Recent results from the DANSS experiment

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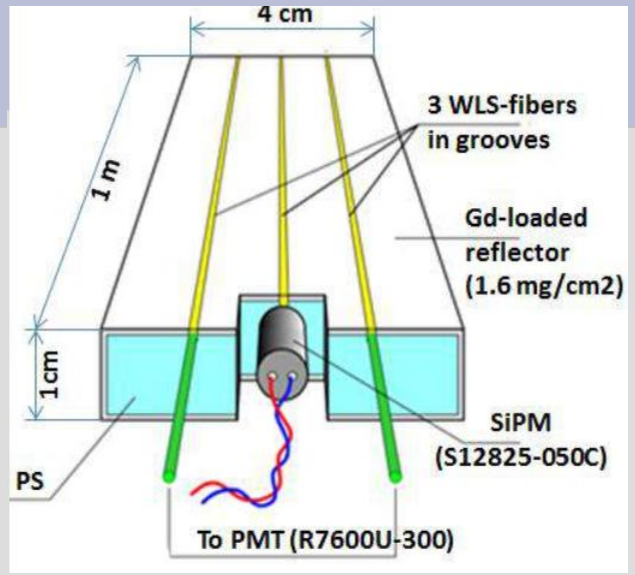
for the DANSS collaboration

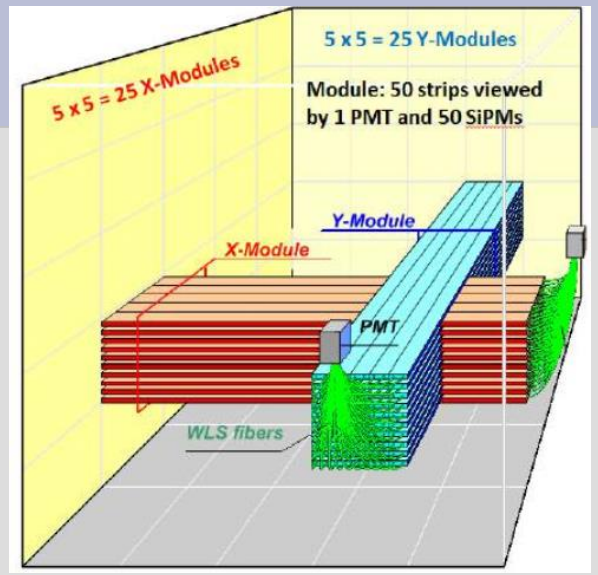
25/06/2020

The DANSS design

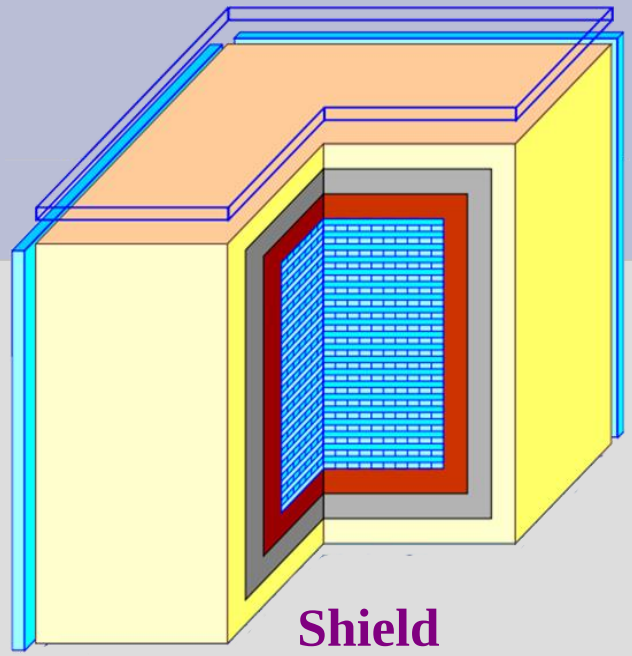
Strip



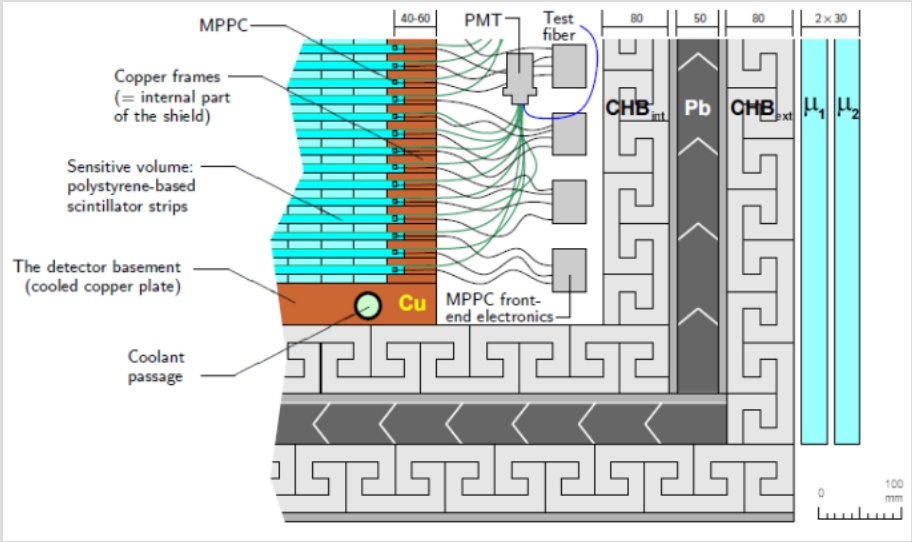
Module



Detector

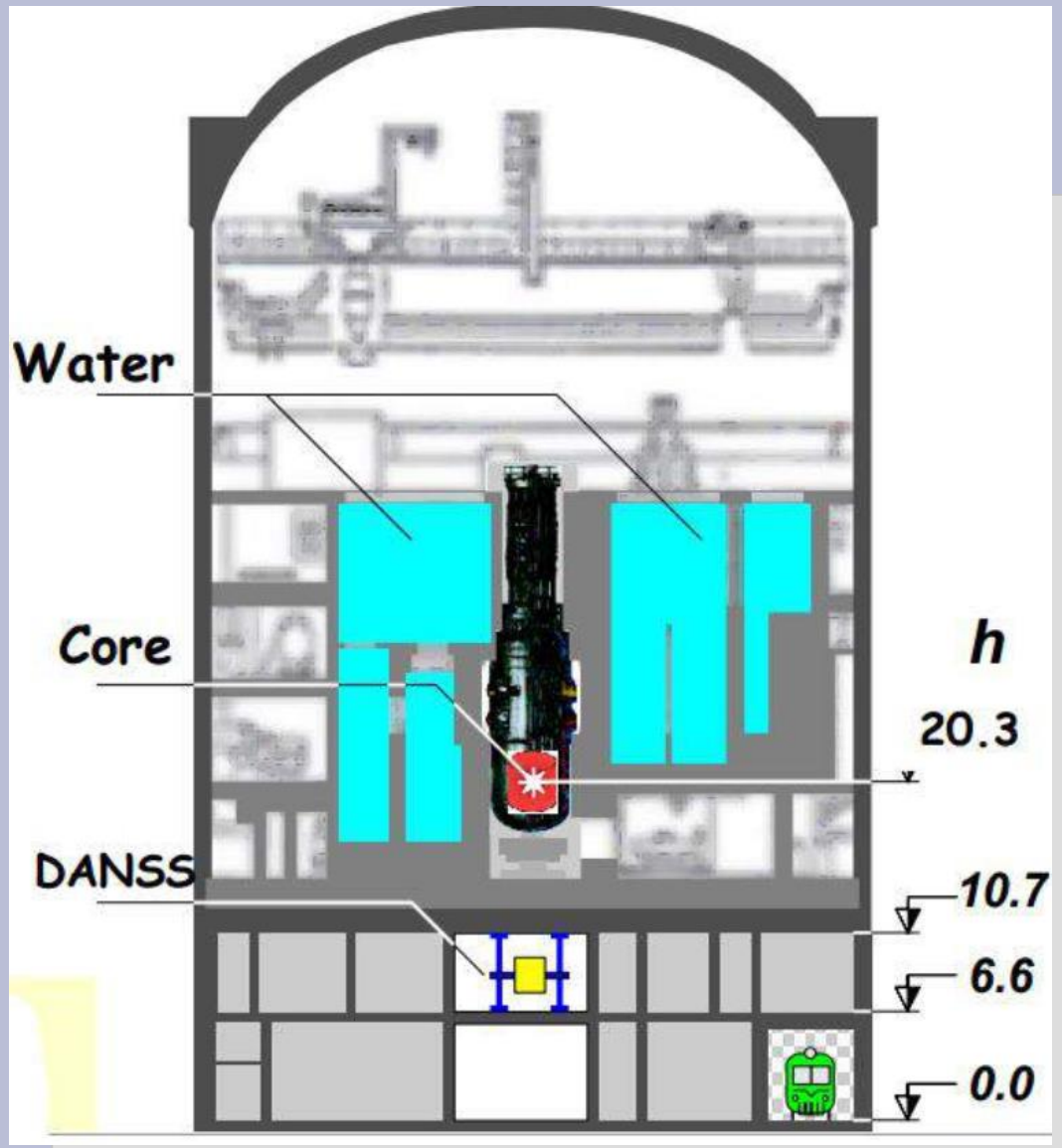


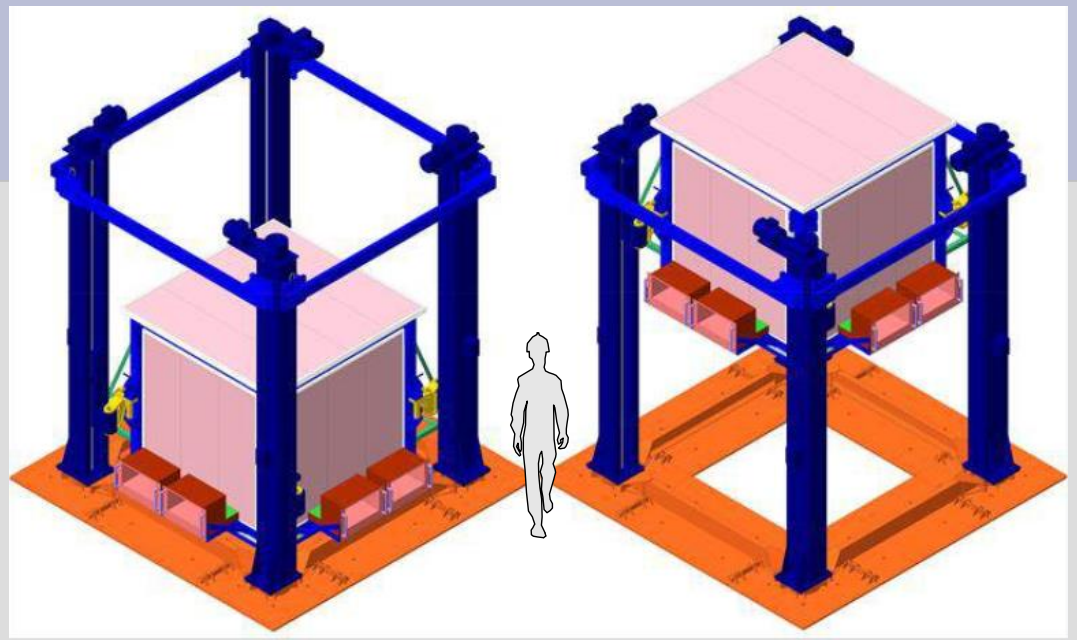
Shield



- Cubic meter highly segmented neutrino spectrometer made of 2500 PS strips viewed by 2500 SiPMs & 50 PMTs.
- Multilayer passive shielding: Cu/CHB/Pb/CHB=5/8/5/8 cm
- Active muon veto made of 2 x 3 cm PS plates from all sides except bottom.

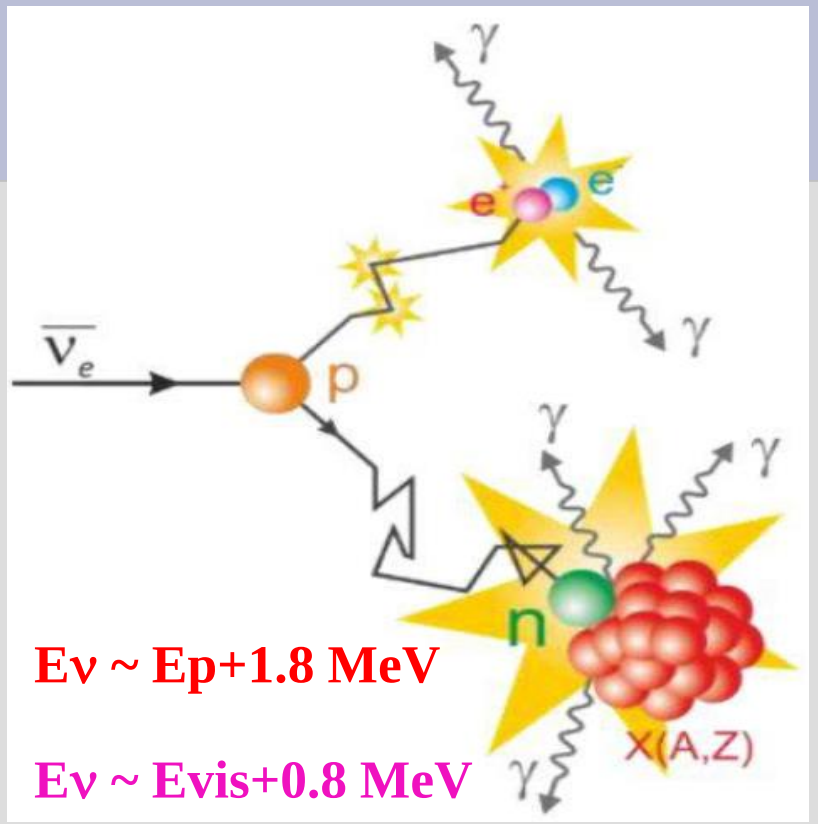
The location and movable platform

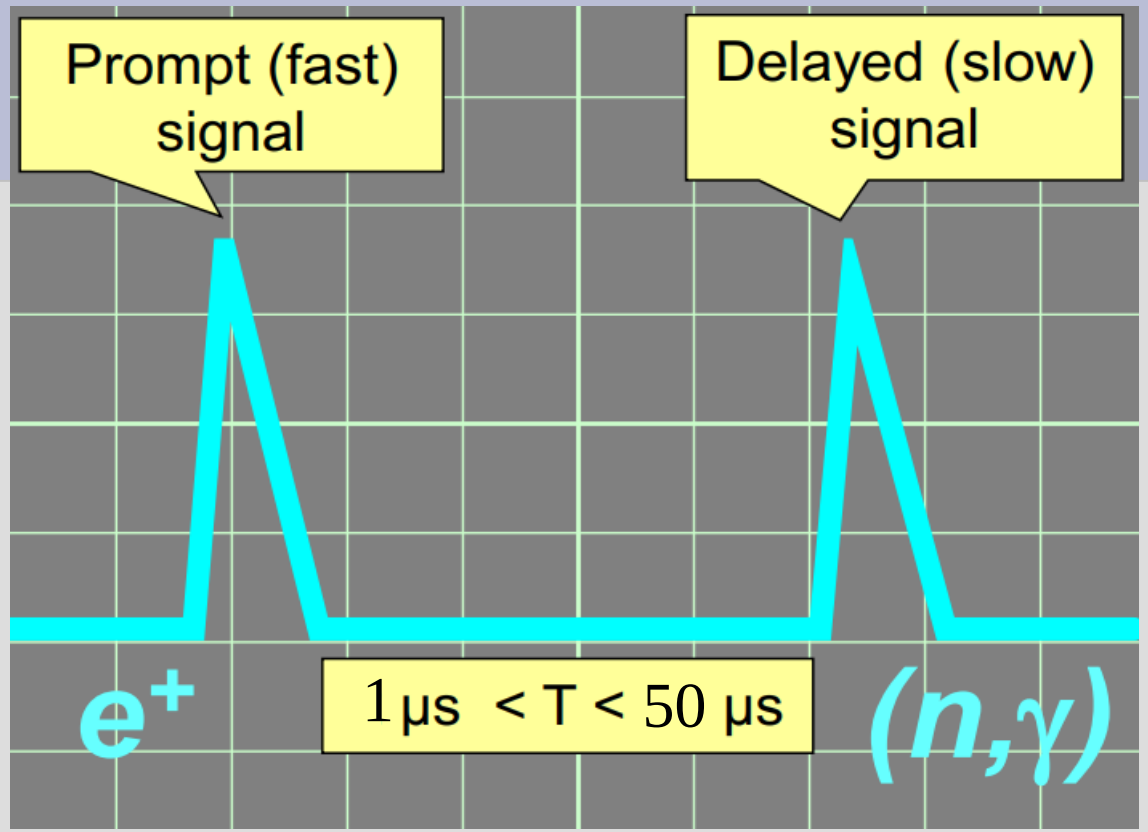




- The DANSS is located at Kalininskaya NPP (KNPP) under 3 GW WWER-1000 reactor (H=3.6 m, ∅ =3.1 m), which provides ~ 50 m.w.e. (6-fold μ reduction and no cosmic n).
- The detector is built on a movable platform. Data are taken at 3 distances 10.9 m (Up), 11.9 m (Middle), and 12.9 m (Down) from the reactor (center to center), changed sequentially 3 times per week.

IBD signal pattern & basic cuts





Main cuts:

- **Prompt signal (E > 0.5 MeV)**
- **Delayed signal (E>2-4.5 MeV)**
- **Time between signals is in [1, 50] μs**
- **No muons before prompt signal in 90 μs**

Additional cuts:

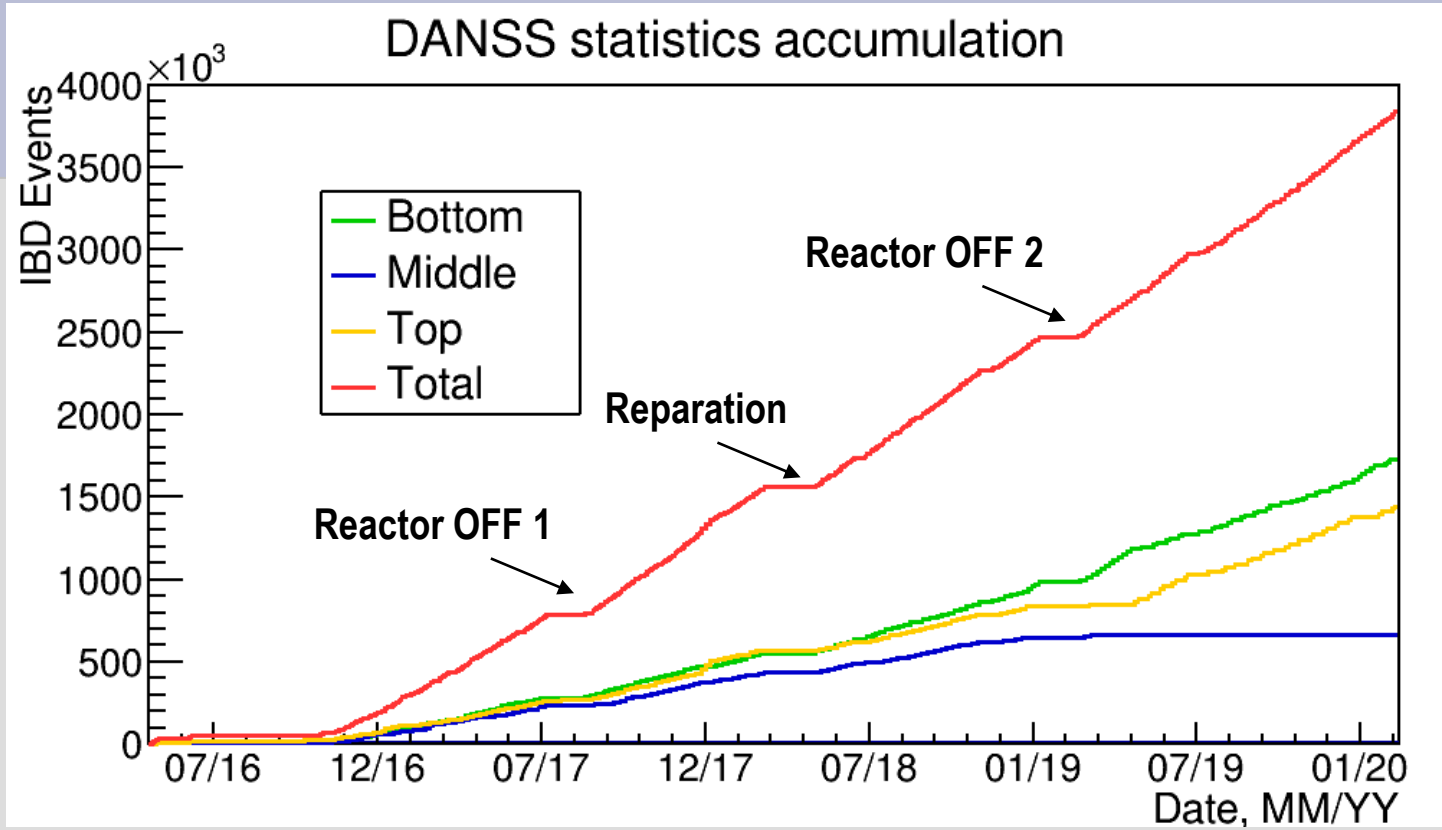
- **Spatial cut on distance between fast and slow signal vertices**
- **Hit multiplicities for both signals**
- **Positron clustering pattern cuts**

Improvements in analysis*

- **Using STEREO datasets made on base of FIFRELIN library (arXiv: 1905.11967) to simulate neutron capture in Gd: essential improvement of neutron signal.**
- **Improved strip surface description corrected on real measurements.**
- **Corrected (on real data) signal models of SiPM (17.7 p.e./MeV and 0.37 X-talks) & PMT (15.9 p.e./MeV)**
- **Positron energy dependent distance and neutron energy cuts. This allowed to increase the total number of reconstructed IBD-events, especially in the high-energy part of spectra, more sensitive to the effect searched.**
- **Improvement of ^{12}B energy calibration (reconstruction with higher statistics) used as main calibration for the DANSS spectrometer.**
- **Reconstruction of Michel electrons following decay of muons stopped at DANSS**
- **Relative Rate + Shape analysis was implemented.**
- **More detailed study of systematics.**

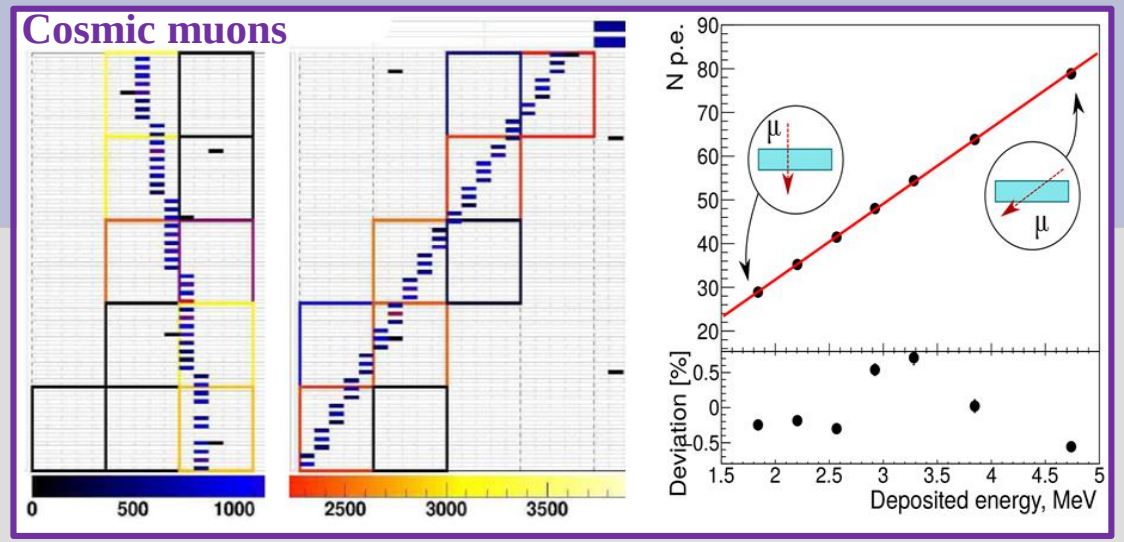
***) in comparison with our previous presentations in 2019**

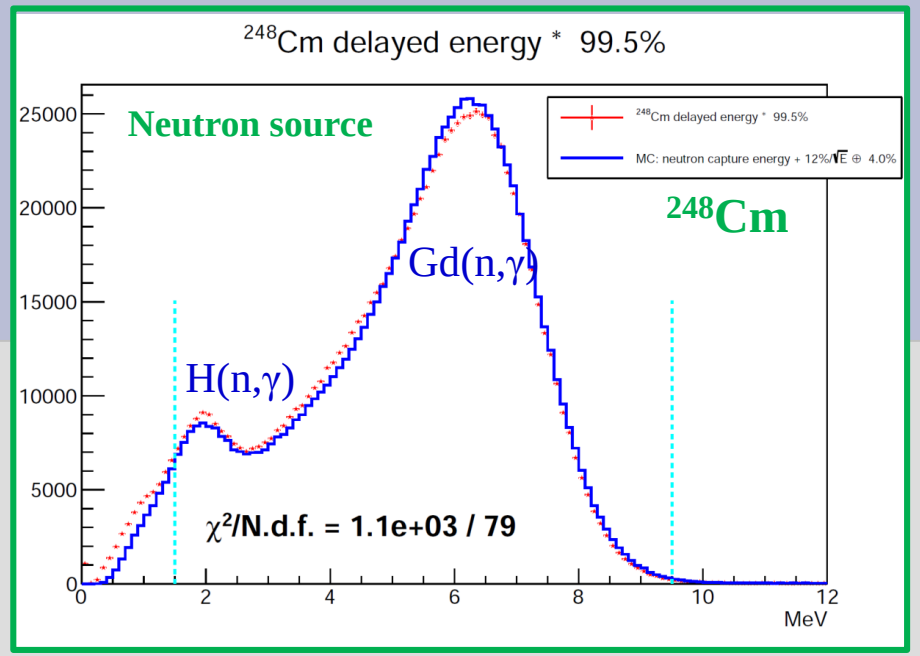
Statistics accumulated

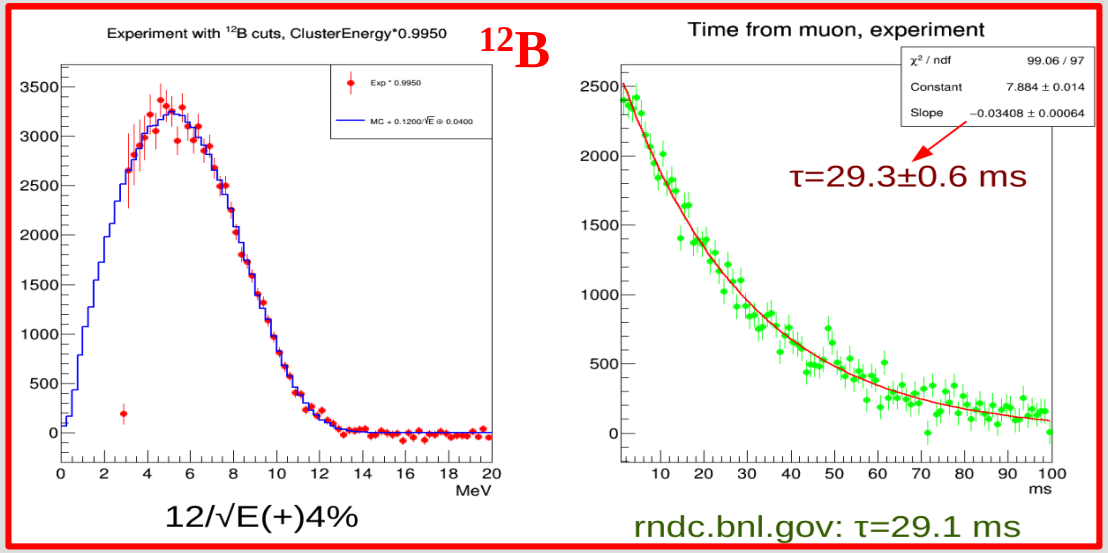


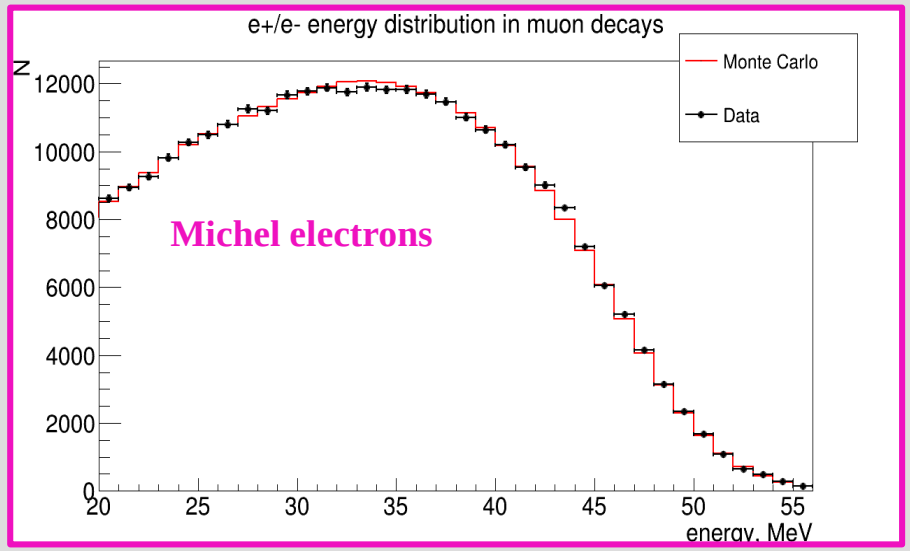
- **Total statistics accumulated is close to 4M IBD-events, including 1.4M/1.5M events in Top/Bottom position**
- **Sensitivity of experiment has been improved by a factor of ~ 1.5-2 in 1 eV region.**
- **Energy resolution for calibration sources is still worse than in MC and additional smearing of 12%/√E ⊕ 4% has been added to MC.**

Calibrations



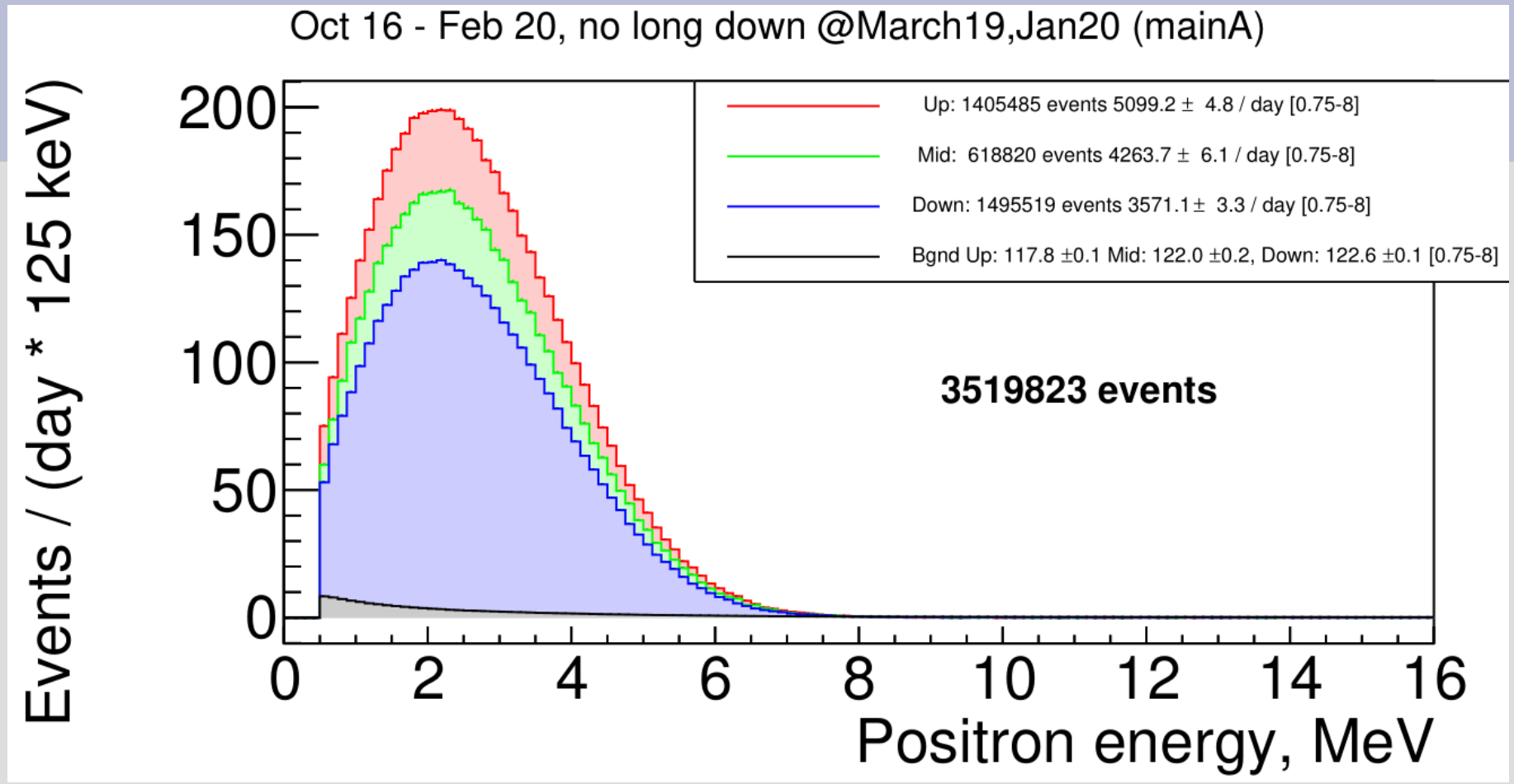






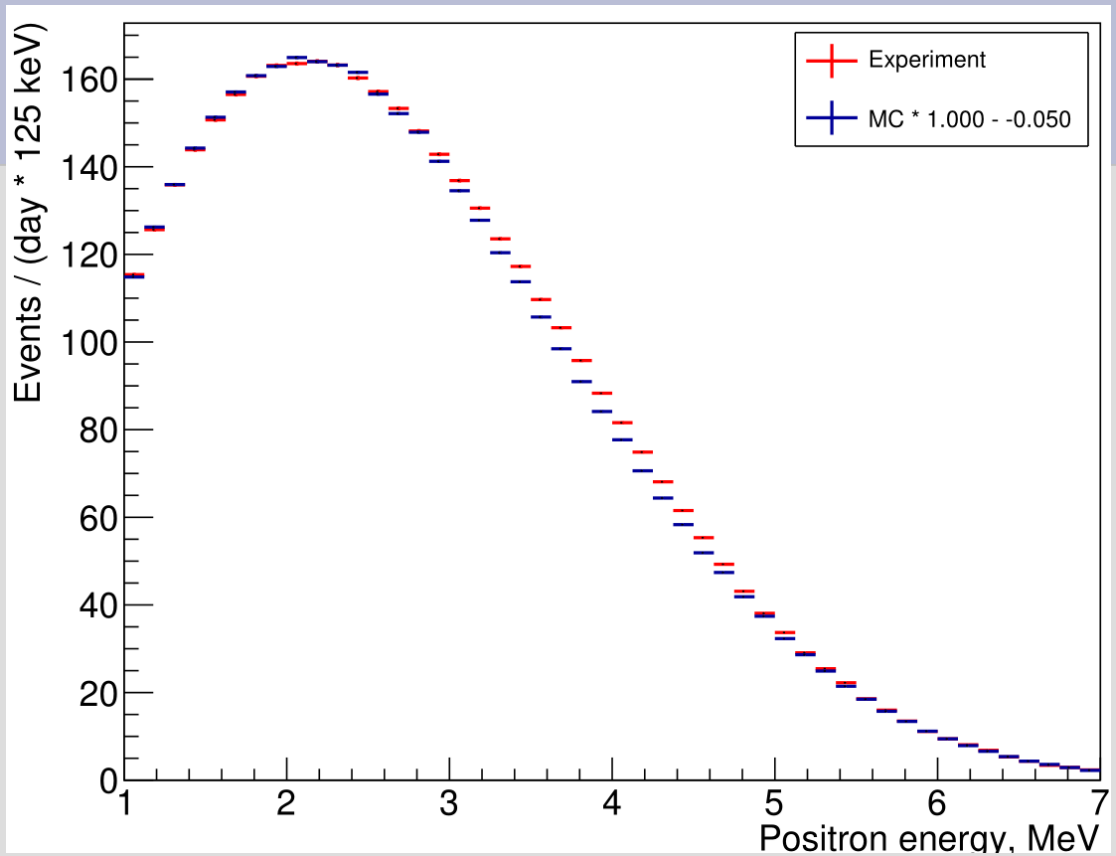
- **Energy scale has been fixed using β-spectrum of ^{12}B, which is similar to positron signal**
- **Systematic error on E scale of +/-2% (will be reduced soon) has added due to source response uncertainties**

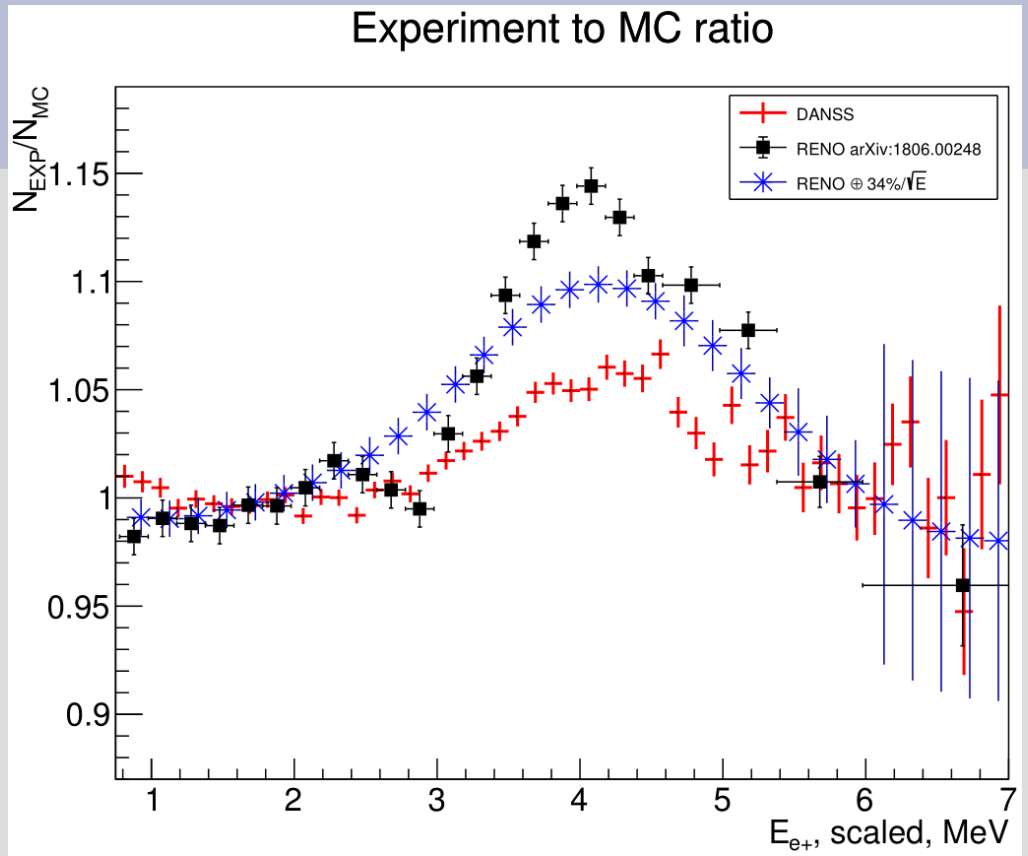
Positron spectrum of IBD-signal



- **Pure positron spectra @ 3 positions (no annihilation photons)**
- **~5000 eve/d (~4000 eve/d in previous analysis) in detector fiducial volume (78% of full volume) @ 'Up' position (closest to the reactor).**

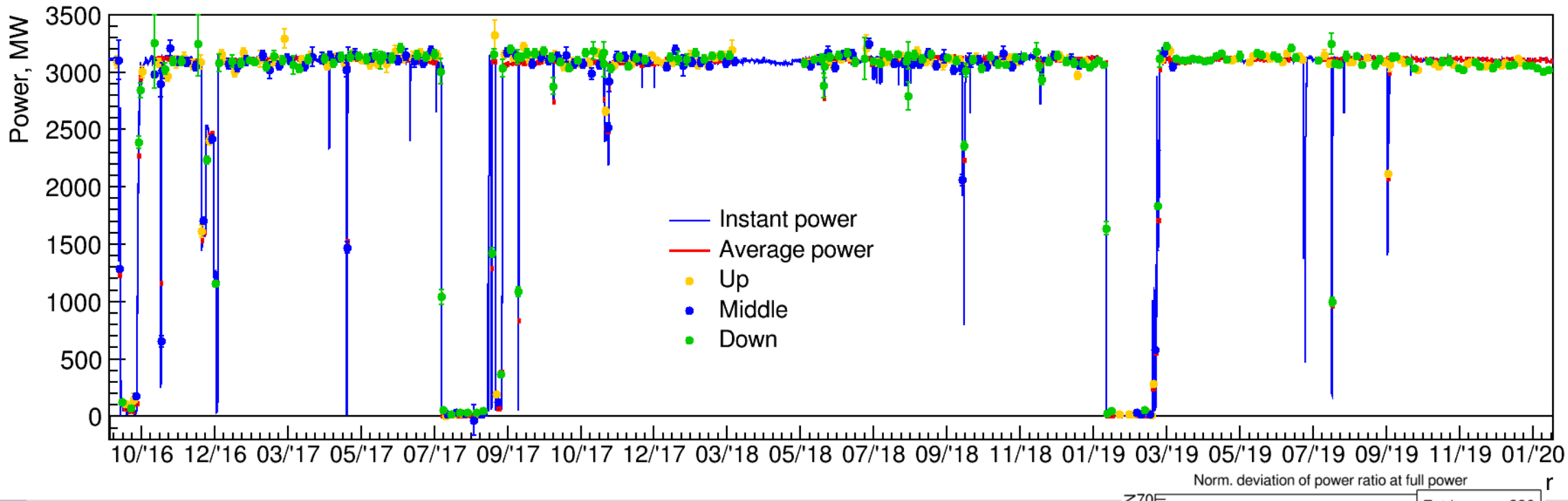
Positron spectrum: experiment vs. theory

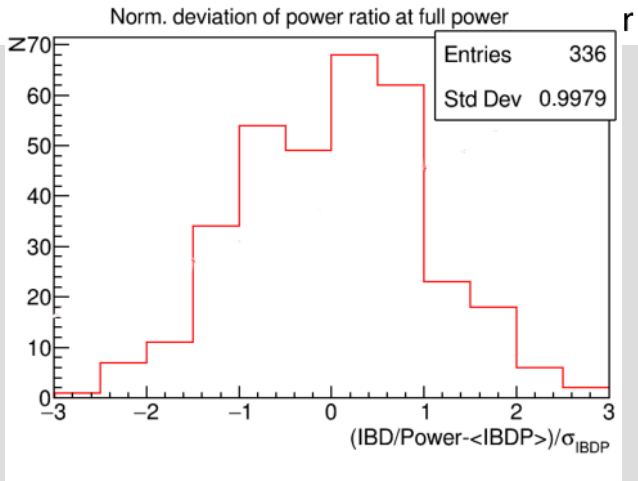




- **In order to reach best agreement with H-M model our MC spectrum was shifted on +50 keV w.r.t. experimental data. The nature of this shift is still under investigation.**
- **With such a shift we see a bump in e+ spectrum similar to other experiments.**
- **However, we can not claim its existence yet because of high sensitivity of the shape on E scale and shift.**

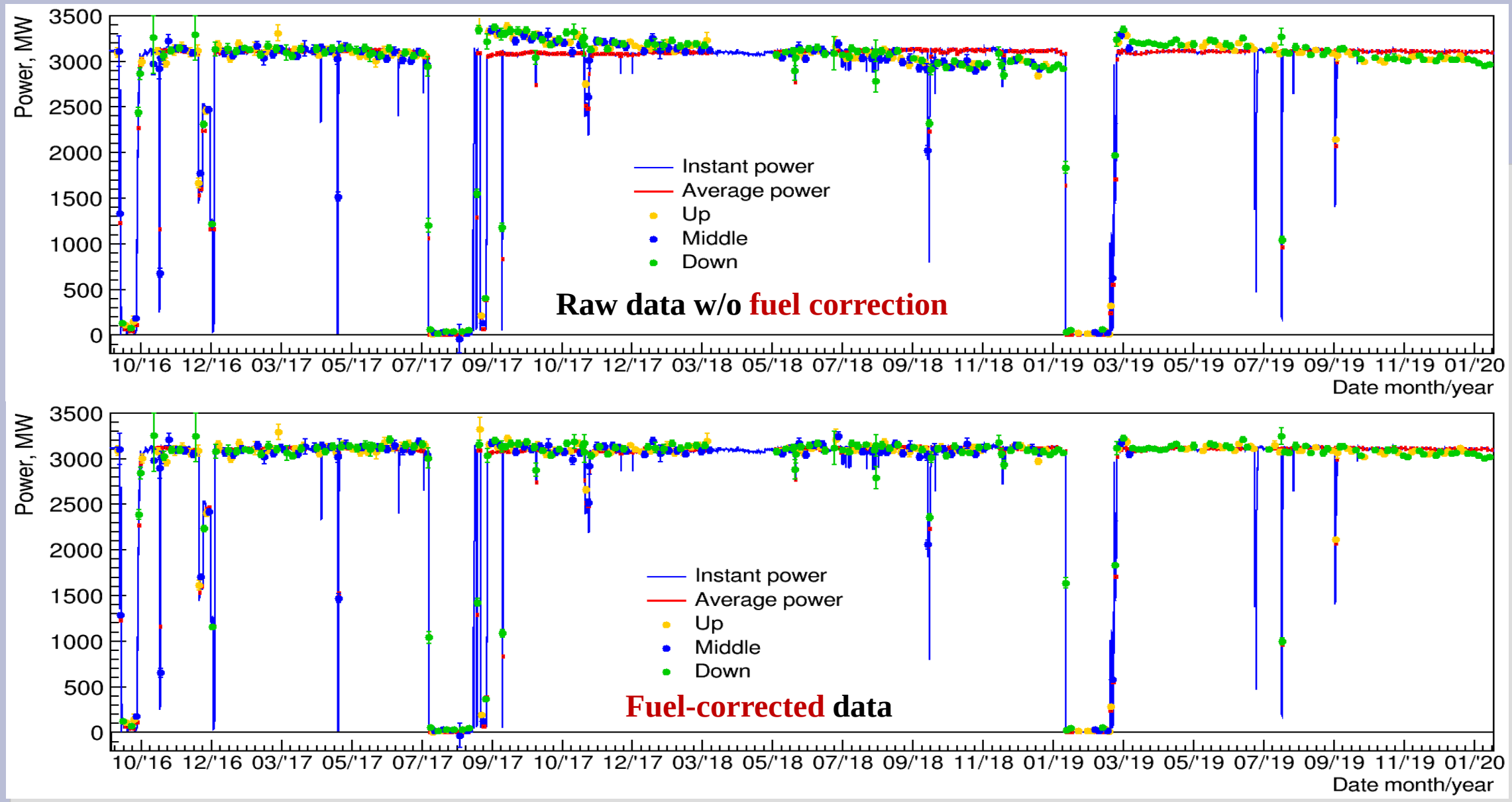
Reactor power monitoring



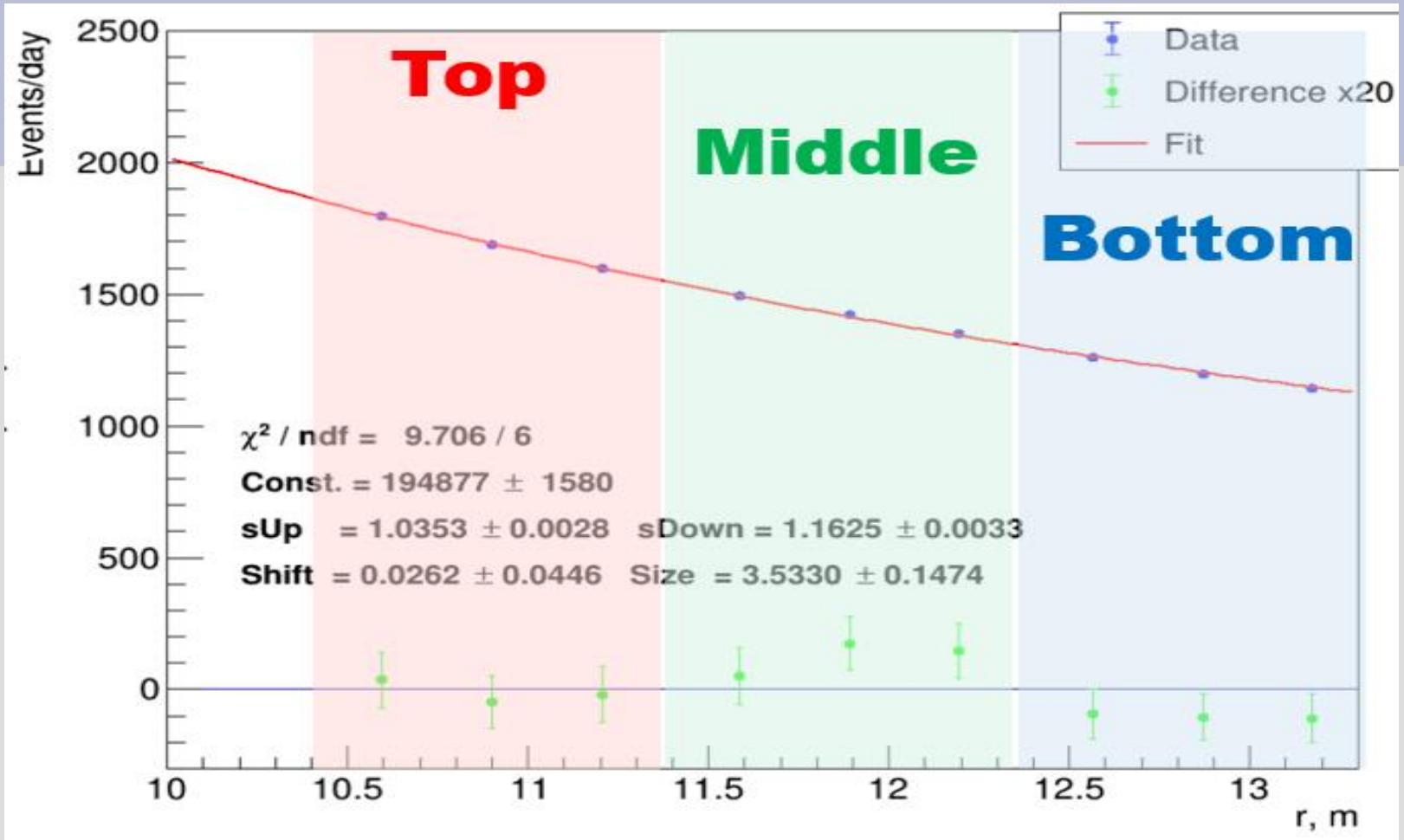


- **DANSS points after all corrections (all backgrounds including adjacent reactor fluxes (0.6%), fuel composition, etc.).**
- **Reactor power is measured by the DANSS with neutrino flux with 1.5% accuracy in 2 days during 3+ years, no evidence for systematic effects has been observed.**

Fuel sensitivity: Up – Middle – Down data

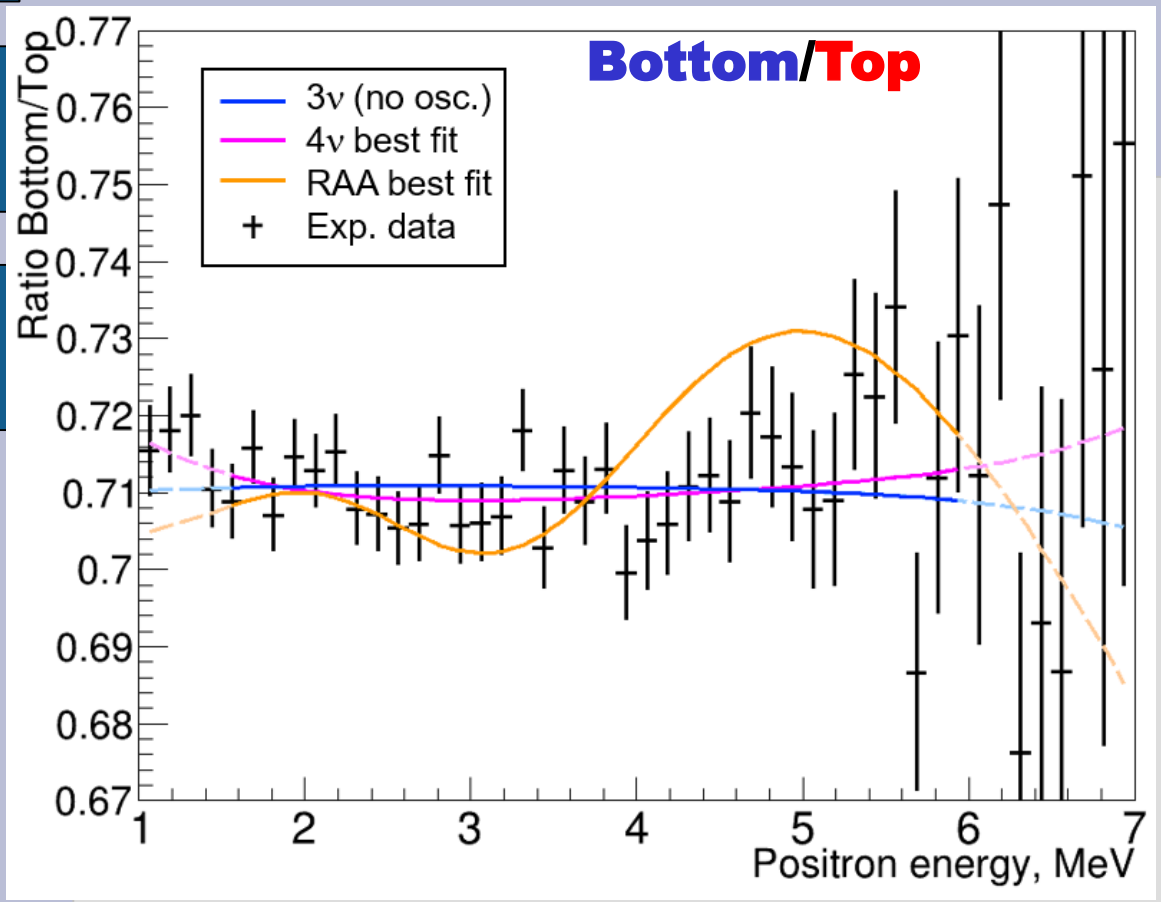


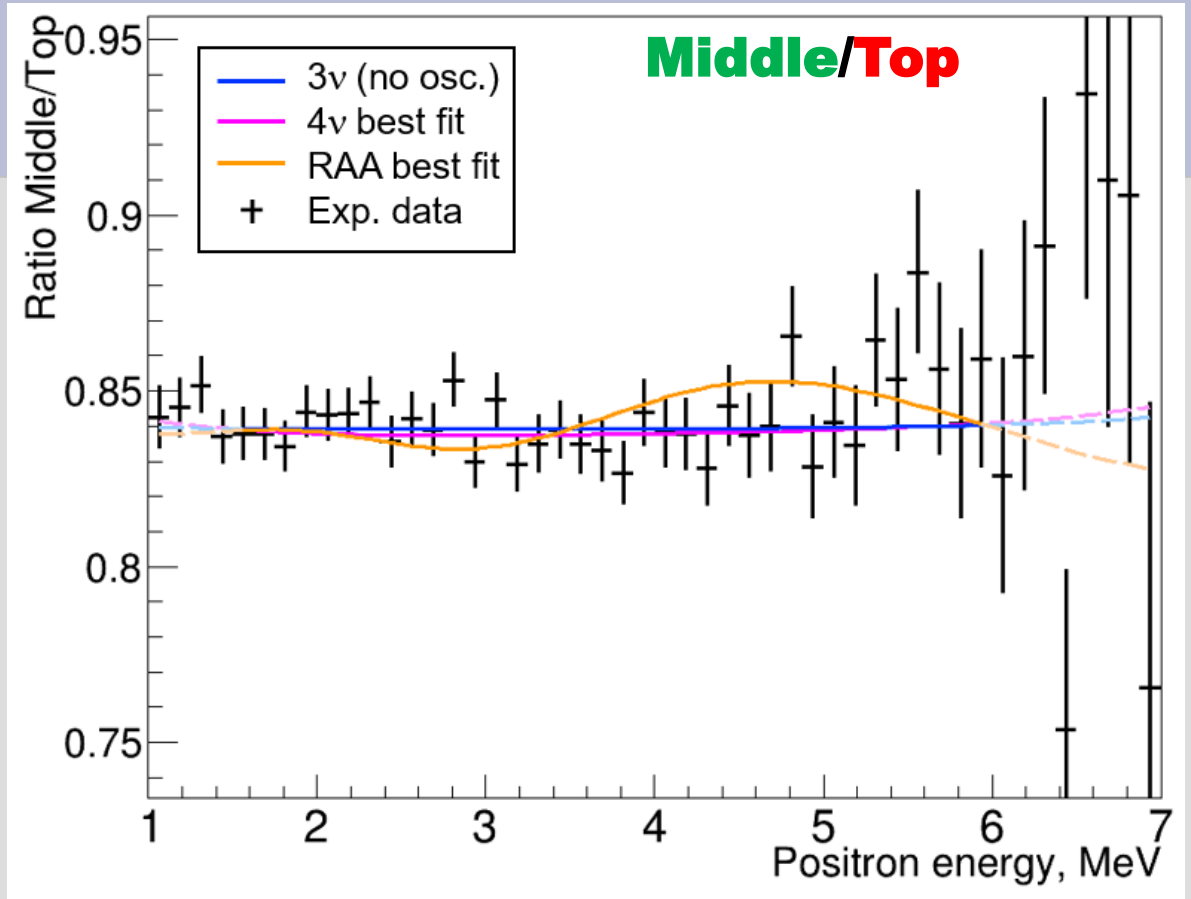
IBD total rate vs. effective distance



- **IBD intensity follows reasonably the $1 / L^2$ dependence.**
- **Detector was divided on 3 parts in each position.**

The DANSS: ratio of positron spectra

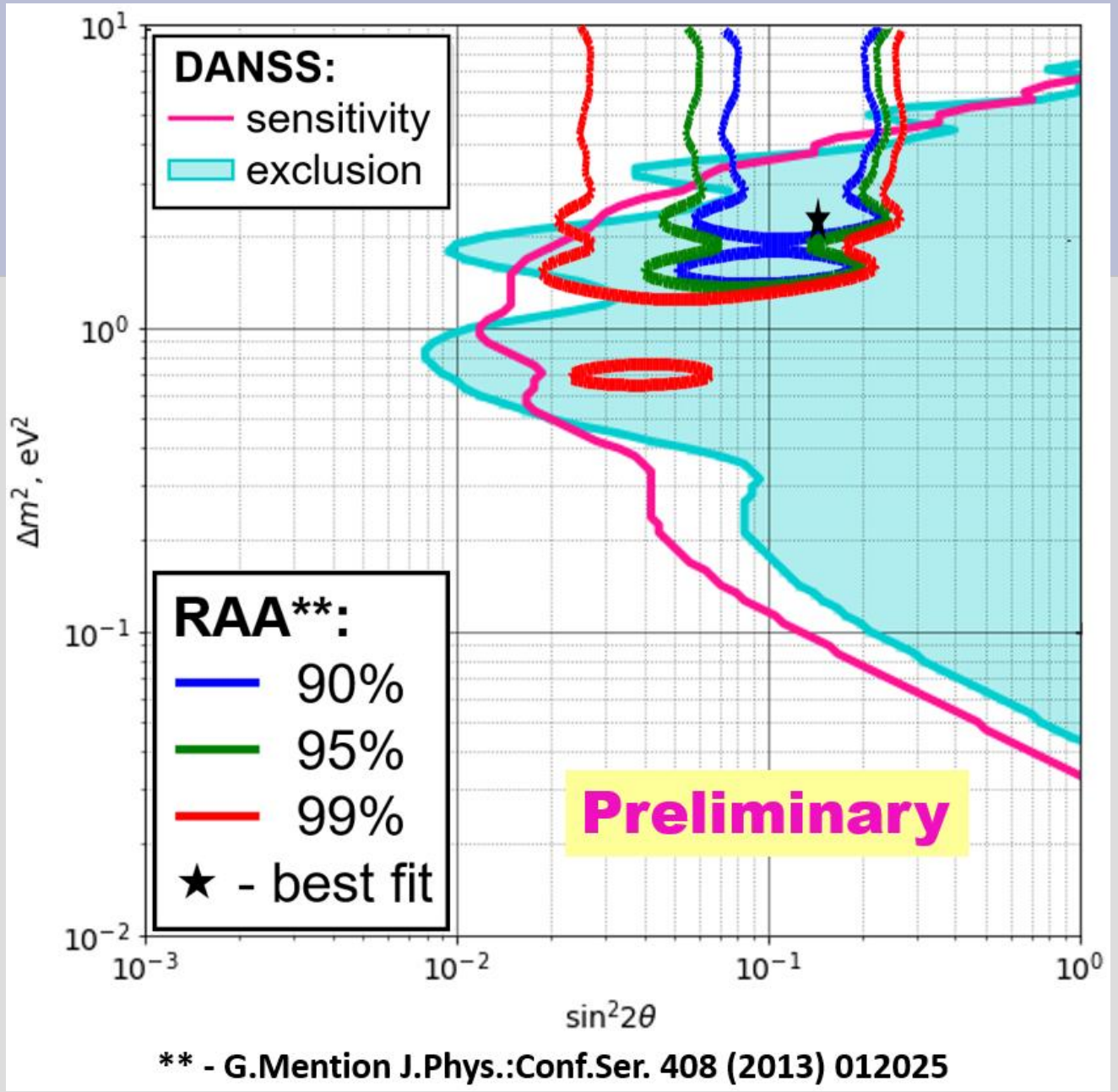




- **On the current statistics 2016-2020 (~3 million events in Bottom/Top) we see no indication of 4ν signal (ΔX^2=5.5 (< 1.5 σ) for 4ν hypothesis). RAA has been excluded with ΔX^2= 53.6 (>5 σ).**
- **Ratio Middle/Top was used only for cross-checks. Correlated and consistent with Bottom/Top**

The DANSS results

- Exclusion region was calculated using Gaussian CLs method (for e^+ in 1.5-6 MeV to be conservative), which is also more conservative than usual CI method.
- Systematics included:
  - Energy resolution +/-10%
  - Energy scale +/-2%
  - Cosmic background +/-25%
  - Fast neutron background +/-30%
  - Distance to reactor: +/-0.15%
  - Relative detector eff.: +/- 0.2%
- Systematics influence is small, results of our method are independent from shape of ν-spectrum and detector efficiency.
- New data allowed to extend excluded area of 4ν phase space in comparison with previous results shown in 2019.

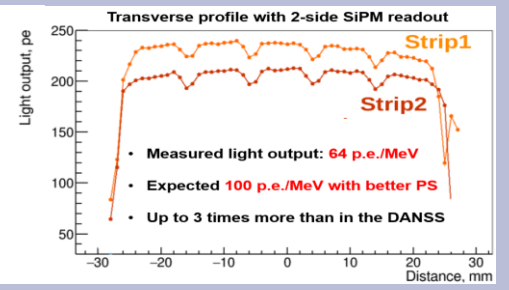


** - G.Mention J.Phys.:Conf.Ser. 408 (2013) 012025

The DANSS upgrade

Strip prototypes are testing on π-beam

Upgrade timescale: ~2 years.



Main goal: to reach resolution **15%/√E** w.r.t. current 34%/√E.

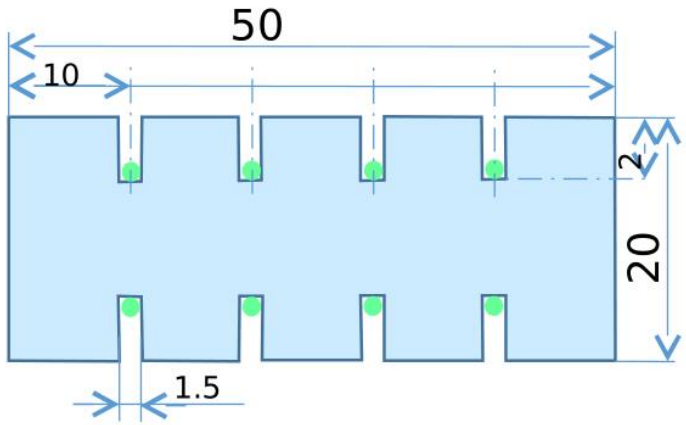
New geometry:

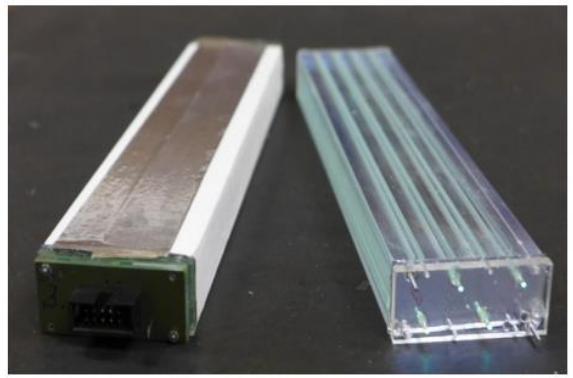
Strips: 2x5x120 cm with **2-side** SiPM readout

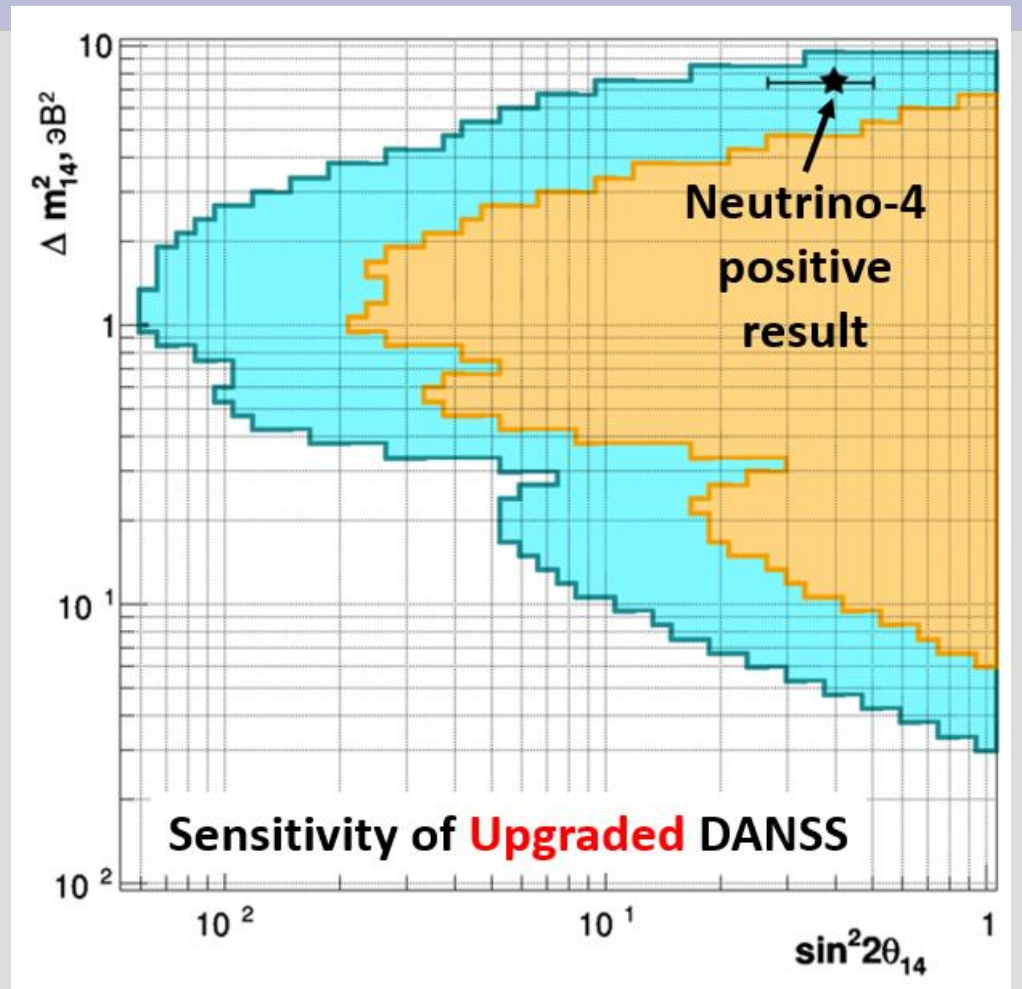
Structure: 60 layers x 24 strips: **1.7 m^3** setup used **the same shield and moving platform**.

Gd is in foils between layers.

Upgraded strip:





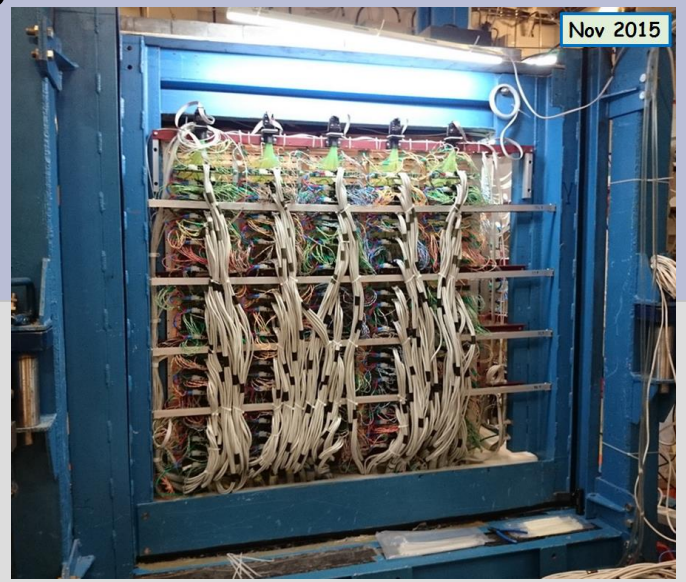


Summary

- **DANSS is in operation since April 2016 with regular (physics) data taking since October 2016 at a rate of ~5000 events per day with cosmic background ~ 1.7%.**
- **Reactor power was measured using anti-ν rate with statistical error of ~1.5% in two days during 3+ years of operation. Sensitivity to fuel composition was clearly demonstrated in several reactor campaigns.**
- **With current data set 2016-2020 (~ 3M events) we have no significant sign of sterile ν oscillations.**
- **Preliminary DANSS analysis excludes a large fraction of available parameter space for sterile neutrino using only ratio of e^+ spectra at two distances (and relative rates). This method is independent from shape of ν-spectrum and detector efficiency (+ small systematics influence).**
- **Future plans: further improvements of MC & calibrations. Upgraded DANSS (in plan) will cover bigger phase space and will check the positive claim of Neutrino-4 experiment.**

Backup slides

Detector Assembly

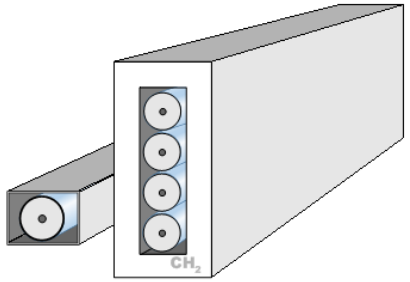


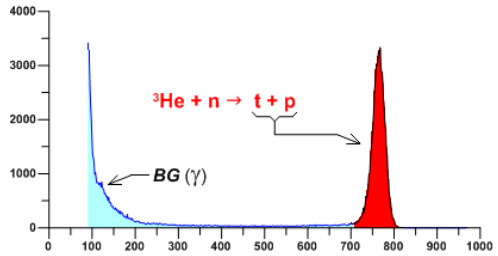
Background monitoring

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

  no (ON – OFF) visible difference

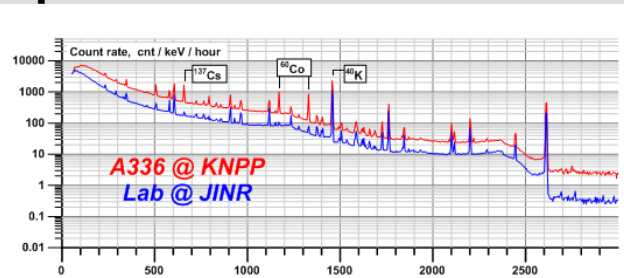
- **Permanent monitoring of neutron flux with three ^{3}He neutron counters: 1 inside + 2 outside the shield**

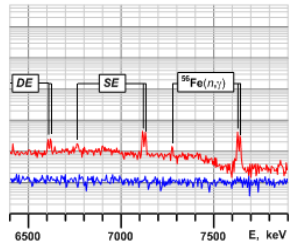


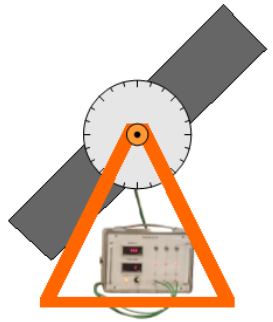


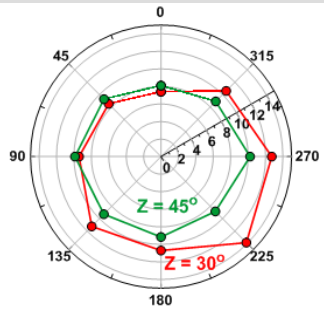
Φn =	0.57	outside (OFF)
Φn =	300.4	outside (ON)
Φn =	0.03	inside (OFF)
Φn =	0.04	inside (ON)
Φn =	6.0	en plein air

- **Episodic measurements with HPGe and "MuMeter"**

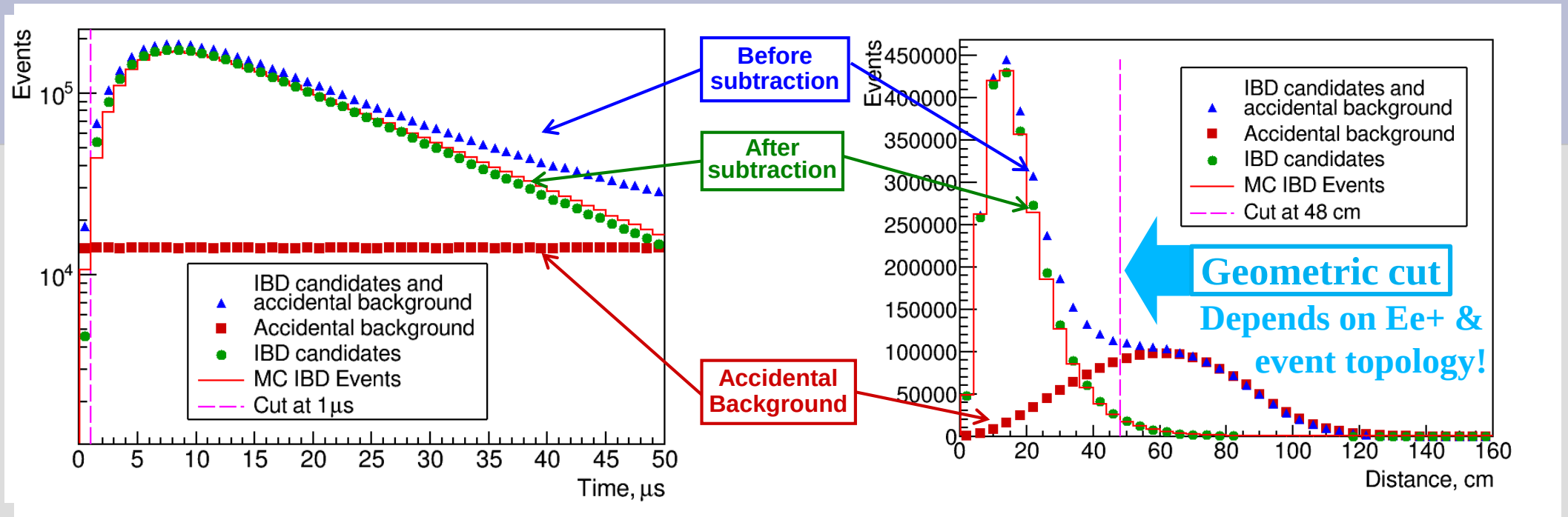






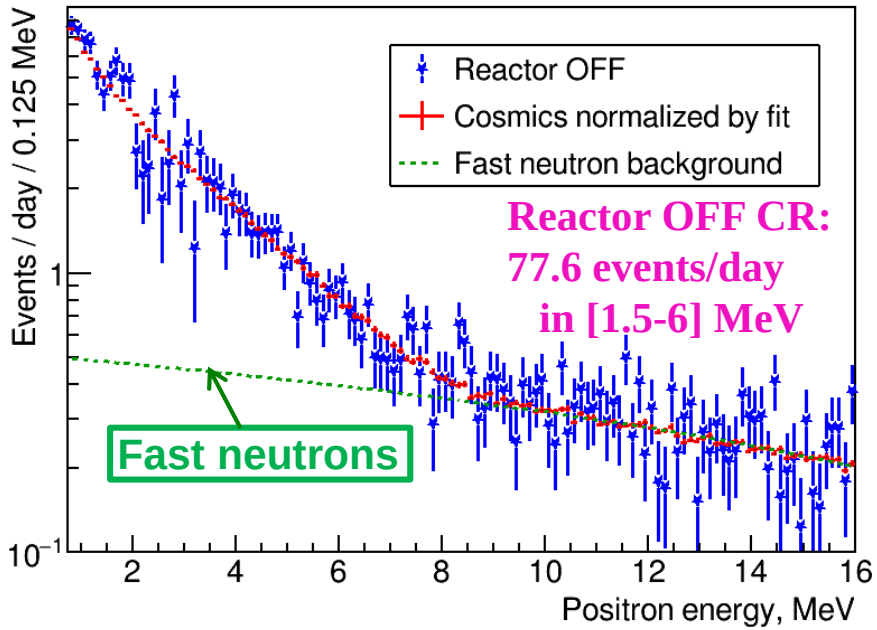


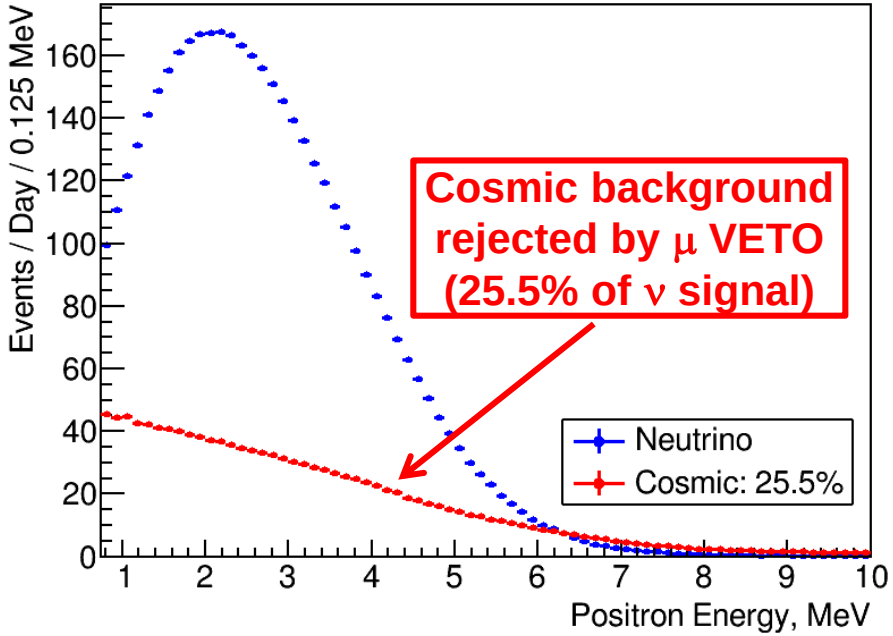
Accidental coincidence background



- **Accidental coincidence of 2 uncorrelated signals (e+-like and neutron-like) in a IBD window [1-50] μs → accidental coincidence background (ACB)**
- **ACB spectrum is constructed directly from data applying the same physics cuts as for IBD signal except coincidence time taken outside IBD time window [1-50] μs in numerous non-overlapping intervals (large statistics is essential to decrease statistical errors of subtraction).**
- **ACB rate is 17.6% of IBD rate (up detector position in [1-50] μs).**
- **Selection of cuts (e.g. geometric) to reduce ACB ⇒ smaller statistical errors**

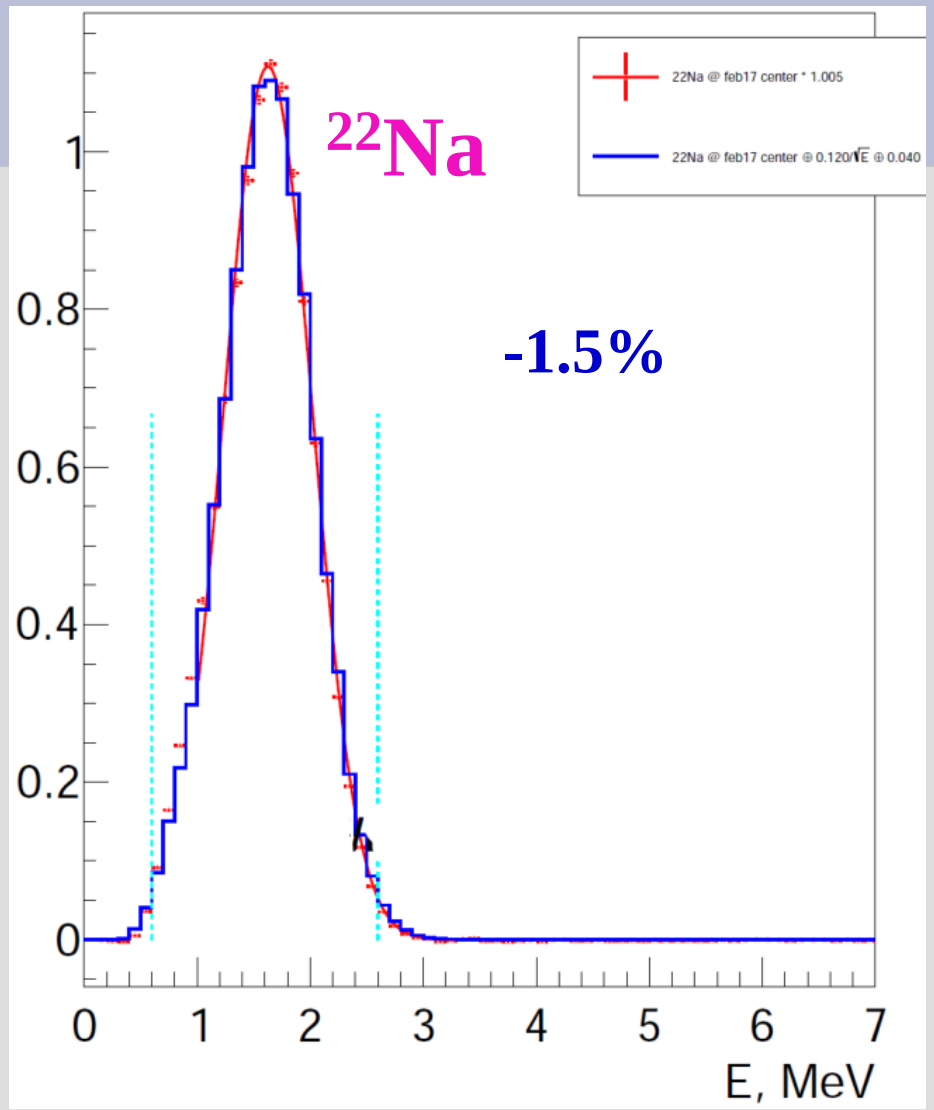
Subtraction of residual backgrounds

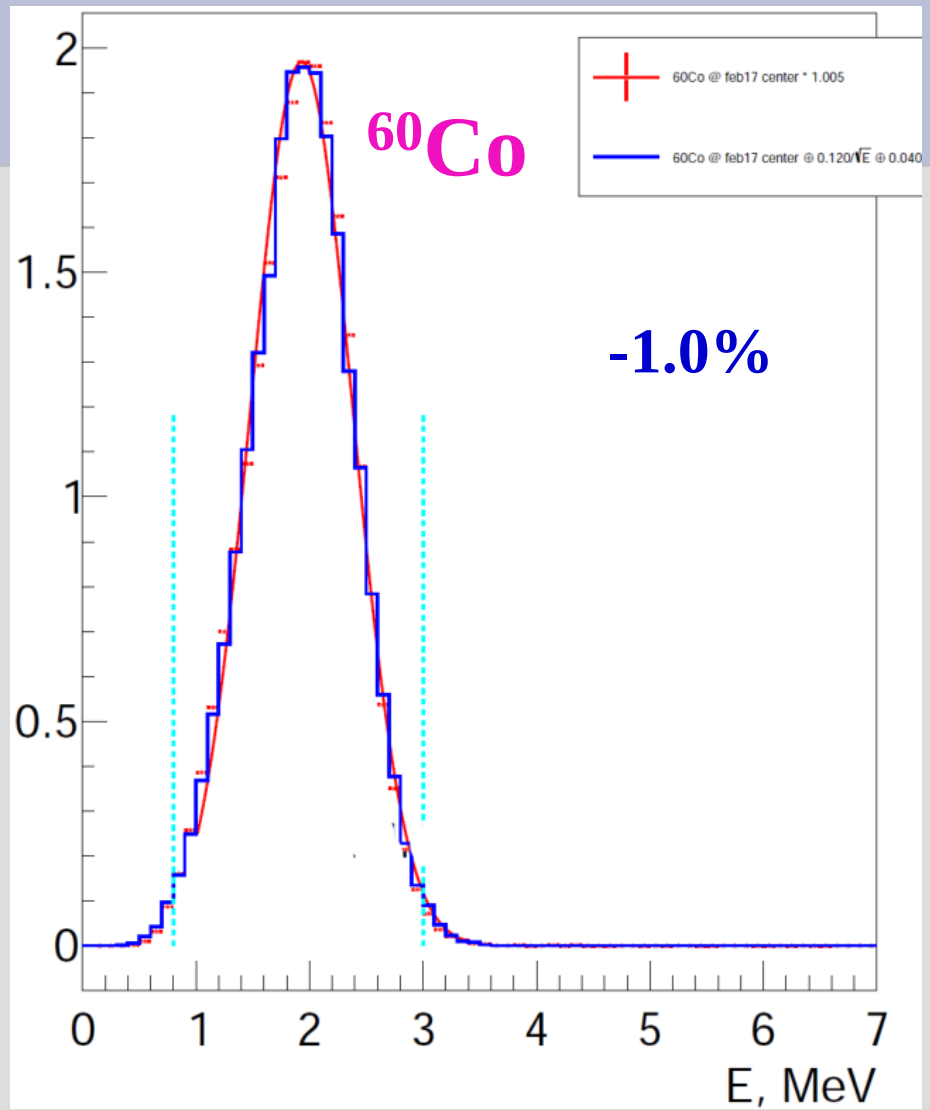




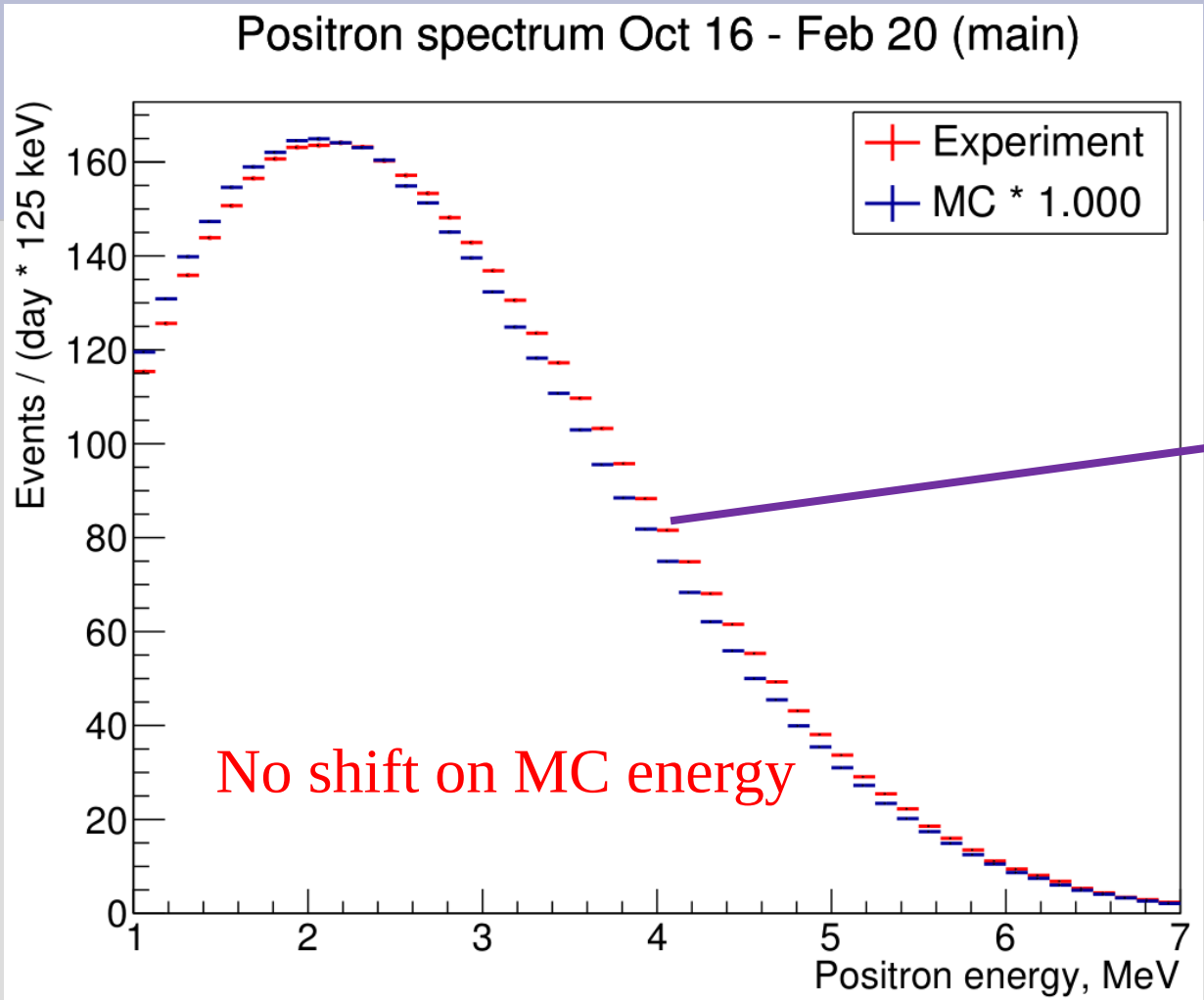
- **Fast neutrons: linearly extrapolate from high energy region and subtract separately from positron and visible cosmic spectra, CR (fast neutron) = 15.78 events/day (in 1.5-6 MeV range)**
- **Visible cosmic background (CB) has been directly rejected by VETO, it is 25.5% of neutrino signal (for up position in [1.5-6 MeV] range)**
- **Additional CB presents in the IBD-signal due to VETO inefficiency, which was found to be ~5% from reactor OFF spectra.**
- **Not vetoed CB fraction (due to VETO inefficiency) at level of ~1.3% (=5%*25.5%) of IBD-signal has been subtracted from IBD signal (positron spectrum).**
- **Final anti-neutrino spectrum (Ee^+ + 1.8 MeV) has no background!**

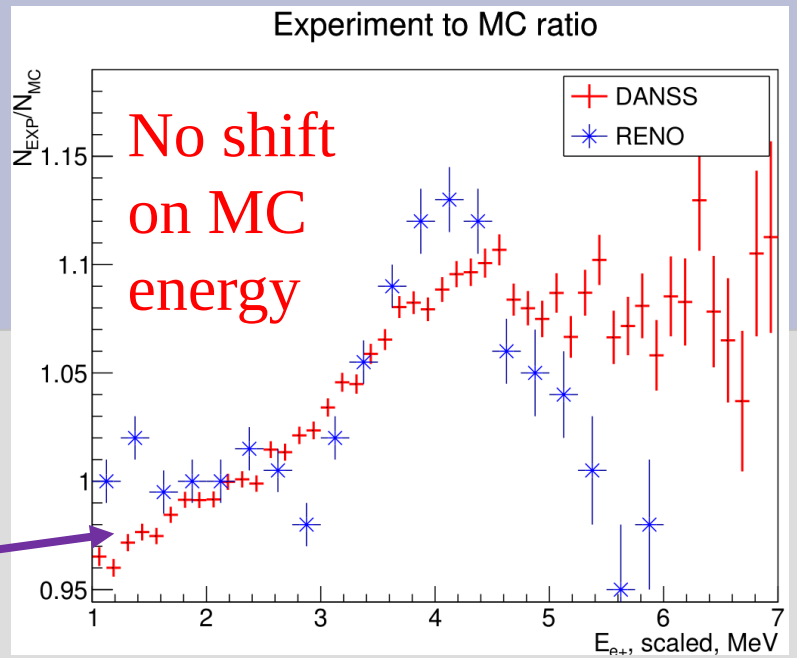
Calibrations: radioactive sources

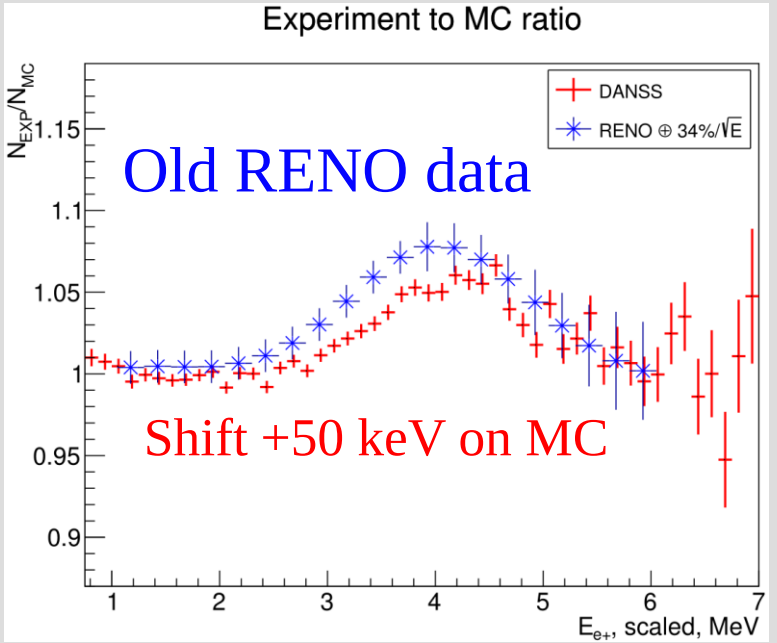




Positron spectrum: exp vs. theor

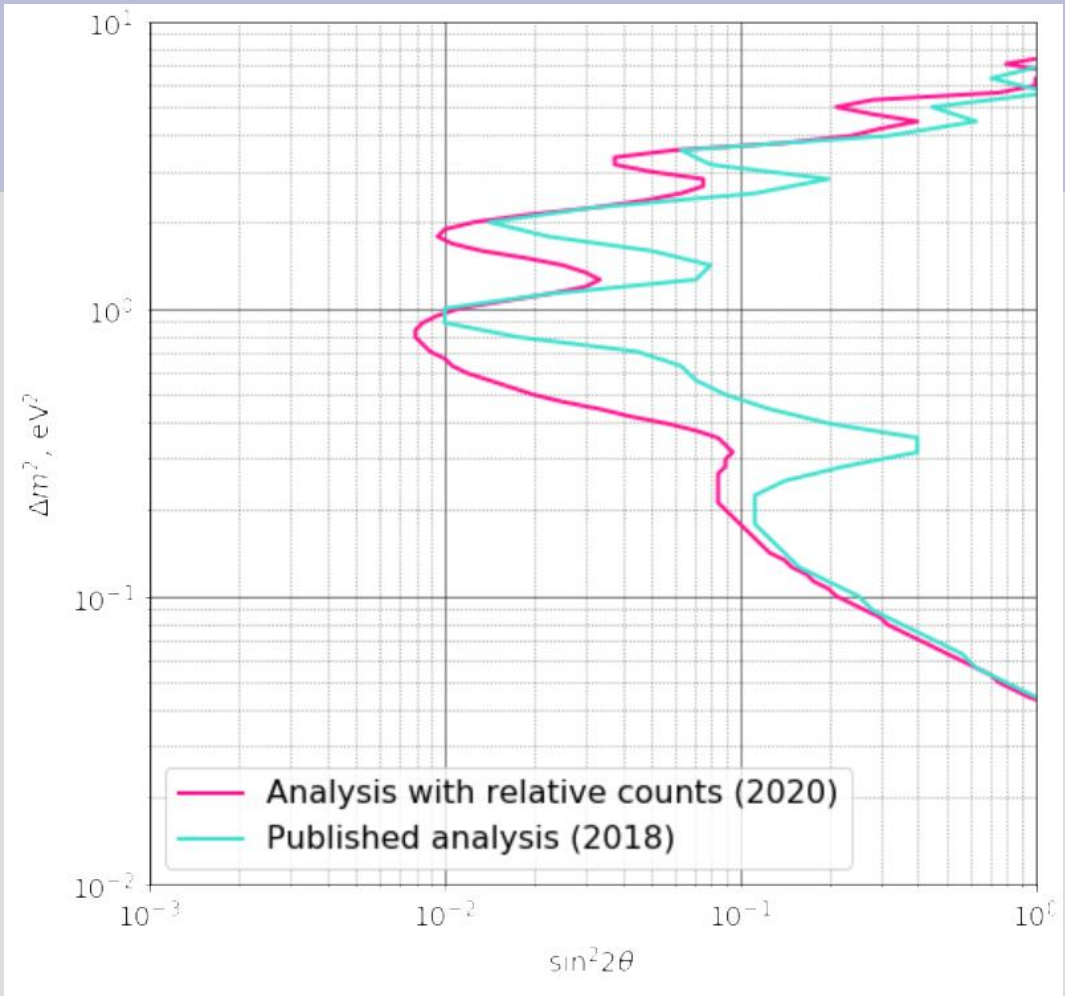


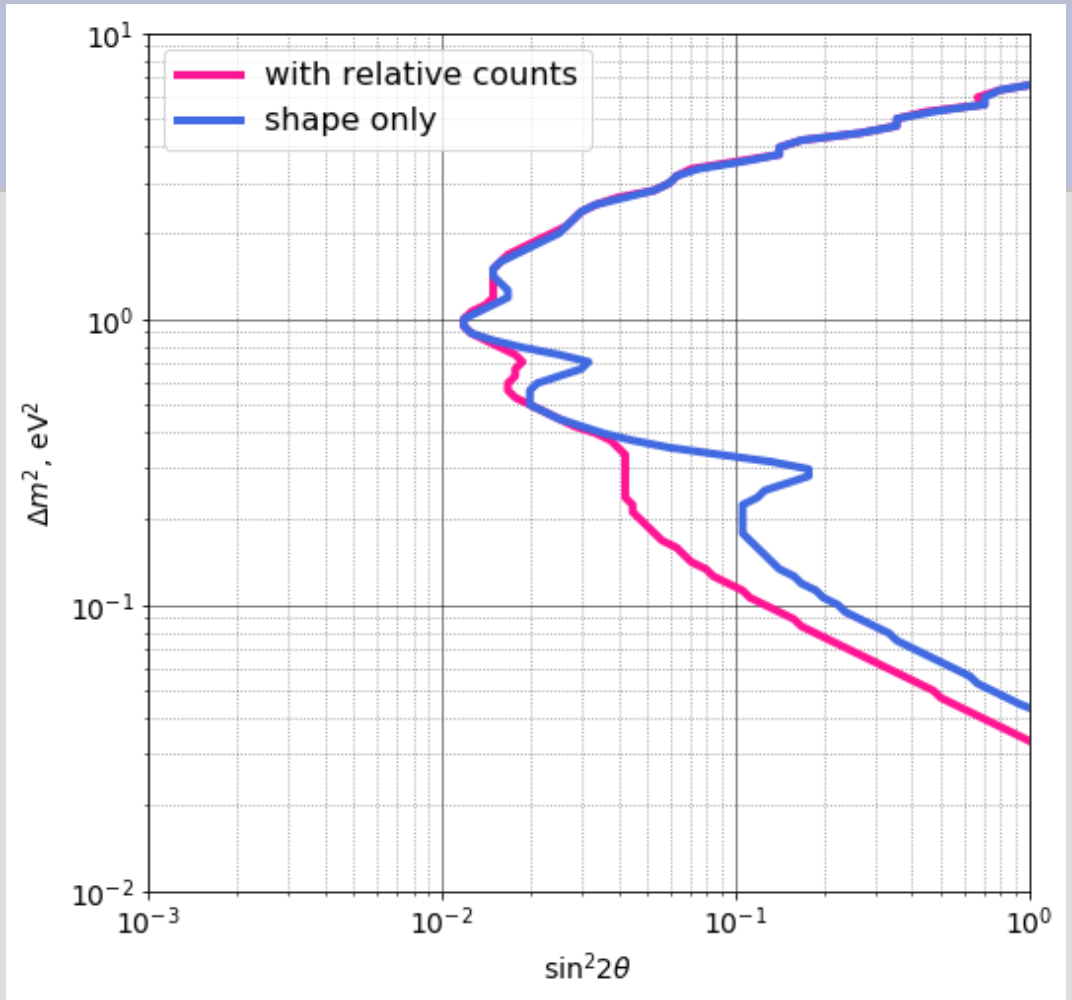




- **High sensitivity to energy scale.**
- **Better agreement with old RENO data.**

Comparison of results





- **Exclusion plots: progress of analysis since published results.**
- **Sensitivity plots: relative rate analysis contributes mostly at low mass region**