K_∞ and K_τ from the Giant Monopole Resonance

Me2-Rex

U-REX

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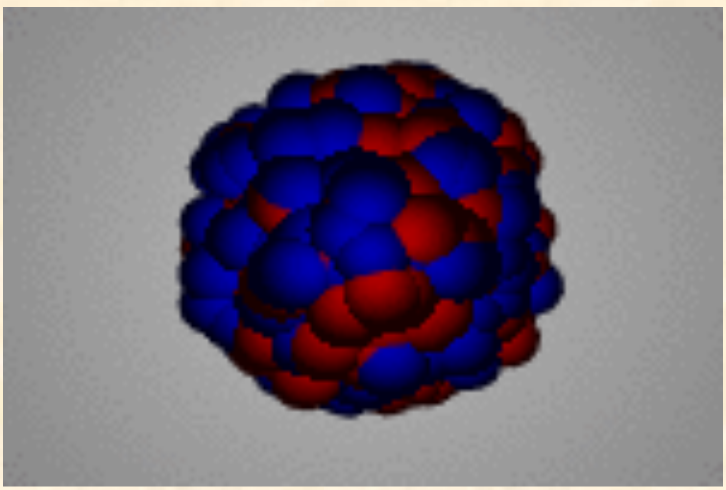
The Compressional Mode Giant Resonances

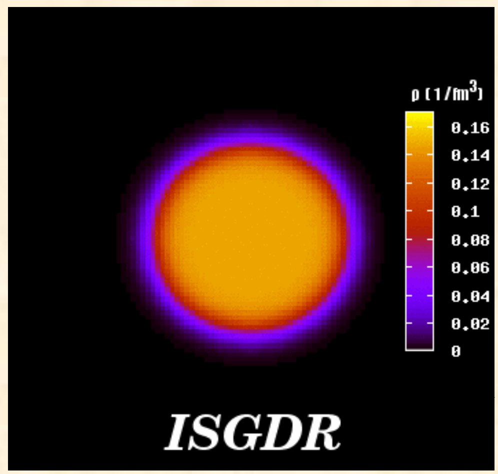
GMR	ISGDR
l = 0	l = 1



"Breathing Mode"

$$\sum r_i^2$$

$$2\hbar\omega$$



"Squeezing Mode"

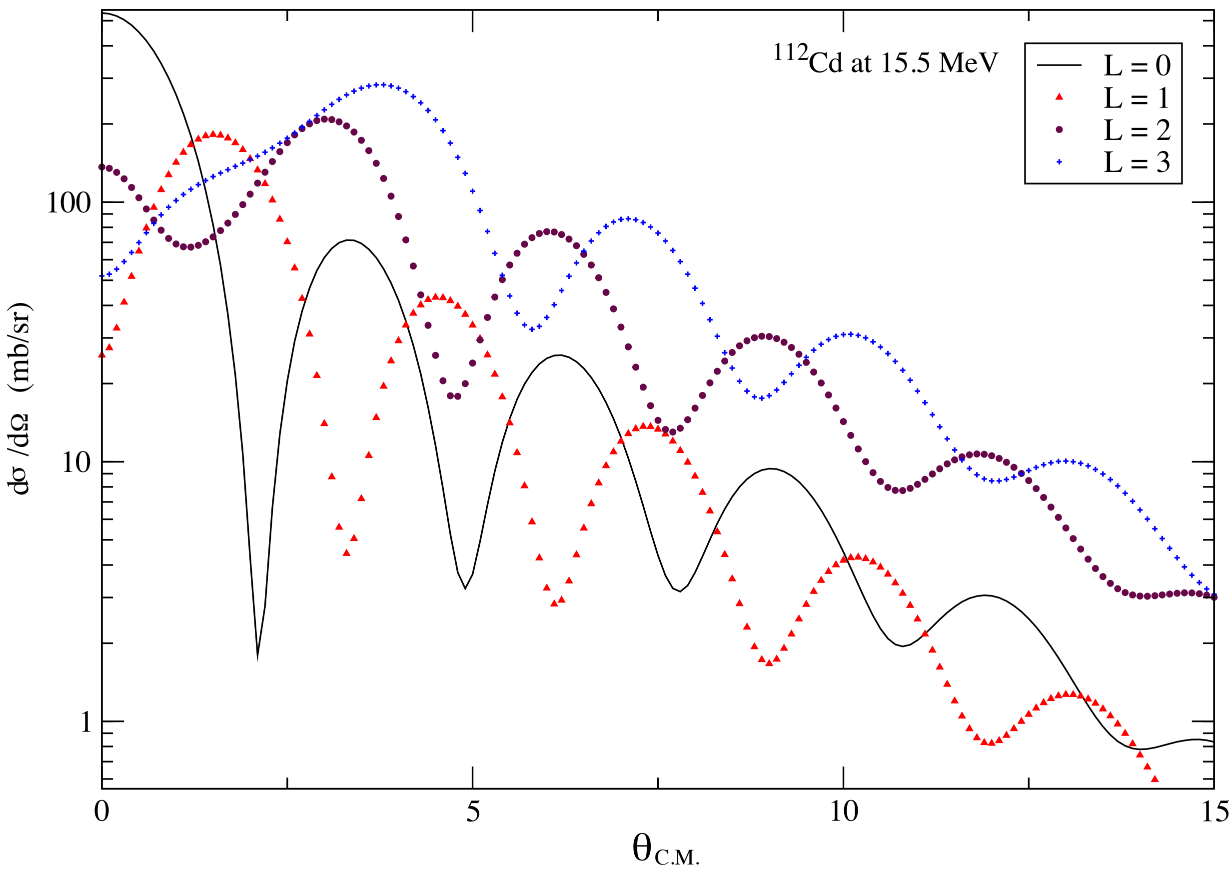
$$\sum r_i^3 Y_1$$

$$3\hbar\omega$$

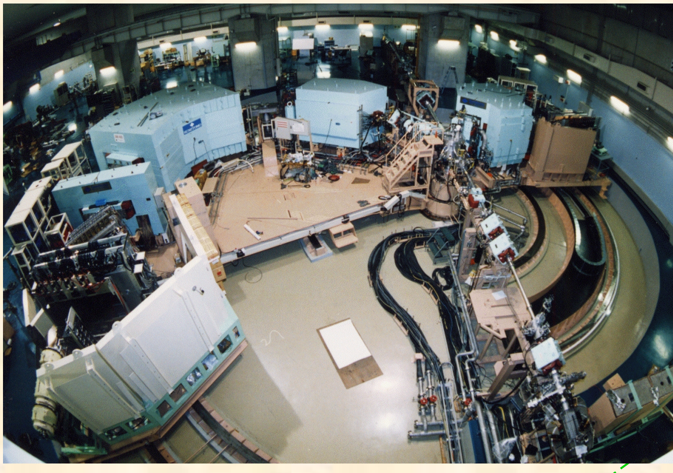
The energies of both these resonances are directly related to Nuclear Incompressibility.

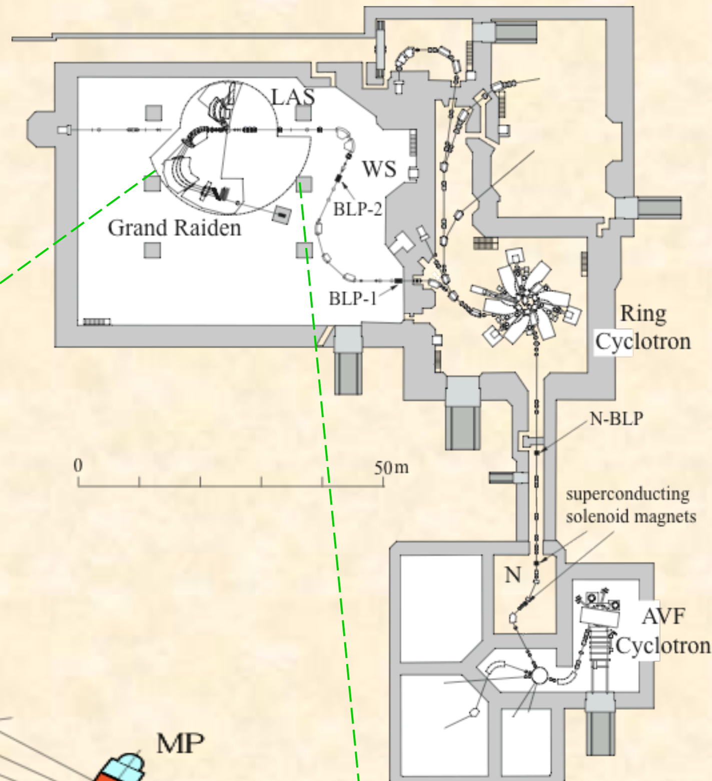
$$E_{GMR} = \hbar\sqrt{\frac{K_A}{m\langle r^2\rangle}}$$

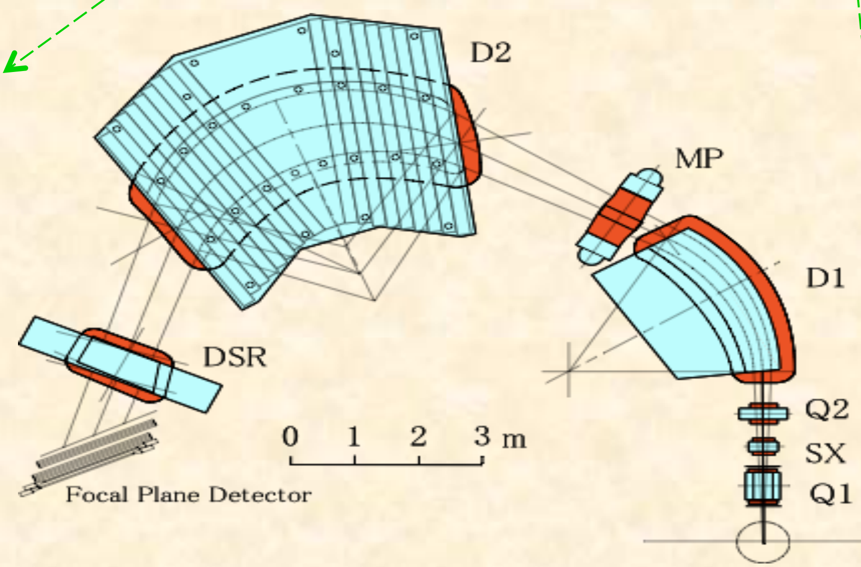
$$E_{ISGDR} = \hbar\sqrt{\frac{7}{3}\frac{K_A + \frac{27}{25}\varepsilon_F}{m\langle r^2\rangle}}$$

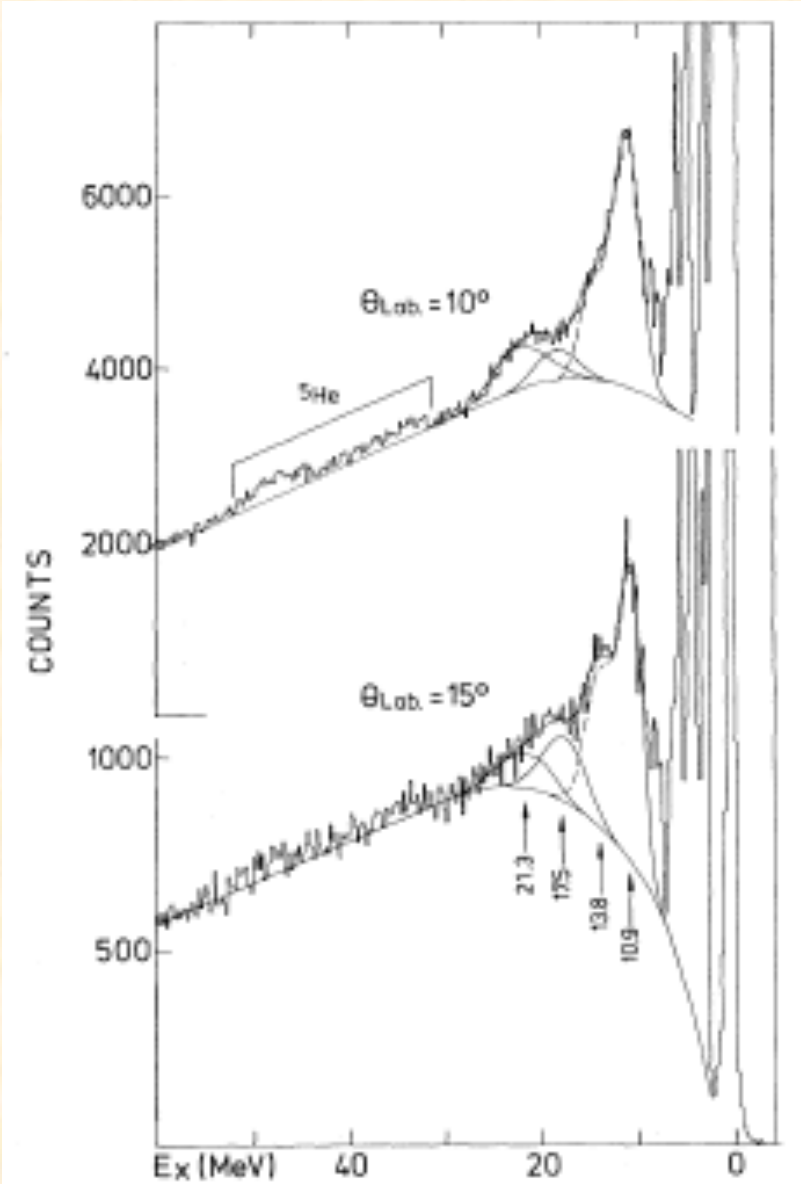


(α,α’) at 400 MeV

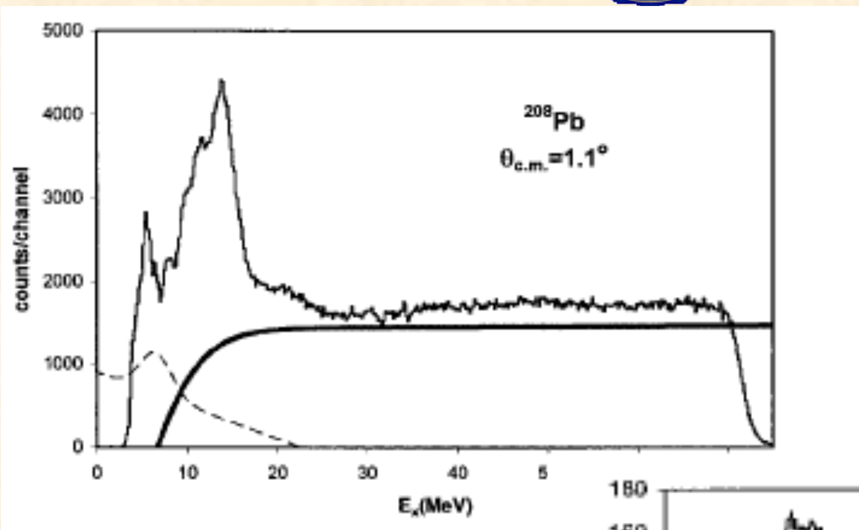


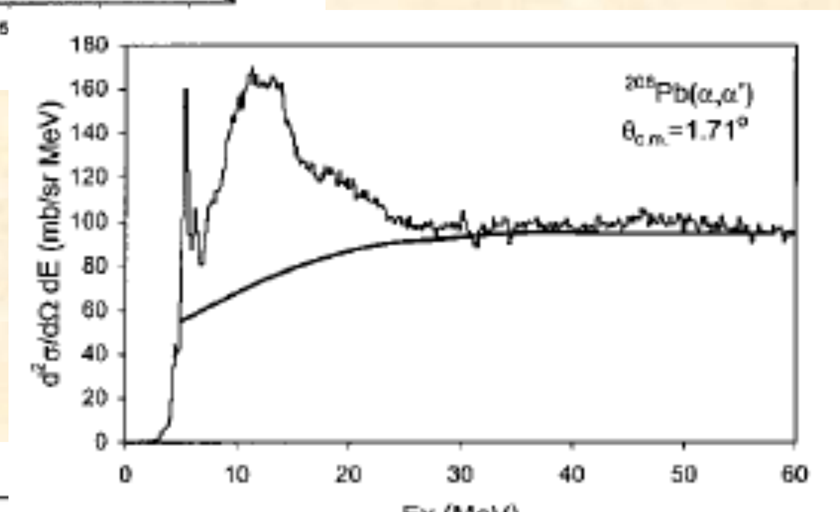

LAS
WS
BLP-2
Grand Raiden
BLP-1
Ring
Cyclotron
N-BLP
0
50m
superconducting
solenoid magnets
N
AVF
Cyclotron

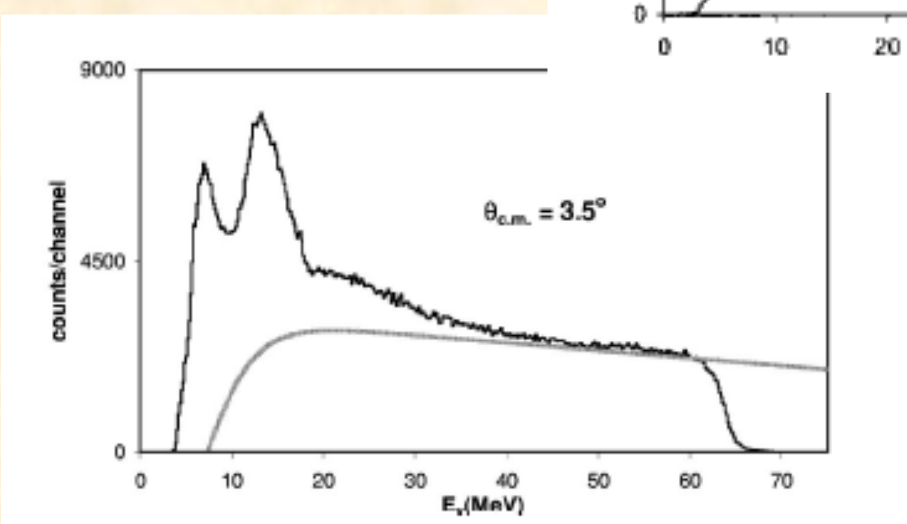

D2
MP
D1
DSR
0 1 2 3 m
Q2
SX
Q1
Focal Plane Detector



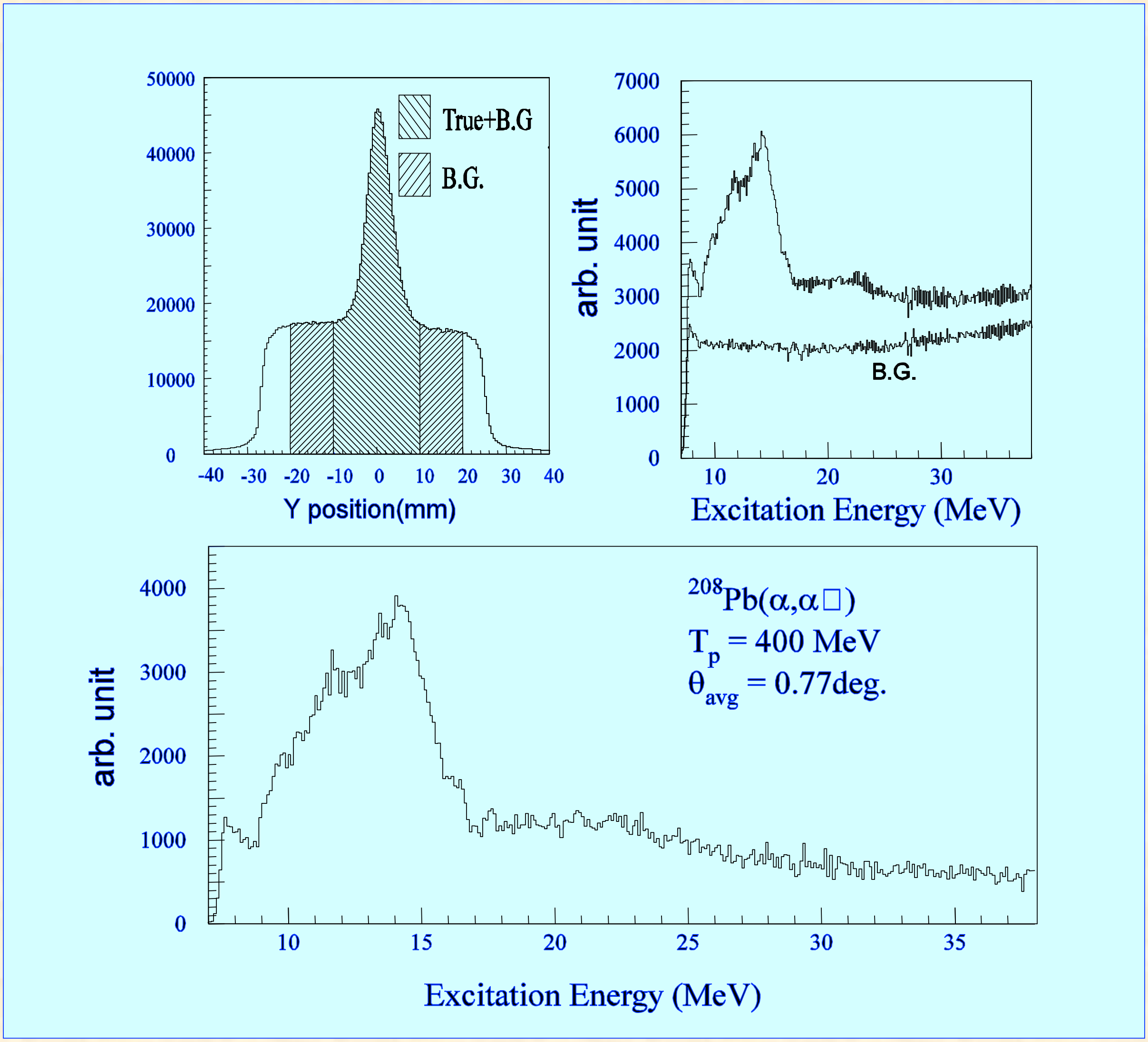
H. P. Morsch *et al.*. Phys. Rev, Lett. **45**, 337 (1980)



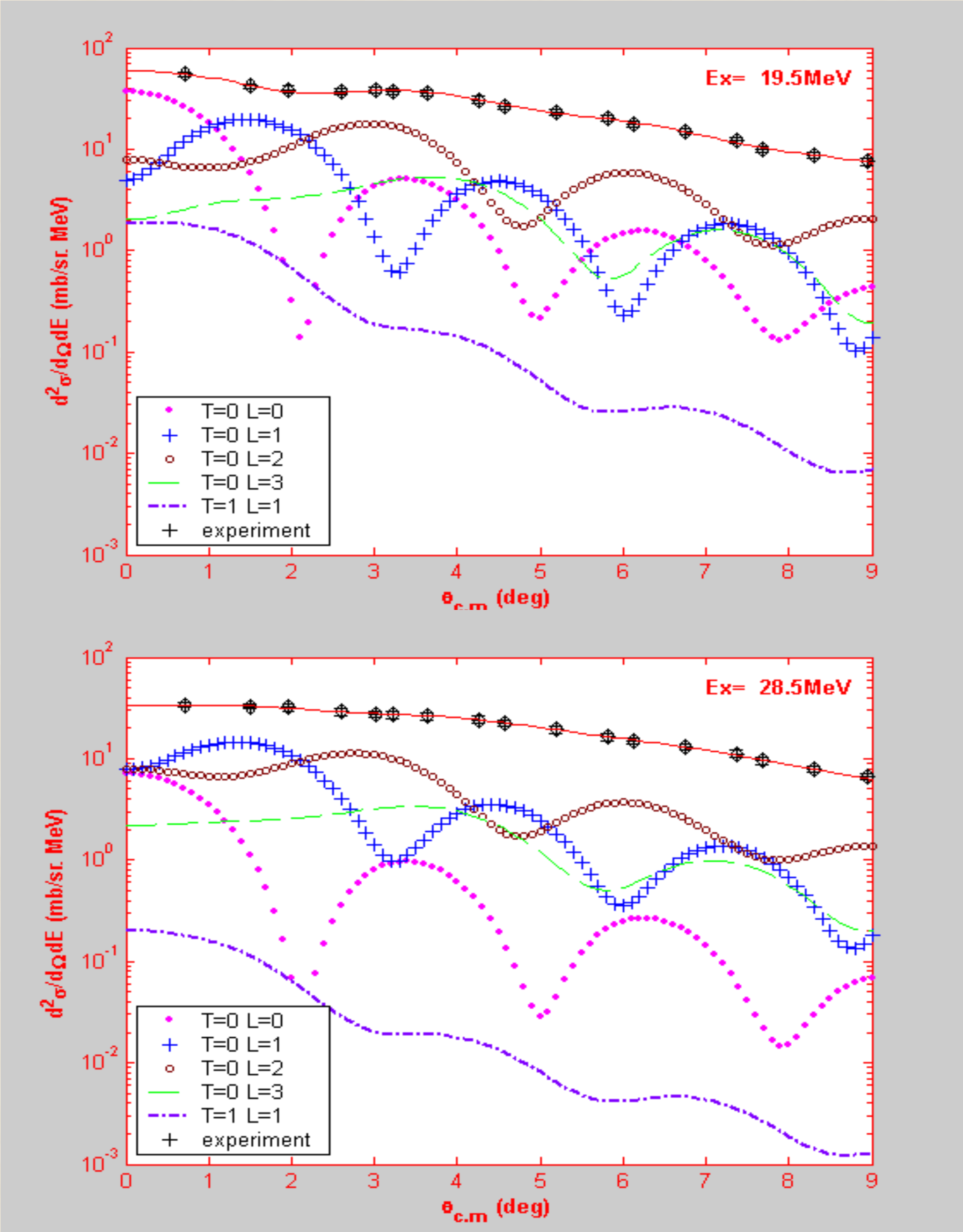


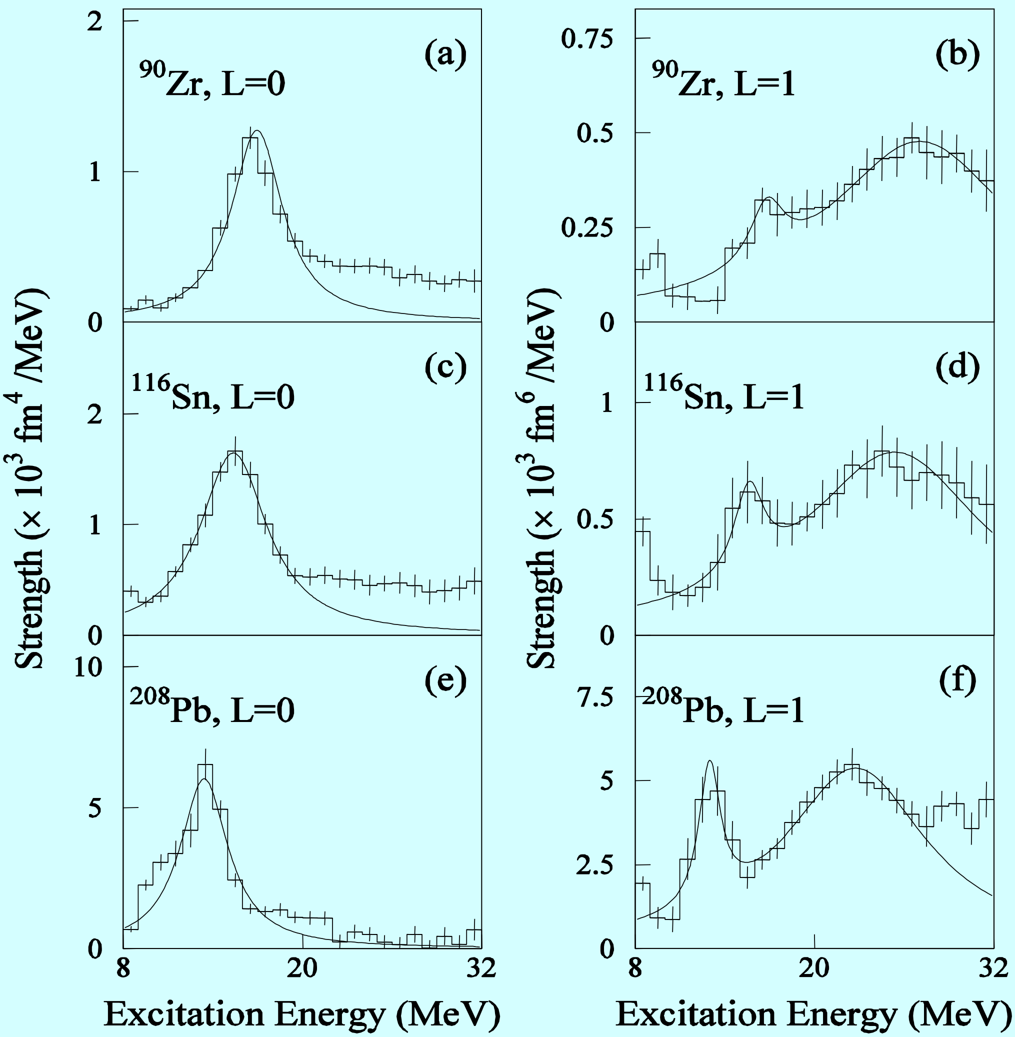


240 MeV (α,α') [Texas A & M]


True+B.G
B.G.
Y position(mm)
arb. unit
Excitation Energy (MeV)
B.G.
$^{208}Pb(\alpha,\alpha')$
T_p = 400 MeV
θ_{avg} = 0.77deg.
arb. unit
Excitation Energy (MeV)

^{112}Sn


Ex= 19.5MeV
d2σ/dΩdE (mb/sr. MeV)
θc.m (deg)
T=0 L=0
T=0 L=1
T=0 L=2
T=0 L=3
T=1 L=1
experiment
Ex= 28.5MeV
d2σ/dΩdE (mb/sr. MeV)
θc.m (deg)
T=0 L=0
T=0 L=1
T=0 L=2
T=0 L=3
T=1 L=1
experiment



(a)
^{90}Zr, L=0
(b)
^{90}Zr, L=1
(c)
^{116}Sn, L=0
(d)
^{116}Sn, L=1
(e)
^{208}Pb, L=0
(f)
^{208}Pb, L=1
Strength (× 10^3 fm^4 /MeV)
Strength (× 10^3 fm^6 /MeV)
Excitation Energy (MeV)
Excitation Energy (MeV)

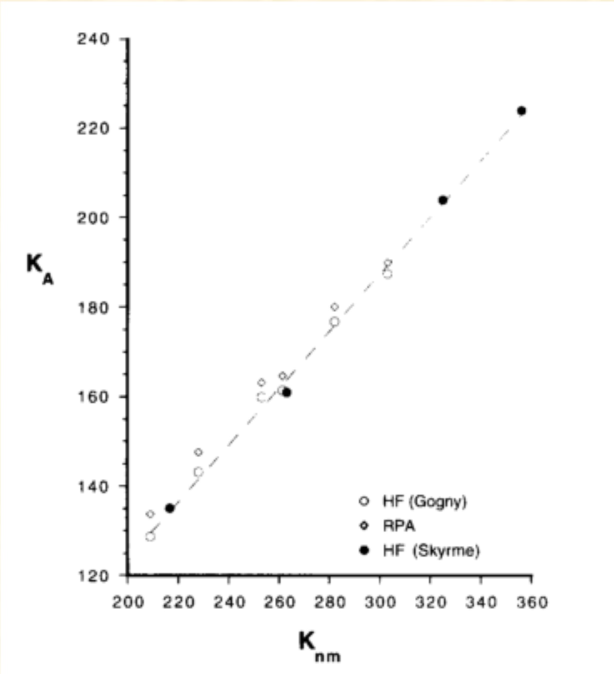
From K_A to K_∞

Build Energy Functionals $E(\rho)$

Each such parameter set is characterized by a K_∞

Obtain GMR strength distributions in a self-consistent RPA calculation

The K_∞ value associated with the functional that best characterizes the observed GMR distributions is the “correct” K_∞.



From GMR data on ^{208}Pb and ^{90}Zr

$K_\infty = 240 \pm 20$ MeV

This number is consistent with both GMR and ISGDR data and with non-relativistic and relativistic calculations

We know K_A from E_{GMR}:

$$E_{GMR} = \hbar\sqrt{\frac{K_A}{m\langle r^2\rangle}}$$

In an approximate way, K_A may be expressed as:

$$K_A \sim K_\infty\,(1 + cA^{-1/3}) + K_\tau\,((N - Z)/A)^2 + K_{Coul}\,Z^2A^{-4/3}$$

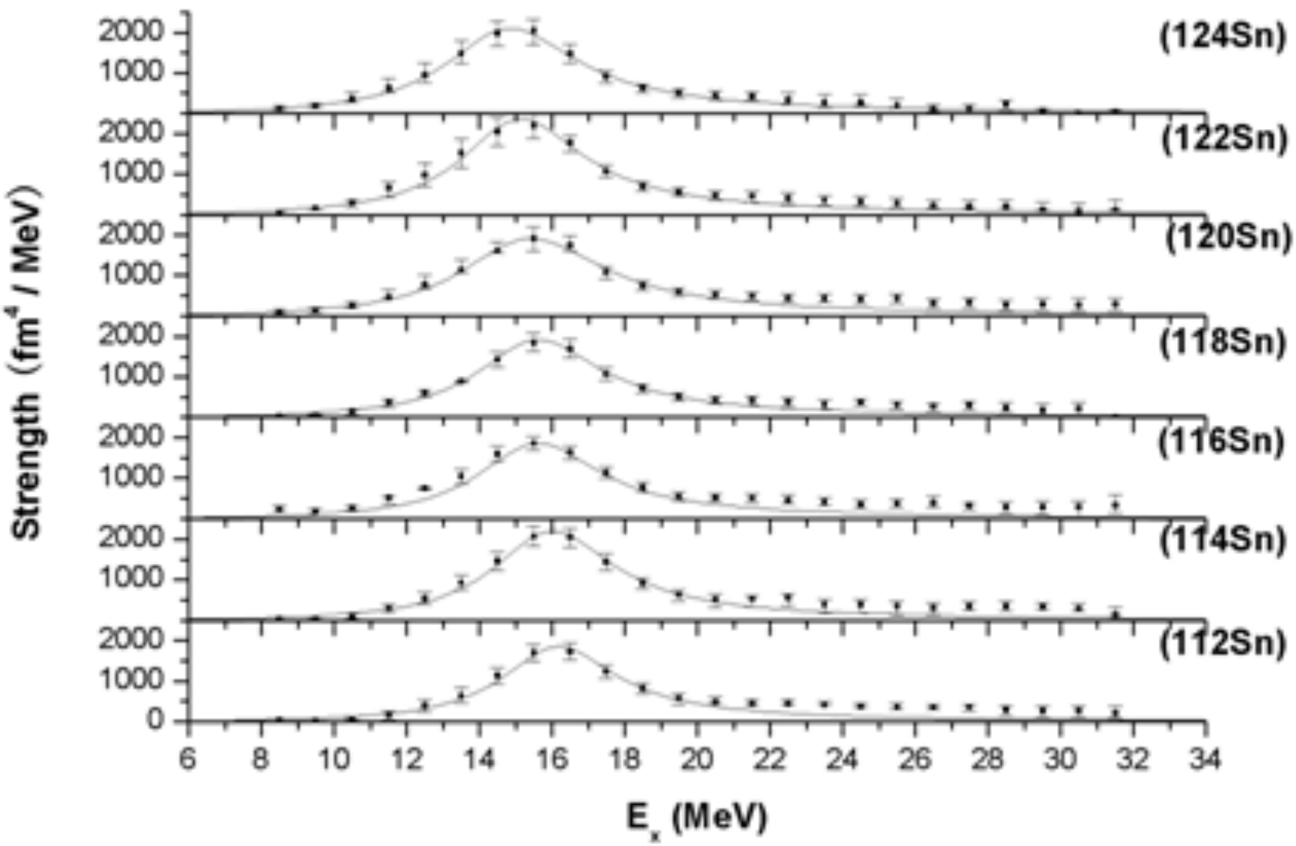
$$c \sim -1$$

K_{Coul} is, basically, model independent

K_τ ??

Measurements over a series of isotopes gives K_τ

$$K_\tau = K_{sym} - 6L - \frac{LQ}{K_\infty}$$

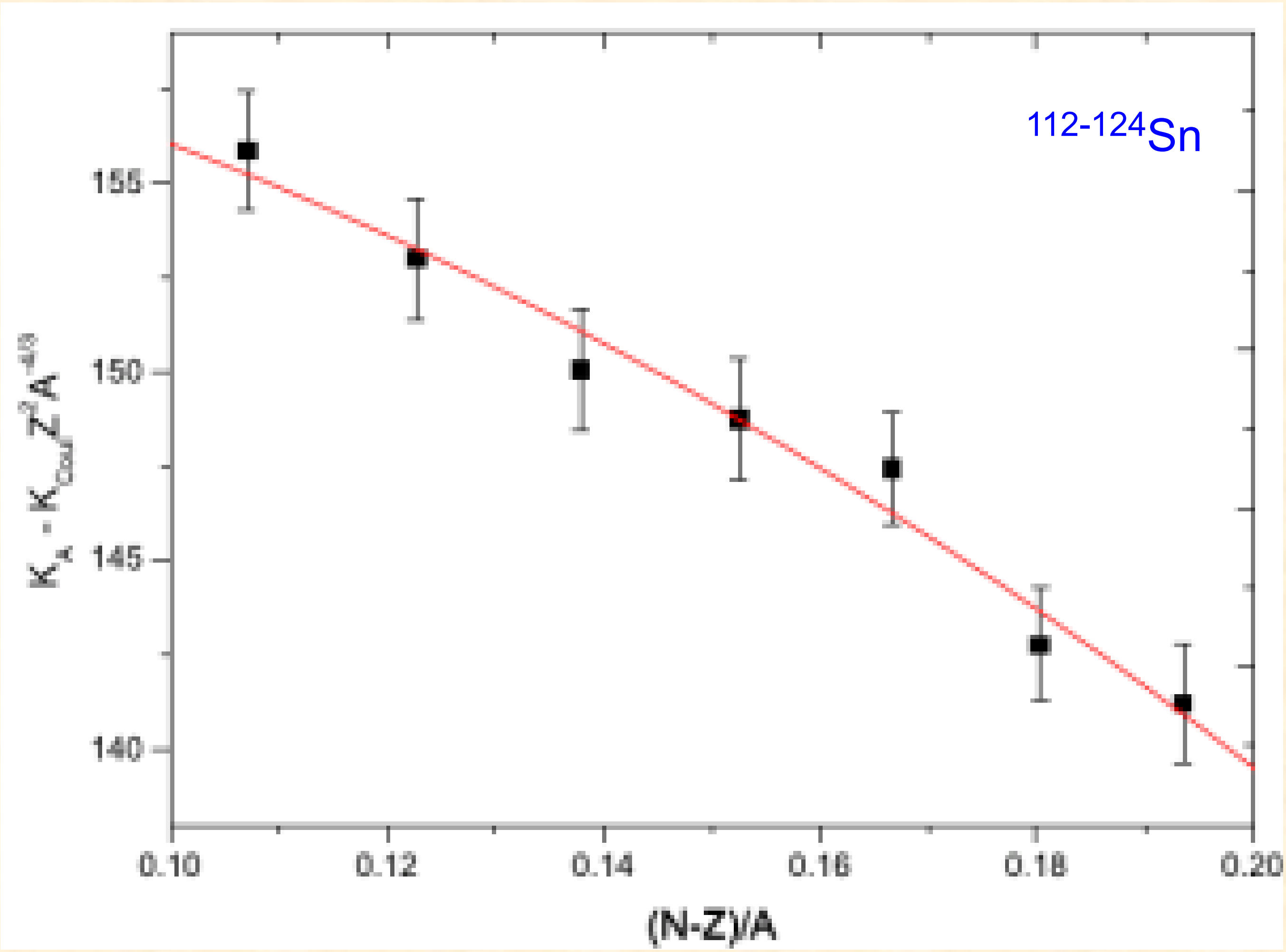

(124Sn)
(122Sn)
(120Sn)
(118Sn)
(116Sn)
(114Sn)
(112Sn)
Strength (fm^4 / MeV)
E_x (MeV)
2000
1000
0
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34

$$K_A \sim K_{vol} (1 + cA^{-1/3}) + K_\tau ((N - Z)/A)^2 + K_{Coul} Z^2A^{-4/3}$$

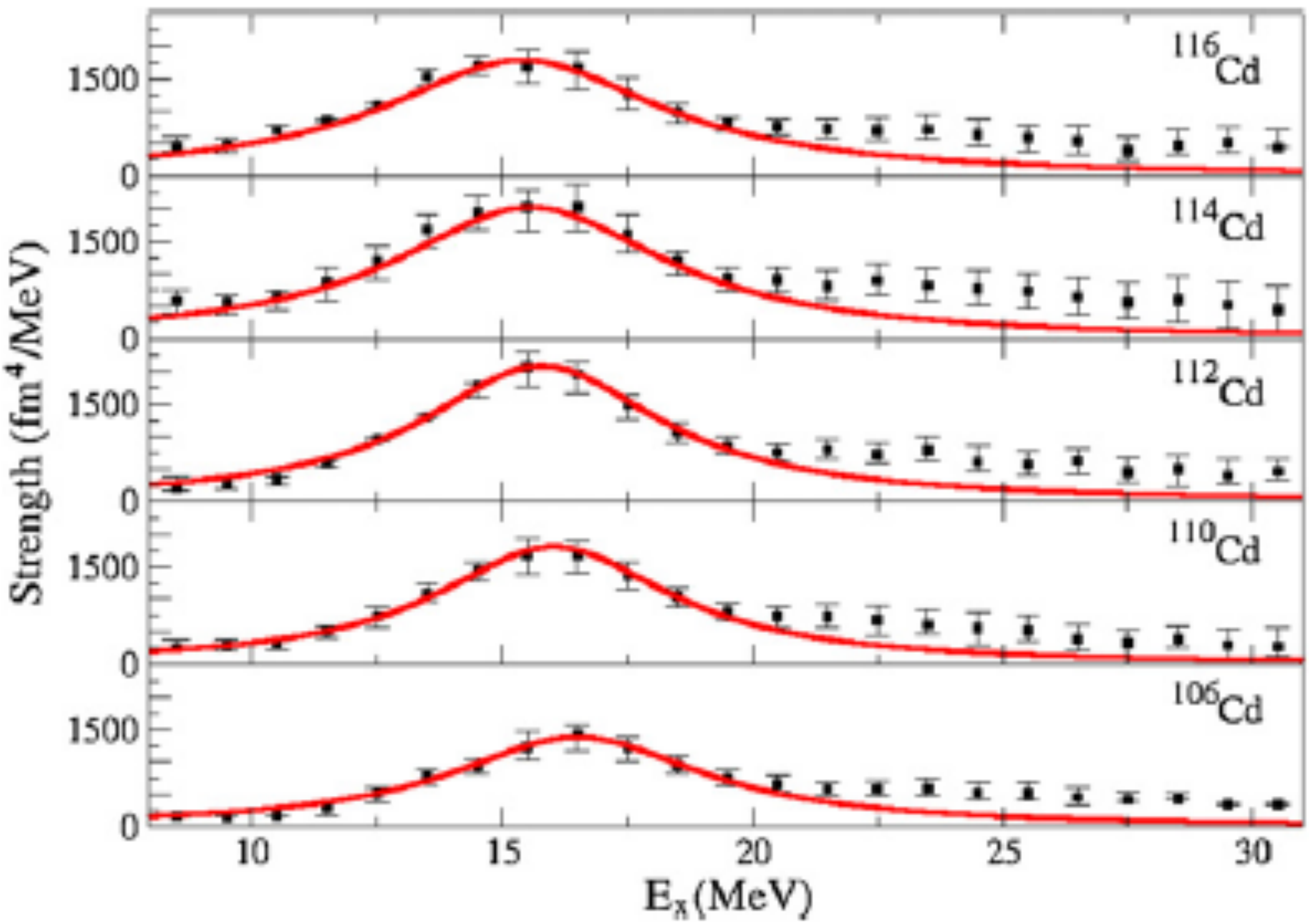
$$K_A - K_{Coul} Z^2A^{-4/3} \sim K_{vol} (1 + cA^{-1/3}) + K_\tau ((N - Z)/A)^2$$

$$\sim \text{Constant} + K_\tau ((N - Z)/A)^2$$

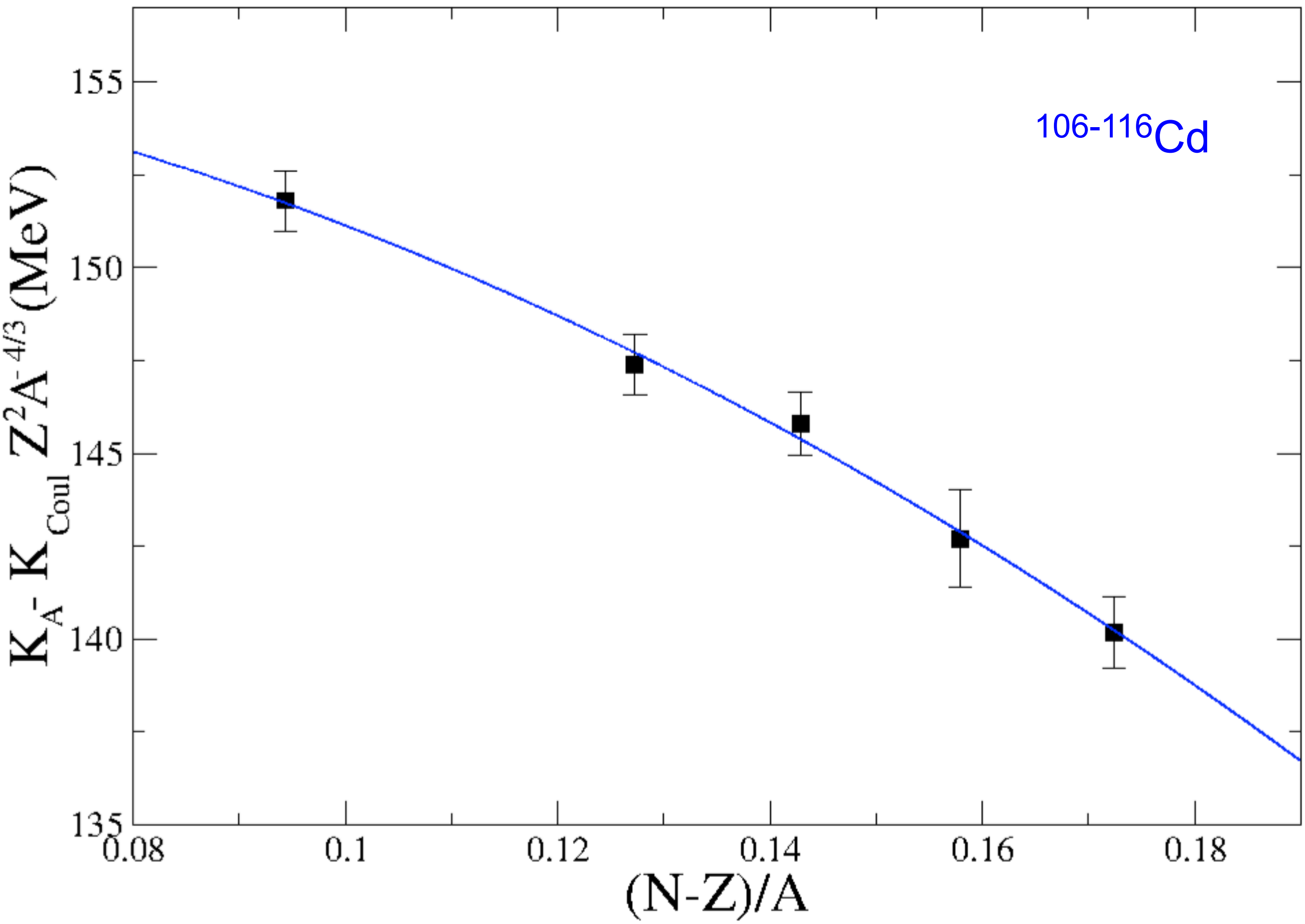
We use K_{Coul} = - 5.2 MeV (from Sagawa)



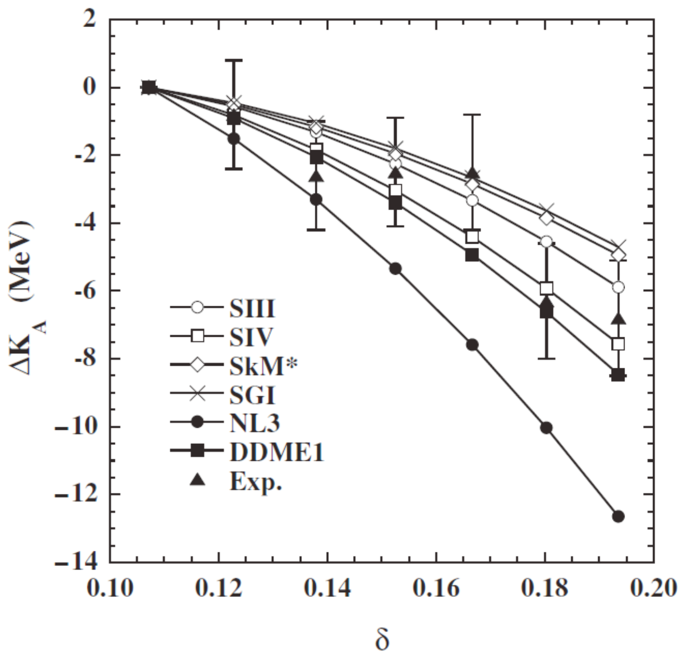
$$K_\tau = -550 \pm 100 \text{ MeV}$$



D. Patel *et al.*. Phys. Lett. B **718**, 447 (2012)



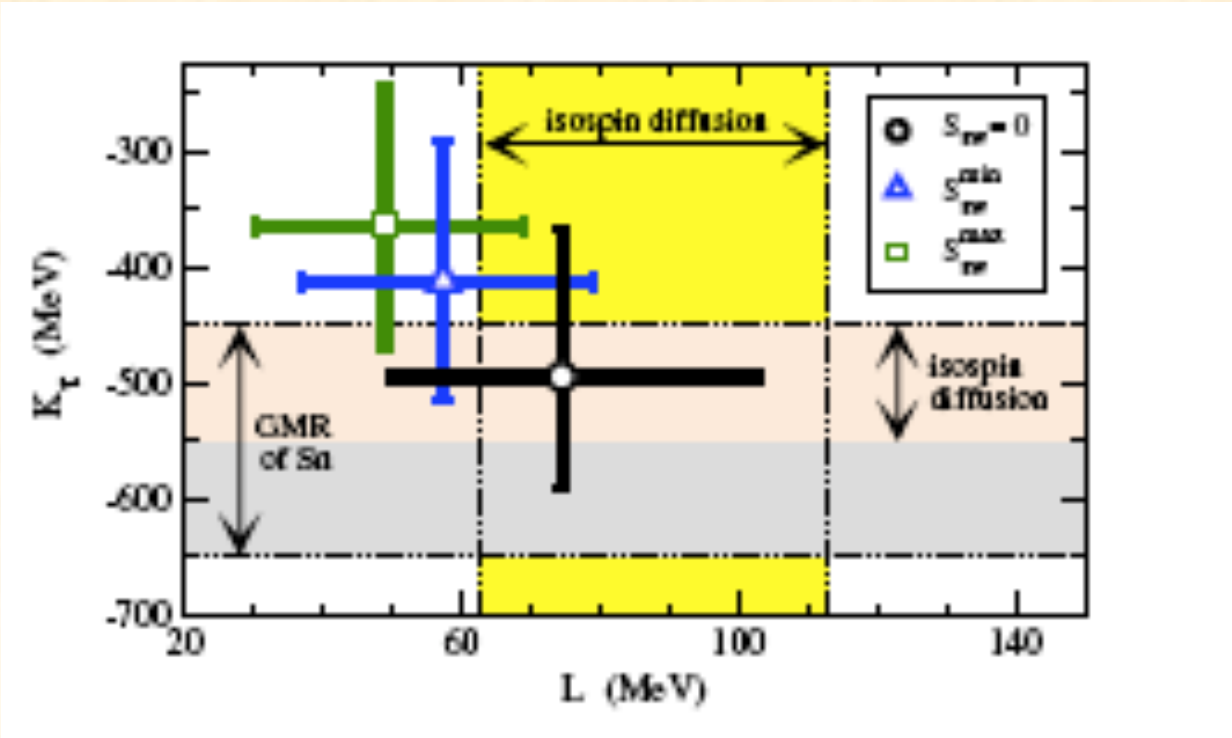
$K_\tau = -555 \pm 75$ MeV



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

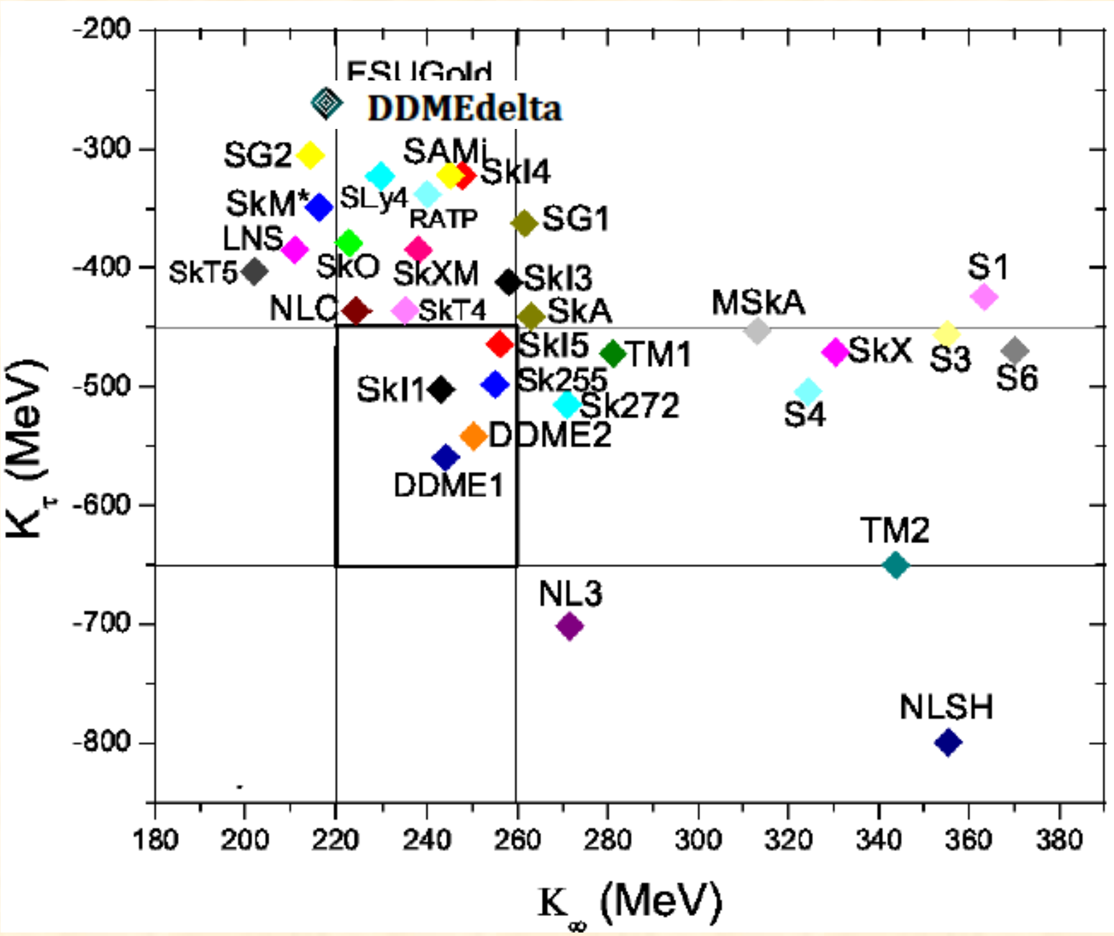
The difference of incompressibility $K = K_A - K_{A=112}$ as a function of $\delta = (N-Z)/A$. Experimental data are determined by using the excitation energies of ISGMR.

K_τ = -500 ± 50 MeV



$$K_\tau = -500^{+125}_{-100} \text{ MeV}$$

M. Centelles *et al*., Phys. Rev. Lett. **102**, 122502 (2009)



$$K_\tau = K_{\tau,v} + K_{\tau,s} A^{-1/3}$$

Data from H. Sagawa *et al.*, Phys. Rev. C **76**, 034327 (2007)

Towards very neutron-rich nuclei

- K_τ
- K_{core} and K_{skin}

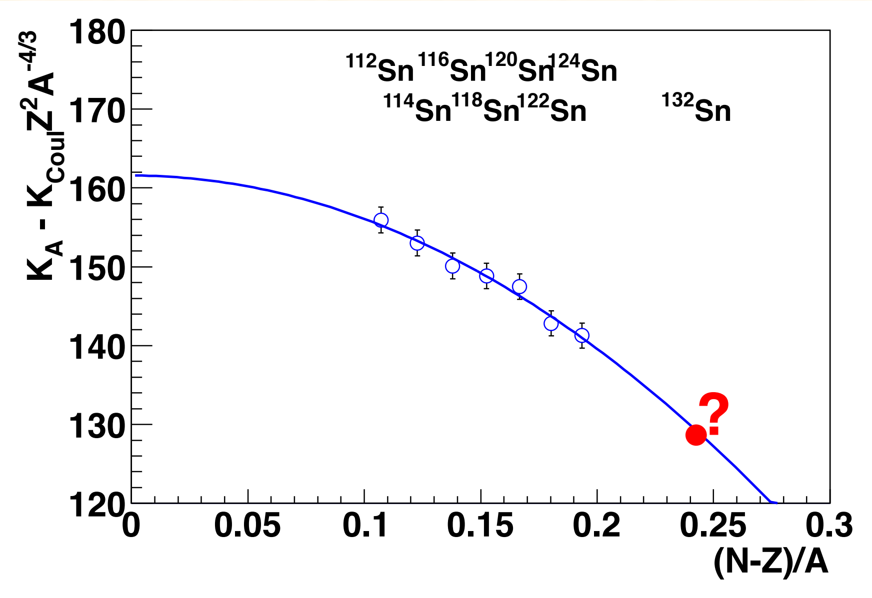
"soft GMR" akin to pigmy GDR's.

- Need inverse reactions
  ^{2}H, ^{4}He, or ^{6}Li targets
  beams of 35-100 MeV/A

- First experiments performed at GANIL and at RIKEN

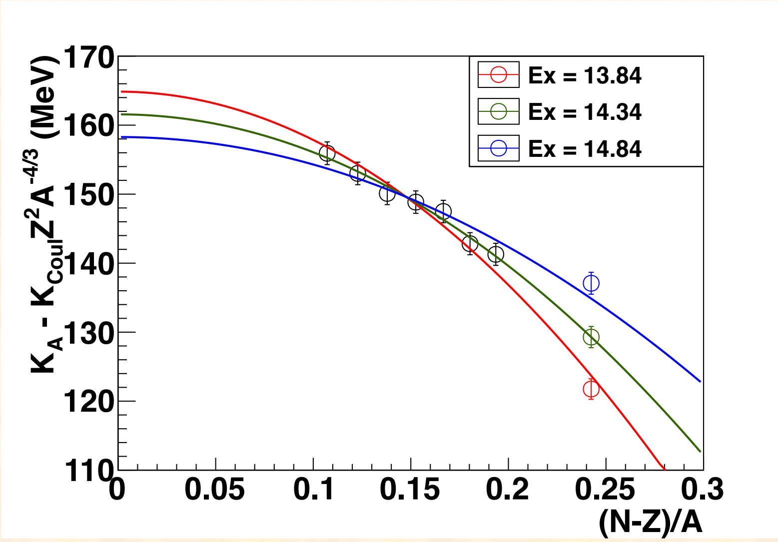
  ^{56}Ni + ^{2}H, ^{68}Ni + ^{4}He, ^{132}Sn + ^{2}H

  with active targets



⇒ Uncertainty in K_τ can be reduced to <50 MeV.

⇒ 0.5 MeV difference in E_{GMR} corresponds to 80 MeV difference in K_τ



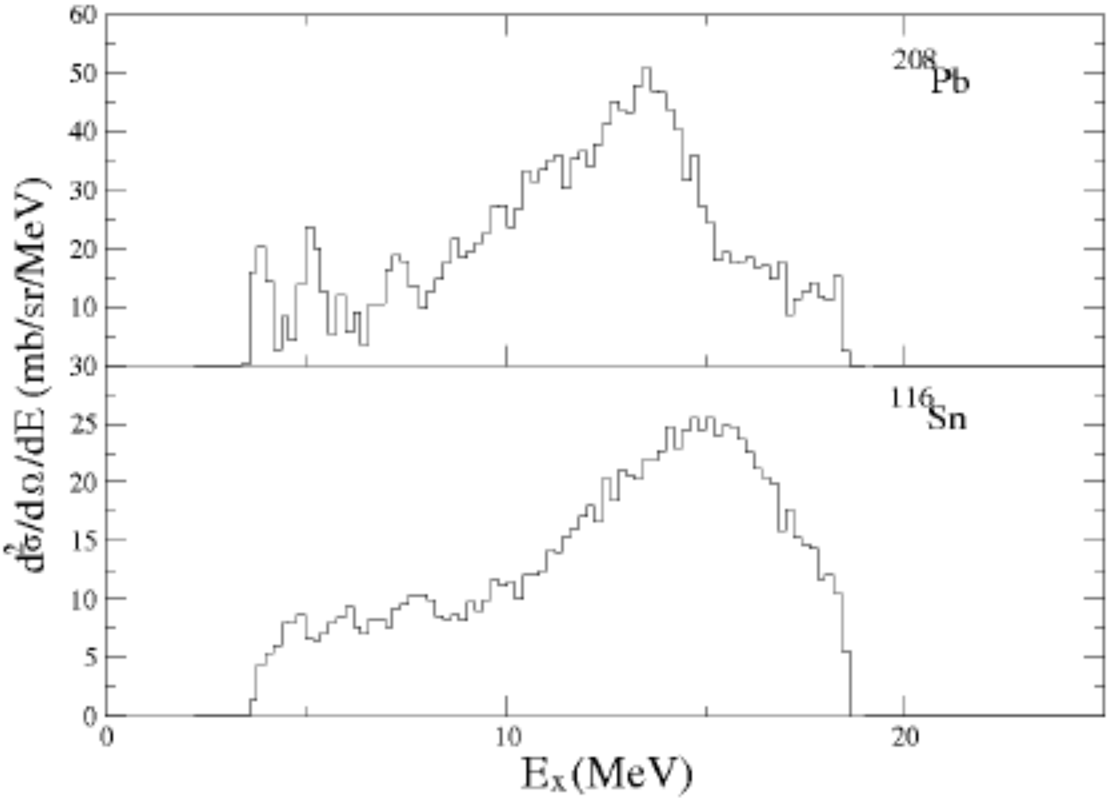
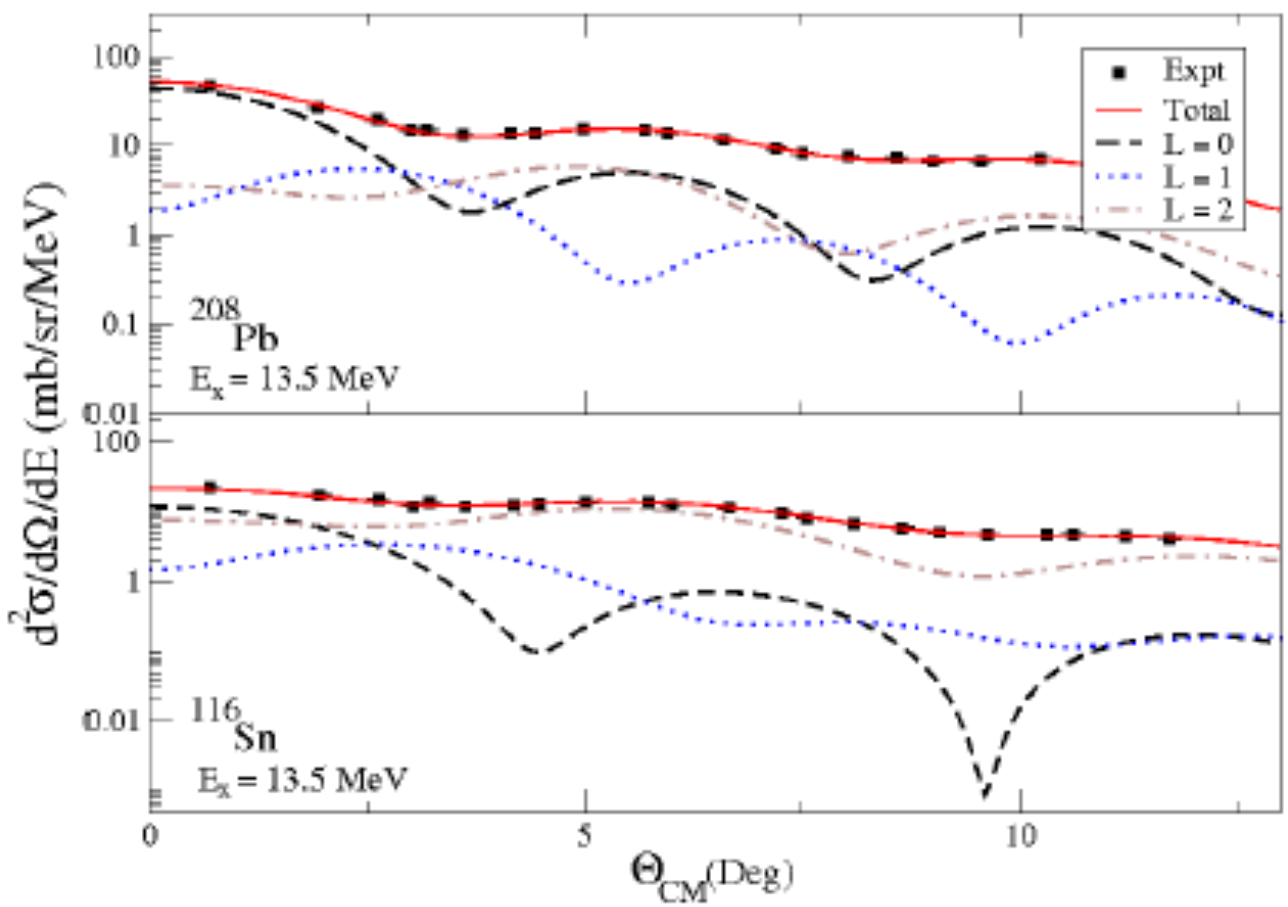
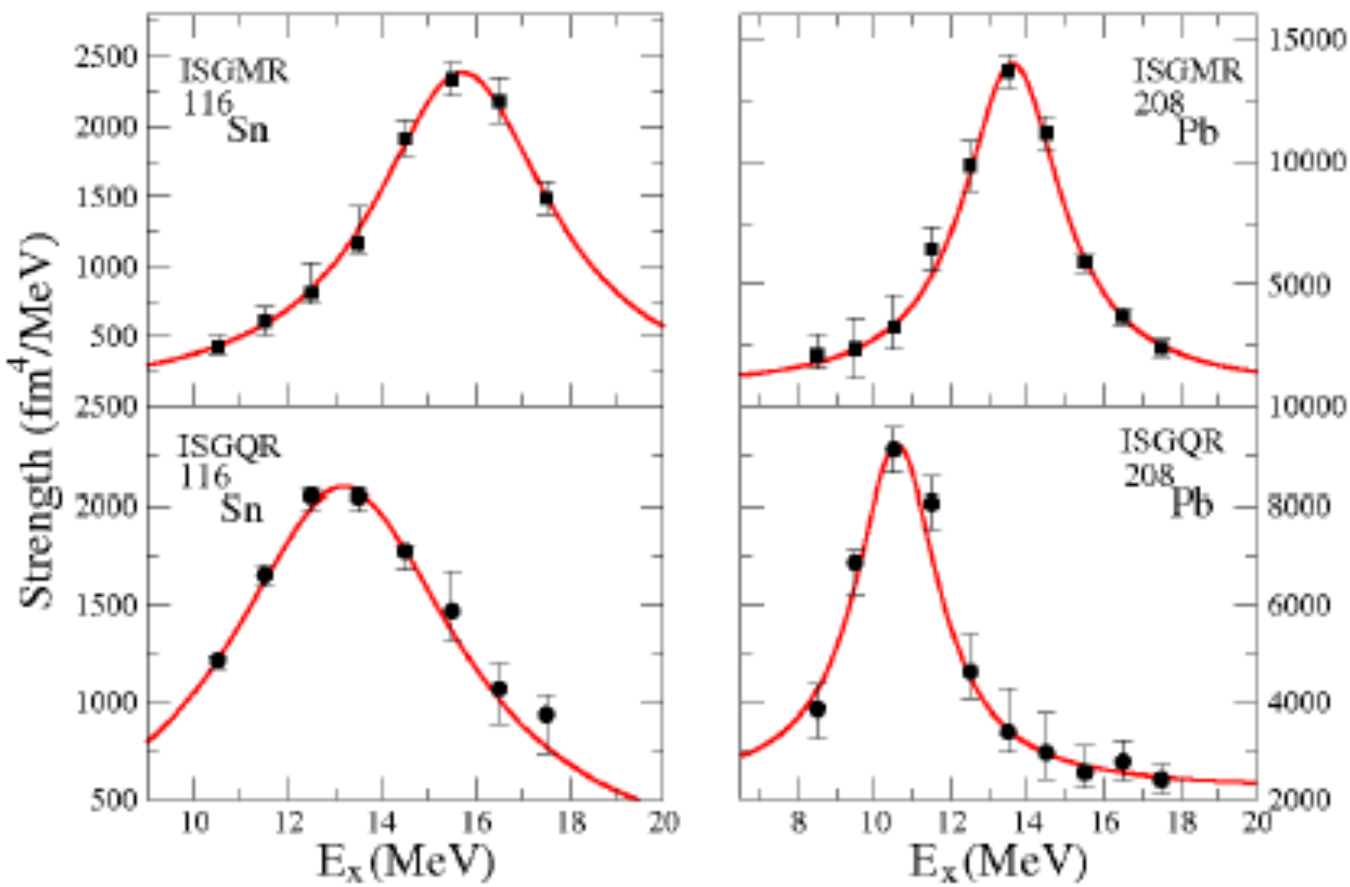


FIG. 1. Excitation-energy spectra from inelastic deuteron scattering for ^{208}Pb (upper panel) and ^{116}Sn (lower panel) at an incident energy of 196 MeV and an "average" scattering angle of 0.7°.

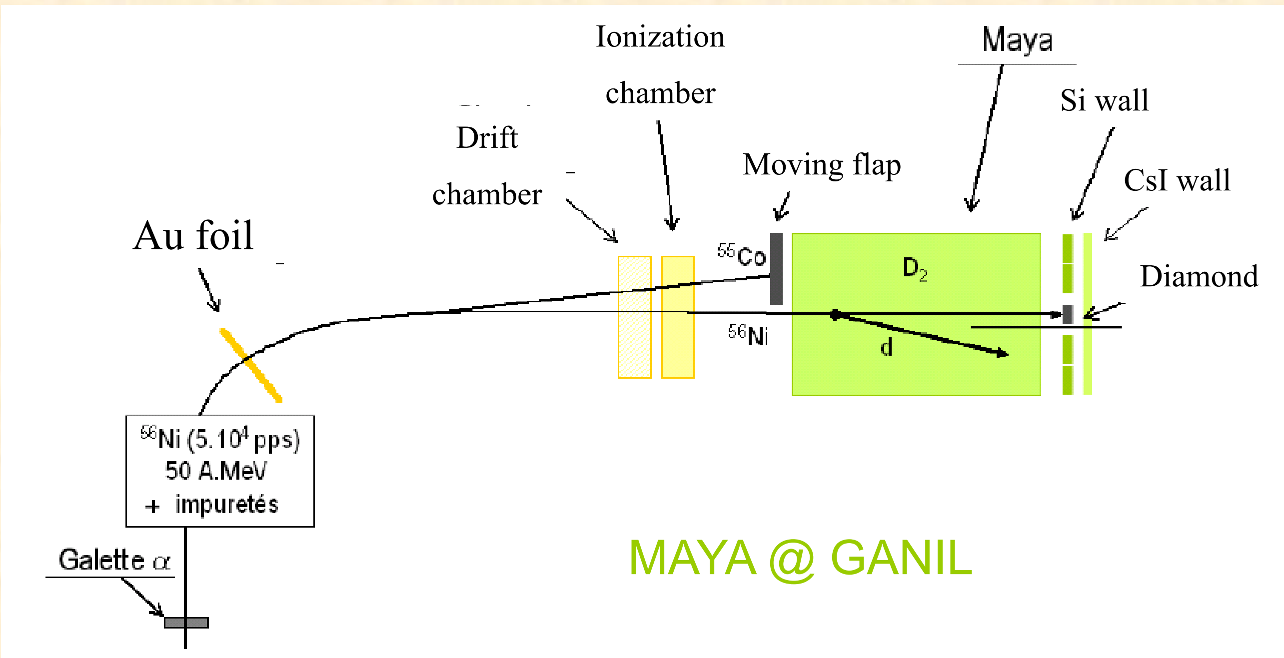
(*d, d'*) @ 100 MeV/A

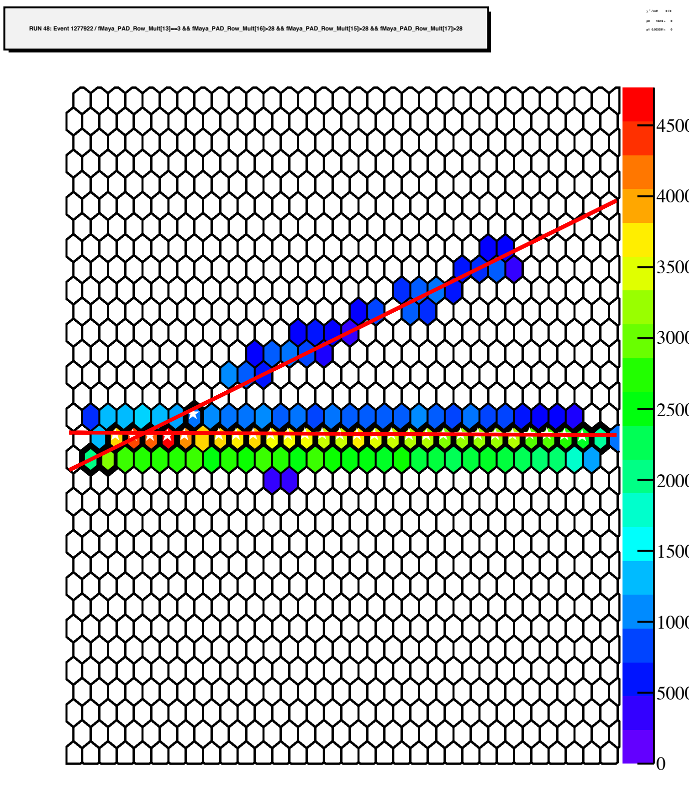


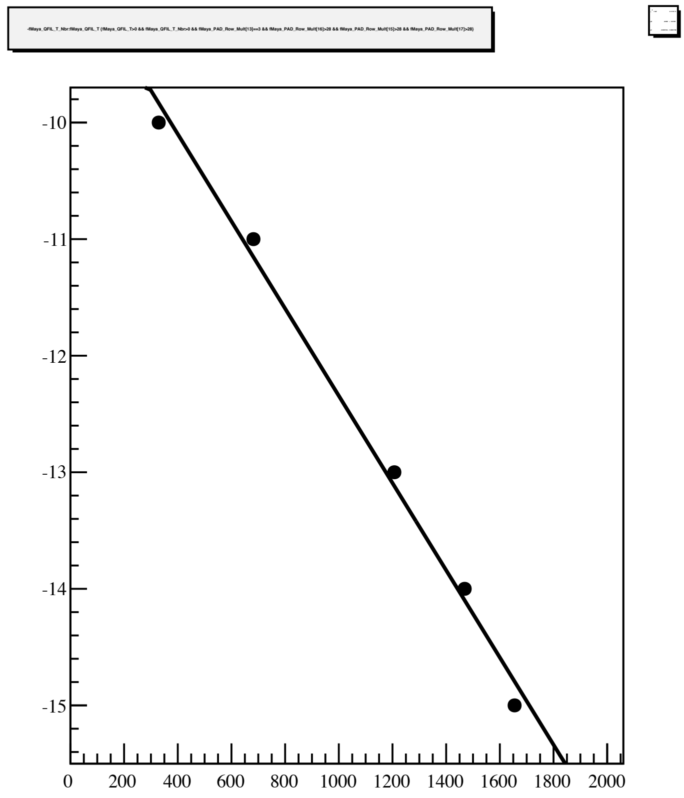
Expt
Total
L = 0
L = 1
L = 2
208Pb
Ex = 13.5 MeV
116Sn
Ex = 13.5 MeV
d2σ/dΩ/dE (mb/sr/MeV)
ΘCM(Deg)



D. Patel *et al.*. Phys. Lett. B **735**, 387 (2014)


Ionization chamber
Maya
Si wall
Drift chamber
Moving flap
CsI wall
Au foil
^{55}Co
D_2
Diamond
^{56}Ni
d
^{56}Ni (5.10^4 pps)
50 A.MeV
+ impuretés
Galette α
MAYA @ GANIL


RUN 48: Event 1277922 / fMaya_PAD_Row_Mult[13]==3 && fMaya_PAD_Row_Mult[16]>28 && fMaya_PAD_Row_Mult[15]>28 && fMaya_PAD_Row_Mult[17]>28
4500
4000
3500
3000
2500
2000
1500
1000
5000
0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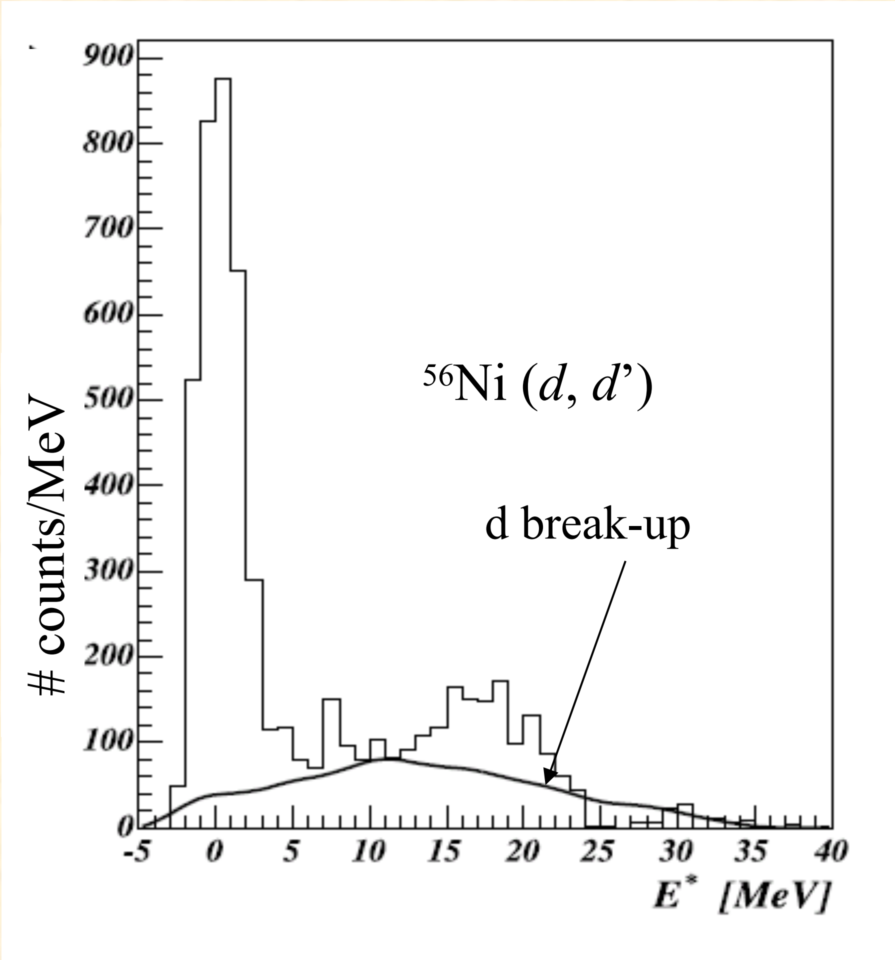
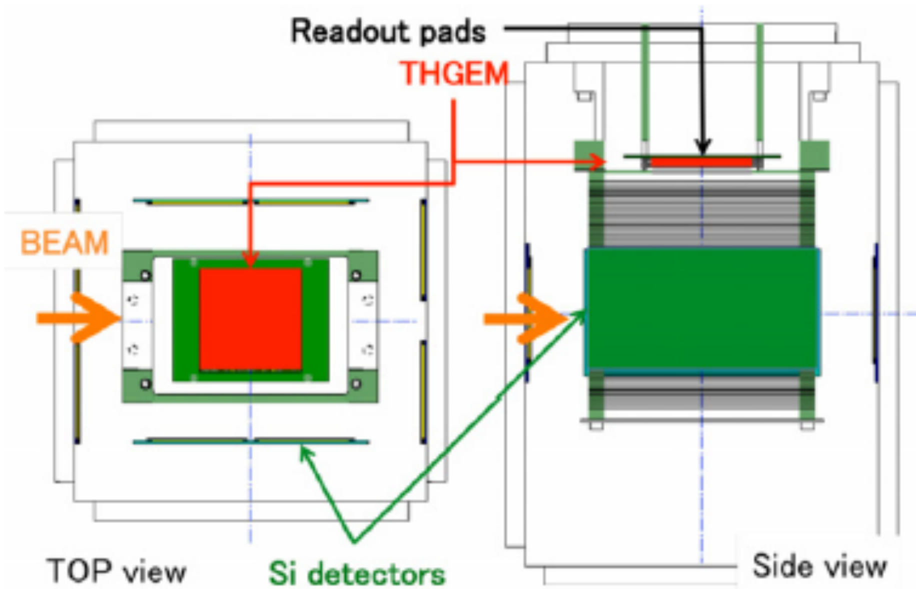
-10
-11
-12
-13
-14
-15
0
200
400
600
800
1000
1200
1400
1600
1800
2000



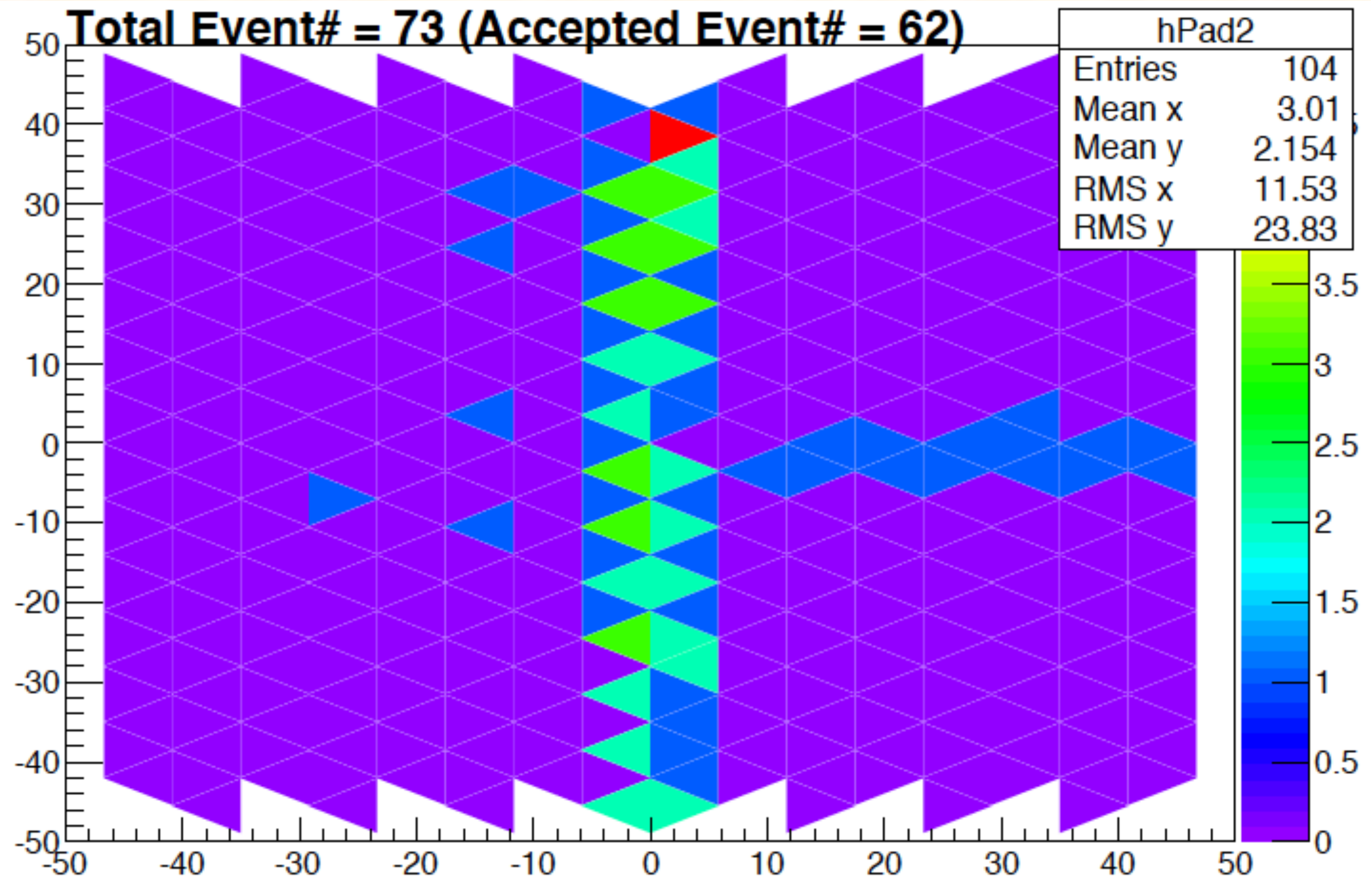
MAYA @ GANIL

C. Monrozeau *et al.*, Phys. Rev. Lett. **100**, 042501 (2008)



RIBF 113

^{132}Sn + ^{2}H
100 MeV/A
>50 kHz ^{132}Sn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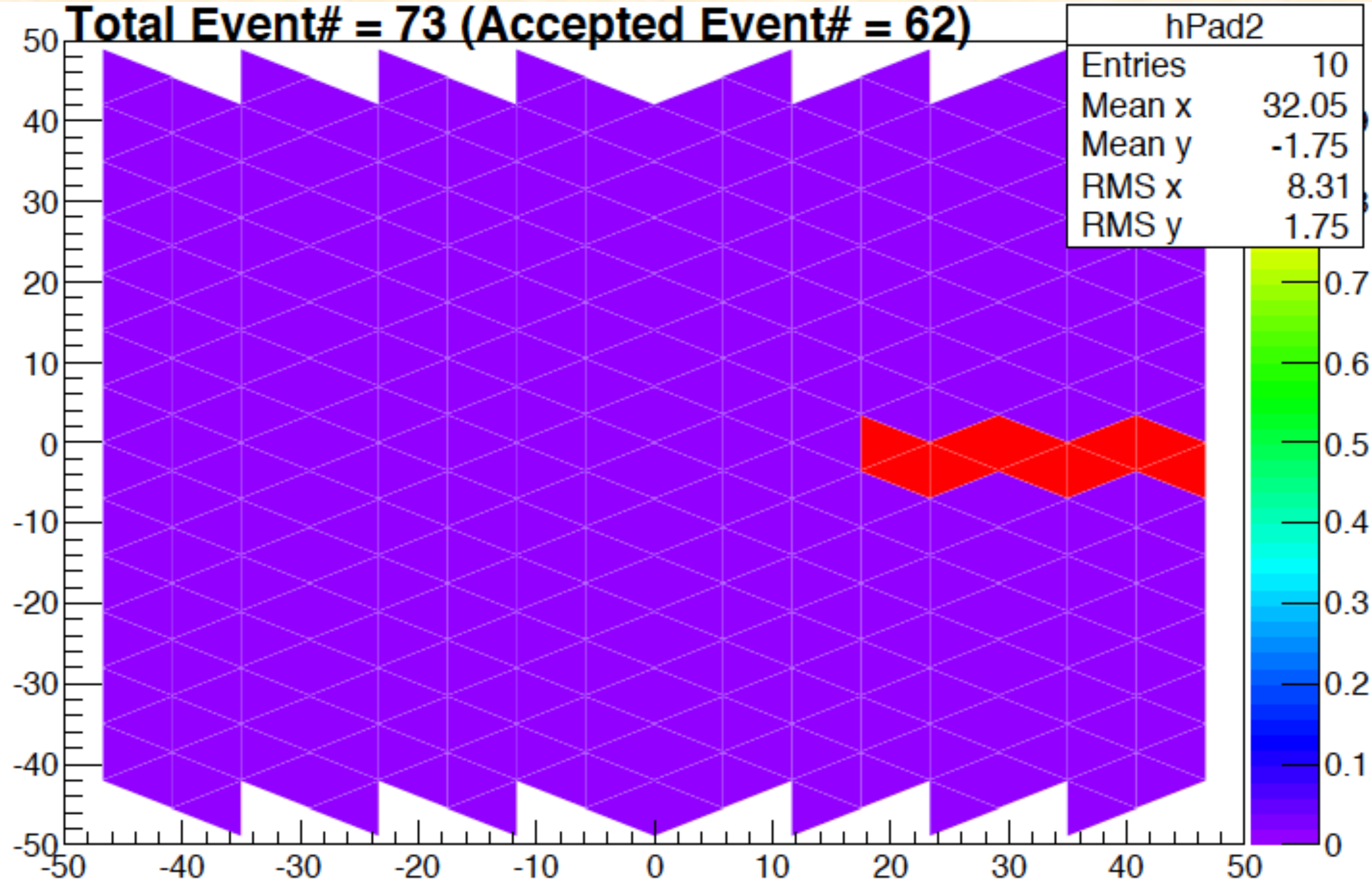
hPad2
Entries 104
Mean x 3.01
Mean y 2.154
RMS x 11.53
RMS y 23.83



Total Event# = 73 (Accepted Event# = 62)
hPad2
Entries 10
Mean x 32.05
Mean y -1.75
RMS x 8.31
RMS y 1.75

- From compressional-mode giant resonances, we have an "experimental" value for **K_∞= 240 ± 20 MeV.**

- From GMR in the Sn and Cd isotopes, we get an "experimental" value for **K_τ = -550 ± 100 MeV.**

- The combination of these two values provides a constraint on the standard interactions used in EOS and nuclear structure calculations.

- To further constrain the value of **K_τ**, we are doing measurements with radioactive ion beams, now feasible using "active" targets. Wait ~1 year for RIKEN results!

U. Garg, G.P.A. Berg, J. Hoffman, M. Koss, T. Li,
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S. O...
...iversity

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...ima, M. Uchida, Y. Yasuda, J. Zenihiro
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Konan University

T. Adachi, M.N. Harakeh
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CAT Collaboration

I S N A P

J I N A

Danke Schön

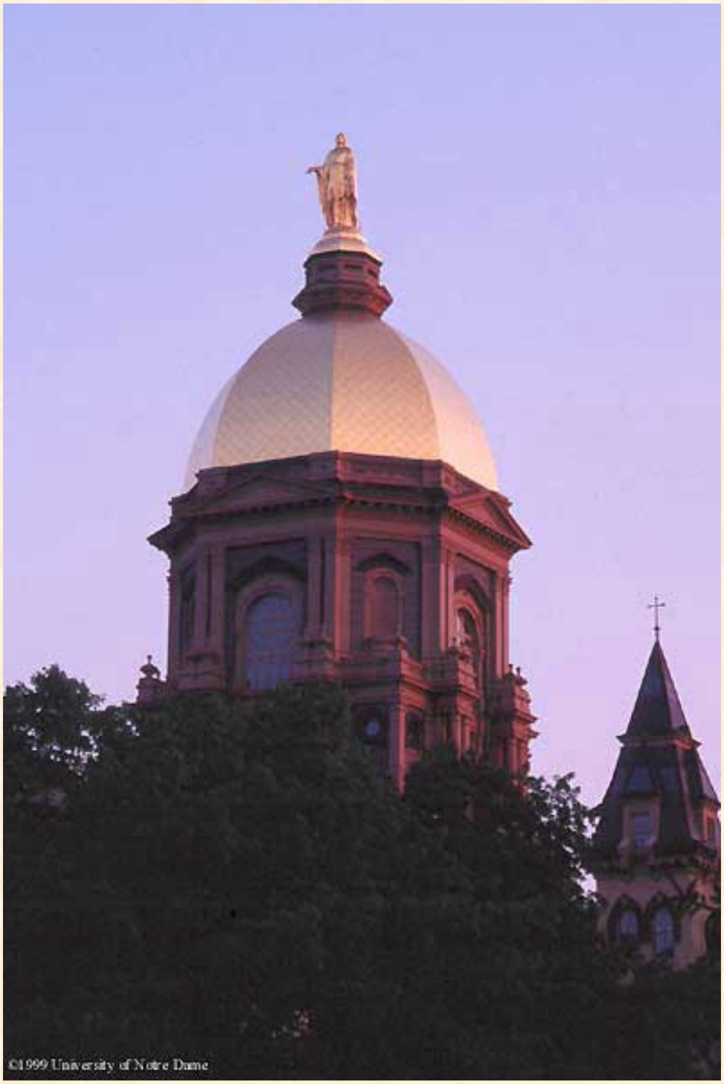
ありがとう

धन्यवाद

Thanks!

The Question Kitten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