NEDA (NEutron Detector Array)

J.J. Valiente Dobón (LNL-INFN)

on behalf of the NEDA collaboration

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)

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

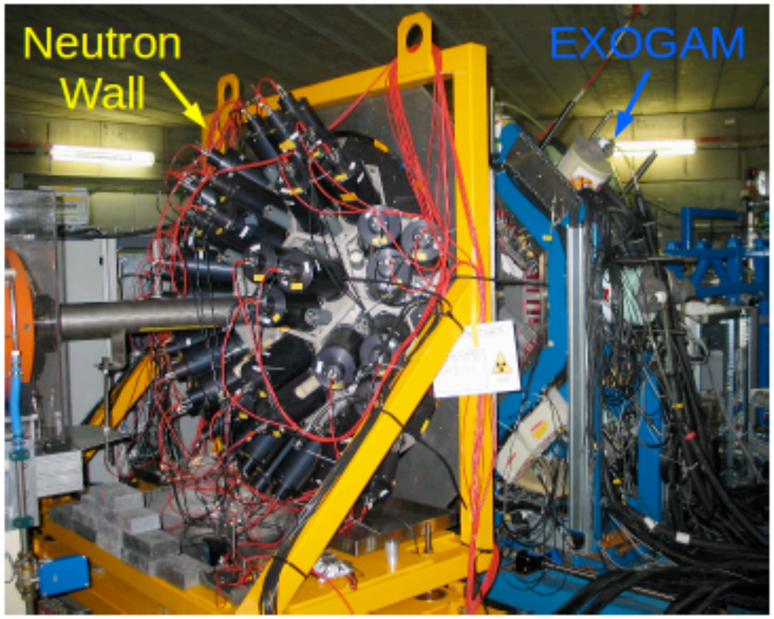
Working groups

- **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, . . .).

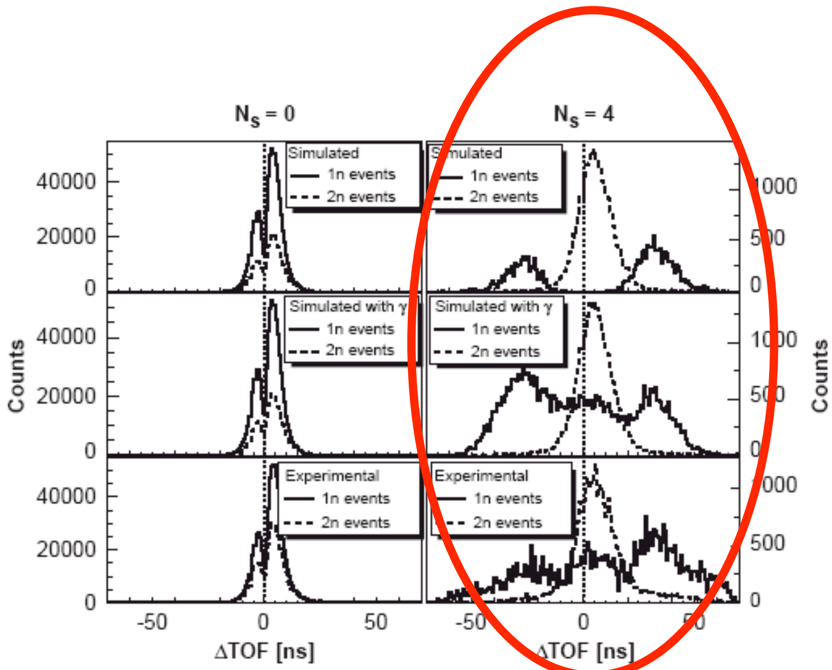


GANIL home base since 2005.

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

Next campaign (two experiments): GANIL 2012.

Cross talk – low 2n cross section



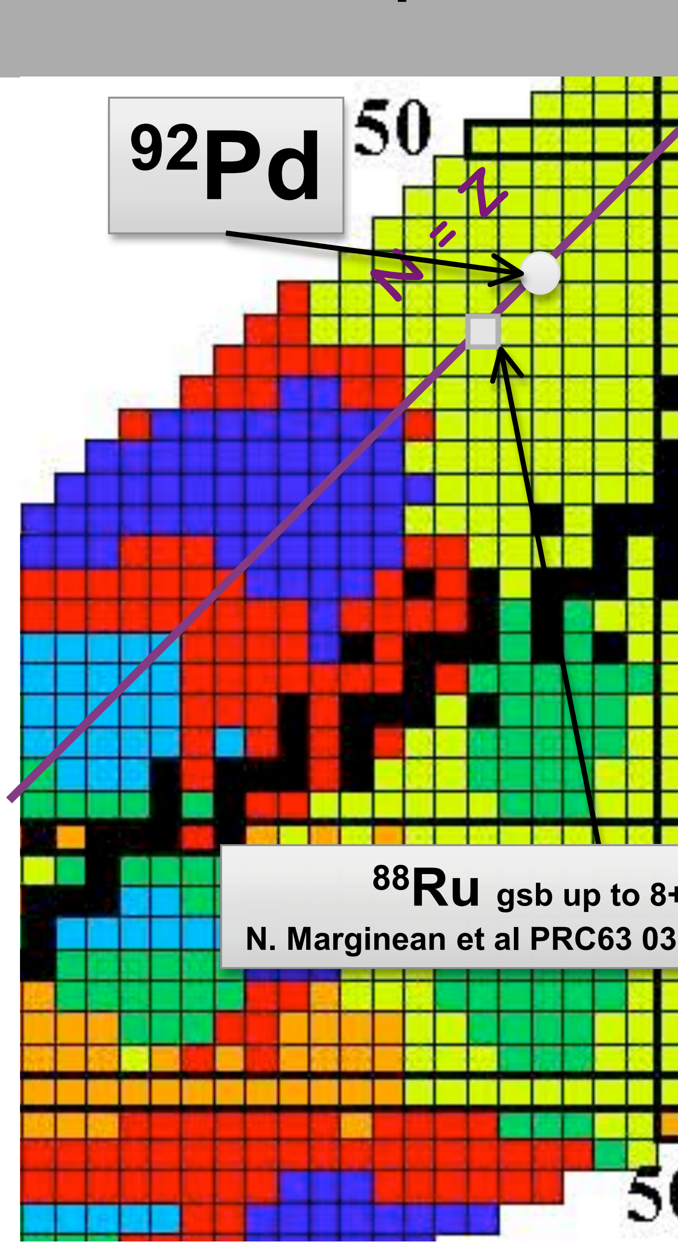
J. Ljungvall et al., NIMA528 471 (2004)

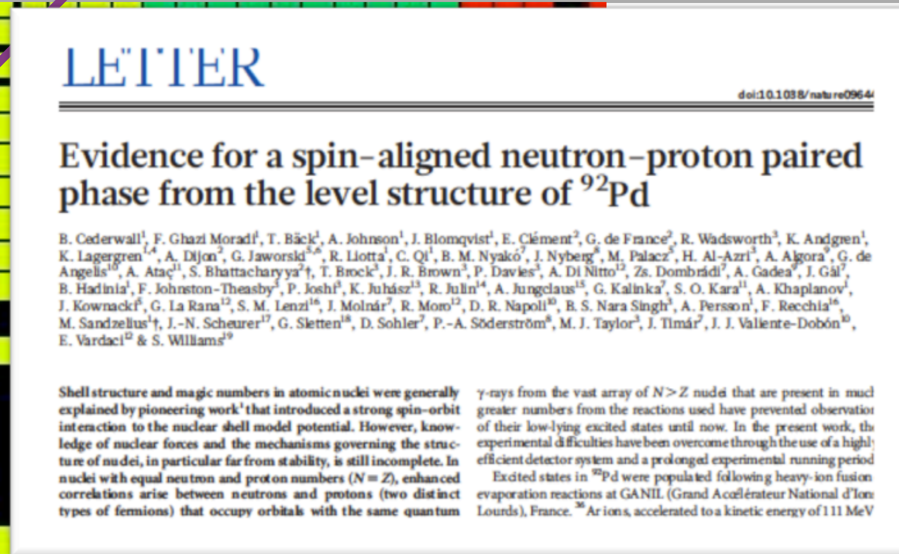
- High cross talk between neighboring detectors
- It is not possible to differenciate between 2n real events or just 1n scattered.
- Therefore neighbouring detectors are dismiss in the analysis and the efficiency decreases to 1-2%.

Possible to improve 2n efficiency using TOF among detectors

One aim of NEDA is to be able to distinguish between real 2n events and scattered neutrons → Increase of the 2n efficiency.

In beam spectroscopy of ^{92}Pd





LETTER

doi:10.1038/nature0964

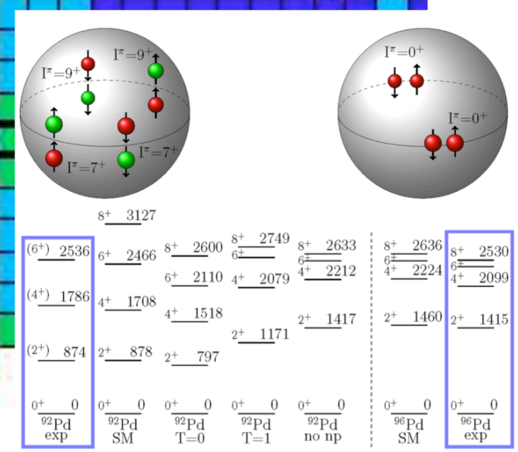
Evidence for a spin–aligned neutron–proton paired phase from the level structure of ^{92}Pd

B. Cederwall[1], F. Ghazi Moradi[1], T. Bäck[1], A. Johnson[1], J. Blomqvist[1], E. Clément[2], G. de France[2], R. Wadsworth[3], K. Andgren[1], K. Lagergren[1,4], A. Dijon[2], G. Jaworski[5,6], R. Liotta[1], C. Qi[1], B. M. Nyakó[7], J. Nyberg[8], M. Palacz[5], H. Al-Azri[3], A. Algora[9], G. de Angelis[10], A. Ataç[11], S. Bhattacharyya[2]†, T. Brock[3], J. R. Brown[3], P. Davies[3], A. Di Nitto[12], Zs. Dombrádi[7], A. Gadea[9], J. Gál[7], B. Hadinia[1], F. Johnston-Theasby[3], P. Joshi[3], K. Juhász[13], R. Julin[14], A. Jungclaus[15], G. Kalinka[7], S. O. Kara[11], A. Khaplanov[1], J. Kownacki[5], G. La Rana[12], S. M. Lenzi[16], J. Molnár[7], R. Moro[12], D. R. Napoli[10], B. S. Nara Singh[3], A. Persson[1], F. Recchia[16], M. Sandzelius[1]†, J.-N. Scheurer[17], G. Sletten[18], D. Sohler[7], P.-A. Söderström[8], M. J. Taylor[3], J. Timár[7], J. J. Valiente-Dobón[10], E. Vardaci[12] & S. Williams[19]

Shell structure and magic numbers in atomic nuclei were generally explained by pioneering work[1] that introduced a strong spin–orbit interaction to the nuclear shell model potential. However, knowledge of nuclear forces and the mechanisms governing the structure of nuclei, in particular far from stability, is still incomplete. In nuclei with equal neutron and proton numbers ($N = Z$), enhanced correlations arise between neutrons and protons (two distinct types of fermions) that occupy orbitals with the same quantum

γ-rays from the vast array of $N > Z$ nuclei that are present in mucl greater numbers from the reactions used have prevented observatio of their low-lying excited states until now. In the present work, th experimental difficulties have been overcome through the use of a highl efficient detector system and a prolonged experimental running period

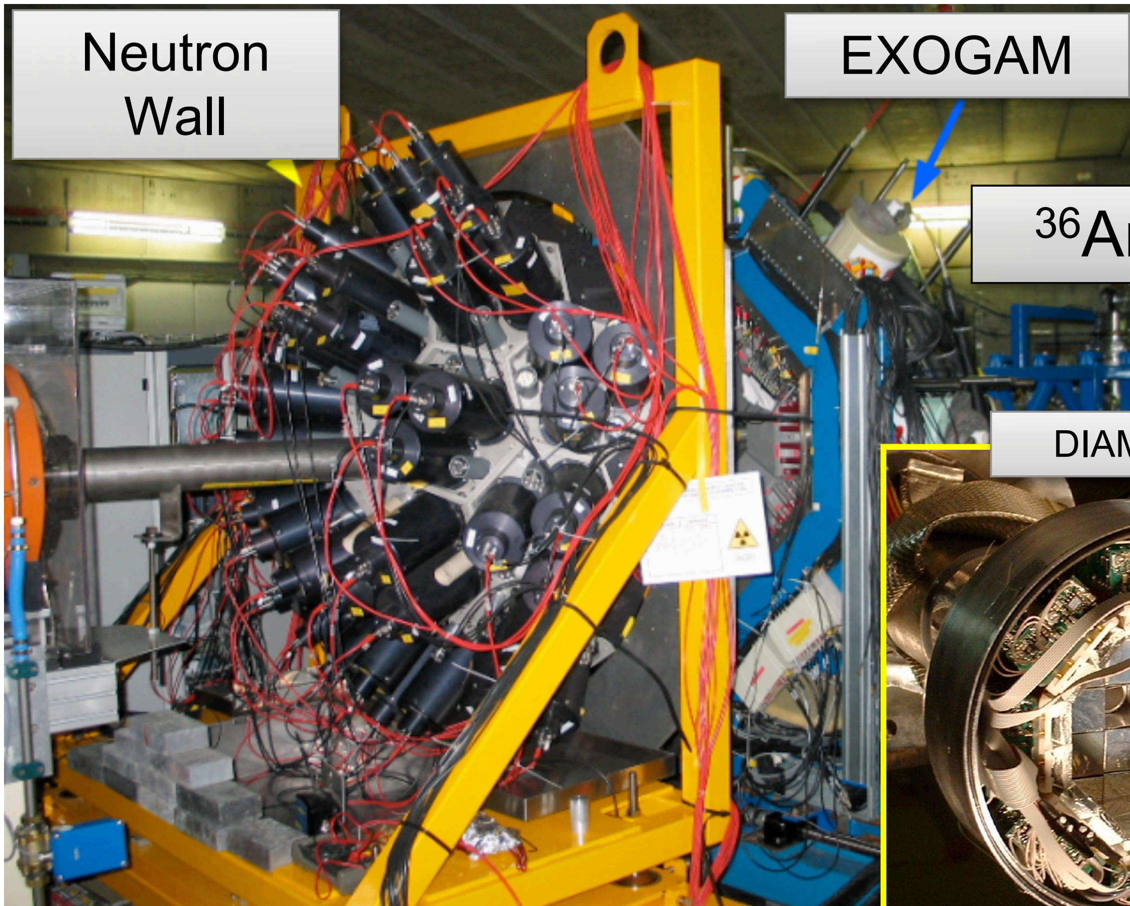
Excited states in ^{92}Pd were populated following heavy-ion fusion evaporation reactions at GANIL (Grand Accélérateur National d'Ion Lourds), France. ^{36}Ar ions, accelerated to a kinetic energy of 111 MeV



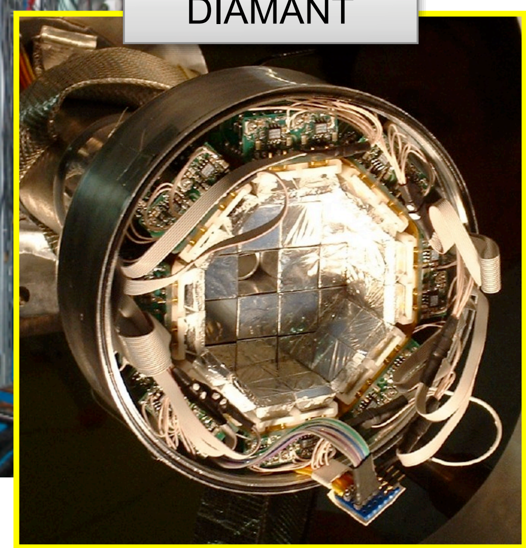
Shell model calculations by J. Blomqvist et al.

Calculations done in several model spaces,:i.e., 0g9/2, 0g9/2-1p1/2 and 0g9/2-1p1/2-0f5/2-1p3/2 which all give similar results . Int. parameters determined to reproduce exp energies in ^{94,95}Pd, ^{93,94}Rh

Experimental approach



$^{36}Ar+^{58}Ni \rightarrow ^{92}Pd+2n$



$^{40}Ca + ^{58}Ni \rightarrow ^{98}Cd^* \rightarrow ^{96}Cd + 2n$

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, GANIL, Stockholm, York)
  - Coulomb Energy Differences in isobaric multiplets: T=0 versus T=1 states (Warsaw, LNL, GANIL, York)
  - Coulomb Energy Differences and Nuclear Shapes (York, Padova, GANIL)
  - Low-lying collective modes in proton rich nuclei (Valencia, Krakow, Istanbul, Milano, LNL)
- **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)

Aim and strategy of NEDA

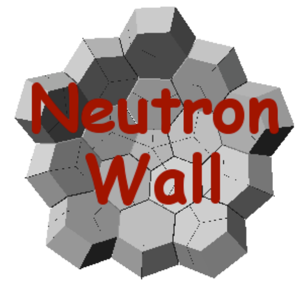
Aim

•Develop a neutron detector array to be used with AGATA, GALILEO, EXOGAM2, 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: ε(1n) ≈ 40% (20-25%), ε(2n) ≈ 6% (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

•Optimise size of detector units, distance to target, geometry of the array, . . .

•Investigate other detector materials than ordinary liquid scintillator.

•Adopt digital electronics which are fully compatible with AGATA, GALILEO, EXOGAM2, PARIS . . .

•Develop advanced on-line and off-line algorithms for neutron-gamma discrimination, neutron scattering rejection.

Simulations: Single cell unit

Detailed study of GEANT4 simulations for a single detector of NEDA.

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

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

ELSEVIER

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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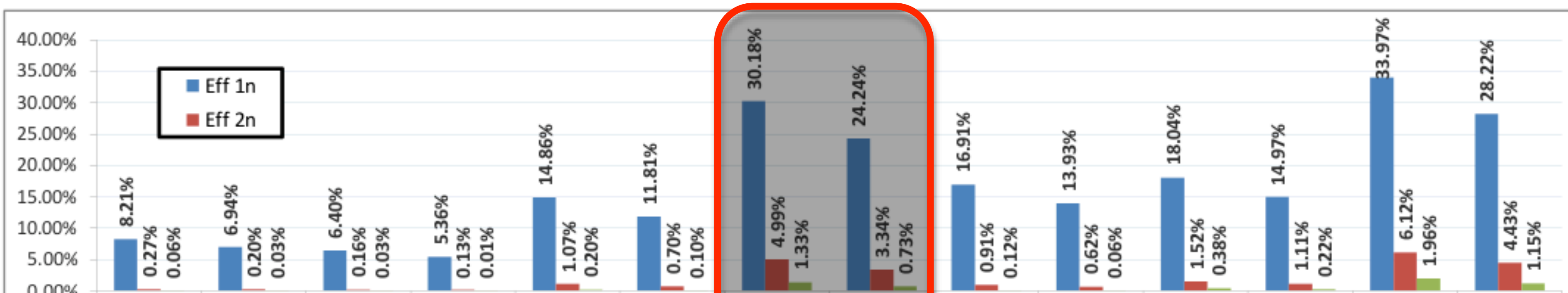
Monday and Thursday talk by G. Jaworski

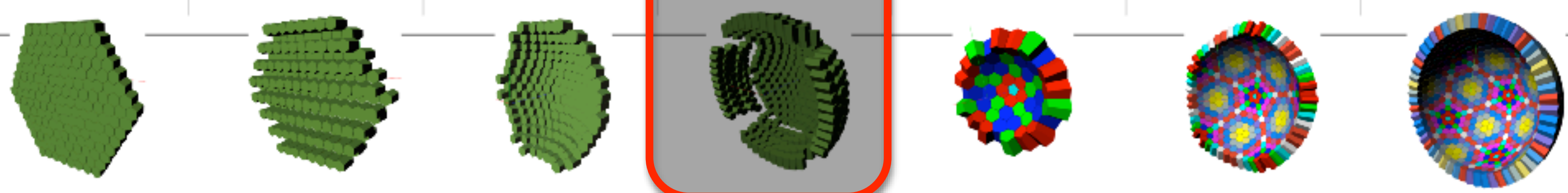
G. Jaworski et al., NIM A 673 (2012) 64-72

Overview efficiency geometries

T. Huyuk (IFIC-CSIC, Valencia, Spain)



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+

See poster by T. Hüyük

Statistical Model – PACE2

T. Huyuk (IFIC-CSIC, Valencia, Spain) & M.N. Erduran (Istanbul Sabahattin Zaim U.)

Evaporation probability

$$P(i,l,\ \ )\,\#\ T_l(\ \ )\,!_{residual}$$

Fission probability

$$R_f(E_i,J_i,B_f,j)\,\#\,\frac{2J_i}{\hbar}\,\frac{!\,(E_i\quad B_f,j)}{!\,(E_i,J_i)}$$

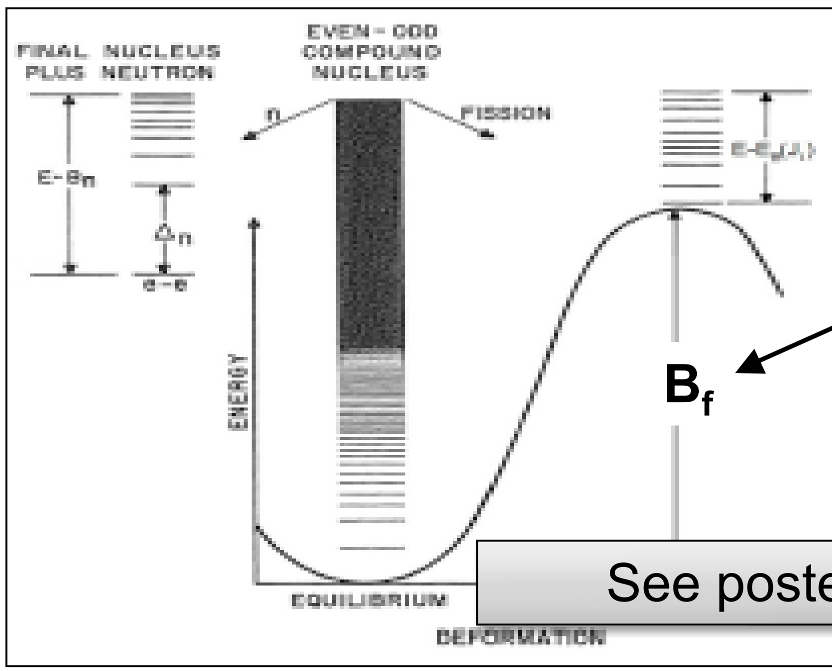
MOST SIGNIFICATIVE PRESCRIPTIONS

T_l Optical Model (OM) or Fusion Systematics (FS)

r Fermi gas level density with different prescriptions:

a= A/12 – A/6

Yrast line: Liquid Drop Model (LDM) or Rigid Sphere (RS) (r_0=1.2 fm)

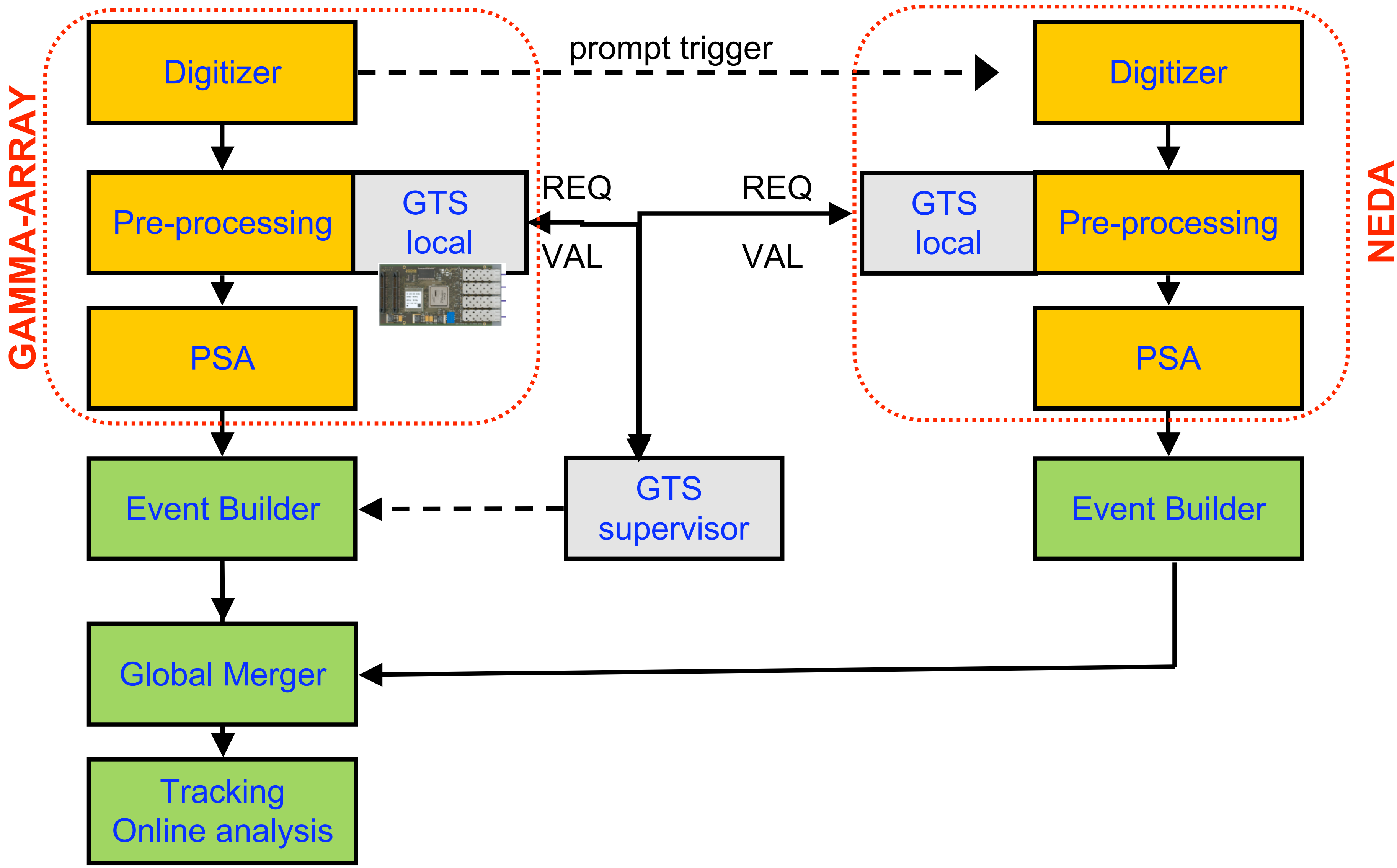


Fission barriers from Finite Range Liquid Drop Model

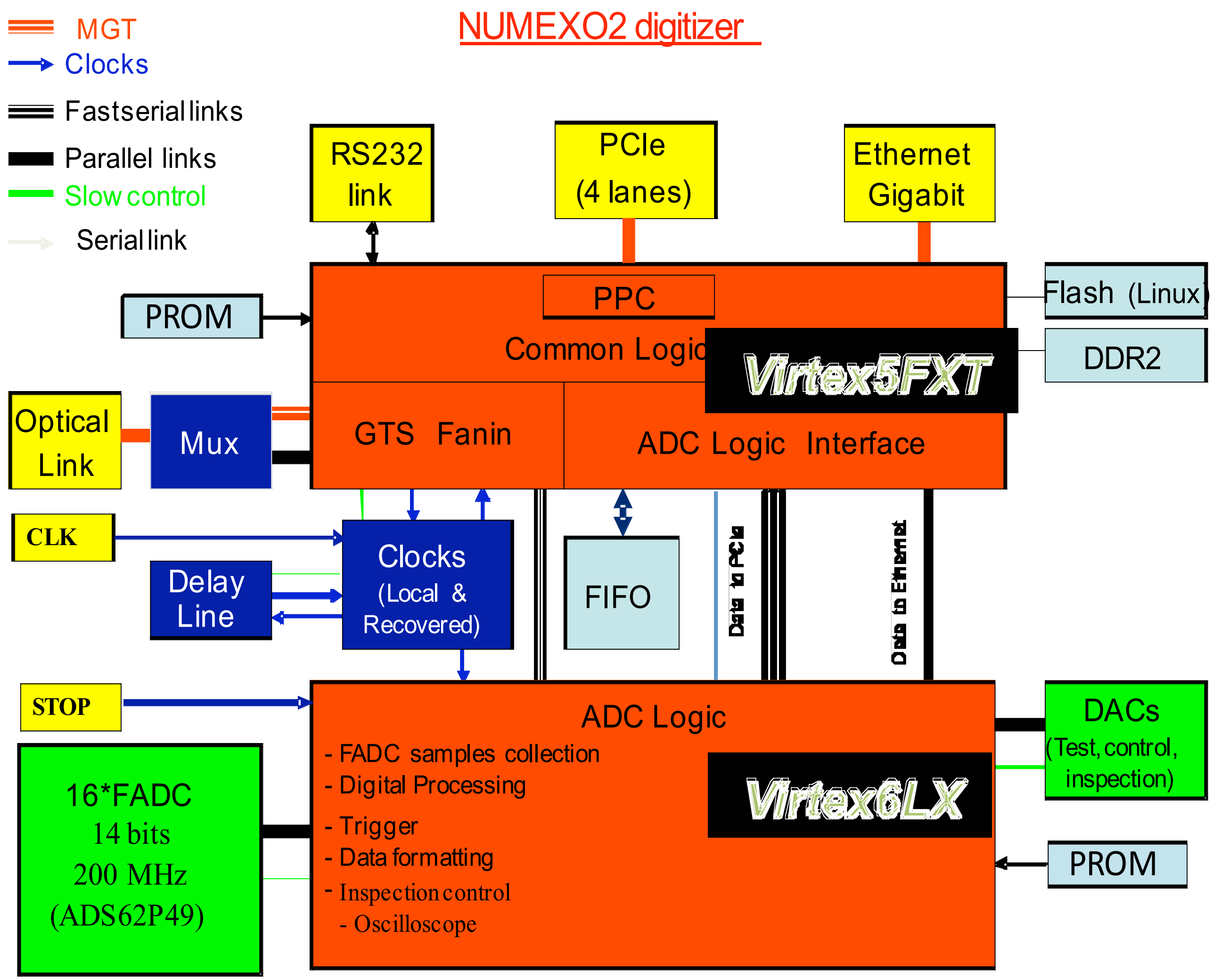
See poster by T. Hüyük

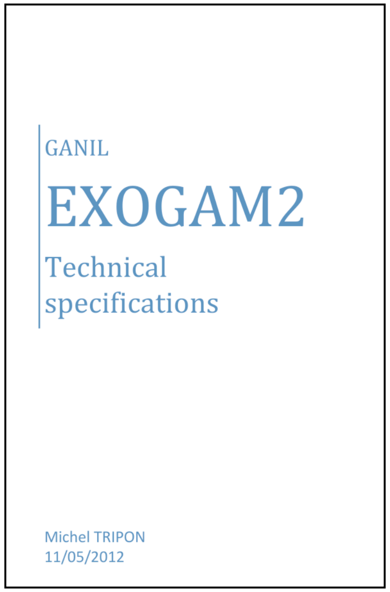
$^{58}Ni+^{56}Fe$

NEDA coupled to AGATA/GALILEO/EXOGAM2/PARIS



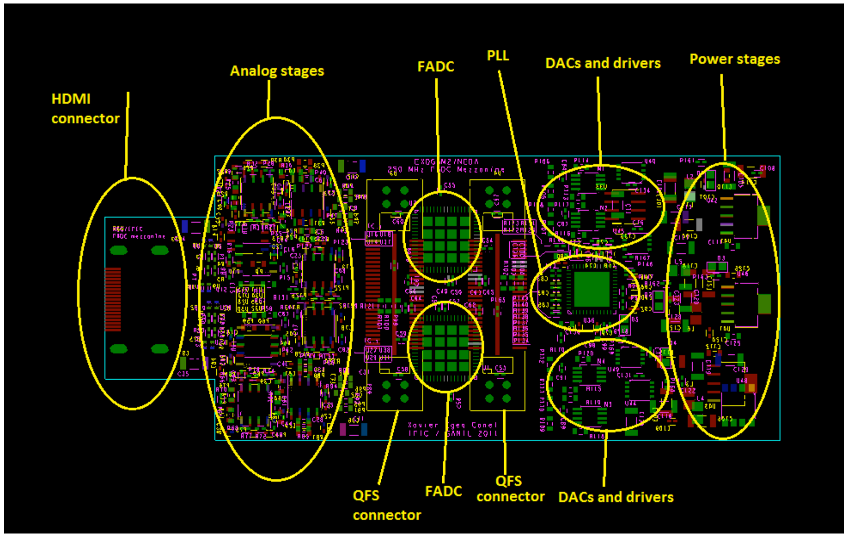
Digital electronics: EXOGAM2-NEDA-PARIS





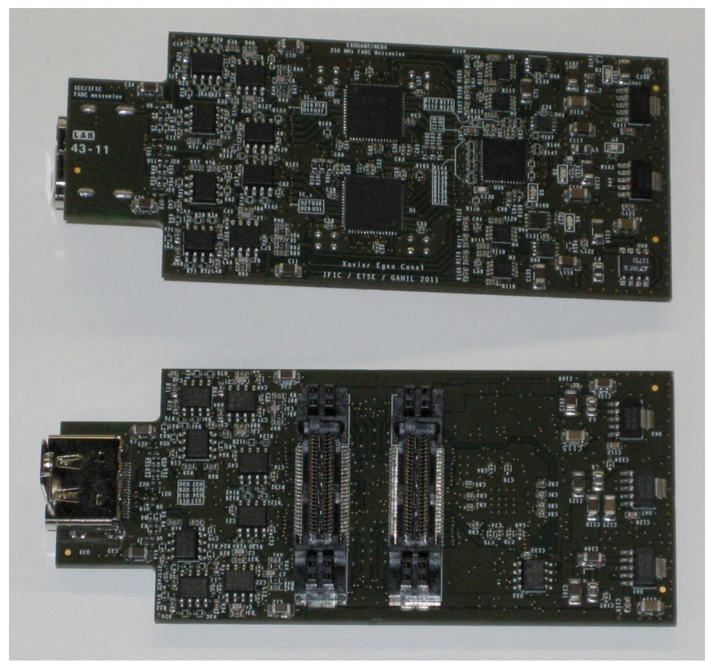
FADC Mezzanine

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



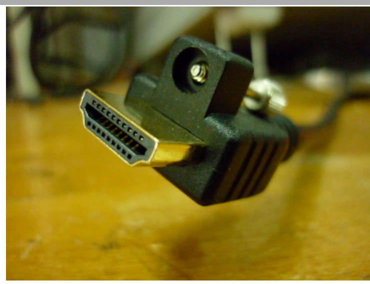
- **4-channel acquisition with a sampling rate of 250 Msps and 14-bit resoltion.**
- Use of a PLL for jitter cleaning and clock synchronization
- 6 W power consumption at 250 MHz.
- Possibility to use a variable offset by using a 16-bit digital-to-analog converter.
- Includes 2 QFS-026-04,75-LD-PC4 connectors, 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.

- 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 Virtex 6.
- It has been used a SPI control for all the devices.

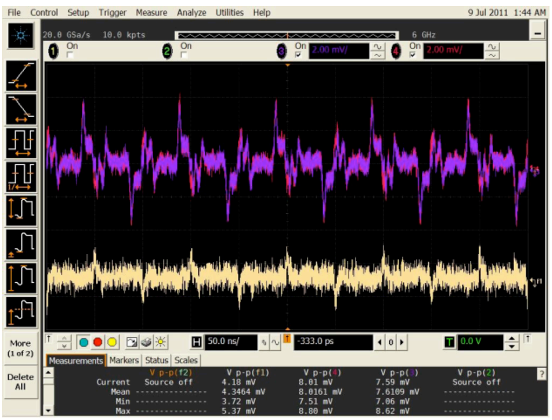


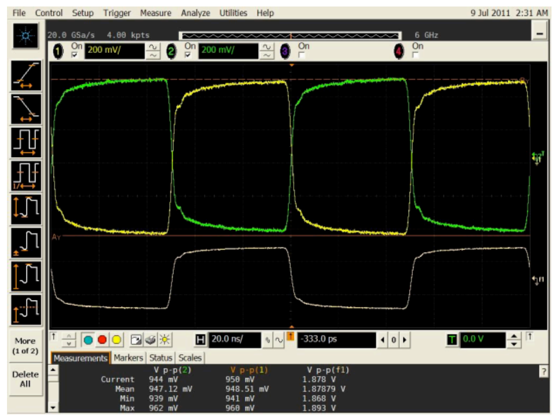
HDMI NEDA Cable results

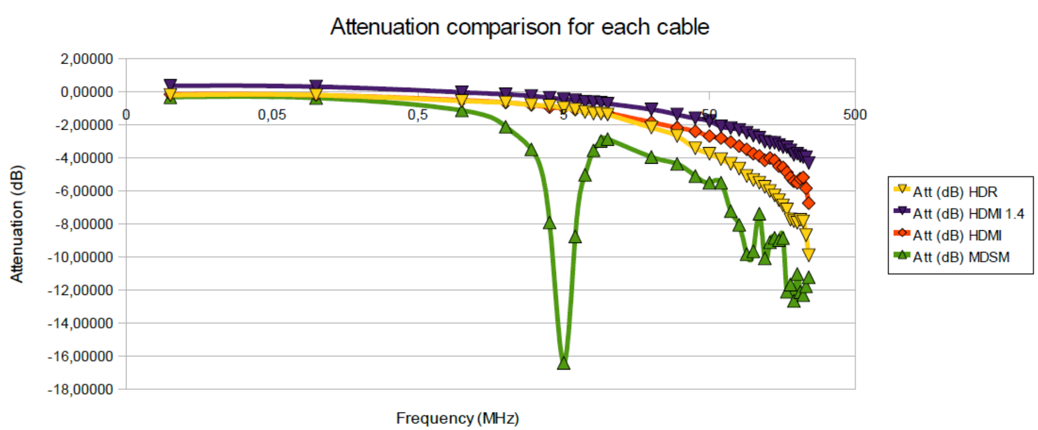
X. Egea (IFIC,CSIC, Valencia) & M. Tripon (GANIL)



- 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.







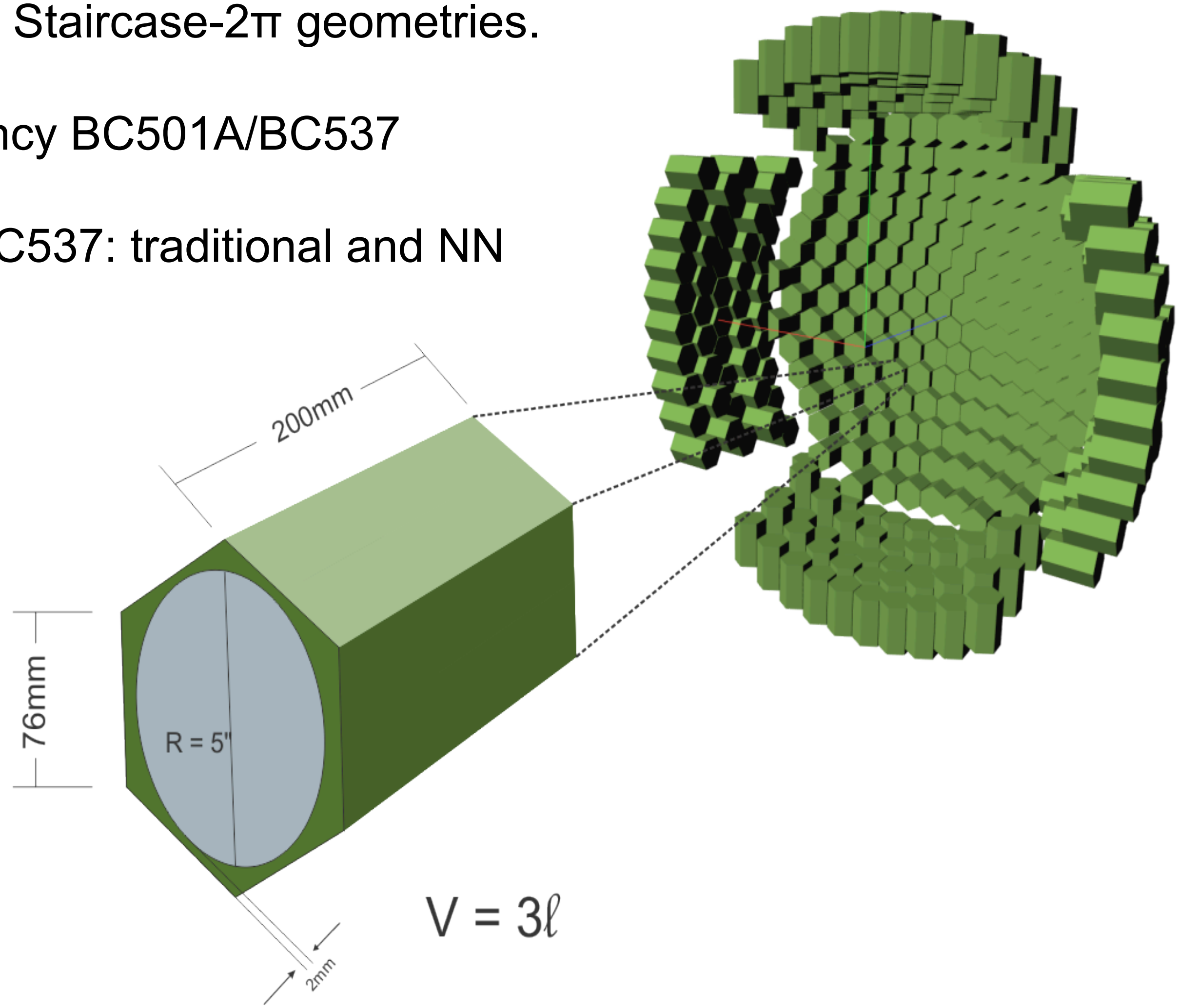
- Top → (From left to right): Crosstalk, reflections and EMC measurements. Bottom → Bandwidth
- The HDMI 1.4 has a big stiffness and it might be a little bit problematic mechanically.

Tests at LNL BC501/BC537

Starting point, unitary detector:

- One unit cell → Staircase-2π geometries.

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

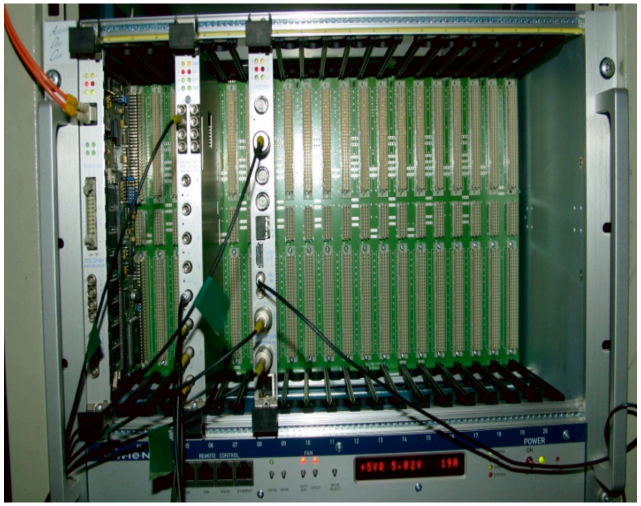


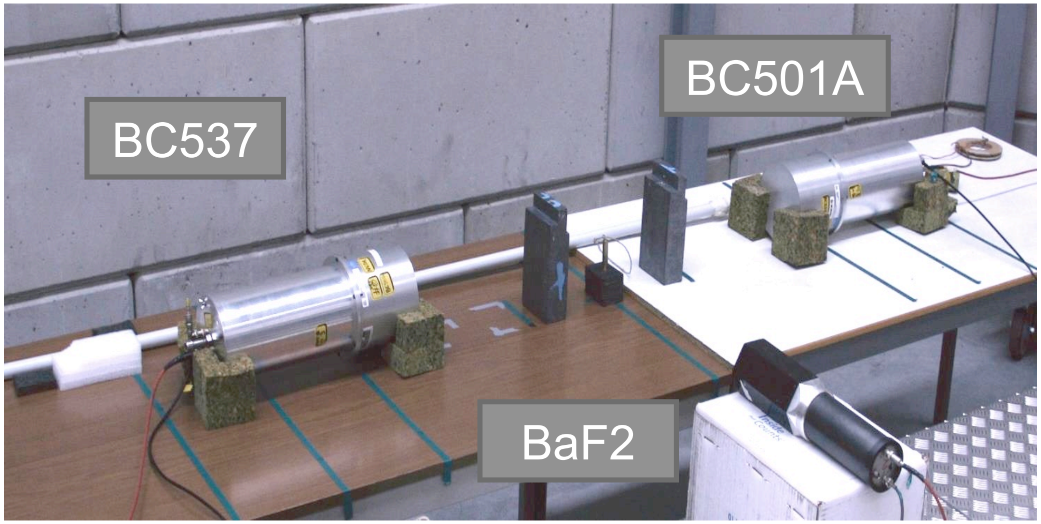
NEDA test setup

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, 14 bits 4 ch. digitizer
- DAQ by IFIC, J. Agramunt

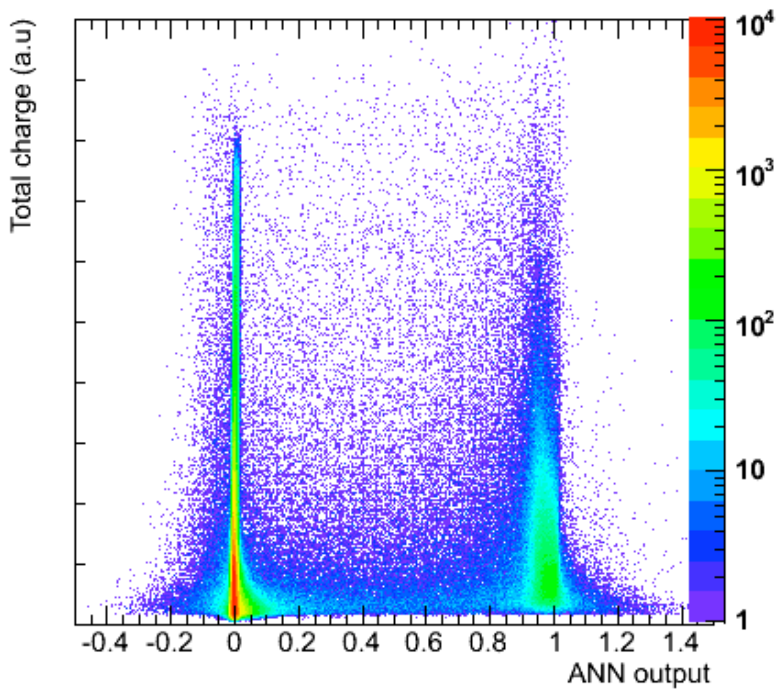
- Digital PSA
- Relative efficiency performance
- Cross-talk between the detectors

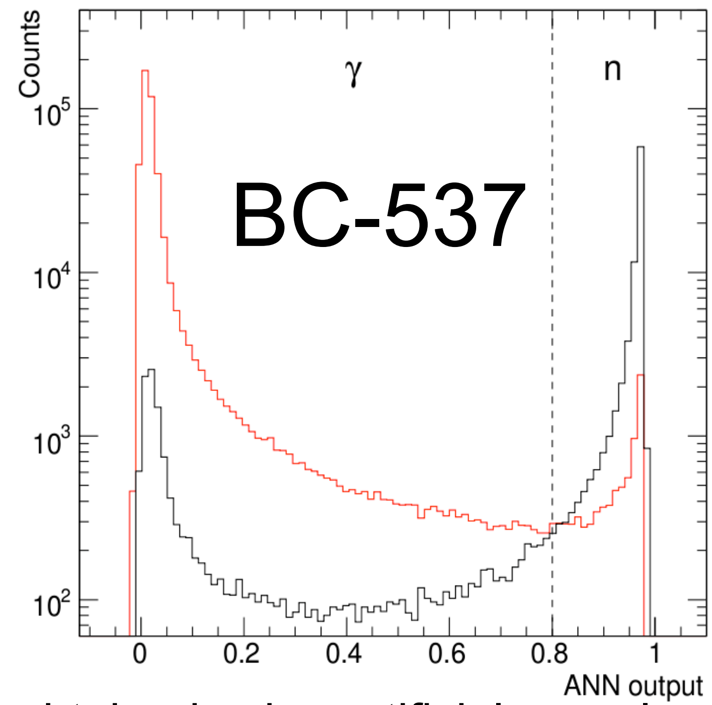




NEDA test: PSA Neural Network

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 energy range
- Slower implementation limits counting rate

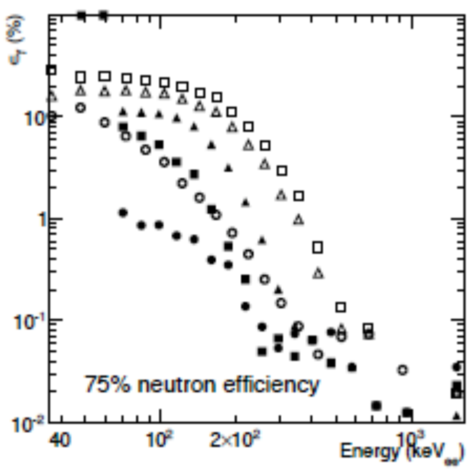
Monday and Thursday talk by G. Jaworski

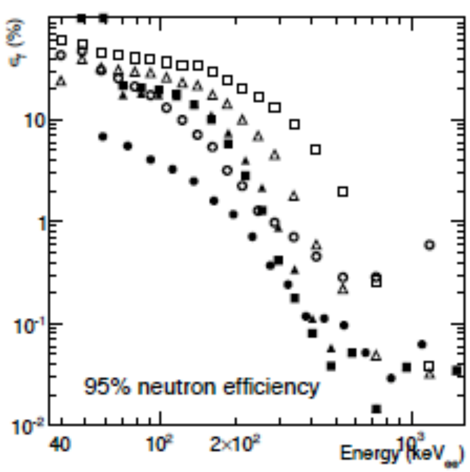
NEDA test: PSA Neural Network

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

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

Preliminary results





Shown in plots:

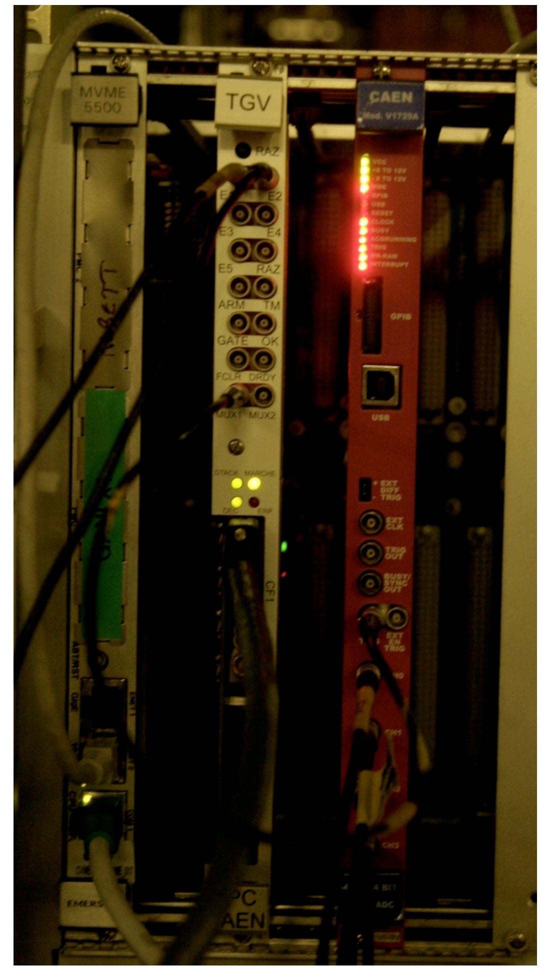
- y-axis: ϵ_γ = fraction of γ rays identified as neutrons.
- x-axis: energy deposited in the detector in units of keV$_{ee}$ (keV electron-equivalent).
- Top (bottom) figure: 75% (95%) of the neutrons remain after neutron-gamma discrimination.
- Filled (open) symbols: BC501A (BC537)
- Digital neutron-γ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

In beam test with the NW

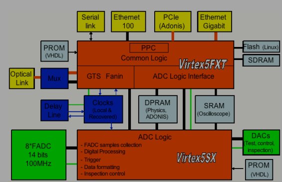
- First in-beam waveform taking (two weeks ago @GANIL)
- 124 MeV ^{40}Ca onto ^{58}Ni 6 mg/cm2 and ^{12}C 0.5 mg/cm2
- PSA algorithms
- MATACQ digitizer, 1GS/s, 14 bit



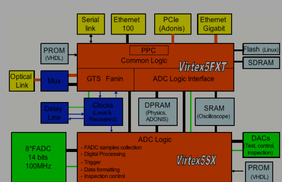
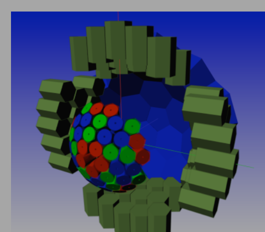
Phases of NEDA

NEDA will be built in four different phases:

- Phase 0: Upgrade of Neutron Wall with digital electronics.

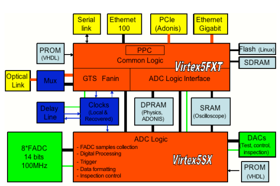
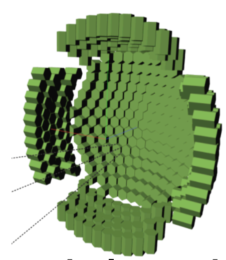



- Phase 1: Construction of 90 NEDA det. combined with NW

MoU (4 years) signed in march 2012

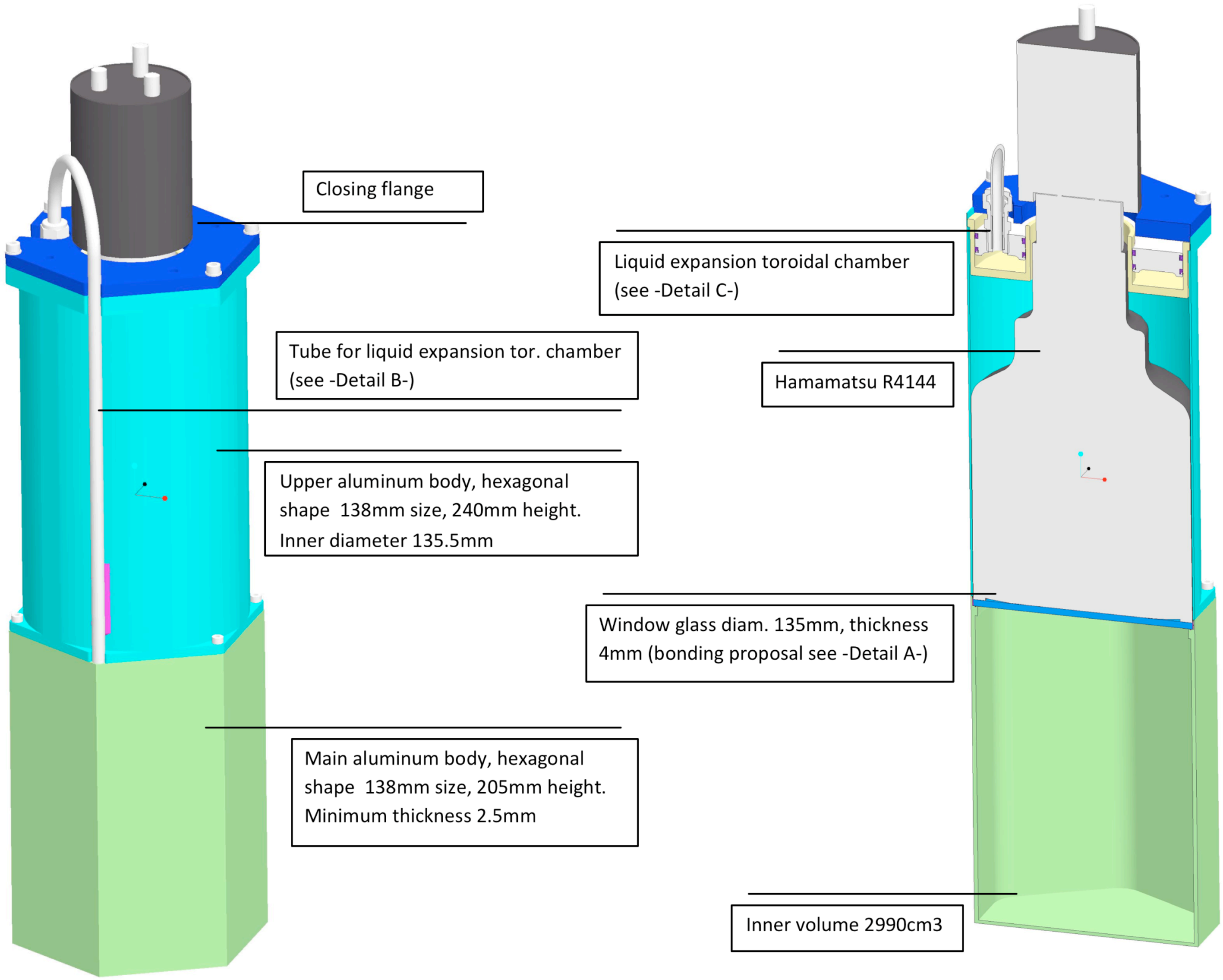
- Phase 2: Final construction of NEDA 2π – 355 detectors

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

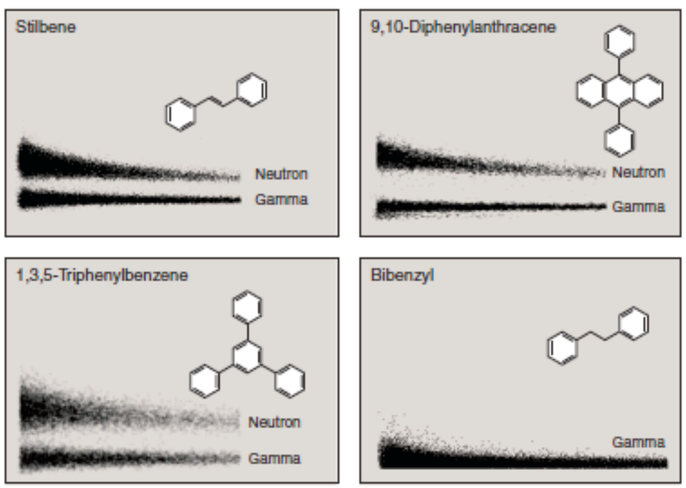
Preliminary design NEDA cell

Self production



New materials for neutron detection

In the 1990s, Natalia Zaitseva developed a rapid-growth technique for producing very large crystals in record-shattering time. She now leads a team that grows organic crystals for use in fast-neutron detectors.



EJ-299-33 PSD PLASTIC SCINTILLATOR PROVISIONAL DATA SHEET

This revolutionary plastic scintillator possesses pulse shape discrimination properties enabling the separation of gamma and fast neutron signals on the basis of their timing characteristics using conventional PSD electronics systems. It is, at this time, still under development in regard to optimized composition and manufacturing procedures. Cylinders up 51mm diameter x 76mm long have been manufactured.

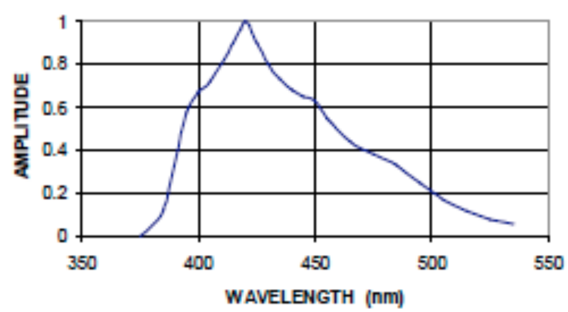
The following physical properties are representative of the more successful formulas.

Physical and Scintillation Constants:

Light Output, % Anthracene	56
Scintillation Efficiency, photons/1 MeV e^-	8,600
Wavelength of Max. Emission, nm	420
No. of H Atoms per cm^3, x 10^{22}	5.13
No. of C Atoms per cm^3, x 10^{22}	4.86
No. of Electrons per cm^3, x 10^{23}	3.55
Density, g/cc:	1.08

Chemical Compatibility: Is attacked by aromatic solvents, chlorinated solvents, ketones, solvent bonding cements, etc. It is stable in water, dilute acids and alkalis, lower alcohols and silicone greases. It is safe to use most epoxies and "super glues" with EJ-299-33.

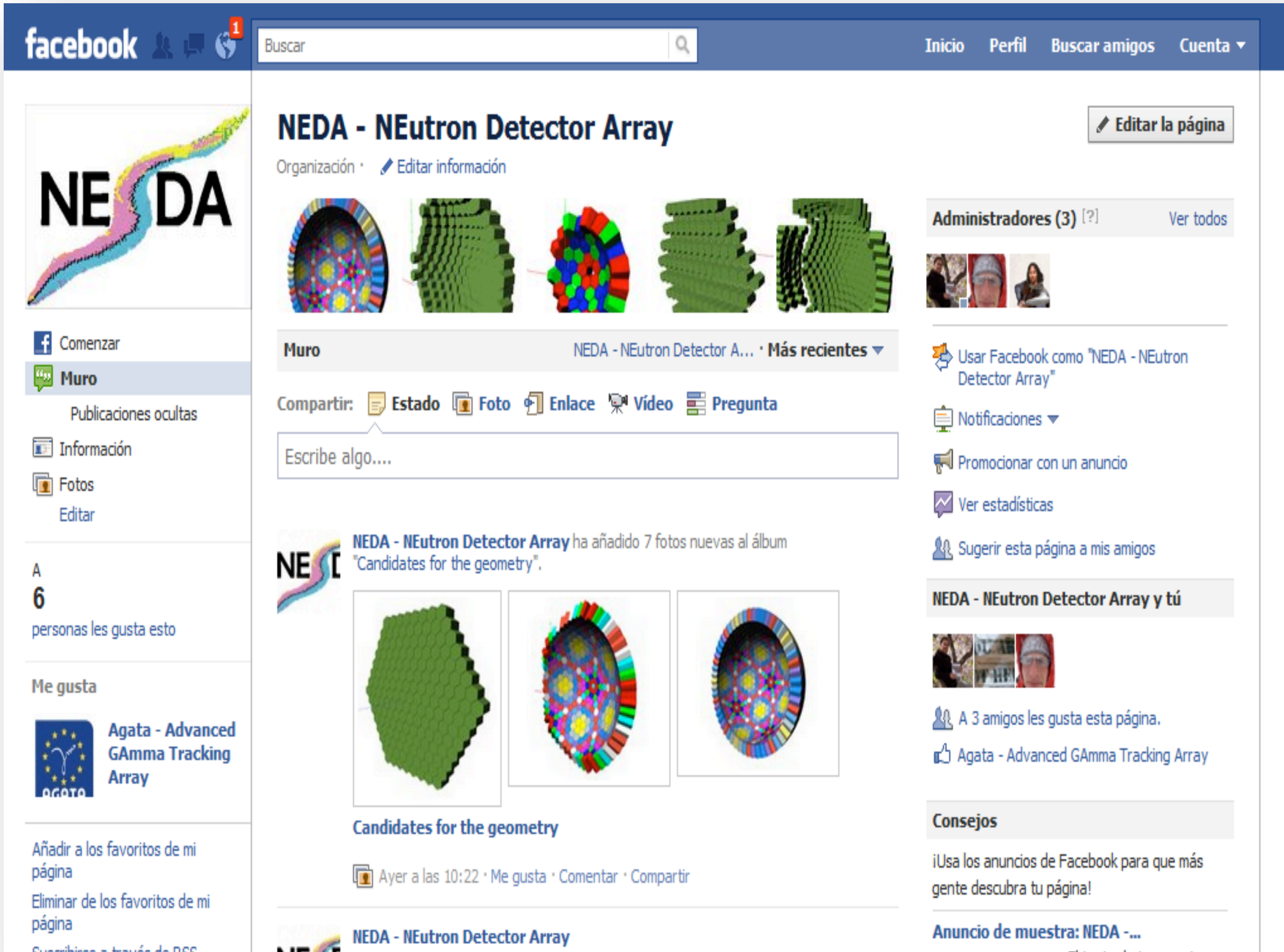
EJ-299-33 EMISSION SPECTRUM



Summary

- NEDA will be a neutron detector to 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.*
- GEANT4 simulations
  - Code validated for simulations of interactions of fast neutrons with energies up to about 10 MeV in liquid scintillators.
  - Optimal size of detector units: 20 cm length, 5" diameter.
  - BC501A better than BC537 for our needs.
  - Conceptual design: staircase geometry, 2, r = 1.0 m, 355 units.
- Tests BC537 and BC501A
- Development of electronics in synergy with EXOGAM2 and PARIS
- Strong synergies with other neutron communities: MONSTER, DESIR, NEULAND
- NEDA will be built in phases: MoU signed March 2012.
- Future R&D of new materials and light readout detectors.
- Creating a community of young gamma spectroscopists with experience on neutron detection.

To be updated visit us on Facebook

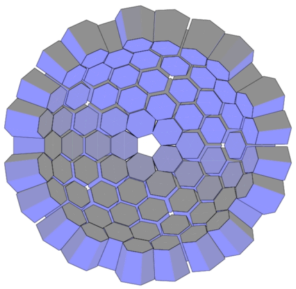


http://agata03.ific.uv.es/boceto01/nedahome.htm

Collaboration

J. Agramunt Ros, G. de Angelis, E. Clement, G. de France, A. Di Nitto, J. Egea, M.N. Erduran, S. Erturk, E. Farnea, A. Gadea, V. Gonzalez, T. Hüyük, G. Jaworski, J. Nyberg, M. Palacz, B. Roeder , P.-A. Söderström, E. Sanchis, R. Tarnowski , A. Triossi , R. Wadsworth, J.J.V.D.

BC501 vs. BC537 response

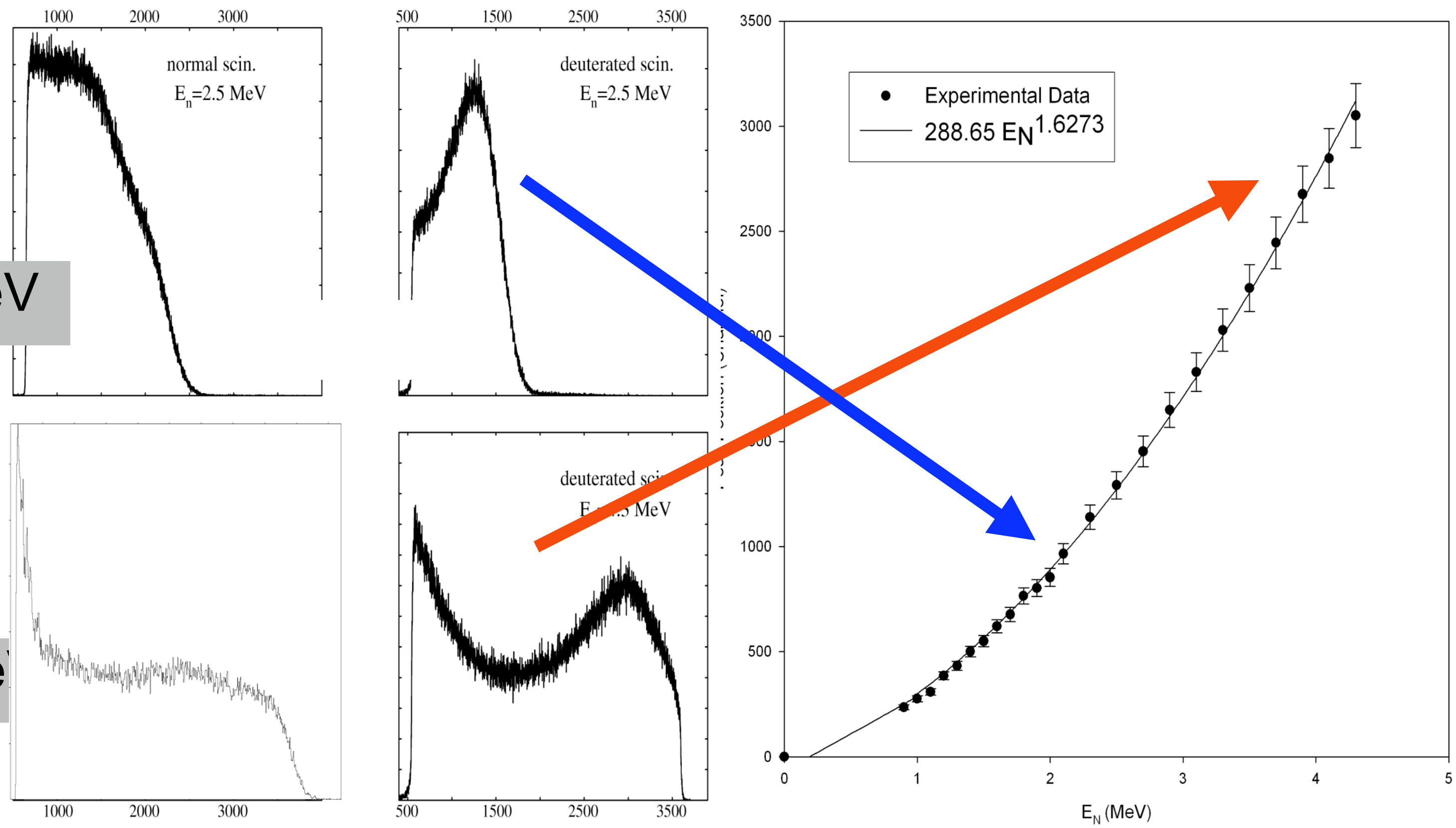


DESCANT

E_n = 2.5 MeV

E_n = 4.3 MeV

BC501 BC537 Depth 2.5cm



Courtesy of P. Garrett, University of Guelph.

Proton Pygmy Dipole resonance

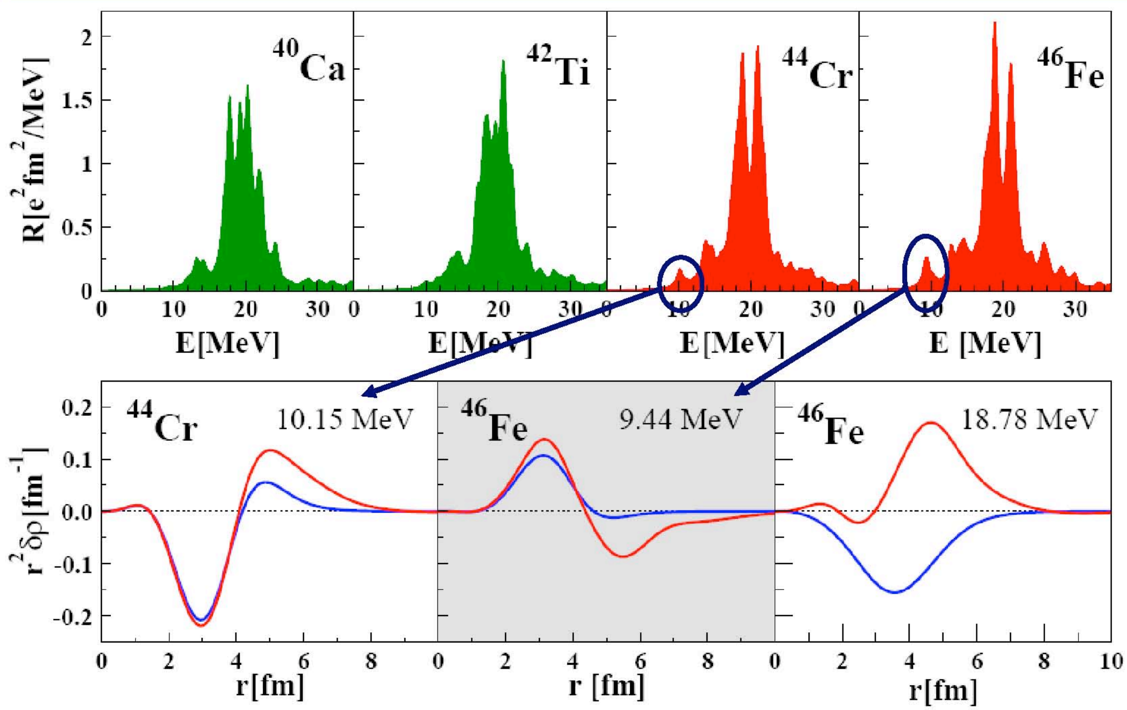
PARIS + NEDA

Low-lying collective modes in proton rich nuclei

Evolution of low-lying E1 strength in proton-rich nuclei

Paar, Vretenar, Ring, Phys. Rev. Lett. 94, 182501 (2005)

RHB+RQRPA isovector dipole strength distribution in the N=20 isotones.
DD-ME1 effective interaction + Gogny pairing.



N=20

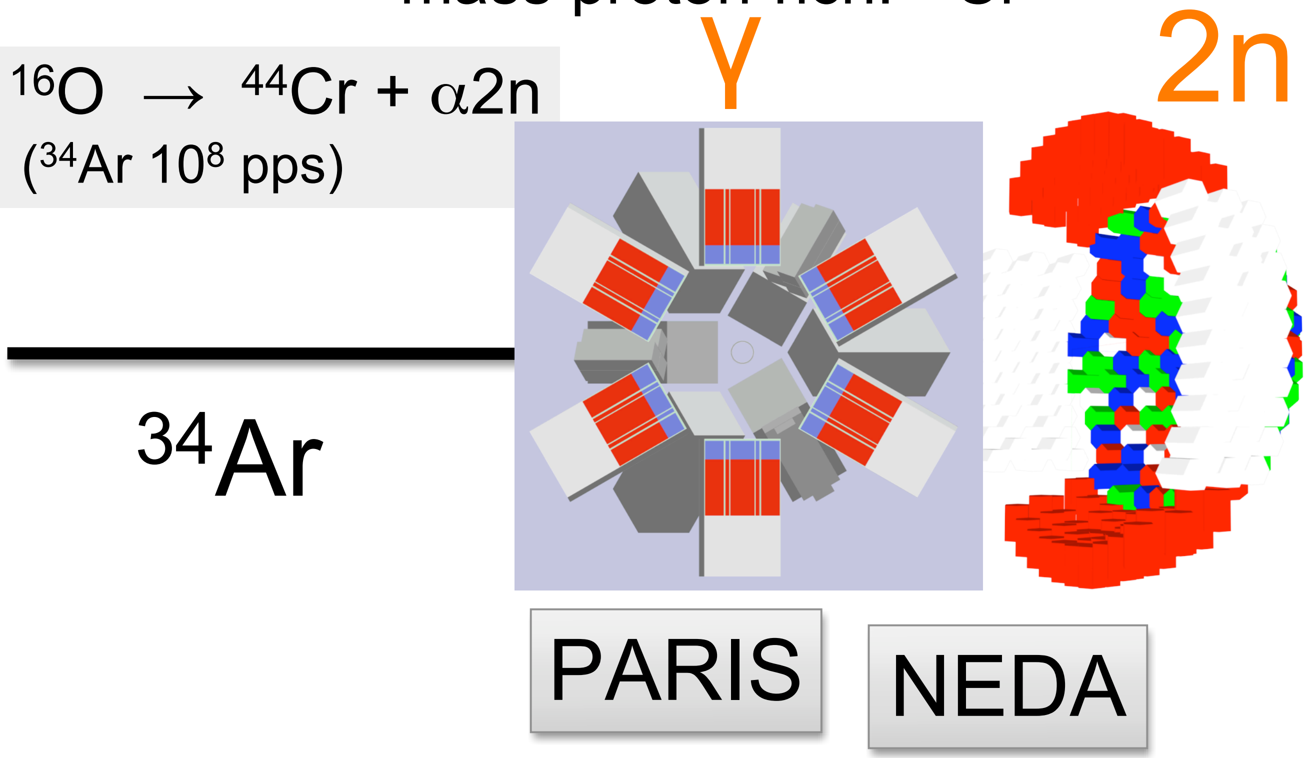
Transition densities

Experiment PARIS + NEDA

Proton pygmy dipole states develop in light and medium mass proton-rich: ^{44}Cr

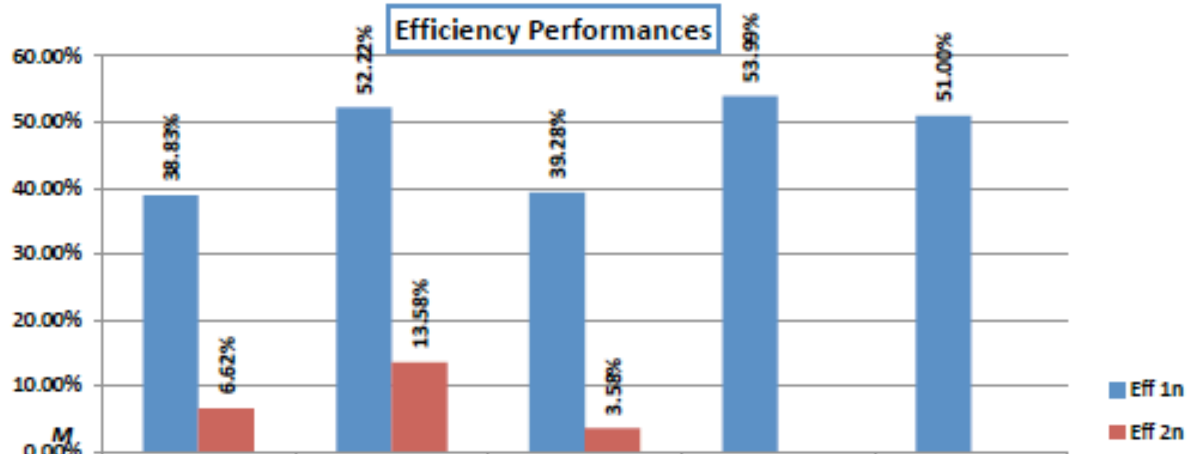
$^{34}Ar + ^{16}O \rightarrow ^{44}Cr + \alpha 2n$

(^{34}Ar 10^8 pps)



The p and n transition densities show that the PDR states correspond to the oscillation of the proton excess against and approximately isospin saturated core.

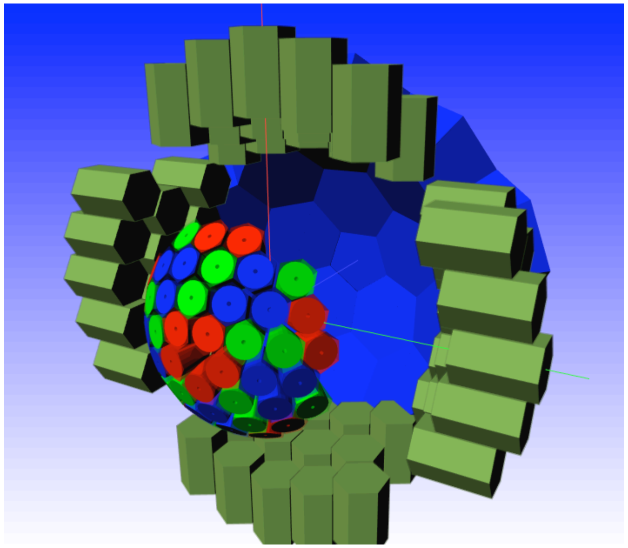
NW + NEDA



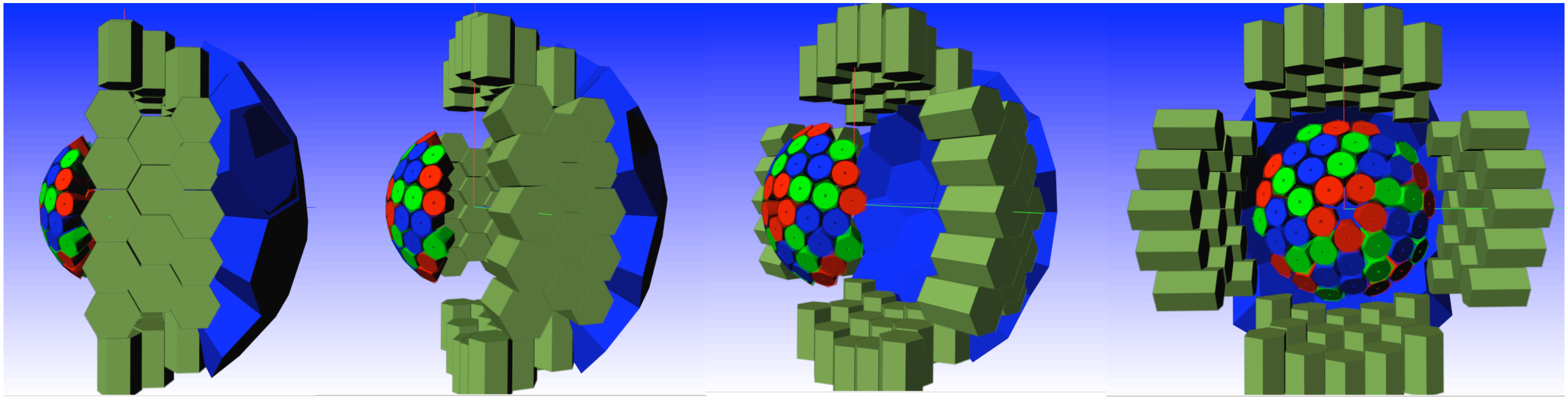
M	BC501A	BC501A	BC501A	BC501A	BC501A
Ω	0.92	1.88	1	~2	~2
AV	3	3	3.2 / 1.1	3 / 3.2 / 1.1	3 / 3.2 / 1.1
V	489	1065	149.5	419.5	317.5
N	163	355	50	140	56 + 50
R	1m	1m	0.51 m	0.75 / 0.51	0.5 m
	Staircase	Staircase 2pi	Nwall	NEDA + NWR	NEDA + Nwall

R	Distance from the origin / Radius (meter)	Simulated neutron source:	Event input file (58Ni+56Fe)
N	Granularity (Number of modules)	Depth of the detectors (NEDA):	20 cm
V	Total Volume (liter)	Neutrons were shot in 4π solid angle	
AV	Average Volume (liter)	1E+7 statistics have been recorded	
Ω	Solid angle coverage (π)		
M	Material		

NEDA + NW + AGATA

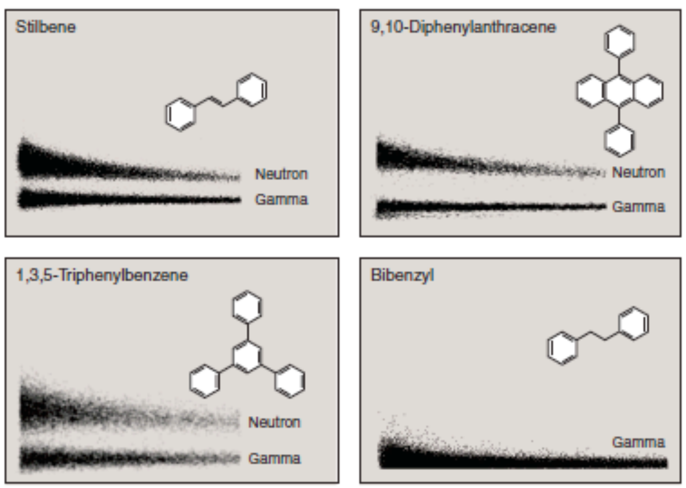


First phases – NW +NEDA coupled to a gamma ray array.



Solid scintillators for neutron detection

In the 1990s, Natalia Zaitseva developed a rapid-growth technique for producing very large crystals in record-shattering time. She now leads a team that grows organic crystals for use in fast-neutron detectors.



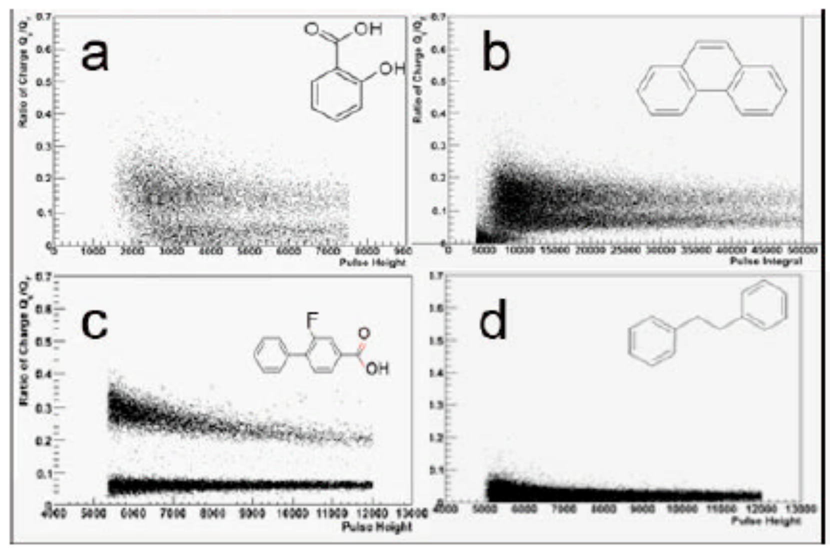
Neutron detection with single crystal organic scintillators

Natalia P. Zaitseva*, Jason Newby, Sebastien Hamel, Leslie Carman, Michelle Faust, Vincenzo Lordi, Nerine J. Cherepy, Wolfgang Stoeffl, and Stephen A. Payne

Lawrence Livermore National Laboratory, Livermore, CA

ABSRACT

Detection of high-energy neutrons in the presence of gamma radiation background utilizes pulse-shape discrimination (PSD) phenomena in organics studied previously only with limited number of materials, mostly liquid scintillators and single crystal stilbene. The current paper presents the results obtained with broader varieties of luminescent organic single crystals. The studies involve experimental tools of crystal growth and material characterization in combination with the advanced computer modeling, with the final goal of better understanding the relevance between the nature of the organic materials and their PSD properties. Special consideration is given to the factors that may diminish or even completely obscure the PSD properties in scintillating crystals. Among such factors are molecular and crystallographic structures that determine exchange coupling and exciton mobility in organic materials and the impurity effect discussed on the examples of trans-stilbene, bibenzyl, 9,10-diphenylanthracene and diphenylacetylene.



Collaboration meetings

- Three collaboration meetings + two technical meetings, where the physics, simulations and electronics have been discussed as well as the synergies with other detectors/projects such us: AGATA, GALILEO, EXOGAM2, PARIS, FARCOS, DESCANT, MONSTER, neutrons DESIR, NEUTROMANIA, etc
  - Kick off meeting - Warsaw 5/10/2007
  - Collaboration meeting - Istanbul 18/6/2009
  - Collaboration meeting - Valencia 3/10/2010
  - Technical meeting – Valencia 30/05/2011
  - Technical meeting – LNL 10/06/2011
  - Collaboration meeting – Nigde xx/xx/2012

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€

Geometries

There are two possible main geometries, either spherical or planar.

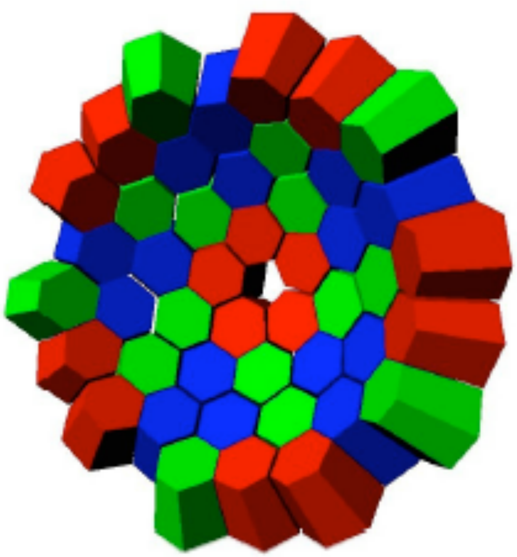
•The spherical geometry presents the full symmetry.

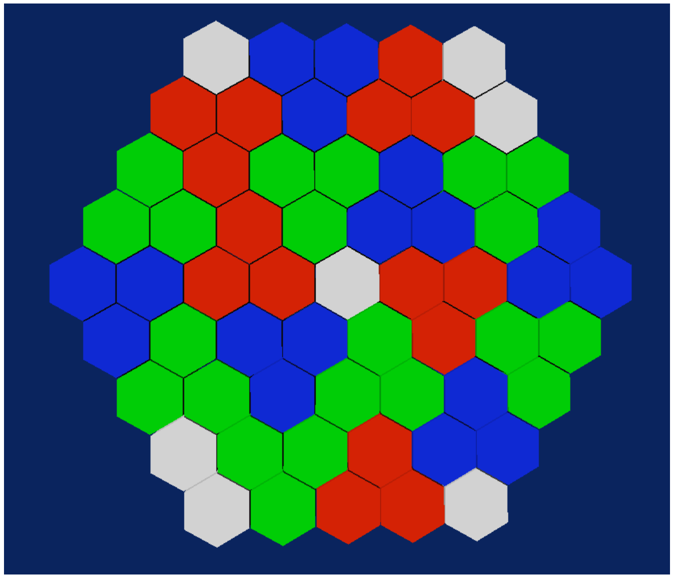
•The planar has some advantages, than the spherical does not present.

-Flexibility – different arrangements of the detectors, e.g. zig-zag

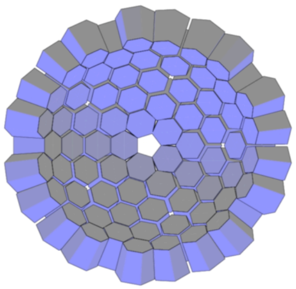
-Different focal posistions (500cm, 1000cm, 2000cm)

-Budget issues





BC501 vs. BC537 response

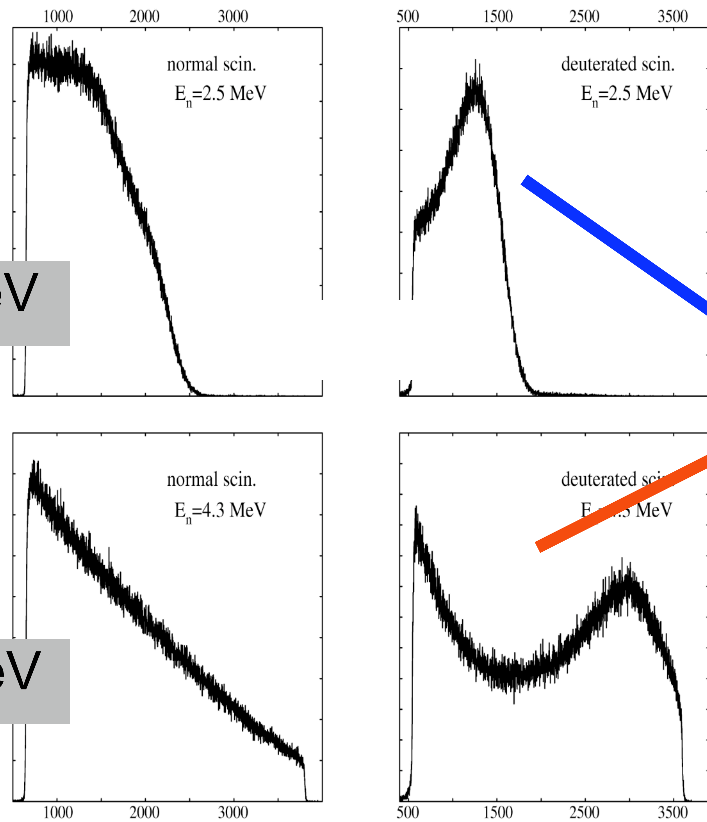


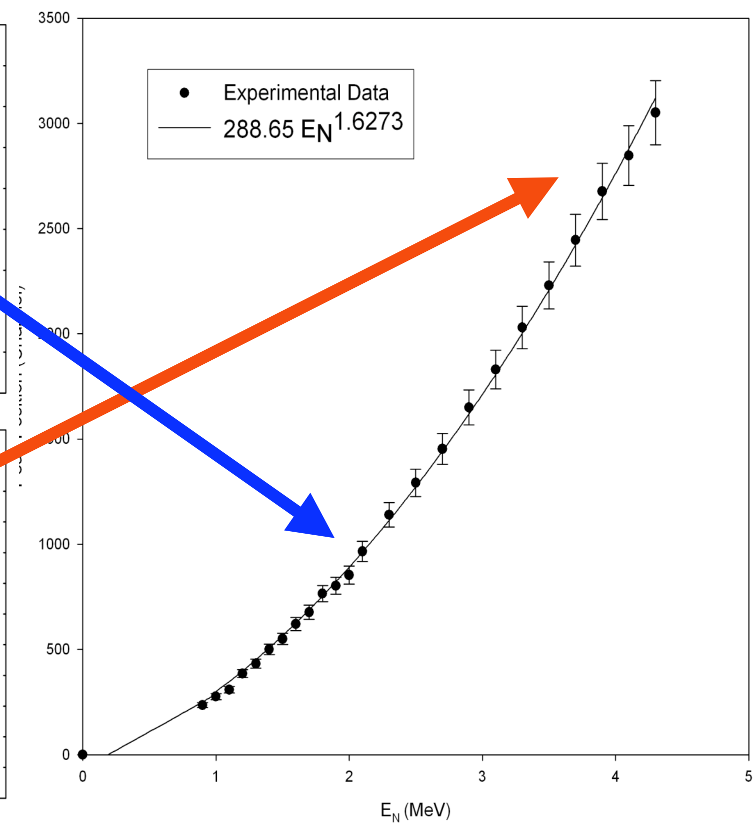
DESCANT

E_n = 2.5 MeV

E_n = 4.3 MeV

BC501 BC537

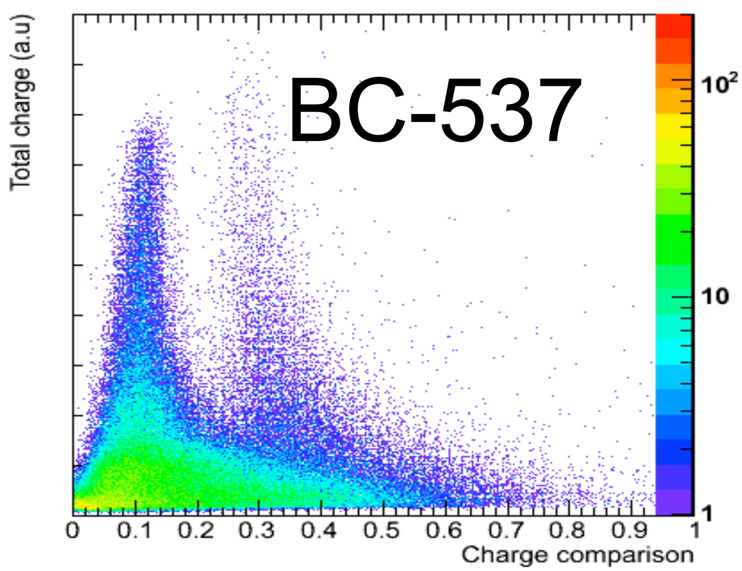


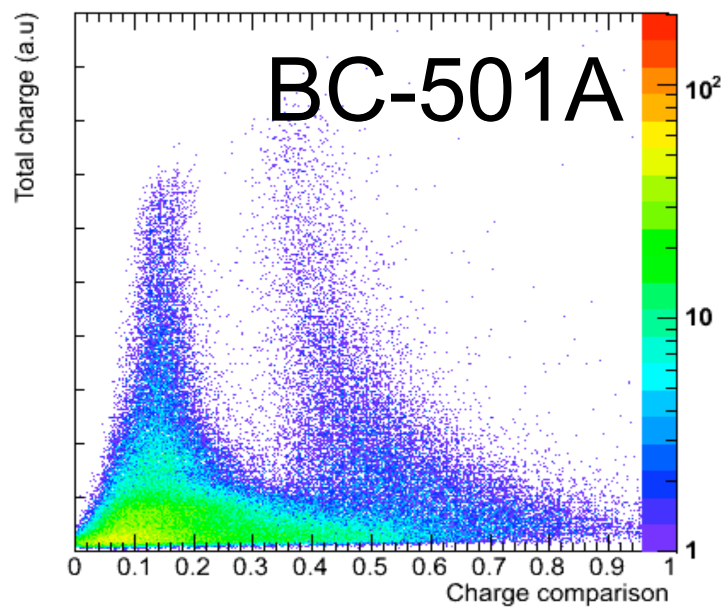


Courtesy of P. Garrett, University of Guelph.

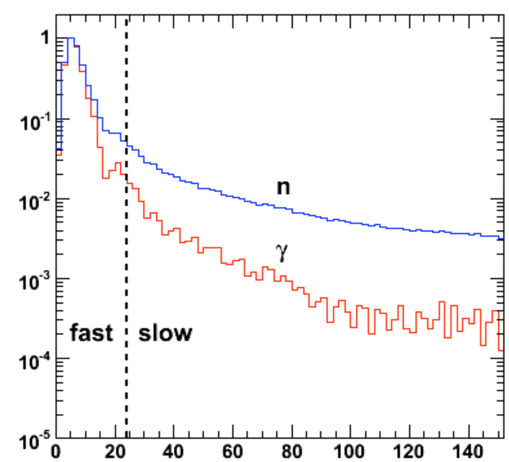
NEDA test: PSA Charge Comparison

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



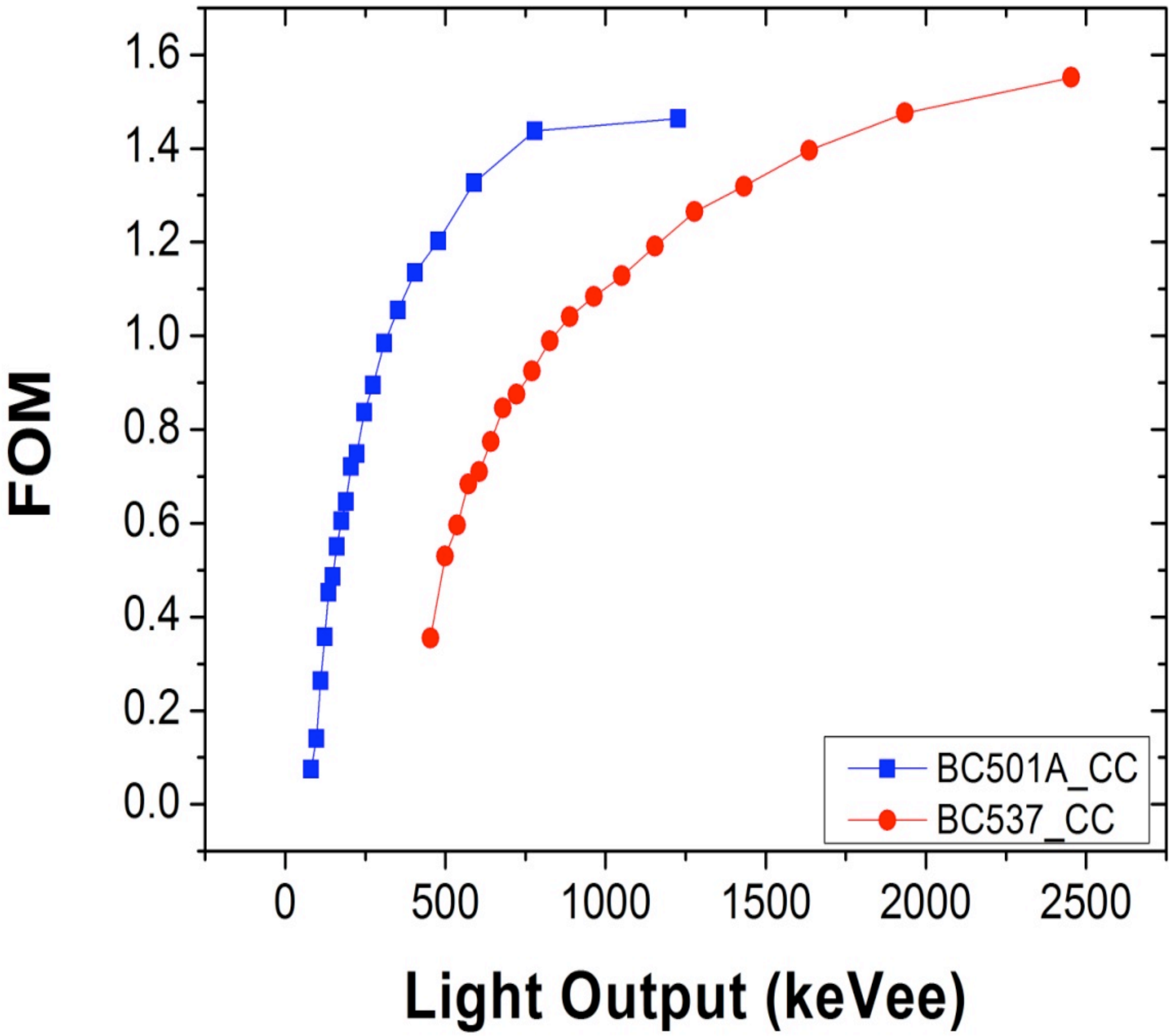


Charge comparison:
+ Very fast application time for online triggering
- Non-optimal discrimination, especially at low energies

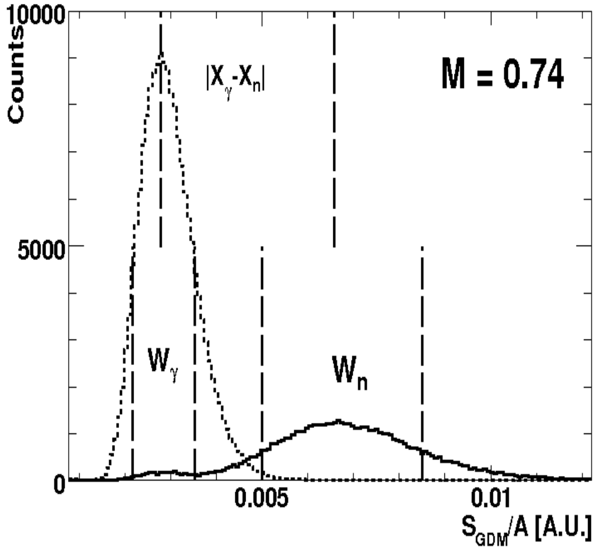


NEDA test: PSA Charge Comparison

A. Pipidis (LNL-INFN, Italy)

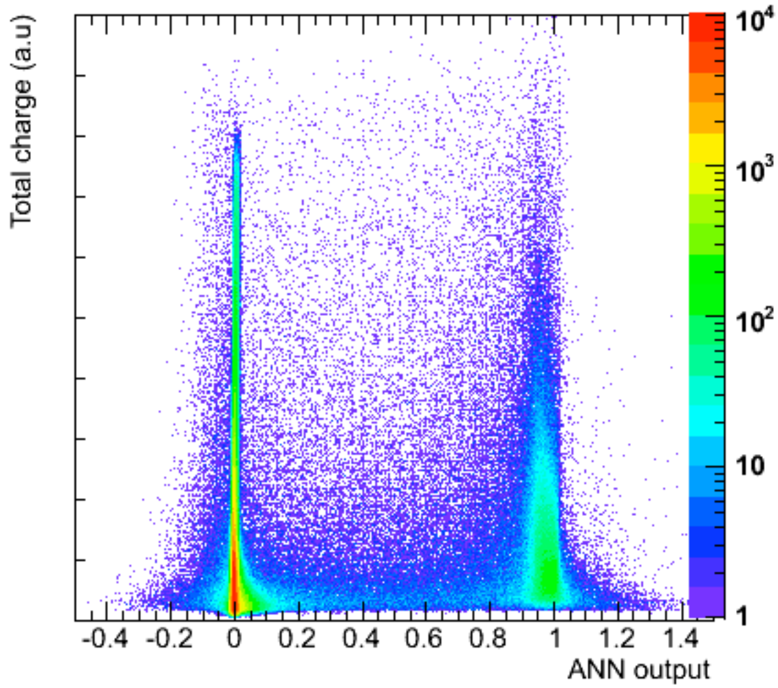


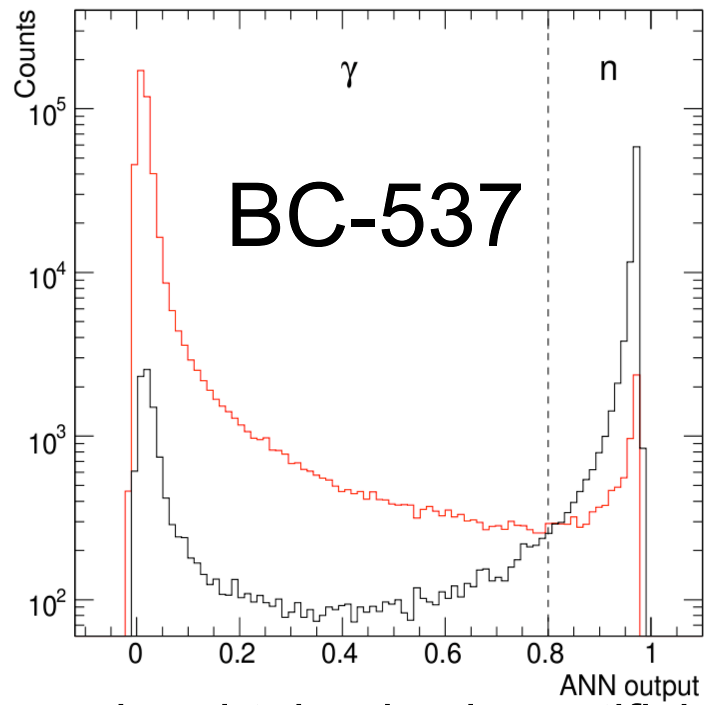
$$M = \frac{|X_\gamma - X_n|}{W_\gamma + W_n}.$$



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