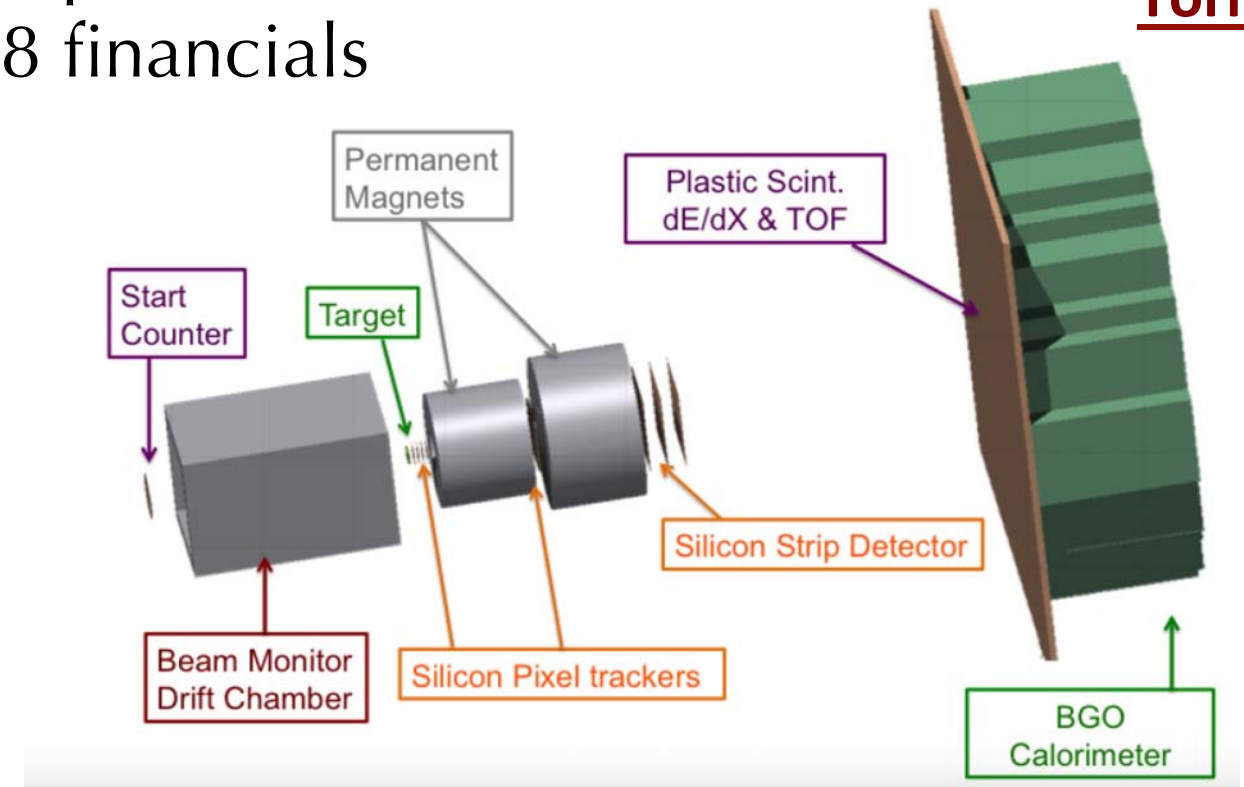
the FOOT calorimeter

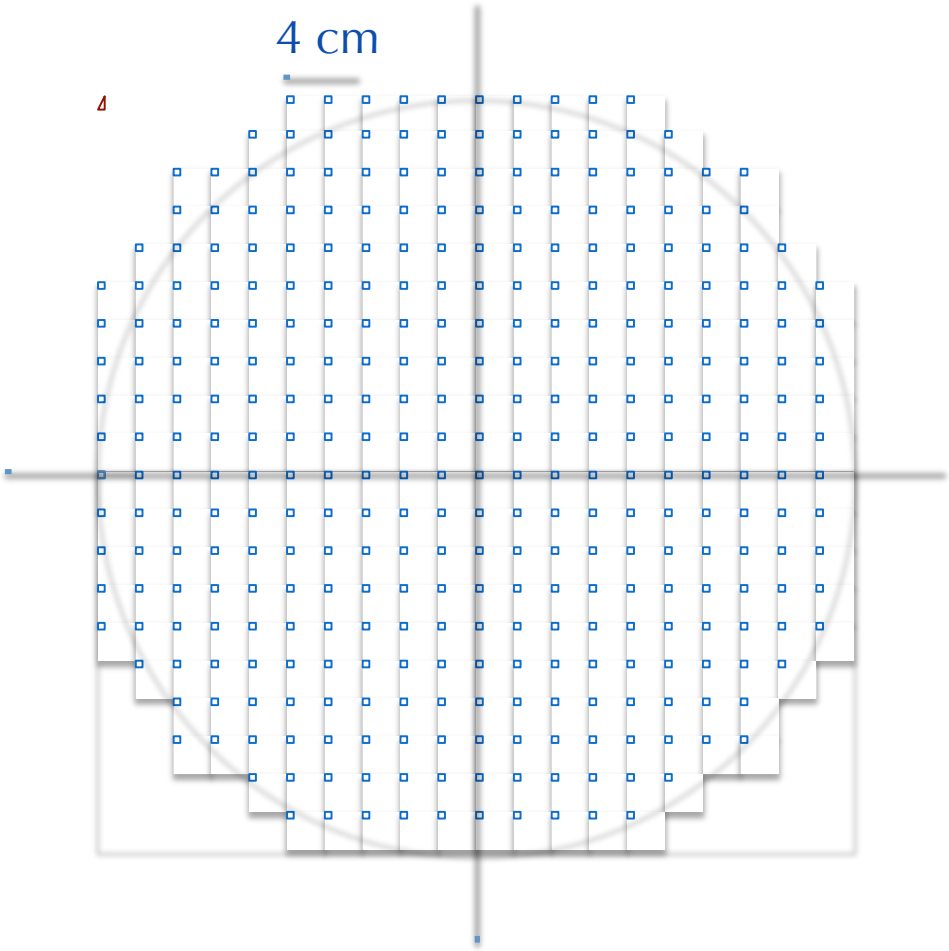
- Specifications
- the photo-detector
- the CNAO beam test
- 2018 plans
- 2018 financials

Torino



the FOOT calorimeter

- No TOF, high density and good energy resolution -> **BGO**
- TOF requires 1.2 m lever arm ->
  R = 20 cm covers up to 11 deg
- **2x2 cm²** granularity due to the minimum track separation (1 deg)
- Thickness must contain the heavier fragment @ 200 MeV/u -> **7 - 21 cm**
- Number of crystals: 2x2x7(21) cm^3
  BGO units: **344 (+16 spares)**



Read-out: high light yield, low rate (PMT, SiPM?)

the FOOT calorimeter

- No TOF, high density and good energy resolution -> **BGO**
- TOF requires 1.2 m lever arm ->
  R = 20 cm covers up to 11 deg
- **2x2 cm²** granularity due to the minimum track separation (1 deg)
- Thickness must contain the heavier fragment @ 200 MeV/u -> **7 - 21 cm**
- Number of crystals: 2x2x7(21) cm^3
  BGO units: **344 (+16 spares)**

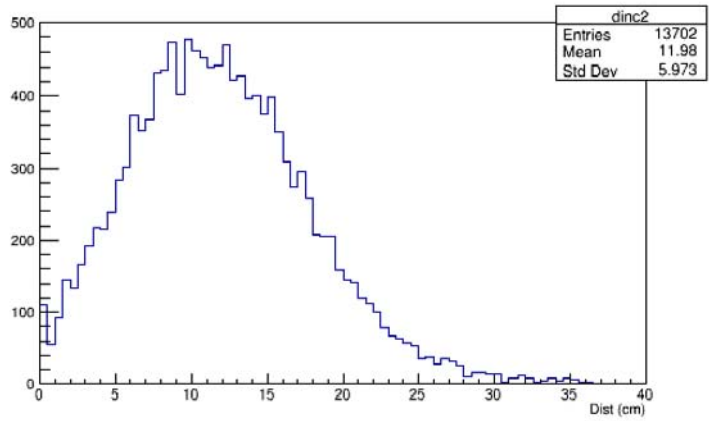


Figure 64 – Mean distance between fragments at calorimeter entrance face.

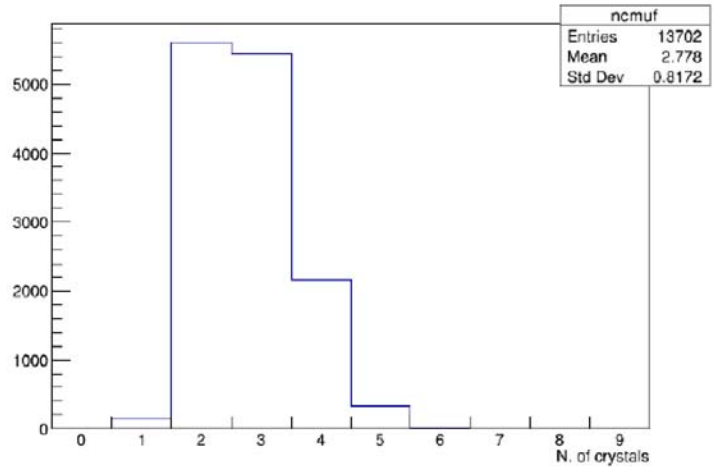
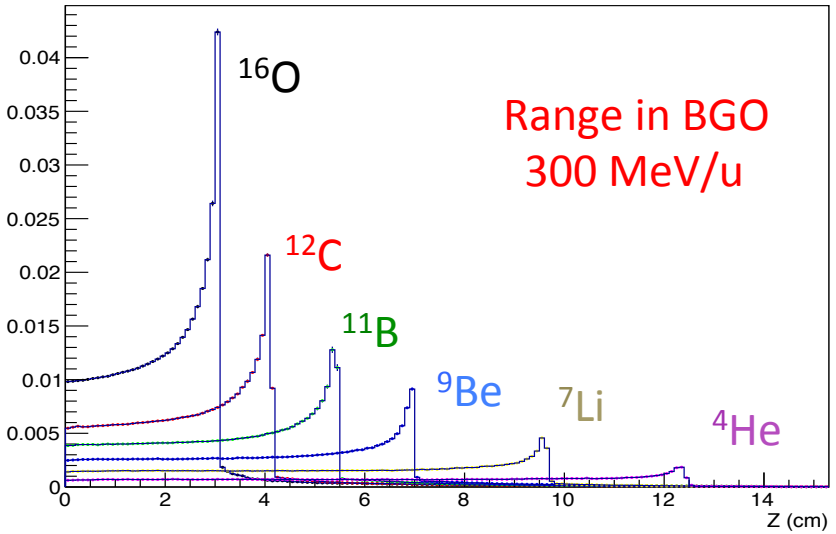


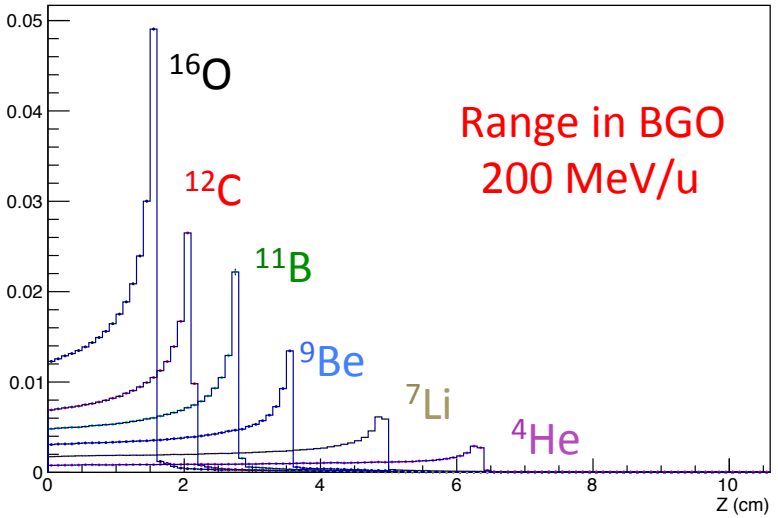
Figure 65 – Number of crystals hit by more than one fragment in multi-fragments events.

Read-out: high light yield, low rate (PMT, SiPM?)

the FOOT calorimeter

- No TOF, high density and good energy resolution -> **BGO**
- TOF requires 1.2 m lever arm ->
  R = 20 cm covers up to 11 deg
- **2x2 cm²** granularity due to the minimum track separation (1 deg)
- Thickness must contain the heavier fragment @ 200 MeV/u -> **7 - 21 cm**
- Number of crystals: 2x2x7(21) cm^3
  BGO units: **344 (+16 spares)**





Read-out: high light yield, low rate (PMT, SiPM?)

the FOOT calorimeter

- Is it a trigger source?
  - Could be: it could validate the event (yes/no fragments)
- Is it triggerable?
  - Yes, threshold on the total released energy
- Number of channels (344 crystals)
  - PMT readout: **344**
  - SiPM readout (5 mm pitch): 344* 16 = **5504**
- Average event size:
  - PMT: **3 - 6 bytes**
  - SiPM: ~ **3 – 100 bytes**
- Maximum data rate
  - BGO: decay time: 300 ns x 3 ~ 1 μs **1 MHz**
- Dead time ~ **1 μ s**

the FOOT calorimeter

- 2017
  - Open issues
    crystal thickness
    photodetector: PMT or SiPM?
  - the SiPM option is more elegant and compact, but it must be verified that the dynamic range can be covered without saturation
  - Construction of a 2x1 prototype
    - Laboratory test
    - Test @ CNAO with p and ^{12}C beams
    - Test @ Heidelberg

the FOOT calorimeter

- Crystal Thickness
  - 7–21 cm. Simulations show the recovery of neutrons does not significantly change when increasing the thickness. The final choice will depend on the source of BGO crystals
    - Buying or L3 recycling (how many crystals could be get?)

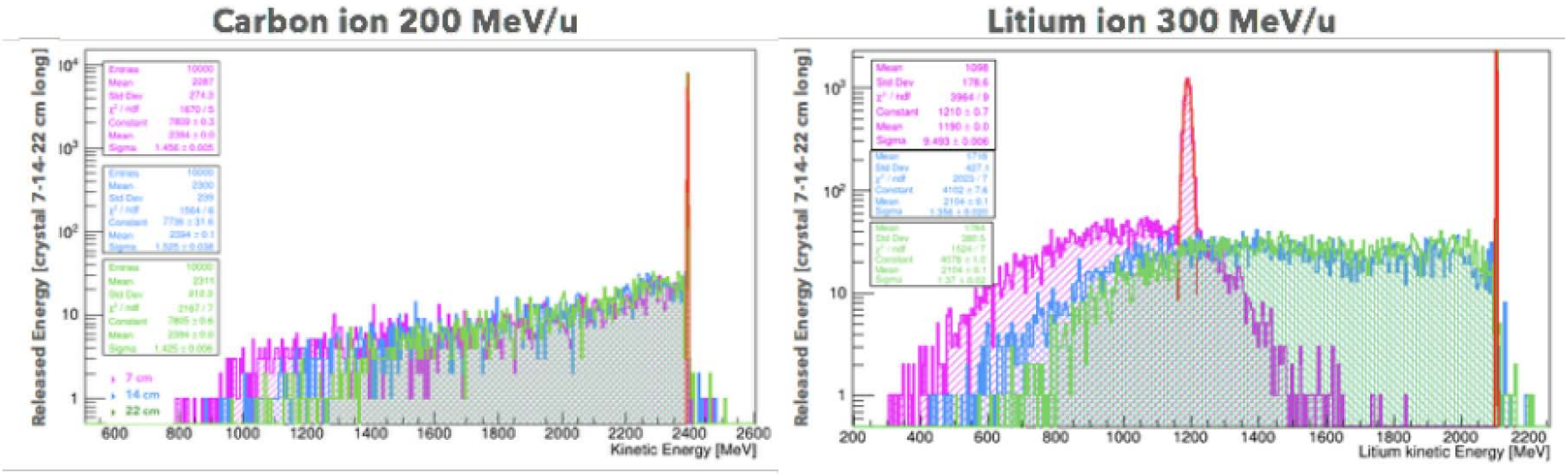


Figure 61 – Total energy deposited in the calorimeter for three different crystal lengths 7 cm (magenta), 14 cm (blue) and 21 cm (green). Simulation performed with 200 MeV/u monochromatic ^{12}C fragments.

the FOOT calorimeter

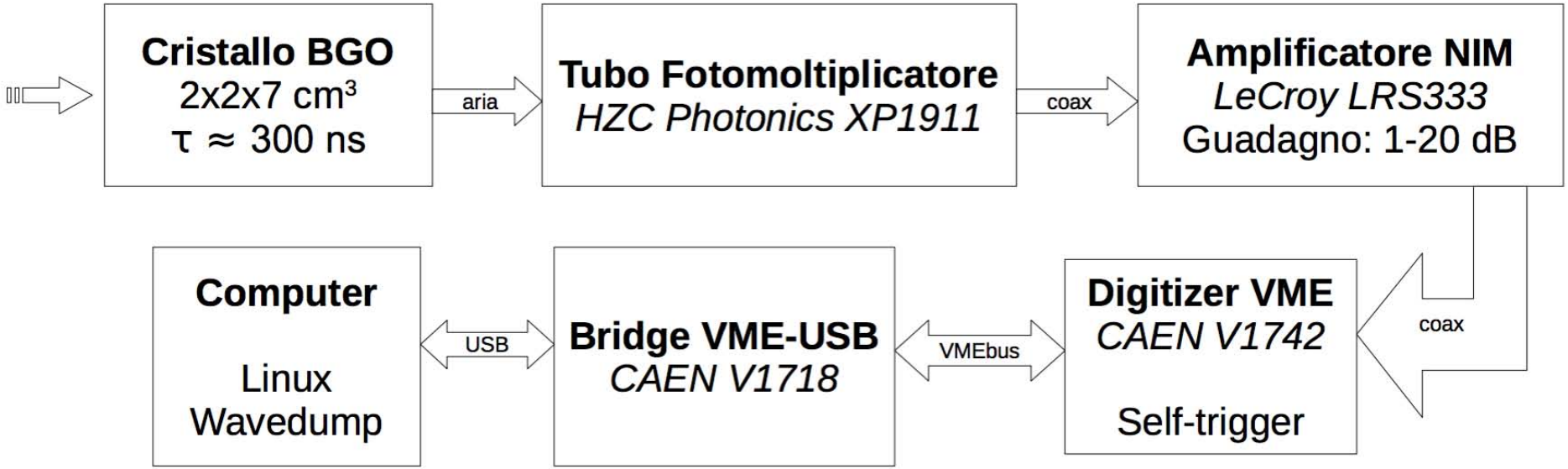
- Photodetector
  - Signal Dynamic Range: LYSO vs. BGO

	LYSO	BGO	Difference
Signal	0.5 Mev	~ 4 GeV	X 8000
Light Yield	x	(1/4) x	: 4
SiPM cell	x (50 um)	(1/4) x (25 um)	: 4
Channels	1	16 (5 mm pitch on 2x2 cm2)	: 16
Decay time	~ 40 ns	~ 300 ns	: 8
Total			**x 4**

the FOOT calorimeter

- The prototype
  - BGO: 4 crystals (2x2x7 cm3) available, tested on ^{60}Co source in lab. with PMTs
  - PMTs: arrived on May, 25th.
  - SiPM: to be evaluated
- Test: CNAO, June, 26th, 2017
  - Energy scan with protons and carbon ions
    - Energy resolution, linearity: not achievable

the FOOT calorimeter



the FOOT calorimeter

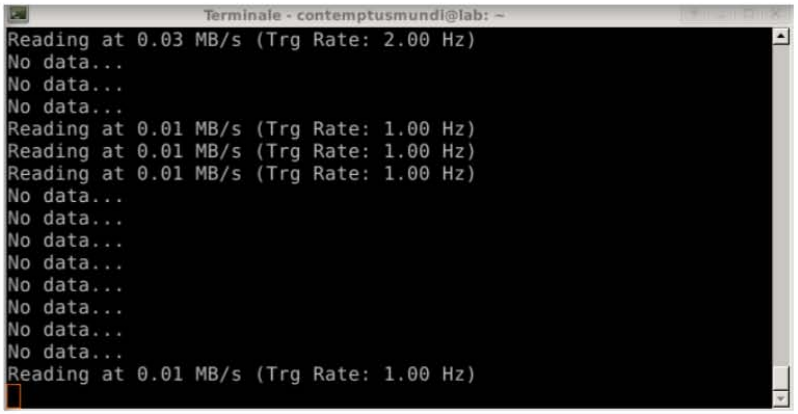
Scelta del modulo per l'acquisizione:

CAEN V1742

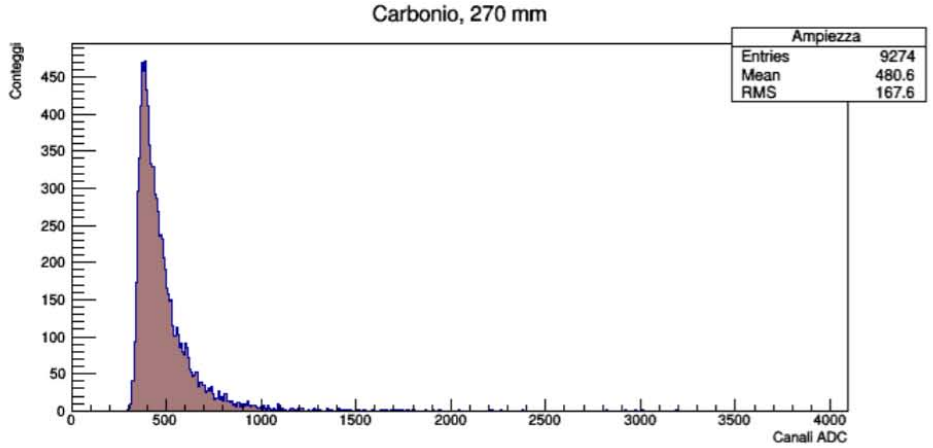
Waveform digitizer VME

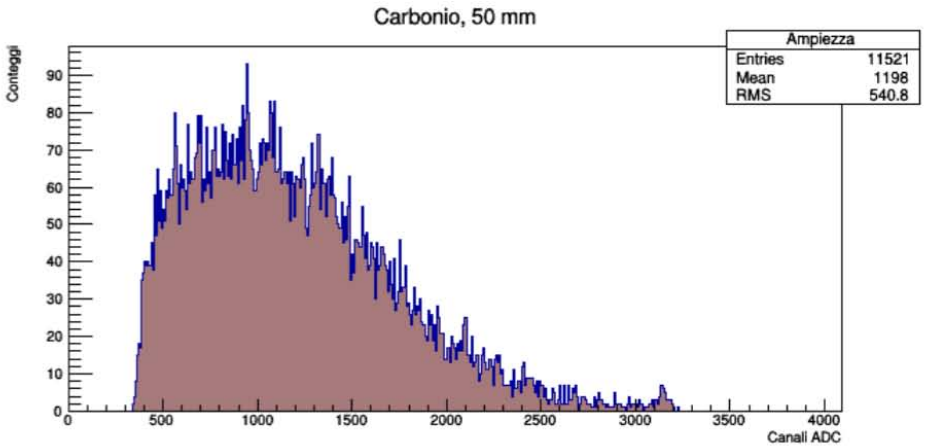
- 12 bit
- 32 canali (+2 per trigger ext)
- Range di 1 V_{pp}
- Frequenza di sampling fino a 5 GHz
- 4 tipi di trigger: esterno, low-latency, self-trigger, software

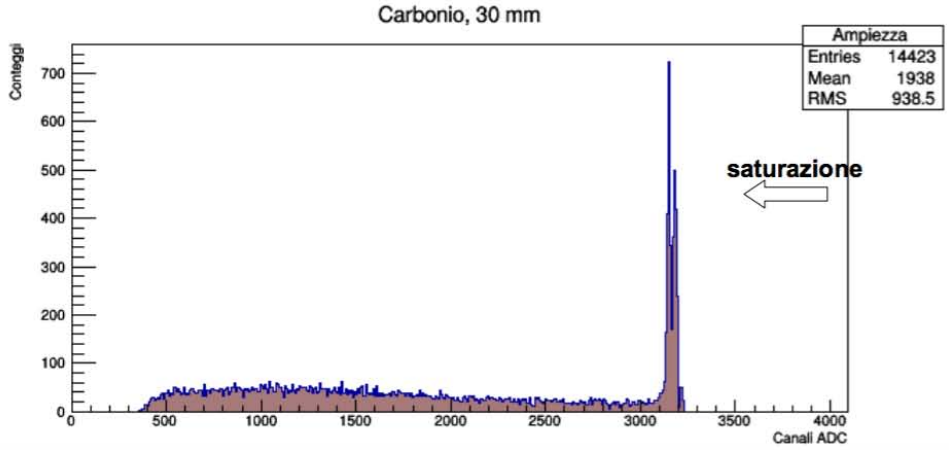
Controllo tramite software, attraverso un bridge VME-USB (CAEN V1718)



the FOOT calorimeter







Si osserva la **frammentazione del fascio** con le energie più basse ma anche la saturazione del digitizer

→ cambio di configurazione

the FOOT calorimeter

- Plans until 12/2017
  - Ongoing contacts with S. Ting to recycle old L3 BGO crystals (N. Pastrone)
  - Beam test in Heidelberg (joint with the Aachen group, probably in November) with SiPM tiles in production at FBK
    - RGB-HD, 4mm pitch, 15 um
    - RGB-HD, 4mm pitch, 20 um
    - NUV-HD, 4mm pitch, 30 um

the FOOT calorimeter

- 2018 plan
  - Design mechanical structure
  - Select photo-detector
  - Issue orders for (part of the) BGO crystals
  - Issue orders for (part of the) Photodetectors
  - Front-end electronics
    - Digitizers (if PMT)
    - Design front-end board and select ASIC (if SiPM)
      - support granted, if required, by A. Rivetti
  - Build a sub-unit and test/calibrate it in Heidelberg

the FOOT calorimeter

- 2017 financials
  - integration of travels to cover the beam test in Heidelberg, originally not foreseen: 6 k€ (4 people x 1 week)

- 2018 financials

  - Crystals: **154 k€**
    - the request covers half the cost if we will have to buy new crystals (half is left for 2019), but it could be enough for the whole detector if we manage to reuse L3 crystals (they must be cut). A mixed scenario is also possible
  - Photodetectors: PMTs or SiPM: **72 k€**
    - the request is tuned to the safe (PMTs) solution
  - Front-End Electronics:
    - Digitizers**: 25 k€**
    - Power supply: **25 k€**
  - Mechanics: **24 k€**
    - the manpower to design the mechanical structure is allocated
    - the structure will be modular (module size will depend on the weight – i.e., the crystal thickness)
    - A quarter of the calorimeter (20x20 cm^2) is covered by the beam span, so it is the optimal unit for the calibration
  - Travels:
    - 10 k€: beam tests (2)
    - 6.5 k€: meetings