Detectors for light charged particles, neutrons and fission fragments produced in low energy nuclear physics experiments

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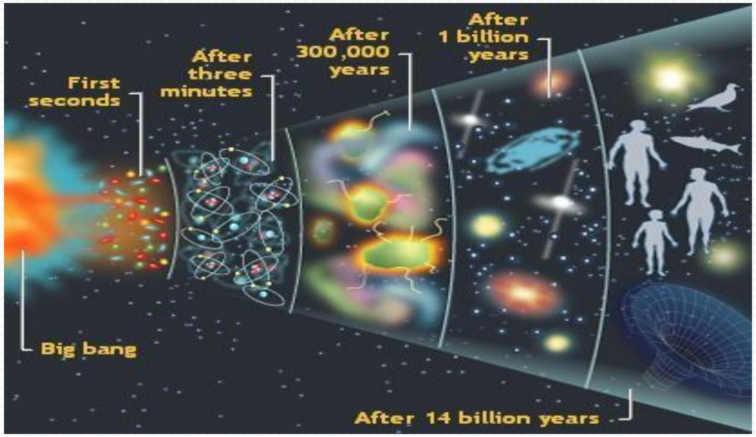
Outline

- Different kinds of detectors
- Array of semiconductor detectors
- Array of plastic scintillation detectors
- Gas detectors
- Summary

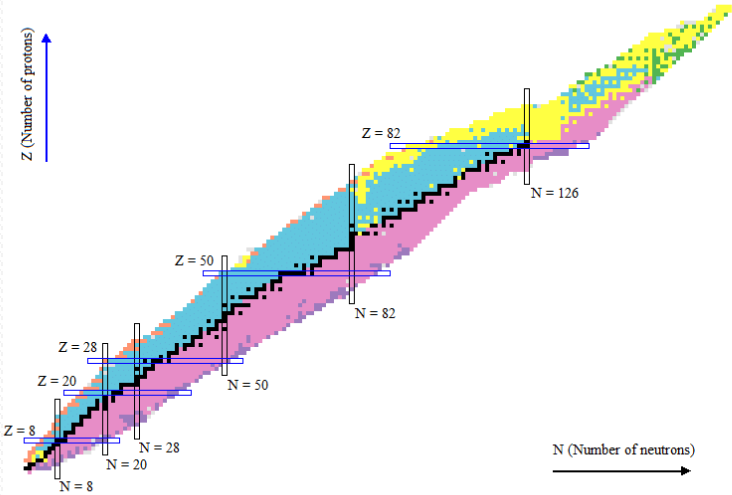
Open problems in low energy nuclear physics

- Nuclear astrophysics
  (γ,p),(γ,n), (γ,α), (p,γ), (p,n),(n,f)…



- Properties of exotic nuclei
  (γ, n, p, α, FF…)

- Synthesis of super-heavy elements
  (ER,FF,α …)



- Fission for basic and applied research
  (FF,n,γ …)

Requirement: detectors for neutron, gamma, light charged particles to fission fragments

Different kinds of detectors

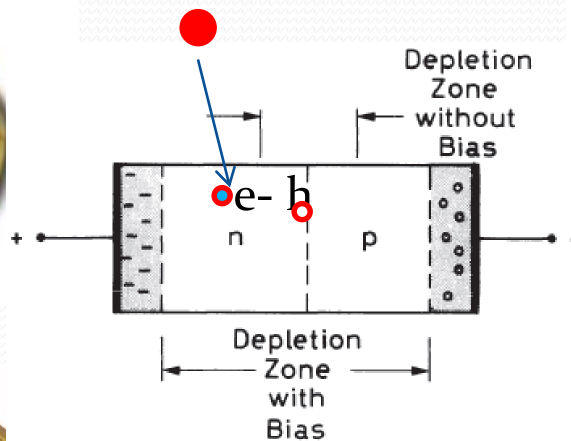
Interaction depends on types of incident radiation

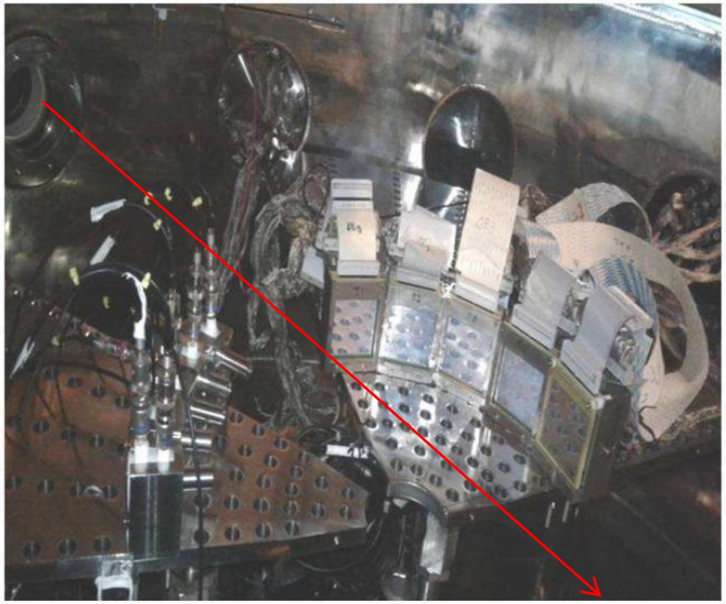
- light charged particles → semiconductor detectors
  → Particle identification (Z,A)
  → Energy& position measurement
- Neutron detectors → scintillation detectors
  → discrimination of neutrons & gamma
  →time of flight measurement
- Heavy-ions like FF → Gas detectors
  → discrimination from light charged particle
  → time of flight and position measurement

Semiconductor detectors

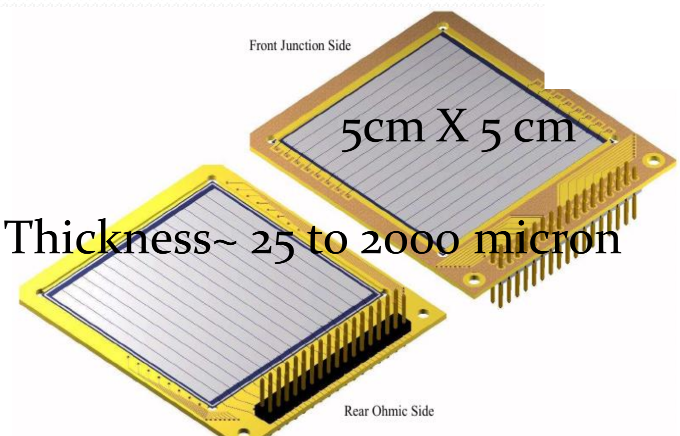
Diameter: 0.5-1 cm

Thickness: 15-2000 μm





Array of silicon strip detectors with ~100 deg angular coverage at BARC-TIFR Pelletron –Linac facility

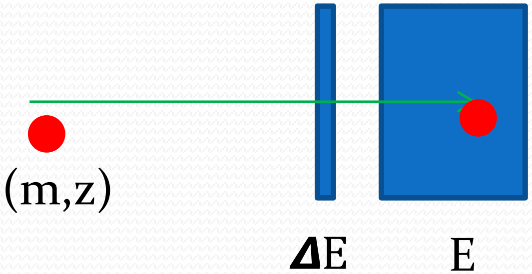


5cm X 5 cm

Thickness~ 25 to 2000 micron

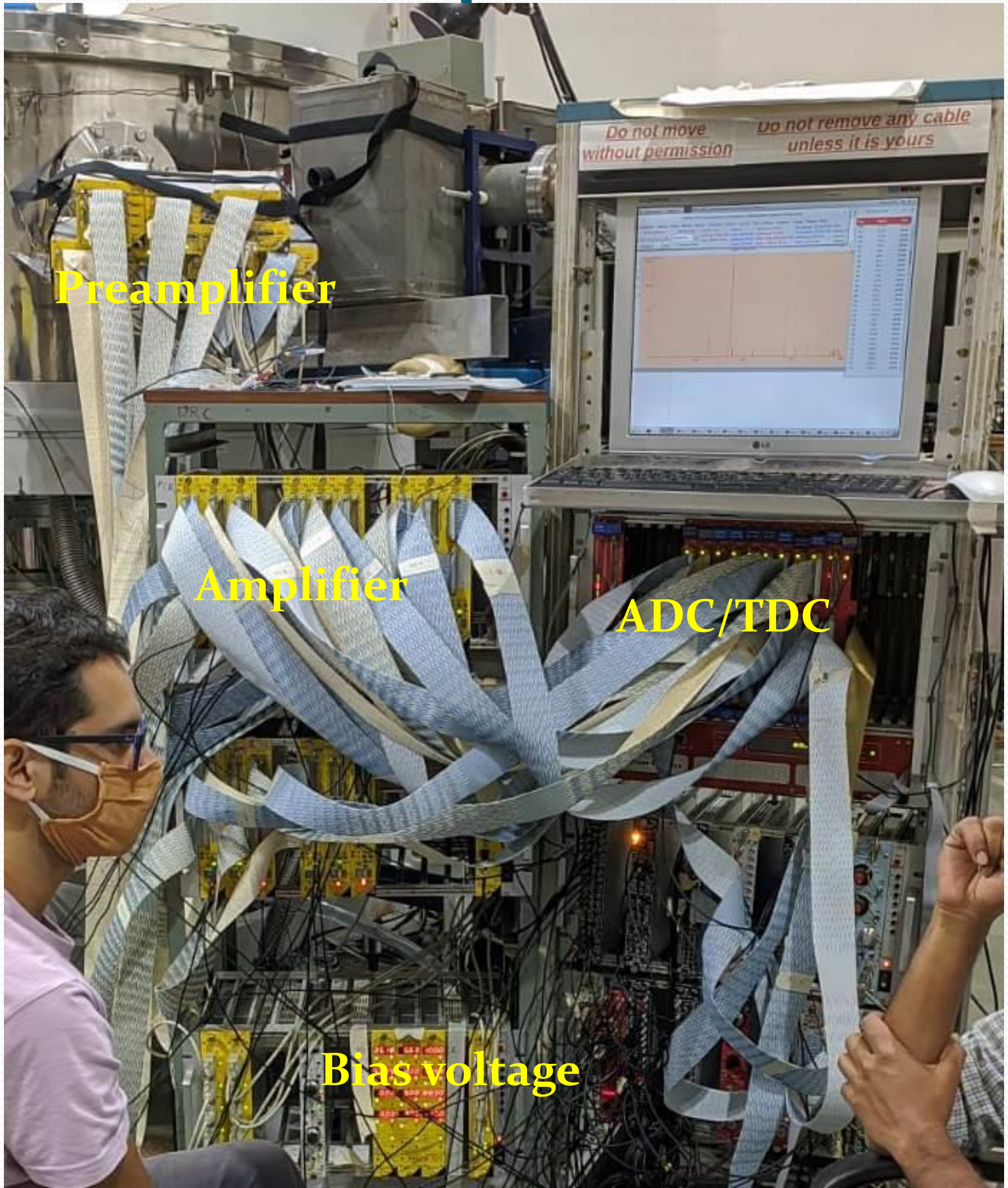
Read out through individual strip

X,Y positions could be read out



Particle identification:
$\Delta E \sim mz^2/E$

Data acquisition setup



- No. of parameters
  → Energy signal: 240
  → Timing signal: 80

Bias voltage: 5-200 Volts

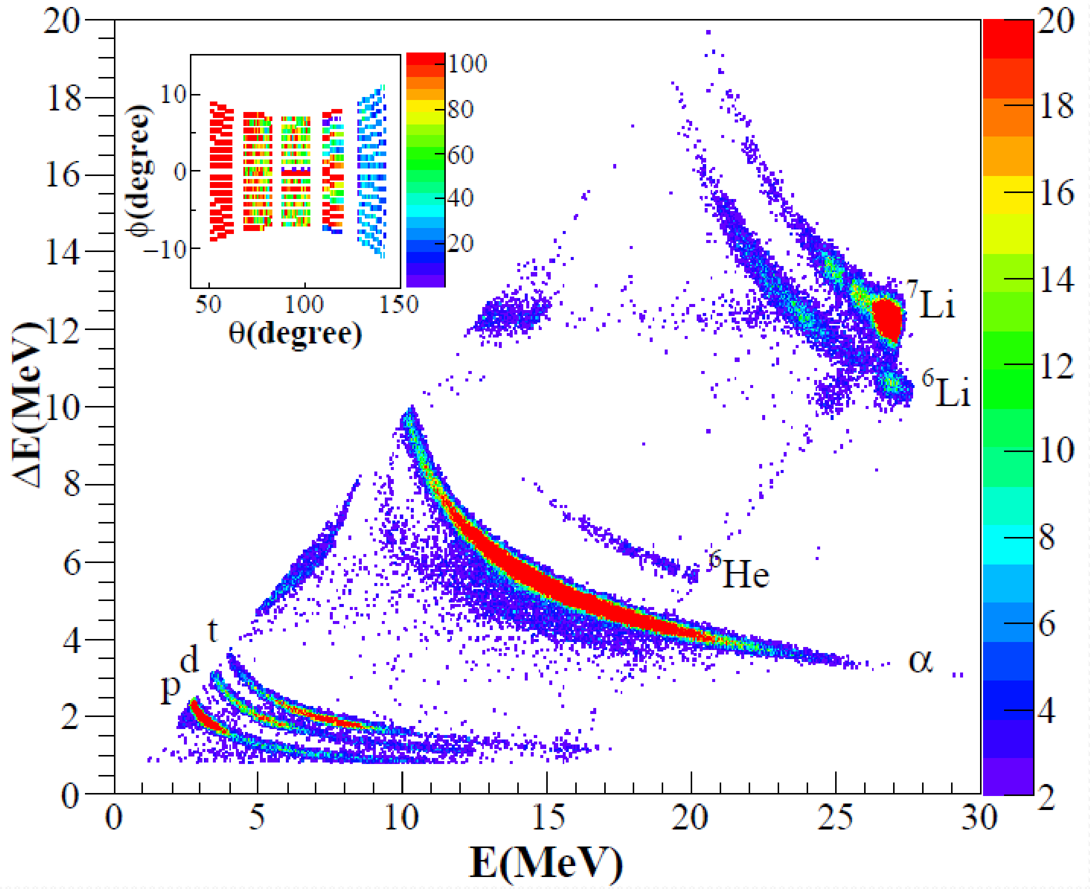
Pulse height of energy signals: <8 V

Rise time of timing signals: 30 ns

Master gate width~ 4 μs

Dead time~ < 5 % at
event rate 5KHz

Spectra



Reaction: $^{7}Li + ^{112}Sn \rightarrow ^{7}Be + ^{112}Sb$

↓

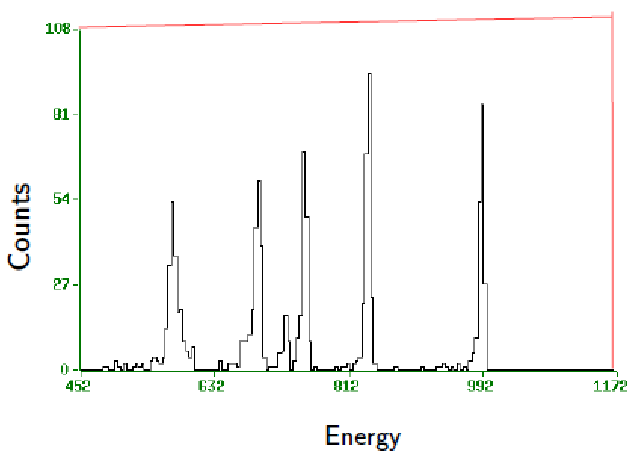
$^{4}He + ^{3}H$

Particle identification:

$\Delta E \sim mz^2/E$

Energy calibration:

^{229}Th alpha source



Energy resolution: 60 KeV

Measured: E1, E2

$\Theta_1, \Phi_1, \Theta_2, \Phi_2$

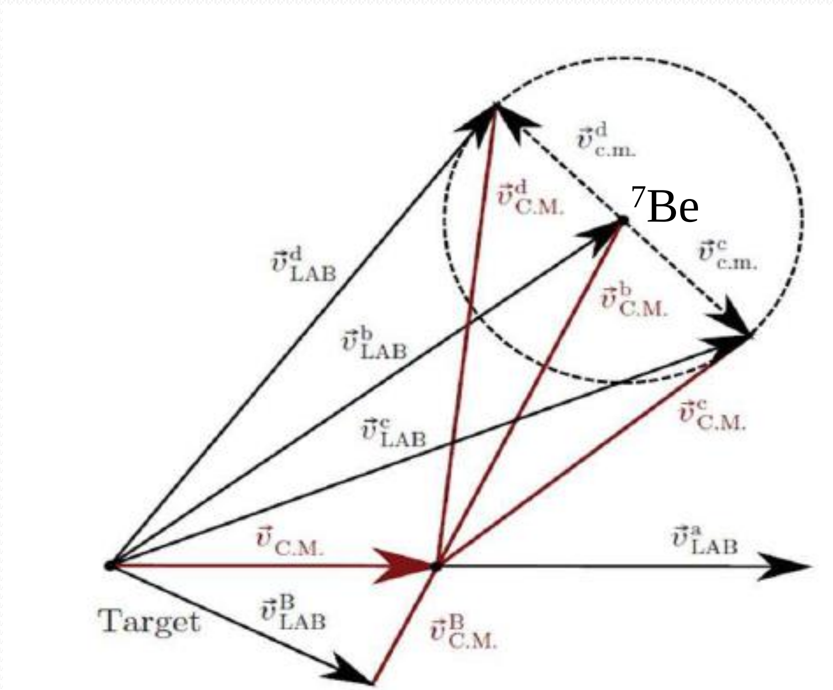
Reconstructed: momenta,

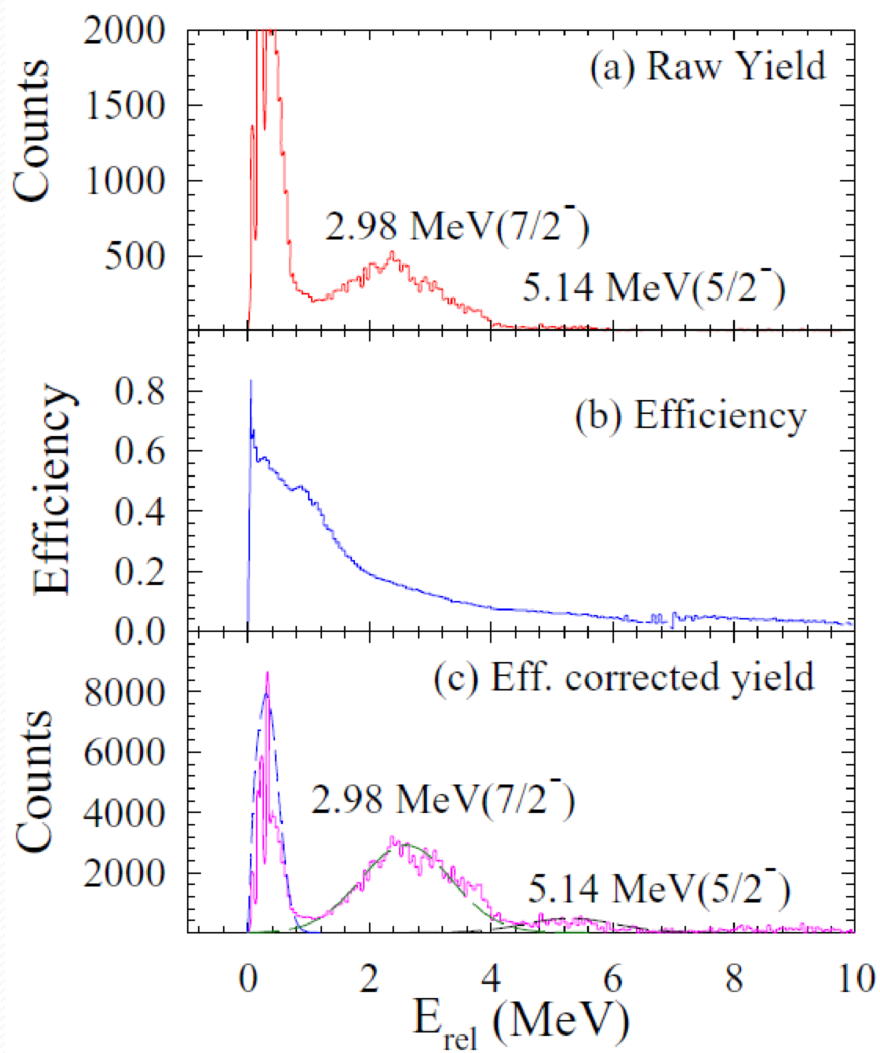
relative energy

q value

excitation energy

Monte Carlo simulation for coincidence efficiency





D. Chattopadhyay, S. Santra, **A. Pal** et al.
JPS Conf. Proc 32, 010009 (2020)

A.Baishya, S. Santra, **A. Pal** et al.
Phys. Rev. C **104, 024601 (2021)**

Important results

- Discovery of resonance states in ^{6}Li at 5.65 MeV

→ D. Chattopadhyay, S. Santra, **A. Pal** et al. Phys. Rev. C 94, 061602(R) (2016)

- Discovery of resonance states in ^{7}Li at 6.68 MeV

→ D. Chattopadhyay, S. Santra, **A. Pal** et al. Phys. Rev. C 97, 051601(R) (2018)

- Discovery of resonance states in ^{8}Be at 11.35 MeV

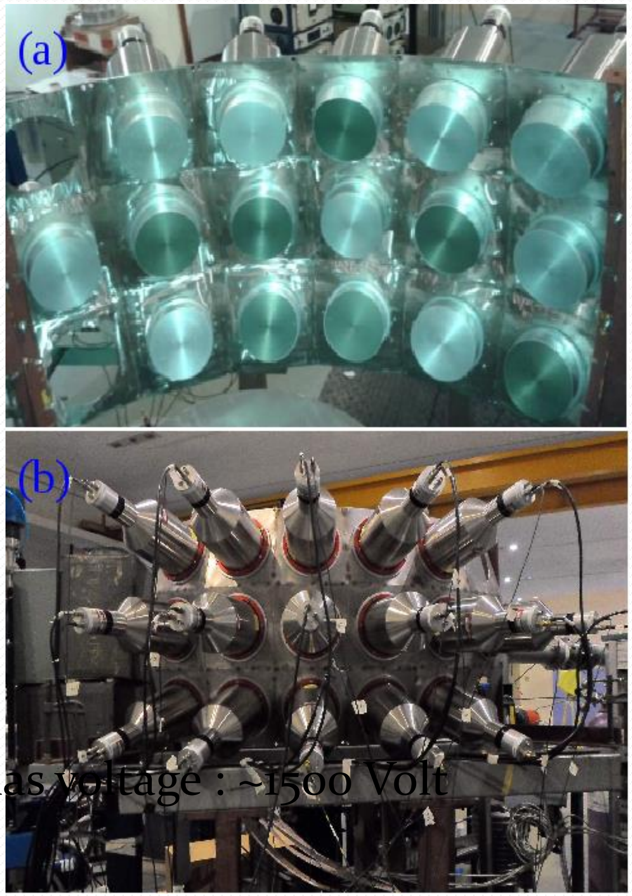
→ D. Chattopadhyay, S. Santra, **A. Pal** et al. Phys. Rev. C 98, 014609 (2018)

- Discovery of resonance states in ^{7}Be at 4.5 and 6.7 MeV

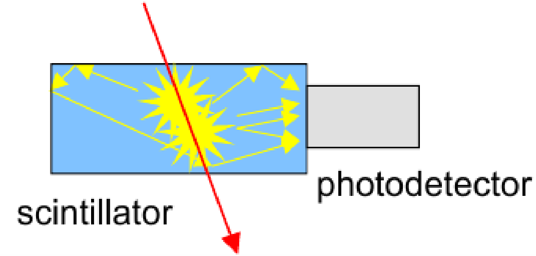
  → D. Chattopadhyay, S. Santra, **A. Pal** et al. Phys. Rev. C 102, 021601(R) (2020)

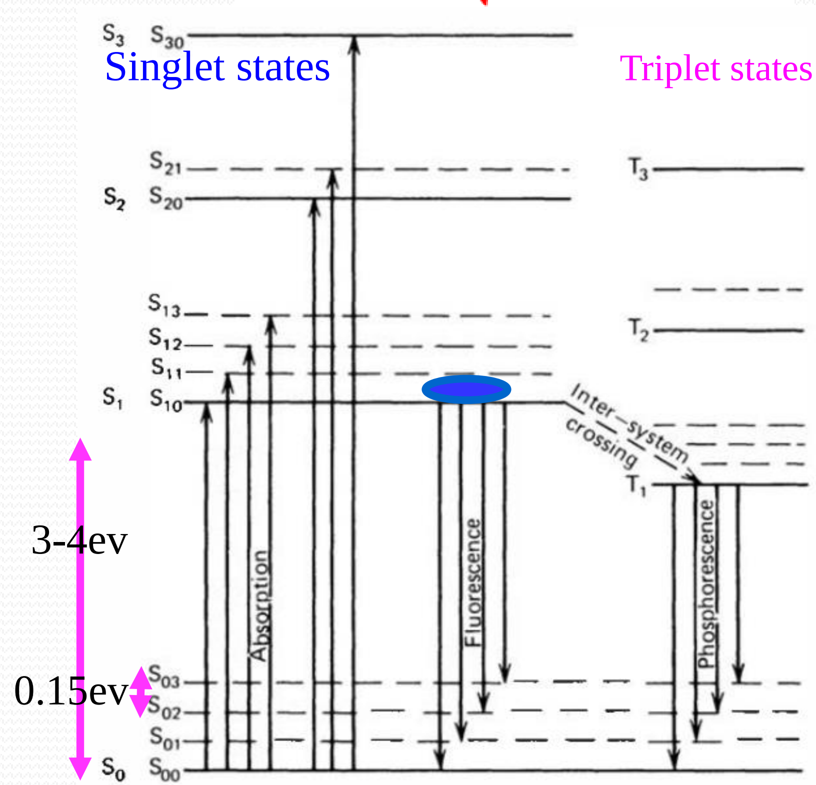
- Study on Hoyle state in ^{12}C

Scintillation detectors for neutrons



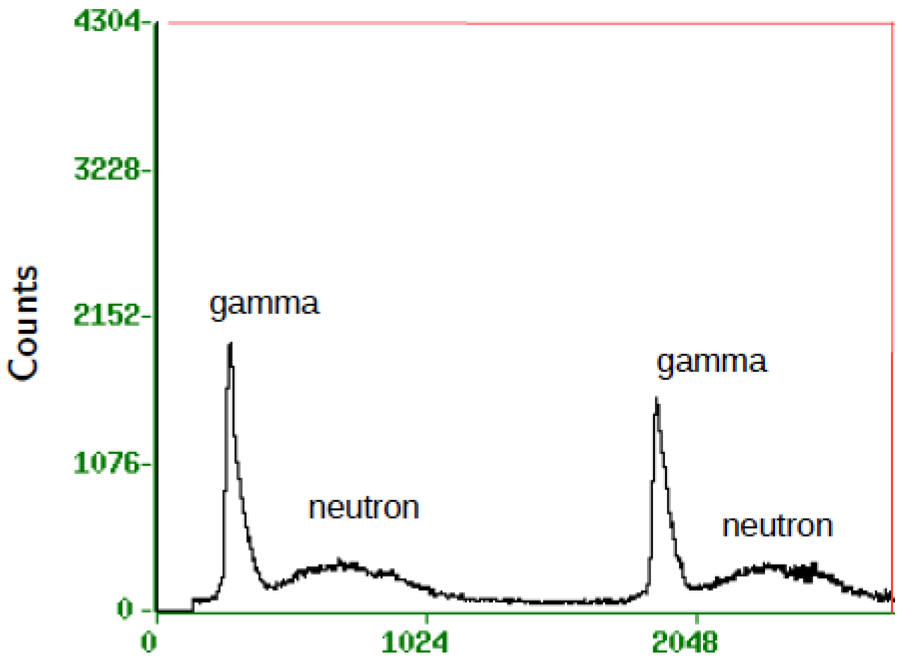
Bias voltage : ~1500 Volt



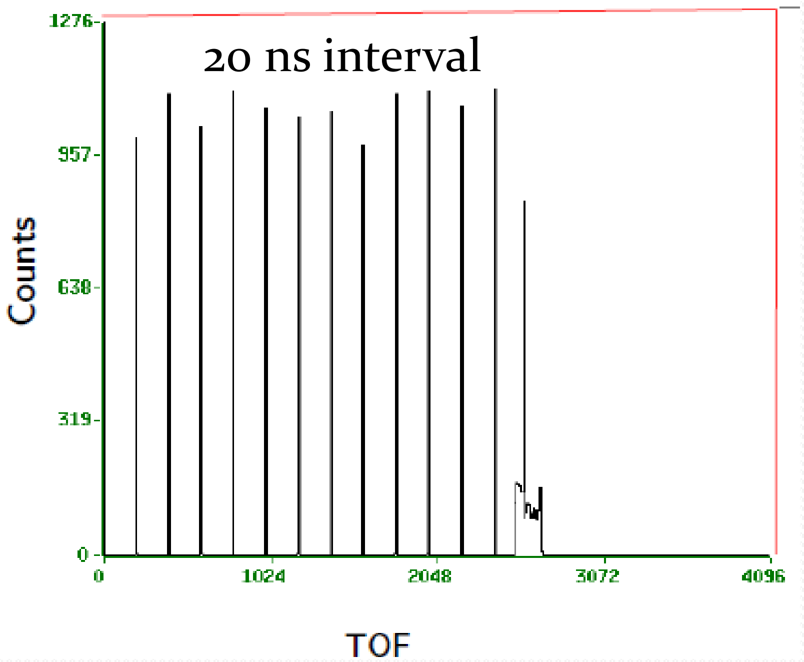


Array of liquid scintillators covering 60-150 deg at BARC-TIFR Pelletron –Linac facility

TOF spectra

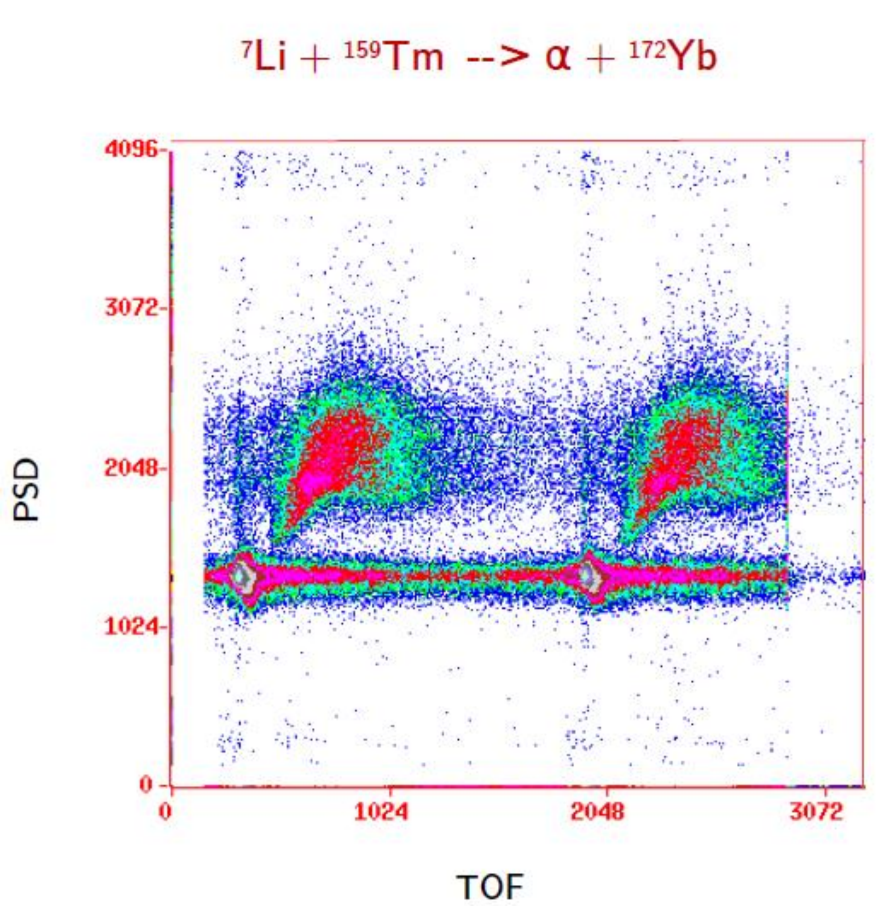


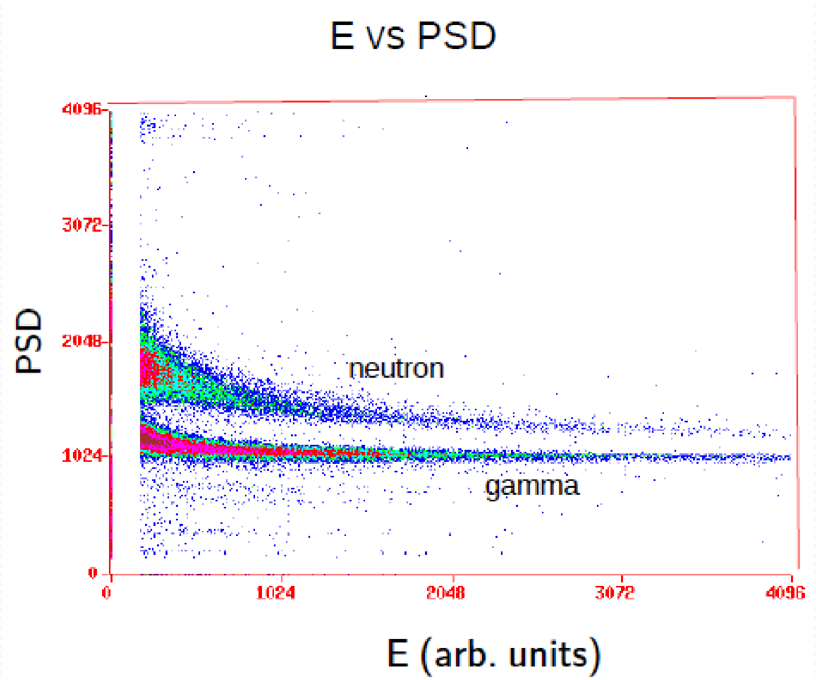
Distinguishing neutron and gamma



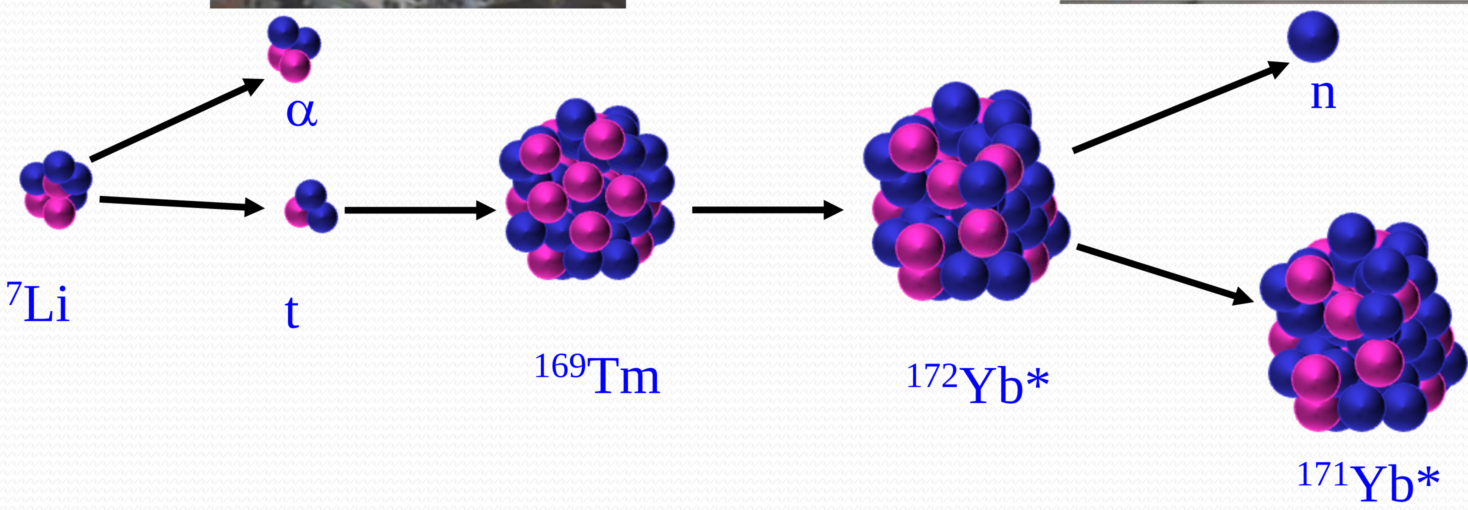
Calibrating TOF spectra with time calibrator

Clear distinction between neutron and gamma



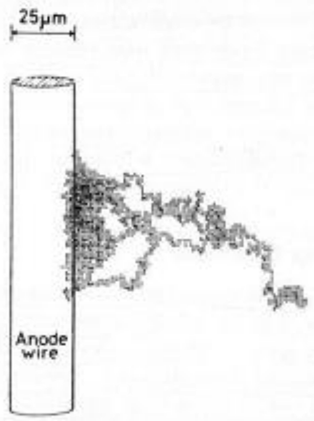


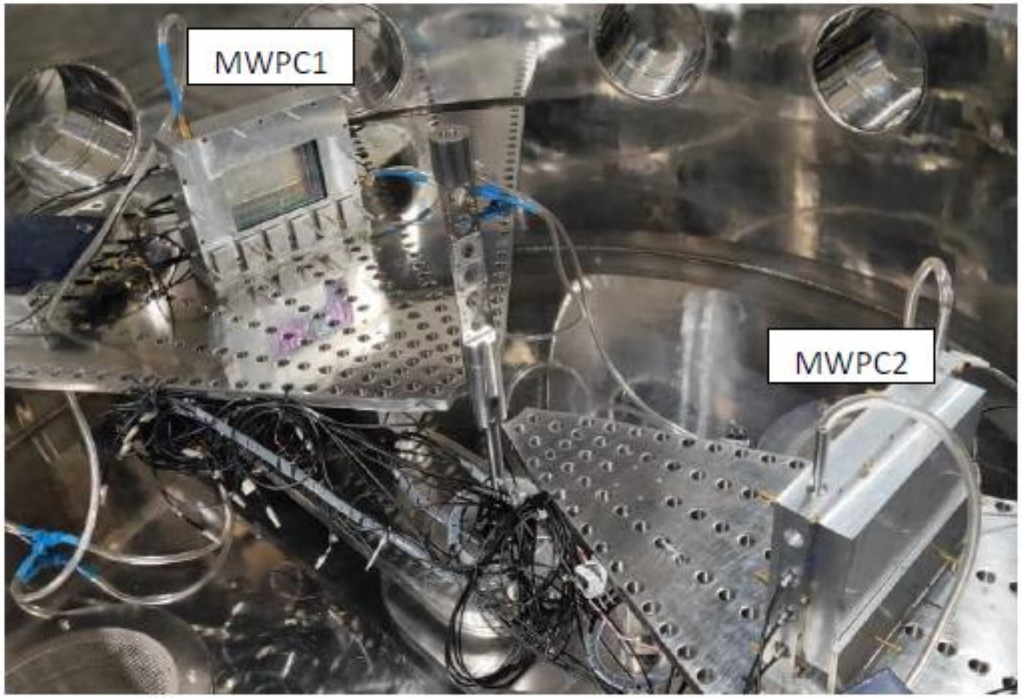
Recent study using LS array

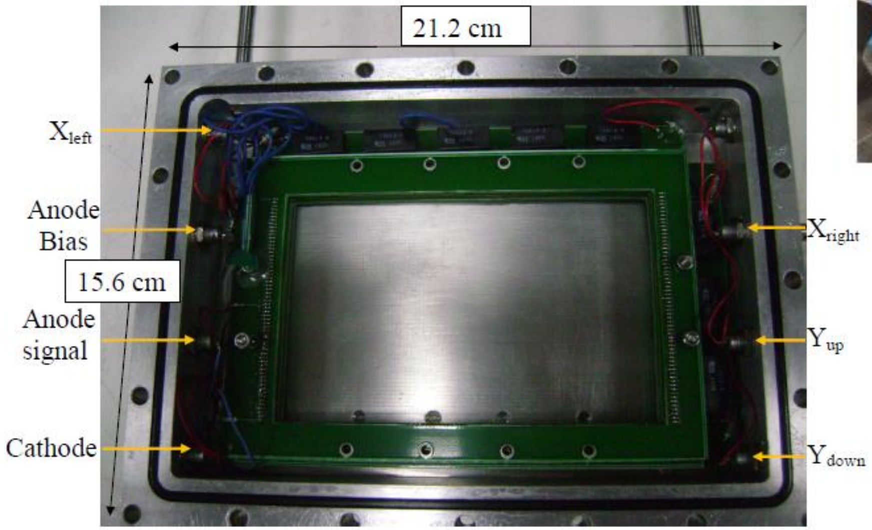


T. Santhosh et al. Submitted to DAE-BRNS symposium on Nuclear Physics

Gas detectors for fission fragments

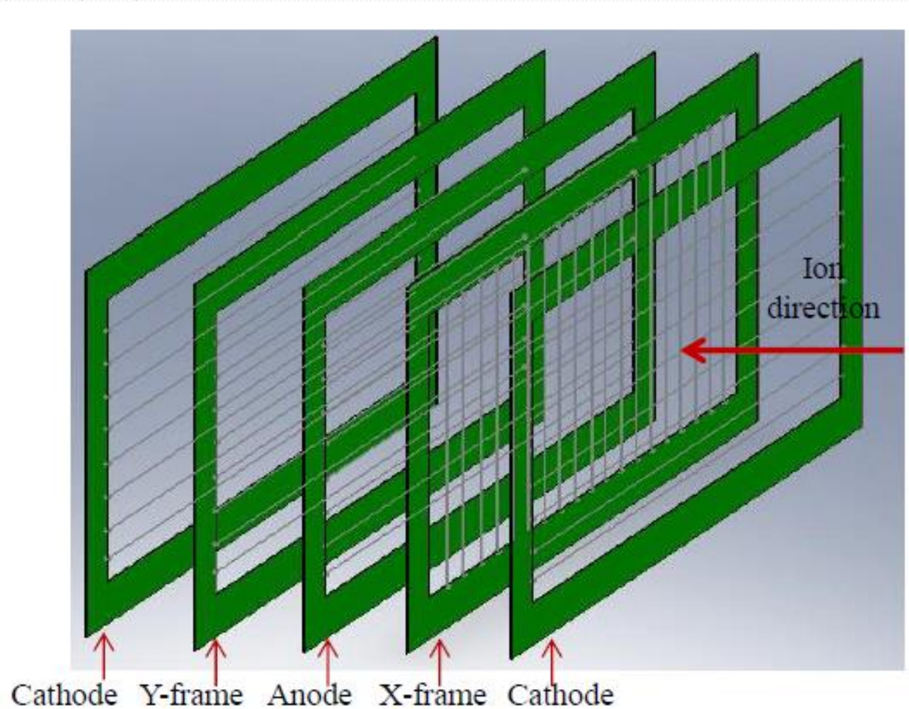






A. Pal et al. JINST 15, P02008 (2020)

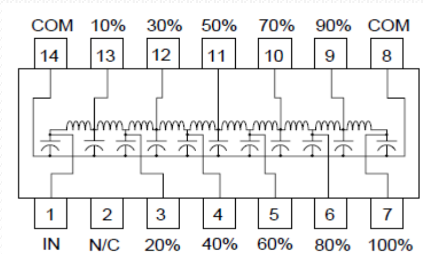
Electrodes

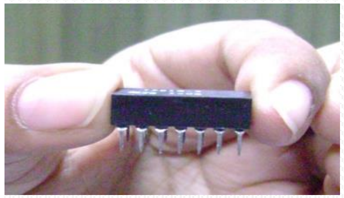


Distance between adjacent wire frames ~3 mm
Gold plated tungsten wire : diameter~ 20 micron
Distance between adjacent wires=.05 inch

X frames : 100wires, Y frames: 60 wires; wires are shorted in pairs

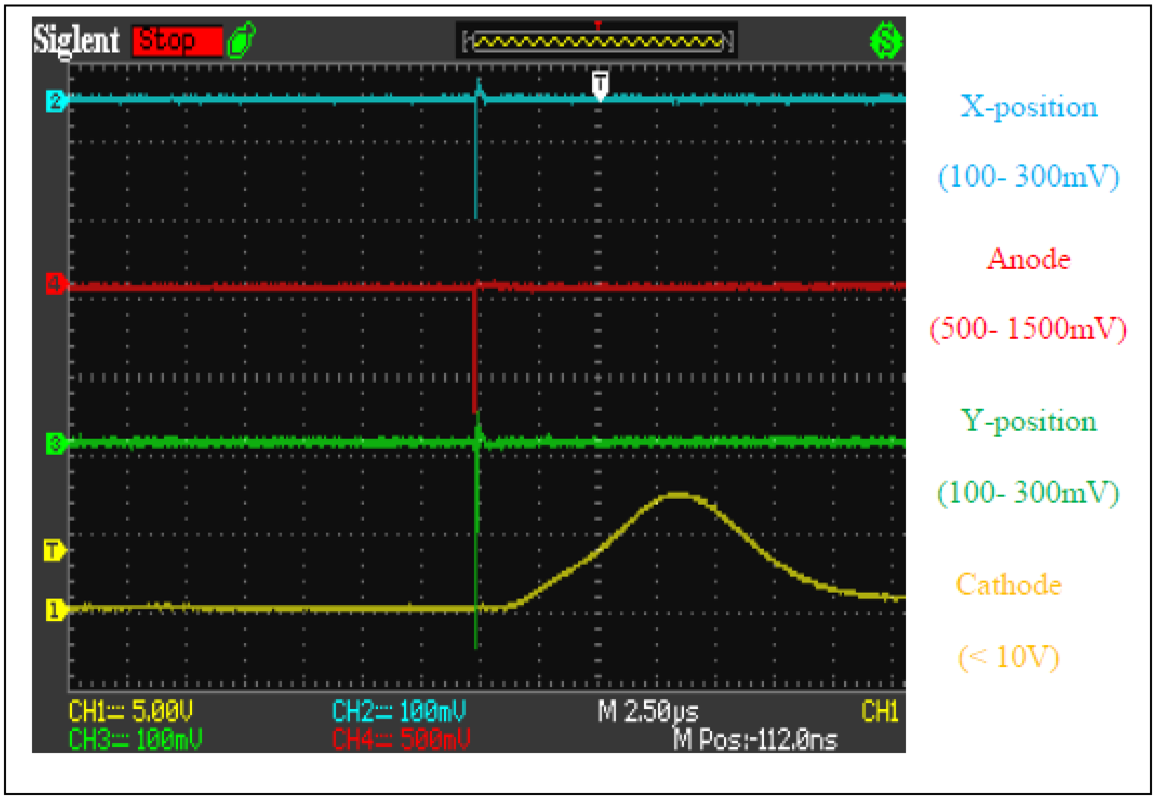
Position information: Rhombus delay line chips (model TZB 12-5); each chip has ten taps with delay of 2 ns/tap

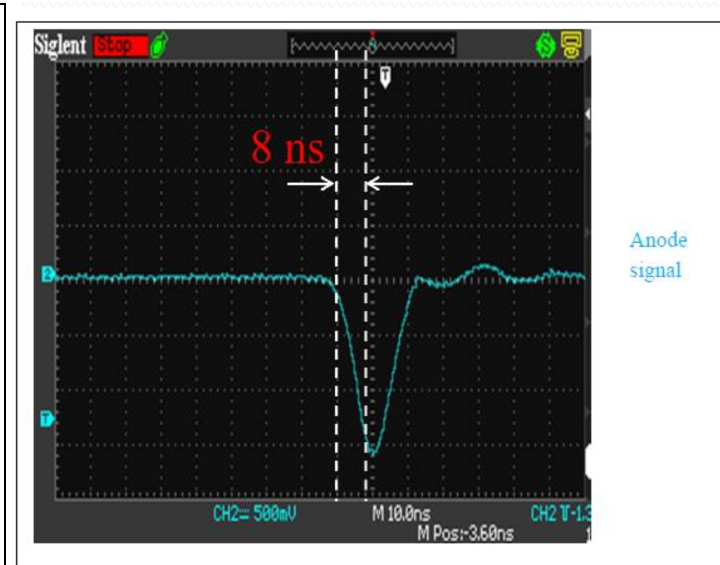




Detector response

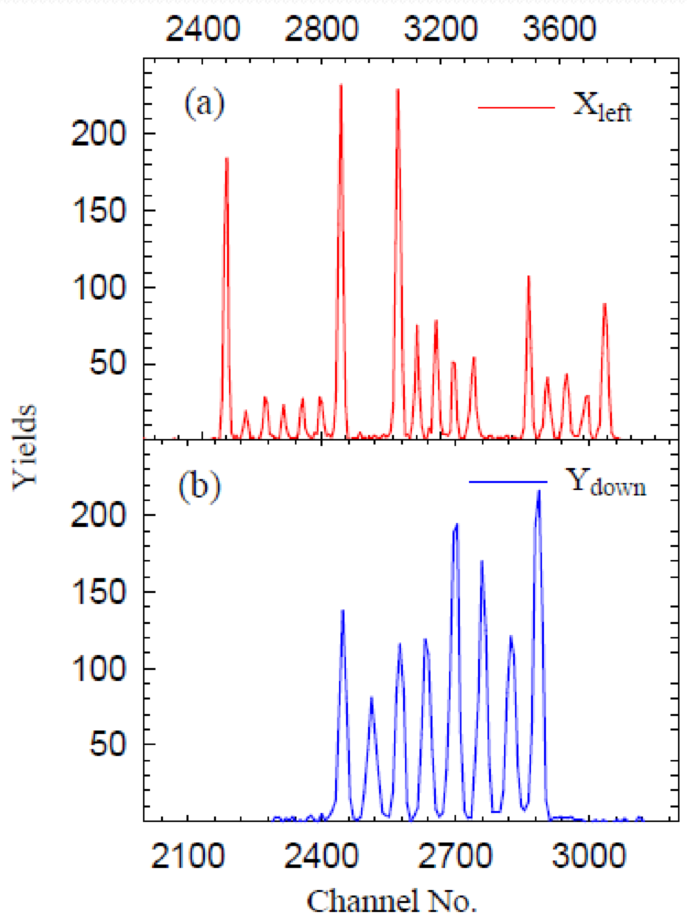
Voltages: Cathode -180 V, Anode +380 V; Gas: isobutane (~3 mbar pressure)

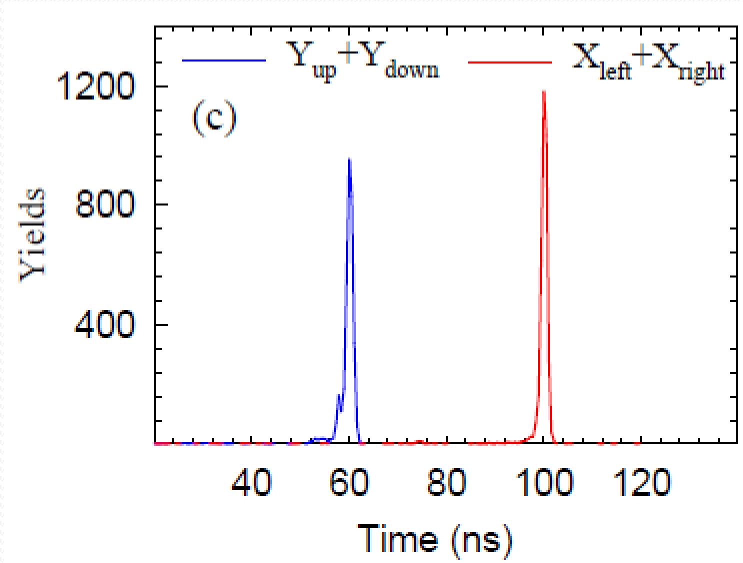


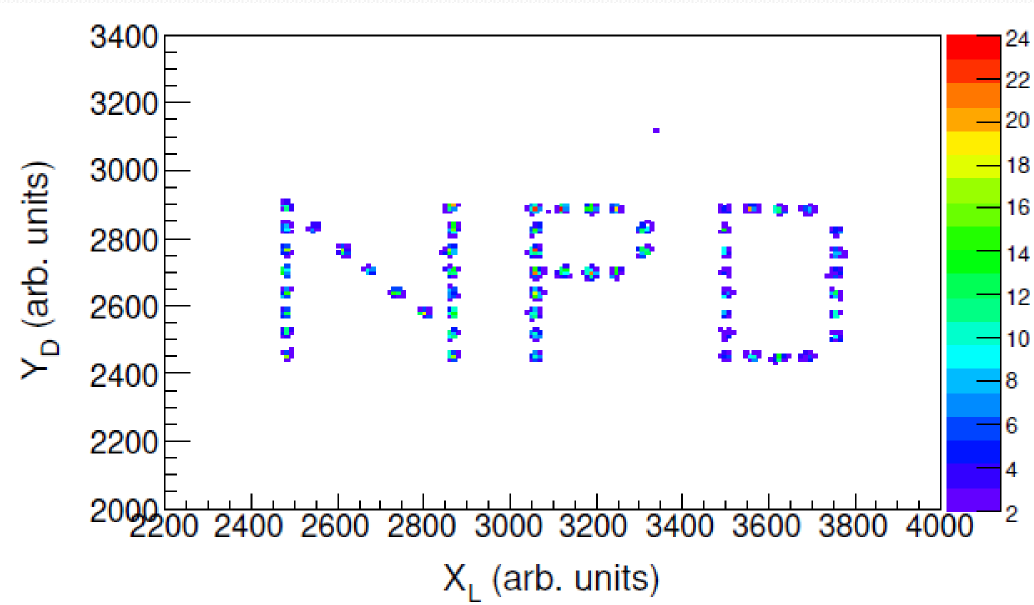


Rise time ~ 8 ns

Position

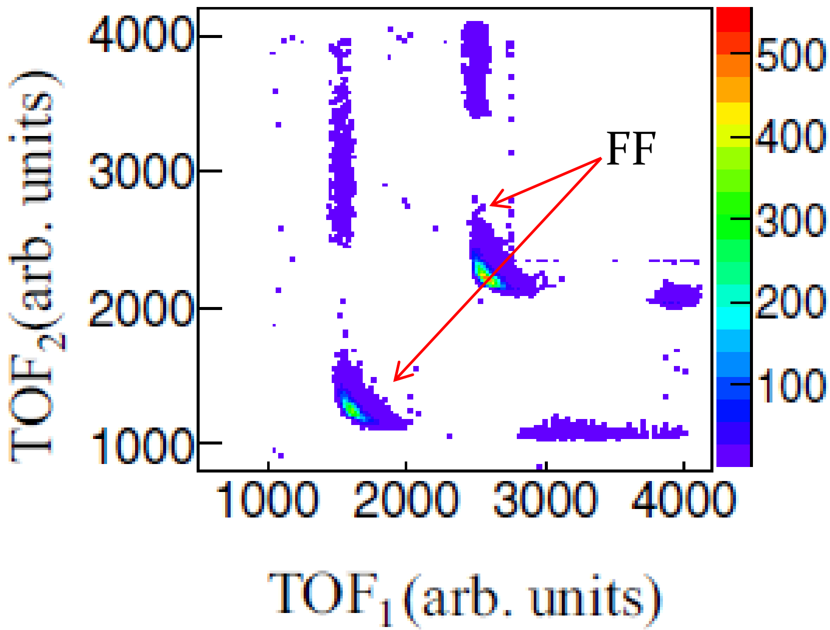


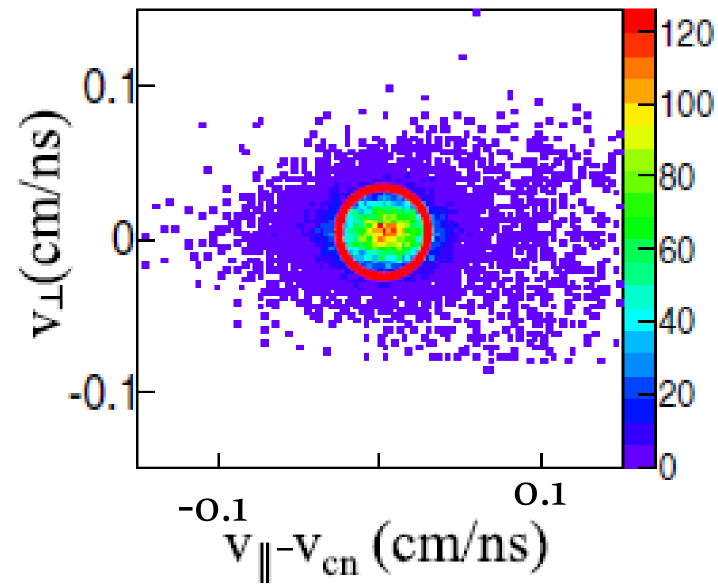




Position resolution: 1.4 mm (x)
1.6 mm (y)

Spectra





Measurables: time of flight, position of two fission fragments
Reconstructed: FF velocity, mass, TKE etc.

A.Pal et al. Phys. Rev. C (Letter) 104, L031602 (2021)
T.N. Nag,…, **A. Pal** et al. Phys. Rev. C 103, 034612 (2020)

Summary

- Array made of silicon strip detector telescopes and experiments using that array
- Neutron detector array in combination with silicon array used for the measurement of level density .
- MWPC detectors developed in-house and used in several experiments

Thanks

Micro-channel plate based detectors for fission measurement