First look at isotope identification using the CNAO2020 setup

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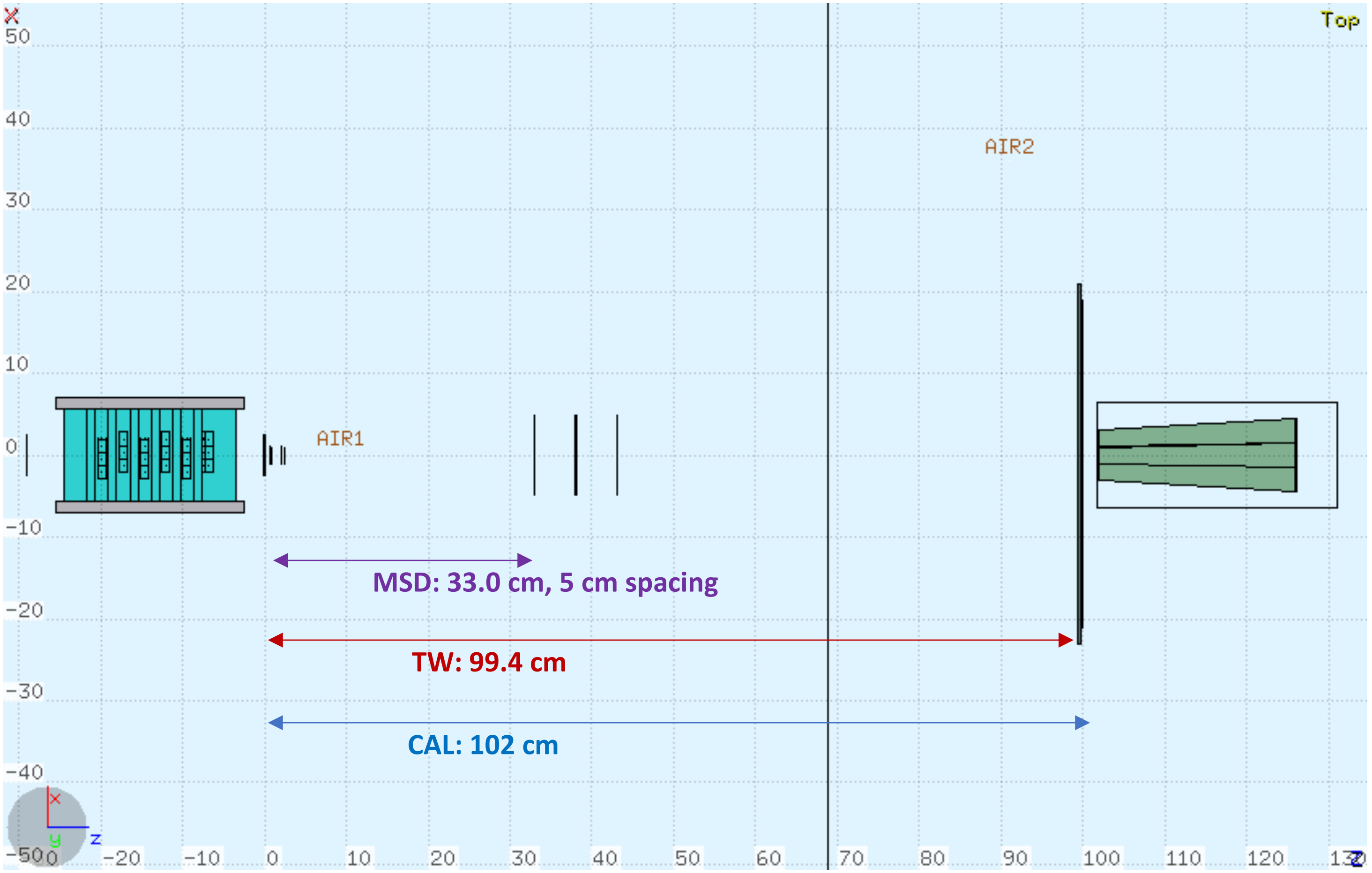
Introduction

- In December 2020, we showed some preliminary considerations about physics measurements using the CNAO2020 design
- As we introduced in the previous physics meeting (April 2021), while waiting for the magnets, the presence of a calorimeter module gives us the chance to test the capability of A reconstruction by ToF and Calorimetric measurements
- We estimated A resolutions with CNAO2020, based on MC truth
- Today: another step further
  - A and Z in MC truth
  - A and Z in MC local reco
- All very preliminary!!!



Software used

- Ran DecodeMC on CNAO2020 production: ^{12}C on C target 10^7 primaries
- Master branch (March 30 2021)
- Macro developed starting from Giuseppe's/Yun's ReadShoe.C and Lorenzo's PrintCalClusMcInfo.C (and shoe tutorial studied)
  - MC truth
    - TAMCntuhits (using shoe-tree branches of TW, Calo, STC)
    - mcNtuEve
  - MC local reco
    - TATWntuPoint for TW
    - TACAntuCluster for calorimeter

Analysis: overview

Goal is to do a combined TW+Calorimeter analysis in order to extract

- A reconstructed vs A true: how good are we in detecting a given fragment with true mass A ?
- Z reconstructed vs Z true: how good are we in detecting a given fragment with true charge Z?

MC **truth** TW analysis:
Evaluate bars fired in each event, dE
TOF, A truth, Z truth

MC **truth** Calo analysis:
Evaluate crystals fired in each event and what energy

MC **local reco** TW analysis:
Evaluate bars fired in each event, dE
TOF, Z reco

MC **local reco** Calo analysis:
Evaluate crystals fired in each event event and what energy

A_{true} and Z_{true} in “good” TW positions, i.e., TW positions with a crystal behind it

A_{reco} and Z_{reco} in “good” TW positions, i.e., TW positions with a crystal behind it

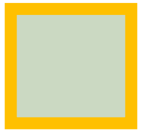
COMPARE event per event in a fired (true) position

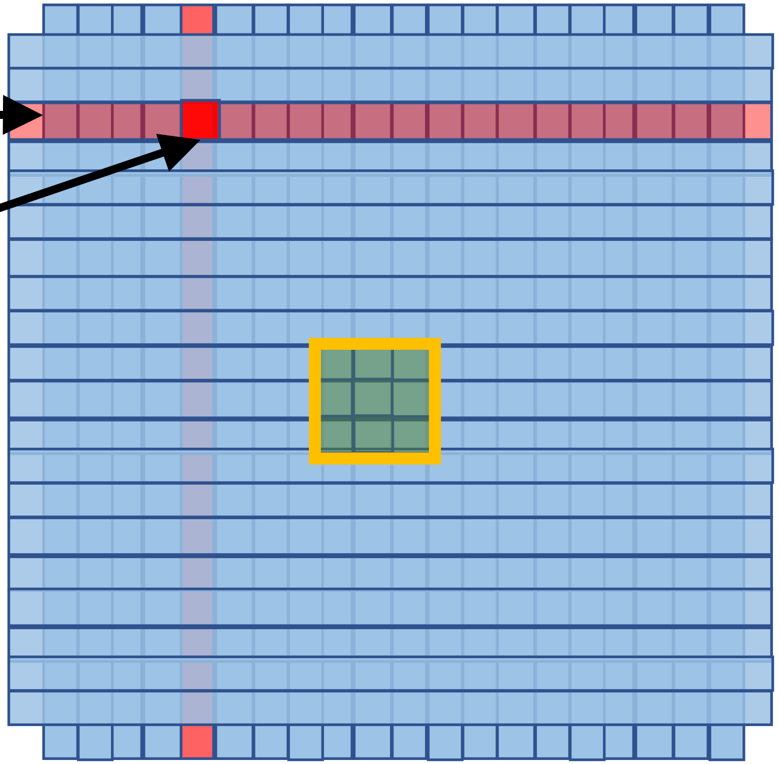
Analysis MC truth: TW selection

- Determine energy and TOF in front and rear bars (TAMCntuHit *twMChits)
- Select only positions (a crossing between a front and a rear bar) that are associated with bars with:
  - >=1 MeV in Front bar**: fired bar**
  - >= 1 MeV in rear bar**: fired bar**
- Verify for that position the front-rear consistency:

$$\frac{|E_F - E_R|}{(E_F + E_R)/2} < 0.05$$

- If position passes, call it '**fired position**'
- For a selected position, find the corresponding hit and evaluate true Z and A
  - Makes only sense when 1 fragment passes per position
- If a fired position is one of the **9** central positions, call it '**good**'

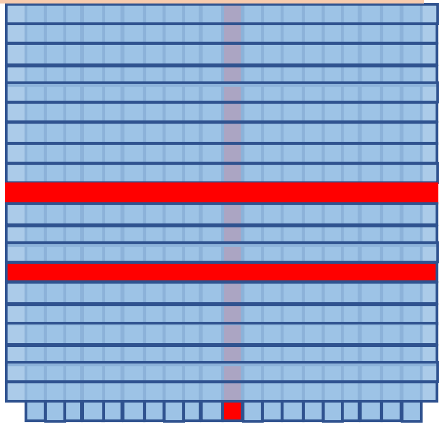




MC truth: how many SCN bars are fired per layer in each event?

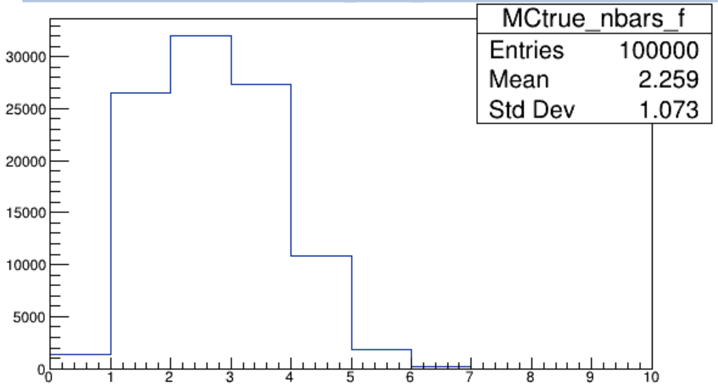
For each event, count N_{bars}, i.e., number of bars that are fired (=DeltaE>1)

Example:
$N_{bars,F}$=2
$N_{bars,R}$=1

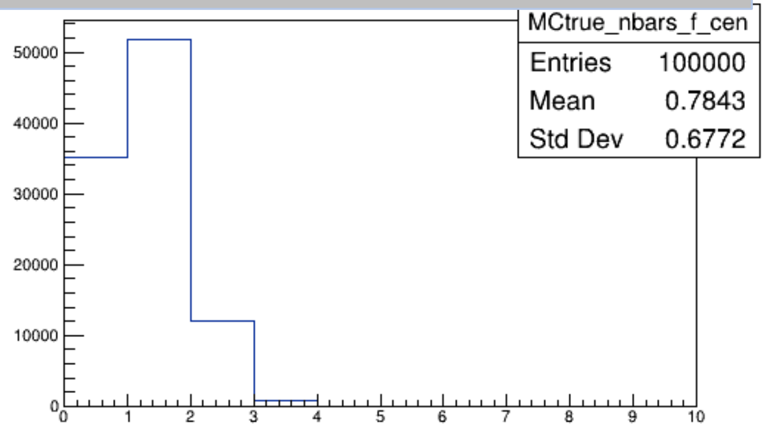


- In whole TW, average nr of hit bars per layer ~2.2
- Even when considering only central bars, still often multiple bars fired

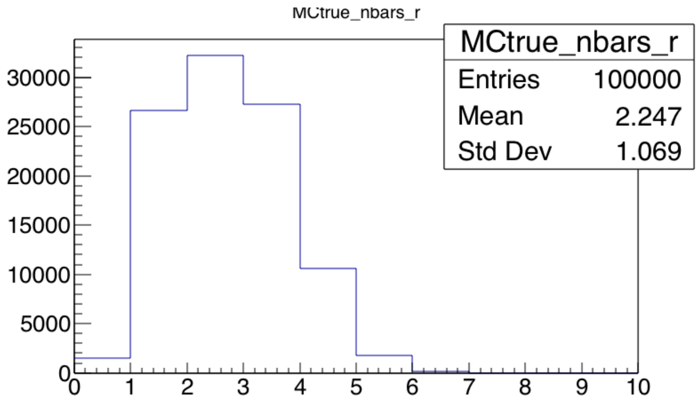
Whole TW: MC truth N_{bars} in front



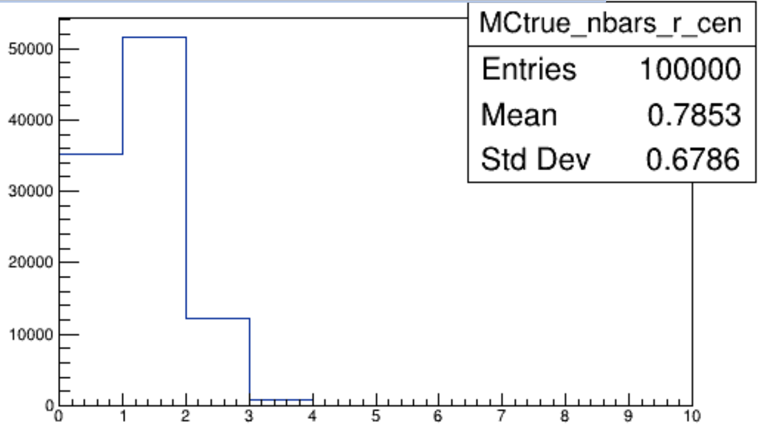
Central bars (8,9,10): MC truth: N_{bars} in front



Whole TW: MC truth N_{bars} in rear

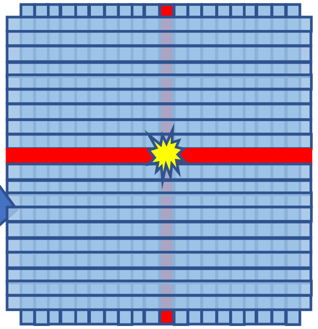


Central (8, 9, 10):MC truth: N_{bars} in rear

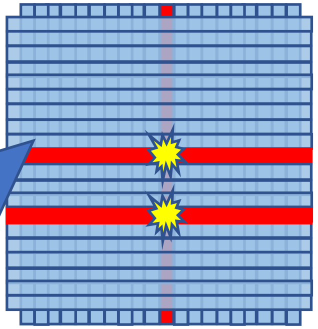


MC truth: how many fired TW positions per event?

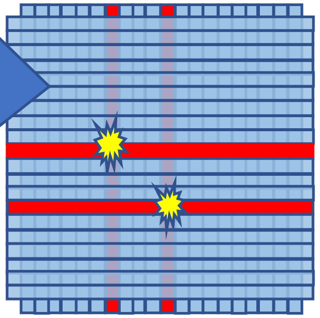
Example:
Event has N_{pos}=1, since energy deposit in F and R is typically similar



Such events are mostly (but not fully, see next slide) excluded, since F and R deposits typically don't match

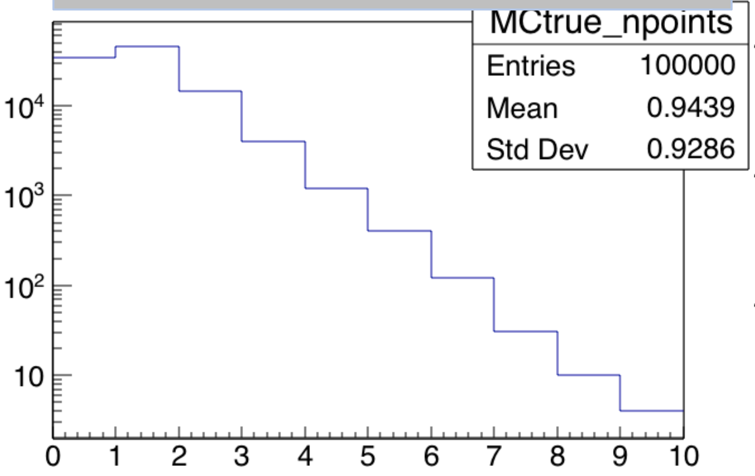


Events like this would typically result in N_{pos}=2, given that two different fragments leave different energy deposit

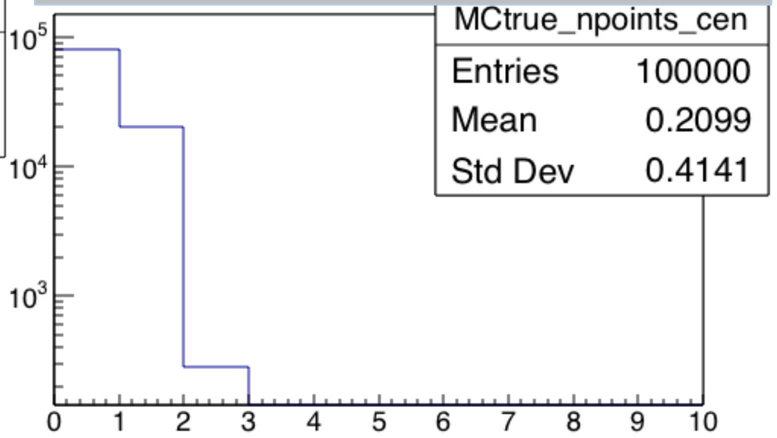


- For each event, evaluate how many of the positions are 'fired positions' (strongly correlated with nr of fragments passing)

Nr of positions N_{pos} fired per event (entire TW)



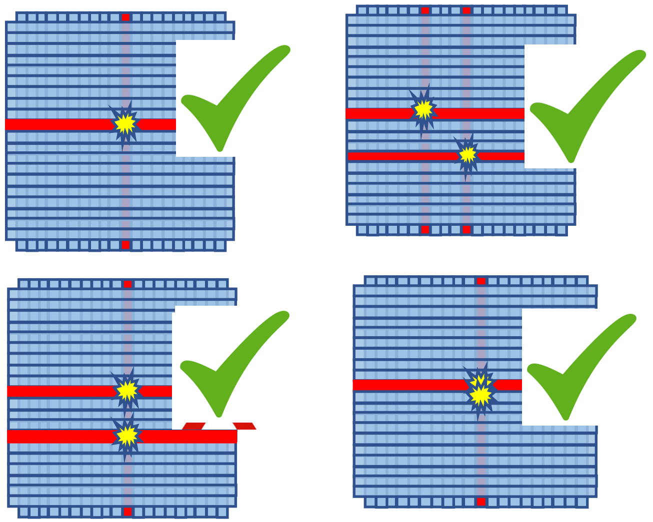
Nr of good positions N_{pos} fired per event (central positions)



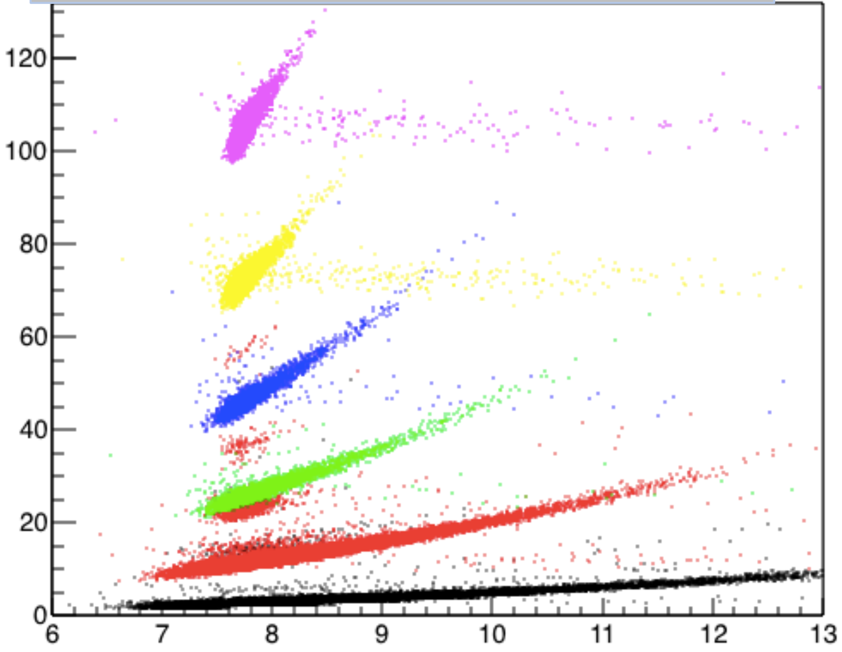
- About 65% of all events fire at least 1 position in the TW
- About 15% of all events fire at least 2 positions in the TW
- About 20% of all events fire at least 1 good position (with calorimeter crystal behind)

MC truth: Delta E vs TOF for selected positions

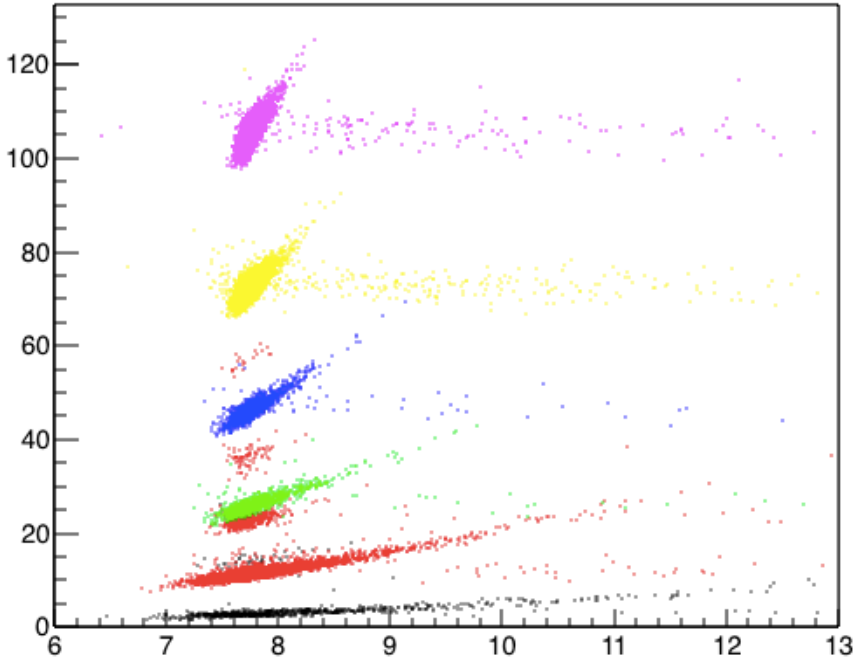
For each event, evaluate for the fired positions ΔE_{SCN} vs TOF



MC truth: ΔE_{SCN} vs TOF in whole TW



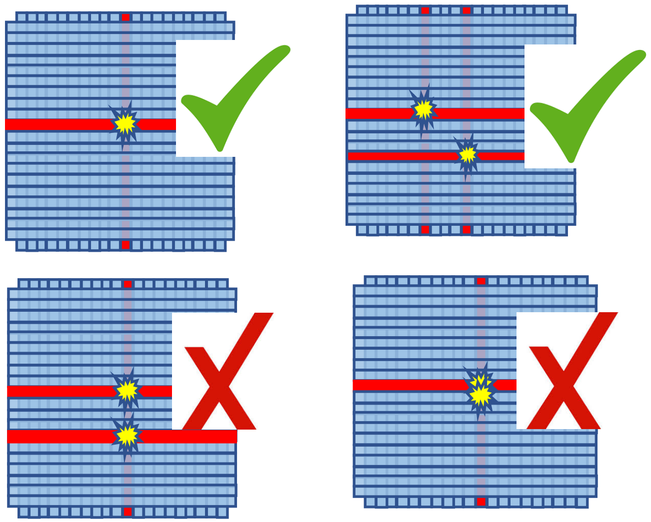
MC truth: ΔE_{SCN} vs TOF in centre TW



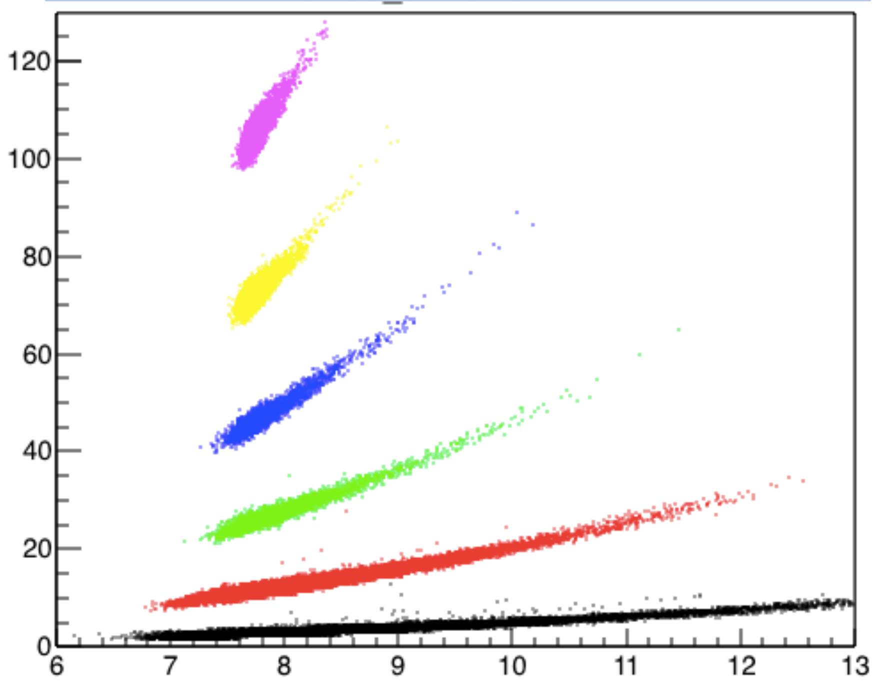
- In centre positions, dominated by heavy fragments (no surprise)
- Positions associated to bars with more than 1 hit can disturb Z identification. But only at most 6%.

MC truth: Delta E vs TOF: 1 hit per bar

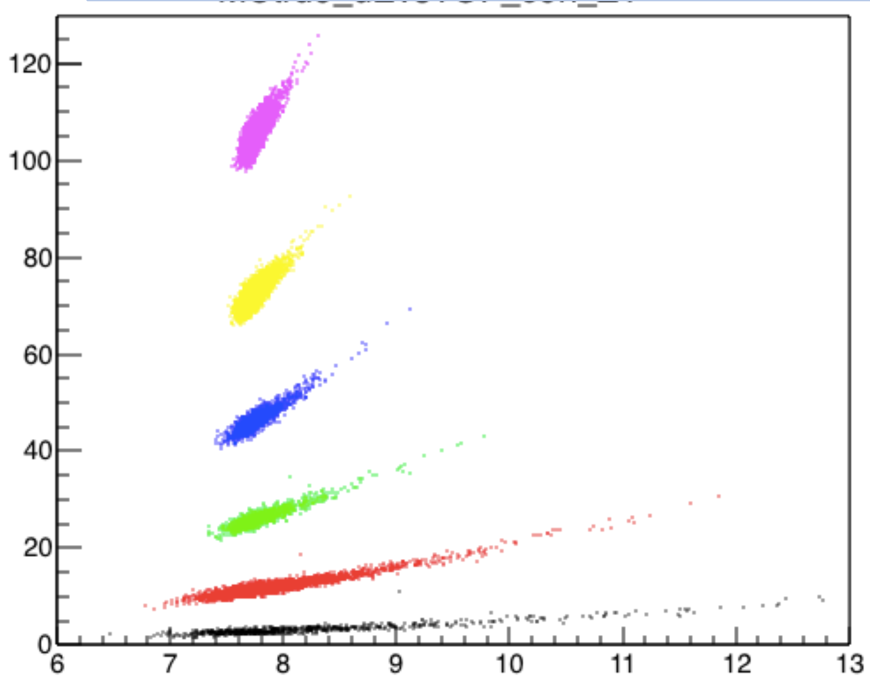
For each event, select the fired positions (see slide 4) that are associated with bars that have N_{hits}=1
Evaluate ΔE_{SCN} vs TOF



ALL MC truth: ΔE_{SCN} vs TOF in whole TW



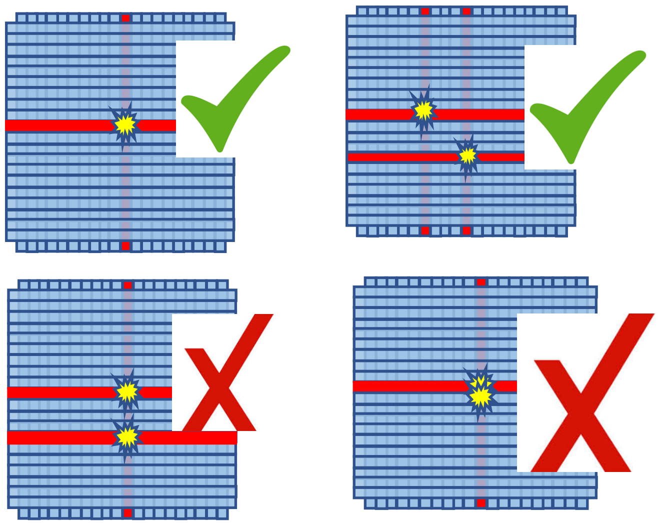
CENTRE MC truth: ΔE_{SCN} vs TOF in centre T



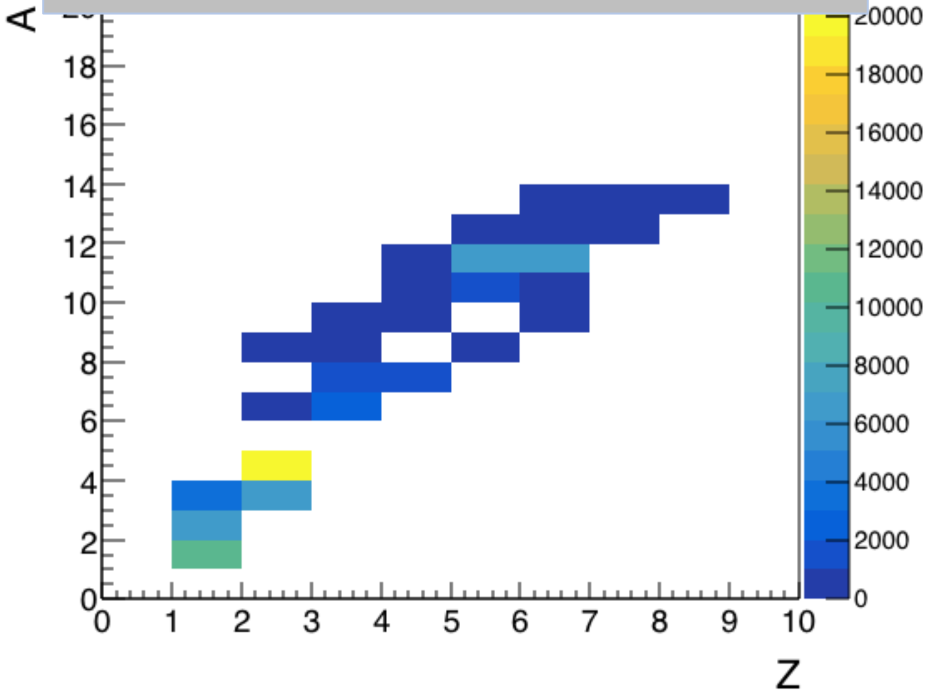
Excluding such events with bars with double-hits, distribution is clean

MC truth: A vs Z: 1 hit per bar

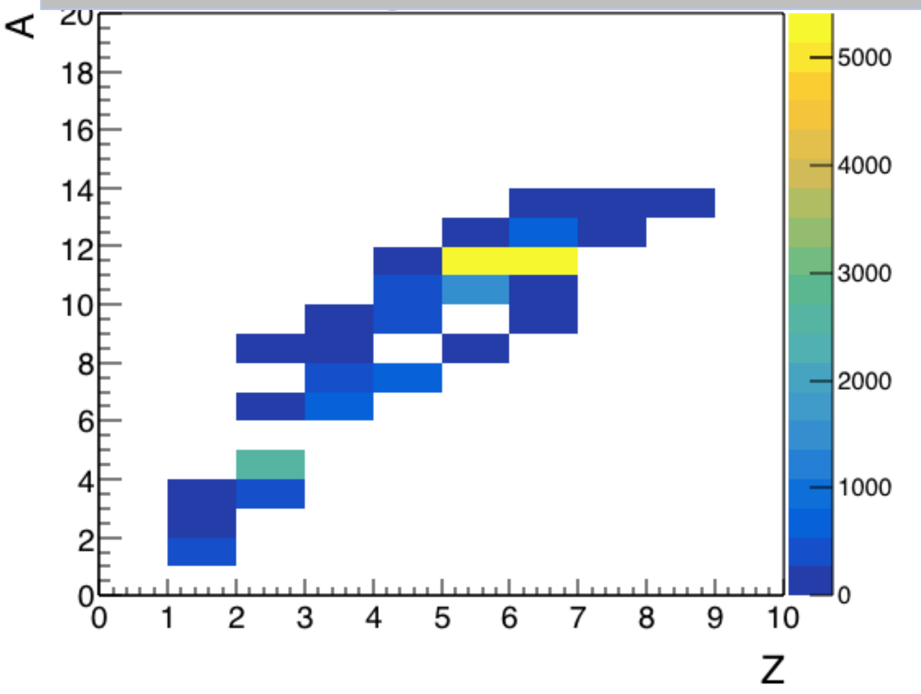
For each event, select the fired positions that are associated with bars that have N_{hits}=1
Evaluate Atrue vs Ztrue



ALL MC truth: ΔE_{SCN} vs TOF in whole TW



CENTER MC truth: ΔE_{SCN} vs TOF in centre TW



Mostly heavy fragments present in central positions (no surprise)

MC truth: Calorimeter

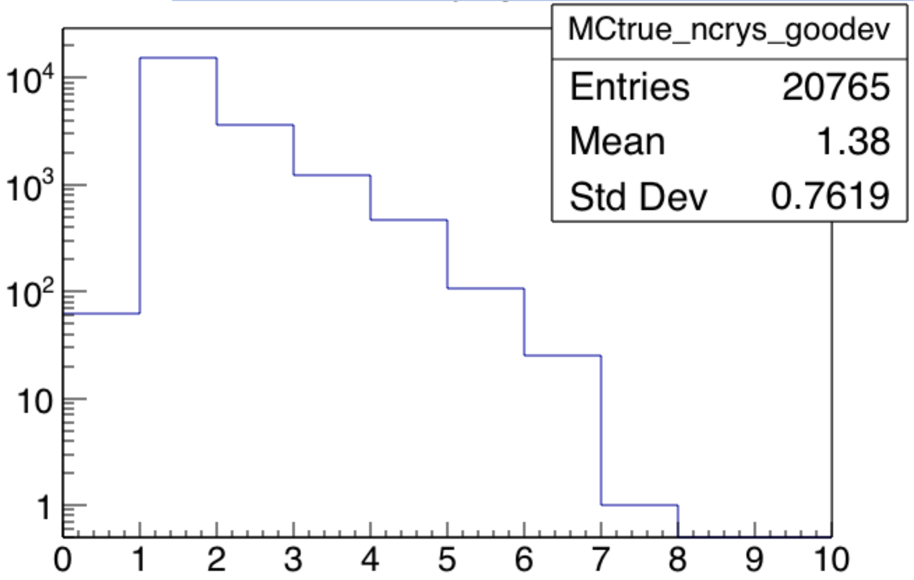
For each event, store calorimeter deposits (threshold 10 MeV)

- Total
- In each crystal

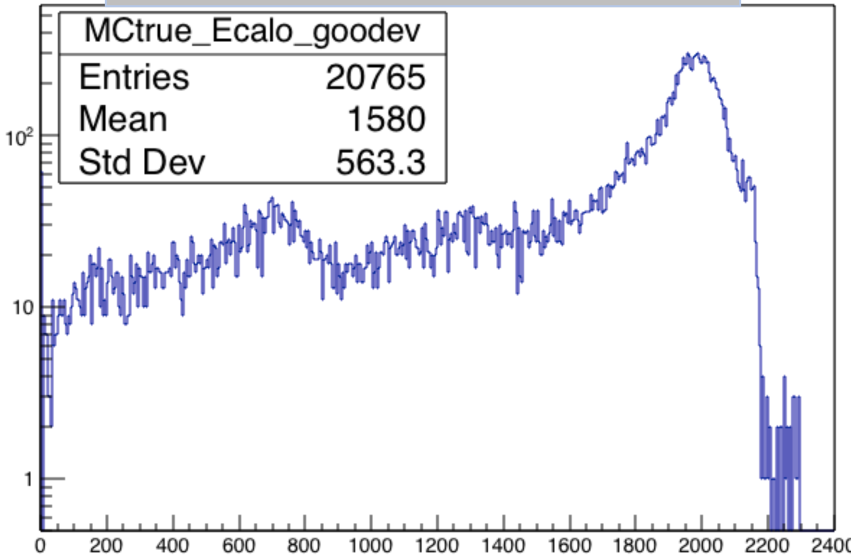
(thanks to Lorenzo)

- About 20% of all events have at least 1 crystal with E>10 MeV

MC truth: nr crystals with E>10 MeV with good TW position in front



MC truth: total energy deposited with good TW position in front

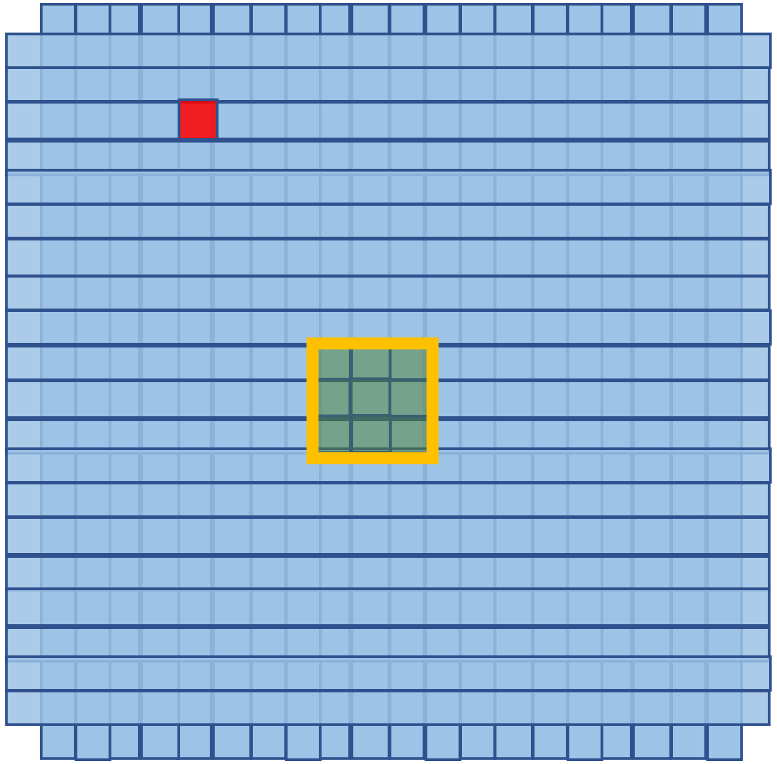


Analysis MC local reco

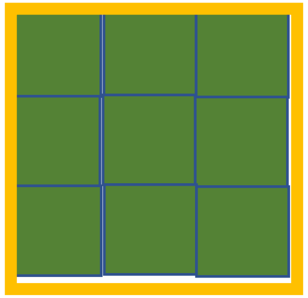
- Exactly as in slide 5!!!! Two differences:
  - Determine energy and TOF in front and rear bars starting **from TWpoints.**
  - **Z and A determination (see below)**
- Select only positions (a crossing between a front and a rear bar) that are associated with bars with:
  - >=1 MeV in Front bar**: fired bar**
  - >= 1 MeV in rear bar**: fired bar**
- Verify for that position the front-rear consistency:

$$\frac{|E_F - E_R|}{(E_F + E_R)/2} < 0.05$$

- If position passes, call it '**fired position**'
- For 'good' positions (calorimeter behind), evaluate associated calorimeter deposit (see next)
- Store a global event reconstructed value for A and Z for that position
  - Makes only sense when 1 fragment passes per position (see slice 10)



Enable TWZmc n
Enable TWnoPU n
Enable TWZmatch y

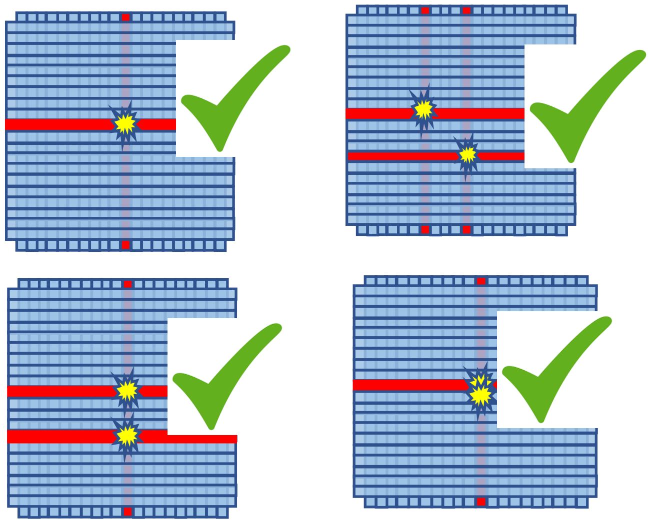


- Z: use Z from TWPoint (a true Z associated to the point)
- A: reconstruct it from:

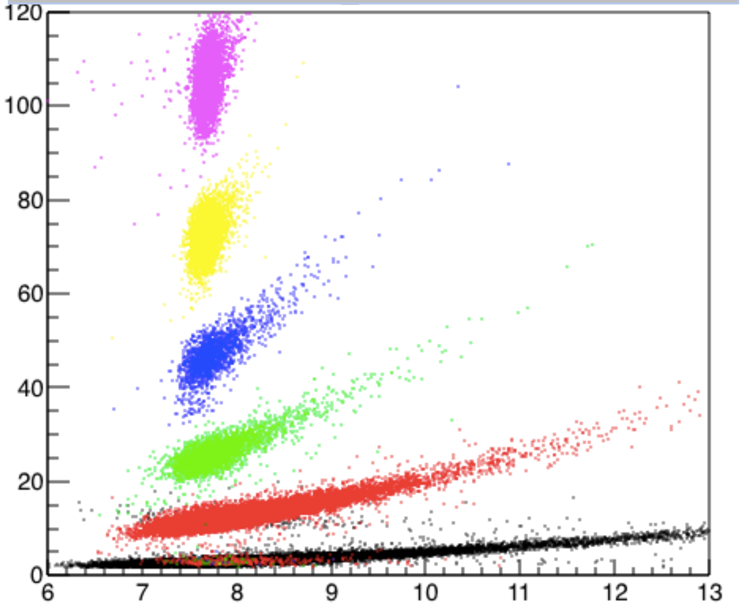
$$\text{A} = \frac{E_{calo}}{931.5(\gamma - 1)}$$

MC reco: Delta E vs TOF for selected positions

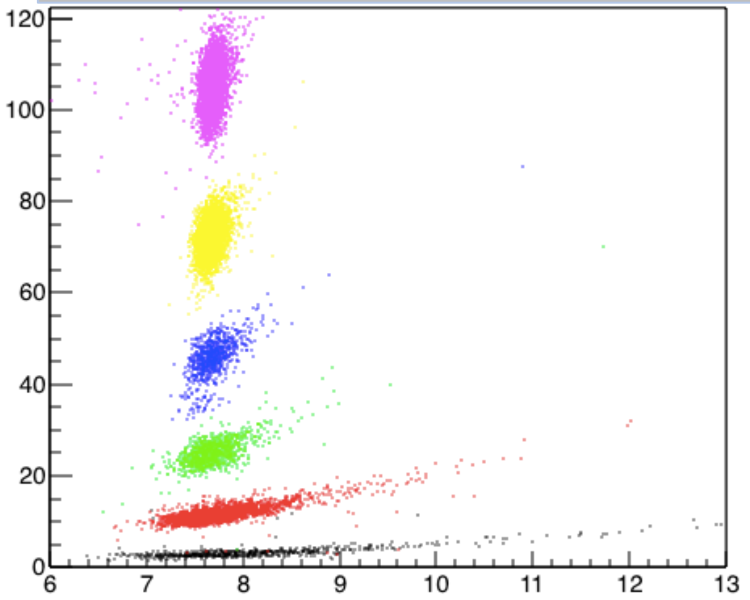
For each position in each event, evaluate for the fired positions ΔE_{SCN} vs TOF



MC reco: ΔE_{SCN} vs TOF in whole TW



MC reco: ΔE_{SCN} vs TOF in centre TW

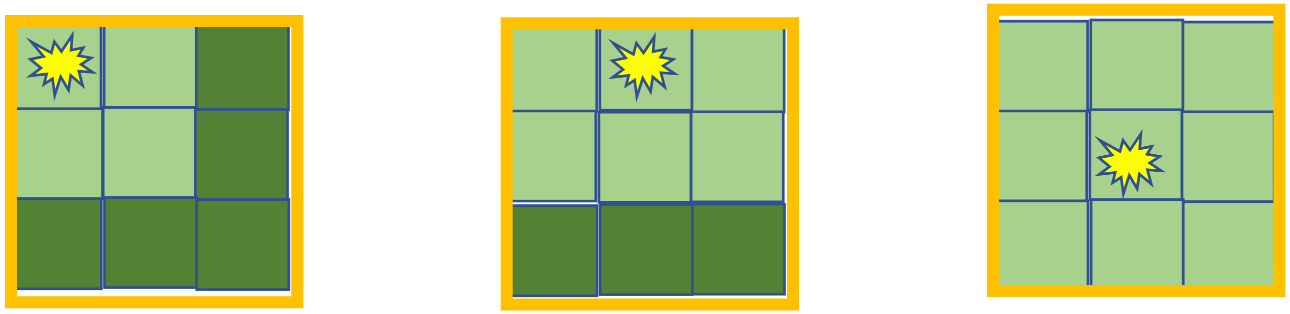


To be investigated what happens with double hits and what is the reconstructed Z…

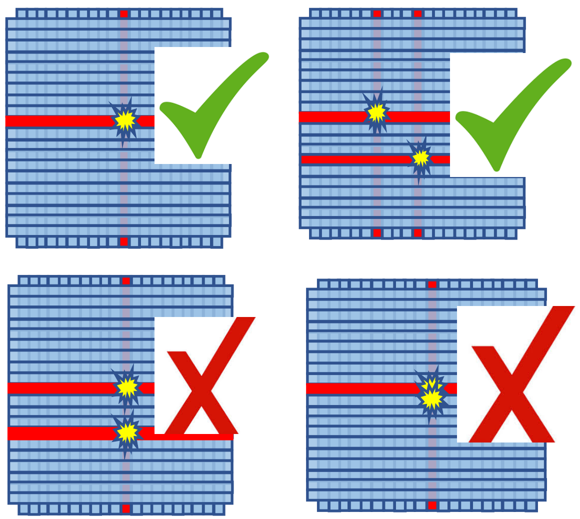
Analysis MC local reco: calorimeter deposits

- Starting from Clusters, in each event fill 9 crystals (threshold 10 MeV)
- Checked for a fired TW position which crystals can be associated to it (neighbours)
- Examples below
- Sum the energy of the associated crystals
- Threshold 10 MeV (tested various thresholds)
- Then we have for a given 'good' TW position:
    - the gamma (from beta)
    - the calorimeter energy

$$A = \frac{E_{calo}}{931.5(\gamma - 1)}$$

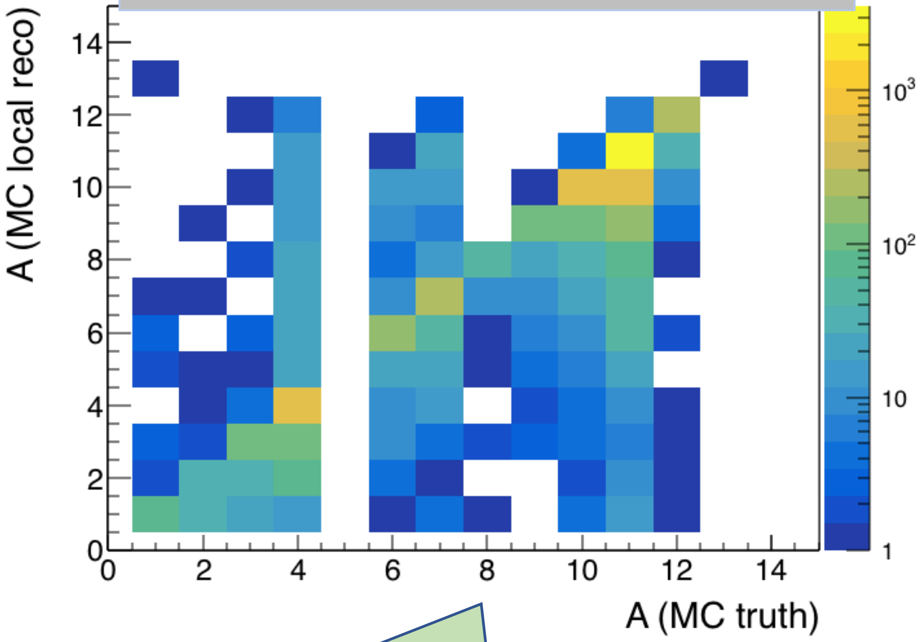


Local Reco: TW+Calorimeter

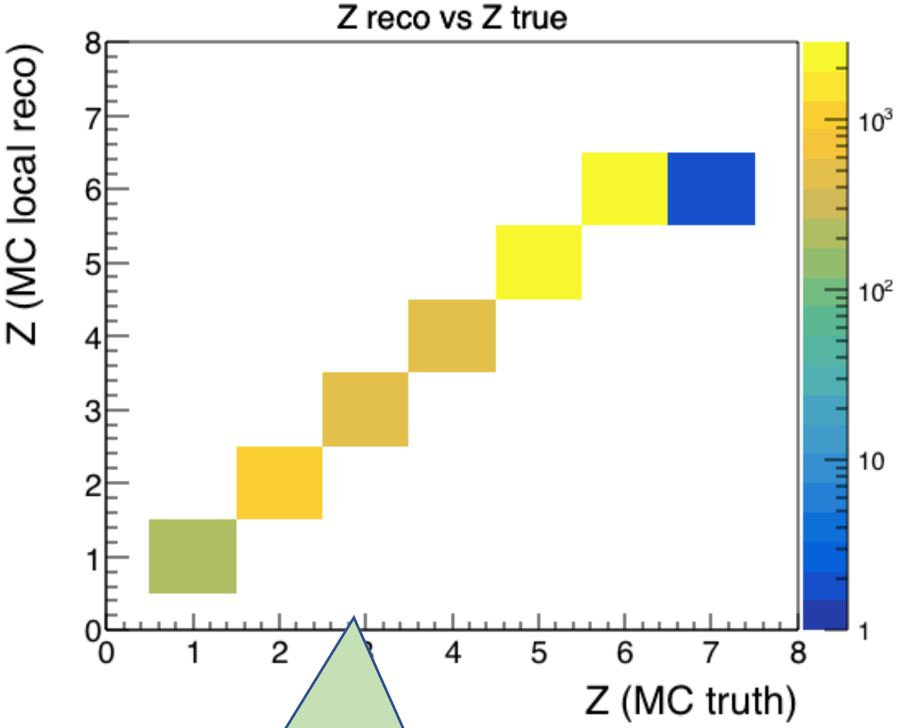


For the moment, positions that are associated with double hits in a bar are excluded

“Cross-feed”



- To be investigated: the reconstructed A. is somewhat low (see next)
- Example A_{MCtrue} =11: relative efficiency to be riconstructed correctly is 80%

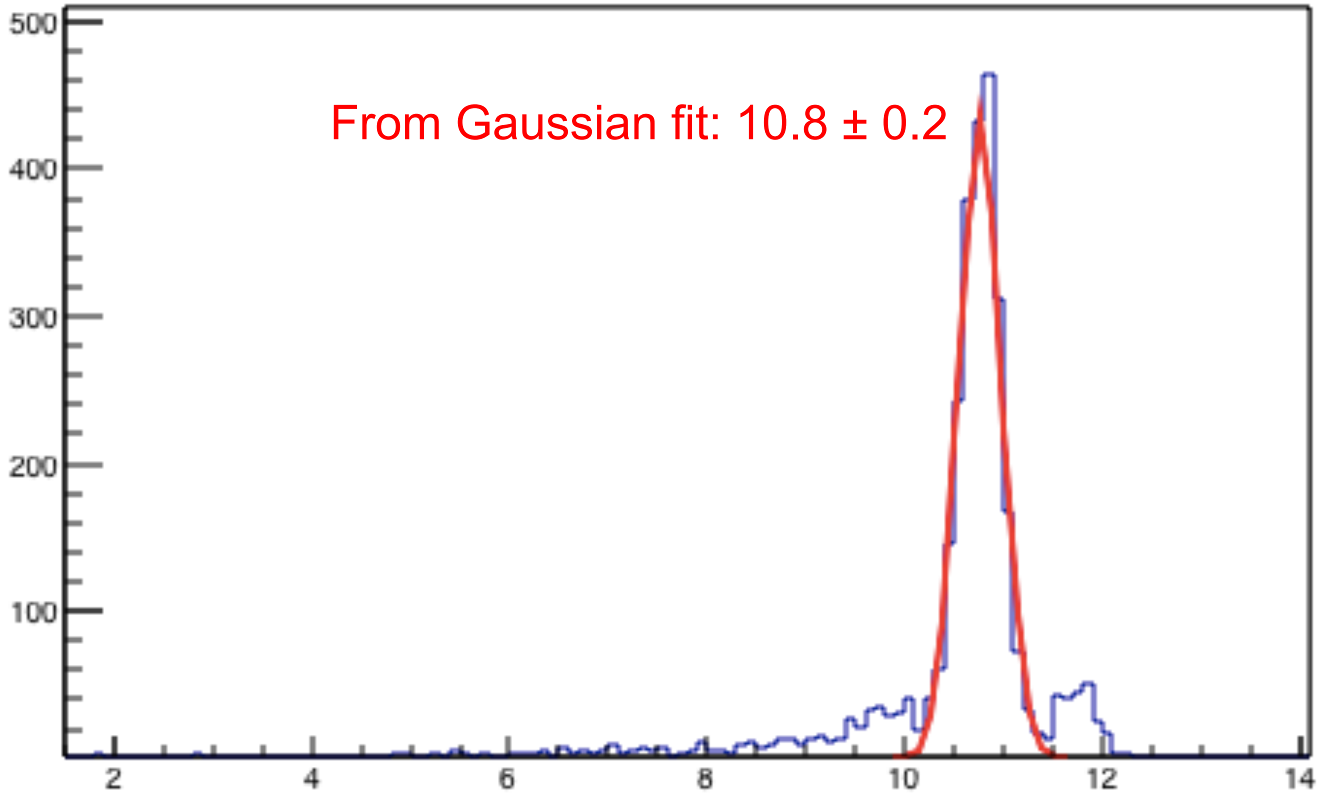


Too good! To be investigated: the reconstructed Z. Is probably the true Z (used TWPoint)

Local Reco: TW+Calorimeter

- Mass resolution for heavy fragments about 2-3%
- Mass resolution for lighter fragments worse (5-8%)
- Underestimation of mass: seems related to value of the TOF of the TWPoints, to be understood…

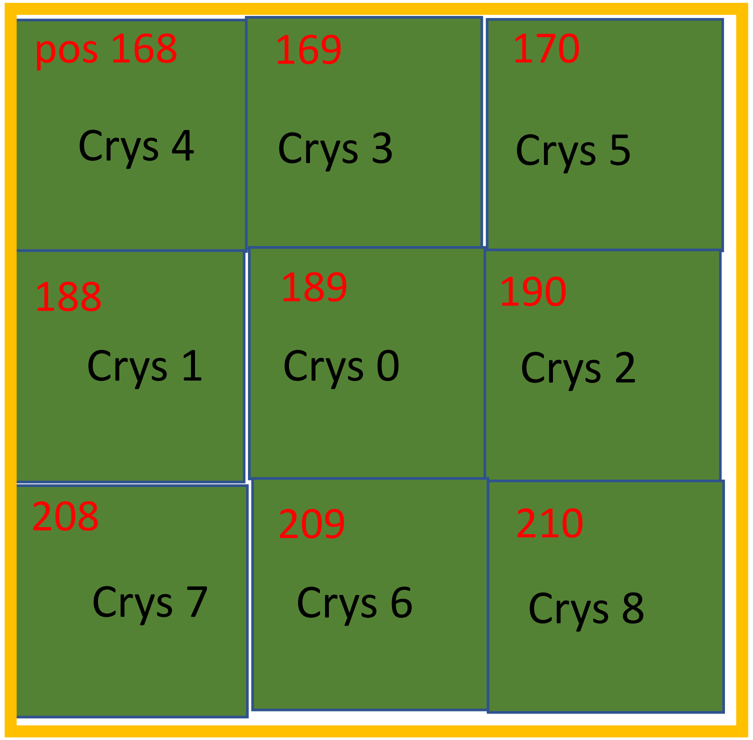
Example (preliminary!) of MC reconstructed A for Z=6

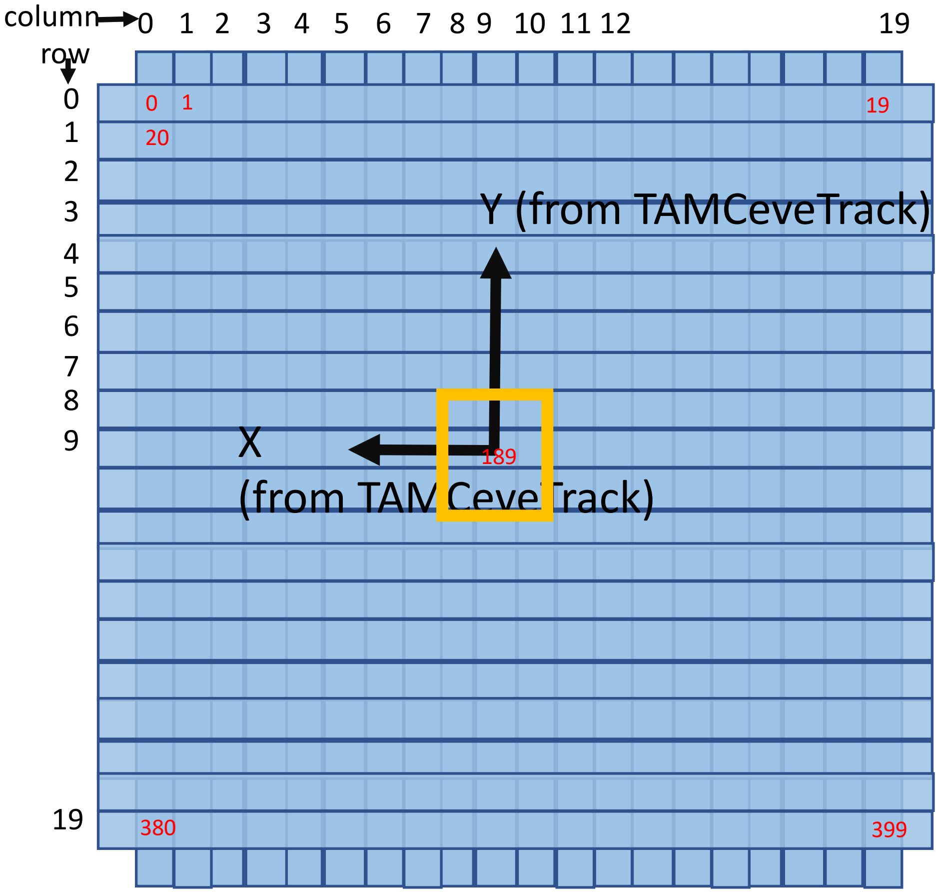


Conclusions

- We had a first look at A reconstruction with 9 calorimeter crystals
  - CNAO2020 setup
  - 200 MeV/u ^{12}C on C target
- To be done:
  - Decide a strategy on how to evaluate double hit events (events where a single bar is hit more than once): we'll have them.
  - Decide strategy on how to determine A and Z cross feed and efficiency in more detail
  - Repeat analysis on GSI2021 setup (see talk by. S. Muraro): ^{16}O of 200 MeV/u and 400 MeV/u
  - Use updated Shoe version

Presumed Calorimeter numbering





(0,0) in front bar 9 and rear bar 9

Presumed TW axis and numbering

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