On the edge of neutron detection

- innovative NEDA tests

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The goal of the NEDA project:
to build the neutron array which will have neutron detection efficiency larger then the Neutron Wall?

ε(1n) ≈ 40% (20-25%),
ε(2n) ≈ 6% (1-3%),
ε(3n) ≈ 1% (0.1 %),

BC501A (proton-based) and BC537 (deuterated) scintillators considered

4 geometrically identical detectors bought by NEDA – 2x BC501A and 2x BC537, 5”x5” cylinders - unique opportunity for experimental comparison

Aims of the tests:

→ to optimise digital PSD techniques: NGD and time resolution;

→ to measure efficiency, x-talk, time resolution, NGD capabilities for BC501A / BC537;

→ to determine minimum sampling frequency for digital ToF;

→ to check light to neutron energy dependence.

NEDA test setup

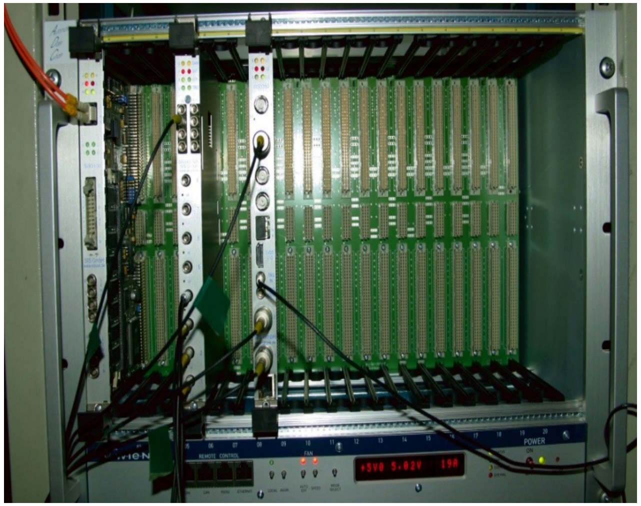
The tests were performed at LNL.

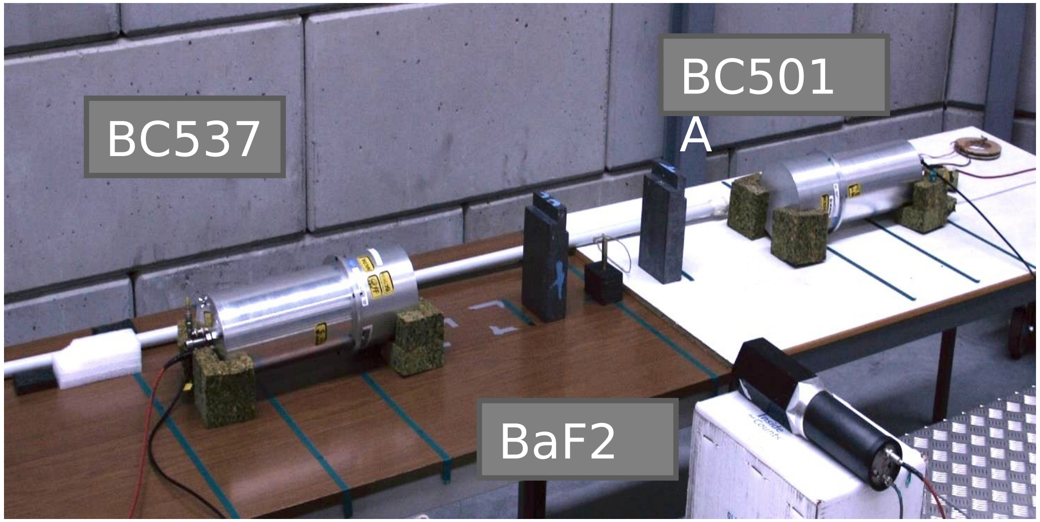
Measurements with pairs of detectors placed 1 m from ^{252}Cf source.

BaF_2 used for timing purposes.

2 x BC501A (5” x 5” cylindrical test detector)
2 x BC537 (5” x 5” cylindrical test 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





Results of the tests:

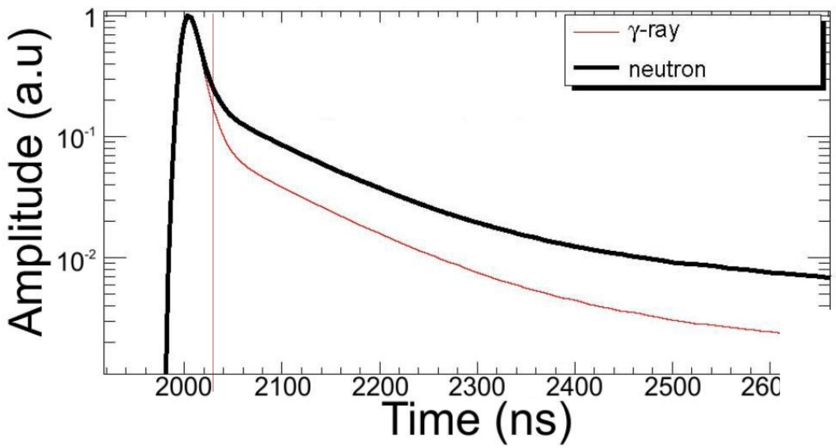
→ efficiency measured: proton based scintillator is ~22% more efficient;

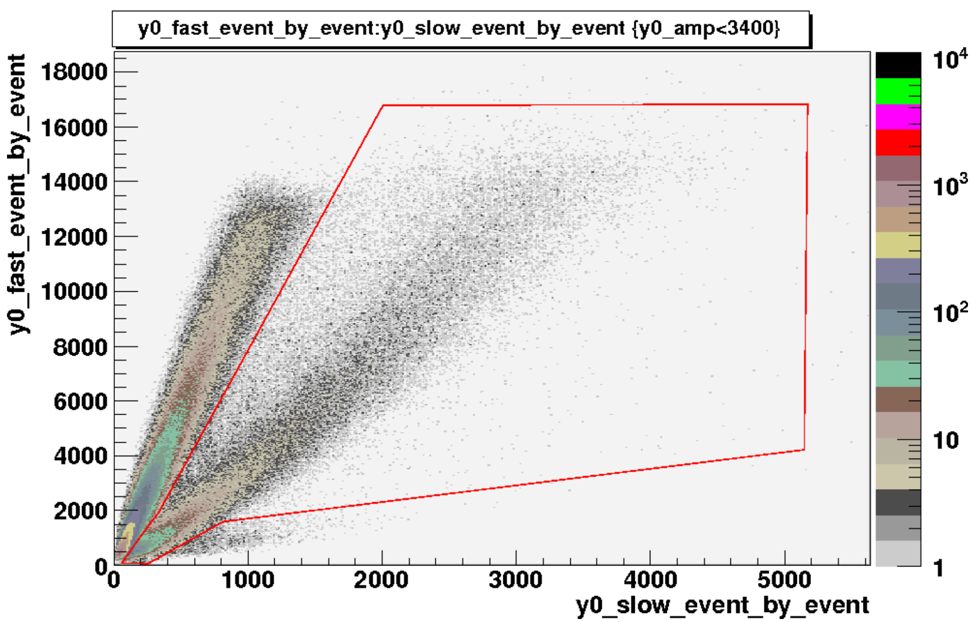
→ different n/γ discrimination techniques studied;

→ time resolution investigated;

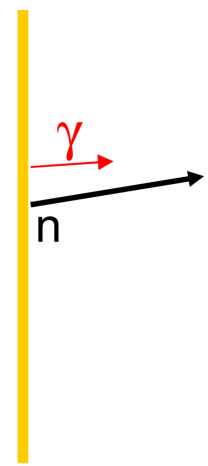
Digital n-γ discrimination

Charge comparison method





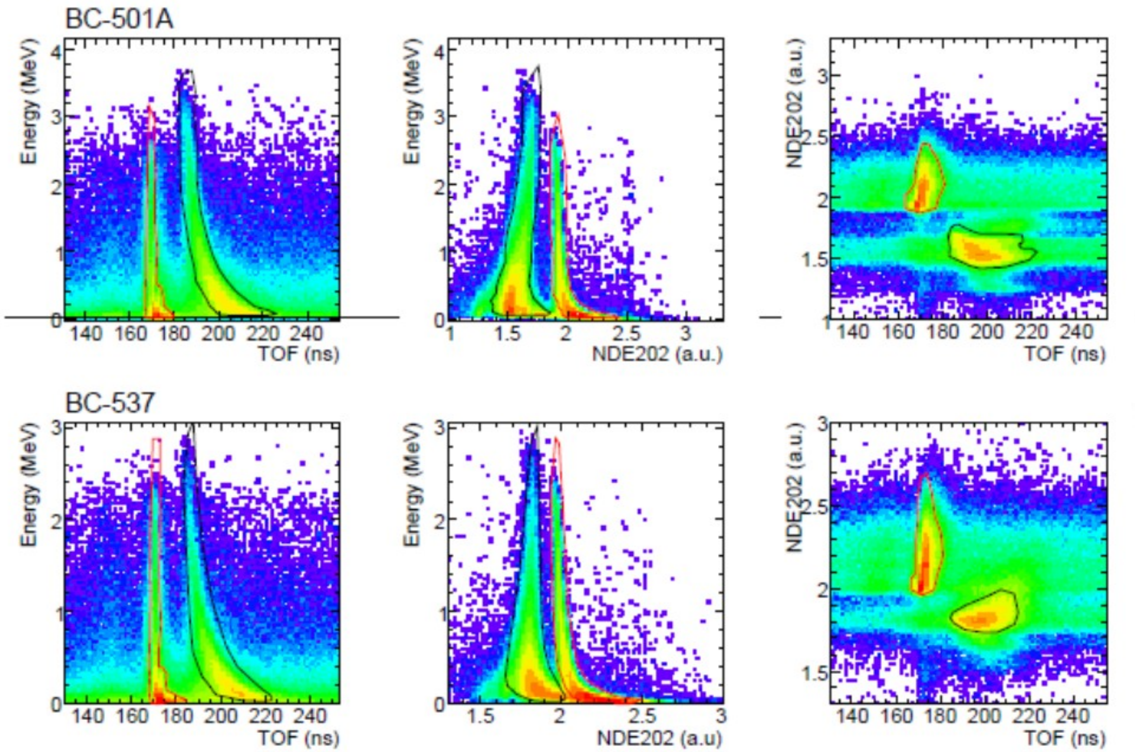
Integrated rise time



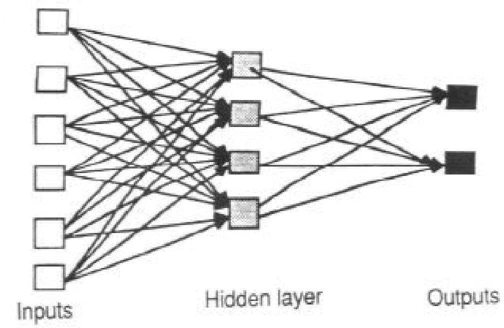
72%

10%

Artificial Neural Network

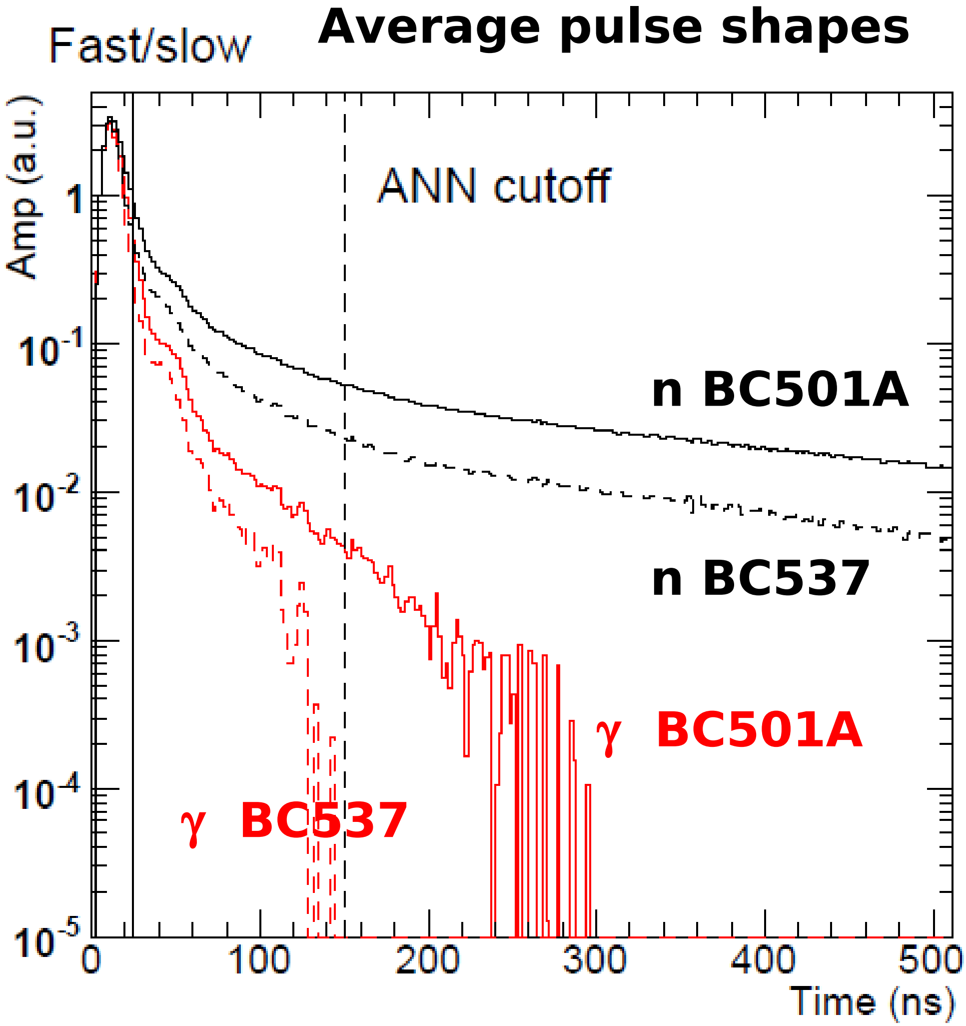


Trained on the waveforms gated on analog signals.



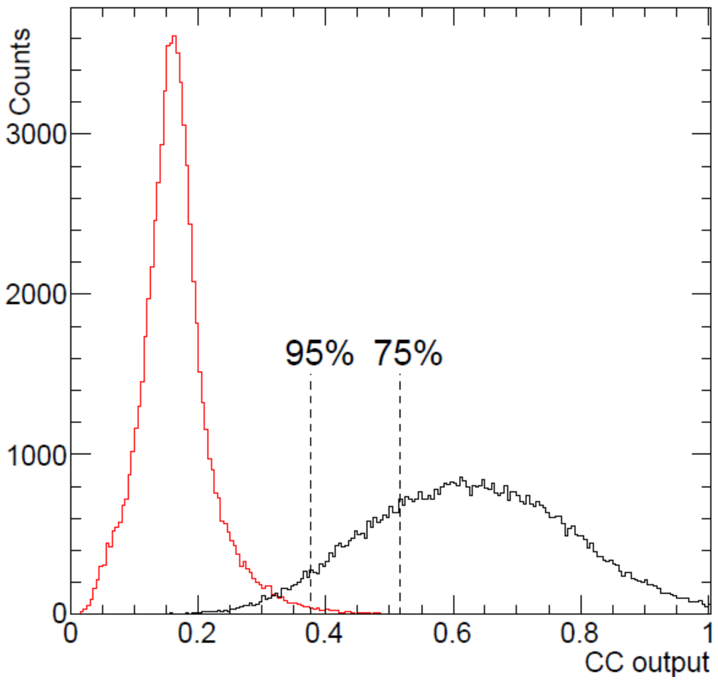
- 75 signal probes – 2 ns distance, first 150 ns of the signal;
- 2 hidden layers: the first made of 20 nodes, the second 5 nodes;
- One output with a value in the interval 0-1 (0= gamma-rays, 1= neutrons)
- Networks for the two scintillators trained separately, using 1e5 signals (≈ 50% neutrons) each

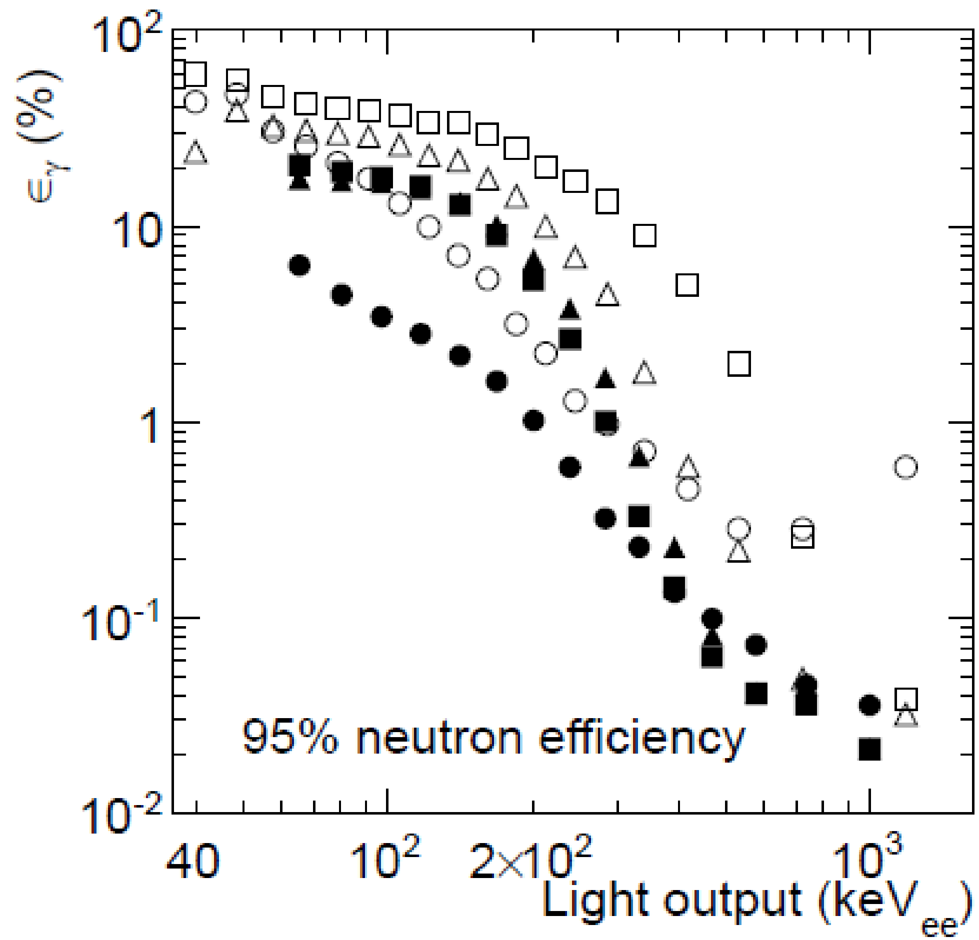
Signals from the two scintillators



by P-A. Söderström

Neutron – gamma discrimination – comparison of the methods





■ ANN

● CC

Δ IRT

BC501A

BC537

by P-A. Söderström

Summary:

→ BC501A more efficient by ~22%;

→ digital PSD better then analog methods;

→ BC537 gives less light, thus NGD algorithms works worse;

→ so far only off-beam analysis;

→ best NGD obtained with ANN.

TODO:

→ time resolution with digital techniques;
→ light to energy correlation;
→ scattering between detectors.

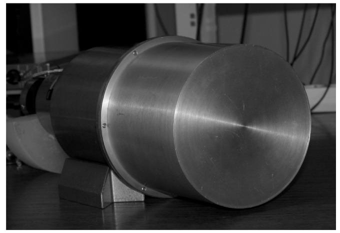
Collaborators

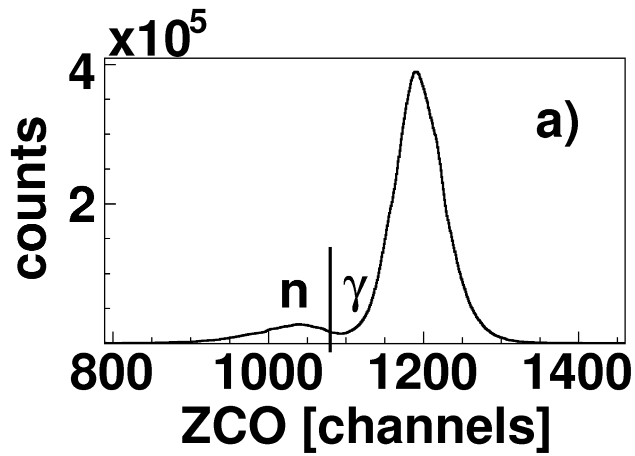
J. Agramunt Ros, G. de Angelis, M. Clement, G. de France, A. Di Nitto, J. Egea, N. Erduran, S. Erturk, E. Farnea, A. Gadea, V. Gonzalez, T. Hüyük, J. Nyberg, M. Palacz, B. Roeder, P.-A. Söderström, E. Sanchis, R. Tarnowski, A. Triossi, R. Wadsworth, J.J. Valiente Dobon and G. J.

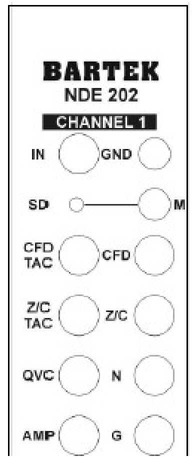
Thank you for your attention.

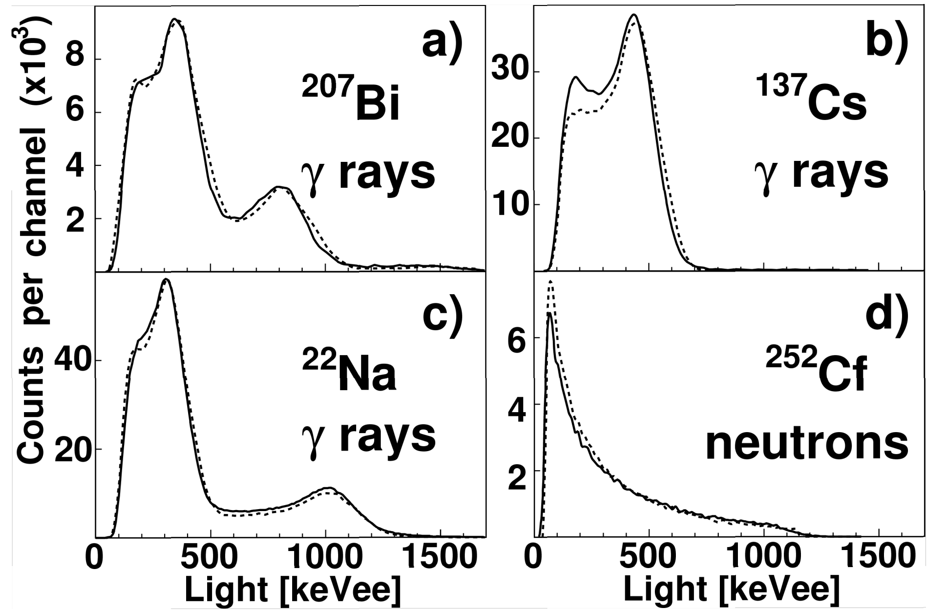
it's good for you!

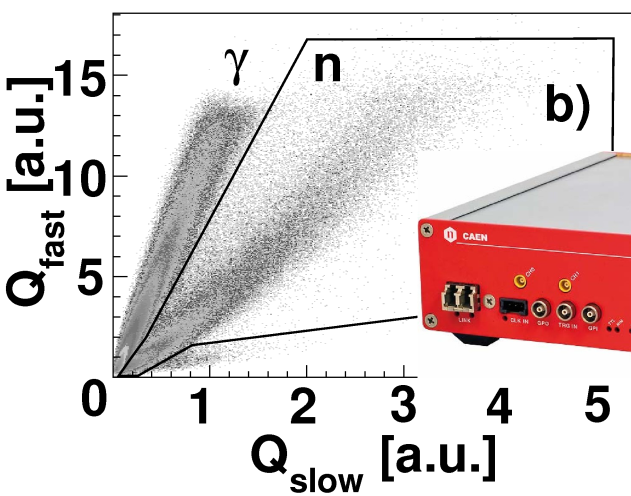
Validation of the simulations





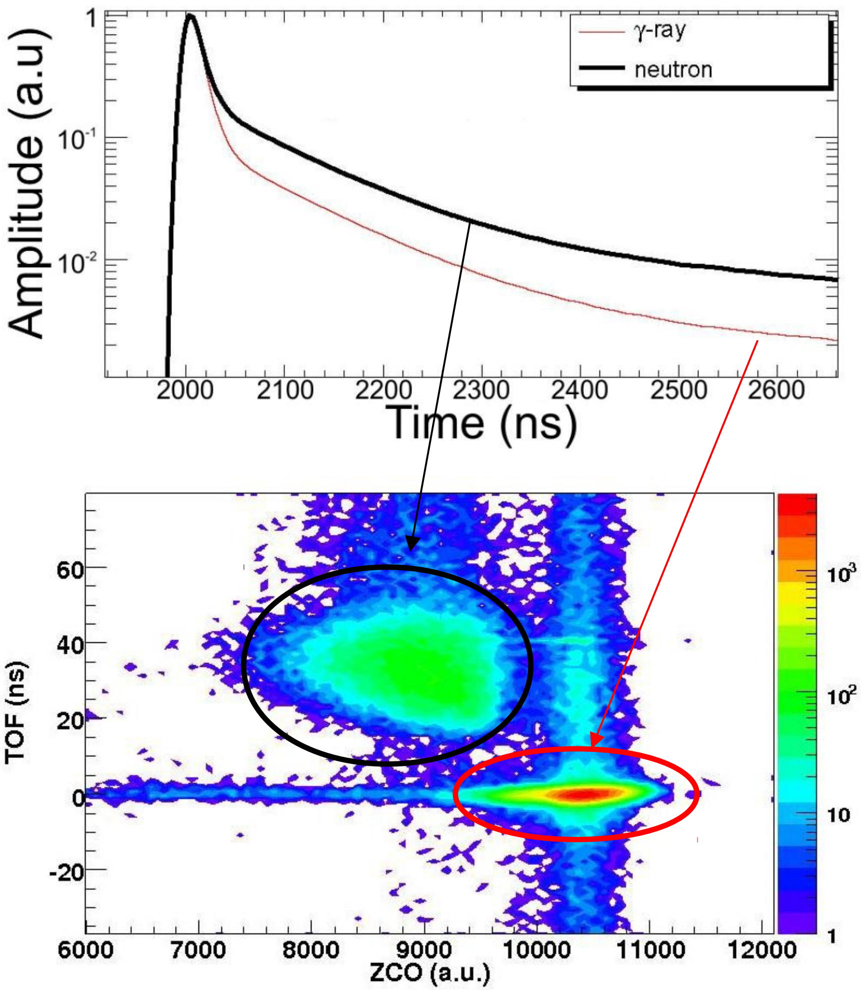






Detector and radioactive source	Efficiency (%) Absolute Exp.	Sim.
NORDBALL:		
^{137}Cs γ rays, 50 cm	0.30(1)	0.285(1)
^{252}Cf neutrons, 51 cm	0.174(9)	0.241(2)
Cylindrical:		
^{252}Cf neutrons, 5 cm	6.1(3)	6.64(2)

Analog n-γ discrimination



Differences in pulse shapes for neutrons and gammas.

Well known, working in analog units: the Zero Cross-Over (ZCO) method

Signal shaped to bipolar & the zero crossing is extracted.

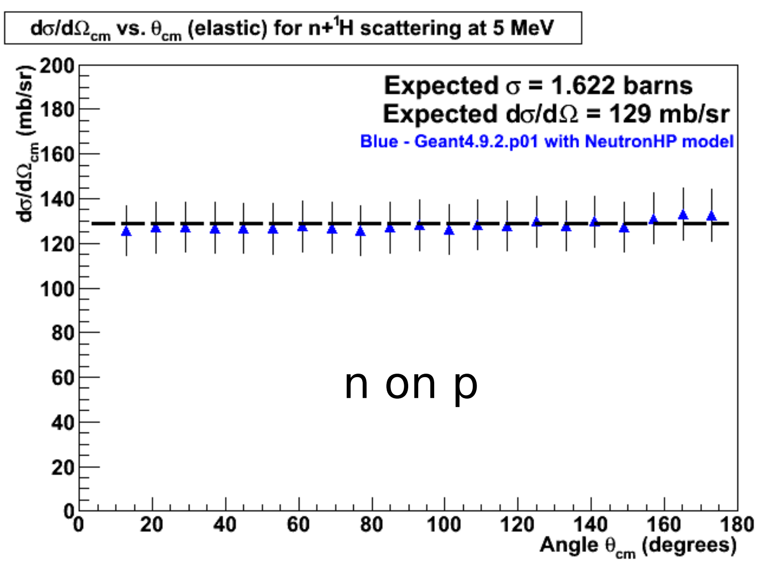
Usually apply 2-D gates, with ToF, for clean separation.

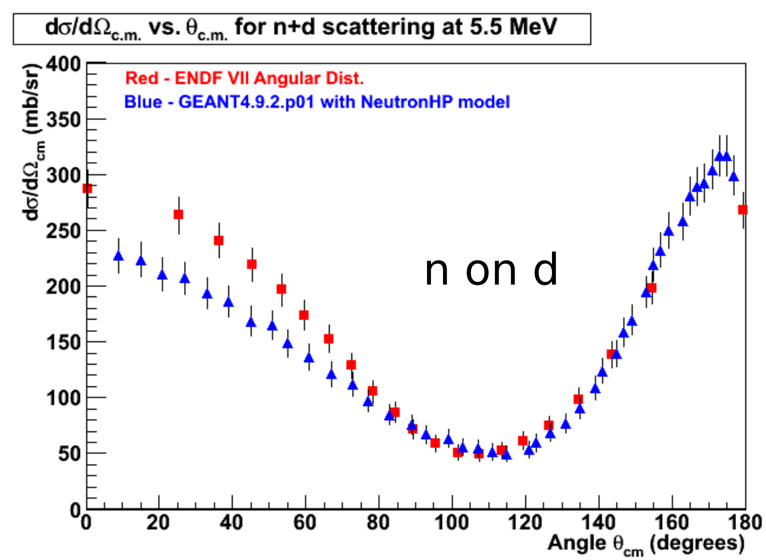
BC501A and BC537

Commonly used scintillator for neutron detection: C_8H_{10} – BC501A, NE213, BC501 – xylene. Nordball NWall, NWall, NRing, NDA@HRIBF, NShell, ...

New option: deuterated scintillator: C_6D_6 – BC537, NE230, deuterated benzene. DESCANT (TRIUMF).

anisotropic scattering of n on d, may produce signals which are more correlated with the incoming neutron energy – could be used to improve multiple neutron discrimination.





plots by B. Roeder