Scintillator studies for an active neutron veto for next generation of SuperCDMS

Italian Summer Internship

Sept, 26th 2013

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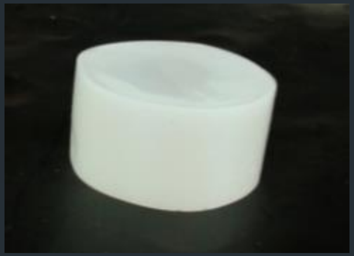
My activity

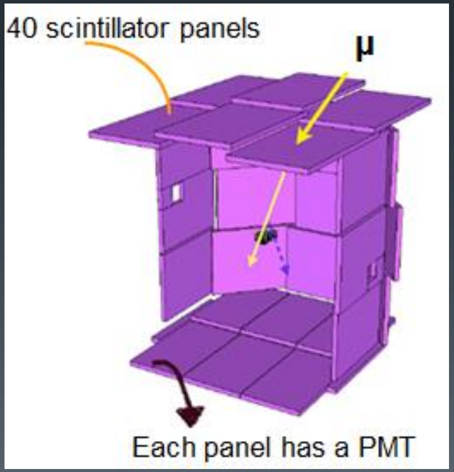
1) Mostly focused:

Scintillator studies for Neutron Veto for the next generation of CDMS (~200kg deployment of Ge at SNOLAB)



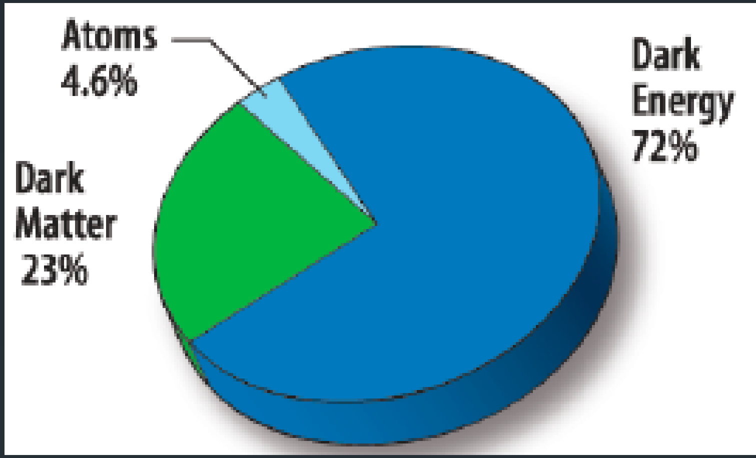
2) Last weeks:

Muon veto of CDMS II (Soudan)



What is dark matter?

- Several evidences for dark matter (more than 20% of Universe)
- But Unknown identity



We know that is:
- Massive
- Non barionic
- Non relativistic

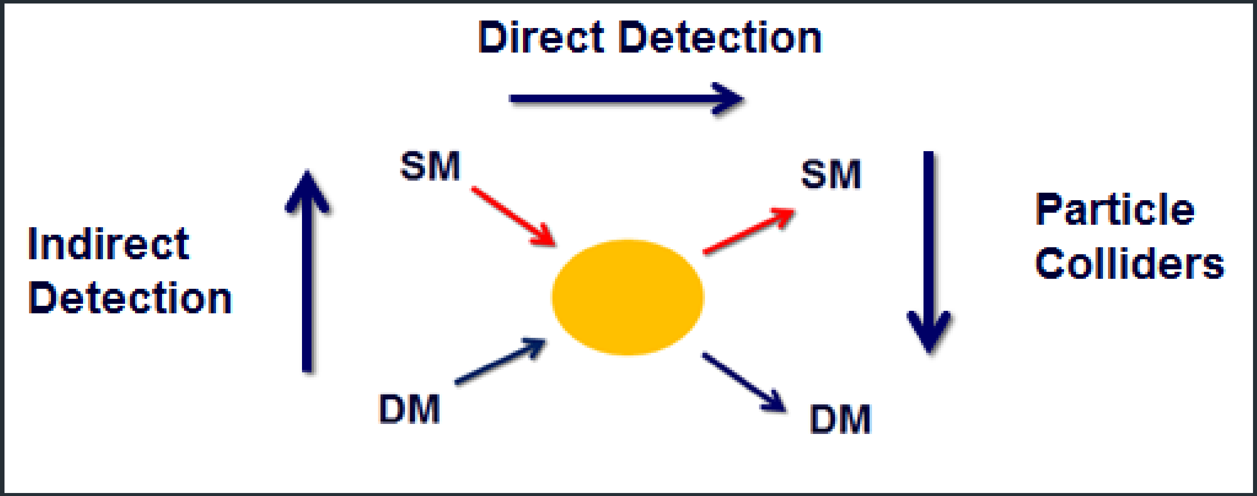
We do not know:
- Mass
- Spin
- Constituents

Popular candidates->WIMPs (Weakly Interacting Massive particles)

AIM: To detect dark matter

How to detect it?

Three ways:



Direct detection:

Expected signal is a Nuclear Recoil:

A WIMP elastic scattering deposits small amounts of energy into recoiling nucleus

->extremely rare events: expected few events per year per ~ton

Background

The background could cover the signal:

-> reduce as more as possible every kind of background

- Environmental radioactivity
- Cosmic Rays
- Muons
- Neutrons

- Low levels of radioactive contaminants
- Underground laboratories
- Active veto
- Passive shielding

Neutrons -> one of the primary WIMPs contaminations

Neutrons

Single scatter neutrons are indistinguishable from WIMPs

Three categories:

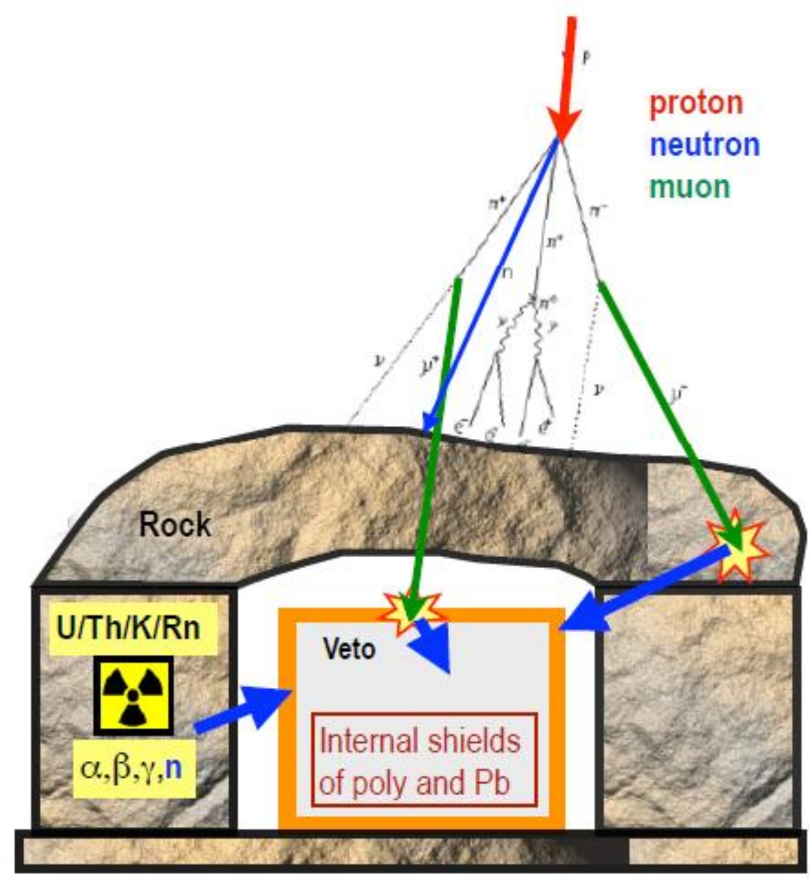
1) Internal radiogenic neutrons

2) Cosmogenically produced neutrons

3) Radiogenic rock neutrons

Sensitivity is increasing:
->necessity to suppress neutron background

-> Necessity to replace the passive veto with an active veto



How to realize an active neutron veto?

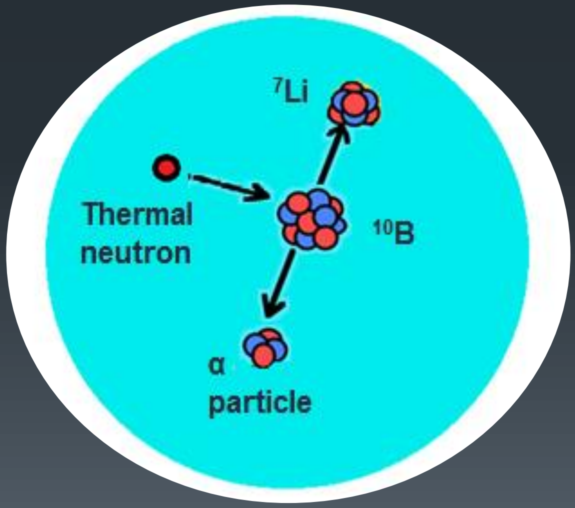
- Surrounding the internal detector with a scintillator able to detect neutrons

- Detect neutrons -> load the scintillator with something that has a high neutron capture cross section

- -> Boron loaded scintillators:

The neutron capture for Boron is:

1) $^{10}B + n \rightarrow {}^{7}Li + \alpha$ (6.4%)
2) $^{10}B + n \rightarrow {}^{7*}Li + \alpha$;
$^{7*}Li \rightarrow {}^{7}Li + \gamma\ (478KeV)$ (93.7%)



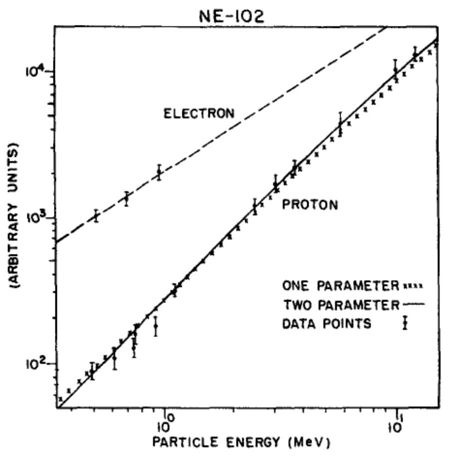
Idea->detect a neutron trough the detection of the α particle

Problem…

the energy of the alfa particle produced is of a few MeV

But…
the light output is heavily quenched for an α particle

$$\frac{dL}{dx} \sim \frac{1}{1 + k\frac{dE}{dx}} \frac{dE}{dx}$$



so the energy of the particle is equivalent to 40-50KeVee

-> is needed a scintillator with a high light yield

We are looking also for a good pulse-shape discrimination (PSD)

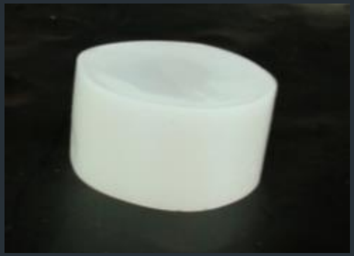
For this reason CDMS is making an effort to find the best "scintillator cocktail"

My work

Several samples of liquid and plastic scintillators doped with:

- Trimethyl borate (TMB)
- Highly efficient fluorescent dyes (PPO, POPOP, DPA)

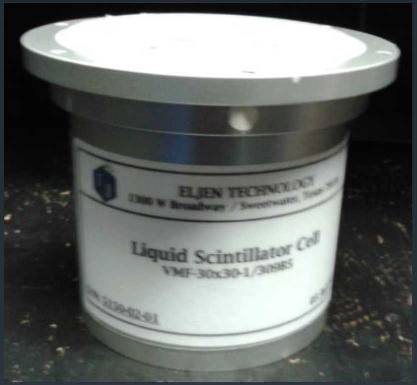
~1cm



~2.5cm

~1cm

~2.5cm



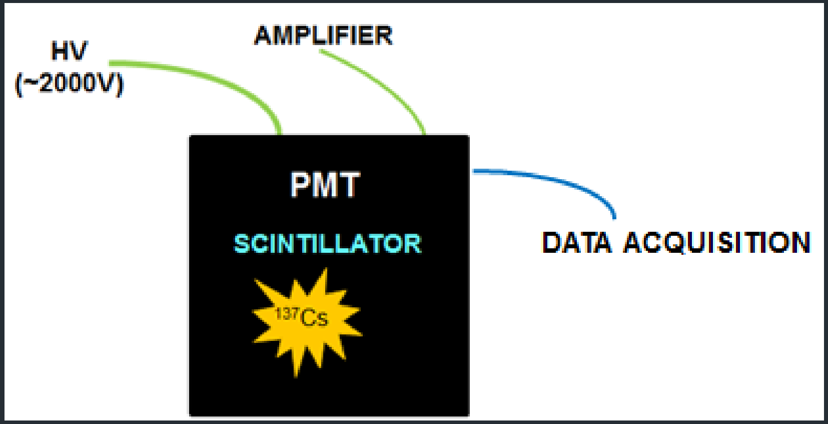
~10cm

~10cm

First:

find the best configuration to collect all the light produced in order to estimate the light yield of the scintillators

Set Up



^{137}Cs source:

$$^{137}Cs \rightarrow {}^{137}Ba + e^{-} + \bar{\nu} + \gamma(662KeV) \qquad 93.5\%$$

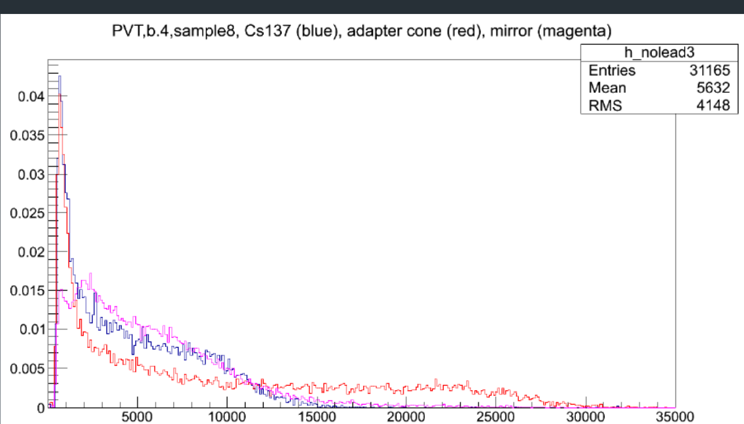
$$^{137}Cs \rightarrow {}^{137}Ba + e^{-} + \bar{\nu} \qquad 6.5\%$$

Evaluation of the gain of the PMT-> LED

Configurations

PLASTIC

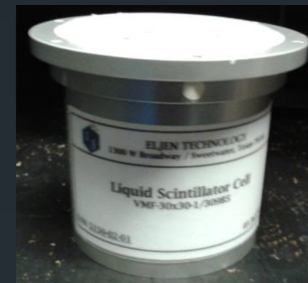
Adapter cone
reflective cap



LIQUID

Rectangular vial
White ring
Acrylic disk
reflective cap

LIQUID - COMMERCIAL SAMPLE



Alluminium foil

Problems encountered

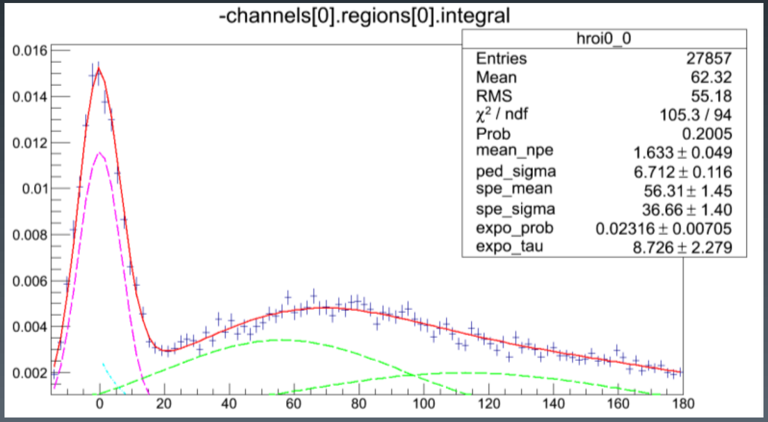
Gain of PMT (Spe mean):

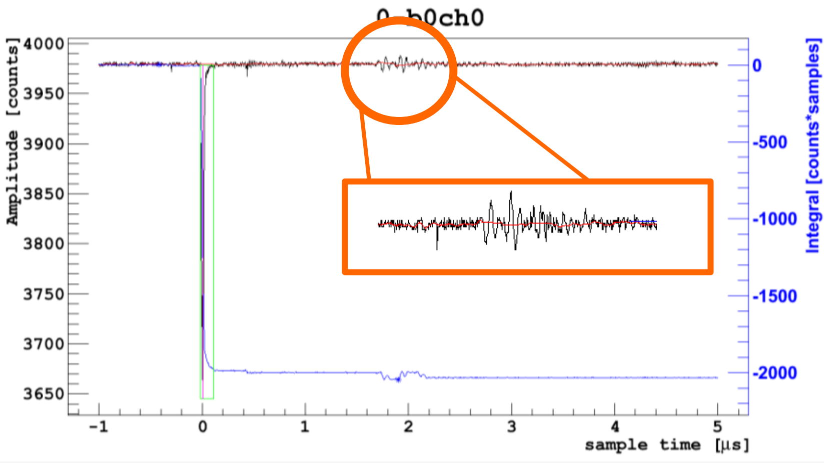
- not only function of HV, changes during data acquisition
- Fit sensitive to the range

- Monitoring the situation necessity of other measurements
- I have improved the fit

Presence of noise bursts in the data:

- Attempts to remove noise -> still there but situation improved





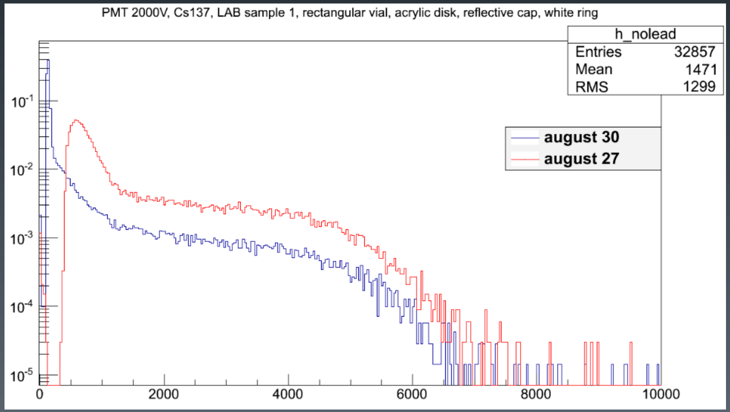
Problems encountered

Distorsions in the real spectra:

- a larger peak at low energy,
- a cut at low energy,
- a low energy cut with a peak at zero energy

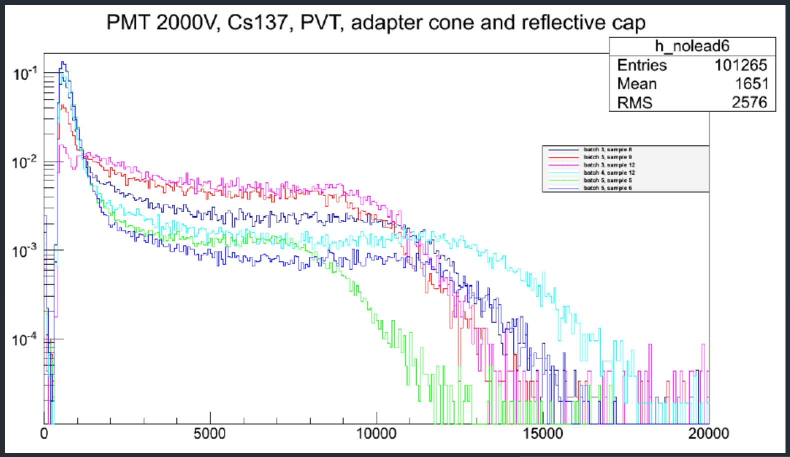
- Backscattering ?
- threshold effect ?
- presence of

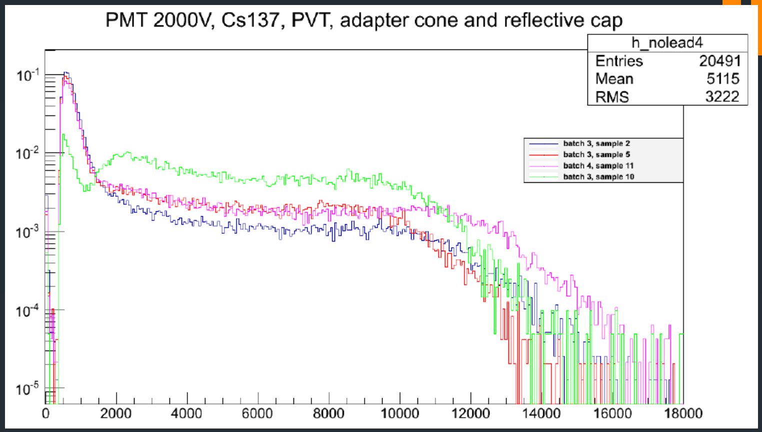
  noise bursts ?



- Physical process… Nothing to do
- Lower the threshold
- Look at those events
- Evaluation of signal to background ratio for a 50KeV peak

Solid Scintillators





Best light output for PVT:

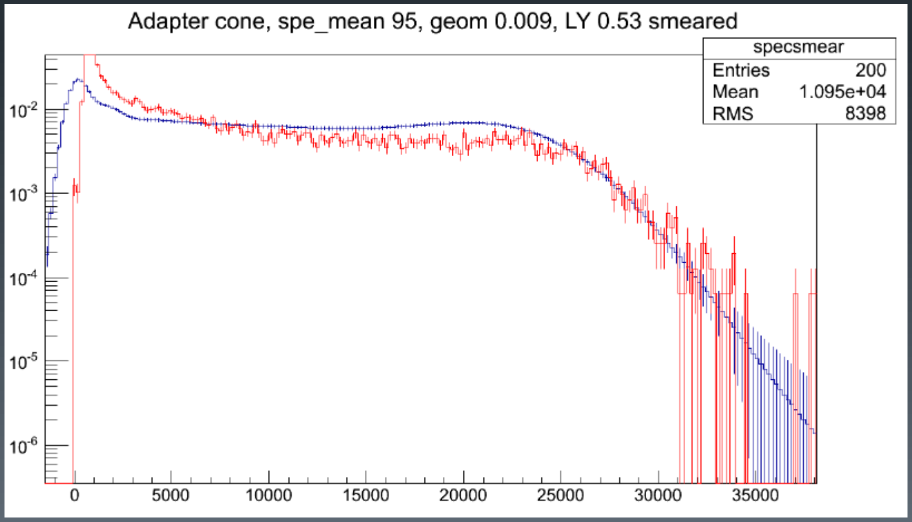
10%PPO, 0.2%POPOP, 10% TMB

10%PPO, 0.2%DPA, 10% TMB

Comparison to a simulation to

Evaluate the light yield:

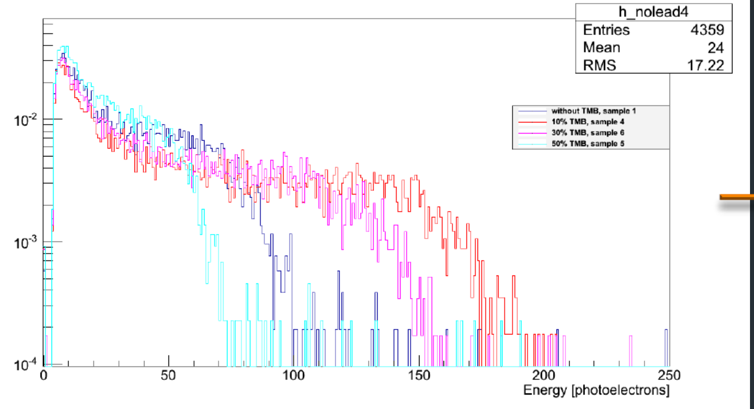
LY 0.53



LIQUID Scintillators - LAB

Linear Alcohol Benzene (LAB) scintillators:

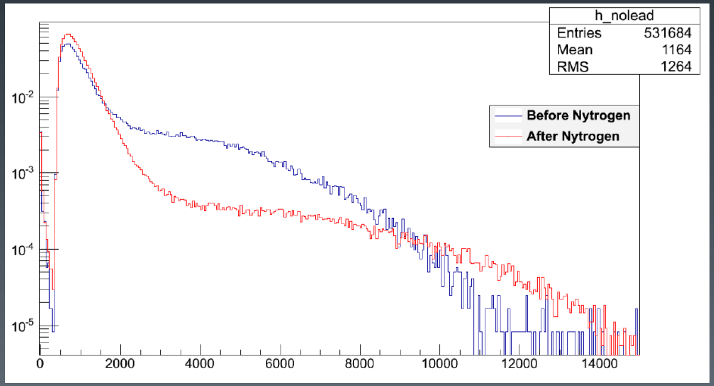
- Find a good configuration -> different vials
- Look at different samples (different concentrations)



Best:

- 0.1%PPO, 0.0015% bis MSB, 10% TMB
- 0.1%PPO, 0.0015% bis MSB, 30% TMB

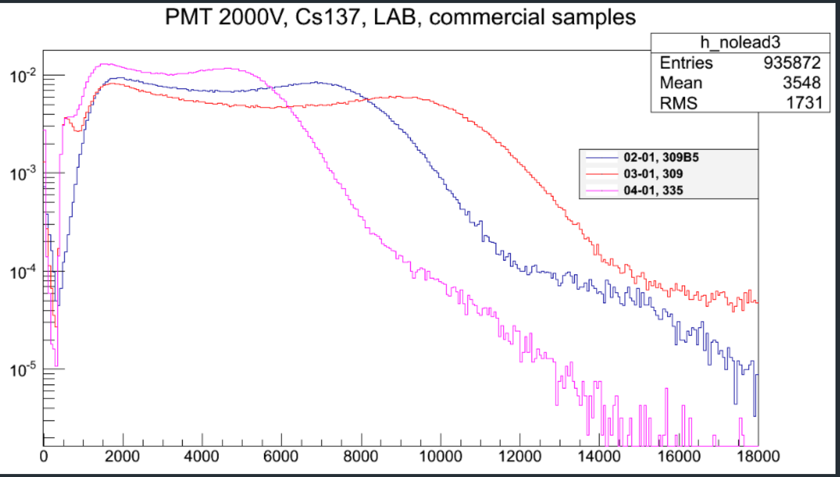
- Remove Oxygen-> Bubbling Nytrogen, several trials -> confusing results



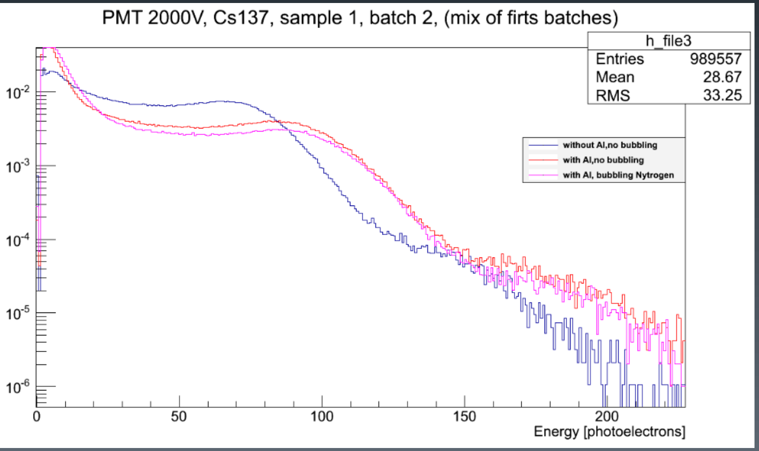
-> needs checks

LIQUID Scintillators - commercial

Three commercial samples:

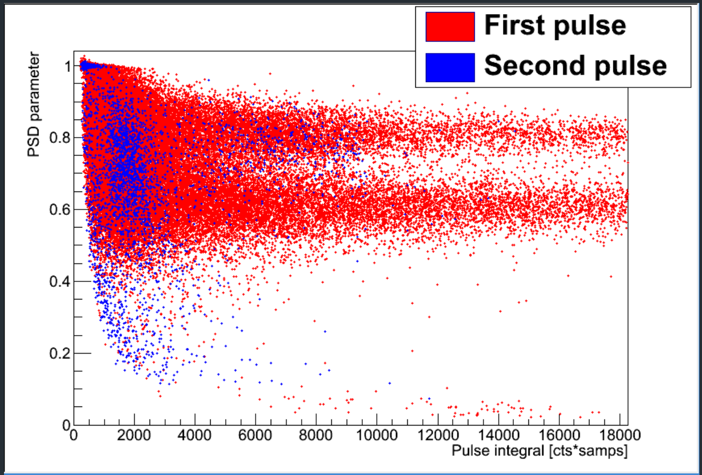


- Remove Oxygen-> Bubbling Nytrogen



Finally… neutron source

Preliminary measurements with a Cf252 source



Aim:
pulse shape discrimination

Analysis still on working
-> First results:
for one sample we are able to see the alfa peak in one of the commercial sample

-> next effort : see the alfa peak in the LAB sample

Conclusions

I took several measurements to:

- To find the best configurations to collect all the light produced
- To find which one of every kind of scintillators have the best light yield
- Monitor the trend of the gain of the PMT

I have:

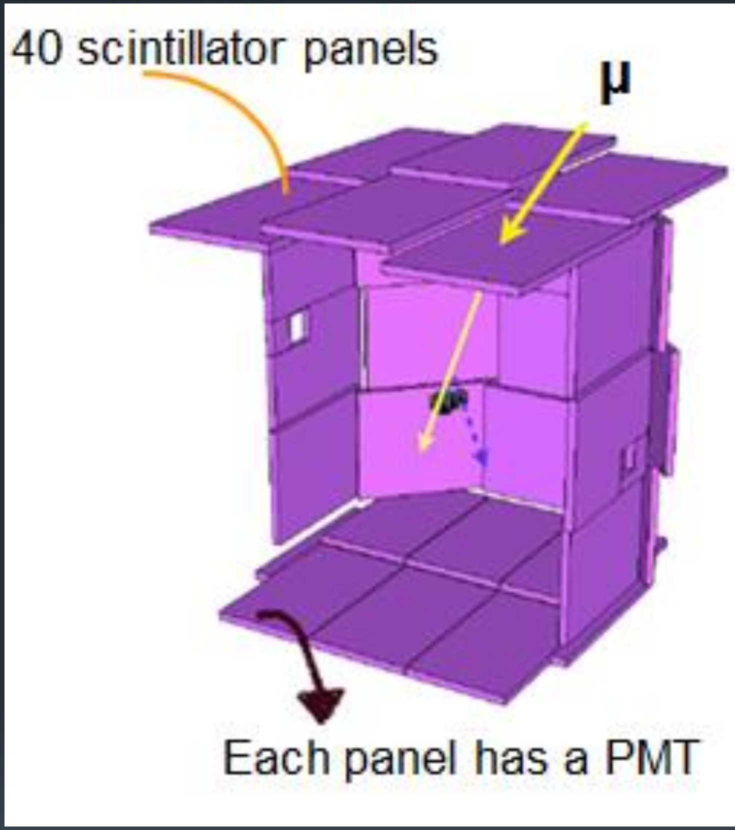
- Dealt with the experimental problem we encoutered
- Investigated the causes of the spectra distorsion we observed
- Improved the PMT response fit
- Compared the real spectra to spectra from simulations

Future prospect:

- Investigate better the pulse shape analysis

ACTIVE MUON VETO SuperCDMS Soudan

Aim:
Evaluate the muon veto rate for data between March 2012 and July 2013 -> anomalous variation



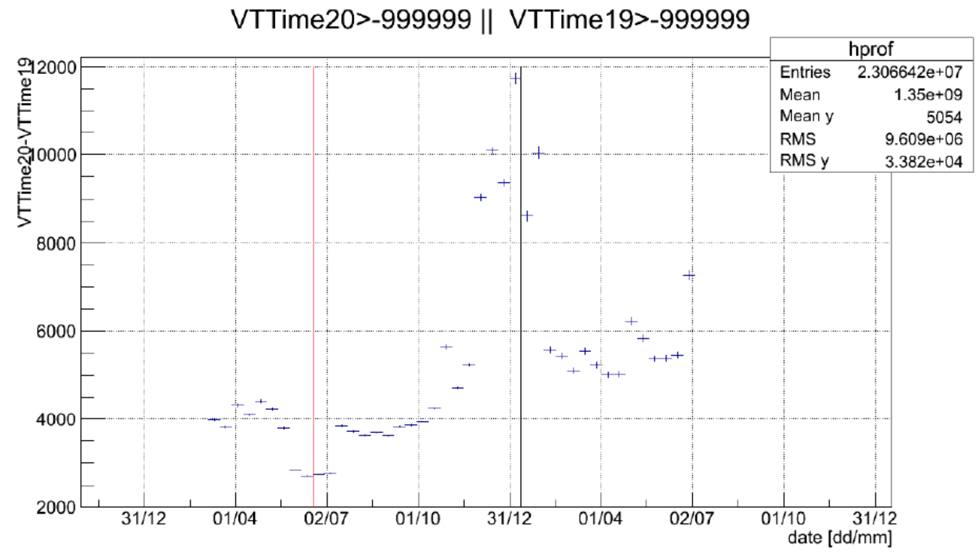
Idea:

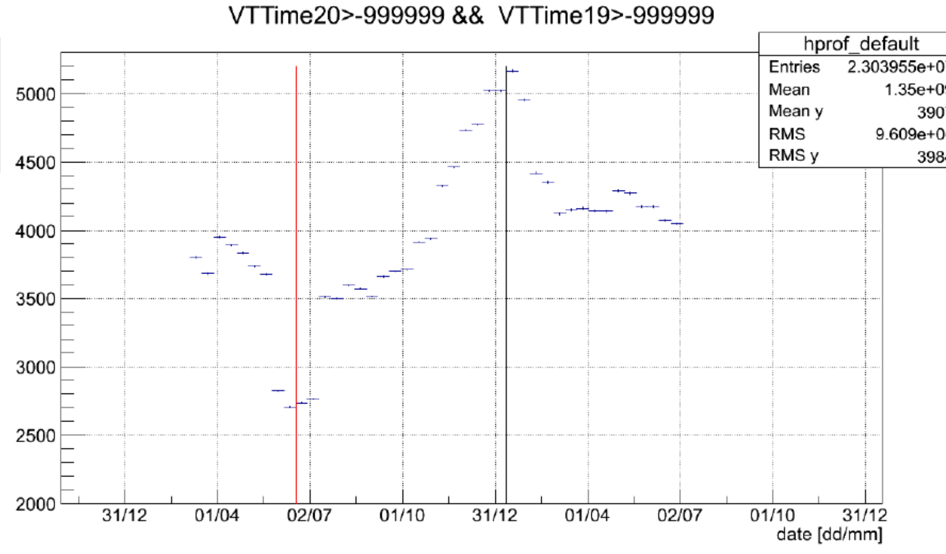
Global trigger starts if:

- Several panels of the muon veto register a signal
- Signal in the internal detectors (Zip)

To study the veto rate:
->Plot the time between two consecutive veto triggers

Veto rate: my work





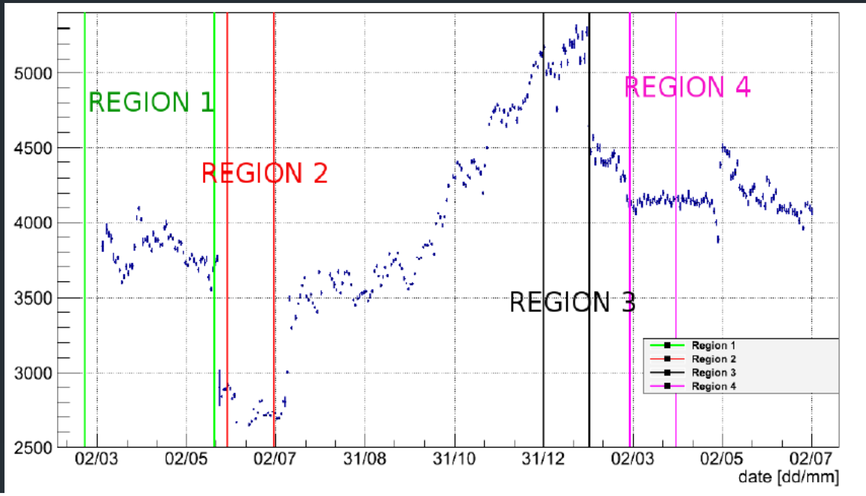
Previously found:
Anomalous variation of ~10000μs
Veto rate ~80Hz-370Hz

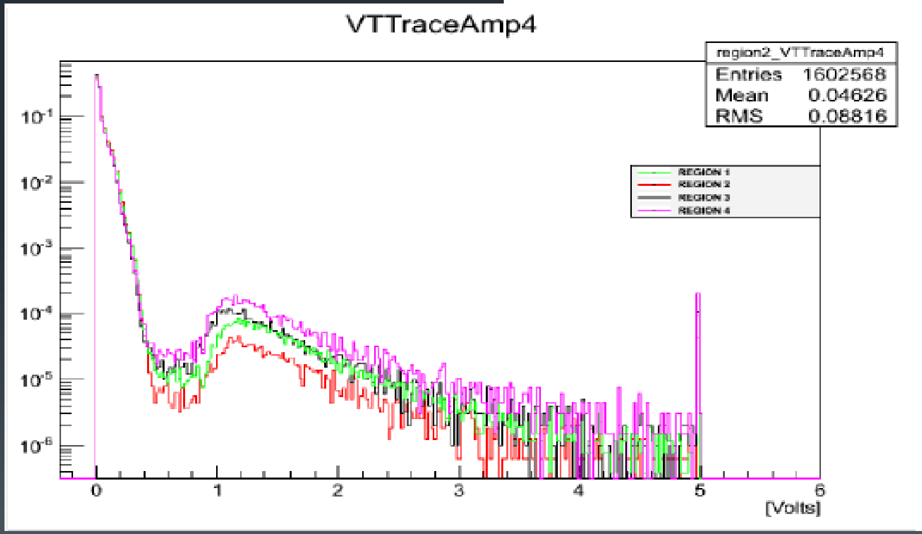
My correction:
Variation of about ~1600μs
Veto rate ~190Hz-370Hz

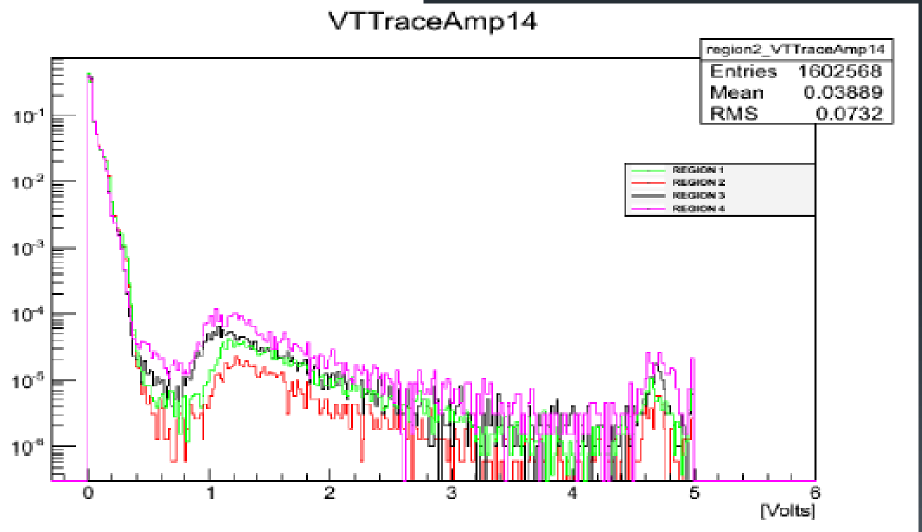
Problem -> excluded default values

POSSIBLE CAUSES

Degradation of the scintillators?



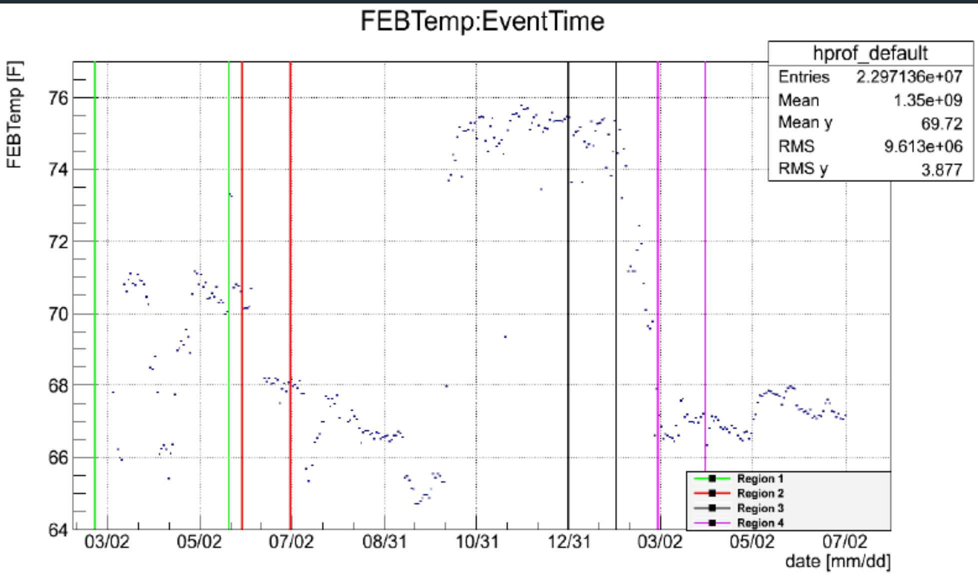


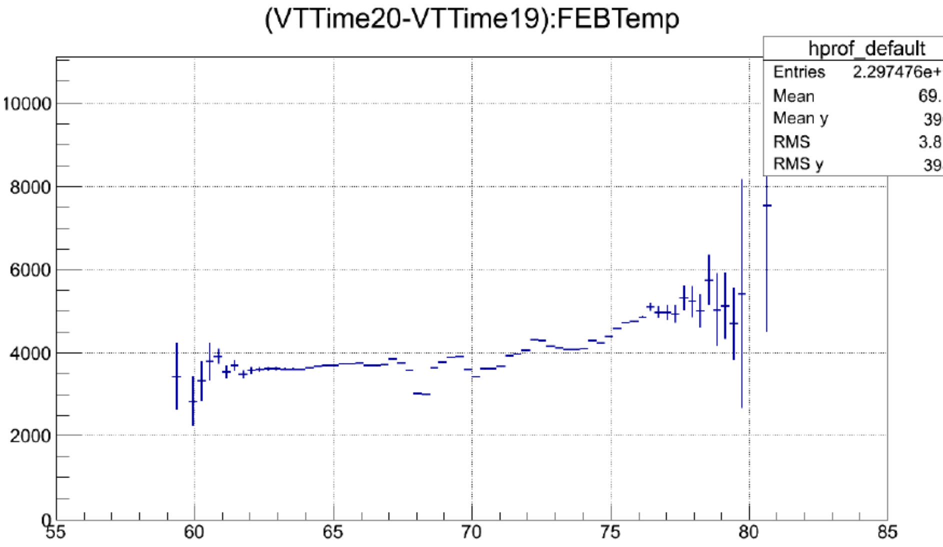


In top and bottom panels we see a little spectrum contraction

POSSIBLE CAUSES

Temperature correlation ?





Found a strong correlation between the veto rate and the electronic rack temperature of the muon veto

Necessity of further tests!

Conclusions

I found :

- The correct dependance on time of the veto rate
- Top and bottom scintillator panels show a degradation with the passing of time
- Strong correlation between the veto rate and the electronic rack temperature of the muon veto

The situation seems to be clearer but necessity of further tests!

Thank you for the attention

and

Thank you to all the staff
who helped me during these mounths