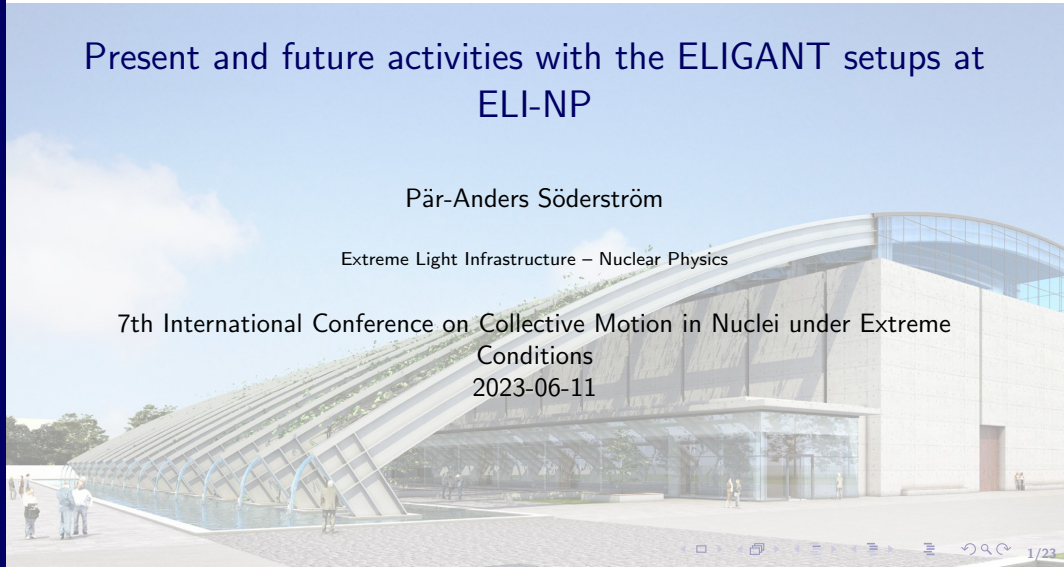
Present and future activities with the ELIGANT setups at ELI-NP

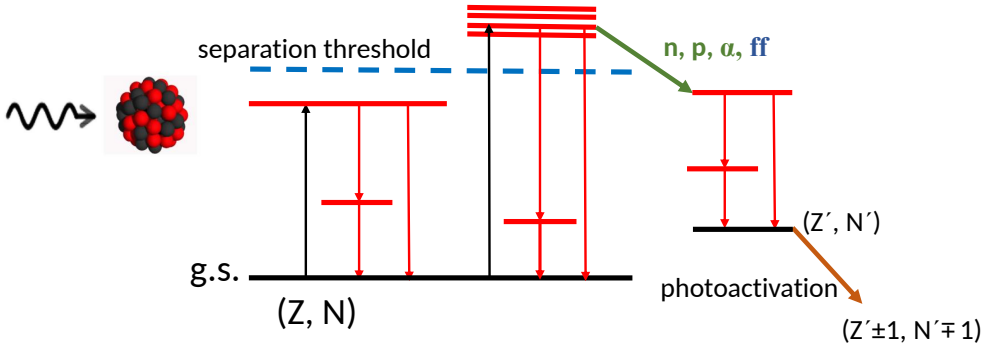
Pär-Anders Söderström

Extreme Light Infrastructure – Nuclear Physics

7th International Conference on Collective Motion in Nuclei under Extreme Conditions
2023-06-11

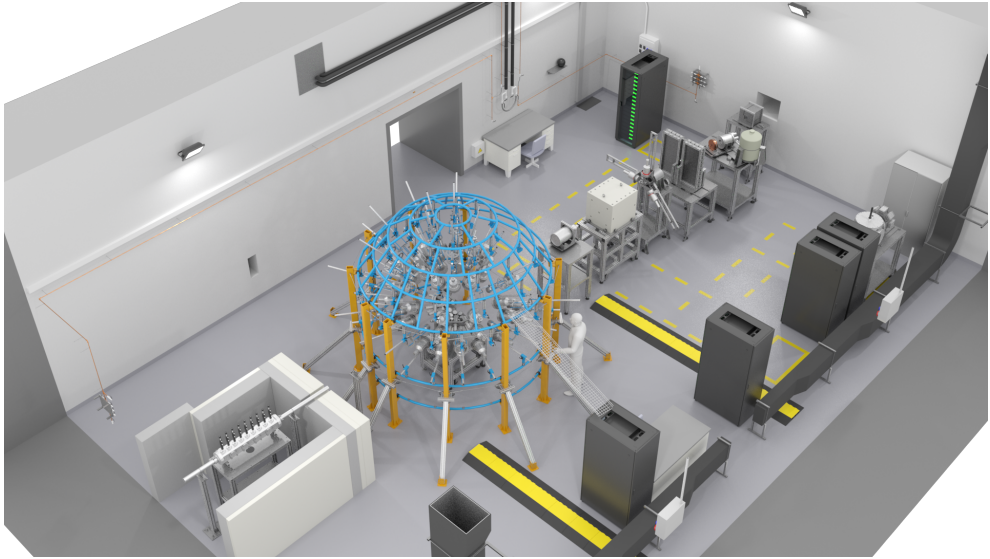


Photonuclear physics

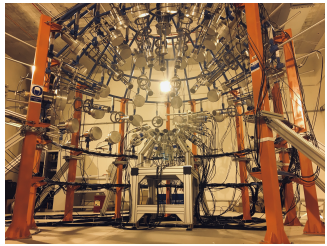


- Incoming γ ray can select individual states to excite
- Above particle separation threshold, particle decay to neighbouring nucleus, fission, etc.
- ... or γ-decay. This type of branching probabilities will be one key topic for measurements

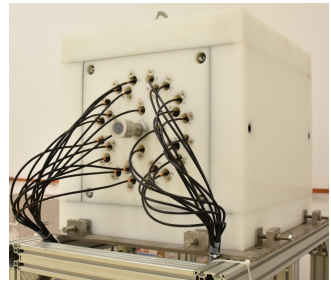
E9 area



ELIGANT - ELI Gamma Above Neutron Threshold



- An array of CeBr and LaBr for γ-rays, liquid scintillators and Li-glass detectors for neutrons
- All the ELIGANT-GN detectors installed at ELI-NP
- Tested in-beam (6 months campaign at ROSPHERE, IFIN 9MV)

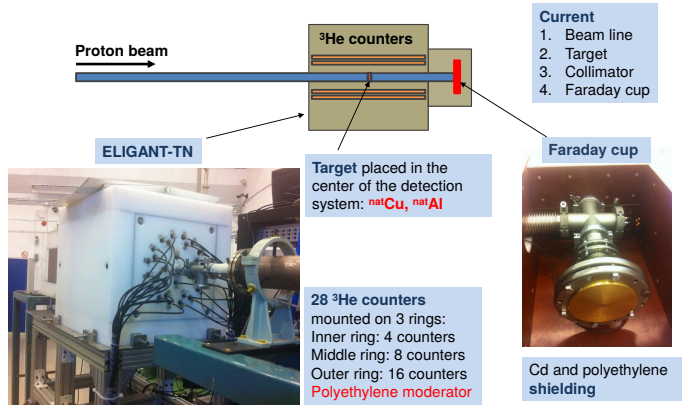


- ^{3}He tube array contained in a paraffin moderator for neutron counting
- Detector is operational
- Tested in-beam

ELIGANT at IFIN

Preparatory Gamma Above Neutron Threshold experiment

„Test and calibration of the ELIGANT-TN flat efficiency neutron detection system", IFIN-HH



- Experiment performed with proton beam at the 9MV Tandem facility
- Constantin - 23 $LaBr_3$, collimators

First in-beam commissioning of ELIGANT-TN

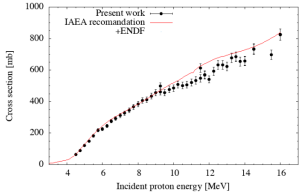


Figure 6. Preliminary ^{nat}Cu(p, xn) cross sections.

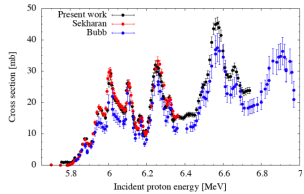


Figure 7. Preliminary ^{27}Al(p, n) cross sections.

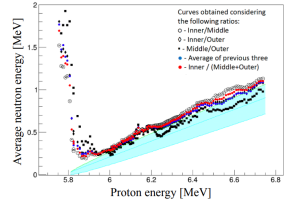


Figure 8. Ring-ratio deduced average energies for the neutrons emitted in ^{27}Al(p, n). The cyan area represents the neutron emission energies considering the upper limit for forward- and the lower limit for backward-neutron emission. The average neutron emission energy for isotropic emission in the center of mass system is represented by the cyan continuous line.

- Setup is able to successfully reproduce known data
- Possible to measure mean neutron energies
- Can be used for preparatory campaigns before start of ELI-NP beams

C. Clisu, et al. EPJ Web Conf. 284 (2023) 01015

Cross section measurements of low-energy charged particle induced reactions using moderated neutron counter arrays

Cristina Clisu[1,2,*], *Ioana* Gheorghe[1,2], *Dan* Filipescu[1], *Therese* Renstrøm[3], *Esra* Acıksoz[3], *Marian* Boromiza[1], *Nicoleta* Florea[1], *Giulia* Gosta[4], *Alina* Ionescu[1], *Mateusz* Krzysiek[5], *Adam* Maj[5], *Constantin* Mihai[1], *Alexandru* Negret[1], *Cristina* Nita[1], *Adina* Olacel[1], *Cristina* Petrone[1], *Andreea* Serban[1], *Christophe* Sotty[1], *Irina* Stiru[1], *Lucian* Stan[1,2], *Rares* Suvaila[1], *Sebastian* Toma[1], *Andrei* Turturica[1], *Gry M.* Tveten[3], *Sorin* Ujeniuc[1], *Oliver* Wieland[4], *Fabio* Zeiser[3], *Franco* Camera[4], and *Hiroaki* Utsunomiya[6]

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[4]Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milano 20133, Italy
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[6]Konan University, Department of Physics, 8-9-1 Okamoto, Higashinada, Japan

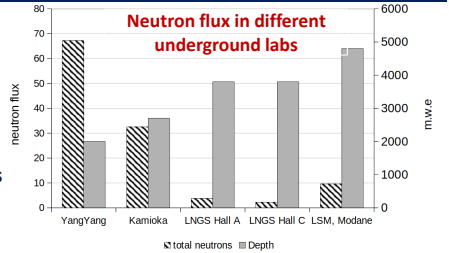
Introduction

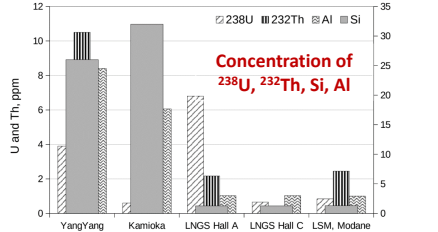
Importance of (α, n) reactions:

- Safeguards Applications
- Low Background Measurements
- Astrophysics

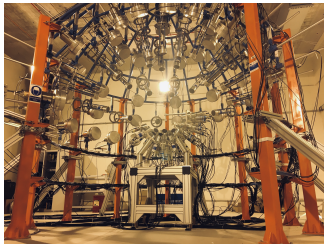
Underground neutron sources:

- Spontaneous fission
- Cosmic rays
- (α, n) reactions





ELIGANT - ELI Gamma Above Neutron Threshold



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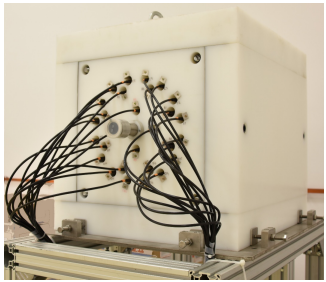

- ^{3}He tube array contained in a paraffin moderator for neutron counting
- Detector is operational
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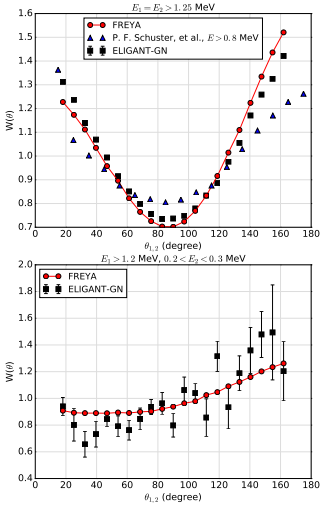
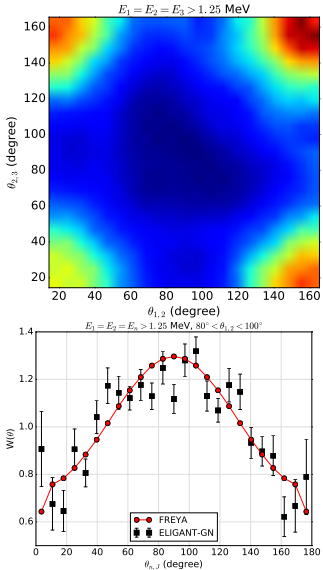
ELIGANT-GN ^{252}Cf array performance

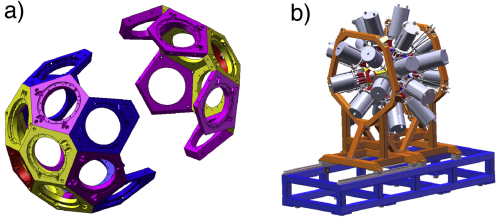


- Simple angular correlations works well
- Low-energy - high-energy neutron angular correlations
- Can obtain the three-neutron angular correlations
- Assume neutrons emitted in a plane $\perp$ to the spin axis J:
- Let two neutrons define the plane
- Angular distribution of third neutron relative to J

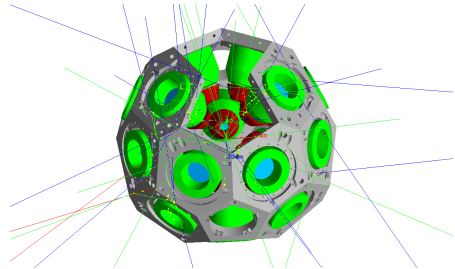


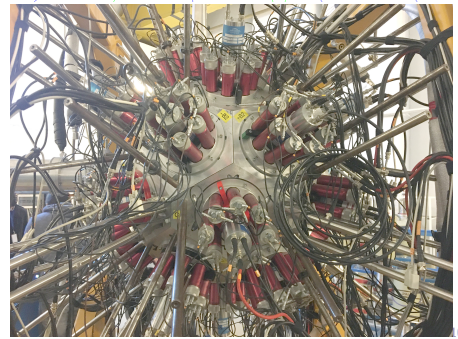
ELI-NP, IFIN-HH, and Tandem → ELIFANT

- Combining the large volume γ-ray detectors with the ROSPHERE anti-Compton shields
- In-beam experiments using the 9MV Tandem at IFIN-HH
- Collaboration between ELI-NP and Department of Nuclear Physics
- Clean measurements of high-energy γ-rays

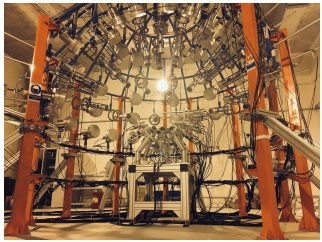


D. Bucurescu, et al.: Nucl. Instrum. Methods Phys. Res. A 837, 1 (2016)

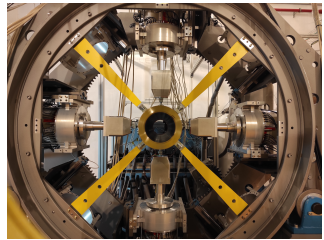




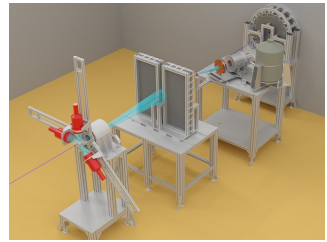
Several different detector systems together



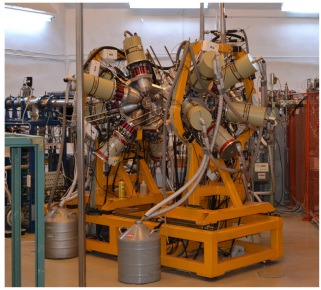
ELIGANT-GN



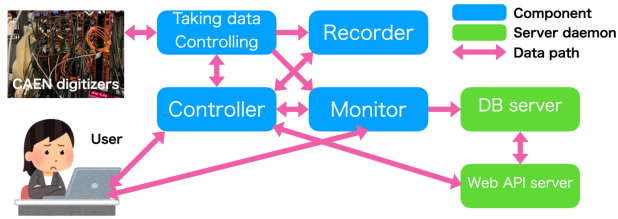
ELIADE



Beam Diagnostics



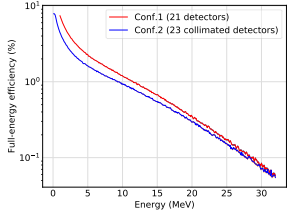
ROSPHERE

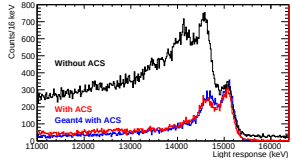


DELILA

Special ROSPHERE setup performance

- Two example configurations:
  - Configuration 1: 21 $LaBr_3$, no collimators
  - Configuration 2: $LaBr_3$, collimators
- Efficiency $\sim$ 1% at 10 MeV
- ACS peak-to-total $\sim$ 10% at 20 MeV (>1.5 MeV background)





- BGO rejection significantly improve the spectum quality at high energies
- In-beam test with ^{11}B beam on CD_2 target
- 15.1 MeV γ ray much more prominent, background reduced alsmost an order of magnitude

Approved experiments (so far...)

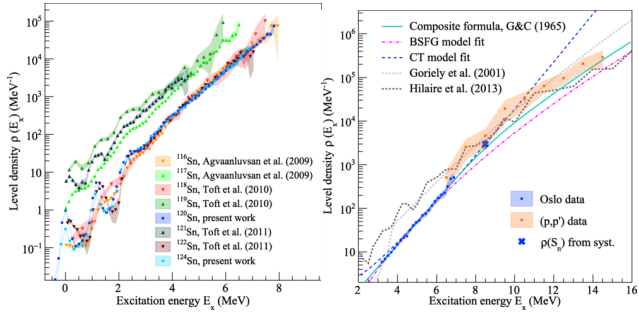
2022

- A. Oberstedt, A. Dragic et al. The ^{72}Ge(p,p'γ) reaction cross-section and $\gamma\gamma$ decay measurements (2021)
- B. Million, F. Camera, et al. Position-Sensitivity in large volume $LaBr_3$:Ce:Sr and performances of the ELIGANT-GN detectors using 15.1 MeV gamma-rays (2021)
- C. Borcea, et al. GDR excitations of fission fragments (2021)
- D. Nichita, P.-A. Söderström, et al. Study of dipole strength below particle separation energy in ^{56}Fe (2021)
- F. Camera, F. Crespi, et al. Study of the isospin symmetry in ^{72}Kr at low temperature (2021)
- O. Wieland, E. Gamba, et al. Search for pygmy dipole strength in ^{58,60}Ni at finite temperature (2021)
- P. Constantin, P.-A. Söderström, et al. Spectroscopy of the first excited 2^+ state of ^{10}B with inelastic proton scattering (2021)
- S. Pascu, et al. Detailed investigation of low-lying states of ^{144}Sm (2021)
- T. Kawabata, et al. Measurement of the Radiative-Decay Probability of the Hoyle State (2021)

2023

- A. Kusoglu, M. Weinert, et al. Investigating the single-particle content of the sub-threshold electric dipole response of ^{88}Sr (2022)
- D. Nichita, P.-A. Söderström, et al. Study of dipole strength below particle separation energy in ^{56}Fe (2021)
- P.-A. Söderström, M. Markova, et al. Gamma strength function measurements in ^{112,114}Sn (2022)

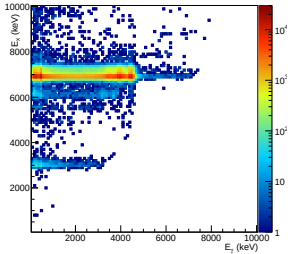
Level densities in tin

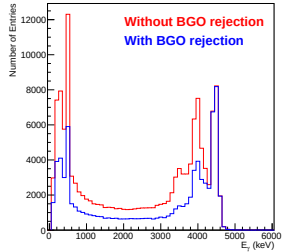


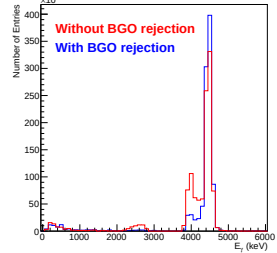
M. Markova, et al.: Phys. Rev. C 106 (2022) 034322

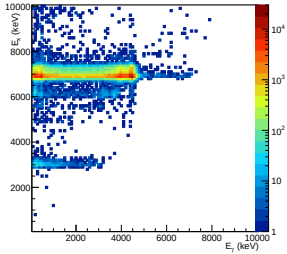
- The tin isotopic chain is interesting from a nuclear structure point of view as it is the longest chain of stable isotopes
- ^{112}Sn and ^{114}Sn also have significant interest for astrophysical reaction rates
- Several statistical theory approaches. Constant temperature model, the back-shifted Fermi gas model, the generalised superfluid model, Skyrme-Hartree-Fock, Skyrme-Hartree-Fock-Bogoliubov, or Gogny-Hartree-Fock-Bogoliubov

From raw matrix to unfolded matrix in ^{12}C



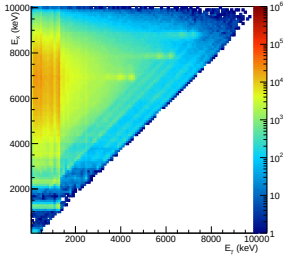


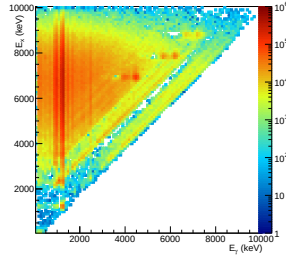


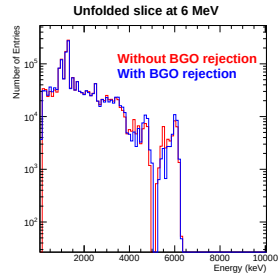


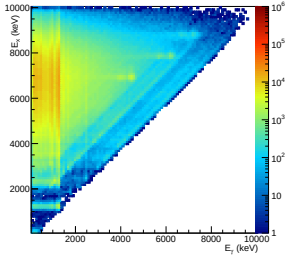
- Preliminary
- Top: Without BGO
- Bottom: With BGO
- Unfolded spectrum looks very clean, only single 4.4 MeV peak
- Especially for the BGO rejected case
- Puts some confidence in the simulations and unfolding procedure

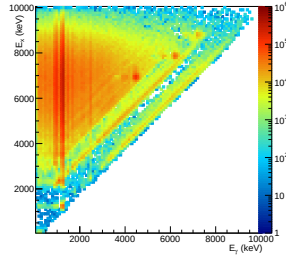
From raw matrix to unfolded matrix in ^{112}Sn











- Preliminary
- Top: Without BGO
- Bottom: With BGO
- Consistent unfolded spectrum, slightly more pronounced peaks with BGO

Collaboration

ELIGANT-GN:

- Pär-Anders Söderström
- A. Kuşoğlu

ELITHGEM:

- Mihai Cuciuc

ELI-NP core team:

- Soichiro Aogaki
- Dimiter Balabanski
- Mihai Cuciuc
- Asli Kusoglu
- Alfio Pappalardo
- Dmitry Testov

ELIGANT-TN:

- Pär-Anders Söderström
- D. Testov
- A. Kuşoğlu
- D. Choudhury
- R. Roy

IFIN-HH core team:

- Ruxandra Borcea
- Cristian Costache
- Constantin Mihai
- Radu Mihai
- Lucian Stan
- Andrei Turturica

Spokespersons: A.Oberstedt, A.Dragic, B.Million, F.Camera, C.Borcea, D.Nichita, P.-A.Söderström, F.Crespi, O.Wieland, E.Gamba, P.Constantin, S.Pascu, T.Kawabata, A.Tamii, A. Kuşoğlu, M. Weinert, M. Markova

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