Coulomb Excitation Studies

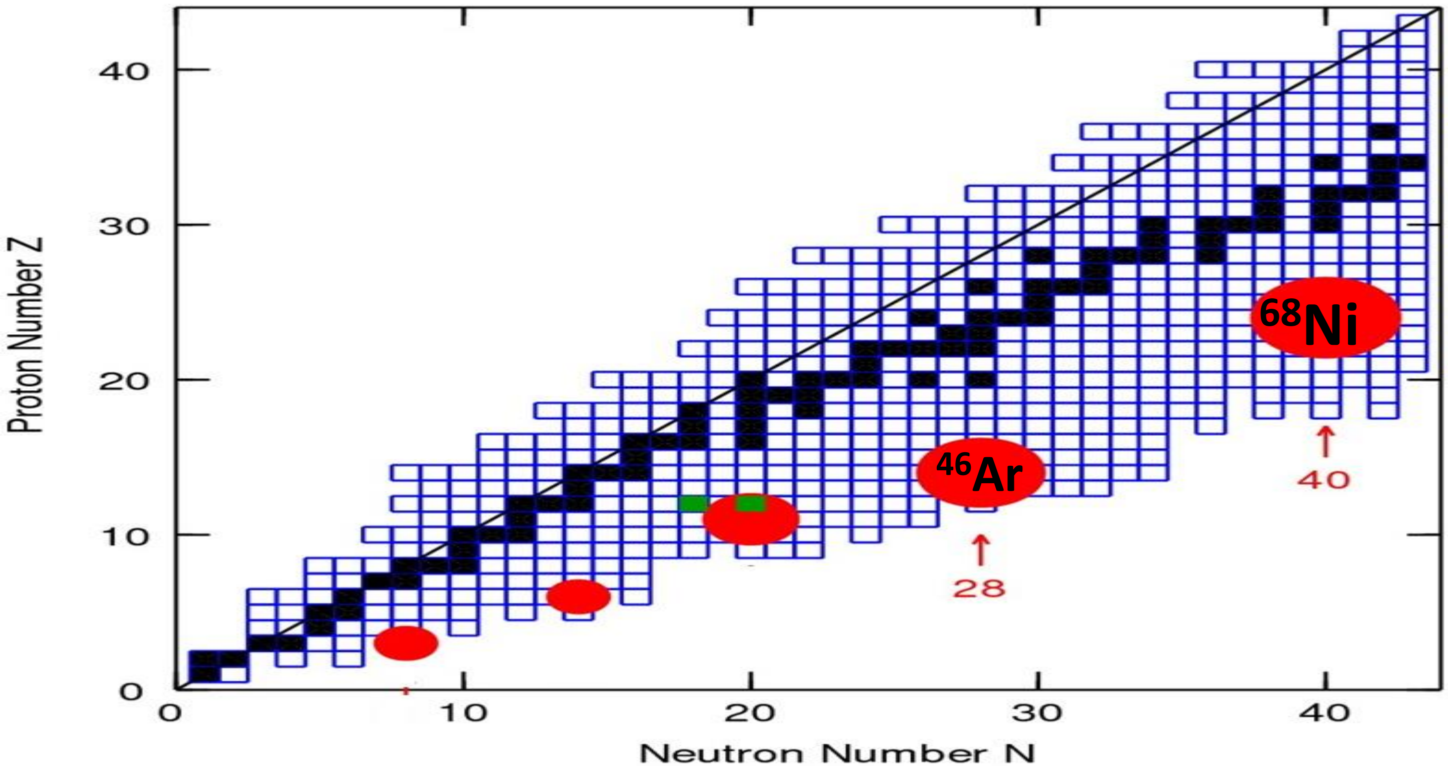
I) Study of ^{44}Ca, ^{46}Ar and ^{43}S through Coulomb excitation at Intermediate energies

S Calinescu, O. Sorlin *et al*. –GANIL, IFIN-HH ..

II) Study of magicity and pygmy dipole resonance in the neutron-rich ^{68}Ni

I. Matea, S Calinescu *et al*. – IPN ORSAY, GANIL, IFIN-HH

III) Future plans

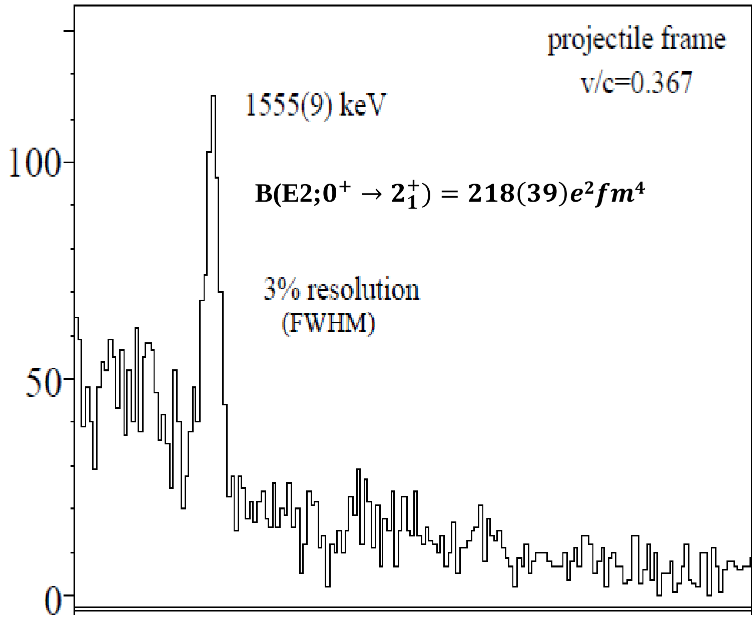


Magicity at N=28: ^{46}Ar

Coulomb excitation:

$B(E2; 0^+ \rightarrow 2_1^+) = 196(39) e^2 fm^4$

H. Scheit et al., Phys.Rev.Lett **77** (1996)

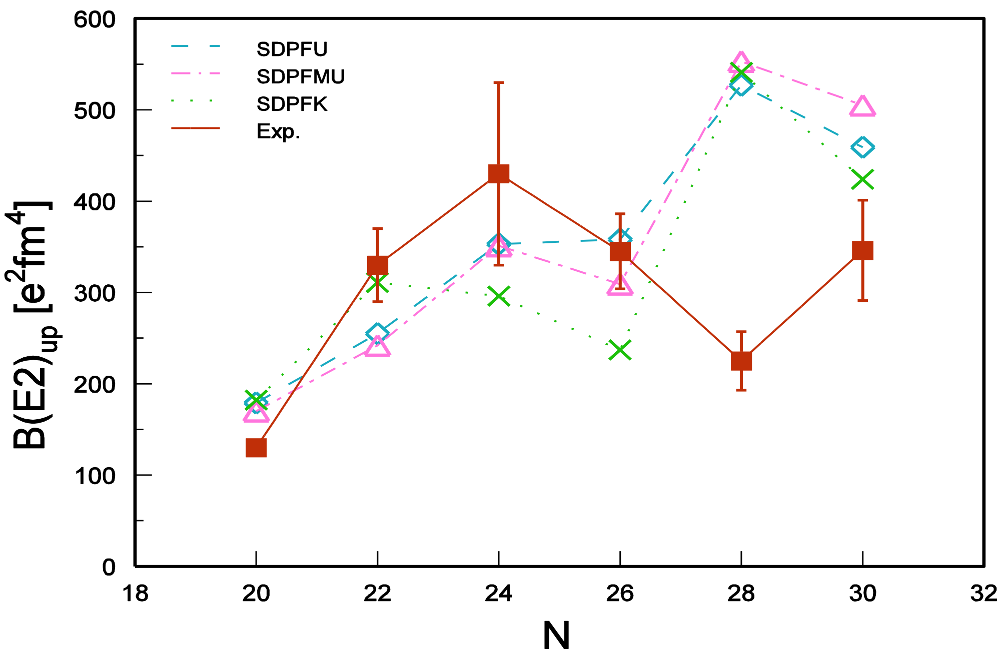


A. Gade et al., Phys. Rev. C 74 (2006)

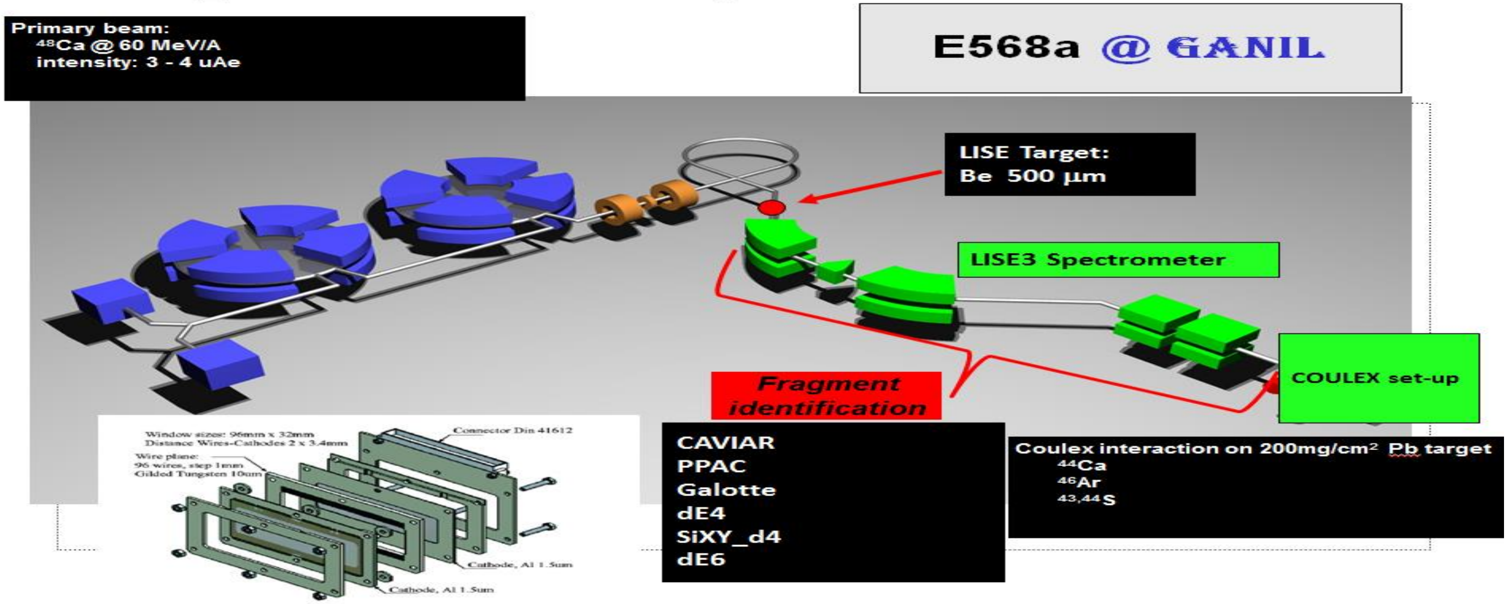
Lifetime measurement

$B(E2; 0^+ \rightarrow 2_1^+) = 570(335) e^2 fm^4$

D. Mengoni et al., Phys.Rev.C 82 (2010)

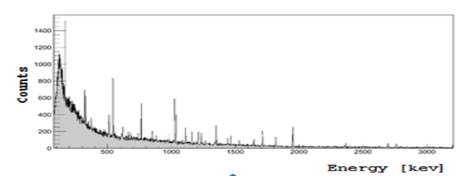


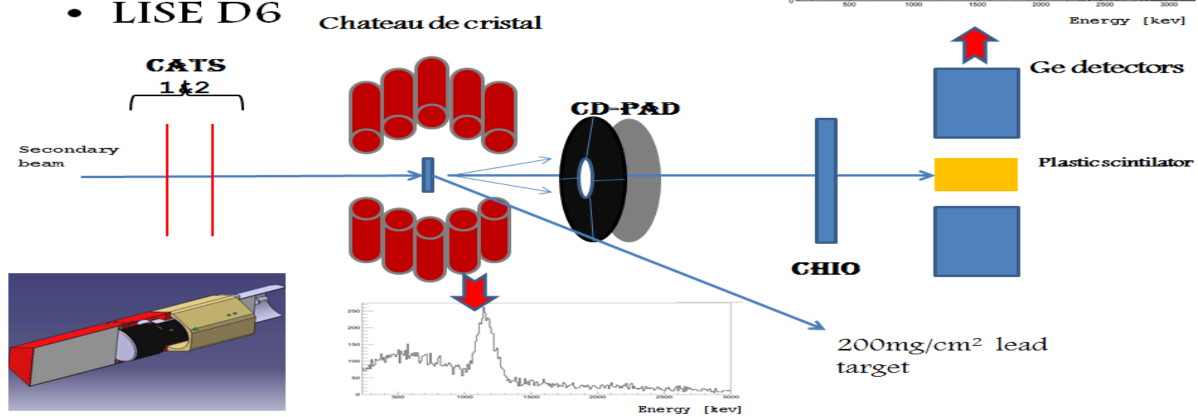
Experimental set–up



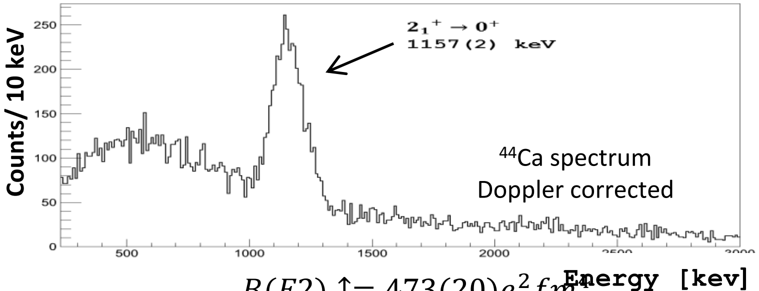
Coulex set–up

- LISE D6



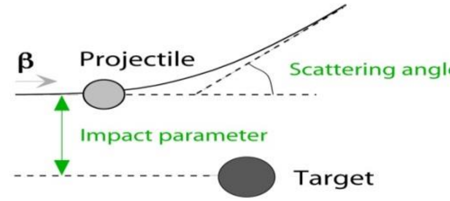


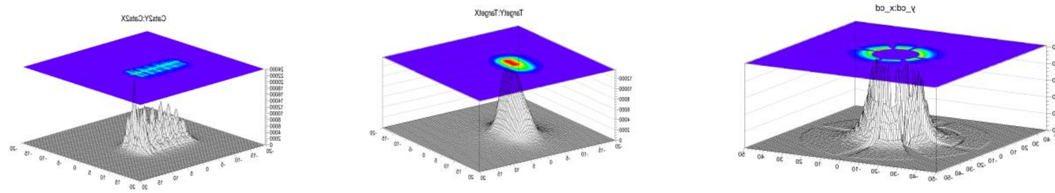
^{44}Ca



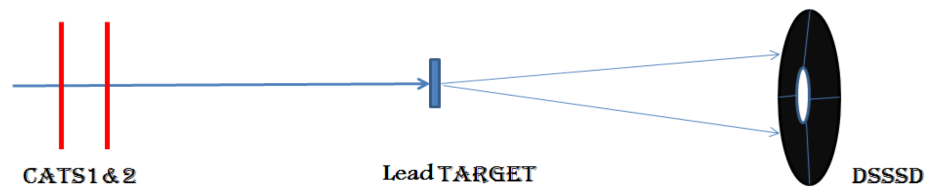
$B(E2) \uparrow = 473(20)e^2 fm^4$

***D. Cline** et al., N. Phys. A 204, 1973. 574*

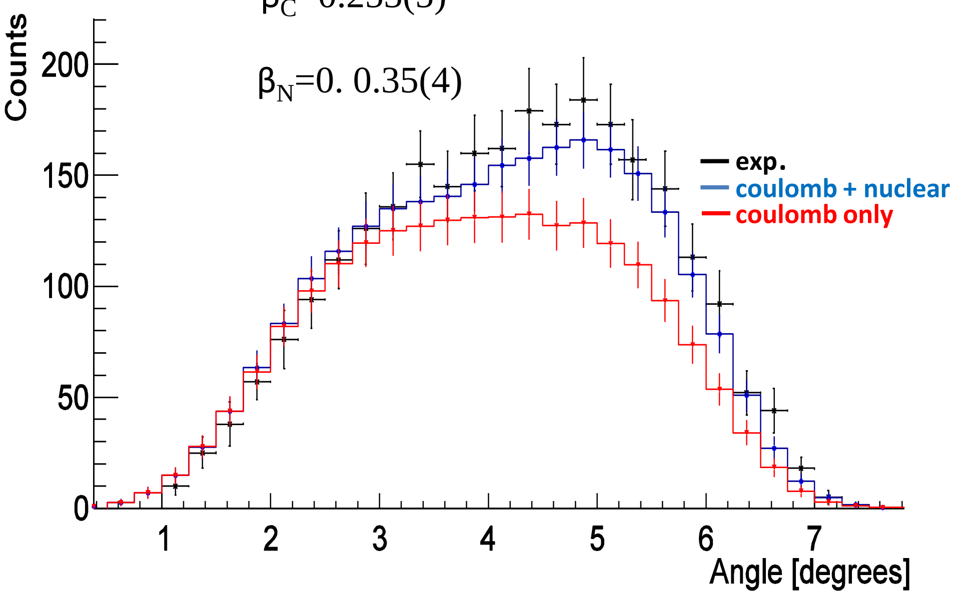




$b_{safe} = R_t + R_p + 6 + \frac{\pi a}{2\gamma}$ =18.4 fm➔ $\theta_{safe} = 4^0$



Absolute cross section measurement



Best fit for safe zone : **B(E2) = 475 (42) e^{2}fm^4**

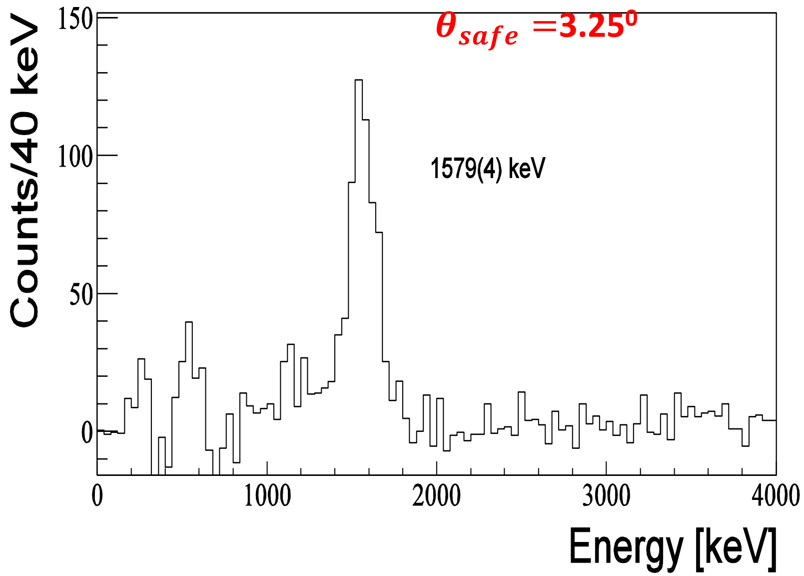
Adopted value in literature : **B(E2) = 473 (20) e^{2}fm^4**

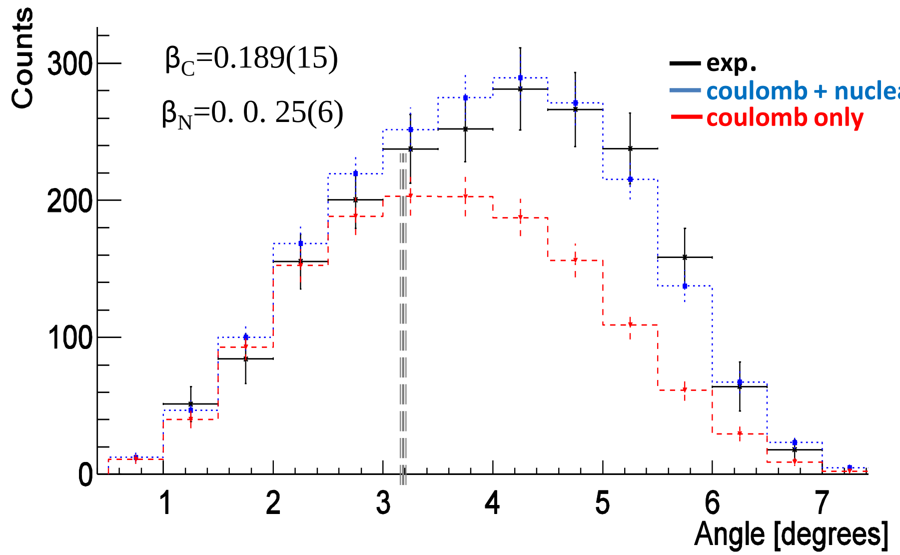
Weighted average value
from *(e,e'), Coulex, DSAM etc.:* **B(E2) = 495(35) e^{2}fm^4**

Very good agreement between the measured value of the B(E2) in this experiment and the adopted value from literature!

^{46}Ar

Extraction of B(E2:0_1^+->2_1^+) in ^{46}Ar from absolute cross section measurement and relative to the known B(E2) in ^{44}Ca

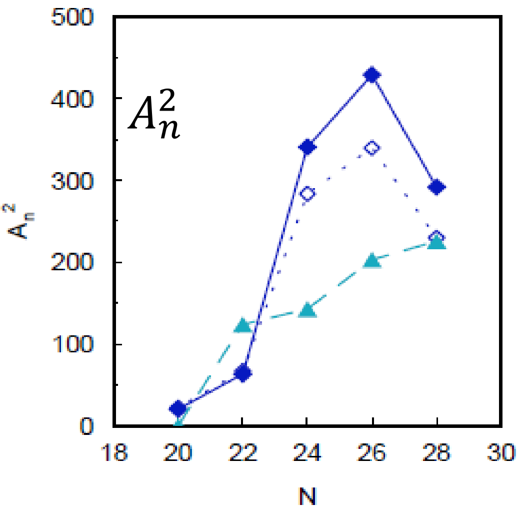


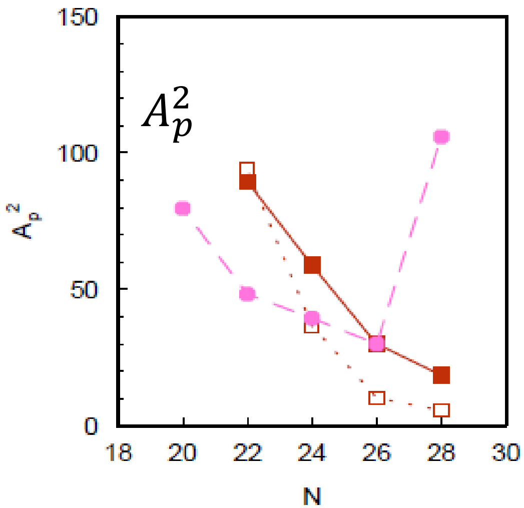


Best fit for safe zone : B(E2) = 225(29) e^{2}fm^4

Relative to ^{44}Ca: B(E2) = 234(19) e^{2}fm^4

In agreement with previous Coulomb excitation measurements





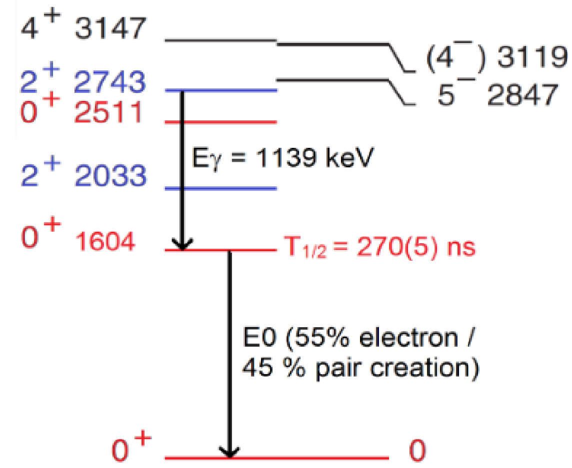
Phys. Rev. C 93, 044333 (2016)

S. Calinescu, L. Caceres, S Grevy, O. Sorlin et al.

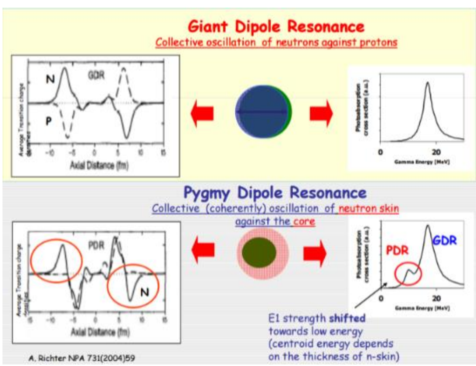
Doubly magic ^{68}Ni ?

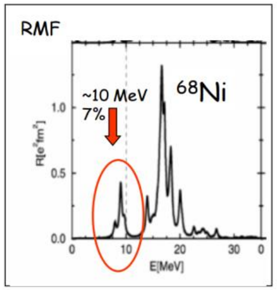
B(E2:0_1^+->2_1^+) = 280(60) e^2fm^4

(O. Sorlin et al.)

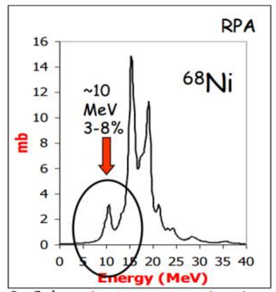


What is the nature of the PDR in ^{68}Ni ?





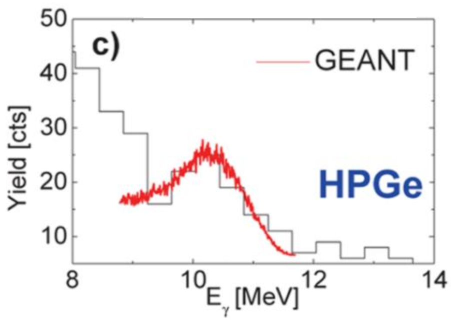
D. Vretnar et al. NPA 692(2001)496



G. Colo private communications

Theoretical predictions

Until now, the only measurements of PDR of in ^{68}Ni were made using electromagnetic probes.



$\Delta R_{n,p}$=0.2(15) fm

GSI ^{68}Ni@600 MeV/A by Coulomb excitation

probes (*O.Wieland et al., PRL 102 (2009)*)

			This work	Literature
GDR	E_m	[MeV]	17.1(2)	17.84
	Γ	[MeV]	6.1(5)	5.69
	S_{EWSR}	[%]	98(7)	100
PDR	E_m	[MeV]	9.55(17)	11.0(5)
	σ	[MeV]	0.51(13)	<1
	S_{EWSR}	[%]	2.8(5)	5.0(1.5)

$\Delta R_{n,p}$=0.17(2) fm

D. M. Rossi et al., PRL 111, 242503 (2013)

Content

Low-energy

Coulomb excitation of ^{70}Zn and doubly magic(?) ^{68}Ni on a 220 mg/cm^{2} ^{208}Pb target

- B(E2) values
- β_n

High energy

^{68}Ni on electromagnetic (Pb) and nuclear probes (CH_2, C) @ 47MeV/A

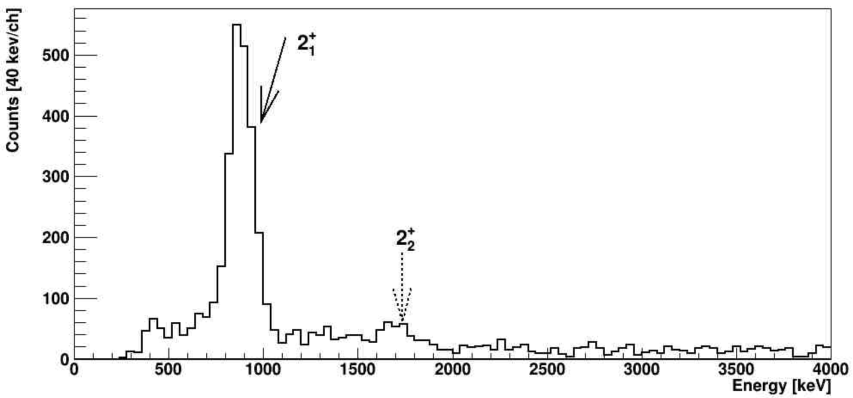
- Nature of PDR in ^{68}Ni ??

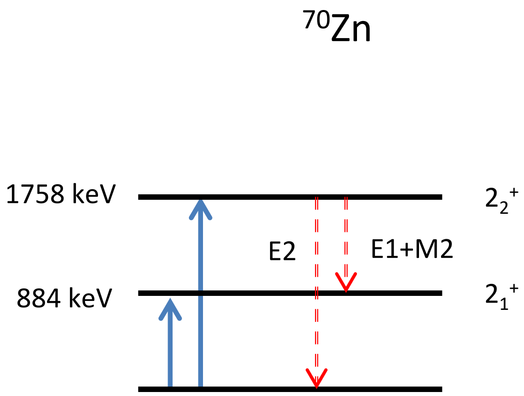
^{70}Zn data analysis

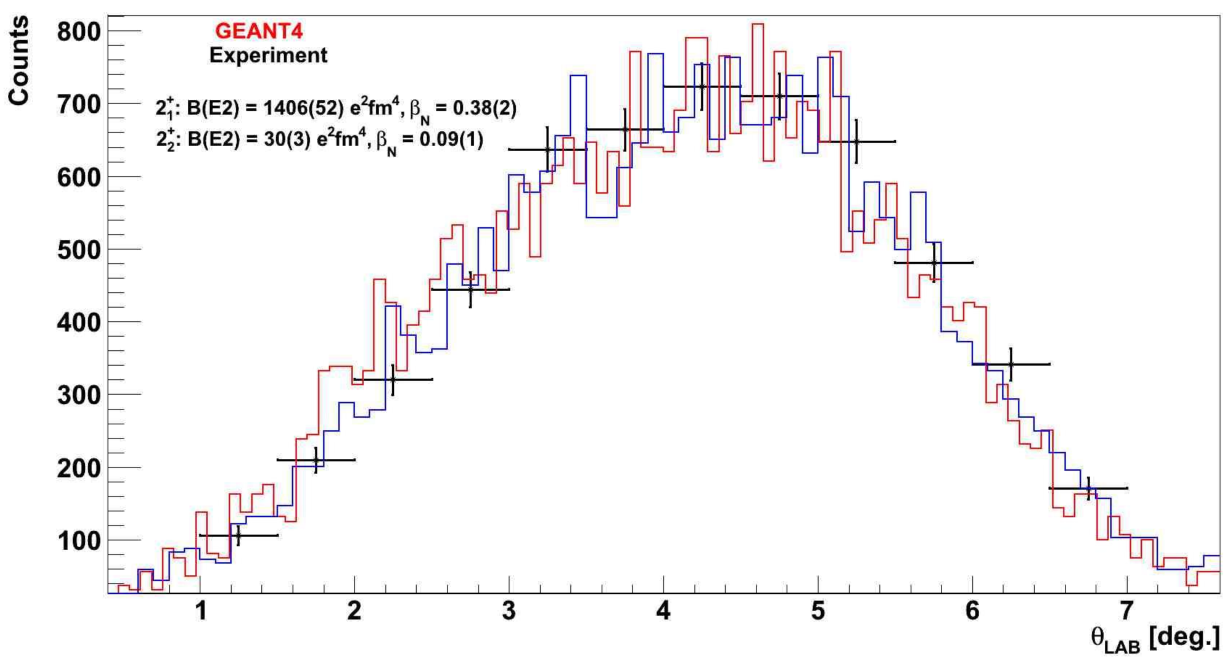
θ_{safe}=3.3^0

$B(E2)\uparrow = 1600(280)e^2fm^4$

O. Sorlinet *al., PRL 88 (2002)*





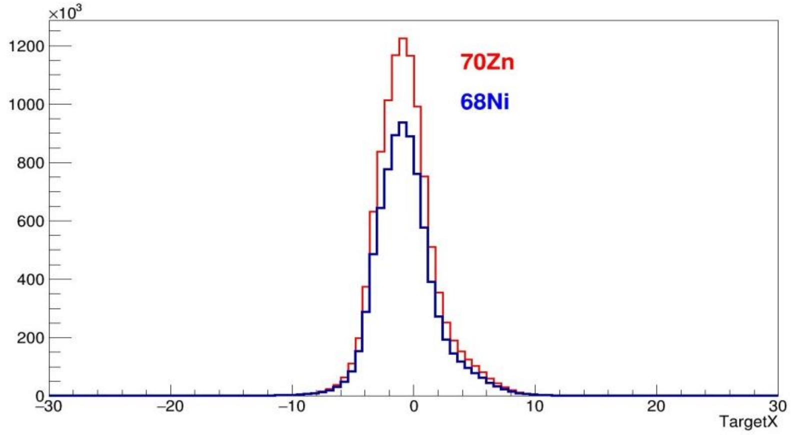


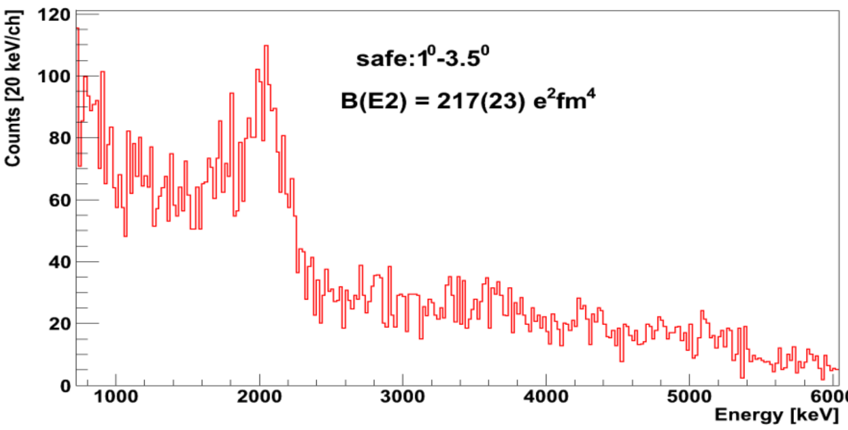
^{68}Ni data analysis

$\theta_{safe} = 3.5^0$

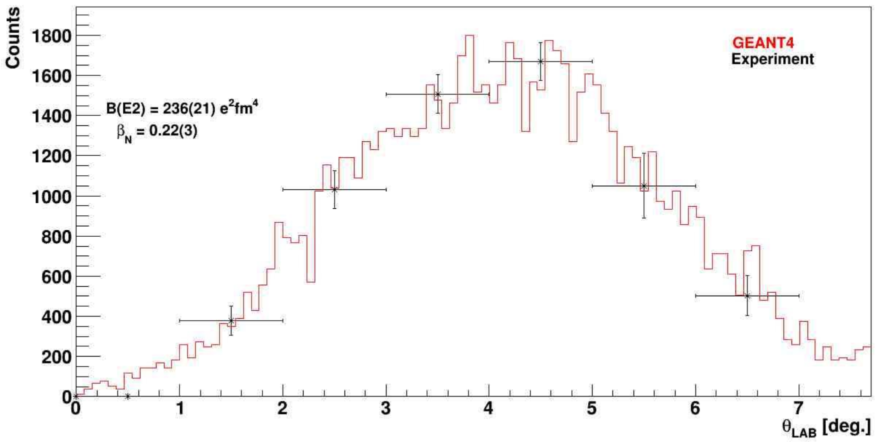
1) Extraction of the B(E2:$0_1^+ \to 2_1^+$) in ^{68}Ni relative to the known B(E2:$0_1^+ \to 2_1^+$) in ^{70}Zn

- ✓ same beam profile requested for all nuclei
- ✓ killed strips for ^{70}Zn in order to have same DSSSD efficiency





2) Extraction of B(E2:$0_1^+ \to 2_1^+$) in ^{68}Ni from absolute cross section measurement

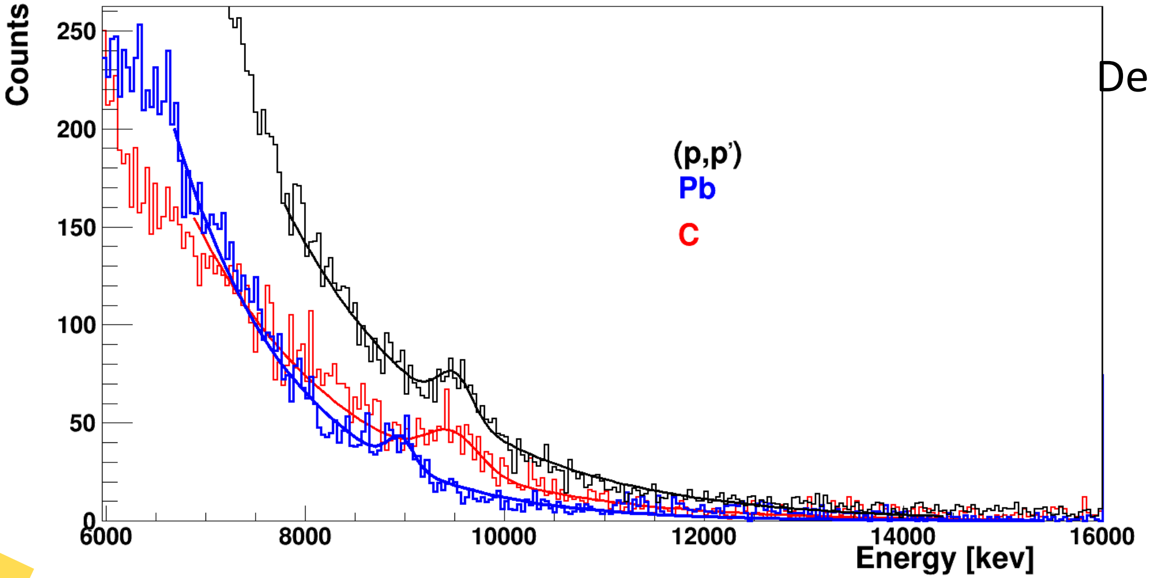


B(E2) = 236(21) e^{2}fm^4

Good agreement with the previous B(E2) measurement of 280(60) e^{2}fm^4.

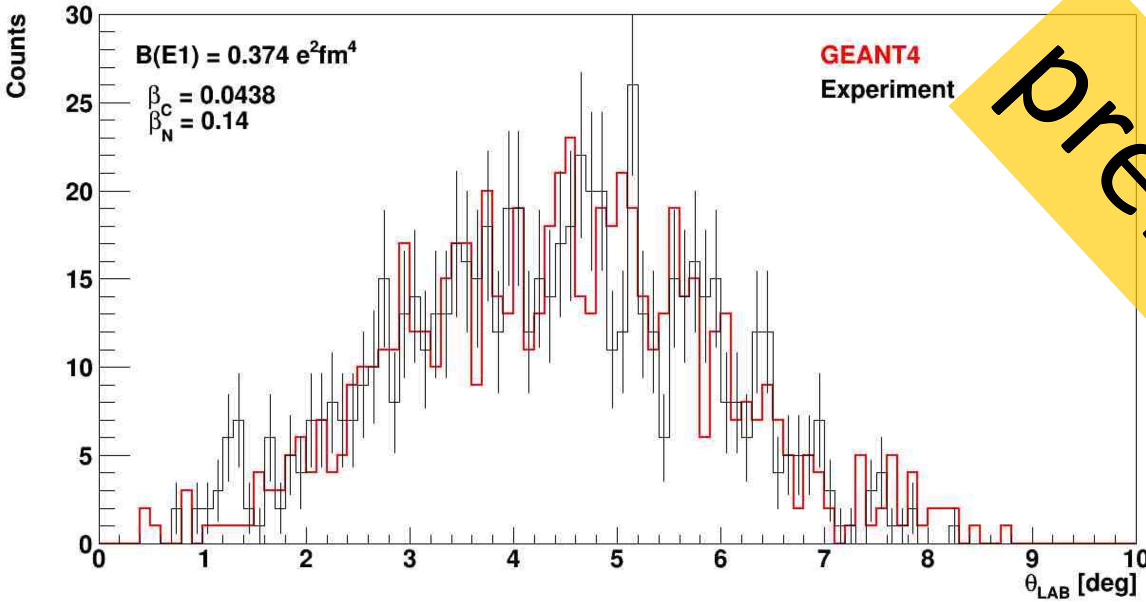
To be submitted

PDR in ^{68}Ni



Depending target response!

Under work



preliminary

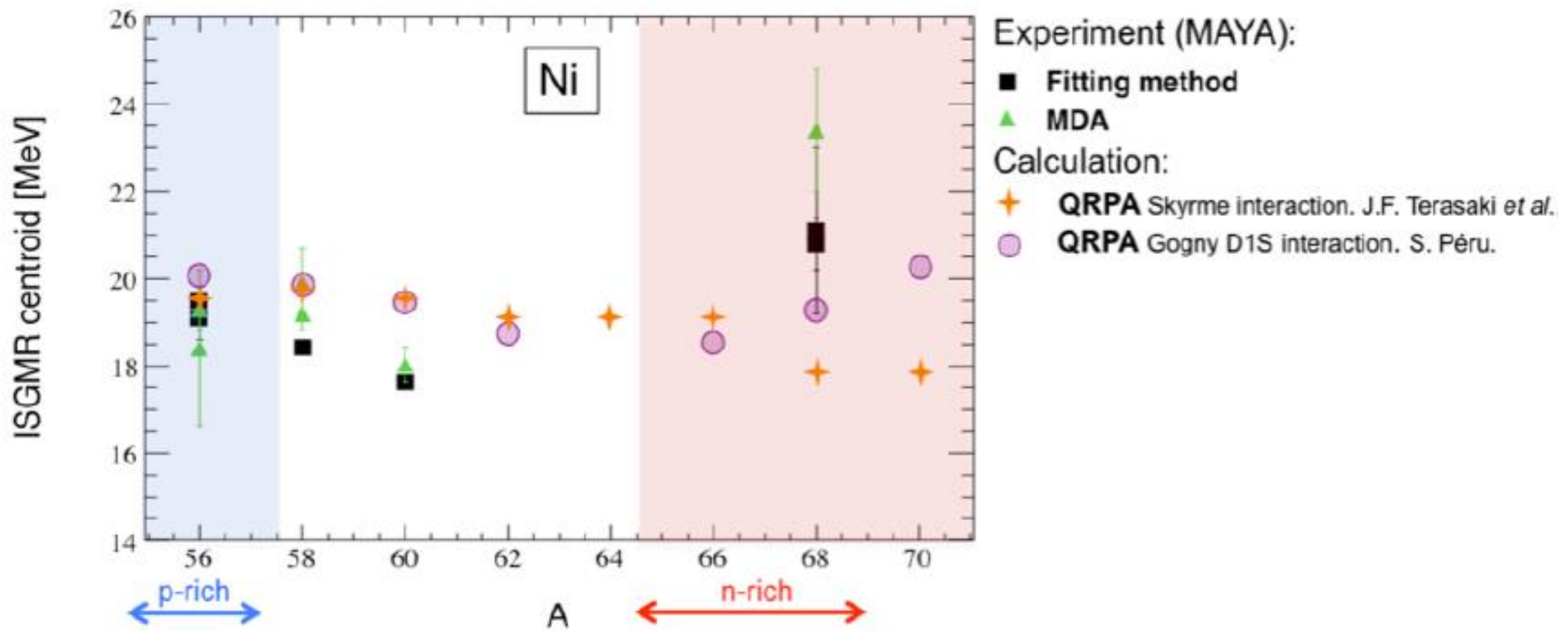
Future Plan

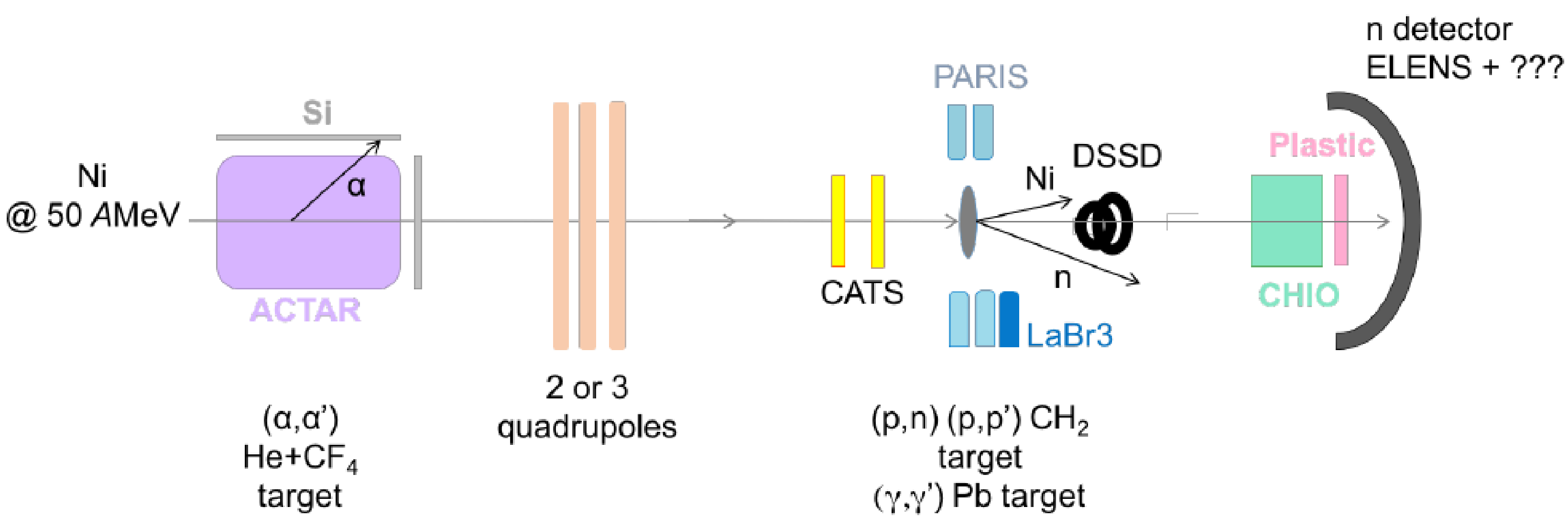
- **M_n/M_p ratio ; model independent B(E2) value**

- **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.**

Next step?

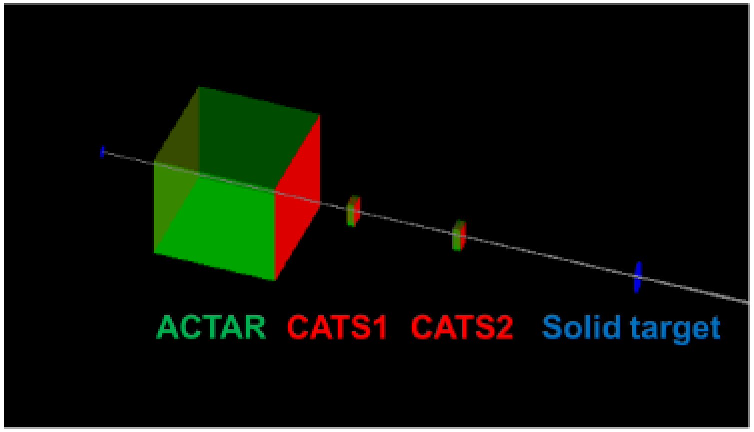
Study of giant and pygmy resonances in exotic nuclei at LISE (LOI)

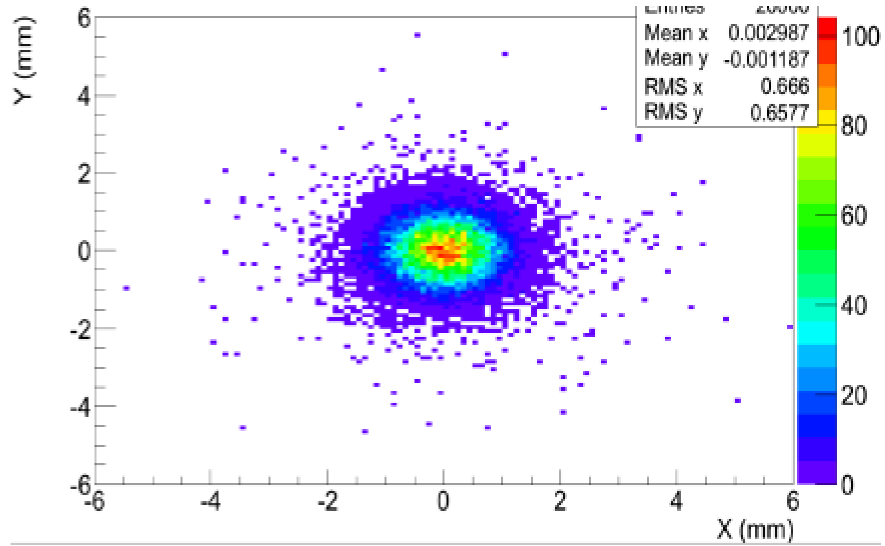




What are the challenges?

1) Beam optics





2) ACQ

➔ run with 2 acquisitions: one for the ACTAR part, and one for the PDR part. Only the zero degree part (CATS, CHIO, Plastics) would be in coincidence with ACTAR event on the one hand, and with PDR event on the other hand. This is a problem that has to be solved for example by having another independent acquisition for the beam detectors and "stamp" the events with the two parts of the experiment.

3) Detectors

ACTAR

- beam of ^{58}Ni at 4MeV/u sent in ACTAR filled with iC4H10 at 100mbar
- The extracted resolution for the elastic peak is around σ = 100keV, meaning one order of magnitude better than what has been obtained previously in the ^{68}Ni(α,α') ^{68}Ni* experiment in 2010 with MAYA (track lengths comparable in the two experiments).
- increasing the granularity of the pads plane an efficiency of around 10% efficiency is expected, according to preliminary simulations
- The cubic chamber is now in construction and would be ready for the ACTAR commissioning experiment middle 2017. The detector should be ready for commissioning experiment middle 2018.
- sides of the ACTAR cubic box will be flexible, allowing to put different kind of Si detectors inside

PARIS

- 8 clusters of PARIS in 2019. At 15cm, it would correspond to a total efficiency of 3%, which is around the same efficiency we got in the e611 experiment with Chateau de Cristal
- PARIS could be completed with LaBr3 detectors

NEUTRON DETECTORS

- ELENS detector would be available in 2019
- 5% efficiency
- More neutrons detectors to increase the efficiency.
- increase target thickness

ToDo List

- Wait some news of Omar Kamalou and Vincent Morel to see if it is possible to have the ACTAR/quadrupoles/CATS… configuration

- Test on the zero degree detection. Is it possible to identify Z and A in nuclei around Ni isotopes?

- Simulation to study the propagation of the beam in the different detectors

- Simulation (p,n) reaction with PARIS and neutron detector

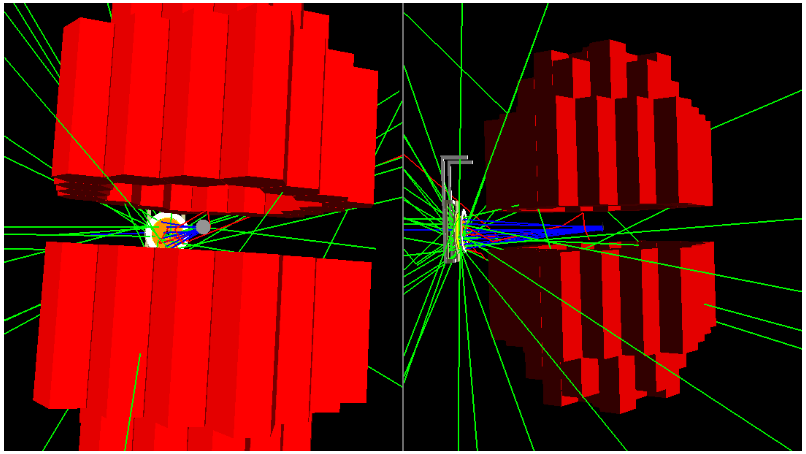
THANK YOU!

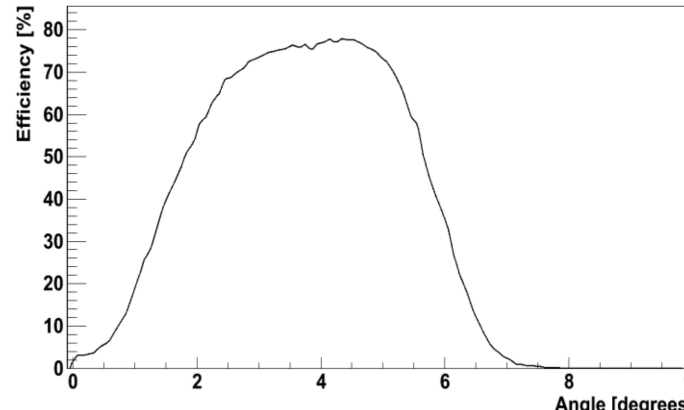
Future Plan

- **M_n/M_p ratio ; model independent B(E2) value**

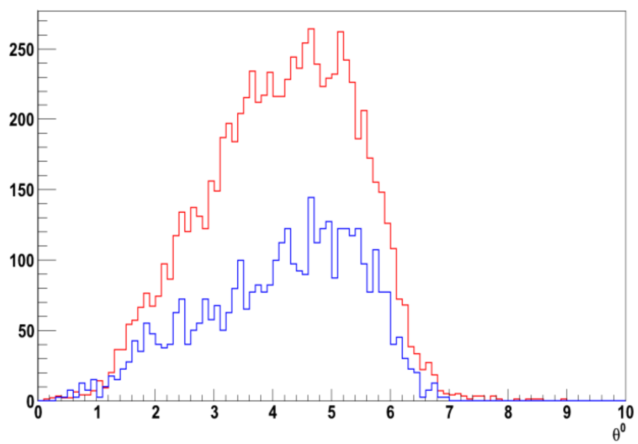
- **microscopic calculations will provide the proton and neutron transition densities that will be injected into a reaction code (ECIS or FRESCO for inelastic channel and for coulomb excitation channel) to obtain calculated cross sections.**

Comparison between experiment and DWEIKO calculation trough GEANT4 simulations

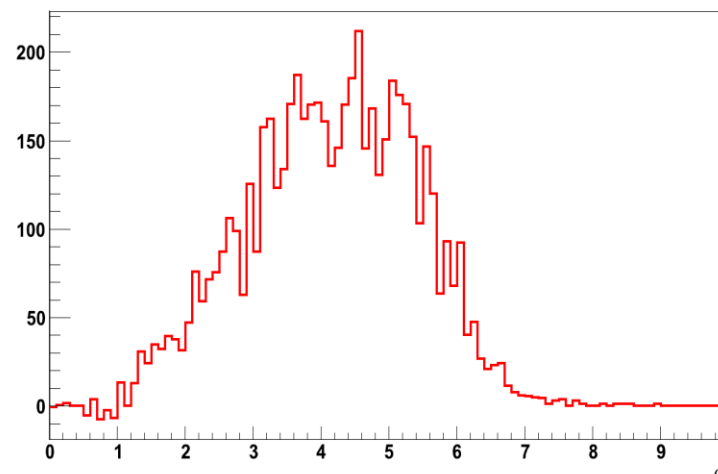




Angular response of DSSSD for the ^{70}Zn scattered nuclei



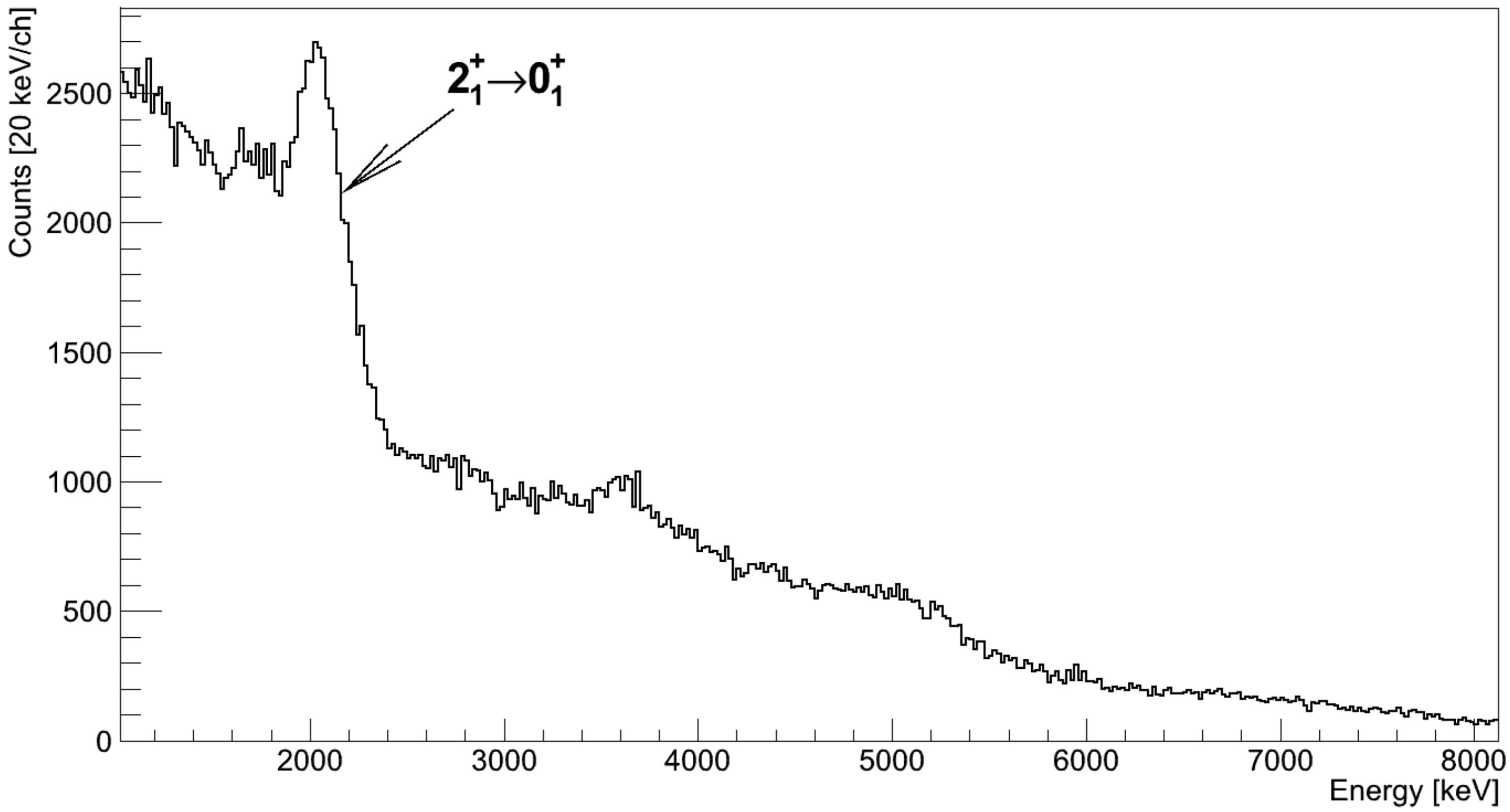
Angular distribution gated by the first 2^+(red line) and gated by the second 2^+ (blue), corrected by BR and corresponding γ-ray efficiency



Angular distribution gated by the first 2^+ from which the contribution of the second 2^+ was extracted)

^{68}Ni data analysis

$\theta_{safe} = 3.5^0$



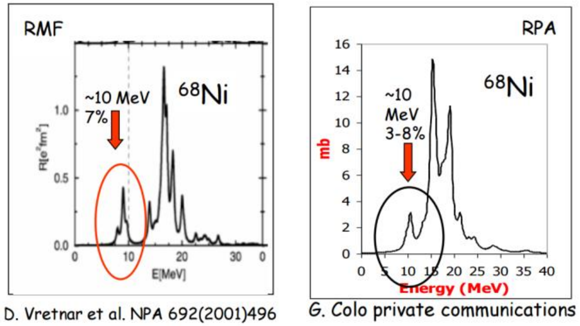
Prompt γ-ray spectra background substracted gated by ^{70}Zn scattered ions

e611 MOTIVATION

➢Pygmy Dipole Resonance (PDR), is often associated with the (collective) oscillation of the neutron skin against the core.
➢ Observed in stable heavy nuclei (e.g., ^{208}Pb)
➢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, $^{129\text{-}132}$Sn, ^{133,134}Sb. The PDR strength seems to be higher in unstable nuclei that in the stable ones.
68Ni.

<u>What is the nature of the PDR in 68Ni ?</u>

➢ 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



Theoretical predictions

Experimental evidence:

@GSI ^{68}Ni@600 MeV/A by Coulomb excitation (*O.Wieland et al., Phys.Rev.Lett.102 (2009)*)
➢ showed evidence of a small peak at 11 MeV
➢ measured (γ*, γ') within RISING campaign
➢ several "issues"

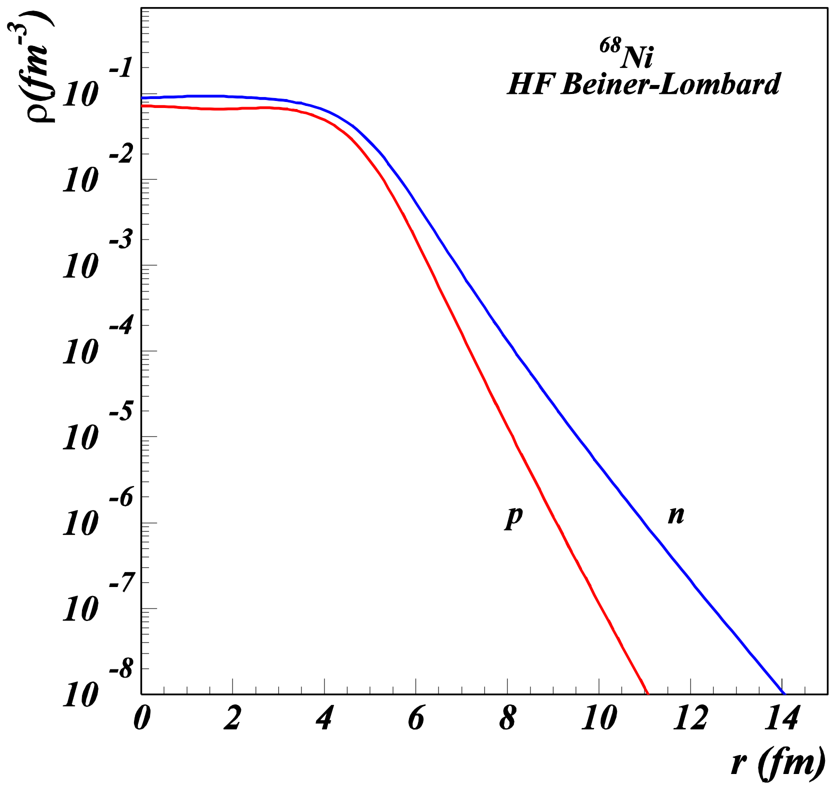
E611 @GANIL using LISE3

- ^{70}Zn^{28+} beam at 70 MeV/u and 1.5 μAe on Beryllium target (500 μm) ➔ 71000 ^{68}Ni / sec (measured)
- Beam purity ~ 87%
- Coulomb excitation on 315 mg/cm2 Pb target ($\theta_{gr} \cong 5°$)
- Inelastic scattering on 160 mg/cm2 C target

Detection : **Château de Cristal**

✓ 74 detectors at ~ 20 cm from target
✓ Coverage of more than 80% of 4pi
✓ high efficiency
✓ very good n-gamma discrimination

HF calculations



r_p= 3.827 fm
r_n=4.029 fm

$\Delta R_{n,p}$=0.2 fm

CdC internal radioactivity evolution during the runs