Data-driven validation of the ProtoDUNE-Vertical Drift geometry using calibration systems

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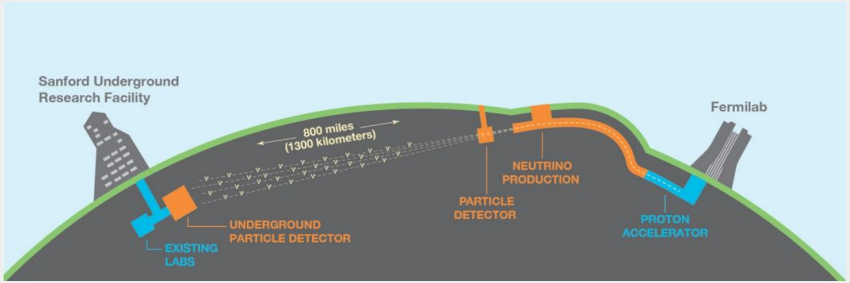
Workshop summer internship LIP

The Deep Underground Neutrino Experiment (DUNE)

DUNE is a long baseline neutrino oscillation experiment based in the USA.

DUNE's science goals include:

- Measurement of the δ_{CP} phase;
- Determining the neutrino mass ordering.



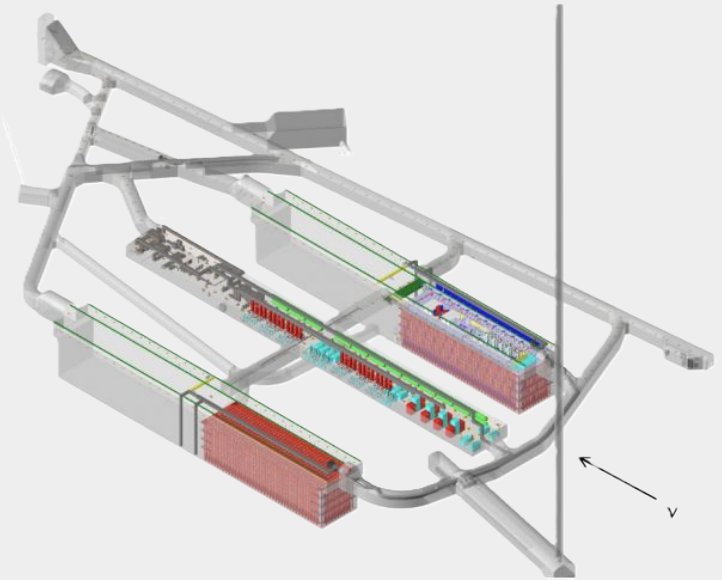
The experiment consists of 3 main components:

- Powerful neutrino beam;
- Near detector 574 m downstream from the source;
- Far detector 1285 km downstream from the source and 1.5 km underground.

Far Detector

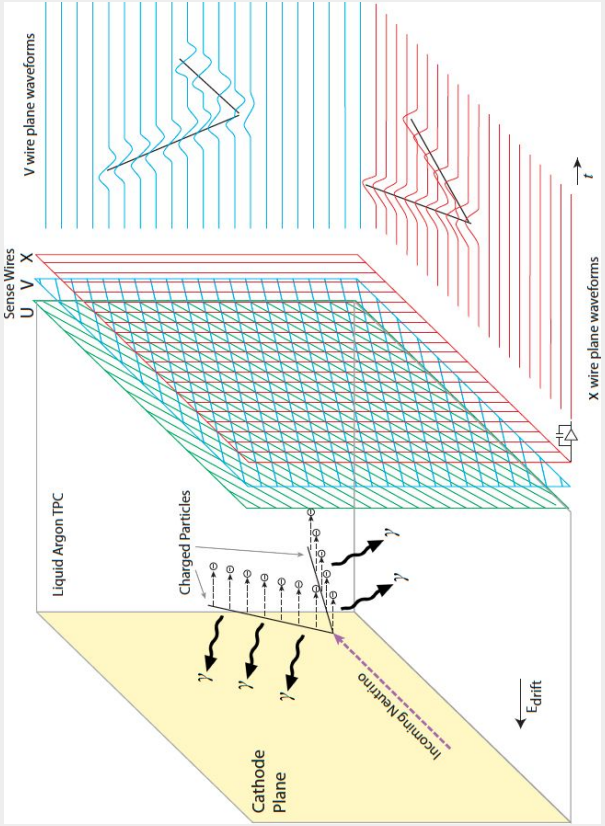
The far detector will be composed of four modules, where at least three will be liquid argon time projection chambers (LArTPC).

Each module will have a total LAr mass of 17.6 kt and a length of 62 m.



Vertical-Drift Technology

- Neutrino interactions produce charged particles which ionise the argon atoms;
- The ionisation electrons will drift opposite to the electric field and are then collected in strips;
- Combining the 2D projection of the ionisation tracks with the drift time, we can reconstruct the event in 3D;
- In VD, the electric field is vertical.



Working principle of a LArTPC.

Motivation

- Liquid Argon only exists at temperatures around 87K.
- At this temperatures the field cage bars can shrink down and move a little.
- The electric field inside the field cage must be as constant as possible
- So we have to know exactly here are the field cage bars.

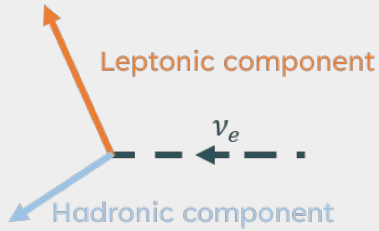
Detector Calibrations

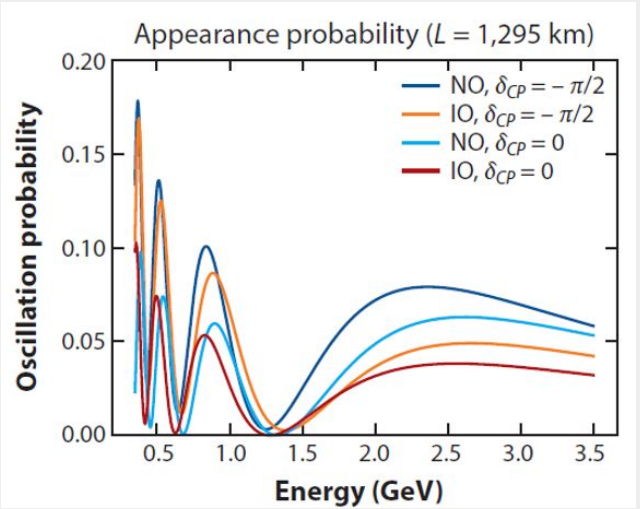
The neutrino oscillation probability depends on the energy. It is crucial to have a good neutrino energy reconstruction.

This is impacted by several parameters such as:

- Drift velocity;
- Electron lifetime;
- Electron-ion recombination;

$$E_\nu = E_{lep} + E_{had}$$





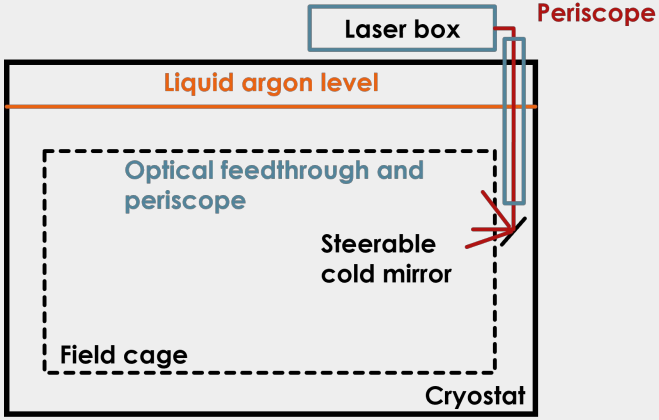
The ν_e appearance probability in a DUNE-like experiment. NO – normal ordering, IO – inverted ordering.

Laser System

Using an intense, UV laser beam, liquid argon can be ionized, creating long straight tracks.

With this we can calibrate several aspects:

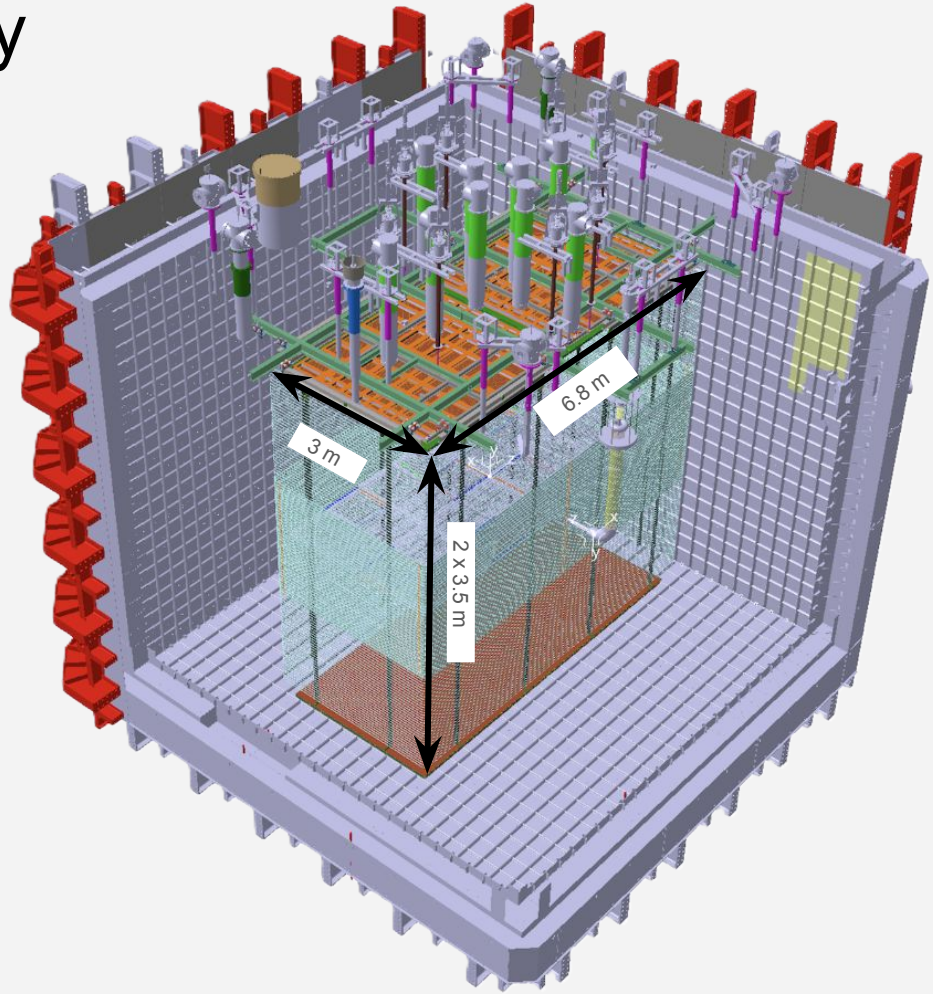
- Measure drift velocity;
- Measure the spatial and temporal uniformity of the electric field;
- Characterize the fiducial volume;
- Measure electron lifetime.



Detector

protoDUNE VD Geometry

- Three horizontal planes - Two Charge Readout Planes (CRP) and one cathode.
- Group of Field Cage Bars surrounding the three planes.
- Pool of Liquid Argon to interact with the particules.



Charge Readout Plane (CRP)

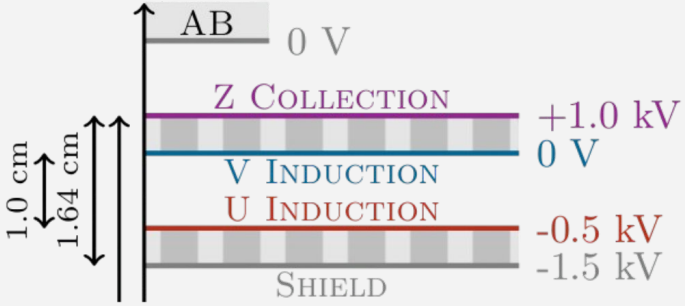
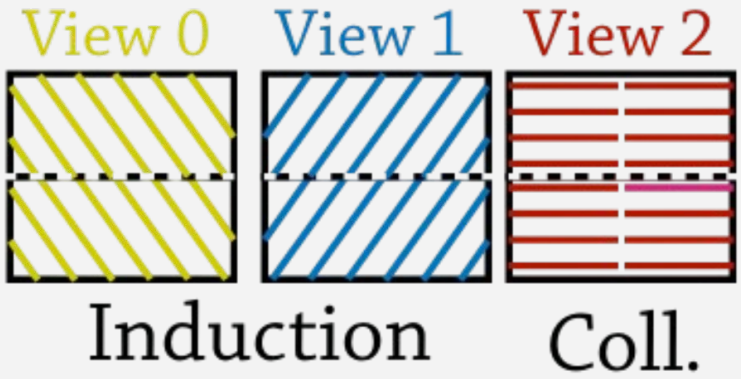


Illustration of PCBs views



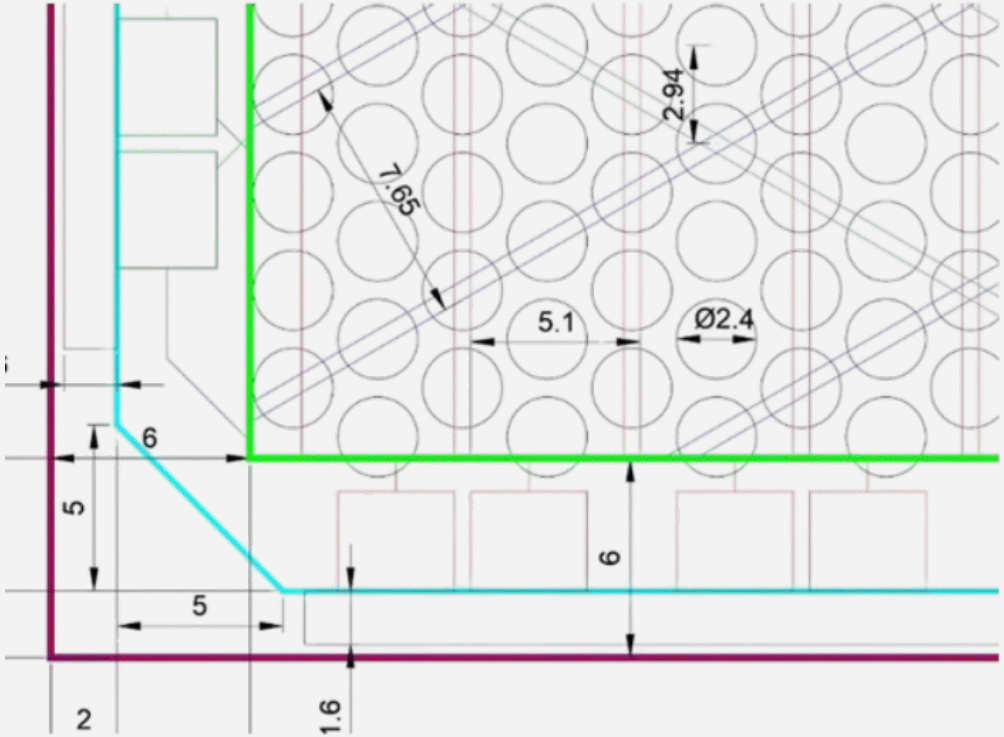
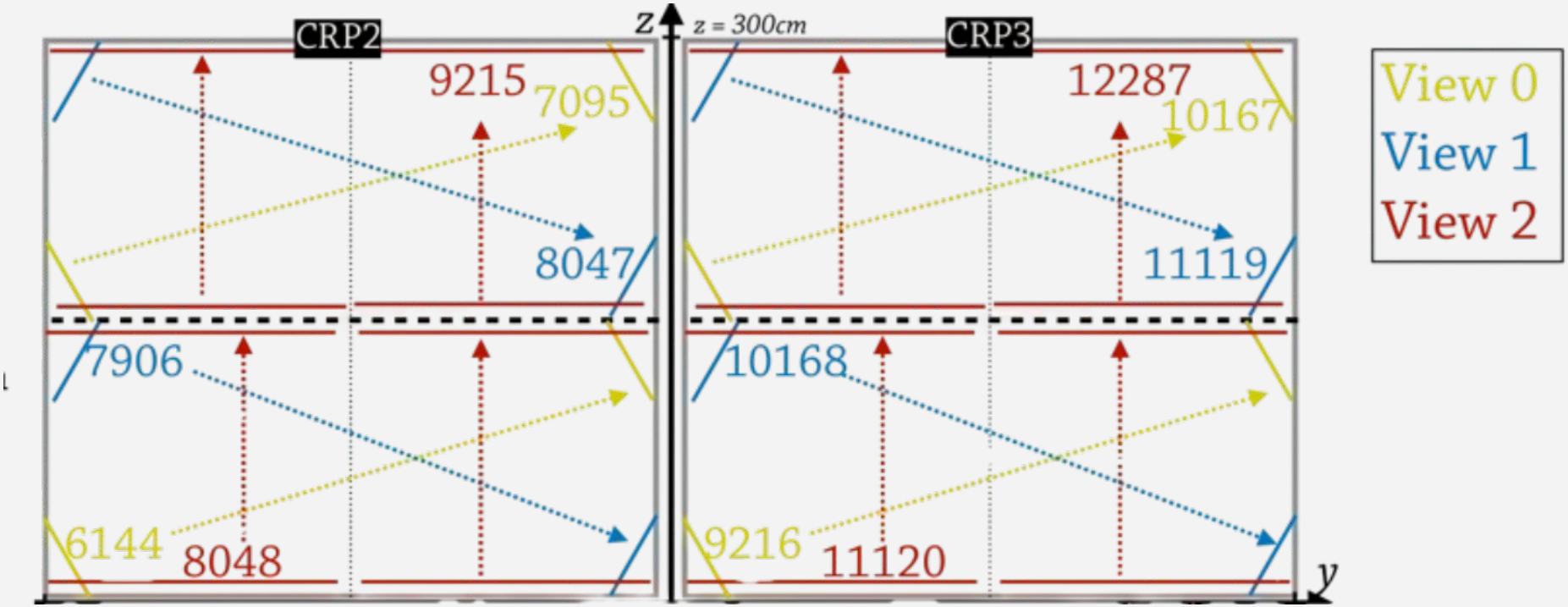


Illustration of all stripes and the holes

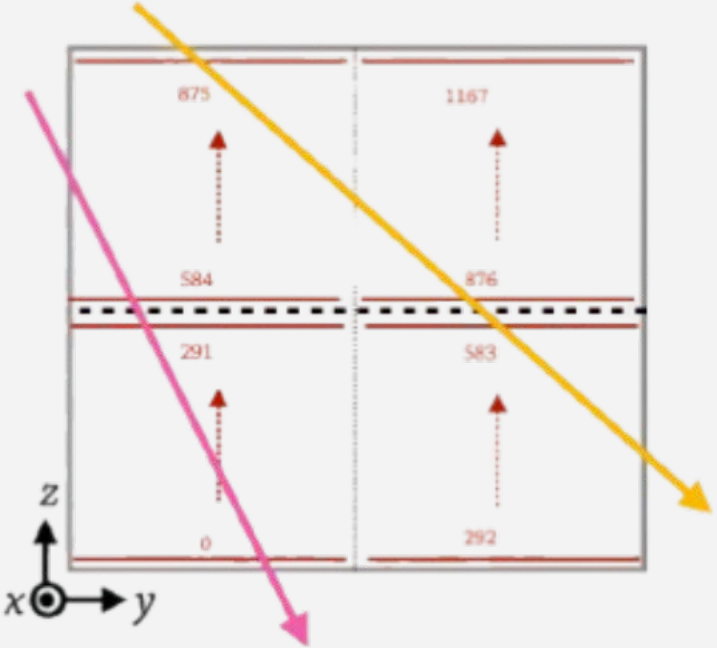
Histograms Interpretation



View of the top CRPs.

Histogram Interpretation

Examples, channels of the collection view



What it would look like on the event display

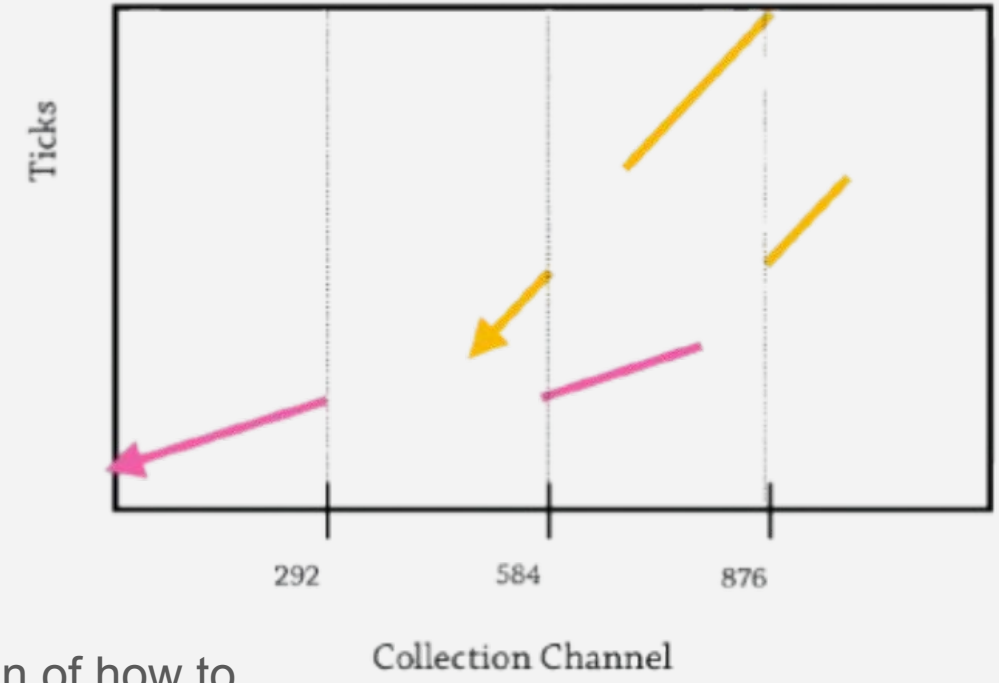
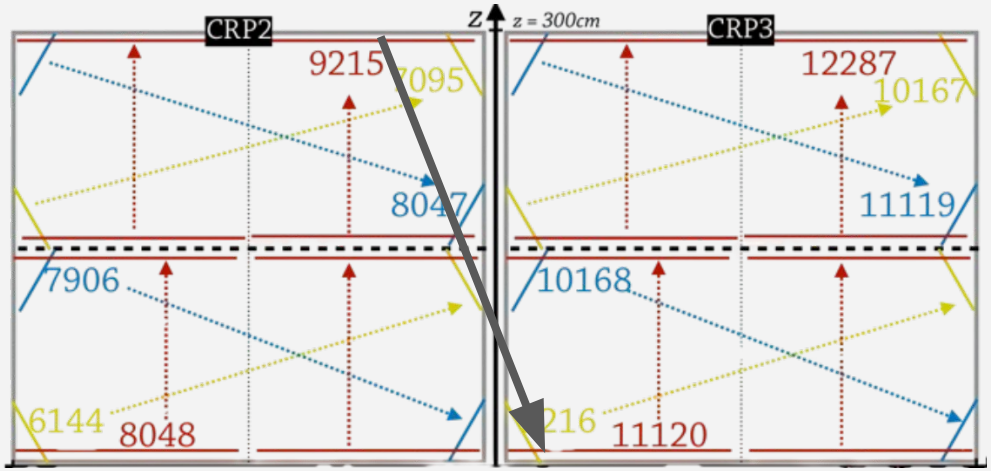
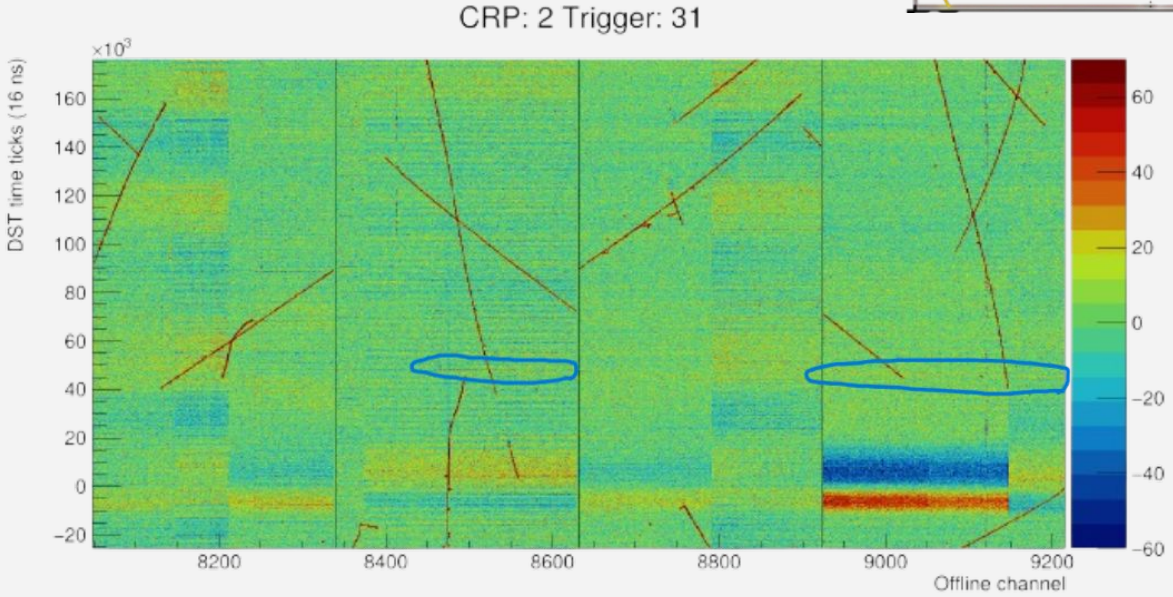


Illustration of how to interpret a histogram.

Histograms Interpretation

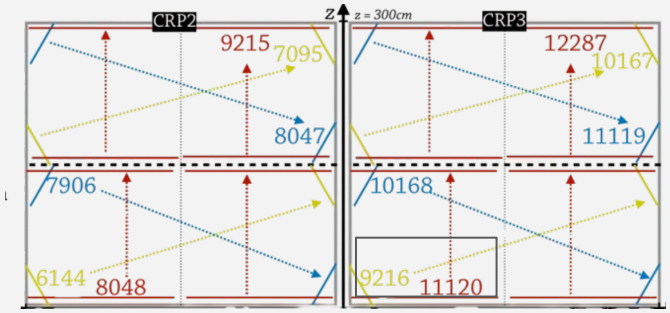




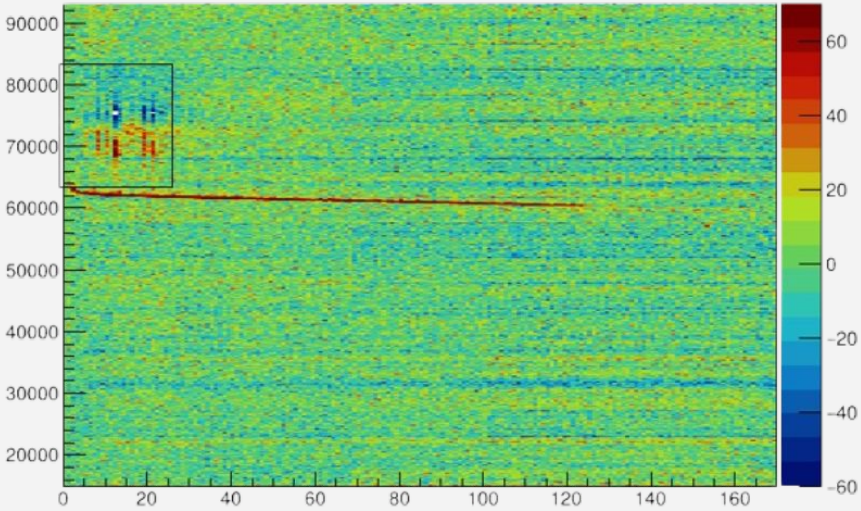
Event display of a laser run.

The work

Analysed Run

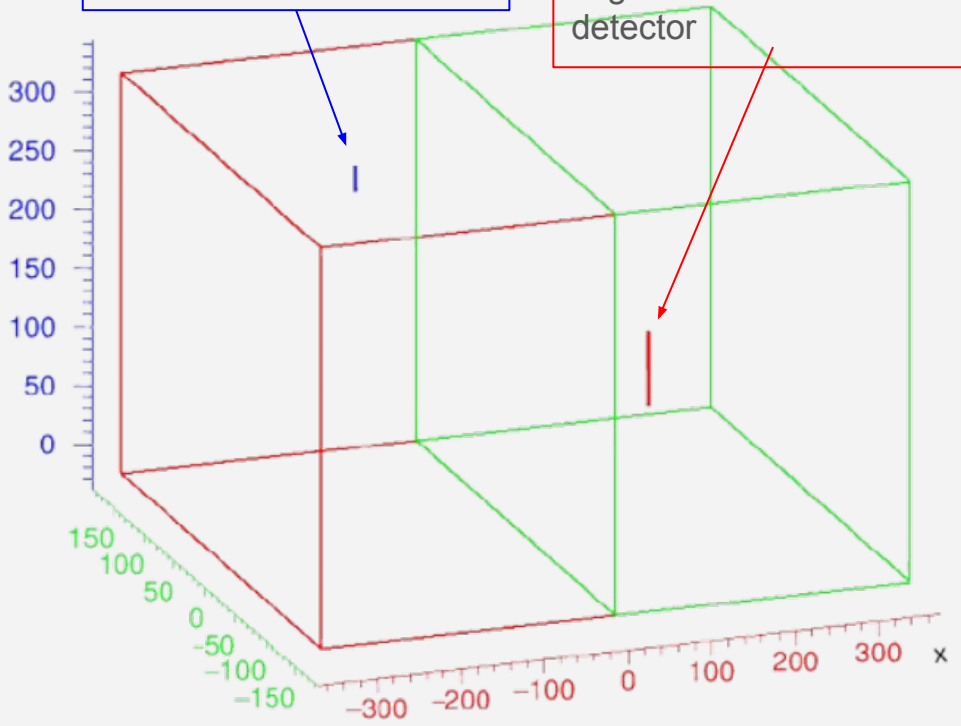


CRP: 3 Trigger: 5



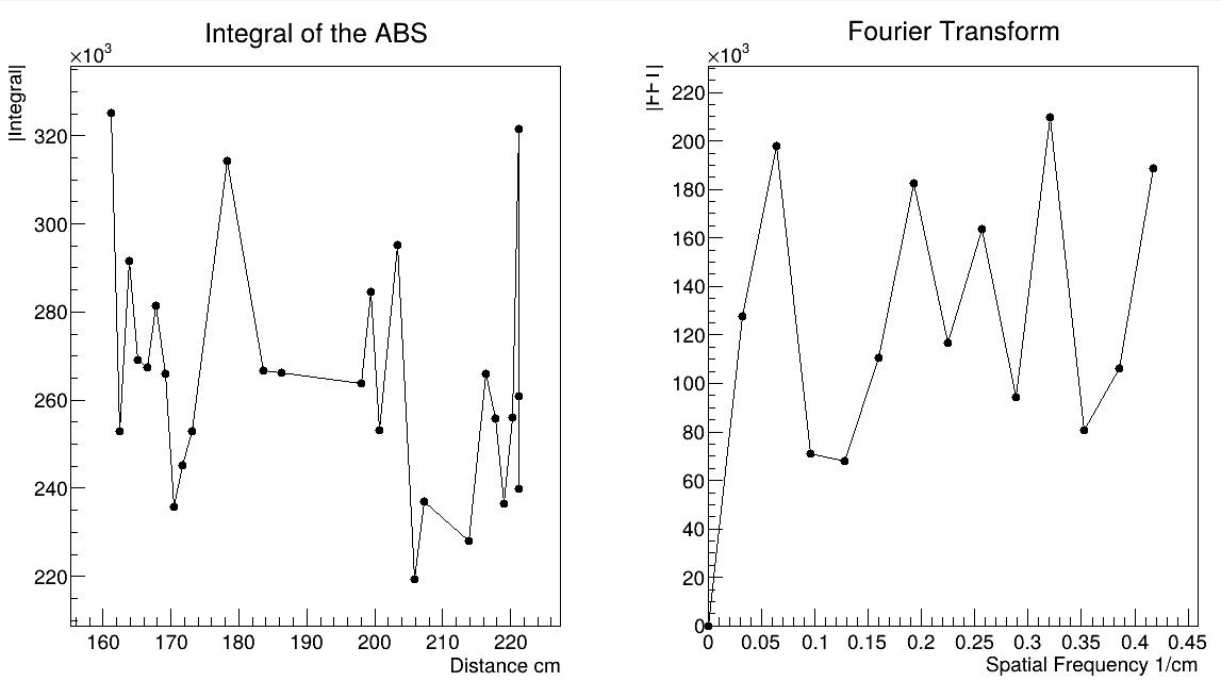
Laser intersects the field cage as it enters the detector

Laser intersects the field cage as it exits the detector



Zoomed-in laser track in CRP3.

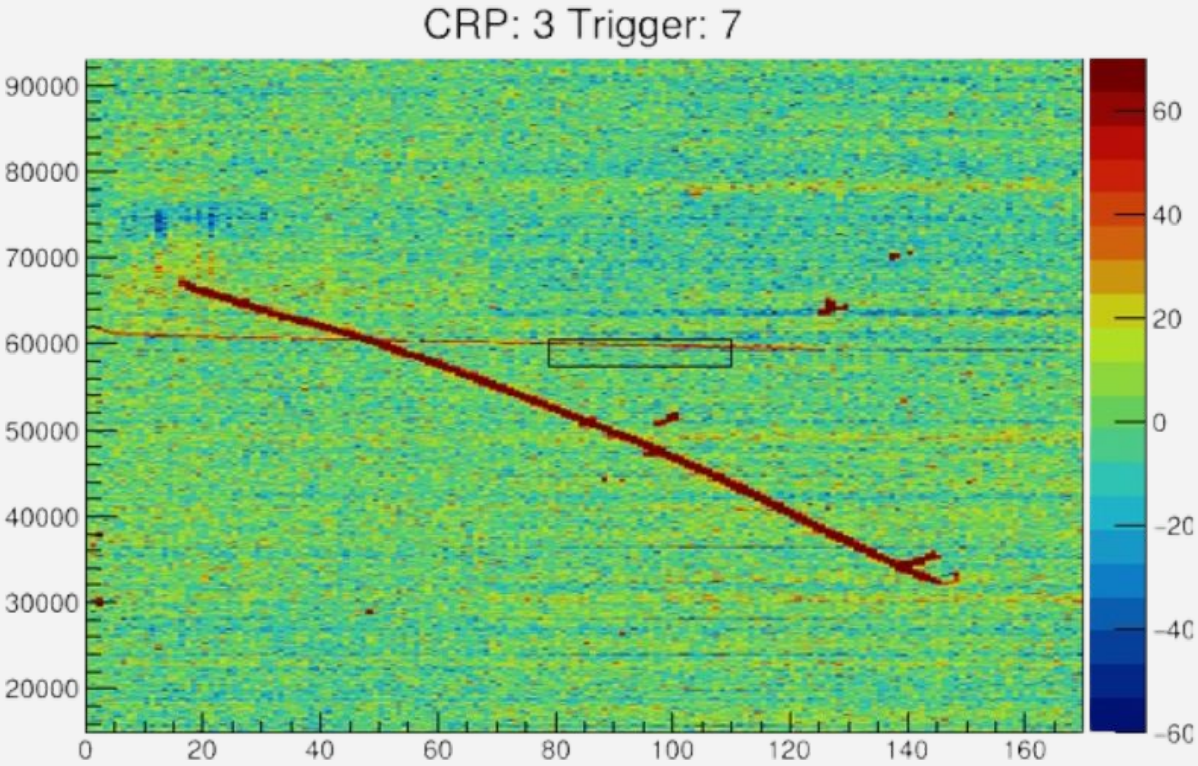
Analysing Diffuse Reflections



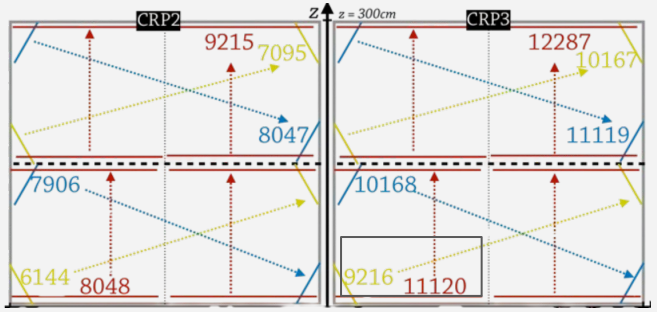
- There are spaces with more than 2 cm with no data, which means that we can be skipping bars.
- The missing lasers, due to the entrance of the field cage, affect the analysis.

Integral in an area, of the ABS and respective Fourier Transform

Analysing Existence of Laser

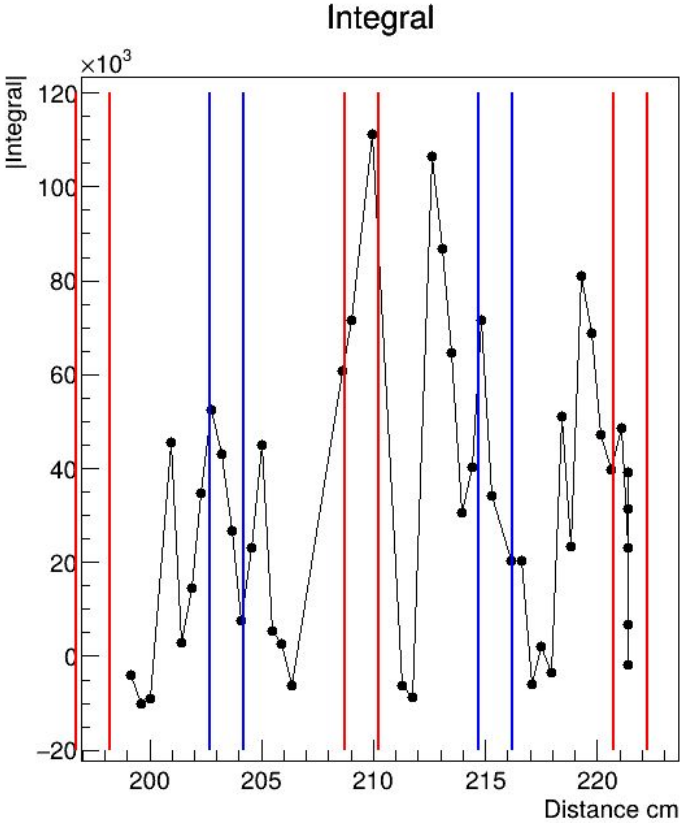


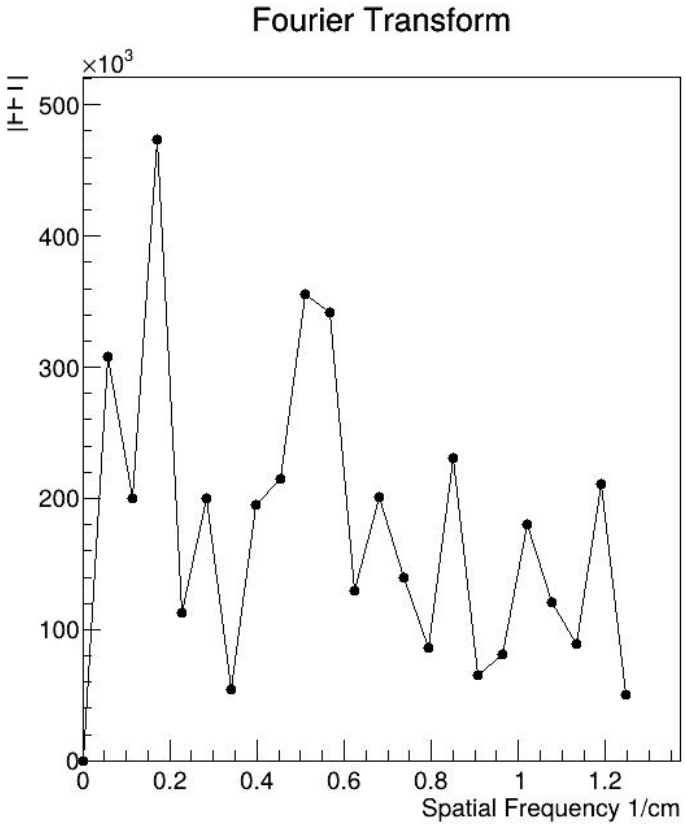
Chosen area to verify
the existence of a laser.



Zoomed area.

Analysing Existence of Laser

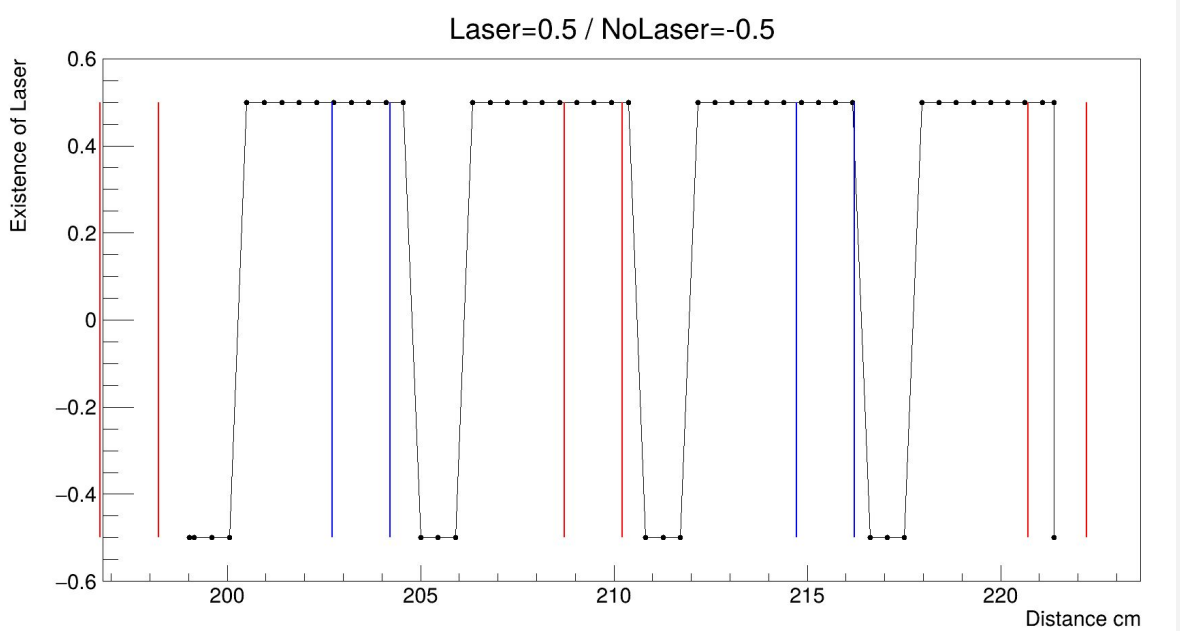




First peak: 0.170
Expected: 0.167

Results offset

- Offset of about 2 cm.
- The field cage bars seem to shrink a little.
- The offset fluctuates a little bit.



Manually inserted data. Red and blue stripes represents bars

Final considerations

- Analysis of the laser reflections showed that it is difficult to obtain consistent information using this technique.
- There is a correlation between the field cage geometry and the presence of a laser.
- This correlation can be easily studied.
- There is a varying offset between the actual bar positions and their theoretical positions.

Any questions?