# System of the spectrometric measurement of a source activity in the BEST experiment

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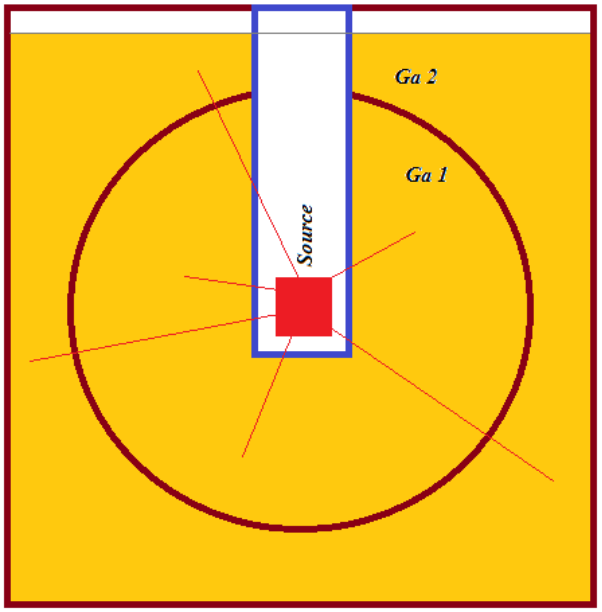
# The BEST experiment




50 t of metallic Ga

~ monochromatic ν source $^{51}$Cr,

3 MCi ($10^{17}$ /sec), $E_\nu = 750$ keV

$$P_{ee} = 1 - \sin^2 2\theta \cdot \sin^2\left(1.27 \frac{\Delta m^2(eV^2) \cdot L(m)}{E_\nu\,(MeV)}\right)$$

Search for parameters ($\Delta m^2 \sim 1$ eV$^2$, $\sin^2 2\theta \sim 0.1$) by the difference of capture rates in 2 zones of the target with two different distances to the source

The same path length in each zone – the same neutrino capture rate w/o oscillations

Systematic uncertainties ≈ statistic uncertainties for whole target ≈ 2.6 %

Expected uncertainty of the source activity measurement ~ 1 %

2 methods of the activity measuring:

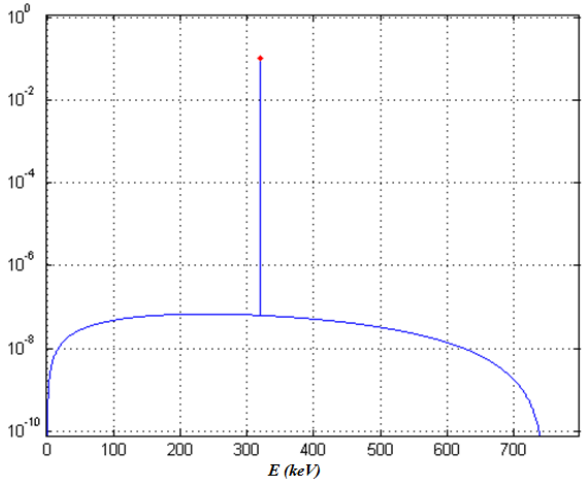
- calorimetric (650 W / 3 MCi)
- spectrometric (IB spectrum)

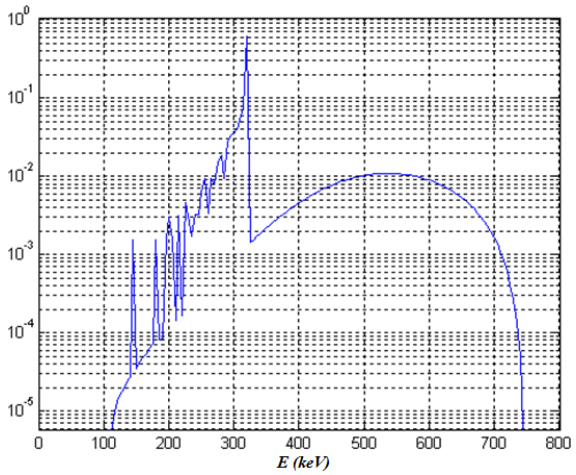
# Gamma radiation of $^{51}Cr$

1. 320 keV, 10% decays
2. IB, <750 keV, $3.8 \cdot 10^{-4} \times 0.902$
3. IB, <430 keV, $1.2 \cdot 10^{-4} \times 0.0983$

Internal Bremsstrahlung:

$$y(x) = A \cdot (1 - x)^2 \cdot x \qquad x = \frac{E}{Q}$$




N(320) / N(IB) ~ 300 - in the source

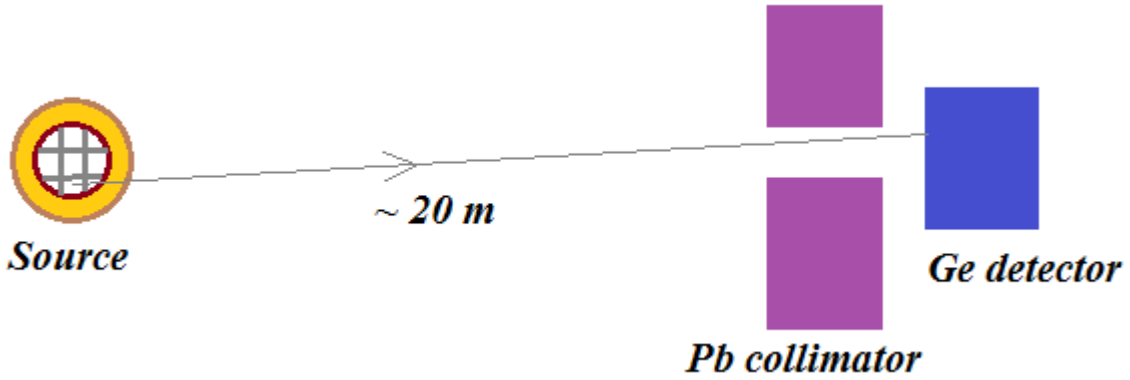
Large source (~1 liter) with non-homogeneity and self-absorption

Measurement of activity on a continuous spectrum of IB

After W primary shield

N(320) / N(IB) ~ 1.5 (decreases 200 times)

# Spectrometric method of source activity measurement




Detector registers a signal – the sum of signals from all parts :

$$S(E) = \sum_{i=1}^{N} S_i(E)$$

Photons of different energies pass through the shield in different ways:

Separation continuous spectrum on $N_j$ ($\geq N$) parts:

$$S_j = \sum_{i=1}^{N} \varepsilon_{ij}' \cdot B_i$$

$\varepsilon_{ij}'$ – efficiencies

$$B = (\varepsilon')^{-1} \cdot S$$

$B_i$ – activities of the parts

Activity of the source:

$$A = \sum_{i=1}^{N} B_i$$

(Gorbachev, Malyshkin. IET (2015) № 3, p. 418)

# Expected counting rate

From Monte Carlo (Geant4)

Beyond the primary shield:

320 keV – $2.8 \cdot 10^{-6}$

IB 750 keV – $5.1 \cdot 10^{-4}$

IB 430 keV – $1.5 \cdot 10^{-6}$

The total number of photons outside the shield $5.1 \cdot 10^{10}$ $s^{-1}$

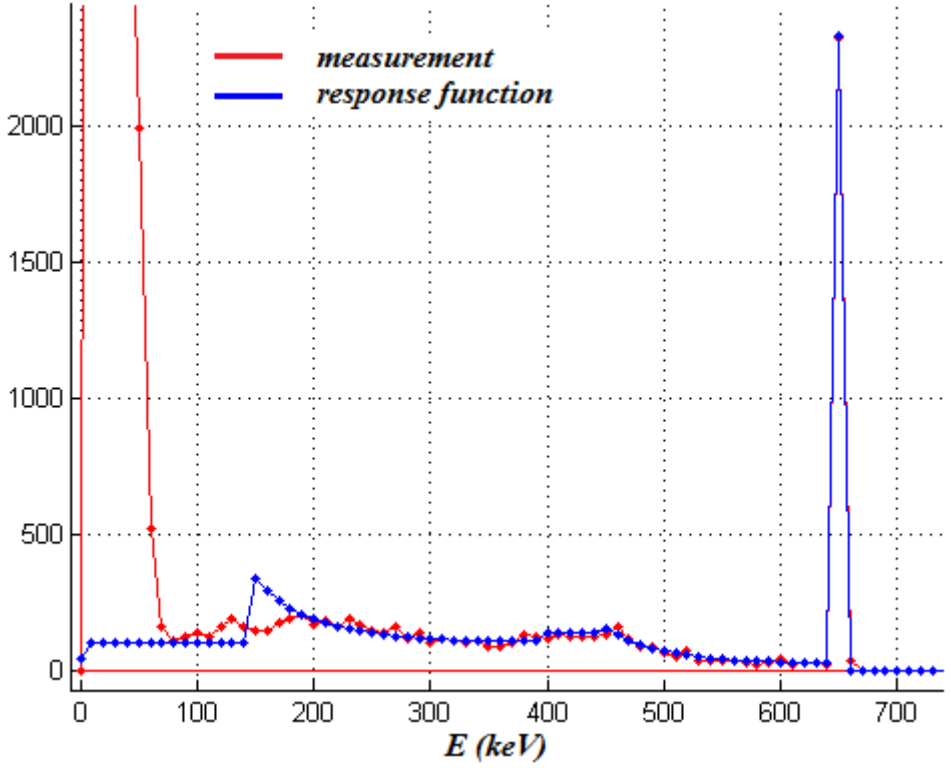
320 keV – 61%, IB 750 keV – 39%, IB 430 keV– $4 \cdot 10^{-3}$ %

At a distance of 20 m with collimator 1 cm one can expect 750 photons/sec

For better separation of the spectra the source will be displaced from the axis of the collimator, reducing the count rate in the detector 4 times

# Method of the reconstruction of the spectra

Elimination of the influence of the detector on the shape of the spectrum of the source (suppression of Compton radiation from monochromatic lines)




The recurrence formula of the recovery spectrum for the detector with resolution $R$~0

$$y_{0k} = \frac{y_{2k} - \sum_{j=k+1}^{N} y_{1jk} \cdot y_{0j}}{y_{1kk}}$$

$y_0$ – restored spectrum

$y_2$ – measured spectrum

$y_{1jk}$ – the response function for energy $E=E_j$ at a point $E=E_k$

Response functions calculated by MC and adjusted for the measured spectra of the standard sources ($^{137}$Cs, $^{22}$Na, …)

# Counting system

- Ge semiconducting detector, 0.5 kg
  in Pb passive shield
  installed, tested in long time bg measurements, $E_\gamma < 3$ MeV
- Carried out measurements of response functions of the detector through a collimator for several standard point sources
- Ready for the $^{51}$Cr 3 MCi source activity measurements

To test the ability of measurement of continuous spectra:

Measurements with pair of low intense point-like $^{51}$Cr sources w/o shield

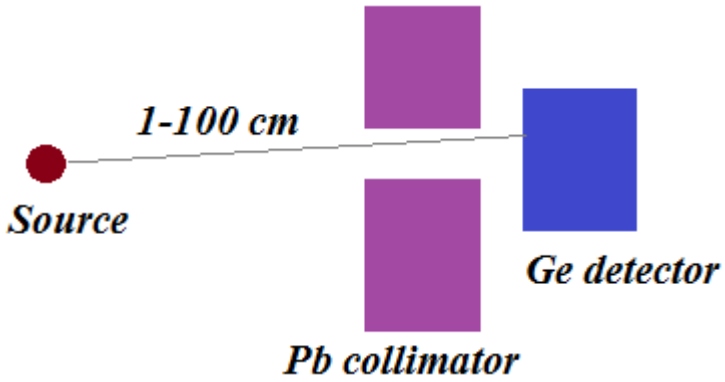
- Real IB $^{51}$Cr spectrum measurements
- Found values of the main uncertainties

# IB spectrum measurement (>320 keV)

Counting rate ~30-50 $sec^{-1}$

IB counting rate ~0.1 $sec^{-1}$ ~ $10^4$ $day^{-1}$

Bg counting rate ~1.5 $sec^{-1}$, IB / Bg ~ 1/15




Measurements with two $^{51}Cr$ sources:

1.Gamma spectrum from Cr-1 source, 1 GBq

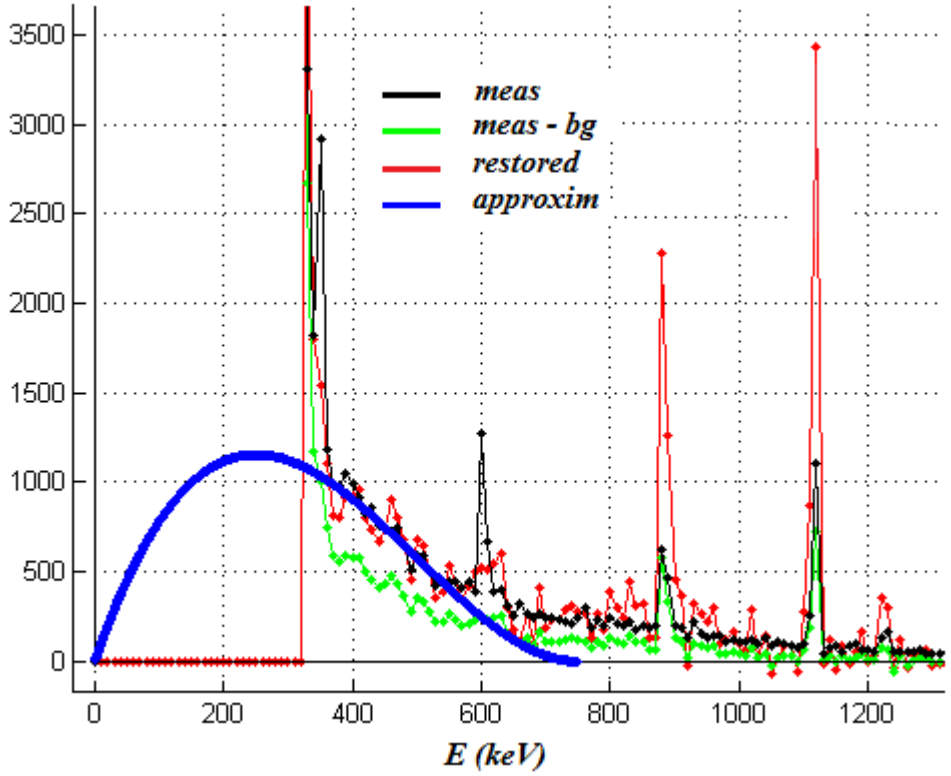
2.The exact decay rate of Cr-1 source:

1)intensity of 320 keV line in the spectrum from Cr-2 source, 10 kBq

2)counting rate of Cr-2 in NaI detector (eff > 99 %)

# Measurement of the IB spectrum at energies 360-580 keV

- measured gamma spectrum $^{51}Cr$
- subtract the background of the detector
- perform the recovery procedure
- select the site, do the approximation




Activity measured on line 320 keV (3.3% + ) is consistent with the activity spectrum of IB within 6%

# Discussion

The measurements of IB spectrum is limited by the intense γ line 320 keV

In measurements with the 3MCi source this will be decreased by the primary W shield, and the uncertainty will decrease

But:

For the restored spectra we used the response functions which were calculated by MC and then adjusted in accordance with measurements of monochromatic sources

Now we don't know the reason of the need for the adjustment

It could be connected with

- the passing of a portion of the photons through lead of the collimator
- reflections of the photons, which have passed through the Ge crystal, from the internal shield walls
- heterogeneity of Ge crystal

Now we try to solve it by methods of Monte Carlo

# Conclusion

- Method for determining the activity of the $^{51}Cr$ source by measurement of continuous-spectrum IB radiation is developed
- A tracking system to measure the IB spectra is created
- Measurements of the spectrum of the source were carried out , the recovery procedure of the spectra and determination of activity by the measured spectrum checked