Search for Pygmy strength at finite temperature

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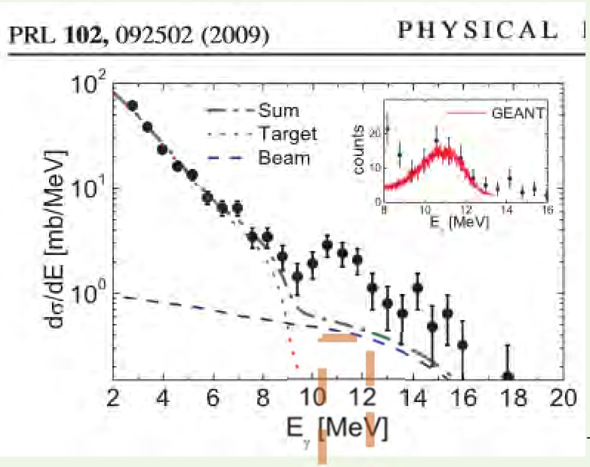
HOT PYGMY STRENGTH at finite temperature

- INTRODUCTION (very brief)
- The experiment
- Analysis
- Results

EXTREME: **It was shown in <u>2004(</u>2009) at GSI and confirmed in 2018 at RIKEN-RIBF that with RVPS <u>at 600*A*MeV</u>**
one can measure successfully **Pygmy-strength** around the threshold **<u>in EXOTIC n-rich Ni NUCLEI !</u>**



O. Wieland et al. PRL 102, 092502 (2009)

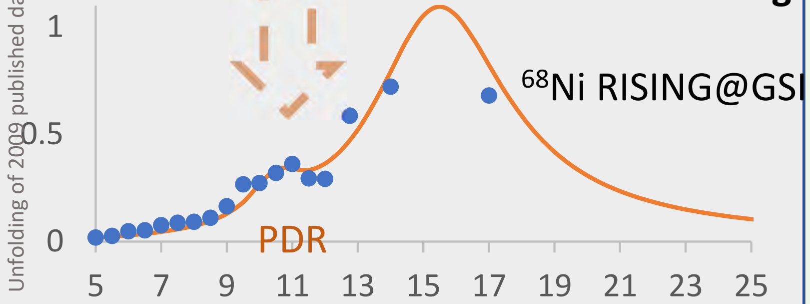
^{68}Ni

EuroBall-HECTOR

$$\frac{d\sigma_{c\gamma}}{dE_\gamma} = RF\left\{\frac{1}{E_\gamma} N_\gamma(E_\gamma)\cdot\sigma_\gamma(E_\gamma)\cdot R_\gamma(E_\gamma)\right\}$$

(γ*,γ‘)

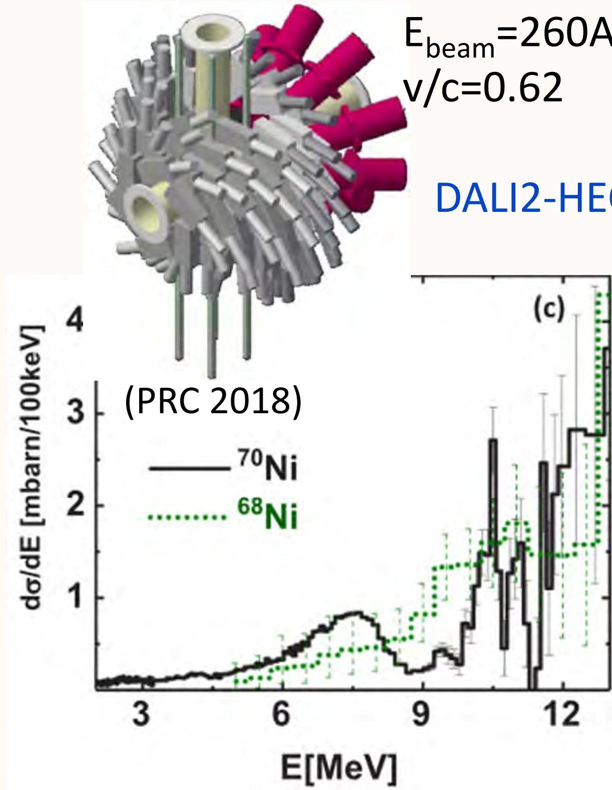
Virtual Photon Scattering



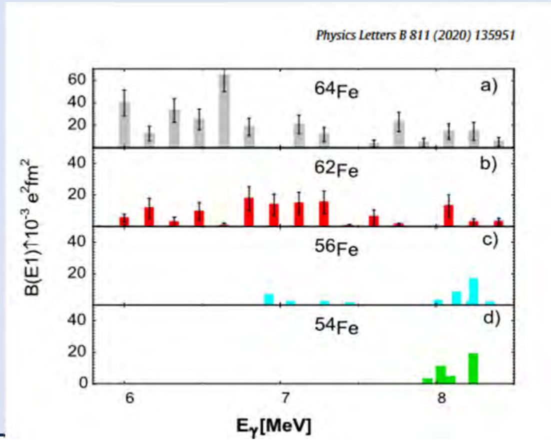
^{70}Ni

RIKEN-RIBF
E_{beam}=260AMeV
v/c=0.62

DALI2-HECTOR+



AGATA-HECTOR+
@GSI (PLB 2020)
Ebeam 400AMeV
Only
3 phonon model
can explain



^{64,62}Fe

Whats next ?

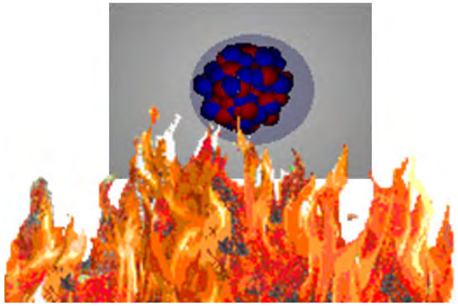
Whats next ?

^{80}Ni

→

EVEN MORE Serious and additional test-benchmark for theory will be to **go from cold to HOT** nuclei and test if the **PDR survives temperature, rotation, deformation, shape fluctuations and short livetime in excited CN**

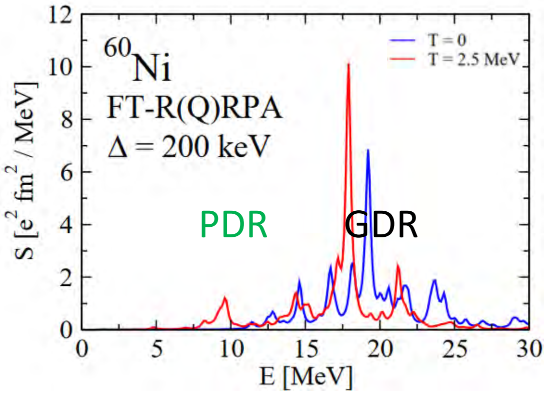
→ Search for pygmy dipole strength in ^{6X}Ni at finite temperature ????



Predictions

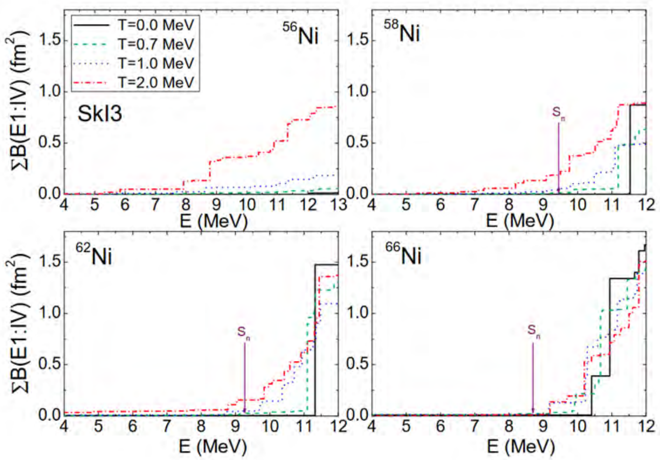
Theory

Elena Litvinova



At ZERO temperature only little PDR strength is present !
It arrives at finite Temperature and more Neutrons

Esra Yüksel



The global temperature (mass) dependence of the proton R_p , neutron R_n radius and <u>skin thickness</u> of the Ni isotopes

PHYSICAL REVIEW C 95, 024314 (2017) A. N. Antonov et al.

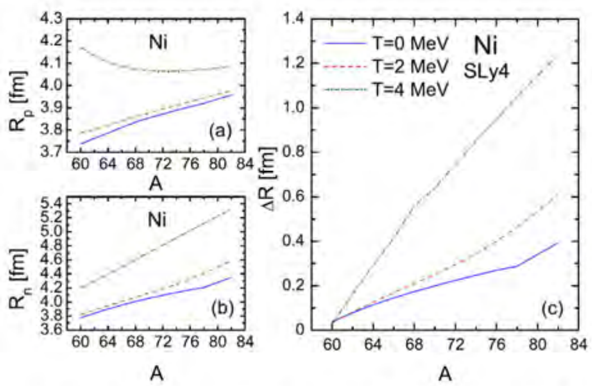


FIG. 4. Mass dependence of the proton R_p (a) and neutron R_n (b) radius of the Ni isotopes ($A = 60$–82) calculated with the SLy4 interaction at $T = 0$ MeV (solid line), $T = 2$ MeV (dashed line), and $T = 4$ MeV (dash-dotted line). Neutron skin thickness ΔR as a function of A (c) for the Ni isotopes.

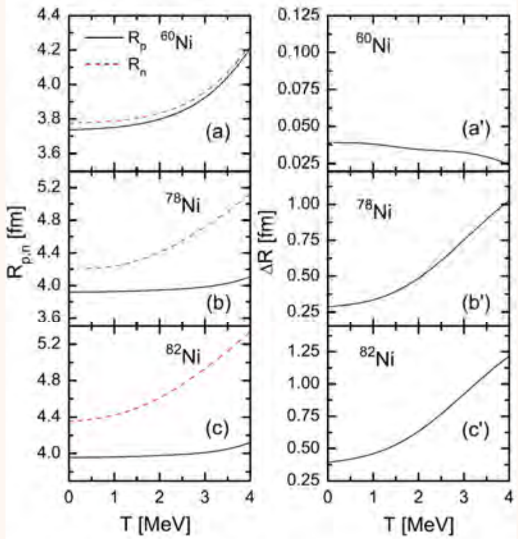
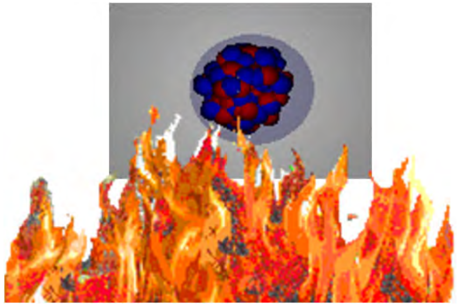


FIG. 7. Left: Proton R_p (solid line) and neutron R_n (dashed line) radius of ^{60}Ni, ^{78}Ni, and ^{82}Ni isotopes with respect to the temperature T calculated with SLy4 interaction. Right: Neutron skin thickness ΔR for the same Ni isotopes as a function of T.

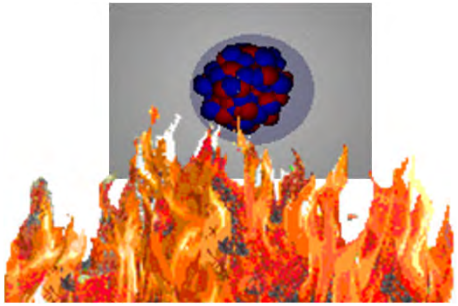
<u>skin thickness and r_n grows faster than deformation, and r_p !?</u>



How we want to **built** a nucleus with temperature and spin ?

With **fusion evaporation reactions** and the measurement of the γ **decay** from the **Compound nucleus (CN)** system.

→ Measure and calculate Statistical decay cascade γ and of particles (mainly n, p, alpha)



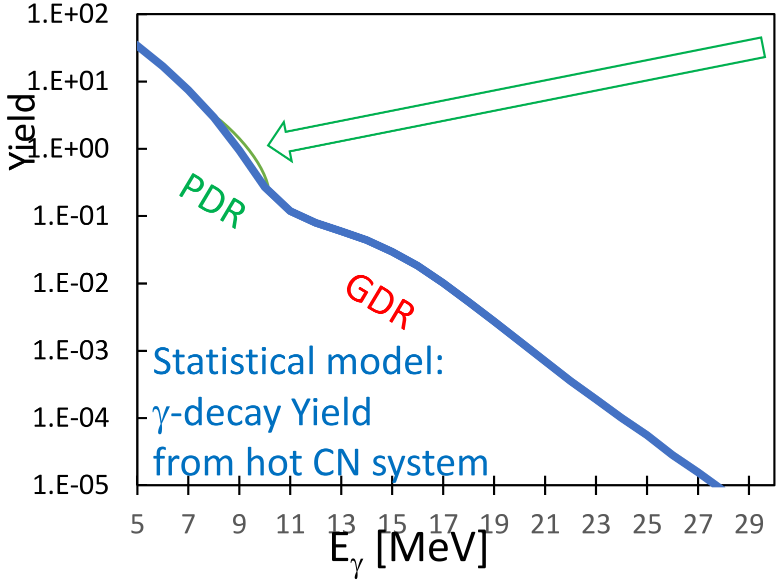
How we want to search for the HOT PDR in CN ?

We want to measure Hot PDR with the difference
of Gamma Yield from CN
of N=Z and N=(Z+X) nucleus built in *fusion evaporation reaction*
no PDR PDR

Predictions

we expect to see it in the experiment

$^{3x}S + ^{2x}Mg \rightarrow ^{xy}Ni^* \rightarrow \gamma, n, p, \alpha, \ldots +$ Residues

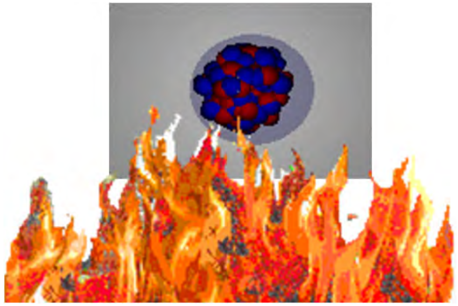


PDR gives Small effect* below 10 MeV

NEED of:

→high statistics measurement
→excellent time resolution
→good detector resolution

ELIFANT



HOT PDR in ^{56,60,62}Ni CN

Three Experiments	[MeV] before target	[MeV] loss in gold layer	[MeV] after gold 0.1mg/cm2	target 1mg/cm2	[MeV] loss until center	[MeV] energy in center target	CN	[MeV] E*	bass L	[mb] Fusion cross section	days	mb day	v/c beta	[MeV] Sn	Neutron excess
36S PDR1	78	0.3	77.5	26Mg	7.4	70.087	62Ni	49.3	12.1	246.8	5.0	1233.8	0.06459	10.6	N=Z+6n
34S PDR2	79	0.3	78.7	26Mg	7.3	71.432	60Ni	49.3	14.6	337.8	3.5	1182.3	0.06709	11.4	N=Z+4n
32S PDR3	90	0.3	89.7	24Mg	7.7	81.998	56Ni	49.1	19.1	530.2	1.5	795.2	0.07406	16.6	N=Z

<T>≈2MeV, similar formation and angular momentums, no preequilibrium

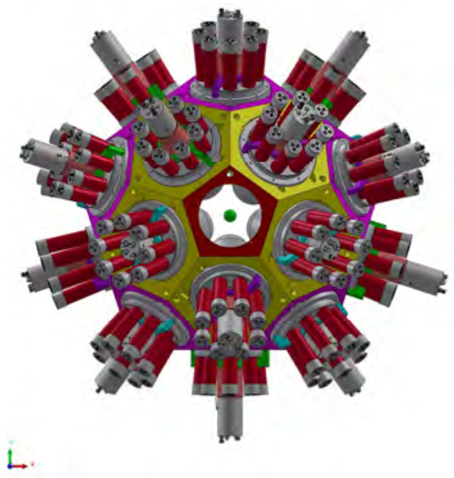
The experiment

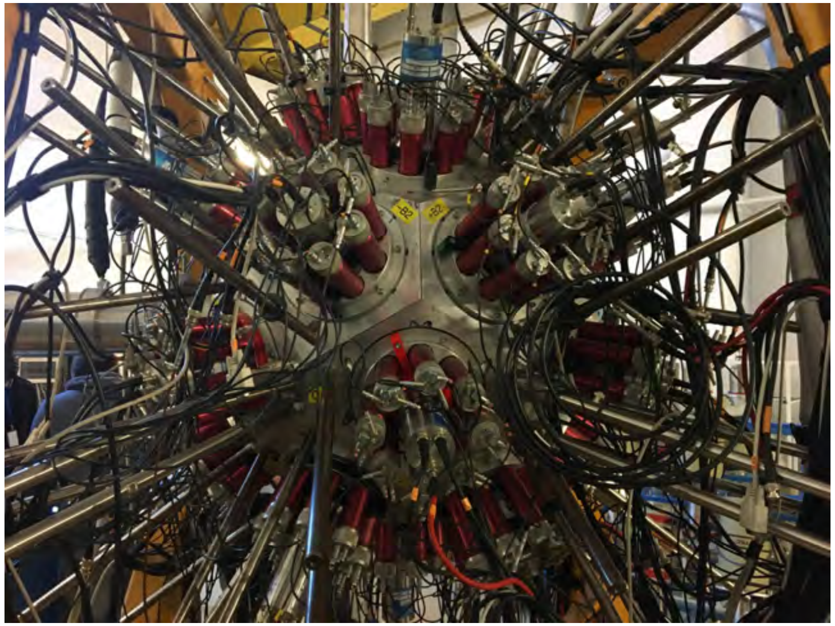
ELIFANT-GG@IFIN 2022

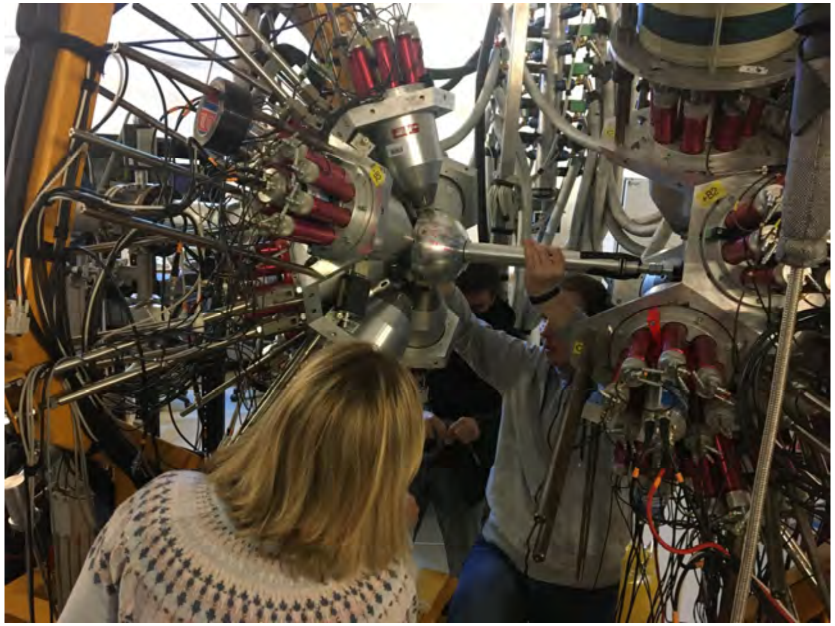
21 Bromide* scintillator Detector-array with AC-shield and 4 HPGe

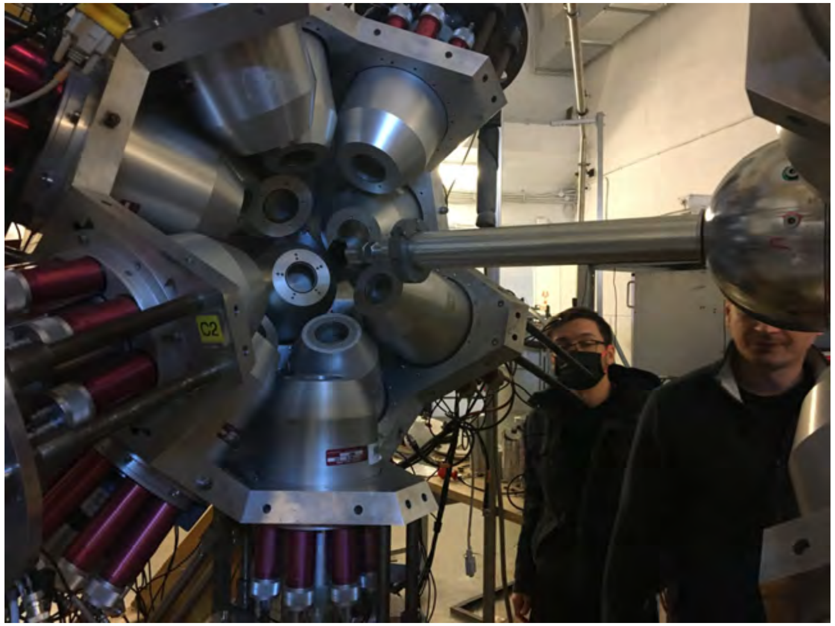
*****

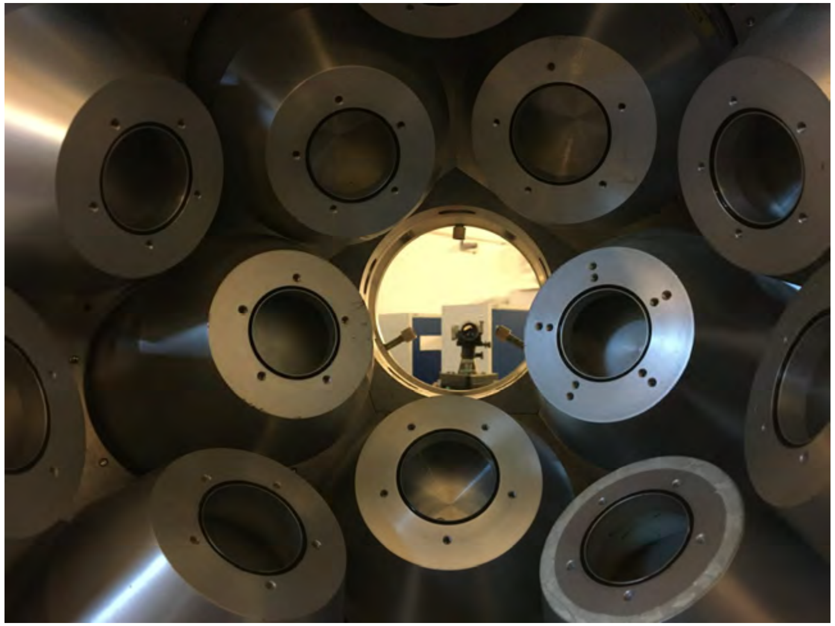
11 3x3 inch $LaBr_3$:Ce
10 3x3 inch $CeBr_3$

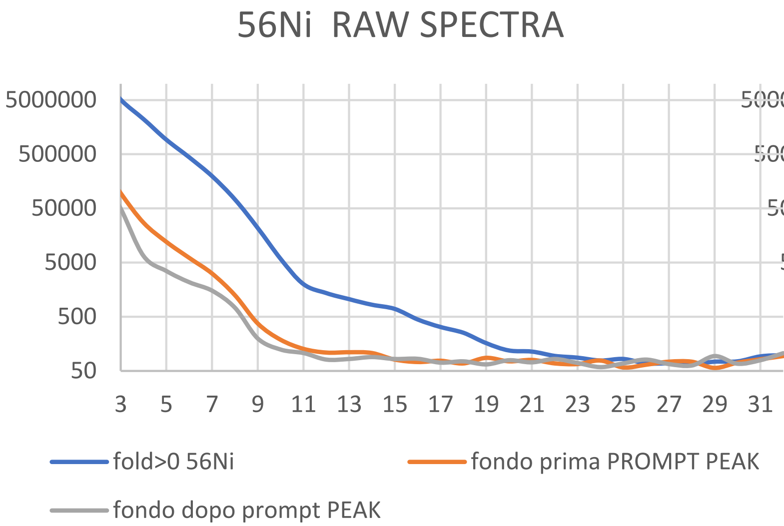


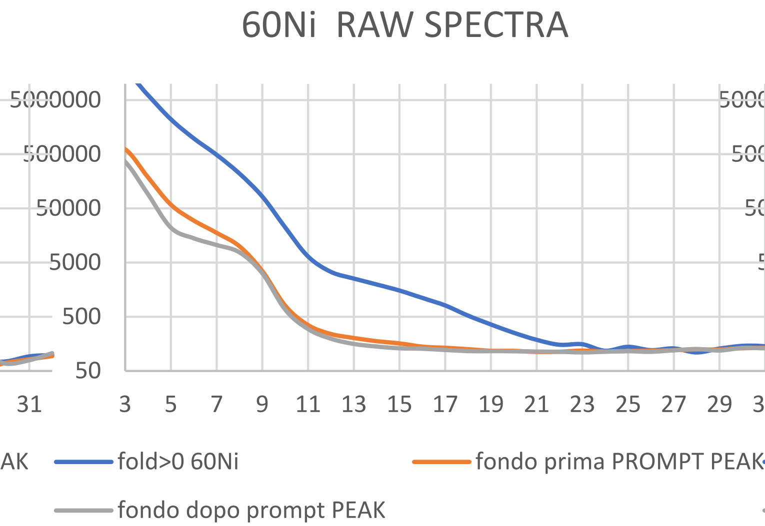


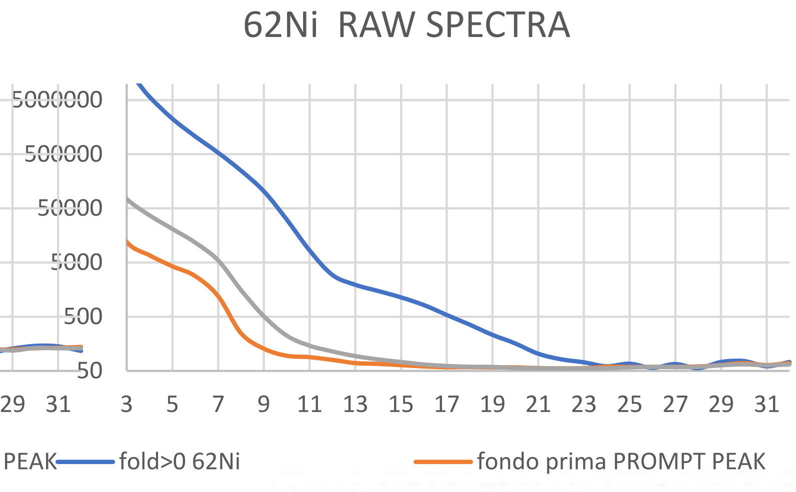




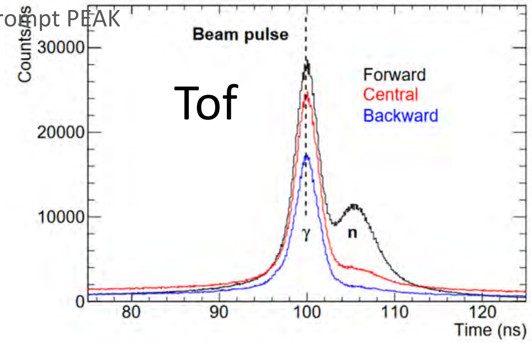






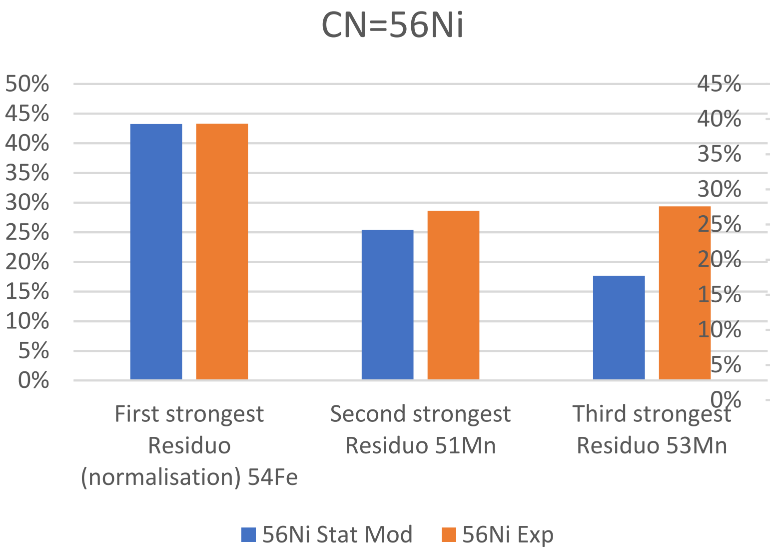


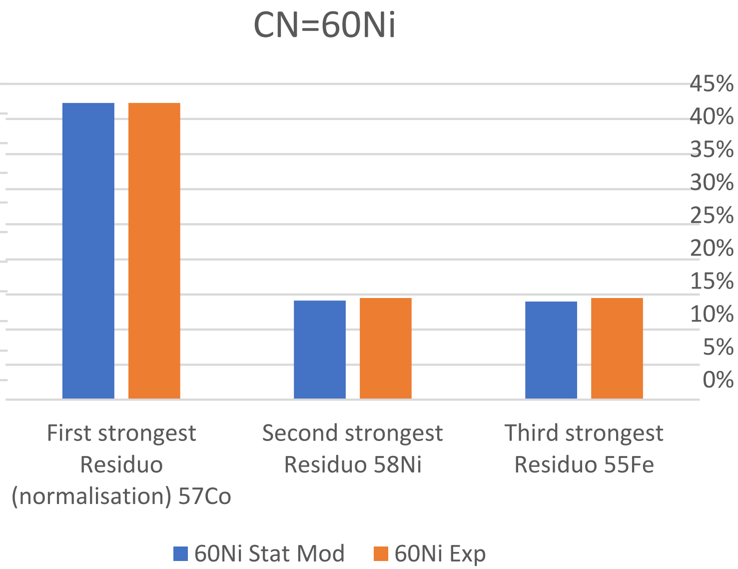
(all spectra are based mainly on DELILA analysis with big help from Dmitry Tesov and Asli Kusoglu)

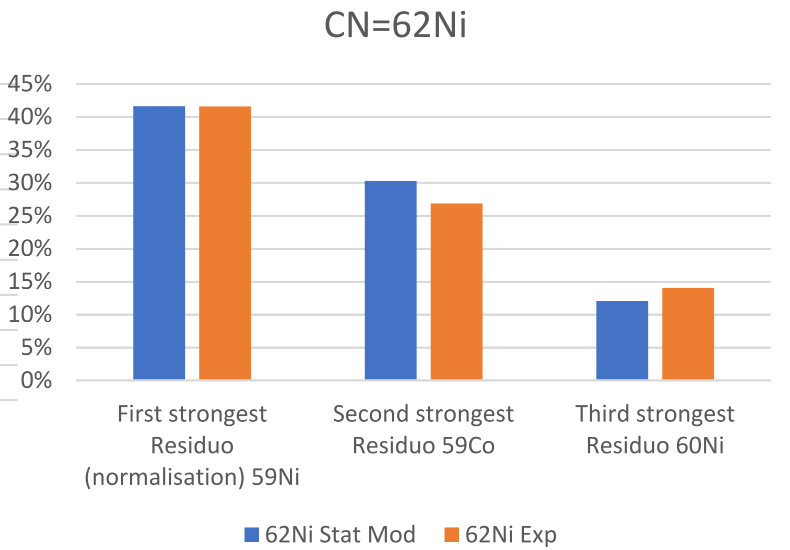


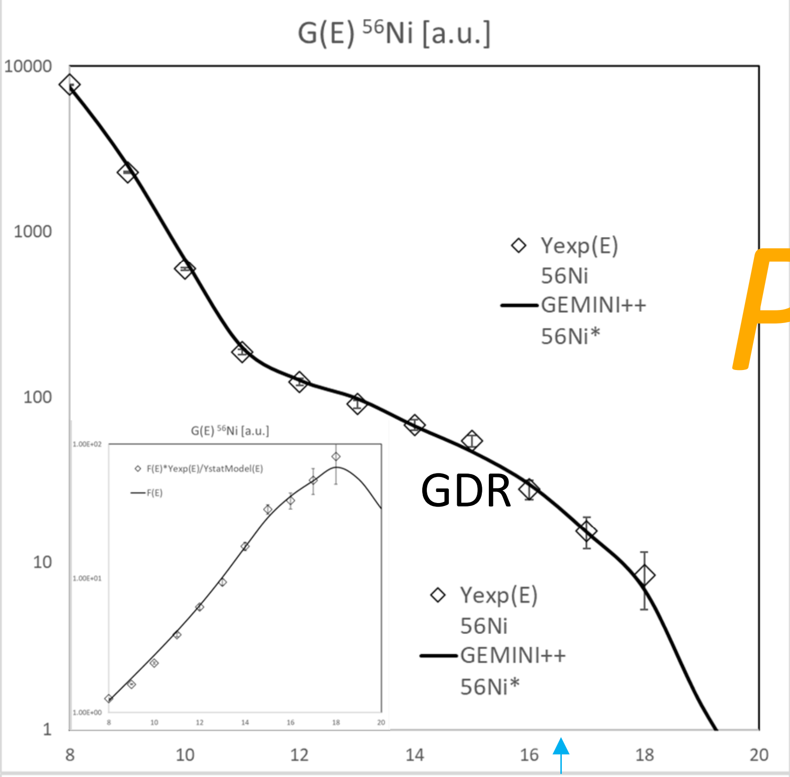
Statistical Model analysis to simulate GDR decay
(with MonteCarlo Code Gemini (Michal Ciemala))

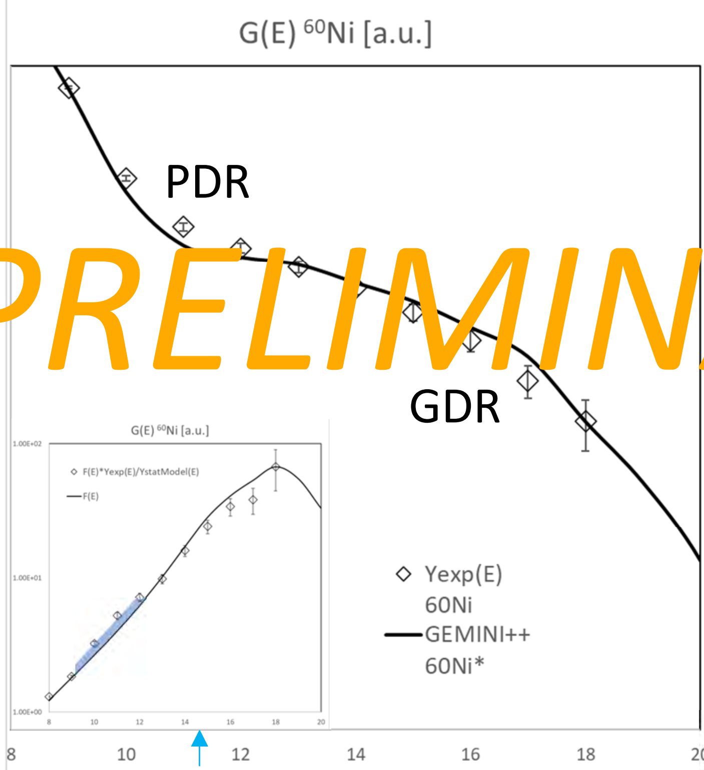
Residues population check (HPGe Detectors)

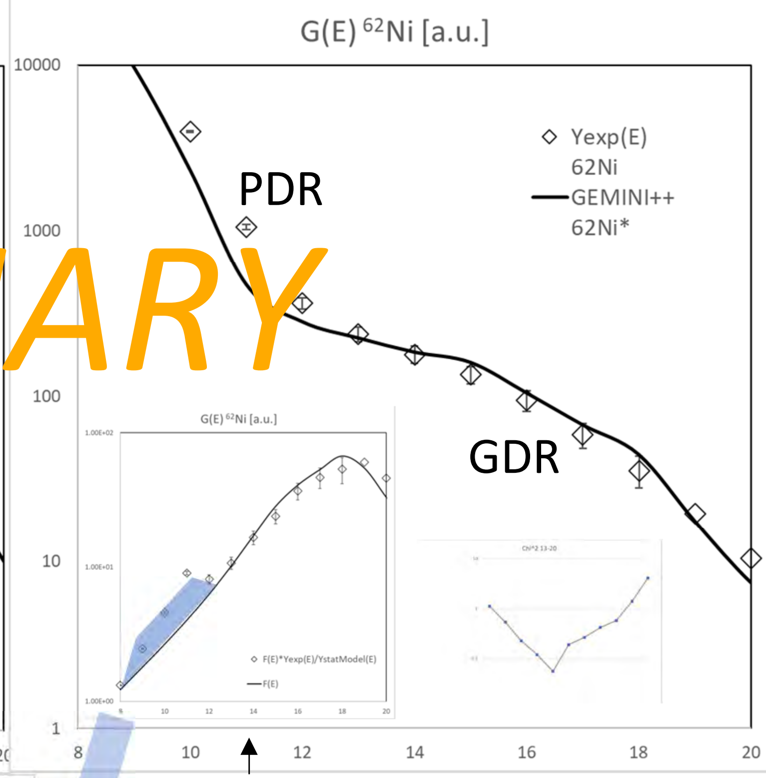


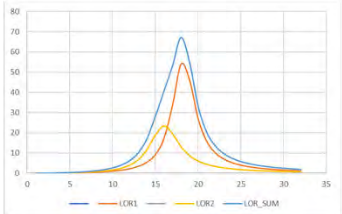




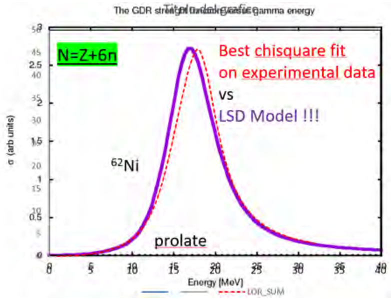








Little deformation is needed to fit GDR part (even with extreme, unphysical deformation, the extra strenght may not be reproduced)

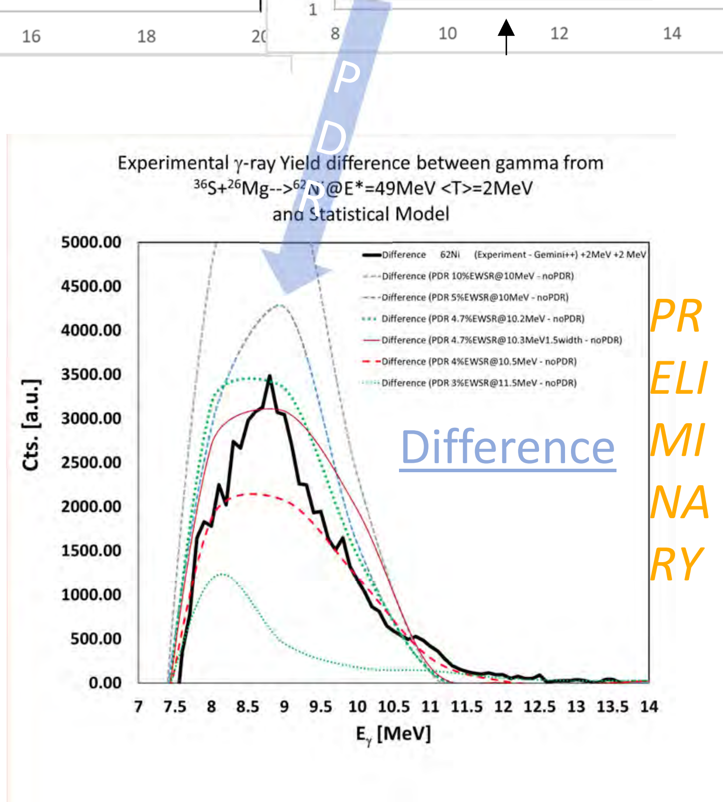


beta	
	56Ni
0.151	56
	60Ni
0.2052	60
	62Ni
0.1977	62

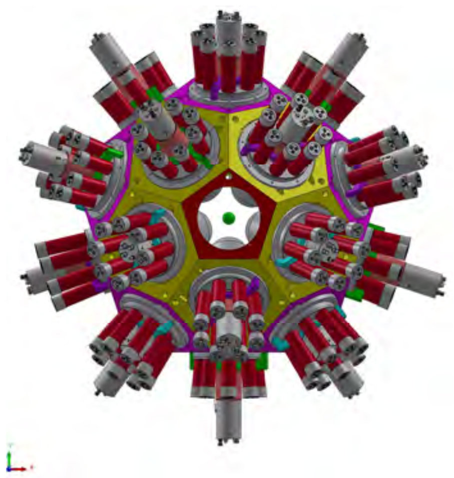
Lublin-Strasbourg Drop (*LSD*) *model*

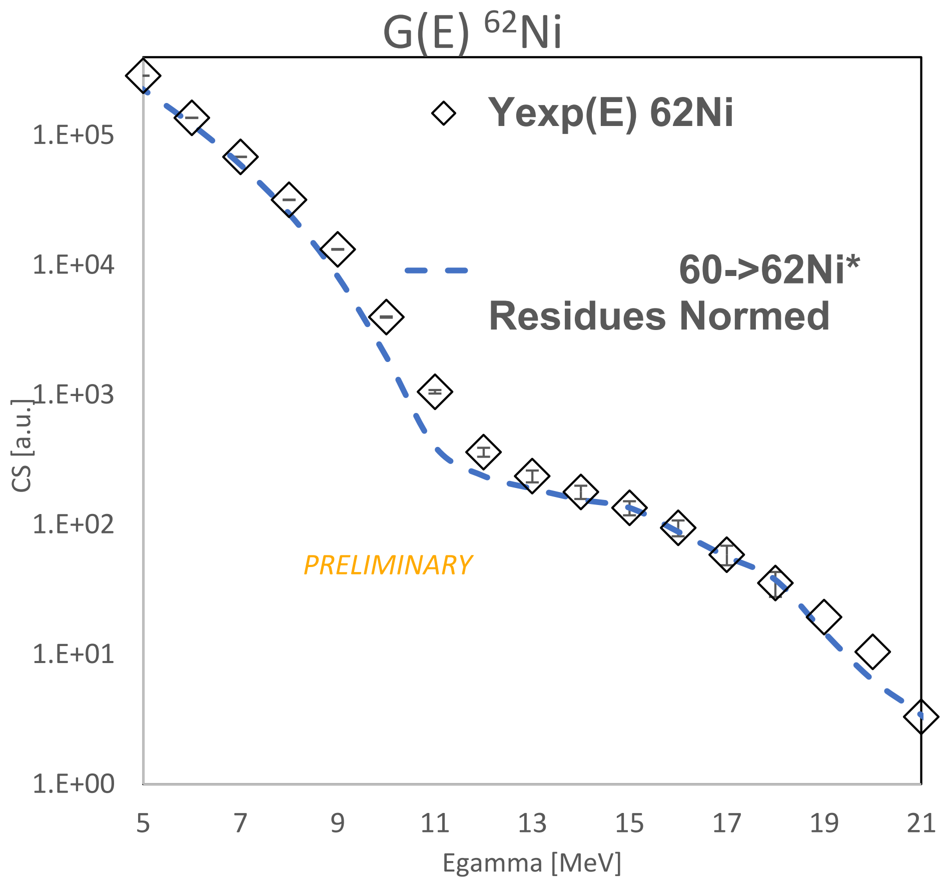
Yield@ T(CN)≈2MeV
Difference can be
Reproduced with

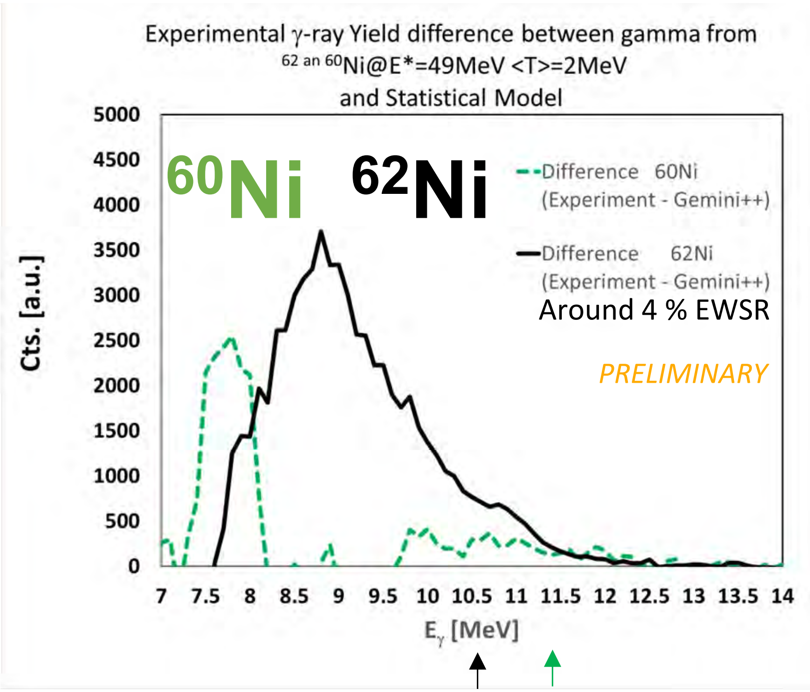
Adding
PDR ≈4 % EWSR
@ 10.5 MeV

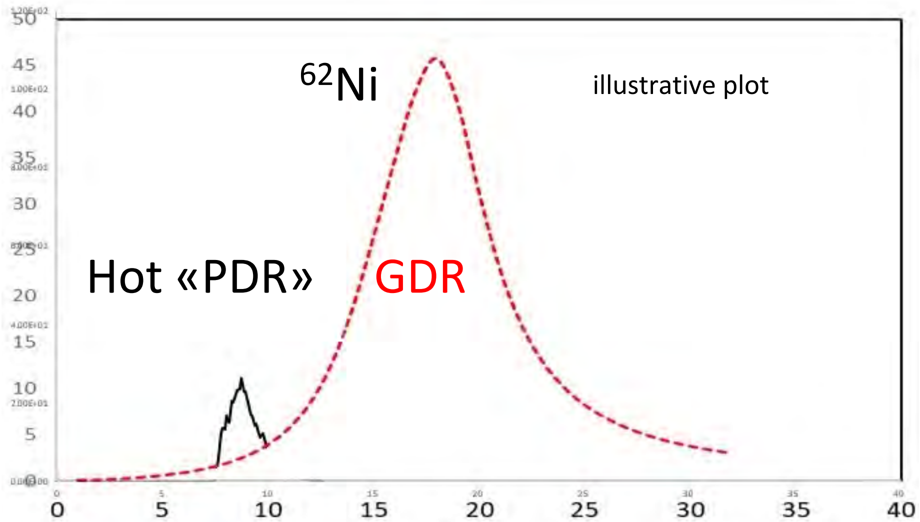


Result on search for Hot Pygmy in ^{60,62}Ni CN









Resume:

- Some evidence of a possible extra strength
- Not from deformation (angular momentum) effects
- located bellow GDR and with Strength around 2-4% of total GDR-EWSR
- appears not in N=Z nucleus but (only) in N=Z+xn nucleus at high excitation energy (CN Temperature up to 2 MeV) in rotating nucleus formed in fusion evaporation reaction

- **To do, in order to conclude**:

-Should go on in the Ni chain to **^{64}Ni** and measure also

LCP+residues+decay branching (n,y and PDR->2$^+$) and angular distribution

-**We will Built** ^{64}Ni also at **lower T… around 1 or 1.5 MeV** ! extremly difficult due to very low cross section !

→ **<u>next IFIN PAC</u>**

- **do complementary measurements (p,p',γ) @Cracov**

Theory

Include rotation and angular momentum in predictions

Cold PDR has STRONG impact on stellar processes, neutron star collisions, mergers,… : *HOT PDR at 0.5 1 1.5 or 2 MeV* ?

Thanks a lot to collaborators from **INFN, IFIN, ELI, IFJ-PAN**

A. Bracco[1], F. Camera[1], F. Crespi[1], O. Wieland[1], G. Benzoni[1], S. Bottoni[1], S. Brambilla[1], S. Leoni[1], B. Million[1], M. Ciemala[2], M. Kmiecik[2], A. Maj[2], T. Balabanski[4], M. Cuciuc[4], D. Testov[4], A. Kusoglu[4], P.-A. Söderström[4] U. Clisu[5], C. Costache[5], D. Filipescu[5], N. Florea[5], I. Gheorghe[5], A. Ionescu[5], N. Margiean[5], C. Mihai[5], R. Mihai[5], C. Nita[5], L. Stan[5], A. Turturica[5]

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