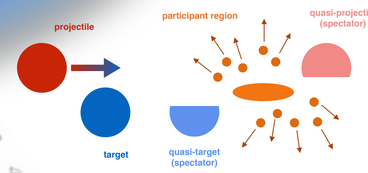
The FragmentatiOn Of Target Experiment (FOOT) and its DAQ system



The FOOT experiment is a **fixed target experiment** aiming for high precision (<5%) measurement of **fragmentation cross section** for **hadrontherapy and radio-protection in space** purposes, using mainly ***proton***, ***Carbon*** and ***Oxygen*** beams [1].

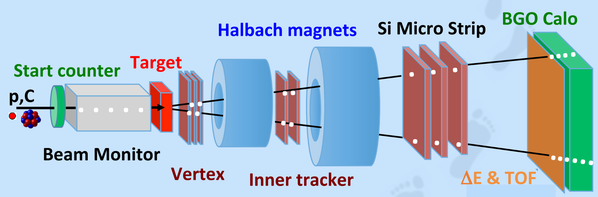
- In **Particle Therapy** (PT), when the charged particles travel through the patient, nuclear interactions occur producing **nuclear fragments that can cause side effects in regions outside the cancer volume**.
- A deeper **exploration of the Solar System** is foreseen in the near future, involving long term human missions as the expedition to Mars. Health risks are associated to exposure to Galactic Cosmic Radiation (GCR), that produces **showers of light fragments and neutrons by nuclear fragmentation when hitting the spaceship shields**.

The FOOT detector

Nuclear fragmentation produces both light and heavy fragments: the first are produced in a cone of about 5-10° along the beam line while the second fragments at wider angles. To detect both types of fragments, the FOOT detector consists of two different configurations: an electronic setup and an emulsion chamber.

angular acceptance **± 10°**

☆ **ELECTRONIC SETUP:**
devoted to the measurements of fragments with Z ≥ 3



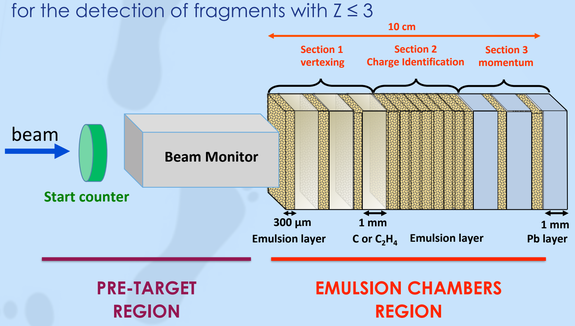
- A fast and thin plastic scintillator (**SC**) detects the incoming beam and starts a Time Of Flight (**TOF**) measurement;
- a drift chamber (**BM**) measures the beam direction and recognises possible nuclear fragmentation of the beam in the **SC**.

- Three stations of silicon detectors: the first (**VTX**) is composed of 4 layers of pixels, the second (**ITR**) of two layers of pixels and the third of three double layers of strips (**MSD**);
- two permanent magnets providing a field of 1T max.

- Two orthogonal planes of thin plastic scintillator strips coupled to silicon PMTs for **ΔE/Δx** measurement and for the TOF stop (TOF Wall, **TW**);
- a calorimeter (**CALO**, BGO scintillating crystals) for the kinetic energy measurement at the end of the apparatus.

☆ **EMULSIONE CHAMBER SETUP:**
for the detection of fragments with Z ≤ 3

angular acceptance **± 70°**



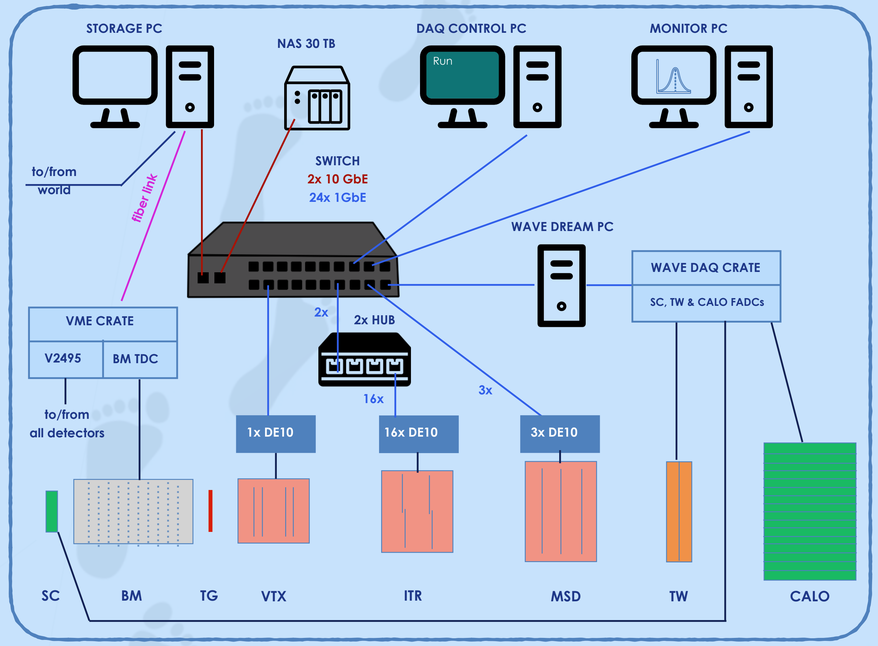
- **pre-target** is the same as the electronic setup.

- **Section 1** made of C and C_2H_4 layers (as target) interleaved by emulsion films to detect the reaction vertex and the first track segment of the fragments;
- **Section 2** consists of only emulsion films for the charge identification;
- **Section 3** is made of Pb layers interspersed with emulsion films for momentum determination.

Trigger and Data Acquisition system - electronic setup

The DAQ system is designed to acquire the largest sample size with high accuracy in a controlled and online-monitored environment

- **flexible hierarchical distributed system** based on Linux PCs, SoC-FPGA boards, VME crates and boards and standard communication links;
- the **maximum acquisition rate** depends on the beam characteristics and/or on the slowest detectors in the experiment;
- the system works **in different laboratories and in different conditions**.



The estimated average event data size is of the order of 60 kB to be acquired at an average rate of 1 kHz

- data collection capability of the system at the busiest node (the storage PC) to be of the order **60 MB/s** on average
- Taking into consideration a safety factor of 4, a **minimal bandwidth of 90 MB/s is considered in the DAQ system design**
- the storage PC is connected with central switch network via a **10 Gb/s ethernet link**
- the storage PC has been equipped with a **1 TB SSD element** (transfer rate ~400 MB/s) for temporary storage during data takings.

The trigger of the experiment can be generated with different conditions and it is distributed system-wide along with a redundant time-tagging mechanism that helps to correctly associate the generating trigger with the data fragments acquired

- Several buffers and pipelines in the systems are used to reduce the dead-time and the data losses.

The data collected are processed in real time for quality assessment and are available to the DAQ crew and detector experts during data taking.

Several sets of online monitoring information are available:

- **simple information pieces**, like counters or rates, are coming from each sub-detector;
- **histograms filled on each PC in the system using local data**: detector occupancies, particle arrival times, particle energies, collected charges and so on;
- **a fast online event reconstruction performed on the fly on a fraction of events**: track momentum spectra, TOF, A and Z reconstructed for charged tracks.

[1] "Measuring the impact of Nuclear Interaction in Particle Therapy and in Radio Protection in Space: the FOOT experiment", The FOOT collab. - accepted for publication in Frontiers in Physics

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