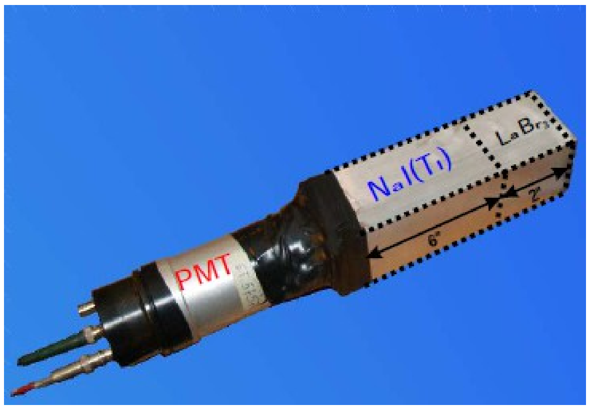
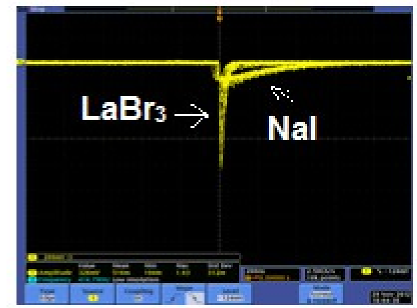
PARIS tests in Mumbai

V. Nanal (TIFR)
on behalf of PARIS- India



Dr. Chandan Ghosh

Dr. Balaram Dey



- Detailed characterization of LaBr3-NaI (E ~ 34 MeV)
- In beam tests with V1730 digitizer
- Neutron response study
- Study of CeBr3-NaI

C. Ghosh *et al* 2016 *JINST* **11** P05023
B. Dey *et al* arXiv:1708.06346, to appear in Advanced detectors for Nuclear, High energy and Astroparticle physics (Springer Nature Singapore Pvt Ltd, 2018)

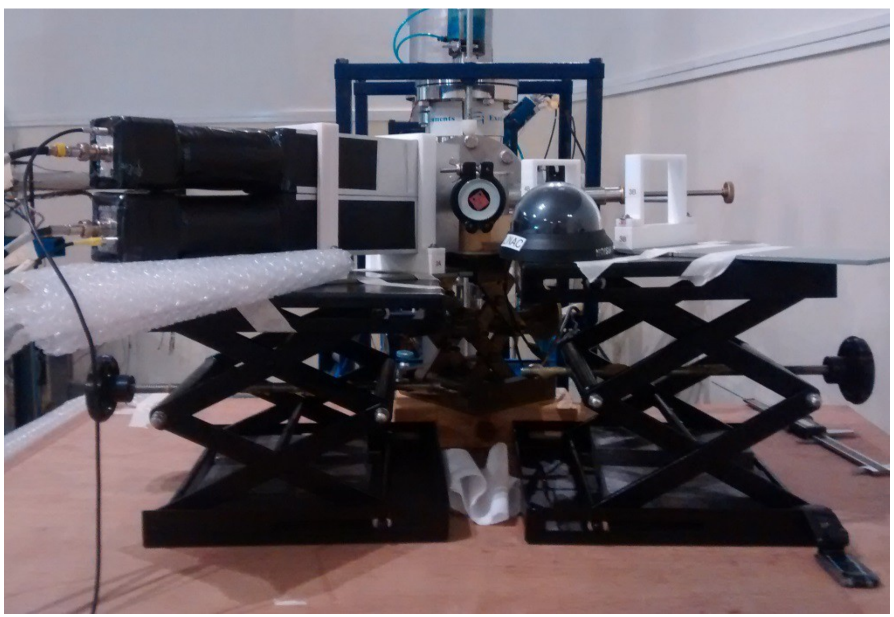
Source and Reaction Details

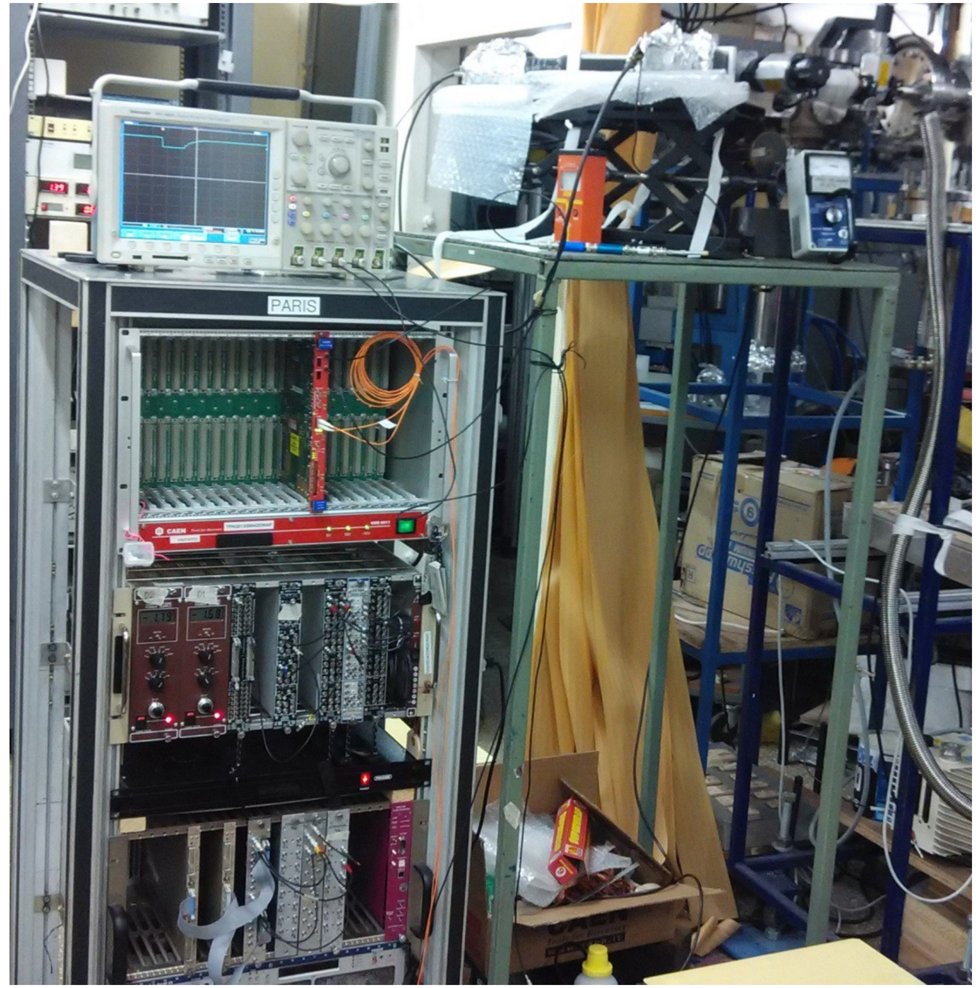
Source	Eγ (MeV)
22Na	0.511, 1.275
137Cs	0.662
54Mn	0.835
60Co	1.173, 1.332
241Am-9Be	4.439
239Pu-13C	6.130

Reaction	Eγ (MeV)	Place of Expt.
11B(p,γ) at 163 keV	4.439, 11.680	ECR lab, TIFR
11B(p,γ) at 7.2 MeV	4.439, 5.020, 18.118, 22.557	Pelletron Linac Facility, TIFR

Cosmic Ray : 34 MeV in LaBr3(Ce)

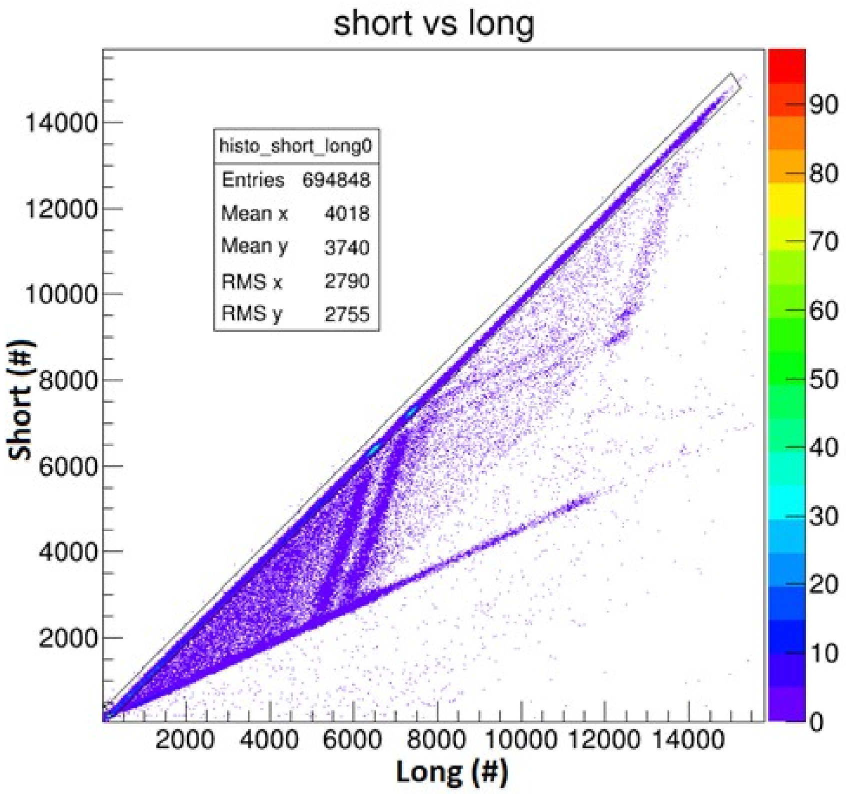
Set-up Pictures



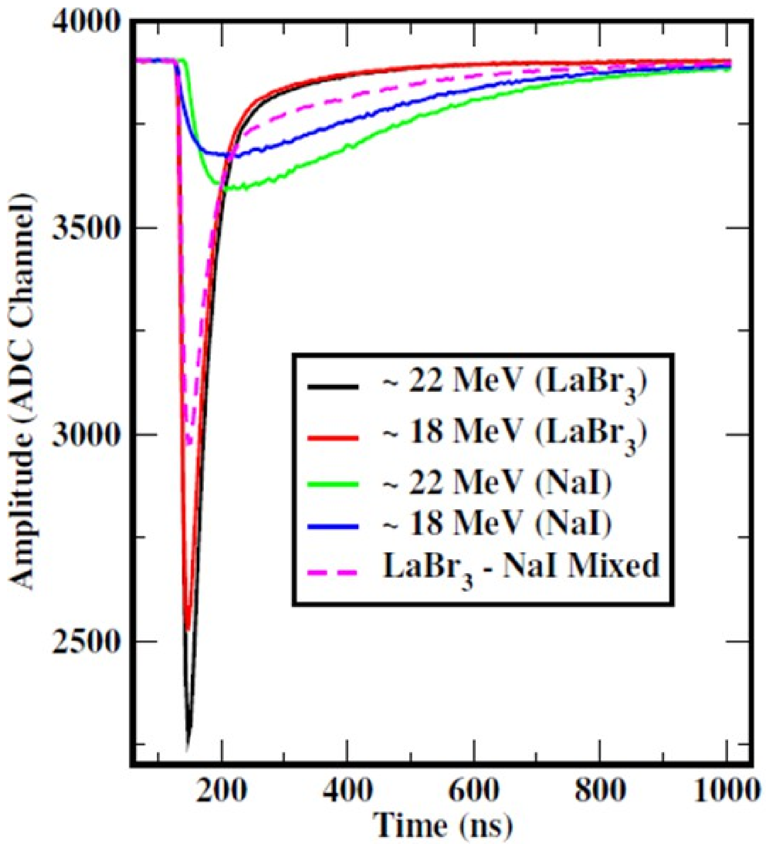


Electronics set up: Digital & Analog

Phoswich pulses



DPP-PSD firmware



wavedump software

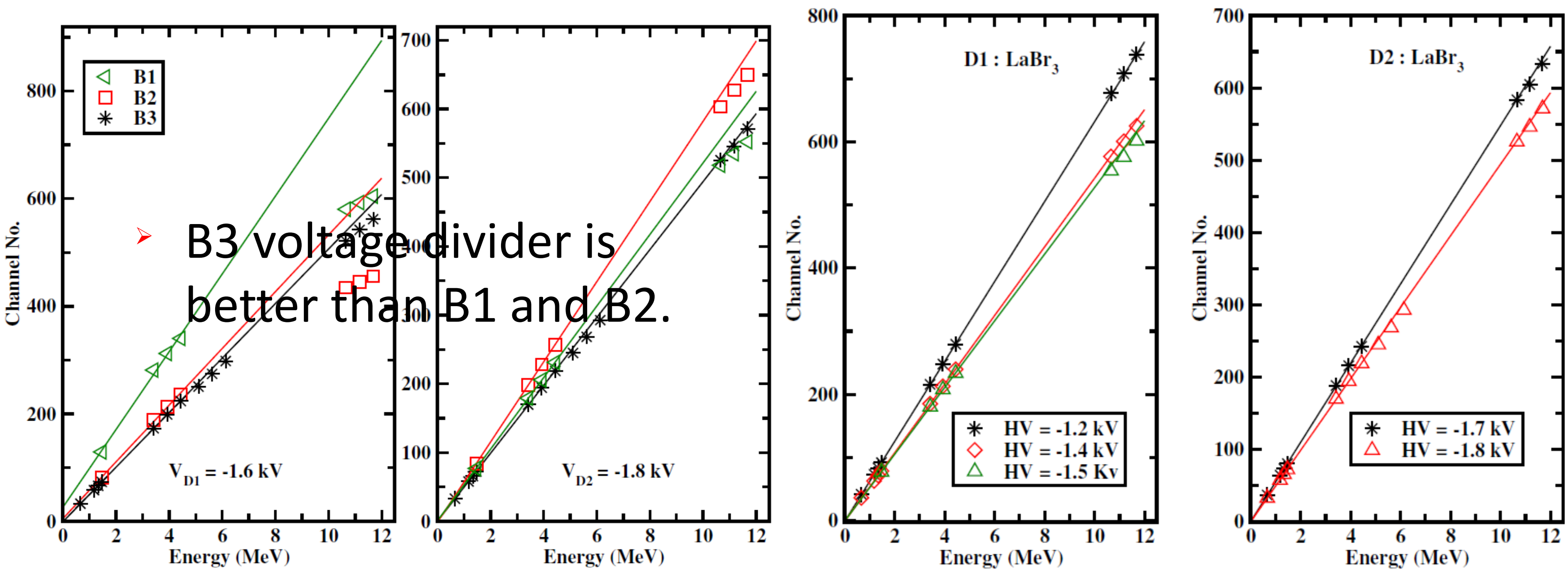
- ROOT based program is developed for analyzing data.
- LAMPS acquisition-cum-analysis software is also used for analysis.

Linearity Studies with Different Voltage Dividers

Very high light yield of LaBr3(Ce)
(63 photons/keVγ) leads saturation of PMT response.

Voltage divider circuits for PMT :

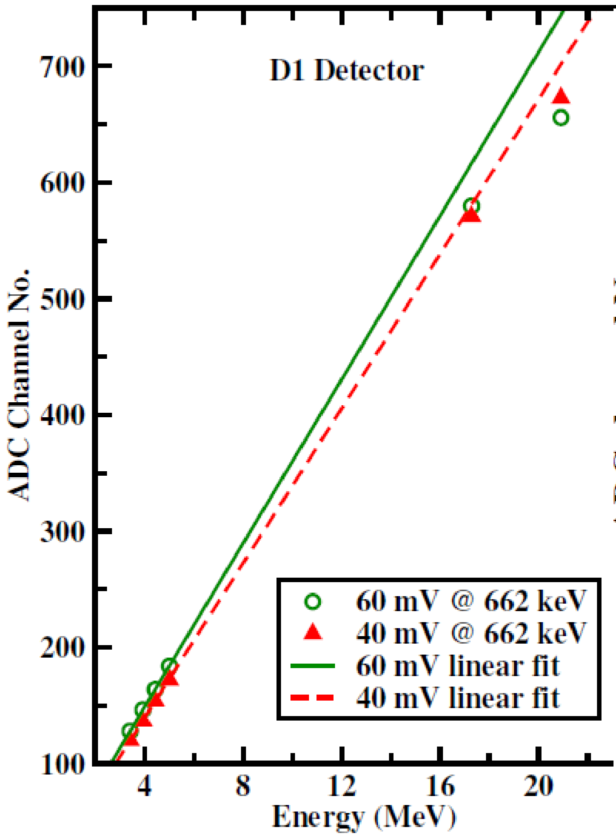
1. Hamamatsu E5859-15 (B1)
2. Modified E5859-15 (B2)
3. Voltage Divider made by Strasbourg group (B3)



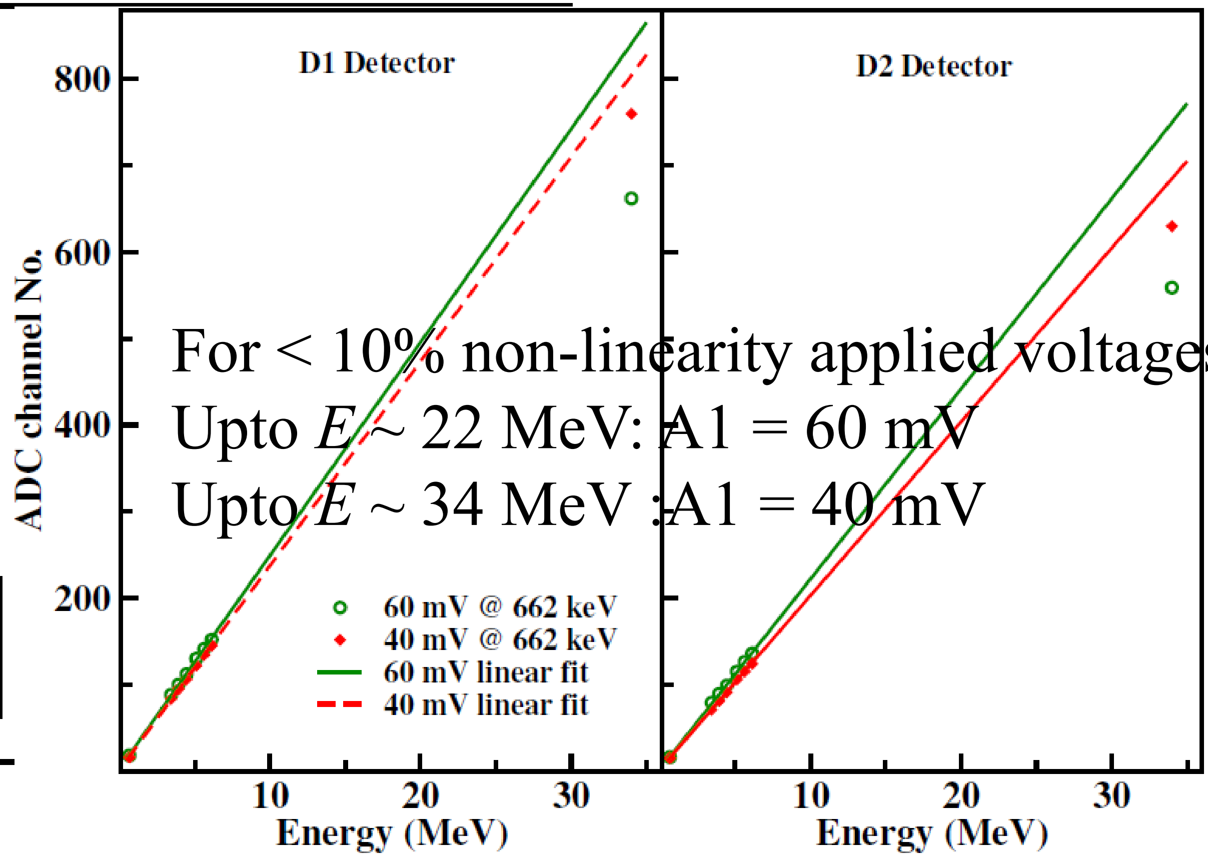
- B3 voltage divider is better than B1 and B2.

Linearity upto 22.5 MeV with B3 divider

Initial PMT supply voltage : Best linear voltage from ECR experiment.



Using cosmic muon

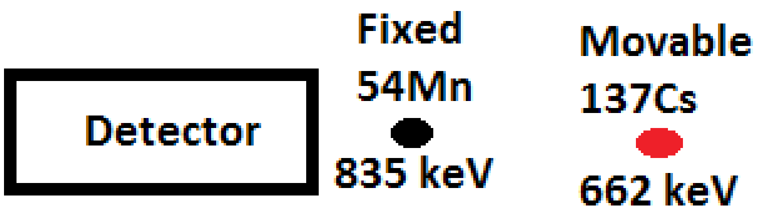


For < 10% non-linearity applied voltages

Upto $E \sim 22$ MeV: A1 = 60 mV

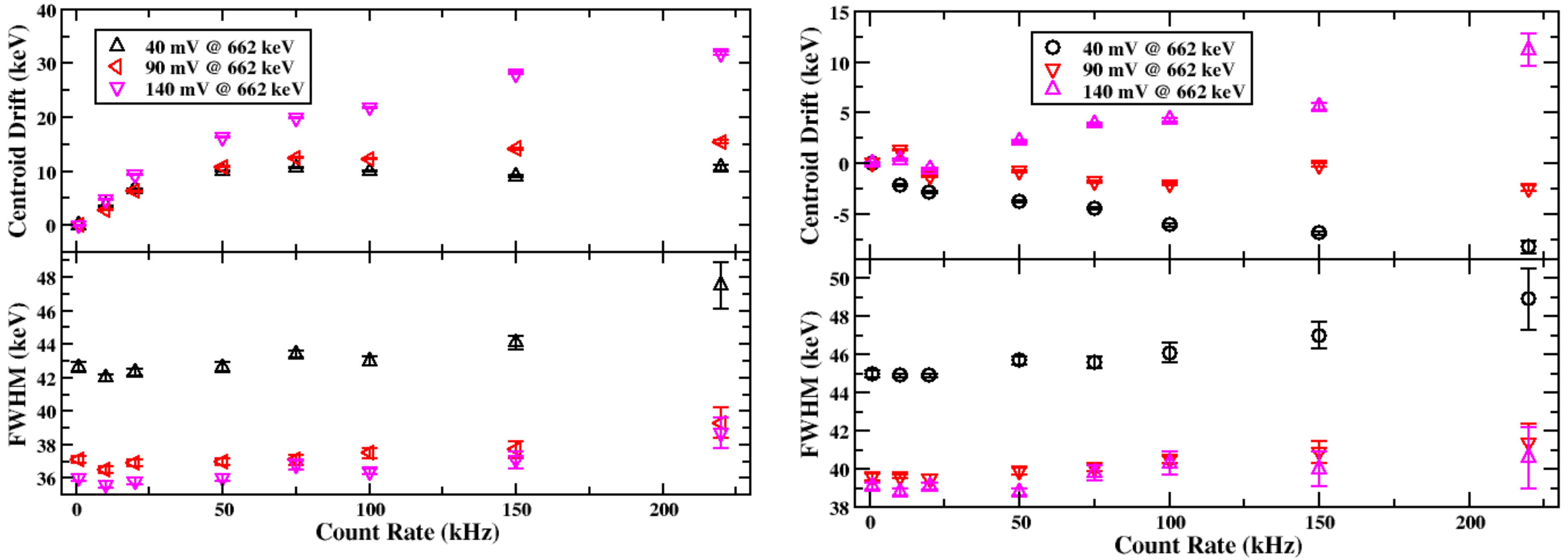
Upto $E \sim 34$ MeV : A1 = 40 mV

Count Rate Effect with B3 Voltage Divider

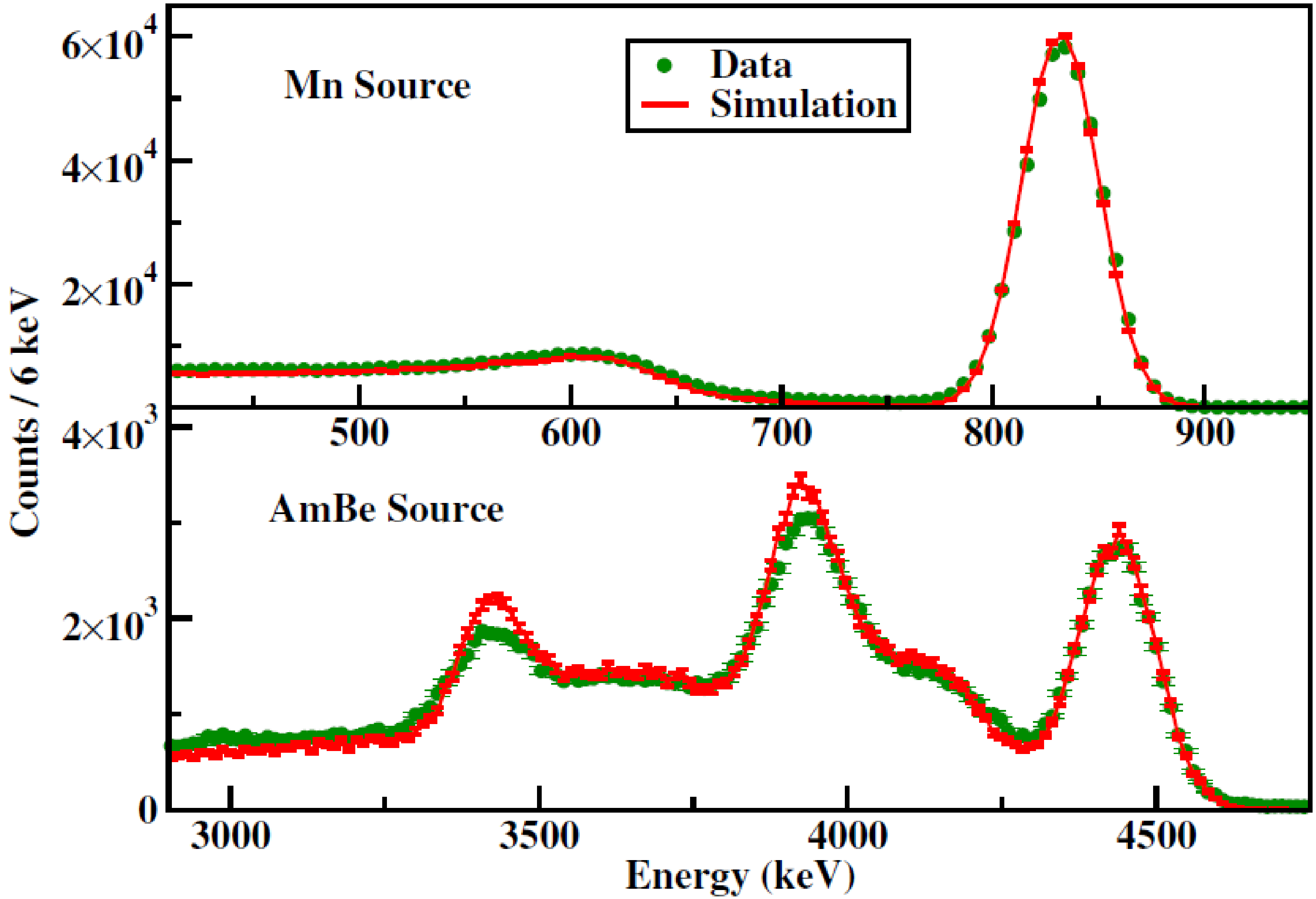


D1

D2

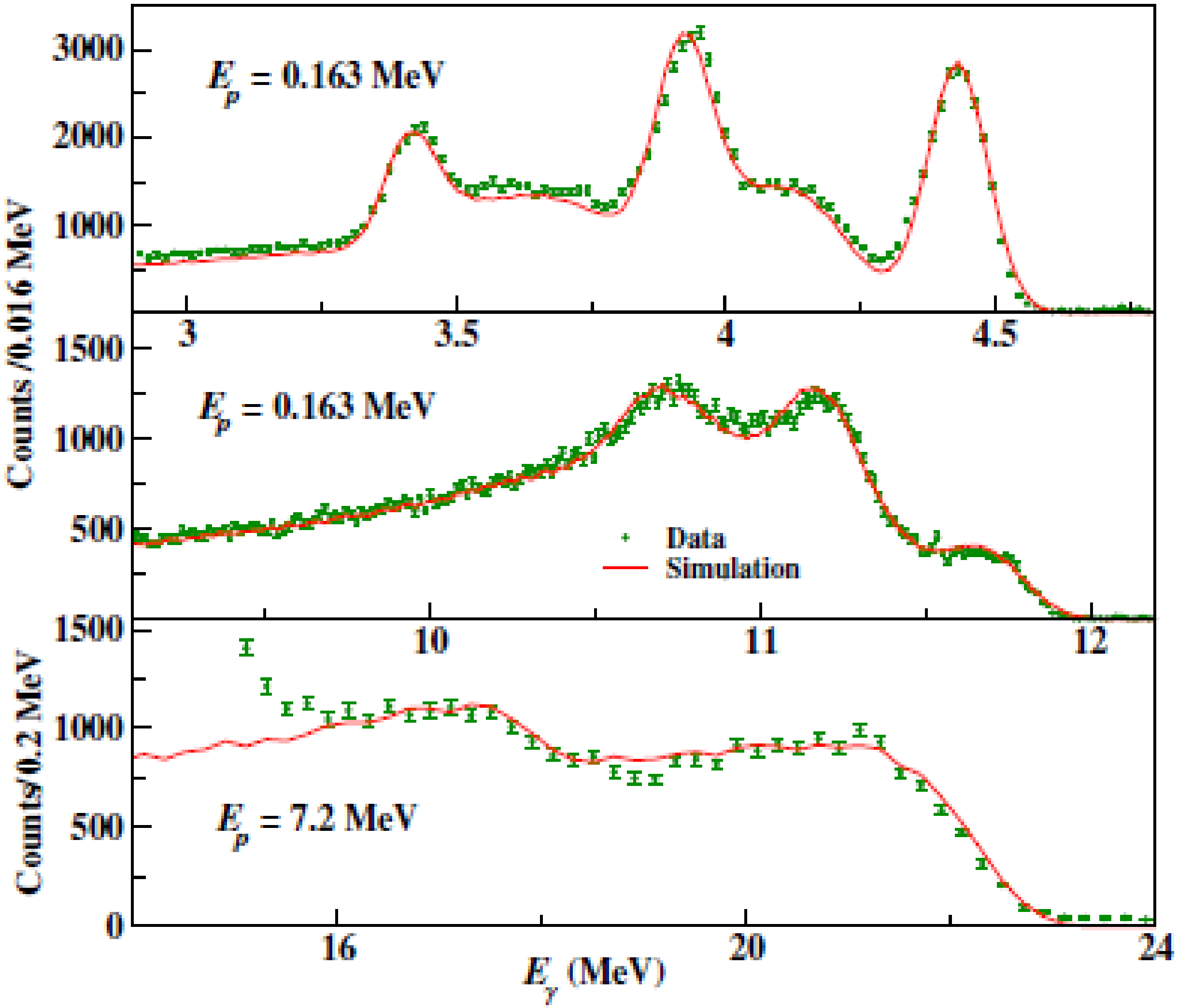


Absolute scale GEANT4 Simulation



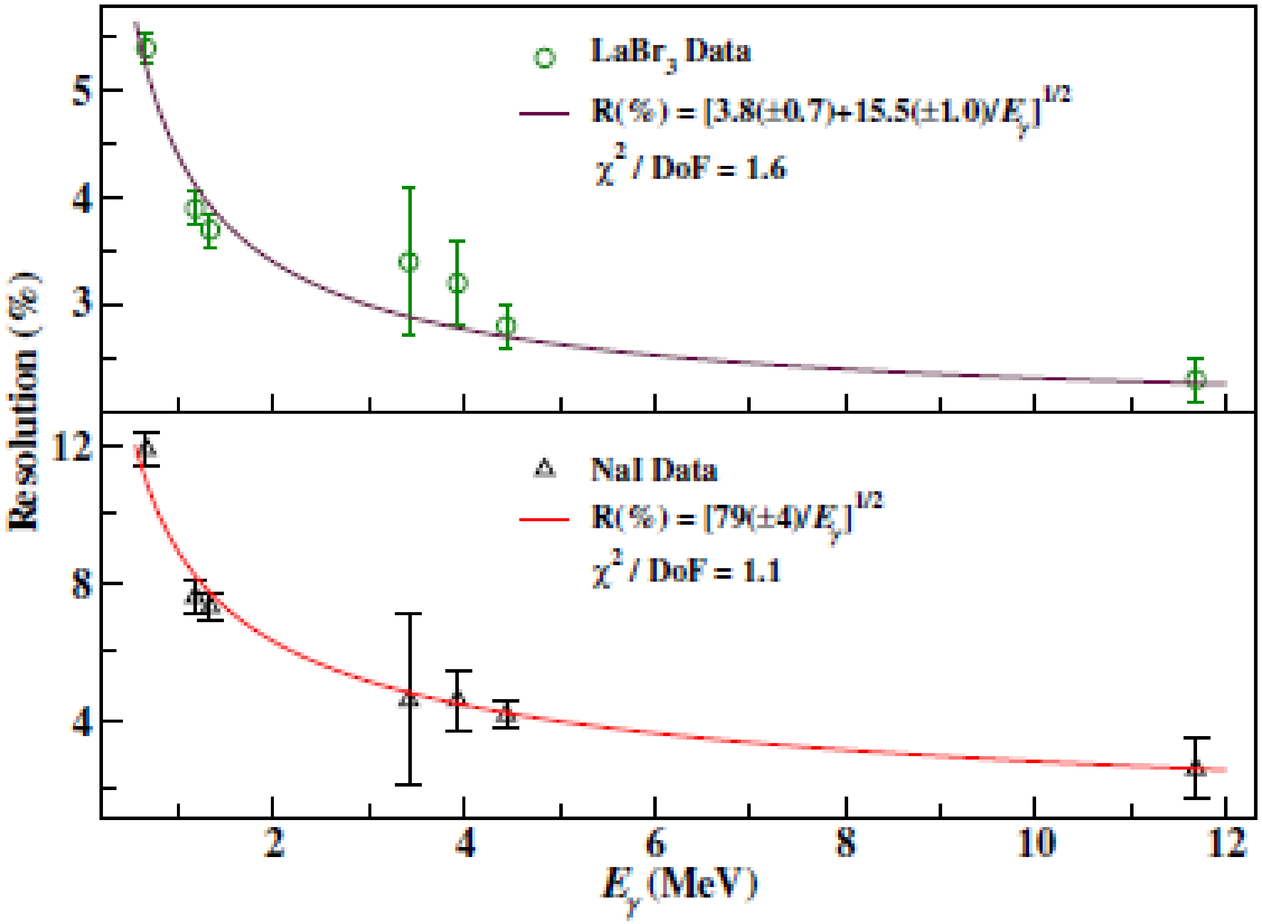
Neutron background leads to discrepancy in AmBe source spectrum

Geant4 Simulation



C Ghosh *et al.*, JINST P05023 (2016)

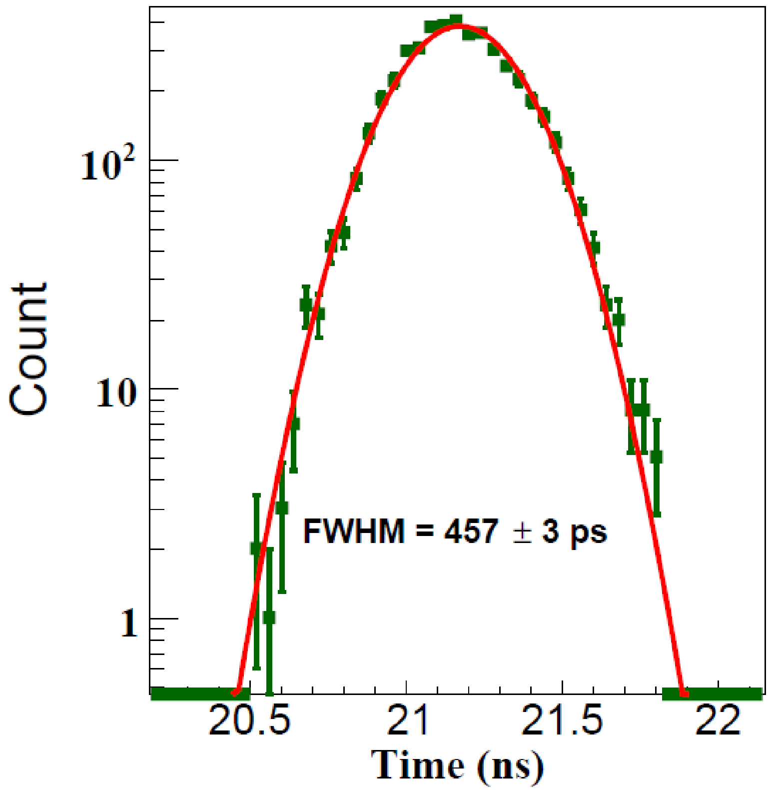
Energy Resolution



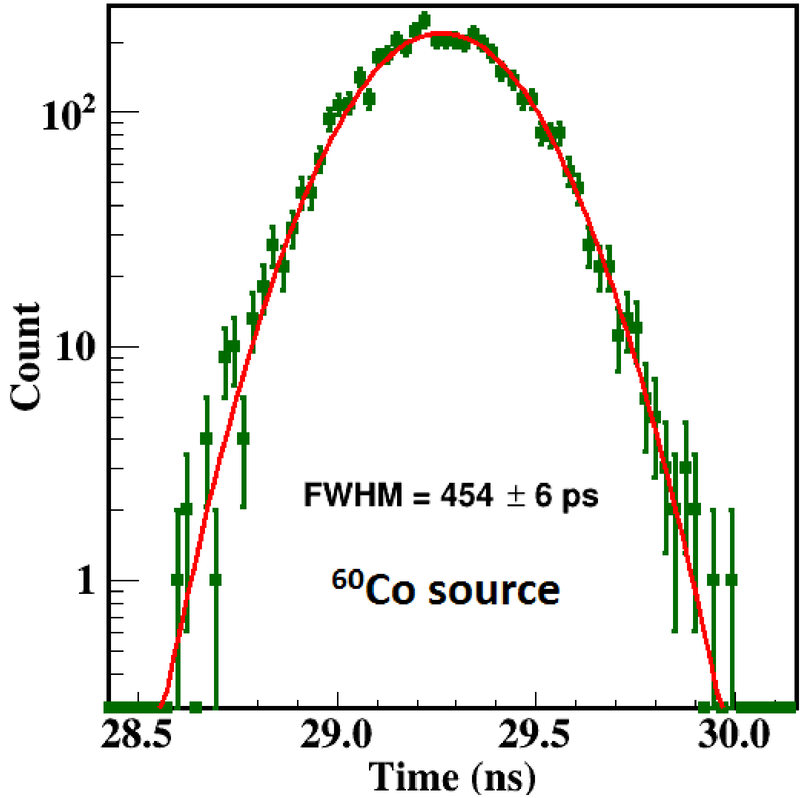
LaBr3 resolution at 4.4 MeV ~ 2.8% and at 11.7 MeV ~ 2.3%

Time Resolution

Digitizer (1 GS/s)



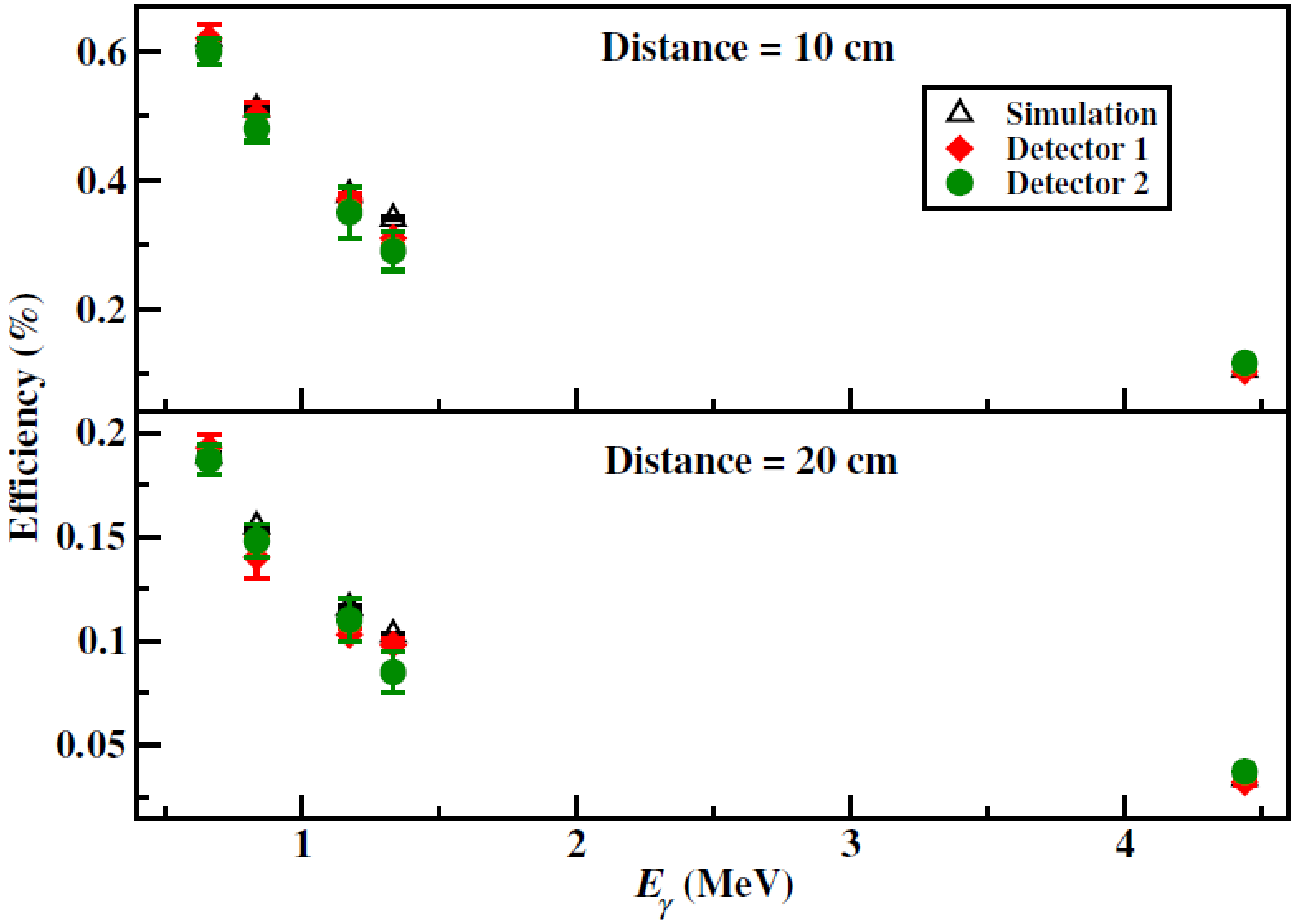
Analog



VD1= - 1.6 kV, VD2 = - 1.8 kV

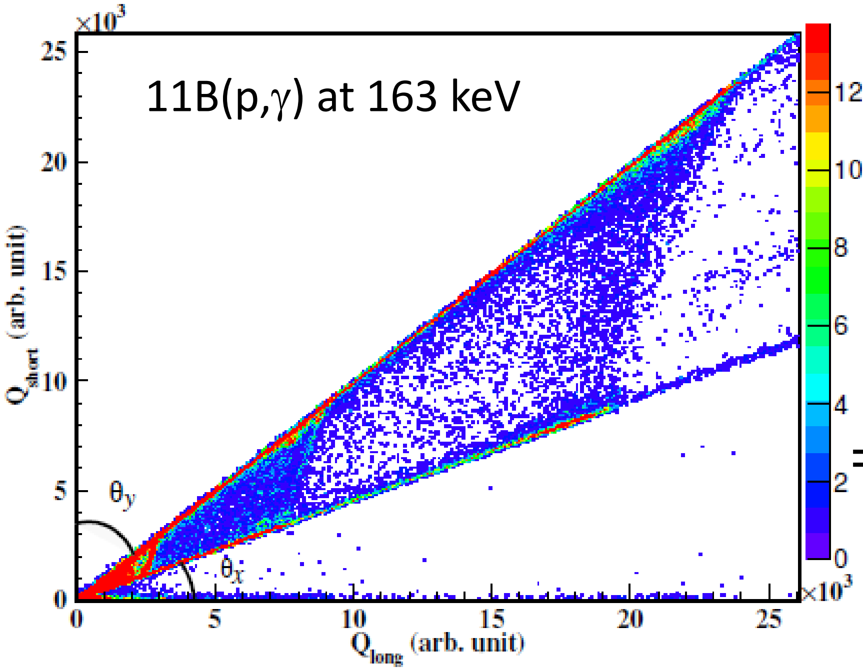
Voltage divider : B3

Efficiency of LaBr3 up to 4.4 MeV

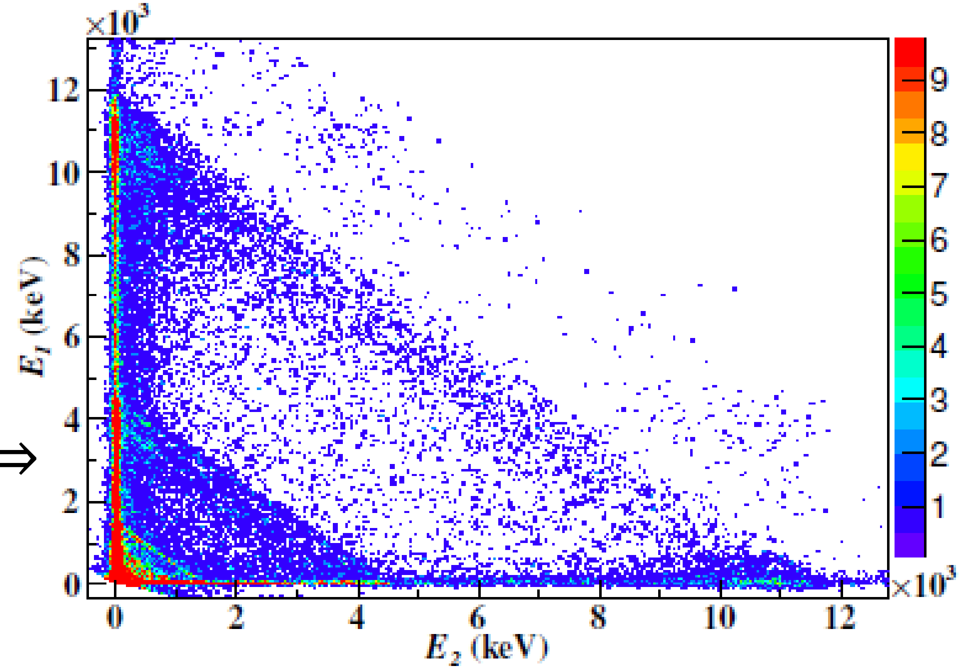


Excellent match with simulation

Construction total energy spectrum



⟹



$$Q_{short} = q_1(E_1)cos\theta_y + q_2(E_2)sin\theta_x$$

$$Q_{long} = q_1(E_1)sin\theta_y + q_2(E_2)cos\theta_x$$

⟹

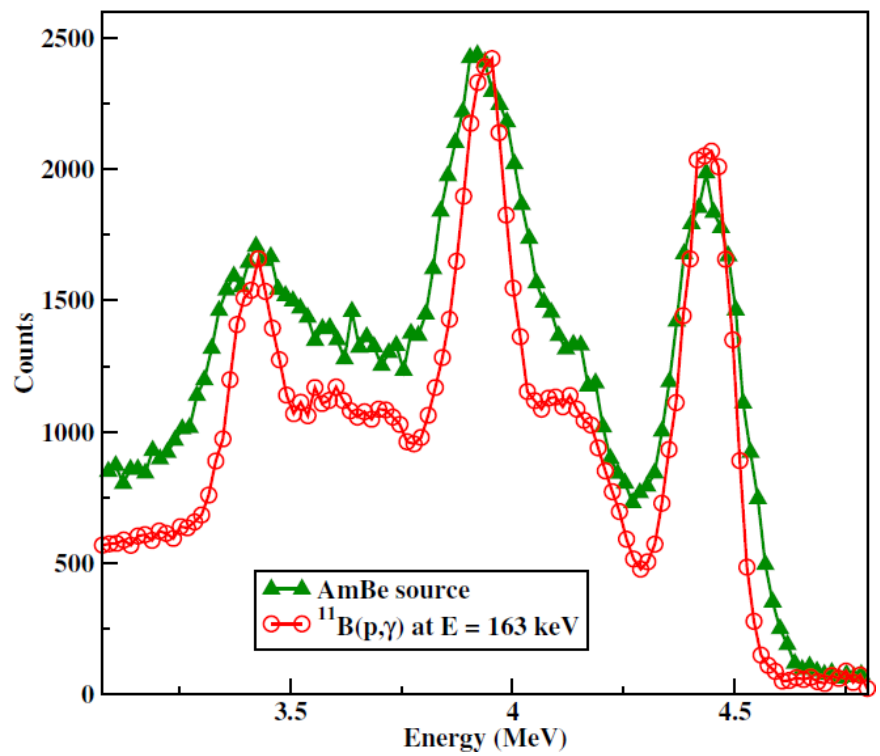
$$q_1(E_1) = k\times(Q_{short}cos\theta_x - Q_{long}sin\theta_x)$$

$$q_2(E_2) = k\times(-Q_{short}sin\theta_y + Q_{long}cos\theta_y)$$

- Calibration of q1 and q2
- $E_{tot} = E_1 + E_2$

$$k = \frac{1}{\cos(\theta_y + \theta_x)}$$

Intrinsic Broadening of AmBe Source
demonstration of phoswich resolution



The broadening due to source recoil ~ 2%

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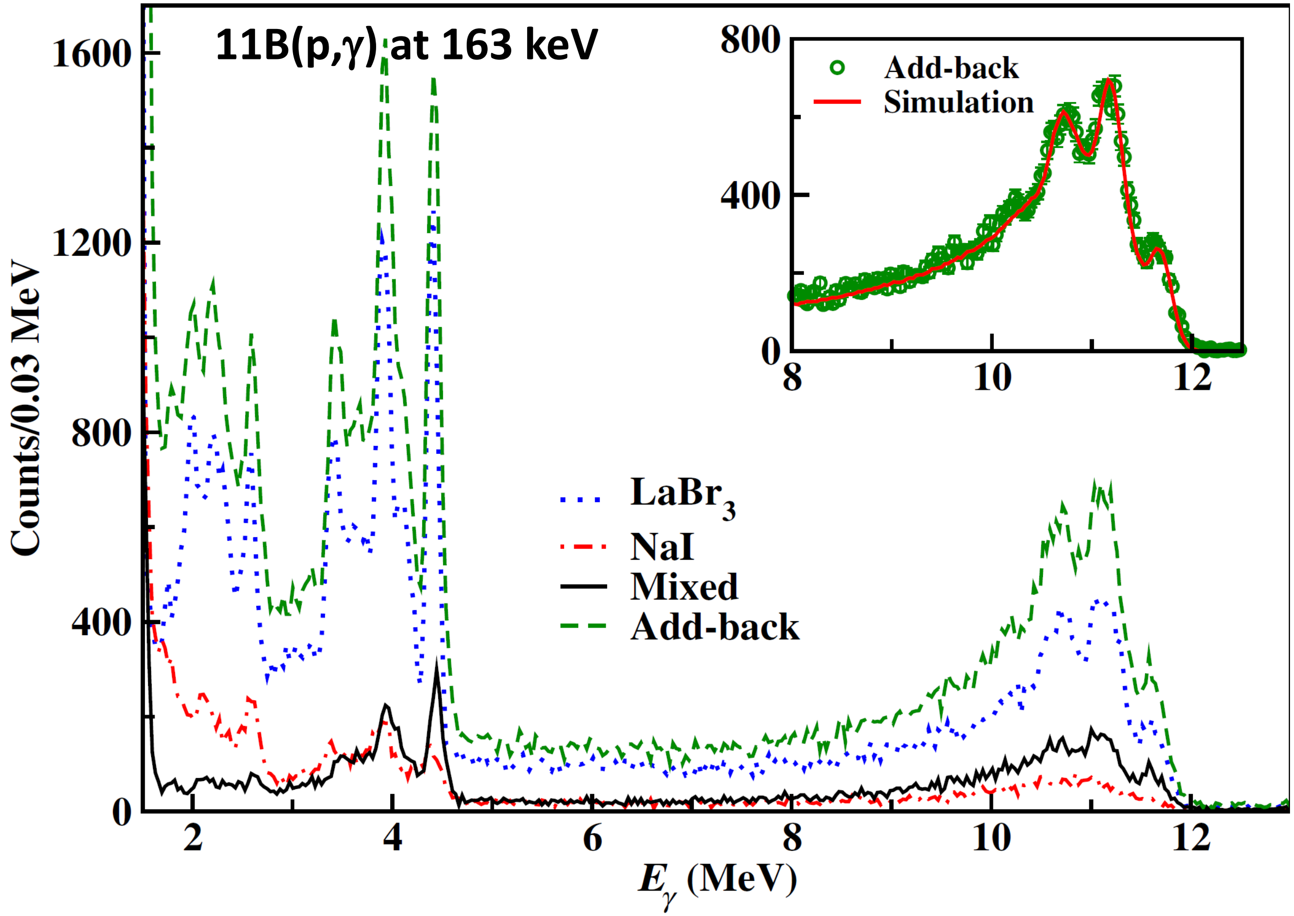
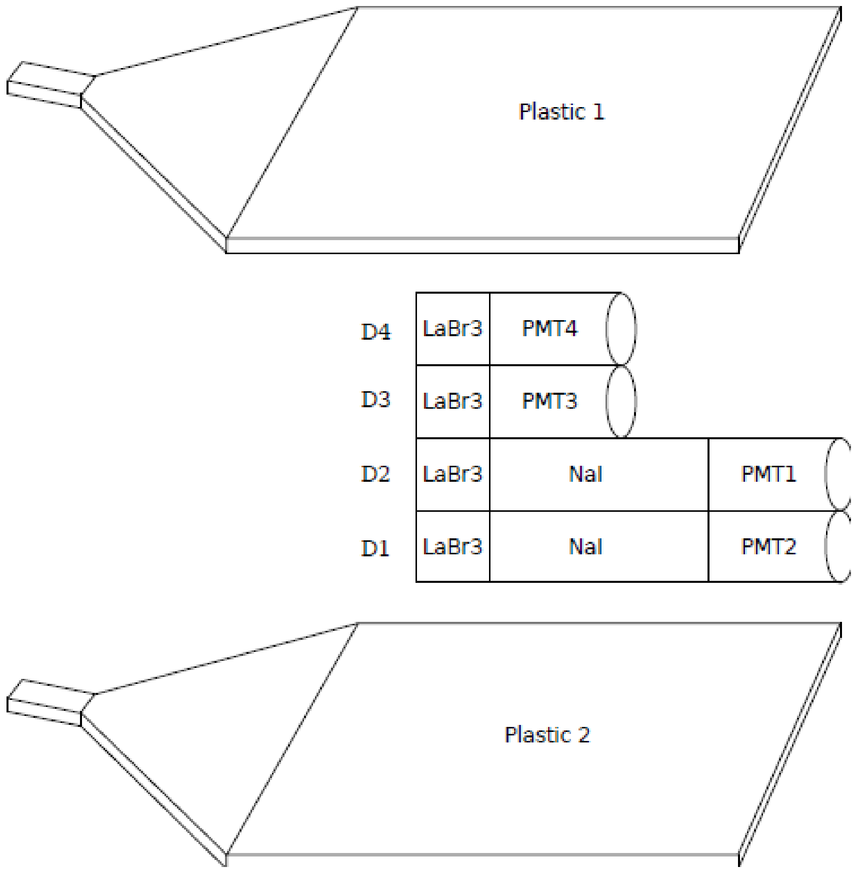
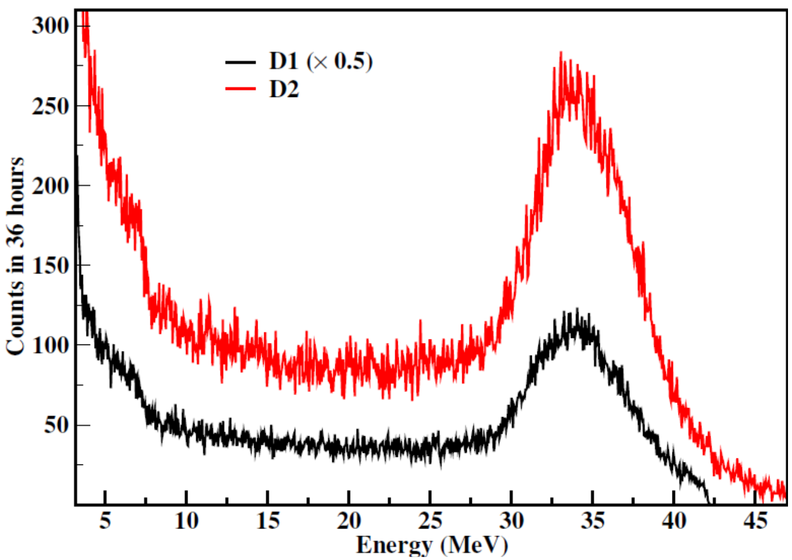
demonstration of phoswich add back concept (4-12 MeV)



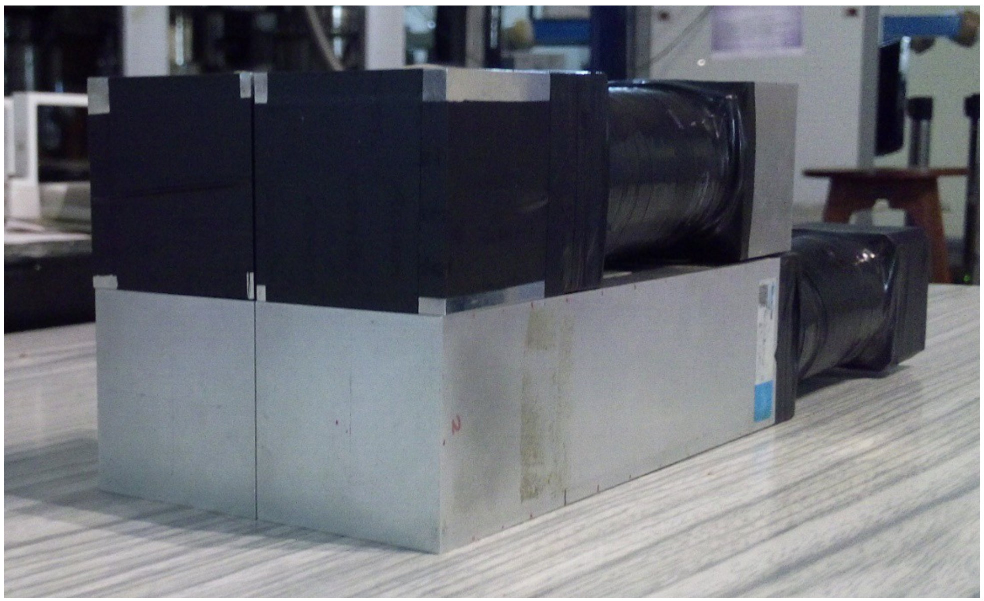
N(Eadd)/N(E1) ~1.4 @4.4 MeV

~ 1.5 @ 12 MeV


Plastic 1
D4
LaBr3
PMT4
D3
LaBr3
PMT3
D2
LaBr3
NaI
PMT1
D1
LaBr3
NaI
PMT2
Plastic 2


D1 (× 0.5)
D2
Counts in 36 hours
Energy (MeV)
300
250
200
150
100
50
5
10
15
20
25
30
35
40
45

In-beam test of PARIS mini-cluster (2x2) @ Mumbai



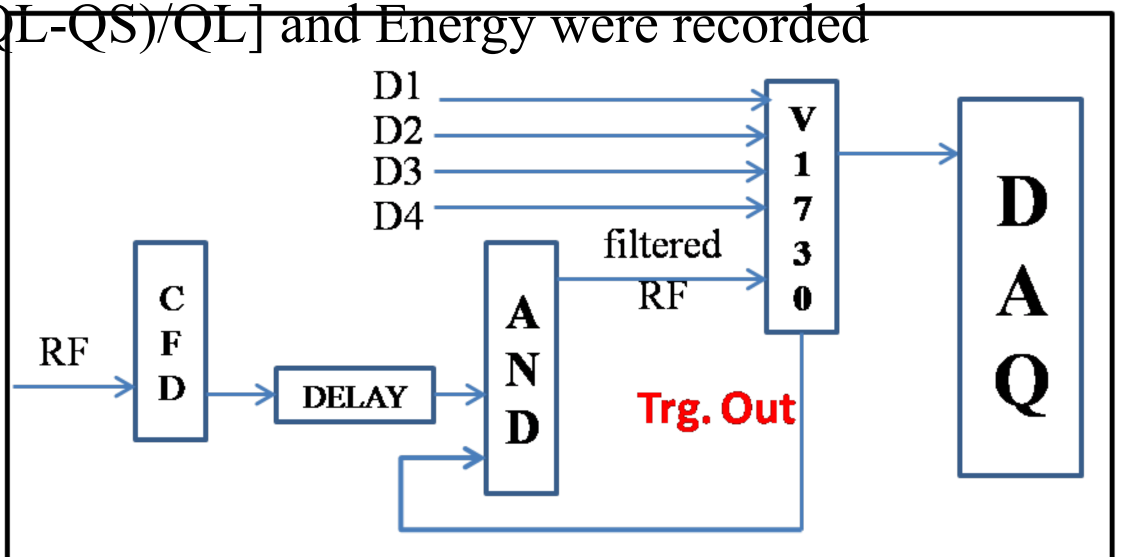
Two $LaBr_3$-NaI phoswich & Two $LaBr_3$ (2”x2”x2”)

DAQ: V1730 (16 Ch, 14 bit, 500 MS/s, 2 Vpp) with digiTES-4.2.

Test Experiment Details

- Test carried out as a satellite in the experiment to study Jacobian shape transitions using 16O (Elab = 125 MeV) on 12C target at PLF, Mumbai

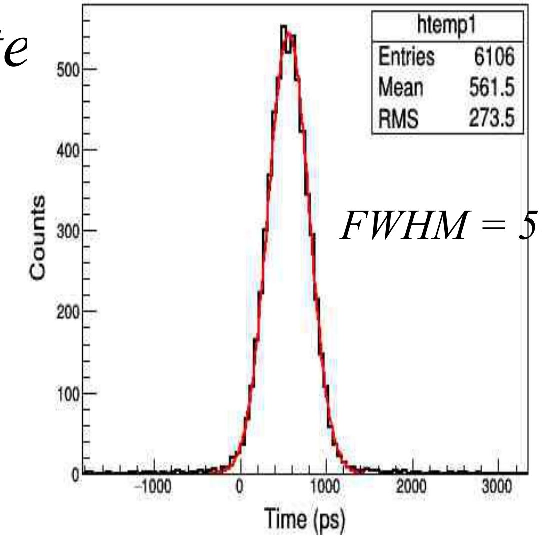
- With V1730 digitizer and digiTES-4.2.6, for each event Time stamp, PSD [(QL-QS)/QL] and Energy were recorded



Electronics Block Diagram

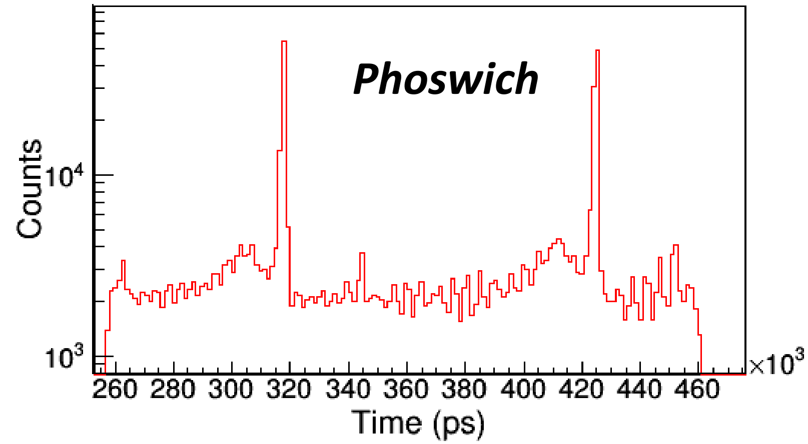
- TOF measured w.r.t. beam pulse (RF).
- The RF (~4.68MHz) was filtered using 'OR' output of V1730 with suitable masking for inputs.
- Filtered RF was recorded as input

Energy gated (60Co) time spectrum with two phoswich dete



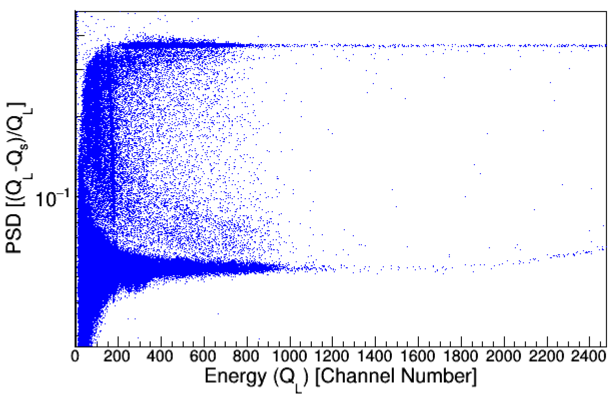
FWHM = 560 ps

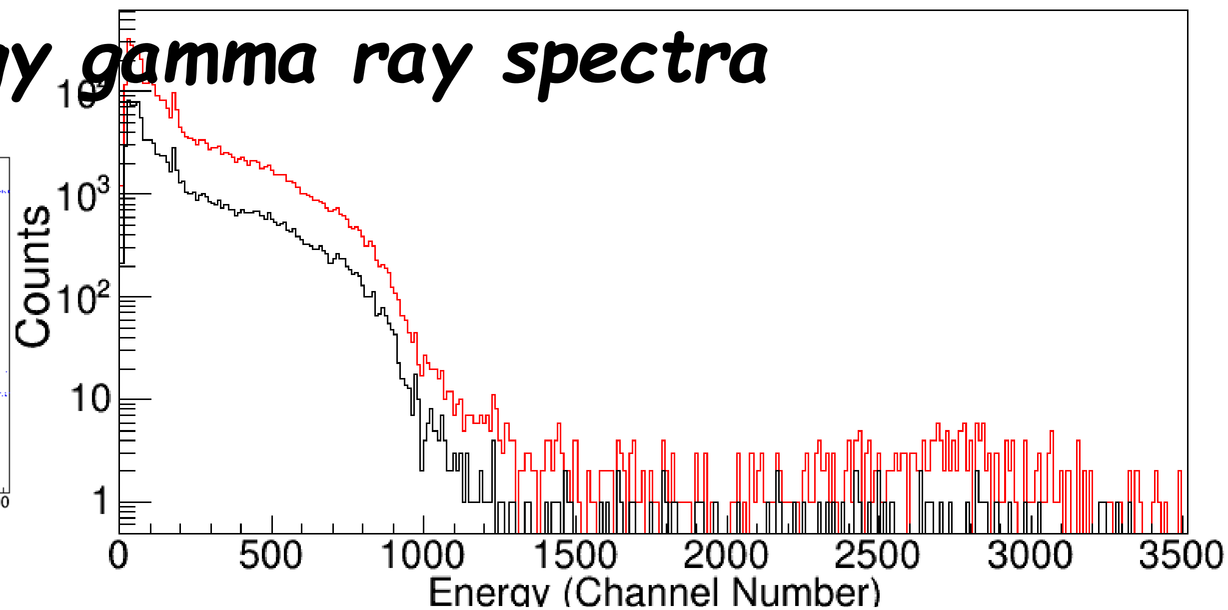
RF- TOF spectrum



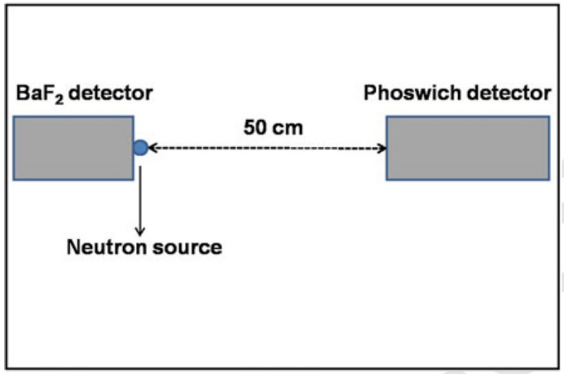
FWHM = 1.2 ns (beam width)

PSD & high-energy gamma ray spectra





Neutron response study



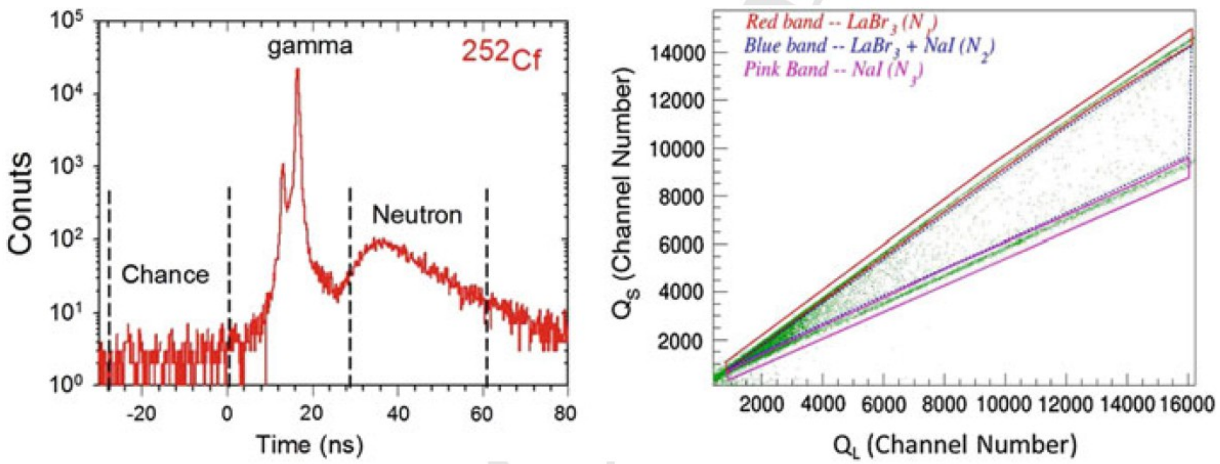


Fig. 2 Time-of-flight spectrum (left panel) and PSD spectrum (right panel) using ^{252}Cf source

Relative neutron Fraction : fi= Ni/Ntot

N1 – energy only in LaBr3,

N2 – Energy in both LaBr3 and NaI,

N3 – Energy only in NaI

f12= N1+ N2 (~primary interaction in LaBr3)

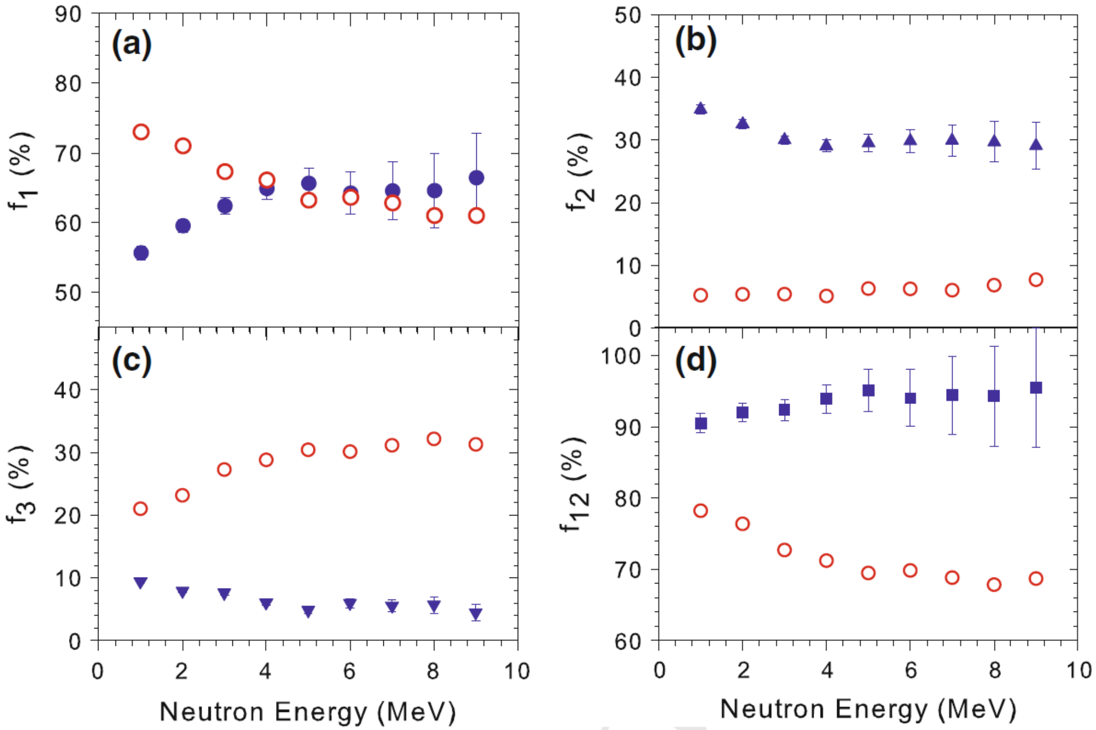


Fig. 3 Relative detection efficiency of neutrons in the phoswich detector (see text for details). Filled symbols represent the experimental data (^{252}Cf) and simulations are shown by open symbols

Discrepancy with simulation for low energy neutrons

- For En > 3 MeV

  ~ 90-95% neutrons have primary interaction in $LaBr_3$

  n-γ discrimination possible even at 15 cm

- For slower neutrons (E < 3 MeV), TOF > 6ns @15 cm and n-γ discrimination possible in NaI .

At 15 cm flight path, overall ~ 90% neutron rejection is feasible for PARIS phoswich cluster

Tests of CeBr3-NaI phoswich

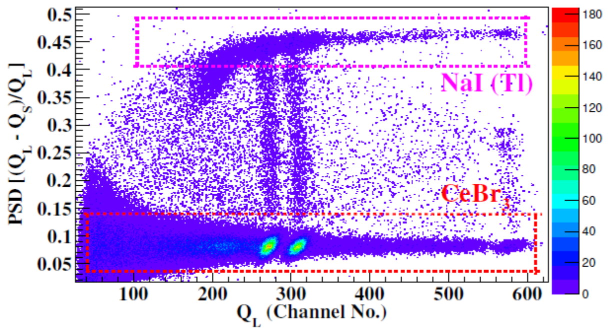


FIG. 2: A PSD spectrum with ^{60}Co source in Detector D.

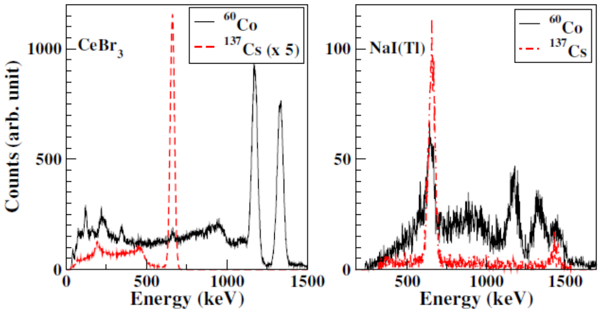


FIG. 3: PSD gated spectra of ^{60}Co and ^{137}Cs in individual crystals (a) $CeBr_3$ (b) NaI(Tl) for detector D.

TABLE I:

Resolution of $CeBr_3$ and NaI(Tl) crystals.

Detectors	Measured[a] Resolution (%) CeBr₃	NaI(Tl)	Peak to Valley ratio
A	4.9	7.6	29.3
B	5.1	8.4	28.9
C	5.9	8.2	23.6
D	4.7	8.0	30.3

[a]Error in resolution is ~ 0.5%.

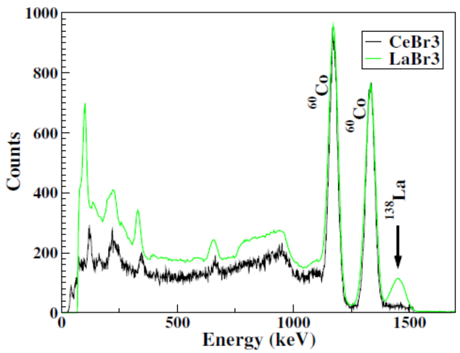


FIG. 4: A comparison of γ-ray spectra using $CeBr_3$-NaI(Tl) and $LaBr_3$(Ce)-NaI(Tl) detectors.