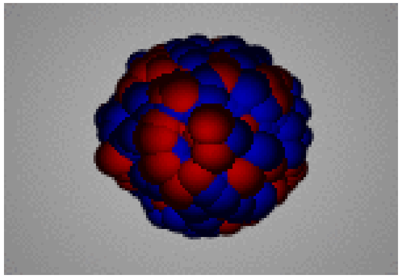

Giant Dipole Resonance with at very low temperatures and the critical behavior

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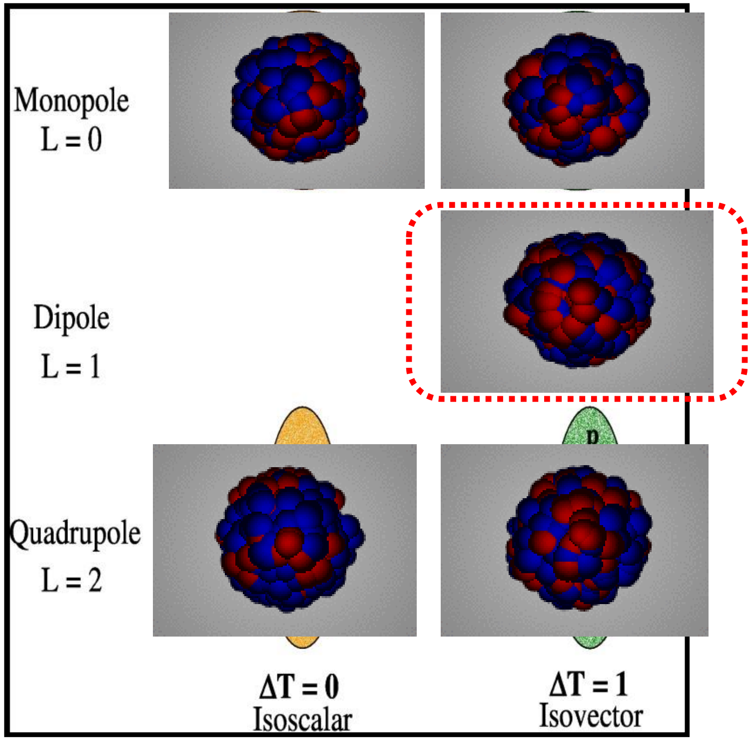
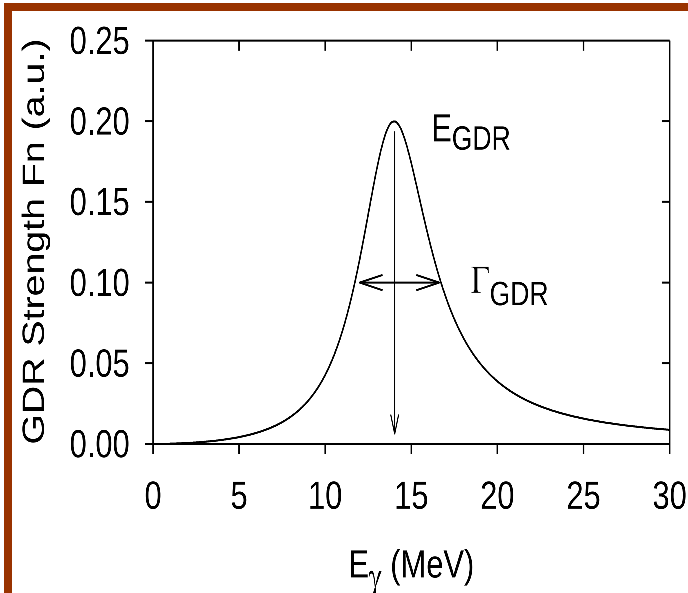
Giant Resonance : Collective modes of vibration of nucleus



Giant Dipole Resonance

$$F(E_\gamma) = \frac{E_\gamma^2 \Gamma^2_{GDR}}{(E^2_\gamma - E^2_{GDR})^2 + E_\gamma{}^2 \Gamma^2_{GDR}}$$

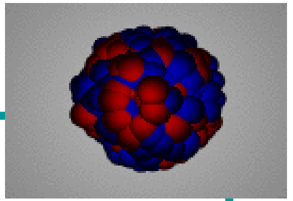


Centroid Energy : Inversely proportional to the linear dimension of the nucleus.

Strength Function: Gives an idea about the nuclear shape degrees of freedom.

Resonance Width : Related to the damping mechanism of the collective motion.

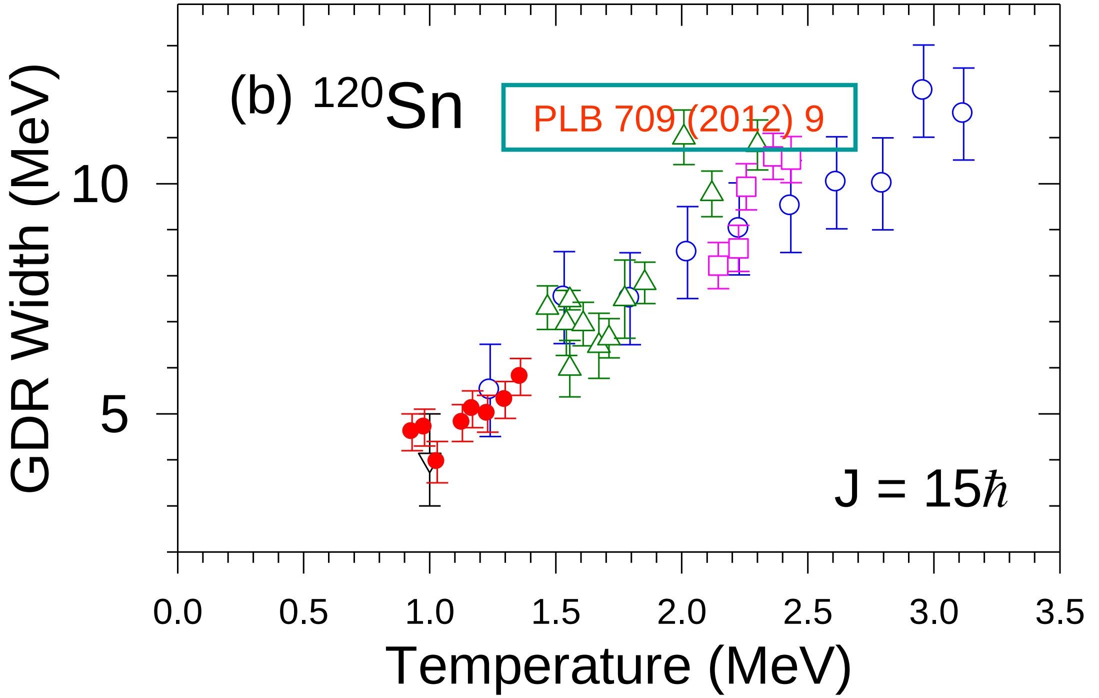
Evolution of GDR width as a function of temperature



Experimental observation

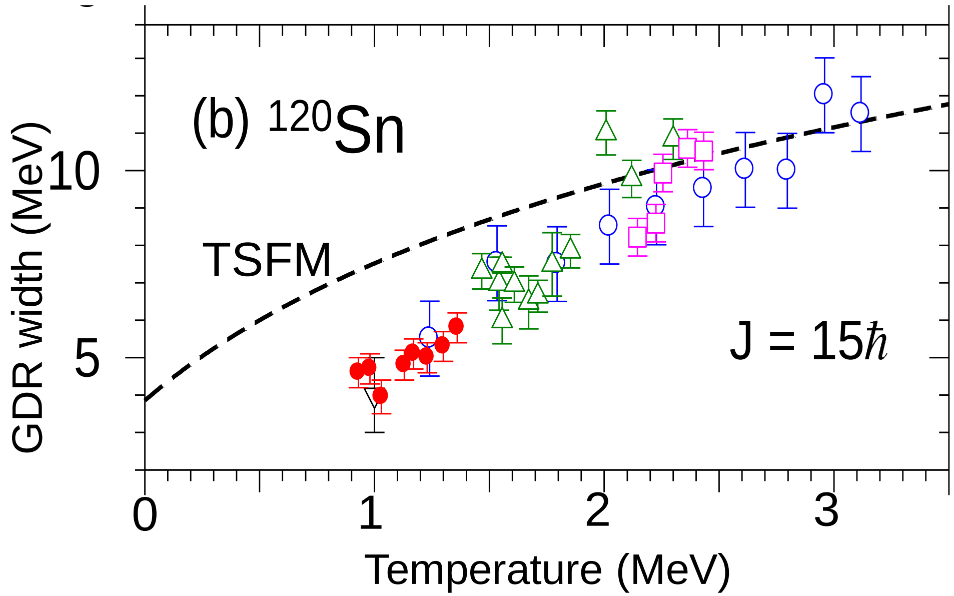
Mostly investigated Nucleus → ^{120}Sn

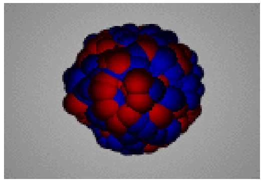
Experimental systematic shows→ GDR width increases monotonically with temperatures (typically 6-10 MeV for change in 'T' of 1.5-2.5 MeV)



Why GDR width increases with increase in temperature ???

Thermal Shape Fluctuation Model : (Δβ vs T)





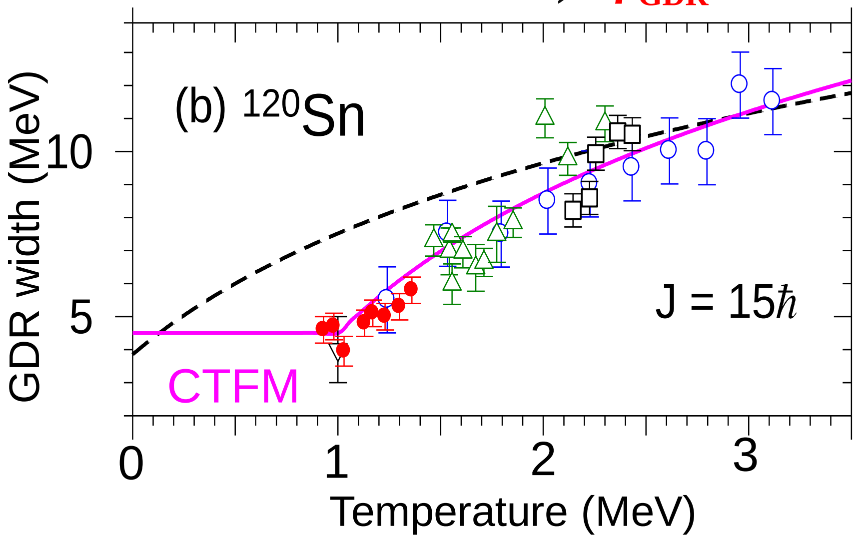
!! At low temperatures (T<1.5 MeV), the picture is not clear !!

Critical Temperature Fluctuation Model : Including an important physics point

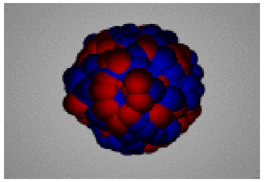
GDR vibration itself produce a quadrupole moment causing the nuclear shape to fluctuate even at T = 0 MeV (GDR vibration induced intrinsic fluctuation) : β_{GDR}

Critical behavior :

- At low T : $\beta_{GDR} > \Delta\beta$
- **β_{GDR} → Independent of T**
- **$\Delta\beta$ → Increases with temperature**
- **Competition between β_{GDR} and $\Delta\beta$**



The effect of thermal fluctuation on GDR width will appear only when it becomes greater than the intrinsic fluctuation.



MY WORK:

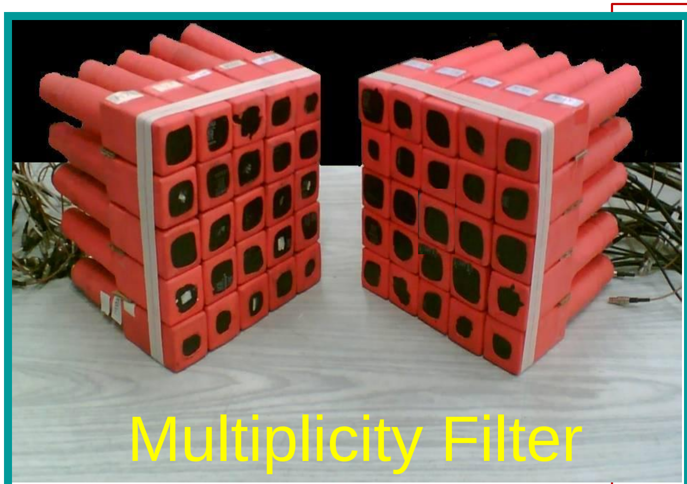
- Study of GDR width at very low temperatures (T < 1.5 MeV).

- Verify the critical behavior : The number of GDR width measurements at low T < 1 MeV are inadequate to conclude that GDR width remains same at below the critical point.

- Mass dependence of the critical behavior.

We probed A=100 mass region at very low temperature (T ~ 0.8 to 1.5 MeV) to understand exact nature of the damping mechanism inside the nucleus.

Experimental Details



Projectile : ^{4}He

Target : ^{93}Nb

E_{lab} : 28, 35, 42, 50 MeV

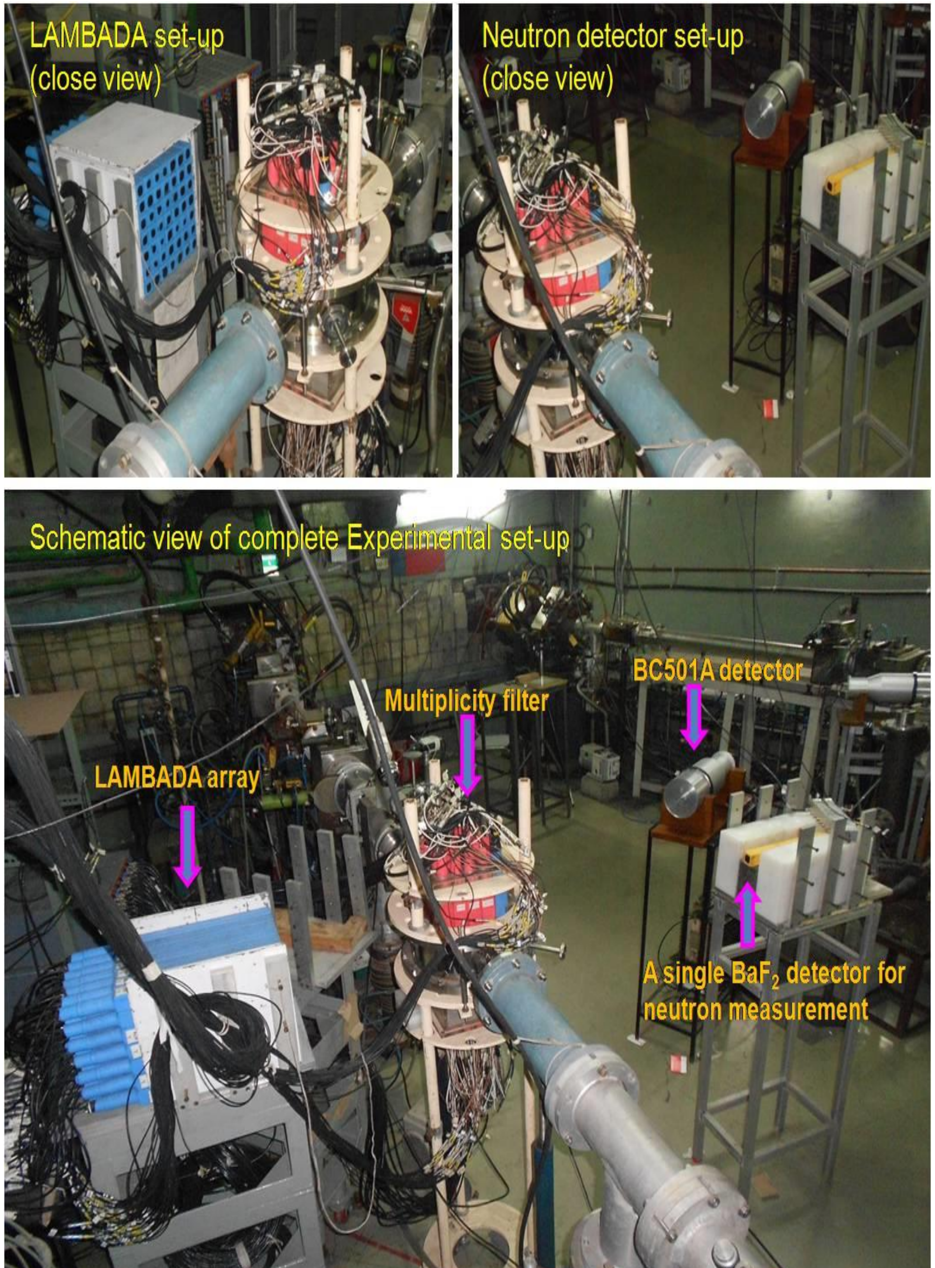
$^{4}He + ^{93}Nb \rightarrow ^{97}Tc^{*}$

E* : 29.3, 36.0, 43.0, 50.4 MeV

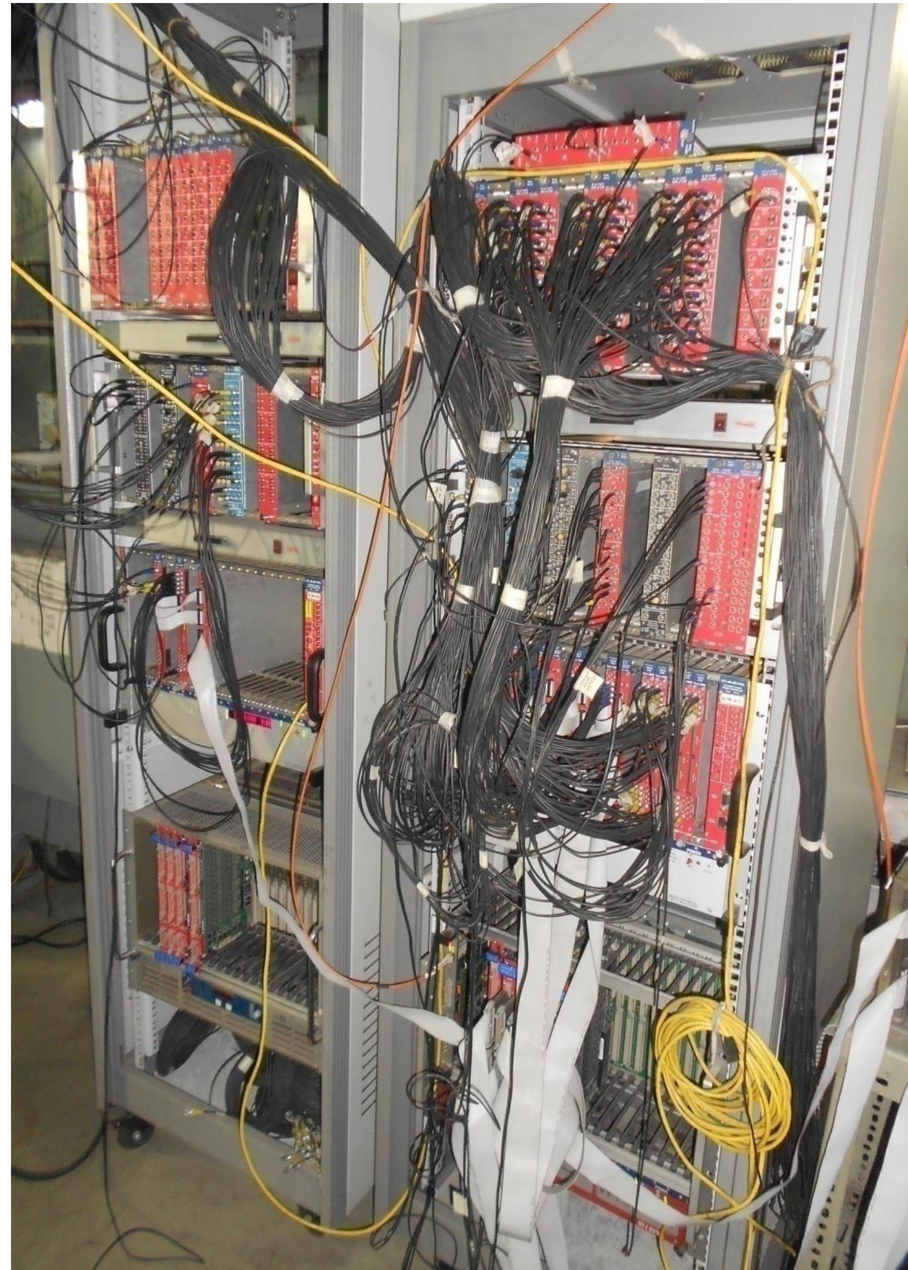
J = 10 – 20 h

High energy gamma photons are the main tools to study GDR characteristics → Need a detector system with high detection efficiency and very good time resolution.

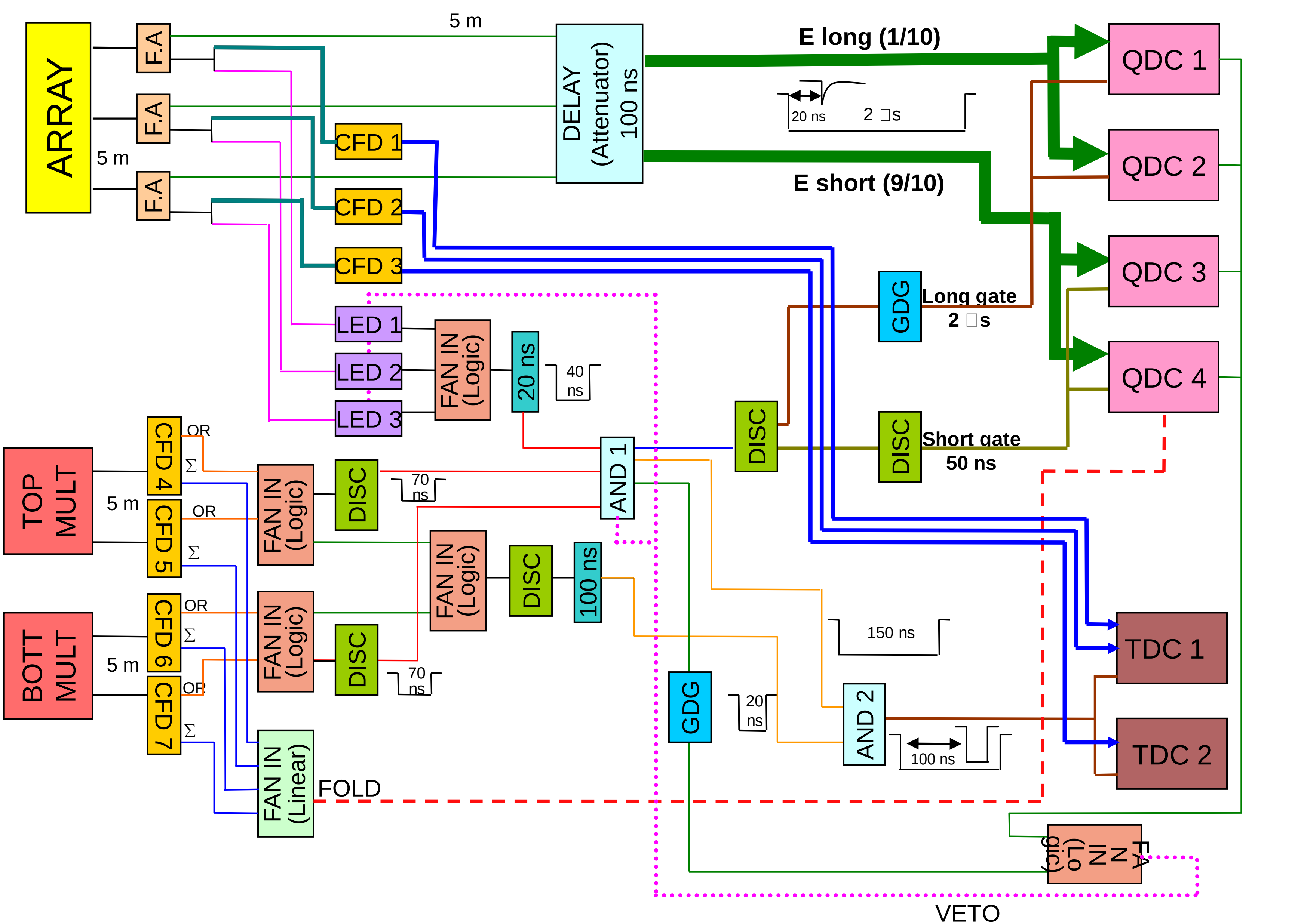
Experimental Setup



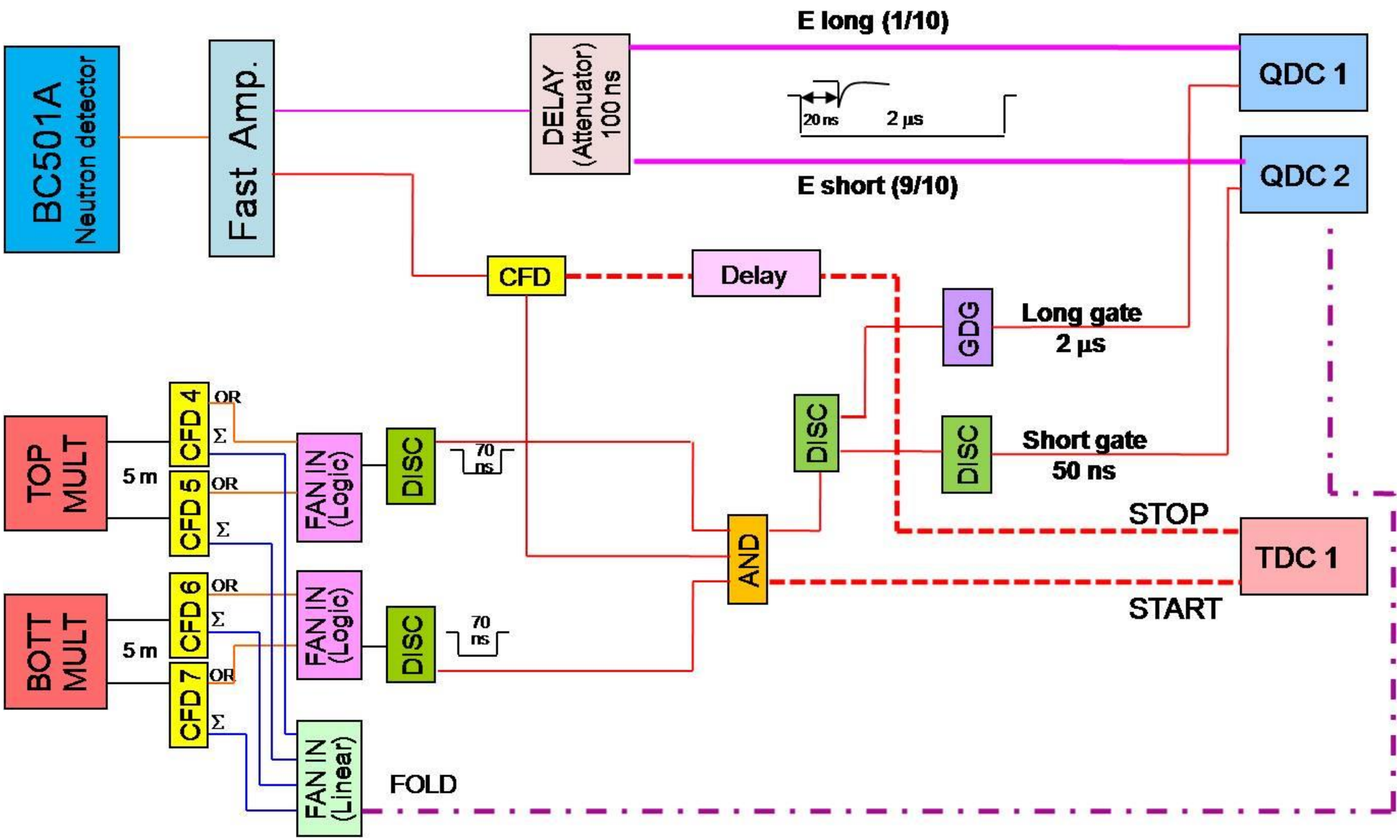
Electronics Setup



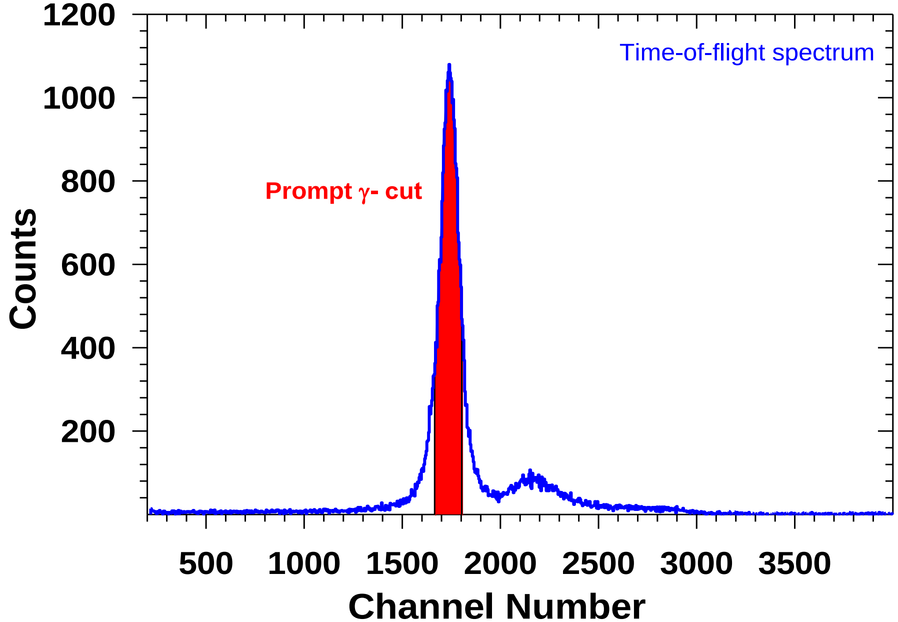
Schematic Electronics Circuit Diagram for LAMBDA and Multiplicity



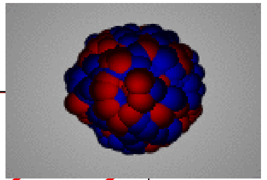
Schematic Electronics Circuit Diagram for BC501A

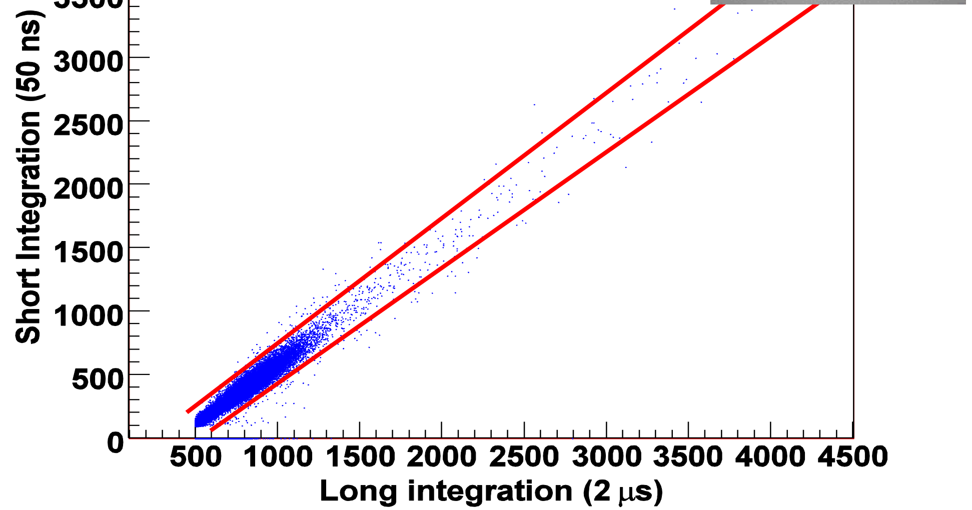


TOF Spectrum

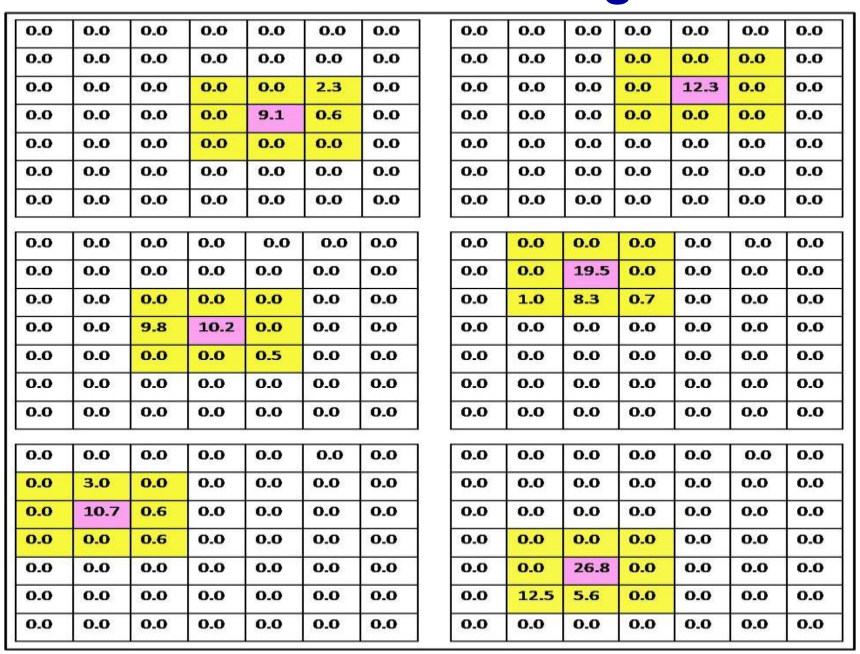


PSD spectrum

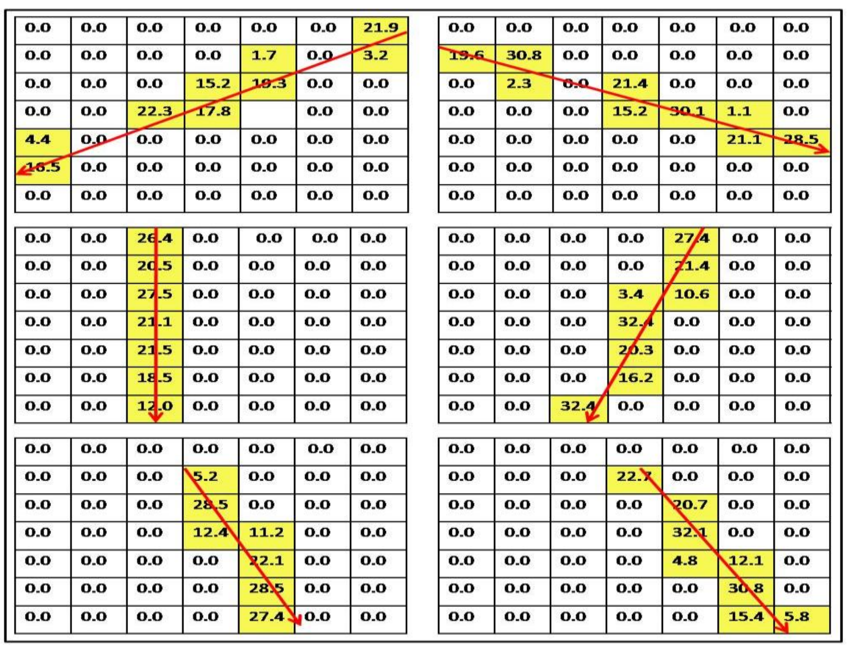




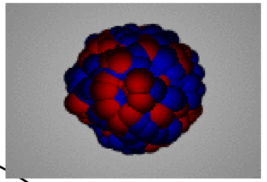
cluster summing

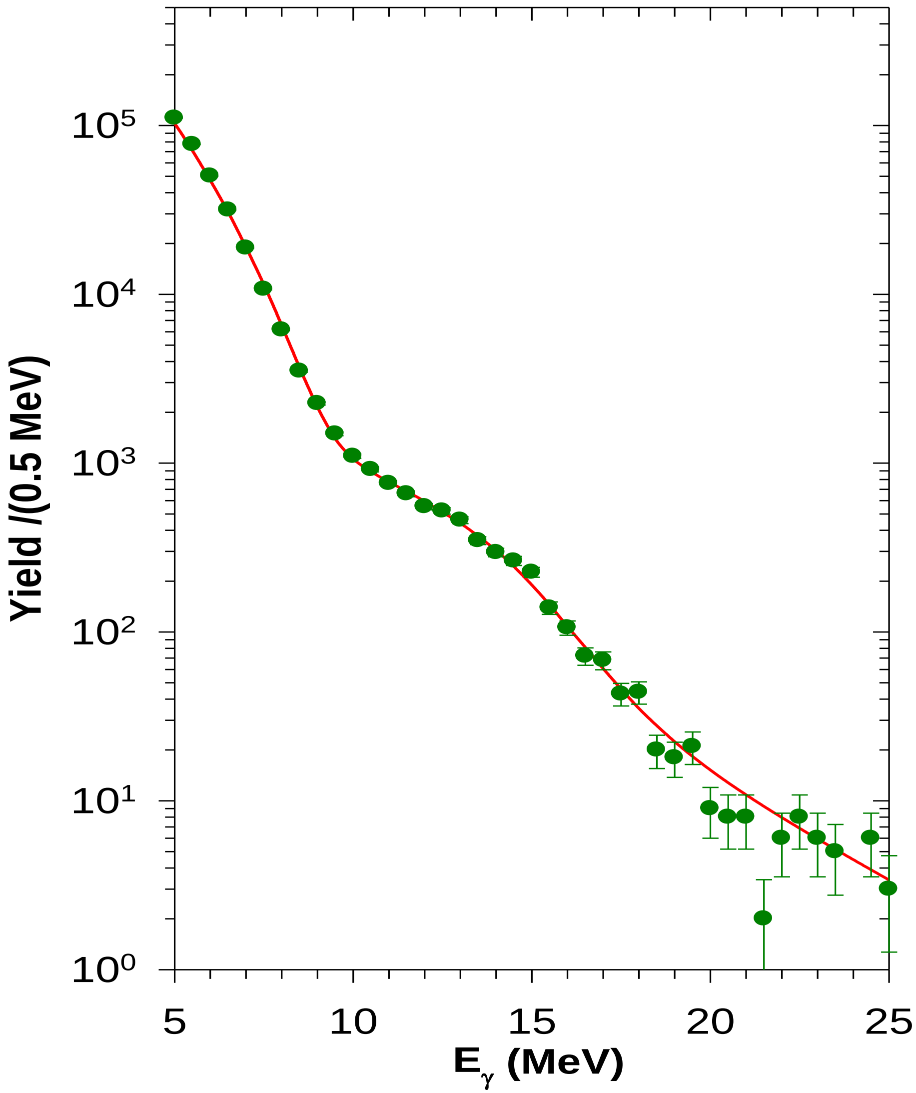


Cosmic rejection



Extraction of GDR parameters



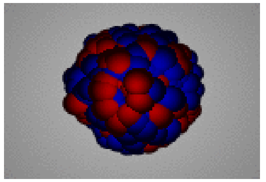


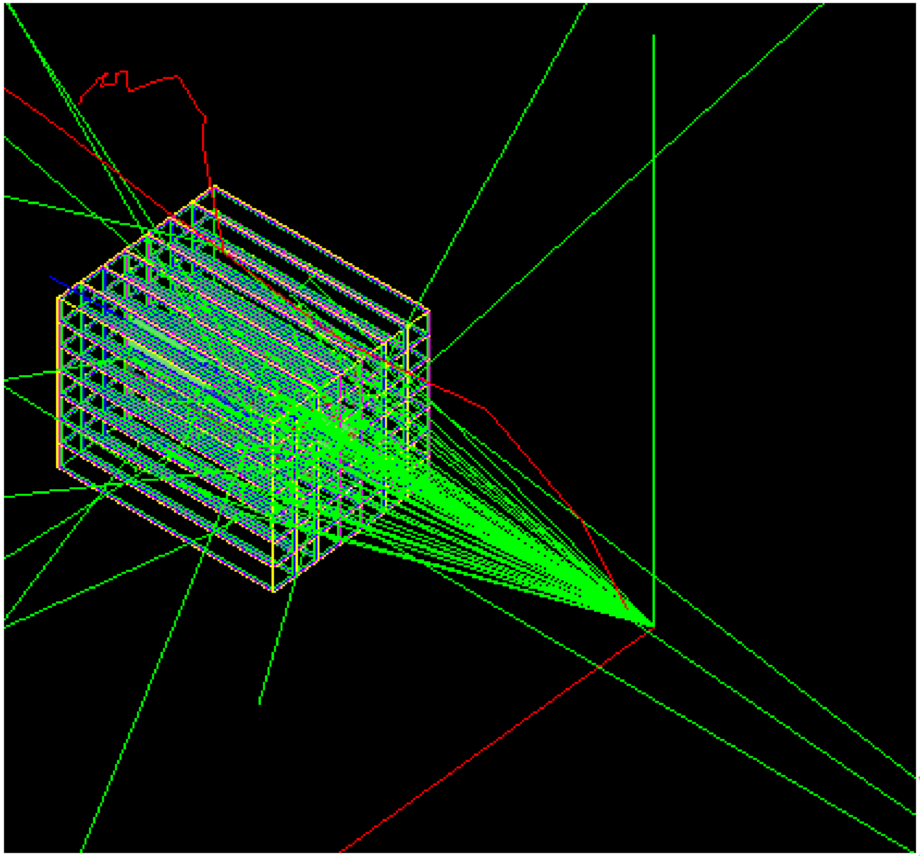
Experimental data compared with a theoretical model (CASCADE) to extract the GDR parameter

!! The following steps are essential !!

- **Detector Response Function**
- **Measuring angular momentum distribution**
- **Measuring Nuclear Level Density parameter**

(1) Detector simulation studies using GEANT4





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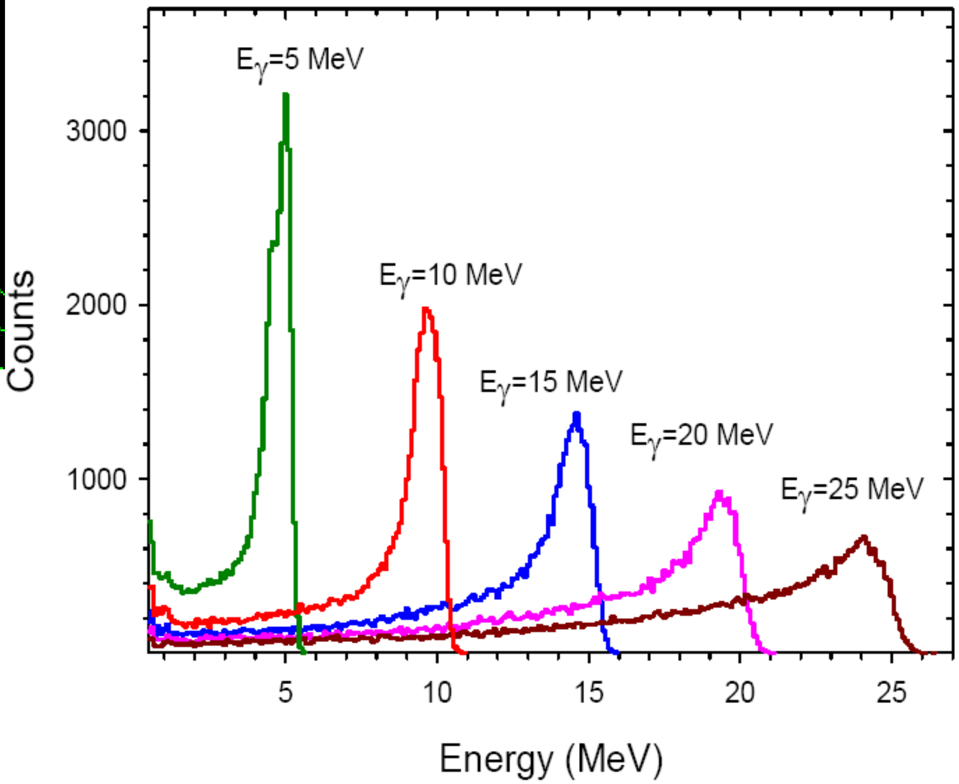
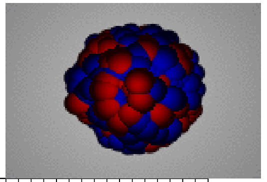
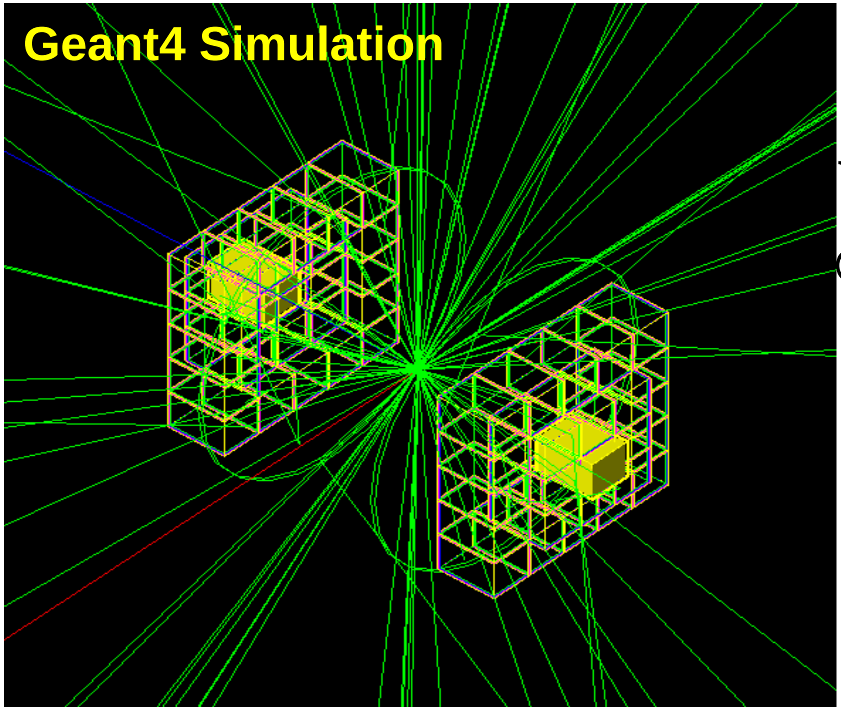
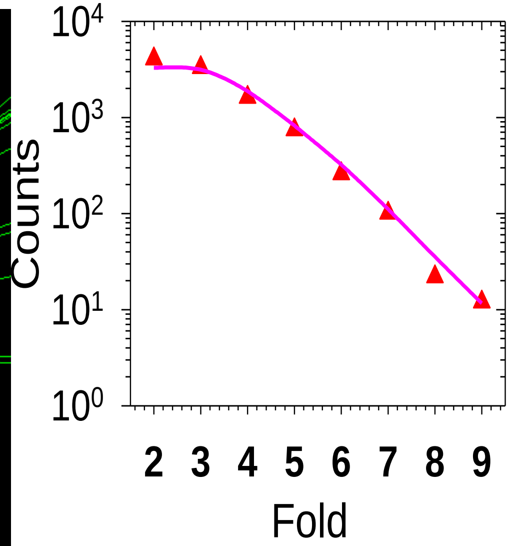
Detector response function must be folded with CASCADE calculation. Only after that it can be compared with experimental spectrum

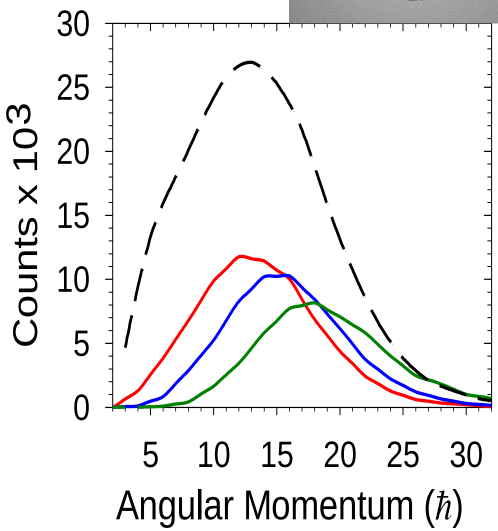


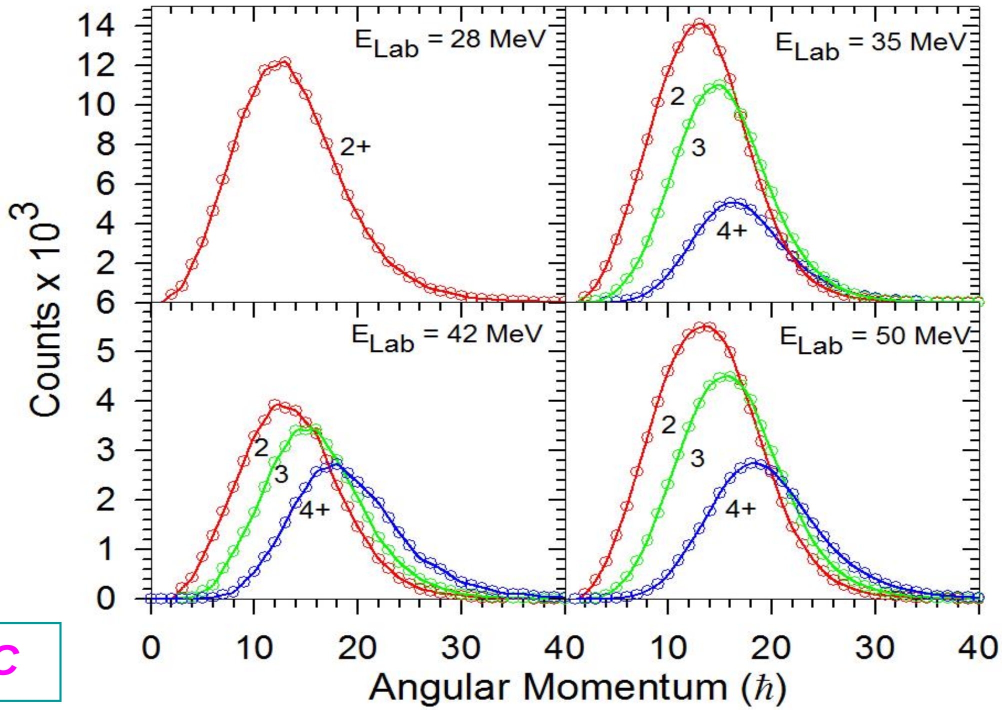
(2) Mapping of experimental Fold to Angular Momentum space with a very realistic technique











Very essential

- ❑ To determine average angular momentum
- ❑ To determine average rotational energy
- ❑ To construct initial population matrix for CASCADE calculation

Incident distribution :

$$P(M_\gamma) = \frac{2M_\gamma + 1}{1 + \exp\left[\left(M_\gamma - M_{\max}\right)/\delta m\right]}$$

$$J = 2M_\gamma + C$$

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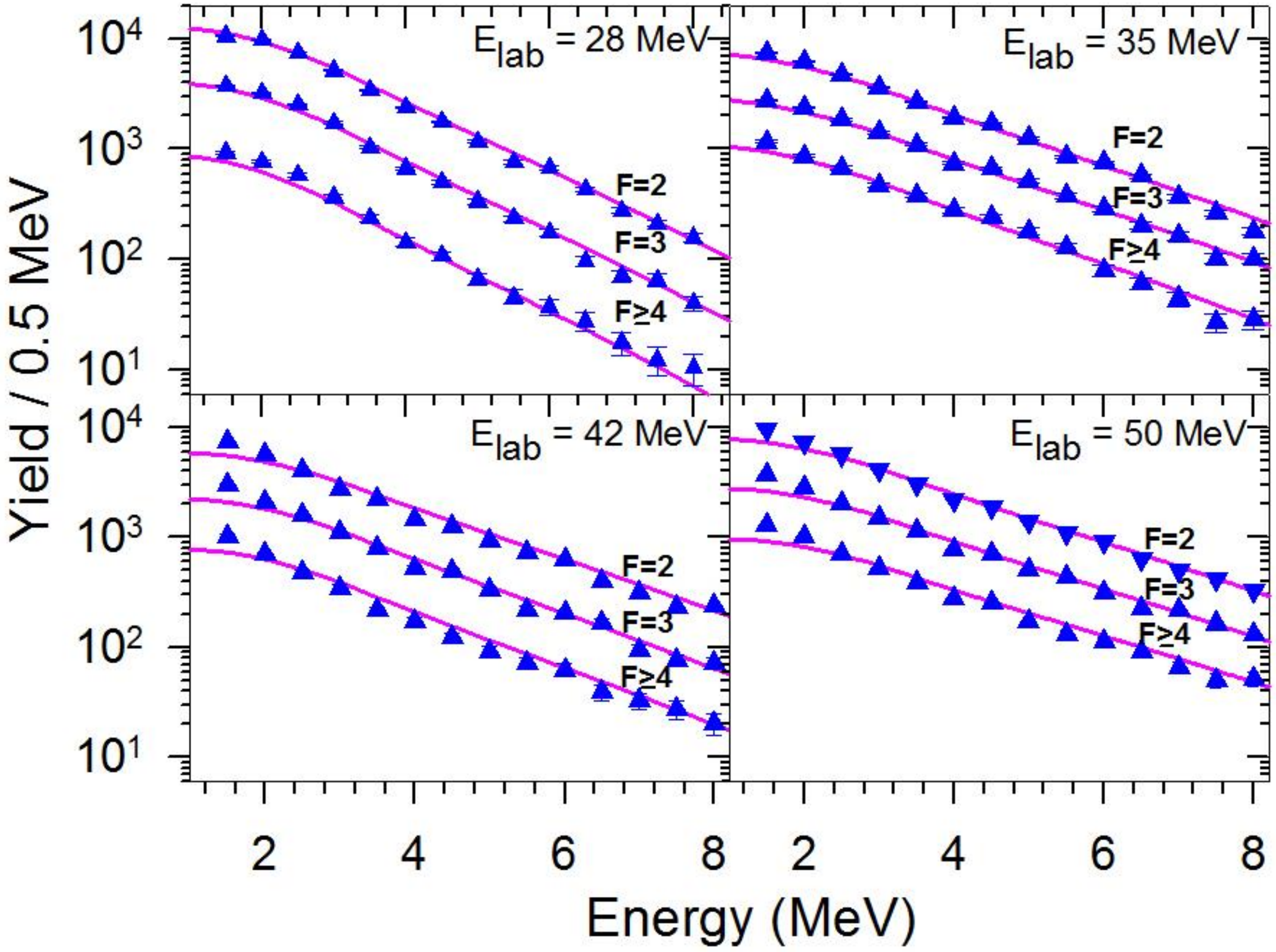
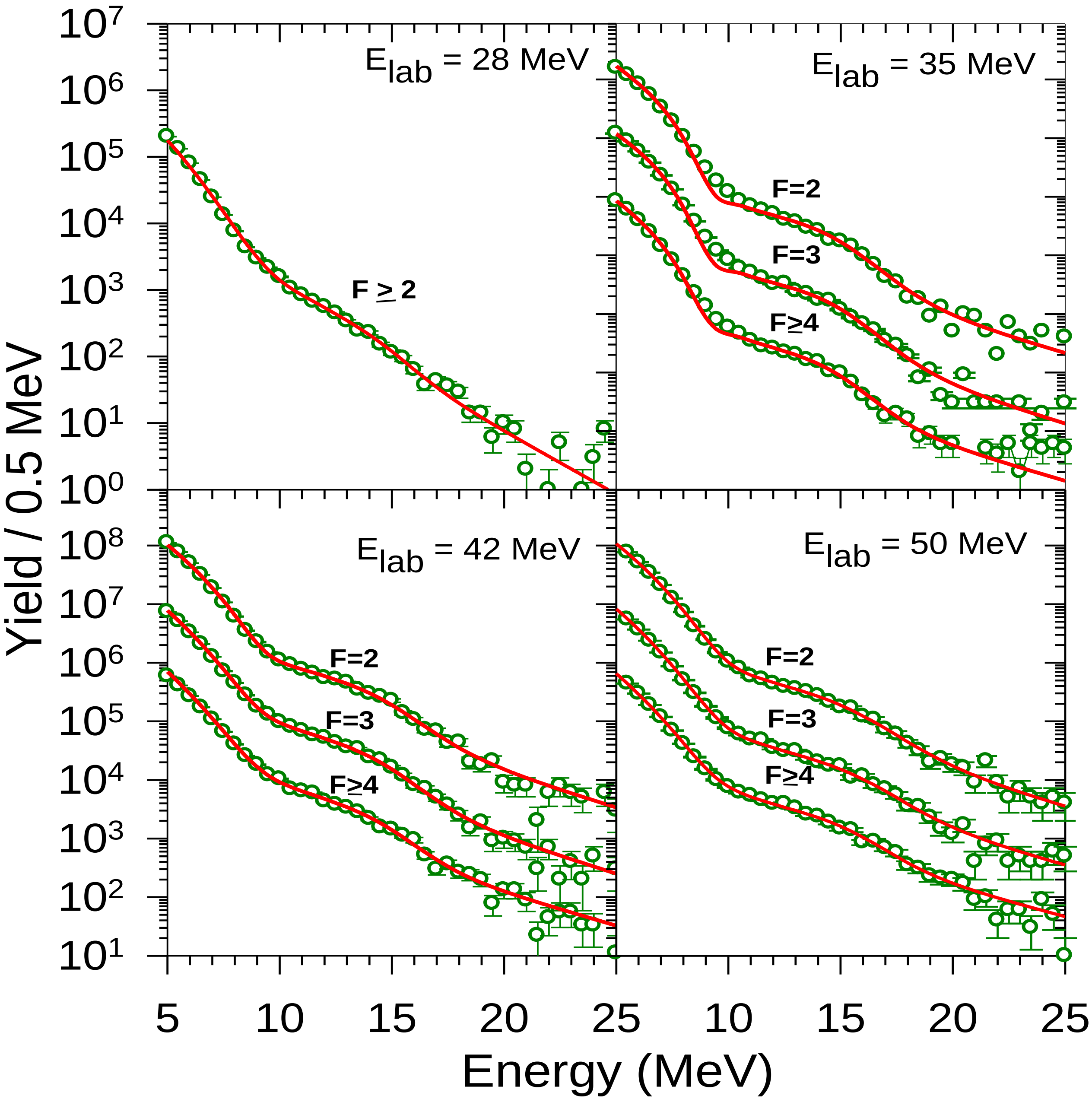
(3) Nuclear level density parameter from neutron evaporation spectrum

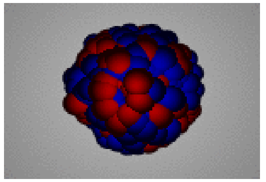
Crucial input for CASCADE Calculations & important for the proper estimation of nuclear temperature



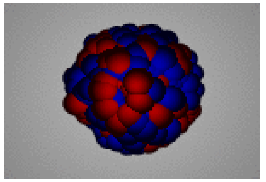
Neutron detector (BC501A) is generally used to measure the neutron energy spectrum by TOF technique

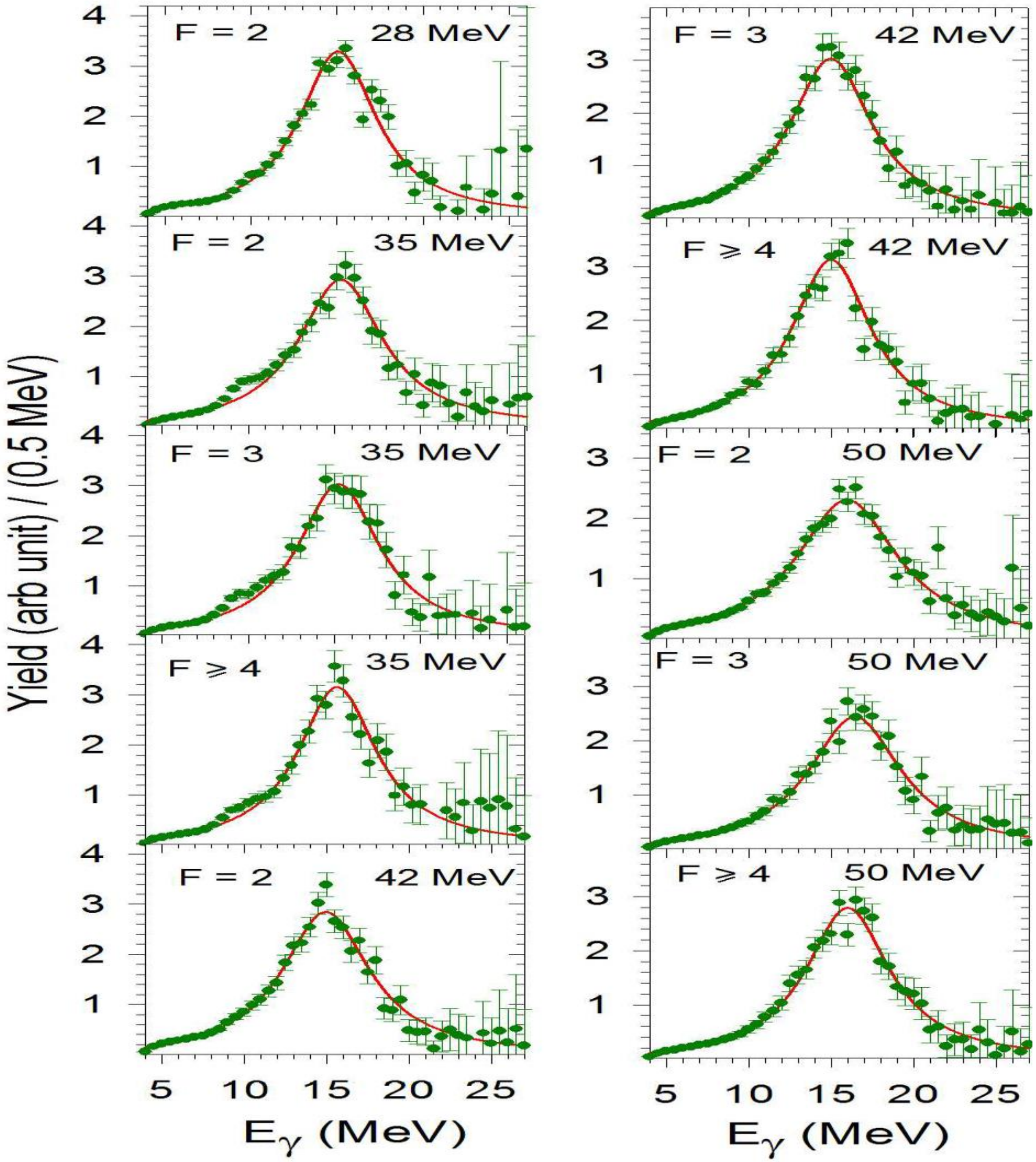
High energy gamma spectra along with CASCADE calculation



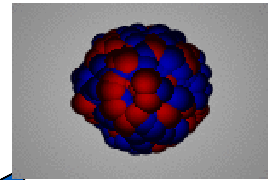


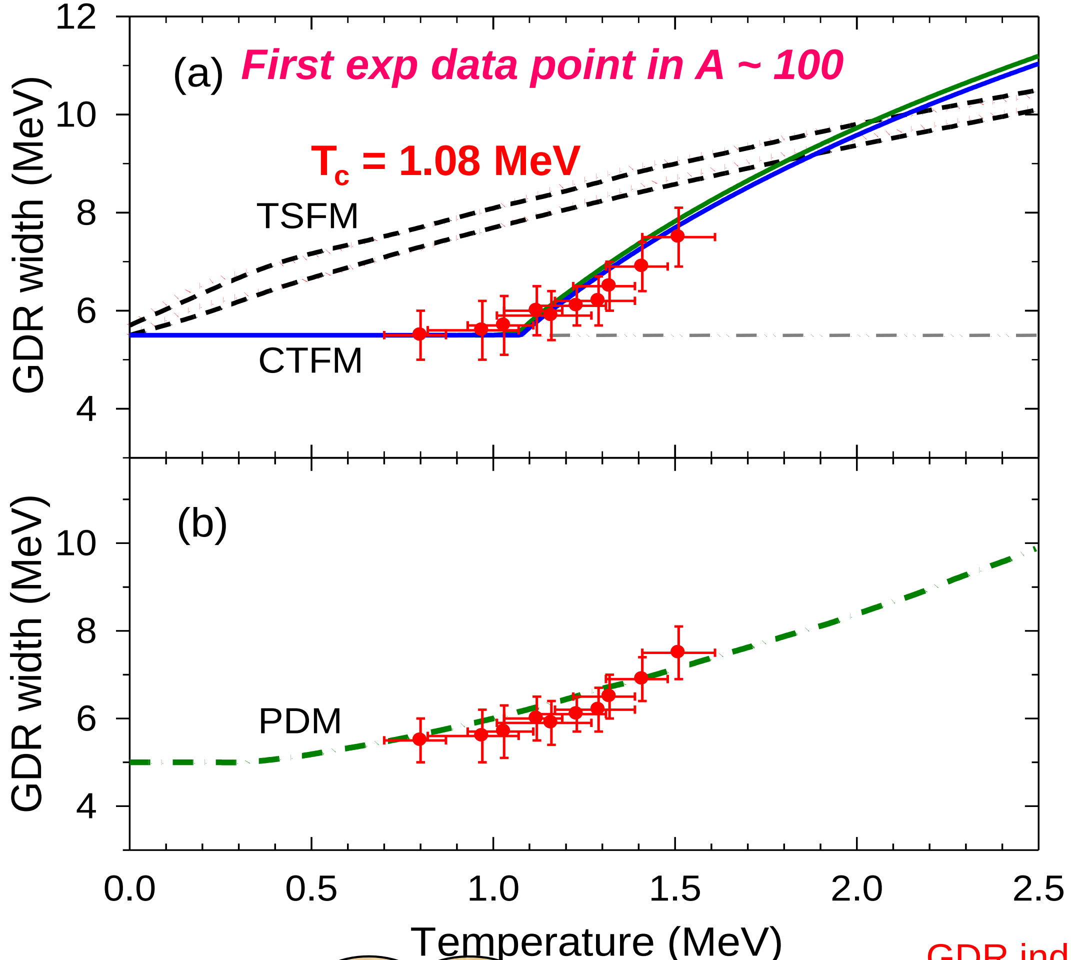
Final GDR spectra along with CASCADE calculation





Results and Discussion





TSFM (dotted line) over predicts the data ???

Exp data follows the CTFM and PDM predictions (continuous line) !!!

GDR induced intrinsic fluctuation could play a decisive role in describing the increase of GDR width as a function of T.

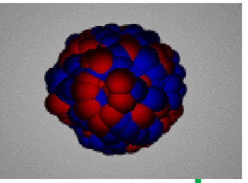
First experimental data at below and above the critical temperature

Intrinsic fluctuation due to GDR vibration should be incorporated in TSFM (macroscopically) to explain the behavior of GDR width at low T.

PDM : PRC 86 (2012) 044333

Balaram Dey et al., Physics Letter B 731 (2014) 92

Summary and conclusion



❑ A systematic study of the Giant Dipole Resonance width at very low temperature (T = 0.8 – 1.5 MeV) in A ~ 100 mass region.

❑ GDR widths have been compared with different theoretical calculations (TSFM, CTFM and PDM).

❑ TSFM fails to explain the experimental data where as CTFM and PDM calculation nicely matches with the experimental data.

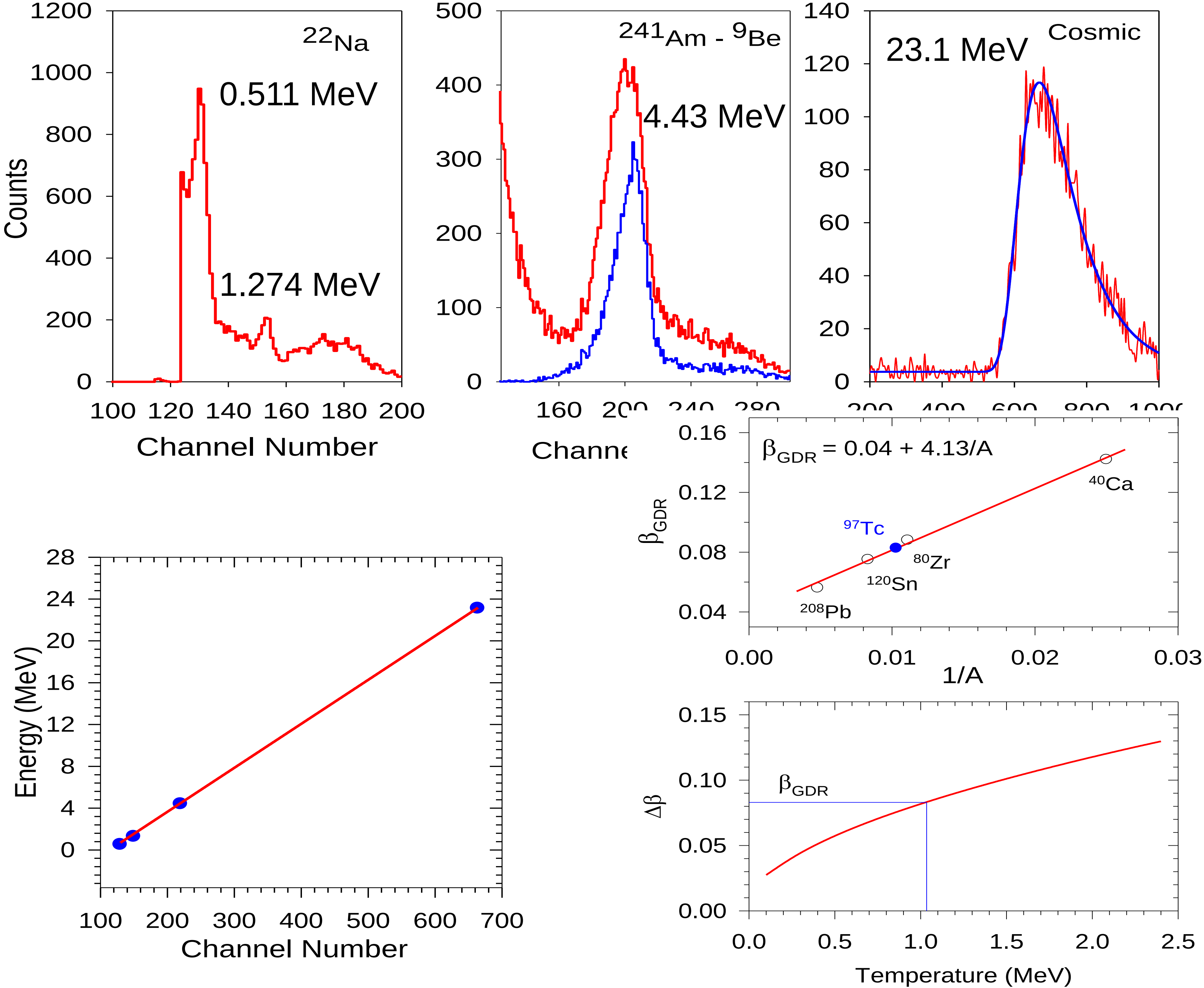
❑ GDR induced intrinsic fluctuation plays an important role in describing the evolution GDR width as a function of temperature

❑ First experimental data at below and above the critical temperature.

❑ Microscopic PDM (with pairing fluctuation) also explain the data very well.

❑ It would also be interesting if the pairing fluctuation can be included in the TSFM calculation.

GDR group at VECC, kolkata, India



22Na
0.511 MeV
1.274 MeV
Counts
Channel Number
241Am - 9Be
4.43 MeV
Cosmic
23.1 MeV
βGDR = 0.04 + 4.13/A
40Ca
97Tc
80Zr
120Sn
208Pb
βGDR
1/A
Energy (MeV)
Channel Number
Δβ
βGDR
Temperature (MeV)

Detector properties

- **The time resolution of**

  35cm BaF2 detector = 960 ps

  5cm BaF2 detector = 460 ps

- **The energy resolution of**

  35cm BaF2 detector = 16/
  thus 20% at 0.662 MeV

  5cm BaF2 detector = 12%
  MeV

- **The intrinsic efficiency o**

  35cm BaF2 detector = 95
  0.662 MeV, 93 % 10 MeV.

  5cm BaF2 detector = 80 %
  MeV, 73% at 1 MeV.

- **The photopeak efficiency**
  cluster summing techniq

  35cm BaF2 detector = ~ 5
  energy range 10MeV

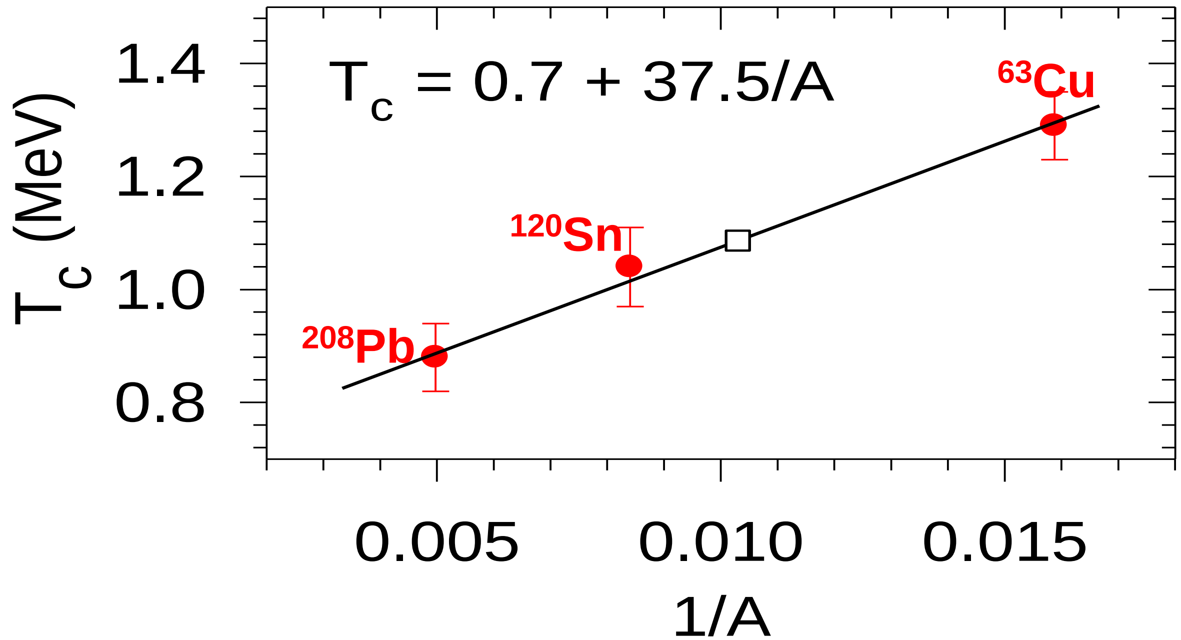
- **The photopeak efficiency of cluster summing technique(7x7)**

  35cm BaF2 detector = ~ 70 % from
  energy range 10 MeV

What is the advantage of BaF2 detector over NaI detector?

- BaF2 are non-hygroscopic where as NaI is highly hygroscopic.

- NaI detectors cannot be used



for high energy detection.

- BaF2 has high Z (56) than NaI(53) which is required for high energy gamma

  detection. Also BaF2 has low capture cross section for thermal neutrons due to