08.09.2021

Preliminary Calorimeter data analysis GSI-2021

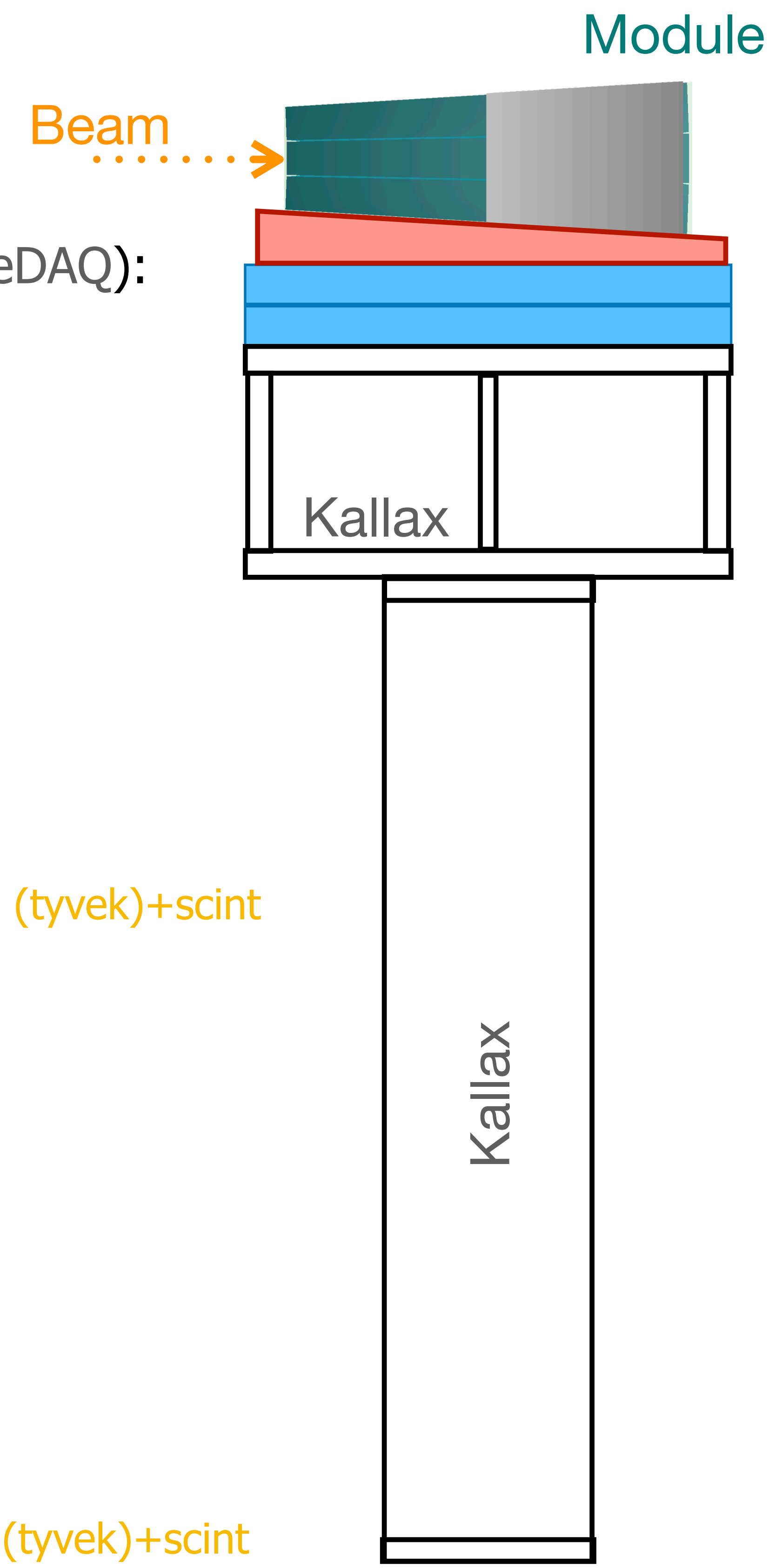
Physics meeting

N. Bartosik, P. Cerello, L. Scavarda

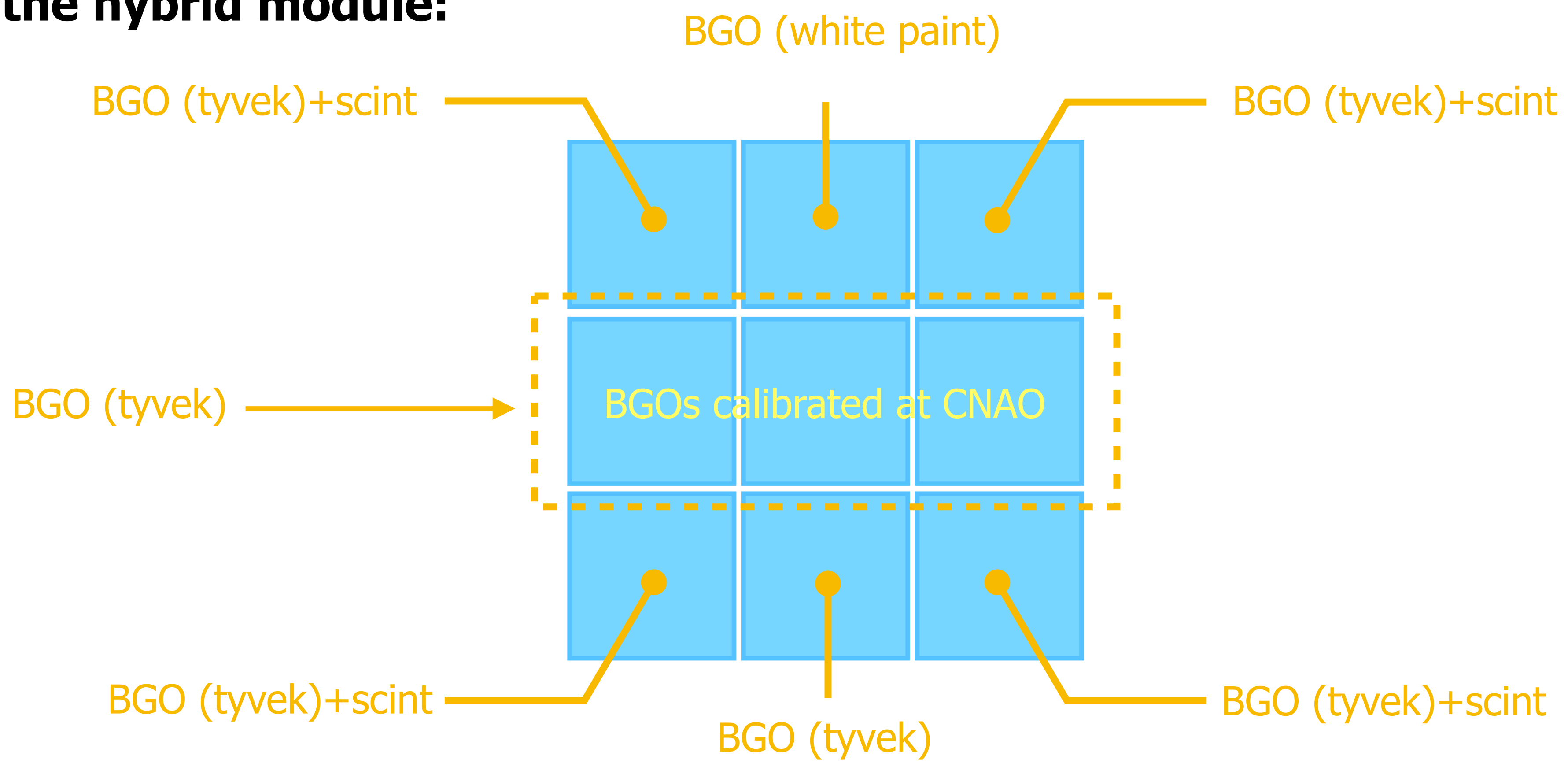
Calo Setup @GSI

Setup
- Calorimeter setup: one Module (9 crystals)
- Mechanics: 2 kallax from IKEA + supports for the Module

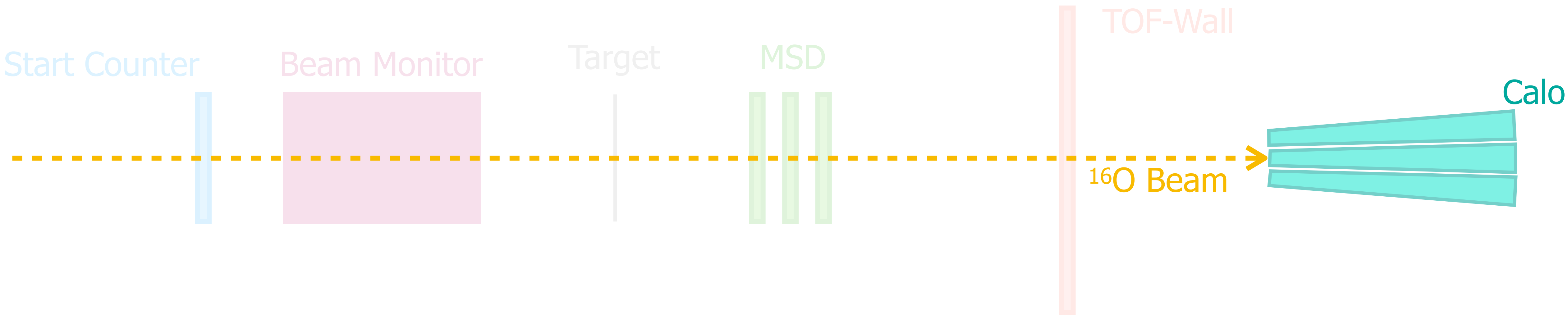
Measurements:
- No detectors/target upstream the calorimeter (standalone acquisition - WaveDAQ):
  - 200 MeV/u: standard voltage (34.5 V)
  - 400 MeV/u: lower voltage (33 V)
  - 200 MeV/u: lower voltage (33 V)
- Full FOOT apparatus (global-DAQ):
  - no targets
  - C target (5mm thick)
  - C_2H_4 target (5-10mm thick)
  - calorimeter rotated by 2-4°



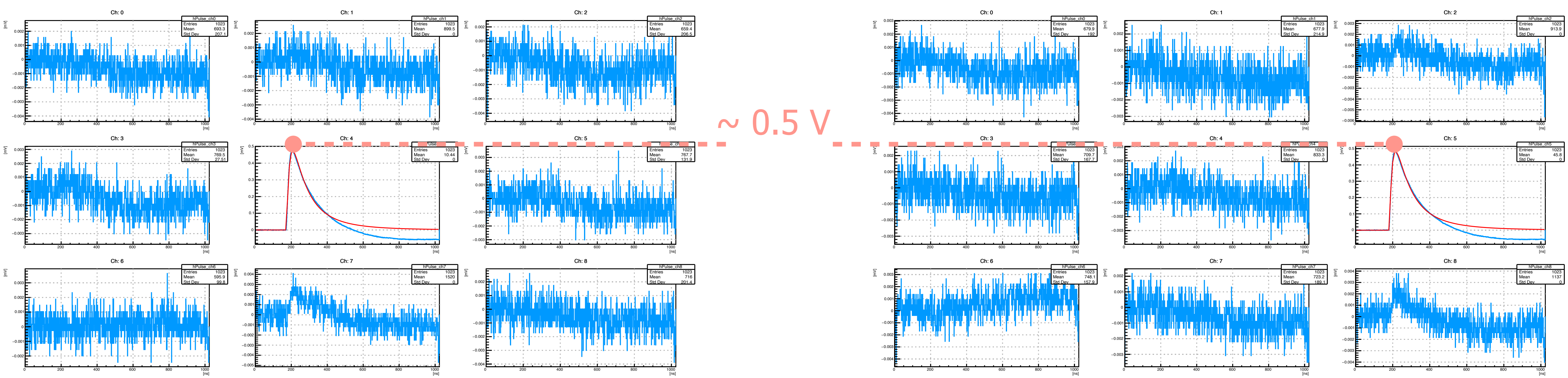
Back view of the hybrid module:



@200 MeV/u - SiPM HV: 34.5V



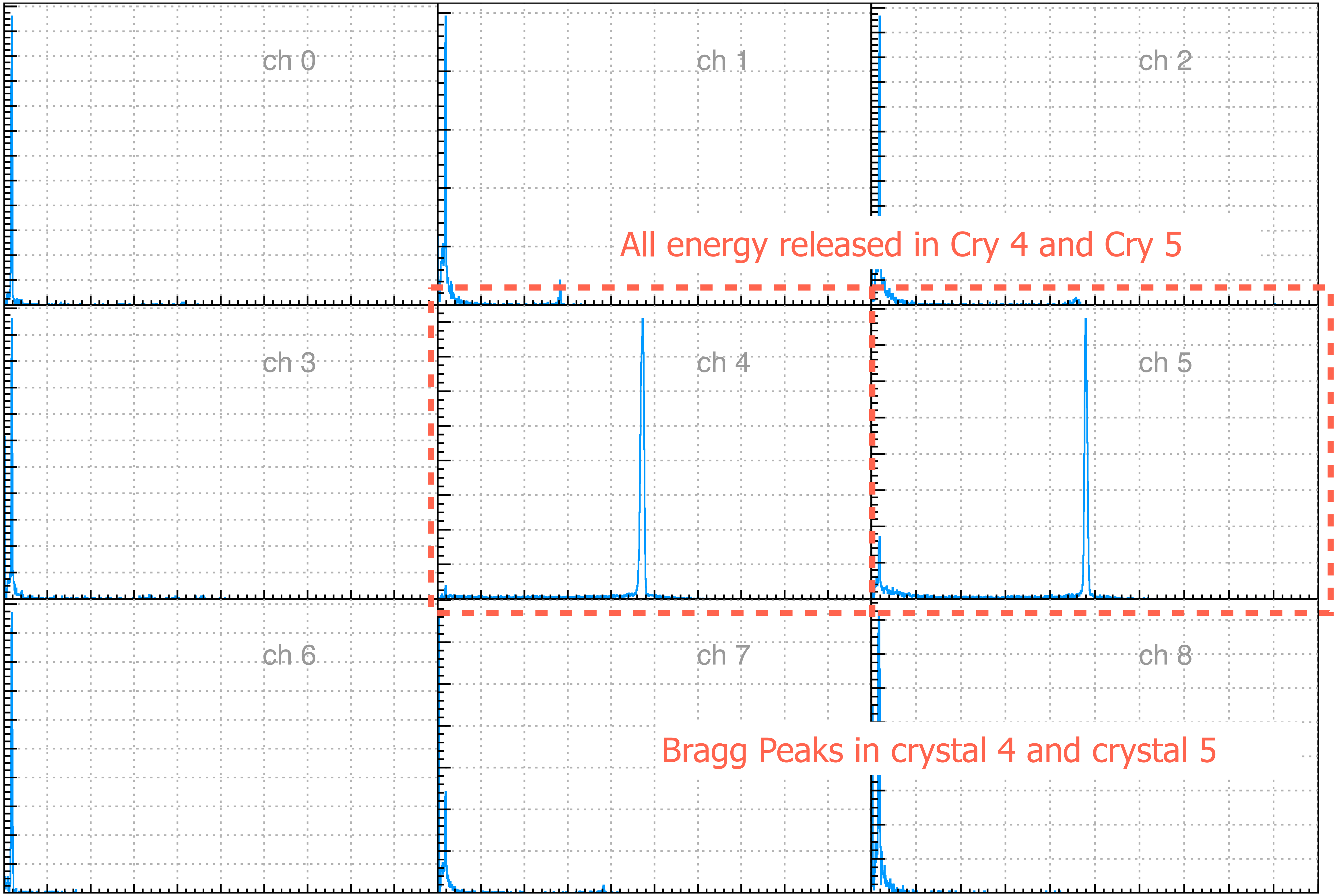
- **beam**: 200 MeV/u ^{16}O
- **Setup**: calorimeter standalone
- **SiPM HV**: 34.5V
- WaveDAQ



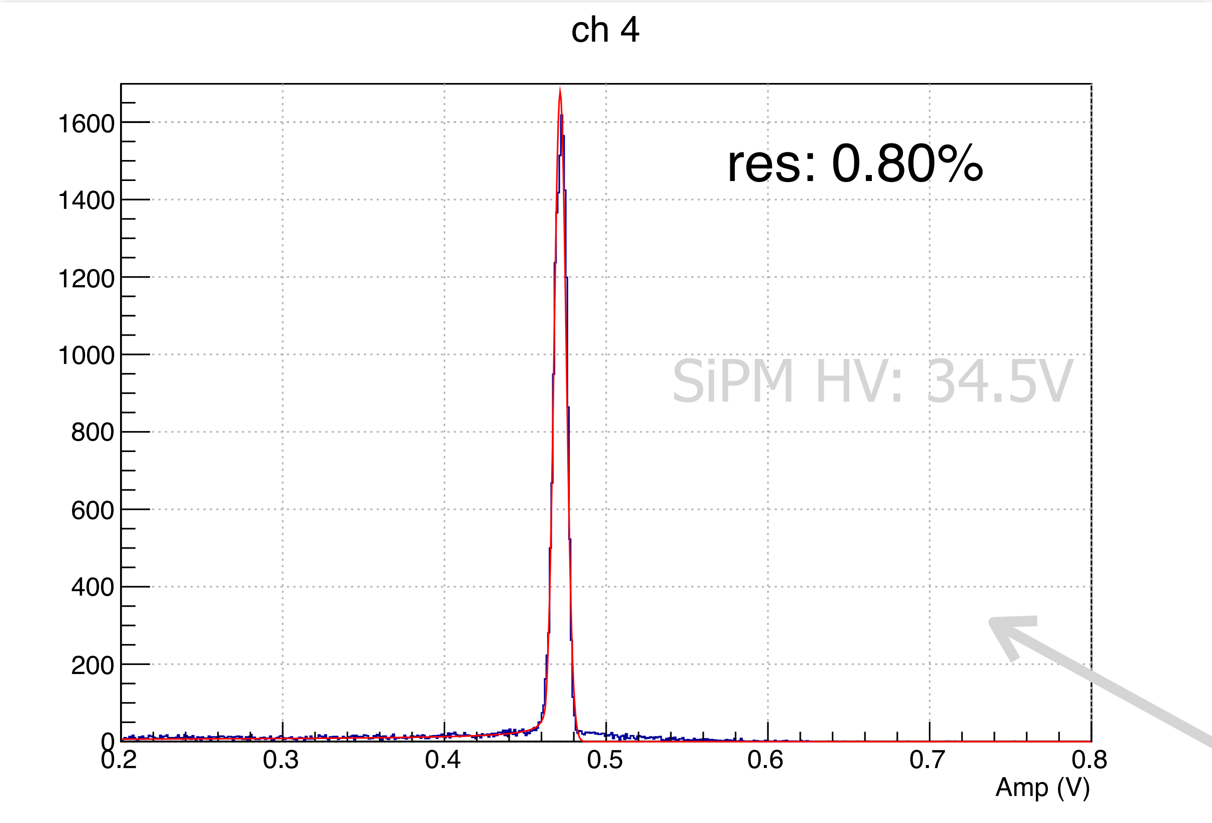
- Example of signals in two different events
- The beam position was not perfectly stable, but oscillated between Crystal 4 and Crystal 5

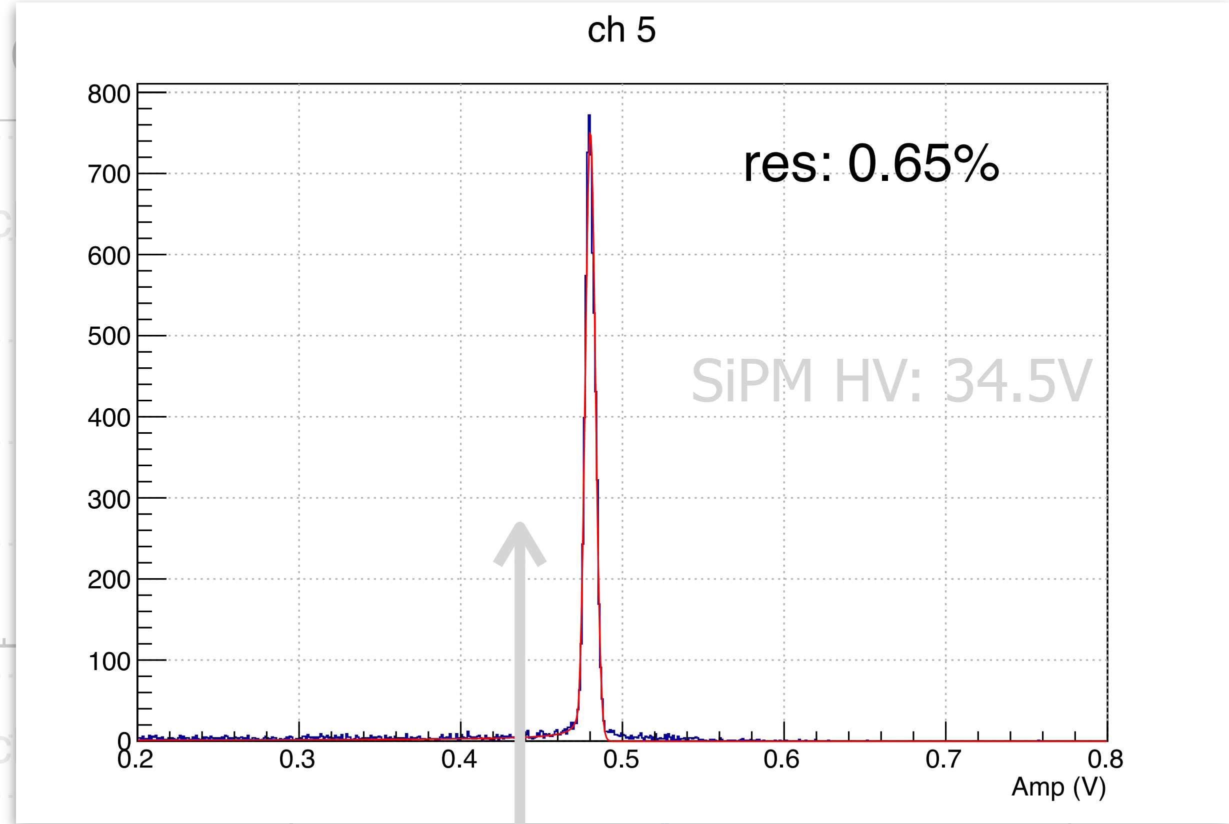
@200 MeV/u - SiPM HV: 34.5V

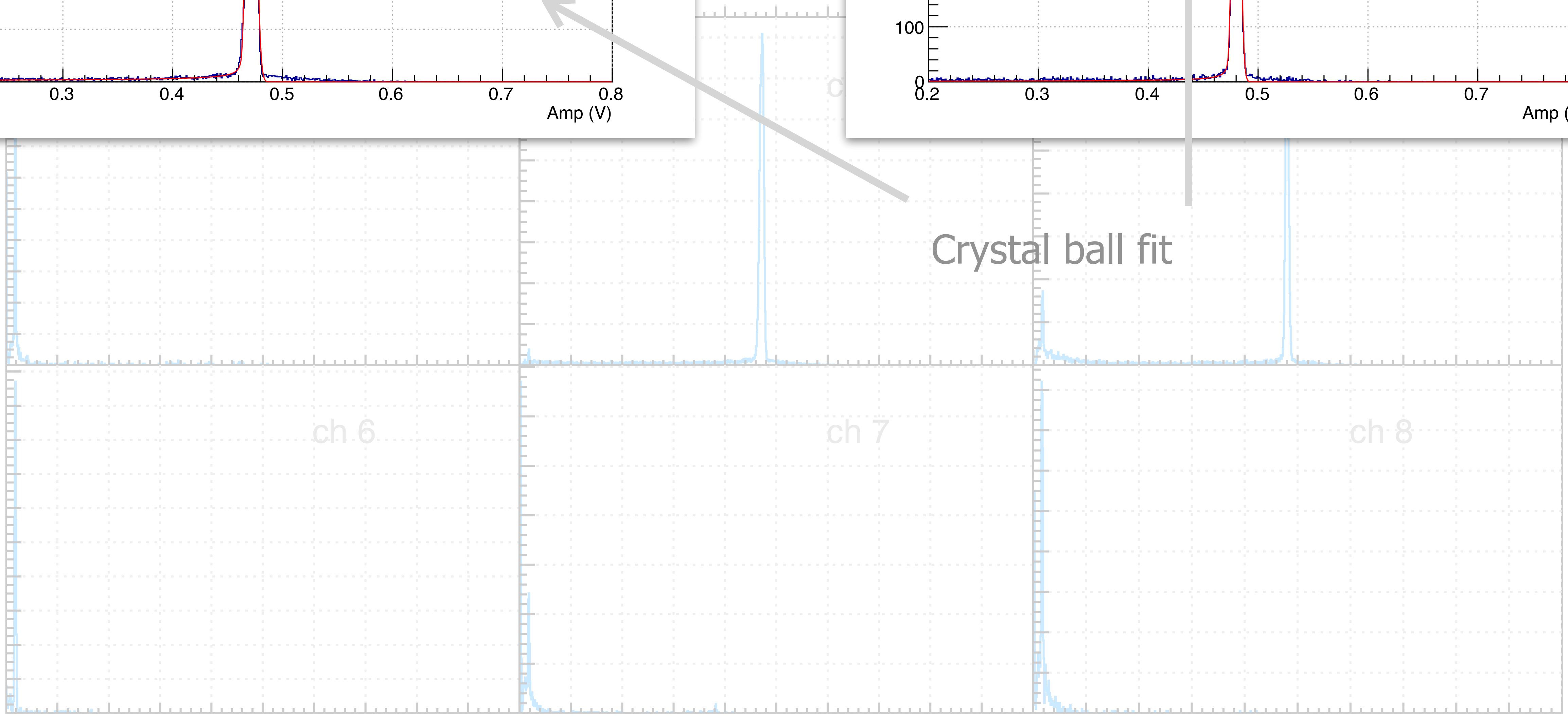
Amplitude distributions @200 MeV/u ^{16}O



@200 MeV/u - SiPM HV: 34.5V

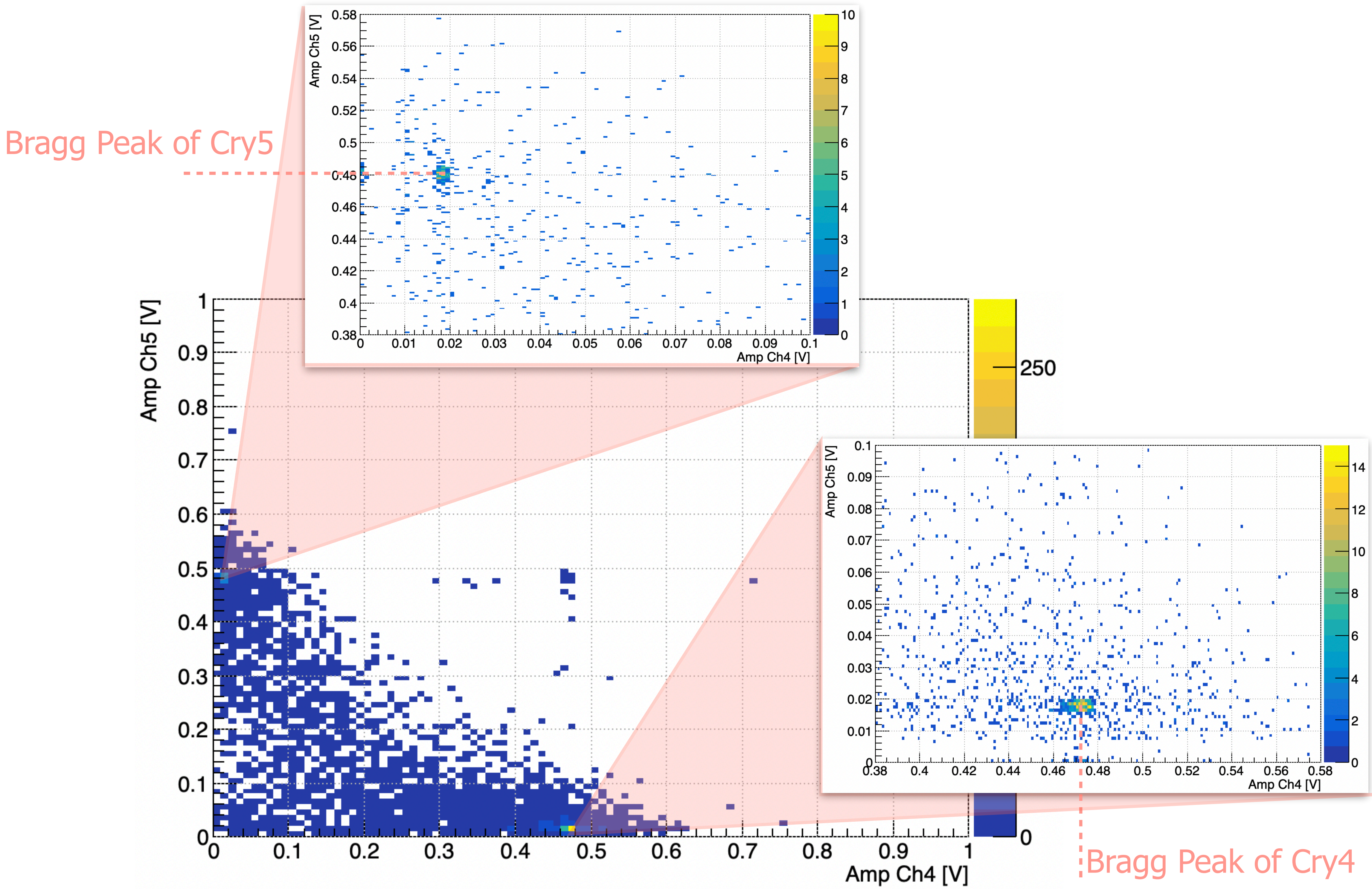


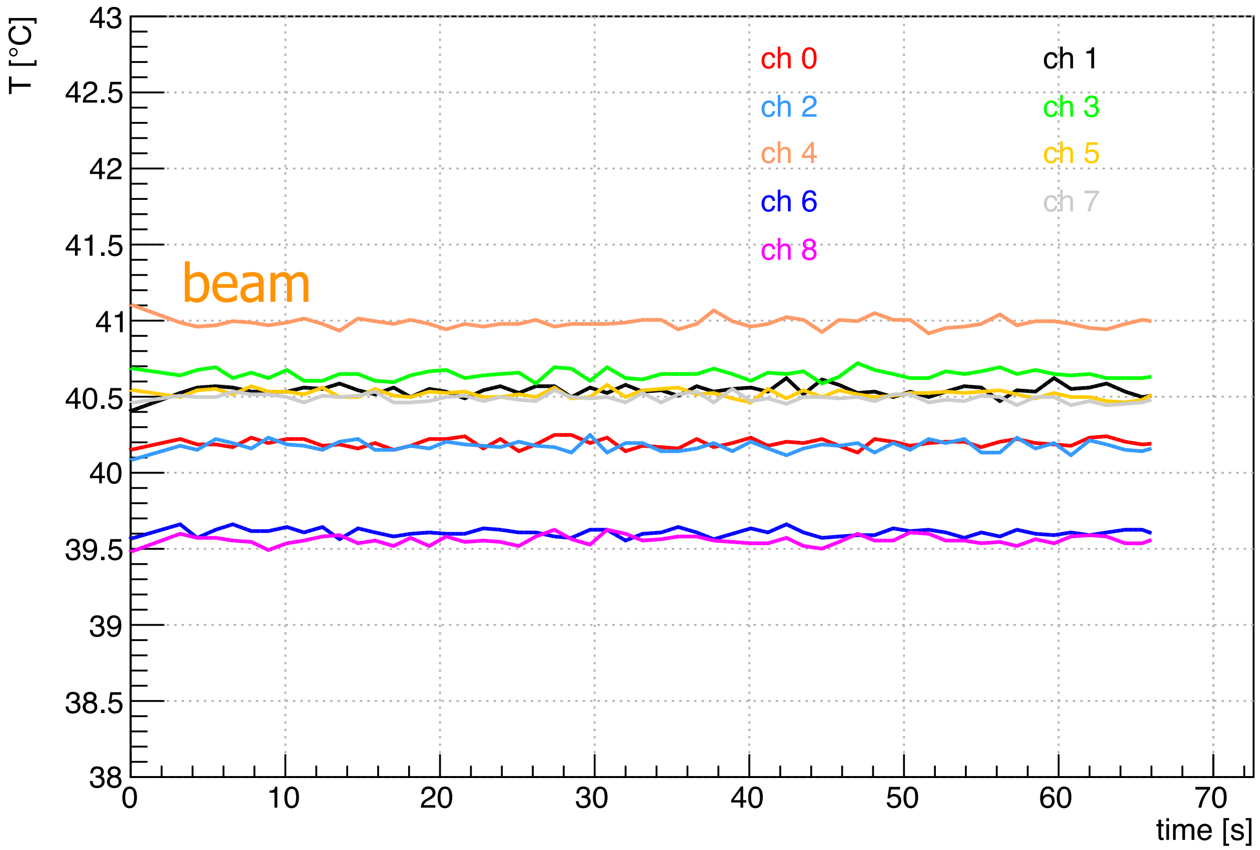




Crystal ball fit

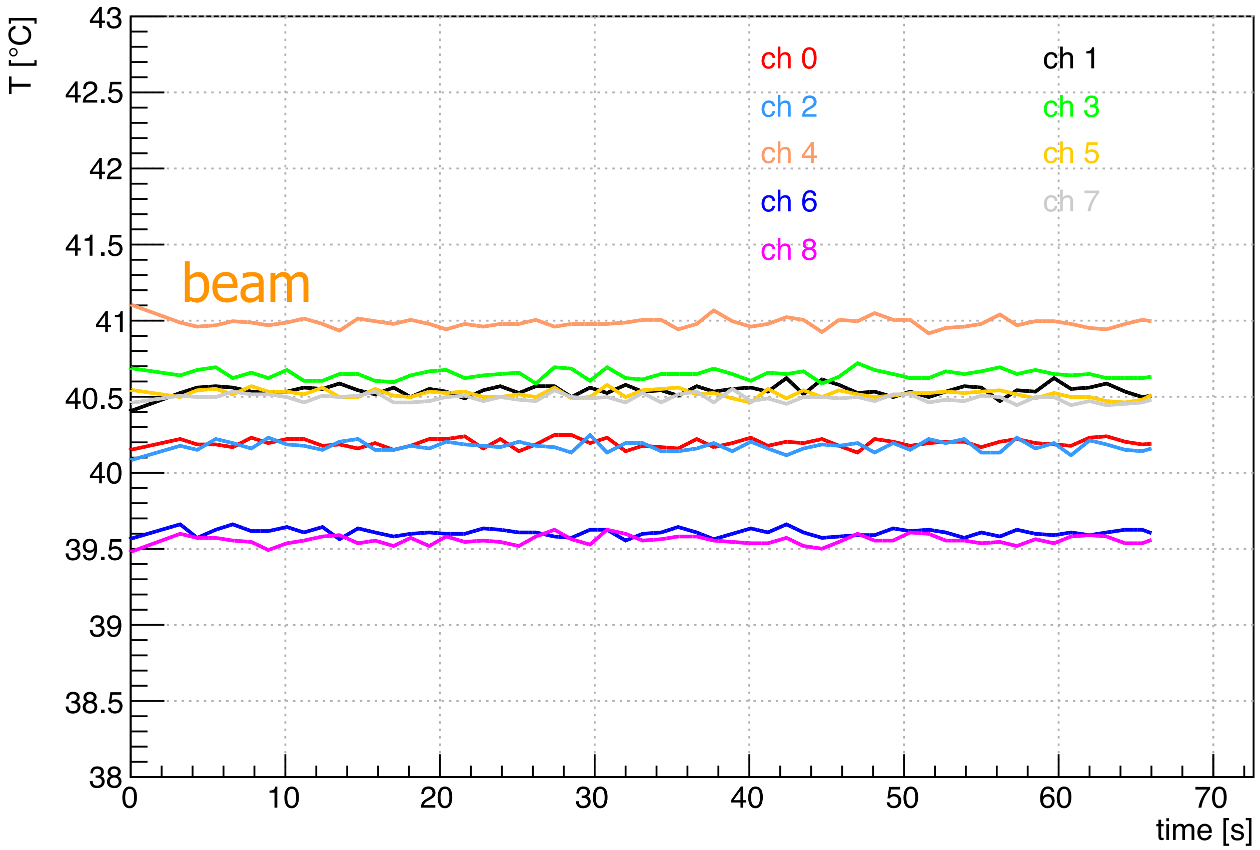
Amplitude of crystal 5 vs Amplitude of crystal 4





- Temperature stable in each crystal during the run
- Higher temperature in central crystal (**ch4**) hit by the beam
- Air temperature at GSI (Cave A) significantly higher than at CNAO → higher SiPM temperature (~40º at GSI vs ~30º at CNAO) → T correction needed for the comparison with CNAO data

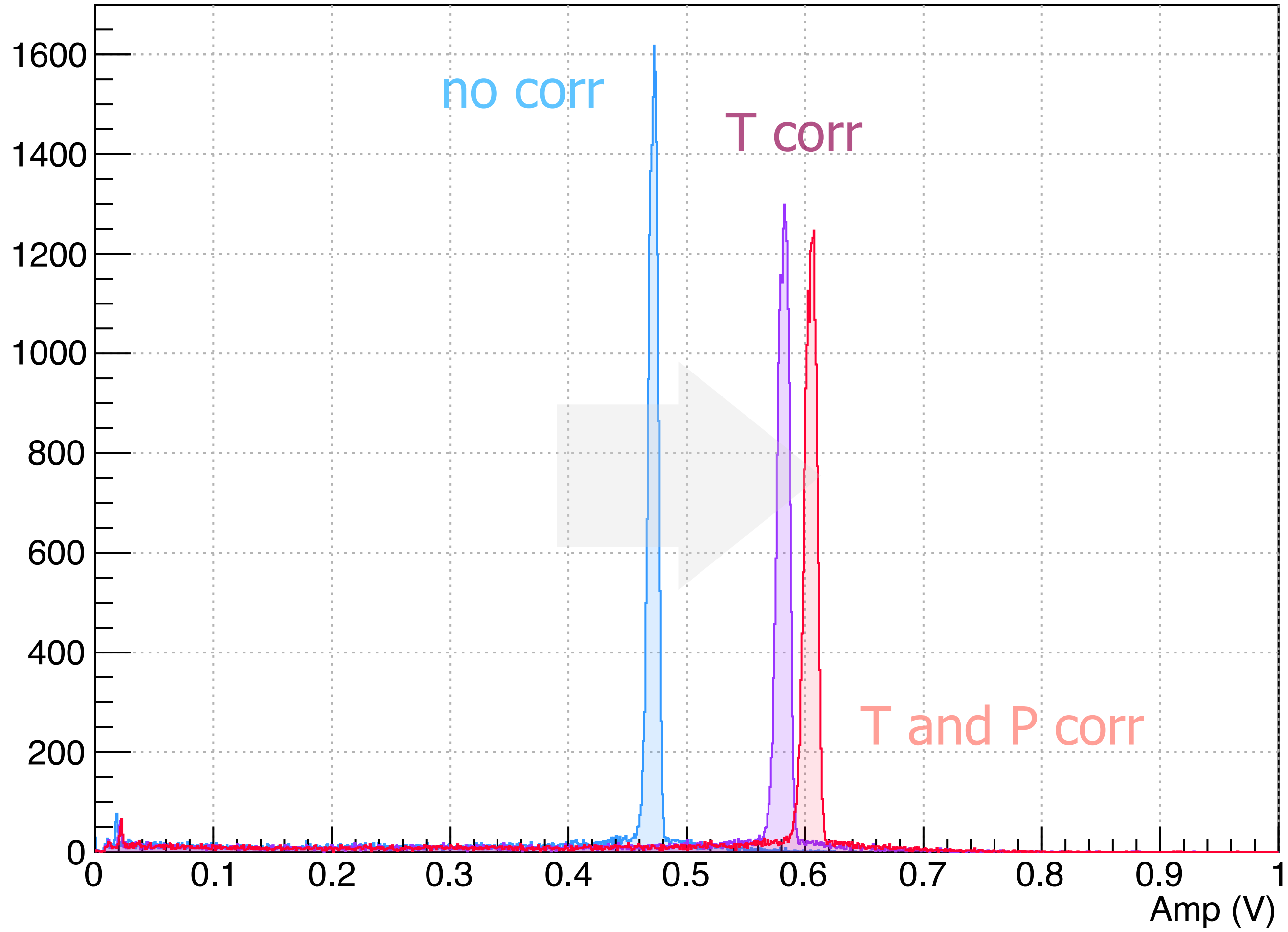
@200 MeV/u - SiPM HV: 34.5V



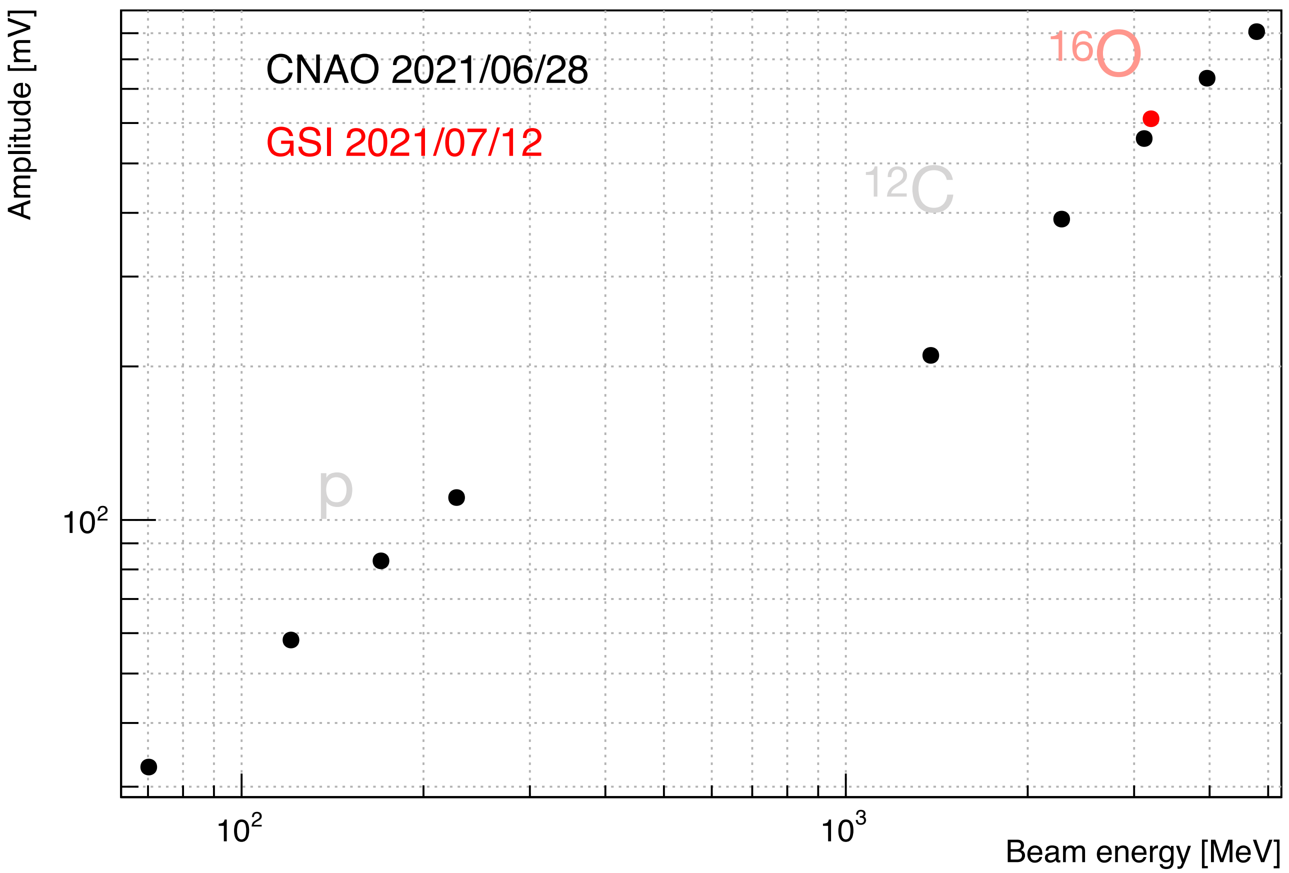
- Temperature stable in each crystal during the run
- Higher temperature in central crystal (**ch4**) hit by the beam
- Air temperature at GSI (Cave A) significantly higher than at CNAO → higher SiPM temperature (~40º at GSI vs ~30º at CNAO) → T correction needed for the comparison with CNAO data

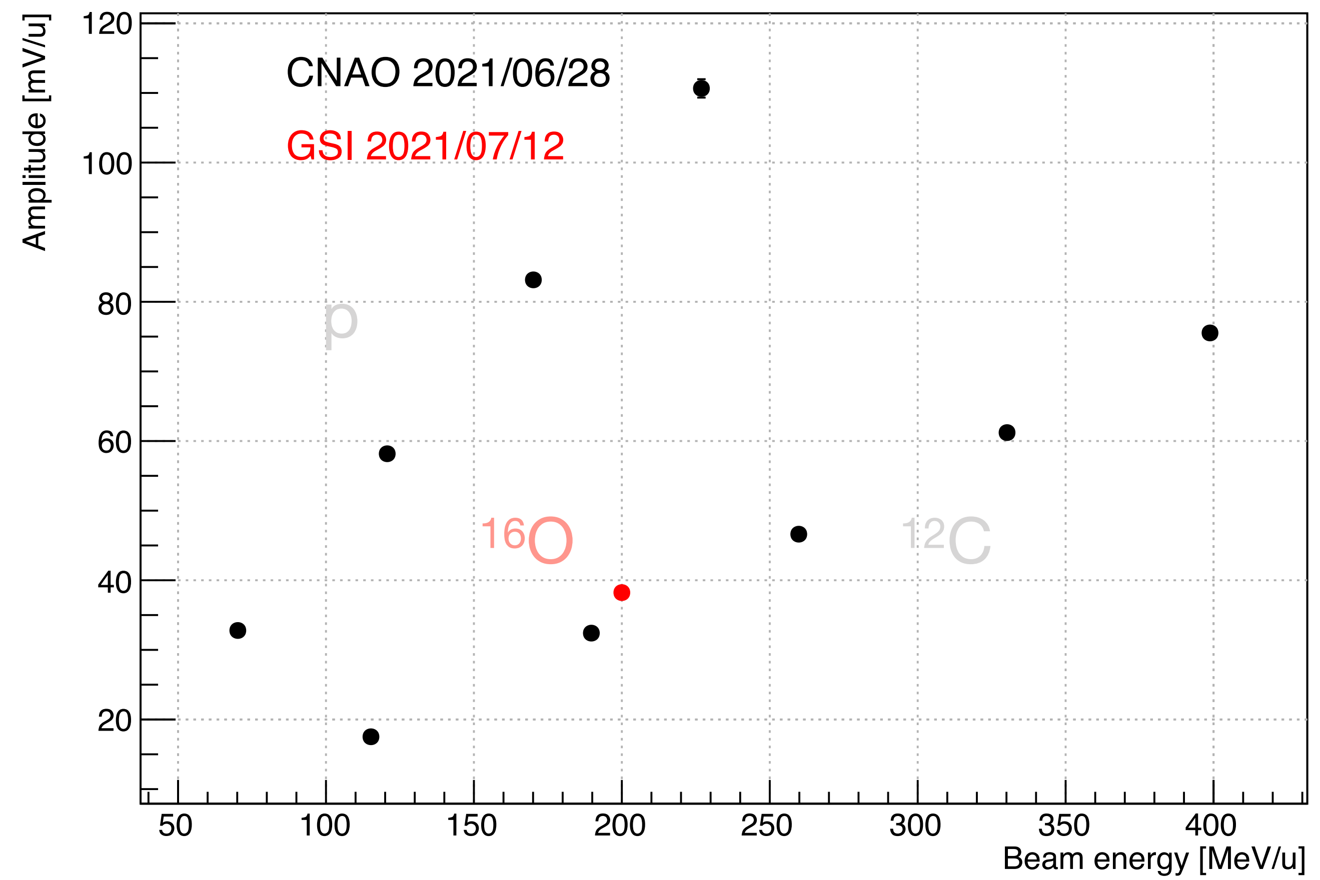
- In order to compare carbon data (@CNAO) and oxygen data (GSI) the range particle correction is needed too.
- Indeed the light collected by the SiPM depends on the range of the particle inside the crystal

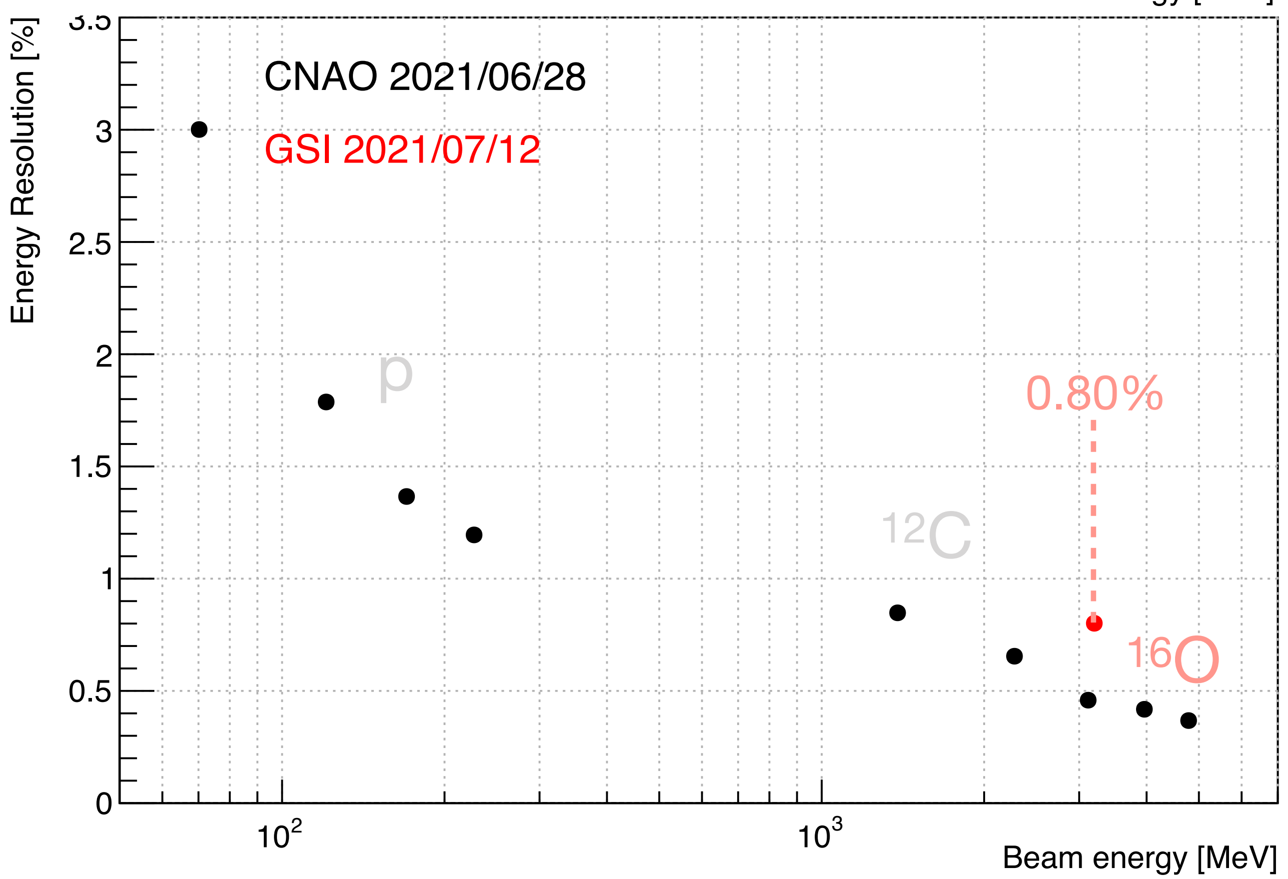
[E. Ciarrocchi, L. Scavarda et al., Simulation of the optical photon propagation in the FOOT calorimeter module] EB review



@200 MeV/u - SiPM HV: 34.5V

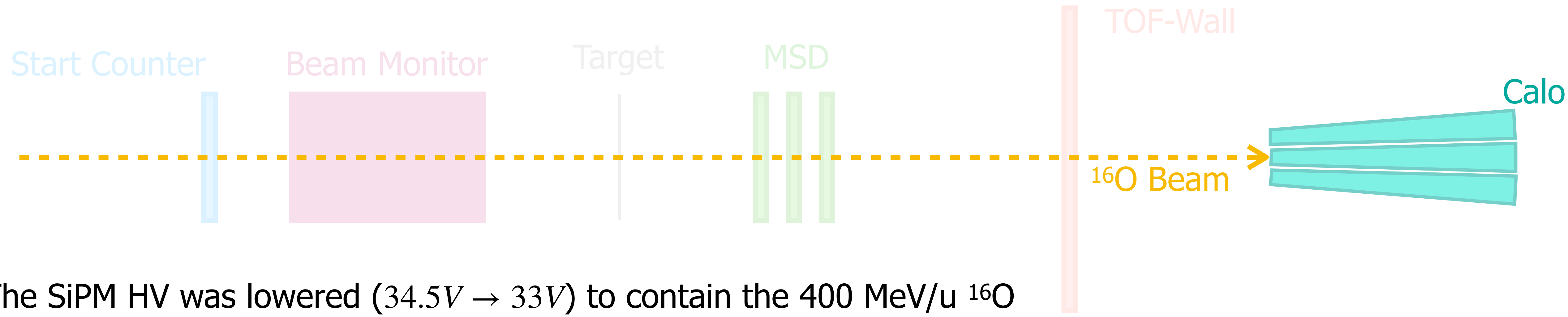




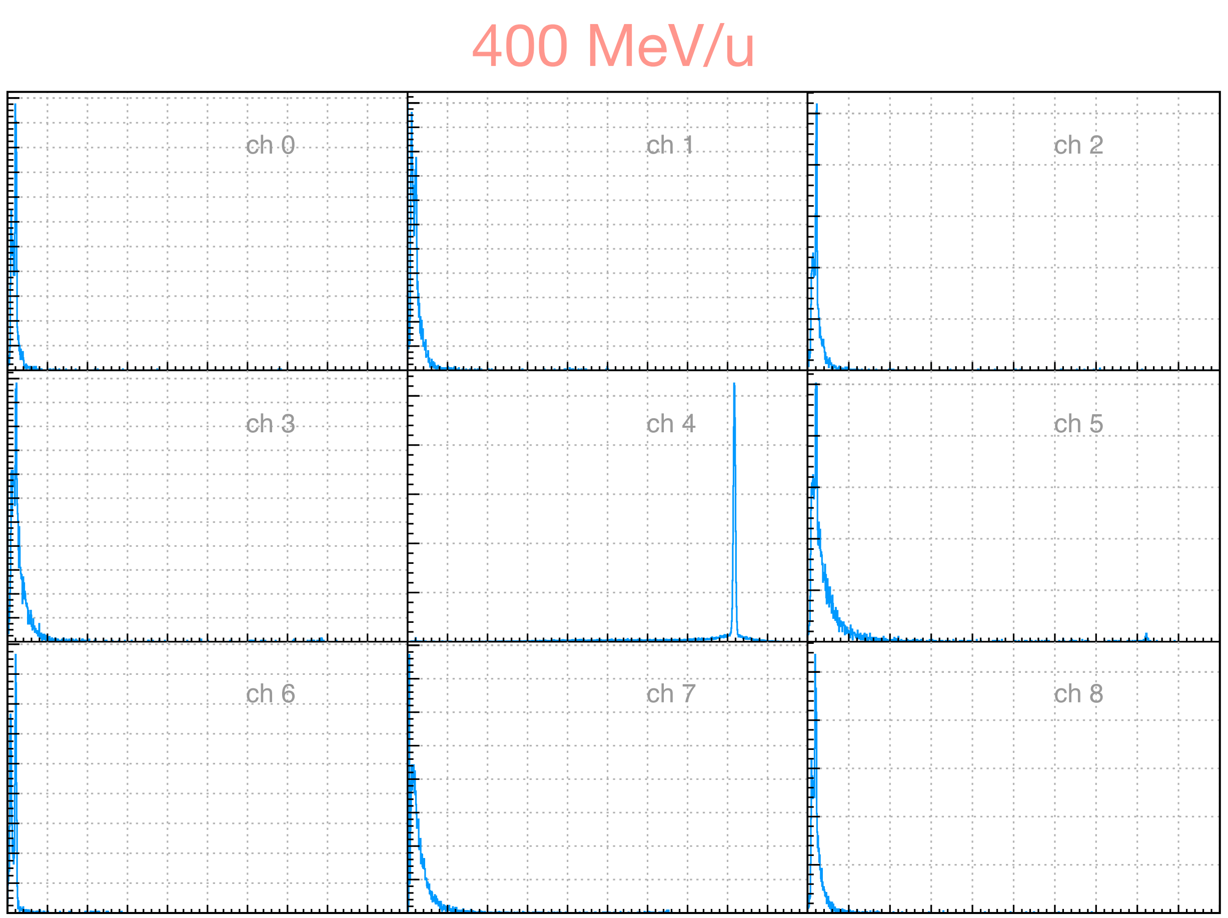


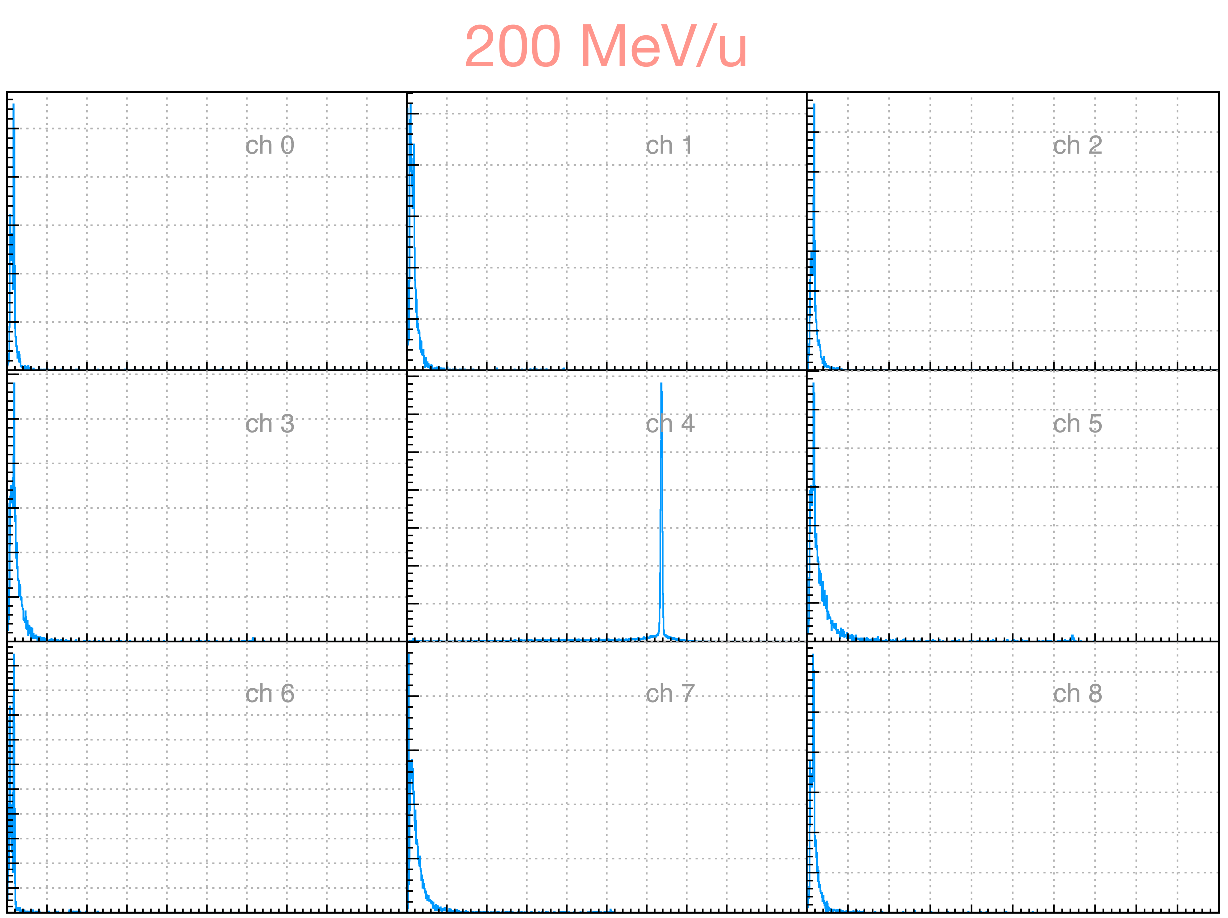
- Only this GSI run has the same working condition of the CNAO data of 28/06/2021 and can be used for the comparison (**200 MeV/u, 34V**)
- The degraded energy resolution may be a combination of two effects:
  - the high HV and higher temperature compared to CNAO may increase the noise and cross-talk between the microcells
  - longer path of the ^{16}O ion in the air before hitting the crystal
- Temperature correction has to be revised because the calorimeter response was not calibrated up to such high temperature. This not properly correction might be responsible for the higher amplitude for ^{16}O

@200-400 MeV/u - SiPM HV: 33V

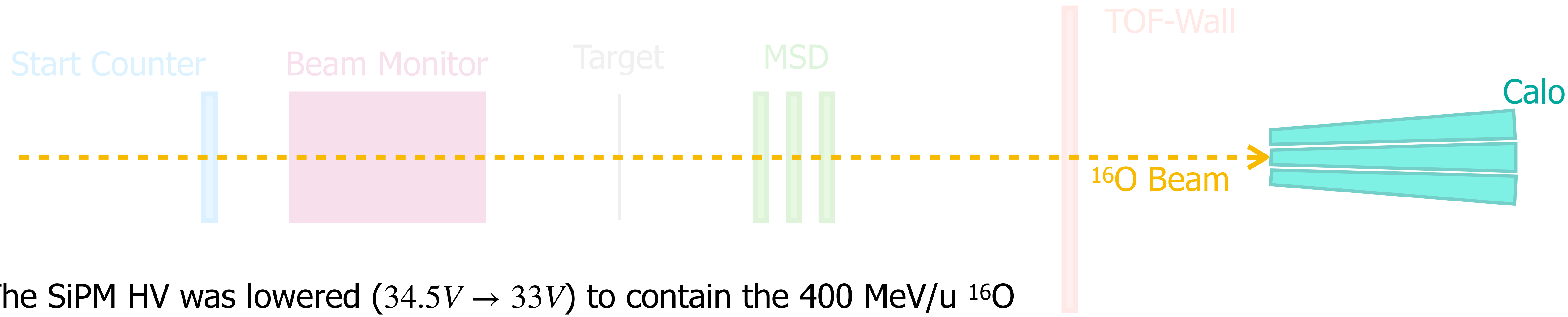


- The SiPM HV was lowered ($34.5V \rightarrow 33V$) to contain the 400 MeV/u ^{16}O
- Beam position more stable: Bragg Peak only in the central crystal (ch4)
- Better resolution ($0.80\,\% \rightarrow 0.55\,\%$) may be due to the lower HV of the SiPM → lower noise in the microcells
- No comparison with CNAO data in the linearity plot is possible (different SiPM HV used)

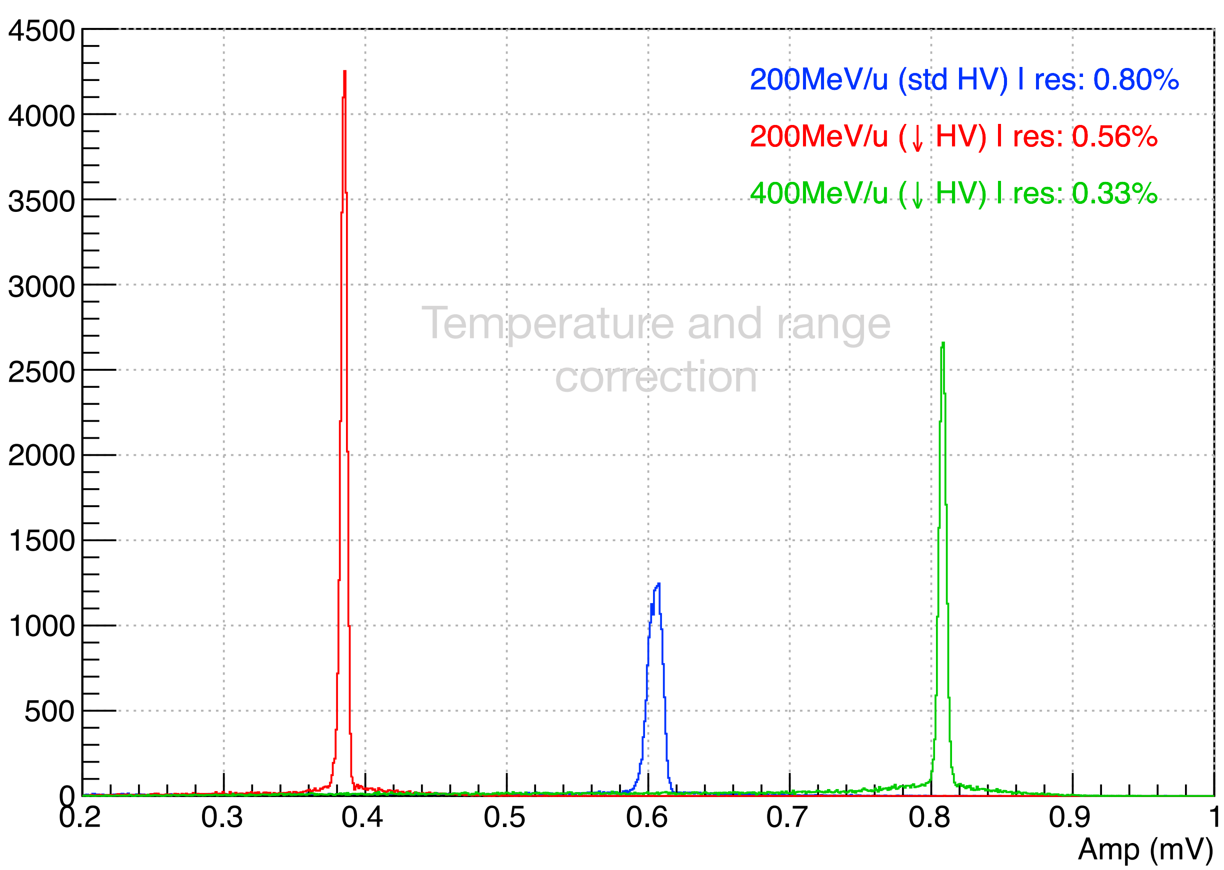


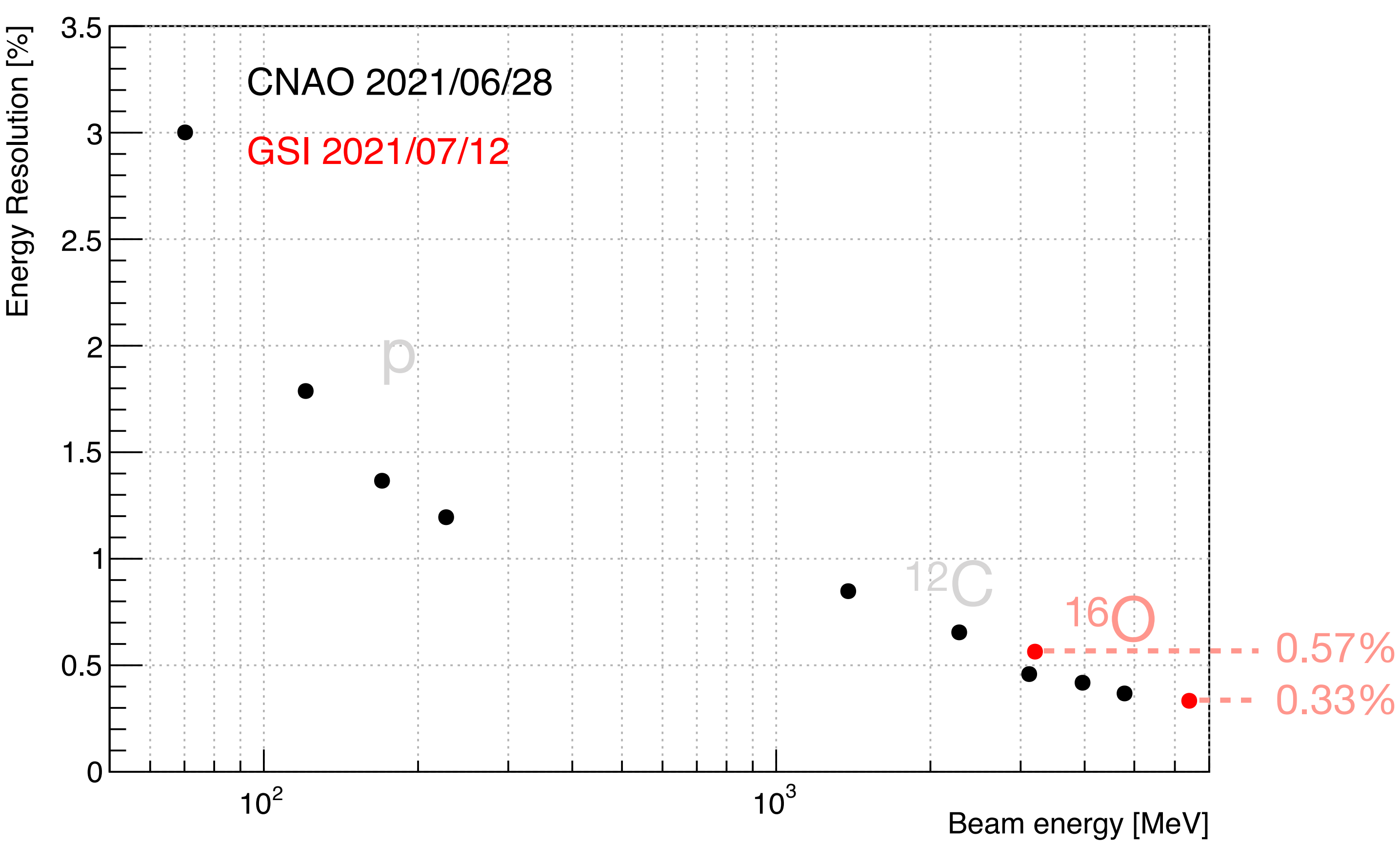


@200-400 MeV/u - SiPM HV: 33V



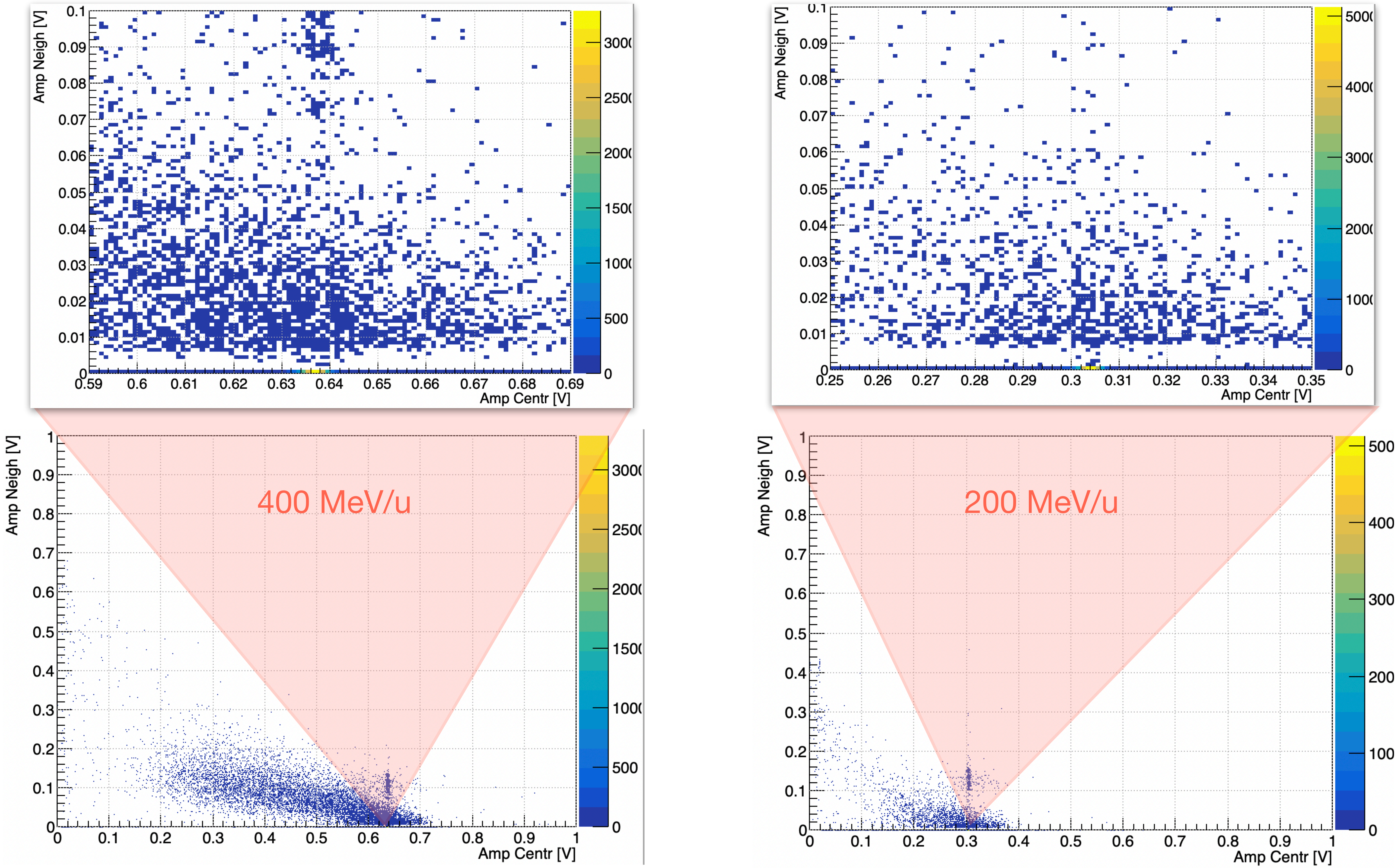
- The SiPM HV was lowered ($34.5V \rightarrow 33V$) to contain the 400 MeV/u ^{16}O
- Beam position more stable: Bragg Peak only in the central crystal (ch4)
- Better resolution ($0.80\,\% \rightarrow 0.57\,\%$) may be due to the lower HV of the SiPM → lower noise in the microcells
- No comparison with CNAO data in the linearity plot is possible (different SiPM HV used)



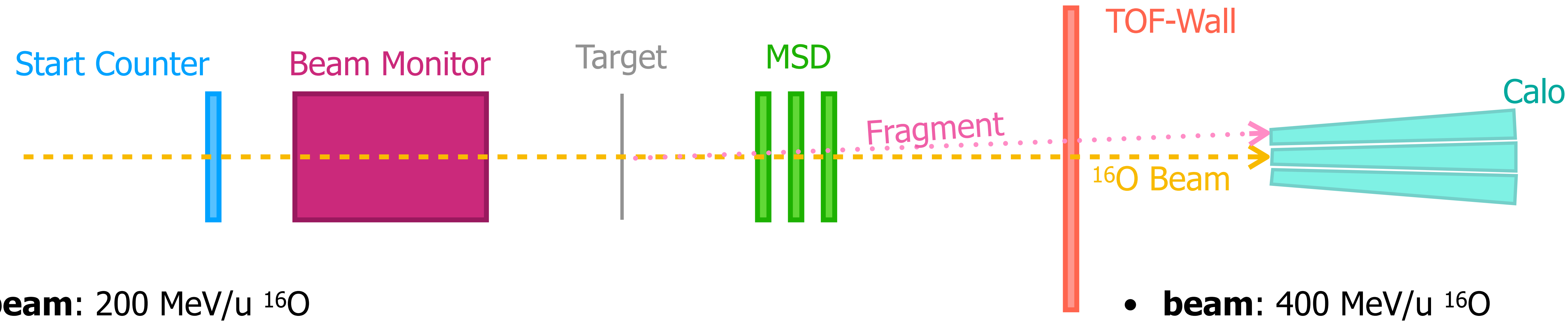


@200-400 MeV/u - SiPM HV: 33V

Sum of the amplitudes in the neighbours vs Amplitude in the central crystal (ch 4)

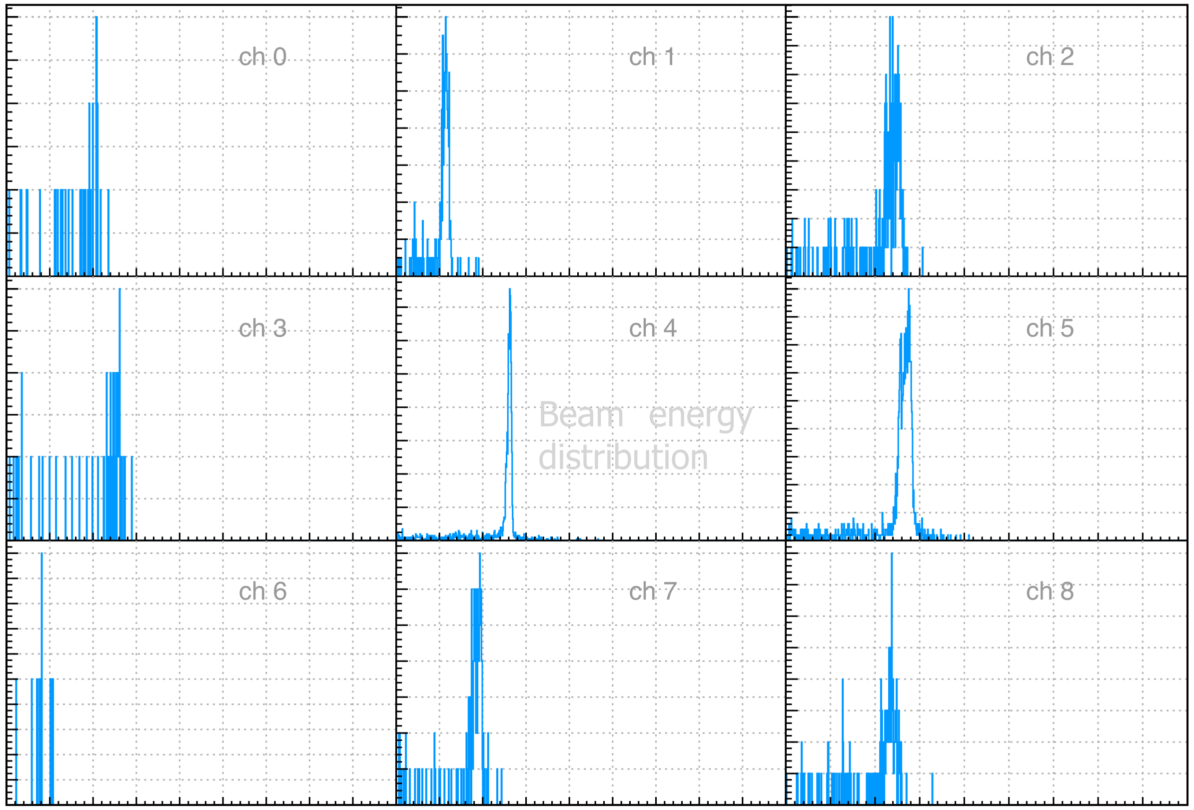


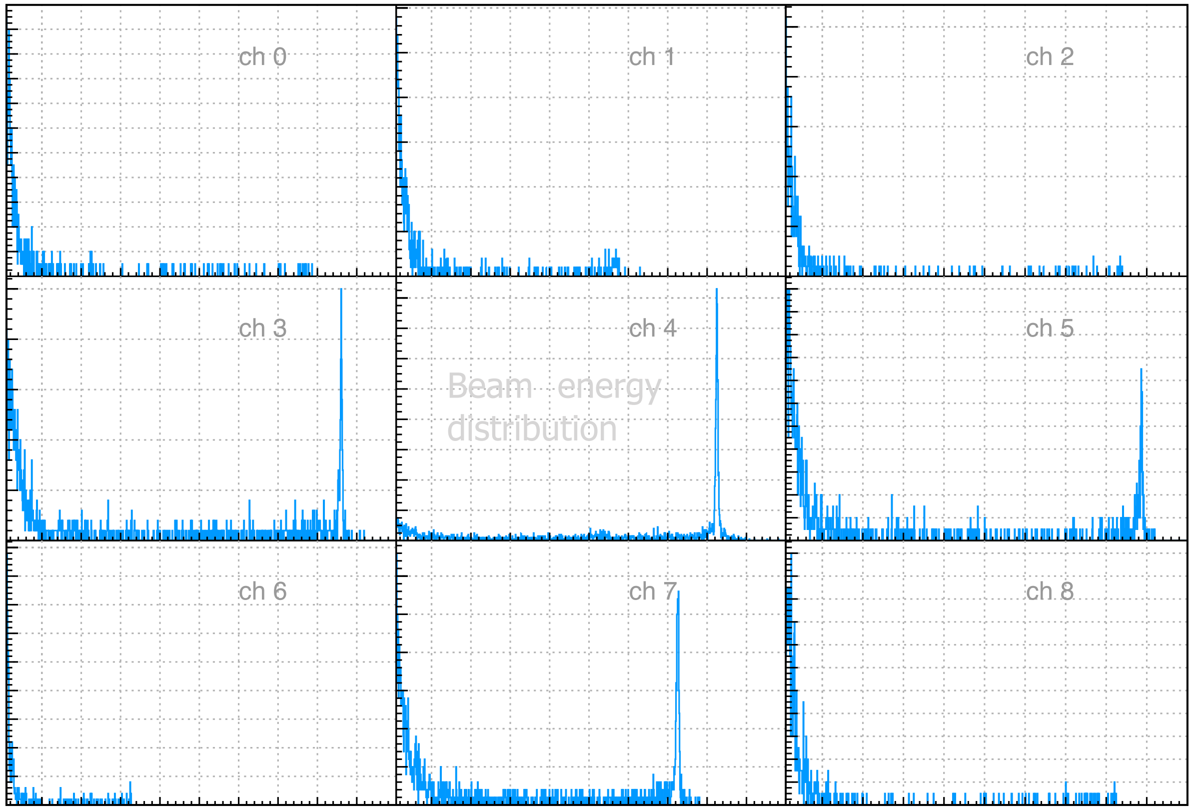
@200-400 MeV/u - Full FOOT setup



- **beam**: 200 MeV/u ^{16}O
- **target**: 5mm C
- **SiPM HV**: 34.5V
- **Global DAQ**

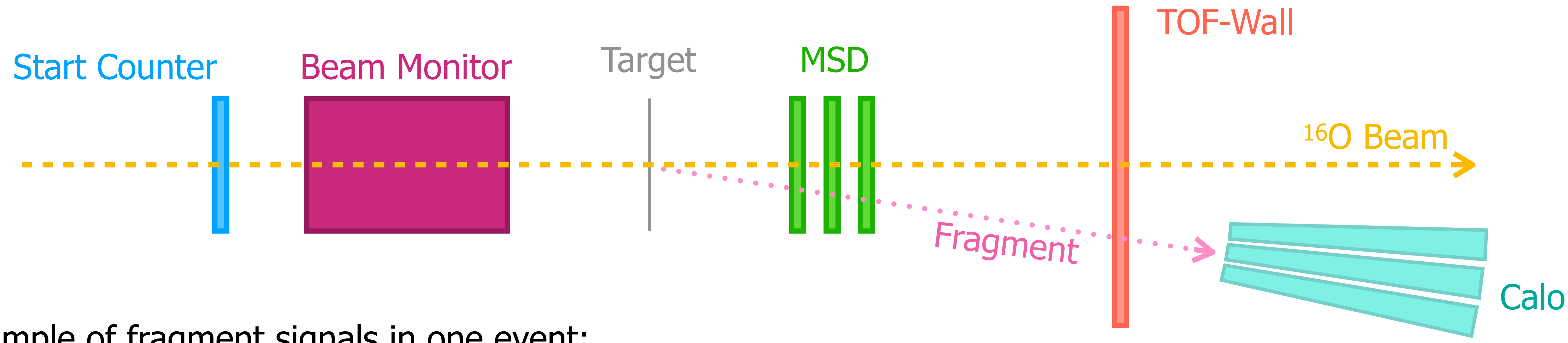
- **beam**: 400 MeV/u ^{16}O
- **target**: 10mm C_2H_4
- **SiPM HV**: 33V
- **Global DAQ**



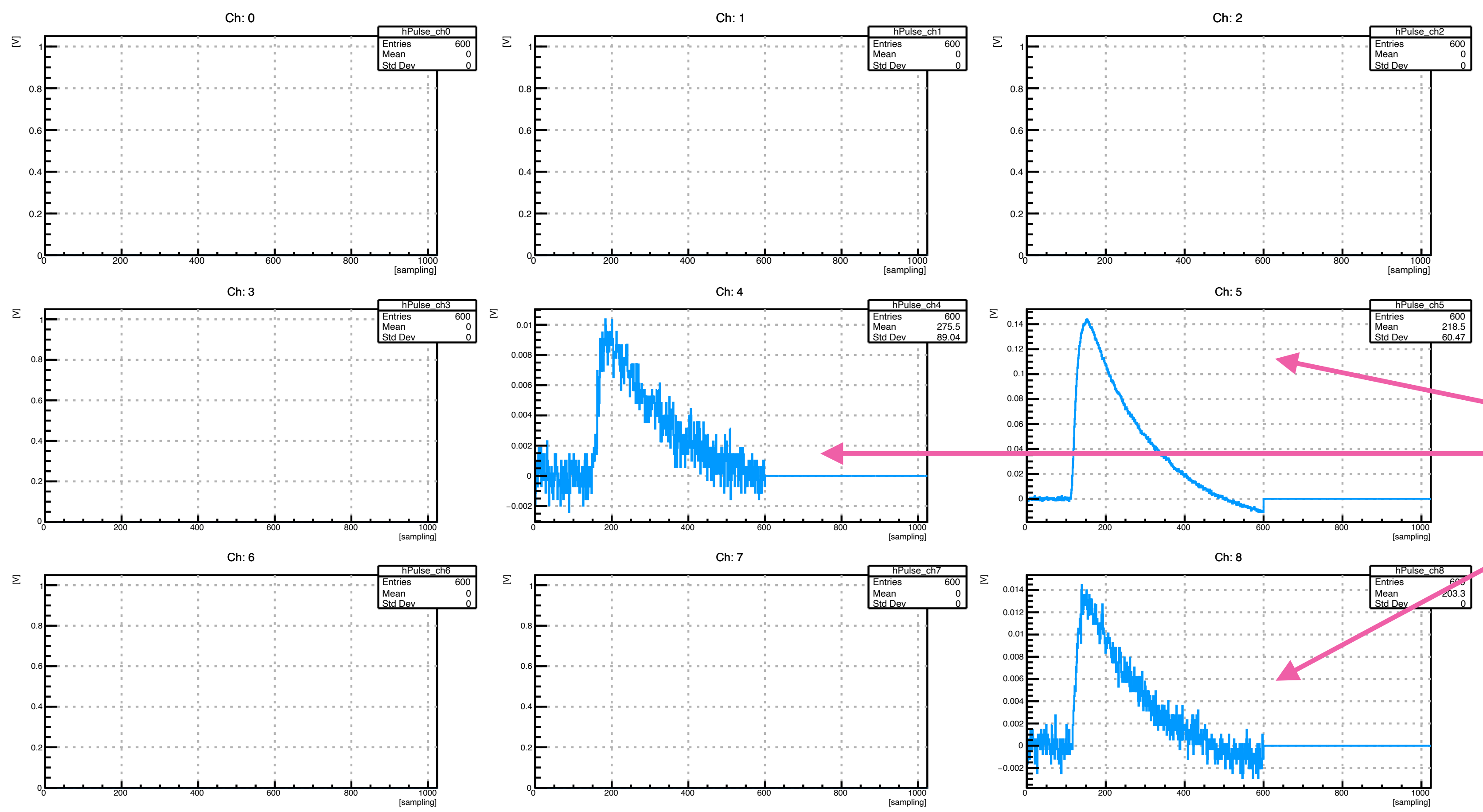


For these runs a cross analysis TOF - Calorimeter is needed

Calo rotated 2-4° - Full FOOT setup



Example of fragment signals in one event:



- **beam**: 200 MeV/u ^{16}O
- **target**: 10mm C_2H_4
- **SiPM HV**: 34V
- **Global DAQ**
- Calorimeter rotated by 4°

Fragments

For these runs a cross analysis TOF - Calorimeter is needed

Conclusions & Next Steps

Conclusions:

The GSI testbeam was the first integration test of the calorimeter in the global DAQ:

- Temperature monitored for several days continuously
- data acquired in standalone mode (only WaveDAQ) with no detectors/target upstream the calorimeter, useful for CNAO data comparison:
  - Good energy resolution ($\leq 0.5\%$), comparable to what was achieved with Carbon ions at CNAO
  - Only 200 MeV/u can be directly compared to CNAO data at the moment. Calibration at CNAO with lower SiPM voltage necessary for the comparison with 400 MeV/u point.
- data acquisition included successfully in the global DAQ:
  - data acquired with different targets (C and C_2H_4) and target thick (5 mm and 10 mm)
  - data acquired in different calo configuration (rotation of 2-4°)

Next Steps:

A lot of work still to be done:

- a more detailed and in-depth analysis with the other detectors (in particular with TOF-Wall). Probably a meeting with the Pisa group will be organised for the next weeks
- integration of the temperature monitoring system in the global DAQ
- development of the "calorimeter trigger" in the global DAQ (for dedicated calibration runs)
- start with the real construction of the calorimeter