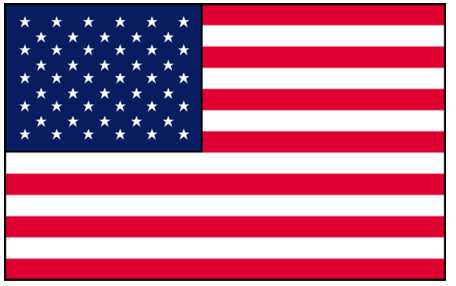
Detector Development, a Survey

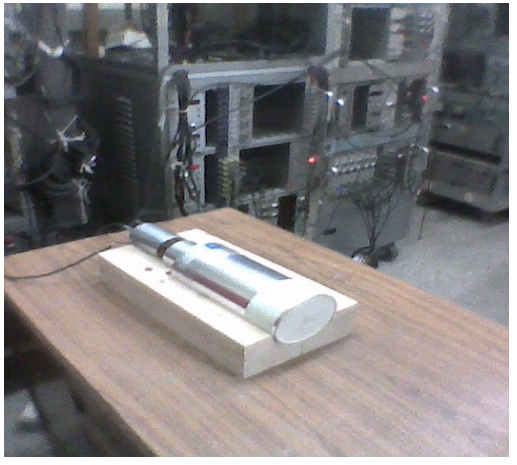
Project-X Interaction Meeting

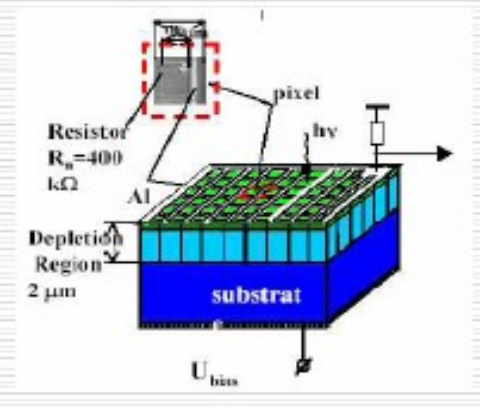
TIFR, Mumbai, 14 January 2011



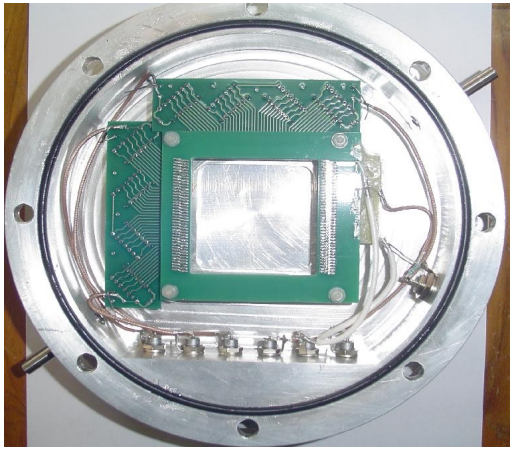
Sunil K. Gupta

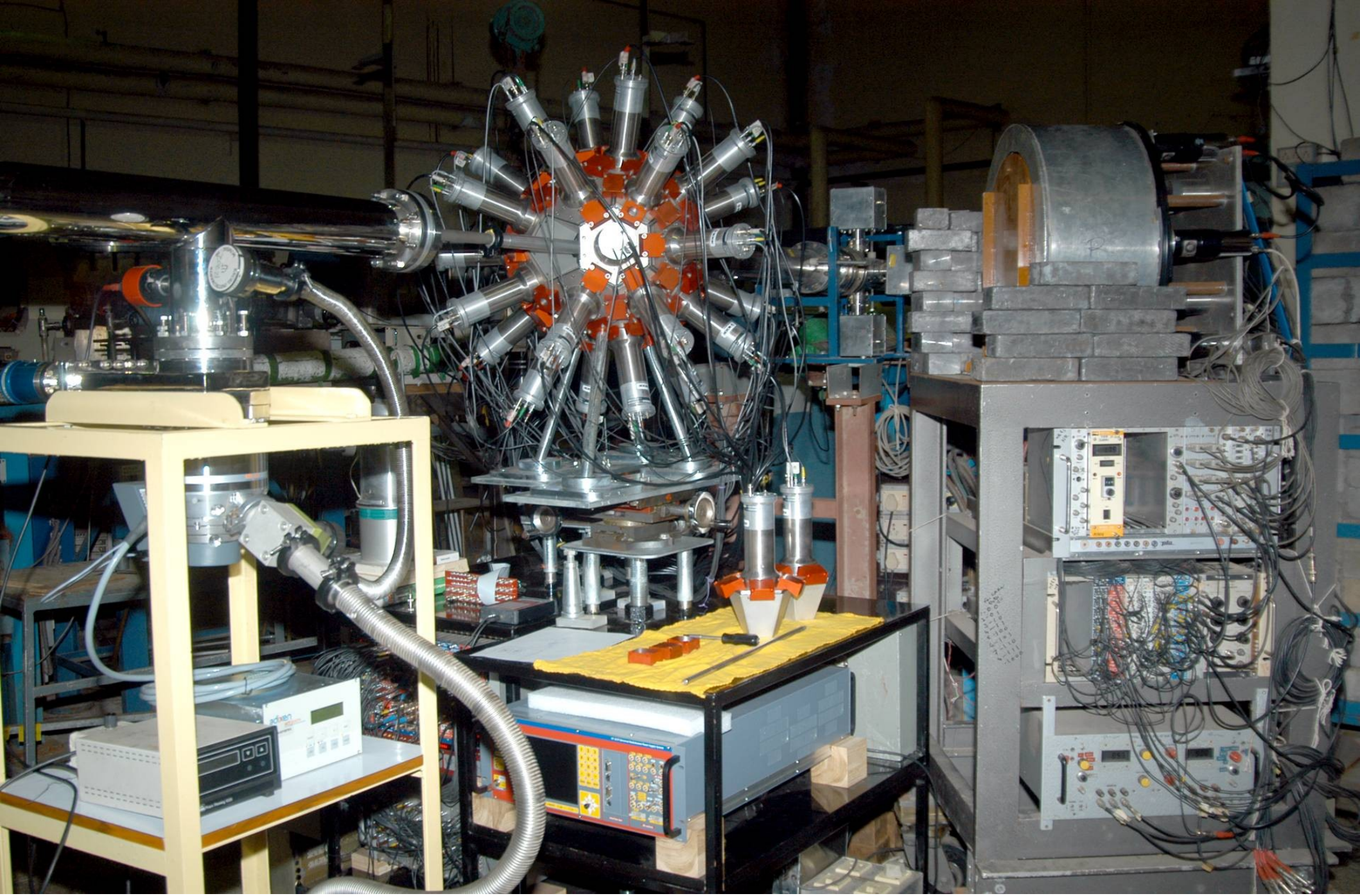
Tata Institute of Fundamental Research, Mumbai





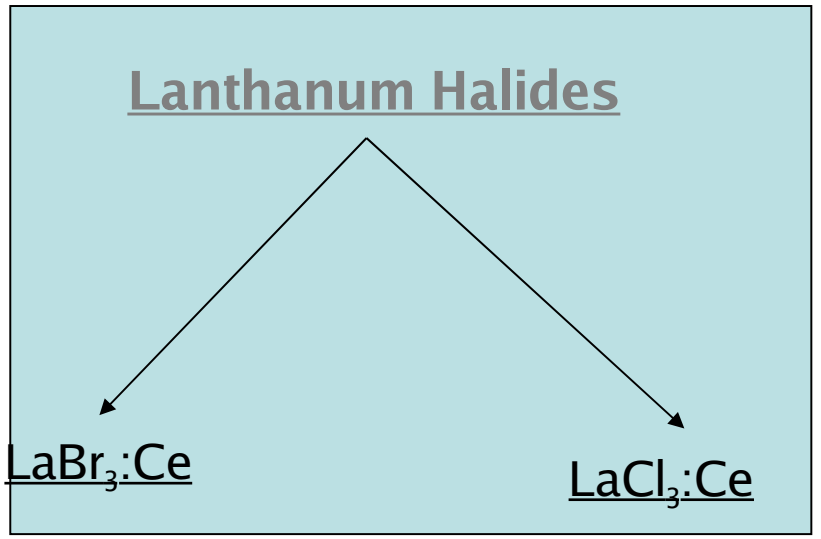
1. Gaseous
2. Scintillator
3. Semiconductor



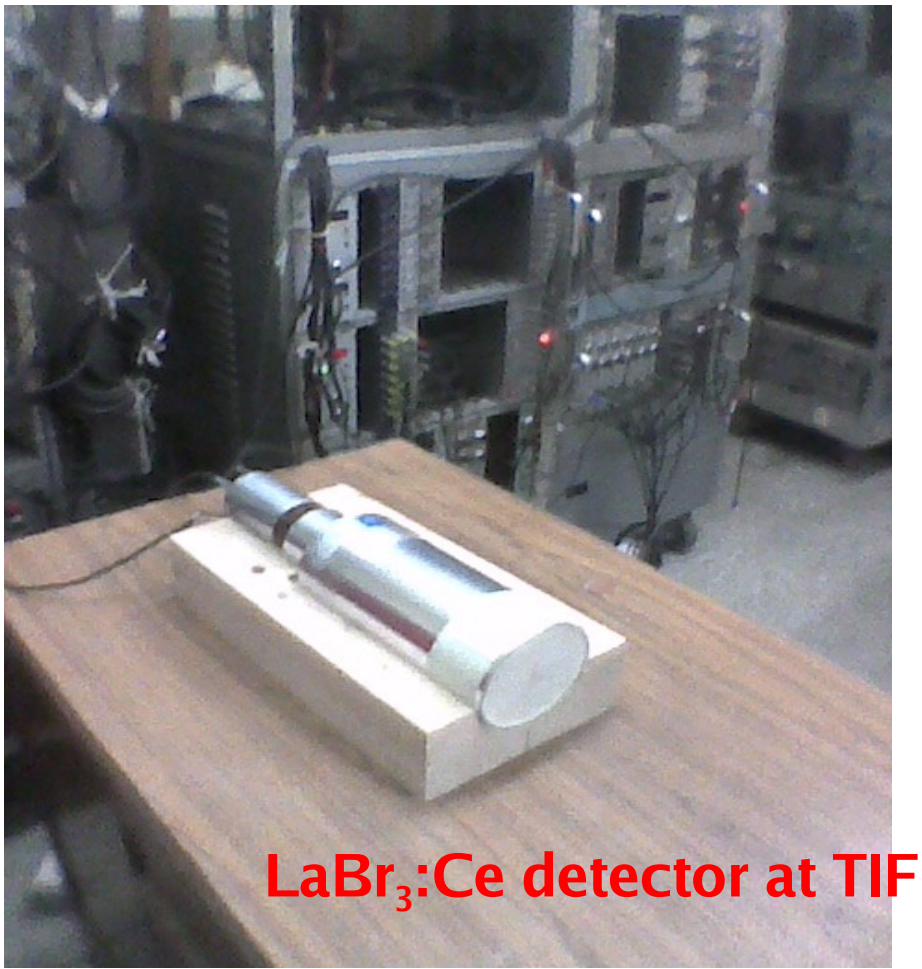


Indranil Mazumdar & Co-workers Nucl. Instrum. Methods A **611** (2009) 76

High Detection Efficiency
Energy Resolution
Time Resolution
Uniformity
Linearity
Temperature Stability

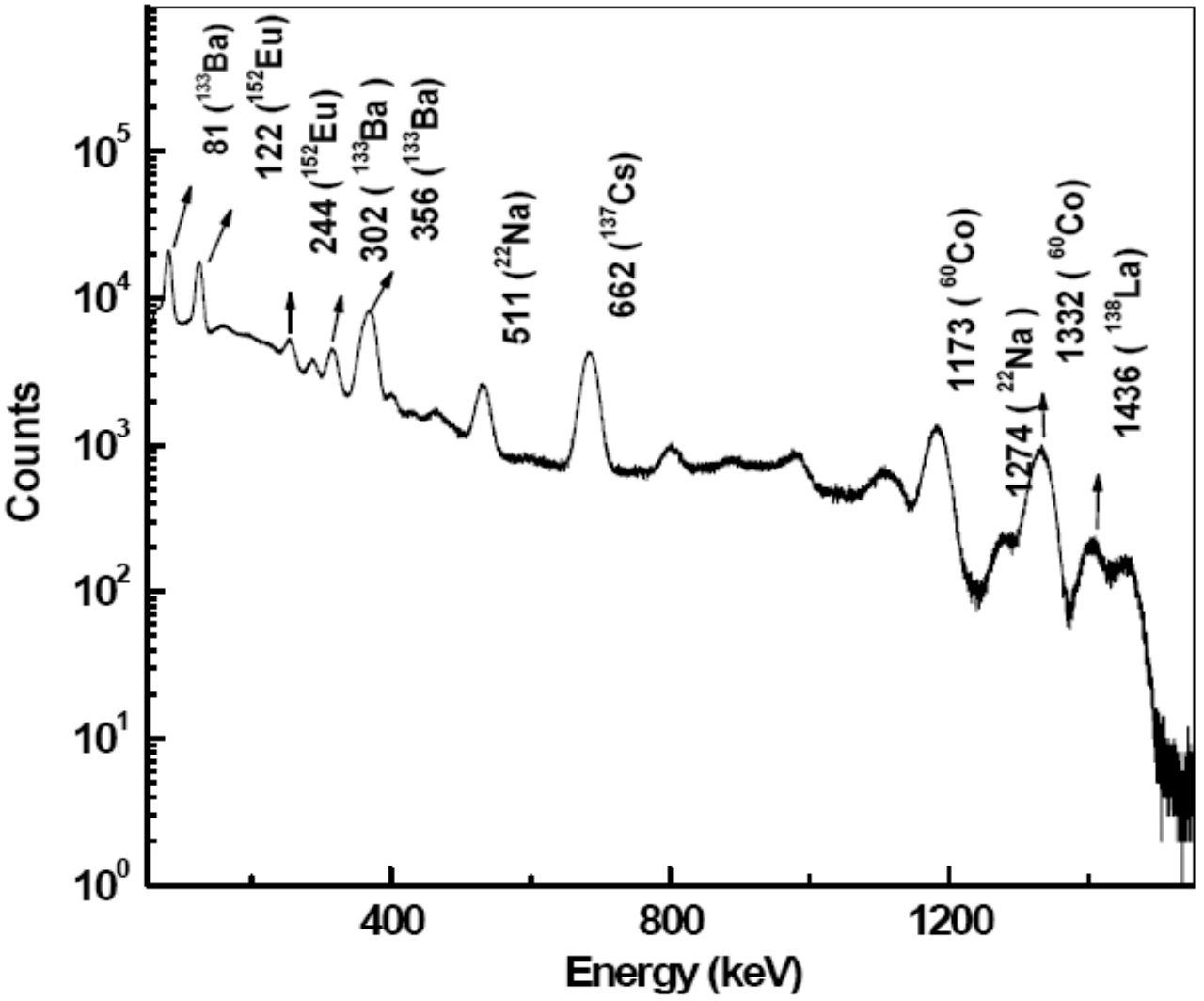


Ref: Indranil Mazumdar & Co-workers
Nucl. Instrum. Methods A 609 (2009),
Nucl. Instrum. Methods A 610 (2009),
Nucl. Instrum. Methods A 611 (2009),
Nucl. Instrum. Methods A 623 (2010).



$LaBr_3$:Ce detector at TIFR

Measurements with a small $LaBr_3$:Ce



1" x 1" Cylinder

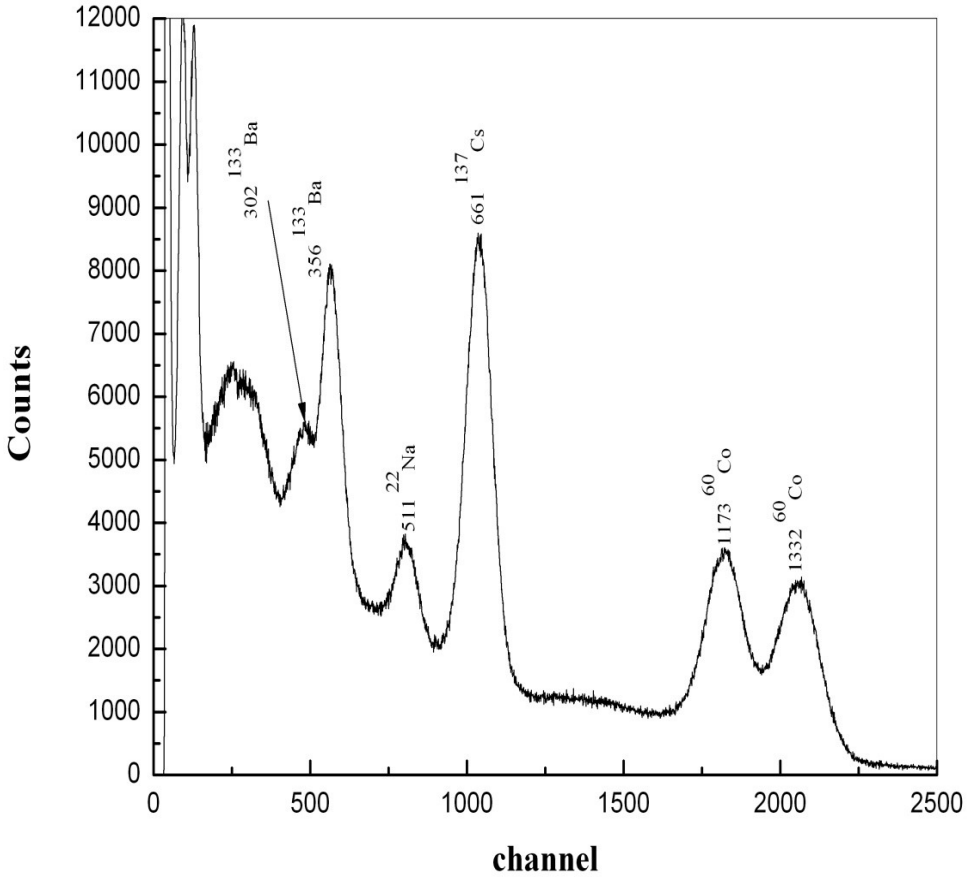
0.5 mm Al casing

Glass light guide

Typical spectrum with low energy gamma sources

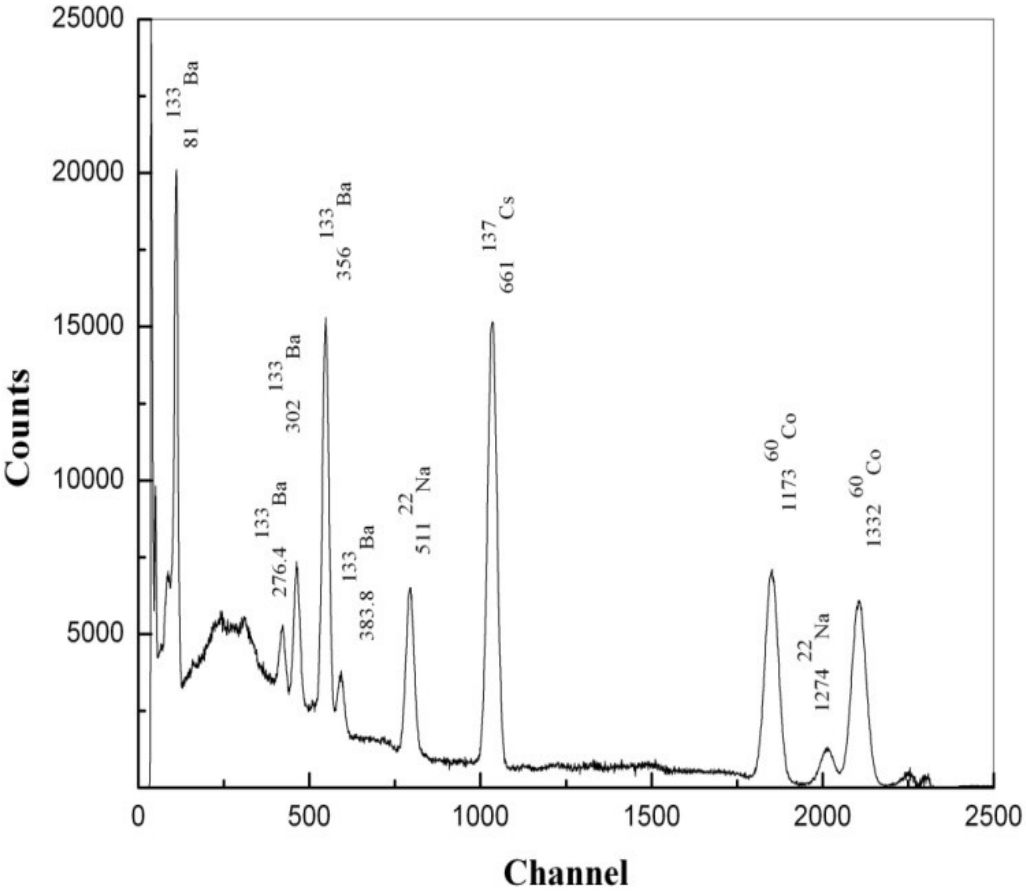
NaI(Tl)

Resolution: 7.5% @661.6 keV



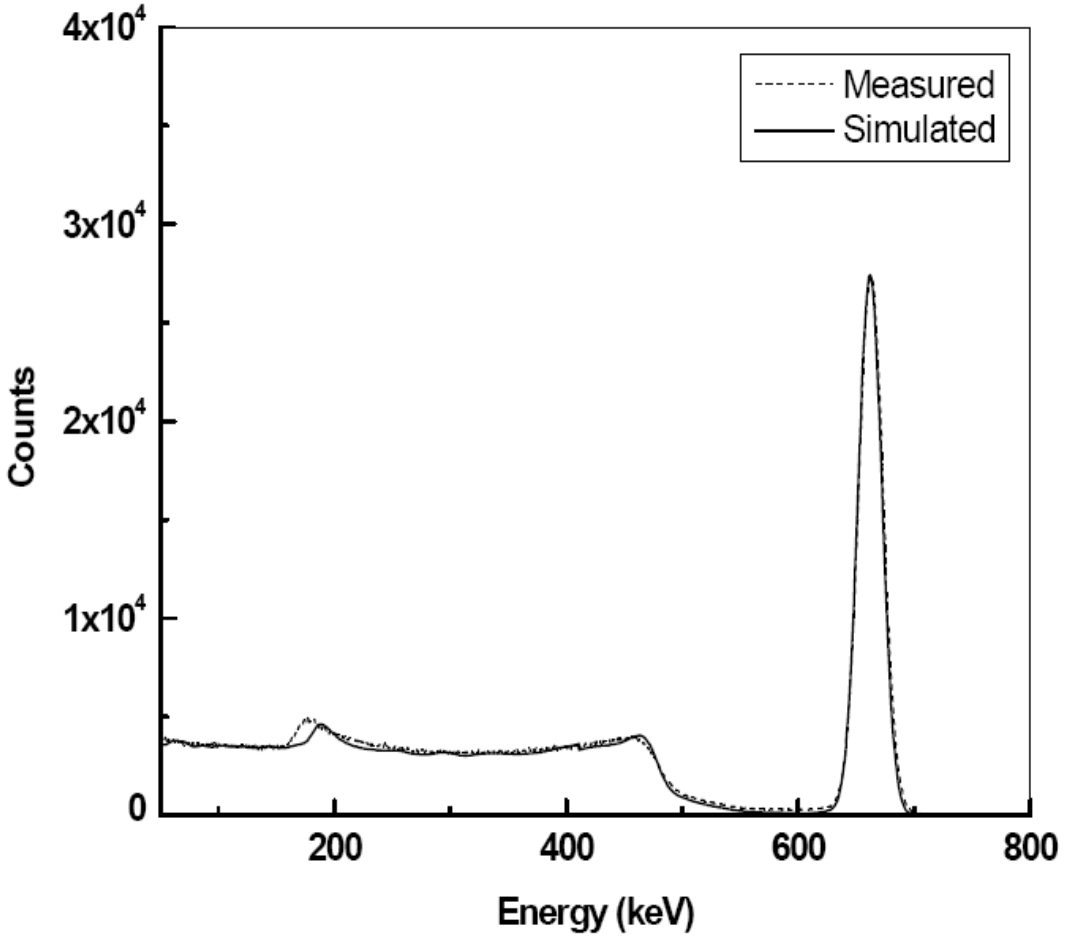
$LaBr_3$:Ce

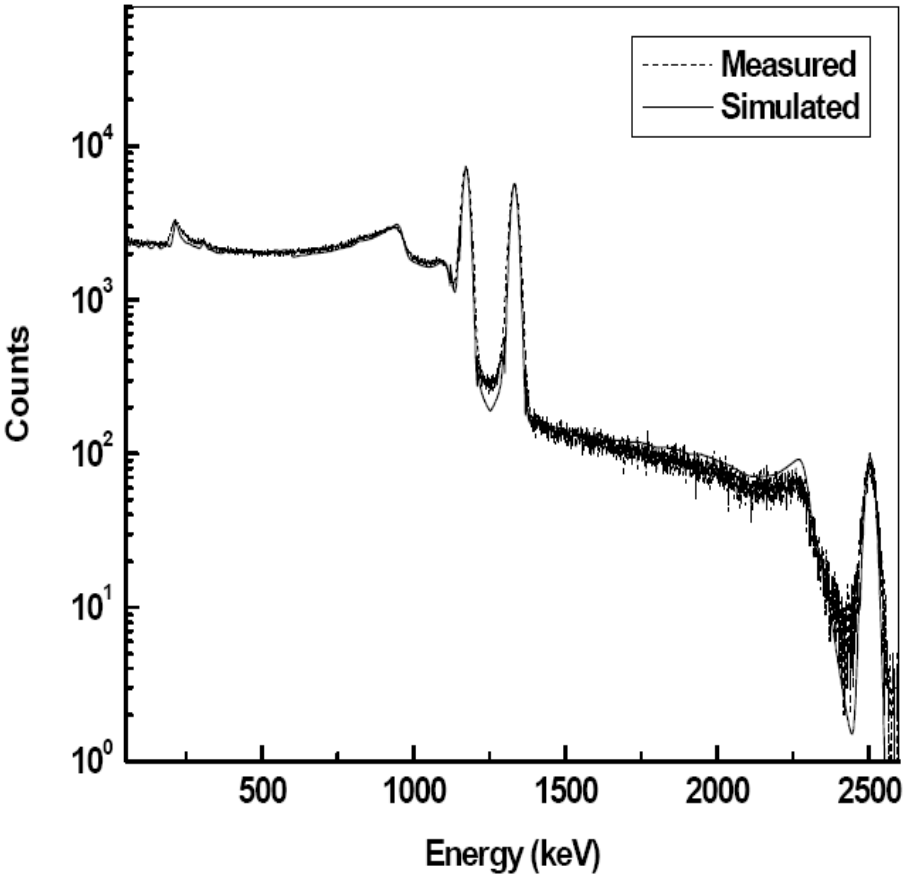
Resolution: < 3% @661.6 keV



Note:

- Diifferences in energy resolutions
- Differences in p/v ratios
- New peaks in LaBr spectrum





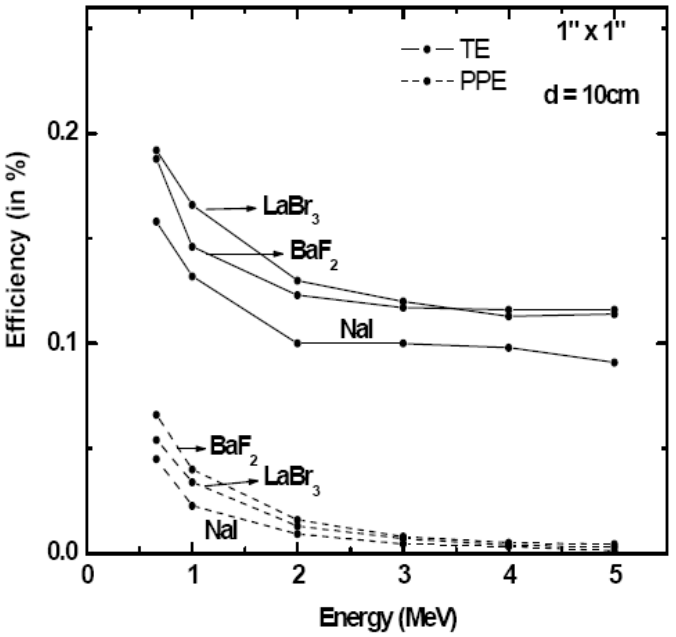
Calibrated sources used.

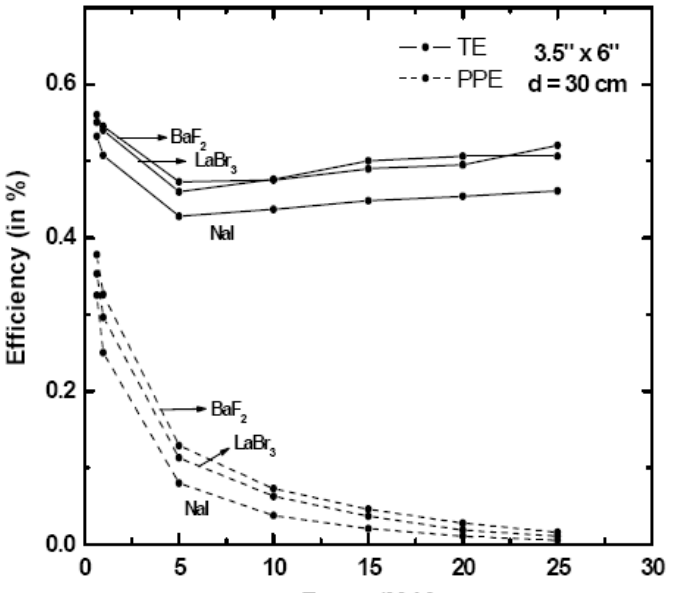
No normalization in the comparison

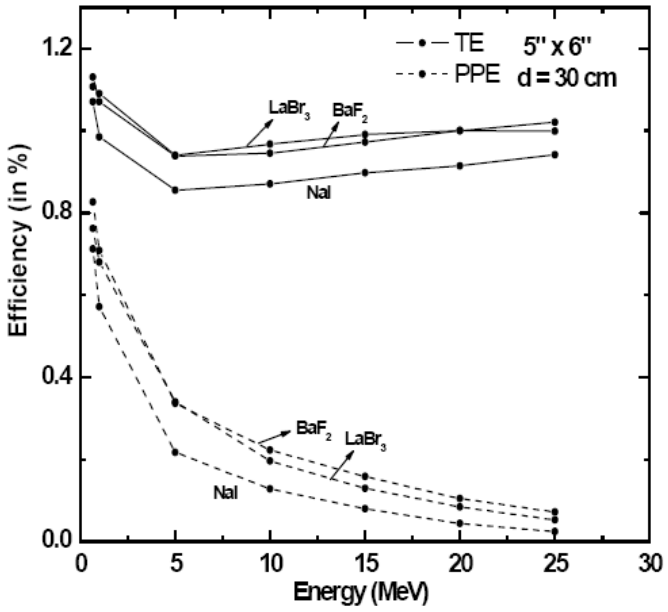
Measured and GEANT4 simulated spectra for ^{137}Cs (662 keV) and ^{60}Co (1173, 1332 keV).

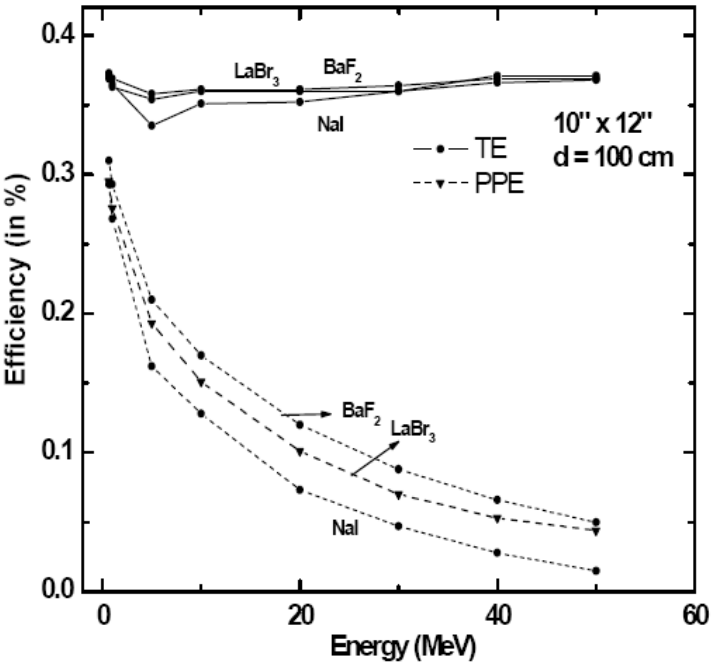
GEANT4 Simulation

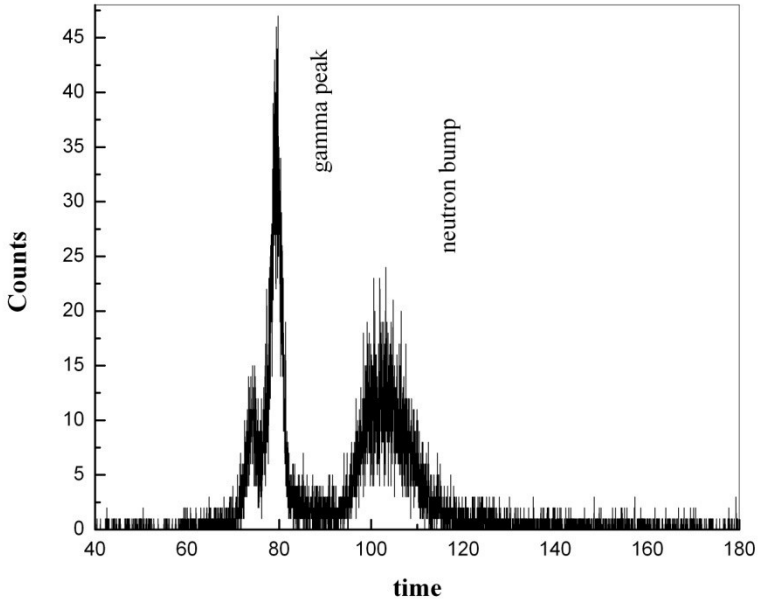
Distance (cm)	ε_{Total}		ε_{peak}	
	GEANT4	Exp	GEANT4	Exp
15	0.105 (0.012)	0.114 (0.005)	0.030 (0.004)	0.027 (0.001)
25	0.041 (0.003)	0.044 (0.002)	0.011 (0.001)	0.010 (0.001)


1" x 1"
d = 10cm
TE
PPE
LaBr3
BaF2
NaI
Efficiency (in %)
Energy (MeV)


3.5" x 6"
d = 30 cm
TE
PPE
BaF2
LaBr3
NaI
Efficiency (in %)

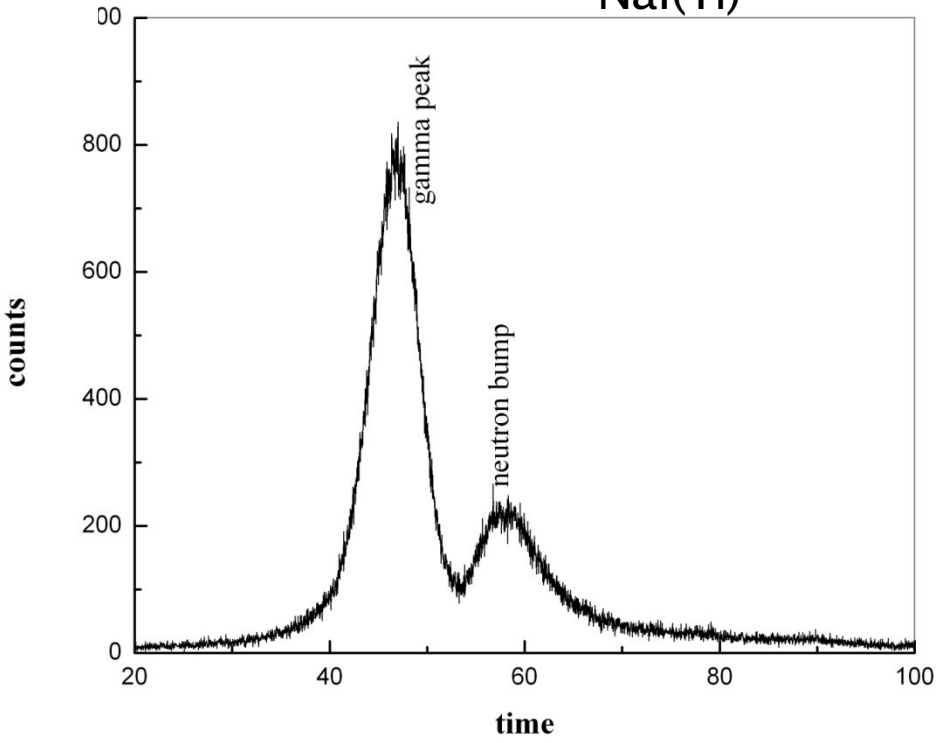

5" x 6"
d = 30 cm
TE
PPE
LaBr3
BaF2
NaI
Efficiency (in %)
Energy (MeV)


10" x 12"
d = 100 cm
TE
PPE
LaBr3
BaF2
NaI
Efficiency (in %)
Energy (MeV)



LaBr

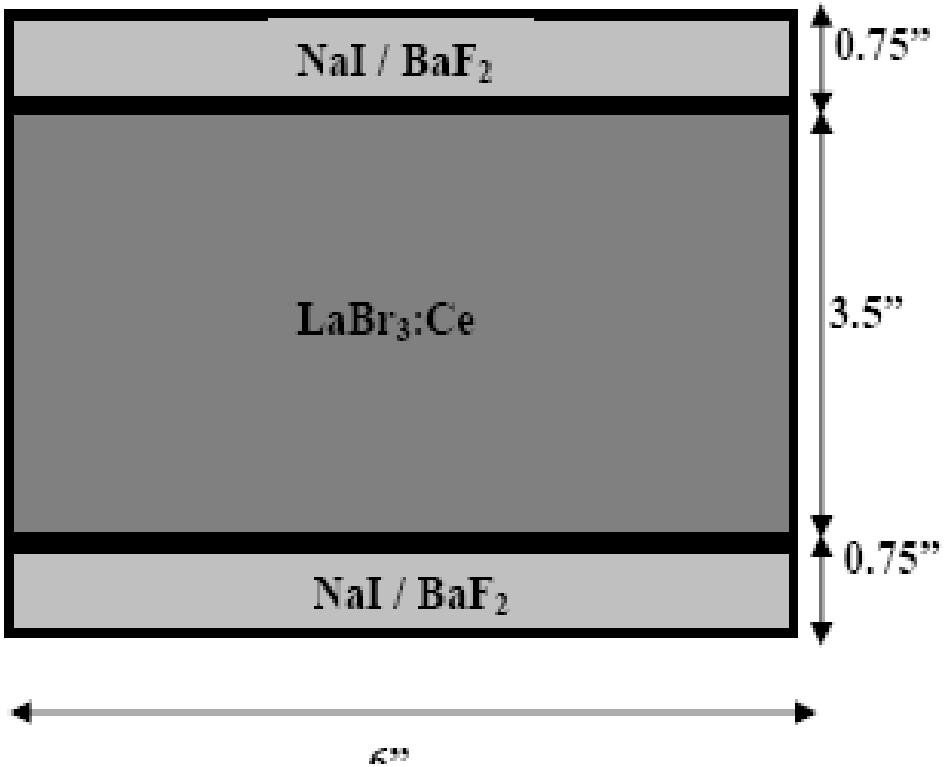
NaI(Tl)



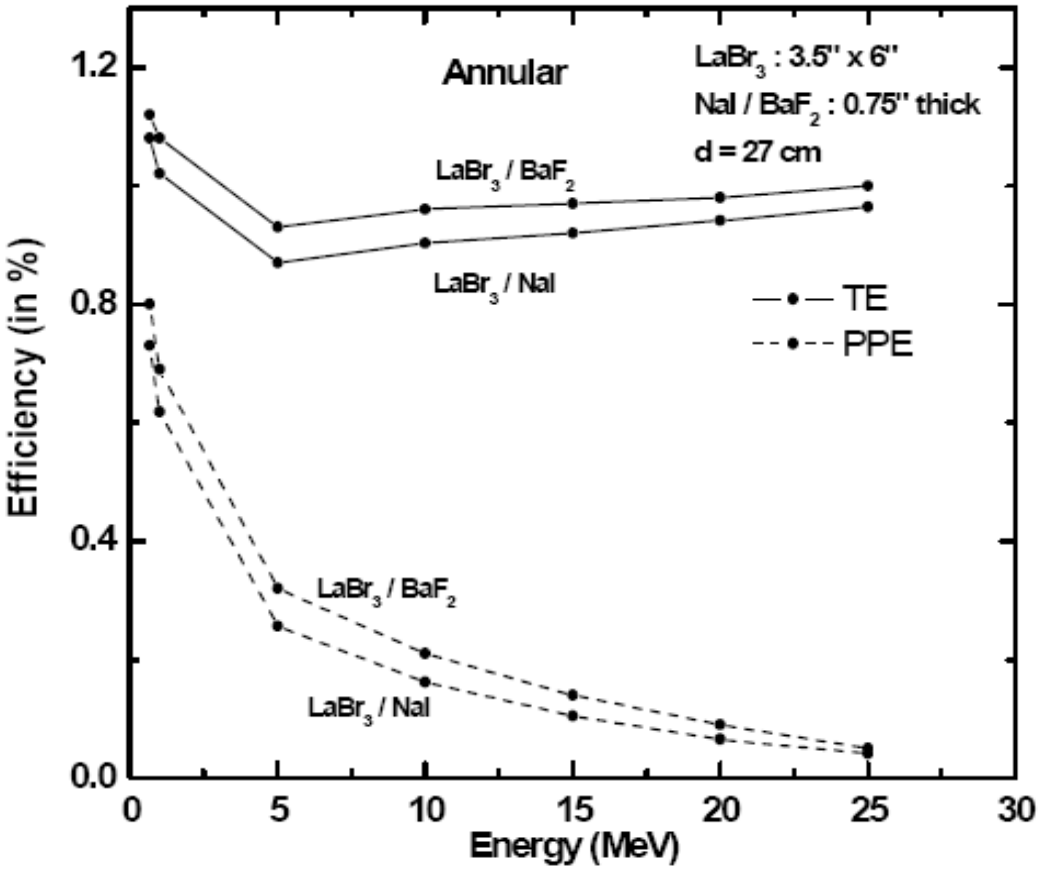
Note:

The difference in n-γ separation for the two cases

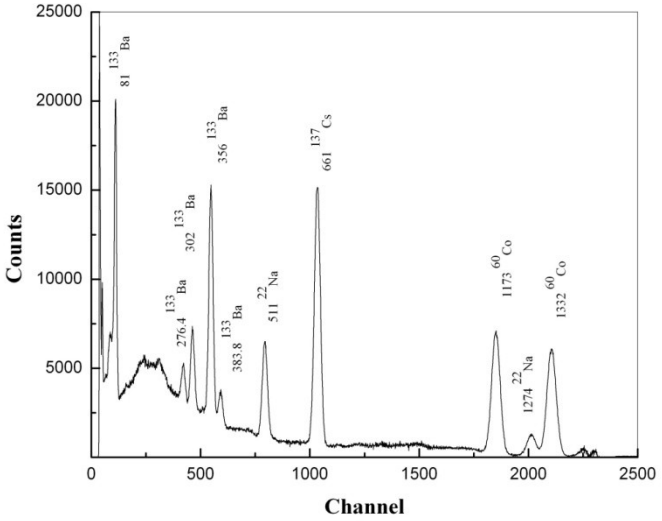
Combination of crystals for full confinement of γ-rays

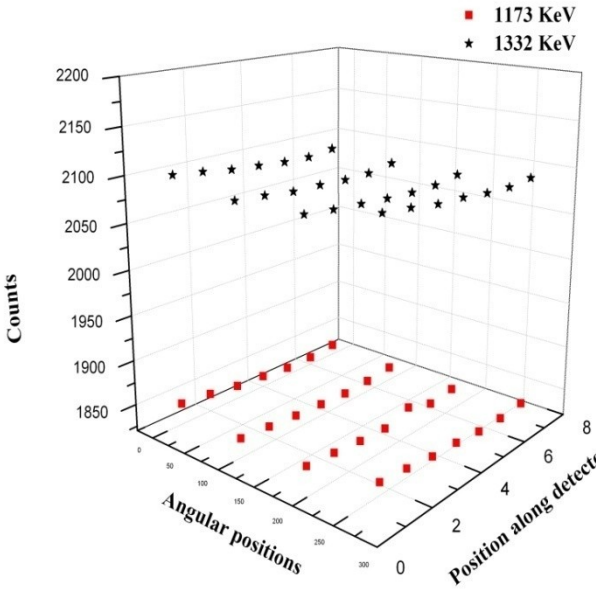


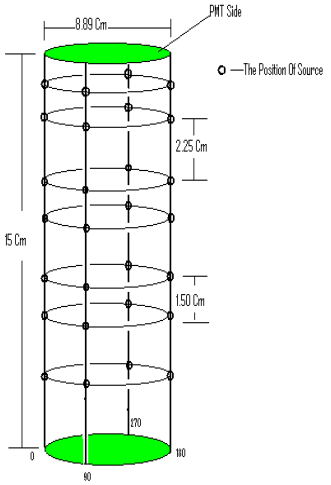
Measurements with this arrangement are on

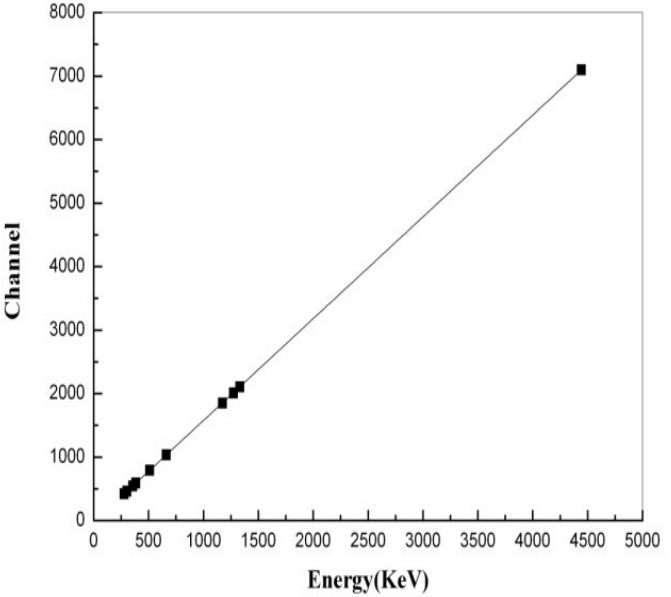


Spectrum recorded with a 3.5” X 6” $LaBr_3$:Ce



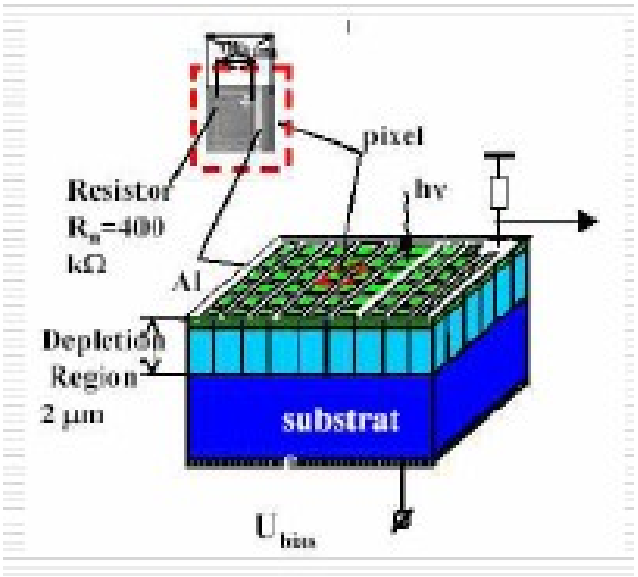


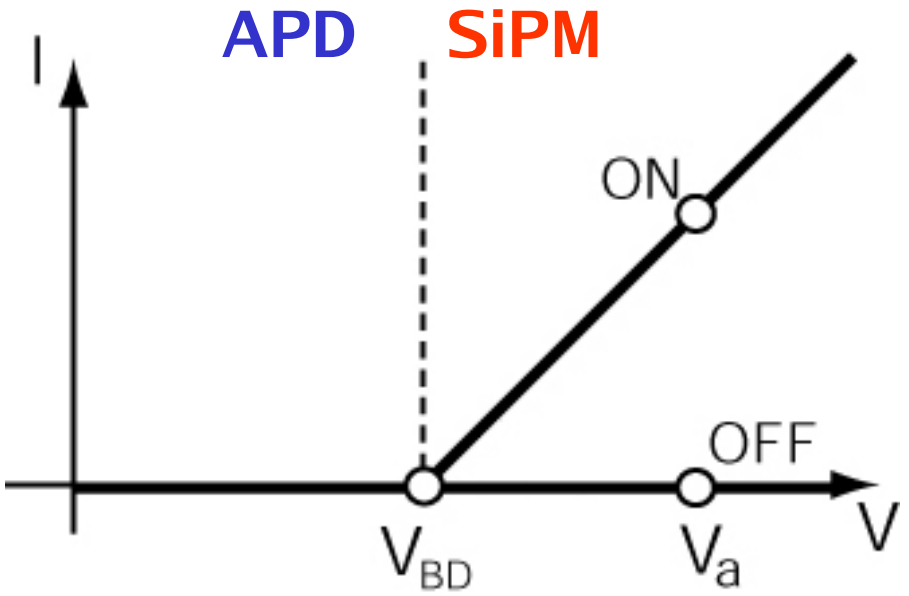




Silicon Photomultiplier

- APD operated above breakdown voltage
  - Geiger response mode
- Essentially a logical device
  - Photon counting by an array of diodes in small area





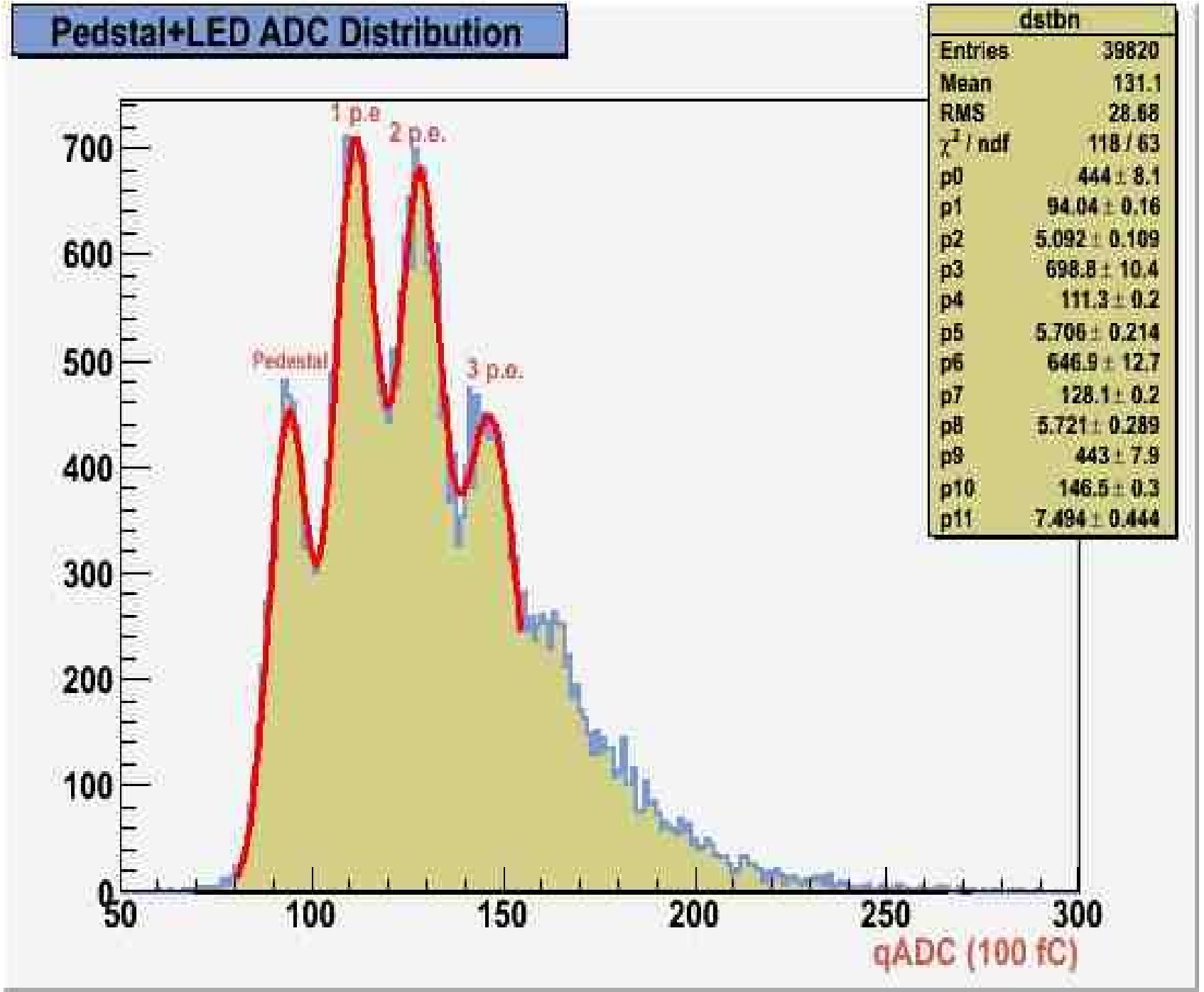
Silicon Photomultiplier Development

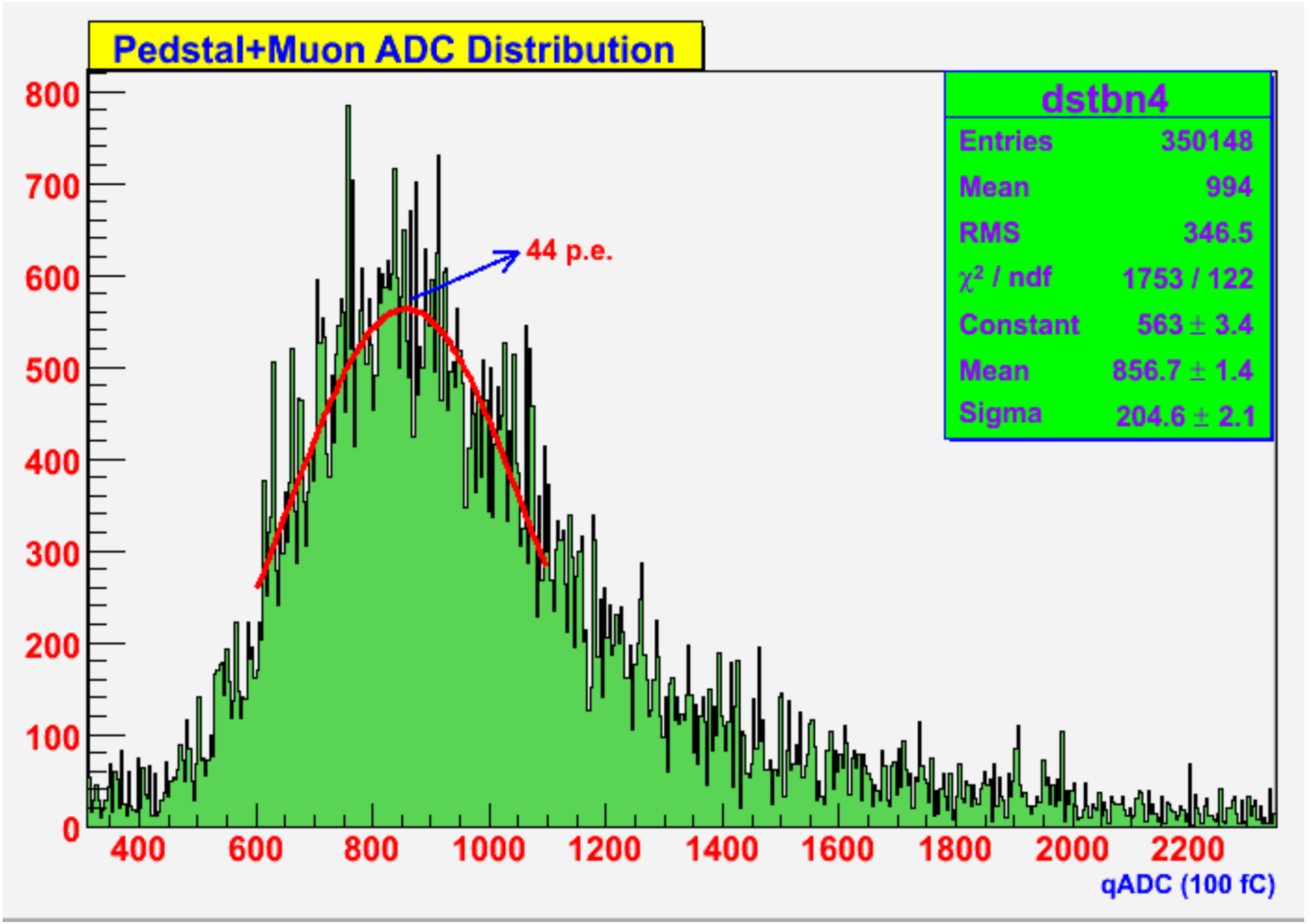
- SiPM characterization facility at GRAPES-3 in Ooty
  - Setup for V-I characteristic, single pixel calibration, linearity, MIP sensitivity etc.
  - Micron resolution optical scanner for studying pixel-to-pixel response to be developed soon at TIFR, Mumbai
- Packaging and assembly of the device
  - For bare SiPMs from HCAL-CMS at BEL, Bangalore
- Device and Process Simulation
  - Under progress
- Fabrication
  - BEL, Banglore
  - Semiconductor Complex Limited, Chandigarh
  - 1st Prototyping Run anticipated in 2011-2012

CMS-HO Upgrade with Silicon Photomultiplier Readout

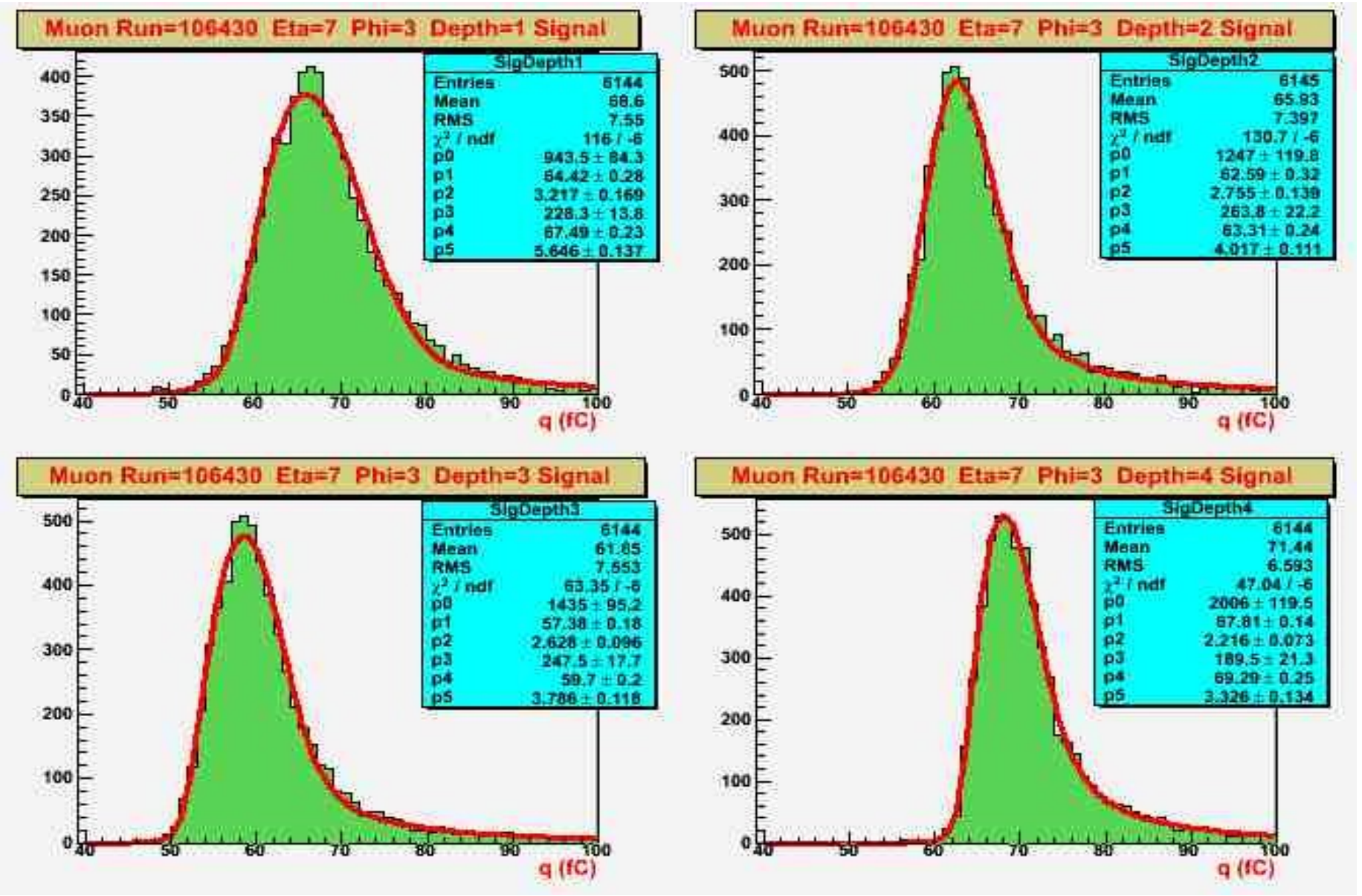
- Validation of SiPM for CMS environment
  - Test beam studies, stability, radiation hardness, magnetic field immunity, saturation effects
- SiPM Control Boards
  - Prototype fabrication of this board carried out in India
  - Entire production and QC of 120 boards to be carried at Ooty
- SiPM Boards:
  - Each board consists of SiPM
  - Fabrication and QC of 120 boards (2160 channels) at Ooty
- Installation
  - Assembly of Readout boxes, QC and burn-in tests at CERN, jointly by CERN/India

SiPM Response using LED at Ooty



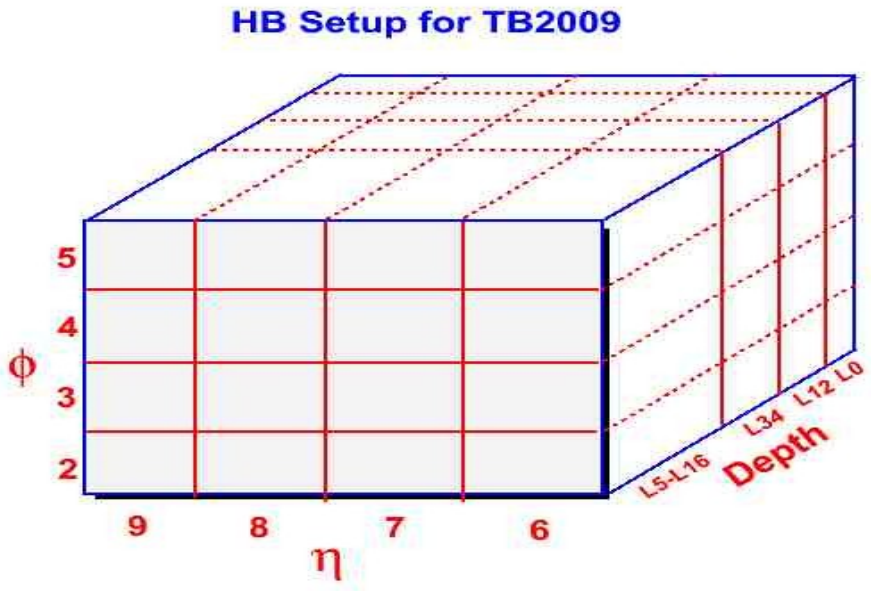

Pedstal+Muon ADC Distribution
dstbn4
Entries 350148
Mean 994
RMS 346.5
χ² / ndf 1753 / 122
Constant 563 ± 3.4
Mean 856.7 ± 1.4
Sigma 204.6 ± 2.1
44 p.e.
800
700
600
500
400
300
200
100
0
400
600
800
1000
1200
1400
1600
1800
2000
2200
qADC (100 fC)

HB Calibration with 150 GeV Muons



All 16 Towers x 4 Depths are calibrated

HB+HO with SiPM Readout: TB2009 at CERN

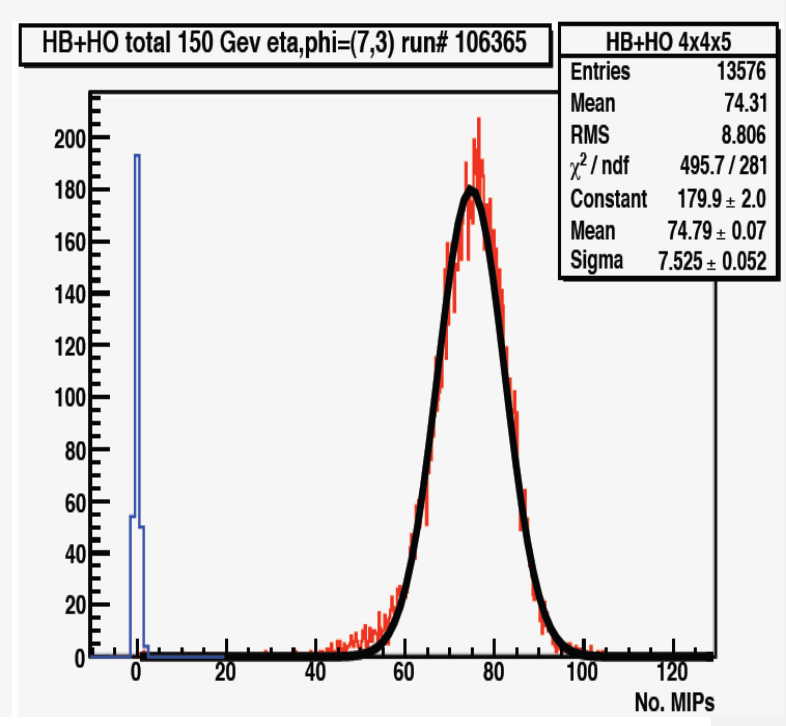


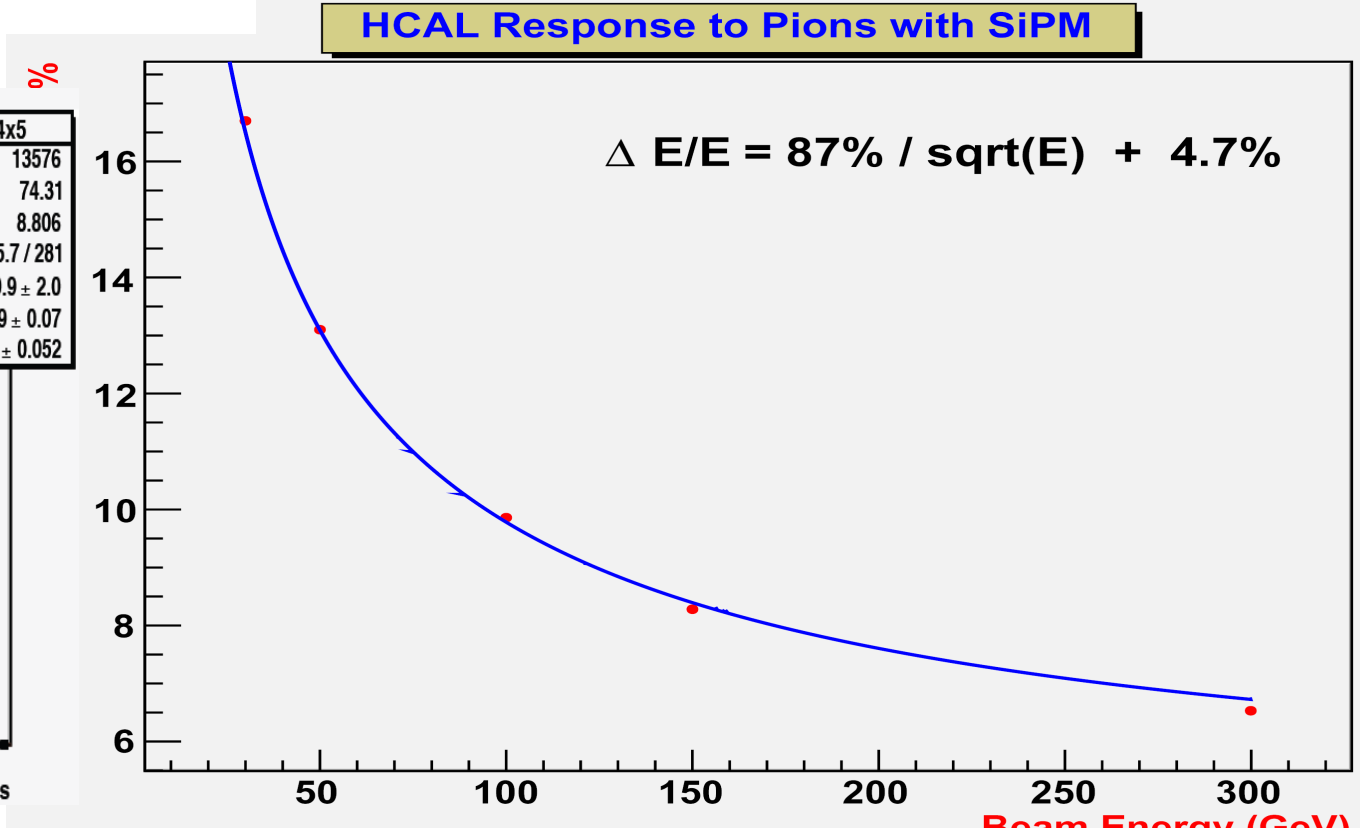
HB readout by Zecotek

HO readout by Hamamatsu & Zecotek

Phi=2,3 by Hamamatsu SiPM

Phi=4,5 by Hamamatsu SiPM





GRAPES-3 Experiment Ooty (11.4N, 76.7E, 2200m)

400 Scintillator detectors (1 m^2 area)

560 m^2 muon detector (E_μ=1 GeV)

Objective: Universe at high energies

Acceleration, propagation of highest energy particles,
Extreme conditions may require new physics ...

1. Acceleration of particles in atmospheric electric field
   Energy ~100 MeV Scale ~10^5-10^6 cm

2. Solar flares, Coronal Mass Ejections
   Energy ~10 GeV Scale ~10^{11}-10^{13} cm

3. Galactic Cosmic Rays at " Knee "
   Energy ~1 PeV Scale ~10^{21}-10^{23} cm

4. Diffuse multi-TeV γ-rays
   Energy ~100 EeV Scale ~10^{24}-10^{26} cm

Fabrication of Plastic Scintillator

Plastic Scintillator development:

Decay Time= 1.6 ns

Output = 54% Anthracene

Timing 25% faster

Atten. Length λ= 100 cm

Low Cost

Max Size 100 cmX100 cm

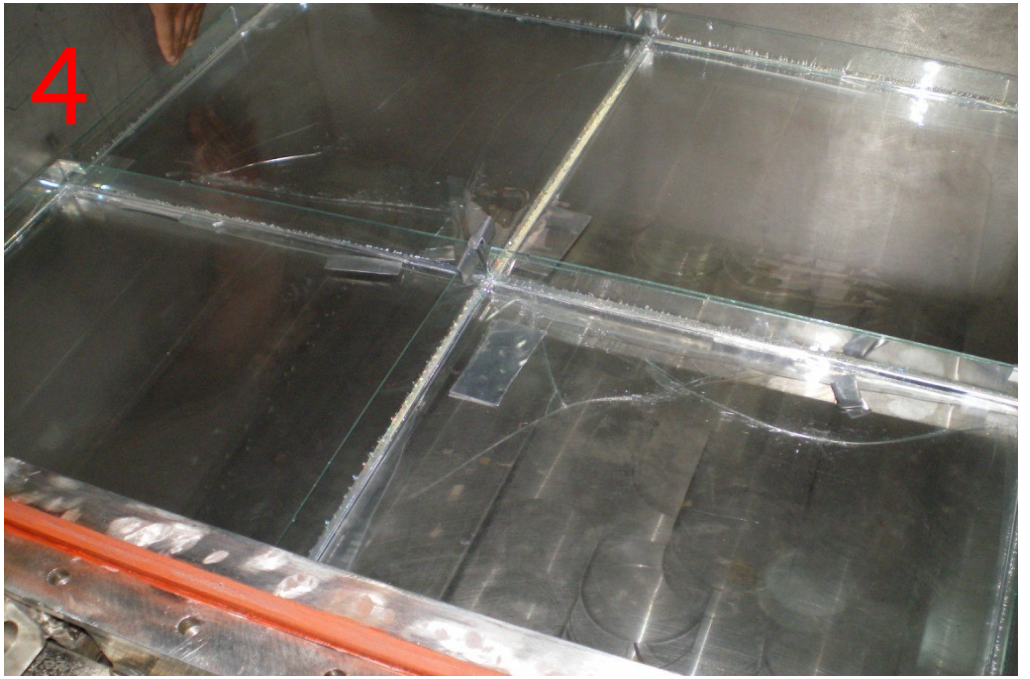
Total > 2000

TIFR, CERN, Osaka, IUAC Delhi, Bose, VECC, etc.


1


2


3


4


15

Monte Carlo simulations using Bethe-Block energy loss in Scintillator and Landau distribution;

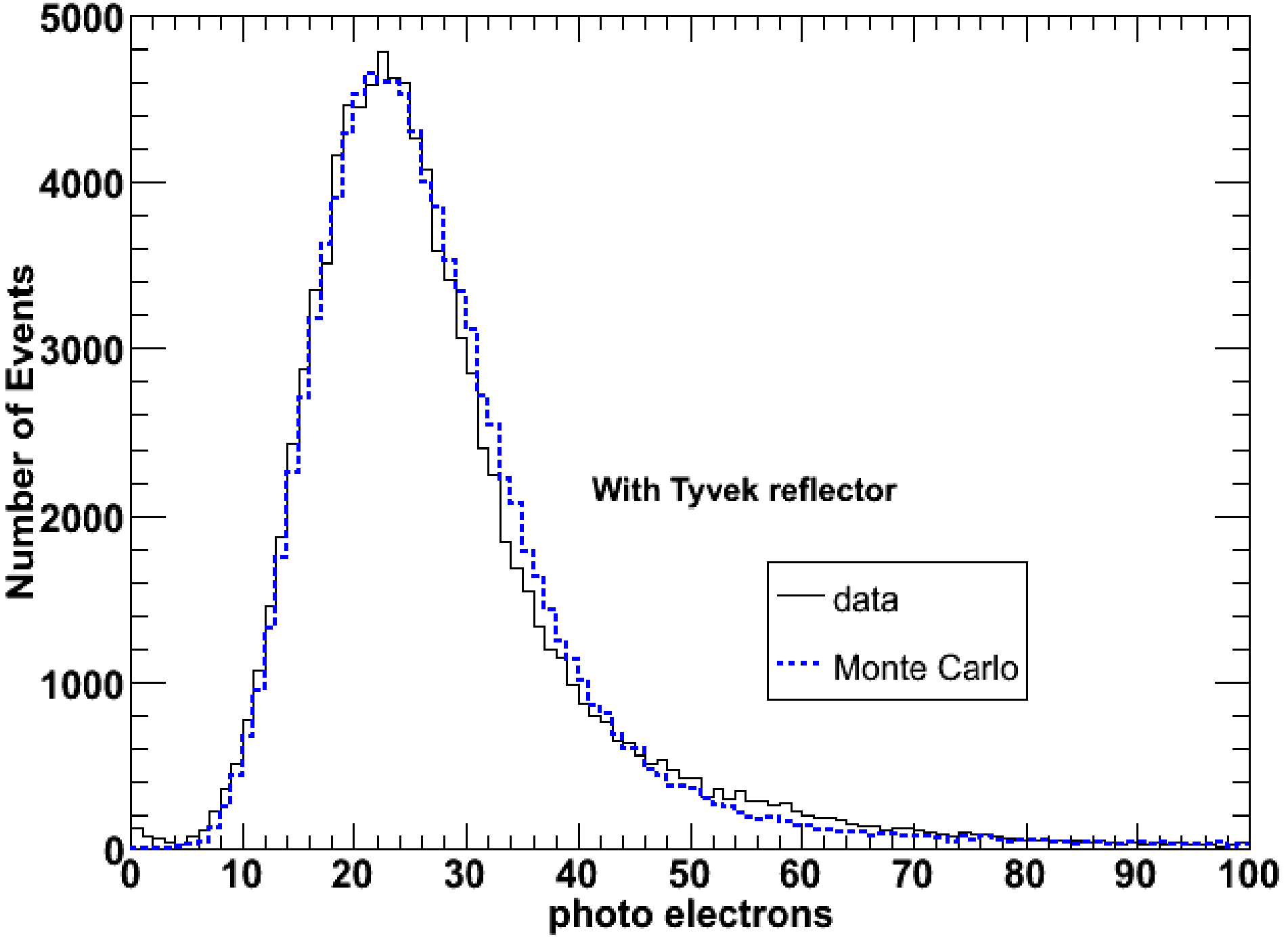
Photon conversion Efficiency = 100 eV/photon

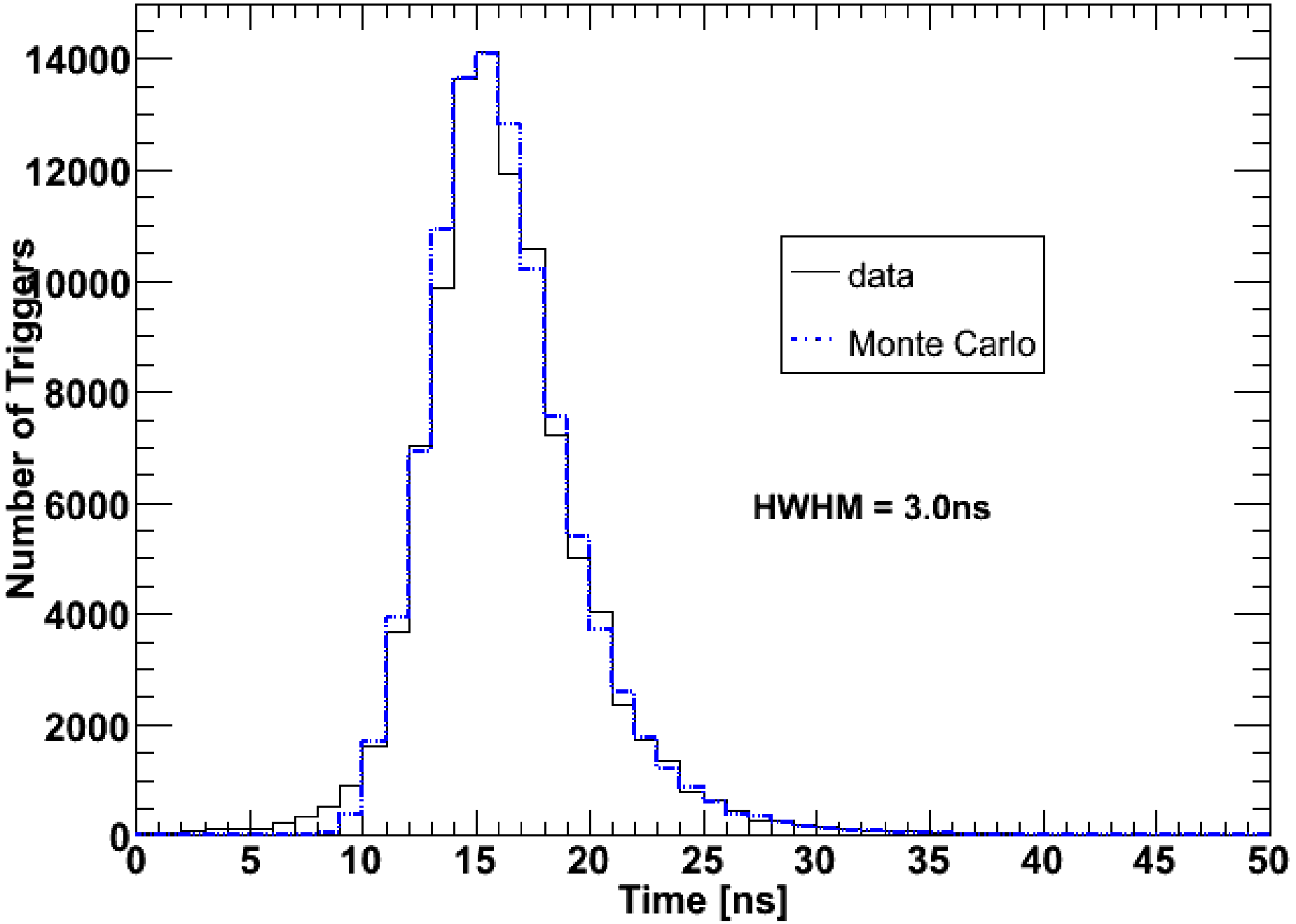
$\lambda_{scintillator}$ = 100 cm $\lambda_{WLS\ fiber}$ = 300 cm

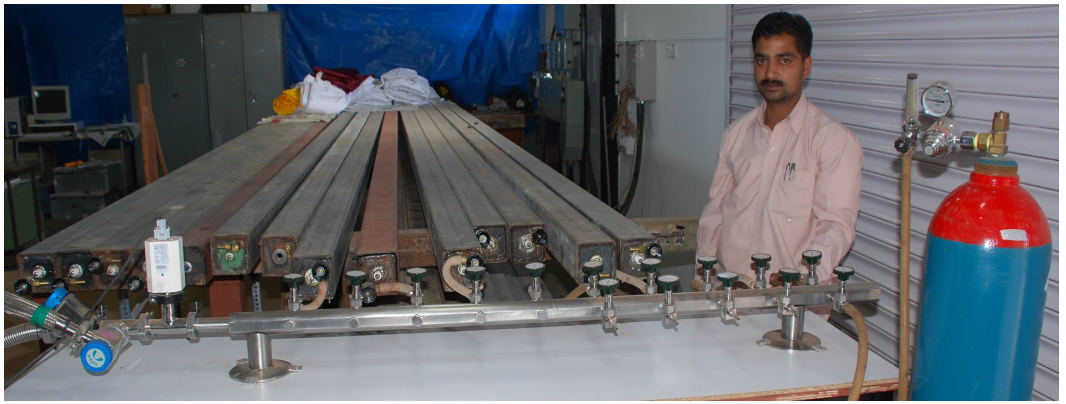
$\tau_{scintillator}$ = 1.6 ns $\tau_{WLS\ fiber}$ = 6.1 ns

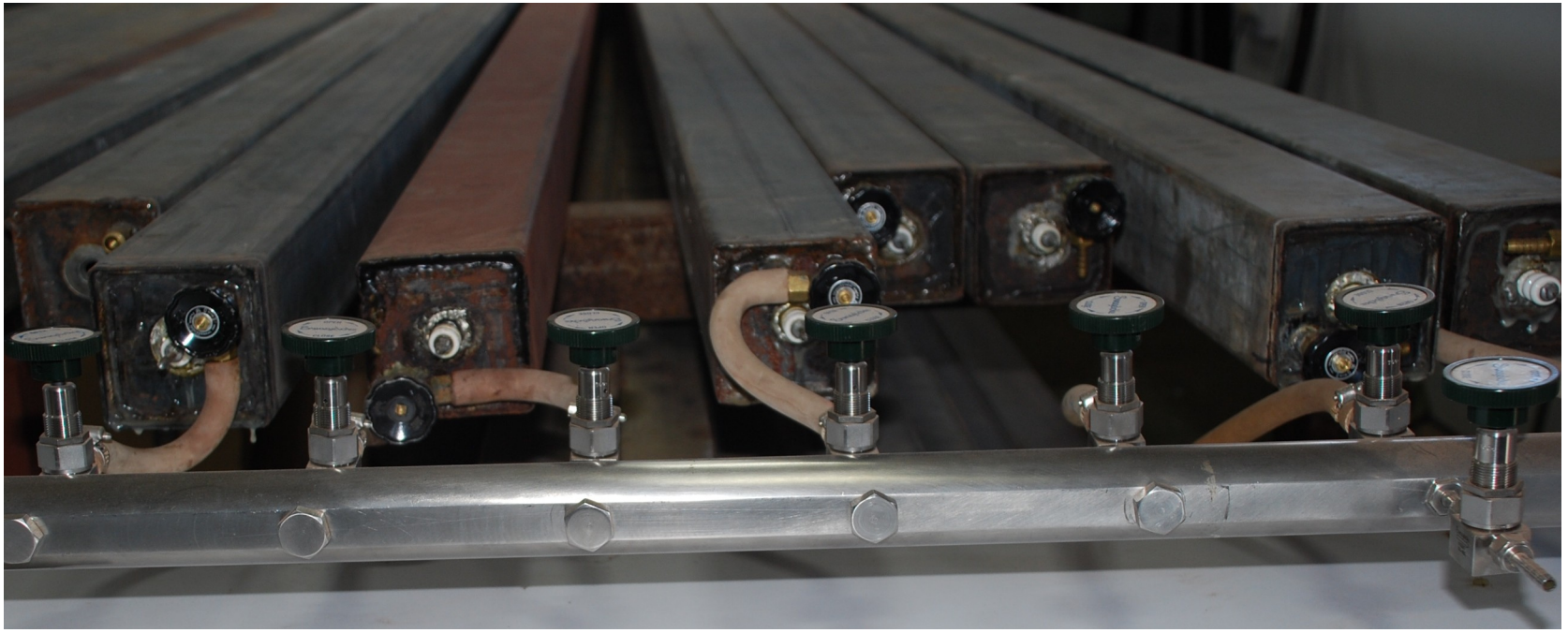
Effective Scintillator TIR = 98.5%; Tyvek Reflectivity = 90%

PMT Quantum Eff. = 9% ; Photo-electron width = 20%

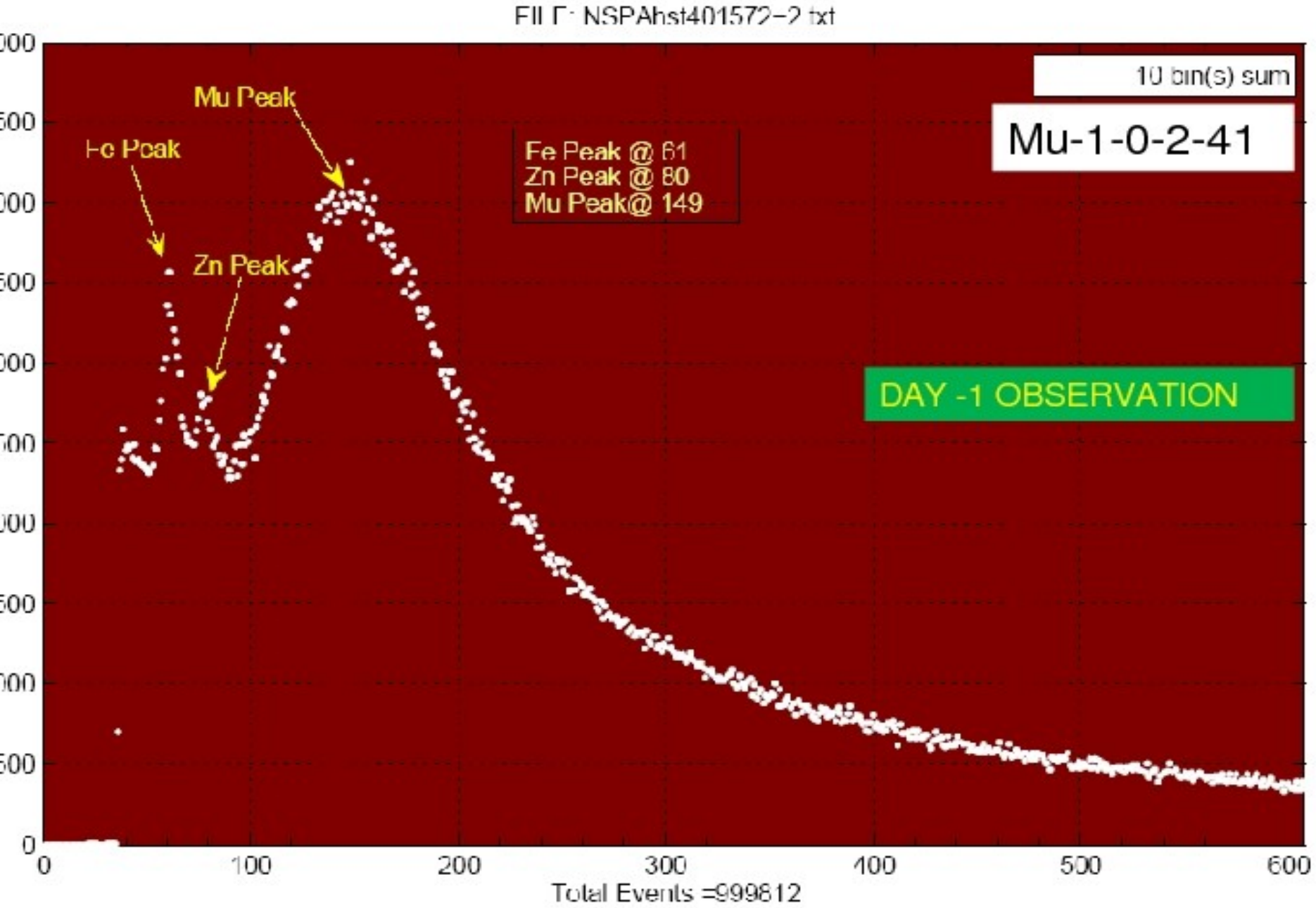

5000
4000
3000
2000
1000
0
Number of Events
0
10
20
30
40
50
60
70
80
90
100
photo electrons
With Tyvek reflector
data
Monte Carlo


14000
12000
10000
8000
6000
4000
2000
0
Number of Triggers
0
5
10
15
20
25
30
35
40
45
50
Time [ns]
data
Monte Carlo
HWHM = 3.0ns





Proportional Counter Test Setup


Mu Peak
Fe Peak
Zn Peak
Fe Peak @ 61
Zn Peak @ 80
Mu Peak@ 149
10 bin(s) sum
Mu-1-0-2-41
DAY -1 OBSERVATION
0
100
200
300
400
500
600
Total Events =999812

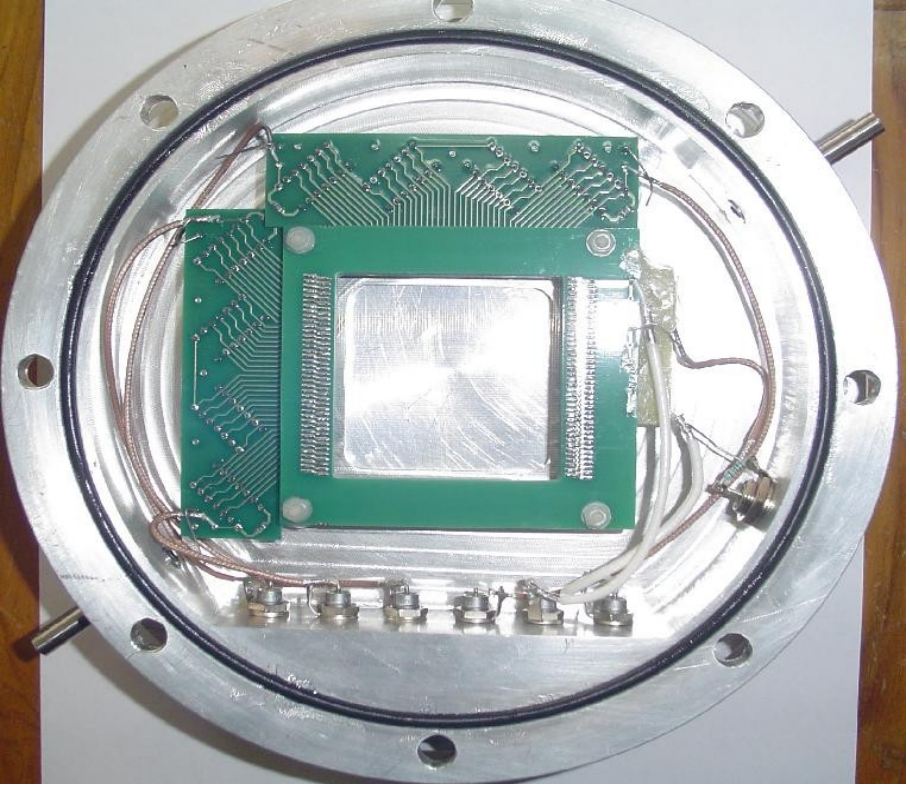
MWPC development at IUAC, New Delhi

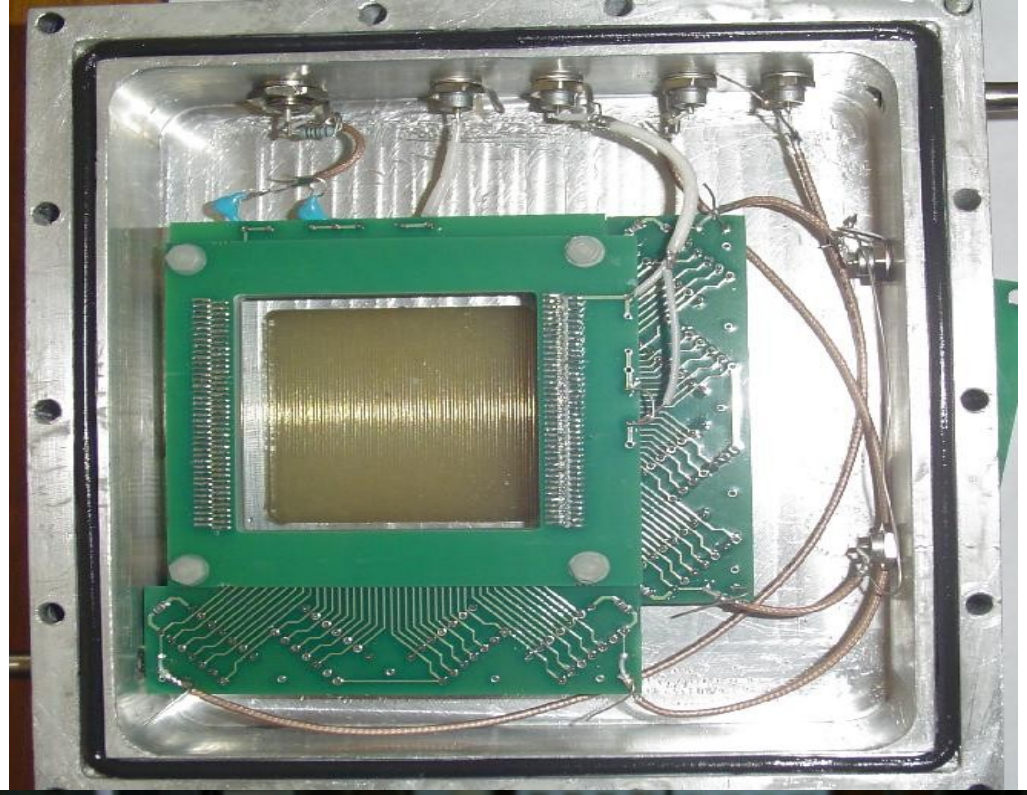
TOF System for fission experiments

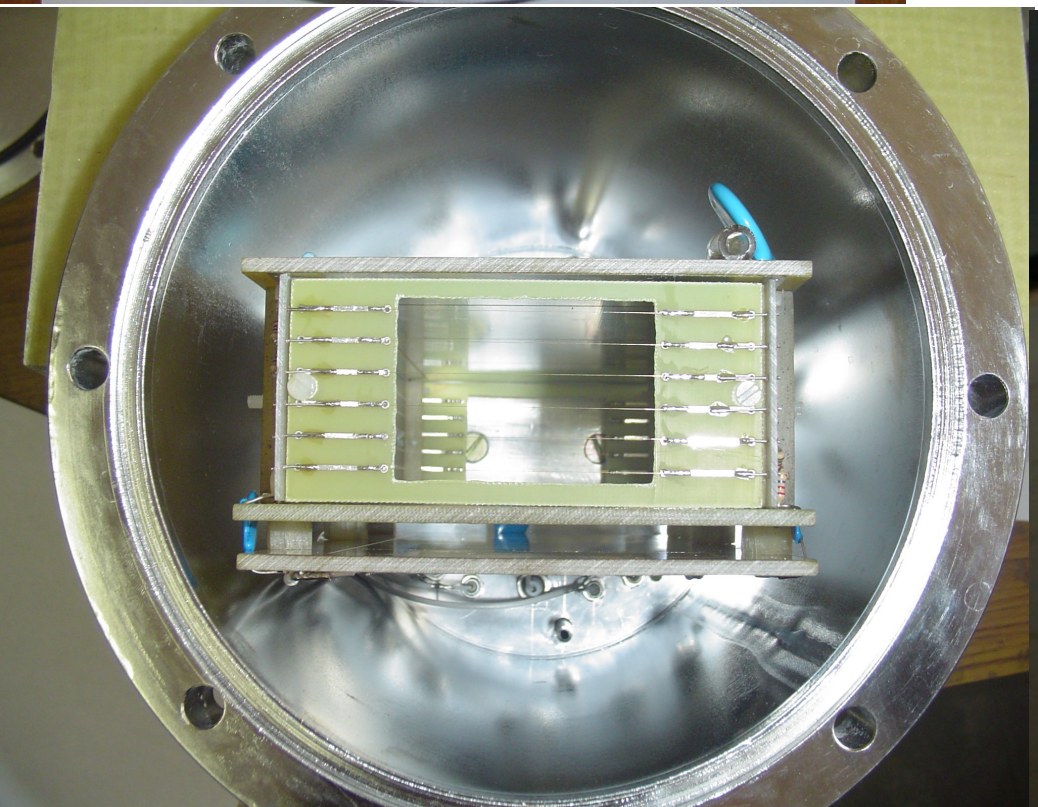
MWPC 8 ”X 4 ”
Electrodes : Au plated W wires – 20μ
Electrode separation : 3.5 mm
Rise time ~ 10 ns
TOF ~ 1 ns (fwhm), Positions ~ 1 mm (fwhm)

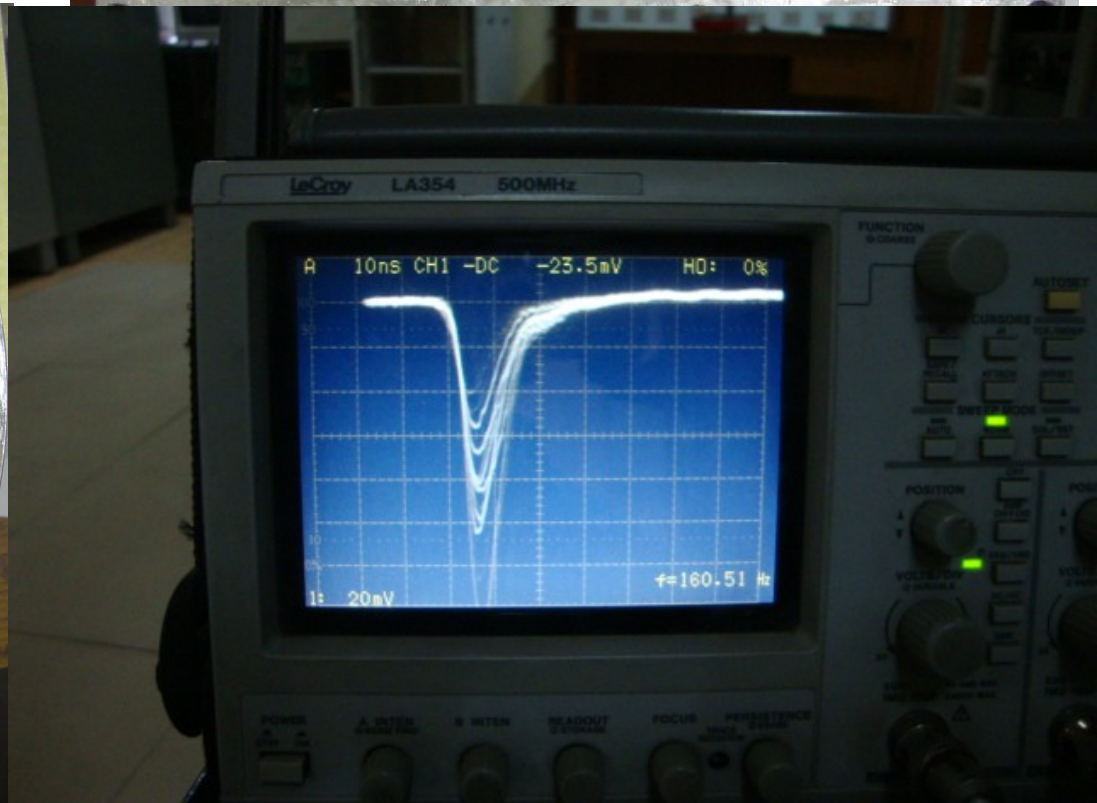
Small transmission MWPC 1.5 ” X 1.5 ”
Electrodes : Au plated W wires – 20μ
Electrode separation : 2 mm
Entrance and exit foils : 0.5μ mylar.
Rise times ~ 3.5 ns, TOF < 0.5 ns

Ref : A. Jhingan et. al. Rev. Sci. Instr. **80**, 123502 (2009)

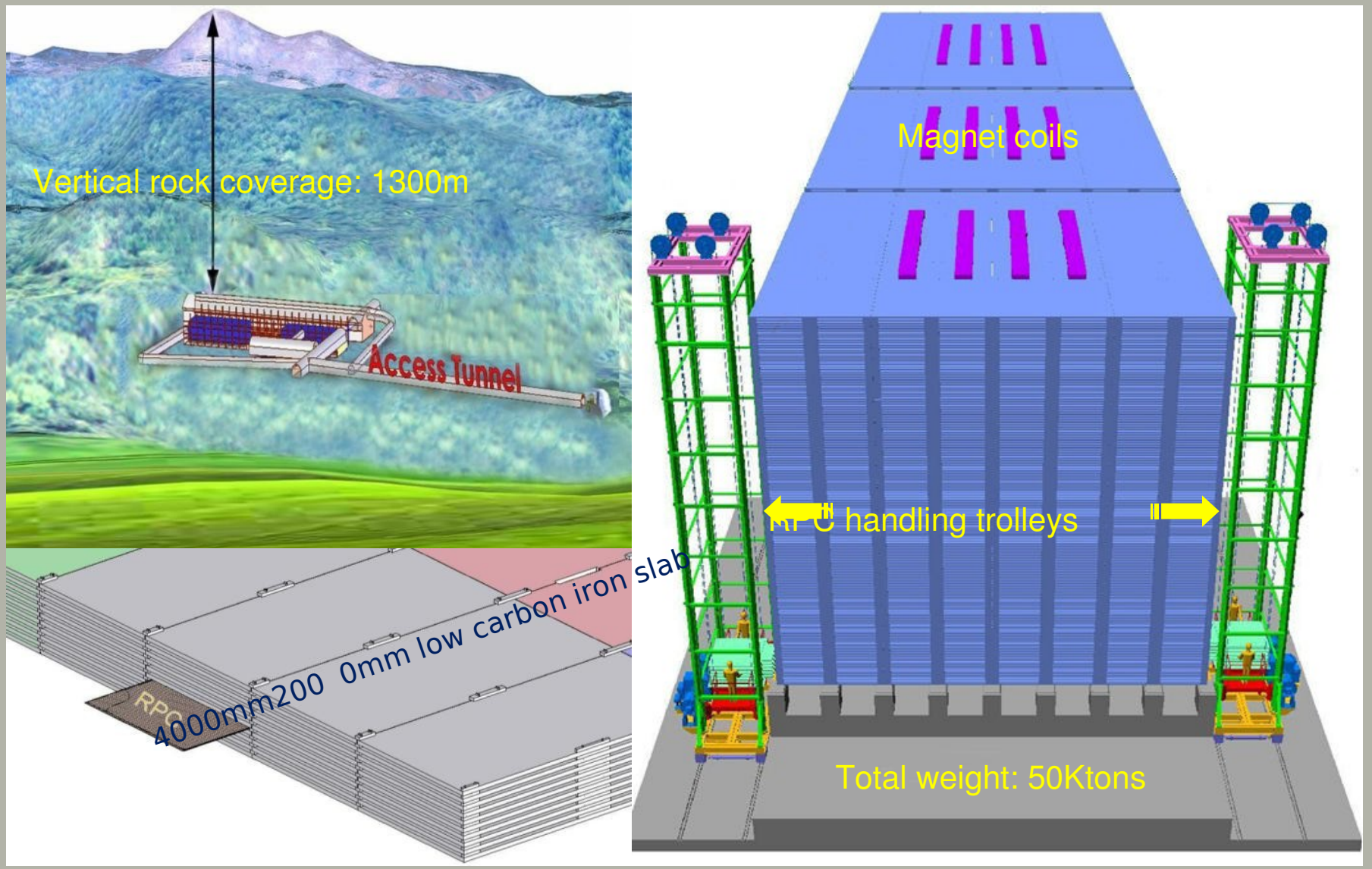







LeCroy LA354 500MHz
A 10ns CH1 -DC -23.5mV HD: 0%
1: 20mV
f=160.51 Hz

INO cavern and detector



http://www.ino.tifr.res.in/ino/talks.php

Details of INO detector

No. of modules	3
Module dimensions	16m × 16m × 14.5m
Detector dimensions	48.4m × 16m × 14.5m
No. of layers	150
Iron plate thickness	56mm
Gap for RPC trays	40mm
Magnetic field	1.3Tesla
RPC dimensions	1,840mm × 1,840mm × 24mm
Readout strip pitch	3 0mm
No. of RPCs/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
No. of RPC units	28,800 (97,505m2)
No. of readout strips	3,686,400

http://www.ino.tifr.res.in/ino/talks.php

2mx2m RPC: Gas gap

Bottom glass in place

Template for button positions placed below the bottom glass Buttons placed on 20cm x 20cm grid

Gluing of buttons

Currently glue dispensed manually Protective template placed on the glass Auto timer-based glue dispenser being designed

http://www.ino.tifr.res.in/ino/talks.php

2mx2m RPC: Gas gap

Preparing to glue bottom

Ready to glue top-side spacers

2mx2m RPC: Gas gap

Leak testing the gap

Fully fabricated gas gap

2mx2m RPCs in Cosmic test

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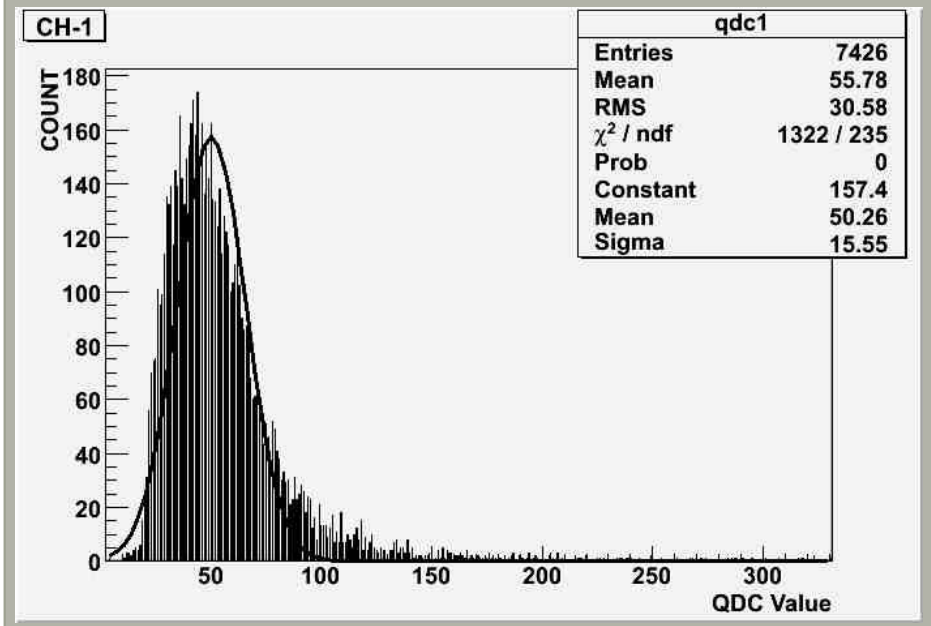
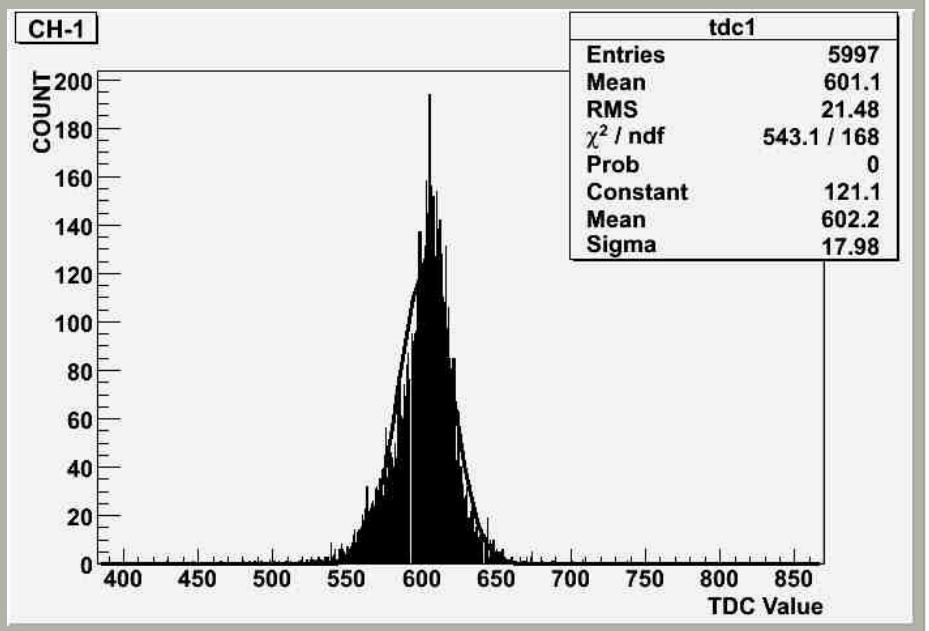
Charge and time distributions

Charge



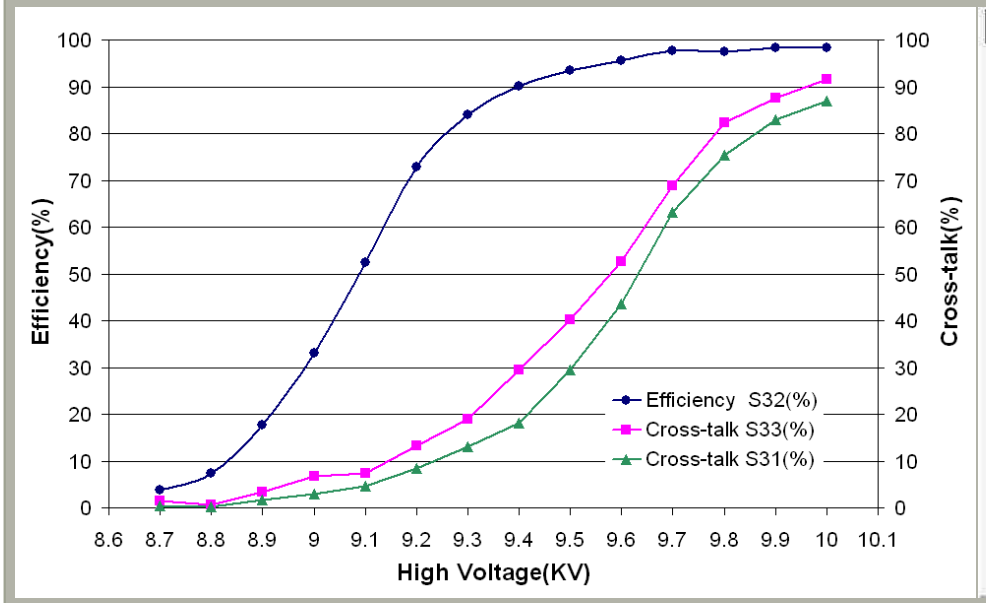
Timing



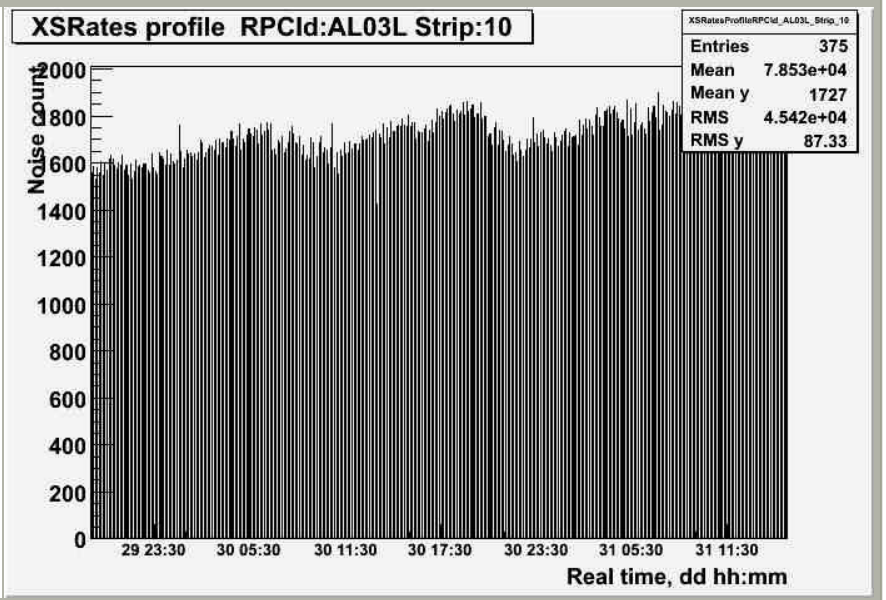
http://www.ino.tifr.res.in/ino/talks.php

Monitoring operating

Efficiency plateau



Noise rate profile



http://www.ino.tifr.res.in/ino/talks.php

Summary

Gaseous Detectors:

- Proportional Counters
- Multi Wire Proportional Counters
- Resistive Plate Chambers

Scintillator Detectors:

- Inorganic Crystals
- Plastic Scintillators

Semiconductor Detectors:

- Double-sided Silicon Multistrip & Pixel Detectors
- Silicon Photomultipliers

THANKS