Neutron production during TGEs

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Neutron generation connected with thunderstorms. Evidences and explanations

- The first evidence -> Shah et. al, 1985 ,BF3 counters enriched by B^{10}, by lightning

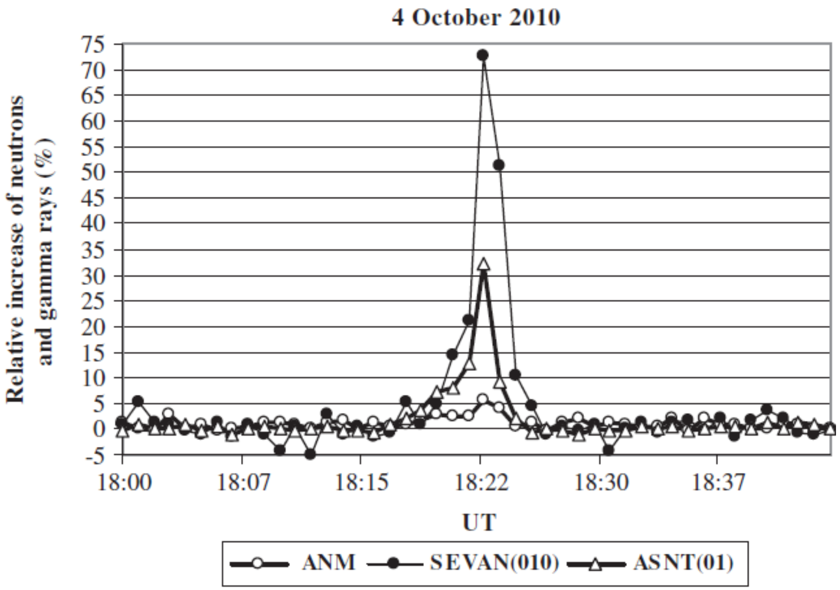
  Lead free Neutron Monitor (GNM)

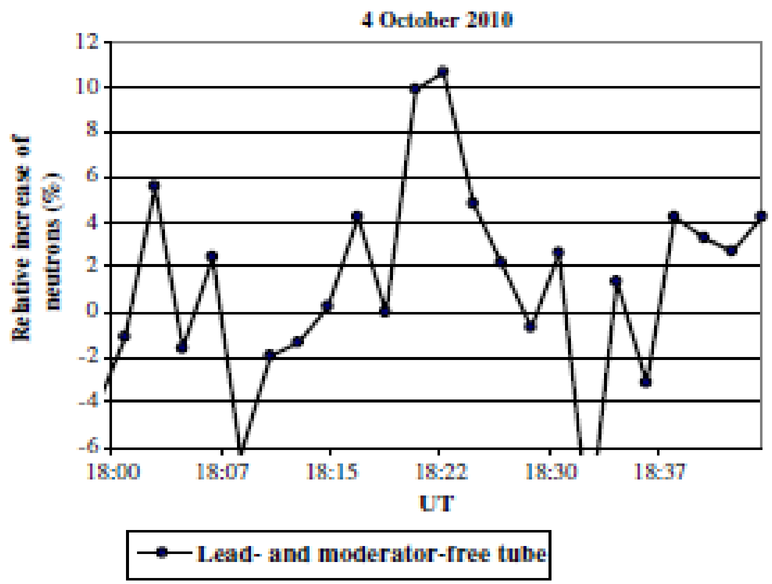
  Explanation by authors – nuclear fusion in lightning plasma $^{2}H + ^{2}H \rightarrow ^{3}He + n(2.45MeV)$
- Shyam and Kaushik, 1999
- Shah et. al, 2007
- Babich & Roussel Doupre, 2007 -> The temperature in lightning strokes is too low for neutron production by fusion. Another explanation of neutron generation.
- The photonuclear reaction from RREA gamma rays, with energies > 10 MeV is suggested to be a source of neutron generation.
- Less exotic source – photonuclear reaction $\gamma + ^{14}N \rightarrow ^{13}N + n$, *threshold energy* – $E_{\gamma} \sim 10MeV$

Recently published works

1. Chilingaryan et. al, Neutron bursts associated with thunderstorms, Physical Review D 85, 085017, 2012.
2. Gurevich et al. 2012. Strong Flux of Low-Energy Neutrons Produced by Thunderstorms, PRL 108, 125001. Fluxes of neutrons
3. Tsuchiya et al., 2012. Observation of thundercloud-related gamma rays and neutrons in Tibet, Phys. Rev. D 85, 092006. Neutron generation is explained by photonuclear reaction In lead
4. Chilingaryan et. al Remarks on recent results on neutron production during thunderstorms,

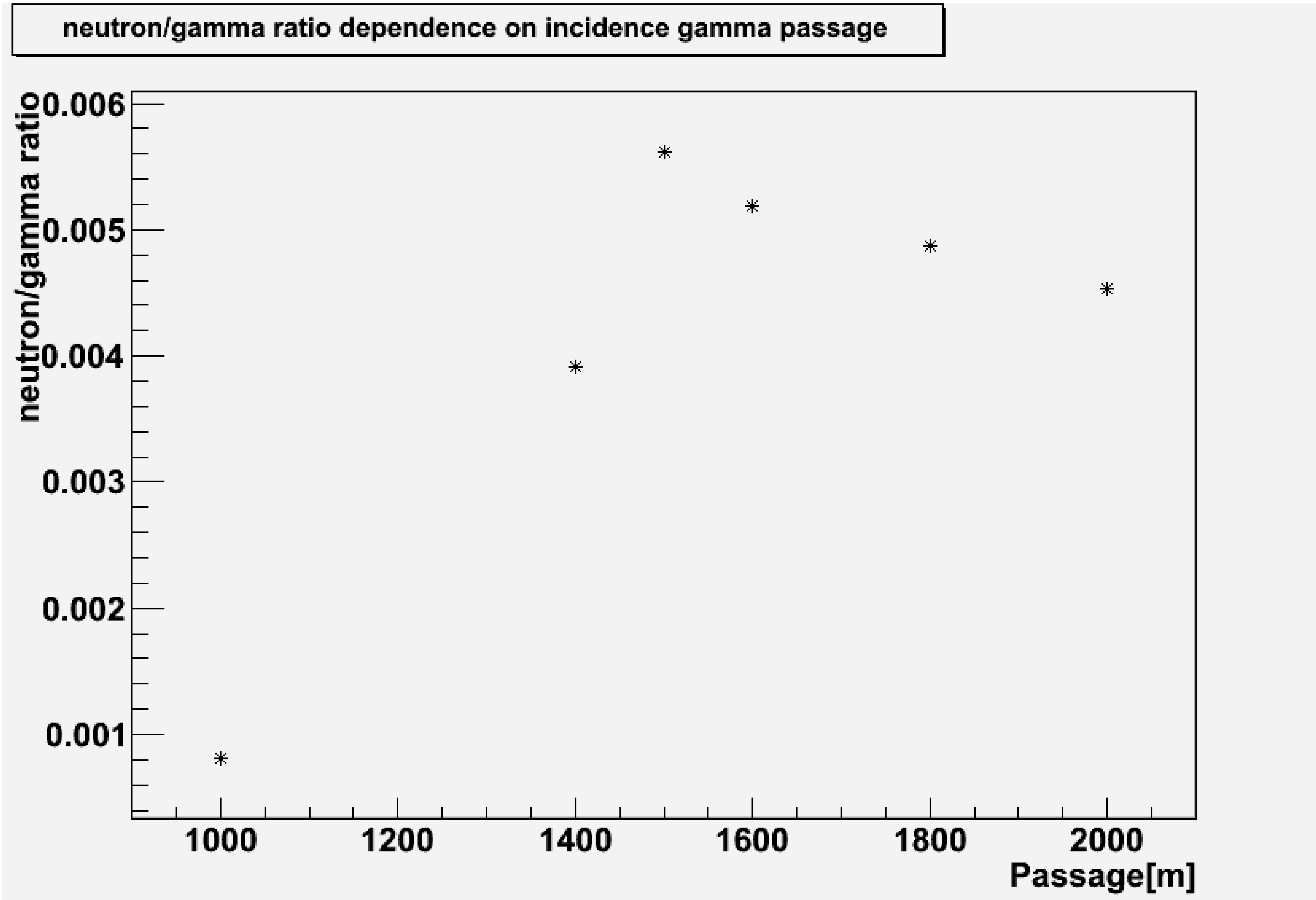
The count rates of the ANM, SEVAN, ASNT (01) combination (left) and Time series of the neutrons detected by bare proportional counter, located just on the ANM on 4 October 2010





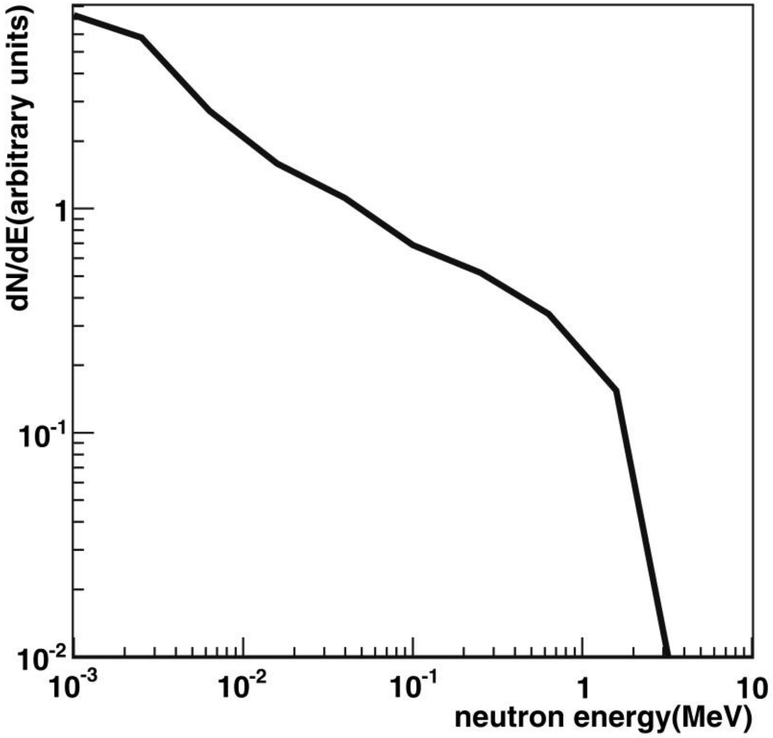
The list of the parameters of the 12 TGE events with neutron content (2009–2010).

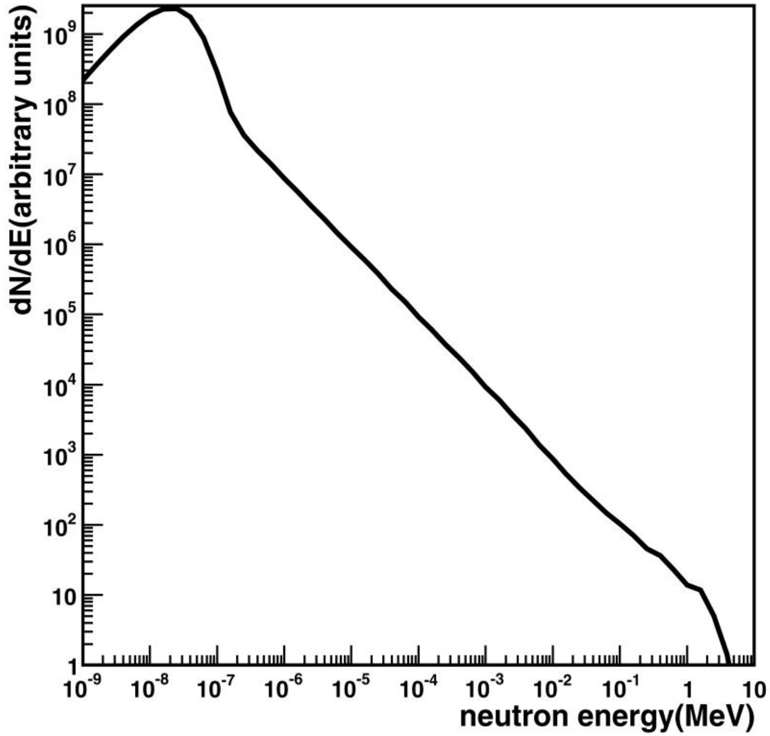
Day/Month/ Year	Enhancement of ANM count rate at the minute of maximal increase(ΔN/N(σ))	Enhancements of ASNT count rate(01 combination) at the minute of maximal excess	Required photonuclear neutron intensity (/min/m^2)	Ratio of neutron to gamma ray flux/ ration of recovered intensities n/γ
21/05/09	83/5	1920	3420	0.043
21/05/09	94/5.7	1921	3847	0.049
03/06/09	88/5.2	1215	3613	0.072
03/06/09	89/5.2	1076	3666	0.083
08/07/09	63/3.5	1116	2591	0.056
08/07/09	64/3.6	1290	2624	0.050
09/07/09	74/4.2	1690	3050	0.044
20/08/09	51/3.3	940	2110	0.054
02/09/09	50/3.2	900	2032	0.055
19/09/09	63/3.7	7452	2574	0.008/0.025
02/11/09	50/3.1	1101	2041	0.045
04/10/10	124/7.7	10280	5091	0.012/0.033



neutron/gamma ratio dependence on incidence gamma passage
neutron/gamma ratio
0.006
0.005
0.004
0.003
0.002
0.001
1000
1200
1400
1600
1800
2000
Passage[m]

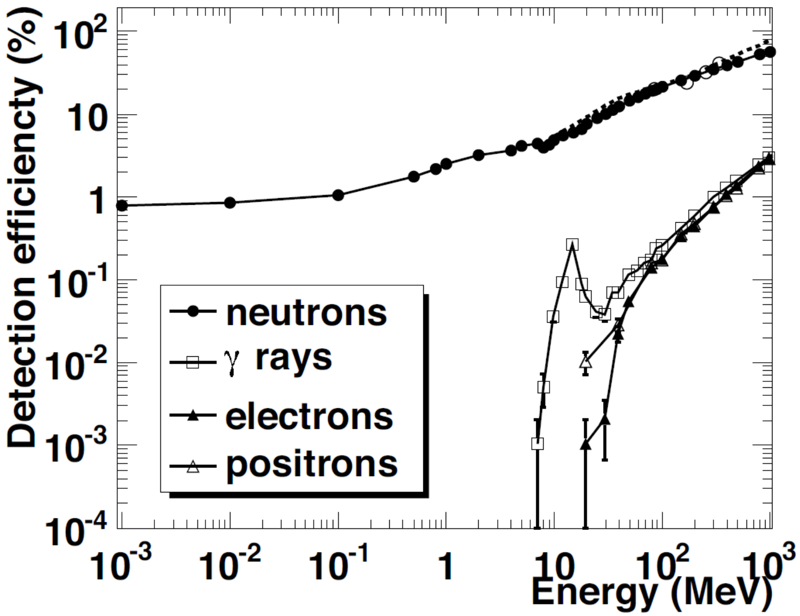
Differential energy spectrum of neutrons born in photonuclear reaction and reached to the ground level; gamma ray source is located at 4700m, and neutron detectors at 3200 m.

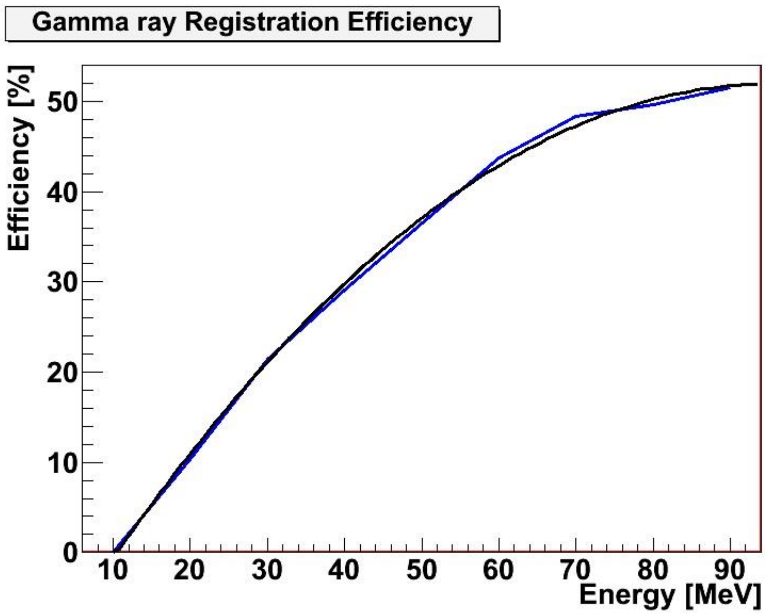




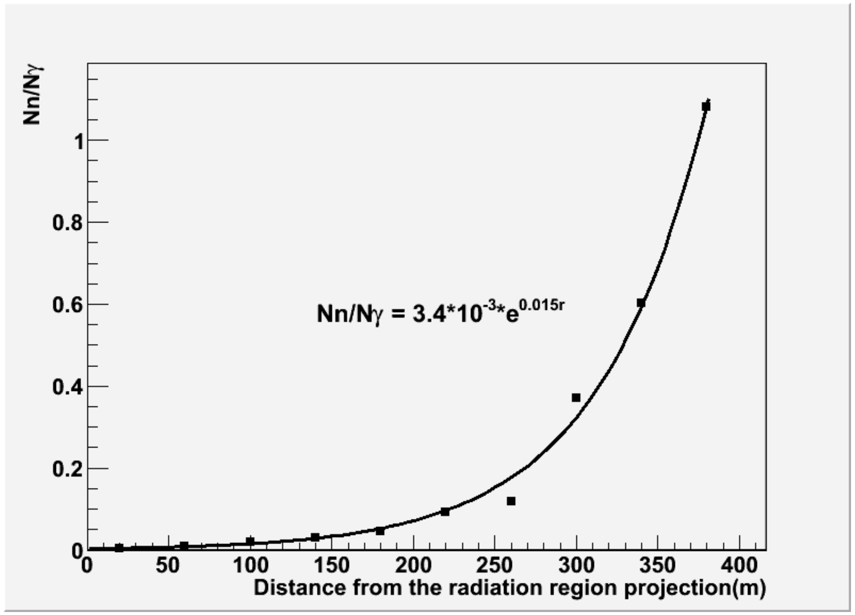
Neutron, γ- ray, electron and positron registration efficiencies of NM64(left).

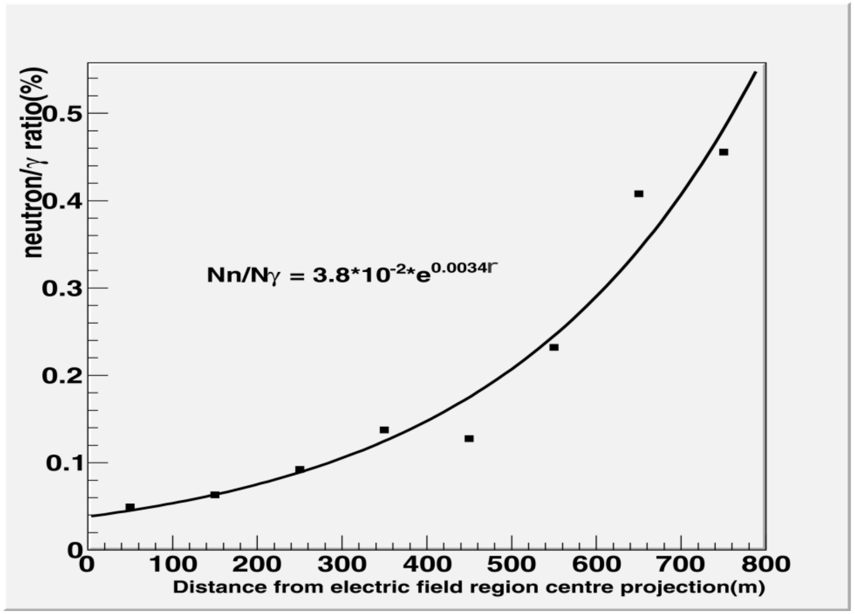
γ ray registration efficiency of ASNT 01 combination (right).



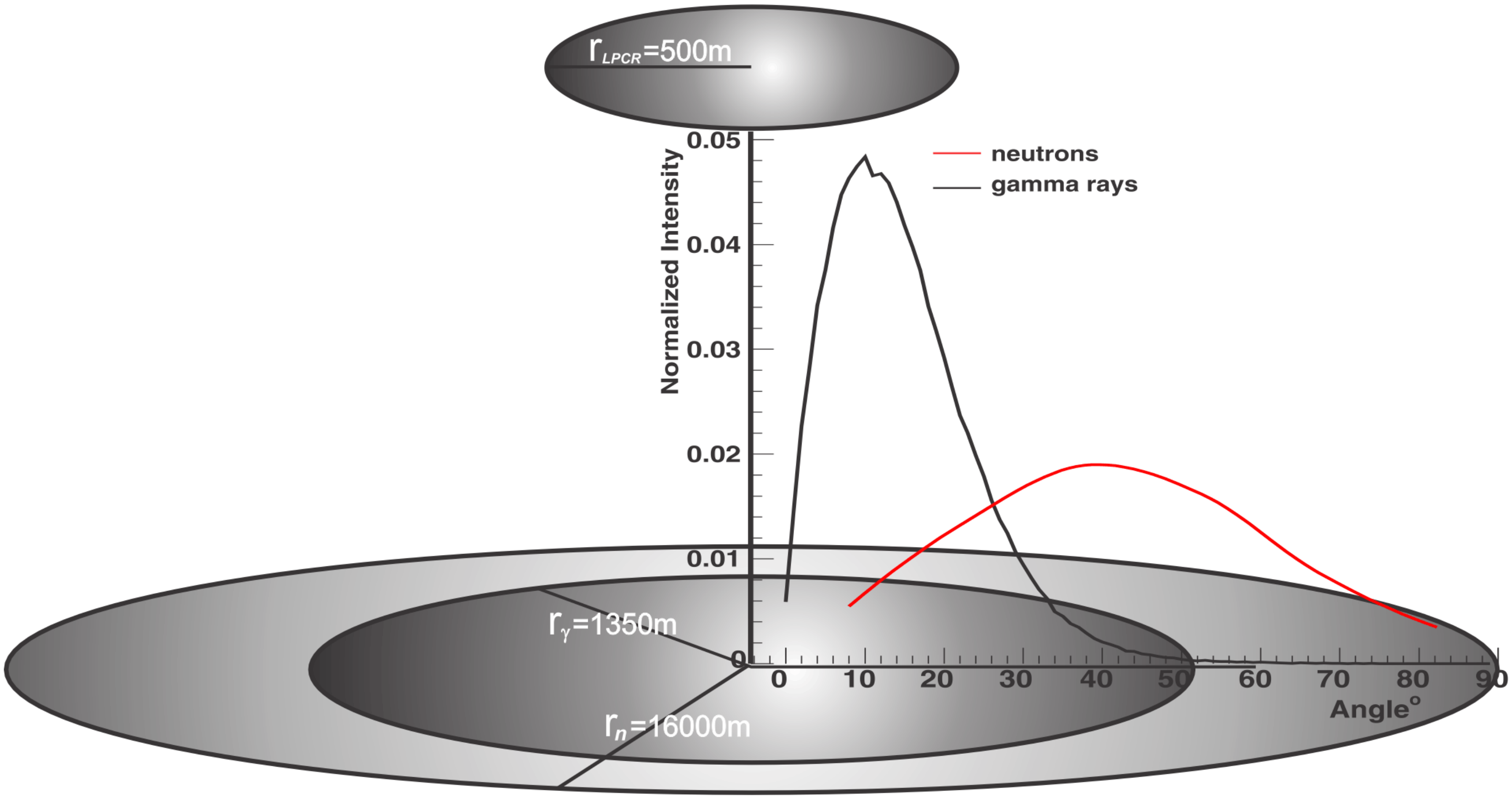


The dependence of the neutron/gamma ray ratio on distance from the LPCR projection center

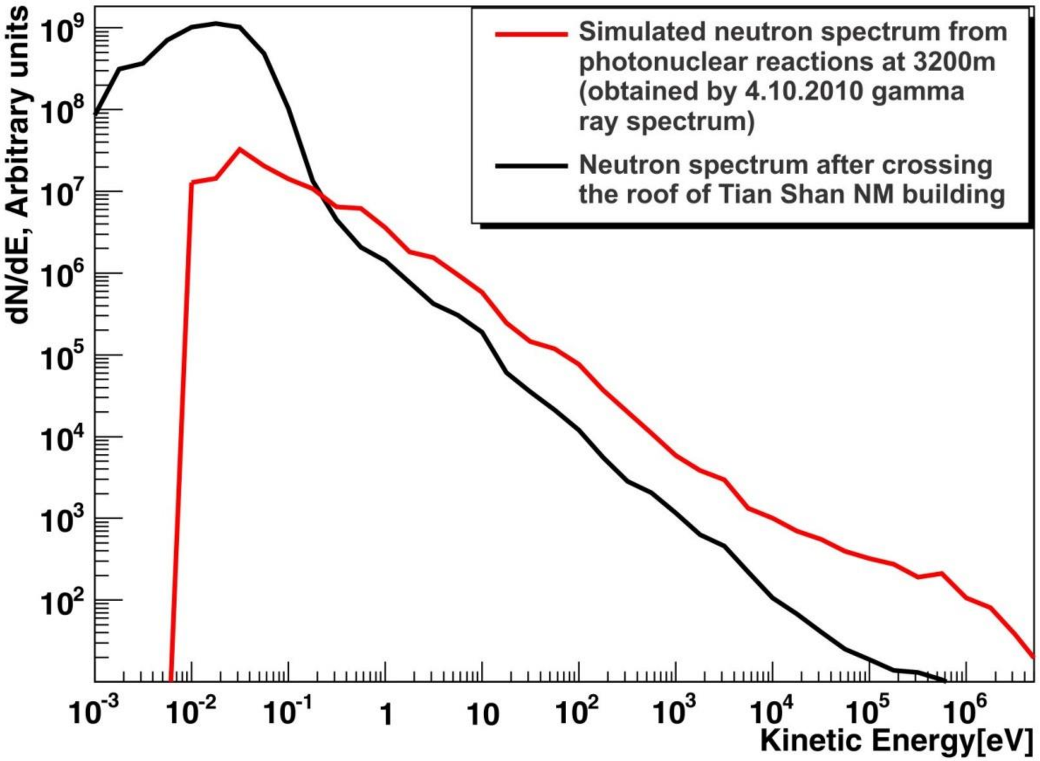




Lateral distributions of TGE neutrons and gamma rays, if the gamma source (LPCR) is located at 4700m. Due to differences in angular distributions of gamma rays and neutrons we can obtain “required” n/gamma ration, which strongly depends on the position of the detector



Energy spectra of photonuclear neutrons at ground level and in the building of Tien-Shan NM after crossing the roof matter



Conclusions

The neutron enhancements are created by TGE gamma rays. The source mechanism is the photonuclear reaction. There are two scenarios of enhancements of NM count rates: directly registrations of gamma rays by NM and neutron generation via photonuclear reaction