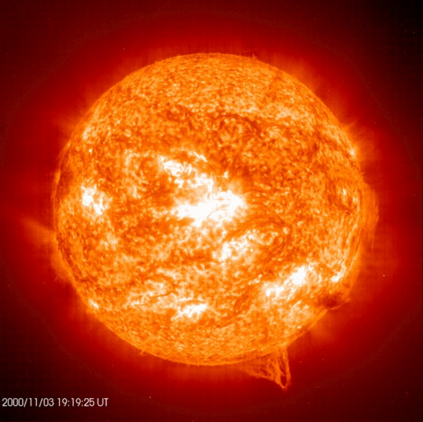


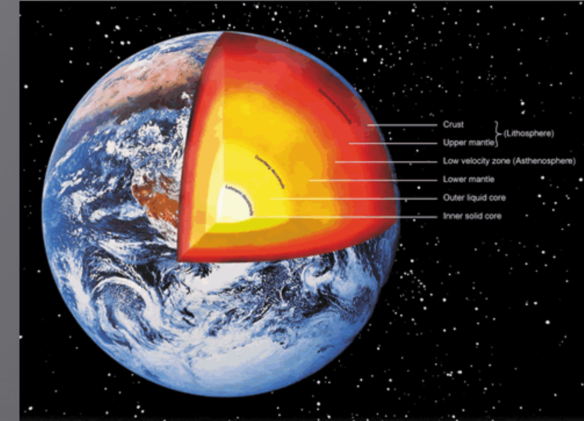


# Terrestrial $^{40}$K geoneutrinos and Solar CNO neutrinos

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in collaboration with

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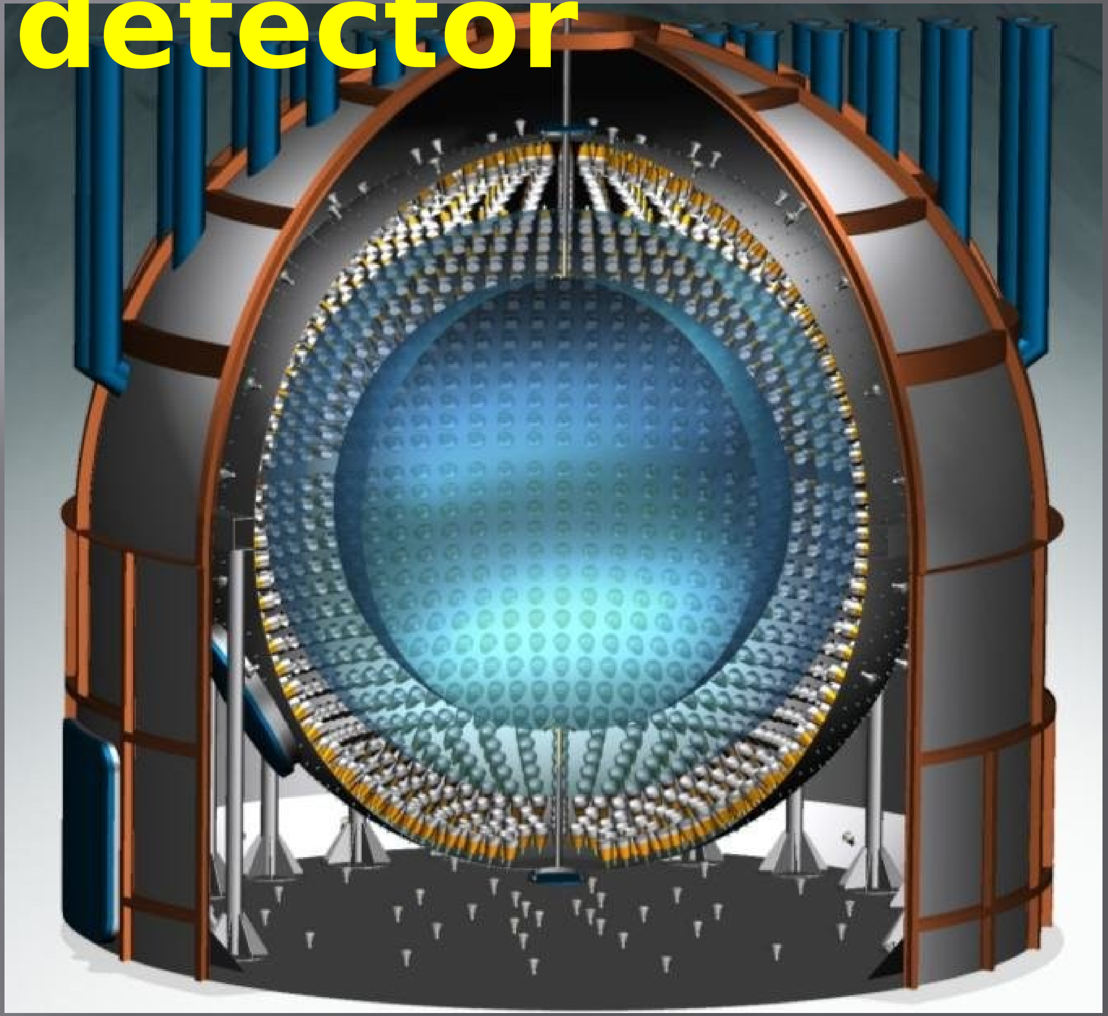
Neutrino Geoscience 2019, Prague, October, 21-23

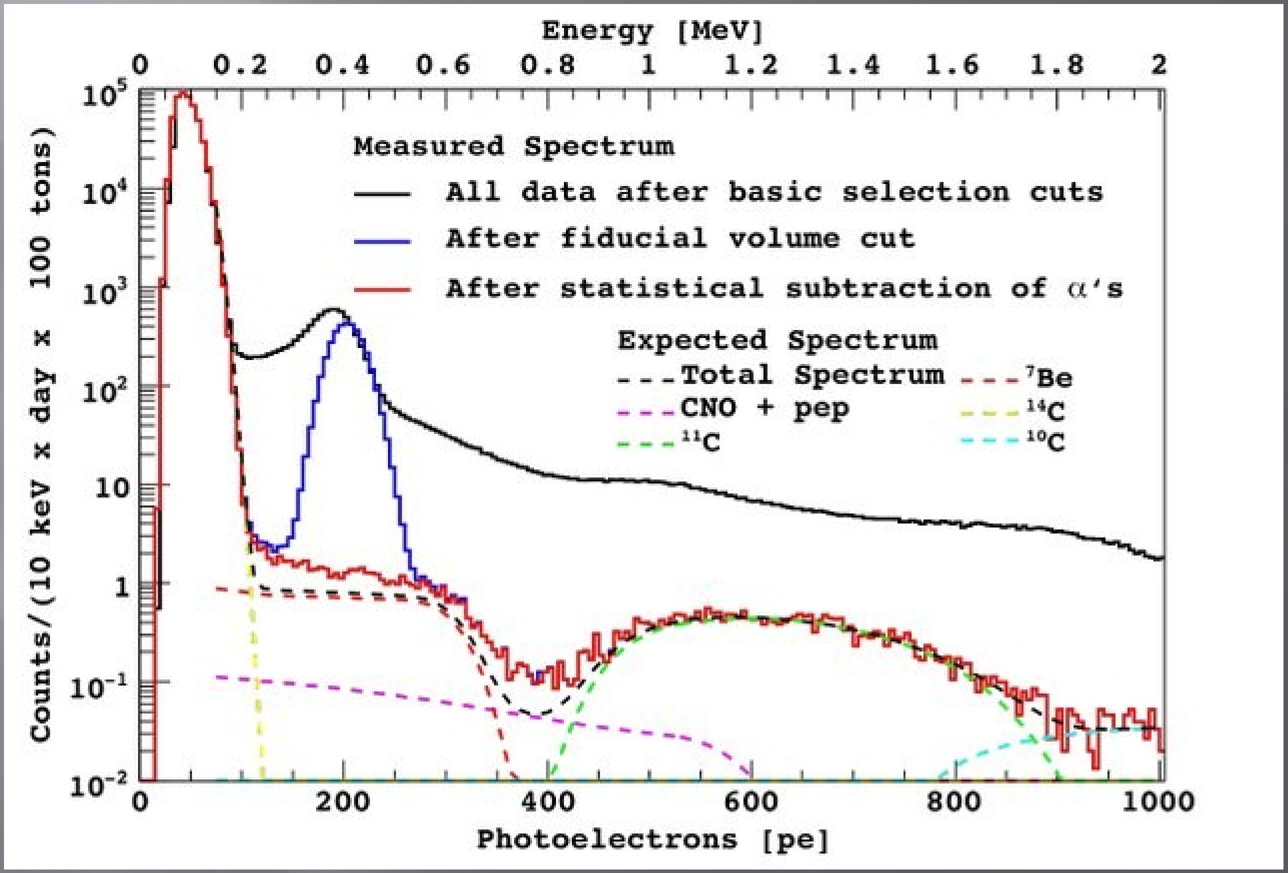
**Detectors on the Earth surface register solar neutrinos (Homestake, GALLEX and SAGE, SNO, Borexino, KamLAND and Super-Kamiokande) and geoneutrinos (antineutrinos from $^{238}U$ and $^{232}Th$) (Borexino, KamLAND).**

**Borexino is the only detector measured with high accuracy solar neutrinos and geoneutrinos.**

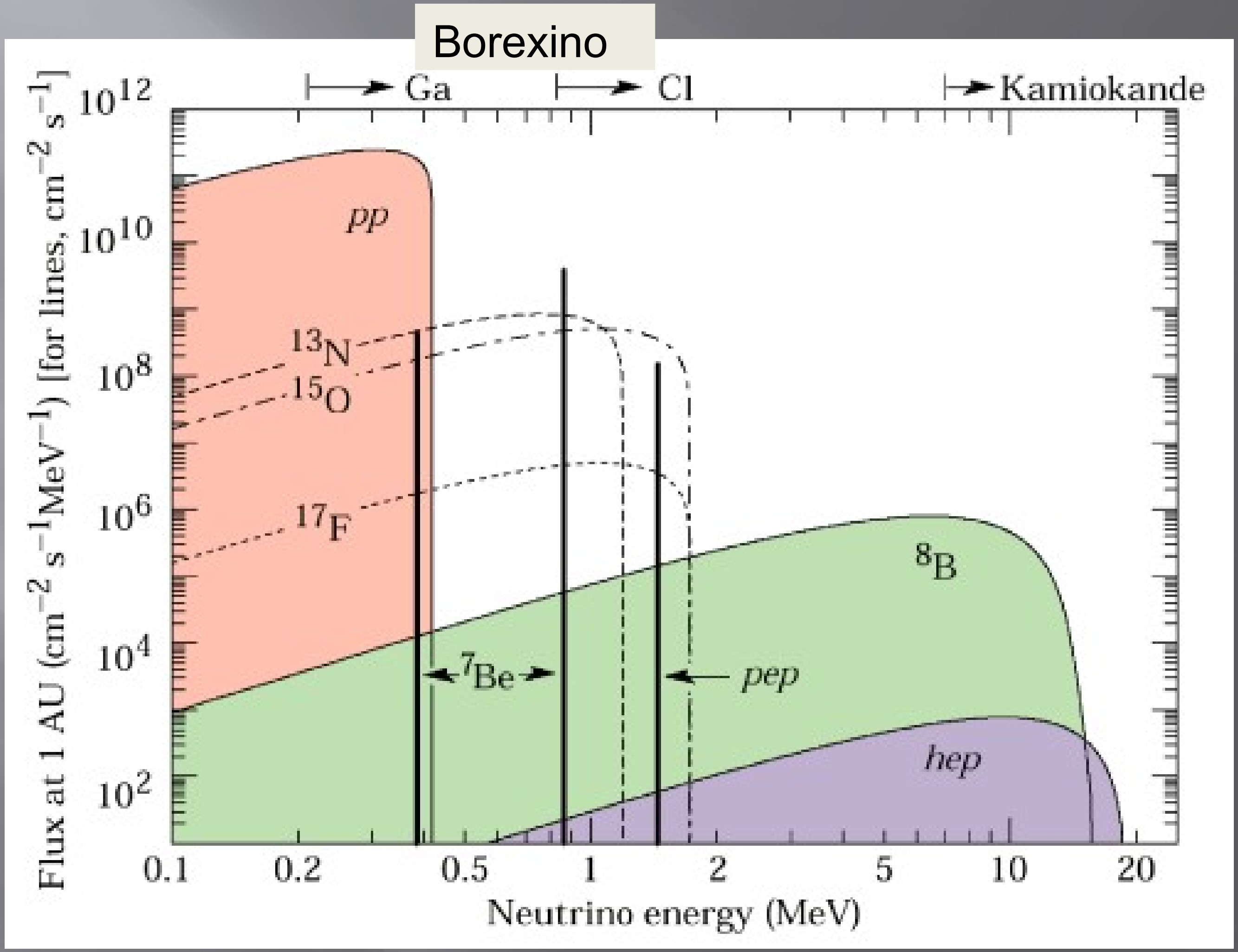
# Schematic view of Borexino detector



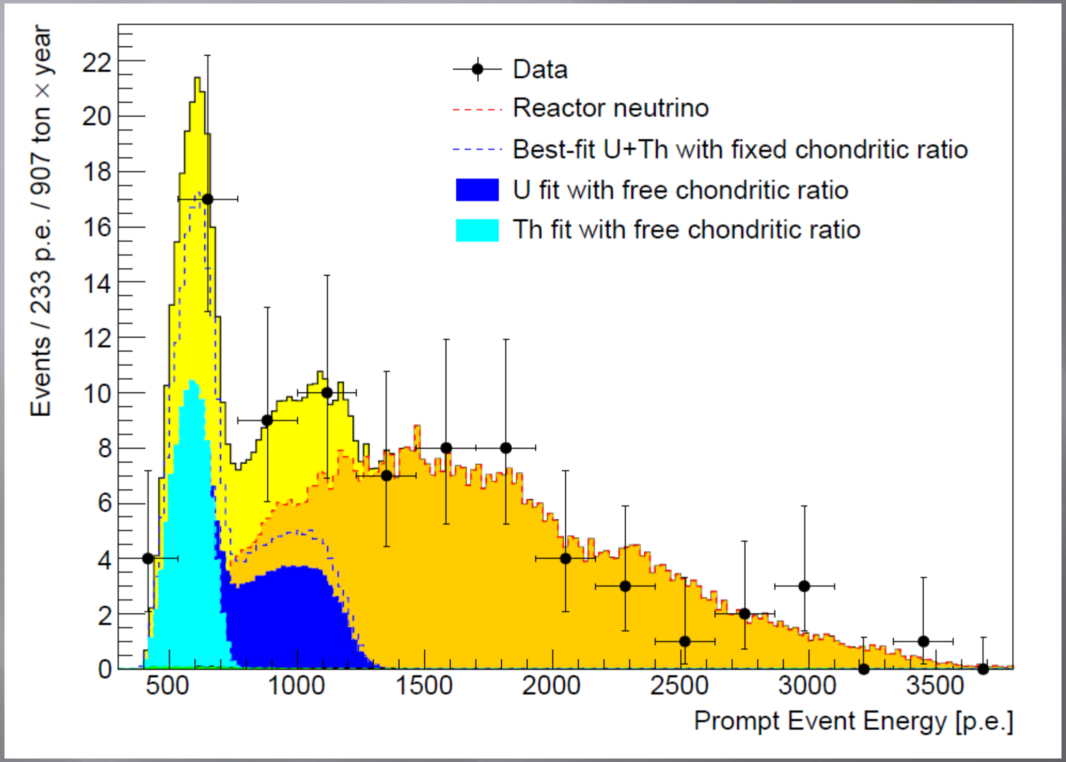
# Measured energy spectrum by Borexino



# Solar neutrino fluxes



# Geoneutrinos detected by Borexino




M. Agostini et al. Phys. Rev. D 92, 031101 (2015).

Tmeas = 2056 days (5.6 years)

Np = $(0.977 \pm 0.05) \times 10^{31}$ protons on target

Exposure $(5.5 \pm 0.3) \times 10^{31}$ proton years

$23.7^{+6.5(st)+0.8}_{-5.7(st)-0.6}$ geo-nu events

43.5 TNU

**Number of detected solar neutrino events are in a good agreement with predicted solar neutrino fluxes taking into account neutrino oscillations.**

**Number of geoneutrino events also in a good agreement with BSE model with 47 TW of Earth heat flux.**

# Summary of thermal Earth flux values

Earth

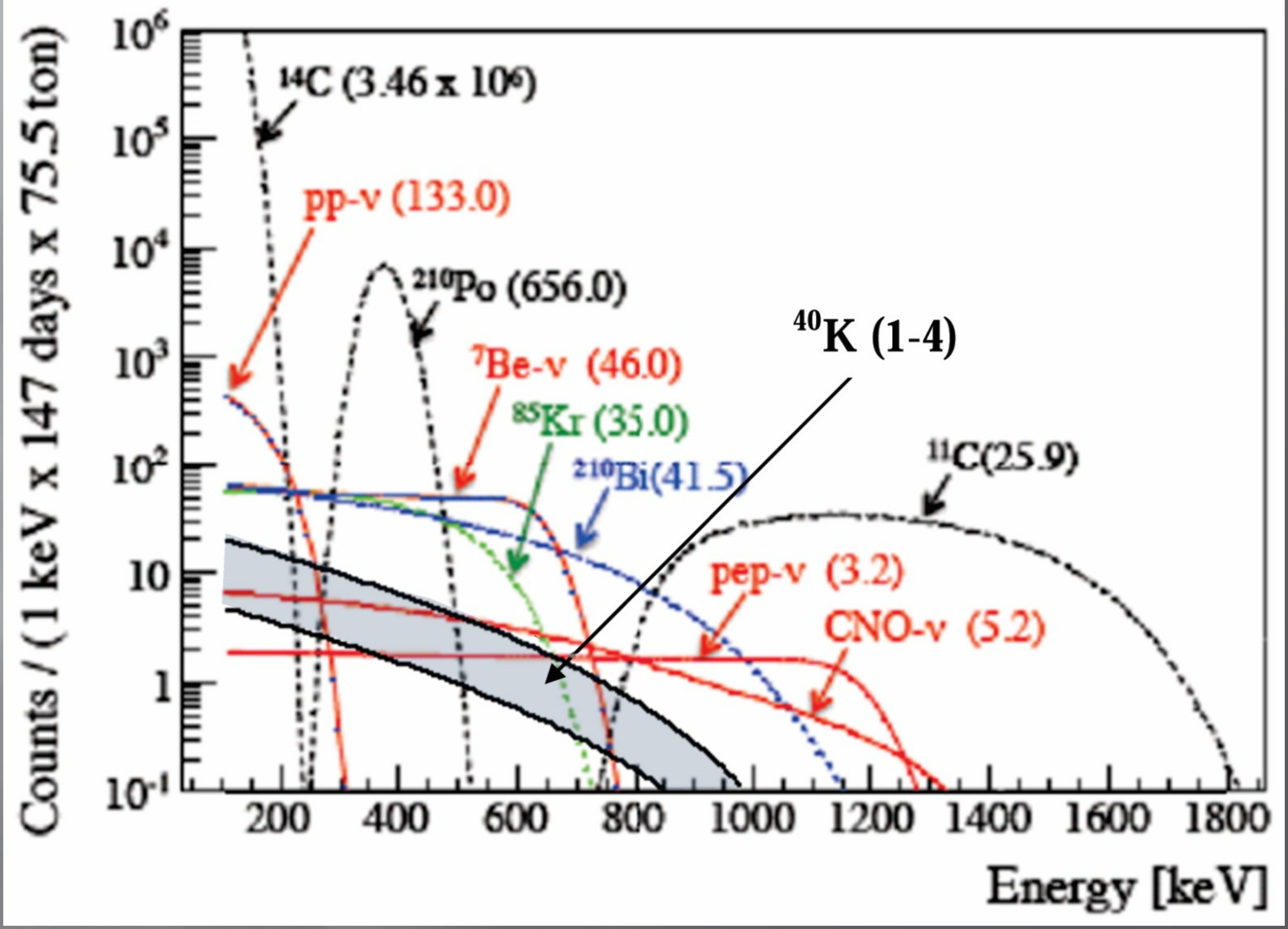
- Bore-hole temperature gradient 46±3 TW
- ARGO Earth's energy imbalance 220±50 TW
-
- Moon recalculated to Earth heat flux $M_e/M_m=81.3$
- Apollo 15, 17 drilling 49-65 TW
- Russian radio emission exp. 168 TW
- LRO temperature map 254 TW

We consider the value of 200-250 TW as the most favorable to explain the all experimental data.

**To understand high Earth heat flux it is necessary to propose high abundance of potassium with natural isotope $^{40}K$.**
**Modern BSE model this rejects.**
**Could we check how much of potassium inside the Earth?**
**Yes. We need to measure $^{40}K$ flux (spectrum).**

# Recoil electrons spectrum from $^{40}K$ in BOREXINO

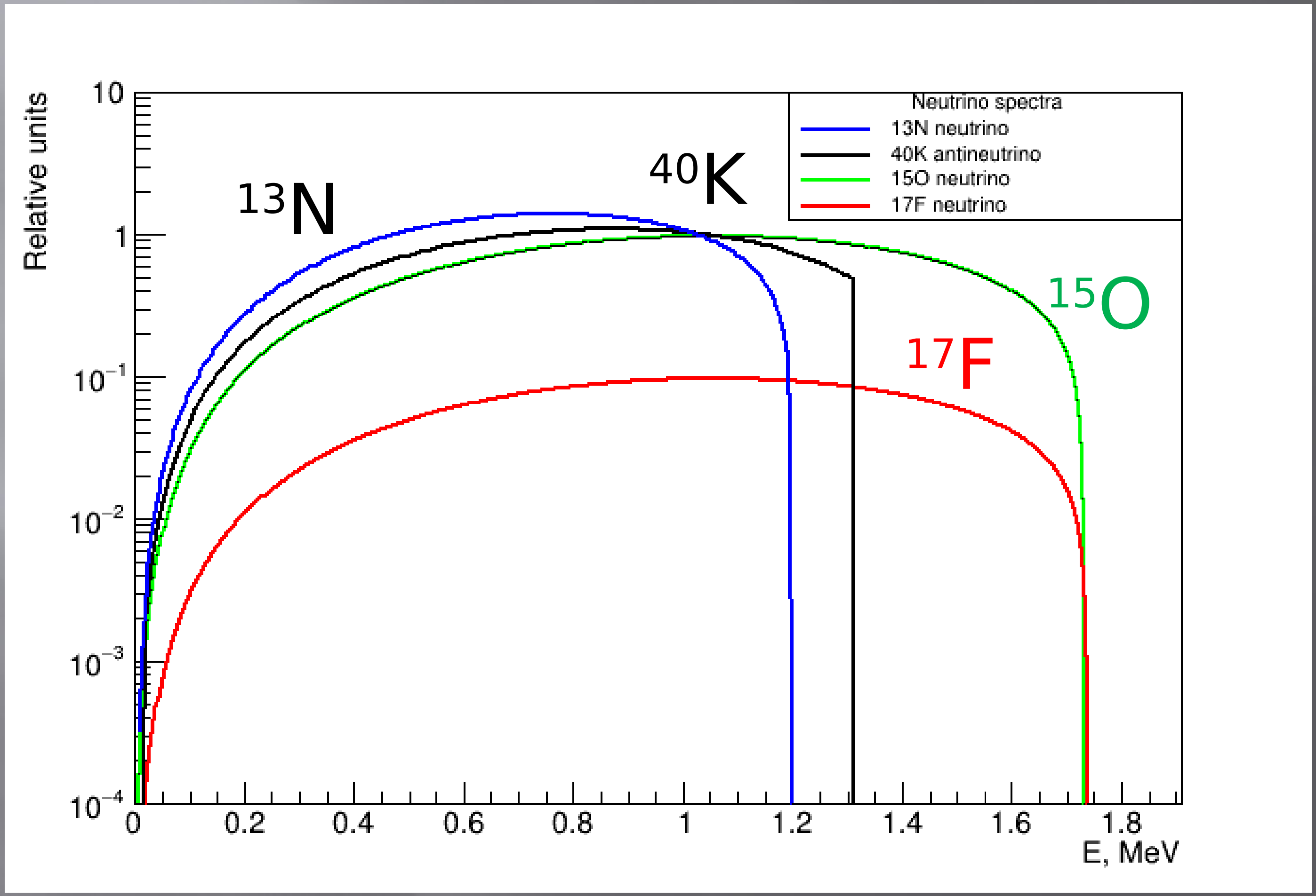
## $\nu_e + e \rightarrow \nu_e + e$



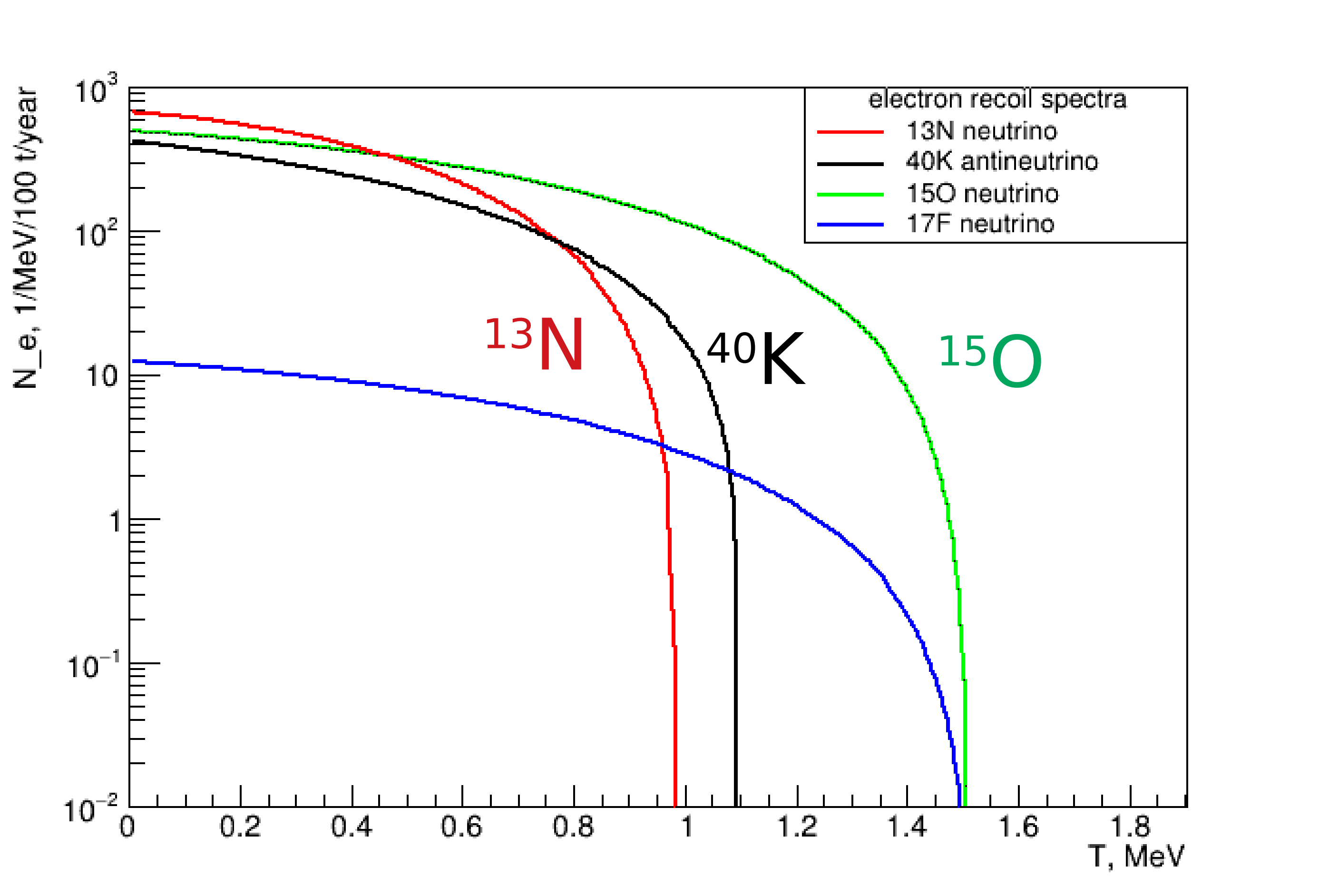

Physics of Particles and Nuclei ***46**, 186 (2015);* ArXiv:1405.3140[hep-ex]

# Let's see in detail on CNO neutrinos spectra and $^{40}K$ spectrum

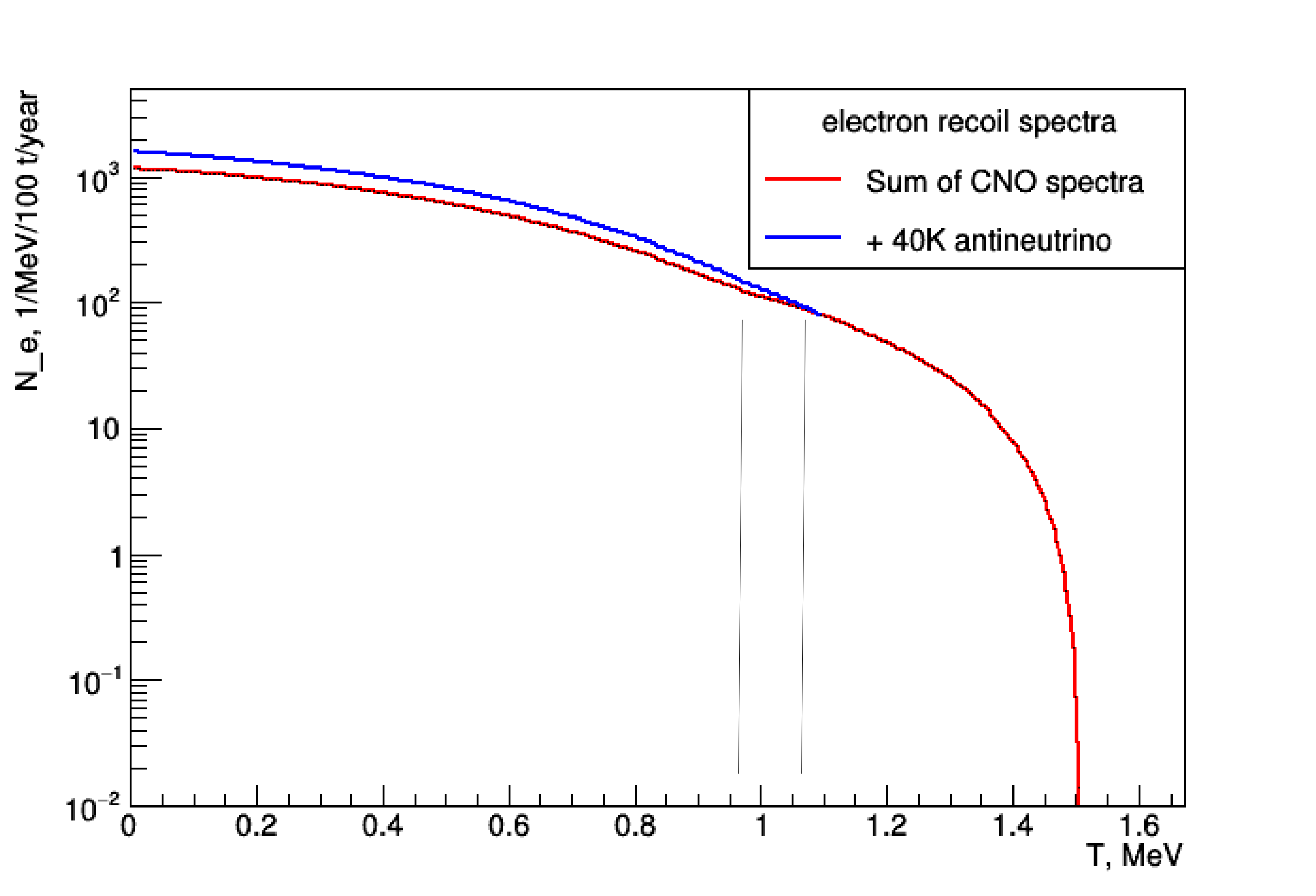
# CNO neutrinos and $^{40}K$ antineutrinos spectra



# Spectra from CNO cycle neutrinos and $^{40}K$ antineutrinos in a detector as recoil electrons

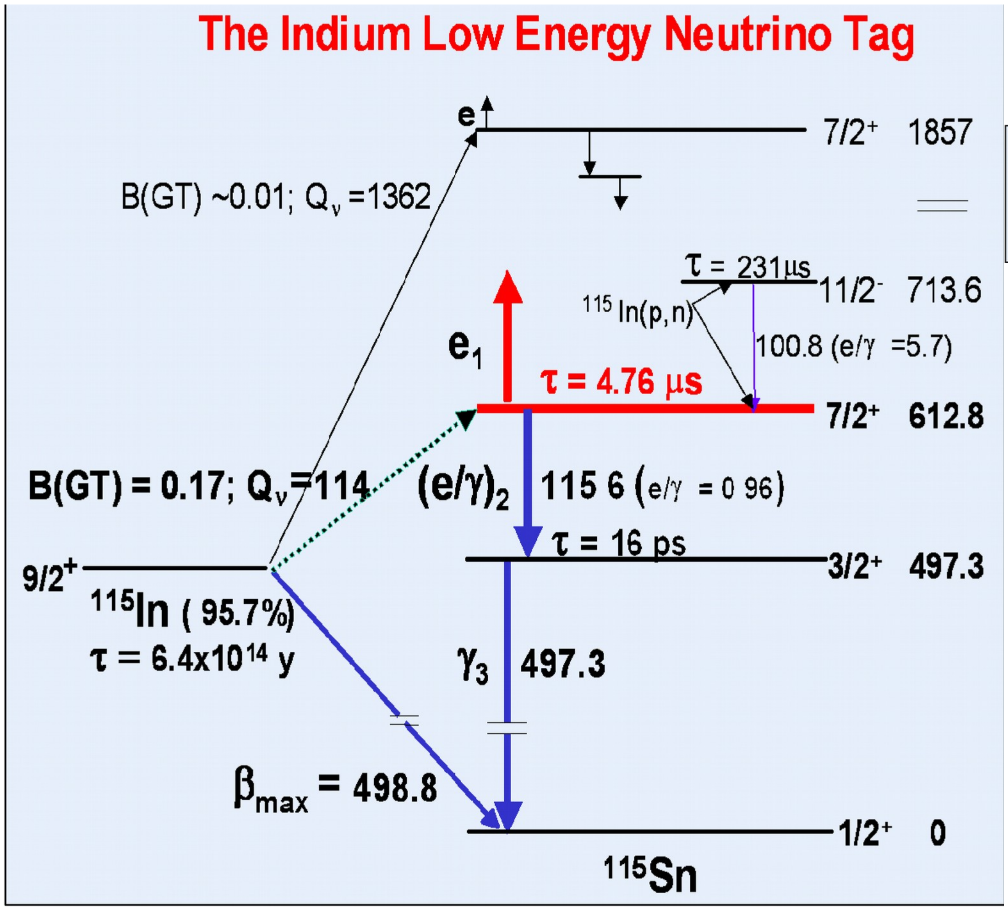


# Prediction of possible observation $^{40}K$ with CNO neutrinos in 100 t of Borexino detector



# Detector using $^{115}In$ as neutrino target can measure solar neutrinos from CNO cycle

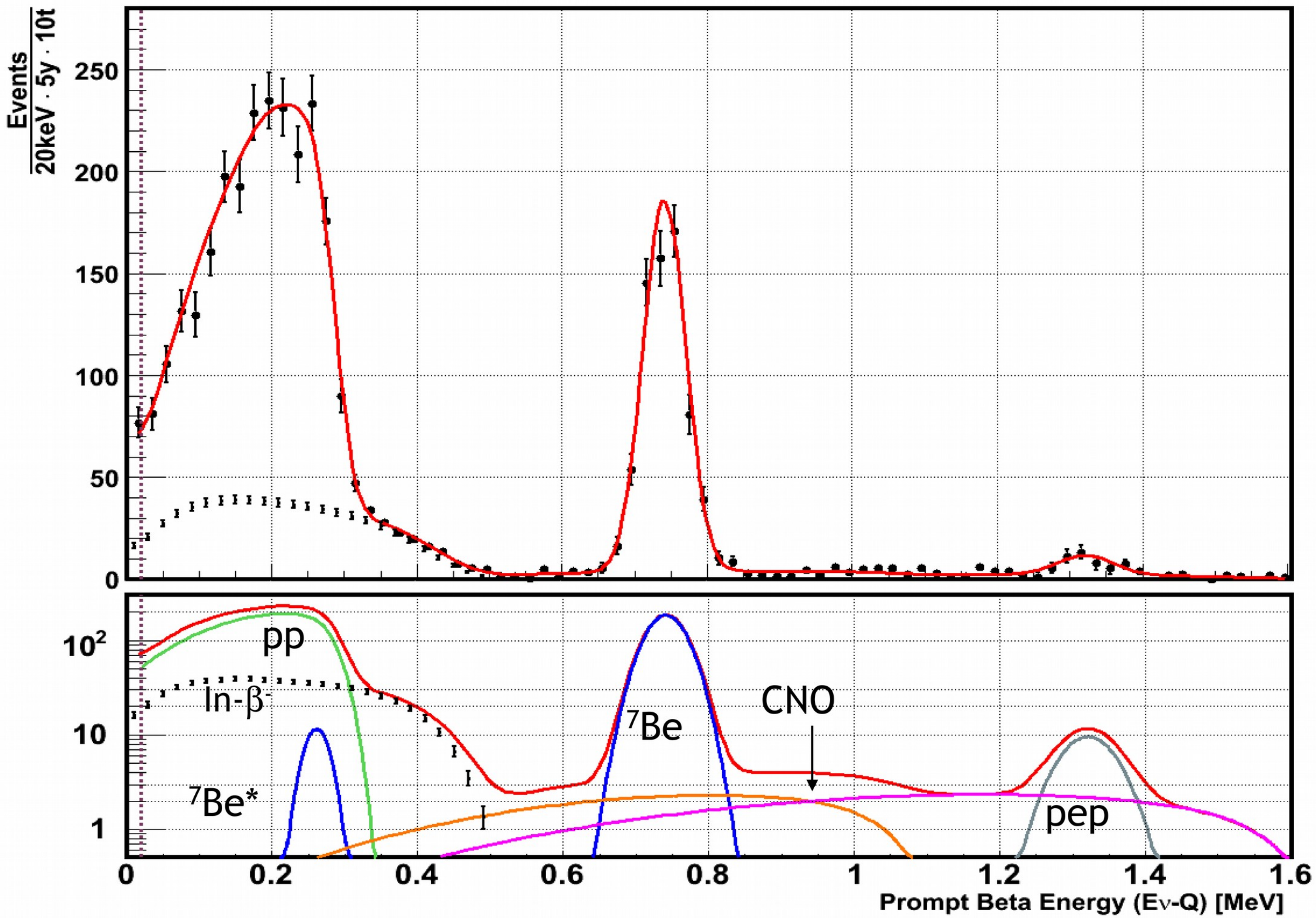
# $^{115}$In decay scheme and method of neutrino detection




$$\nu_e + {}^{115}In \rightarrow \underbrace{e^-}_{\substack{\text{Prompt} \\ (E=E_\nu - 114\,\text{keV})}} + \underbrace{\gamma + (\gamma / e^-)}_{\substack{\text{Delayed Tag} \\ (\tau=4.76\,\mu s,\ E_{Tag}=614\,\text{keV})}} + {}^{115}Sn$$

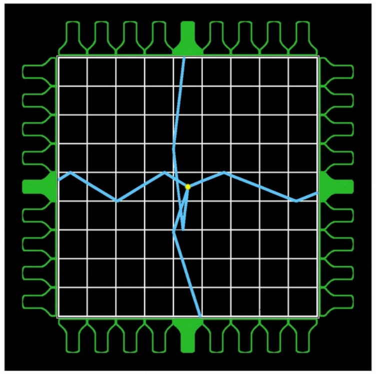
Proposed by R. Raghavan

# Spectrum that could be measured by detector with 10 t of $^{115}$In in 5 y

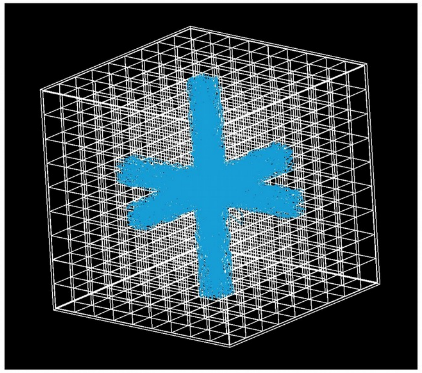


# Detector Design: The Scintillation Lattice Chamber

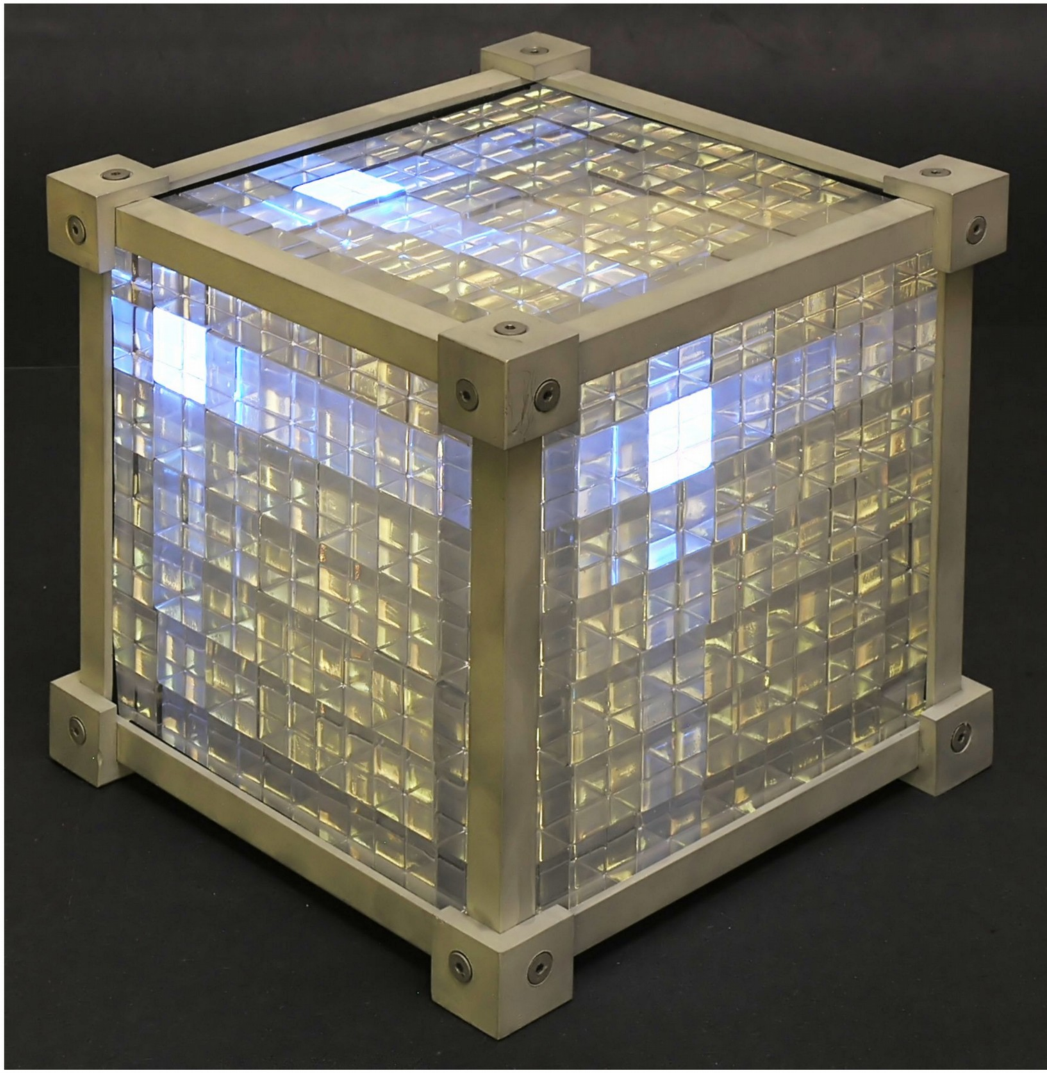
- Segmentation of liquid scintillator volume into small cubic cells using transparent double-layered films with a microscopic air gap between the two layers;
- Total internal reflection channels light along the three main axes of the cells, PMTs on the outside register the signal;
- Position reconstruction of an event relies on PMT channel identification rather than time-of-flight information;
- Position resolution is the size of the basic cell element, and can be adjusted to optimize the detector design. It is independent of the event energy, which is key for low-energy events.
- The time-of-flight information is redundant and can be used to examine the shower structure.



Schematic representation of the Scintillation Lattice Chamber: Photons are guided along the main axes towards the PMTs.



Channeling of isotropically emitted light in 3 dimensions;



Light propagation in a small model of the Scintillation Lattice Chamber;

# Our proposal of Detector with $^{115}In$

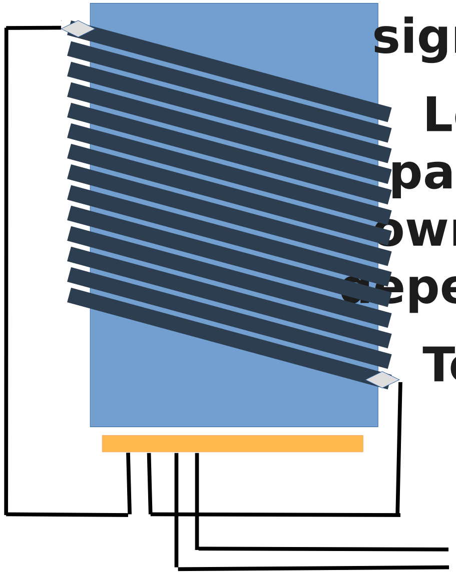
**Cylinder about 1 litre in volume filled with LAB + In**

**Covered by 2 fibers with shifter viewed by 2 SiPMs. Coincidences of signals assure that it is a physical signal.**

**Each detector has own processor that analyses on line what kind of signal appeared in.**

**Logically we recognize what a particle registered. Single detector hited – own background (U,Th or In). Several – than depends on topology.**

**Totally ~100 000 l (10%$_{wheight}$ $^{115}In$ (95.71%))**



- **Possible site for CNO neutrinos detector could be Pyhasalmi mine in Finland.**
- **It is needed European collaboration for the Project.**

# Conclusion

As well as neutrinos from CNO cycle Borexino could detect $^{40}K$ antineutrinos.

Several events per day counting rate for $^{40}K$ antineutrinos in 100 t of Borexino target means the potassium abundance in the Earth at the level more than 1% by mass.

We know that 1% of potassium in the Earth produces about 200 TW of heat.

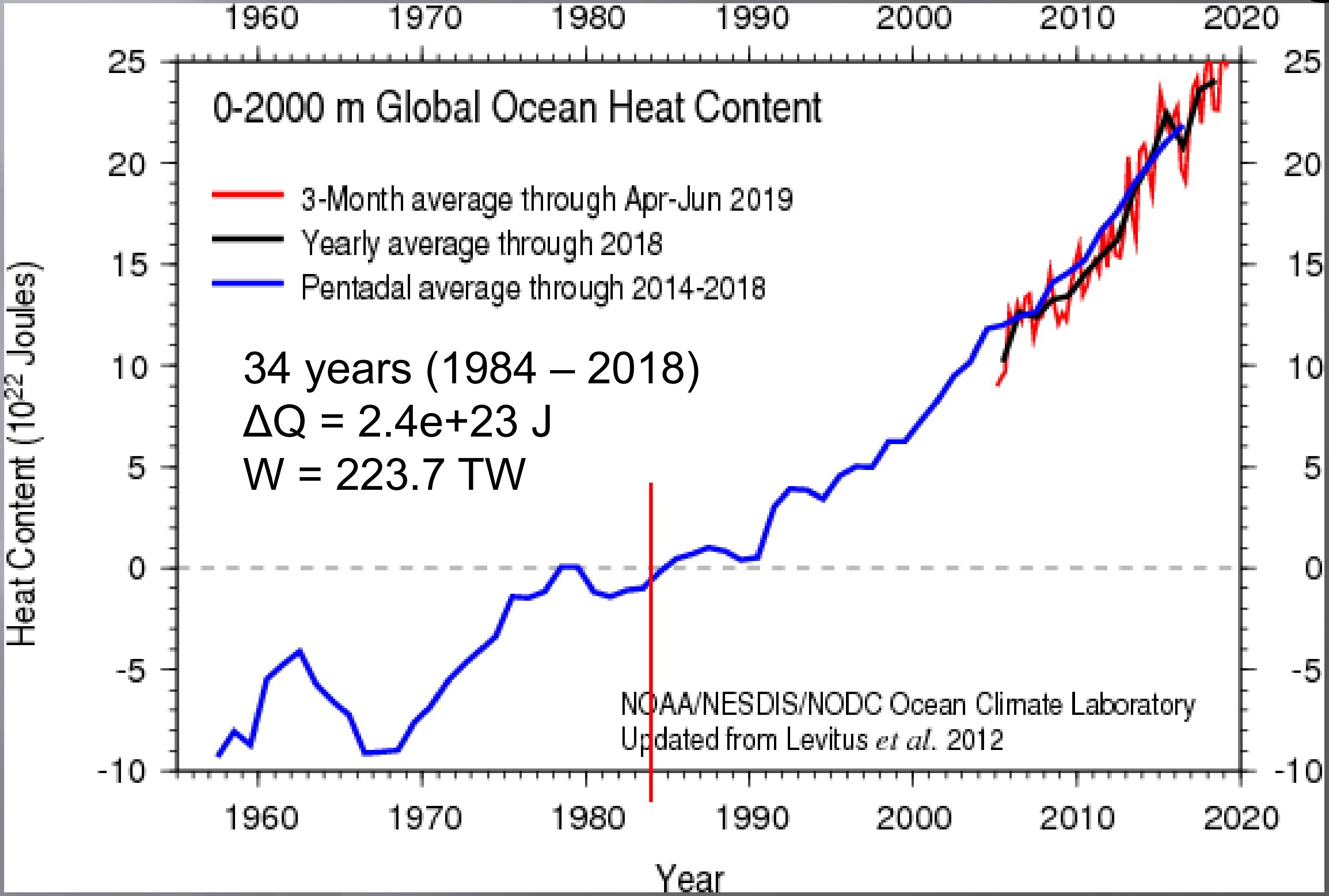
To solve the problem of $^{40}K$ we need to have independent measurement of CNO cycle neutrinos from the Sun.

Project LENS should be recalled again.

# Thank you for the attention

# Backup slides

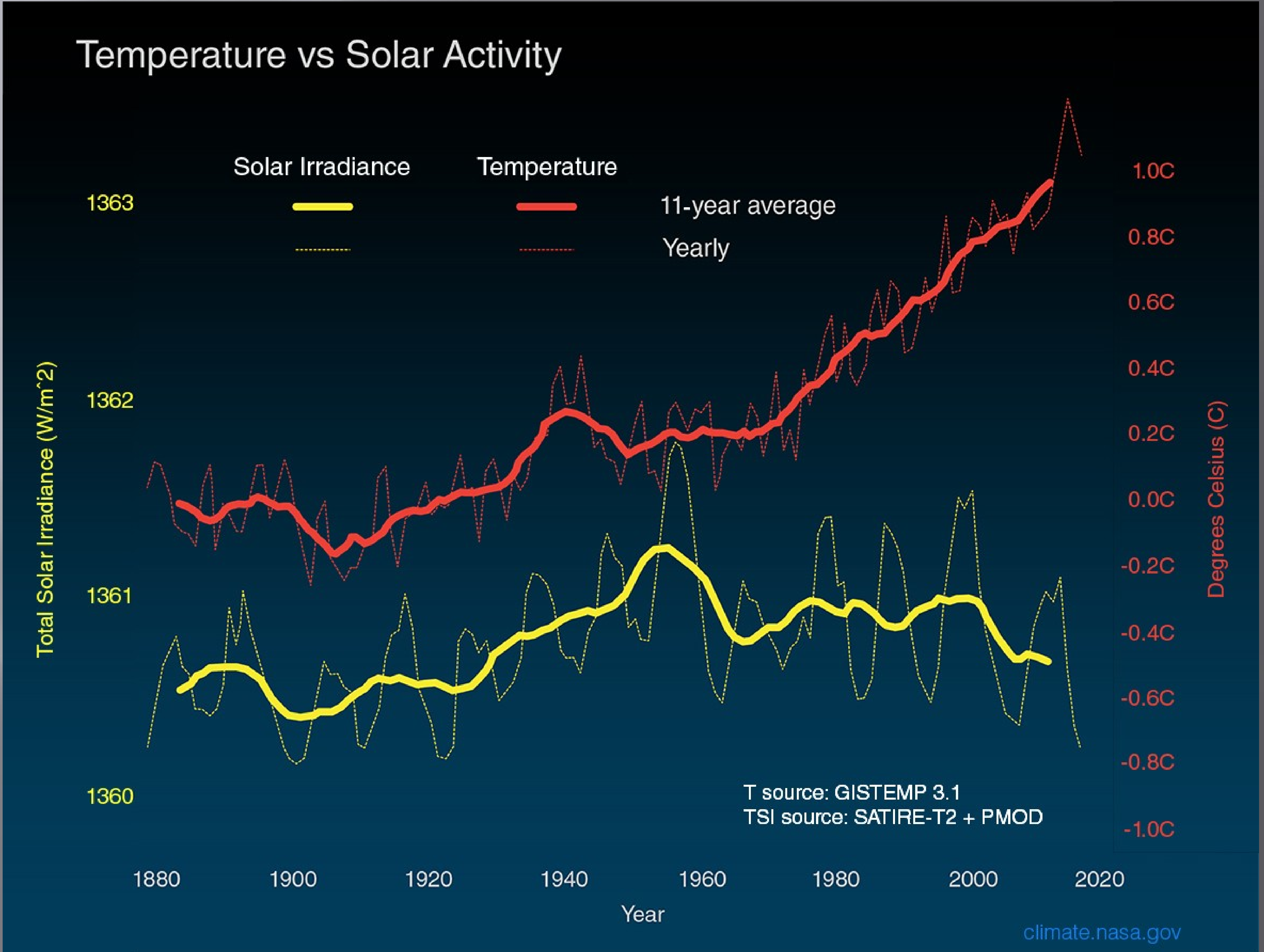
# World ocean surface heating




https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/
https://en.wikipedia.org/wiki/Ocean_heat_content

# Solar irradiation

Sun emits $3.828 \times 10^{26}$ W
Distance to Earth $1.496 \times 10^{11}$ m
So, at Earth orbit we have 1361.13 $W/m^2$
Earth albedo ~31%
In average Earth receives 214.38 $W/m^2$


Temperature vs Solar Activity
Solar Irradiance
Temperature
11-year average
Yearly
1363
1362
1361
1360
Total Solar Irradiance (W/m^2)
1.0C
0.8C
0.6C
0.4C
0.2C
0.0C
-0.2C
-0.4C
-0.6C
-0.8C
-1.0C
Degrees Celsius (C)
T source: GISTEMP 3.1
TSI source: SATIRE-T2 + PMOD
1880
1900
1920
1940
1960
1980
2000
2020
Year
climate.nasa.gov

# Temperature inside the Earth