Links between ^{80}Sr compound nucleus' shape and its residue's deformation studied with the GDR using Nu-Ball2+PARIS

Michał Ciemała
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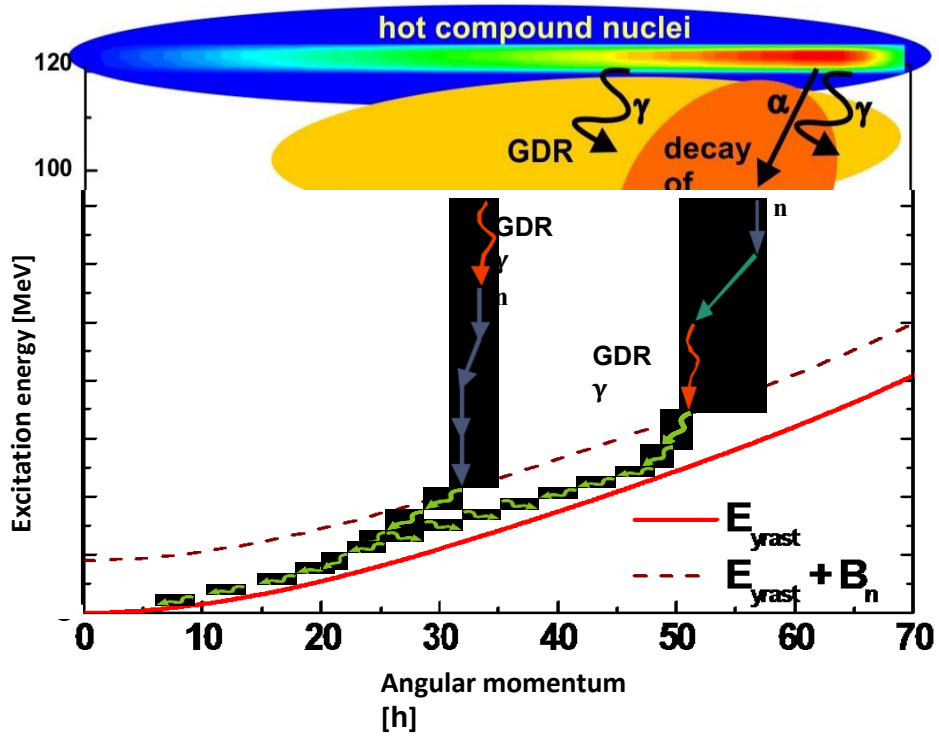
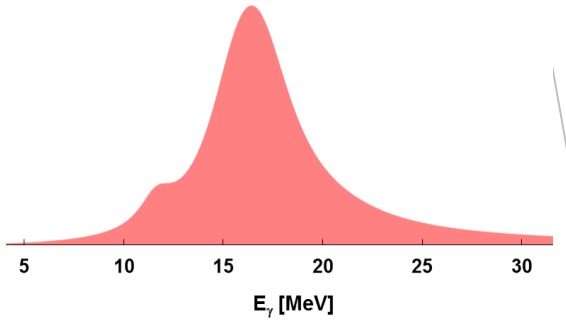
Nuball2 workshop, Milano, 4/07/2024

Motivation

Link between deformation of hot compound nucleus and deformation of cold evaporation residue by the measurement of GDR decay of compound nucleus

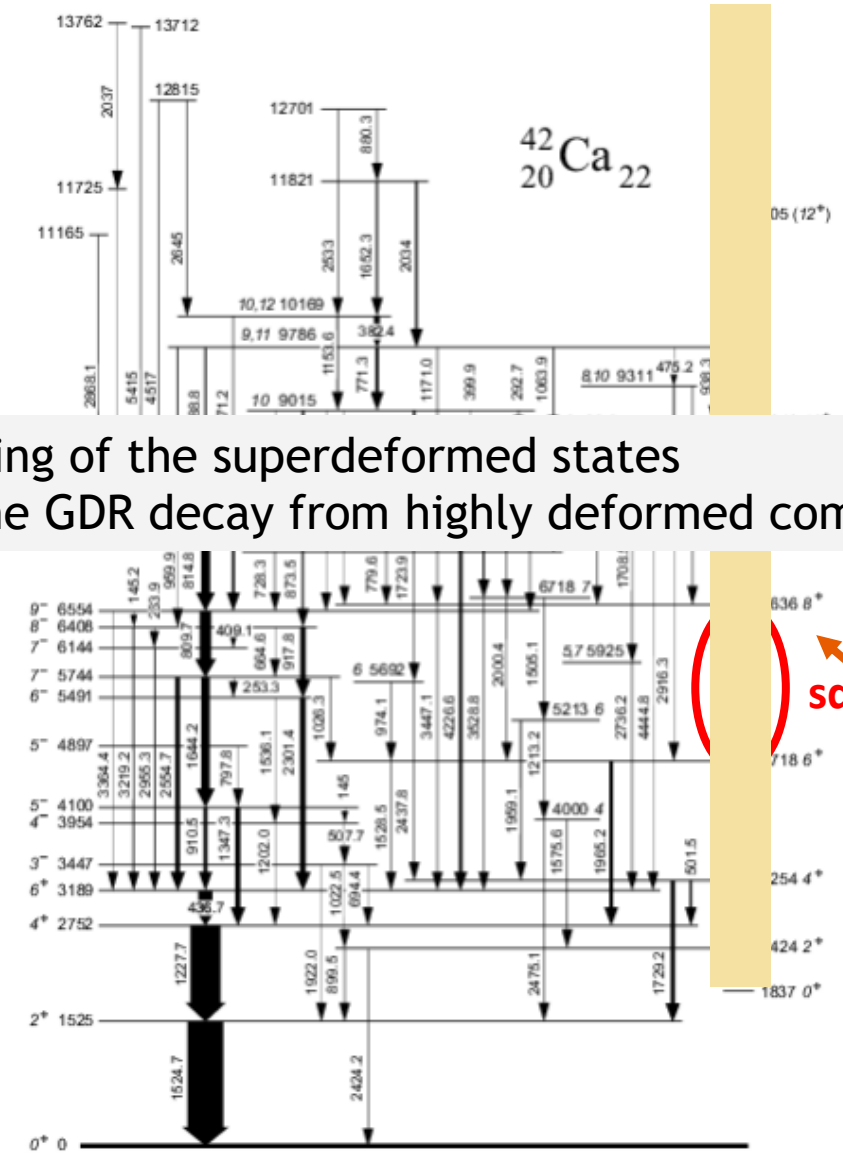




- GDR high energy gamma rays
  - hot nucleus shape
- low energy transitions
  - deformation of excited residue

Choosing the particular decay path
by coincidence measurement of high and low-energy γ rays

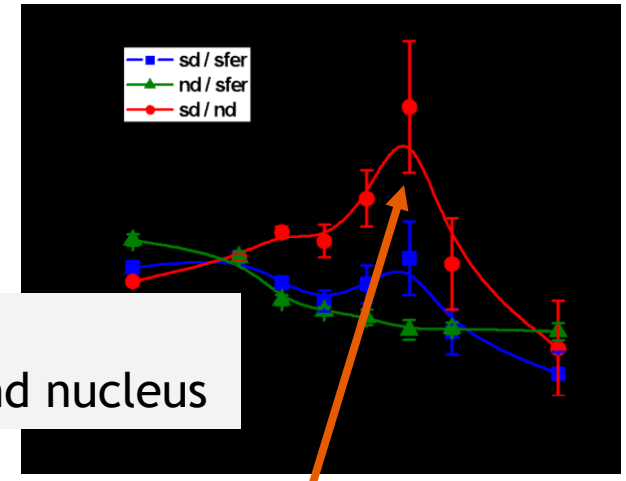
^{46}Ti* decay to ^{42}Ca



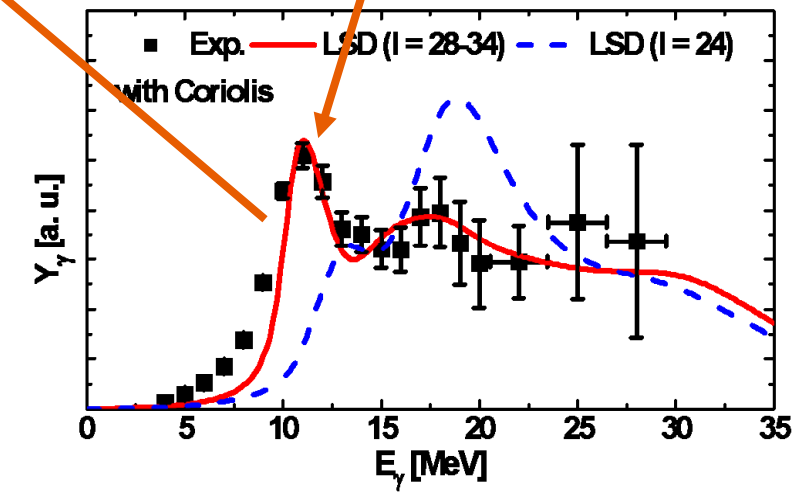
feeding of the superdeformed states
by the GDR decay from highly deformed compound nucleus

M. Lach et al., Eur Phys J. A12, 381 (2001)

EUROBALL + HECTOR + EUCLIDES
105 MeV ^{18}O + ^{28}Si ⇒ ^{46}Ti*



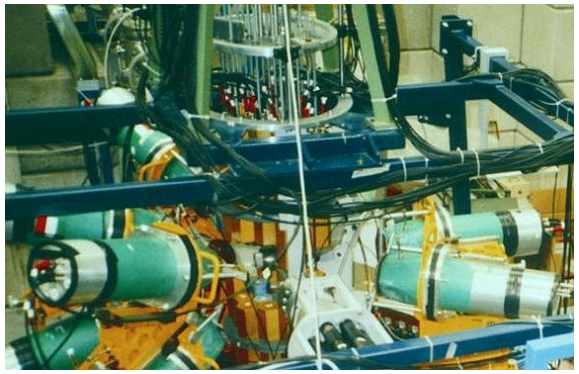
M. Kmiecik et al., Acta Phys. Pol. B36 (2005) 1169



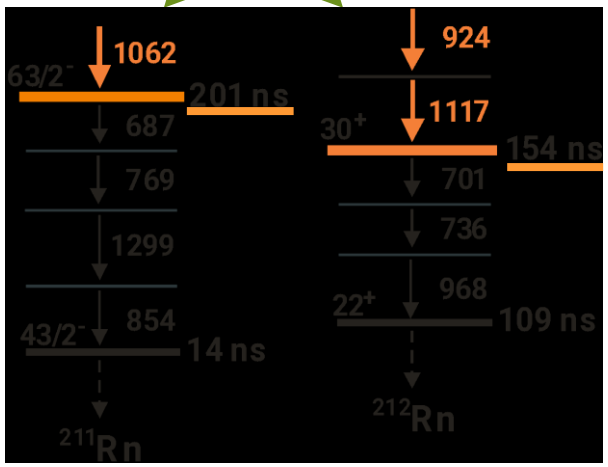
measured:
GDR γ decay
from ^{46}Ti CN
in coincidence
with transitions
in ^{42}Ca residue

^{216}Rn* decay to isomeric states in ^{211,212}Rn

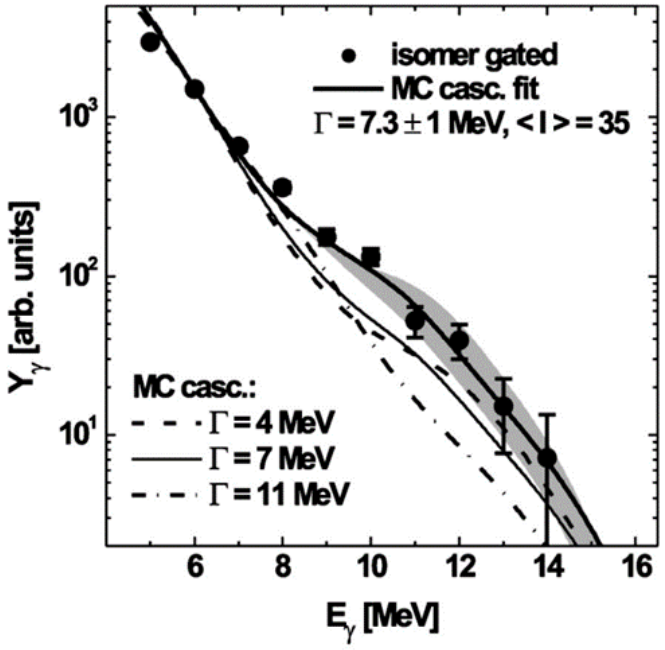
HECTOR + Ge + BGO + Catcher @ LNL



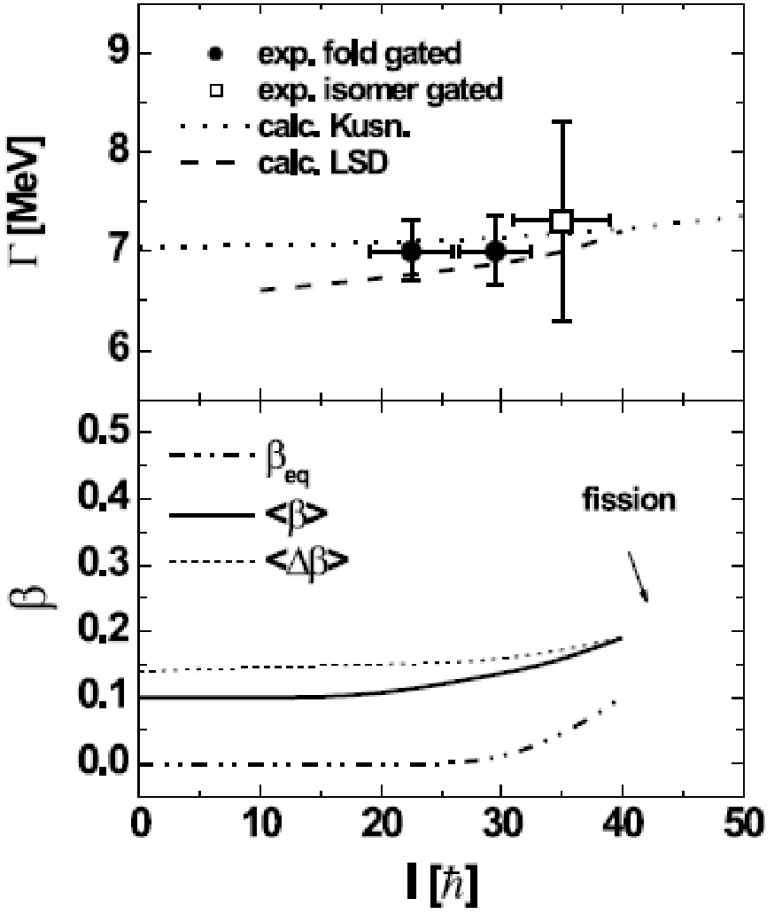
96 MeV ^{18}O + ^{198}Pt → ^{216}Rn*



GDR in coincidence with isomeric states



gating on isomers – choosing nuclei at highest spins surviving fission



small increase of deformation for highest spin - nucleus remains almost spherical up to the fission limit

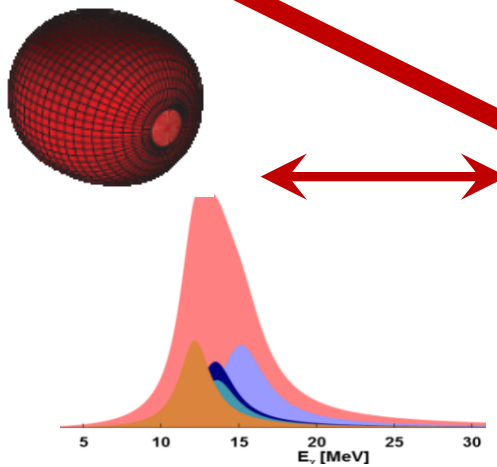
M. Kmiecik et al. Phys.Rev. C70, 064317 (2005)

The ^{192}Pt* decay to ^{188}Pt residue

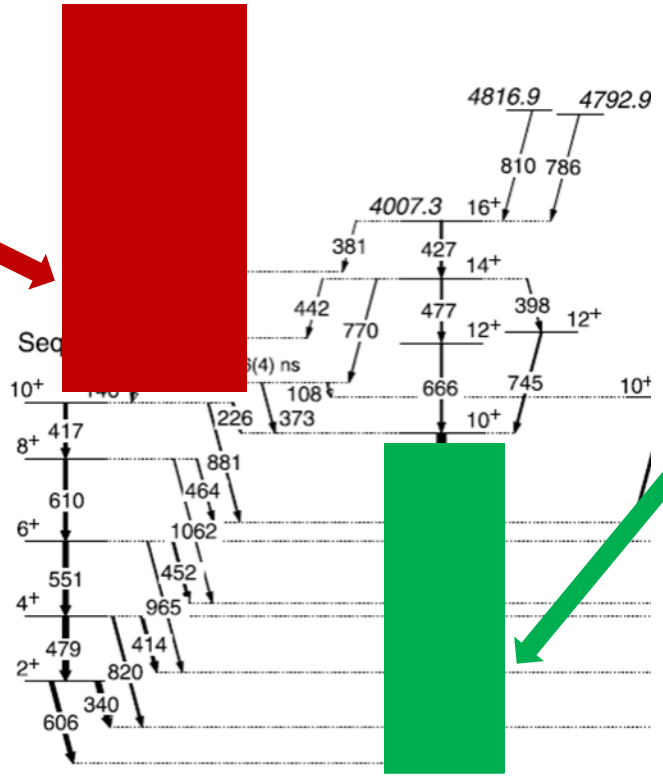
High-energy γ rays from ^{192}**Pt*** CN decay in **4n channel** in coincidence with low-energy transitions in ^{188}**Pt**

How the deformation changes along the decay path?

β=0.16 and γ=−40°
triaxial

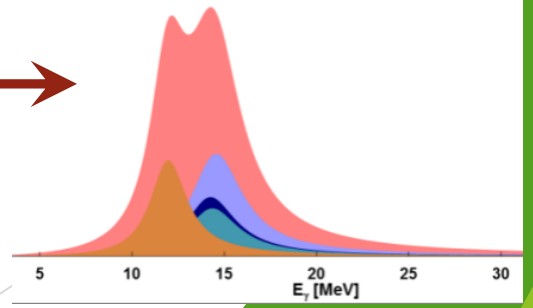


Gate on transitions



β =0.18 and γ=−6°
near prolate

GDR strength functions for CN decaying to particular states of ^{188}Pt

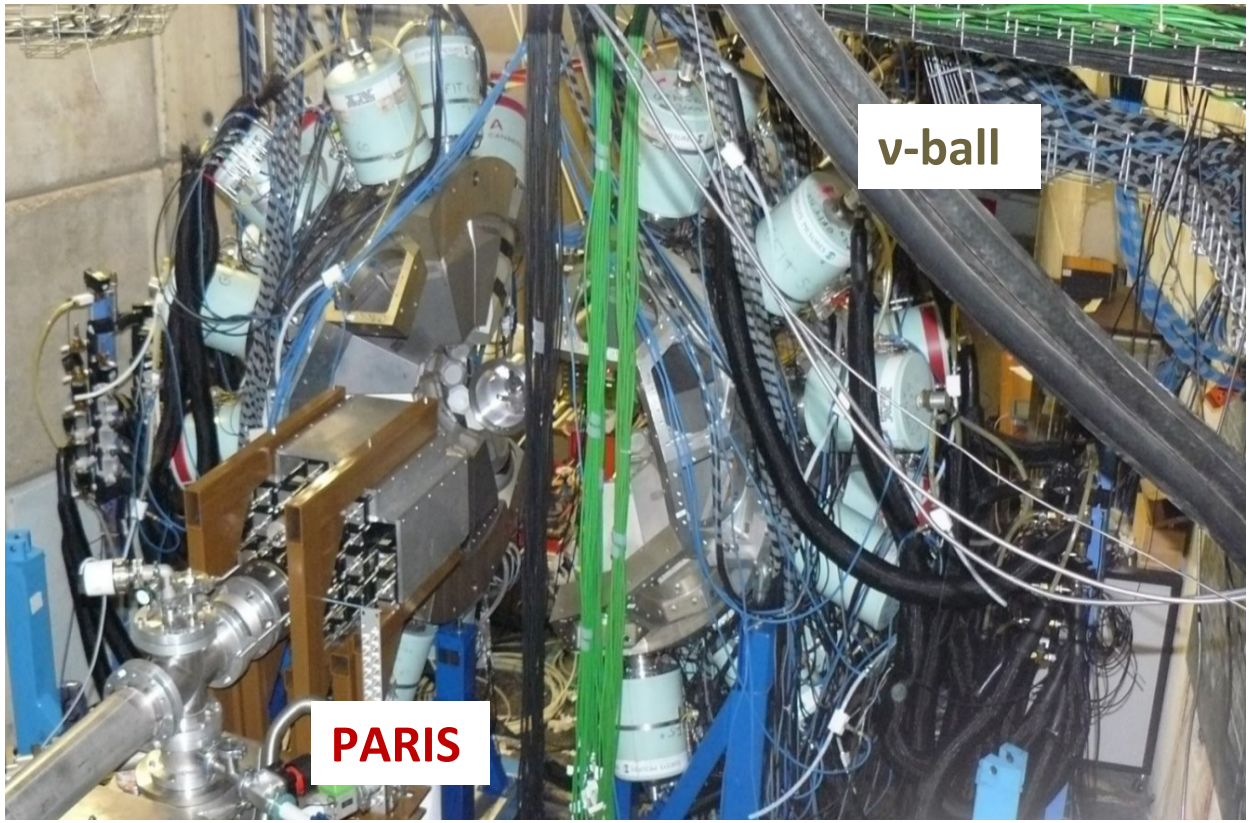


S. Mukhopadhyay et al., Phys. Lett. B 739, 462 (2014)

The nuBall + PARIS experiment at IPN / IJCLab

v-ball array: 33 Clovers +10 Coaxial HPGe
coupled to 33 **PARIS** detectors:
11 $CeBr_3$:NaI phoswiches,
22 $LaBr_3$:NaI phoswiches.

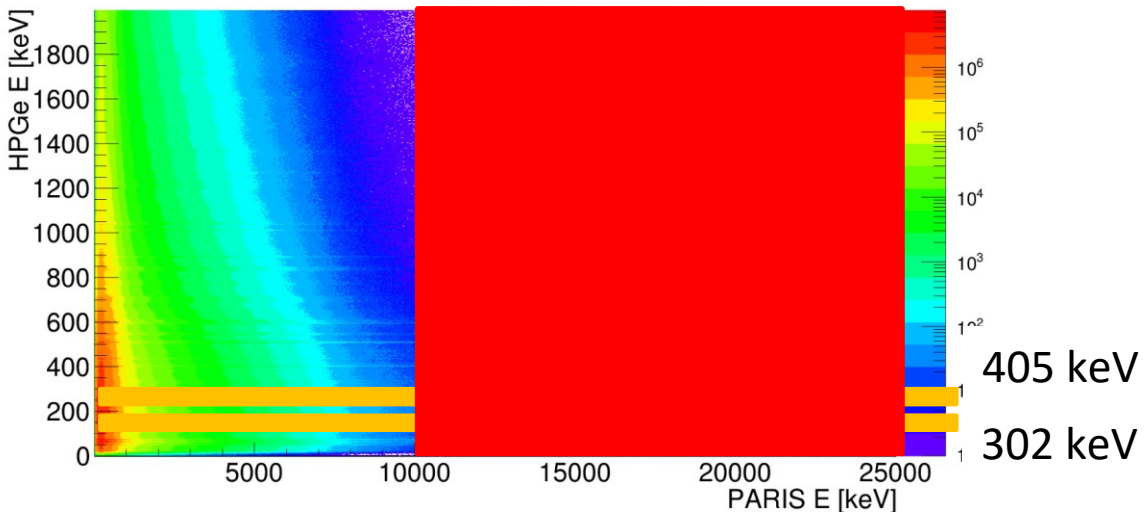
Triggerless DAQ by FASTER digitizer

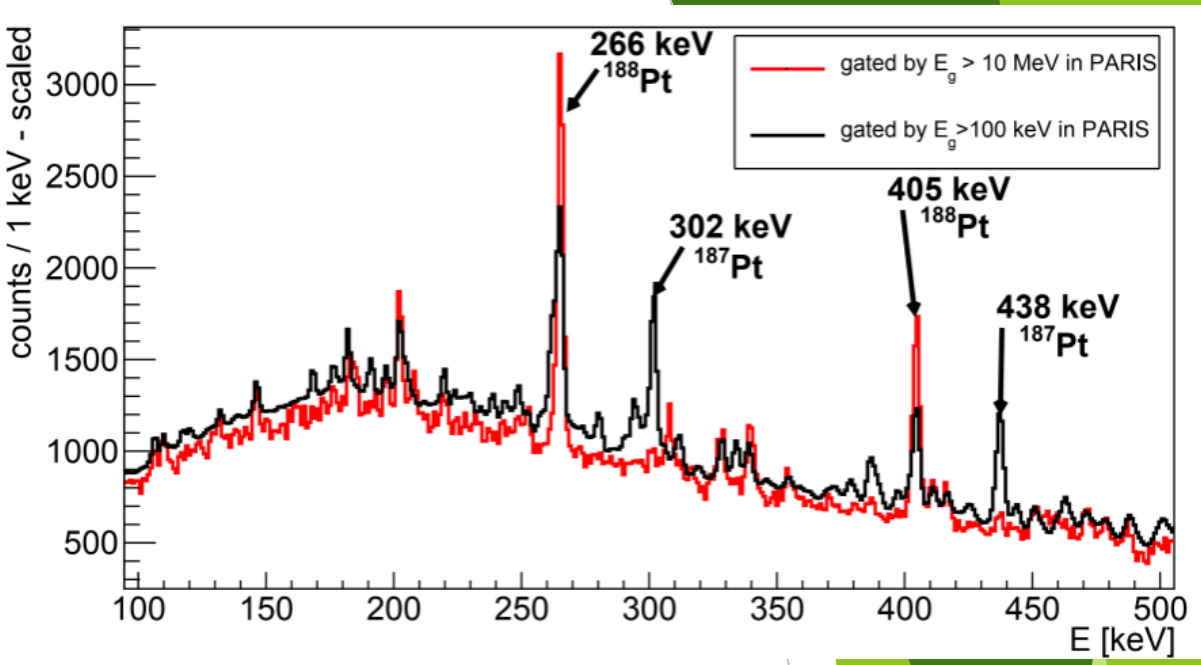


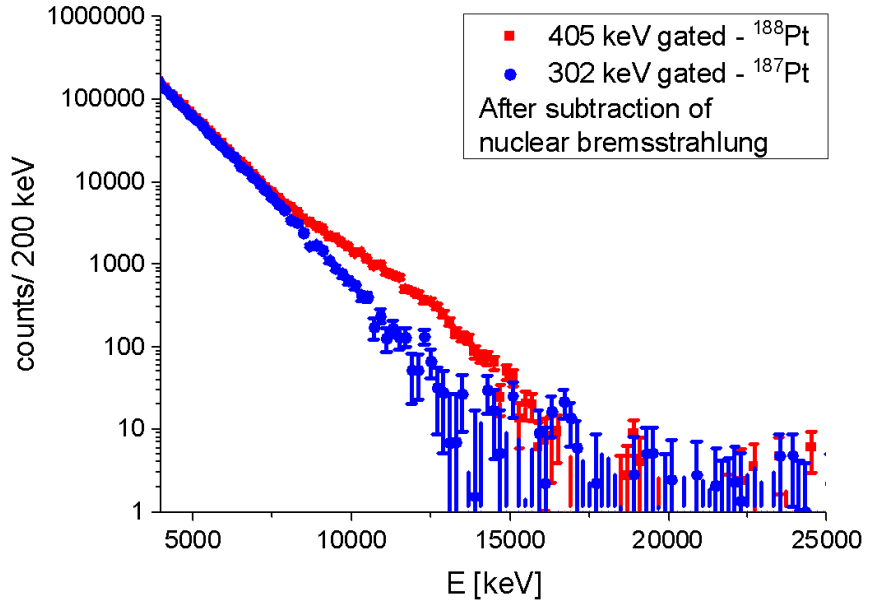
$^{18}O + {}^{174}Yb \rightarrow {}^{192}Pt$

- Beam energy: 90 MeV
- E* = 59 MeV
- T = 1.5 MeV
- L_{max} = 38 ħ
- Target thickness:
  1.5 mg/cm^2
- AmBe+Ni
  used for high energy
  callibration (up to 9 MeV)

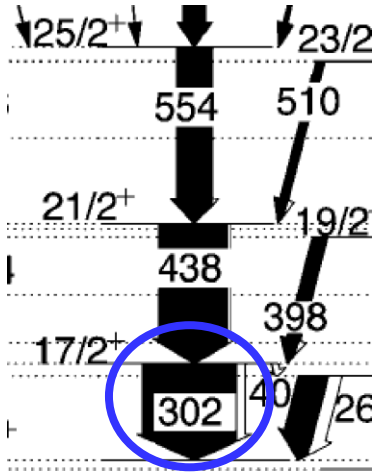
γ - γ HPGe vs PARIS



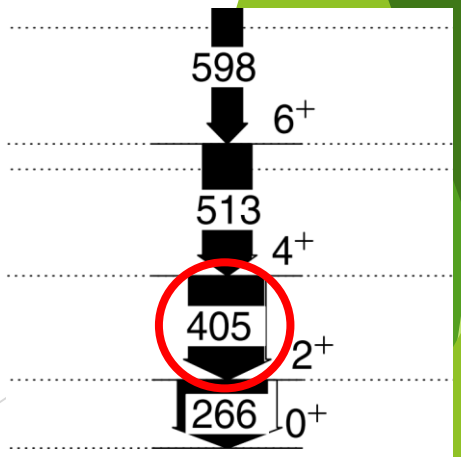




90 MeV ^{18}O + $^{174}Yb \rightarrow {}^{192}Pt$



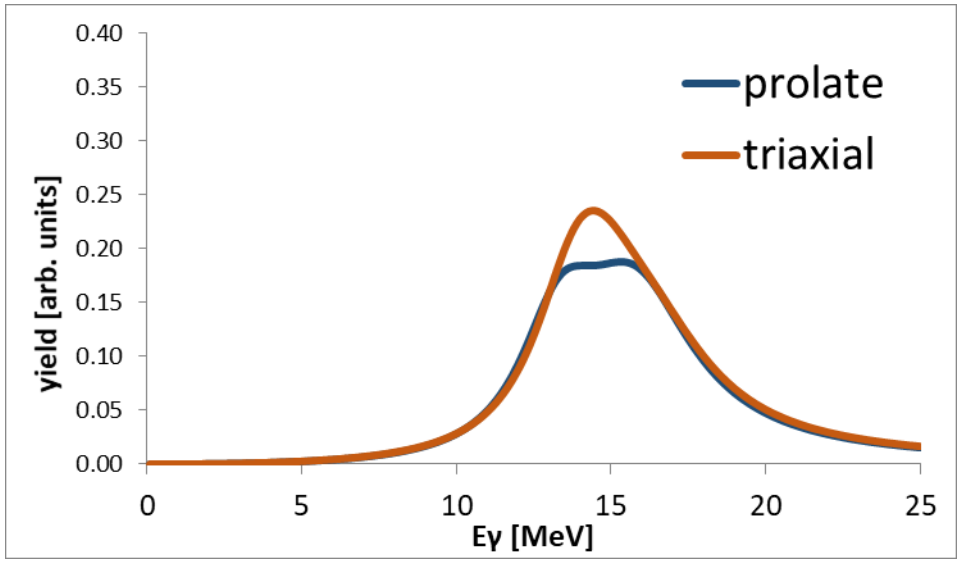
^{187}Pt



^{188}Pt

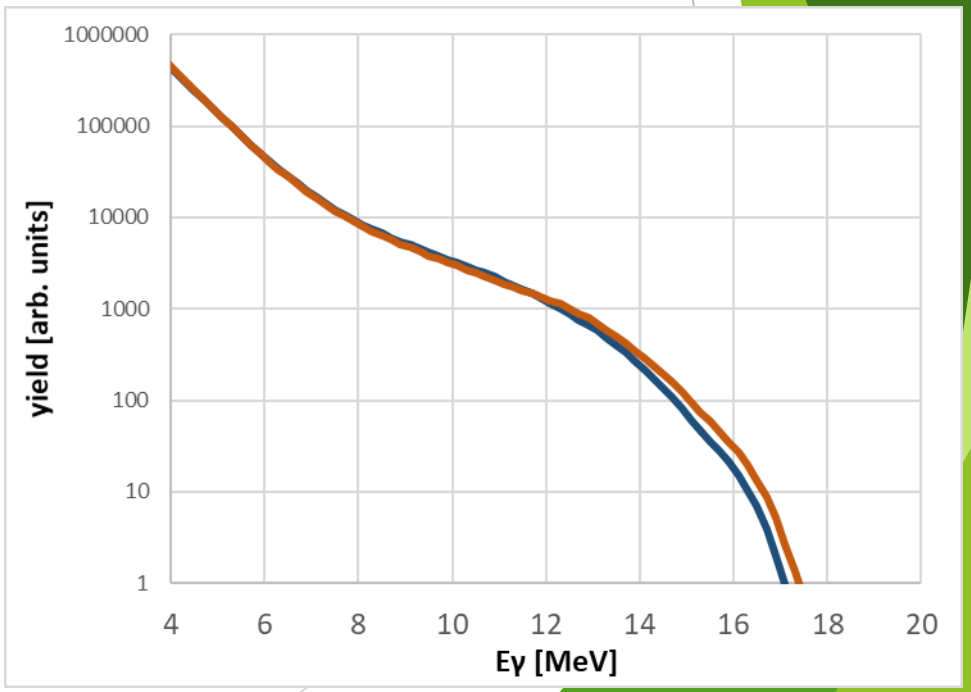
Analysis – Statistical model – GEMINI++

The GEMINI++ Monte Carlo statistical code by ***R.J. Charity, Phys. Rev. C82, 014610 (2010)***
with added GDR Decay ***M. Ciemała et al. Acta Phys. Pol. B44, 611 (2013)***
Used in the analysis by example in: ***M. Ciemala et al. Phys. Rev. C91, 054313 (2015)***

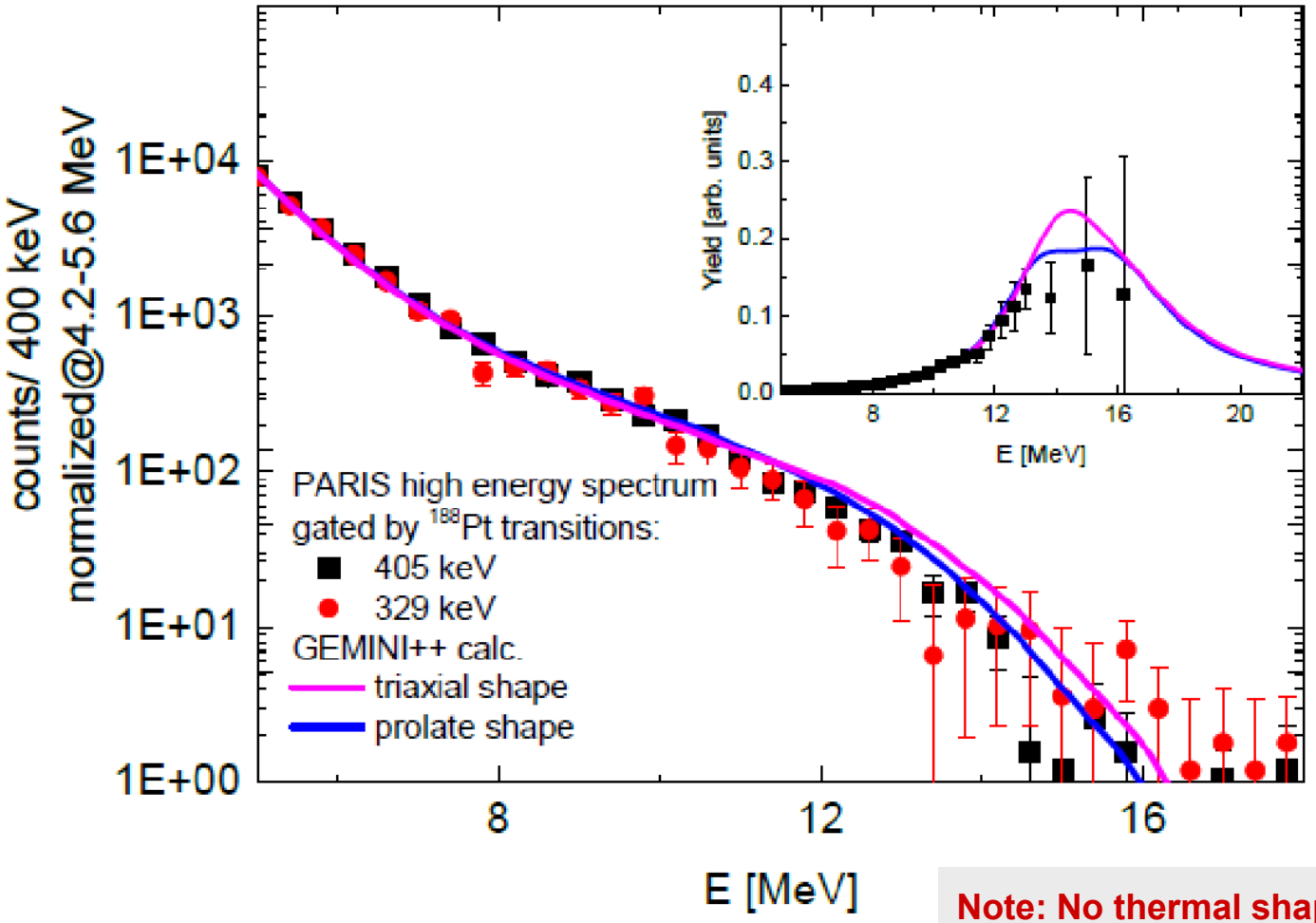


β=0.16 and γ=–40°
triaxial

β =0.18 and γ=–6°
near prolate



Comparison to statistical model



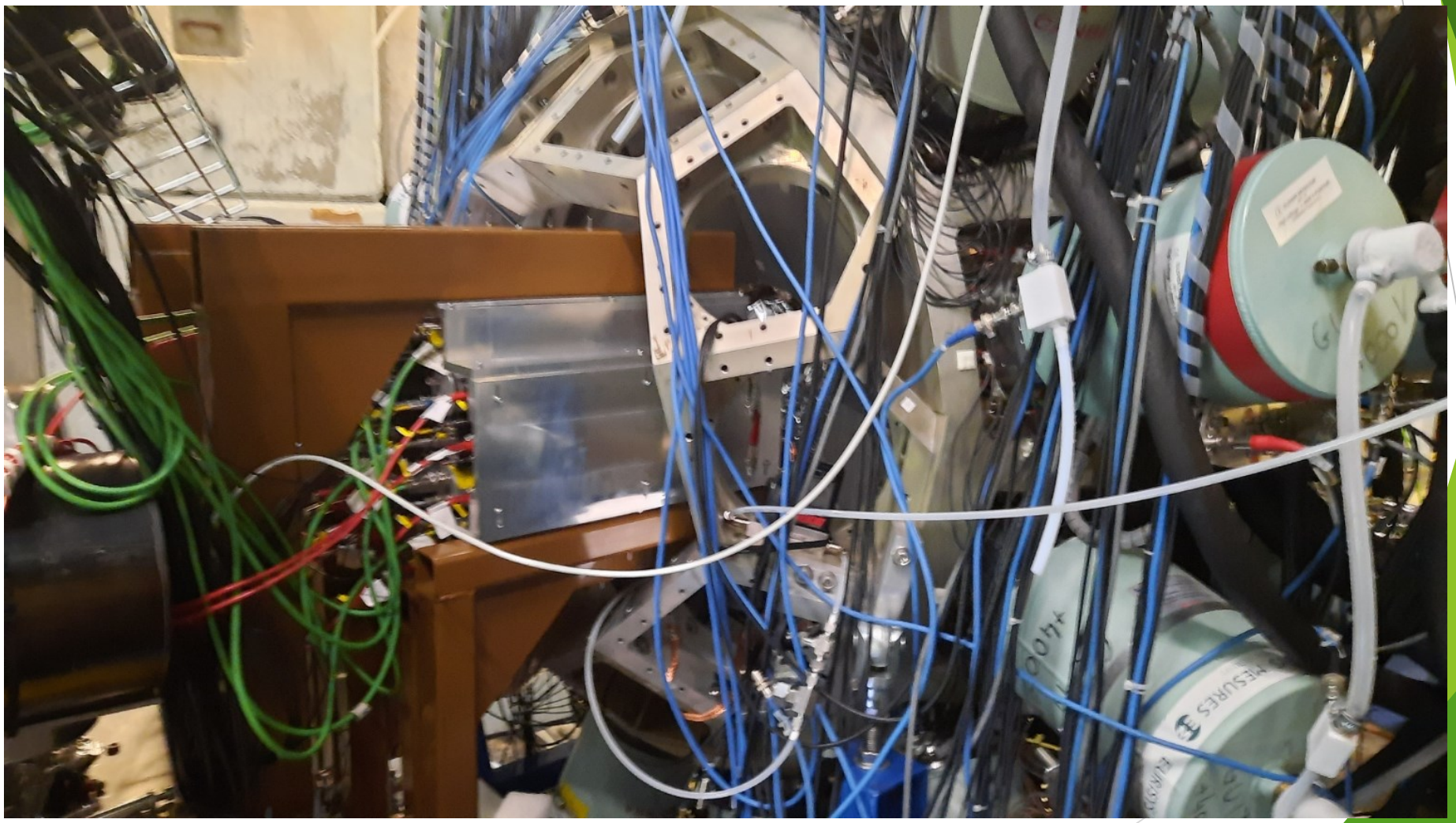
Better agreement to experimental data is seen for the calculations assuming prolate-like shape of the nucleus.

Suggestion that either:
the assignment of the triaxial deformation for 12+ isomer is wrong
or
the nucleus does not preserve the shape during the decay.

Note: No thermal shape fluctuations were used for the GDR strength calculations. Will be done at the the next steps.

M. Ciemała et al., Acta Phys. Pol B Proc. Suppl. 16, 4-A3 (2023)

The PARIS + NuBall2 experiments
from November 2022 to June 2023



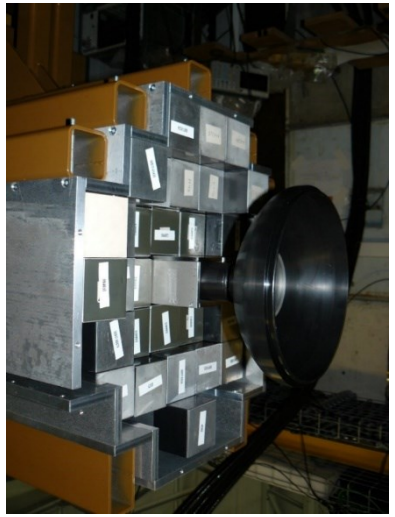
N-SI-122: Links between ^{80}Sr compound nucleus' shape and its residue's deformation studied with the GDR using Nu-Ball2+PARIS

Spokespersons: M.C., F.C.L. Crespi

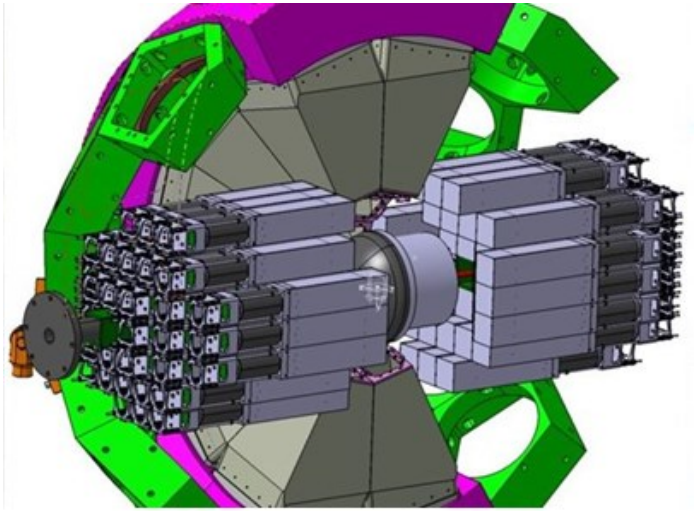
Study:

- links between deformation of hot compound nucleus ^{80}Sr and different deformation of the final state of the ^{76}Kr residues;
- population of states of different deformation fed by high-energy γ–rays from GDR decay.

By measurement of high-energy gamma rays from the GDR decay in hot **^{80}Sr** compound nucleus by **PARIS array** (in wall geometry) in coincidence with discrete gamma transitions in **^{76}Kr** evaporation residue by **nu-Ball2 array.**



PARIS@Nu-Ball

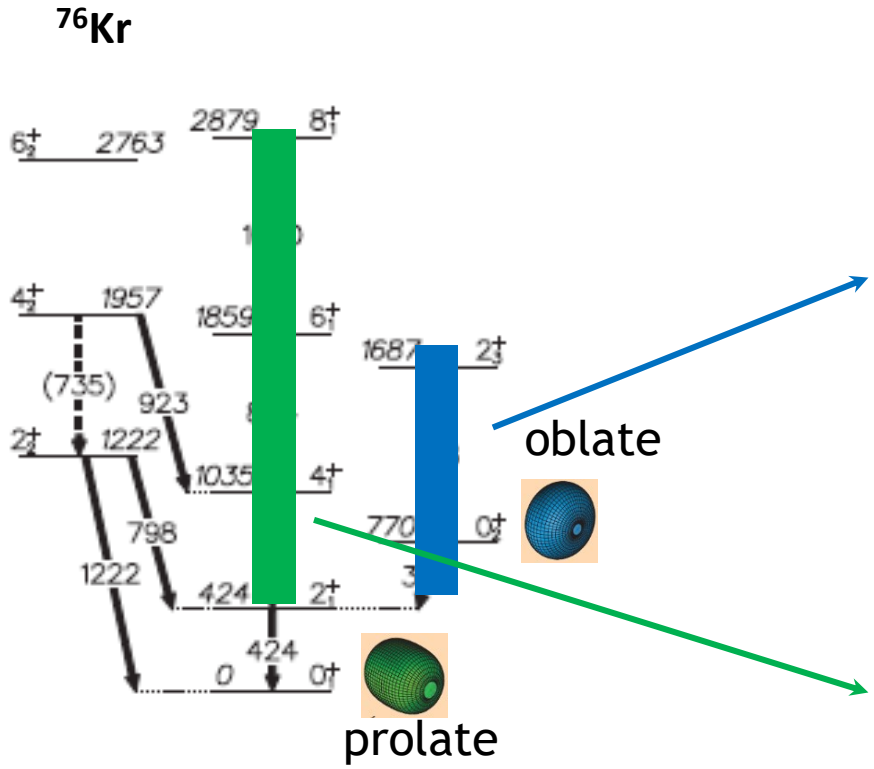


PARIS@Nu-Ball2

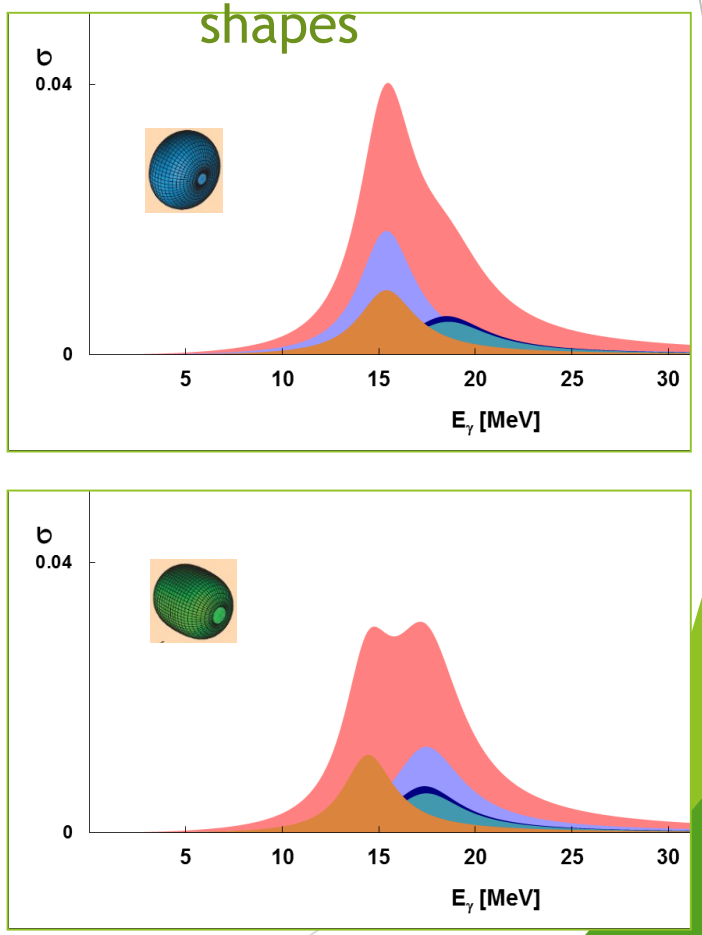
The GDR excited in ^{80}Sr CN

High-energy gamma rays from the GDR decay in hot ^{80}Sr compound nucleus measured in coincidence with discrete gamma transitions in ^{76}Kr evaporation residue

E. Clement et al., Phys. Rev. C 75, 054313 (2007)



GDR line-shapes



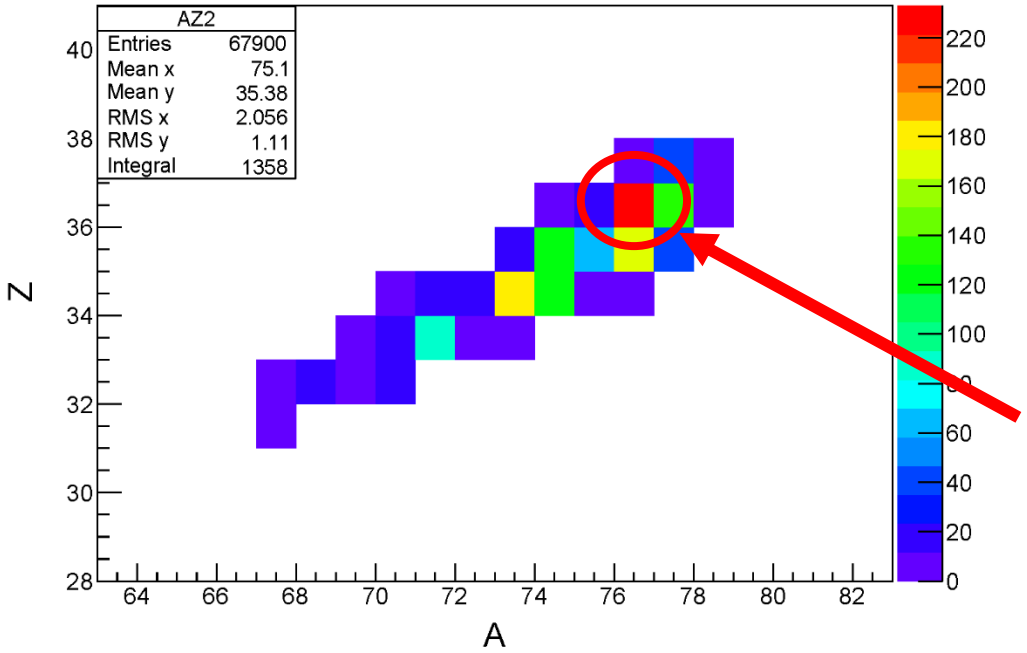
result: GDR strength → nuclear shape

Reaction

^{16}O @ 95 MeV on $^{64}Zn \rightarrow {}^{80}Sr^* \rightarrow {}^{76}Kr$

Injected Ion species	Injected Intensity (nA)	charge	Terminal voltage (MV)	Energy (MeV)	I analysed électrique (nA)	I analysed max. Possible	Frequency pulsation (ns)
	2 200 800	7^- $7^+ / 8^+$	14,84 14,25	119 128	1 200 75	80	400 ns

^{16}O@95 MeV on ^{64}Zn->$^{80}Sr^*$
^{76}Kr residue ~20% of fusion cross-section, 240 mb
GEMINI++ calculations



Residue yield with requested GDR emission in the first steps

^{76}Kr the strongest population

others: $^{73,74}Se$; $^{74,76}Br$; ^{77}Kr

The PARIS + NuBall2 experiment

Performed Nov 2022

Reaction:

^{16}O @ 95 MeV on $^{64}Zn \rightarrow {}^{80}Sr^* \rightarrow {}^{76}Kr$

Target: 1 mg/cm^2; pulsed beam,

Setup:

- **nu-Ball2 array:** Ge detectors around 90 degrees, ~4.5% efficiency at 1MeV
- **2 × 36 PARIS phoswiches** 3% (at 23 cm) efficiency for 15 MeV gamma rays

Measurement:

- high-energy gamma rays from the GDR Decay in hot ^{80}**Sr** compound nucleus by PARIS array (in wall geometry)
- discrete gamma transitions in ^{76}**Kr** evaporation residue by nu-Ball2 array,
- Event-by-event FOLD – (PARIS and nu-Ball2)

Data taking:

Planned from
14/11/2022 to 22/11/2022 – **8 days**
Problems with beam-pipe (too short) 5 days delay in the start, data taking:
19/11/2022 to 25/11/2022 – **6 and ½ days**
PARIS, high energy callibration:
Am+Be source - 12 h

Data status

- ~10 TB raw data of .fast in triggerless mode acquired

(with Am+Be callibration included)

- Standard faster2root conversion programme used to convert to ROOT: 7.1 TB

- Homemade event-builder created for Nuball1 dataset used

Events created basing on the Delta T versus RF time signal, Delta T = 200 ns

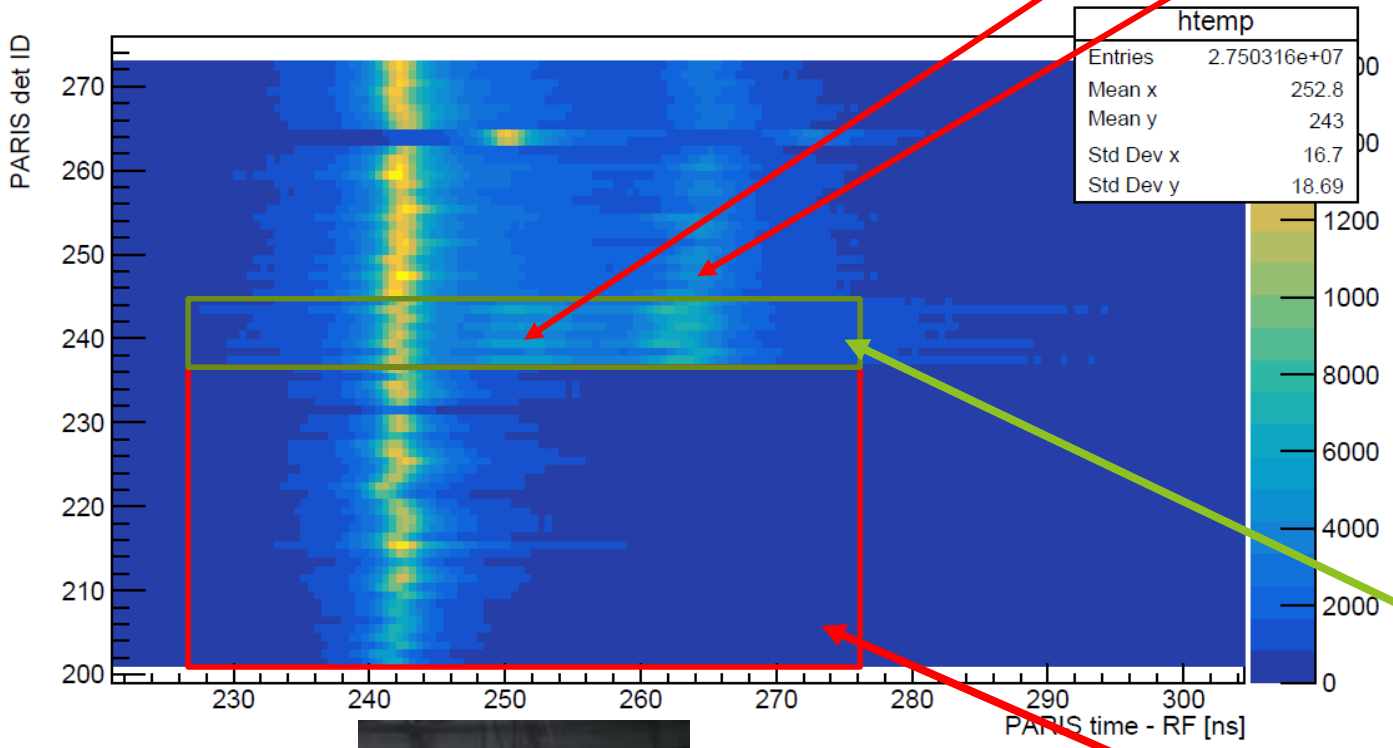
Clover addback, and anti-Compton, data filesize: 2.9 TB

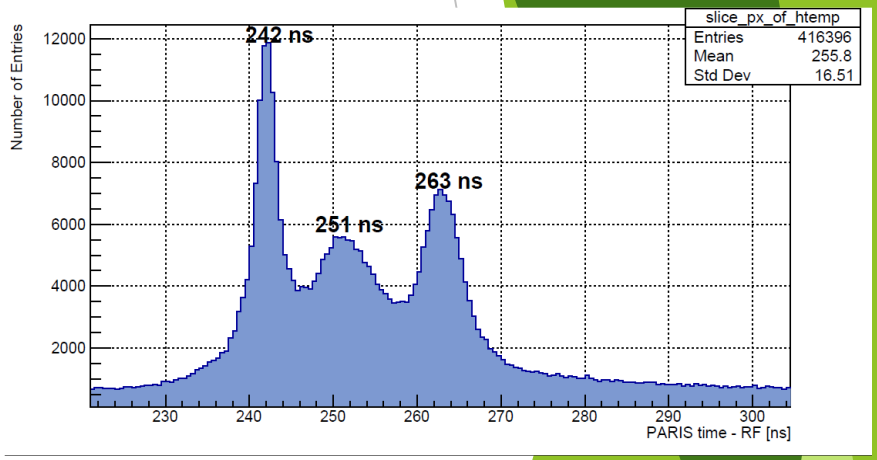
Importance of good timing

16O beam touch plastic beam pipe AND neutrons

Possible from beam dump, beam v ~ 3.35 cm/ns

RF – PARIS time, sigma = **1 ns** in the most of the runs



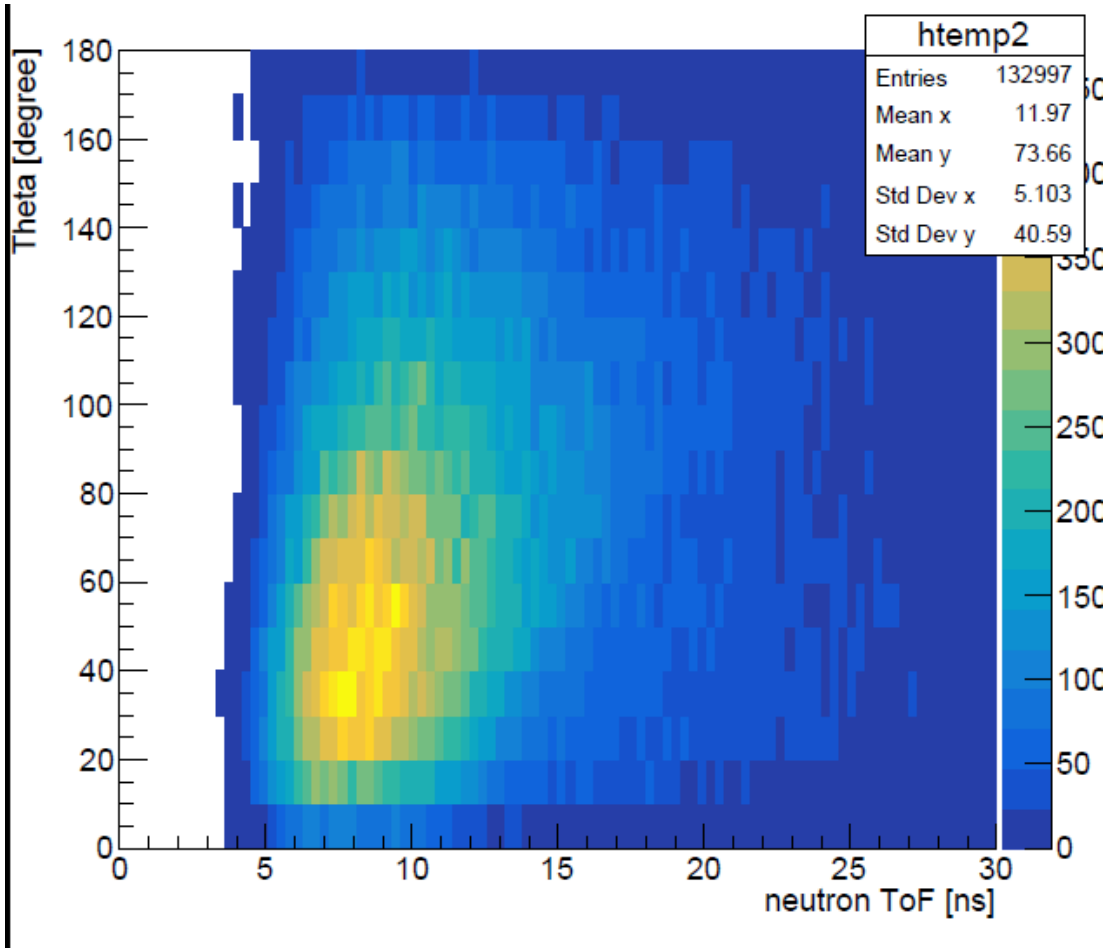


The most forward PARIS in respect to beam direction

back PARIS in respect to beam direction

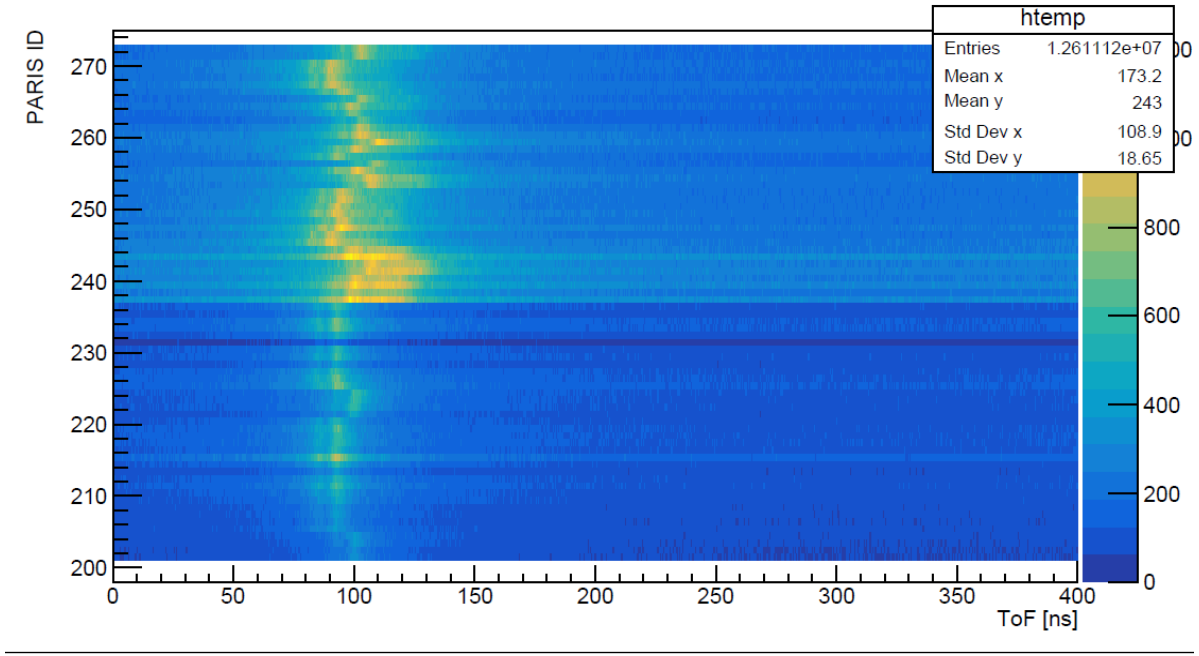
Importance of good timing

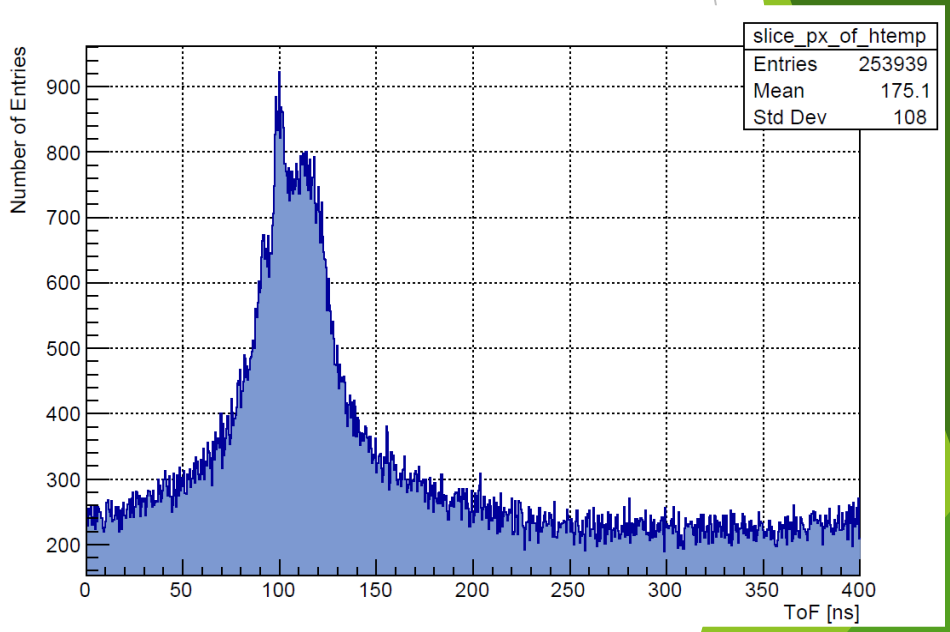
Simulated neutron ToF for invesitaged fusion-evaporation reaction with use of GEMINI++



Importance of good timing

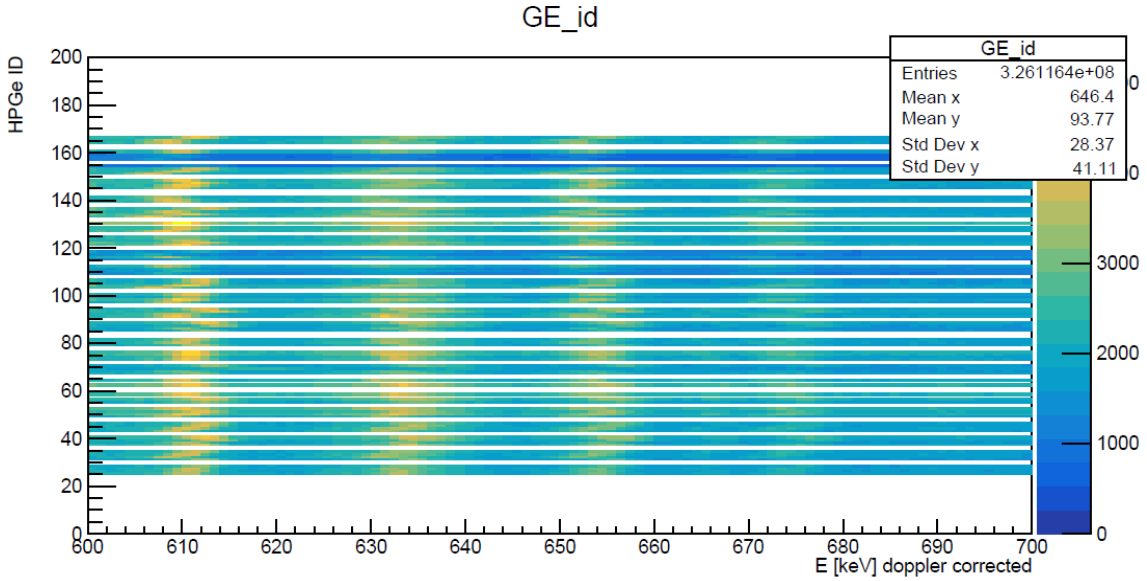
- In around ~8 h (integrated value) of the beam time in total RF signal quality was degraded!

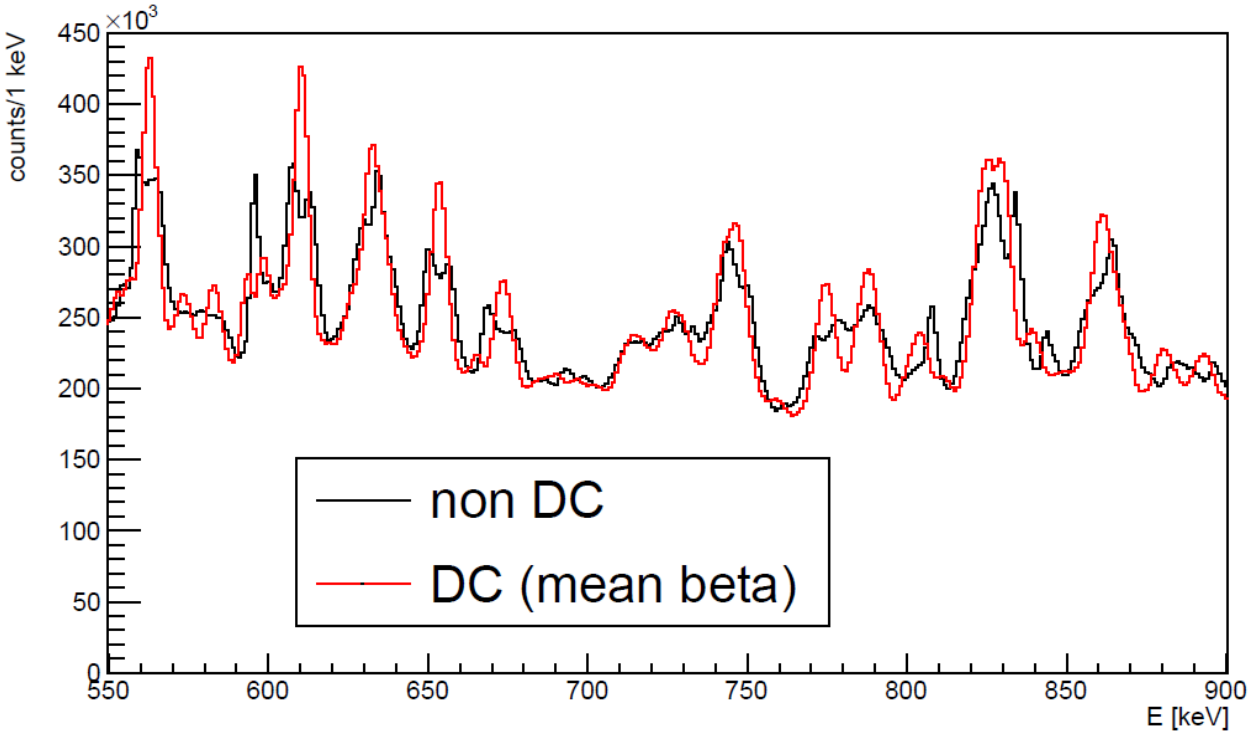




^{76}Kr discrete gamma-ray, Doppler eff.

Use of **mean doppler correction**, beta = 0.0226 c, fusion-evaporation reaction

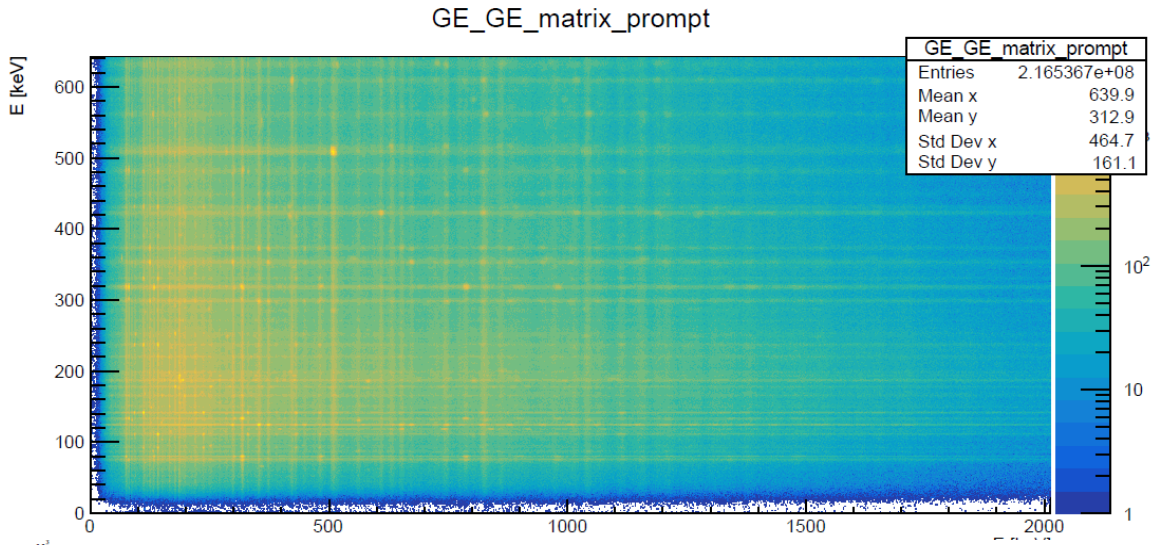


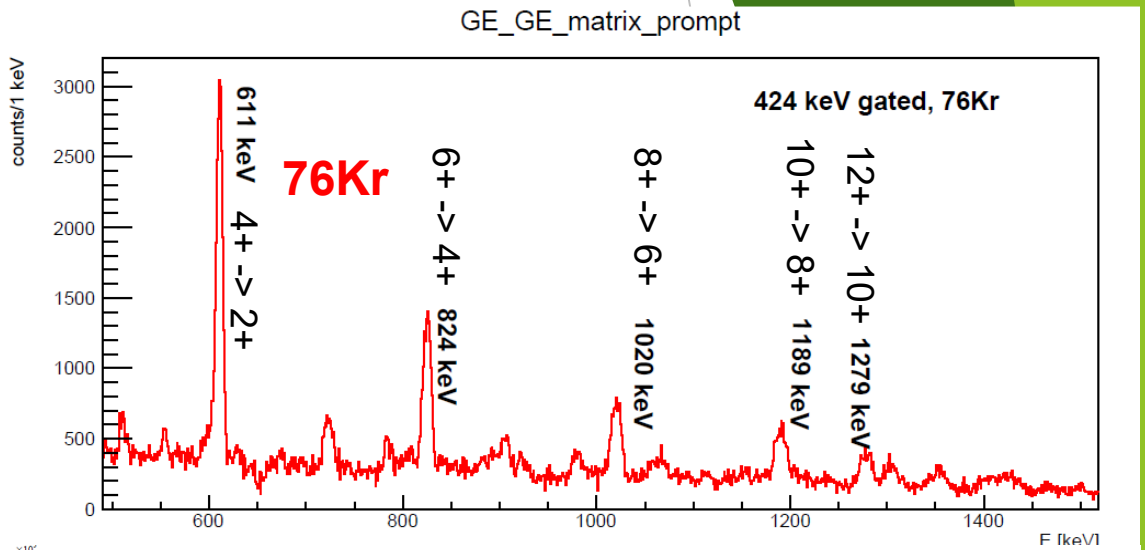


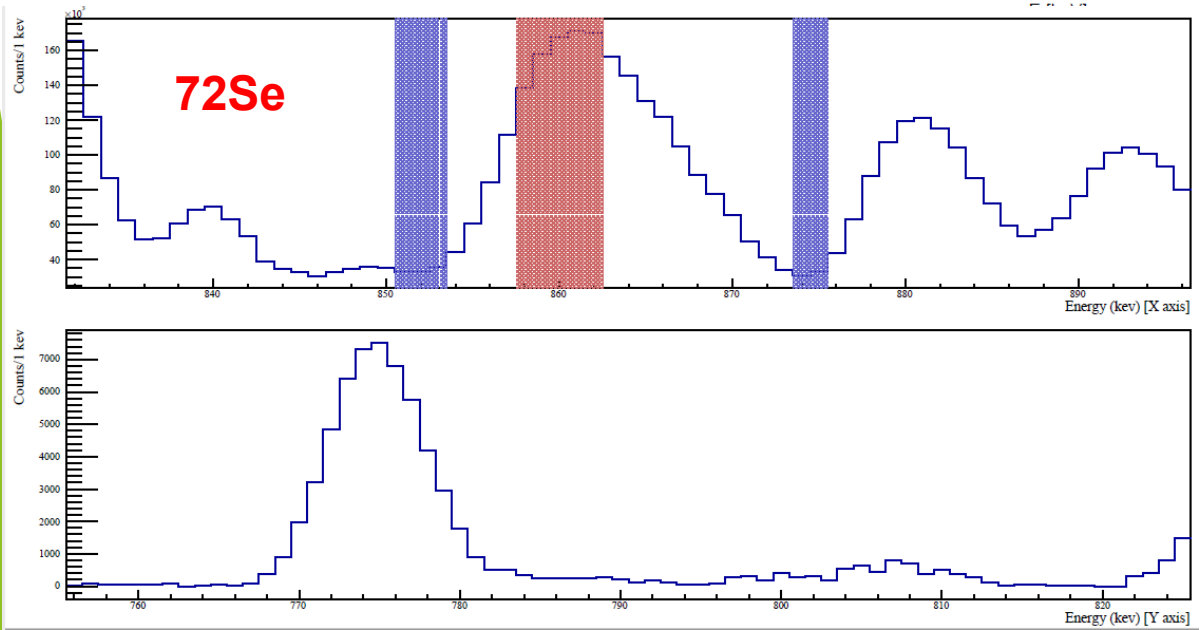
Theta of the CLOVER crystals:
75, 82.5, 97.5 and 105 degrees

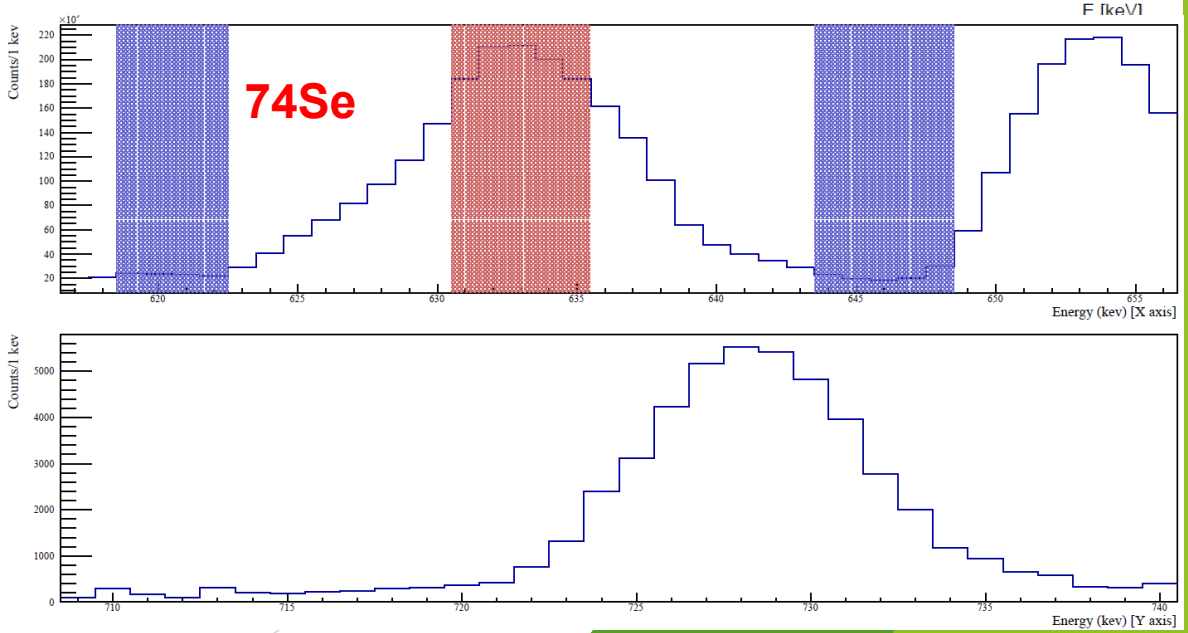
Discrete gamma-rays

Prompt HPGe-HPGe matrix



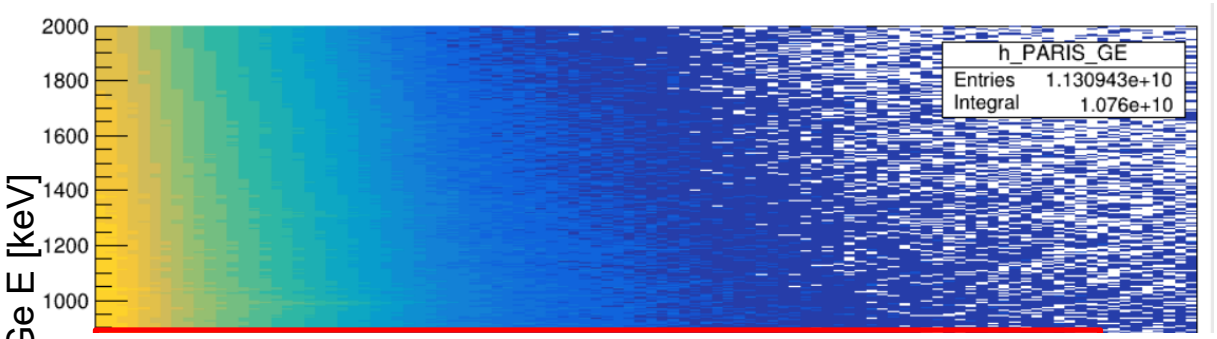


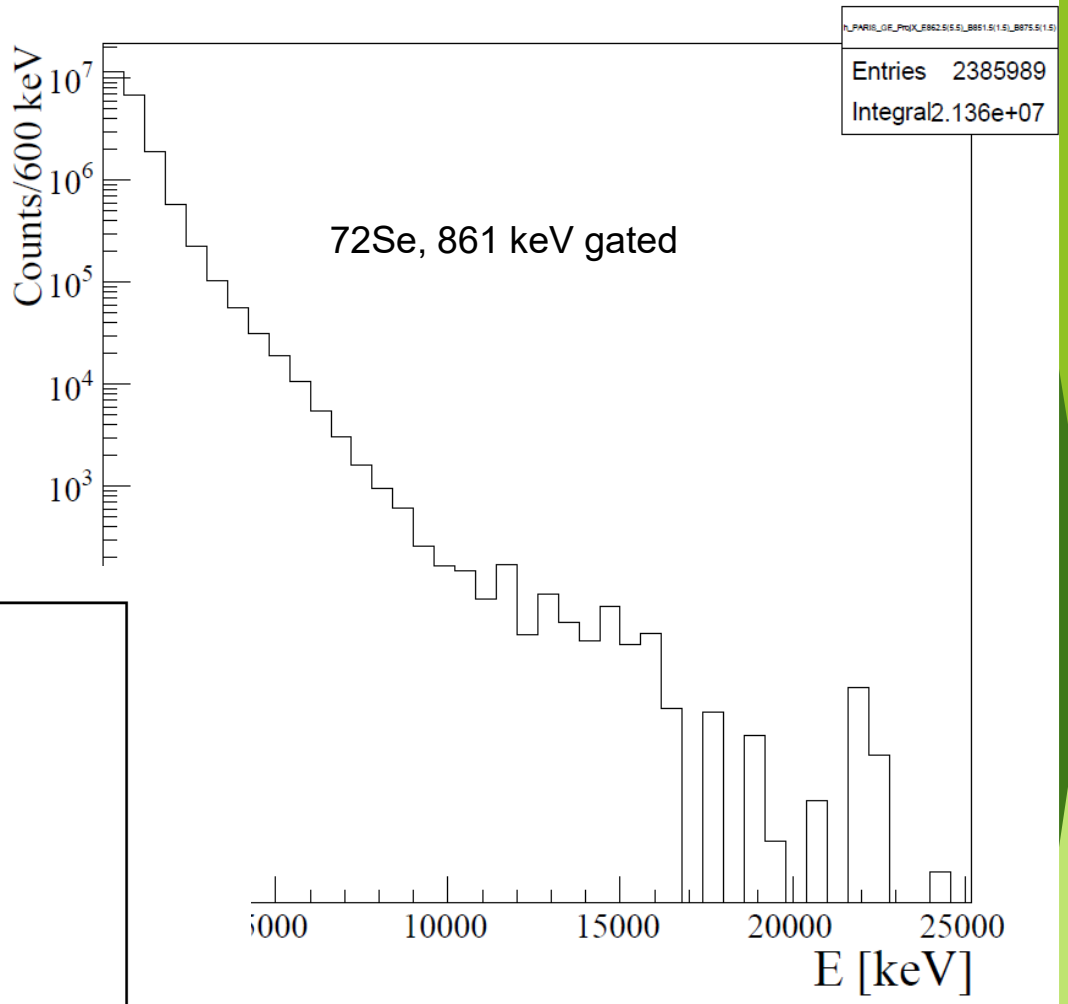


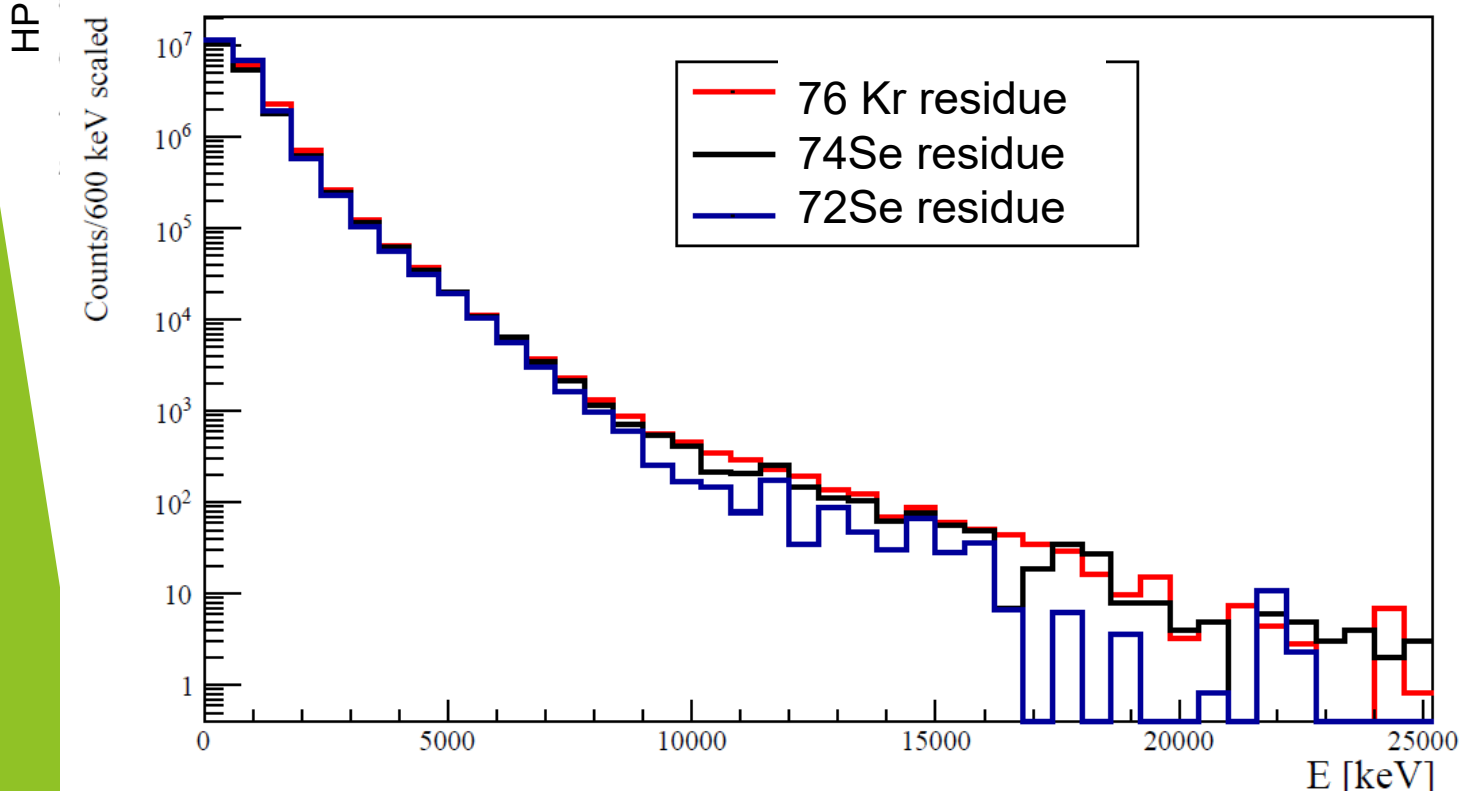


HPGe-PARIS matrix

Prompt HPGe-PARIS matrix







Summary

- For the reaction populating $^{80}Sr^*$ CN with use of ^{16}O on ^{64}Zn target we had effective data taking of ~6 days, with good intensity of beam allowed to collected high statistic.

- Observed problems with RF signal quality and stability during the experimental time. Observed high background coming from beam dump (in the „forward” PARIS) and other sources of the backgrounds – only good timing allows to remove them.

- Analysis of the GDR shapes obtained with use of differen discrete gamma-ray gating is ongoing.

Acknowledgements

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The Nuabll2 and PARIS collaboration

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