Electron-Neutron Detector Array (ENDA), Status and Coincidence with the LHAASO Detectors

Presenter: Bingbing Li

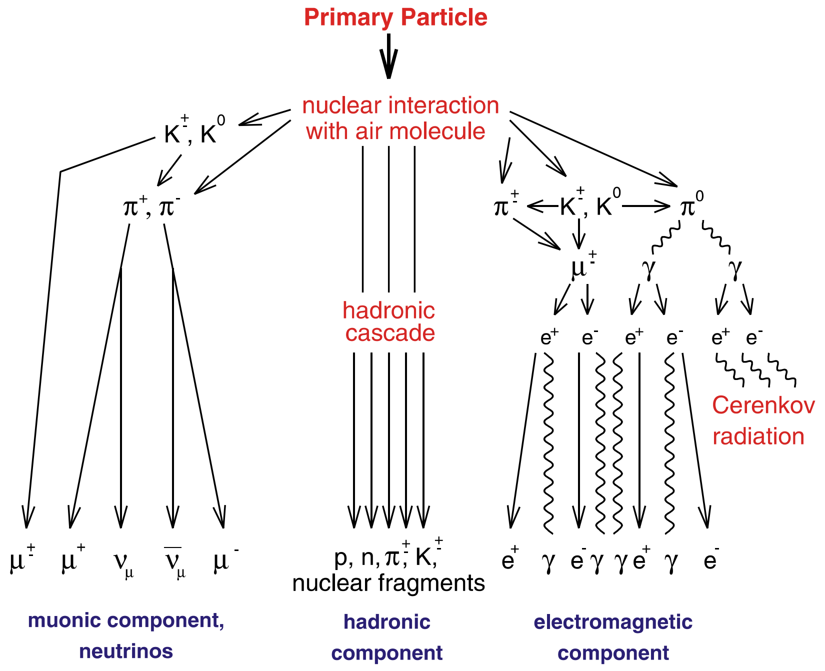
Hebei Normal University

37th ICRC 2021, Berlin

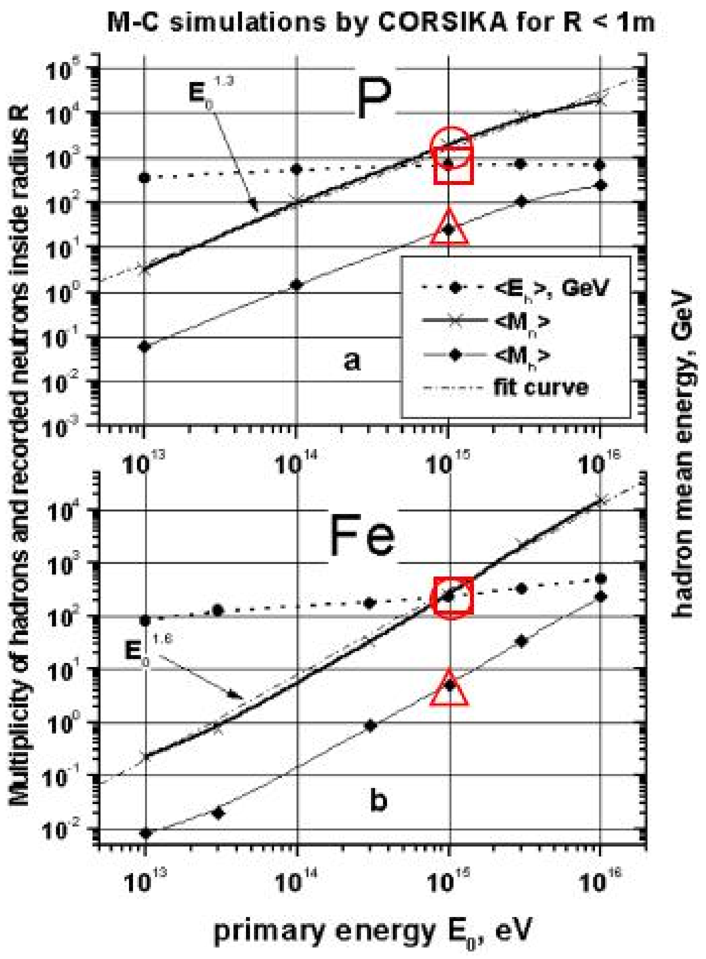
outline

1. **Physical motivation**
2. **EN-detector**
3. **Early study at high altitude**
4. **ENDA in LHAASO**
5. **Summary**

1. Physical motivation



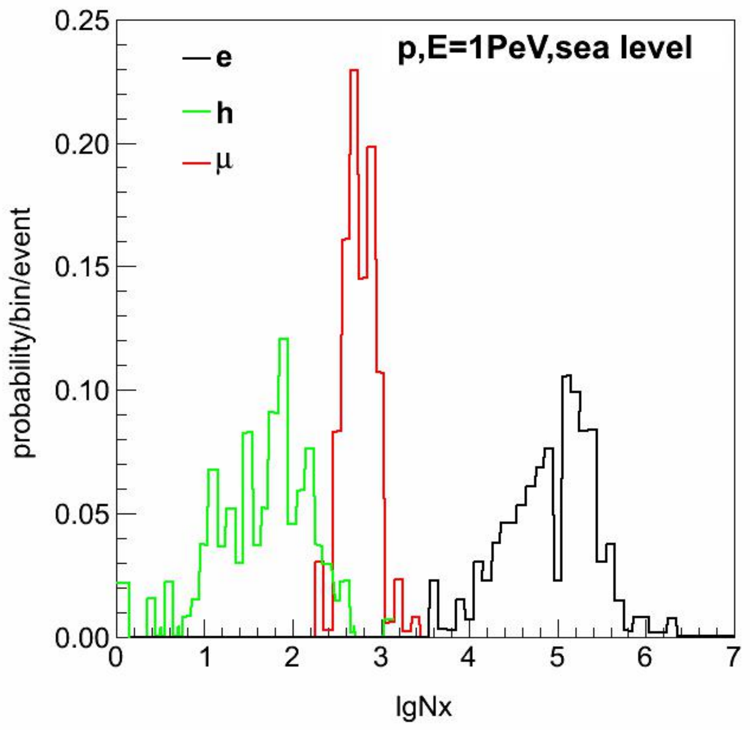
- Hadrons are the backbone of the shower development, very sensitive to primary composition.
- Hadrons can generate amount of fast neutrons in ground media (soil, building, etc.). Fast neutrons are moderated to thermal neutrons.

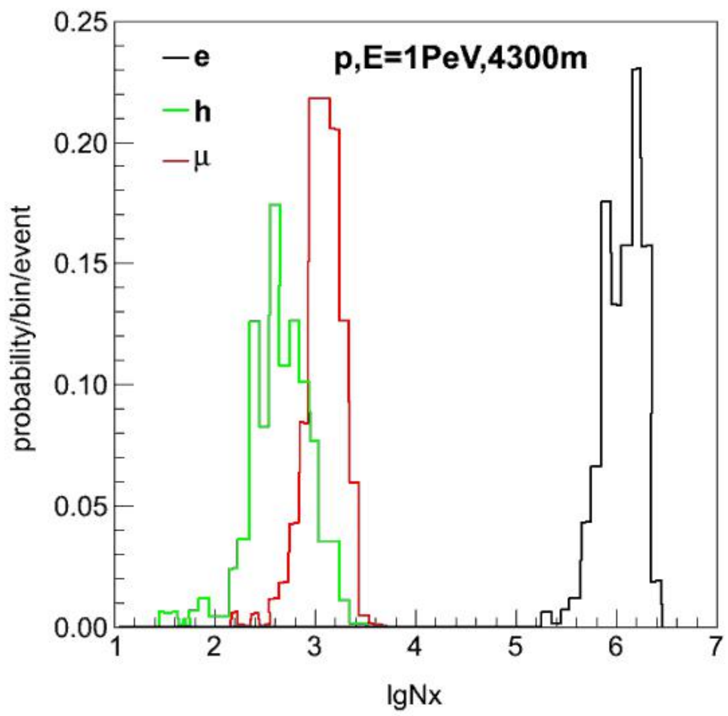


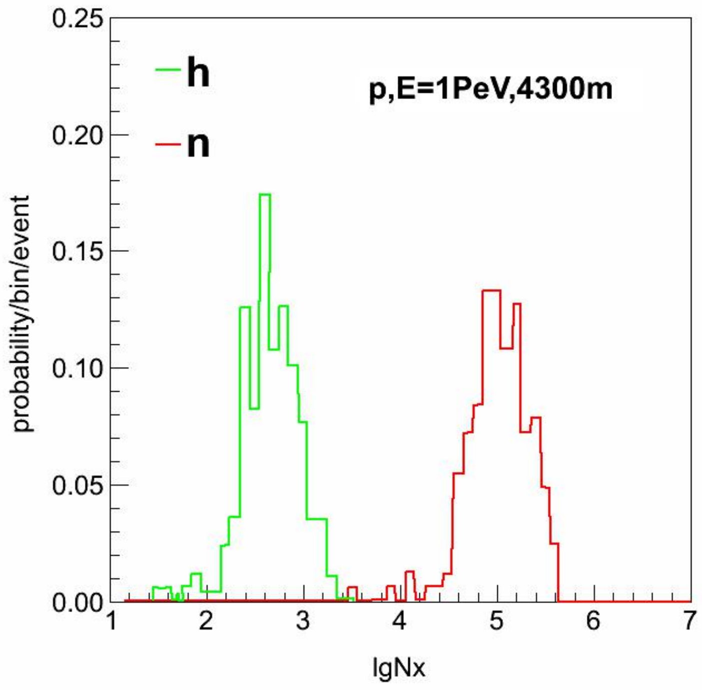
Modern Physics Letters A, Vol. 17, No. 26 (2002) 1745-1751

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





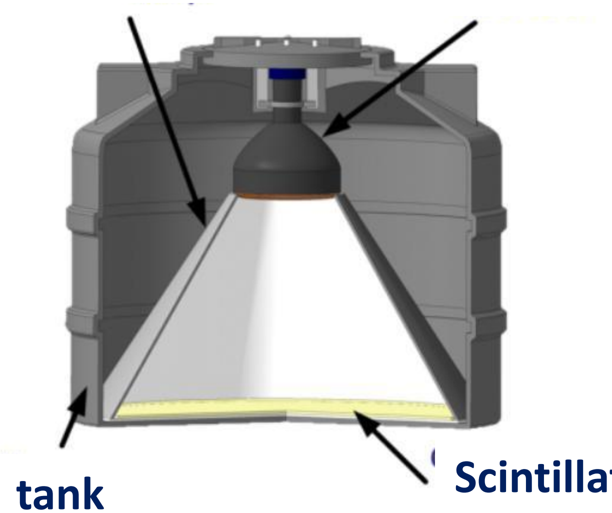


- **Thermal neutrons are 2-3 orders more than hadrons.**
- **thermal neutrons are 1-2 orders at high altitude more than one at sea level**

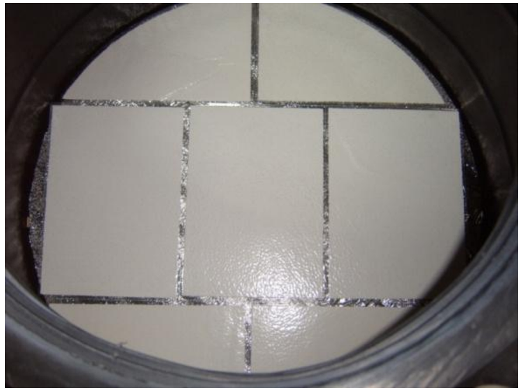
2. EN-detector

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

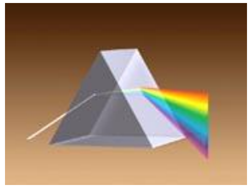


Thermal neutron recording efficiency ~20%.
Scintillator effective thickness 30 mg/cm^2 .



ZnS(Ag)+^{6}LiF

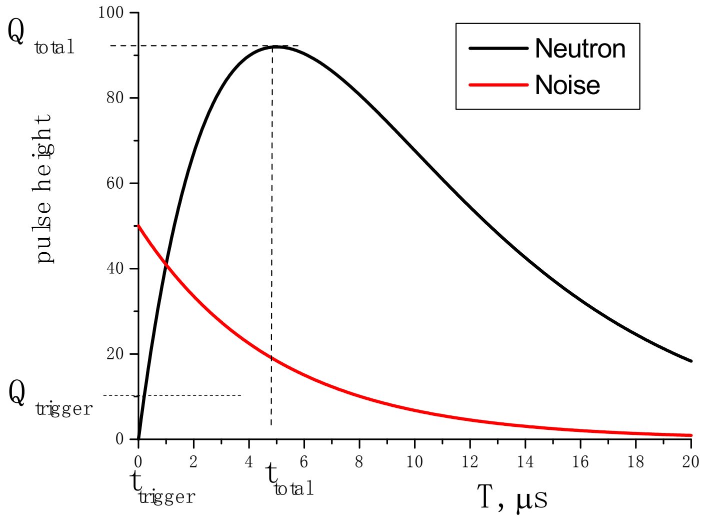
ZnS(Ag)+$^{10}B_2O_3$

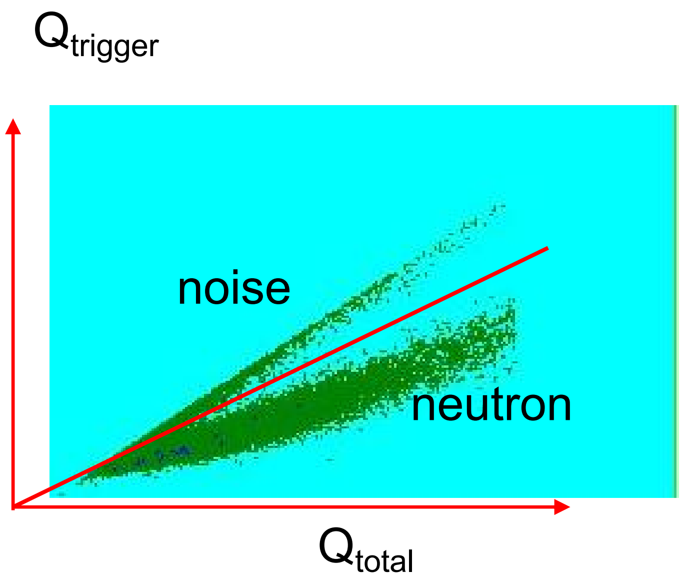


PRISMA(PRImary Spectrum Measurement Array)

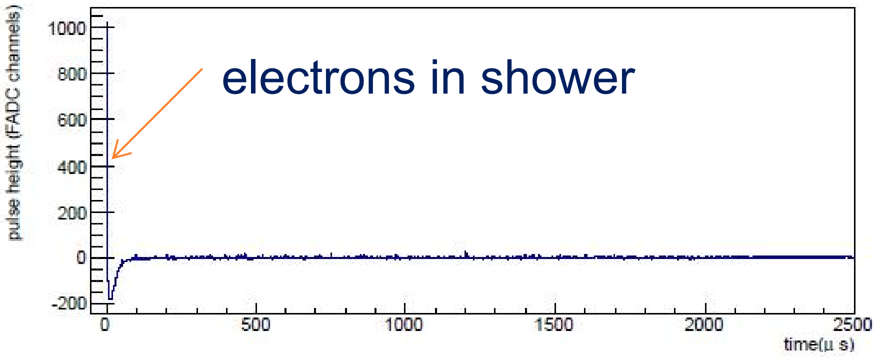
Nucl. Phys. B (Proc. Suppl.), 196, (2009), p. 293-296.

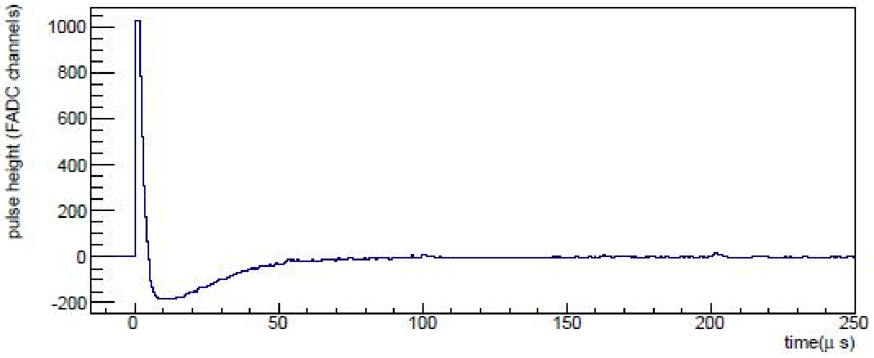
neutron / noise separation

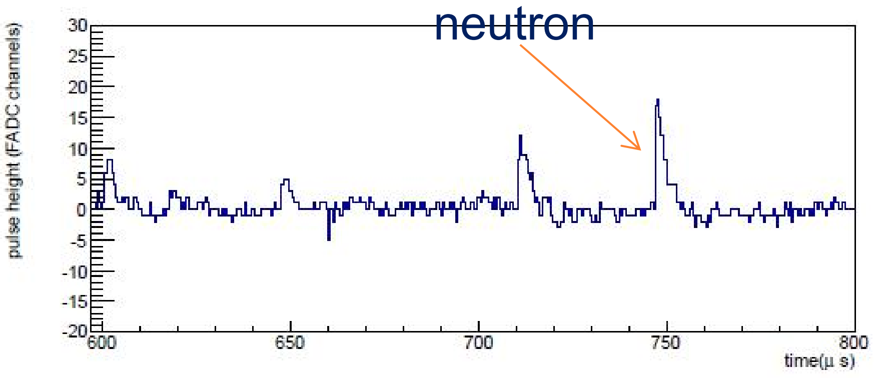




electrons / neutron separation in one shower

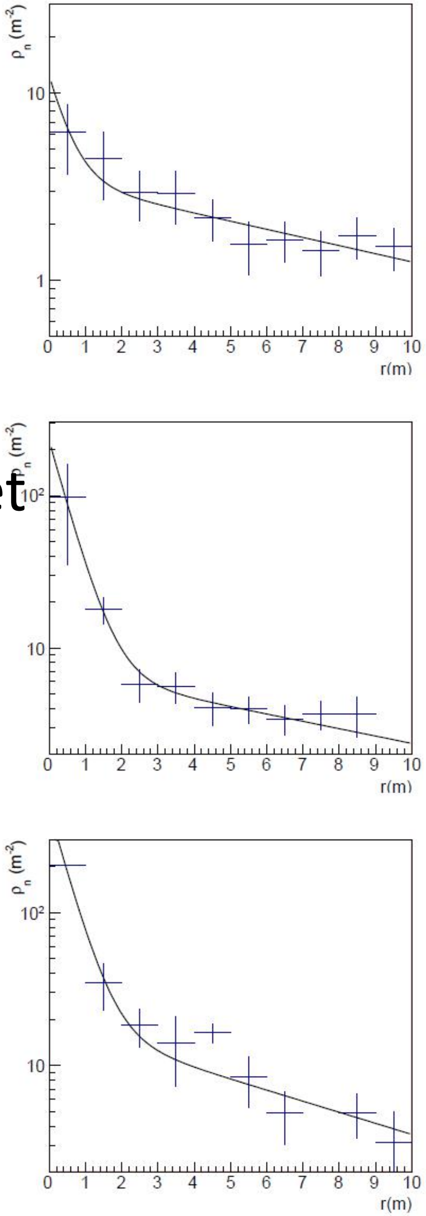






3. Early study at high altitude

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



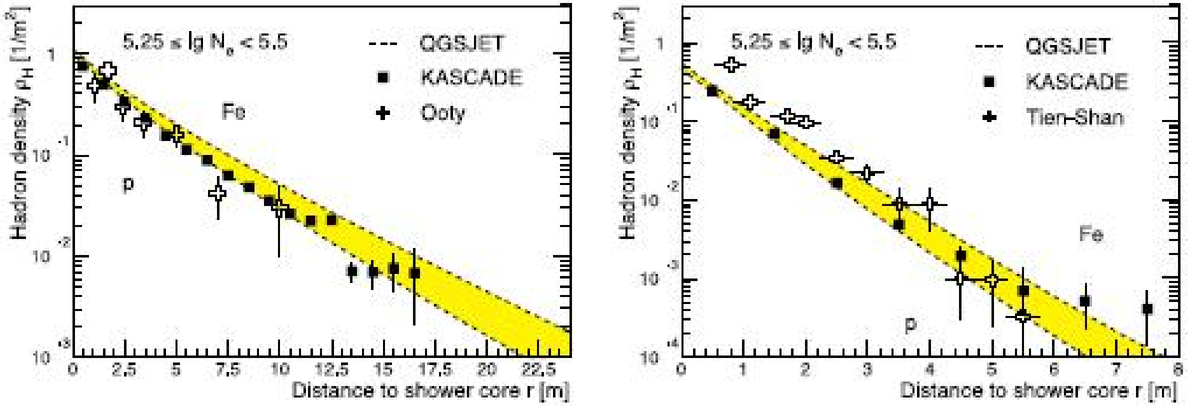
thermal neutron lateral distribution

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

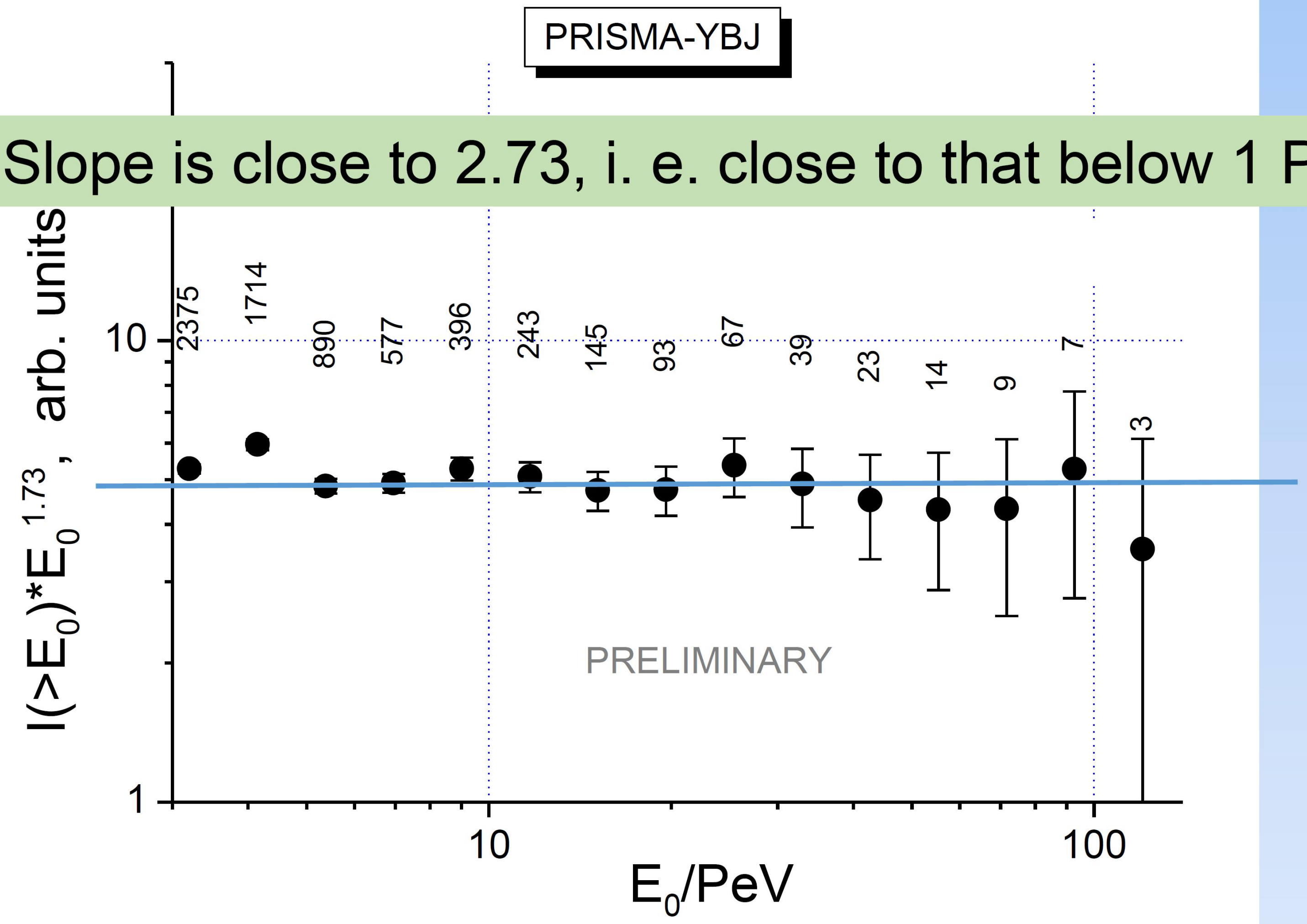
hadron lateral distribution, KASCADE HCAL, sea level



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

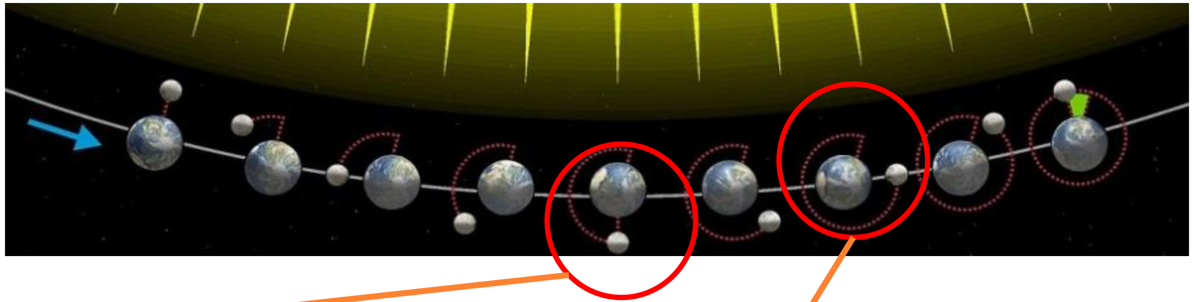
Result of PRISMA-YBJ from Nn measurement

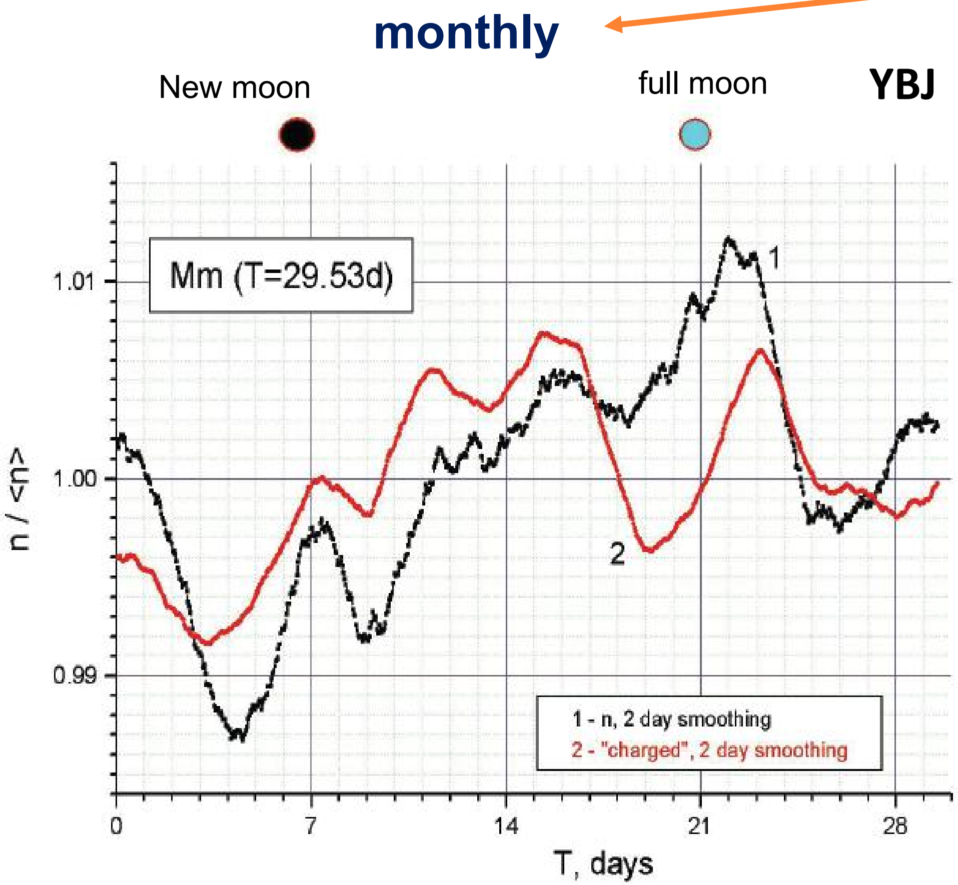
Slope is close to 2.73, i. e. close to that below 1 PeV

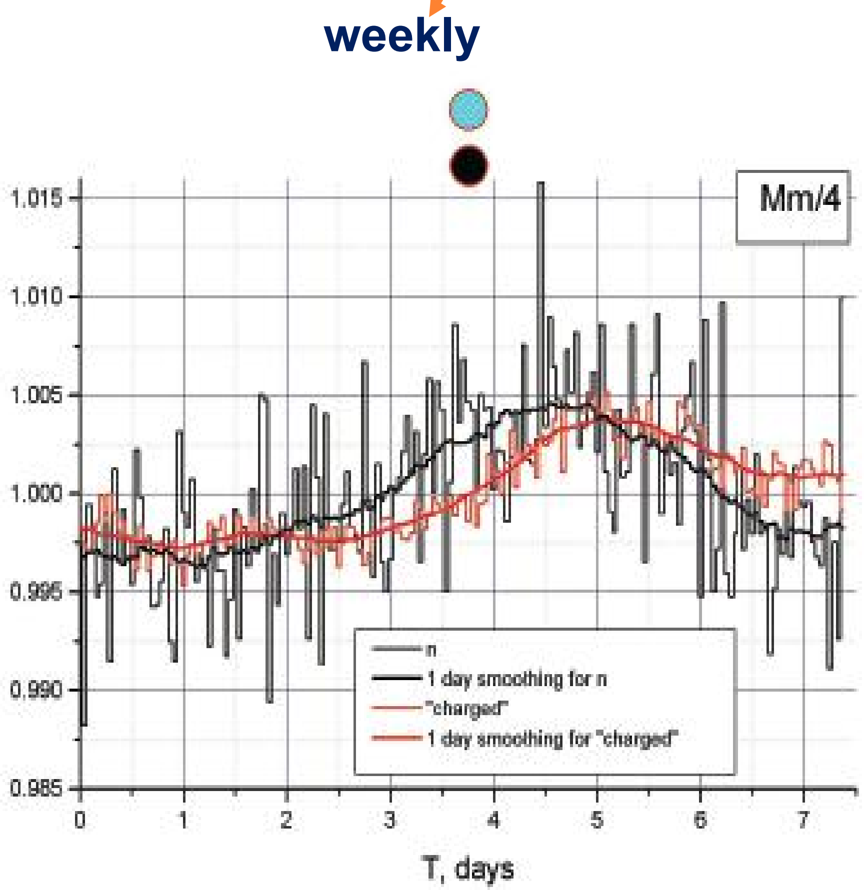


Our preliminary result indicates that no significant slope changing above 3PeV

lunar tidal effect



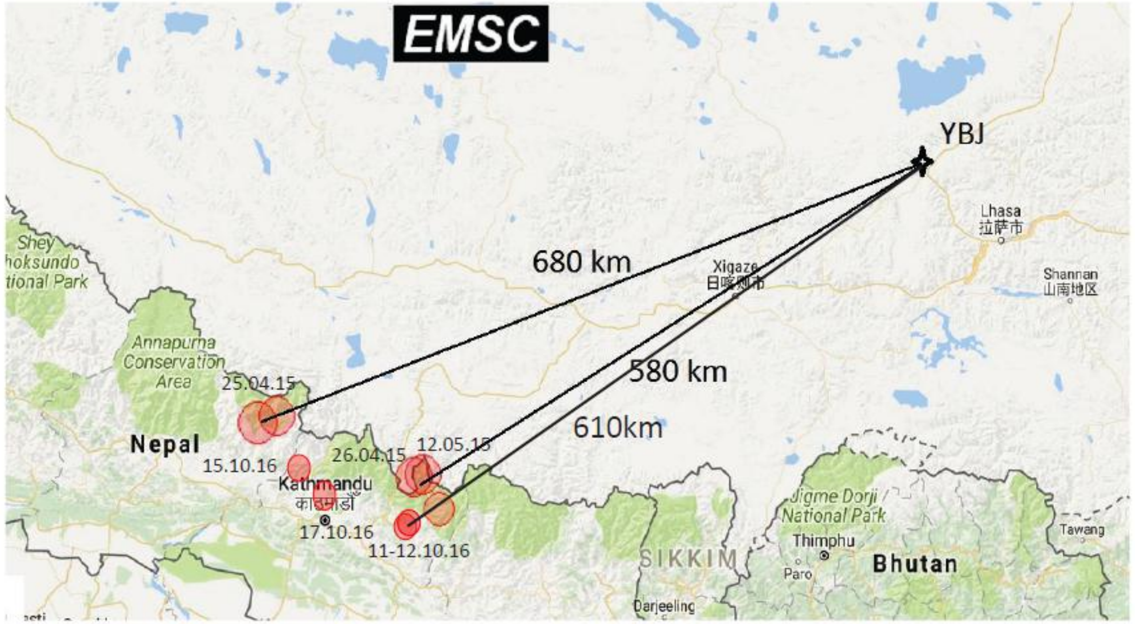


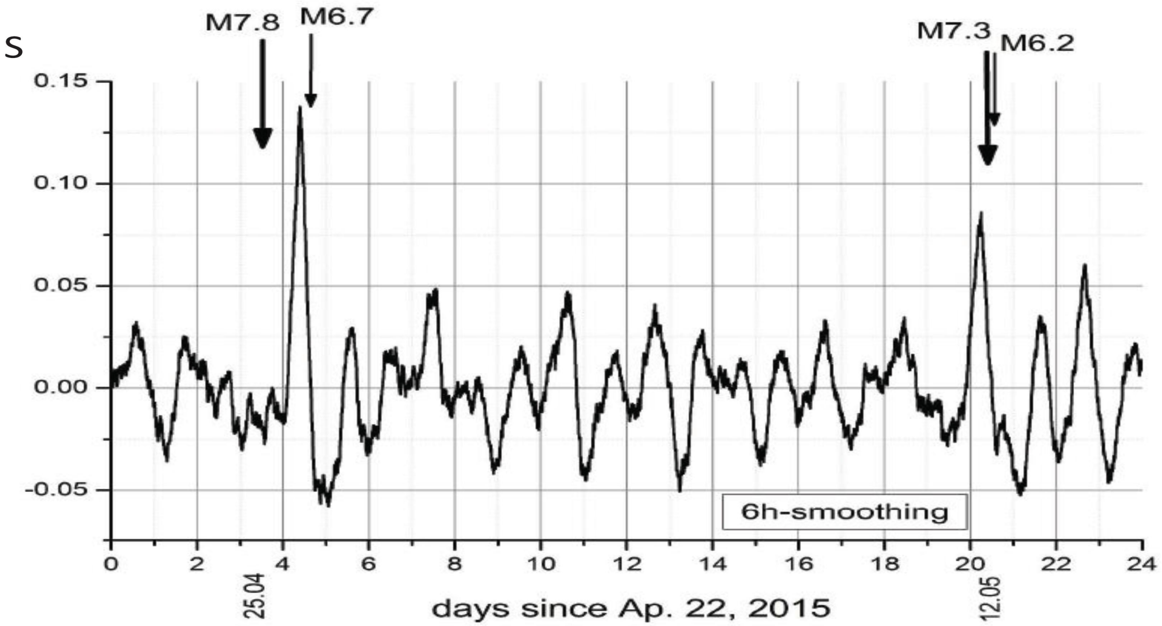


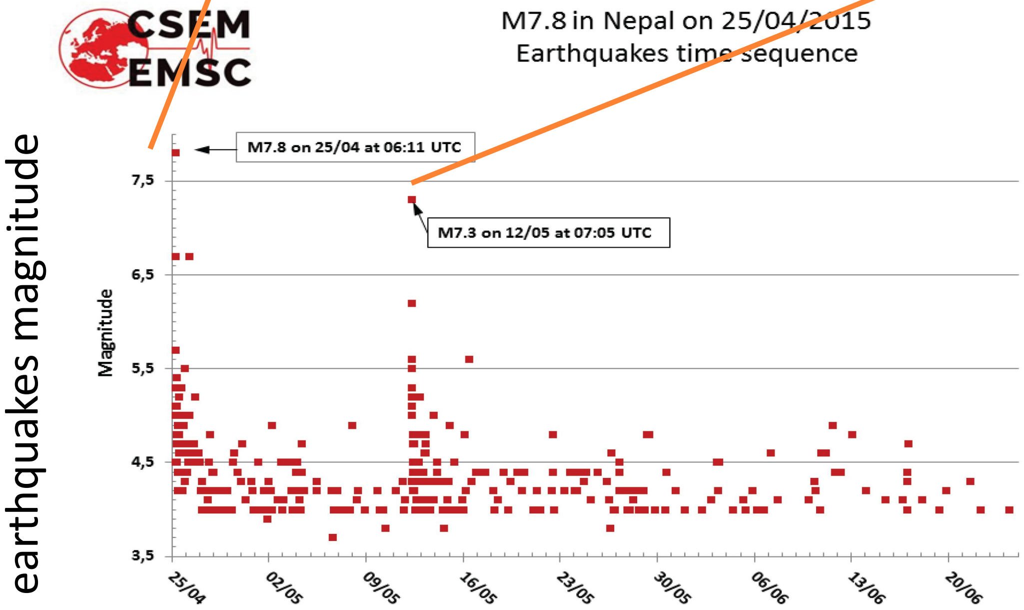
superimposed epoch analysis

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

Response of PRISMA-YBJ to 2015 Nepal earthquakes



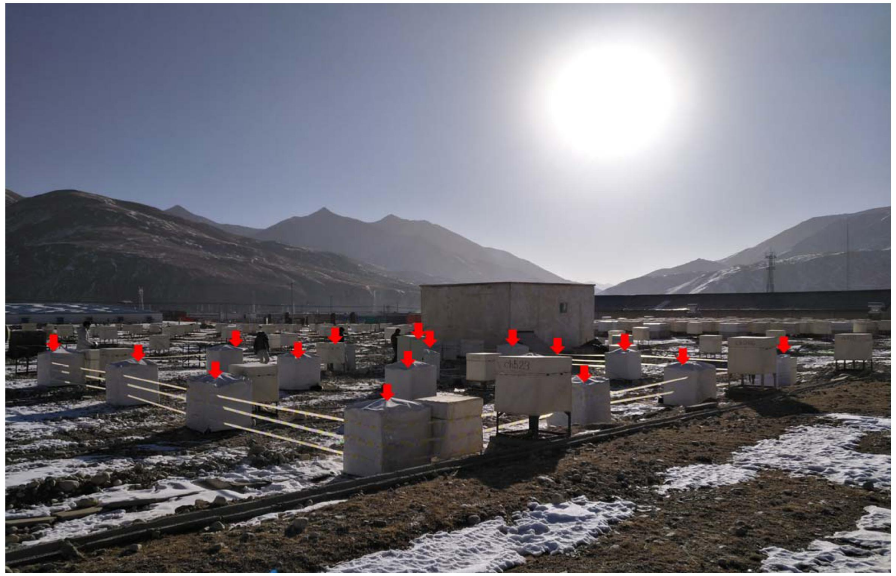


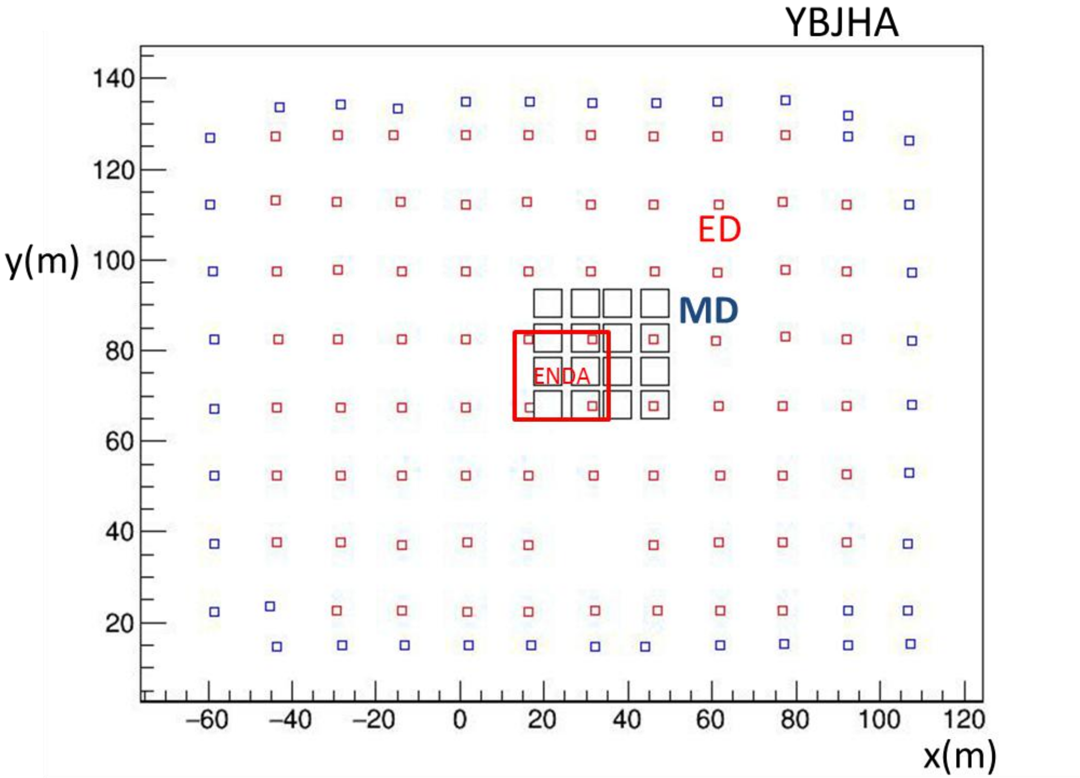


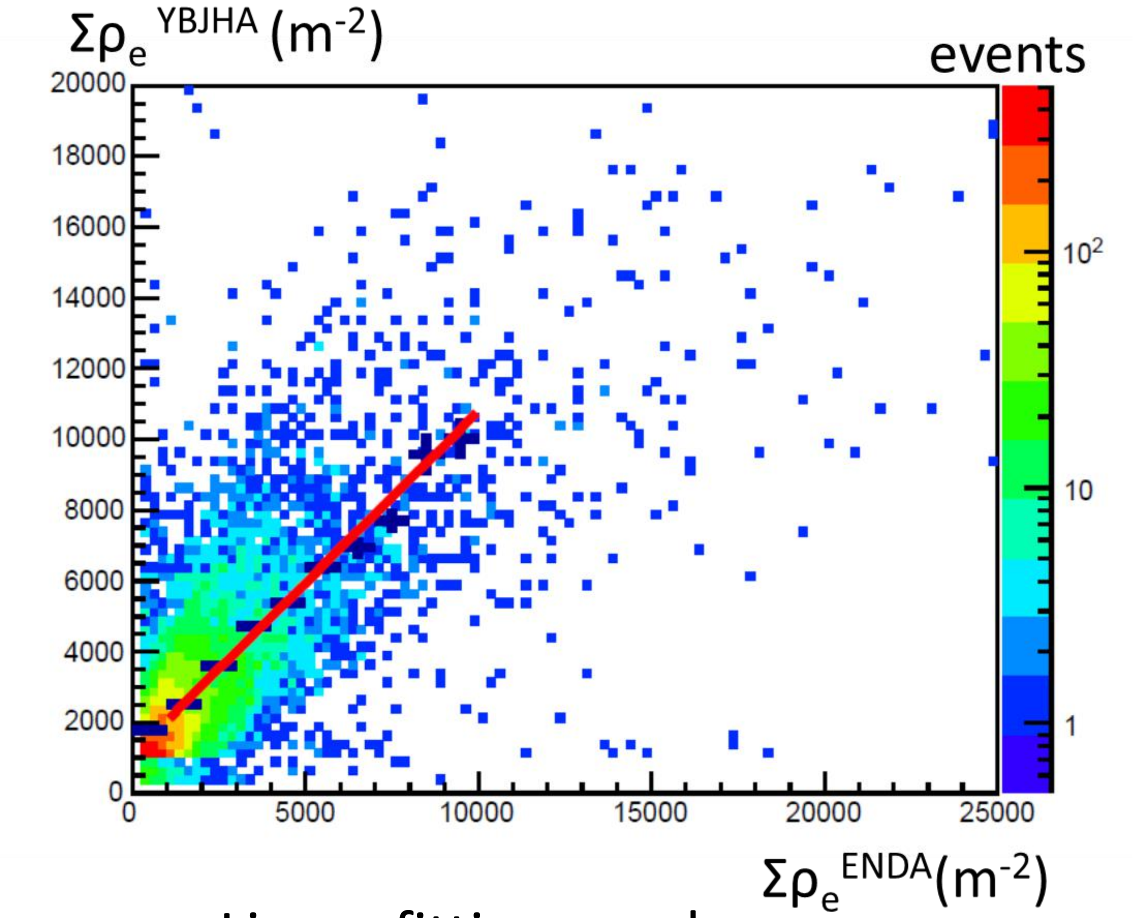
Journal of Environmental Radioactivity 208-209 (2019) 105981

PRISMA-16 at Tibet University and Yangbajing

2017 JINST 12 P12028



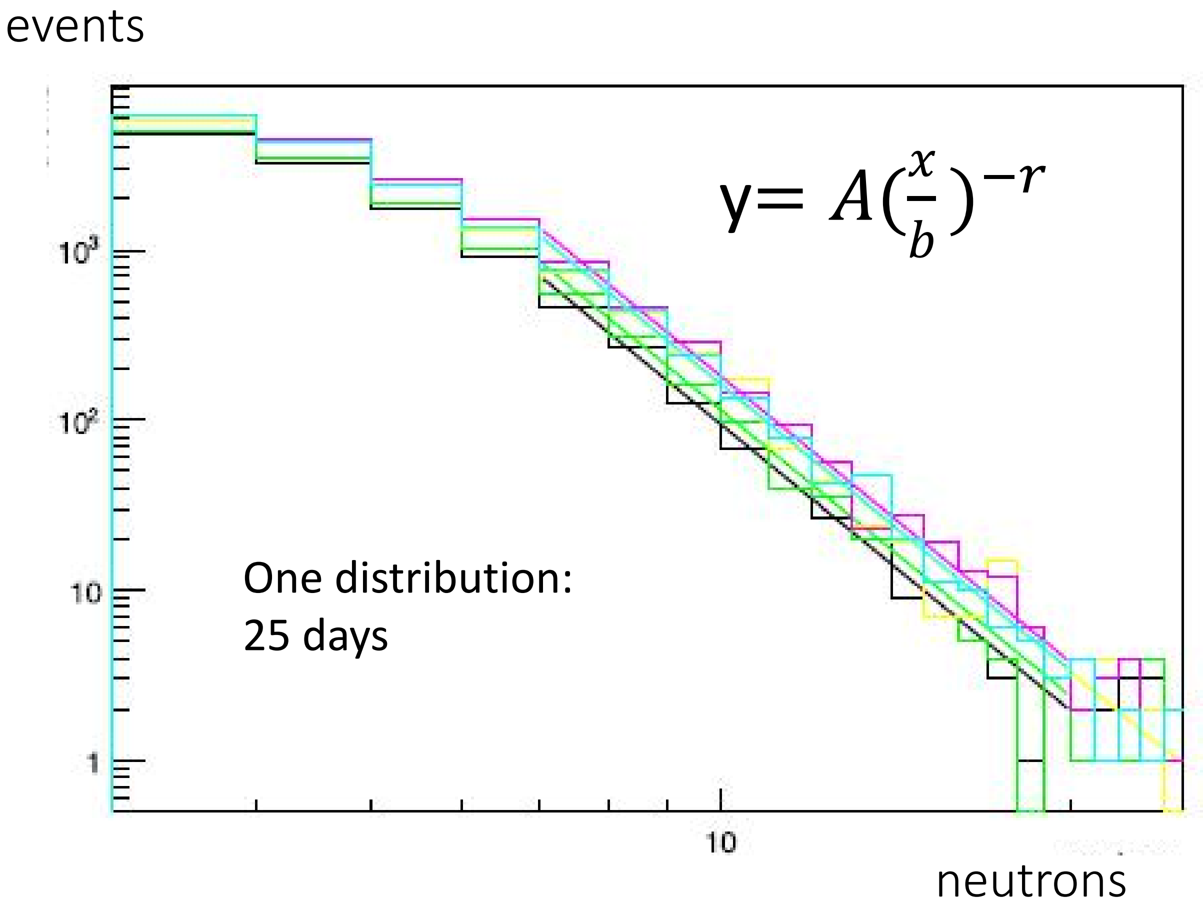


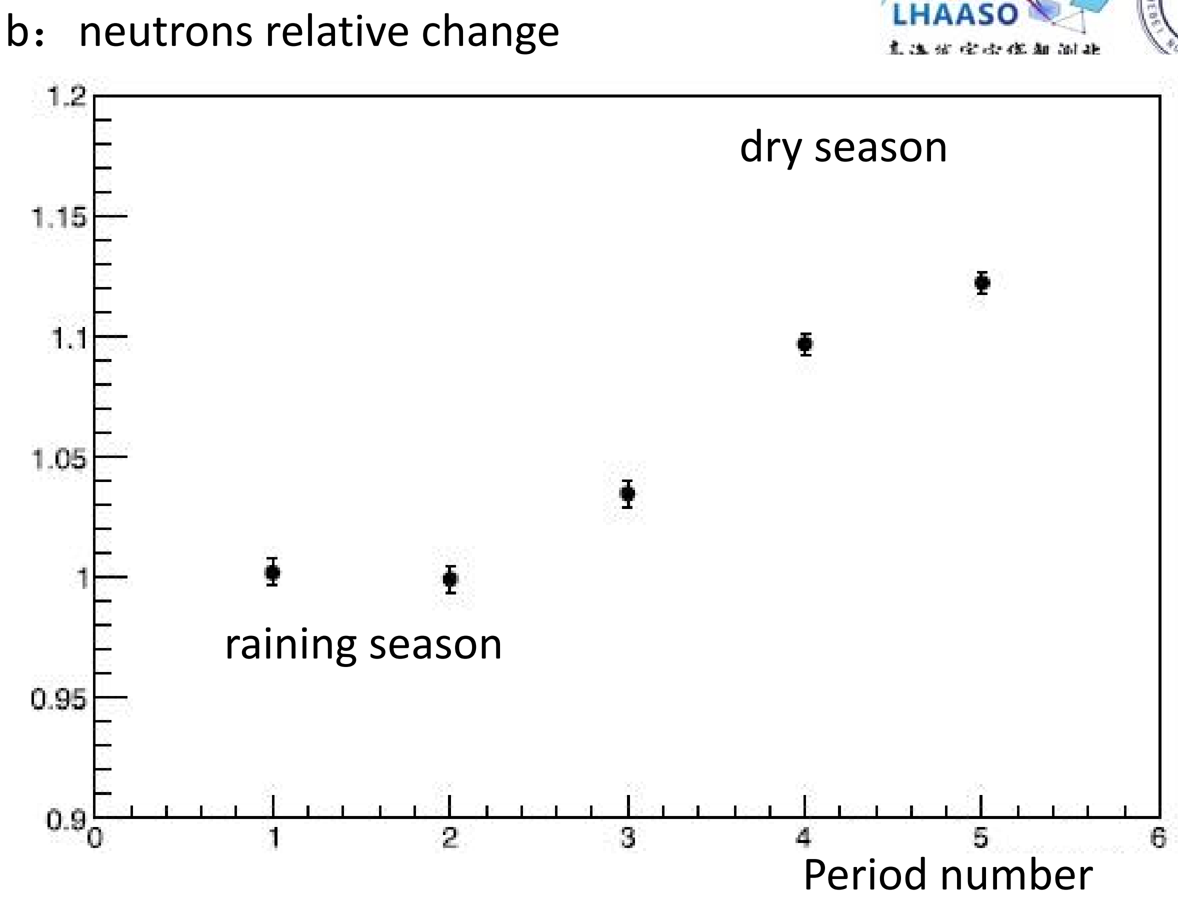


Linear fitting y=a+bx

b=0.97±0.02

a=1099±43

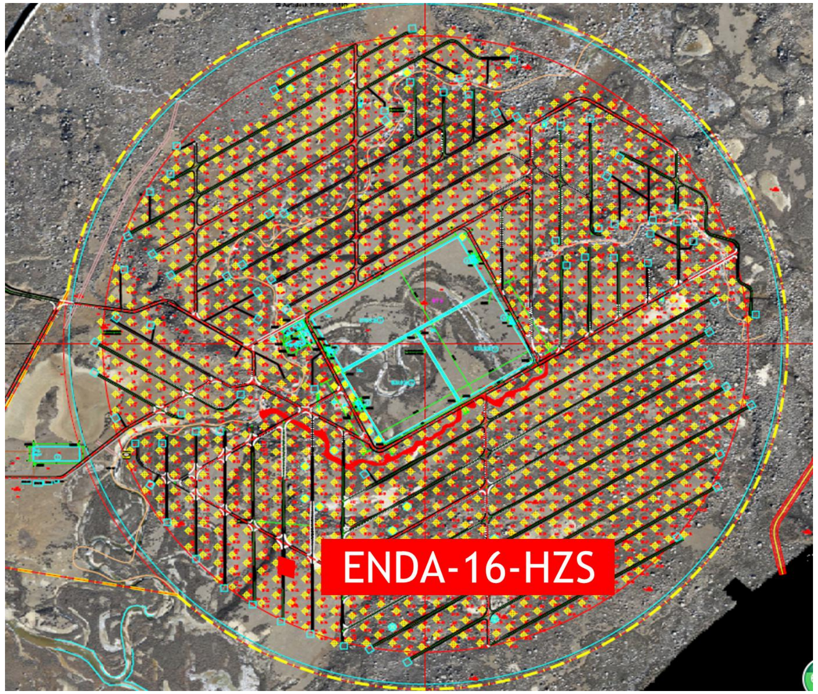




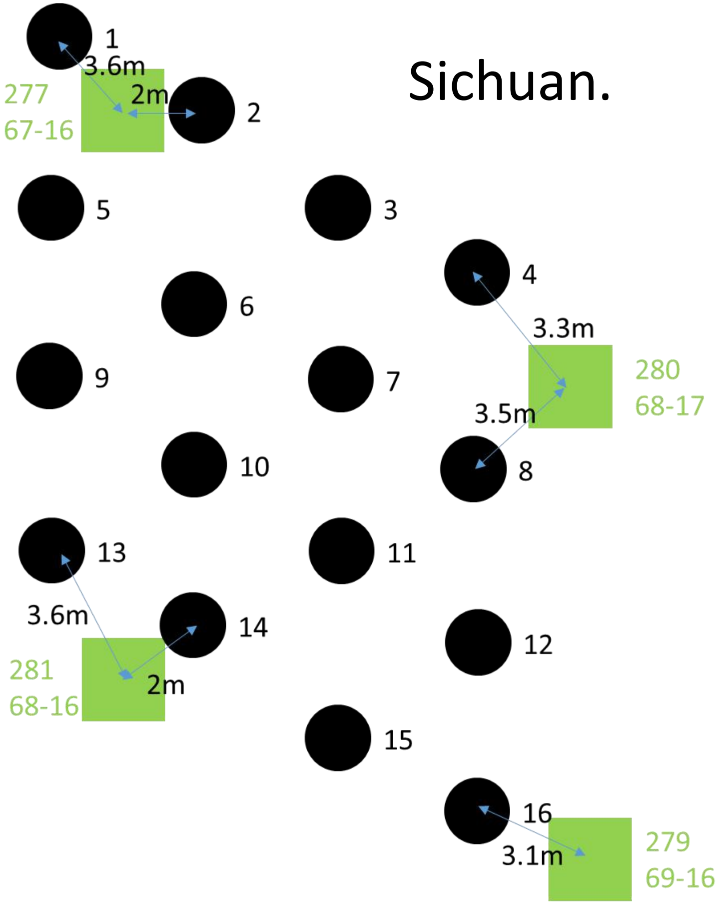
Neutrons in rain season are 10% less than ones in dry season because more water in soil.

Astrophysics Space Science (2020) 365:123

4. ENDA (EN-Detector Array) in LHAASO

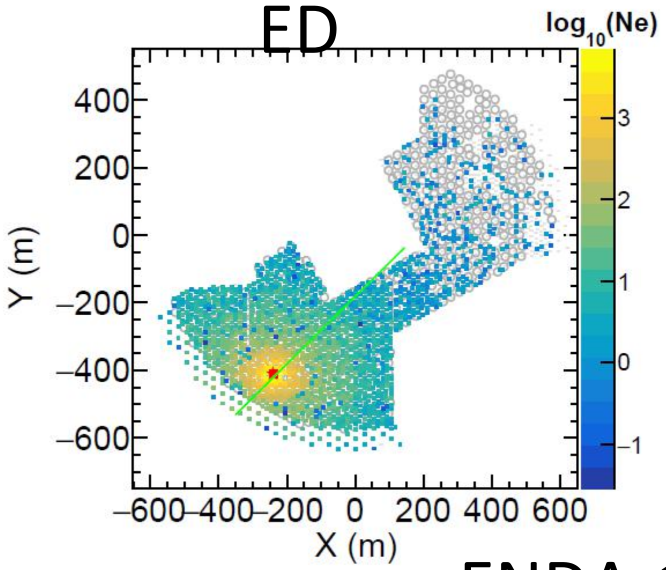


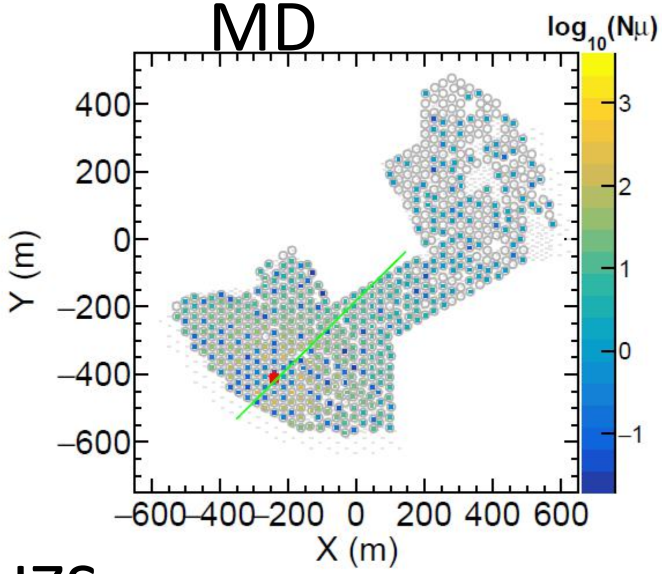
In 2019, a cluster so called ENDA-16-HZS was installed at LHAASO in Haizishan (HZS), Sichuan.

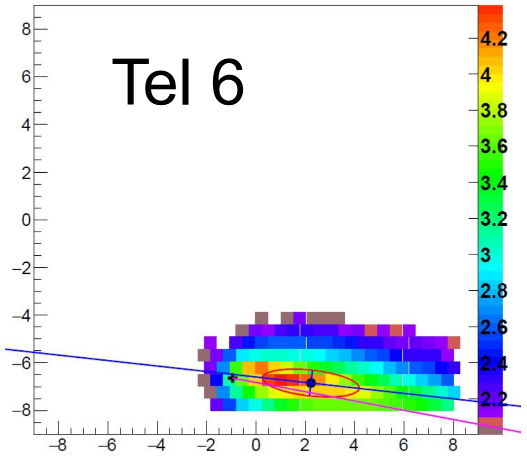


One Coincident event 1

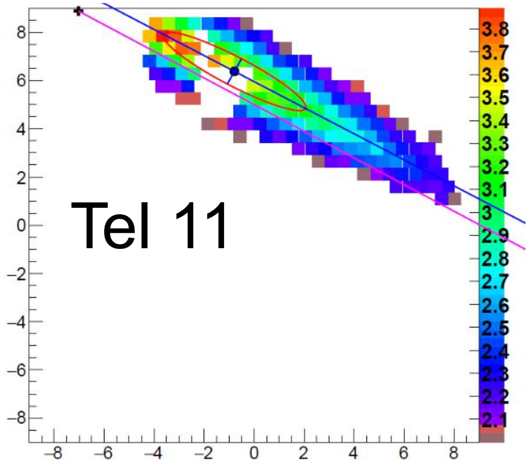
20210205_event4531

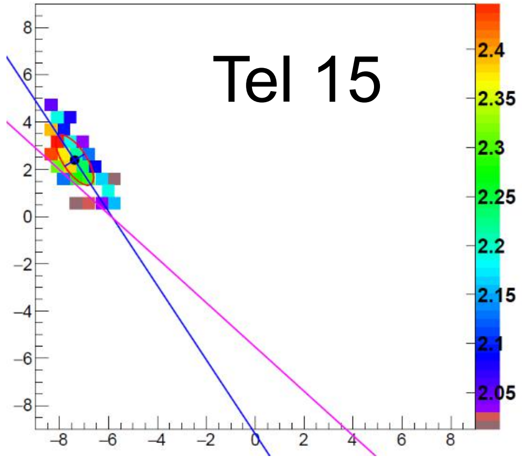




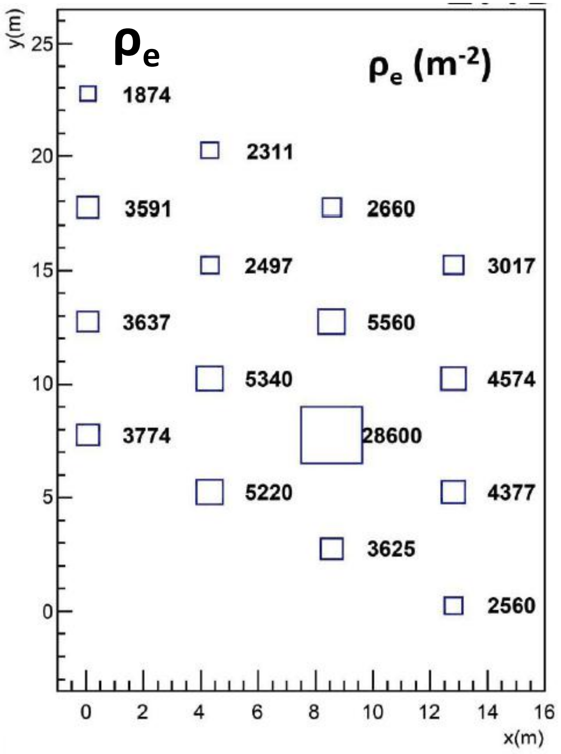


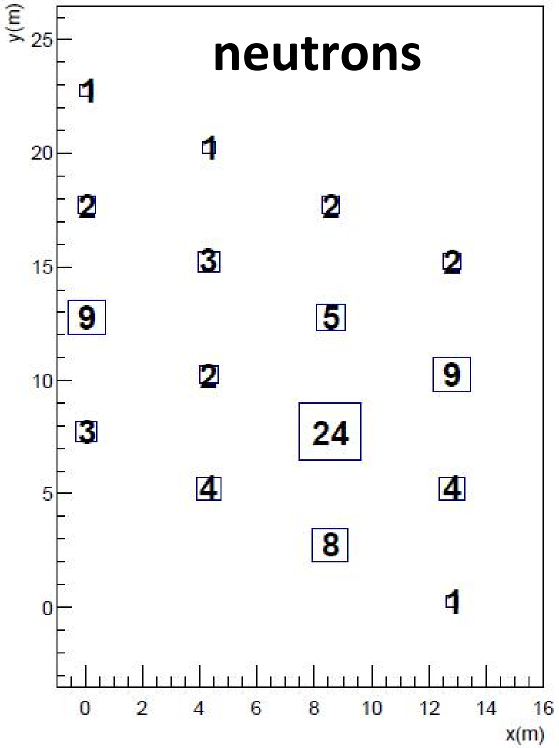
WFCTA

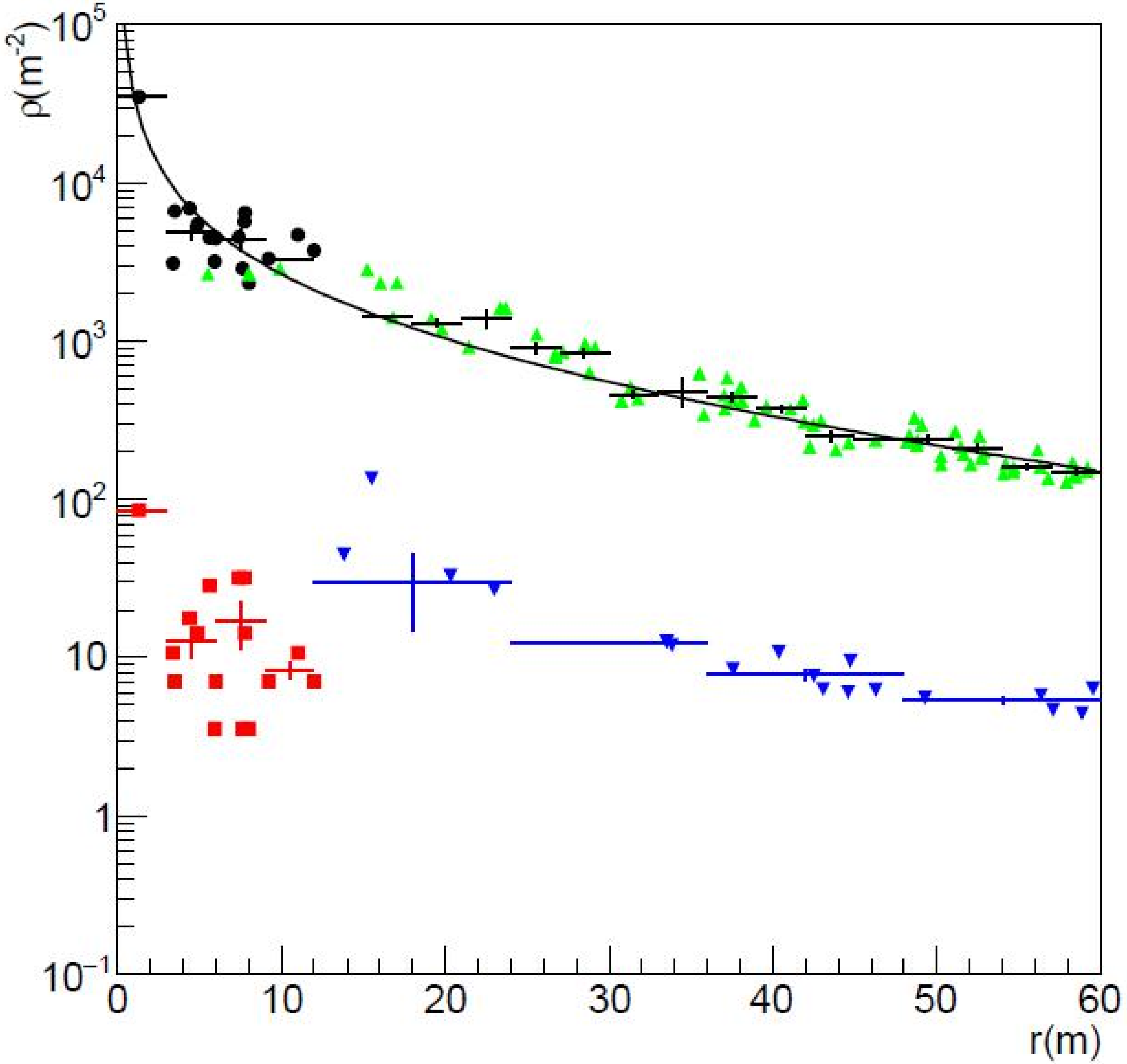




ENDA-16-HZS







Lateral distribution of the coincident event.

Red square: neutrons by ENDA.

Blue triangle: muons By KM2A-MD.

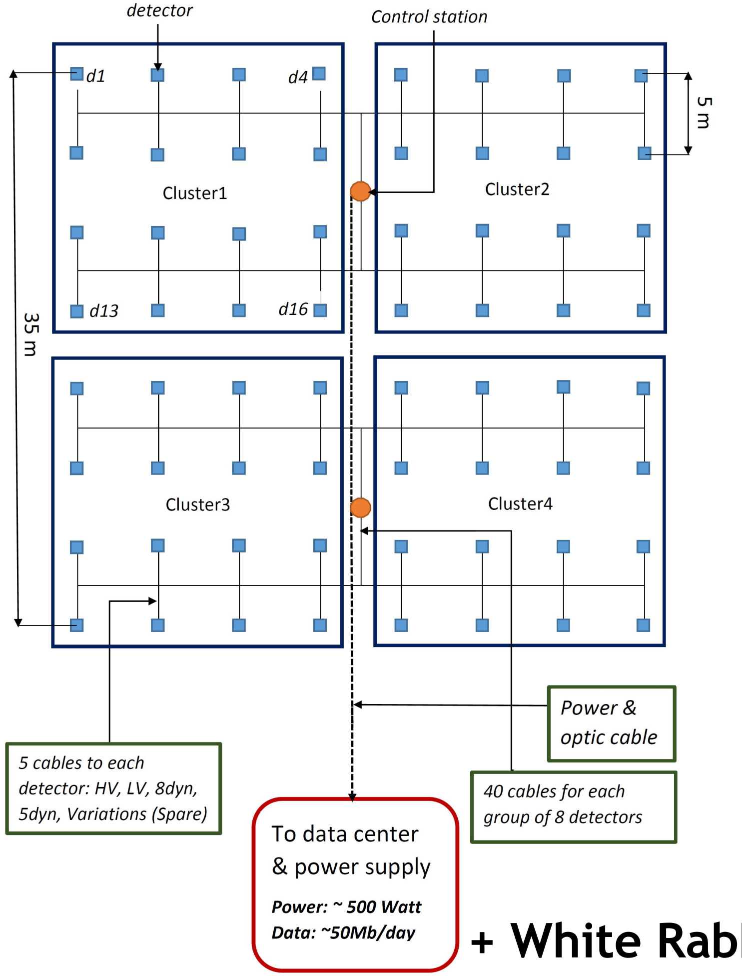
Black dot: electrons by ENDA.

Green triangle: electrons by KM2A-ED.

The black line is NKG function fitting.

64 EN-detectors are made and will be added into LHAASO.

ENDA-64 (1100m^2)

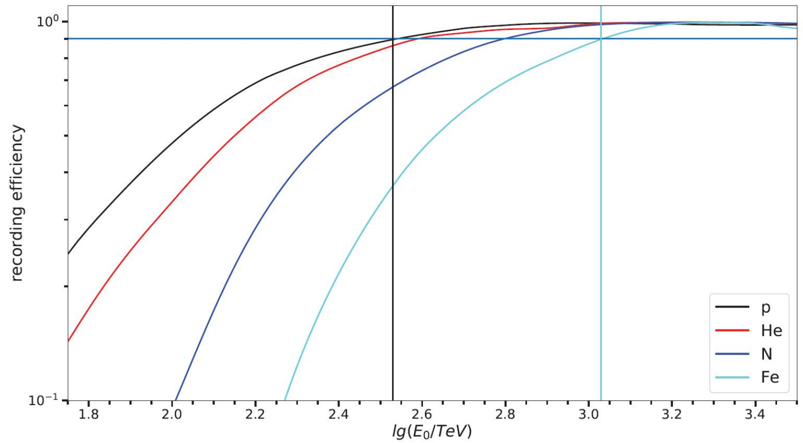


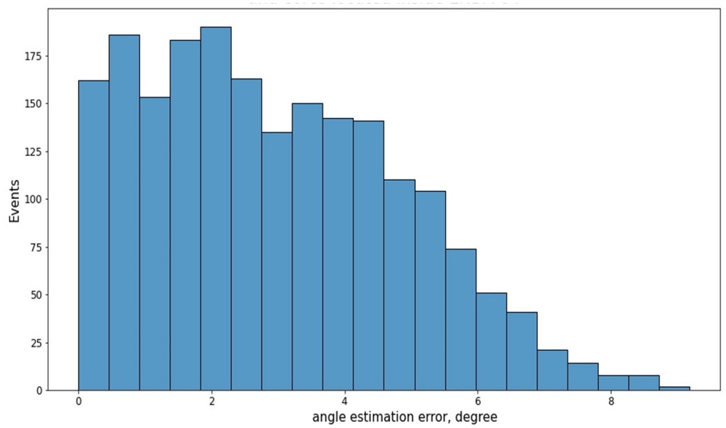
+ White Rabbit clock system

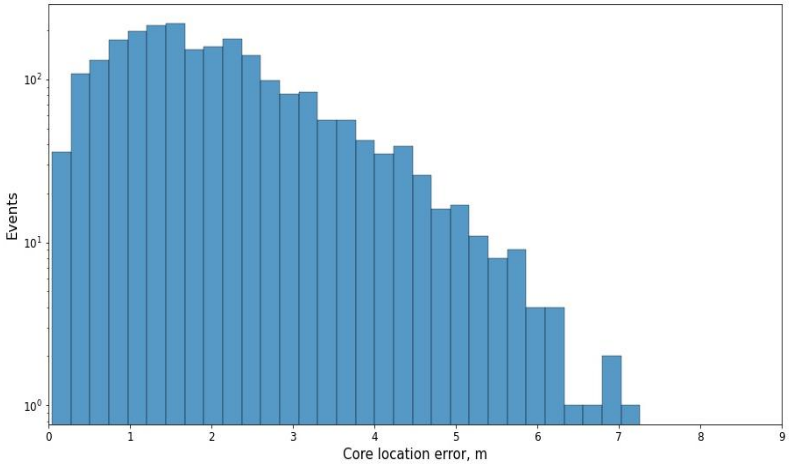
Bulletin of the Russian Academy of Sciences: Physics, 2021, Vol. 85, No. 4, pp. 405–407

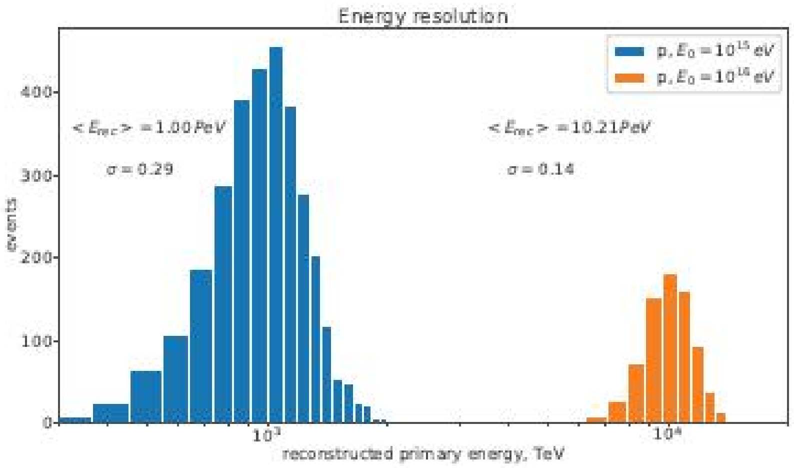
EN-detectors at Hebei Normal University
FADCs are made by Sichuan University

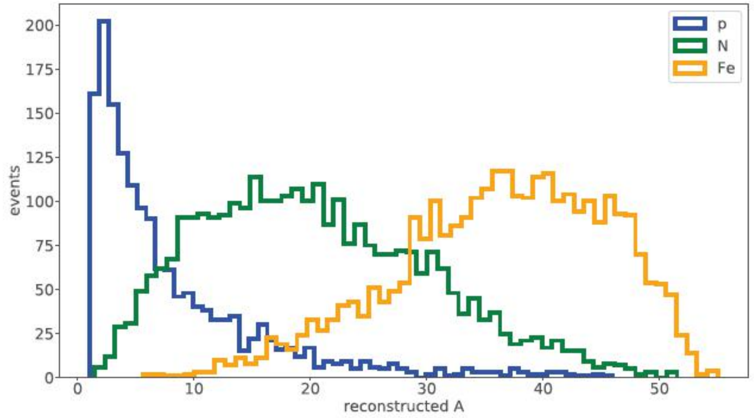
ENDA-64 simulation











At 1PeV

Efficiency: 90%

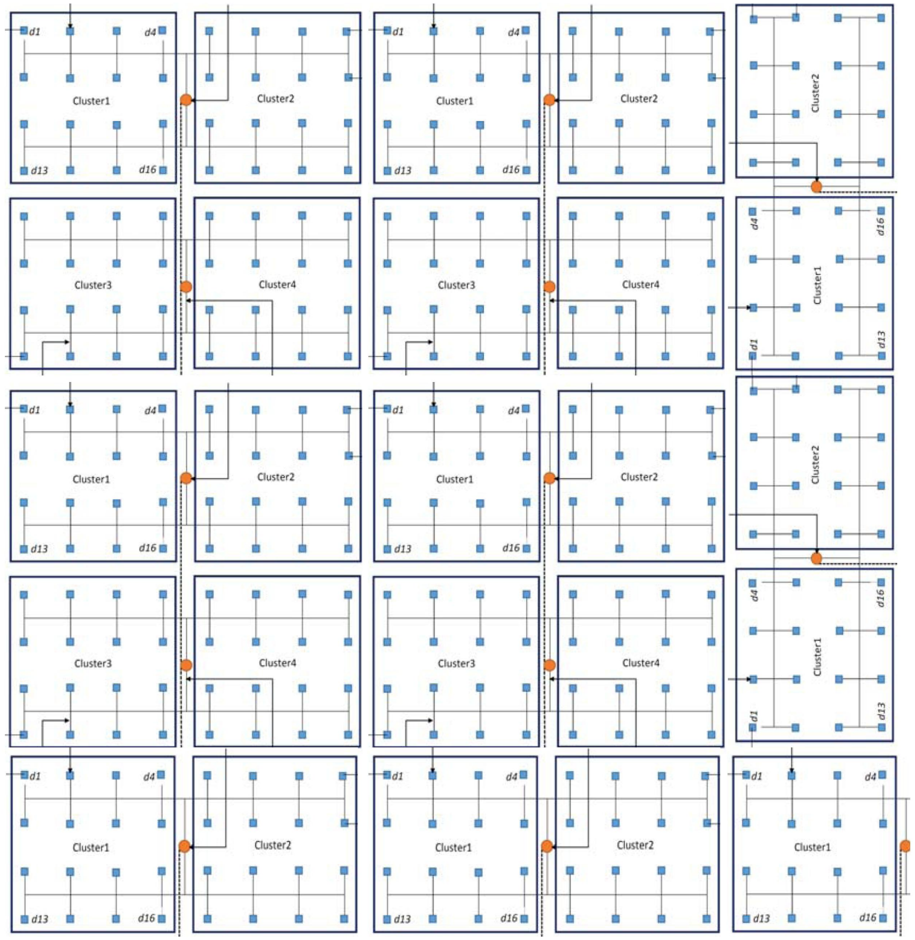
Angular resolution: 4º

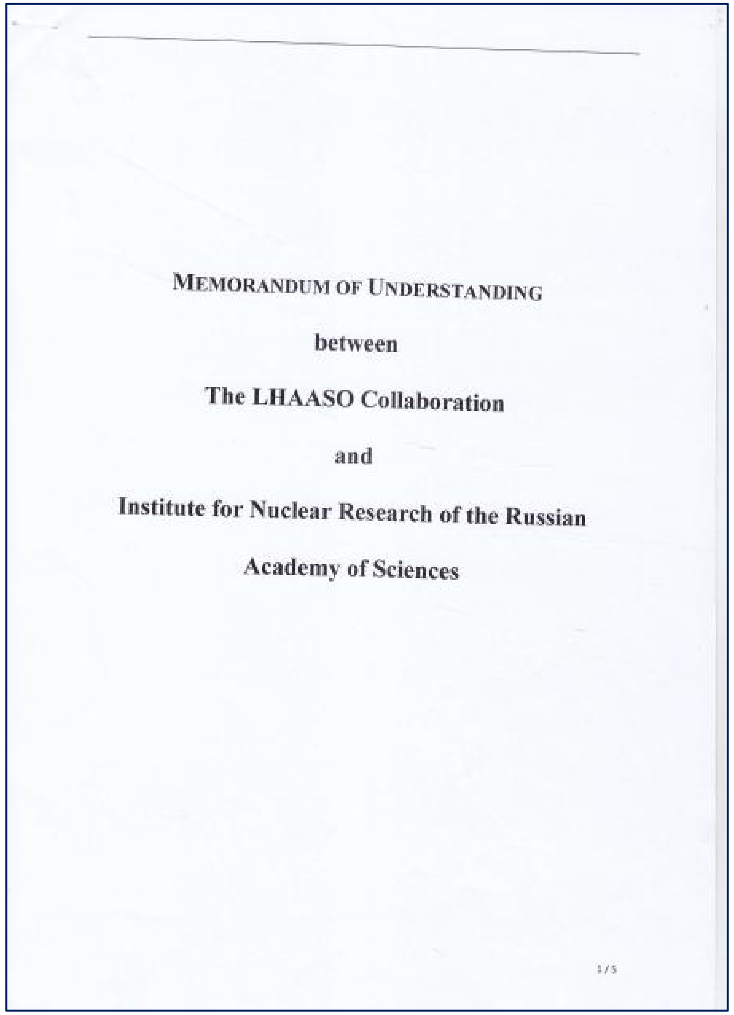
Core position resolution: 3m

Energy resolution: 30%

ENDA-400: written into MoU

ENDA-400 ($10000 m^2$)





MEMORANDUM OF UNDERSTANDING

between

The LHAASO Collaboration

and

Institute for Nuclear Research of the Russian Academy of Sciences

1/5

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

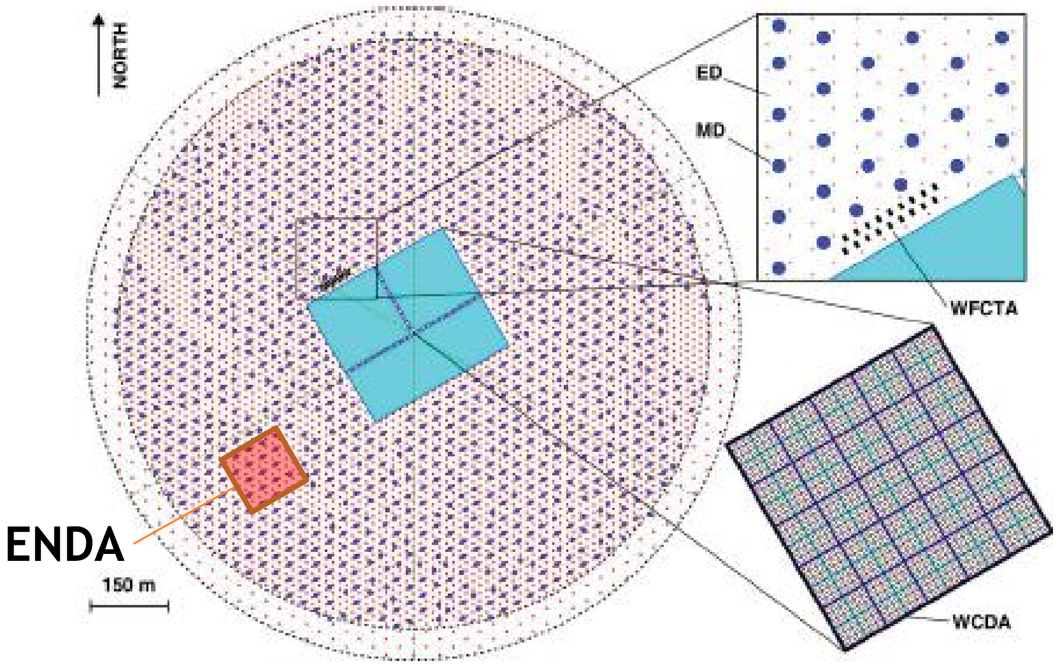
This Memorandum of Understanding is prepared in English only. It has been prepared and signed in two copies, one for each Party.

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	Mar. 25 2019

4/5

LHAASO at the knee region

- ED : e
- MD, WCDA: μ
- WFCTA: Č
- WCDA++: γ family at core →h0
- **ENDA: thermal neutrons →h+h-**



→ ***Full particle measurement of cosmic showers!***

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

Thanks!