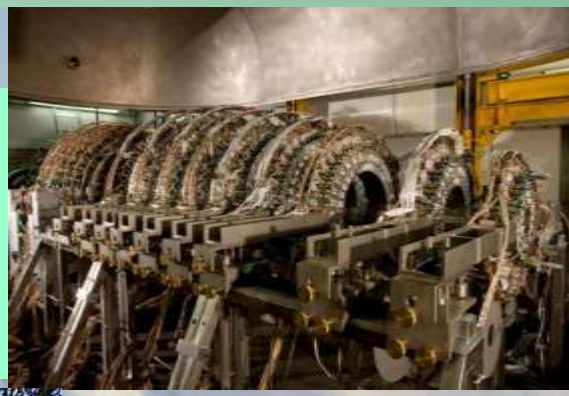
Elastic scattering and neutron transfer in neutron rich light nuclei

G.Cardella
for the
EXOCHIM collaboration

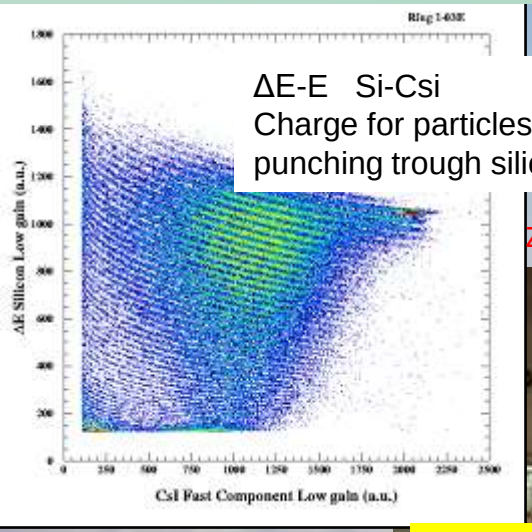


DREB2014 - Direct Reactions with Exotic Beams
June 30 - July 4, 2014 Darmstadtium

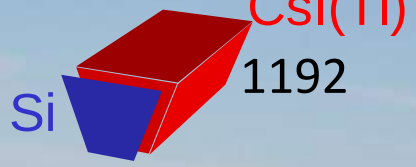
Outline

- Short presentation of the CHIMERA detector and LNS fragmentation beams
- Can one get precise angular distributions without extremely segmented detectors?
- Extension of the method using coincidence γ-ray
- Break-Up
- Neutron detection
- Conclusions and perspectives

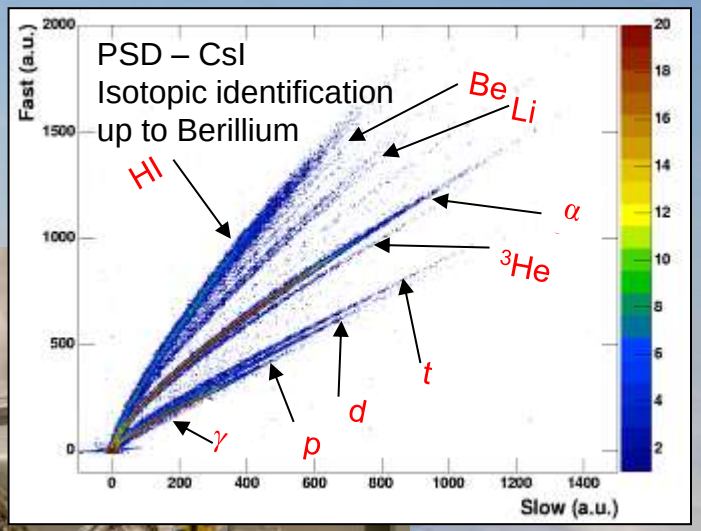
The CHIMERA detector : particle identification methods

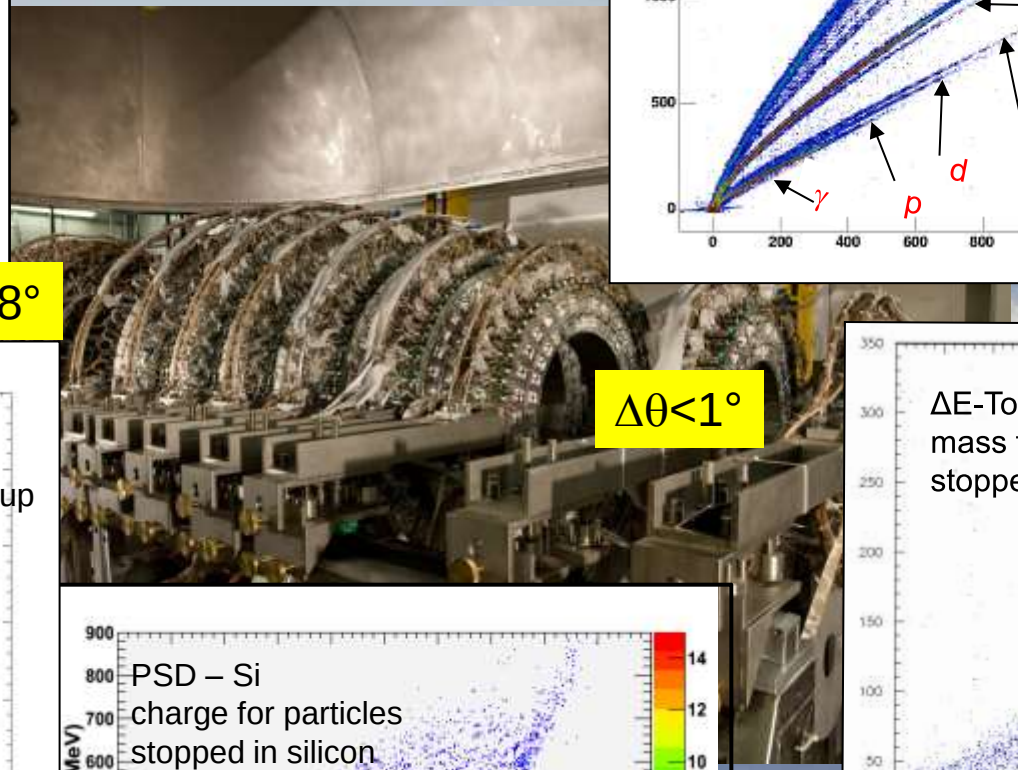


ΔE-E Si-Csi
Charge for particles
punching trough silicon



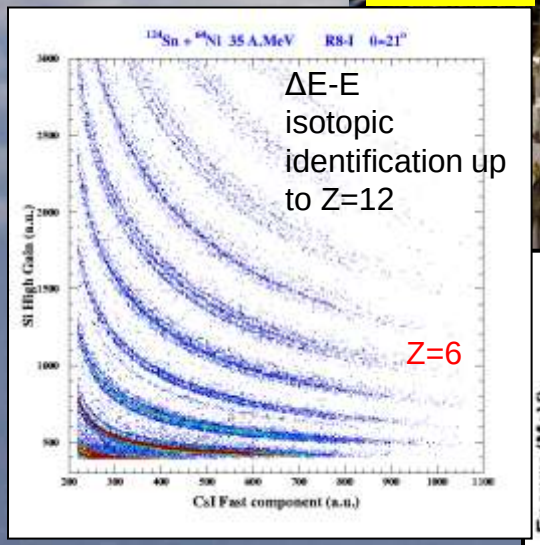
Z=50

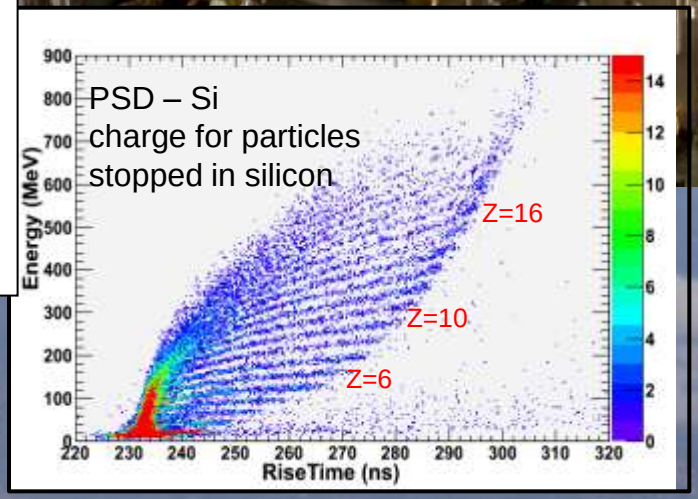


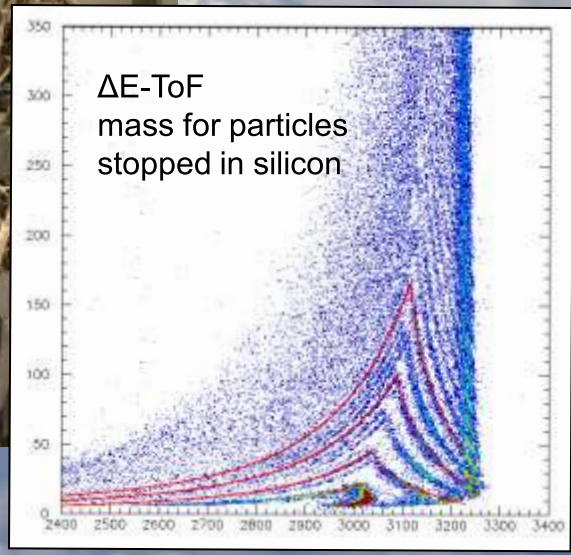


Δθ=8°

Δθ<1°







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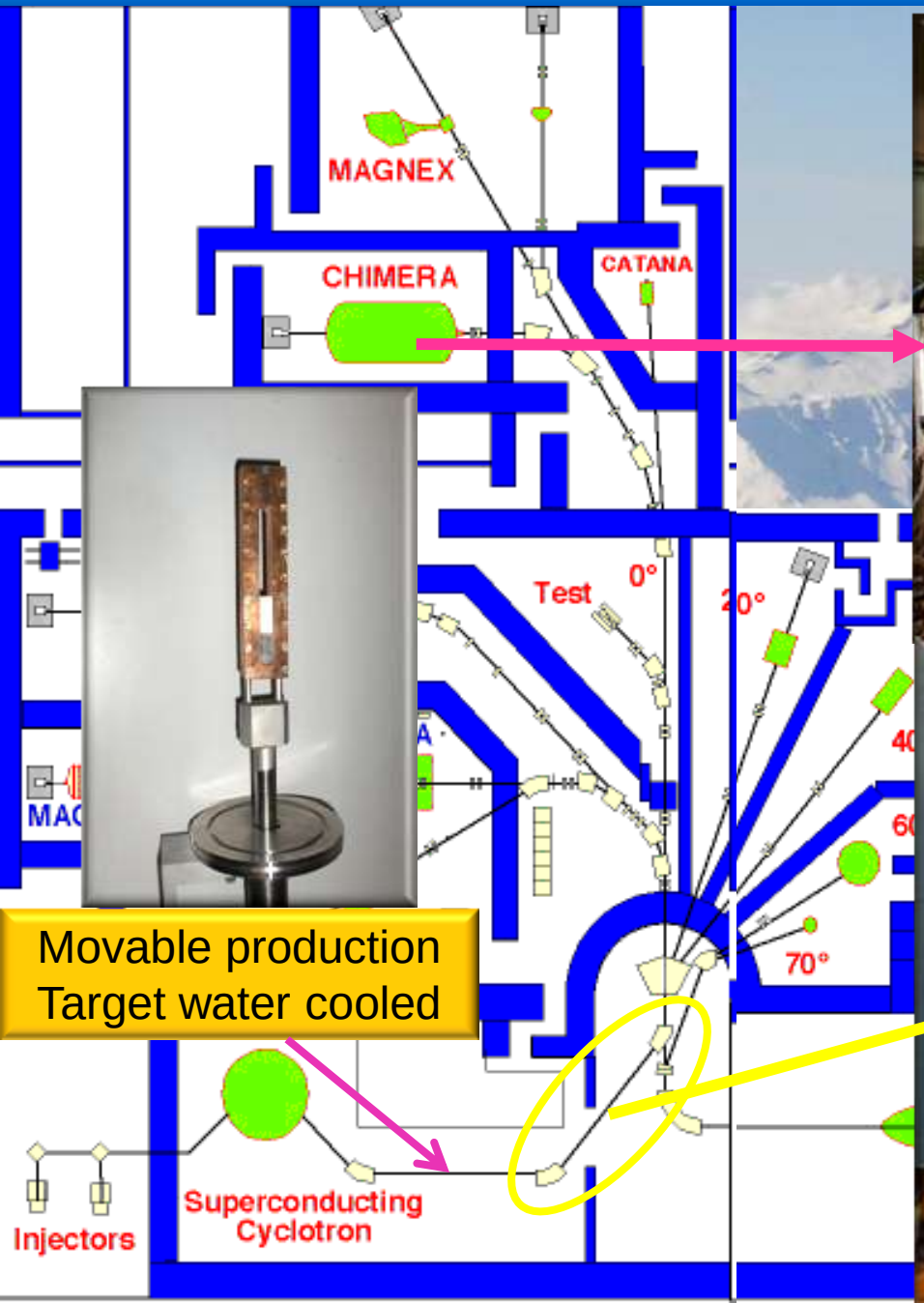
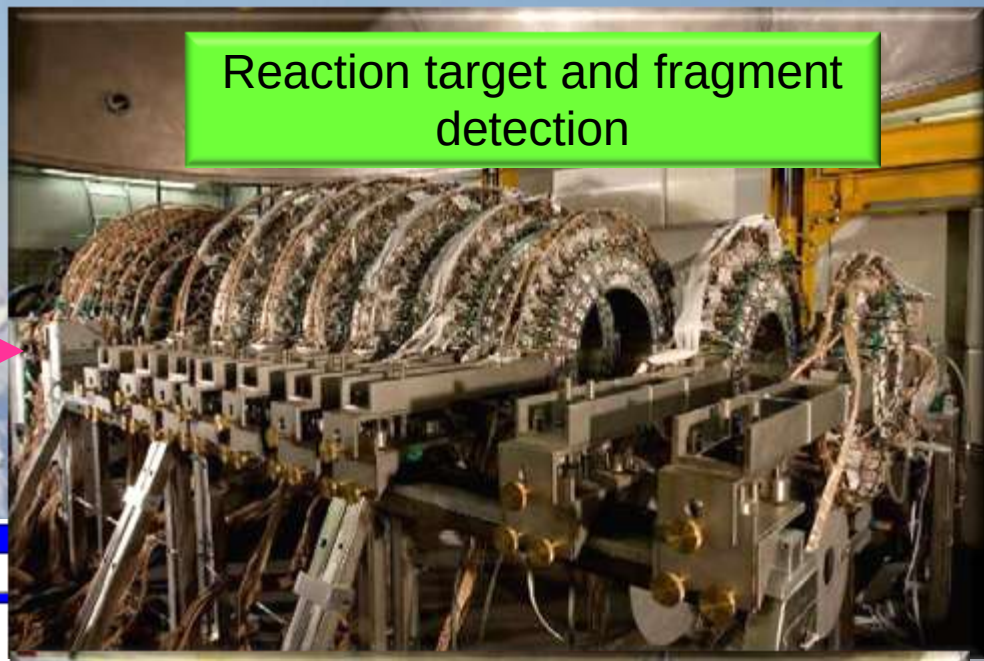
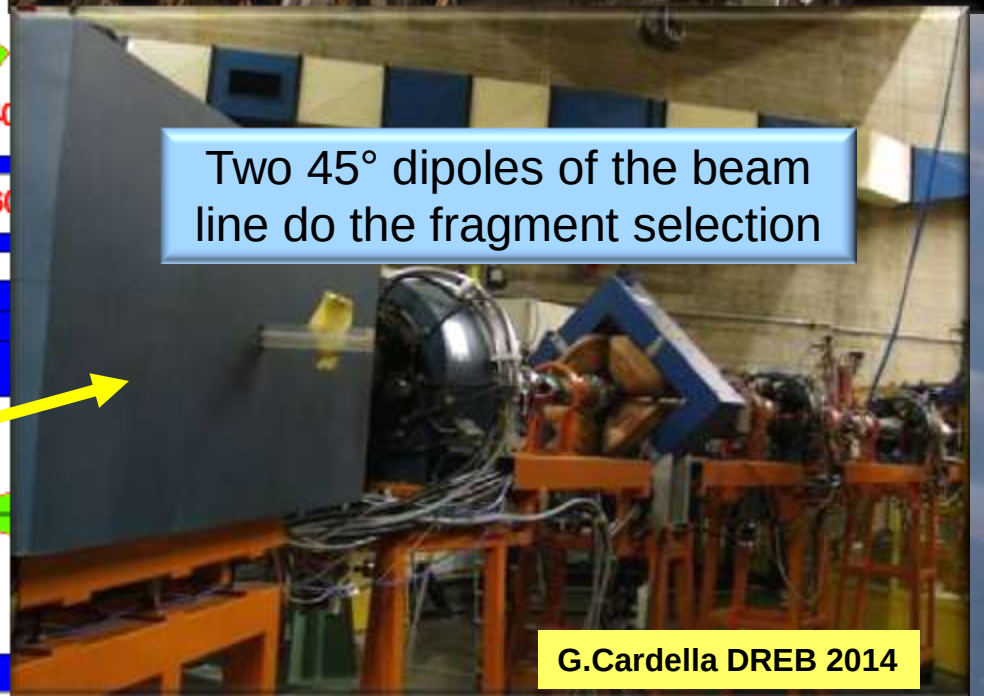
Fragmentation beams at INFN-LNS - Catania



Movable production
Target water cooled



Reaction target and fragment detection

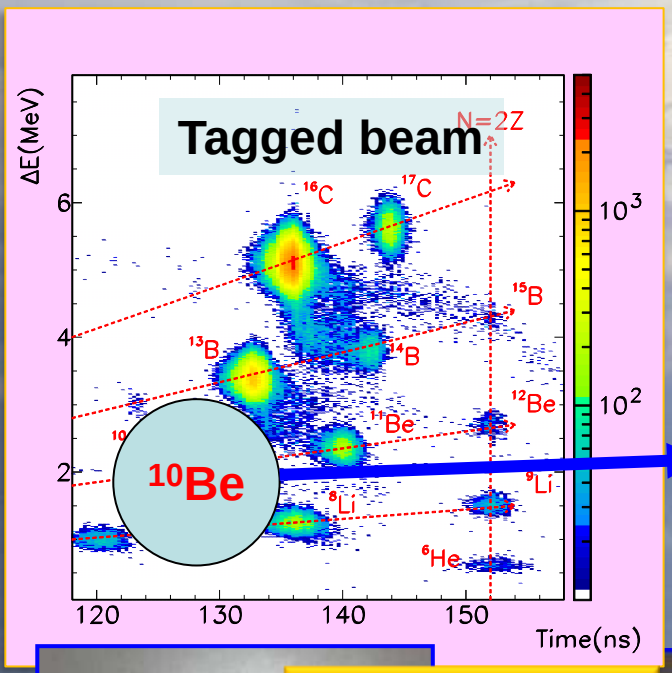


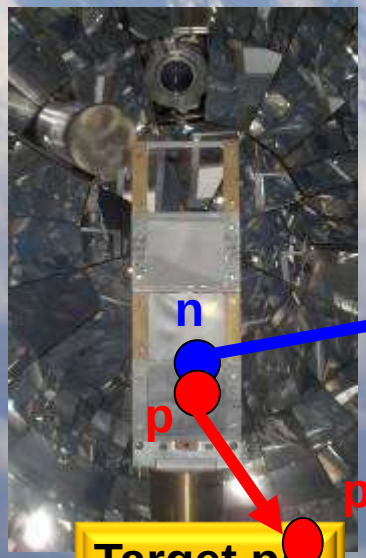
Two 45° dipoles of the beam line do the fragment selection

-Neutron transfer reactions near halo nuclei -

In this experiment we studied 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





Target p/d

Tagging system

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

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

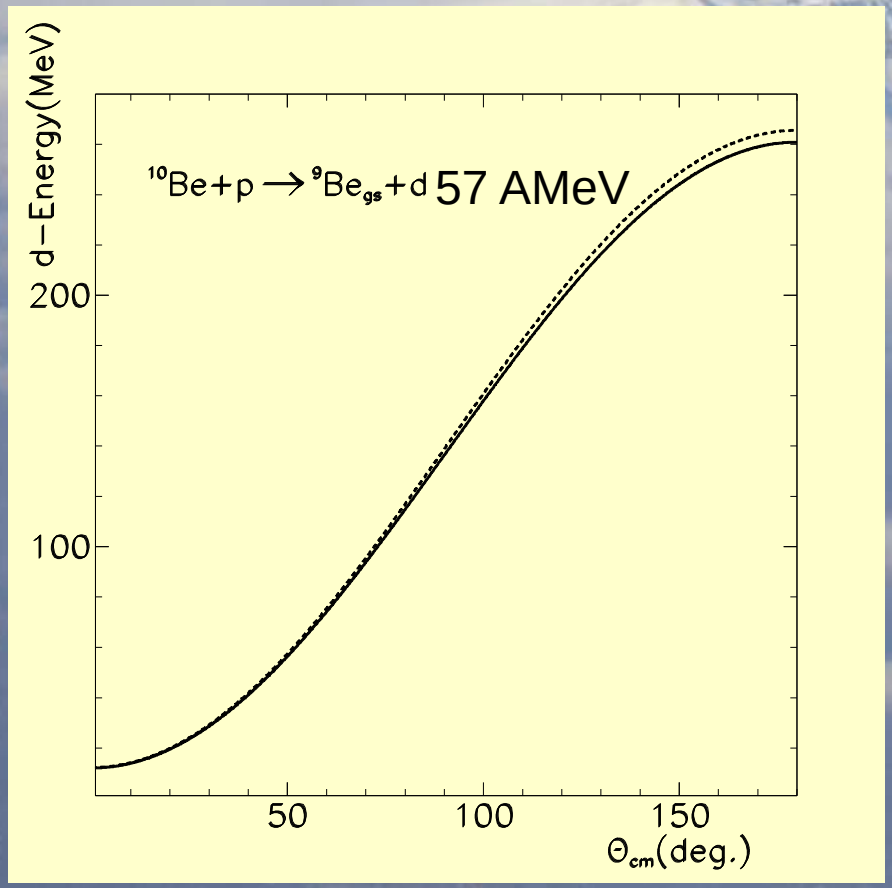
Contents lists available at SciVerse ScienceDirect

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

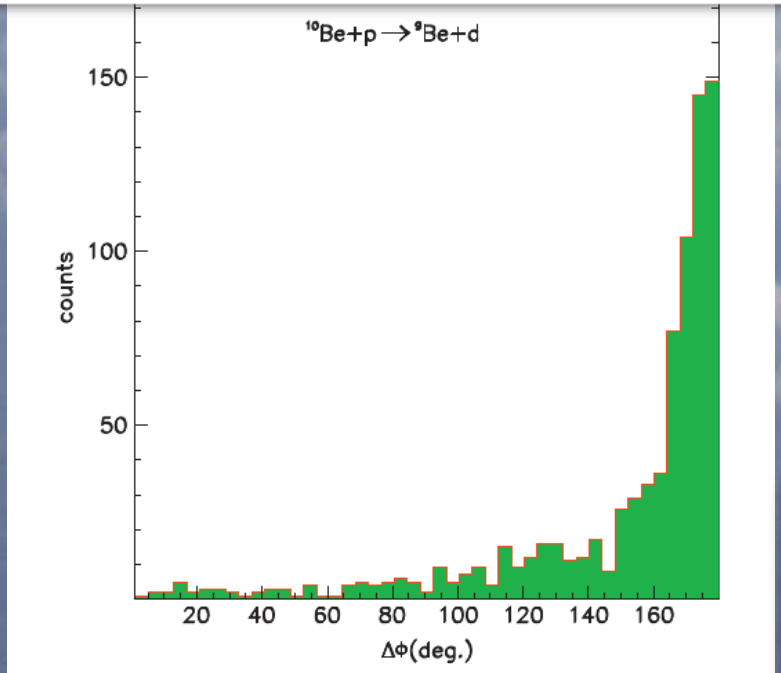
Due to the relatively good energy resolution we can obtain an angular distribution with much better resolution than the one determined by the size of the detectors

– STEPS of the analysis ^{10}Be+p→^{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



telescopes selected in coincidence in the 80° is due to kinematical coincidences.

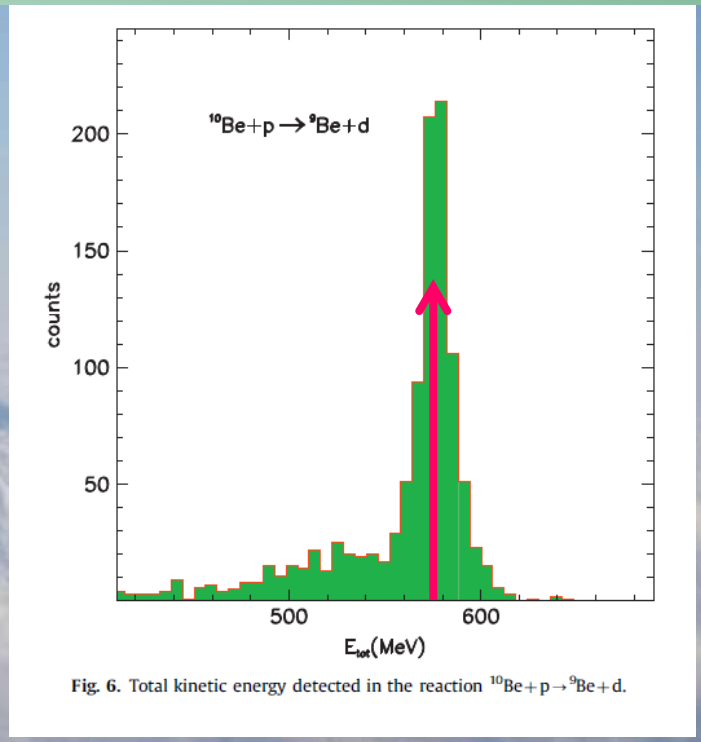


Fig. 6. Total kinetic energy detected in the reaction ^{10}Be+p→^{9}Be+d.

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)

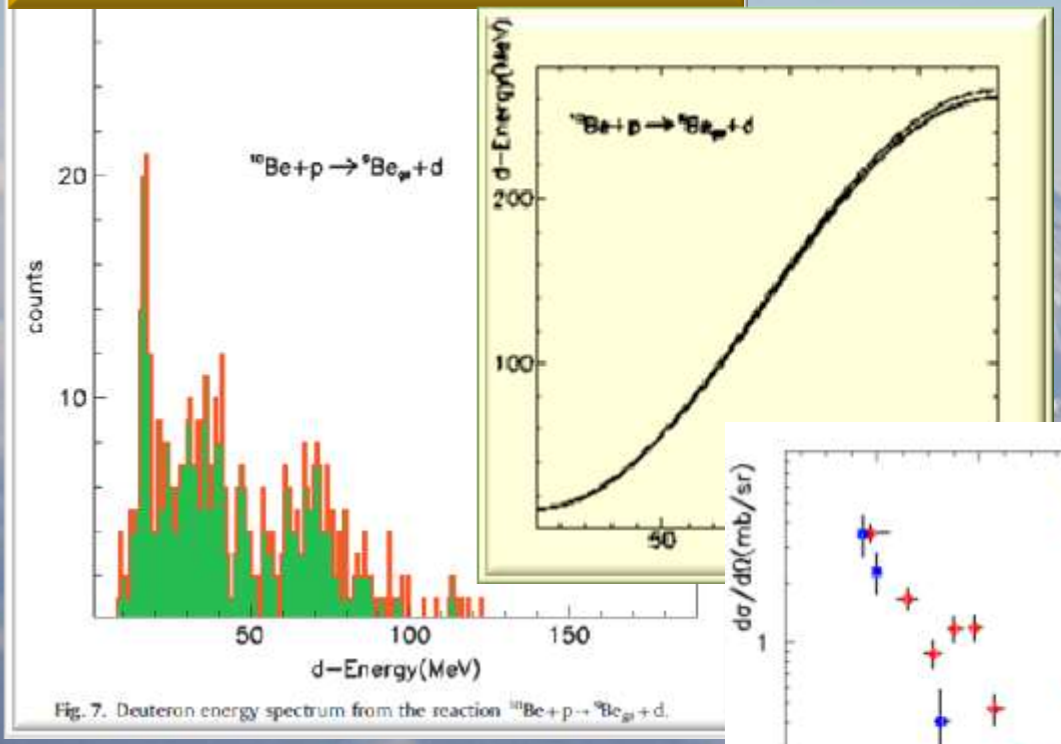
Notwithstanding the scarce total energy resolution we see only GS events

^{9}Be*→ n+α+α

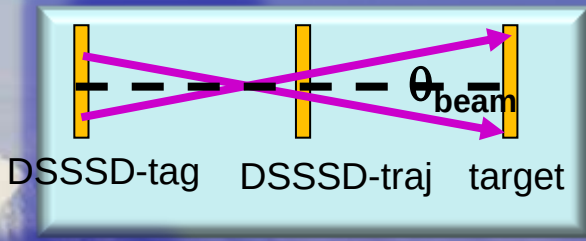
S_n=1.66 MeV

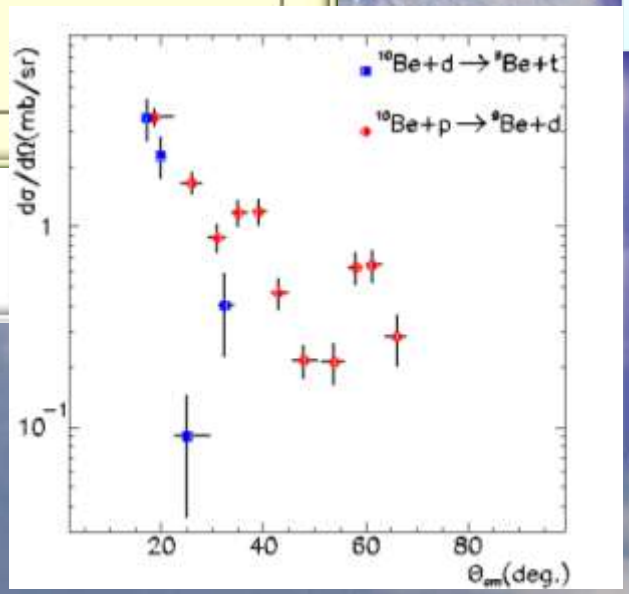
– The $^{10}Be+p \rightarrow {}^{9}Be_{g.s.}$ + d angular distribution -

From the analysis we get the deuteron energy spectrum

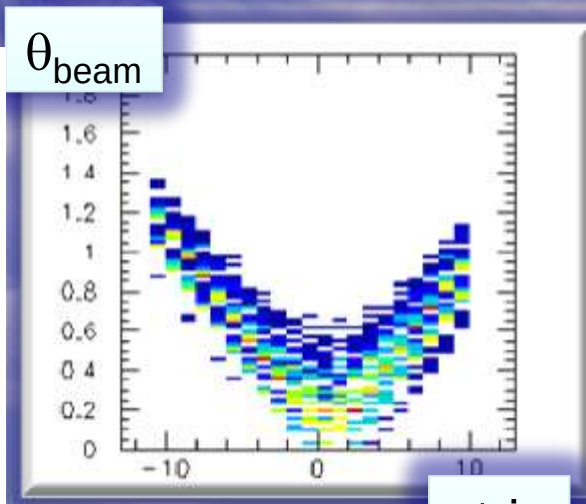


Using kinematics we can convert it from dN/dE → dN/dθ





After efficiency correction taking into account few rings missing for a GSI experiment we get the angular distributions



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

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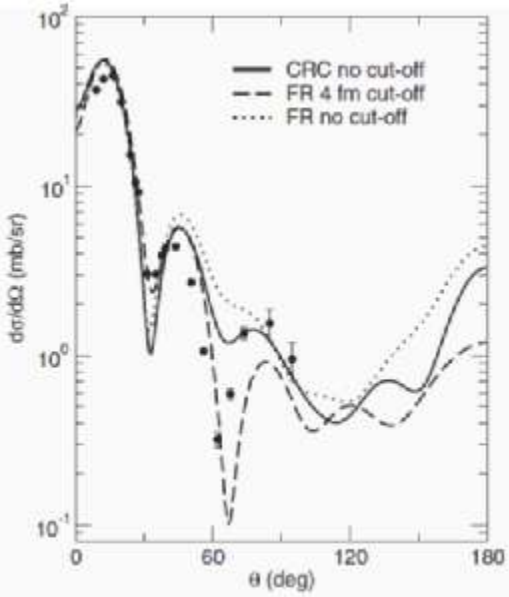
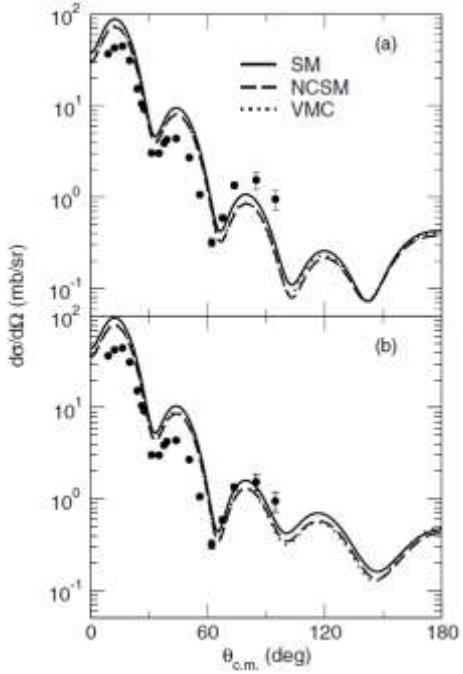
– Preliminary results from CRC calculations -

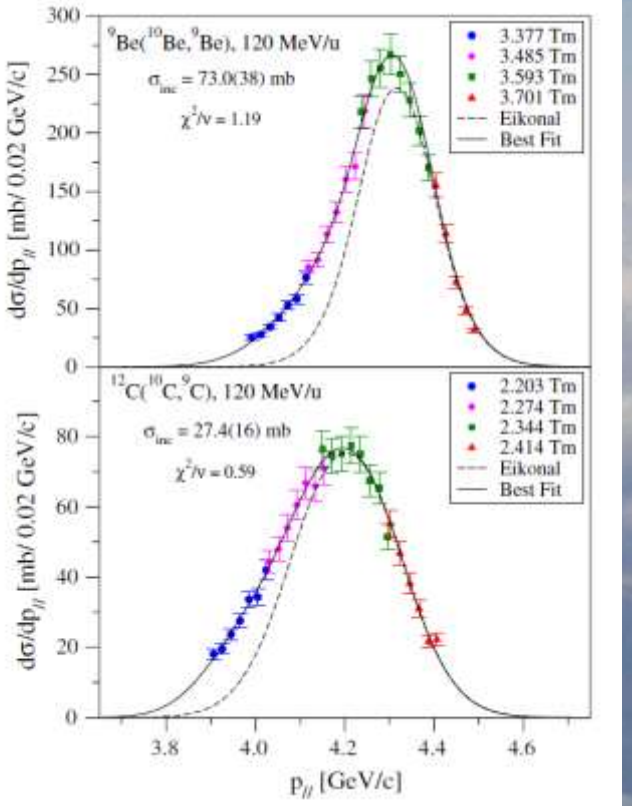


N.Keeley et al
PRC86,014619(2012)

It is very interesting a comparison with previous d,t data with 16 MeV deuteron beam direct kinematics from Auton *Nuclear Physics A157 (I970) 305*

And also see if transfer reactions get same spectroscopic results as knockout reactions





G.F.Grinyer et al
PRL106,162502(2011)

In the Keeley work one see that using the same <10Be|9Be + n> bound-state form factors from the knockout analysis one overestimate transfer cross section of about 30-40%

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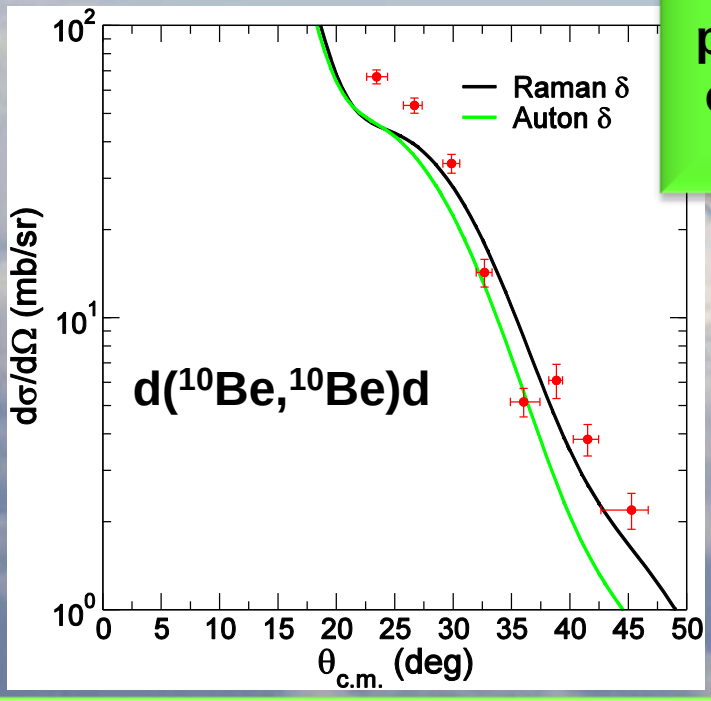
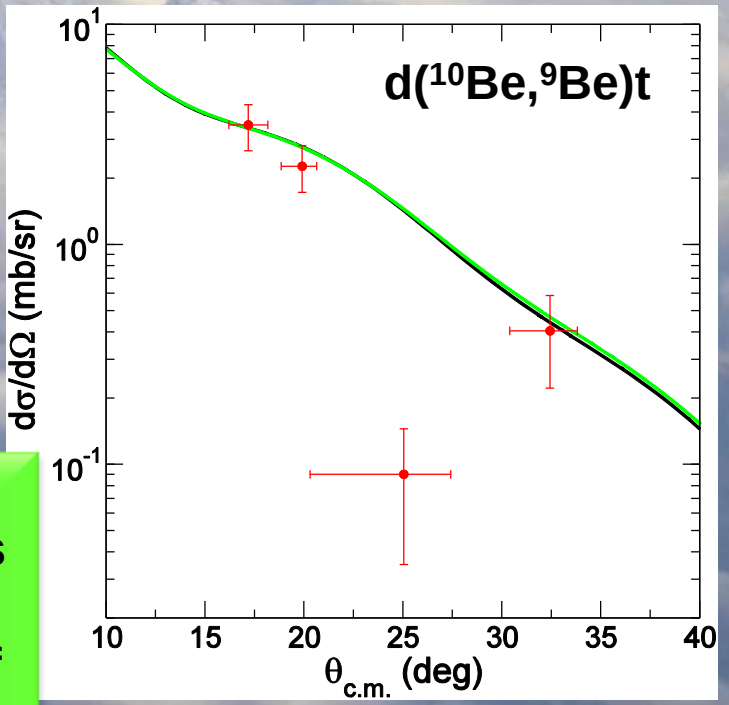
– Preliminary results from CRC calculations -

Our data at around 50 MeV/A could be useful to verify if part of the problem is due to the quite different beam energy (15 for transfer and 120 for knockout)

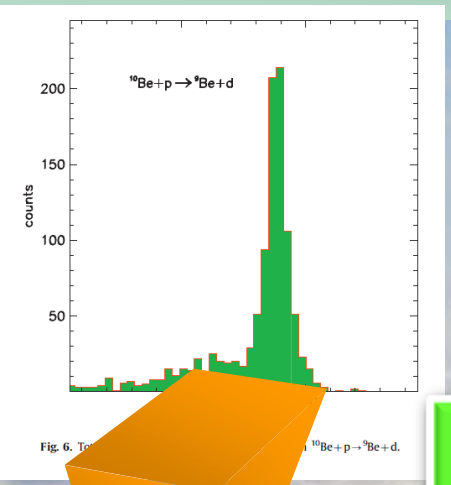
using elastic and quasi-elastic channels to fix other parameters in CRC calculations (first excited state of ^{10}Be has been included in calculations with two different assumptions for BE2 transition)





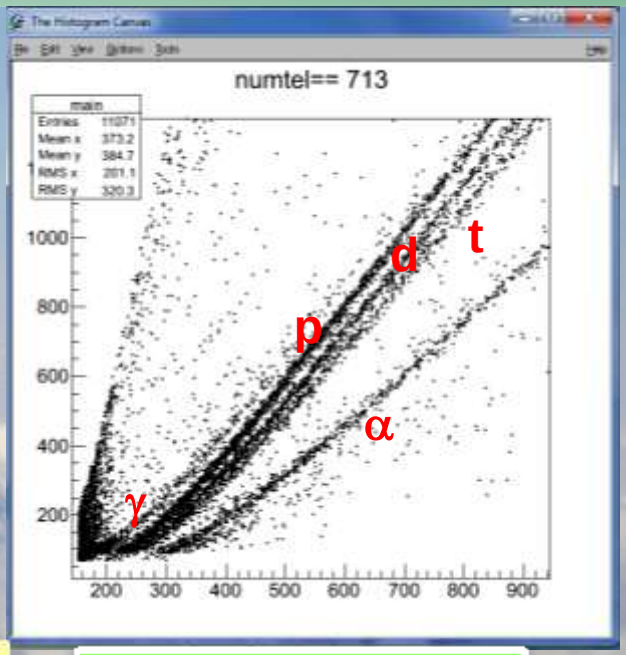
the normalization problem using knockout form factors persists - we had to normalize calculations again using a factor around 0.7 - however more work is necessary also from experimental point of view to improve data quality – Moreover one should investigate if non relativistic calculations are correct enough at 50 MeV/A

– Excited levels - γ-ray tagging? -

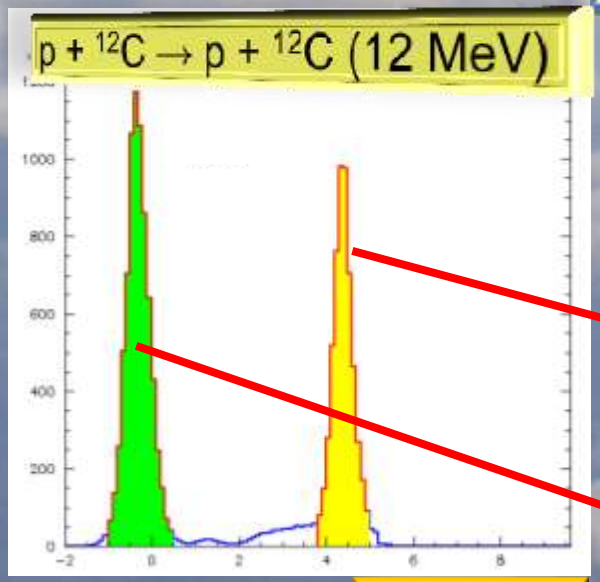


γ-ray tagging could be a solution to extend the method in case of excited levels - How to combine efficient γ-ray detectors and CHIMERA?

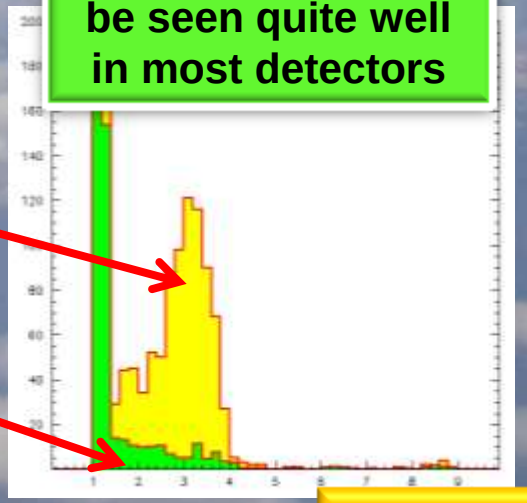
CsI(Tl) have a large efficiency for γ-ray detection



We have calibrated 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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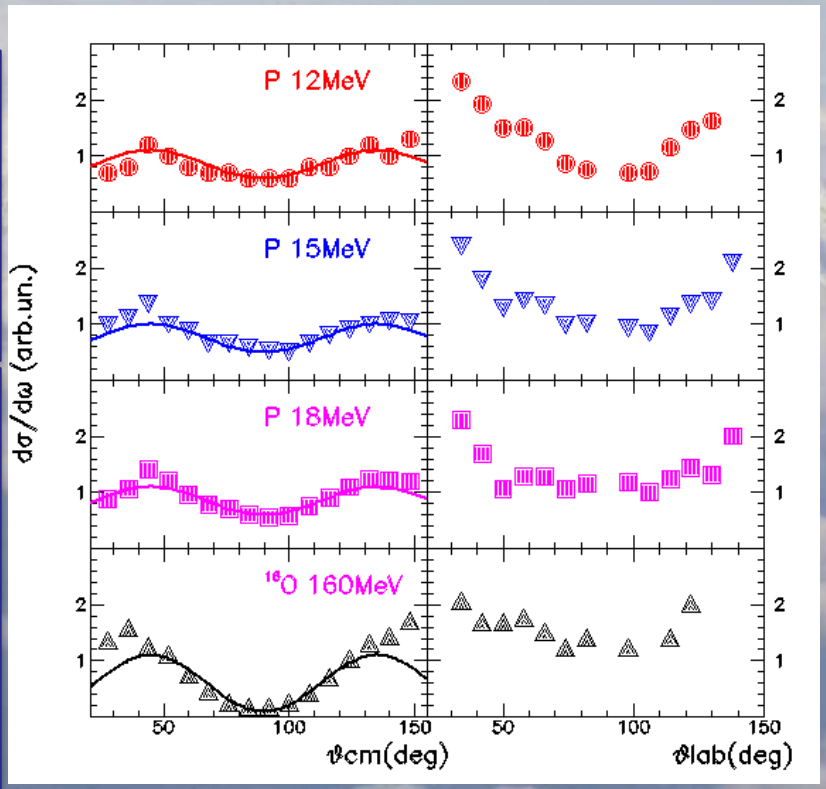
CHIMERA and γ-rays: angular distribution

We have a large efficiency (around 30-40% at 4 MeV) and we can extract accurate angular distributions both in Lab and in the frame of recoiling excited $^{12}C^{4.44}$ with our data taken at various proton energies

In the CM we can reproduce data as P+^{12}C →E2+cost. similar results for all energies

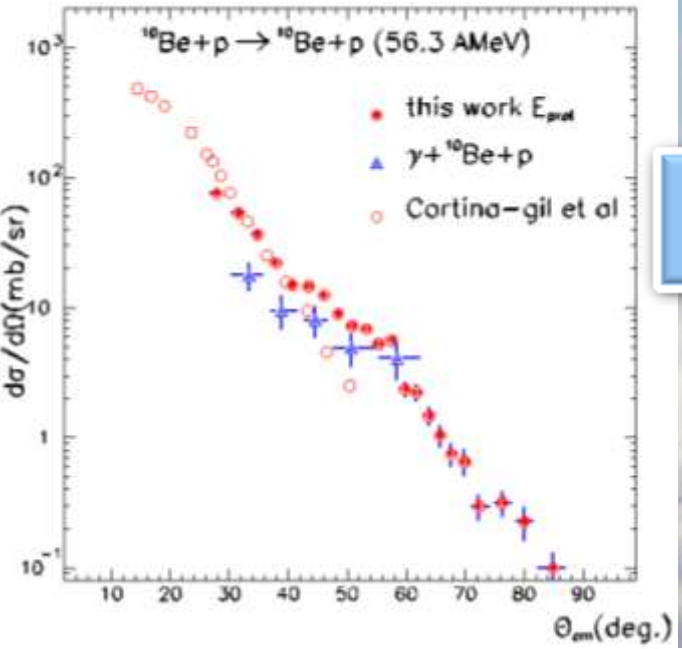
However exciting the 4.44 with ^{16}O beam we get much stronger polarization effect and we can reproduce data with pure E2
^{16}O +^{12}C → E2



The symmetry around 90° in the LAB ensure us of the quality of efficiency reconstruction

We are investigating to exclude trivial reasons for this strange effect

– Using the γ-ray tagging: the ^{10}Be+p →^{10}Be+p case -

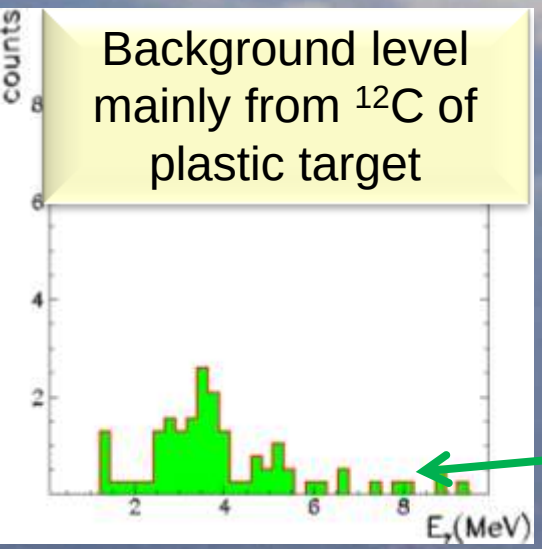


The angular distribution we measure for this channel shows a slope change around 40°

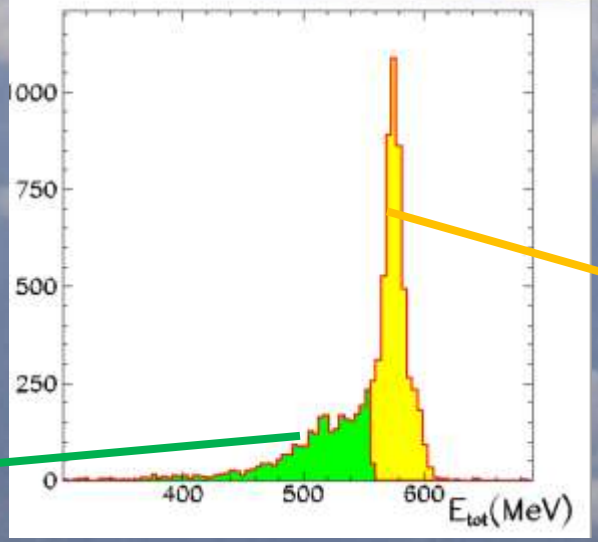
This change of slope is not seen in previous data measured by Cortina-Gil et al Phys.Lett.b 401(1997)9

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

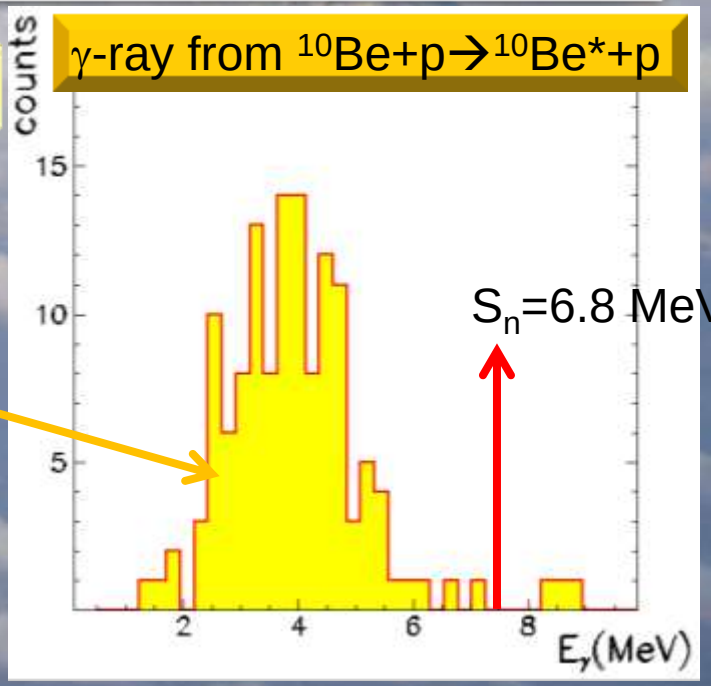
^{10}Be + p → ^{10}Be + p



Background level mainly from ^{12}C of plastic target



γ-ray from ^{10}Be+p→^{10}Be*+p



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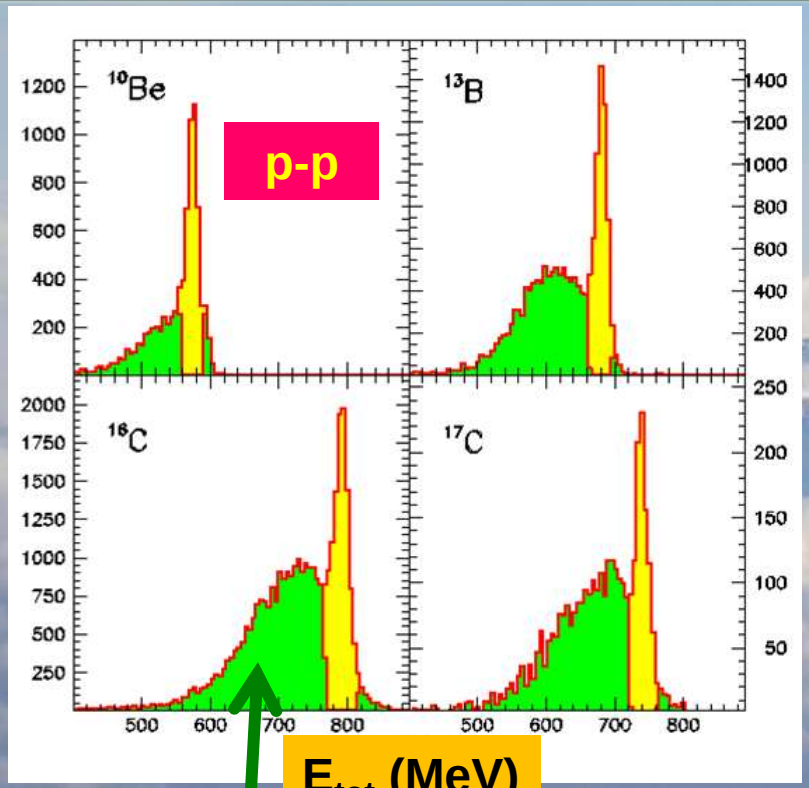
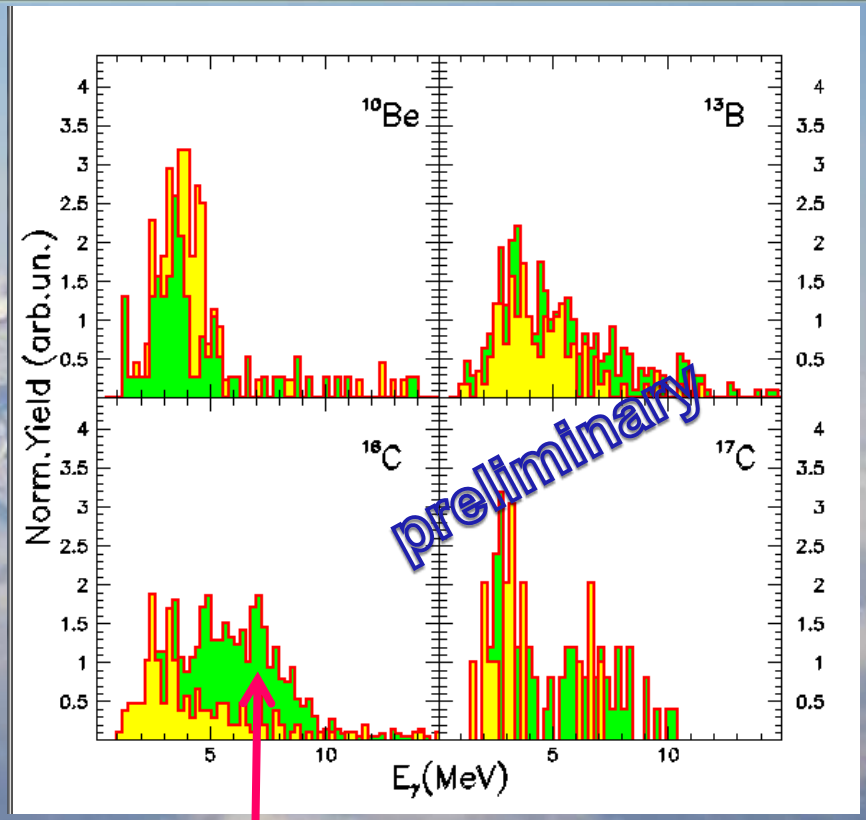
CHIMERA and γ-rays: normalized energy γ-spectra





xn channel

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

We are going to extract angular distributions of events tagged with γ-rays and also to look to γ-ray angular distributions to check spin and parities

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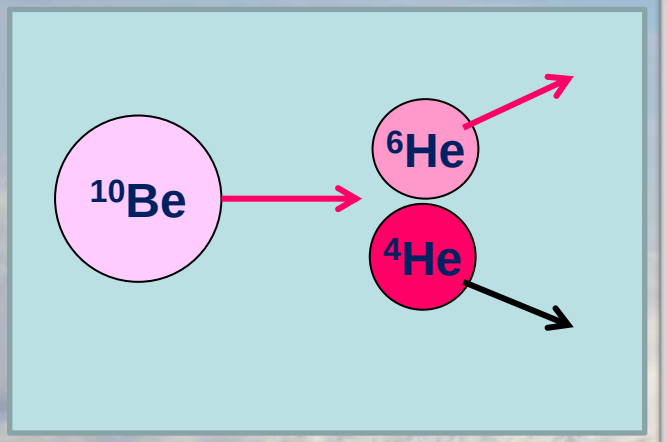
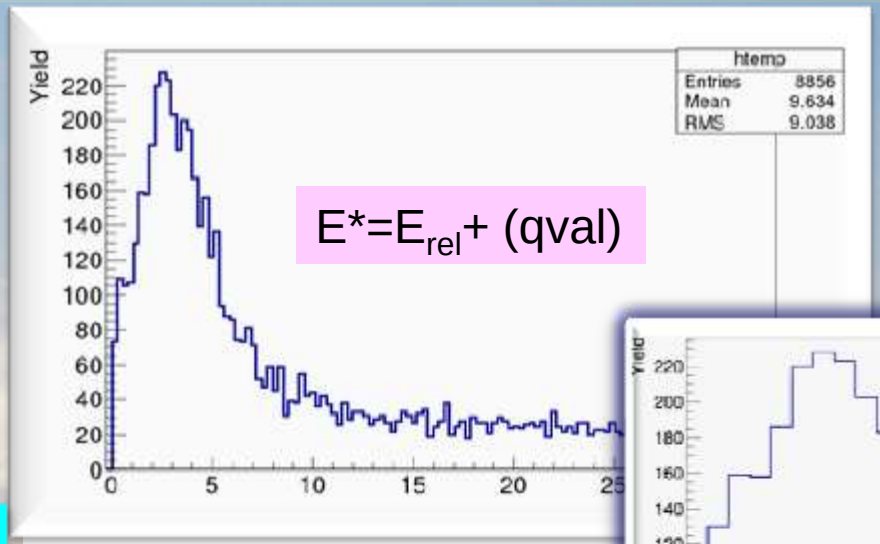
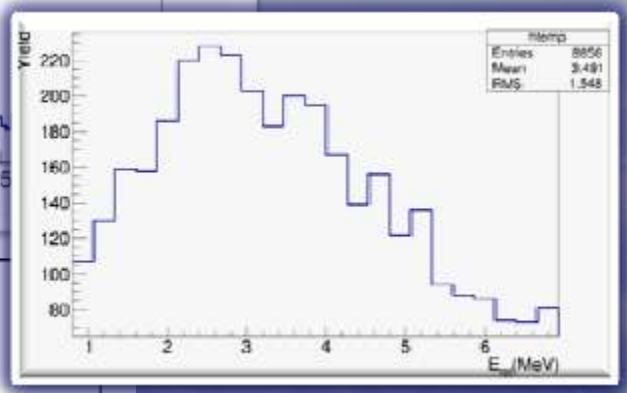
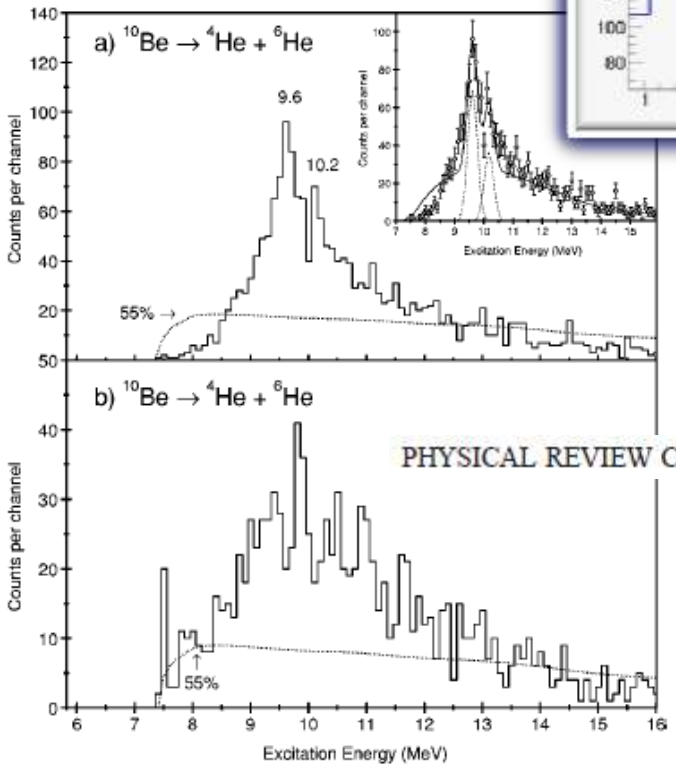
Not only transfer: Break-up at 56 MeV/A







We are doing a check with published data measured around 30 MeV/A to verify calibrations and efficiency



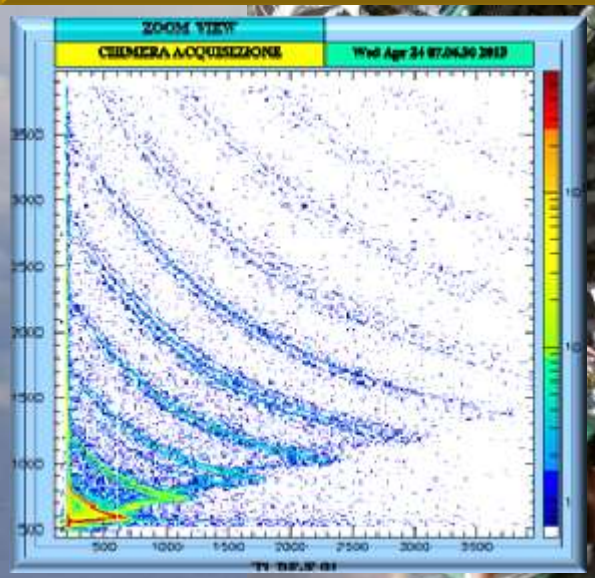
PHYSICAL REVIEW C 69, 024303 (2004)

A new dedicated experiment with more complete angular coverage and better resolution to look for such exotic states in ^{10}Be but also in ^{16}C and all the other beams produced will be performed at the end of this year

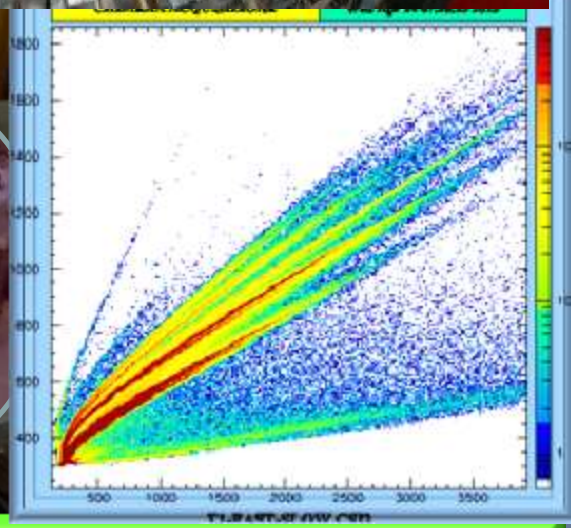
Next measurements : FARCOS prototye as forward angle spectrometer

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



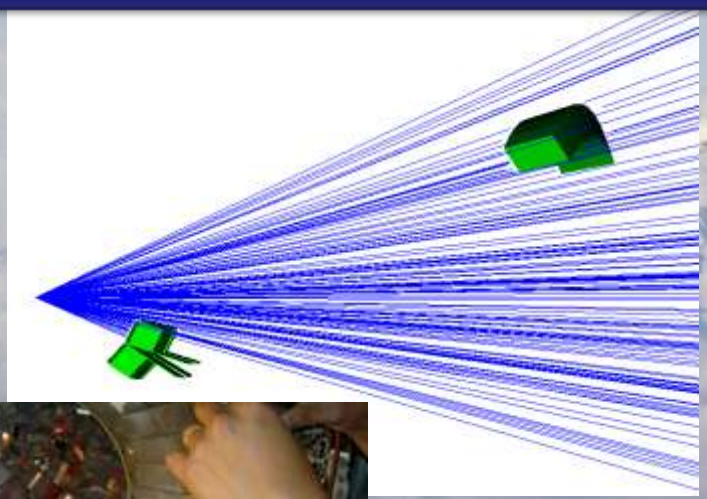
First test stand-alone July - 2012

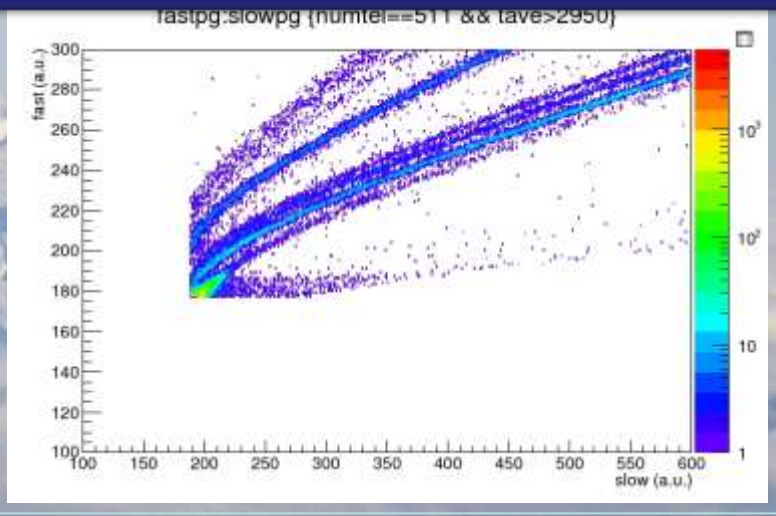


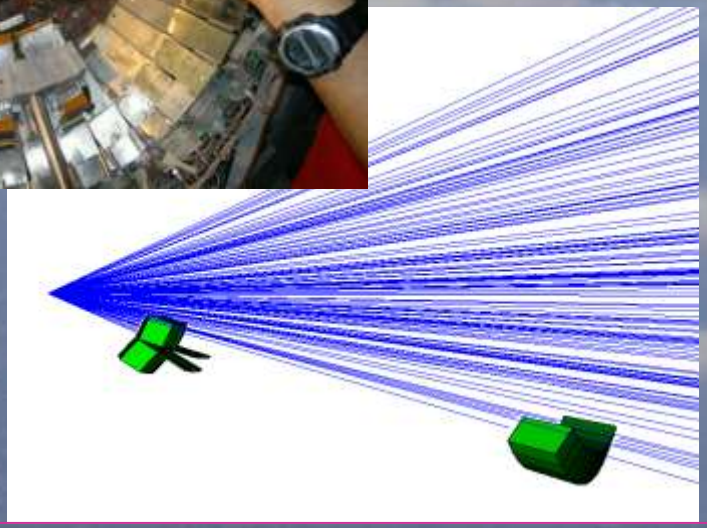
- **Improved CsI(Tl) energy resolution due to corrections for the particle detection position**
- **Improved energy calibrations/resolution also due to the two stages of silicon detectors**
- **Improved θ/ϕ granularity and isotopic identification**

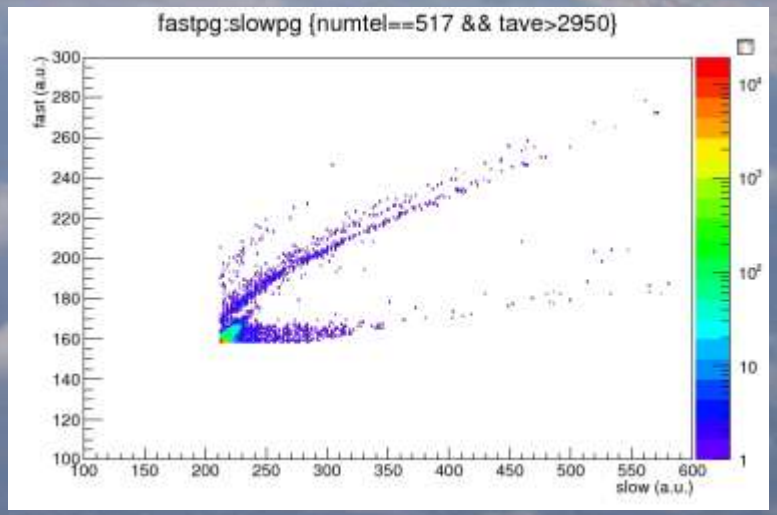
CHIMERA & Neutrons

Experiment **INKIISSY** @LNS: $^{124}Xe+^{64}Zn$@35AMeV
Some of the CHIMERA RINGS were covered by FARCOS – in such telescopes we can identify neutrons trough the particles produced in CsI









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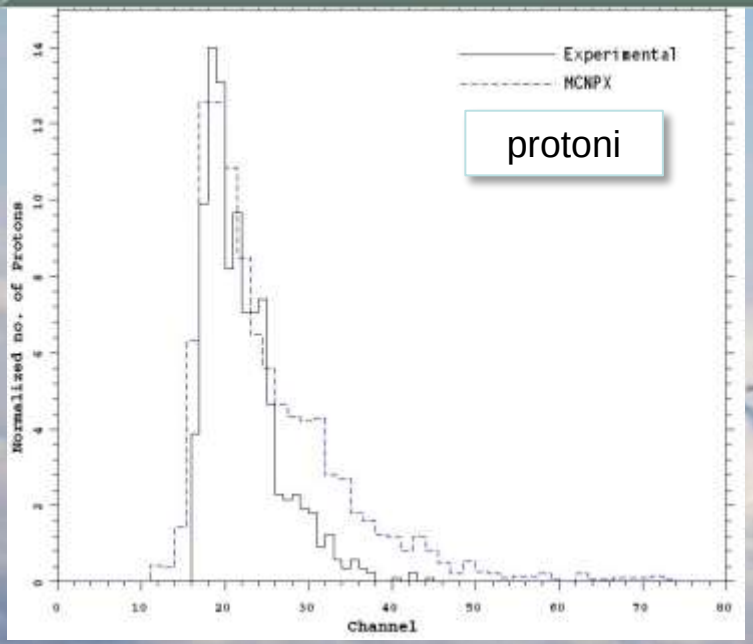
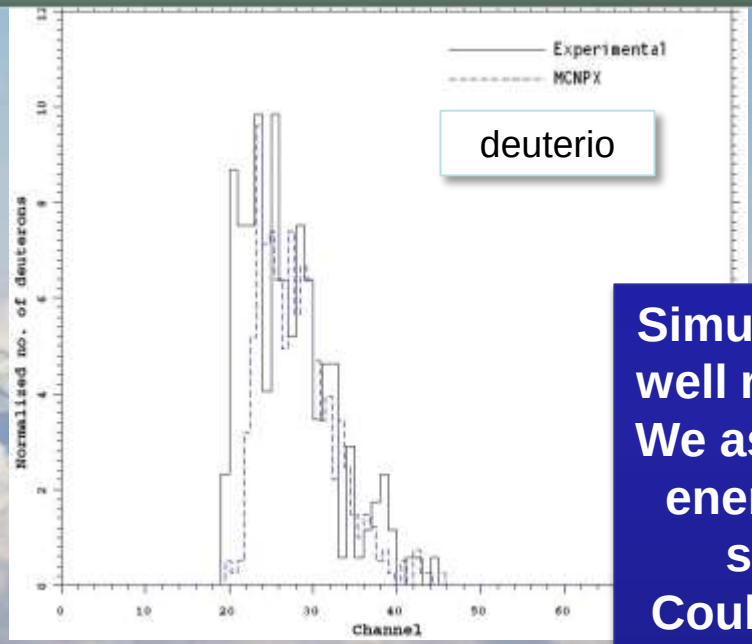
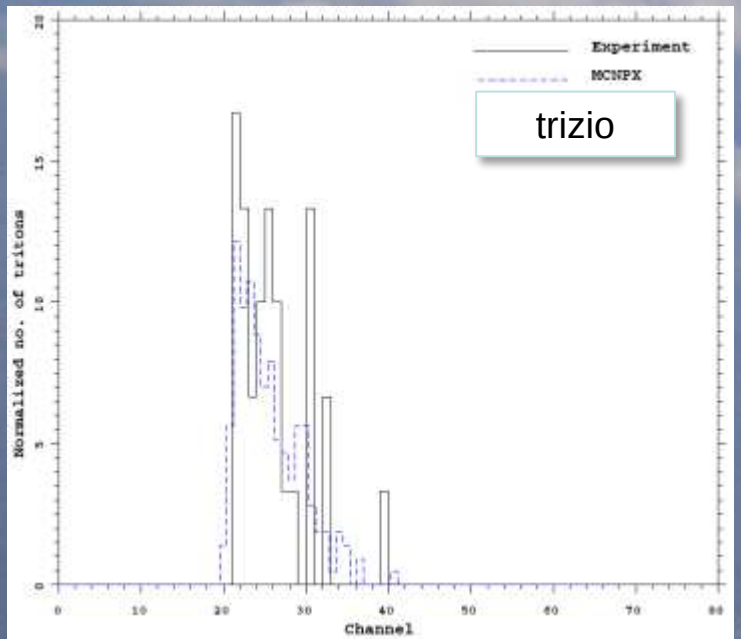
CHIMERA & Neutrons

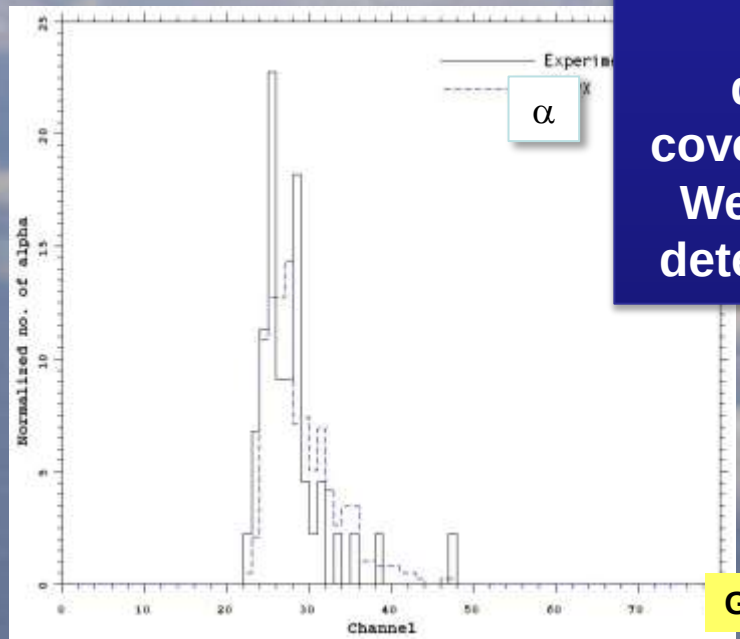




Tel. n. 517

Simulations relatively well reproduce data - We assume a neutron energy distribution similar (apart Coulomb effects) to the one of proton measured in detectors not covered by FARCOS We are evaluating detection efficiency





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Conclusions and perspectives

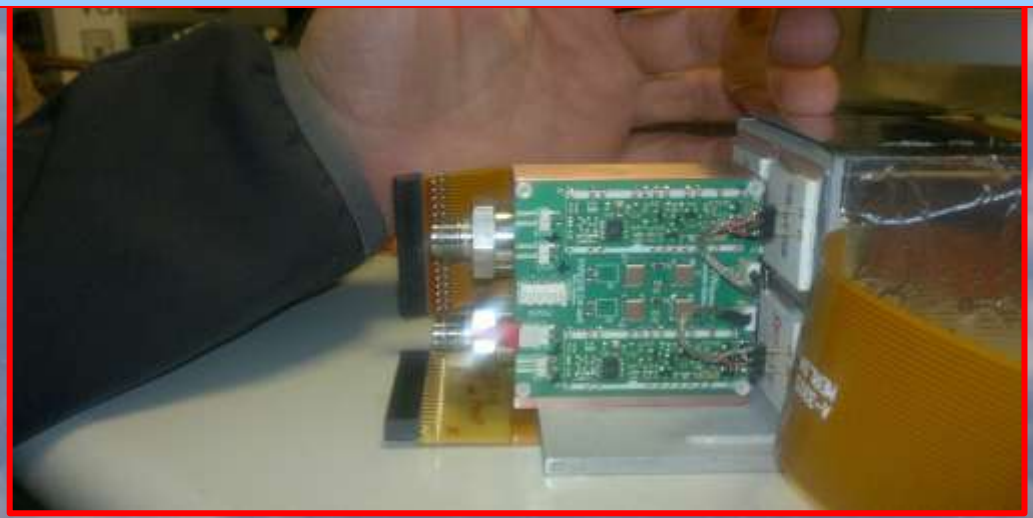
Using cocktail of neutron rich beams with the CHIMERA detector we are able to extract angular distributions for many reaction channels searching for structure effects on cross sections

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

We can also measure and identify γ-rays and neutrons with our CsI(Tl) detectors in order to tag excited levels or particular decay channels

Break-up reactions can be also very well seen

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



I wish to thank all my collaborators

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