Detecting Fast Neutron for Double Chooz : DCTPC

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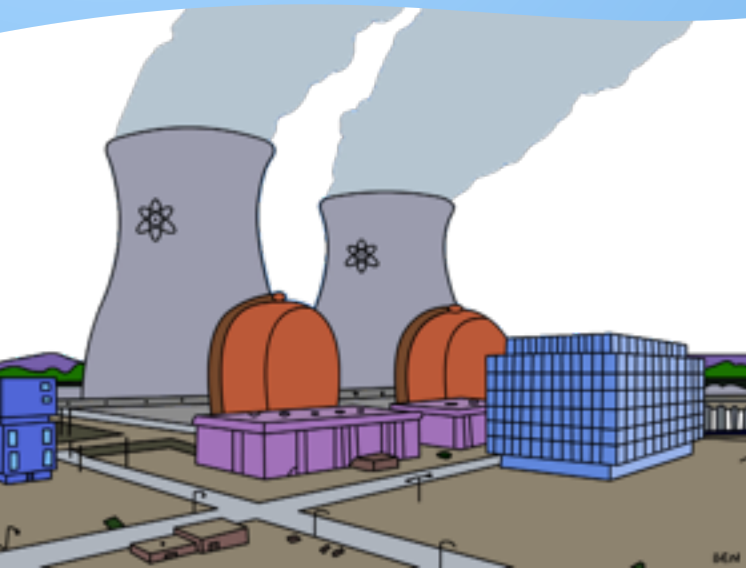
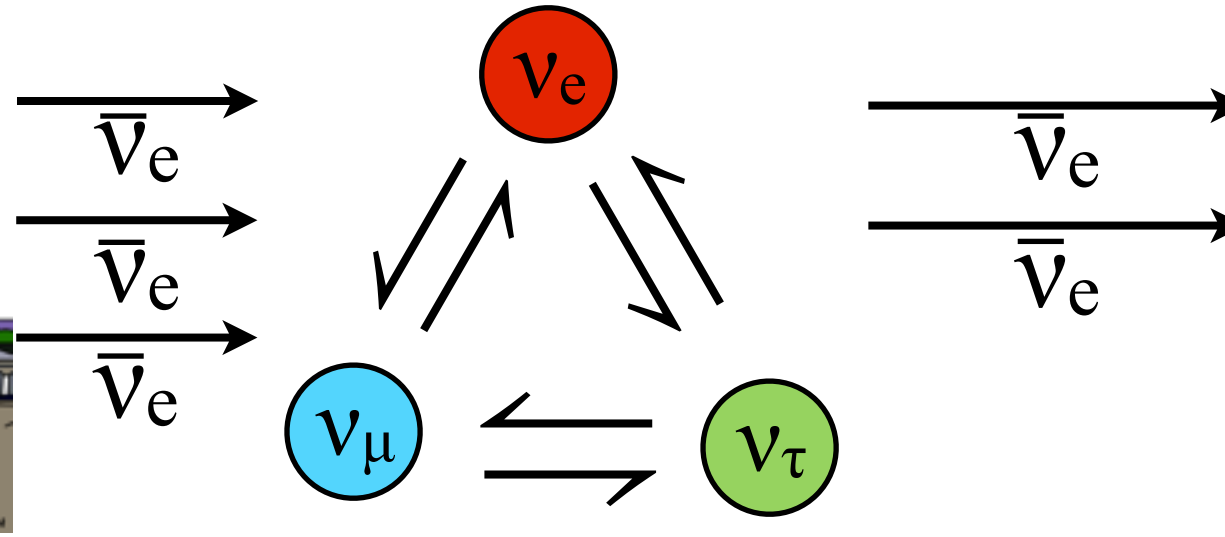
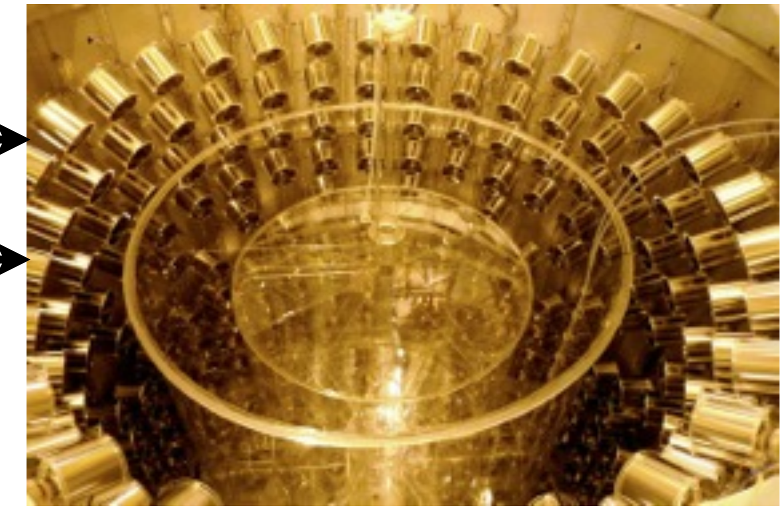
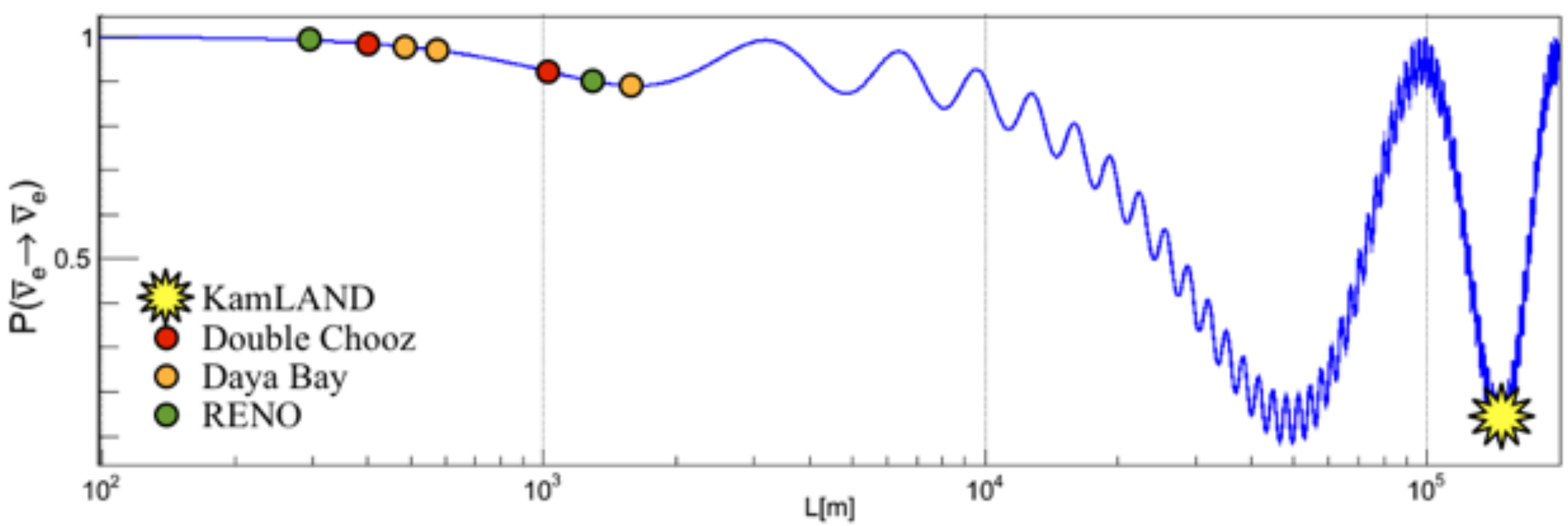
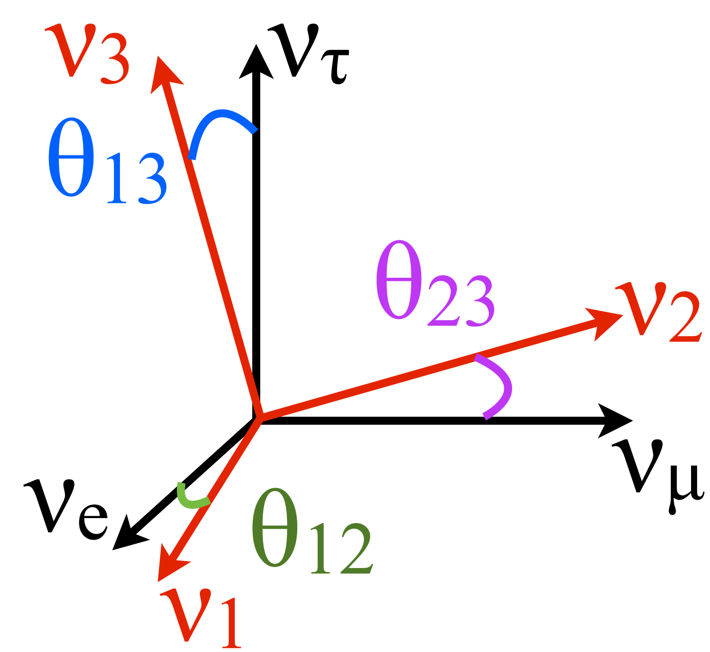
Neutrino Oscillations







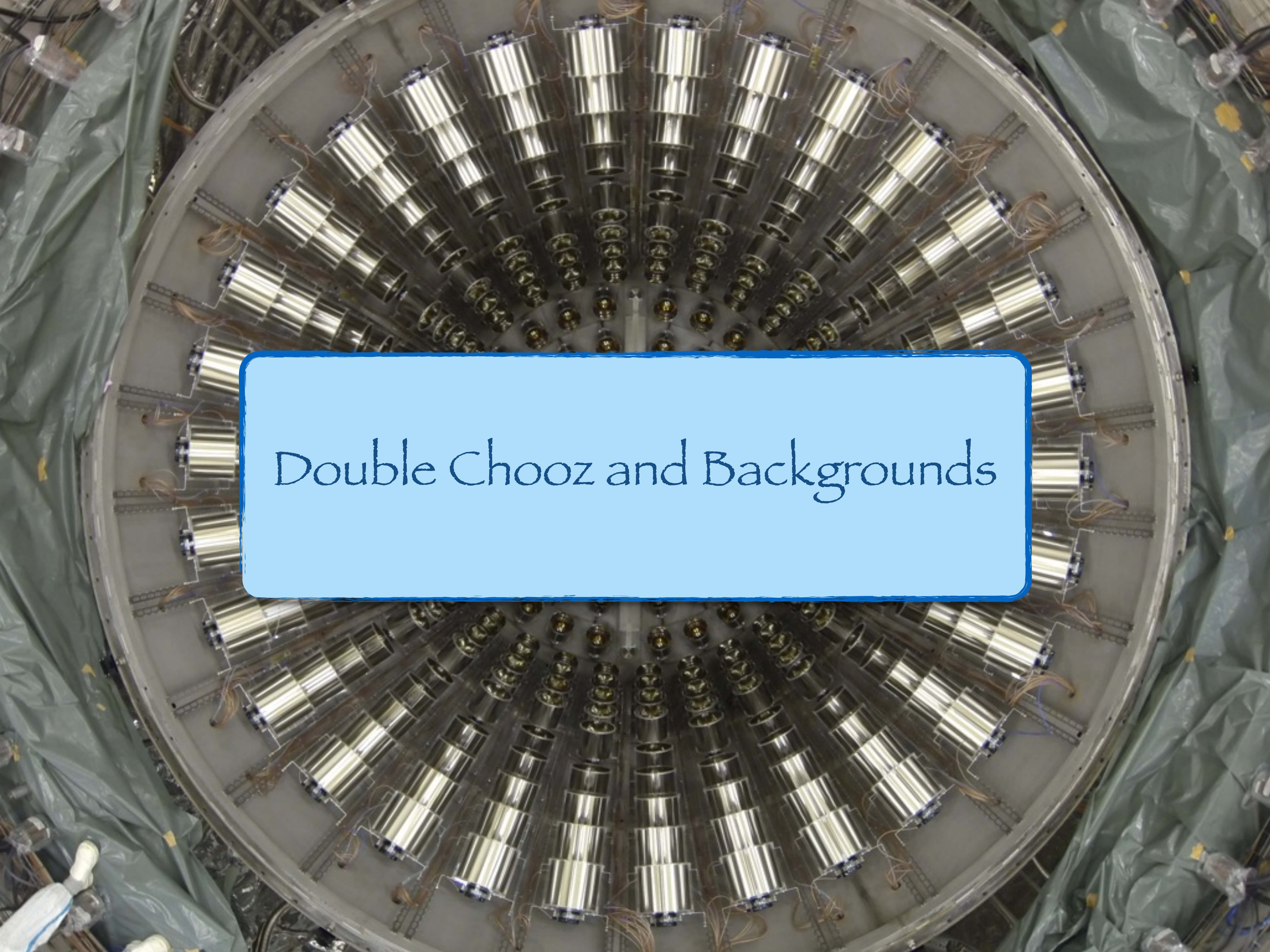




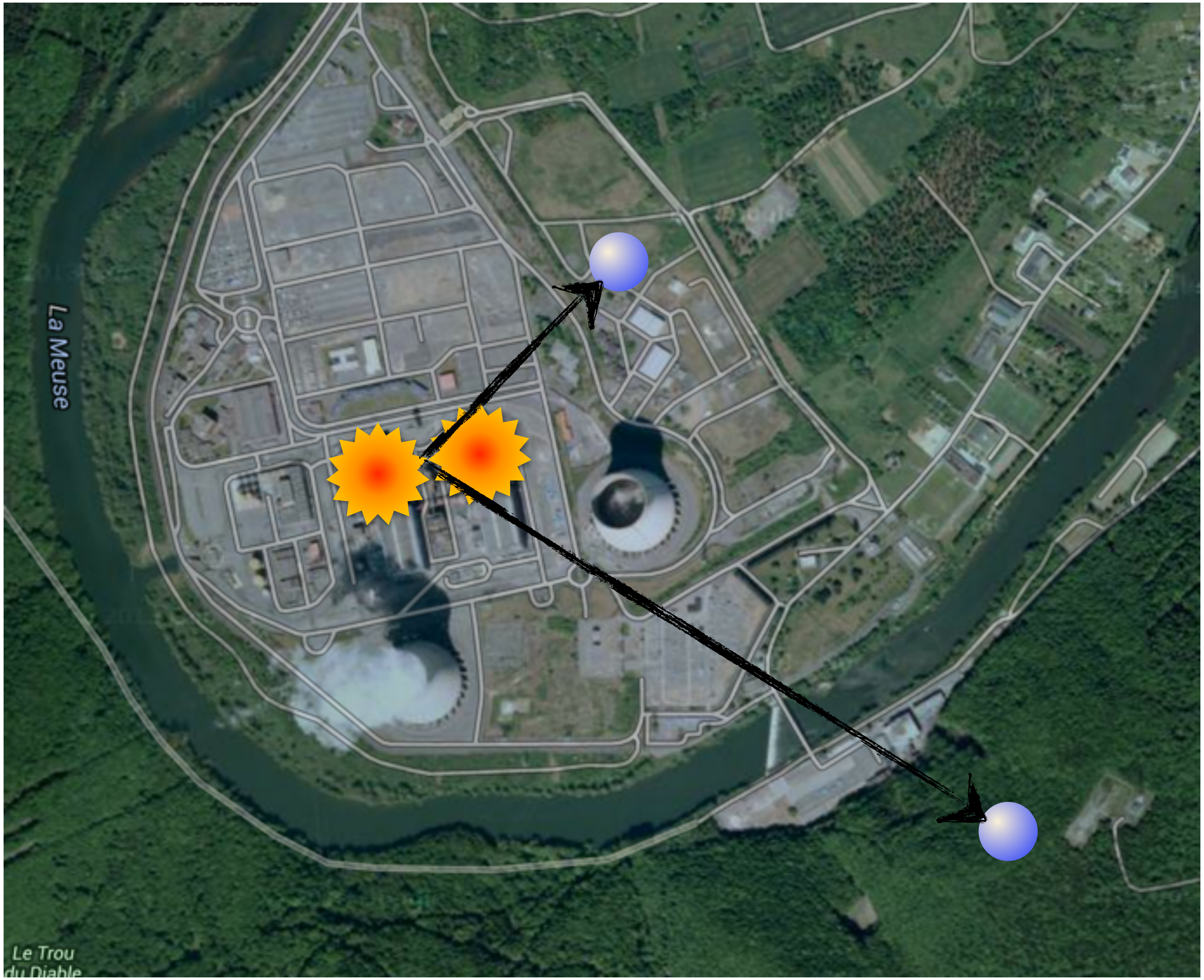
Two different bases:

- Flavor (black)
- Mass (red)

Double Chooz and Backgrounds



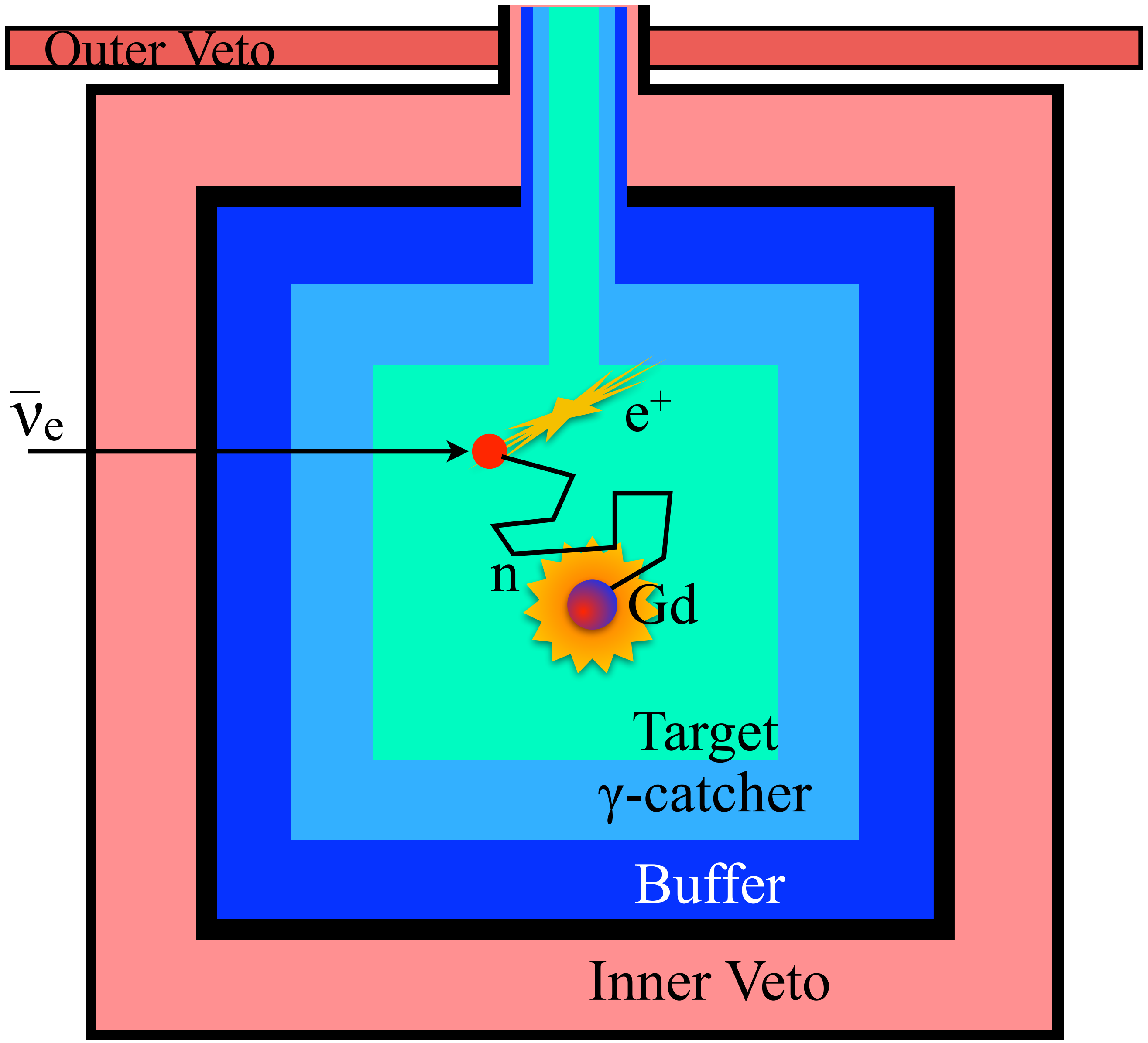
Double Chooz



2 detectors :

- far hall
  1050 m baseline, 300 m.w.e
- near hall
  400 m baseline, 120 m.w.e

Neutrino detection in DC



Inverse Beta Decay (IBD)

$$\overline{\nu}_e + p \longrightarrow e^+ + n$$

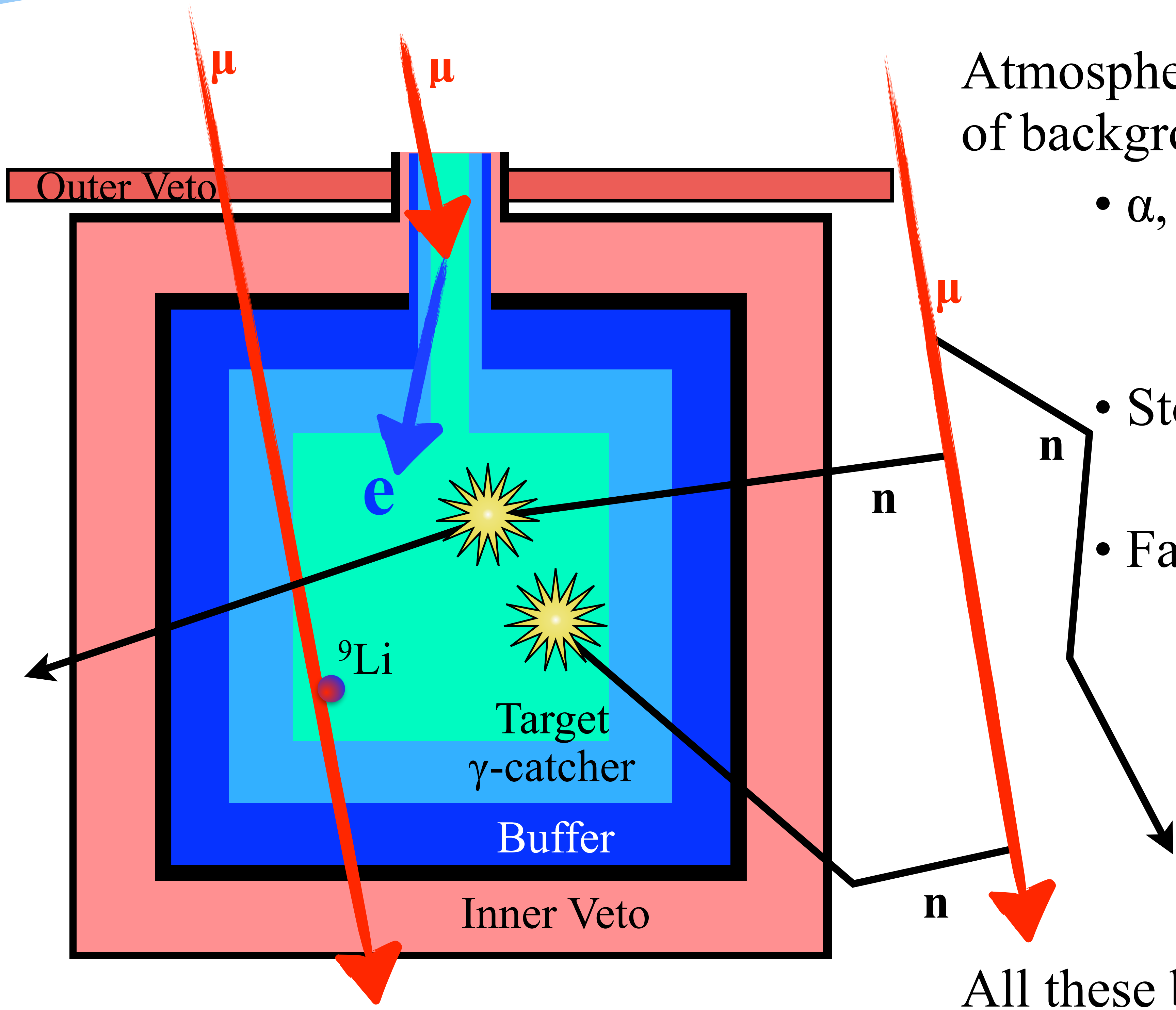
2 scintillation signals :

- e^+ scintillation (~ E_ν - 0.78 MeV)
- n-Gd capture (~ 8 MeV, τ_{cpt} ~ 25 µs)

neutrons can also capture on hydrogen (2.2 MeV, τ_{cpt} ~ 100 µs)

ΔT coincidence : 150 µs (800 µs for n-H)

Cosmogenic backgrounds in DC

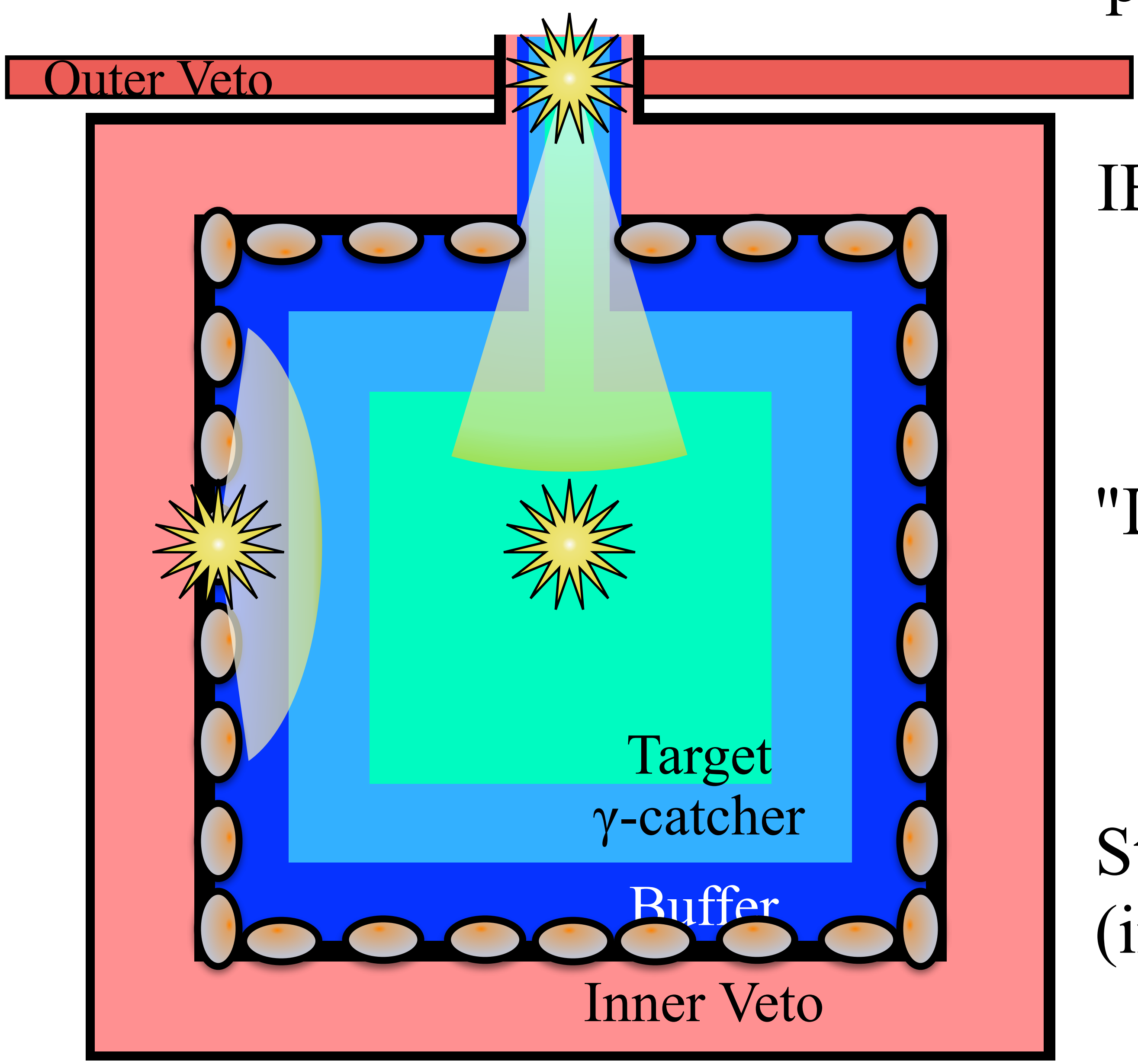


Atmospheric muons are a major source of backgrounds :

- α, n emitter spallation products (^{9}Li, ^{8}He) in the volumes
- Stopping muons and Michel e^-
- Fast neutron showers from spallation in surrounding rock

All these backgrounds can be studied independently except for fast neutrons

Unexpected Background



Event reconstruction based on a point-like energy deposition in the target

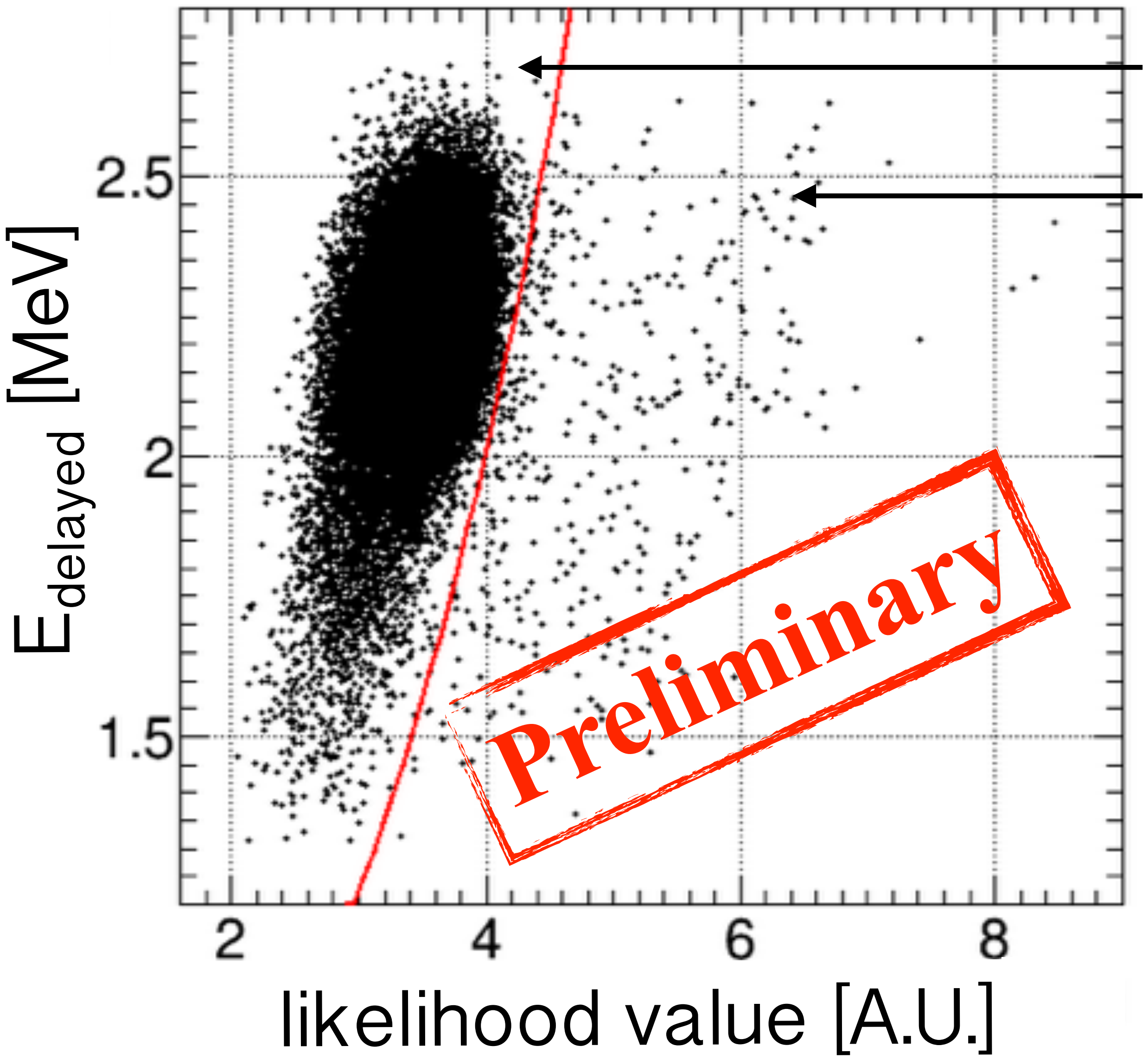
IBD-like events → all PMT hit
→ same amount of light
→ same time

"Light noise" → only a few PMT
→ high light RMS
→ high time RMS

Stopping Muons have a similar behavior (in the chimney)

part of my PhD consist in rejecting these backgrounds

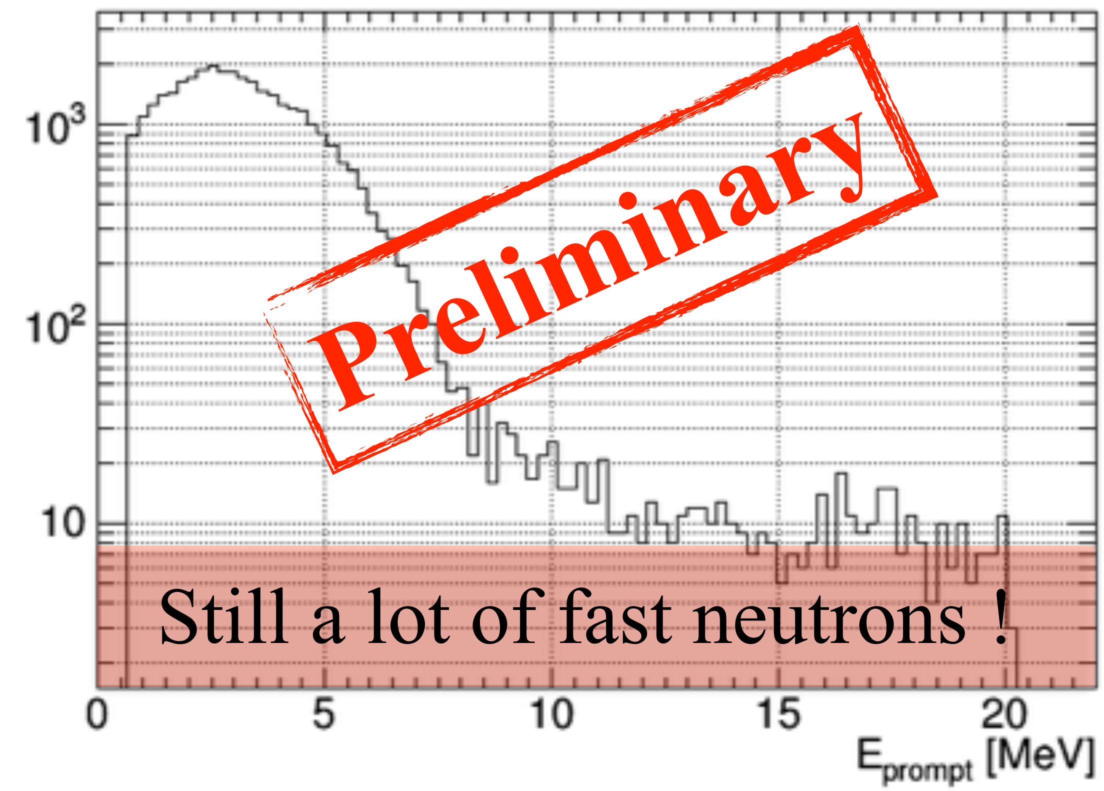
Stopping μ and LN Rejection



Neutrinos + Fast neutrons

Stopping μ + LN

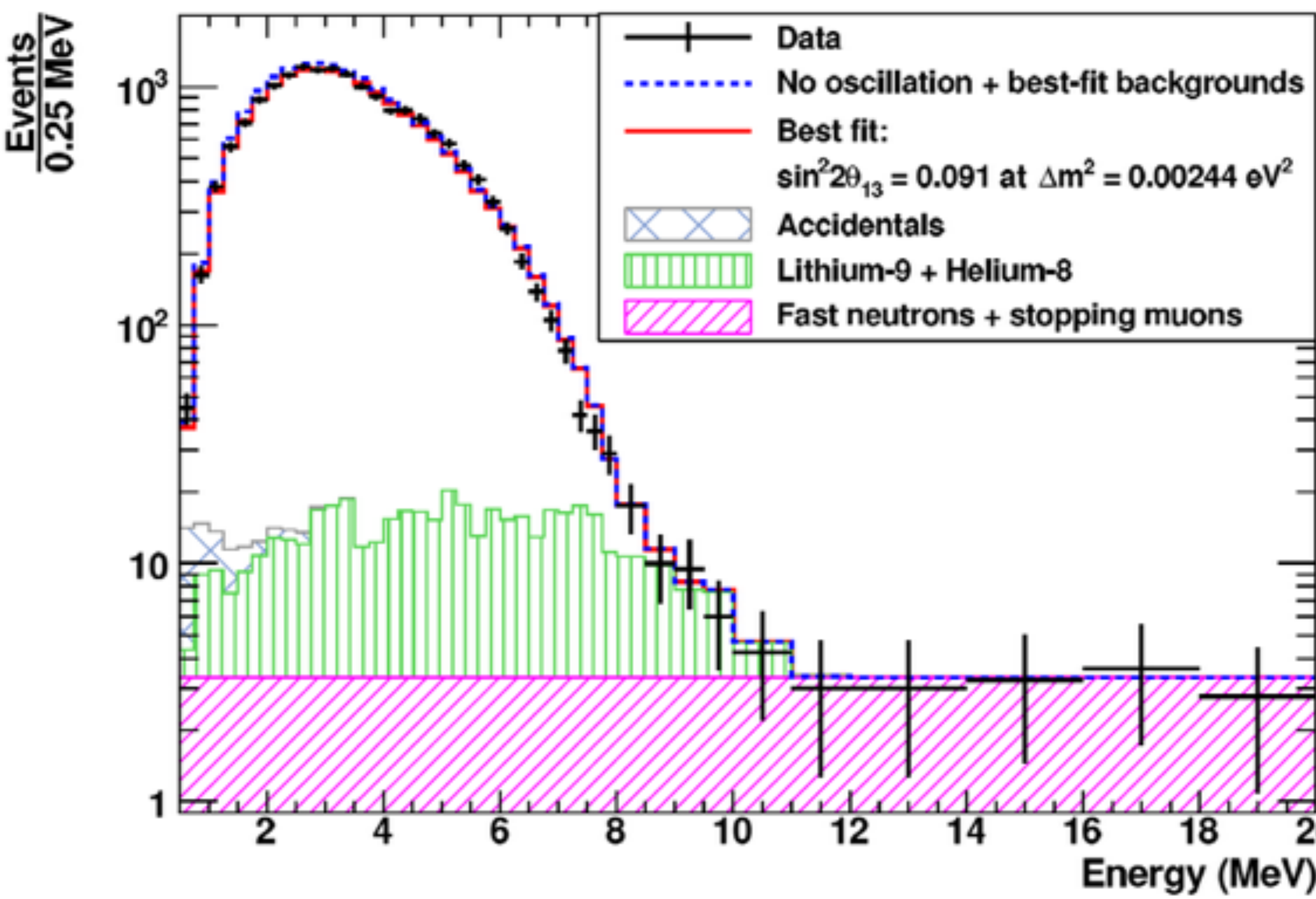
Likelihood function of the event reconstruction algorithm takes into account the charge collected on each PMT, and the time of arrival of the photons



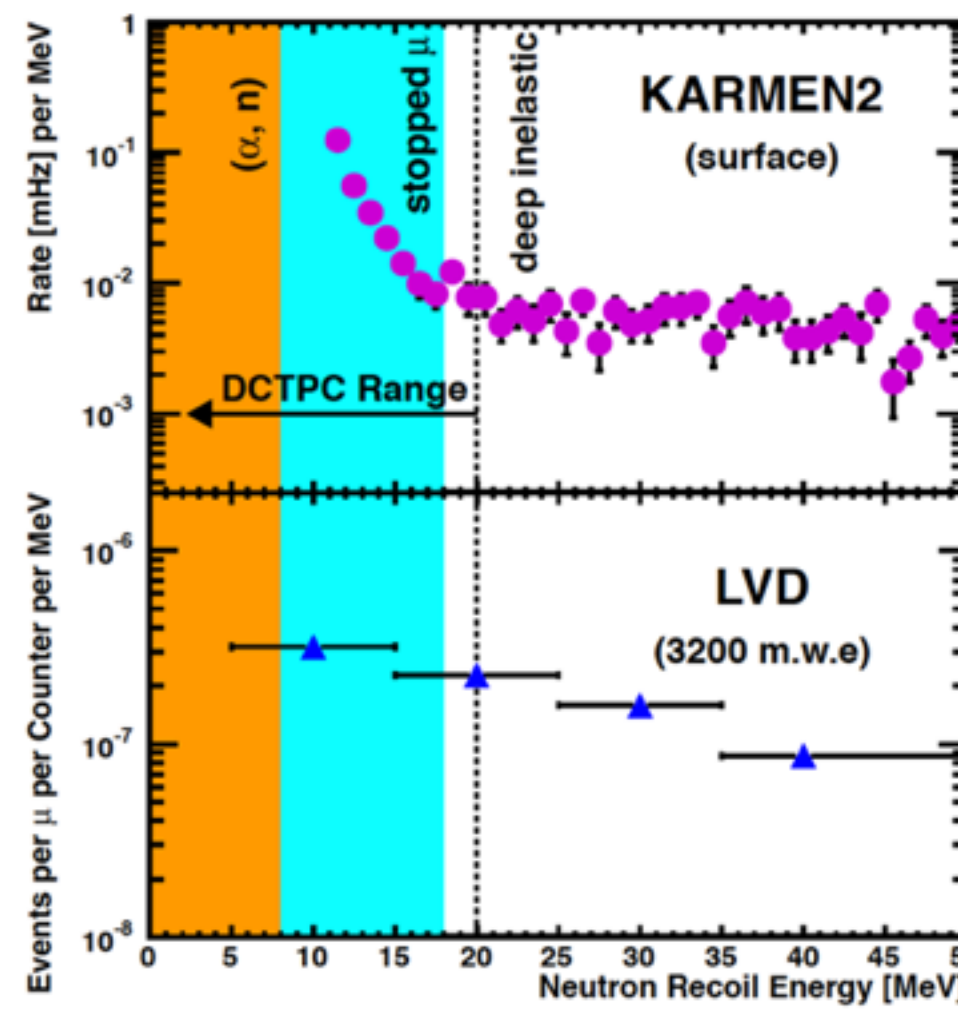
No simple way to reject fast neutrons, measured at high energy and extrapolated at low energies assuming a flat spectrum

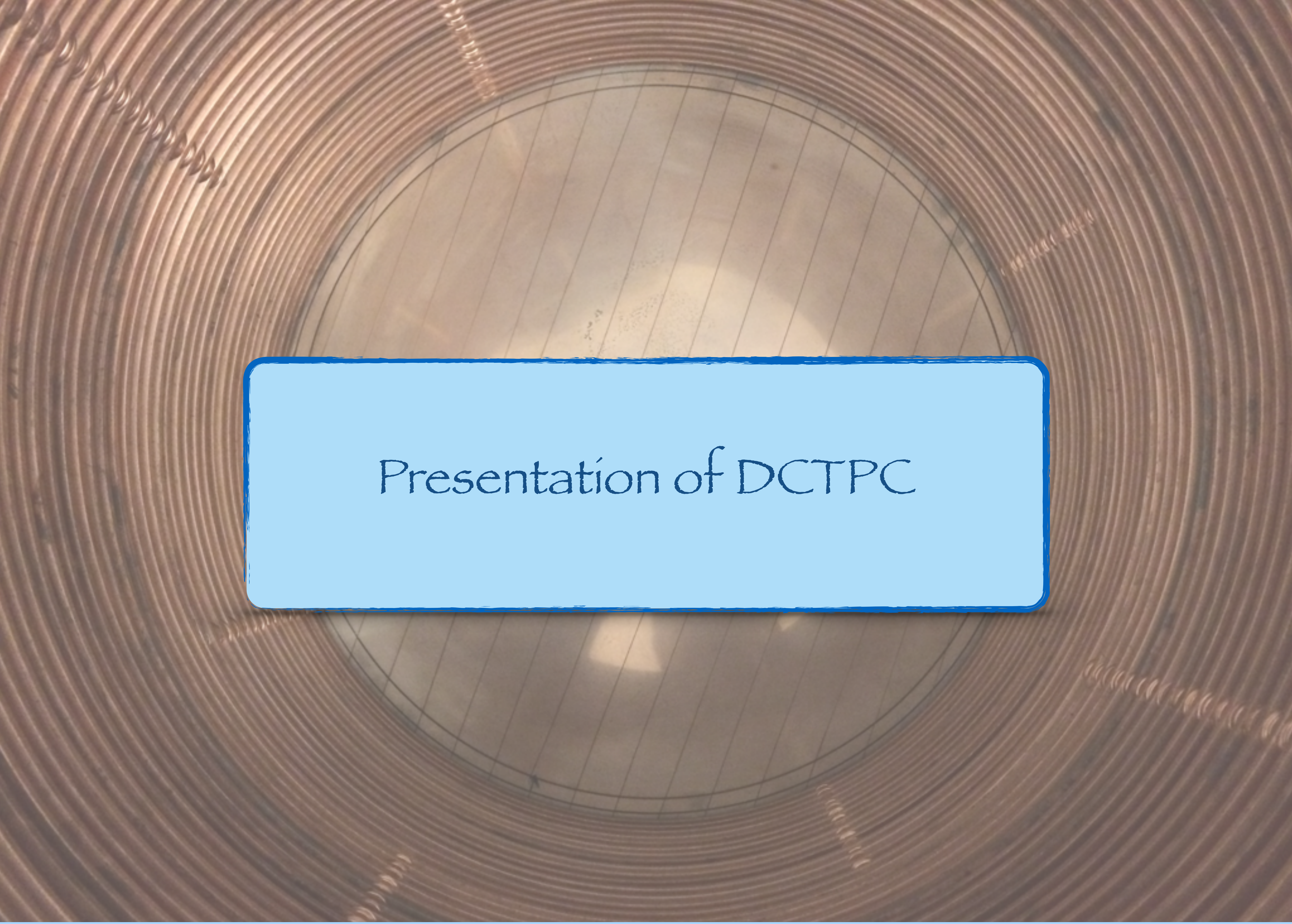
Motivations for DCTPC

- Very few neutron measurements at shallow depths
- Important background for neutrino oscillation, double beta decay, or dark matter experiments
- Measurement in Double Chooz near and far hall will provide a crucial calibration point for the fast neutron background model in MC



Double Chooz 2014





Presentation of DCTPC

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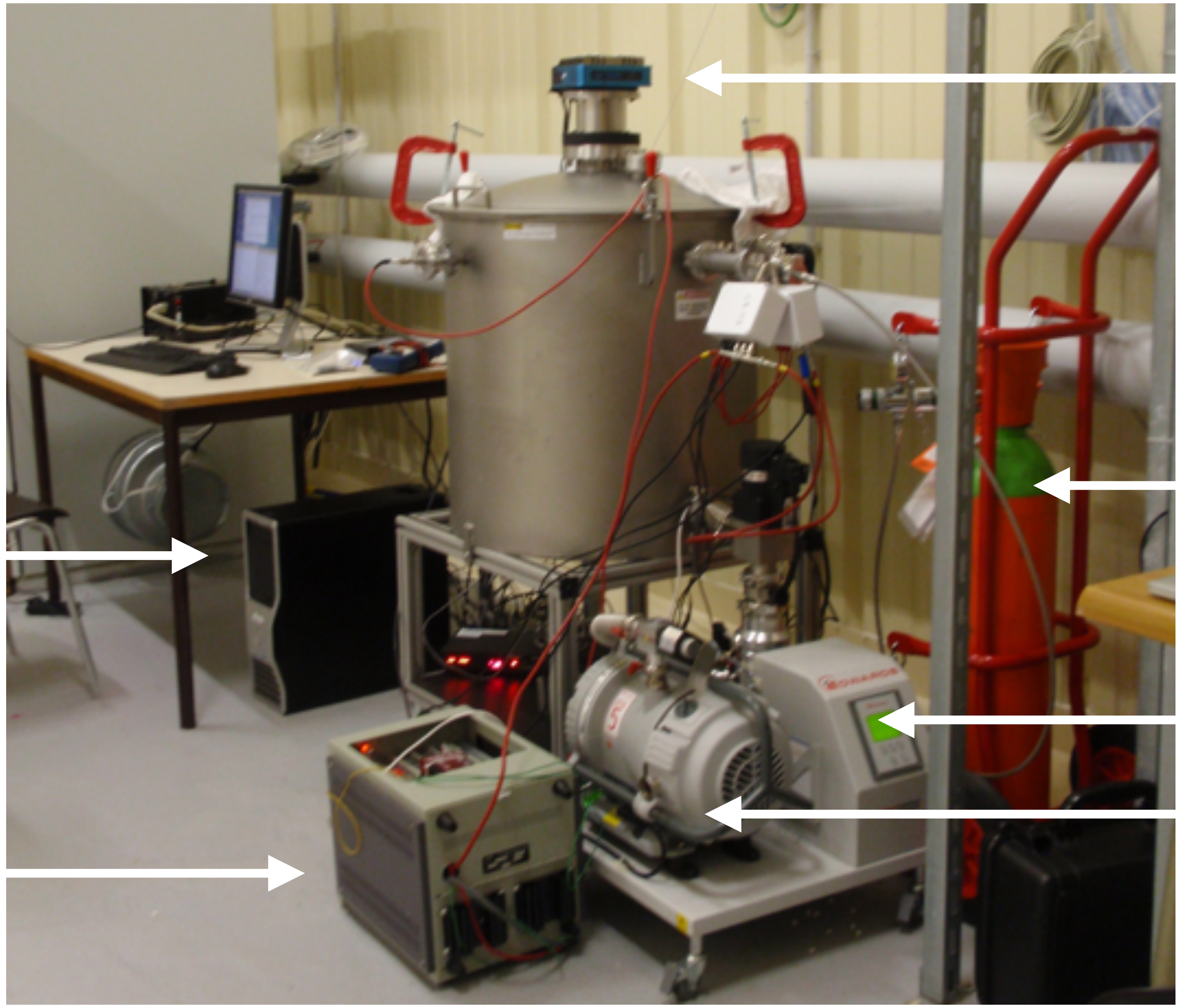


TPC took six months of data in DC's near lab
it has currently been taking data in DC's far lab for one month

Presentation of DCTPC

0.8 bar
CF4 (12.5%)
He (87.5%)

CCD camera

Cathode mesh

Drift cage
(160 V.cm^{-1})

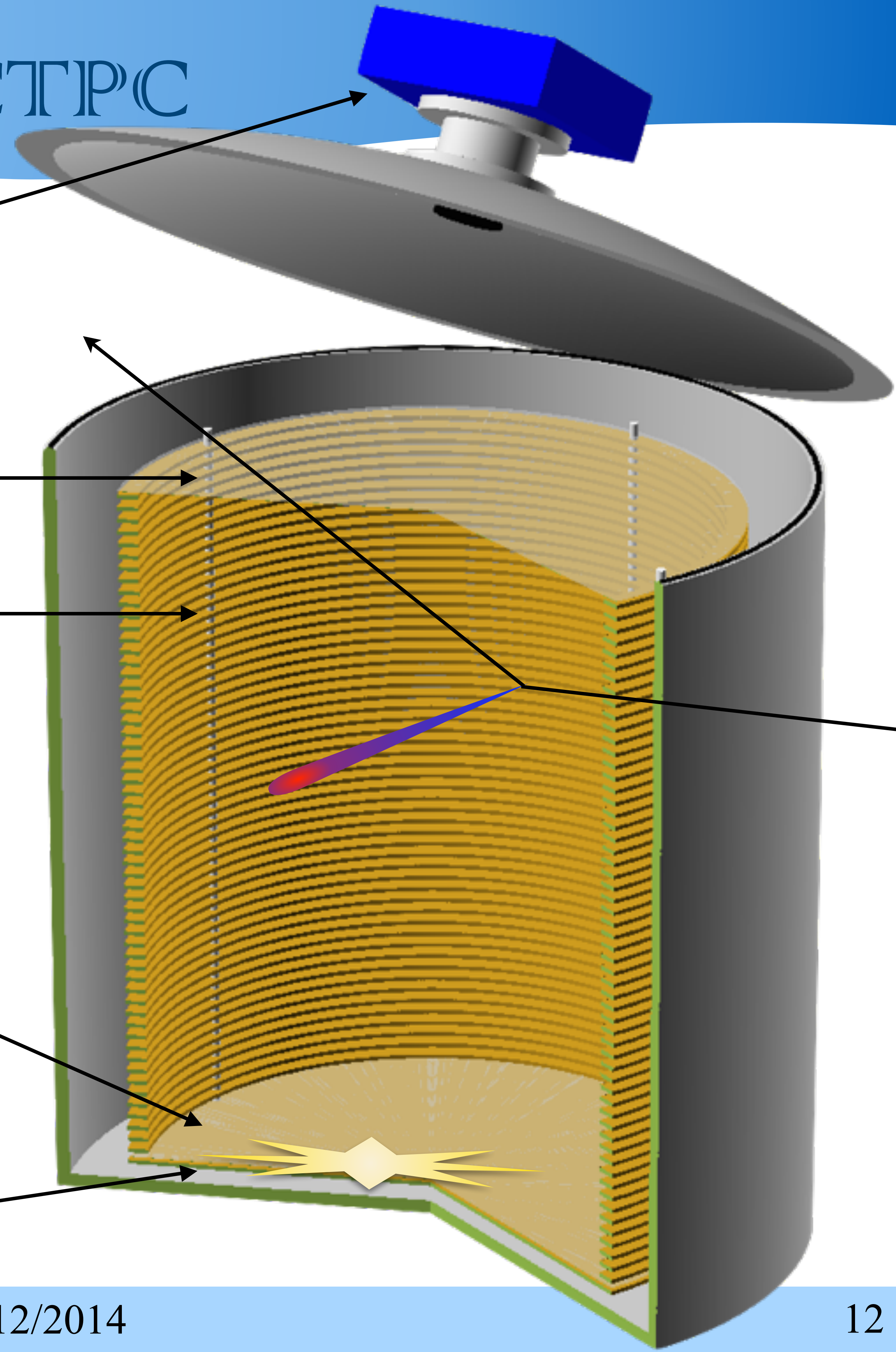
Primary ionization track

Drift

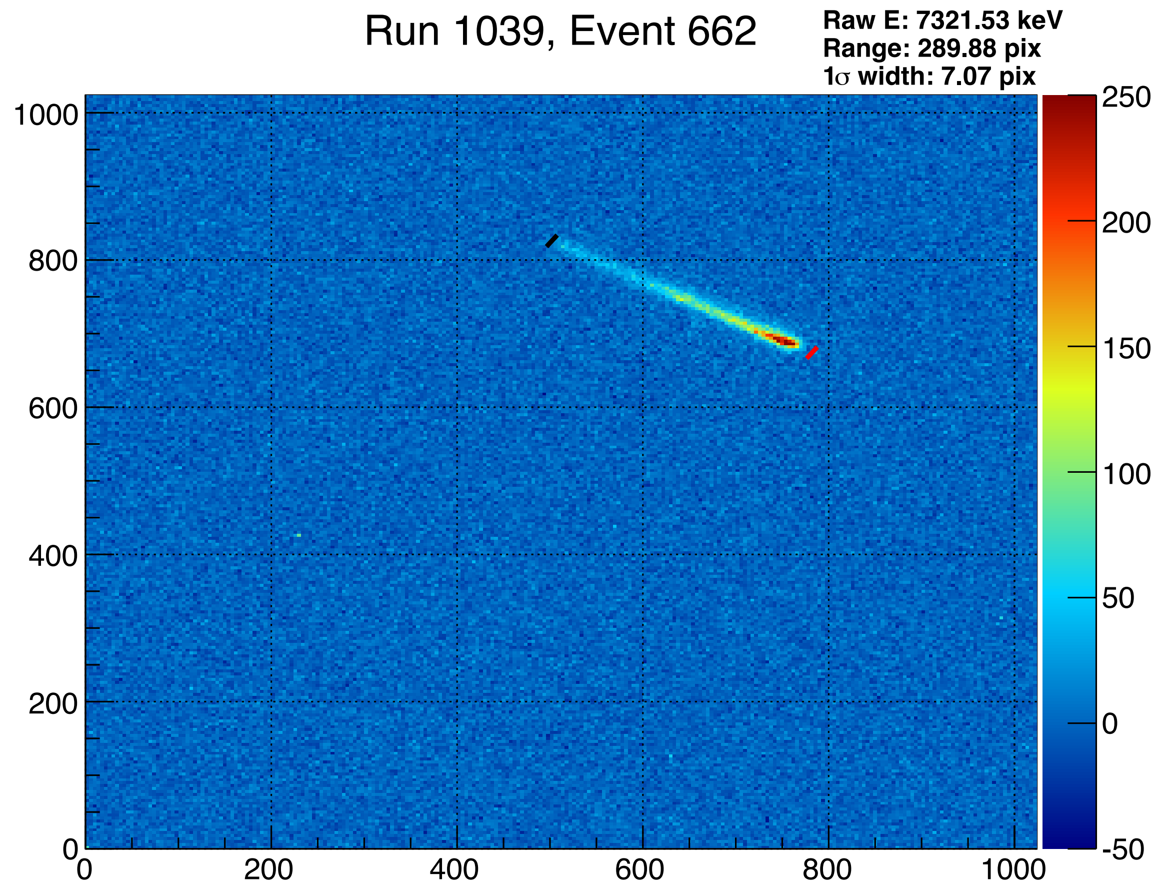
Ground mesh

Amplification

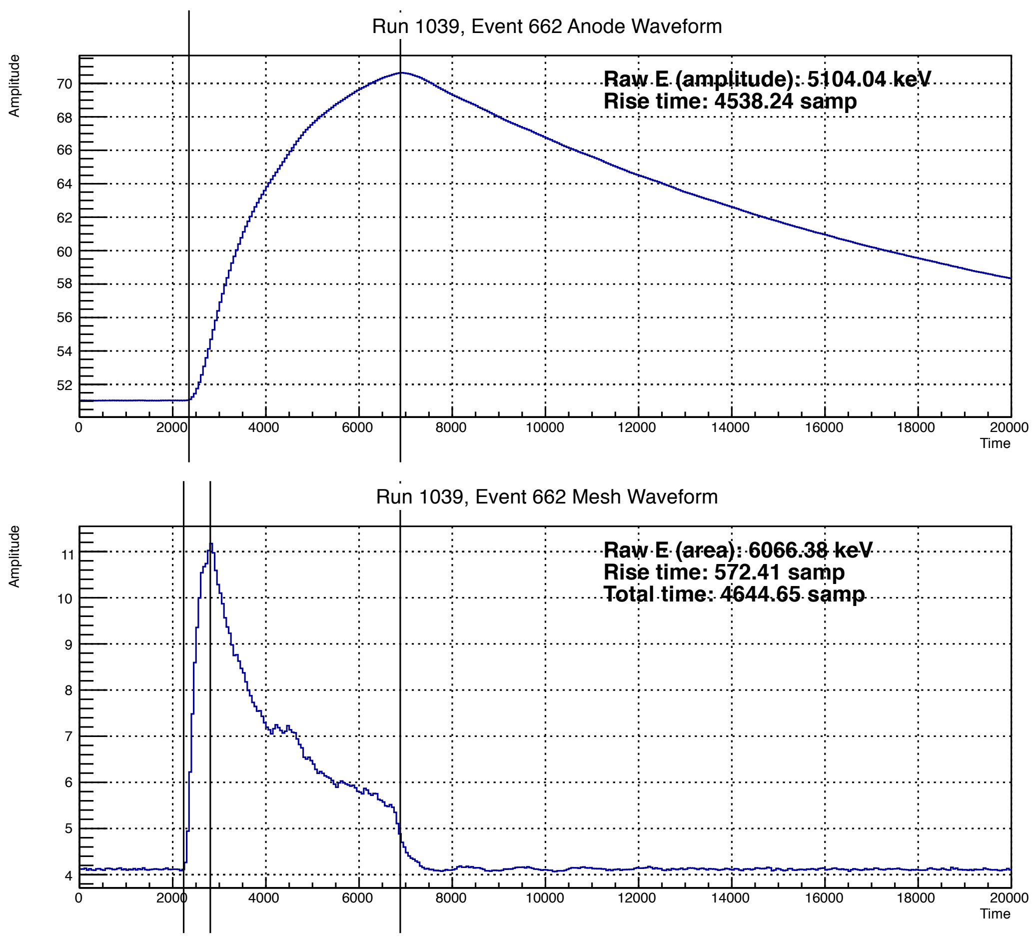
Anode plate
(2 kV.cm^{-1})



Event Read-out



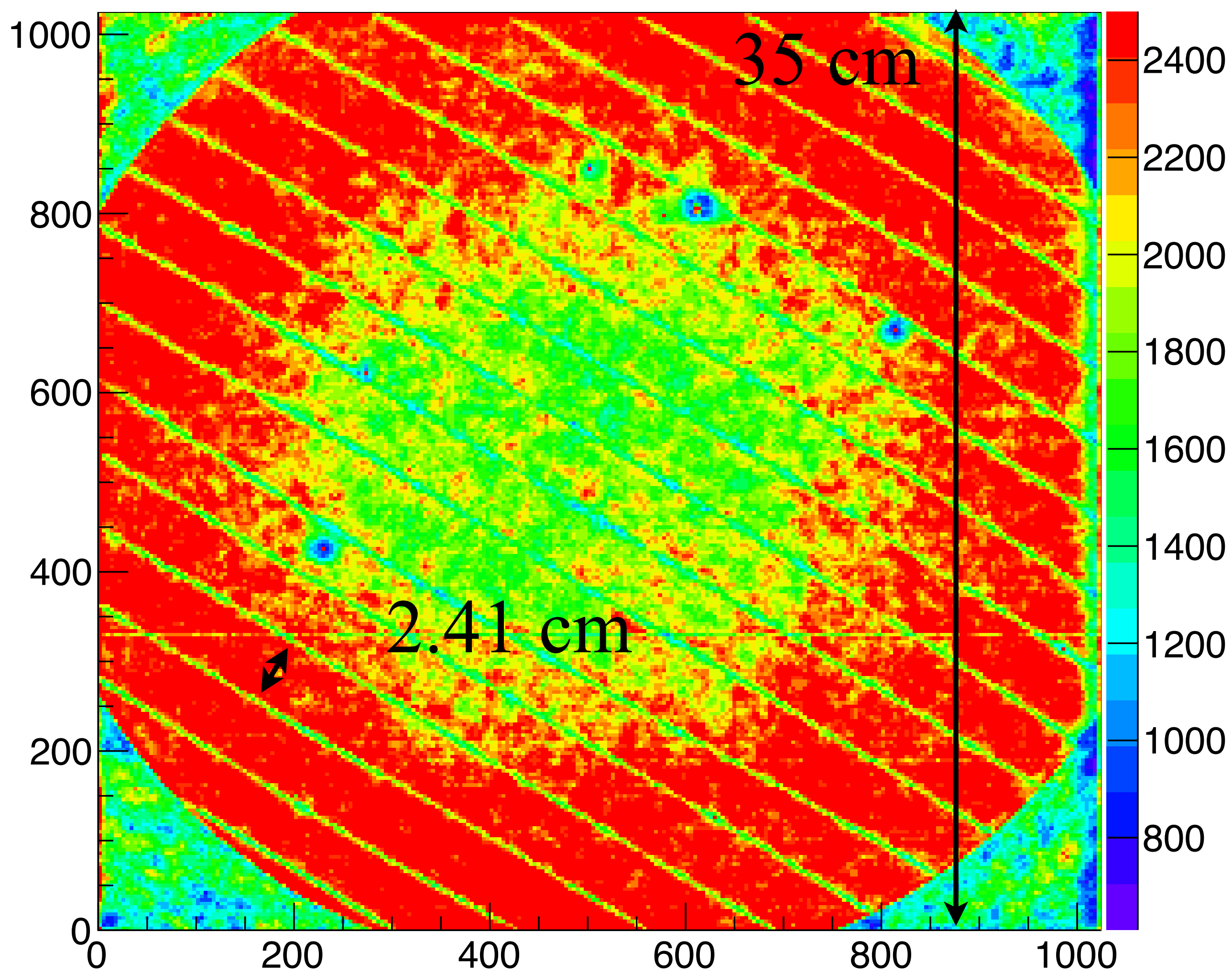
CCD read-out, 1s integration time

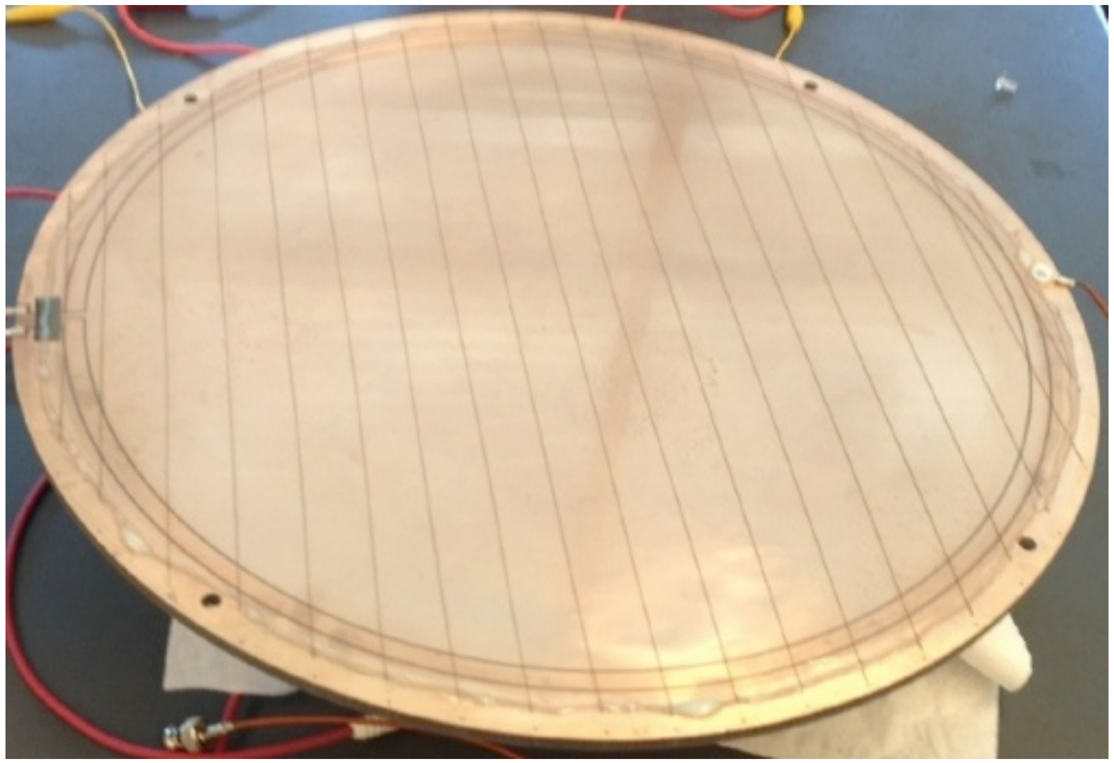


Waveform read-out, on anode plate (top) and ground mesh (botom)

All three read-outs provide an energy measurement
The CCD provides the position and the projected length of the track
The WF provide the e^- collection time

Spatial Calibration





By adding up all CCD images between two lid openings, we are able calibrate the position of the camera w.r.t. the center of the anode and to get the resolution of the images. (0.28 mm/pixel)

The lines with lower gain are spacers to keep a constant distance between the ground mesh and the anode plate.

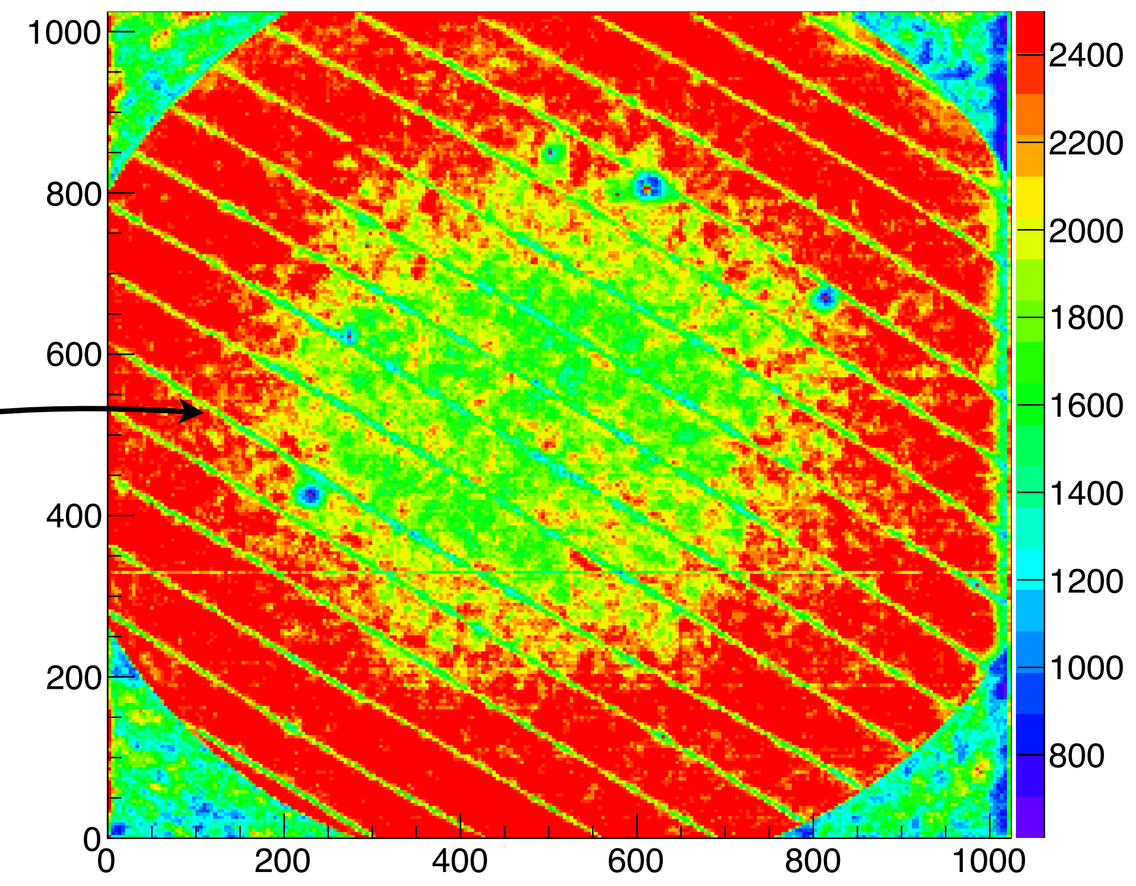
DCTPC Energy Resolution

Expected Background

Low pressure gas + high CCD sensitivity threshold : not sensitive to MIP

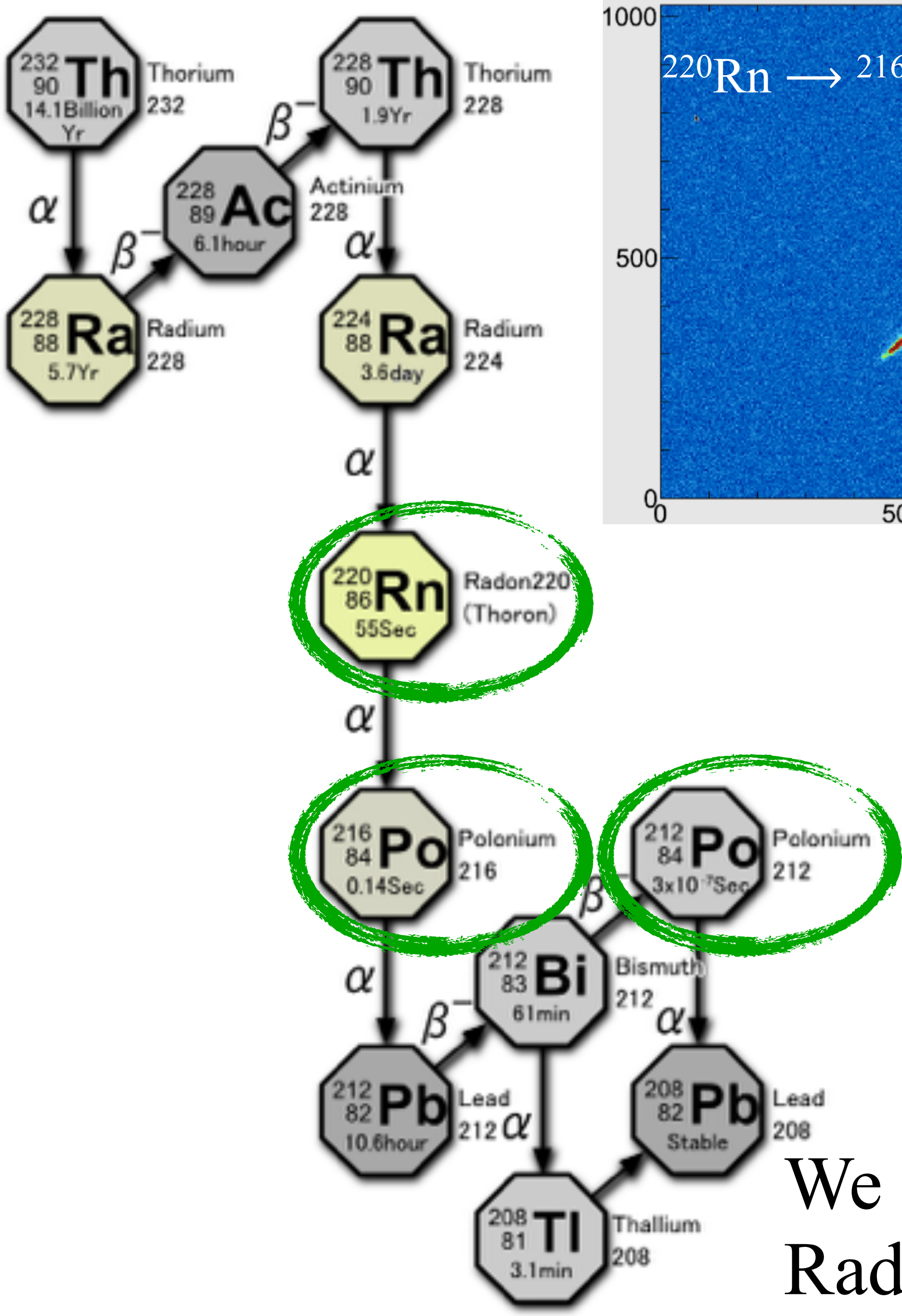
- No atmospheric muon
- No gamma
- No electron

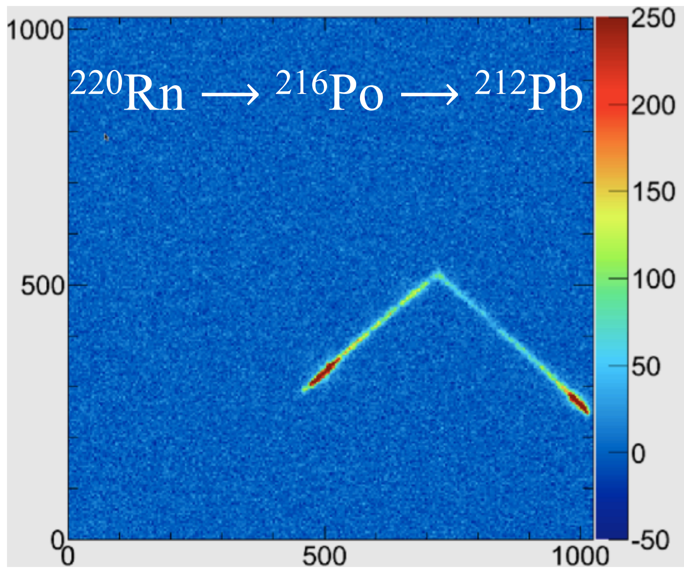
only background : α from the rings and from Radon outgasing from the vessel

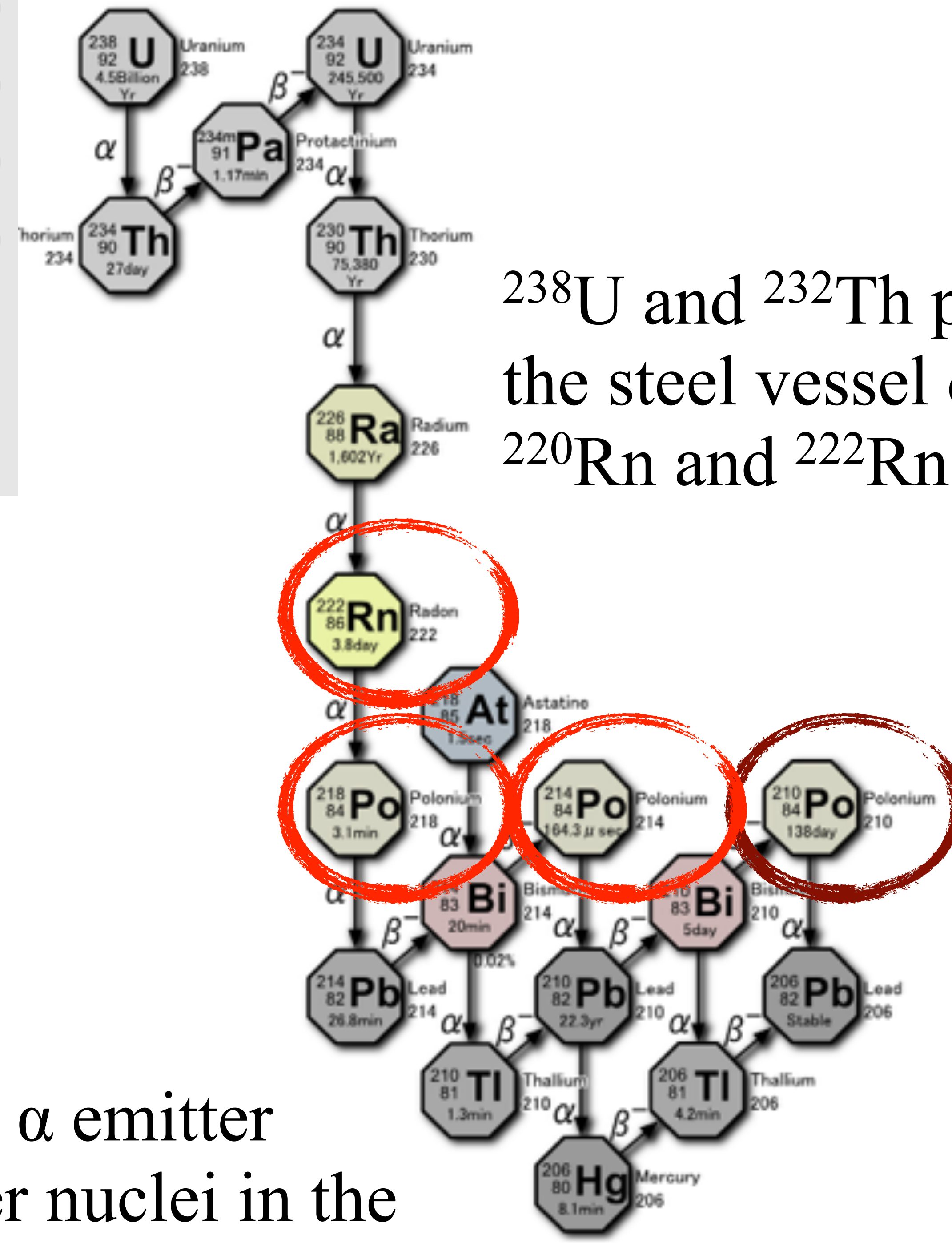


Dead time induced by sparks and pos-spark recovery

Alpha contamination from Rn



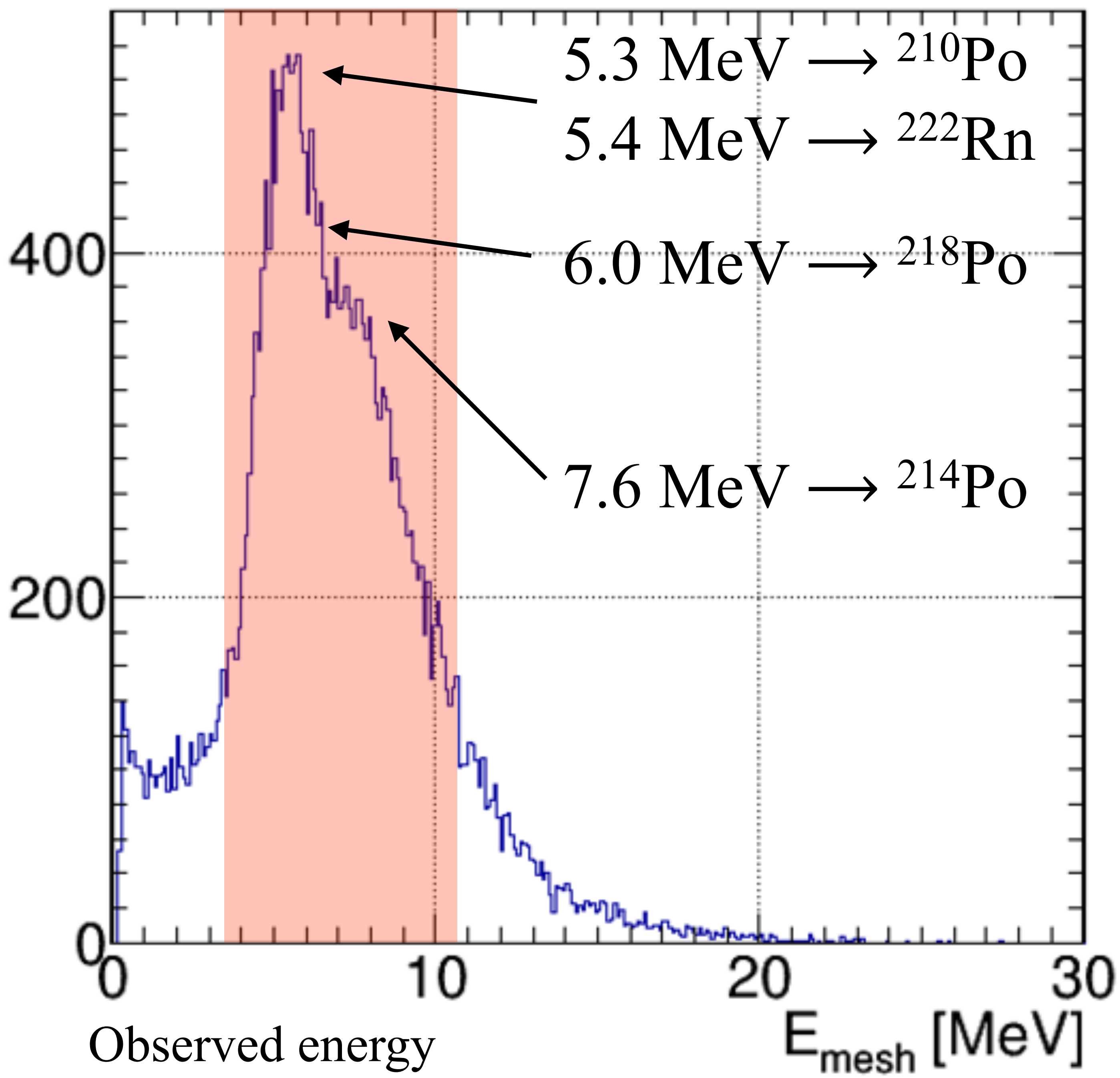




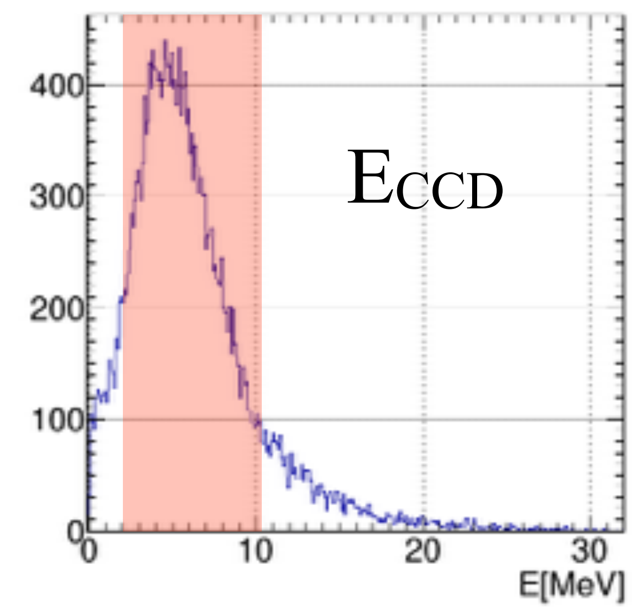
^{238}U and ^{232}Th present in the steel vessel decay into ^{220}Rn and ^{222}Rn

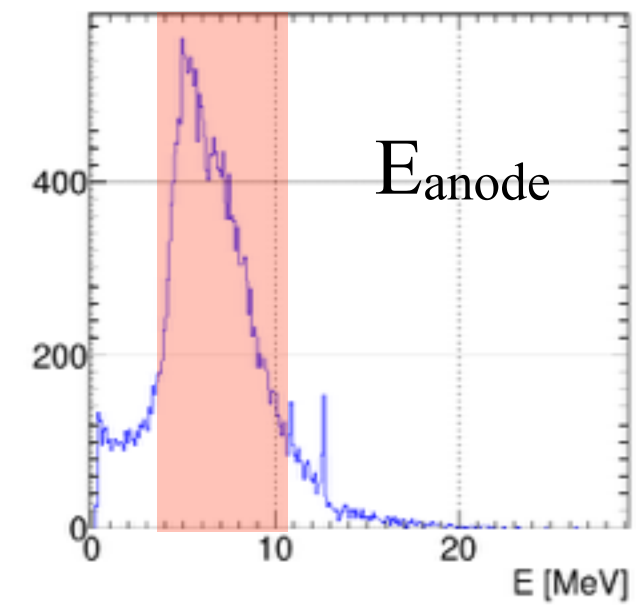
We can see the α emitter Radon daughter nuclei in the TPC

Built-in energy measurement



Observed energy



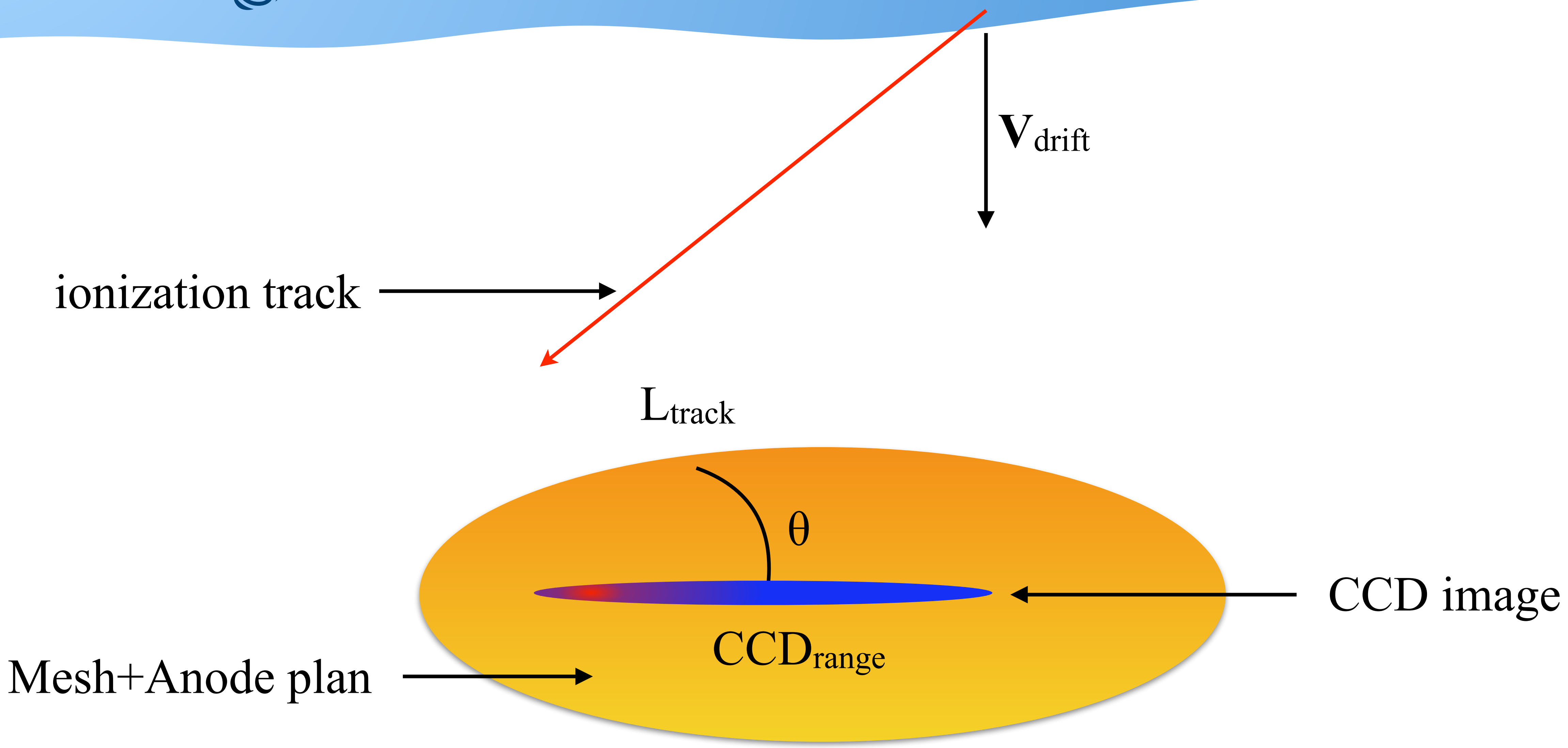


Measurement of energy by integrating the WF collected on the ground mesh

Resolution of ~10%
we can distinguish isotopes from ^{222}Rn decay chain

Biased by after pulses and pedestal choice

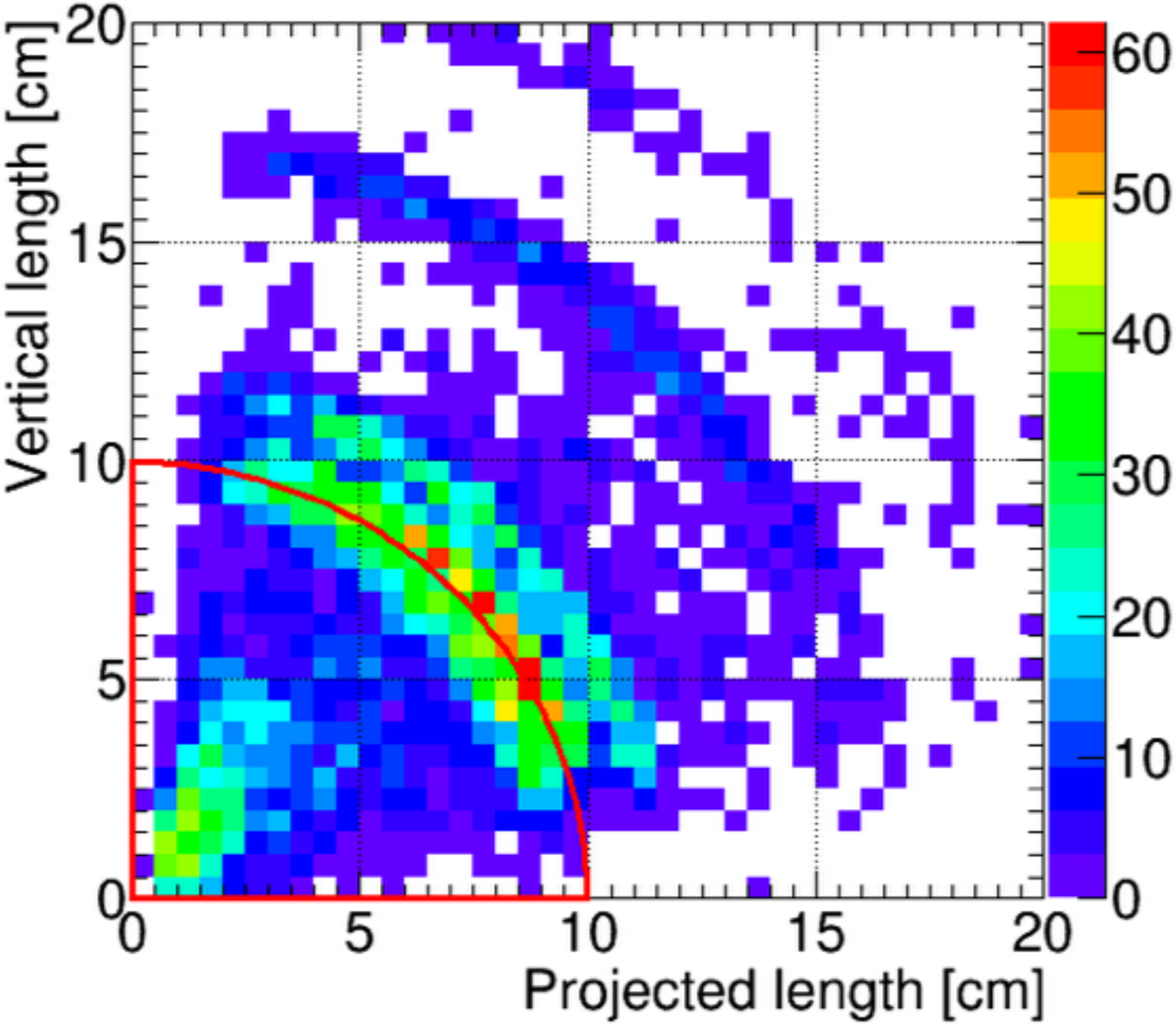
3D length reconstruction



$$L_{track} = \sqrt{CCD_{range}^2 + (T_{deposit}V_{drift})^2}$$

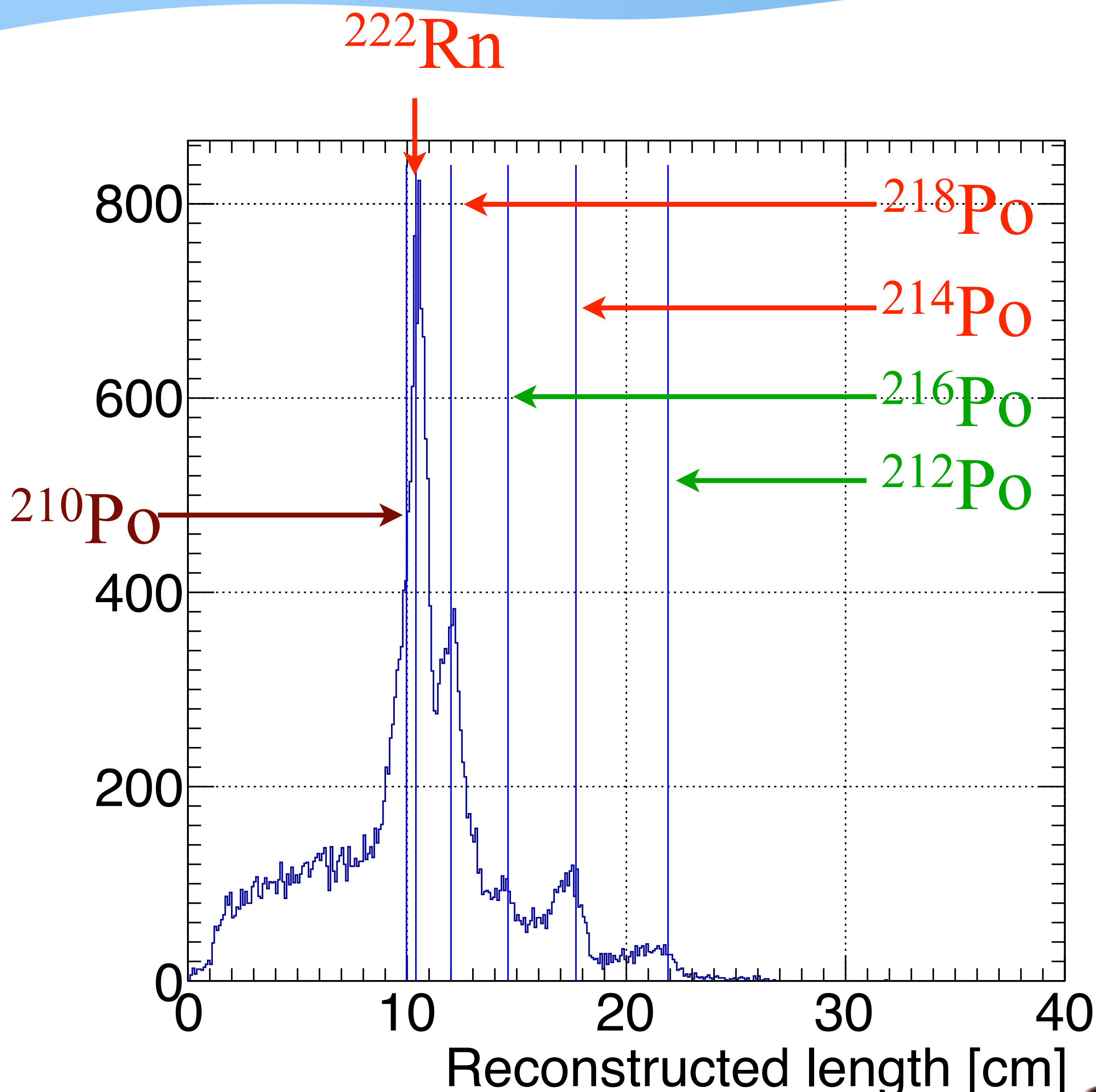
Drift speed measurement

$$L_{track} = \sqrt{CCD^2_{range} + (T_{deposit}V_{drift})^2}$$



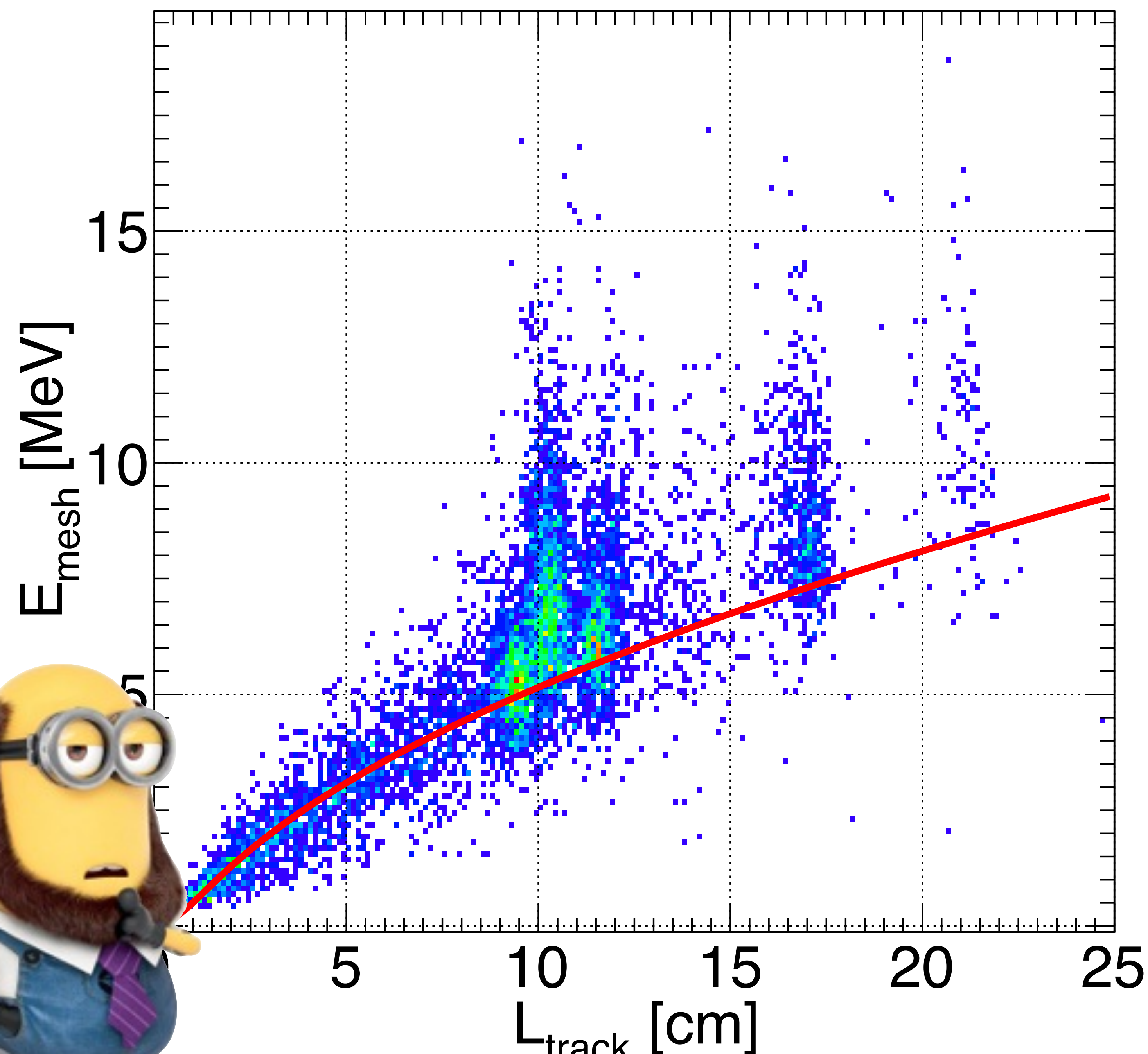
Events with the same energy (i.e. same length) are expected to line up on a portion of circle in the (projected length v.s. vertical length) plane if we have the right drift speed

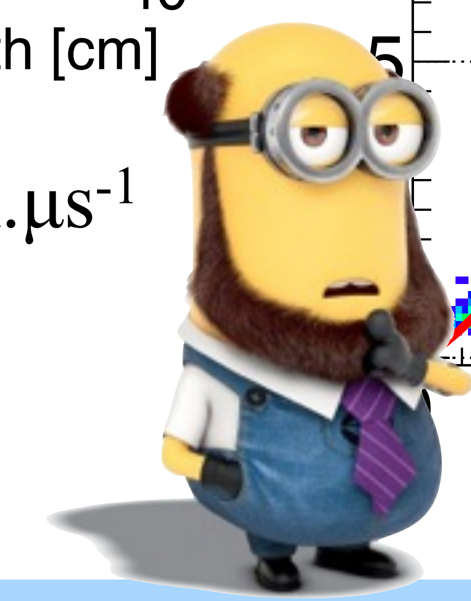
3D length reconstruction



$V_{drift} = (1.33 \pm 0.005)\ cm.\mu s^{-1}$

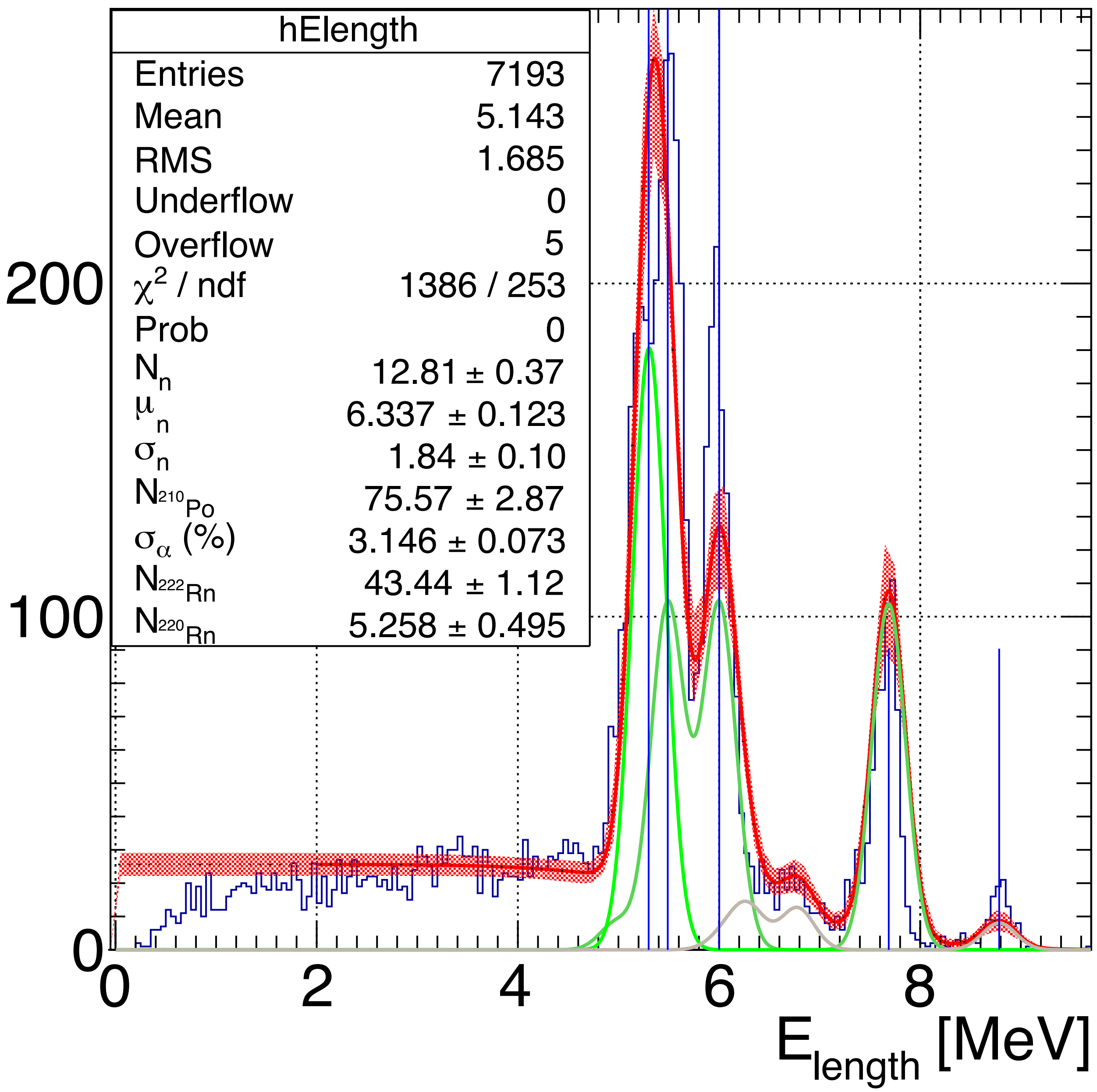
The energy/length correlation fits the theoretical curve (red line)





Improved energy measurement

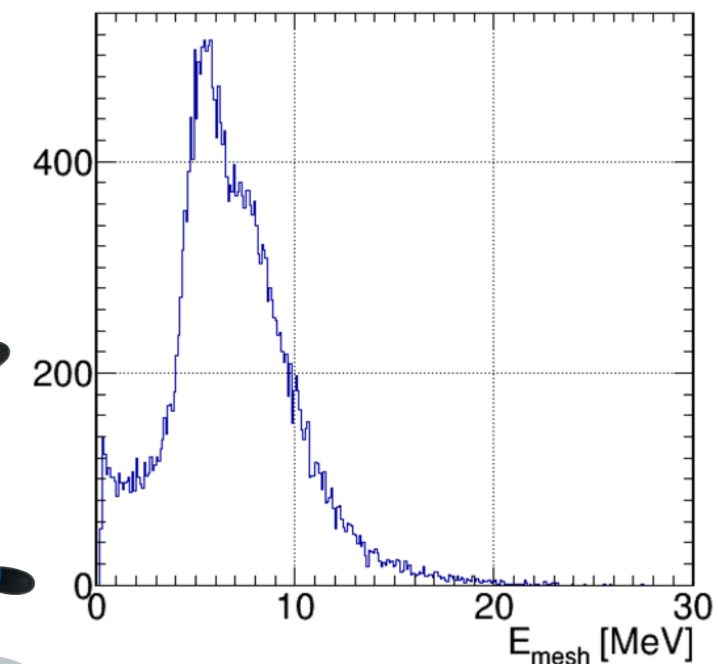
3D length-based energy



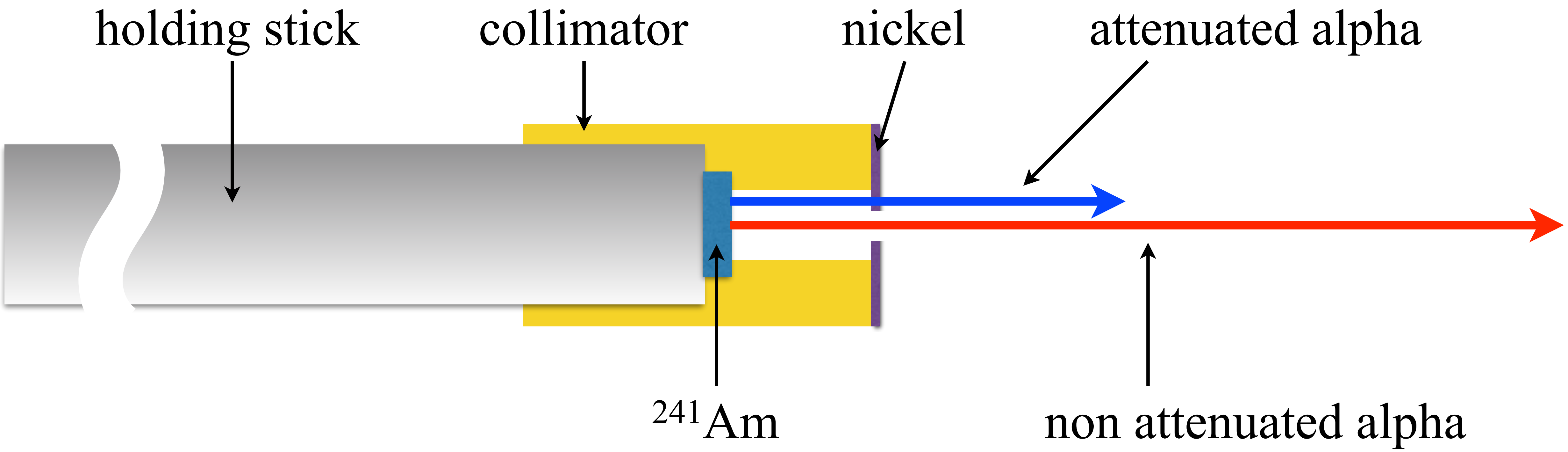
Much better energy resolution by using the 3D length information on the track (3% instead of 10%)

Resolution of the fit limited by our knowledge of the underlying neutron spectrum

α from Radon decays are good calibration sources at high energy, how to be sure we don't have distortions at low energy?

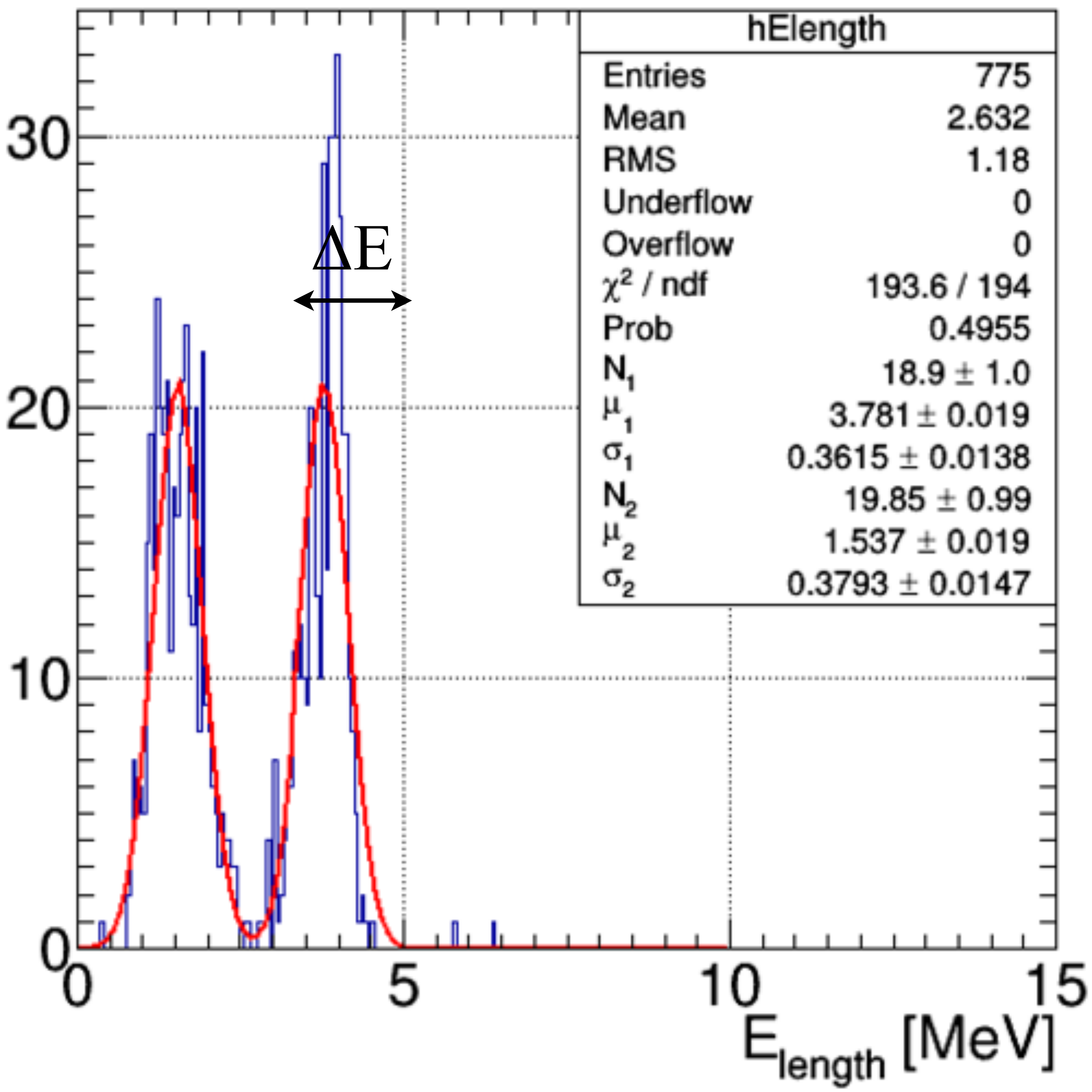


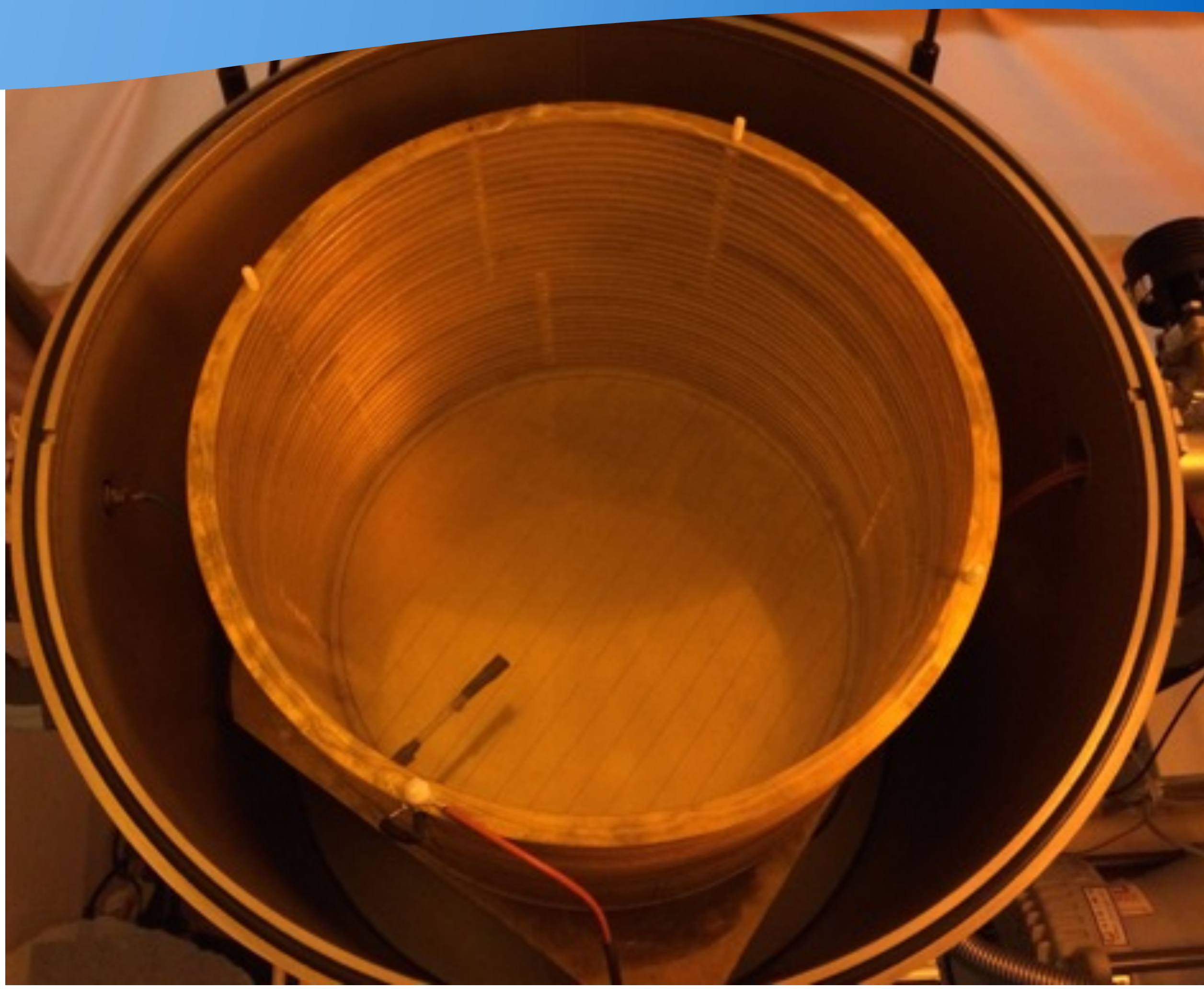
Low Energy calibration source



^{241}Am source attenuated by a 4µm-thick nickel source. We don't know a priori the energy of the α from ^{241}Am (source from a smoke detector) so we left out a hole in the nickel, to measure the energy loss in the foil and have an absolute calibration

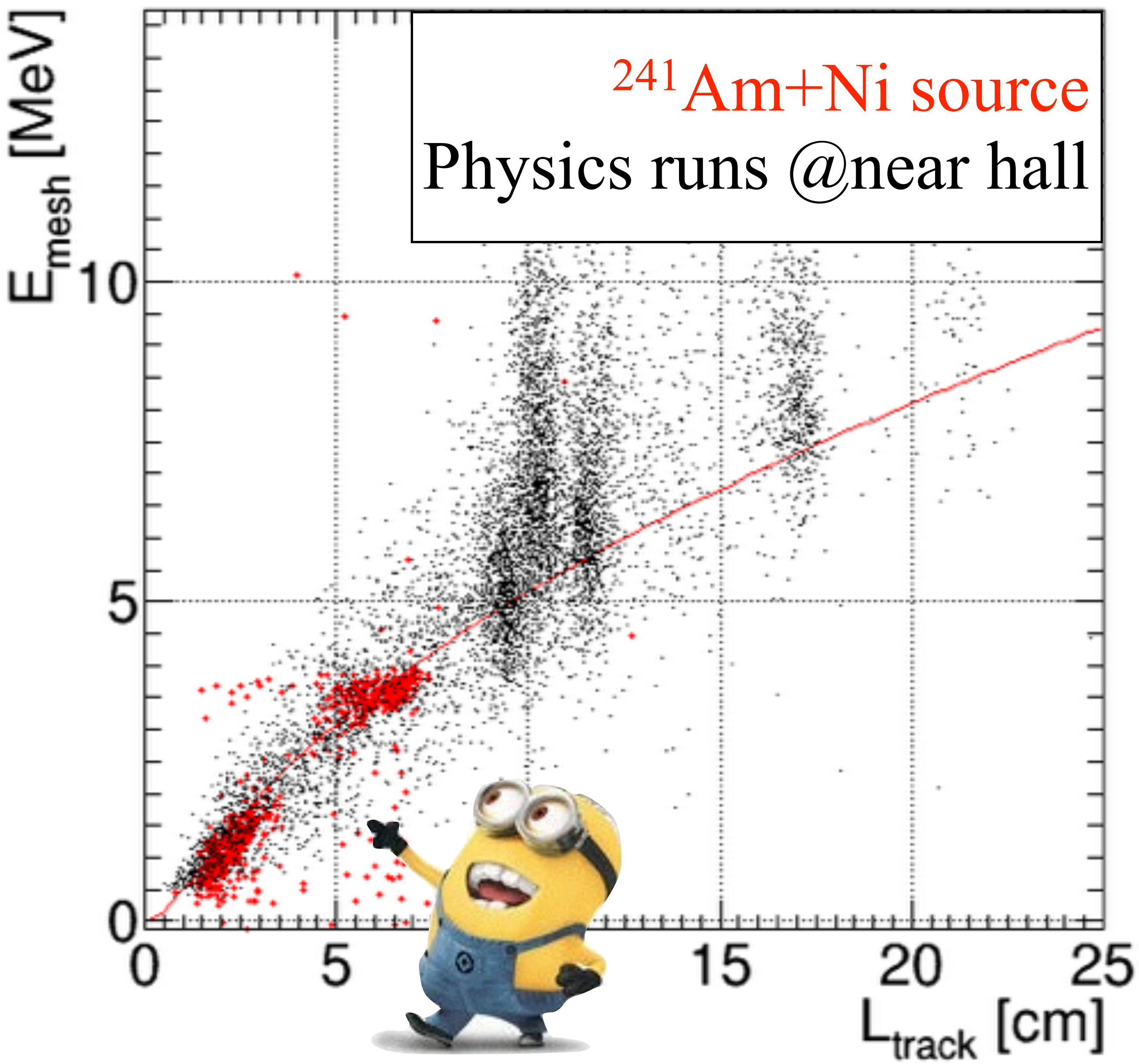
Low Energy calibration source





we measure $\Delta E = 2.24$ MeV for an unattenuated energy of 3.78 MeV, this is compatible with a 3.99 μm thick nickel foil!

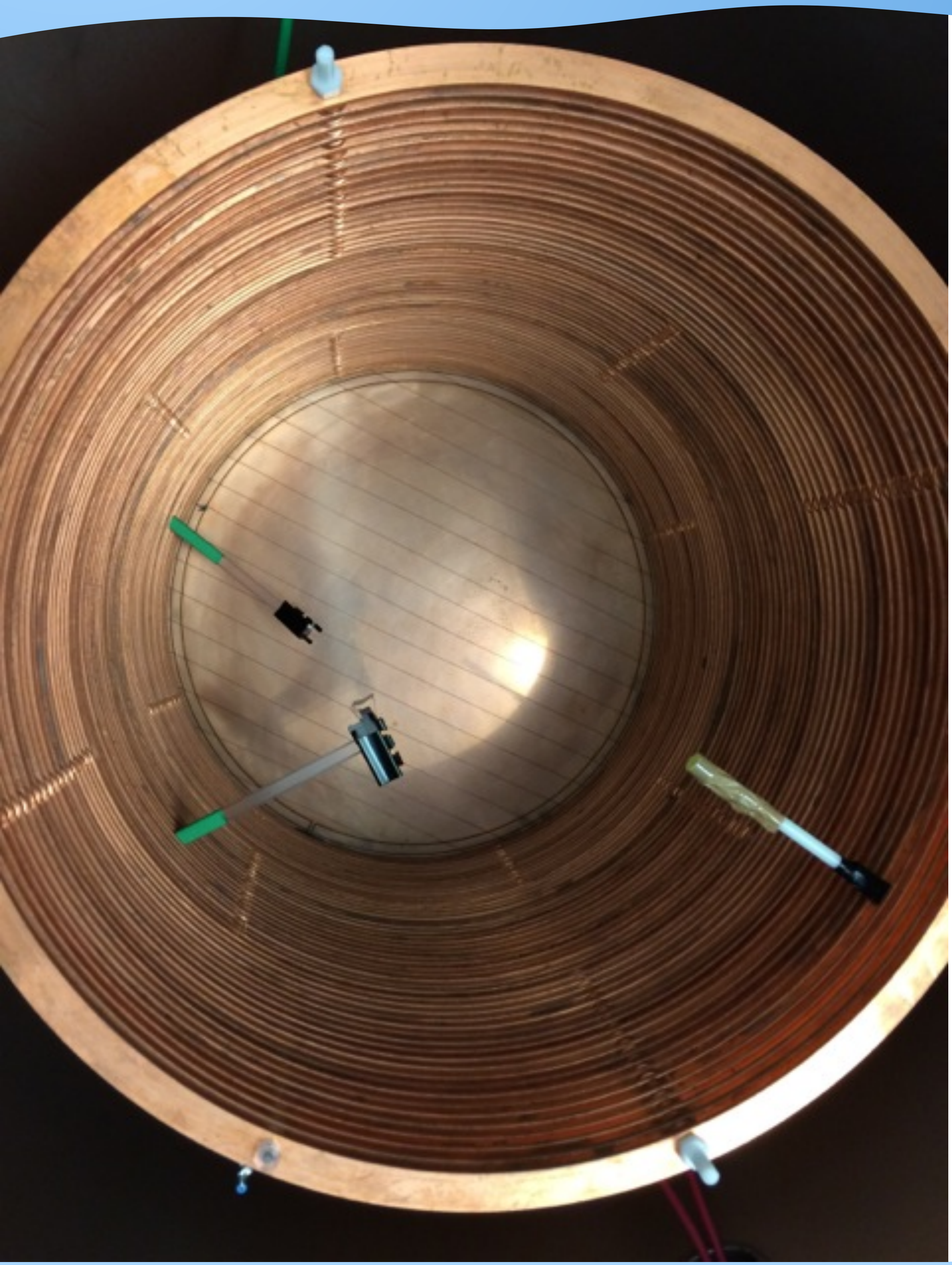
Comparing calibration to data



Calibration points line up perfectly on the expected curve and with our data points :

Our length measurement is a valid way of measuring energy for low energies as well as high energies

Absolute z calibration



Long drift → loss of primary e^-
→ lower gain
→ more diffuse tracks
→ shorter reconstructed tracks

α expected:

- from the rings (fiducial volume)
- from Rn (gas → homogeneous)
- from Po (deposited → bottom parts)

We need to reconstruct the altitude of the tracks to improve our energy resolution and reduce the background

Plans for DCTPC the future

- Take data at the far hall
- Absolute z reconstruction
- Calibration altitude/visible energy
- Simulation of the TPC's behavior
- Computation of the detection efficiency
- Neutron spectrum
- Move to US (MicroBOONE)

Summary

- DCTPC's energy resolution improved up to 3%
- We have a good knowledge of our background (better than our actual signal!)
- Calibration at high energy comes for free!
- Calibration at low energy to make sure we don't bias our reconstruction
- Still a lot of excitement to come!

Thank You For Your Attention !