NEDA

Grześ Jaworski

on behalf of NEDA collaboration

NUSPIN Kick-off, San Servolo, June 30th, 2016

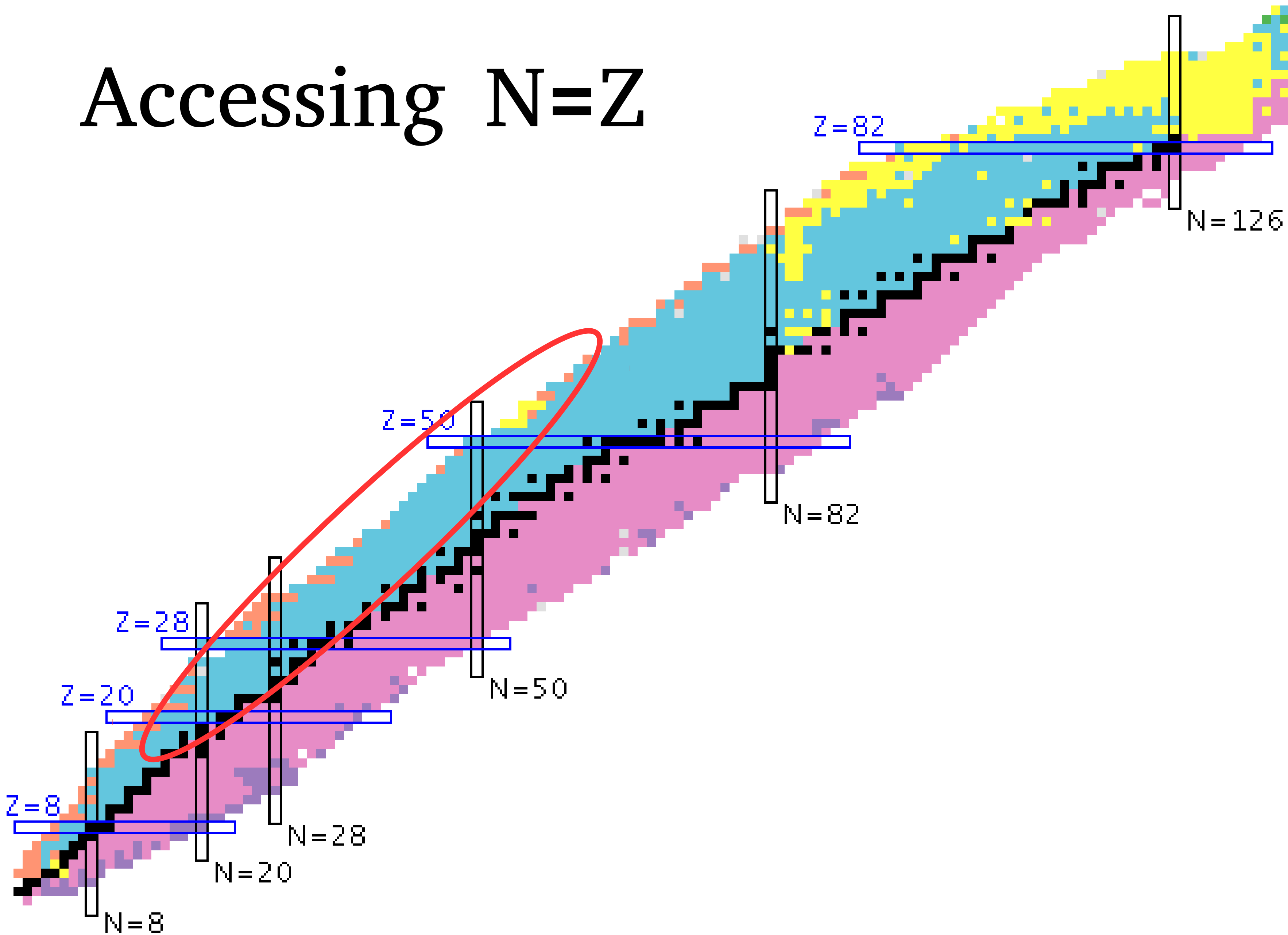
Outline

→ Why neutron multiplicity filter and why to built a new one?

→ Let's start form scratch (howto)
- single cell;
- scintillator;
- full geometry;
- PMT;
- timing;
- NGD;
- electronics;
- NEDA + NW @ GANIL geometry;
- production (ongoing);
- final characteristics (todo).

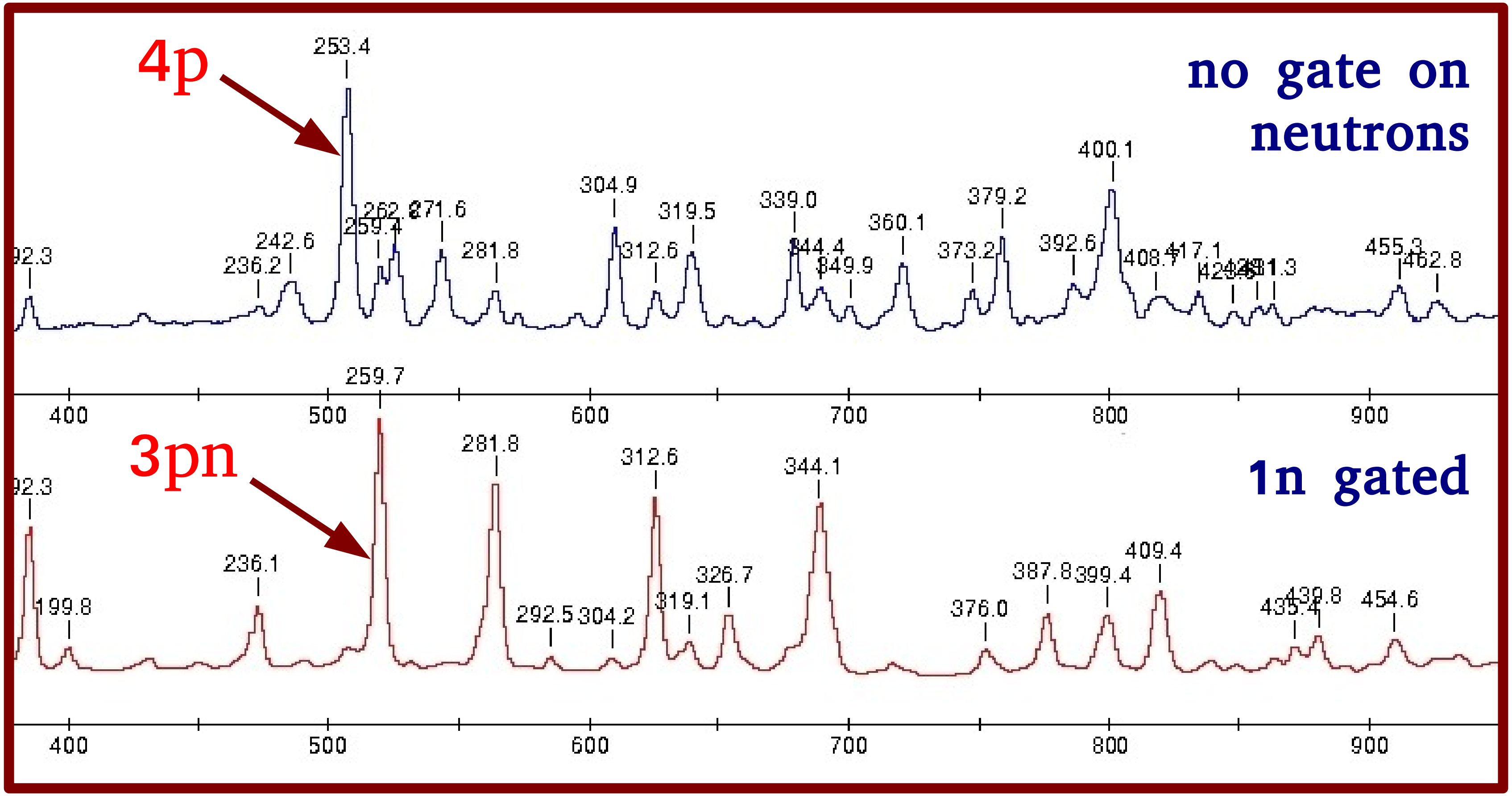
→ Physics with NEDA
- GANIL 2018

Accessing N=Z



n selection

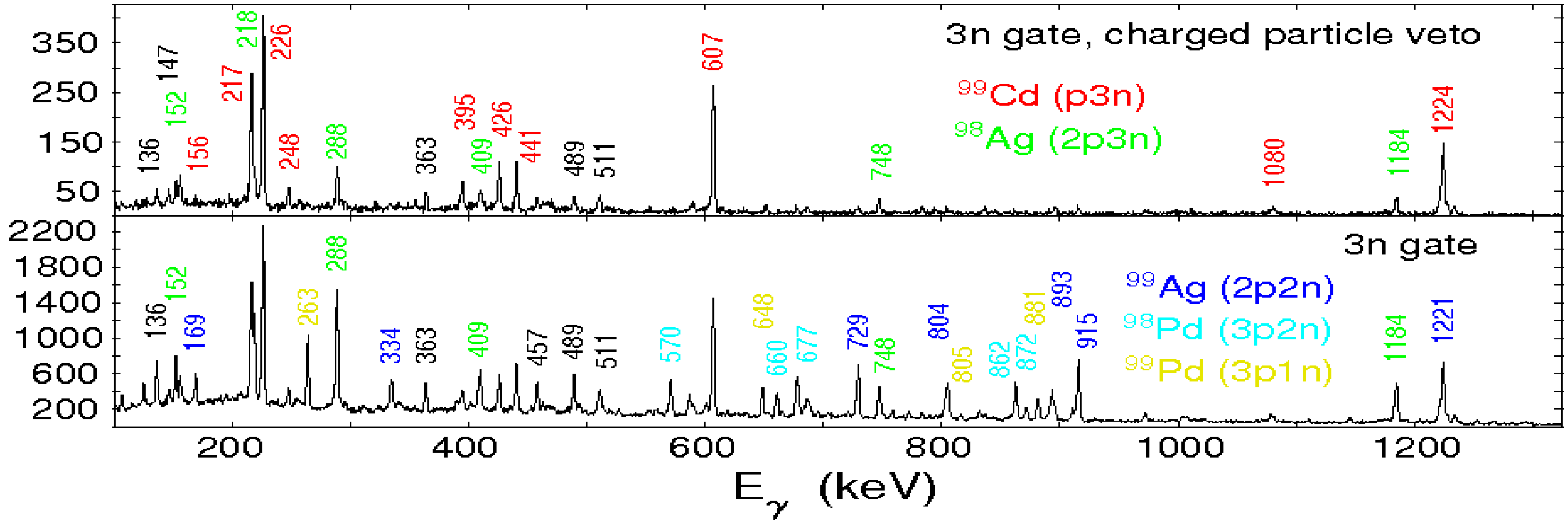
EXOGAM experiment: ^{58}Ni (240 MeV) + ^{54}Fe



Why not NW?

NEDA

An example:
Attempt to study ^{100}In – 1ν 1π^{-1} outside ^{100}Sn
3n evaporation channel – the only 3n case with NWall (+ EUROBALL)

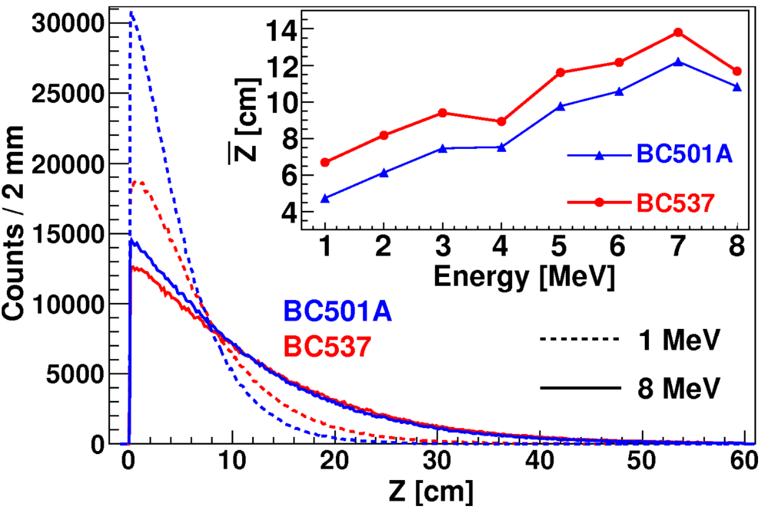


^{100}In not observed, but observation only a matter of statistics.

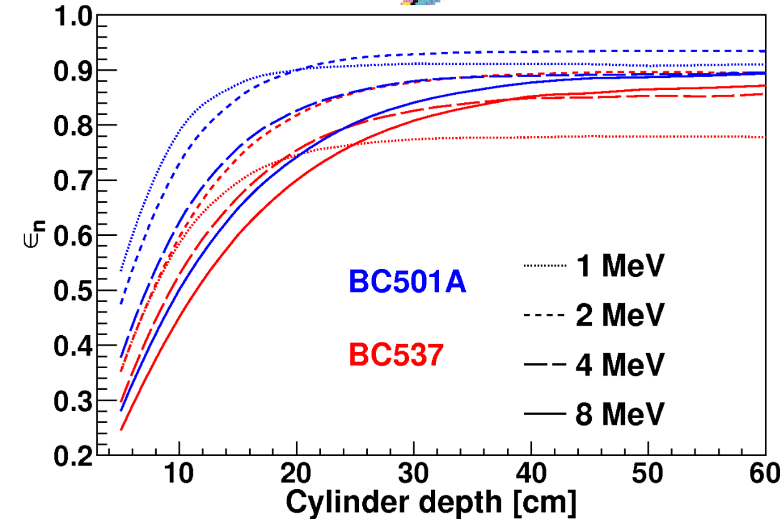
10x statistics: → ½ a a year with EXOGAM + NWall,
→ 2-3 weeks with EXOGAM + NEDA.

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

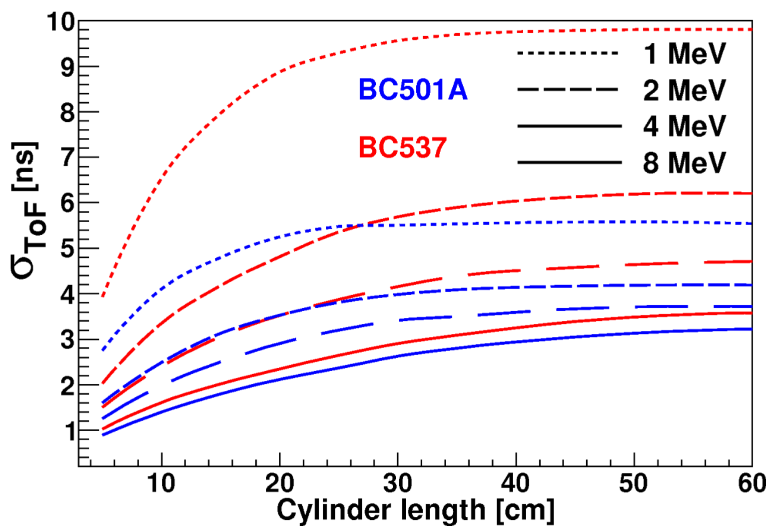
Single cell



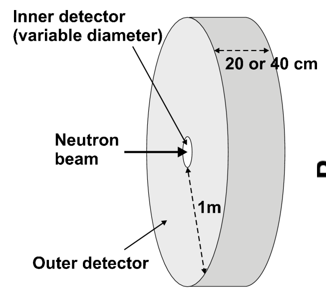
Counts / 2 mm
Z [cm]
$\overline{Z}$ [cm]
Energy [MeV]
BC501A
BC537
1 MeV
8 MeV



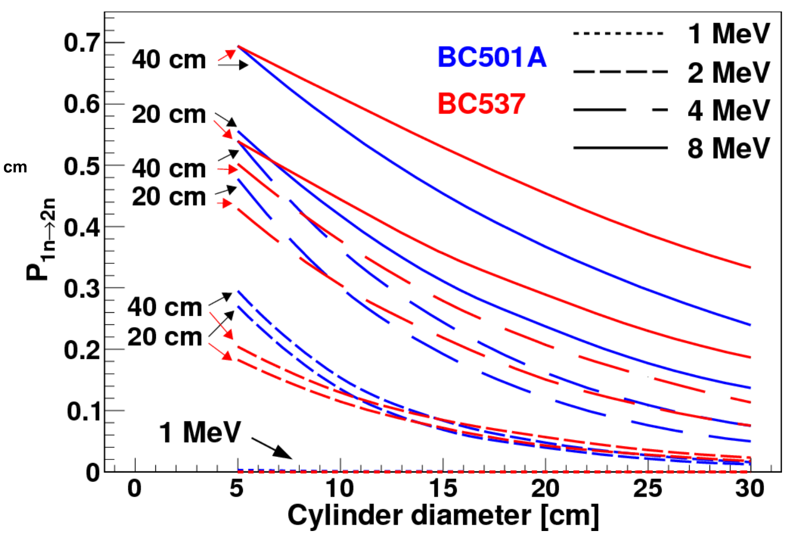
ϵ_n
Cylinder depth [cm]
BC501A
BC537
1 MeV
2 MeV
4 MeV
8 MeV



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



$P_{1n\rightarrow 2n}$
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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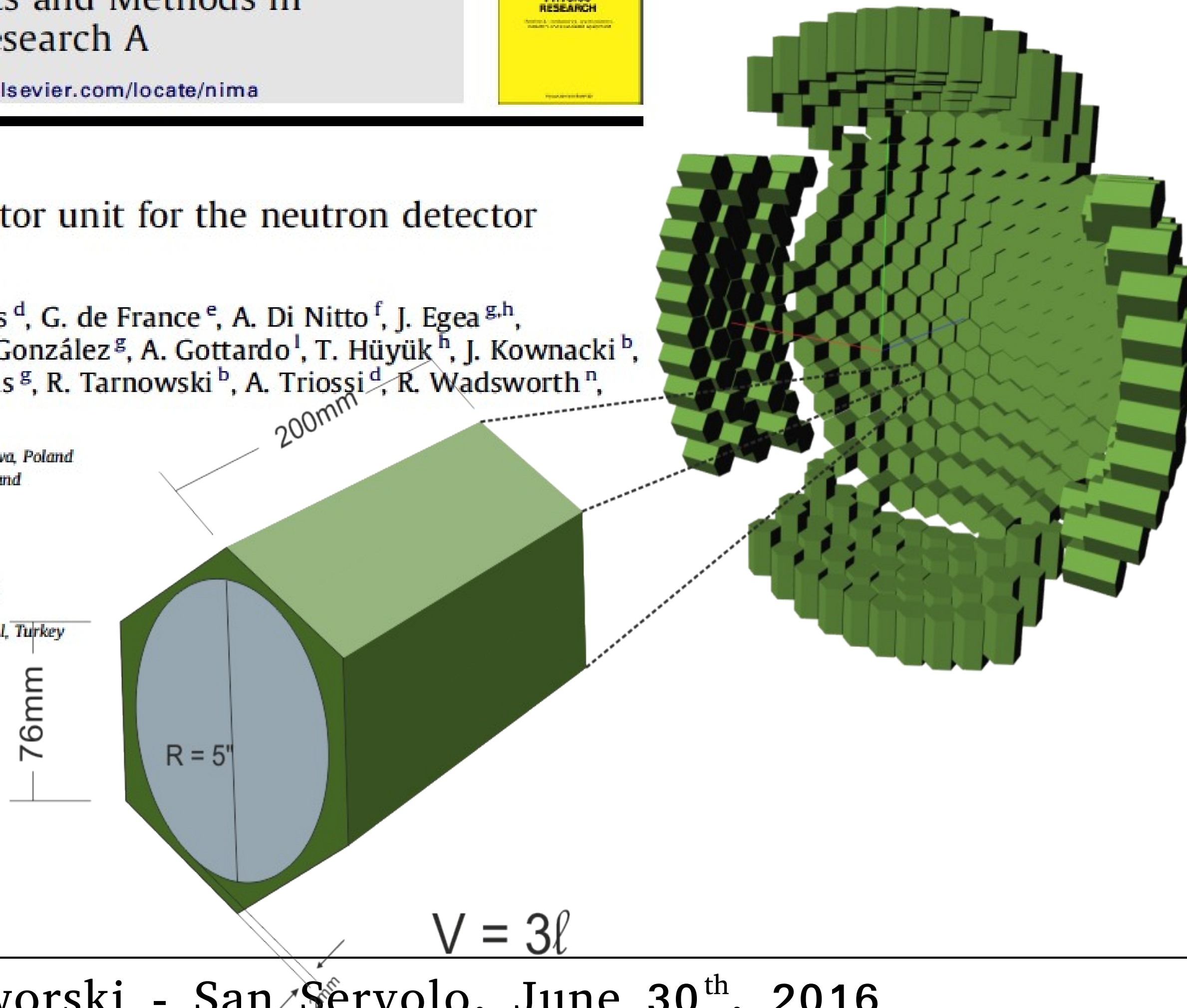
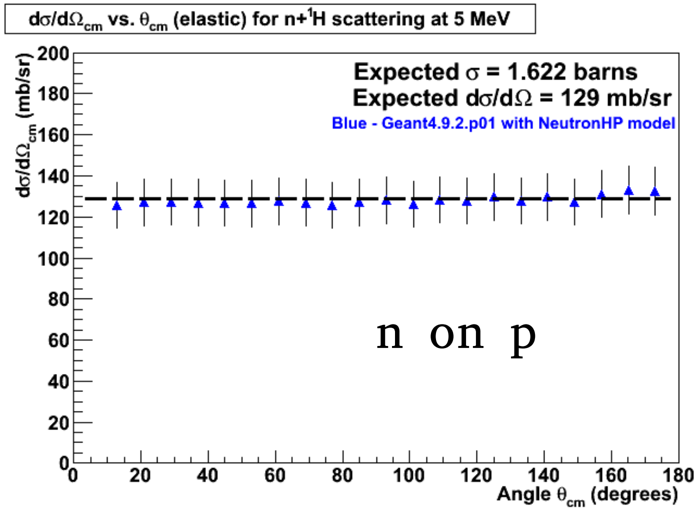
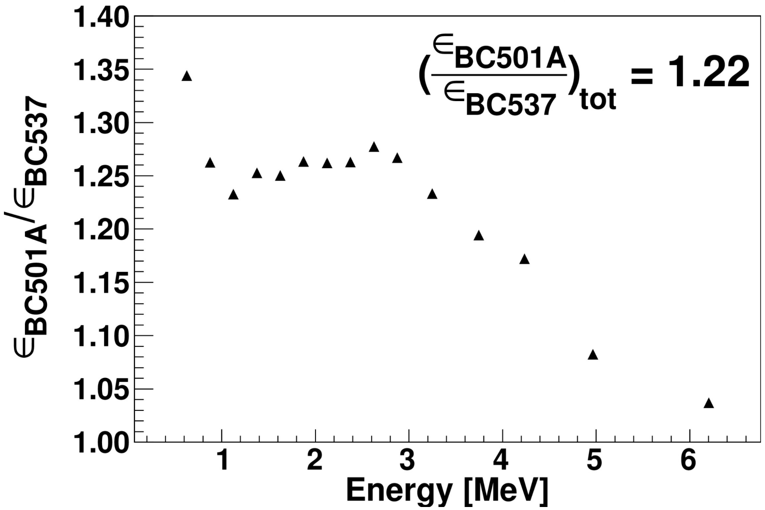


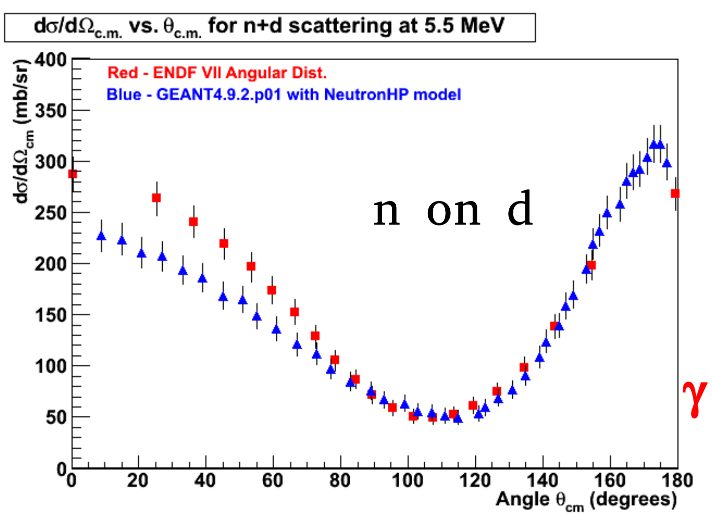
Scintillator

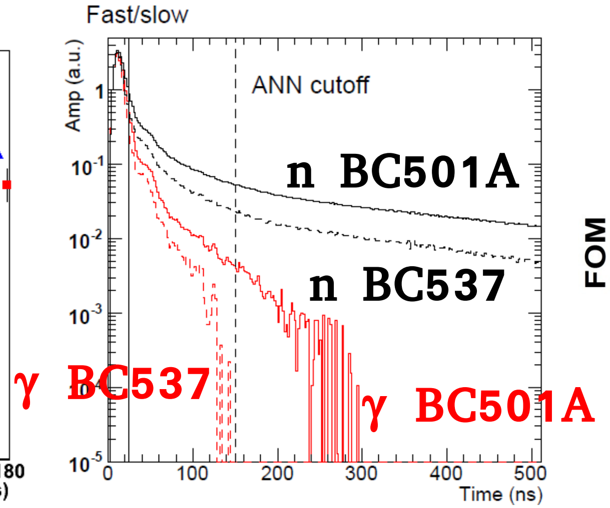
? BC501A / BC537 / EJ299 / ... ?

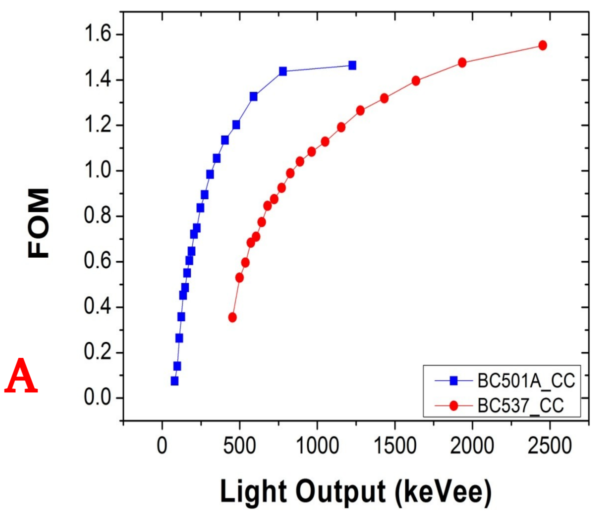




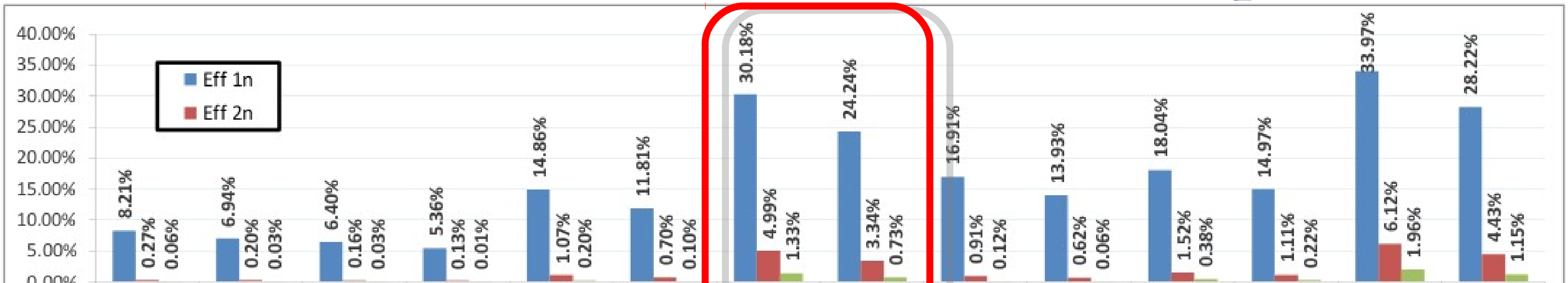
preliminary



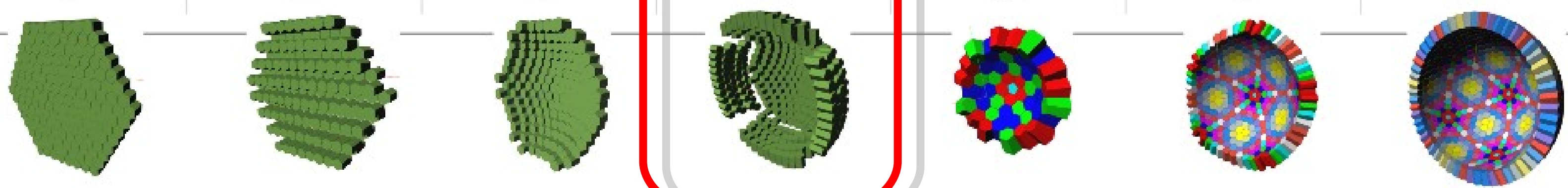




Full geometry



M	BC501A	BC537	BC501A	BC537	BC501A	BC537	BC501A	BC537	BC501A	BC537	BC501A	BC537	BC501A	BC537
Ω	0.52		0.45		0.92		1.88		1.00		1.00		2.00	
AV	3		3		3		3		4.5		2		2	
V	507		507		489		1065		202.5		652		1212	
N	169		169		163		355		45		326		606	
R	1m		1m		1m		1m		0.5 m		1m		1m	



R Distance from the origin / Radius (meter)
N Granularity (Number of modules)
V Total Volume (liter)
AV Average Volume (liter)
Ω Solid angle coverage (π)
M Material

Simulated neutron source: Cf-252
Depth of the detectors: 20 cm
Neutrons were shot in 2π solid angle
1E+7 statistics have been recorded

Timing

NEDA

Digital timing algorithm for various 5” PMTs

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

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

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

ELSEVIER

Digital pulse-timing technique for the neutron detector array NEDA

CrossMark

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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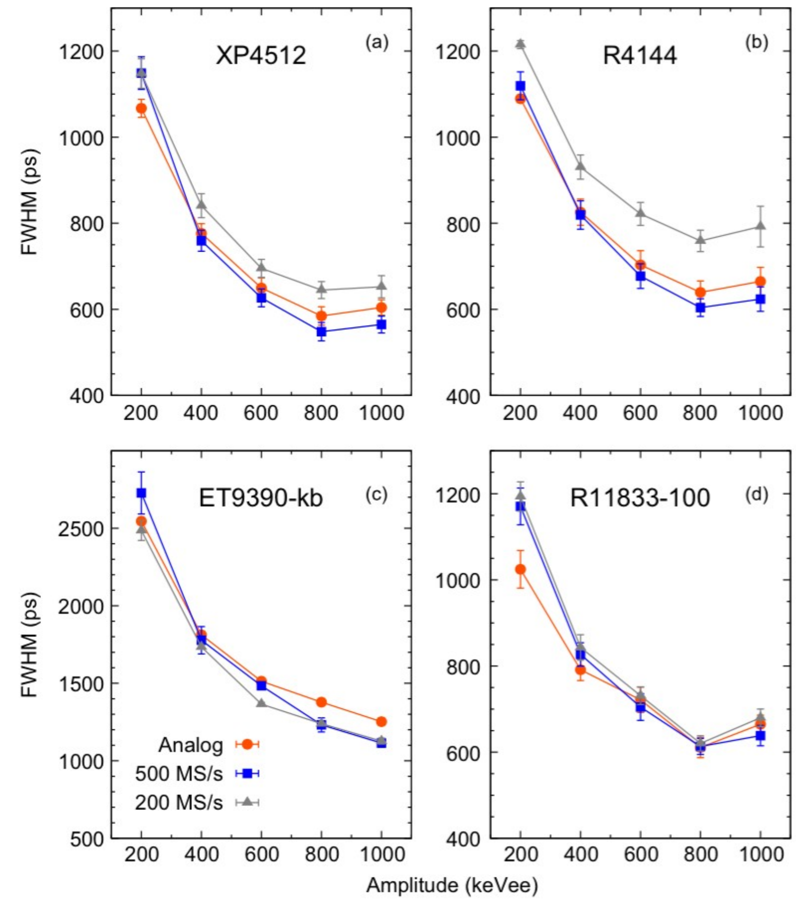

PMT tests for best timing for NEDA

NGD

Digital PSA algorithm for various 5" PMTs

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

Contents lists available at ScienceDirect

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
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[i] Faculty of Physics, Warsaw University of Technology, ul. Koszykowa 75, 00-662 Warszawa, Poland
[j] Heavy Ion Laboratory, University of Warsaw, ul. Pasteura 5A, 02-093 Warszawa, Poland
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[l] Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany
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[n] Department of Physics, University of York, Heslington, York YO10 5DD, UK

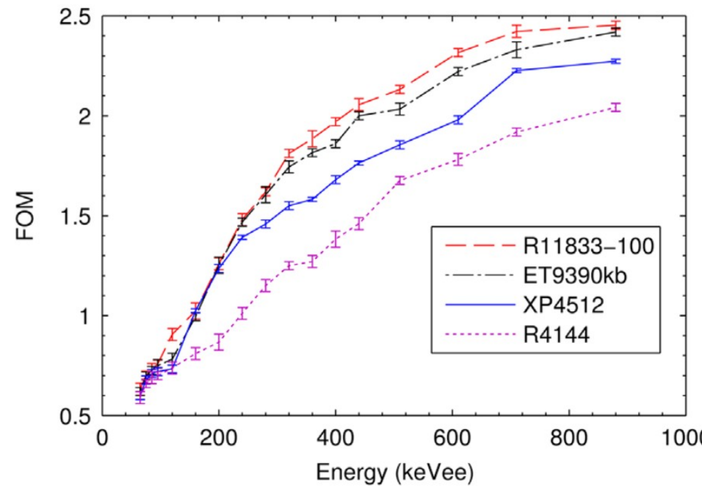
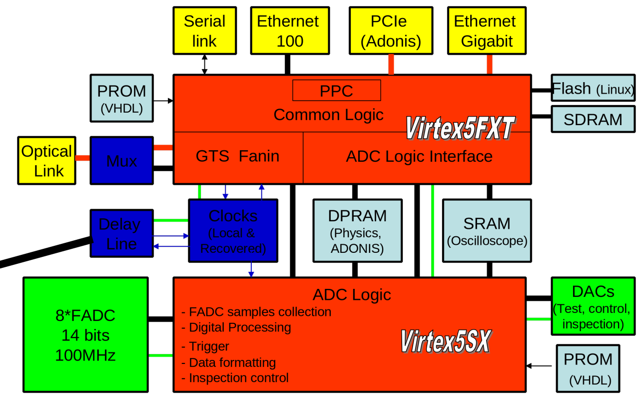


Fig. 10. FOM values of the IRT method for PMT ET9390kb, R11833-100, XP4512, and R4144 as a function of energy window (the widths of the windows are 10, 40, and 100 keVee in energy regions of 50–100, 100–500, and 500–1000 keVee, respectively).

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



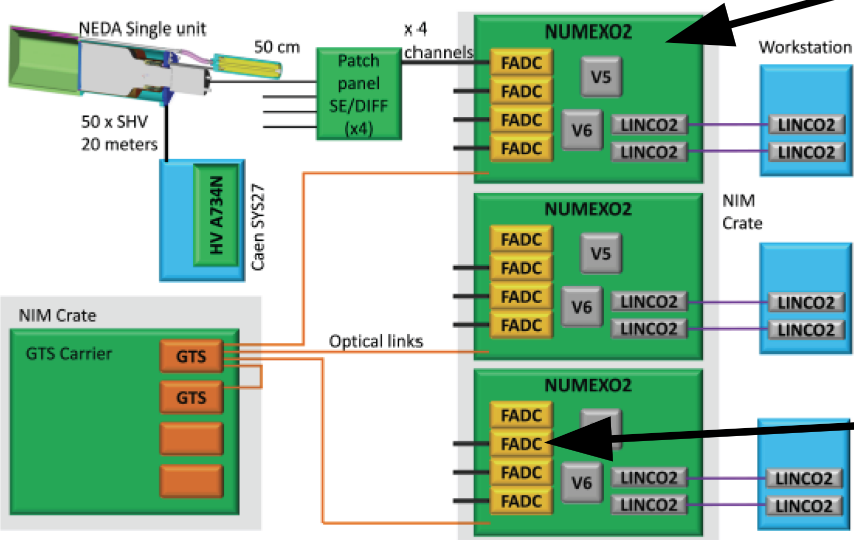
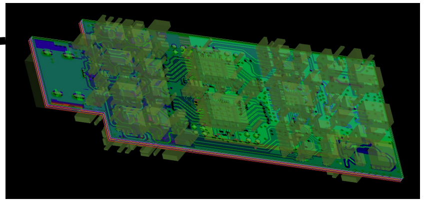
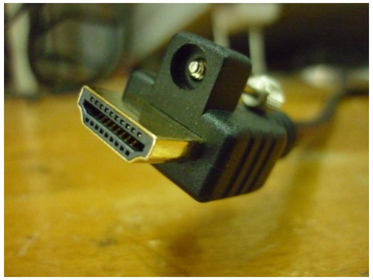


Figure 20: Global electronics layout for 48 NEDA detectors





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]

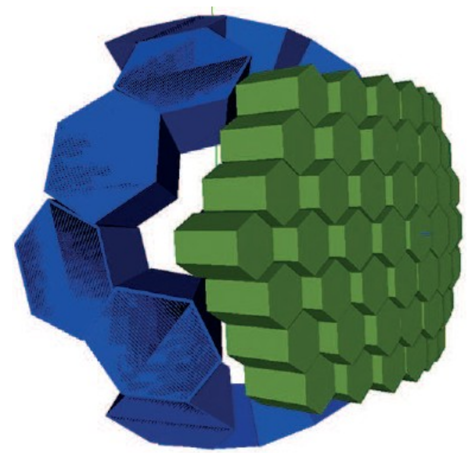


Table 4. One-, two- and three-neutron efficiencies obtained from simulations of a fusion-evaporation reaction $^{58}Ni + ^{56}Fe$ at 220 MeV for the different detector configurations. Errors quoted are statistical.

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)

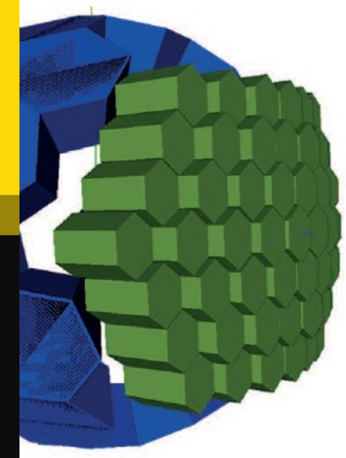
NEDA @ GANIL

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 earl
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

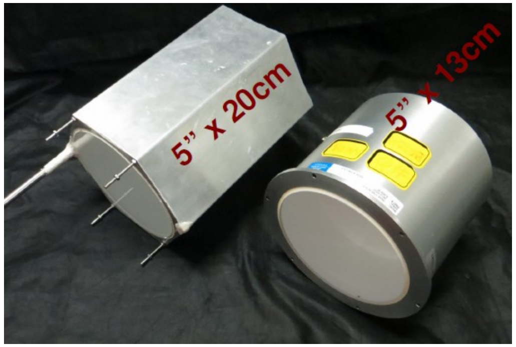


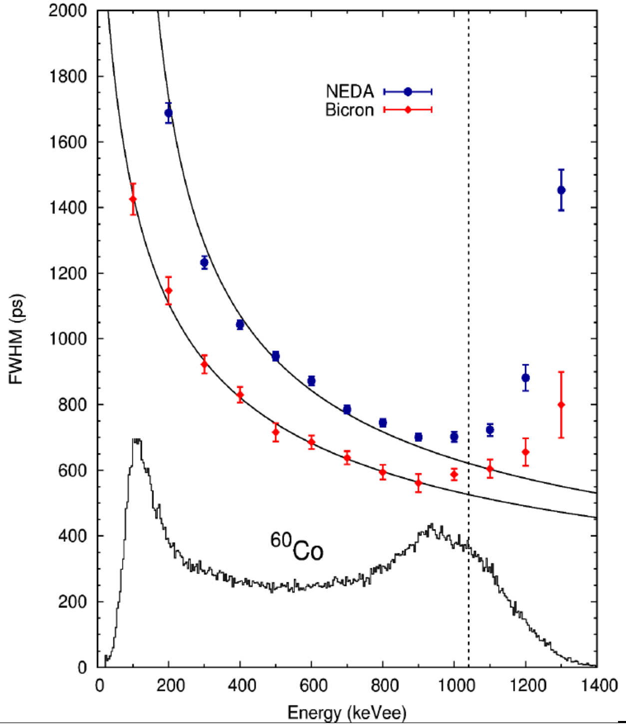
ree-neutron efficiencies obtained
vaporation reaction ^{58}Ni + ^{56}Fe
detector configurations. Errors

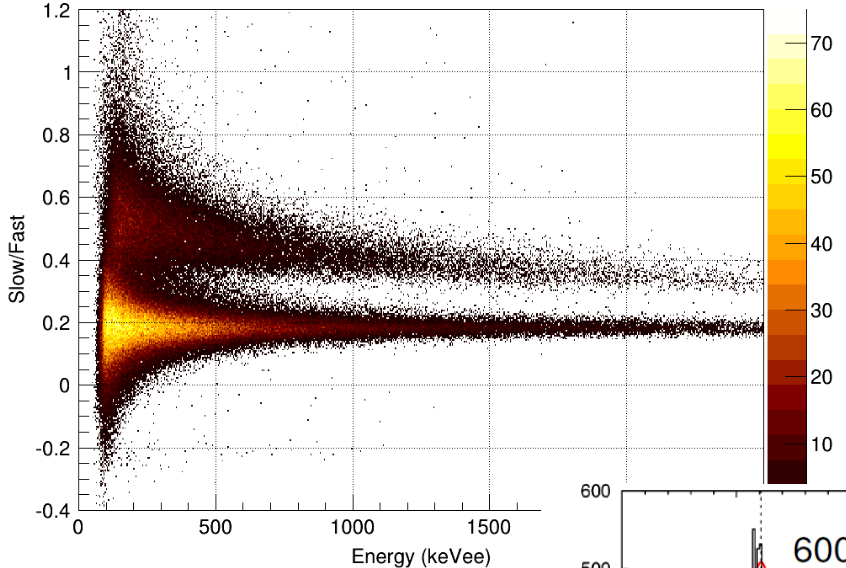
[%]	ε'_{2n} [%]	ε'_{3n} [%]
00 (5)	3.93 (10)	0.55 (14)
70 (5)	6.37 (11)	1.66 (12)
30 (5)	7.62 (11)	1.89 (11)

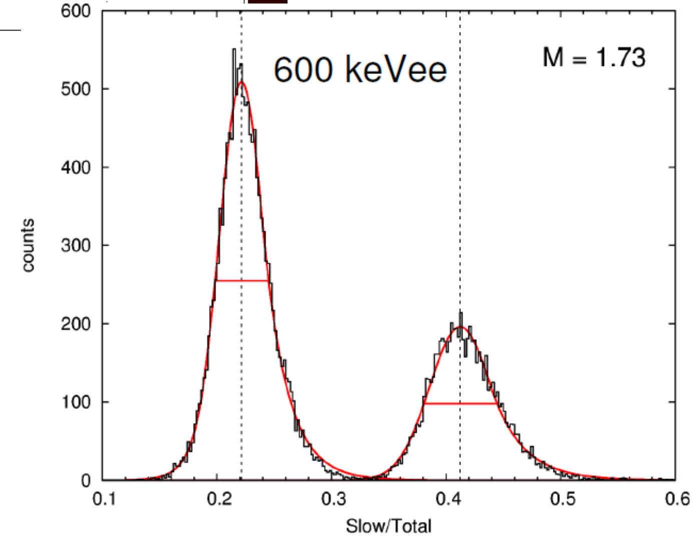
Prototype

NEDA









Construction

Self production among collaboration, using:

→ 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

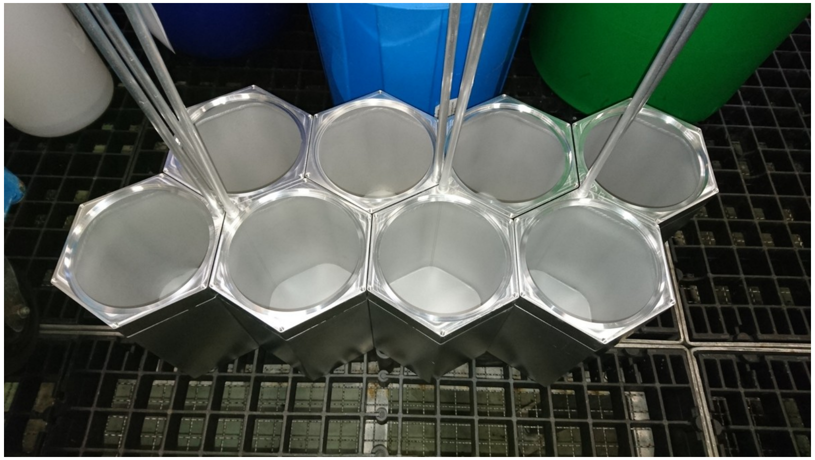
→ mu-metal shielding (1 mm)

→ NUMEXO2

→ Single ended to differential converter (progress)

→ Array structure (under design)

→ cables (some have, some testing)



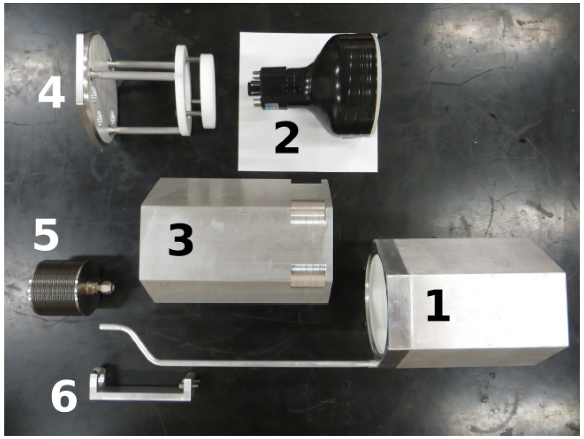
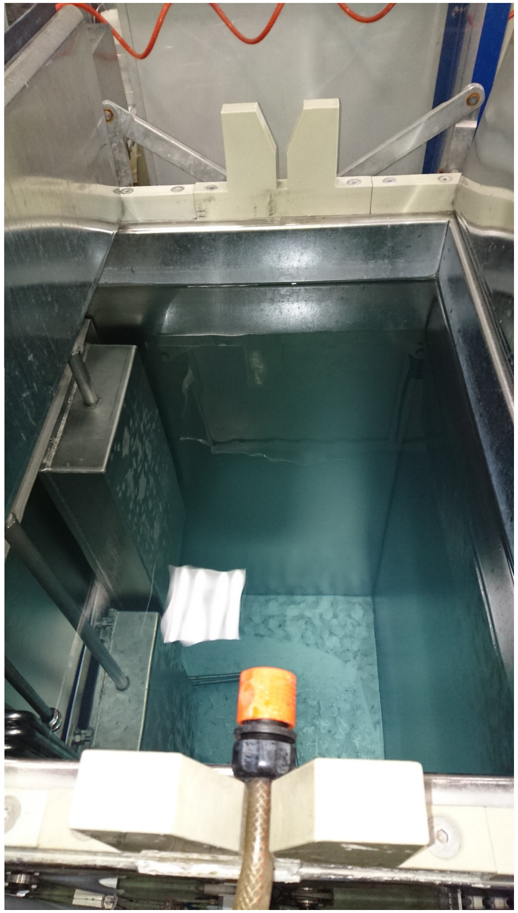
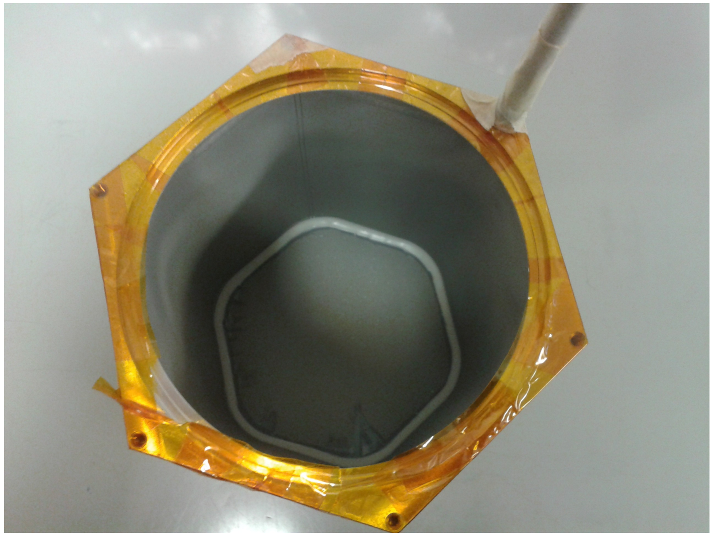


Fig. 1. Elements used for the construction of the NEDA detector: detector cell, with extension pipe (1); PMT (2); PMT housing (3); PMT pusher (4); the bellow (5) and the support for the bellow (6).

Etching & Gluing corners

Painting & glass sealing

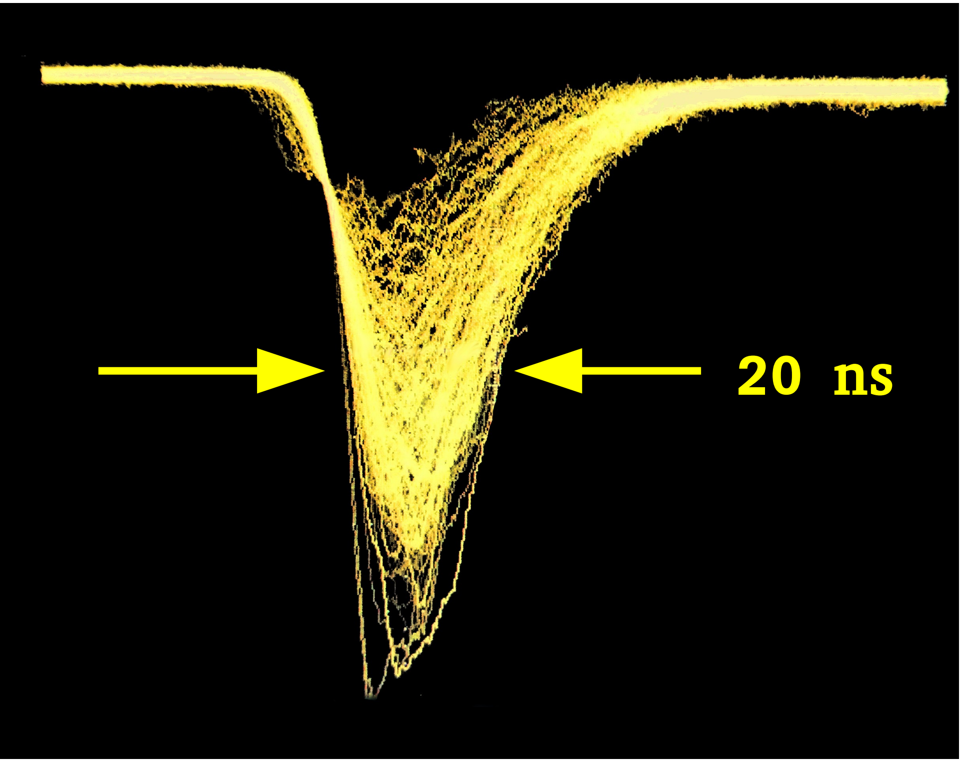
Mounting bellow, checking leakage

Filling and bubbling

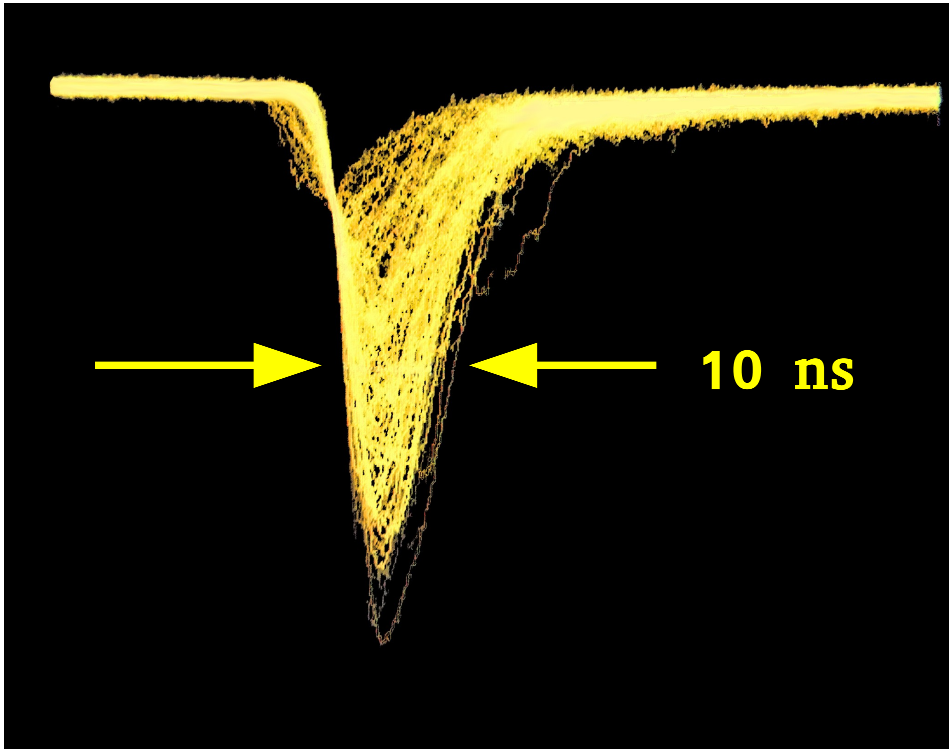
Mounting and testing

Construction

NEDA

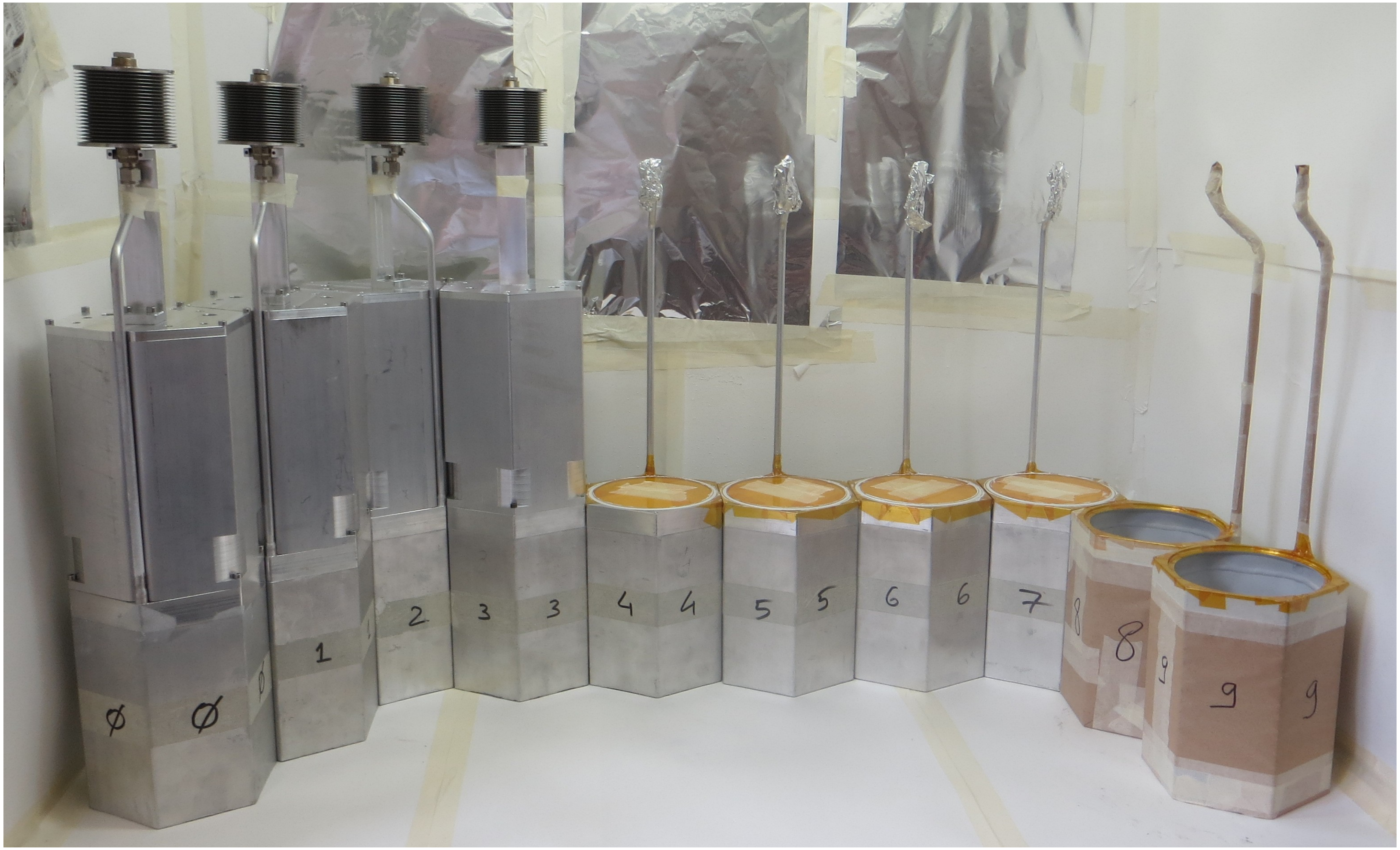


NWall



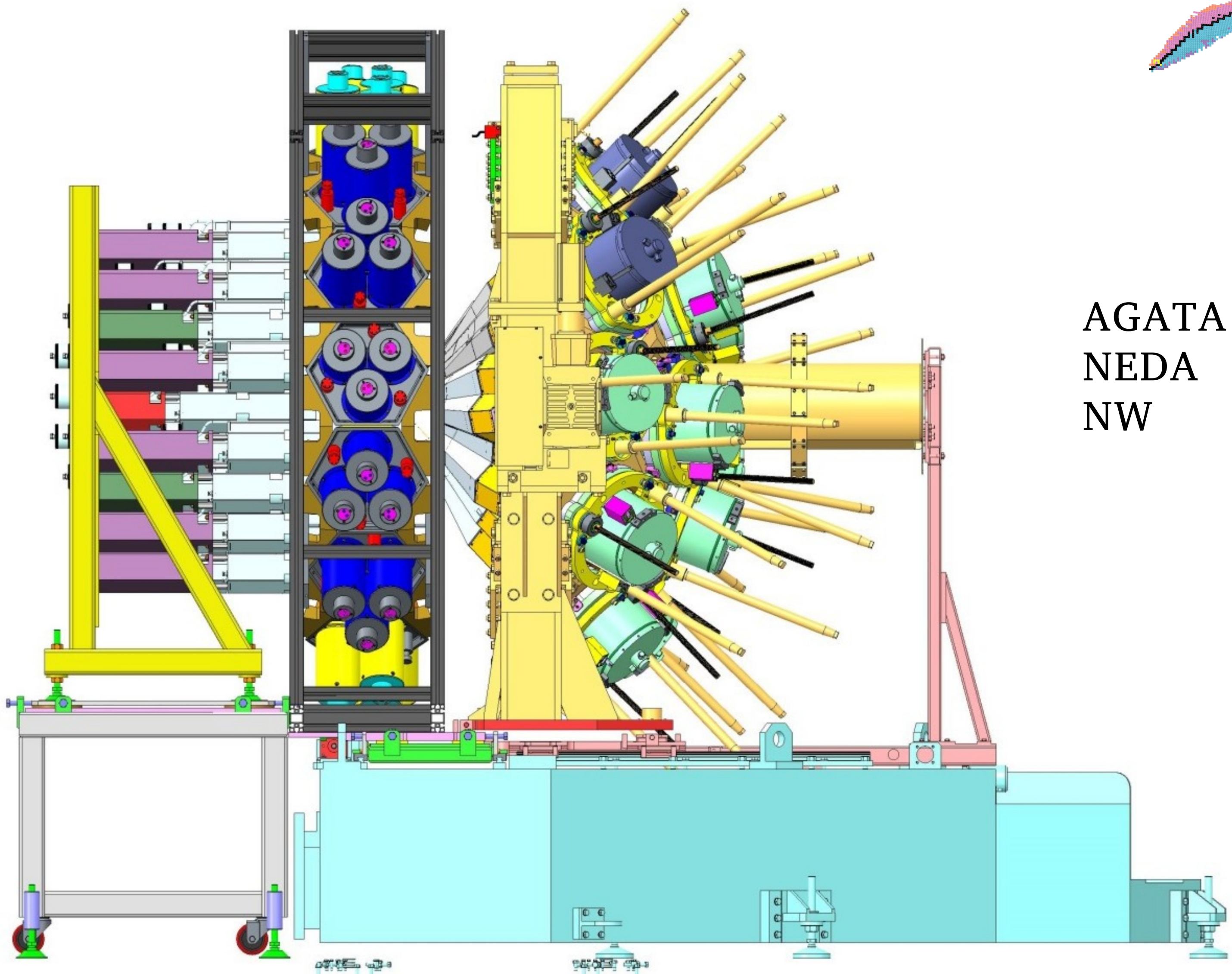
Quality starts from the initial signal.

Construction



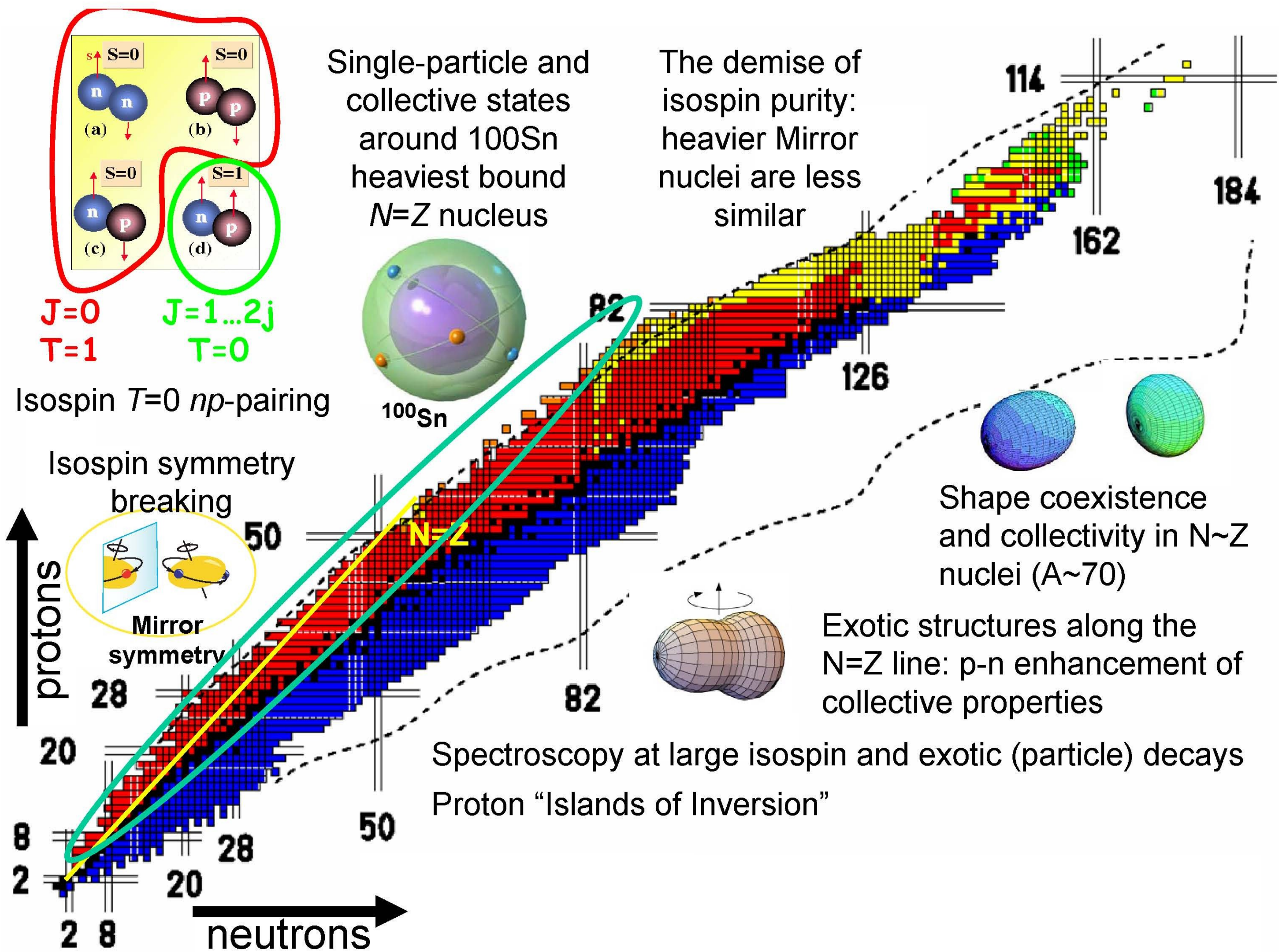
Construction

GANIL 2018: AGATA + NEDA

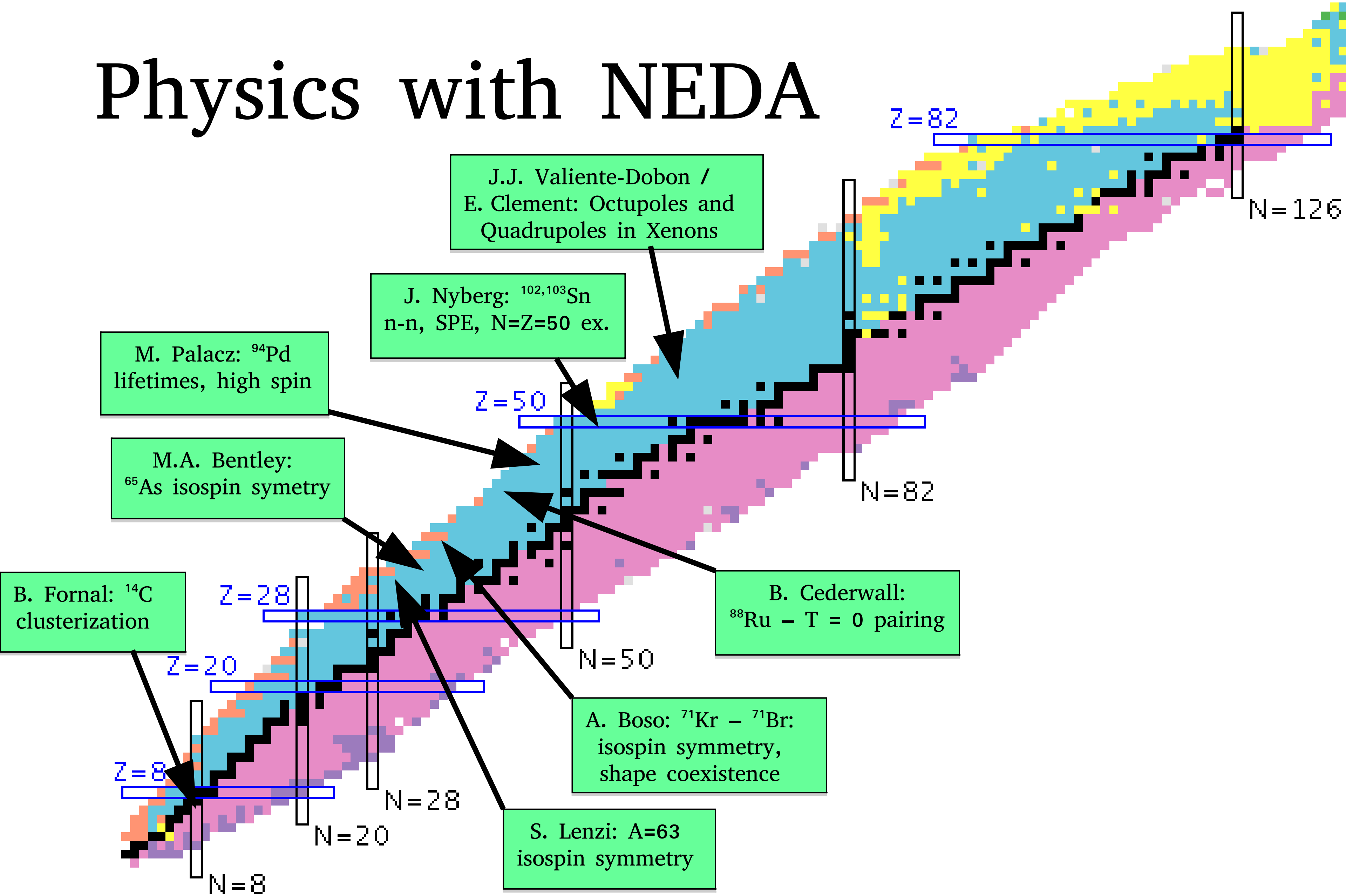


AGATA @ 145 mm
NEDA @ 510 mm
NW @ 650 mm

Physics with NEDA



Physics with NEDA



GANIL 2018: AGATA + NEDA

M. Bentley: In beam gamma-proton coincidence spectroscopy in ^{65}As – isospin symmetry at the limits of proton binding.

A. Boso: Isospin symmetry breaking and shape coexistence in mirror nuclei ^{71}Kr – ^{71}Br.

B. Cederwall: Search for isoscalar pairing in ^{88}Ru.

B. Fornal, S. Leoni & M. Ciemała: Gamma decay from near-threshold states in ^{14}C: a probe of clusterization phenomena in open quantum systems.

S. Lenzi: Effects of Isospin Symmetry Breaking in the A=63 mirror nuclei.

J. Nyberg: Studies of excited states in ^{102,103}Sn to deduce two-body neutron interactions, single-particle energies and N = Z = 50 core excitations.

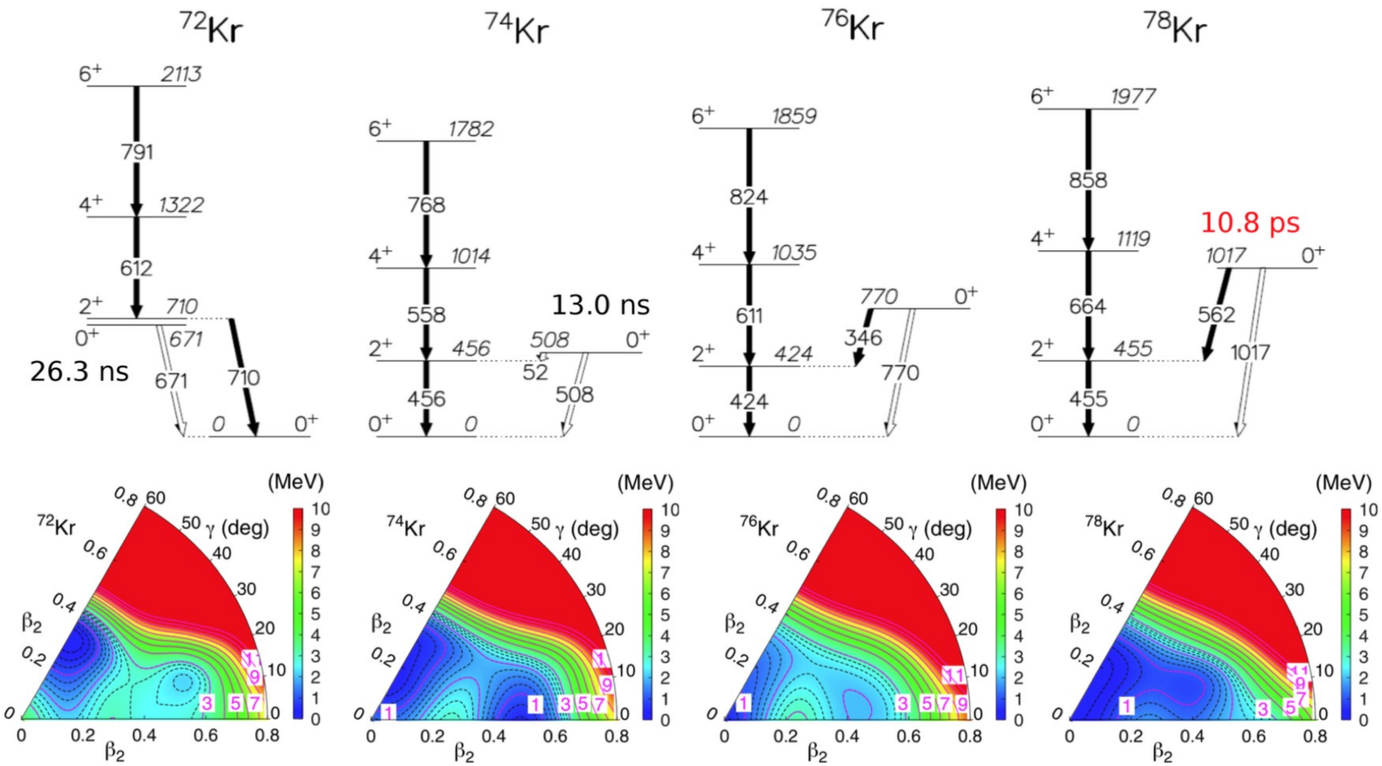
M. Palacz: Purity of the $g^{n}_{9/2}$ configuration based on lifetime measurements and energies of excited states in ^{94}Pd.

J.J. Valiente Dobon & E. Clément: Shell evolution of neutron-deficient Xe isotopes: Octupole and Quadrupole Correlations above ^{100}Sn.

RIB: n tagging in transfer reactions

Lifetime measurements

Reachable via
(d,n)
(^{3}He,n)
(^{4}He,n)



E.Clement et al. Int.J.Mod.Phys. E20, 415 (2011)
T.R. Rodríguez Phys.Rev. C 90, 034306 (2014)

Summary

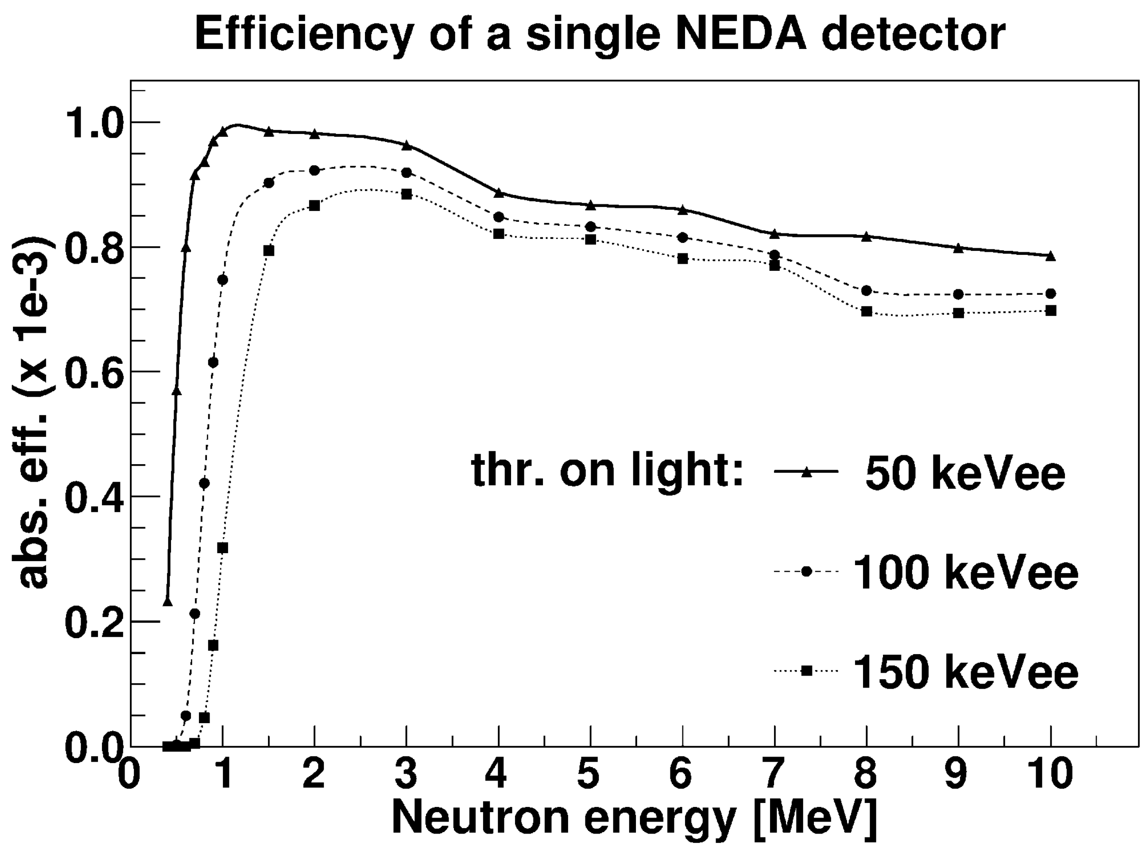
- Versatile neutron detector to be coupled to γ-ray arrays and charged particle detectors.
- High performance neutron multiplicity filter based on the liquid scintillator EJ301 with good neutron-gamma discrimination capabilities.
- The first campaign of physics will be NEDA coupled to AGATA@ GANIL with stable beams in 2018:
  - Fusion evaporation reactions along N=Z.
- 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, E. Clement, X. Egea, N. Erduran, S. Ertürk, G. de France, A. Gadea, V. Gonzalez, T. Hüyük, M. Jastrząb, V. Modamio, M. Moszyński, A. Di Nitto, J. Nyberg, M. Palacz, E. Sanchis, P.-A. Söderström, A. Triossi, J.J. Valiente Dobon, R. Wadsworth and G. J.

It's good for you!

Backup slides follow



Efficiency of a single NEDA detector
abs. eff. (x 1e-3)
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
Neutron energy [MeV]
thr. on light:
50 keVee
100 keVee
150 keVee

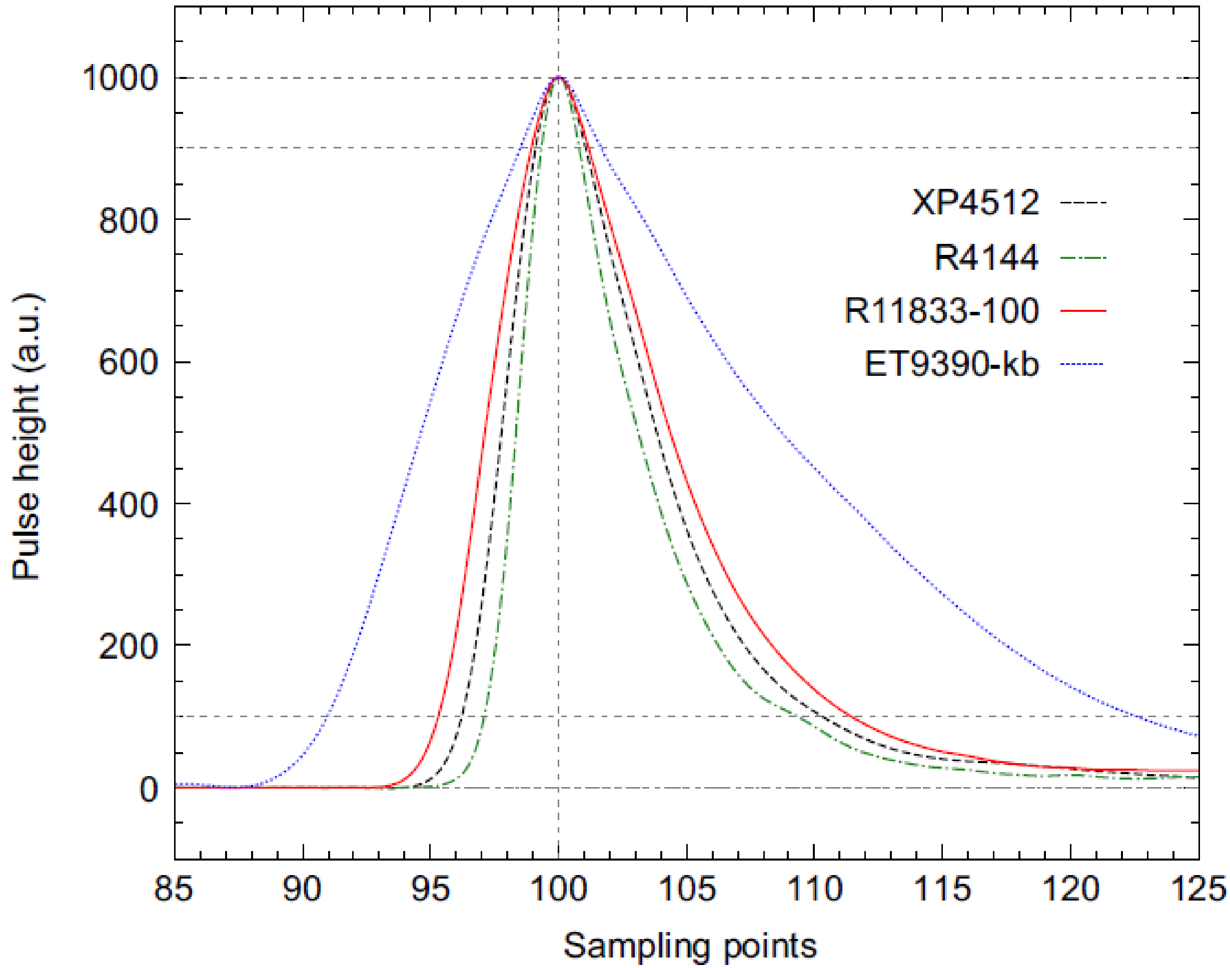


Fig. 2. Digitized waveforms averaged over 10^5 events for the four 5 in. PMTs coupled to a cylindrical 5 in. by 5 in. BC501A. The sampling frequency of the digitizer was 500 MS/s. The waveforms were normalized to a pulse height of 1000 and time aligned at the maximum of the signal. Dashed lines are drawn at 10%, 90%, at the maximum and at the baseline of the waveform to guide the eye.

Aim of NEDA

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

The array should have:

→ Increased neutron detection efficiency compared to Neutron Wall: $\varepsilon(1n) \approx 40\%$ (20-25%), $\varepsilon(2n) \approx 6\%$ (1-3%), $\varepsilon(3n) \approx 1\%$ (0.1 %)

→ Excellent neutron-gamma discrimination.

→ Superiour 1n/2n/3n discrimination.

→ Capability to run at much higher count rates than current arrays.

→ Cope with large neutron multiplicities in reactions with neutron-rich RIBs.

→ Improved neutron energy resolution for reaction studies.

Is it worth the effort ?

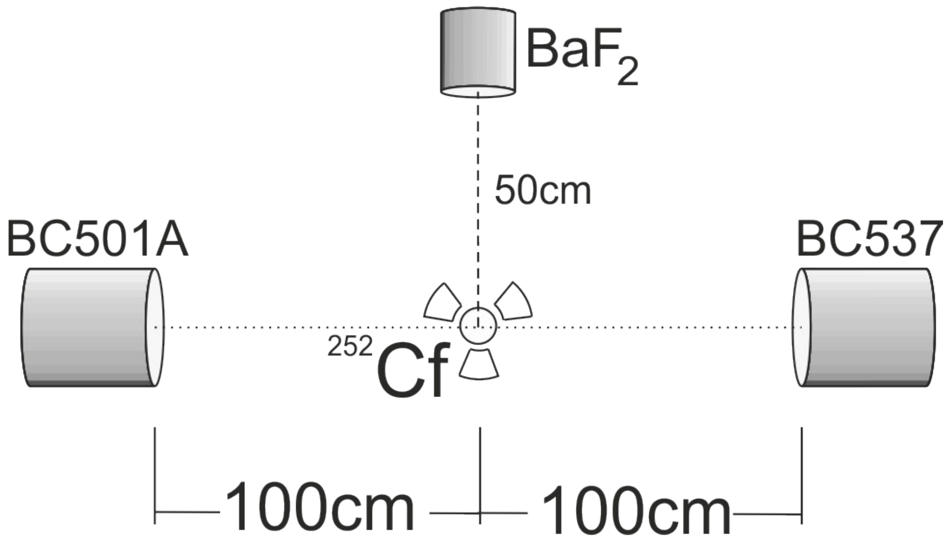
$\varepsilon(1n) \approx 40\%$ (20-25%), $\varepsilon(2n) \approx 6\%$ (1-3%).
$\varepsilon(3n) \approx 1\%$ (0.1 %)

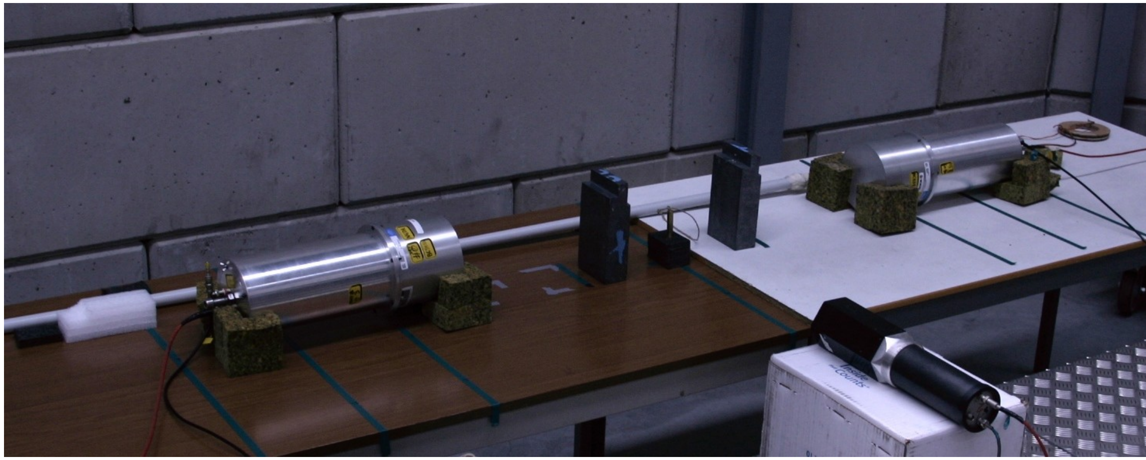
- The primary application of NEDA is to act as neutron multiplicity filter in γ-ray fusion-evaporation studies of very neutron deficient nuclei, close to N=Z
  - probe of T=0 correlations (like ^{92}Pd)
  - ^{100}Sn region: SPE, nucleon-nucleon interactions and core excitations
  - Coulomb Energy Differences in isobaric multiplets, T=0 vs. T=1 states
  - Low-lying collective modes (proton pygmy dipole resonance, $^{34}Ar+^{16}O \rightarrow ^{44}Cr+\alpha 2n$, with PARIS)
- The power of the new neutron detector can be especially demonstrated in studies in which detection of 2 or more neutrons is required

Tests of NEDA prototype detectors

Legnaro

- 5x5 inch cylinders
- BC501A and BC537 – 2 of each type
- Photonis XP4512
- Struck SIS3350 (500 MHz, 12 bit)
- VME-based DAQ system by J. Agramunt-Ros
- BaF_2 for time reference



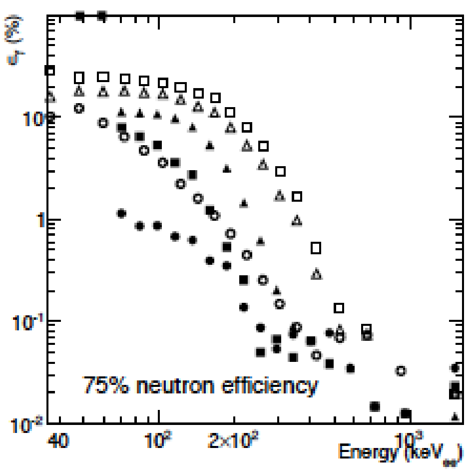


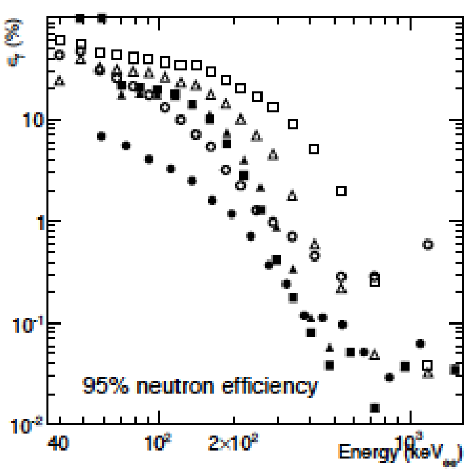
NEDA tests: digital neutron/γ discrimination

P.-A. Söderström (RIKEN, Nishina, Japan; Uppsala University, Uppsala, Sweden)

Figure of merit: ϵ_γ = fraction of γ rays mis-identified as neutrons.

NIM draft





Shown in plots:

- y-axis: ϵ_γ = fraction of γ rays identified as neutrons.
- x-axis: energy deposited in the detector in units of keV$_{ee}$ (keV electron-equivalent).
- Top (bottom) figure: 75% (95%) of the neutrons remain after neutron-gamma discrimination.
- Filled (open) symbols: BC501A (BC537)
- Digital neutron-γ discrimination methods:
  - Circles: Artificial neural network
  - Triangles: Integrated rise-time
  - Squares: Charge-comparison

Conclusions:

- ANN is best in particular at small energies.
- BC501A is better than BC537.

Conclusions on deuterated vs proton-based scintillator

→ better light to energy correlation for deuterated scintillator only for small detectors – not NEDA case.

Proton-based BC501A:

→ gives more light;

→ has higher efficiency;

→ has better time resolution;

→ has better n/γ discrimination;

→ has smaller scattering probability ($p_{1n->2n}$);

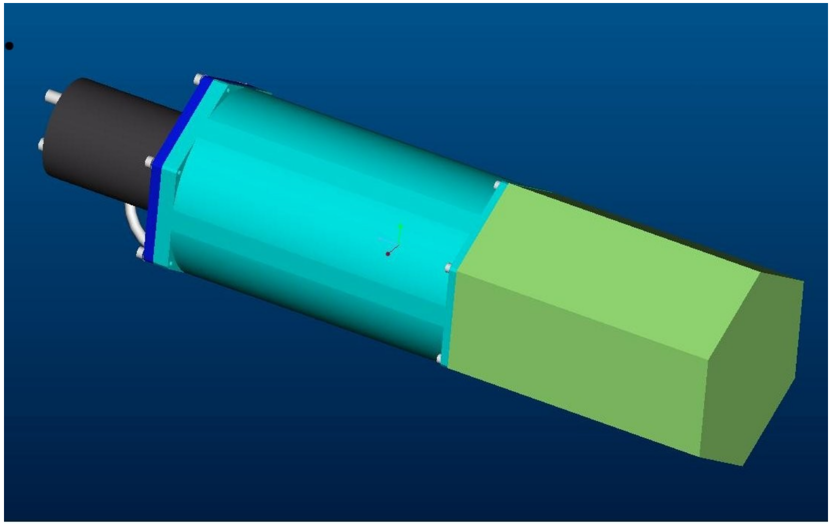
→ is much less expensive.

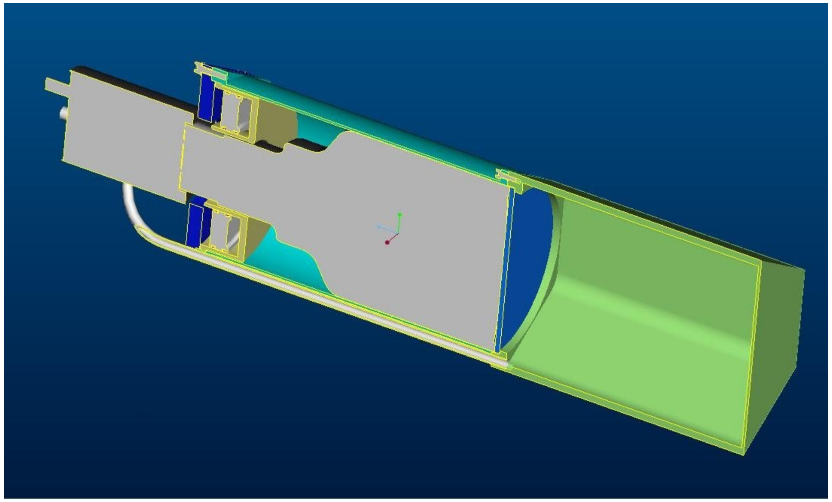
NEDA decided to use standard proton based scintillator

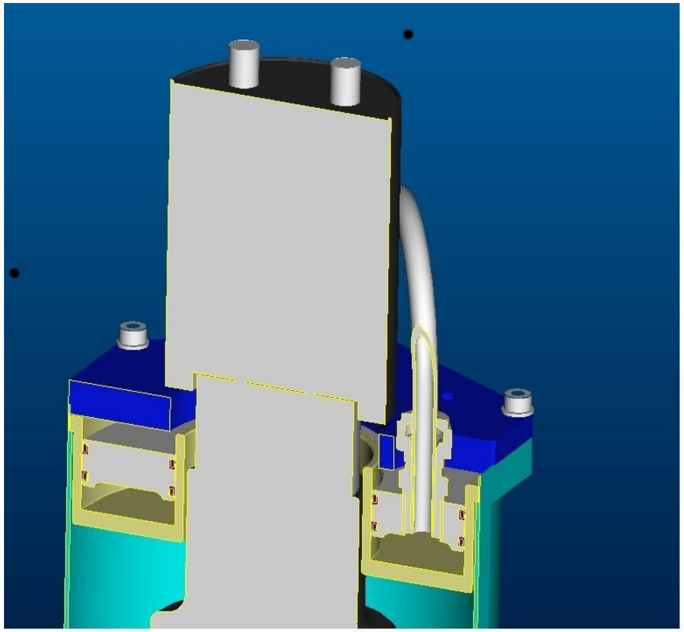
Design of a NEDA detector

ϕ = 127 mm - PMT diameter

L = 200 mm - length



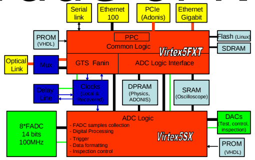


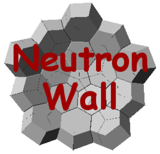


drawings by Nicola Lollo

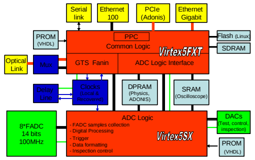
Phases of NEDA

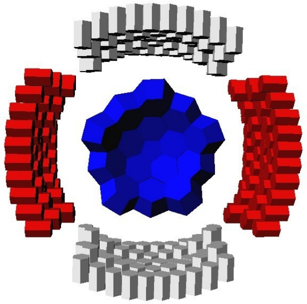
- Phase 0: Upgrade of NWall electronics (going digital)





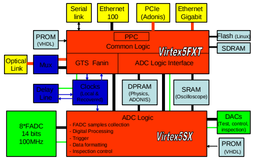
- Phase 1: Construction of 1π array, combined with NWall

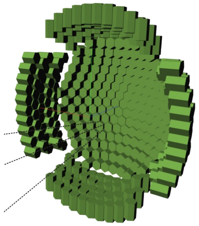




MoU (4 years) signed in March 2012

- Phase 2: Final construction of 2π array, 355 detectors





- Phase 3: R&D on new material and light readout systems for a highly segmented neutron detector array.

Phases 0 to 2 (90 detectors)

	2012				2013				2014				2015			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Electronics																
Manufacturing Tests	■	■	■	■	■	■										
Mass Production							■									
Tests								■	■							
Detectors																
Design single det.	■	■	■	■												
Production single det.					■	■	■	■								
Test detectors									■	■	■	■				
Mechanics																
Design Mechanics			■	■												
Production Mechanics					■	■	■	■								
Voltage Dividers																
Design								■	■	■						
Production											■	■				
Tests													■	■		
Photo Multipliers																
Launch purchase					■	■	■	■								
Final Asembly													■	■	■	
General Tests															■	■

Estimated cost phase 0 to 2: ~ 0.5 MEuro
full NEDA ~ 1.3 MEuro

Summary and outlook

→ NEDA will be a neutron detector array to address the physics of neutron-rich and neutron-defficient nuclei in conjuntion with γ-ray arrays like EXOGAM2, AGATA, GALILEO, PARIS.

→ Geant4 simulations:
- model validated;
- optimal size of detector units: 20 cm length, 5" diameter;
- BC501A better then BC537 for our needs;
- conceptual design: staircase geometry, 2Π, r = 1.0 m, 355 units.

→ experimental tests BC501A and BC537: proton based better: efficiency, NGD.
→ self production of the cells.
→ development of electronics in synergy with EXOGAM2 and PARIS.
→ NEDA will be built in phases: MoU signed in March 2012.

→ work on digital PSD, multiplicity identification and timing algorithms in progress.
→ mechanical design of detector units in progress.

Organization of NEDA

Spokesperson: J.J.V.D. (LNL-INFN)

GANIL Liason: M. Tripon (GANIL)

Management board:

-B. Wadsworth (U. of York)

-N. Erduram (Istanbul Sabahattin Zaim U.)

-G. De France (GANIL)

-J. Nyberg (U. of Uppsala)

-M. Palacz (U. of Warsaw)

-A. Gadea (IFIC - Valencia)

-D. Tonev (INRNE – Bulgaria)

FP7-INFRASTRUCTURES-2007-1

SPIRAL2 PREPARATORY PHASE

FIRB

FUTURO IN RICERCA (MIUR)

Parties of the collaboration

Parties

•Bulgaria: Institute for Nuclear Research and Nuclear Energy (INRNE)

•France: GANIL

•Italy: Istituto Nazionale di Fisica Nucleare (INFN)

•Poland: Consortium of Polish Governmental and Public Institutions (COPIN)

•Spain: Conselleria d'Educació, Generalitat Valenciana/Secretaría de Estado de Investigación, Desarrollo e Innovación/Ministerio de Economía y Competitividad/Centro Superior de Investigaciones Cientificas (CSIC)/ Universidad de Valencia/Istituto de Física Corpuscular (IFIC)

•Sweden: Uppsala University

•Turkey: The Scientific and Technological Research Council of Turkey (TUBITAK)/ Turkish Atomic Energy Authority (TAEK)

•United Kingdom: York University

NuPNET

NEutron DEtector developments for Nuclear Structure, Astrophysics and Applications (NEDENSAA)

NuPNET
ERA-NET for Nuclear Physics Infrastructures

9.1. Work Packages (WP) and contribution of the partners to the different WPs

WP	Title	Partner No.	Country	Name
WP1	Development of new materials	No. 1	Italy	A. Quaranta
	Responsible: L. Stuttgé	No. 2	France	L. Stuttgé
		No. 3	France	M. Hamel
WP2	Characterisation of scintillator materials for neutron detection	No. 2	France	F. Delaunay
	Responsible: H. Penttilä	No. 4	Finland	H. Penttilä
		No. 5	Spain	D. Cano-Ott
		No. 6	Germany	T.E. Cowan
		No. 8	Spain	A. Algora
WP3	Innovative detector concepts	No. 5	Spain	D. Cano-Ott
	Responsible: D. Cano-Ott	No. 8	Spain	A. Algora
WP4	Photosensors	No. 1	Italy	J.J. Valiente-Dobon
	Responsible: T.E. Cowan	No. 6	Germany	T.E. Cowan
		No. 10	Sweden	J. Nyberg
WP5	Processing Technologies	No. 1	Italy	A. Triossi
	Responsible: D. Tonev	No. 2	France	F. Delaunay
		No. 5	Spain	D. Cano-Ott
		No. 7	Bulgaria	D. Tonev
		No. 8	Spain	A. Algora
		No. 9	Turkey	N.M. Erduran
		No. 10	Sweden	J. Nyberg
WP6	Optimal design of neutron detectors and gamma-ray detectors	No. 1	Italy	J.J.Valiente-Dobon
	Responsible: A. Algora	No. 5	Spain	D. Cano-Ott
		No. 8	Spain	A. Algora
		No. 9	Turkey	N.M. Erduran
WP7	Training and Networking	No. 1	Italy	A. Quaranta
	Repsonsible: A. Quaranta	No. 2	France	L. Stuttgé
		No. 3	France	M. Hamel
		No. 4	Finland	H. Penttila
		No. 5	Spain	D. Cano-Ott
		No. 6	Germany	T.E. Cowan
		No. 7	Bulgaria	D. Tonev
		No. 8	Spain	A. Algora
		No. 9	Turkey	N.M. Erduran
		No. 10	Sweden	J. Nyberg

- Three years project
- Eight countries (Bulgaria, Finland, France, Germany, Italy, Spain, Sweden, Turkey)
- MONSTER, NEULAND, n-detector DESIR, NEDA, Neutromania, ...

Kick-off meeting 15th-17th February – Madrid.

Next meeting – Catania February 20th to 22nd 2013

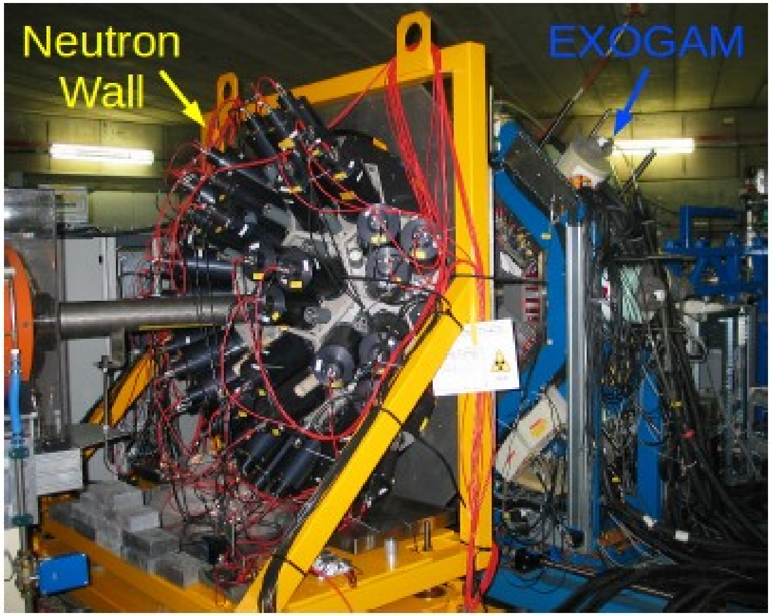
Working groups

- **Detector characteristics** (Physics interests of NEDA to define the detector specifications).
  - *Responsible: B. Wadsworth*
- **Geometry** (Make a full study of geometry to determine (materials) efficiency, reduce cross-talk, ... Comparison between different codes: Geant4, MCNP-X. Simulate effect of other ancillaries, neutron scattering.).
  - *Responsible: M. Palacz*
- **Study New Materials** (Exploring new materials, solid scintillators, deuterated liquid scintillators).
  - *Responsible: L. Stuttgé*
- **Digital Electronics** (Flash ADCs, GTS, NUMEXO electronics, ..)
  - *Responsible: A. Gadea*
- **PSA** (Pulse shapes analysis, PSA algorithms, ...).
  - *Responsible: J. Nyberg*
- **Synergies other detectors** (Detectors that can be considered in synergy with NEDA: AGATA, EXOGAM2, GALILEO, PARIS, AGATA, FAZIA, GASPARD, DIAMANT, DESCANT, FARCOS, RIPEN, Neutron spectroscopy at DESIR, MONSTER, NEUTROMANIA, ...).
  - *Responsible: P. Bednarczyk*

Neutron Wall

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).

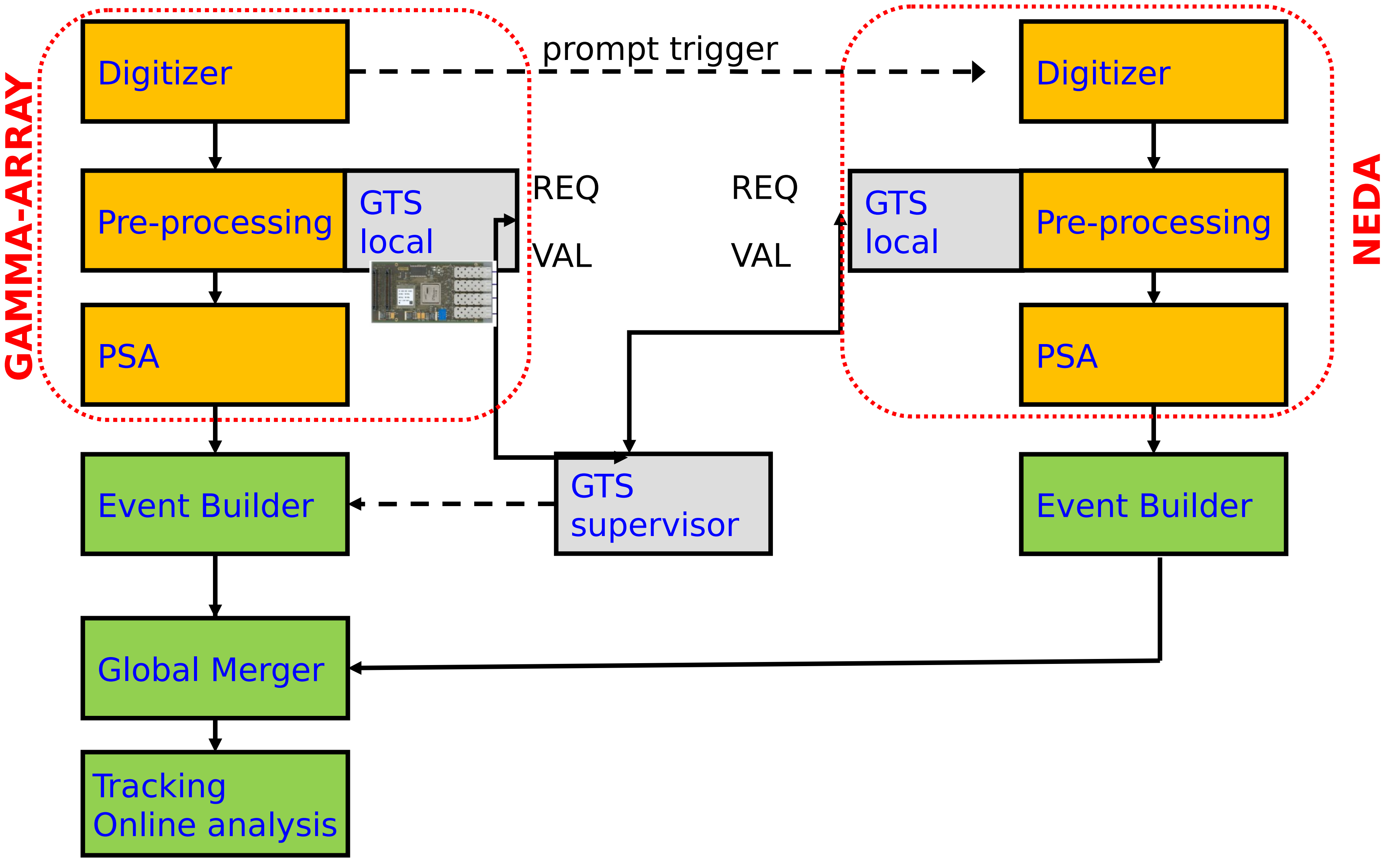
Next campaign (two experiments): GANIL 2012.

Physics with NEDA

NEDA will address the physics of neutron-rich as well as neutron-deficient nuclei, mainly in conjunction with gamma-ray detector arrays like AGATA, GALILEO, EXOGAM2 and PARIS.

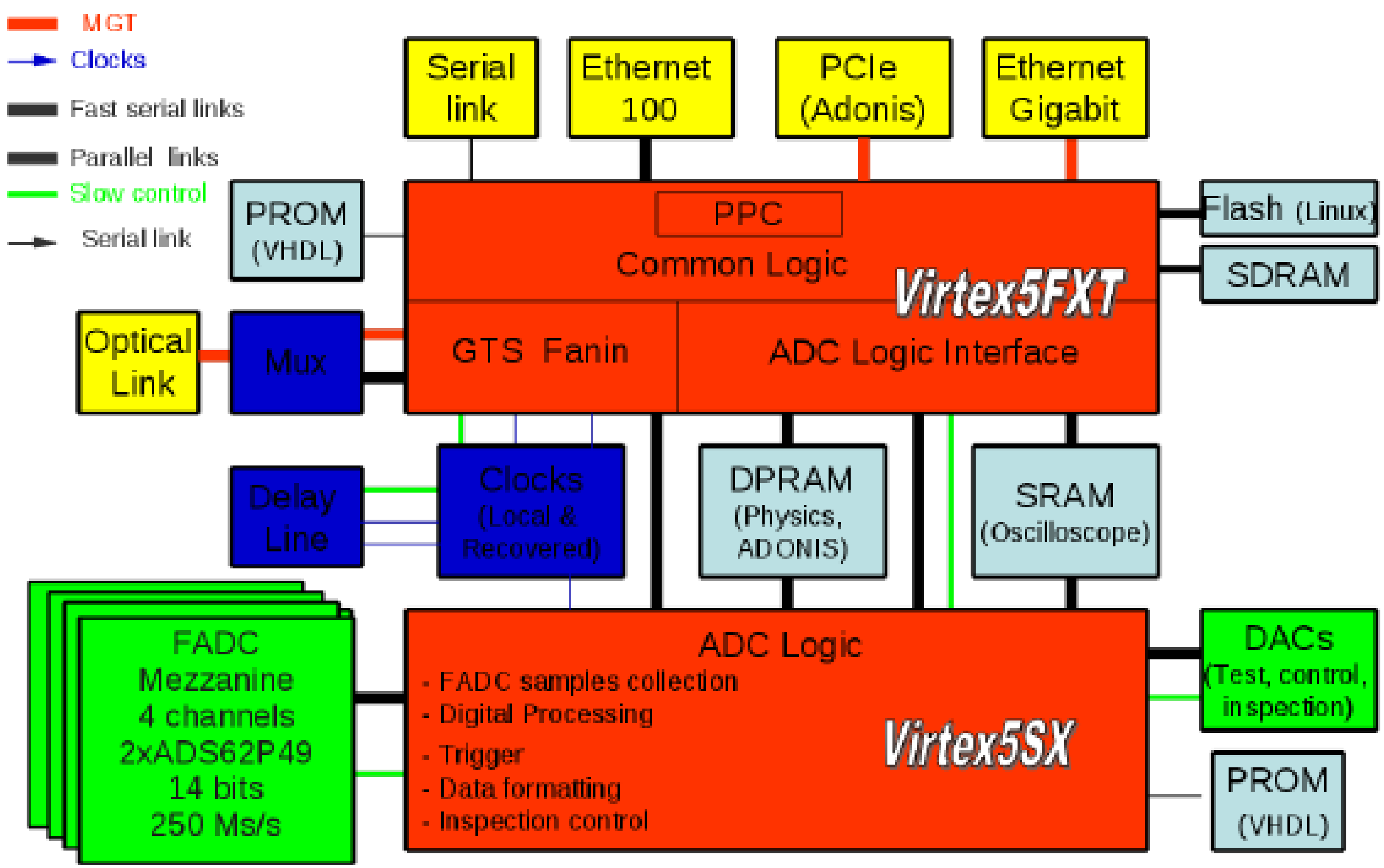
- **Nuclear Structure**
  - Probe of the T=0 correlations in N=Z nuclei: the structure beyond ^{92}Pd (Uppsala, LNL, Padova, GANIL, Stockholm, York)
  - Coulomb Energy Differences in isobaric multiplets: T=0 versus T=1 states (Warsaw, LNL, Padova, GANIL, York)
  - Coulomb Energy Differences and Nuclear Shapes (York, Padova, GANIL)
  - Low-lying collective modes in proton rich nuclei (Valencia, Krakow, Istanbul, Milano, LNL, Padova)
- **Nuclear Astrophysics**
  - Element abundances in the Inhomogeneous Big Bang Model (Weizmann, Soreq, GANIL)
  - Isospin effects on the symmetry energy and stellar collapse (Naples, Debrecen, LNL, Florence)
- **Nuclear Reactions**
  - Level densities of neutron-rich nuclei (Naples, LNL, Florence)
  - Fission dynamics of neutron-rich intermediate fissility systems (Naples, Debrecen, LNL, GANIL)

NEDA coupled to
AGATA/GALILEO/EXOGAM2/PARIS



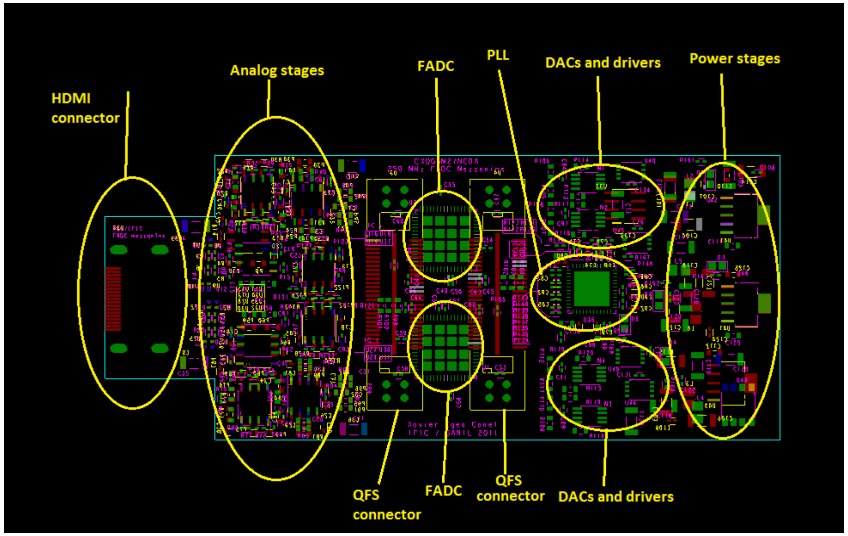
Digital electronics: EXOGAM2-NEDA-PARIS

NUMEXO2

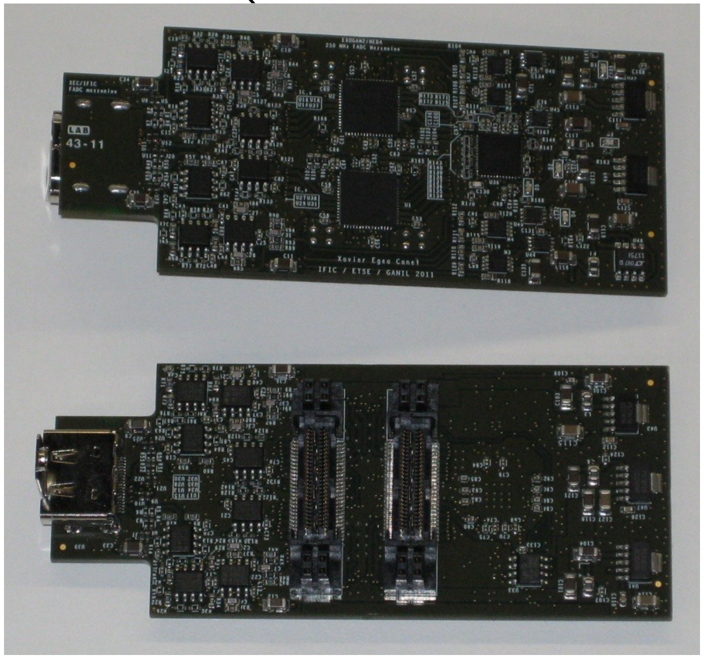


FADC Mezzanine

X. Egea and A. Gadea (IFIC,CSIC, Valencia)



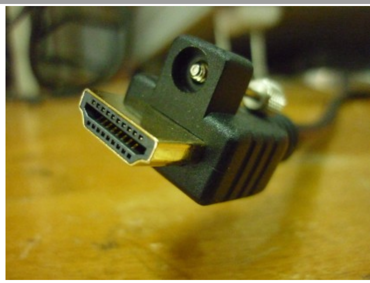
- 10 layers have been used in order to make possible this design by using high-speed layout techniques.
- The FADC follows an easy and straigthforward placement and routing. Besides, symmetry has been provided in order to make an easier design.
- The board dimensions fit on the NIM standard, where 4 of these will be inserted into the crate. (42mm wide + 98.5 mm long)
- Most of the QFS lines are linked to the



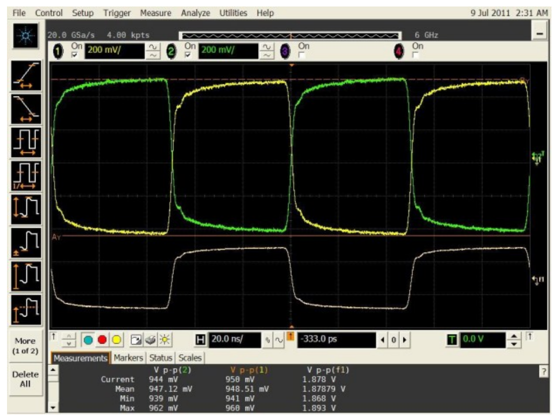
- **4-channel acquisition with a sampling rate of 250 Msps and 14-bit resoltion.**
- Use of a PLL for jitter cleaning and clock synchronization
- 6 W power consumption at 250 MHz.
- Possibility to use a variable offset by using a 16-bit digital-to-analog converter.
- Includes 2 QFS-026-04,75-LD-PC4 connectors, and thorugh them, differential signals, control lines and power lines are transmitted by using the same connector.
- Includes an HDMI PCB receptacle, which will link the front-end electronics with the FADC mezzanine.

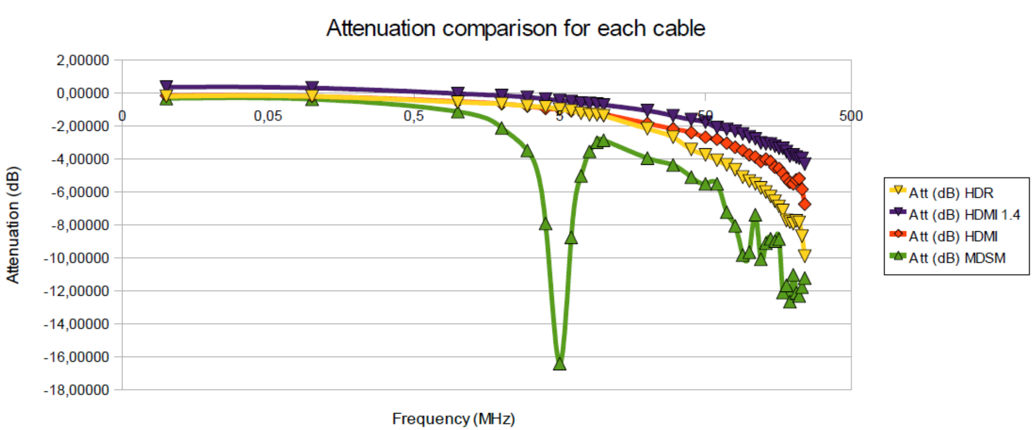
HDMI NEDA Cable results

X. Egea (IFIC,CSIC, Valencia) & M. Tripon (GANIL)



- Several tests have been applied to different cables in order to test their performance.
- Among them we may mention the bandwidth, crosstalk, impednace and reflections, and EMC (electromagnetic compatibility).
- On the picture on the left it is shown the **HDMI cable.**
- The HDMI 1.4 version, including a double shield, makes an important improvement against high-voltage peaks.



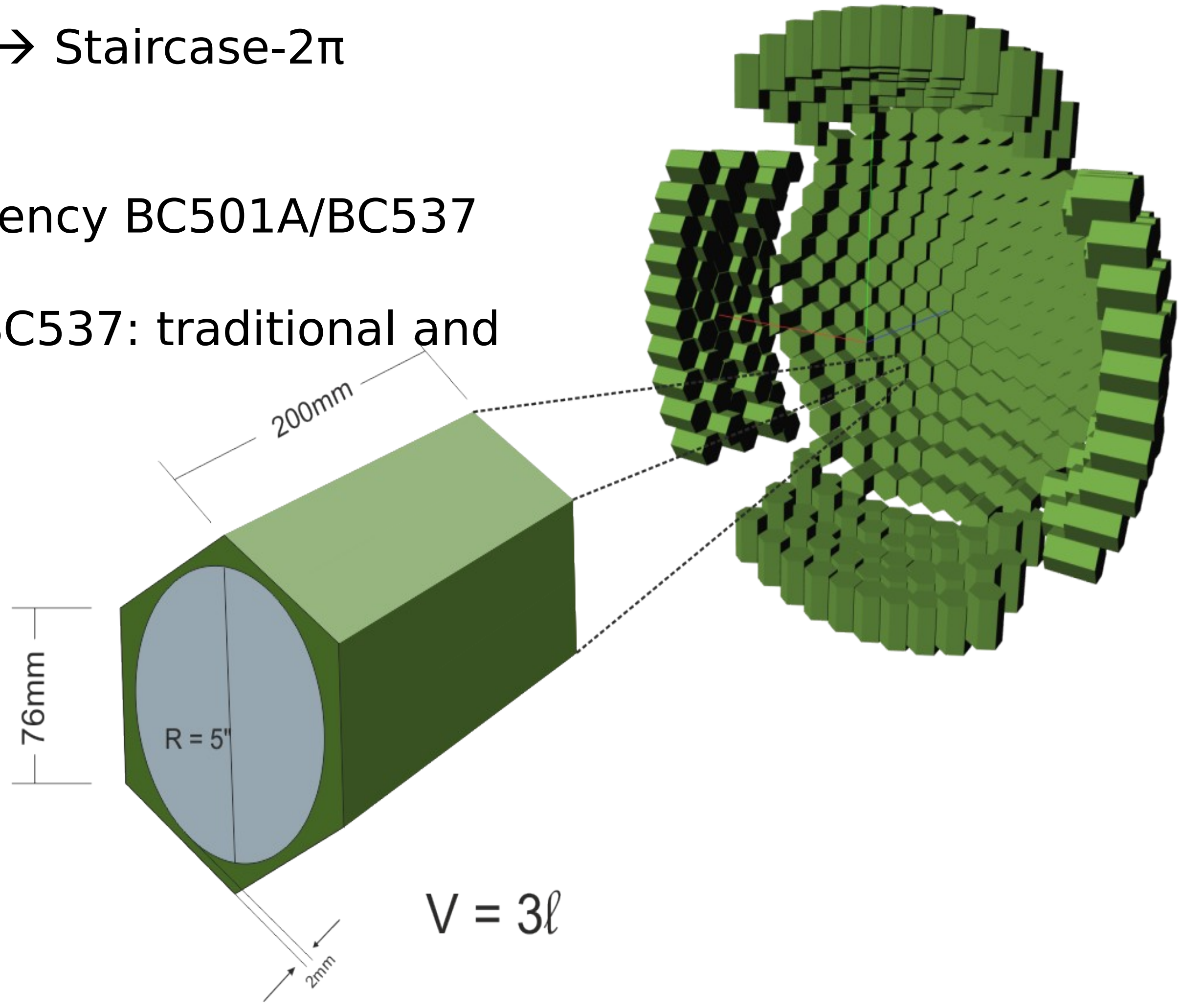


- Top → (From left to right): Crosstalk, reflections and EMC measurements. Bottom → Bandwidth
- The HDMI 1.4 has a big stiffness and it might be a little bit problematic mechanically.

Tests at LNL BC501/BC537

- One unit cell → Staircase-2π geometries.

- Relative efficiency BC501A/BC537
- Timing
- PSA BC501A/BC537: traditional and NN

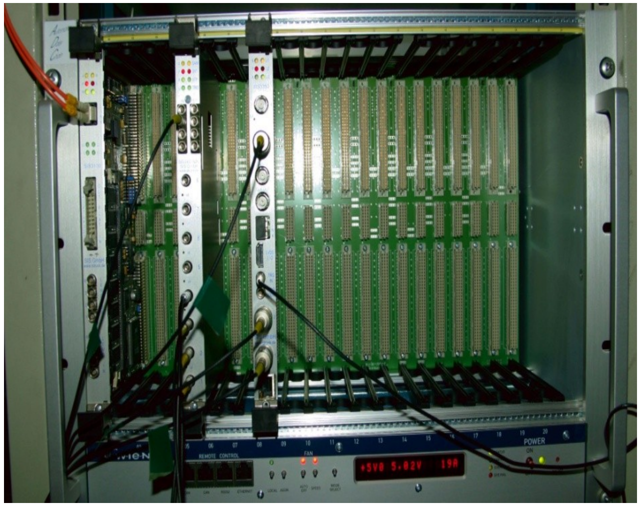


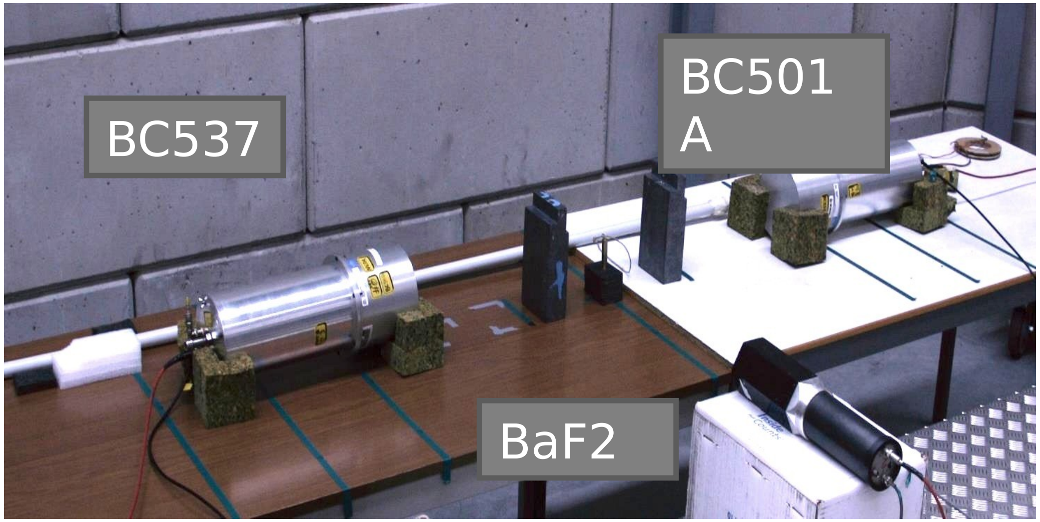
NEDA test setup

The tests are being performed at LNL with the following instrumentation:

- 2 x BC501A (5” x 5” cylindrical prototype detector)
- 2 x BC537 (5” x 5” cylindrical prototype detector)
- SIS3302 100 MS/s, 16 bits 8 ch. digitizer (analog setup)
- SIS3350 500 MS/s, 12 bits 4 ch. digitizer
- DAQ by IFIC, J. Agramunt

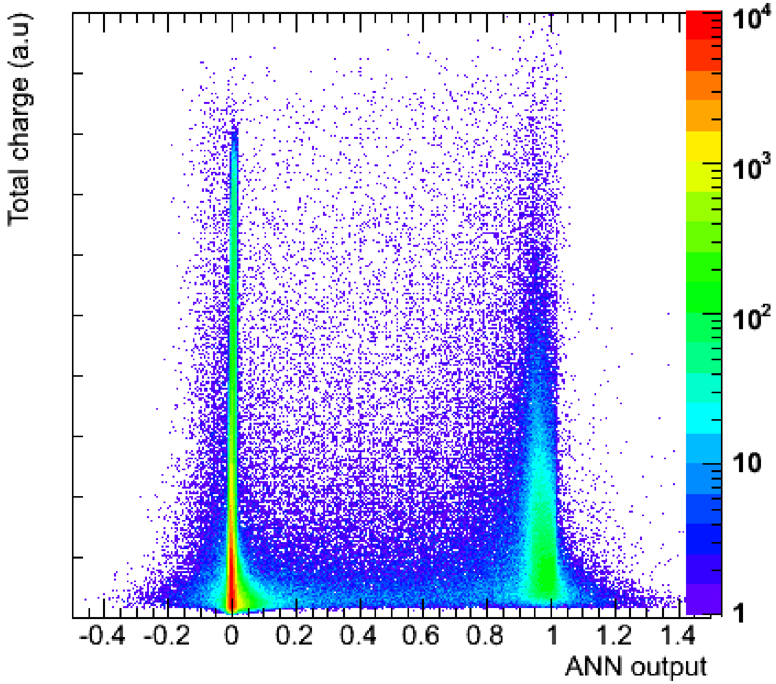
- Digital PSA
- Relative efficiency performance
- Cross-talk between the detectors

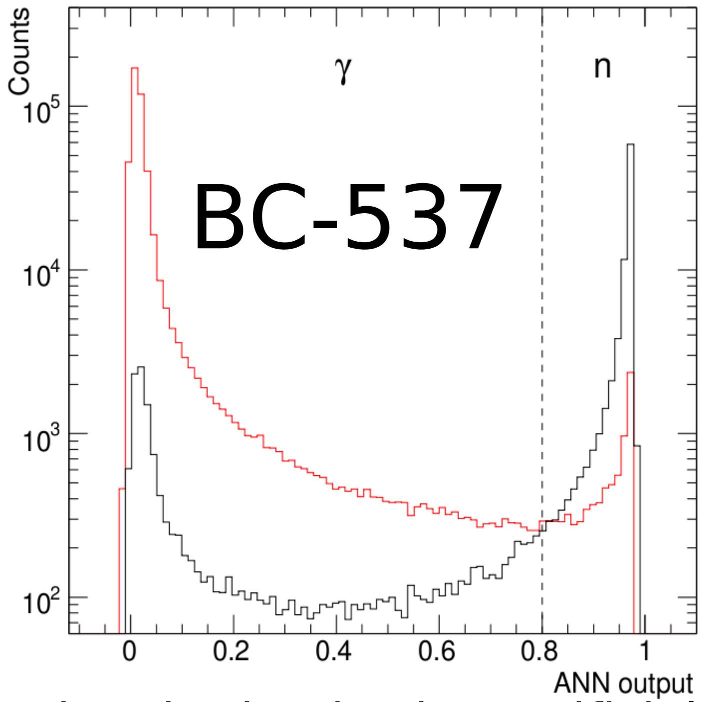




NEDA test: PSA Neural Network

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





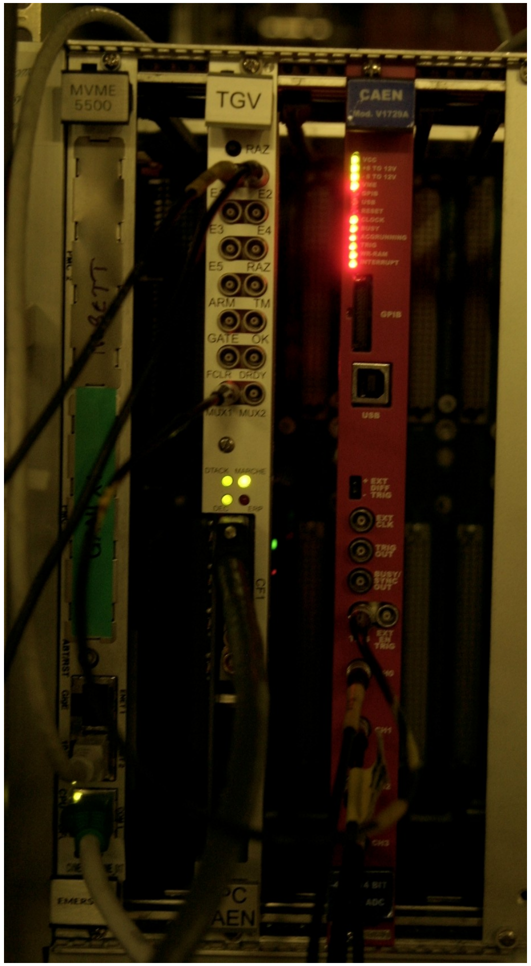
Full advantage of digital electronics can be obtained using artificial neural networks to perform pulse-shape discrimination. This method is currently being investigated both for BC537 and BC501A.

+ Optimal discrimination over a large ene
- Slower implementation limits counting ra

Monday and Thursday talk
by G. Jaworski

In beam test with the NW

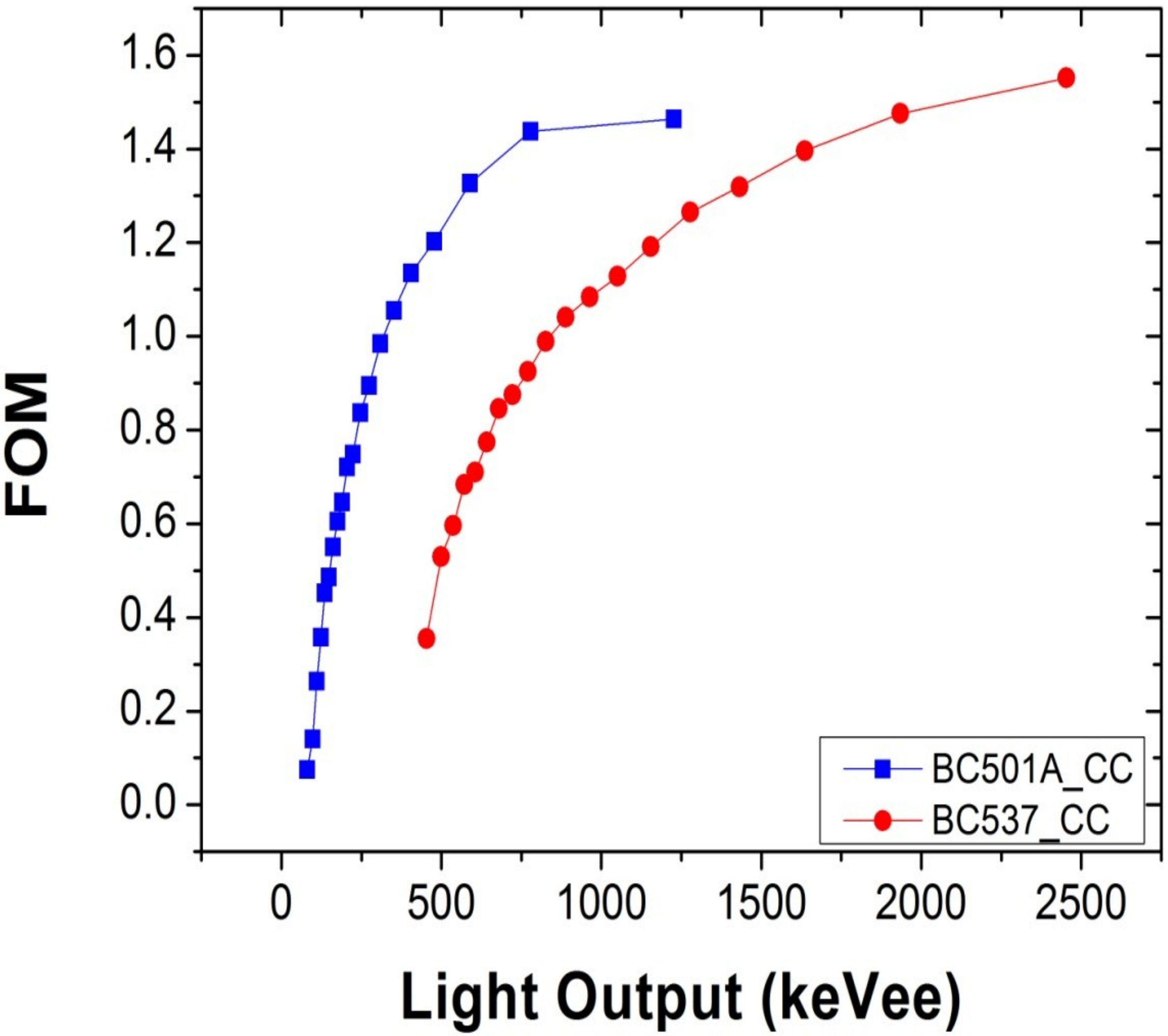
- First in-beam waveform taking (two weeks ago @GANIL)
- 124 MeV ^{40}Ca onto ^{58}Ni 6 mg/cm2 and ^{12}C 0.5 mg/cm2
- PSA algorithms
- MATACQ digitizer, 1GS/s, 14 bit



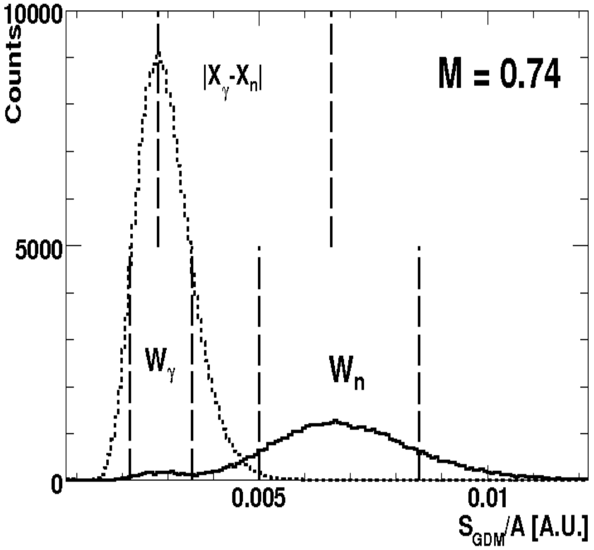
With current technological status …

- Three main options:
  - 200 detectors BC501A – PM readout –Digital electronics
    - Total cost: 600K€ (BC501A) + 200K€(Elec.) + 40K€ (mechanics) = 840 K€
  - 200 detectors BC537 – PM readout – Digital electronics
    - Total cost: 2000K€ (BC537) + 200K€(Elec.) + 40K€ (mechanics) = 2240 K€
  - Upgrade Neutron Wall - Phase 0 (Digital electronics)
    - Total cost (50 channels) = 40K€

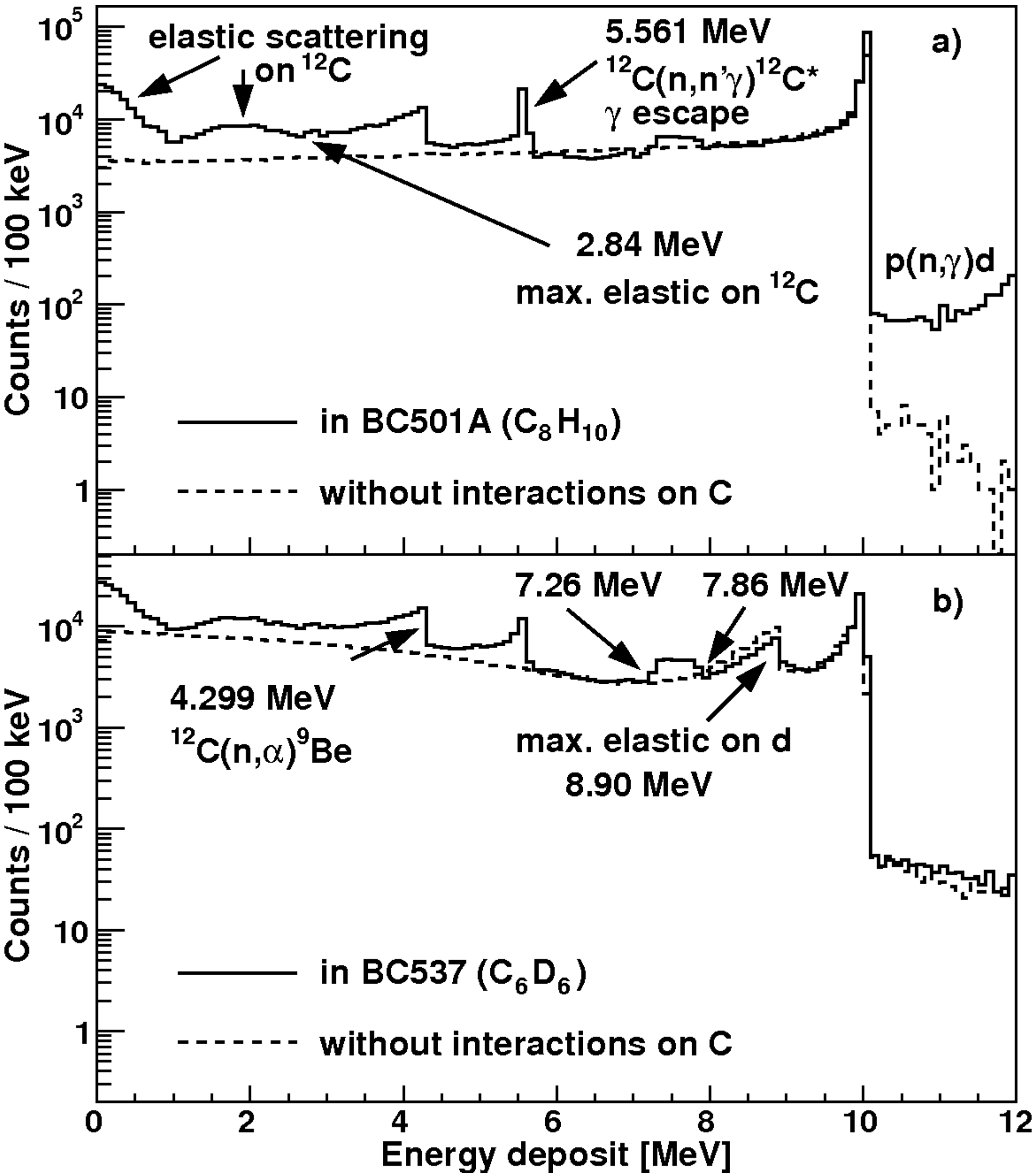
NEDA test: PSA Charge Comparison

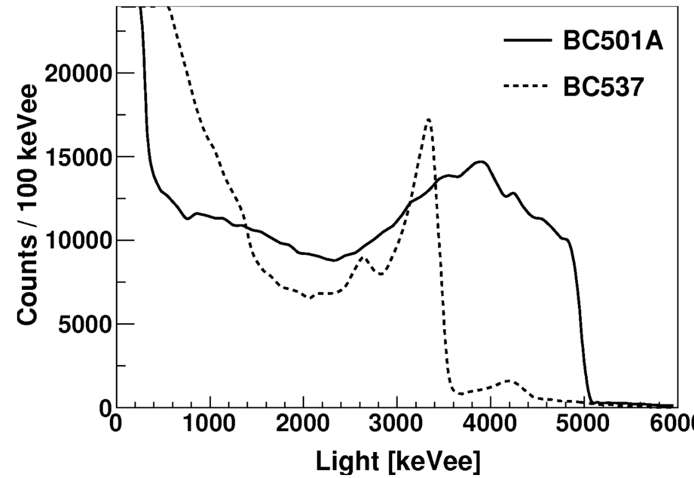


$$M = \frac{|X_\gamma - X_n|}{W_\gamma + W_n}.$$



Interactions of neutrons in the scintillator





G.Jaworski et al. NIM A673 (2012) 64

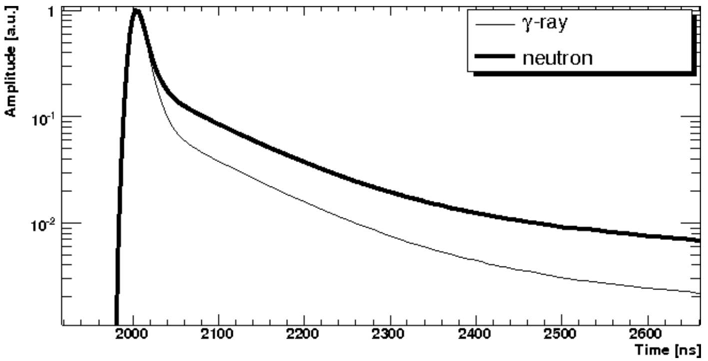
Neutron – gamma discrimination

Liquid scintillators give a difference in signal pulse shapes for neutrons and gamma rays:

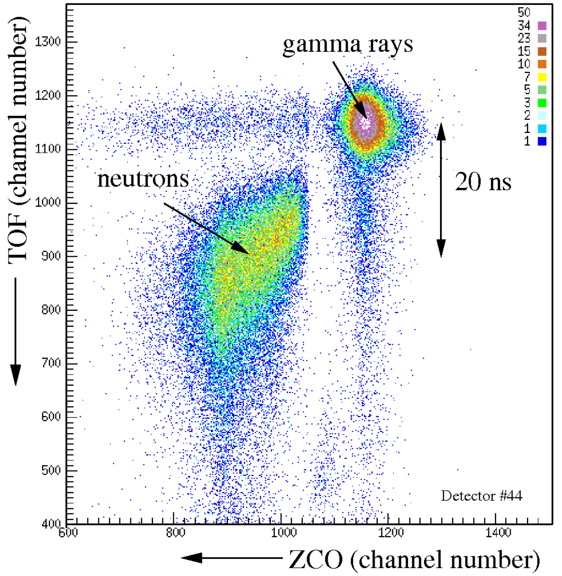
- neutrons (recoiling protons) - slow light component (τ~300 ns)
- γ rays (electrons) - fast light component (τ~3 ns)

Pulse shape combined with TOF gives w γ-ray as neutron interpretation probability ~0.1 %.

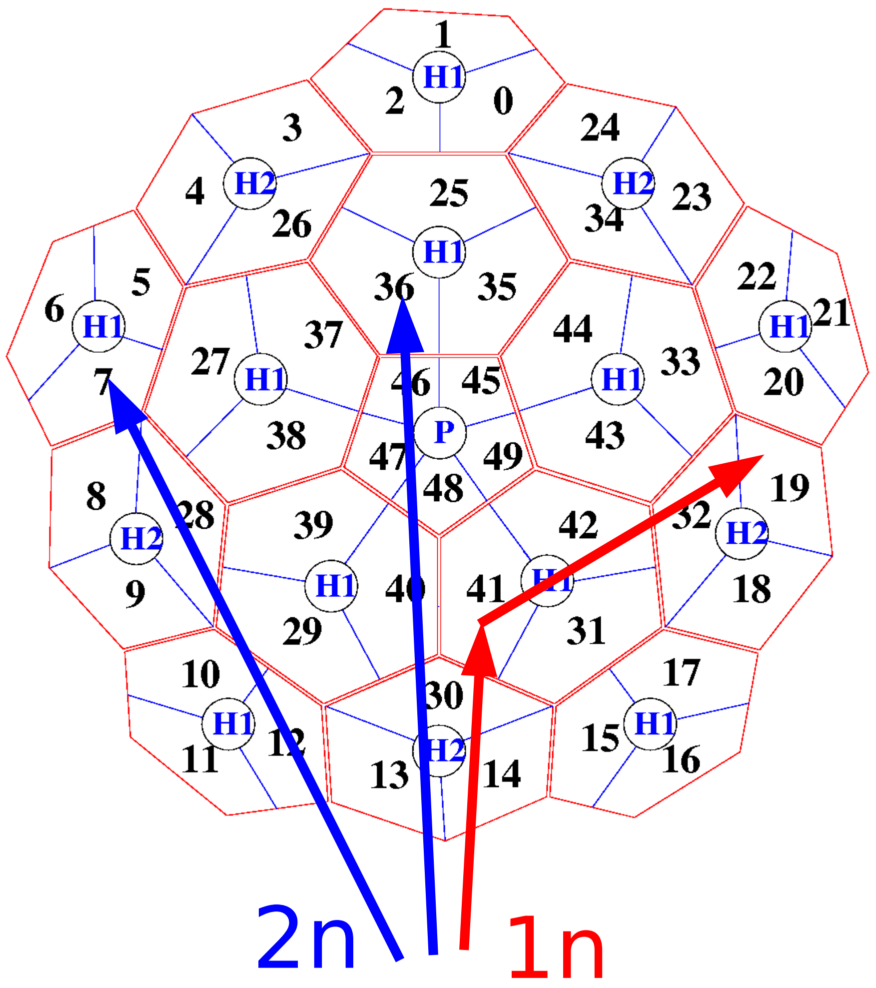
Present NWall: pulse shape discrimination analog.
NEDA will use digital techniques.



plot by P.-A. Soderstrom

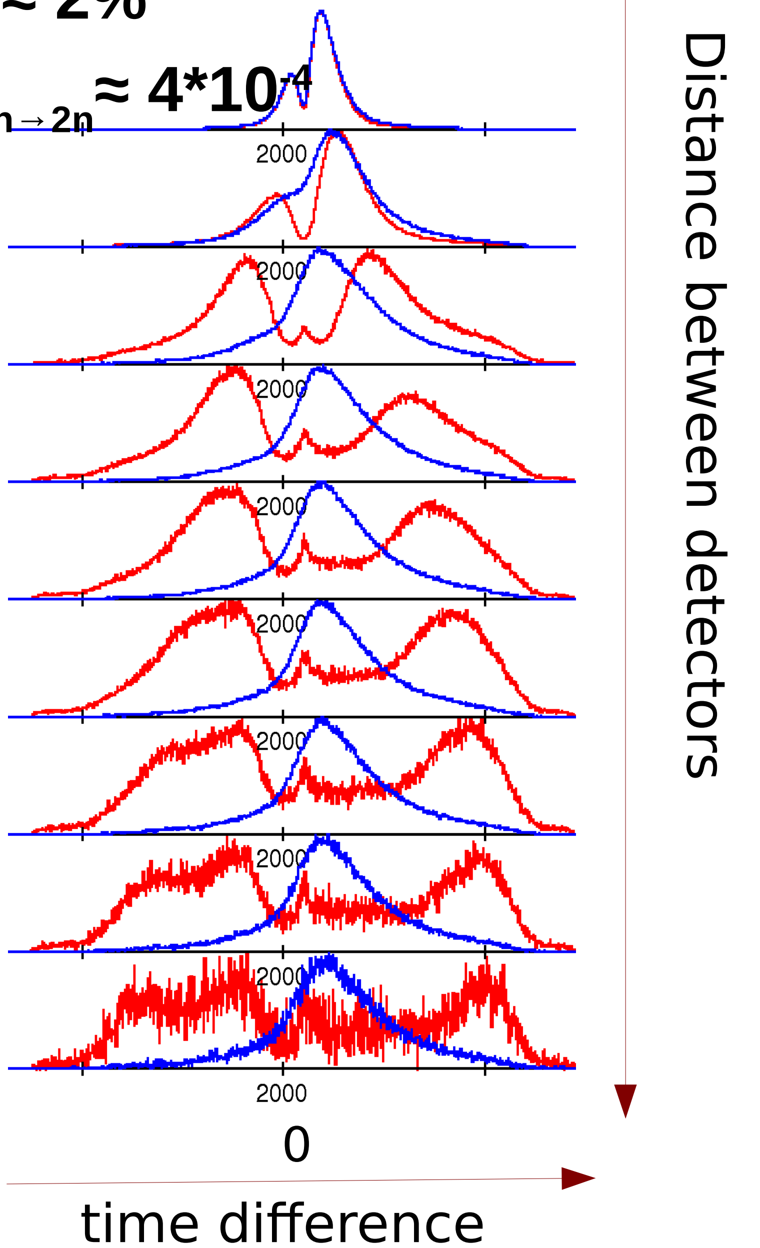


1n/2n/3n discrimination



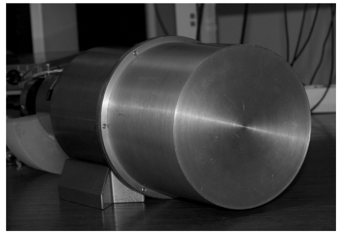
$\varepsilon_{2n} \approx 2\%$

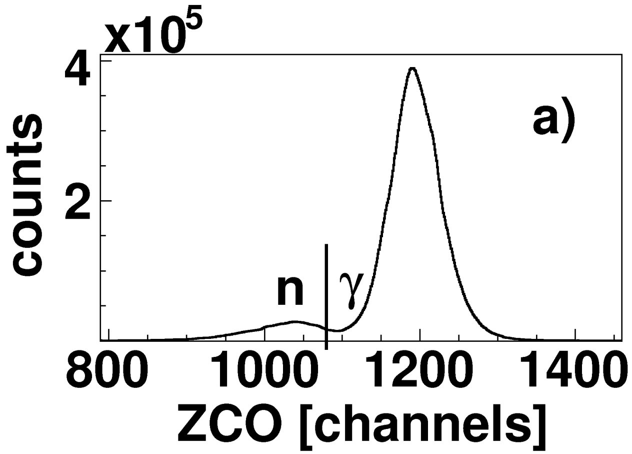
$P_{1n \rightarrow 2n} \approx 4*10^{-4}$

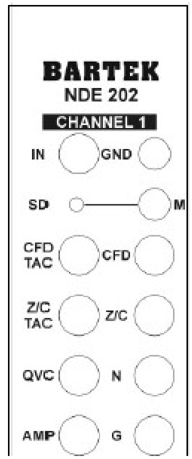


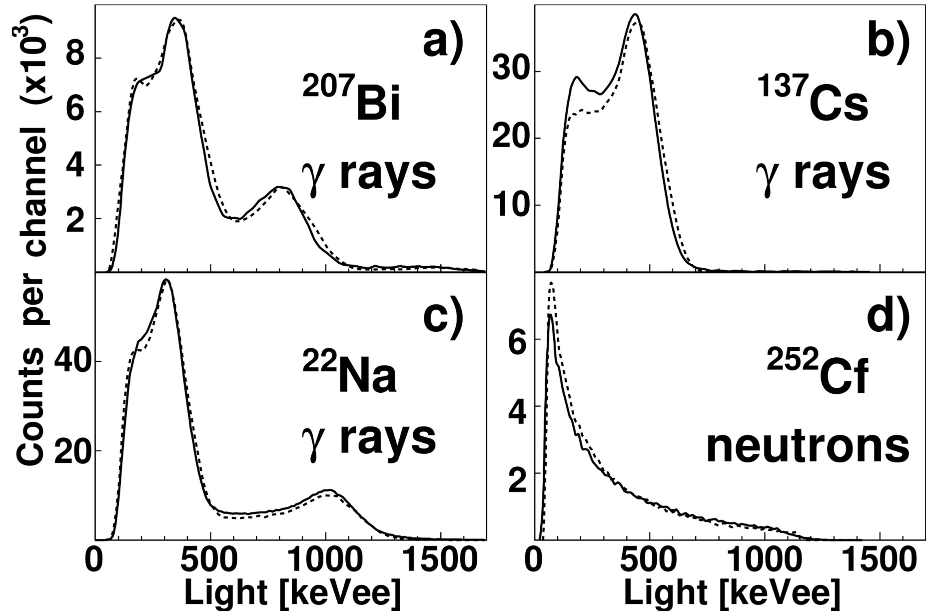
J. Ljungvall et al. NIM A528 (2004) 741

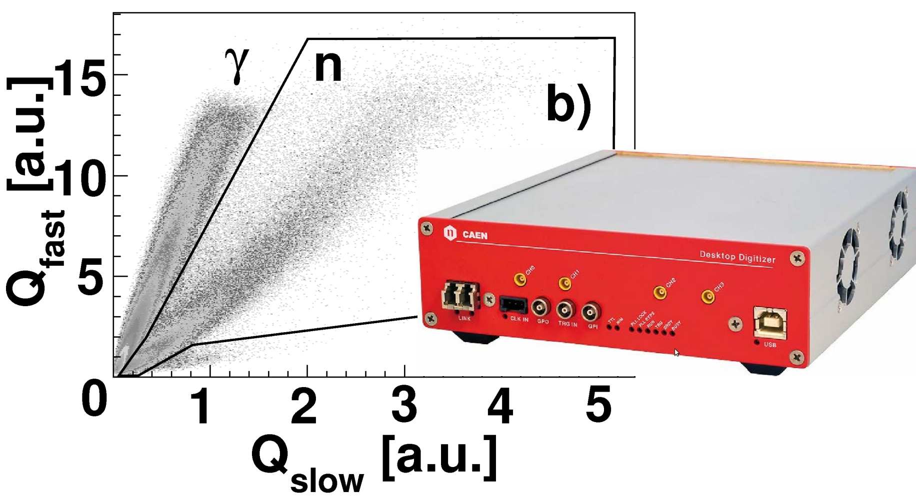
Validation of the simulations









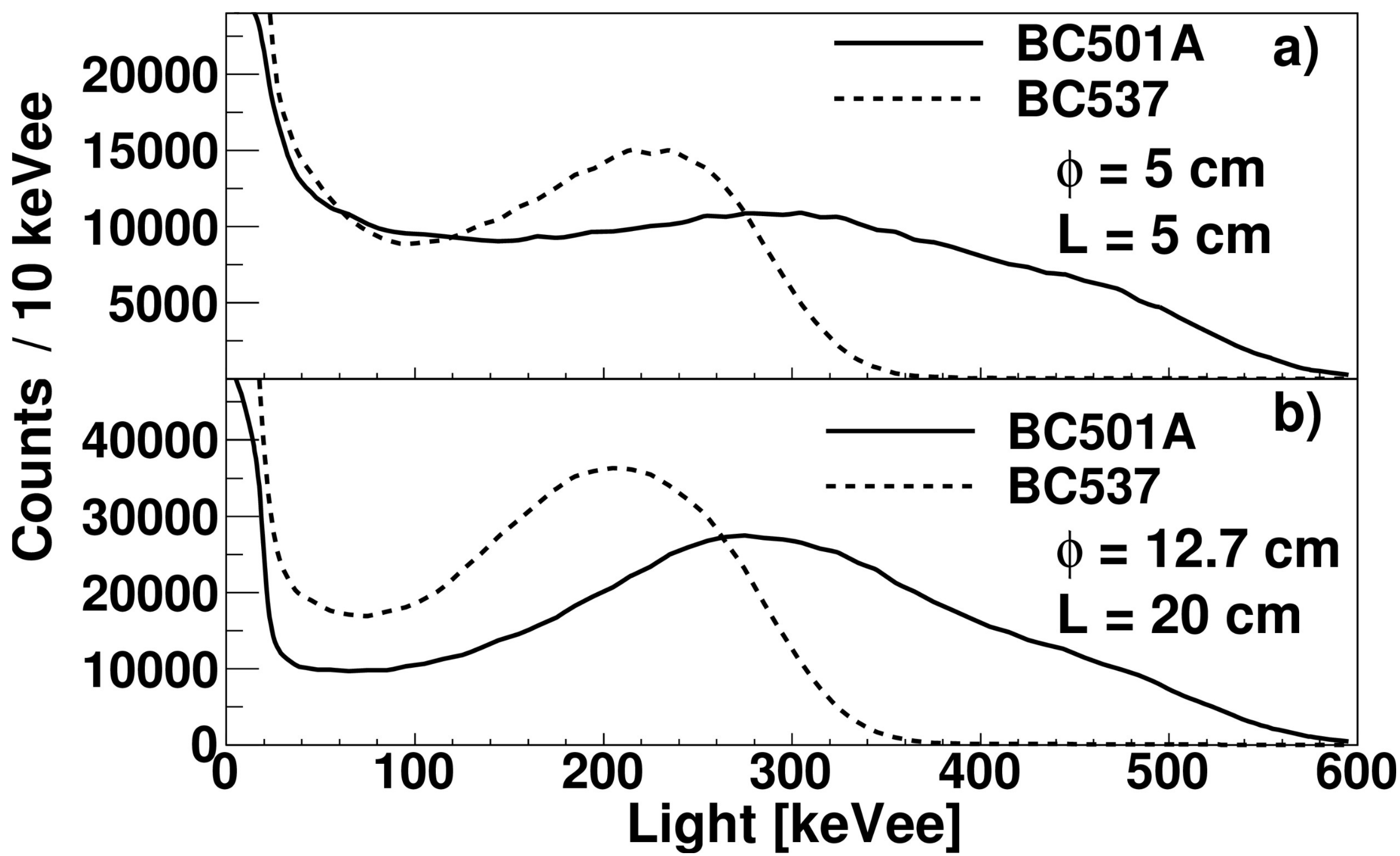


Detector and radioactive source	Efficiency (%) Absolute	
	Exp.	Sim.
NORDBALL:		
^{137}Cs γ rays, 50 cm	0.30(1)	0.285(1)
^{252}Cf neutrons, 51 cm	0.174(9)	0.241(2)
Cylindrical:		
^{252}Cf neutrons, 5 cm	6.1(3)	6.64(2)

Geant 4 simulations

Light to energy dependence

Light output for 2 MeV neutrons
Instrumental response function included



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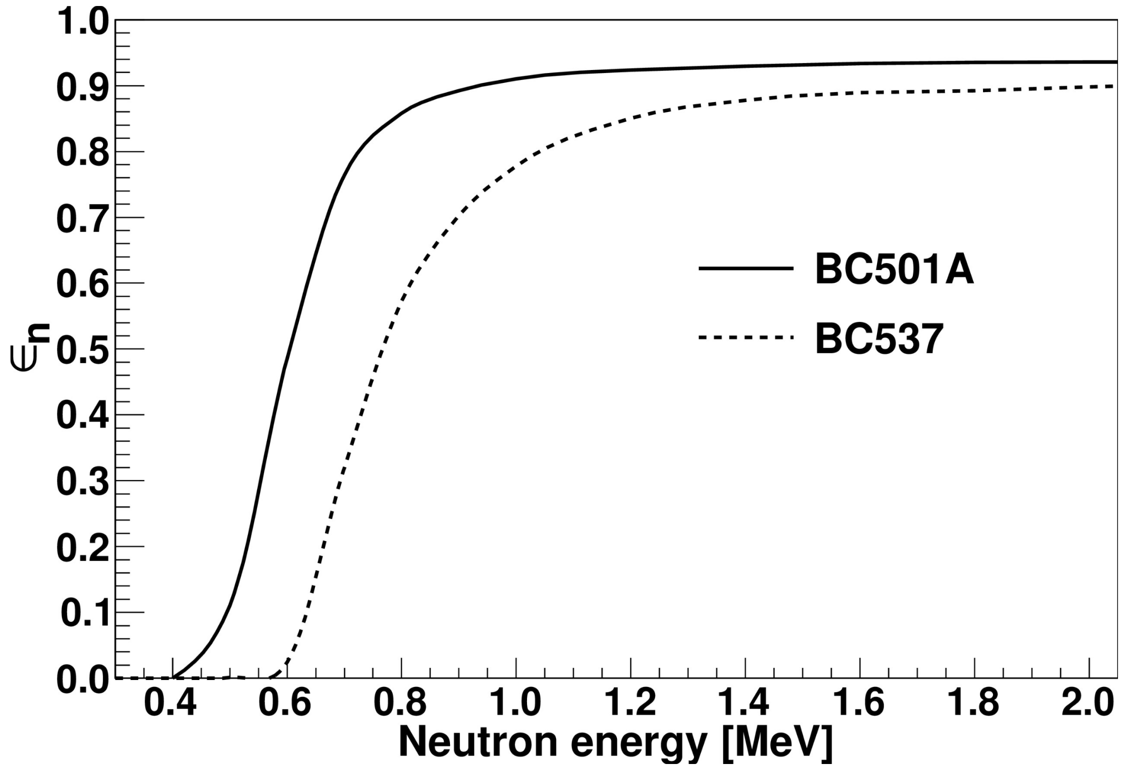
Geant 4 simulations

Neutron detection efficiency



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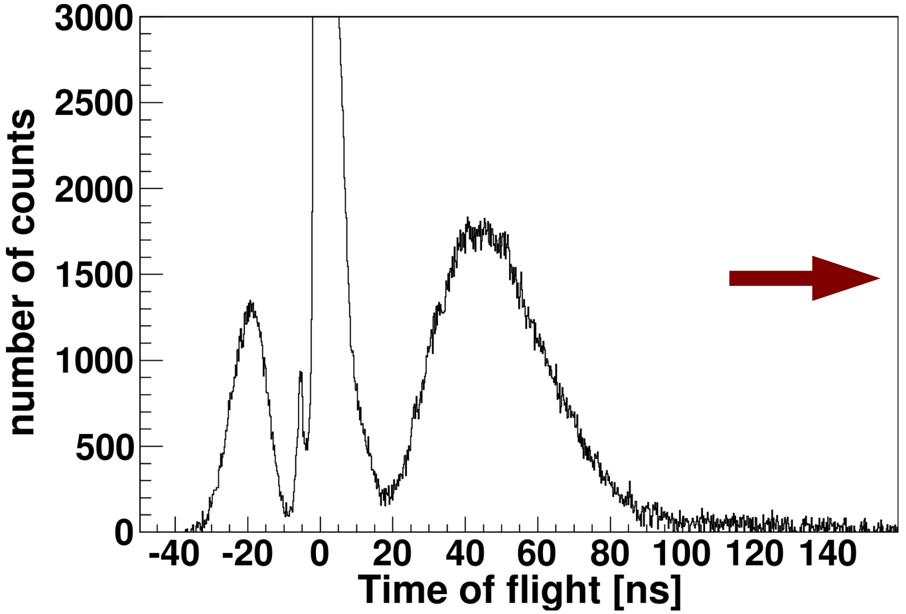
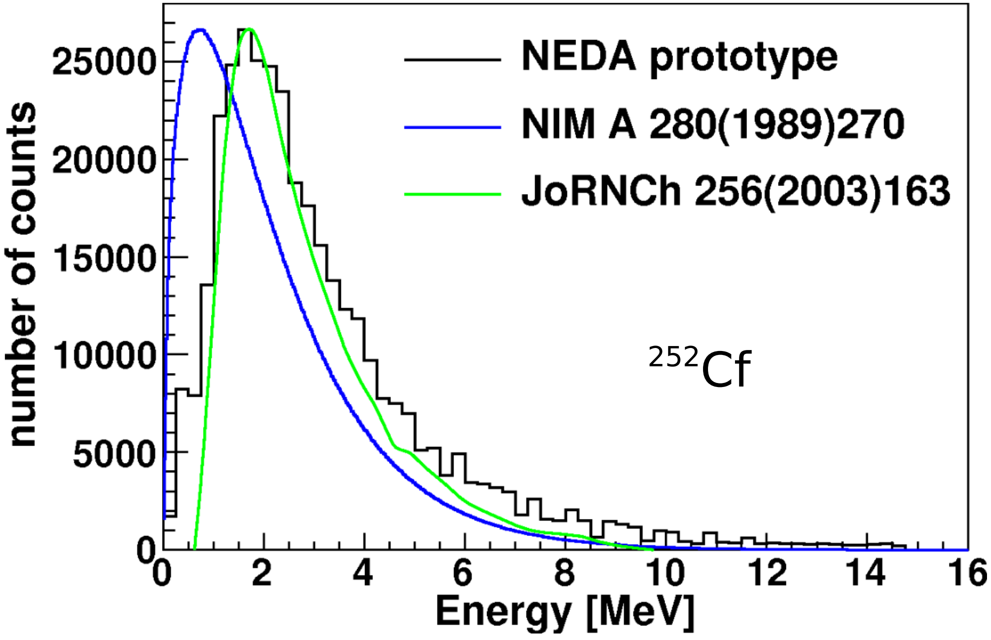
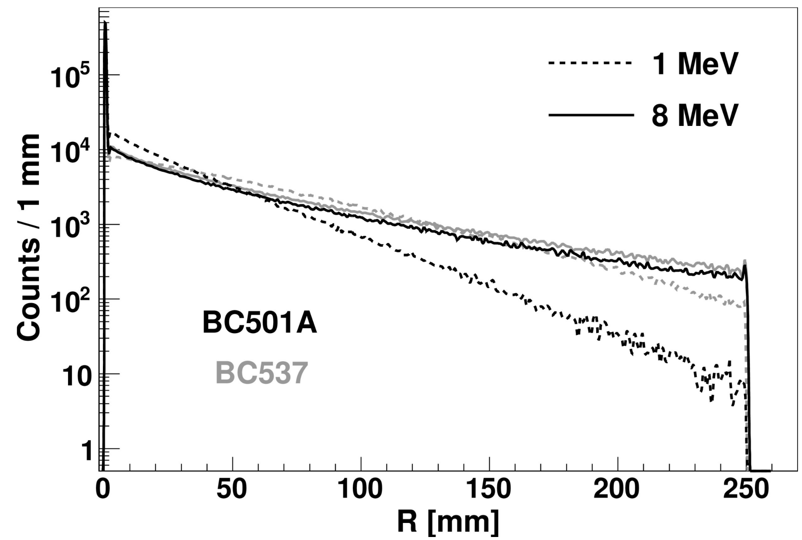
Tests of NEDA prototype detectors



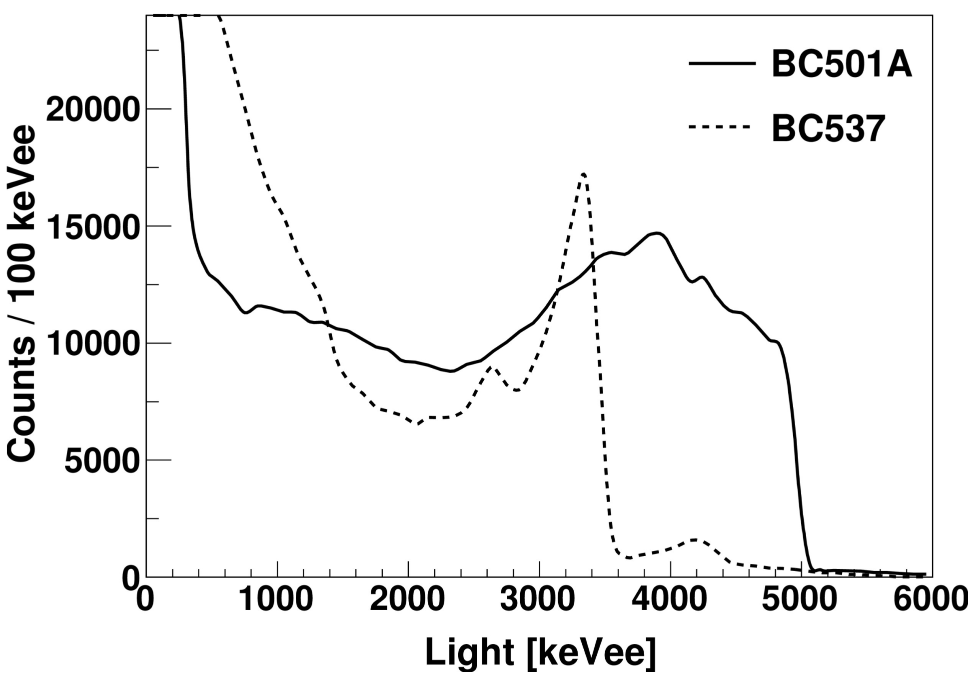


^{252}Cf neutron energy distribution

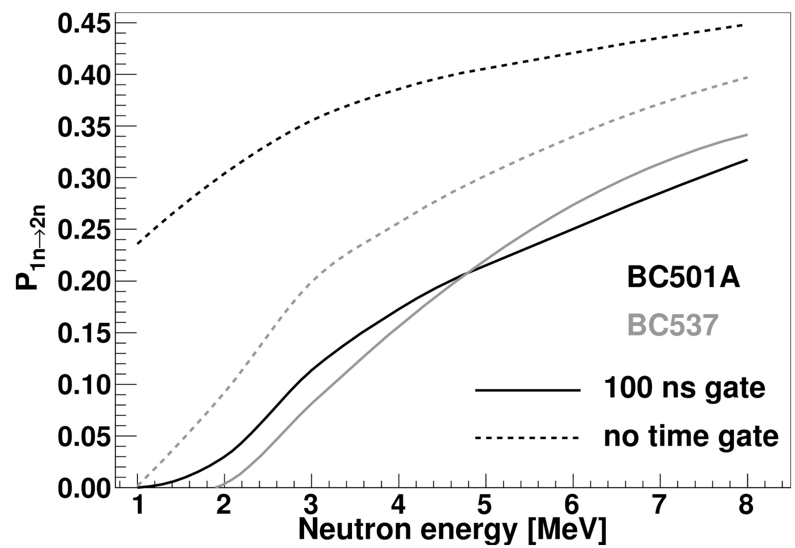
Transverse position of the sig. interaction



Light output for 10 MeV neutrons
An instrumental response function not included



Influence of the 100 ns detection time limit on the p(1n→2n).

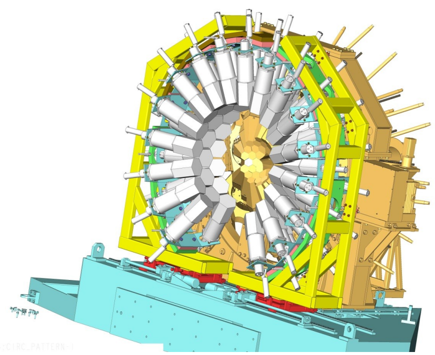


Preliminary time line of NEDA

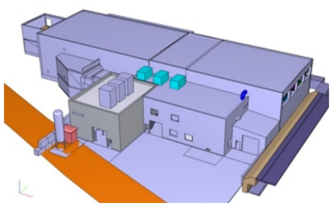
2016 | 2017 | 2018 | 2019 | 2020 | 2021

CERN Shutdown

Production of NEDA | NEDA/AGATA@ GANIL | NEDA SPES | HIE-ISOLDE



SPES exotic beams for science



2022 | 2023 | 2024 | 2025 | 2026

HIE-ISOLDE | v | HISPEC LNS?

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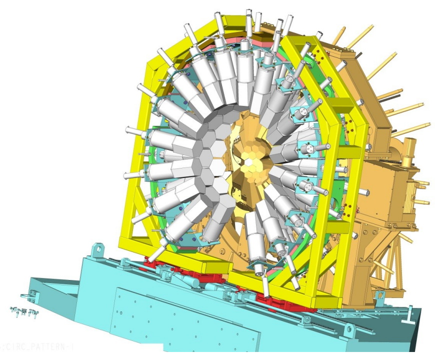
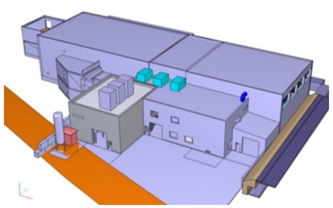


SPES
exotic beams for science



2022 | 2023 | 2024 | 2025 | 2026

HIE-ISOLDE | v | HISPEC LNS?