Report on intercalibration - TB CNAO 2021/06/28

Università degli Studi di Torino e INFN, Sezione di Torino
FOOT Collaboration

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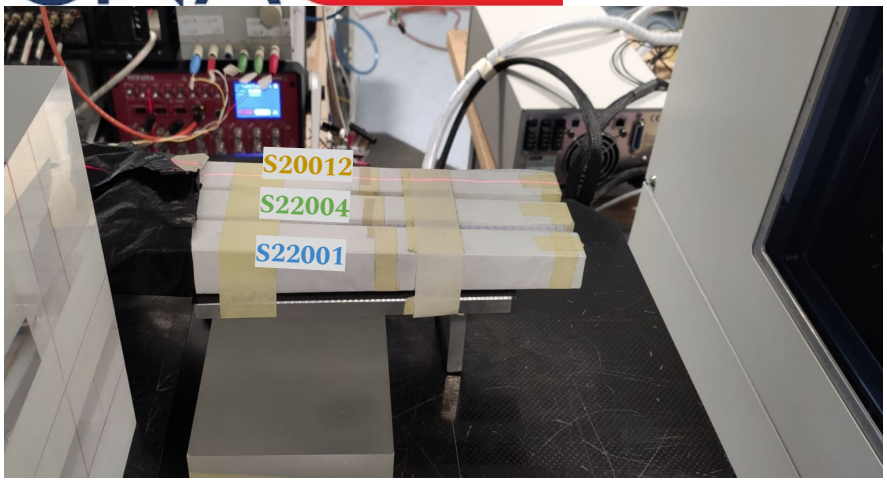
CNAO Test Beam

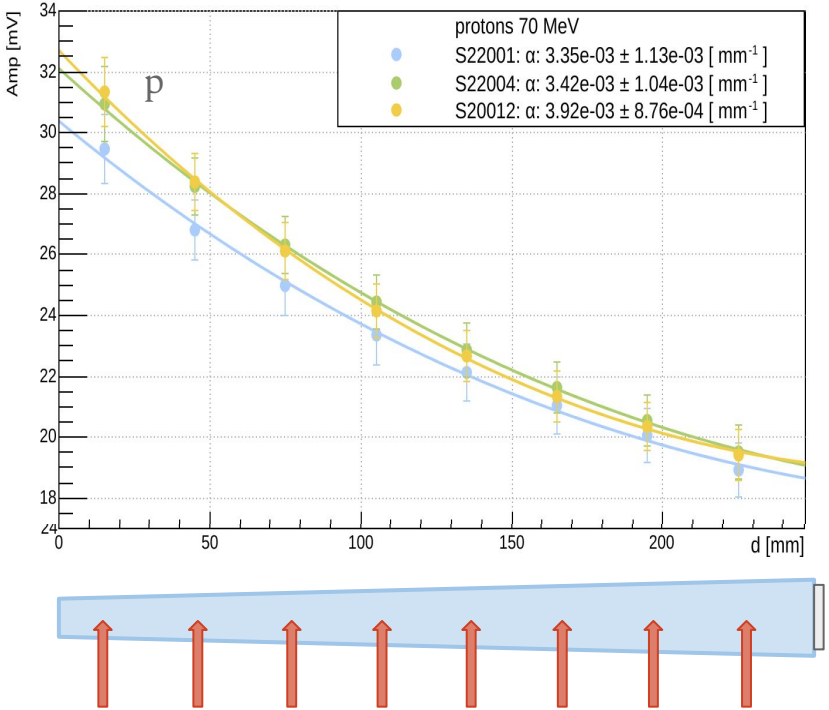
Main goal: define the best calibration protocol for the calorimeter



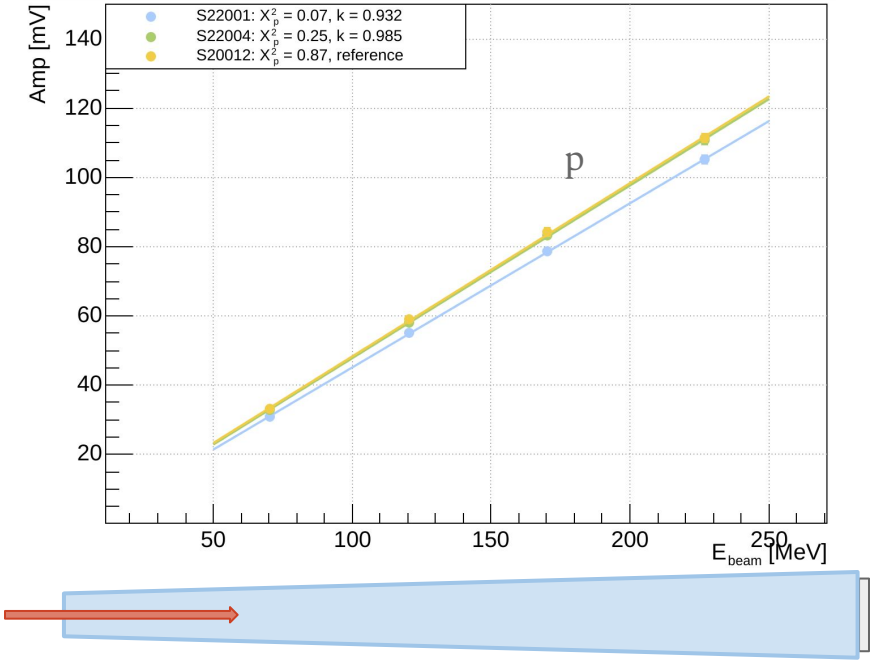
- **Find intercalibration factors** in order to equalize the response of each crystal of the calorimeter:
  - 3 crystals tested with IDs: S22001, S22004, S20012
  - Energies available @CNAO
    protons: 70,120,170,227 MeV
    Carbon ions: 115, 190, 260, 330, 400 MeV/A
  - Two methods tested:
    - Frontal Scans
    - Lateral Scans
- Temperature has been monitored: data have been corrected using **temperature correction**

CNAO Test Beam - overview

- First night: **Lateral** Scan on 3 crystals
  - p70 MeV and C115 MeV/A
  - @15, 45, 75, 105, 135, 165, 195, 225 mm

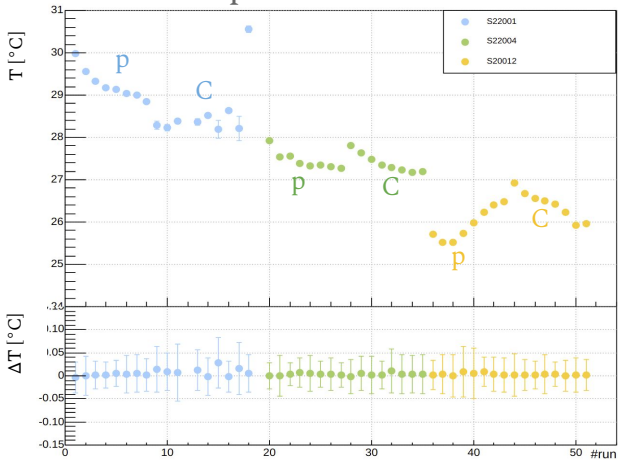


- Second night: **Frontal** Scan on 3 crystals
  - **protons**: 70, 120, 170, 227 MeV
    Carbon ions: 115, 190, 260, 330, 400 MeV/A



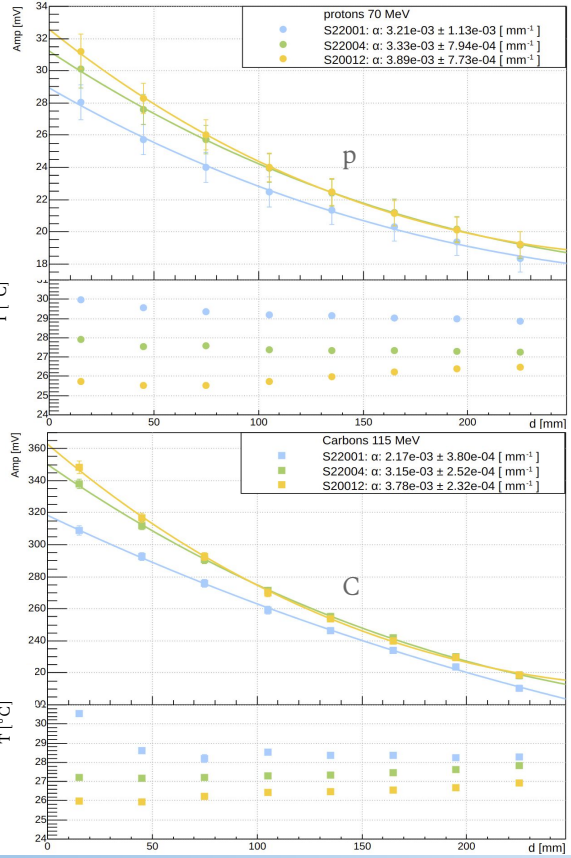
Temperature monitoring and correction - **Lateral** Scan

Temperature vs Run

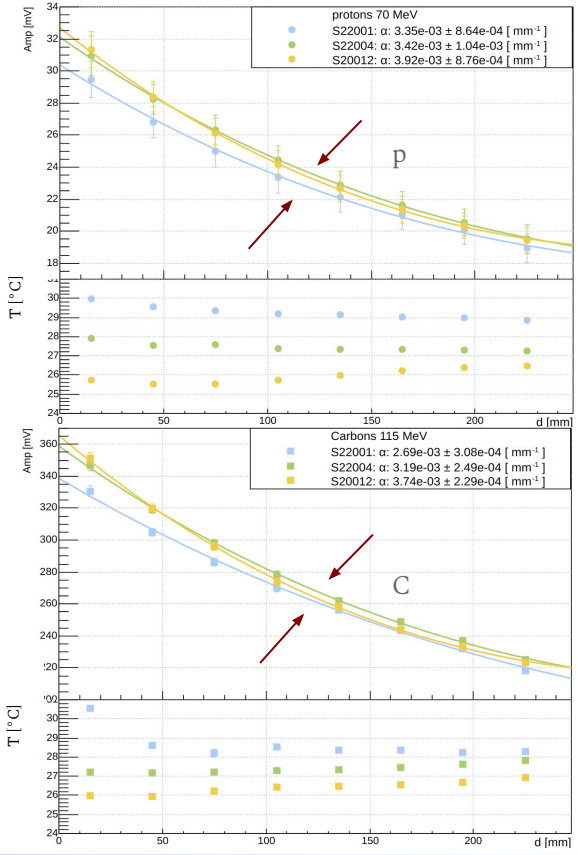


- During the run we acquired the **temperature each second**
- We often entered in the treatment room and turned off the HV to change the crystal position: T decreasing
- ΔT~0: **T stable during the run**.
- Points of the scan get closer after T correction

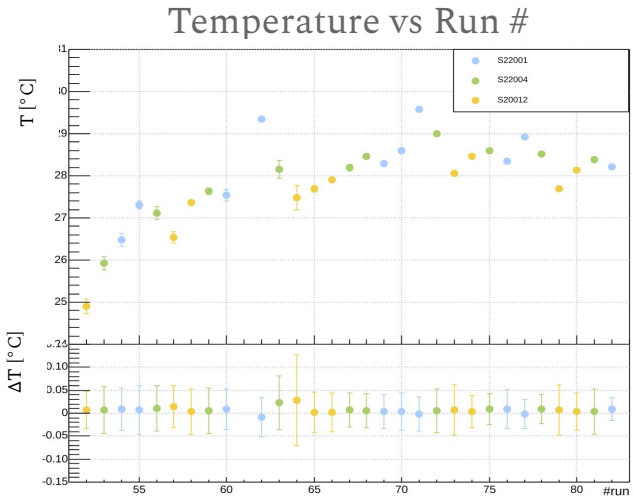
Raw data



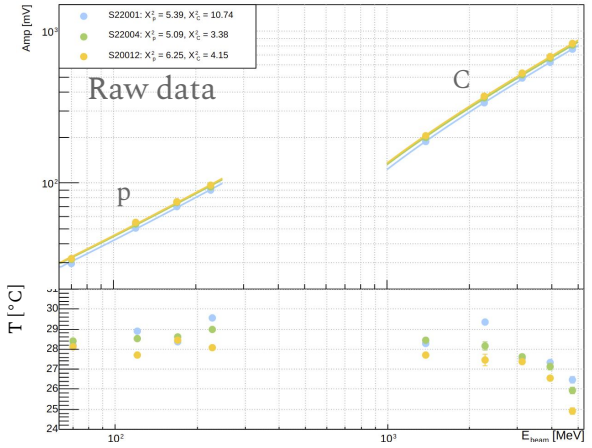
Temperature corrected data

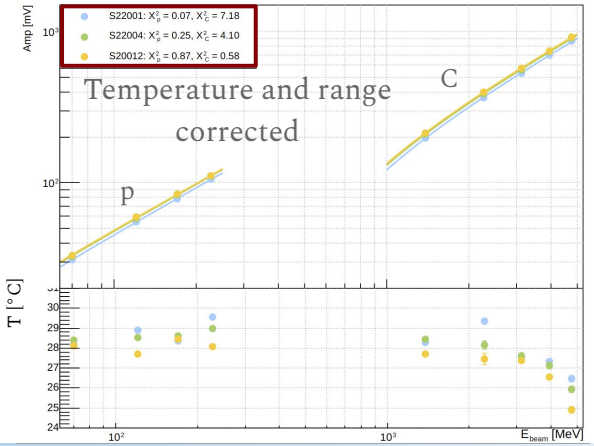


Temperature monitoring and correction - **Frontal** Scan

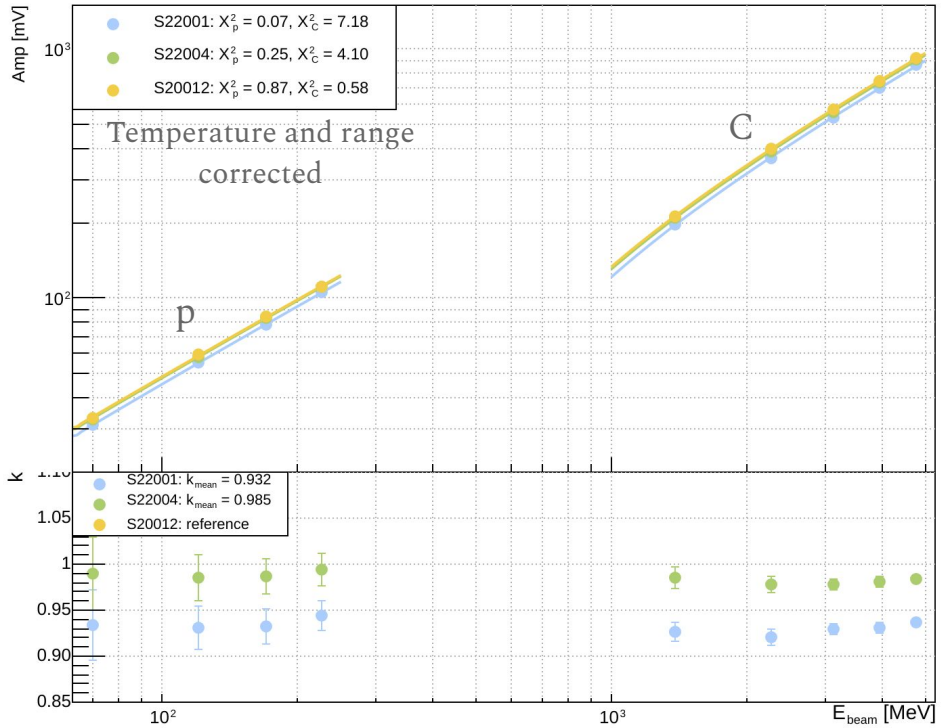


- Globally T is increasing.
- ΔT~0: **T stable during the run**.
- Linearity get better if we perform both temperature correction and range correction



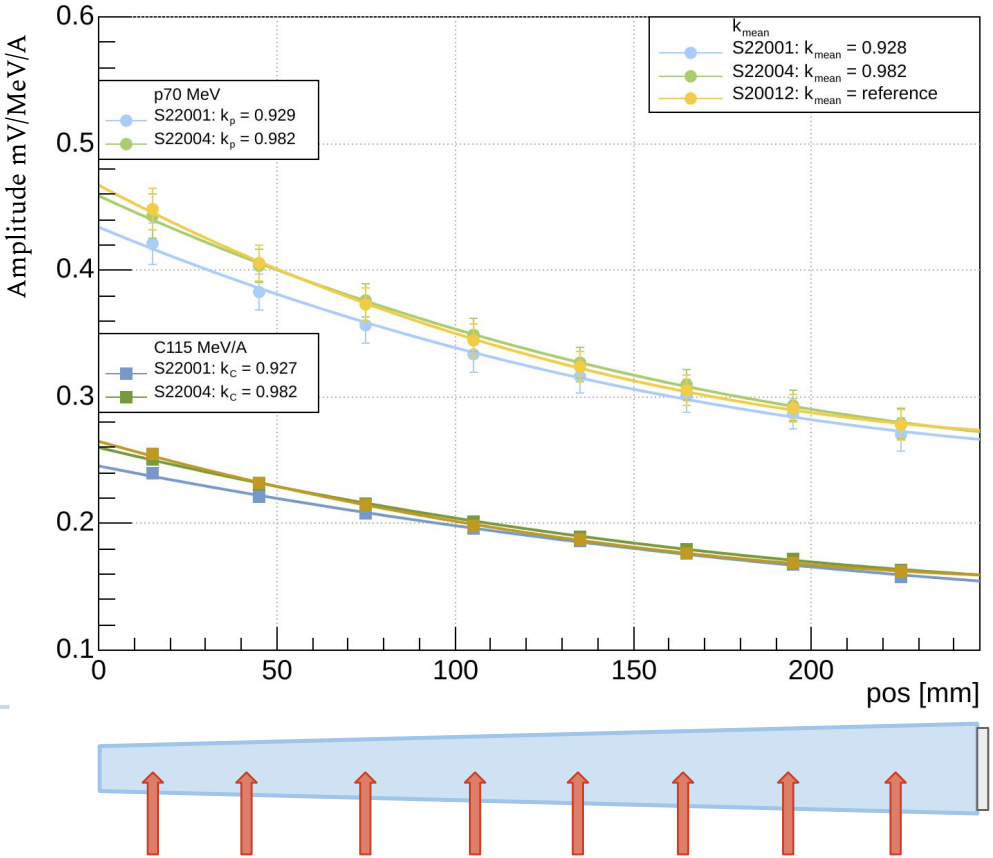


Computing the intercalibration factors from **frontal** scan



- From Amplitude vs Energy Beam plot:
  - Reference crystal is chosen - 'S20012' in this case
  - Compute $\mathbf{k_i = amp_i/amp_{ref}}$ for each energy point
  - Compute the **mean of the set of k_i** for each crystal

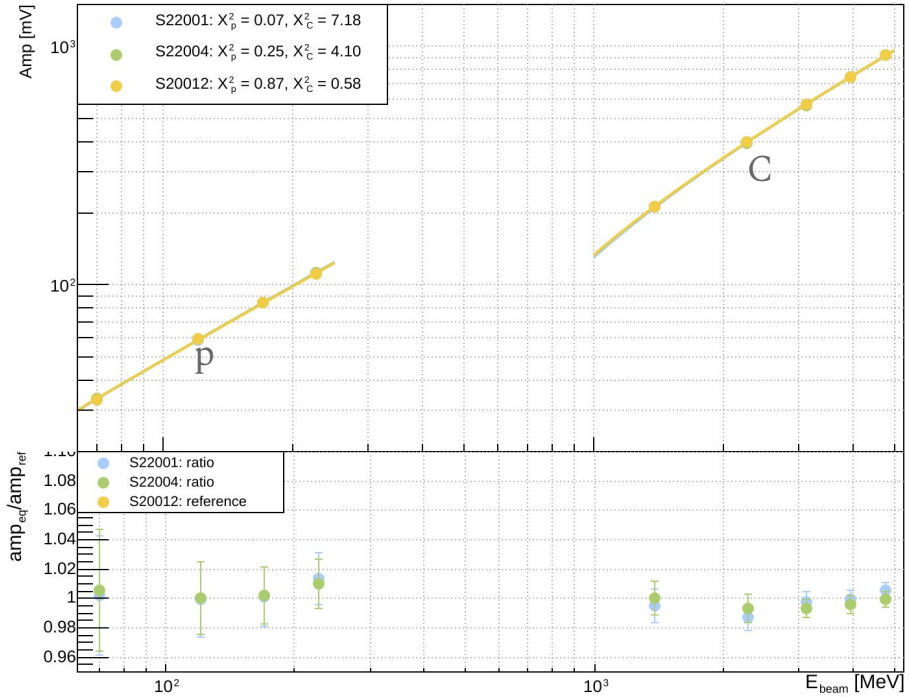
Computing the intercalibration factors from **lateral** scan



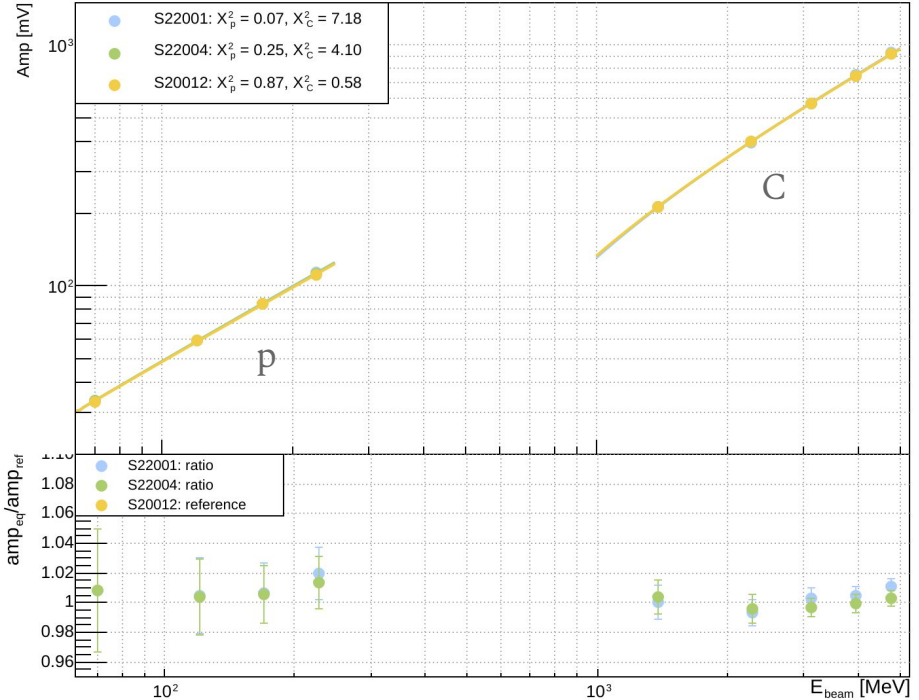
- Amplitude decreases when the beam is closer to the SiPM - optical photons absorption
  - Reference crystal is chosen - 'S20012' in this case
  - Compute **k = amp(0)/amp$_{ref}$(0)** for each crystal
- Computed the **mean** of the intercalibration k of p 70 MeV and C 115 MeV/A
- Furthermore, from lateral scan plots, the correction factors for **range correction** can be evaluated!

Linearity plot intercalibration

Calibration using factors from **frontal** scan

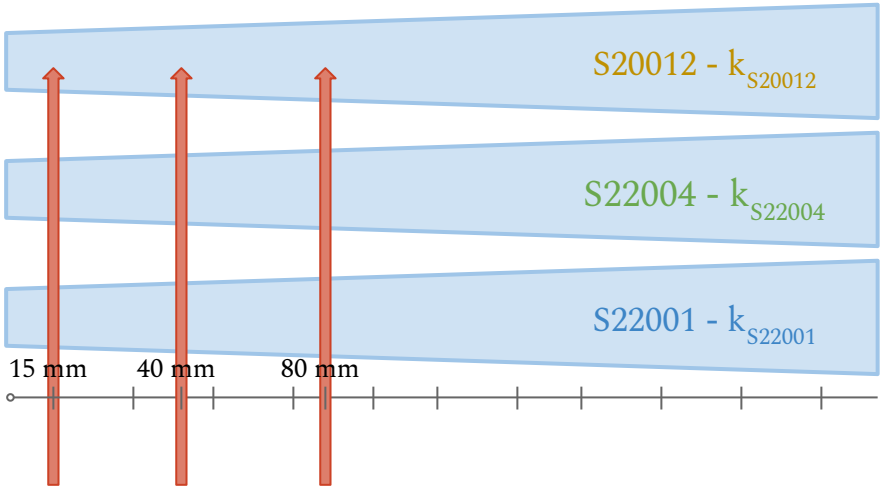


Calibration using factors from **lateral** scan

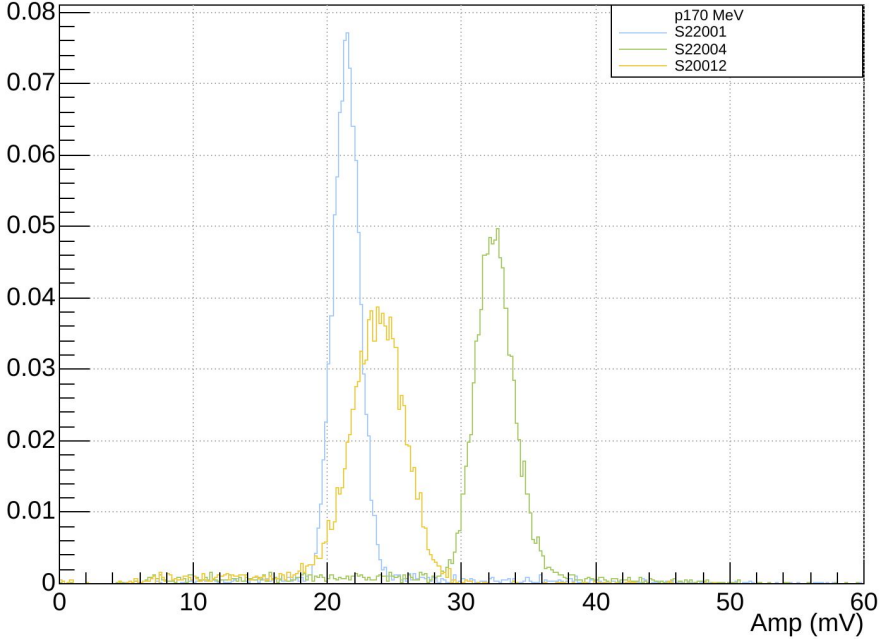


- Equalized the response of each crystal to the reference one and evaluated the ratio between the equalized amplitudes and the reference amplitudes: **ratio ~ 1**, good equalization for both methods

Verify the method - p170 MeV through 3 crystals

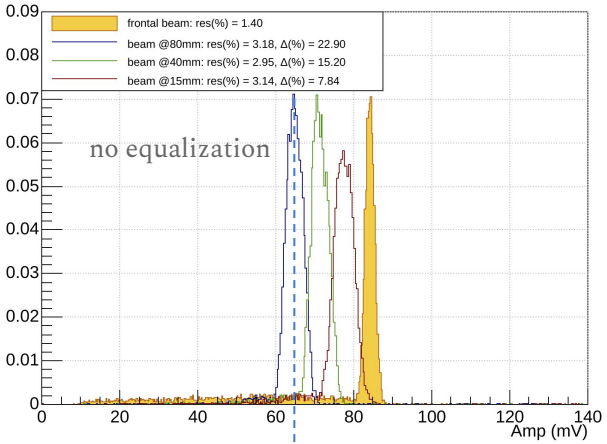


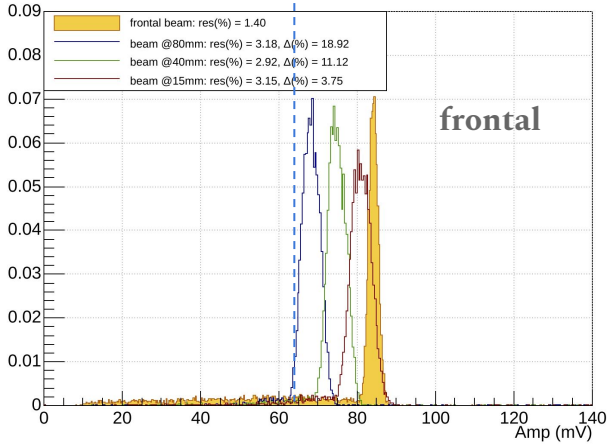
Raw amplitude distribution for each crystal (@15mm)



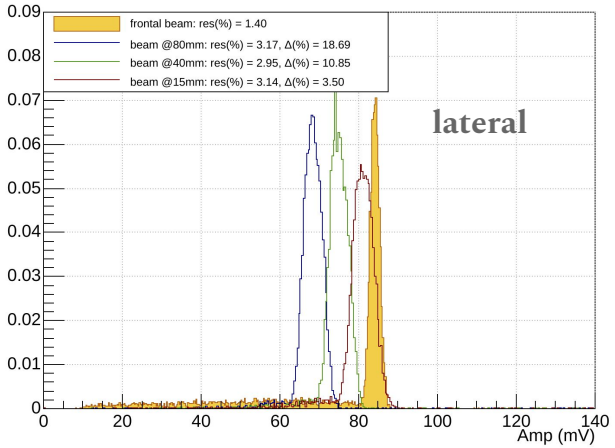
- p 170 MeV: energy deposition on 3 crystal
  - @15, 40, 80 mm
- Use the intercalibration factors to **equalize and sum** the three contributions

p170 MeV: Summing and calibrating

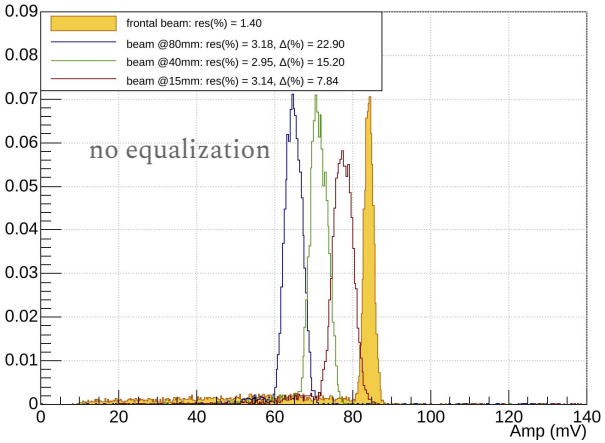


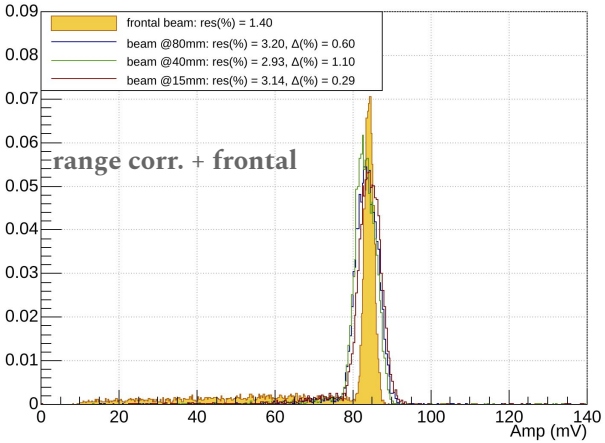


- Either using factors from frontal or from lateral, **resolution doesn't get worse**
- Distributions of the sum and distribution of the frontal scan are not peaked at the same value: **range correction is missing**!

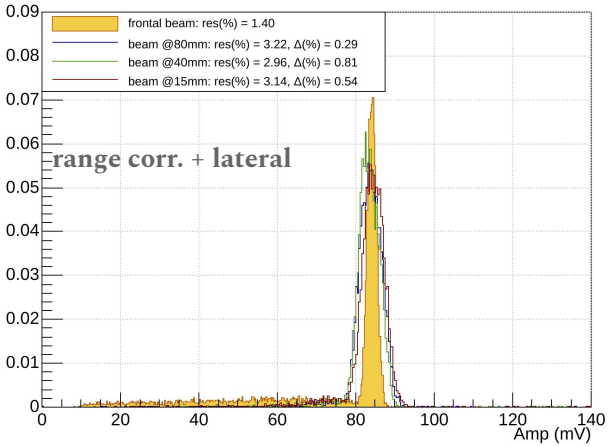


p170 MeV: Applying range correction

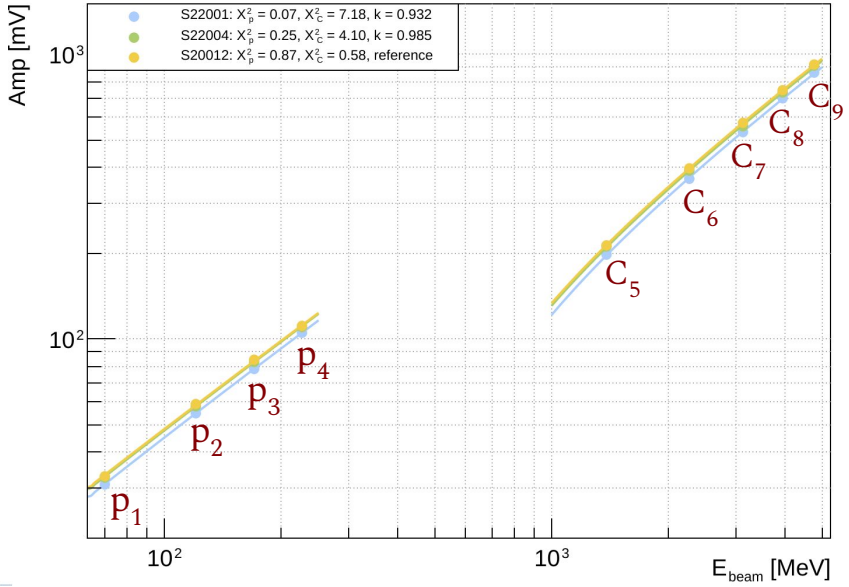


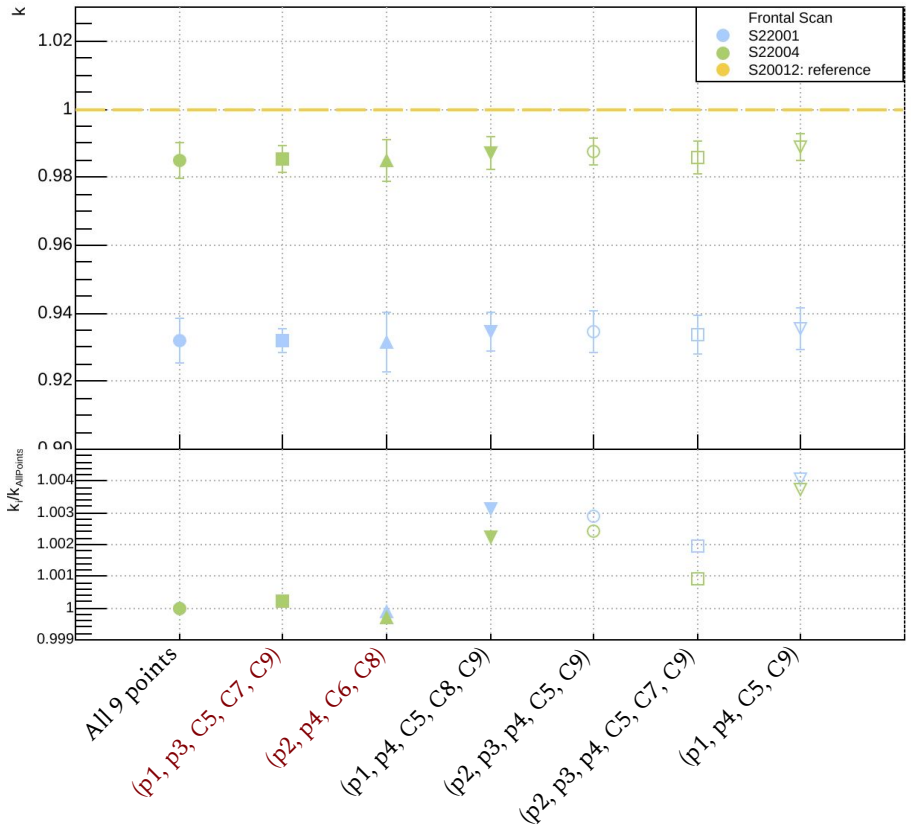


- The **range correction** moves the peaks to the same value of amplitude
- Calibration and range correction seem to work properly!
- **Discrepancy** of the peaks with the respect of the amplitude value of the frontal scan is < **1%** both in intercalibration using frontal scan and the one using lateral scan



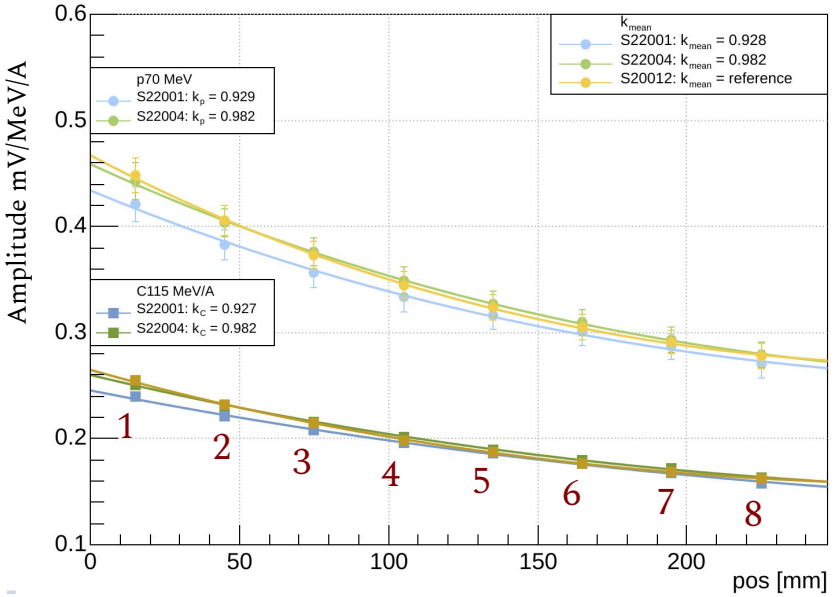
Evaluate the $k_{frontal}$ with less points

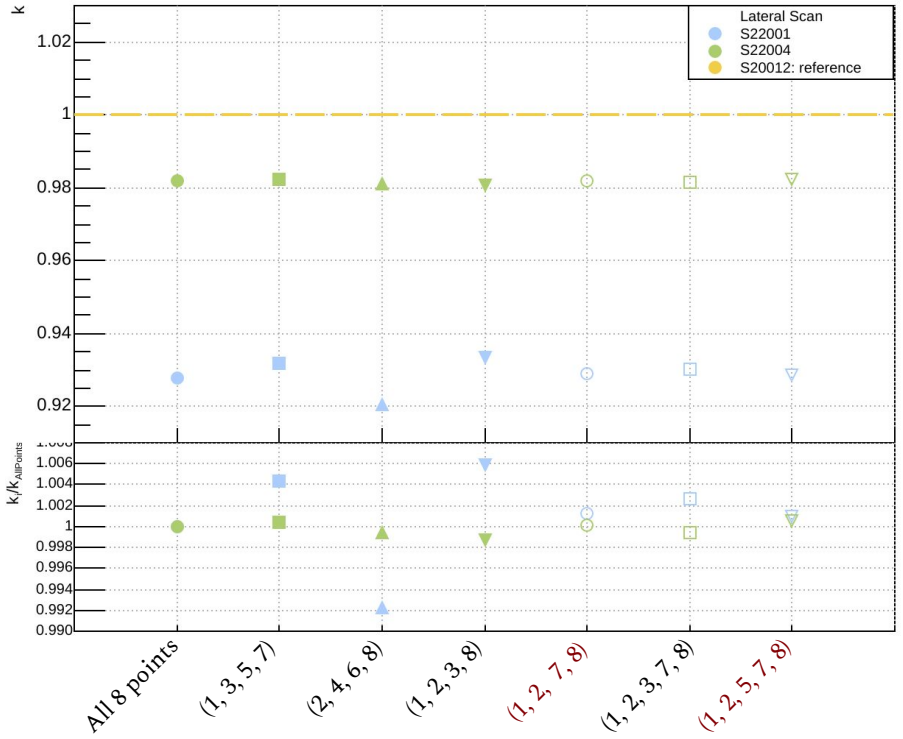




- Compare the intercalibration factors evaluated with **frontal scan using all the 9 points** of the scan with the intercalibration factors found using less points
- $k_i/k_{allPoints}$ shows that the first two combinations of points are quite better: $k_i/k_{allPoints} \sim 1$
- (p_2, p_4, C_6, C_8) maybe better: just 4 points. Make the calibration procedure faster

Evaluate the $k_{lateral}$ with less points





- Compare the intercalibration factors evaluated with **lateral scan using all the 8 points** of the scan with the intercalibration factors found using less points
- $k_i/k_{allPoints}$ shows that (1,2,7,8) and (1,2,5,7,8) combinations of points are quite better: $k_i/k_{allPoints} \sim 1$
- (1,2,7,8) maybe better: just 4 points. Make the calibration procedure faster

Conclusions

- Intercalibration factors calculated both from **frontal** scan and from the **lateral** scan allow us to calibrate the crystals with a **precision < 2%**

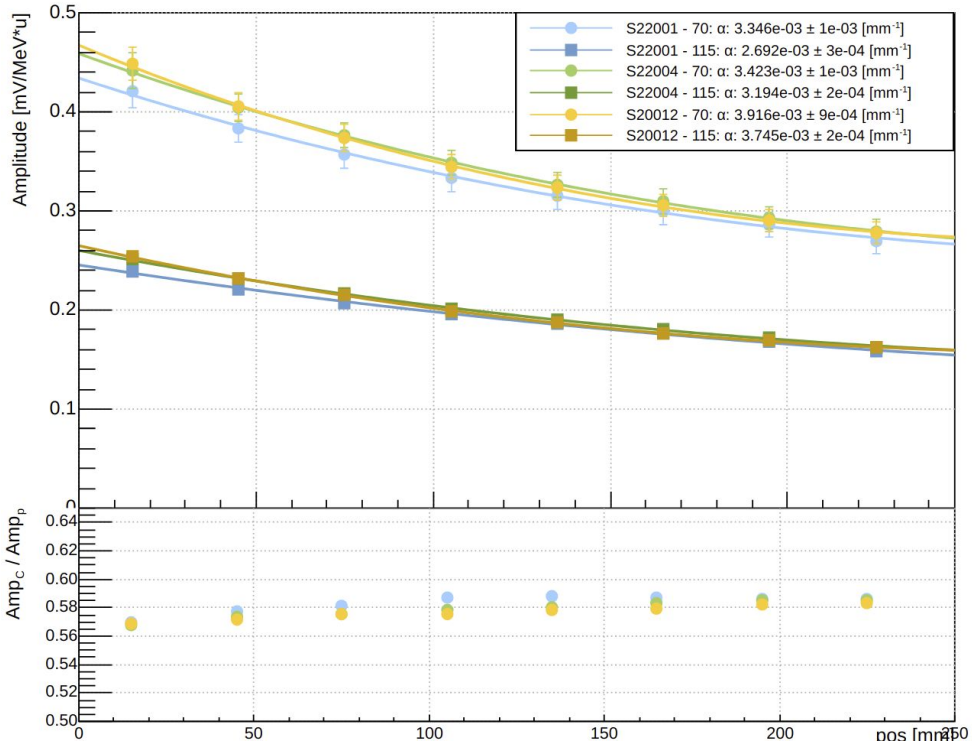
- Furthermore, the **lateral scan** can provide also the **range correction factors!**

- Evaluating the factors **using a proper combination** of points of the scan doesn't affect the intercalibration in a critical way: the values of the factors have a maximum discrepancy of the 0.4-0.8% to those evaluated using all the points of the scans. Using less points makes the **calibration procedure faster!**

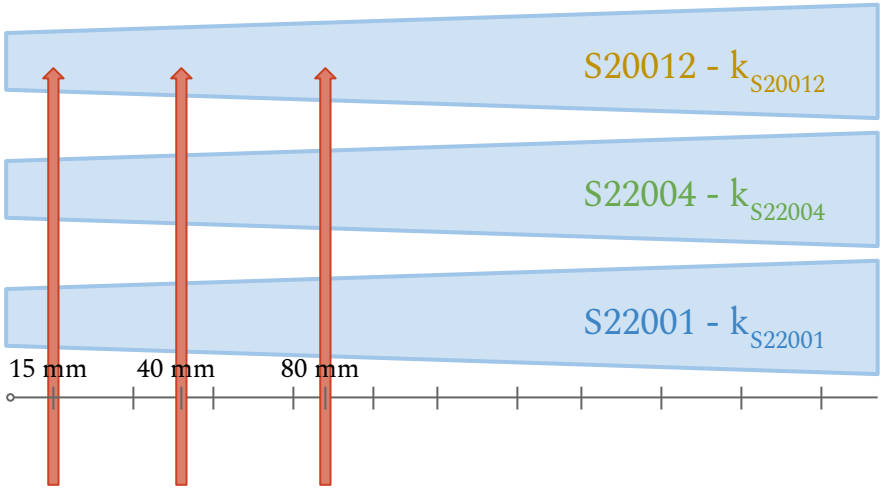
Backup

Definition of the calibration protocol

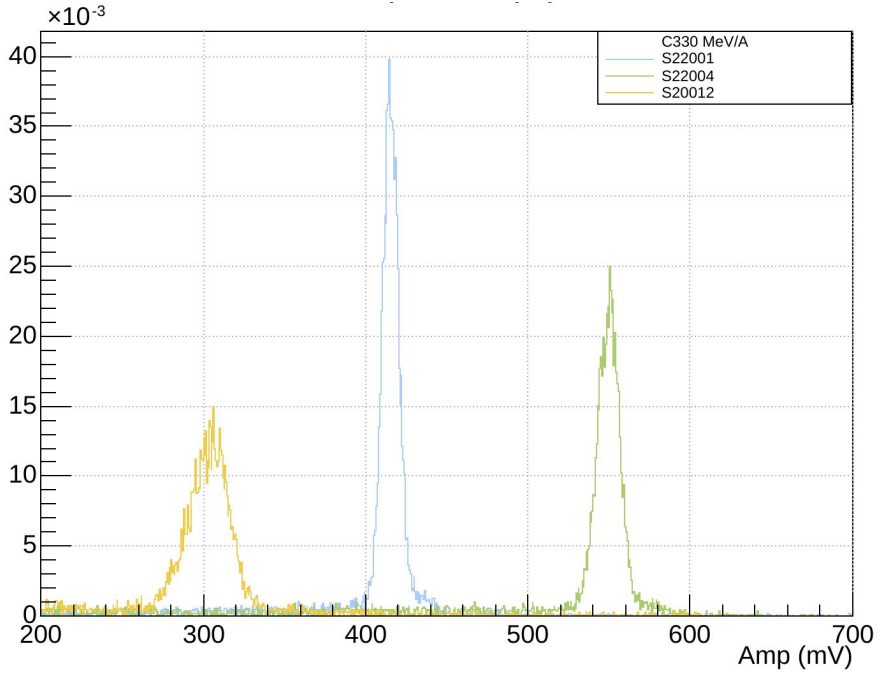
Amplitude vs position and ratio amp_C/amp_p



Verify the method - C330 MeV/A through 3 crystals

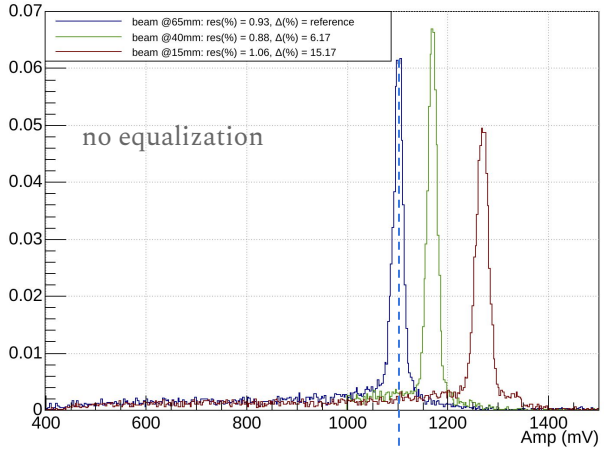


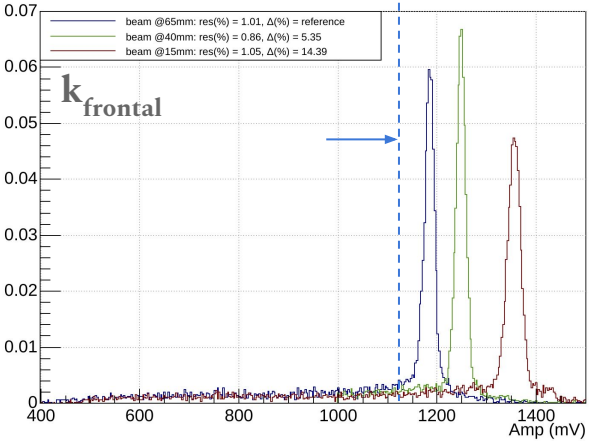
Raw amplitude distribution for each crystal - beam

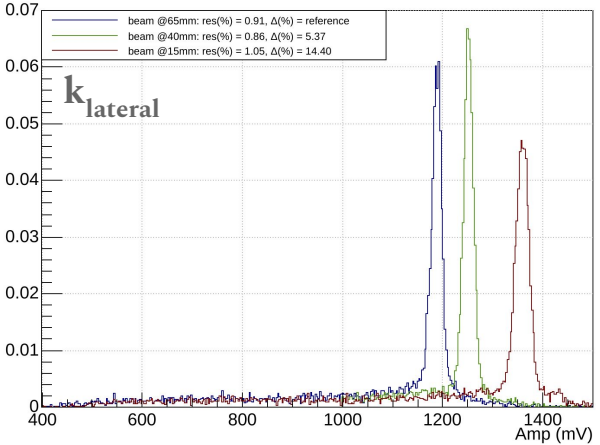


- p 170 MeV: energy deposition on 3 crystals
  - @15, 40, 80 mm
- Use the intercalibration factors to equalize and sum the three contributions

p170 MeV: Summing and calibrating







p170 MeV: Applying range correction