LOMSKAYA I.S. ON BEHALF OF THE BOREXINO COLLABORATION

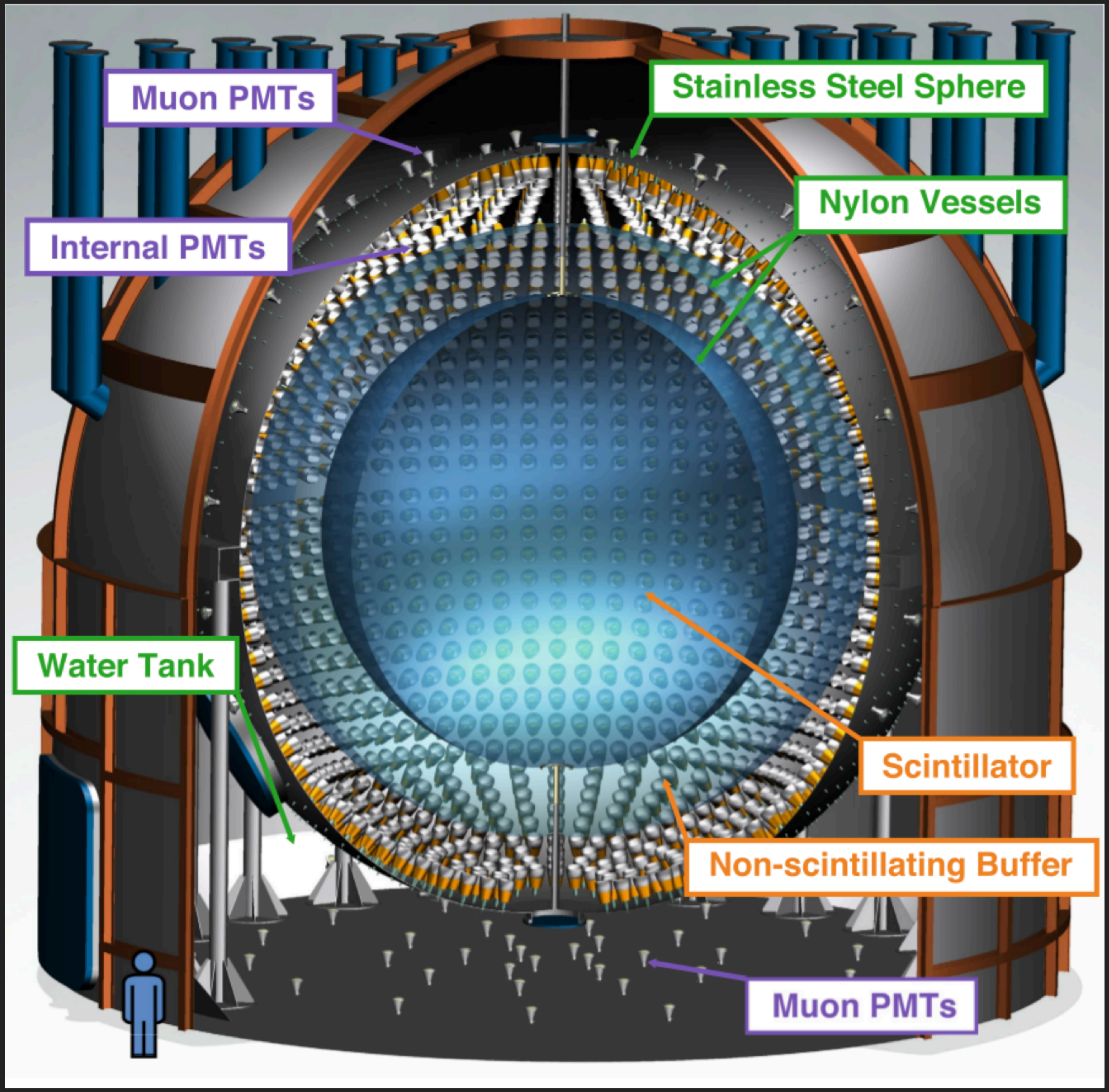
SEARCH FOR LOW-ENERGY BOREXINO'S SIGNALS CORRELATED WITH GAMMA-RAY BURSTS, SOLAR FLARES AND GRAVITATIONAL WAVE EVENTS

MOTIVATION FOR THE STUDY

Rare processes from the astrophysical sources such as gamma-ray bursts (GRB), solar flares (SF) and gravitational wave (GW) are of concern for astroparticle physics, particularly for the neutrino physics.

Our analysis is devoted to search for the correlations between low-energy neutrinos and GW events obtained by LIGO/Virgo runs (O1, O2, O3), GRB and SF.

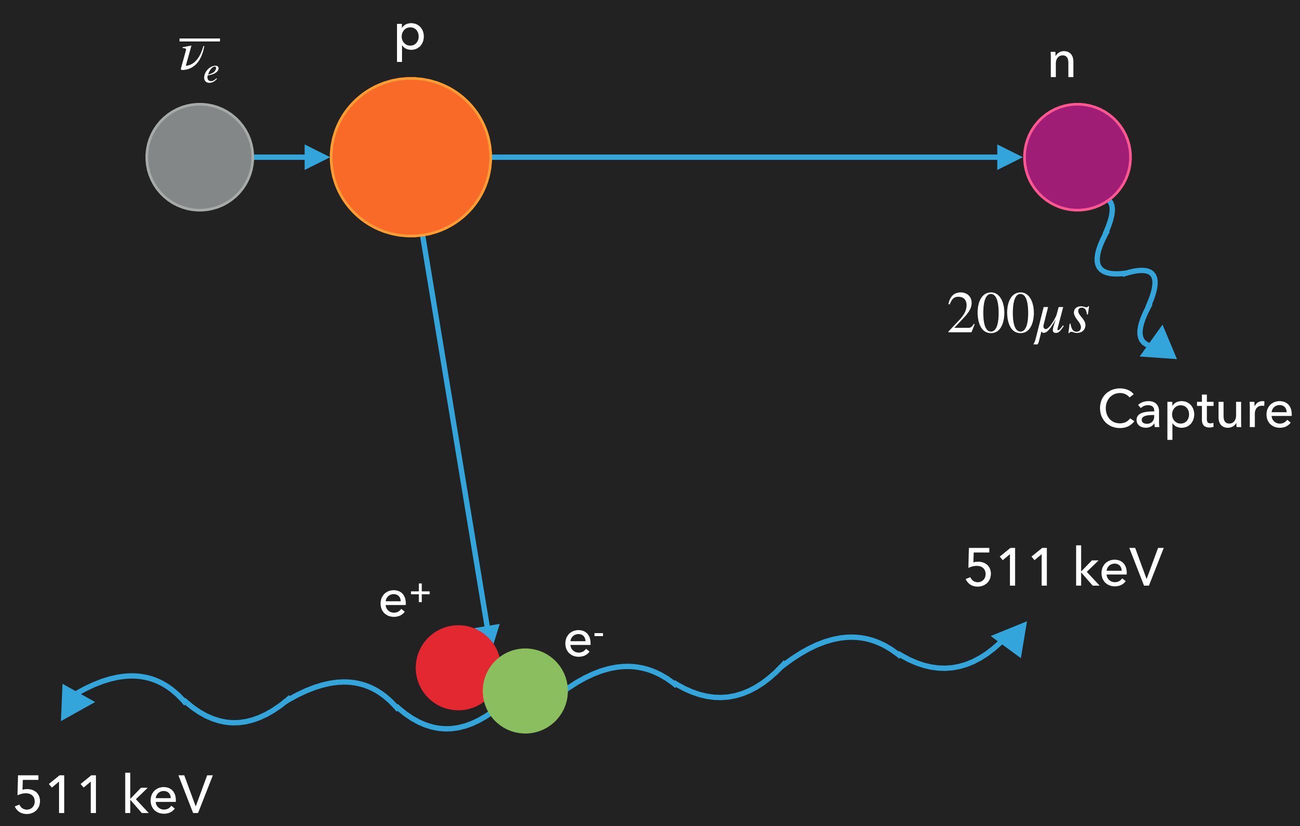
BOREXINO DETECTOR



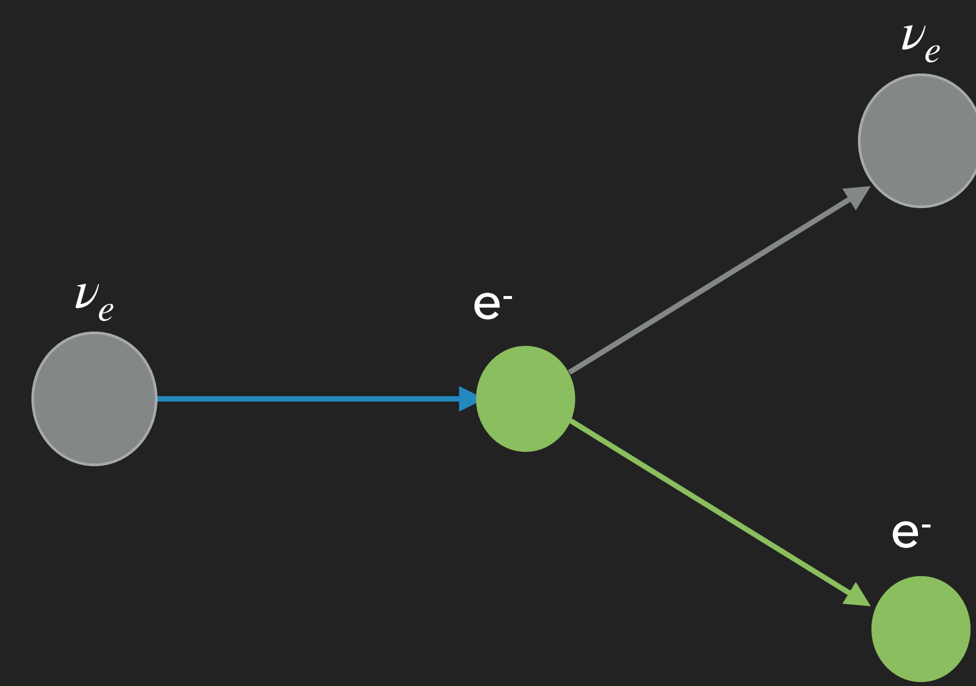
- Scintillator mass 278 t in the inner vessel
- 2209 8" PMTs
- 208 8" PMTs in the water tank with 4800 t of ultra-pure water as Cherenkov veto
- Unprecedentently low radioactive background level

REGISTRATION METHODS

Inverse β-decay (IBD)



Neutrino-electron elastic scattering (ES)

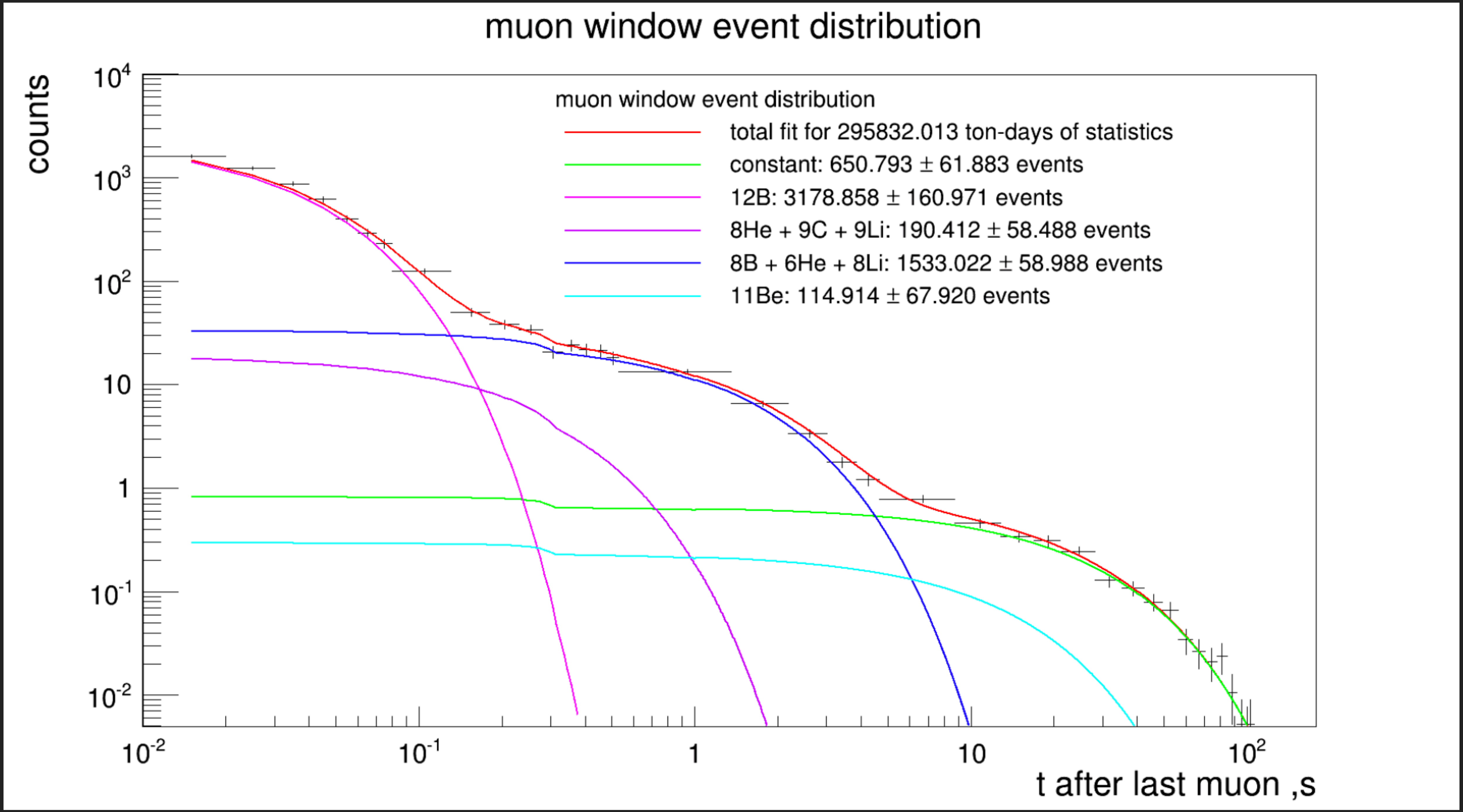


DETECTOR'S RADIOACTIVE BACKGROUND

- Short-lived cosmogenic backgrounds (τ) produced within the detector fiducial volume, such as ^{12}B, ^{8}He, ^{9}C, ^{9}Li etc.
- Other cosmogenic backgrounds, produced within detector fiducial volume, such as ^{11}Be, ^{10}C, ^{11}C etc.
- Backgrounds of the inner nylon vessel, such as ^{210}Po and Uranium/Thorium decay chains
- Natural background contained in the bulk of the detector fluid such as ^{14}C, ^{85}Kr, ^{210}Po, ^{210}Bi and ^{210}Pb

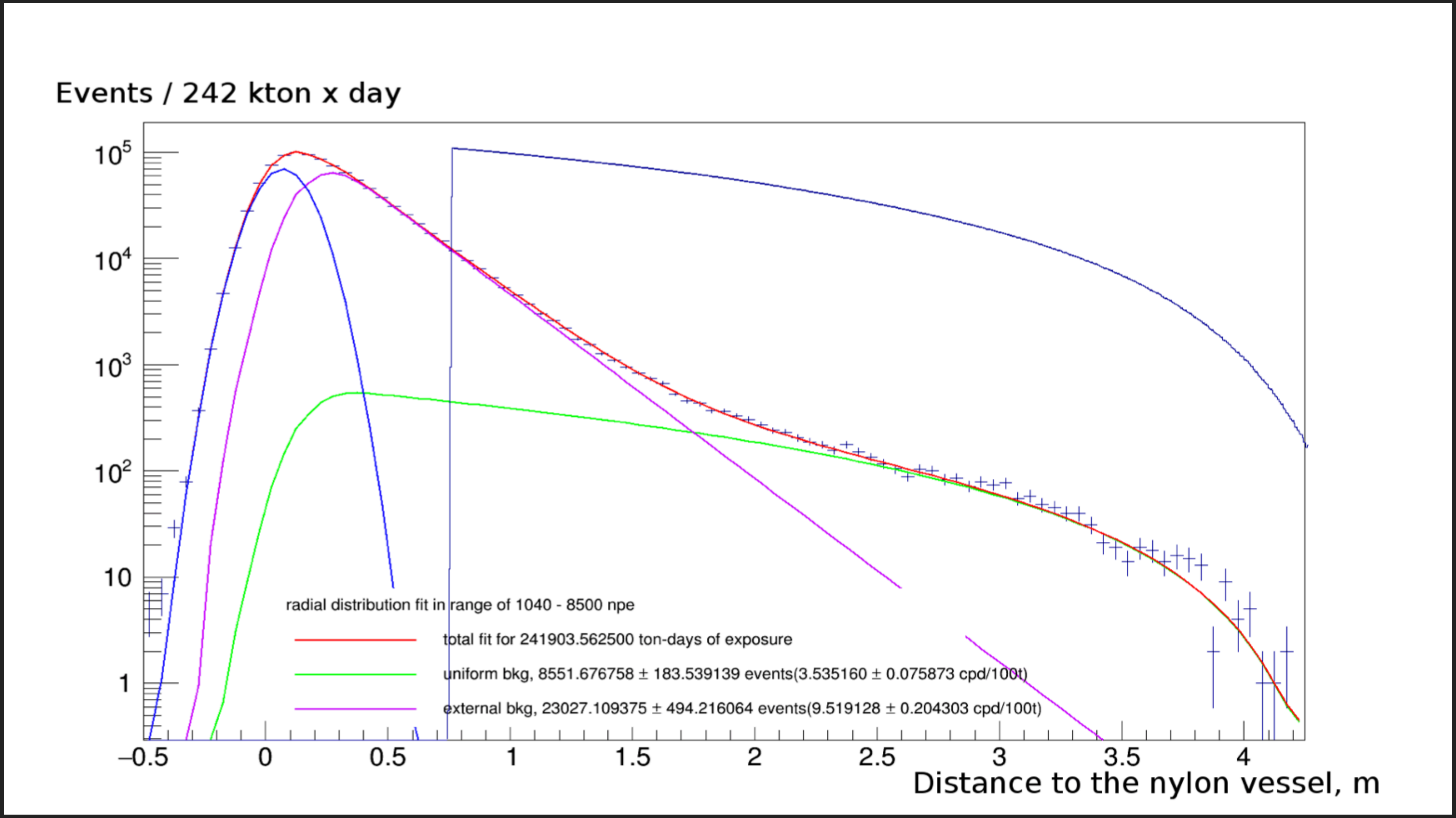
Short-lived cosmogenic background

The method of suppression the short-lived cosmogenic background is based on 0.3 s after muon veto since the contribution of cosmogenic is minor

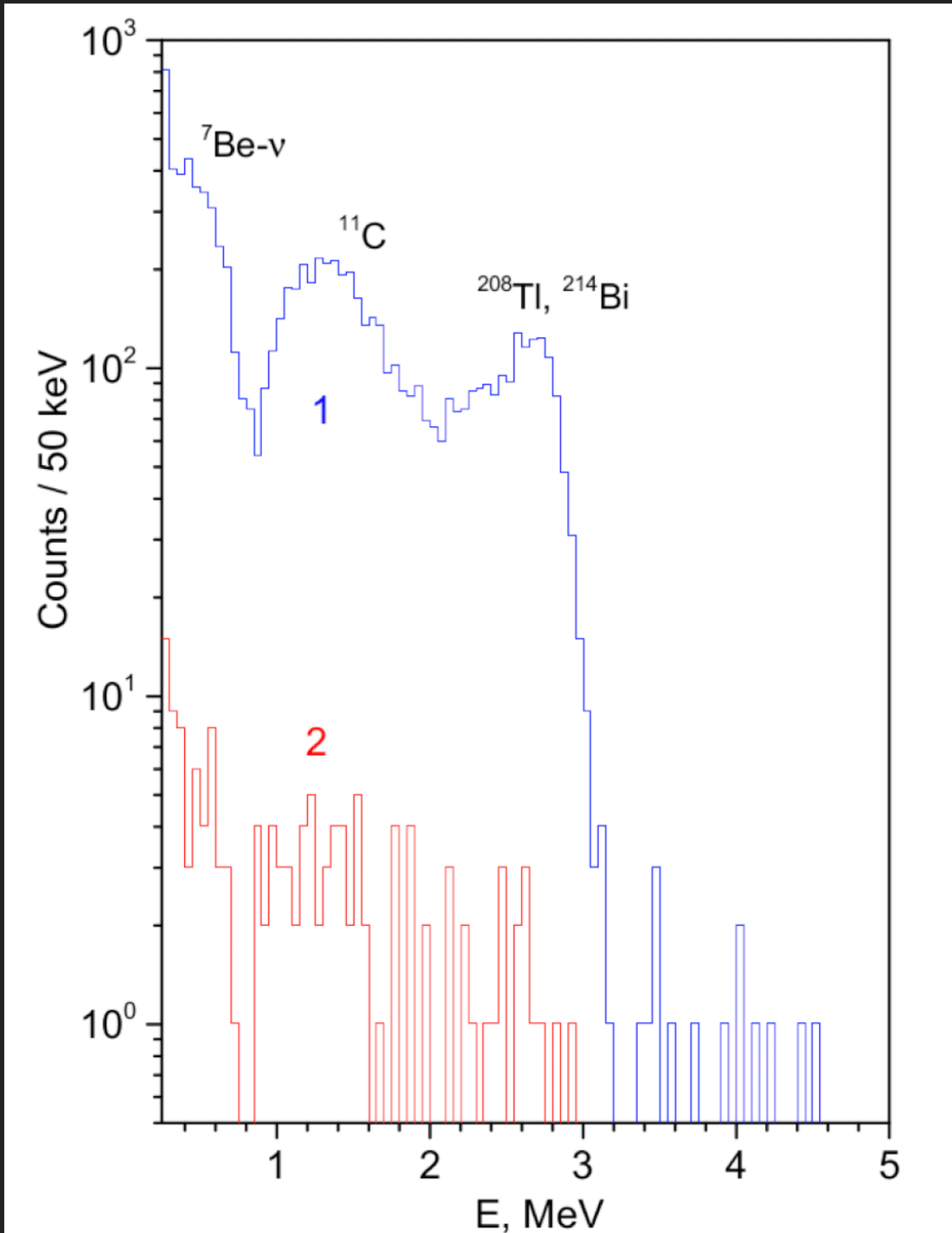


Background of the inner nylon vessel

For the providing a good separation of vessel events, the "Seasonal Be" was used (0.75 m from IV)



Background in the inner nylon vessel



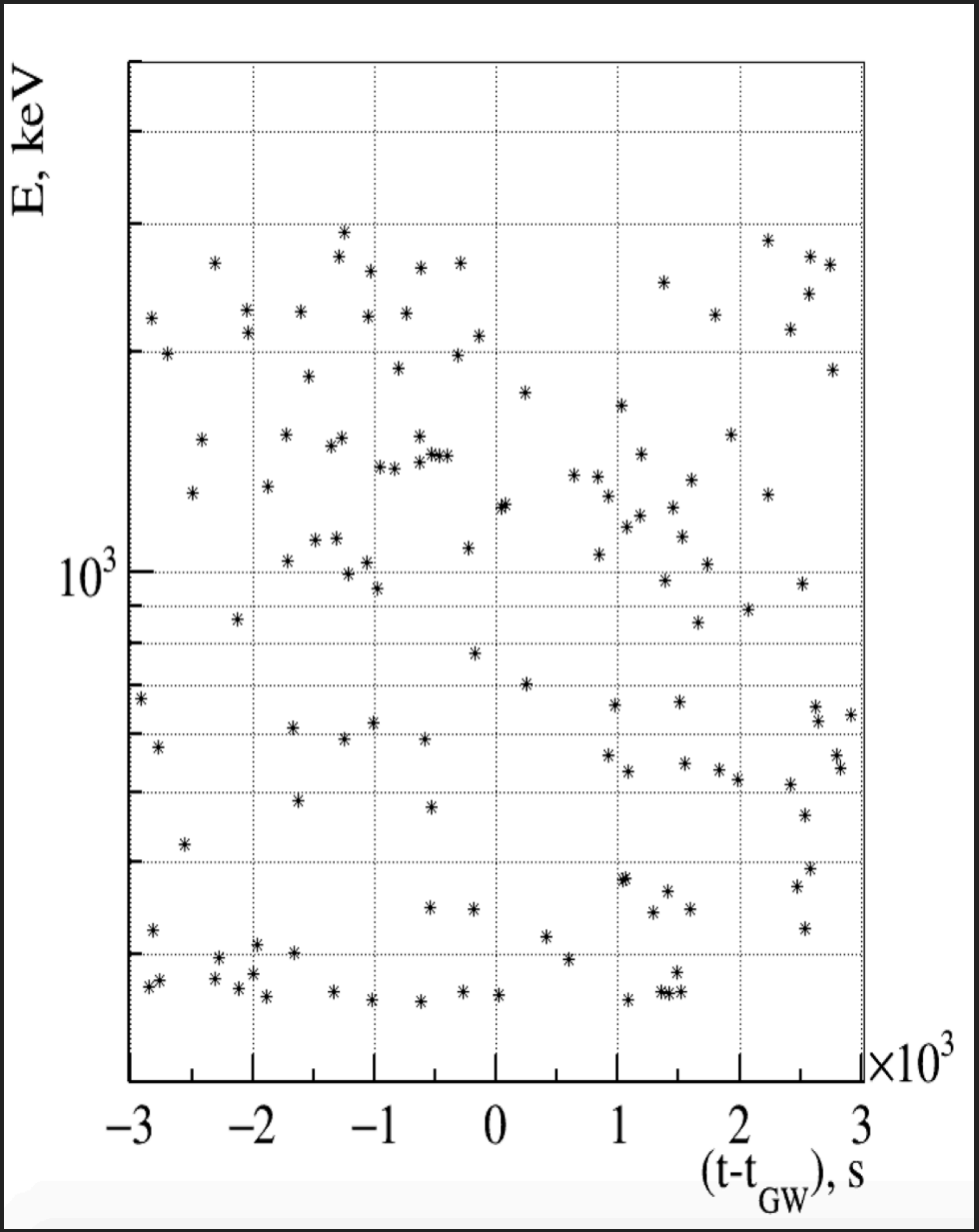
^{14}C was cut out by 250 keV threshold chosen. Also MLP has been applied for α- β- discrimination of ^{210}Po

1 - the Borexino (BX) spectrum of selected events uncorrelated with GW events

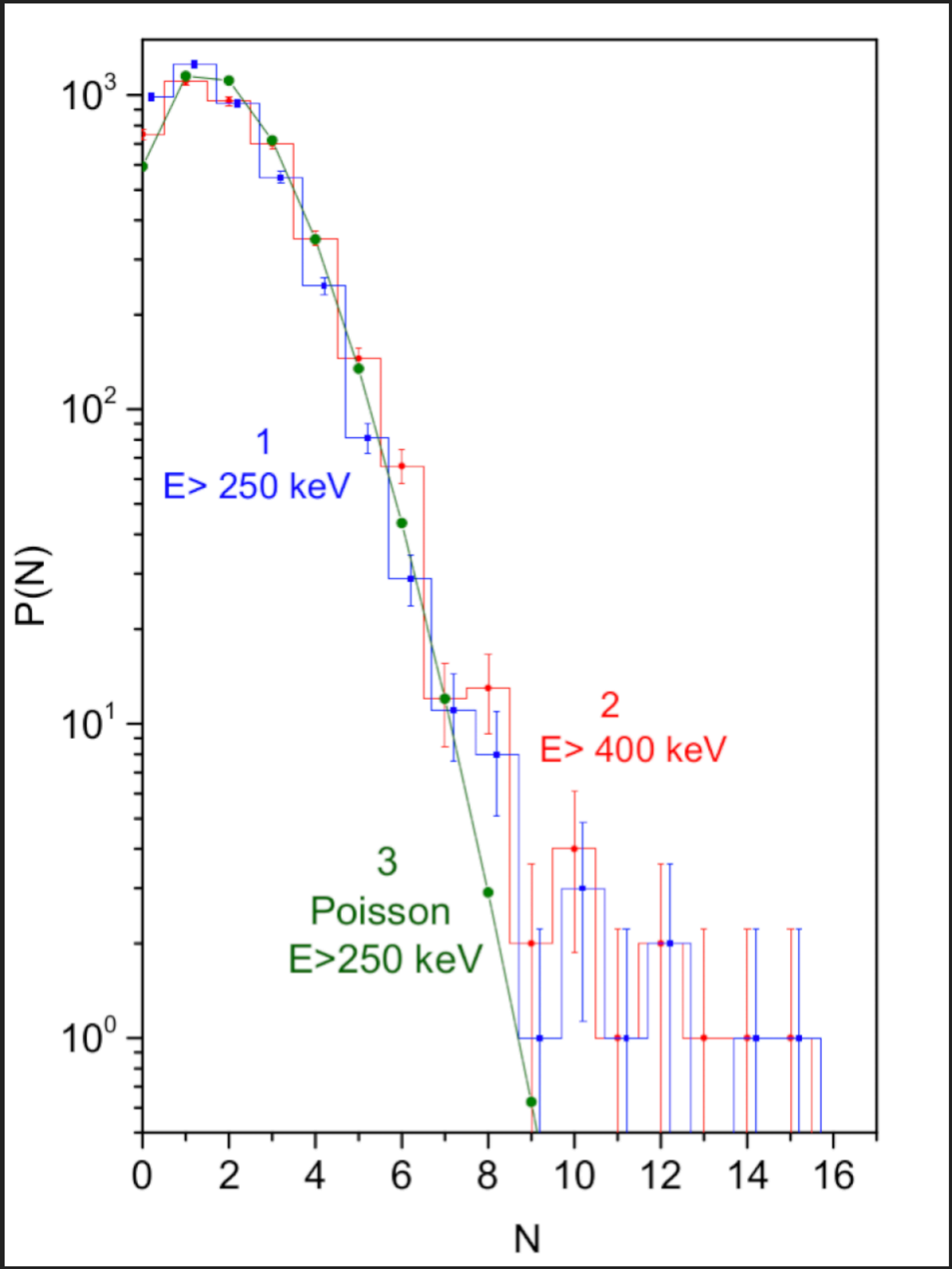
2 - spectrum of selected events within windows around GW events

Borexino data in time window

Two windows at ±500 s and +1500/-500 s were used, where second window was used in order to compensate time delay from 410 keV neutrino arrival from the furthest GW events for the maximum neutrino mass (70 meV according to Fermi-LAT results). The count rate compatible with background rate



Distribution for events in 1000 s window



We have obtained distribution of events in 1000 s windows uncorrelated with GW events in order to test our data statistics. The distribution generally shows agreement with Poisson distribution. The Feldman-Cousins analysis is applicable.

Data treatment

- **STEP 1:**

The expected background rate is evaluated from the weekly spectra obtained in the same way with scaling by time

- **STEP 2:**

The counts from all events are summed up as well as expected backgrounds rate

- **STEP 3:**

These values N_{ev} and N_{bkg} are injected into Feldman-Cousins algorithm providing limit at 90% C.L. (N_{90})

- **STEP 4:**

This limit derived is scaled per one event

Limit derivation

Limits are calculated as

$$\Phi_{lim} = \frac{N_{90}(E_\nu, n_{obs}, n_{bkg})}{\epsilon N_e(E_{th}, E_\nu)}$$

where $N_{90}(E_\nu, n_{obs}, n_{bkg})$ comes from FC

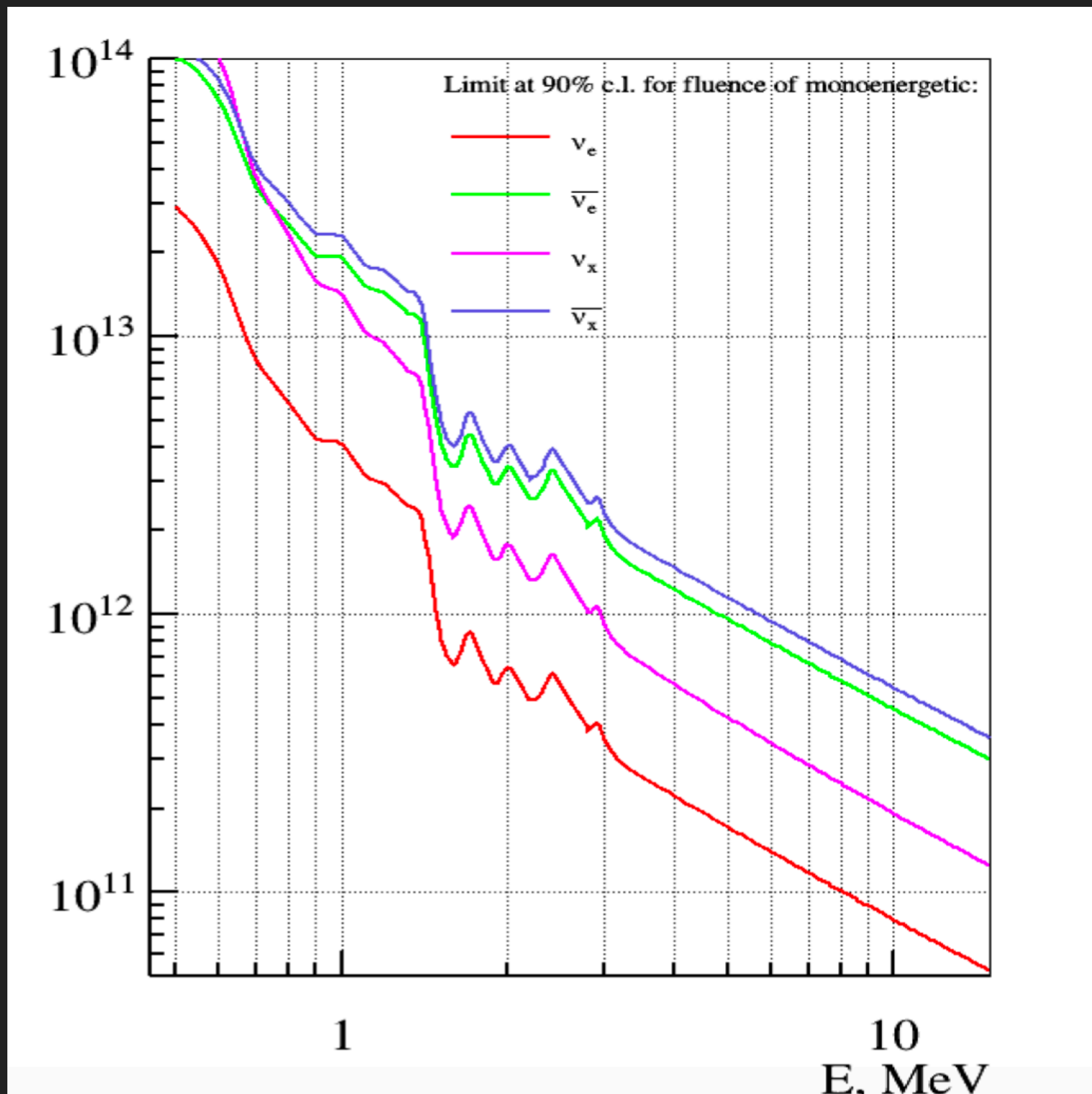
full cross-section

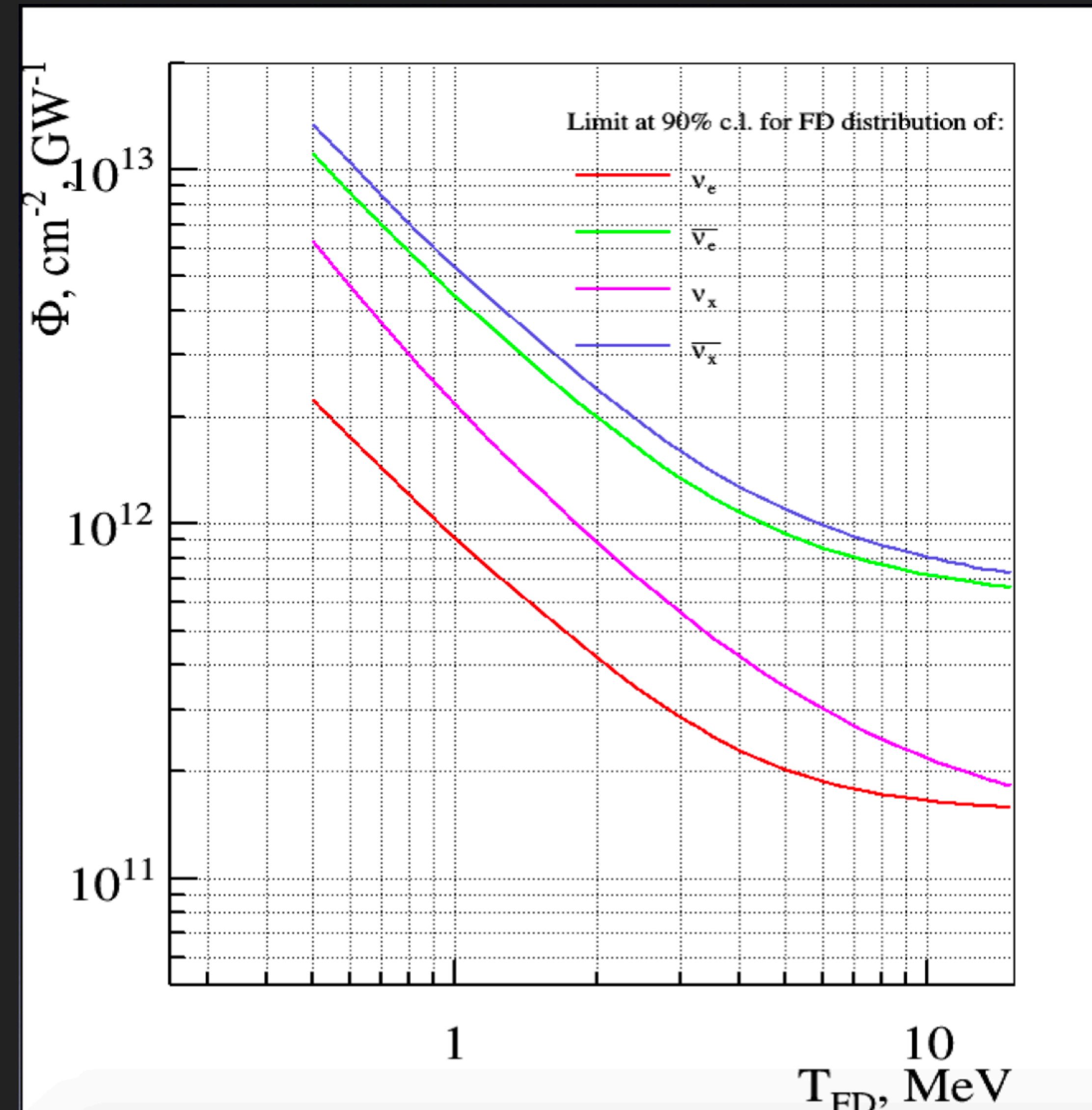
$$\sigma(E_{th}, E_\nu) = \int \frac{d\sigma(E_\nu, E_e)}{dE_e} dE_e$$

for continuous neutrino spectrum

$$\sigma(E_1, E_2) = \iint \frac{d\sigma(E_\nu, E_e)}{dE_e}, \phi(E_\nu) dE_e dE_\nu$$

Limits of monoenergetic neutrinos





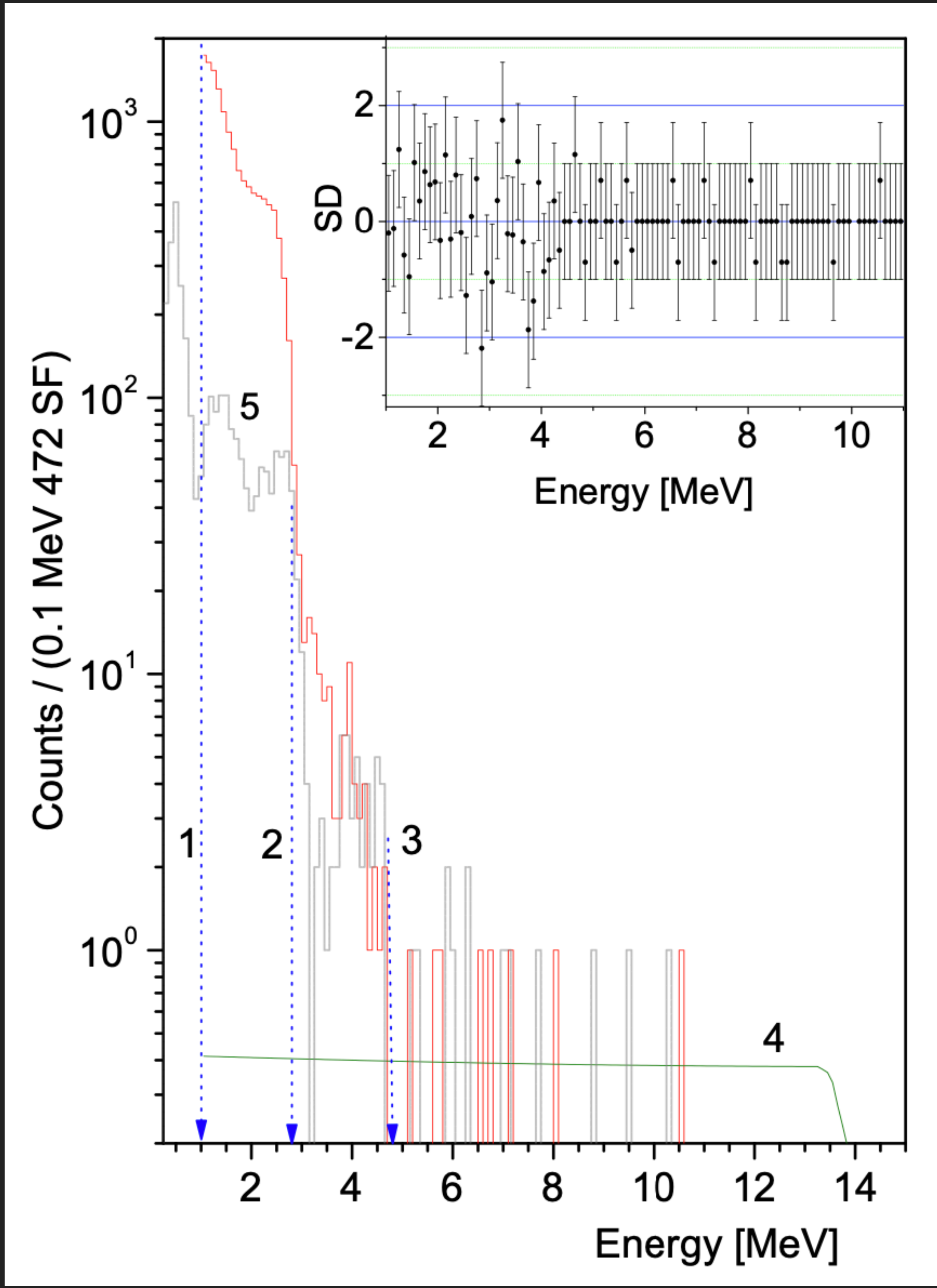
This limits was calculated with floating threshold (individual FC analysis for allowed recoil electron energies).

Limits of neutrino with Fermi-Dirac distribution for the various temperatures also was performed

Solar flares data treatment

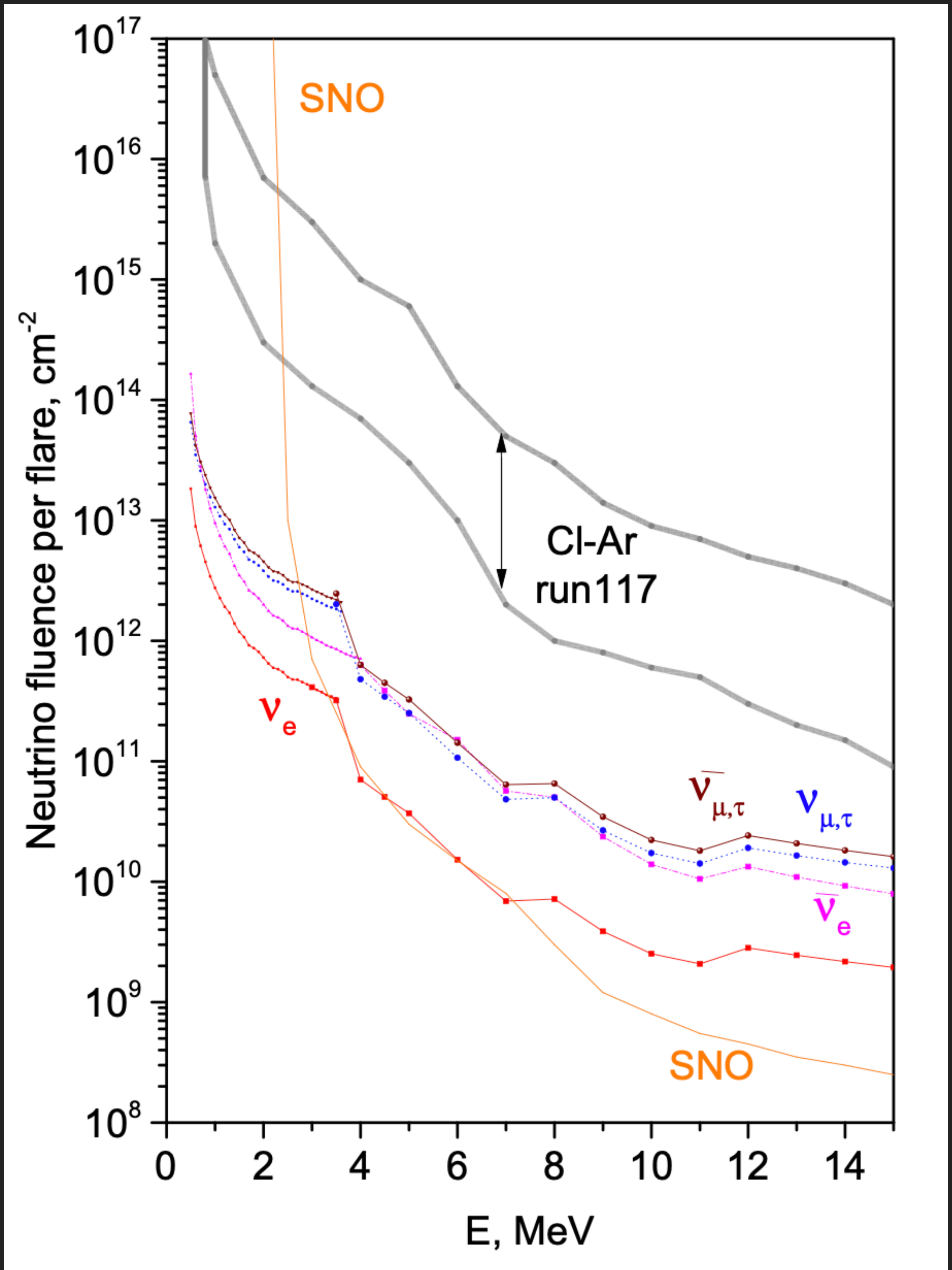
- The used data was taken from GOES data-base;
- The flares were analysed with the lower threshold of $2x10^5$ photons
- The Borexino data were selected and analysed in the same way as we used for GW analysis
- The temporal window corresponded to duration of a flare itself

Energy spectrum for single events



Borexino energy spectrum of single events in correlation with solar flares, measured by FADC system within 1–15 MeV range (red line) and by the primary DAQ system within 0.25–15 MeV (grey). Blue dotted arrows indicate the three energy regions chosen for the separate analysis. Green line shows the expected spectrum of recoil electrons for 14 MeV neutrinos per one flare with the fluence $1x10^{10}$ cm^{-2}

Limits on monoenergetic neutrino fluence

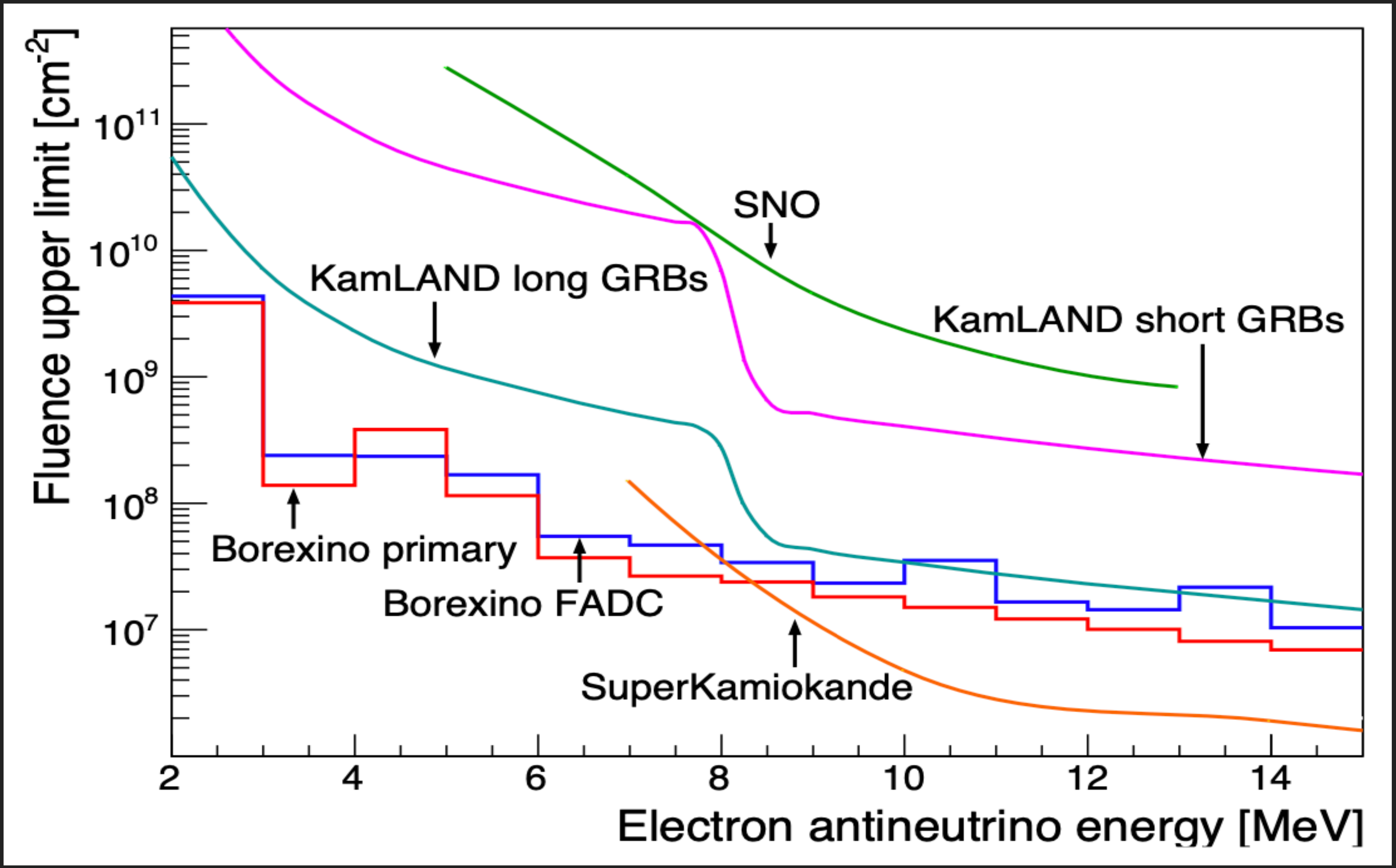


Borexino 90% C.L. fluence upper limits obtained through neutrino-electron elastic scattering for ν_e, $\bar{\nu}_e$, $\nu_{\mu\tau}$ and $\bar{\nu}_{\mu\tau}$. In the plot the limits obtained for ν_e by SNO are labelled and the range of fluences that would have explained the Cl-Ar Homestake

Gamma-Ray Bursts data treatment

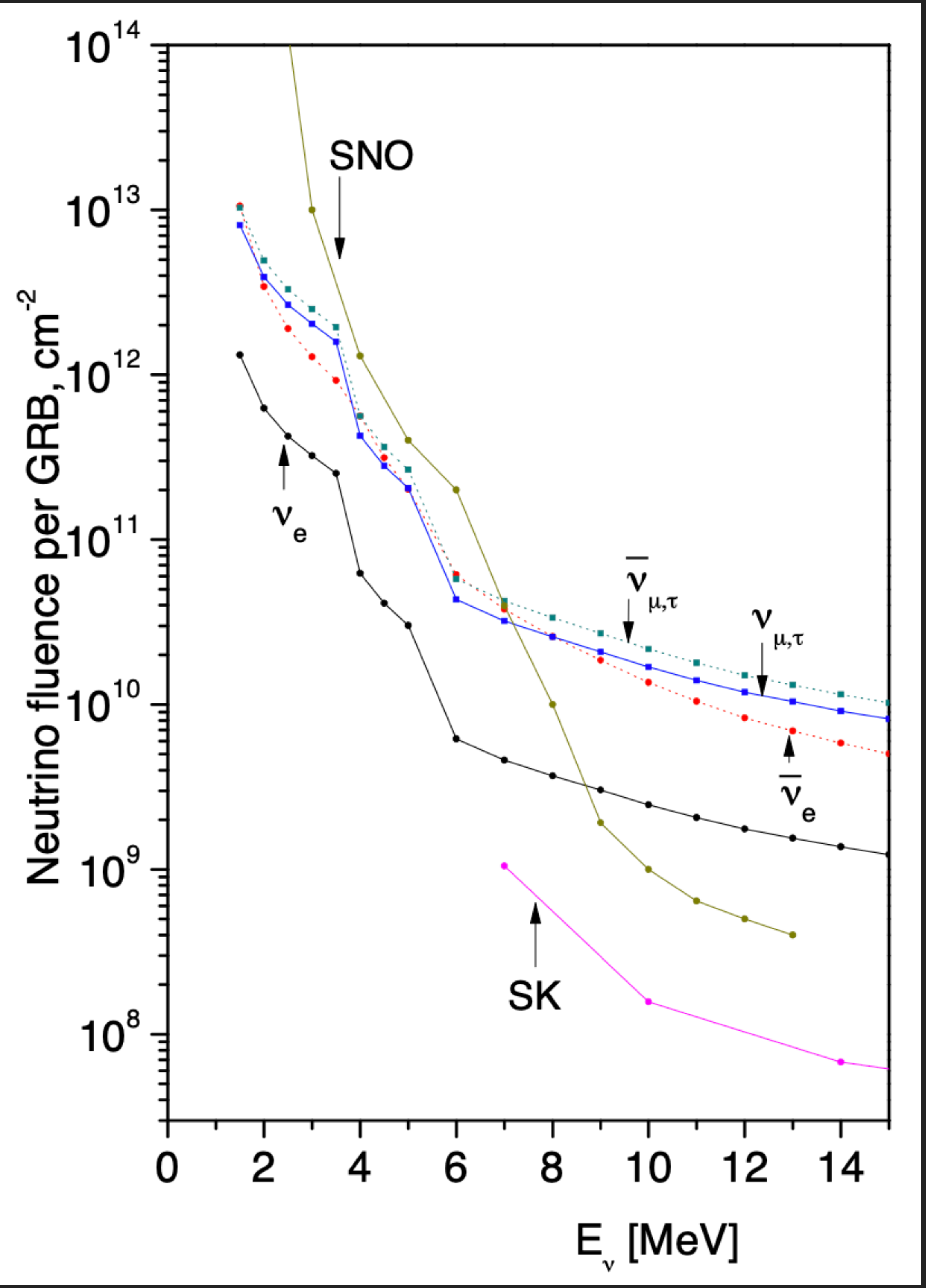
- The used data was taken from data-base compiled by IceCube;
- The dataset of used GRBs consisted of 980 events for ES and 1114 for IBD
- The Borexino data were selected and analysed in the similar way with respect to the one used for GW and SF analysis
- The limits obtained were normalised per 1 GRB

Limits for electron antineutrino



Fluence upper limits for electron antineutrinos from GRBs versus antineutrino energy.

Limits on elastic neutrino-electron scattering



Borexino 90% C.L. fluence upper limits obtained through neutrino-electron elastic scattering for ν_e, $\bar{\nu}_e$, $\nu_{\mu\tau}$ and $\bar{\nu}_{\mu\tau}$. Given are also the limits obtained for ν_e by SNO and SuperKamiokande

CONCLUSION

- We have performed the search for low-energy neutrino signal of Gravitational wave events, Solar Flares and Gamma-Ray Bursts with the Borexino detector
- The search was performed through two ways based on inverse beta-decay and elastic neutrino-electron scattering
- We have obtained the best current upper-limits for GW, SF and GRB events
- Homestake run 117 excess was fully covered

THANK YOU FOR YOUR ATTENTION!!!

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