

ПОИСК НЕЙТРОННОГО СИГНАЛА ОТ МОЛНИЕВЫХ РАЗРЯДОВ В ЭКСПЕРИМЕНТЕ «ГРОЗА»

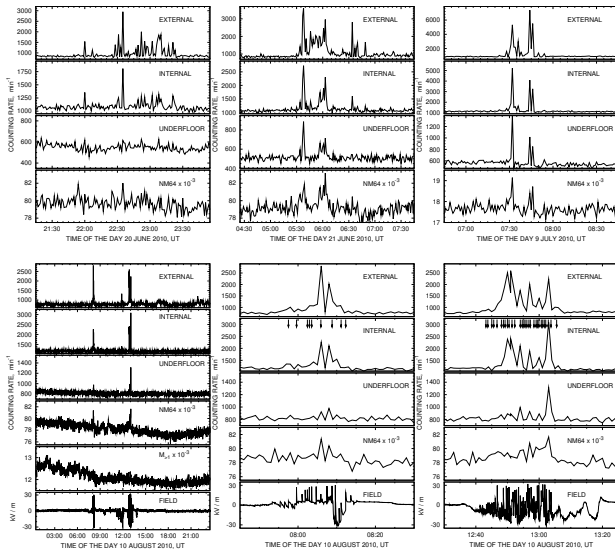
ТШВНС ФИАН

2013-2016

СОДЕРЖАНИЕ

- История исследования сигналов, поступающих от нейтронных детекторов ТШВНС во время грозы (что сделано? – 2010-2013гг).
 - интенсивность вариационных сигналов в нейтронном мониторе НМ64;
 - измерения с высоким временным разрешением и триггером от молниевых разрядов;
 - нейтронные детекторы ТШВНС и расчет их эффективности;
 - оценки эффективной энергии нейтронного излучения и величины его потока;
 - моделирование процессов развития электронно-фотонной лавины в атмосфере;
 - суммарный спектр излучений, наблюдаемых во время грозы (текущая публикация 2016г).
- Современная схема постановки эксперимента:
 - регистрация молниевых разрядов;
 - типы нейтронных детекторов;
 - процедура регистрации и обработки нейтронных данных.
- Результаты работ по поиску нейтронных сигналов, проводившихся на ТШВНС в 2014-2015гг.
- Эксперименты «ЭРГ» (ФИАН) и «Чибис» (МГУ).

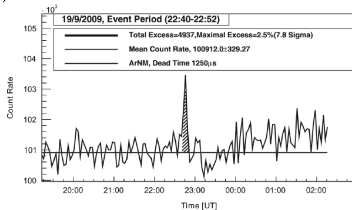
2010г: возрастание интенсивности сигналов от нейтронных детекторов ТШВНС во время грозы



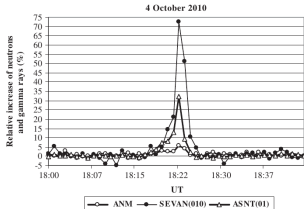
Нейтронные сигналы во время гроз...

• Арагац

Chilingarian, A. *et al* Ground-based observations of thunderstorm-correlated fluxes of high-energy electrons, gamma rays, and neutrons // *Phys. Rev. D*, 82, 043009 (2010).

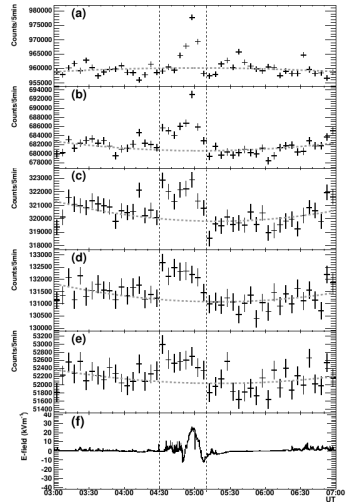


Chilingarian, A. *et al* Neutron bursts associated with thunderstorms // *Phys. Rev. D*, 85, 085017 (2012).



• Тибет

Tsuchiya, H. *et al* Observation of thundercloud-related gamma rays and neutrons in Tibet // *Phys. Rev. D*, 092006 (2012).



Нейтронные сигналы во время гроз...

● МГУ

Кужевский, Б. М. Генерация нейтронов в молниях // Вестник МГУ Сер.3 Физика Астрономия, 5, 14-16 (2004).

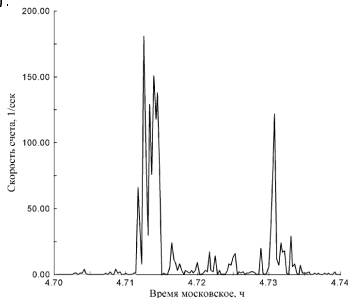


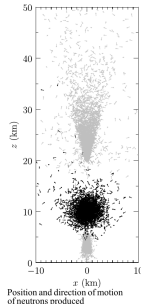
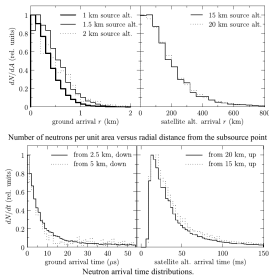
Рис. 2. Секундная развертка всплеска нейтронов, наблюдавшегося в момент молниевго разряда во время грозы 31.05.1998

● Индия

Shyam, A. and Kaushik, T. C. Observation of neutron bursts associated with atmospheric lightning discharge // J. Geophys. Res., 104, 6867-6870 (1999).

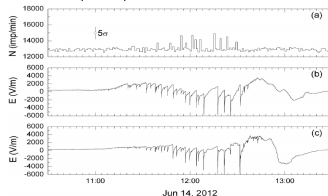
● Space Satellites

Carson, B. E. et al Neutron production in terrestrial gamma ray flashes // J. Geophys. Res., 115, A00E19 (2010).

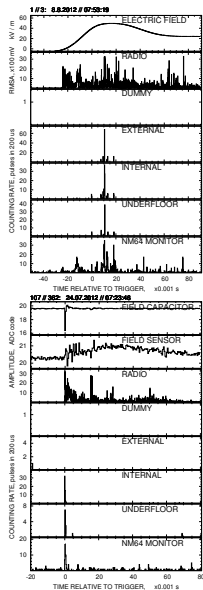
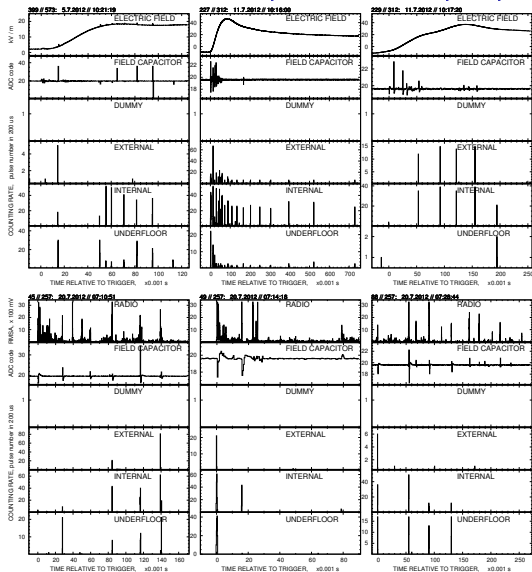


● Якутск

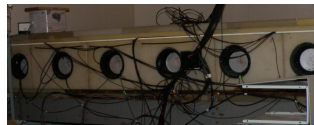
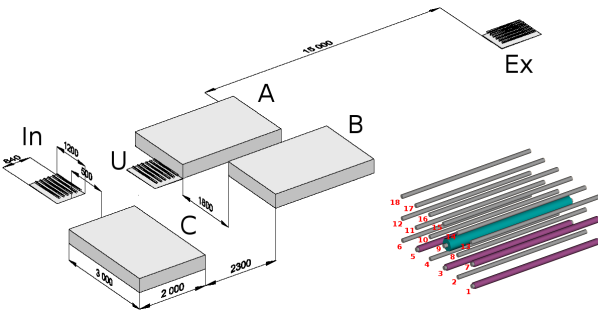
Kozlov, V. I. et al Recording neutrons with 10- μ s resolution during a thunderstorm in Yakutsk // Bull. Russ. Acad. Sci. Phys., 79, 685-687 (2015).



2011-2012г: измерения с высоким временным разрешением

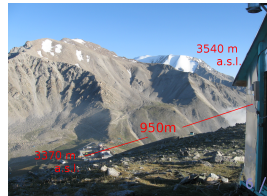


Нейтронные детекторы ТШВНС

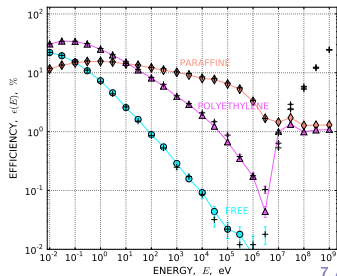
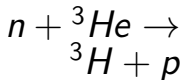
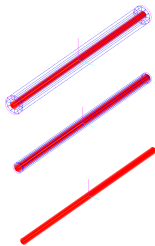
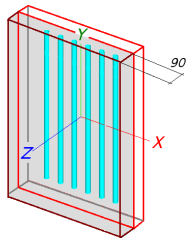
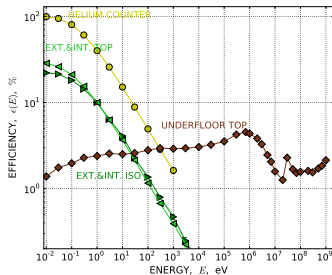
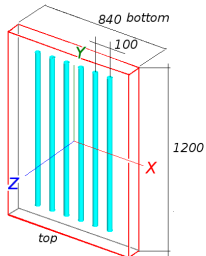


Нейтронные детекторы:

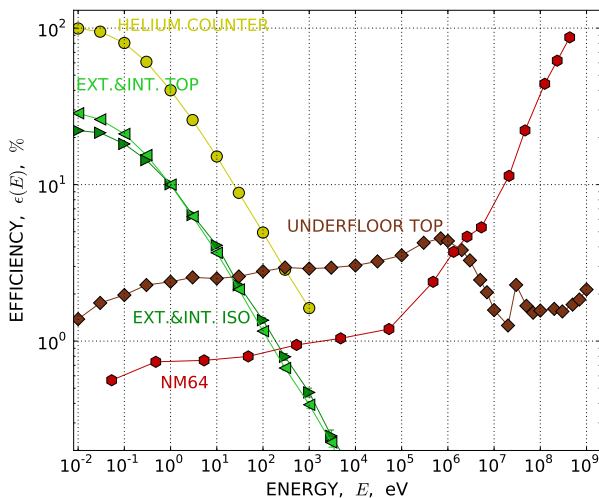
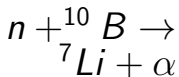
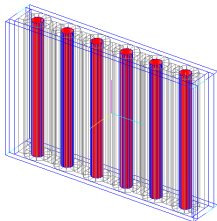
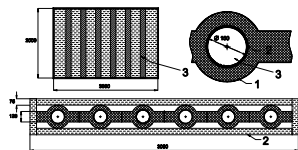
- внешний (External);
- внутренний (Internal);
- экранированный (Underfloor);
- нейтронный супермонитор НМ64 (А, В, С);
- детекторы в пункте 160М(РUP).



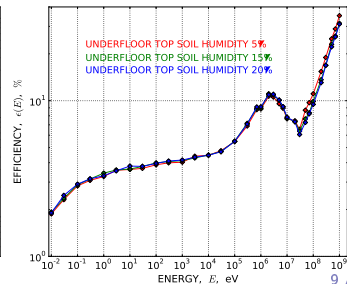
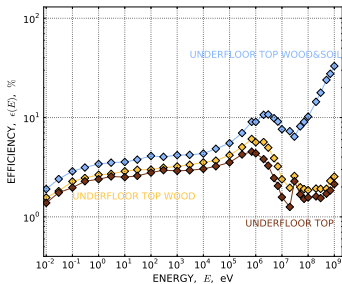
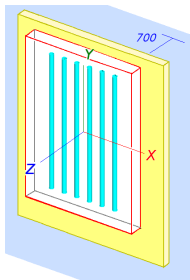
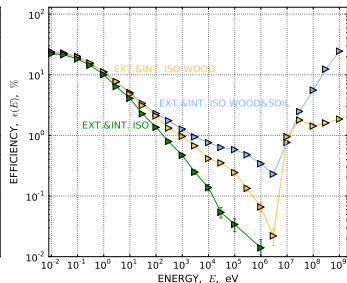
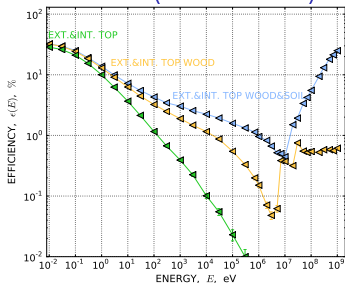
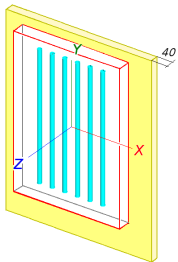
ЭФФЕКТИВНОСТЬ НЕЙТРОННЫХ ДЕТЕКТОРОВ (*GEANT4*)



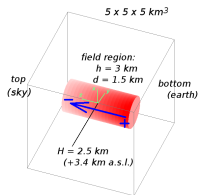
ЭФФЕКТИВНОСТЬ НЕЙТРОННОГО МОНИТОРА (*GEANT4*)



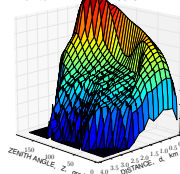
НЕЙТРОННЫЕ ДЕТЕКТОРЫ & ВНЕШНЯЯ СРЕДА (*GEANT4*)



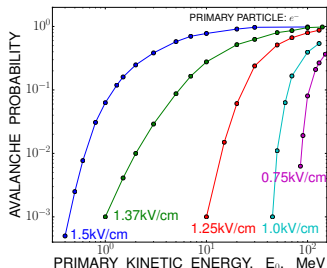
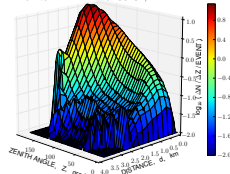
РАЗВИТИЕ ЭЛЕКТРОННО-ФОТОННОЙ ЛАВИНЫ В ПОЛЕ ГРОЗОВОГО ОБЛАКА (GEANT4)



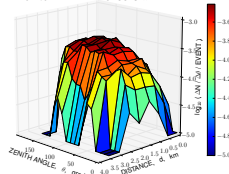
PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000 MeV
FIELD: 1.5 kV/cm PRODUCTS: e^-



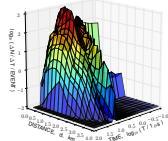
PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000 MeV
FIELD: 1.5 kV/cm PRODUCTS: γ



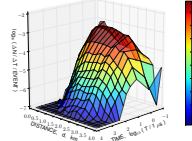
PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000 MeV
FIELD: 1.5 kV/cm PRODUCTS: α



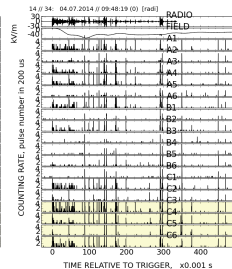
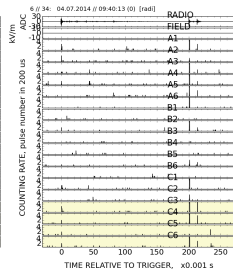
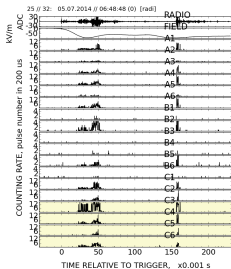
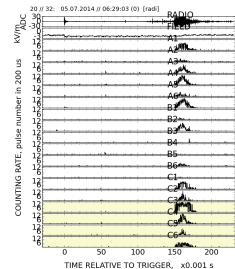
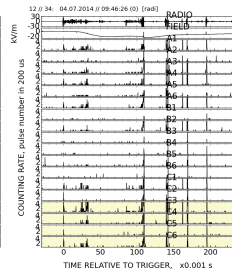
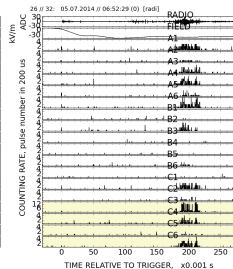
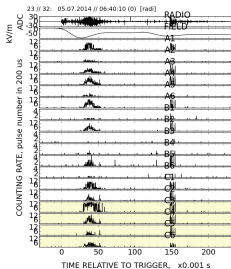
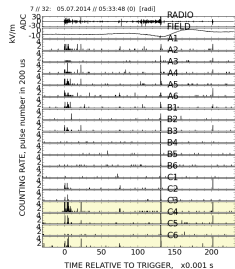
PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000 MeV
FIELD: 1.5 kV/cm PRODUCTS: e^-



PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000 MeV
FIELD: 1.5 kV/cm PRODUCTS: α

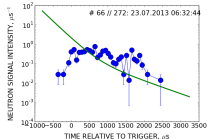
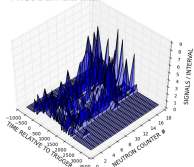


Сигналы от нейтронных счетчиков монитора - /

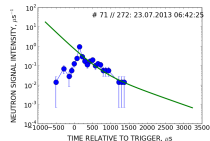
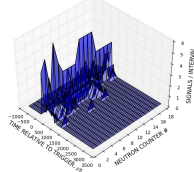


Сигналы от нейтронных счетчиков монитора НМ64 - //

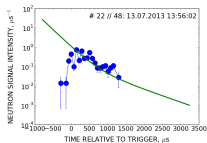
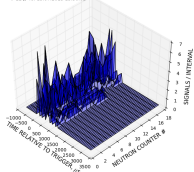
66 // 27.07.2013 06:32:44



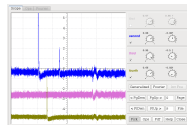
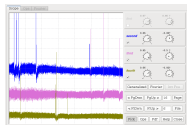
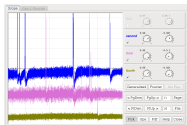
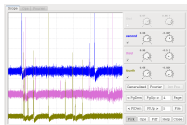
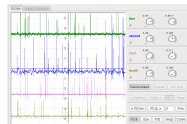
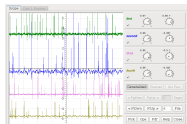
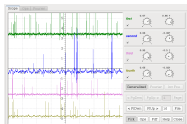
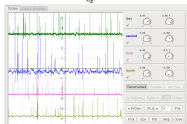
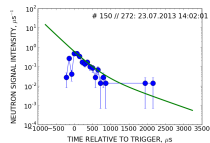
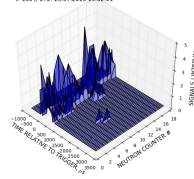
71 // 27.07.2013 06:42:25



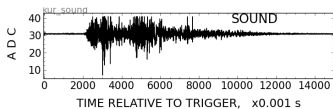
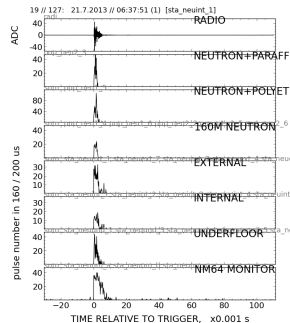
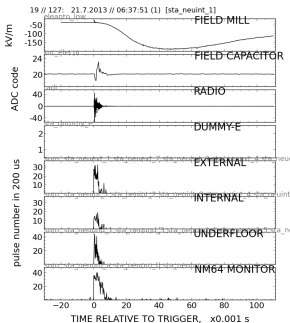
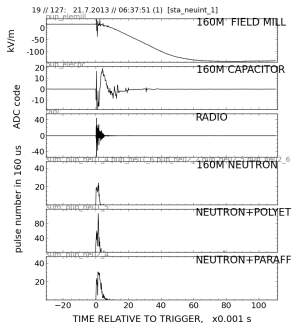
22 // 48: 13.07.2013 13:56:02



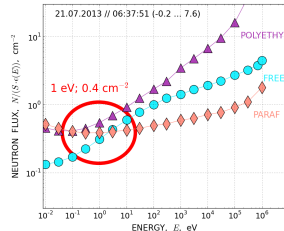
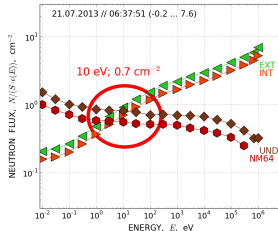
150 // 27.07.2013 14:02:01



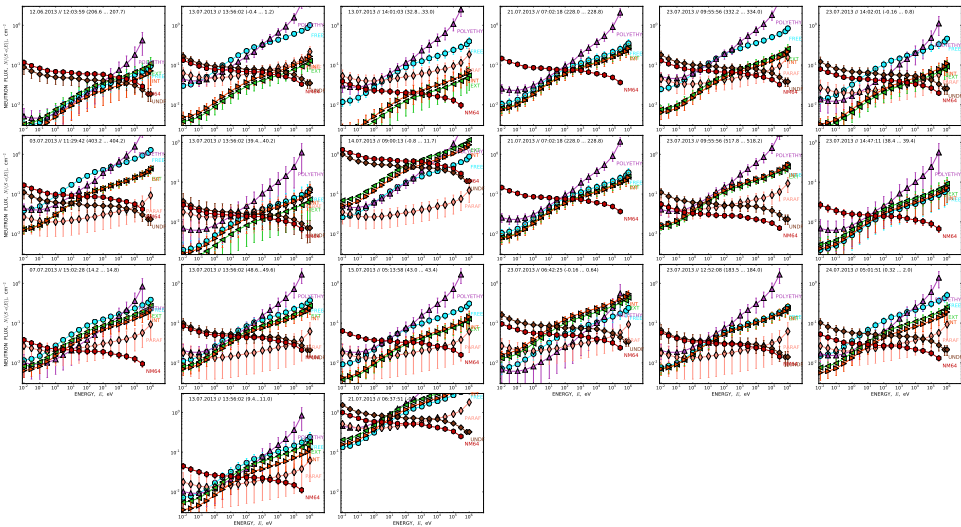
Эффективная энергия и величина нейтронного потока



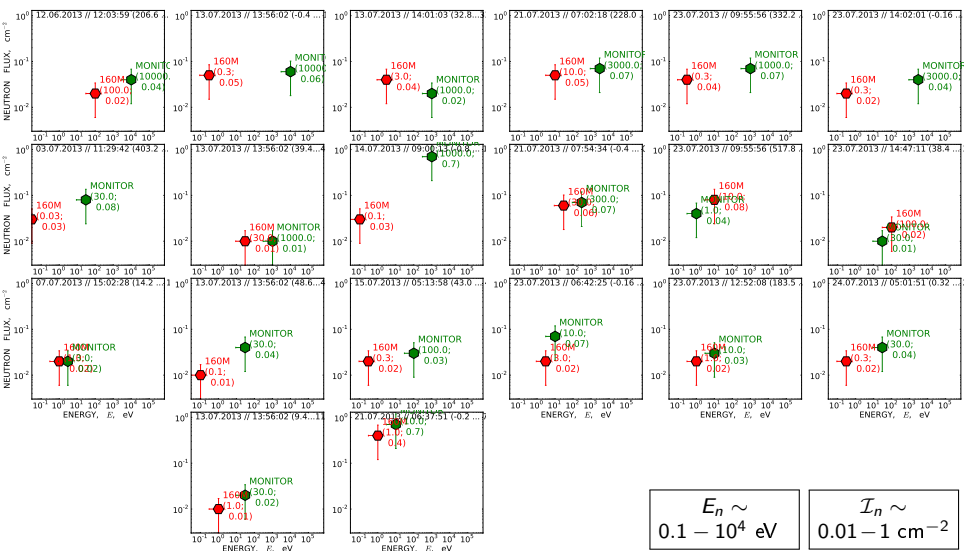
$$F = N_p / (S \cdot \epsilon(E))$$



ОЦЕНКИ ПОТОКОВ & ЭНЕРГИЙ (2013г) (I)

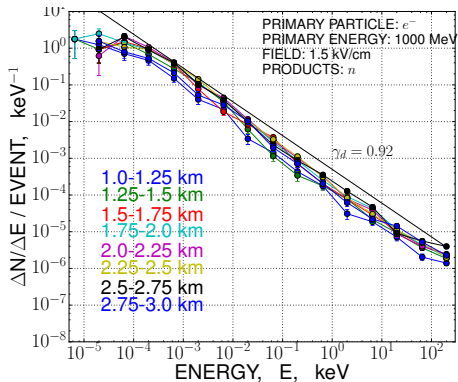
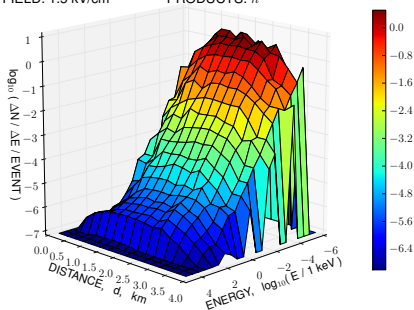


ОЦЕНКИ ПОТОКОВ & ЭНЕРГИЙ (2013г) (II)



GEANT4 об энергии нейтронов (в предположении фотоядерного механизма генерации)

PRIMARY PARTICLE: e^- PRIMARY ENERGY: 1000
FIELD: 1.5 kV/cm PRODUCTS: n



Observations of high-energy radiation during thunderstorms at Tien-Shan

A.V. Gurevich, A.P. Chubenko, G.G. Mitko, M.O. Ptitsyn,

V.A. Ryabov, A.L. Shepetov, and K.P. Zybin

P.N. Lebedev Physical Institute of the Russian Academy of Sciences (FIAN),

119991, Leninskii pr., 53, Moscow, Russia

A.M. Almenova, T.Kh. Sadykov, and N.N. Zastrozhnova

Institute for Physics and Technology, Almaty, 050032, Ibragimova, 11, Kazakhstan

V.P. Antonova, O.N. Kryakunova, V.Yu. Lutsenko, and N.M. Salikhov

Institute of Ionosphere, 050020, Kamenskoye plato, Almaty, Kazakhstan

A.N. Karashtin

Research Radiophysics Institute, 603950,

Bolshaya Pechyorskaya, str., 25/12a, Nizhny Novgorod, Russia

V.V. Piscal and L.I. Vi'danova

Tien Shan Mountain Cosmic Ray Station,

050020, Mitina str., 3, Almaty, Kazakhstan

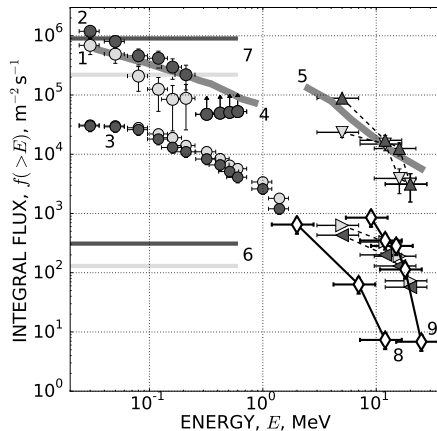
Yu.V. Shlyugayev

Institute of Applied Physics of RAS, 603950,

Ul'yanova str., 46, Nizhny Novgorod, Russia

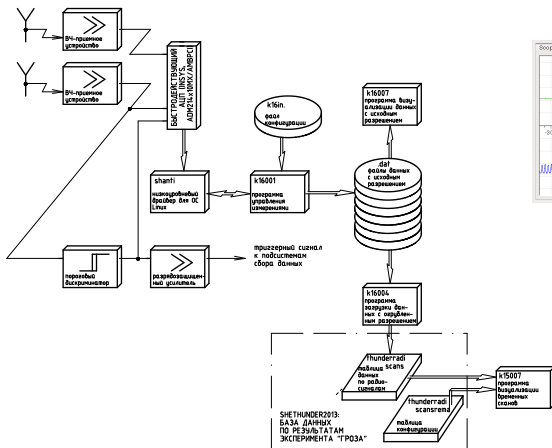
W.M. Thu

Moscow Institute of Physics and Technology (State University), 117303, Moscow, Russia

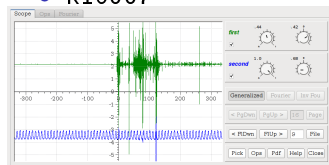


Energy spectra of gamma-radiation (circles) and accelerated electrons (triangles). 1 and 2 — two spectra for the transient bursts around lightning; 3 — average spectra calculated over monitoring type measurements at Tien Shan in thunderstorm days; 4 and 5 — the gamma-ray and electron spectra obtained in Geant4; 6 and 7 — the levels of neutron intensity at a quite time and just in the moment of transient bursts; 8 and 9 — electron spectra registered in two thunderstorm events at Mt Aragats.

Регистрация молниевых разрядов по их радио-излучению



• k16007



• k15007

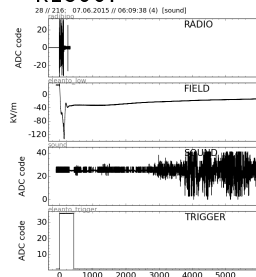
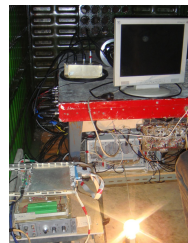
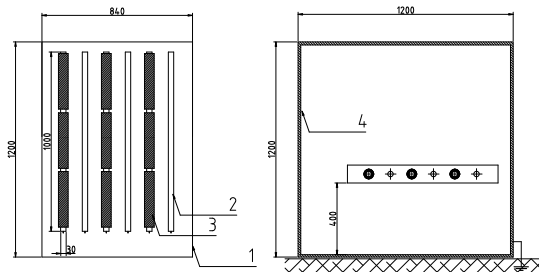


Схема обработки радио-сигналов и

Экранированный (*SHIELDED*) нейтронный детектор



1 – коробка из алюминия
толщиной 1 мм;
2 – нейтронный счетчик
«Гелий-2»,
3 – парафиновый
цилиндр-замедлитель с
толщиной стенки 10 мм;
4 – сплошной
электромагнитный экран из
2 см железа.

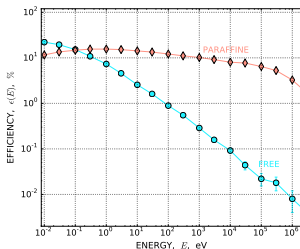
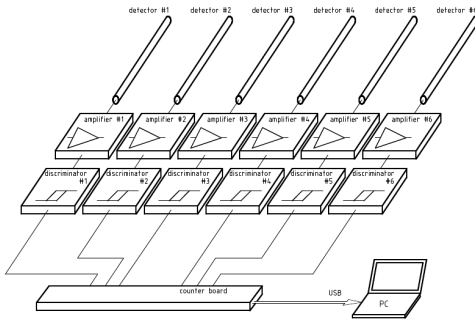
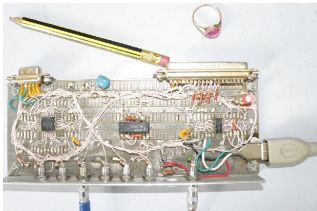


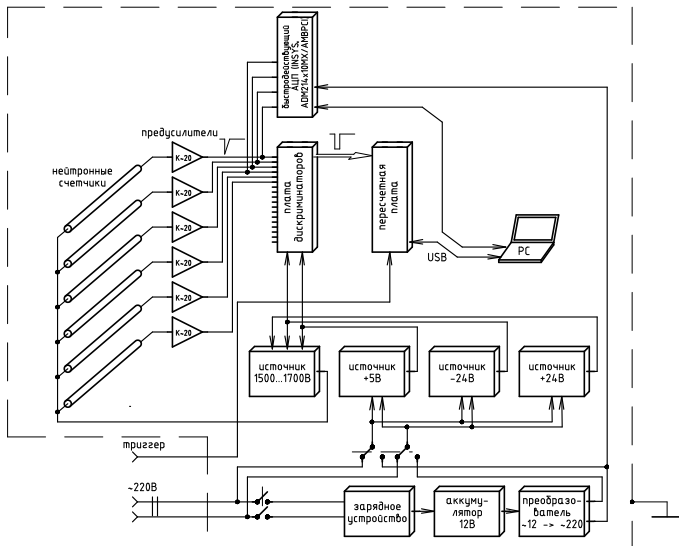
Схема измерения интенсивности сигналов



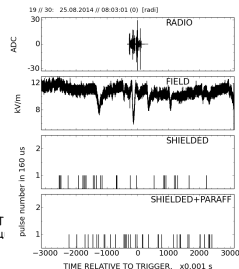
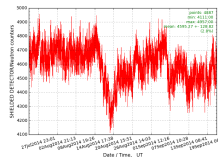
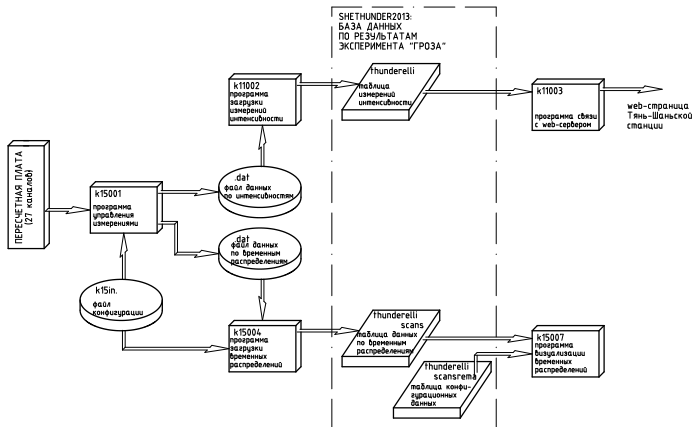
- непрерывные измерения интенсивности импульсов с низким временным разрешением (1-10 с);
- измерения с высоким разрешением порядка 160-200 мкс, синхронизованные с триггерным сигналом от электрического разряда (как правило, $\pm 1-3$ с относительно момента триггера).



Электрическая схема экранированного детектора

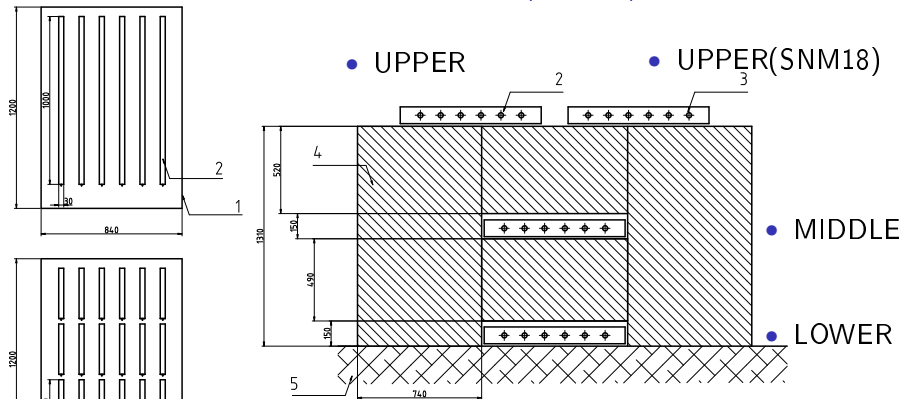


Программный комплекс K15



УСТАНОВКА "ЭКРАНИРОВАННЫЙ НЕЙТРОННЫЙ ДЕТЕКТ
Блок-схема программ сбора и обработки информац

Нейтронный детектор с глубоким (*DEEP*) поглотителем



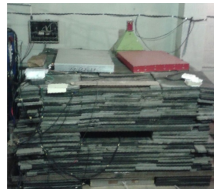
1 – коробка из алюминия толщиной 1 мм;

2 – нейтронный счетчик «Гелий-2»;

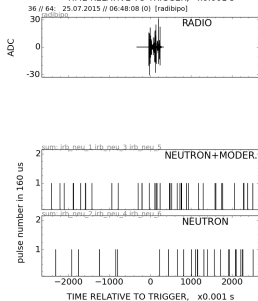
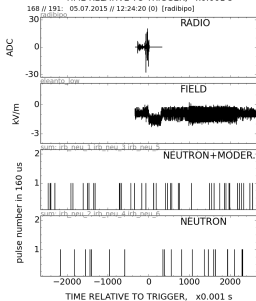
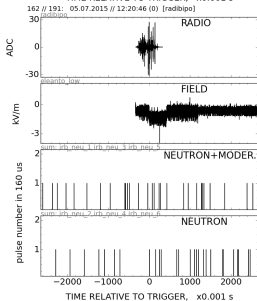
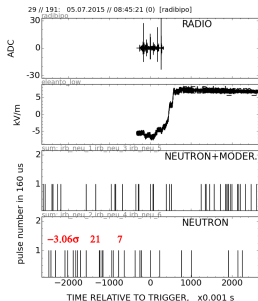
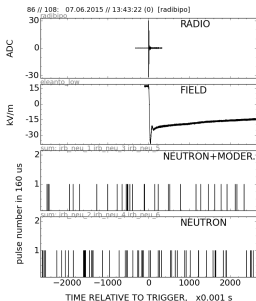
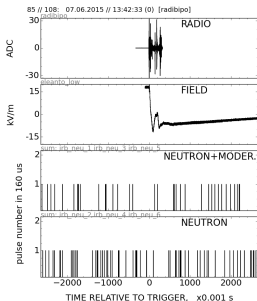
3 – нейтронный счетчик «СНМ-18»;

4 – поглотитель/отражатель нейтронов из резины (C_2H_2)_n;

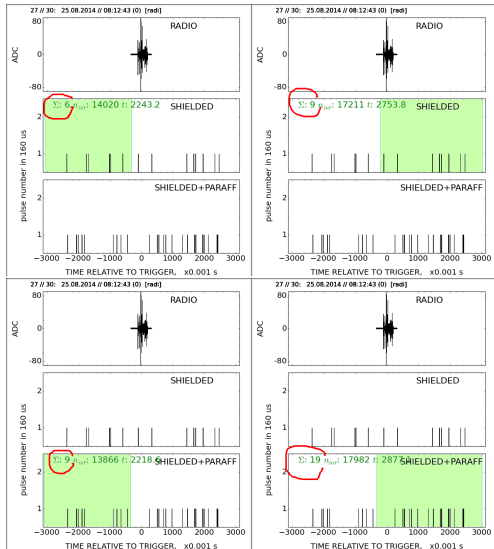
5 – бетонное перекрытие.



Примеры событий: *SHIELDED* детектор

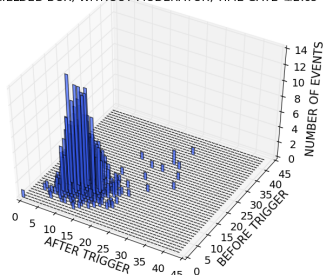


Определение интенсивностей «before» & «after»

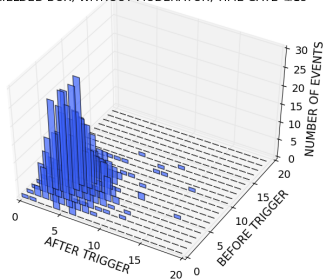


Результаты-2015: *SHIELDED* детектор

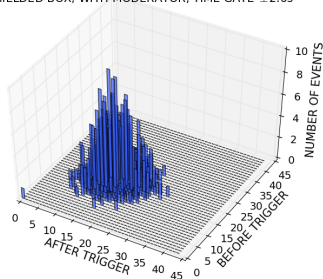
SHIELDED BOX, WITHOUT MODERATOR, TIME GATE ± 2.6 s



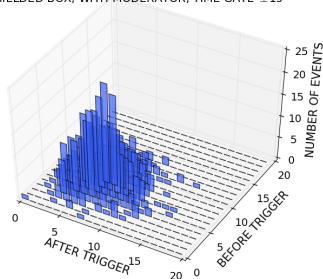
SHIELDED BOX, WITHOUT MODERATOR, TIME GATE ± 1 s



SHIELDED BOX, WITH MODERATOR, TIME GATE ± 2.6 s

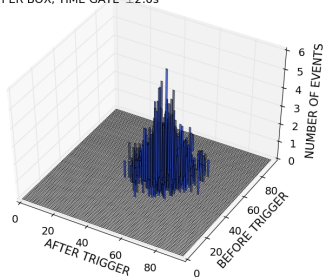


SHIELDED BOX, WITH MODERATOR, TIME GATE ± 1 s

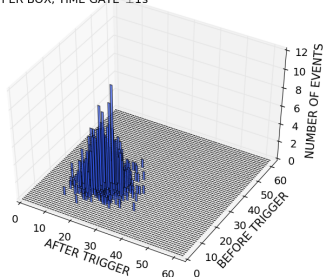


Результаты-2015: *UPPER* детекторы

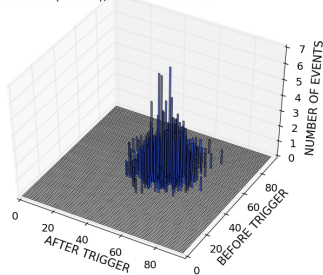
UPPER BOX, TIME GATE ± 2.6 s



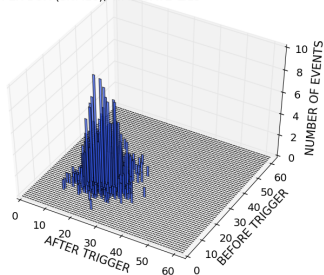
UPPER BOX, TIME GATE ± 1 s



UPPER BOX (SNM18), TIME GATE ± 2.6 s

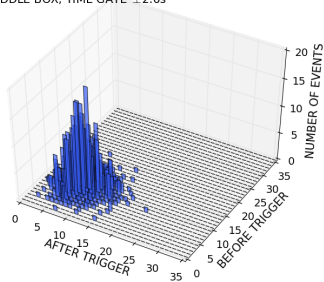


UPPER BOX (SNM18), TIME GATE ± 1 s

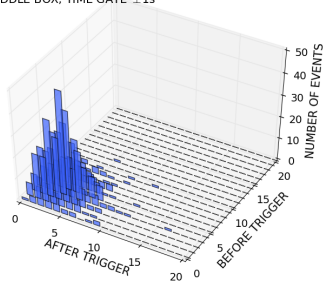


Результаты-2015: *MIDDLE* и *LOWER* детекторы

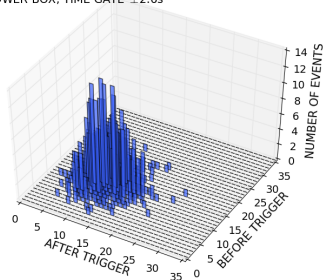
MIDDLE BOX, TIME GATE ± 2.6 s



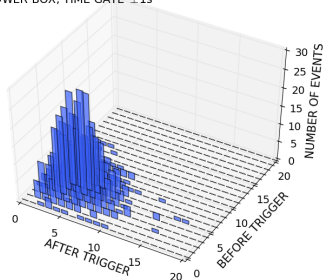
MIDDLE BOX, TIME GATE ± 1 s



LOWER BOX, TIME GATE ± 2.6 s

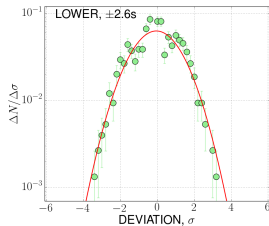
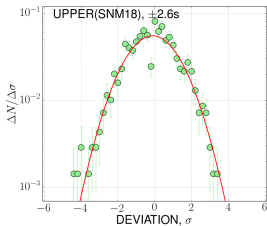
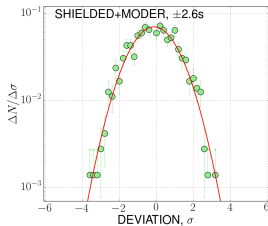
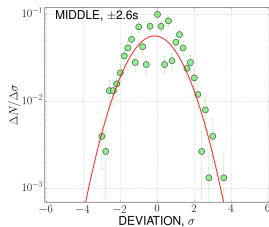
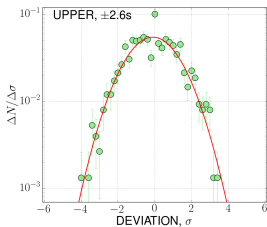
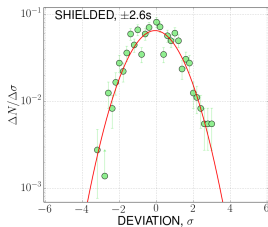


LOWER BOX, TIME GATE ± 1 s



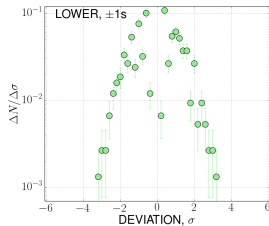
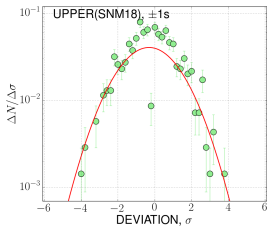
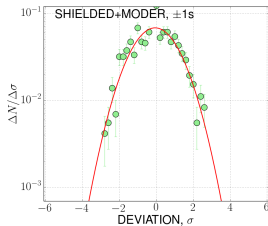
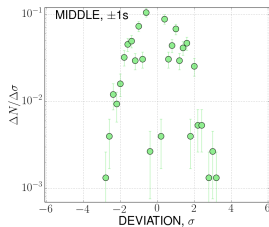
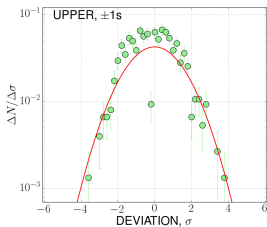
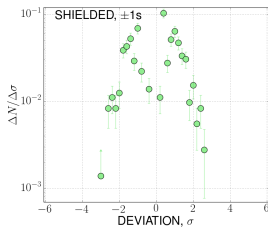
Распределение отклонений ($\pm 2.6\sigma$)

$$\sigma = (N_{\text{after}} - N_{\text{before}}) / \sqrt{\max(N_{\text{after}}, N_{\text{before}})}$$

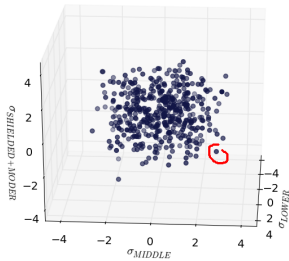
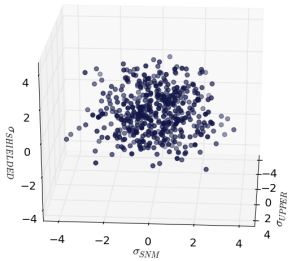
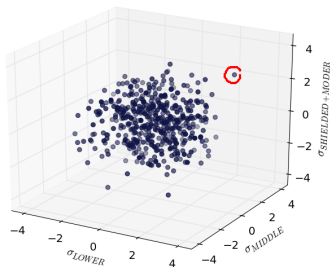
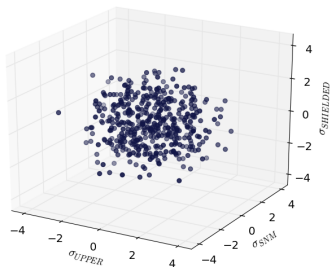


Распределение отклонений ($\pm 1s$)

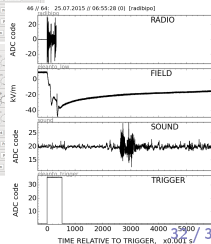
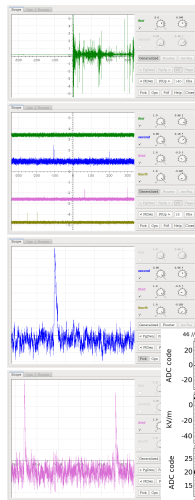
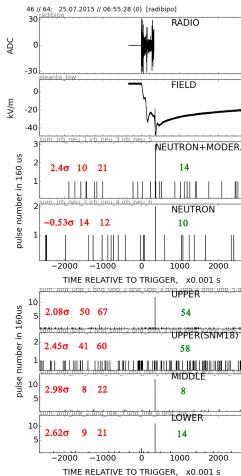
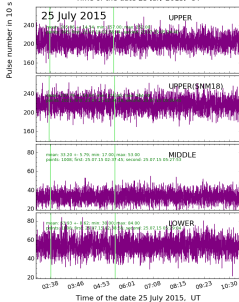
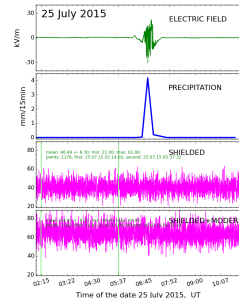
$$\sigma = (N_{after} - N_{before}) / \sqrt{\max(N_{after}, N_{before})}$$



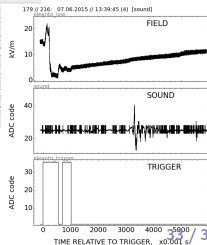
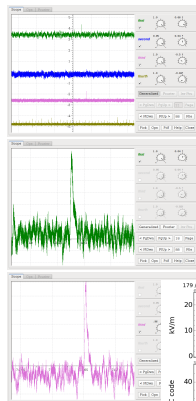
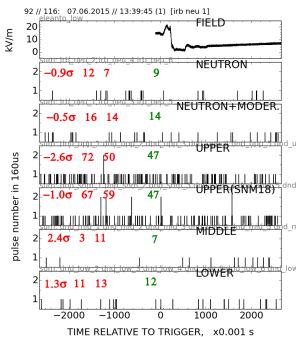
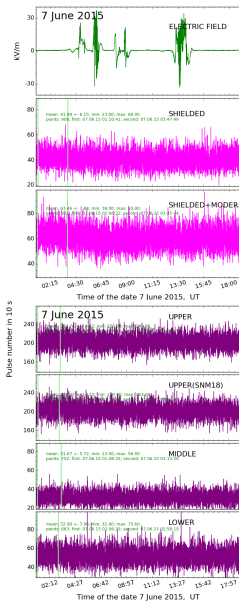
Корреляция отклонений ($\pm 2.6\sigma$)



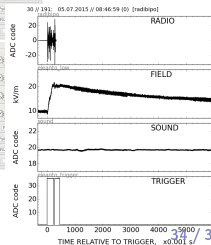
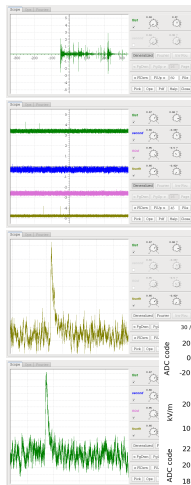
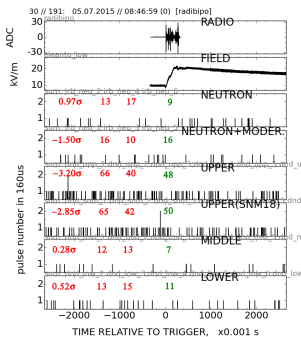
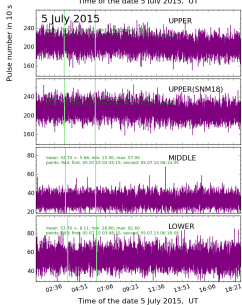
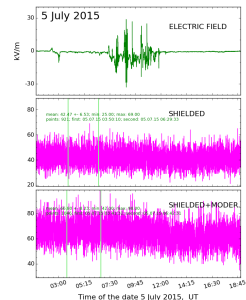
25 JULY 2015 // 06:55:28



7 JUNE 2015 // 13:39:45

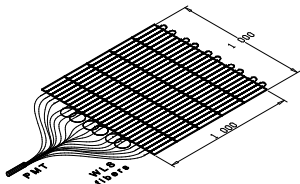


5 JULY 2015 // 08:46:59



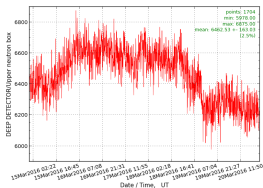
Планы на сезон 2016 года: *SHIELDED* детектор

- сцинтилляционный детектор большой площади

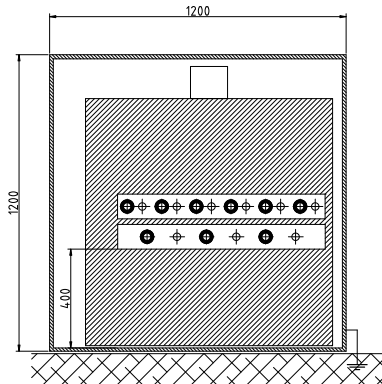
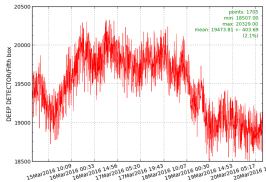


- сцинтиллятор большой площади как средство увеличить эффективную площадь регистрации нейтронов в экранированном детекторе

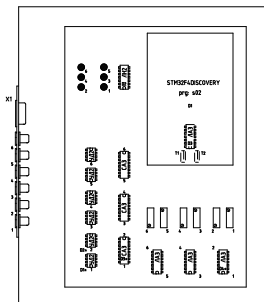
- интенсивность нейтронов (нейтронные счетчики)



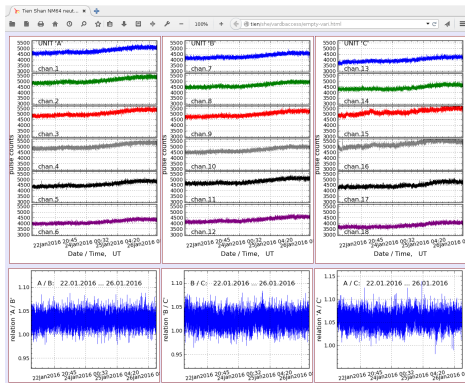
- интенсивность сцинтилляций



Планы на сезон 2016 года: новая система сбора данных для нейтронного монитора



СИСТЕМА СБОРА ДАННЫХ НА МИКРОПРОЦЕССОРНОМ
МОДУЛЕ "STM32F4DISCOVERY"
ВАРИАНТ НА 6 ИНФОРМАЦИОННЫХ КАНАЛОВ
Схема расположения



Эксперимент «ЭРГ» (ФИАН)

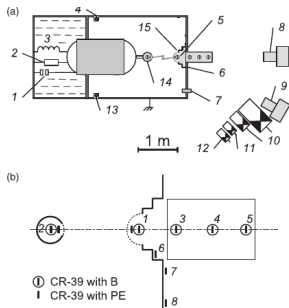
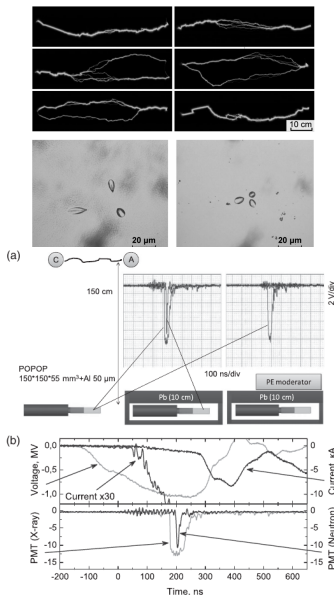


FIG. 1. The scheme of the laboratory experiment. (a) Layout of diagnostics: 1, 2, capacitive and active dividers; 3, high voltage input from Marx generator; 4, 13, magnetic probes; 5, track detectors; 6, anode shunt; 7, Rogowski coil; 8, 9, integral cameras; 10, scintillation detectors; 11, UV radiation detector; 12, PMT to visible light; 14, cathode; 15, anode. (b) Layout of CR-39 track detectors: 1, inside the anode; 2, inside the cathode; 3, 4, 5, axially placed in water; 6, 7, 8, radially placed at different distances from the discharge.

A.V.Agafonov, A.V.Bagulya, O.D.Dalkarov *et al*
Observation of neutron bursts produced by
laboratory high-voltage atmospheric discharge //
Phys. Rev. Letters 111, 115003 (2013)

A.V.Agafonov, V.A.Bogachenkov, A.P.Chubenko
et al Observation of hard radiations in a laboratory
atmospheric high-voltage discharge // Submitted to
Phys. Rev. Letters (2016)



Эксперимент «Чибис» (МГУ)

