Thermal neutron background variations at high altitudes

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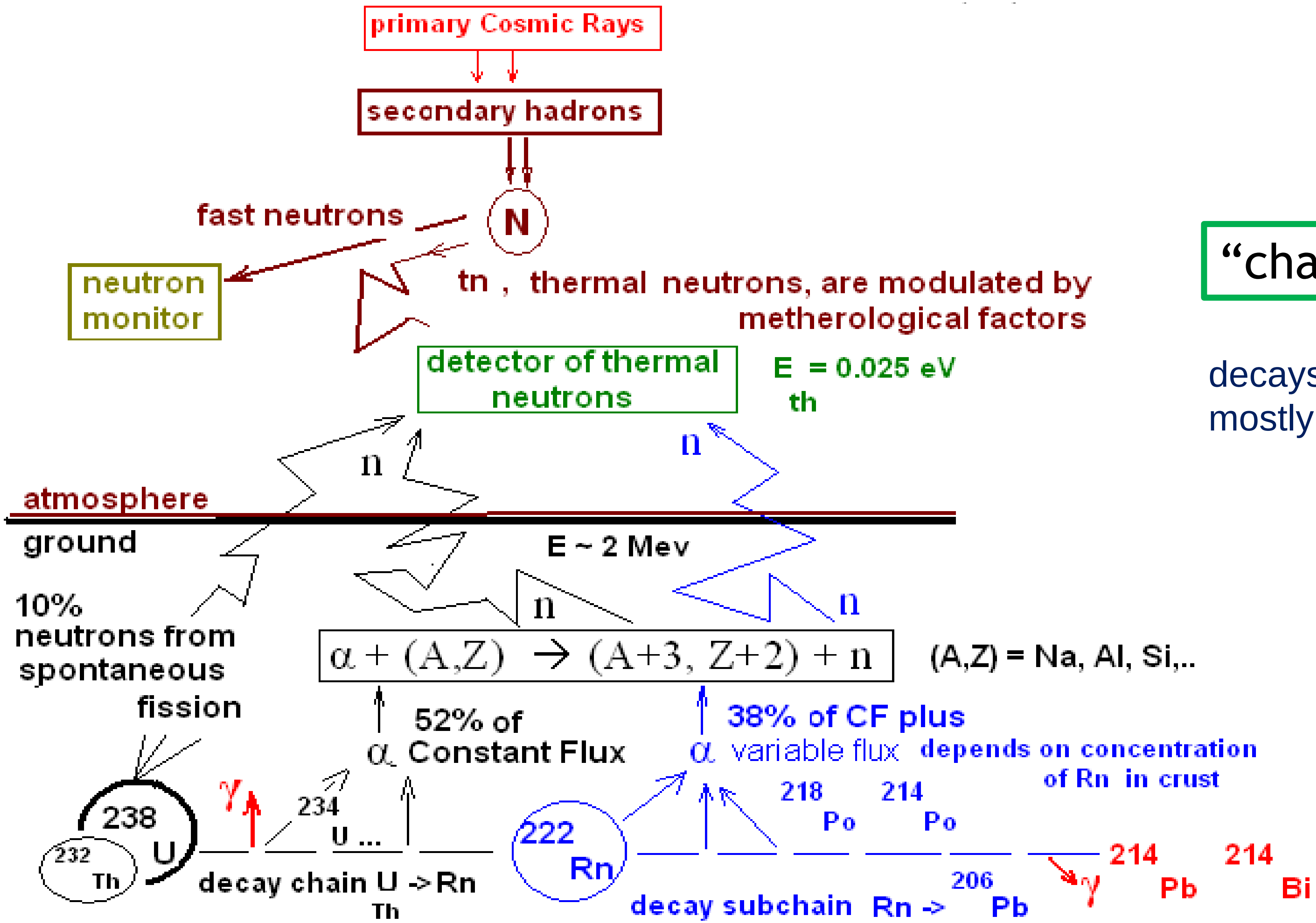
The 9th international Workshop in Air Shower Detection at High Altitudes (WASDHA)

2018, Moscow

outline

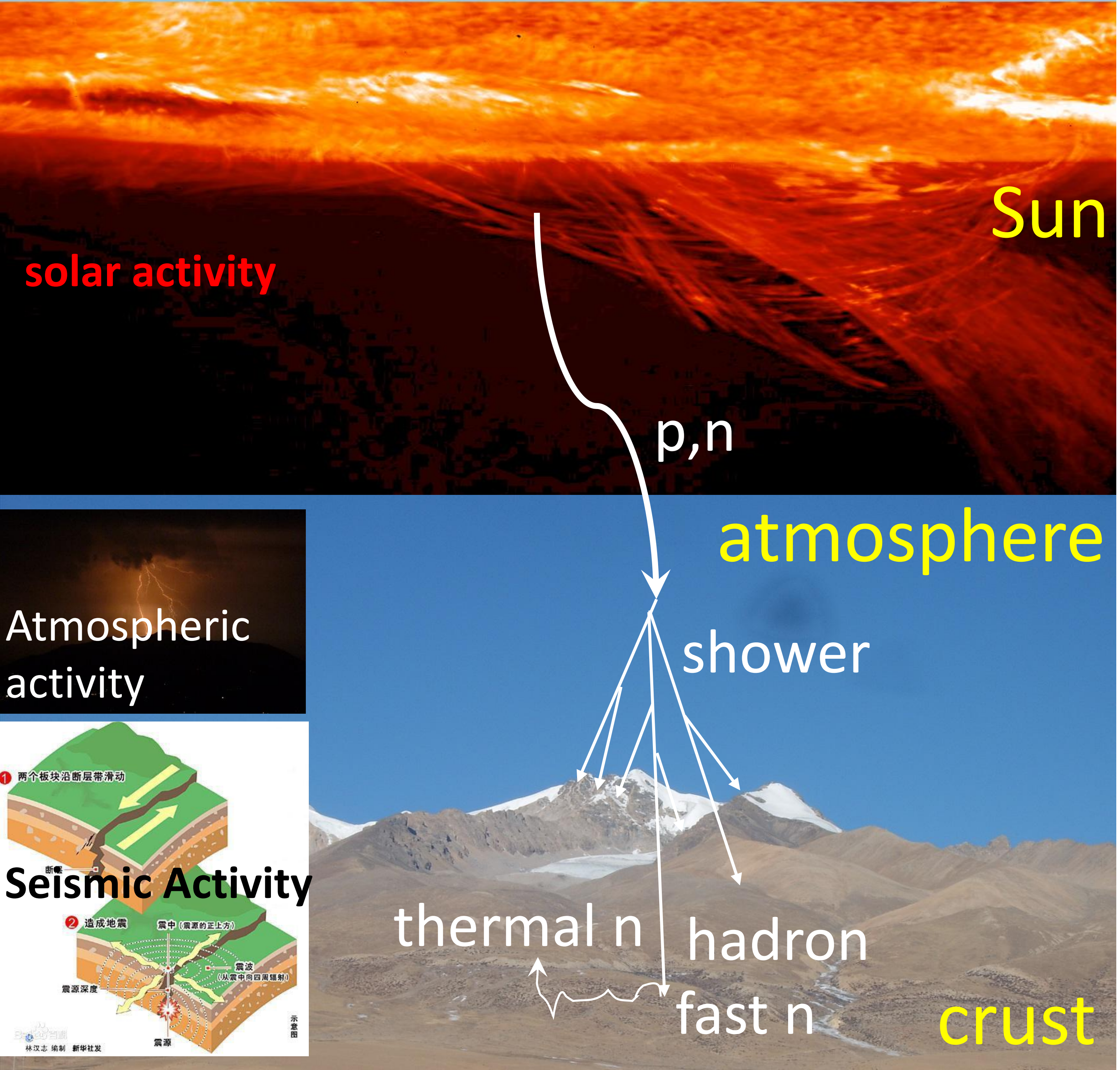
1. Physical motivation
2. EN-detector and arrays
3. physical results
4. Summary and action in LHAASO

Thermal neutron variation as background



“charged”

decays of Rn chain in air, mostly Bi-214 and Pb-214



1. Physical motivation

both charged and thermal neutron background variation can be disturbed by external “sources”

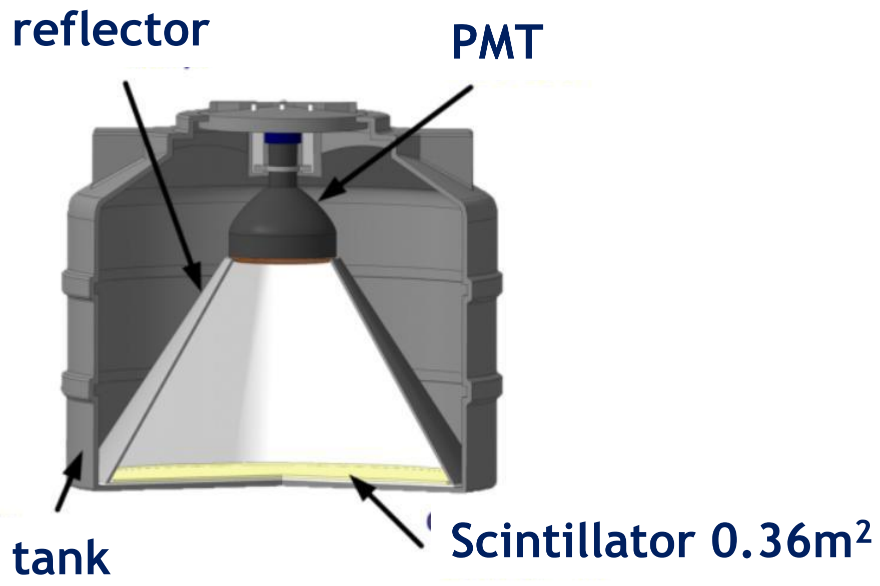
→

- **Solar physics**
- **Atmospheric physics**
- **Geophysics**

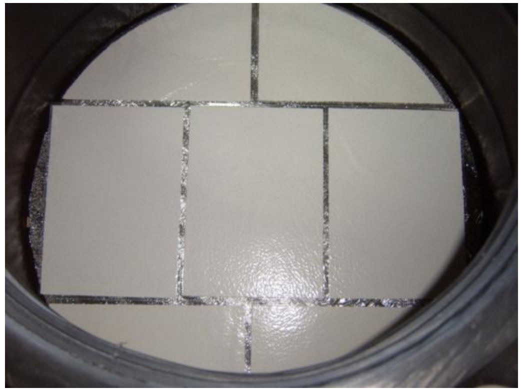
2. EN-detector

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

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



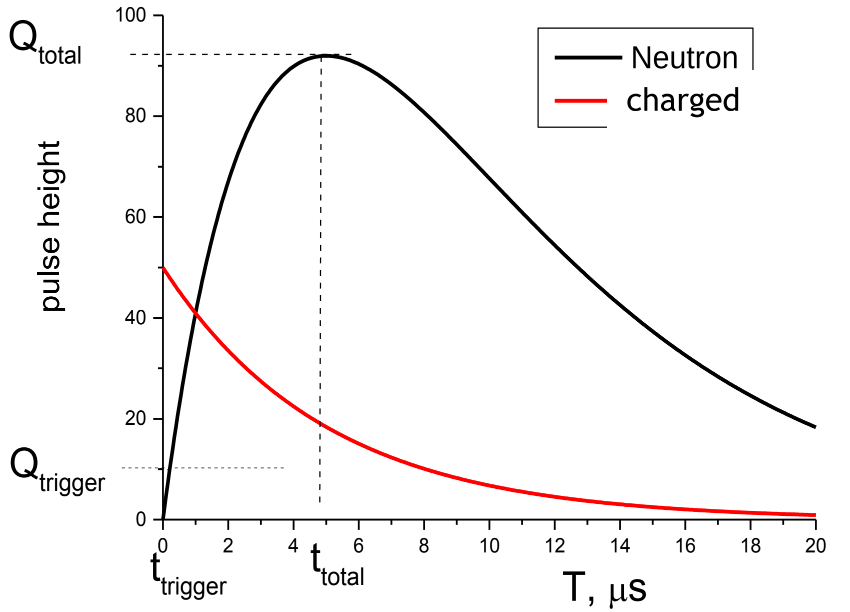
Thermal neutron recording efficiency ~20%
Scintillator effective thickness 30 mg/cm^2

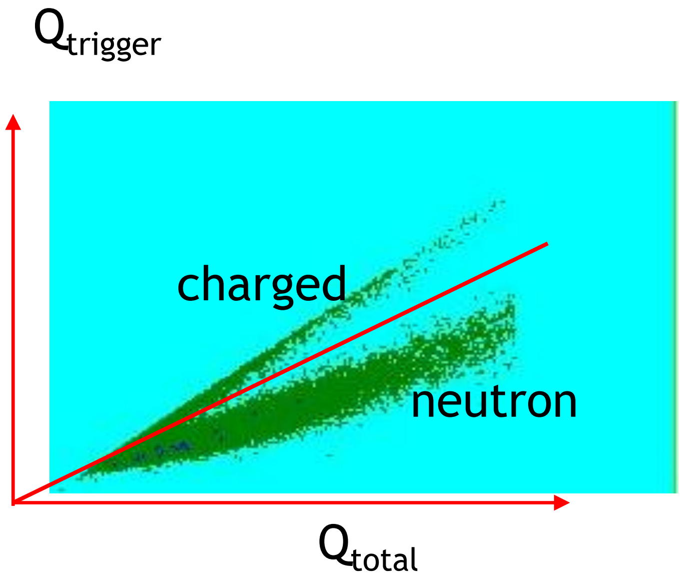


ZnS(Ag)+^{6}LiF

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

neutron / charged separation





Global net of EN-detectors

Single particle mode

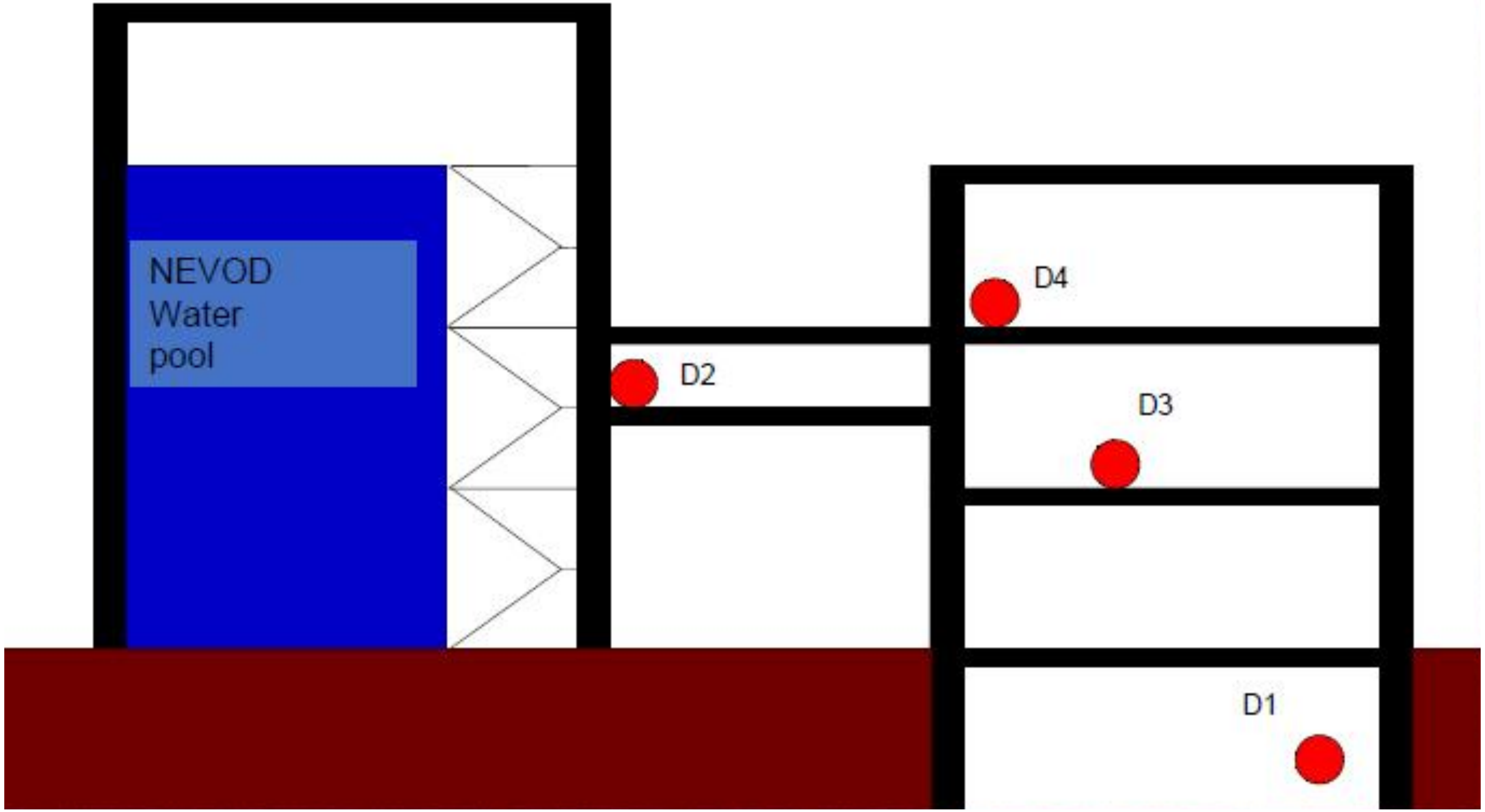
“n–BNO” array at Baksan

inside a concrete hangar

apart of NM

above neutron monitor

"Neutron" Array at MEPhI (Moscow)



PRISMA-YBJ(2013-2017) → PRISMA-TU(2017-now)

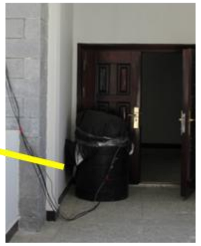
The ARGO-YBJ hall

Scaler mode

Tibet University

D3, 第四层 the 4th floor

D4, 地面, ground

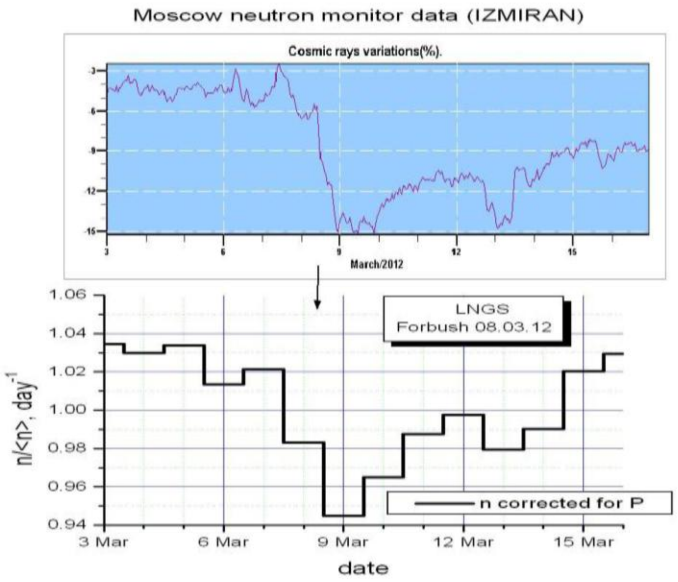


D2, 第二层, the 2nd floor

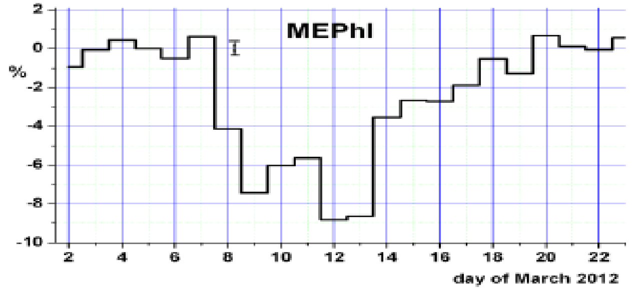
D1, 第一层, the 1st floor

3.1 Solar physics

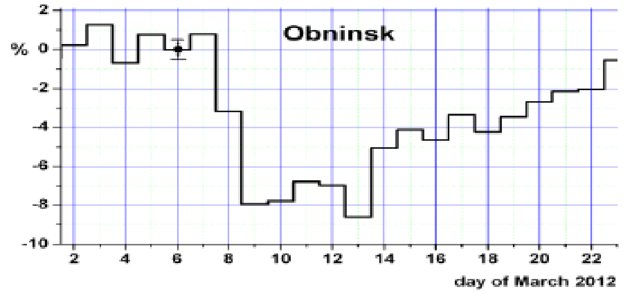
3.1.1 Forbush decrease

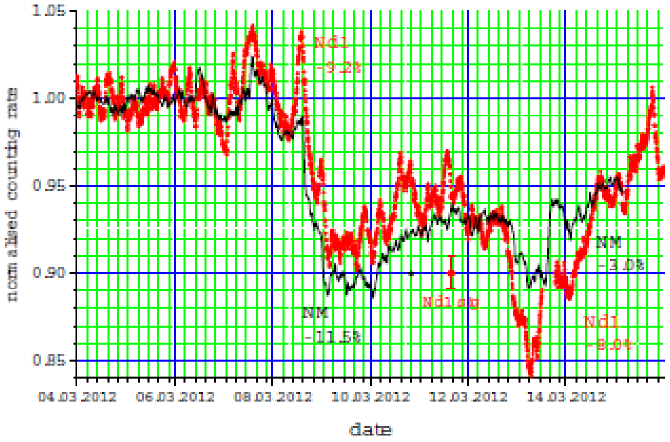


One Forbush decrease on March 8, 2012 detected by (from top to bottom) (1) Moscow neutron monitor, (2) Gran Sasso (Italy), (3) MEPhI (Moscow Engineering Physics Institute) and (4) Obninsk (Moscow).



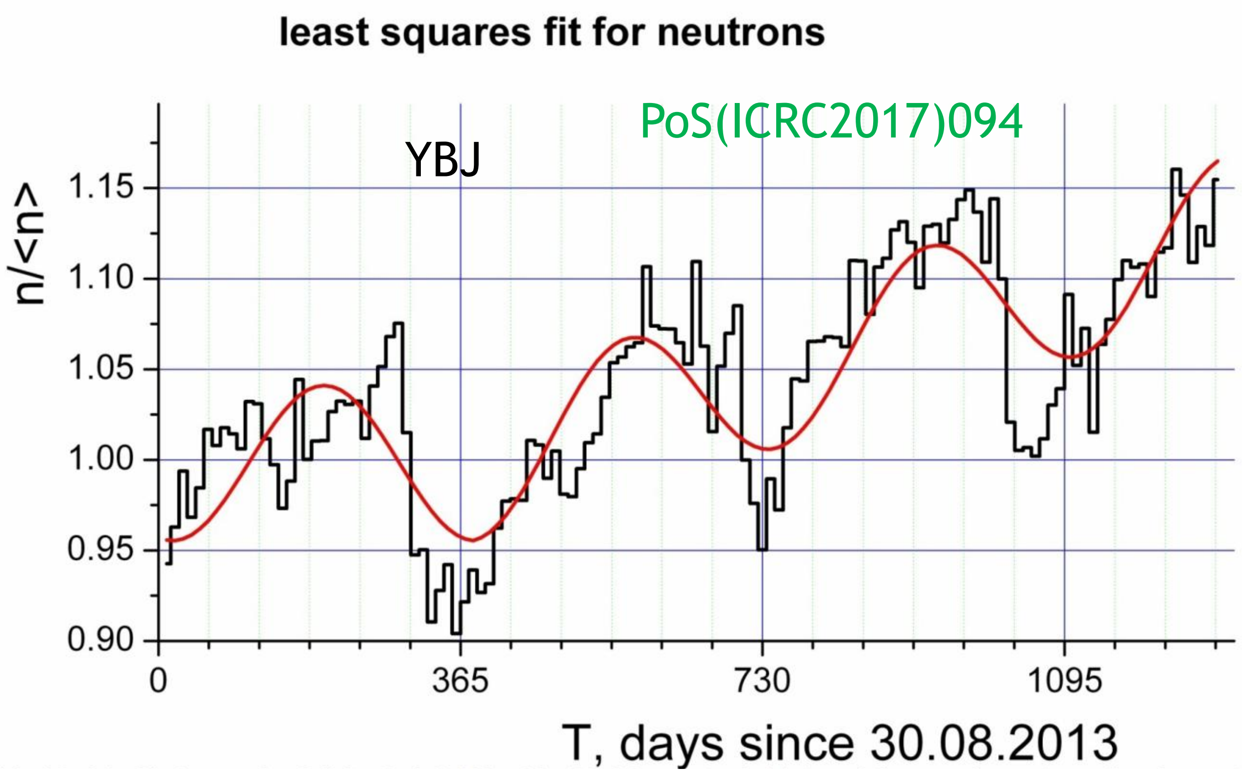
Journal of Physics: Conference Series 409 (2013) 012190





ICRC 2013

3.1.2 Solar activity



the solar maximum was ~ 4 years ago.

in 3.5 years, solar activity becomes weaker to cause cosmic ray flux and then neutron flux increasing.

Bulletin of the Russian Academy of Sciences: Physics, 2017, Vol. 81, No. 2, pp. 160-161.

3.2 Atmospheric physics

3.2.1 Thunderstorm neutrons: rain – yes, lightning – no

PRL 114, 125003 (2015) PHYSICAL REVIEW LETTERS week ending 27 MARCH 2015

Decrease of Atmospheric Neutron Counts Observed during Thunderstorms

V. Alekseenko,[1] F. Arneodo,[2] G. Bruno,[3,*] A. Di Giovanni,[2] W. Fulgione,[3,4] D. Gromushkin,[5] O. Shchegolev,[6] Yu. Stenkin,[5,6] V. Stepanov,[6] V. Sulakov,[7] and I. Yashin[5]

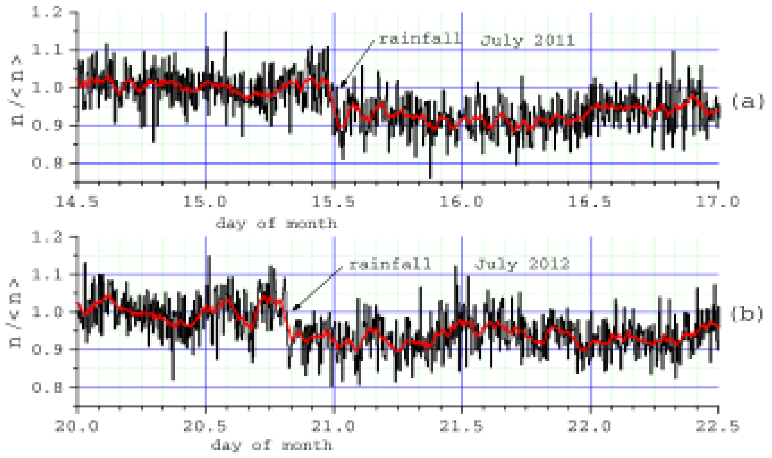


FIG. 5 (color online). Neutron counting rate as a function of the time for two different rainfalls [panels (a) and (b)]. Pressure corrected data.

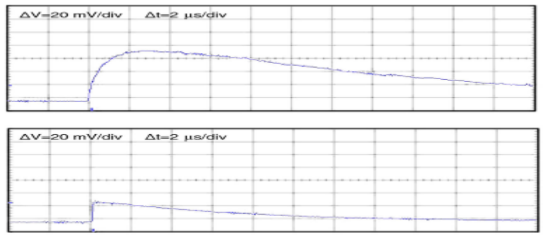


FIG. 2 (color online). Pulse induced by neutron capture ("neutrons," top panel) and background "sharp" pulse (bottom panel).

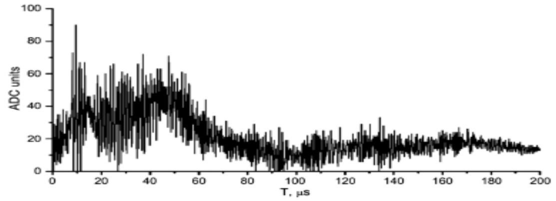
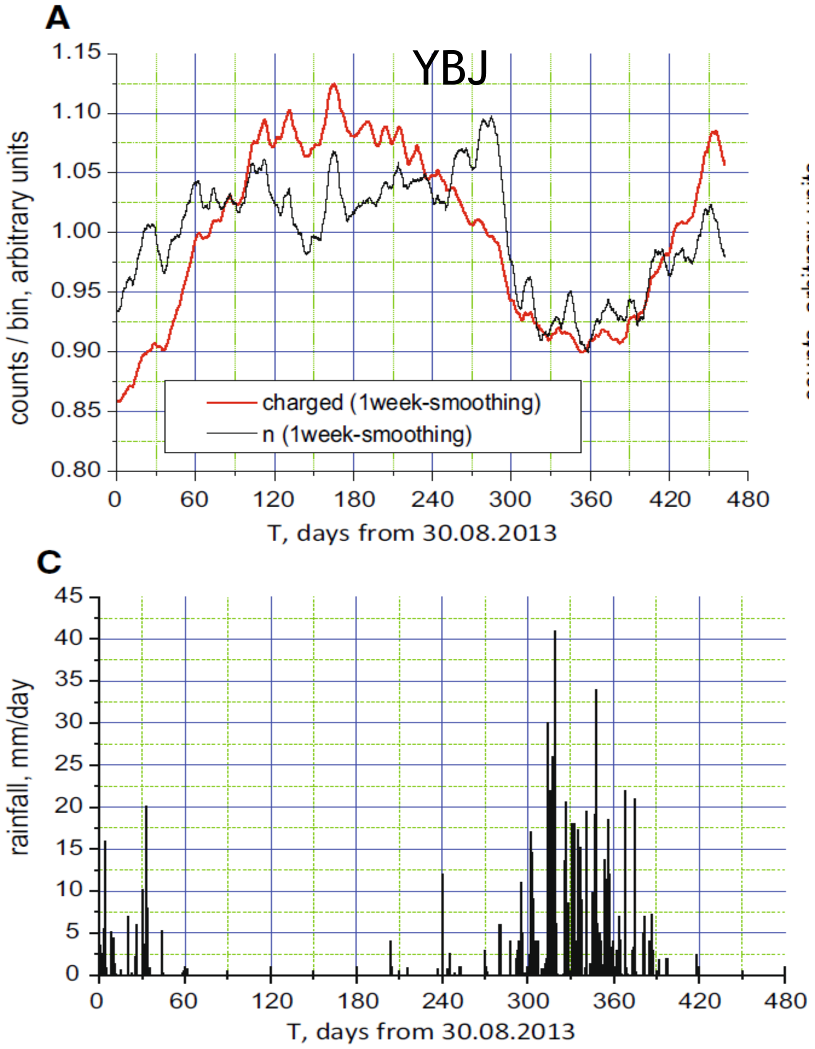
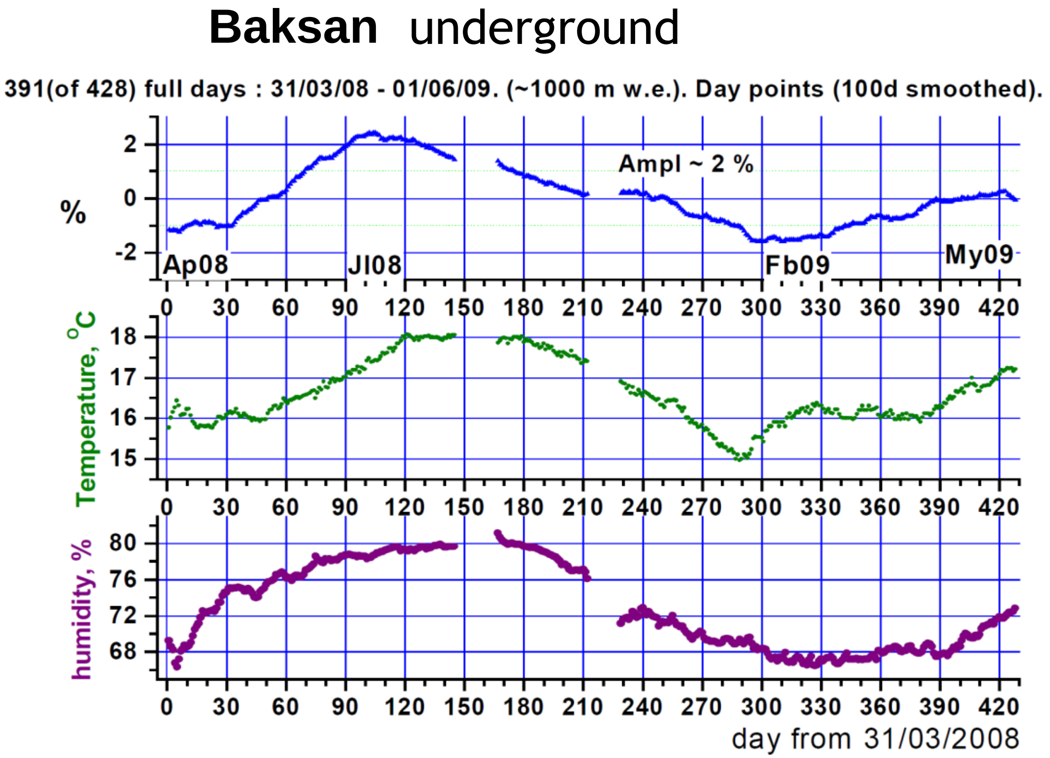


FIG. 3. Noise pulse shape produced by lightning.

Summary: no any neutron excess during thunderstorms but instead sometimes we see decrease of neutron flux

3.2.2 Seasonal effect



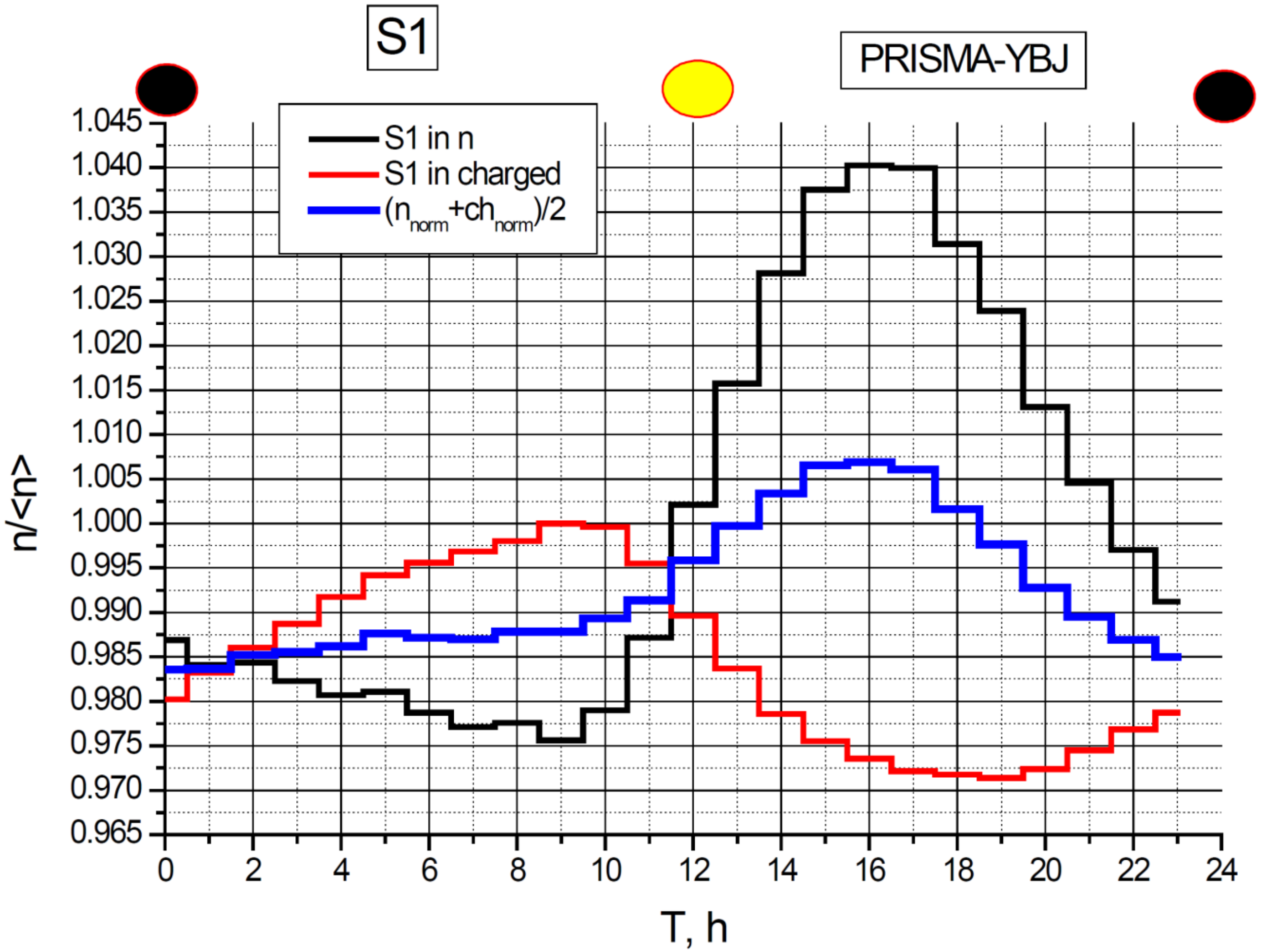


Journal of Physics: Conference Series 203 (2010) 012045 (TAUP 2009)

The fall of the neutron flux intensity coincides with the beginning of the rain period in summer.

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

3.2.3 diurnal periodicities



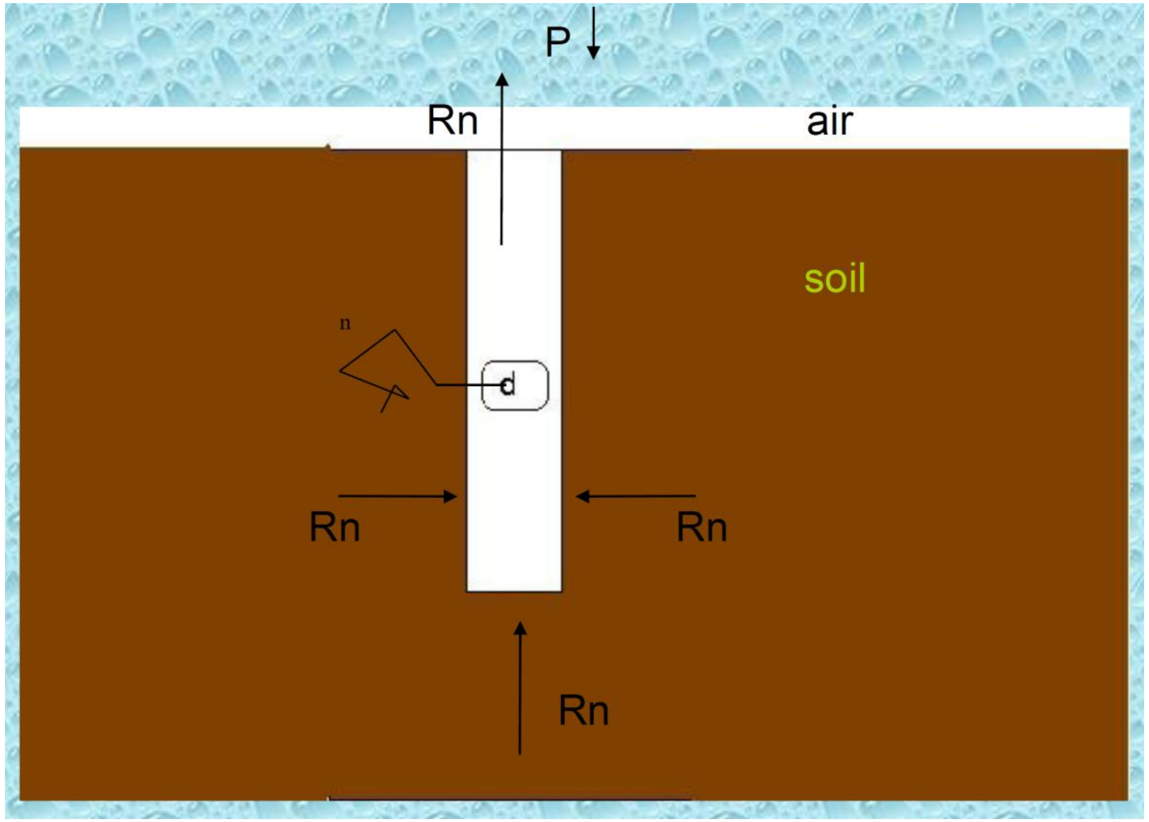
ECRS 2018

3.3 Geophysics

Terrestrial crust acts

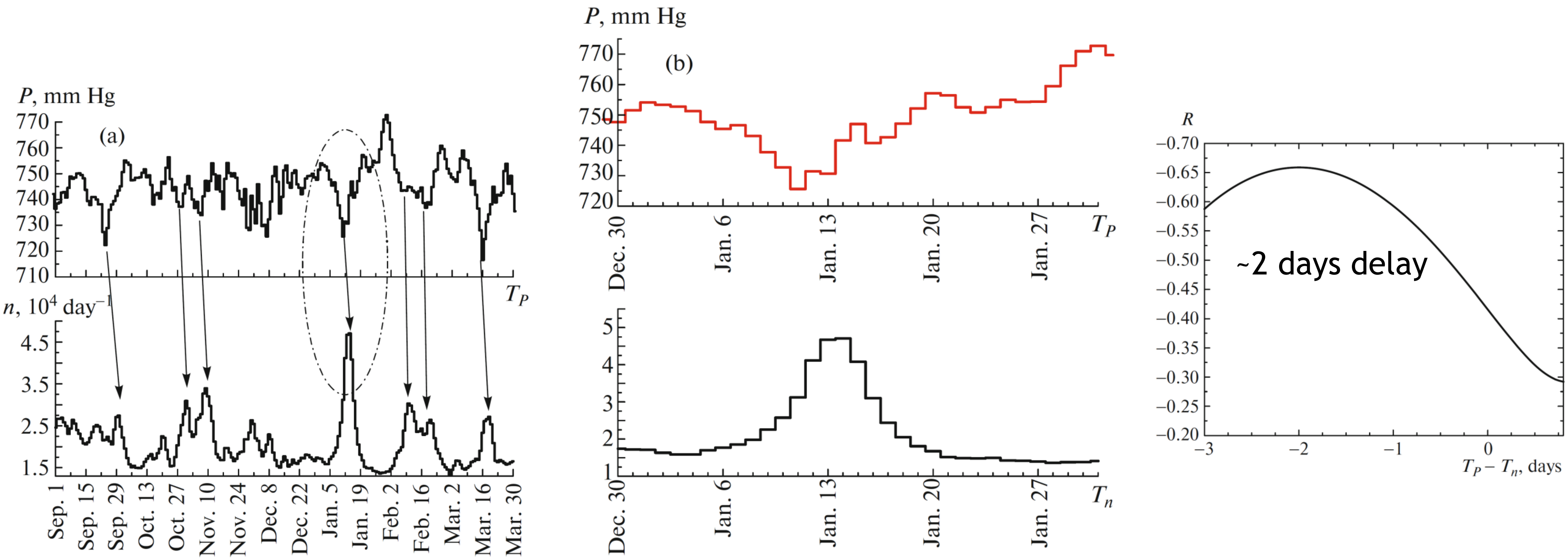
- **Quietly → 3.3.1 Barometric pumping effect**
- **Slowly and Weakly → 3.3.2 lunar tidal effect**
- **Abruptly and Strongly → 3.3.3 earthquake**

3.3.1 Barometric pumping effect in underground neutrons



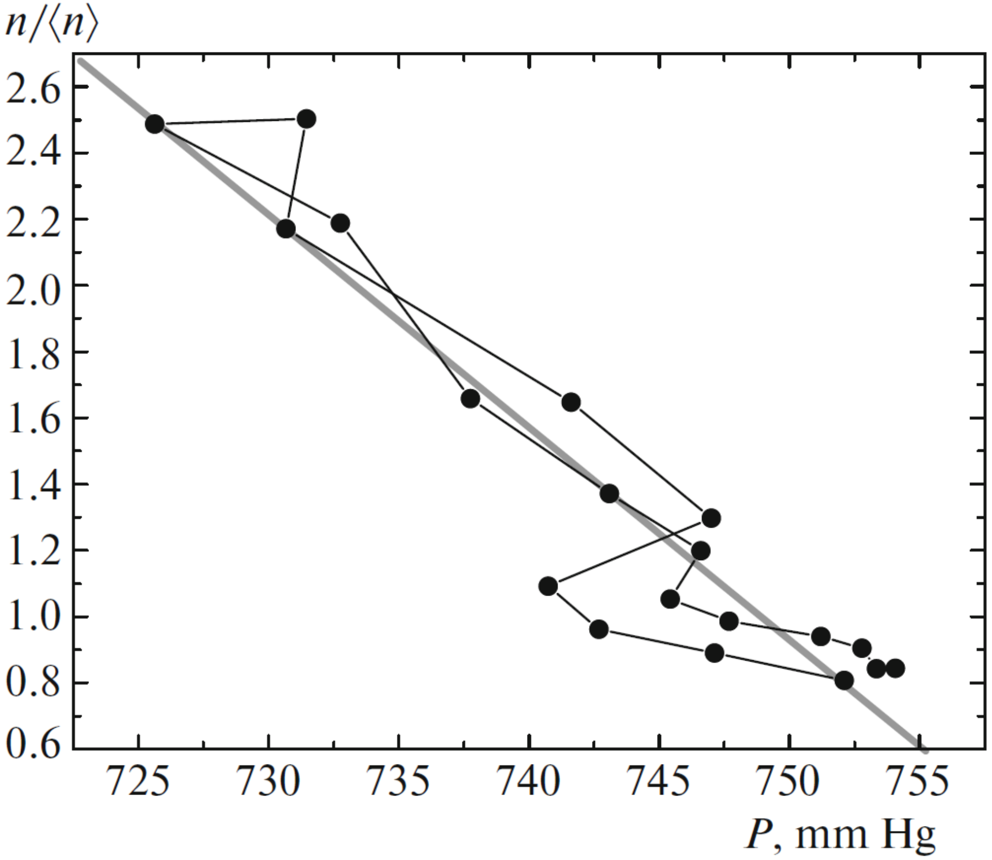
The soil air and other gases (including radon) diffuse from deeper soil layers to upper layers and then from soil to atmosphere, when atmospheric pressure decreases → variations in neutron concentration.

MSU



Journal of Experimental and Theoretical Physics, 2017, Vol. 124, No. 5, pp. 718-721.

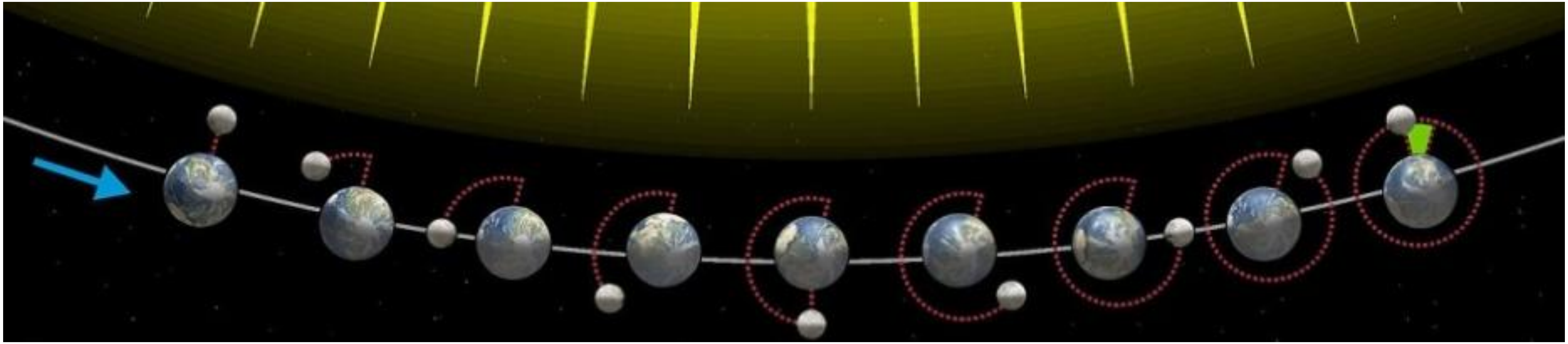
2-days delayed correlation between pressure and neutron



Regression coefficient = –(6.4 ± 0.6)%/mm Hg, much higher than that on surface!
This effect should be taken into account in underground experiments (DM or 2β0ν， etc.)

Journal of Experimental and Theoretical Physics, 2017, Vol. 124, No. 5, pp. 718-721.

3.3.2 lunar tidal effect

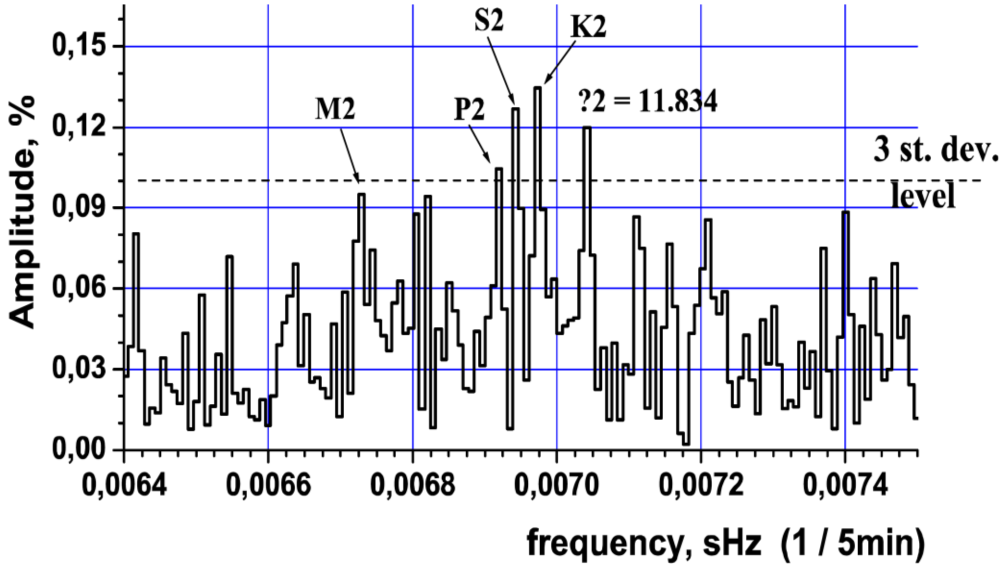


rising

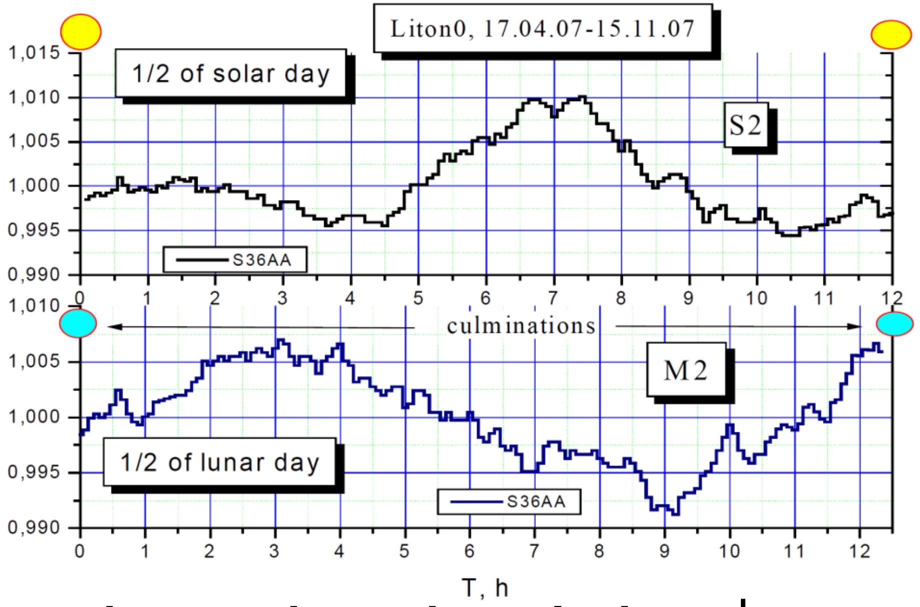
ebb

semidiurnal periodicities

Baksan



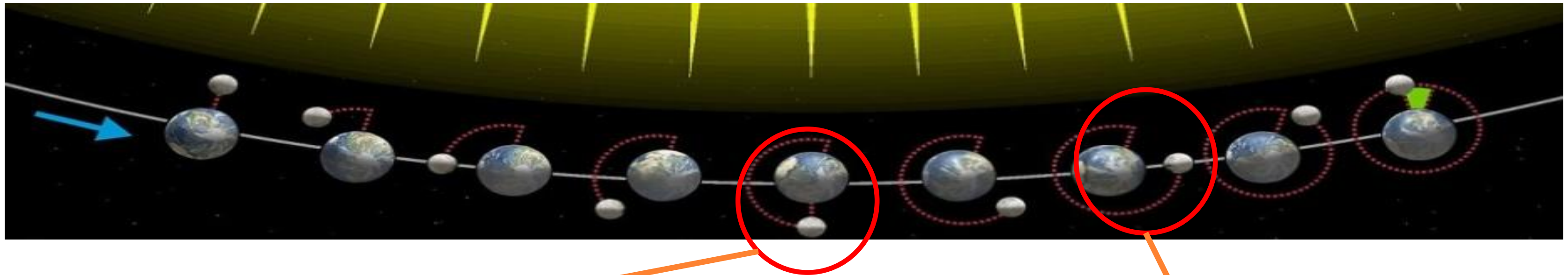
FFT method Surface



superimposed epoch analysis underground

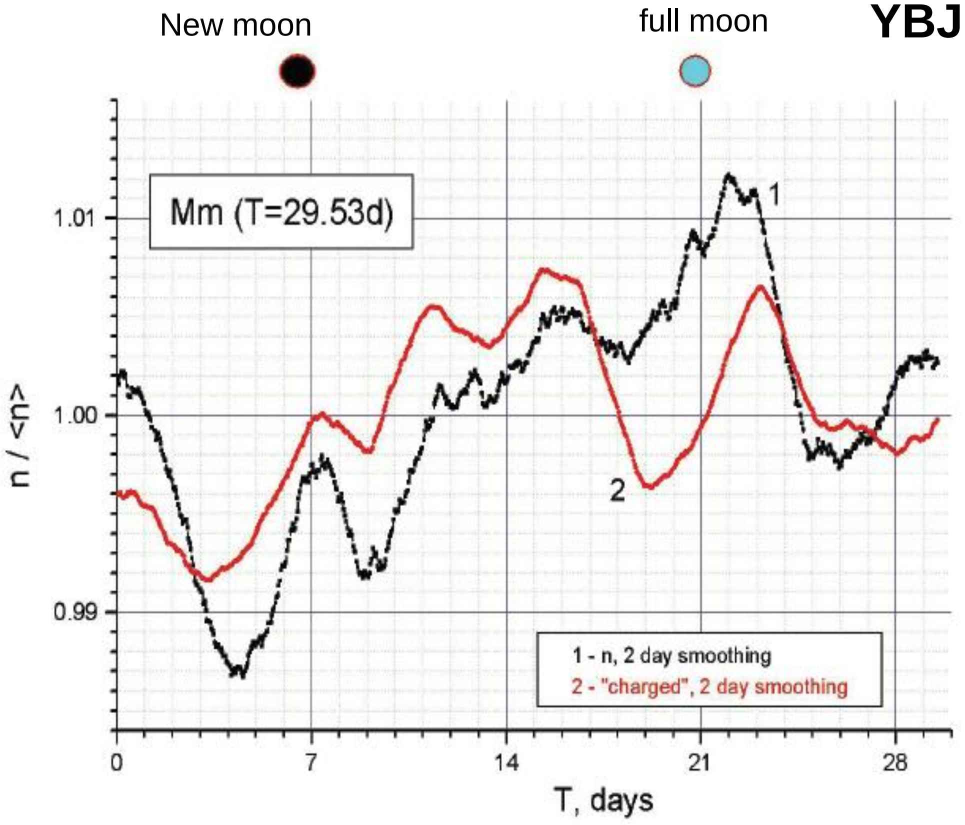
S2 is a half of a solar day, while M2, P2, K2 are different modes of second harmonics of Moon day.

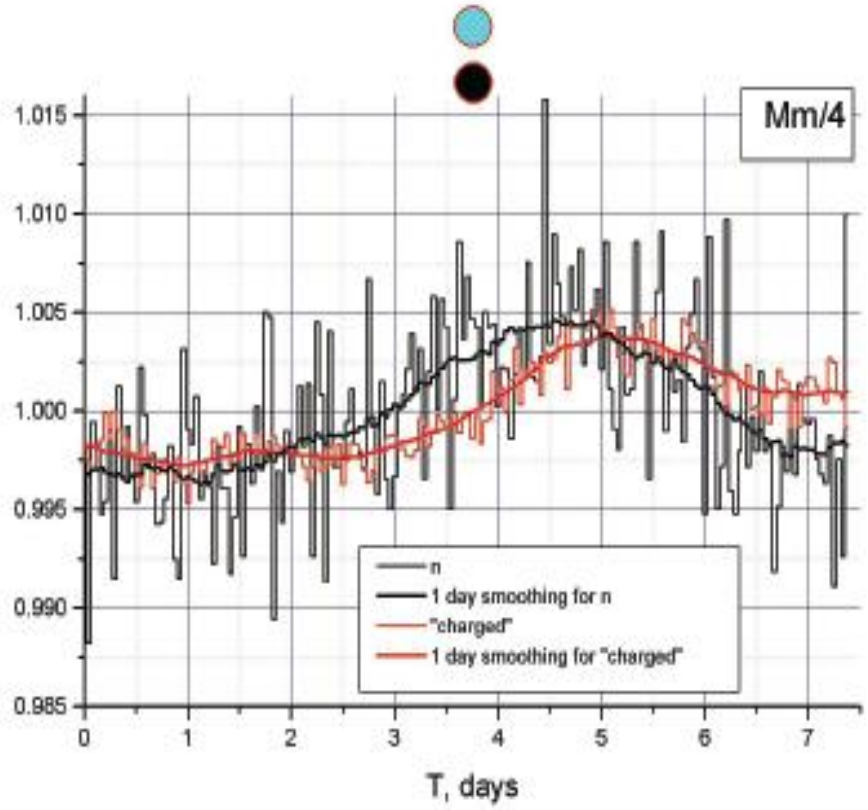
Journal of Physics: Conference Series 203 (2010) 012045 (TAUP 2009)



monthly **weekly**

YBJ



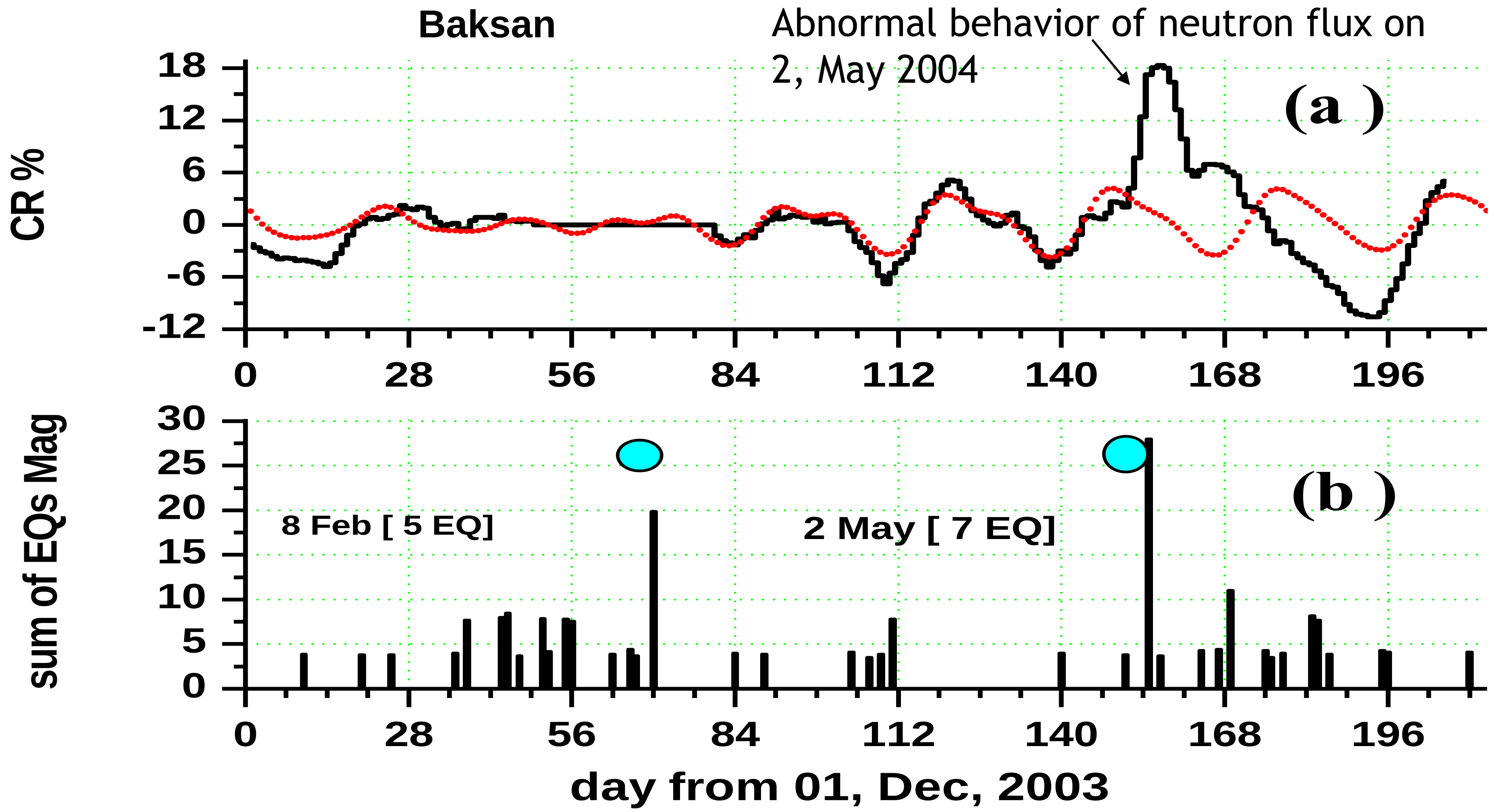


superimposed epoch analysis

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

3.3.3 earthquake (1)

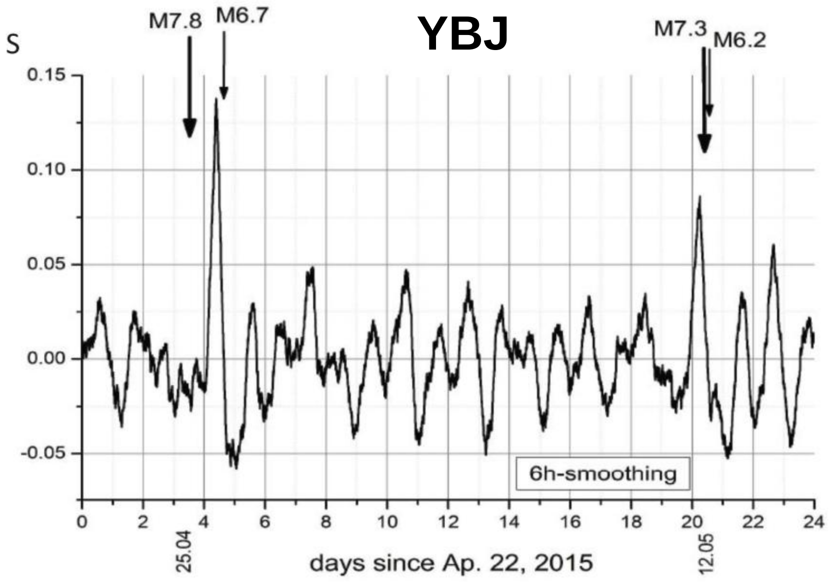
ISSN 1069-3513, Izvestiya, Physics of the Solid Earth, 2009, Vol. 45, No. 8, pp. 709-718. © Pleiades Publishing, Ltd., 2009.

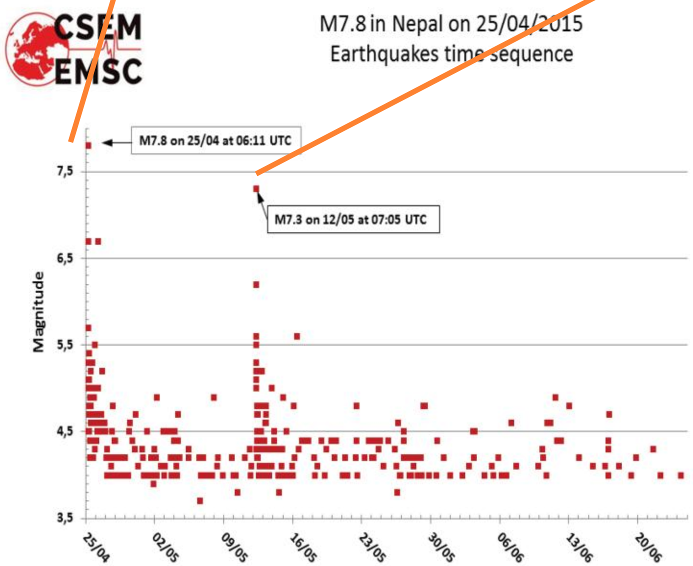


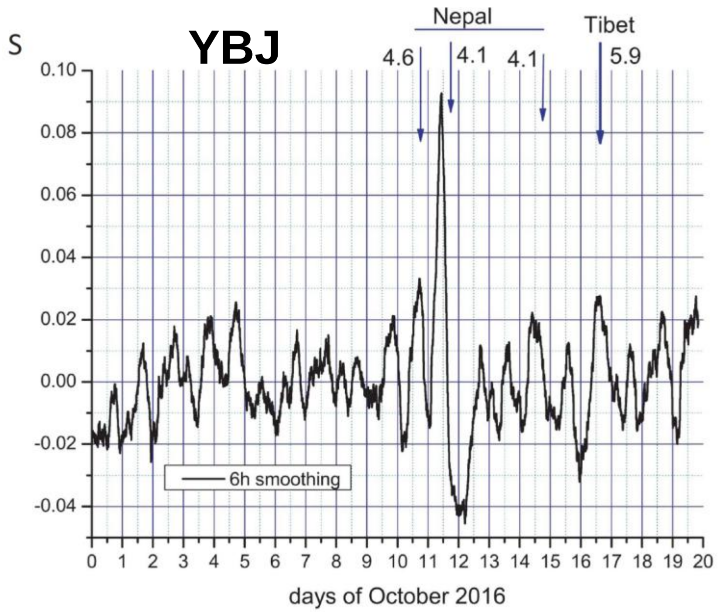
Local North Caucasus seismic activity and full Moon

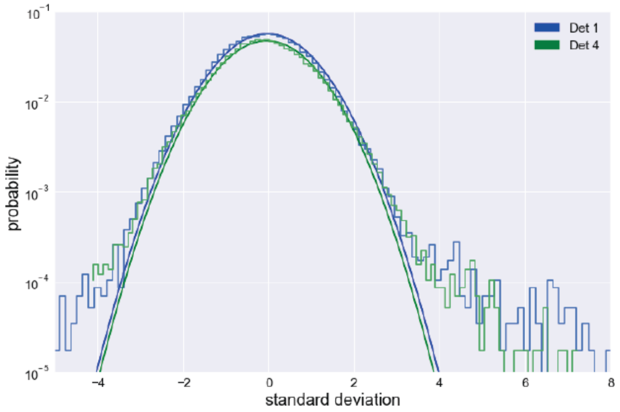
3.3.3 earthquake (2) Nepal, 2015

$$S = \frac{Nn}{< Nn >} + \frac{Nch}{< Nch >} - 2$$

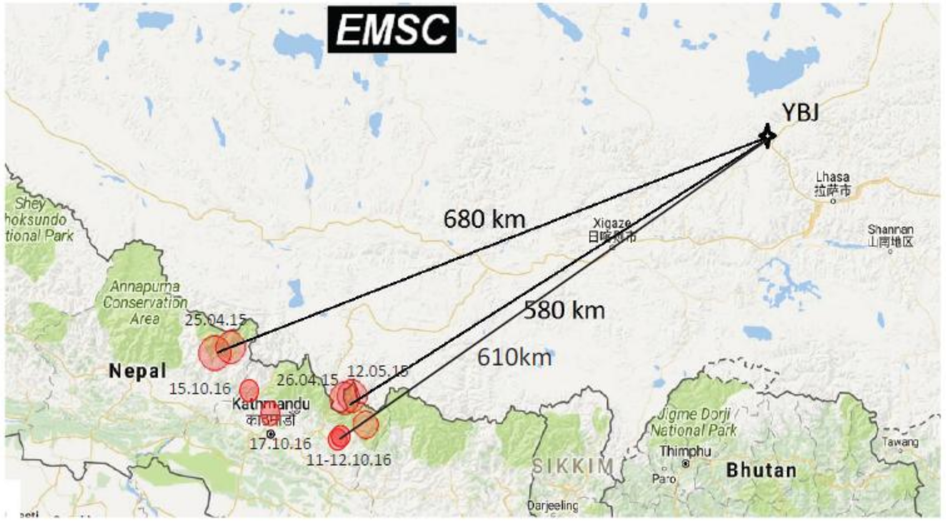


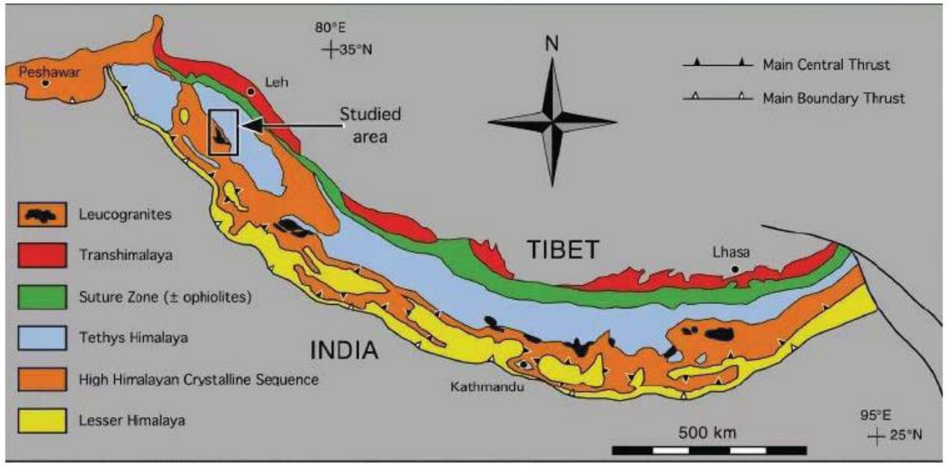


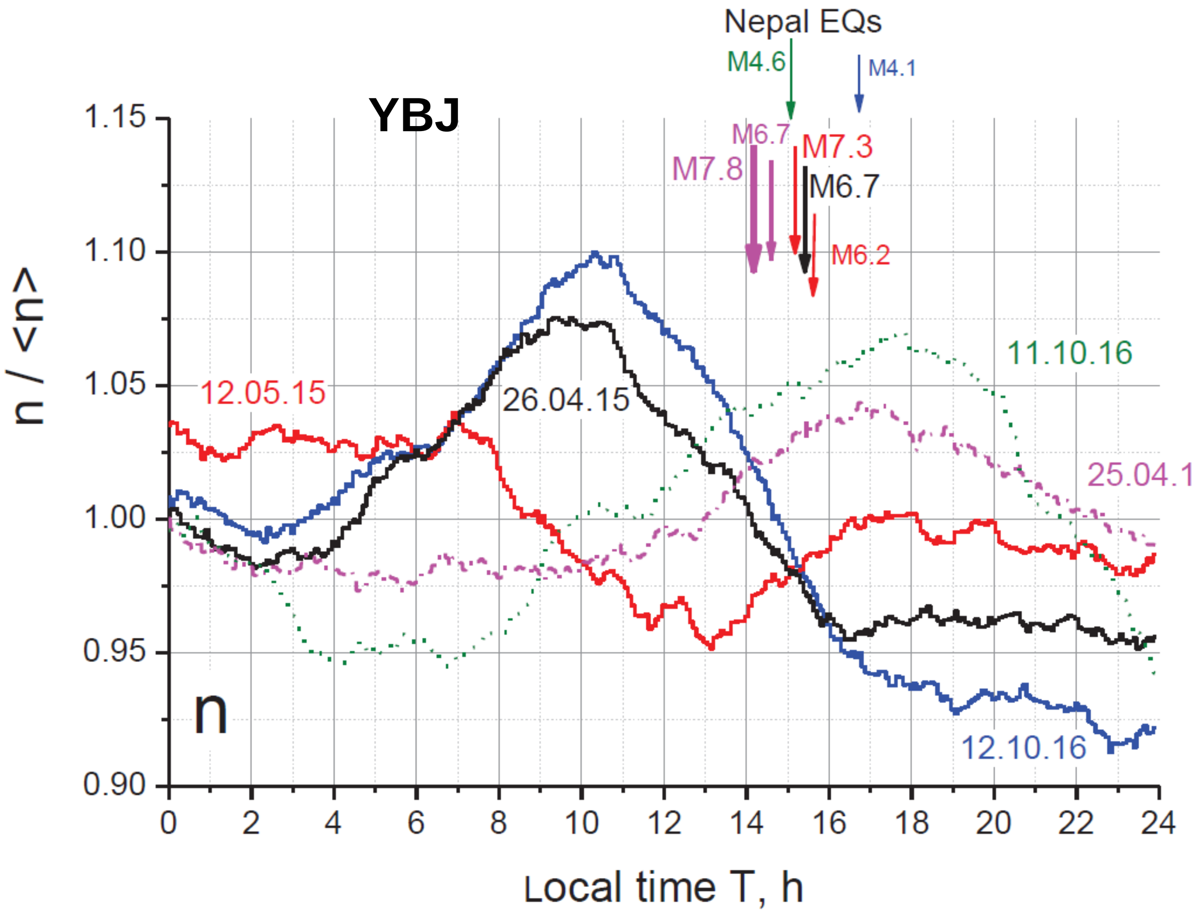


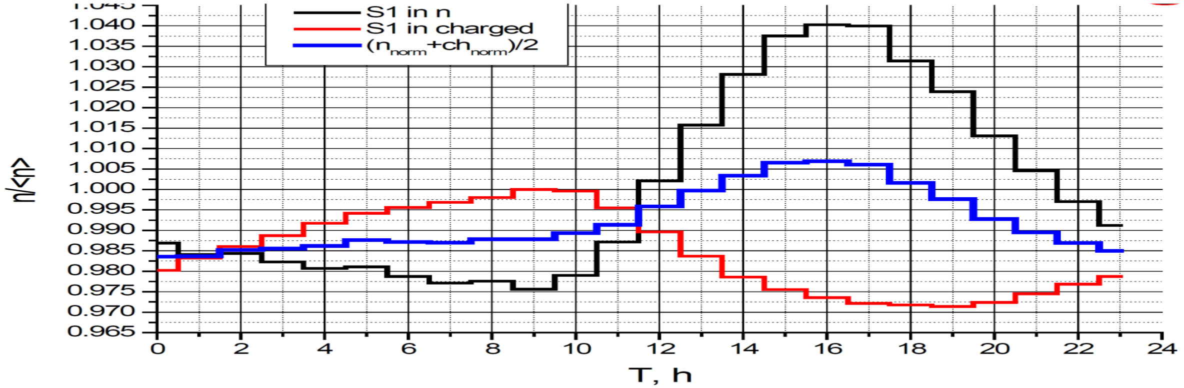


Response of PRISMA-YBJ detectors to Nepal earthquakes, submitted to PAAG

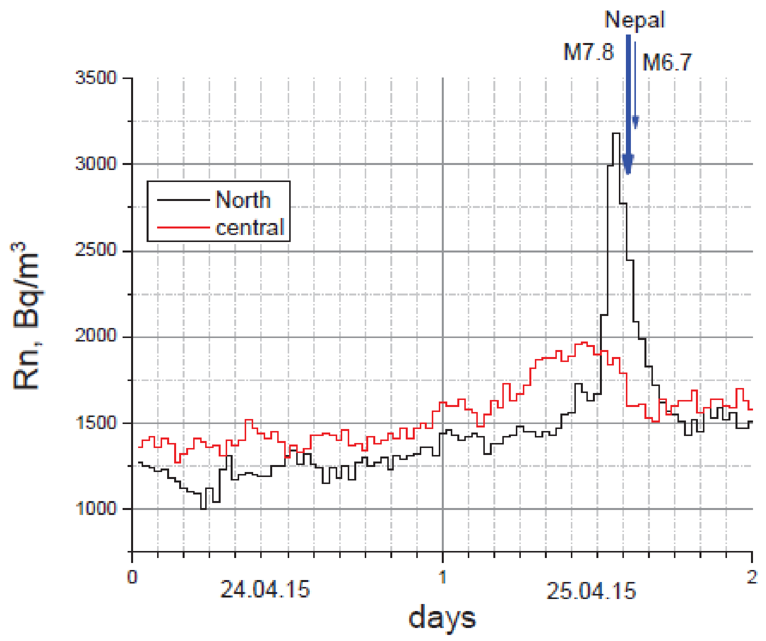

EMSC
YBJ
Lhasa
拉萨市
Xigaze
日喀则市
Shannan
山南地区
680 km
580 km
610km
Annapurna Conservation Area
25.04.15
Nepal
26.04.15
12.05.15
15.10.16
Kathmandu
काठमाडौं
17.10.16
11-12.10.16
SIKKIM
Jigme Dorji National Park
Thimphu
Paro
Bhutan
Tawang
Darjeeling

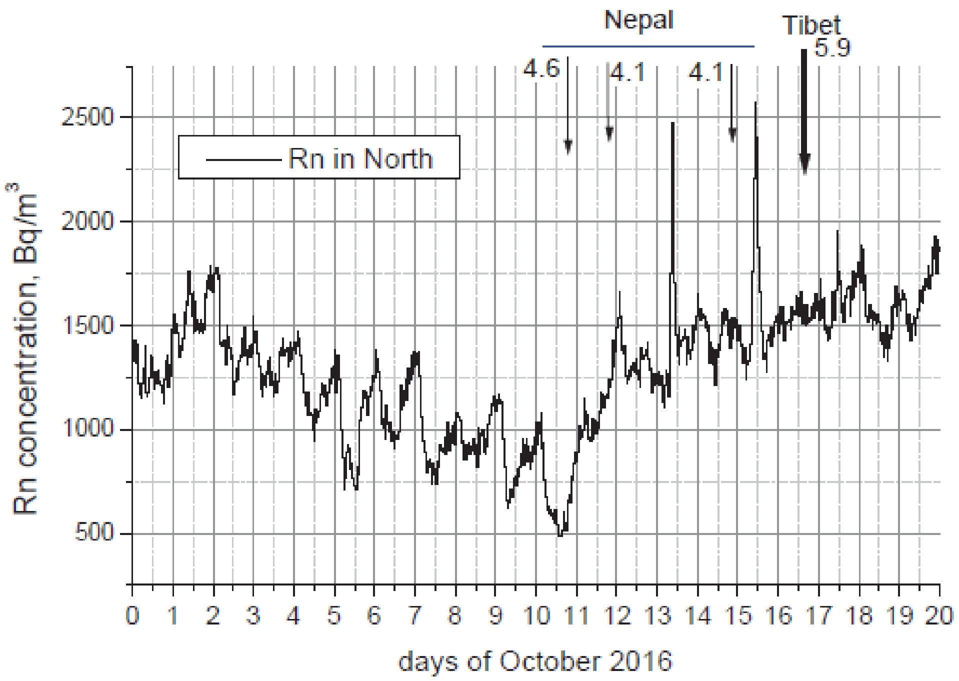

80°E
35°N
N
Peshawar
Leh
Studied area
Main Central Thrust
Main Boundary Thrust
Leucogranites
Transhimalaya
Suture Zone (± ophiolites)
Tethys Himalaya
High Himalayan Crystalline Sequence
Lesser Himalaya
TIBET
Lhasa
INDIA
Kathmandu
500 km
95°E
25°N

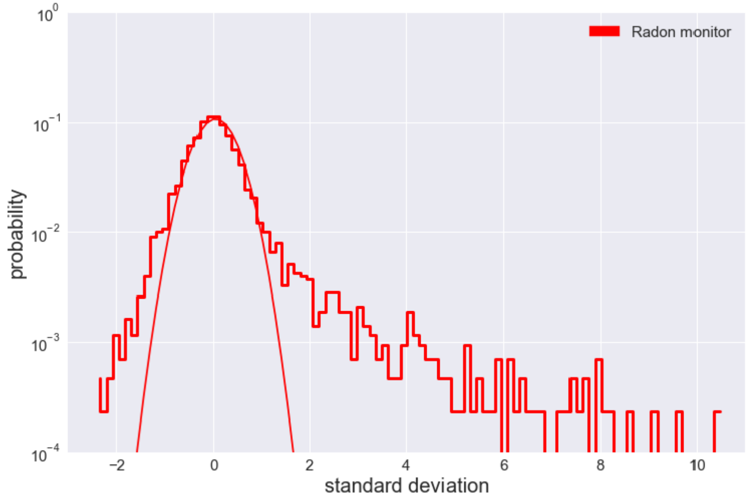

Nepal EQs
M4.6
M4.1
YBJ
M6.7
M7.8
M7.3
M6.7
M6.2
n / <n>
12.05.15
26.04.15
11.10.16
25.04.15
12.10.16
n
Local time T, h


S1 in n
S1 in charged
$(n_{norm}+ch_{norm})/2$
n/<n>
T, h

Radon meter **YBJ**







- ***Radon meter*** is based on recording of α,β-particles resulting from decay processes of radon nuclei ***in air***, which is strongly affected by environmental situation such as humidity, atmospheric wind or ventilation.
- ***EN-detector*** measure flux of thermal neutrons which are generated from radon and thoron ***inside the crust***, which is insensitive to environmental influence but is sensitive to the crust condition.

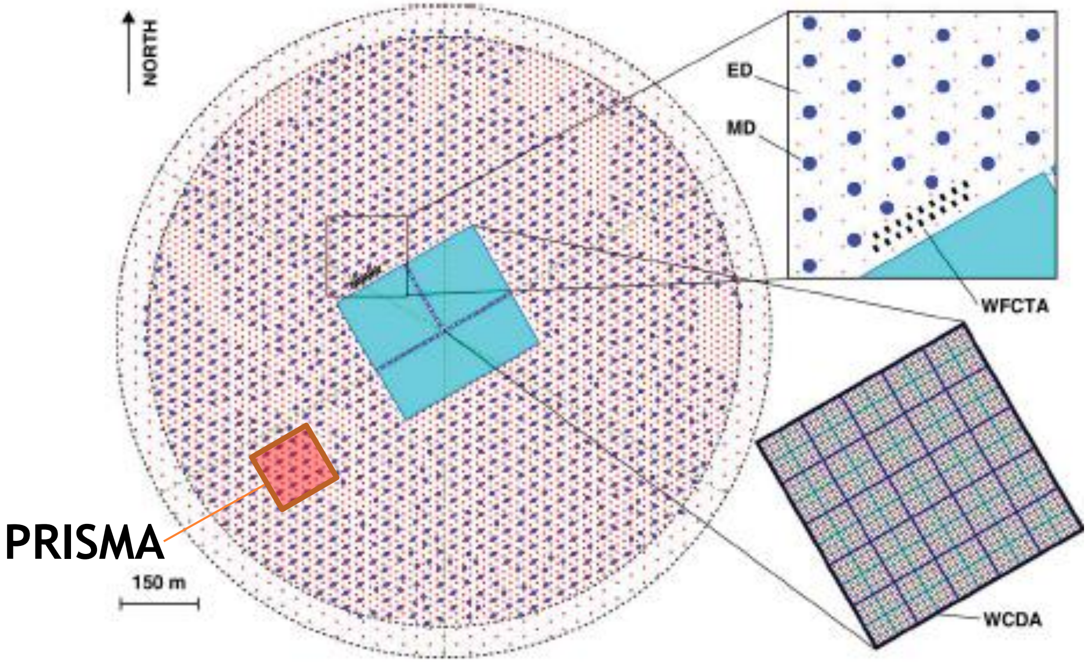
4. Summary and action in LHAASO

- **Thermal neutron flux variation from ground reflects activity of the Sun, atmosphere and terrestrial crust.**
- **The PRISMA global net of the EN-detectors achieved several significant results on these fields.**

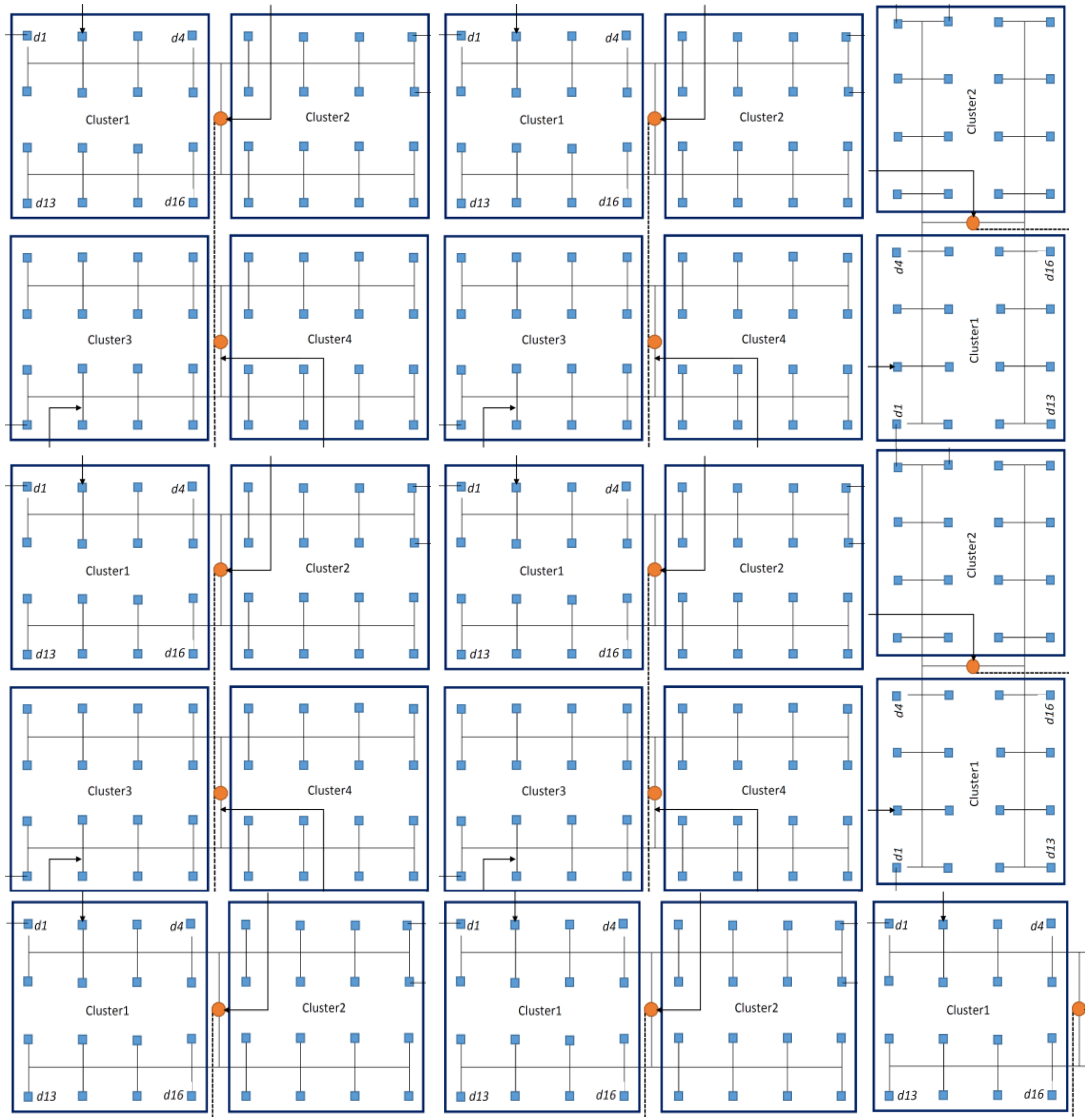
LHAASO：

- KM2A : e,μ
- WCDA: e,μ
- WFCTA: Č/F
- WCDA++: γ family at core →π0

⊕ PRISMA: thermal neutrons (trigger mode) →π+π-



PRISMA-LHAASO-400 layout



These researches will be continued with PRISMA-LHAASO array.

1/4 of thermal neutron detectors will be used simultaneously in single-particle mode to provide much more accurate detection in Solar physics, atmospheric physics and geophysics.

Thanks !