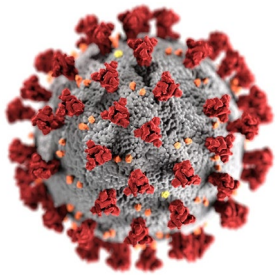
Detector performance and physics analyses: brief summary



Covid slowed down sperimental activities, but the same FOOT carried on a lot of work

This summary not include the performed work of the software group and in the hardware field

Monthly meeting (1° Wednesday at 14.30): if you want to be included to the mailing list send me a mail

https://agenda.infn.it/category/1375/

In each detector there is an ongoing analysis to improve the performance

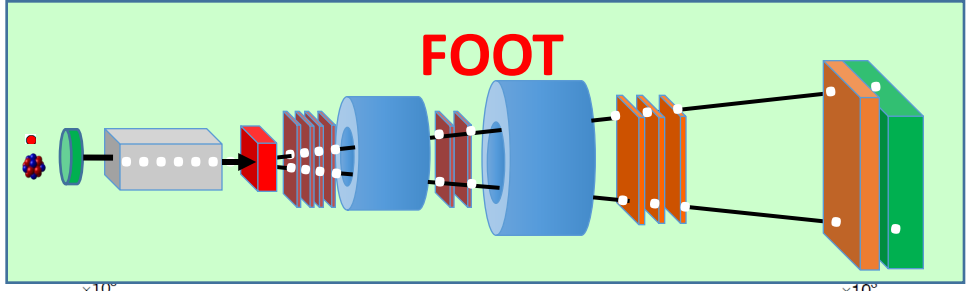
- SC
- BM
- Vertex
- MSD
- TOFWall
- Calo
- DAQ

Analyses in physics environment

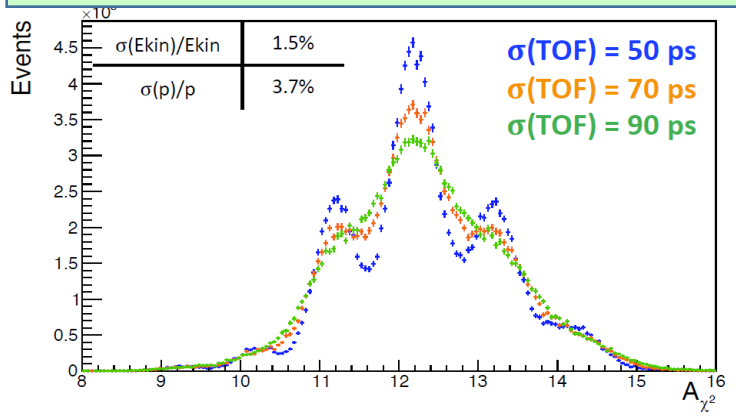
- Real Data
  - CNAO: Cross Section of 12C fragmentation
  - GSI Data: Emulsion chamber
  - GSI + CNAO Data: SC + TOFWall
    - Detector performance and physics results
- MC Data:
  - Update on the generation samples
  - Cross Section feasibility
  - Neutron analysis

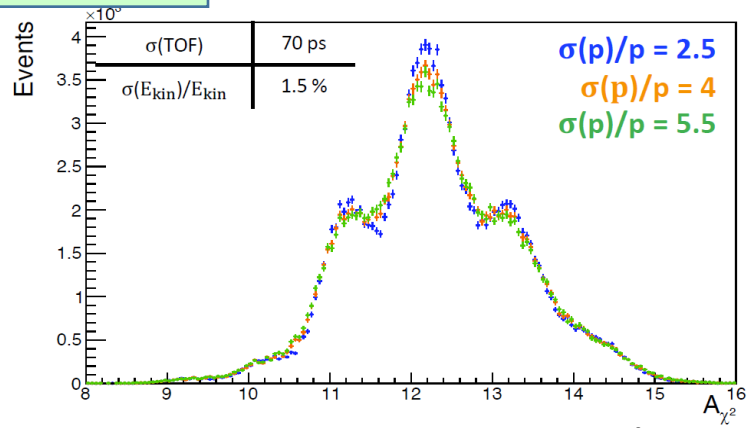
A lot of involved people: many many many … thanks

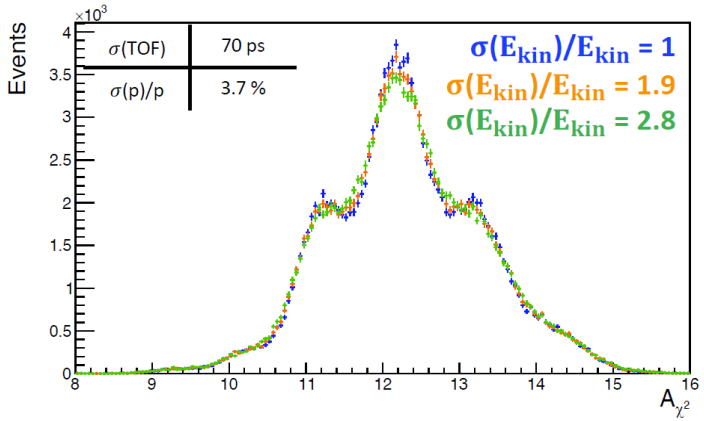
Thanks to Giuseppe and all the Milan group to produce a huge amount of MC following all our requests



Detector performance







Beam Energy: 200 MeV/u

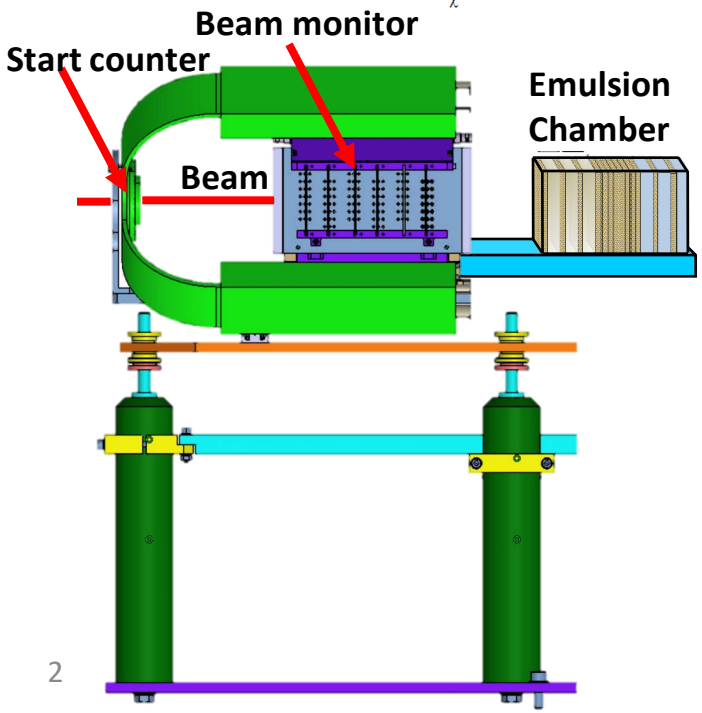
We have to remember:

- tof: 70 ps or better
- p: 4% or better
- E_{kin}: 1.5% or better
- ΔE: 4% or better

Beam Energy: 700 MeV/u

Analysis without calorimeter:

- Tof, p, ΔE: more precise



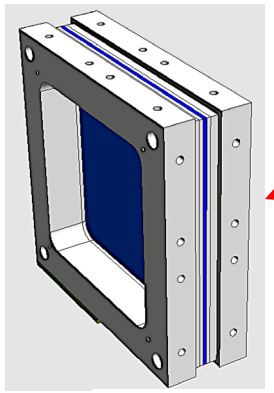
Reconstruction of:

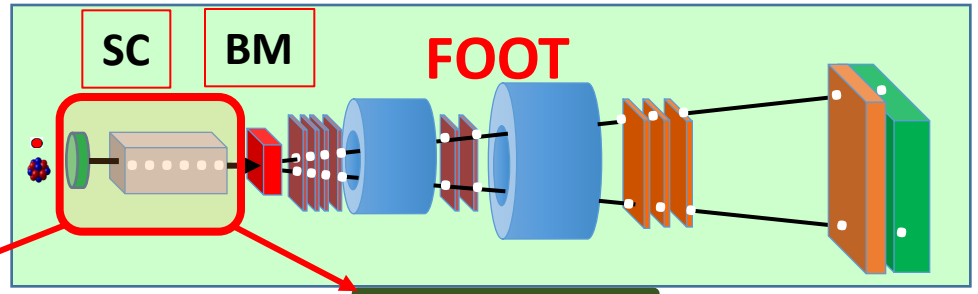
- vertex
- p with range
- p with multiple scattering
- Z id: (thermal treatment)
- E_{kin}: range measurement

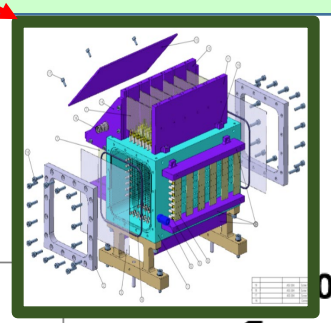
Beam definition

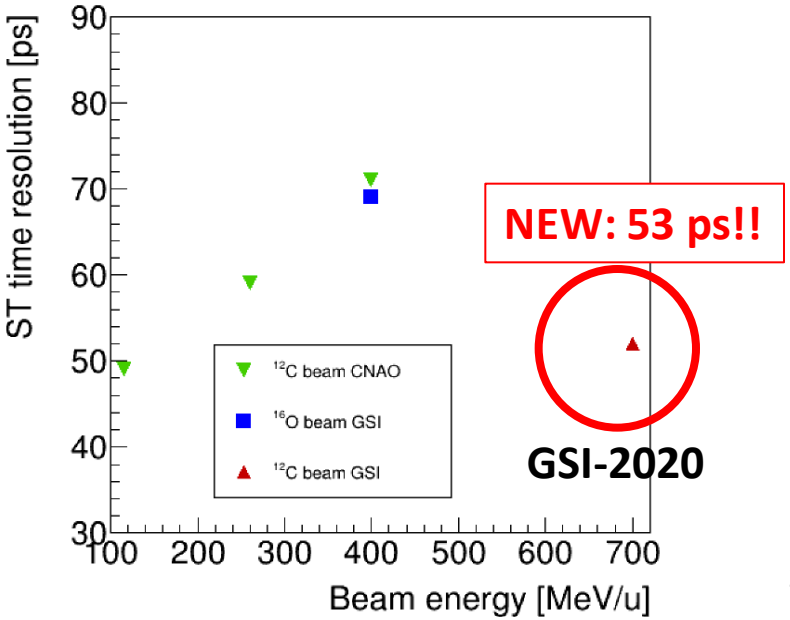
$$\frac{d\sigma_f}{dE_{kin}} = \frac{(Y_f - Bkg_f)^U}{N_{Prim} \cdot N_t \cdot \Omega_{Ekin}\, \epsilon_f}$$

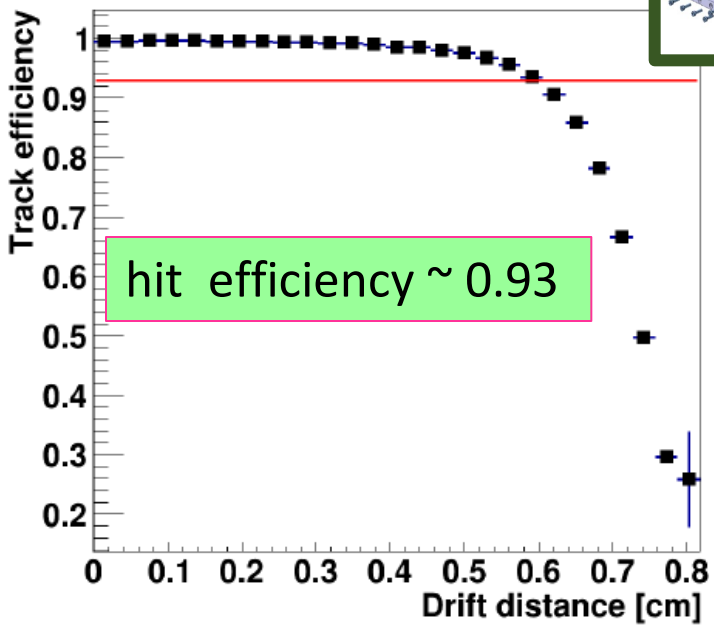
- Count n° of particles
- Initial Trigger
- Time start
- Discard SC fragmentation
- Extrapolate vertex direction
- Evaluate beam direction

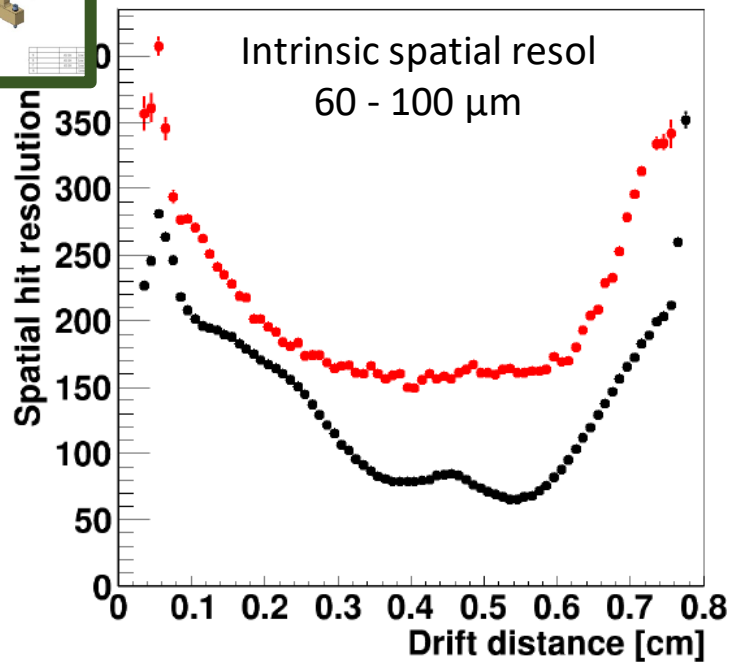








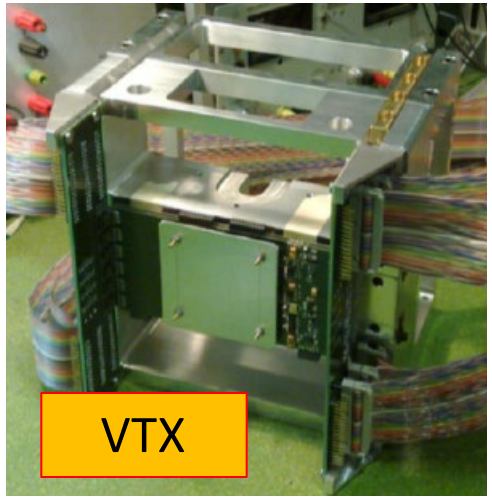


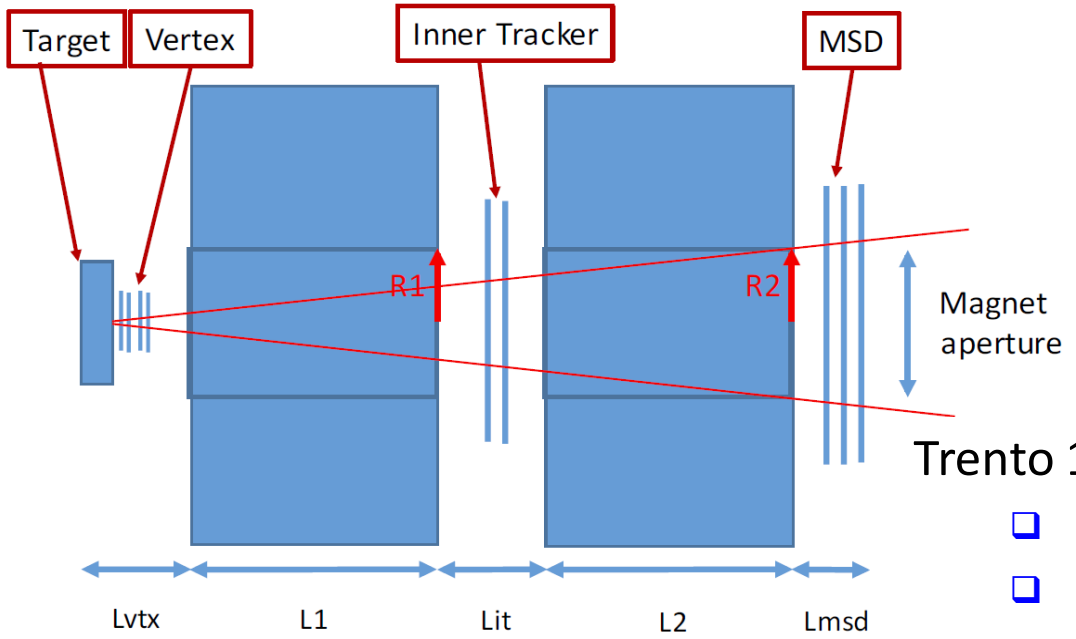


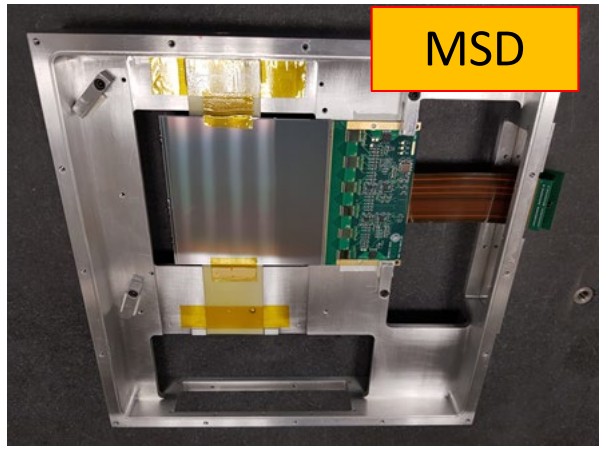
Angular resolution:
- 1.6 mrad p@228 MeV/u
- 2.1 mrad p @ 80 MeV/u

Spatial resolution:
- 150 ± 10 µm p@228 MeV/u
- 300 ± 10 µm p@ 80 MeV/u

Tracking system







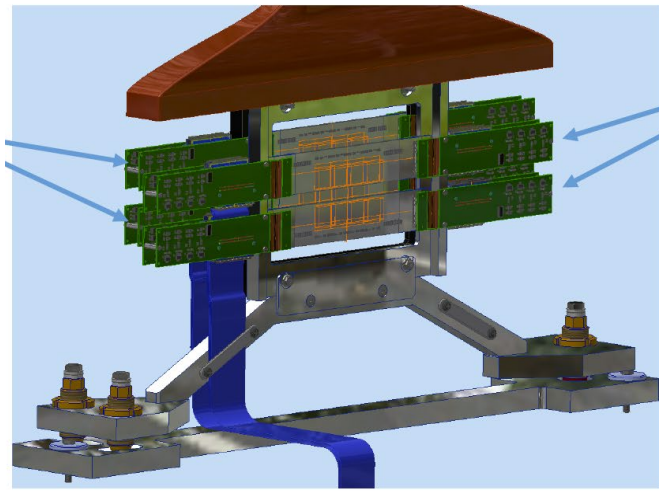
GSI (2019) data taking:

- Track efficiency ~25%

BTF (july 2019)

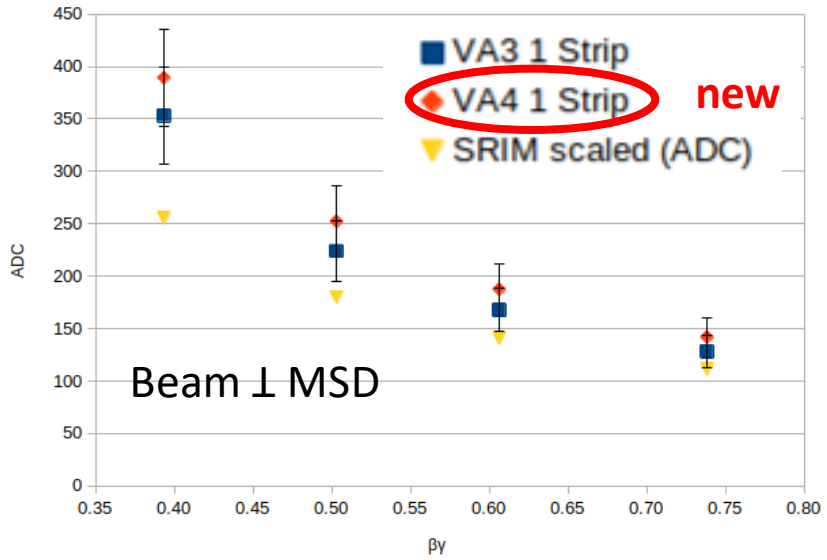
- Firmware → eff.~ 100%

ITR



Trento 12/2019

- p energy: 10, 112, 159, 228 MeV
- Comparison OLD/NEW chips

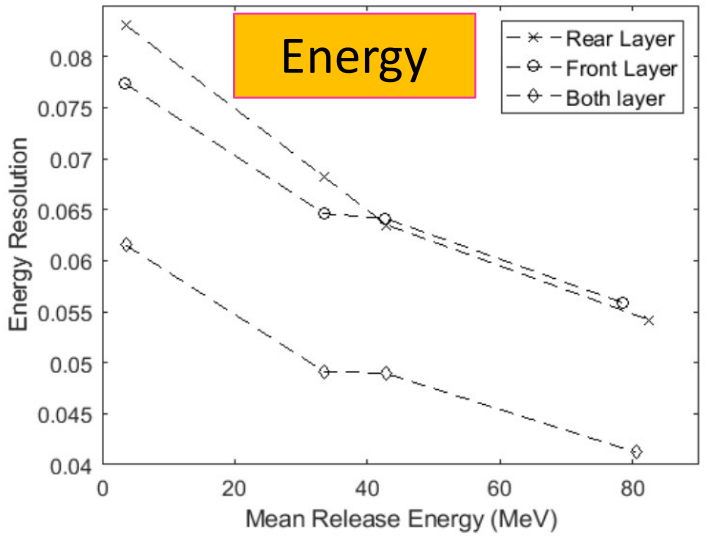


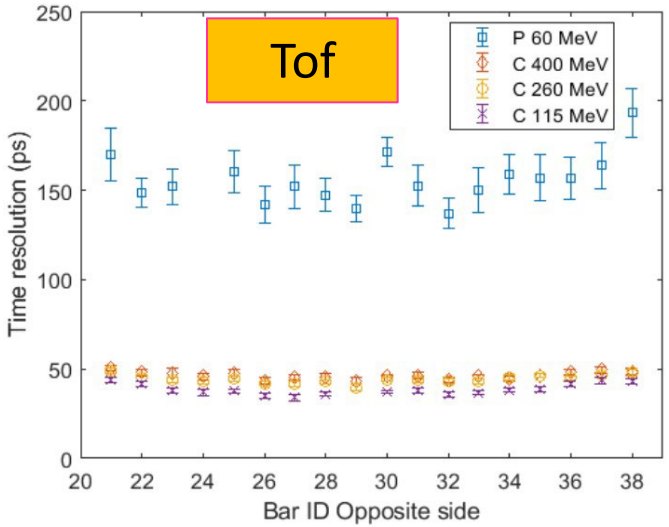
Saturation when beam at 5° wrt MSD

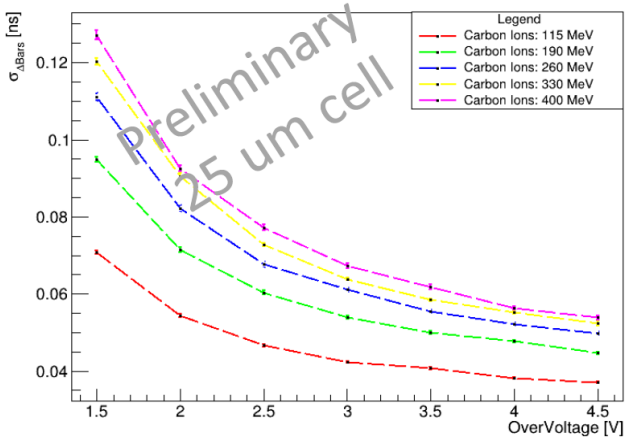
Tof Wall

Detector is complete

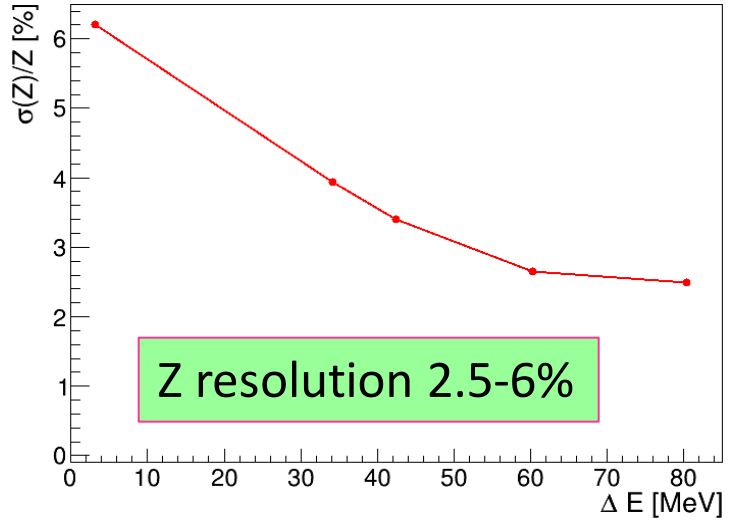
Data taking at CNAO-GSI (march-april 2019) and CNAO (dec 2019)

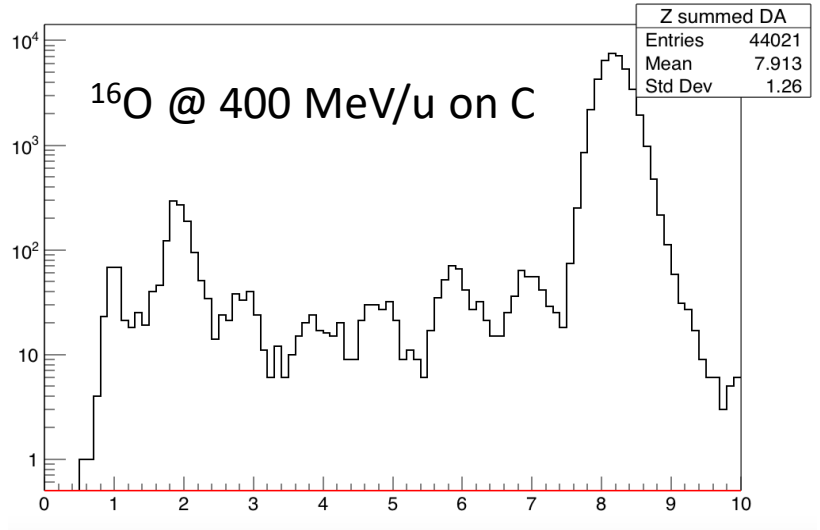






CNAO + GSI

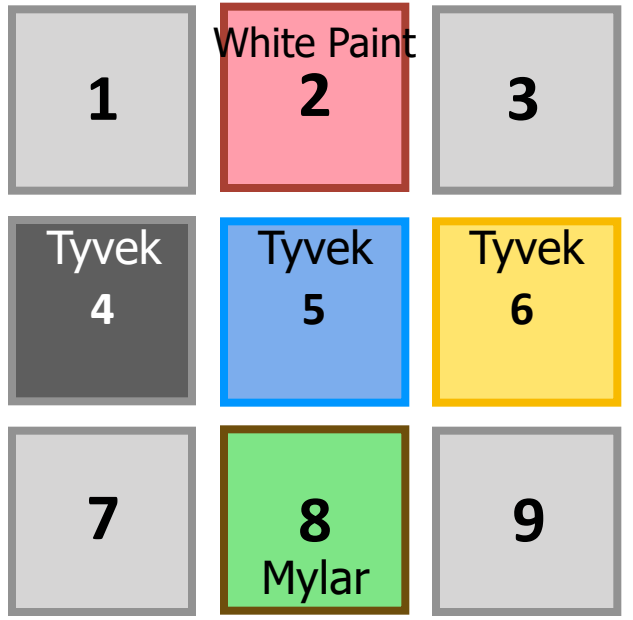




Resolution:

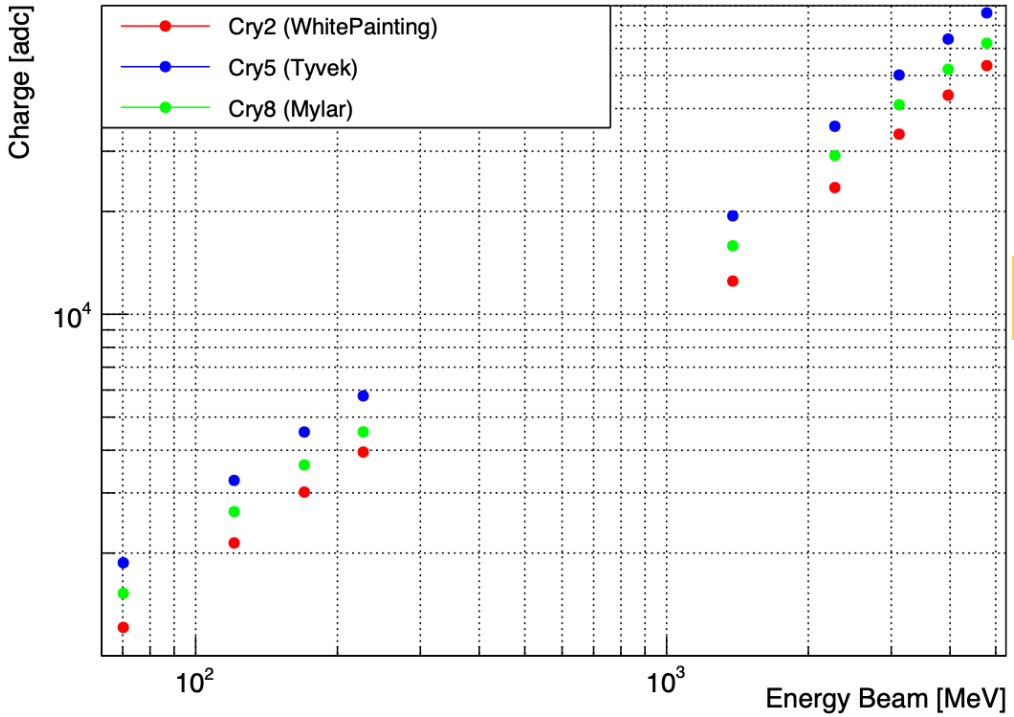
- Energy: 4-6 %
- Time SCN: 40-50 ps for ^{12}C and 150-190 ps for p
- Tof (SC+TofW): 50-75 ps for ^{12}C – ^{16}O
  250 ps for p
- Position: 7 mm for 12C and 15 mm for p

Calorimeter, 1



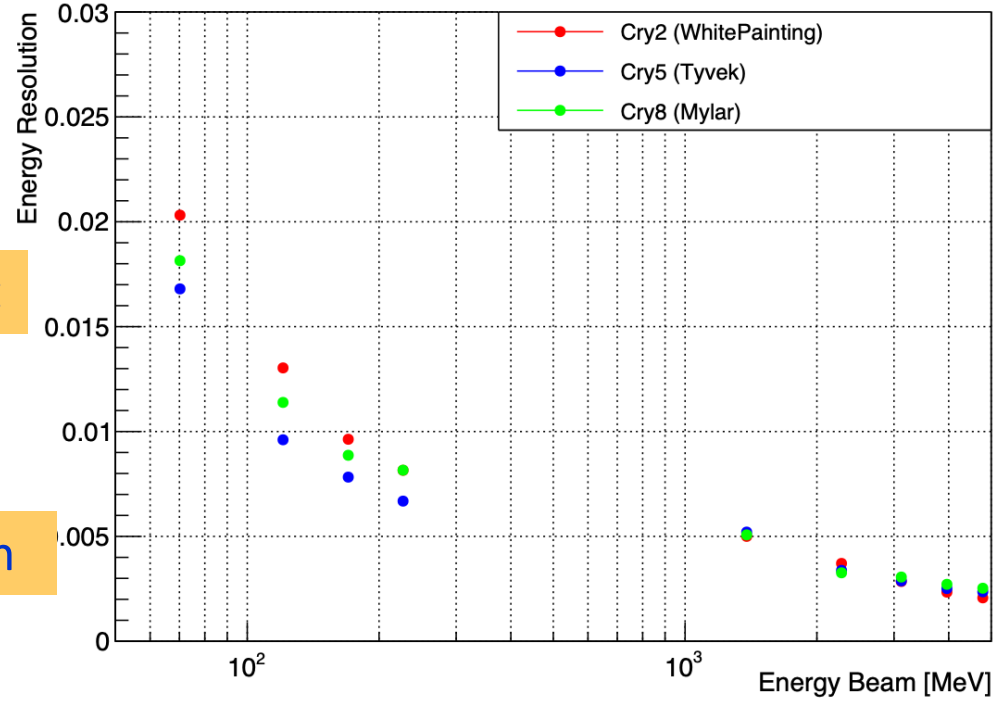
TEST BEAM OVERVIEW:

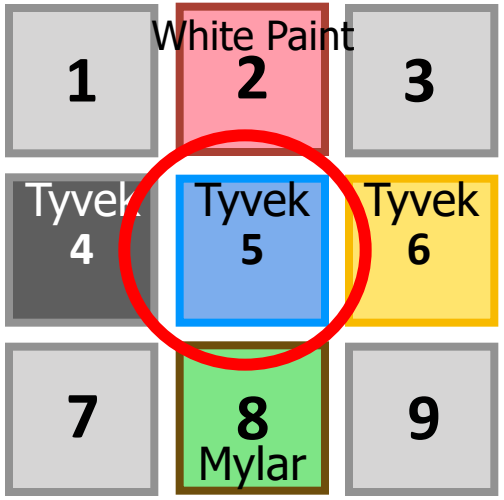
- 9 crystals
- 15 µm SiPM arrays
- 3 reflective wrappings: White Painting, Mylar and Tyvek
- Proton Energy: 70, 120, 170, 227 MeV
- Carbon Energy: 115, 190, 260, 330, 399 MeV/A
- Temperature part:
  - For each energy 4 different temperature



Tyvek reflects more light

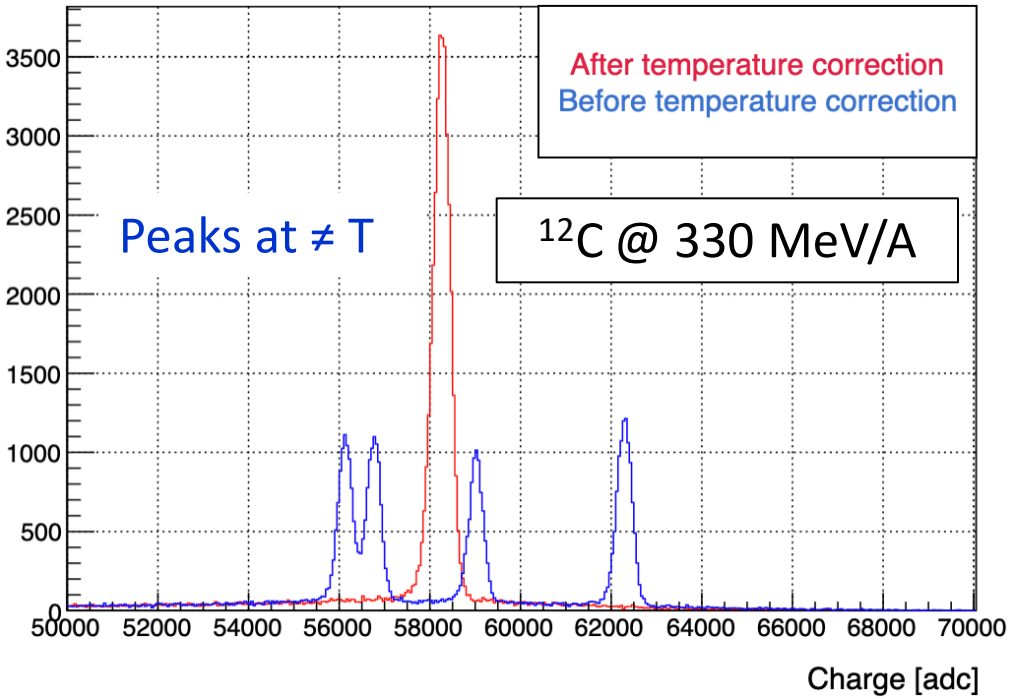
Better Energy Resolution

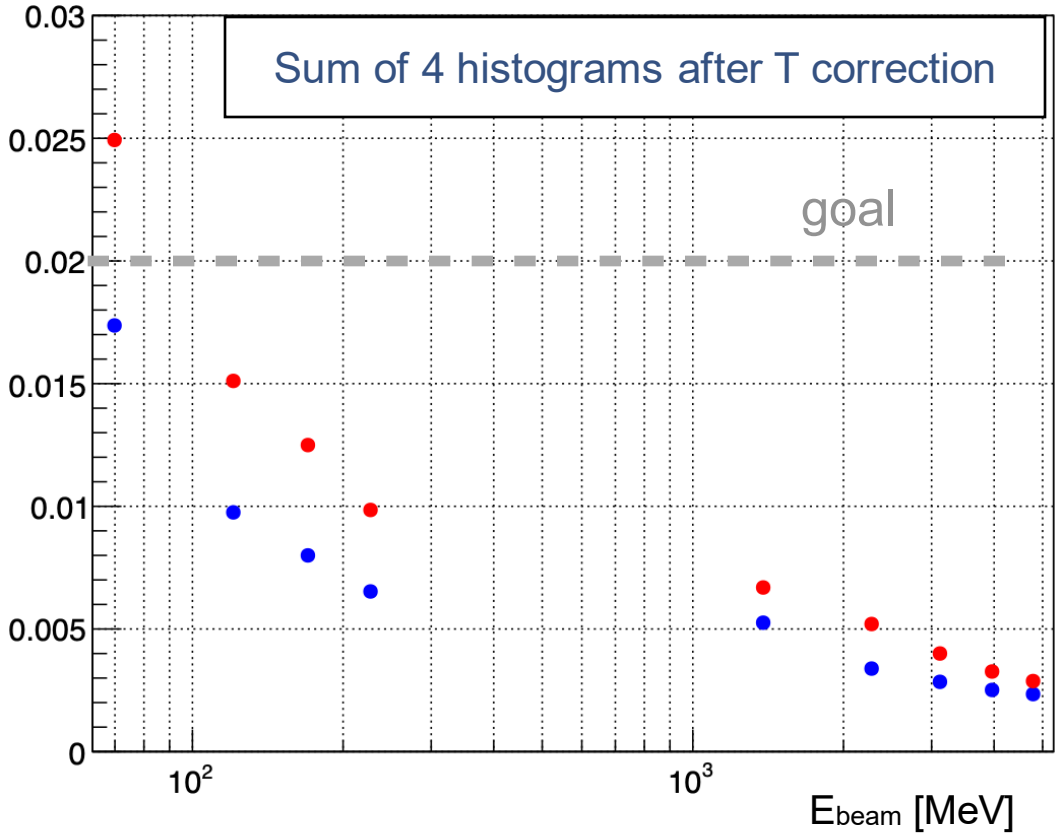




Calorimeter, 2

Signal depends on temperature (max fluctuation ~ 10%)
temperature sensor?





Slightly worsening resolution, but
better than 2% after T correction

Crystals: all set
Mechanics: full design
SiPMs: in production
DAQ: integration to global to be started

Physics measurements

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TRPMS.2020.2972197, IEEE Transactions on Radiation and Plasma Medical Sciences

Data taking @CNAO

Measurement of ^{12}C Fragmentation Cross Sections on C, O and H in the Energy Range of interest for Particle Therapy Applications.

I. Mattei[1], A. Alexandrov[6], L. Alunni Solestizi[21,7], G. Ambrosi[7], S. Argirò[8,9], N. Bartosik [8], G. Battistoni [1], N. Belcari[10,11], S. Biondi[12,13], M.G. Bisogni[10,11], G. Bruni[12], N. Camarlinghi[10,11], P. Carra[10,11], E. Catanzani [21,7], E. Ciarrocchi[10,11], P. Cerello[8], A. Clozza[14], S. Colombi[15,16], G. De Lellis[6,17,32], A. Del Guerra[10,11], M. De Simoni[5,2], A. Di Crescenzo[17,6], M. Donetti[18,8], Y. Dong[1,19], M. Durante[15], A. Embriaco[1], M. Emde[20],

First Cross Section measurement published by FOOT

Data taking @GSI (2019-20)

Emulsion setup:

- April 2019
- February 2020

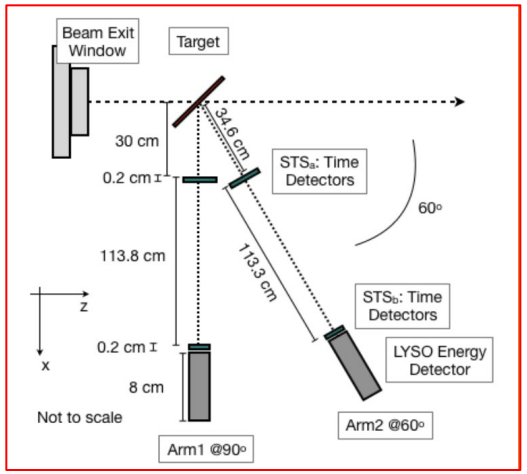
Data taking @CNAO & GSI (2019)

Experimental Setup (partial)

Cross Section measurements
Analyses ongoing

Differential Cross Section measurements

Detector: scintillators + crystal



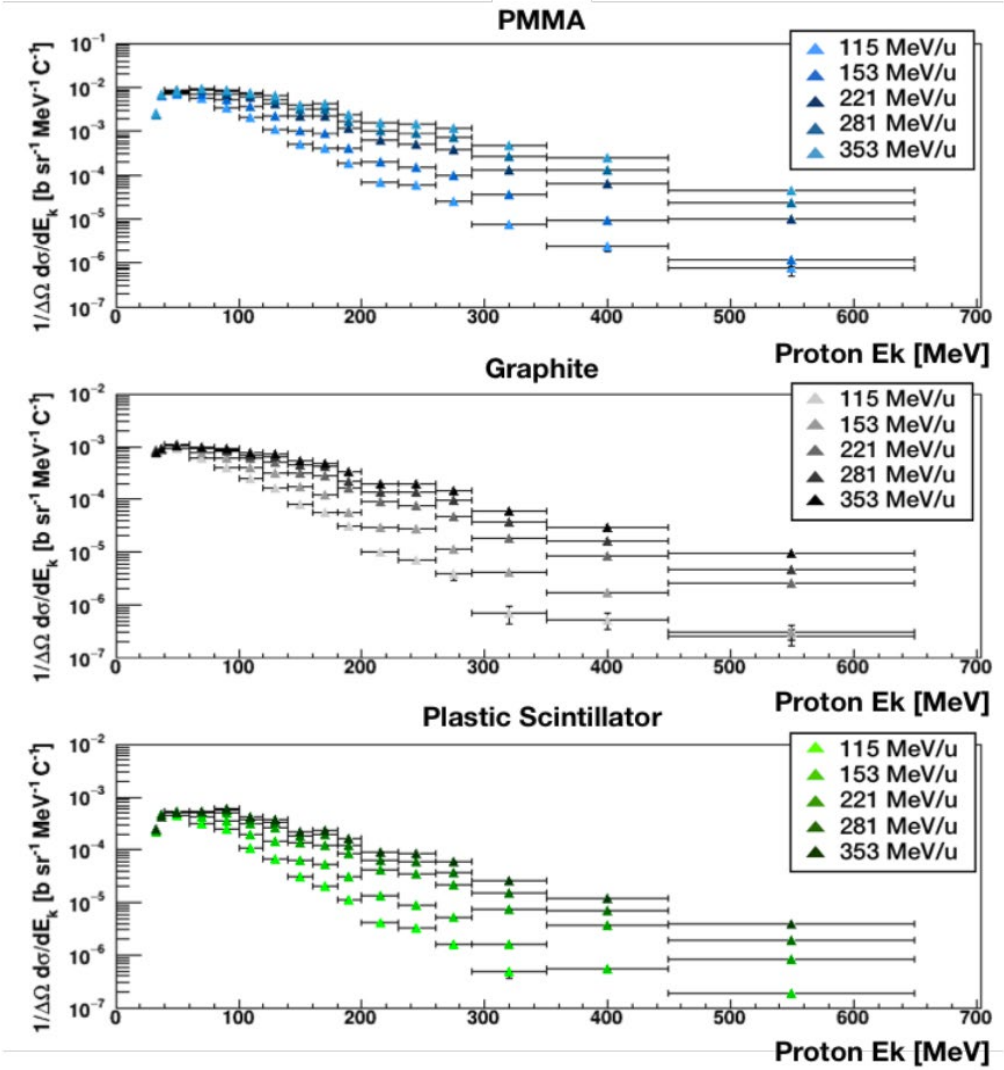
Published:

- 60° and 90°

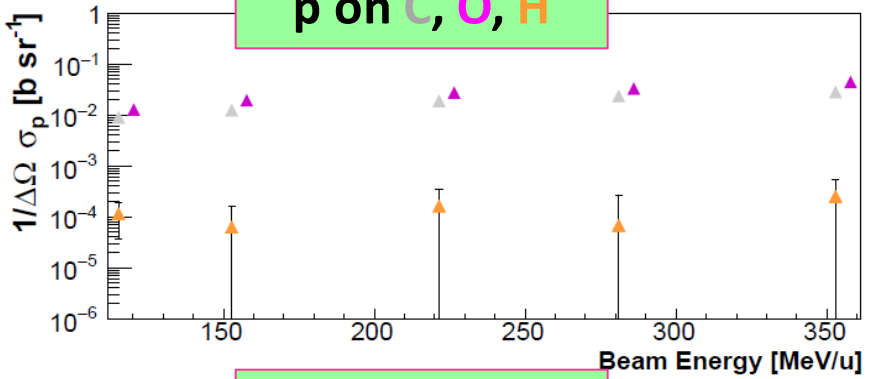
Ongoing

- 32° and 50°

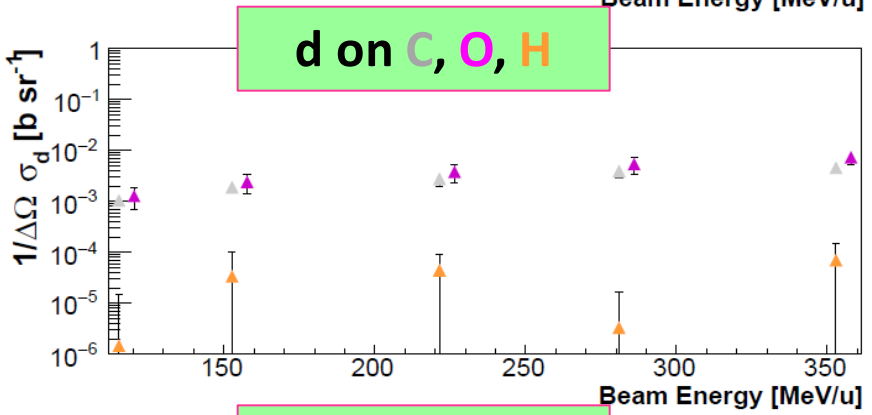
p production



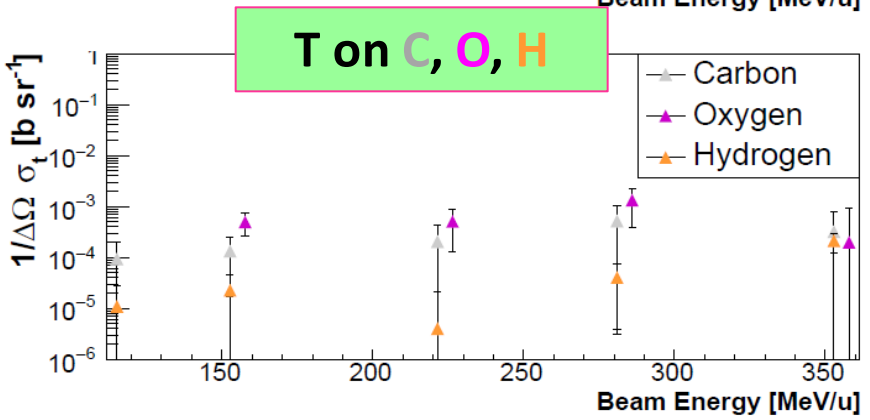
p on C, O, H



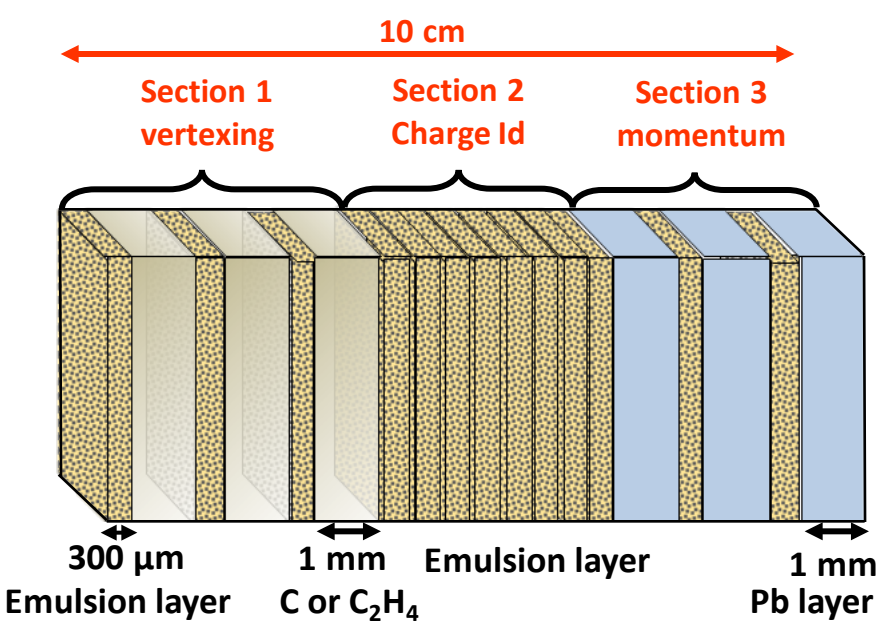
d on C, O, H



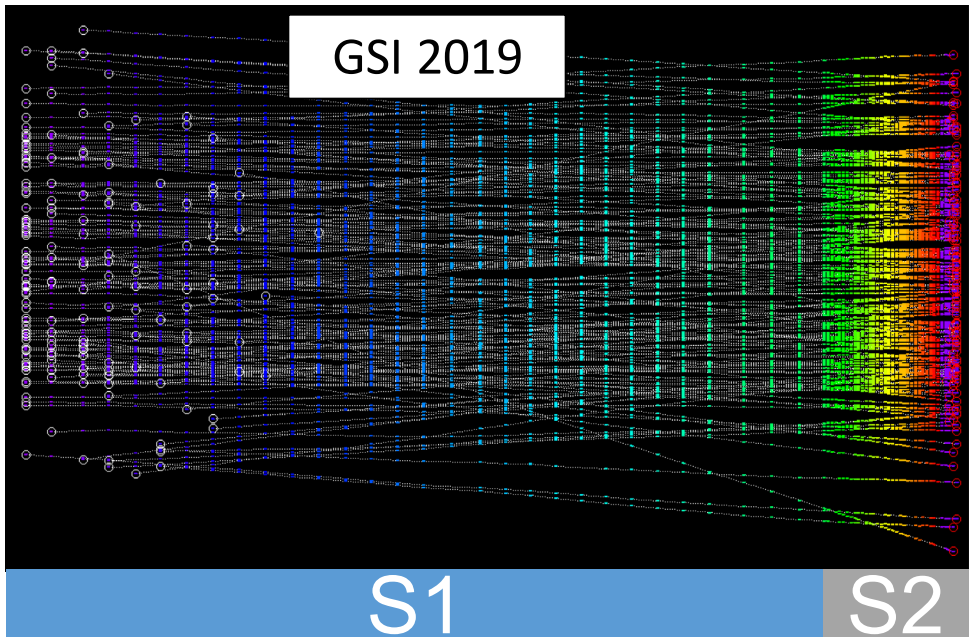
T on C, O, H

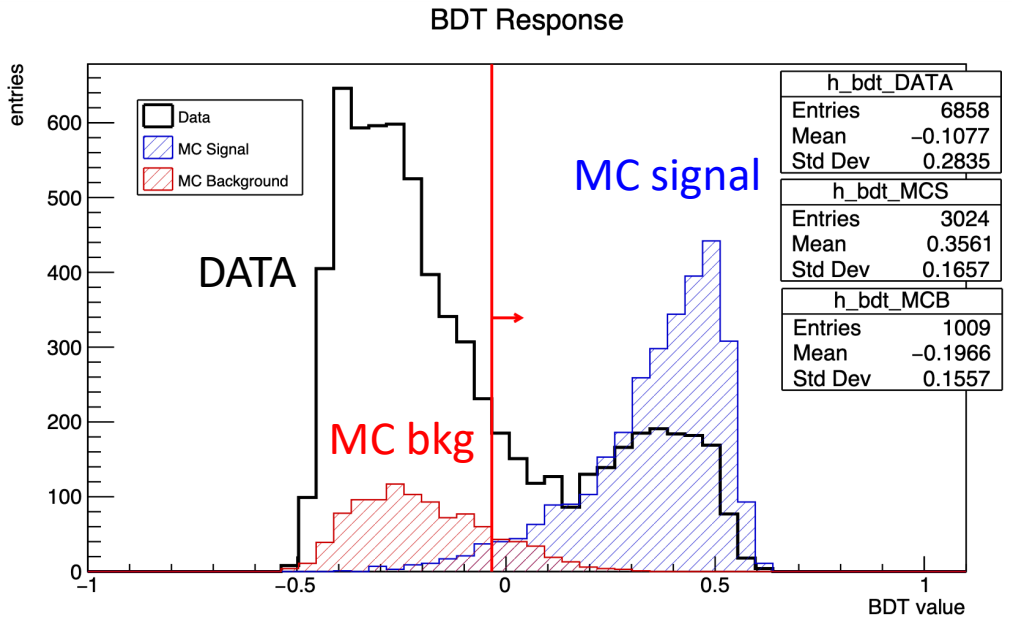


Emulsion setup: Tracks and vertices

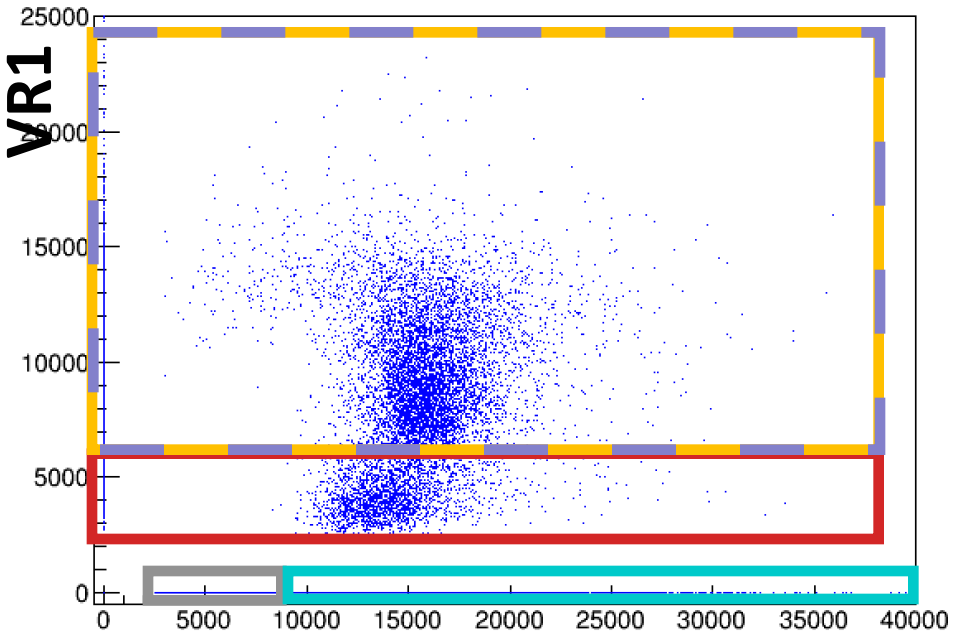


- Track reconstruction done separately for each section
- Merge tracks in two sections: 13026 tracks crossing > 30 layers
- BDT multivariate analysis to select good vertexing out of bkg
  - MC: 72% of true vertices selected
  - DATA: ~ 40% of expected vertices reconstructed
- Vertex search to be improved

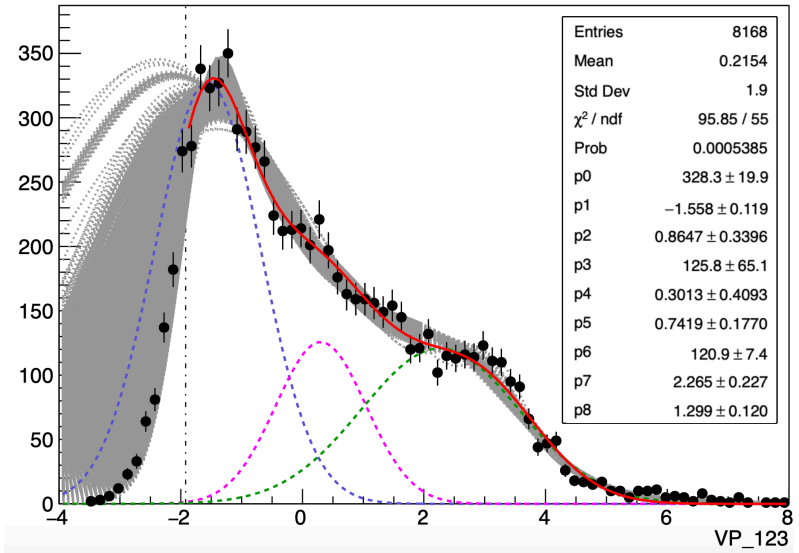




Emulsion setup: charge measurement



VR0



Cosmic Rays
Z=1 High Energy
Z=1 Low Energy
Z=2 nseg2<2 & nseg3<2

Sharp cuts

Z=2 TPrincipal
Z=3
Z>=4

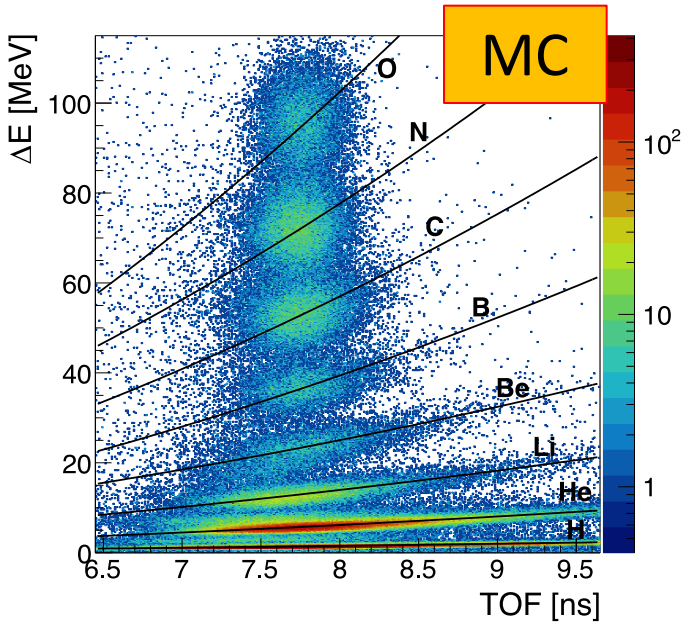
Principal Components Analysis

Charge assigned to 99.4% of reconstructed tracks

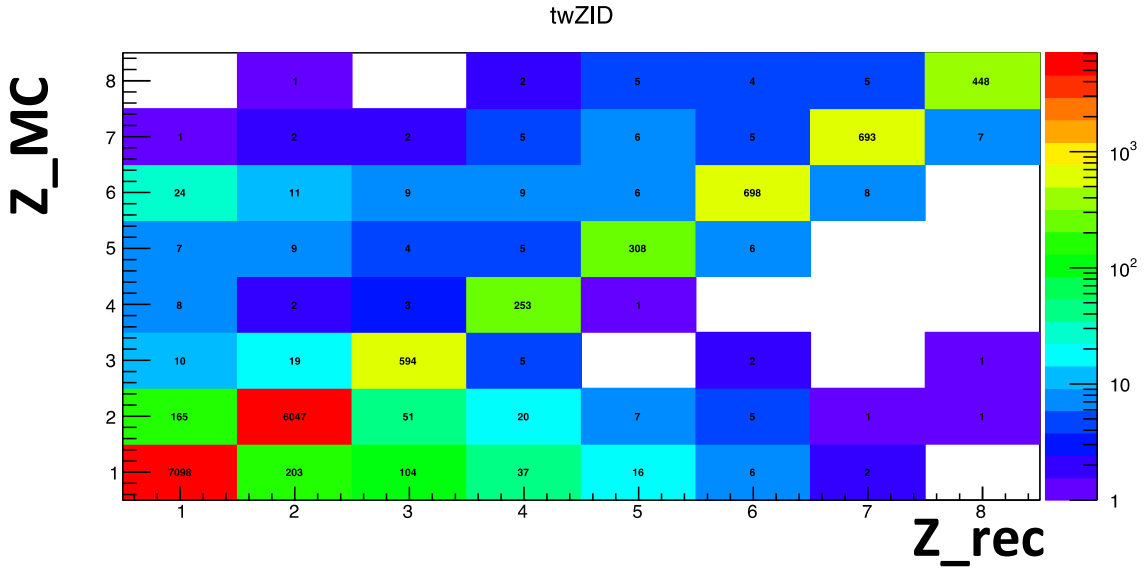
Charge assigned to 91.4% of tracks attached to a vertex

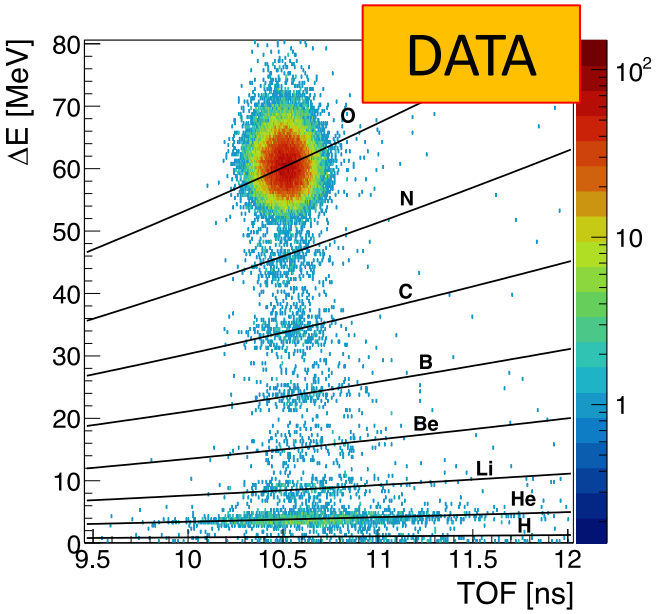
Z	% on total charged reconstructed tracks			
	Result	Systematic err	Gauss Par err	Statistic err
1	67.9%	5.3%	/	0.5%
2	19.8%	1.2%	0.02%	0.4%
3	7.0%	0.6%	0.03%	0.2%
≥4	5.3%	0.3%	0.01%	0.2%

Cross section with CNAO-GSI data (2019): electronic setup

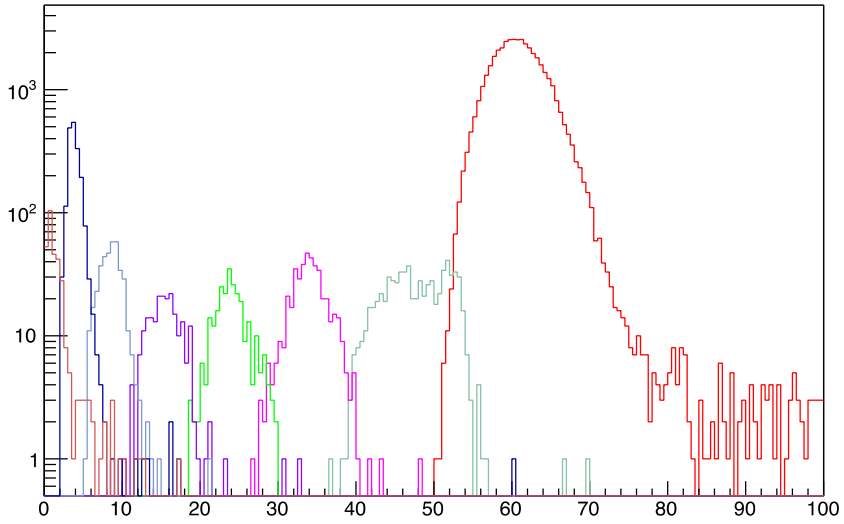


MC: ^{16}O – 200 MeV/u





DATA



- Fragments Z identification in SHOE available
- Good ZID performances (wrong Z charge assigment < **4.8%**)

Feasibility of the Cross Section Measurement (example on Carbon)

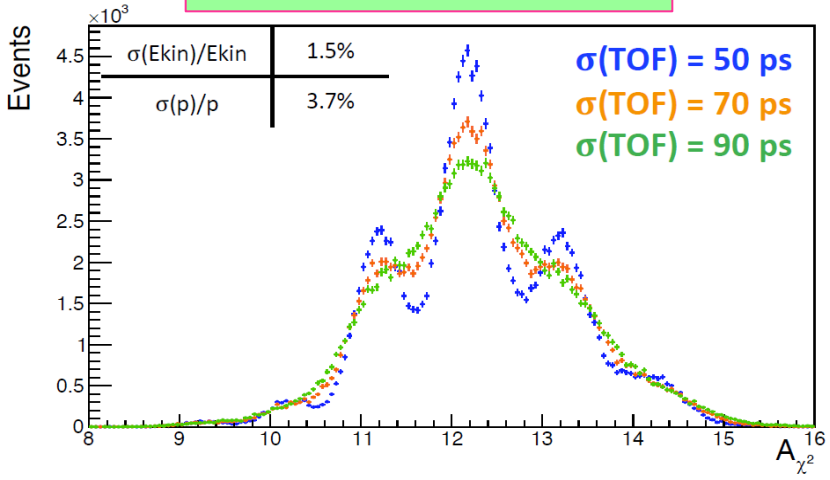
Implemented all the machinery for the Cross Section evaluation

Differential cross section of each produced fragment

$$\frac{d\sigma_f}{dE_{kin}} = \frac{(Y_f - Bkg_f)^U}{N_{Prim} \cdot N_t \cdot \Omega_{Ekin}\, \epsilon_f}$$

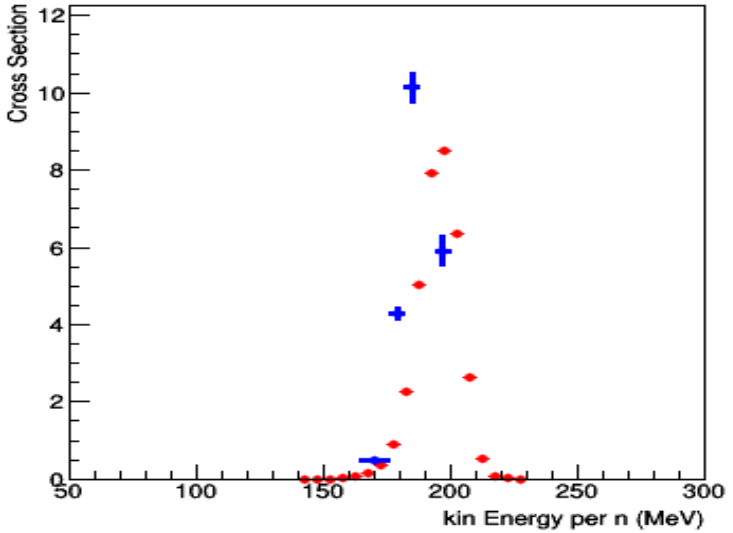
To include in SHOE

Mass Identification

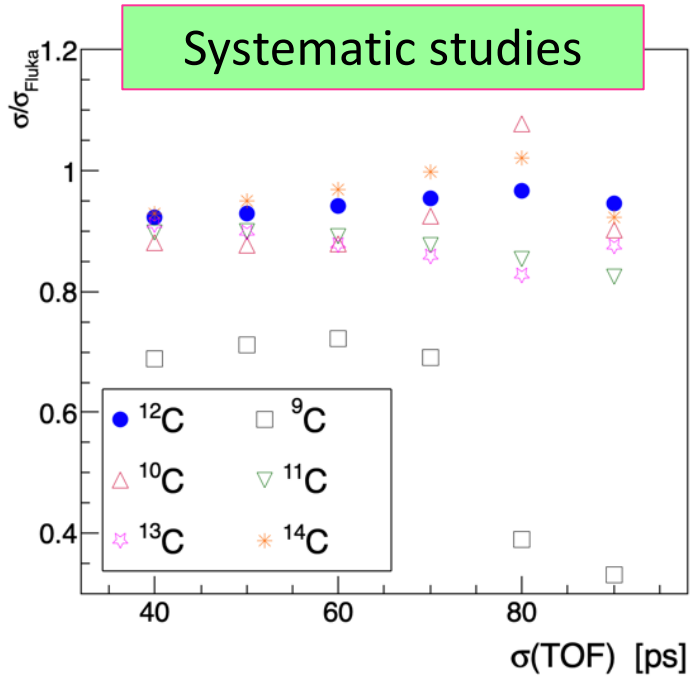


Crucial: high Tof precision

Differential Cross Section



Systematic studies

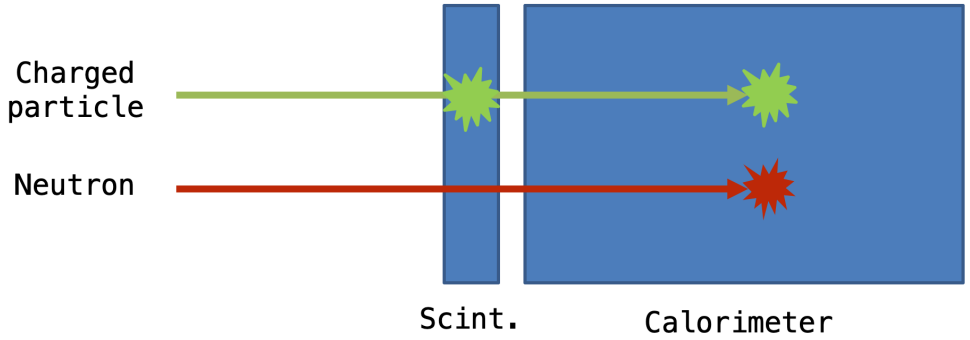


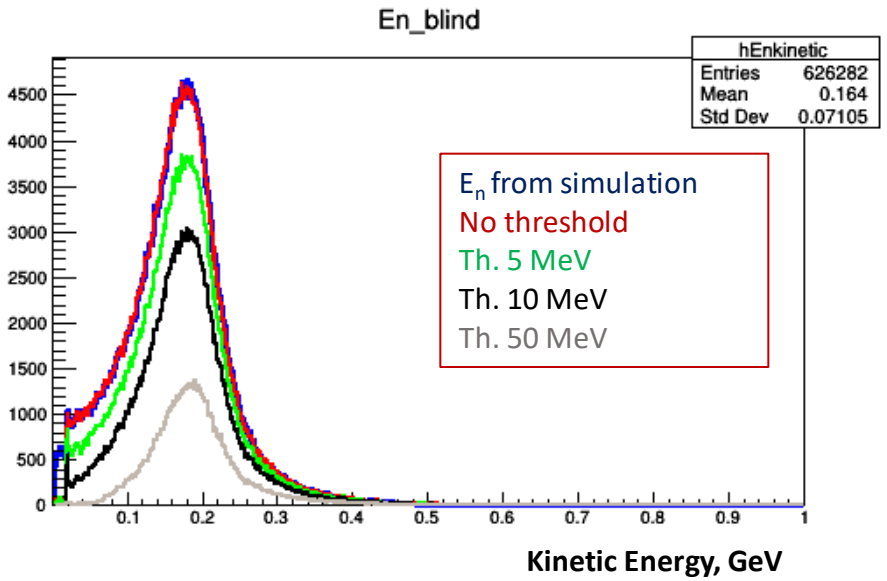
Underestimation to be investigated
Constant distribution

Neutron @ FOOT

Preliminary studies on $^{16}O+C_2H_4$ @200 MeV/u (MC data)

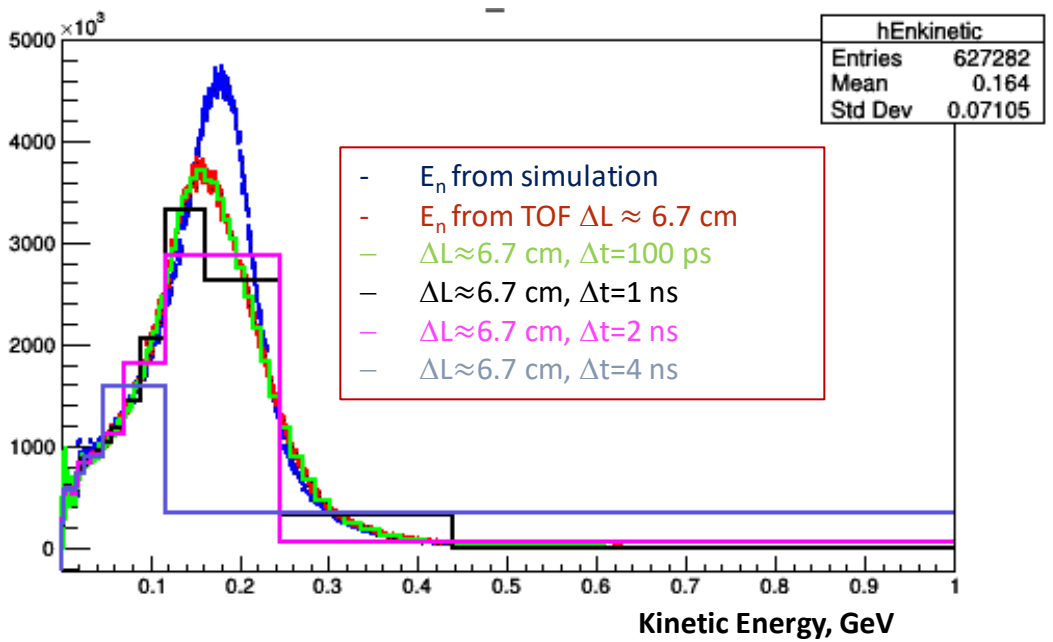
Investigate the possibility to use SCN & CALO to detect neutrons





Reliable Calorimeter Threshold ~ 20 MeV
→ ε ~ 25% accettable
→ γ Bkg contribution negligible

Neutron detection and energy measurement with TOF method



Calorimeter Time resolution better 1 ns

Conclusion

Huge amount of great work!!!

My compliment, go on!!!