NEDA (NEutron Detector Array)

J.J. Valiente Dobon (LNL-INFN)

on behalf of the NEDA collaboration

Organization

Spokeperson: J.J. Valiente Dobon (LNL-INFN)

GANIL LIASON: M. Tripon (GANIL)

Steering committee:

-B. Wadsworth (U. Of York)

-N. Erduram (U. Of Istanbul)

-L. Sttugge (IRES – Strasbodurg)

-J. Nyberg (U. Of Uppsala)

-M. Palacz (U. Of Warsaw)

-A. Gadea (IFIC - Valencia)

FP7-INFRASTRUCTURES-2007-1

SPIRAL2 PREPARATORY PHASE

INFN : coordination of the overall design, defining the parameter list.

UU, COPIN, IU, AU, NU: simulations and design: definition of the geometry, Monte Carlo simulations.

UU and IRES: tests of new materials for neutron detection.

INFN, KTH, GSI : tests of the detector performances using digital electronics

Working groups

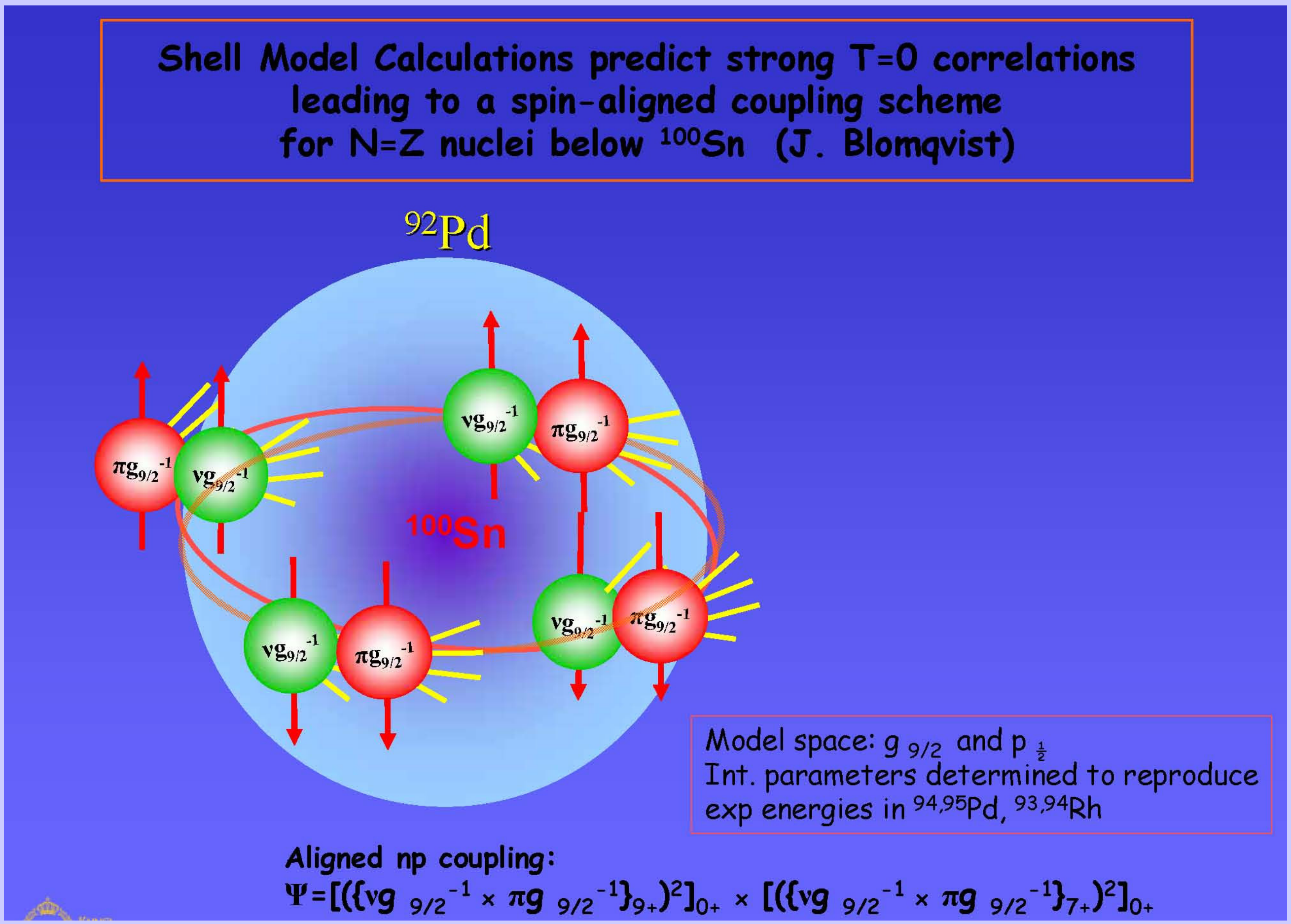
- **Detector characteristics** (Report on physics of interest, this will help to define the detector specifications).
  - *Responsible: B. Wadsworth*
- **Geometry** (Make a full study of geometry to determine (materials) efficiency, reduce cross-talk, ... Comparison between different codes: Genat4, MCNP-X. 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, commercial, EXOGAM-like electronics, ..)
  - *Responsible: A. Gadea*
- **PSA** (Simulations of Pulse shapes, PSA algorithms, ...).
  - *Responsible: J. Nyberg*
- **Synergies other detectors** (Detectors that can be considered in synergy with the new neutron wall. EXOGAM2, PARIS, AGATA, FAZIA, GASPARD, DIAMANT, DESCANT, DESPEC/HISPEC, NEUTROMANIA, ...).
  - *Responsible: P. Bednarczyk*

Physics with NEDA

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

First day experiment

Nuclear structure N=Z beyond ^{92}Pd : ^{96}Cd, etc



NEDA+PARIS experiment

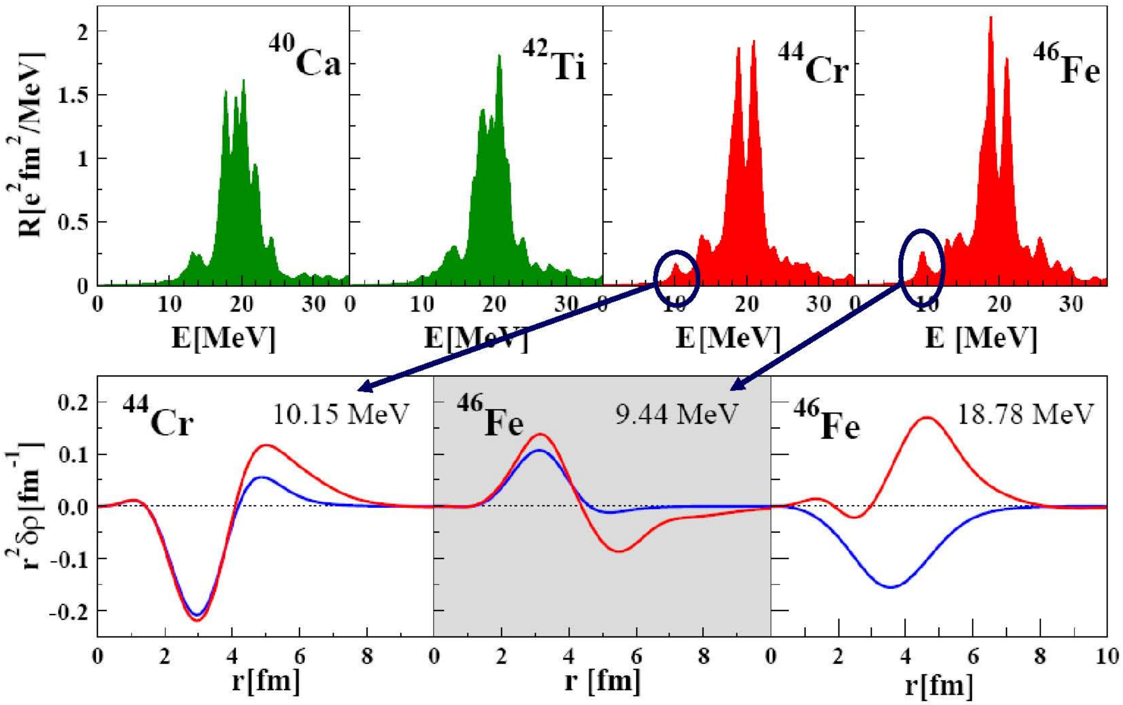
Second day experiment.

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

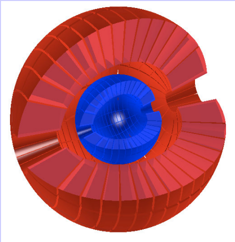
NEDA+PARIS experiment

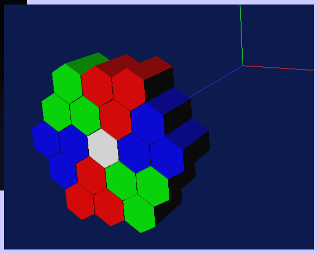
Light and N=Z RIB at SPIRAL 2

Rough Estimation of Yields (Examples)

RI Beam	Reaction	Production method	Yield (min. - max.) in pps
^{6}He	$^{9}Be(n,\alpha)^{6}He$	ISOL	$5x10^{7}$ - 10^{12}
^{11}C	$^{14}N(p,\alpha)^{11}C$	ISOL	10^{7} - $3x10^{11}$
^{15}O	$^{15}N(d,2n)^{15}O$	ISOL	$3x10^{7}$ - 10^{10}
^{18}Ne	$^{19}F(p,2n)^{18}Ne$	ISOL	$6x10^{6}$ - $7x10^{9}$
^{34}Ar	$^{35}Cl(p,2n)^{34}Ar$	ISOL	$2x10^{6}$ - $2x10^{8}$
^{56}Ni	$^{58}Ni(p,p2n)^{56}Ni$	Batch mode	$2x10^{4}$ - 10^{8}
^{58}Cu	$^{58}Ni(p,n)^{58}Cu$	Batch mode	10^{4} - 10^{8}
^{80}Zn	$^{24}Mg+^{58}Ni$	In-flight	$< 3x10^{4}$

Courtesy M. Lewitowicz





The reaction to study the Pigmy resonance in ^{44}Cr

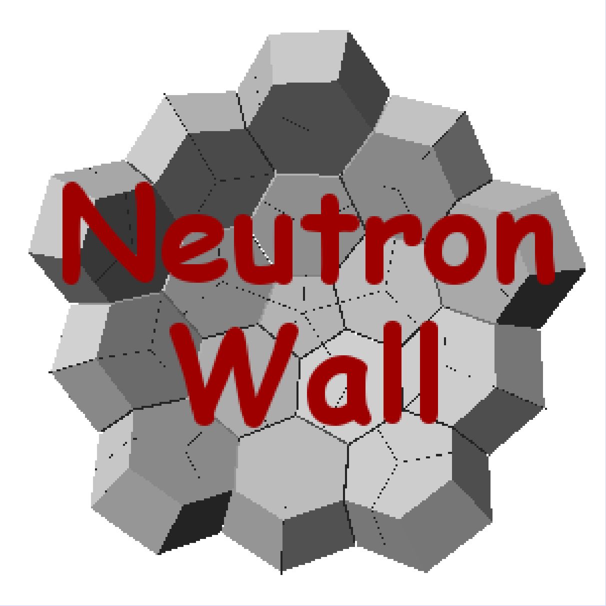
$^{34}Ar + ^{16}O \rightarrow ^{44}Cr + \alpha 2n$ (^{34}Ar 10^{8} pps)

Problem definition

-Neutron detectors to be used coupled to AGATA/EXOGAM/PARIS and if requested open to do Neutron spectroscopy (energy of the neutrons).

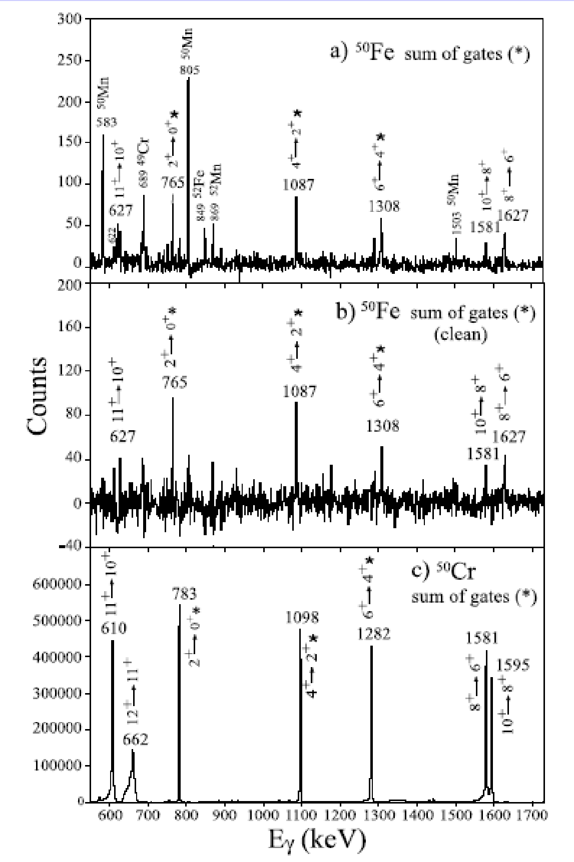
-Previous experience with the NWall (BC501)

- -High efficiency 30% for one neutron.
- -Good gamma/neutron discrimination.
- -Low efficiency for 2n (2-3%) or more neutrons.
- -Problems with cross talk



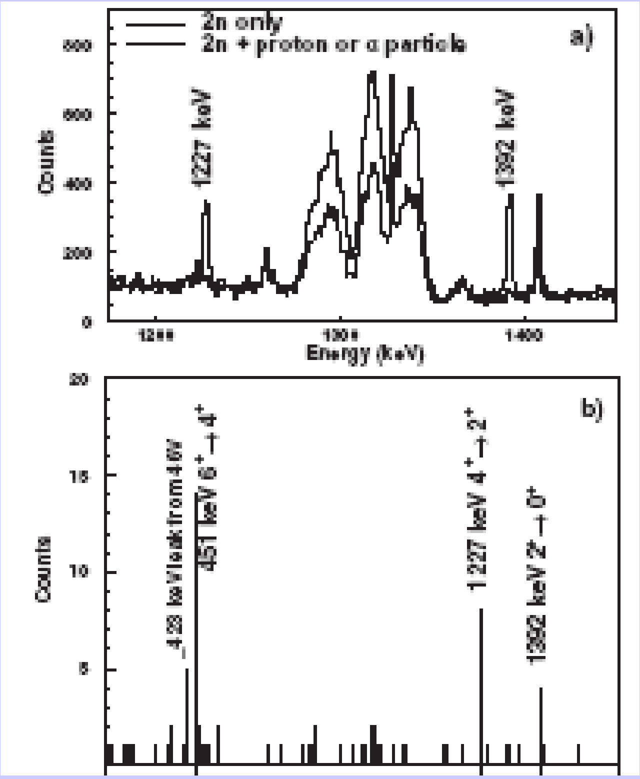
Neutron Wall: N=Z-2

$^{28}Si(^{28}Si,2n\alpha)^{50}Fe$



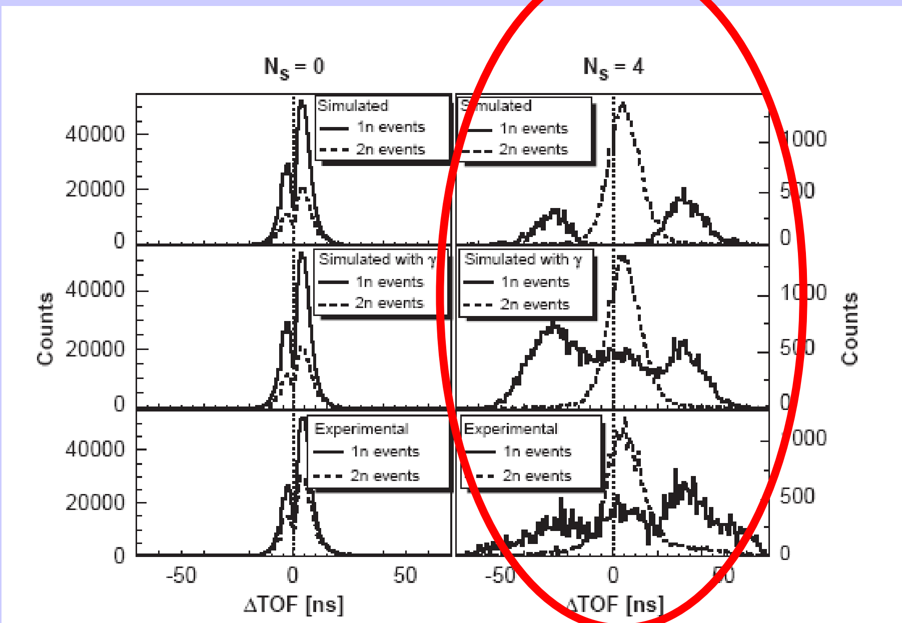
S. Lenzi et al., PRL87, 122501 (2001)

$^{24}Mg(^{32}S,2n)^{54}Ni$



A. Gadea et al., PRL97, 152501 (2006)

Cross talk – low 2n cross section



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

•High cross talk between neighboring detectors → 7% all the events.

•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 2-3%.

Possible to improve 2n efficiency using TOF among detectors

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

Strategy of NEDA

-Use of the TOF information in addition to the measured energy to disentangle the 1n scattered events from the real 2n channels

-Use of the deuterated scintillator BC537

-Pulse height proportional to incident neutron energy

-Provides another method of determinig neutron energy beyond TOF

-Can lead to a better discrimination of high multiplicity neutron events and scattered events.

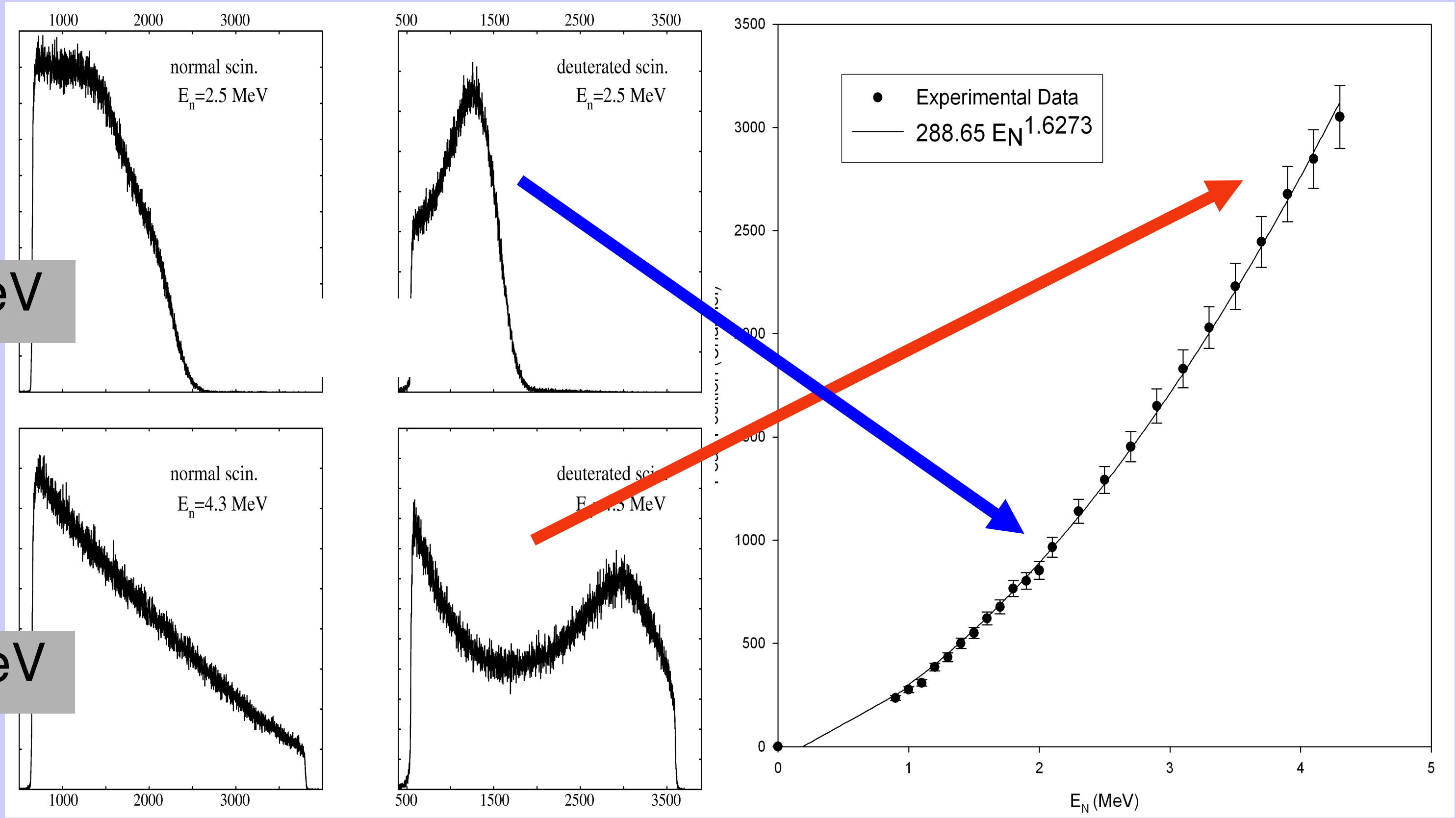
-Possible better gamma-neutron discrimination, since more events are at higher energies.

BC501 vs. BC537 response

BC501 BC537

E_n = 2.5 MeV

E_n = 4.3 MeV



Courtesy of P. Garrett University of Guelph.

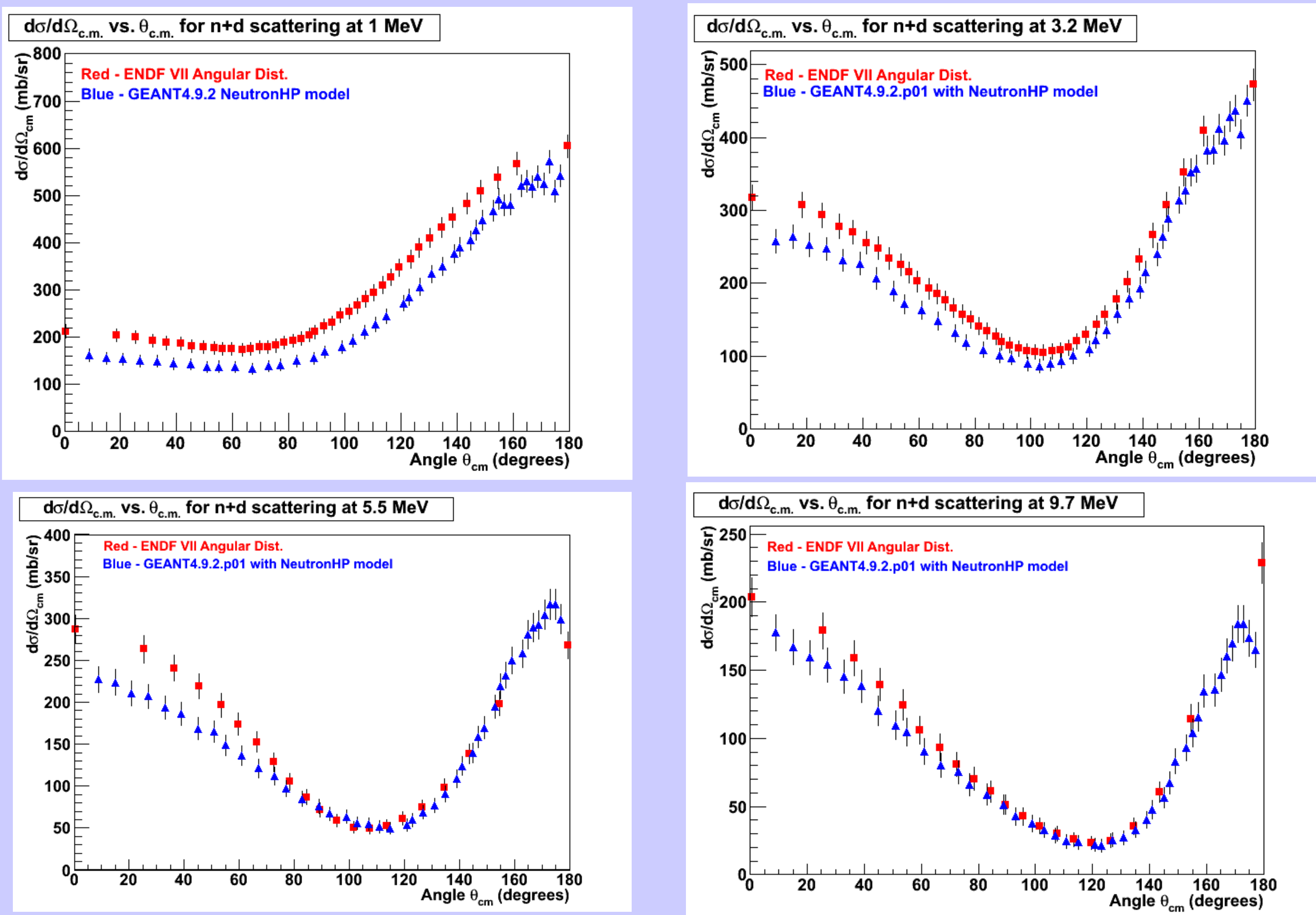
Simulations Validation

- Neutron HP model in G4.9.2.p01 (rel. March 2009) much improved comparing to earlier versions
- Total cross sections and angular distributions for elastic scattering on p, d, and ^{12}C reasonable
- Correct (high energy) γ-ray lines produced
- Inelastic interactions not fully validated yet.
  Wrong kinematics (angular distributions?) in the $^{12}C(n,\alpha)^{9}Be$ reaction.
- Important reactions still missing, like $^{12}C(n,n')3\alpha$

***Existing defficiencies* not significant in the <~10MeV energy range, which if interest for NEDA**

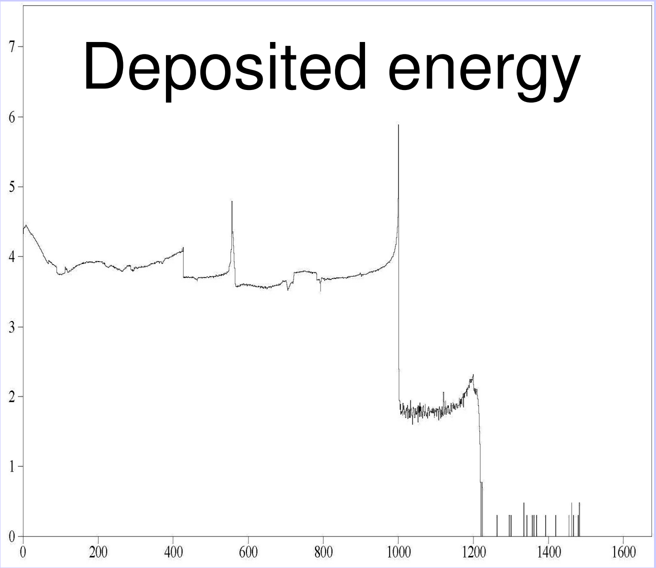
σ(θ) elastic neutron scattering on d

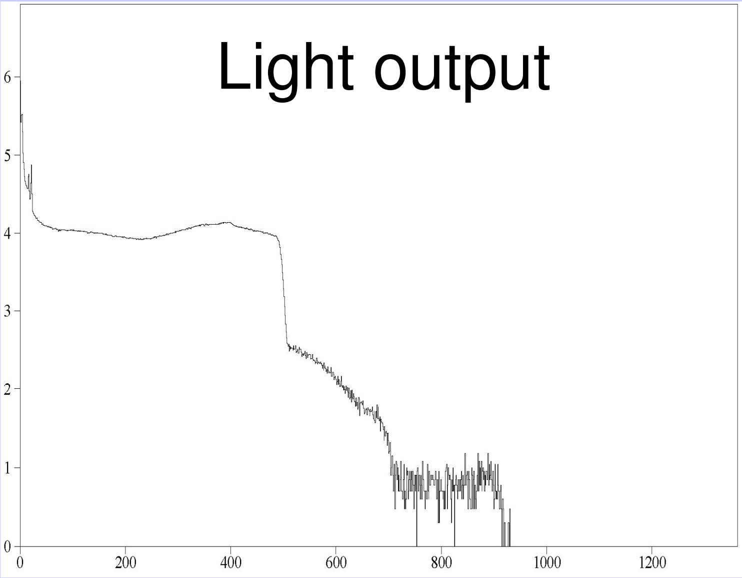
by Brian Roeder



Light output

•The light-output L is usually given in MeVee: the particle energy required to generate 1 MeVee of light is defined as 1 MeV for fast electrons
•L is generally less for heavier particles such as protons, deuterons, alphas, beryllium, carbon…
• Therefore, the light output L in a certain path *dx* is a function of the deposited energy E in *dx:* L(E)

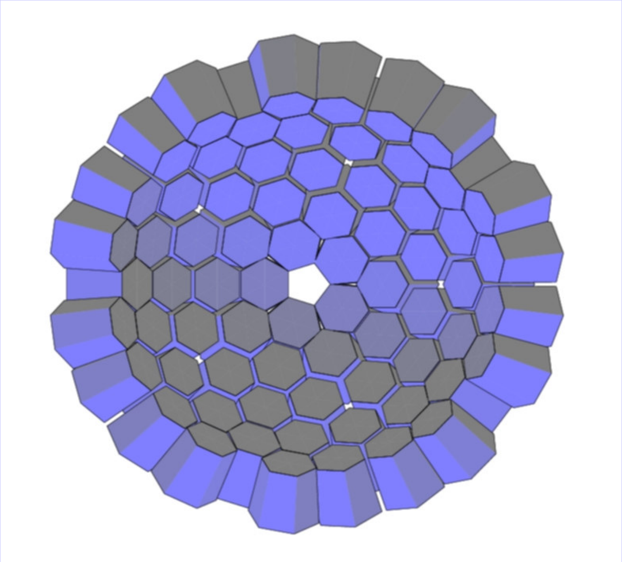




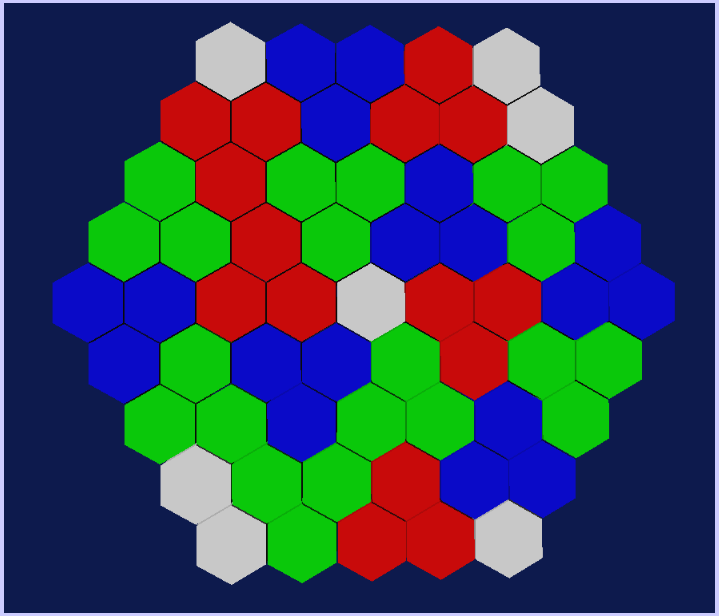
Dekempeneer et Liskien NIM A 256 (1987) 489-498: NE213

Geometries

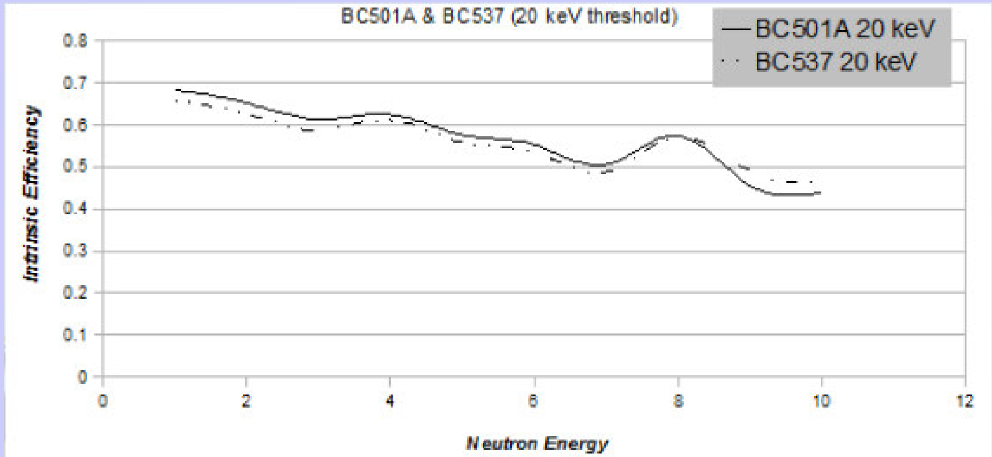
- There are two possible geometries, either spherical or planar.
- The spherical geometry presents the full symmetry.
- The planar has some advantages, than the spherical do not present.
  - -Flexibility – different possible arrangements of the detectors
  - -Different focal posistions (500cm, 1000cm, 2000cm)
  - -Budget issues

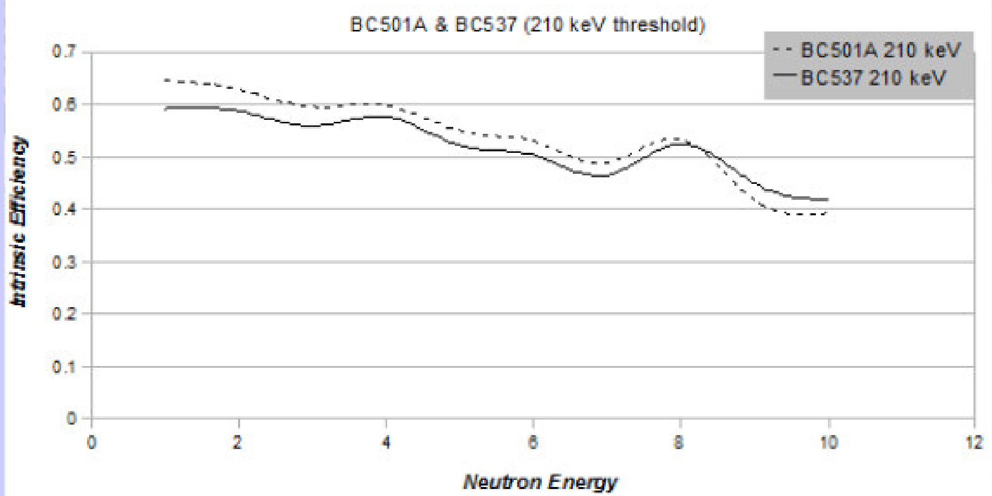


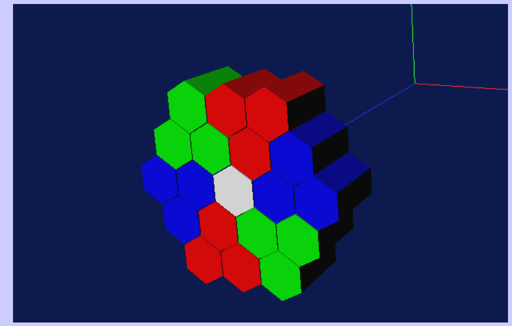
DESCANT geometry

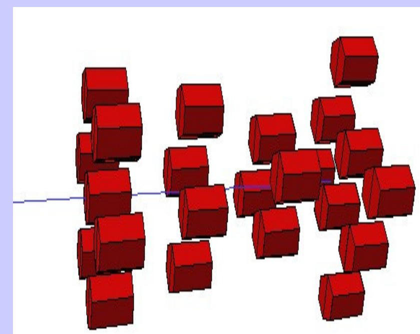


Efficiency for the planar









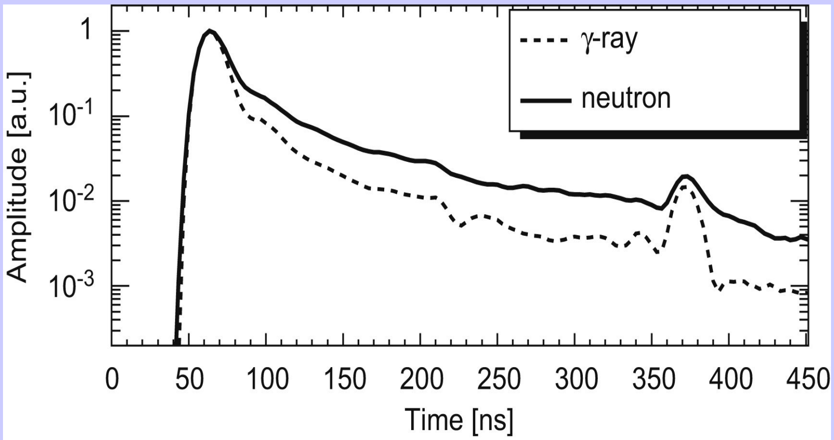
Versatility of the planar

- 2.5 mm Al encapsulation
- 159 mm depth
- .60 side lenght.

$\Delta E/E = 2\Delta t/t$

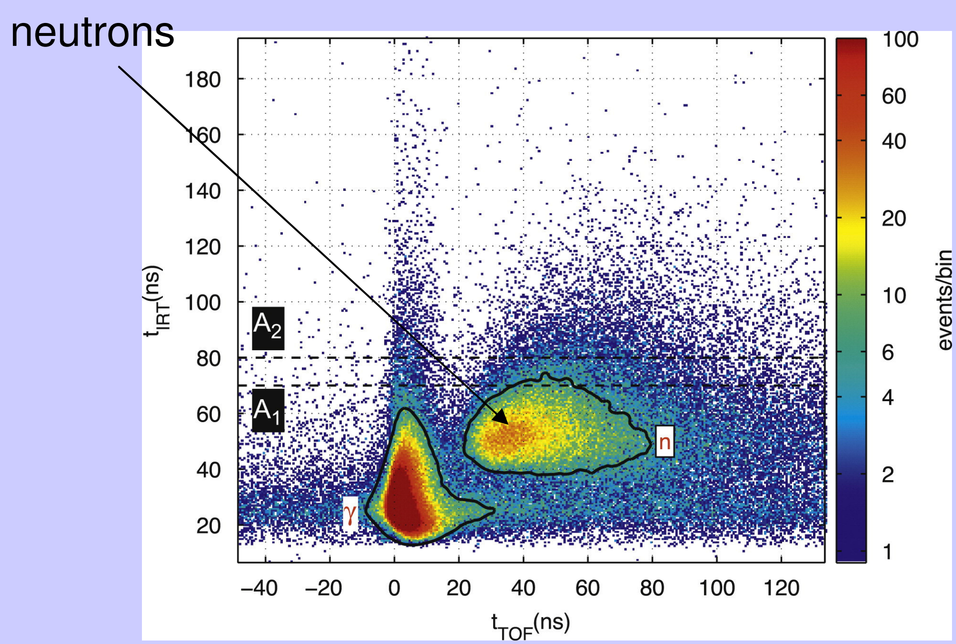
Efficiency of NEDA with 61 hexagonal detectors around 30%

Discriminating neutron/gamma



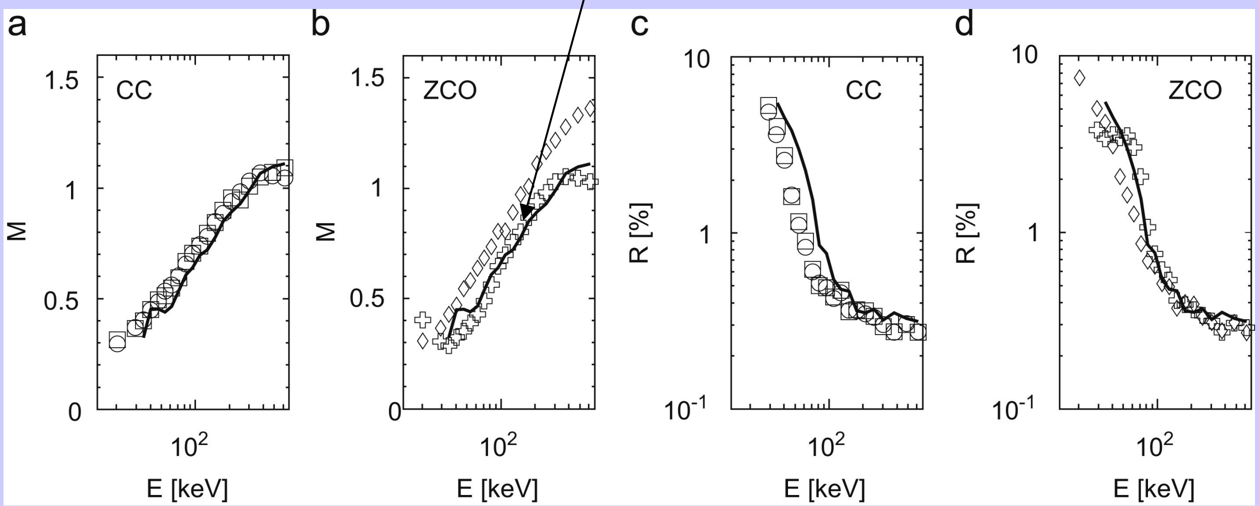
- Pulse shapes from the detector differs between neutrons and gamma rays

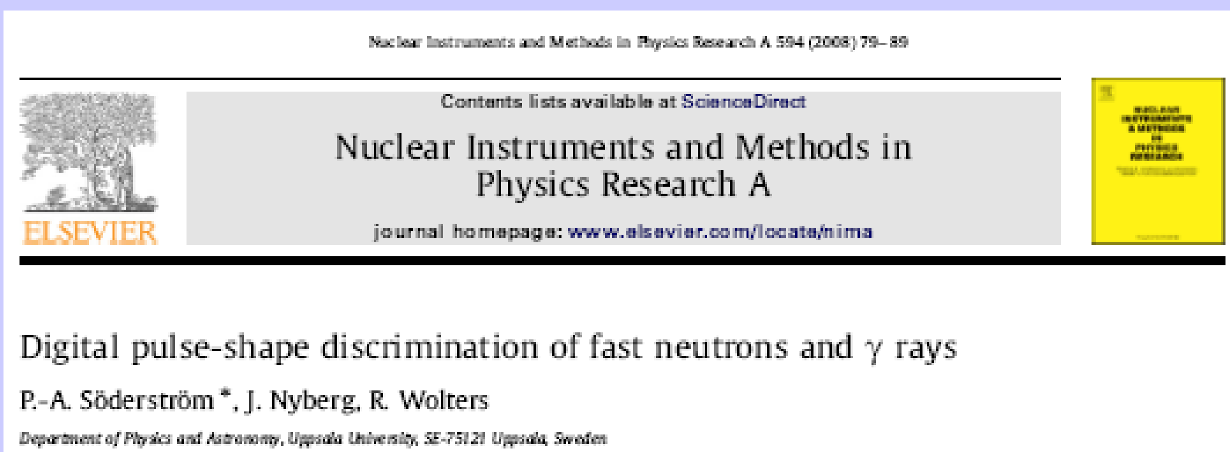
- Usually both pulse shape analysis using analogue electronics and the time-of-flight information is used for discrimination



Digital electronics: PSA

It is possible to obtain better quality using same algorithms but digital electronics





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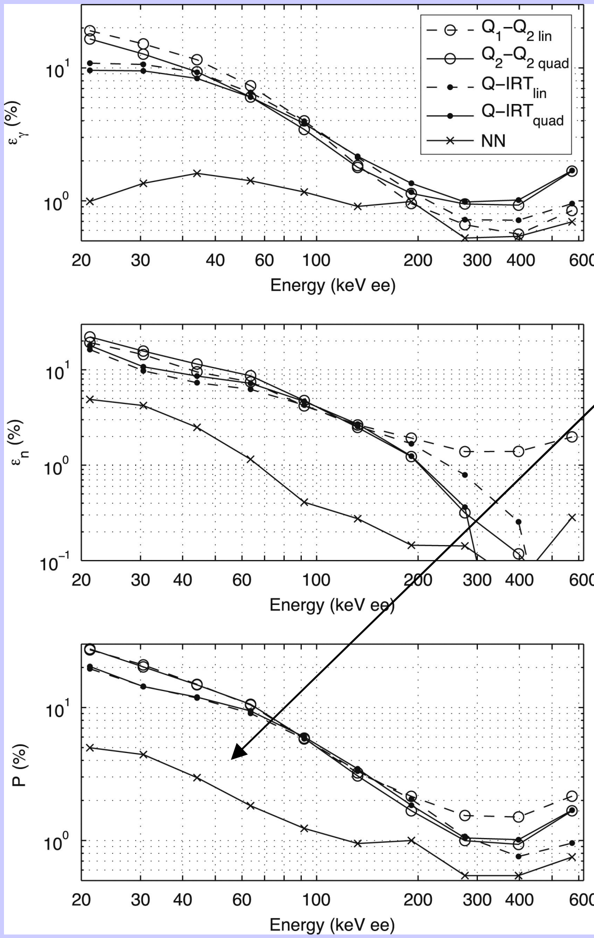
ELSEVIER

Digital pulse-shape discrimination of fast neutrons and γ rays

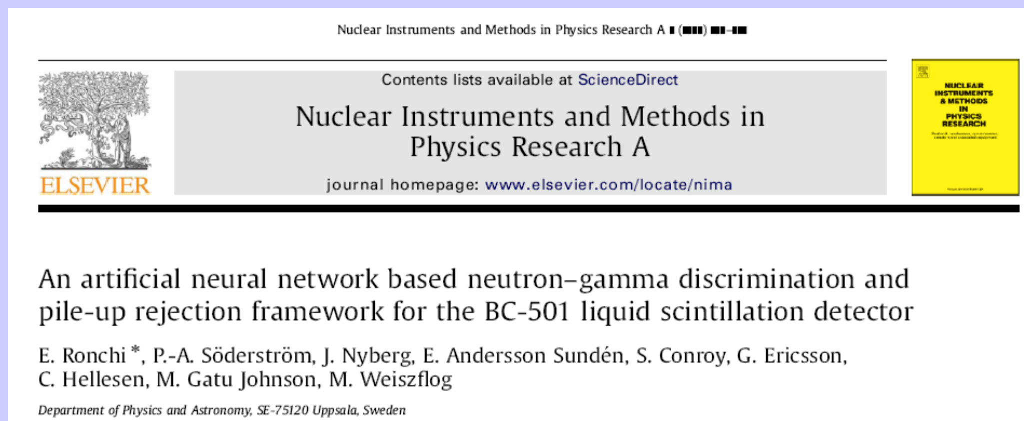
P.-A. Söderström *, J. Nyberg, R. Wolters

Department of Physics and Astronomy, Uppsala University, SE-75121 Uppsala, Sweden

Digital electronics: Neural Network



- Applying an artificial neural network can increase the quality even further



Nuclear Instruments and Methods in Physics Research A ∎ (∎∎∎) ∎∎–∎∎
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ELSEVIER

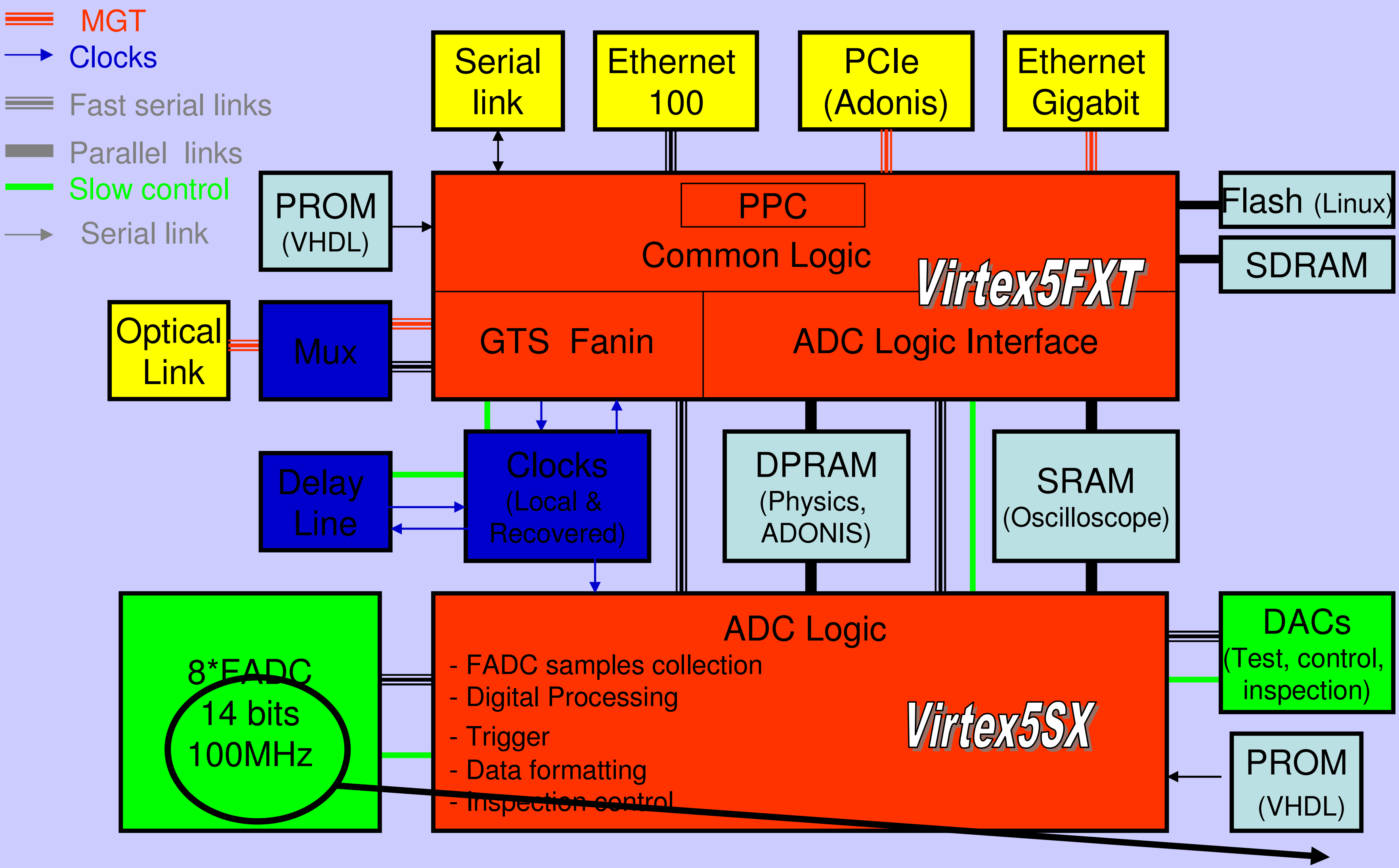
An artificial neural network based neutron–gamma discrimination and pile-up rejection framework for the BC-501 liquid scintillation detector

E. Ronchi *, P.-A. Söderström, J. Nyberg, E. Andersson Sundén, S. Conroy, G. Ericsson, C. Hellesen, M. Gatu Johnson, M. Weiszflog
Department of Physics and Astronomy, SE-75120 Uppsala, Sweden

$$P=\mathrm{sqrt}(\varepsilon_n^2+\varepsilon_\gamma^2)$$

Digital electronics: EXOGAM - NEDA

M. Tripon



The basic diference EXOGAM/NEDA is the higher frequency of the ADC

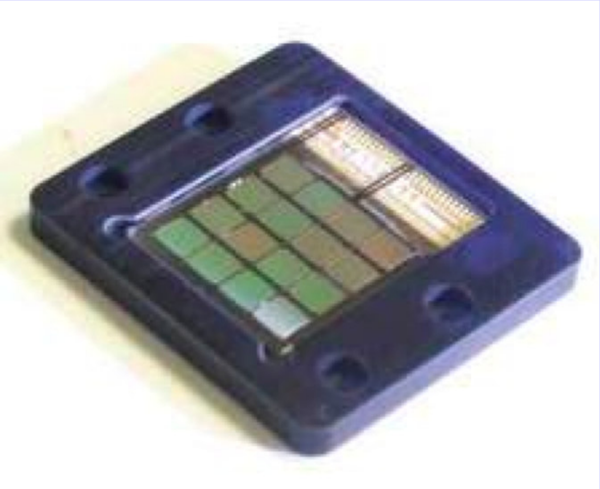
Commercial electronics: Struck

4 channel VME digitizer/transient recorder with a sampling rate of up to 500 MS/s (for the individual channel) and 12-bit resolution

Programmable FPGAs

Avalanche Photodiodes

SPMPlus



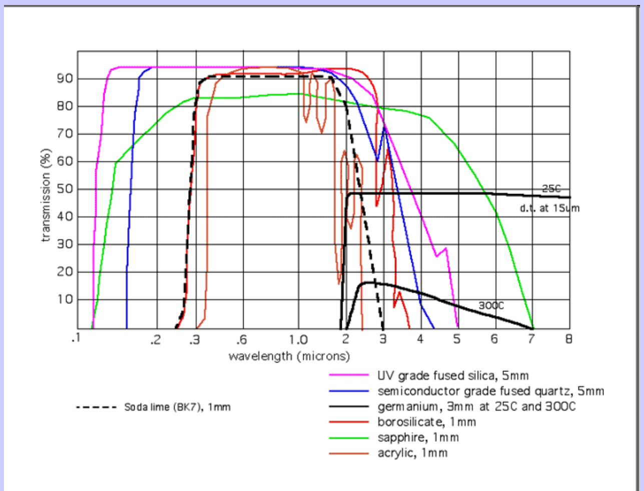
- Direct replacement for photomultiplier tube
- Insensitive to magnetic fields
- Can operate in vacuum
- Large sizes possible
- Attractive for simultaneous PET and MRI scanning
- Gain stabilisation as function of temperature must be achieved

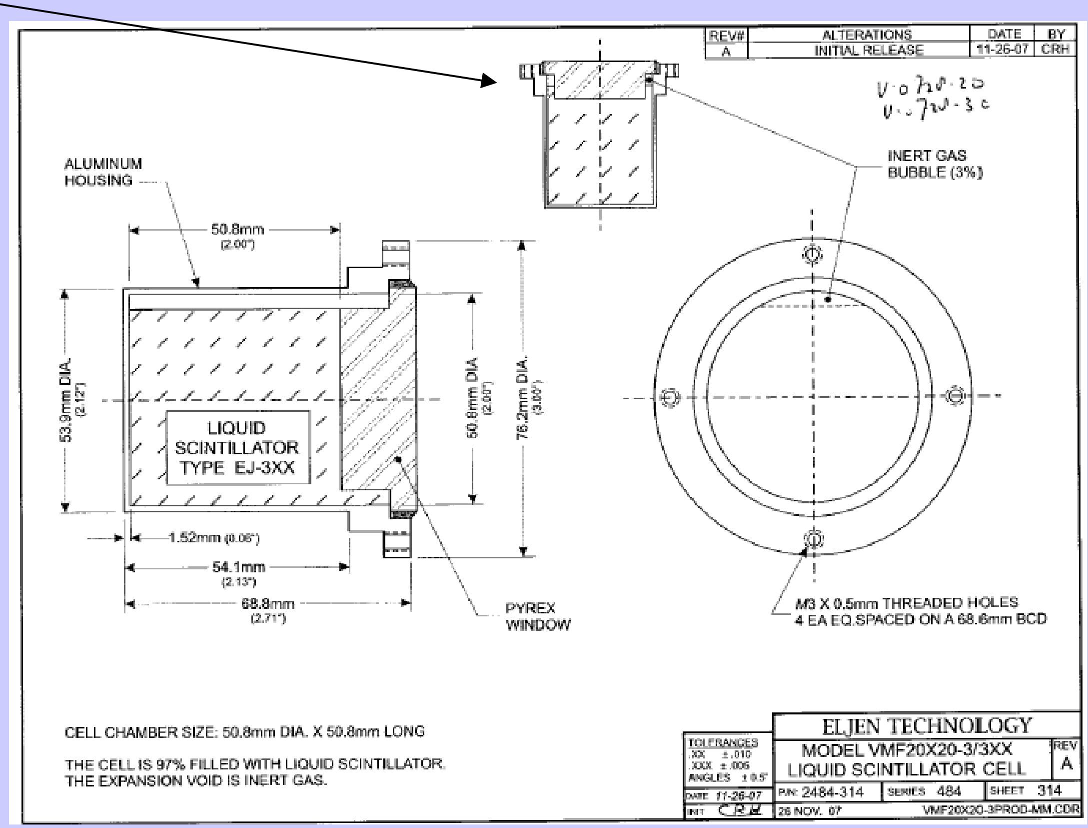
Synergy with PARIS – D. Jenkins

BC501 and BC537 detectors

Currently buying commercial detectors for tests: ELJEN, BICRON?

Quartz window





ELJEN technology

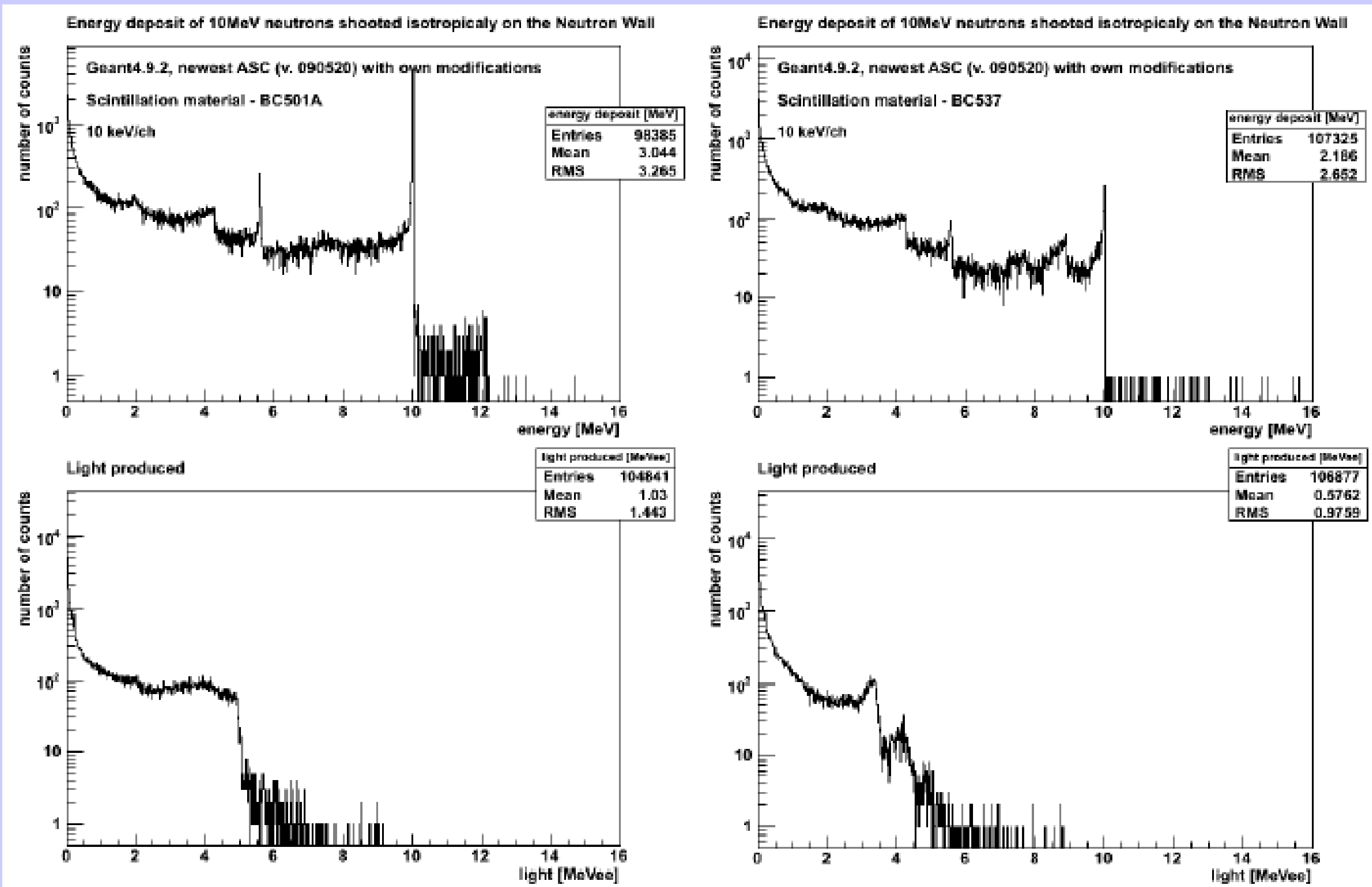
Summary and future work

- NEDA – Looks at improving efficiency for 2n channels – BC537
- Validated simulatons – realistic results for BC501 and BC537
- Included light production according to latest measurements
- PSA algorithms to discriminate neutron-gamma – Neural Network great perspectives.
- Synergies – PARIS: Physics and SPMPlus - EXOGAM: electronics

FUTURE WORK

- Currently buying BC537 and BC501 commercial detectors to test:
  - cross talk
  - light production
  - PSA
- Test of SPMPlus from York in BC537 and BC501 Soon?
- Development of electronics and currently buying a commercial Struck digital board – programmable FPGA

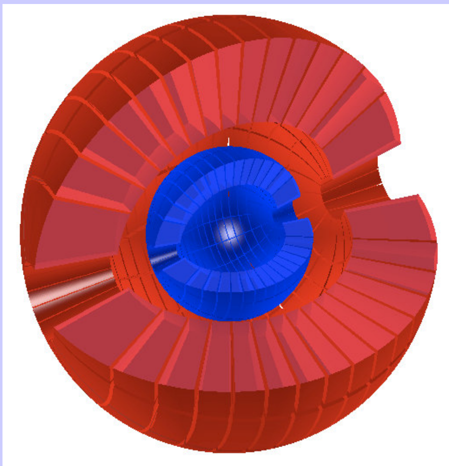
Light output



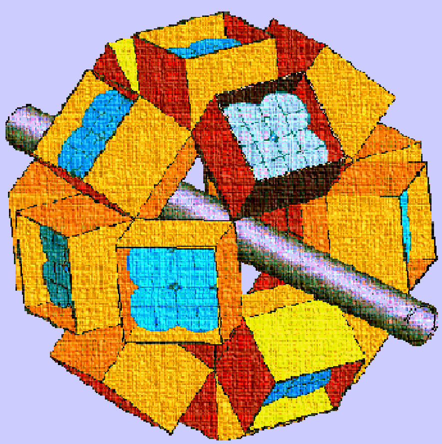
Time scale

	2008	2009				2010		
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Validation GEANT4 neutorn simulations								
Geometry definition								
Digital algorithms for PSA								
Detector prototype								
Test prototype								
Electronics								
Negoziations MoU								
MoU signature								

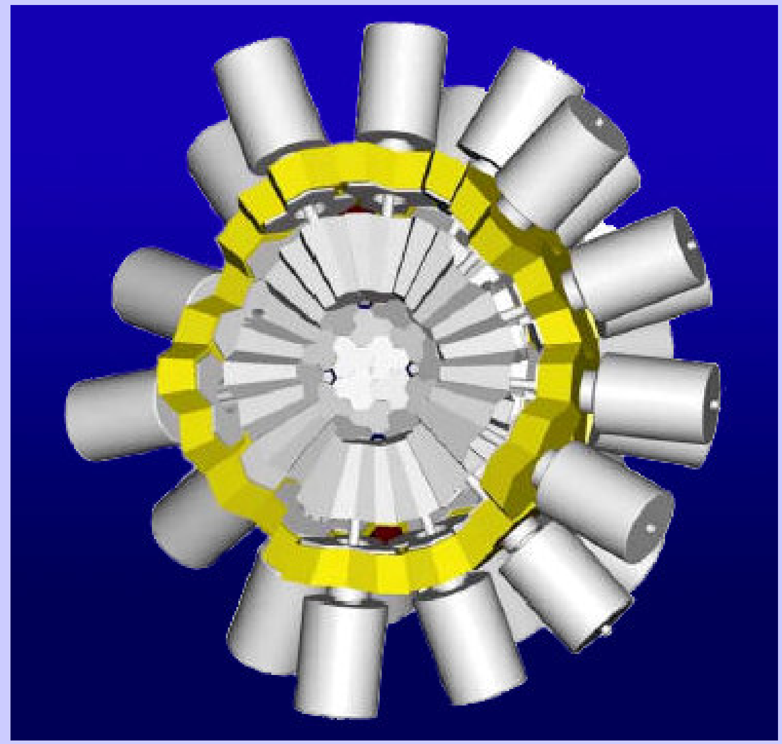
Synergies



PARIS



EXOGAM array



ADVANCED GAMMA TRACKING ARRAY