Chapter 4

Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

4.1 Introduction

The giant dipole resonance (GDR), built on highly excited nuclear states, is the main experimental probe to study the shapes of hot rotating nuclei. Hot nuclei are formed in heavy ion fusion reactions where the relative kinetic energy of the colliding nuclei is converted into internal excitation energy and high angular momentum of the compound nuclei. These nuclei at high spin may undergo a Jacobi shape transition, an abrupt change of shape from an oblate ellipsoid rotating around the symmetry axis to an elongated prolate or triaxial shape rotating perpendicularly around the symmetry axis, similar to one, which occurs in rotating gravitating stars [Cha69]. In the search for exotic nuclear shapes, the light and medium mass nuclei are of special interest. This is because these nuclei are expected to undergo Jacobi shape transition at values of the angular momentum which are relatively low and below the fission limit. Signatures of such shape transitions in $^{45}$Sc [Kin93] and $^{46}$Ti [Maj04, Kmi07] have been seen from the study of GDR lineshapes built on excited states.

Recently, the deformation of the excited $^{47}$V nucleus has been grossly estimated from an inclusive $\alpha$-particle measurement [Apa06]. These studies, how-
ever, only indicate the overall deformation in an indirect way. Hence, it is worthwhile to complement the above study by measuring the deformation, in more direct manner, via the GDR $\gamma$-decay since it is also expected to undergo Jacobi shape transition similar to $^{46}\text{Ti}$ [Maj04] at these conditions.

### 4.2 The multiplicity filter

In heavy-ion fusion reaction, the compound nucleus is formed at a well-defined excitation energy, but with a wide range of angular momenta. The hot compound nucleus loses most of the excitation energy via particle and gamma emissions above the yrast line. The remainder of the excitation energy and angular momentum are generally removed by the low energy discrete gamma emission [Har01]. A precise measurement of this $\gamma$-multiplicity is very important since the number of $\gamma$-rays emitted are directly related to the angular momenta populated in the system. The multiplicity of gamma rays is measured with an array of detectors placed close to the target having high gamma detection efficiency and granularity. The fold (number of multiplicity detectors fired) distribution is recorded on an event-by-event basis in coincidence with the high-energy gamma rays. Finally, the angular momentum distribution is extracted from this fold distribution in offline analysis.

At the Variable Energy Cyclotron Centre, Kolkata, India, a 50 - element gamma-multiplicity filter made of BaF$_2$ has been designed and developed for the measurement of angular momentum of the compound nucleus in an event by event mode [Dee10c].

#### 4.2.1 Multiplicity detector fabrication

The preparation of BaF$_2$ detector from the bare crystal is a very involving as well as an interesting job. Standard procedures were followed for detector fabri-
cation from bare barium fluoride crystals. First, the bare crystals were cleaned thoroughly using pure dehydrated ethyl alcohol. Each crystal was wrapped with 6 layers of 15 μm white teflon tape since the scintillation light components are in the ultra violet (UV) region and teflon (C₂F₂) is a very good reflector of UV light. Next, aluminium foil of 10 μm (3-4 layers) was used to enhance the light collection and to block the surrounding light from entering into the crystal. Fast, UV sensitive photomultiplier tubes (29mm dia, Phillips XP2978) were coupled with the crystals using highly viscous UV transmitting optical grease (Basylone, 300000 cstokes). This coupling need to be done very carefully so that no air bubble remains in the grease over the crystal surface, because air bubbles provide unwanted reflecting surfaces amounting to a loss of scintillation light and degrades the timing property. Specially designed aluminium collars were also used around the coupling area to provide additional support. A squared shape teflon reflector (3.5cm × 3.5cm) with a 3.0 cm hole at the centre was placed at the PMT end of the crystal to reflect back UV light which would otherwise escape from the PMT. A PMT voltage divider base was then attached to the PMT for applying the high voltage. After that, the whole assembly was covered with black electrical tape for light-tightness, and finally with heat-shrinkable PVC tube for providing mechanical stability to the detector. The total fabrication process is shown in Fig.4.1 and Fig.4.2. The multiplicity filter assembly arranged in two blocks of 5×5 arrays is shown in Fig.4.3.

### 4.2.2 Energy and time resolution

The individual detector elements were tested with lab standard gamma ray sources. The energy spectra measured in individual detector is shown in Fig.4.4. The observed energy resolution is 7.2% at 1.17 MeV of ⁶⁰Co source. The time resolution between two BaF₂ detectors was measured with the ⁶⁰Co γ-ray source. The source was placed in between two identical detectors, which were kept 180°
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.1: The step by step process for detector fabrication from a bare crystal. Clockwise from the top left side. I. Cleaning of the bare BaF$_2$ crystal with pure dehydrated ethyl alcohol. II. The wrapping of the crystal with white teflon tape. III. The wrapped aluminium foil over the teflon wrapped crystal. IV. The black electric tape wrapped over the aluminium tape for light tightness.

Figure 4.2: The step by step process for detector fabrication from a bare crystal. Clockwise from the top left side. I. Highly viscous optical grease over the crystal surface before connecting to PMT. II. Coupling of the PMT with the crystal. III. The specially designed aluminium collar being put around the coupling area to provide additional support. IV. The total assembly covered with black electric tape and finally with heat shrinkable tube to provide mechanical stability to the detector.
apart. The energies and their relative times were measured simultaneously in an event by event mode. The energy gated (1.0-1.4 MeV) time spectrum is shown in Fig.4.5. The value obtained for the time resolution is 450 ps [Dee10c].

4.2.3 Crosstalk probability

The crosstalk probability was measured with $^{22}$Na, $^{137}$Cs and $^{60}$Co sources at different thresholds. Twenty-five detectors were arranged in a $5 \times 5$ matrix. A start signal was generated from an external large BaF$_2$ detector ($3.5\times 3.5\times 35$ cm$^3$). The detectors of the multiplicity filter were gain matched and equal thresholds were applied to all. The events were collected only if 1.33 MeV gamma ray from $^{60}$Co source (or 1.274 MeV in case of $^{22}$Na) gave a photo-peak in the large BaF$_2$ detector, ensuring that exactly one gamma ray (1.17 MeV or 511 keV for $^{60}$Co or $^{22}$Na sources, respectively) was incident on the multiplicity filter. In the case of $^{137}$Cs, since only one gamma (662 keV) is emitted from the source no coincidence could be made. The background events were collected in an identical condition without the source and subtracted from the data. The
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.4: Energy spectra from a single multiplicity detector for different laboratory standard gamma ray sources.

Figure 4.5: Time resolution of an individual detector using $^{60}$Co $\gamma$-source.

data for different hit patterns were collected by counting in a scalar module. The crosstalk probabilities for the three energies at different thresholds of the multiplicity filter are shown in Fig.4.6 (solid points). The crosstalk probabili-
ties were also calculated using Monte Carlo GEANT3 simulations and are also shown in Fig. 4.6 (lines). The crosstalk probability is more for higher energy and decreases with increasing the threshold of the multiplicity detectors [Dee10c].

4.3 Experimental details

The LAMBDA spectrometer [Muk07] and the 50-element multiplicity filter [Dee10c] were employed for measuring the high-energy gamma rays from the decay of GDR and low energy multiplicity gamma rays, respectively, for $^{47}$V nucleus in an in-beam experiment.

The experiment was performed at the Variable Energy Cyclotron Centre, Kolkata using the 224 cm K-130 AVF room temperature cyclotron. A stable beam of $^{20}$Ne accelerated by the cyclotron was bombarded on a 1 mg/cm$^2$ thick target of $^{27}$Al. The initial excitation energy of $^{47}$V compound system was $E_x = 108$ MeV corresponding to a projectile energy $E_{proj} = 160$ MeV. The corresponding critical angular momenta was $L_{cr} = 38\hbar$. This value extends well beyond the critical angular momentum values of $28\hbar$ at which the Jacobi transitions are
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

predicted to occur for this nucleus. The $^{47}$V compound nucleus was formed in an identical condition as in the previous charged particle measurement reported earlier [Cha05, Apa06].

The high-energy photons were detected using a part of the LAMBDA spectrometer [Muk07] arranged in a $7 \times 7$ matrix. It was centered at 55° to the beam direction and at a distance of 50 cm from the target, subtending a solid angle of 0.227 sr (1.8 % of $4\pi$). Lead sheets of 5 mm thickness were placed in front and sides of the array, to cut down the intensity of the low energy gamma rays. The beam was stopped in a downstream dump placed at 3m from the target. The neutrons and the gamma rays from the dump were shielded using borated paraffin and lead, respectively. The low energy $\gamma$-ray multiplicity was measured, in coincidence with the high-energy $\gamma$-rays, using the in-house developed 50-element multiplicity filter. It was split into two blocks of 25 detectors each, which were placed on the top and the bottom of the scattering chamber in castle type geometry. The distances of the detectors from the target were adjusted to equalize their efficiencies (solid angle). The overall efficiency of the multiplicity setup was $\sim$30% as calculated using GEANT3 simulation. The detectors of the multiplicity filter were gain matched and equal thresholds were applied to all. The experimental setup is shown in Fig.4.7.

4.3.1 Trigger generation

The scheme of the complete electronic set-up is shown in Fig.4.8. The signals from the photo-multiplier tube (PMT) outputs of the spectrometer were first pre-amplified using a fixed (×10) gain fast amplifiers (CAEN N412). The amplified signals were split into two parts for the subsequent linear and logic paths. Each of the signals in the linear path was given a 100 ns delay and was split into two parts, with an amplitude ratio of 1:10 before sending them to
a pair of QDCs for long and short integration. The signals in the logic path were sent to CAMAC leading-edge-discriminators (LED) (CAEN C894) and constant-fraction-discriminators (CFD) (CAEN C671). A level-1 trigger (A) was generated when the signal in any of the detector elements of the LAMBDA spectrometer crossed a high threshold (> 4 MeV). Another trigger (B) was generated from the multiplicity filter array when any detector of the top block and any detector from the bottom block fired in coincidence. The coincidence between top and bottom multiplicity biased the selection of the angular momentum measurement towards the high spin region. A coincidence of these two triggers ‘A’ & ‘B’ generated the master trigger ensuring the selection of the high-energy photon events from the compound nucleus and the rejection of background. The signals from the multiplicity filters were fed to constant-fraction-discriminators (CFD) (CAEN C808) which gives a current sum output (50mV per hit) corresponding to the number of detectors fired. The current
sum outputs from the four CFDs were summed in a Linear-Fan-in module. The summed output was fed into a QDC (V792) gated by the master trigger to generate, on event-by-event basis, the experimental fold (F) distribution with condition (F ≥ 2). The master trigger was also used for generating the integration gates (2μs, 50ns) and the common-start trigger of the TDCs. Each TDC was stopped by the individual delayed outputs from the CFDs (with a uniformly low threshold of 300 keV) for the generation of the individual time spectrum for each element of LAMBDA. For each of the 49 elements of LAMBDA, the long and short gate integrated energies and time were recorded for each triggered event.
Chapter 4. Giant dipole resonance \( \gamma \)-rays from hot \( ^{47}\text{V} \) nucleus

Figure 4.9: Top panel: The Am-Be spectrum in one of the large BaF\(_2\) detectors during calibration. The left panel shows the comparison between raw spectrum (red circles) and no-leak spectrum (blue circles) while the no-leak spectrum is shown independently in the right panel. Bottom panel: Cosmic muon spectrum in the same detector during calibration. In the left panel, the raw spectrum (red line) is shown along with the vertically fired condition (blue line). The spectrum for vertically fired condition is shown in the right panel. The spectrum is fitted with Landau function to extract the most probable energy (continuous line).

4.3.2 Calibration of the detectors

All the 49 detectors of the LAMBDA spectrometer were calibrated using lab standard \( \gamma \)-ray sources and with minimum ionizing cosmic muons. The low energy calibration points were obtained using \( ^{22}\text{Na} \) (0.511 and 1.274 MeV) and \( ^{241}\text{Am-}^{9}\text{Be} \) (4.43 MeV). Due to the small cross-sectional area of individual detector element, 4.43 MeV \( \gamma \)-ray from Am-Be source does not deposit its full energy always and is dominated by the escape peaks (Fig.4.9). During offline analysis, the photo-peak (full energy peak) is observed cleanly by generating the spectrum under the condition that only a single detector has been fired without any leakage to the neighboring detectors in the event (no leak condition). The spectrum of 4.43 MeV \( \gamma \)-ray is shown in Fig.4.9 (left top panel) along with the
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

![Graph showing the $^{22}$Na spectrum during calibration with energy channels and counts.]

Figure 4.10: The $^{22}$Na spectrum during calibration is shown in the top panel while the calibration curve is shown in the bottom panel.

no-leak spectrum. The no-leak spectrum is shown individually in Fig.4.9 (right top panel). The $^{22}$Na spectrum obtained during calibration is shown in Fig.4.10 (top panel).

Minimum ionizing cosmic muons deposit 6.6 MeV/cm in BaF$_2$ material. Hence, while travelling the width of our detector (3.5 cm) vertically, they deposit 23.1 MeV of energy in the detector volume. The typical cosmic muon spectrum in the individual detector element, without any condition, during the calibration is shown in Fig.4.9. In offline analysis, the spectrum of cosmic muon is generated when all the seven detectors in a vertical column fire in a single event. This ensures that the muons travel the width of the crystal in a minimum path. The offline generated spectrum is compared with the no condition cosmic spectrum in Fig.4.9 (bottom left panel). The vertically fired spectrum is shown independently in right panel. The most probable energy was obtained by fitting
the spectral shape with a Landau function (continuous line in Fig. 4.9) and used for calibration.

The energy response of the detectors were found to be linear up to 4.43 MeV. The calibration curve is shown in Fig. 4.10 (bottom panel). This calibration was extrapolated to 23.1 MeV (energy lost by cosmic muons) and found to match nicely ensuring a linear energy response of the detectors up to at least 23 MeV.

4.4 Extraction of angular momentum

During the experiment, the multiplicity fold distributions from the low energy yrast \(\gamma\)-rays were measured in an event-by-event mode using the multiplicity filter array. To remove the contributions of any non-fusion events, the final experimental fold spectrum was generated, offline, by gating with high energy gamma rays (>10 MeV) (filled circle in Fig. 4.11) [Sri08]. The approach based on Monte Carlo GEANT3 simulation [Dee10c] was adopted to convert the experimental fold distribution to the angular momentum space. In this simulation, the realistic experimental conditions (including the detector thresholds and trigger conditions) were taken into account. Two blocks of 25 detectors arranged in \(5 \times 5\) arrays were kept on the top and bottom of the scattering chamber, similar to the experiment. The incident multiplicity distribution was considered triangular and is given as, for a multiplicity \(M\),

\[
P(M) = \frac{2M + 1}{1 + \exp((M - M_{\text{max}})/\delta M)}
\]

where, \(M_{\text{max}}\) is the maximum of this distribution and \(\delta m\) is the diffuseness.

The different input multiplicities of the low energy \(\gamma\)-rays were obtained by creating a random number according to the multiplicity distribution \(P(M)\). Low energy gamma rays, for each randomly generated multiplicity, were thrown
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.11: The experimental fold spectrum (symbols) fitted with GEANT simulation (solid line).

Figure 4.12: The incident multiplicity distribution used in GEANT simulation (symbols along with dotted line). The multiplicity distributions obtained for different folds are also shown in the figure. The solid line represents fold 2 while the dashed line represents fold $\geq 3$.

isotropically from the target centre and the corresponding fold was recorded for that event. Two hundred thousand events were thrown to generate the simulated fold distribution. The energy distribution of the incident multiplicity was considered a gaussian with peak at 0.5 MeV and width 0.65 MeV.

The angular momentum distribution of the reaction $^{20}$Ne + $^{27}$Al was ob-
tained from statistical model code CASCADE. The conversion of the angular momentum distribution to multiplicity distribution is achieved using the relation \( J = 2 \cdot M + C \), where \( C \) is the free parameter which takes into account the angular momentum loss due to particle evaporation and emission of statistical \( \gamma \)-rays. The parameters \( M_{\text{max}} \) and \( \delta m \) of the multiplicity distribution was obtained from the J-distribution by varying the free parameter \( C \) until the best fit between measured \( F \)-distribution and simulated \( F \)-distribution was achieved. The value of \( C \) was obtained as 6 and the parameters of the M-distribution were extracted as \( M_{\text{max}} = 14.0 \) and \( \delta m = 2 \) for best fit. The simulated fold distribution generated using the triangular distribution is shown by solid line in Fig.4.11. Next, the constrained multiplicity distributions for different folds were generated. The incident multiplicity distribution (dotted line along with symbol) and the multiplicity distributions for different fold windows are shown in Fig.4.12. The continuous line and the dashed line indicate the multiplicity distributions gating on the events with folds 2 and folds \( \geq 3 \) respectively. The average angular momentum values for different folds are summarized in Table 4.1.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Fold</th>
<th>( \langle J \rangle ) ( \hbar )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ^{20}\text{Ne} + ^{27}\text{Al} @ 160 \text{MeV} )</td>
<td>2</td>
<td>28.0 ± 7.0</td>
</tr>
<tr>
<td></td>
<td>( \geq 3 )</td>
<td>31.3 ± 8.0</td>
</tr>
</tbody>
</table>

### 4.5 Experimental data analysis

The high-energy gamma spectra were generated from the offline analysis of the data recorded in the event-by-event mode after putting proper cuts on the time of flight (TOF) and pulse shape discrimination (PSD)(discussed in Chapter 2).
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

After application of different conditions, in a valid event, the energies deposited in the detectors were summed using the nearest neighbor event reconstruction technique [Muk07](also discussed in Chapter 2). Finally the energies were Doppler corrected assuming the source velocity same as the compound nucleus velocity. The high-energy $\gamma$-ray spectra were generated for fold 2 and fold $\geq 3$ in the multiplicity filter which correspond to average angular momentum values of $28\hbar$ and $31\hbar$, respectively. The high-energy $\gamma$-ray spectra is shown in Fig. 4.13.

The measured individual high-energy $\gamma$-ray spectrum corresponding to fold 2 and fold $\geq 3$ were fitted using the statistical model decay code CASCADE along with a bremsstrahlung component to extract the GDR strength function. The estimated spin distributions, using GEANT3 simulation for different folds, were used as inputs in the statistical model calculation. The non statistical con-
Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

The bremsstrahlung contribution arising due to bremsstrahlung was parameterized using the relation $\sigma_{\text{brem}} = A \cdot \exp(-E_{\gamma}/E_0)$. The slope parameter was taken according to the prediction $E_0 = 1.1 \cdot [(E_{\text{lab}} - V_c)/A_p]^{0.72}$, where $E_{\text{lab}}$, $V_c$ and $A_p$ are the beam energy, Coulomb barrier and projectile mass, respectively [Nif90]. The CASCADE calculations have been performed with the same parameters as used in the charged particle analysis to explain the inclusive $\alpha$-spectrum in $^{20}$Ne + $^{27}$Al reaction at 160 MeV [Apa06]. The $r_0$, $\delta_1$ and $\delta_2$ parameters were taken as 1.30 fm, $4.5 \times 10^{-4}$ and $2.0 \times 10^{-8}$, respectively. The level density prescription of Ignatyuk et al. [Ign75] was used with the asymptotic level density parameter $\tilde{a} = A/8.0$ MeV$^{-1}$. Finally, the theoretical spectrum was folded with the detector response function, generated using the Monte Carlo GEANT3 simulation [Muk07], to compare with the experimental spectrum. It needs to mention that a conventional two-component Lorentzian strength function, which can be related to a prolate or an oblate shape of the excited and rotating nuclei, could not fit the data. The reason for this could be the fact that the $^{47}$V nucleus is experimentally populated at high spin of $28\hbar$ and $31\hbar$. According to the rotating liquid drop model, the $^{47}$V nucleus is predicted to undergo Jacobi shape transition at these angular momentum values consisting of five GDR components altogether (discussed in Chapter 3). Hence, calculations were performed using the theoretical formalism developed in Chapter 3 to extract all the five GDR components at the experimental $J$. It is interesting to note that the statistical model calculation, considering these parameters, represent the experimental data remarkably well for both the angular momentum windows. The CASCADE calculation along with the bremsstrahlung component folded with the detector response function is shown in Fig.4.14 (continuous line) together with the experimental data (filled circles). The linearized GDR spectrum was generated by the quantity $F_L(E_{\gamma}) \cdot Y_{\text{exp}}(E_{\gamma})/Y_{\text{cal}}(E_{\gamma})$. In this expression $Y_{\text{exp}}(E_{\gamma})$ and $Y_{\text{cal}}(E_{\gamma})$ are the
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.14: The high-energy $\gamma$-ray spectra (filled circles) along with CASCADE prediction (continuous line) consisting of five GDR component for $^{47}$V nucleus.

Table 4.2: The extracted GDR components for two angular momentum windows for $^{47}$V.

<table>
<thead>
<tr>
<th>$&lt;J&gt;$ = 28 $\hbar$</th>
<th>$&lt;J&gt;$ = 31 $\hbar$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_i$ (MeV)</td>
<td>$\Gamma_i$ (MeV)</td>
</tr>
<tr>
<td>9.9±0.5</td>
<td>3.0±0.5</td>
</tr>
<tr>
<td>14.5±0.4</td>
<td>5.3±1.1</td>
</tr>
<tr>
<td>18.3±1.0</td>
<td>8.1±0.9</td>
</tr>
<tr>
<td>23.1±0.8</td>
<td>11.3±1.4</td>
</tr>
<tr>
<td>27.3±1.5</td>
<td>15.5±1.7</td>
</tr>
</tbody>
</table>

experimental and calculated spectra, respectively. The best fit GDR strength function $F_L(E_\gamma)$ in this case consists of 5-component Lorentzian function (table 4.2). The linearized GDR plots for the two angular momentum windows are
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.15: The linearized experimental GDR strength function (filled circles) together with best fitting 5-Lorentzian function (continuous line) and its individual components.

shown in Fig. 4.15 along with the five GDR components used in the CASCADE calculation. Since, the width of the experimental angular momentum windows are large and the spin distributions corresponding to two different fold cuts (2 & $\geq$ 3) largely overlap, the GDR parameters and the overall GDR lineshapes are similar.

4.6 Result

The most striking feature of $^{47}$V populated at $28\hbar$ and $31\hbar$ is the strong enhancement in the $\gamma$ yield at $\sim$10 MeV similar to one observed in $^{46}$Ti [Maj04]. It is characteristics of a large deformation and the effect of Coriolis splitting due to very high angular velocity in the system [Dee10a]. Such very high an-
Chapter 4. Giant dipole resonance $\gamma$-rays from hot $^{47}$V nucleus

Figure 4.16: The predicted line shapes from the free energy minimization technique (continuous lines) are compared with the linearized GDR strength functions for $^{47}$V for the two angular momentum windows. The filled circles are the experimental data.

Angular velocities are usually achieved by the system normally beyond the Jacobi transition point. The average temperature of $^{47}$V nucleus was calculated using the relation $E_x = \tilde{a}T^2$ where $E_x = E^* - E_{\text{rot}} - E_{\text{GDR}}$ and $\tilde{a} = A/8$. $E^*$ is the excitation energy of the compound nucleus and $E_{\text{rot}}$ the energy bound in rotation. The GDR energy was extracted considering a single lorentzian from the relation $E_{\text{GDR}} = 18 \cdot A^{-1/3} + 25 \cdot A^{-1/6}$ [Gaa92]. The average temperatures corresponding to fold 2 and fold $\geq 3$ were 2.9 and 2.8 MeV, respectively.

In order to interpret the extracted GDR strength functions in the entire $\gamma$-ray energy range (5 - 32), we performed the thermal shape fluctuation calculation to generate the theoretical GDR strength function. The resulting GDR strength function, obtained as a weighted average (with the weight given by
the Boltzmann factor) of strength functions calculated at each $\beta, \gamma$ point (also including the Coriolis effects), is displayed with the full line in Fig. 4.16 and compared with the experimental data. It describes the data for $^{47}\text{V}$ remarkably well for both the experimentally measured spin windows of $28\hbar$ and $31\hbar$ at corresponding temperatures of 2.9 and 2.8 MeV, respectively. This remarkable good agreement between the theoretical predictions and the present experimental results is very much in favour of the onset of the Jacobi transition. Moreover, the appearance of a GDR component at $\sim$10 MeV is only possible due to the Coriolis splitting at very high angular frequency of the lowest vibrational frequency (which corresponds to the dipole vibration along the longest axis of the well deformed prolate or triaxial shape) [Dee10a]. In fact, for oblate shapes, typical for the equilibrium deformation at rotational frequencies lower than the critical value for the Jacobi transition, the Coriolis splitting is always absent [Nee82]. A further signature for the Jacobi transition is the presence of a broad tail in the 20-30 MeV region, in addition to the main peak at $E_\gamma \sim 18$ MeV. This result shows the importance of the selection of high rotational frequencies in the investigation of nuclear shapes through the GDR $\gamma$-decay.

The Jacobi shape transition has also been confirmed in our other experiment [Drc12] populating $^{46}\text{Ti}$ via the reaction $^{19}\text{F} (75, 125 \text{ MeV}) + ^{27}\text{Al}$ performed at the Pelletron accelerator of the Tata Institute of Fundamental Research, Mumbai, India. A sharp low-energy (at $\sim$10 MeV) component has been observed in the gamma-ray strength function superimposed on a broad distribution. At the higher beam energy, the component becomes more prominent at higher angular momentum, whereas for the lower beam energy the component disappears for higher fold. The comparison of the data at the two beam energies indicates that the critical angular momentum for the Jacobi transition is consistent with the theoretical prediction of $\sim 28\hbar$. 