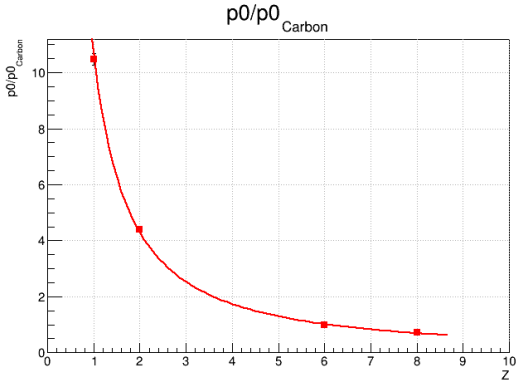
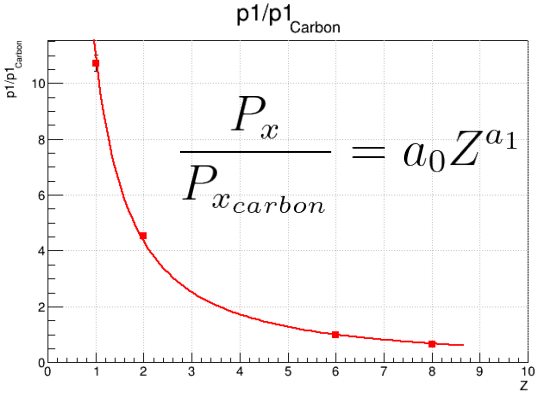
# CALO calibration status and preliminary mass reconstruction @ CNAO2024

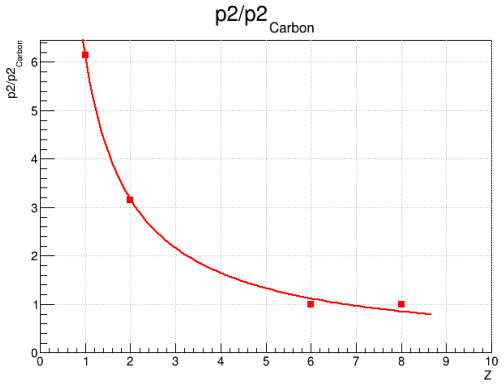
**L. Buonincontri on behalf of the Turin group**

# Previously, @ last collaboration meeting...




$$\frac{P_x}{P_{x_{carbon}}} = a_0 Z^{a_1}$$




We tried using the power-law coefficient $(a_0, a_1)_{pi}$ extrapolated from HIT2022, to reconstruct proton MBF parameters ($p_0$, $p_1$, $p_2$) for each crystal @ CNAO2024 (see Alessandro's presentation).

Modified Birk's Function (MBF) $$ADC(E) = \frac{P_0 E^2}{1 + P_1 E + P_2 E^2}$$

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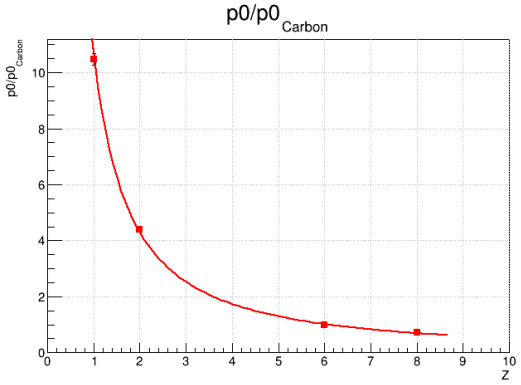


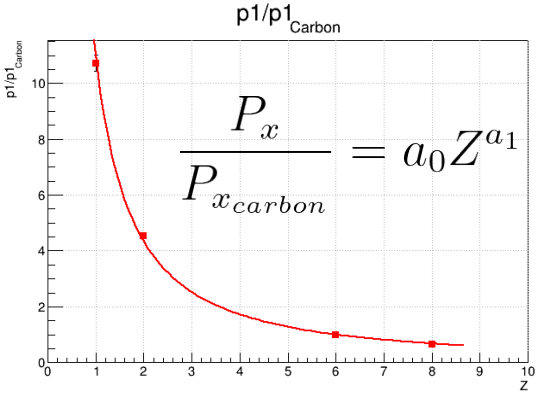


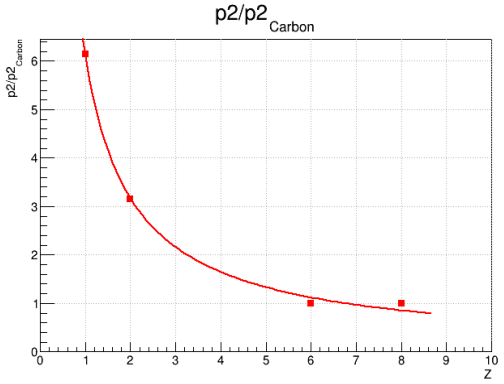


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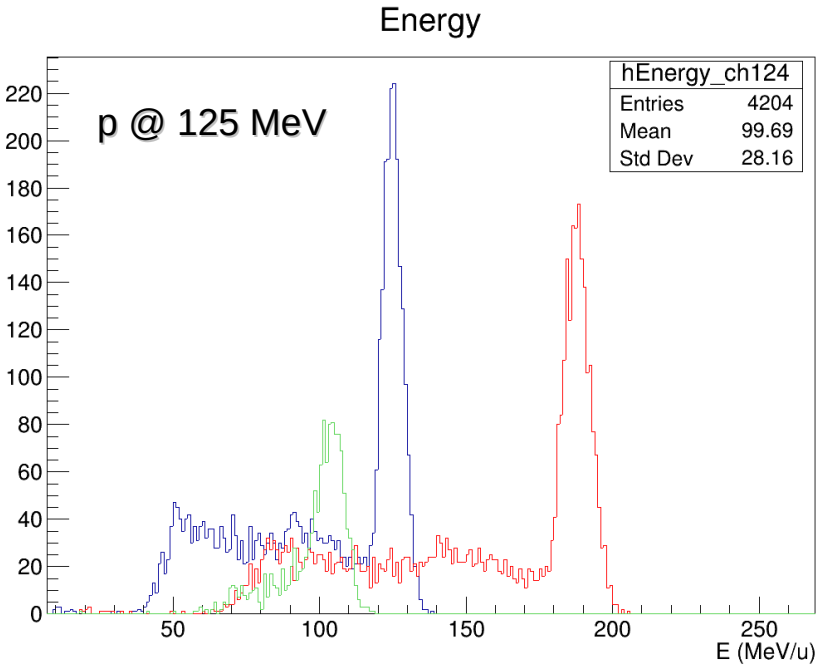
**Blue**: RecEnergy in **ch124** via direct MBF fit
**Red**: RecEnergy in ch124 via $p_i$ extrapolation
**Green**: RecEnergy in **ch127** via $p_i$ extrapolation.



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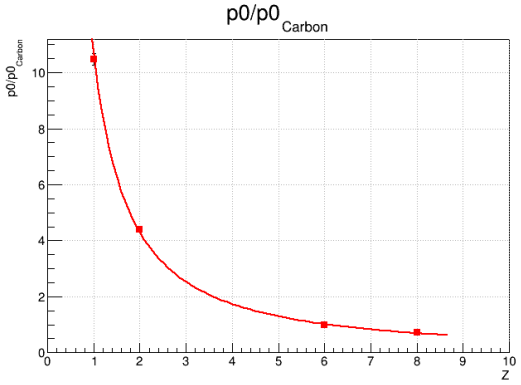


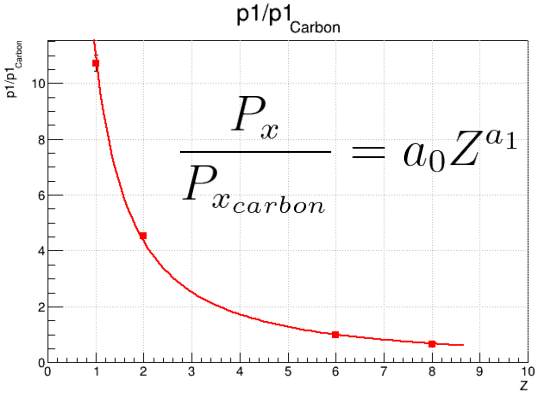


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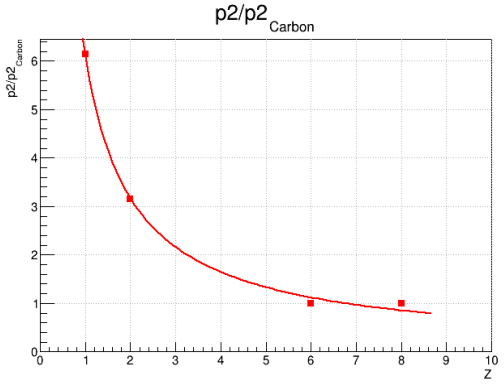


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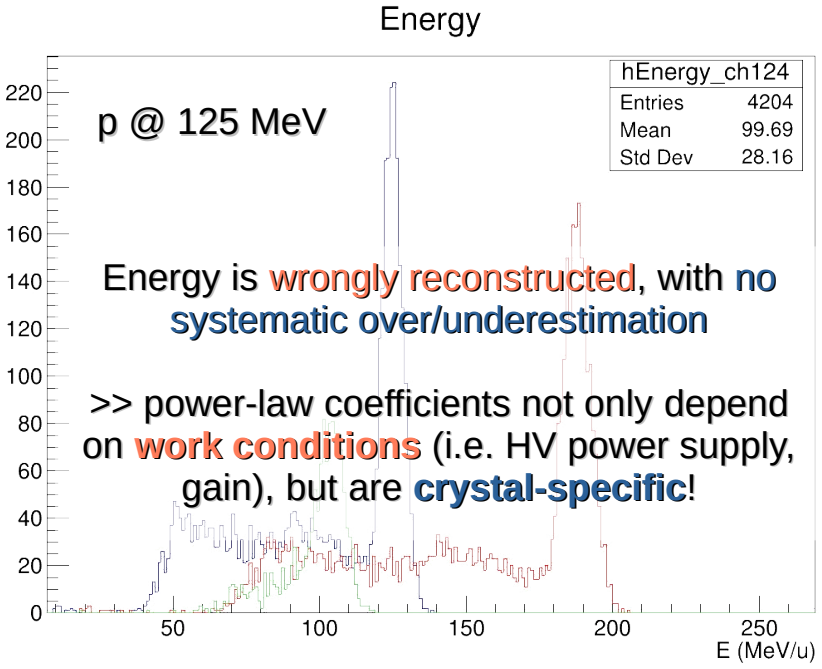
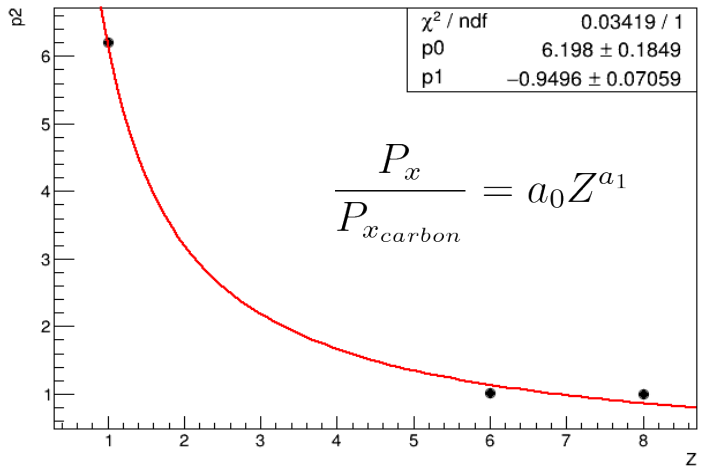



Energy is wrongly reconstructed, with no systematic over/underestimation

>> power-law coefficients not only depend on work conditions (i.e. HV power supply, gain), but are crystal-specific!

# MBF extrapolation for He with HIT2022 parameters




Different crystals → different power-law parameters >> we tried extracting $a_0$, $a_1$ without He and then reconstructing $p_0$, $p_1$, $p_2$ for He on **the same crystal**.

$a_0$, $a_1$ have uncertainties → uncertainties are propagated to $p_0$, $p_1$, $p_2$ → $p_i$ have gaussian distribution.

```
He reconstruction
p0: 0.08744075296368738 +/- 0.0008360178346736805 . Rel error: 0.9560963353333246 %
Deviation from original value: 3.421719204036523%
p1: 0.03676877877248003 +/- 0.0002568808818726325 . Rel error: 0.6986582006893678 %
Deviation from original value: 6.513192190414534%
p2: 6.669800491474491e-05 +/- 3.812436730307579e-06 . Rel error: 5.71596816903404 %
Deviation from original value: 0.7659565160875947%
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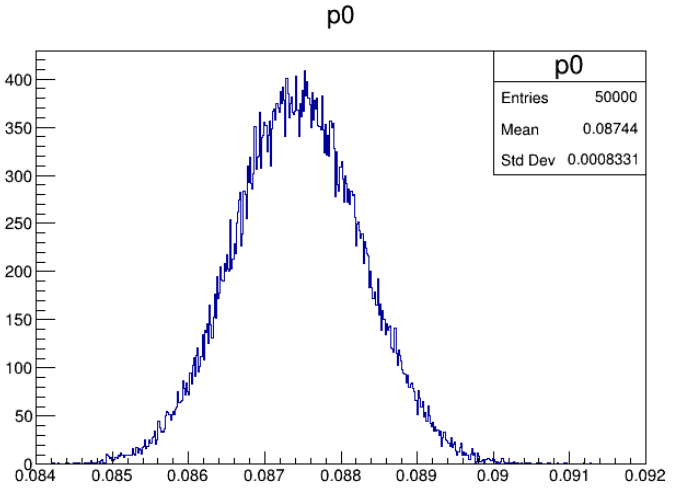

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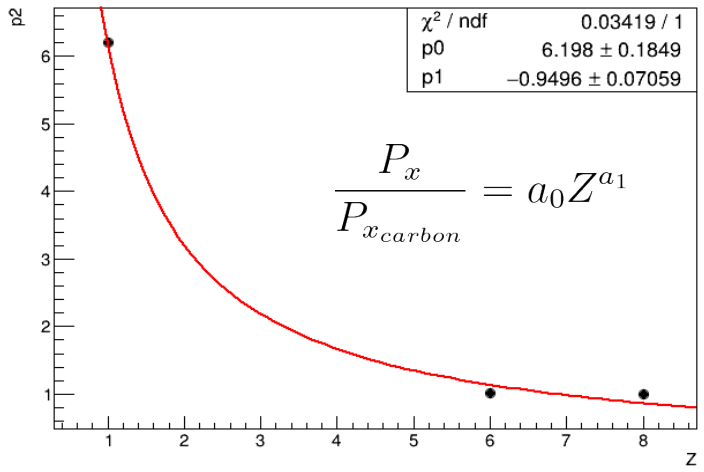


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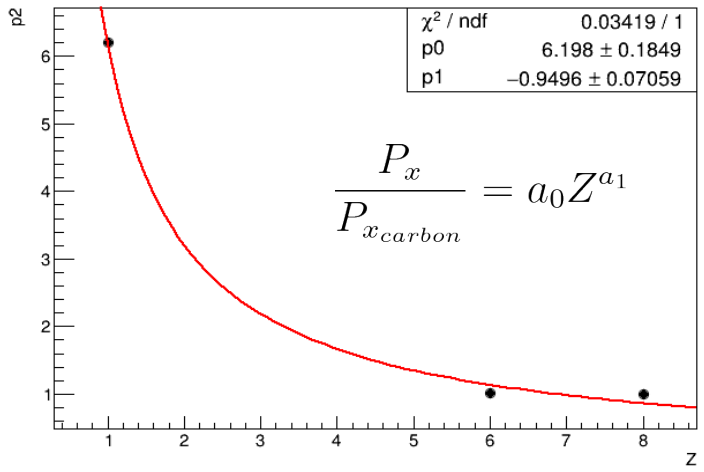


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```
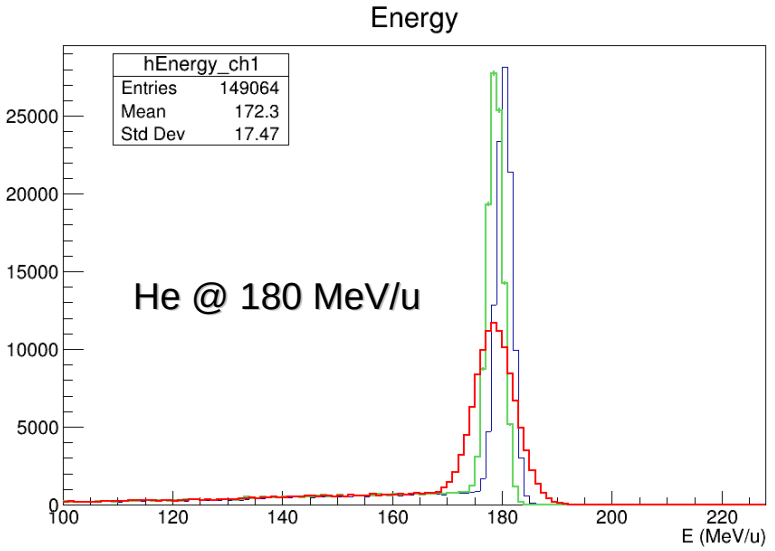
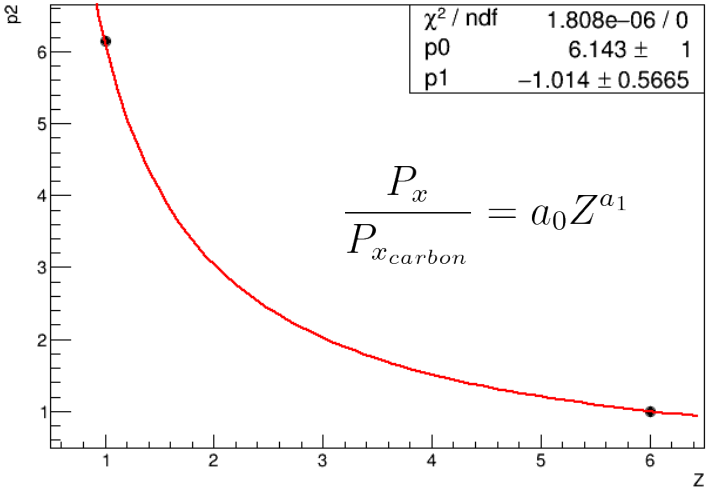

Blue: RecEnergy via direct MBF fit
Green: RecEnergy via $p_i$ extrapolation.
Red: RecEnergy via $p_i$ extrapolation + smearing.

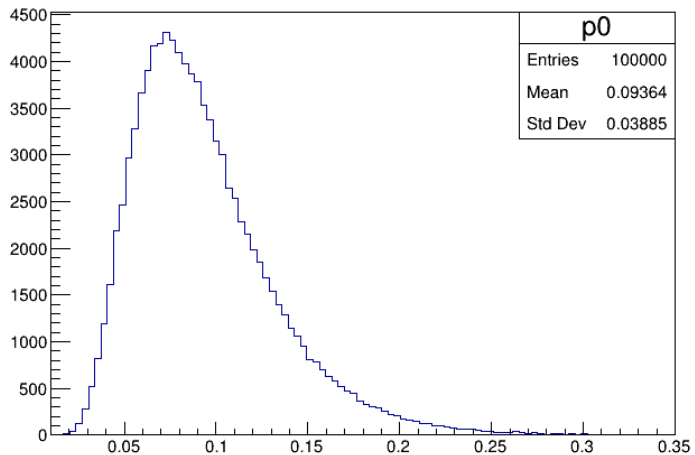
Accuracy on reconstructed $p_i$ has small impact on peak reconstruction.

However, due to uncertainties on $p_i$ resolution worsens from 0.1% to 2.5%.



# MBF extrapolation with only p and C points



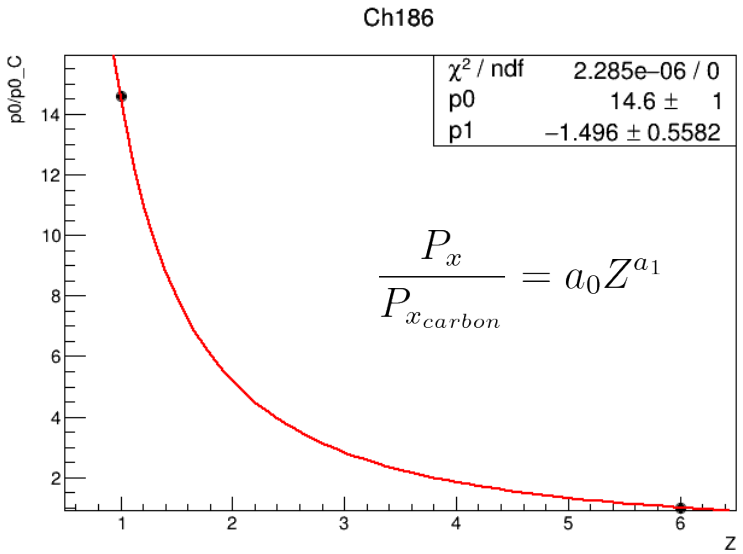

Since @CNAO we only have p and C, we tried reconstructing MBF parameters $p_0$, $p_1$, $p_2$ on our HIT2022 test crystal, this time with only p and C.

For He, deviation from direct MBF parameters is now between 1-4%, but uncertainty is between 41-44%.

```
He reconstruction
p0: 0.09346761757172017 +/- 0.03838876868498624 . Rel error: 41.07173123946325 %
Deviation from original value: 3.2469936118692893%
p1: 0.03971126137579105 +/- 0.016416264426824867 . Rel error: 41.33906569090404 %
Deviation from original value: 1.3791084866544094%
p2: 6.879405659685064e-05 +/- 3.044305509944019e-05 . Rel error: 44.252449419931224 %
Deviation from original value: 3.7894689248053206%
```

In addition to this, $p_i$ distribution is not Gaussian anymore → Poisson/Landau function (?)
Suggestions are welcome

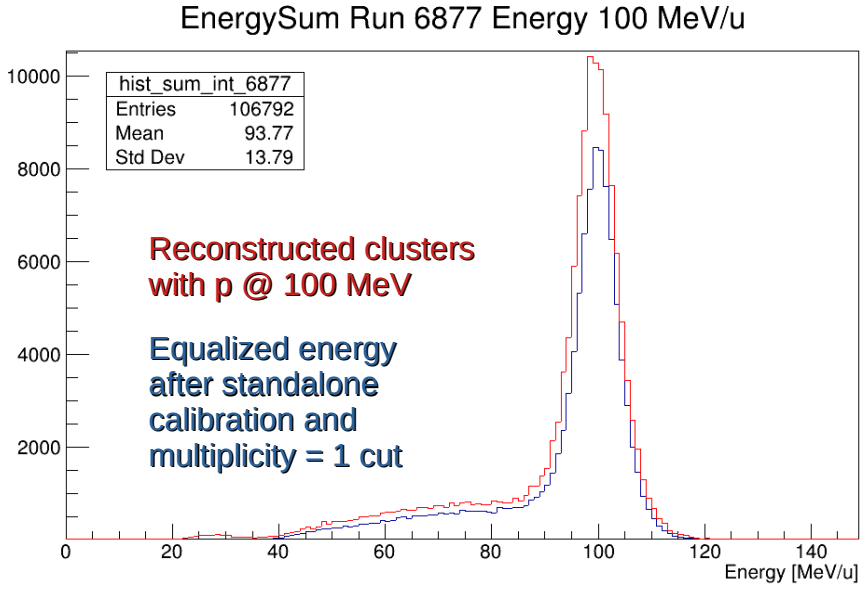
# Power law functions implementation in SHOE




Now, $E_{kin}$ reconstruction is done in SHOE via 9 parameters:

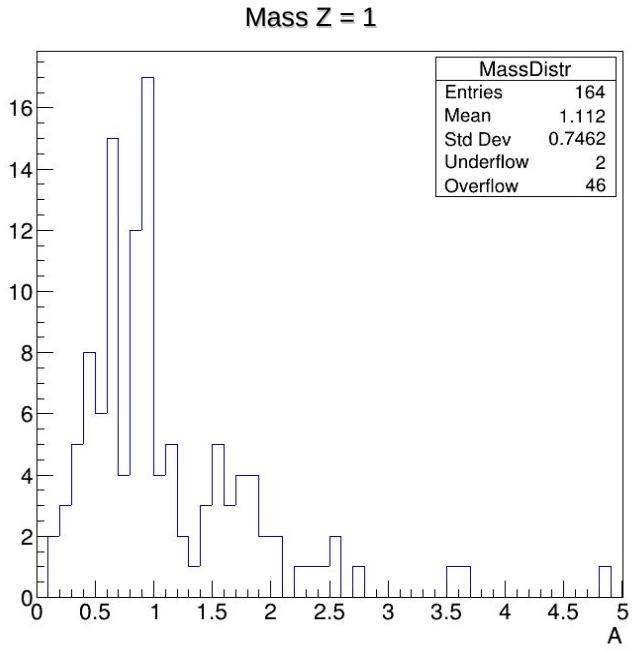
$p_0 \rightarrow a_0\_p_0$
$p_1 \rightarrow a_1\_p_0$
$p_2 \rightarrow a_0\_p_1$
$p_3 \rightarrow a_1\_p_1$
$p_4 \rightarrow a_0\_p_2$
$p_5 \rightarrow a_1\_p_2$
$p_6 \rightarrow p_0$_Carbon
$p_7 \rightarrow p_1$_Carbon
$p_8 \rightarrow p_2$_Carbon

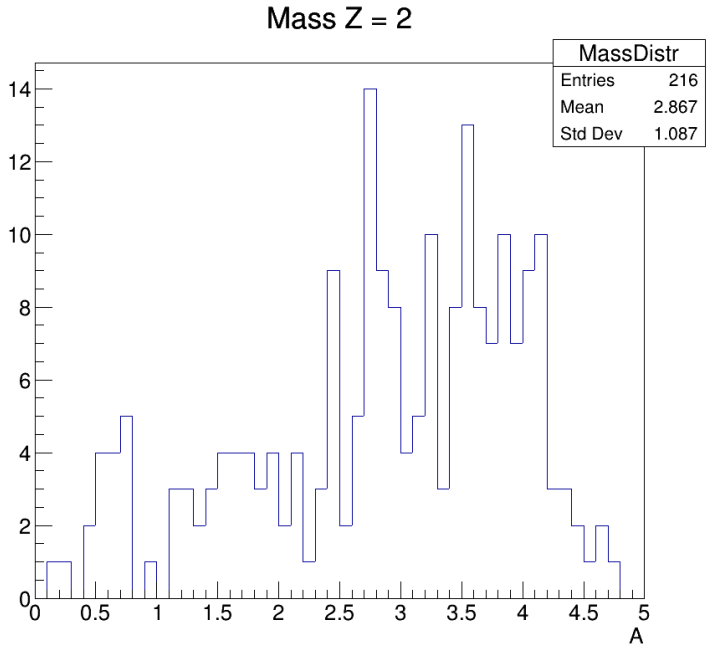
For all calibrated crystals @ CNAO2024, crystal-specific MBF conversion parameters ($a_0$, $a_1$) with respect to Z were extracted via power-law fit.




Calibration was tested on CALO clusters reconstructed in shoe, for a calibration run with p @ 100 MeV (6877) >> response and FWHM unmodified with respect to previous, standalone results.

# Mass reconstruction test on physics run 7029




Mass reconstruction for Z = 1 and Z = 2 fragments was attempted by matching CALO clusters with the closest TW hits, by using power-law calibration functions with respect to Z. Note that:

>> for Z = 1, the error coming from CALO calibration should be negligible (calibration is direct);
>> about 1/5 CALO clusters (47/263 for He) contains not calibrated hits;
>> less than 10% of CALO He clusters are successfully matched (wrong centroid position?...).

# Centroid position calculation

In order to match TW and CALO hits,
we need to find out the pair with minimum distance

Weighted centroid position ($\Sigma_i x_i E_i / \Sigma_i E_i$) (i = hit Id) must be calculated for each cluster

...but in order to calculate $E_i$ properly we need Z

...in order to find out Z we need to match CALO cluster with a TW hit

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Shoe starts by sorting TW-CALO pairs with not calibrated positions

However, there is a chance that some “matchable” clusters never find their corresponding TW hit because they don’t find it in first place (without calibration).

We computed the calibrated position, called the matching algorithm again and saw that in 2/263 cases for He clusters do not match anymore

# Summary

- We have implemented crystals calibration functions with two power-law parameters (with no uncertainties) in shoe at CNAO2024

- We used Z dependence to evaluate the performance in p and He mass reconstruction by using shoe software
  - No tracking system involved in the reconstruction
  - TW calibration seems reliable at least for central crystals (see p mass distribution)
  - We are going through the TW-CALO matching algorithm