Performances on A and Z identification

Napoli, 25/5/2017

GOALs:

- Resolution on A and Z identification;
- Reconstruction efficiency

INPUT DATA:

- gpfs…/Simulation/V10.2/16O_C2H4_200_Calo21.root → 58400 evt in rootuple → $5 \bullet 10^6$ primary

Analysis

Studied fragments, one per charge

Z	1	2	3	4	5	6	7	8
A	1	4	7	9	11	12	14	16

To understand the capability of the algorithms to reconstruct/identify A-Z

All tracks considered

To understand the capability to disentangle different A-Z

TRACK SELECTION FOR BOTH ANALYSES:

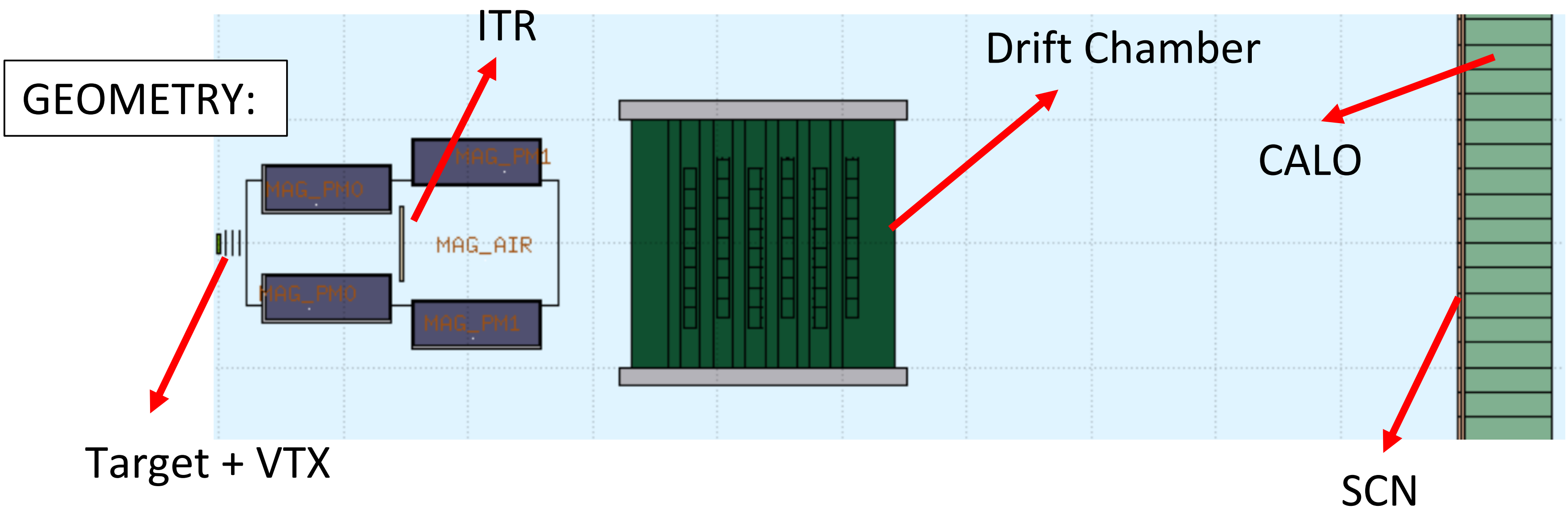
- Tracks that cross all subdetectors

Geometry used

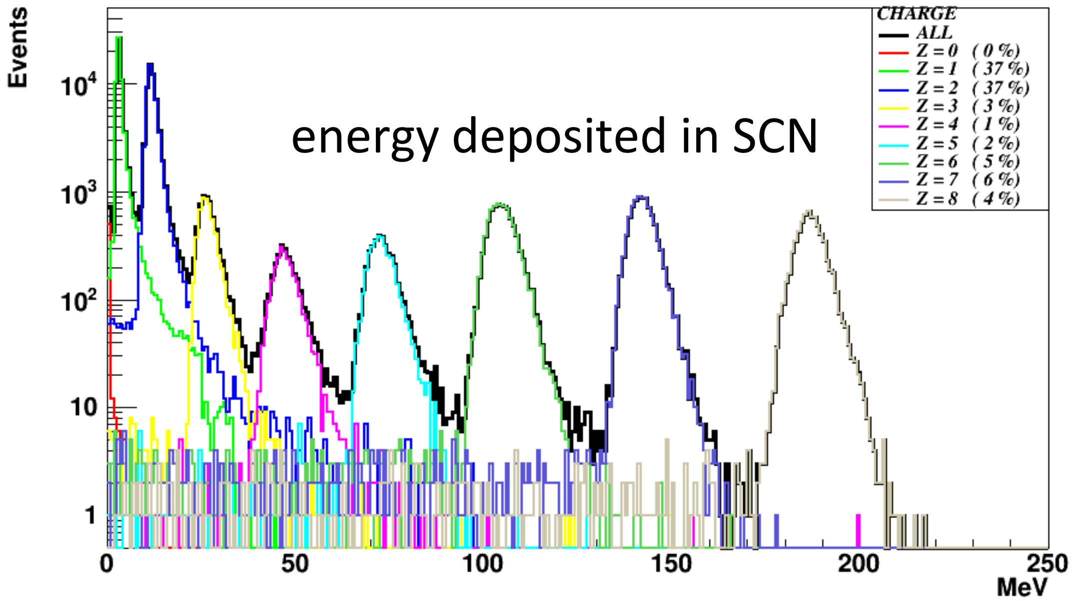
Standard geometry:

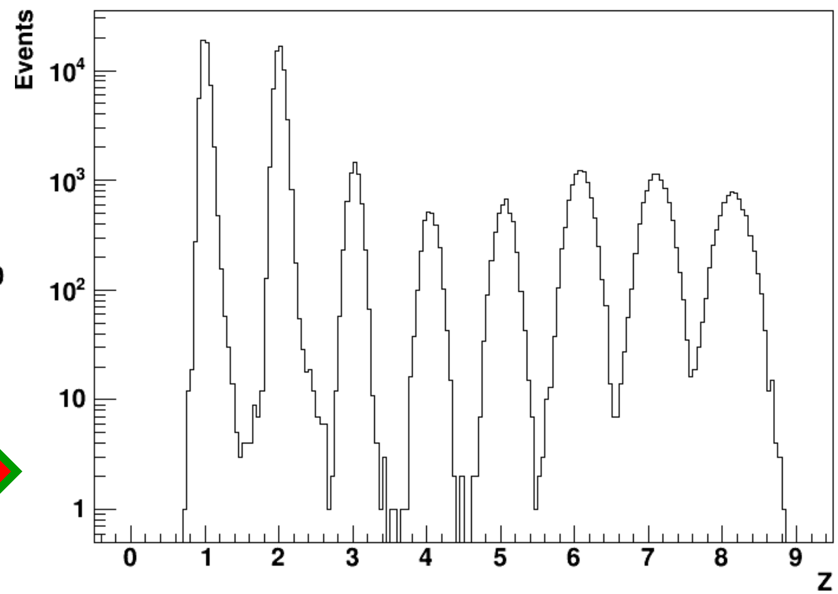
- VTX → 3 silicon layers 50 μm each
- ITR → Pixel detector 2 silicon layers 50 μm each
- DCH standard configuration
- SCN → 2 scintillator layers 3 mm each
- CALO → BGO 21 cm depth

} FRONT END not simulated



Z reconstruction





Using the Bethe formula → energy deposited in scintillator + β measurement

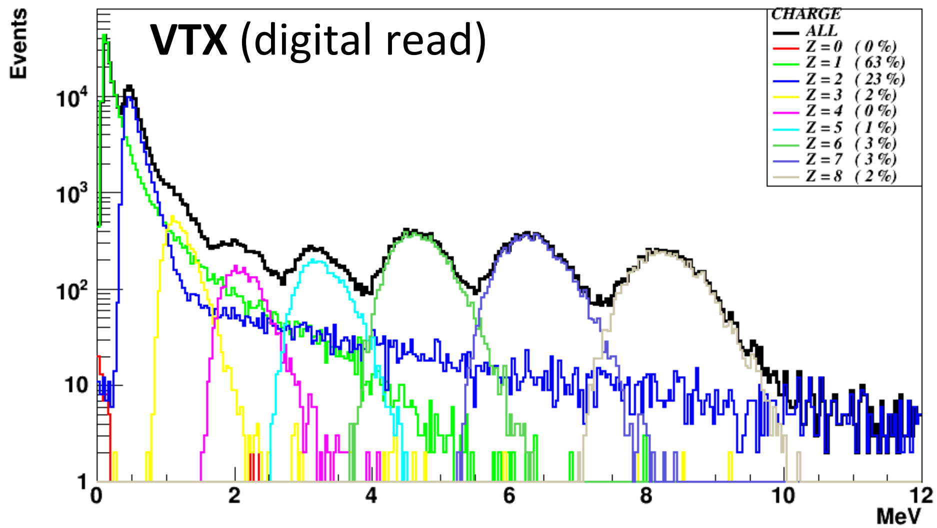
	^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
	1	2	3	4	5	6	7	8
	1.01 ± 0.05	2.02 ± 0.06	3.03 ± 0.08	4.05 ± 0.10	5.07 ± 0.11	6.09 ± 0.14	7.11 ± 0.16	8.15 ± 0.18
Resol:	5%	3%						2.2%

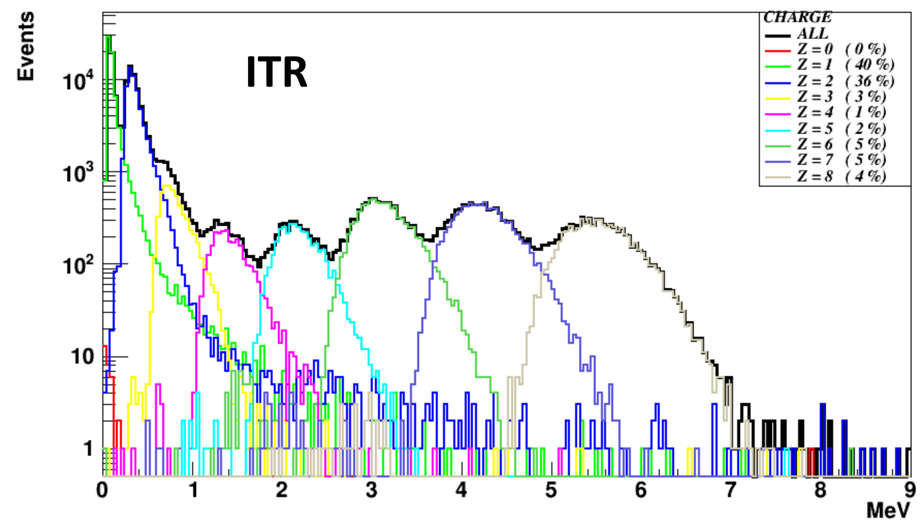
Z Resolution: [2-5%] << minimum distance between charges (~10% between 7 and 8)

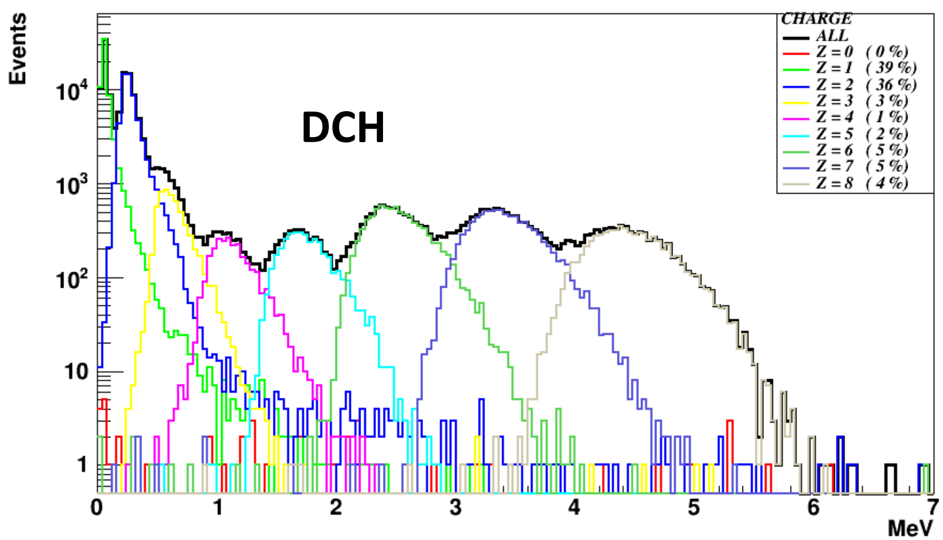
Remember: the front-end is not simulated

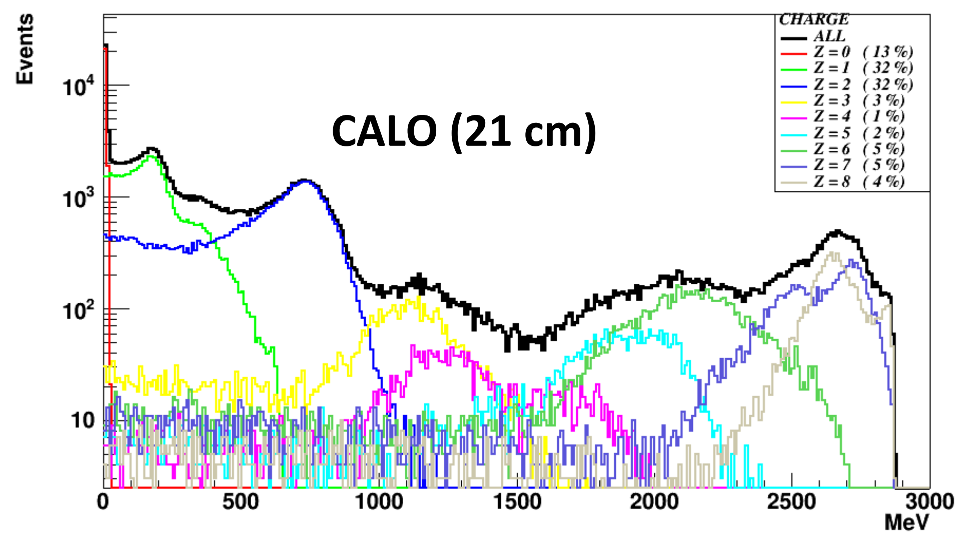
Z-A identification

Deposited energy of different charged fragments





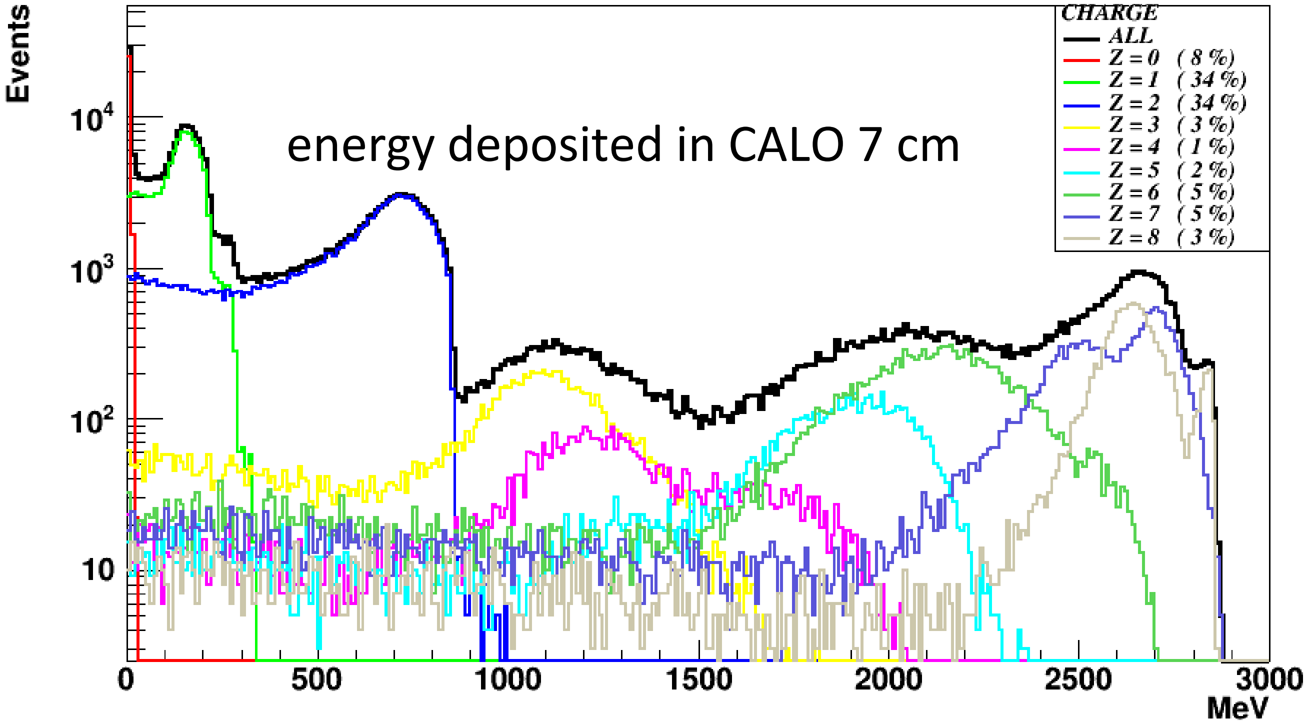


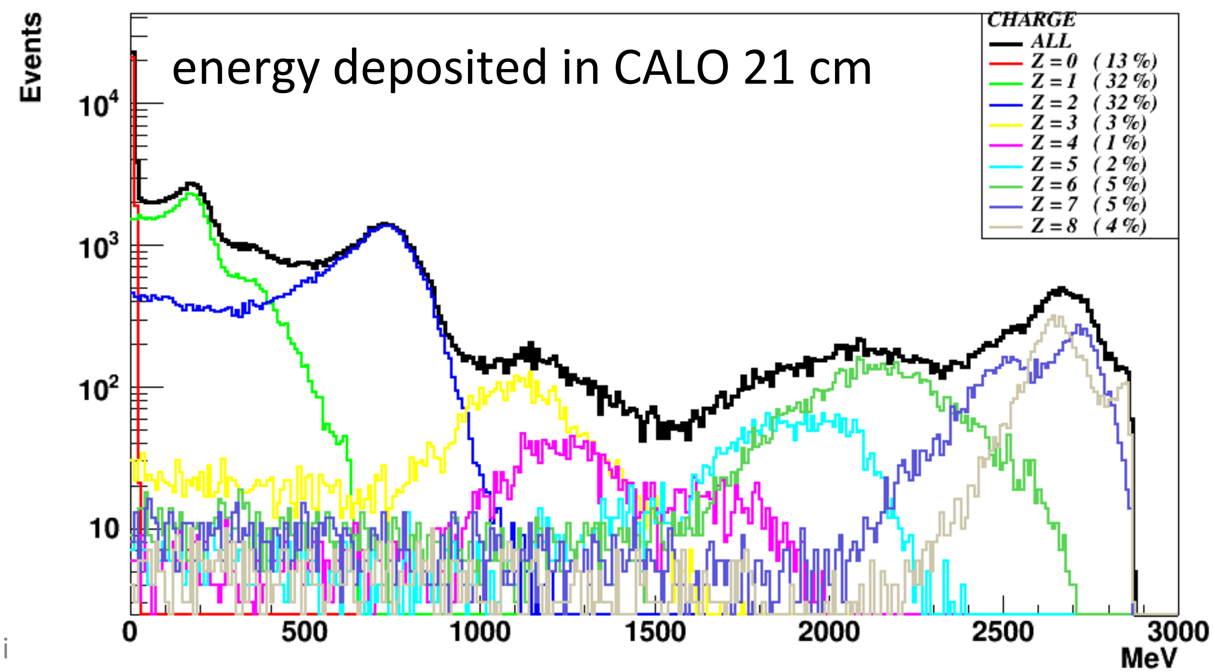


	VTX	ITR	DCH	SCINT	CALO
Depo Energy	**0.04**	**0.03**	**0.02**	**1**	**20**

Edepo,700

Calo 7 – Calo 21





A Reconstruction of the fragments

RECO QUANTITIES

- **Tof (β)**
  - Time VTX/SCINT & resol 100 ps

$$tof_{reco} = gaus(t_{scint} - t_{vtx}, 100\ ps)$$

~ 1.6-1.7%%

- **Momentum (p)**
  - Standard resolution (4%)

$$p_{reco} = gaus(p_{gen}\ , 4\%)$$

- **Kinetic energy (T)**
  - E CALO + SCINT & resol 3%

$$T_{reco} = gaus(E_{calo} + E_{scint}, 3\%)$$

TOF (β) – TRACKER (p)

$$A_1 = \frac{m}{U} = \frac{p}{U\,\beta\,\gamma}$$

TOF (β)– CALO (T)

$$A_2 = \frac{m}{U} = \frac{T}{U(\gamma - 1)}$$

TRACKER (p) – CALO (T)

$$A_3 = \frac{m}{U} = \frac{p^2 - T^2}{2T}$$

A fitting

- **Standard χ^2 Fit**
  - Taking into account the correlation between A_1, A_2 and A_3

$$f = \left(\frac{(tof_{reco} - t)}{\sigma tof_{reco}}\right)^2 + \left(\frac{(p_{reco} - p)}{\sigma p_{reco}}\right)^2 + \left(\frac{(T_{reco} - T)}{\sigma T_{reco}}\right)^2 + (A_1 - A \quad A_2 - A \quad A_3 - A)\begin{pmatrix} C_{00} & C_{01} & C_{02} \\ C_{10} & C_{11} & C_{12} \\ C_{20} & C_{21} & C_{22} \end{pmatrix}\begin{pmatrix} A_1 - A \\ A_2 - A \\ A_3 - A \end{pmatrix}$$

$$C = (A \cdot A^T)^{-1} \qquad A = \begin{pmatrix} \frac{\partial A_1}{\partial t} dt & \frac{\partial A_1}{\partial p} dp & 0 \\ \frac{\partial A_2}{\partial t} dt & 0 & \frac{\partial A_2}{\partial T} dT \\ 0 & \frac{\partial A_3}{\partial p} dp & \frac{\partial A_3}{\partial T} dT \end{pmatrix}$$

- **Augmented LagrangianFit (ALM)**

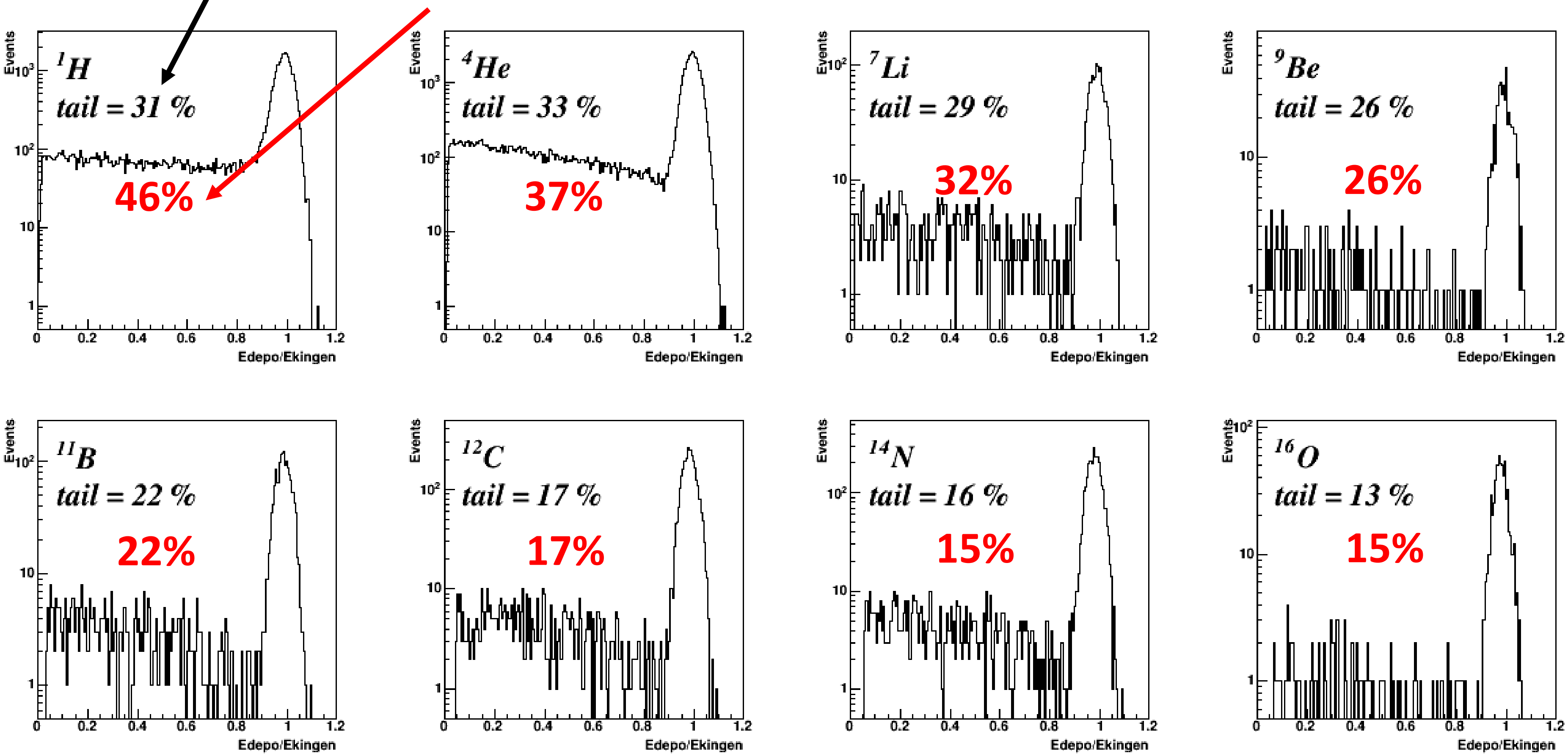
$$\tilde{\mathcal{L}}(\vec{x}\,; \lambda,\, \mu) \equiv f(\vec{x}) - \sum_a \lambda_a c_a(\vec{x}) + \frac{1}{2\mu} \sum_a c_a^2(\vec{x}).$$

Deposited Energy

% Events outside peak (ratio<0.9), calo 21 cm

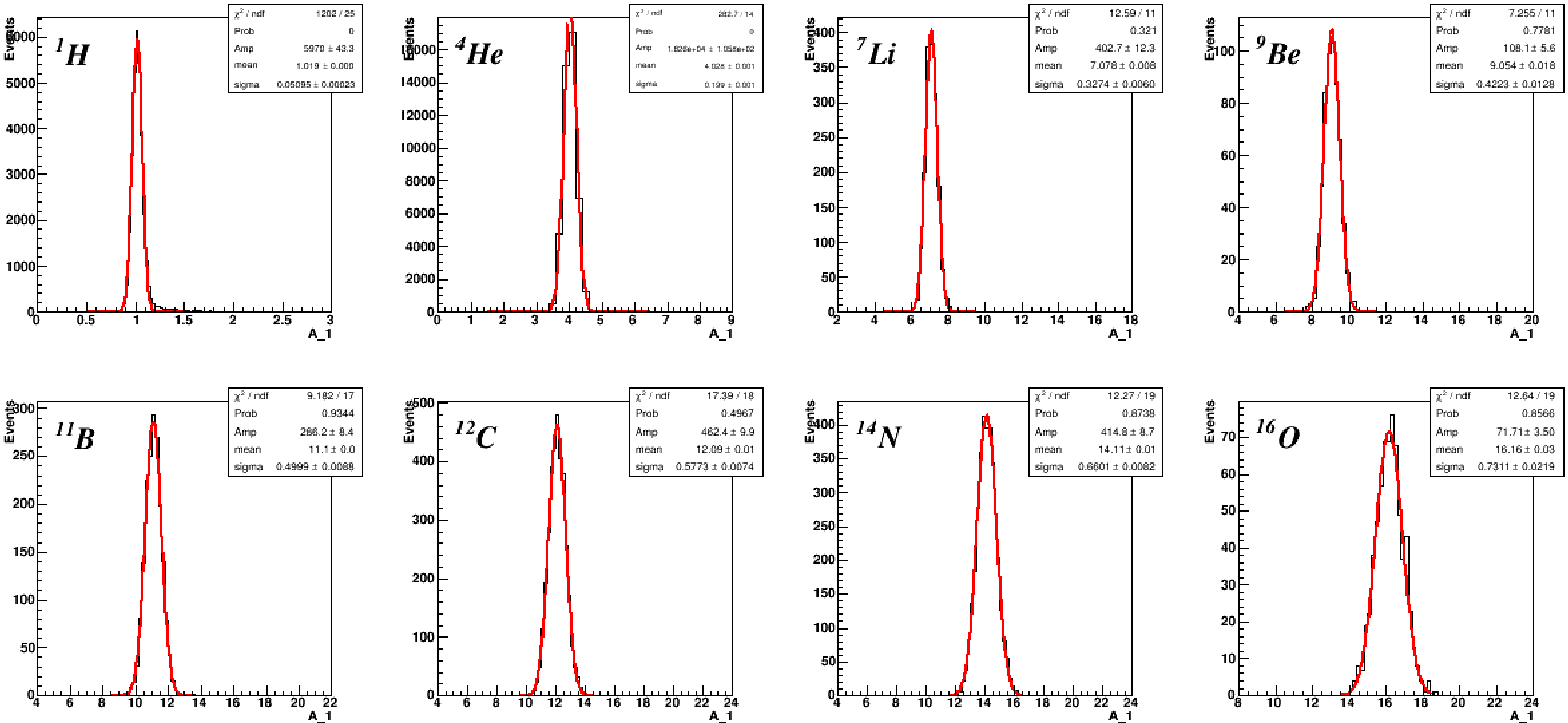
Energy deposited SCINT + CALO / Kinetic Energy generated

calo 7 cm



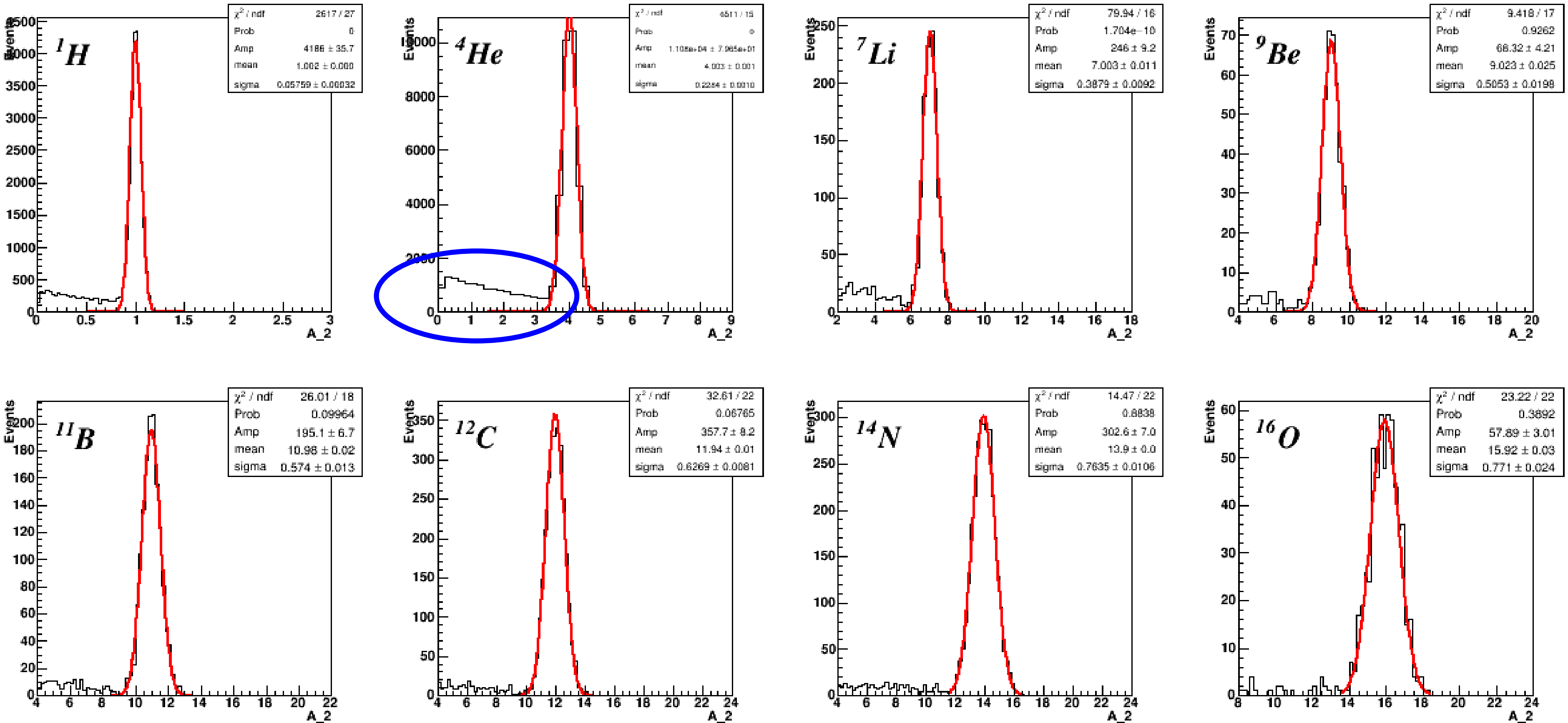
^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
0.985	0.990	0.988	0.985	0.981	0.975	0.972	0.968

A1: tof + tracker



A2: tof + calo

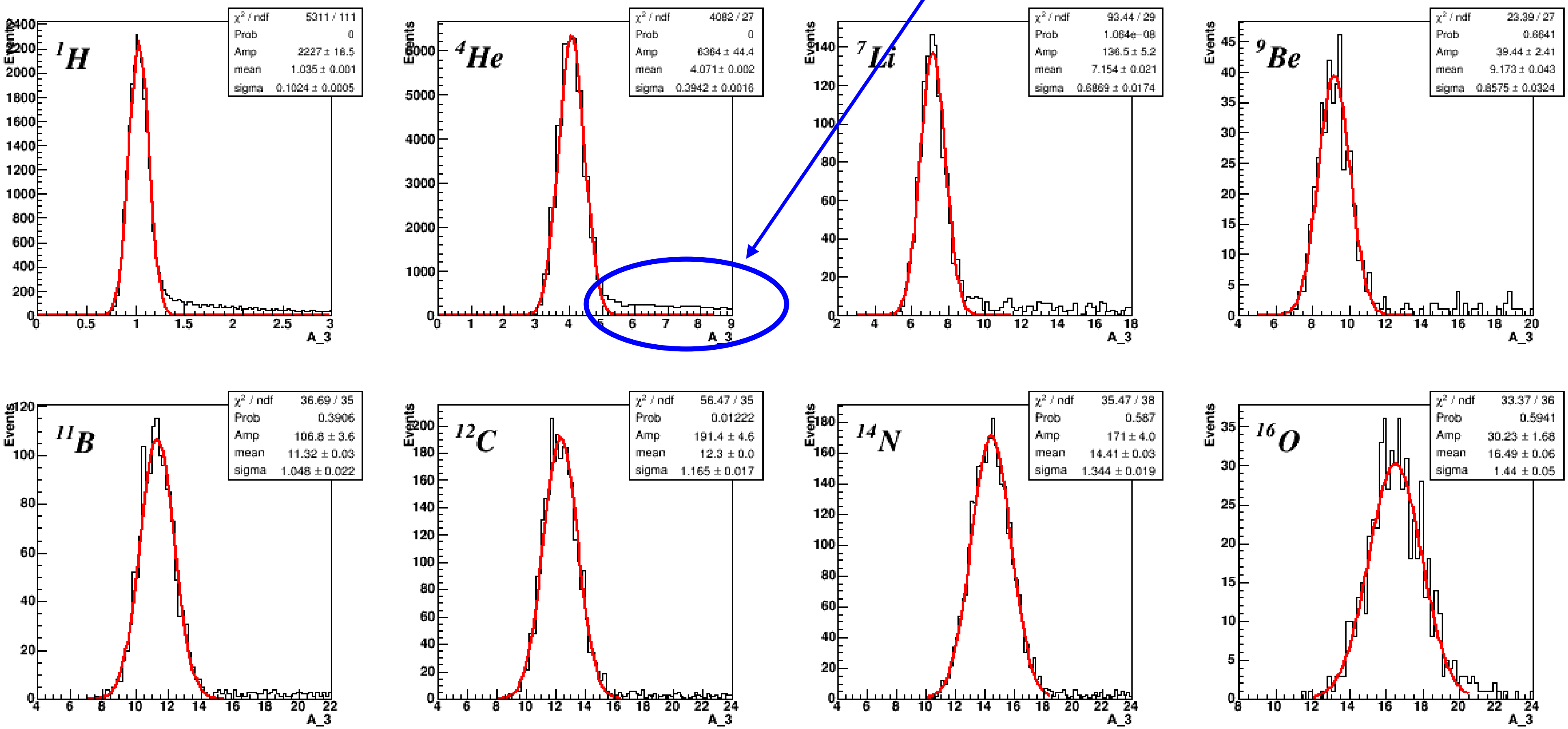
calo suffers for the neutron escape energy



A3: tracker + calo

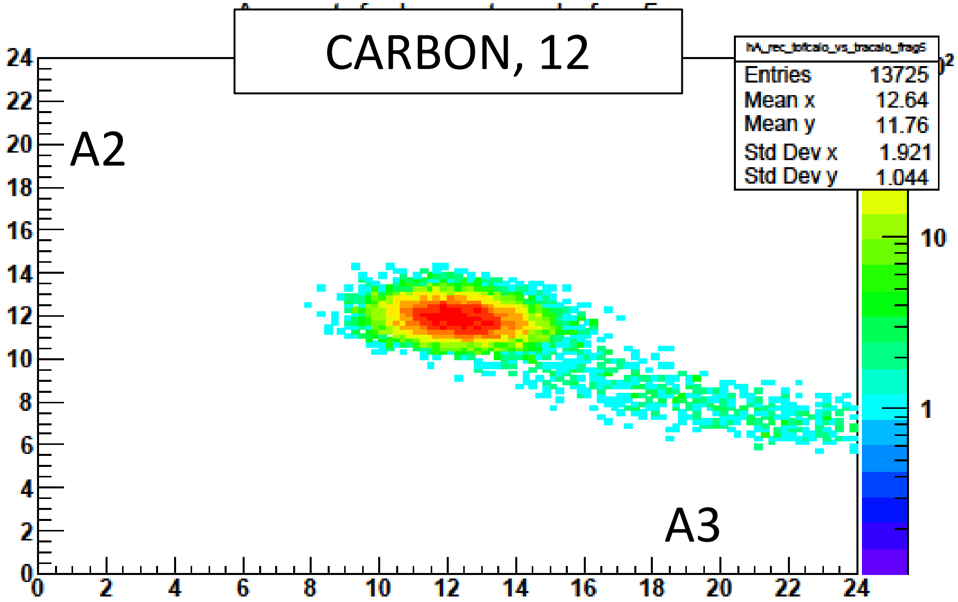
calo suffers for the neutron escape energy

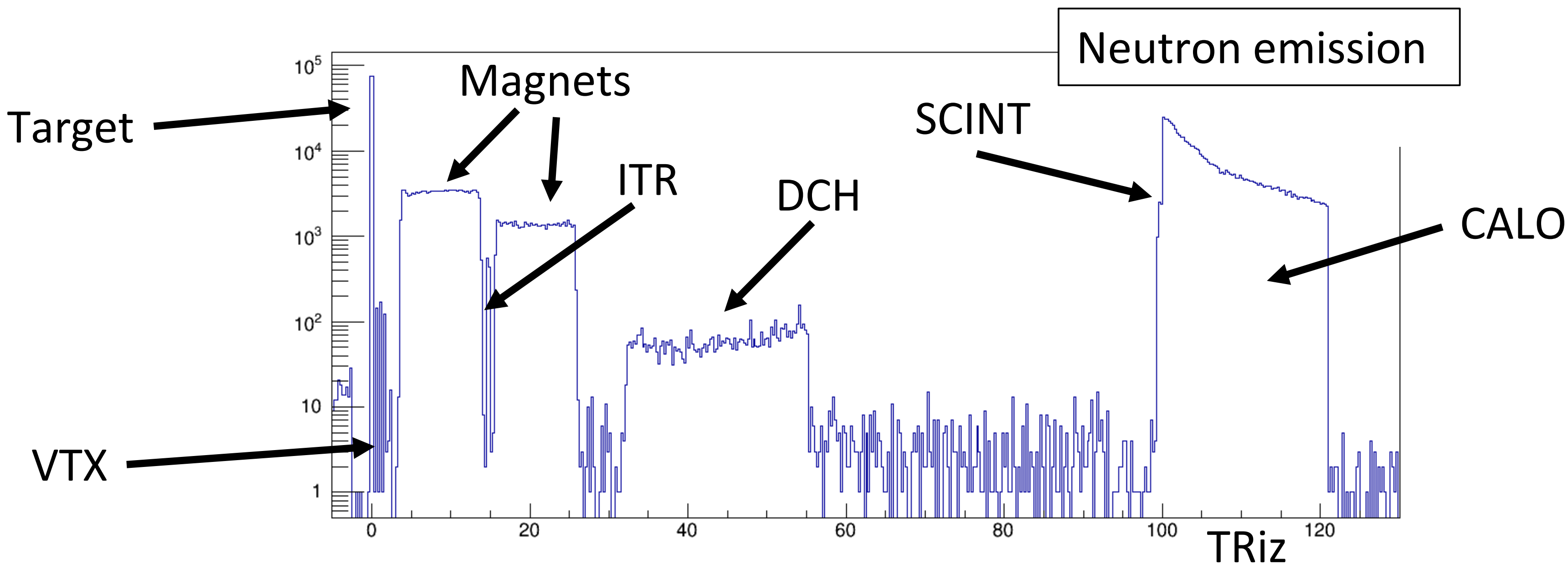
Same events as before



^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
1.02 ± 0.05	4.02 ± 0.20	7.06 ± 0.33	9.09 ± 0.42	11.09 ± 0.51	12.11 ± 0.57	14.18 ± 0.66	16.24 ± 0.75
1.00 ± 0.06	3.98 ± 0.23	6.99 ± 0.39	8.98 ± 0.49	10.94 ± 0.60	11.91 ± 0.64	13.91 ± 0.74	15.88 ± 0.85
1.0 ± 0.1	4.1 ± 0.4	7.2 ± 0.7	9.2 ± 0.9	11.3 ± 1.1	12.4 ± 1.2	14.5 ± 1.4	16.8 ± 1.4

Possible source of energy loss

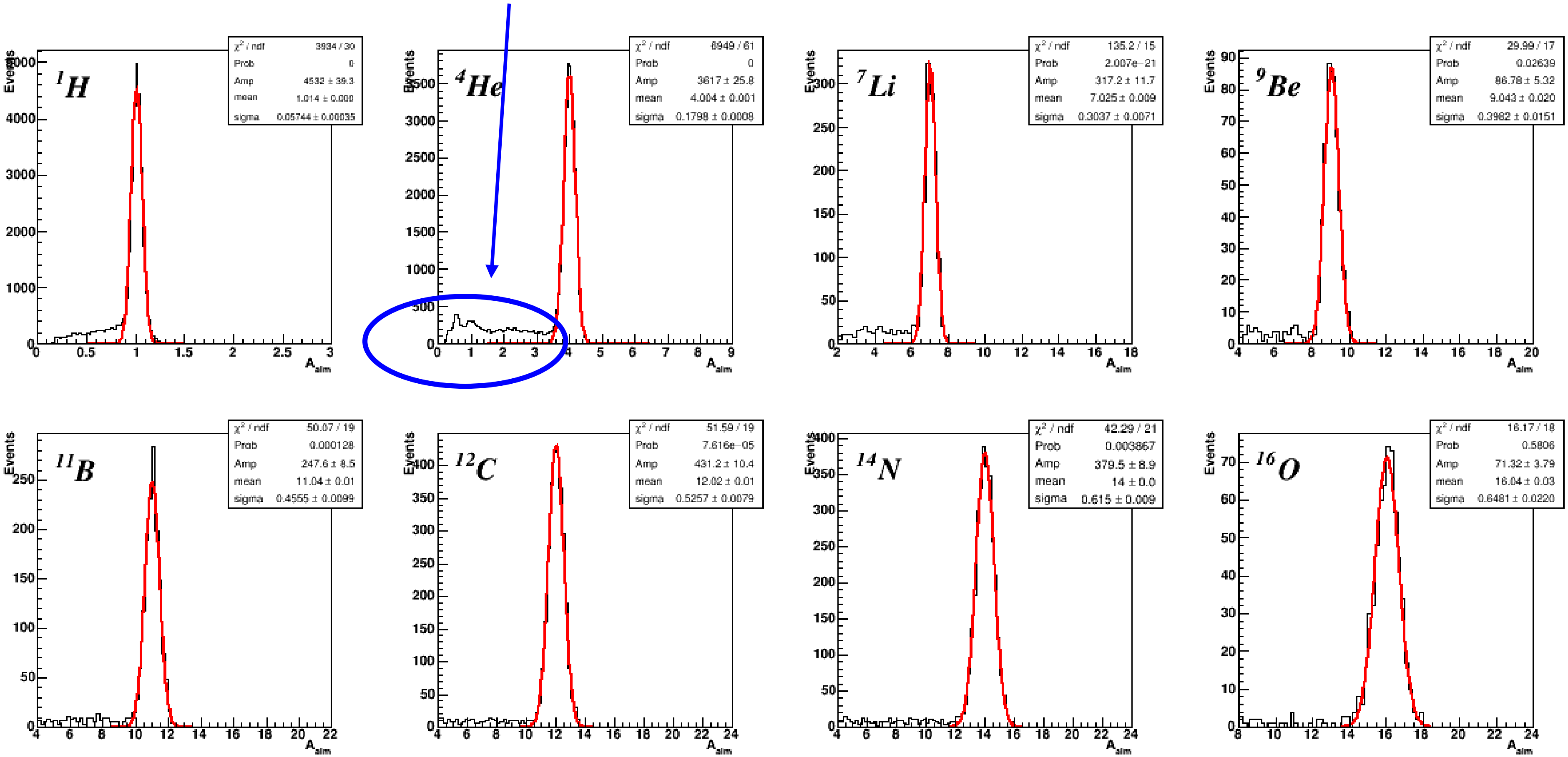




EventTree->Draw("TRiz","Trfid==8")

A fit: ALM method

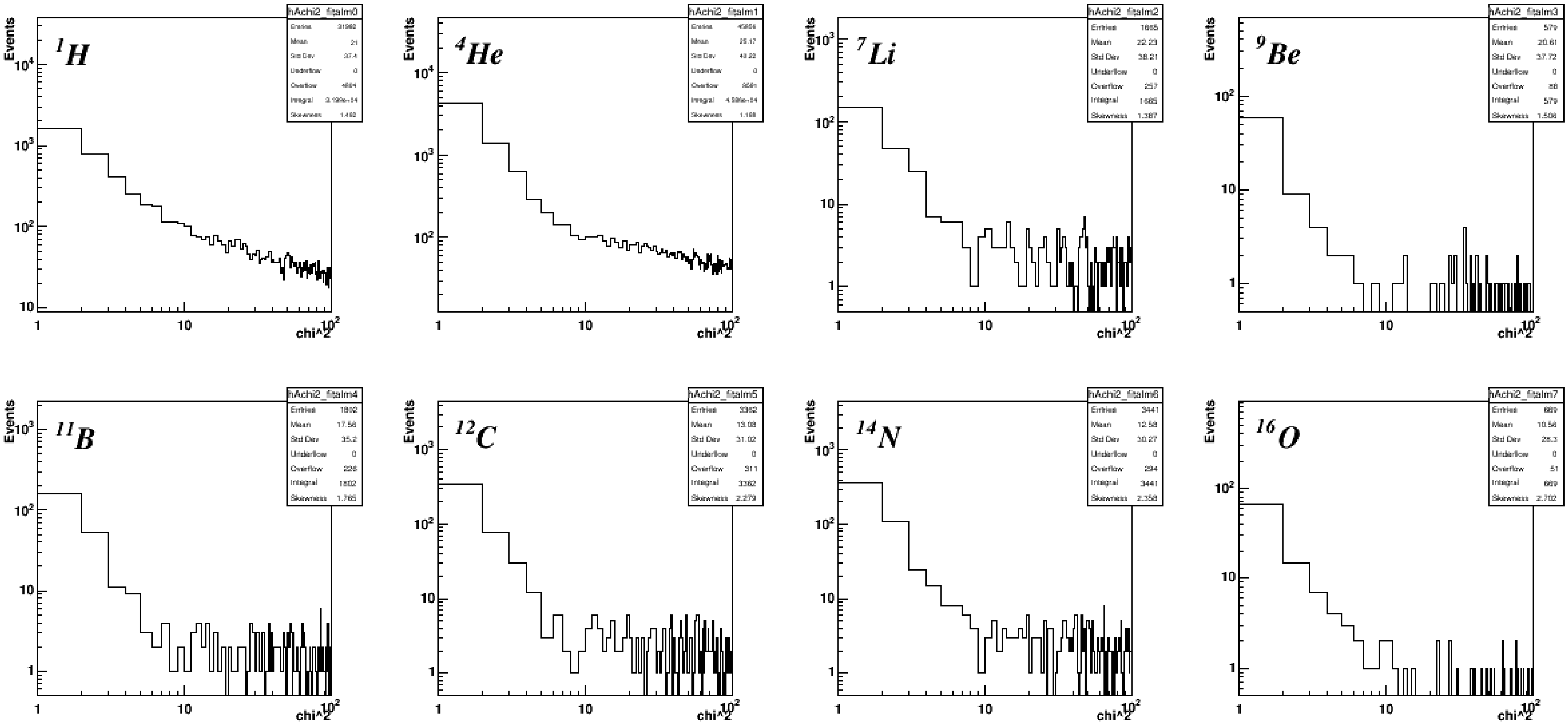
It is possible to identify those events



^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
1.00 ± 0.05	3.99 ± 0.18	7.01 ± 0.32	8.99 ± 0.39	11.00 ± 0.48	12.00 ± 0.52	14.03 ± 0.61	16.02 ± 0.65
1.00 ± 0.07	3.98 ± 0.19	7.01 ± 0.32	9.01 ± 0.39	11.00 ± 0.48	12.01 ± 0.52	14.04 ± 0.61	16.06 ± 0.65

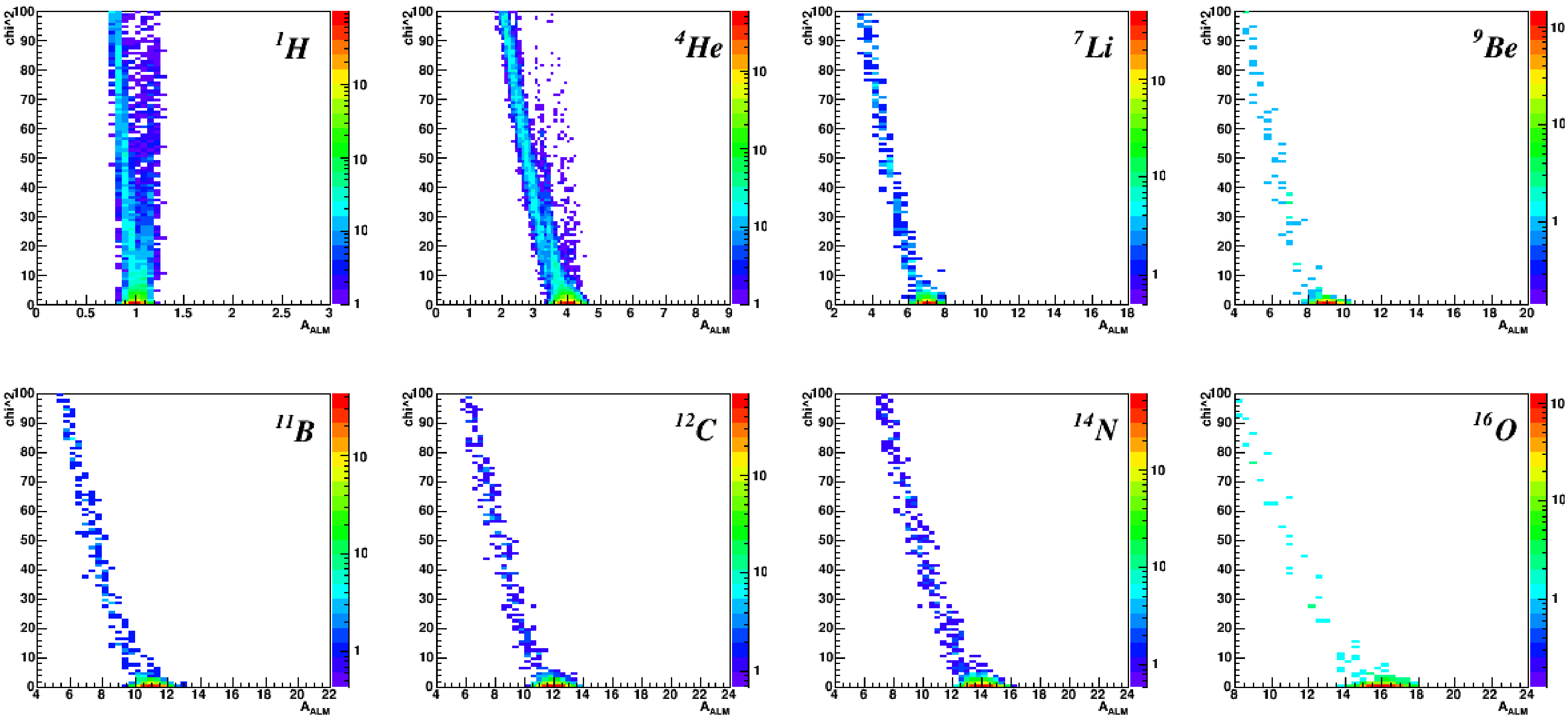
χ^2 ALM method

Standard method and ALM have similar distributions

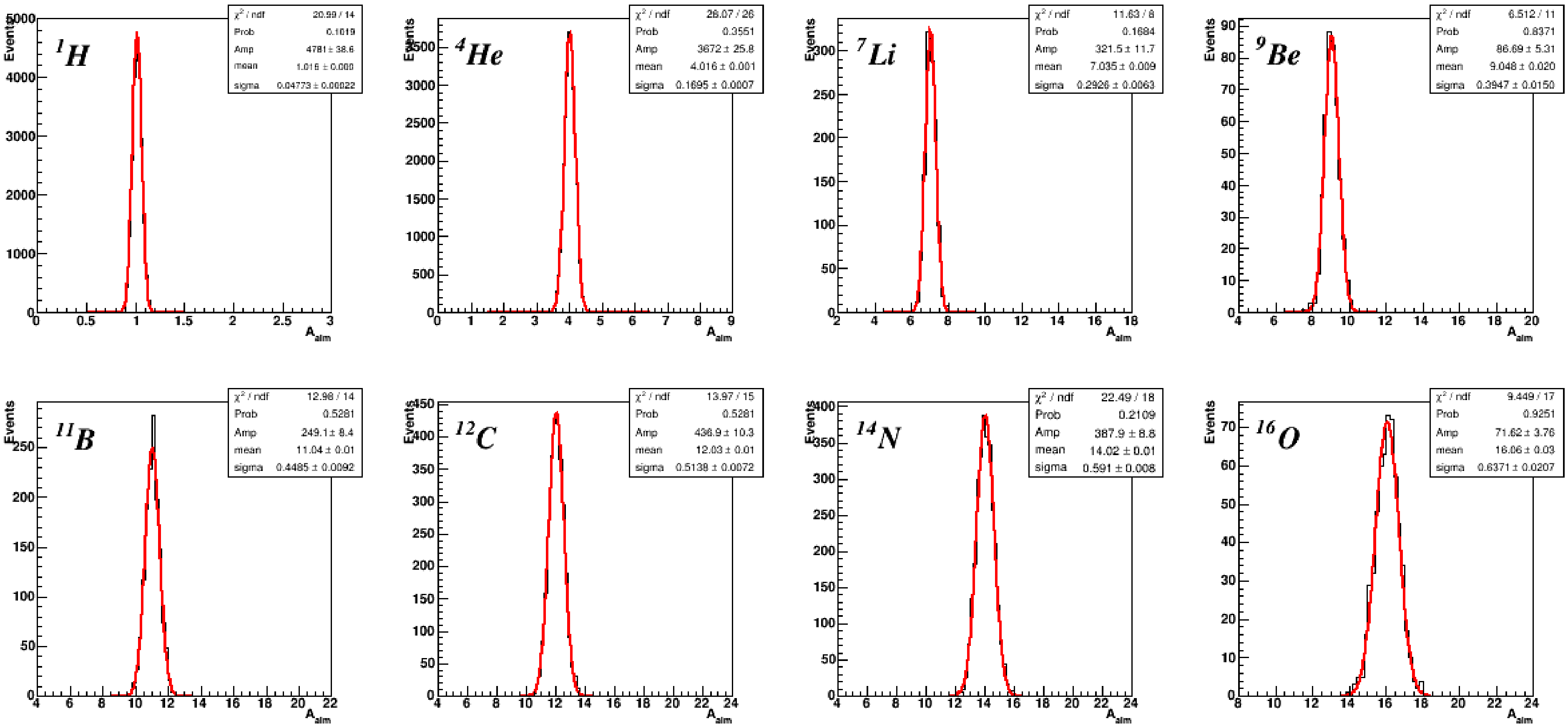


X^2 vs A fit: ALM method

A cut on χ^2 exclude the events in the tail (at the moment fixed a cut chi2<5)

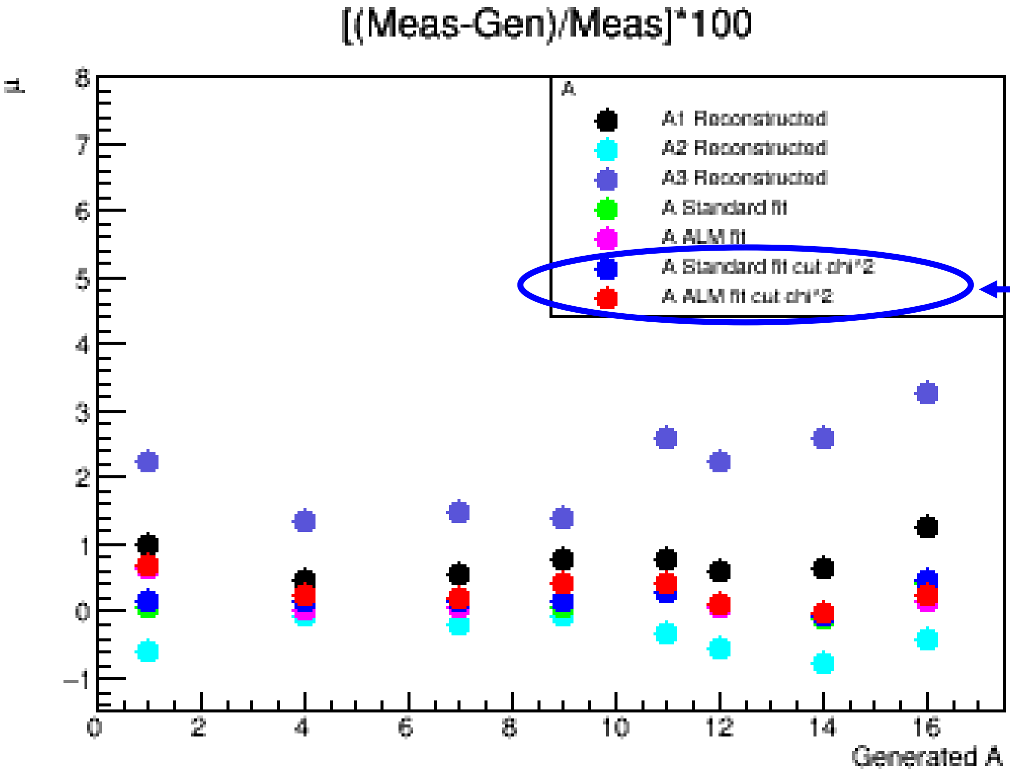


A fit: ALM method + chi2<5



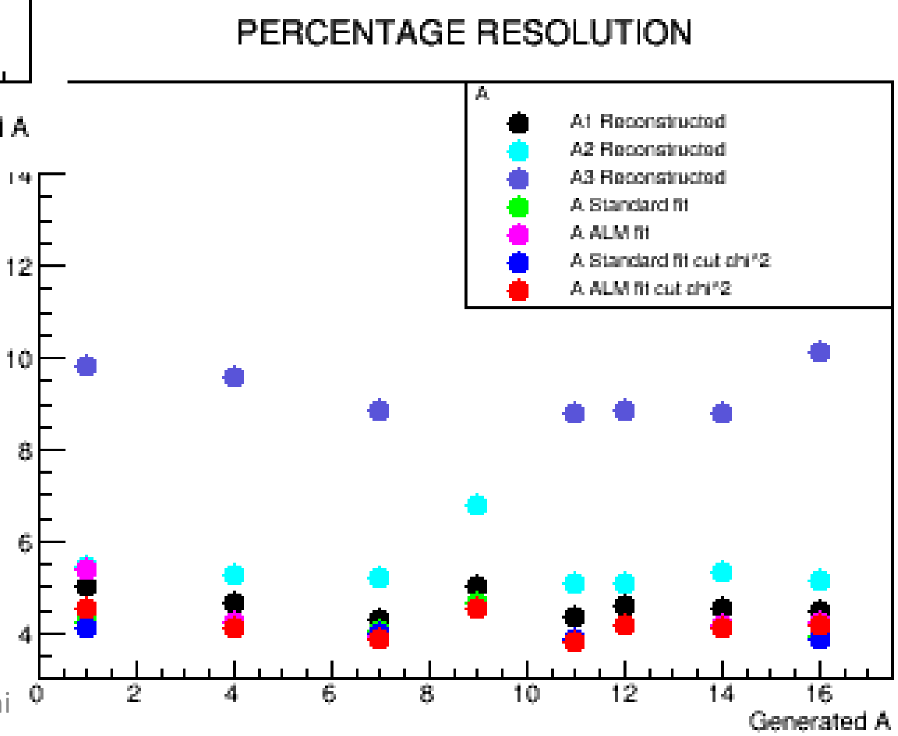
^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
1.01 ± 0.04	4.00 ± 0.17	7.02 ± 0.30	9.01 ± 0.37	11.02 ± 0.46	12.02 ± 0.51	14.05 ± 0.59	16.05 ± 0.64
1.02 ± 0.05	4.01 ± 0.17	7.03 ± 0.30	9.02 ± 0.37	11.02 ± 0.46	12.03 ± 0.51	14.06 ± 0.59	16.08 ± 0.66

A: percentage deviation and resolution



Fit methods with cut on χ^2

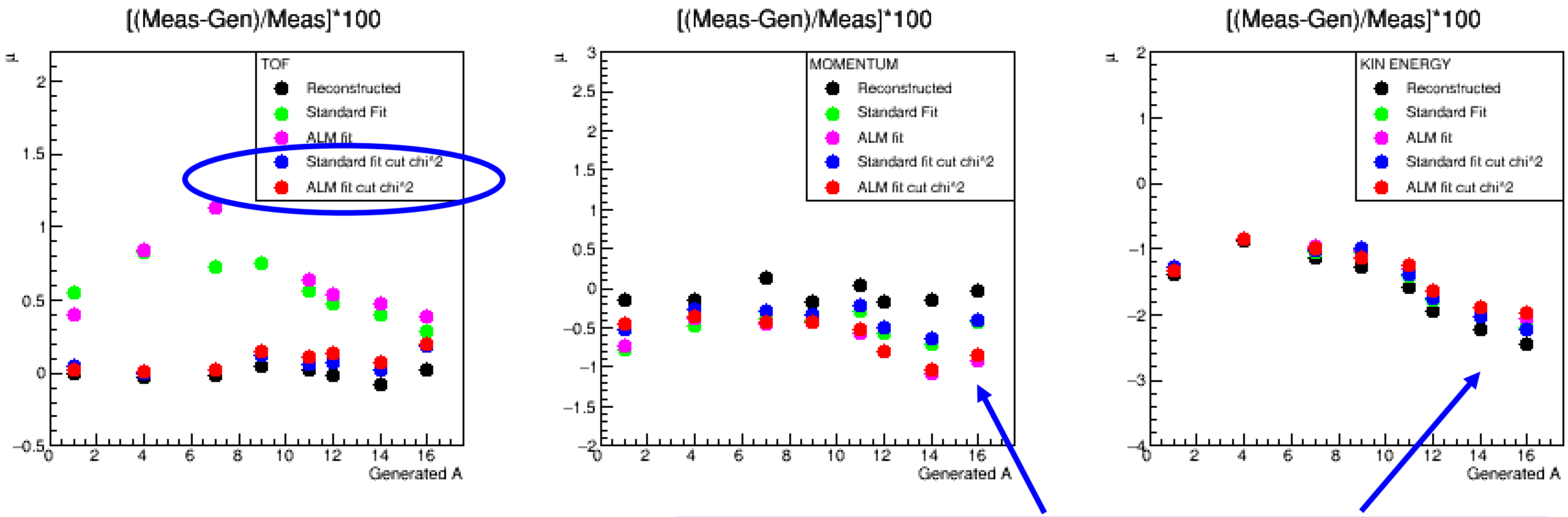
deviation wrt the correct position < 1%



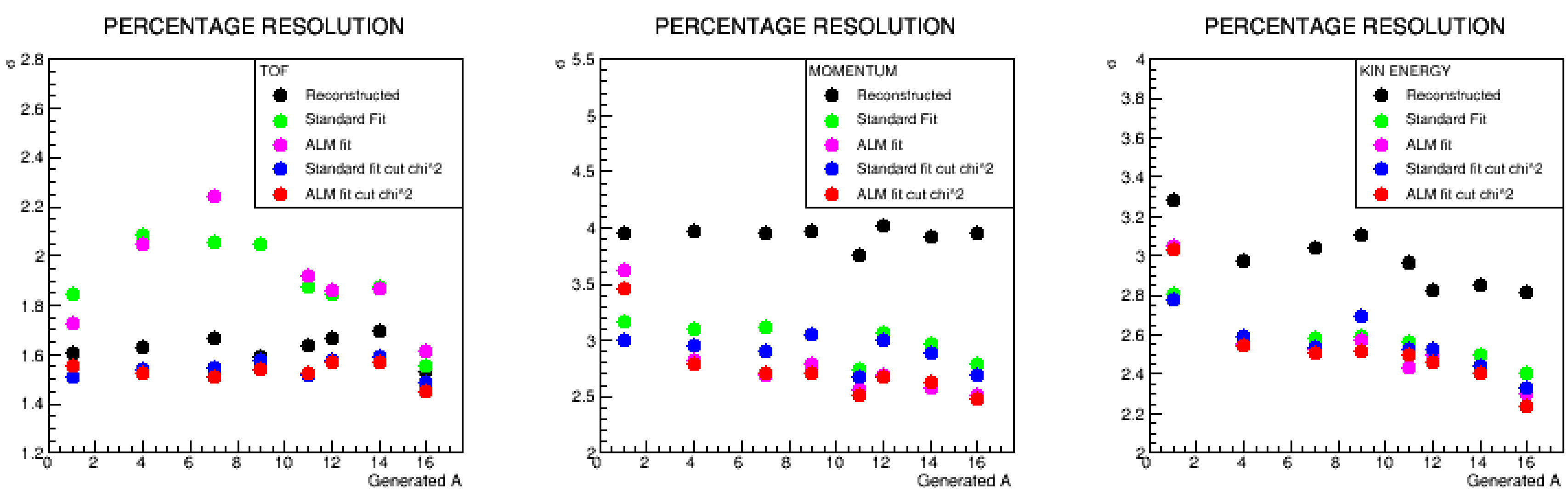
Tracker + Calo

Resolution ~ 4%

Tof (t), Momentum (p), kine energy (k) from fit

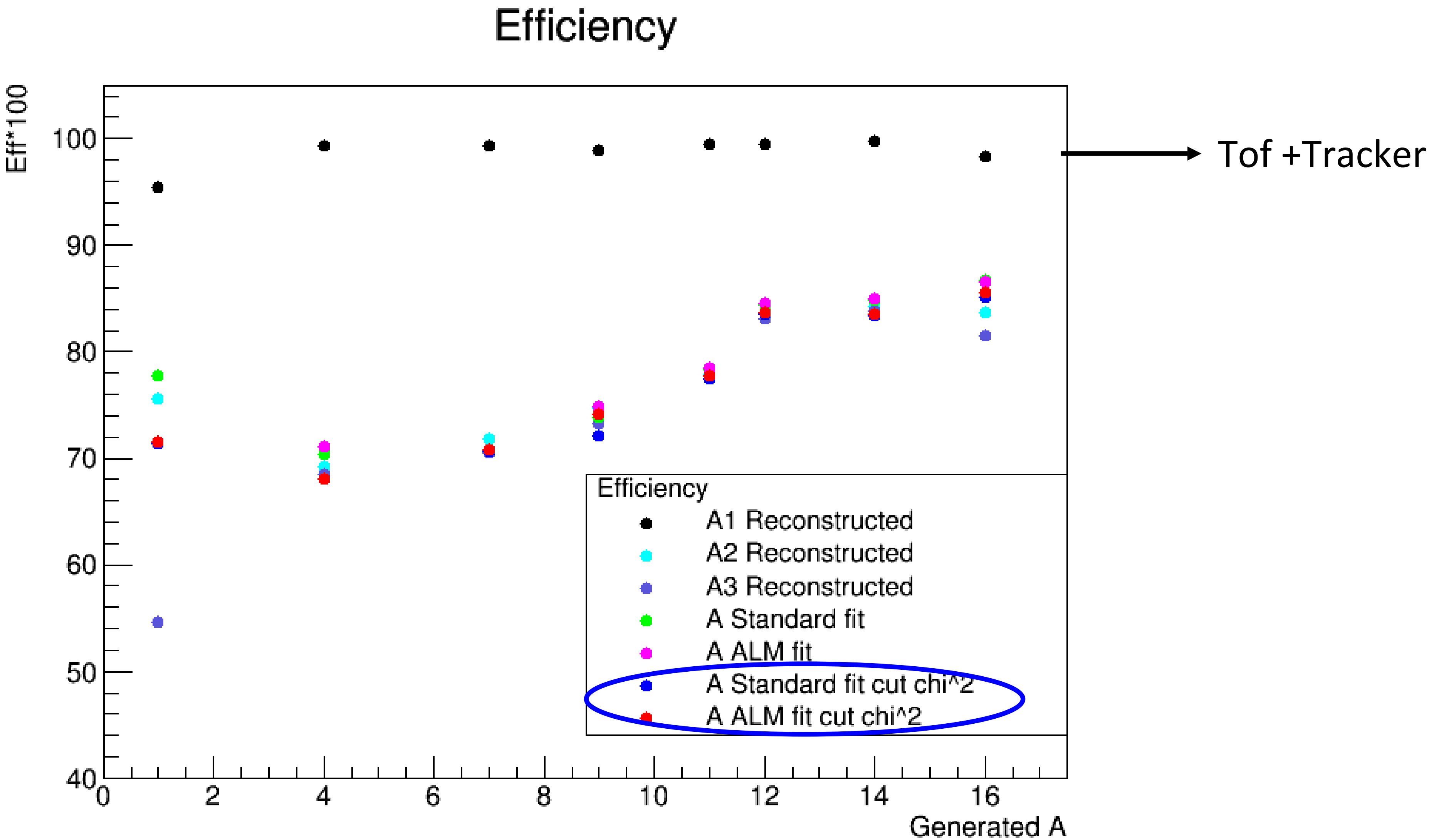


deviation wrt the correct value of p and K



Resolution: t =1.5% (1.6-1.7%); p=3% (4%); k=2.5% (3%)

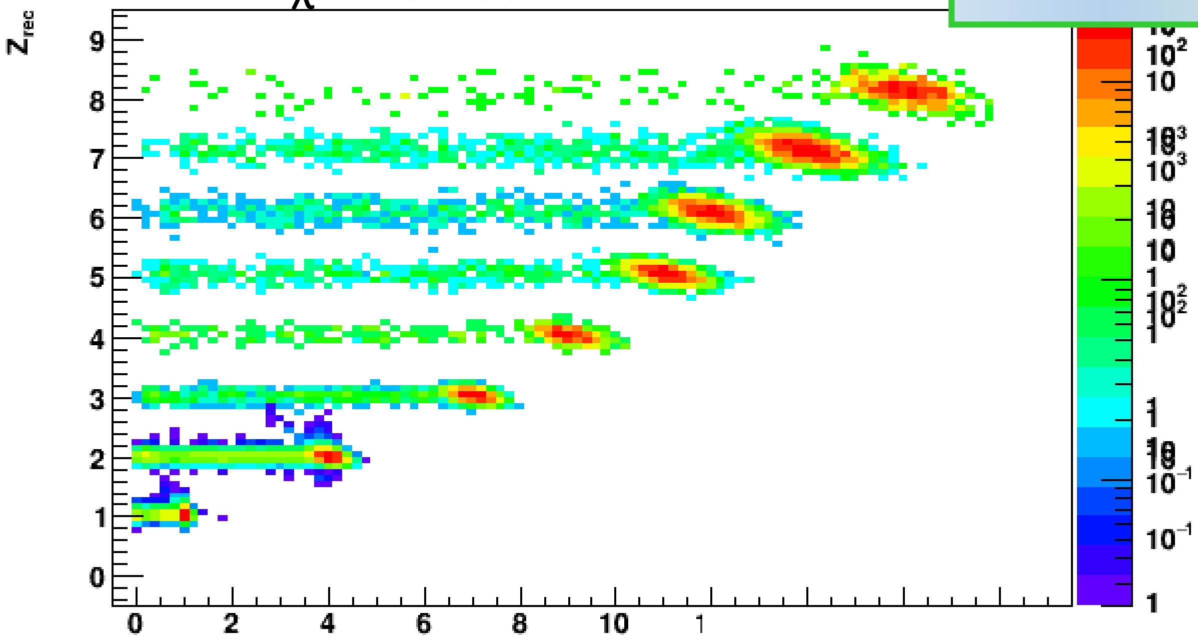
A reconstruction efficiency



Reconstruction efficiency ~ 70-80 % depending on the fragment

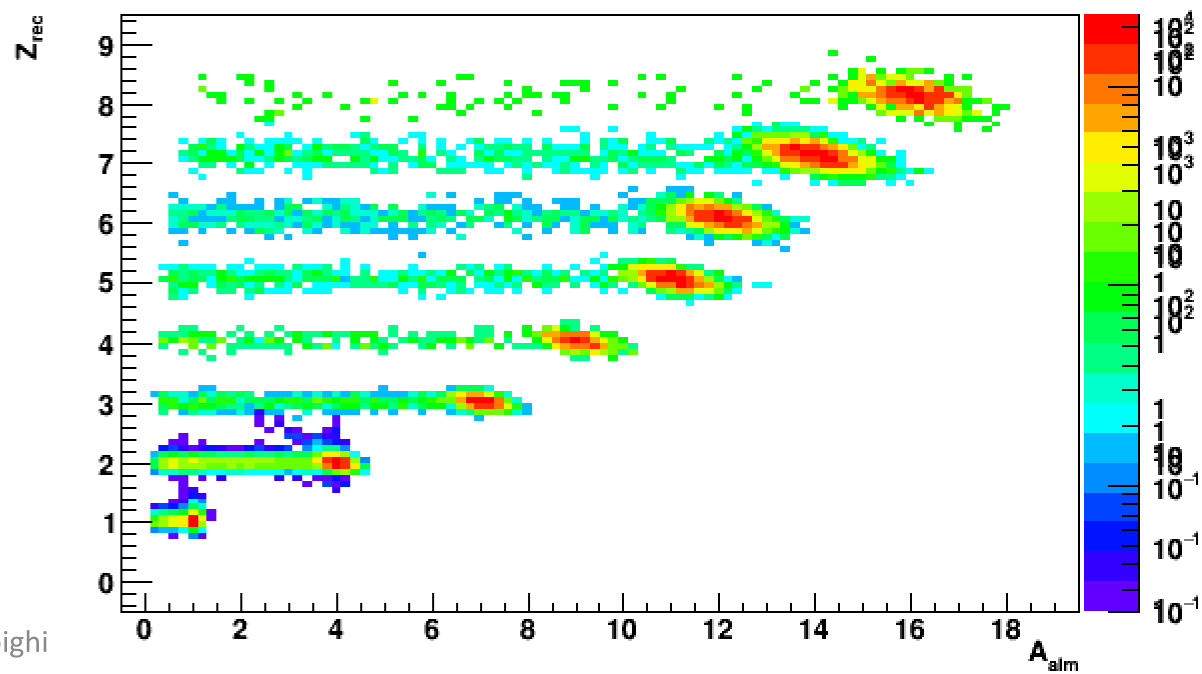
Z-A identification without chi2 cut

χ^2 method

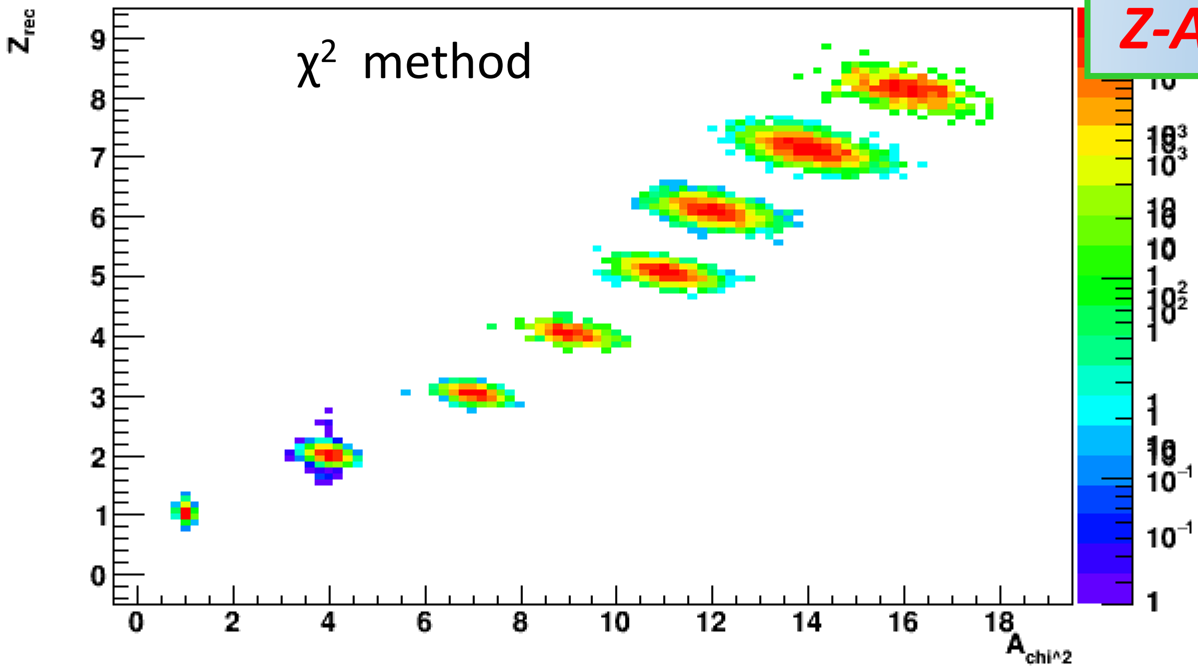


For the 8 fragments

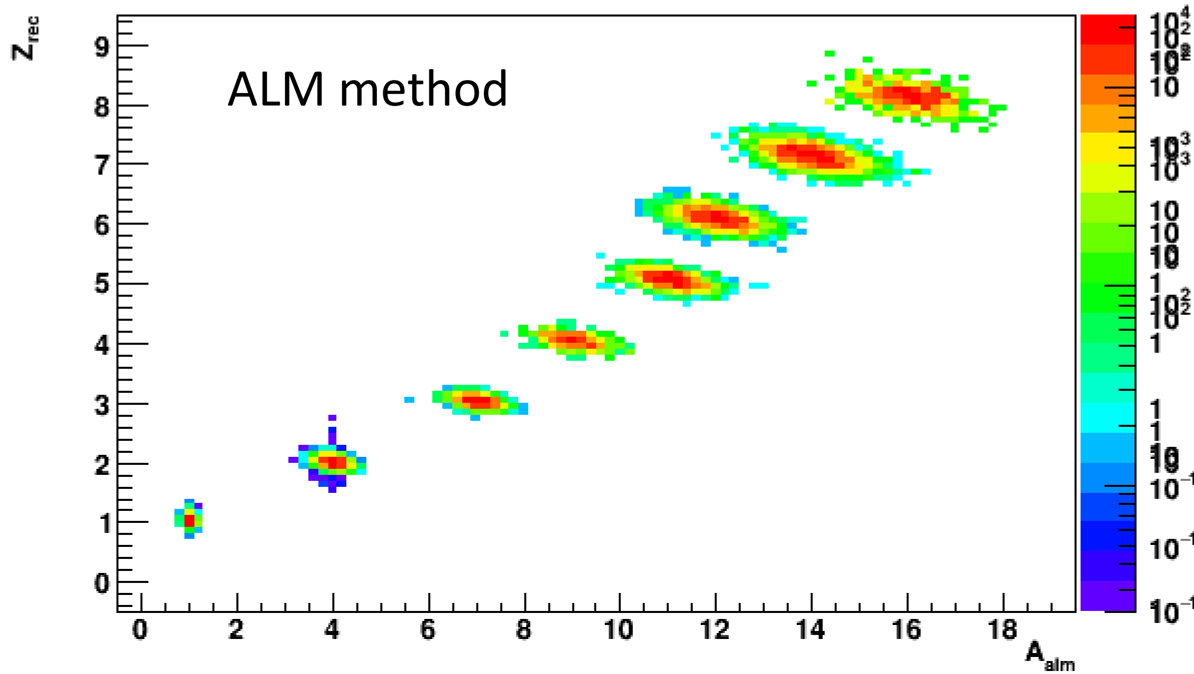
ALM method



Z-A identification with χ^2 cut



For the 8 fragments

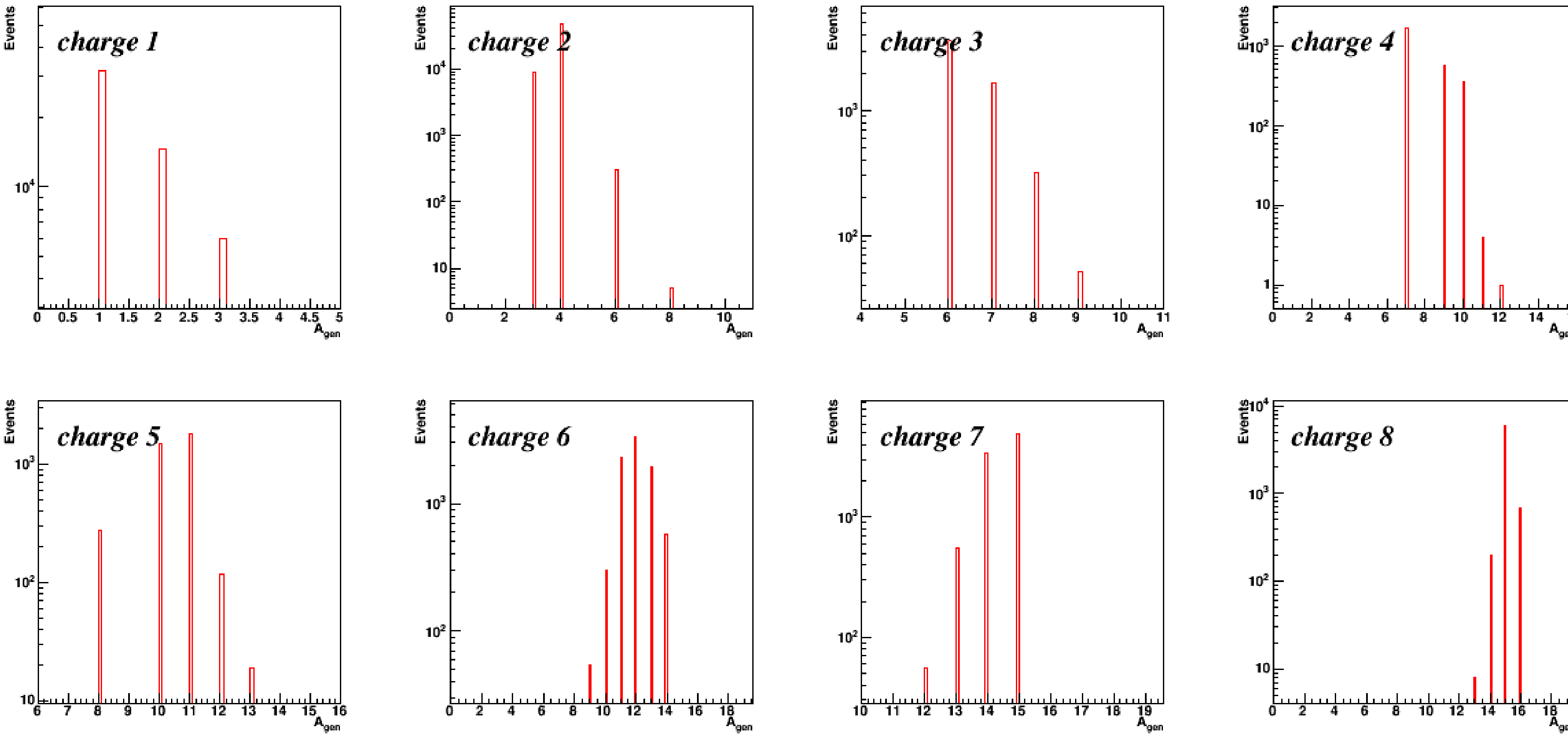


Question:

Is this Z-A identification good enough to disentangle the various isotopes?

ALL tracks produced by $^{16}O \rightarrow C_2H_4$

From 3 – 6 isotopes for each charge



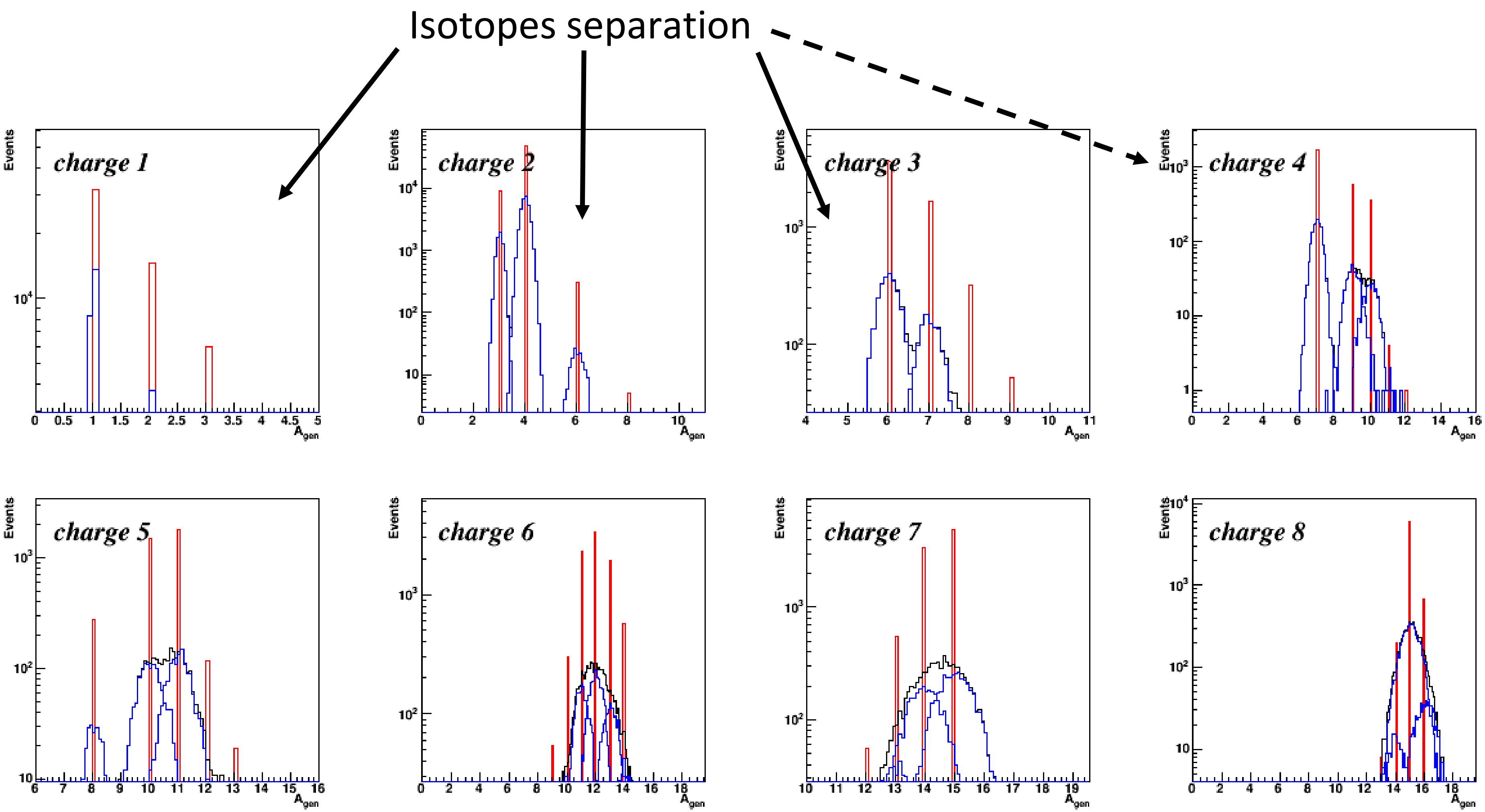
Z resolution is [2-5%] << minimum distance between charges

A resolution is ~ 4% → is it enough? Obviously easier at low A, for Oxygen the A distance for 2 isotopes is 6% → very very difficult!!!

Z resol

Isotopes separation

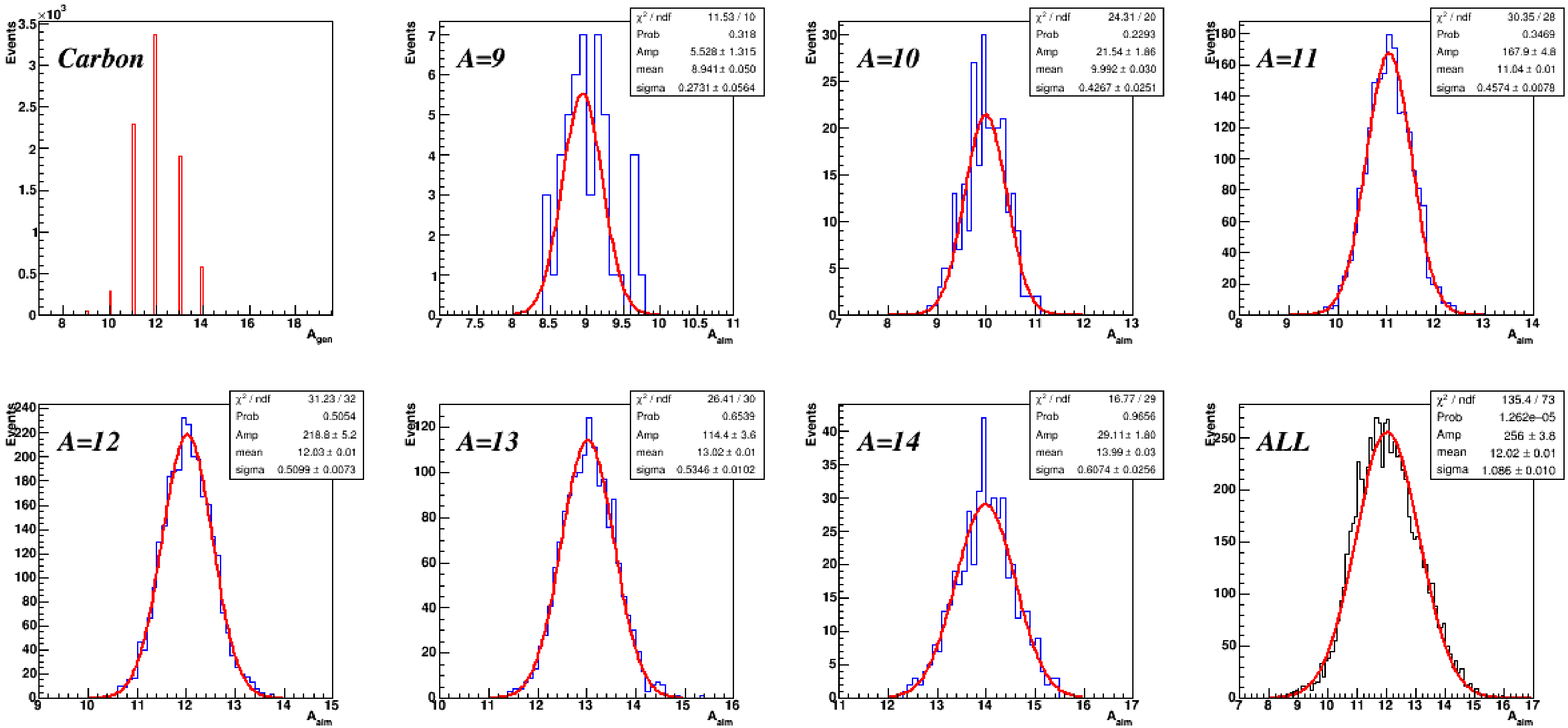
ALM method with χ^2 cut (similar result for the standard fit)



Unfortunately we re interested to the heavy fragments

Isotopes separation: Carbon

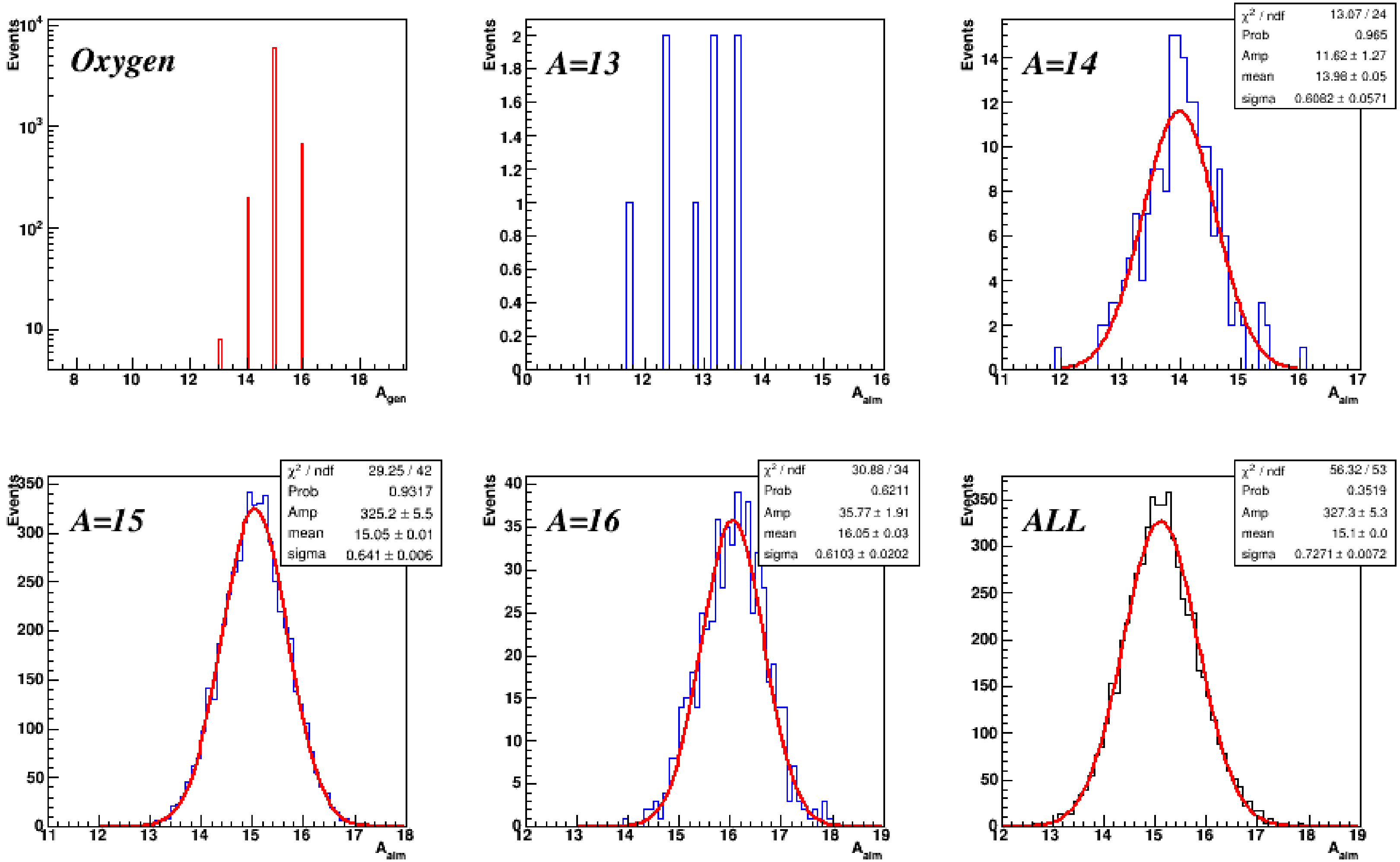
ALM method with χ^2 cut (similar result for the standard fit)



The single isotopes are well reconstructed (Resolution ~ 4%), but the overall peak is (at the moment) NOT resolved

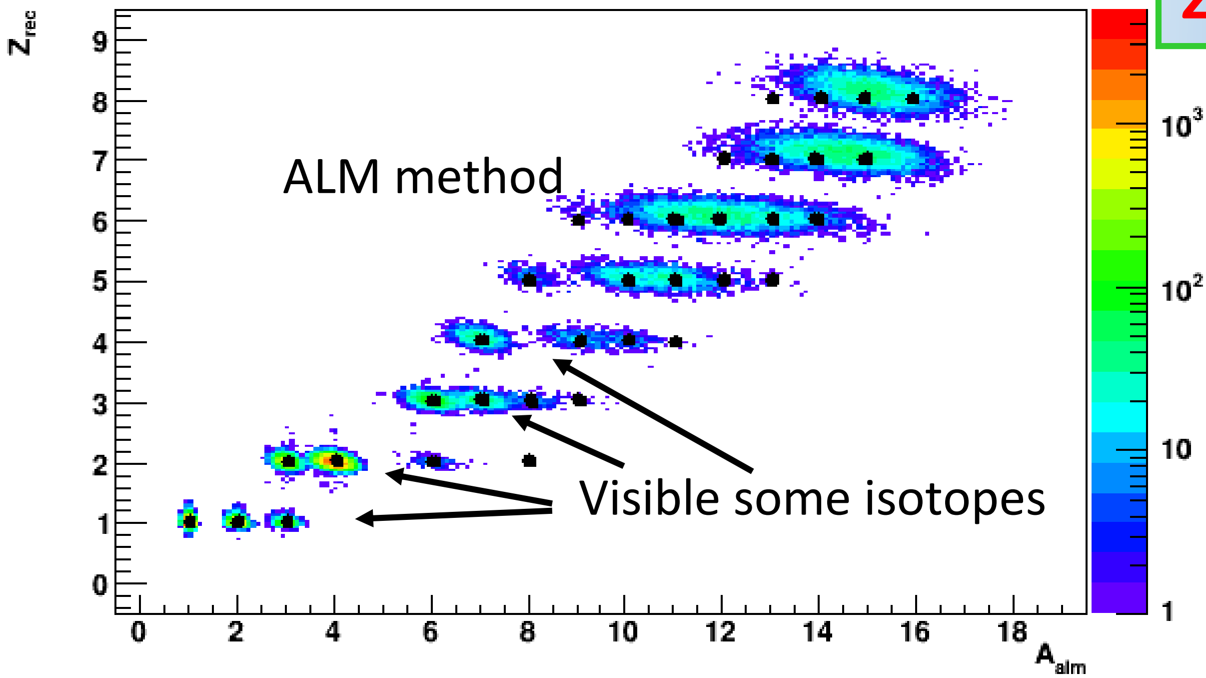
Isotopes separation: Oxygen

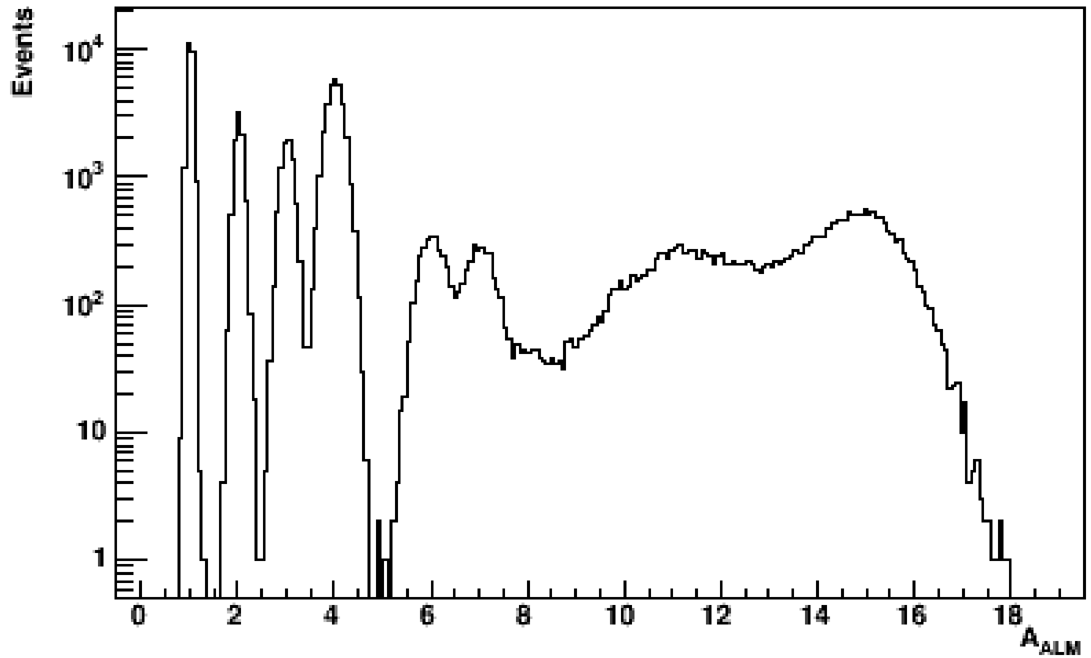
ALM method with χ^2 cut (similar result for the standard fit)



The single isotopes are well reconstructed (Resolution ~ 4%), but the overall peak is (at the moment) NOT resolved

Z-A with χ^2 cut: ALL tracks





Similar results with standard χ^2 fit

High Energy, ^{16}O with 700 MeV/nucleon

GOALs, the same as for the 200 MeV/nucl

- Resolution on A and Z identification;
- Reconstruction efficiency

INPUT DATA:

- gpfs…/Simulation/V10.2/16O_C2H4_700_Calo21.root → 24456 evts → $2 \bullet 10^6$ primary

ANALYSIS:

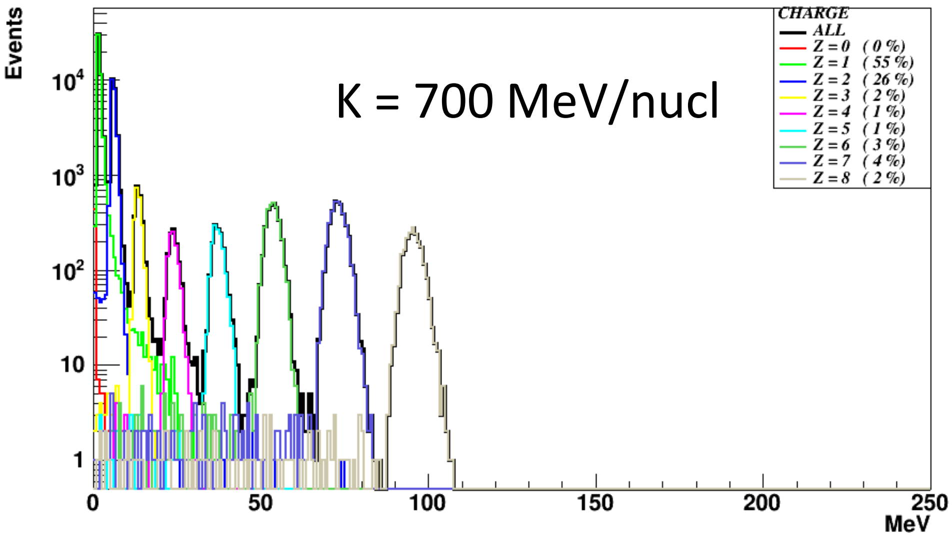
- Same as 200 MeV/nucl

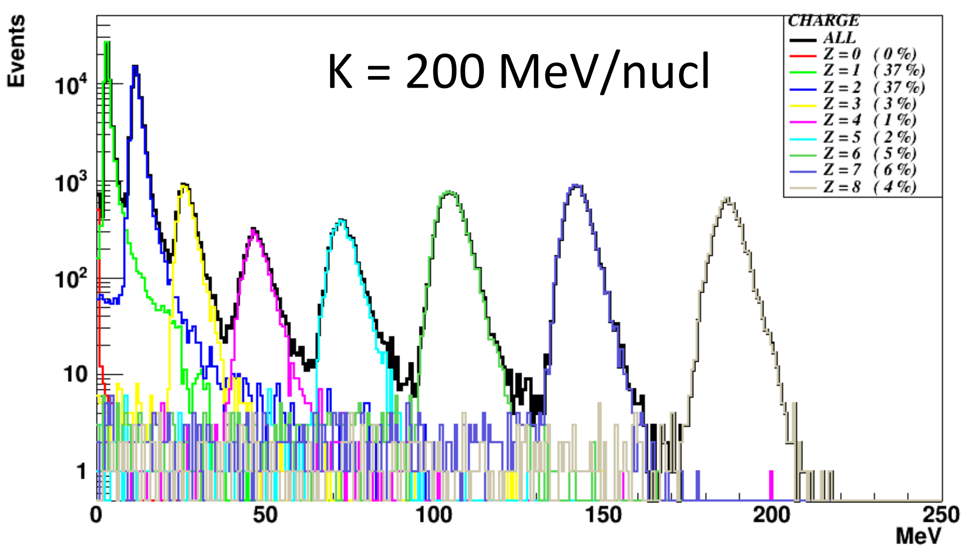
TRACK SELECTION:

- Tracks that cross all subdetectors

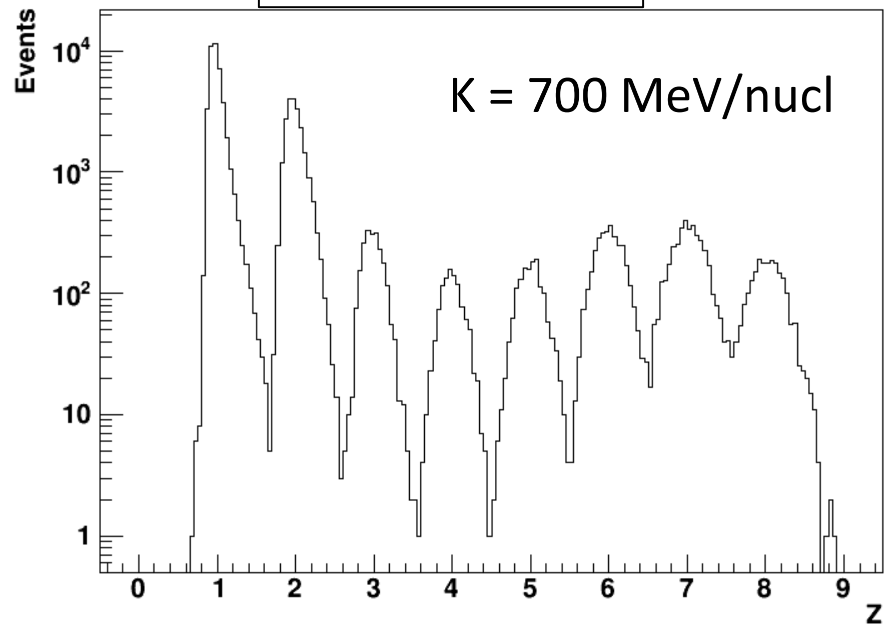
Z reconstruction: 700 MeV/nucl

energy deposited in SCN





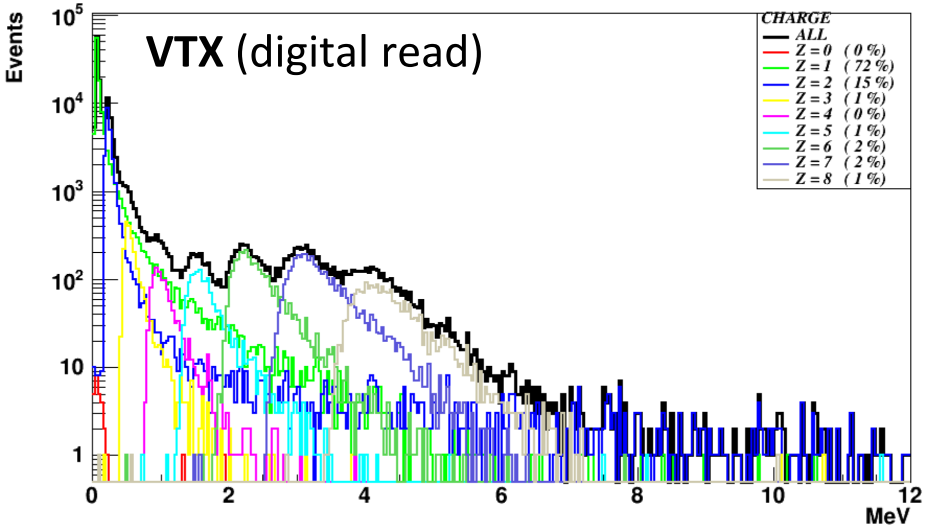
reconstructed Z

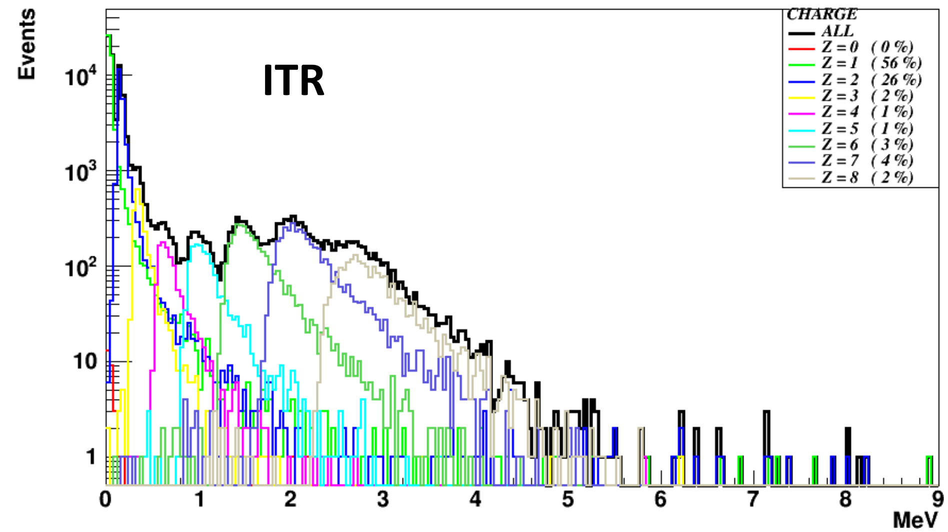


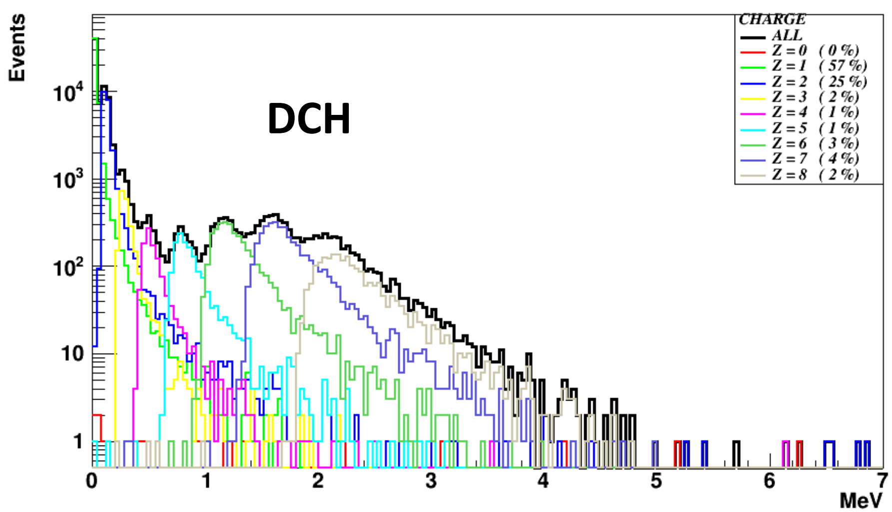
Z:	1	2	8
Resol (200 MeV):	5%	3%	2.2%
Resol (700 MeV):	6%	3%	2.8%

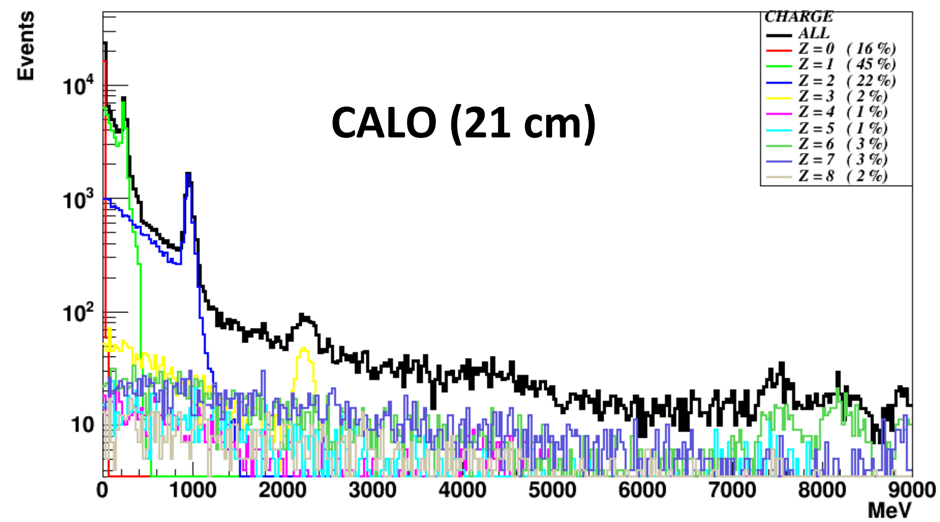
Remember: front-end not simulated

Deposited energy of different charged fragments, 700 MeV/nucl









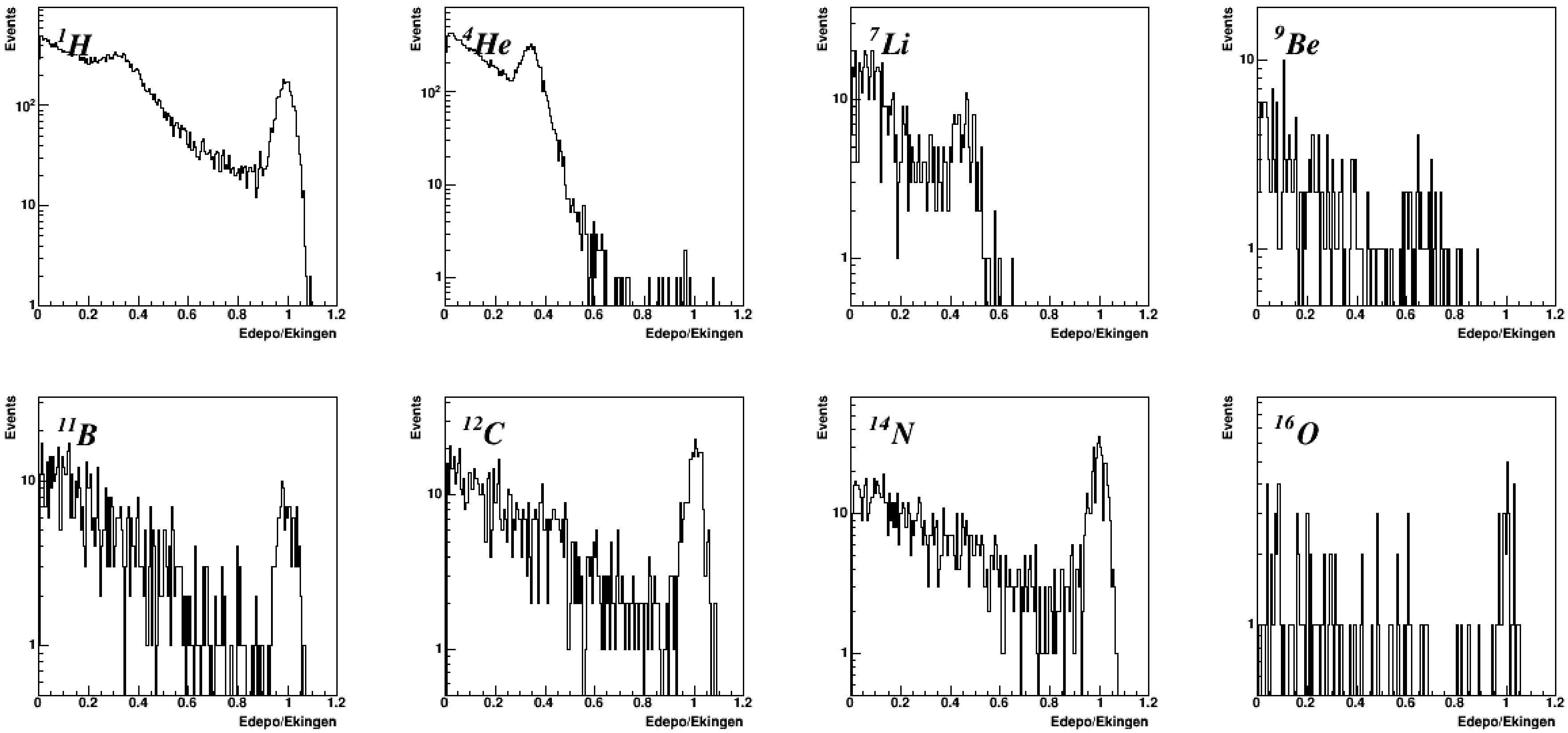
Energy deposited decreased by a factor 2 wrt 200 MeV/nucl (obviously not in CALO)

Edepo,200

Deposited Energy, calo 21 cm

Energy deposited SCINT + CALO

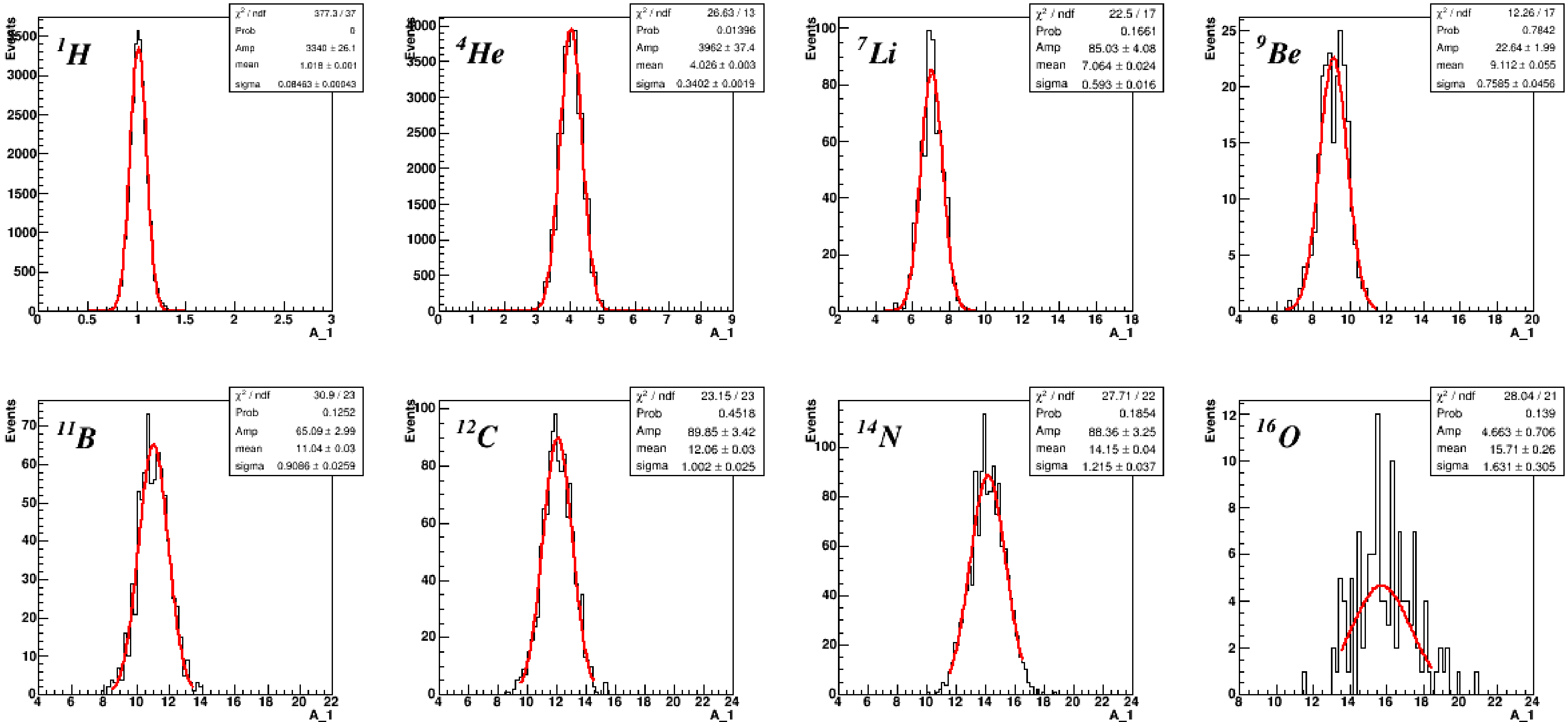
Kinetic Energy generated



A lot of energy is loose (otherwise deeper CALO)

A reconstruction using only TOF and TRACKER

A1: tof + tracker, 700 MeV/nucl

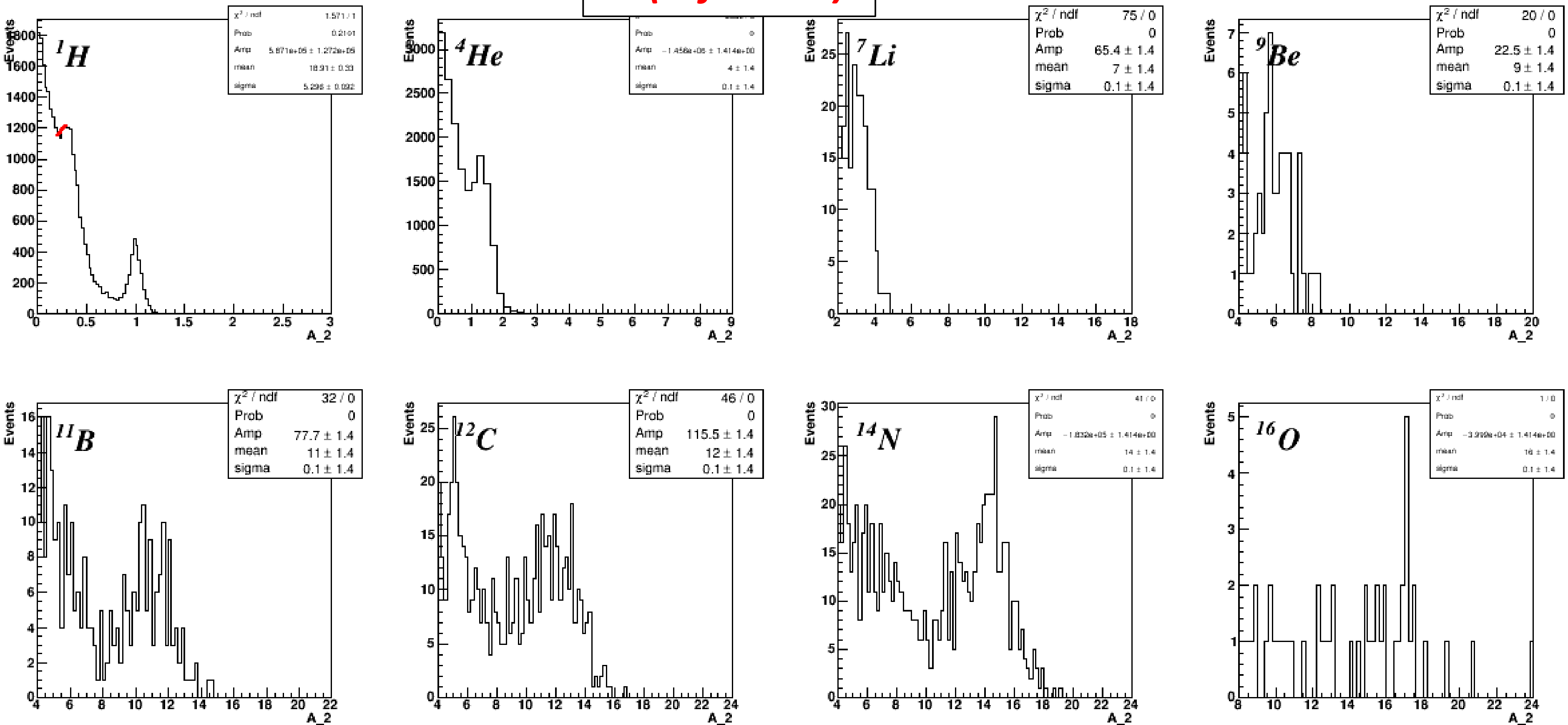


^{1}H	^{4}He	^{7}Li	^{9}Be	^{11}B	^{12}C	^{14}N	^{16}O
1.02 ± 0.05	4.02 ± 0.20	7.06 ± 0.33	9.09 ± 0.42	11.09 ± 0.51	12.11 ± 0.57	14.18 ± 0.66	16.24 ± 0.75
1.02 ± 0.08	4.03 ± 0.34	7.06 ± 0.59	9.11 ± 0.76	11.0 ± 0.9	12 ± 1	14 ± 1.2	16 ± 1.6

Resolution decreas by a factor 2

A2(tof + calo) and A3 (tracker + calo)

A2(tof + calo)



Obviously similar for A3

calo suffers for the neutron escape energy

At the moment NO fit procedures, we will try using only t,p,k and A1

Summary

- **Z RECONSTRUCTION:**
  - Resolution in the range **[2-5]%** → correct charge identification
  - if needed we can use also other subdetectors

- **A RECONSTRUCTION FOR FIXED FRAGMENTS**
  - Percentage deviation wrt the correct value **< 1%**
  - Resolution **~ 4%**
  - Reconstruction efficiency **~ 70-80%**

- **A RECONSTRUCTION OF ALL FRAGMENTS**
  - Disentangle light isotopes, not possible for heavy ones

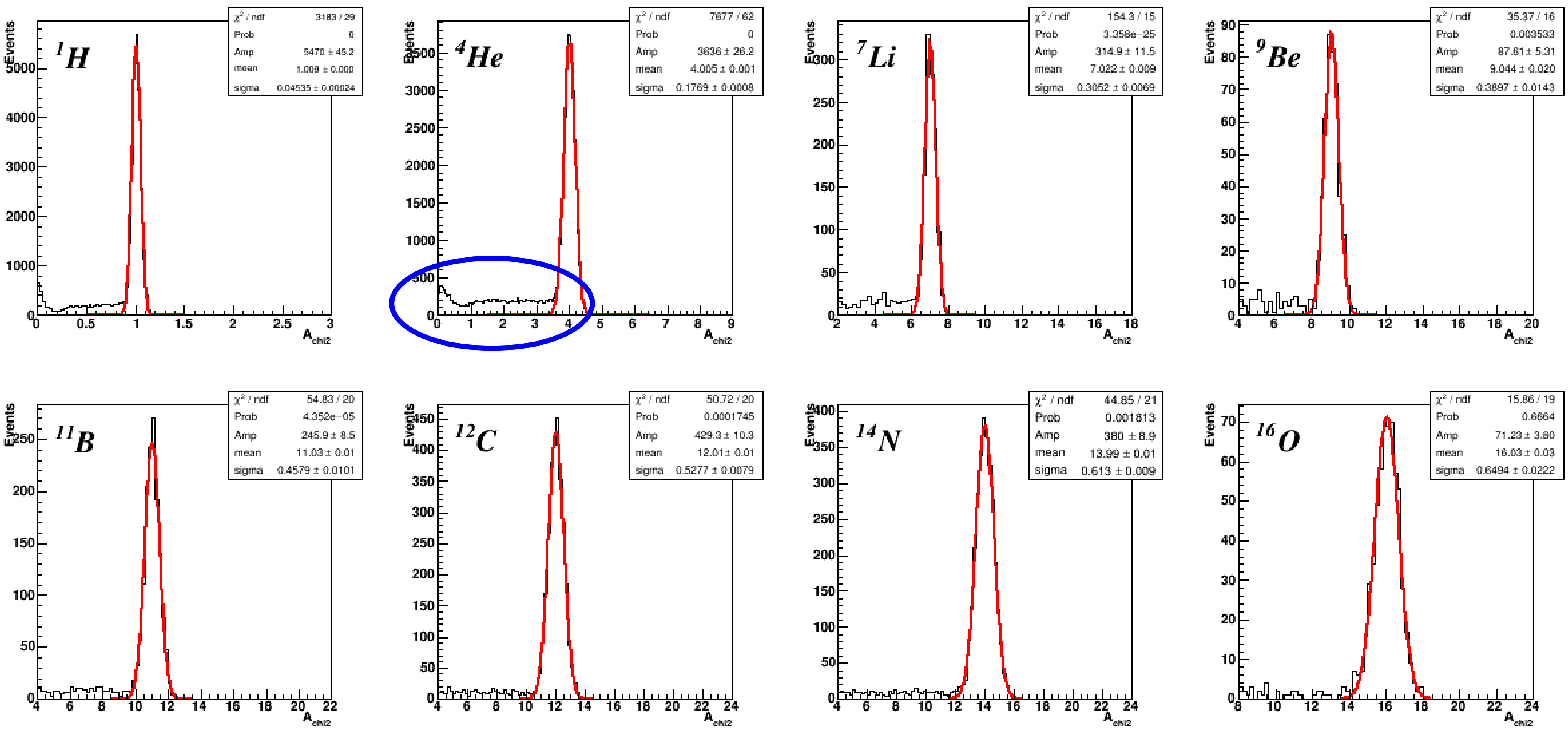
- **TOF, MOMENTUM AND KINETIC ENERGY RECONSTRUCTED FROM THE FIT**
  - Percentage deviation wrt the correct value of 1% for p and 2% for k
  - Resolution: **Tof : 1.5%**, **Momentum: 3%**, **Kinetic Energy: 2.5%**

- **A,Z RECONSTRUCTION FOR HIGH MOMENTUM FRAGMENTS**
  - Resolution in the range **[3-6]%** → correct charge identification
  - A Reconstruction → too energy loss

- **FUTURE** →Try new methods or a way to recover neutron energy, or …

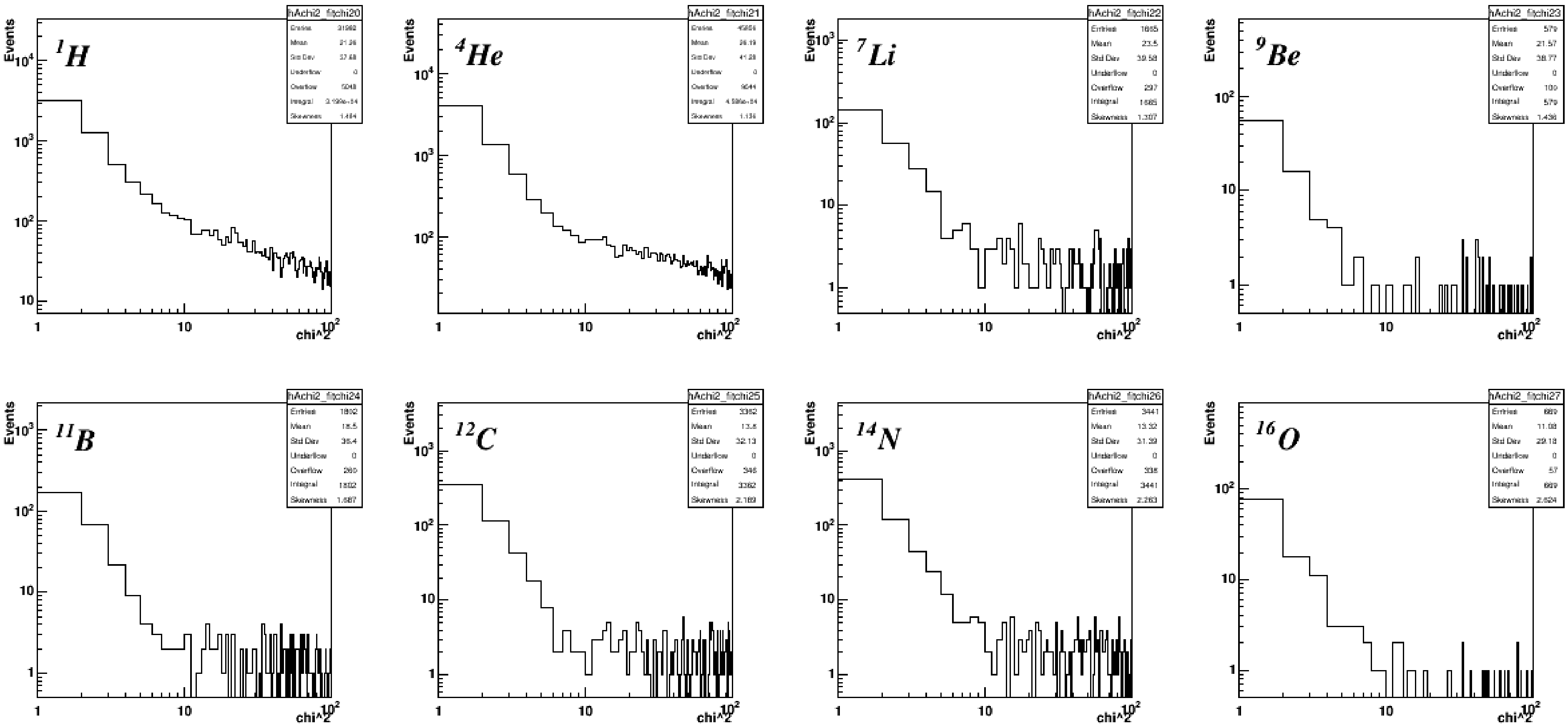
A fit: χ^2 method

Chi2 and ALM fits give similar results

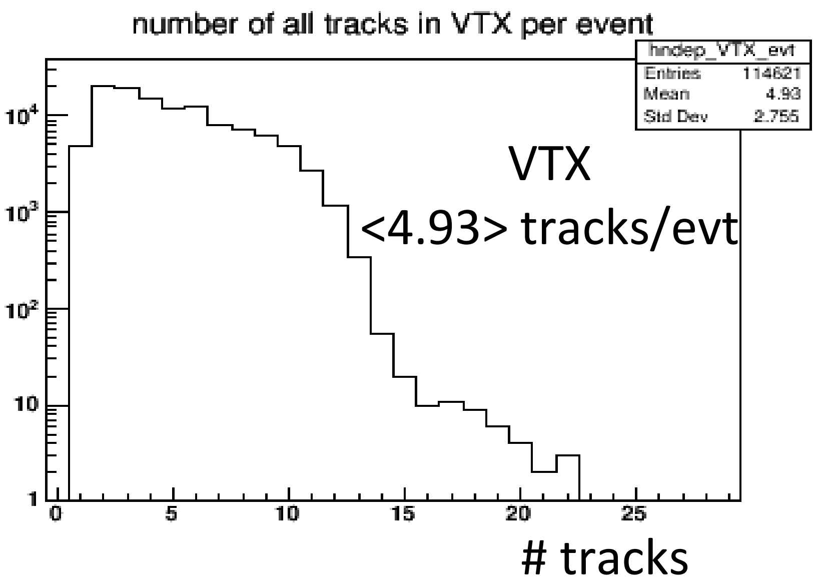


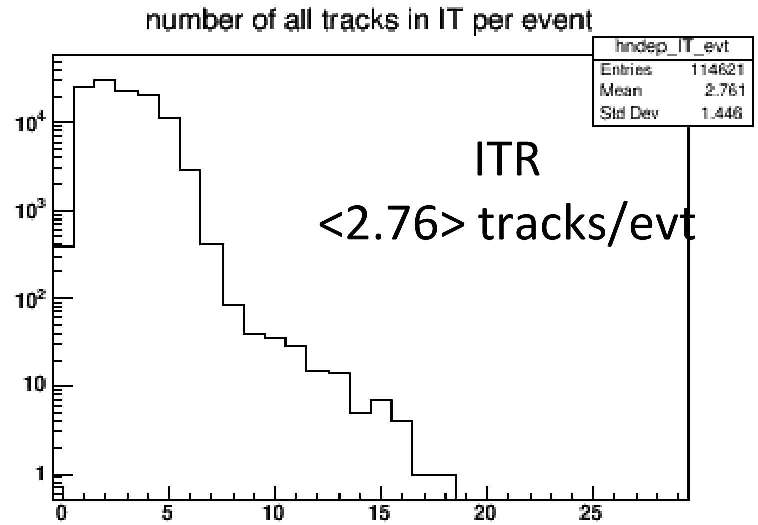
χ^2 standard method

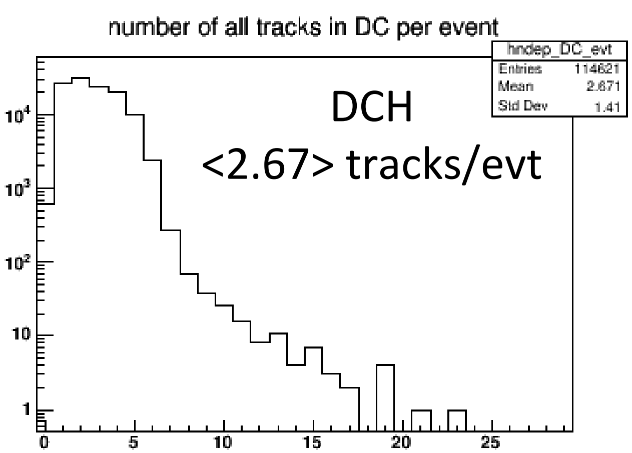
Standard method and ALM have similar distributions

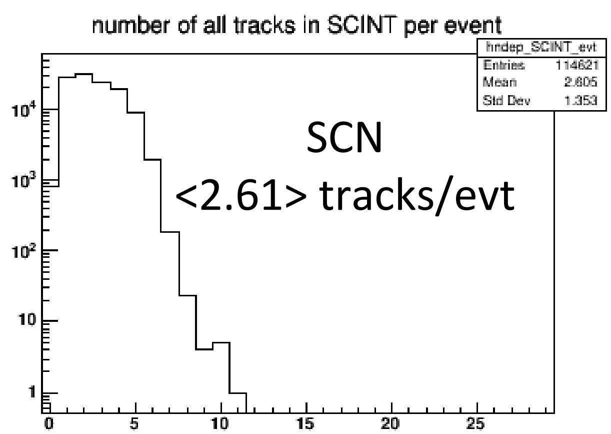


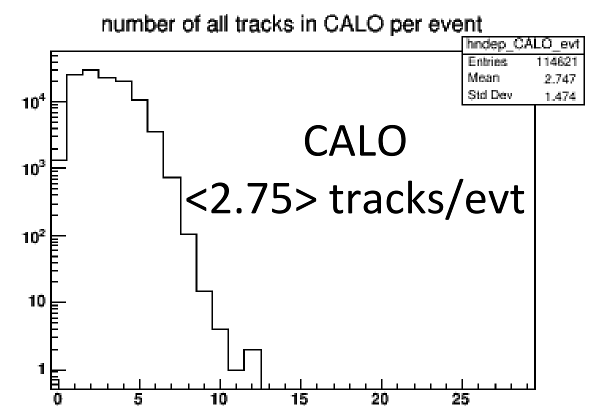
Number of tracks in the subdetectors (-3 < Trzin < 80 cm)



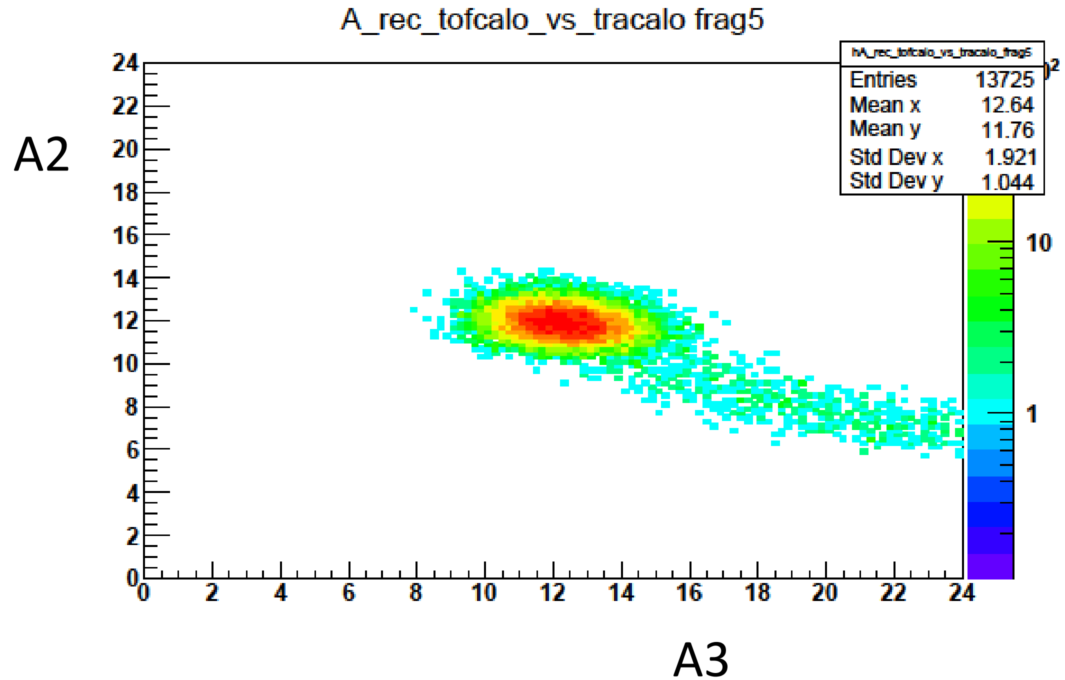


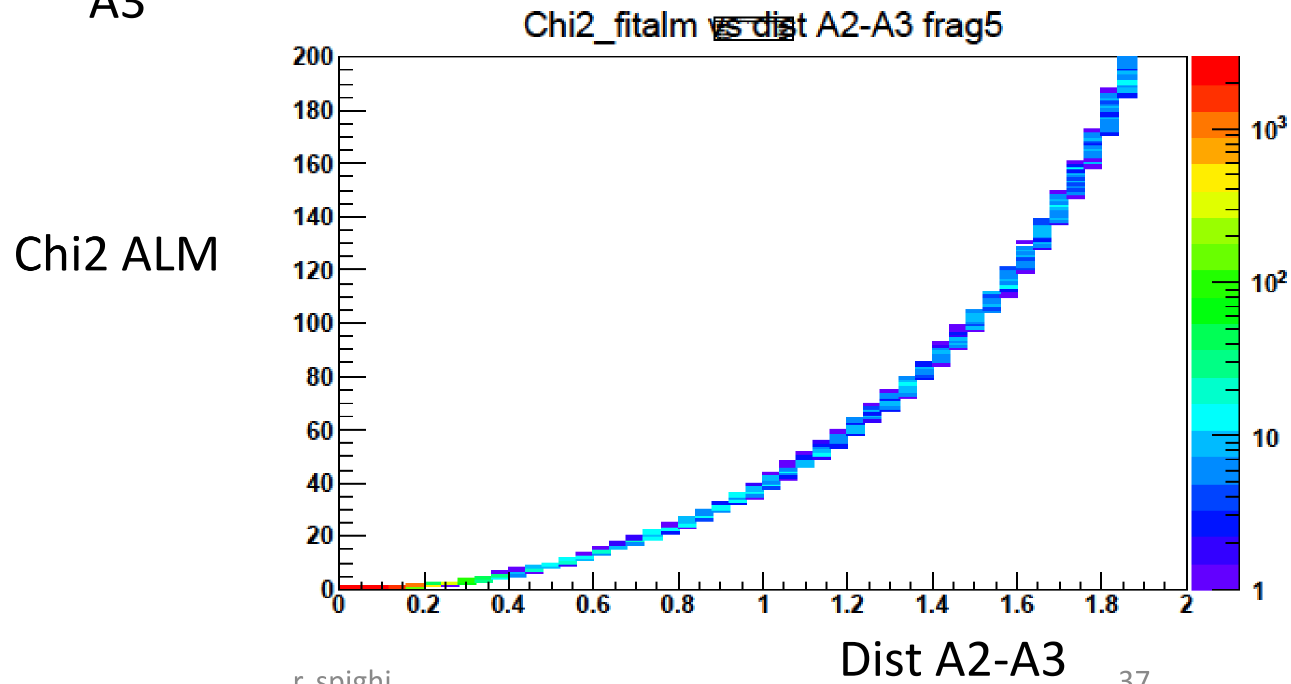






A2 vs A3: Carbon





Possible source of energy loss