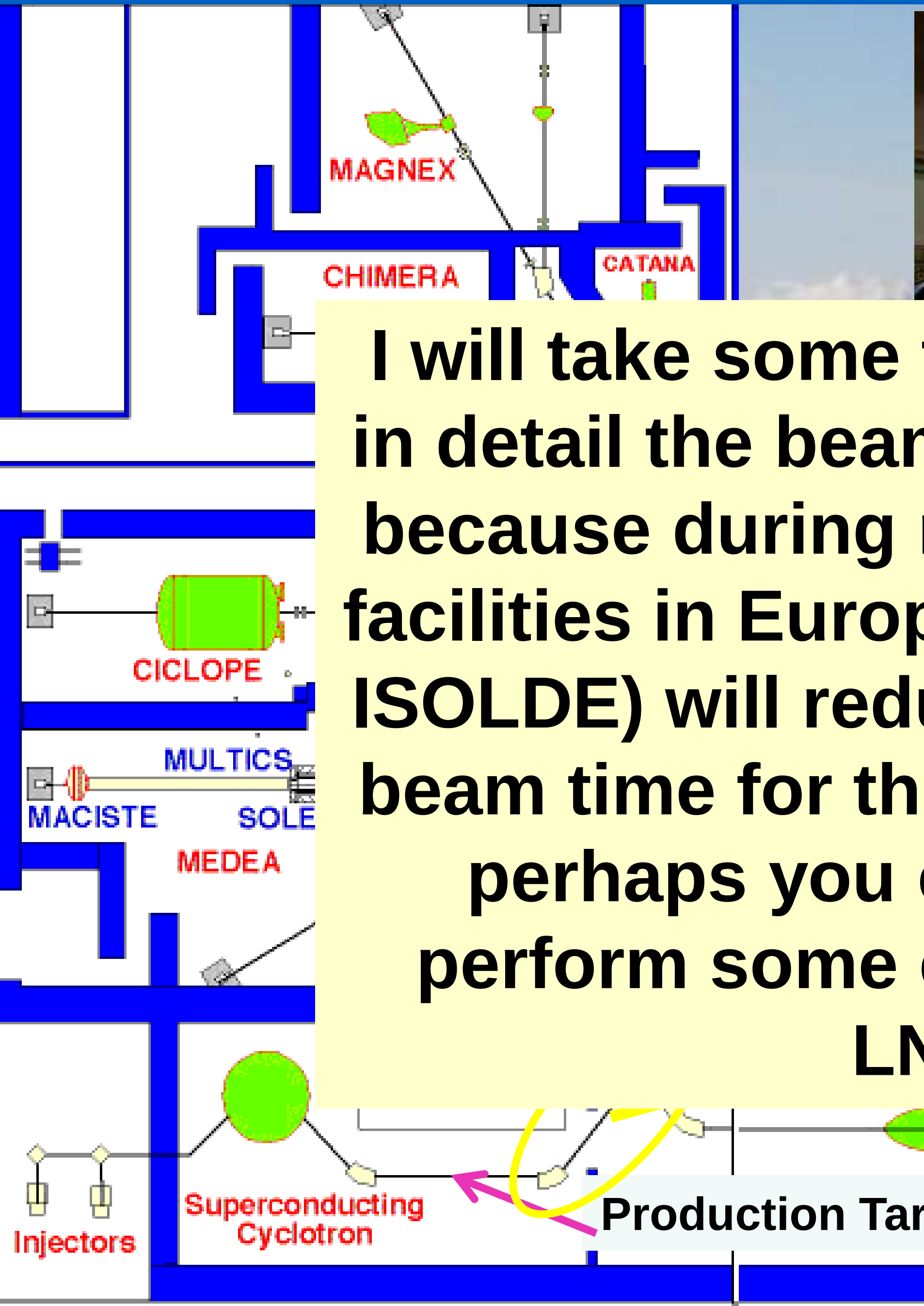
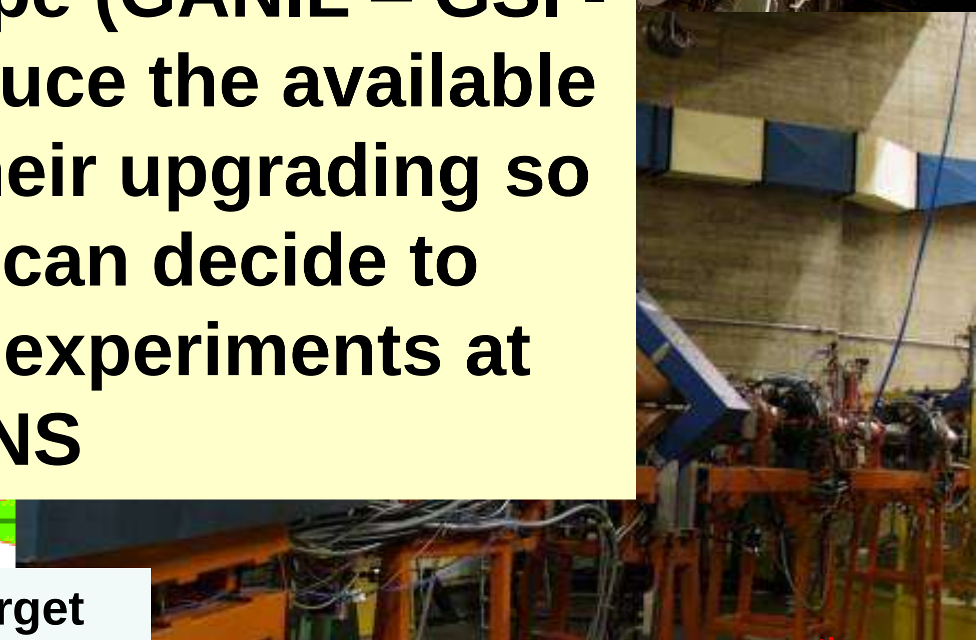
Use of fragmentation beams at LNS with CHIMERA detector

G.Cardella
For the EXOCHIM collaboration

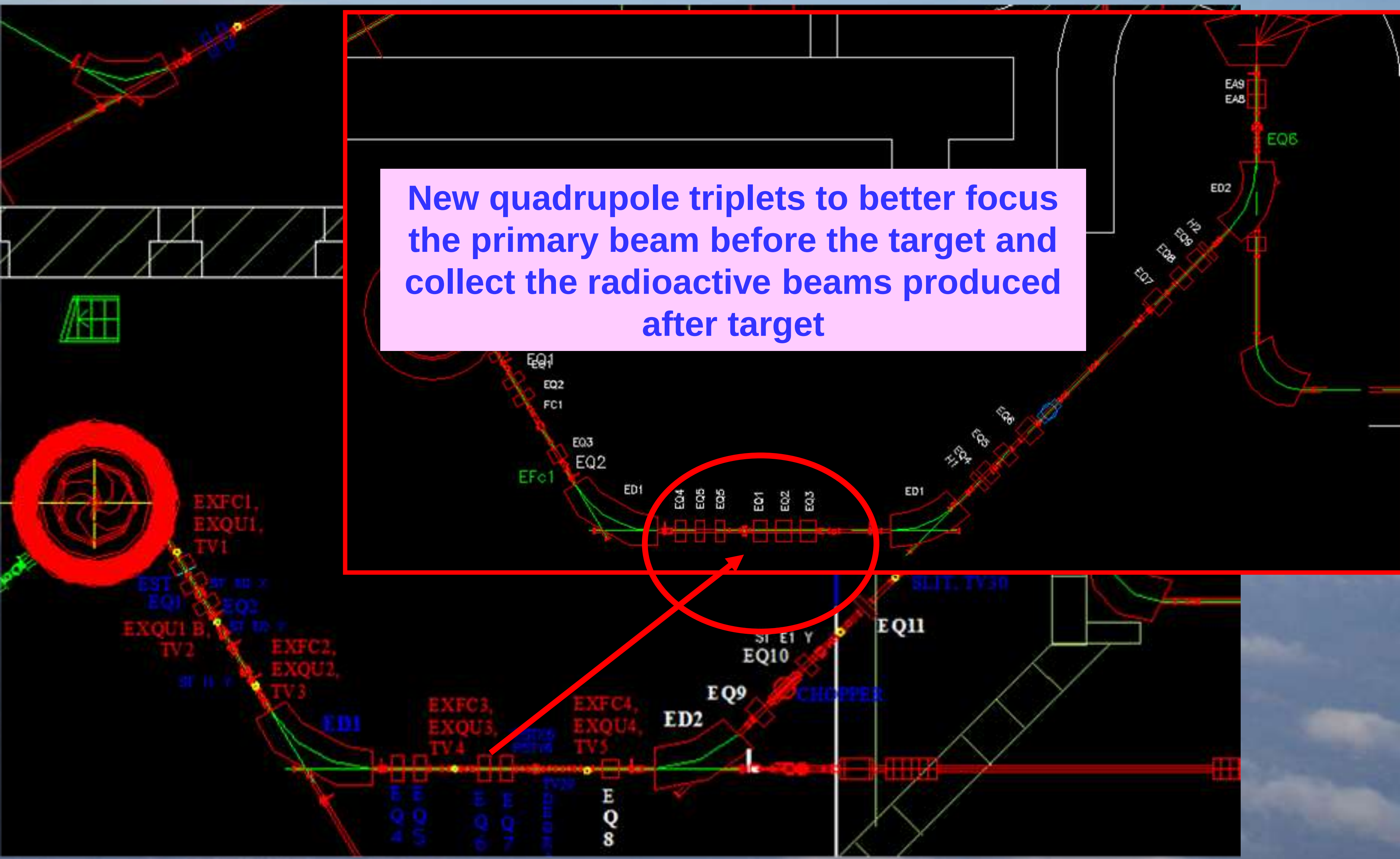
Fragmentation beams at INFN-LNS in Catania





I will take some time to describe in detail the beam characteristics because during next years many facilities in Europe (GANIL – GSI - ISOLDE) will reduce the available beam time for their upgrading so perhaps you can decide to perform some experiments at LNS

The upgraded LNS Fragmentation beam



Beam diagnostic

The EXCYT diagnostic was essential to improve the beam transport efficiency respect to previous transports based on Pilot beams **A.Amato,..G.Cosentino et al LNS report 2009**

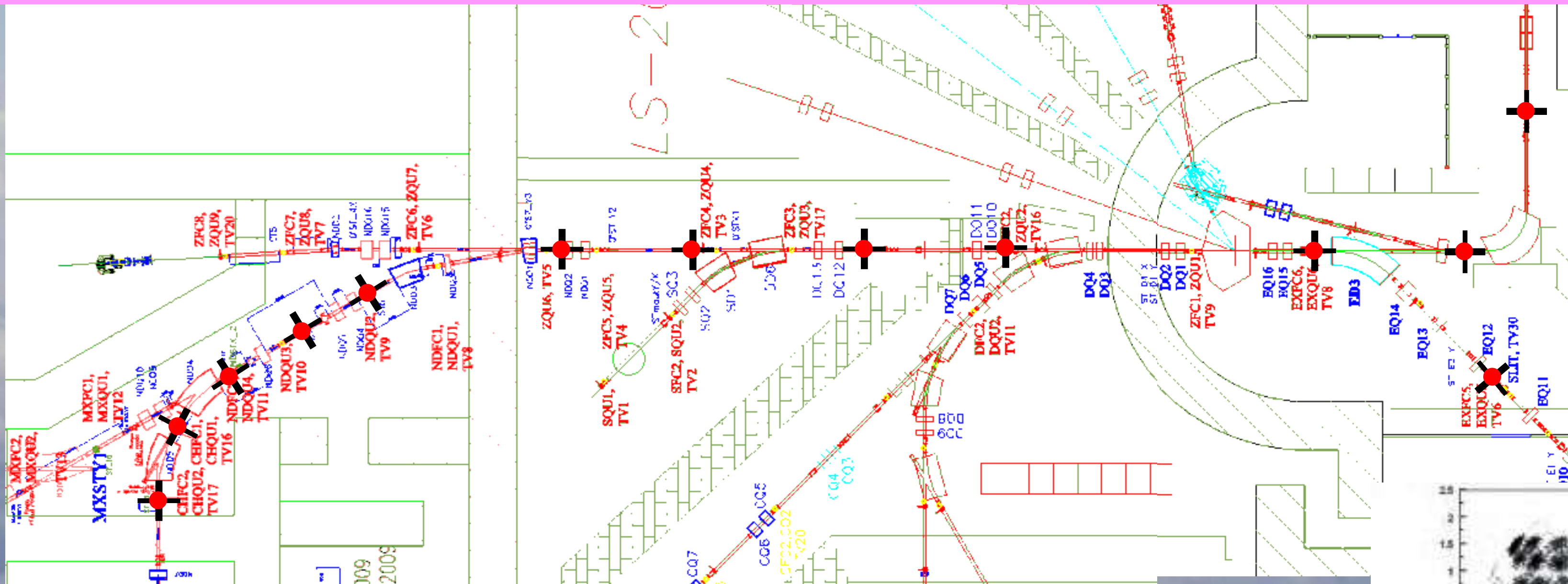


Fig. 2. Beam particle counter, based on a plastic scintillator coupled to a photomultiplier.

Fig. 3. PSSD mounted in a pneumatic actuator. The mask made by brass is 2mm thick.

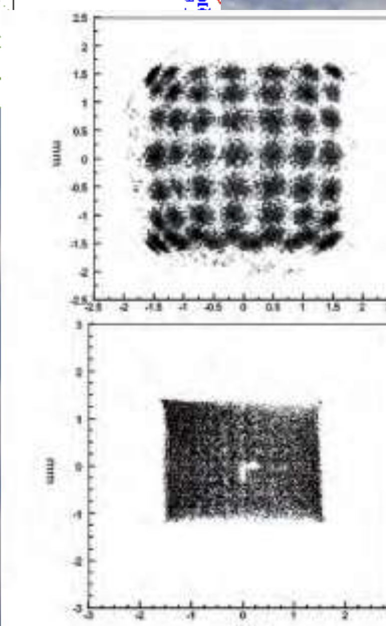
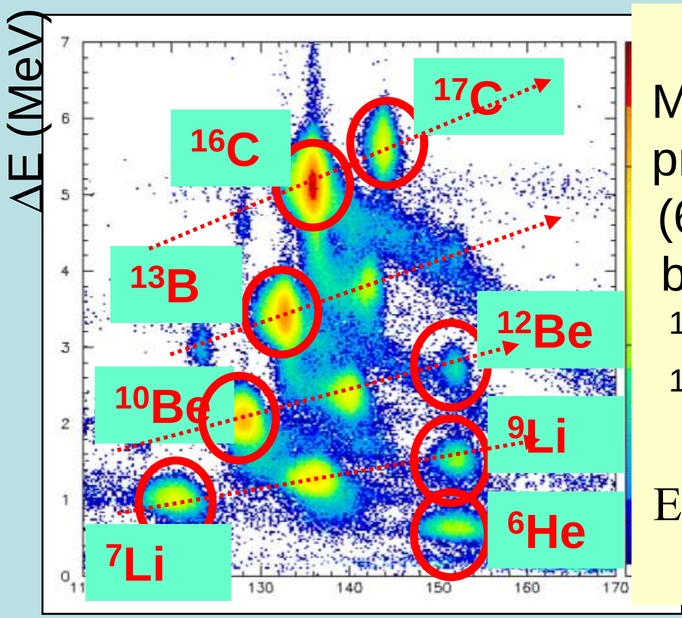


Fig. 4. Corrected beam profiles of EXCYT (a) and … two different masks.

Intensities of some beams available in the CHIMERA Hall

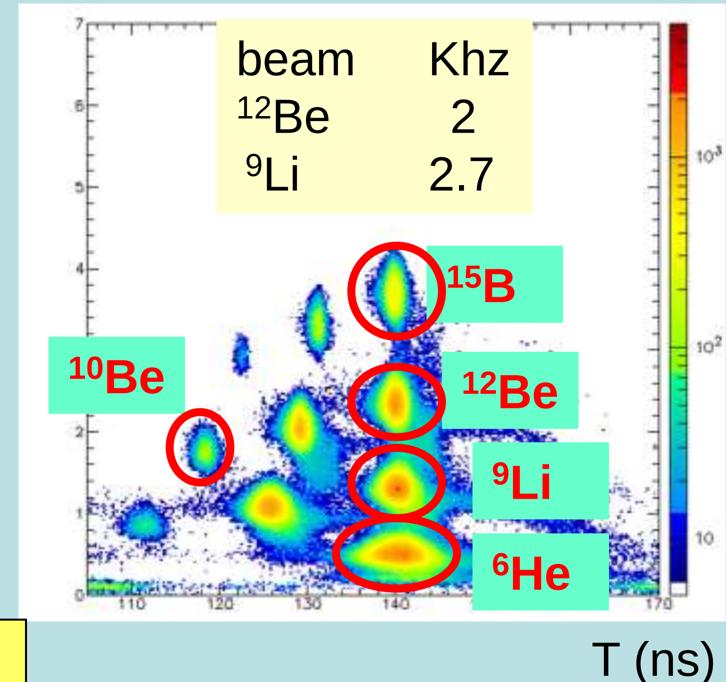


^{18}O 55 MeV/A 100 W primary beam (6.3×10^{11} p/s)

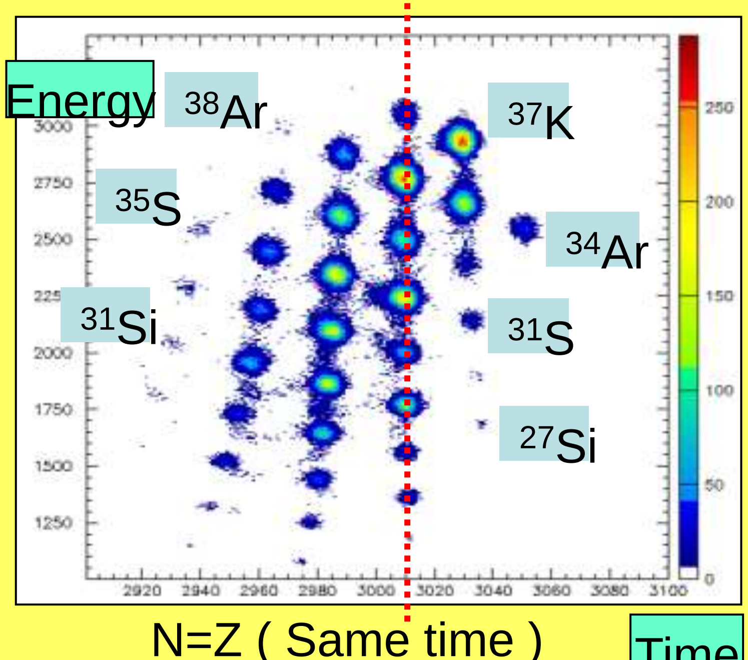
beam	Khz
^{16}C	60
^{13}B	40

E~50 MeV/A

ΔP/P <1%



beam	Khz
^{12}Be	2
^{9}Li	2.7



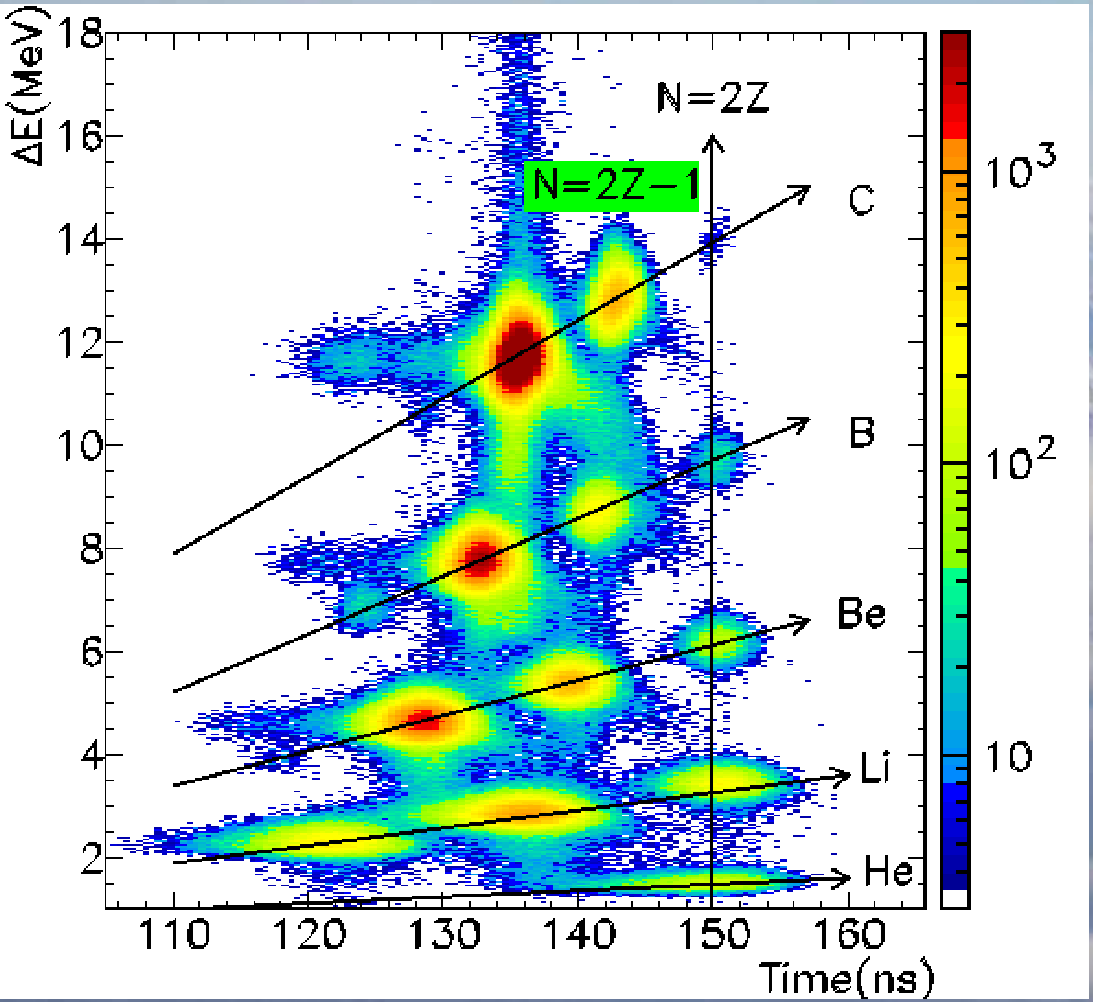
Beam	Khz
^{37}K	14
^{34}Ar	1.8

Primary beam ^{36}Ar

Energy ~ 20-25 MeV/A

(25 W)

Beam identification



A fragmentation beam is generally a mixed beam and many efforts are devoted to improve its purity

In our case we decided to begin with a more simple approach – to identify event by event all beam nuclei performing many experiments at the same time

The tagging system is therefore of fundamental importance

Tagging system: flow chart I DSSSD

I cannot change too much the beam characteristics if I want to use it

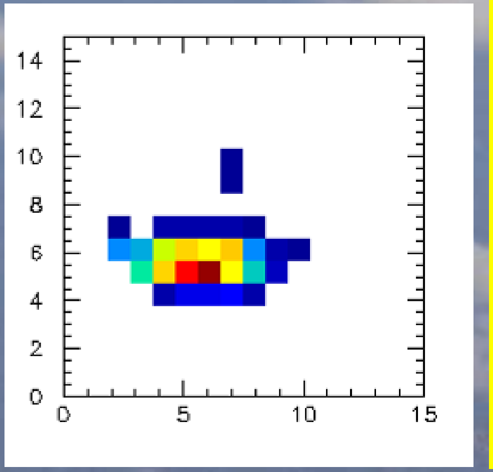
ΔE-E?

I cannot stop the beam in the tagging detector

ΔE-T?

What can I use for ΔE?

Double side Silicon strip detector



Two main advantages:
From the position of the strip I can also get the XY image of the beam

Many strips can sustain a larger rate than a single detector

Tagging System: flow chart II - RF-timing

ΔE-E?

I cannot stop the beam in the tagging detector

ΔE-T?

Possible but

how

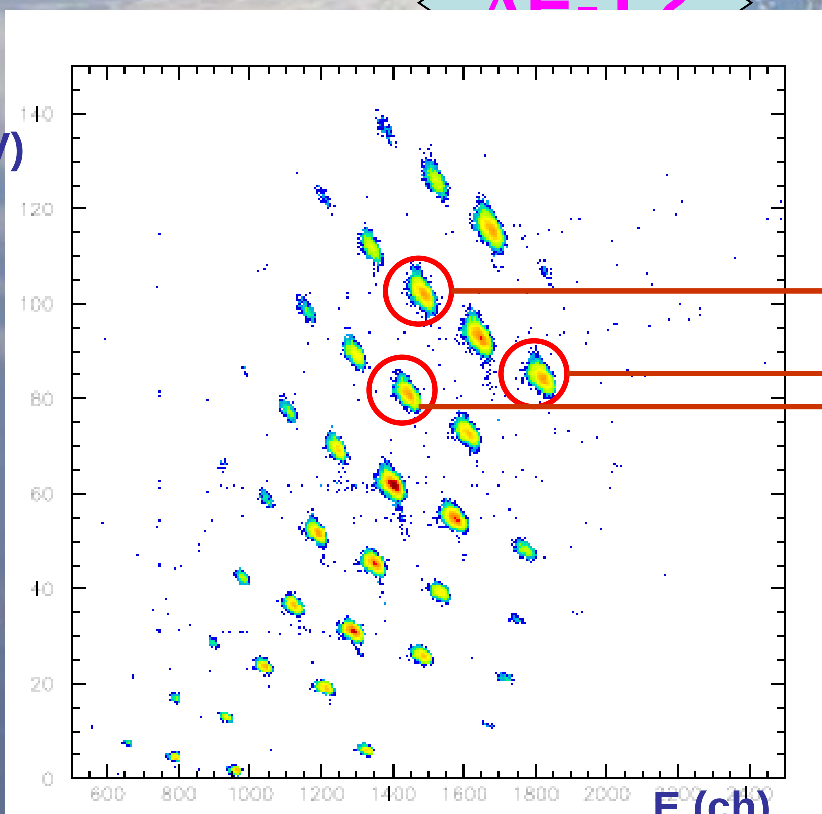
Ma

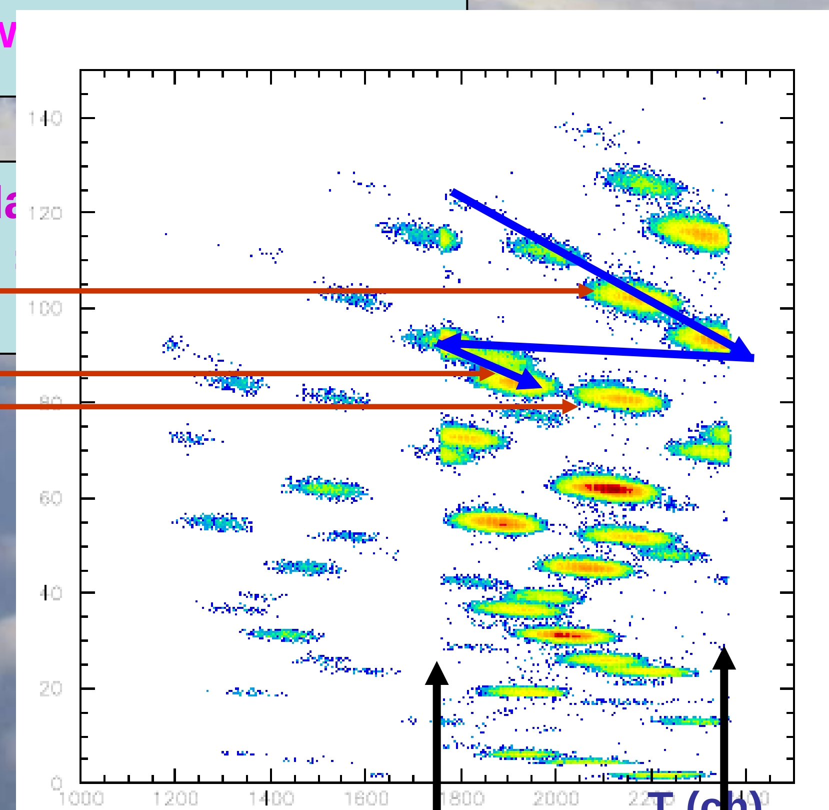
^{20}Ne

^{18}Ne

^{18}F

ΔE (MeV)





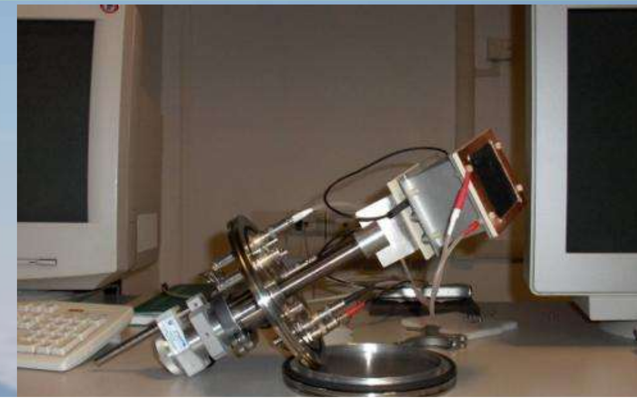
IWM-2011 CAEN Nov 4th 2011

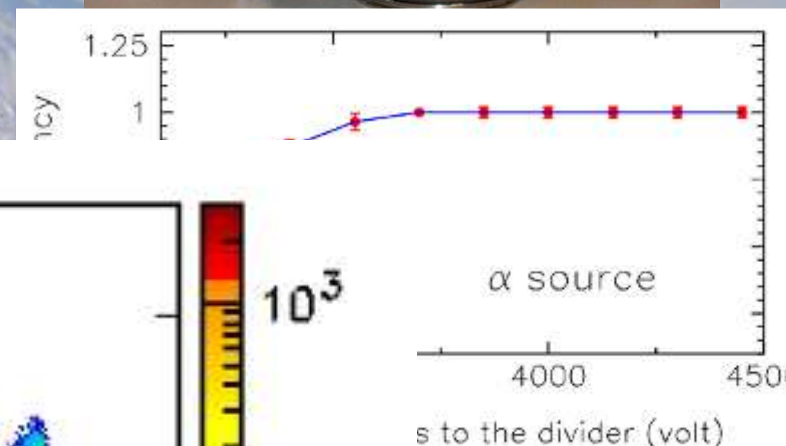
Tagging system : flow chart III MCP timing

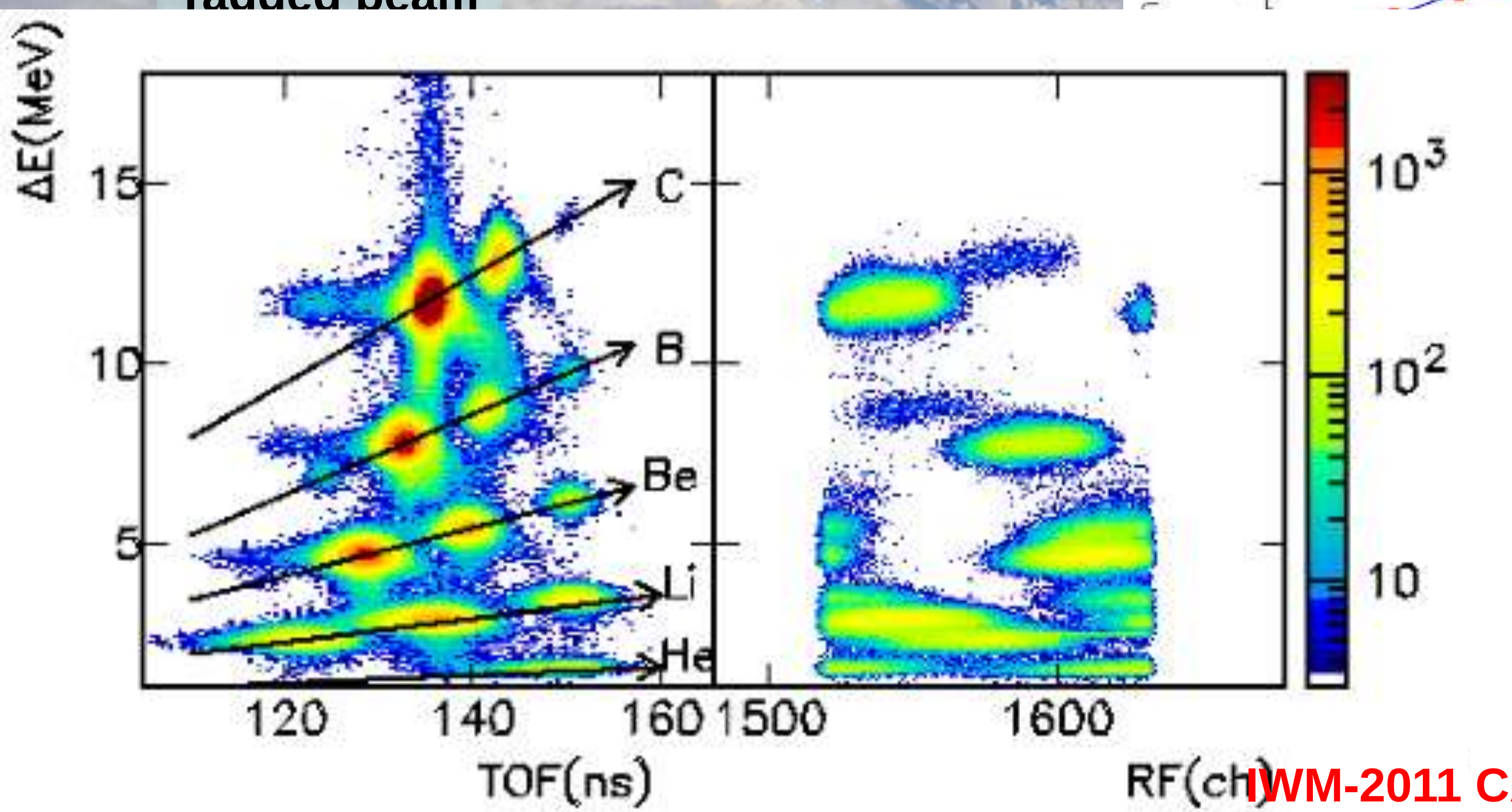
DE-E?

I cannot stop the beam in the tagging detector

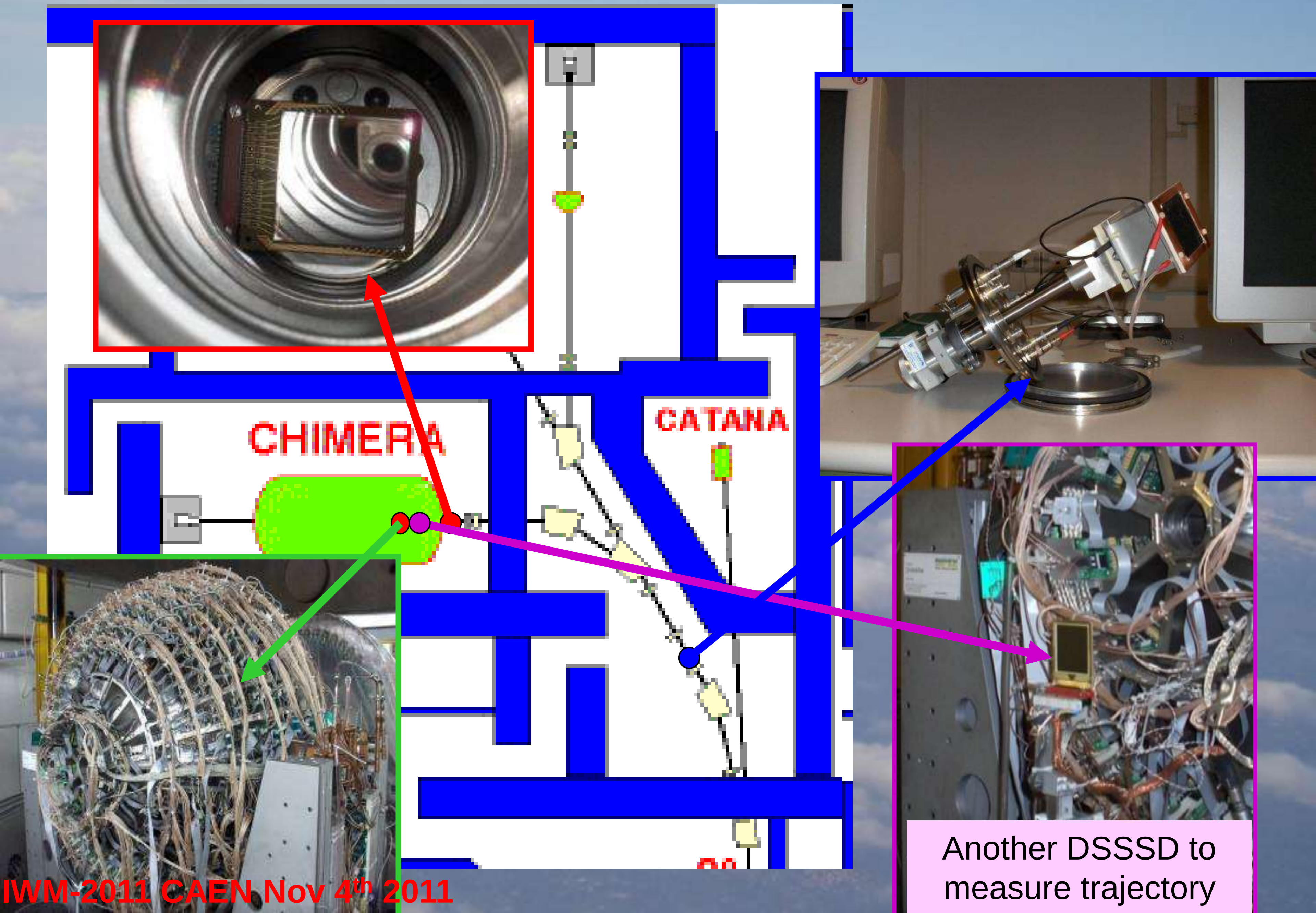
Tagged beam



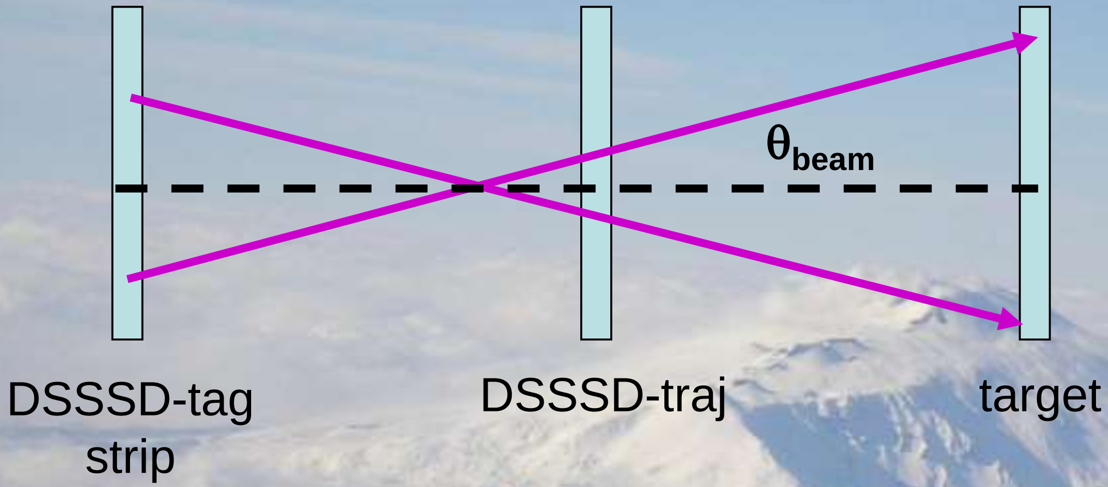


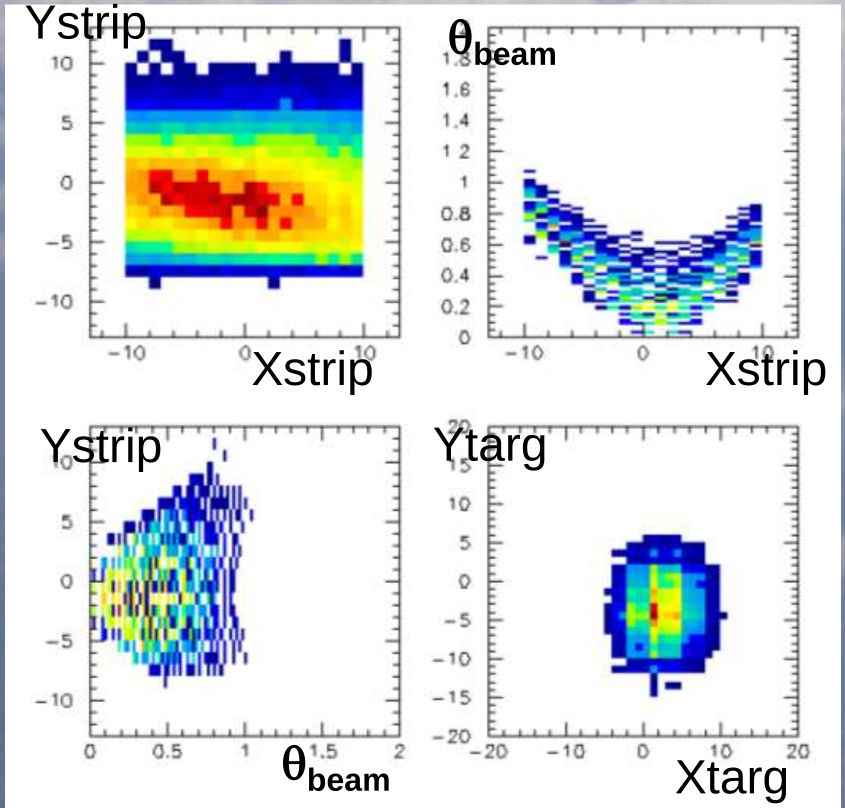


Tagging system: layout



Production and transport test: beam trajectory

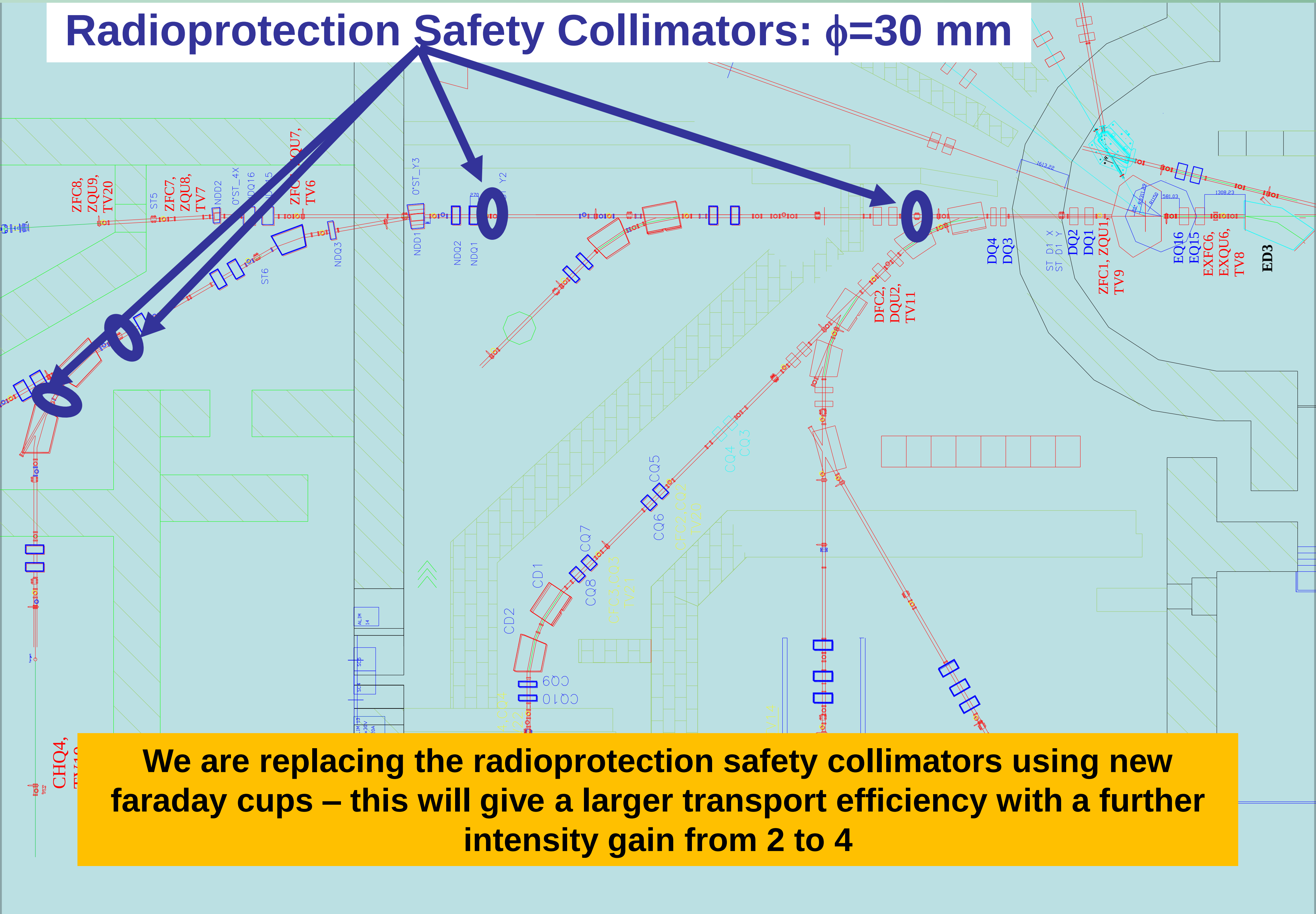




It is possible to produce a very beautiful beam on target – with very small divergence

Next improvements

Radioprotection Safety Collimators: ϕ=30 mm



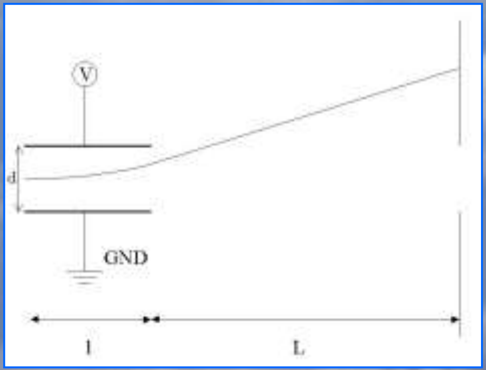
We are replacing the radioprotection safety collimators using new faraday cups – this will give a larger transport efficiency with a further intensity gain from 2 to 4

Next improvements

Chopper - 500

The production of consecutive accelerated bunches with a separation time of up to 200 ns and a width of 500 ps FWHM, is the goal of this new chopping beam system. The chopper 500 should cut the present length of the accelerated beam bunches, delivered from the superconducting cyclotron, from 1.5÷2 ns to 0.5 ns.

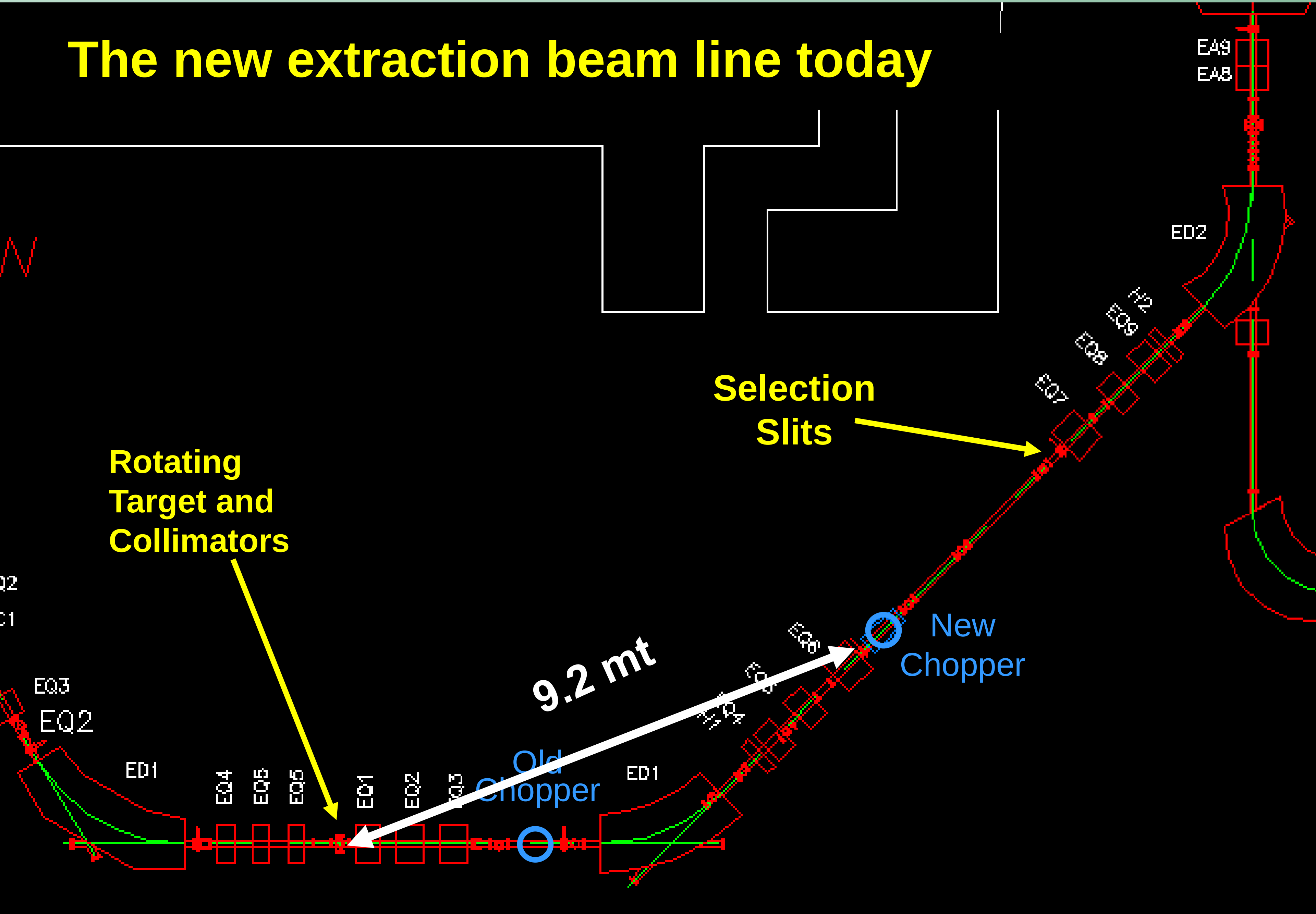
From separation time 20-66 ns
Width of single bunch 1.6-5 ns



To separation time ≤ 200 ns
Width of single bunch 500 ps

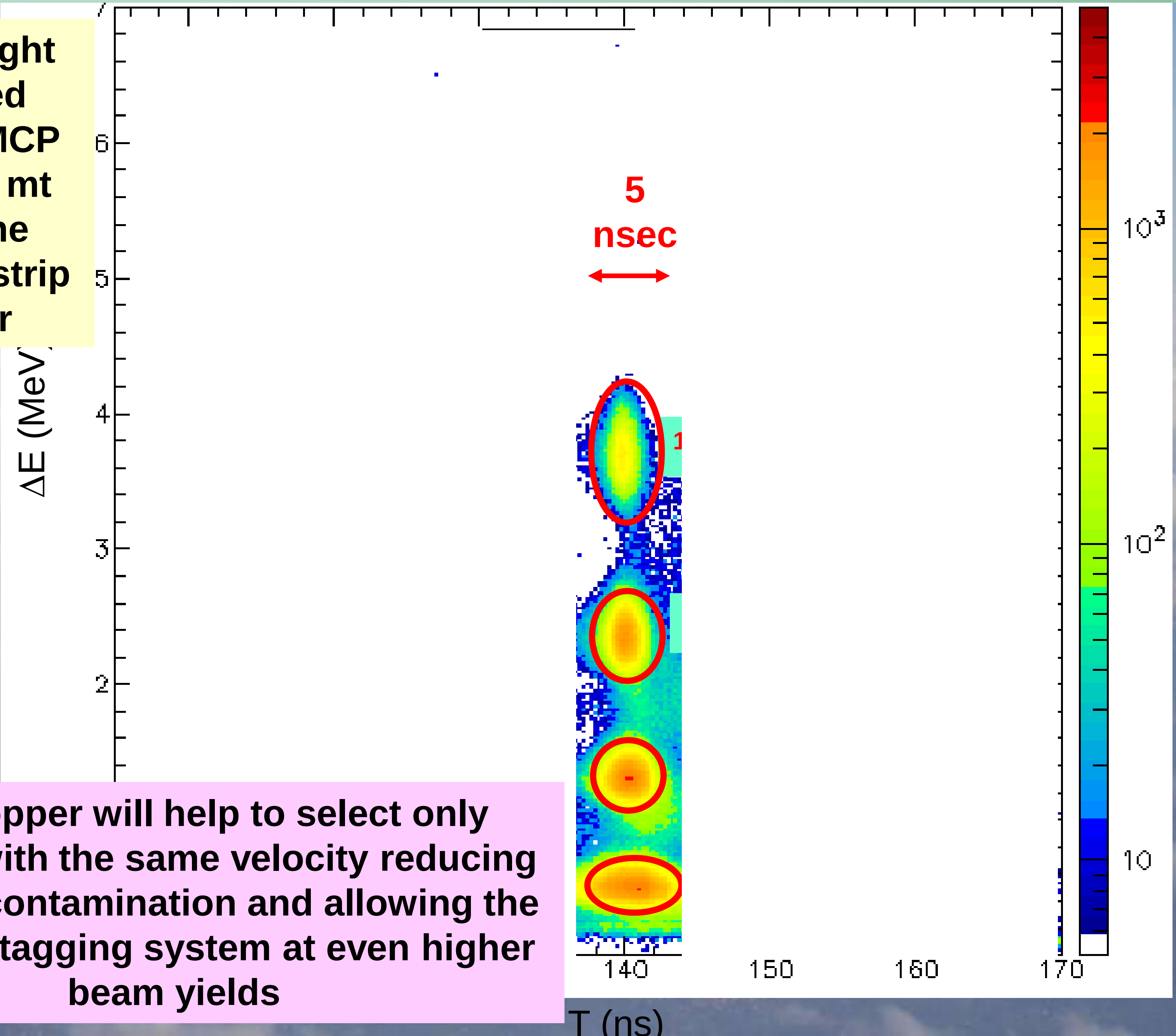
Chopper-500 cavity

Next improvements



Next Improvvements

Time of flight measured between MCP placed 13 mt before the CHIMERA strip detector



The chopper will help to select only particles with the same velocity reducing the beam contamination and allowing the use of the tagging system at even higher beam yields

Physics program of CHIMERA with fragmentation beams

The first experiments where on the structure of light neutron rich nuclei with elastic scattering and transfer reactions measurements on p, d targets – this choice was suggested by the need to have some results also with relatively low beam intensity

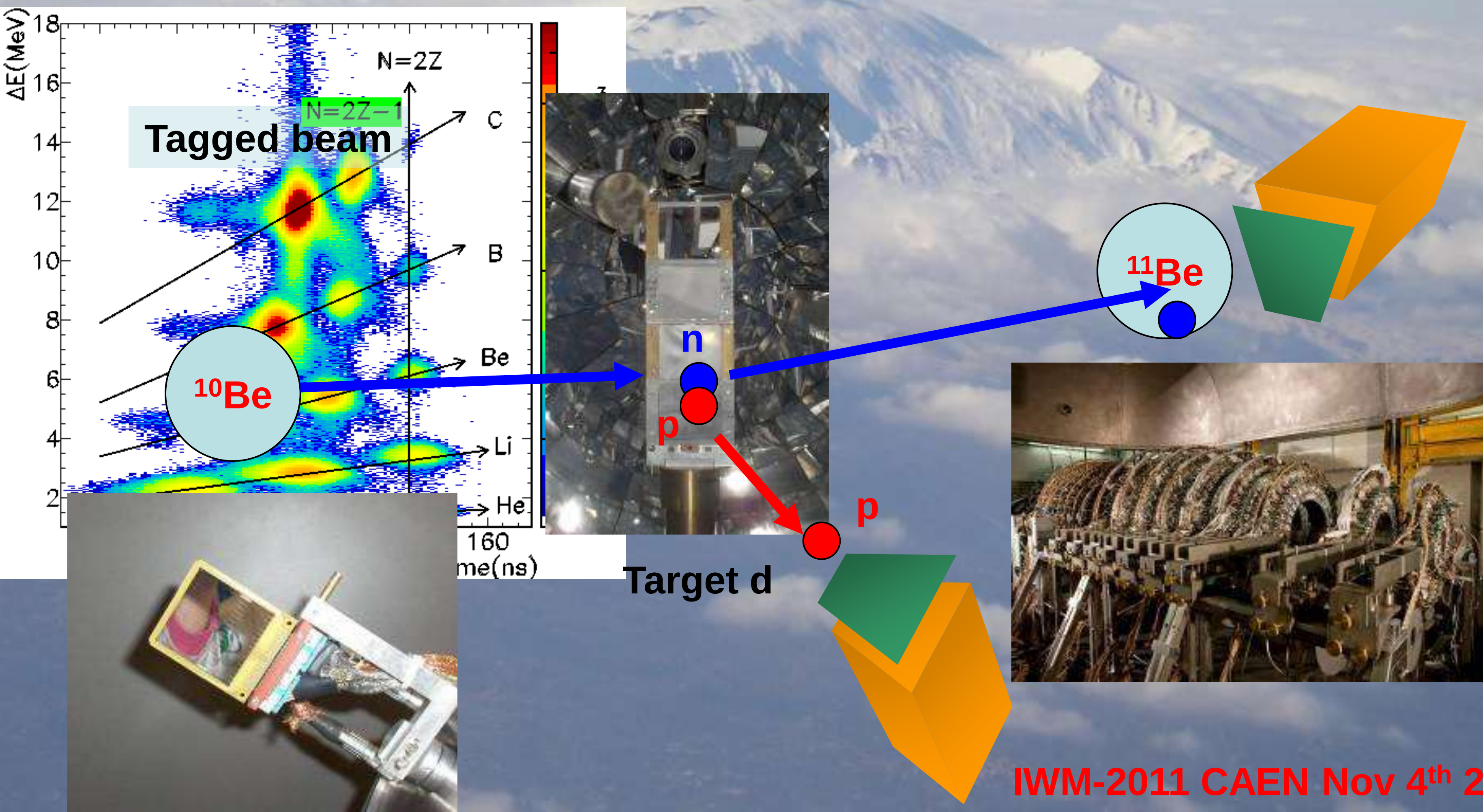
Now we are pushing at the extreme this light nuclei line with attempt to produce very exotic nuclei like ^{8}He

On the other hand we are also trying to produce more heavy beams to extend the "standard" CHIMERA isospin physics

-Elastic scattering and neutron transfer reactions near halo nuclei -

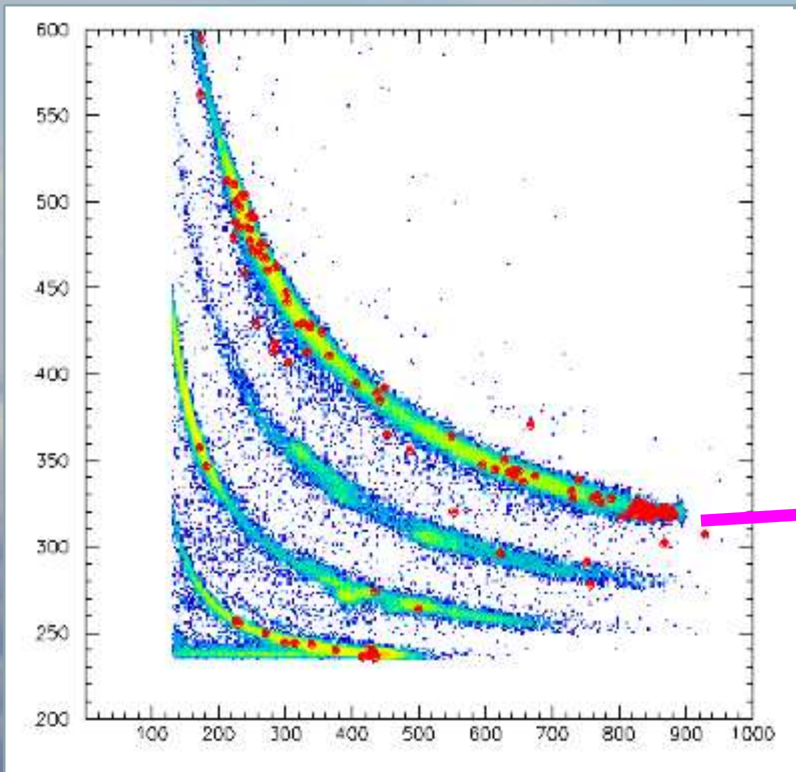
We want study elastic scattering and transfer reactions of light nuclei on p, d targets to look for halo or other nuclear structure effects

EVENT SELECTION performed with kinematic coincidences – we measure in binary reactions both reaction partners cleaning the events

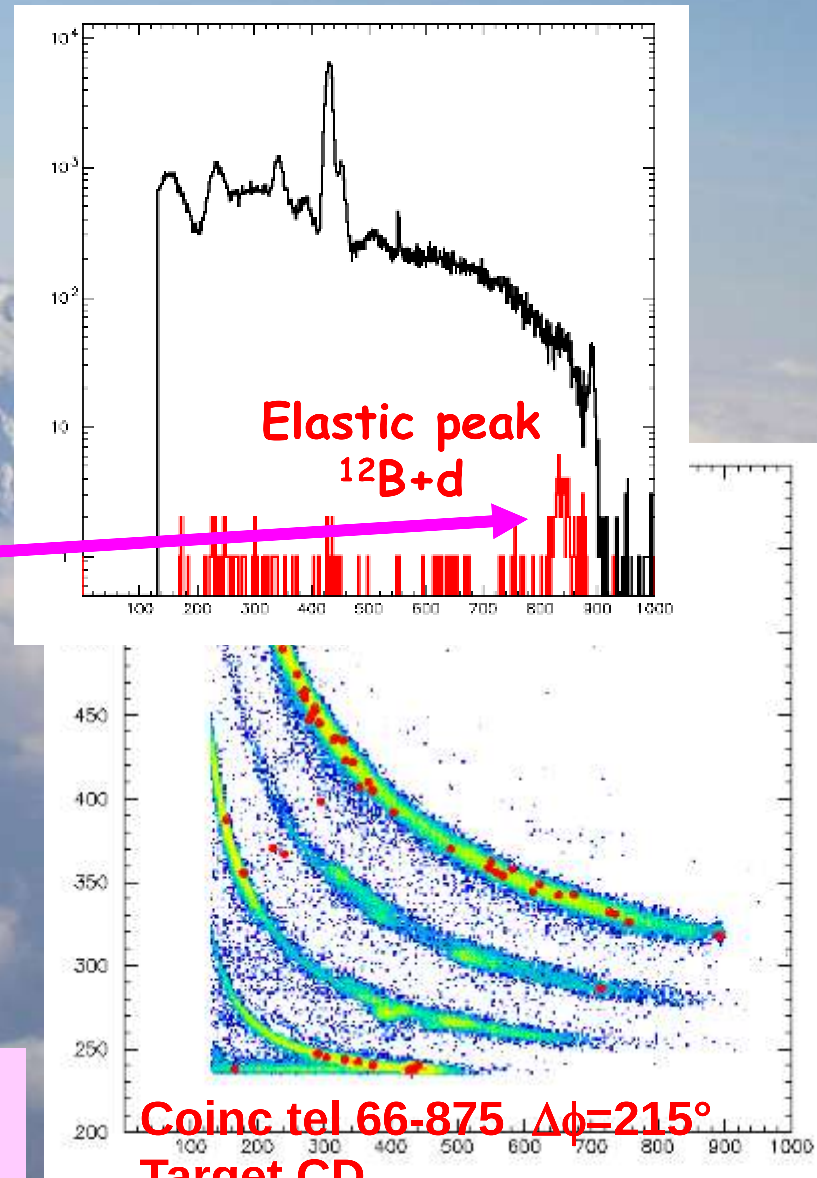


IWM-2011 CAEN Nov 4th 2011

DETECTION : kinematical identification



Coinc tel 38(3.1°)-870(66°) Δϕ=180°
Target CD beam 12B

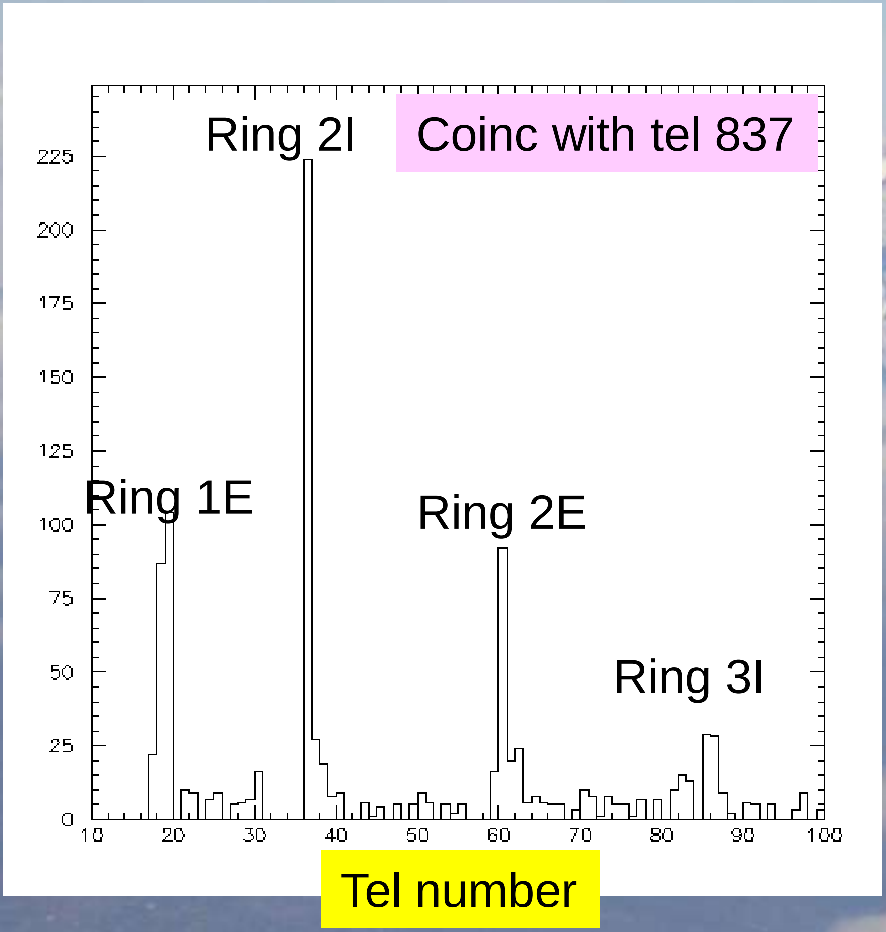


Coinc tel 66-875 Δϕ=215°
Target CD

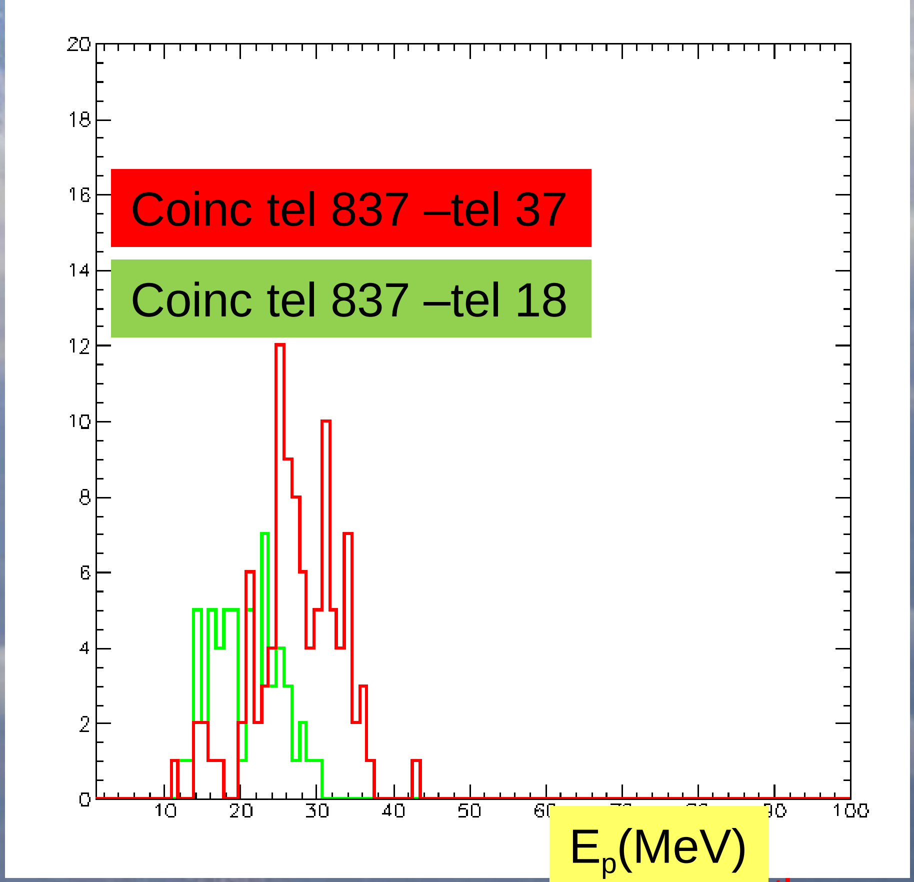
Very clean measurement – coincidences are observed only if Δϕ=180°

– Some preliminary results on elastic scattering

The kinematical coincidence is a simple and fascinating idea however needs some trick to be really used



However when we look in detail to the energy spectrum we have a large spread for instance in the elastic channel why?

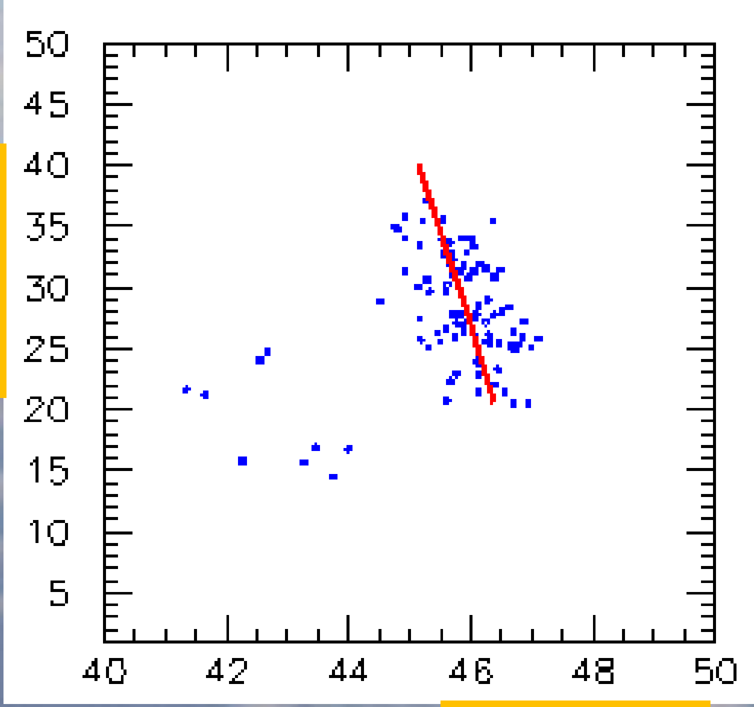


As shown before the coincidence rate is enhanced with telescopes at the right azimuthal angle

– Some preliminary results on elastic scattering

Part of the spread is due to kinematics

Coinc p-^{16}C tel 36-837



E_p(MeV)

E_C(MeV/A)

We are able to follow the kinematics but the E1-E2 experimental line is too large

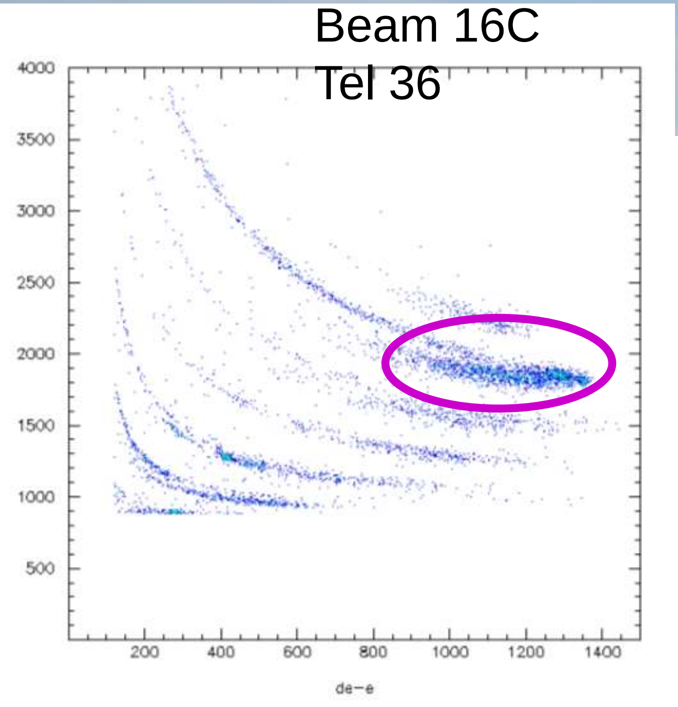
We must remember that the fragmentation beam is not a perfect beam
We have a momentum spread of about 1% due to the acceptance of the beam line
i.e. 2% Beam energy spread
we have to take into account this

We have in principle various possibilities to measure the beam energy

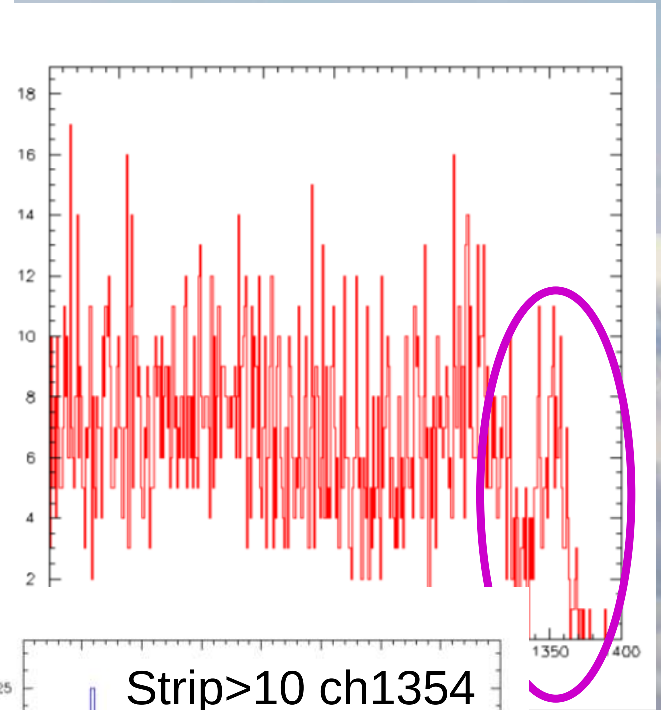
TOF (beam TOF from mcp to tagging detector)
ΔE (energy loss in tagging detector)
Bρ (from trajectory measurements after a magnet)

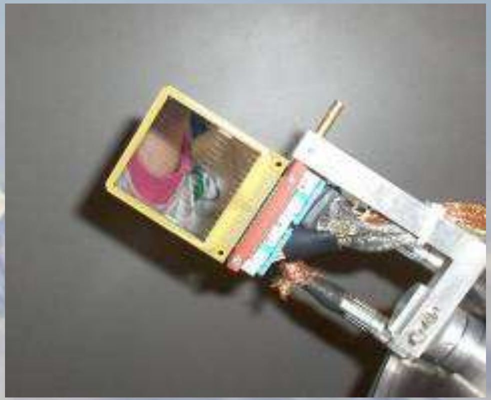
Energy Loss of 50 MeV/A ^{16}C in 62 micron tagging is 5 MeV – but the straggling is ≈200 keV so it is impossible to use it for the energy calculation

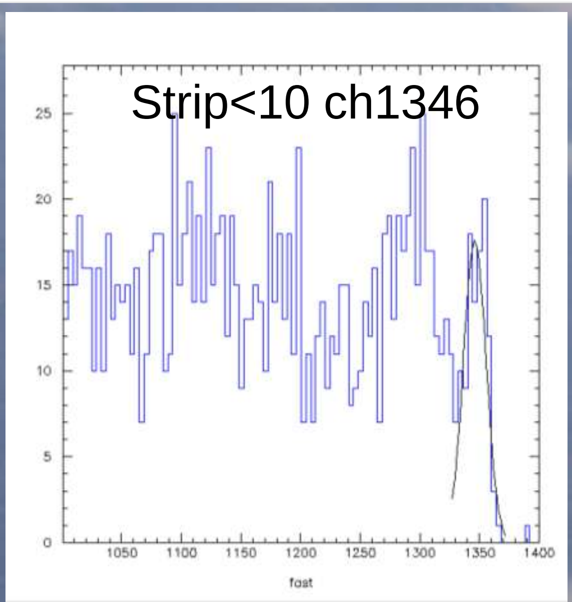
– Some preliminary results on elastic scattering

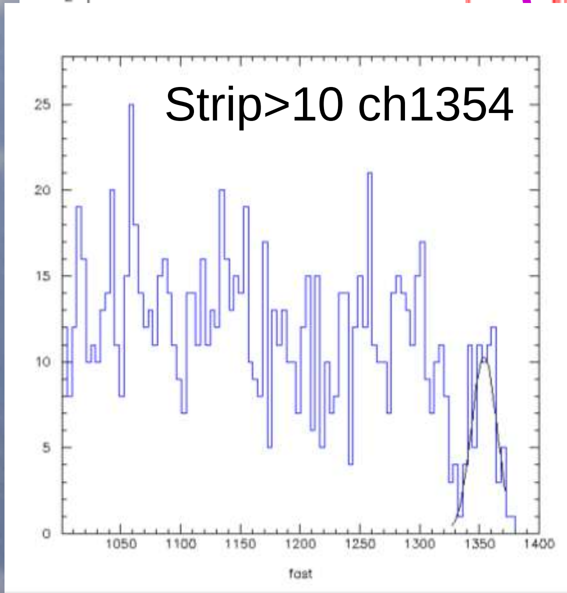


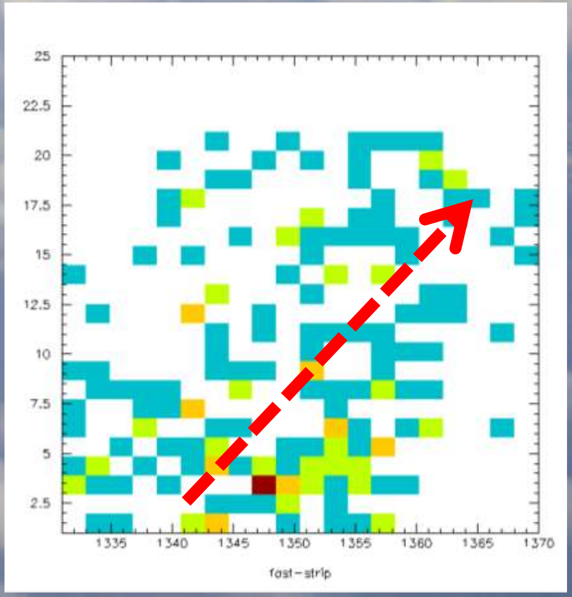
Bρ measurement at work





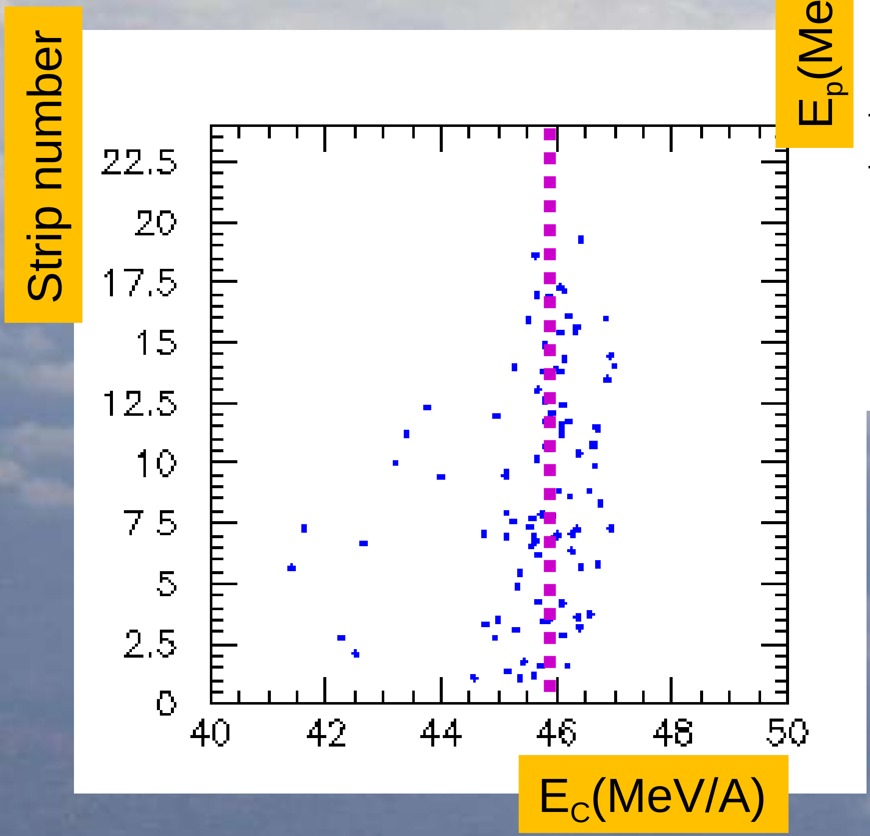


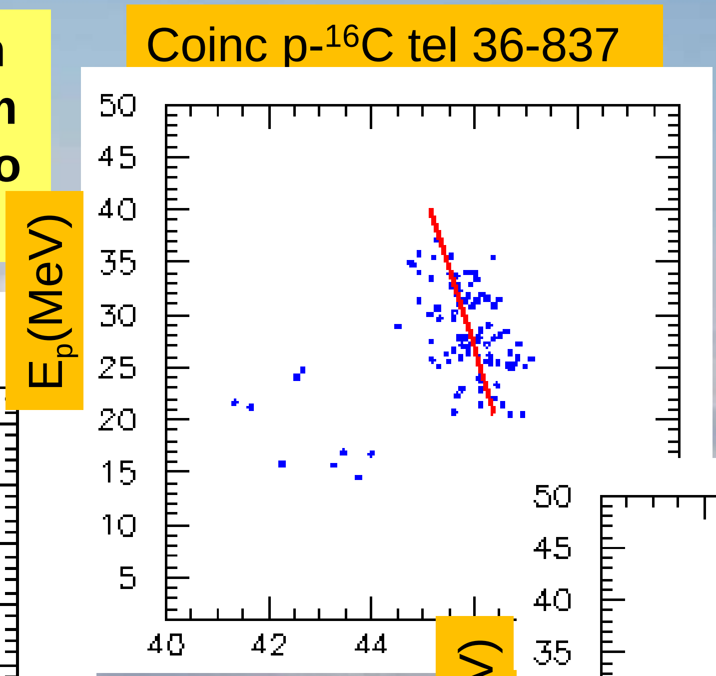


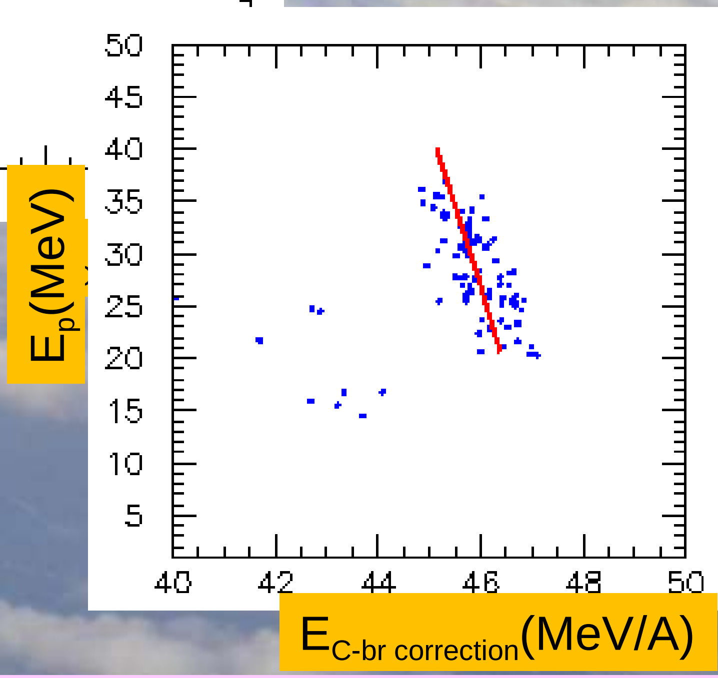


– Some preliminary results on elastic scattering

Also the ^{16}C scattered by proton show the same dependence from the strip position so we can try to correct the Ep-EC plot



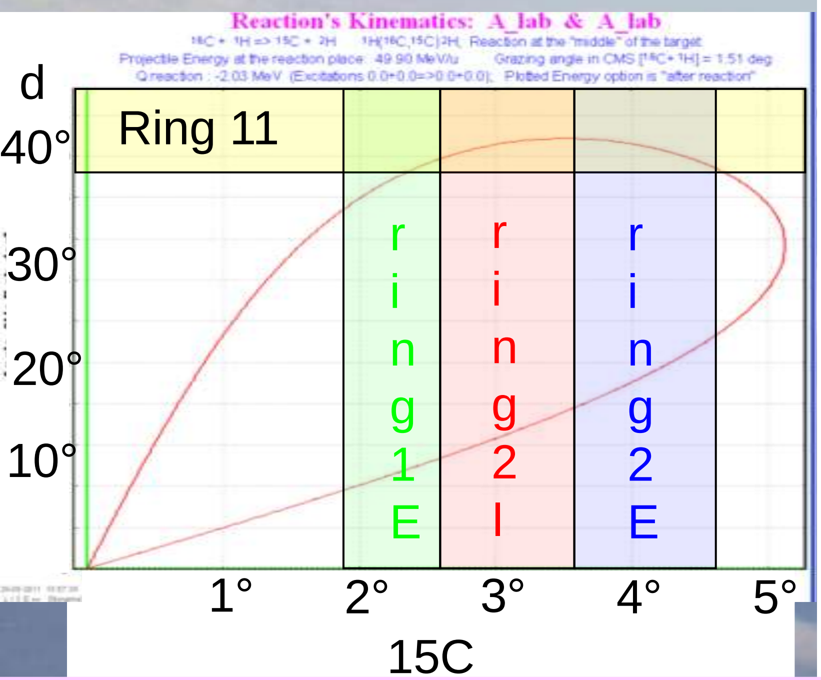


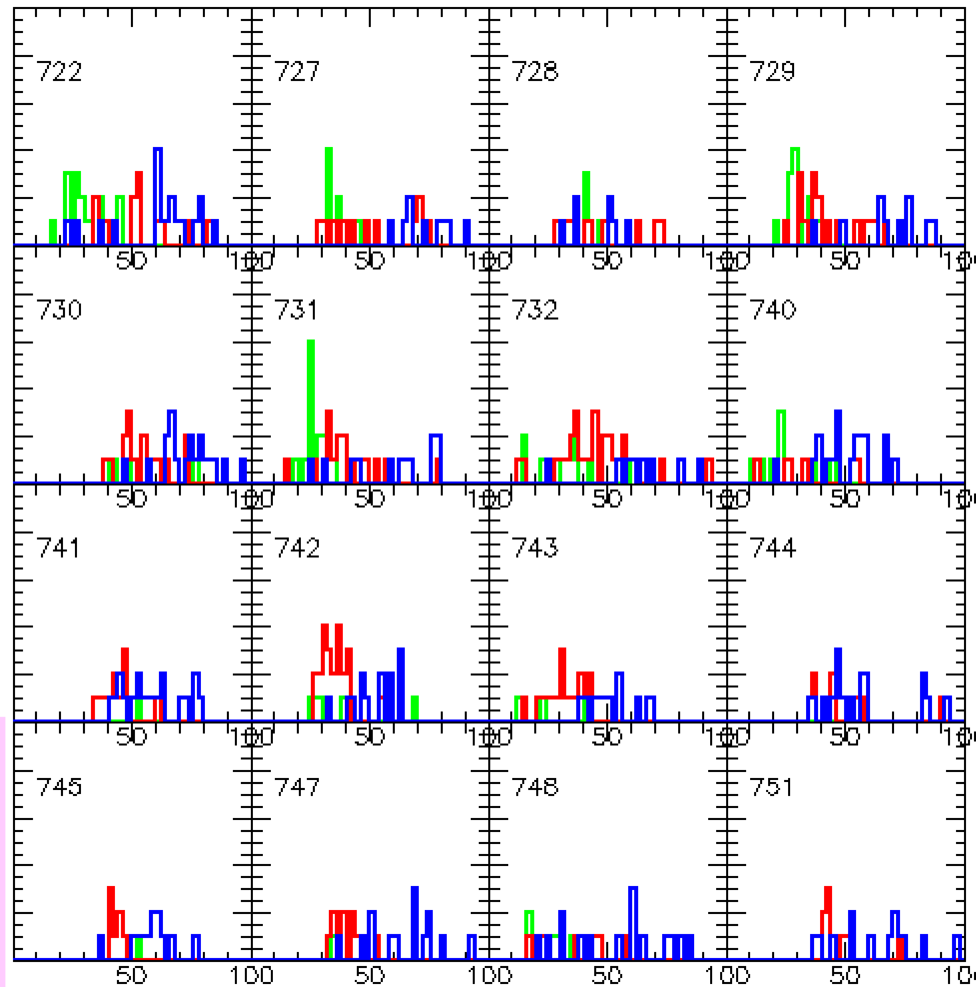


The results are promising we must do better taking into account also the trajectory measurement - work is also in progress to use the TOF together with bρ measurements

– Some preliminary results on transfer reactions -

We can look the ^{16}C+p->^{15}C+d reaction searching for deuterons in coincidence with carbon – we look to kinematics and we see that deuterons detected around 40° (ring 11) are in coincidence with carbon from 2° to about 5° (rings1E, 2I, 2E)



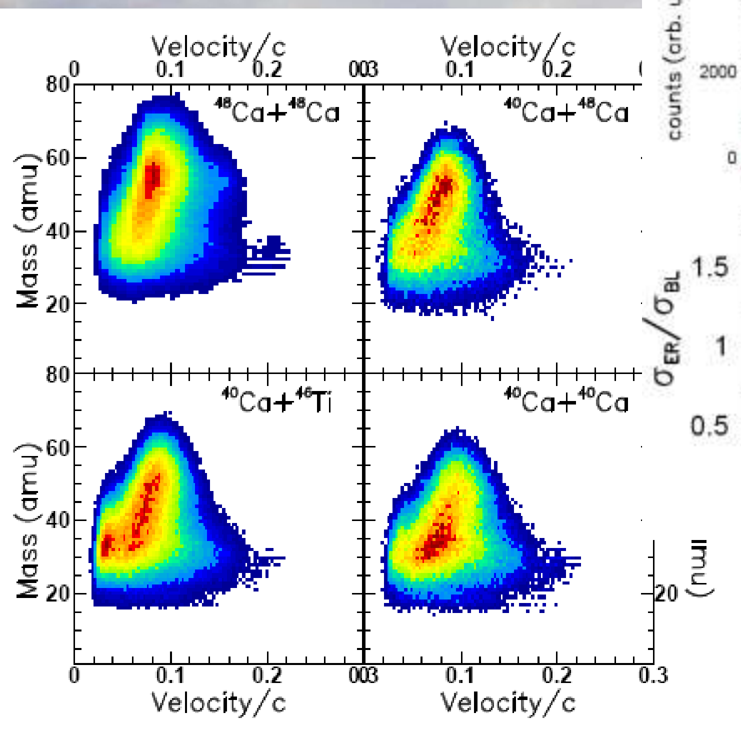


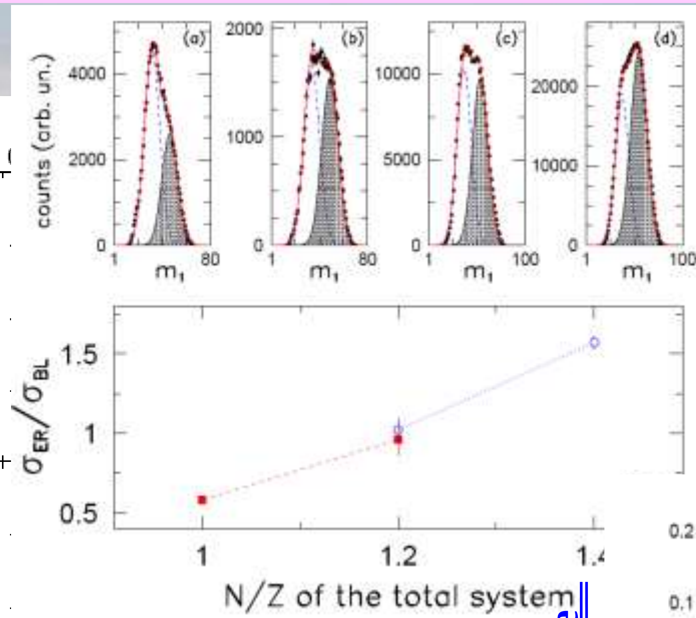
E_d(MeV)

We can observe some reasonable kinematical behavior – we must correct for the beam trajectory and energy - however it seems we have enough statistics to extract a reasonable angular distribution

Experiment in progress - Isospin dependence of reaction mechanisms

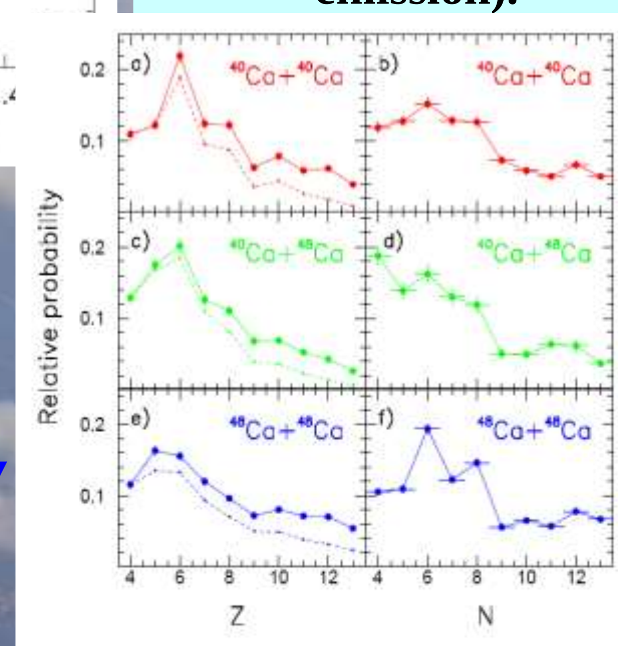
You have seen in the Ivano Lombardo presentation the results obtained in reactions induced by $^{40,48}Ca$ at 25MeV/A on $^{40,48}Ca$, ^{46}Ti.





By increasing the N/Z of the entrance channel increases the ratio between ER production and other mechanisms (such as binary-like and multi-fragment emission).

N/Z increase



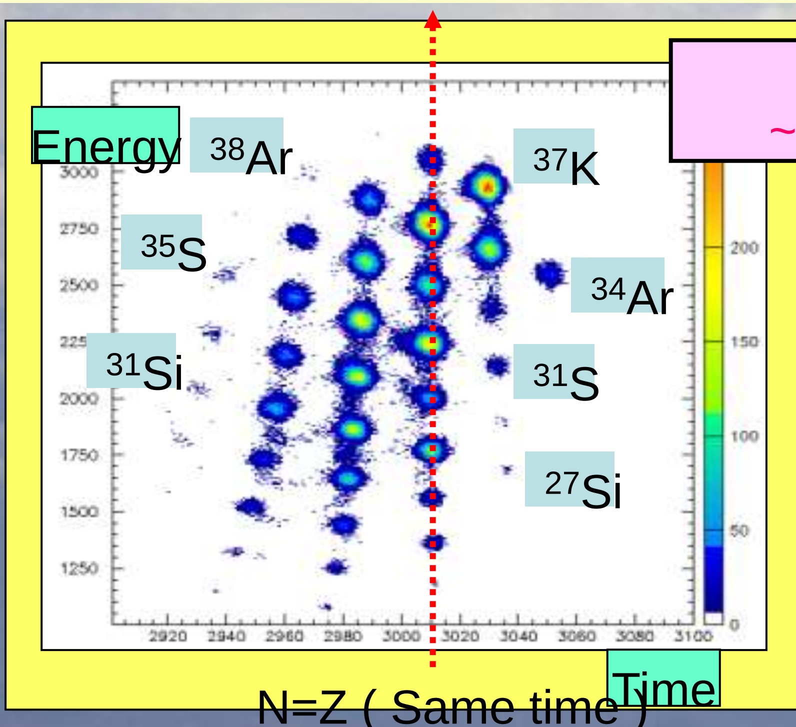
Z/N increase

Width of even odd staggering in Z and N distribution depending on the N/Z of the system

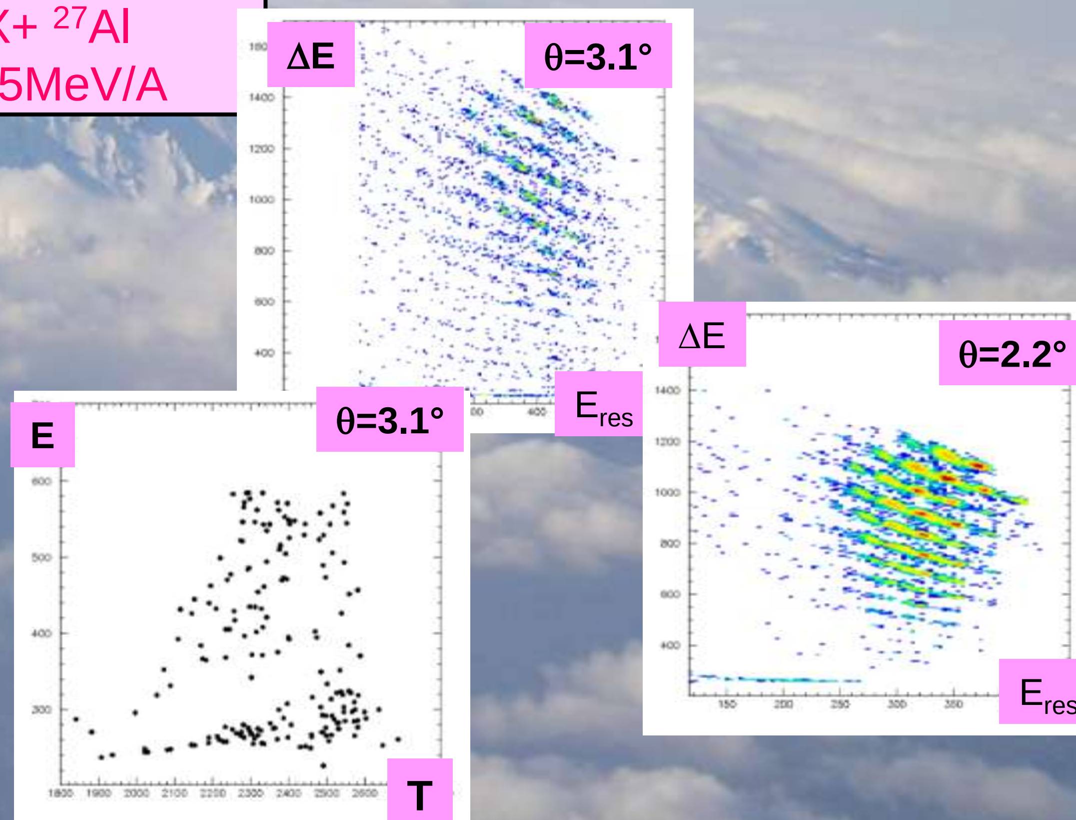
Experiment in progress - Isospin dependence of reaction mechanisms

Following these results we decided to extend the investigations to a larger range of N/Z of the total system.

A first attempt was performed on February this year. The exotic mixed beams produced by fragmentation of ^{36}Ar was sent on a ^{27}Al target and reaction products where detected with CHIMERA

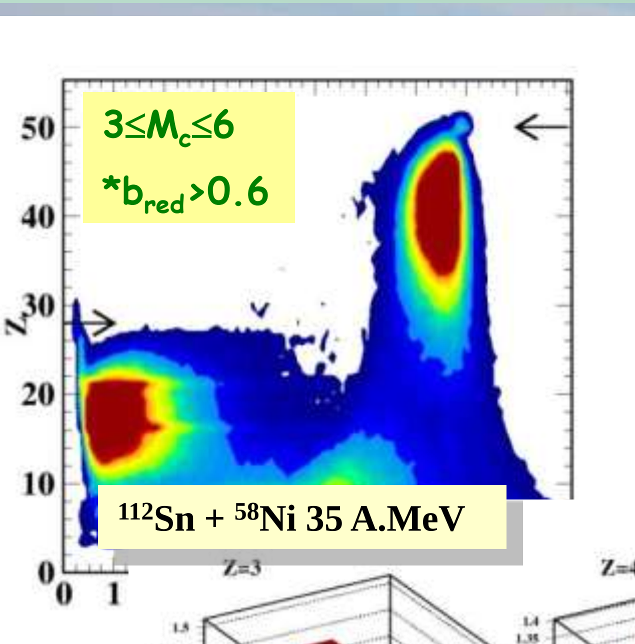


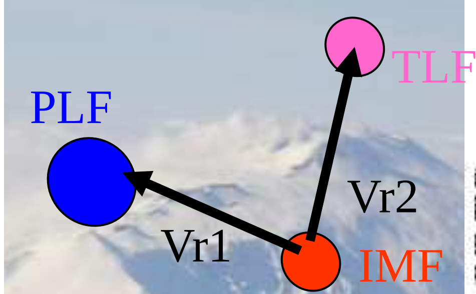
X+ ^{27}Al
~25MeV/A

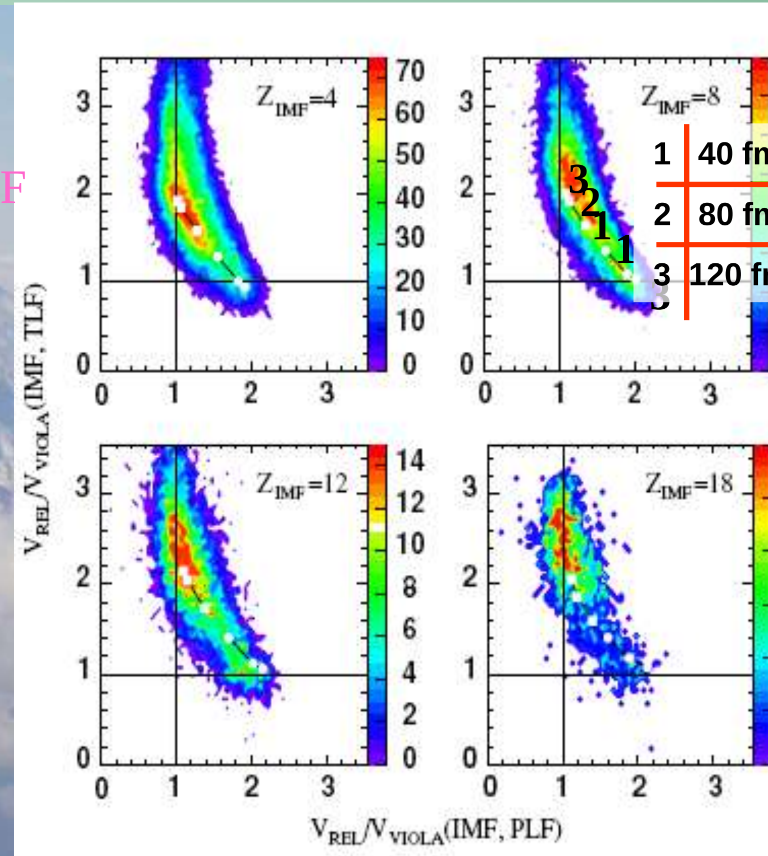


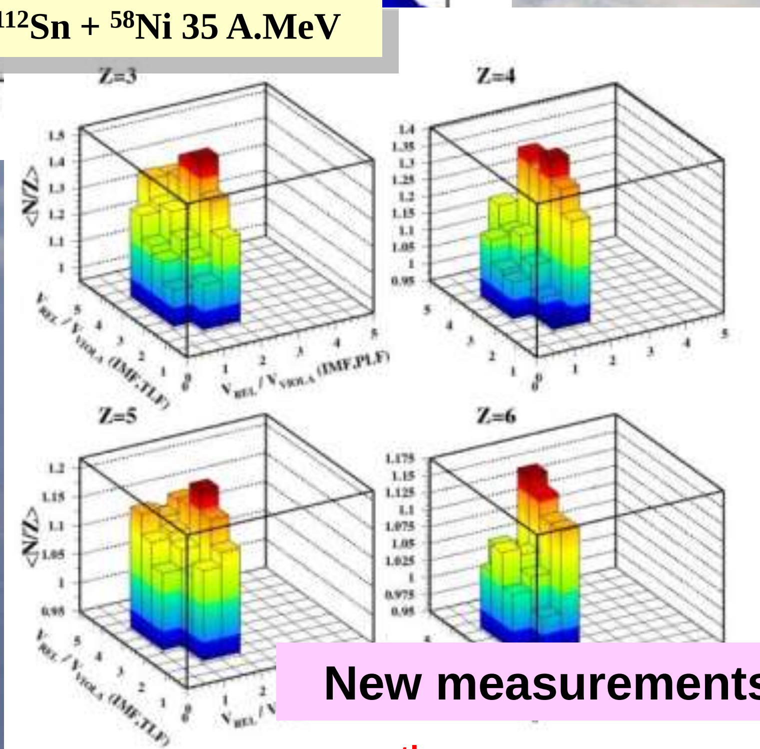
The analysis is going

Experiment in program: - Angelo Pagano has shown IMF Emission Timescale in reactions induced by Ni ions on Sn – Isospin dependence -





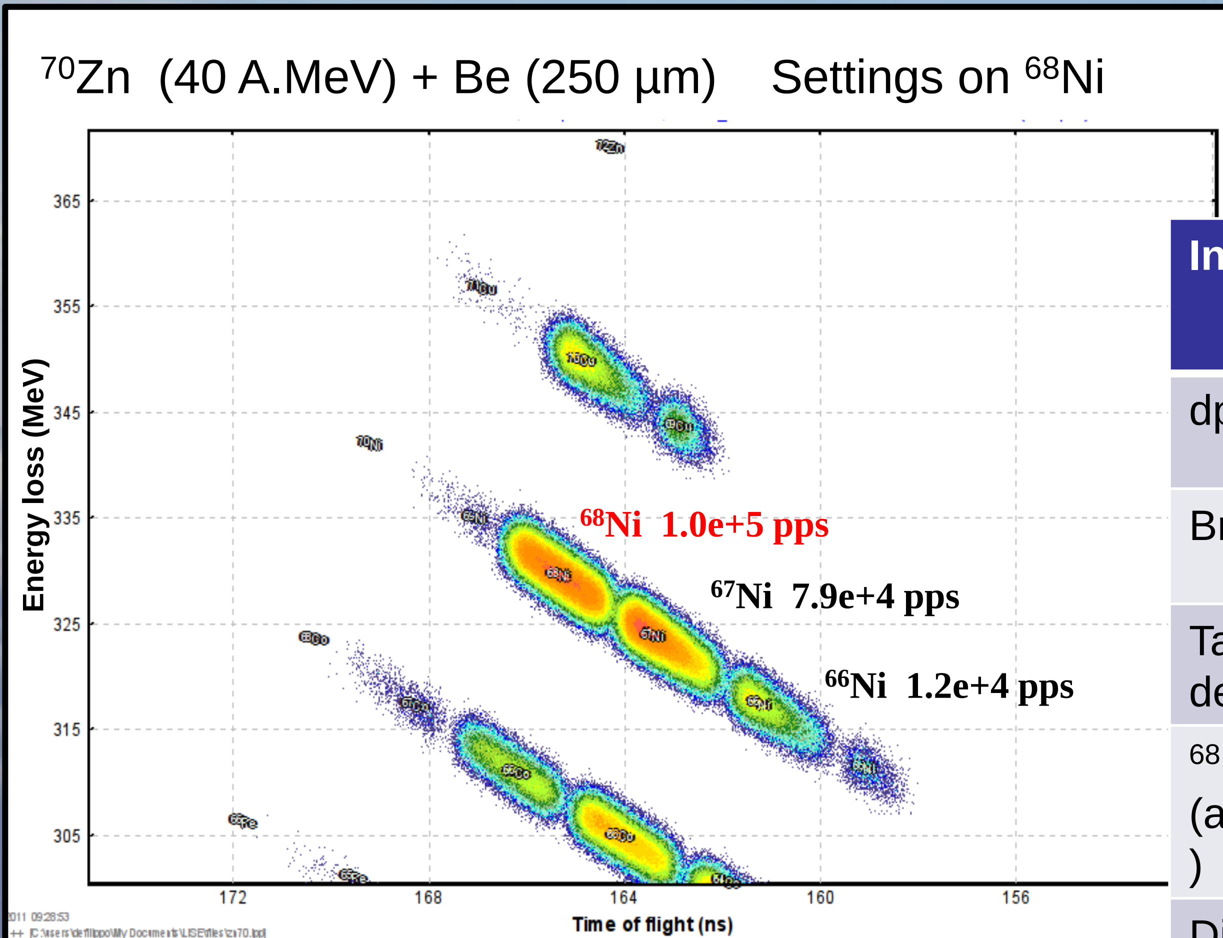




Measurements already performed with $^{64,58}Ni + ^{112,124}Sn$ (direct and inverse kinematics)

New measurements with beams of ^{68}Ni (fragmentation of ^{70}Zn)

LISE++ simulations for ^{70}Zn primary beam at 40 A.MeV



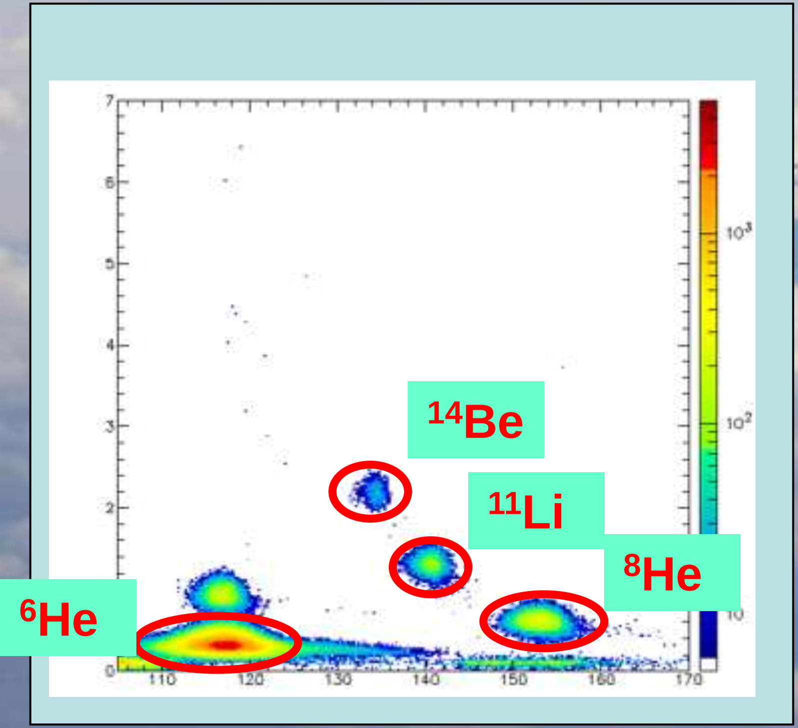
Intensity	0.1 kW (1071 enA)
dp/p	≈1.0%
Brho	2.03Tm
Tagging detector	Si 140 µm
^{68}Ni Energy (after tagging)	≈ 28 A.MeV
Distance MCP-DSSSD (time of flight path)	12.9 m

Lise++ settings for IFEB@LNS simulating the TOF-DE scatter plot of the tagging system for the chosen ^{68}Ni isotope

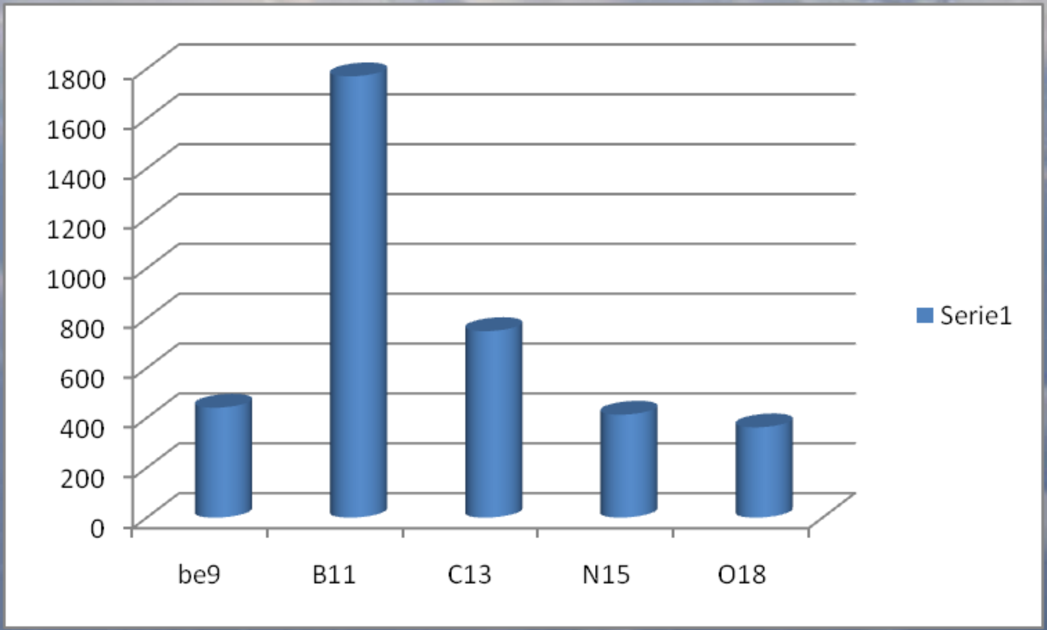
Lise++: O.B. Tarasov, D. Bazin, NIM B266 (2008) 4657.

Other test experiments coming

Another experiment in program approved by the PAC is the ^{8}He production by using a ^{11}B primary beam



^{8}He was already produced with ^{18}O as primary beam – with ^{11}B a much larger yield is foreseen – 2kHz are expected by simulations



Work is in progress at LNS to test the safe production of ^{11}B beam

Conclusions

❖I hope I was able to convince you that at LNS we have now enough intense intermediate energy radioactive beams that can be used for various kind of experiments

❖We already did various experiments and we are planning new ones both on structure and reaction mechanisms

❖If needed we can help peoples that want to submit new proposals for the use of such beams (support for travel is also available at LNS via ENSAR)

L.Acosta1, C.Agodi1, A.Amato1, F.Amorini1,3, A.Anzalone1, L.Auditore4, I.Berceanu9, L.Calabretta1, C.Calì1, G.Cardella2,*, S.Cavallaro1, M.B.Chatterjee10, L.Cosentino1, M.D'Andrea2, B.Diana1, A.Di Stefano1, E.De Filippo2, N.Giudice2, L.Grassi2,3, A.Grimaldi2, N.Guardone2, E.La Guidara2,5, F.Ferrera1, E.Furia1, G.Lanzalone1,6, P.Litrico1, I.Lombardo1,6, D.Loria4, S.Marino1, A.Maugeri1, T.Minniti4, A.Pagano2, M.Papa2, A.Pappalardo1, S.Passarello1, G.Passaro1, S.Pirrone2, G.Politi2,3, F.Porto1,3, S.Pulvirenti1, C.Rapicavoli2, D.Rifuggiato1, G.Rizza2, F.Rizzo1,3, A.Rovelli1, P.Russotto1,3, G.Saccà2, S.Salamone1, S.Santoro4, F.Sarta1, A.Seminara1, A.Trifirò4, M.Trimarchì4, G.Verde2, M.Vigilante8

1) INFN Laboratori Nazionali del Sud, Catania, Italy

2) INFN, Sezione di Catania, Catania, Italy

3) Dipartimento di Fisica e Astronomia Università di Catania, Italy

4) INFN gruppo collegato di Messina & Dipartimento di Fisica e Astronomia Università di Messina, Italy

5) Centro Siciliano di Fisica Nucleare e Struttura della Materia, Italy

6) Università Kore di Enna, Enna, Italy

7) INFN Sezione di Milano & Dipartimento di Fisica e Astronomia Università di Milano, Italy

8) INFN Sezione di Napoli & Dipartimento di Fisica e Astronomia Università di Napoli, Italy

9) Institute for Physics and Nuclear Engineering, Bucharest, Romania

10) Saha Institute of Nuclear Physics, Kolkata, India