Photonuclear spectroscopy with the ELIADE array at ELI-NP: Status and perspectives

Pär-Anders Söderström

Extreme Light Infrastructure – Nuclear Physics

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Outline

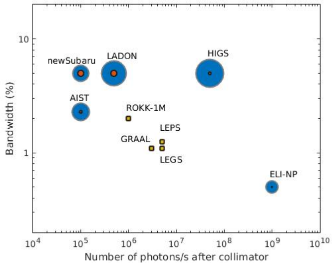
Extreme Light Infrastructure – Nuclear Physics

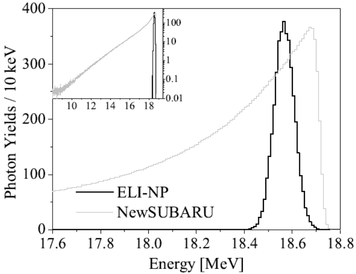
- ELI consist of three pillars: ELI Beamlines, Czech Republic, ELI Attosecond Light Pulse Source, Hungary, ELI Nuclear Physics, Romania
- ELI-NP is based on two main components: High-power lasers, High-brilliance gamma-beam system

Properties of the gamma beam system

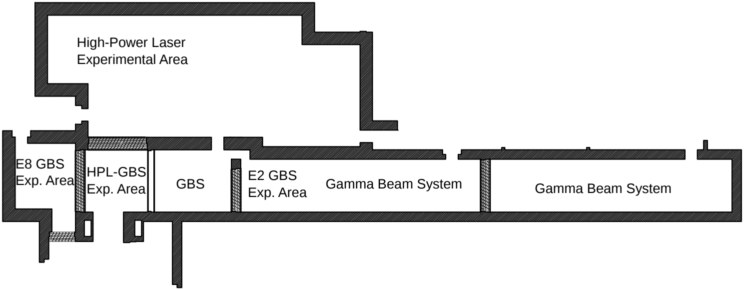
- Gamma beam created from inverse Compton scattering of a 515 nm Yb:YAG laser with 720 MeV electron beam
- Selection of energies based on angular distributions
- Almost monoenergetic γ-rays

Energy (MeV)	0.2 – 19.5
Spectral Density (ph/s·eV)	> $0.5 \cdot 10^4$
Bandwidth rms (%)	≤ 0.5
Linear polarization (%)	> 95
Macro repetition rate (Hz)	100
# pulses per macropulse	32
Pulse–to–pulse separation (nsec)	16



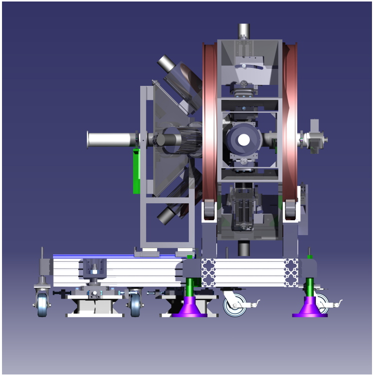


The gamma beam system - experimental areas



- The gamma beam system will have three main experimental areas
- The low-energy area (E2) with energies up to 3.5 MeV
- The high-energy area (E8) with energies up to 19.5 MeV
- The high-power laser and high-brilliance gamma-beam interaction area

ELIADE – ELI Array of Detectors

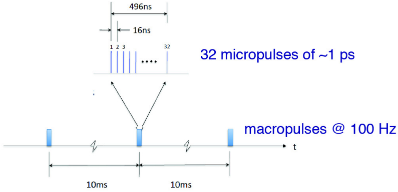


- Eight HPGe segmented Clover detectors
- Four detectors at angles around 90°
- Four detectors at 135°
- Retractable for optimization of geometry depending on experimental conditions
- 19 cm from the target when closest, up to 37 cm

Challenges for ELIADE

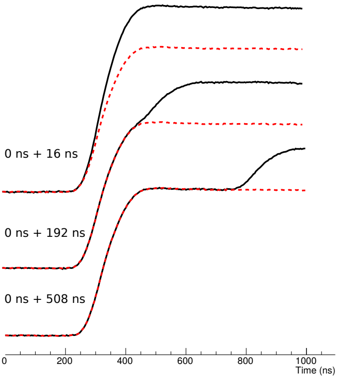
Environmental boundries:

- Measure in a sea of γ-rays (10^6 γ/pulse), primarily 511 keV
- Anti-Compton not possible, reject everything
- Well defined beam structure



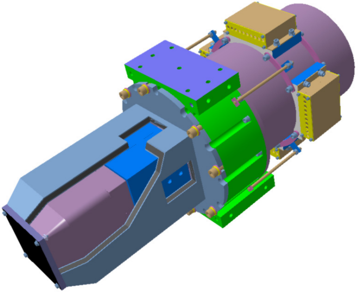
Solutions:

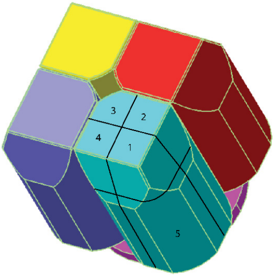
- Heavy shielding
- Segmented HPGe detectors
- Save front of traces



Superimposed waveforms from A. Kusoglu, G.V. Turturica, et al. experiment "Detector efficiency calibration and polarization sensitivity for high energy γ-rays", IFIN-HH 3MV Tandem, Mar 2018

Solutions for the ELIADE detectors





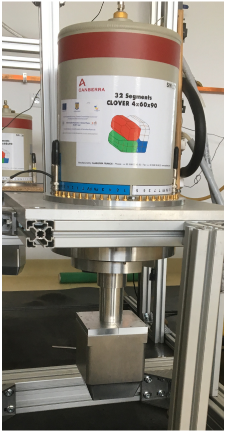
Example: NRF of a 2 cm thick ^{238}U target with and without 2 cm Pb shields

	E_γ (MeV)	γ/s	γ/s (Pb)
NRF	2.1	566	199
CS 98°	0.36	61966	1
CS 135°	0.26	43359	0
e^+e^-	0.511	59020	1521

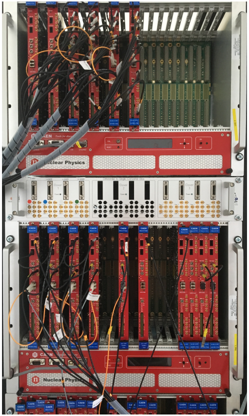
- NRF yield reduced by 1/3
- Background strongly reduced
- Interested in high-energy γ-rays

- We need one γ ray per macropulse = 100 Hz max
- Using segmented Clover detectors we can increase this to 16 γ rays
- Most low-energy γ-rays interact in the front segments

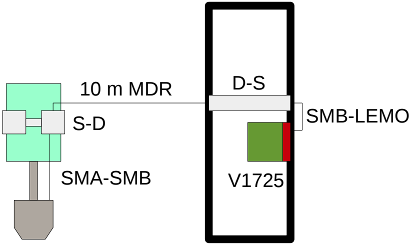
Details of the ELIADE detectors



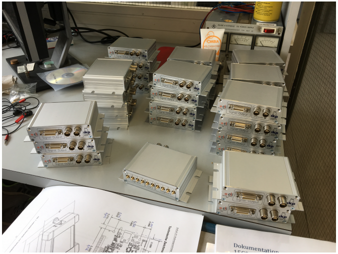
- 8 Canberra 4x60x90 Seg32 Clover detectors
- 32 v1725 CAEN 14 bit 250 MS/s 16 ch digitizers
- 32 v1730 CAEN 14 bit 500 MS/s 8 ch digitizers
- CAEN SY4527 High-Voltage supply

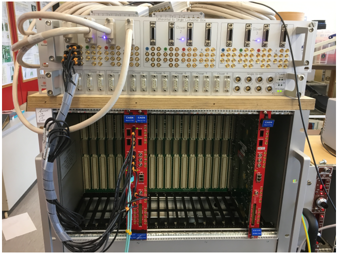


Signal transmission and readout



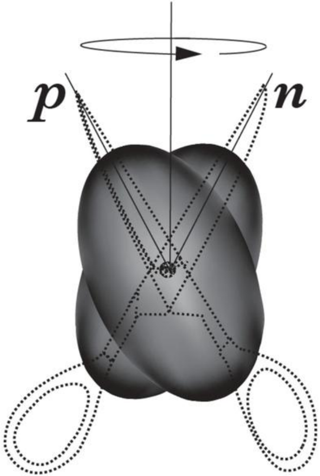
- Single-ended signals read out from the preamplifiers
- Differential cables for low-noise signal transmission
- Single-ended signals for digitization
- System developed by IKP Köln
- CAEN v1725 digitizer boards
- MIDAS DAQ software from Daresbury





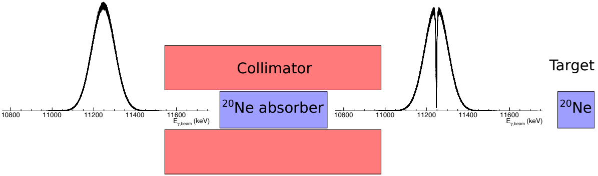
Matrix elements for $0\nu\beta\beta$-decay

- Decay rate ($\lambda_{0\nu\beta\beta}$) depends on neutrino mass (m_ν) and nuclear matrix element ($M^{(0\nu)}$)
- $\lambda_{0\nu\beta\beta} = G_{0\nu} \left| M^{(0\nu)} \right|^2 \left(\frac{\langle m_\nu \rangle}{m_e} \right)^2$
- Matrix element needs to be calculated from nuclear structure physics and depends strongly on pn coupling
- Scissors mode particulary sensitive to pn coupling
- Example: ^{150}Sm with large $0\nu\beta\beta$ branching both to 0^+_1 and 0^+_2
- Ideal case to determine parities of $J = 1$ states and measure scissors branching to 0^+_2 using NRF

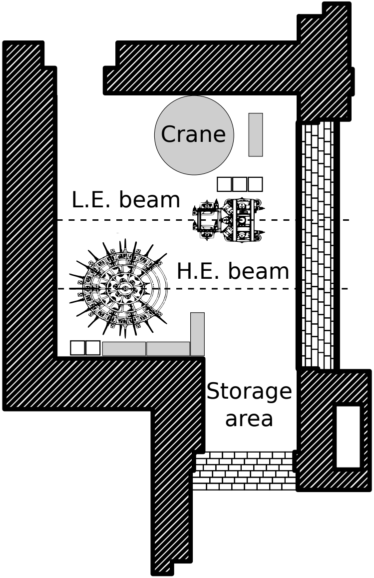


Parity violation in ^{20}Ne

- Parity a fundamental symmetry in both the electromagnetic and strong force, but not in weak force
- In the effective nuclear force this can introduce a small parity violating term $\beta \sim 10^{-4}$ as $|J^-\rangle = \alpha|\phi^-\rangle + \beta|\phi^+\rangle$
- In ^{20}Ne, a $1^\pm$ parity doublet with $\Delta E = 3$-4 keV at 11.2 MeV
- Cross section for $1^+ \sim 50$ times higher than 1^-
- Thick ^{20}Ne absorber to remove all 11.259 MeV beam γ-rays
- At ELI-NP: 100% linear polarization
- Measure β from angular distributions of 11.255 MeV γ-rays
- $\langle 0^+|T(E1) + T(M1)|1^-\rangle =$
  $\alpha\langle 0^+|T(E1)|\phi^-\rangle + \beta\langle 0^+|T(M1)|\phi^+\rangle$



Status of E8 installation as of Aug 2018



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2007-2013

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Nuclear Physics

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The ELIADE collaboration

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ELI-NP:

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- Calin Alexandru Ur
- Luigi Capponi
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- Violeta Iancu
- Gabriel Turturică
- Cristian Petcu
- Emil Udup

Collaborators:

- Jacob Beller, IKP, TU Darmstadt
- Vera Derya, IKP, University of Cologne
- Ivan Kojouharov, GSI Darmstadt
- Bastian Löher, IKP, TU Darmstadt
- Constantin Mihai, IFIN-HH Bucharest
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- Christopher Romig, IKP, TU Darmstadt
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- Andreas Zilges, IKP, University of Cologne
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- Julius Wilhelmy, IKP, University of Cologne