GDR Studies in $^{28}Si + ^{124}Sn$ at $E^{*}(^{152}Gd) \sim 71$ MeV

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Motivation

Giant Dipole Resonance

A collective dipole oscillation between neutrons and protons

GDR built on excited states of nuclei is a useful probe to study the properties of hot and rotating nuclei.

GDR Centroid Energy (E_{GDR}) and Width (Γ_{GDR})

$\Downarrow$

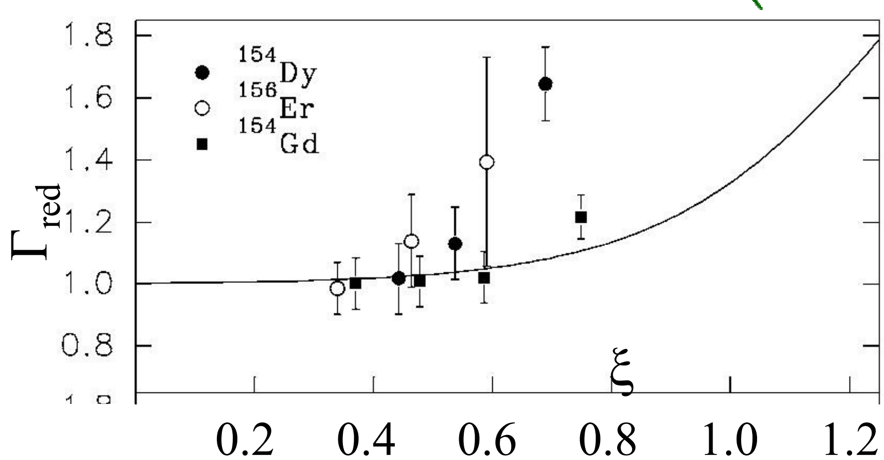
Evolution of nuclear properties as a function of temperature (T) and angular momentum (J_{CN})

Motivation

Kusnezov *et al*. PRL, 81, (1998), 542

$$\xi = J_{CN}/A^{5/6} \quad ; \Gamma_{red} = [\Gamma_{GDR}(T,J_{CN}) / \Gamma(T,0)]^{\{(T+3)/4\}}$$

$$\Gamma(T, J_{CN} = 0, A) = \left(6.45 - \frac{A}{100}\right) \ln\left(1 + \frac{T}{T_0}\right) + \Gamma_0(A)$$



"Universal behavior of GDR width"

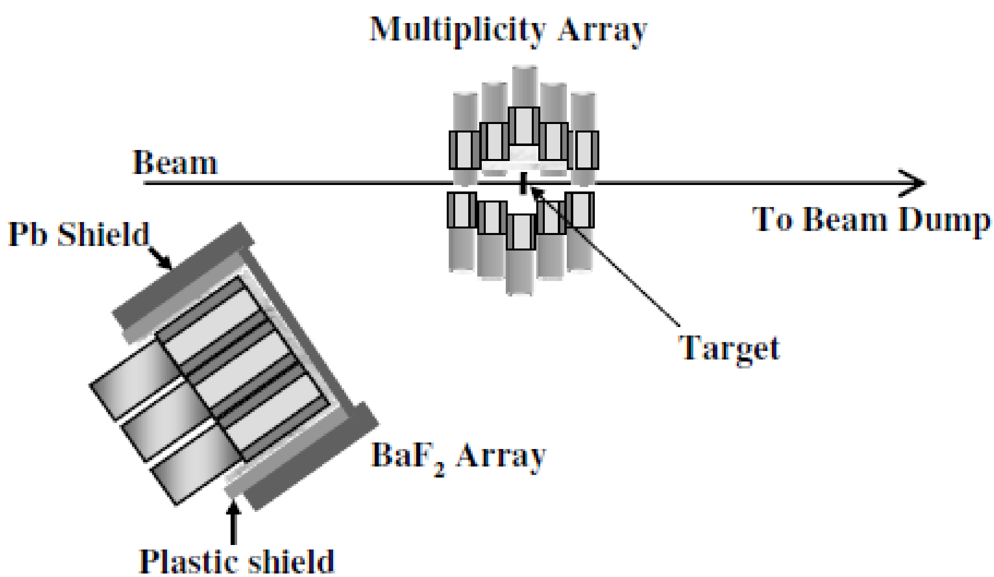
Differences observed in A ~150 region

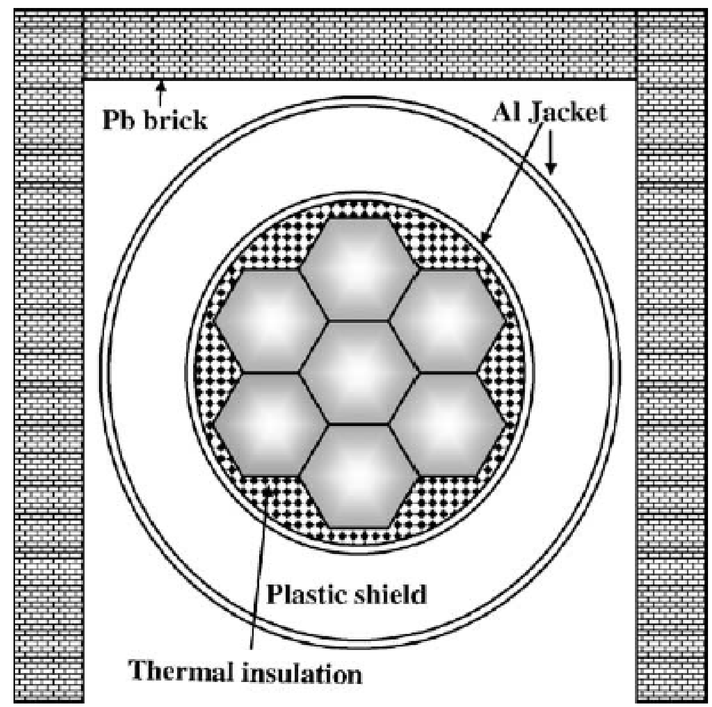
- Variation of Γ_{GDR} in ^{152}Gd ($^{28}Si+^{124}Sn$) is studied at E^*~87 and 116 MeV (NPA **770** (2006) 126; J. Phys. G **37** (2010) 055105)
  – Discrepancy observed in the Γ_0 at two energies.
  – Γ_{GDR} at higher T explained with collisional damping + LDM contribution.

➢ Present work: Γ_{GDR} variation at lower T and J_{CN} for the same system at E^* ~ 71 MeV; $\langle J_{CN}\rangle$ ~ 24ħ and J_{max} ~ 48ħ

Experimental Details

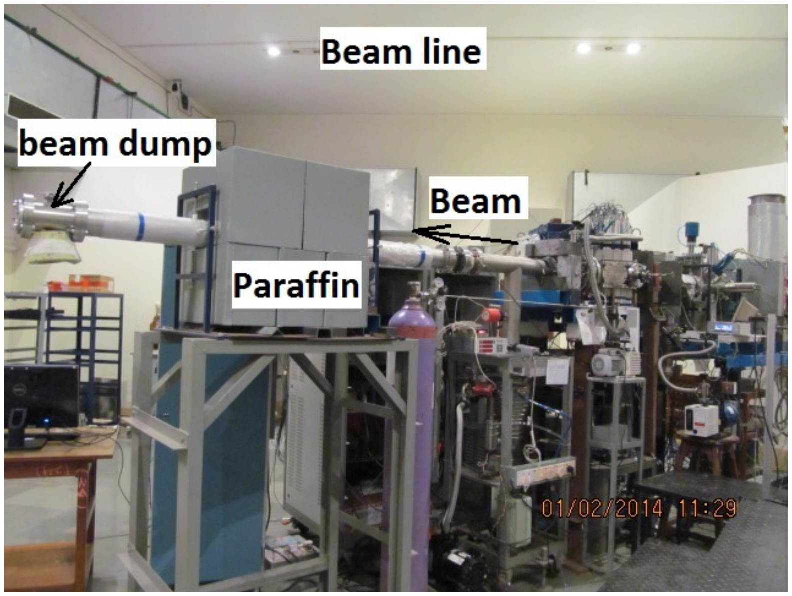
- 2.0 mg/cm^2 enriched (99.90%) ^{124}Sn target was bombarded with 135 MeV ^{28}Si pulsed-beam from Pelletron Linac Facility at TIFR.
- Data was taken for 0.1 pmC of incident beam particles.

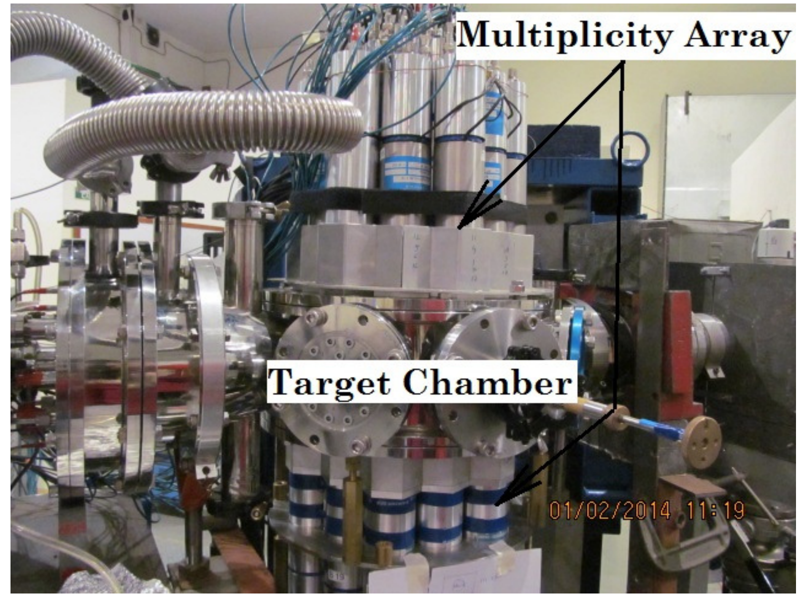


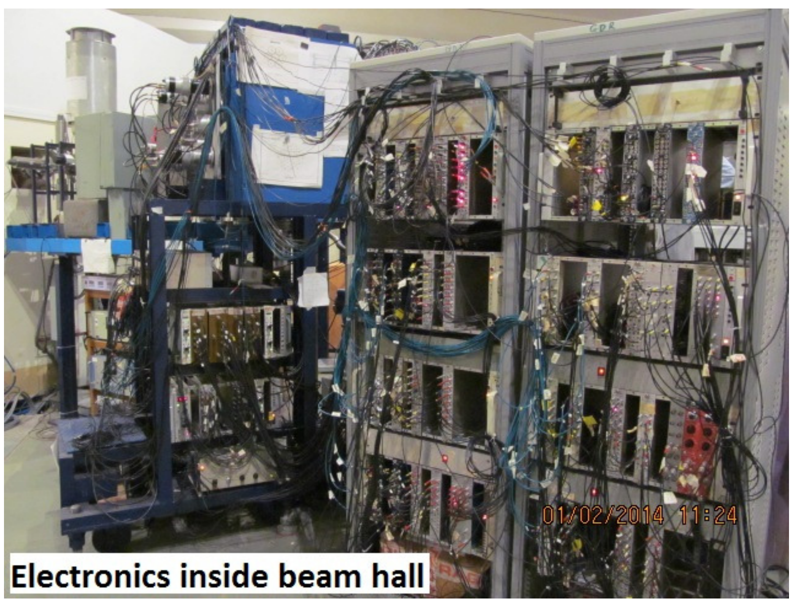


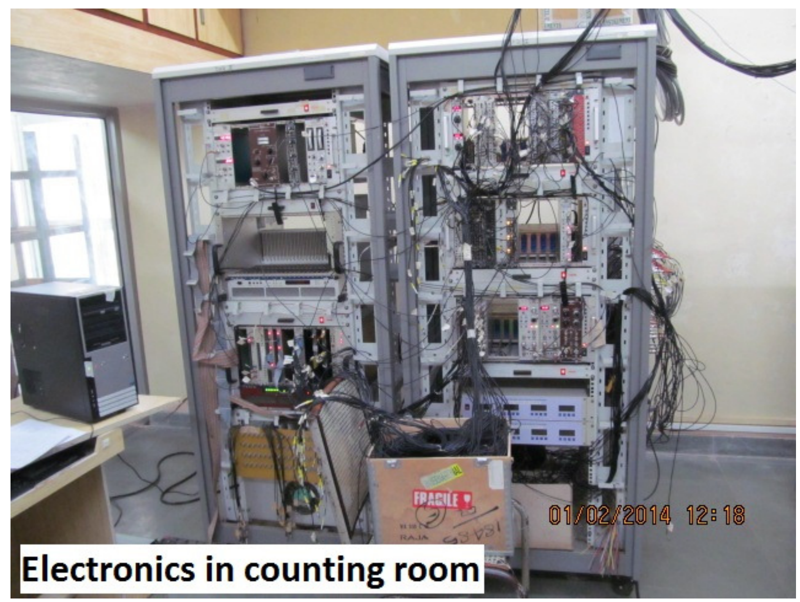
cosmic background reduction using plastic veto ~94%

Setup pictures

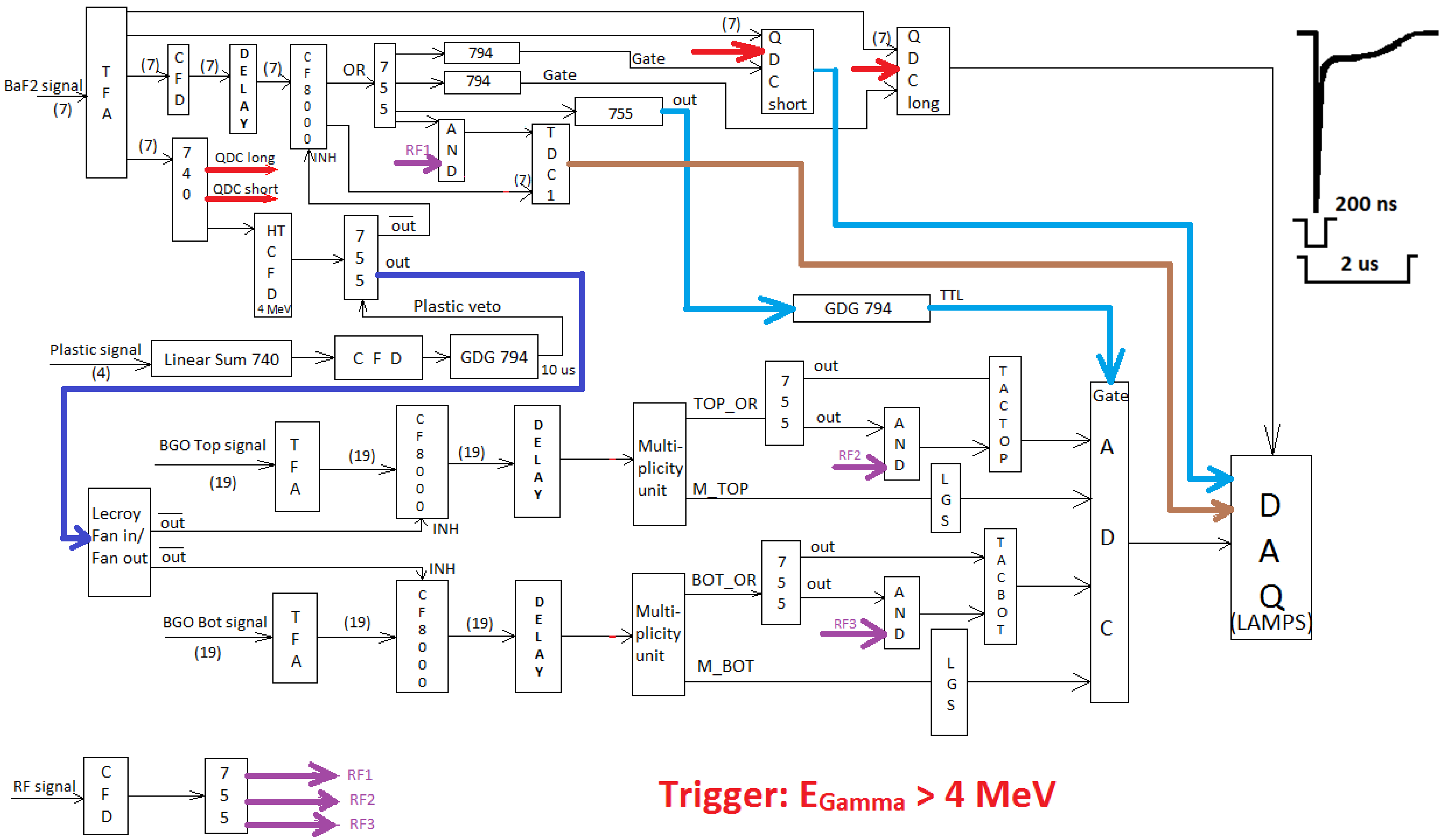








Electronics Block Diagram

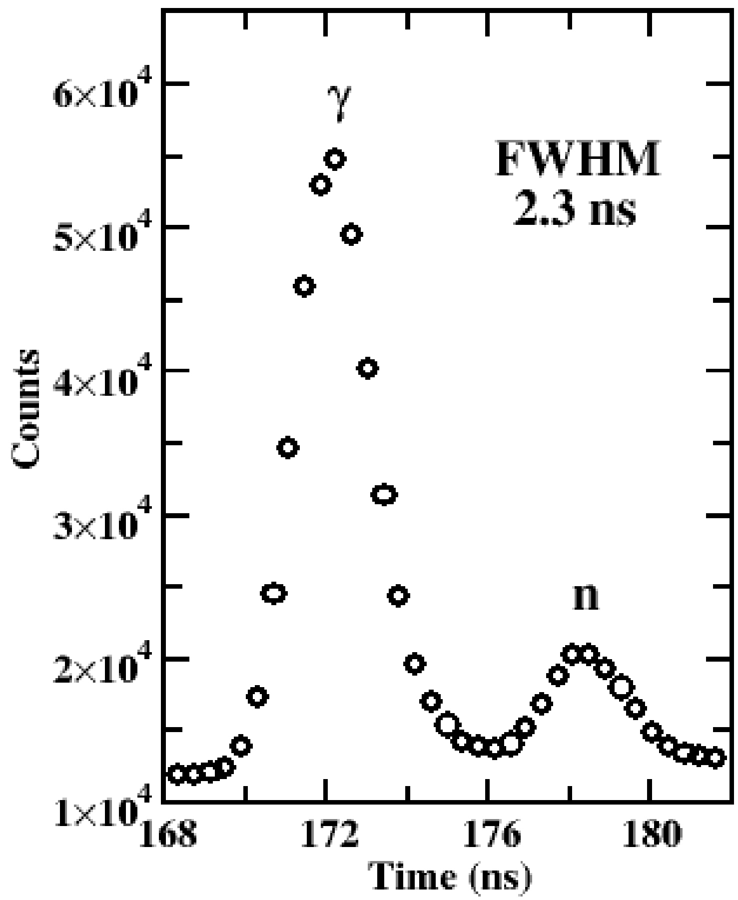


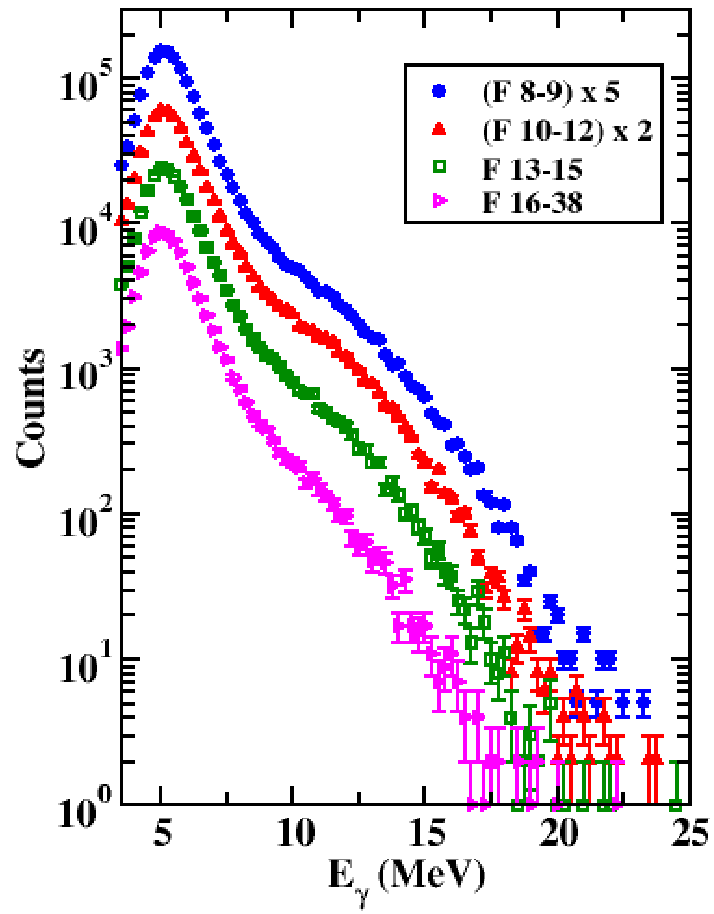
Trigger: E_{Gamma} > 4 MeV

Data Analysis

- Gain stability : Periodic monitoring was done with ^{137}Cs, ^{60}Co and Am-Be sources. Observed drift $\pm$ 2.0% at 4.4 MeV.
- Pile up rejection: Integrating the detector pulse in two window having gate widths 200 ns and 2 μs (~3%).
- Time prompt : Events were accepted if they were within the individual RF-BaF_2 and RF-BGO TOF γ-prompt window.
- Chance correction : Chance correction in RF-BaF_2 and RF-BGO TOF spectra is considered (~2%).
- Doppler correction : The γ-ray energy is corrected for velocity of the recoil nuclei (β = 0.018).

Experimental Spectra





Statistical Model Calculation

- Simulated Monte Carlo Cascade (SMCC) is used for extraction of GDR parameters (D. R. Chakrabarty, NIMA 560 (2006) 546)
- Ignatyuk level density prescription is used with $a=A/8.5\ MeV^{-1}$.
- We assume the GDR exhausts the 100% of the sum rule ($S_1+S_2=1$).
- The γ-ray spectrum is fitted with function having two components Lorentzian of the form

$$F_L(E, E_i, \Gamma) = \frac{E^2\Gamma^2}{(E^2-E_i^2)^2+E^2\Gamma^2}$$

- The GDR centroid is calculated as

$$E_{GDR} = (S_1E_1+S_2E_2)/(S_1+S_2).$$

- The temperature of the final state is calculated as

$$U = aT_f^2, \qquad \text{where } U = E_f - E_{rot}(J_f) - \Delta_P.$$

Statistical Model Calculation

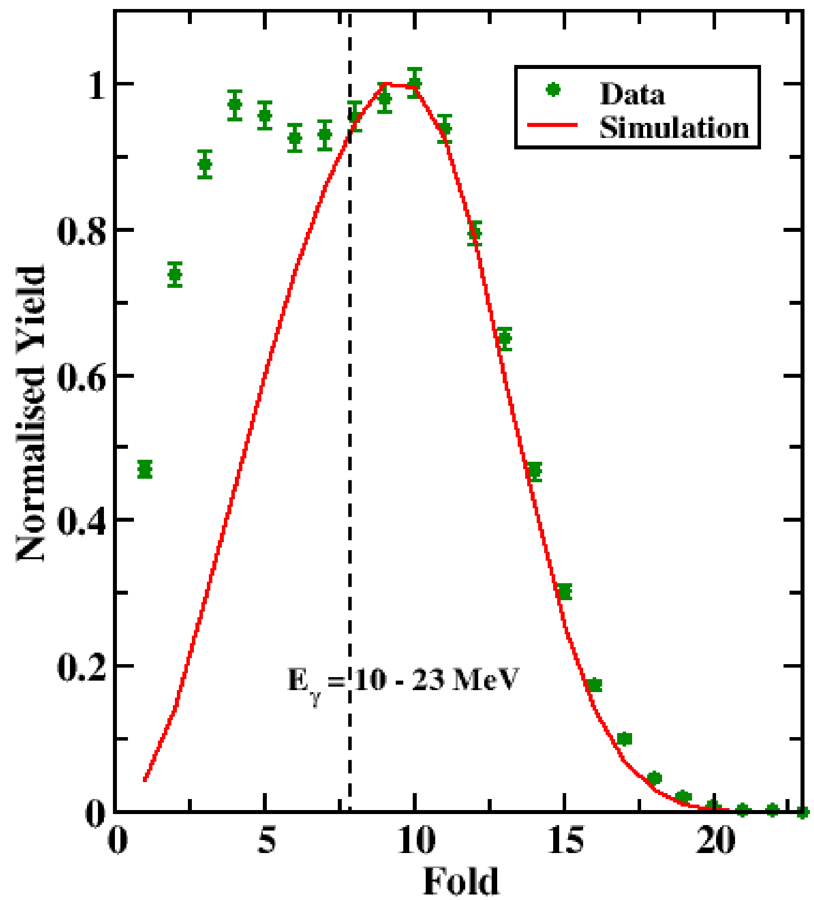
- Compound nucleus spin distribution

$$\sigma_1(J_{CN}) = \frac{2J_{CN}+1}{1+\exp[\frac{J_{CN}-J_0}{\delta J}]}$$

- Residue spin (J_R) distribution of all the residues as a function of E_γ for each $J_{CN} \Longrightarrow$ **$\sigma_2(E_\gamma, J_R)$**
- Multiplicity (M) for all residues **$\sigma_3(J_R, M)$** is calculated incorporating
  - relative transition probability of $\Delta J_R = 1$ & $\Delta J_R = 2$ from spin J_R to ground state
  - multiplicity of statistical γ-rays
  - isomers
- The response of BGO multiplicity array - GEANT3 simulations incorporating efficiency and crosstalk probabilities $\Longrightarrow$**$\sigma_4(M,F)$**

$$\sigma(E_\gamma, F) = \sum_{J_{CN}} \sigma_1(J_{CN})\, \sigma_2(E_\gamma, J_R).\, \sigma_3(J_R, M).\, \sigma_4(M, F)$$

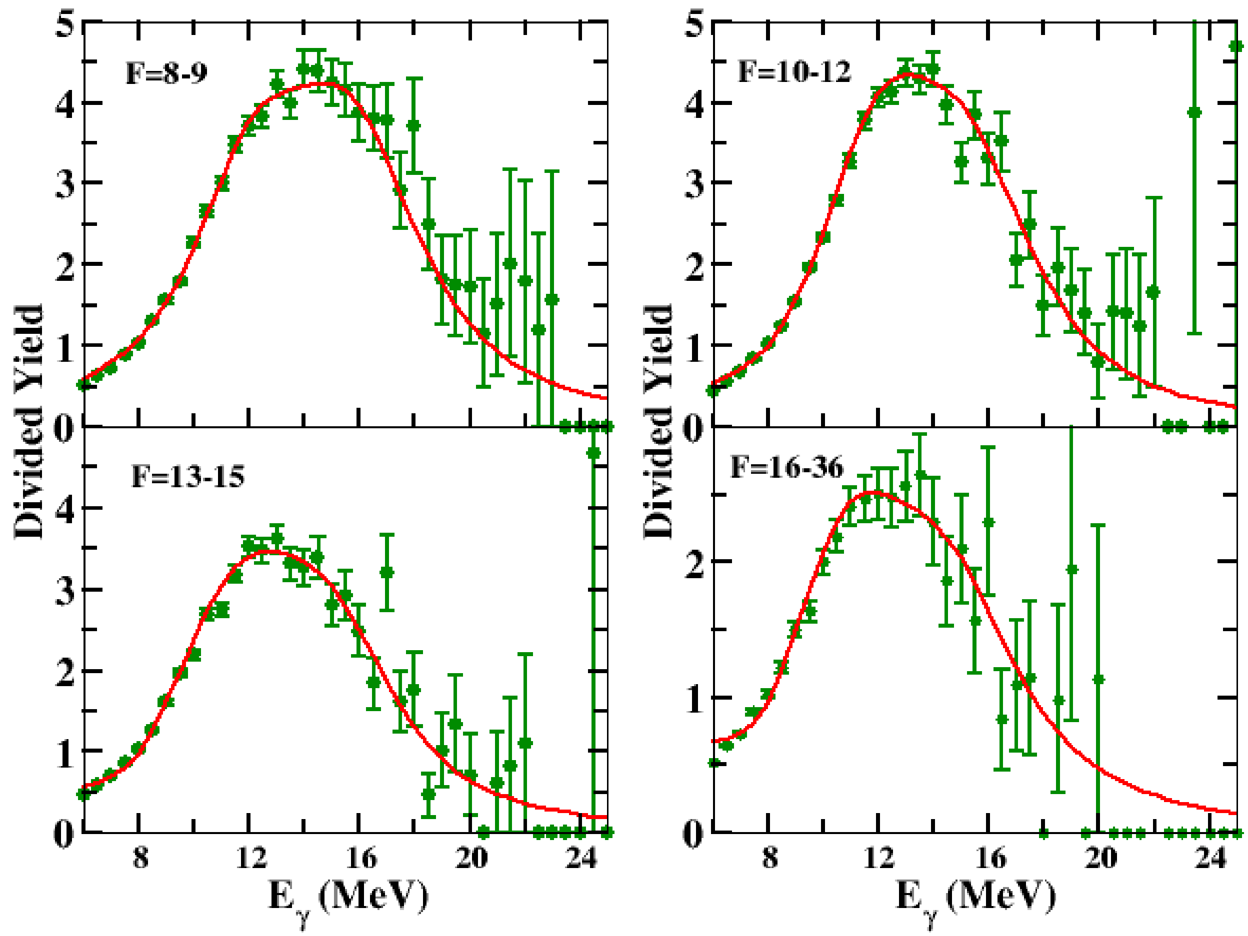
Fold Distribution



- Good agreement for fold ≥ 8
- Peak at lower fold could be due to impurities in the target (like C, O)

Fold Gated Gamma Ray Spectra

Divided plots with constant E1 strength (0.2 W.U.) data and statistical model fits



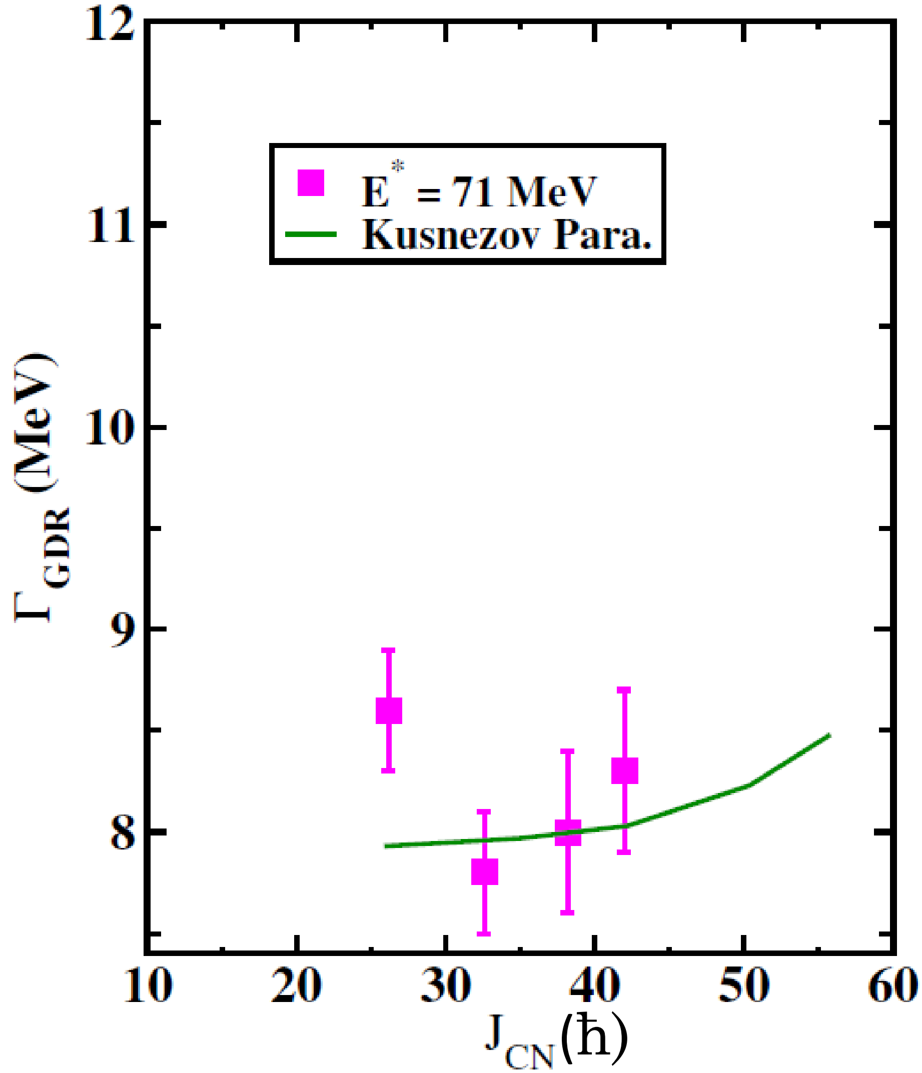
Results

Extracted GDR parameters

Fold	$\langle J_{CN} \rangle$	$\langle T \rangle$ (MeV)	E_1 (MeV)	Γ_1 (MeV)	E_2 (MeV)	Γ_2 (MeV)	S_2	E_{GDR} (MeV)	Γ_{GDR} (MeV)
8-9	26(9)	1.37 (29)	12.8 (1)	4.8 (2)	16.5 (2)	5.8 (2)	0.67 (2)	15.3 (2)	8.6 (3)
10-12	33(8)	1.33 (28)	12.7 (1)	4.6 (2)	16.1 (2)	6.2 (2)	0.70 (2)	15.1 (2)	7.8 (3)
13-15	38(7)	1.29 (27)	12.5 (1)	5.6 (2)	16.0 (2)	6.2 (3)	0.70 (2)	15.0 (2)	8.0 (4)
16-36	42(6)	1.25 (26)	12.3 (1)	5.9 (2)	15.8 (2)	6.0 (3)	0.70 (2)	14.8 (2)	8.3 (4)

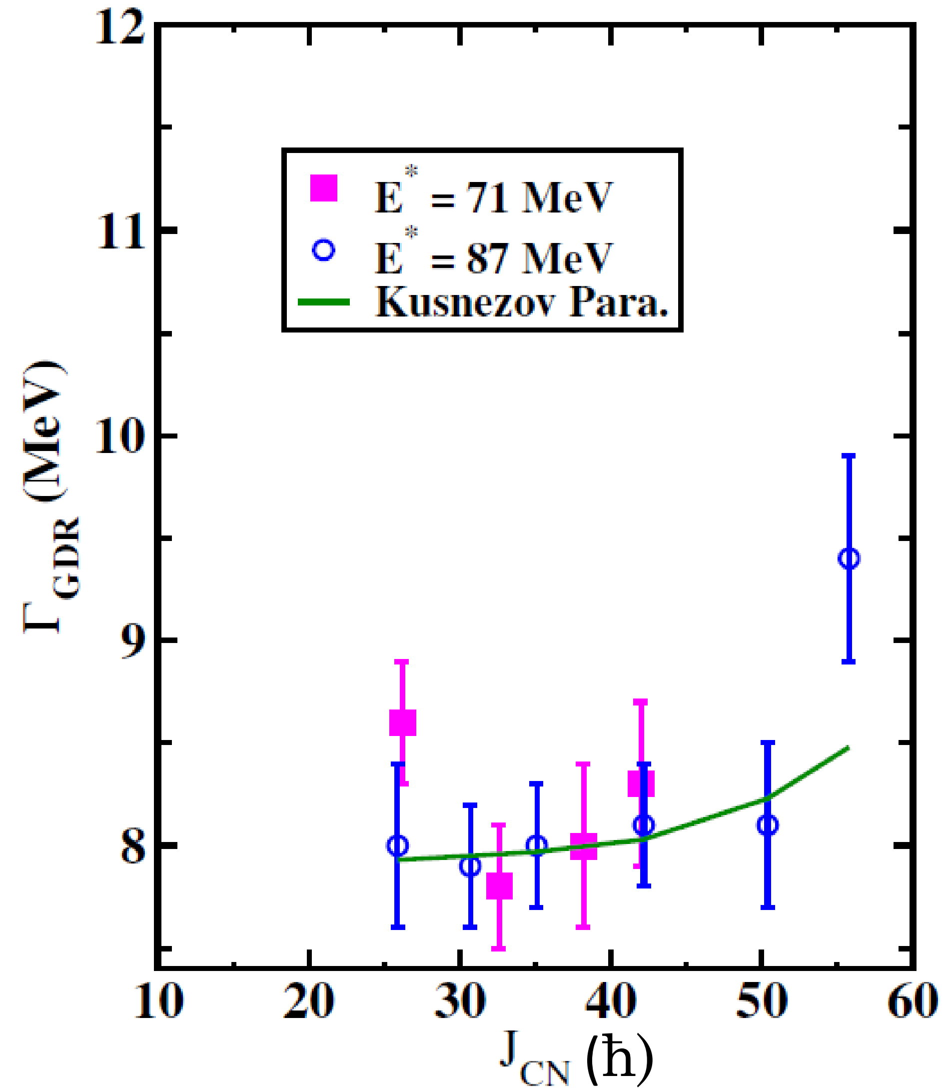
E_{GDR} ~ constant, average shape ~ Prolate

GDR width variation as a function of J_{CN}



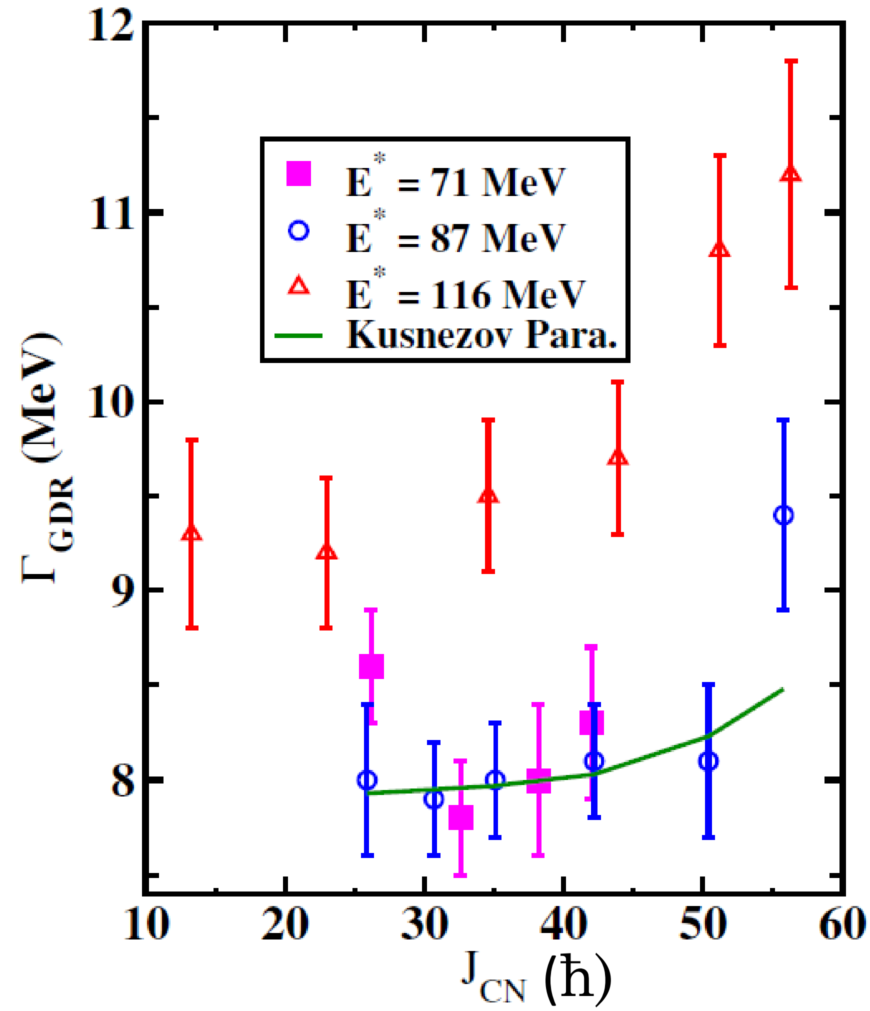
- Data consistent with Kusnezov Parameterization Γ_0 = 3.2 MeV
  →behaviour is consistent with liquid drop model

GDR width variation as a function of J_{CN}



Γ_0 = 3.2 MeV explains both present and E*= 87 MeV data (NPA **770** (2006) 126)

GDR width variation as a function of J_{CN}

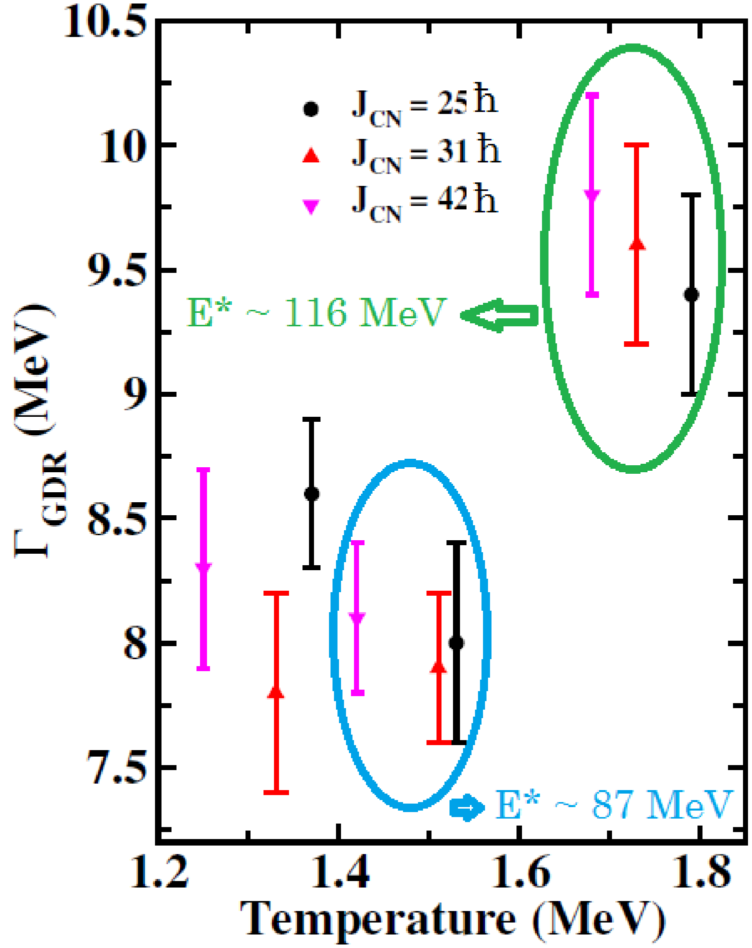


Comparison of all measurements in ^{152}Gd

Γ_{GDR} ~ constant upto J_{CN} ~ 45 ħ

(NPA **770** (2006) 126, J. Phys. G **37** (2010) 055105)

GDR width variation as a function of T



- Γ_{GDR} ~ constant T ~ 1.2 - 1.5 MeV and increases rapidly at higher T

(NPA **770** (2006) 126, J. Phys. G **37** (2010) 055105)

Summary

- Exclusive measurement of GDR is performed in ^{152}Gd at E^{*}~71 MeV
- Statistical model calculations (using Simulated Monte Carlo Cascade) have been done for extraction of GDR parameters.
- The GDR centroid energy is constant for T, J_{CN} range studied
- Observed behavior of GDR width as a function of angular momentum is consistent with liquid drop model.
- Present data together with earlier measurements indicates that
  - Γ_{GDR} ~ constant for T~ 1.2 - 1.5 MeV & increases rapidly at higher T
  - Γ_{GDR} shows nearly constant upto J_{CN} ~ 45 $\hbar$ (weak J dependence)
- It will be interesting to compare the data with TSFM calculations

Acknowledgement

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