~~Grześ Jaworski~~
Pär-Anders Söderström

on behalf of NEDA collaboration

NUSPIN, GSI, June 28th, 2017

Outline

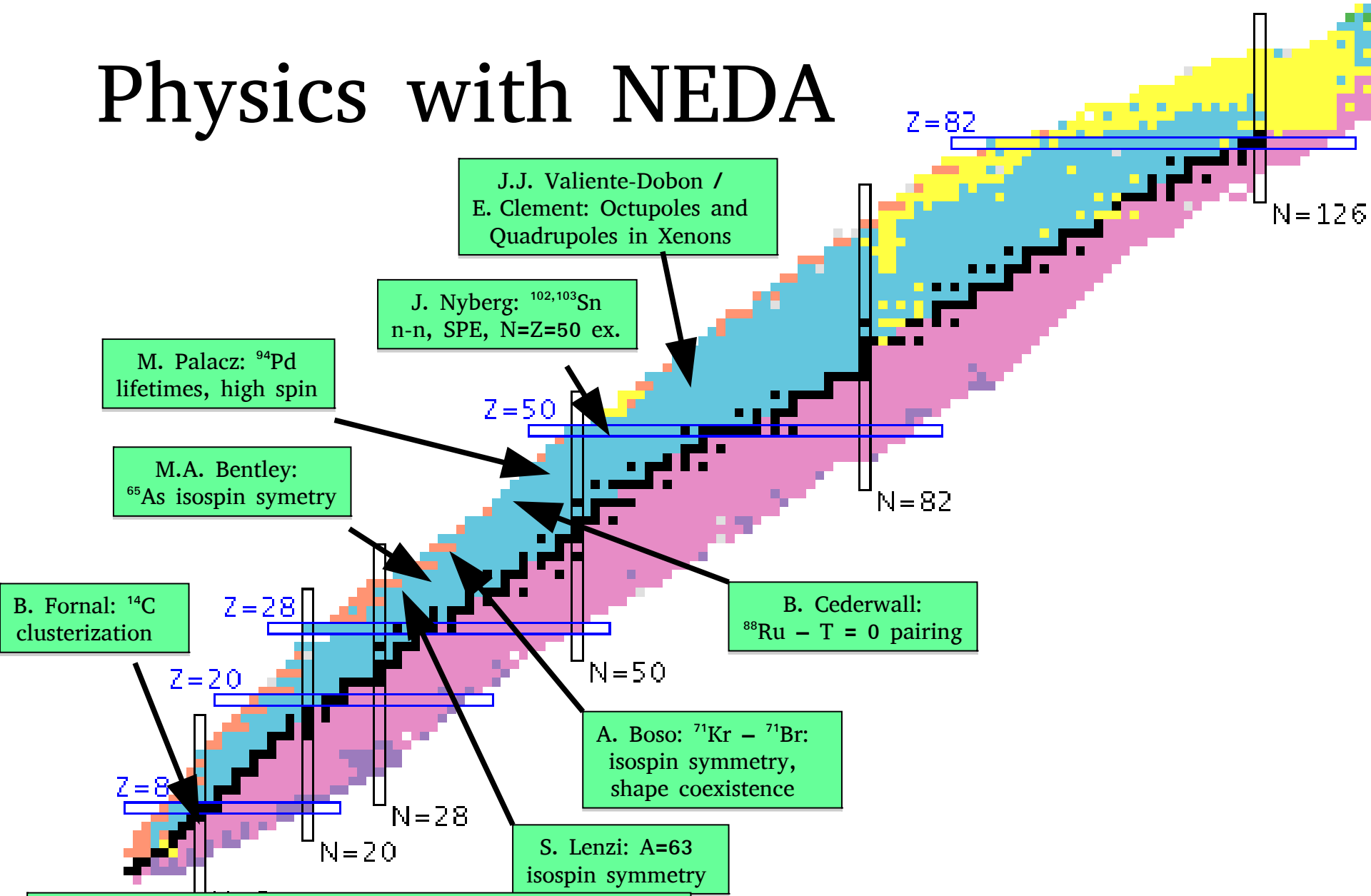
→ Physics with NEDA.

→ Why (a new) neutron multiplicity filter and how to built one?

→ R&D:
- single cell;
- scintillator;
- full geometry;
- PMT;
- timing;
- NGD;
- electronics;
- NEDA + NW @ GANIIL geometry;
- Production and characterisation (ongoing).

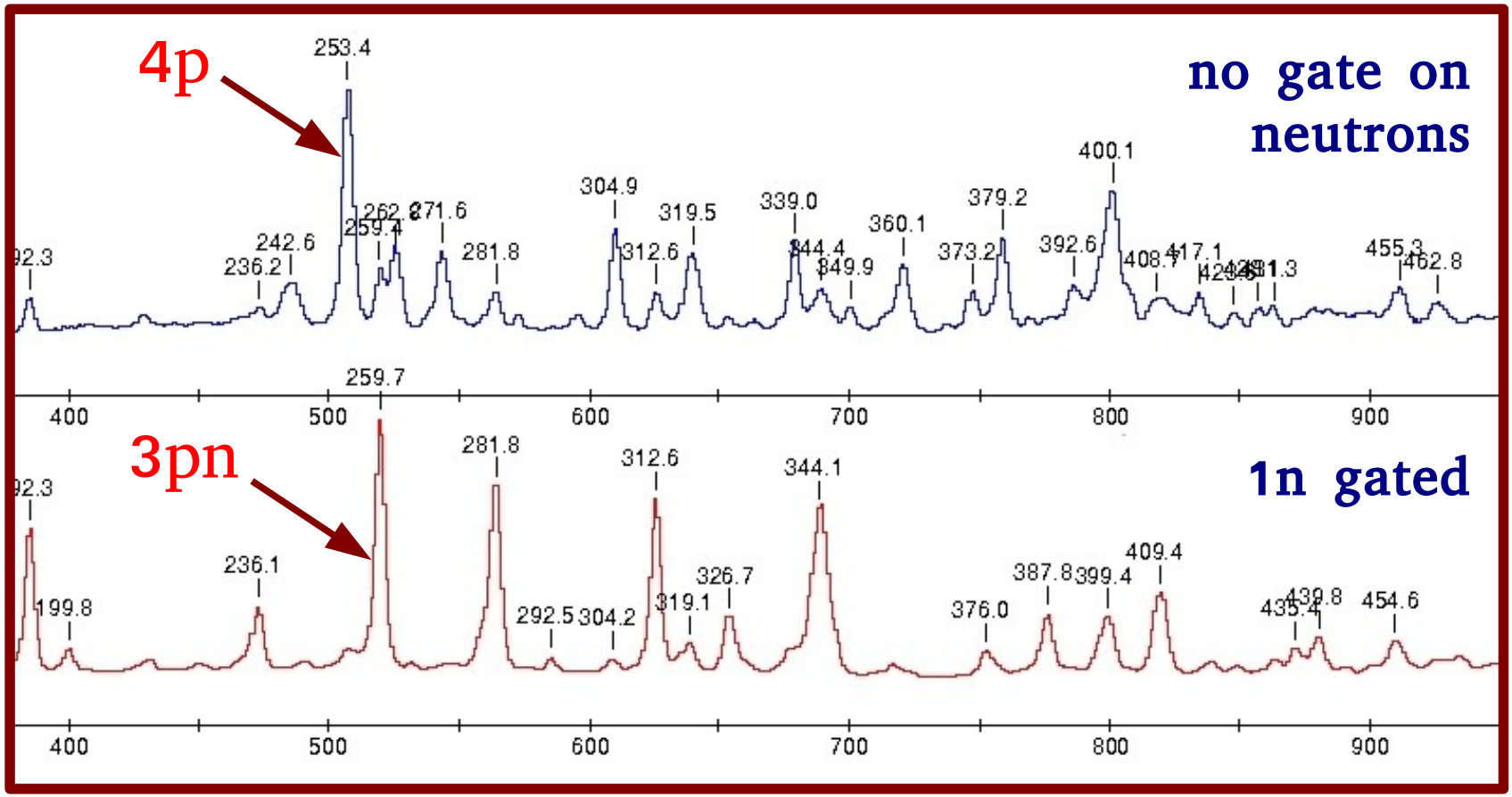
→ AGATA + NEDA campaign coming.

Physics with NEDA



n selection

EXOGAM experiment: ^{58}Ni (240 MeV) + ^{54}Fe

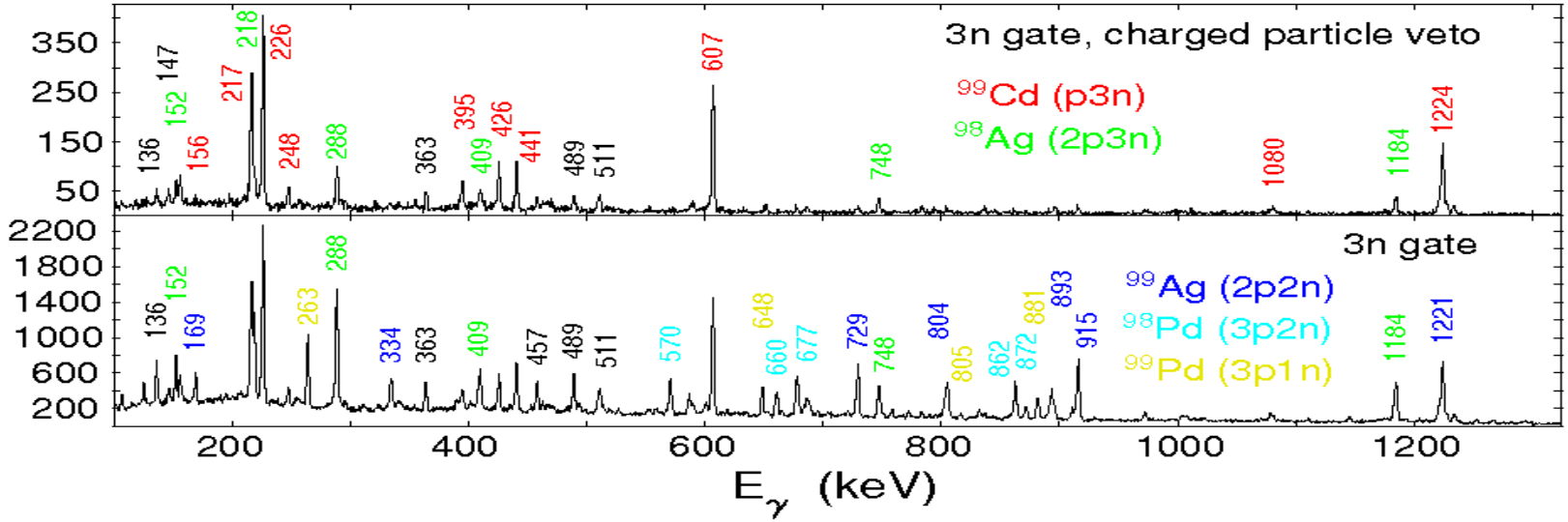


Why a new array?

An example:

Attempt to study ^{100}In – 1ν $1\pi^{-1}$ outside ^{100}Sn

3n evaporation channel – the only 3n case with NWall (+ EUROBALL)



^{100}In not observed, but observation only a matter of statistics.

10x statistics: → ½ a a year with EXOGAM + NWall,
→ 2-3 weeks with EXOGAM + NEDA.

Other crucial nuclei accessible in 3n evap. channels, including ^{101}Sn.

New array

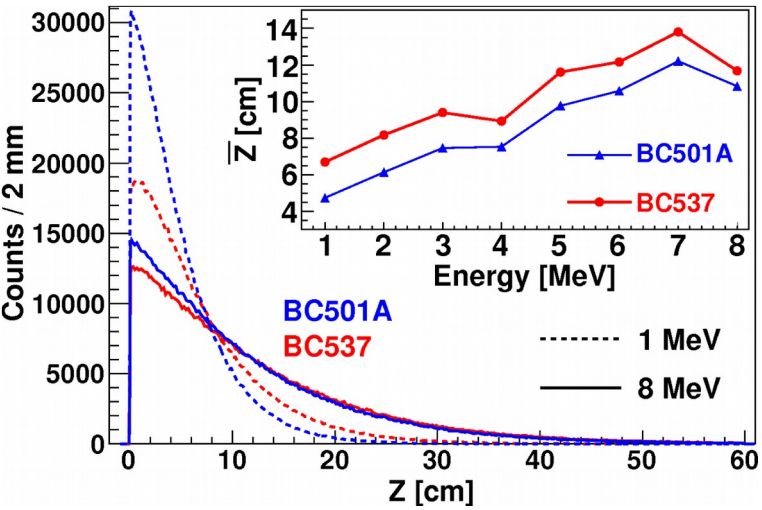
→ Goal: develop a neutron detector array to be used with AGATA, GALILEO, EXOGAM2, etc. for experiments with high intensity stable and radioactive ion beams (SPES, SPIRAL2, …)

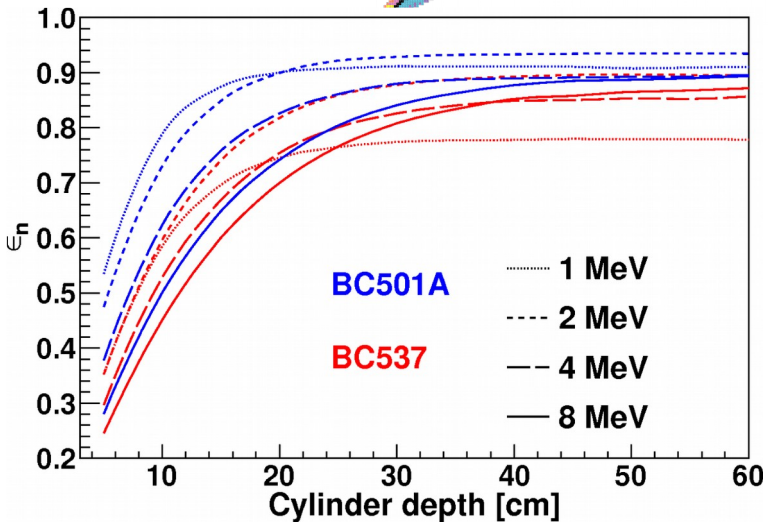
→ Requirements:

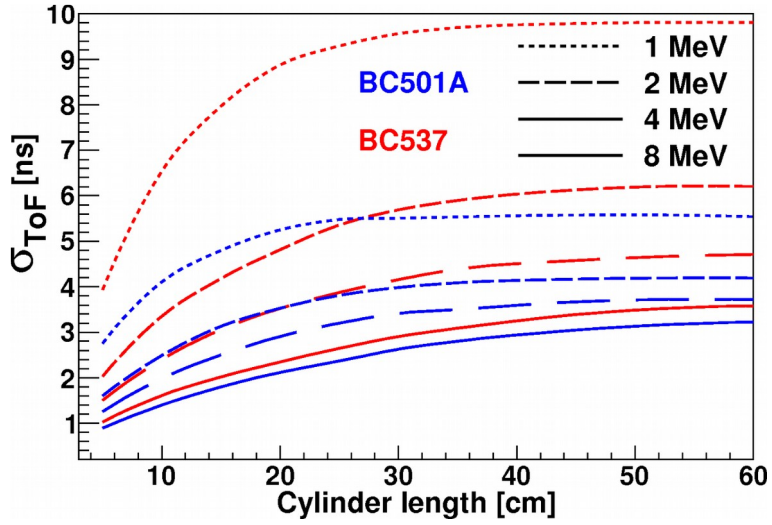
- excellent neutron-gamma discrimination (NGD);
- good timing;
- superior 1n/2n/3n/… discrimination;
- capability to run at high counting rates;
- be versatile (energy resolution for reaction studies;
- cope with large neutron multiplicities (reactions with neutron-rich RIBs).

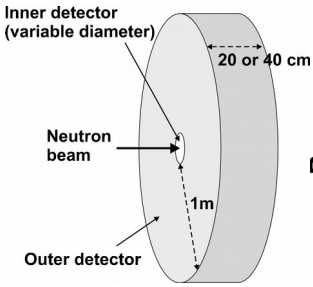
Want best quality → do it yourself!

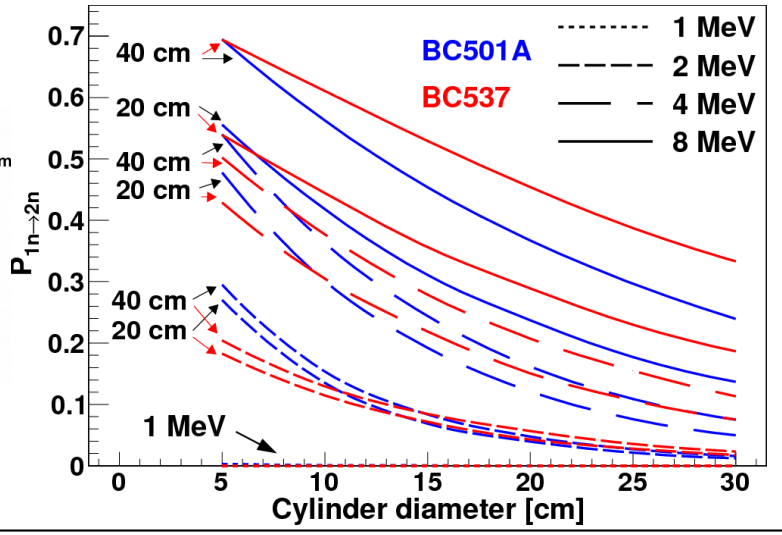
Single cell


Counts / 2 mm
Z [cm]
$\overline{Z}$ [cm]
Energy [MeV]
BC501A
BC537
1 MeV
8 MeV


ϵ_n
Cylinder depth [cm]
BC501A
BC537
1 MeV
2 MeV
4 MeV
8 MeV


σ_{ToF} [ns]
Cylinder length [cm]
BC501A
BC537
1 MeV
2 MeV
4 MeV
8 MeV


Inner detector
(variable diameter)
20 or 40 cm
Neutron
beam
1m
Outer detector


$P_{1n\to2n}$
Cylinder diameter [cm]
BC501A
BC537
1 MeV
2 MeV
4 MeV
8 MeV
40 cm
20 cm
40 cm
20 cm
40 cm
20 cm
1 MeV

Single cell

Nuclear Instruments and Methods in Physics Research A 673 (2012) 64–72

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Monte Carlo simulation of a single detector unit for the neutron detector array NEDA

G. Jaworski [a,b], M. Palacz [b,*], J. Nyberg [c], G. de Angelis [d], G. de France [e], A. Di Nitto [f], J. Egea [g,h], M.N. Erduran [i], S. Ertürk [j], E. Farnea [k], A. Gadea [h], V. González [g], A. Gottardo [l], T. Hüyük [h], J. Kownacki [b], A. Pipidis [d], B. Roeder [m], P.-A. Söderström [c], E. Sanchis [g], R. Tarnowski [b], A. Triossi [d], R. Wadsworth [n], J.J. Valiente Dobon [d]

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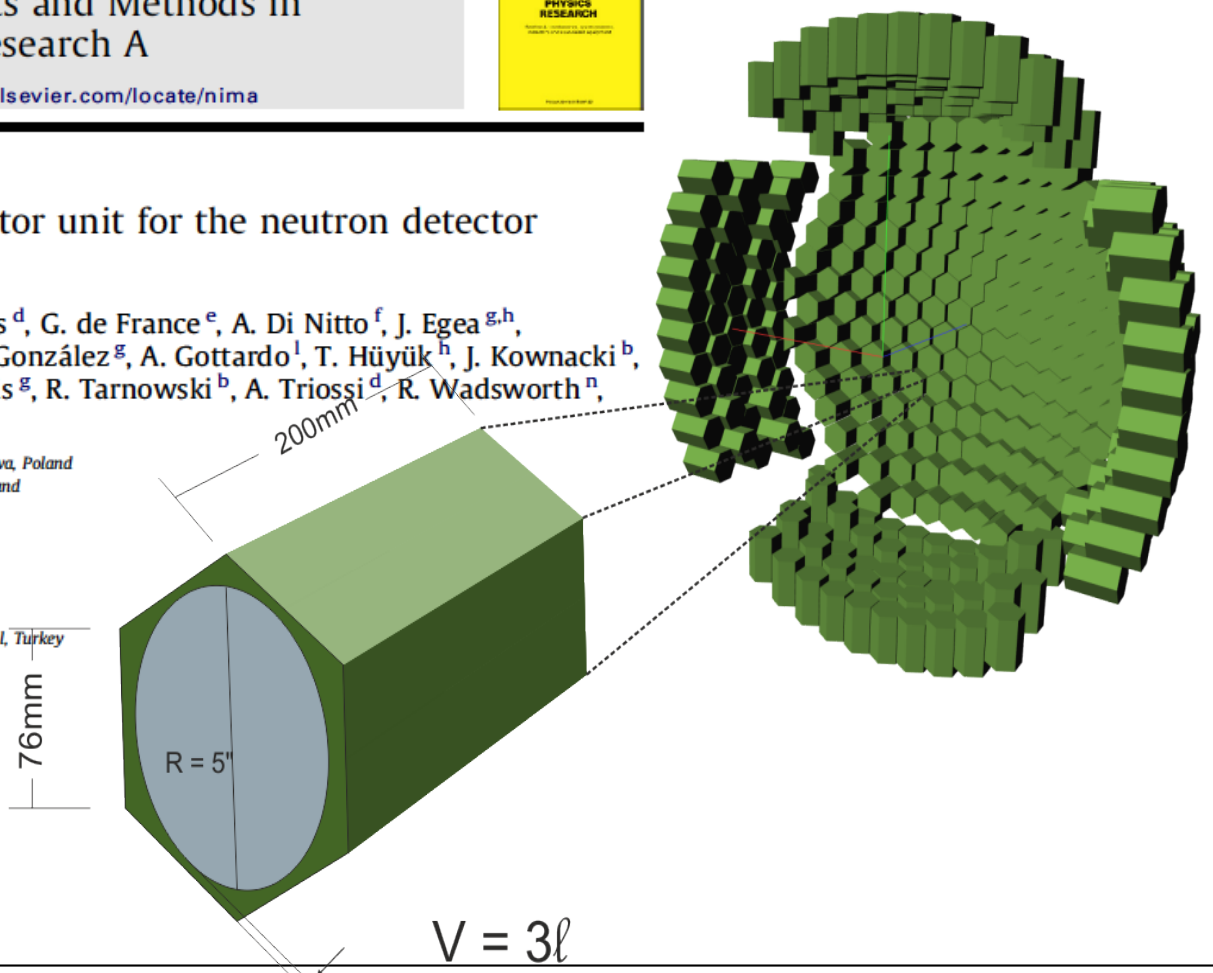
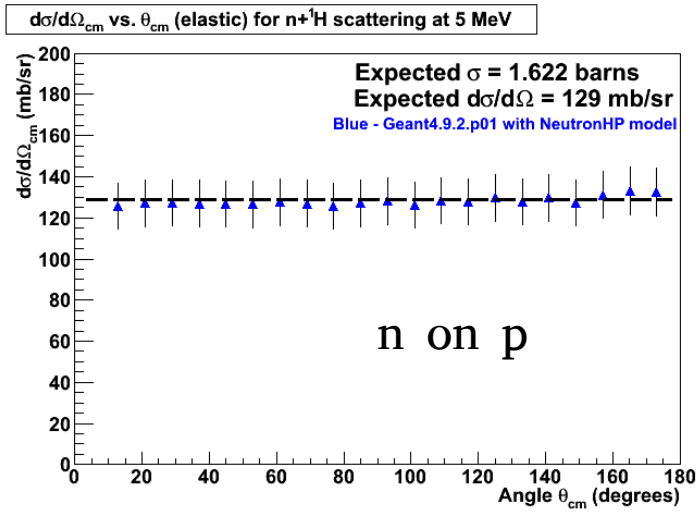
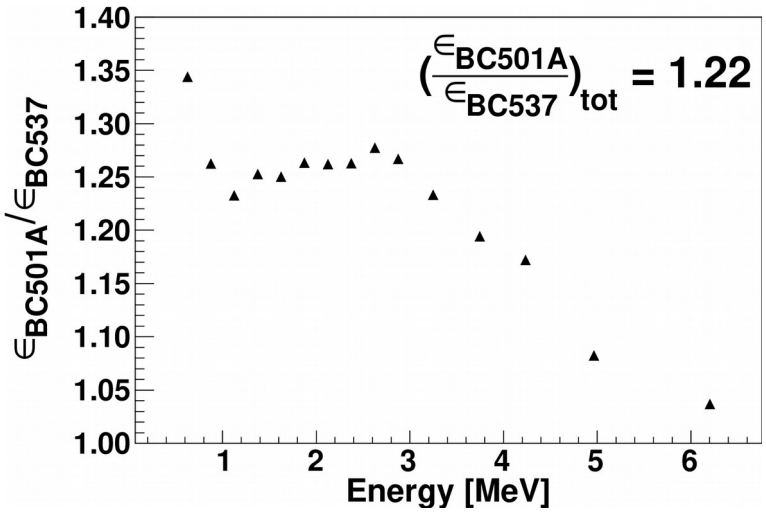
[m] LPC-Caen, ENSICAEN, IN2P3/CNRS et Université de Caen, Caen, France
[n] Department of Physics, University of York, York, United Kingdom

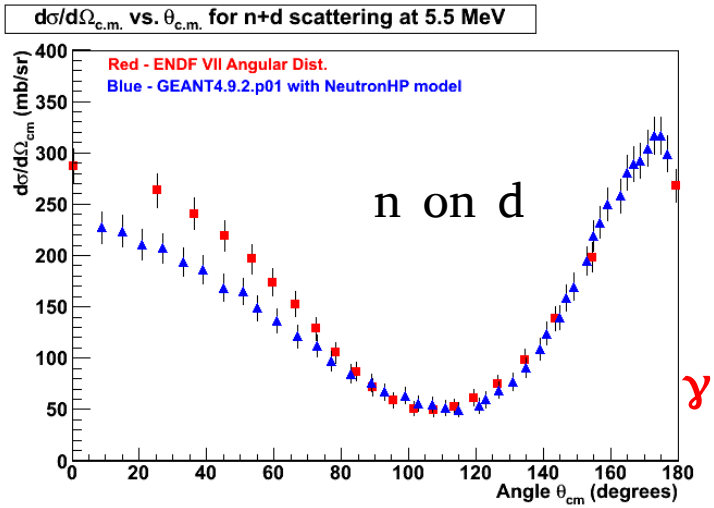


Scintillator

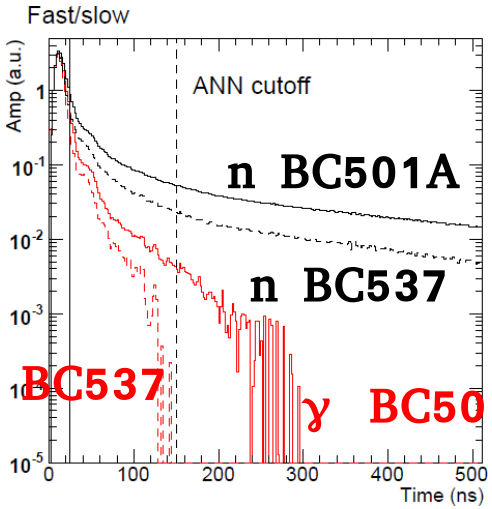
? BC501A / BC537 / EJ299 / … ?



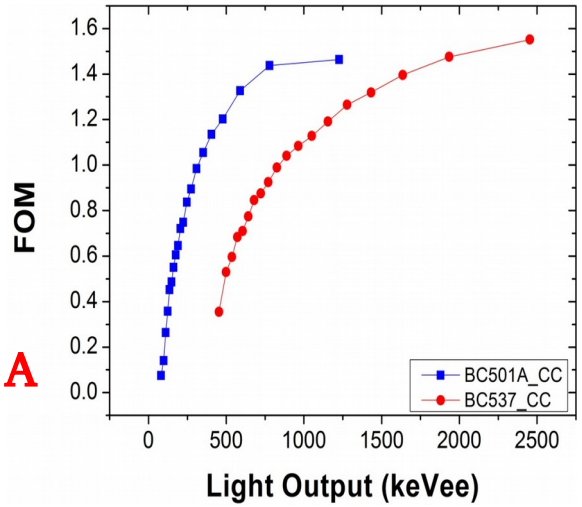




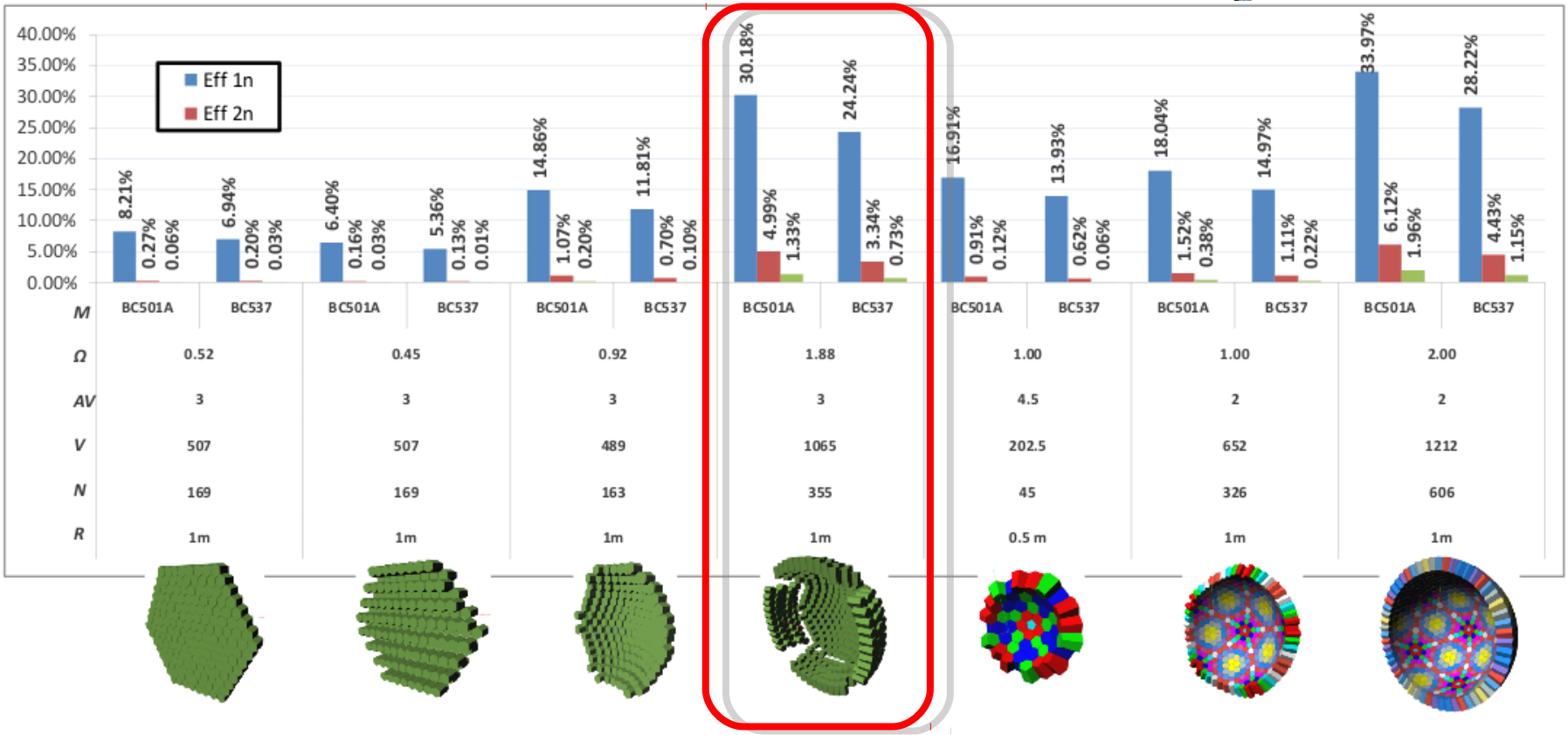
γ BC537



γ BC501A



Full geometry



R	Distance from the origin / Radius (meter)	Simulated neutron source:	Cf-252
N	Granularity (Number of modules)	Depth of the detectors:	20 cm
V	Total Volume (liter)	Neutrons were shot in 2π solid angle	
AV	Average Volume (liter)	1E+7 statistics have been recorded	
Ω	Solid angle coverage (π)		
M	Material		

Timing

Digital timing algorithm for various 5” PMTs

Nuclear Instruments and Methods in Physics Research A 775 (2015) 71–76

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Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Digital pulse-timing technique for the neutron detector array NEDA

V. Modamio [a,*], J.J. Valiente-Dobón [a], G. Jaworski [b,c], T. Hüyük [d], A. Triossi [a], J. Egea [d,e], A. Di Nitto [f], P.-A. Söderström [g], J. Agramunt Ros [d], G. de Angelis [a], G. de France [h], M.N. Erduran [i], S. Ertürk [j], A. Gadea [d], V. González [e], J. Kownacki [c], M. Moszynski [k], J. Nyberg [l], M. Palacz [c], E. Sanchis [e], R. Wadsworth [m]

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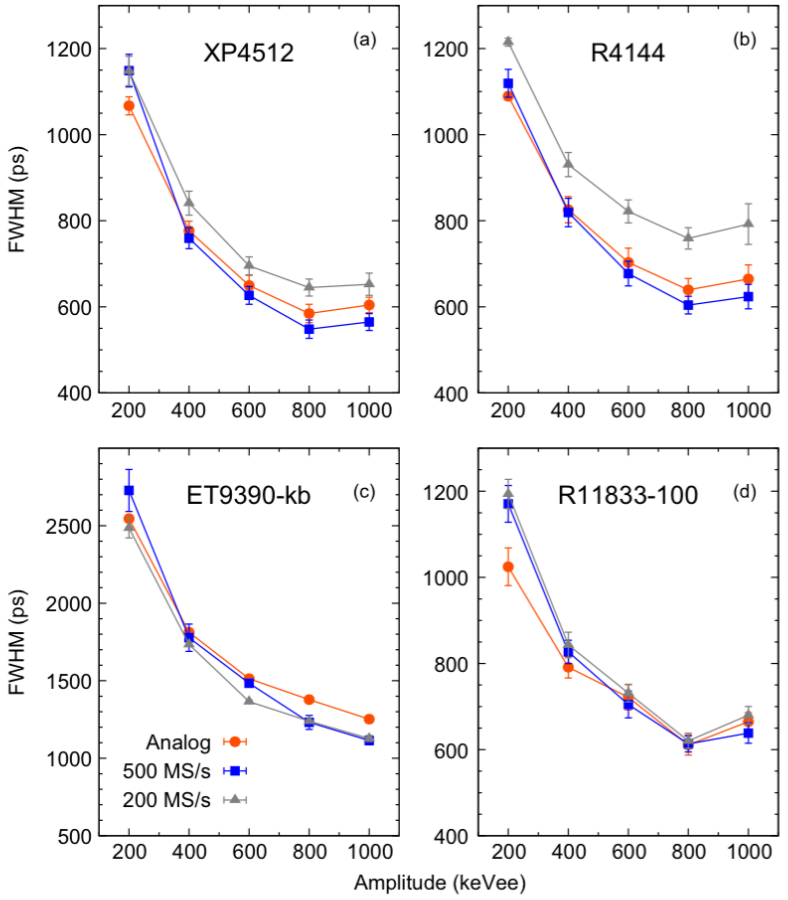

PMT tests for best timing for NEDA

NGD

Digital PSA algorithm for various 5” PMTs

Nuclear Instruments and Methods in Physics Research A 767 (2014) 83–91

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Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Test of digital neutron–gamma discrimination with four different photomultiplier tubes for the NEutron Detector Array (NEDA)

X.L. Luo [a,b,*], V. Modamio [c], J. Nyberg [b], J.J. Valiente-Dobón [c], Q. Nishada [b], G. de Angelis [c], J. Agramunt [d], F.J. Egea [d,e], M.N. Erduran [f], S. Ertürk [g], G. de France [h], A. Gadea [d], V. González [e], T. Hüyük [d], G. Jaworski [i,j], M. Moszyński [j,k], A. Di Nitto [l], M. Palacz [j], P.-A. Söderström [m], E. Sanchis [e], A. Triossi [c], R. Wadsworth [n]

[a] Department of Instrument Science and Technology, College of Mechatronics and Automation, National University of Defense Technology, Changsha, China
[b] Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden
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[d] IFIC-CSIC, University of Valencia, Valencia, Spain
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[f] Faculty of Engineering and Natural Sciences, Istanbul Sabahattin Zaim University, Istanbul, Turkey
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[k] National Centre for Nuclear Research, A. Soltana 7, PL 05-400 Otwock-Swierk, Poland
[l] Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany
[m] RIKEN Nishina Center, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan
[n] Department of Physics, University of York, Heslington, York YO10 5DD, UK

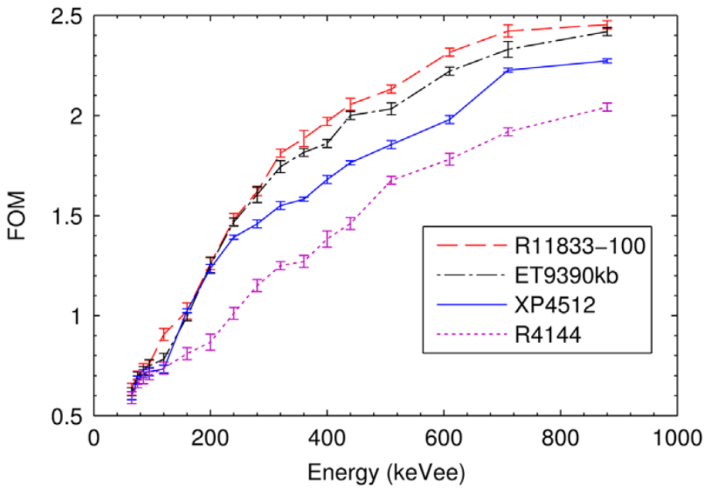


Fig. 10. FOM values of the IRT method for PMT ET9390kb, R11833-100, XP4512, and R4144 as a function of energy window (the widths of the windows are 10, 40, and 100 keVee in energy regions of 50–100, 100–500, and 500–1000 keVee, respectively).

PMT tests for best NGD for NEDA

Electronics

→ NUMEXO2 board
→ GTS on board
→ GTS logic trigger tree
→ 200 MHz, 14 b (11.3 enob)
Mezzanines FADC

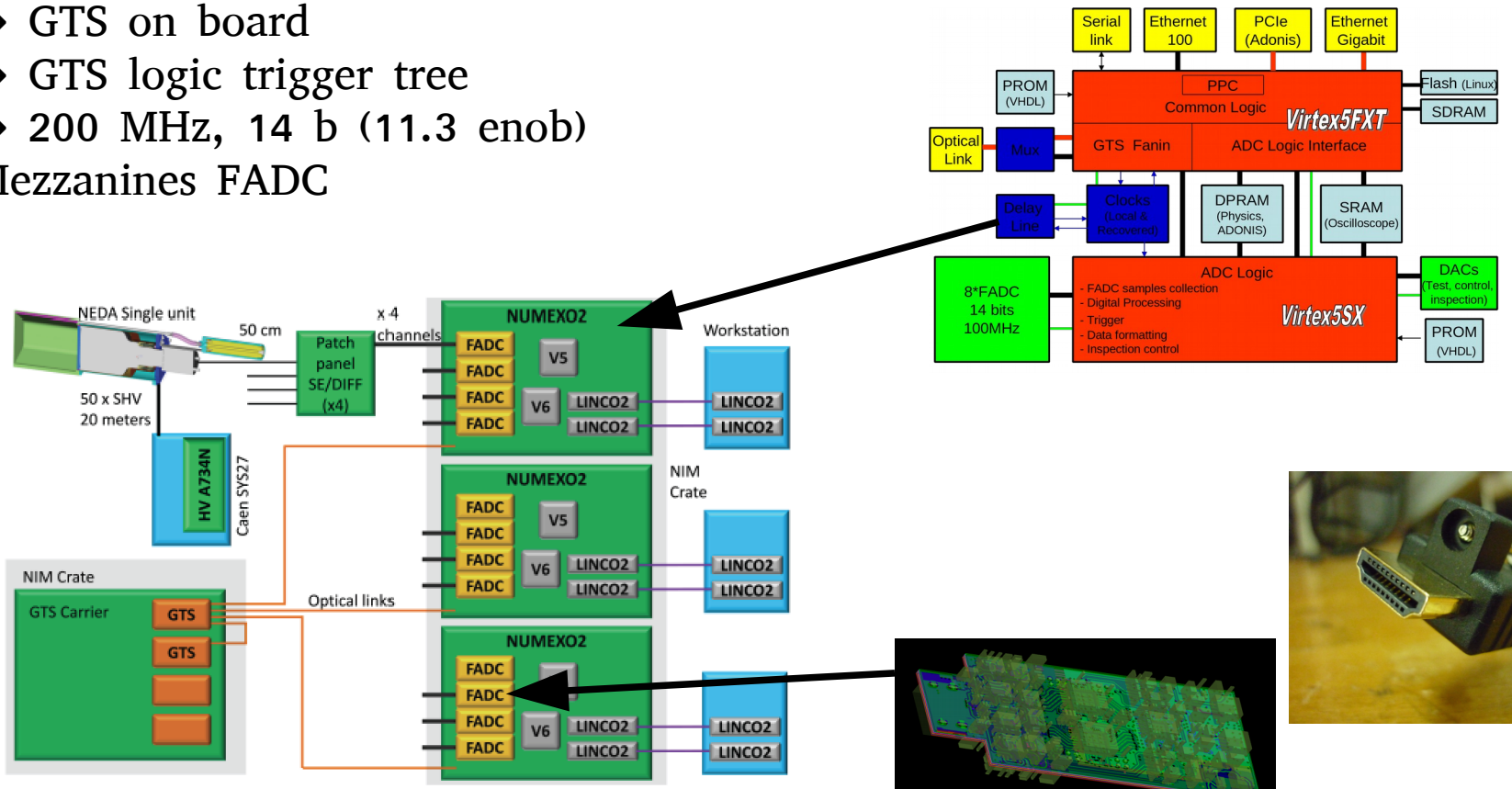


Figure 20: Global electronics layout for 48 NEDA detectors

NEDA @ GANIL

Eur. Phys. J. A (2016) **52**: 55
DOI 10.1140/epja/i2016-16055-8

THE EUROPEAN PHYSICAL JOURNAL A

Special Article – Tools for Experiment and Theory

Conceptual design of the early implementation of the NEutron Detector Array (NEDA) with AGATA

Tayfun Hüyük[1,a], Antonio Di Nitto[2,3], Grzegorz Jaworski[4], Andrés Gadea[1], José Javier Valiente-Dobón[4], Johan Nyberg[6], Marcin Palacz[5], Pär-Anders Söderström[7], Ramon Jose Aliaga-Varea[1,8], Giacomo de Angelis[4], Ayşe Ataç[9,10], Javier Collado[11], Cesar Domingo-Pardo[1], Francisco Javier Egea[11], Nizamettin Erduran[12], Sefa Ertürk[13], Gilles de France[14], Rafael Gadea[8], Vicente González[11], Vicente Herrero-Bosch[8], Ayşe Kaşkaş[9], Victor Modamio[4], Marek Moszynski[15], Enrique Sanchis[11], Andrea Triossi[4], and Robert Wadsworth[16]

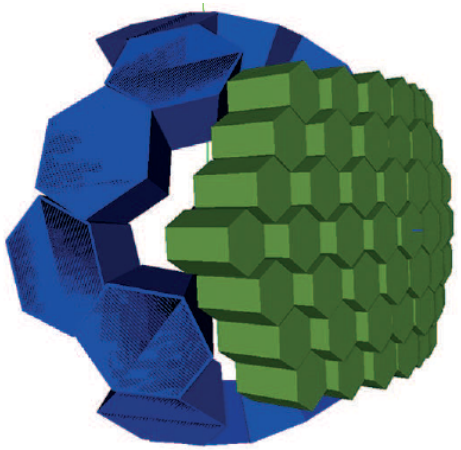


Table 4. One-, two- and three-neutron efficiencies obtained from simulations of a fusion-evaporation reaction ^{58}Ni + ^{56}Fe at 220 MeV for the different detector configurations. Errors quoted are statistical.

Geometry	ε'_{1n} [%]	ε'_{2n} [%]	ε'_{3n} [%]
Neutron Wall (NW)	26.00 (5)	3.93 (10)	0.55 (14)
NEDA + NW	28.70 (5)	6.37 (11)	1.66 (12)
NEDA + NW-ring	31.30 (5)	7.62 (11)	1.89 (11)

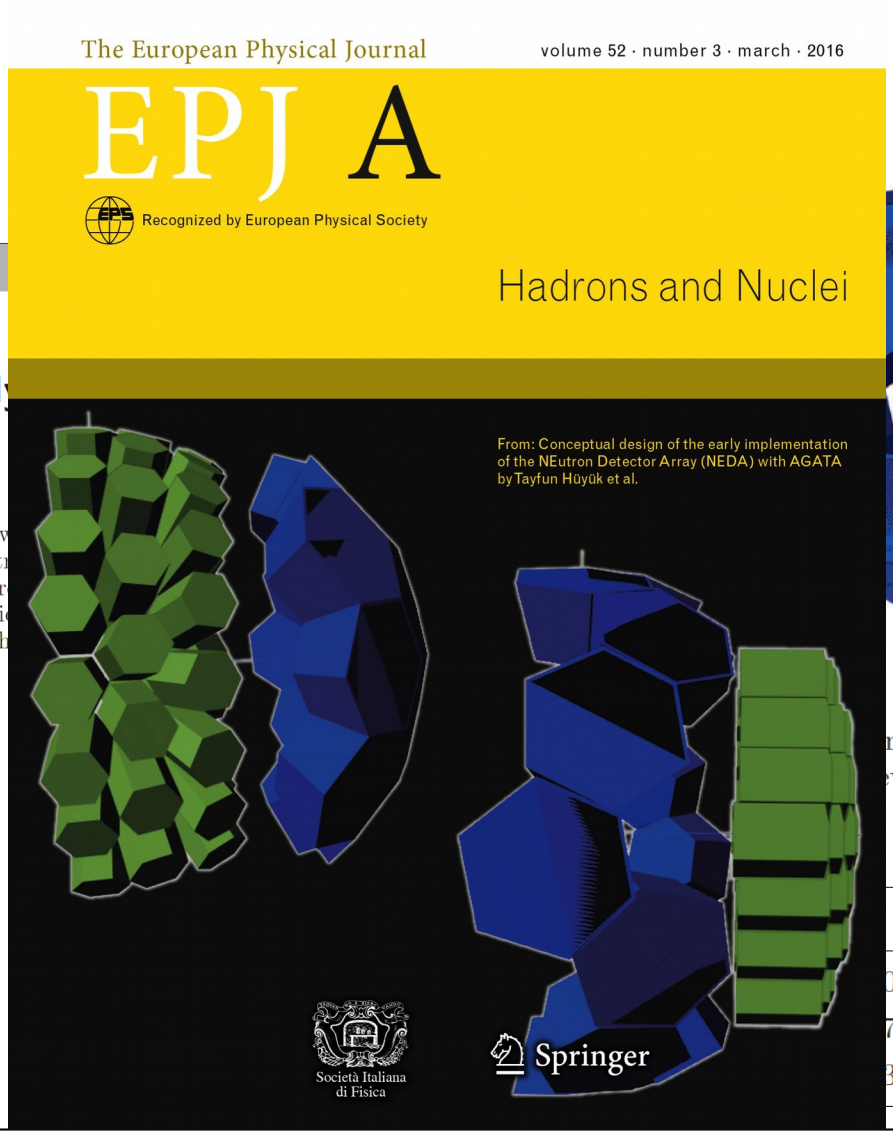
NEDA @ GANIL

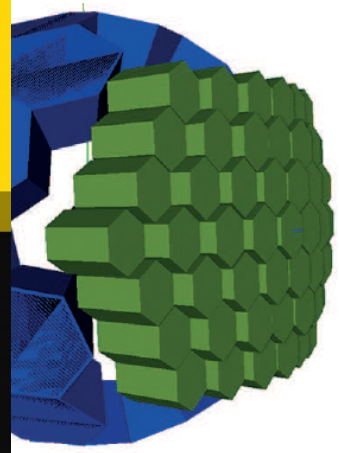
Eur. Phys. J. A (2016) **52**: 55
DOI 10.1140/epja/i2016-16055-8

Special Article – Tools for Experiment and Theory

Conceptual design of the early Detector Array (NEDA) with

Tayfun Hüyük[1,a], Antonio Di Nitto[2,3], Grzegorz Jaw
Johan Nyberg[6], Marcin Palacz[5], Pär-Anders Söderstr
Ayşe Ataç[9,10], Javier Collado[11], Cesar Domingo-Par
Sefa Ertürk[13], Gilles de France[14], Rafael Gadea[8], Vi
Victor Modamio[4], Marek Moszynski[15], Enrique Sanch





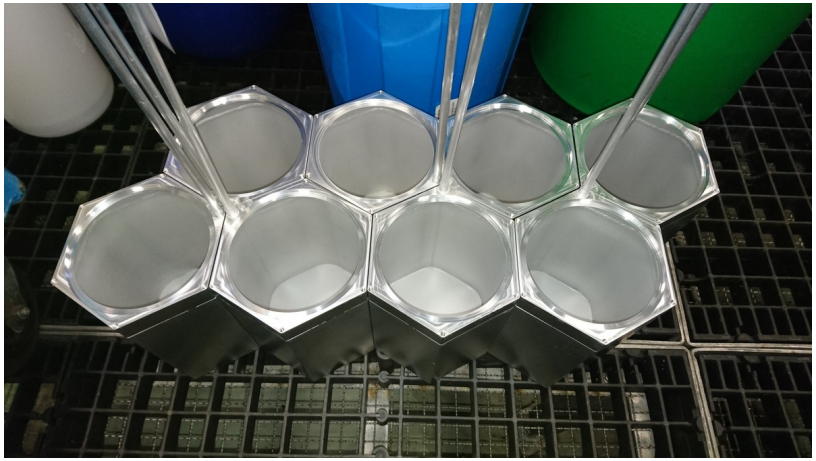
ree-neutron efficiencies obtained
vaporation reaction ^{58}Ni + ^{56}Fe
detector configurations. Errors

	[%]	ε'_{2n} [%]	ε'_{3n} [%]
	00 (5)	3.93 (10)	0.55 (14)
	70 (5)	6.37 (11)	1.66 (12)
	30 (5)	7.62 (11)	1.89 (11)

Self-production

- → Detector vessels and PMT housings are made by welding flanges to hexagonal profiles
- → EJ520 TiO_2 paint; TorrSeal; 5” 5mm BK7 glass
- → Expansion bellow – $\Delta T = 40$ K.
- → EJ301 (BC501) liquid scintillator

- → SBA R11833-100HA 5” PMT (32% Q.E.)
- → custom transistorized VD provided by Świerk
- → mu-metal shielding (1 mm)
- → NUMEXO2
- → Single ended to differential converter (production)
- → Array structure (produced, under tests)



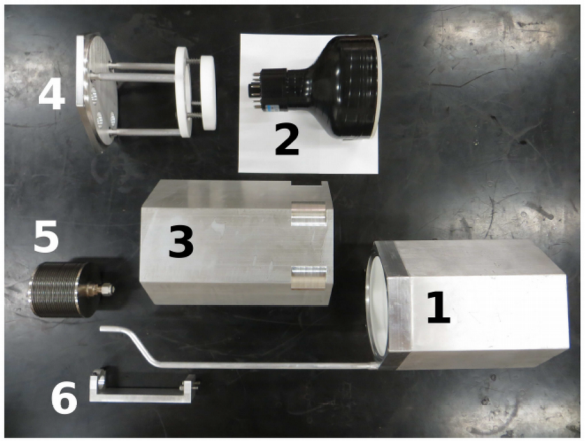
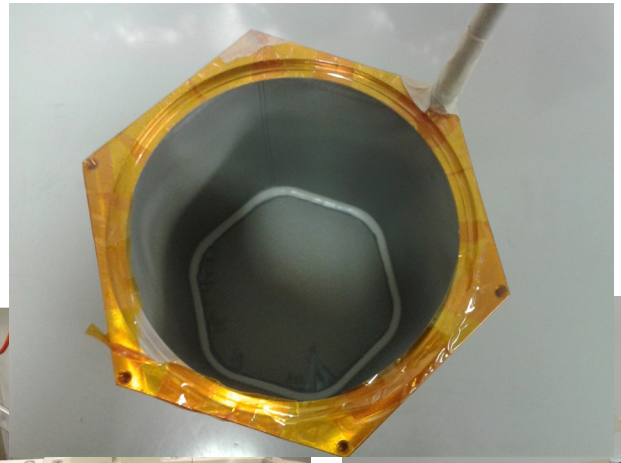
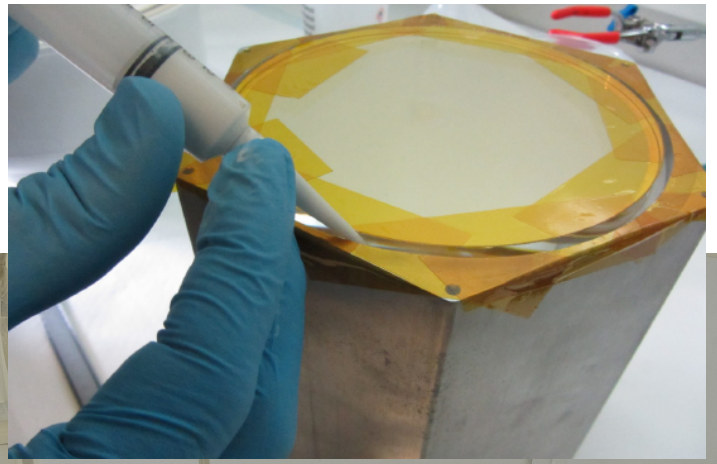


Fig. 1. Elements used for the construction of the NEDA detector: detector cell, with extension pipe (1); PMT (2); PMT housing (3); PMT pusher (4); the bellow (5) and the support for the bellow (6).

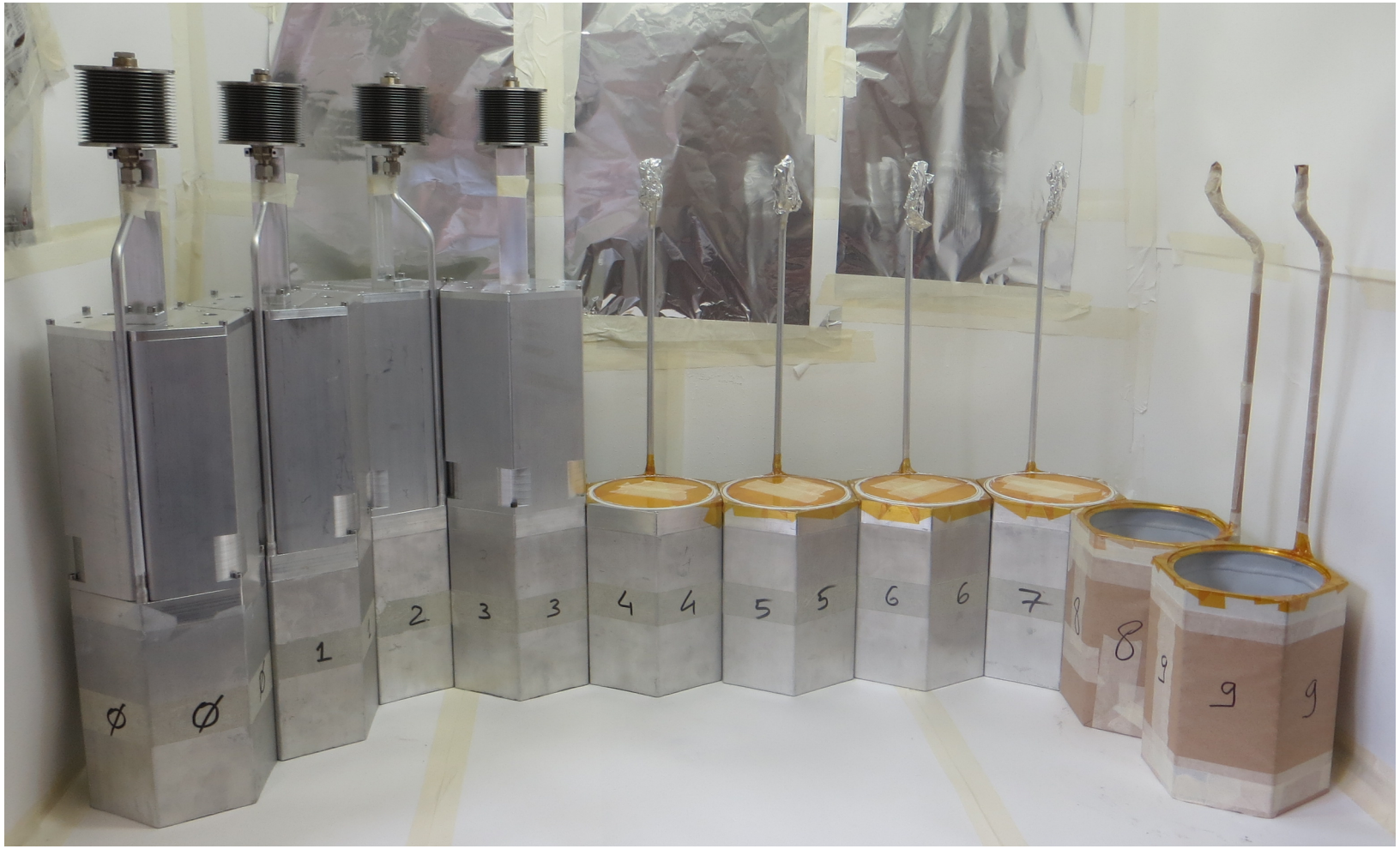
Detector production



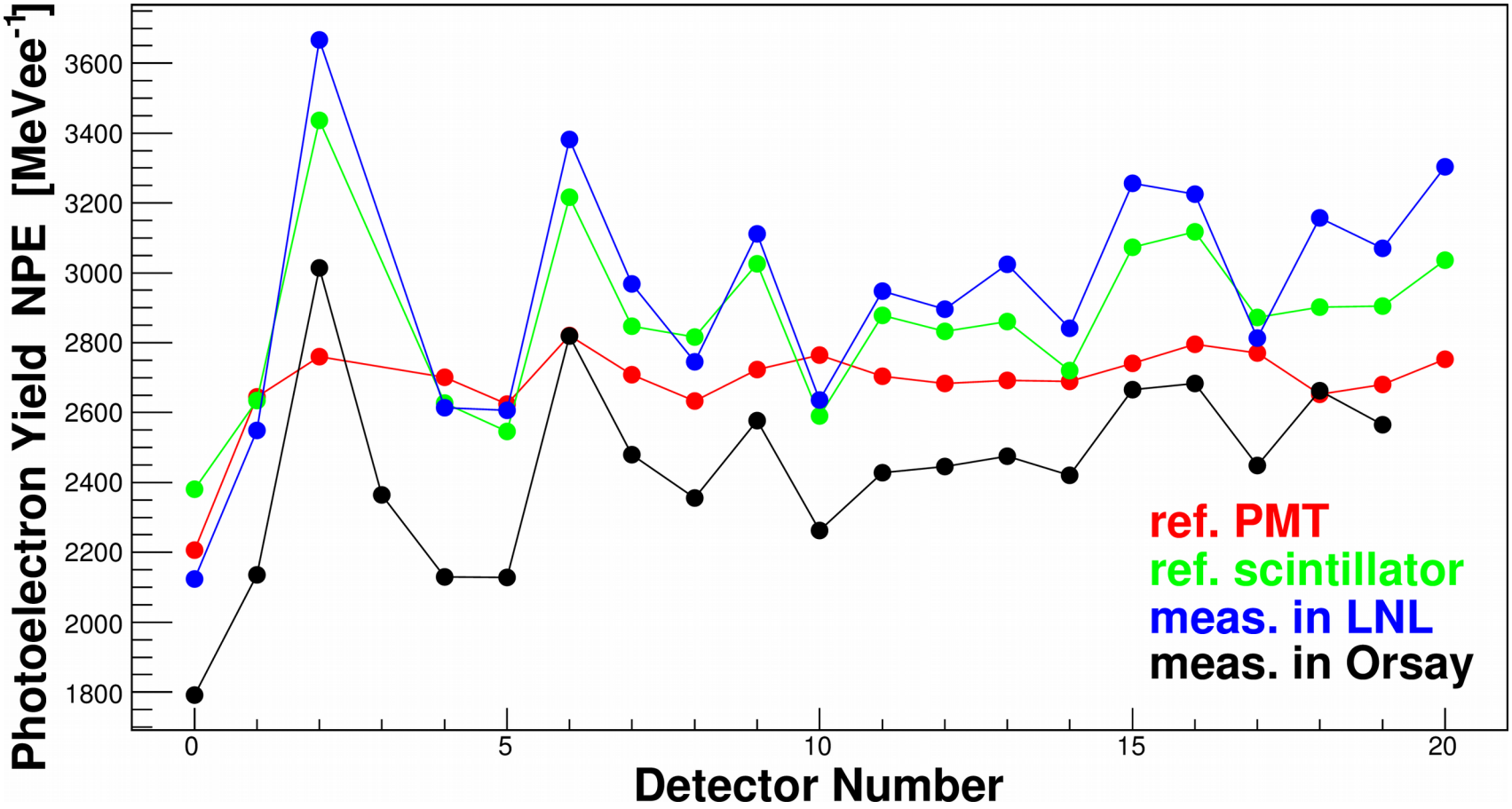


Detector production

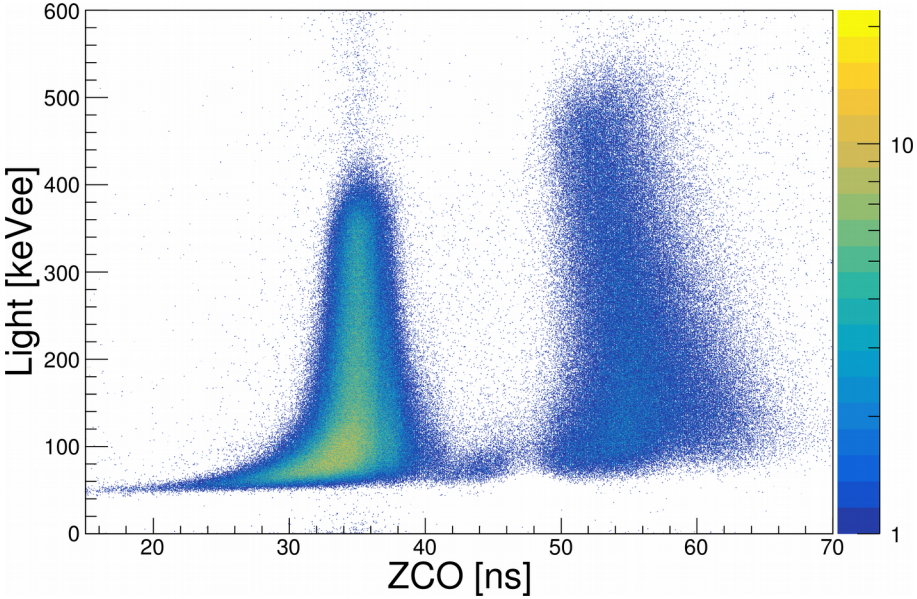
Detector production

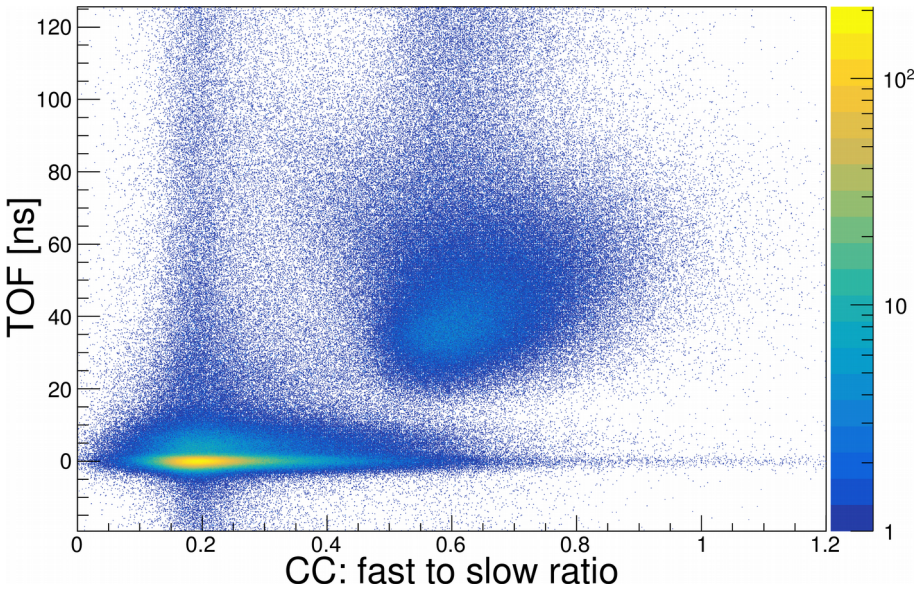


Characterisation

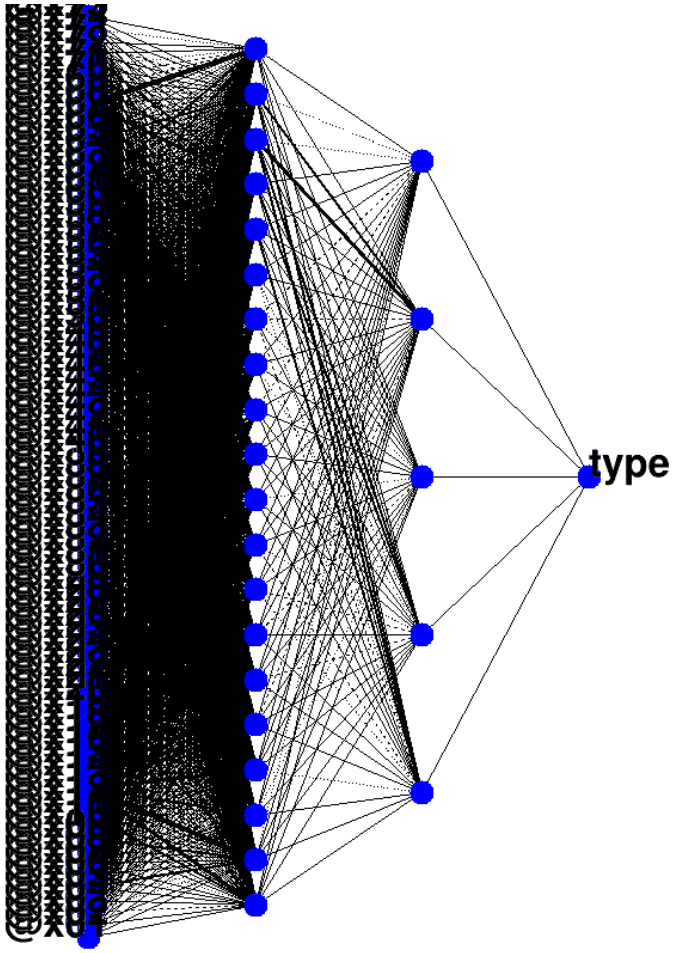


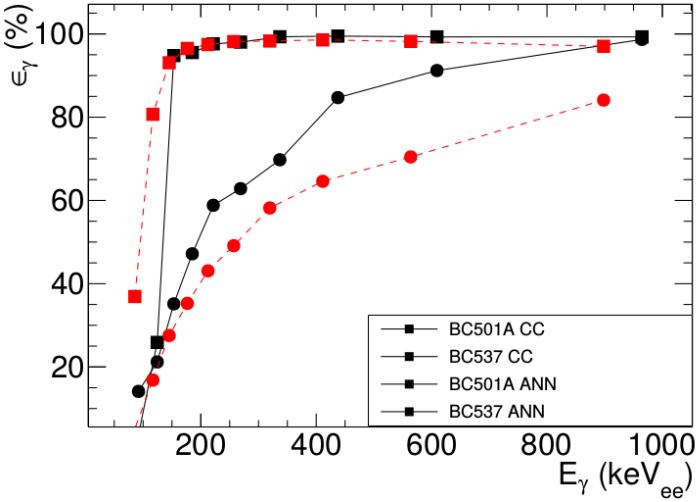
Characterisation

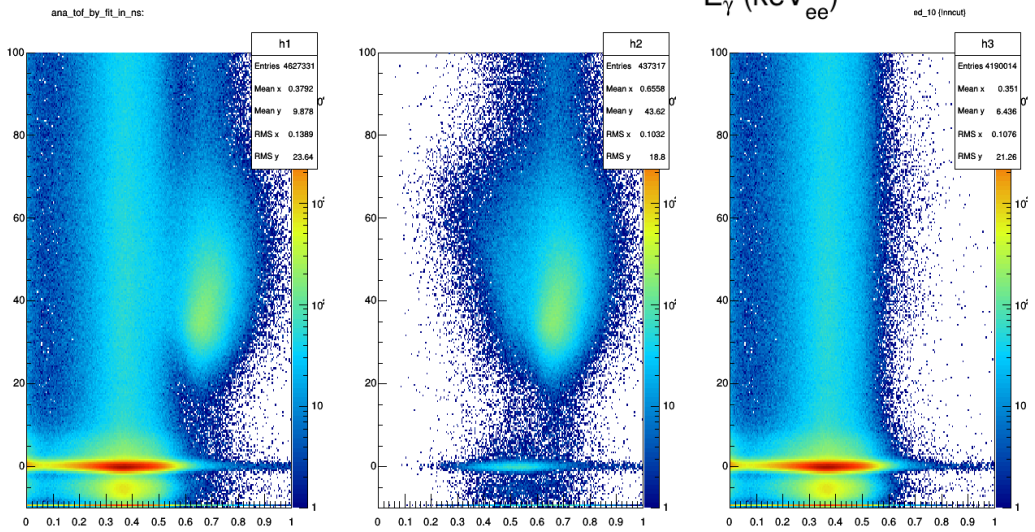




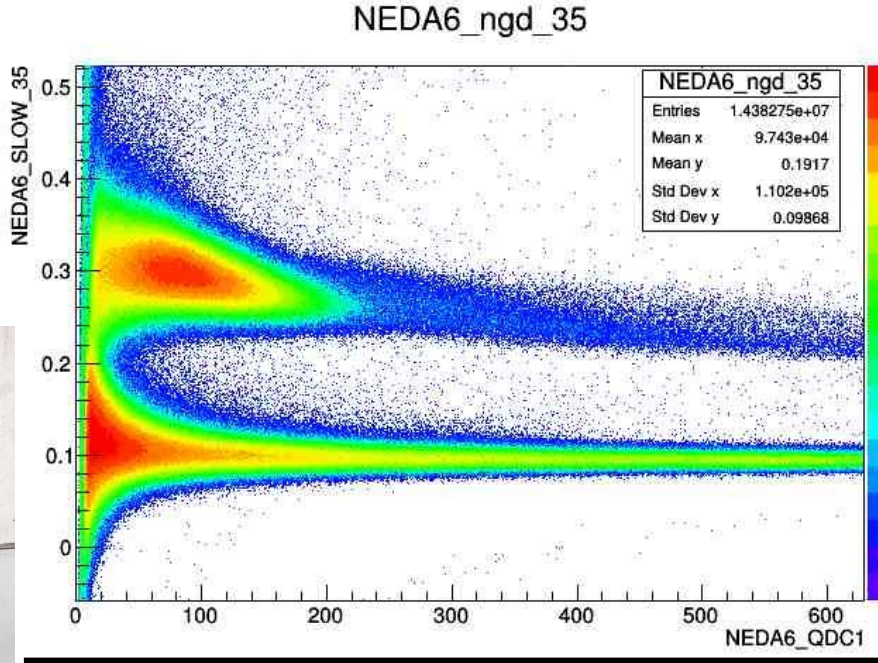
Artificial Neural Networks



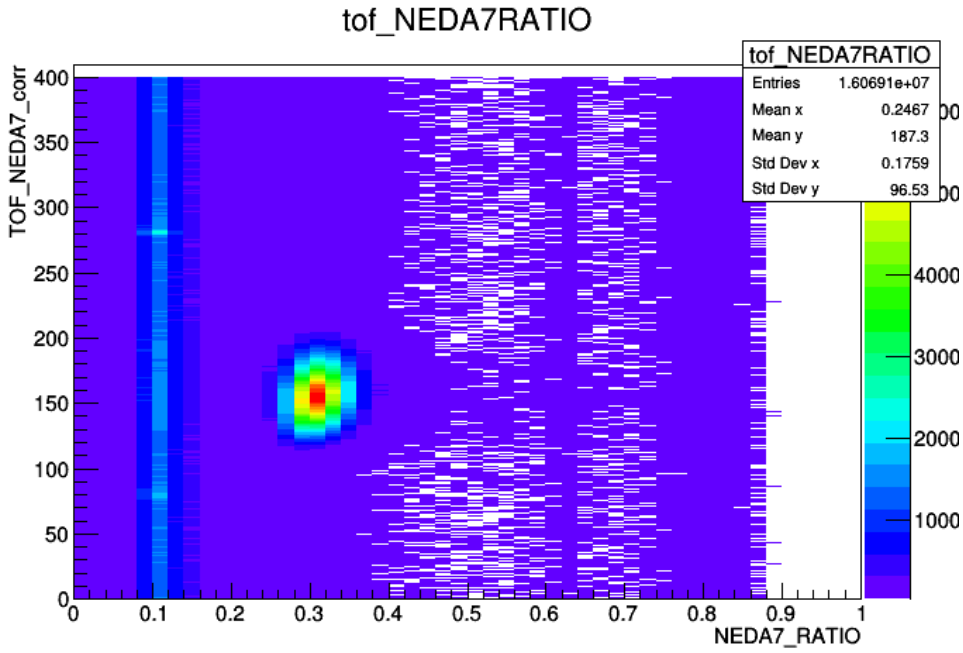


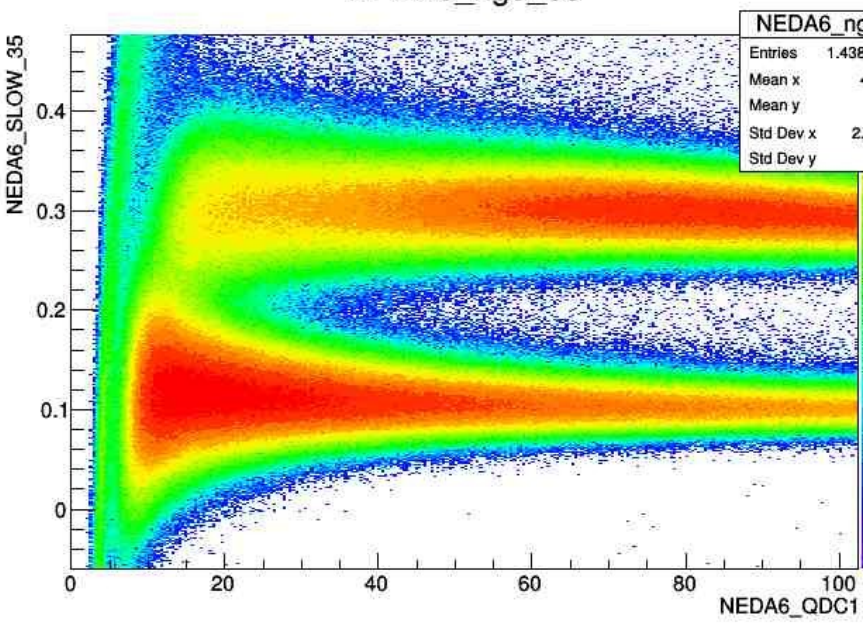


$p(^7Li,n)^7Be$ LICORNE @ ALTO



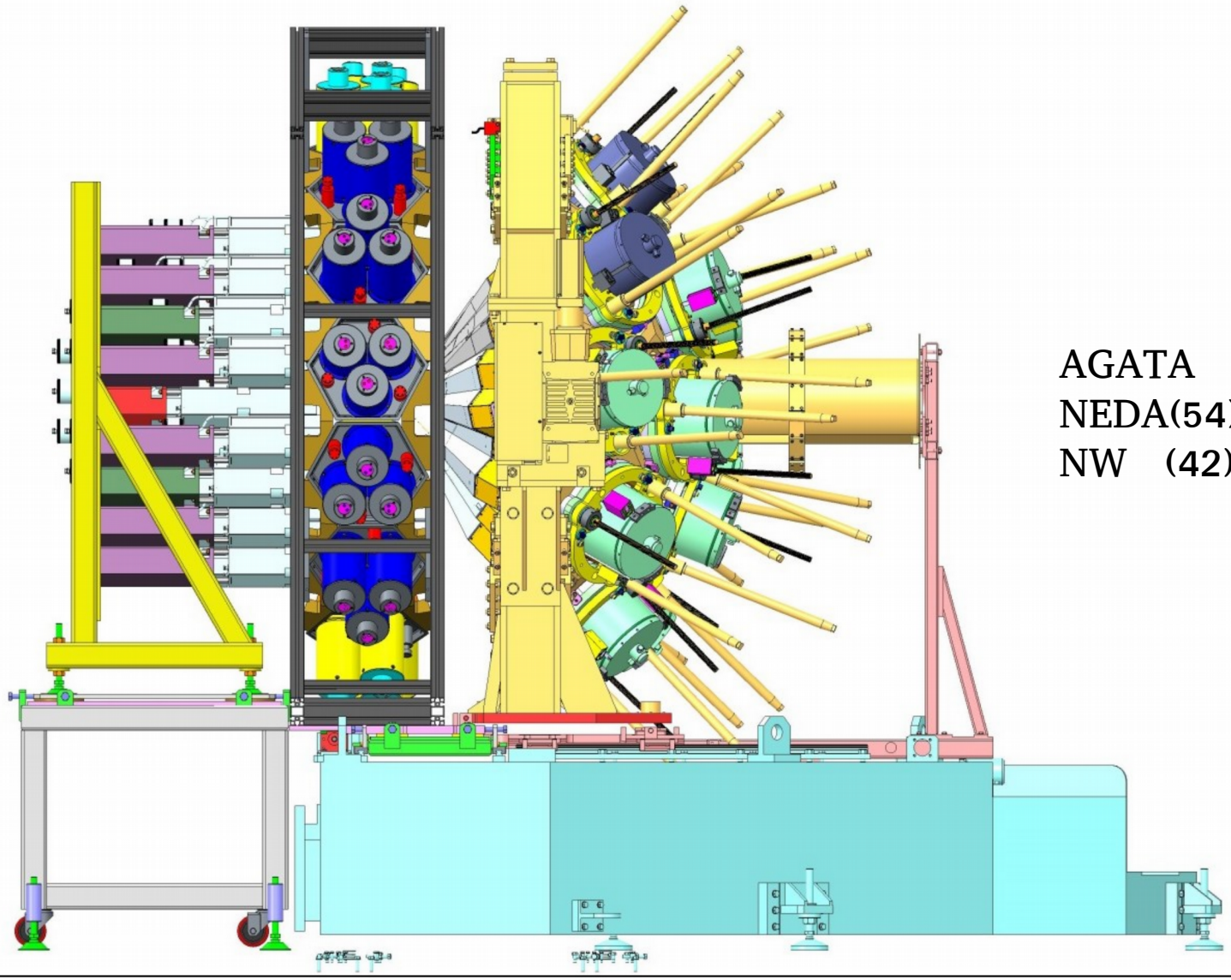
FOM = 1.88 for (50-200)keVee





The work continues....

GANIL 2018: AGATA +



AGATA @ 145 mm
NEDA(54)@ 510 mm
NW (42)@ 650 mm

Summary

- Versatile neutron detector to be coupled to γ-ray arrays and charged particle detectors.

- High performance neutron multiplicity filter based on the liquid scintillator EJ301 with excellent neutron-gamma discrimination capabilities.

- The first campaign of physics will be NEDA coupled to AGATA@ GANIL with stable beams in 2018 - fusion evaporation reactions along N=Z.

- Versetile: Potenciality with future RIB: transfer reactions (3He,n), (d,n); plunger measurements (access to transition probabilities).

- The work continues.... (we will further invest in R&D of new materials and techniques to improve the neutron detection eff., discrimination, ...).

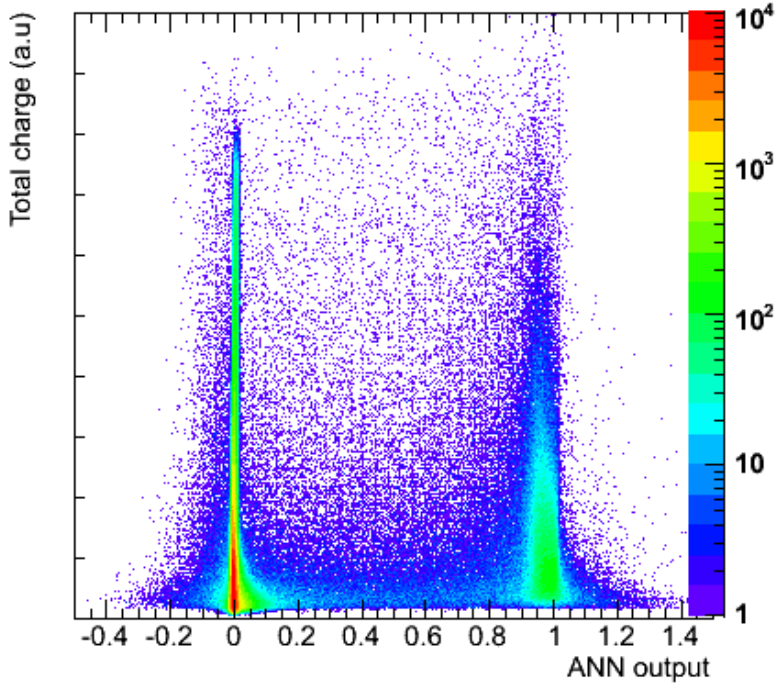
Collaboration

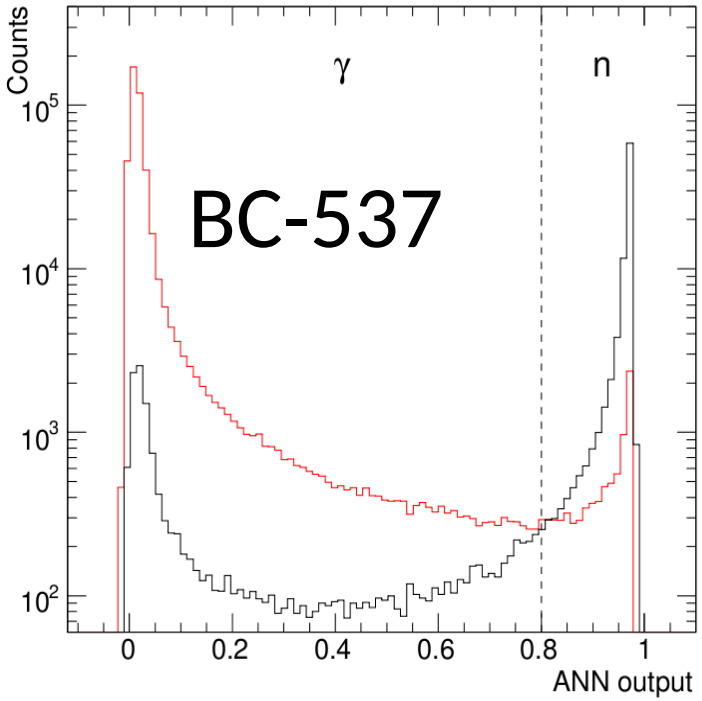
G. de Angelis, S. Carturan, E. Clement, X. Egea, N. Erduran, S. Ertürk, G. de France, A. Gadea, A. Goasduff, V. Gonzalez, K. Hadyńska-Klęk, T. Hüyük, M. Jastrząb, G. Jaworski, V. Modamio, M. Moszyński, A. Di Nitto, J. Nyberg, M. Palacz, E. Sanchis, P.-A. Söderström, D. Testov, A. Triossi, J.J. Valiente Dobon, R. Wadsworth

Backup slides follow

NEDA test: PSA Neural Network

P.-A. Söderström(Uppsala University, Uppsala, Sweden)





Full advantage of digital electronics can be obtained using artificial neural networks to perform pulse-shape discrimination. This method is currently being investigated both for BC537 and BC501A.

+ Optimal discrimination over a large energy range
- Slower implementation limits counting rate

Monday and Thursday talk by G. Jaworski