Perspectives with gamma-ray detectors at GANIL

MICHAŁ CIEMAŁA (IFJ KRAKOW)

GANIL COMMUNITY MEETING, 2022, 18/10/2022

Presentation plan

Gamma-ray detectors used recently at GANIL

EXOGAM, PARIS setups used with VAMOS, LISE and NFS, highlights and perspectives

Recent AGATA campaign at GANIL

AGATA 2 GANIL – (timescale >2025)

Conclusions

Highlights, EXOGAM & PARIS use in 2022

With VAMOS:

Insight into fission from the gamma probe: Going beyond current status with PARIS@VAMOS, *Ch. Schmitt, A. Lemassson, M. Cieamła et al.*

At LISE:

Study of deformed and spherical 2^+ states via Coulomb excitation and first time measurement of PDR in ^{34}Si, *R. Lica, S. Calinescu, O. Sorlin, et al.*

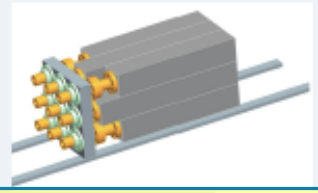
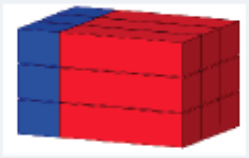
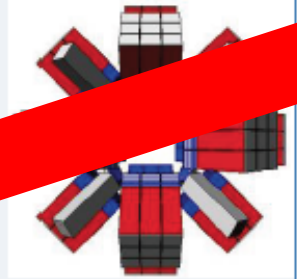
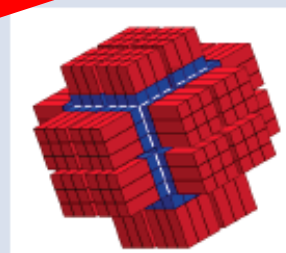
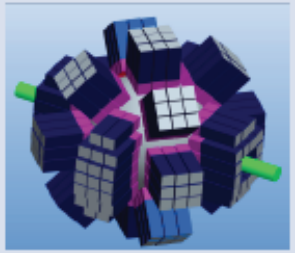
Study of Proton/Neutron contribution along Silicium isotopic chain, S. Grévy, R. Thomas, O. Sorlin et al.

At NFS:

Nuclear structure studies using neutron inelastic scattering reactions, example of the pygmy resonance in ^{140}Ce, *M. Vandebrouck, I. Matea et al.,* talk on Thurdsday

Photon Array for studies with Radioactive Ion and Stable Beam - PARIS (travelling detector)

PARIS phases and cost estimates

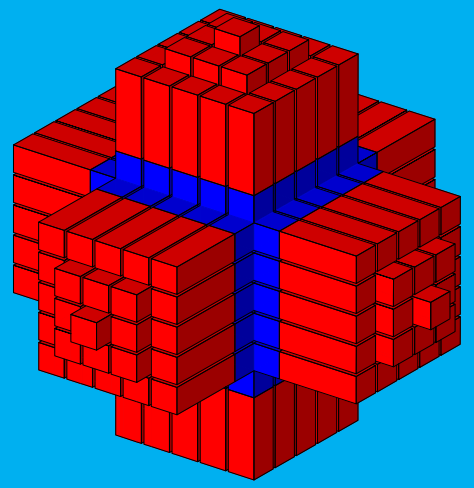
Phase 1 **2011/2012** PARIS cluster	1 cluster: 9 phoswiches		
Phase 2 **2021** PARIS Demonstrator	8 clusters 72 phoswiches		
2025? PARIS 2π	12 clusters: 108 phoswiches		
after2025	>24 phoswiches		

Today we have 8 clusters (72 detectors)

PARIS is made of clusters:
Cluster = 9 phoswiches of $LaBr_3$:NaI or $CeBr_3$:NaI
Digital electronic basing on V1730 digitizer, which can be coupled to NUMEXO2 boards. Also other electronic used, by example FASTER digitizers (NFS exp. and @IJCLab)

Current extension of the MoU on PARIS (2022-2026)
IN2P3 (France), COPIN (Poland), GANIL/SPIRAL2 (France), TIFR/BARC/VECC (India), IFIN HH (Romania), INFN (Italy), UK, Turkey, GSI (Germany)

Goal of the new MoU
4π mini-cube
(150 phoswiches)



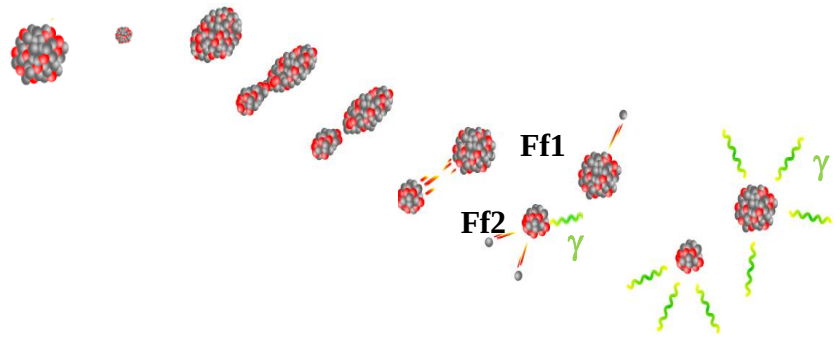
VAMOS + PARIS& EXOGAM

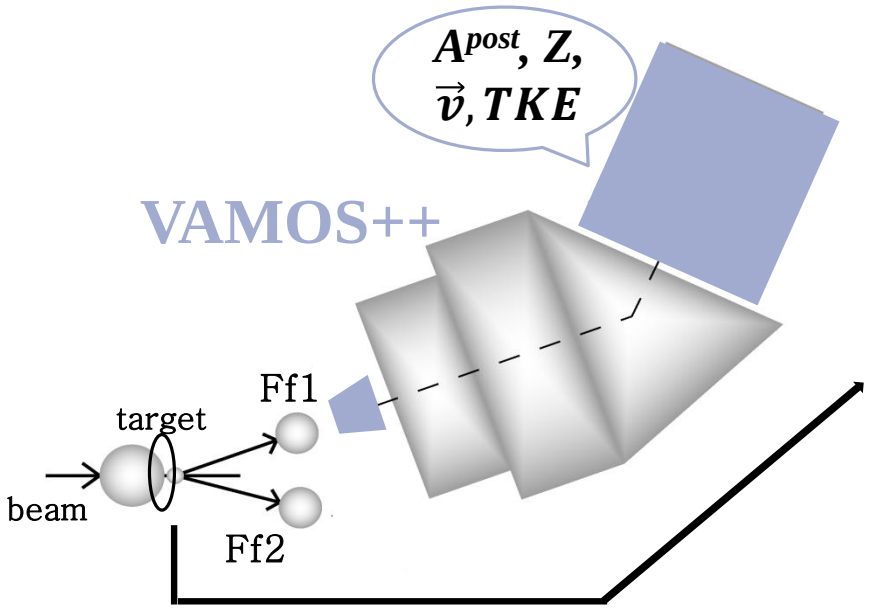
VAMOS+PARIS&EXOGAM experiment (March 2022, E826)

Fusion-fission in inverse kinematics

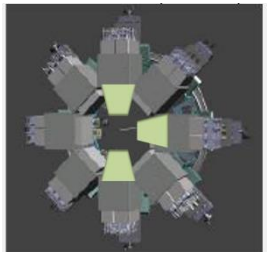
$^{238}U + {}^{9}Be \rightarrow {}^{247}Cm^{*}$ (E^{*}~ 43MeV)

(5.88MeV/u) (500µg/cm2)

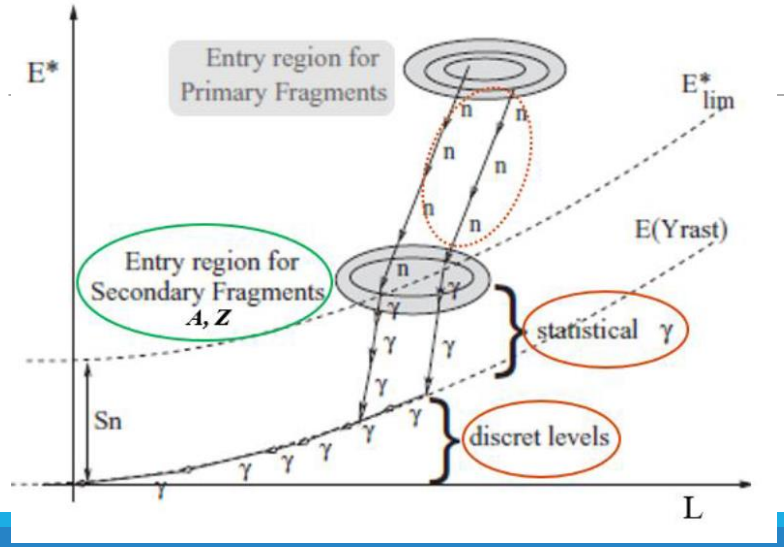




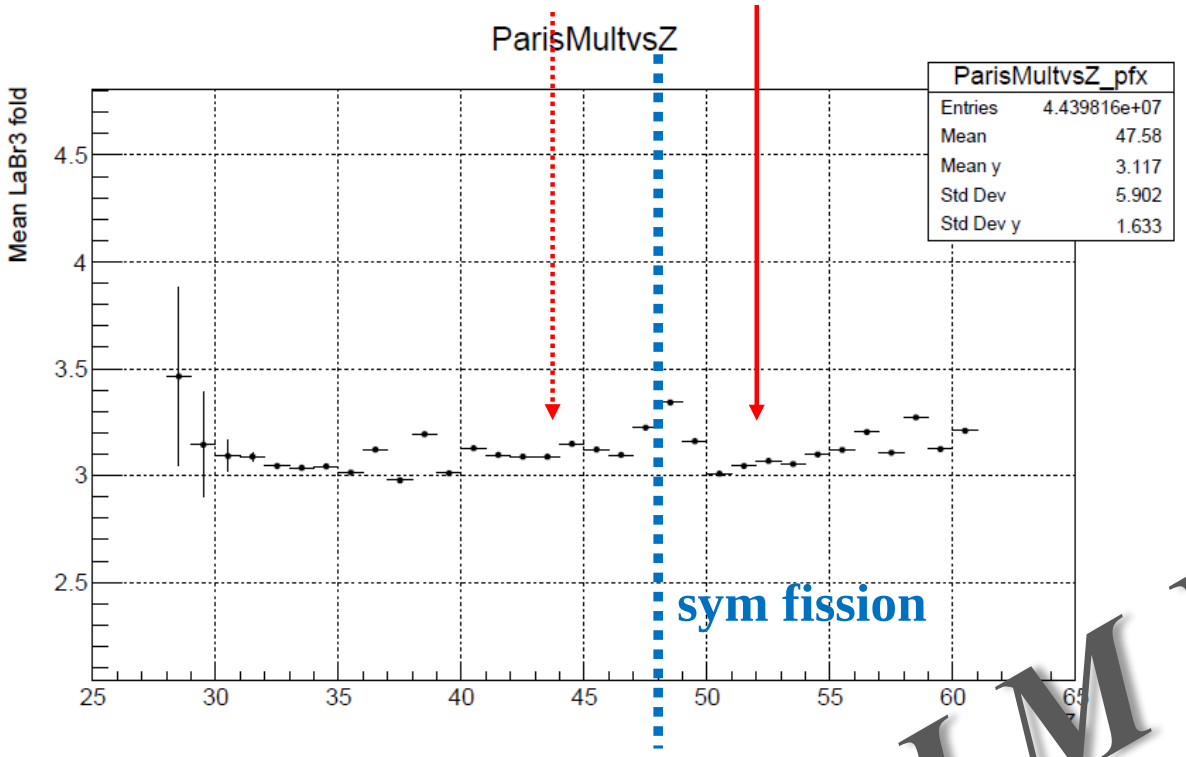
PARIS
Exogam



PFGS
E_γ, E_γ^{sum}, M_γ, M_n

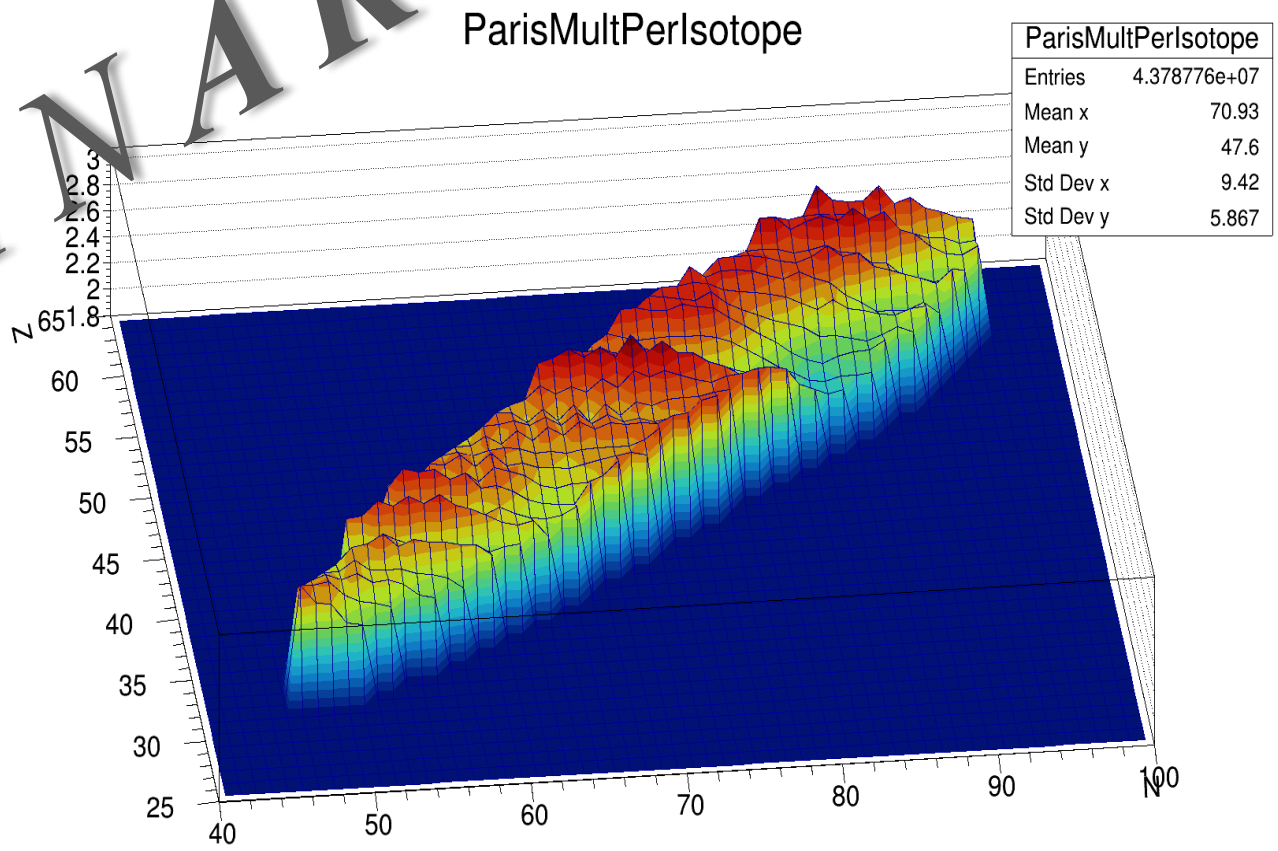


PARIS+EXOGAM



γ fold in PARIS vs. Z in VAMOS++

γ fold in PARIS vs. Z,N in VAMOS++



Perspectives (tentative selection)

Systematic study of fusion-induced fission with, by example, $^{238}U+^{12}C$ and $^{238}U+^{26}Mg$ with use of VAMOS + PARIS + EXOGAM combined setup.

Possible extension by adding second arm or coupling with the SPIDER telescope → evolution of fission properties with excitation energy, as well as to quasi-fission like mechanisms.

LISE + PARIS& EXOGAM

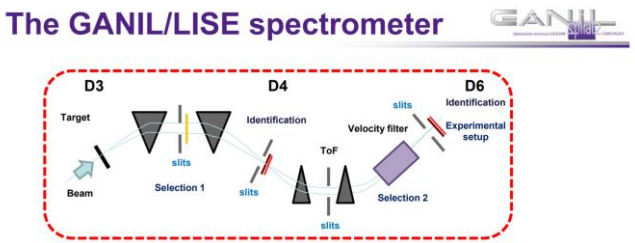
E798_19 experiment at GANIL-LISE (June-July 2022)

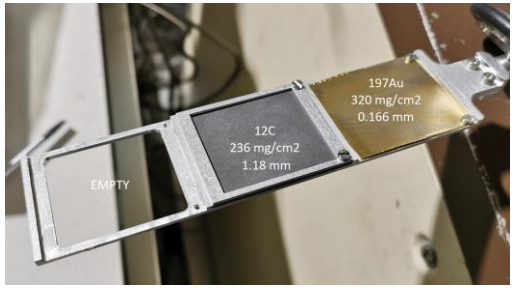
Study of deformed and spherical 2^+ states via Coulomb excitation and first time measurement of PDR in ^{34}Si

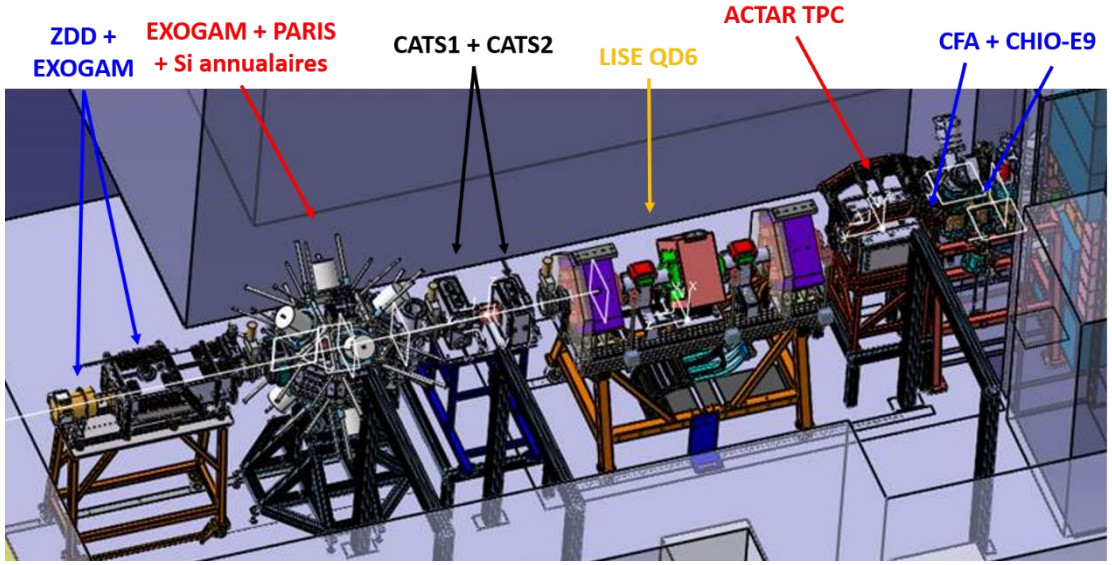
R. Lica, S. Calinescu, O. Sorlin, et al.

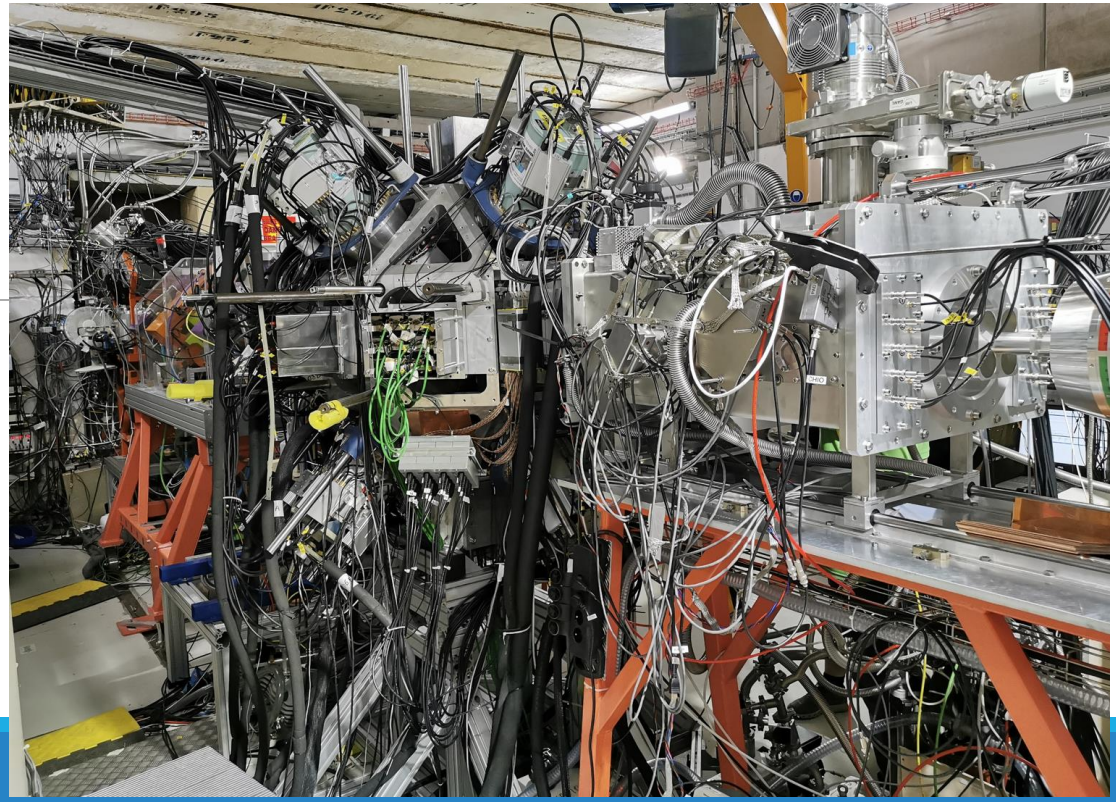
Beams:
^{36}S at ~ 56 MeV/u (5.7 UT)
^{34}Si at ~ 58 MeV/u (20.5 UT)

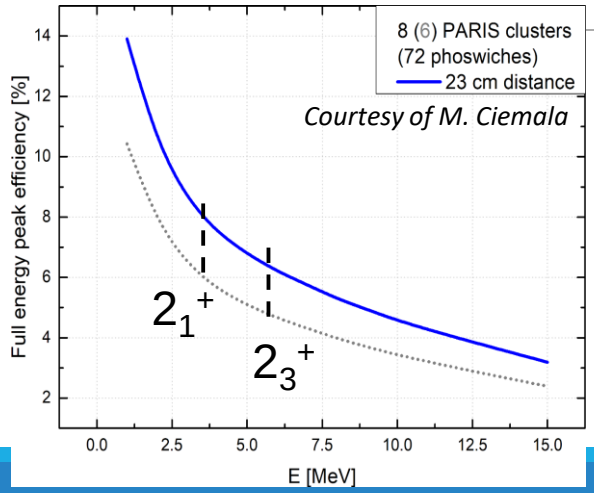
Targets:
^{12}C - 236 mg/cm^2
^{197}Au - 320 mg/cm^2

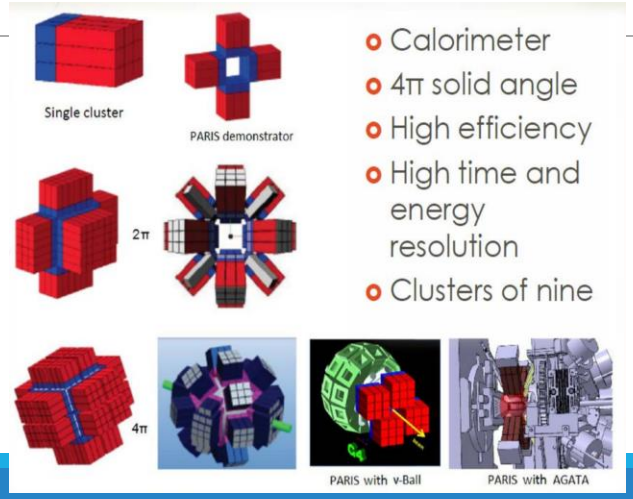








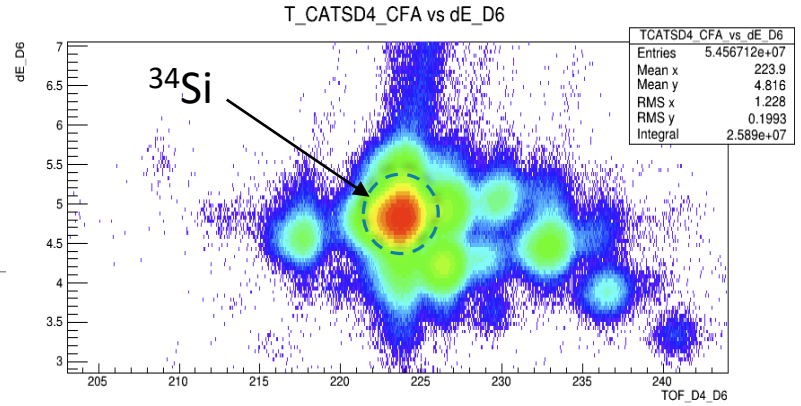




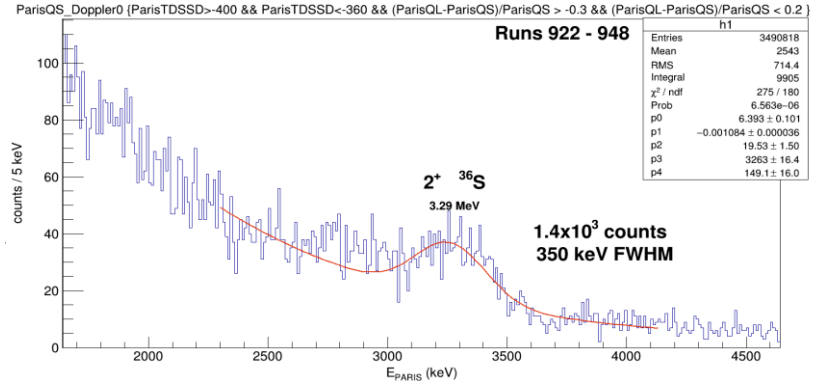
Following the preliminary analysis (partial statistics):

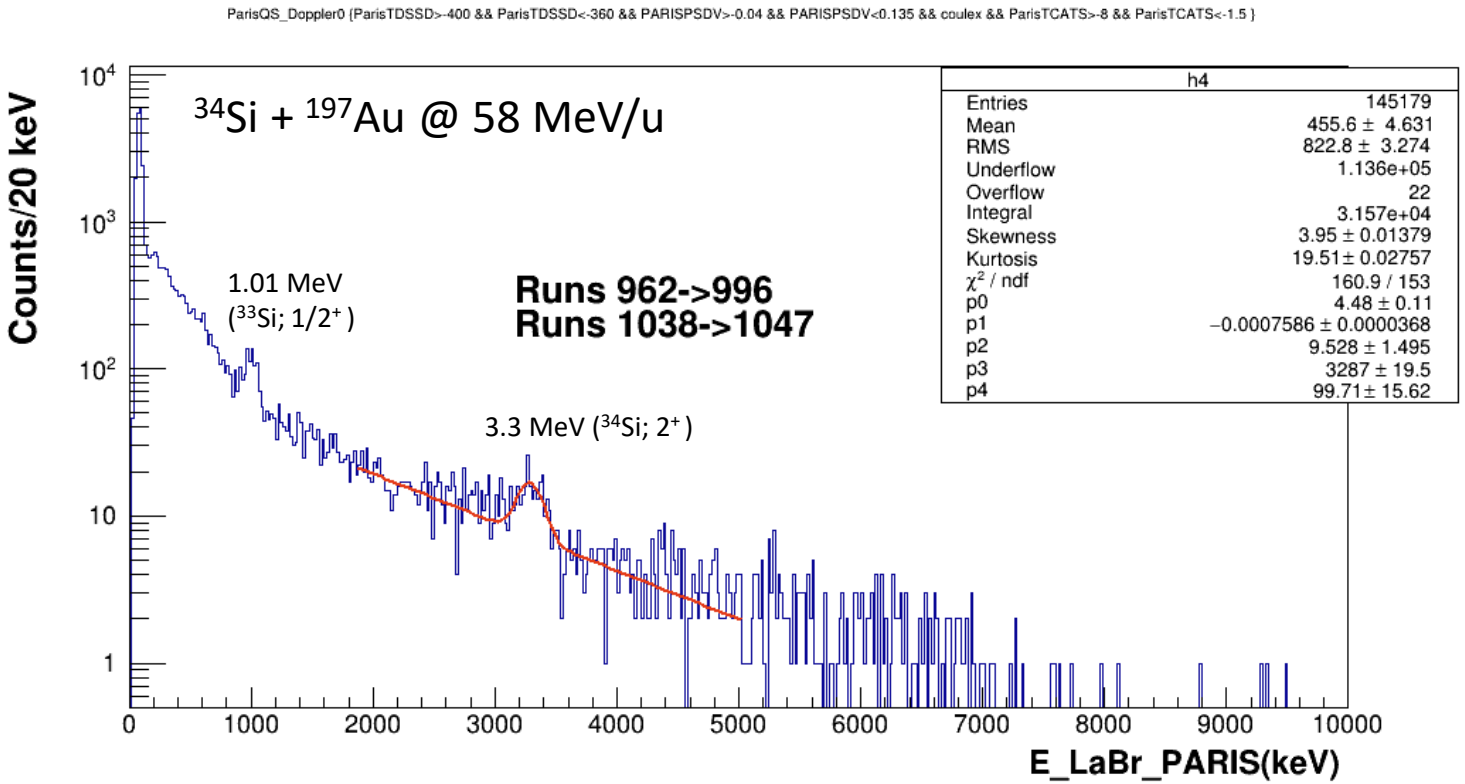
- we managed to acquire the needed statistics to clarify the uncertainty of the B(E2) corresponding to the first excited 2+ state of ^{34}Si (3.3 MeV)
- there are some weak indications for the presence of the spherical 2+ (at 5.3 MeV)
- structures in the spectrum at 6-7 MeV which could be connected to the PDR.

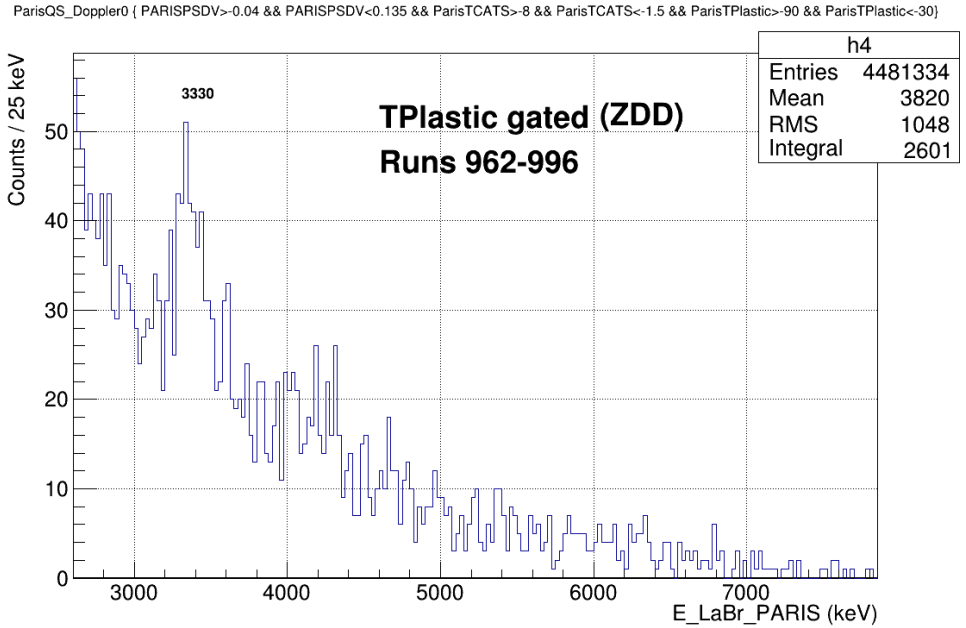
Beam composition: ~90% of ^{34}Si



Validation of the experimental method: ^{36}S beam (well known 2_1^+ at 3.29 MeV, B(E2)=2.83(24) W.u.)



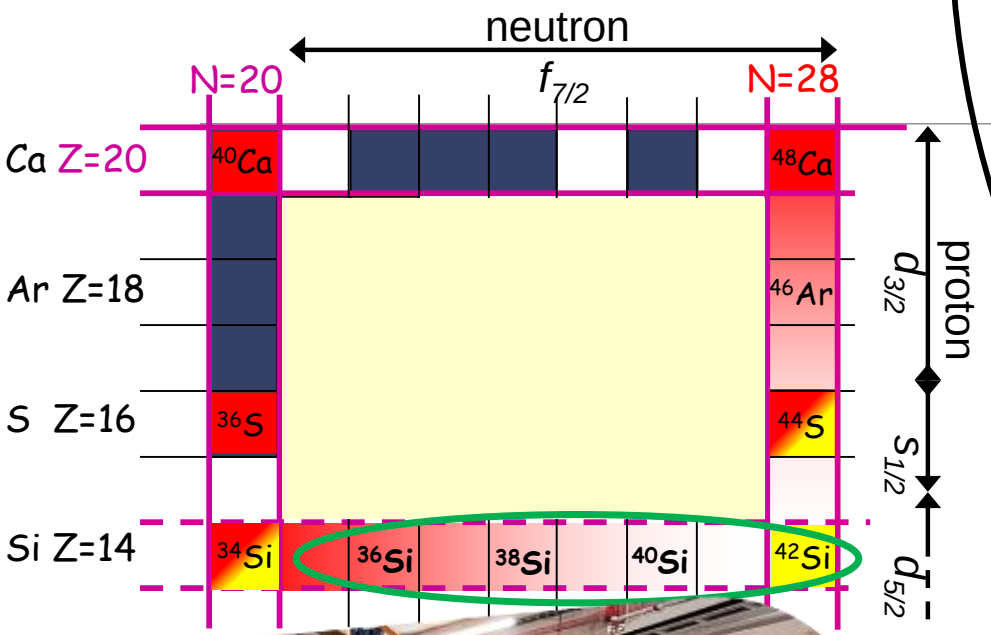




Courtesy of R. Lica

Physics of the N=20-28 shell closure

➢ E823 : Study of Proton/Neutron contribution along Silicium isotopic chain

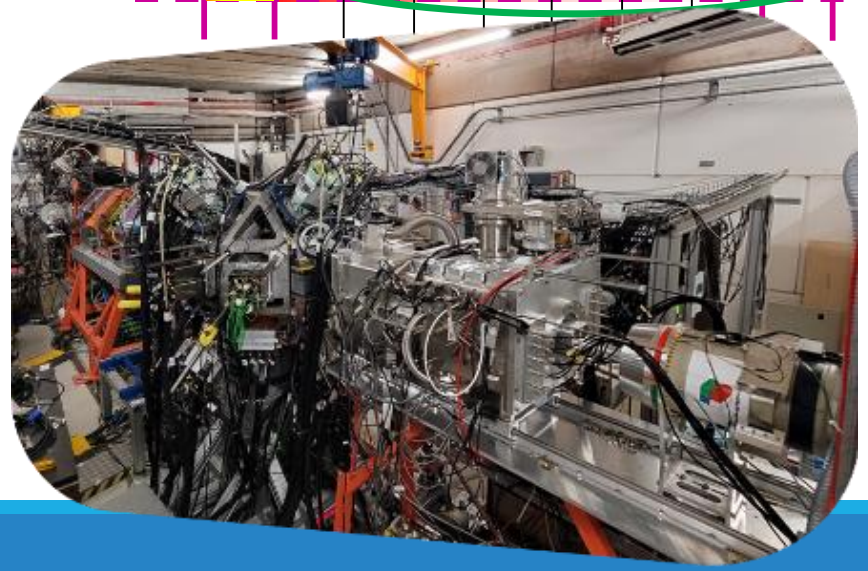


Deformation of Si isotopes has two origins :
- Compression of proton orbitals (gap Z=14) when neutrons fill the f7/2
- Compression of neutron orbitals (gap N=28) when protons are removed from sd orbitals

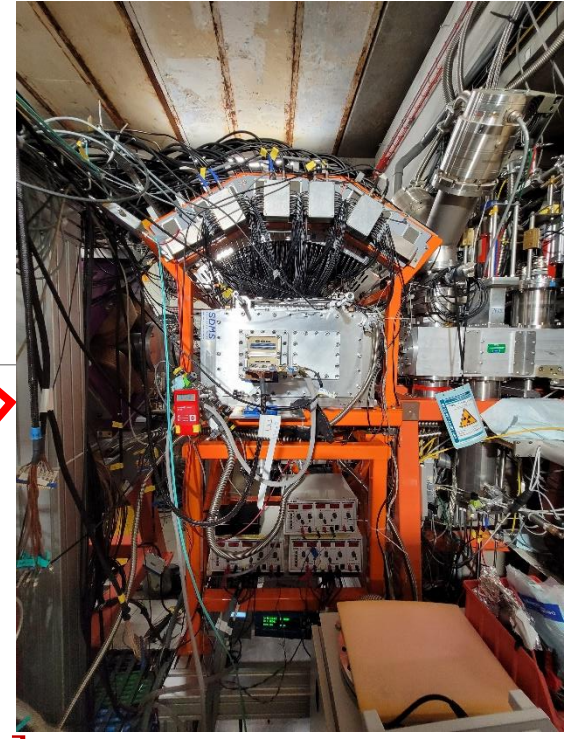
➢ *Proton inelastic scattering to extract (p,p') reaction cross-section*

$$\frac{M_n}{M_p} = \frac{1}{3}\left[\frac{\delta_{pp'}}{\delta_{EM}}\left(1+\frac{1}{3}\frac{N}{Z}\right)-1\right]$$

➢ *Coulomb excitation to measure B(E2) from CouleX cross-section*



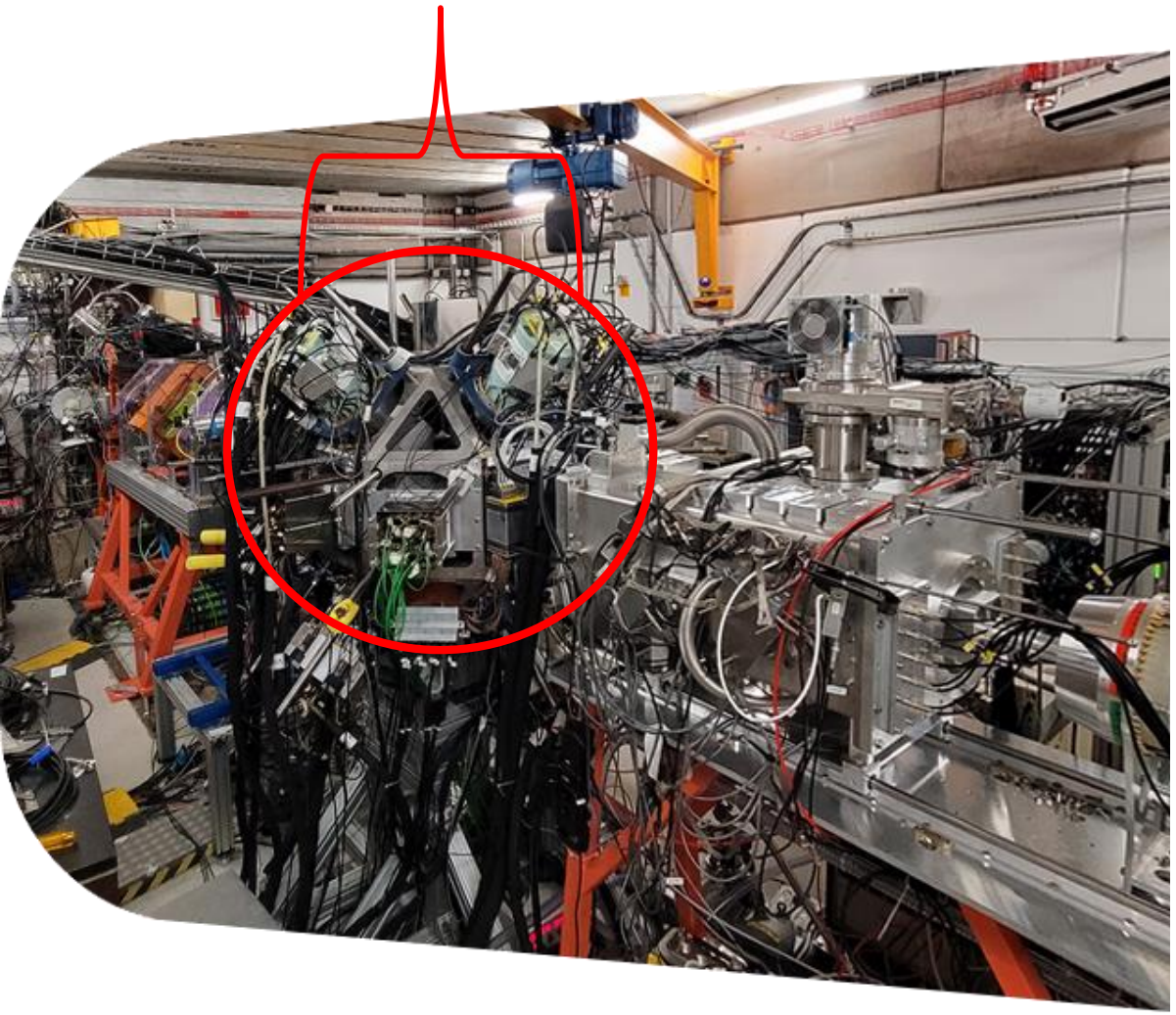
PARIS / EXOGAM Detector



ACTAR

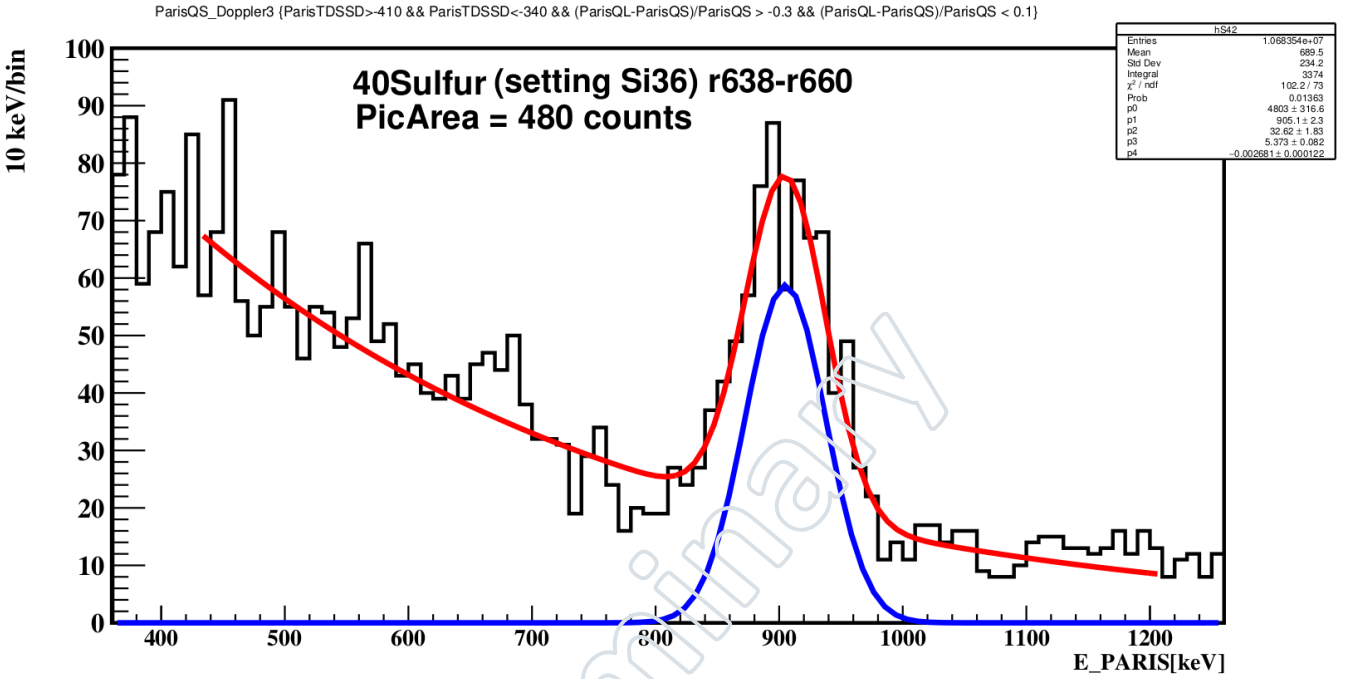
« Brochette » MODE : Both Experiment in the same beam line

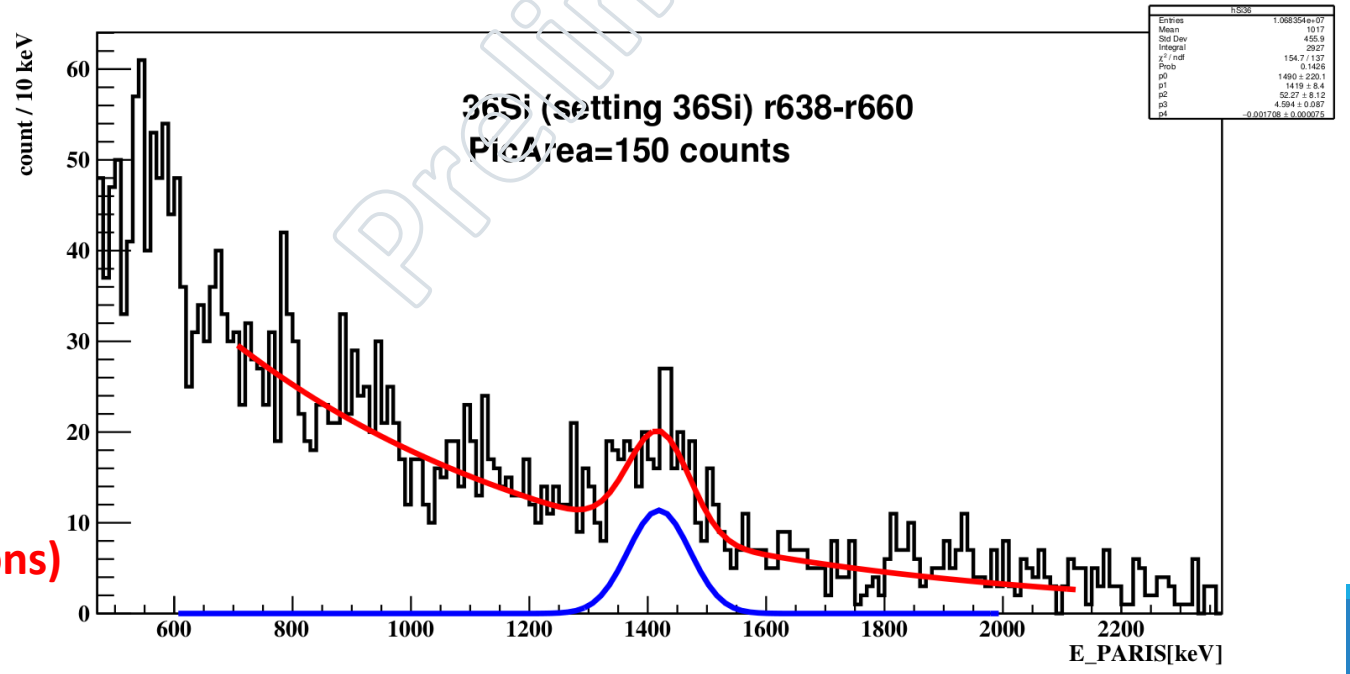
➢ *PARIS detectors*



CouleX Target : Gold (400 mg.cm^{-2})

8 Paris Clusters

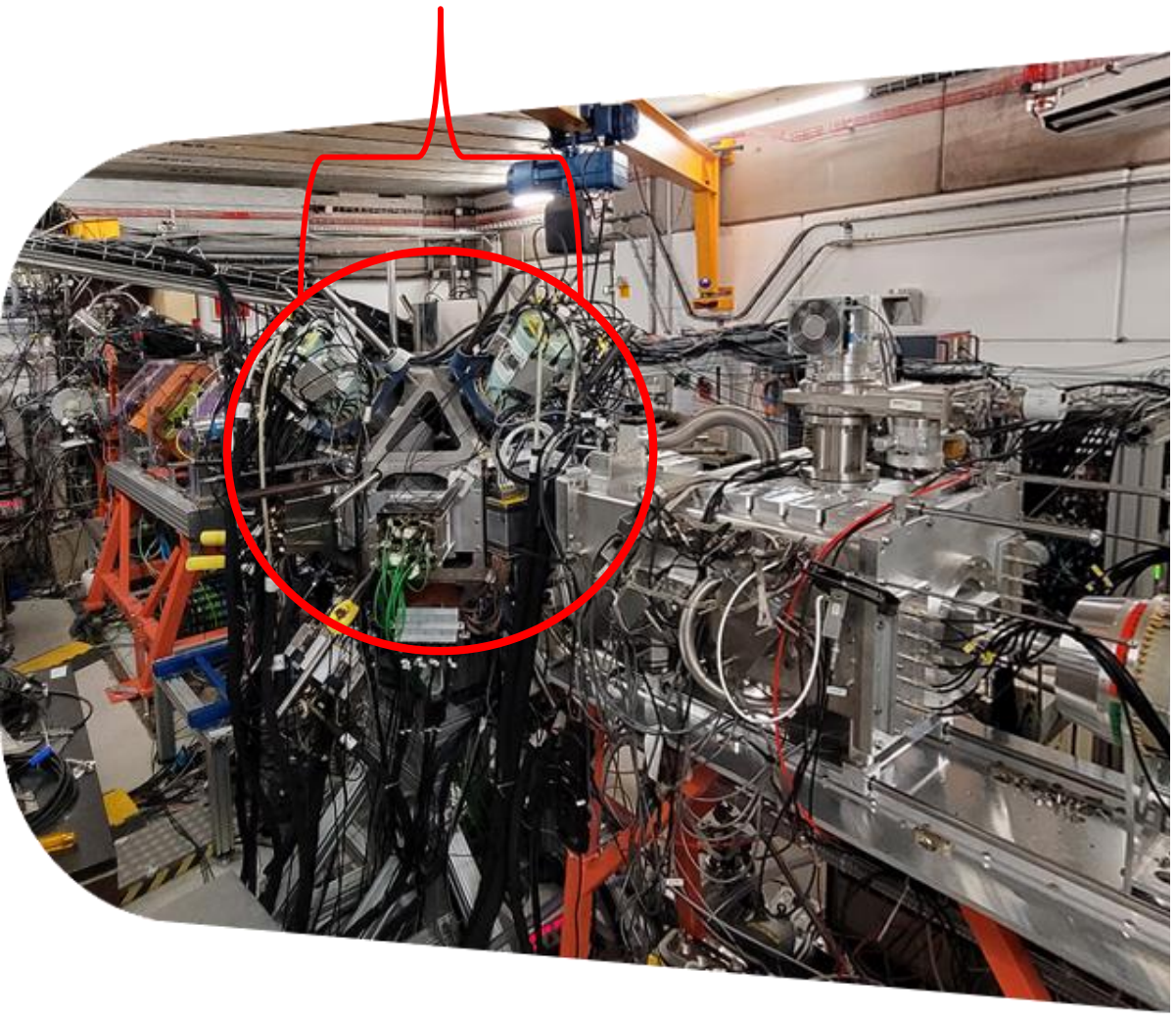




Preliminary - not full statistics - online data (no final selections)

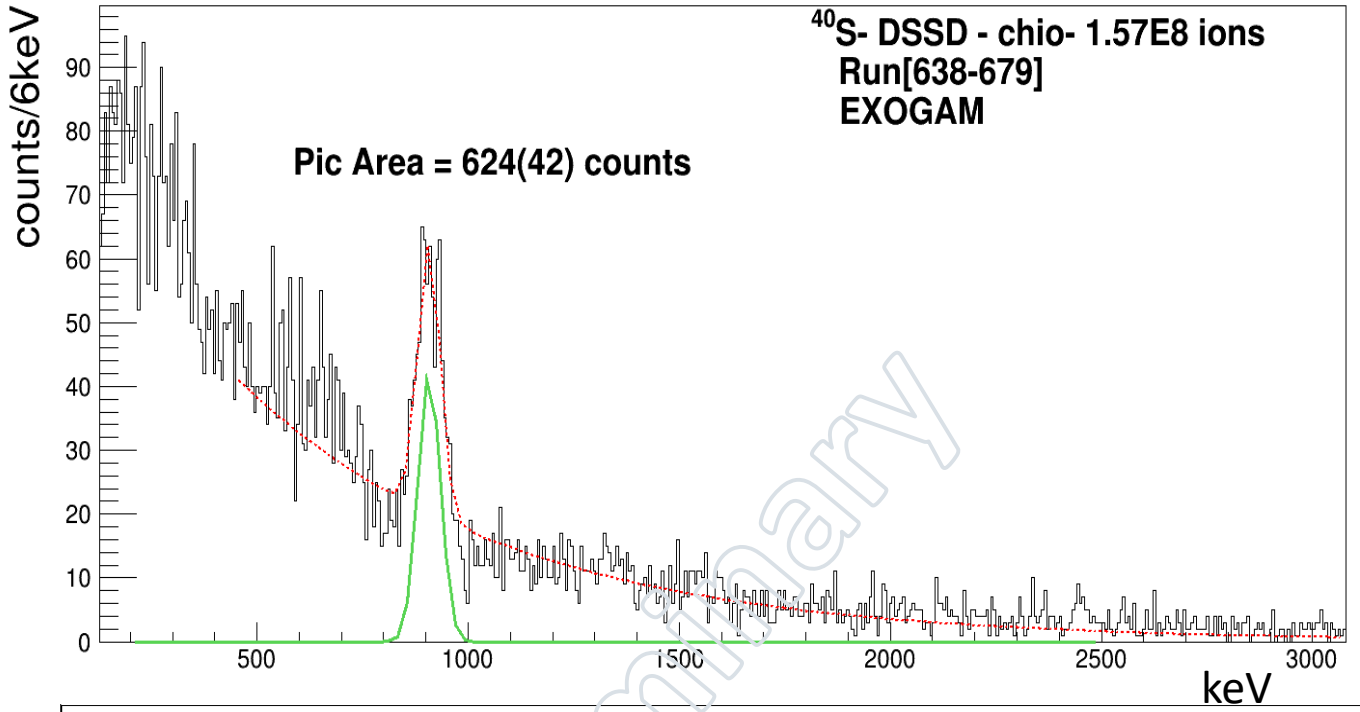
Courtesy of S. Grévy and Q. Delignac

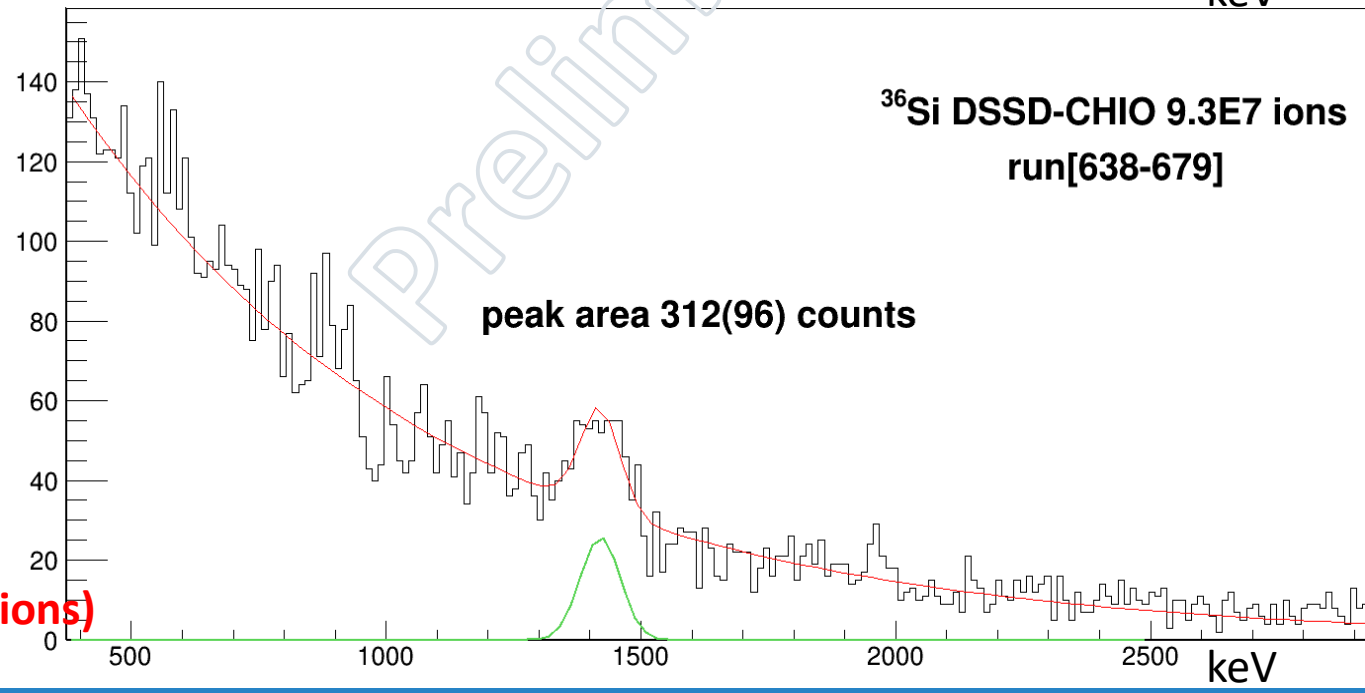
➢ *EXOGAM detectors*



CouleX Target : Gold (400 mg.cm^{-2})
8 Exogam Cluster

Preliminary - not full statistics - online data (no final selections)

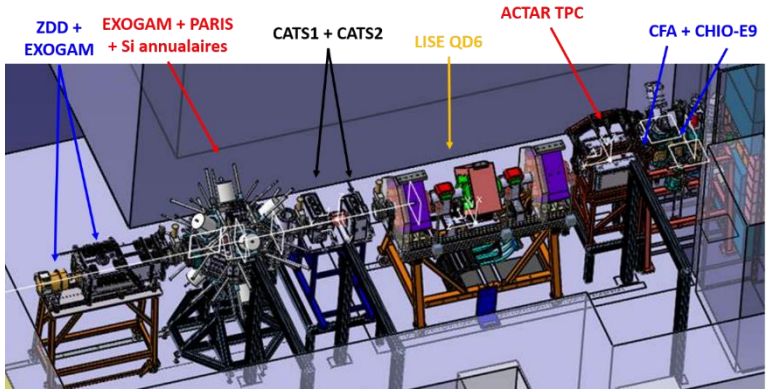




Courtesy of S. Grévy and Q. Delignac

Perspectives (tentative selection)

GRIT/MUGAST coupled to EXOGAM (PARIS?) at LISE for nuclear structure and/or nuclear astrophysics interest.



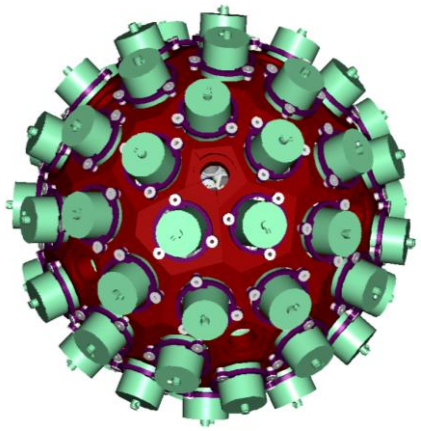
Study collective modes with use of coupled ACTAR and PARIS?

(issues: electronic compatibility, flanges?)

Coulomb excitation and PDR studies in exotic nuclei with EXOGAM and PARIS.

AGATA_2_GANIL

The AGATA project : THE ultimate spectrometer

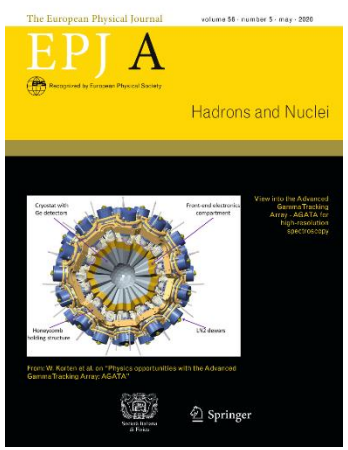


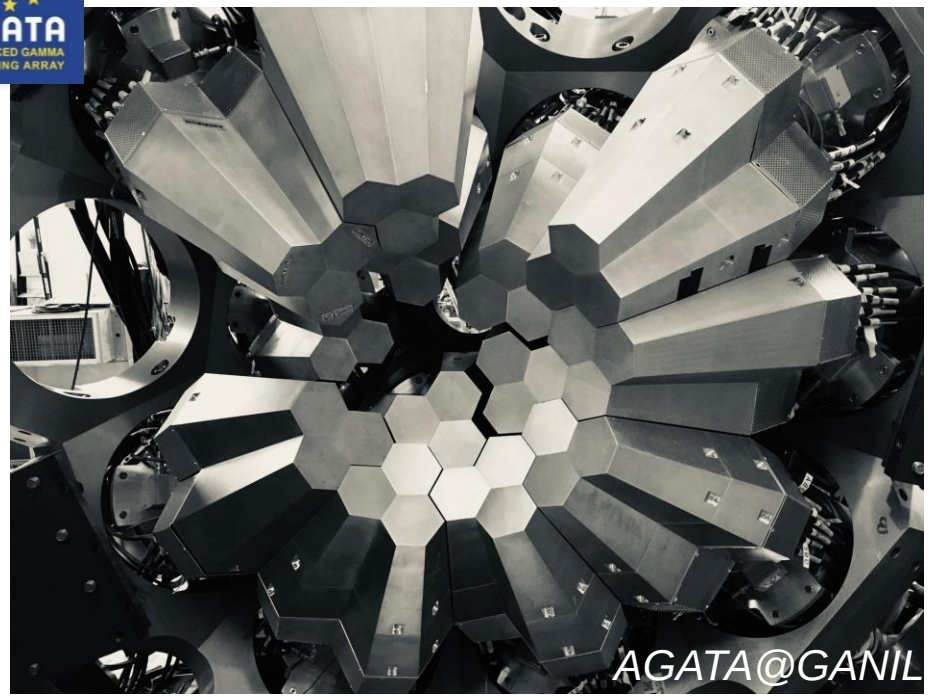
- 180 (60 triple-clusters) 36-fold segmented crystals
- Amount of germanium: 362 kg
- Solid angle coverage: 82 %
- Singles rate >50 kHz
- Efficiency: 43% (M_γ=1) , 28% (M_γ=30)
- Peak/Total: 58% (M_γ=1), 49% (M_γ=30)
- Angular Resolution: ~1°

The project timeline is to complete the array by 2030

Combination of:

- ❑ segmented detector
- ❑ pulse-shape analysis
- ❑ tracking the γ rays
- ❑ digital electronics





S. Akkoyun *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A 668, 26 (2012).
E. Clément *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A 855, 1 (2017).
AGATA White Book : W. Korten et al, Eur. Phys. J. A (2020) 56:137

AGATA campaign at GANIL

After 7 years [2014-2021], the AGATA@GANIL campaign was completed

Presently at LNL with the first experiments completed


AGATA@LNL

29 experiments

558 To of data

6568 hours beam on target

14 034 elog entries

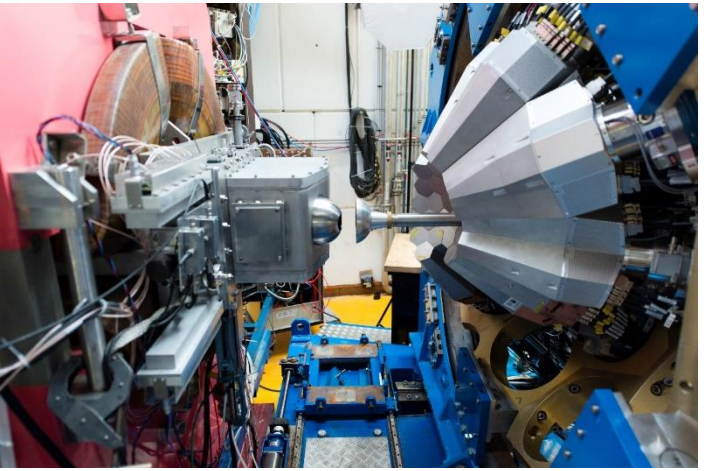
2386 days of LN2 surveillance

11,5 Tons of scientific equipment

AGATA@GANIL were many sub-campaigns

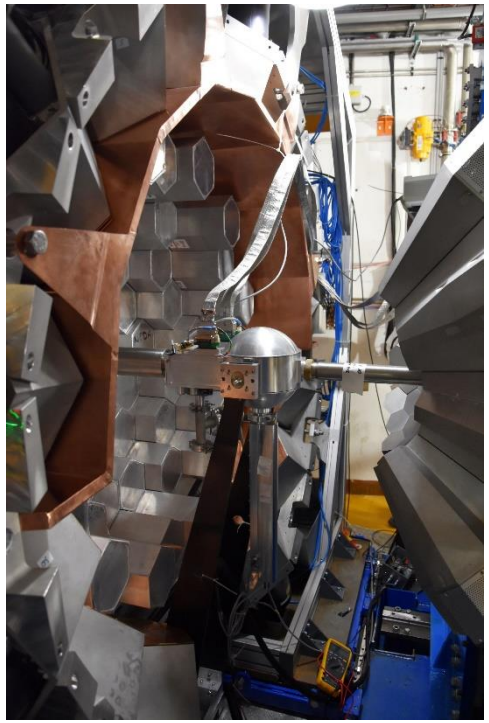
laboratoire commun CEA/DRF — spiral2 — CNRS/IN2P3

2015-2017



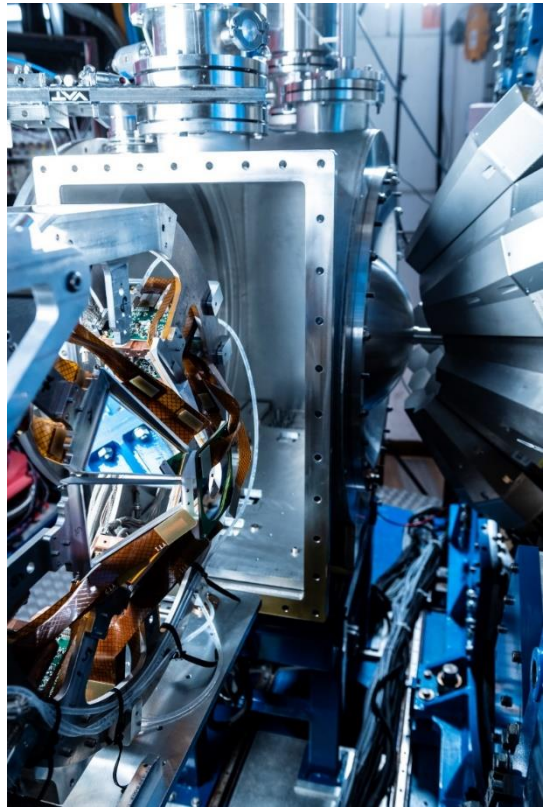
AGATA coupled to VAMOS, FATIMA, PARIS

2018



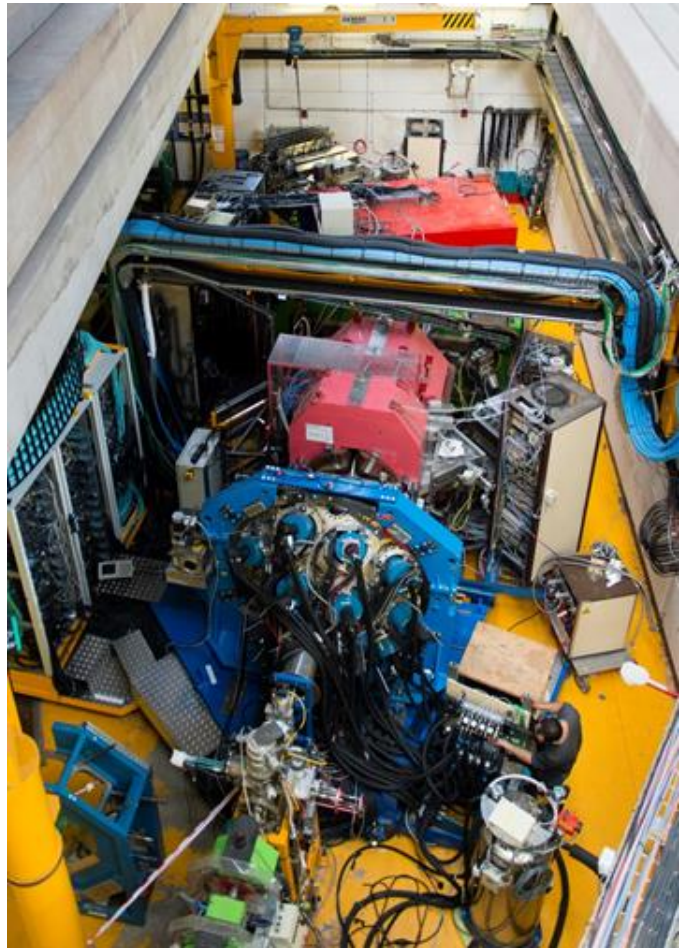
AGATA coupled to NEDA- DIAMANT

2019-2021



AGATA coupled to VAMOS MUGAST

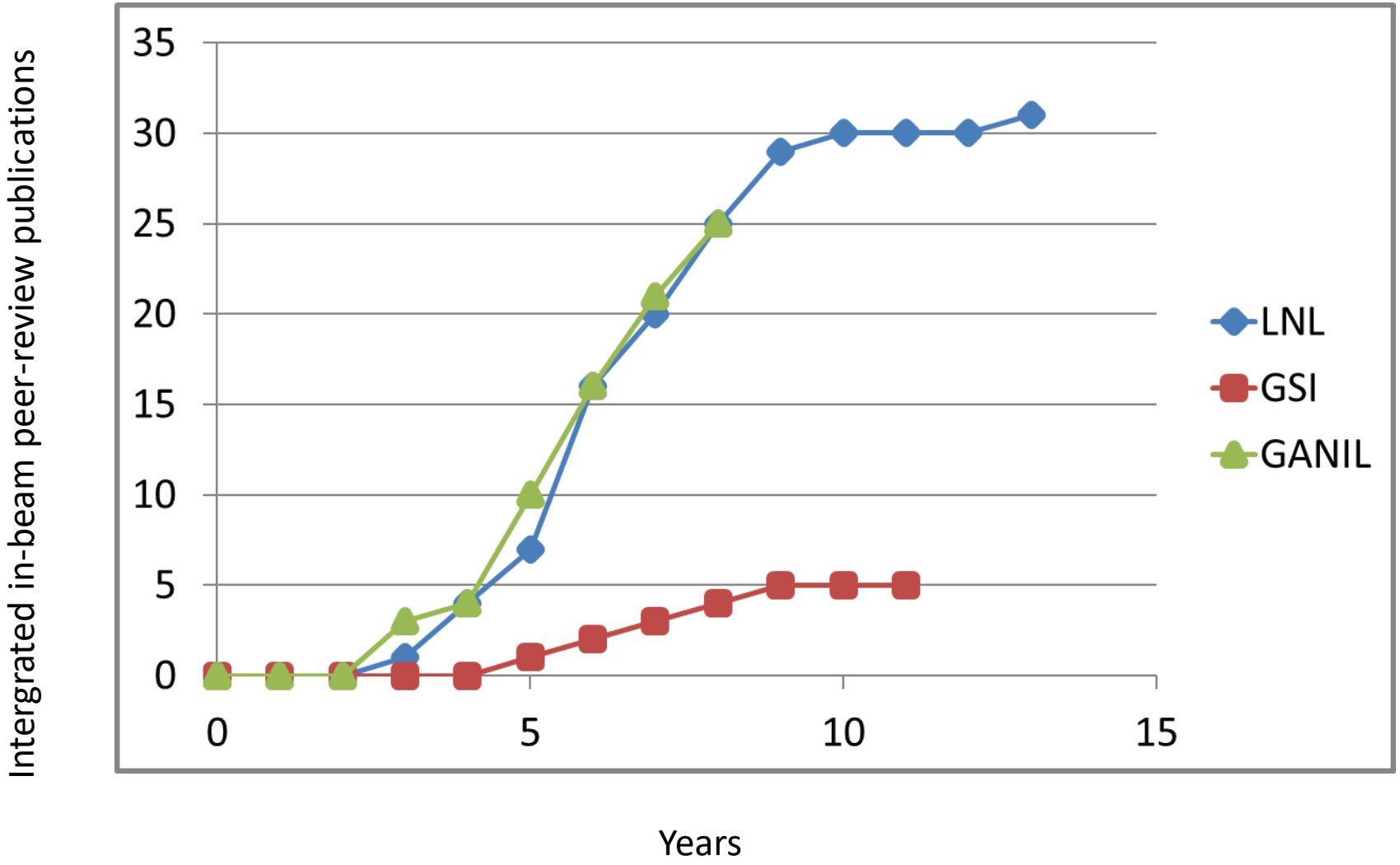
2021



AGATA coupled to VAMOS, EXOGAM, 2nd Arm, LEPS

AGATA campaign at GANIL

A huge scientific impact at GANIL



AGATA is operated under a Memorandum of Understanding

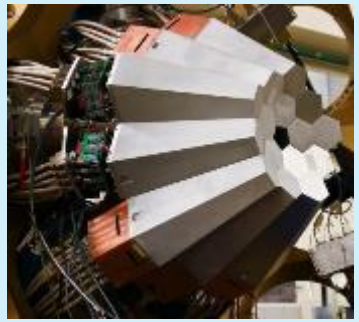
All partners have signed on the 25th of March 2022

New AGATA Spokesperson, chair of the steering :
A. Bracco (INFN-Milano) since 31st of March

MoU Phase 1 + Addendum

MoU Phase 2

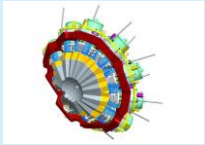
2010-2012
Legnaro, Italy
Intense stable beams
15 detectors



AGATA Demonstrator + PRISMA at LNL

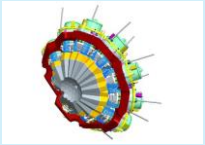
2012-2014
GSI, Germany
Fast fragmentation beams
25 detectors

AGATA at GSI

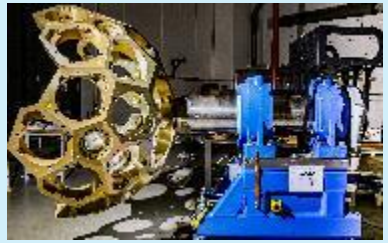


2014- 2021
GANIL, France
ISOL and stable beams
approaching 1π (45)

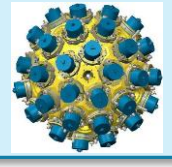
AGATA at GANIL



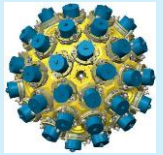
2021--
LNL, Italy
Stable beams
SPES radioactive beams



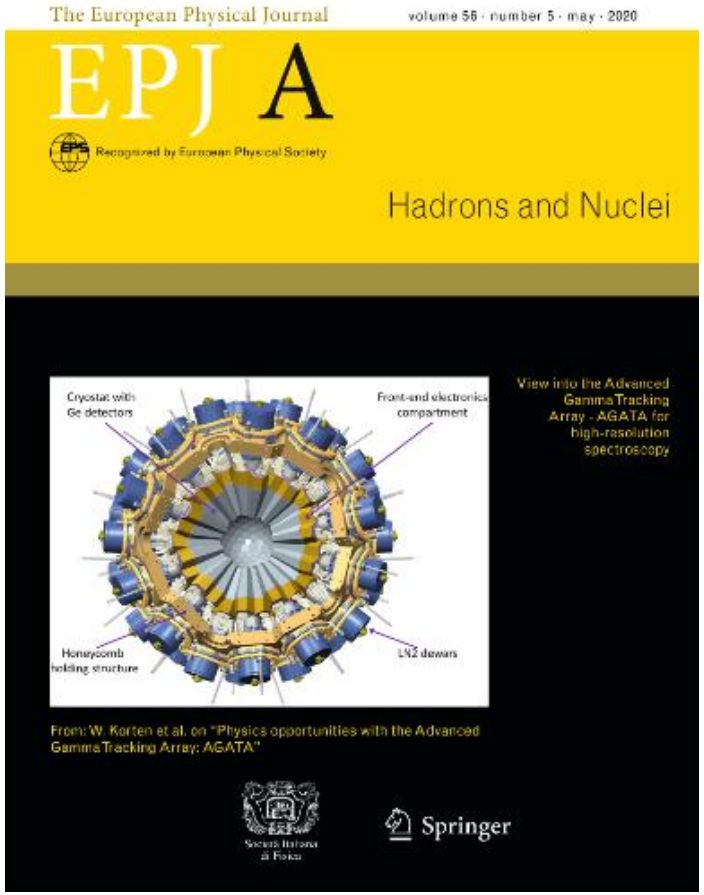
AGATA at LNL 2.0



>2026
FAIR, Germany
ISOLDE, CERN
GANIL, France
RIB at low and high energies



AGATA_2_GANIL (> 2025)



- Heavy beams (Xe, Pb, Th, U) at the Coulomb barrier
- High intensity stable beams
- RIB at ~30-70 MeV/A at the LISE fragment separator

- Uniqueness : Post-accelerated ISOL RIB using the upgraded SPIRAL1 facility for A < 80
- Extensive campaign using the SPIRAL1 beam for
  - Nuclear structure
  - Nuclear Astrophysics
  - Nuclear reaction mechanism
  - Nuclear clustering
  - Coupling with GRIT, VAMOS, LaBr3, neutron detector

Courtesy of E. Clément

Summary

Presented possibilities to use **EXOGAM** (high resolution) and **PARIS** (sub ns time resolution and good high energy gamma-ray efficiency) in upcoming campaigns, i.e., studies with VAMOS++ spectrometer, at LISE and at NFS.

Questions: Fast timing (**FATIMA**)? Connection to other GANIL detector setups like INDRA+FAZIA? Connection of ACTAR to PARIS?

Foreseen come back of AGATA to GANIL
AGATA 2 GANIL will exploit unique possibilities at GANIL in the > 2025 perspective.

Many thanks for delivering slides for

Ch. Schmitt, R. Lica, S. Grévy, Q. Delignac and E. Clément