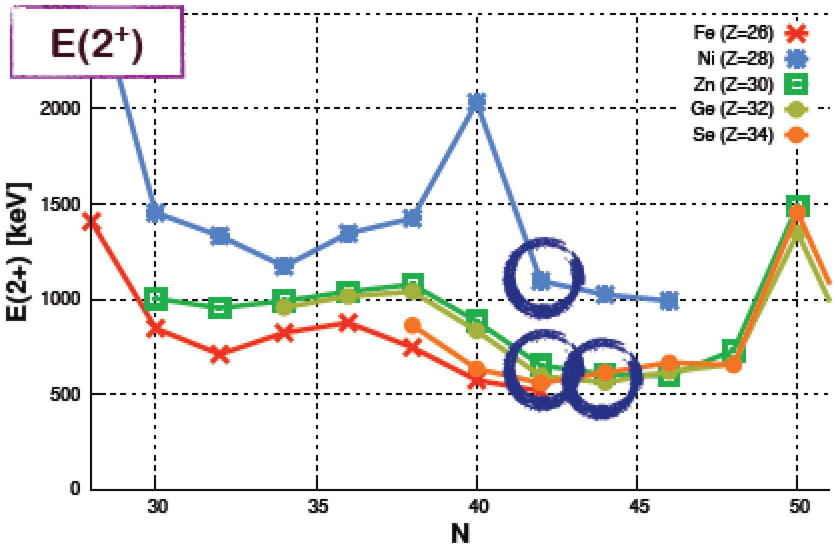
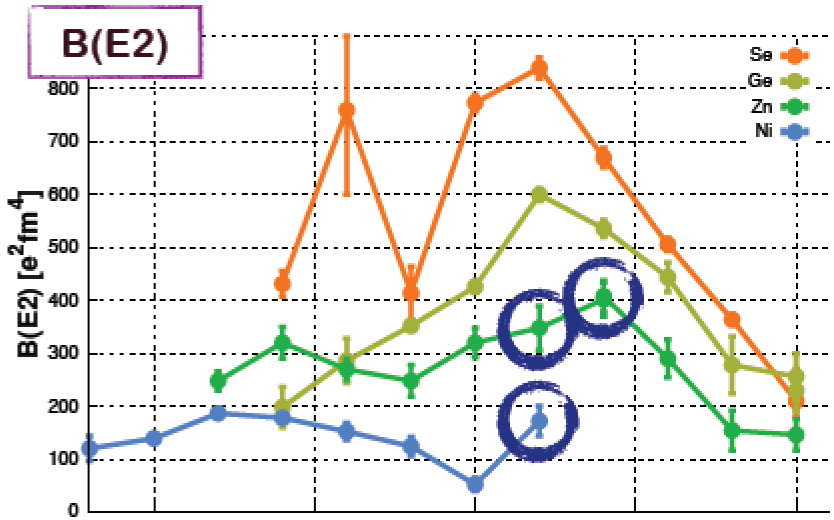
Collaboration IPN-ORSAY – POLAND: Past, Present, Future

Lifetime measurements of 2^+ states in $^{72,74}Zn$ with recoil distance doppler-shift method at GANIL

M. Niikura et al.



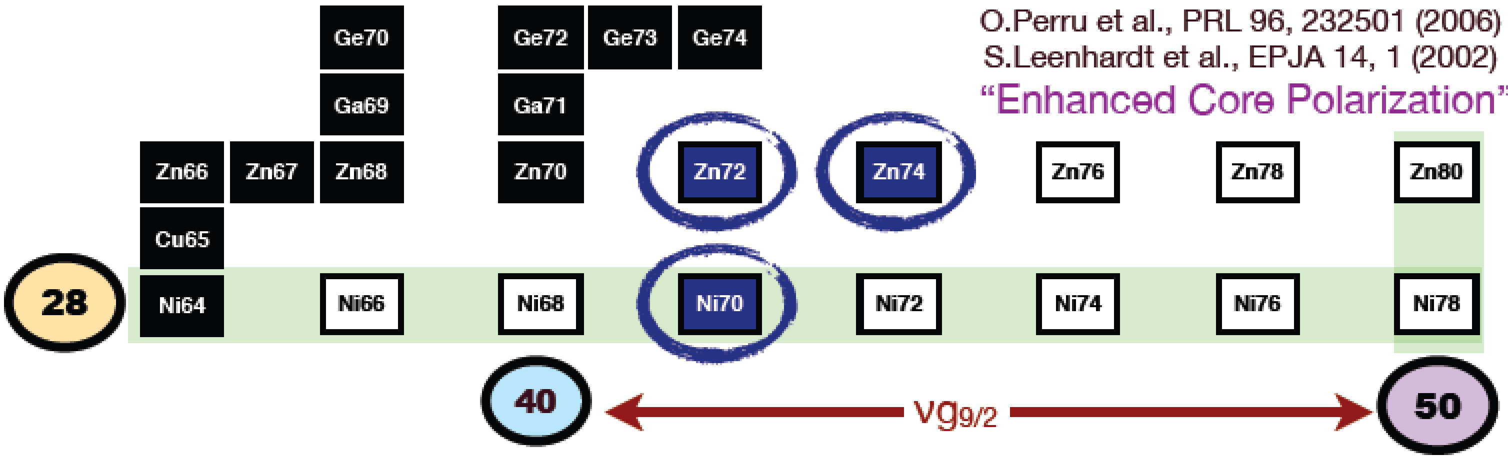


Coulomb excitation exp. at GANIL

O.Perru et al., PRL 96, 232501 (2006)

S.Leenhardt et al., EPJA 14, 1 (2002)

"Enhanced Core Polarization"



Collectivity in $g_{9/2}$ nuclei

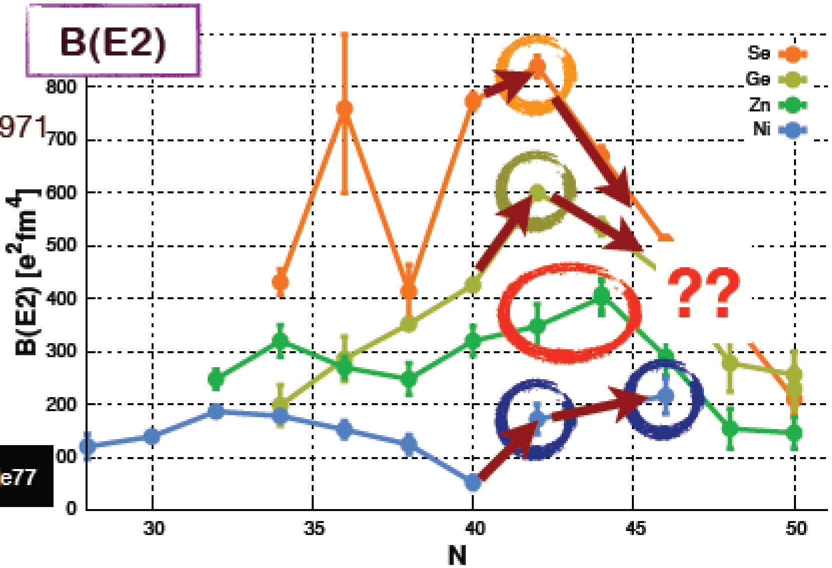
IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

K.Kumer, Colloque sur les Noyaux de Transition (unpublished) 1971
M.Caillau et al., J. Phys. 35, 469 (1974).
D.Ardouin et al., PRC 12, 1745 (1975).

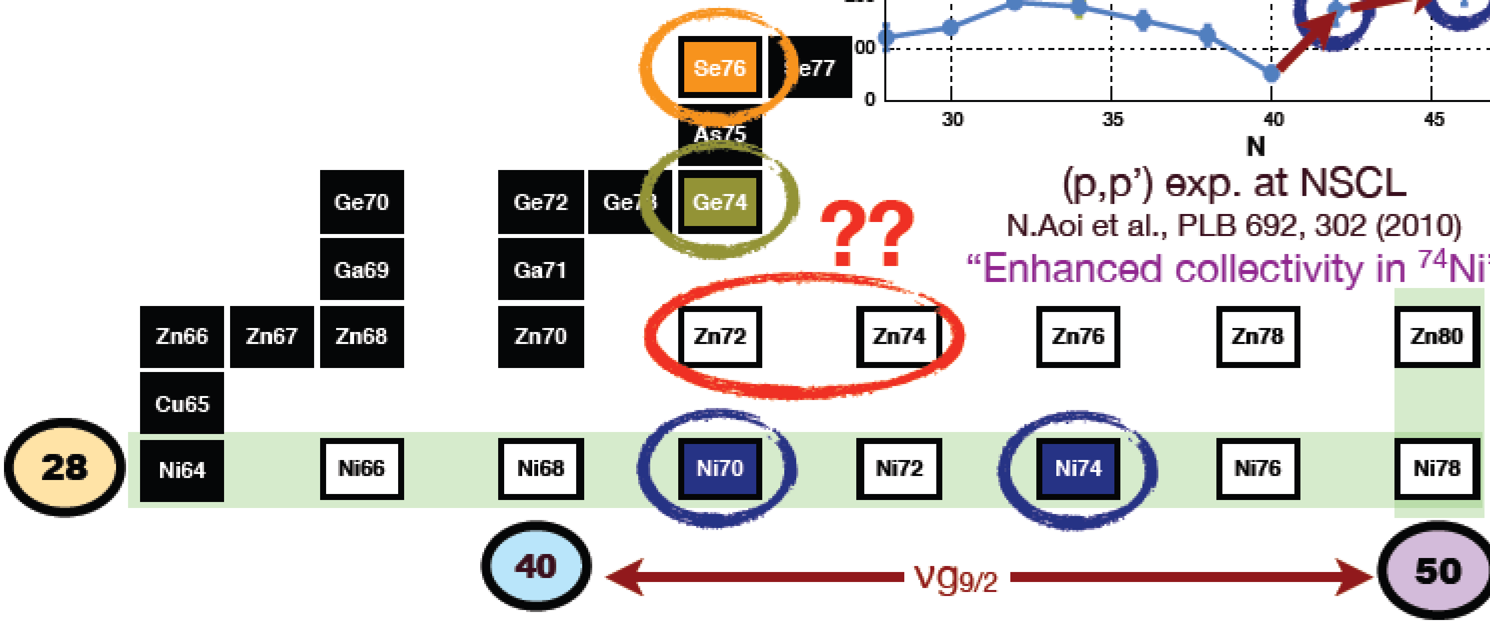
"Shape transition between N=40 and N=42"

↓

How does collectivity develop
in the transitional Zn isotopes?



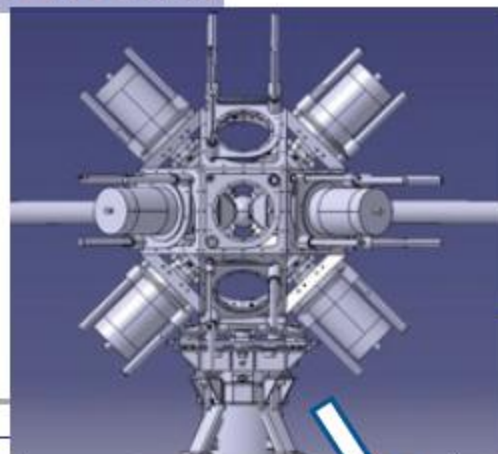
(p,p') exp. at NSCL
N.Aoi et al., PLB 692, 302 (2010)
"Enhanced collectivity in ^{74}Ni"



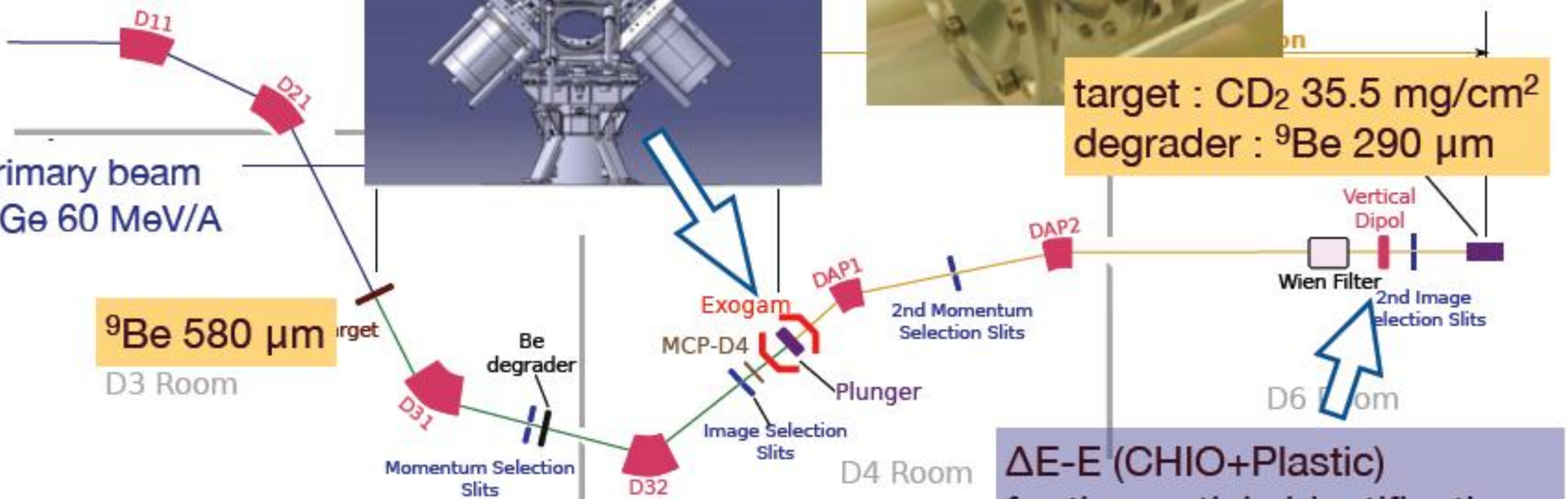
Experimental setup at LISE

LISE at GANIL
in July and Oct. 2009

8 EXOGAM



Cologne plunger



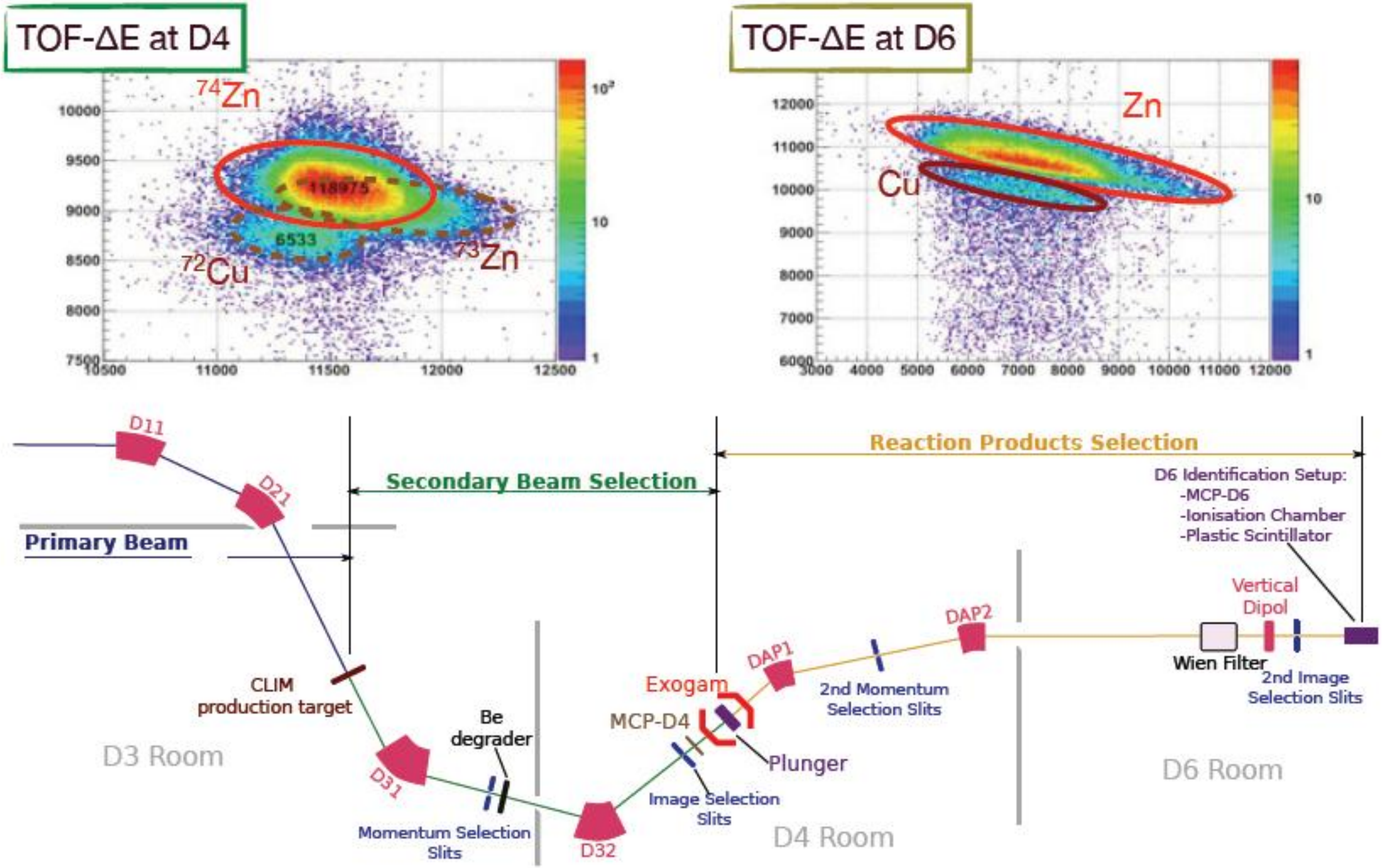
^{9}Be 580 µm

target : CD_2 35.5 mg/cm^2
degrader : ^{9}Be 290 µm

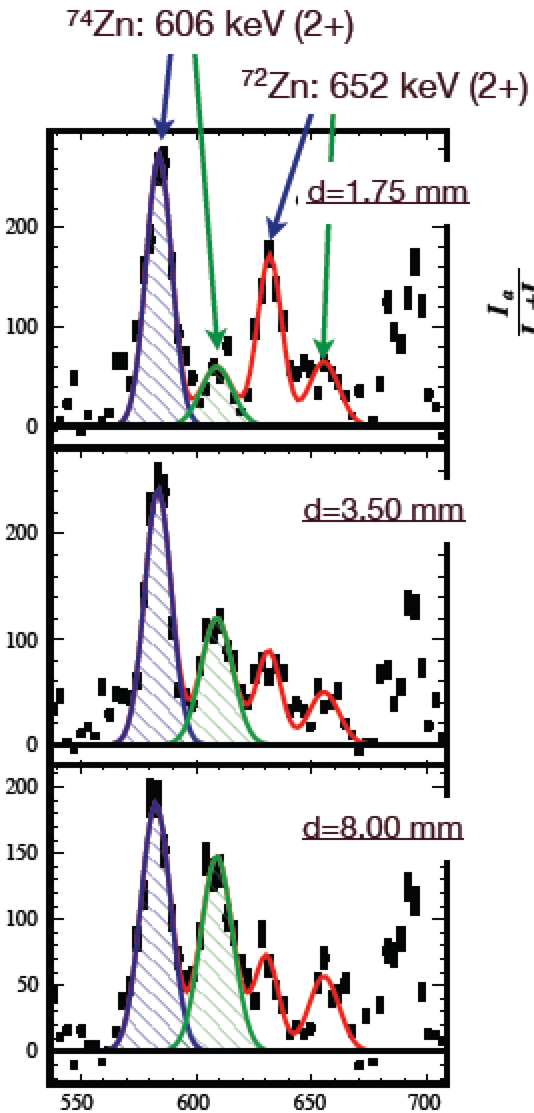
ΔE-E (CHIO+Plastic)
for the particle identification

secondary beam
$^{74,73}Zn$ 35.4 MeV/A, 1.0x10^5 pps

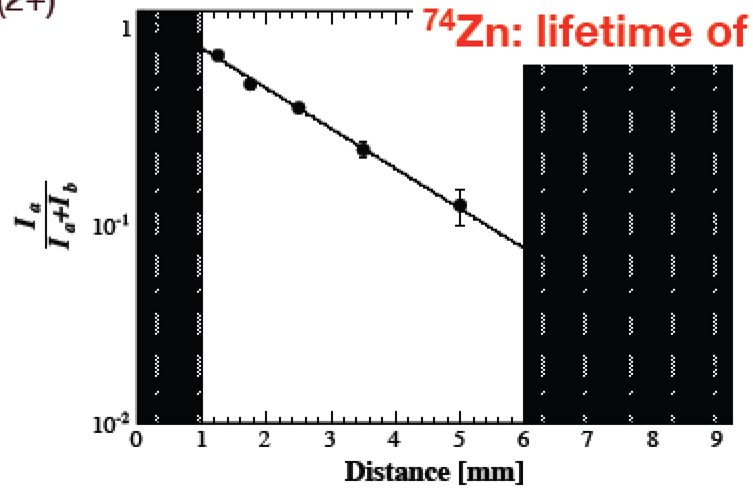
Particle identification for beam and recoils

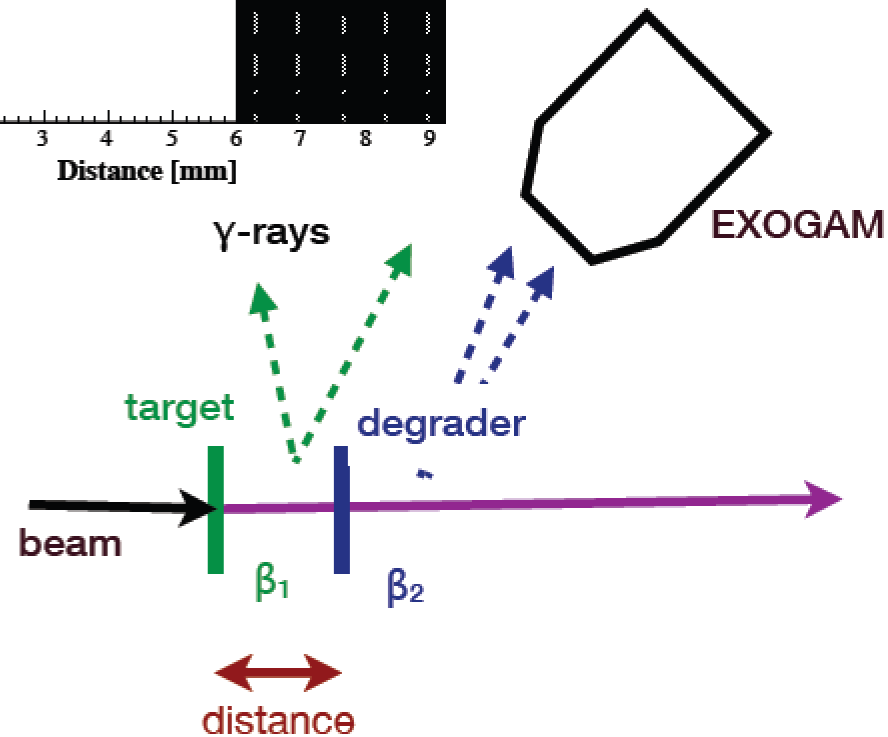


Recoil-distance Doppler-shift method



^{72}Zn: lifetime of 2+ = 17.9(18) ps
^{74}Zn: lifetime of 2+ = 27.0(24) ps





Results and comparisons with other experiments

Lifetime measurement (present work)

- ^{72}Zn: lifetime 17.9(18) ps = 385(39) e^{2}fm^4
- ^{74}Zn: lifetime 27.0(24) ps = 370(33) e^{2}fm^4

B(E2:2$^+$→0$^+$) from Coulomb excitation experiments

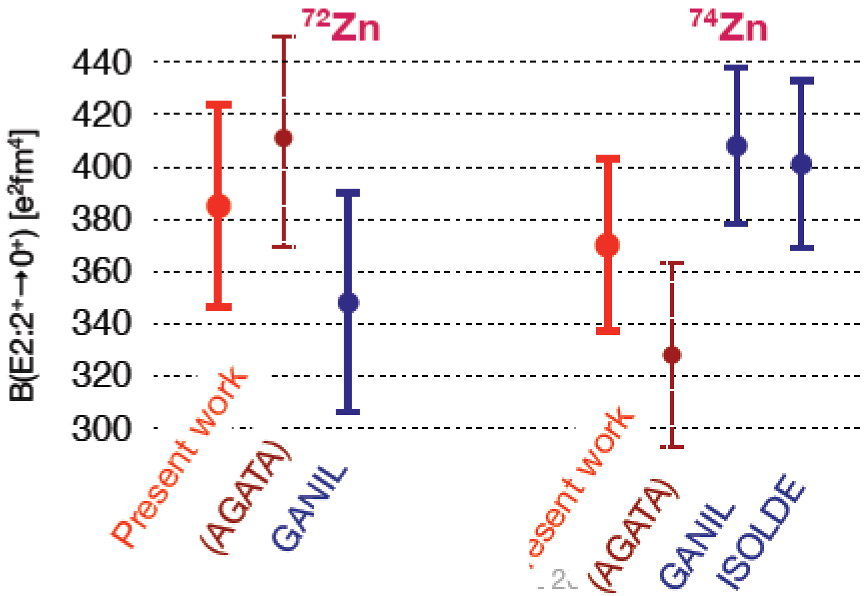
- ^{72}Zn at GANIL : 348(42) e^{2}fm^4 S.Leenhardt et al., EPJA 14 (2002) 1
- ^{74}Zn at GANIL : 408(30) e^{2}fm^4 O. Perru et al., PRL **96** (2006) 232501
- ^{74}Zn at ISOLDE : 401(32) e^{2}fm^4 J. Van de Walle et al, PRC **79** (2009) 014309

intermediate energy Coulex

low energy Coulex

Lifetime measurement with AGATA demonstrator

- ^{72}Zn: lifetime 16.8(17) ps, ^{74}Zn: lifetime 30.5(33) ps



Comparisons with low-energy Coulex experiment

Additional information on the sign and magnitude of the quadrupole moment could be obtained by combining lifetime measurements of the 2^+ state and the data in Fig. 9.

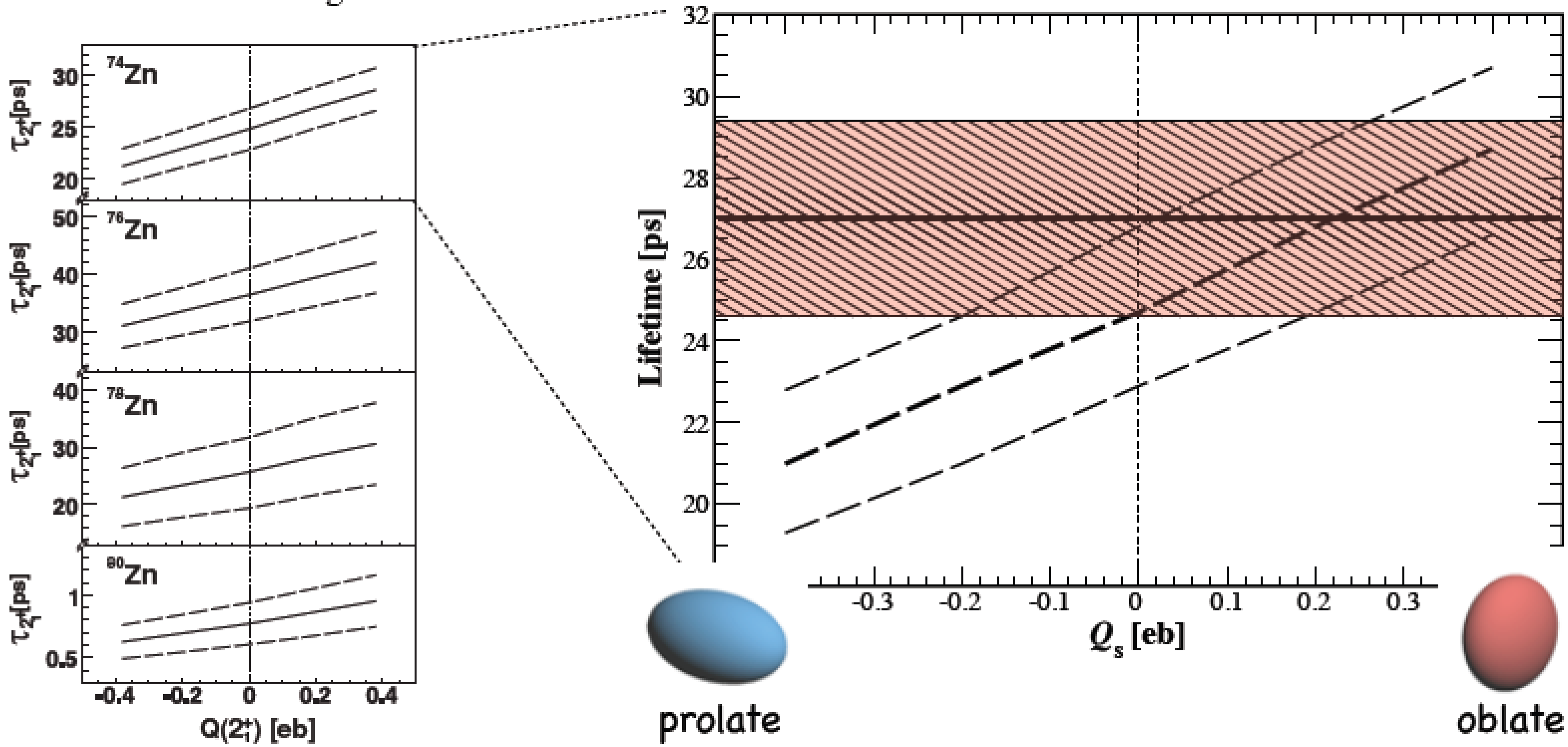


FIG. 9. Dependence of the experimental $\tau_{2_1^+}$ values on the fixed sign and magnitude of quadrupole moment ($Q_{2_1^+}$) in GOSIA2. The dashed lines indicate the error bars associated with the lifetimes.

Q_s = +0.22(30) eb
→ oblate?

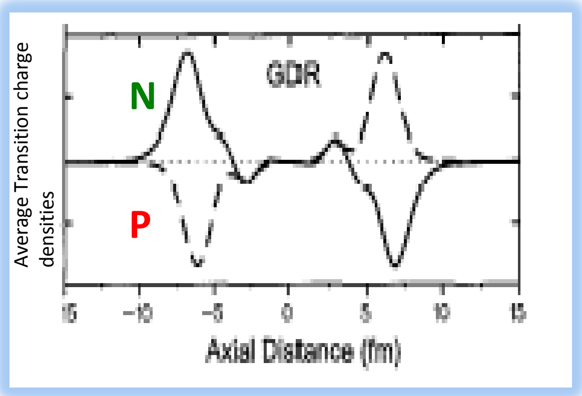
J. Van de Walle et al, PRC 79 014309 (2009)

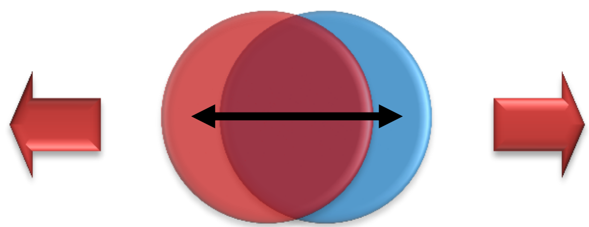
What is the nature of PDR in nuclei ?

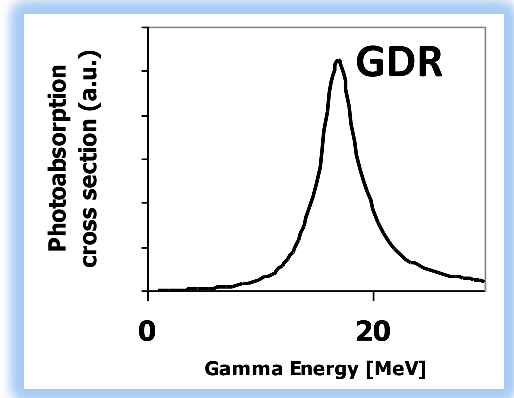
I. Matea et al.

Giant Dipole Resonance ($\Delta L = 1$; $\Delta s = 0$)

- E1 excitation dominated by IVGDR – Collective oscillation of neutrons against protons
- very general phenomenon, well studied in stable nuclei
- more fragmented in light nuclei, Lorentzian shape in heavier spherical nuclei
- excitation energy given by : $E_x \sim 31.2\, A^{-1/3} + 20.6\, A^{-1/6}$ MeV and widths from 2.5 to 5 MeV





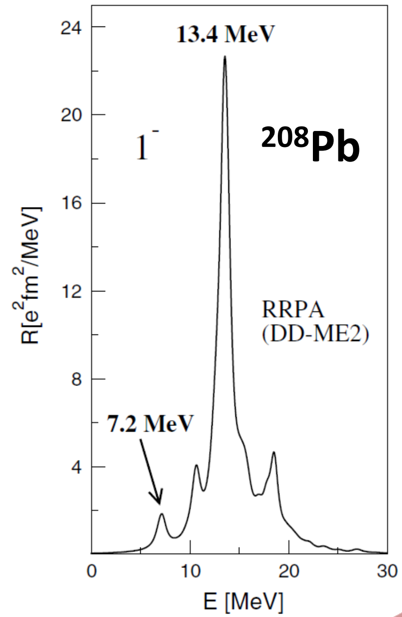


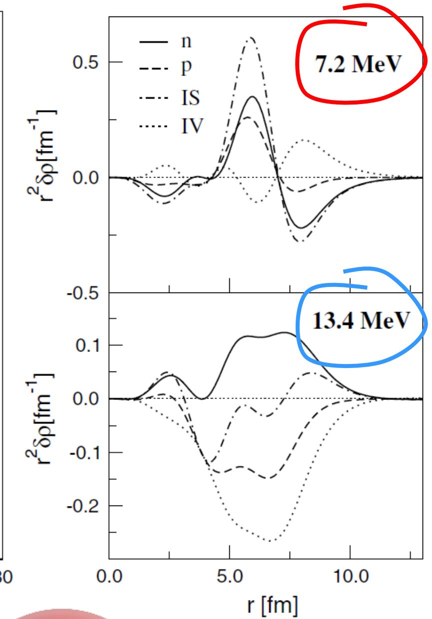
However, a small fraction of the E1 strength (~1% in stable nuclei) is located below IVGDR (5-10 MeV). The dynamics of the low energy part of the E1 strength varies from light to heavy nuclei, and from stable to neutron(proton) rich nuclei.

In medium heavy and heavy (very) neutron rich nuclei, this “soft mode”, called Pygmy Dipole Resonance (PDR), is often associated with the (collective) oscillation of the neutron skin against the isospin saturated core.

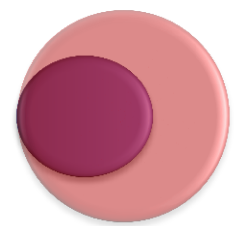
Pygmy Dipole Resonance (PDR)

- Observed in stable heavy nuclei (e.g., ^{208}Pb)
- The dynamic of this mode is very different from the dynamic of the IVGDR:
  - ✓ Proton and neutron transition densities are in phase in the bulk of the nucleus
  - ✓ Only neutron excitation contribute to the transition density in the surface region

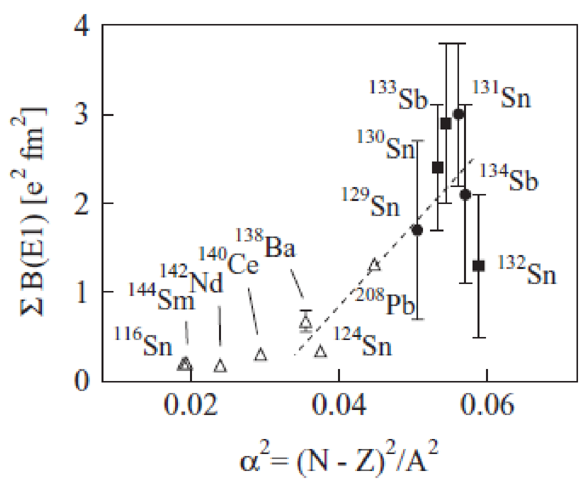




The amplitude of PDR main resonance represents a coherent superposition of many neutron ph configurations.



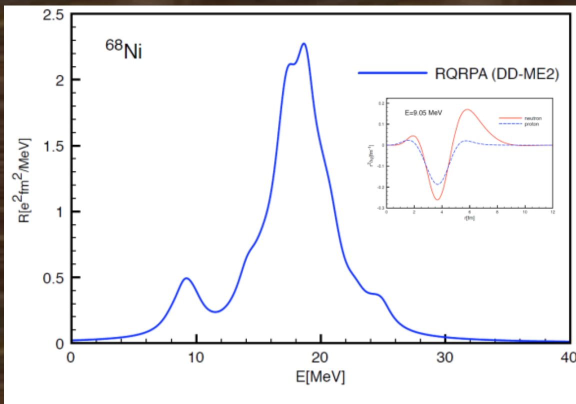
- Its nature is <u>predominantly isoscalar</u> (neutrons and protons oscillate in phase).
- Investigated experimentally only in few radioactive nuclei like ^{20,22}O, ^{26}Ne, ^{68}Ni, $^{129-132}$Sn, ^{133,134}Sb. The PDR strength seems to be higher in unstable nuclei that in the stable ones.



The case of ^{68}Ni

Theoretical predictions:

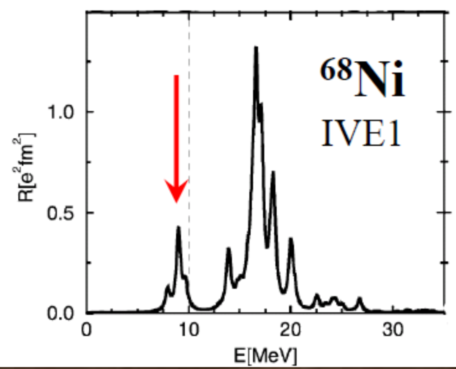
Different models give similar predictions in terms of collectivity, strength and line shape of the PDR



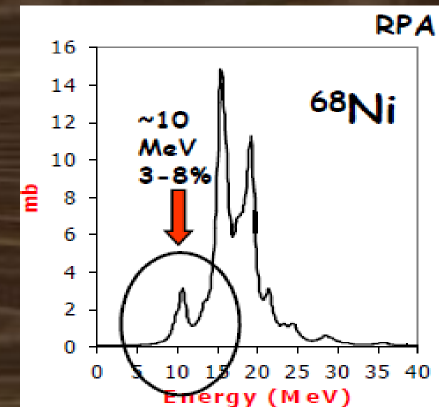
RQRPA (DD-ME2)
N.Paar – private communication

9.0 MeV, 4.3 % EWSR

$1f_{5/2} \to 2d_{5/2}$	0.261
$2p_{3/2} \to 2d_{5/2}$	0.229
$1f_{7/2} \to 1g_{9/2}$	0.113
$2p_{1/2} \to 2d_{3/2}$	0.103
$1f_{5/2} \to 2d_{3/2}$	0.100
$2p_{3/2} \to 3s_{1/2}$	0.082
$2p_{1/2} \to 3s_{1/2}$	0.014
$1f_{5/2} \to 1g_{7/2}$	0.010
$1f_{5/2} \to 2d_{3/2}$	0.003



RRPA
D.Vretenar et al., Nucl.Phys.A692 (2001)



RPA
G.Colo – from A. Bracco presentation, Trento (2009)

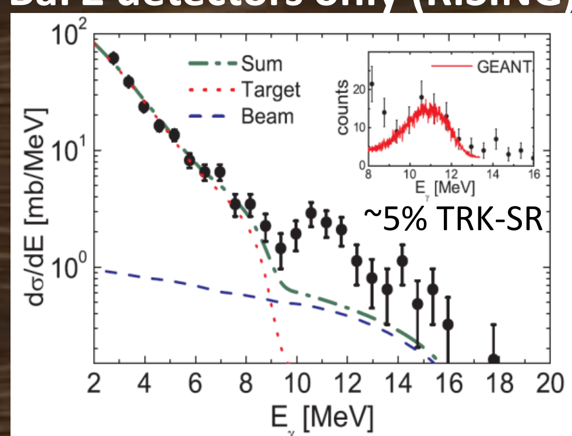
Experimental evidence:

- at GSI, ^{68}Ni@600 MeVA
- by Coulomb excitation
- measured (γ^*, γ') within RISING campaign
- measured (γ^*, n) with LAND array

Deduced

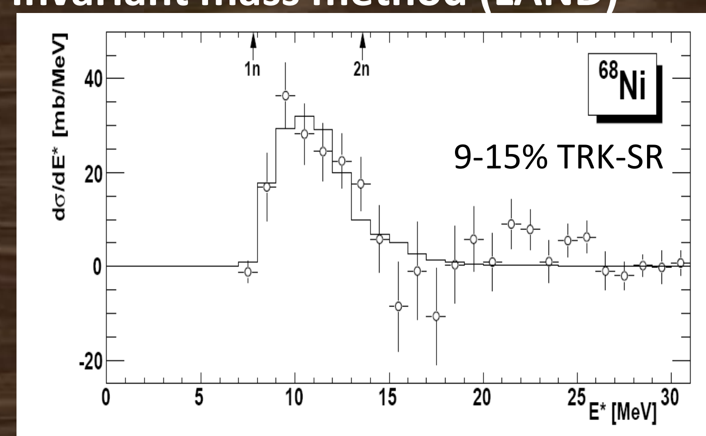
$R_{\gamma 0} \cong 0.02$ to 0.04

BaF2 detectors only (RISING)



O.Wieland et al., Phys.Rev.Lett.102 (2009)

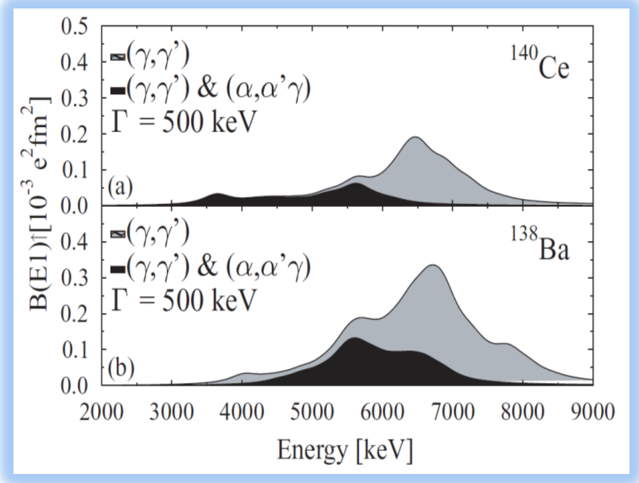
Invariant mass method (LAND)



K.Boretzky – Eurisol-Catania 2009

Motivation:

- **what is the nature of the PDR in 68Ni ?**
  - the only measurements of PDR in ^{68}Ni were made using electromagnetic probes
  - using different probes, the excitation mechanism can change and, consequently, the excitation cross sections of the low lying E1 strength could change
    (as seen in ^{140}Ce and ^{138}Ba – J.Endres et al., Phys.Rev.C80 (2009))



Up to now, no attempt has been done in this direction for unstable nuclei

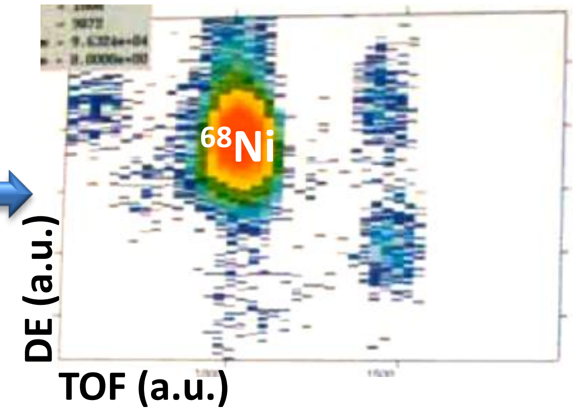
- **How we plan to do it ?**
  - measure the cross section distribution of dipole modes as function of excitation energy for the two probes.

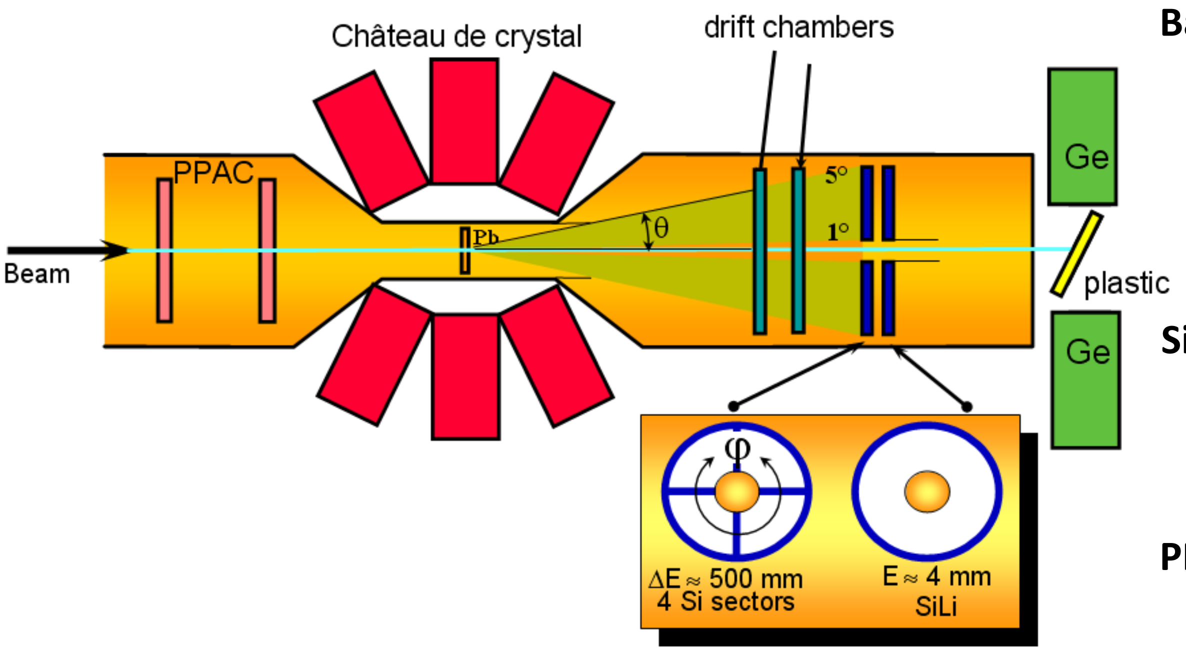
  - microscopic calculations will provide the proton and neutron transition densities that will be injected into a reaction code (ECIS or FRESCO for inelastic channel and for coulomb excitation channel) to obtain calculated cross sections.

  - **analyzing the proton/neutron contributions to the calculated individual states composing the PDR, the nature of PDR as a function of excitation energy in ^{68}Ni can thus be investigated** (similar to what was done for ^{140}Ce and ^{138}Ba – N.Paar et al., Phys.Rev.Lett. 103 (2009))

Experimental details

- $^{70}Zn^{28+}$ beam at 62.5 MeV/u and 1.5 µAe on Beryllium target (500 µm) ⟶ 71000 ^{68}Ni / sec (measured)
- In the last experiment on ^{68}Ni using LISE spectrometer (E507), the contaminants were less than 10%
- Coulomb excitation on 315 mg/cm2 Pb target ($\theta_{gr} \cong 5°$)
- Inelastic scattering on 160 mg/cm2 C target ($\theta_{gr} < 1°$)





BaF2 Château de Cristal:

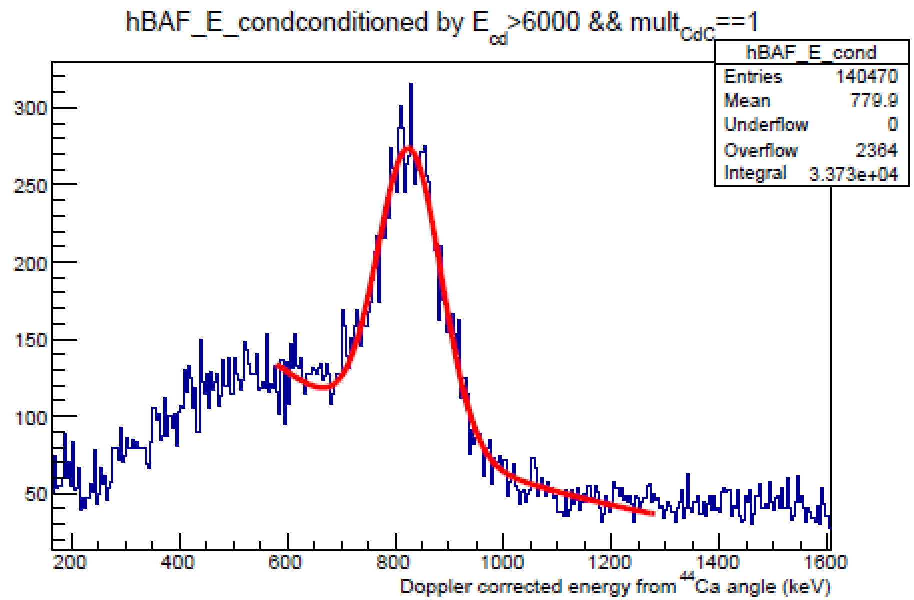
- 74 detectors at ~ 20 cm from target
- Coverage of more than 80% of 4pi
- very good n-gamma discrimination
- 400 keV resolution at 10 MeV
- efficiency around 3% at 10 MeV

Si-SiLi CD telescope:

- for HI detection and selection of Coulex/nuclear reaction channels

PPAC + drift chambers:

- ion trajectory reconstruction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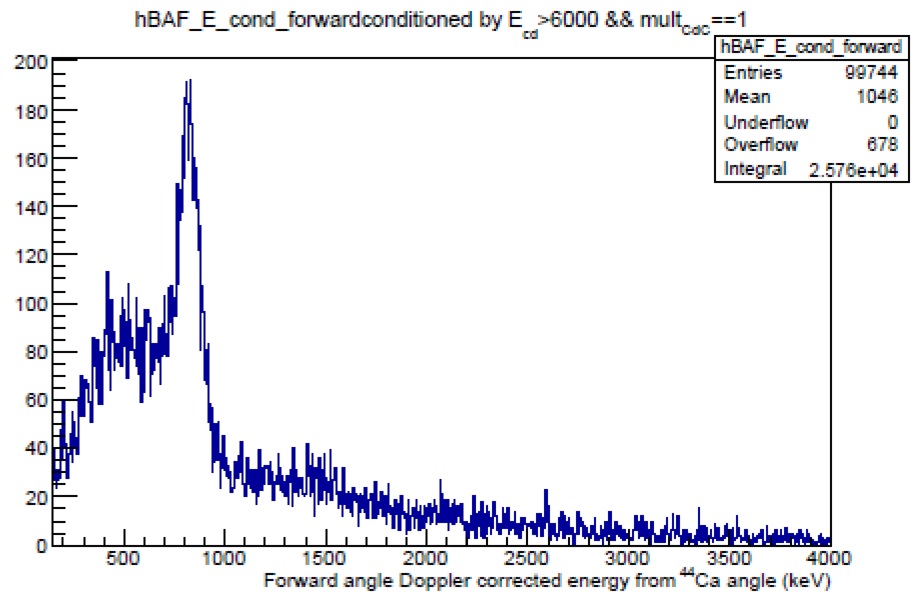
hBAF_E_cond
Entries 140470
Mean 779.9
Underflow 0
Overflow 2364
Integral 3.373e+04
300
250
200
150
100
50
200
400
600
800
1000
1200
1400
1600
Doppler corrected energy from 44Ca angle (keV)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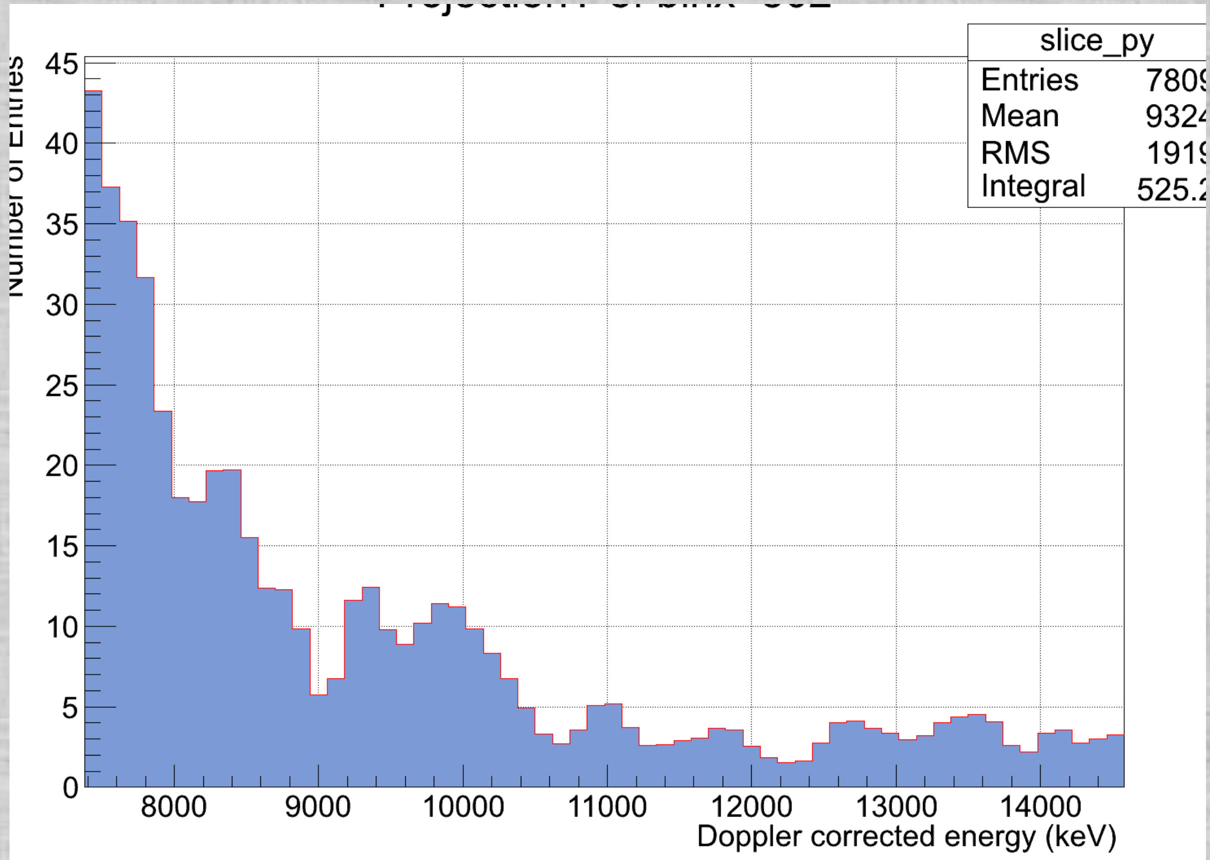
Entries 99744
Mean 1046
Underflow 0
Overflow 678
Integral 2.576e+04
200
180
160
140
120
100
80
60
40
20
0
500
1000
1500
2000
2500
3000
3500
4000
Forward angle Doppler corrected energy from 44Ca angle (keV)


slice_py
Entries
Mean
RMS
Integral
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40
35
30
25
20
15
10
5
0
8000
9000
10000
11000
12000
13000
14000
Doppler corrected energy (keV)

Experiments at ALTO and the tandem **(inauguration of ALTO)**

Experiments at the Krakow and Warsaw cyclotrons

Spectroscopy NE : using IF and MNT reactions.

Experiments at S3 (GANIL/SP2)

Training of future Accelerator physicists and engineers