The MLEM way towards Matter Effects accounting in charged particles based PT online monitoring

ARPG meeting 16/07/2018

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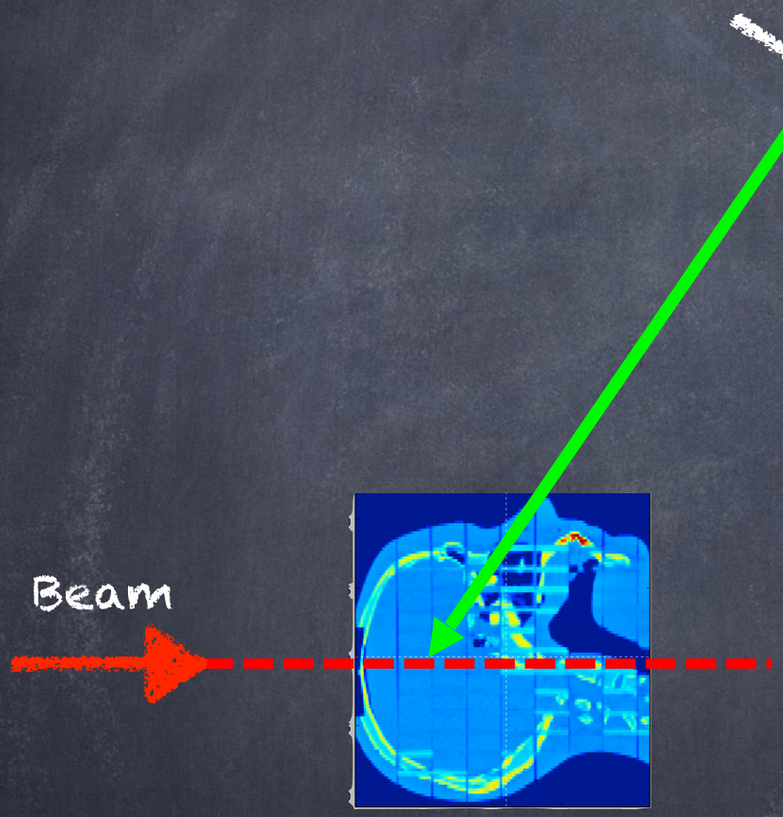
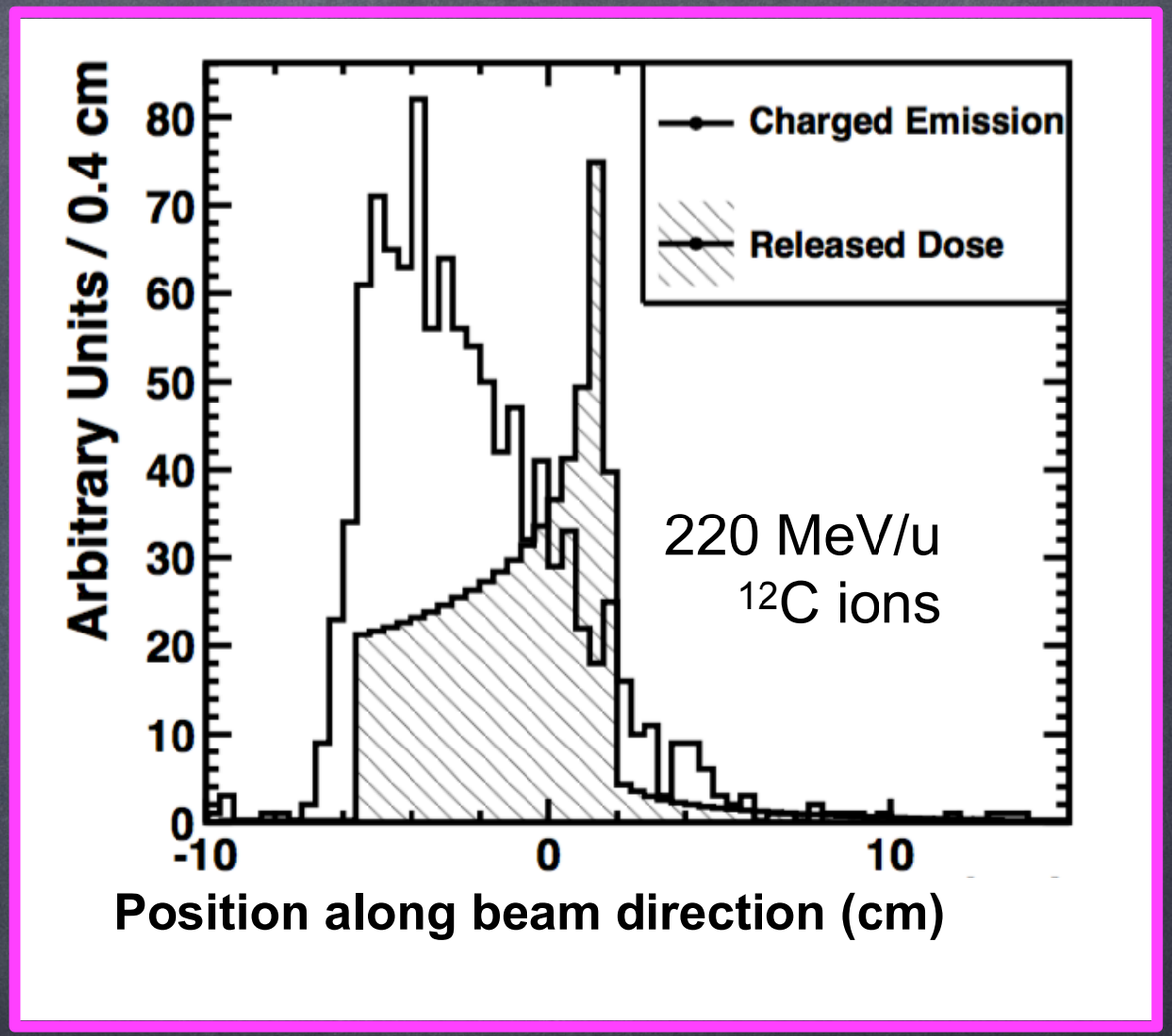
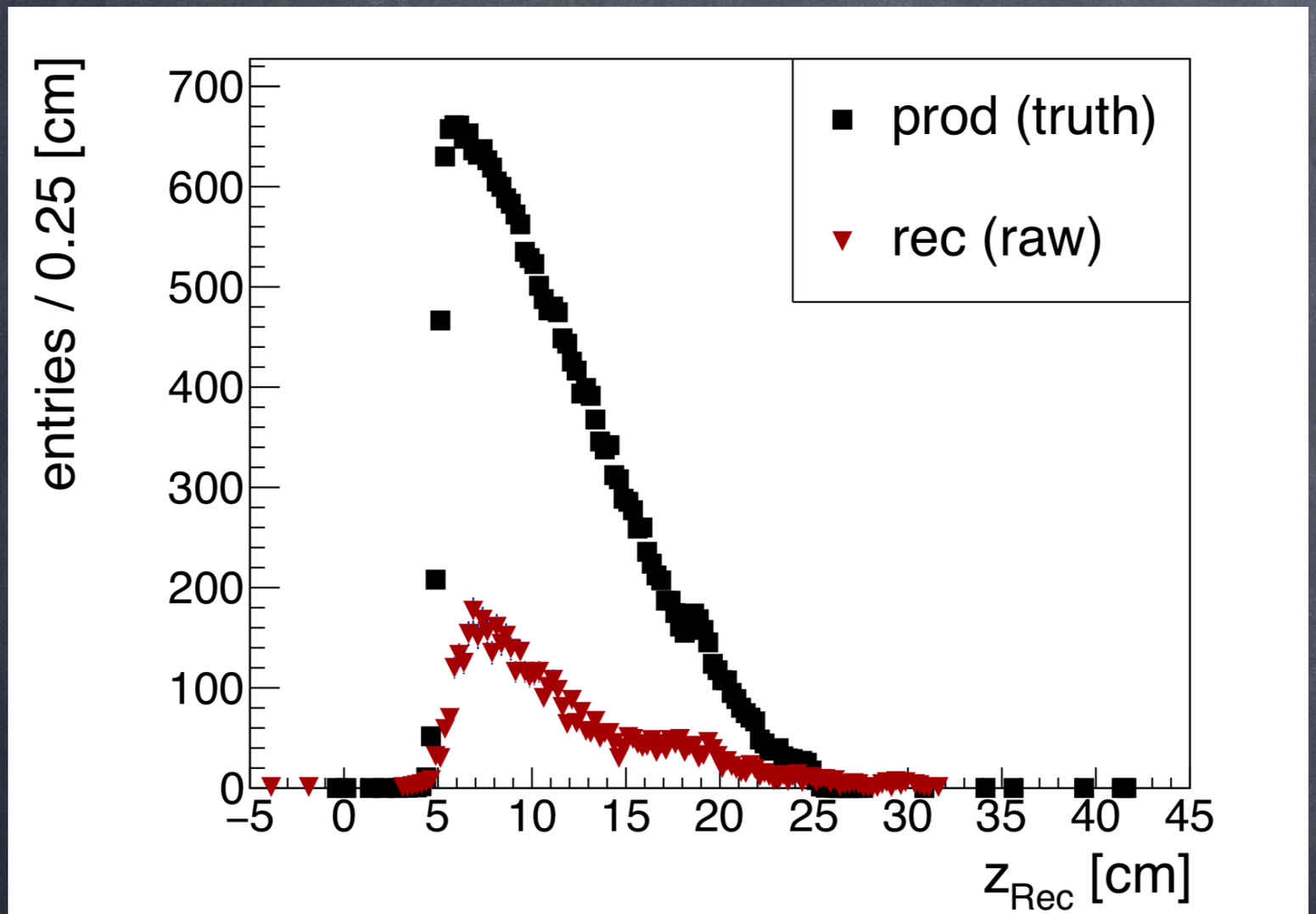
Goal: Correlation of BP with the emission spectrum





Experimentally we do not have access to the charged emission spectrum

FLUKA MC simulation: 10 pencil beam with 300 MeV/u in RANDO



Secondary proton shortcomings:

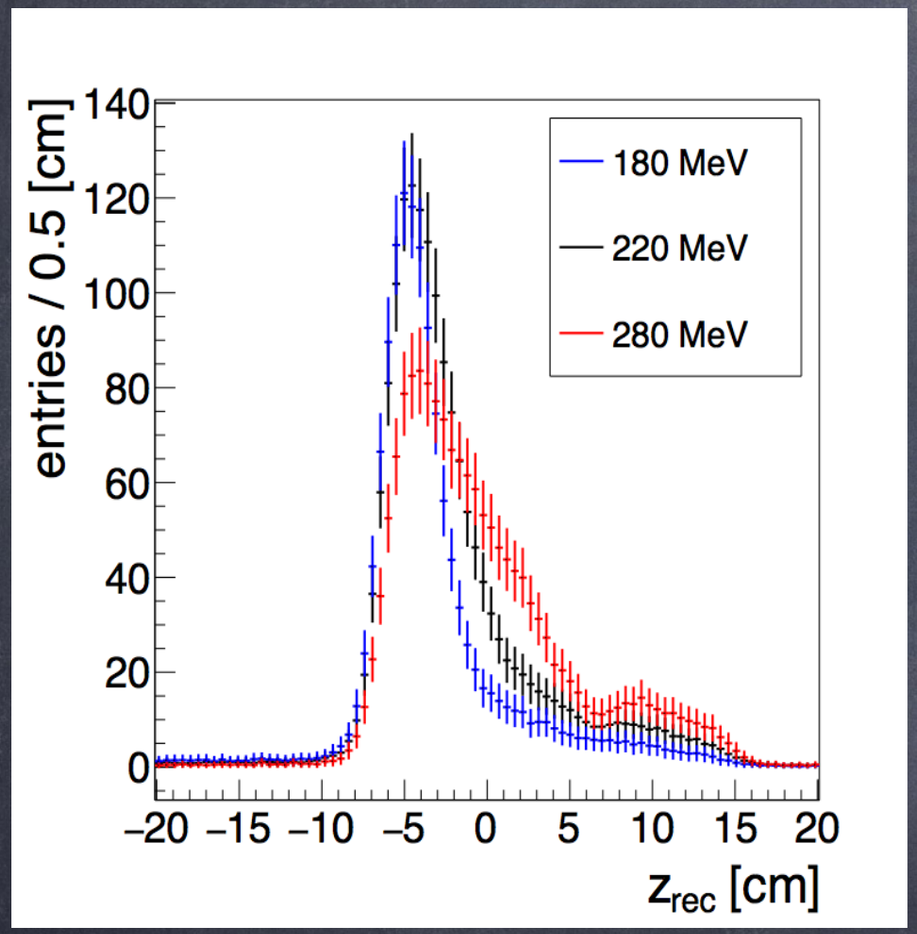
- Multiple Scattering
- Absorption / minimum kinetic energy

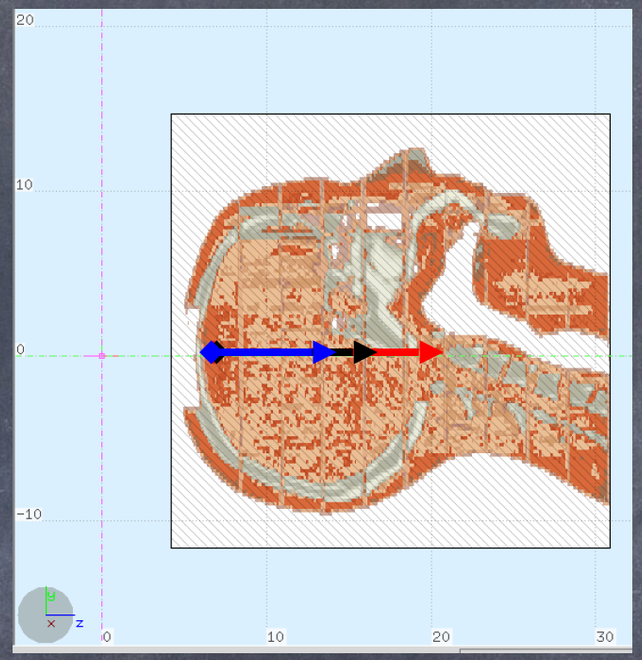
"matter effect"

Raw spectrum (red) -> Emission spectrum (black)

CNAO experience

12C Range : 180 MeV : 7cm; 220 MeV : 10 cm; 280 MeV : 15 cm





Setup MC has been carefully optimised to match the CNAO data taking conditions: FRED and FLUKA

Unfolding the "matter effect"

MLEM

"Weights"

MLEM : iterative algorithm

$$x_i^{(n+1)} = x_i^{(n)} \cdot \frac{1}{\sum_j A_{ij}} \cdot \sum_j A_{ij} \frac{y_j}{\sum_k A_{kj} x_k^{(n)}}$$

n=0

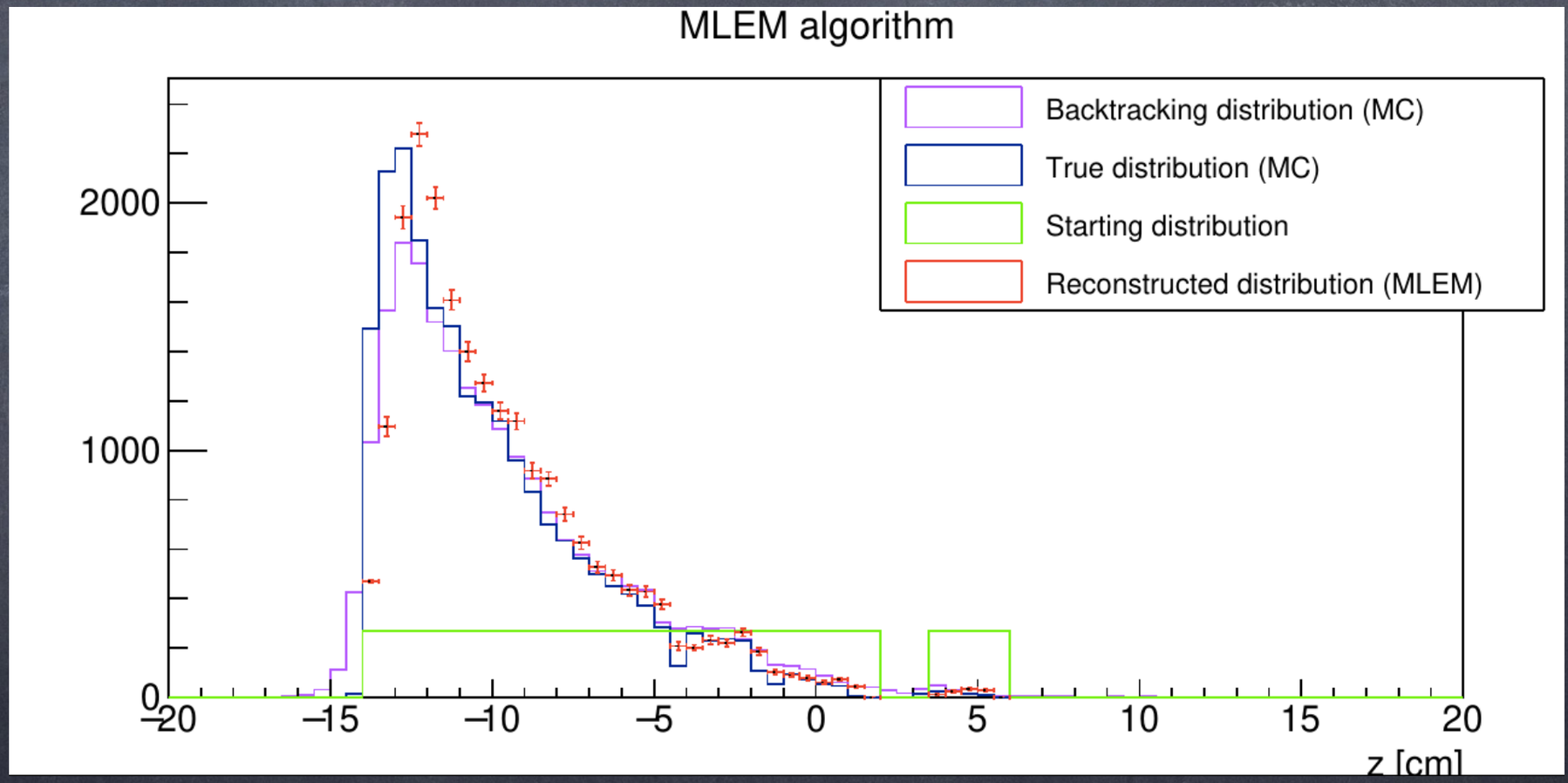
Method for the solution of the inverse problem

$$X^i = A_{ij}^{-1} * X^j$$

Initial distribution:
it doesn't change the final result => flat

Matrix of probability A_{ij}:
Calculated knowing the probability (A_{ij}) that an element from bin I is reconstructed in *j*
(A_{ij} obtained by FRED)

Backtracking:
data from DP (actually simulated by FRED with tot secondary)



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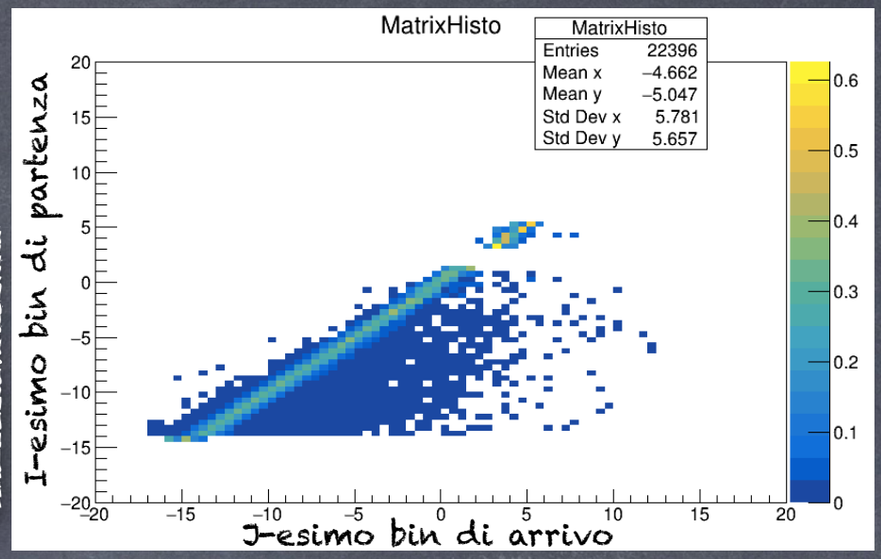

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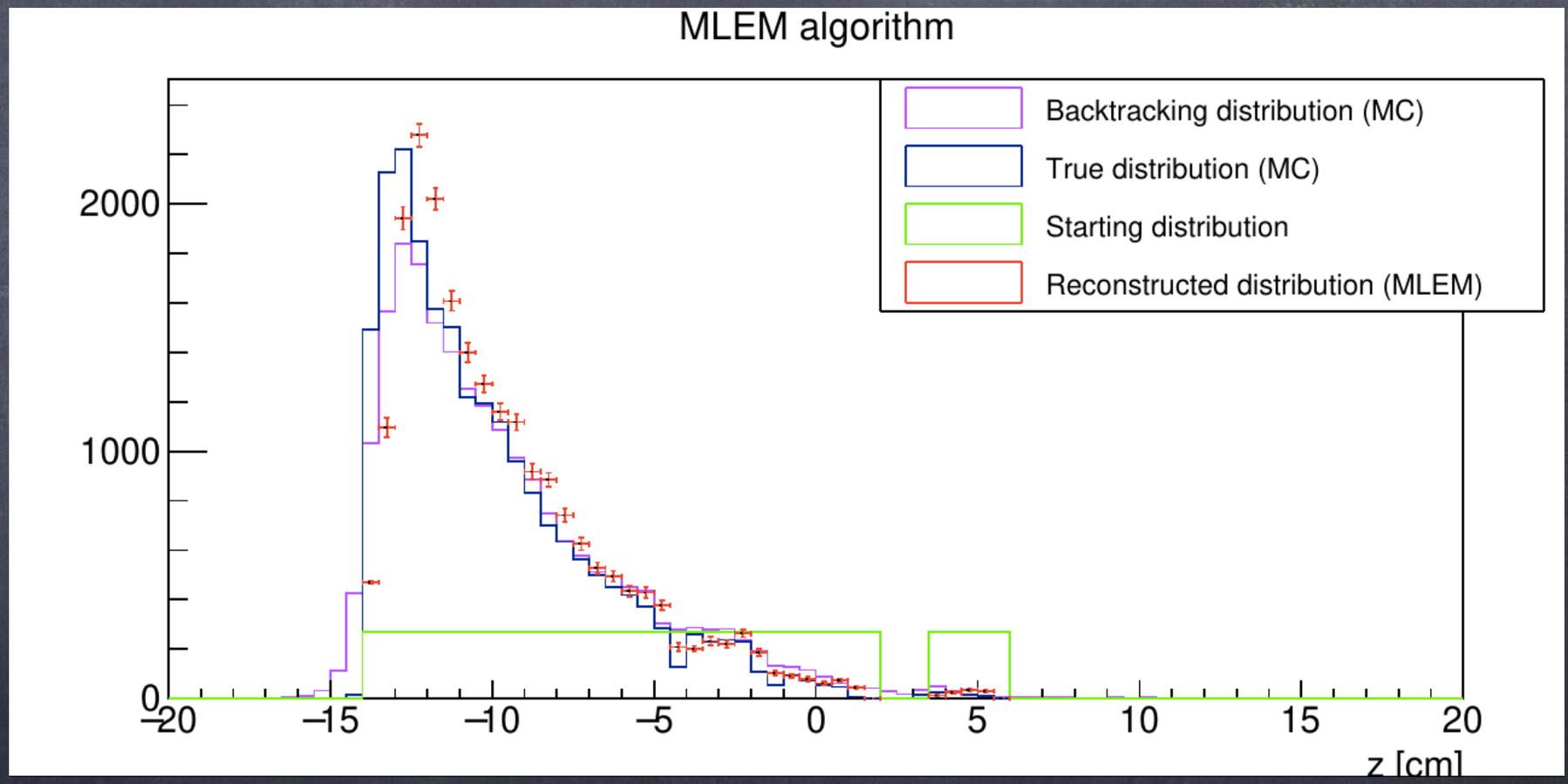

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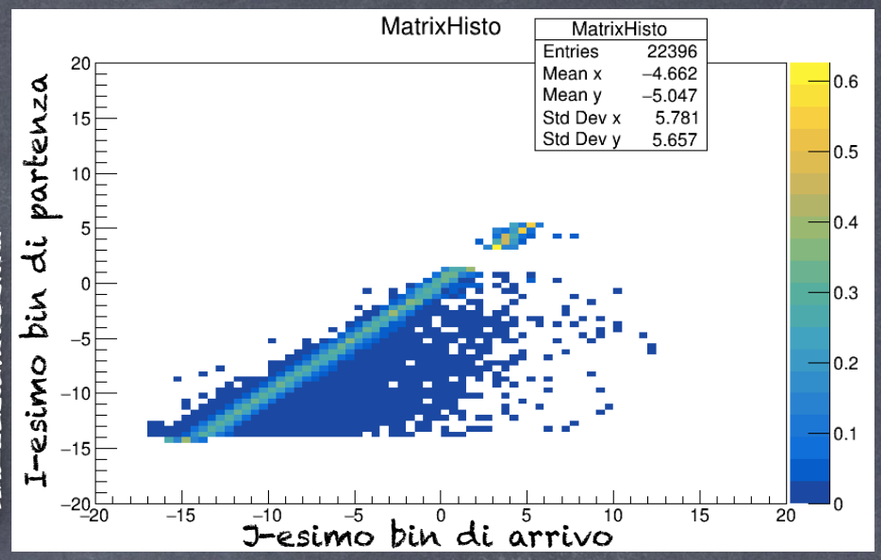

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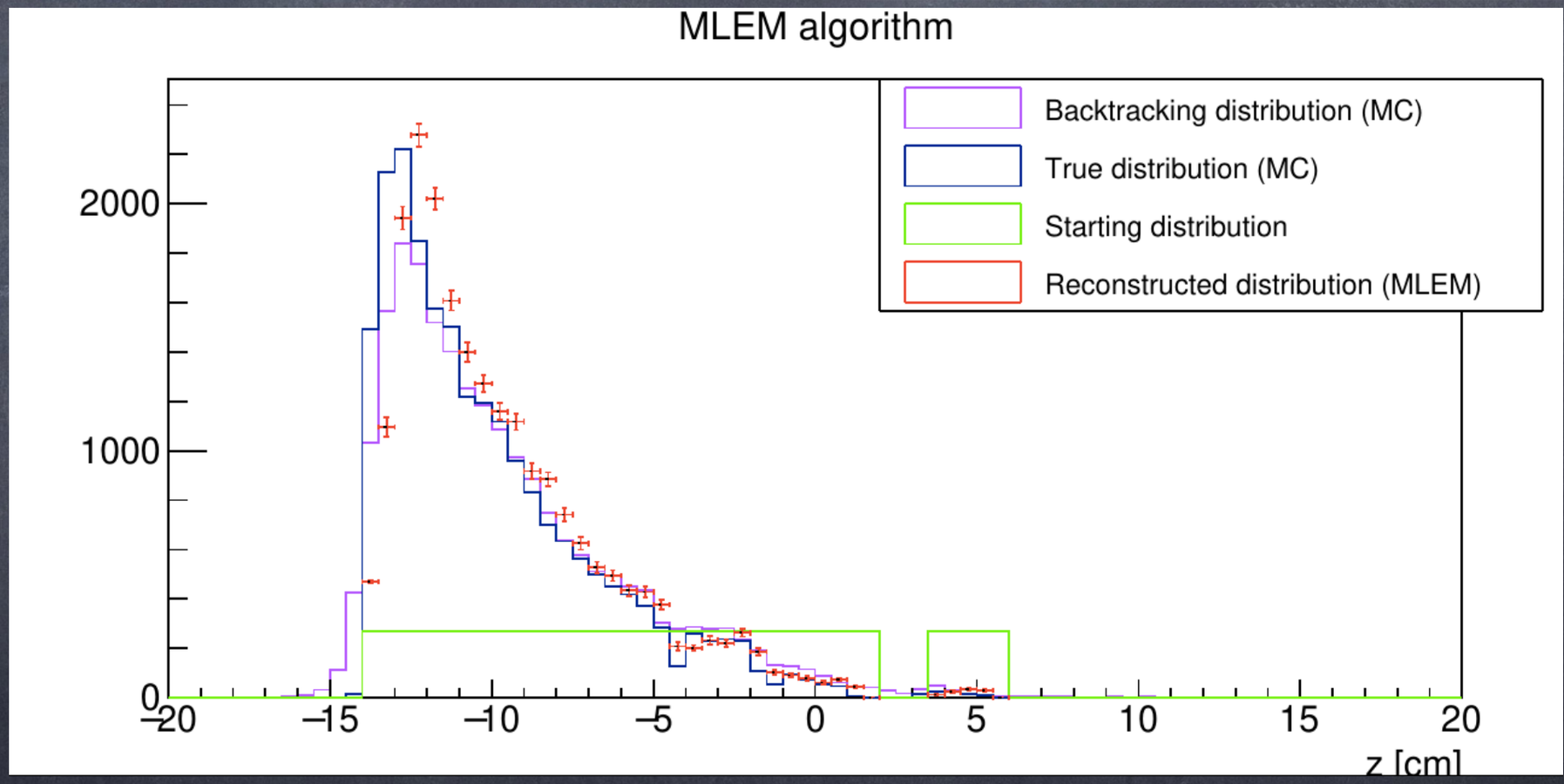

It is not feasible to build a matrix with a 'brute force' / full MC approach -> we need a matrix for each pencil beam (and each patient) ~ 10^4 -> FRED

MLEM : iterative algorithm

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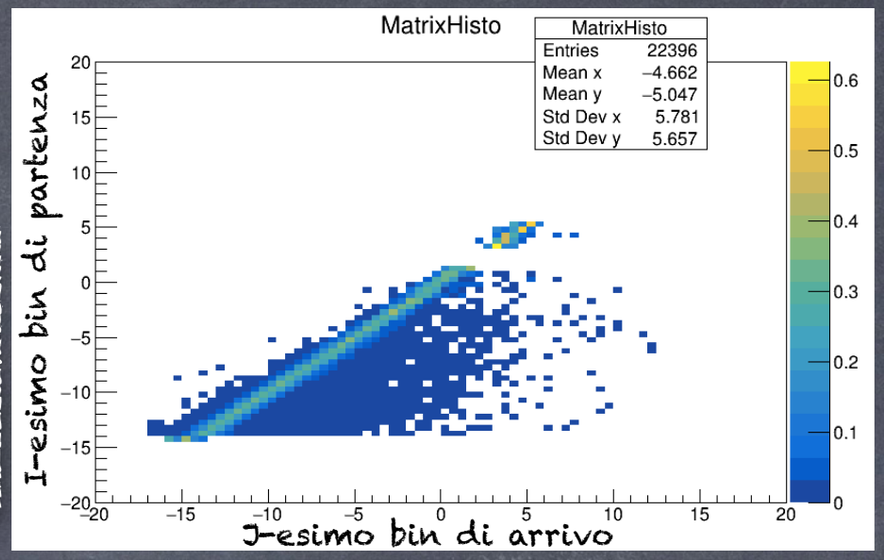

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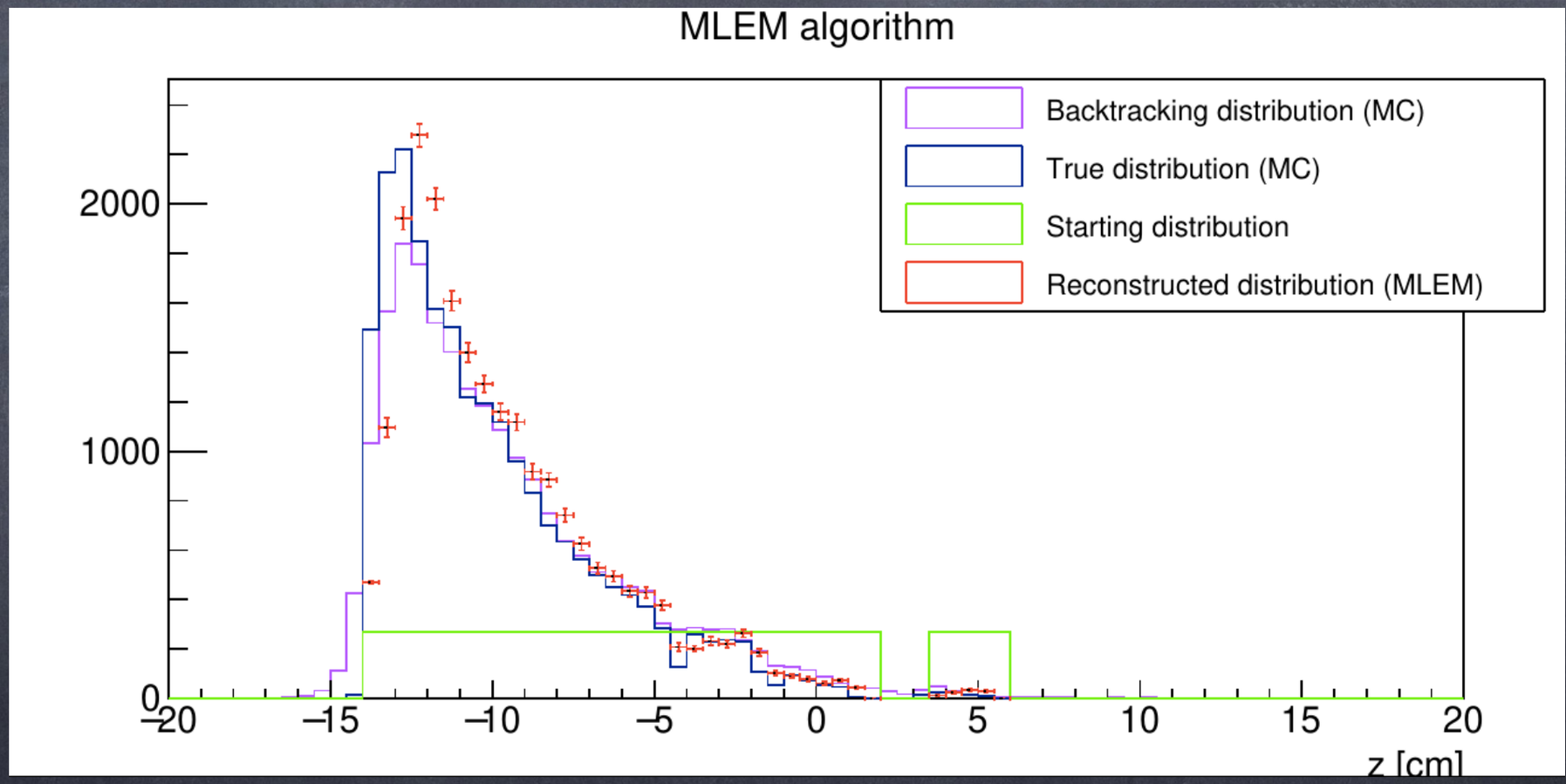

Now: the matrix is built with the secondaries produced by a FLUKA simulation (^{12}C ions and 280 MeV/u) and they are tracked with FRED.

MLEM : iterative algorithm

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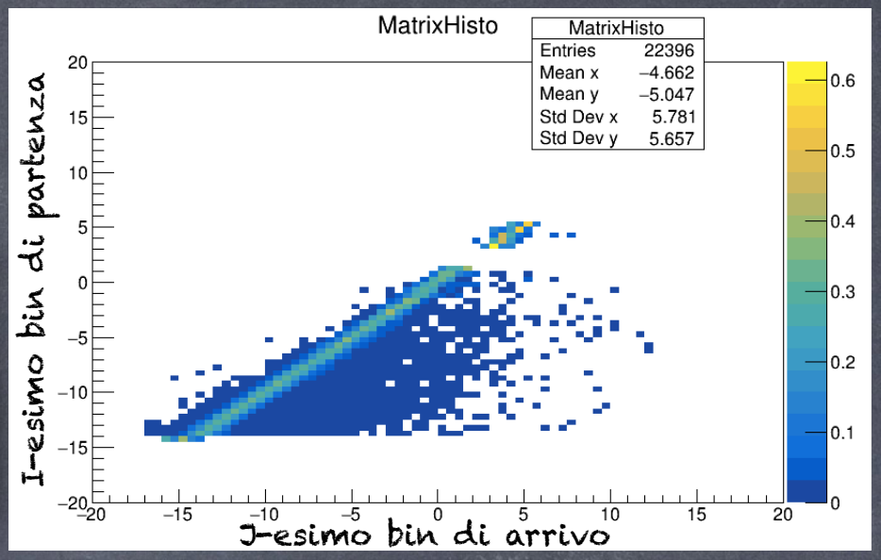
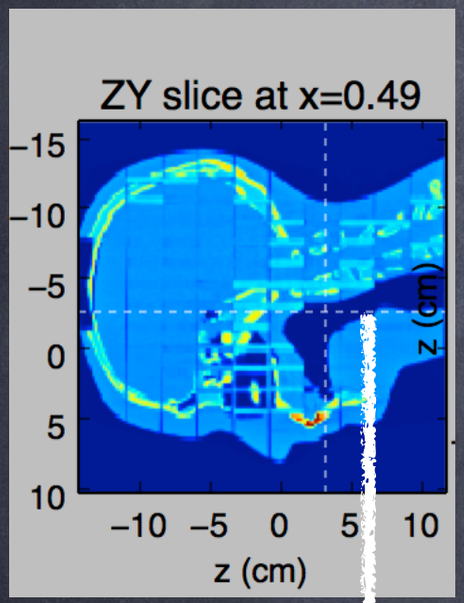
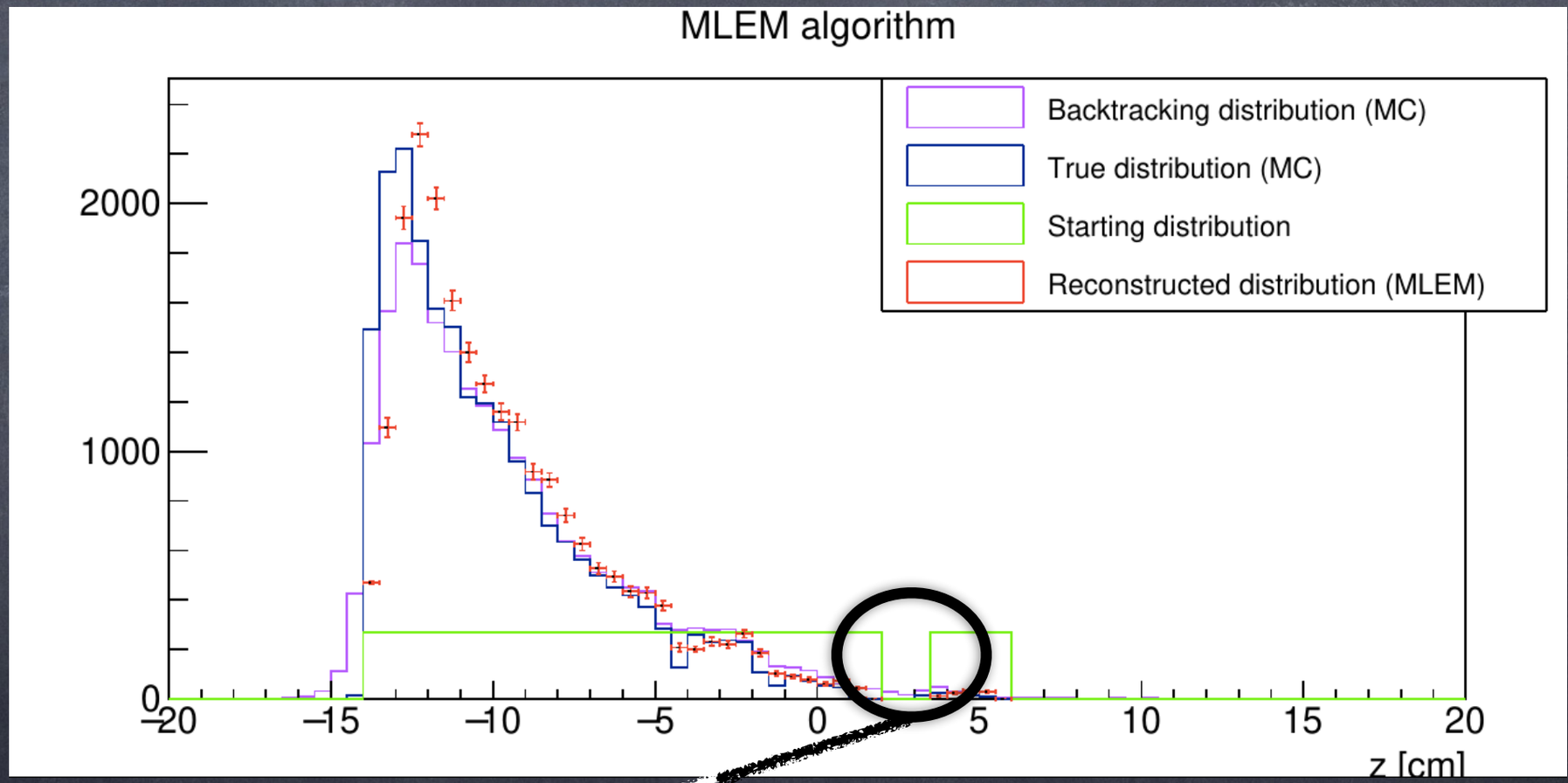
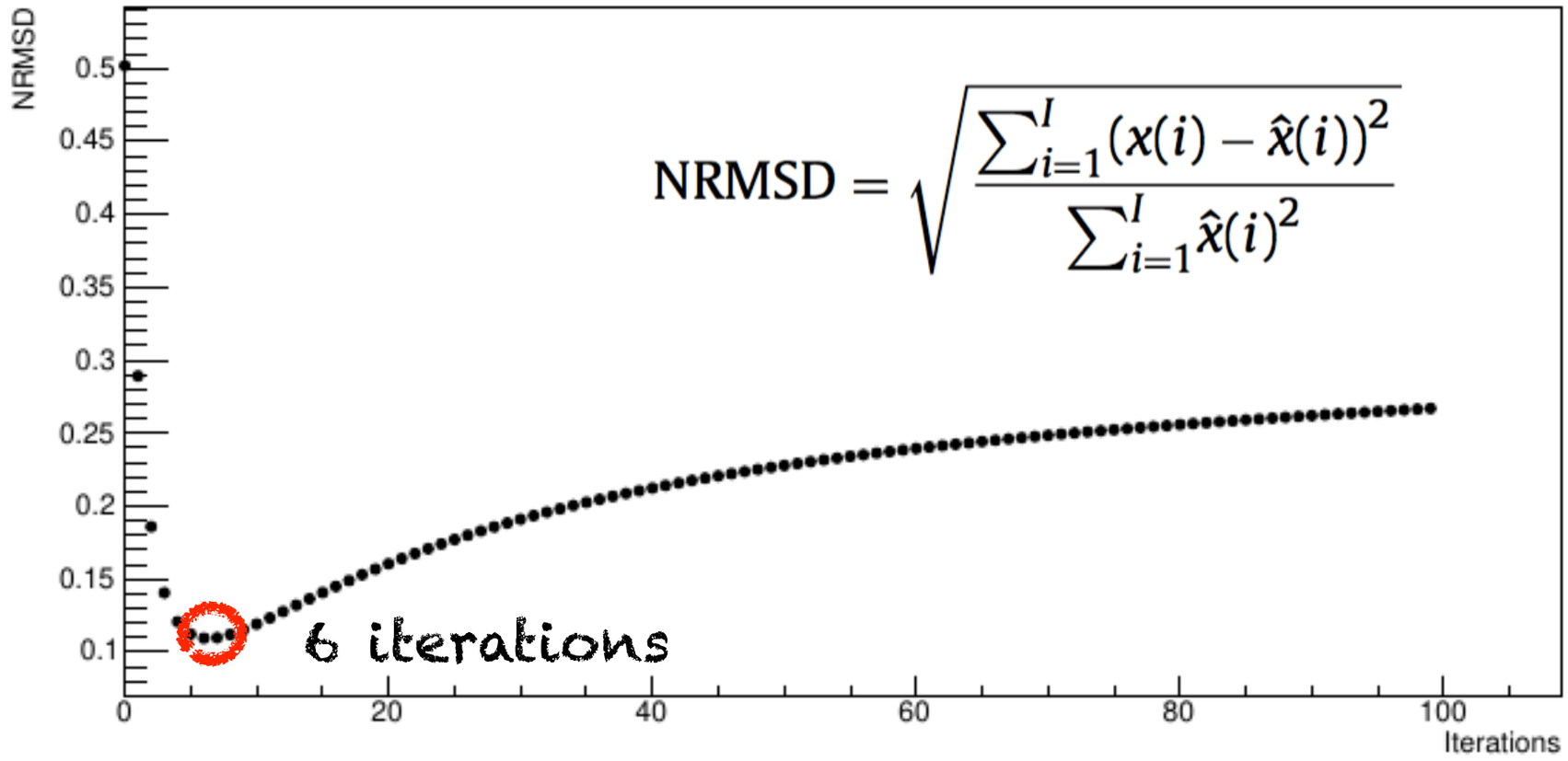






Throat -> under study

Convergence of the algorithm



$$\mathrm{NRMSD} = \sqrt{\frac{\sum_{i=1}^{I}(x(i) - \hat{x}(i))^2}{\sum_{i=1}^{I}\hat{x}(i)^2}}$$

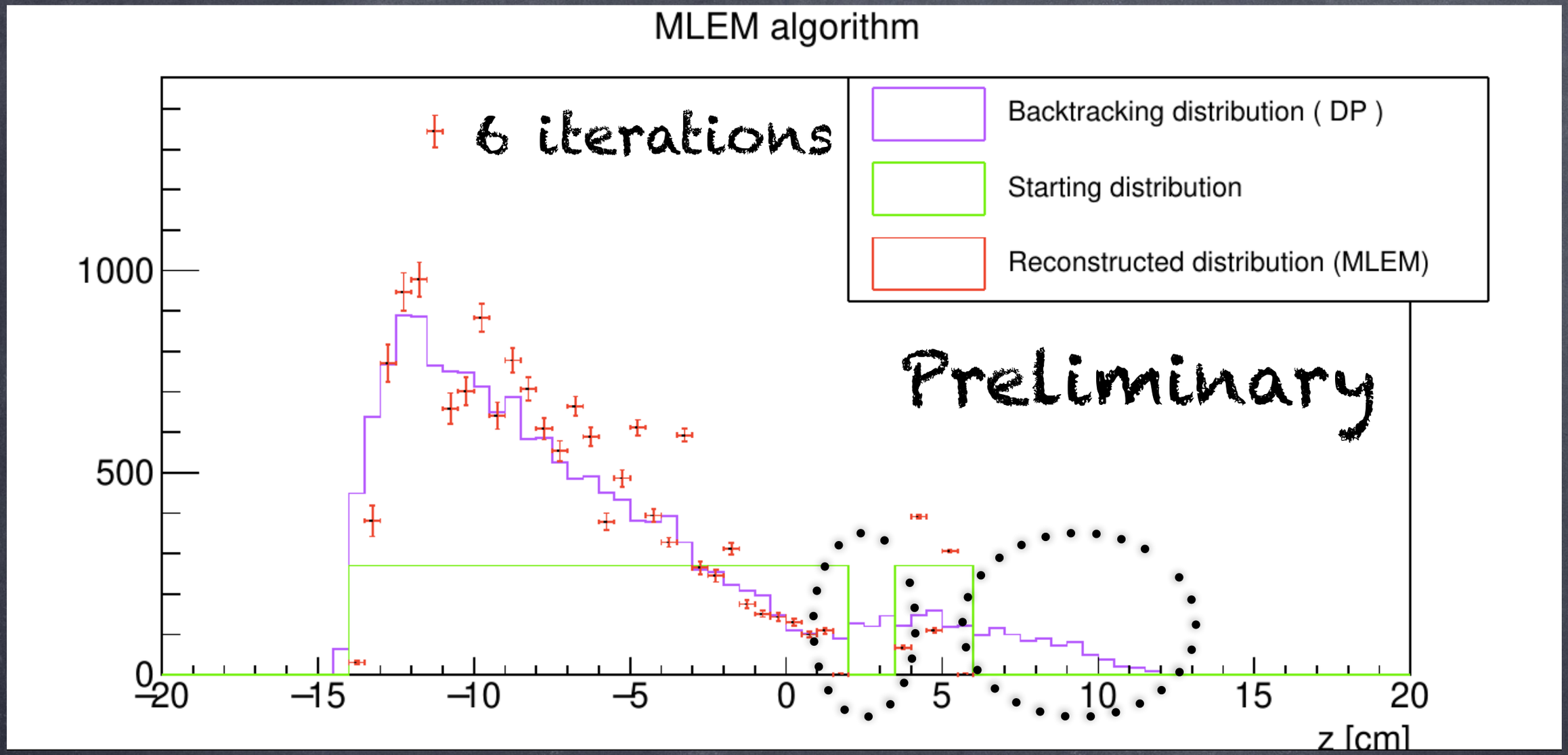
$x(i)$= MLEM distribution

$\hat{x}(i)$ = MC true

A systematic study on how to provide a prescription to perform the data unfolding (choice of best iteration, systematic uncertainty assessment, ..)is ongoing.

Gaitanis, G. Kontaxakis, G. Spyrou, G. Panayiotakis, G. Tzanakos,
"PET image reconstruction: A stopping rule for the MLEM algorithm based on properties of the updating coefficients"

Results with real profiler data

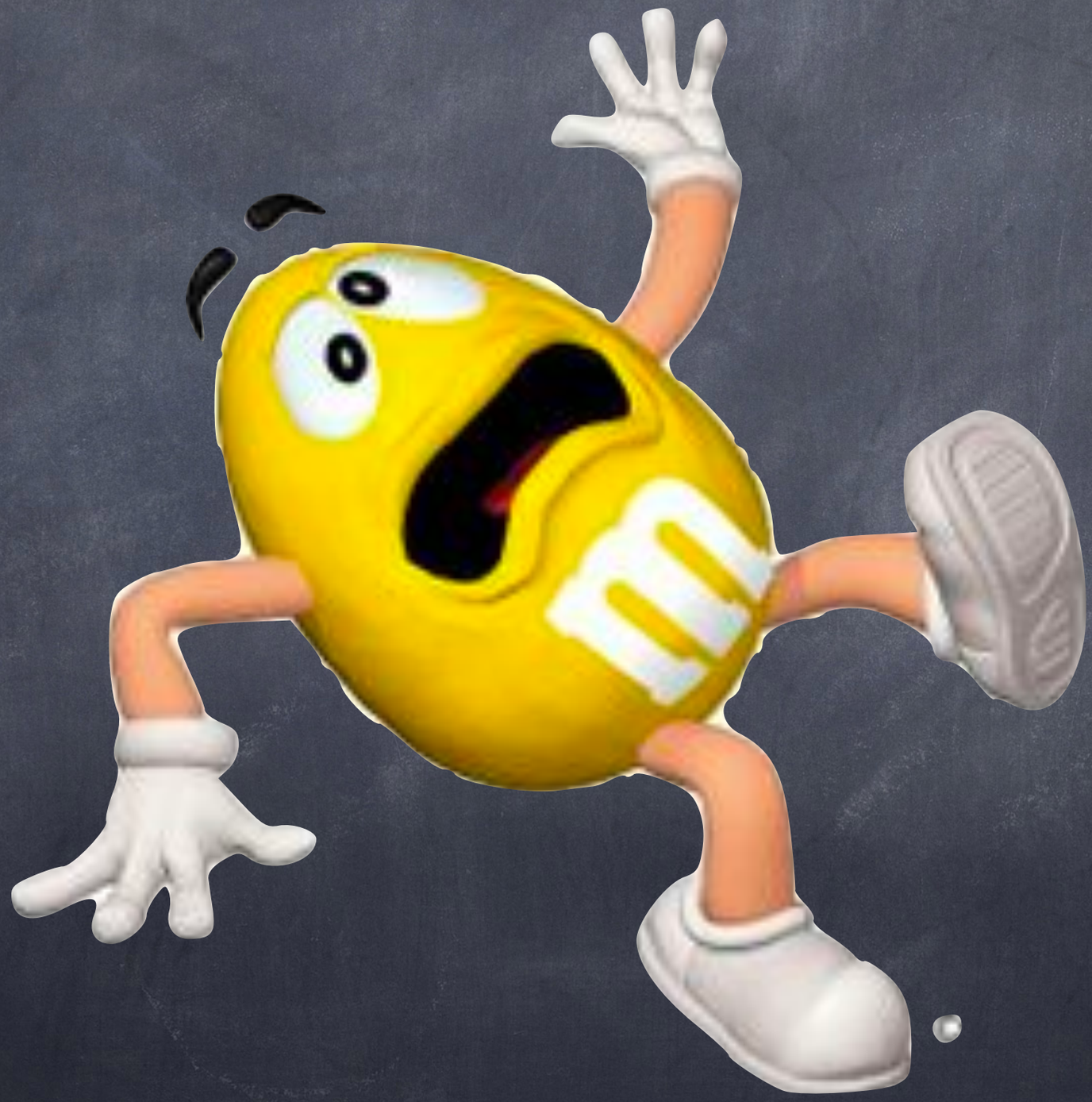


For the first time we were able to unfold the CNAO measured data (in purple) to obtain the 'production' spectrum!!! Many items have yet to be addressed..

Data unfolding: Items being 'attacked'

- Evaluate the implications of the presence of 'holes' in the 'production' information used to build the A_{ij} matrix: are we hitting a wall here?
- In clinical conditions: how many matrixes do we need? (for each Pencil beam?)
- Matrix creation speedup: produce carbon beam directly with FRED
- Test of a FLUKA based method for the unfolding

Grazie



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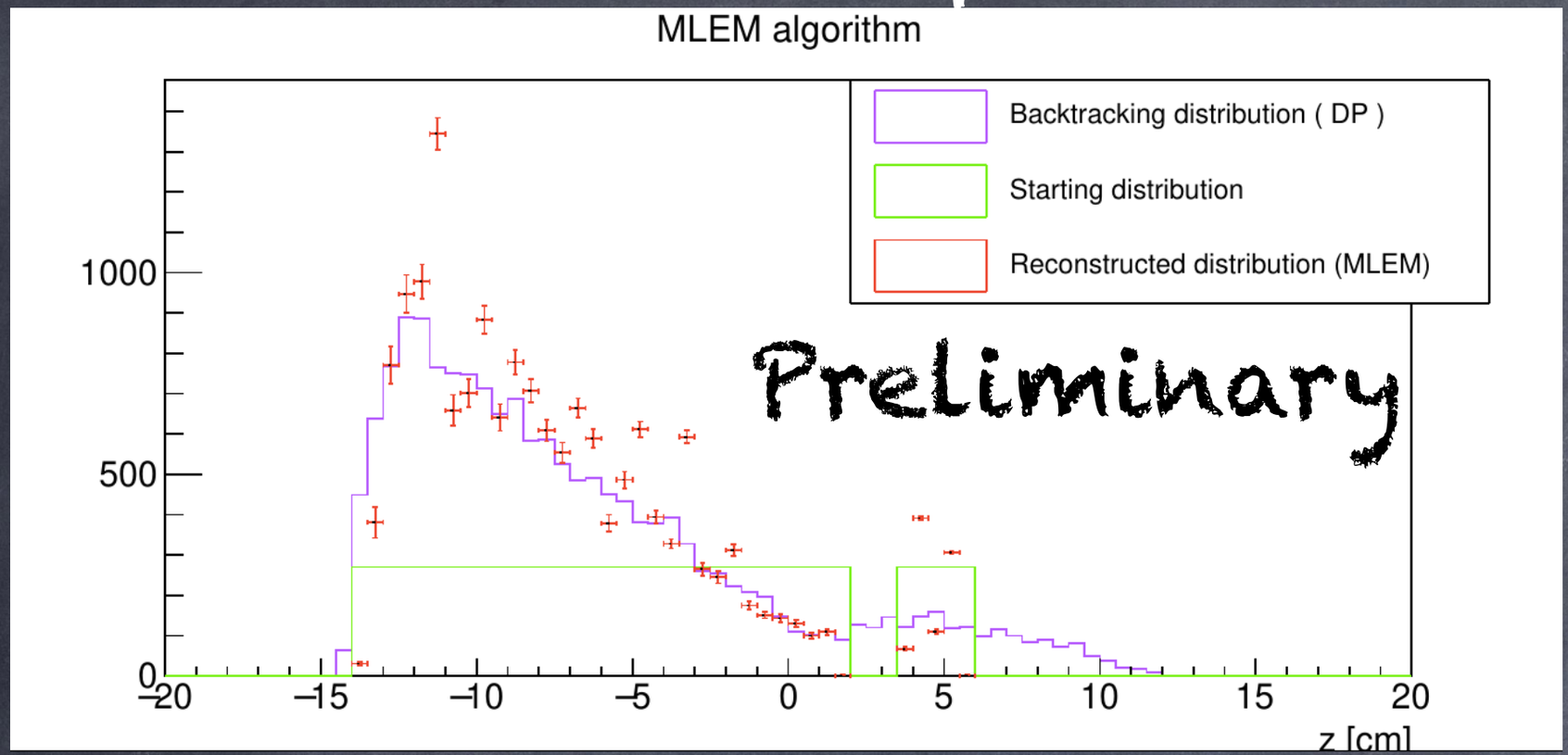
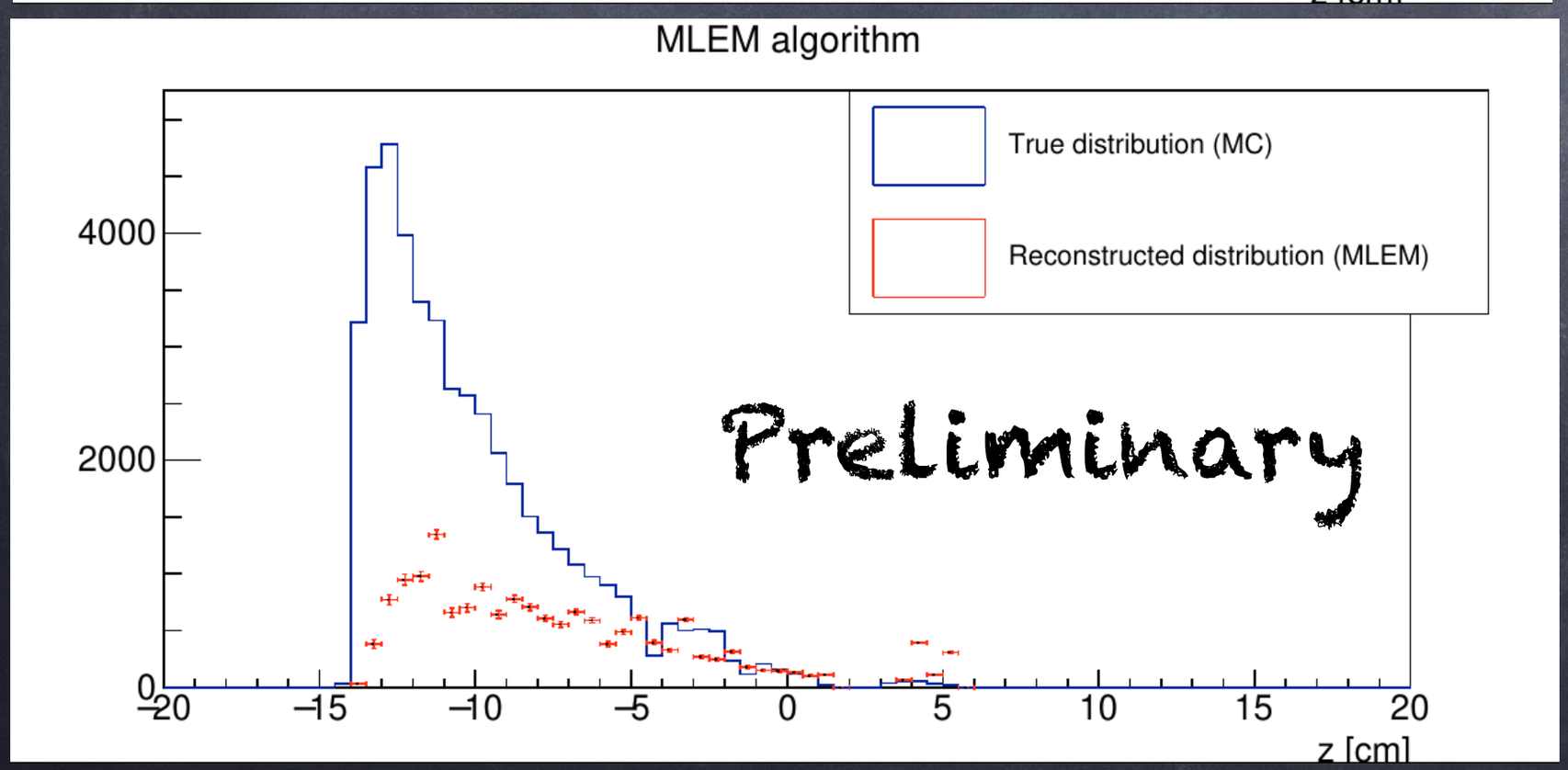


6 iterations



Which is the limits of applicability of this method?