# Analysis of the ANTARES data for SN neutrino detection

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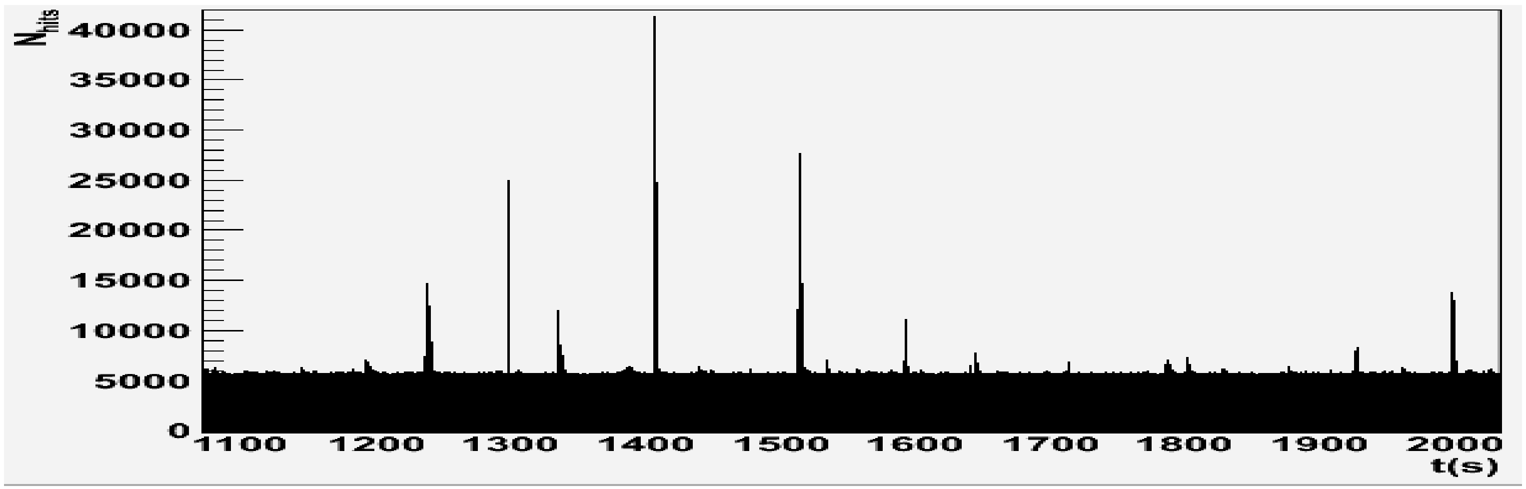
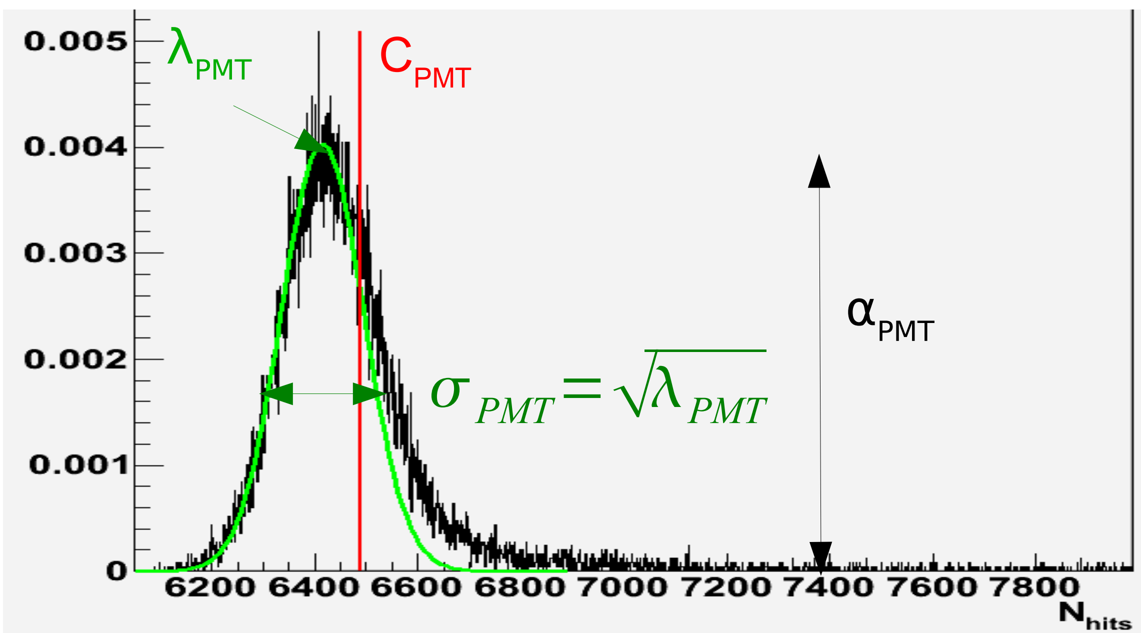
# Hit counts in the detector.

- The number of hits (hit counts) in a time slice (104.8 ms) is used (this information is stored in each run)
- Mean number of hit counts in one PMT is ~5500 (corresponds to ~55 kHz)
- Expected number of hits from SN in 100ms is 11.6 (<< 5500)
- Bioluminescence bursts should be excluded



# Bioluminescence cut

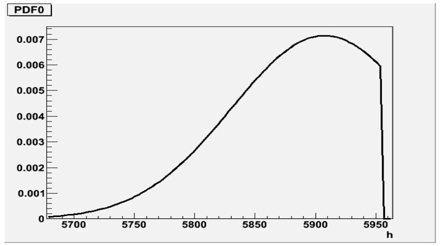
- We have collected distributions of hit counts for each PMT during one K40 run (~45min)
- Usually these distributions consist of 2 parts – Poissonian (due to K40 and plankton bioluminescence) and long tail (due to bioluminescence bursts)




Fit with Poisson distribution.
Free parameters:

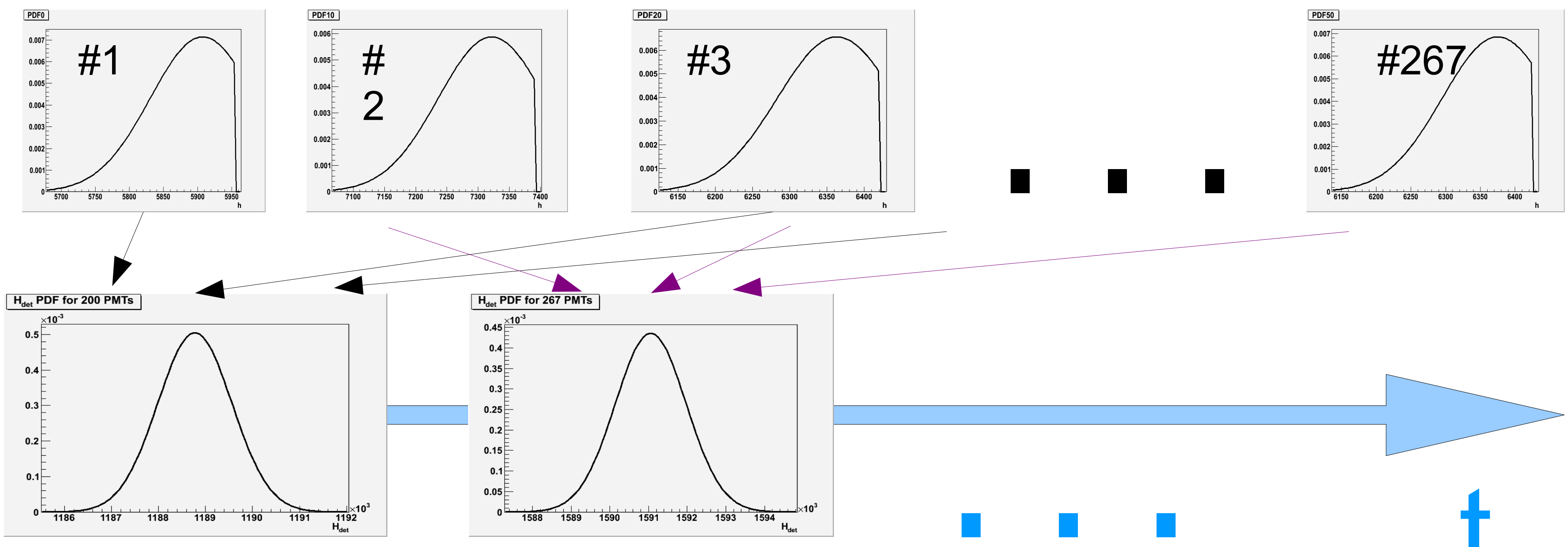
- $\lambda_{PMT}$ (mean value)
- $C_{PMT}$ (fit only until this hit count)
- $\alpha_{PMT}$ (scaling factor)

- This cut Poisson distribution we'll call PDF (probability density function) of hit counts in PMT.



# SN search – $H_{det}$ PDF

- with known $C_{PMT}$ and $\lambda_{PMT}$, we have known PDFs (probability density function) of hit counts in each PMT
- In each time slice the set of PMTs which passed bioluminescence cut is different
- the PDF of the detector (H det PDF) is different for every time slice



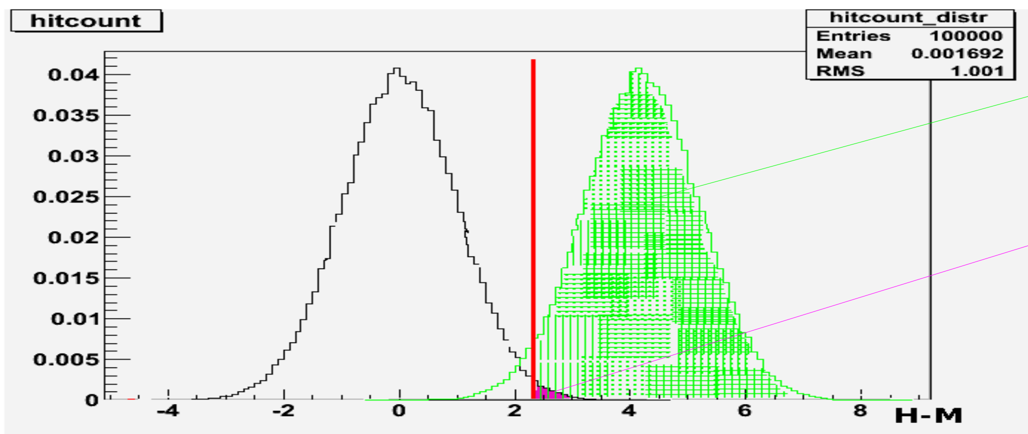

time slice #1

time slice #2

$H_{det}$ PDF is different for every time slice!

# SN search – using 2 $H_{det}$ PDFs

Black curve – $H_{det}$ PDF in absence of SN, green – in presence (just as an example, not real one)




Probability to detect SN

Probability to have fake SN (NB – for calculations we'll use only tail => high accuracy needed)

- Use Hdet PDF in absense of SN to choose $H_{cut}$ (red line) value to have predefined probability to have fake SN (magenta area)
  (for example $P=1.7328*10^{-7}$ if one fake event in week desired)
- Use $H_{det}$ PDF in presence of SN and $H_{cut}$ to calculate probability to detect SN (green area)

# Validity of Gauss shape

1)expected sensitivity with a given number of PMTs: significance S of about 4.5 if 900 active OMs are considered with a pure Poissonian hit distribution and a mean value of 6000

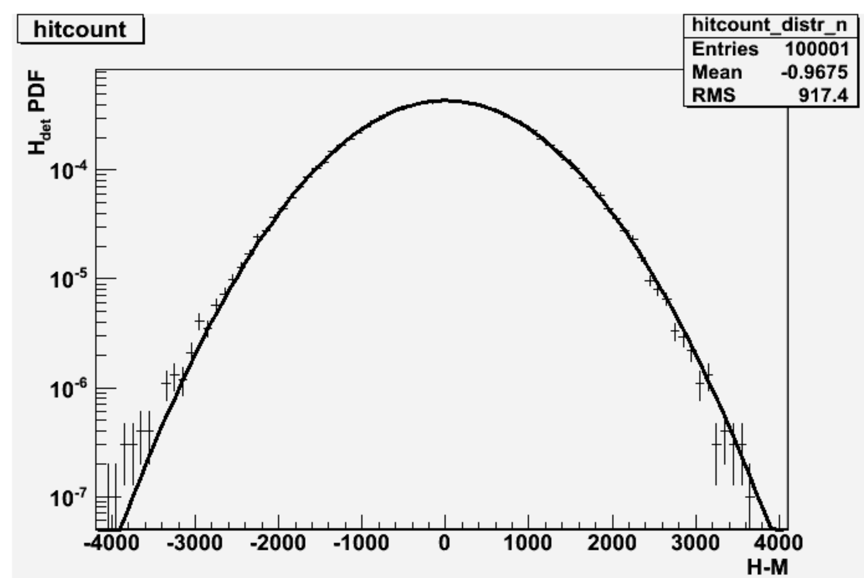
2)we have made a simulation using all the parameters from single PDFs and, as

the distribution is still a Gaussian with an average

where mi is mean of PDF for ith working OM (mathematical expectation

of hit counts in particular OM after bioluminescence filter) and with a

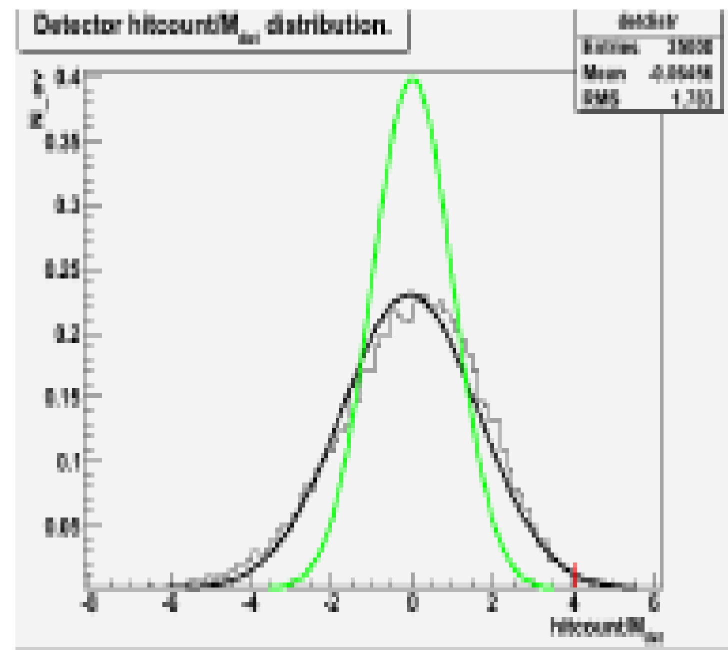
sigma as



# Results for this statistical analysis

unfortunately sensitivity is very low because

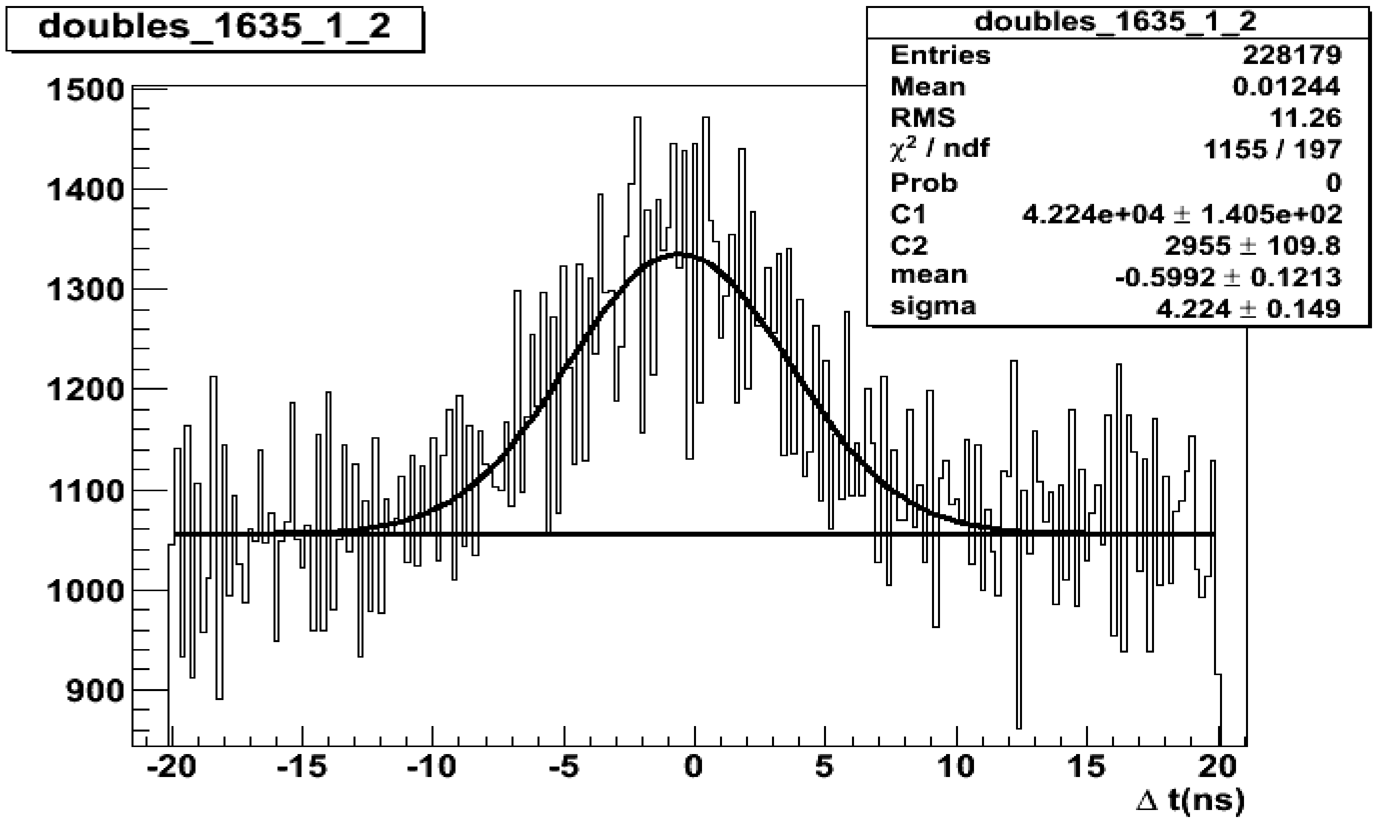
1) on average only about 300 OMs passed the bio cuts for the analysis in every time slice.




2)In addition to the low detection probability another problem was found. The distribution of
Hnorm =(H −M)/ S where H is the number of hits in the detector, M is mathematical expectation from (3) and S is variance from (4) is MUCH LARGER than the expected Gaussian distribution with mean 0 and sigma 1

3) conclusion : with current detector the probability to detect SN using single rates is incredibly low....

# Δt for doubles




- I analyze the distribution of the time difference of the hits in any PMT couple within 40 ns
- Random background gives constant pedestal
- K40 decay, which flushes both OMs, produces Gaussian peak with width ~4ns, corresponds to distance between OMs and time resolution (later I define this rate as $f_{K40}$)

# Search method

- Find coincidence rate for every couple
- apply quality cuts to exclude some couples of OMs not working well due to problems with the high voltage or bad calibration
  - the fit converges
  - the coincidence rate has an uncertainty less than 10%
  - the coincidence rate ranges from 10Hz up to 22Hz the standard deviation of the distribution is between 3 ns and 4.4ns
- For good couples in one time slice collect distribution for all coincidences in the detector. Fit it and find coincidence rate in the detector
- Compare rate with sum of coincidence rates for every couples

# Sensitivity to SN

- Fitting the experiment data, it was carried out $f_{K40}$=16Hz (see Dmitriy's work)
- From Heide's Geant4 simulations $f_{K40}$=22Hz
- SN simulations gives $f_{SN}$=2.8Hz
- Experiment expectations $f_{SN}$=2Hz (using proportion)

•In principle, assuming 900 active OM couples, in one 100ms time slice the total true coincidences is 1.6x 900 = 1440 ± 38 counts. With a SN this number increases on average to 1440+0.28 x900 = 1700 which is at more than a 6 sigma distance

# Couples quality control

As for the evaluation of the singles rate, we apply quality cuts to exclude some couples of OMs not working well due to problems with the high voltage or bad calibration.

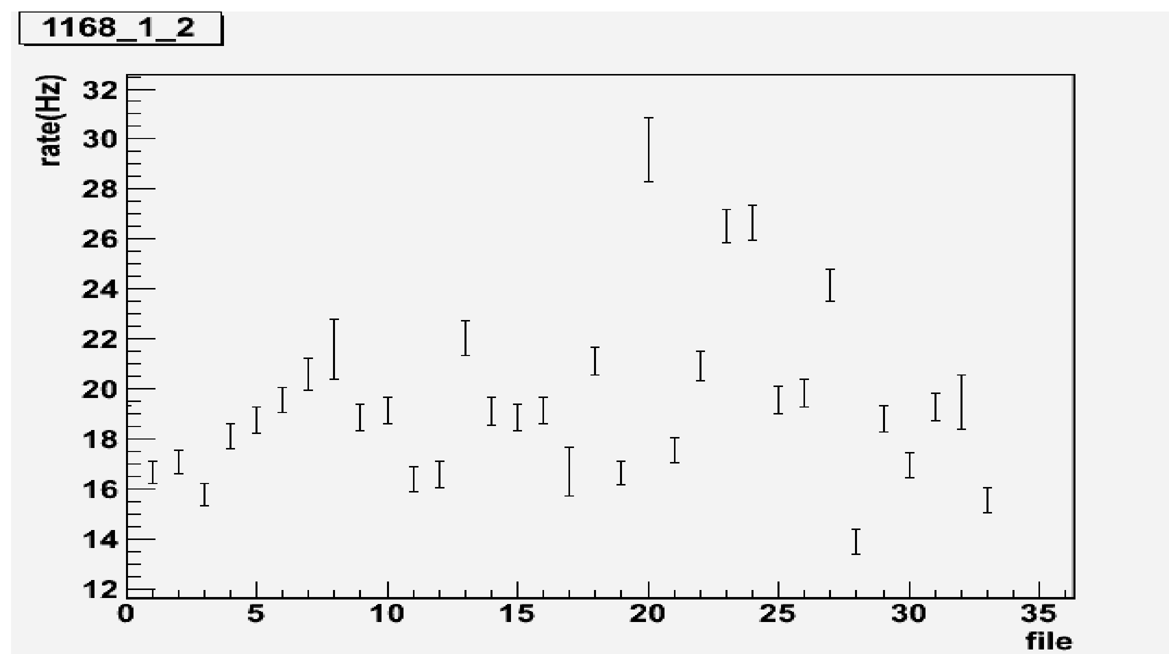
In particular we require that:

- the fit converges
- the coincidence rate has an uncertainty less than 10%
- the coincidence rate ranges from 10Hz up to 22Hz
- the standard deviation of the distribution is between 3 ns and 4.4ns

On average 400 couples out of the 900 are included in the sum which is fitted to determine the total number of true coincidences $h_{\text{time slice}}$ in the detector at a given time slice.

# Coincidence rate variation with time

- Unfortunately, coincidence rate for one couple is not a constant.
- Experimental sensitivity is at least 5.5 times worse than expected



# Method with triples

- Also it's possible to define a triple coincidence
- For them simulations show the best ratio of background to noise, but statistic is very low (tens of triples in the detector during time slice)
- Even theoretical sensitivity seems to be very low due to the low statistic

# Summary

- Different SN detection methods were introduced. Their efficiency compared. Method with double coincidence seems to be preferable.
- Even if using doubles makes good background rejection and rather easy trigger implementation, sensitivity for SN is very low
- For KM3 scale detectors situation is much better