

Beams and sites for testing PARIS

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*Tata Institute of Fundamental Research,
Mumbai*

*PARIS Collaboration Meeting,
Bormio
21st February, 2012*

Plan of the talk

✚ Beams & sites:

calibrations & Determination of response of PARIS at high energies
a few standard reactions & accelerator facilities

✚ Studies with Lanthanum Bromide detectors

testing small volume detectors (WG Talks 2009, 2011)

testing large volume crystal
combined assembly of $\text{LaBr}_3\text{:Ce}$ & NaI(Tl)
some results for 2 "X2"X8" $\text{LaBr}_3\text{:Ce}$ bars

testing of a $\text{LaBr}_3\text{:Ce}$ - NaI(Tl) phoswich

measurements with sources and in-beam and simulations

Collaborators

- *D. A. Gothe*
- *P.B. Chavan*
Tata Institute of Fundamental Research, Mumbai
- *G. Anil Kumar* *IIT-Roorkee*



Calibration & response function from low to high energy;

Sources: ^{137}Cs (661.6) ^{60}Co (1173, 1332), ^{88}Y (897, 1832))

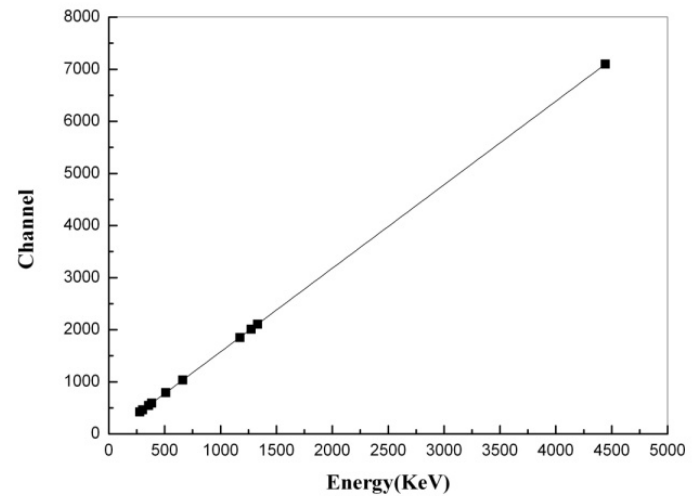
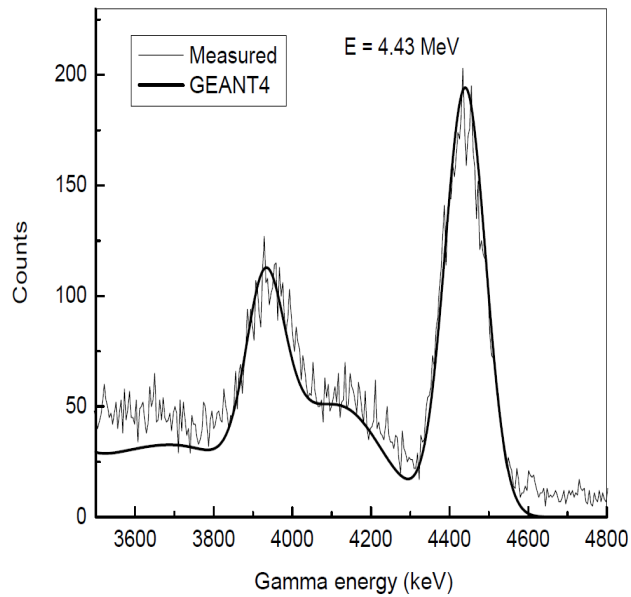
^{244}Am - ^9Be (4.43 MeV) $^9\text{Be}(\alpha, n\gamma)^{12}\text{C}$

^{244}Cm - ^{13}C (6.13 MeV) $^{13}\text{C}(\alpha, n\gamma)^{16}\text{O}$

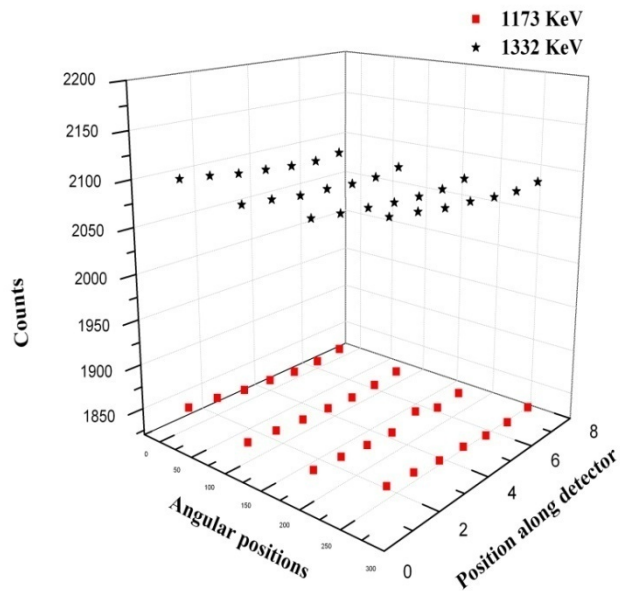
The use: Energy calibration, timing response, efficiencies, linearity, uniformity
neutron response

References:

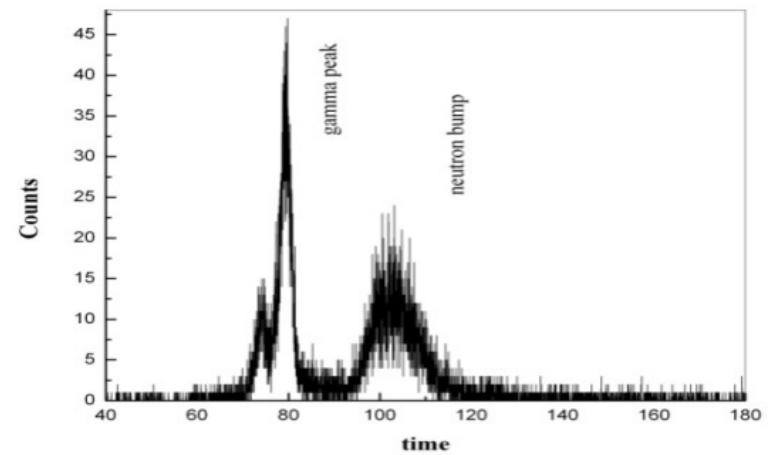
- 1) Nicolini et al., *Nucl. Instr. Meth. A* 582 (2007)
- 2) Ciemala et al., *Nucl. Instr. Meth. A* 608 (2009)
- 3) G. Anil Kumar et al. *Nucl. Instr. Meth A* 610(2009)
- 4) G. Hall et al. *NIM-A (In Press)*, Available on line 25 Oct. 2011



Linearity



Uniformity



Mazumdar,Gothe, Kumar

n-gamma

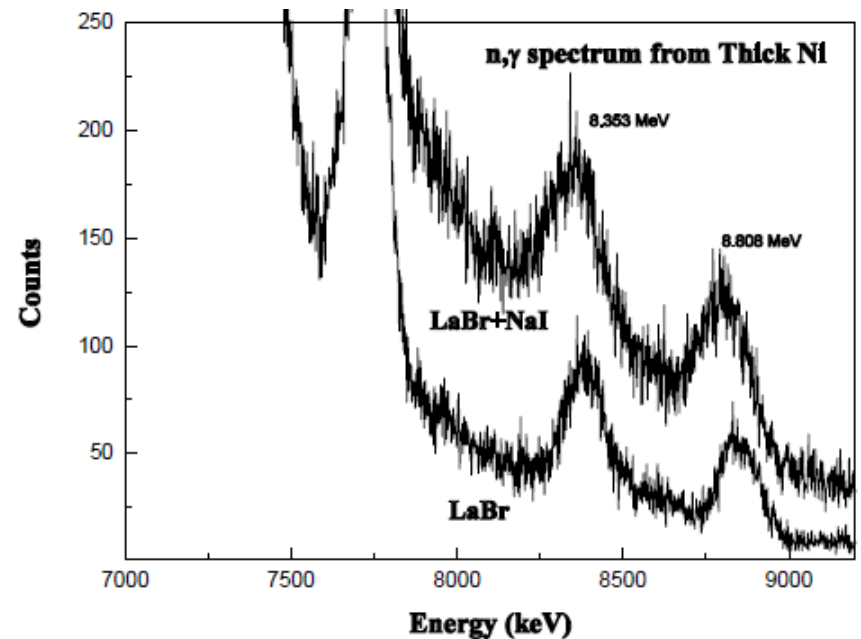
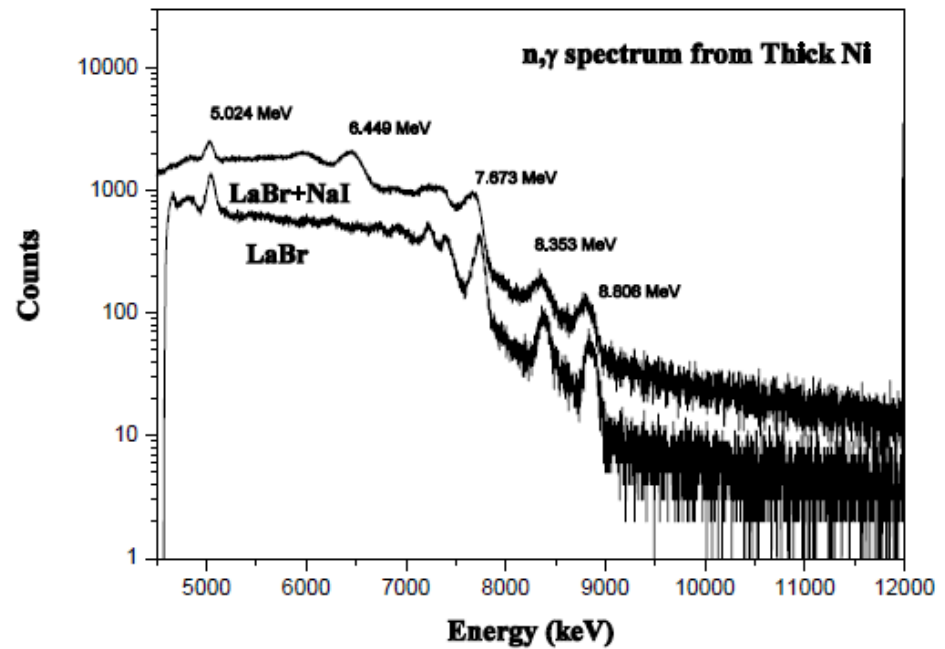
Higher energies beyond Am-Be & Cm-C



Discrete gamma rays up to ~ 9 MeV in lab

Large LaBr + Annular NaI assembly

Discussions with F. Camera gratefully acknowledged



Few standard in-beam reactions at a glance

$^{19}\text{F}(\text{p}, \alpha\gamma)^{16}\text{O}$ proton energy 340 keV $E_\gamma = 6.13 \text{ MeV}$

$^{27}\text{Al}(\text{p}, \gamma)^{28}\text{Si}$ proton energies 992 keV, 770 keV

$E_\gamma = 2.8, 7.7, 10.5, 12.3 \text{ MeV}$

(Thick target yield per incident proton for 10.76 MeV is well known)

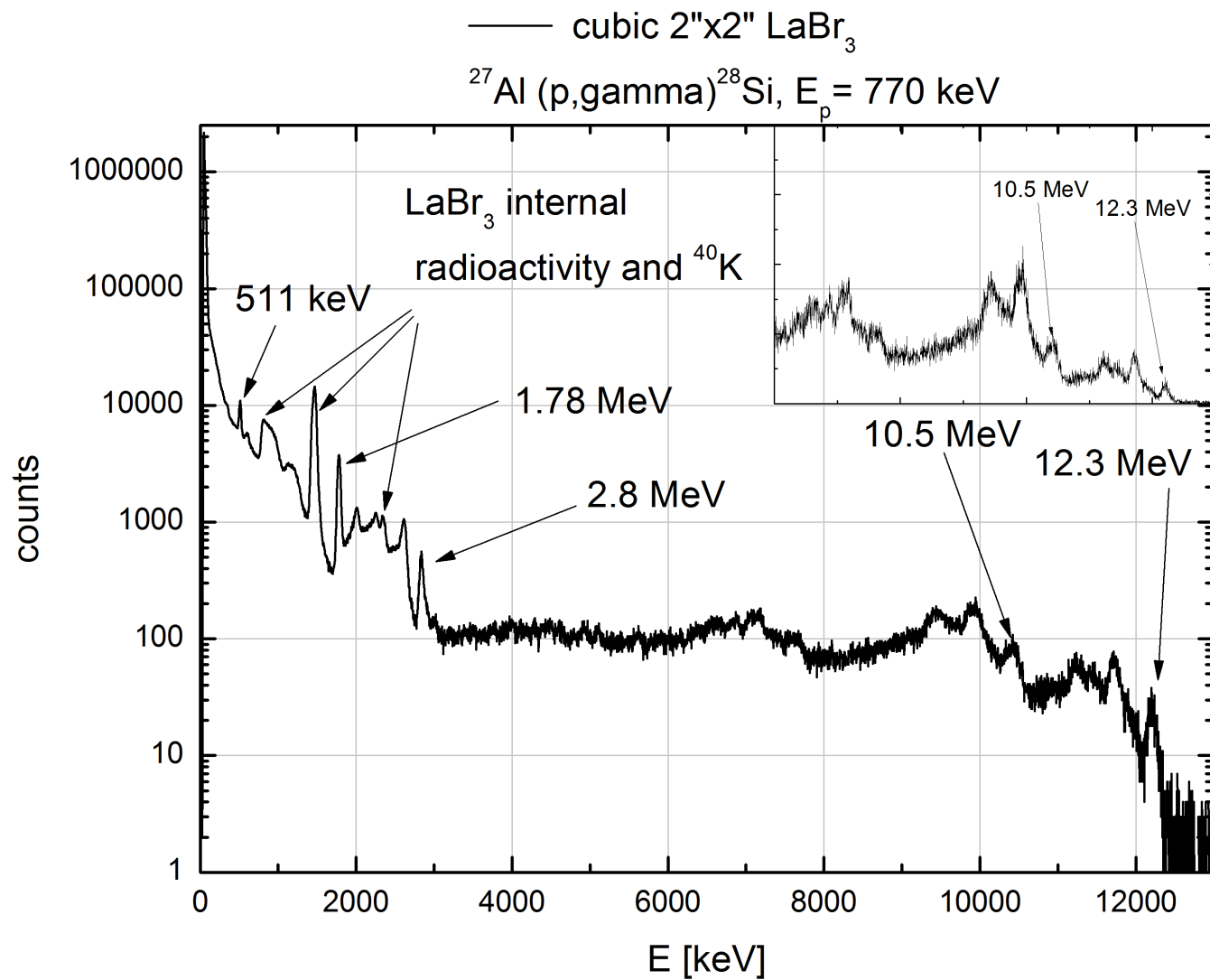
$^{11}\text{B}(\text{p}, \gamma)^{12}\text{C}$ radiative capture of proton gives 22.5 and 18.1 MeV
(maximum cross section at 7.2 MeV)

$^{12}\text{C}(\text{p}, \text{p}')\gamma$ 15.1 MeV gamma rays from inelastic scattering of 22 MeV proton off ^{12}C .

$^{23}\text{Na}(\text{p}, \gamma)^{24}\text{Mg}$ 1.368 , 2.754, 8.925, 11.585 MeV

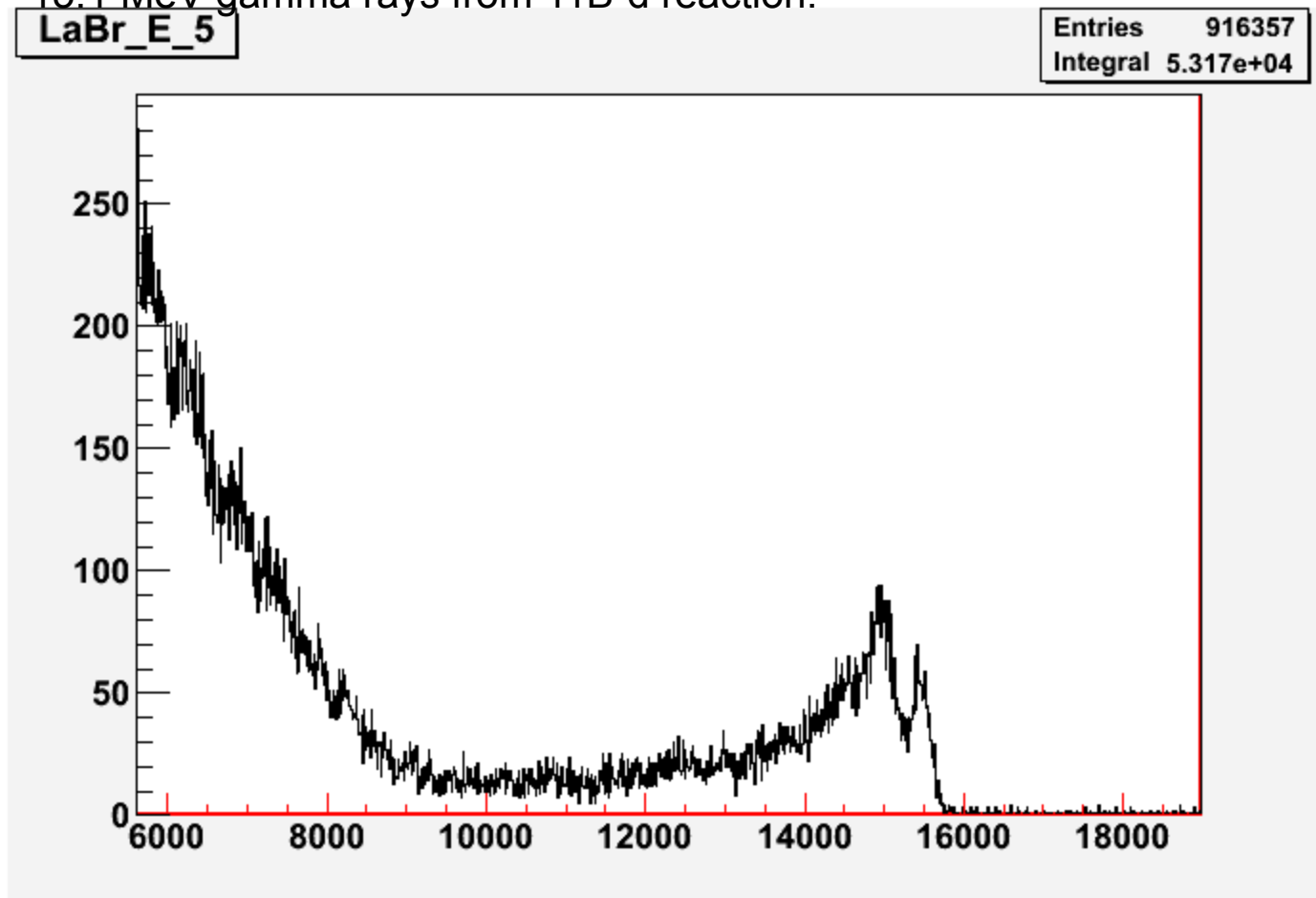
$^{39}\text{K}(\text{p}, \gamma)^{40}\text{Ca}$ 3.904, & 5.736 MeV

$^7\text{Li}(\text{p}, \gamma)^8\text{Be}$ 17.619 MeV

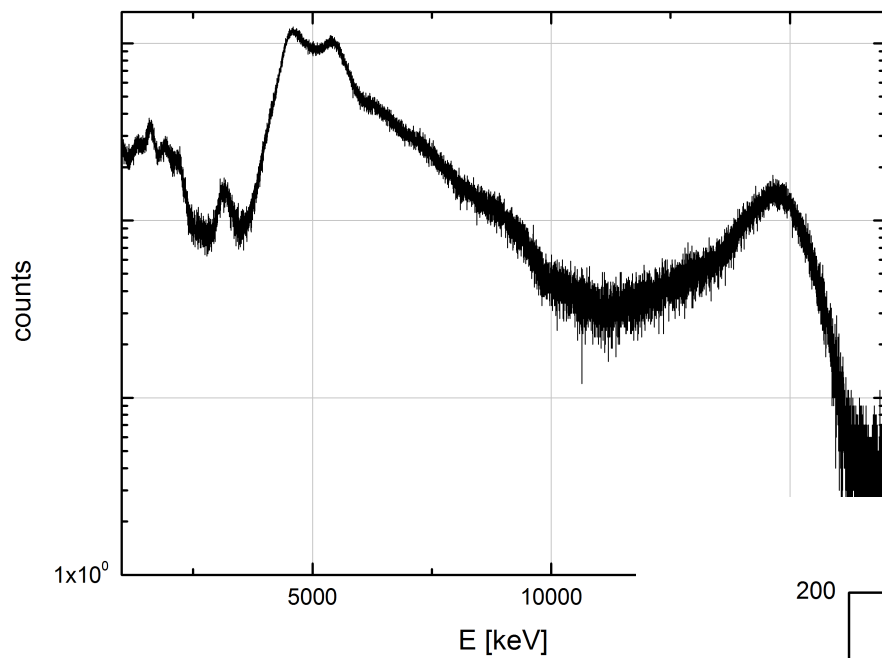


Courtesy: A. Maj

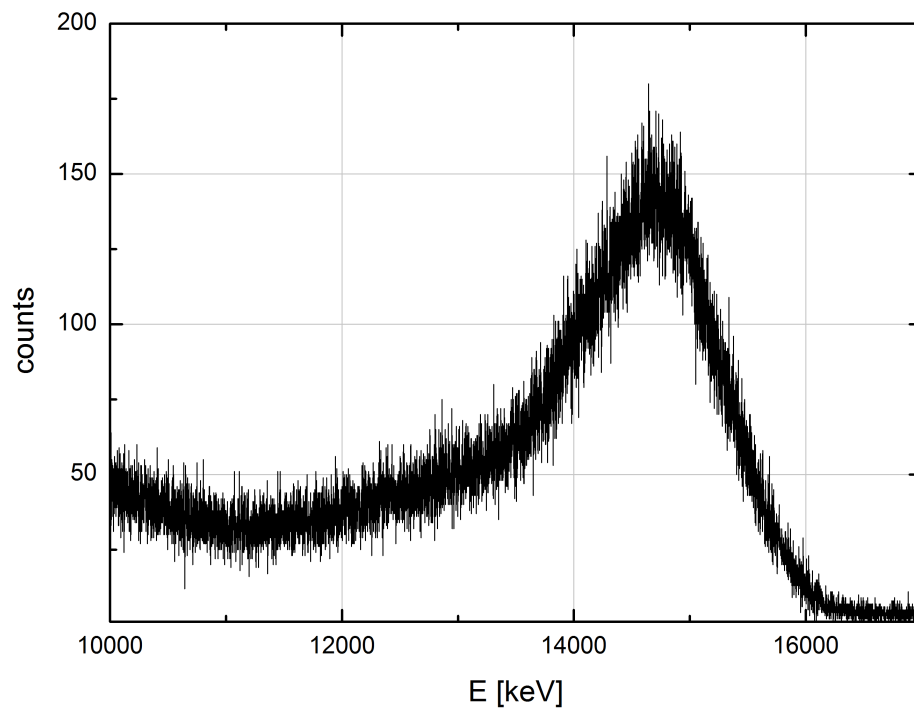
15.1 MeV gamma rays from $^{11}\text{B-d}$ reaction.

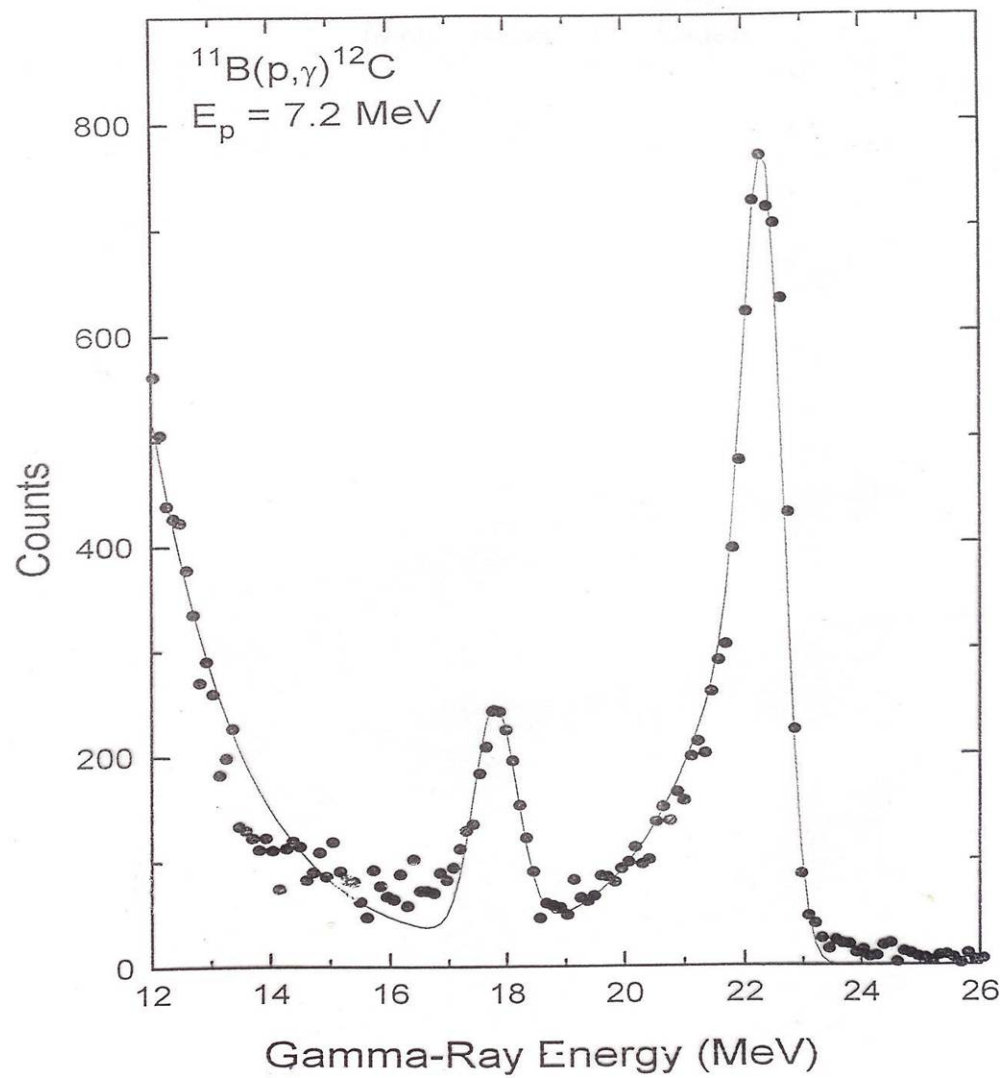


Courtesy: Prof. F. Camera

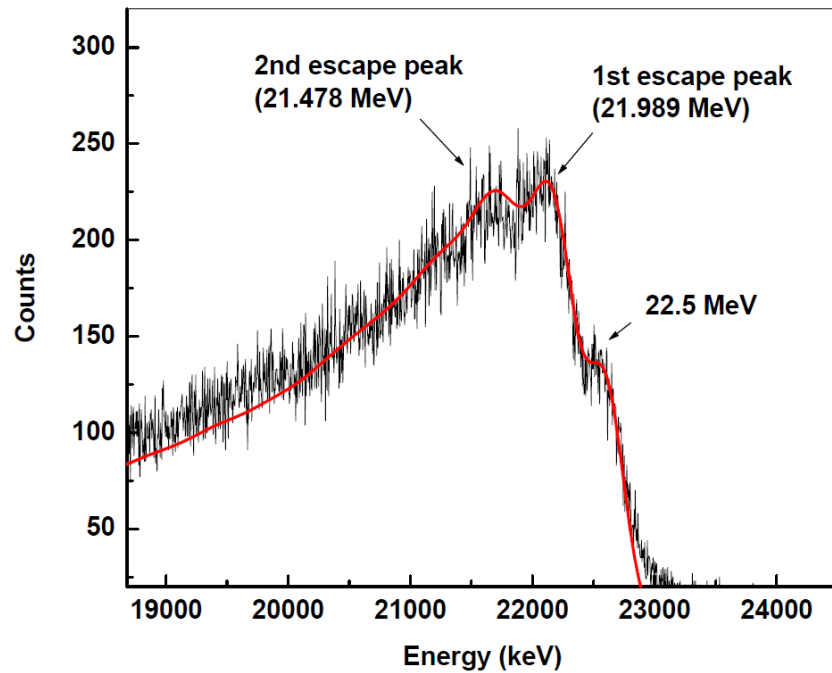


HECTOR spectrum:
Courtesy: Prof. F. Camera





Mazumdar et. al. NIM-A (417)

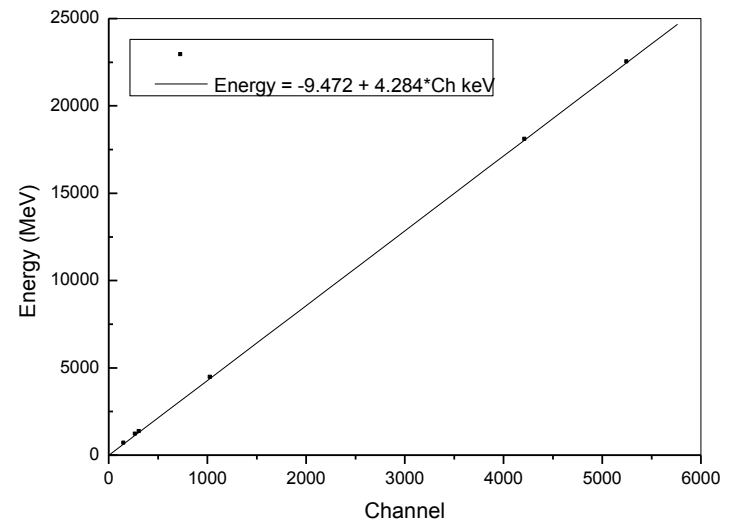
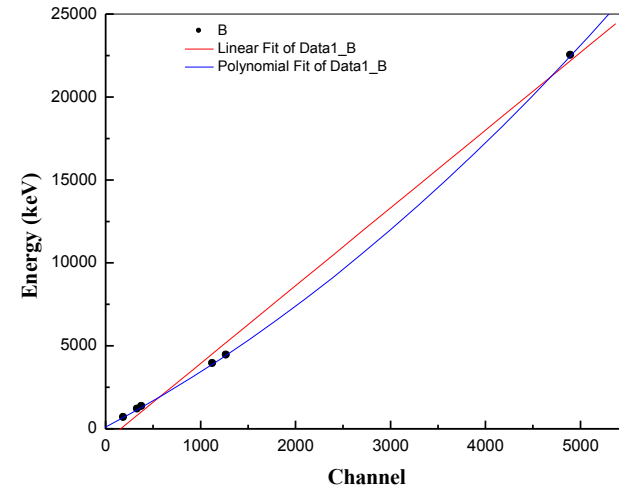


22.5 MeV γ -rays measured at TIFR with the large LaBr.

Mazumdar *et al.*

Ciemala et al. have measured up to 17.6 MeV for 2" X 2" NIM 608 (2009), Fig. 3

Linearity up to 22.5 MeV



Some facilities for in-beam measurements:

IPHC, Strasbourg:

(proton beams of different energies and intensities)

IPNO, Orsay

(protons up to 25 MeV available at high current)

ATOMKI, Debrecen:

Protons between ~150 keV to ~5 MeV at several micro Amp.
(also good stock of useful targets)

IFJ, Krakow:

Protons between 500 keV up to 2.5 MeV

India:

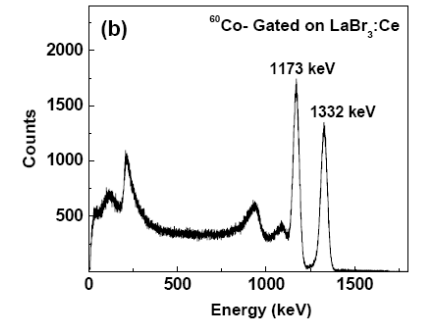
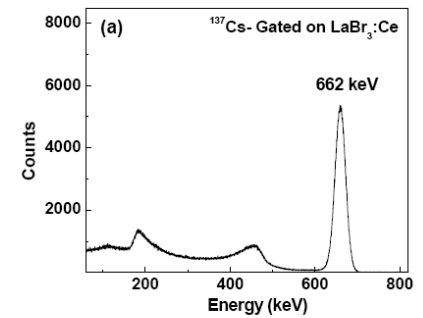
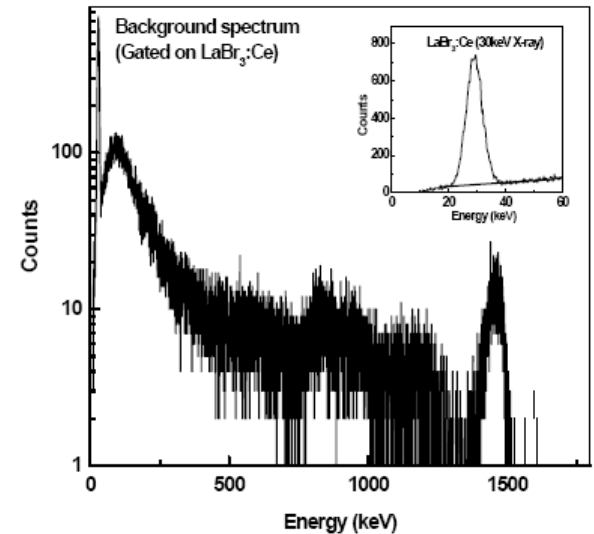
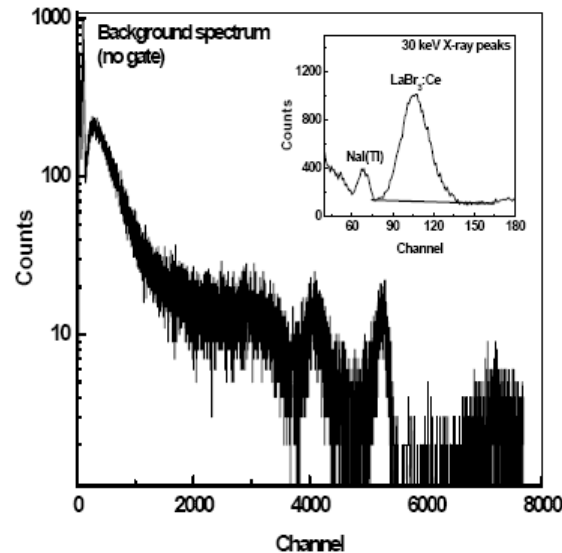
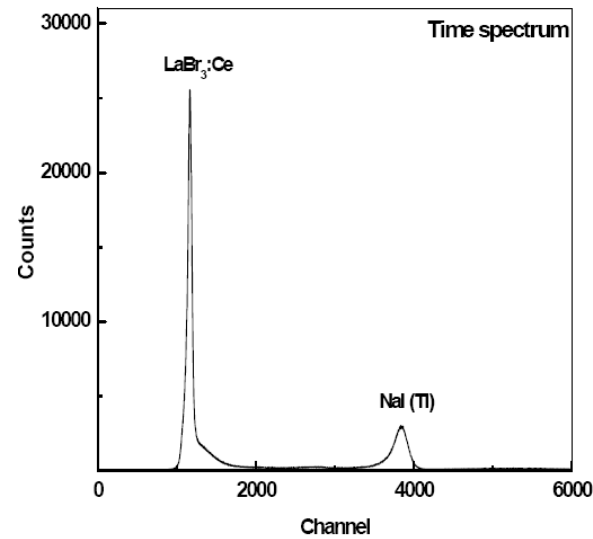
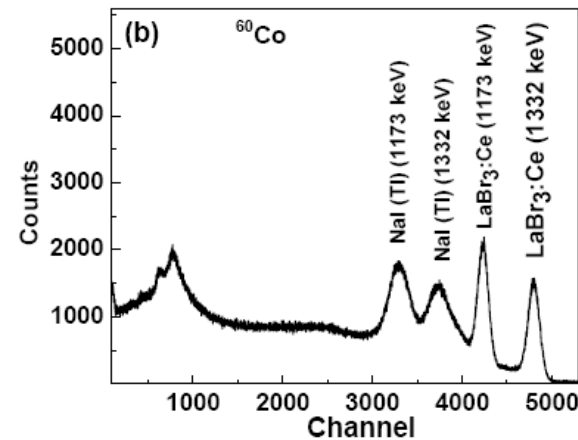
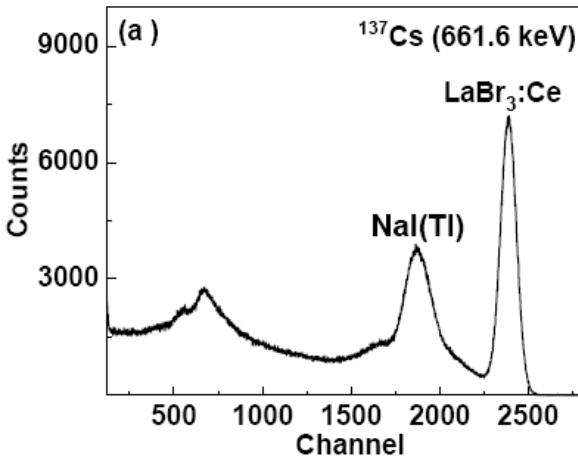
Two heavy-ion Pelletron machines: (TIFR-BARC & IUAC)
Can provide 22 MeV and 7 MeV protons for two of the reactions discussed

FZ Rossendorf, Germany

The ELBE facility is capable of producing photons up to ~18 MeV. The integral flux is about $10^9/\text{s}$ on a target of about 3 cm^2 . It is an user facility.

Phoswich of $\text{LaBr}_3\text{Ce-Nal(Tl)}$ Application to X-ray Astronomy Balloon borne experiments

Mazumdar, Kumar, Gothe, Manchanda
(NIM-A 2010)

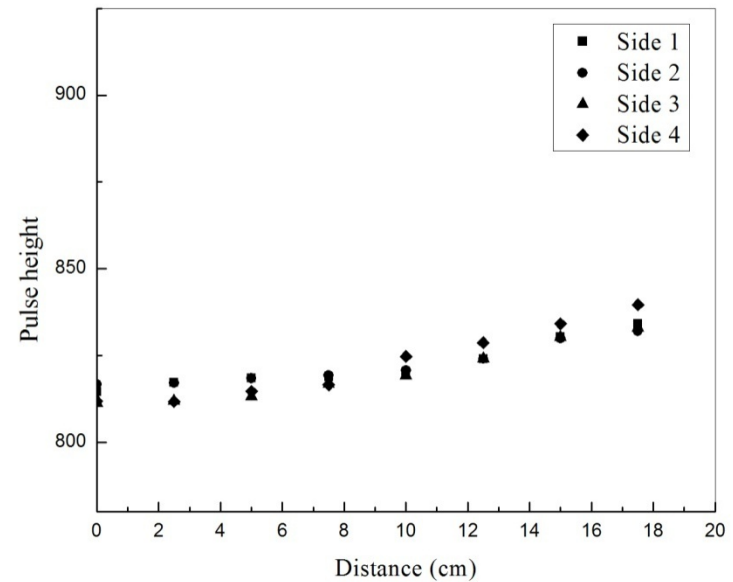
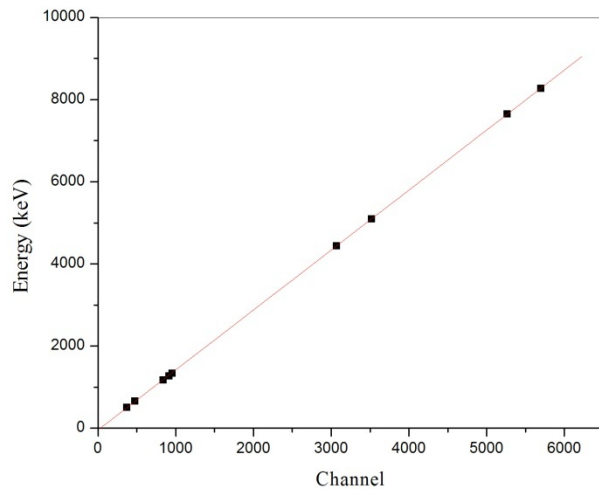
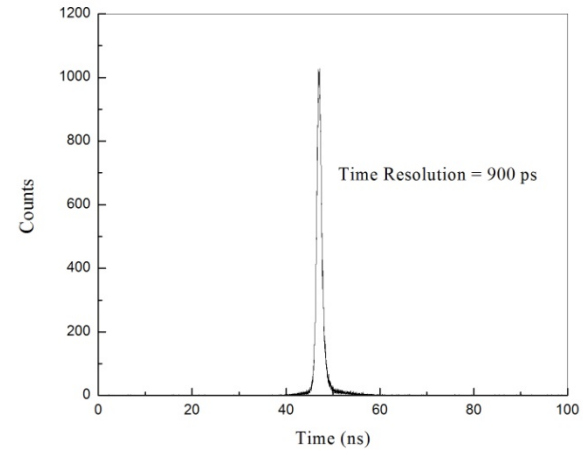
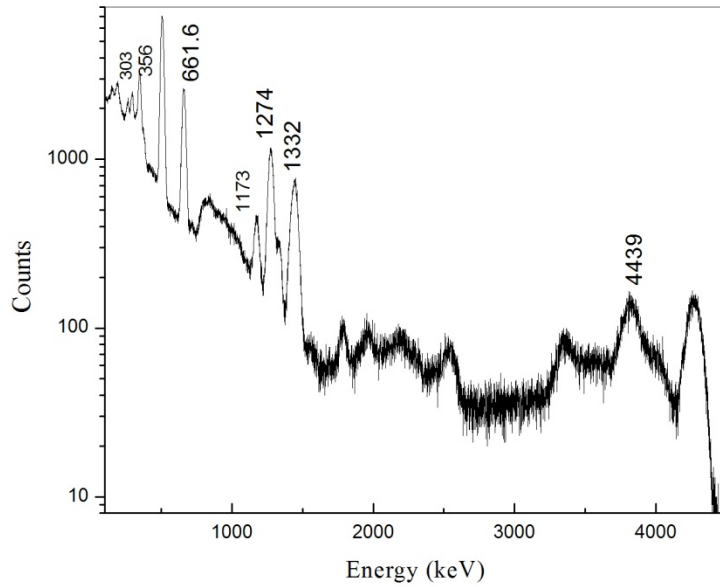


- 1) High energy back ground reduced considerably
- 2) Internal activity around 30 keV reduced
- 3) Energy resolution deteriorates.

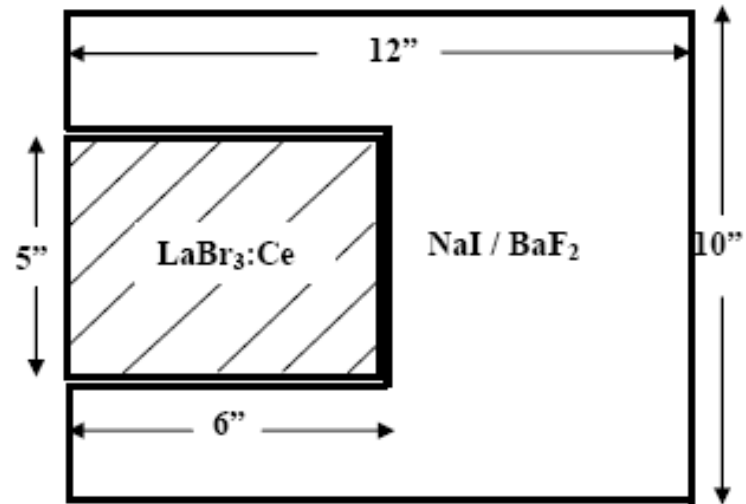
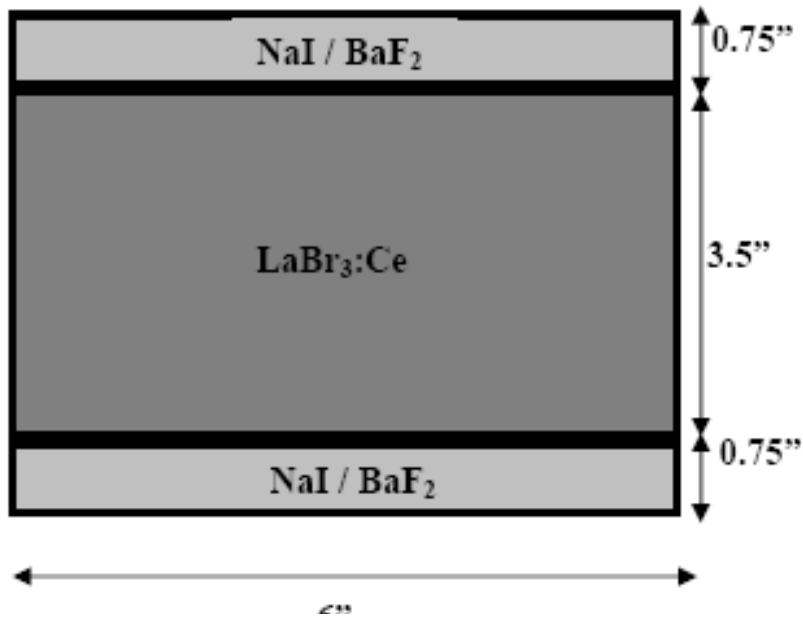
G. Hall et al. nim-A (In Press)
Online 25 Oct. 2011

Detailed GEANT4 simulations reproduce the results very well

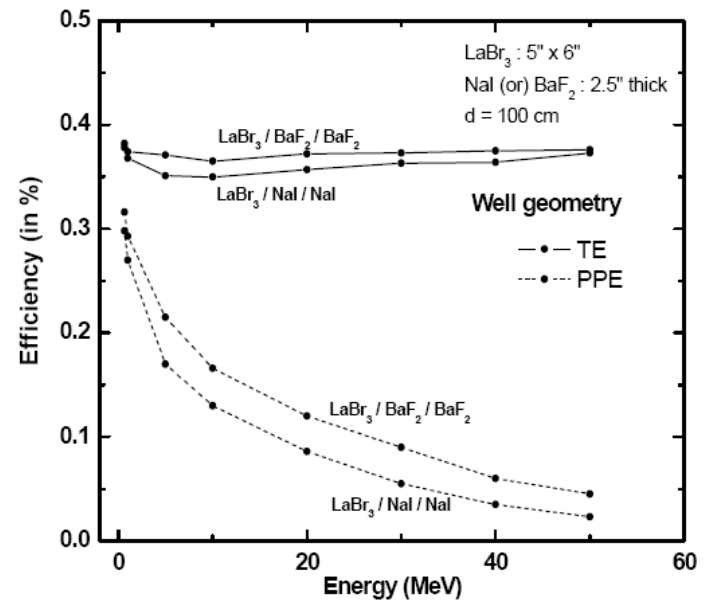
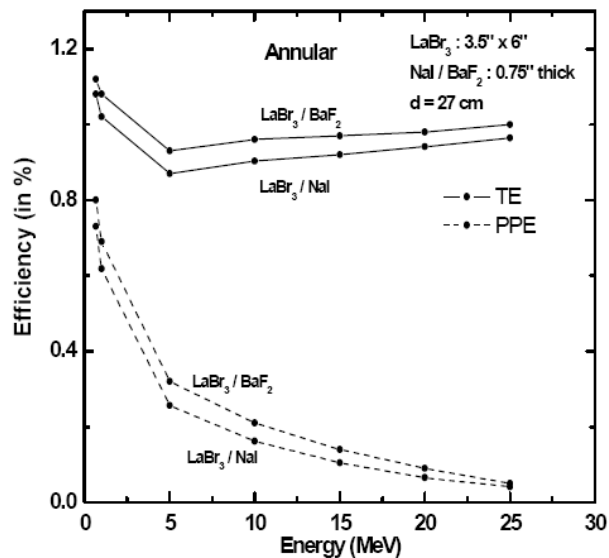
Charactrising a 2"X2"X8" square bar of LaBr₃:Ce



Possible combined arrangement of scintillations for high energy gamma ray measurements

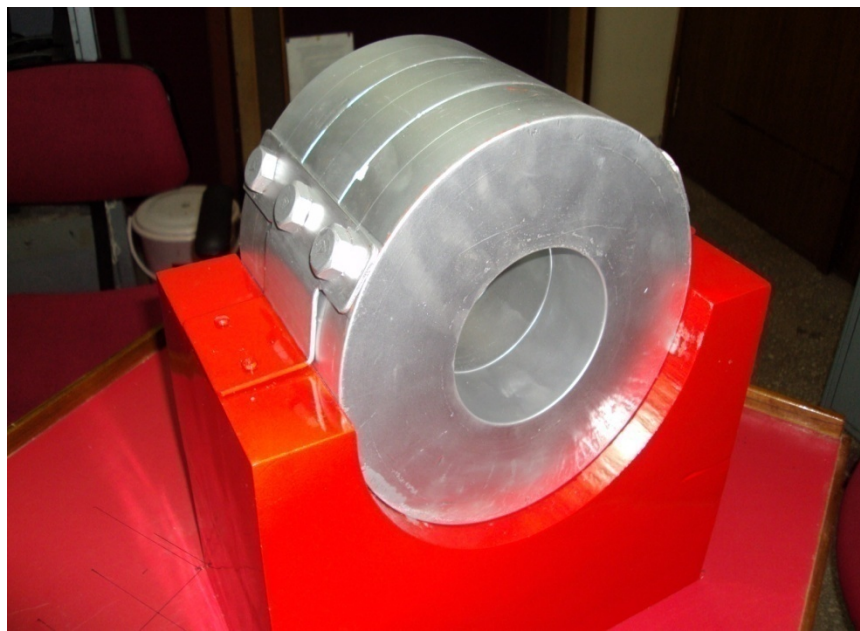
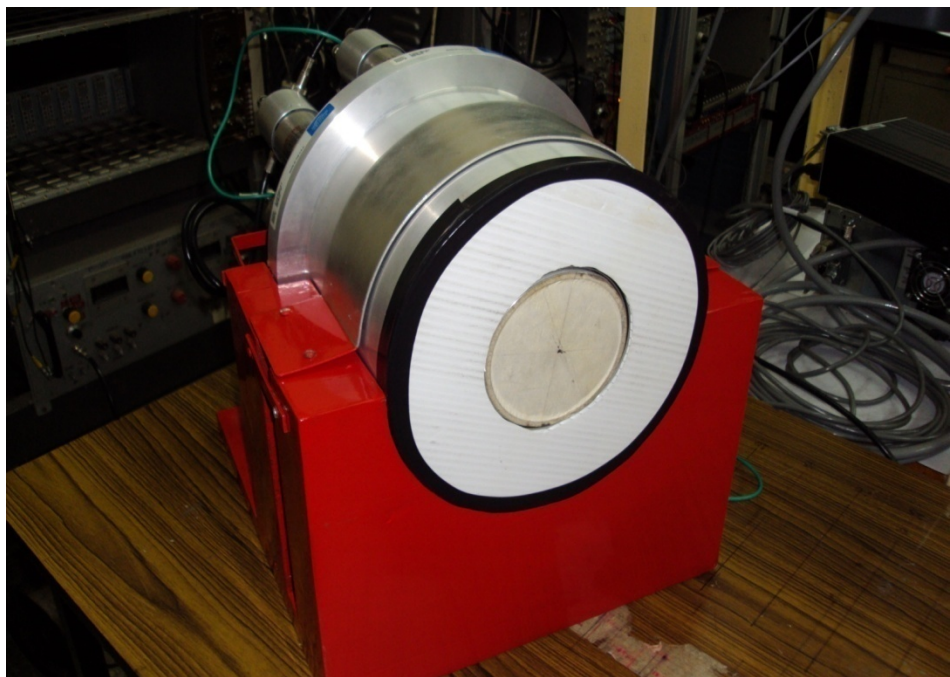
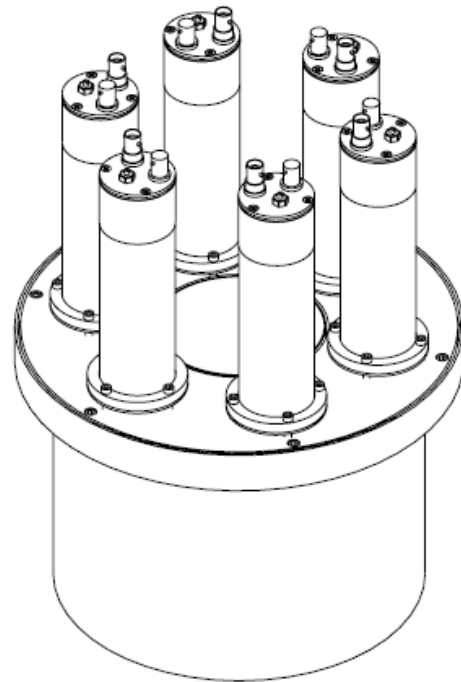


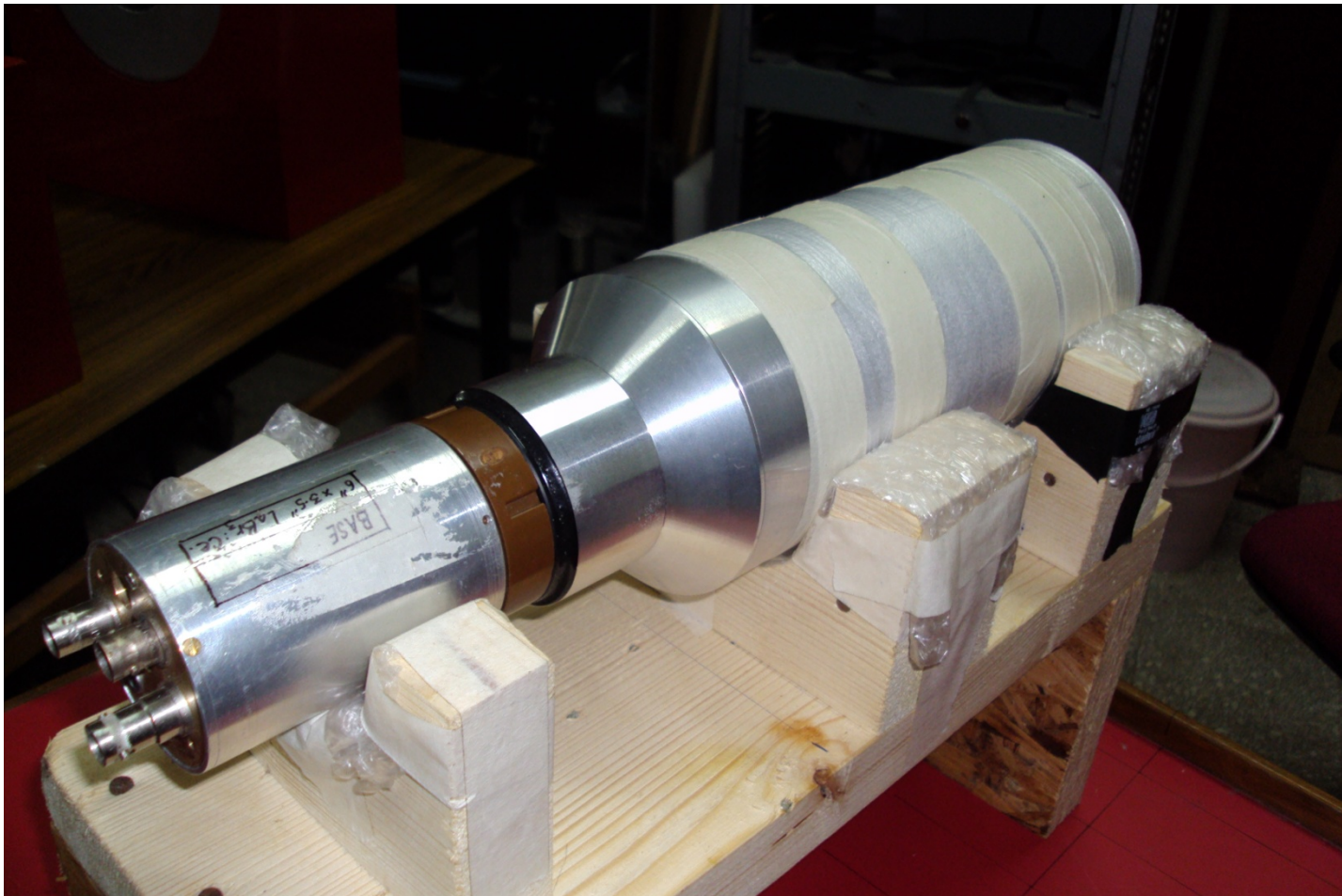
Measurements with this arrangement are on



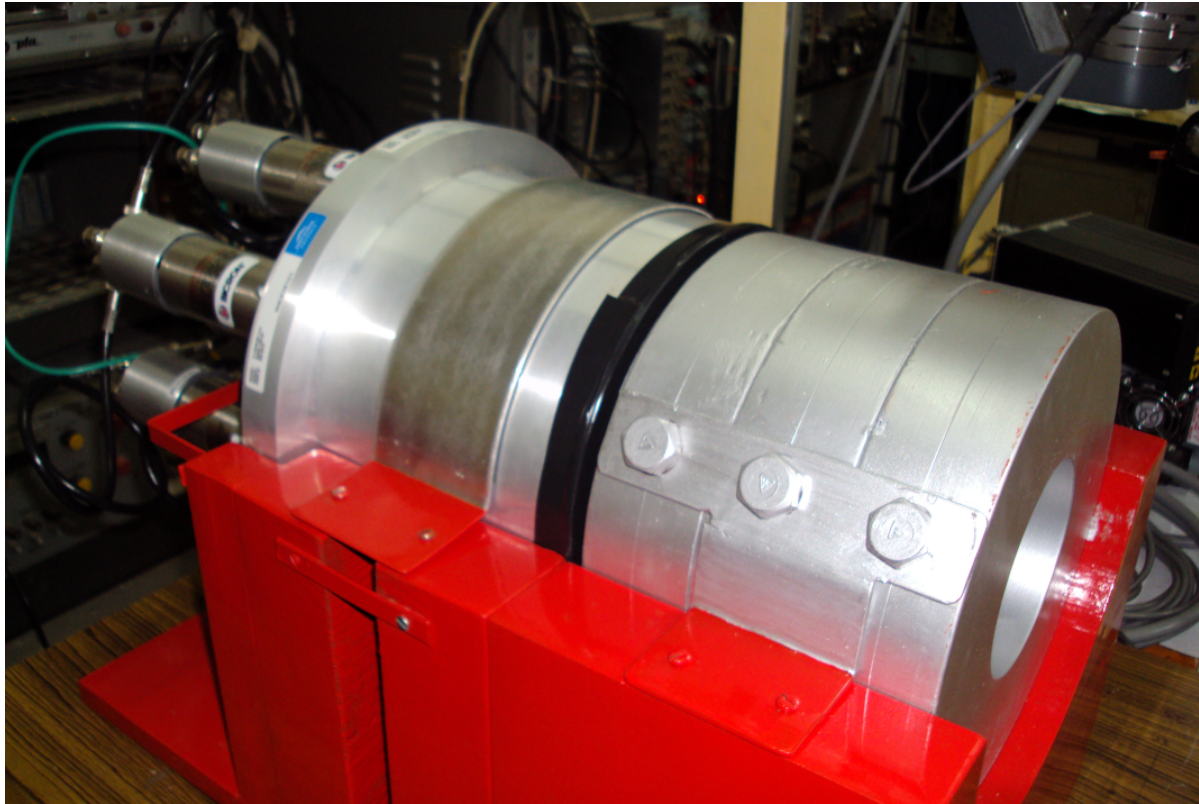


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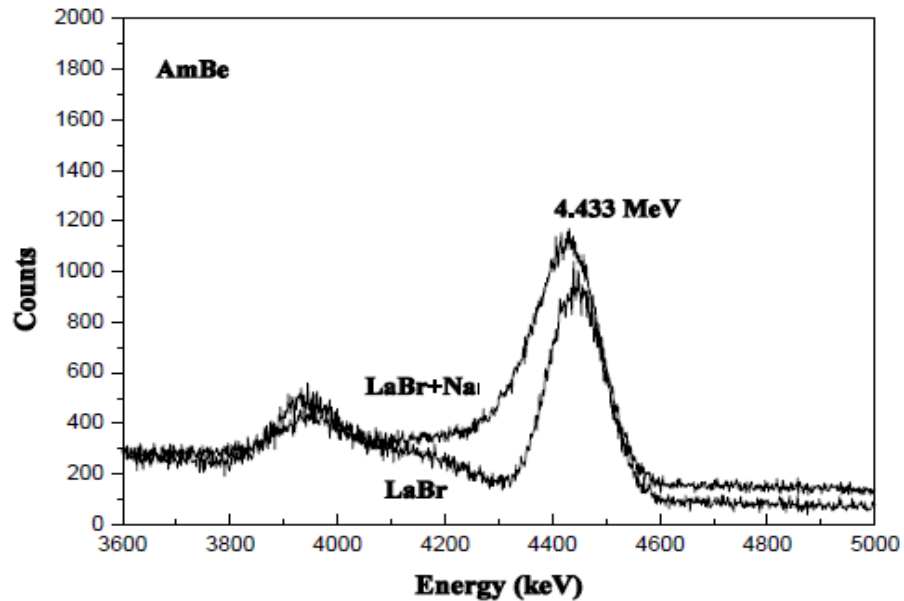
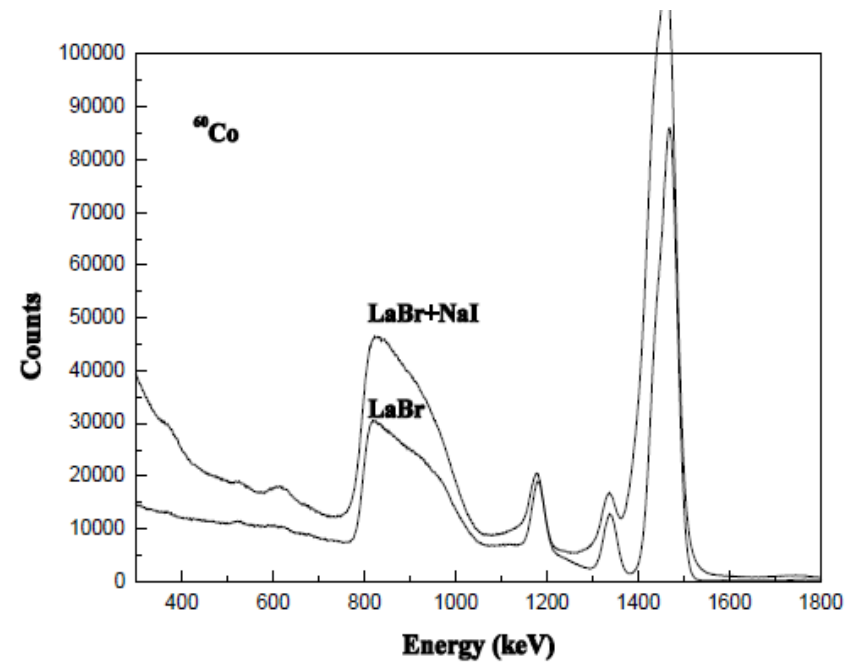
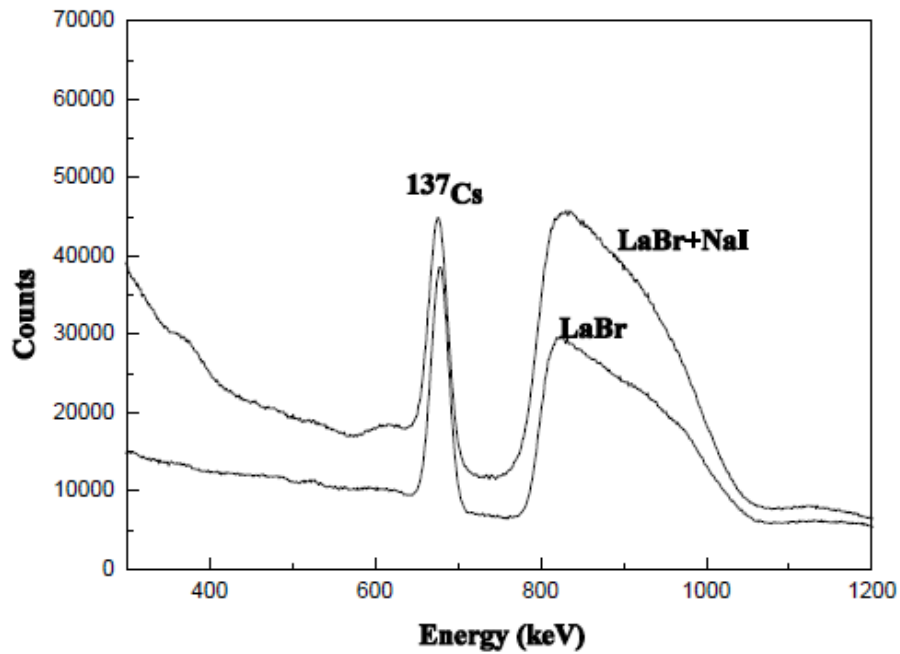




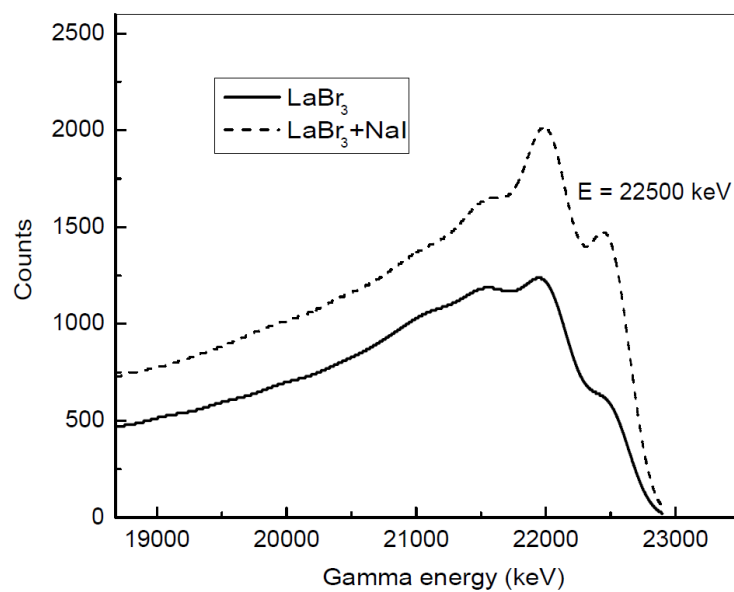
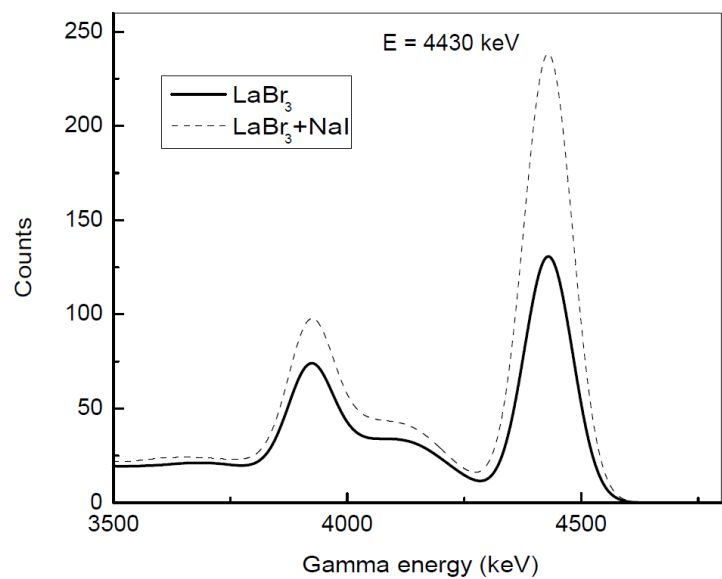
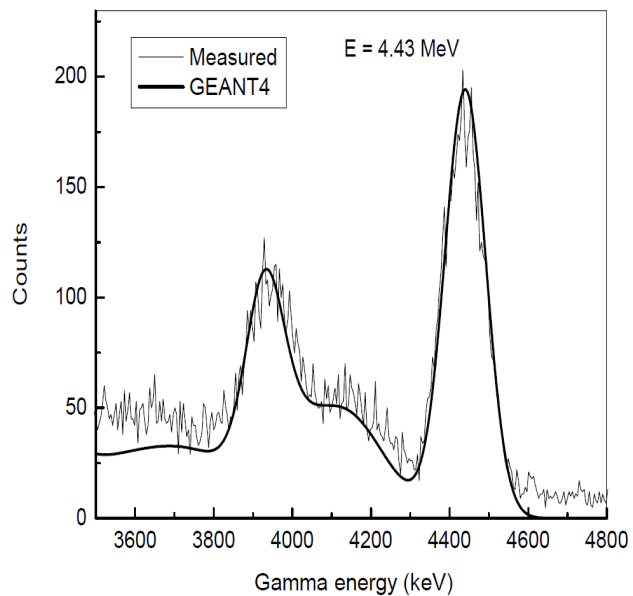
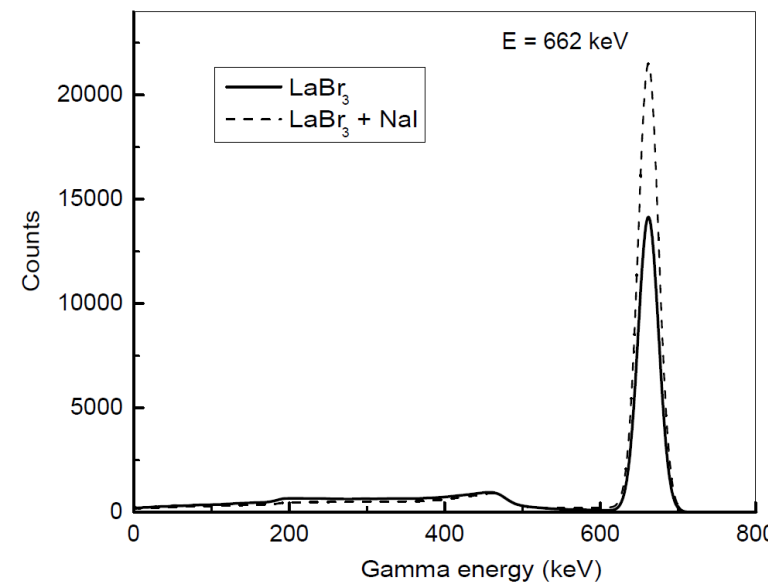
3.5" diameter 6" long cylindrical $\text{LaBr}_3\text{:Ce}$

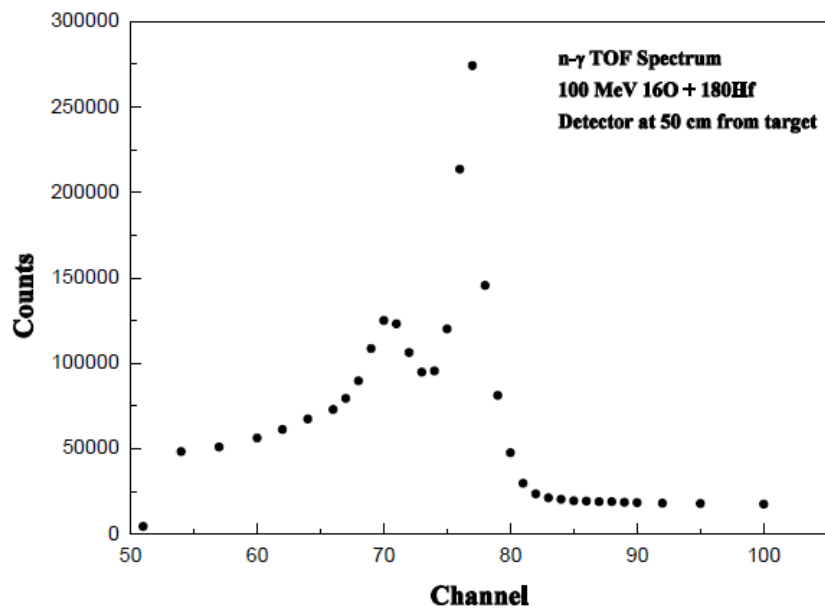
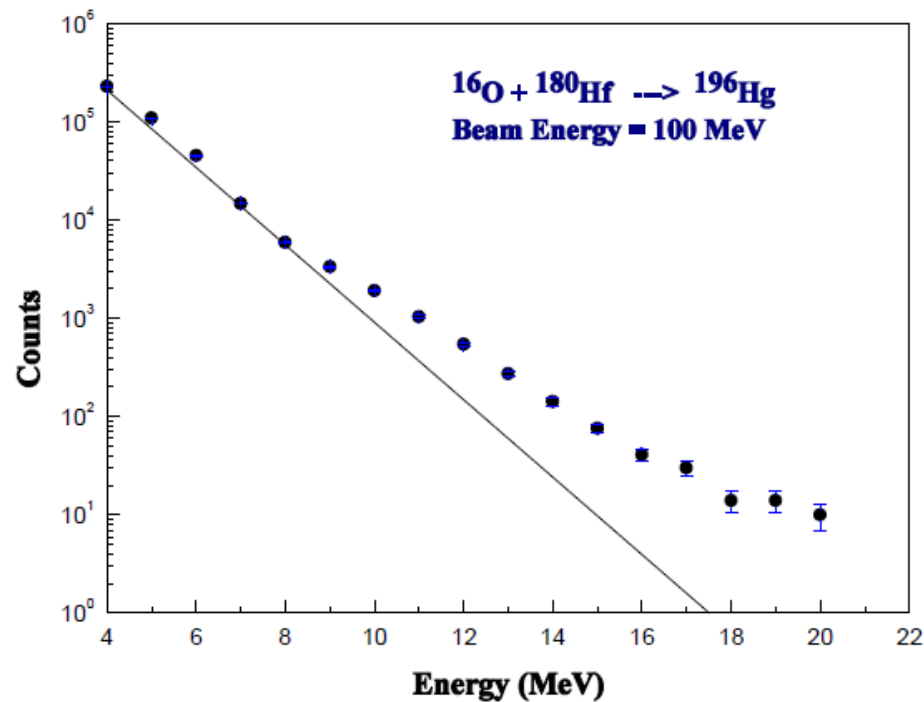
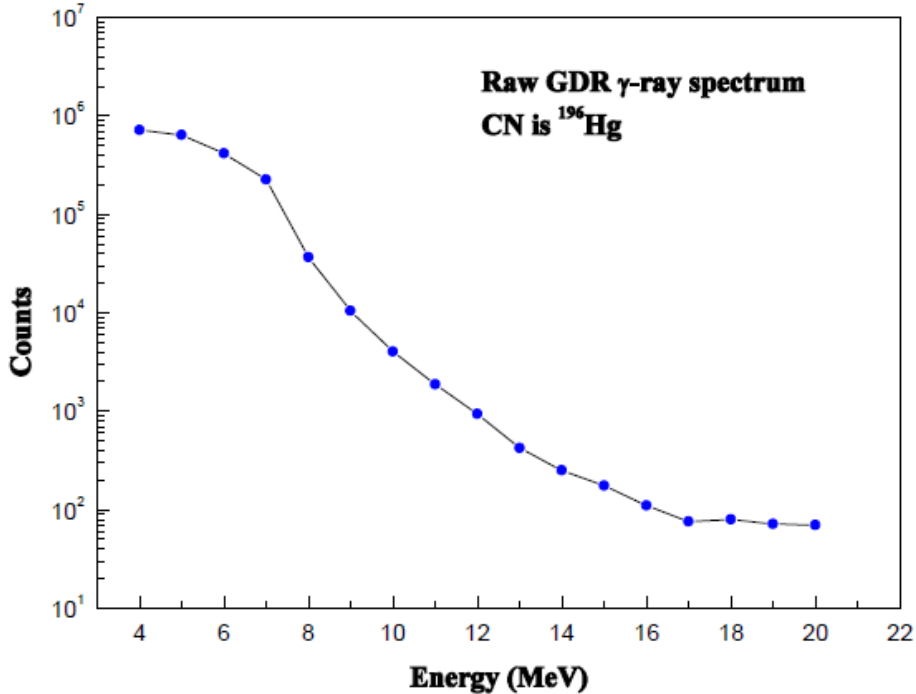


The TIFR Large $\text{LaBr}_3\text{.Ce+NaI(Tl)}$ assembly



Efficiency measurement of the LaBr+ NaI
Assembly : Mazumdar, Gothe, Kumar





Spin gated GDR γ -ray spectrum measured with a combined assembly of large cylindrical $\text{LaBr}_3\text{:Ce}$ and annular $\text{NaI}(\text{Tl})$

Summary:

- Small cylindrical $\text{LaBr}_3:\text{Ce}$ studied in detail, *absolute scale* simulations done for efficiencies
- Large cylinder of 3.5" X 6" studied up to 22.5 MeV
- Combined assembly of $\text{LaBr}_3:\text{Ce}+\text{NaI}(\text{Tl})$ studied, *GDR spectrum measured for hot rotating ^{196}Hg*
- Phoswich of $\text{LaBr}_3:\text{Ce}+\text{NaI}(\text{Tl})$ studied for application in low energy balloon borne astronomy experiments.
- Characterisations of 2"X2"X8" square bars done with sources up to ~ 6 MeV

Thank You

