Neutron Wall and NEDA

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Johan Nyberg

Division of Nuclear Physics
Department of Physics and Astronomy
Uppsala University

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Nuclear Structure Uppsala

UPPSALA UNIVERSITET

Outline

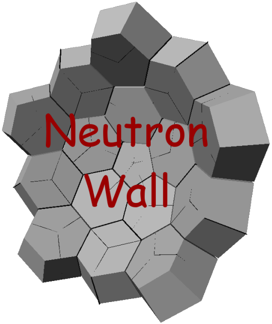
Neutron Wall – 1π neutron detector array

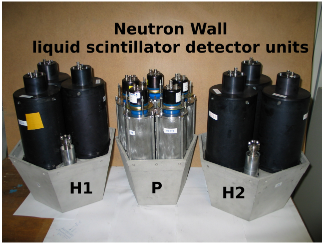
Built 1995-97 to be used with the EUROBALL spectrometer (H. Grawe and Ö. Skeppstedt).

Financed by Sweden, UK, Germany, Poland.

Resource administered by the Owners Committee of the European Gamma-Ray Spectroscopy Pool.

Owners Committee approves applications of use of the array.





50 closely packed liquid scintillator detectors of three types: H1, H2, P.

Liquid: BC501A (xylene), total volume 150 litre.

Distance to target: 51 cm; detector thickness: 15 cm.

Detector angles: from 0° to $\simeq 60^\circ$

Neutron energy range: from $\simeq 0.5$ MeV to $\simeq 10$ MeV

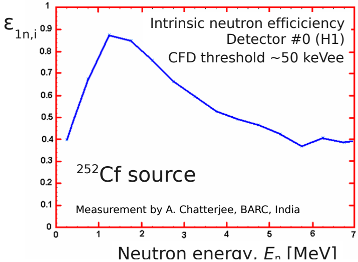
Efficiency and energy resolution

Efficiency

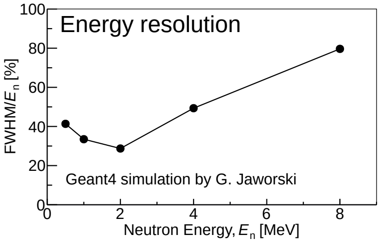
Intrinsic neutron efficiency at $E_n = 2$ MeV:
$\varepsilon_{1n,i} \simeq 80\%$

Total Neutron Wall efficiency for symmetric fusion evaporation reactions:

- One-neutron efficiency: $\varepsilon_{1n} = 20\text{-}25\%$
- Two-neutron efficiency: $\varepsilon_{2n} = 1\text{-}3\%$



Energy resolution (Time-of-Flight)



- Distance source to detector front face: 51 cm
- Thickness of detectors: 14.8 cm
- Time resolution of detectors: FWHM = 1.5 ns

Neutron-gamma discrimination

Liquid scintillators give a difference in signal pulse shapes for neutrons and gamma rays: the slow component ($\tau \sim 300$ ns) of the light is larger than the fast component ($\tau \sim 3$ ns) for neutrons ($\rightarrow$recoil protons) compared to γ rays ($\rightarrow e^-$).

Neutron Wall uses the zero-crossover (ZCO) technique combined with a measurement of ToF measurement for the neutron-gamma discrimination.

ToF requires (preferably) a pulsed beam with a time resolution of FWHM $\lesssim 5$ ns.

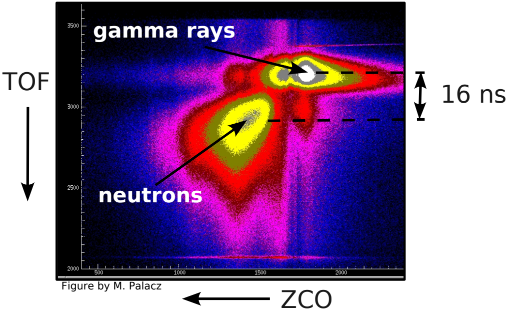


Figure by M. Palacz

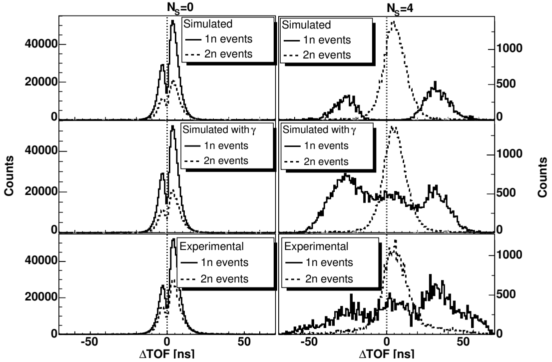
Pulse-shape discrimination electronics is analogue. The plan is to replace it with a fully digital system (NEDA).

Probability of mis-interpreting γ rays as neutrons: $\lesssim 10^{-3}$ (typical value).

Neutron scattering

Probability of 1 neutron giving a signal in 2 or more detectors $\simeq 10\%$.

Serious problem in searches for weakly populated $\geq$ 2n reaction channels: scattered neutrons from much stronger 1n channels are mis-identified as being due to 2n, 3n, . . . channels.



J. Ljungvall et al. NIM A528 (2004) 741

Methods to detect scattered neutrons:

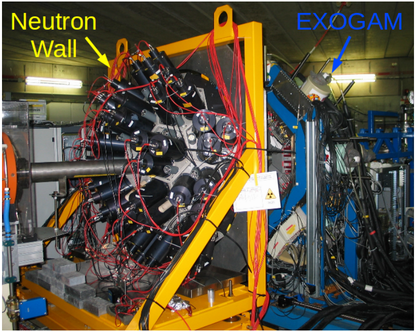
- Neighbor rejection.
- ΔToF. J.Cederkäll et al. NIM A385 (1997) 166.

Small amounts of γ rays mis-identified as neutrons reduces dramatically the quality of the neutron scattering reduction

Experimental campaigns and recent results

Experiments performed with EUROBALL at LNL (1998) and at IReS (2001-2003), and with EXOGAM at GANIL (2005-).

Combined with charged particle detector arrays (EUCLIDES, DIAMANT, CUP, . . .).



GANIL home base since 2005.

Four experimental campaigns at GANIL with EXOGAM + DIAMANT and other detectors (2005-2009).

Next campaign (two experiments): GANIL 2012.

First experiments with radioactive beams

Two experiments with ^{6}He and ^{8}He beams at SPIRAL 2005-2006

1n and 2n transfer with the Borromean nucleus ^{6}He near the Coulomb barrier,
A. Chatterjee, et al.,
Phys. Rev. Lett. 101 (2008) 032701

Neutron correlations in ^{6}He viewed through nuclear break-up,
M. Assie et al.,
Eur. Phys. J. A 42 (2009) 441

Reactions with the double-Borromean nucleus ^{8}He,
A. Lemasson et al.,
Phys. Rev. C 82 (2010) 044627

Pair and single neutron transfer with Borromean ^{8}He,
A. Lemasson et al.,
Phys. Lett. B 697 (2011) 454

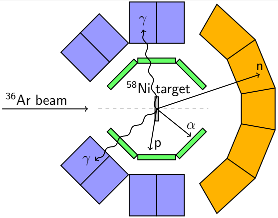
^{92}Pd experiment at GANIL

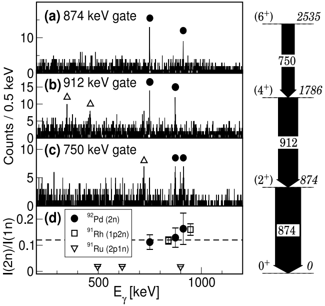
Experiment at GANIL (2009)

EXOGAM + DIAMANT + Neutron Wall

^{36}Ar (111 MeV) + ^{58}Ni $\rightarrow$ ^{92}Pd + 2 n

Cross section: $\sigma(^{92}\text{Pd}) \simeq 1\mu$b, $\sigma(\text{fusion}) \simeq 0.2$ b,

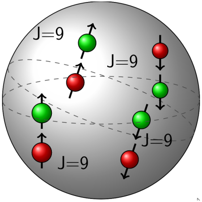




First observation of excited states in ^{92}Pd

Approximately equidistant energy levels

Valence neutrons and protons couple pairwise to $S = 1$, $T = 0$ in the ground and first excited states of ^{92}Pd



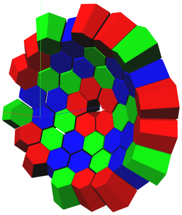
B. Cederwall, F. Ghazi Moradi et al., Nature 469 (2011) 68

Approved GANIL experiment: ^{96}Cd; 14 days; spokepersons B. Cederwall, G. de France, R. Wadsworth.

Outline

Aim and strategy of the NEDA project

Aim



Develop a neutron detector array to be used with AGATA, EXOGAM2, ... for experiments with high-intensity stable and radioactive ions beams at SPIRAL2 and other facilities.

The array should have:

- Increased neutron detection efficiency compared to Neutron Wall: $\varepsilon_{1n} \simeq 40\%$ (20-25%), $\varepsilon_{2n} \simeq 10\%$ (1-3%).
- Excellent neutron-gamma discrimination.
- Capability to run at much higher count rates than with the Neutron Wall.
- Cope with large neutron multiplicities in reactions with neutron-rich RIBs.
- Improved neutron energy resolution for reaction studies.

Strategy

- Optimize size of detector units, distance to target, geometry of the array, ...
- Investigate other detector materials than ordinary liquid scintillator.
- Adopt digital electronics which is fully compatible with AGATA and EXOGAM2.
- Develop advanced on-line and off-line algorithms for neutron-gamma discrimination, neutron scattering rejection, pile-up rejection/recovery.

Organization

Spokesperson

J.J. Valiente Dobon (LNL-INFN)

GANIL liaison

M. Tripon (GANIL)

FP7-Infrastructures-2007-1
SPIRAL2 Preparatory Phase

FIRB
Futuro In Ricerca (MIUR)

Steering committee

N. Erduran (Istanbul), G. de France (GANIL), A. Gadea (Valencia), J. Nyberg (Uppsala), M. Palacz (Warsaw), R. Wadsworth (York).

NEDA Collaboration

Ankara University (Turkey), COPIN (Poland), CSIC-IFIC (Spain), Daresbury Laboratory (UK), GANIL (France), Istanbul University (Turkey), INFN (Italy), IPHC (France), Niğde University (Turkey), University of York (UK), Uppsala University (Sweden).

Working groups

Detector characteristics and physics

Bob Wadsworth

Simulations and conceptual design

Marcin Palacz

Study of new detector materials

Louise Stuttgé

Front-end electronics and DAQ

Andres Gadea

Pulse-shape analysis

Johan Nyberg

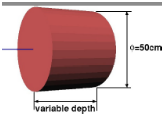
Synergies with other detectors

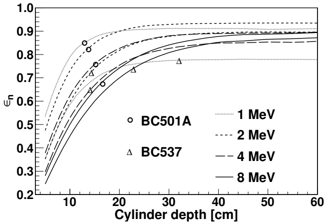
Piotr Bednarczyk

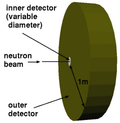
GEANT4 simulations: optimal size of detector units

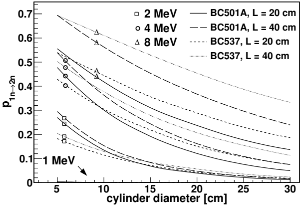
G. Jaworski, M. Palacz (Warsaw)

GEANT4 validated for simulations of interactions of fast neutrons with energies up to about 10 MeV in liquid scintillators.









Optimal depth: $\sim$ 20 cm

Optimal diameter: 5" (PMT)

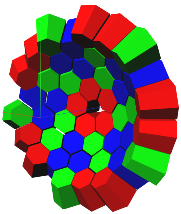
G. Jaworski et al., submitted to Nucl. Instr. Meth. A

Geant4 simulations: conceptual design

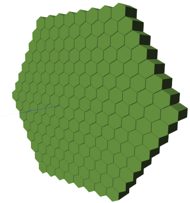
T. Hüyük (Valencia)

Two possible detector geometries: tapered, non-tapered

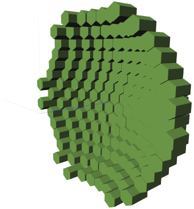
Tapered:
(1π, 0.5 m, 45 cells, 203 l)



Non-tapered: flat
(0.4π, 1.0 m, 169 cells, 507 l)



Non-tapered: staircase
(0.9π, 1.0 m, 164 cells, 489 l)

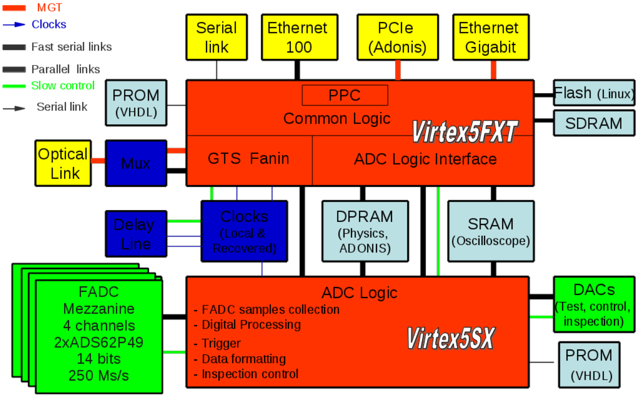


Advantage: can cover $>1\pi$ of the solid angle with "few" cells.

Advantage: flexibility regarding different arrangements of the detectors and the target-detector distance.

Electronics: NEDA digitiser

NUMEXO2: 16 channel NIM unit; FADC 250 MS/s, 14 bit.
Fully compatible with EXOGAM2 and AGATA.



Can be run in time stamped total data readout mode.
Will be used also for the Neutron Wall.
Developments by GANIL and Valencia. Prototype ready 2012.

Phases of NEDA

Phase 0

Upgrade of the Neutron Wall to use digital electronics.

Phase 1

Construction of the NEDA Demonstrator with a limited size.

Phase 2

Construction of the full NEDA array.

Phase 3

R&D on new detector materials and light readout systems for a highly segmented neutron detector array.

Summary and outlook

- The Neutron Wall is being used successfully in experiments at GANIL together with EXOGAM.
- R&D for NEDA – the next generation neutron detector array – is ongoing.
- NEDA will be used mainly with AGATA and EXOGAM2 in experiments with high intensity stable and radioactive beams.

Summary and outlook

- The Neutron Wall is being used successfully in experiments at GANIL together with EXOGAM.
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Neutron Wall at HIE-ISOLDE?

- Is there an interest for a Neutron Wall (or NEDA) campaign at HIE-ISOLDE?
- Neutron Wall + MINIBALL (and/or AGATA) would become a very powerful setup for studies of exotic nuclei at HIE-ISOLDE.
- Call for letters of interest?

Links

Neutron Wall

http://nsg.physics.uu.se/nwall/

NEDA

http://agata03.ific.uv.es/boceto01/nedahome.htm

Thank you!

Acknowledgments to all members of the Neutron Wall and NEDA collaboration.