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A first look at angular SDCS

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S(D)DCS measurements: ingredients

$$\frac{d\sigma_i}{dE,d\theta} = \frac{Y_i}{\boxed{N_{^{12}C}} \times N_{t,S} \times \boxed{BW_E \times BW_\theta} \times \Omega(\theta) \times \varepsilon_{rec}(E,\theta) \times \varepsilon_{sel}(E,\theta)}$$

- N_{12C} is measured from the SC
- $N_{t,S}$ is the number of nuclei of the C and Au target(s)
- Binning is chosen to have a decent statistics:
  - most of the published/available/existing data covers a much wider **angular** range, so not useful for comparisons :(
- The angular acceptance is being measured from MC simulations [B. Liu]
  - depending on the track angles
- Efficiencies are **still** under evaluation (but we can expect big factors probably only for protons...

Counting the ^{12}C ions

- Since we Used a minimum bias trigger (trigger fires whenever the SC gives a signal) the carbon ions counting is really easy: count the triggers!
  - `TATRrawHit::Pattern() && TAGntuEventInfo::trig==1`
  - For now I forget the double carbons (negligible rate, **being checked**)
  - For now I also forget the "fake signals": is that really a Carbon whenever the SC fires? (still believed a negligible contribution but **being checked**)
- Once we count the SC trigger we are basically fine: the dead time and SC efficiency are already taken into account in the "master formula", since I need to normalize to triggered carbons!

Normalization: Ongoing work

- Check the carbon hit timing
  - Frequency of arrival?
  - More than 1 carbon in 30ns?
  - Check for “multiple peaks” in the QDC spectrum (not the case, already checked)

S(D)DCS measurements: target

$$\frac{d\sigma_i}{dE,d\theta} = \frac{Y_i}{N_{^{12}C} \times \boxed{N_{t,S}} \times BW_E \times BW_\theta \times \Omega(\theta) \times \varepsilon_{rec}(E,\theta) \times \varepsilon_{sel}(E,\theta)}$$

- Eleuterio managed to compute Nt,S for our carbon target
  - Target weight: 13.25 g
  - Target Area: 366.781 mm^2
  - Target thickness 8.08 mm
  - density : 4.48 g/cm^3: value ~2*known carbon density!
- Nt,S can be computed as
  - density*thickness*N$_A$/mol weight (12.0107)
- For now **assumed** a 1% relative uncertainty

Solid angle

$$\frac{d\sigma_i}{dE, d\theta} = \frac{Y_i}{N_{^{12}C} \times N_{t,S} \times BW_E \times BW_\theta \times \boxed{\Omega(\theta)} \times \varepsilon_{rec}(E,\theta) \times \varepsilon_{sel}(E,\theta)}$$

- For the A and SA
  - How many tracks from the target are ending inside our detector? compute this for LA and SA analysis
- Strategy
  - Center ourselves in the target , covering the FULL Beam Spot [check the effect of the spread] and shoot [in 2π] fragment with flat p and θ distr
  - Measure the fraction of tracks that leave a signal inside our detector, and weight the geometrical solid angle with this factor.
- To start **we performed a rough calculation assuming a circular crown of Δθ° aperture to calculate *Ω***
  - The uncertainty is fixed to 5% relative (big uncertainty)
  - Working on this item together with B. Liu to measure *Ω* from MC

Efficiencies

Reconstruction/Tracking efficiencies

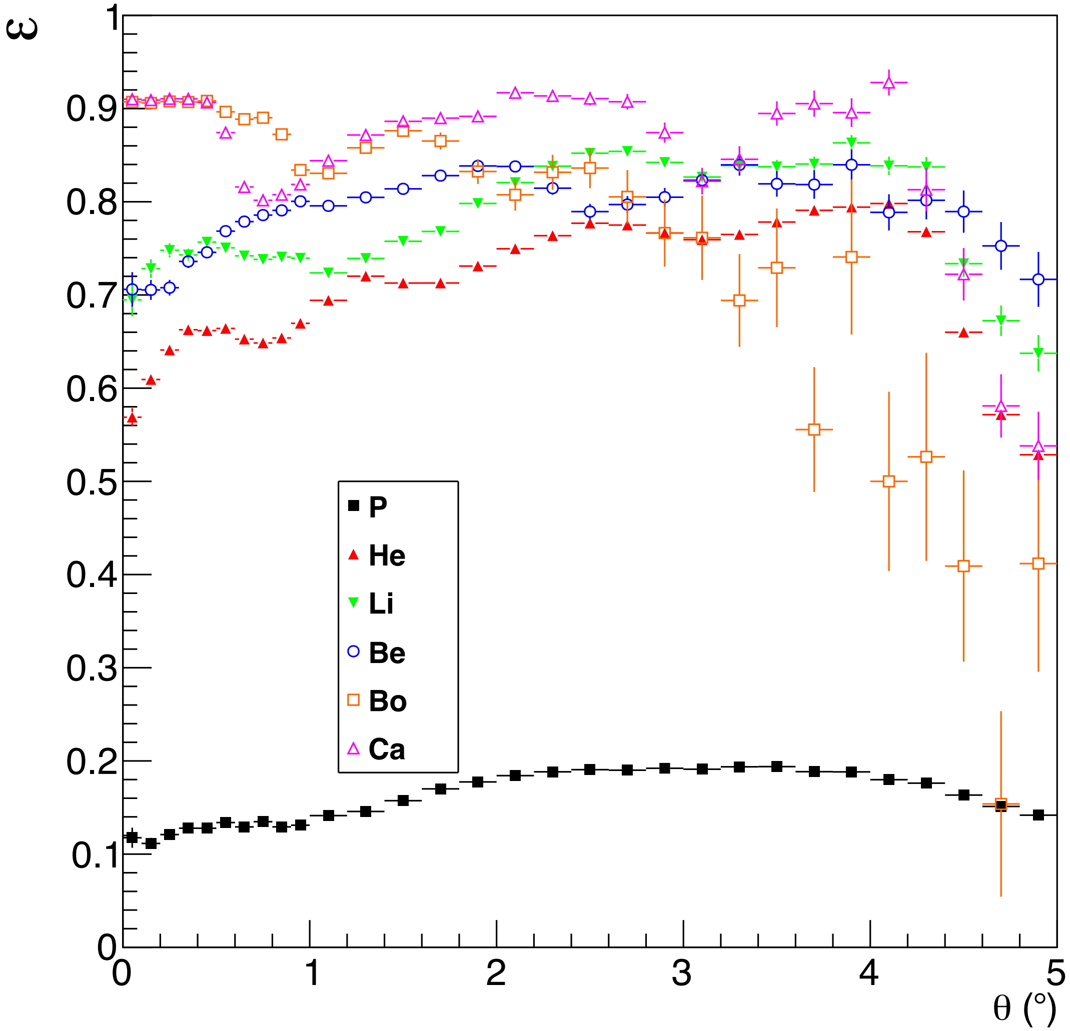
- Once we have a track in our MC how good are we at reconstructing it?
- For each event:

  "A' la Didier" method [biased from Fluka fragmentation model]

  - At Truth level:
    - We pre-select charged particles, require a carbon from the generation region, and fragments from the target only (we do not take into account ALL the possible tracks in the vtx/FIRST detector)
    - Then the tracks are required to go inside the Kentros Window (to be defined as "reconstructible")
    - We remove secondary fragmentation: if a carbon survives the Target and THEN fragments I do not consider it!
    - We require a track that is SCORED in the vtx (and by doing this we ensure that the fragment exits from the target)
- So the efficiency that we compute is not only the tracking efficiency but also the
  - Vtx reconstruction * ToF reconstruction * tracking efficiency
  - Pretty much what we need to convert the yield in a cross section measurement!

ε vs θ distributions (all tracks)

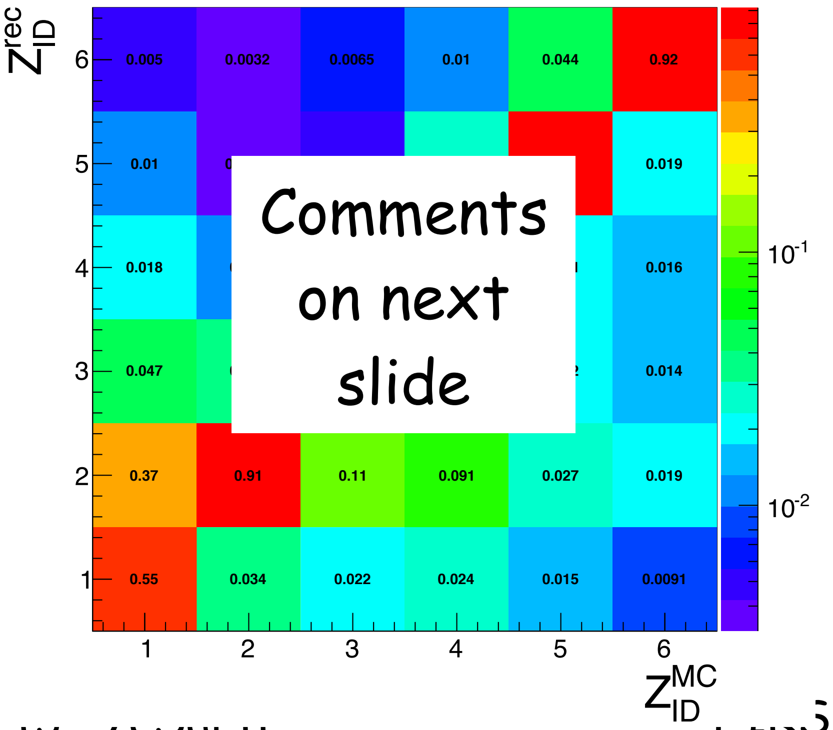
- Statistical uncertainty only
  - Proton spectra is being checked right now
  - Strategies to assess systematics are being investigated



ZID efficiency AND Xfeed

- Trying to evaluate the efficiency of our algorithms and the Xfeed in our mass spectra **directly using reconstructed tracks.**
  - For each reconstructed track I do look at what was the TRUE charge of the fragment and this is how this matrixes are filled. [**beware of the LOG z scale**]
  - **Normalization is done to the column [eff.] or the row [Xfeed]**
  - **Most important info comes from the ROW [how many times what I reconstruct as an X fragment is really X and how many times is some Y or Z]**

ZID efficiency!

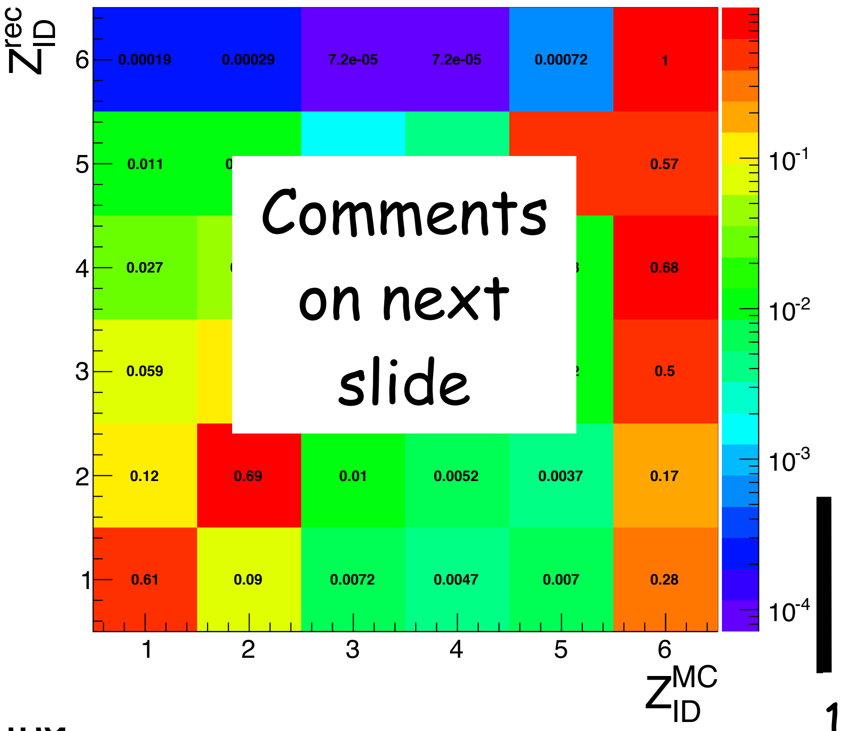


Comments on next slide

ALL tracks!

True charge comes from the MC block using pixels associated to the reconstructed track!

X feed

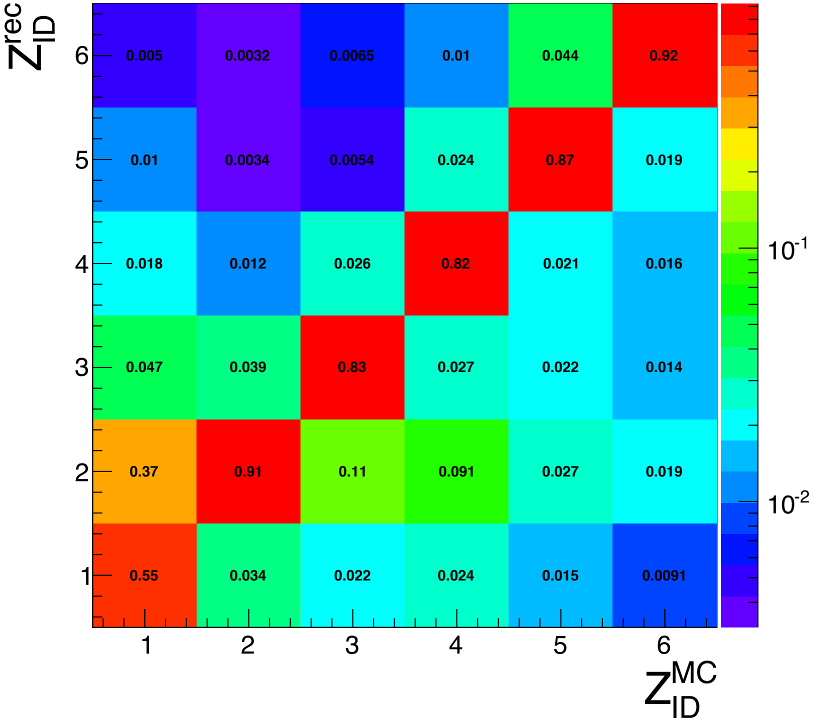


Comments on next slide

ZID efficiency AND Xfeed

- Charge ID efficiency is around 90% (except for protons where we are @ 50% level)
- The X feed for **all tracks** is quite high: we end up with a large pollution from carbons everywhere

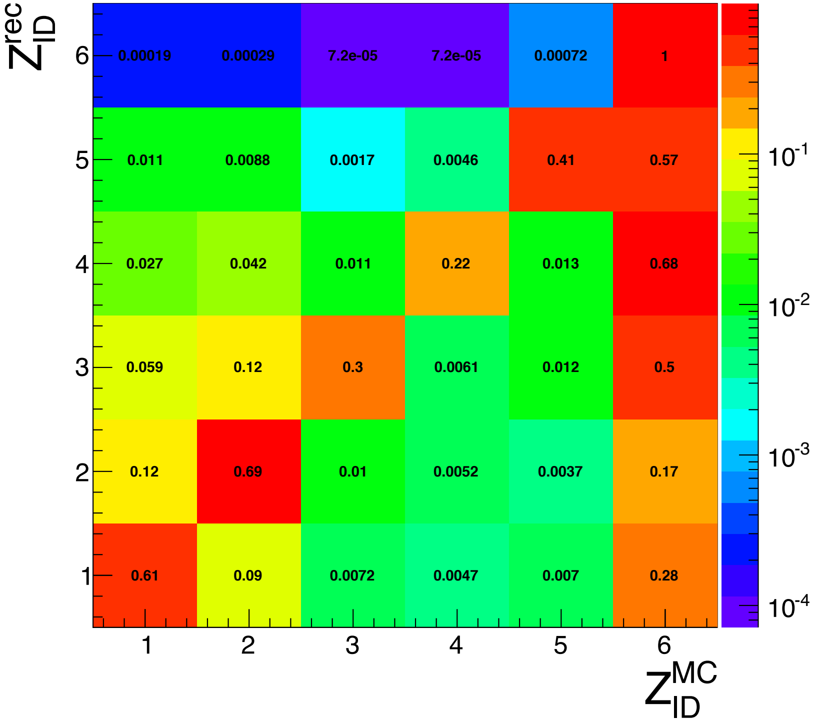
ZID efficiency!



6	0.005	0.0032	0.0065	0.01	0.044	0.92
5	0.01	0.0034	0.0054	0.024	0.87	0.019
4	0.018	0.012	0.026	0.82	0.021	0.016
3	0.047	0.039	0.83	0.027	0.022	0.014
2	0.37	0.91	0.11	0.091	0.027	0.019
1	0.55	0.034	0.022	0.024	0.015	0.0091
	1	2	3	4	5	6

ALL tracks!

X feed

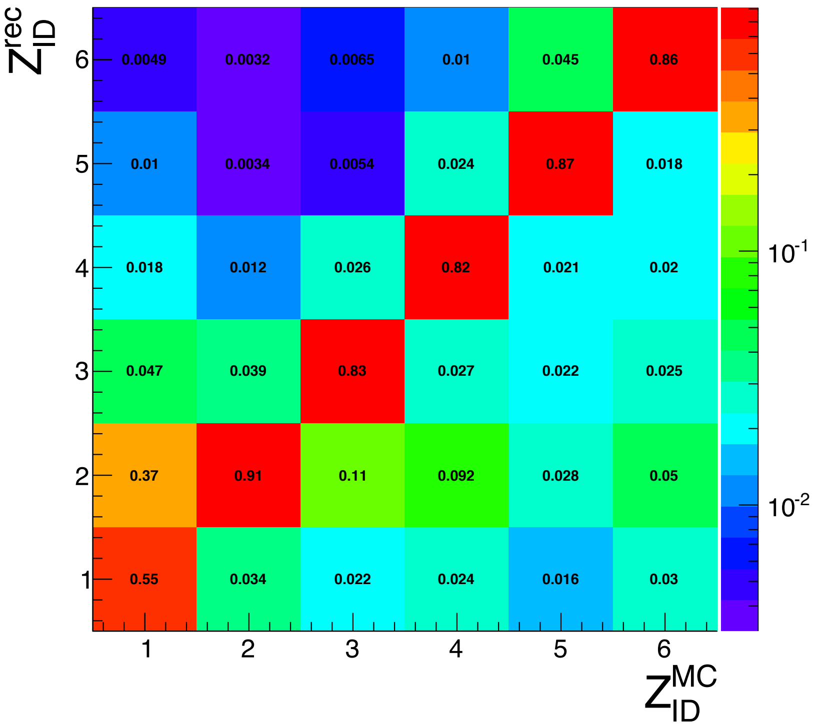


6	0.00019	0.00029	7.2e-05	7.2e-05	0.00072	1
5	0.011	0.0088	0.0017	0.0046	0.41	0.57
4	0.027	0.042	0.011	0.22	0.013	0.68
3	0.059	0.12	0.3	0.0061	0.012	0.5
2	0.12	0.69	0.01	0.0052	0.0037	0.17
1	0.61	0.09	0.0072	0.0047	0.007	0.28
	1	2	3	4	5	6

ZID efficiency AND Xfeed (II)

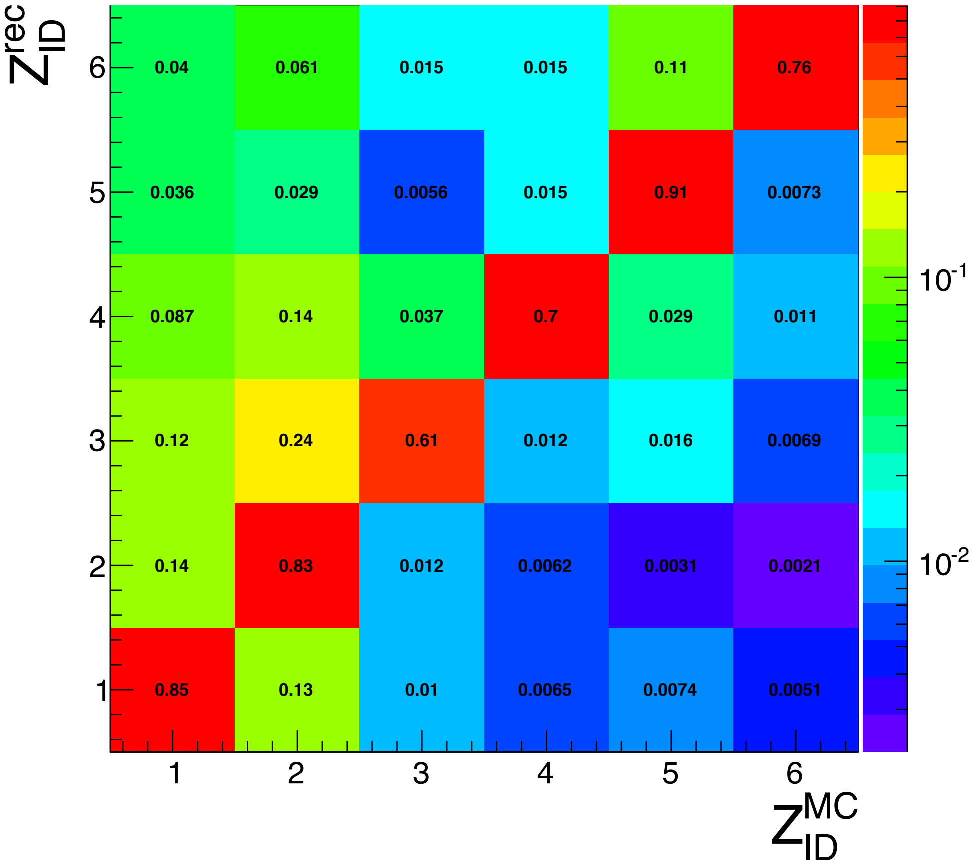
- Situation is greatly improved for “fragmented” events:
  - Same efficiency
  - Xfeed is greatly reduced
- **Fragmented event is flagged using the track multiplicity of the Vertex object associated to a given tr**

ZID efficiency!



	1	2	3	4	5	6
6	0.0049	0.0032	0.0065	0.01	0.045	0.86
5	0.01	0.0034	0.0054	0.024	0.87	0.018
4	0.018	0.012	0.026	0.82	0.021	0.02
3	0.047	0.039	0.83	0.027	0.022	0.025
2	0.37	0.91	0.11	0.092	0.028	0.05
1	0.55	0.034	0.022	0.024	0.016	0.03

Fragmented events

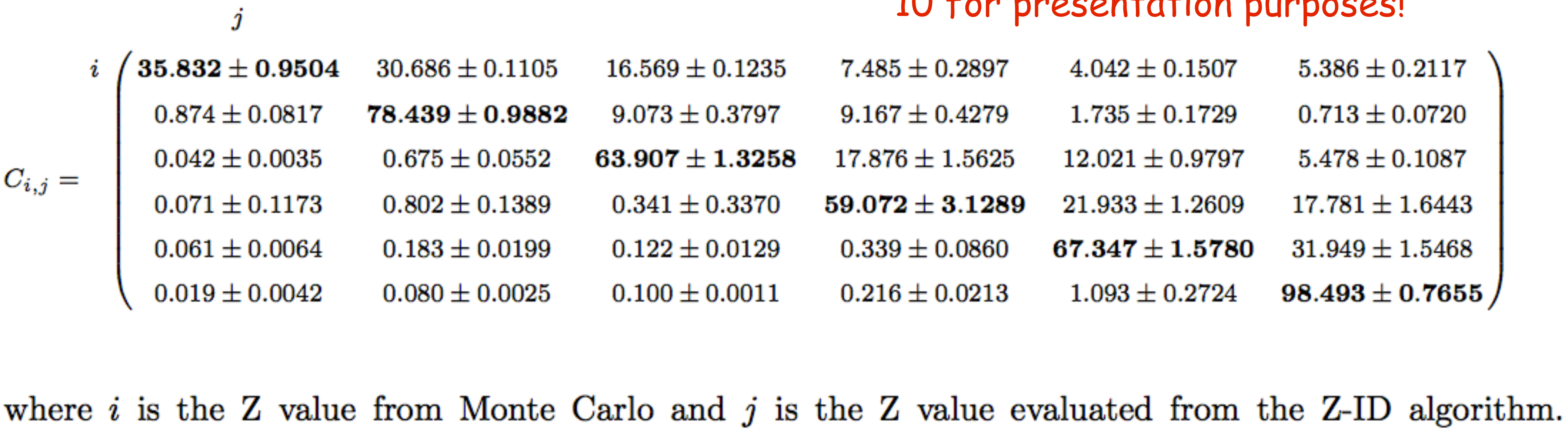


	1	2	3	4	5	6
6	0.04	0.061	0.015	0.015	0.11	0.76
5	0.036	0.029	0.0056	0.015	0.91	0.0073
4	0.087	0.14	0.037	0.7	0.029	0.011
3	0.12	0.24	0.61	0.012	0.016	0.0069
2	0.14	0.83	0.012	0.0062	0.0031	0.0021
1	0.85	0.13	0.01	0.0065	0.0074	0.0051

Systematic uncertainties

- Study done by Sam.

uncertainties are inflated by a factor 10 for presentation purposes!



$$C_{i,j} = \begin{array}{cc} & j \\ i & \begin{pmatrix} \mathbf{35.832 \pm 0.9504} & 30.686 \pm 0.1105 & 16.569 \pm 0.1235 & 7.485 \pm 0.2897 & 4.042 \pm 0.1507 & 5.386 \pm 0.2117 \\ 0.874 \pm 0.0817 & \mathbf{78.439 \pm 0.9882} & 9.073 \pm 0.3797 & 9.167 \pm 0.4279 & 1.735 \pm 0.1729 & 0.713 \pm 0.0720 \\ 0.042 \pm 0.0035 & 0.675 \pm 0.0552 & \mathbf{63.907 \pm 1.3258} & 17.876 \pm 1.5625 & 12.021 \pm 0.9797 & 5.478 \pm 0.1087 \\ 0.071 \pm 0.1173 & 0.802 \pm 0.1389 & 0.341 \pm 0.3370 & \mathbf{59.072 \pm 3.1289} & 21.933 \pm 1.2609 & 17.781 \pm 1.6443 \\ 0.061 \pm 0.0064 & 0.183 \pm 0.0199 & 0.122 \pm 0.0129 & 0.339 \pm 0.0860 & \mathbf{67.347 \pm 1.5780} & 31.949 \pm 1.5468 \\ 0.019 \pm 0.0042 & 0.080 \pm 0.0025 & 0.100 \pm 0.0011 & 0.216 \pm 0.0213 & 1.093 \pm 0.2724 & \mathbf{98.493 \pm 0.7655} \end{pmatrix} \end{array}$$

where i is the Z value from Monte Carlo and j is the Z value evaluated from the Z-ID algorithm.

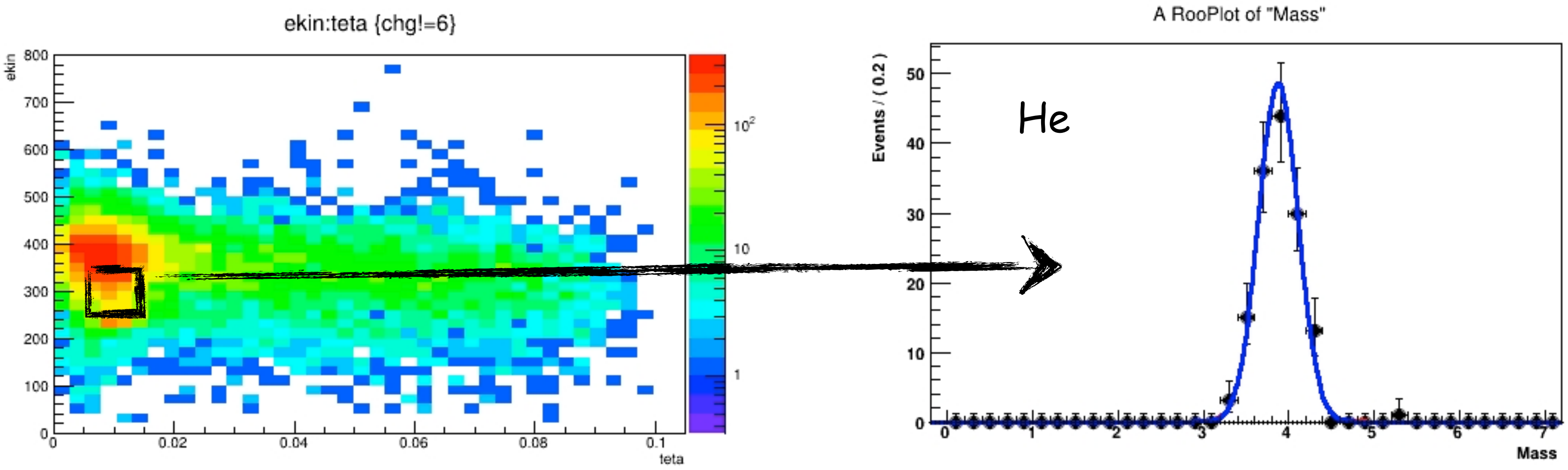
I'd like to redo it taking into account the tracking procedure and evaluate the impact on the final number to be used in the analysis

How to compute yields

$$\frac{d\sigma_i}{dE,d\theta} = \frac{\boxed{Y_i}}{N_{^{12}C} \times N_{t,S} \times BW_E \times BW_\theta \times \Omega(\theta) \times \varepsilon_{rec}(E,\theta) \times \varepsilon_{sel}(E,\theta)}$$

Used unbinned likelihood fits (to avoid binning effects with low statistics bins)

Select a given bin in kinetic energy AND/OR angle and perform a fit to the invariant mass ditribution!

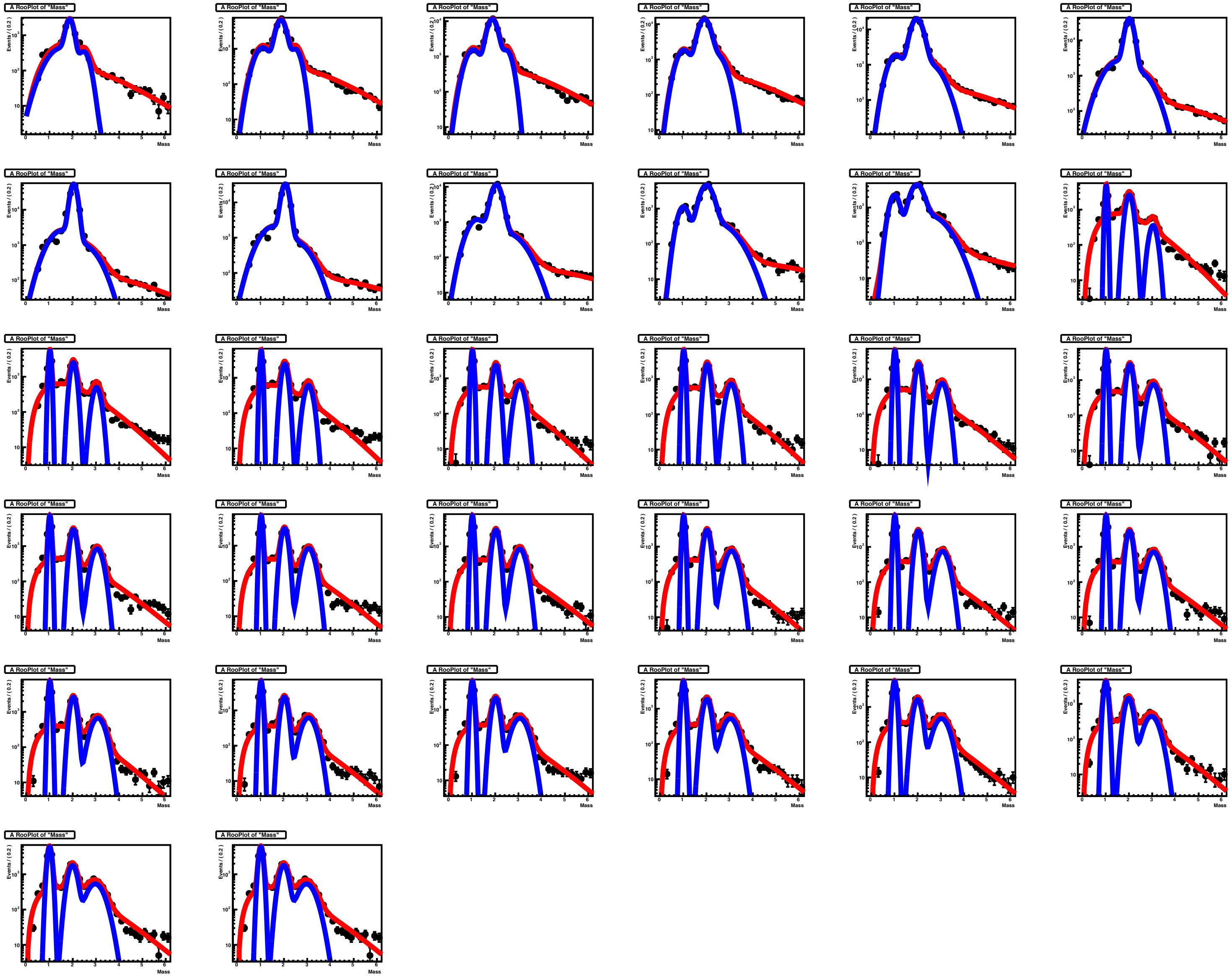


Fitting

- Huge work to control the fits on a wide region of angle, kin energy:
  - Focused on angular distributions (well behaved wrt the energy ones that show strange spectra)
  - Refined signal model
  - Refined bkg model
  - **Not yet taking into account the crossfeed from fragments misid ["the hardest part"]**
- Done an extensive study to understand how well we control the shapes and the yields comparing data and MC
- A careful study of the bkg (on MC events has yet to be done!)

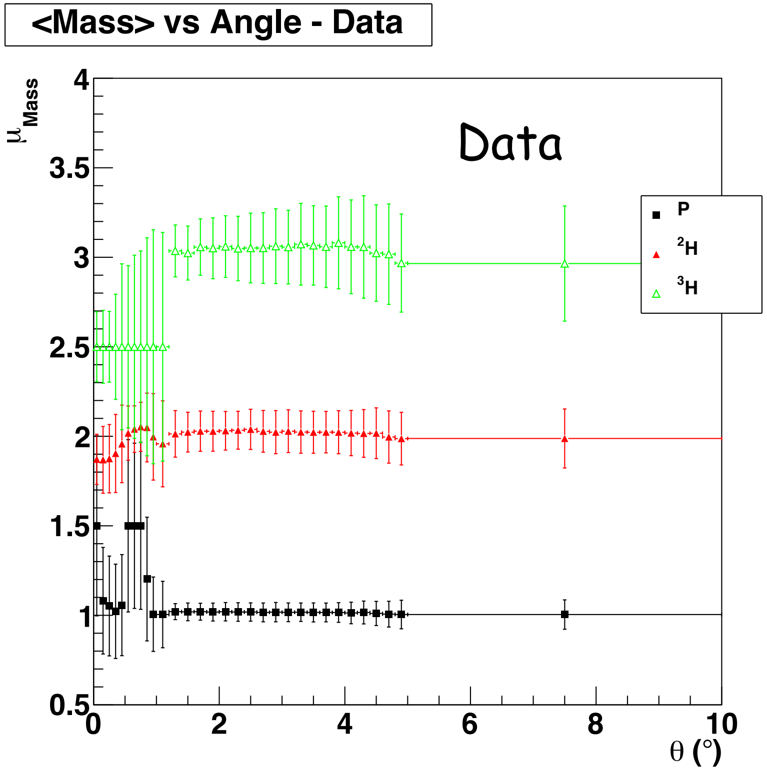
Overall sample plot

- Blue:
  - 3 gaussians (signal Pr, D, T)
- Red:
  - gamma function (bkg) + signal

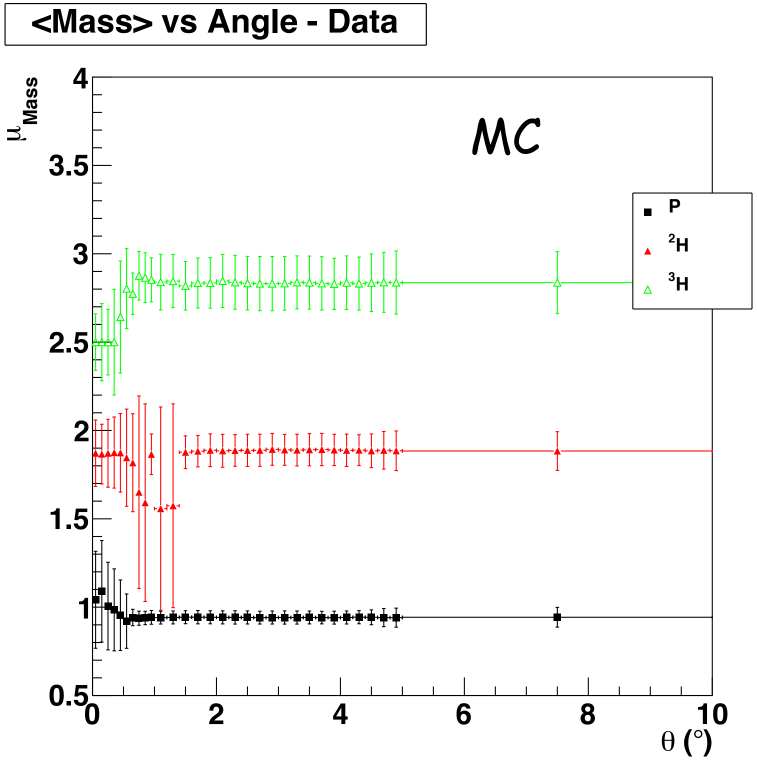


Is the model/fitting under control

- Fit model: stability and godness checks....
  - Info from the signal characteristics in "clean" regions can be used to improve fit quality in presence of high bkg [first bins]
  - Small differences if restricting to only fragmented events (quality of the fit changes really just in the very first bins where the carbon pollution is highest)



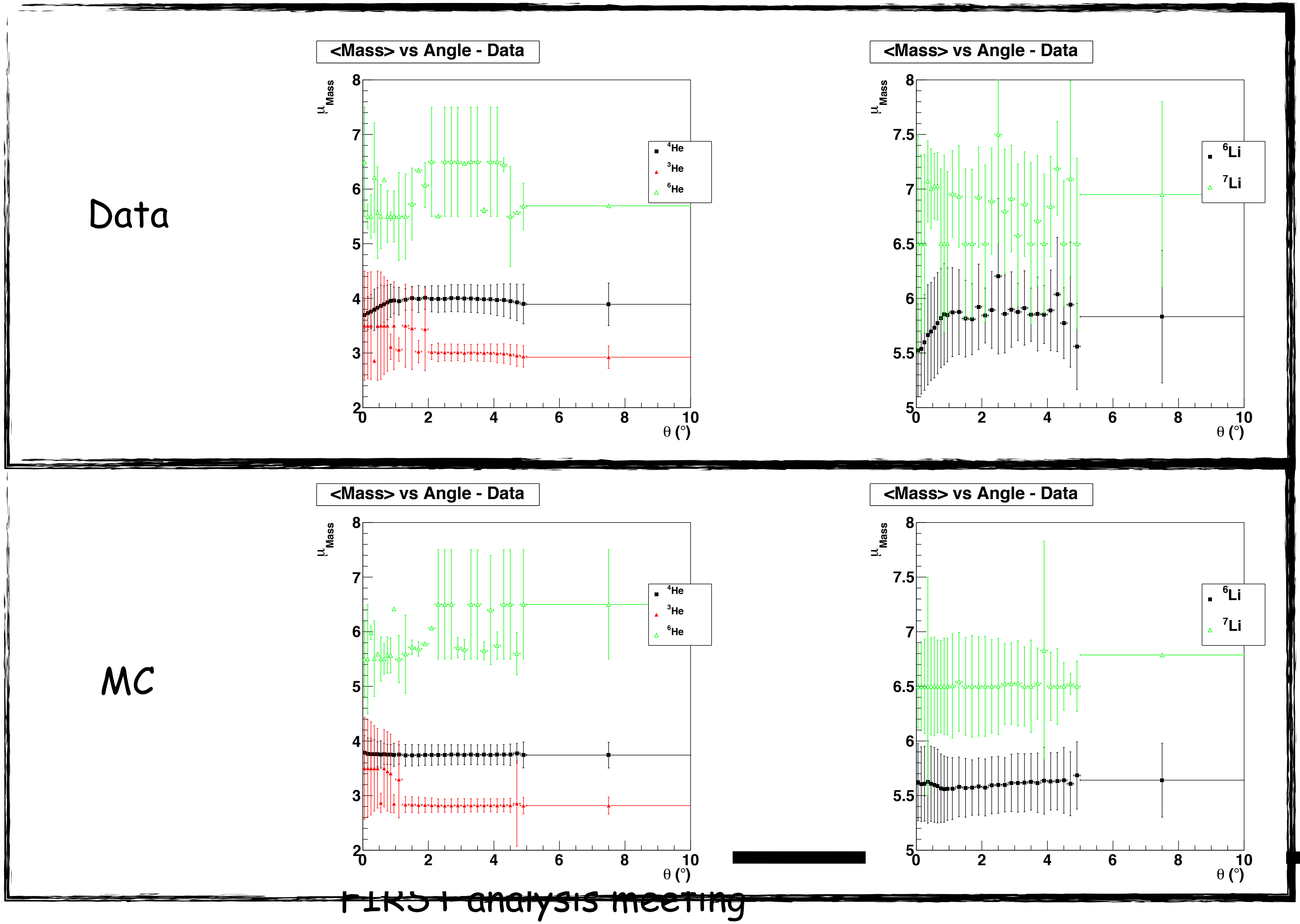
<Mass> vs Angle - Data



<Mass> vs Angle - Data

Data/MC scale difference (He, Li)

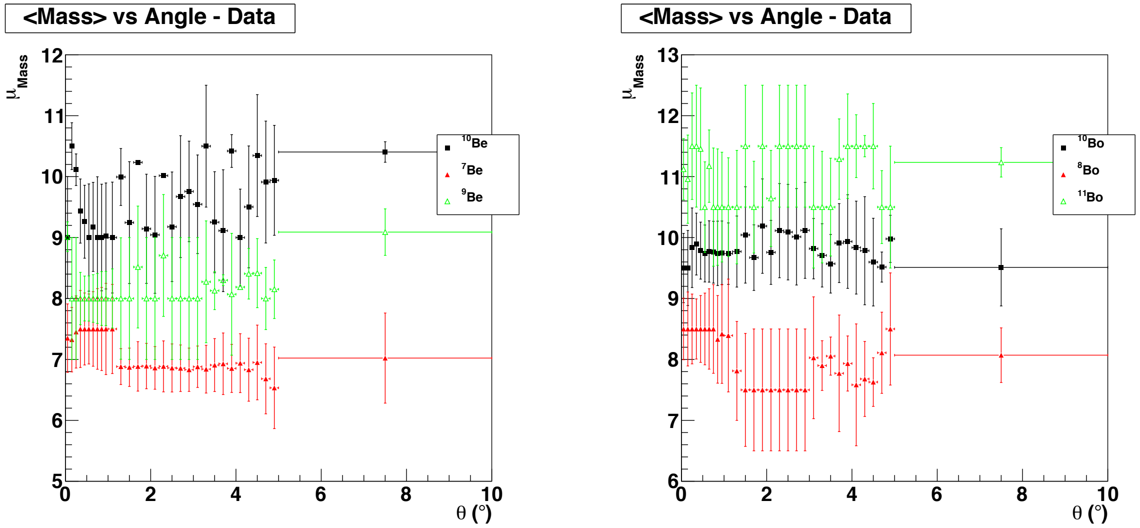
- Before going and take the mass PDFs from MC we need to fix the scale...



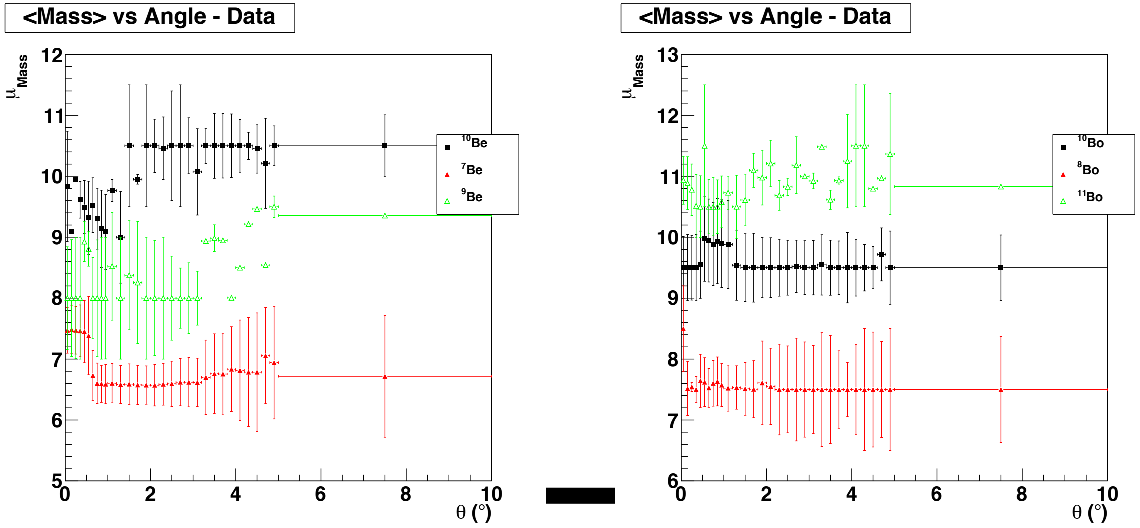
Data/MC scale difference (Be, Bo)

- Before going and take the mass PDFs from MC we need to fix the scale...

Data



MC



Putting everything together

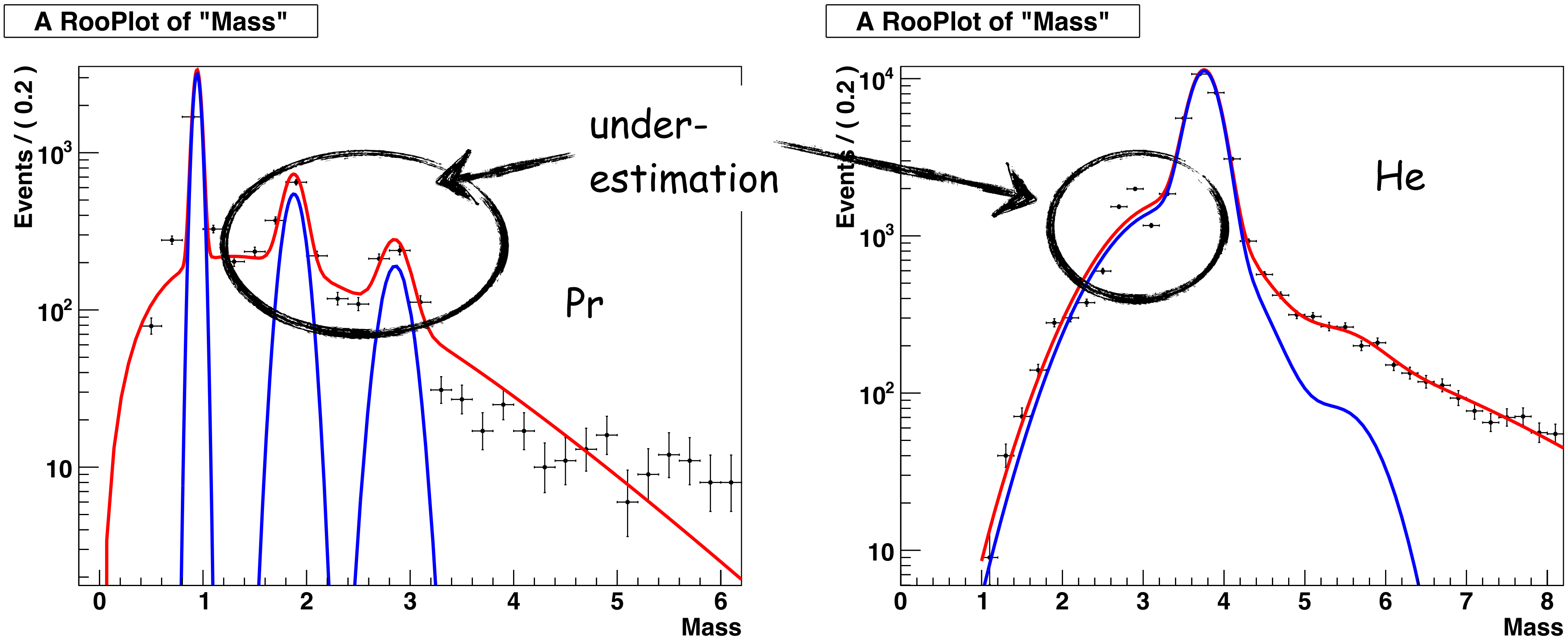
- Uncertainty:
  - assuming all uncertainties are uncorrelated.
- For now only statistical uncertainties are considered.
  - $\sigma(N_{t,S})$ assumed 1% [comes from density, probably overestimated, Eleuterio?]
  - $\sigma(N_{12C})$ assumed $\surd\ N_{12C}$: we are counting the carbons from the SC, poissonian error.
  - **$\sigma(N_i)$ from fit (statistical only)**
  - solid angle: assume 5% uncertainty [should be lower as soon as we start to use our MC]
  - $\sigma(\varepsilon_{sel,rec})$: from efficiency determination itself
- Since we use a lot of events to make all the fits/studies, the stat uncertainty is really small. Need to quickly add a systematic uncertainty to ensure the result robustness for publication.

Systematics!

- Systematic contributions that will have to be determined ASAP.
  - $\sigma(N_{12C})$: should address the solidity of carbon counting looking for time/ charge dist and assign an uncertainty.
  - $\sigma(N_i)$ .. here we have several possible contributions:
    - **Fit model: the fitting model has not yet really validated on MC. This is the next urgent step that we need to foresee in order to check for possible underestimation of the yields (see next slides)**
    - Xfeed
  - $\sigma(\varepsilon_{sel,rec})$: from efficiency determination itself
-

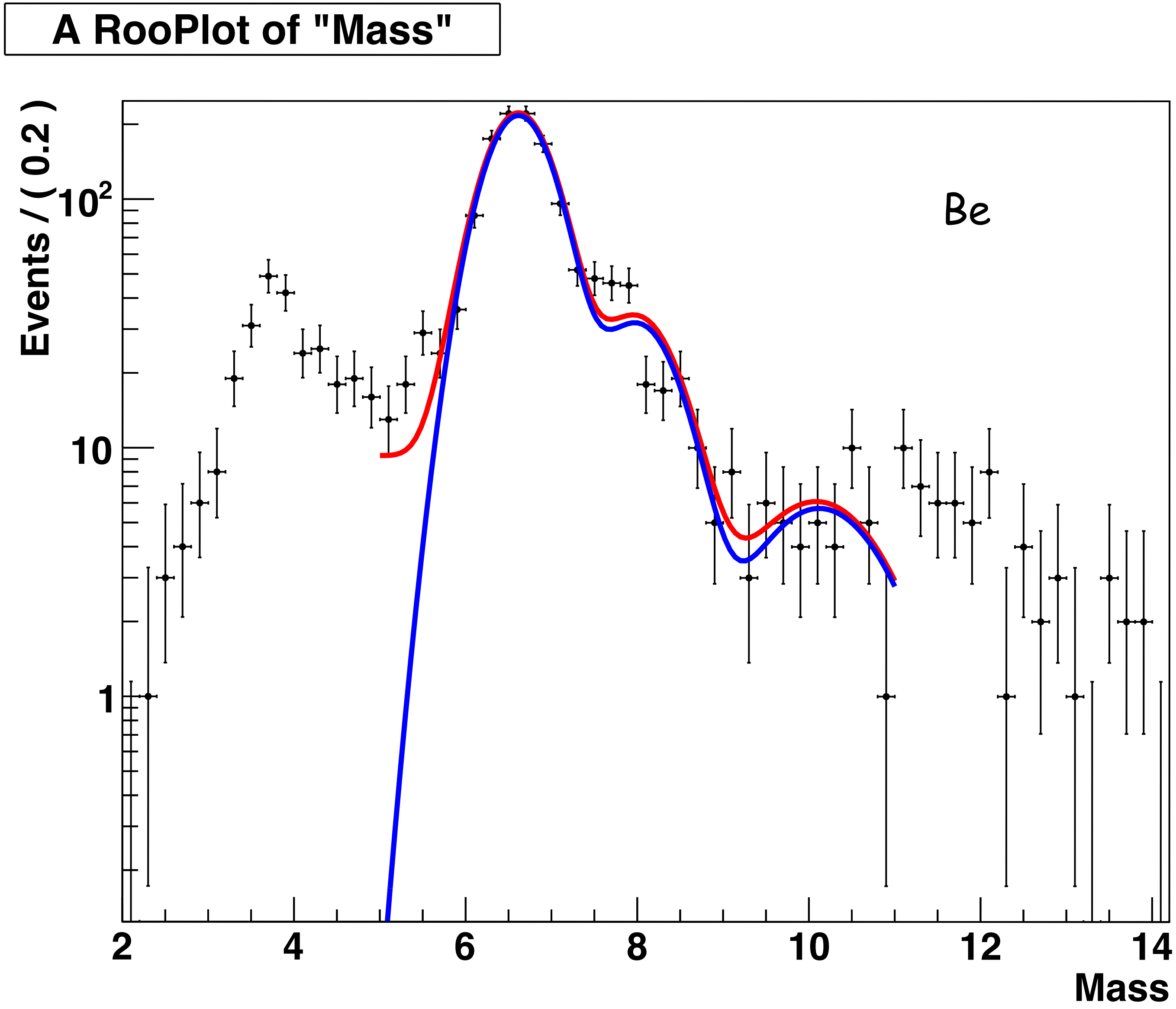
Fit model

- While the fit start to seem decent, a lot of work still has to be done in order to understand possible biases/inefficiencies/fit model dependencies.
  - Right after the meeting I will perform a quick "cut and count" check to see if we can recover some fragments.... [do not expect significant contribution for high mass fragments where fit is properly "counting" the fragments]

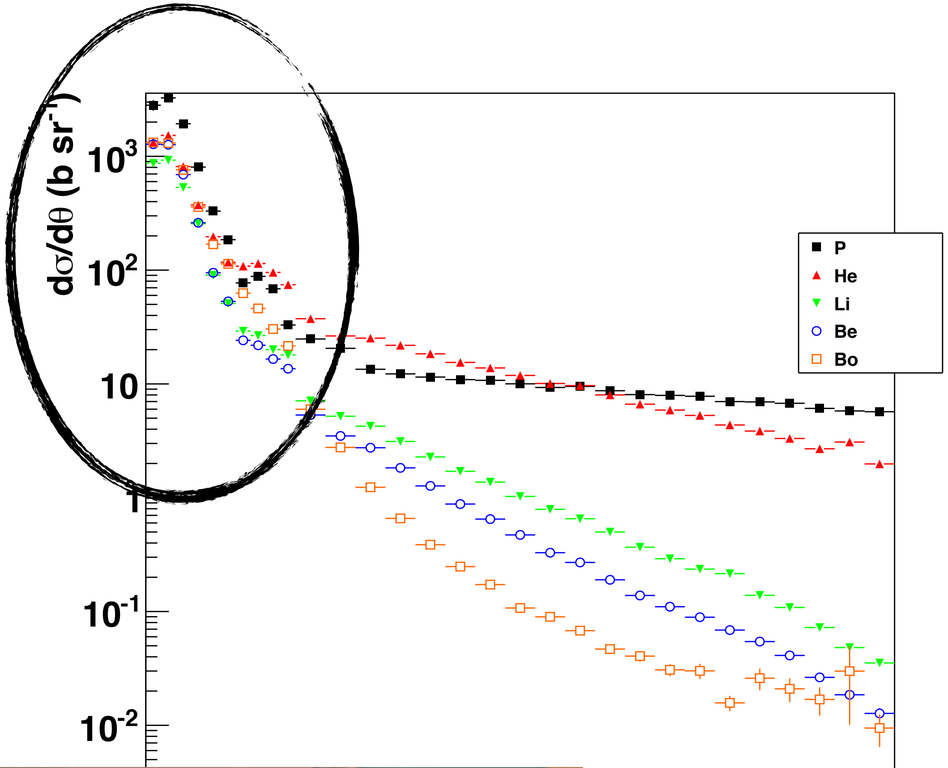


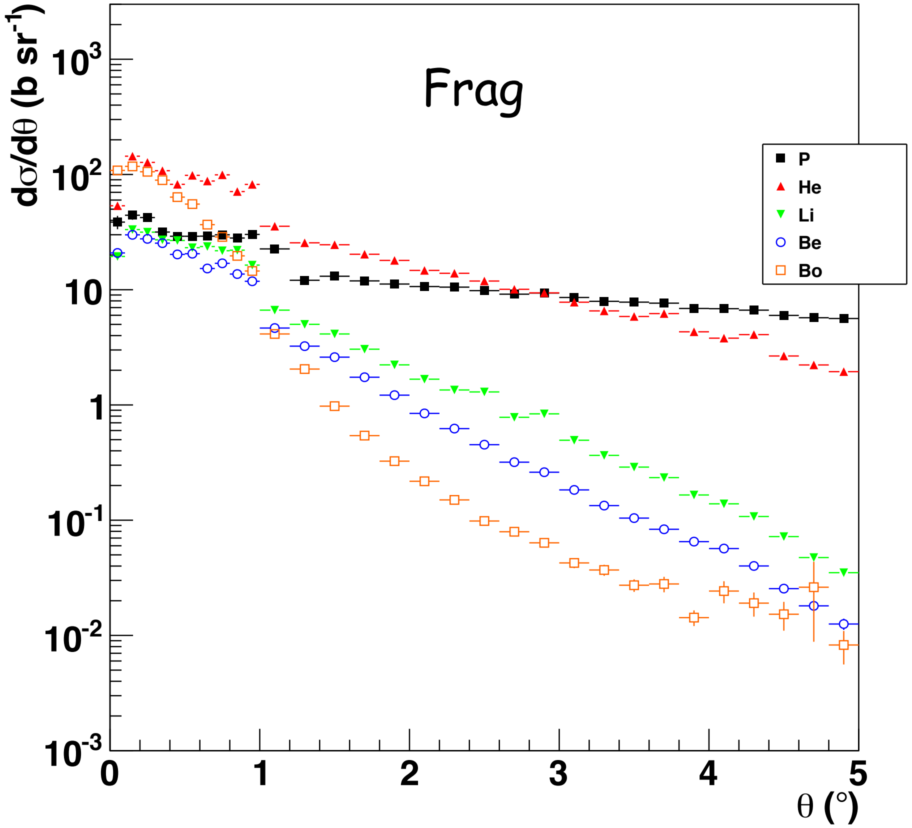
"side peaks"

- Effects can be relevant at large angle
  - a careful MC study has to be performed to understand side peaks



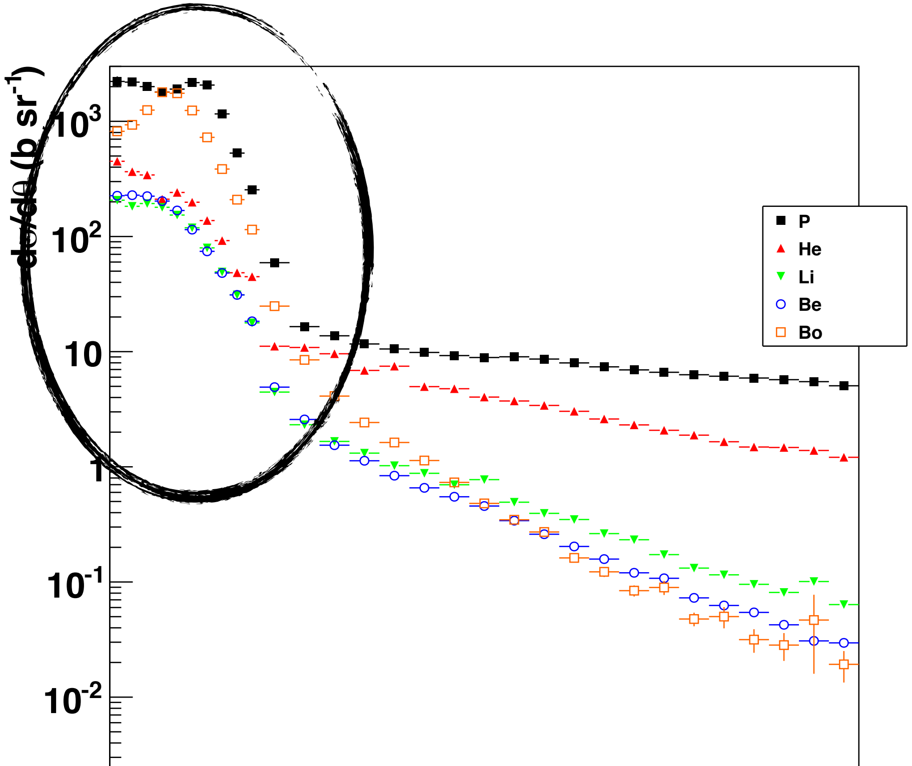
MC


dσ/dθ (b sr^{-1})
10^3
10^2
10
1
10^{-1}
10^{-2}
3
4
5
θ (°)
P
He
Li
Be
Bo

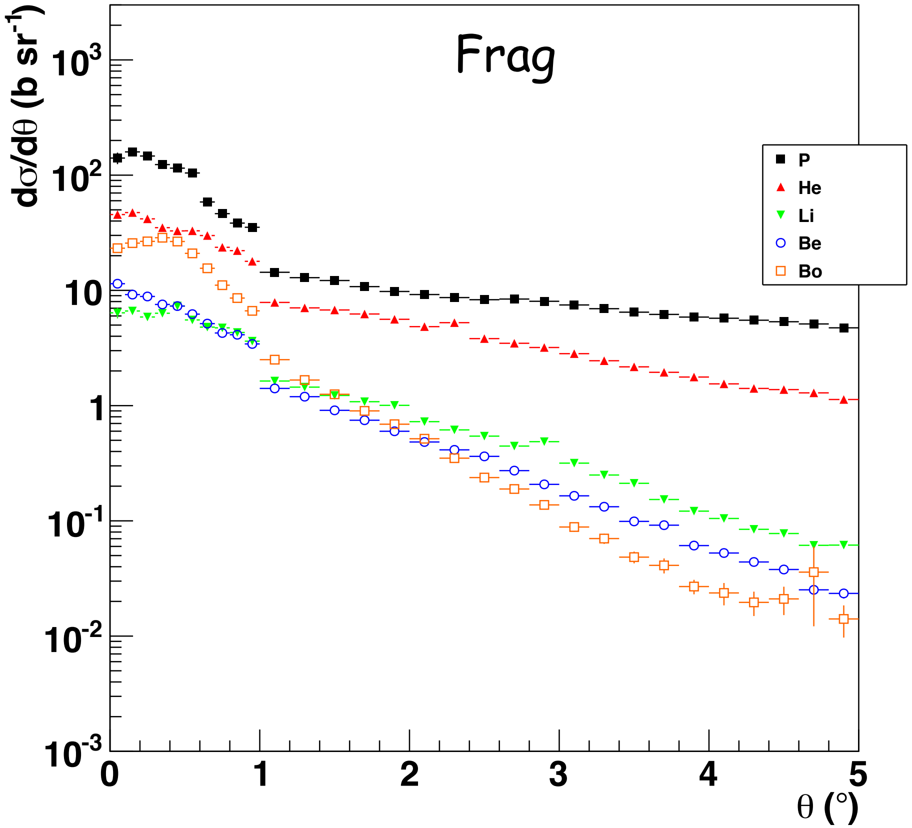

Frag
dσ/dθ (b sr^{-1})
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
θ (°)
P
He
Li
Be
Bo


CARBONS...............
CARBONS EVERYWHERE
memegenerator.net

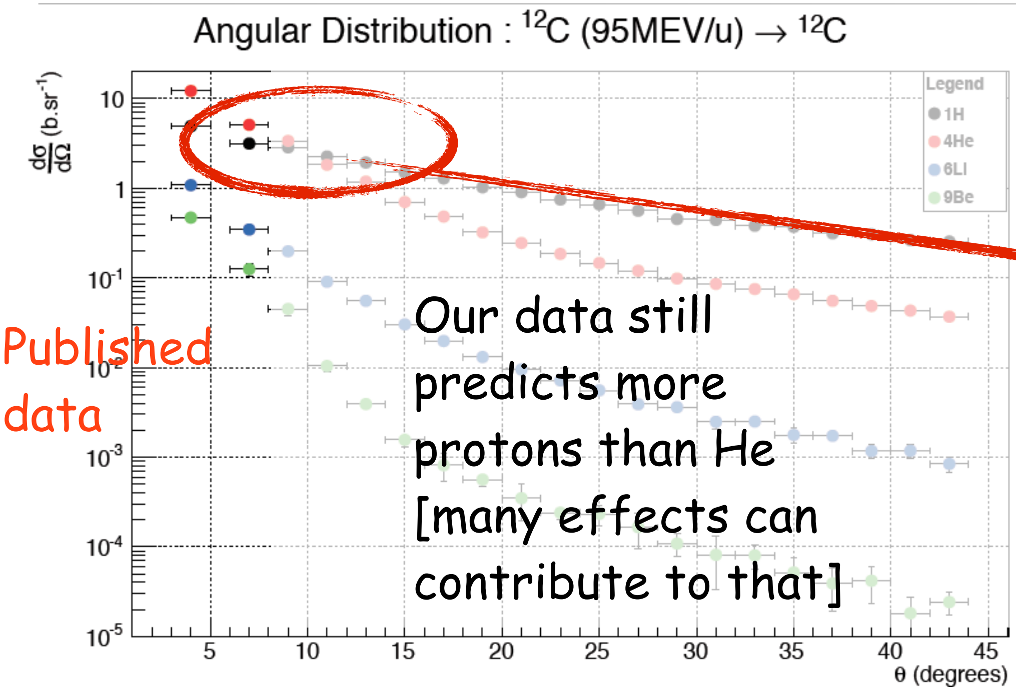
Data


dσ/dθ (b sr^{-1})
10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
4
5
θ (°)
P
He
Li
Be
Bo


CARBONS...............
CARBONS EVERYWHERE
memegenerator.net

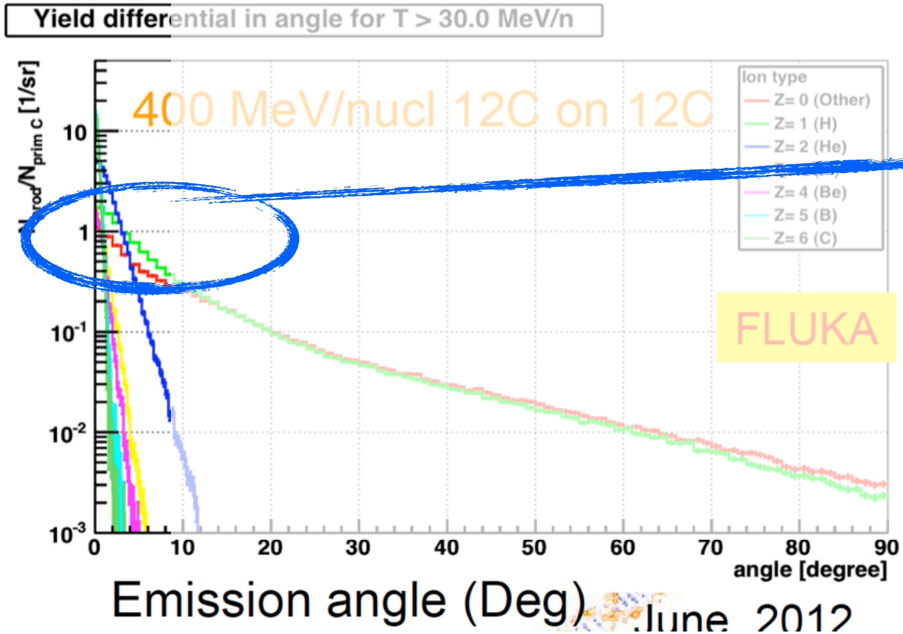

Frag
dσ/dθ (b sr^{-1})
10^{3}
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
θ (°)
P
He
Li
Be
Bo

data summary



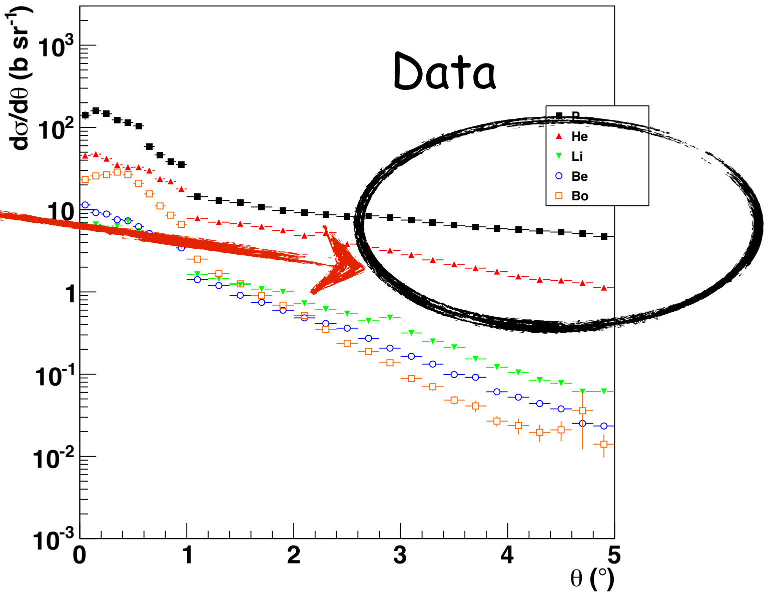
Published data

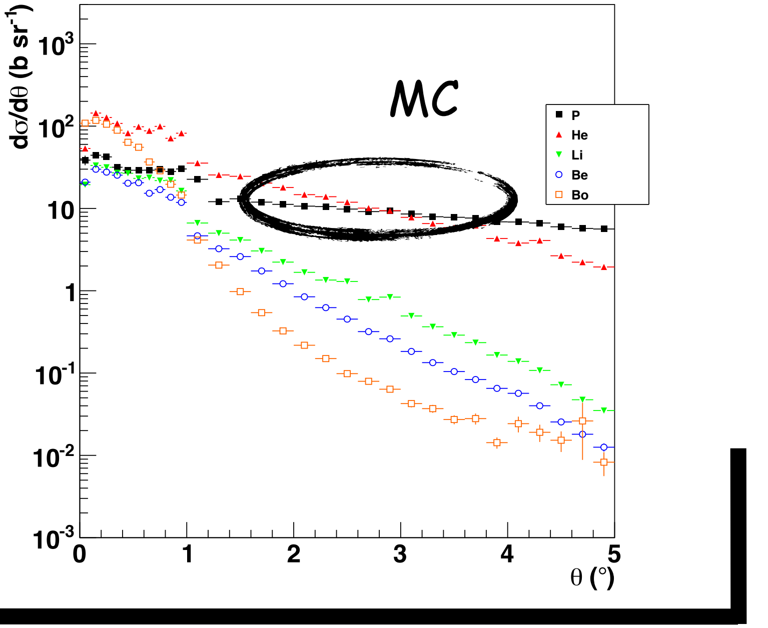
Our data still predicts more protons than He [many effects can contribute to that]



When comparing left and right Consider that the X axis range for our data covers **just the first few bins!**

fragmented events





Comparing results with Ganil

- For the charged particles detection, the setup consists of four DEthin /DEthick /E telescopes mounted two by two on two stages that allows rotation inside the chamber from 0° to 43° with 2° steps at a distance of 204 mm behind the target. The accuracy on the angles has been estimated to ±1° due to mechanical uncertainties on the position of the rotating stages. A fifth telescope was mounted downstream, at a fixed angle of 4° and a distance of 820 mm behind the target
  - This mean that the measurement taken at 4° is done integrating in the +/- 0.65° range… This means that if we want to compare we have to integrate our Xsection from ~3.4 to ~4.6
  - It seems to me that Flux measured by Ganil are correlated btw 7 and whatever: 2° step with a crystal that has 2.6° aperture.

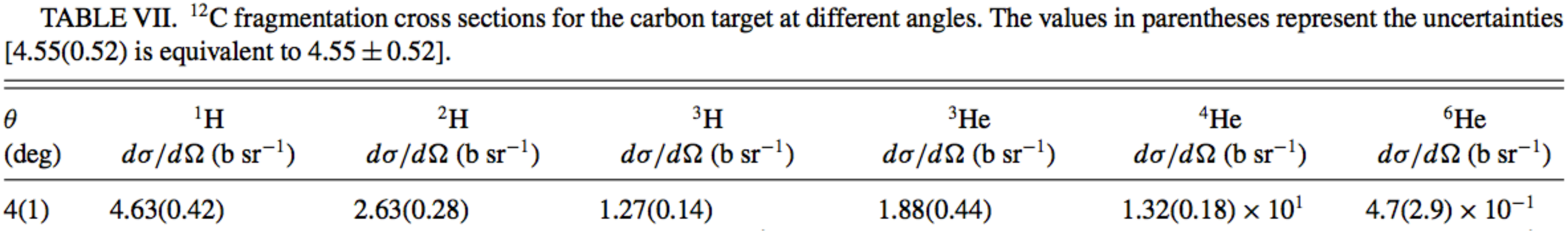


TABLE VII. ^{12}C fragmentation cross sections for the carbon target at different angles. The values in parentheses represent the uncertainties [4.55(0.52) is equivalent to 4.55 ± 0.52].

θ (deg)	^{1}H $d\sigma/d\Omega$ (b sr^{-1})	^{2}H $d\sigma/d\Omega$ (b sr^{-1})	^{3}H $d\sigma/d\Omega$ (b sr^{-1})	^{3}He $d\sigma/d\Omega$ (b sr^{-1})	^{4}He $d\sigma/d\Omega$ (b sr^{-1})	^{6}He $d\sigma/d\Omega$ (b sr^{-1})
4(1)	4.63(0.42)	2.63(0.28)	1.27(0.14)	1.88(0.44)	$1.32(0.18) \times 10^{1}$	$4.7(2.9) \times 10^{-1}$

Xsc @ 4° [3.3 - 4.9]

(b sr-1)	Ganil	DT All	DT Frg	MC All	MC Frg
Pr	4.63(0.42)	5.2+/-0.095	4.8+/-0.088	6.9+/-0.13	6.8+/-0.12
D	2.63(0.28)	3.9+/-0.072	3.6+/-0.067	3.5+/-0.065	3.5+/-0.065
T	1.27(0.14)	2+/-0.039	1.9+/-0.037	1.9+/-0.037	1.9+/-0.037
^{3}He	1.88(0.44)	0.7+/-0.013	0.65+/-0.012	2.2+/-0.041	2.5+/-0.048
^{4}He	13.2(1.8)	2.5+/-0.046	2.4+/-0.043	5.2+/-0.1	5.1+/-0.097
^{6}Li	0.97(0.13)	0.12+/-0.0029	0.096+/-0.0024	0.24+/-0.0054	0.23+/-0.0053
^{7}Li	0.92(0.12)	0.14+/-0.0034	0.13+/-0.0035	0.063+/-0.0019	0.056+/-0.0018
^{7}Be	0.809(0.081)	0.089+/-0.0024	0.078+/-0.0021	0.11+/-0.0028	0.1+/-0.0027
^{9}Be	0.350(0.037)	0.027+/-0.0012	0.024+/-0.0011	0.00072+/-0.00013	0.0018+/-0.00021
^{10}Be	0.184(0.024)	0.02+/-0.00088	0.012+/-0.00064	0.0055+/-0.00038	0.0049+/-0.00036
^{8}Bo	0.110(0.029)	0.019+/-0.0024	0.016+/-0.0034	0.019+/-0.0021	0.018+/-0.0019
^{10}Bo	1.08(0.14)	0.053+/-0.0035	0.037+/-0.0023	0.024+/-0.0027	0.021+/-0.0025
^{11}Bo	1.45(0.19)	0.033+/-0.0033	0.0072+/-0.0015	0.00067+/-0.00018	0.00046+/-0.00013

Xsc @ 4° [3.3 - 4.9]

Good agreement, for both Data and MC btw **the All and Frag values above 1°** [reflected in the integrated value]: the ntrks>2 requirement does not alter dramatically the efficiencies

DT All	DT Frg	MC All	MC Frg
5.2+/-0.095	4.8+/-0.088	6.9+/-0.13	6.8+/-0.12
3.9+/-0.072	3.6+/-0.067	3.5+/-0.065	3.5+/-0.065
2+/-0.039	1.9+/-0.037	1.9+/-0.037	1.9+/-0.037
0.7+/-0.013	0.65+/-0.012	2.2+/-0.041	2.5+/-0.048
2.5+/-0.046	2.4+/-0.043	5.2+/-0.1	5.1+/-0.097
0.12+/-0.0029	0.096+/-0.0024	0.24+/-0.0054	0.23+/-0.0053
0.14+/-0.0034	0.13+/-0.0035	0.063+/-0.0019	0.056+/-0.0018
0.089+/-0.0024	0.078+/-0.0021	0.11+/-0.0028	0.1+/-0.0027
0.027+/-0.0012	0.024+/-0.0011	0.00072+/-0.00013	0.0018+/-0.00021
0.02+/-0.00088	0.012+/-0.00064	0.0055+/-0.00038	0.0049+/-0.00036
0.019+/-0.0024	0.016+/-0.0034	0.019+/-0.0021	0.018+/-0.0019
0.053+/-0.0035	0.037+/-0.0023	0.024+/-0.0027	0.021+/-0.0025
0.033+/-0.0033	0.0072+/-0.0015	0.00067+/-0.00018	0.00046+/-0.00013

Xsc @ 4° [3.3 - 4.9]

(b sr-1)	Ganil	DT All
Pr	4.63(0.42)	5.2+/-0.095
D	2.63(0.28)	3.9+/-0.072
T	1.27(0.14)	2+/-0.039
^{3}He	1.88(0.44)	0.7+/-0.013
^{4}He	13.2(1.8)	2.5+/-0.046
^{6}Li	0.97(0.13)	0.12+/-0.0029
^{7}Li	0.92(0.12)	0.14+/-0.0034
^{7}Be	0.809(0.081)	0.089+/-0.0024
^{9}Be	0.350(0.037)	0.027+/-0.0012
^{10}Be	0.184(0.024)	0.02+/-0.00088
^{8}Bo	0.110(0.029)	0.019+/-0.0024
^{10}Bo	1.08(0.14)	0.053+/-0.0035
^{11}Bo	1.45(0.19)	0.033+/-0.0033

- The integrated Xsection btw 3.3 and 4.9 [comparable to Ganil] seems to be:
  - In a good range for Pr, D and T [where we do expect something larger than Ganil]
  - Too small for all the other fragments [a factor 10-20 below the expected values]: **however it seems that the relative populations among the isotopes are** behaving as expected.
    - Our "naive" approach [fit using gaussians] shows "some" limits :)
  - Xfeed dominates the result and has not yet been taken into account

Xsc @ 4° [3.3 - 4.9]

(b sr-1)	DT Frg	MC Frg
Pr	4.8+/-0.088	6.8+/-0.12
D	3.6+/-0.067	3.5+/-0.065
T	1.9+/-0.037	1.9+/-0.037
^{3}He	0.65+/-0.012	2.5+/-0.048
^{4}He	2.4+/-0.043	5.1+/-0.097
^{6}Li	0.096+/-0.0024	0.23+/-0.0053
^{7}Li	0.13+/-0.0035	0.056+/-0.0018
^{7}Be	0.078+/-0.0021	0.1+/-0.0027
^{9}Be	0.024+/-0.0011	0.0018+/-0.00021
^{10}Be	0.012+/-0.00064	0.0049+/-0.00036
^{8}Bo	0.016+/-0.0034	0.018+/-0.0019
^{10}Bo	0.037+/-0.0023	0.021+/-0.0025
^{11}Bo	0.0072+/-0.0015	0.00046+/-0.00013

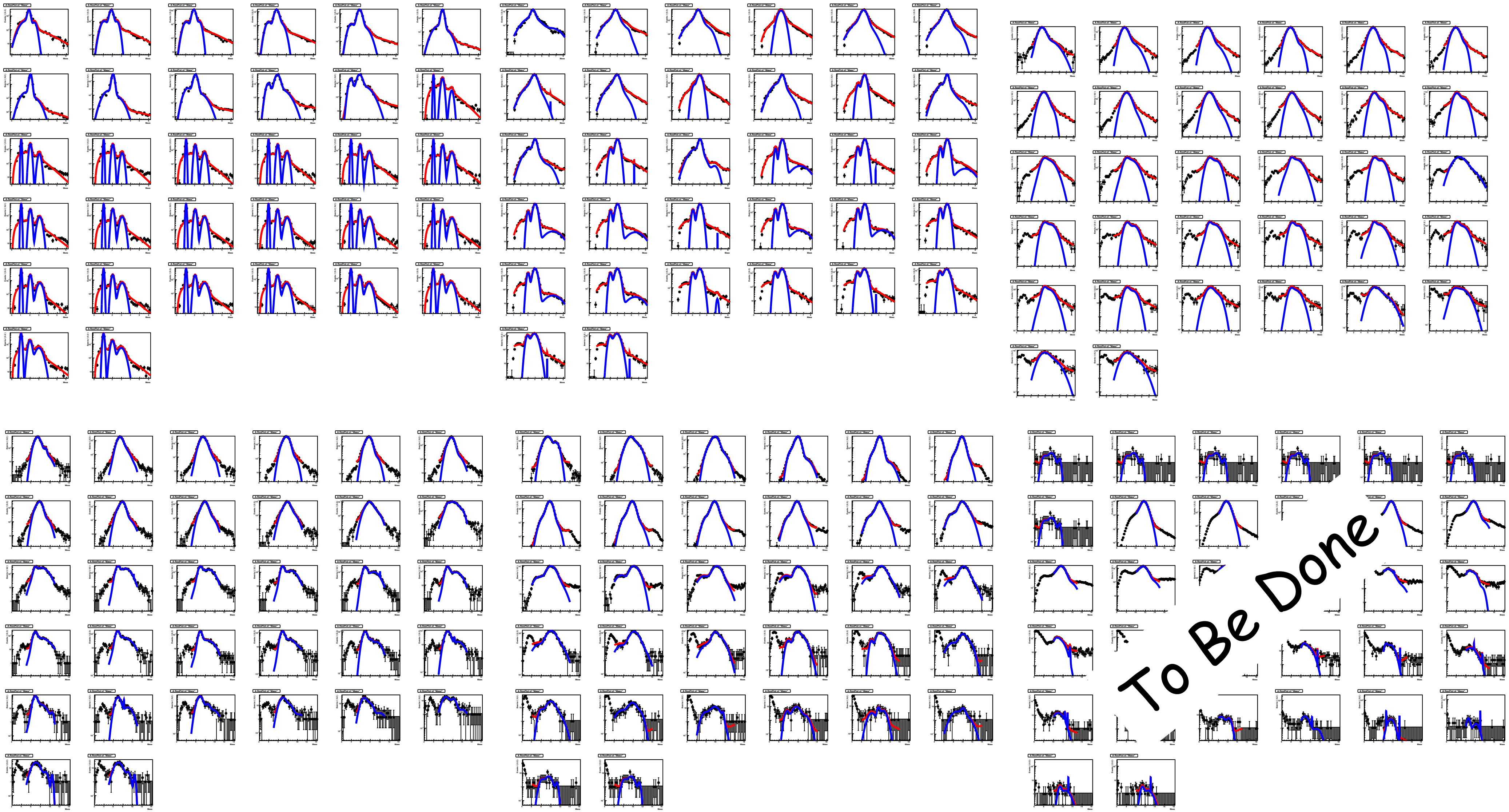
- The data-MC agreement for most of the fragments is decent.
  - I mean within 50% for most cases...

Summary

- A first big refinement has been done to the X-section computation
  - Fit model has been improved and checked against latest MC
  - Last efficiencies used: Chk is needed
- To do list:
  - Validate Xsection measurement against TRUE MC info [V. Patera working on that]
  - Study further analysis strategies
    - Revise in detail the “cut on the number of tracks” strategy
    - Look at the “cut on the #pixels in the vtx” strategy
  - Work to improve the Xfeed handling
  - Work to improve the efficiency determination
  - Work to improve the uncertainty determination
  - Perform a detailed study of the background
  - Start to look at the Energy distributions

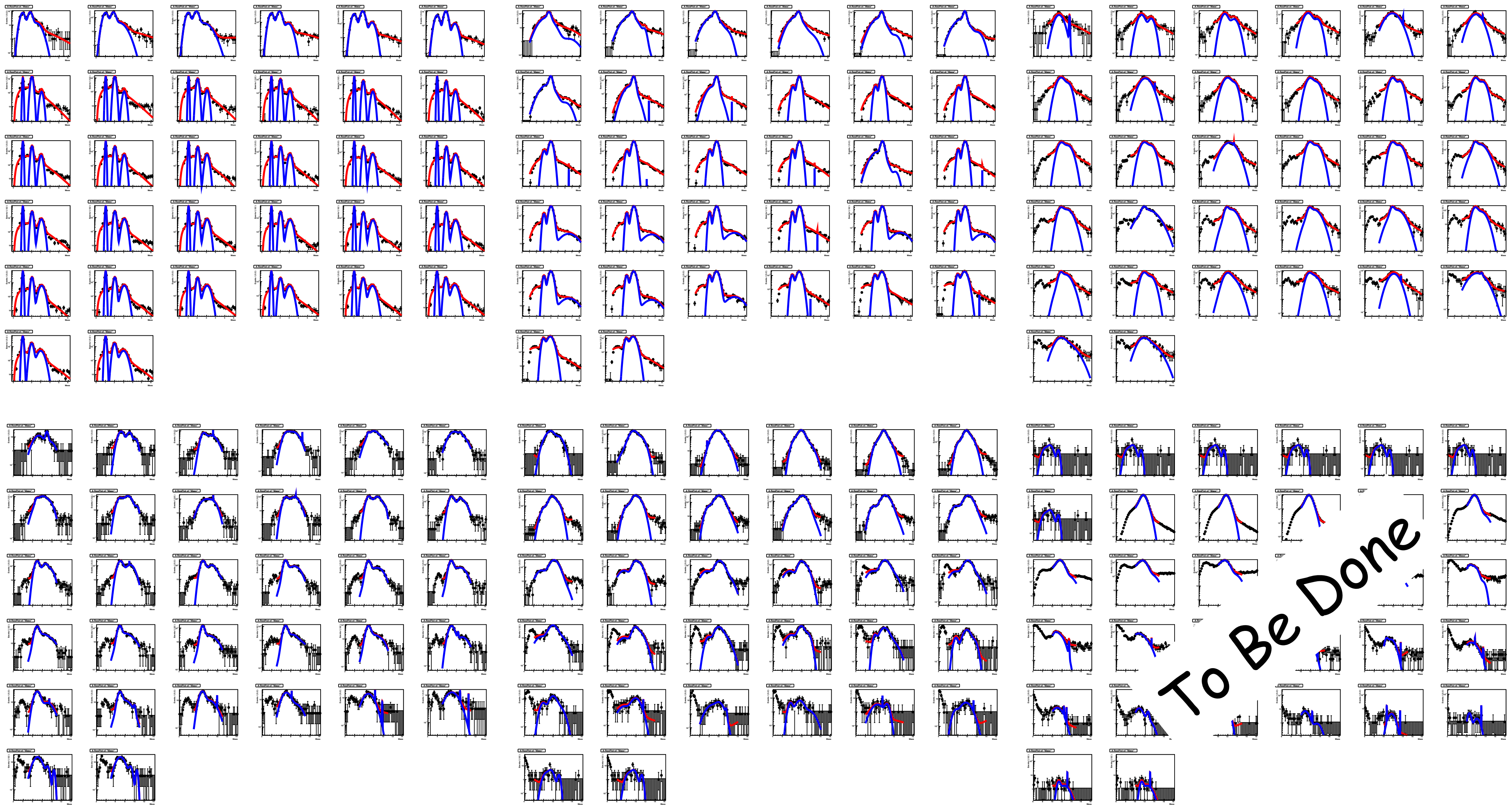
Spares

Angle fits, Data All



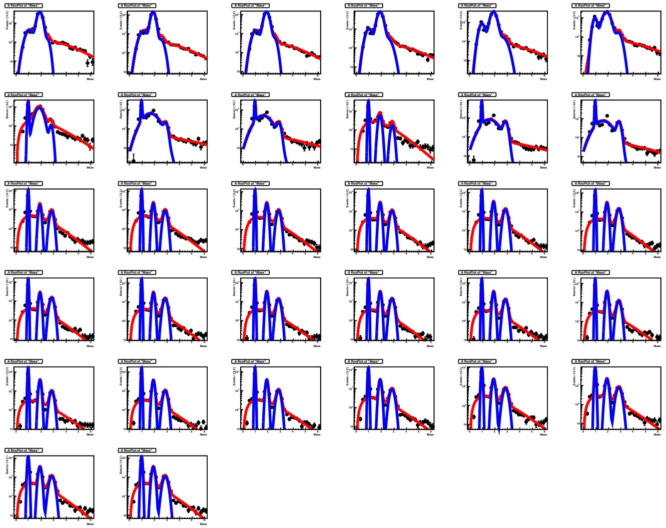
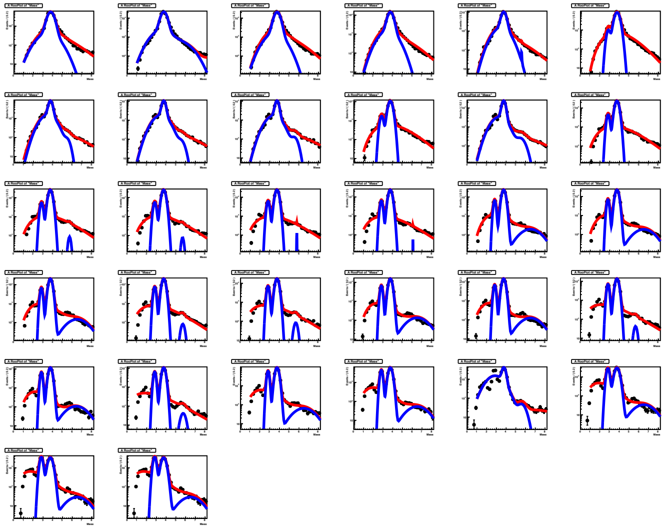
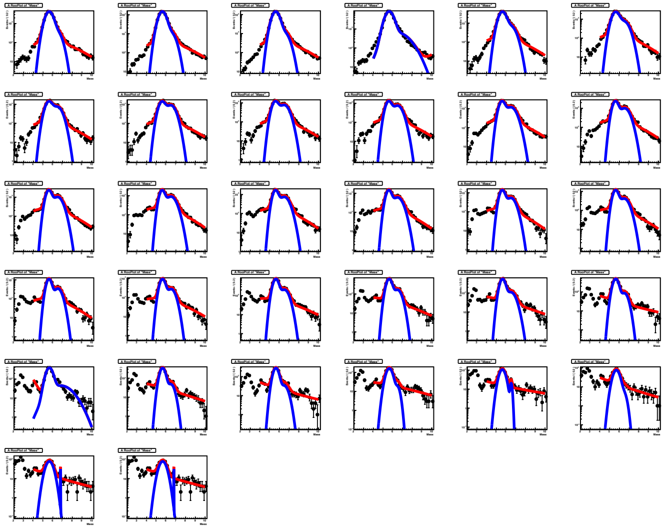
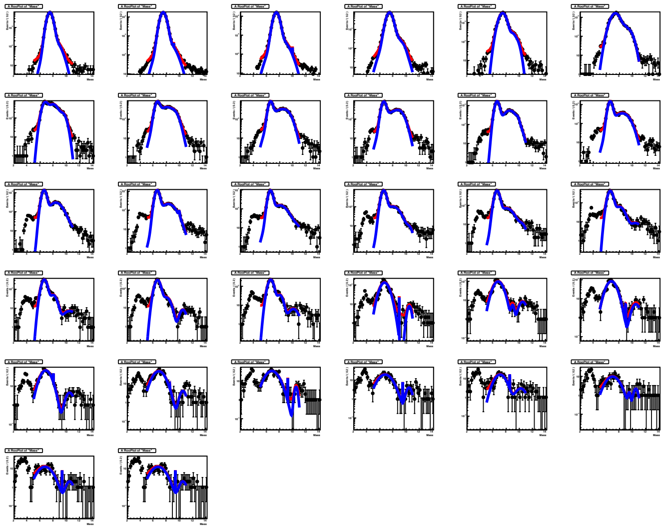
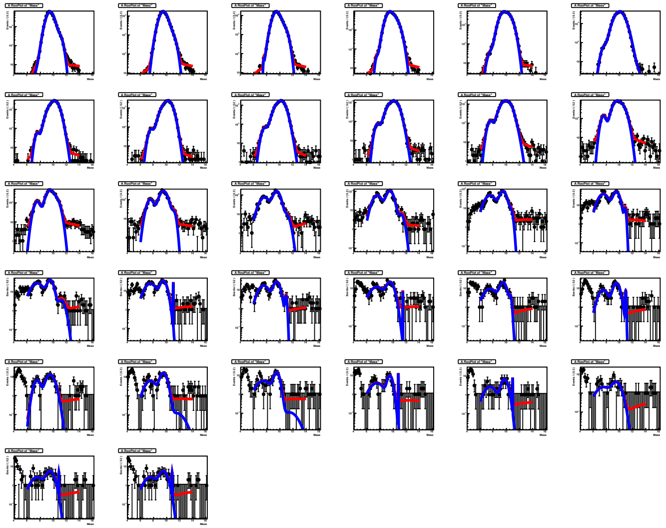
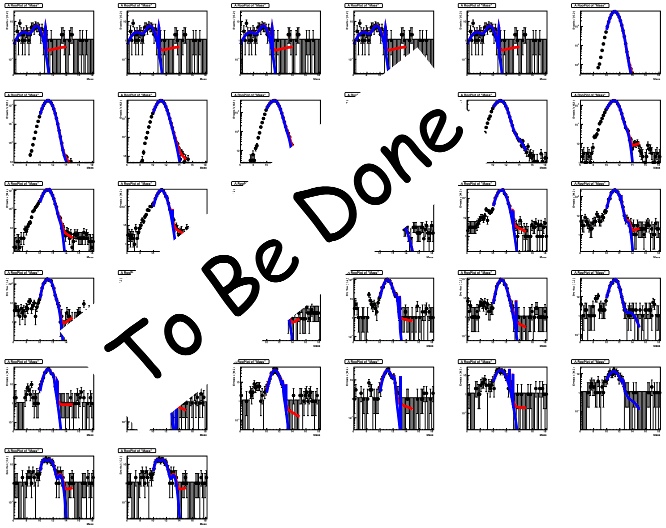
To Be Done

Angle fits, Data Frag



To Be Done

Angle Fits, MC All

To Be Done

Angle fits, MC frag

To Be Done

Todolist: efficiencies

- as explained on http://wiki.gsi.de/cgi-bin/view/FIRST/SimulationSoftware

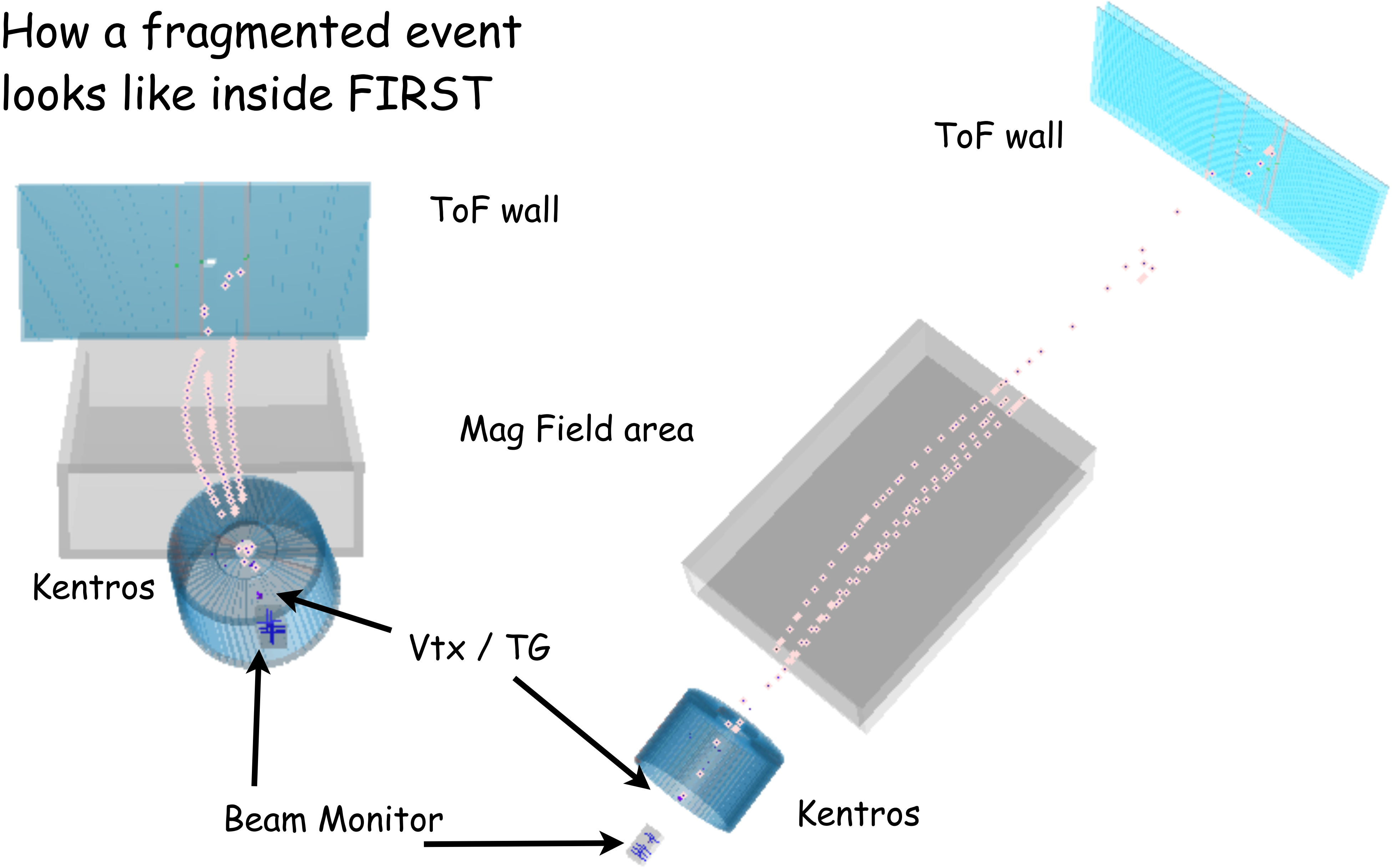
you can discriminate also particles which only hit the virtual plane in front of the TOFWALL and those which really traverse on of the TOFWALL slats of the front or rear wall (e.g. not passing the hole):

// "twn" counts all particles which traverse the plane in front of the TOF-Wall ("twpl...")
//and the particles traversing front and rear wall.
// To mark the regions which where really traversed by the particle i the flags "twSlNbS[i]=1" (for the plane),
// twSlID[0][i]!=0 if a slat was hit in the front wall and twSlID[2][i]!=0 if a slat was hit in the rear wall
// twSlID[1][i]!=0 or twSlID[3][i]!=0 if the same particle i also hit a second slat in the front/rear wall

- P.S: As far as I remember, we don't remove for the moment the corresponding hit in the second wall when we do the matching. Personally, i artificially remove hits coming from corresponding slat +/- 1 in the second wall but it is "raw" and a bit too restrictive, we should do something for that in the future. The second point is that my momentum change in trackforward function is a bit different because I adapt the step while taking into account the distance between the point to hit and the reconstructed point. We have to be sure that with the actual function in svn, we can reach the point to hit in X inside the tight threshold because of the X coordinate randomly generated. I cannot commit my function because it is "handmade" i.e. the numbers are chosen by "feeling" and observations. The problem can be "important" for protons where we can hit extreme slats. The same step in momentum modification for extreme X positions has not the same effect as for the central slats and it could be difficult to reach the X position inside the limits imposed by the tight threshold.

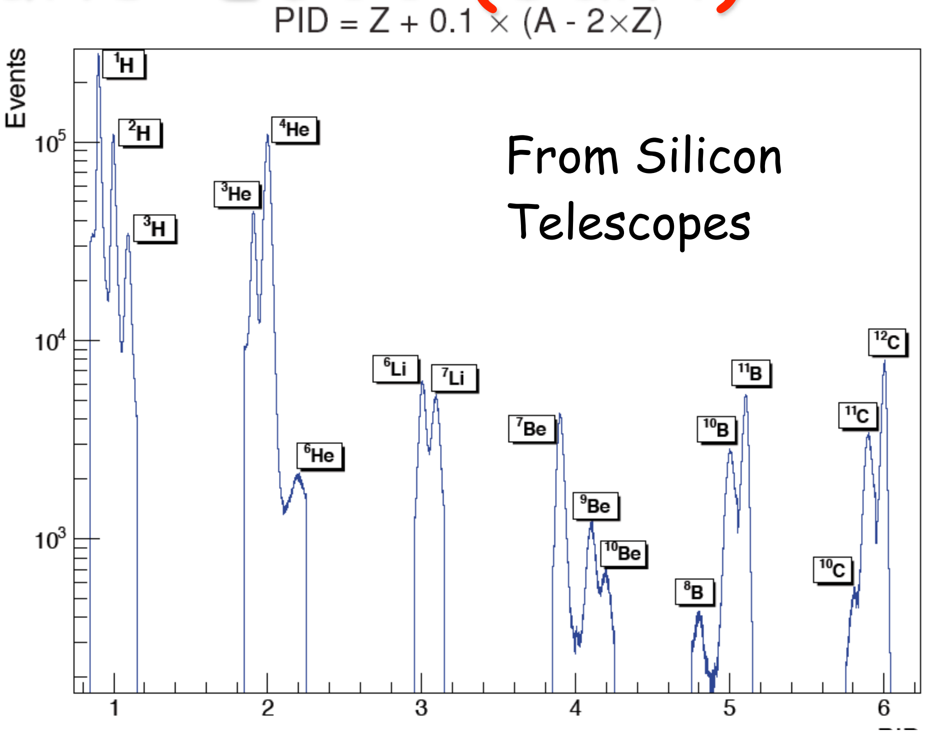
3D ev display

- How a fragmented event looks like inside FIRST

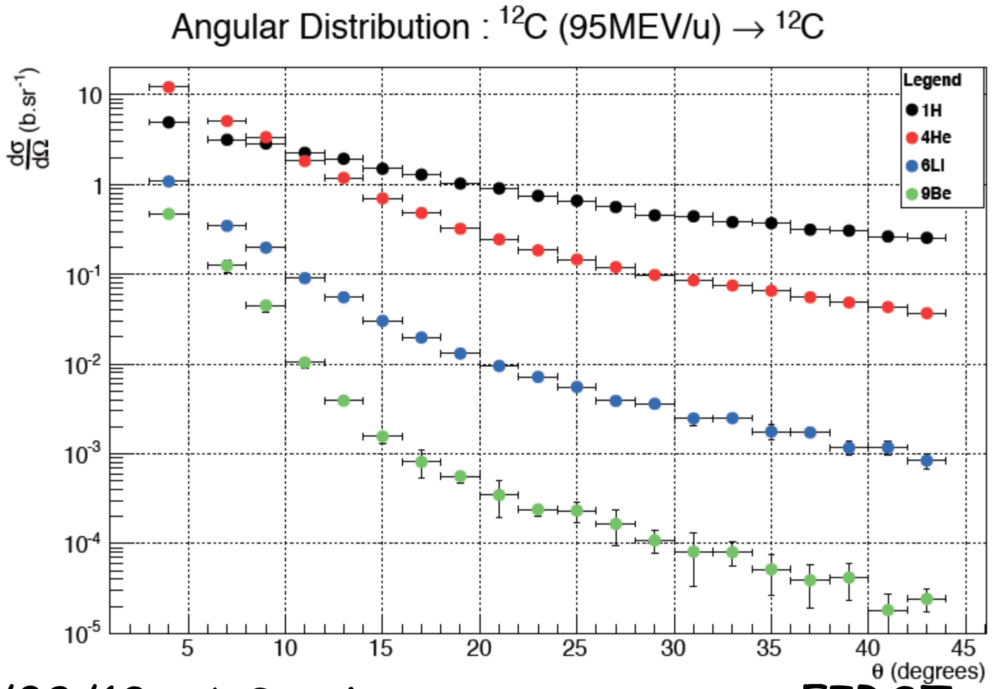


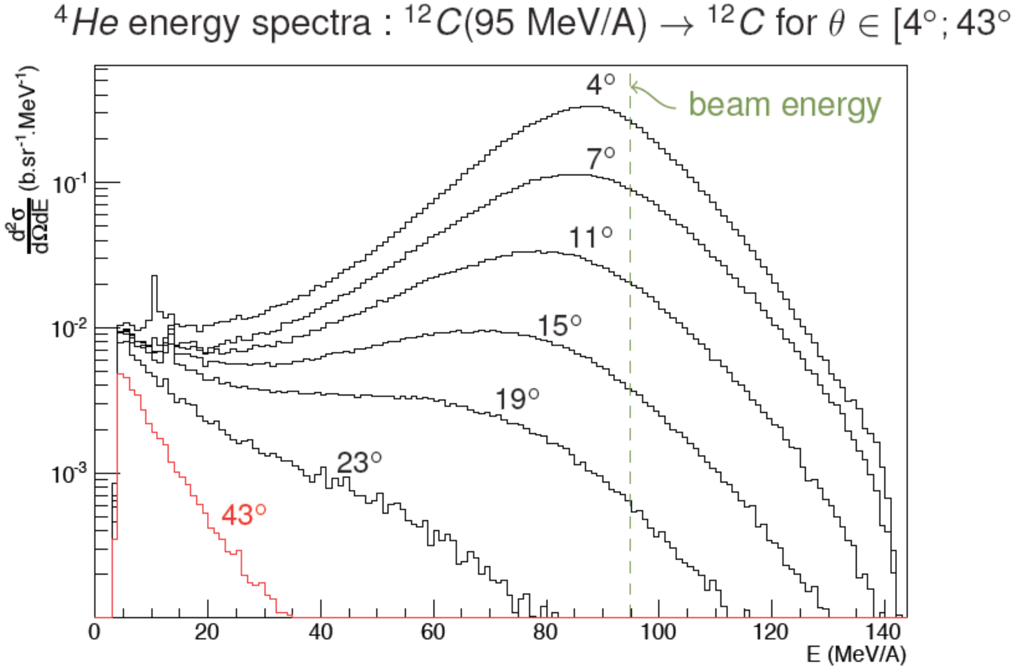
Our "competitors" results: E600 (Ganil)

- Obtained results for SDCS and DDCS
  - one interesting conclusion: Composite targets can be deduced from the cross sections of elemental targets (-> organic tissues)
  - Currently focusing on: **assessing systematics** and comparing with MC to benchmark difference nuclear MC models



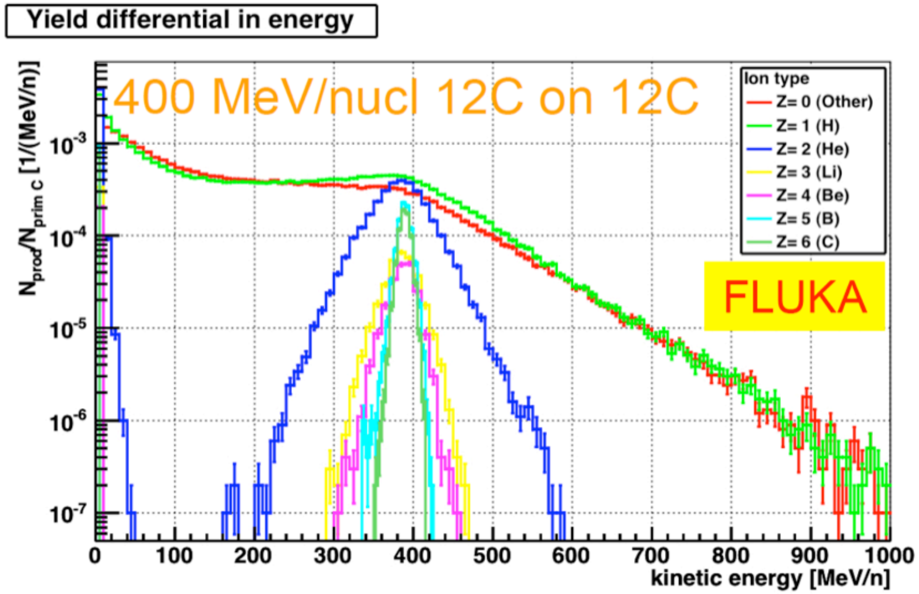
From Silicon Telescopes



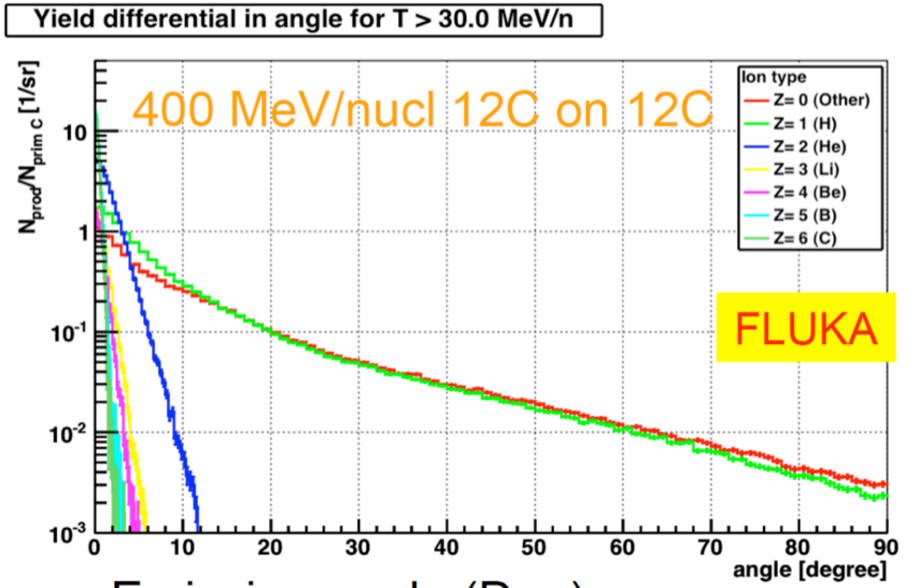


What we expect from simulations

- The Z>2 produced fragments approximately have the same velocity of the ^{12}C beam and are collimated in the forward direction
- The protons are the most abundant charged fragments with a wide β spectrum $0<\beta<0.6$ and with a wide angular distribution with long tail
- The Z>1 fragment are all emitted within 20 deg of angular aperture
- The dE/dx released by the fragment spans from ~2 to ~100 m.i.p.



Kinetic energy (MeV/nucl)



Emission angle (Deg)