EXPERIMENT GEMMA: SEARCH FOR THE NEUTRINO MAGNETIC MOMENT

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Science motivation of the searching for μ_ν

- minimally-extended Standard Model:

$$\mu_\nu \sim \mathbf{10^{-19}}\ \mu_B \times (m_\nu / 1\text{eV})$$

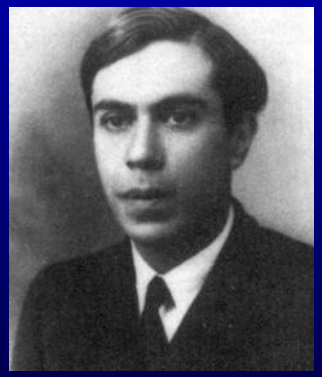
Bohr magneton $\mu_B = e \cdot h / 2\, m_e$

Science motivation of the searching for μ_ν

- number of extensions beyond the MSM:

$$\mu_\nu \leq \mathbf{10^{-14}}\ \mu_B \times (m_\nu / 1\text{eV})$$

Bohr magneton $\mu_B = e \cdot h / 2\, m_e$



$$\mu_\nu \sim \mathbf{10^{-10} - 10^{-11}}\ \mu_B$$

- Observation of ($\mu_\nu \sim \mathbf{10^{-12}}$) => M/D preference

Limits for the NMM from astrophysics

- White dwarfs, luminosity function: $\mu_\nu < 10^{-11}\mu_B$
- Nonstandard neutrino losses would delay the ignition of helium in the degenerate cores of low-mass red giants: $\mu_\nu < 3*10^{-12}\mu_B$
- SN1987A - neutrinos which are trapped in a SN core flip their helicity in electromagnetic interactions, taking them into nearly sterile right-handed states which escape directly from the inner SN core: $\mu_\nu < 3*10^{-12}\mu_B$

The history of the reactor experiments

1976 – Savannah River. ***The first observation of the ν - e scattering.***
F. Reines et al. [P.R.L.37,315(1976)].
~ 16 kg plastic scintillator, ν flux of 2.2×10^{13} ν / cm^2 / s

1989 – ***A revised analysis by P. Vogel and J. Engel [P.R.,D39,3378(1989)]:***

$\mu_\nu \leq (2-4)\times10^{-10}\ \mu_B$

1992 – Krasnoyarsk. ***G.S. Vidykin et al. [Pis'ma v ZhETPh, 55,206(1992)]***
~ 100 kg liquid scintillator C_6F_6, 254 days "on" / 78 days "off "

$\mu_\nu \leq 2.4\times10^{-10}\ \mu_B$ (90% CL)

1993 – Rovno. ***A.V. Derbin, L.A. Popeko et al. [JETP Letters, 57,768(1993)]***
75 kg silicon multi-detector, 600 Si(Li) cells,
ν-flux of ~ 2×10^{13} ν / cm^2 / s , 30 days "on"/17 days "off "

$\mu_\nu \leq 1.9\times10^{-10}\ \mu_B$ (95% CL)

The history of the reactor experiments

2001-2005 – Bugey. ***The MUNU experiment.***

Z. Darakchieva et al. [P.L.B. 615 (2005)].

~ 11.4 kg CF_4 TPC, 66.6 days "on" / 16.7 days "off "

$\mu_\nu \leq 9 \times 10^{-11}\ \mu_B$

1989 – Moscow. Proposed to detect (ν– *e*) scattering with low-background HPGe.

A.Vasenko et al. [P.T.E.(rus), 2,56(1989)]

2001- … – Taiwan. ***The TEXONO experiment***

H.T.Wong et al. [P.R. D75 (2007)]

1 kg HPGe detector, ν-flux of ~ 6.4×10^{12} ν / cm^2 / s

570 days "on" / 127 days "off "

$\mu_\nu \leq 7.4 \times 10^{-11}\ \mu_B$ (90% CL)

2005- … – Udomlya. ***The GEMMA experiment***

A.Beda et al. [P.A.N. (rus), 70(2007)]

1.5 kg HPGe detector, ν-flux of ~ 2.7×10^{13} ν / cm^2 / s ,

216 days "on"/ 77 days "off "

$\mu_\nu \leq 5.8 \times 10^{-11}\ \mu_B$ (90% CL)

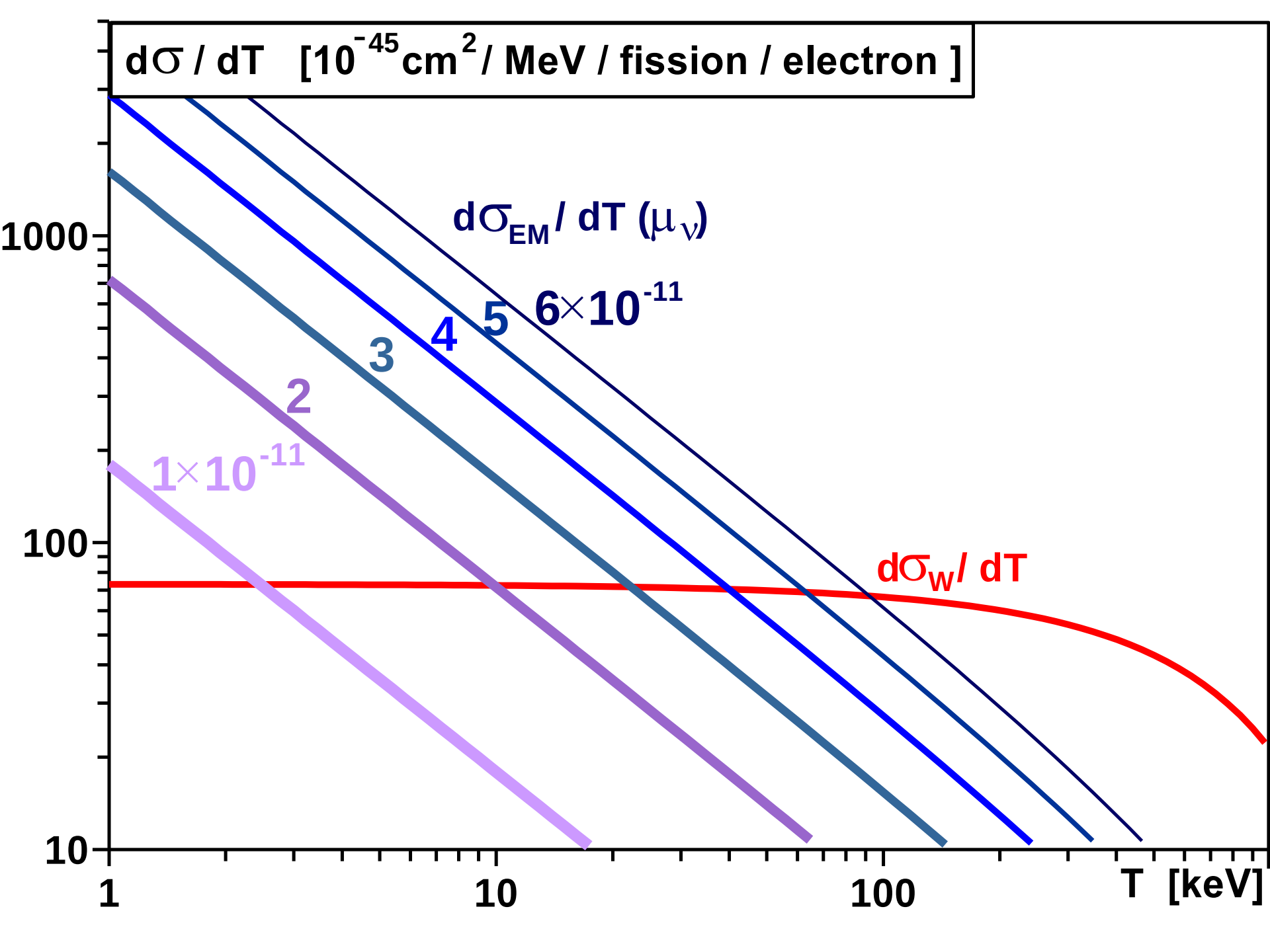
Measurement of the NMM at reactor

- The effects of the NMM can be searched for in the recoil electron spectrum (T) from the ν - e scattering.

- The total cross-section $d\sigma/dT$ is a sum of two:

  $(d\sigma/dT)_W + (d\sigma/dT)_{EM}$

  which depend on the recoil electron energy T in a very different way

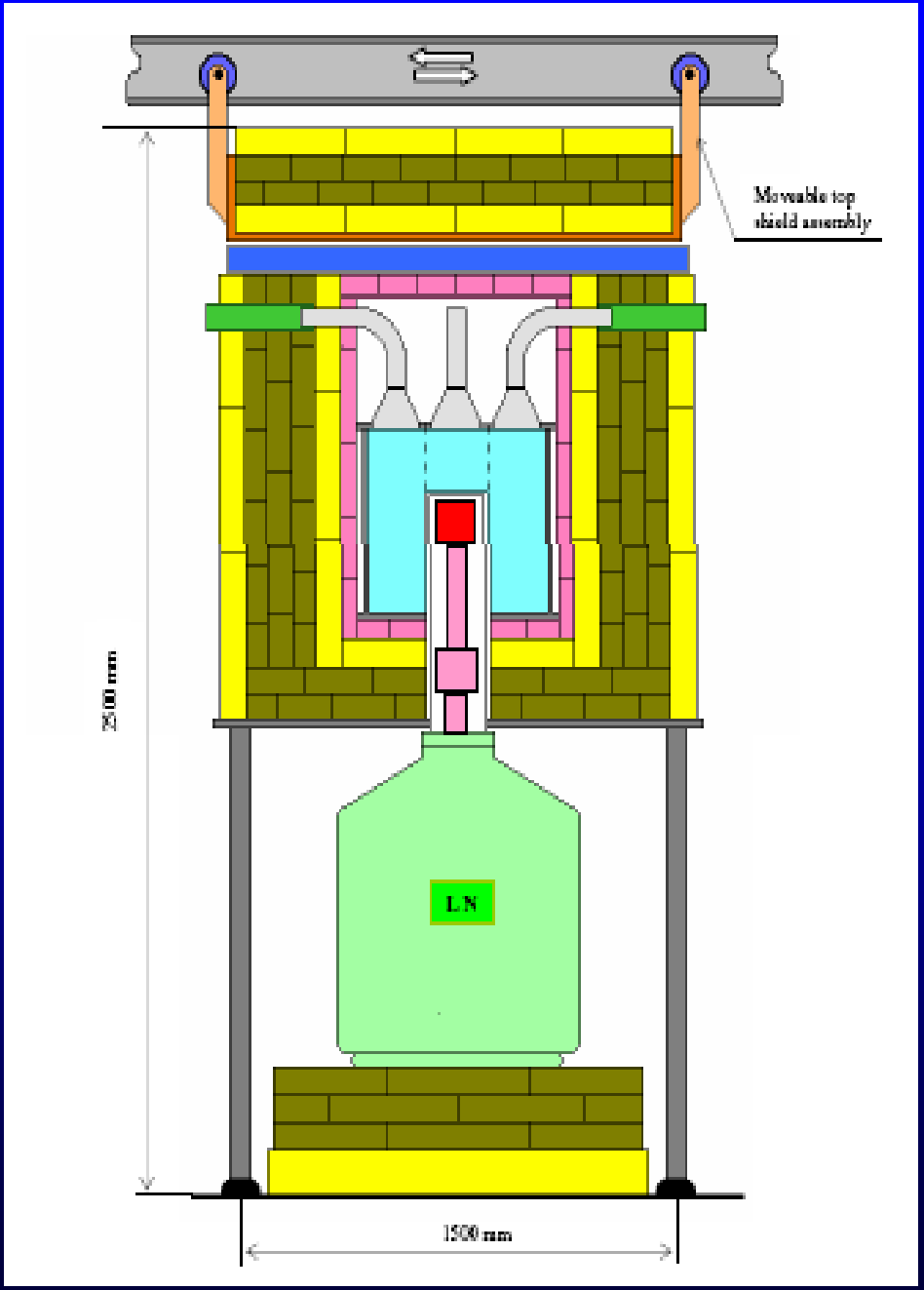

dσ / dT [10^-45 cm^2 / MeV / fission / electron]
dσ_EM / dT (μ_ν)
6×10^-11
5
4
3
2
1×10^-11
dσ_W / dT
1000
100
10
1
10
100
T [keV]

Experiment **GEMMA**

(**G**ermanium **E**xperiment for measurement of **M**agnetic **M**oment of **A**ntineutrino)

*[Phys. of At. Nucl.,**67**(2004)1948]*

- Spectrometer includes a HPGe detector of 1.5 kg installed within NaI active shielding.
- HPGe + NaI are surrounded with multi-layer passive shielding : electrolytic copper, borated polyethylene and lead.

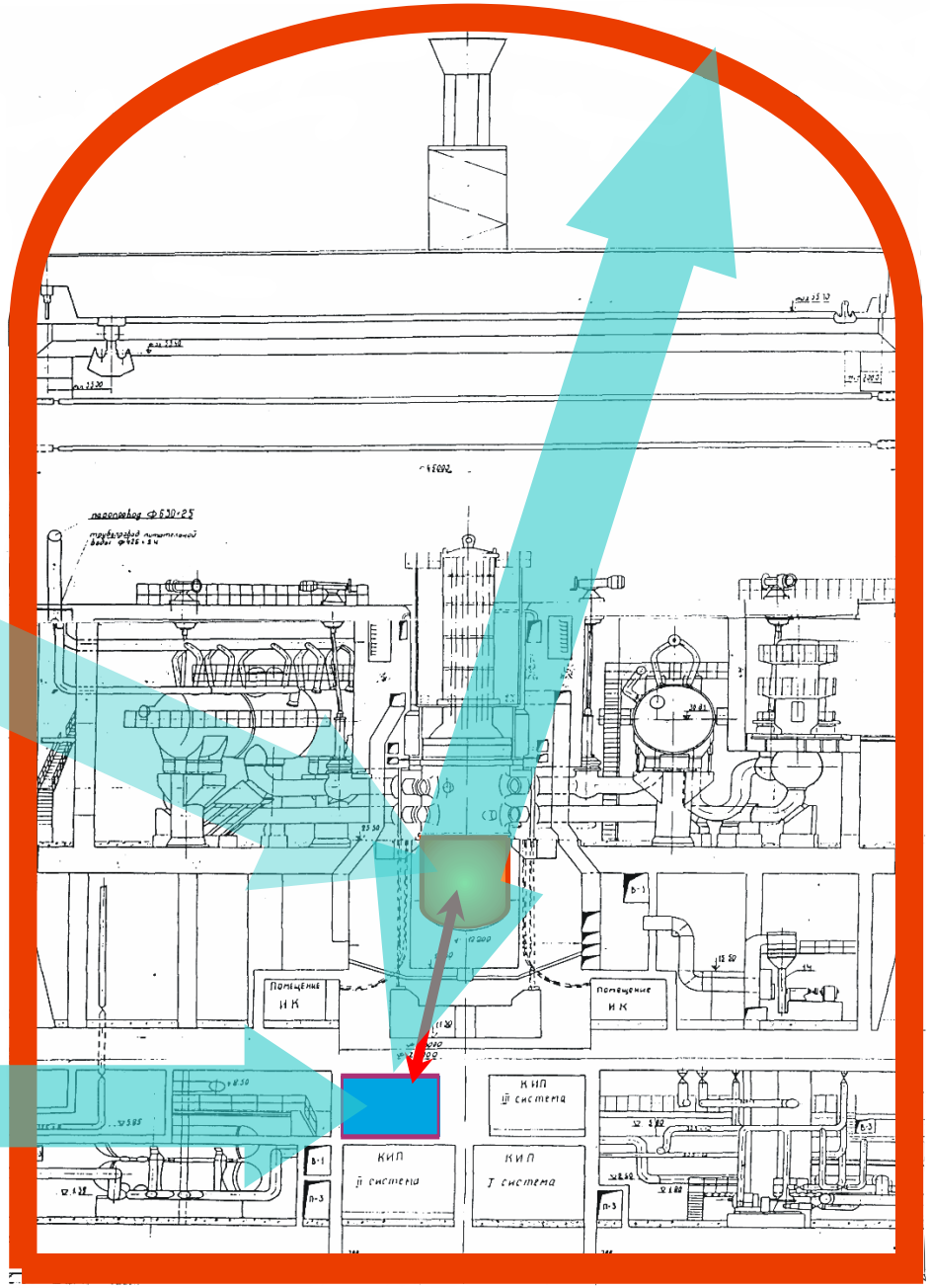


Reactor unit #2 of the
“Kalinin” Nuclear Power Plant
(400 km North from Moscow)

Power: 3 GW
ON: **315** days/y
OFF: **50** days/y

Total mass above
(reactor, building, shielding, etc.):
~70 m of W.E.

Technological room
just under reactor
14 m only!
2.7×10^{13} ν/cm²/s



Phase-1: 13 months (08.2005-09.2006)
= 216 days ON + 77 days OFF

Phase-2: 19 months (09.2006-05.2008)
= 283 days ON + 42 days OFF

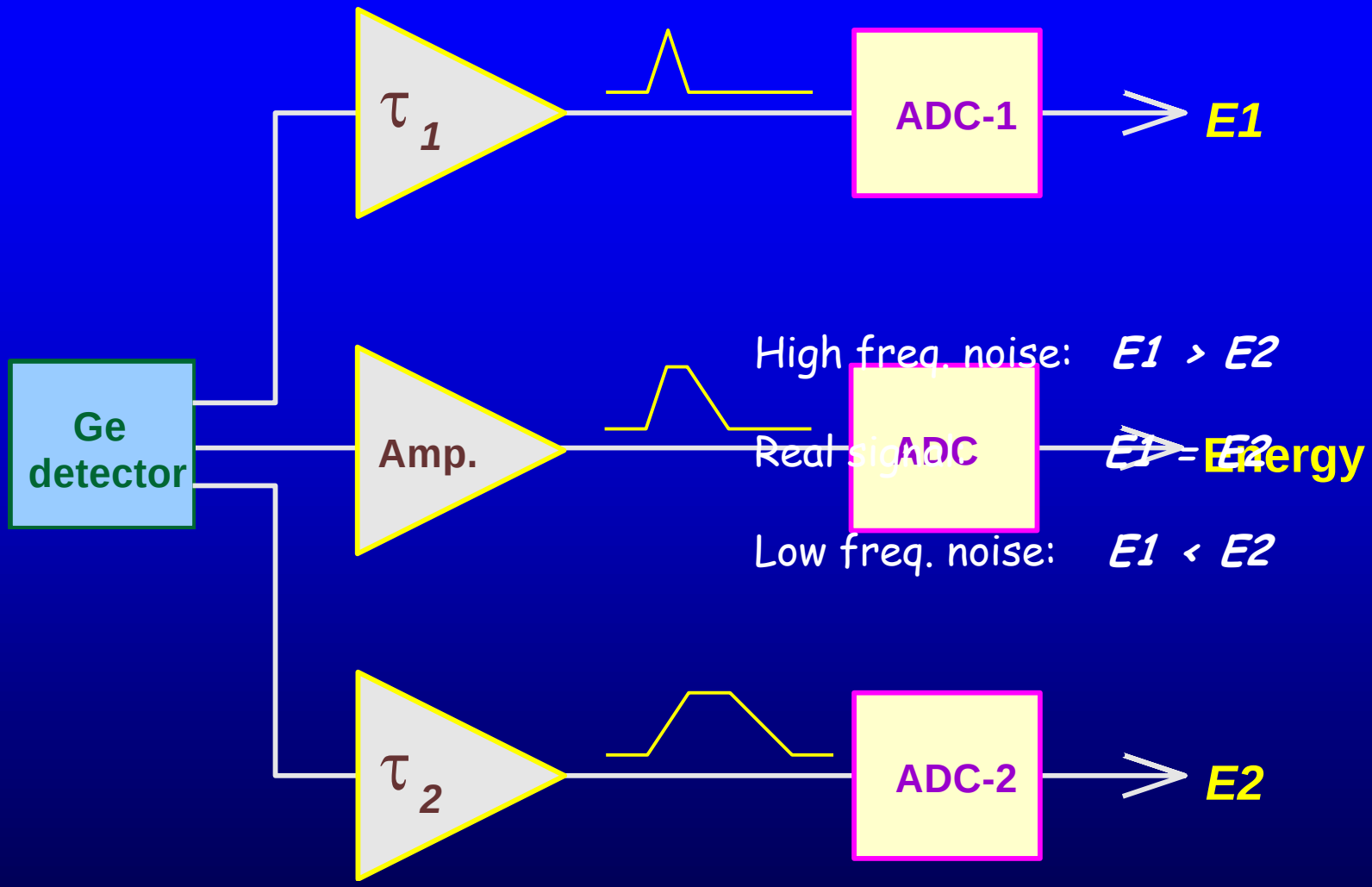
Phase-3: 18 months (05.2008-11.2009)
— *data analysis is in progress…*

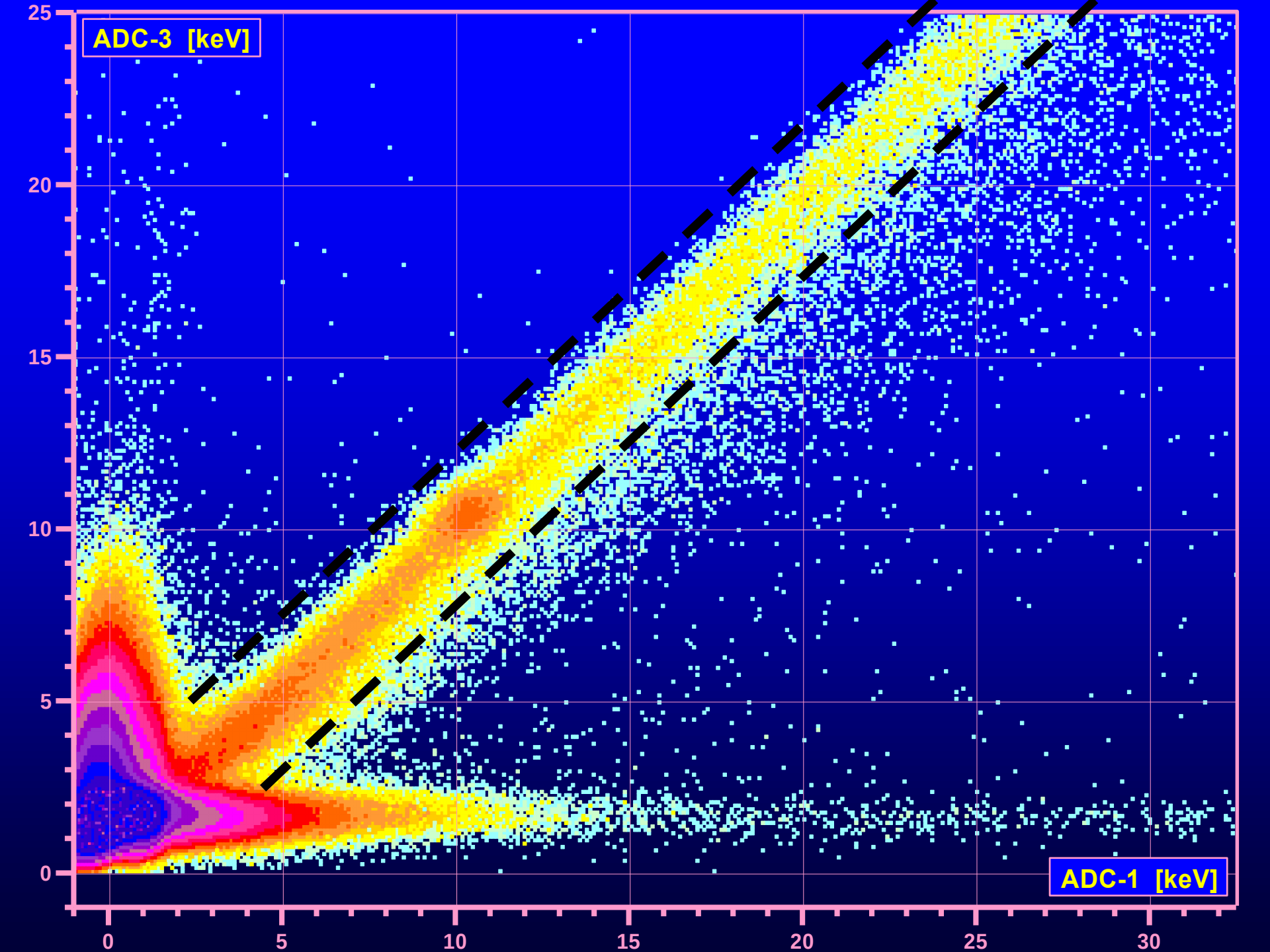
GEMMA background conditions

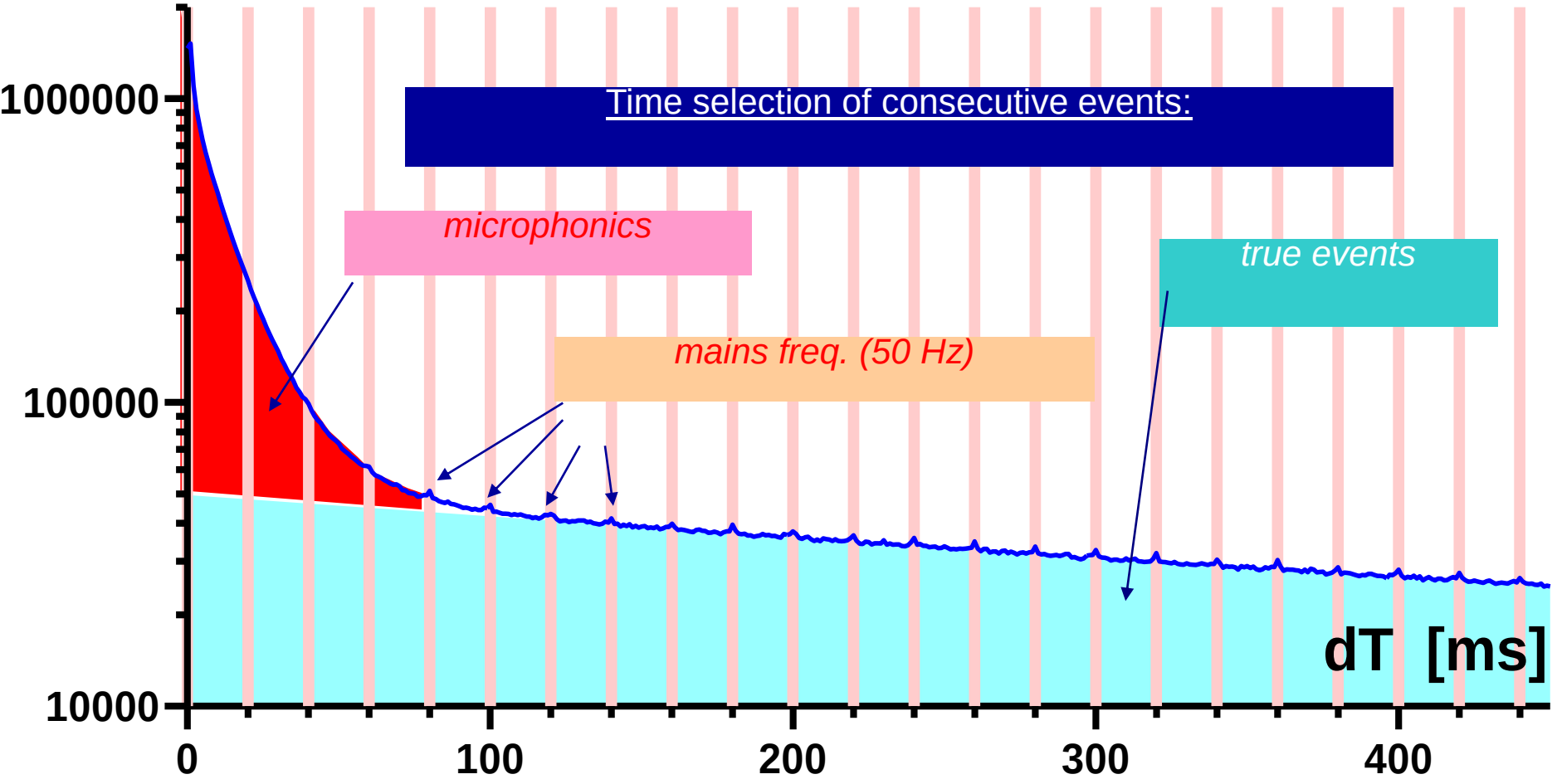
- **γ-rays** were measured with Ge detector. The main sources are: **^{137}Cs , ^{60}Co, ^{134}Cs.**

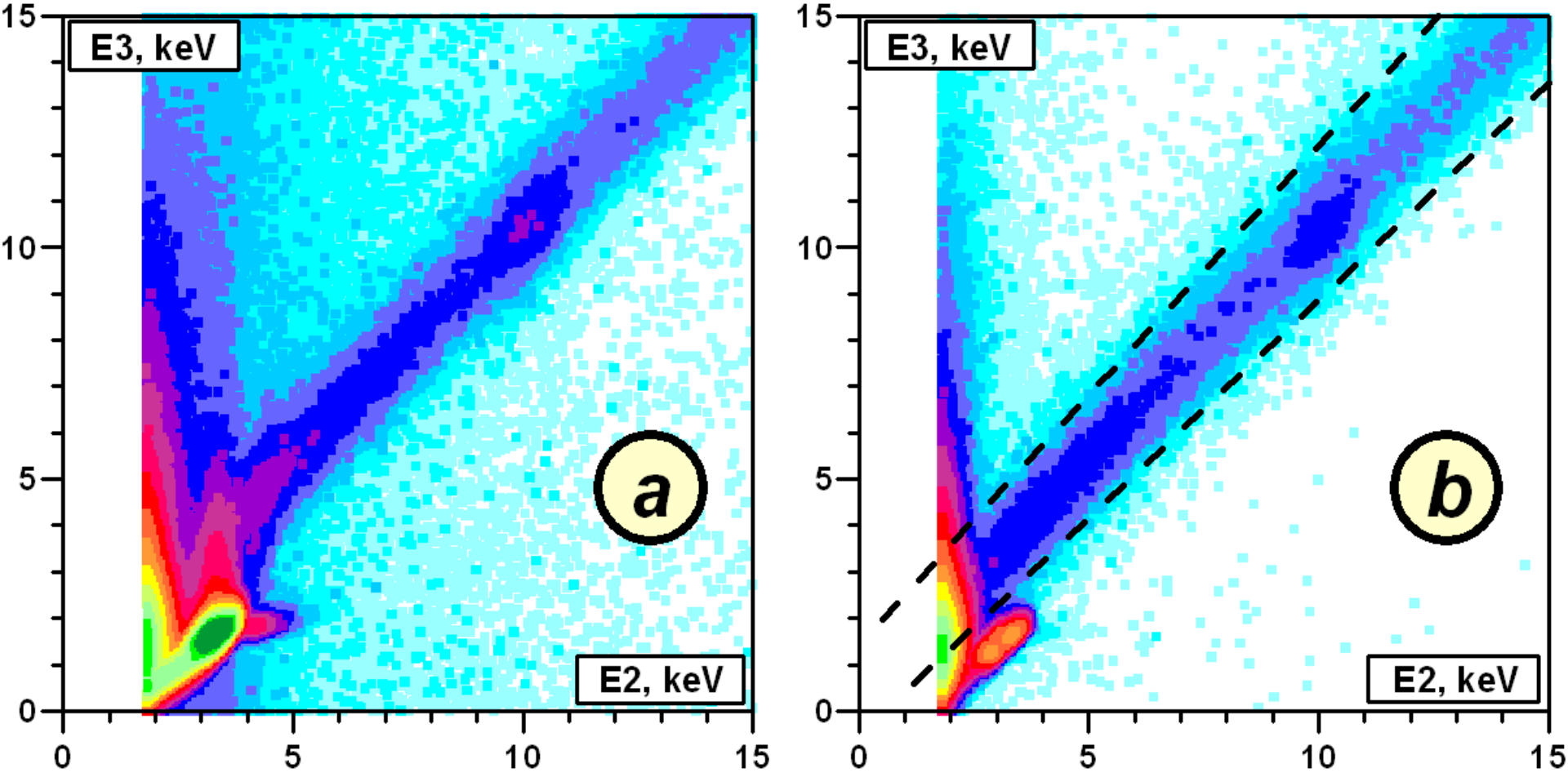
- **Neutron** background was measured with ^{3}He counters, i.e., thermal neutrons were counted. Their flux at the facility site turned out to be **30 times lower** than in the outside laboratory room.

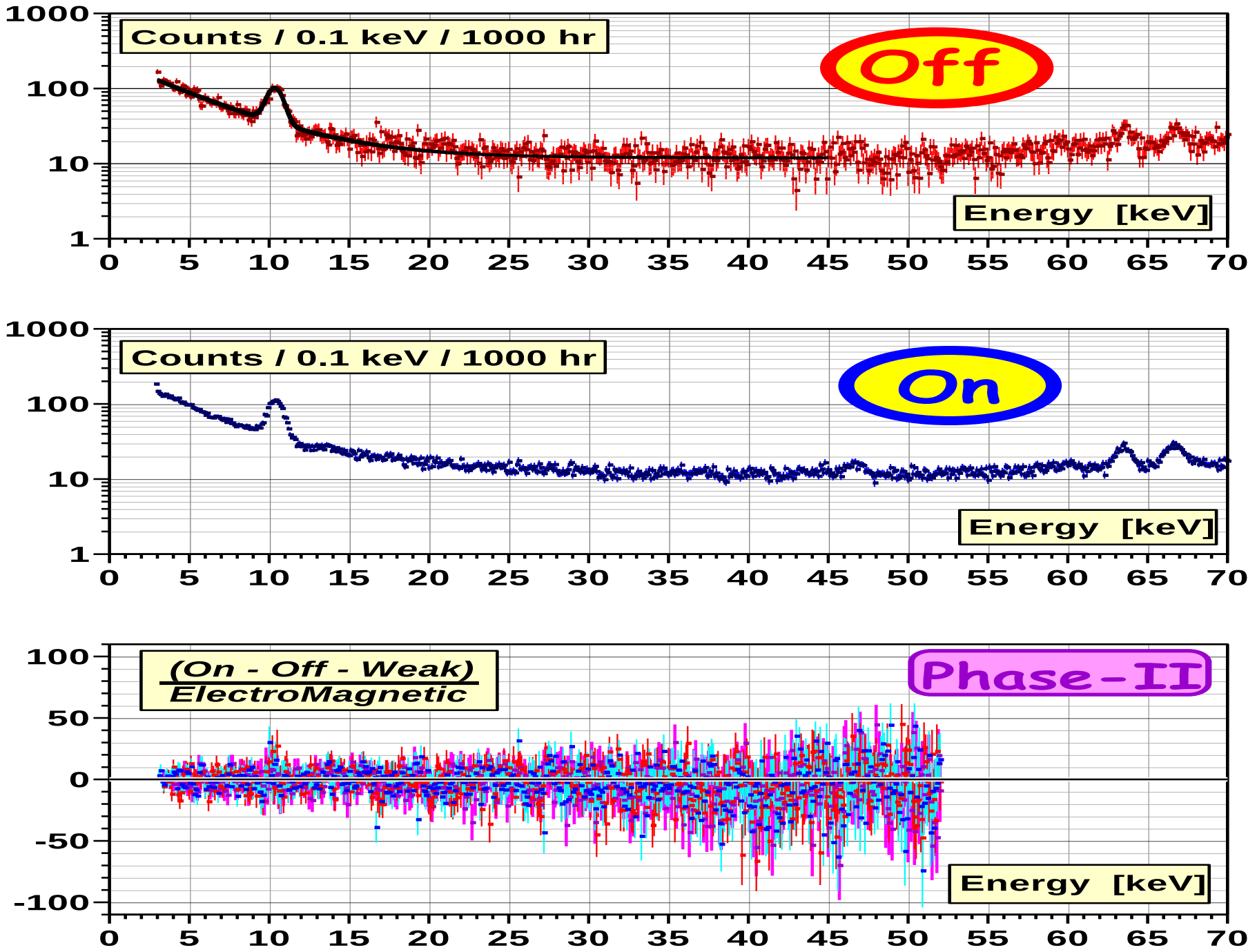
- **Charged** component of the cosmic radiation (**muons**) was measured to be **5 times lower** than outside.

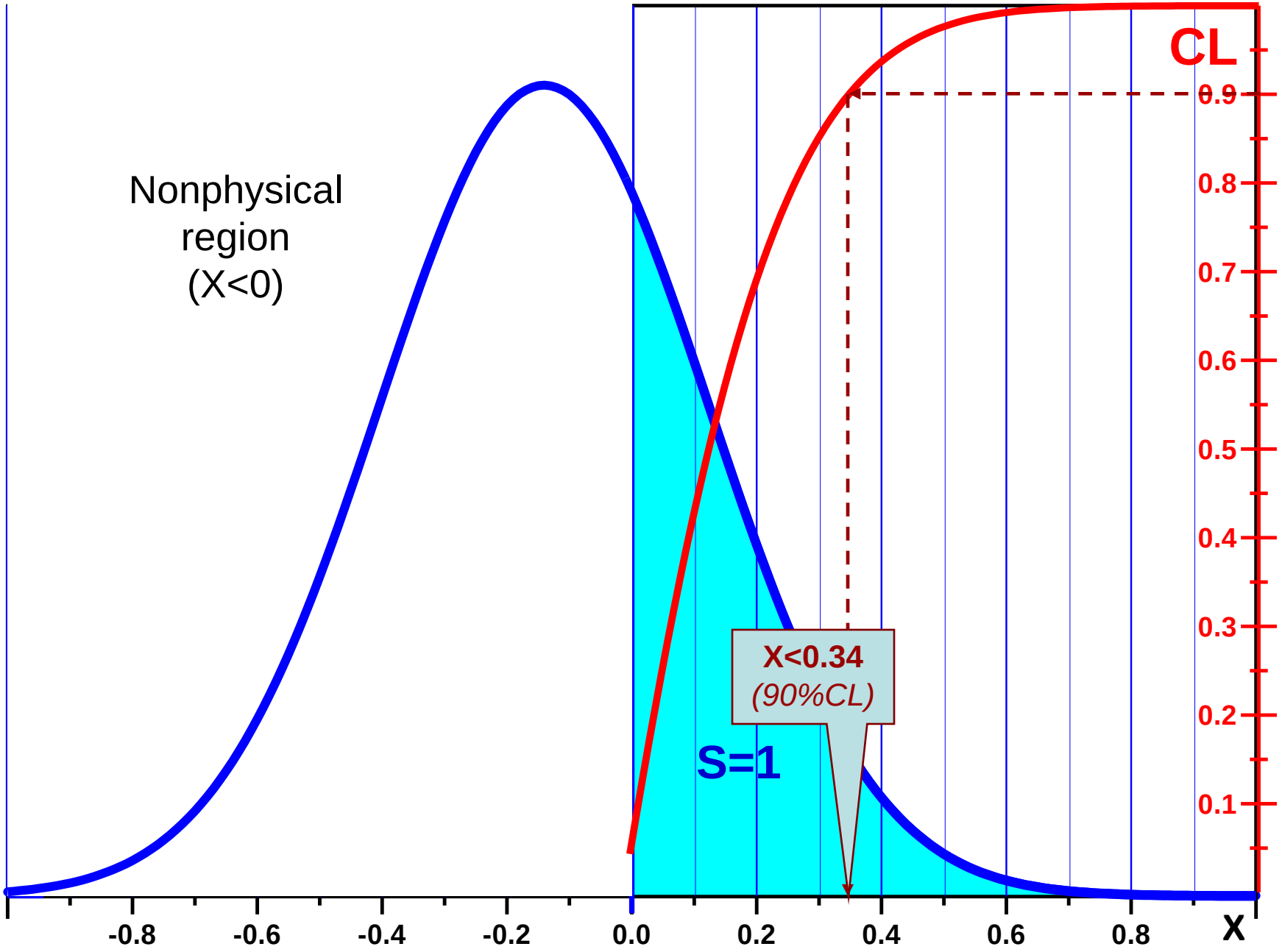

Ge detector
τ 1
Amp.
τ 2
ADC-1
ADC
ADC-2
E1
E2
High freq. noise: E1 > E2
Real signal: E1 = E2
Low freq. noise: E1 < E2
Energy


ADC-3 [keV]
ADC-1 [keV]
25
20
15
10
5
0
0
5
10
15
20
25
30


Time selection of consecutive events:
microphonics
mains freq. (50 Hz)
true events
1000000
100000
10000
0
100
200
300
400
dT [ms]


E3, keV
E2, keV
a
b
0
5
10
15


Counts / 0.1 keV / 1000 hr
Off
Energy [keV]
Counts / 0.1 keV / 1000 hr
On
Energy [keV]
(On - Off - Weak)
ElectroMagnetic
Phase-II
Energy [keV]


Nonphysical
region
(X<0)
CL
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
X<0.34
(90%CL)
S=1
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
X

Experimental sensitivity

$$\mu_\nu \propto \frac{1}{\sqrt{N_\nu}} \left(\frac{B}{mt} \right)^{\frac{1}{4}}$$

N_ν : number of signal events expected
B : background level in the ROI
m : target (=detector) mass
t : measurement time

$N_\nu \sim \varphi_\nu$ (~ *Power / r* ^{2})
~ *log* (T_{max} / T_{min})

GEMMA I 2005 – 2009

φ_ν ~ 2.7 ×10^{13} ν / cm^2 / s
t ~ 4 years
B ~ 2.5 keV^{-1} kg^{-1} day^{-1}
m ~ 1.5 kg
T_{th} ~ 2.5 keV

$$\mu_\nu \leq 3.2 \times 10^{-11} \mu_B$$

hep-ex:1005.2736