JINR
Dubna

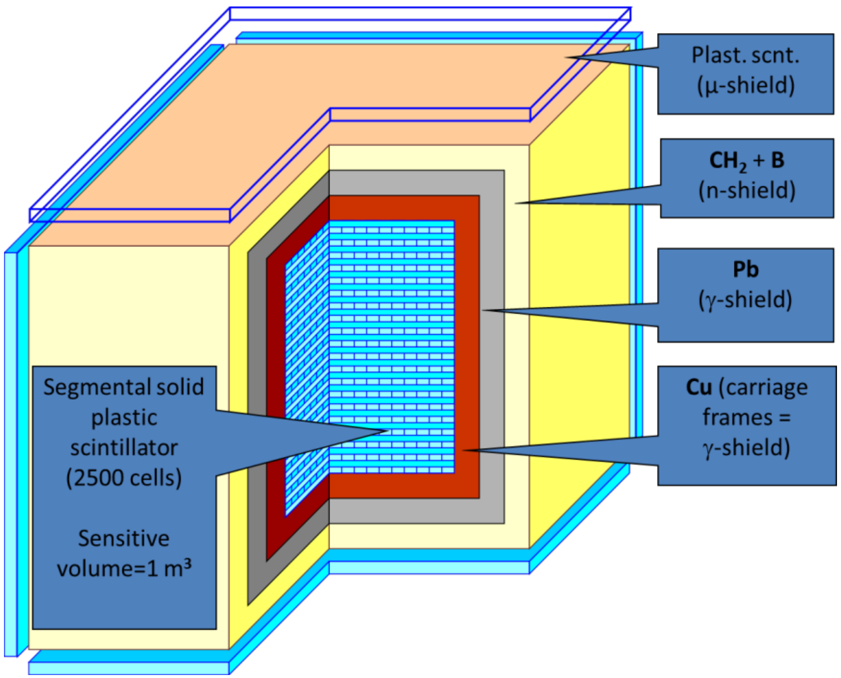
ITEP
Moscow

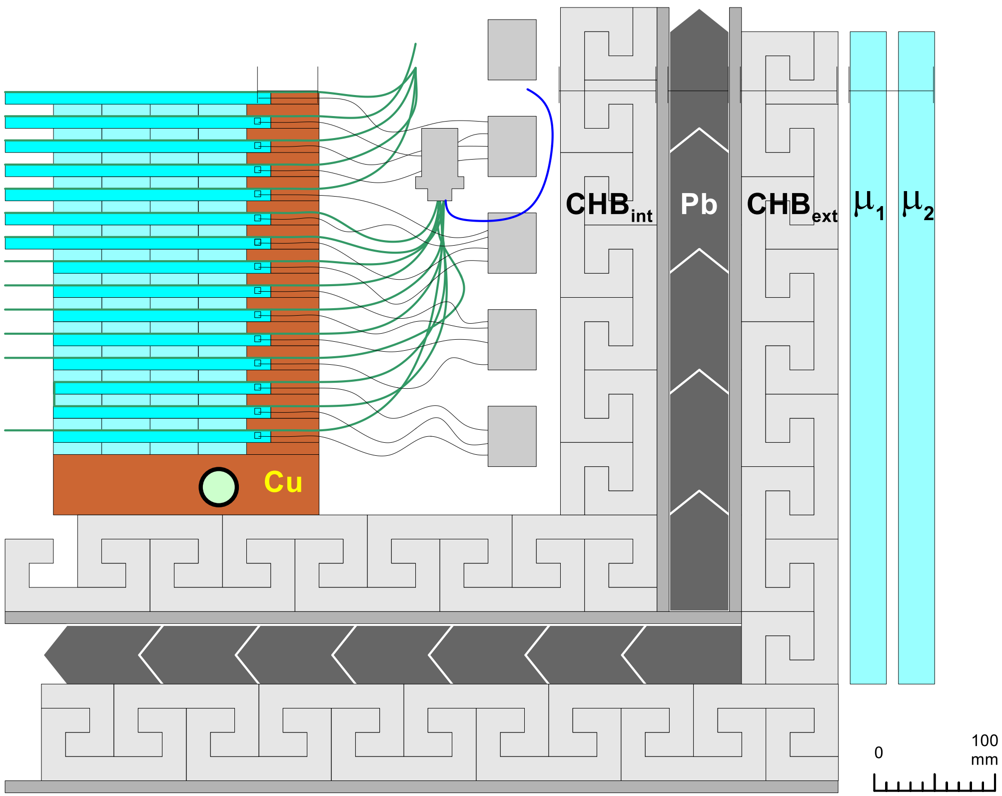
ACTUAL STATUS OF DANSS PROJECT

V. Belov on behalf of DANSS collaboration

DANSS

Detector of the reactor AntiNeutrino based on Solid-state Scintillator



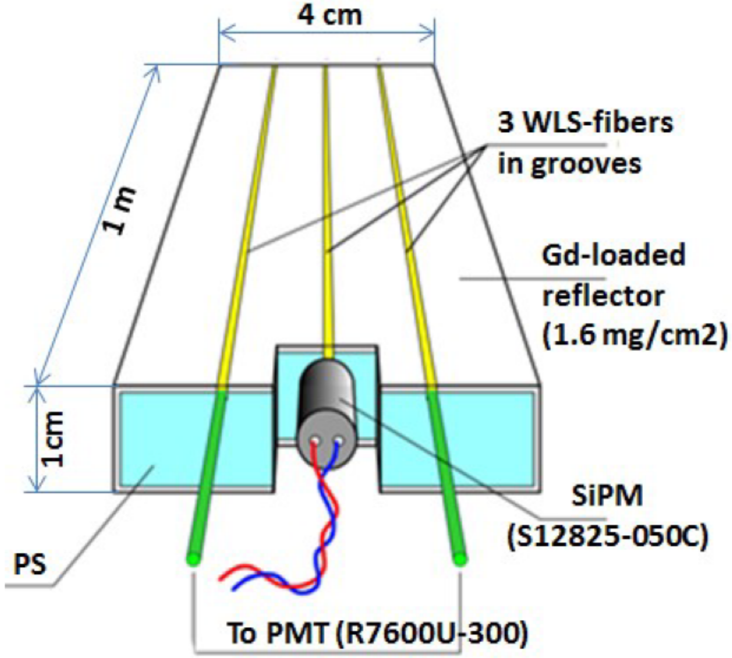


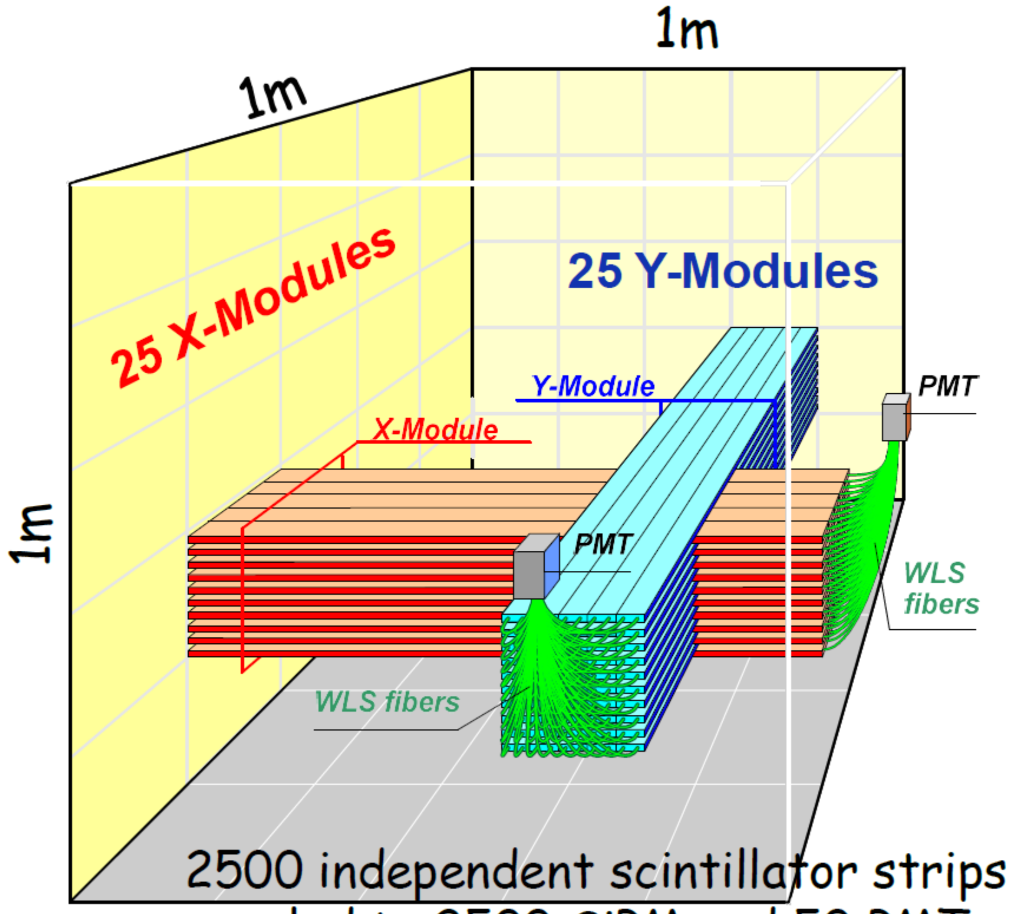
Modular structure provides **3d space pattern** of each event

JINST 11 (2016) no.11, P11011; arXiv:1606.02896 [physics.ins-det]

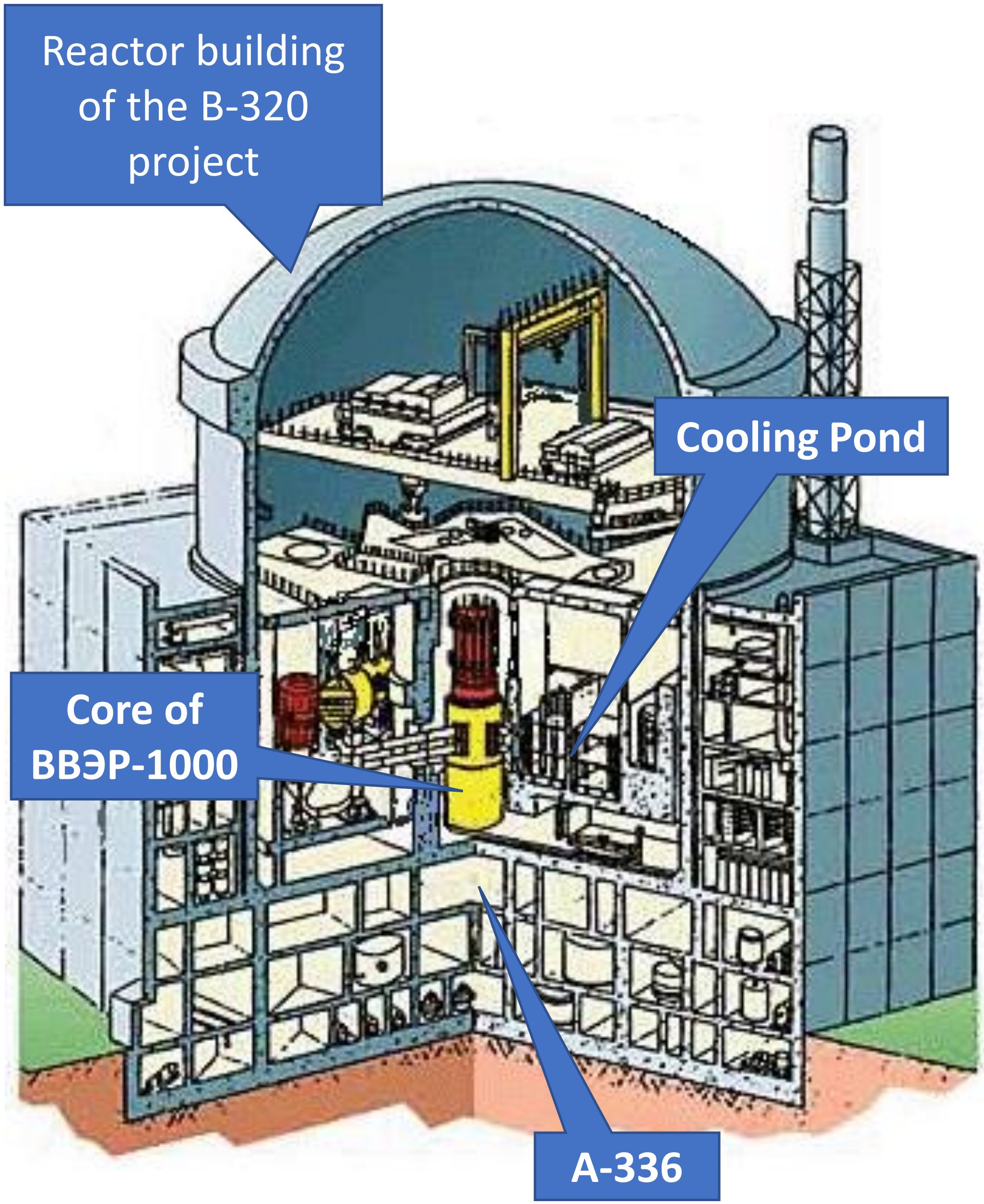
1.1 tonne of PS = 5.1×10^{28} Hydrogen atoms

Basic element:
polystyrene-based
scintillator strip





2500 independent scintillator strips
coupled to 2500 SiPM and 50 PMT



DANSS features:

- Segmented "XY" plastic scintillator (1 m^3) close to the core of the Kalinin NPP reactor #4
- Overburden ~ 50 m w.e. (reactor cauldron, cooling pond, concrete)
- 3D-information about each event
- IBD count rate $\sim 10^4\ \bar{\nu}_e$ / day; Signal / Background ≥ 30
- On-line lifting platform => movable distance (L=10 –12 m)

MOTIVATION

Applied physics

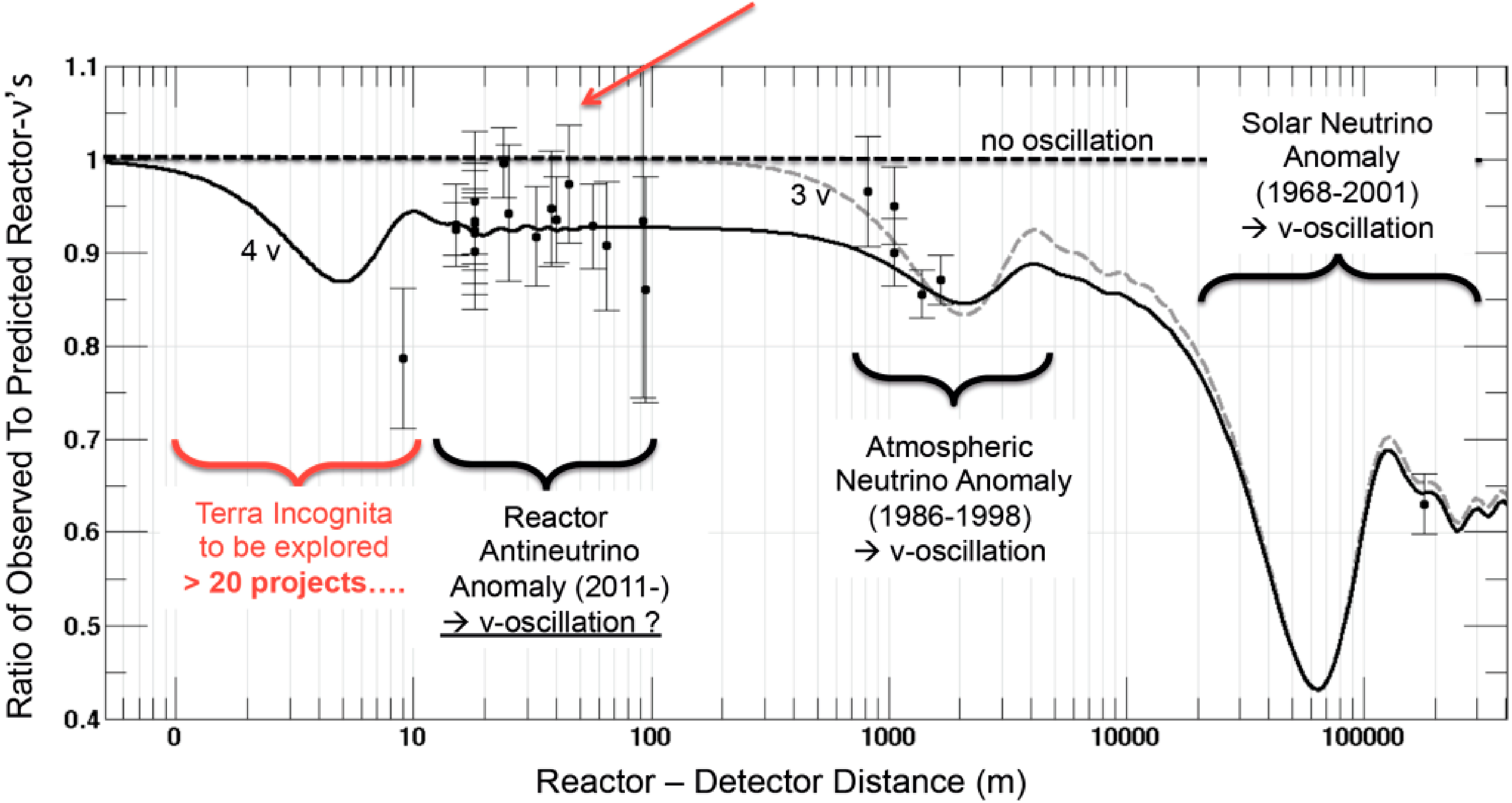
- Measurement of the actual reactor power (Nν)
- Deducing the actual fuel composition (Eν)
- On-line reactor monitoring
- Nonproliferation of nuclear technology *(prevent unauthorized extraction of 239Pu)*

Fundamental physics

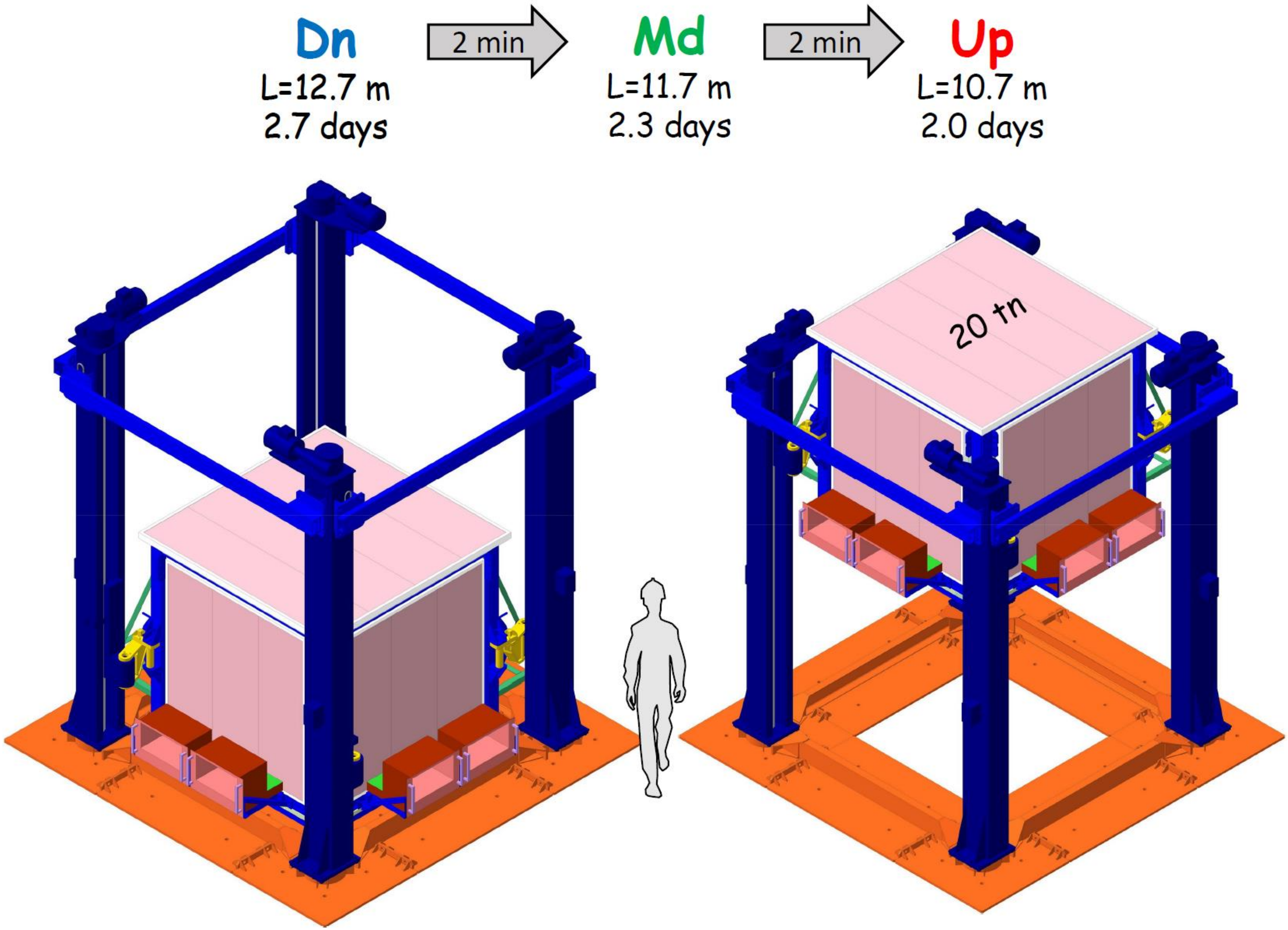
- **Search for short-distance neutrino oscillations**

Reactor antineutrino anomaly

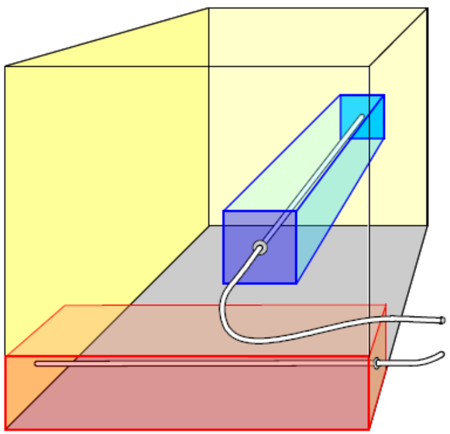
- **Observed/predicted averaged event ratio: R=0.927±0.023 (3.0 σ)**

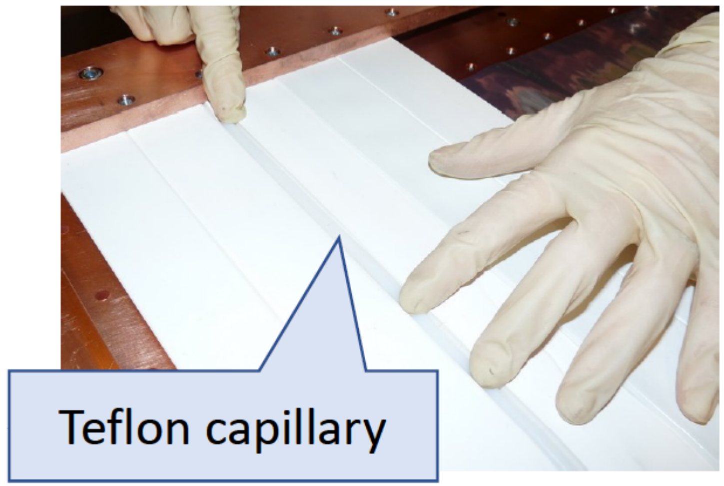


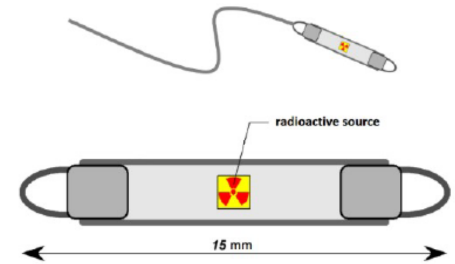
$$P(\tilde{\nu}_e \rightarrow \tilde{\nu}_e) = 1 - \sin^2 2\theta_{14} \ \sin^2\left(1.27 \frac{\Delta m^2_{14}[eV^2]L[m]}{E_{\tilde{\nu}}[MeV]}\right)$$

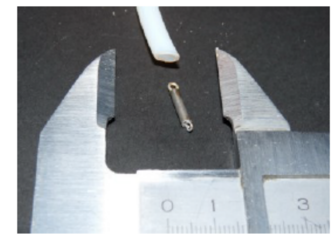

Dn
L=12.7 m
2.7 days
2 min
Md
L=11.7 m
2.3 days
2 min
Up
L=10.7 m
2.0 days
20 tn

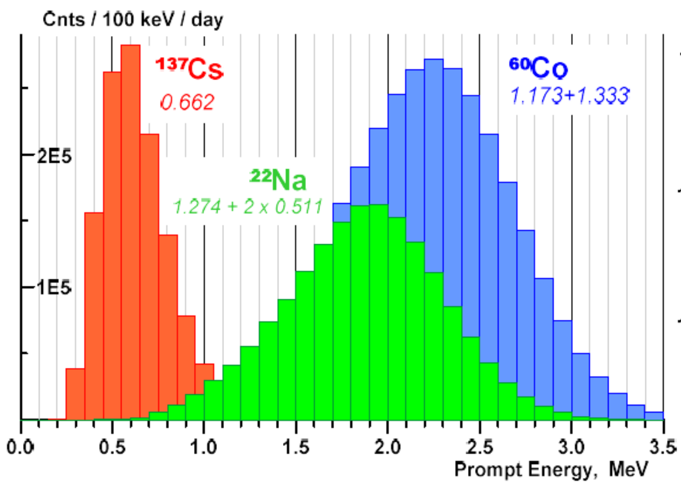
Calibration with ^{22}Na, ^{60}Co, ^{137}Cs, ^{248}Cm (few Bq)

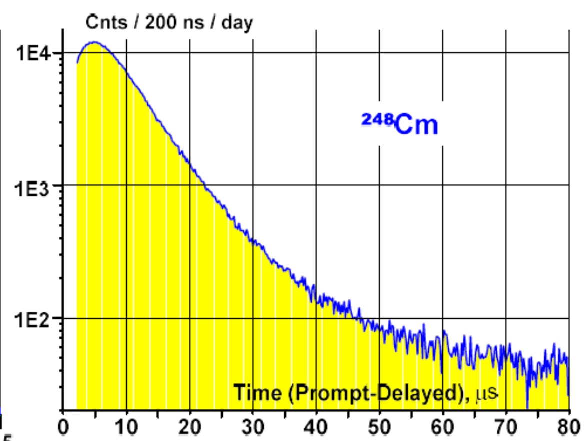


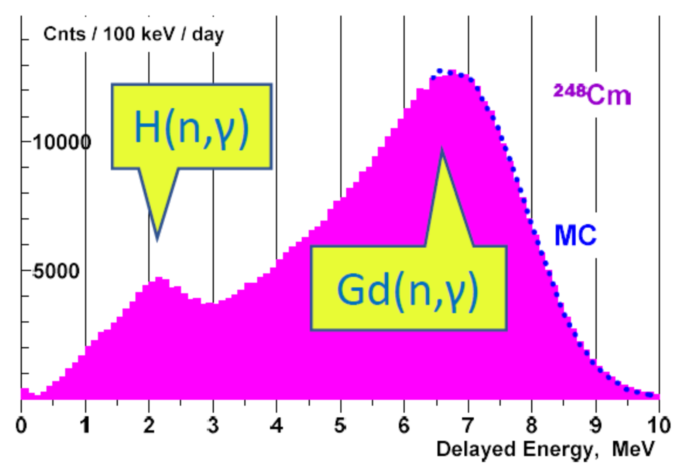




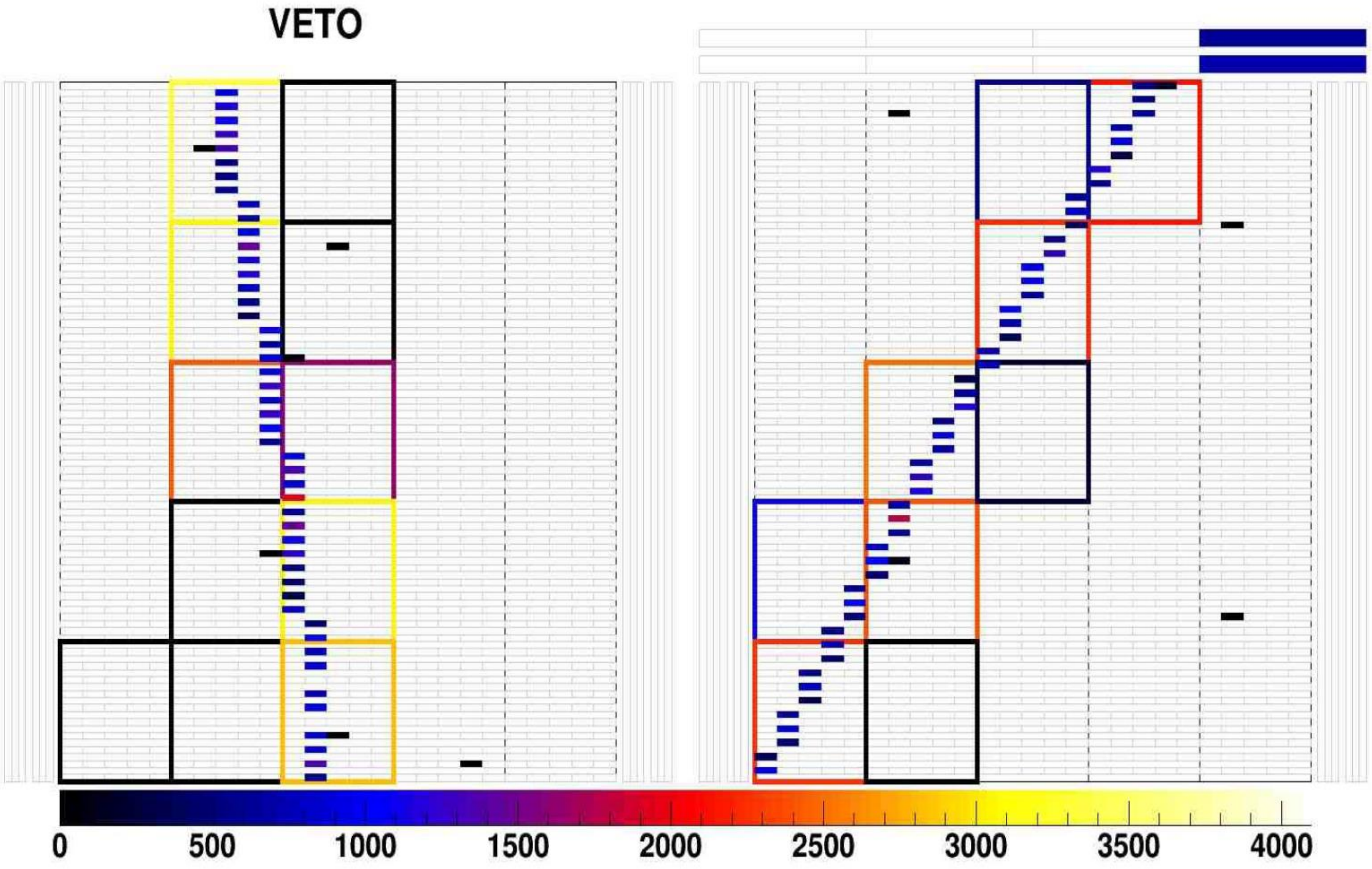








CALIBRATION VIA COSMIC MUONS

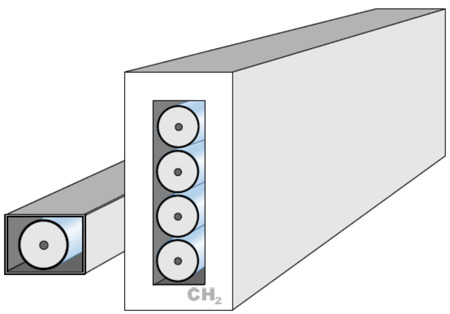


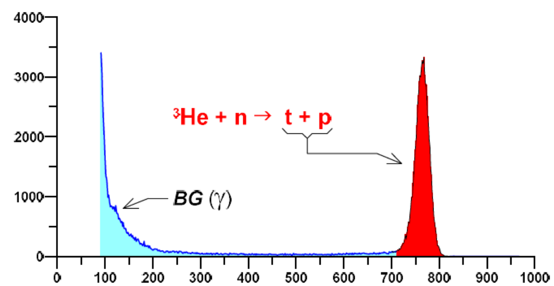
Background monitoring

- Permanent monitoring of gamma-BG with four NaI (3’x3’):1 inside + 3 outside the DANSS shield

no (ON – OFF) visible difference

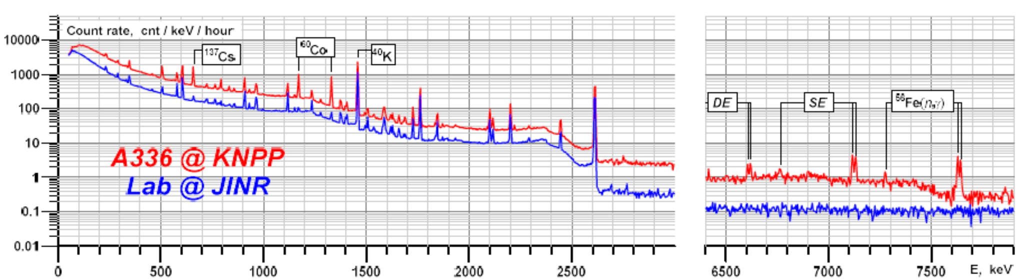
- Permanent monitoring of neutron flux with three ^{3}He neutron counters: 1 inside +2 outside the shield

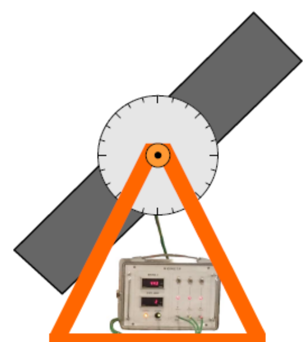


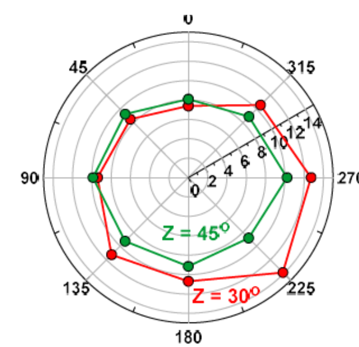


Φn = 0.57 outside (OFF)
Φn = 300.4 outside (ON)
Φn = 0.03 inside (OFF)
Φn = 0.04 inside (ON)
Φn = 6.0 en plein air

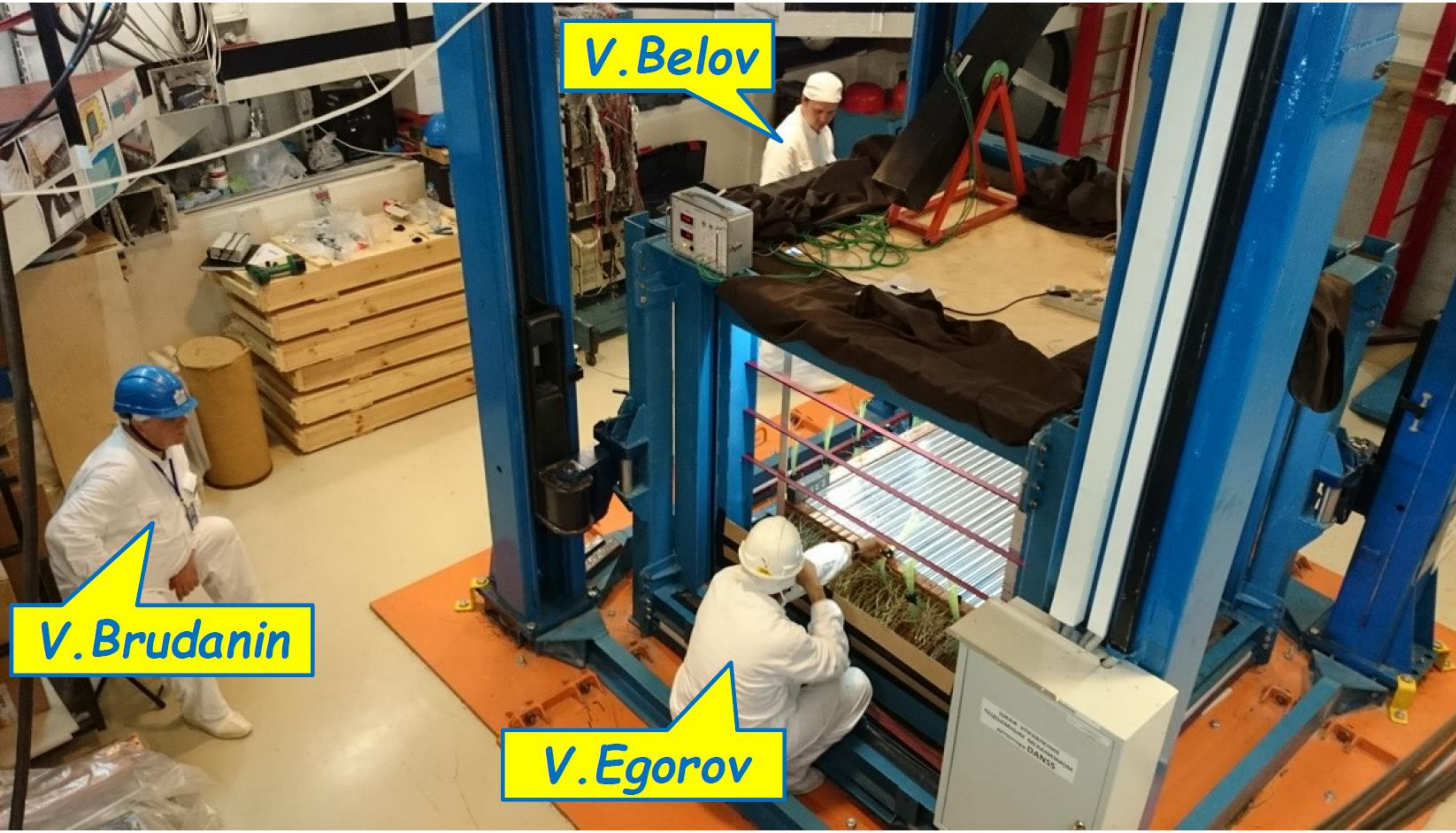
- Episodic measurements with HPGe and “MuMeter”



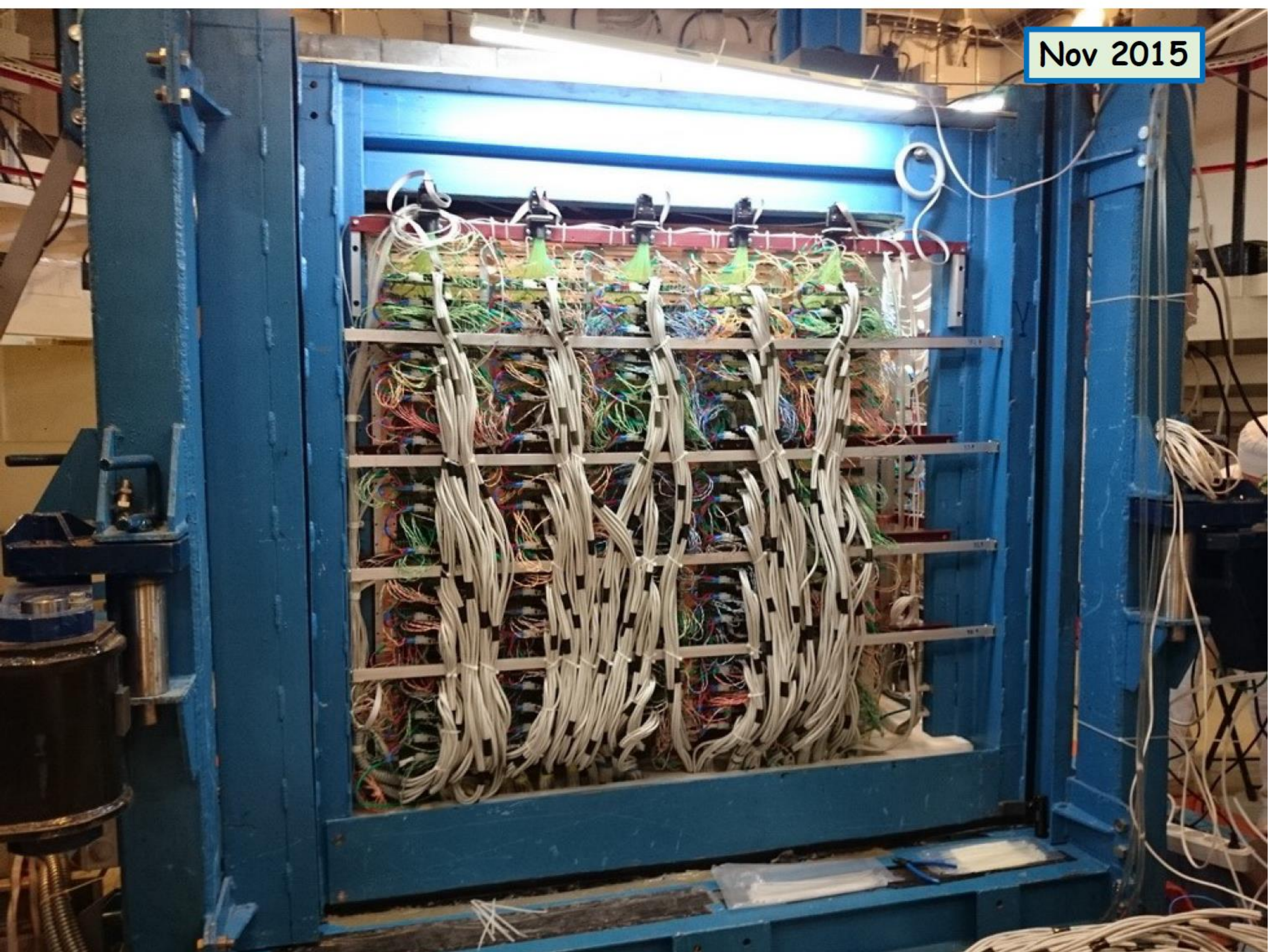


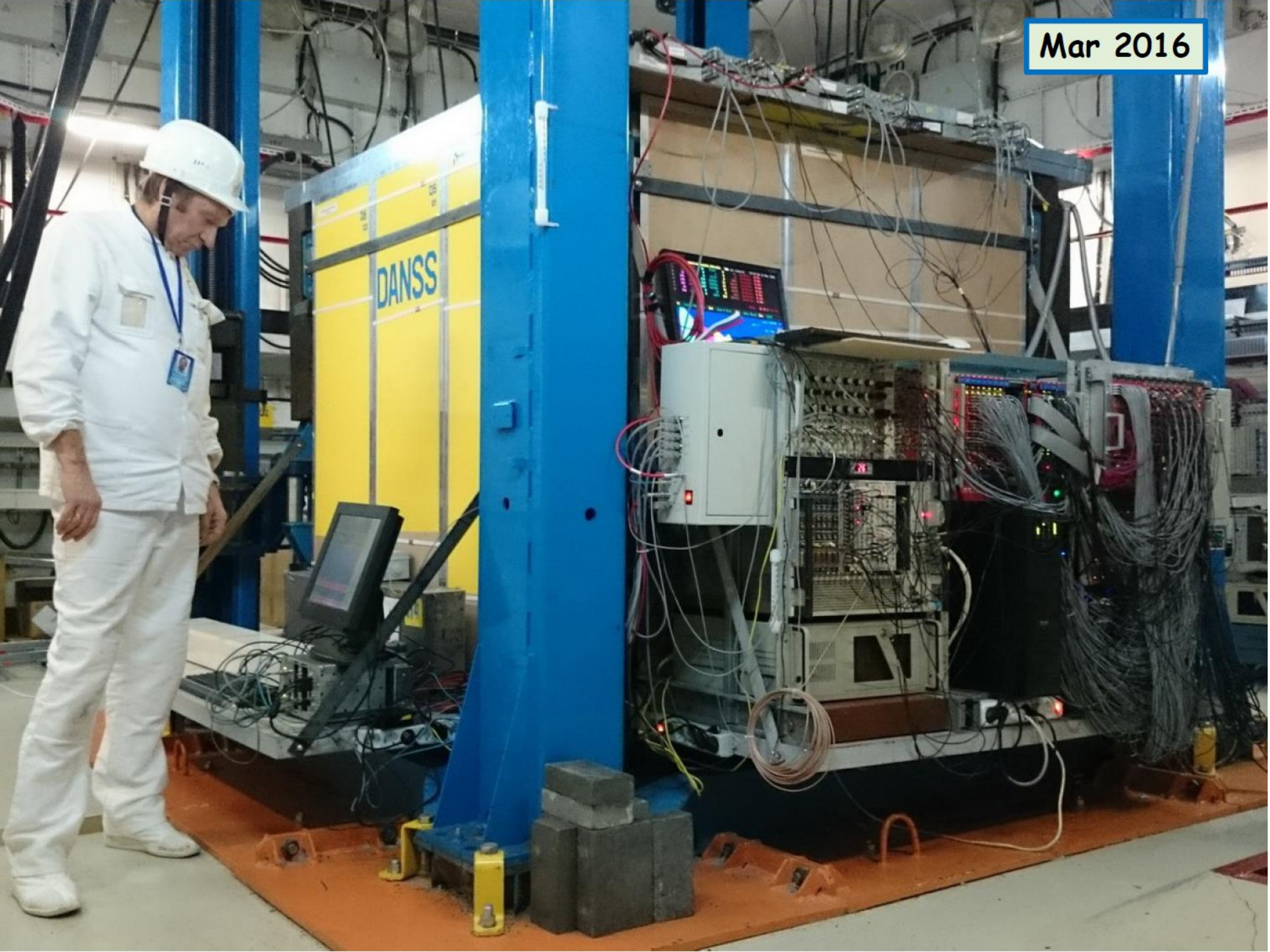


Aug 2015




Oct 2015
I.Zhitnikov

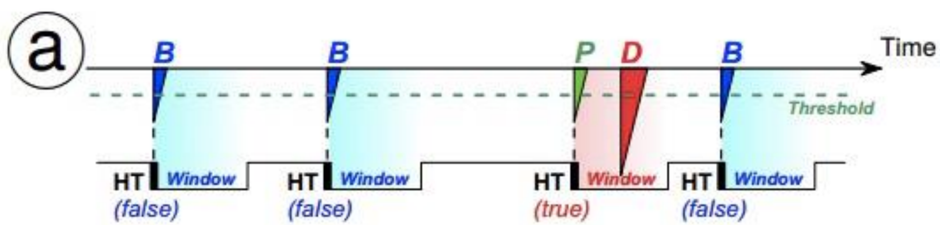

Nov 2015


Mar 2016
DANSS

IBD CRITERIA

Three independent DAQ systems & 2 hard triggers:

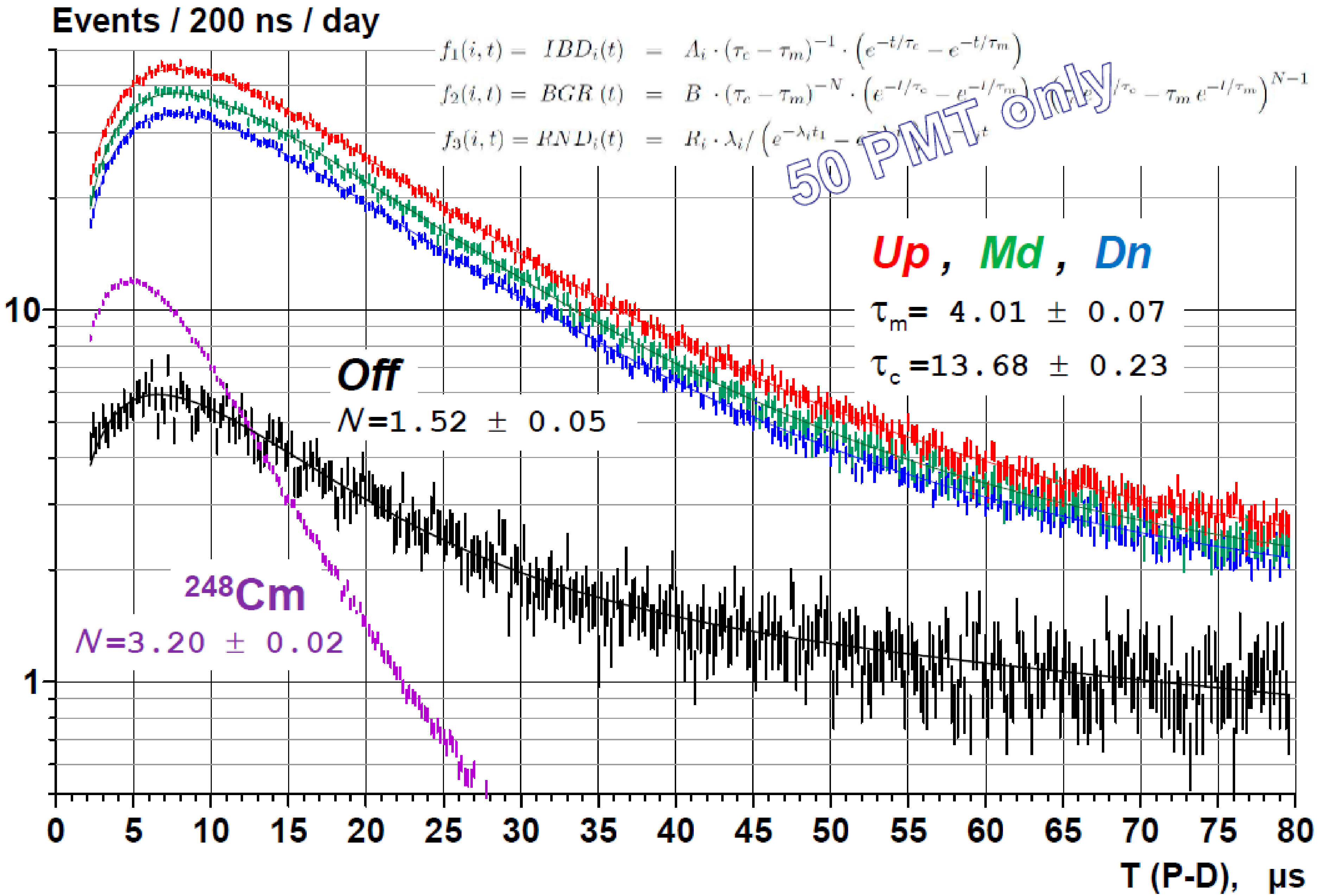
-Trigger 1: pair of pulses, $2\mu s < \Delta T < 80\ \mu s$, at least one $E_{PMT} > 0.5$ MeV for prompt and delayed pulses both, read 100 QDC channels, 100 waveforms (62.5 MS/s)



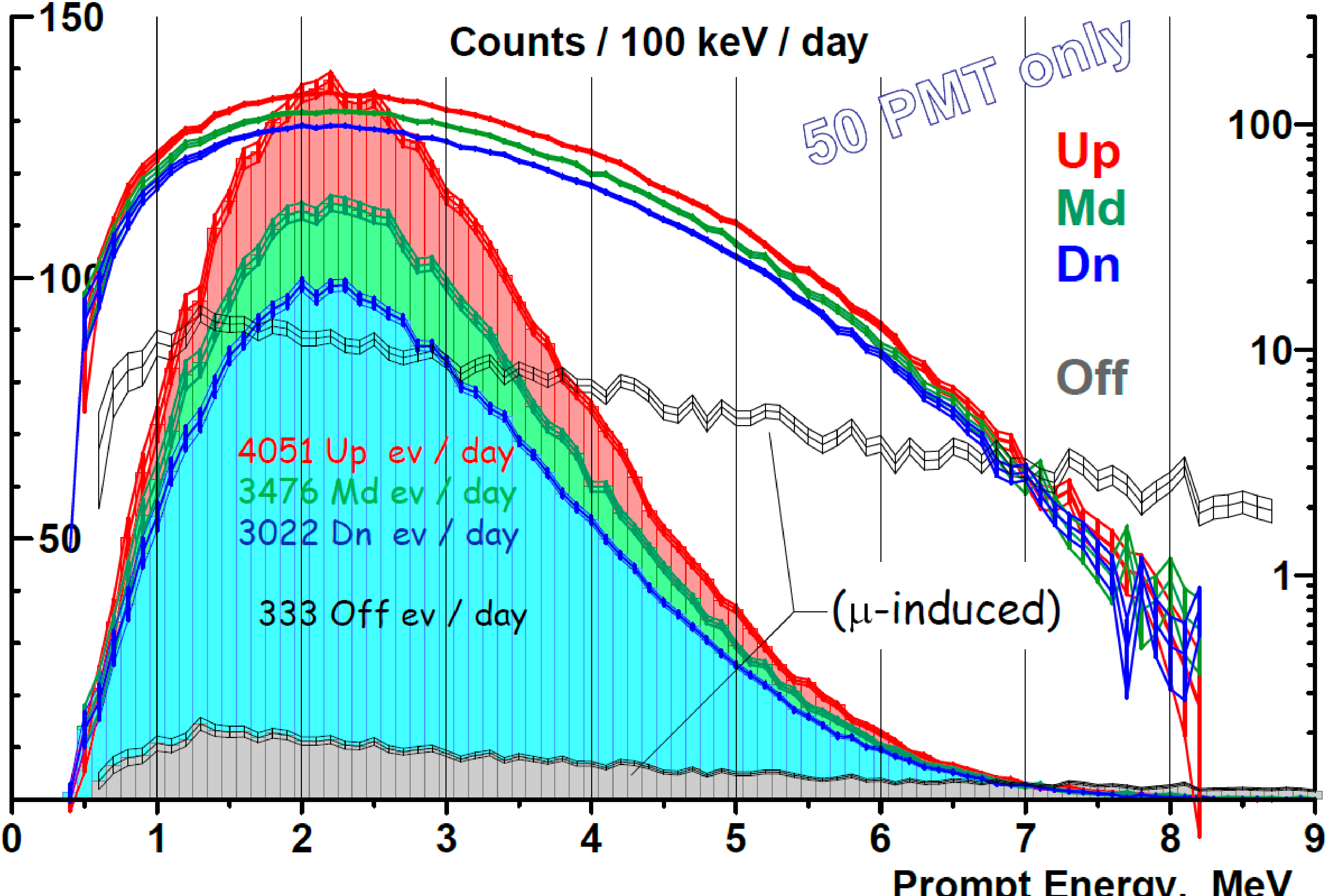
-Trigger 2: $\Sigma E_{PMT} > 0.7$MeV, read 2590 waveforms (125 MS/s) from 50 PMT, 2500 MPPC and 40 μ-veto detectors, look for correlated pairs offline

-Trigger veto

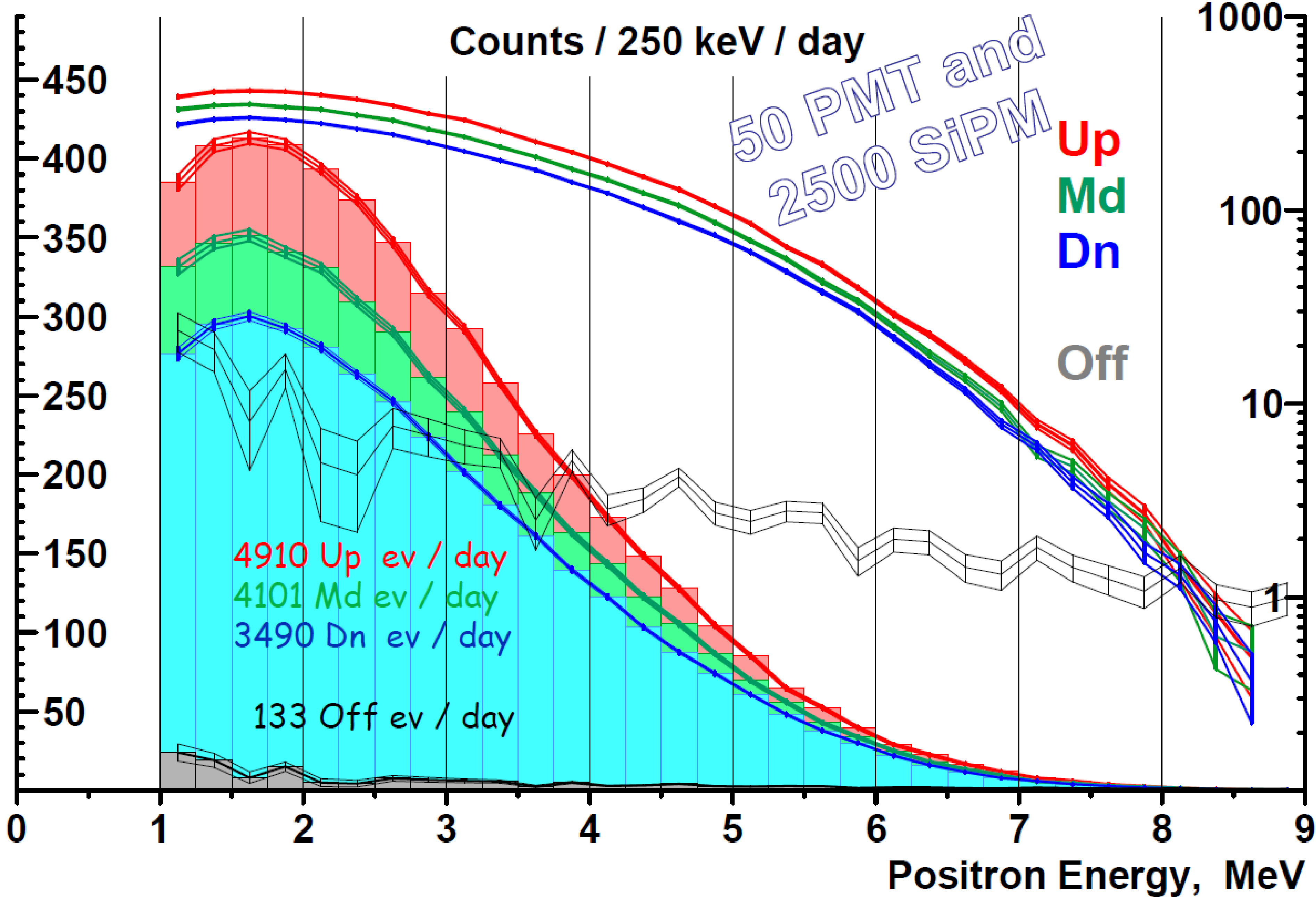
An example of time distributions



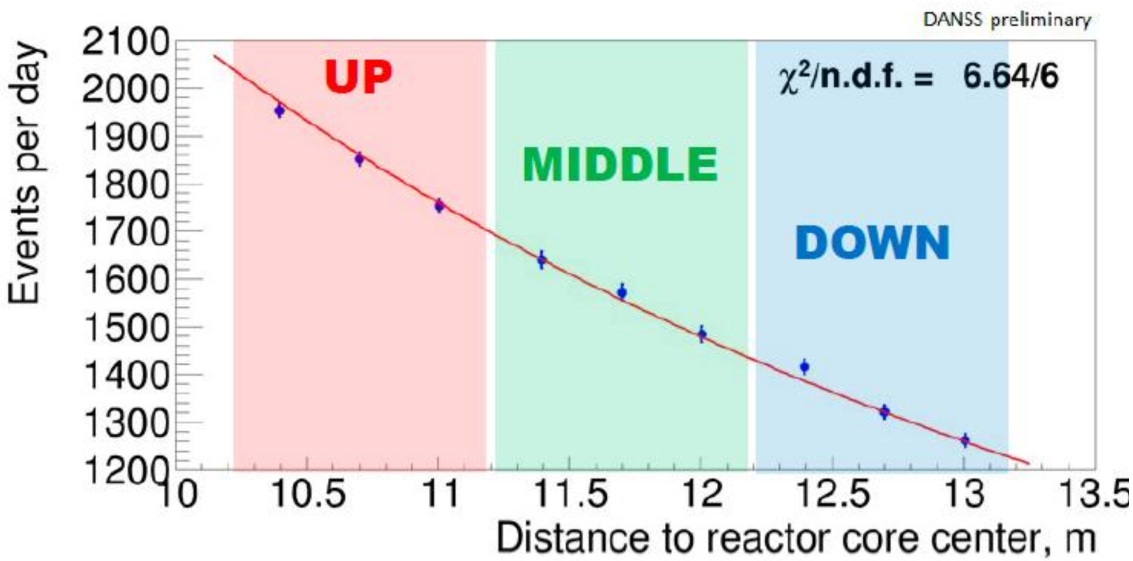
An example of energy spectra (partial segmentation)



An example of energy spectra (full segmentation)



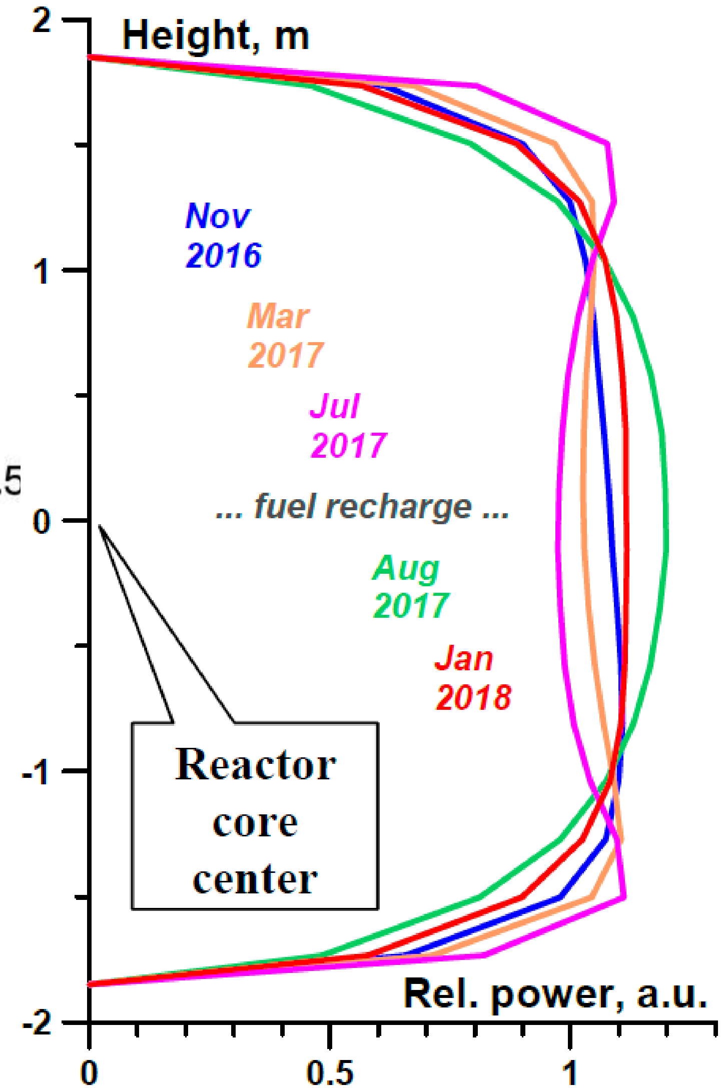
IBD total rate vs effective distance



IBD intensity follows reasonably the $1 / L^2$ dependence.

Effective distance L takes into account real spatial distribution of the detection efficiency and the reactor core burning profile (monitored permanently by the KNPP staff) .

The time variation of reactor core burning profile is taken into account with a precision of 30 min and ~10 cm.



Time evolution of the core burning profile

Reactor power seen by neutrino flux

Data accumulation:

April-June 2016 – start of data taking

July-September 2016 – shutdown for cooling system repair

October 2016 – March 2018 – the first run ~ 1.63·10⁶ IBD events

April 2018 – shutdown to improve grounding and recover ~50 SiPM channels. Trigger threshold was lowered to 0.5 MeV.

May 2018 – the second run started

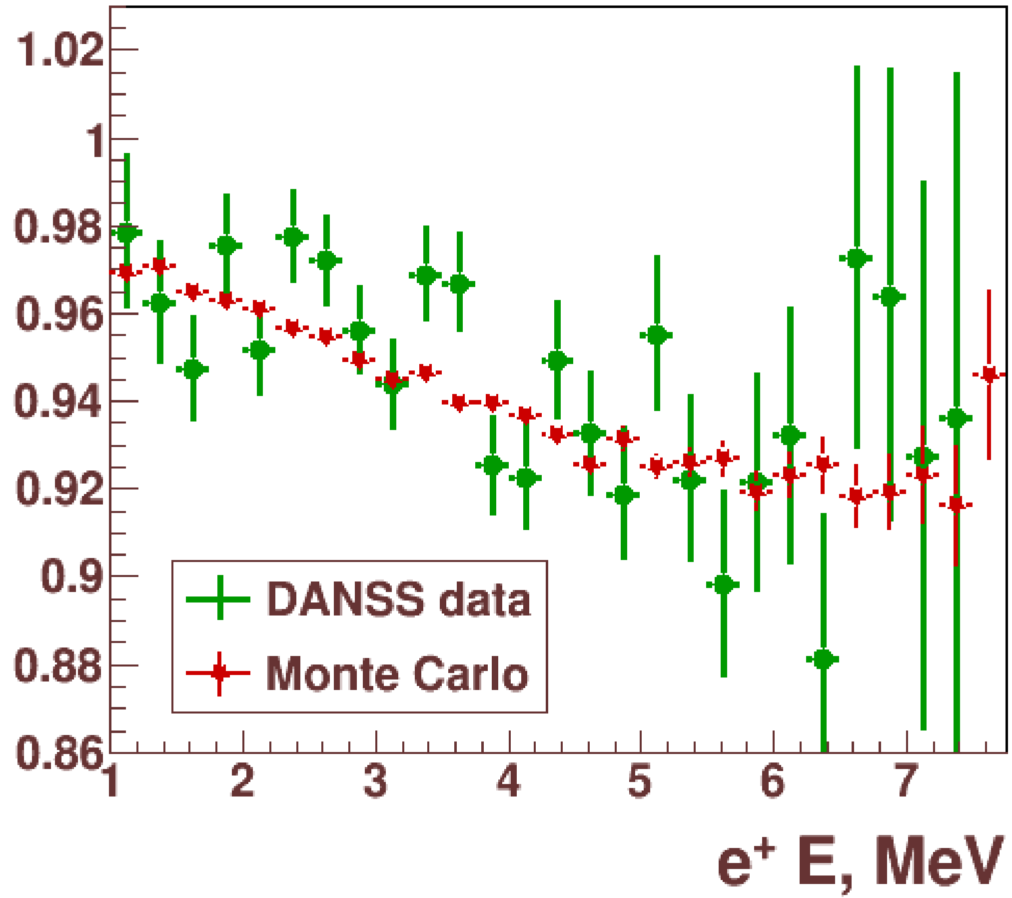
Fuel evolution

	Begin 4	End 4	Begin 5
^{235}U	63.7%	44.7%	66.1%
^{238}U	6.8%	6.5%	6.7%
^{239}Pu	26.6%	38.9%	24.9%
^{241}Pu	2.8%	8.5%	2.3%

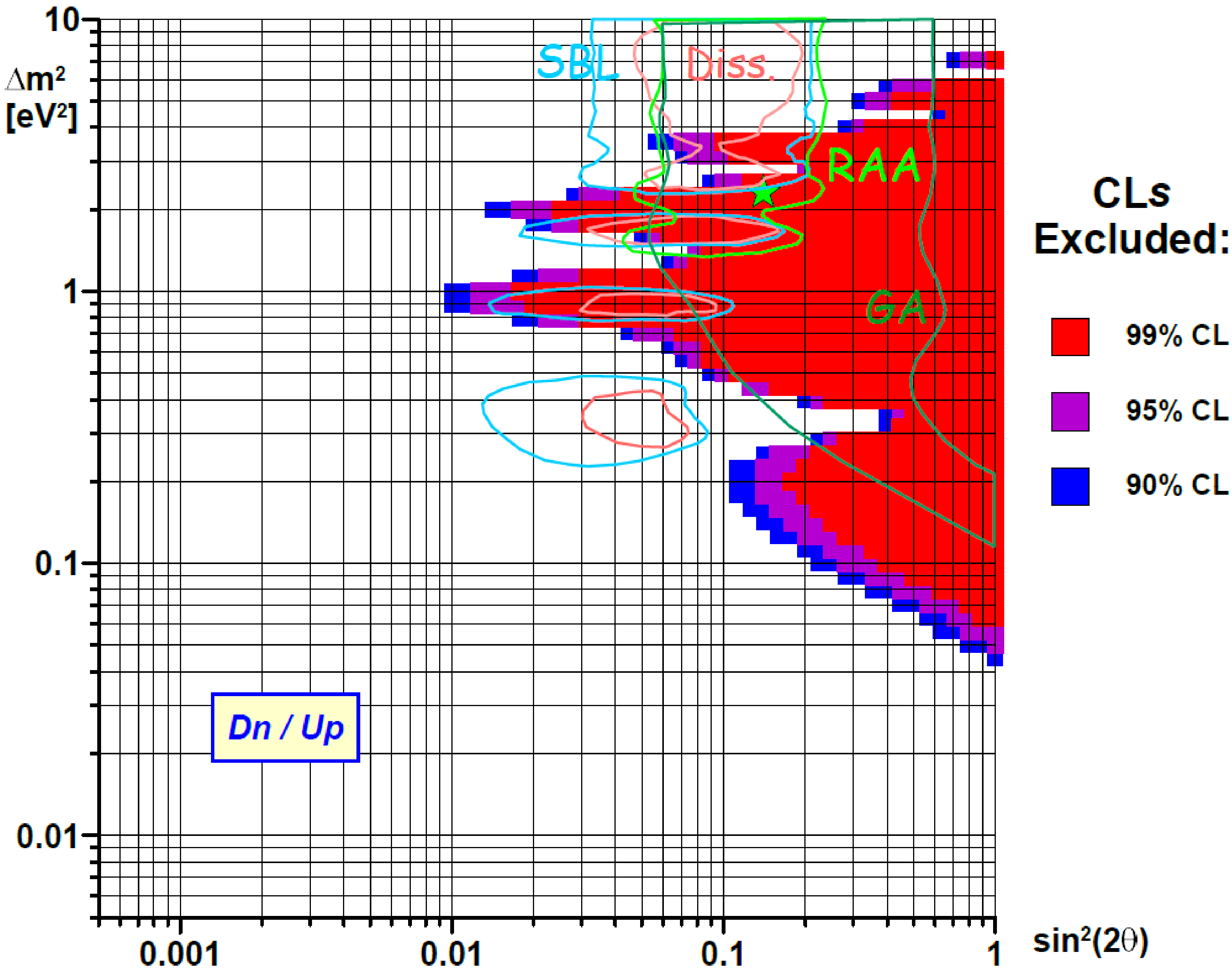
Spectra ratio: 3 months at the very end of campaign 4 to 3 months a month after campaign 5 start.

The first month at the start of campaign skipped because of samarium poisoning of the reactor.

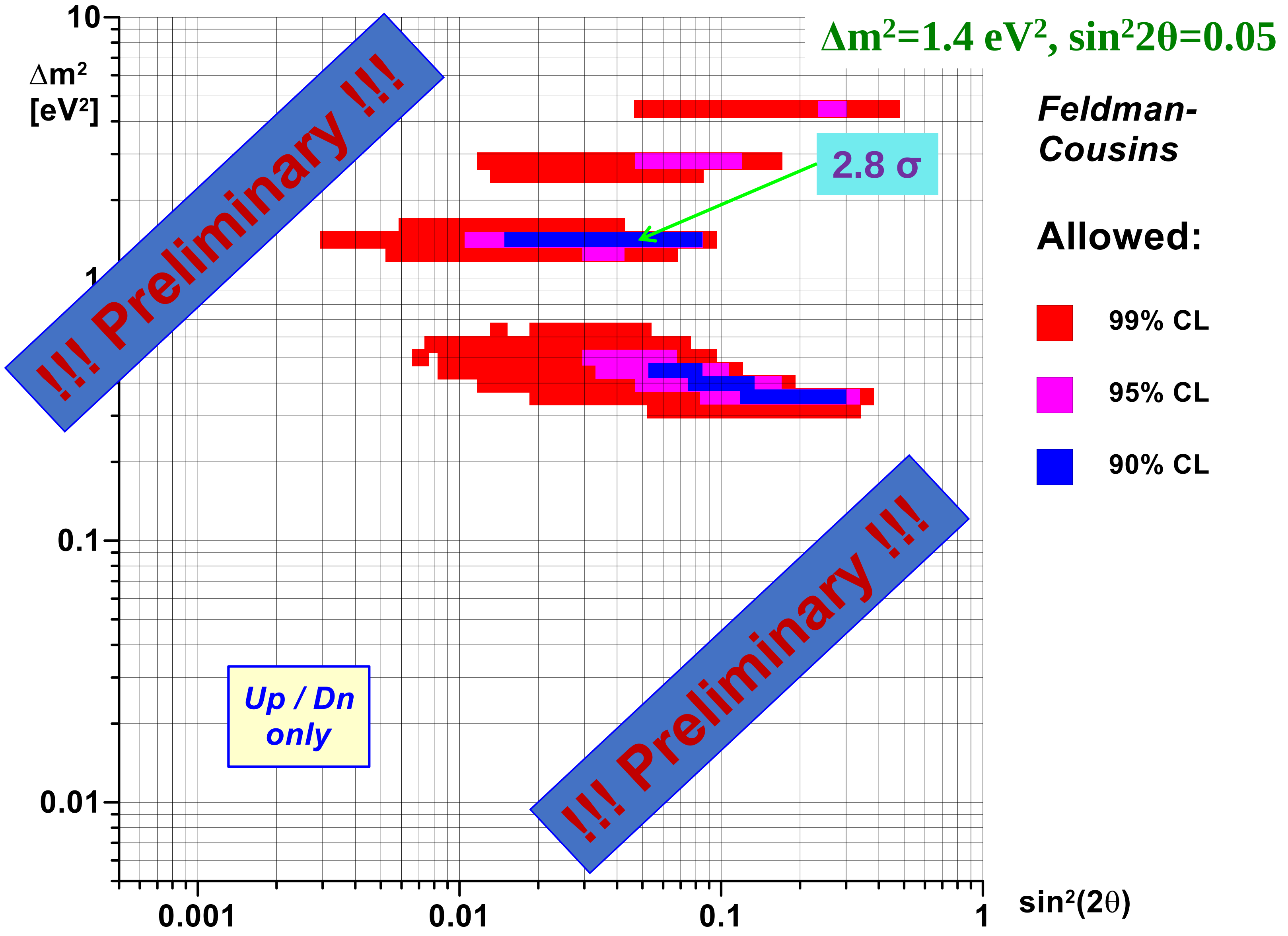
No contradiction to Monte Carlo simulations using Huber and Mueller spectra seen.



Exclusion region



Feldman-Cousins analysis of the best point



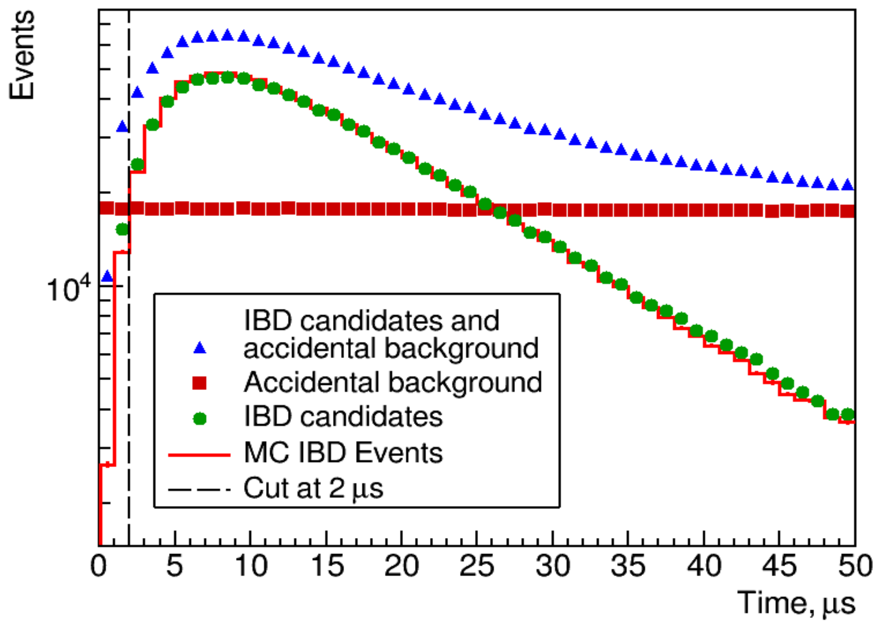
Summary

- DANSS has been taking data since Apr 2016 (data available for analysis – since Oct 2016).
- 4910 IBD events/day are detected in the closest position
- Background: 133 μ-induced events/day (2.7% for Up pos.)
- Spectrum dependence on the fuel composition within the campaign is clearly visible and agrees with HM-prediction
- A large fraction of allowed sterile oscillation parameters region is excluded in a model-independent way. The RAA point (Δm^2=2.3 eV^2, $\sin^2(2\theta)$=0.14) is excluded at 5σ level.
- The best point at (Δm^2=1.4 eV^2, $\sin^2(2\theta)$=0.05) has 2.8σ significance.
- DANSS data taking and analyses: on-going

Spare slides

Trigger and events

- **Trigger = digital sum of PMT > 0.7 MeV or VETO**
  - Total trigger rate ≈ 1 kHz
  - Veto rate ≈ 400 Hz
  - True muon rate ≈ 180 Hz
  - Positron candidate rate ≈ 170 Hz
  - Neutron candidate rate ≈ 30 Hz
  - IBD rate ~ 0.1 Hz
- IBD event = two time separated triggers:
  - Positron track and annihilation
  - Neutron capture by gadolinium
- SiPM noise cut:
  - Time window ± 15 ns
  - Single pixel hits require PMT confirmation



Building Pairs

Positron candidate: > 1 MeV in continuous ionization cluster (PMT+SiPM)

Neutron candidate: > 3.5 MeV total energy (PMT+SiPM), SiPM multiplicity >3

Search positron 50 μs backwards from neutron

Significant background by uncorrelated triggers. Subtract accidental background events: search for a positron candidate where it can not be present – 50 μs intervals 5, 10, 15 ms etc. away from neutron candidate. Use 16 non-overlapping intervals to reduce statistical error. All physics distributions = events - accidental events/16

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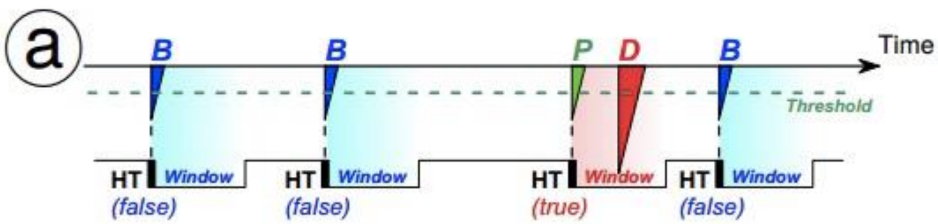

-Trigger 2: $\Sigma E_{PMT} > 0.7$MeV, read 2590 waveforms (125 MS/s) from 50 PMT, 2500 MPPC and 40 μ-veto detectors, look for correlated pairs offline

-Trigger veto

Compensation of the fuel evolution