The Time-of-Flight Detector for the T2K ND280 Upgrade

Irene Andreou
CERN Summer Student 2021
Supervisors: Stefania Bordoni and Prof. Federico Sanchez

BACKGROUND-NEUTRINO PHYSICS

- Neutrinos are the lightest of all fundamental particles.
- Very elusive creatures.
- Three flavours corresponding to each of the charged leptons.
- Appeared to fit well within SM, until some anomalies were detected.

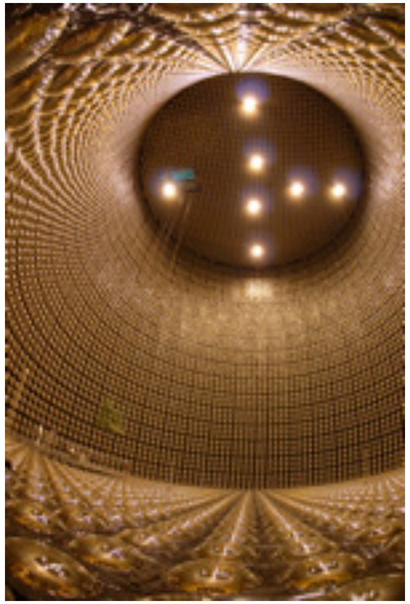
Illustration: © Johan Jarnestad/The Royal Swedish Academy of Sciences

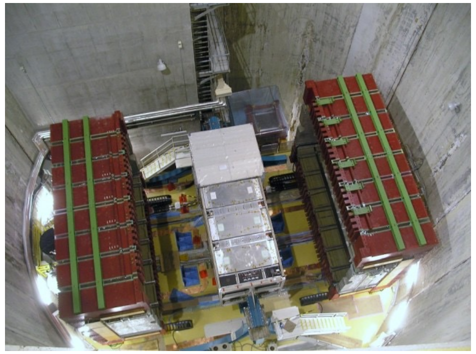
CHAMELEON PARTICLES

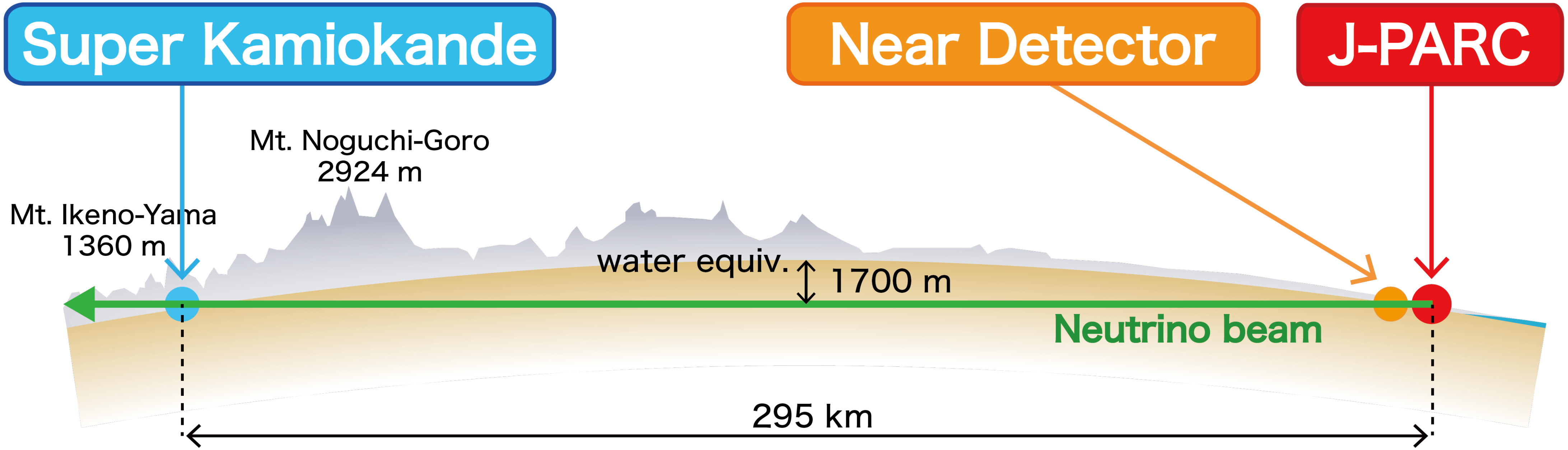
- Super-Kamiokande and the SNO Detector observed fewer electron neutrinos than expected. Why?

NEUTRINO OSCILLATIONS

BACKGROUND-T2K EXPERIMENT

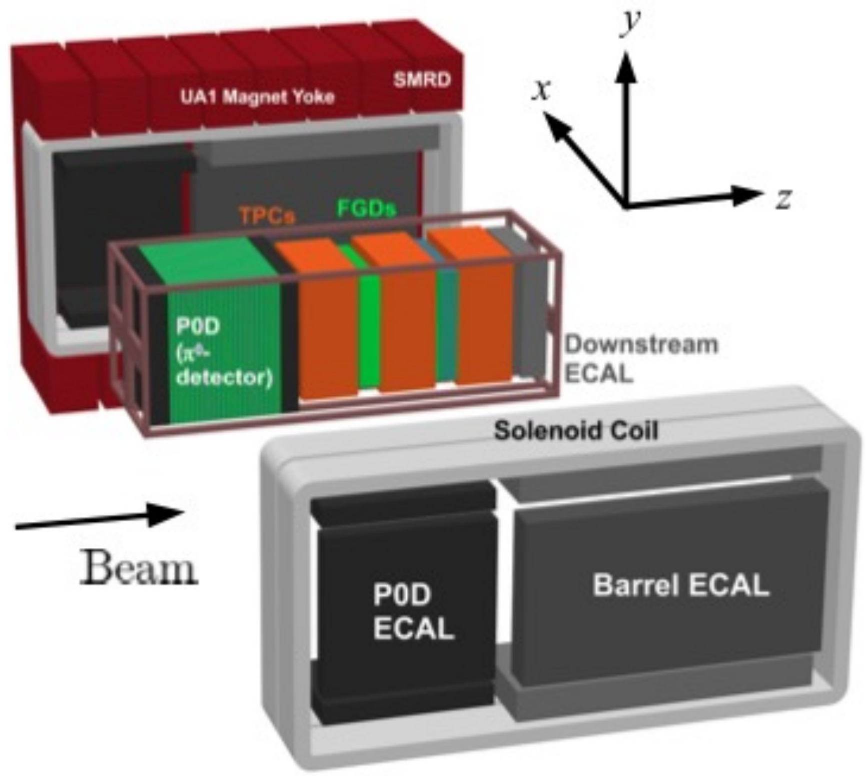






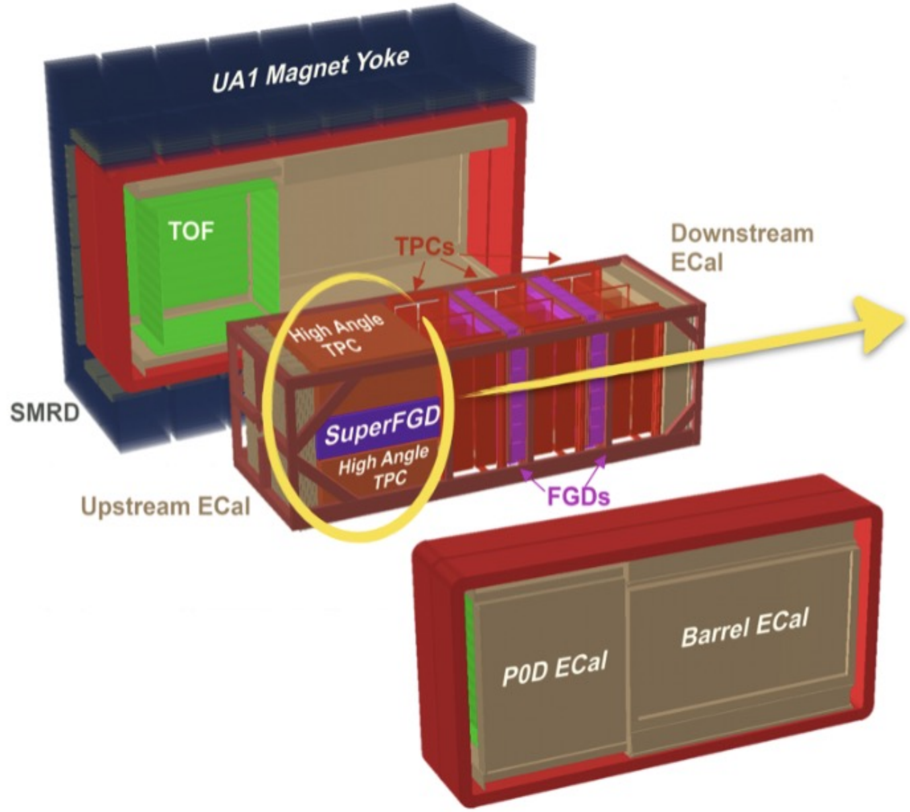
ND280 NEAR DETECTOR

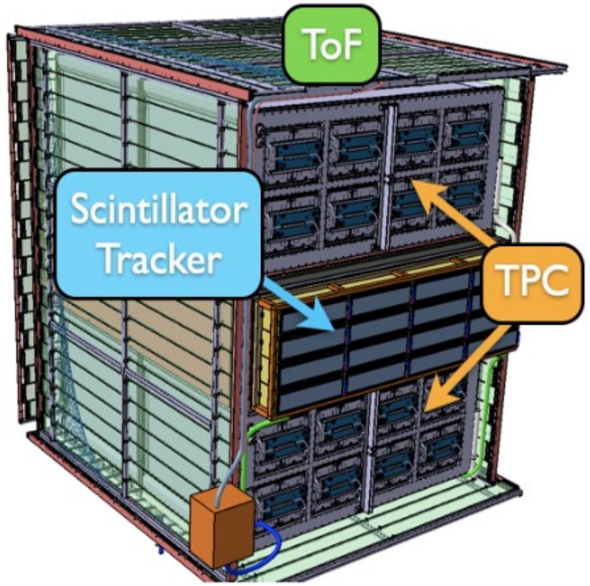
OLD



NEW

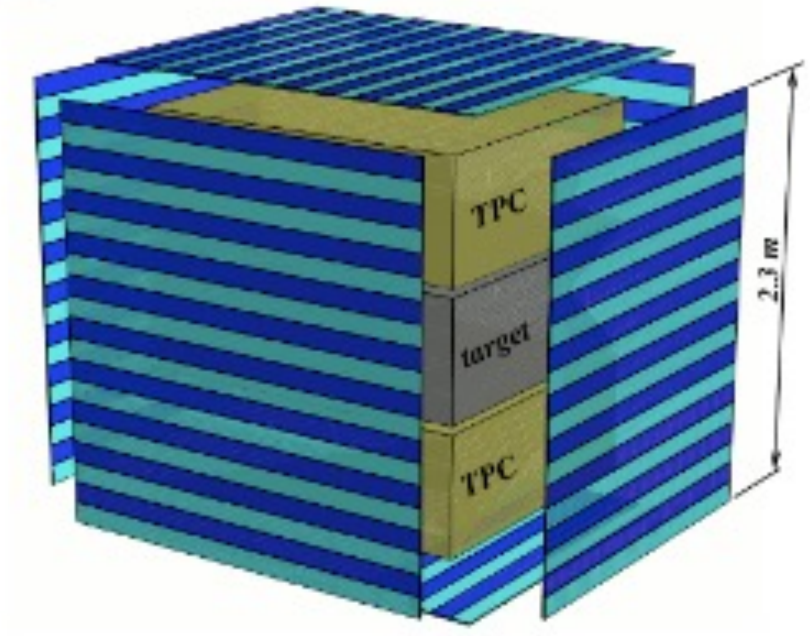
Time-of-Flight = ToF





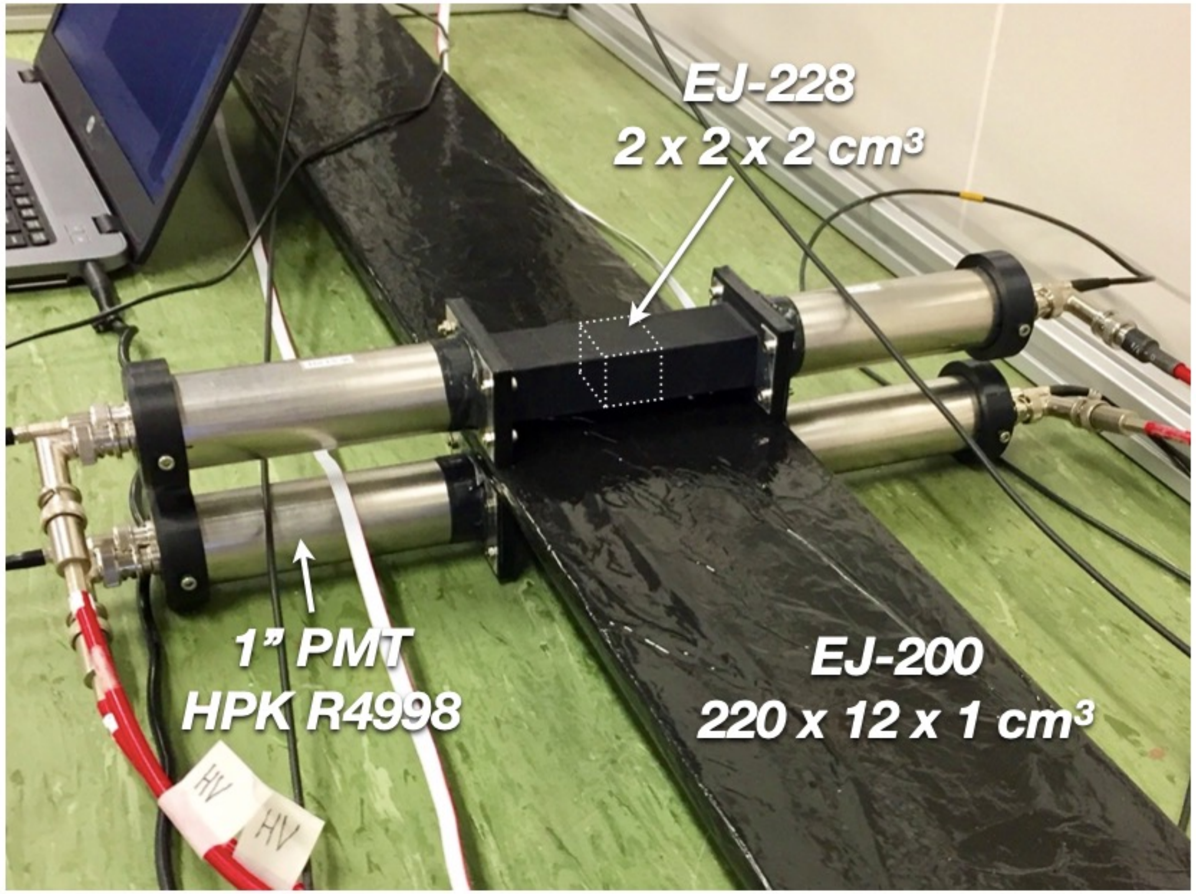
TOF

- Six planes surrounding the SuperFGD and the TPCs. Each plane has 20 bars.
- The scintillation light propagates through the scintillator and is read out at both ends via silicon photomultipliers (SiPM).



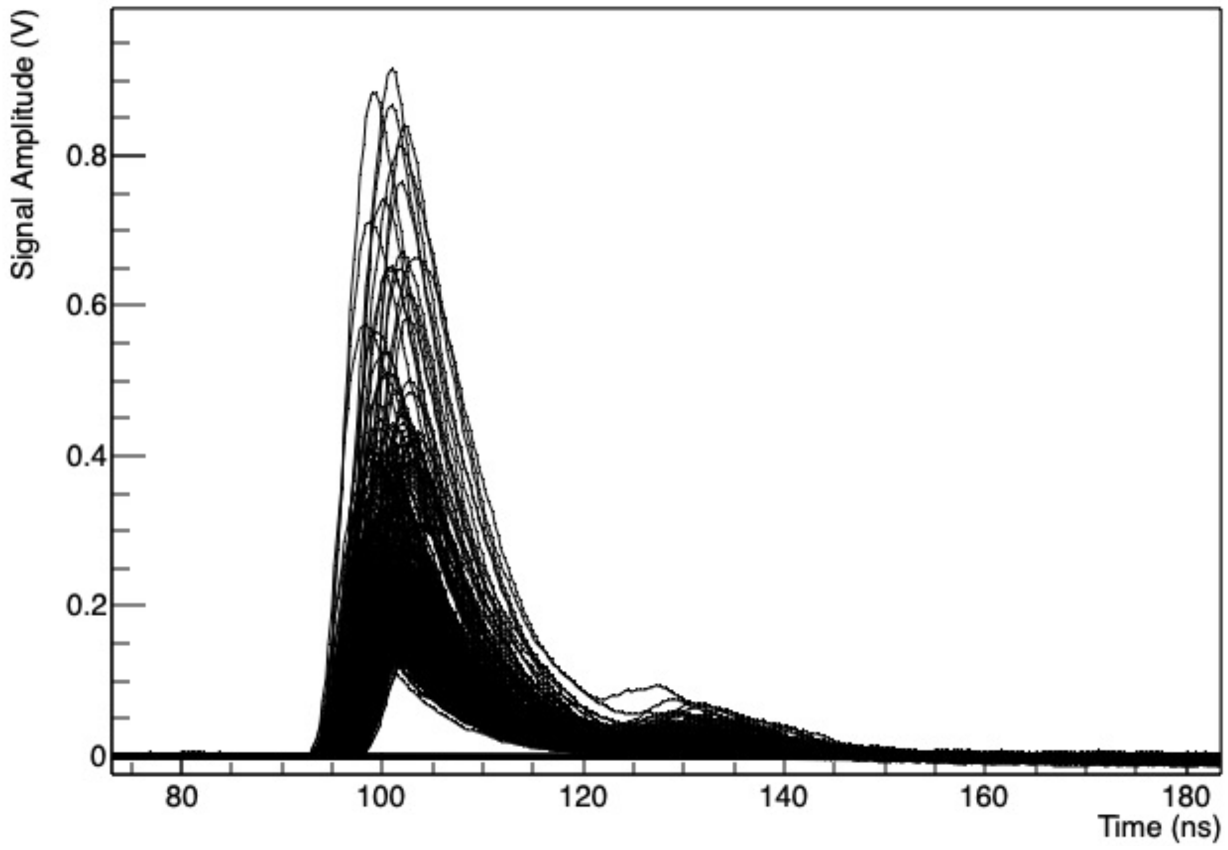
ToF panels assembled at CERN

SINGLE-BAR DATA



- Trigger: Two identical counters located at the top and bottom of the bar.
  - Counters made of a cubic scintillator coupled to PMTs from two sides via 5 cm long light-guides.
  - The trigger time is calculated as the average time registered by the four PMTs.
- 1024 data points per event covering a 320 ns time interval. Thus, it gives complete information about the waveform of all pulses.
- Measurements taken at 11 positions along the 2.2 m axis of the bar with an exposure time of 24 hours for each position.

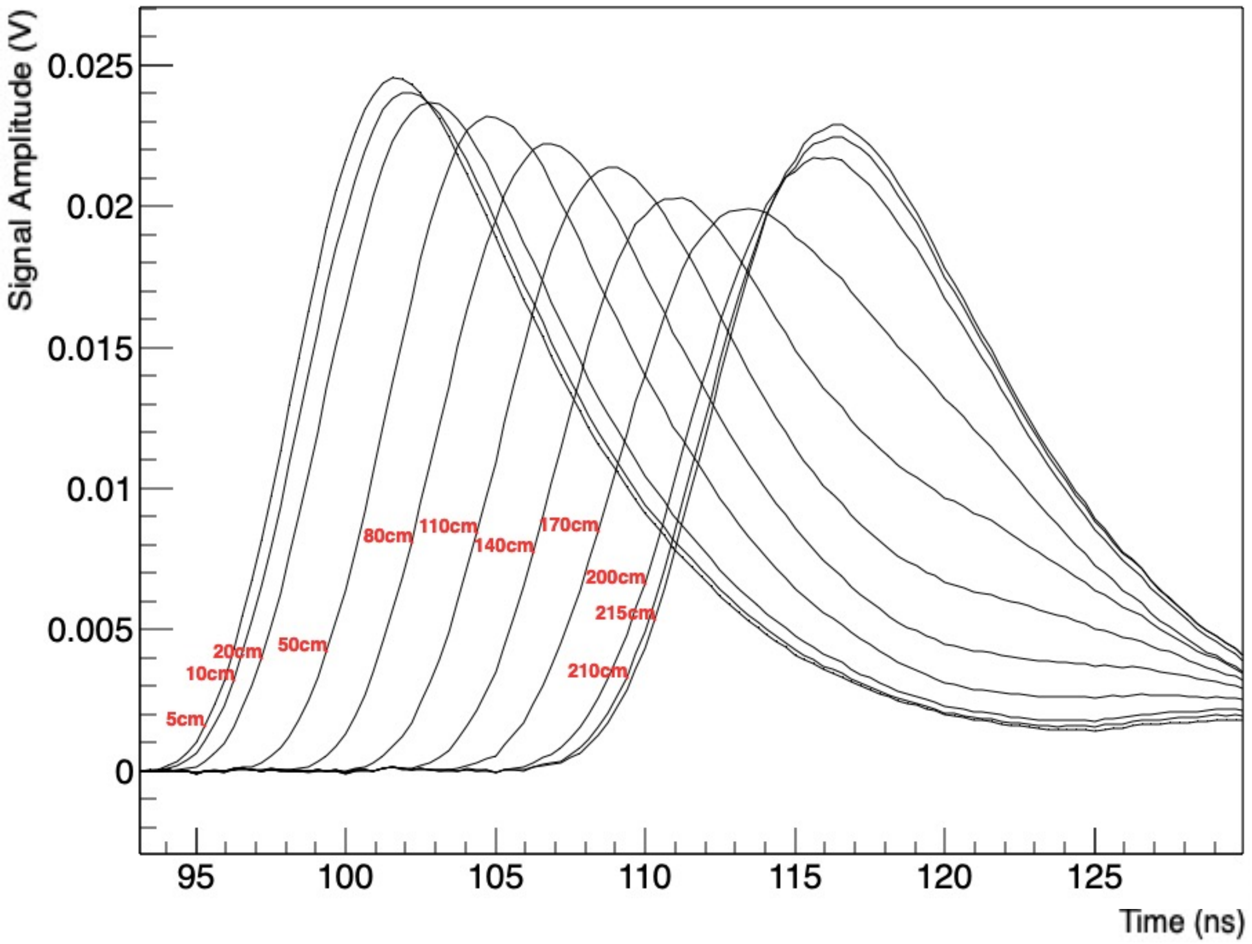
VISUALISATION OF EVENTS



Cleaned-up 5cm events

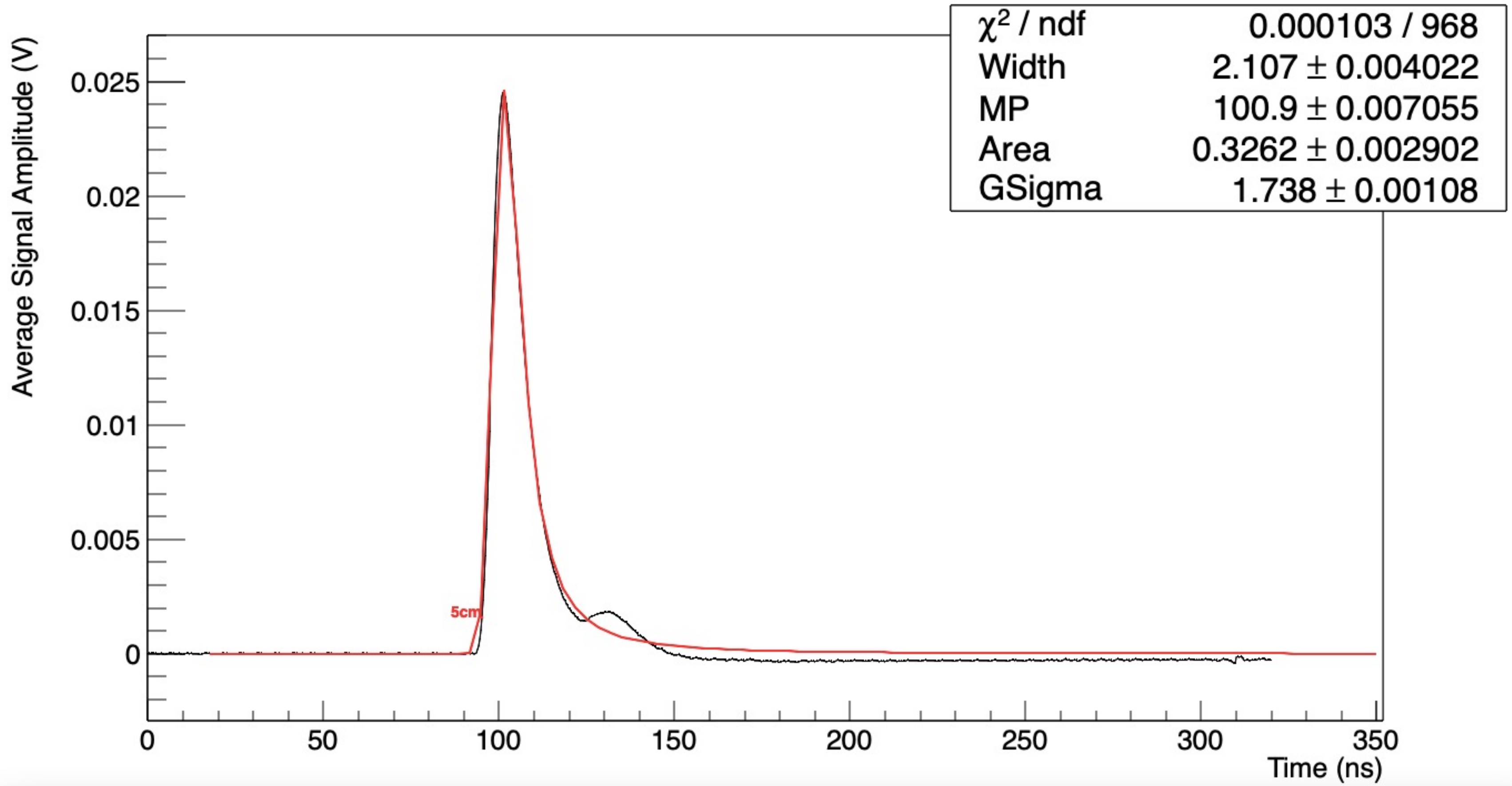
- Reconstruction of the single waveforms one event at a time for each location.
- Envelope of waveforms with some deviations due to noise, double signals and saturation.
- Next step: Clean-up via a series of cuts:
  - Saturation Cut ~5%
  - Trigger Amplitude Cut ~90% Most significant cut
  - Integral/Max Cut ~5%
- Resulting in the accepted events.

WAVEFORMS AT DIFFERENT LOCATIONS

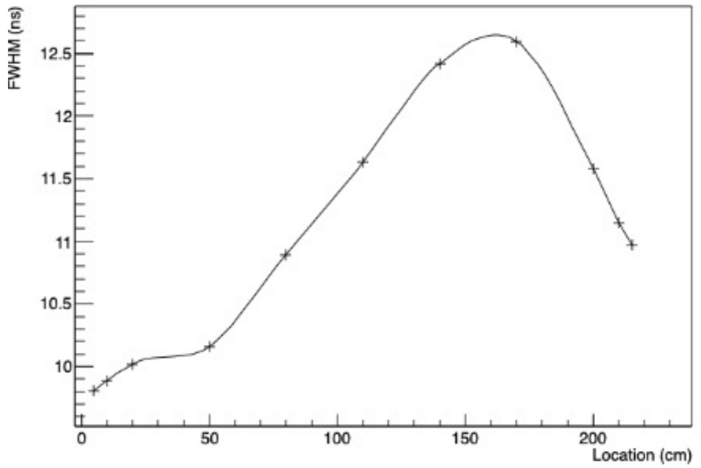


- Waveforms are averaged over all events at a given location and compiled on a single plot.
- Signal amplitude decreases for signals corresponding to trigger positions 5cm-170cm due to the two different contributions of the signal:
  - Direct
  - Reflected
- Last three waveforms show increasing amplitude trend indicating that the two components are more comparable.

FITTING AVERAGED WAVEFORMS AT ALL LOCATIONS

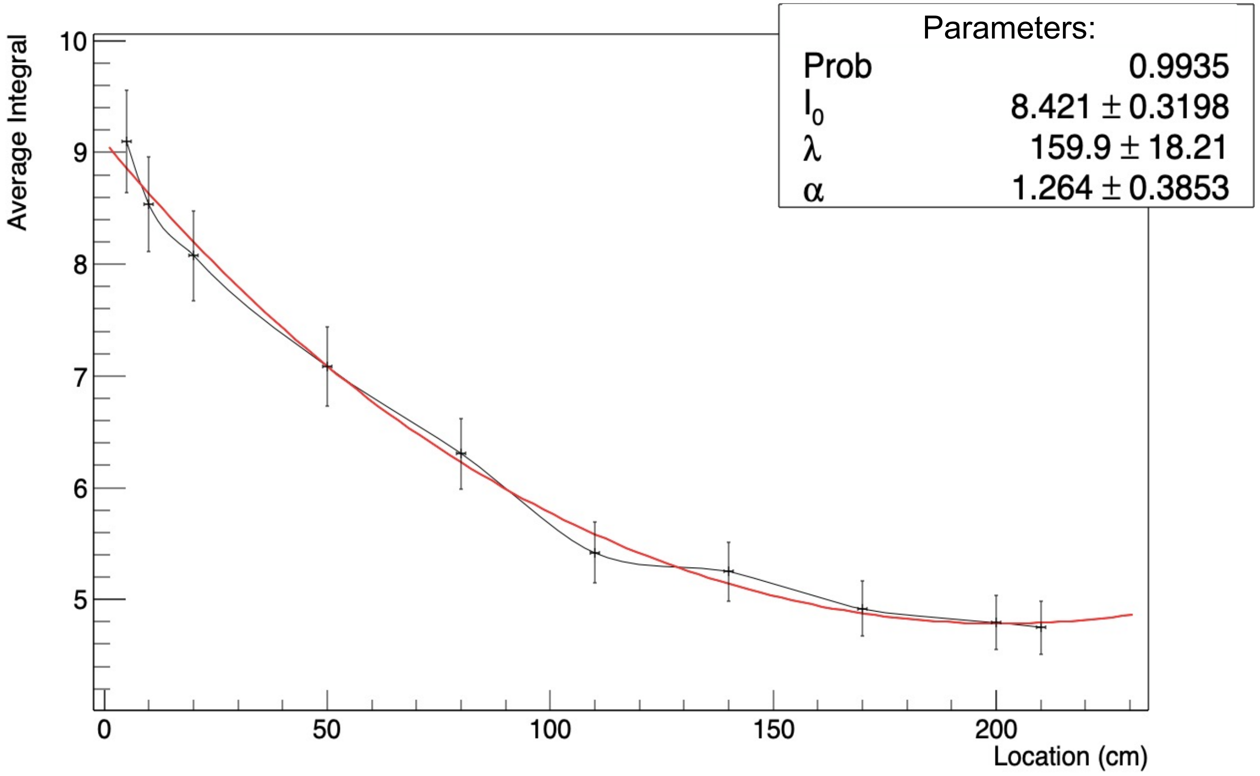


- Fit with convolved Gaussian-Landau function and studied the behavior of the FWHM as a function of location:



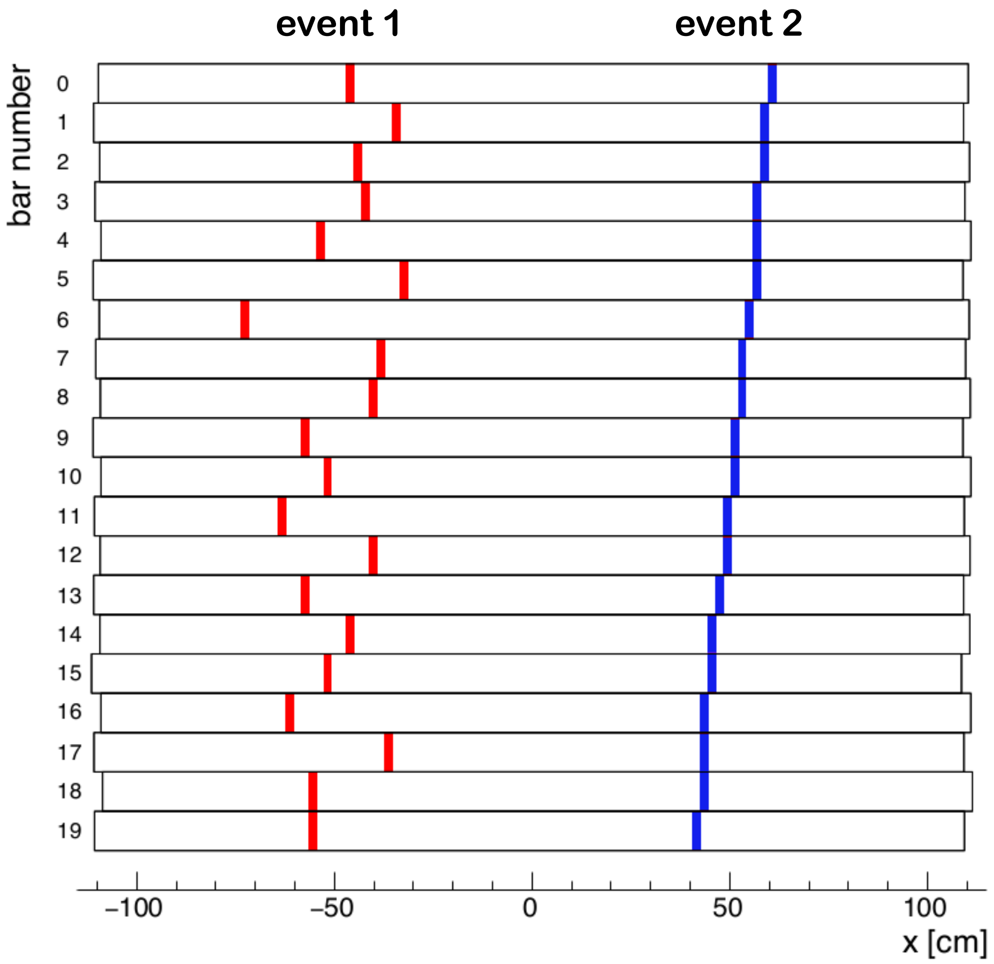
- Behaviour of FWHM can be explained by discussion of previous slide.

INTENSITY BEHAVIOUR HYPOTHESIS



- Based on results from slide 8 and 9, and our physics intuition we formulate the following relationship for the intensity profile. $I = I_0\left(e^{-x/\lambda} + \alpha e^{-(2*220-x)/\lambda}\right)$
    - where I_0 represents the initial intensity of the signal → integral of the waveform, α is the fraction of signal corresponding to the second term and λ is the attenuation length.
    - First term represents direct signal which only suffers from absorption.
    - Second term represents combined direct and reflected signal effect.
- Data agree with hypothesis giving a linear "effective" attenuation length value of around 160 cm but since the light is bouncing, the real expected attenuation is longer due to reflections.

NEXT STEPS



- After digesting the performance of the single-bar data and calculating the velocity, will move onto the data that has already been taken with the six panels.
- Final aim to perform some track reconstruction.

THANK YOU FOR YOUR ATTENTION

Any Questions?

For follow-ups: irene.andreou18@imperial.ac.uk