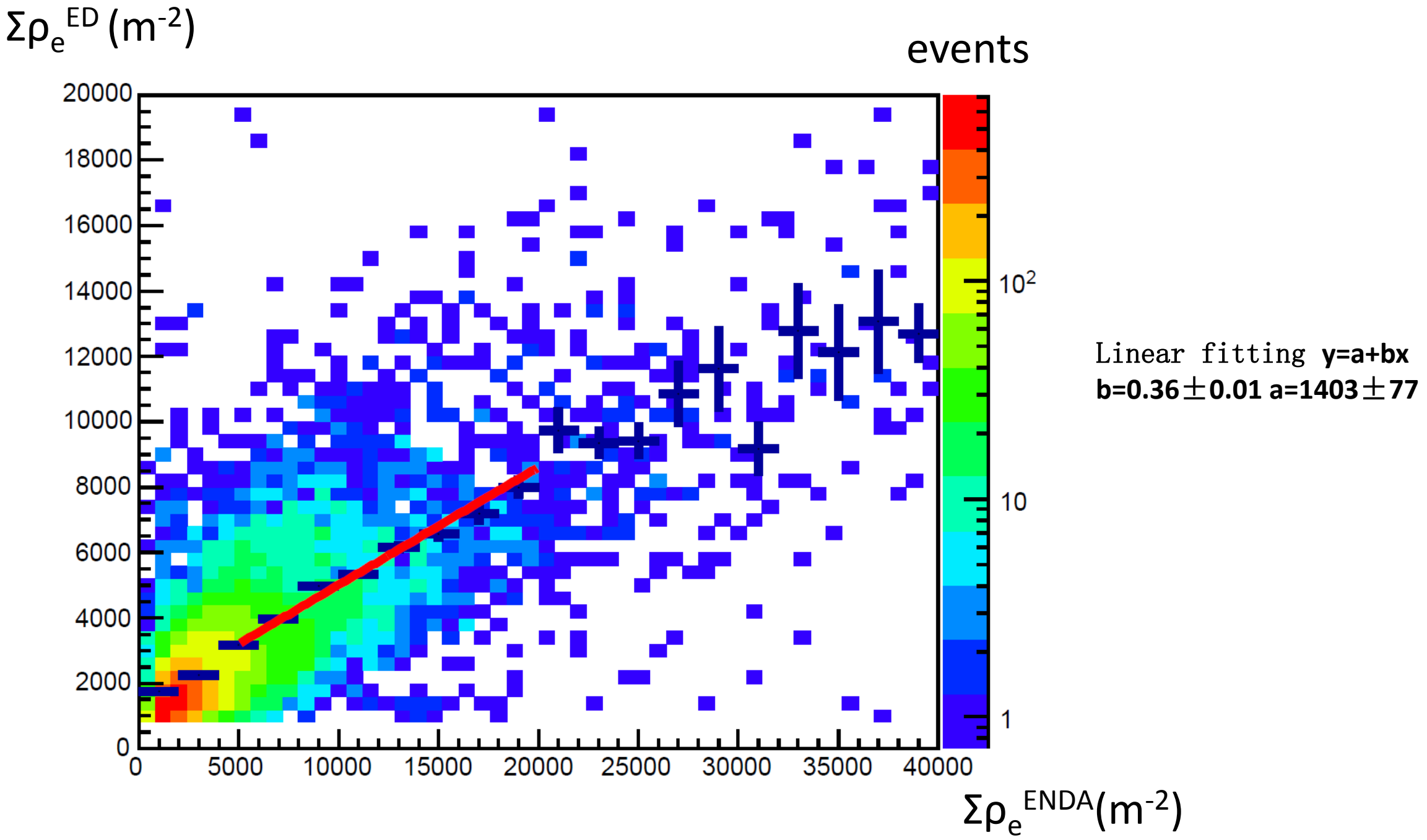


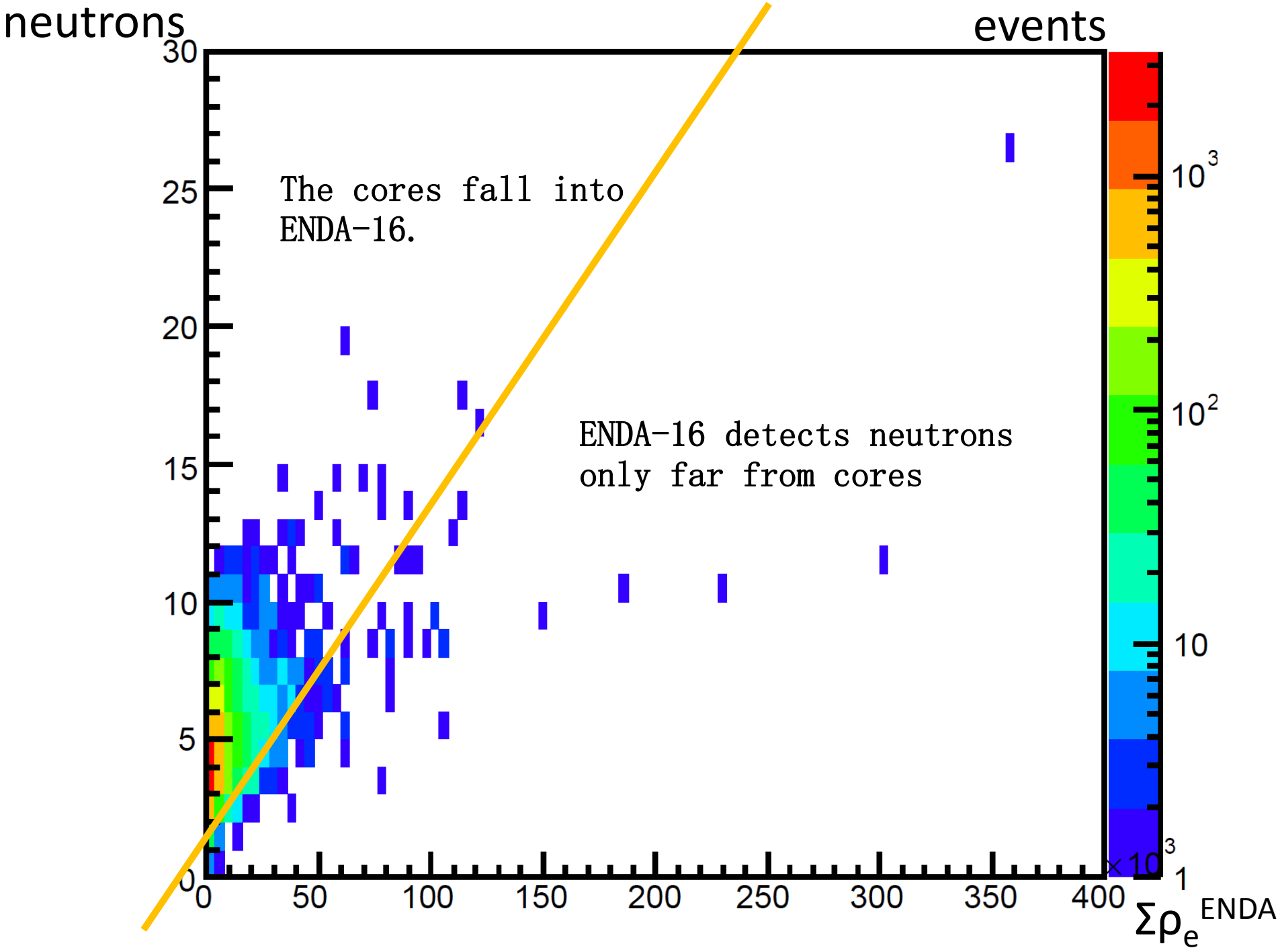




Linear fitting $\lg(y)=\lg(k)+\lg(x)$

Detector of ENDA	Detector of YBJHA-ED	slope lg(k)
1	6	-0.020 ± 0.007
4	7	-0.195 ± 0.007
13	2	-0.181 ± 0.006
16	3	0.011 ± 0.006

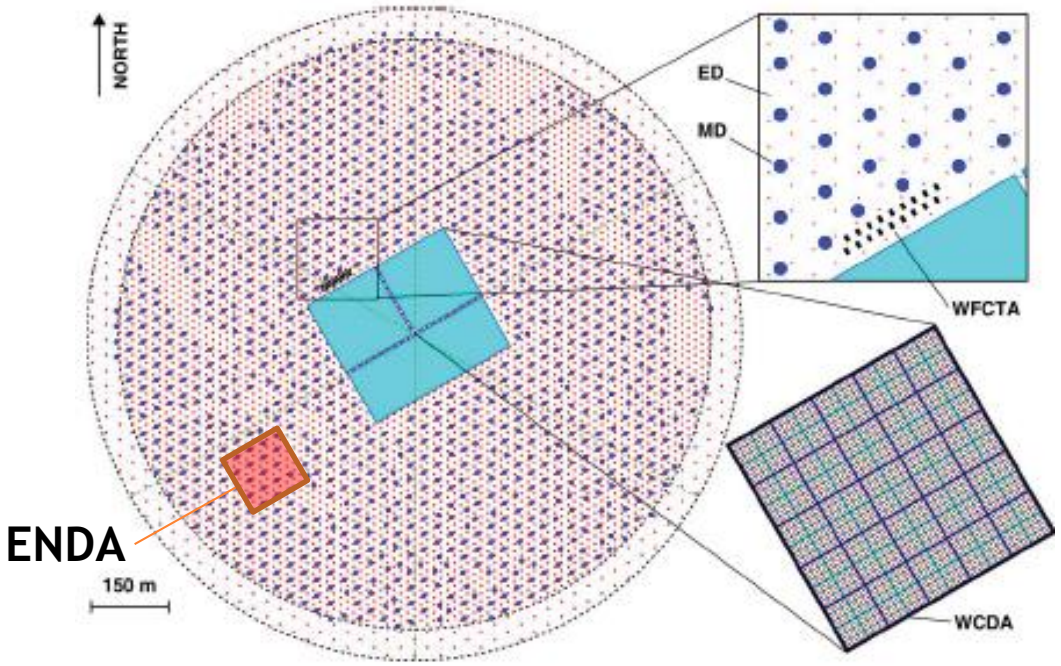

$\Sigma\rho_e^{ED}$ (m^{-2})
events
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
10^2
10
1
$\Sigma\rho_e^{ENDA}$(m^{-2})
Linear fitting **y=a+bx**
b=0.36±0.01 a=1403±77



Simulation:
PoS(ICRC2019)431

LHAASO at the knee region

- ED : e
- MD, WCDA: μ
- WFCTA: Č
- WCDA++: γ family at core →π0
- ENDA: thermal neutrons →π+π-



→ *Full particle measurement of cosmic showers!*

→ *significant capability of component separation and energy determination!*

Thanks!