NEDA w ŚLCJ

NEutron **D**etector **A**rray

Środowiskowe Laboratorium Ciężkich Jonów

Grzegorz Jaworski
ŚLCJ UW

Plan prezentacji

- Projekt i budowa układu NEDA (etap 1) w latach 2007-2018
- AGATA-NEDA w GANIL 2018
- EAGLE-NEDA w ŚLCJ 2022-2023

NEDA kick-off meeting (2007)

NWall at GANIL and New Neutron Detectors for SPIRAL 2

Heavy Ion Laboratory, University of Warsaw
4-5 October 2007
lecture room B

The aim of the first day of the meeting is to evaluate plans of future experiments with the Neutron Wall at GANIL, especially in connection to the current call for proposals, with the submission deadline on 6 November 2007.
The second day of the meeting will be devoted to the construction of the new neutron detector system for SPIRAL 2.

Organisers: Johan Nyberg, Marcin Palacz, Javier Valiente

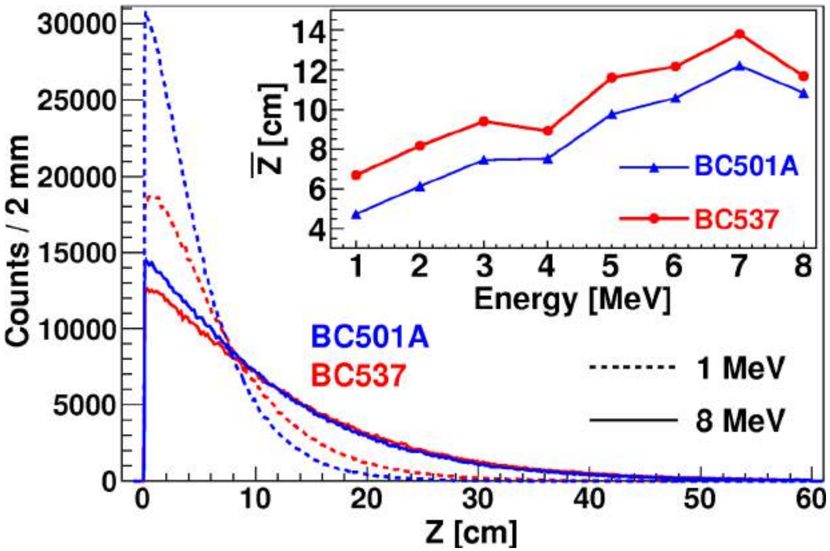
NEDA — goals

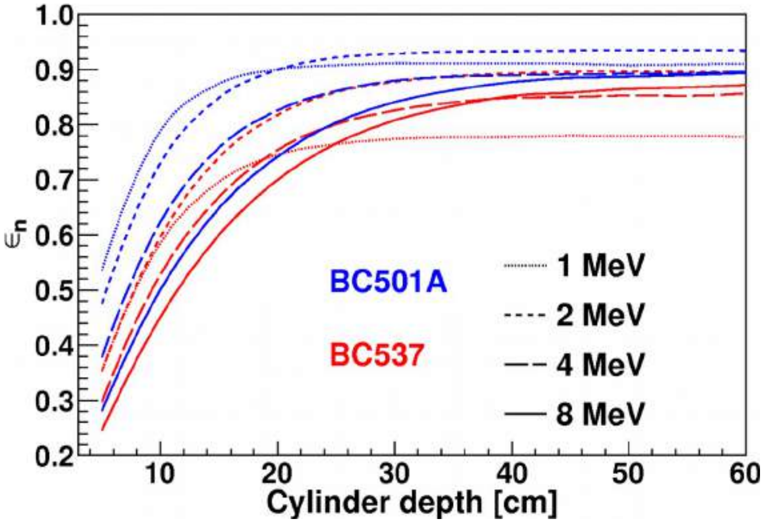
- The primary application of NEDA is to act as neutron multiplicity filter in γ-ray fusion-evaporation studies of very neutron deficient nuclei, close to N=Z, in reactions in which neutron emission is rare.
- The array should have:
  - Increased neutron detection efficiency compared to earlier devices (Neutron Wall):
    $\varepsilon(1n) \approx 40\%$ (20-25%), $\varepsilon(2n) \approx 6\%$ (1-3%), $\varepsilon(3n) \approx 1\%$ (0.1 %)
  - **Excellent neutron-gamma and 1n/2n/3n discrimination**
  - Capability to run at high rates (gamma rays).

NEDA construction — strategy

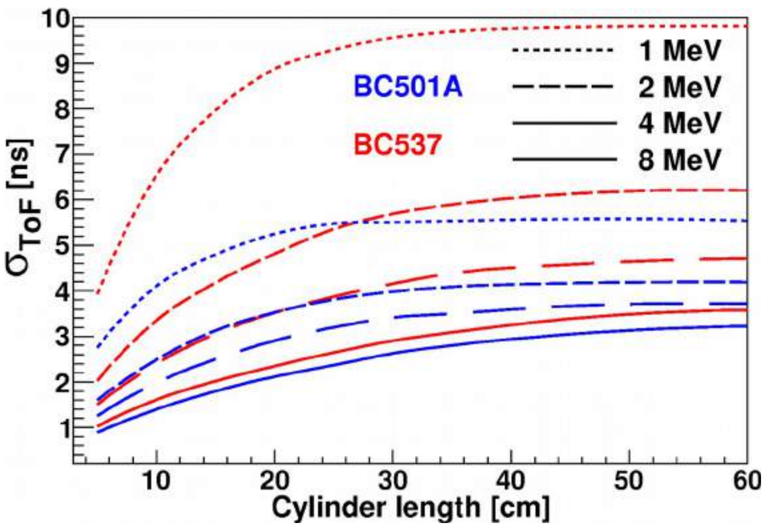
- Optimize size of detector units, distance to target, geometry of the array.
- Choice of the scintillator.
- Choice of PMT, voltage divider.
- Digital electronics.
- Development of efficient on-line and off-line algorithms for the determination of times, neutron-gamma discrimination, neutron scattering rejection, pile-up rejection/recovery.

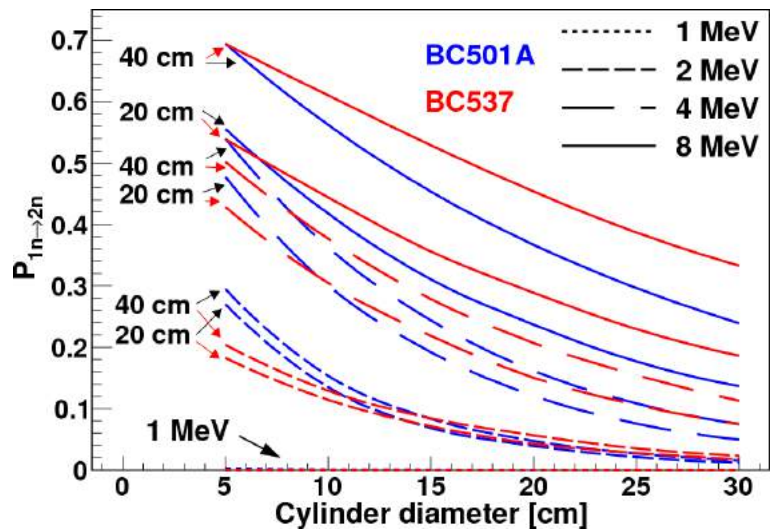
Optimization of a single cell & choice of the scintillator

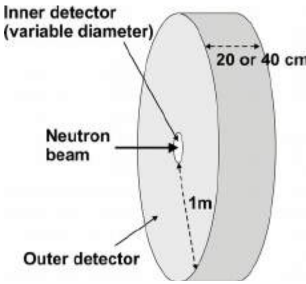




G.Jaworski et al. NIM A673 (2012) 64
G.Jaworski, PhD thesis



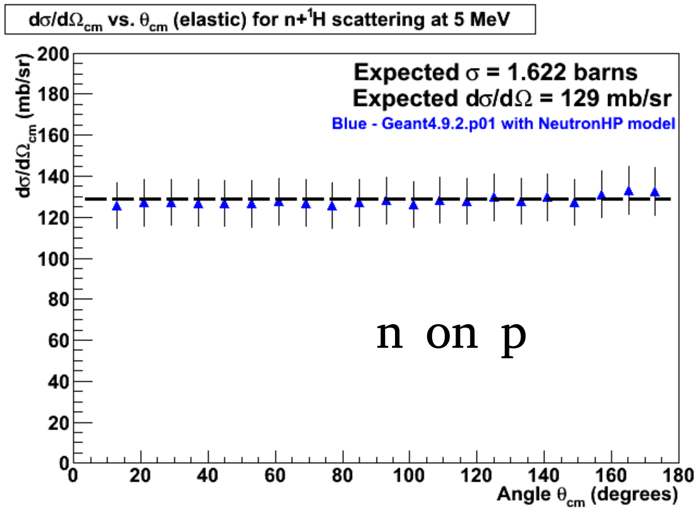


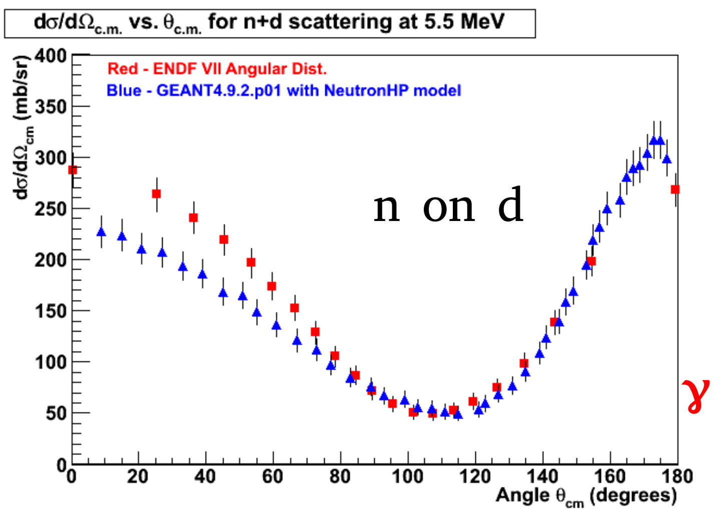


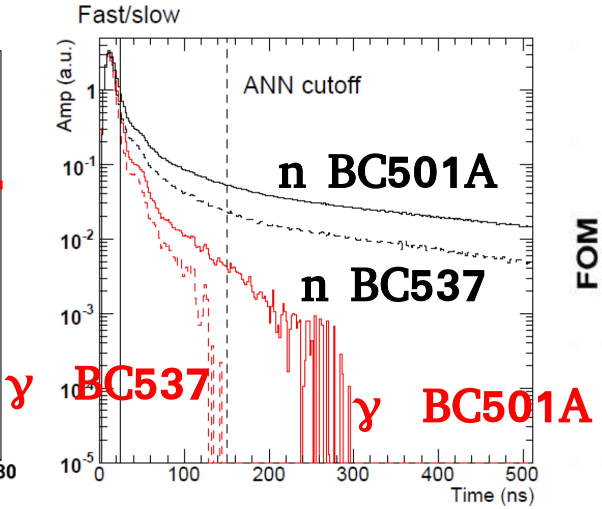
Scintillator

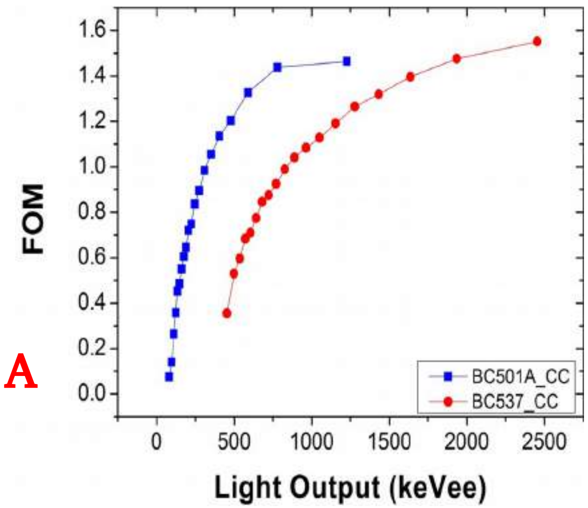
? BC501A / BC537 / EJ299 / ... ?

preliminary



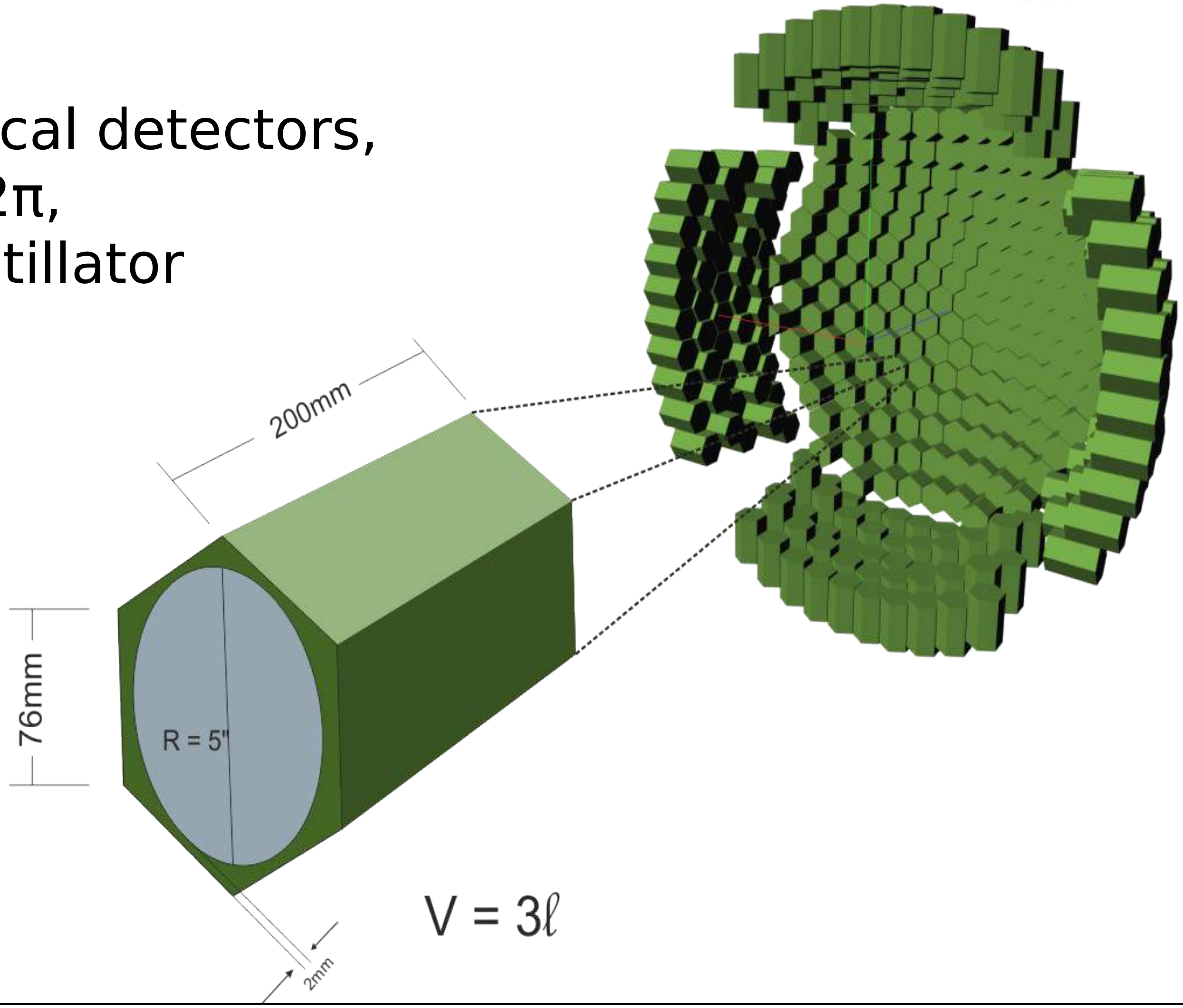




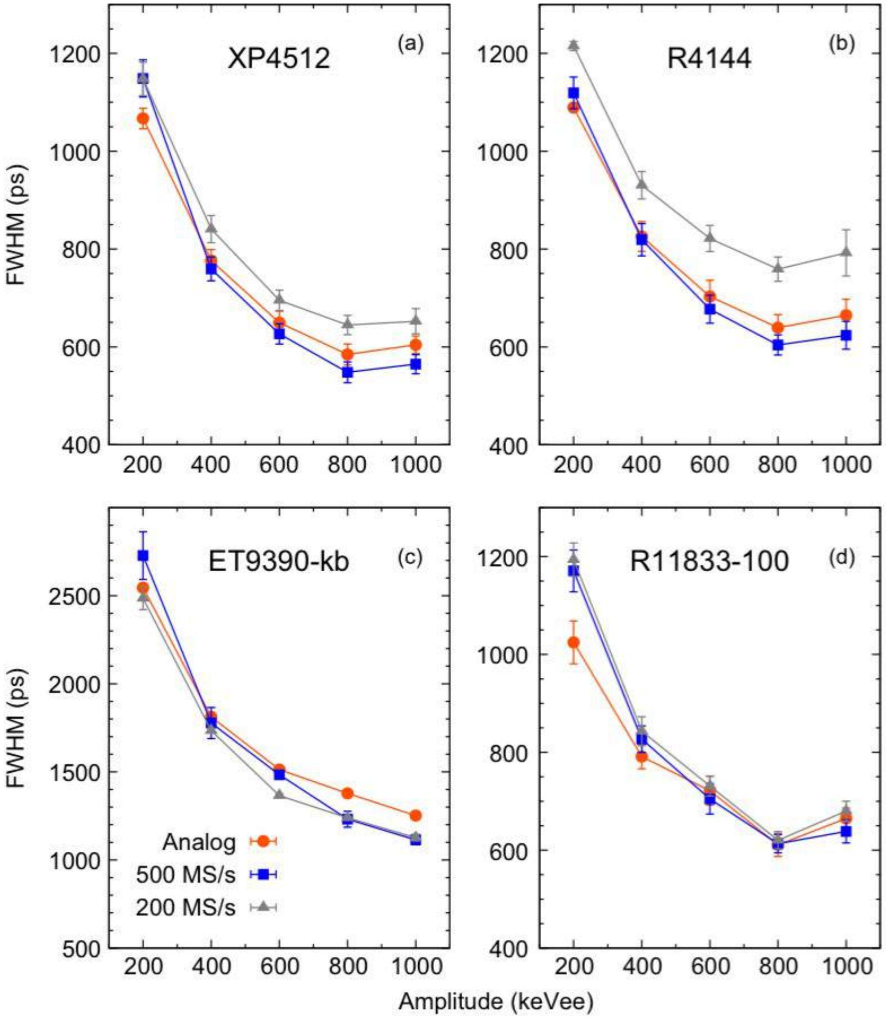


Ultimate goal

355 identical detectors,
covering 2π,
EJ301 scintillator



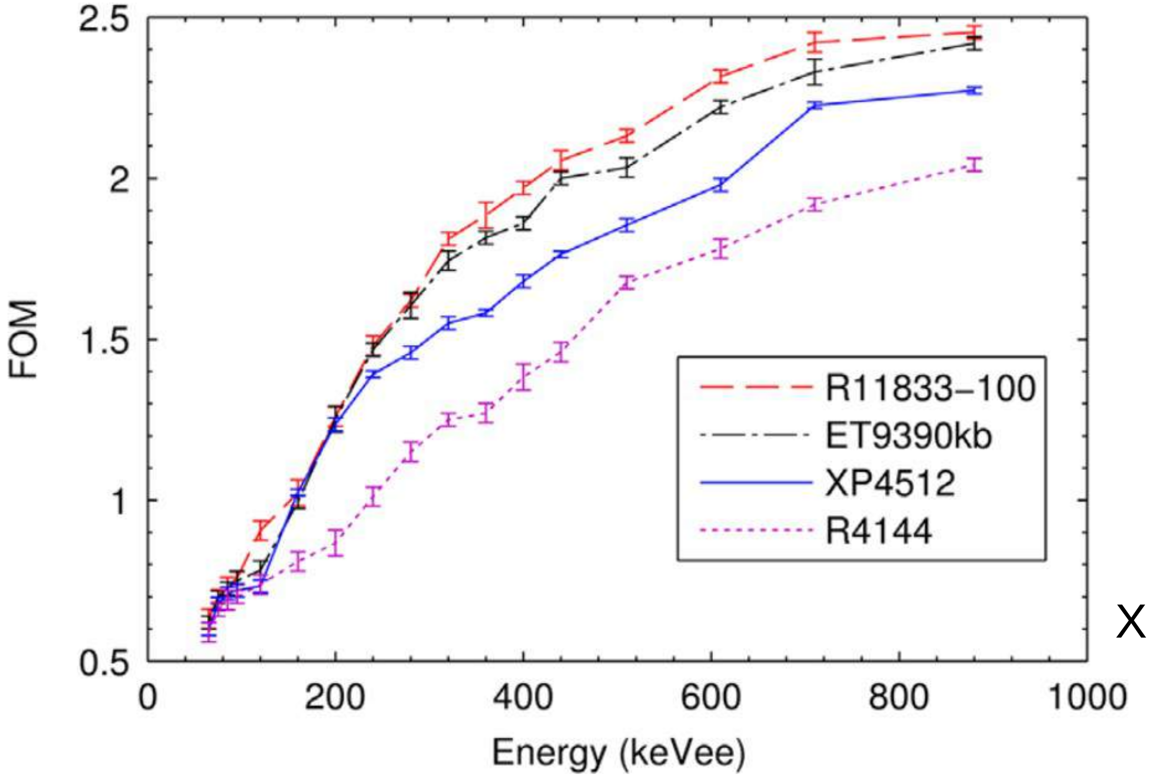
PMT – digital timing

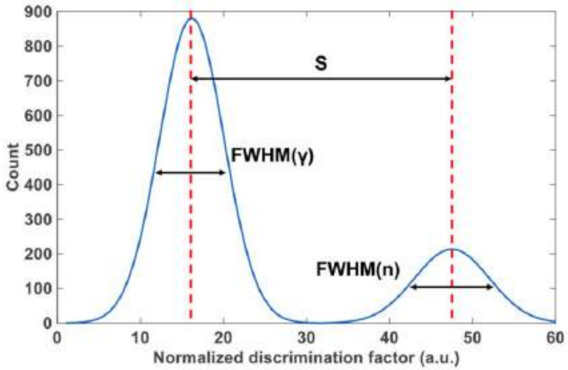


choice of PMT,
digital timing algorithms

V.Modamio et al. NIM A775 (2015) 71

NGD – PMT & algorithms





$$FOM = S / (w_\gamma + w_n)$$

X.L.Luo et al. NIM A767 (2014) 83

Artificial neural networks for the n-gamma discrimination:
P.-A. Söderström et al. NIM A916 (2019) 236
X. Fabian et al. NIM A986 (2021) 164750

Production of detectors

59 detectors constructed

- → Detector vessels and PMT housings are made by welding flanges to hexagonal profiles
- → EJ520 TiO_2 paint; TorrSeal; 5” 5mm BK7 glass
- → Expansion bellow – ΔT = 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)

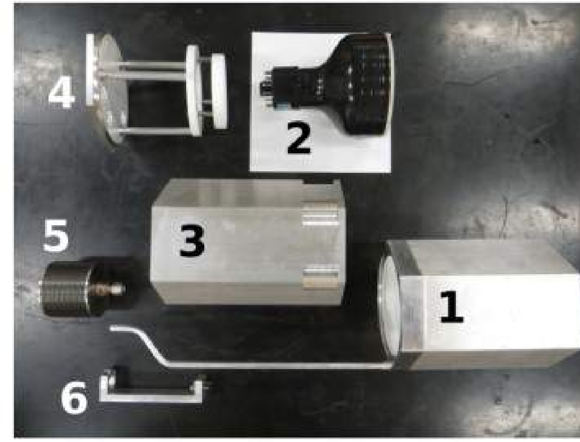
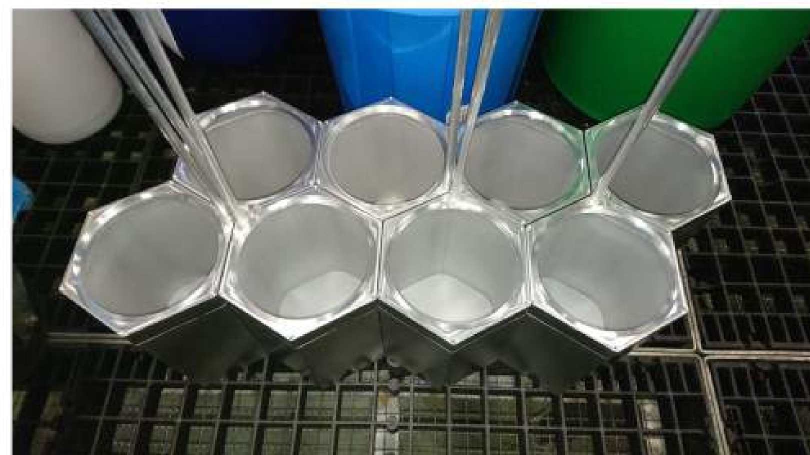
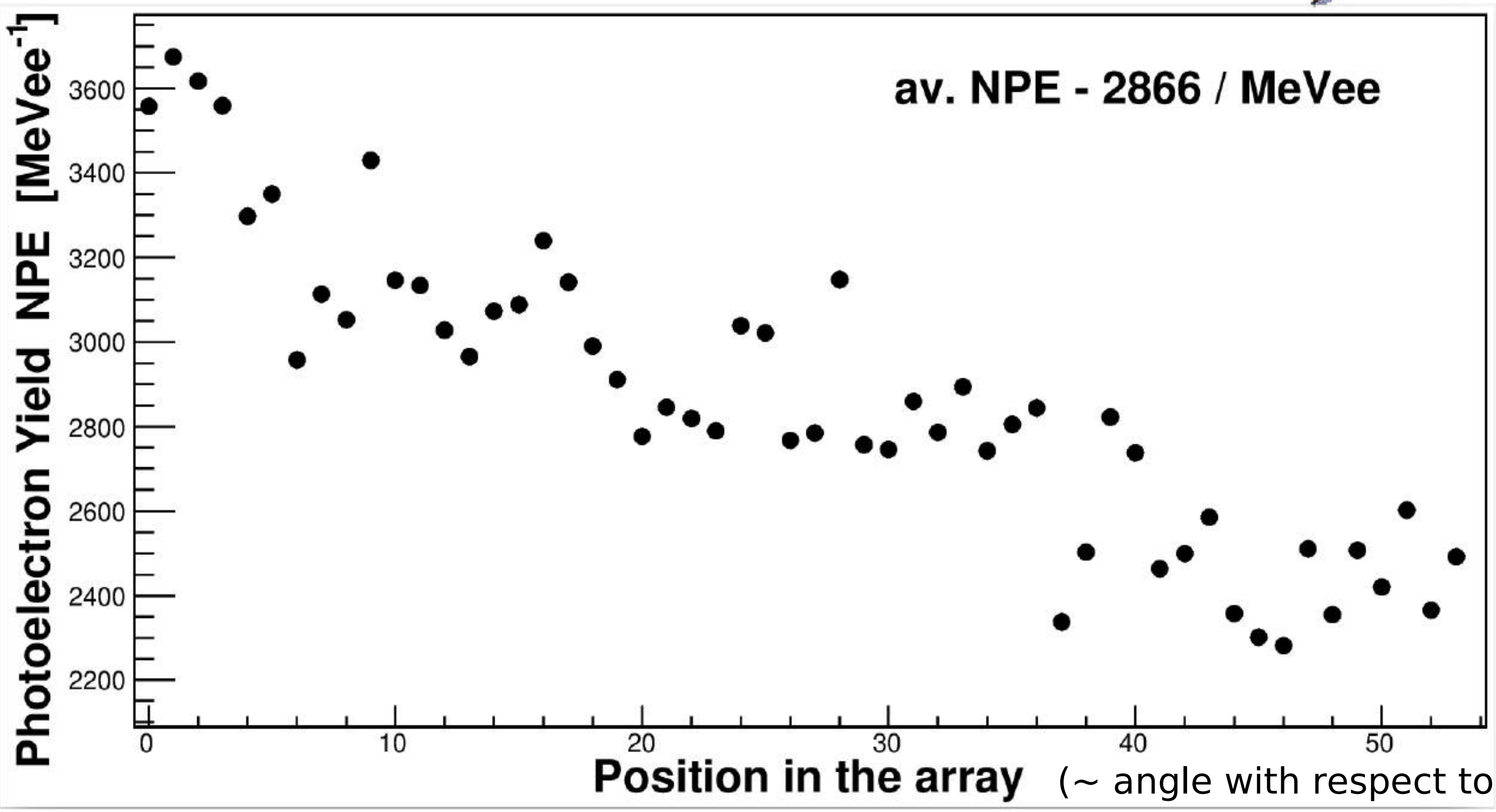


Fig. 1. Elements used for the construction of the NEDA detector: detector cell, with extension pipe (1); PMT (2); PMT housing (3); PMT pusher (4); the bellow (5) and the support for the bellow (6).



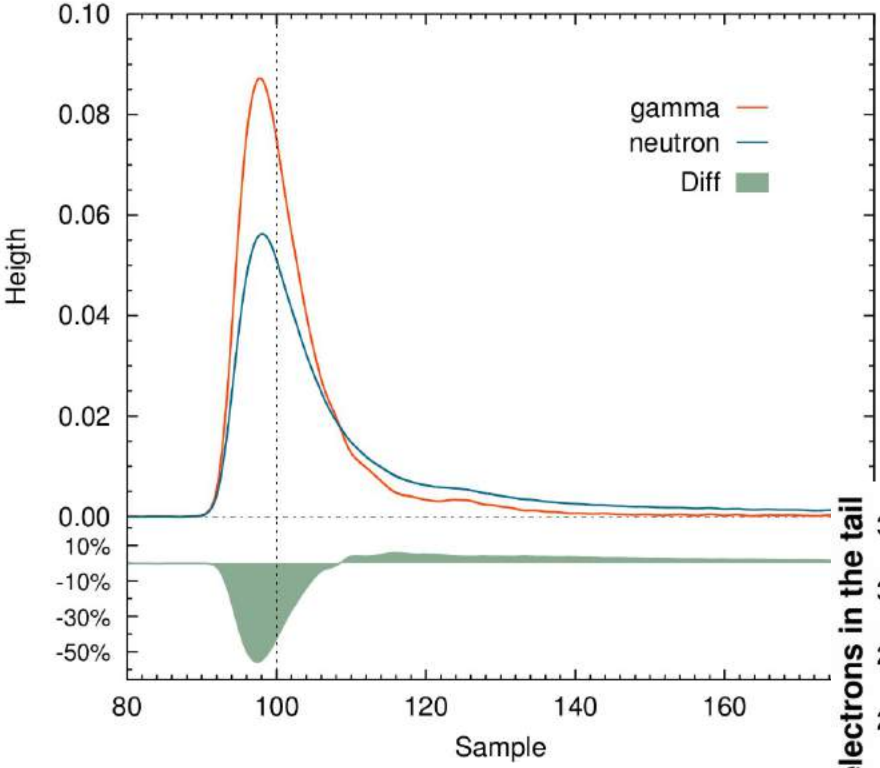
Light produced in the scintillator

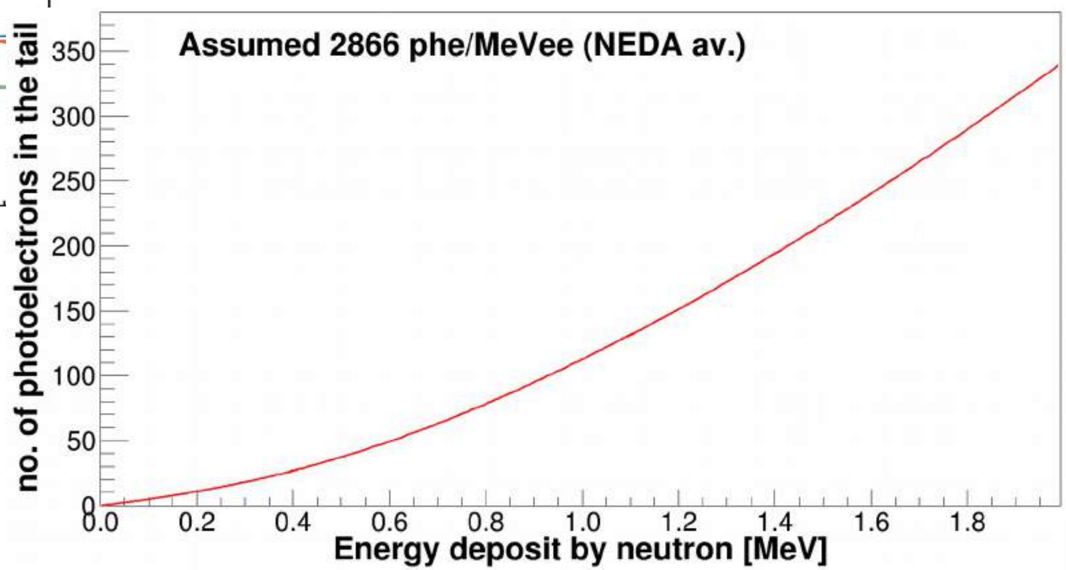


(~ angle with respect to beam)

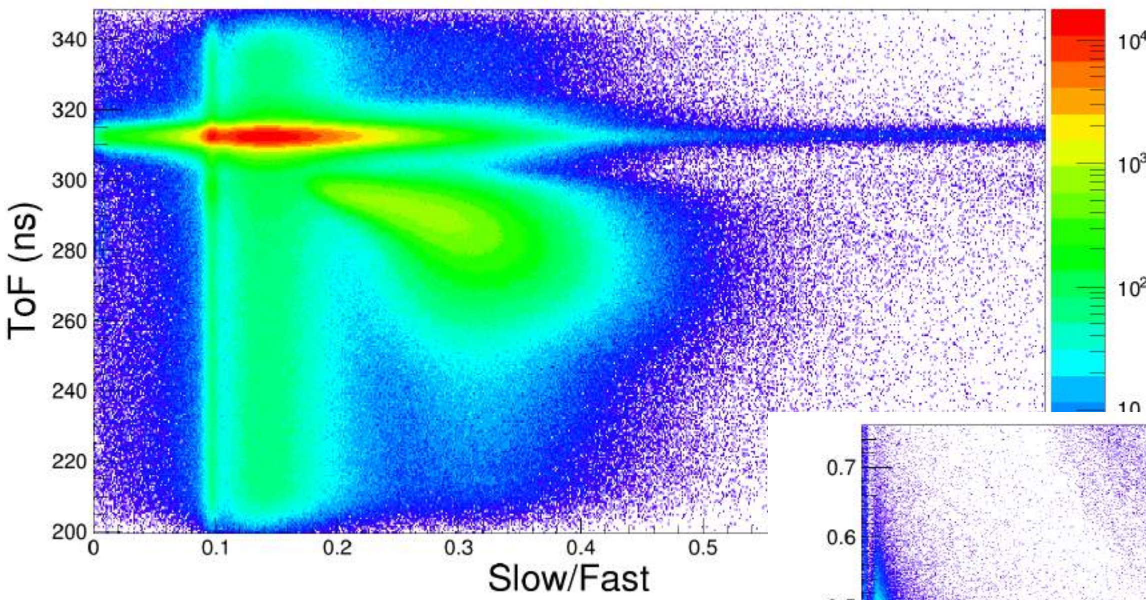
Neutron Wall (1998): ~1300
Commercial 5”x5” Bicron ~1800

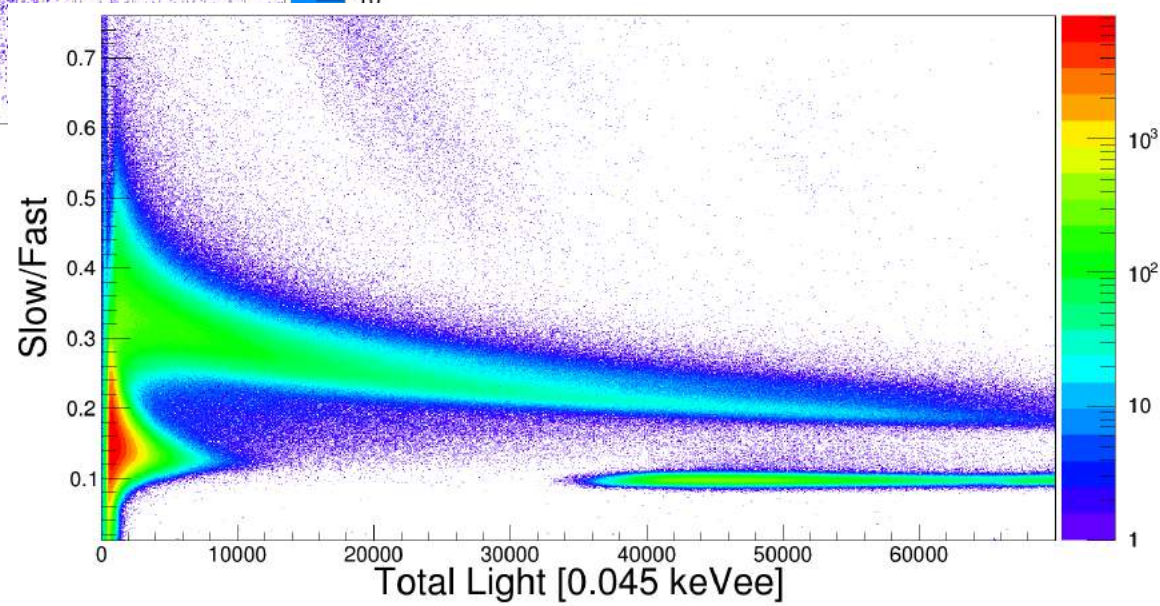
Light matters!



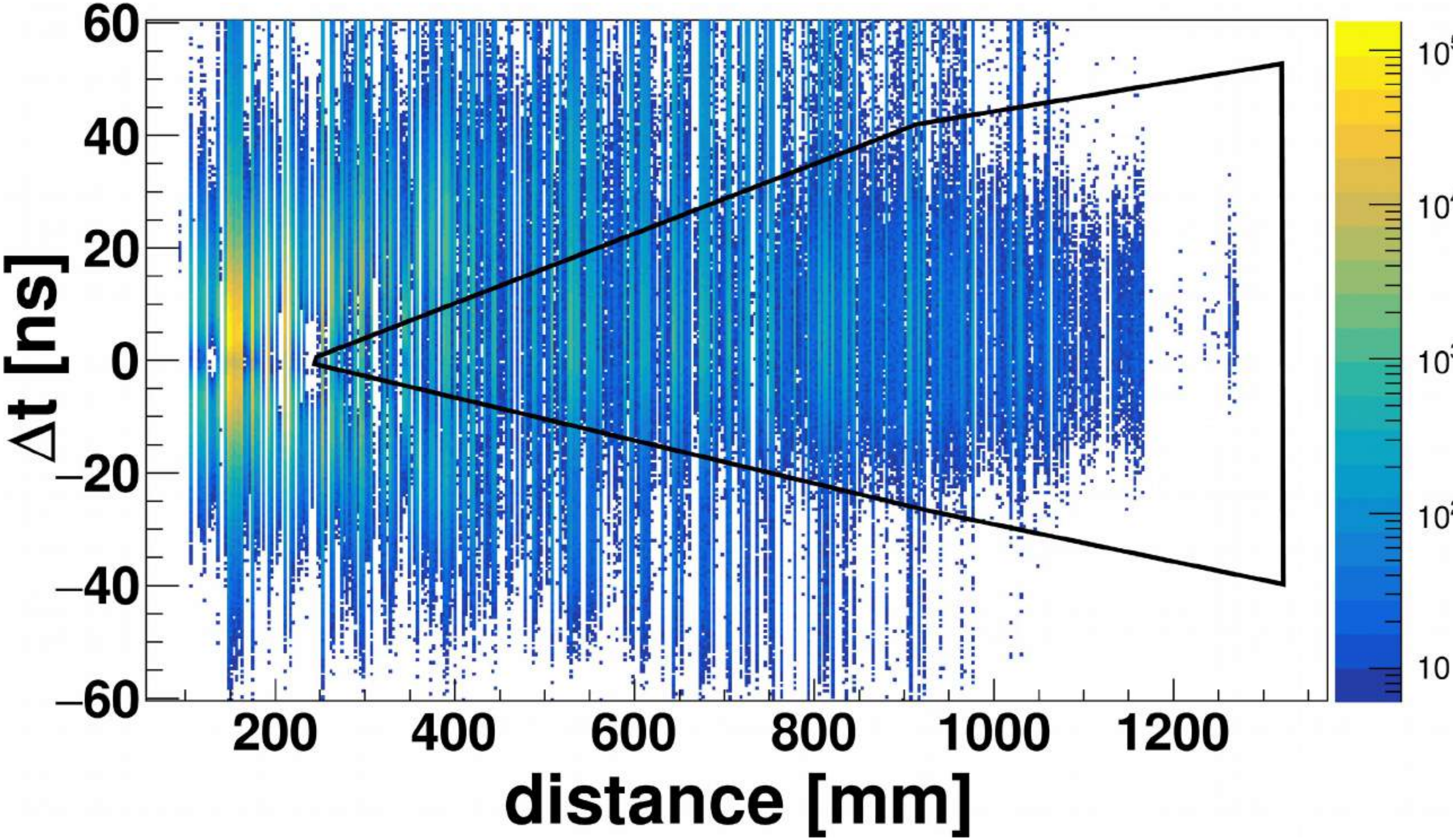


n/γ discrimination



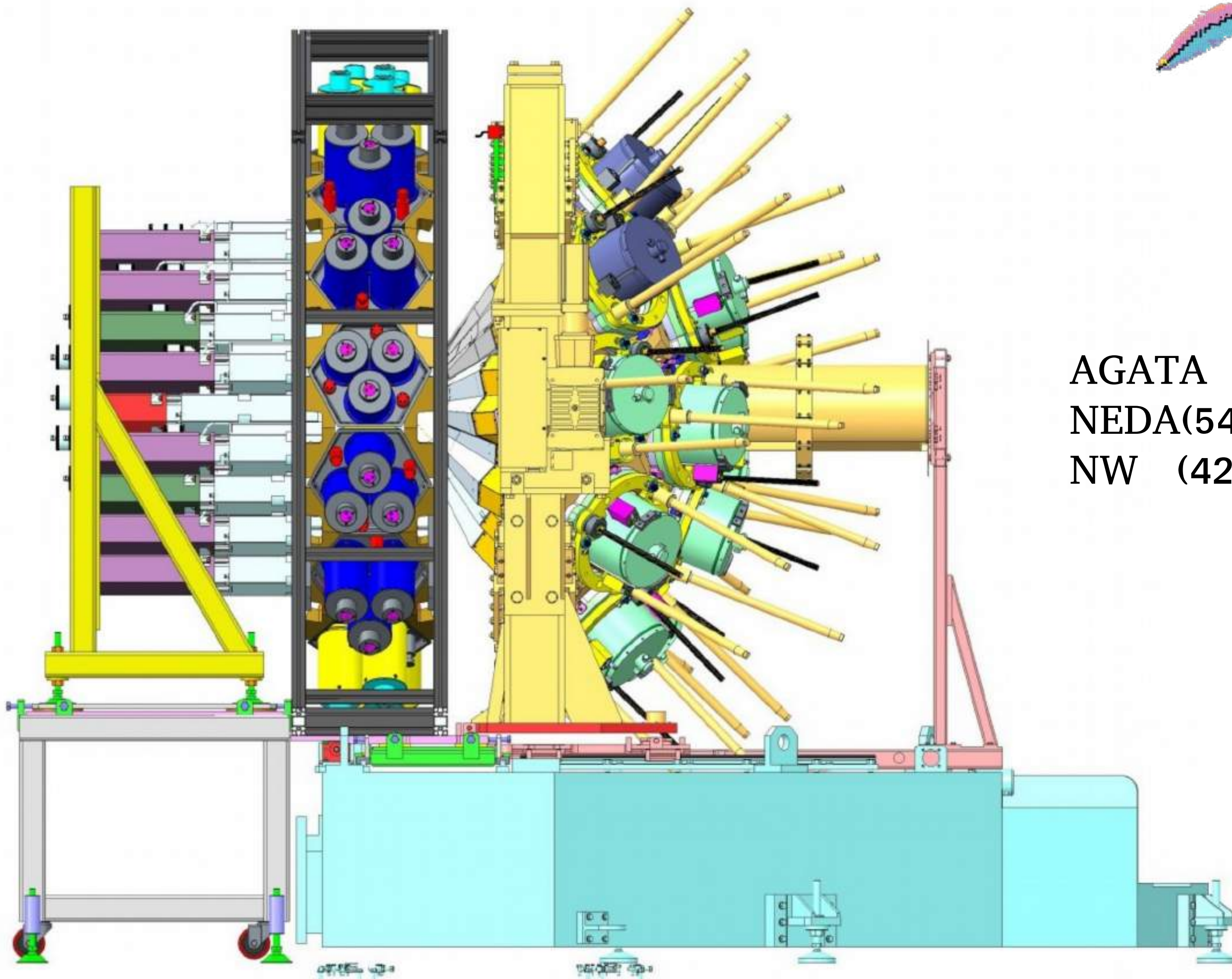


1n / 2n / ...



60
40
20
0
−20
−40
−60
Δt [ns]
200
400
600
800
1000
1200
distance [mm]
10^5
10^4
10^3
10^2
10

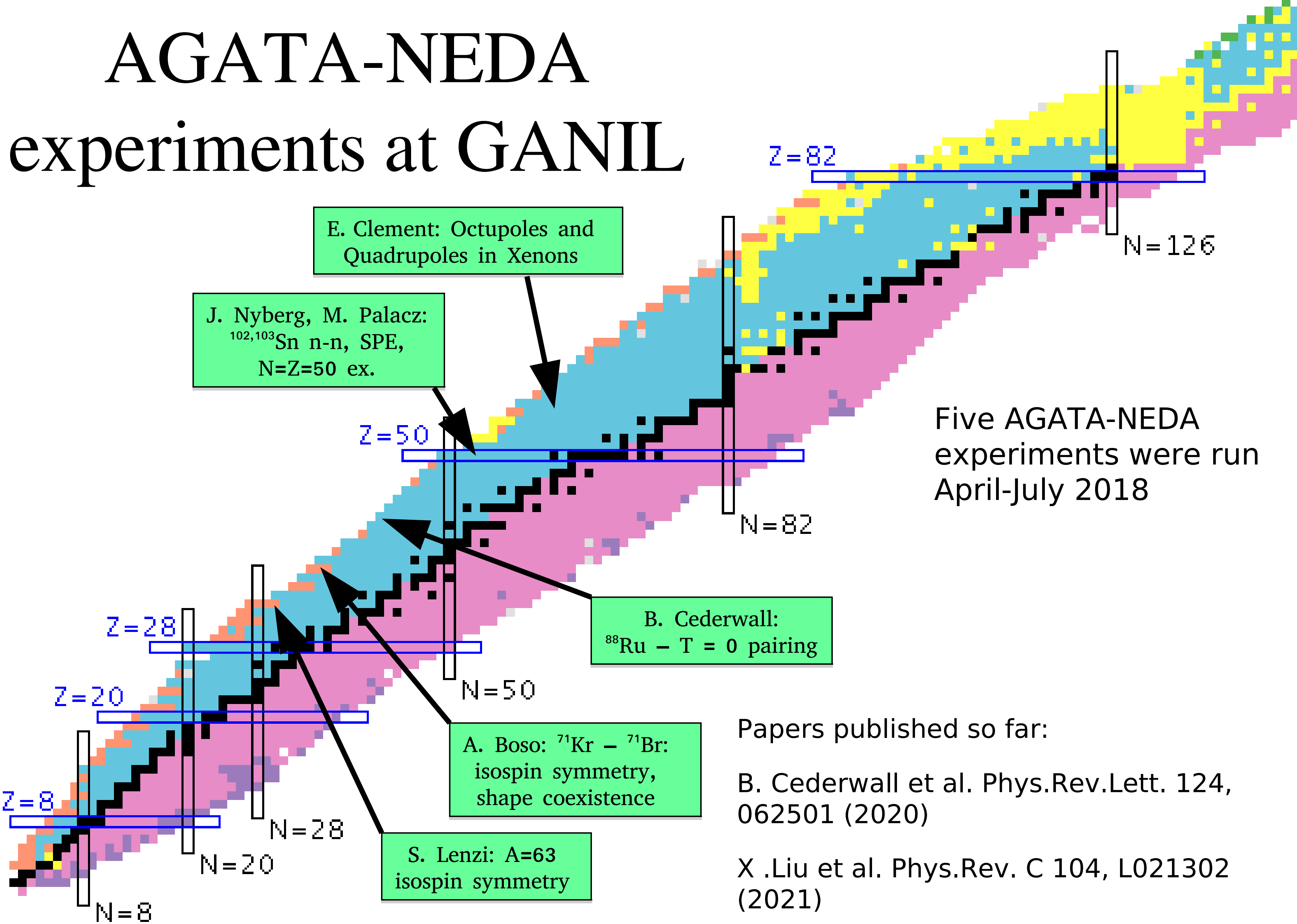
GANIL 2018: AGATA + NEDA



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

GANIL 2018: AGATA + NEDA

AGATA-NEDA experiments at GANIL



Five AGATA-NEDA experiments were run April-July 2018

Papers published so far:

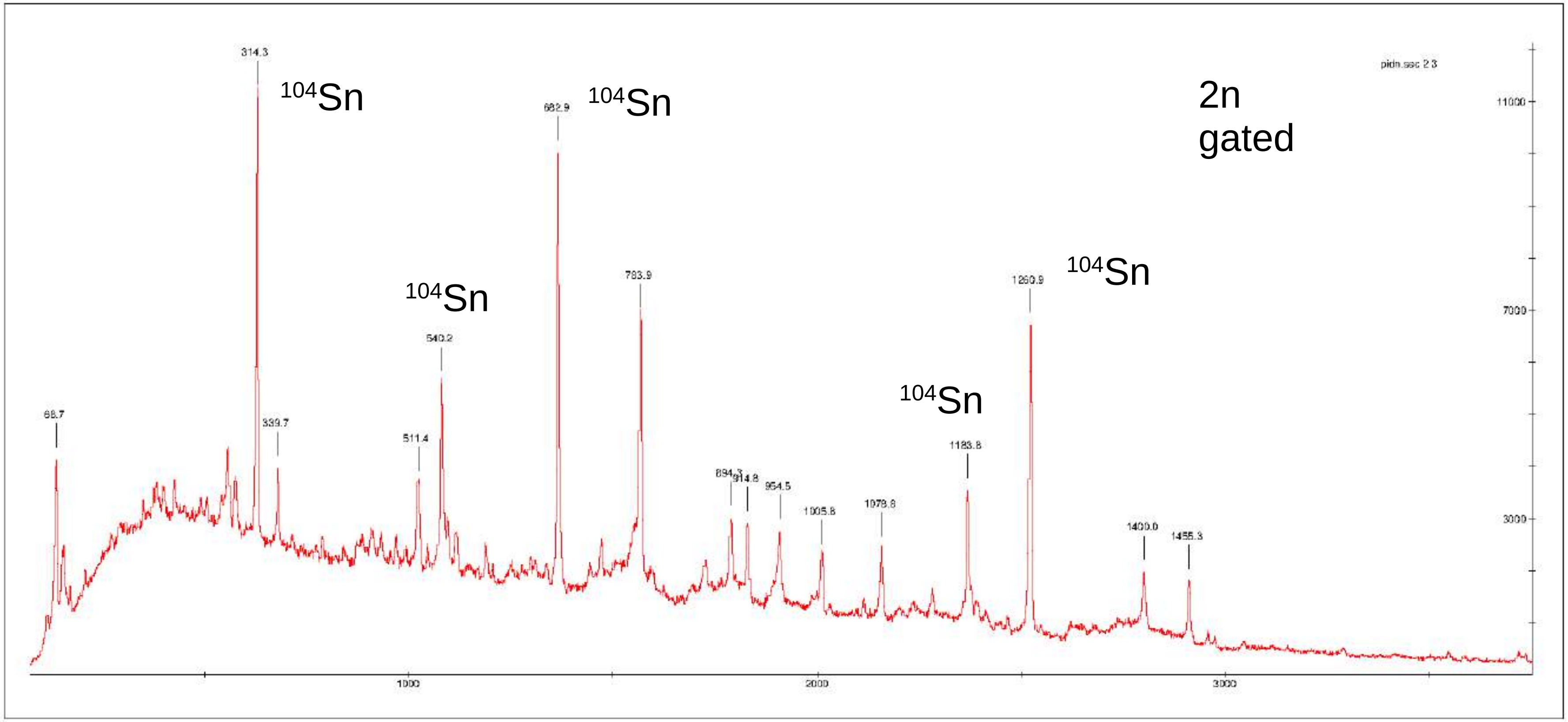
B. Cederwall et al. Phys.Rev.Lett. 124, 062501 (2020)

X .Liu et al. Phys.Rev. C 104, L021302 (2021)

Performance at GANIL (E703 experiment)

^{50}Cr (175 MeV) + $^{58}Ni \rightarrow {}^{108}Te$ (CN)

$\varepsilon_n = 0.3$ $\varepsilon_{2n} \approx 0.06$ $P(\gamma \rightarrow n) \approx 0.001$ $P(1n \rightarrow 2n) \approx 5*10^{-4}$



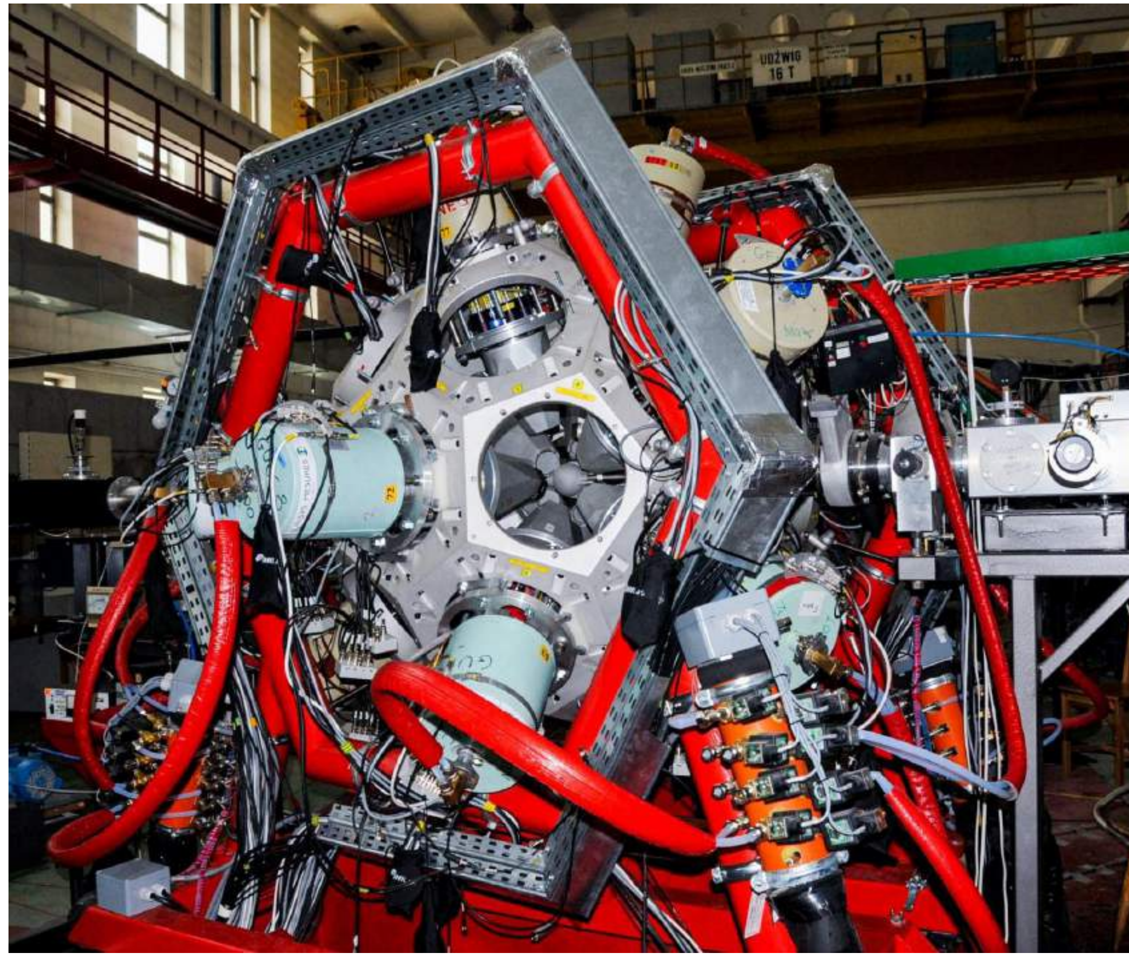
Total fusion x-section ≈ 300 mb

^{104}Sn produced with the emission of 2p2n $\sigma(^{104}Sn) \approx 0.5$ mb

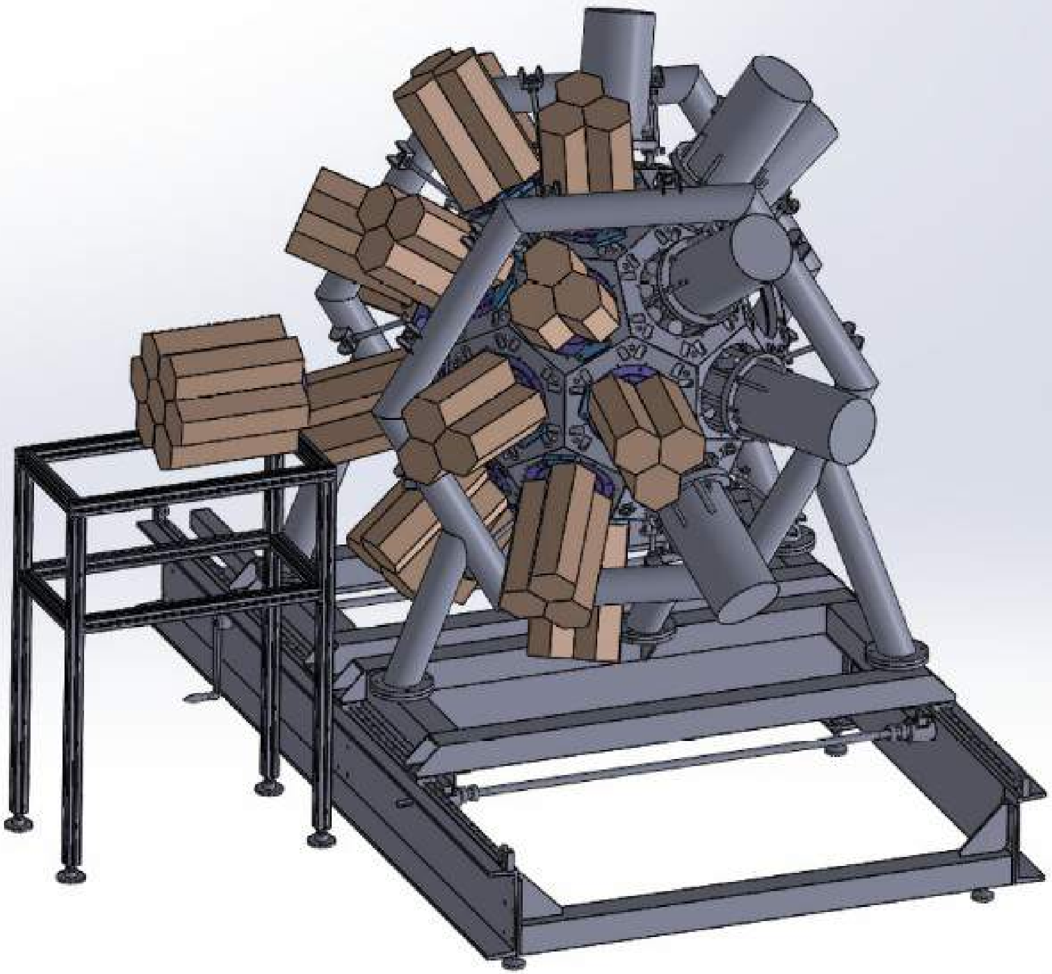
NEDA + EAGLE →

EAGLE

A flexible array able to accomodate up to 30 HPGe detectors with ACS shields, anc ancillary devices



NEEDLE

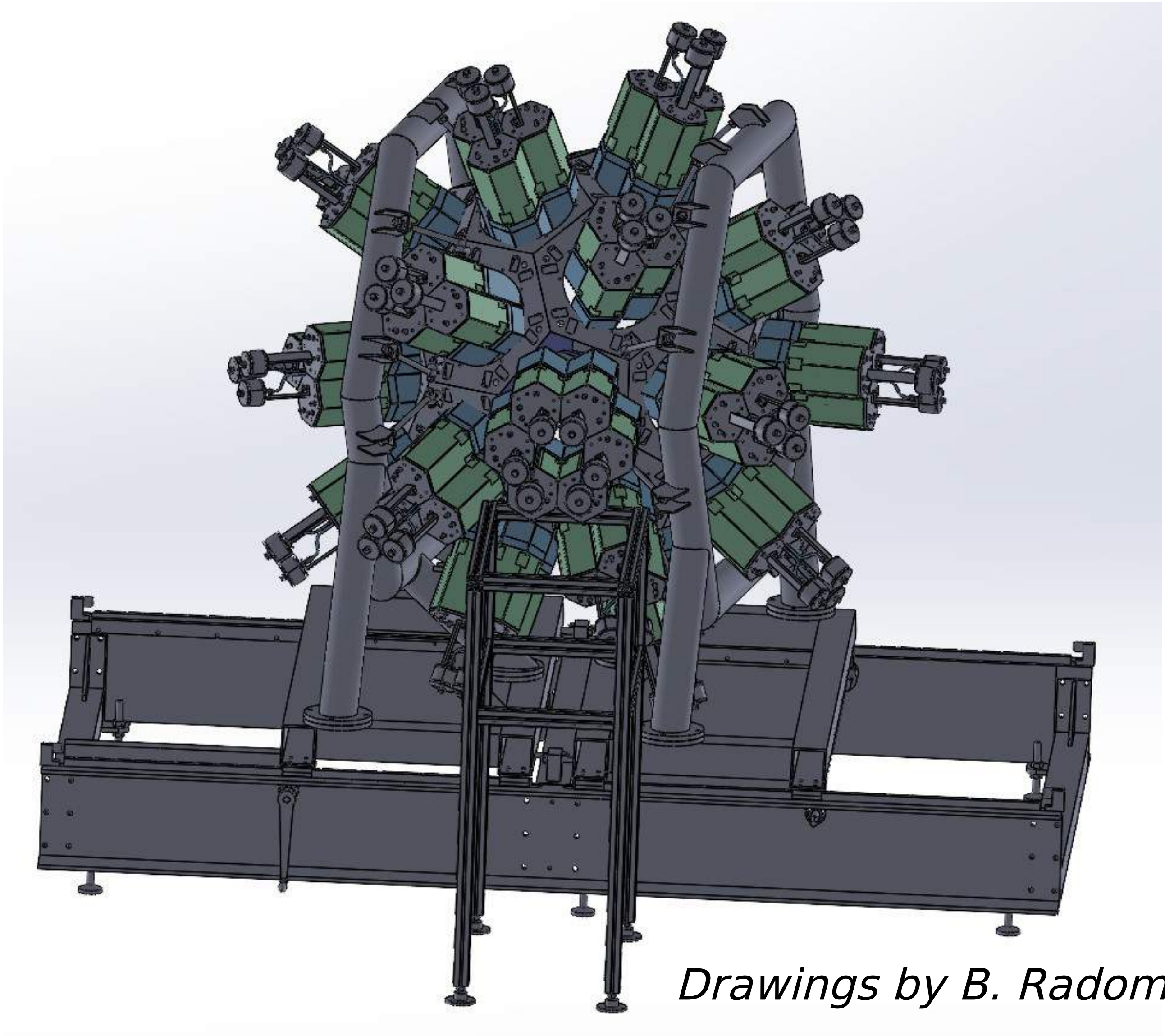


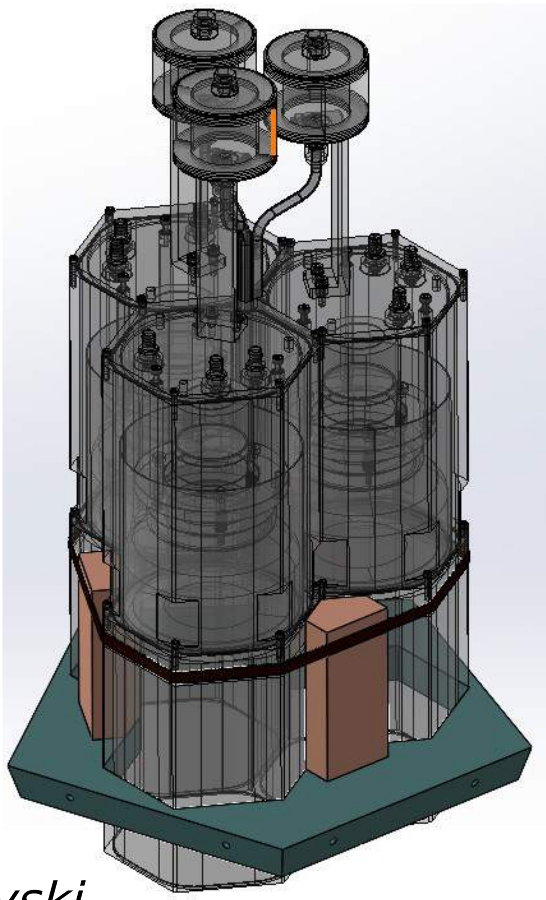
Drawing by B. Radomyski

EAGLE:
- 5 dets @ 101°
- 5 dets @ 117°
- 5 dets @ 143°

NEDA:
- 6 dets ~0°
- 15 dets @ 37°
- 15 dets @ 63°
- 15 dets @ 79°

Mechanics



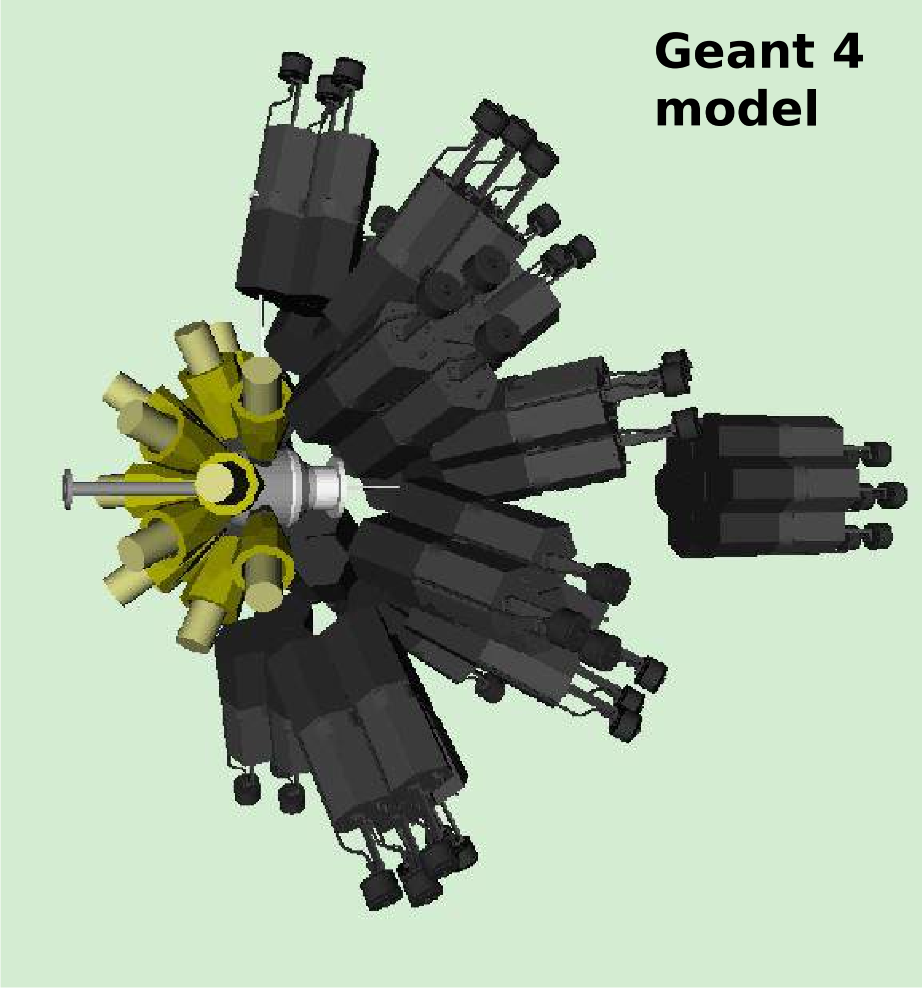


Drawings by B. Radomyski

Efficiencies

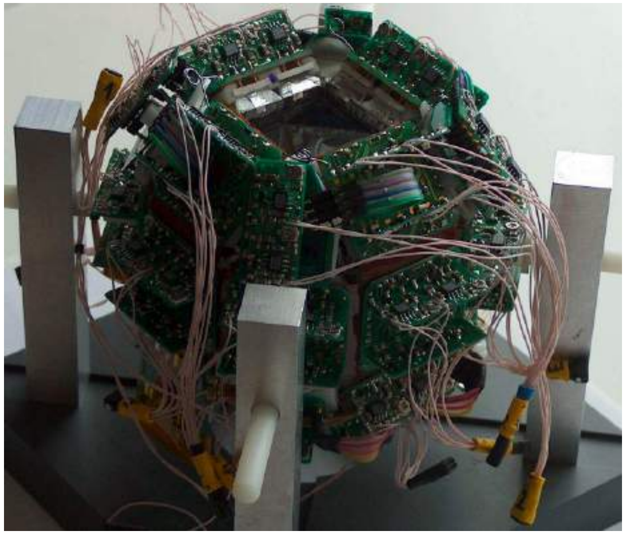
Basic parameters:

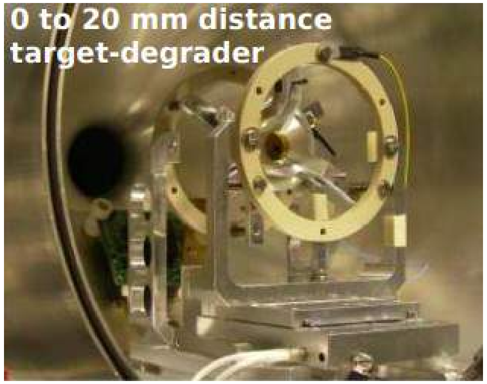
- EAGLE: 15 det. ACS HPGe
  eff(γ) = 1.5% @1.3 MeV
- NEDA: 51 det.
  eff(1n) = 20-25%, eff(2n) = 3%
- NEEDLE: eff(γγ2n) = 6.75e-6



Other ancillaries

- DIAMANT – charged particle detector
- Electron spectrometer
- plunger(s)





Read-out – NEEDLE

NEDA: Caen V1725 x4 with DPP-PSD
EAGLE: V1725 x2 with DPP-PHA

- 250 MHz, 14 bit
- 16-ch VME modules:
  - MCX connectors
- Dynamic range 0.5 and 2 Vpp
  + setable DC offset
- DPP algorithms implemented in FPGA: PHA, PSD
- Read-out – optical link (and VME64)
- 16 programmable LVDS I/Os
- Daisy chain possibility
- COMPASS, C & LabVIEW libraries

NEDA: Amplitude limiters needed

xdaq based DAQ

Beams

Cyklotron K= 90 – 160						
Jon	Energy min [MeV]	Energy max [MeV]	Energy max [MeV/nukl]	Intensity of the extracted beam [nA]	Intensity of the extracted beam [pnA]	Intensity of the extracted beam [p/s]
$^{10}B^{+2}$	51	55	5.5	45	9.0	$5.6\ 10^{+10}$
$^{11}B^{+2}$	40	50	4.5	50	10.0	$6.3\ 10^{+10}$
$^{12}C^{+2}$	38	50	4.2	100	16.7	$1.0\ 10^{+11}$
$^{12}C^{+3}$	53	92	7.7	220	36.7	$2.3\ 10^{+11}$
$^{13}C^{+3}$		90	6.9	90	16	
$^{14}N^{+2}$	32	50	3.6	240	34.3	$2.1\ 10^{+11}$
$^{14}N^{+3}$	57	91	6.5	1500	214.3	$1.3\ 10^{+12}$
$^{15}N^{+3}$		43	2.9	50	7.1	
$^{16}O^{+3}$	46	80	5.0	400	50.0	$3.1\ 10^{+11}$
$^{16}O^{+4}$	80	120	7.5	650	81.3	$5.1\ 10^{+11}$
$^{18}O^{+4}$	100	120	6.7	2000	250.0	$1.6\ 10^{+12}$
$^{19}F^{+3}$	50	66	3.5	10	1.1	$6.9\ 10^{+9}$
$^{20}Ne^{+3}$	45	68	3.4	300	30.0	$1.9\ 10^{+11}$
$^{20}Ne^{+4}$	68	115	5.8	1300	130.0	$8.1\ 10^{+11}$
$^{20}Ne^{+5}$	130	160	8.0	120	12.0	$7.5\ 10^{+11}$
$^{22}Ne^{+3}$	44	55	2.5	260	26.0	$1.6\ 10^{+11}$
$^{24}Mg^{+4}$		77	3.2	120	10	
$^{32}S^{+5}$	79	110	3.4	50	3.1	$2.0\ 10^{+10}$
$^{32}S^{+6}$	*120*(*)	150	4.7	70	4.4	$2.7\ 10^{+10}$
$^{32}S^{+7}$	*120*(*)	142	4.4	50	3.1	$2.0\ 10^{+10}$
$^{40}Ar^{+6}$	*90*(*)	132	3.7	100	5.6	$3.6\ 10^{+10}$
$^{40}Ar^{+7}$	*130*(*)	164	4.1	35	1.9	$1.2\ 10^{+10}$
$^{40}Ar^{+8}$	*180*(*)	200	5.0	40	2.2	$1.4\ 10^{+10}$

(*) estimation, no experimental data

^{58}Ni in spe…

NEDA @ HIL prePAC Workshop, 20-21 October 2021

Wednesday, 20 October 2021				
12:00				Start of the registration
13:00	01:00	14:00		Lunch
Session 1. Chair: Katarzyna Wrzosek-Lipska				
14:00	00:30	14:30	Macin Palacz	Welcome. NEDA - the story and performance of
14:30	00:30	15:00	Grzegorz Jaworski	NEDA at HIL
15:00	00:20	15:20	Christoph Fransen	Köln plunger
15:20	00:15	15:35	Jarosław Perkowski	Electron Spectrometer
15:35	00:30	16:05		Coffee break
Session 2. Chair: Magda Górska-Ott				
16:05	00:25	16:30	Bahadir Saygı	Collectivity of 160Hf, 162W and 138Sm
16:30	00:25	16:55	Bahadir Saygı	Searching for X(5) symmetry in 132Nd
16:55	00:25	17:20	Dmitry Testov	np-correlations in rotational band alignments in light Cs isotopes
17:20	00:25	17:45	Costel Petrache	Lifetimes of bands in proton-rich Ba-Cs nuclei
19:30				Workshop dinner, restaurant "Stara Szafa", ul. Ludna 10

Thursday, 21 October 2021				
09:00	00:30	09:30		Coffee
Session 3. Chair: Katarzyna Hadyńska-Klęk				
09:30	00:10	09:40	Paweł Napiorkowski	Late welcome from the director of HIL
09:40	00:20	10:00	István Kuti	DIAMANT
10:00	00:25	10:25	Marcin Palacz	Single particle states and N=Z=28 core excitations in 57Cu
10:25	00:25	10:50	Bahadir Saygı	Lifetime Measurement of Isobaric Analog States in 45V and 49Mn
10:50	00:30	11:20		Coffee
11:20	00:25	11:45	Bahadir Saygı	Reduced transition probabilities of excited states in non-yrast bands of 166 Yb and 162Er
11:45	00:25	12:10	Rafael Escudeiro	Test of isospin symmetry in E1 transitions in the T=1/2 A=35 mirror pair
12:10	00:10	12:20	Marcin Palacz	Summary
12:20	00:40	13:00		Discussions (in the lecture hall and at the experimental site)
13:00	01:00	14:00		Lunch

The workshop is sponsored by the University of Warsaw within the “Excellence initiative” programme.

During the workshop: 8 LoI presented, ~11 measurements (beam-target combinations)

New LoIs are welcome any time.

Proposals are needed soon (PAC early 2022).

NEEDLE Workshop

→ Test of isospin symmetry in E1 transitions in the T=1/2 A=35 mirror pair

→ Shape coexistence and octupole correlations in the light Xe, Cs and Ba nuclei

→ np-correlations in rotational band alignments in light Cs isotopes

→ Single proton-particle levels at N = Z = 28 and core softness by studying excited states of ^{57}Cu

→ Experiments at the neutron-rich side?

→ e-n-γ coincidences?

NEEDLE – schedule

- NEDA detectors and associated equipment to be transported in mid Nov. 2021
- Mechanical adaptation – ongoing – to be finished in Dec. 2021
Purchases of needed electronics etc – ongoing…
- Installation, configuration of the electronics, tests on the sources – asap – early 2022.
- 1st PAC – first half of 2022 (possible 2nd PAC fall 2022).
- Comissioning
- Experimental campaigns – 2nd half of 2022, 1st half of 2023
- 2nd half of 2023 – NEDA goes to LNL

Podsumowanie

- Skonstruowano 59 wysokiej klasy detektorów neutronów prędkich
- Uniwersalne, wydajność wewnętrzna 70%, doskonałe NGD
- NEDA będzie zainstalowana w Warszawie w połączeniu z EAGLE
- NEEDLE: 1szy PAC – początek 2022
- NEEDLE: eksperymenty – 2ga połowa 2022, 1sza połowa 2023
- Zapraszamy do współpracy!!!

It's good for you!

Finansowanie: polski wkład w budowę układu NEDA, badania jąder bogatych w protony oraz instalacja i wykorzystanie NEDA w ŚLCJ – granty NCN:
2016/22/M/ST2/00269 (HARMONIA)
2017/25/B/ST2/01569 (OPUS)
2020/39/D/ST2/00466 (SONATA)