Charged Particle Production in ^{12}C Fragmentation

Milano + Roma

FOOT Collaboration Meeting

Bologna, 4-5 Dicembre 2017

CNAO Test Beam - July 2017

- Dose Profiler characterisation with secondaries produced by 12C beam at different energy

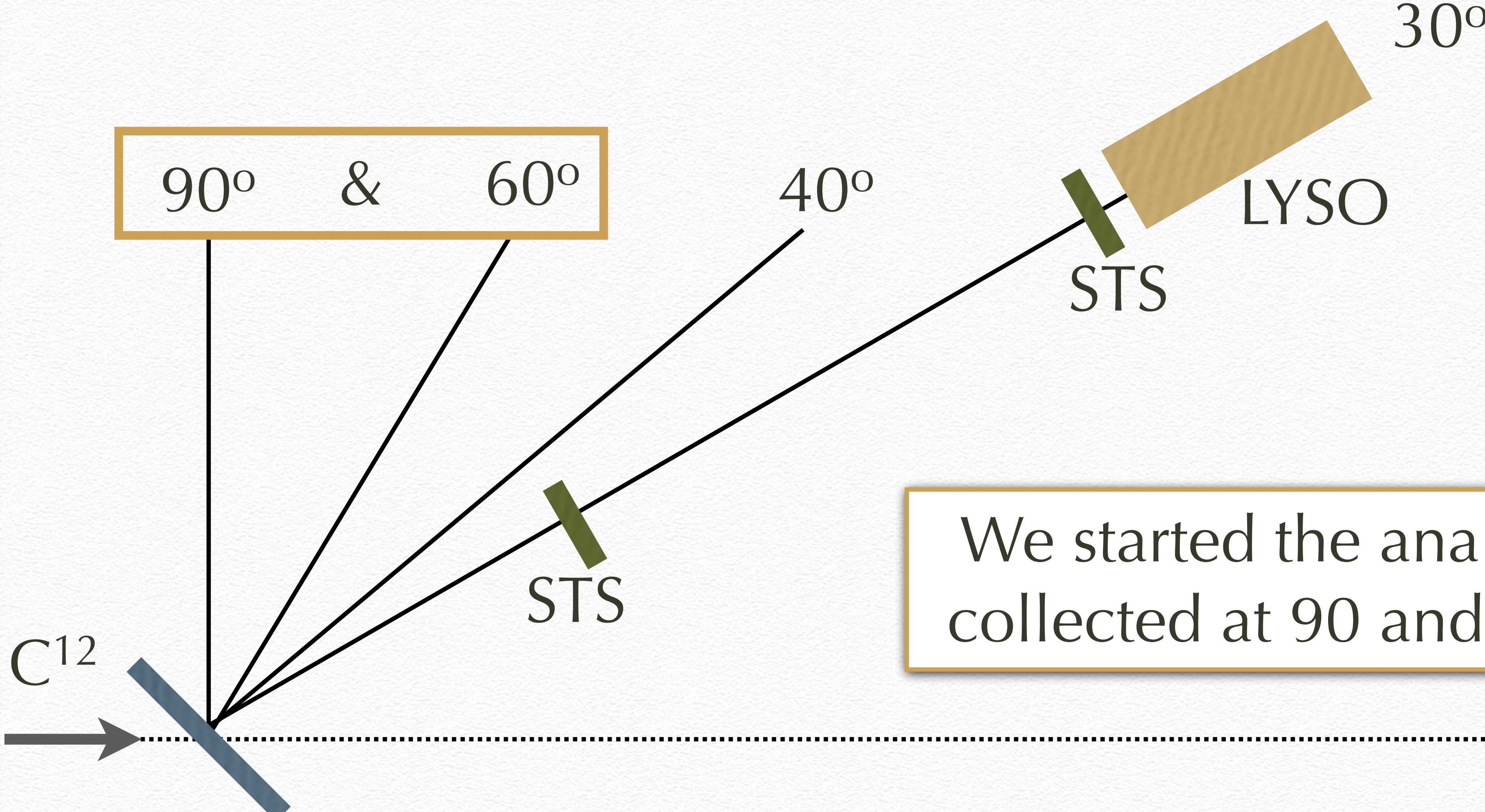
- Double Diff XSec of ^{12}C on H, C, O

- Energy range beyond GANIL (50 MeV/u & 95 MeV/u)
- 2 different angles (GANIL up to 45º)

Experimental SETUP

- 4 STS 2 mm for TOF measurements
- 2 LYSO 8 cm for PID

^{12}C beam energies:
115 MeV/u
151 MeV/u
221 MeV/u
280 MeV/u
352 MeV/u



We started the analysis of data collected at 90 and 60 degrees.

Thin Targets based on C,H and O elements:
C (1mm), C_bH_a (2mm), $C_5O_2H_8$ (2mm)

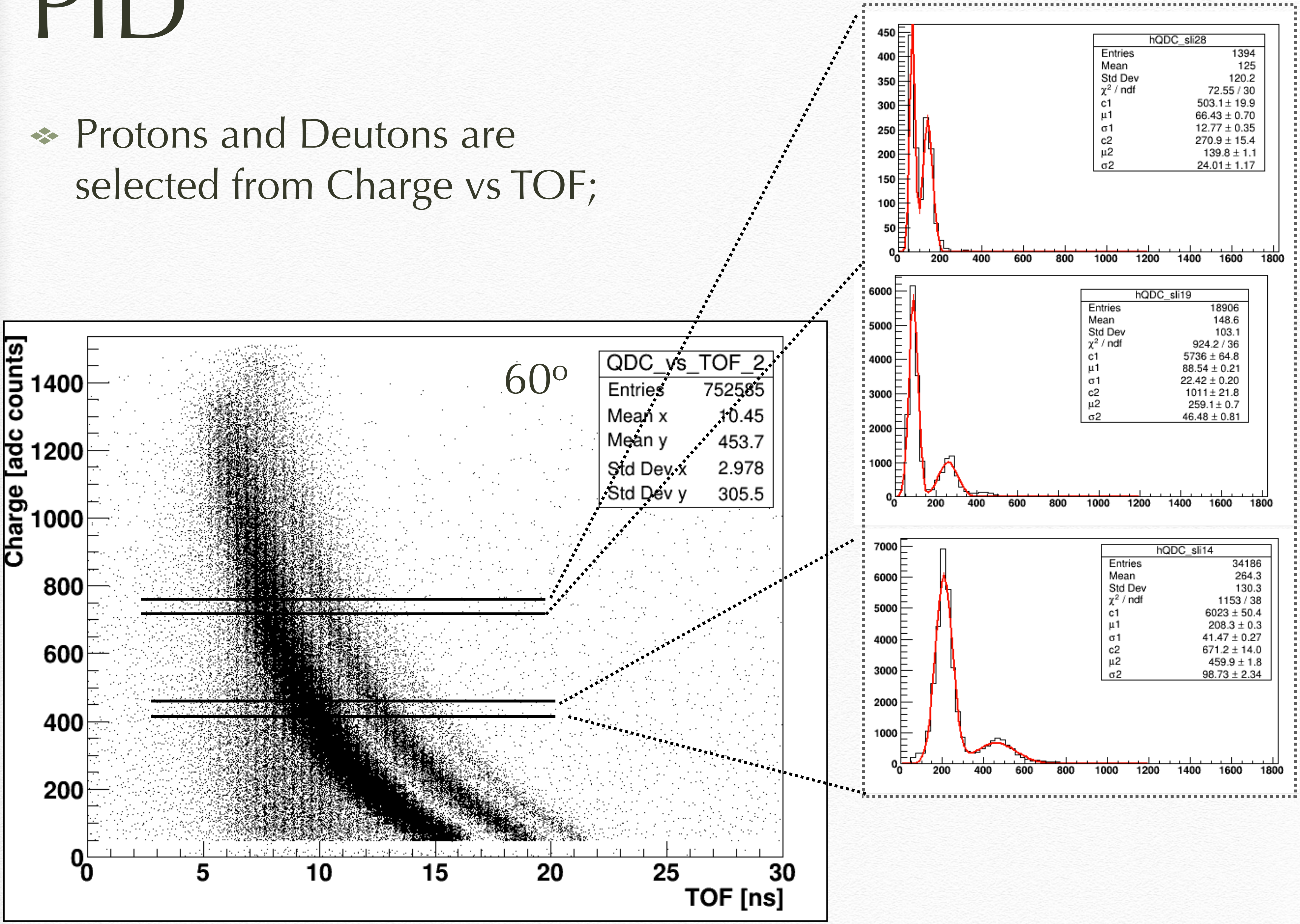
Particle IDentification

- Protons and Deutons (Tritons) are selected from Charge vs TOF;
- The PID is performed on the fragmentation data produced by all targets, all beam energies;

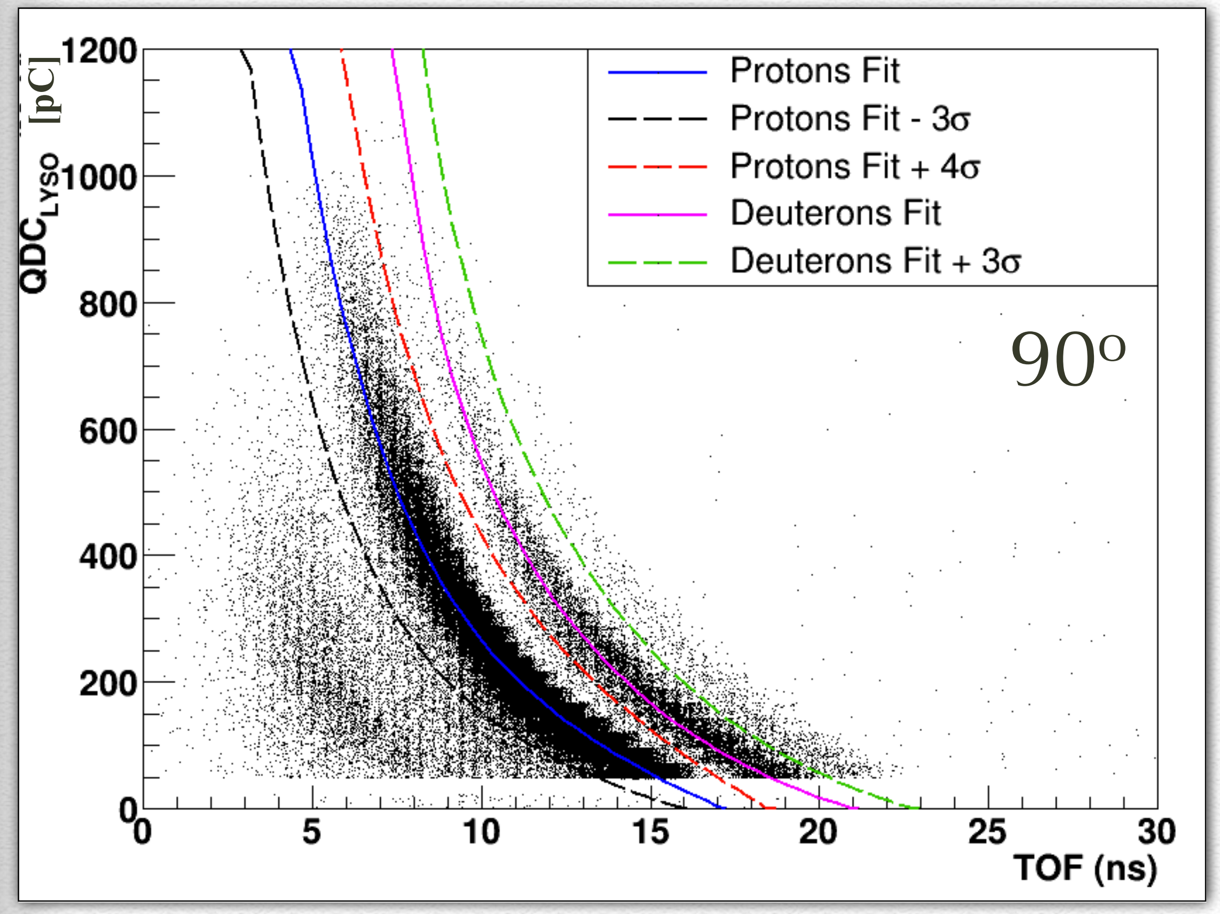
PID

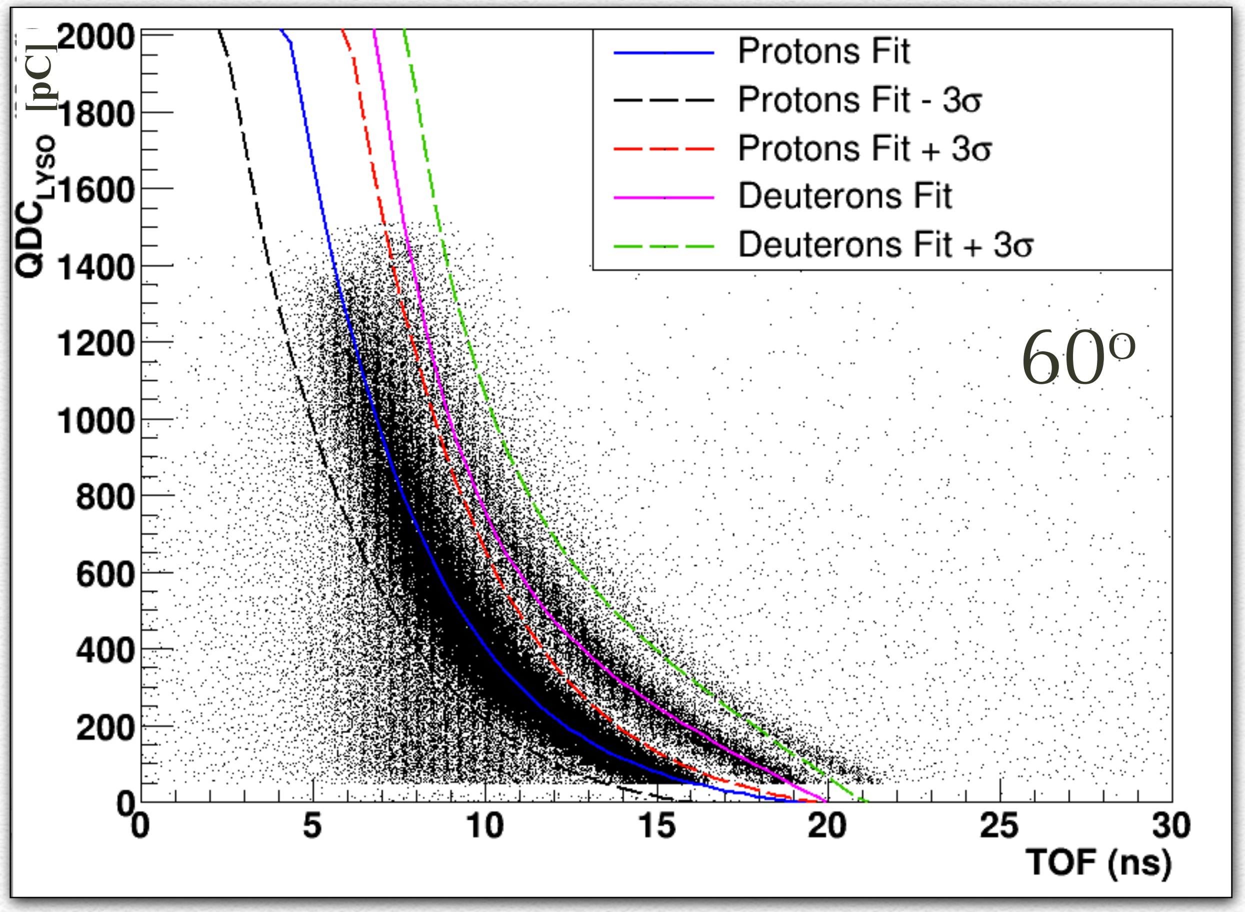
Those are only EXAMPLEs

- Protons and Deutons are selected from Charge vs TOF;



PID

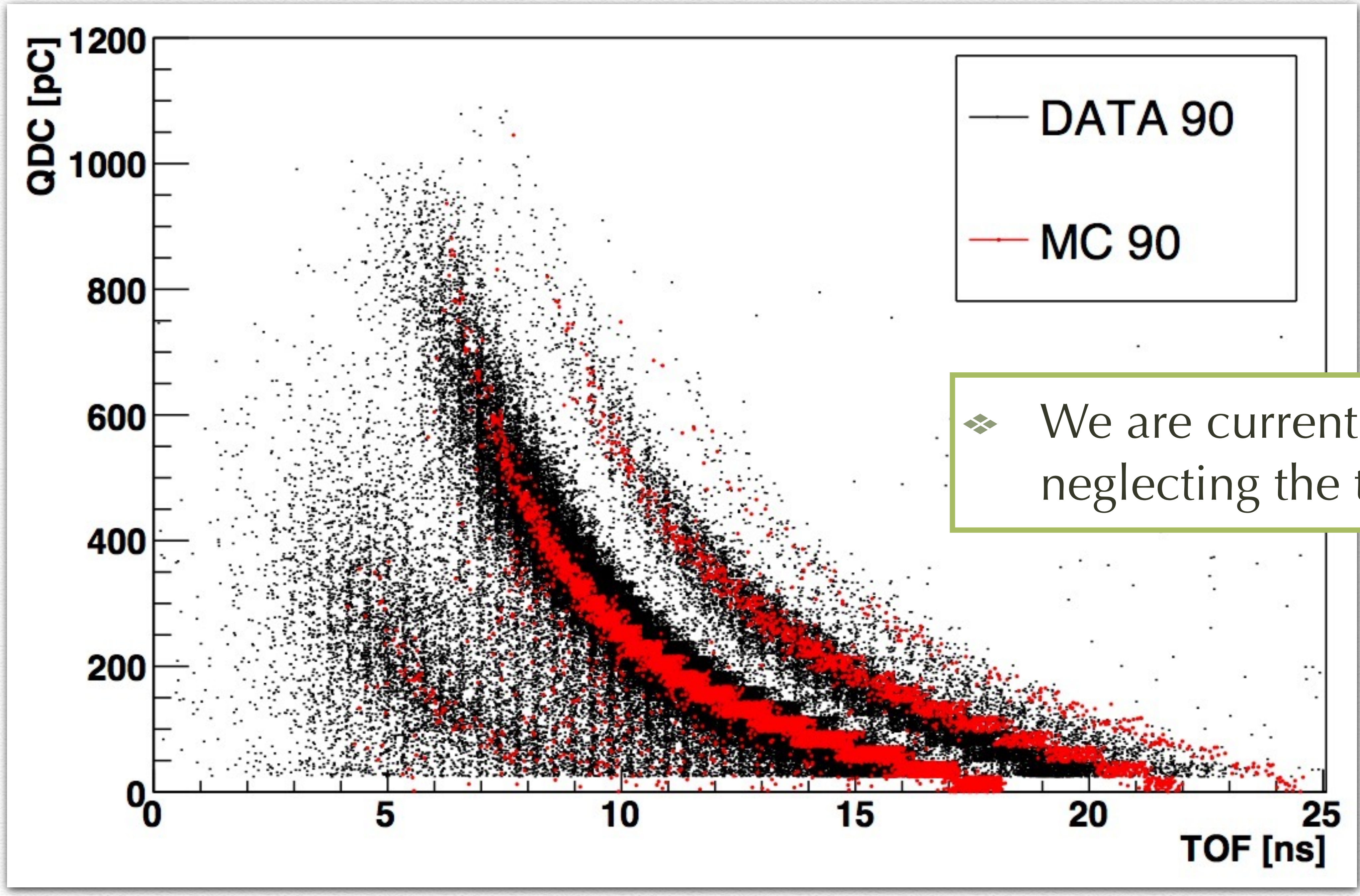




- As expected fragments production decreases for larger angles;

DATA/FLUKA comparison

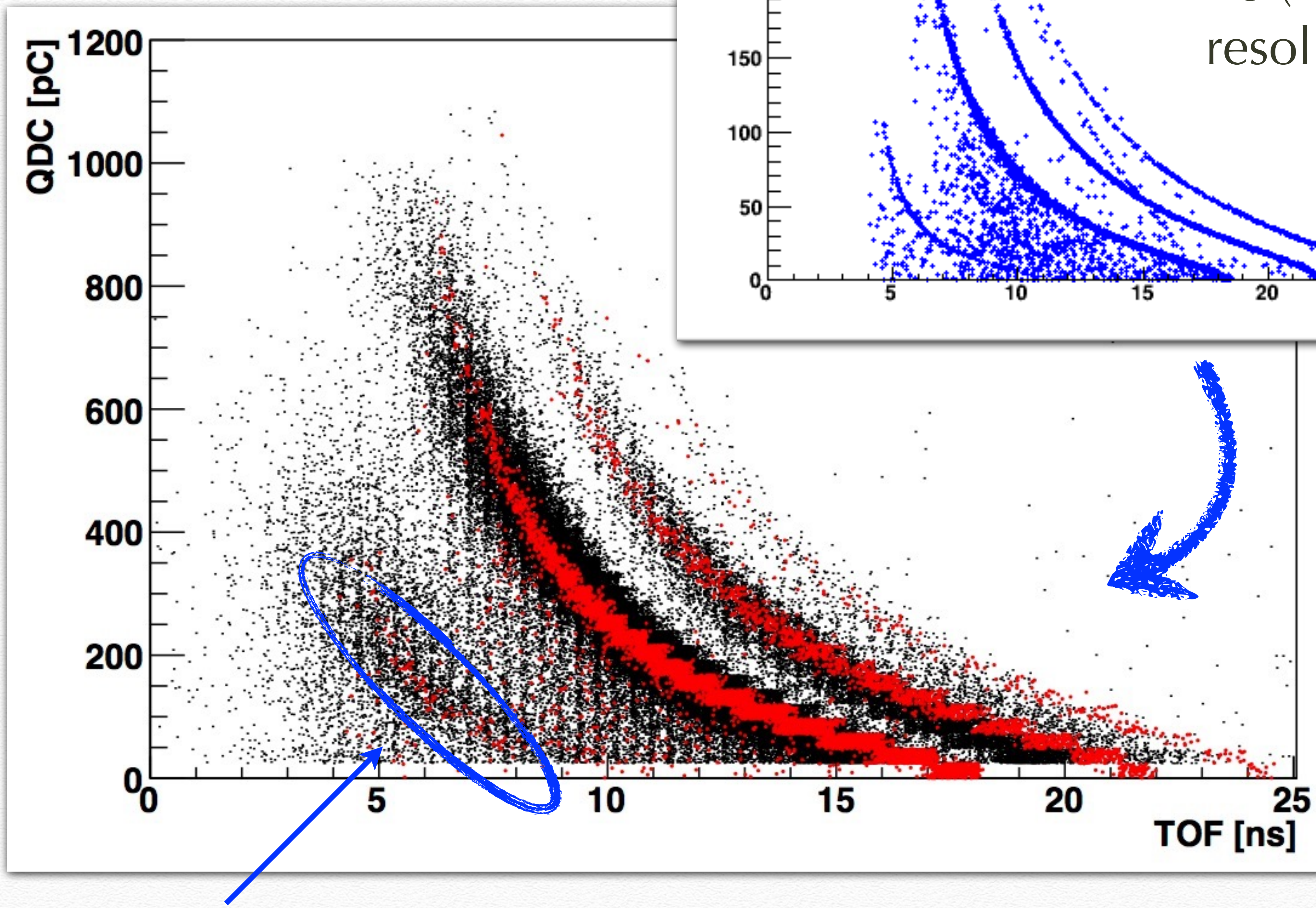
90º

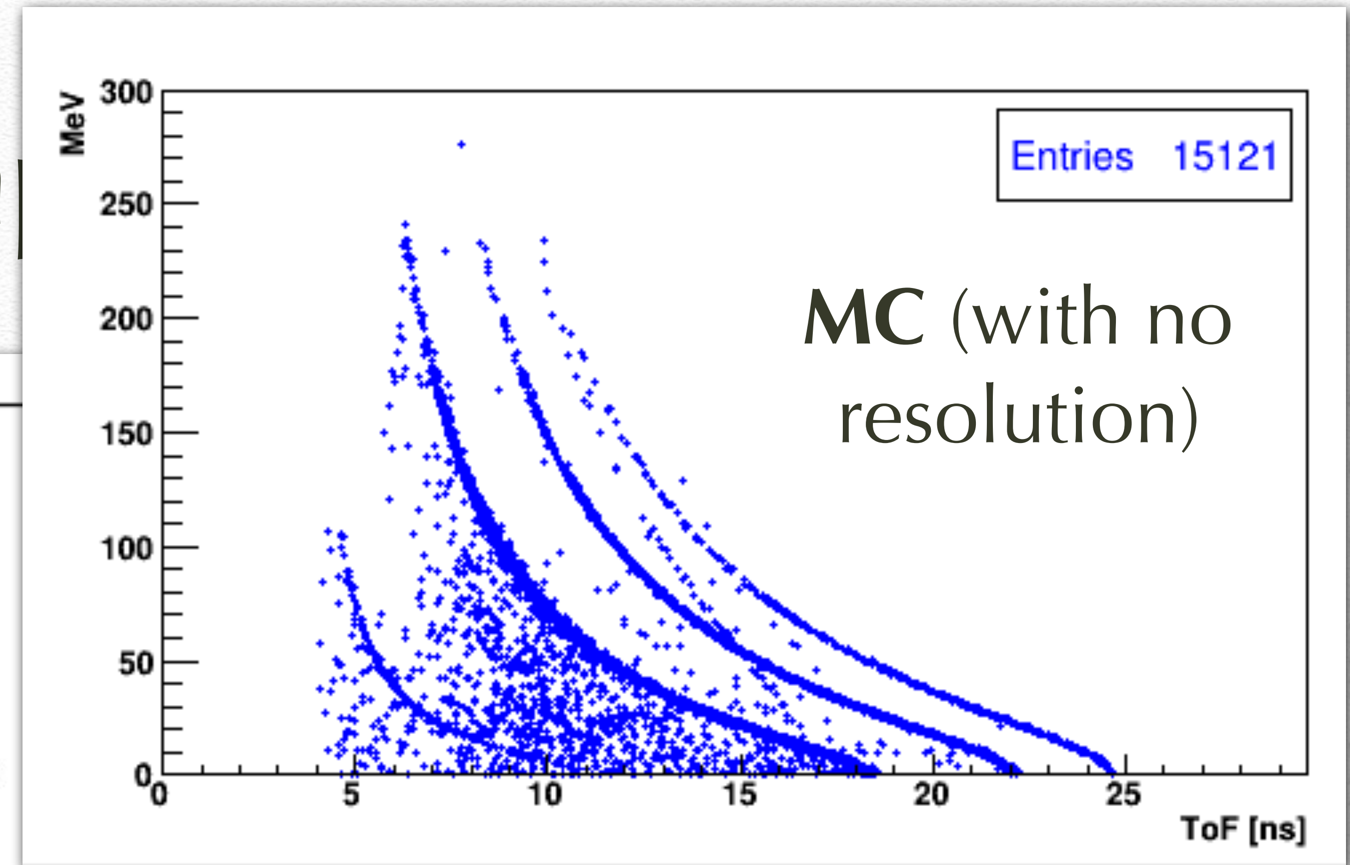


- We are currently neglecting the tritons;

MC and Data are coherent in timing.
The energy resolution in MC still has to be optimised.

DATA/FLUKA comp

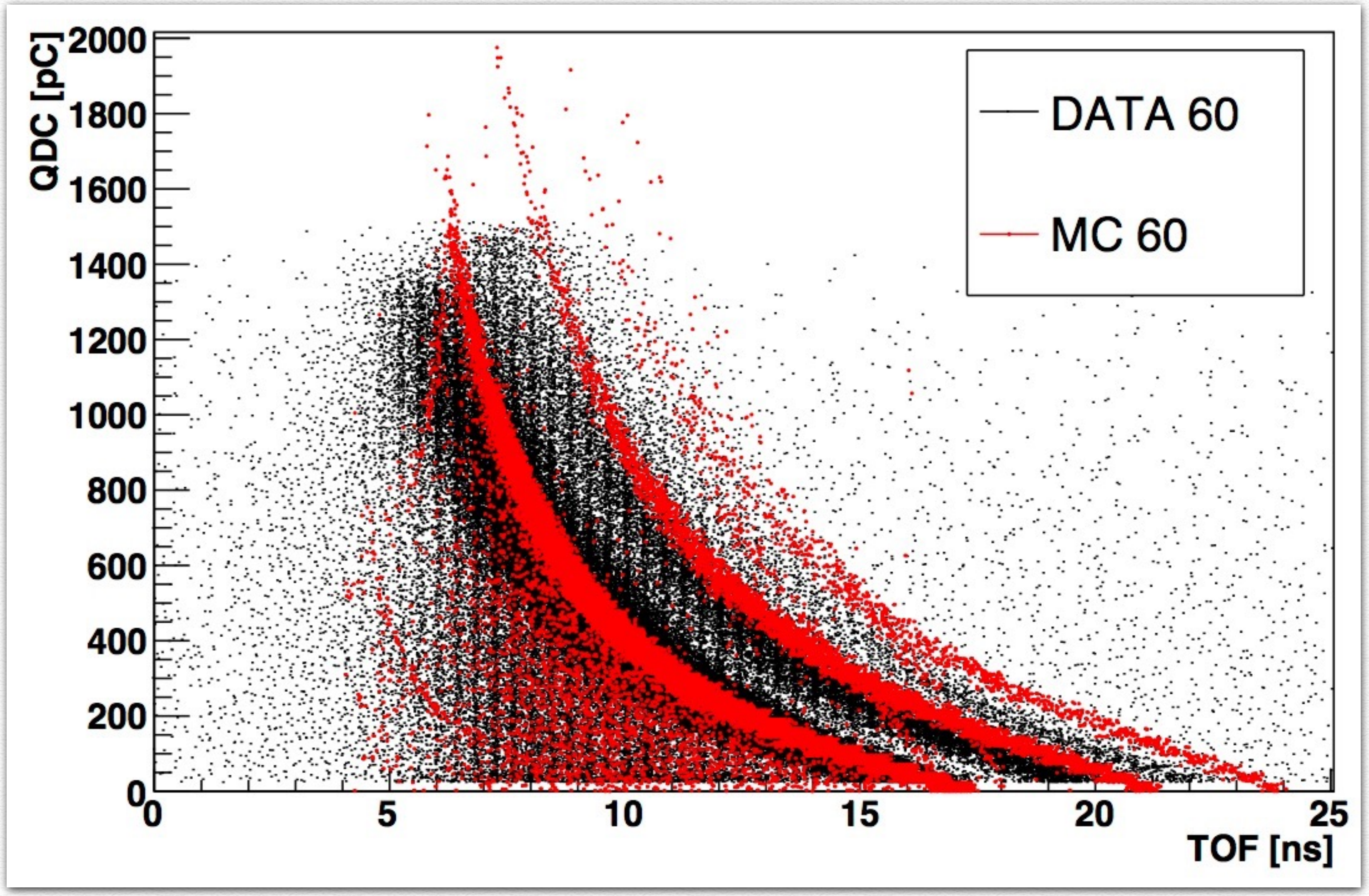




We see Pions! (for 12C-beam of 280 MeV/u and 350 MeV/u)

DATA/FLUKA comparison

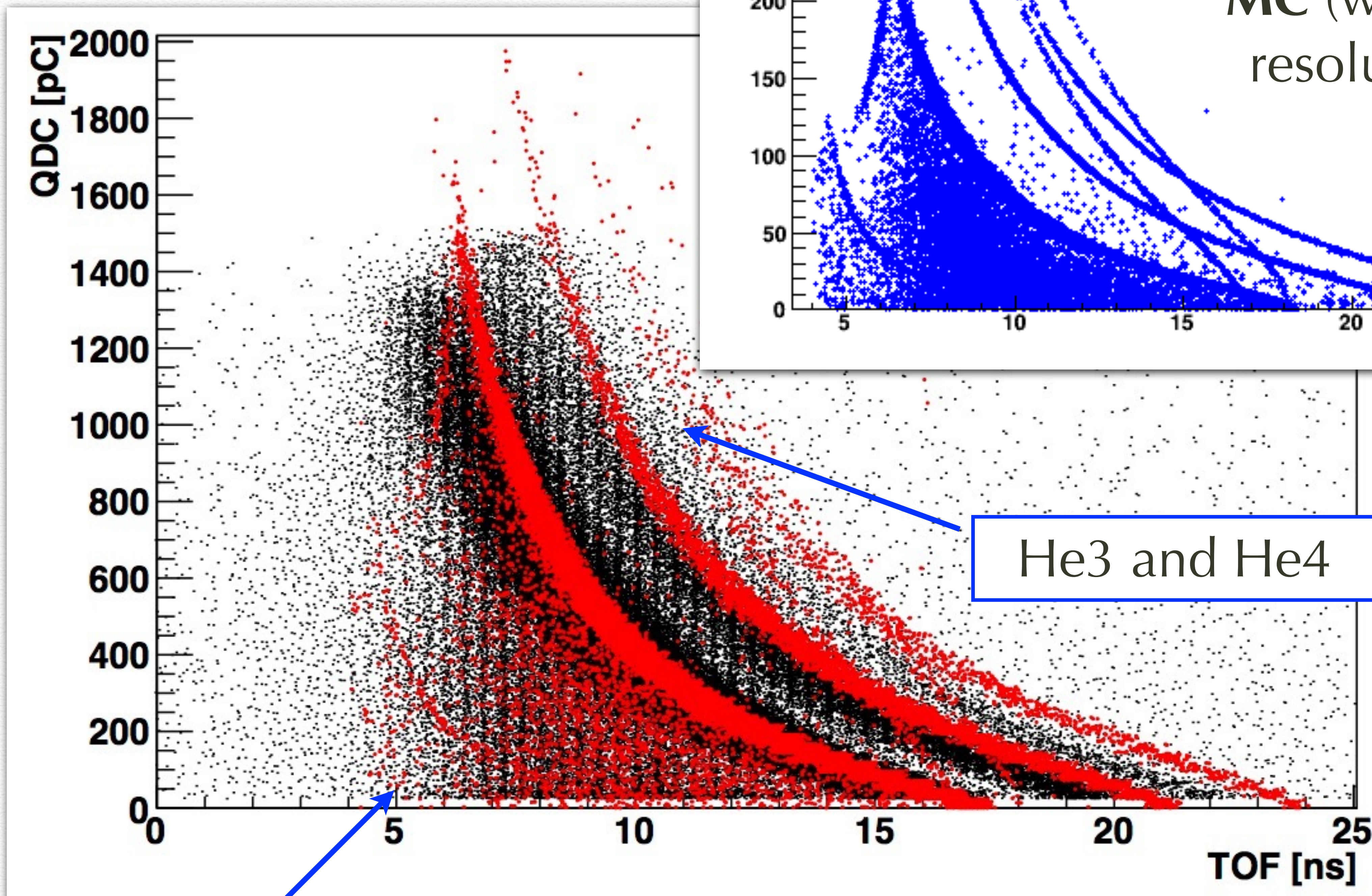
60º

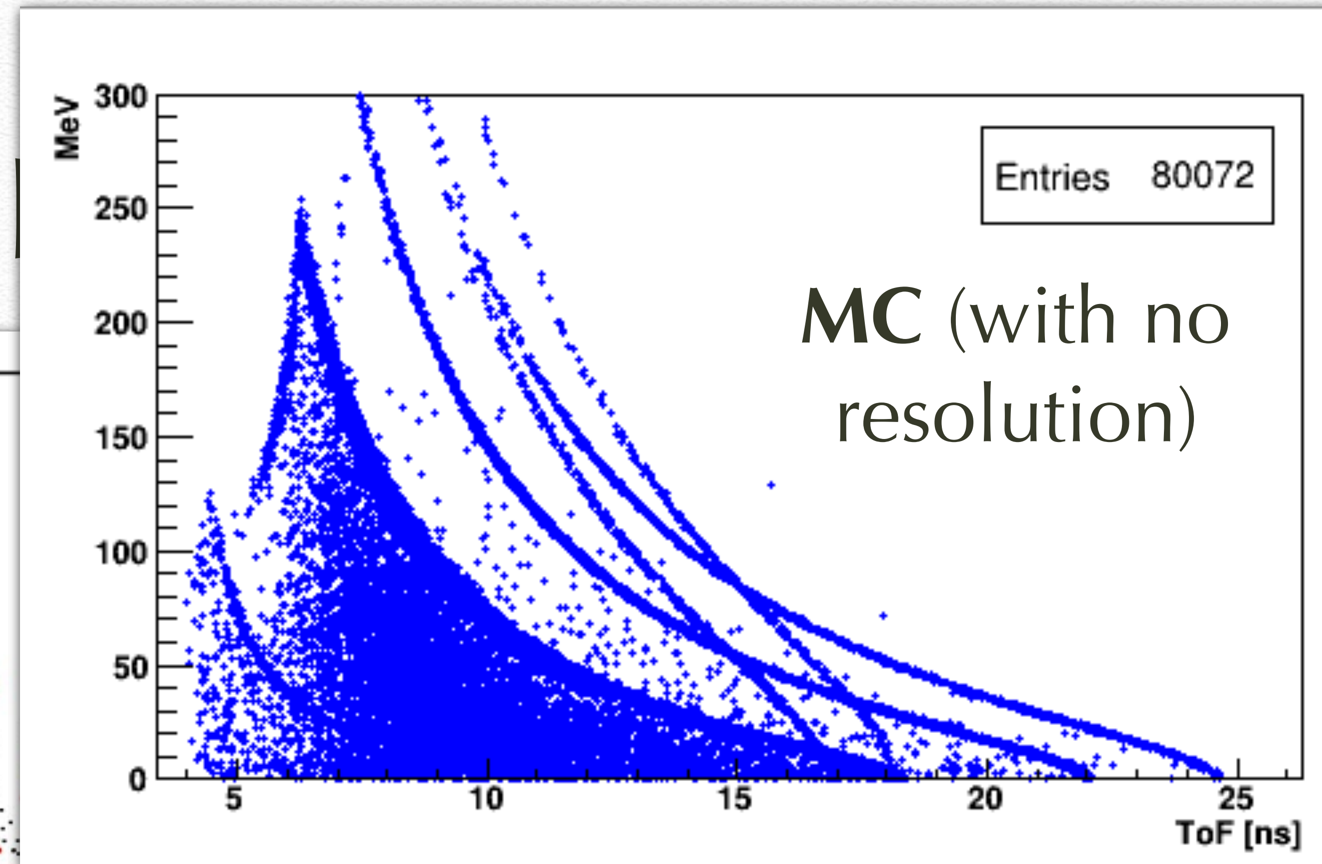


- We are up to now neglecting the tritons;

- As expected the fragments production increases with decreasing angle;

DATA/FLUKA com





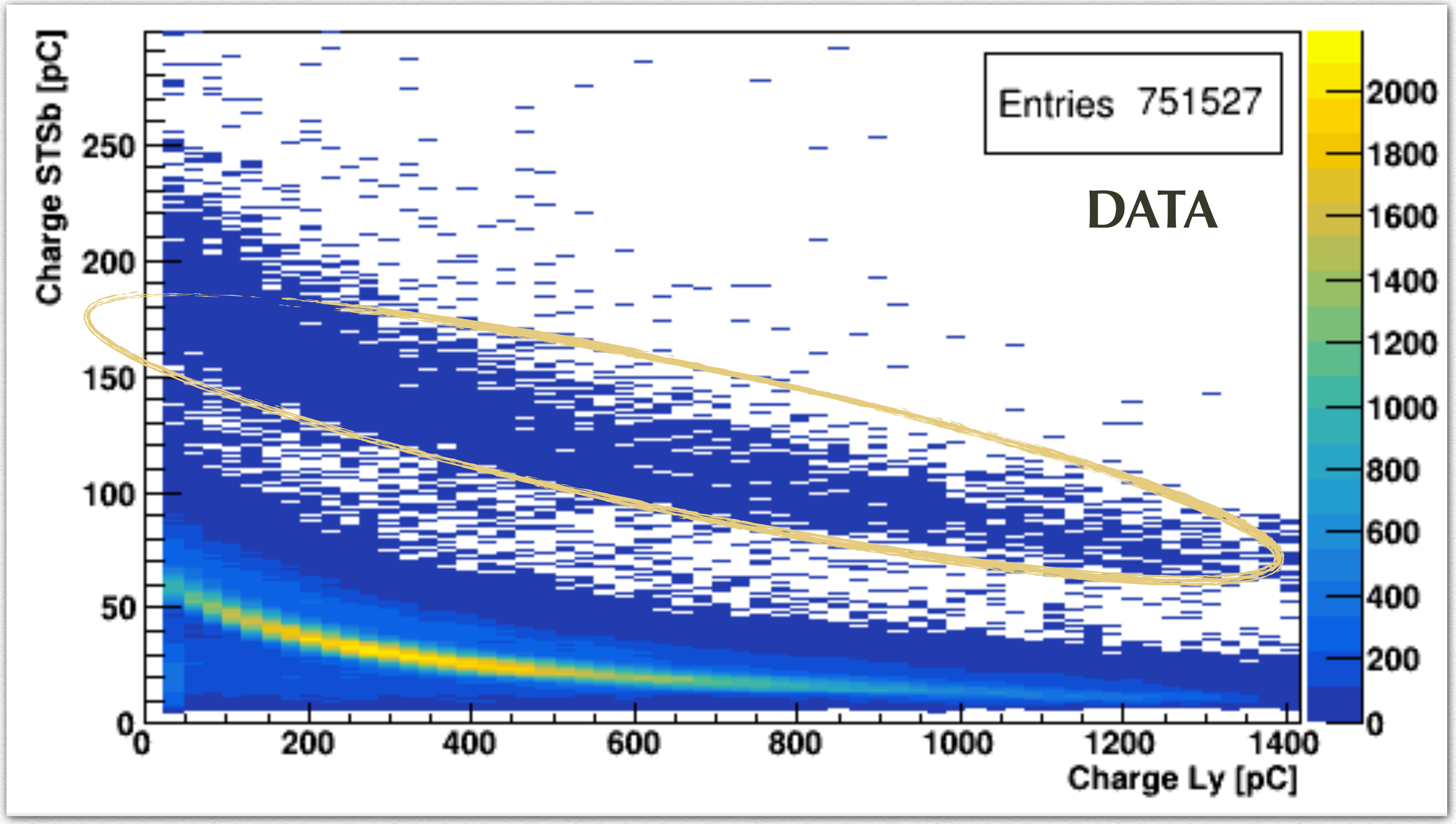
Pions just in MC. Why not in DATA 60º? Under study…

^{3}He and ^{4}He are not easily distinguishable in data but..

DATA/FLUKA comparison

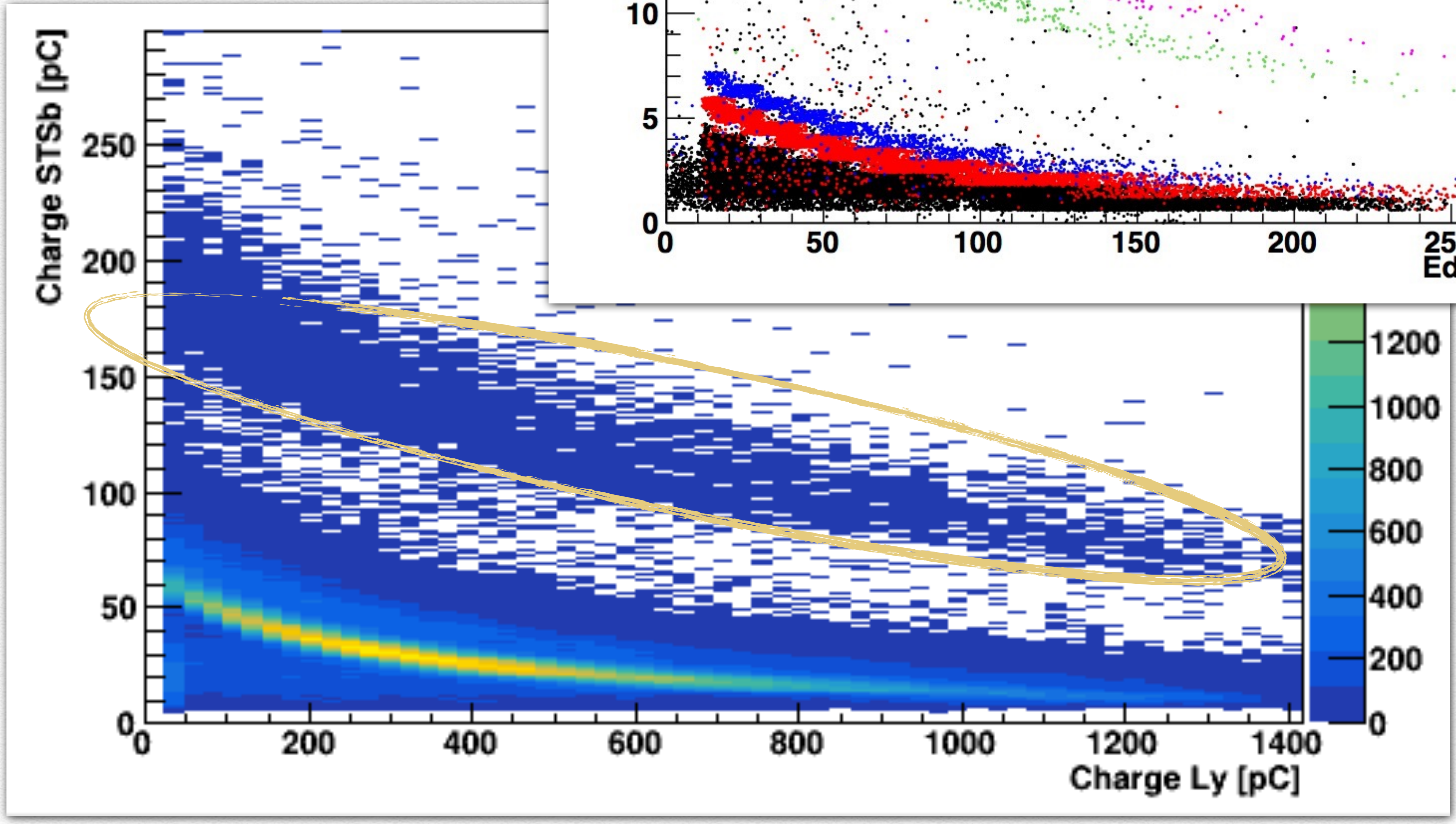
60°

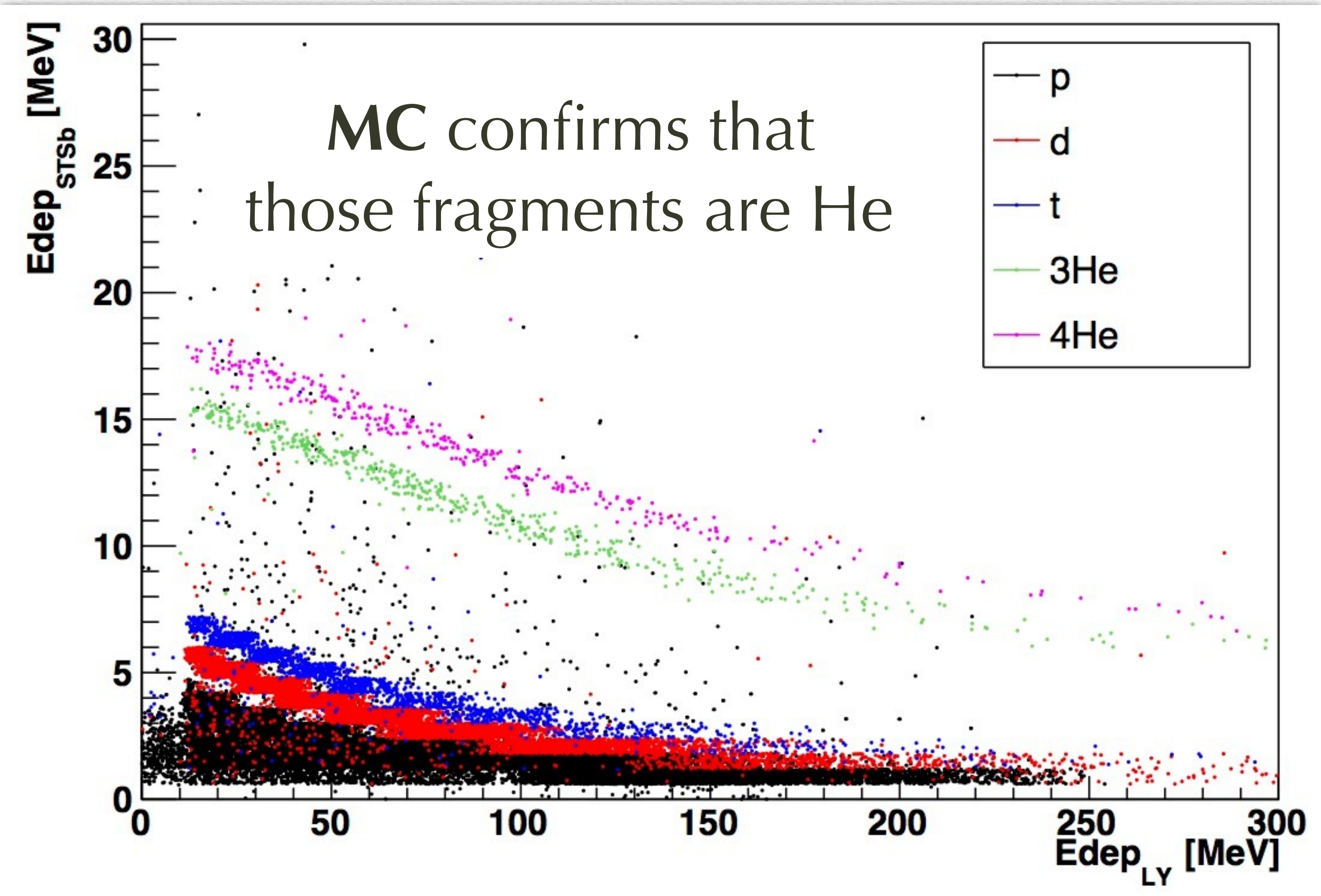
- In order to separate the contribution of **^{3}He and ^{4}He** from Z=1 (p,d,t) fragments we look at **dE/dx** (deposited energy in thin scintillators) and **E** (deposited energy in LYSO).



DATA/FLUKA

- In order to separate
(p,d,t) fragments we
scintillators) and **E** (

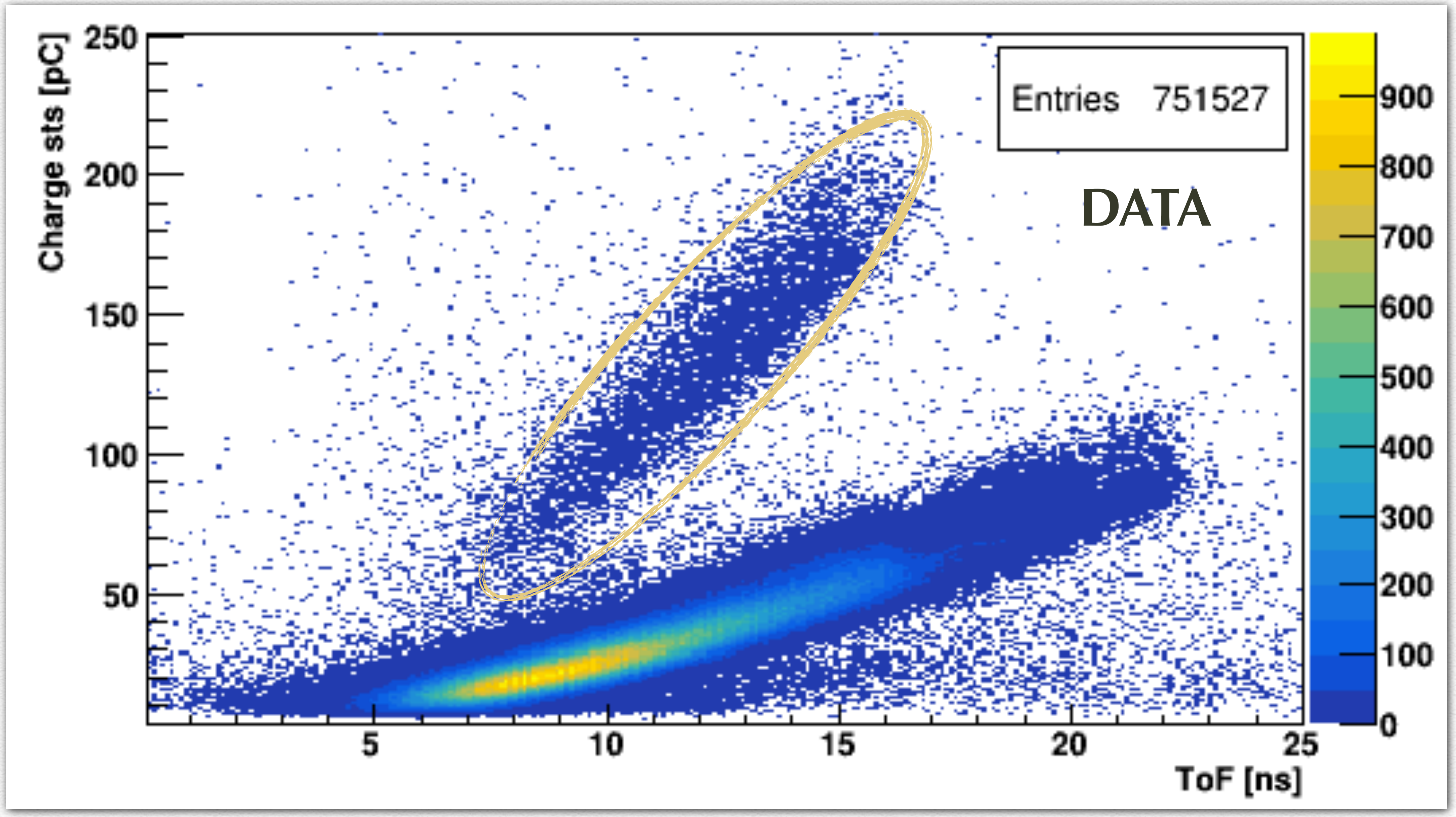




60º

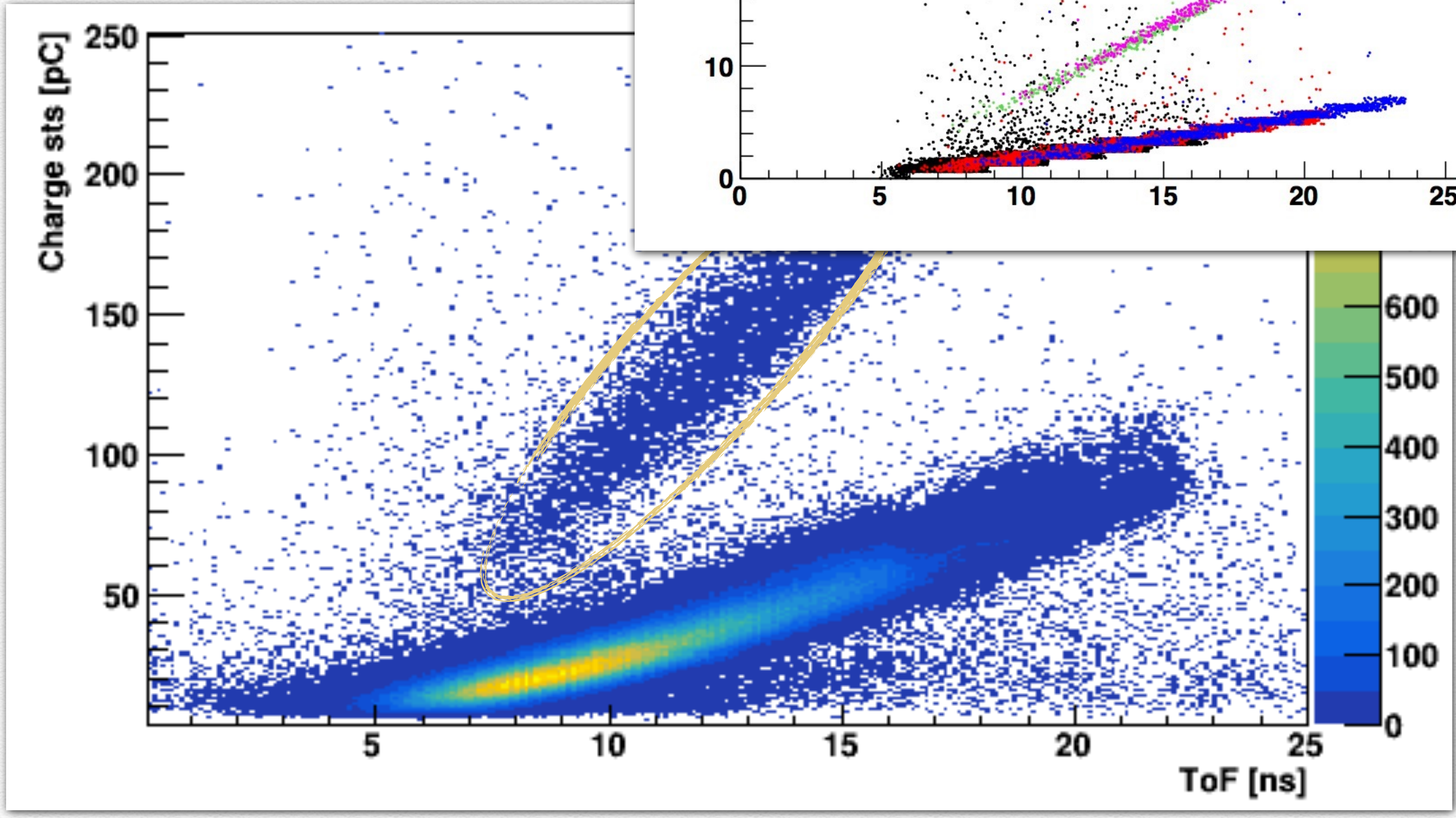
DATA/FLUKA comparison

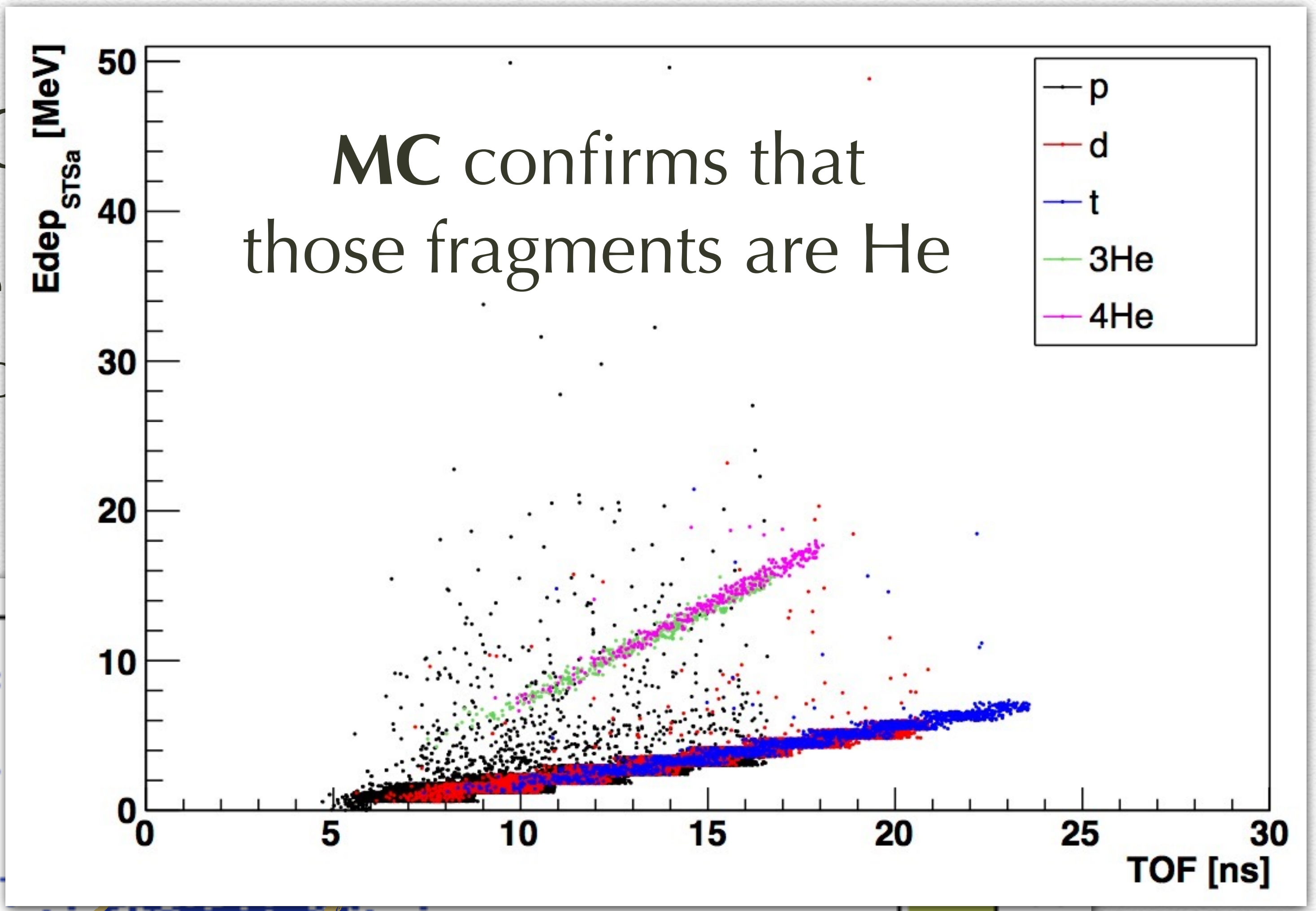
- In order to separate the contribution of ^{3}**He and** ^{4}**He** from Z=1 (p,d,t) fragments we look at **dE/dx** (deposited energy in thin scintillators) and **ToF**.



DATA/FLUKA co

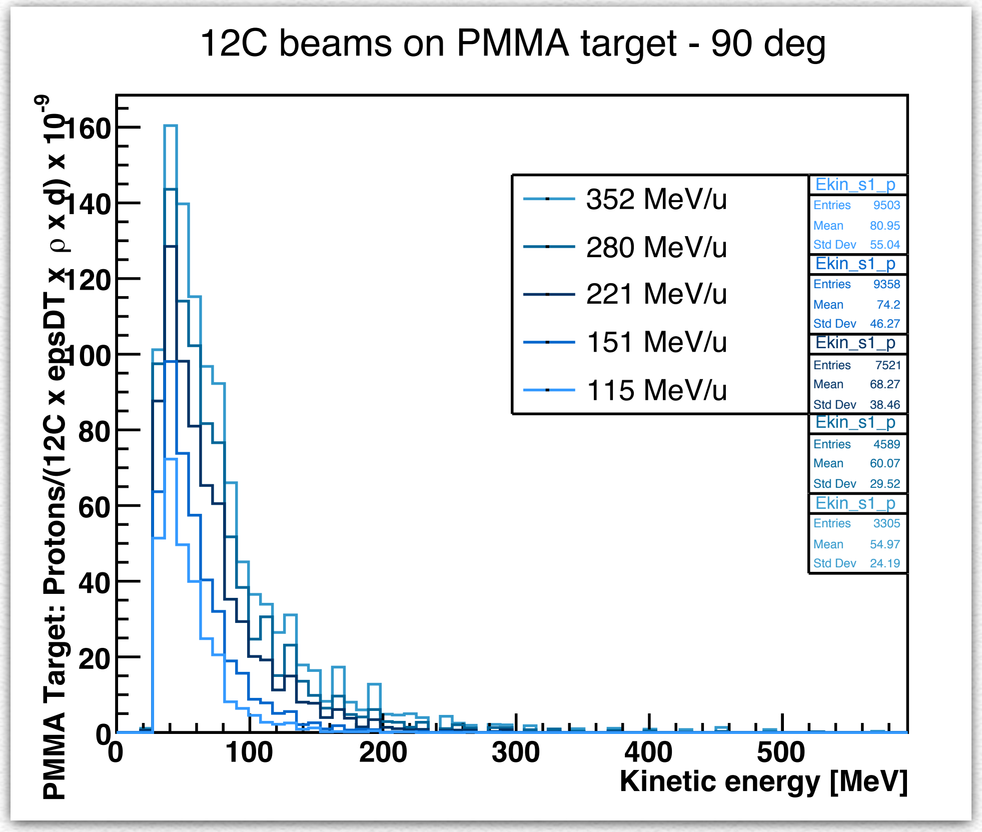
- In order to separate the (p,d,t) fragments we loo scintillators) and **ToF**.

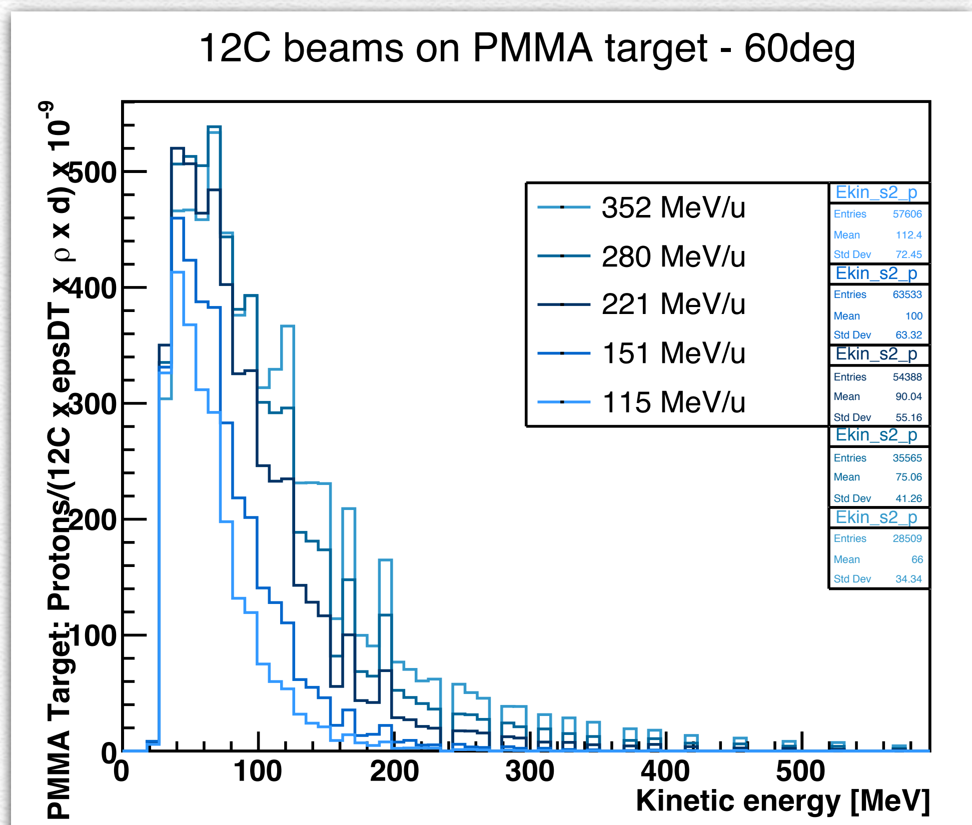




PMMA Target

NOT YET DETECTION and PID EFFICIENCIES!





- **Protons** (no He "decontamination");
- The 60 degree production is about twice the 90 degree one;
- Production is normalised to: N_{12C} x DeadTime x ρ x thickness

> • PMMA = $C_5O_2H_8$
> • thickness x = 2 mm
> • density* ρ = 1.19 g/cm3

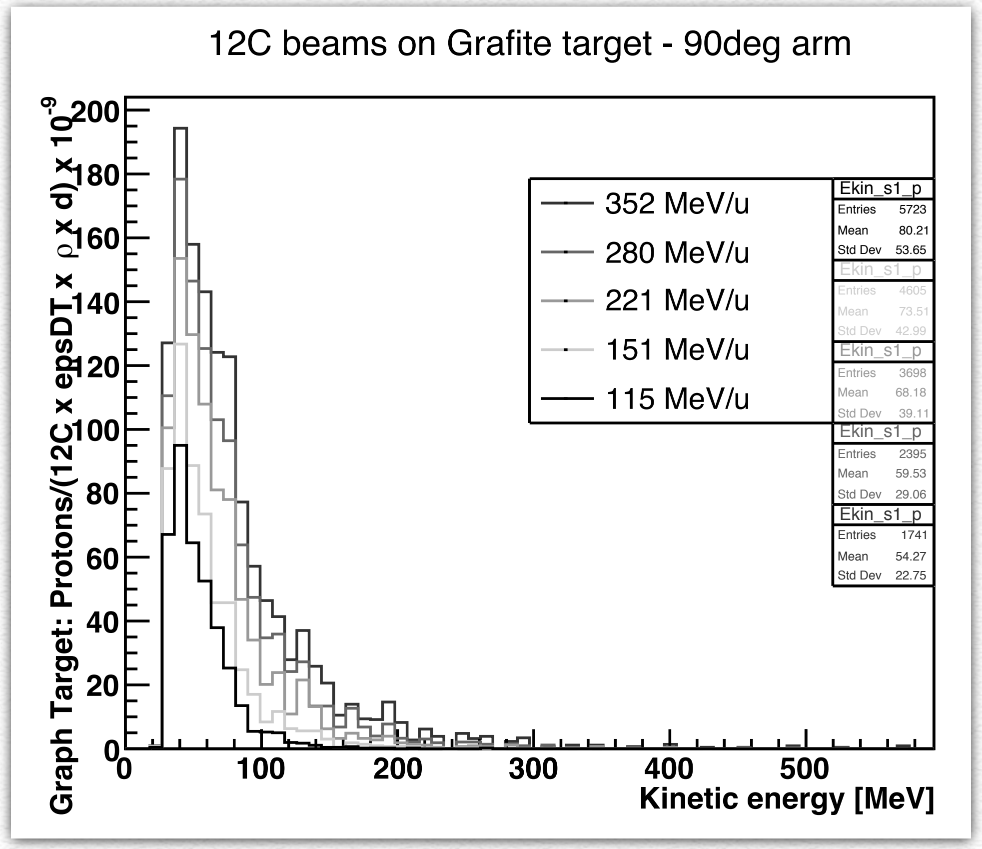
Mi-service Measurements

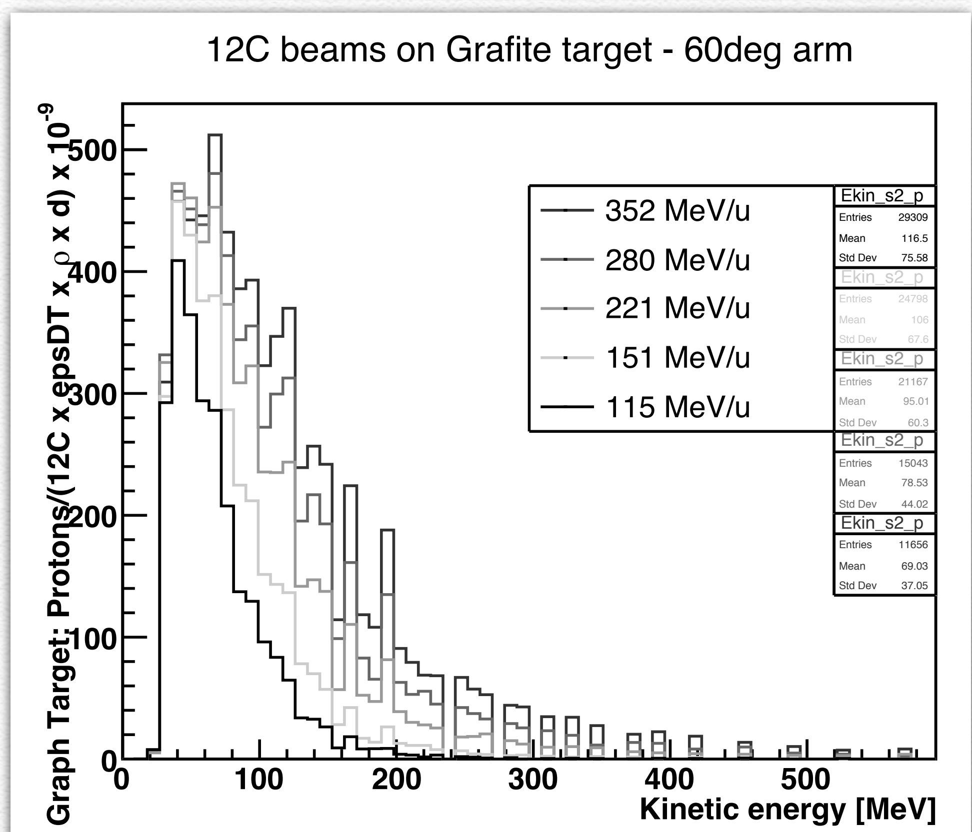
weight = 6.25 g
Volume = 5.30 cm^3
rho = 1.18 g/cm^3 (expected 1.19)

* From Catania

Graphite Target

NOT YET DETECTION and PID EFFICIENCIES!





- **Protons** (no He "decontamination");
- The 60 degree production is about twice the 90 degree one;
- Production is normalised to: N_{12C} x DeadTime x ρ x thickness

• Graphite = C
• thickness x = 1 mm
• flexible graphite 99,8%
• density* ρ = 0.9-1.3 g/cm3

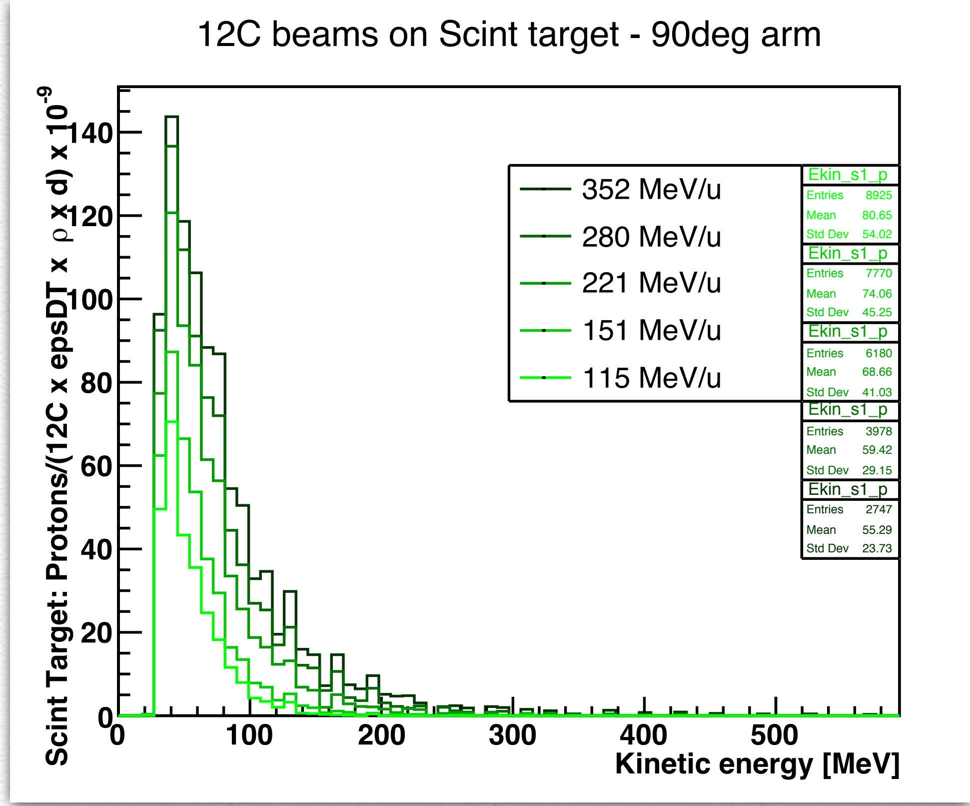
Mi-service Measurements

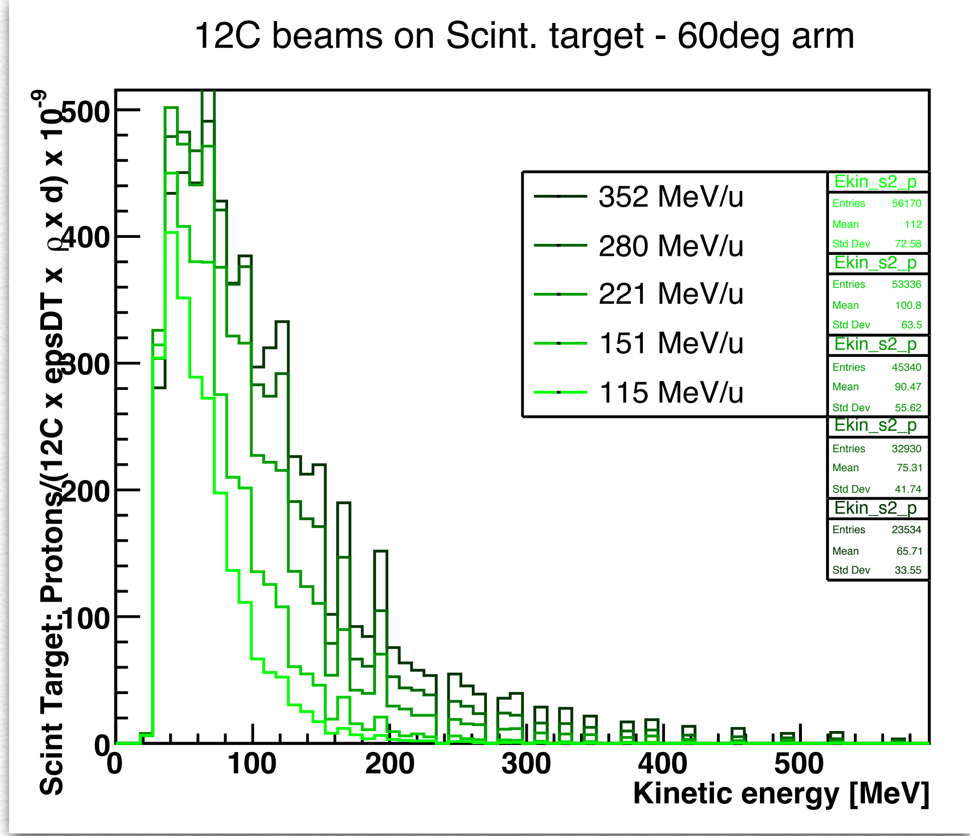
weight = 2.65 g
Volume = 2.83 g/cm^3
rho = 0.94 g/cm^3

* From Catania

Scintillator Target

NOT YET DETECTION and PID EFFICIENCIES!





- **Protons** (no He “decontamination”);
- The 60 degree production is about twice the 90 degree one;
- Production is normalised to: N_{12C} x DeadTime x ρ x thickness

> - EJ-212 = C_bH_a
> - a: 5.17 10^{22} H/cm3
> - b: 4.69 10^{22} C/cm3
> - thickness x = 2 mm
> - density* ρ = 1.023 g/cm3

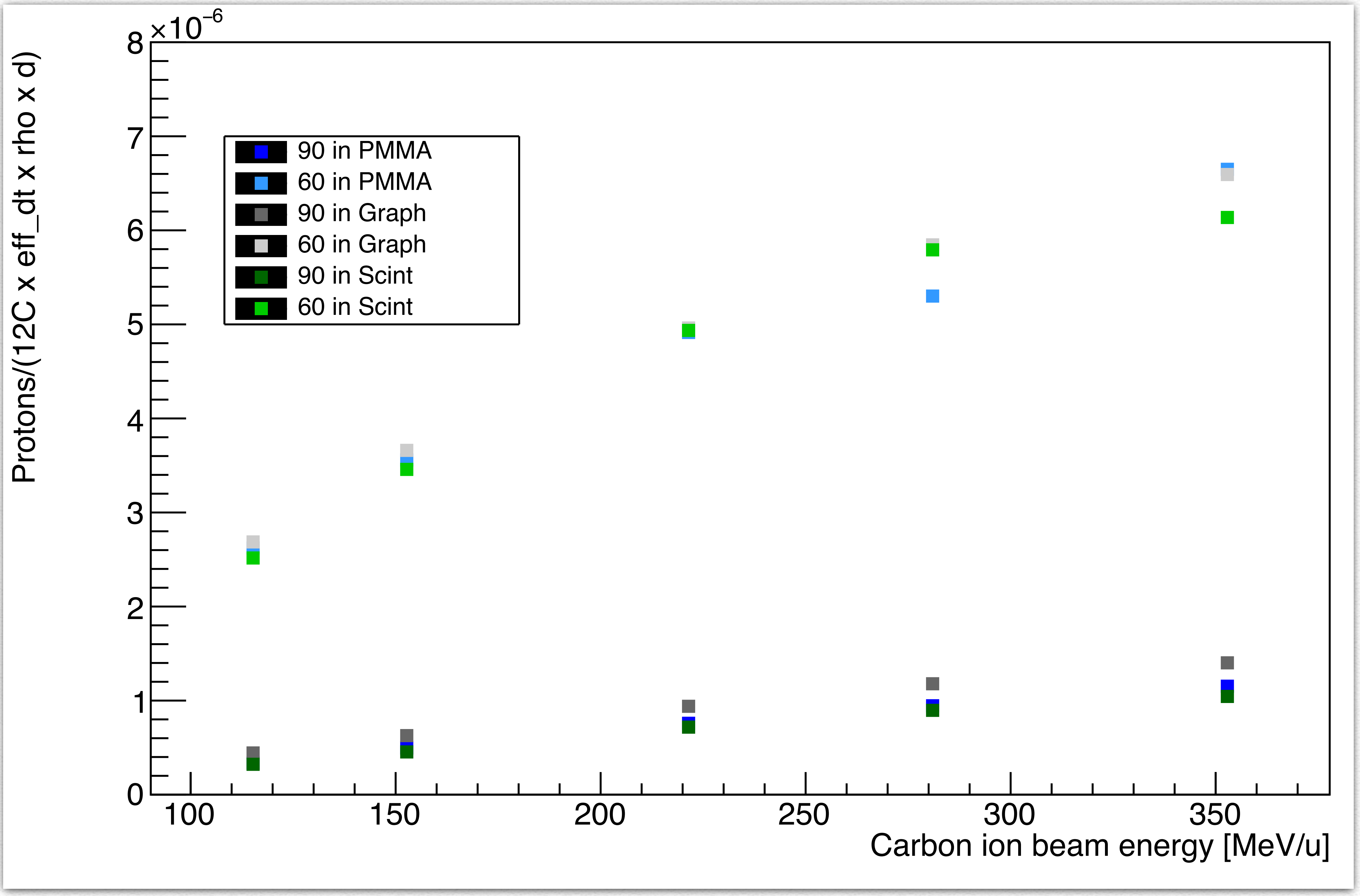
<u>Mi-service Measurements</u>

weight = 5.05 g
Volume = 4.93 cm^3
rho = 1.024 g/cm^3 (expected 1.023)

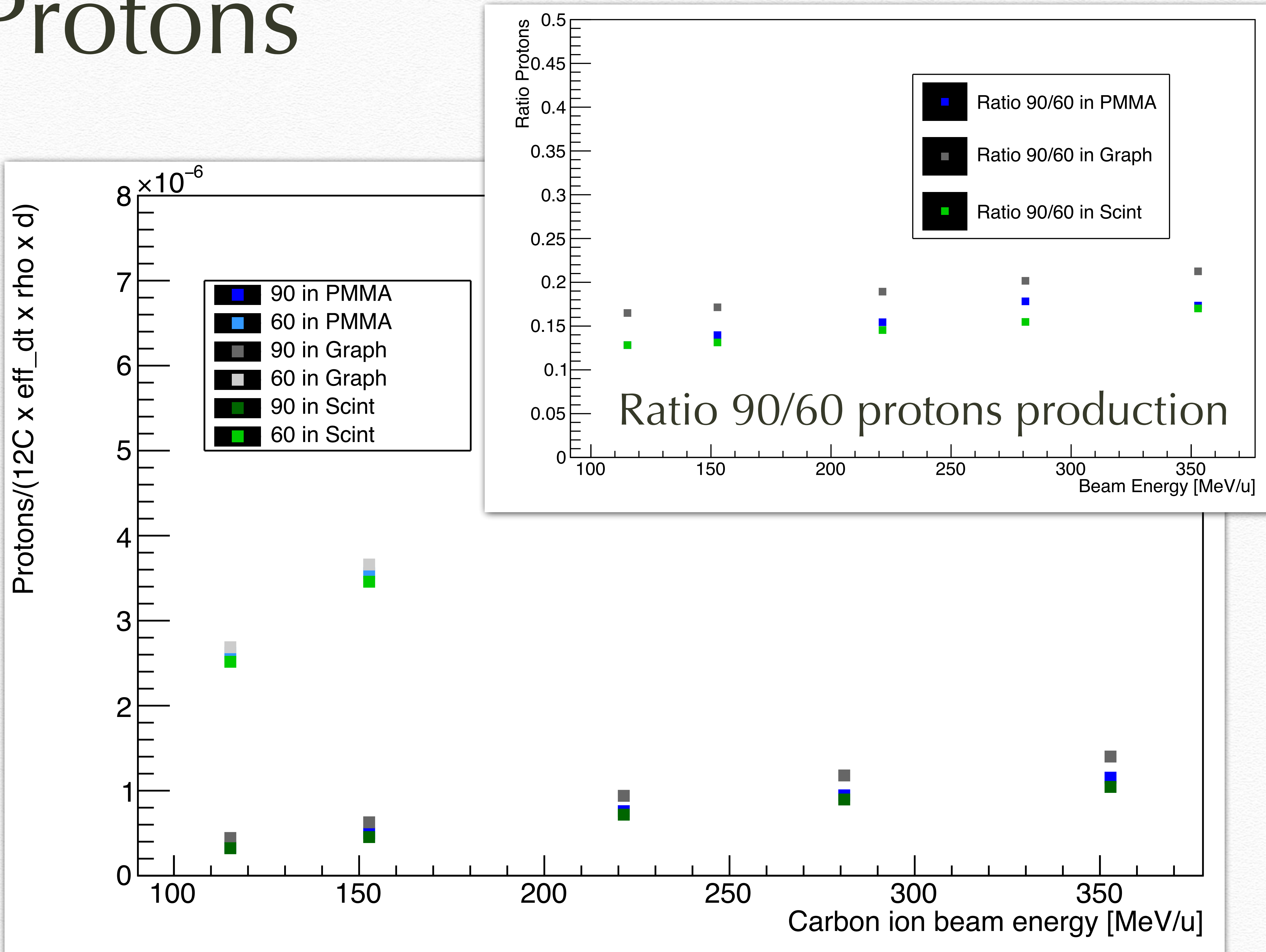
Protons

NOT YET DETECTION and PID EFFICIENCIES!

Only statistical errors included.



Protons

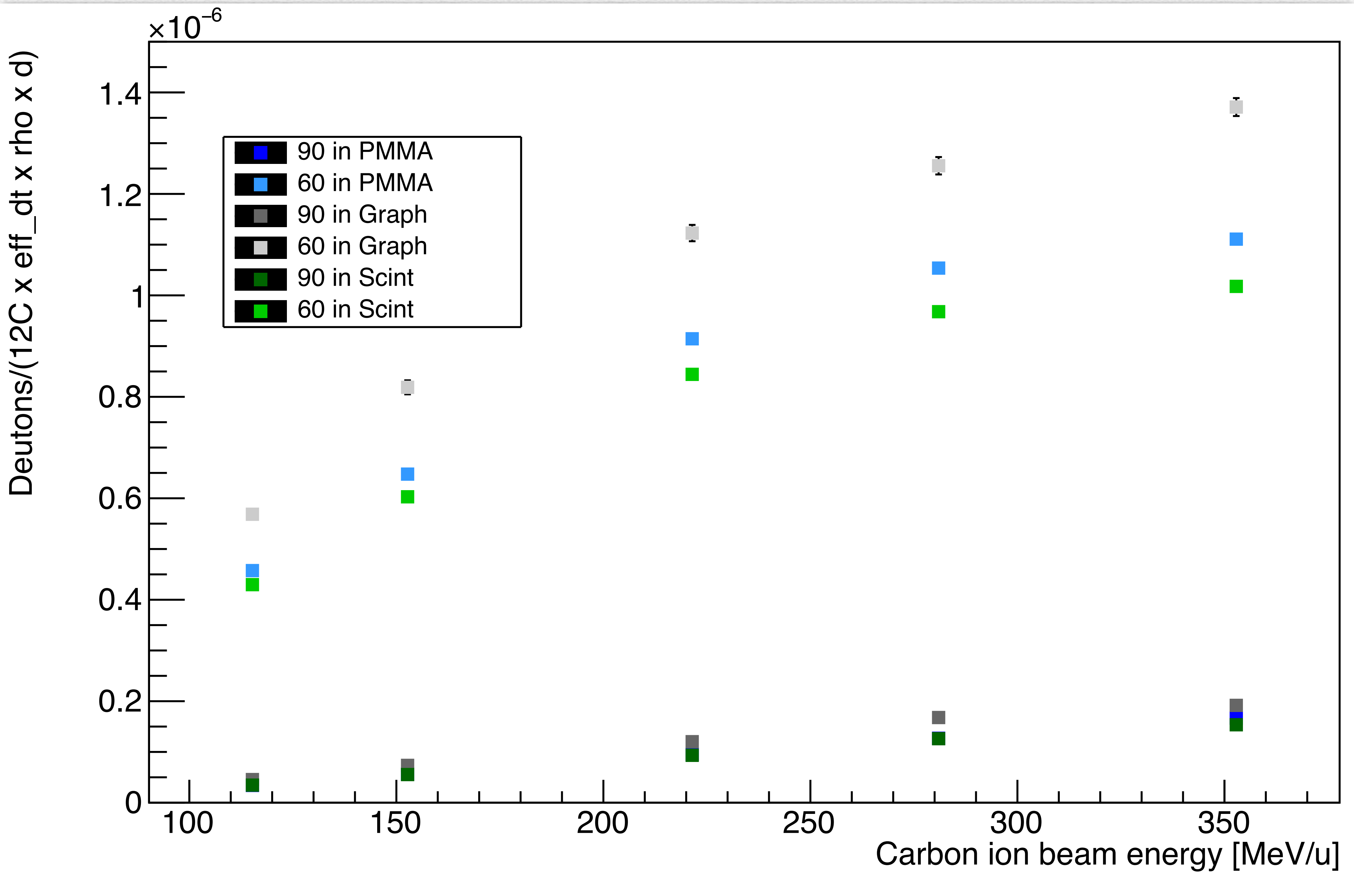


Protons/(12C x eff_dt x rho x d)
×10^-6
90 in PMMA
60 in PMMA
90 in Graph
60 in Graph
90 in Scint
60 in Scint
Carbon ion beam energy [MeV/u]
Ratio Protons
Ratio 90/60 in PMMA
Ratio 90/60 in Graph
Ratio 90/60 in Scint
Ratio 90/60 protons production
Beam Energy [MeV/u]

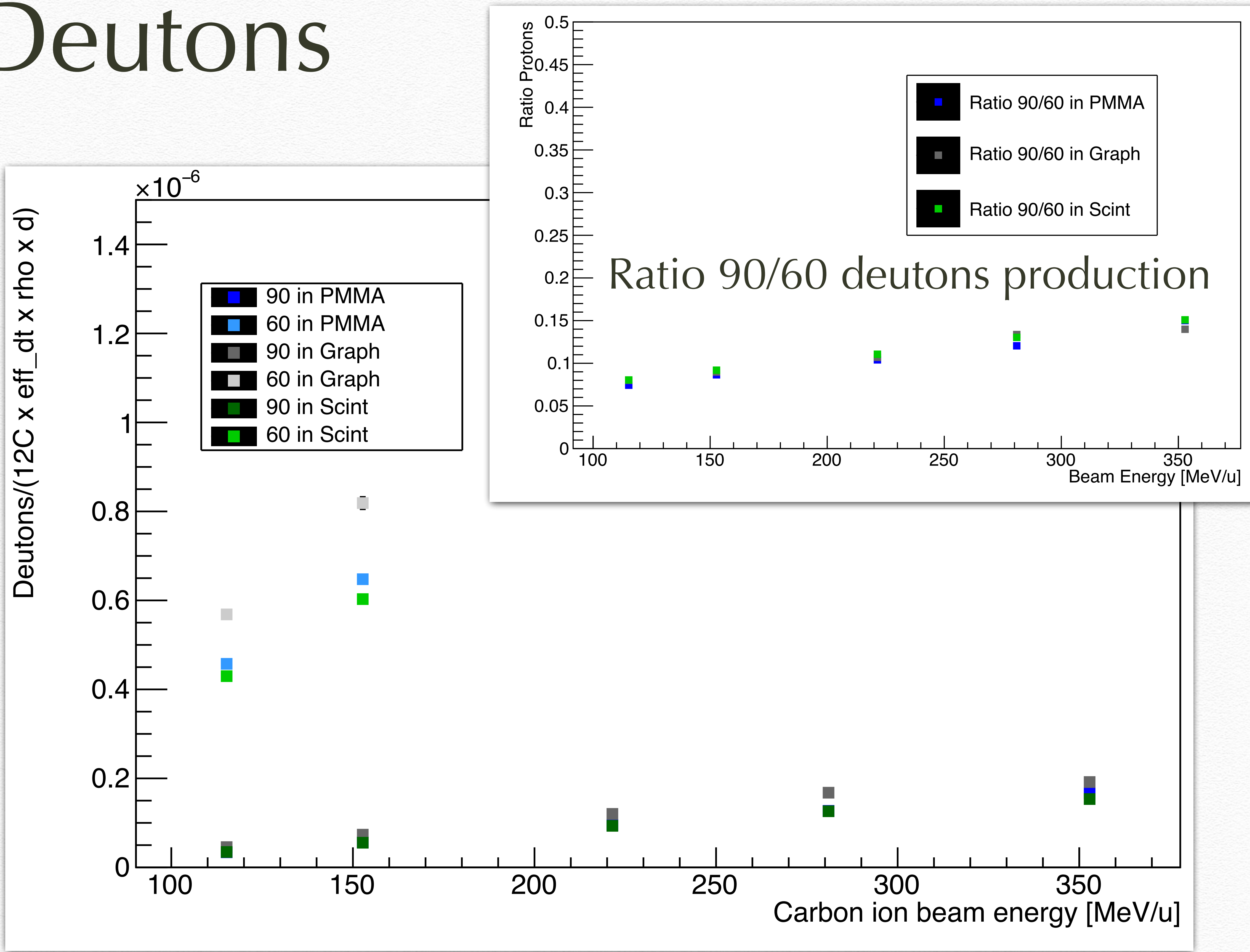
Deutons

NOT YET DETECTION and PID EFFICIENCIES!

Only statistical errors included.



Deutons

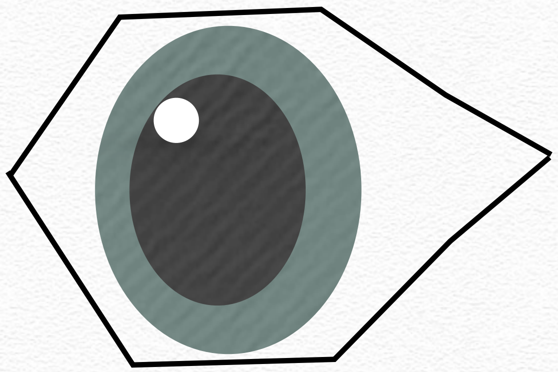


Ratio 90/60 deutons production

To Do:

$$\frac{d^2\sigma}{dEd\Omega}({}^A_ZX) = \frac{N_{{}^A_ZX}}{\epsilon_{DT} \times \epsilon_{PID} \times \epsilon_{DET}} \frac{A_{tgt}}{N_{{}^{12}C} \times \Omega \times E \times \rho \times th \times N_A}$$

- Detectors energy resolution to be optimized in MC
- Detection Efficiency (MC and DATA)
- Optimization of PID selection and efficiency (mixing matrix)
- Systematic errors (Eps_{PID}, Eps_{DT}, N_{12C}…)
- Double Differential XSec final evaluation
- Analysis at all angles (40º, 30º)



Thank You

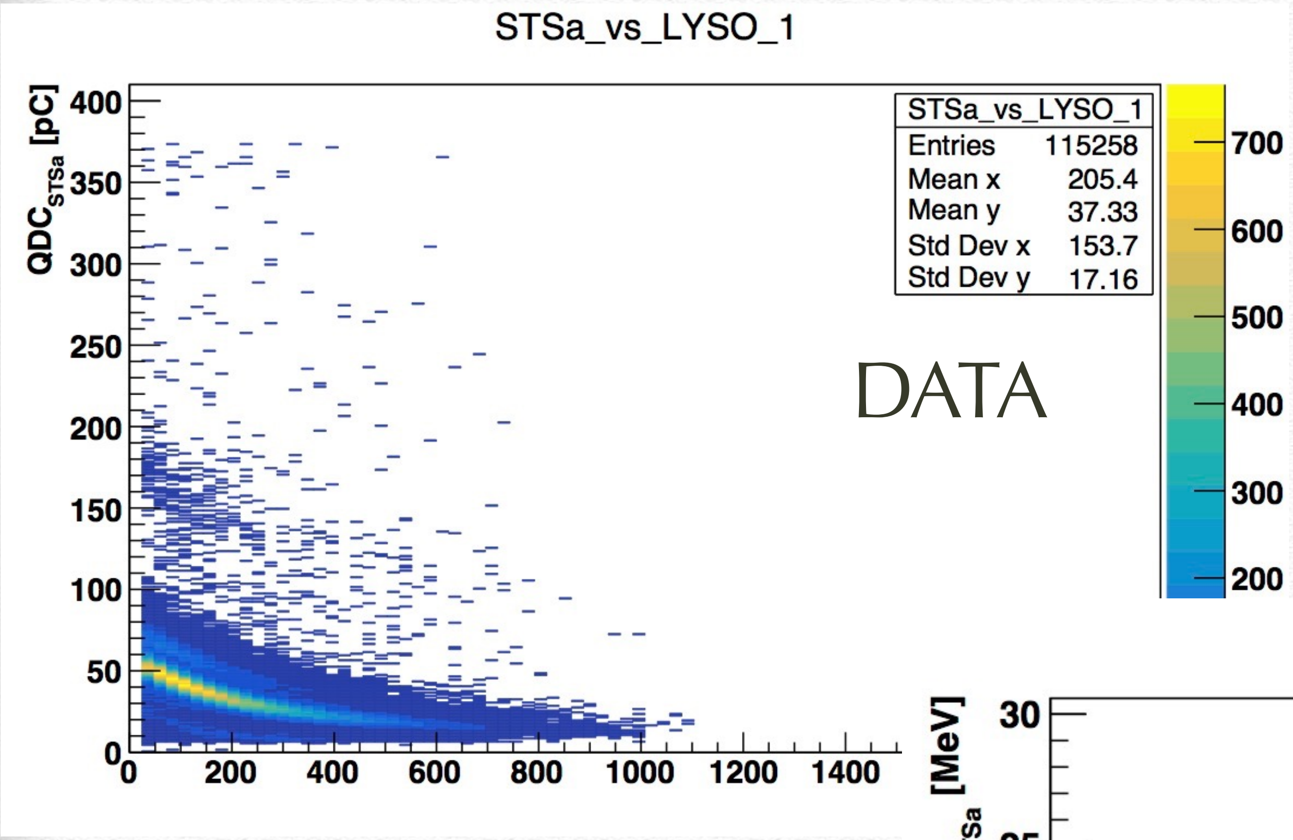
…and thanks to the CNAO staff

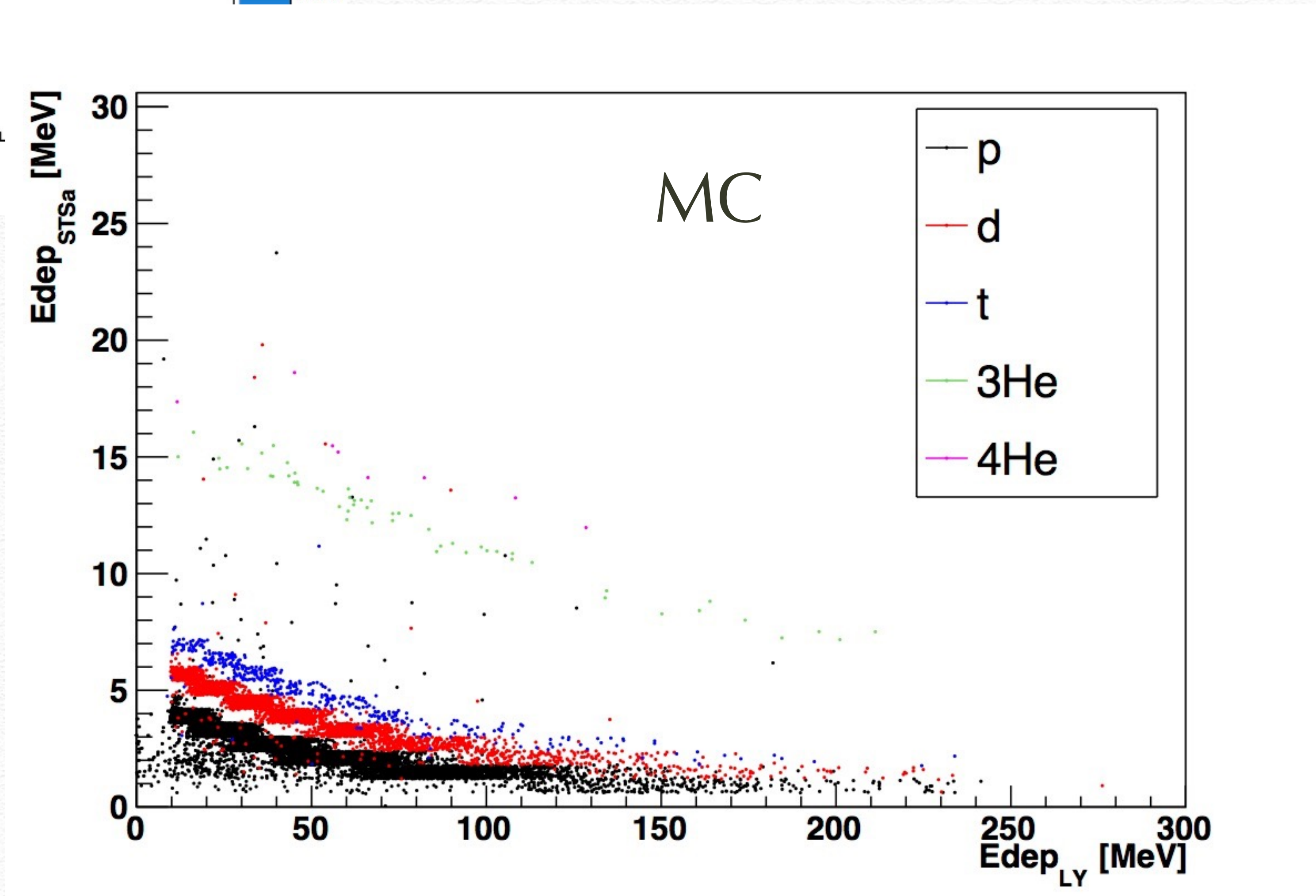
SPARES

DATA/MC comparison

90º

- To separate the contribution of 3He and 4He from protons and deuterons we look at **EdepSTS vs EdepLY**





DATA/MC comparison

- To separate the contribution of 3He and 4He from protons and deuterons we look at **EdepSTS vs TOF**