Status and perspectives of fragmentation beams at LNS with CHIMERA detector

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for the
EXOCHIM collaboration

International Workshop on Multi facets of Eos and Clustering

IWM-EC 2014

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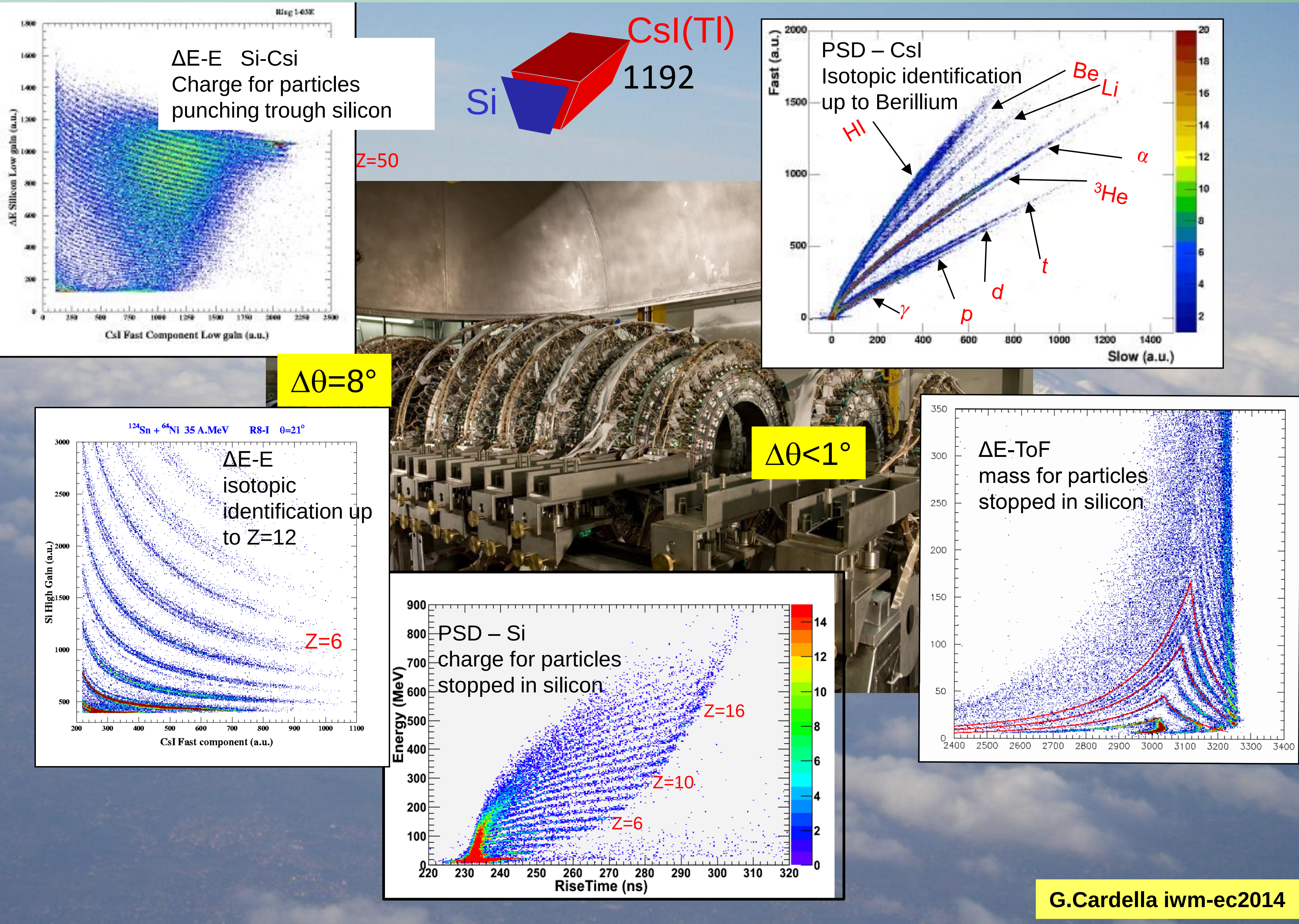
INFN Istituto Nazionale di Fisica Nucleare
Sezione di Catania

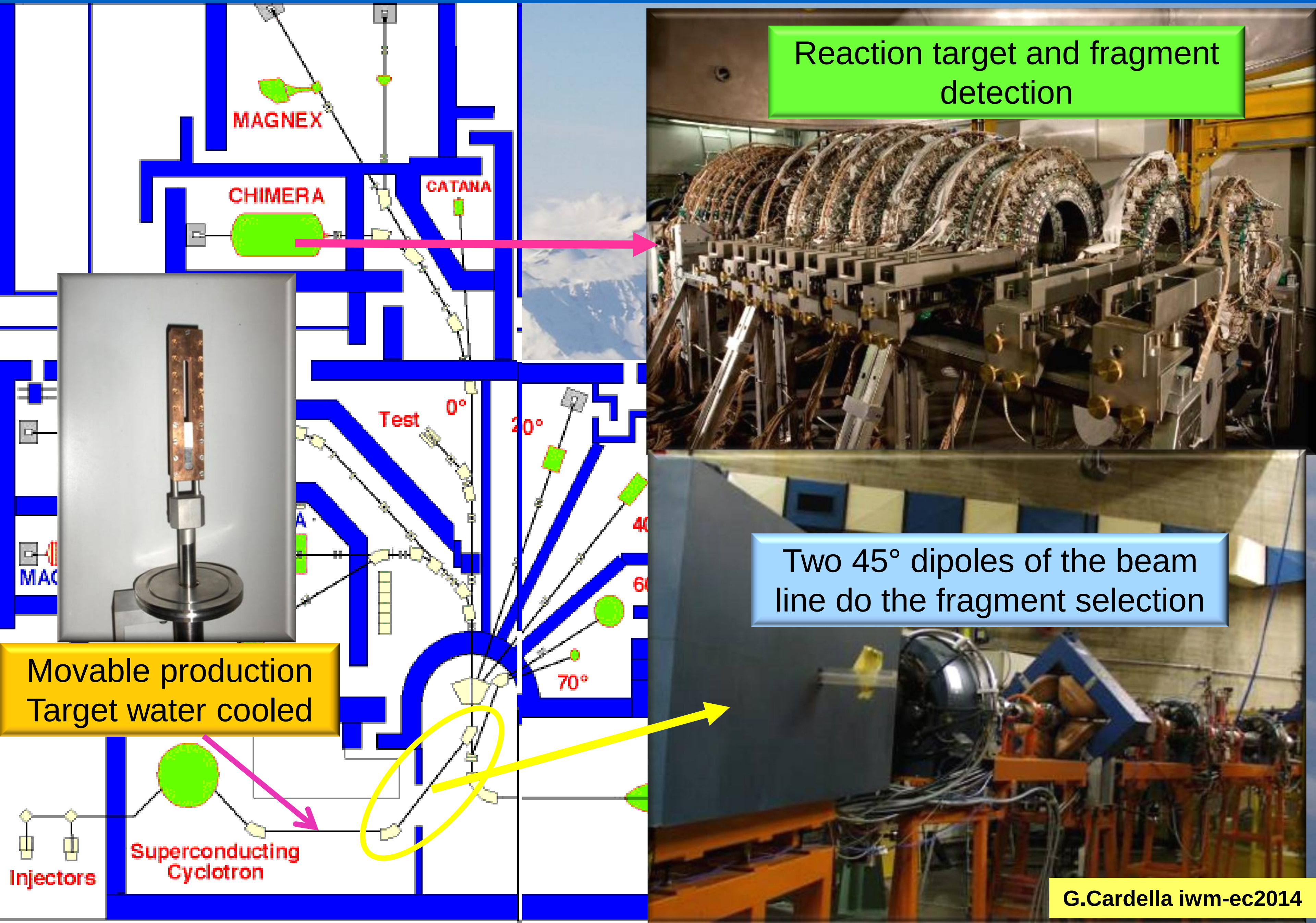
Outline

- ➢CHIMERA detector and LNS fragmentation beams with selected examples:
- ➢Elastic inelastic and Transfer reactions: $^{10}Be+p \rightarrow {}^{9}Be+d$
- ➢^{8}He induced reactions
- ➢Break-up: ^{16}C case
- ➢γ-ray detection with CHIMERA & PIGMY resonance study
- ➢Conclusions and perspectives

The CHIMERA detector : particle identification methods



Fragmentation beams at INFN-LNS - Catania



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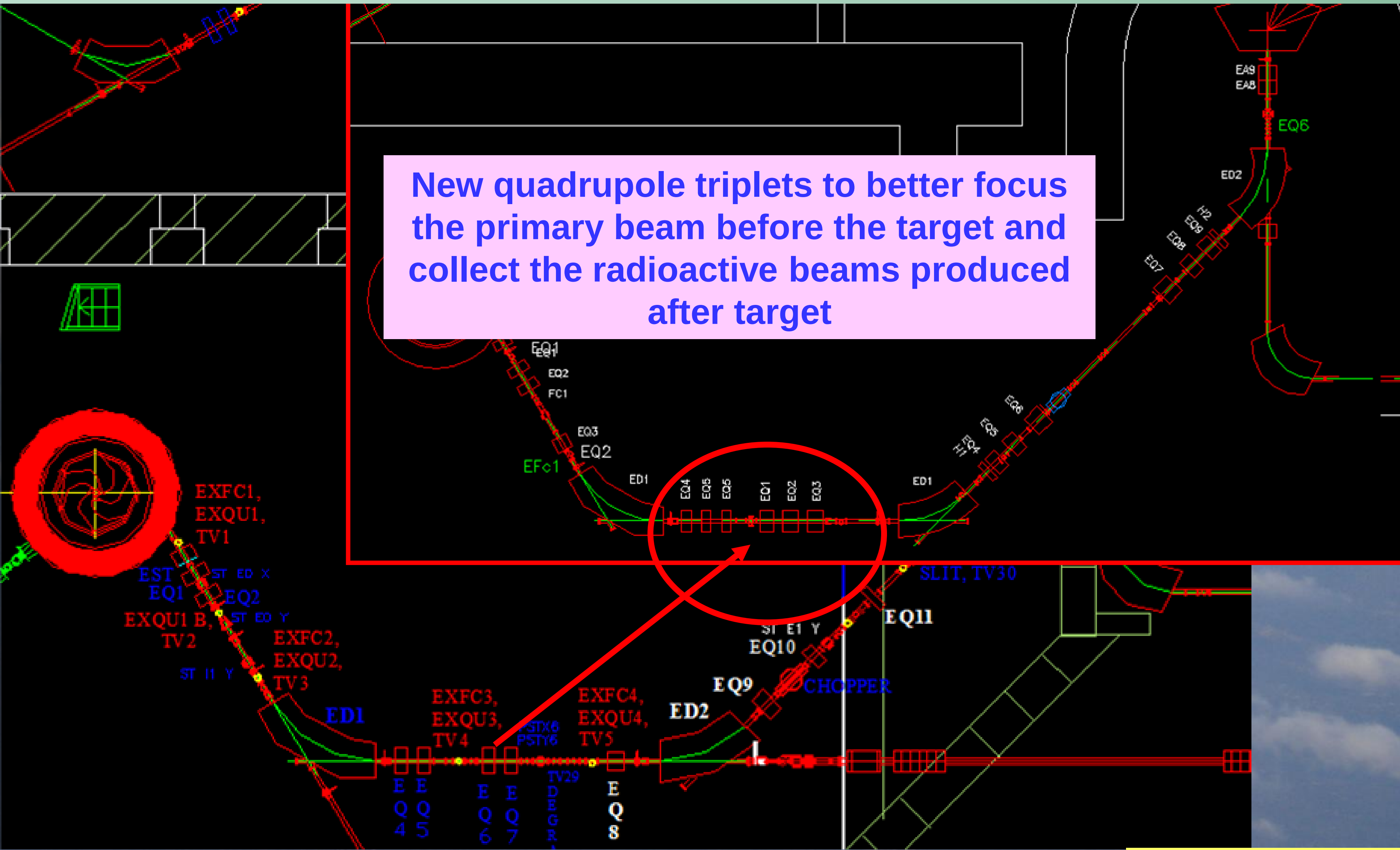
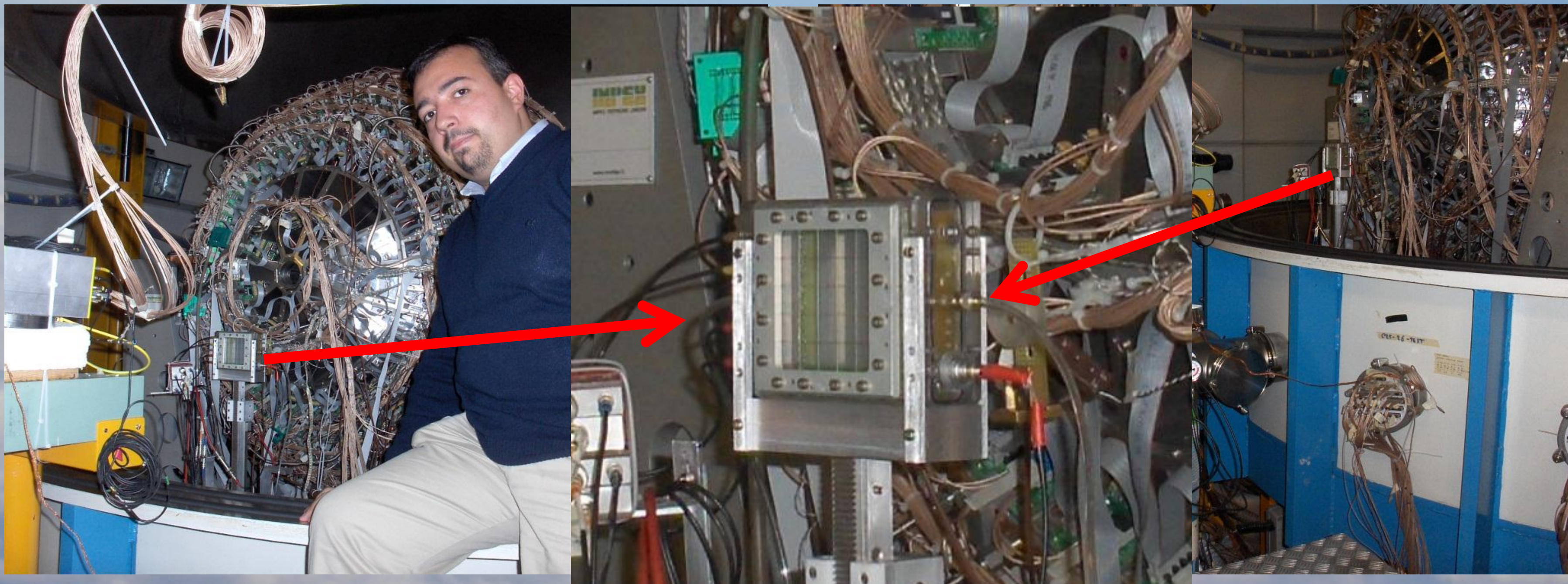
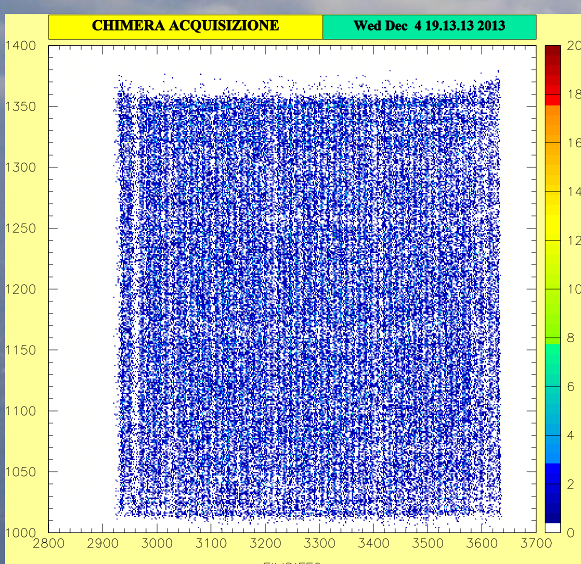
The 2010 upgrading of LNS Fragmentation beam



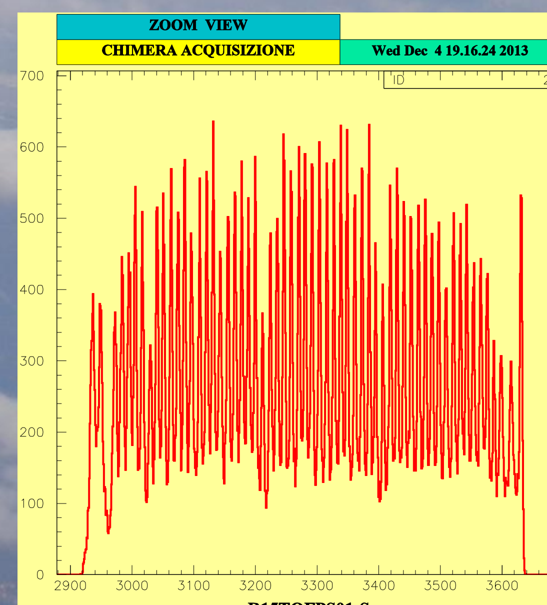
New quadrupole triplets to better focus the primary beam before the target and collect the radioactive beams produced after target

Upgrading of tagging system: test PPAC at LNS





A PPAC was built to better measure beam trajectory



Intensities available from the most recent beams produced

primary beam	beam	intensity (kHz/100W)
18O 55MeV/A	16C	120
setting 11Be	17C	12
	13B	80
	11Be	20
	10Be	60
	8Li	20
18O 55MeV/A	14B	3
setting 12Be	12Be	5
	9Li	6
	6He	12
13C 55 MeV	11be	50
setting 11Be	12B	100
36Ar 42 MeV	37K	100
setting 34Ar	35Ar	70
	36Ar	100
	37Ar	25
	33Cl	10
	34Cl	50
	35Cl	50
20Ne 35 MeV	18Ne	50
setting ne18	17F	20
	21Na	100
70Zn 42MeV		
setting 68Ni	68Ni	20

New beams to be used during 2014

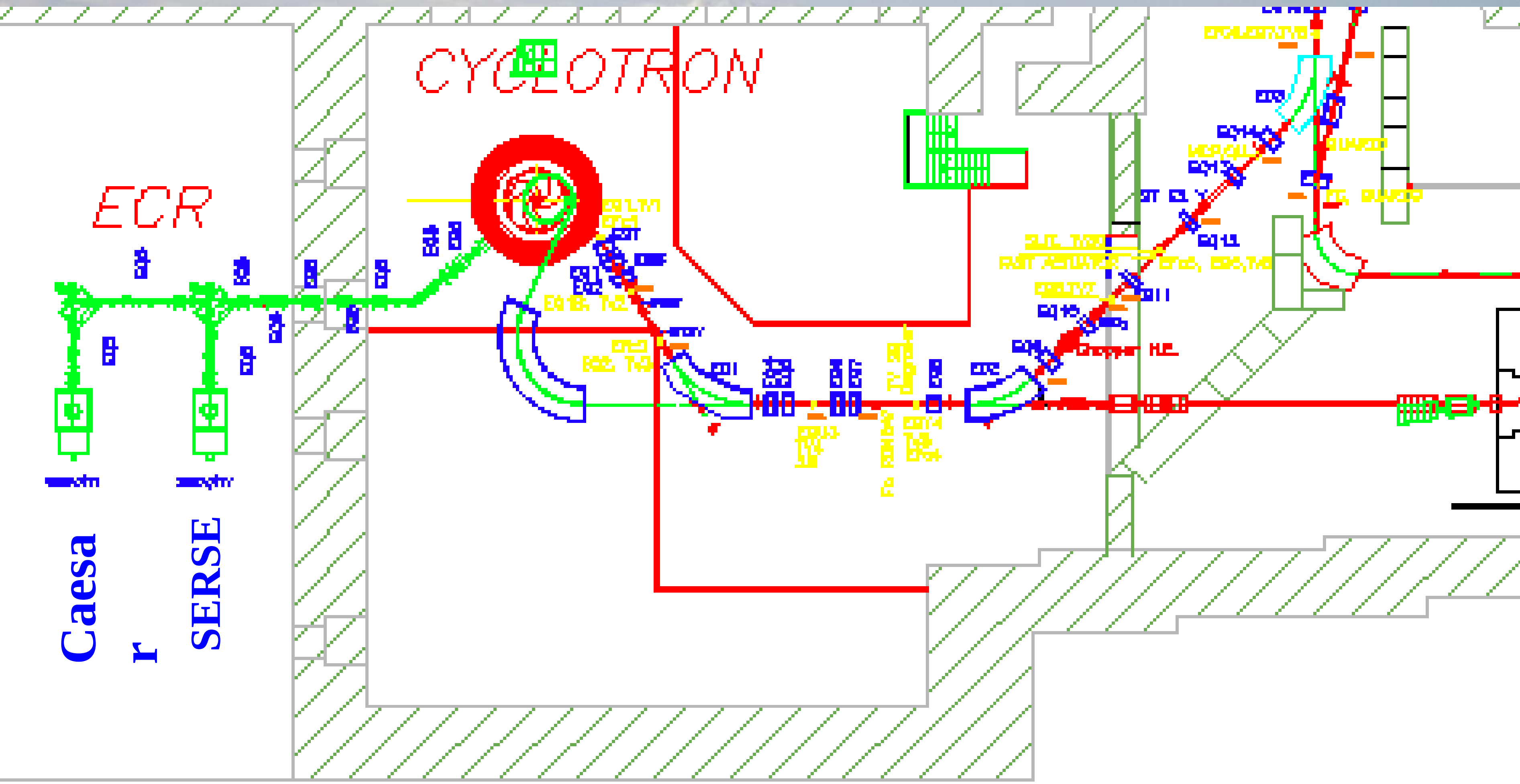
^{8}He (CHIMERA)

^{14}Be (test experiment) collaboration with Leuven

^{38}S (Magnex)

Future

New cryostat and coils for the CS – possibility to extract beam trough stripping – the acceleration of beams with lower charge status will allow an increase of intensity from 20 to 100 – This will be a fantastic perspective for the fragmentation beam

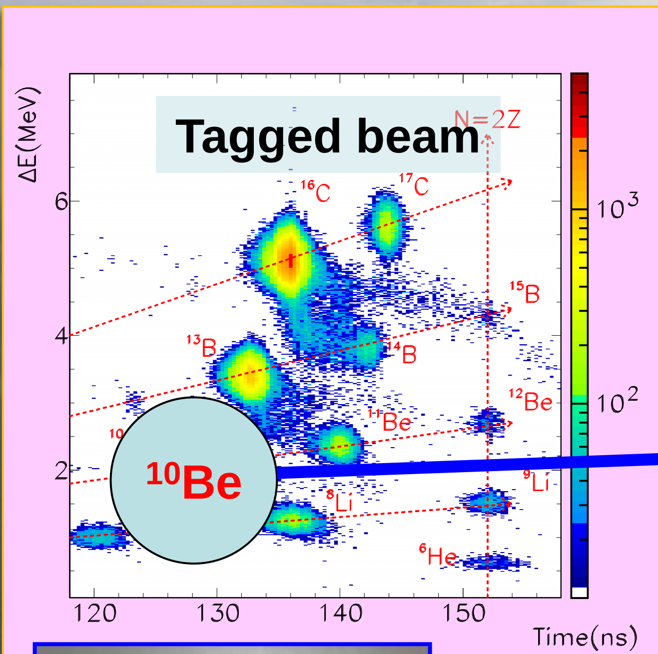


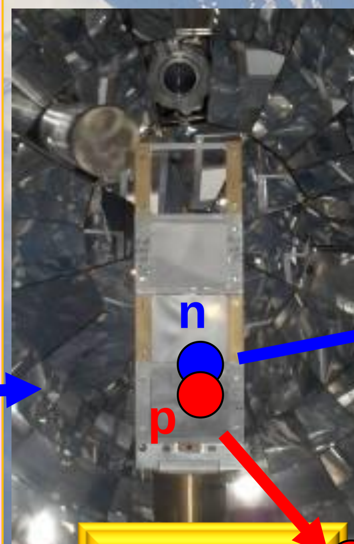
Slide from L.Calabretta

-Neutron transfer reactions near halo nuclei -

We study direct reactions using light exotic nuclei impinging on p, d targets useful to investigate on various structure effects

EVENT SELECTION performed with kinematic coincidences – measuring in binary/ternary reactions all reaction partners we clean the events





Heavy projectile-like fragments detected in forward rings

^{11}Be

Target p/d

p

Tagging system

Light fragments detected in the whole detector

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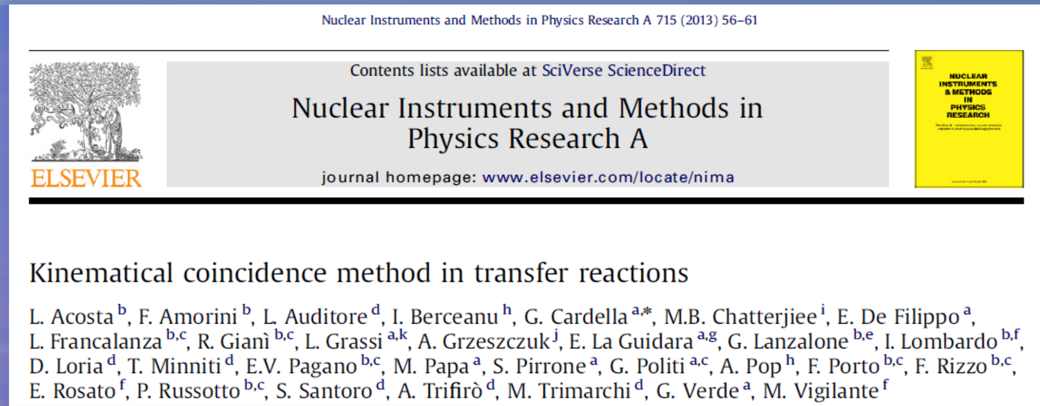
– Advantages of binary kinematics : the $^{10}Be+p \rightarrow {}^{9}Be+d$ case -


Nuclear Instruments and Methods in Physics Research A 715 (2013) 56–61

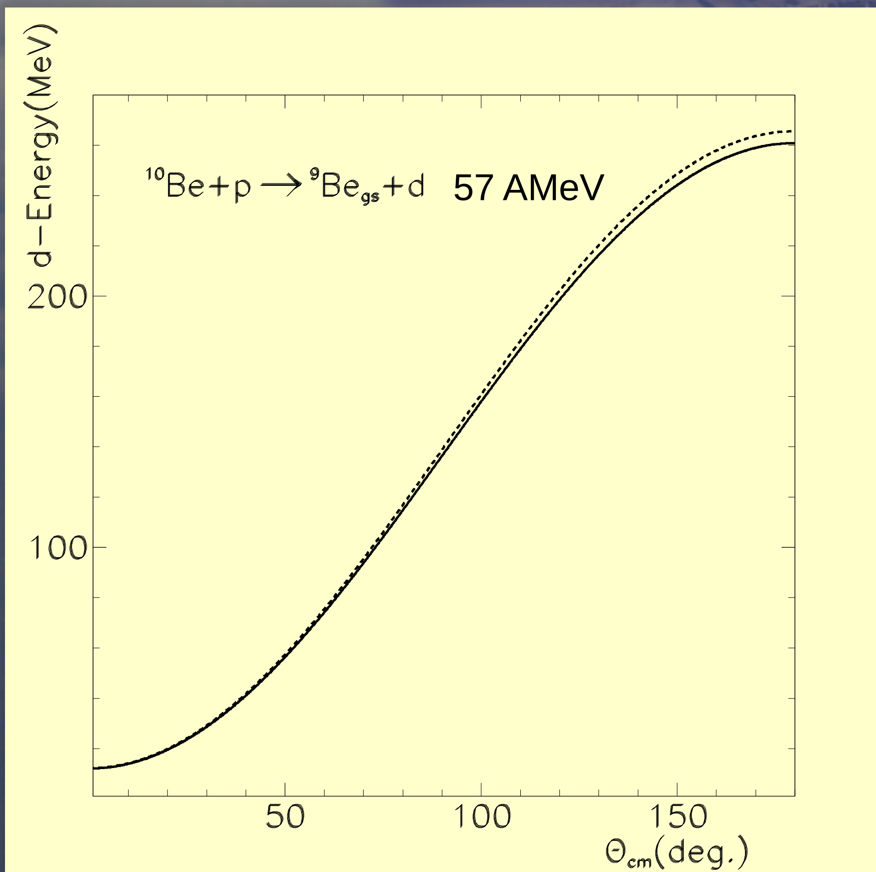
Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Kinematical coincidence method in transfer reactions

L. Acosta [b], F. Amorini [b], L. Auditore [d], I. Berceanu [h], G. Cardella [a,*], M.B. Chatterjiee [i], E. De Filippo [a], L. Francalanza [b,c], R. Gianì [b,c], L. Grassi [a,k], A. Grzeszczuk [j], E. La Guidara [a,g], G. Lanzalone [b,e], I. Lombardo [b,f], D. Loria [d], T. Minniti [d], E.V. Pagano [b,c], M. Papa [a], S. Pirrone [a], G. Politi [a,c], A. Pop [h], F. Porto [b,c], F. Rizzo [b,c], E. Rosato [f], P. Russotto [b,c], S. Santoro [d], A. Trifirò [d], M. Trimarchi [d], G. Verde [a], M. Vigilante [f]



The lab energy of the detected particle determines the CM emission angle

Due to the relatively good energy resolution we can obtain an angular distribution with much better resolution than the one determined by the size of the detectors

– STEPS of the analysis $^{10}Be+p \rightarrow {}^{9}Be+d$

We select only complete events with two detected particles and with total detected charge Ztot=Zbeam+1

We can plot the Δϕ angle between the two coincidence detectors – due to momentum conservation Δϕ must be 180°

Δϕ width due to the finite opening of the detectors

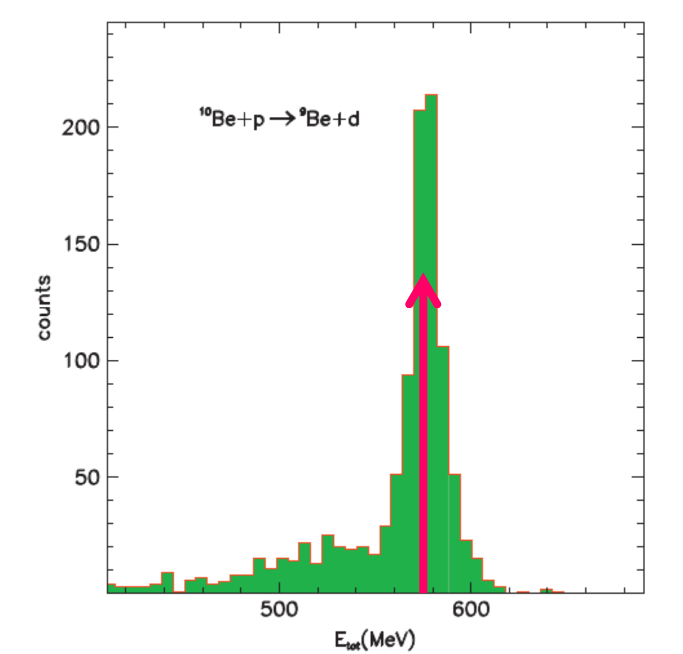


Fig. 6. Total kinetic energy detected in the reaction $^{10}Be+p \rightarrow {}^{9}Be+d$.

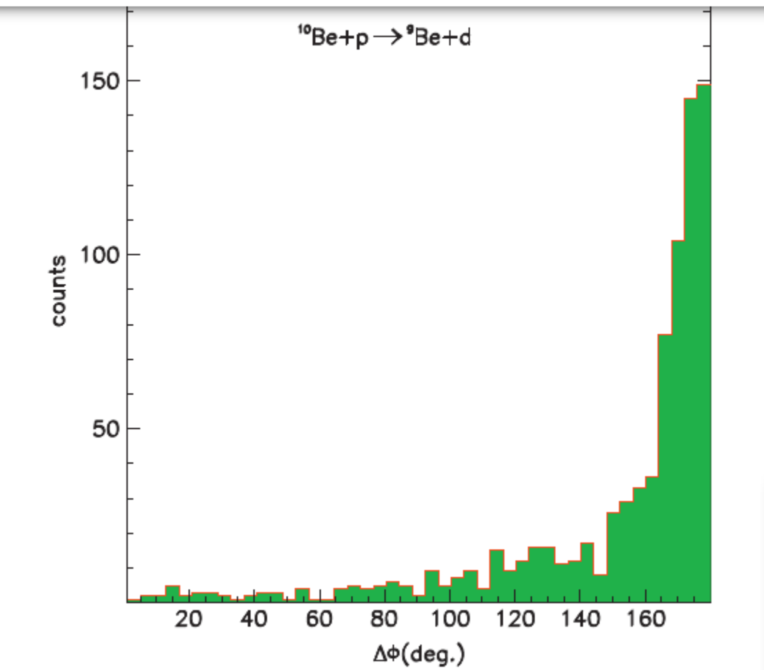


Fig. 5. Relative angle Δϕ between the telescopes selected in coincidence in the reaction $^{10}Be+p \rightarrow {}^{9}Be+d$. The peak at 180° is due to kinematical coincidences.

We also clean the events putting constraints on the total detected energy must be equal to the beam energy 580 MeV + Q_{value} (-4.58 MeV)

Notwithstanding the scarce total energy resolution we see only GS events

$^{9}Be^{*} \rightarrow n+\alpha+\alpha$

S_n=1.66 MeV

– The $^{10}Be+p \rightarrow {}^{9}Be_{g.s.}+ d$ angular distribution -

From the analysis we get the deuteron energy spectrum

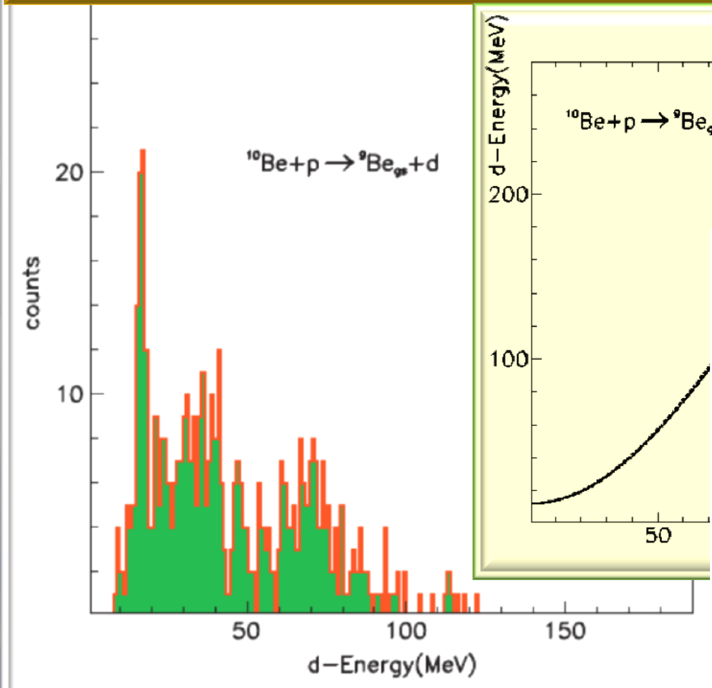
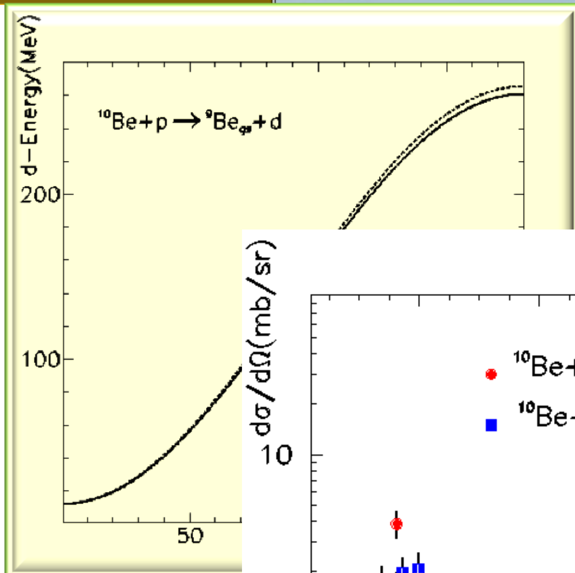
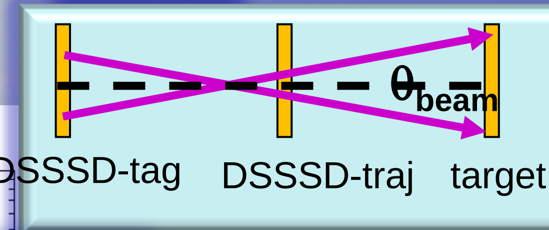
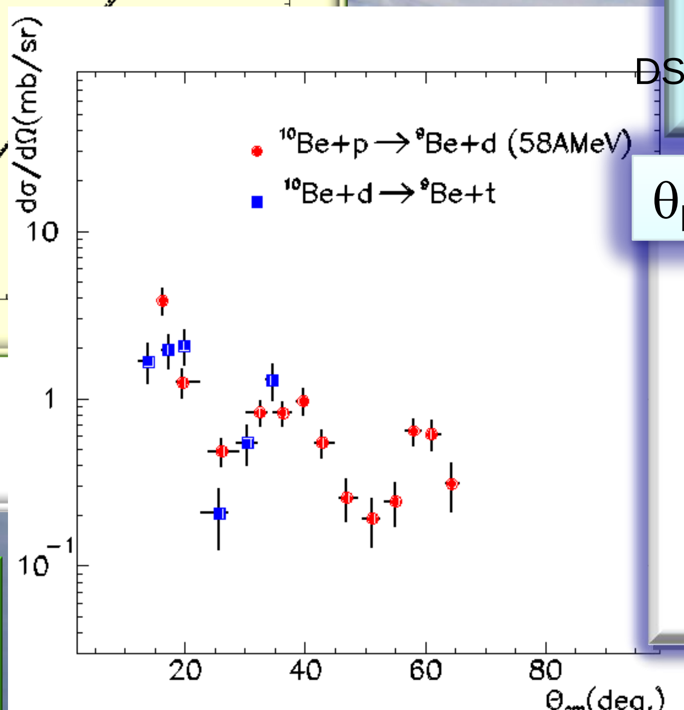


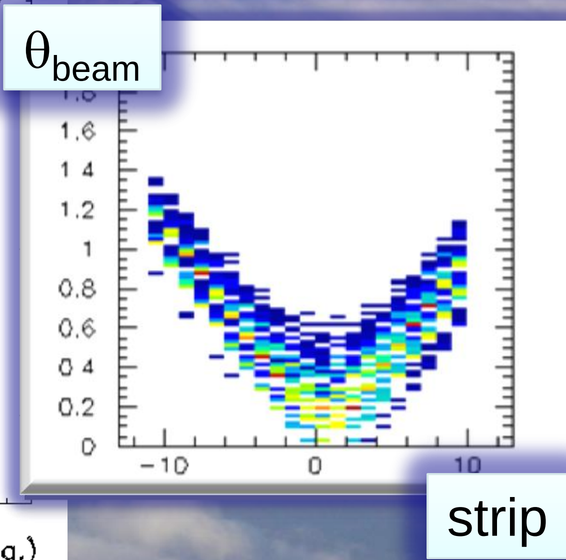
Fig. 7. Deuteron energy spectrum from the reaction $^{10}Be+p \rightarrow {}^{9}Be_{gs}+d$.



Using kinematics we can convert it from dN/dE → dN/dθ







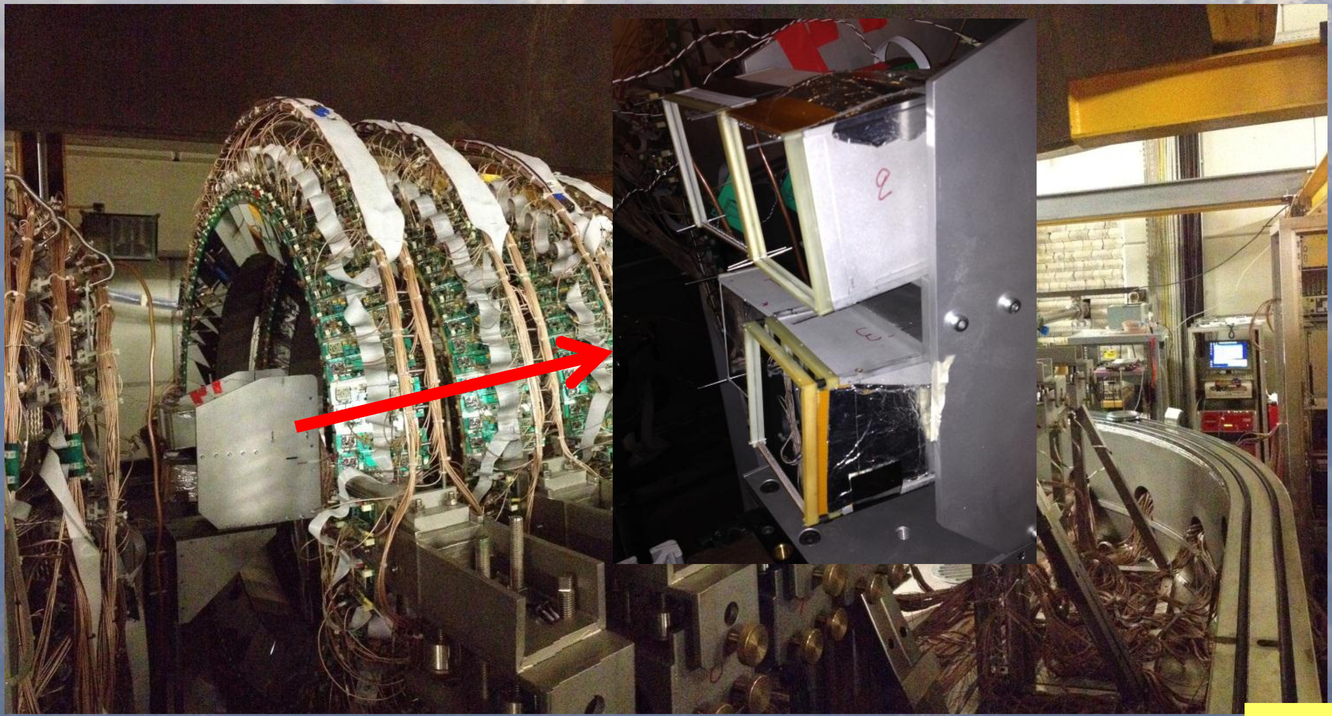
After solid angle and efficiency correction we get the angular distributions

Note that angular distributions are automatically corrected for the fragmentation beam angular spread

Improvement of the detection system

FARCOS 0°

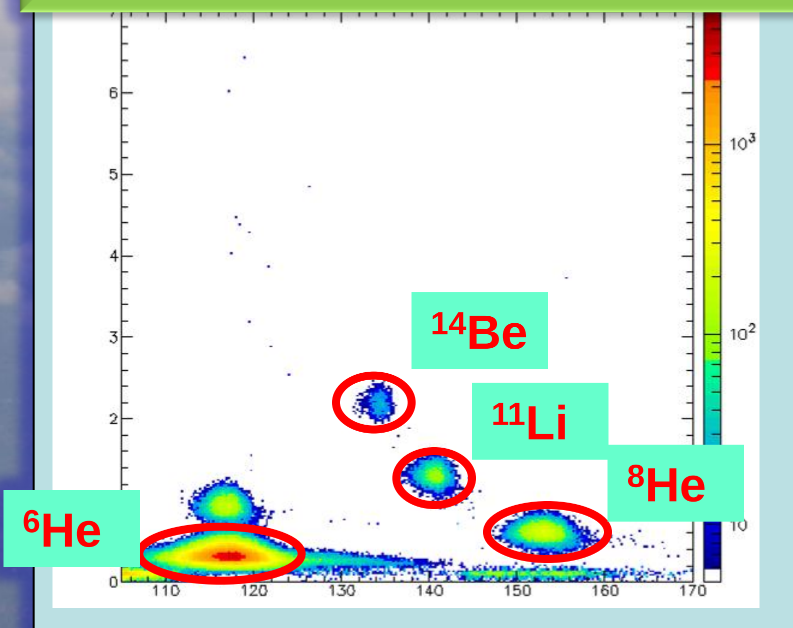
For next experiments we will use FARCOS (see Emanuele talk) in configuration around 0° in order to have a kind of spectrometer to measure the quasi-projectile – light particles will be detected with CHIMERA using kinematical coincidence and beam trajectory measurement we will clean from background and extract more accurate excitation energies and CM angular distributions



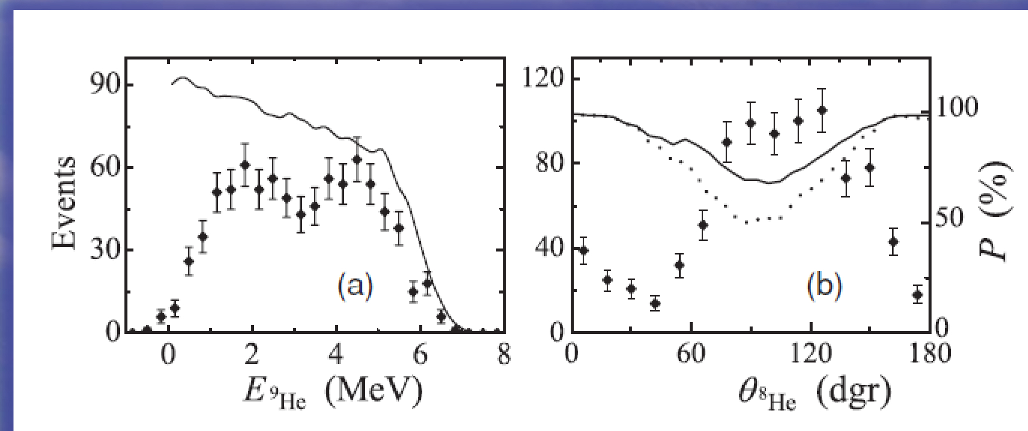
Coming Experiments : Neutron transfer on ^{8}He

One programmed experiment is the ^{8}He+d reaction performed to study the ^{9}He resonance - production will by done using a ^{11}B primary beam – We expect around 2000 particles/sec of beam intensity

Preliminary production test performed with ^{18}O primary beam



Reaction studied at Dubna at 25 AMeV
We will increase the beam energy searching for higher excitation energy structures



M. S. Golovkov et al PHYSICAL REVIEW C 76, 021605(R) (2007)

Coming Experiments : Break-up study - CLIR

(Clusters in Light Ion Reactions)

Break-up of RIBs: coincidences

Self-conjugated nuclei → cluster effect in GS

→ role of *quartetting* in nuclei → unveiled from the existence of *rotational bands*

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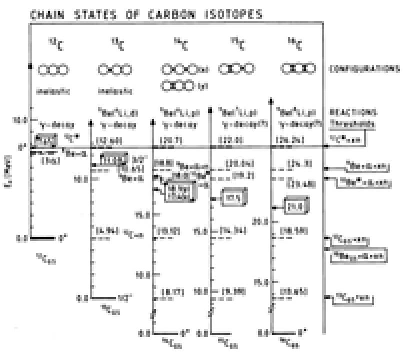
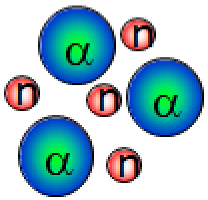
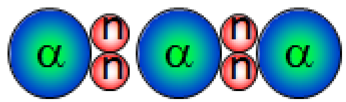
Neutron-rich light isotopes → cluster effect leading to *nuclear molecules* → *covalence bonding* due to neutrons

Light isotopes approaching *n-drip line* → *exotic clustering* effects → also influence of *pairing* in covalent neutrons





^{16}C



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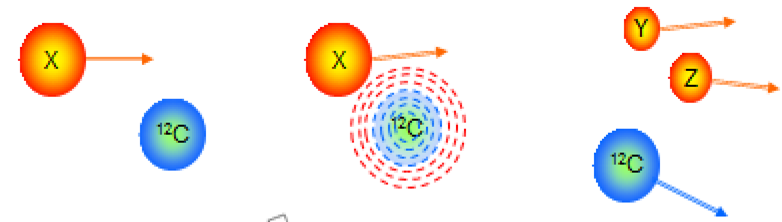
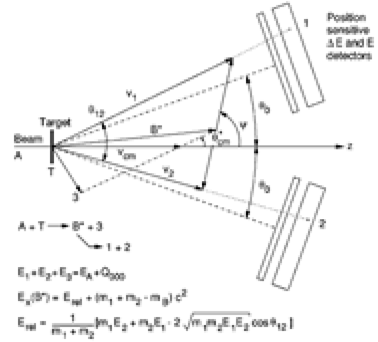
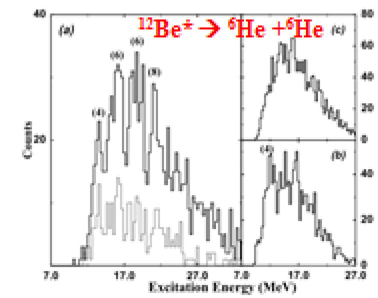
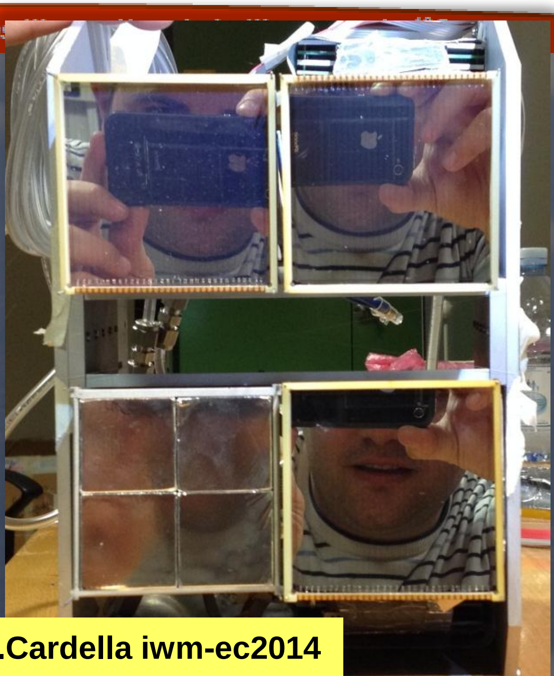






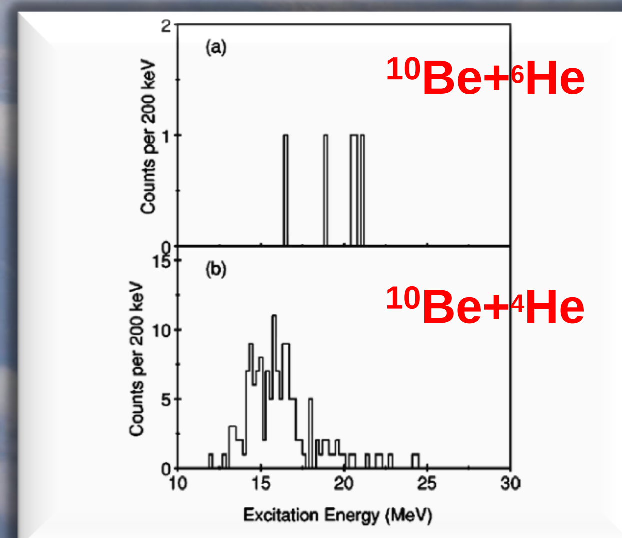
Low statistics & high resolution



$^{16}C+^{12}C$

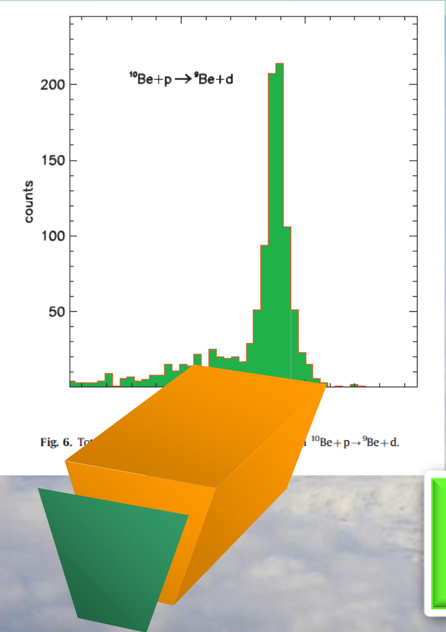
Search for exotic decay of ^{16}C

(and the other available beams $^{10,11}Be$ ^{13}B …..)

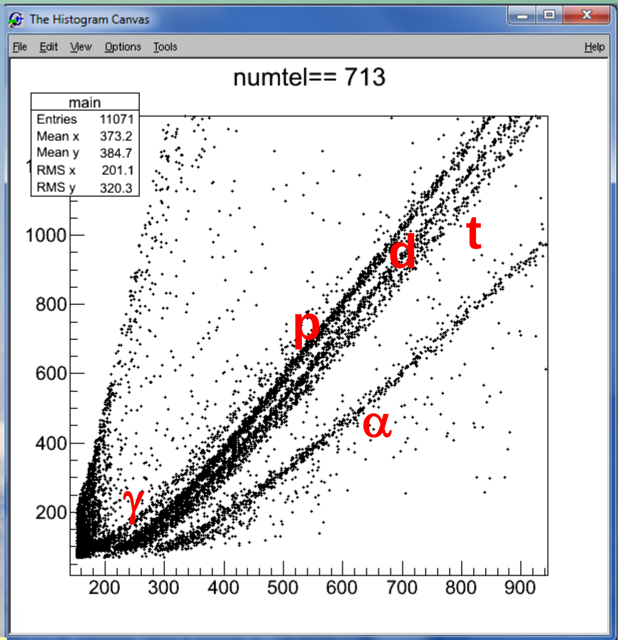


N. I. Ashwood et al Phys.Rew.C 70, 064607 (2004)

– Another improvement - γ-ray tagging? -

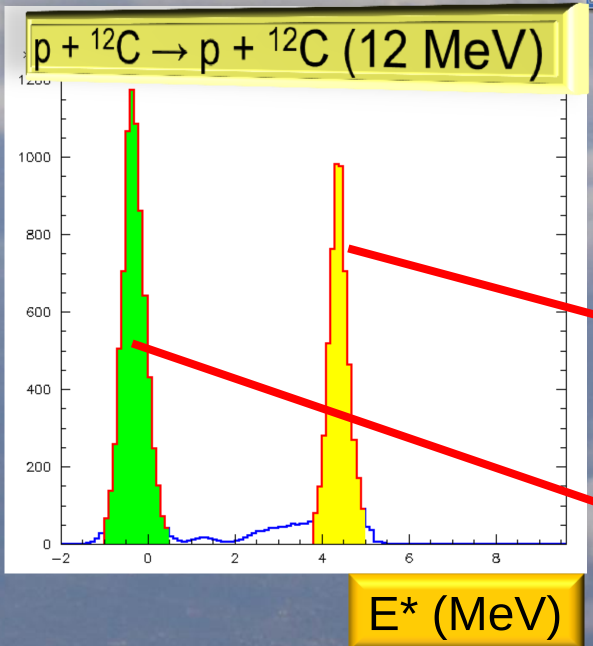


γ-ray tagging could be a solution to improve the kinematical coincidence method in case of excited levels -
How to combine efficient γ-ray detectors and CHIMERA?

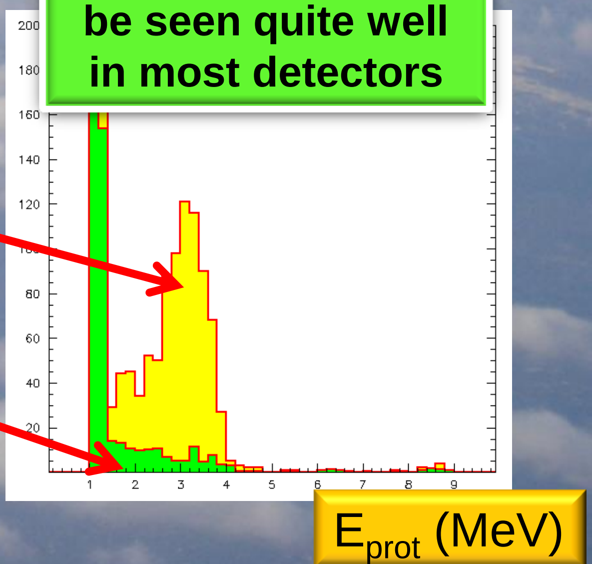


CsI(Tl) have a large efficiency for gamma ray detection

We have measured the γ-ray signals from CsI(tl) using proton beams on carbon target and looking at excitation and decay of the 4.44 MeV ^{12}C first excited state



The 4.44 MeV γ can be seen quite well in most detectors



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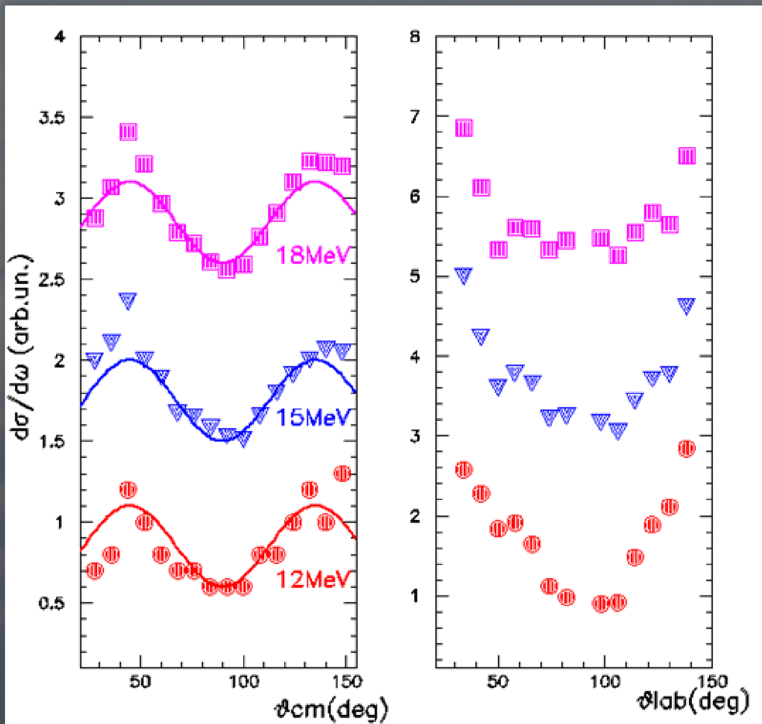
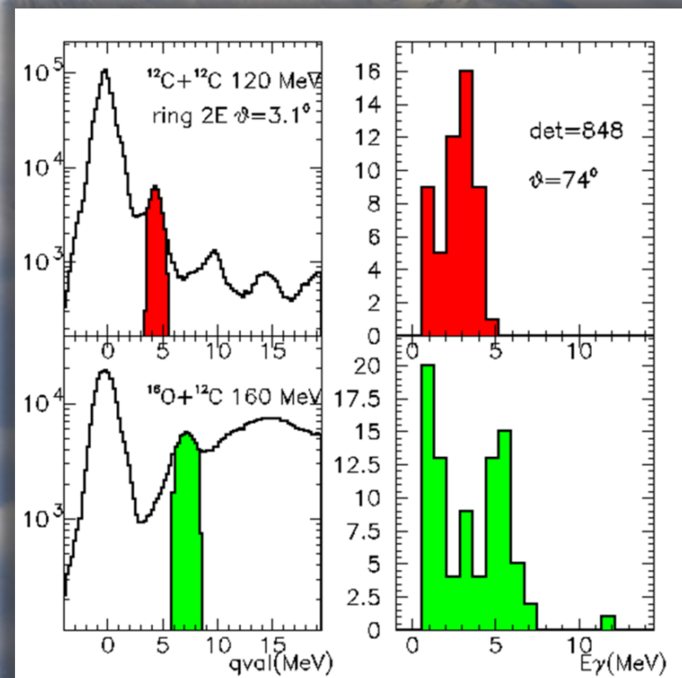
– Using the γ-ray tagging: can we measure γ-rays angular distributions?-

We can also measure γ-ray angular distribution from 4.44 ^{12}C excited state

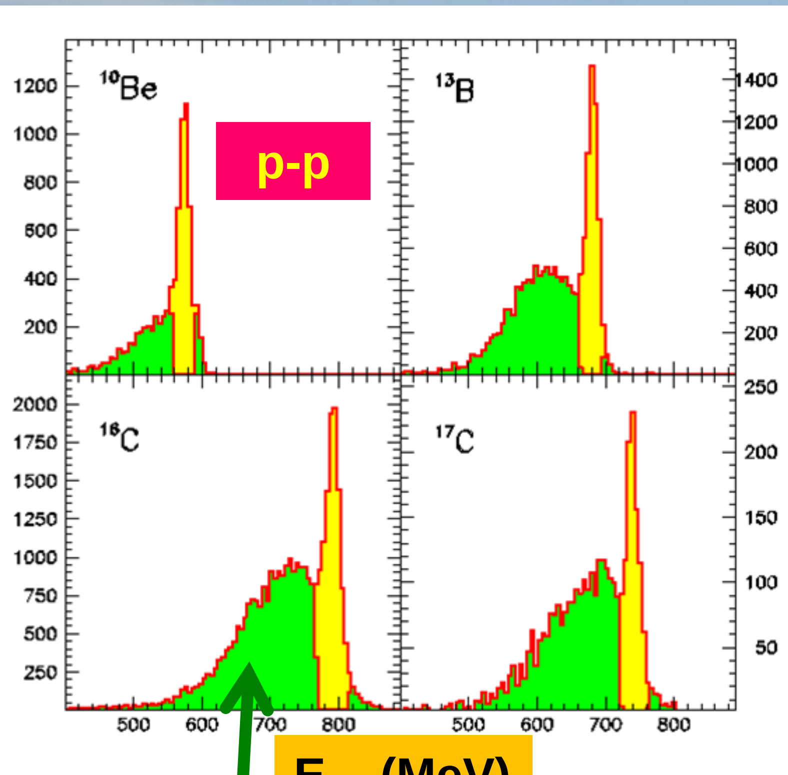


CM angular distribution was evaluated in the system of recoiling ^{12}C after inelastic scattering of protons at various energies



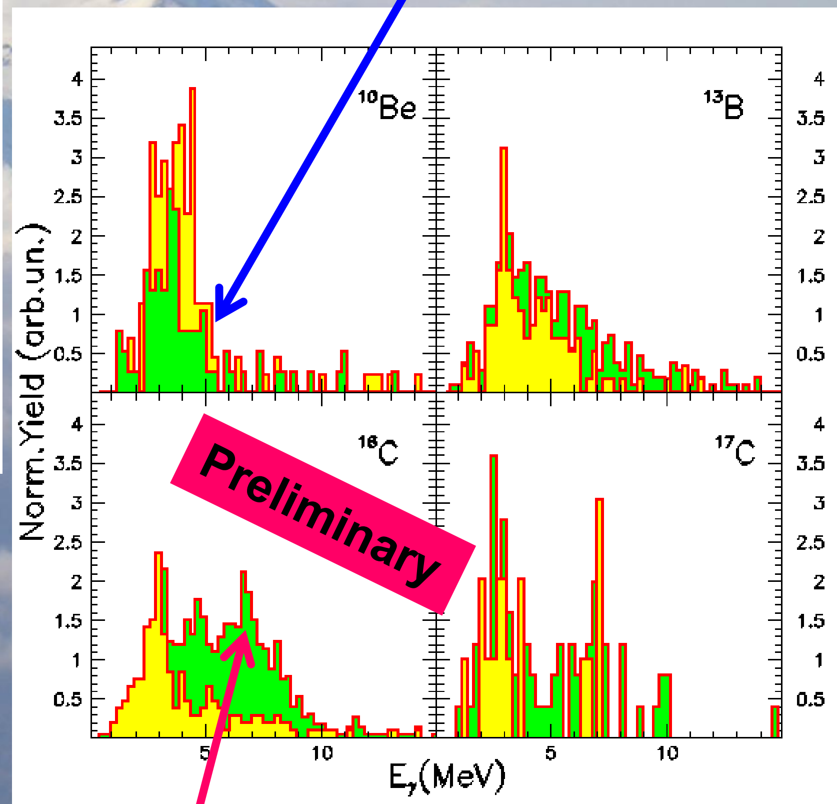
Using calibration beams we see also higher energy γ-rays as those emitted by ^{16}O around 6 MeV with overall efficiency around 30% of 4π (GEANT-IV)

– Using the γ-ray tagging: Preliminary γ spectra with radioactive beams-



xn channel

Just background no γ from xn channel

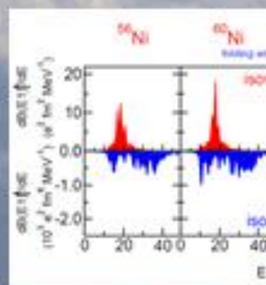


7 MeV 2n-channel? (^{14}C)

Coming Experiments : PIGMY

Search for iso-scalar excitation of the PIGMY resonance in ^{68}Ni nuclei

Spokes: G.Cardella, E.G.Lanza
for the
EXOCHIM collaboration



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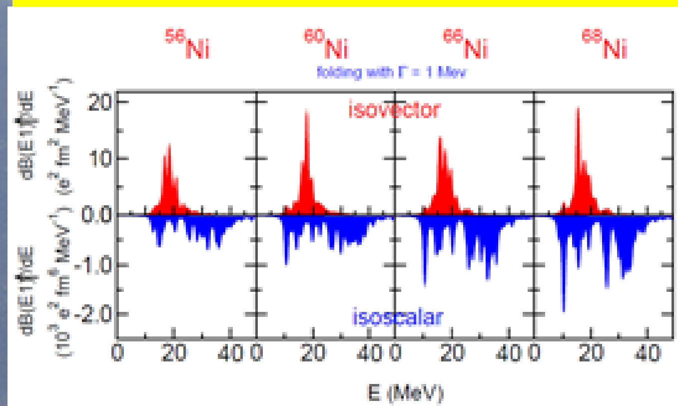
The Pigmy resonance

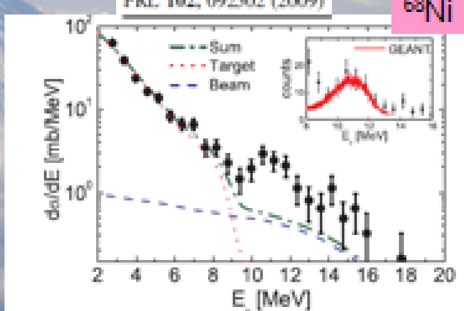
The search for population and decay of the Pigmy resonance was particular stressed in the last years especially due to the results obtained with neutron rich nuclei at GSI. The interest was high also because its sensitivity to the symmetry term of the nuclear equation of state - A recent revue can be found in Progress in Particle and Nuclear Physics 70 (2013) 210 by D. Savran , T. Aumann, A. Zilges

Experiments at GSI were performed using ^{132}Sn and ^{68}Ni – The resonance was excited by virtual photons generated by the Coulomb field of heavy target nuclei, so probing its isovector response function



PRL 102, 092502 (2009)

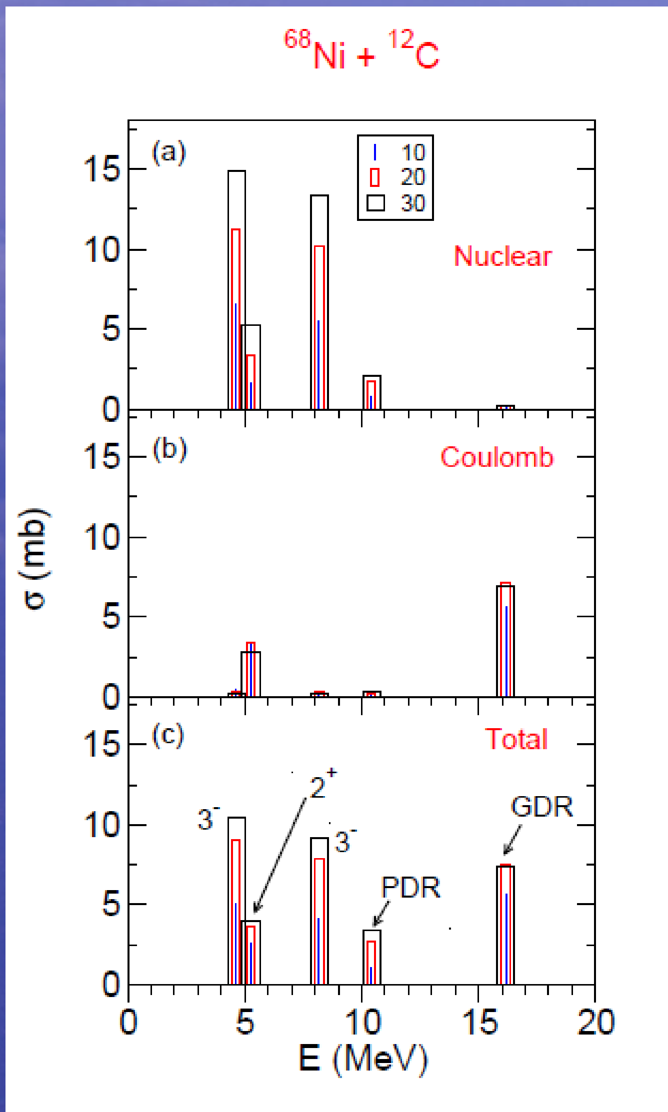
^{68}Ni



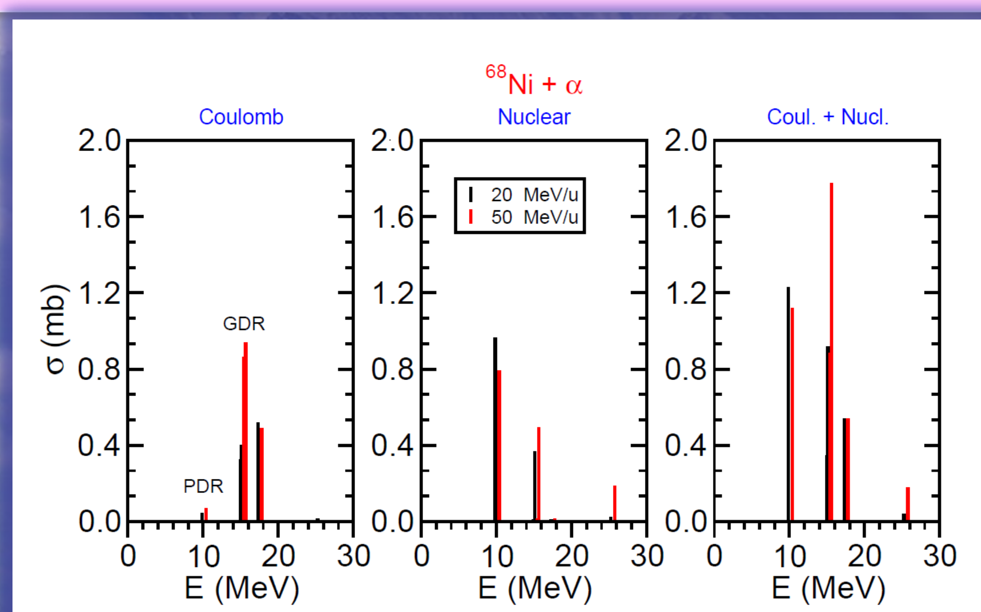
However various calculations show that this resonance can be excited also using isoscalar probes

The Pigmy resonance: cross section predictions

A search for isoscalar population of the pigmy resonance on unstable nuclei is very interesting in order to fully understand the characteristics of such resonance



Semi-classical calculations (based on RPA strengths) predict that the best beam energy for such a search is around 30 A MeV -
A sizeable cross section is predicted for an iso-scalar probe as ^{12}C (around 3mb)



^{12}C seems the best target – its cross section is expected to be at least 2 times larger than α-particles

^{68}Ni Beam for the Pigmy experiment

^{68}Ni beam was recently produced at LNS in the framework of the TIMESCALEZN experiment

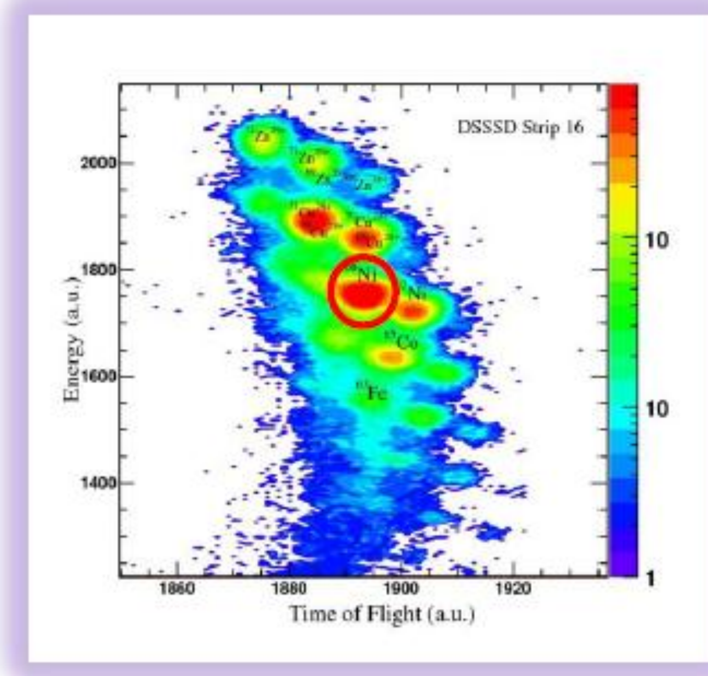


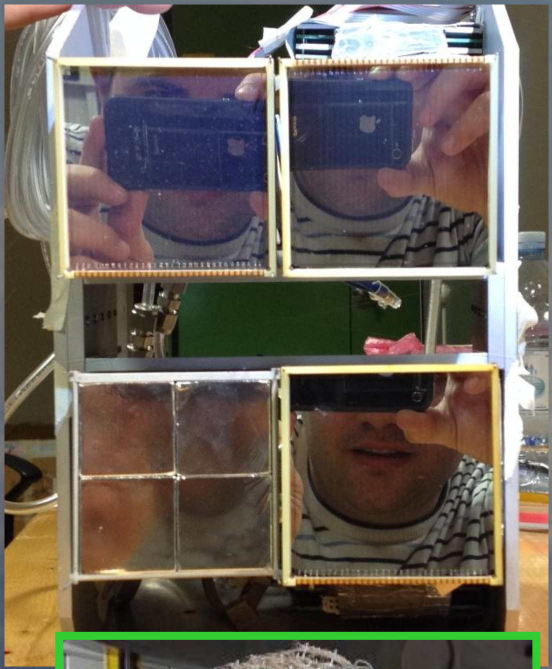
Fig.4 Identification scatter plot of ^{68}Ni fragmentation beam

The beam was produced via fragmentation of ^{70}Zn on a 0.25 mm ^{9}Be target at 40 MeV/A

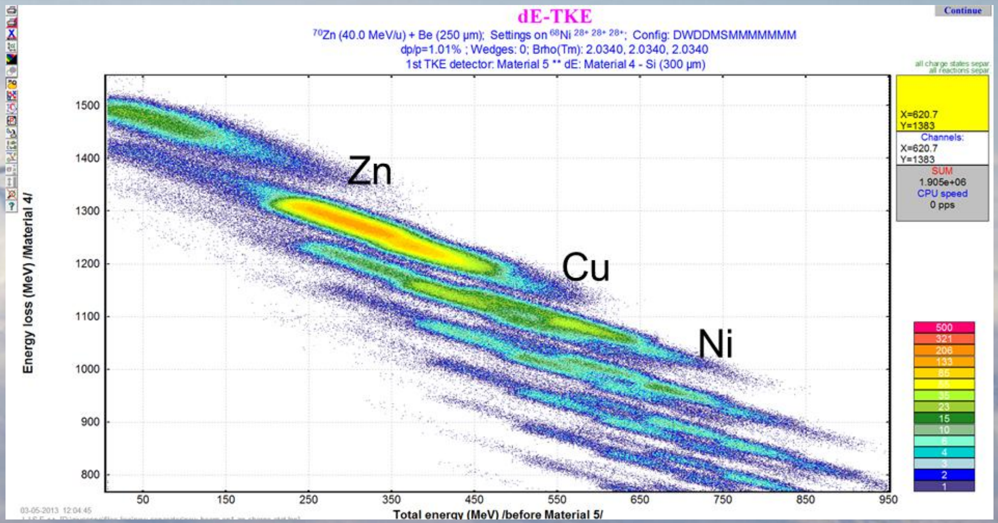
A beam intensity of about $2x10^4$ part/sec/ 100 W primary beam was obtained

We also demonstrated that we can clean our beam from not fully stripped ions - The mylar foil of the tagging MCP is a stripper foil cleaning most of such contaminants – thank to this ^{68}Ni is the most intense beam transported

Detection system for the Pigmy experiment

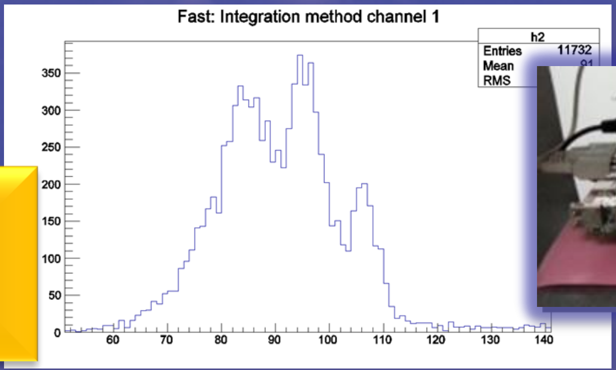


FARCOS will detect and identify ^{68}Ni with good energy resolution (stopped in the two silicon stages of the telescopes)



The Sphere CsI with the new digital GET electronics will provide γ detection

The 4.44 γ-ray seen by a farcos CsI with GET electronics



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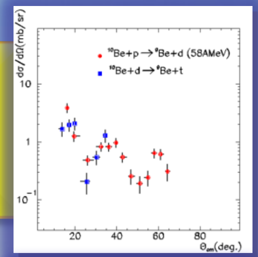
Conclusions and perspectives

Using cocktail of neutron rich beams with the CHIMERA detector we are able to extract angular distributions for many reaction channels searching for structure effects on cross sections



The 4π detection efficiency is very useful and allows extensive use of the kinematical coincidence technique

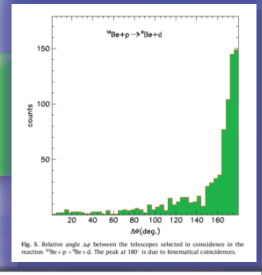
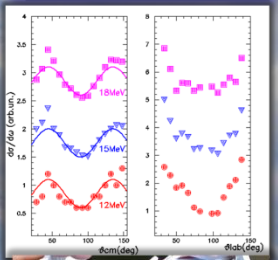
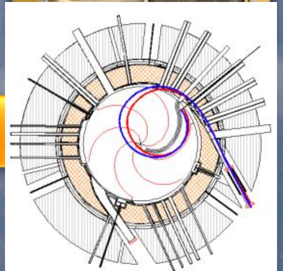


Fig. 5. Relative angle Δφ between the telescopes selected in coincidence in the reaction ^{10}Be+p → ^{9}Be+d. The peak at 180° is due to kinematical coincidences.

We can also detect γ-rays with our CsI(Tl) detectors in order to tag excited levels



For the future experiments we are working to improve our detection capabilities and resolutions also coupling CHIMERA to a new high resolution strip telescope array FARCOS



Very exciting long term perspectives by the intensity upgrade of CS

G.Cardella iwm-ec2014

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