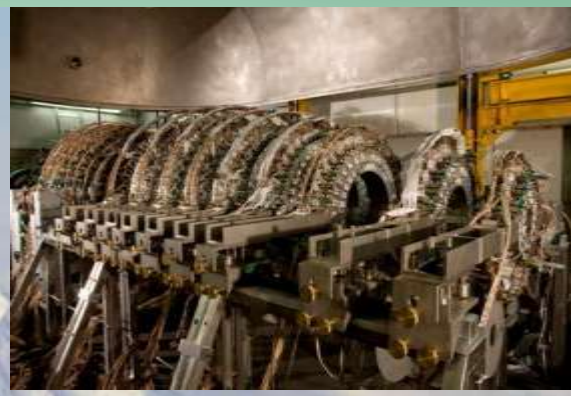
Transfer reactions on light exotic nuclei with CHIMERA detector at LNS

G.Cardella
for the
EXOCHIM collaboration



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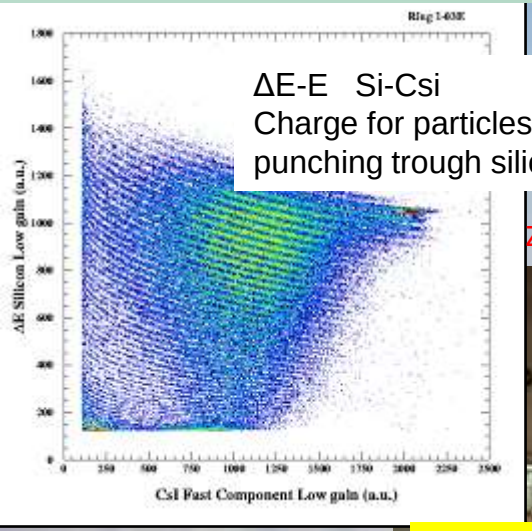
INFN Istituto Nazionale di Fisica Nucleare
Sezione di Catania

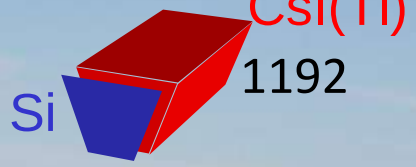
Outline

- Short presentation of the CHIMERA detector and LNS fragmentation beams
- Can one get precise angular distributions without extremely segmented detectors?
- Test case $^{10}Be+p \rightarrow {}^{9}Be+d$
- Extension of the method using coincidence γ-ray
- Conclusions and perspectives

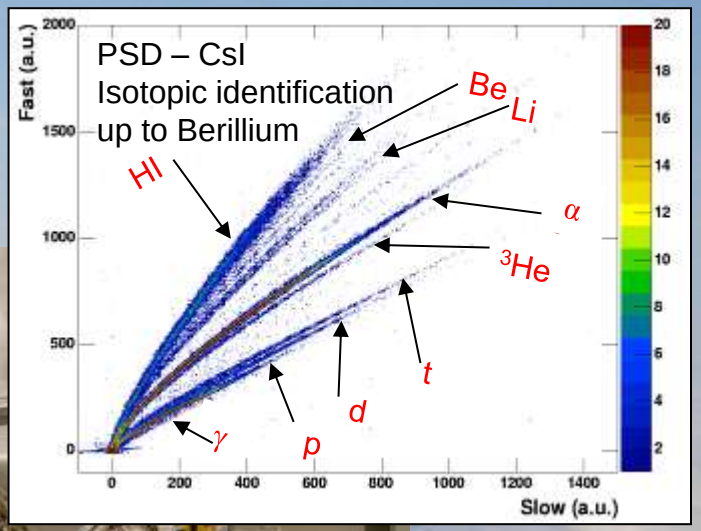
The CHIMERA detector : particle identification methods

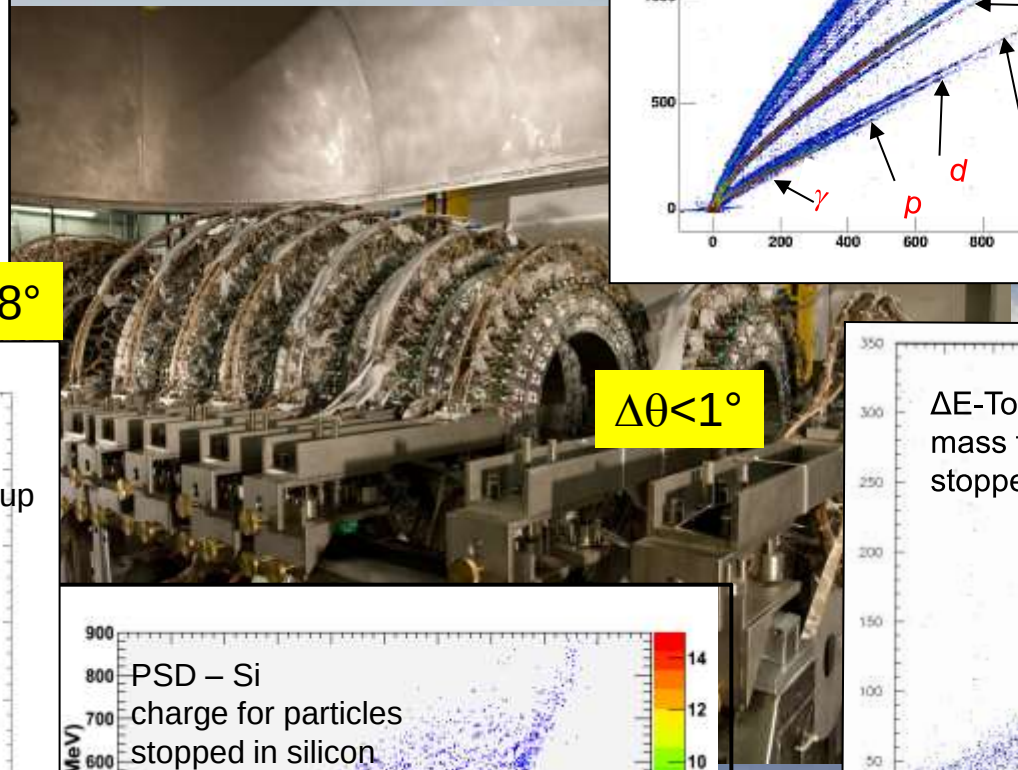


ΔE-E Si-Csi
Charge for particles
punching trough silicon



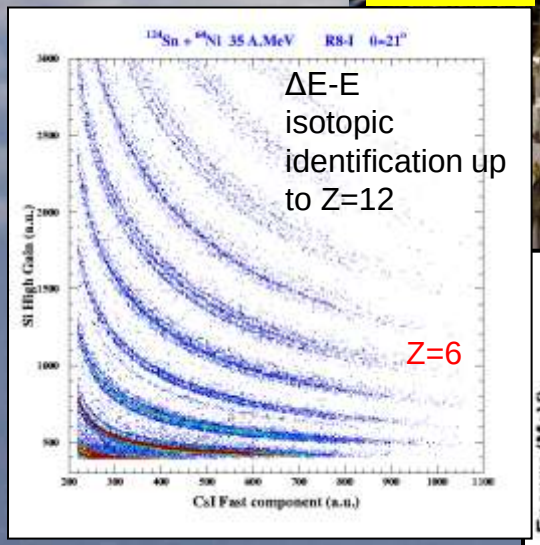
Z=50

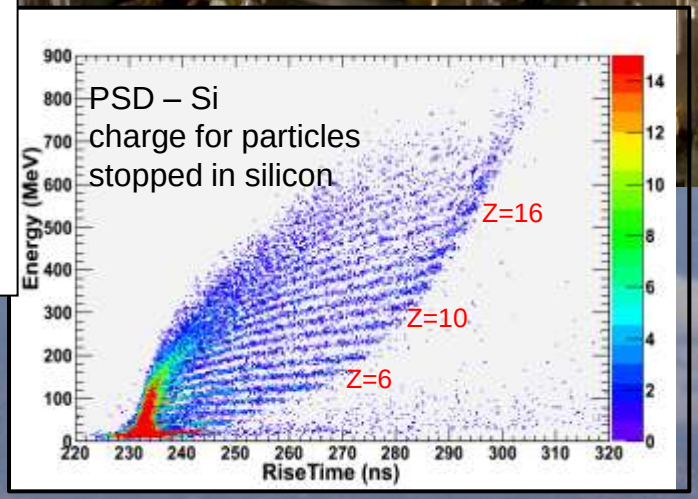


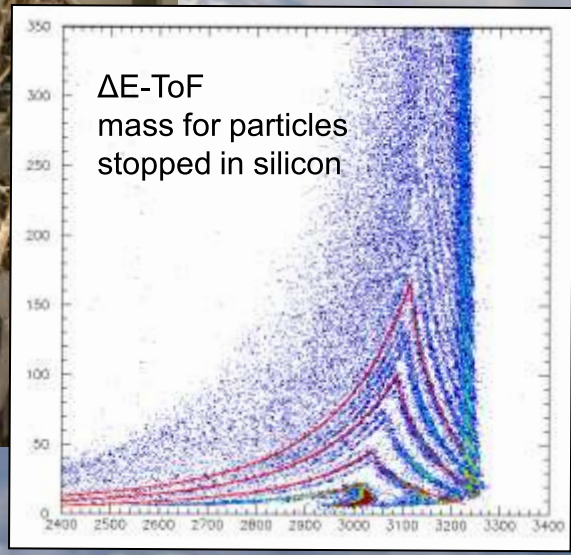


Δθ=8°

Δθ<1°







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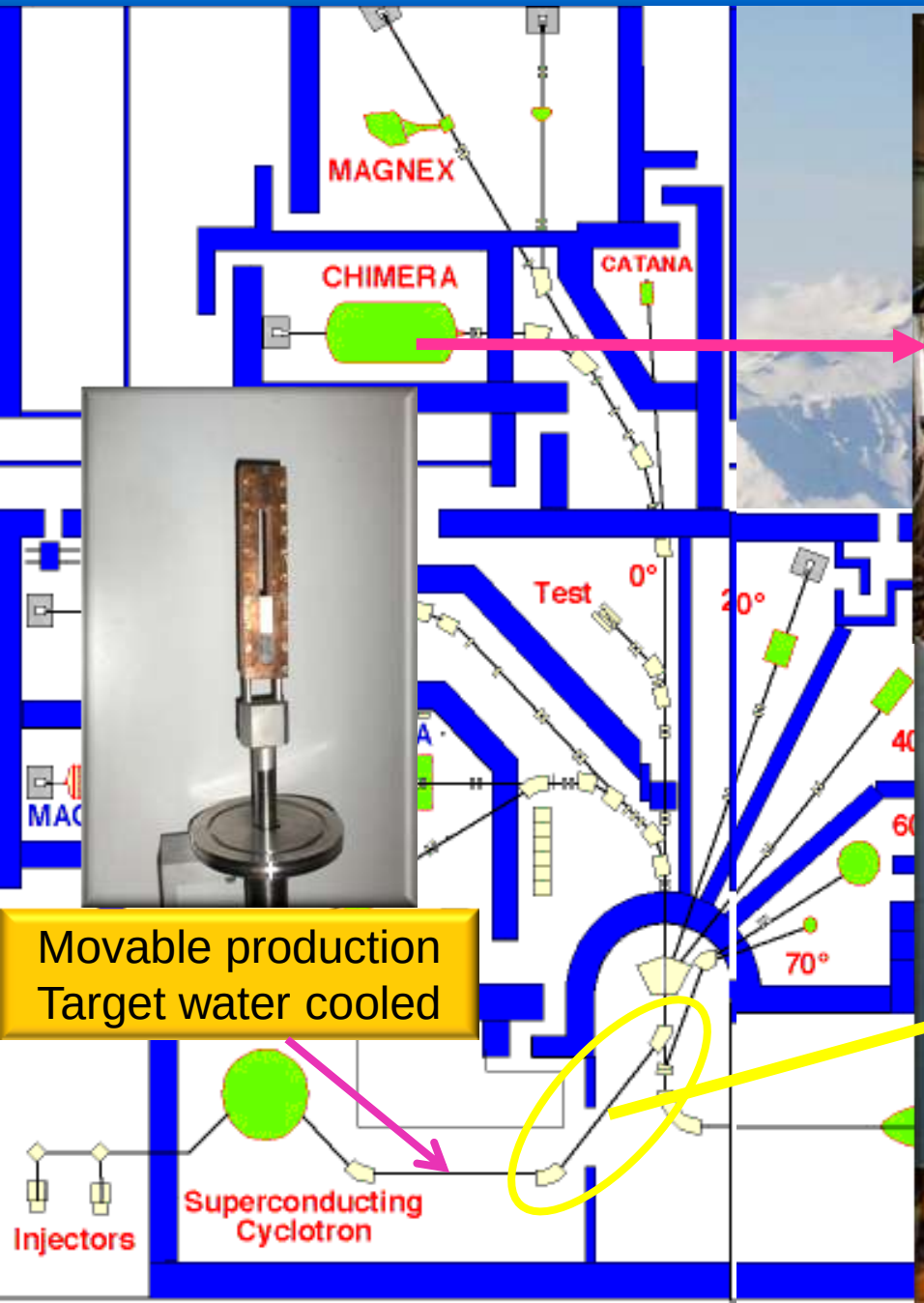
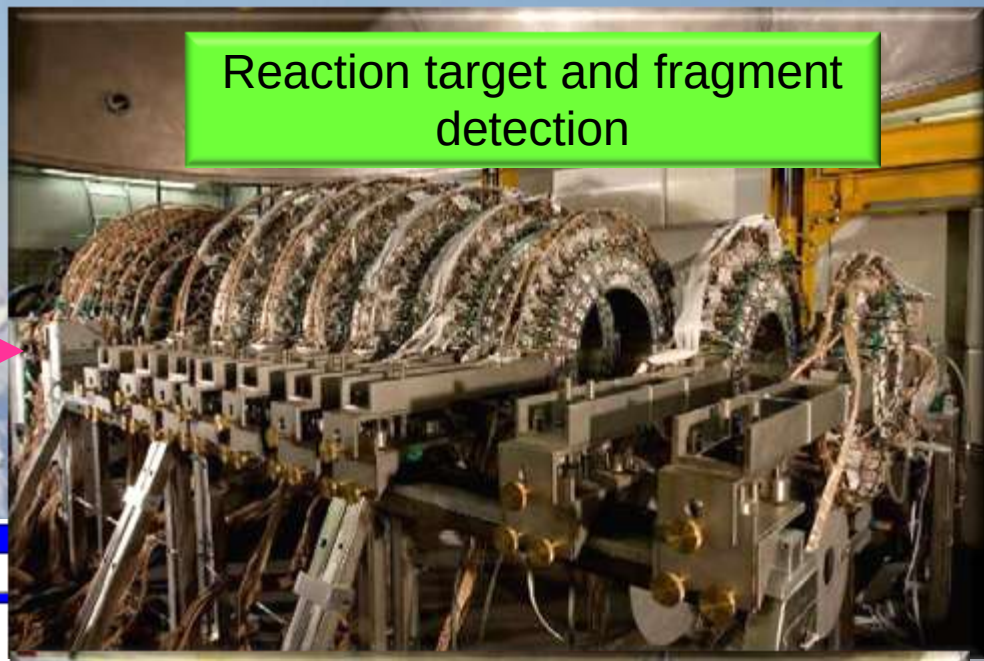
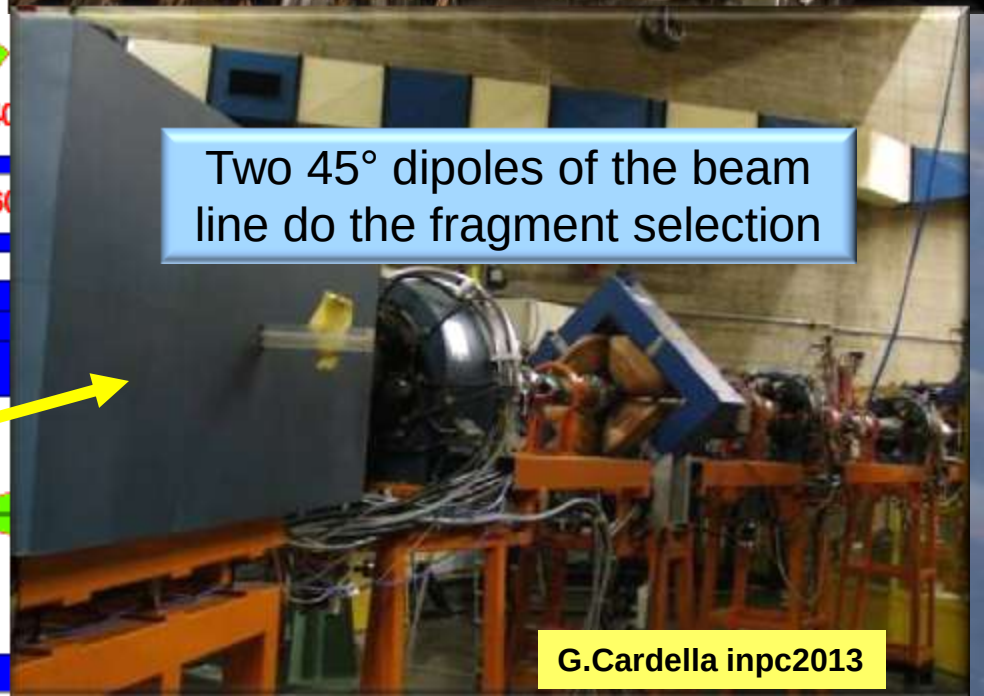
Fragmentation beams at INFN-LNS - Catania



Movable production
Target water cooled



Reaction target and fragment detection

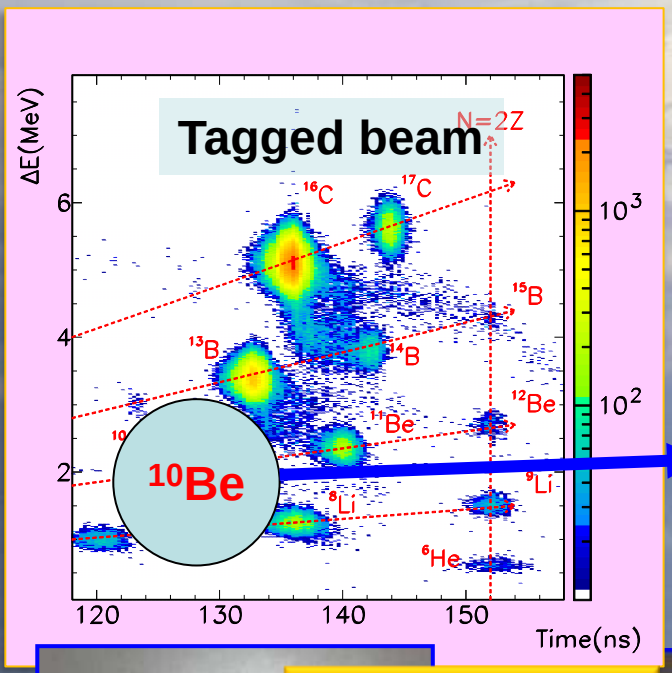


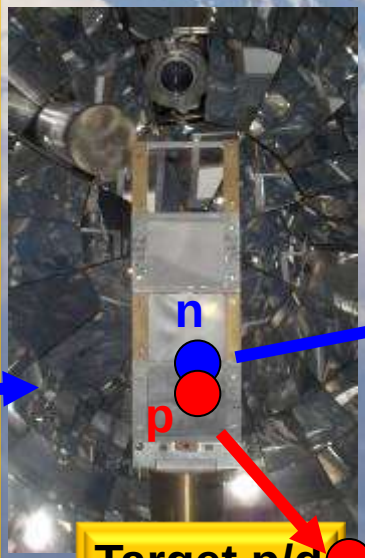
Two 45° dipoles of the beam line do the fragment selection

-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 (see Alexandre Obertelli this morning)

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





Only charge identification in forward rings due to low gain preamplifiers

^{11}Be

^{10}Be

Target p/d

p

Tagging system

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

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Kinematical coincidence method in transfer reactions

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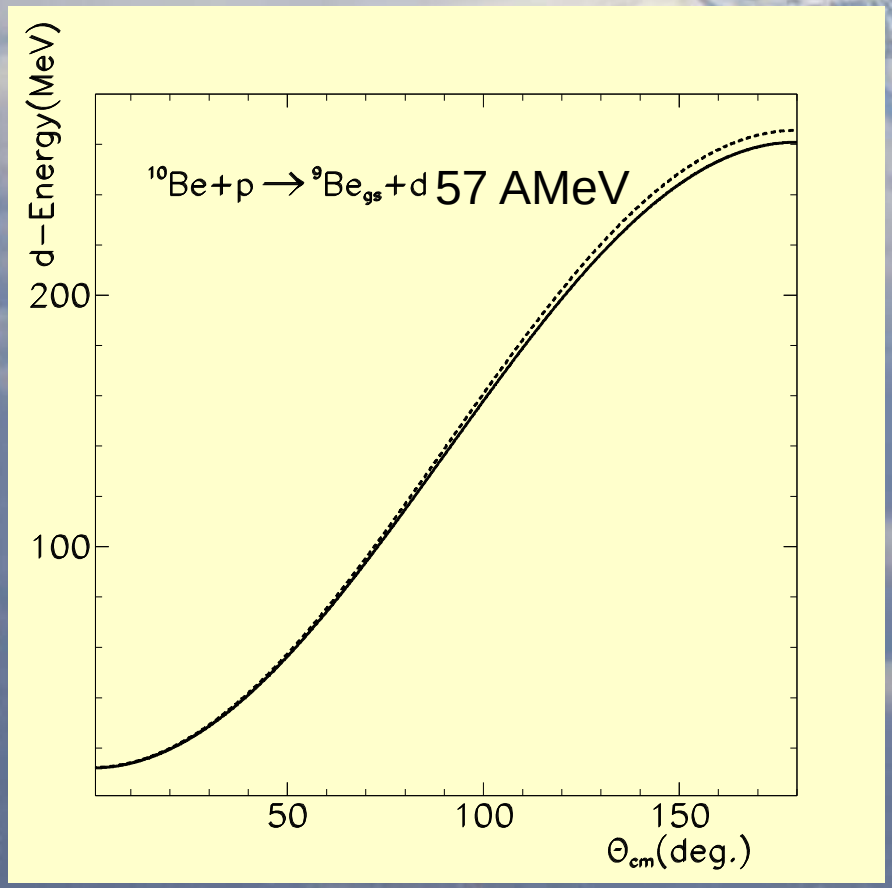


The lab energy of the detected particle determines the CM emission angle

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→^{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

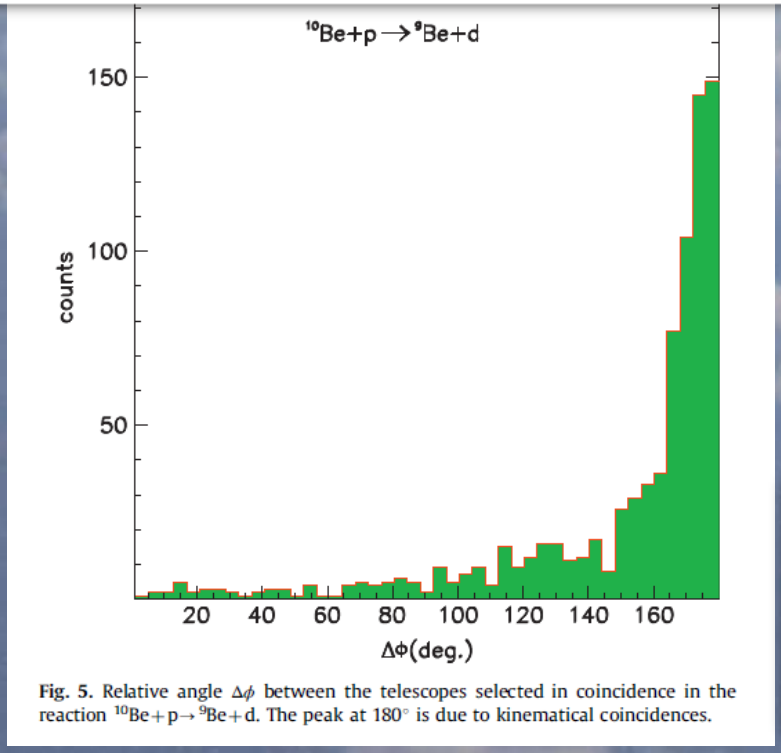


Fig. 5. Relative angle $\Delta\phi$ between the telescopes selected in coincidence in the reaction ^{10}Be+p→ ^{9}Be+d. The peak at 180° is due to kinematical coincidences.

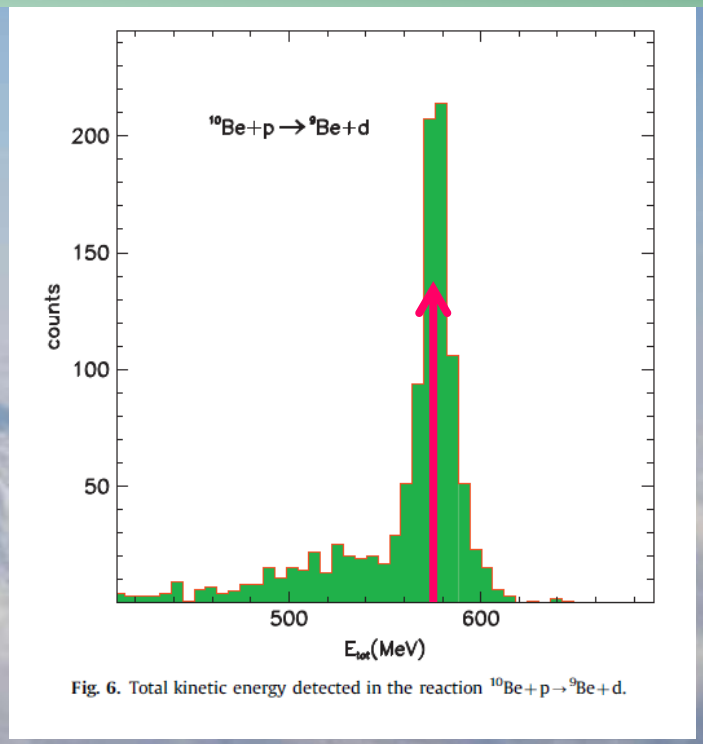


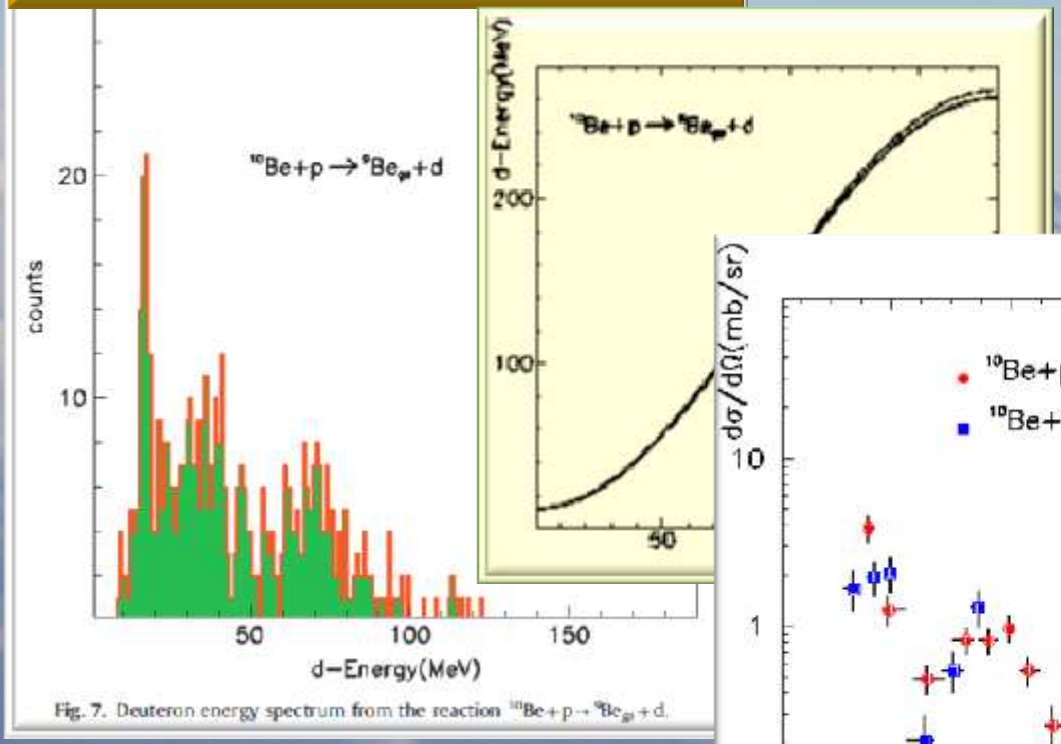
Fig. 6. Total kinetic energy detected in the reaction ^{10}Be+p→^{9}Be+d.

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)

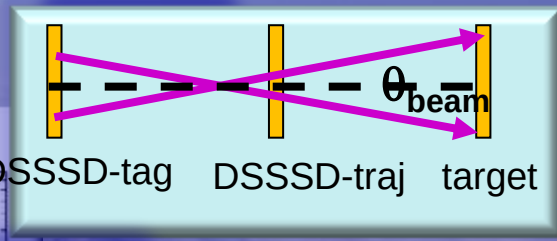
Notwithstanding the scarce total energy resolution we see only GS events
^{9}Be*→ n+α+α
S_n=1.66 MeV

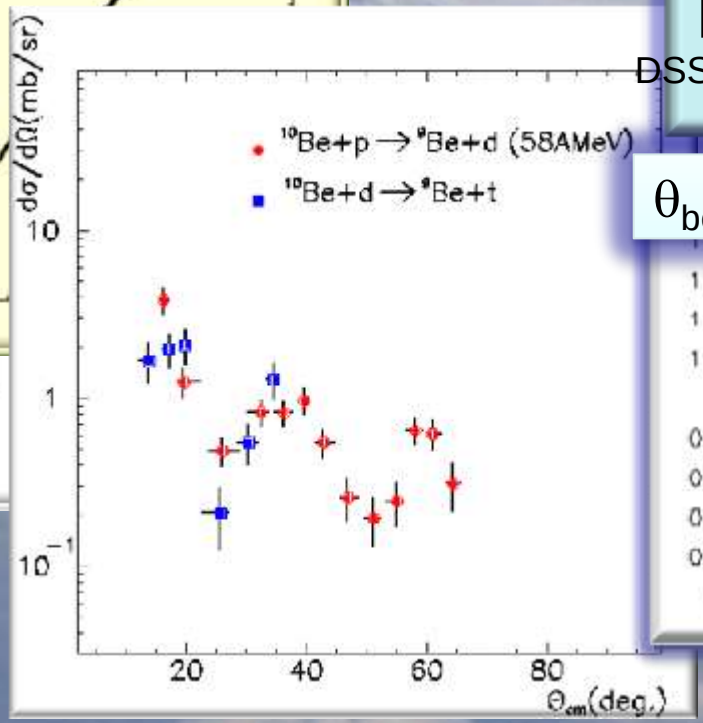
– The $^{10}Be+p \rightarrow {}^{9}Be_{g.s.}$ + d angular distribution -

From the analysis we get the deuteron energy spectrum

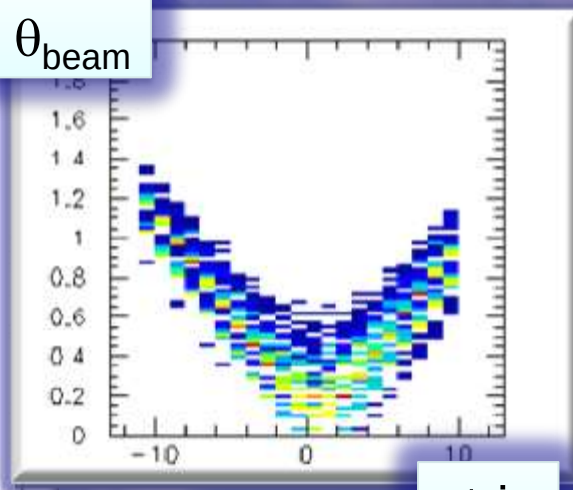


Using kinematics we can convert it from dN/dE → dN/dθ





θ_{beam}



After efficiency correction taking into account few rings missing for a GSI experiment (see P.Russotto C6 on Thursday) we get the angular distributions

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

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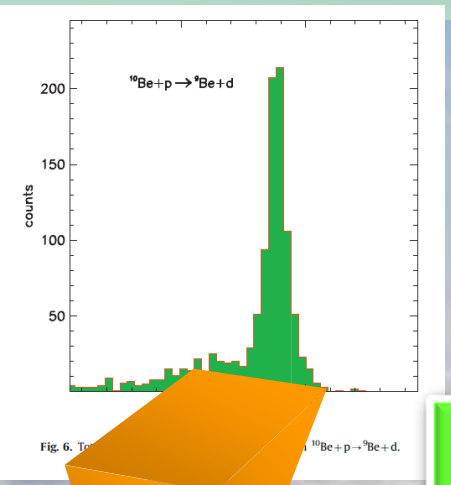
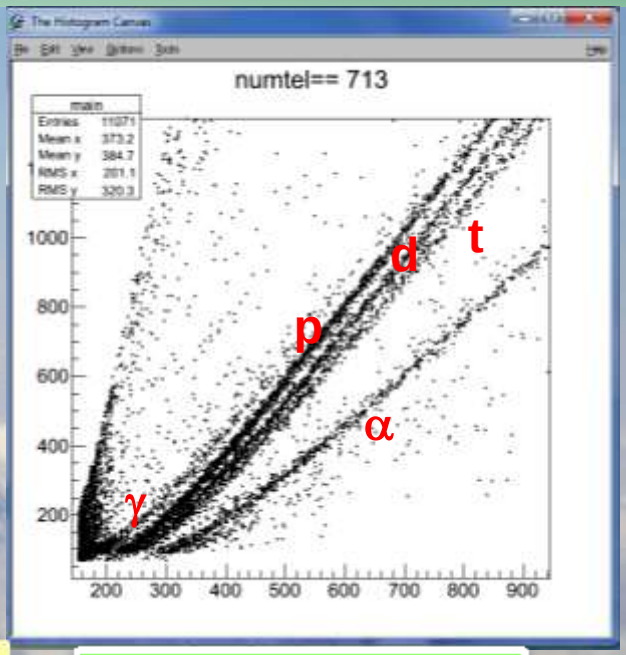
– Excited levels - γ-ray tagging? -

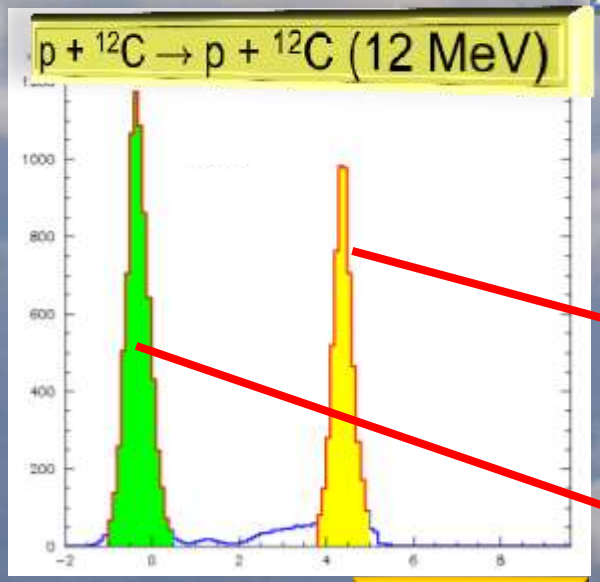


γ-ray tagging could be a solution to extend the method in case of excited levels - How to combine efficient γ-ray detectors and CHIMERA?

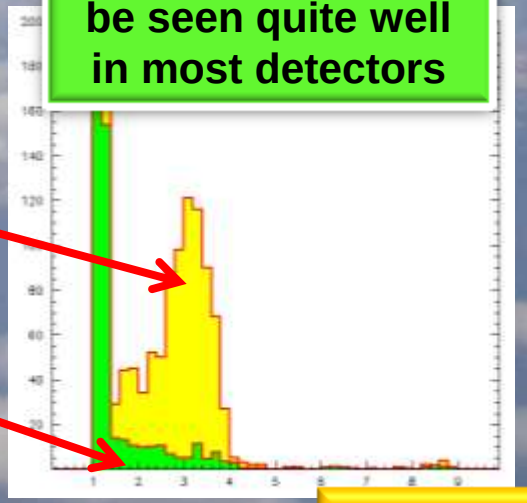
CsI(Tl) have a large efficiency for gamma ray detection



We have measured the γ-ray signals from CsI(tl) using proton beam 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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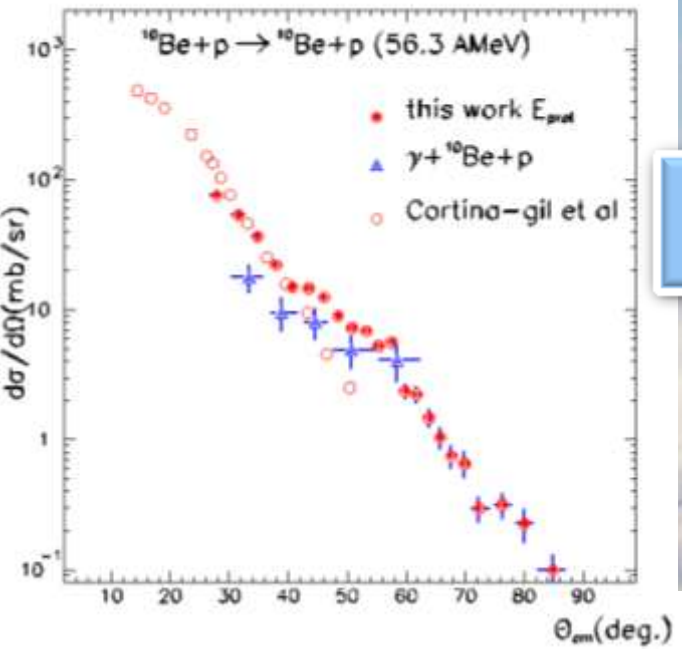
– Using the γ-ray tagging: the ^{10}Be+p →^{10}Be+p case -

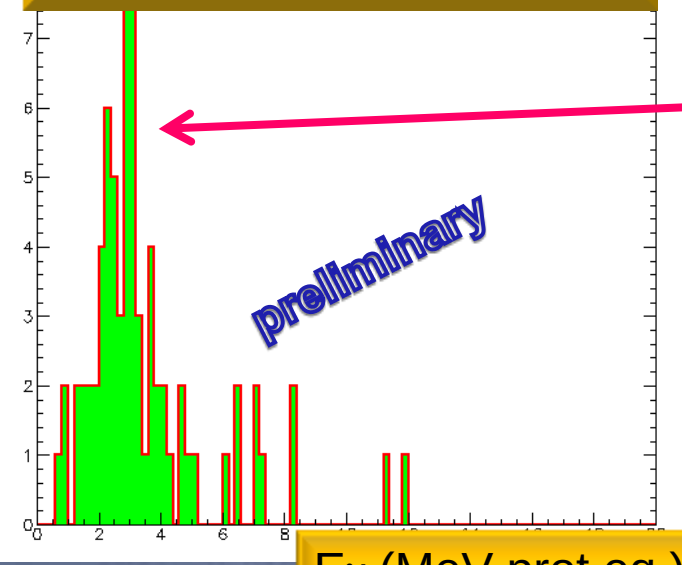


The angular distribution we measure for this channel shows a slope change around 40°

This change of slope is not seen in previous data measured by Cortina-Gil et al Phys.Lett.b 401(1997)9

The proton angular distribution measured in coincidence with γ-rays explains the change of slope and the deviation from Cortina-Gil data

γ-ray from ^{10}Be+p→^{10}Be*+p



E_{level} (keV)	Jπ	$T_{1/2}$	E_γ (keV)	I_γ	γ mult.	Final level	
0.0	0+	1.51E+6 y 4 % β⁻ = 100					
3368.03 3	2+	125 fs [illegible] % IT = 1[illegible]	3367.415 30	100	E2	0.0	0+
5958.39 5	2+	< 55 fs % IT = 100	2589.999 60 5955.9 5	>90 <10	M1 E2	3368.03 0.0	2+ 0+
5959.9 6	1-	% IT = 100	2591.5 6 5958.0 6	17 8 83 8	E1 E1	3368.03 0.0	2+ 0+
6179.3 7	0+	0.8 ps +3-2 % IT ≈ 100	219.4 3 2811 7 6178	24 2 76 2	E1 E2 E0	5959.9 3368.03 0.0	1- 2+ 0+
6263.3 50	2-	% IT = 100	303.4 50 2894.9 50 6261.2 50	≤1 99 1 1 1	 E1 M2	5959.9 3368.03 0.0	1- 2+ 0+

The γ-ray spectrum measured is what we expect from ^{10}Be* excited states decay

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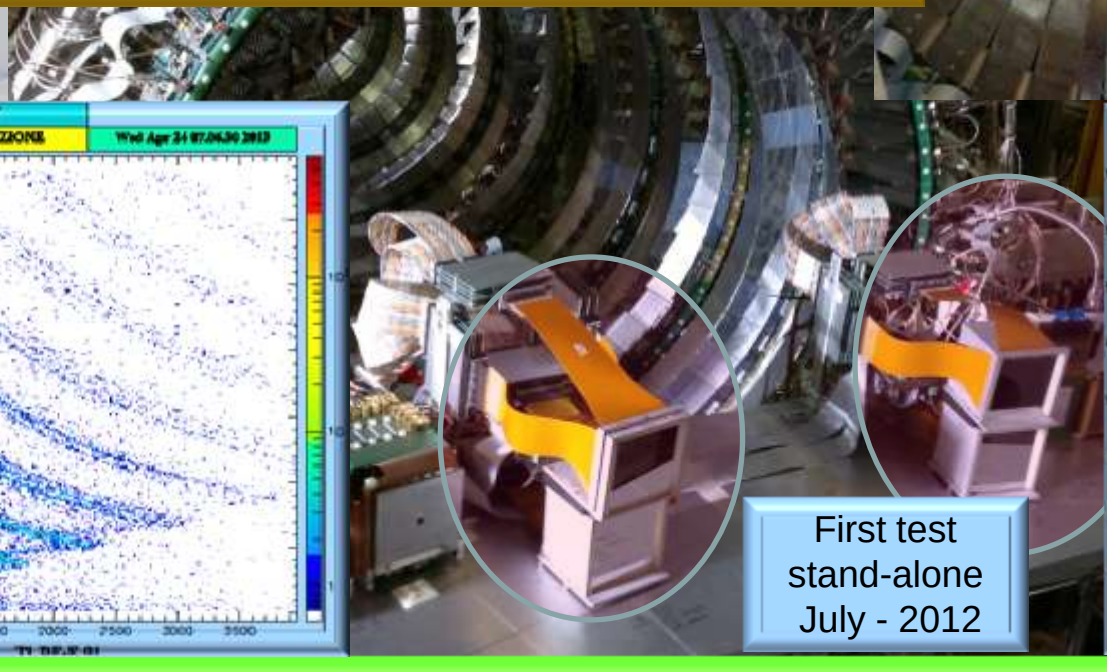
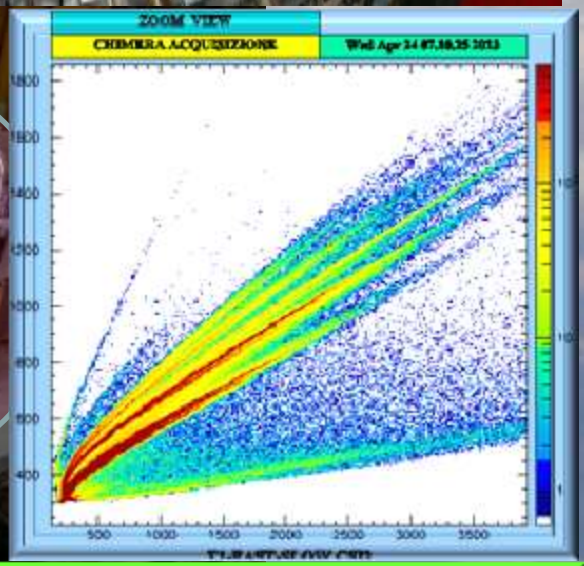
Future improvement : FARCOS as forward angle spectrometer

New triple telescopes Si-Si-CsI
First stage 32x32 strip 6.2x6.2cm^2 300 μm DSSSD
Second stage 32x32 strip 1500 6.2x6.2cm^2 μm DSSSD
Third stage 4 CsI(tl) 3.1x3.1 cm^2 photodiode readout 6 cm thick

First test-experiment coupled with Chimera April 2013 see E.De Flippo next Thursday C6 and Acosta poster Nf001





First test stand-alone July - 2012

- **Improved CsI(Tl) energy resolution due to corrections for the particle detection position**
- **Improved energy calibrations/resolution also due to the two stages of silicon detectors**
- **Improved ϕ granularity and isotopic identification**

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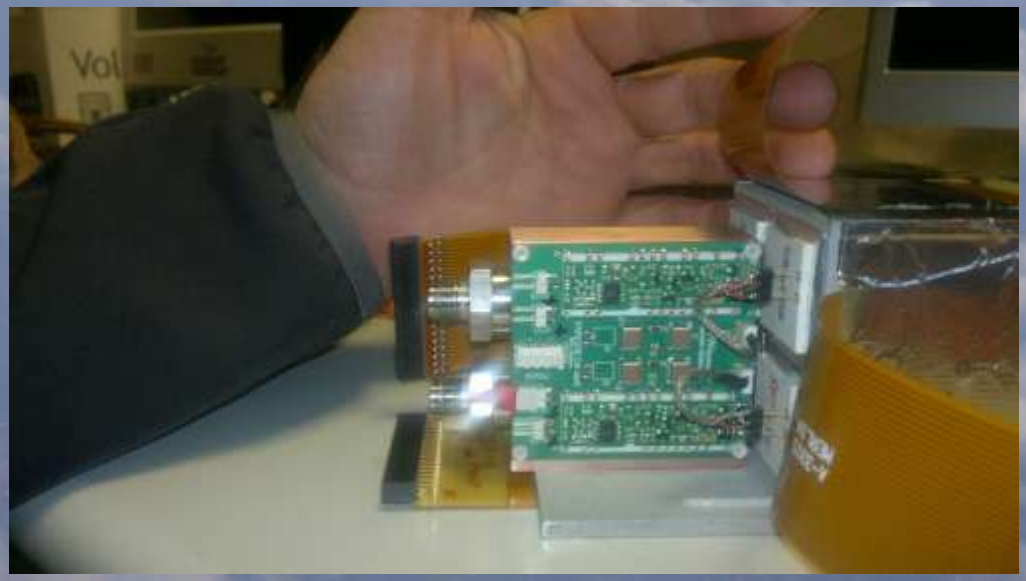
Conclusions and perspectives

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

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 and to neutron detectors



I wish to thank all my collaborators

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