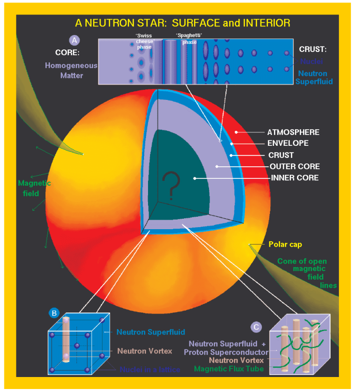
Giant resonances in exotic nuclei

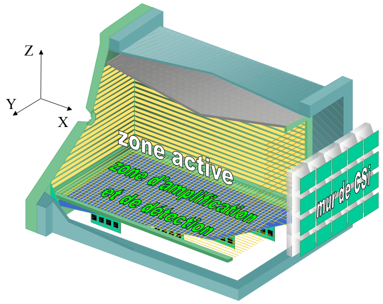


1) Superfluidity and incompressibility

E. Khan, PRC**80**(2009)011307(R) & 057302

2) Measurement of the GMR in unstable nuclei

C. Monrozeau *et al.*, PRL**100**(2008)042501



3) Physics with ACTAR

QuickTime™ and a decompressor are needed to see this picture.

E. Khan
Institut de Physique Nucléaire
IPN Orsay

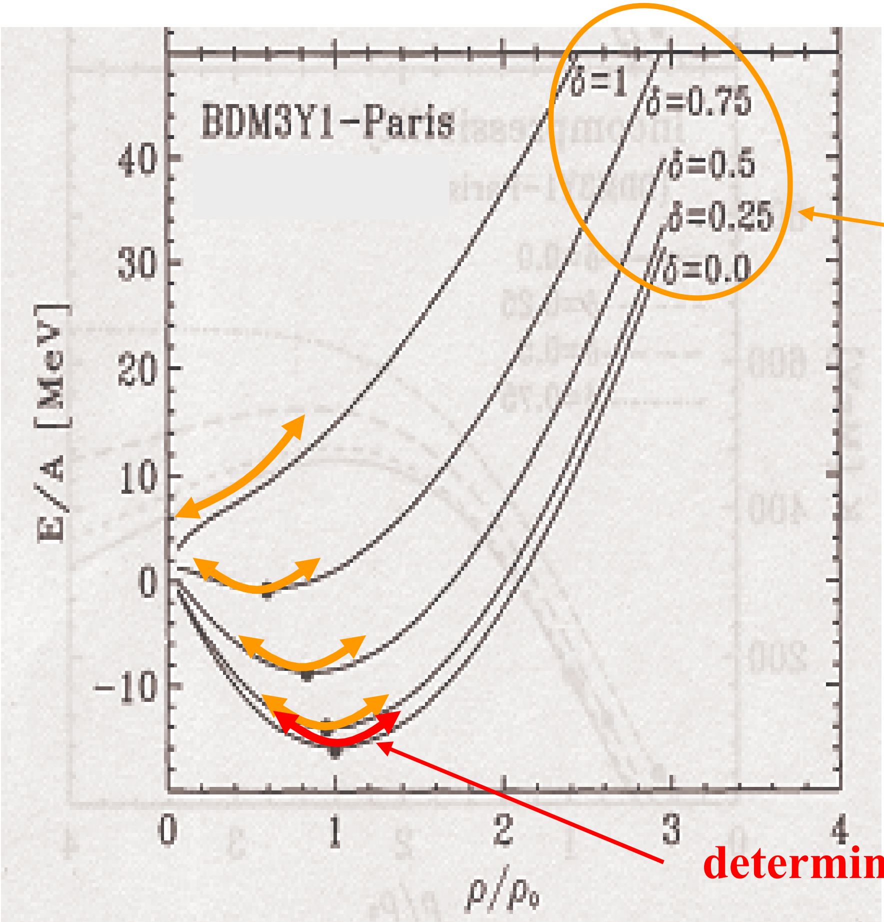
1) Superfluidity and incompressibility

The isospin dependence of the incompressibility modulus

$$E(\rho,\delta) = E(\rho,0) + a_{sym}(\rho)\delta^2$$

: **density** and **neutron excess**

$$\delta = \frac{N-Z}{A}$$



D.T.Khoa *et al.* Nucl. Phys. **A602** (1996) 98

evolution of incompressibility with asymmetry:

$$K(\delta) \hat{=} \frac{1}{2}\frac{\partial^2 E(\rho,\delta)}{\partial \rho^2}\bigg|_{\rho=\rho_0}$$

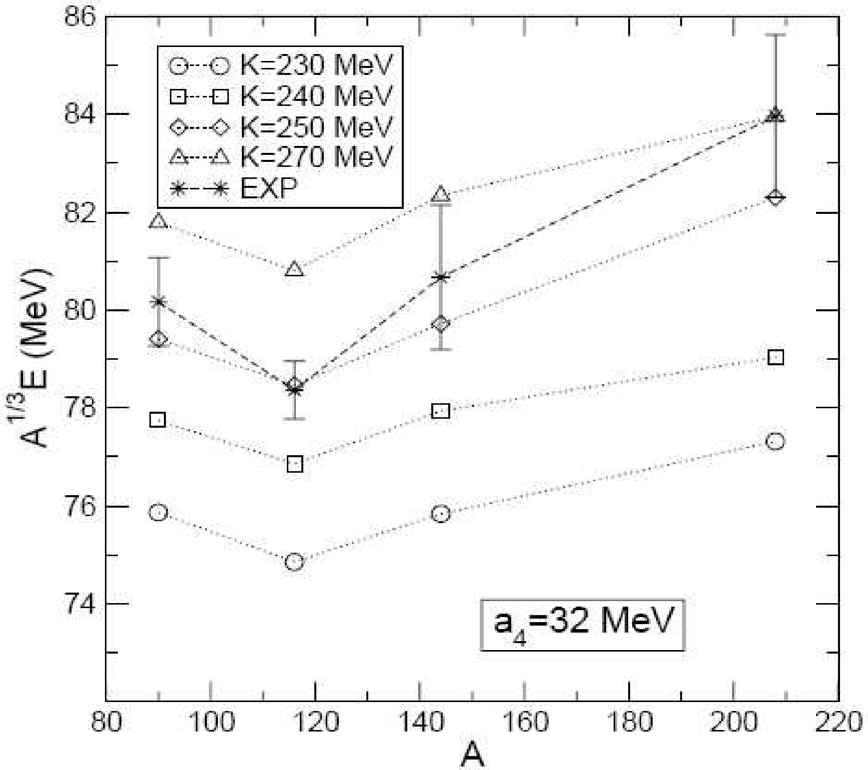
$$K(\delta) = K_\infty + K_{sym}\delta^2$$

$$K_{sym} = \frac{1}{4}\frac{\partial^4 E(\rho,\delta)}{\partial \rho^2 \partial \delta^2}\bigg|_{\rho=\rho_0,\delta=0}$$

determination of K_∞

Determination of K_∞

- **Microscopic method**: prediction of the GMR centroid
- Constrained-HF : K_∞ ~ **235 MeV** with ^{208}Pb but K_∞ ~ **220 MeV** with ^{90}Zr (softer)
- Relativistic approaches : K_∞ ~ **260 MeV**



D. Vretenar et al, PRC**68**(2003)024310

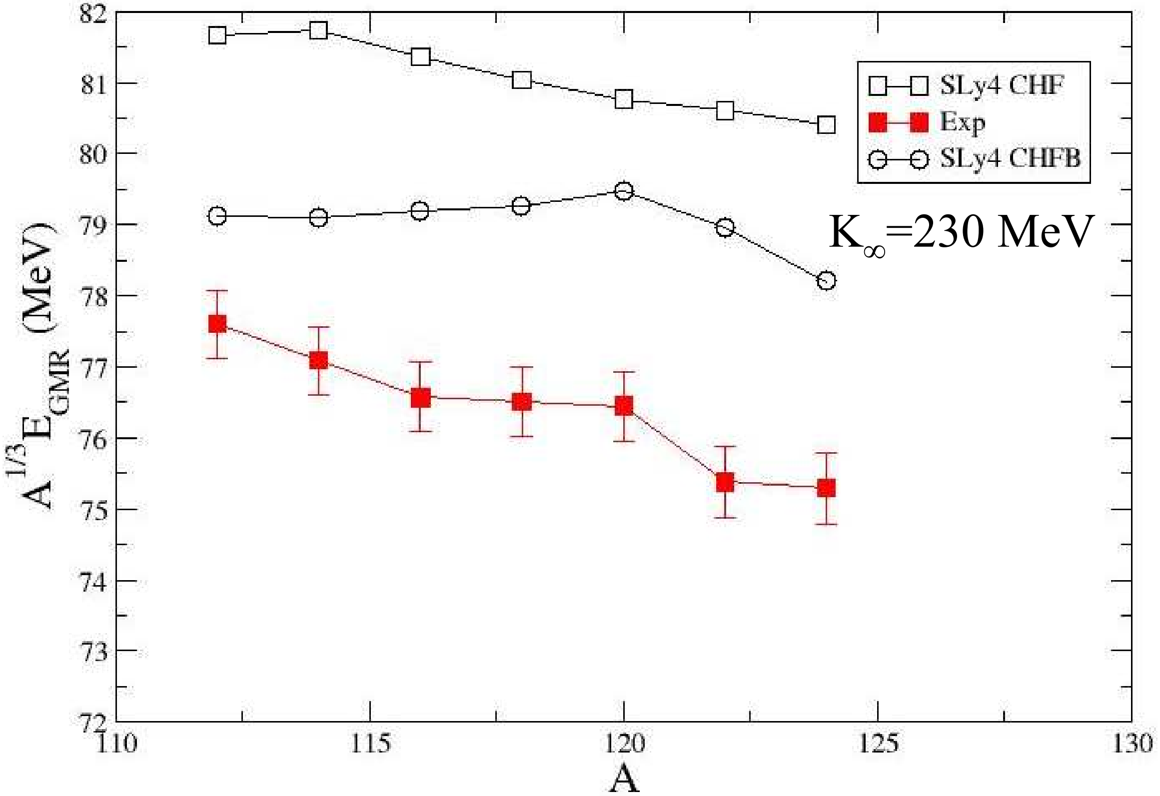
⇒ **Cannot extract separately K_∞, Ksym and the density dependence of the functional**
(G. Colo et al, PRC**70**(2004)024307)

⇒ **Use SEVERAL experimental constraints**

The GMR on isotopic chain

•Recent measurement of the GMR in stable Sn isotopic chain (T. Li et al., PRL**99**(2007)162503)

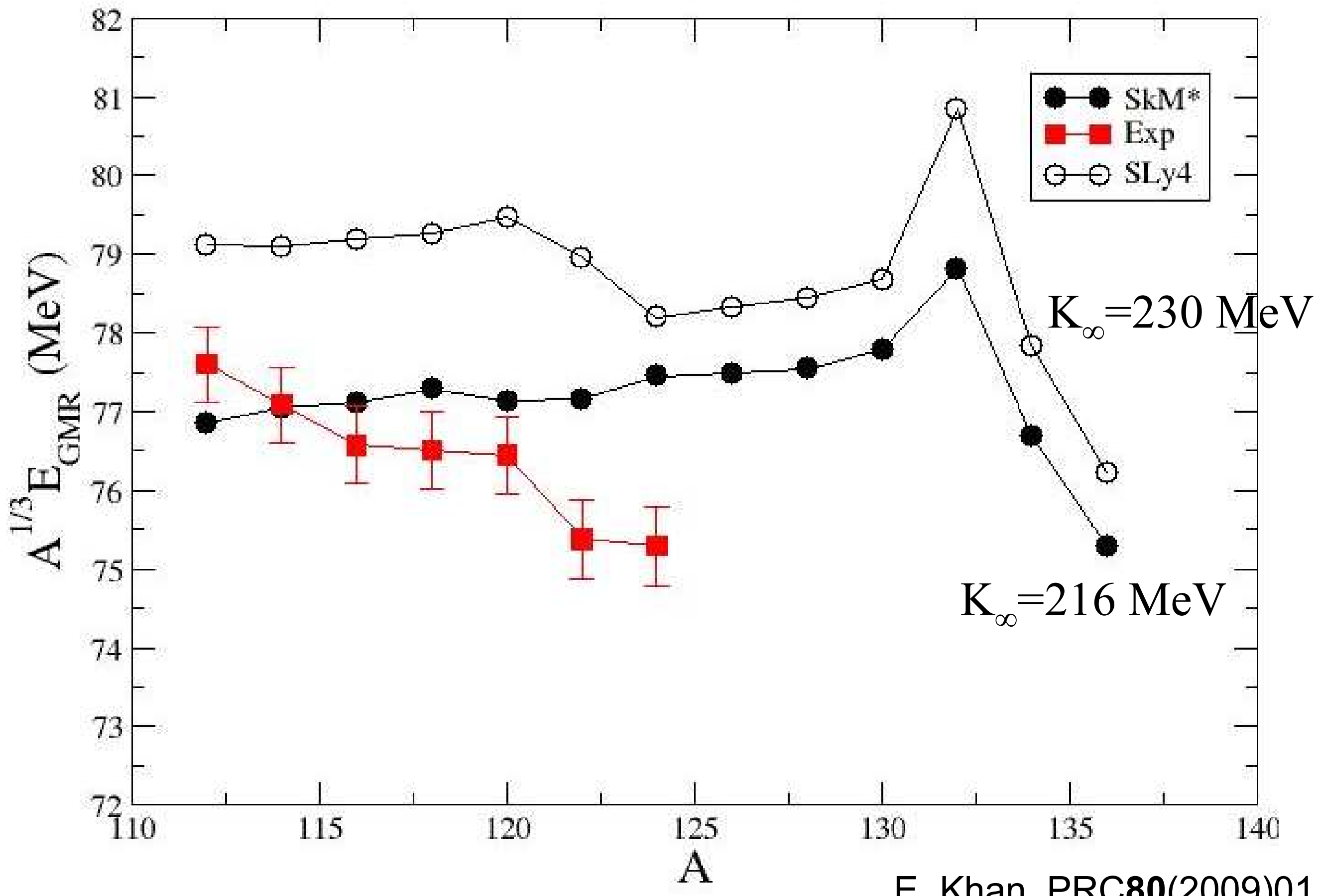
•K_∞ ~ **210 MeV** < Pb : ***Why tin are so soft ?***



• Pairing may explain part of this softness (J. Li et al., PRC**78**(2008)064304)
• Interpretation : nuclear incompressibility comes from the second derivative of the energy functionnal (~Vres)

Shell effects on the GMR

•Pairing ⇒ shell effects on the GMR value
•Doubly magic nucleus : increase of the GMR



E. Khan, PRC**80**(2009)011307(R)

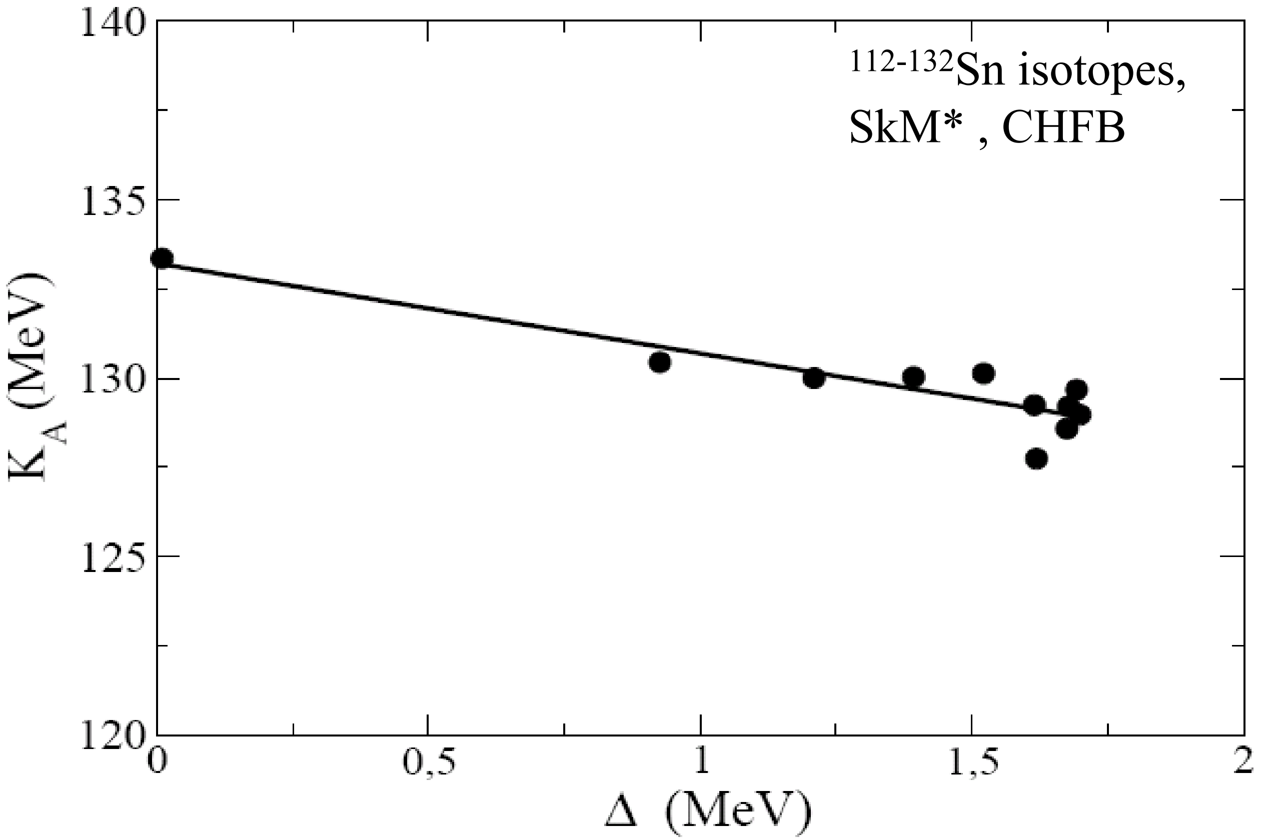
• Doubly magic nucleus : **specific** increase of the GMR

Similar effect with Pb isotopes

QuickTime™ and a
decompressor
are needed to see this picture.

E. Khan, PRC**80**(2009)057302

Nuclear incompressibility vs. pairing



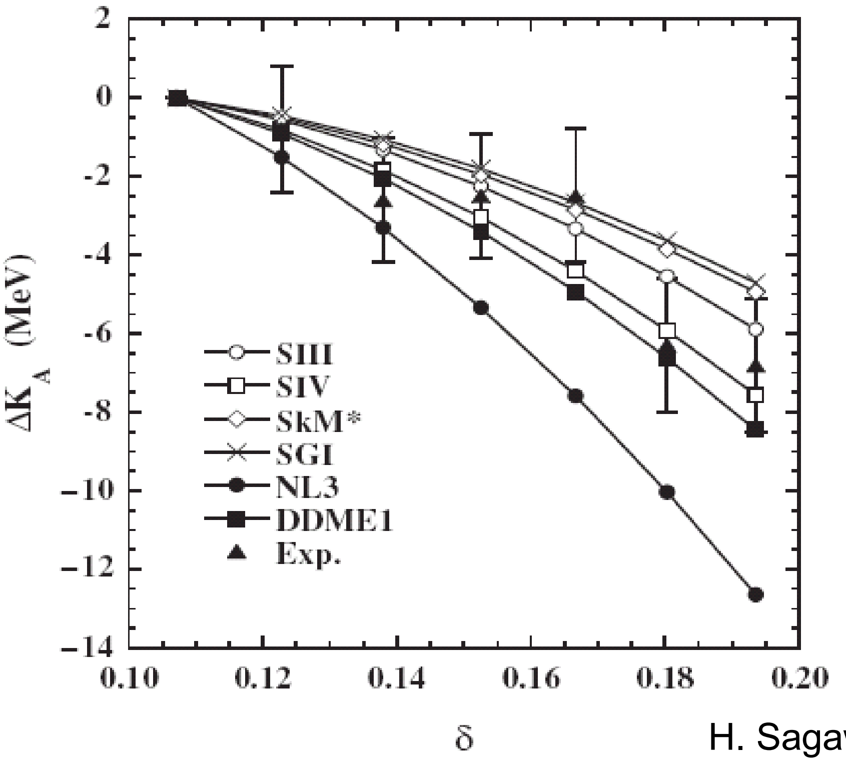
• Cooper pairs favor compressibility

•Incompressibility of **superfluid** nuclear matter: $\mathbf{K_\infty(\Delta)}$?

Macroscopic formula for K_{sym} ?

• Macroscopic formula of K_A (Blaizot) is not adapted because it misses shell effect in the GMR : second derivative of volume, surface and asymmetry terms of LD.

• Shell effect ~ **800 keV on GMR ⇒ ~ 10 MeV on K_A**



H. Sagawa et al., PRC**76**(2007)034327

• Use **only microscopic method both for K_∞ and K_{sym}**

• Or extend the demonstration of Blaizot (not only to leptodermous expansion)

• Cannot extract **only** K_{sym} from an analysis on an isotopic chain.

Conclusions of part 1)

- Tin are so soft because … **^{208}Pb is doubly magic (so stiff) !**
- Difficult to reproduce EGMR both on doubly magic and other nuclei : role of pairing
- Other effects : **mutually enhanced magicity** (MEM) ? Large neutron skin ?

- **Interpretation**: K_A is the second derivative of the energy functional

- Effect especially on low ρ nuclear matter ⟶ large neutron skin

- **Needs for several measurements (isotopic chain)** because we cannot disentangle between the K_∞, K_{sym} and density dependence effects on the GMR.

- Importance to follow up the Sn chain, especially until doubly magic **^{132}Sn**

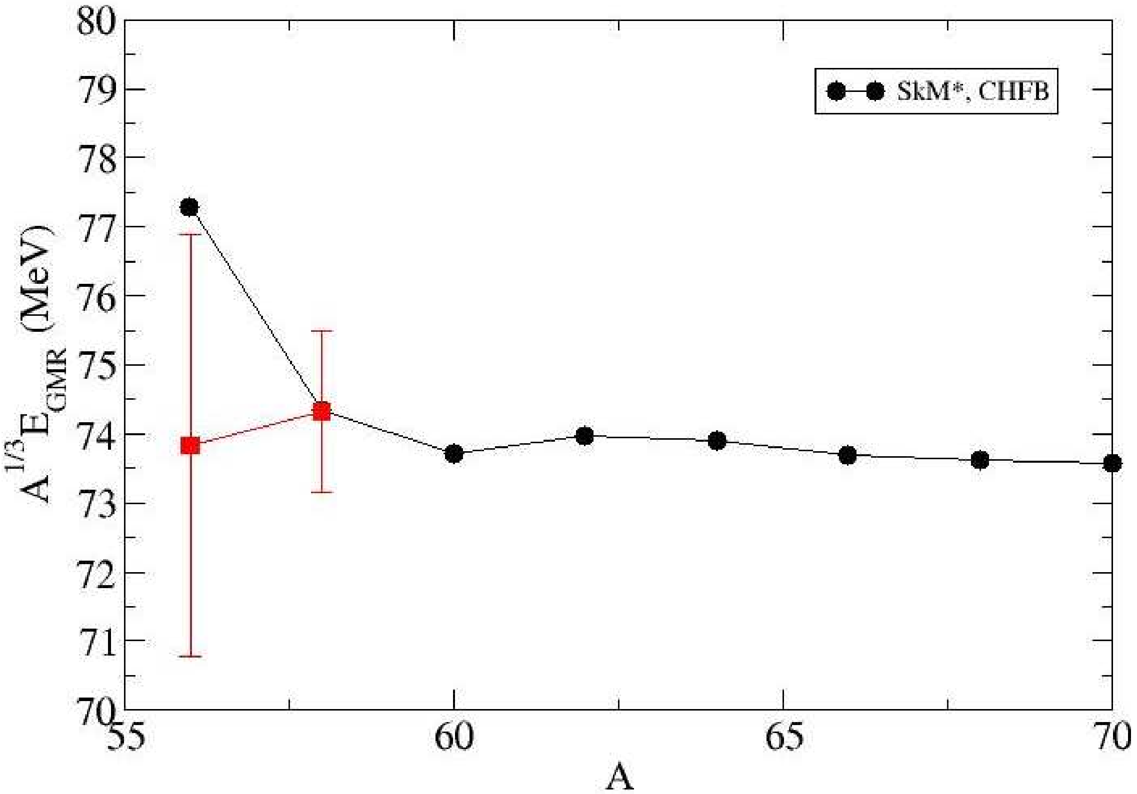
- GMR measurements requested on **Pb isotopic chain** (unstable nuclei)

- Use **only microscopic method both for K_∞ and K_{sym}**

2) Measurement of the GMR in unstable nuclei

Measurement of the GMR in exotic nuclei

- First measurement performed on unstable nucleus: ^{56}Ni
- N=Z=28 nucleus: no K_{svm}, no pairing

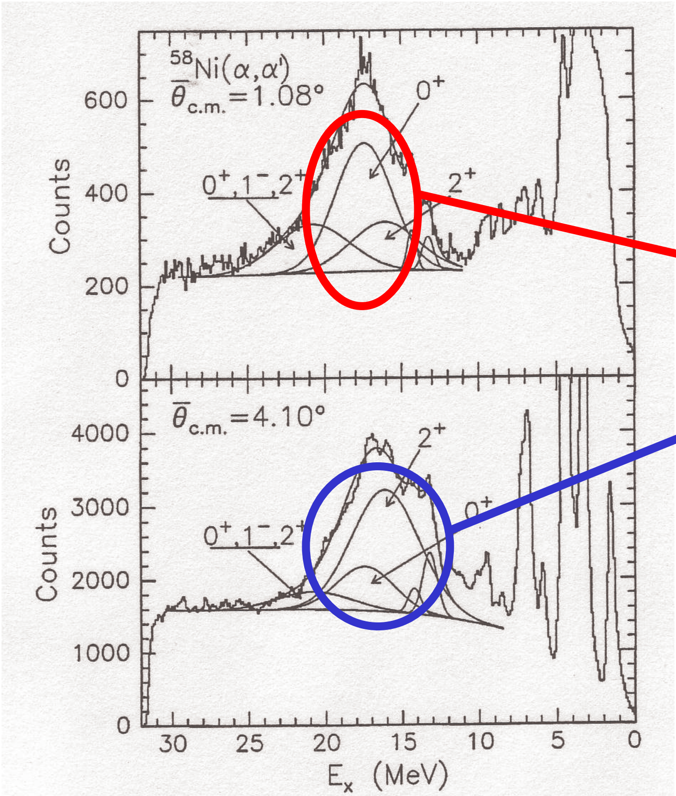


- Enhance the accuracy of the GMR measurement in unstable nuclei

Experimental probes for isoscalar giant resonances

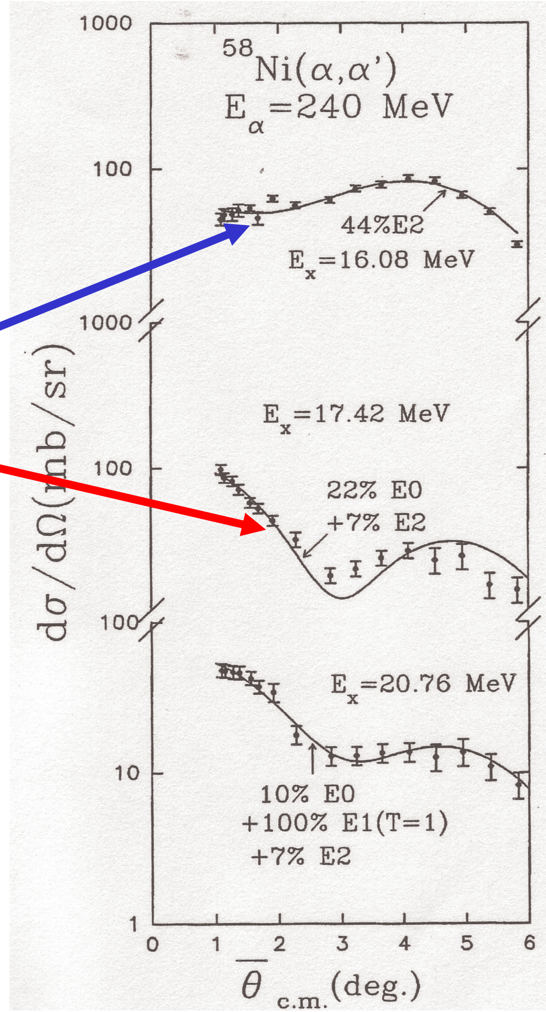
Inelastic scattering : (d,d’) (α,α’) @ E ≥ 25 A.MeV

^{58}Ni (α,α’) E_α=240 MeV



GMR

GQR



GR in ^{58}Ni : analysis mixing 0^+ and 2^+

D.H. Youngblood *et al*, PRL**76**(1996)1429

GMR in unstable nuclei: a specific method

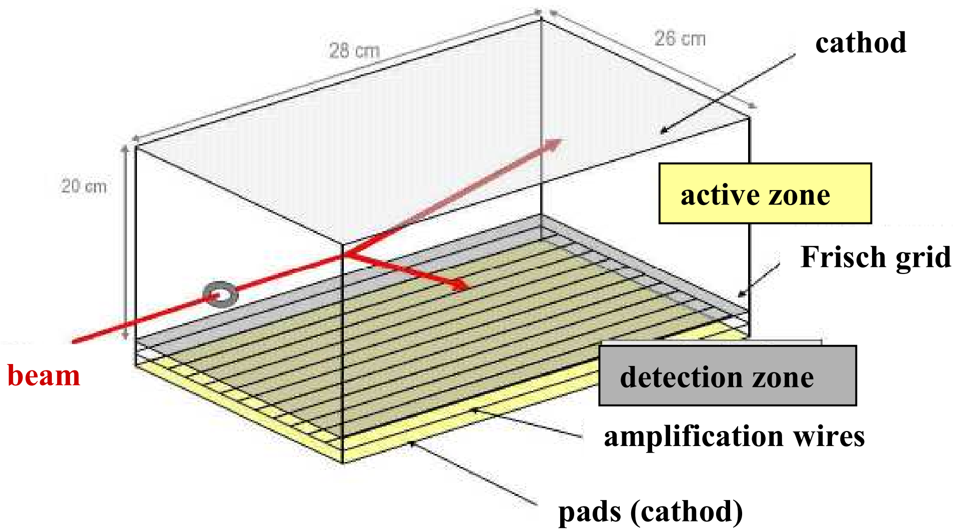
unstable nuclei → reverse kinematics → low energy threshold, thin target, large solid angular coverage

unstable nuclei → low intensity beam → good detection efficiency, thick target

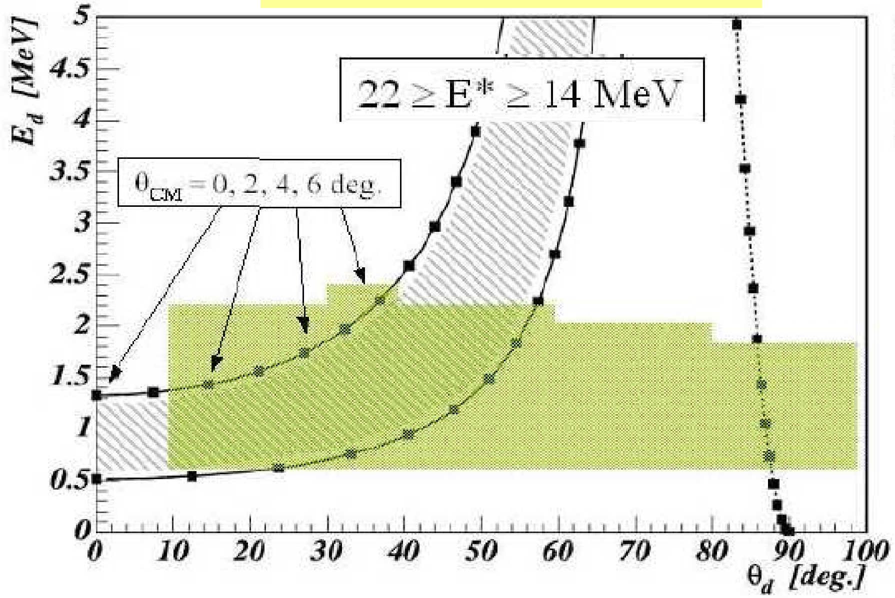
Active target = target + detector

target → deuterium gas : 1,6 mg/cm^2 (6,3 mg/cm^2 CD2)

detector → Time and Charge Projection Chamber



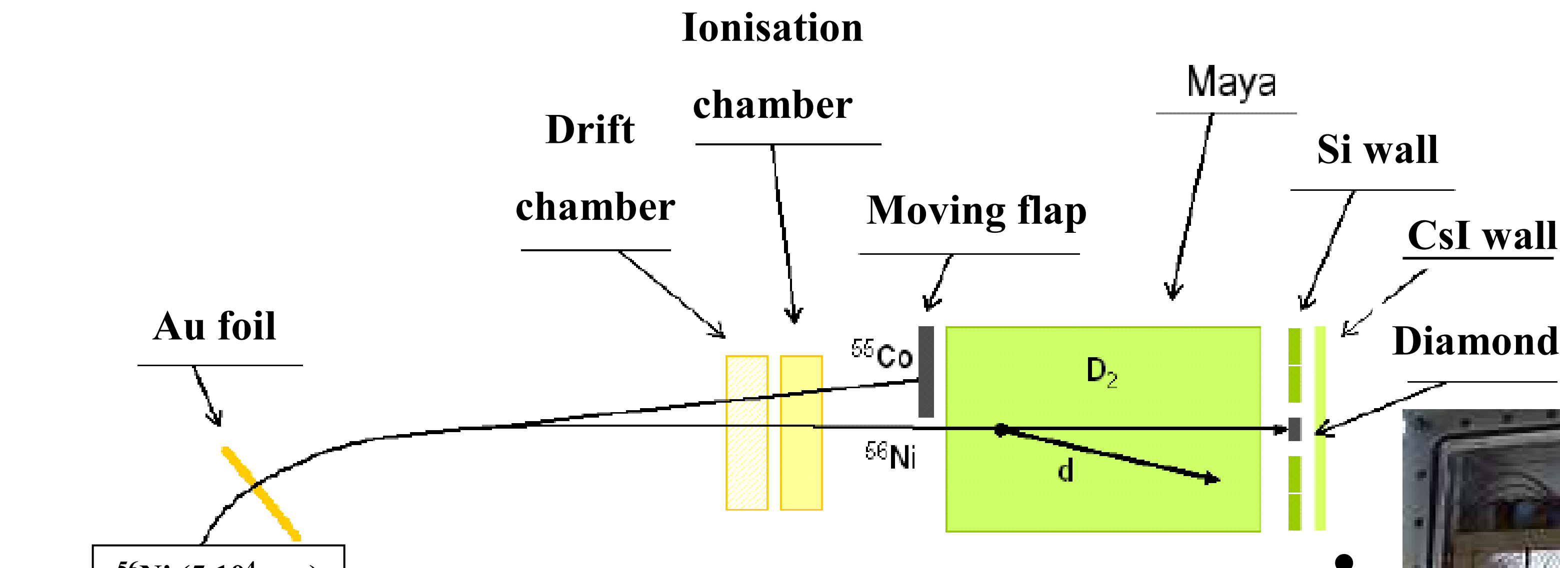
deuteron kinematics
^{56}Ni(d,d') @ 50 MeV/A

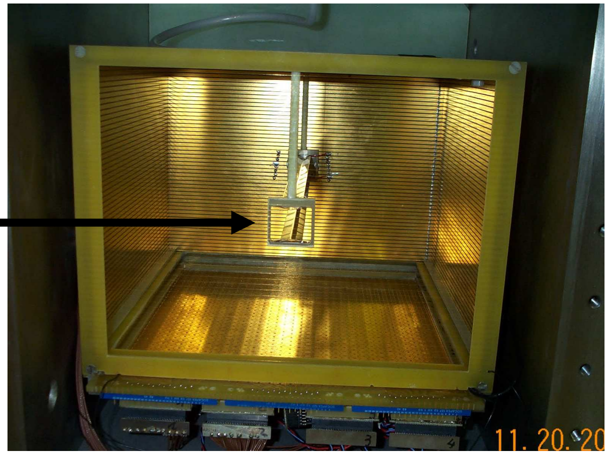


Experimental setup

^{56}Ni @ 50 MeV/A (GANIL - SISSI)

5.10^4 pps

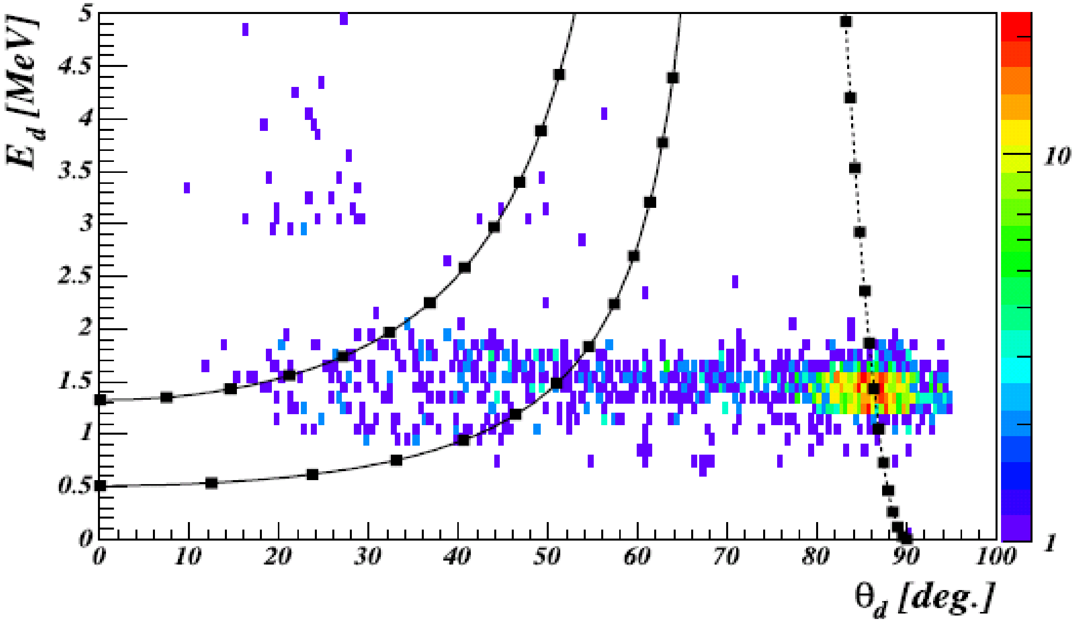




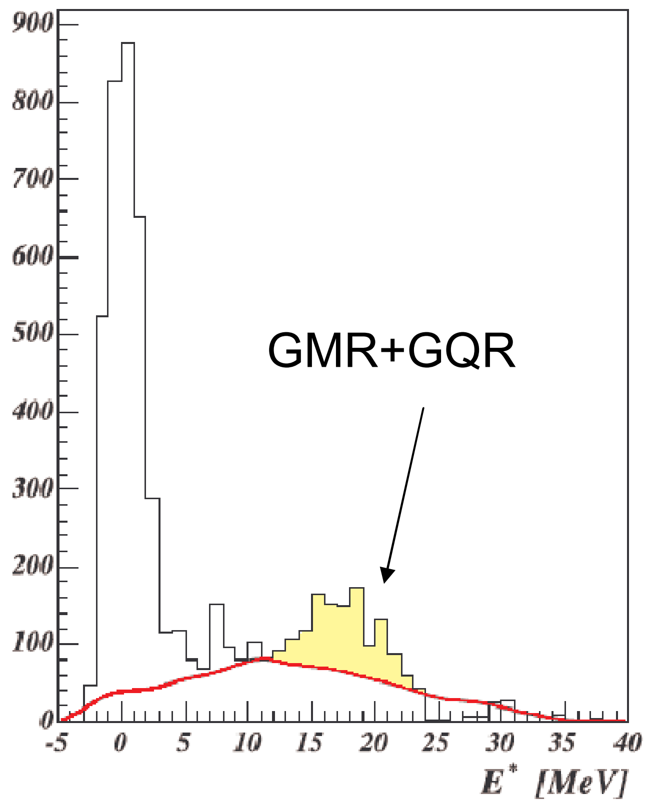
MAYA

Results

recoiling d kinematics

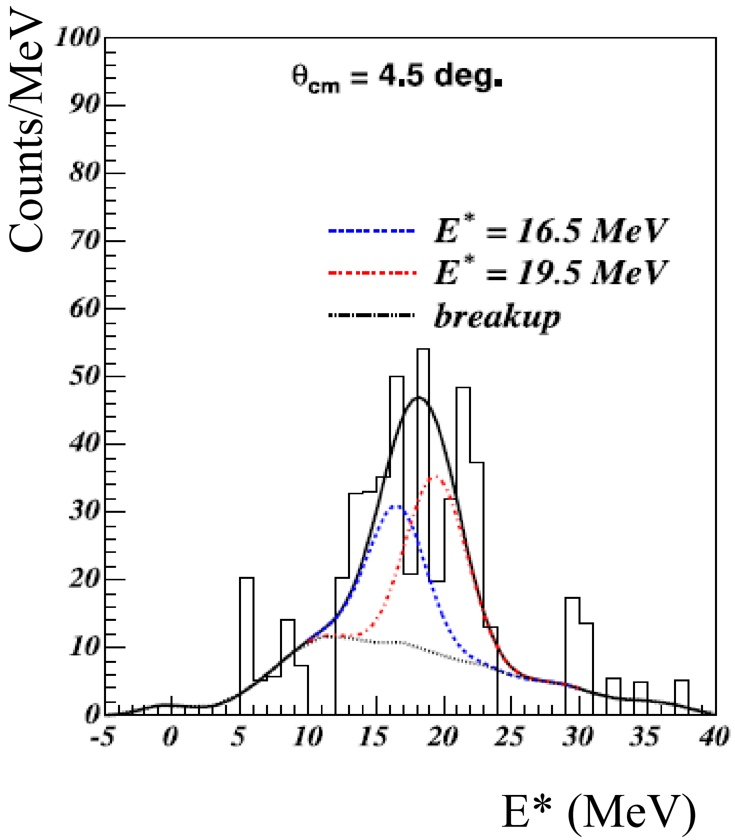


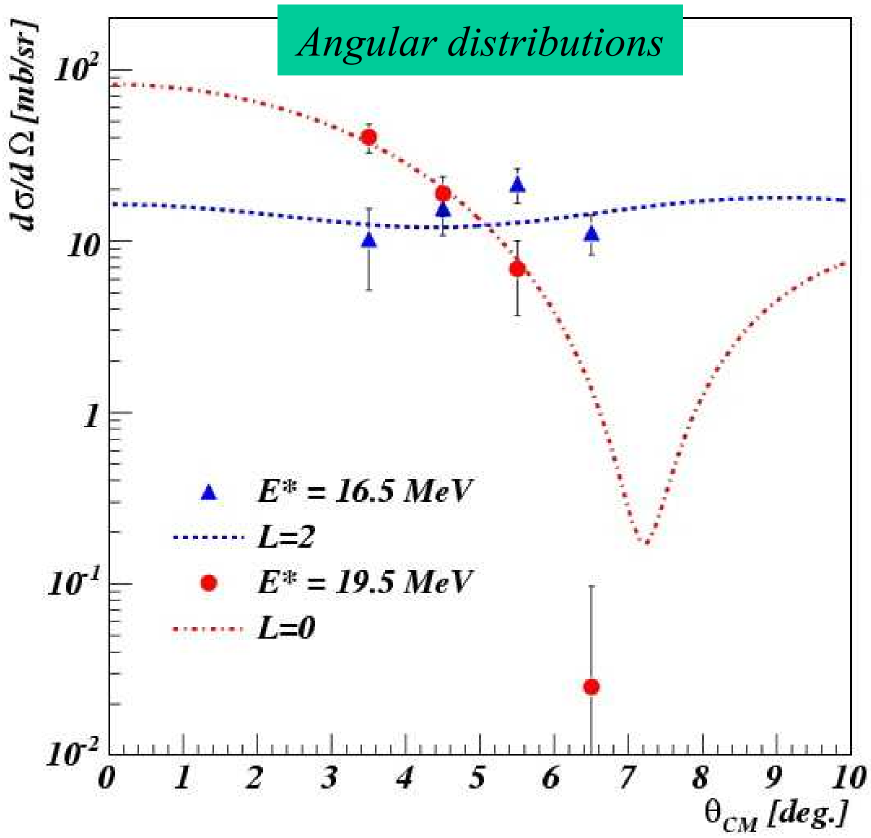
^{56}Ni excitation energy spectrum



C. Monrozeau *et al.*, PRL**100**(2008)042501

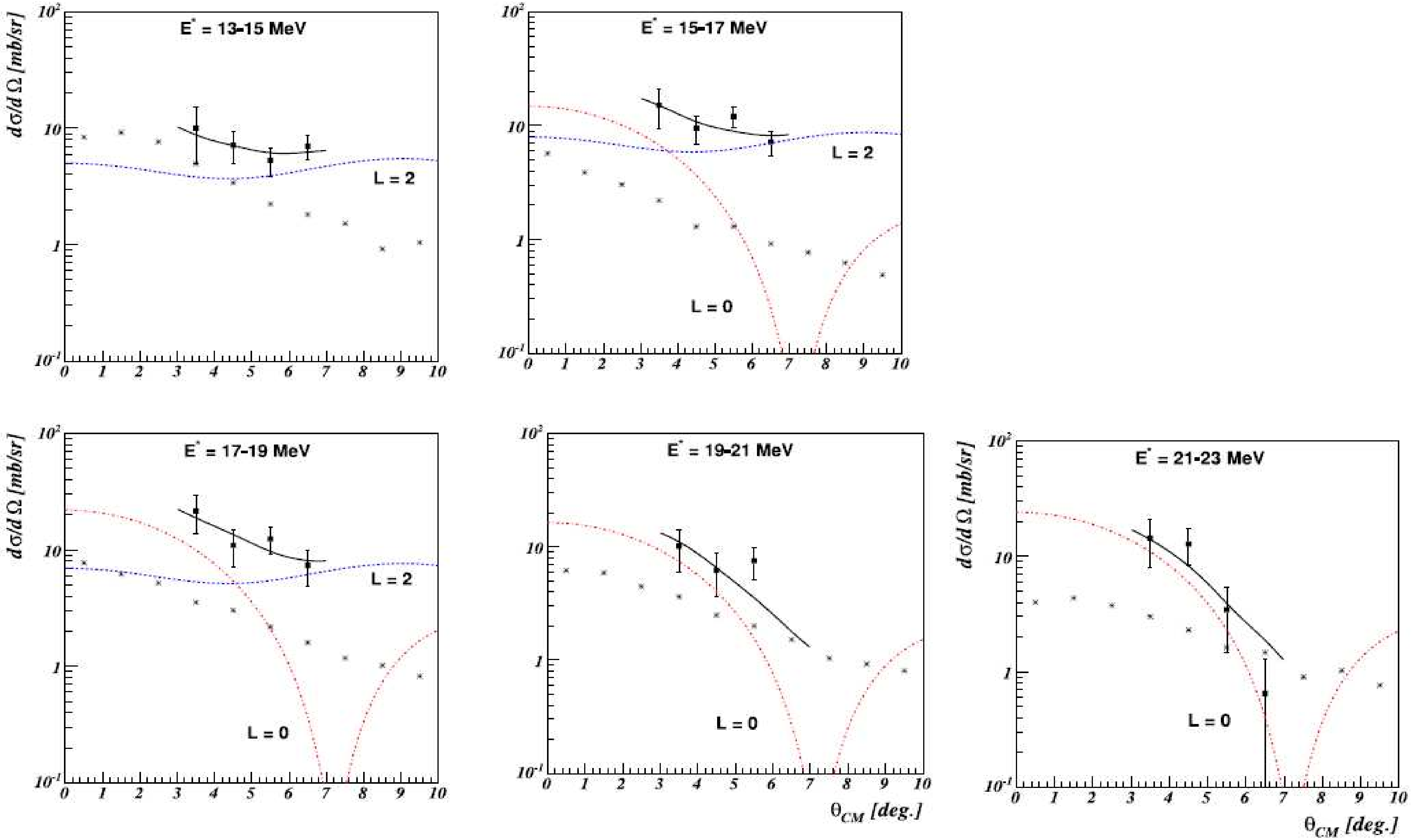
Analysis with gaussian fit





Reaction : DWBA with double folding using HF and RPA ^{56}Ni gs and transition densities

Multipole Decomposition Analysis



MDA	m_1/m_0 [MeV]	rms [MeV]	% EWSR
L=0	19.3	2.3	136 ± 27
L=2	16.2	1.7	76 ± 13

Conclusions of part 2)

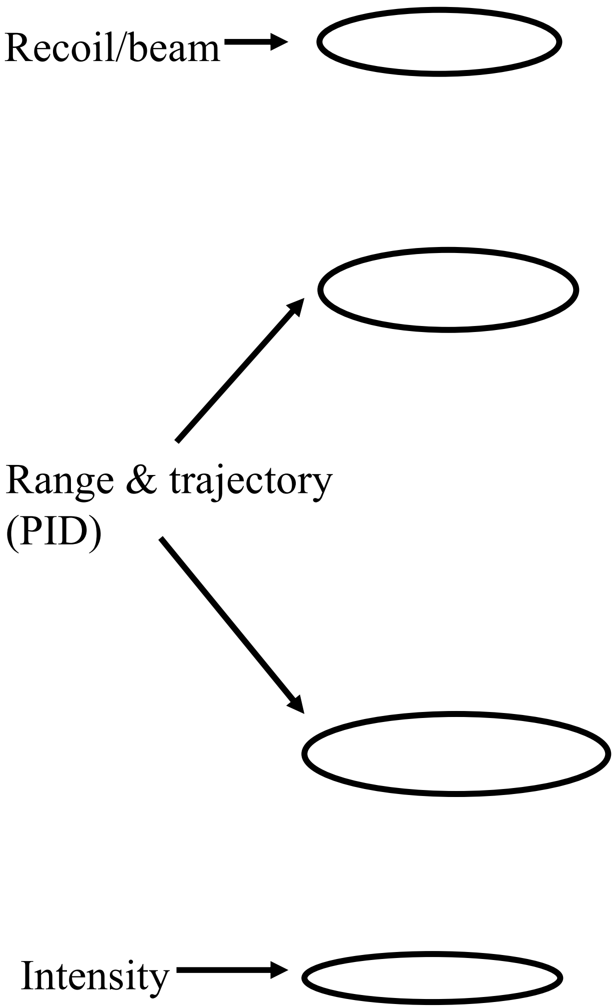
- It is possible to measure IS giant resonances in unstable nuclei
- Use of MAYA active target with d gas
- Isoscalar **GMR** and **GQR** measured in the ^{56}Ni **unstable** nucleus
- 16 h of 10^4 pps beam

- Improvements : identification & d breakup, reaction model, amplification, accuracy (resolution on range, …)
- **Next** : neutron-rich Ni isotopes (**^{68}Ni at GANIL**): $\delta = 0$ to 0.18
- **^{132}Sn, Pb isotopic chain**

3) Physics with ACTAR

- Low I
- Low E
- TPC

ACTAR critical points



QuickTime™ and a
decompressor
are needed to see this picture.

- **Amplification** (Micromegas/GEM)
- **Electronics** (ASIC-GET)
- **Total vs pads size** (Money ?)

1) Low I : very exotic nuclei

• Drip line and beyond nuclei

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

M. Caamano *et al*., PRL**99**(2008)062502

2) Low E : GMR

- Low energy recoil

QuickTime™ and a
decompressor
are needed to see this picture.

+ Spectrometer

- One of the first ACTAR experiment ?
- Dynamics : beam shield, gain adaptation below the beam : heaviest nuclei possible ?
  (p/Zr) OK but (p/Pb) more difficult. Goal : Sn

3) TPC : Decay & Clusters

3) TPC : **Resonances, decay** (2p, …), **cluster structure**

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

K. Miernik *et al*., PRL**99**(2007)192501

Summary & outlooks

• Measure the GMR on an isotopic chain to extract K_∞, K_{sym} and density dependence

•Isoscalar **GMR** and **GQR** measured in the ^{56}Ni **unstable** nucleus with MAYA

•**ACTAR** first experiment : GMR in exotic nuclei (^{132}Sn) ?
•Amplification (dynamic), electronics, size ?

•**Low I** : nuclei closer to the drip line
•**Low E** : GMR
•**TPC** : decay and clusters