The decay pattern of the PDR in $^{128}$Te using the $\gamma^3$-setup

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What is the Pygmy Dipole Resonance?
How to investigate the Pygmy Dipole Resonance?

Nuclear Resonance Fluorescence (NRF)

\[ \Gamma_0 \]

\[ 0^+ \]

\[ 2^+_1 \]

\[ 1^{\pm} \]
How to investigate the Pygmy Dipole Resonance?

Nuclear Resonance Fluorescence (NRF)

\[ \Gamma_i \]
How to investigate the Pygmy Dipole Resonance?

Nuclear Resonance Fluorescence (NRF)

- selective to J=1 states
- model independent
  - spin
  - parity
  - transition strength
- low sensitivity for small $\Gamma_i$
$\gamma$-$\gamma$ coincidence at HI$\gamma$S $\rightarrow \gamma^3$- setup

Nuclear Resonance Fluorescence (NRF)
$\gamma$-$\gamma$ coincidence at HI$\gamma$S $\rightarrow \gamma^3$- setup

Nuclear Resonance Fluorescence (NRF)
$\gamma-\gamma$ coincidence at H$\gamma$S $\rightarrow \gamma^3$- setup

Nuclear Resonance Fluorescence (NRF)

$\Gamma_0 \rightarrow 1^\pm \rightarrow 2_1^+ \rightarrow 0^+$
\( \gamma - \gamma \) coincidence at HI\( \gamma \)S $\rightarrow \gamma^3$- setup

Nuclear Resonance Fluorescence (NRF)
$\gamma^3$-setup

B. Löher et al., NIMA 723 (2013) 136
\( \gamma^3 \) - setup

B. Löher et al., NIMA 723 (2013) 136
γ³ - setup

B. Löher et al., NIMA 723 (2013) 136

- combination of:
  - high energy resolution HPGe
  - high efficiency LaBr
γ³ - setup

- combination of:
  - high energy resolution HPGe
  - high efficiency LaBr

- close setup geometry
- total photopeak efficiency
  - LaBr ~ 6 %
  - HPGe ~ 1.5 %

B. Löher et al., NIMA 723 (2013) 136
Single $\gamma$-ray spectroscopy on $^{128}$Te

- high energy resolution
- state-to-state analysis
Single γ-ray spectroscopy on $^{128}\text{Te}$

- high energy resolution
- state-to-state analysis

- high photopeak efficiency
- average quantities
$\gamma\gamma$ coincidence on $^{128}\text{Te}$

$^{128}\text{Te} \rightarrow E=6.9\text{ MeV}$
$\gamma$-$\gamma$ coincidence on $^{128}$Te

$^{128}$Te $\rightarrow$ E=6.9 MeV
\( \gamma-\gamma \) coincidence on \(^{128}\text{Te}\)

\(^{128}\text{Te} \rightarrow E=6.9\ \text{MeV}\)

\[
\begin{array}{ccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\
\end{array}
\]

\[
\begin{array}{ccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\
\end{array}
\]
\(\gamma-\gamma\) coincidence on \(^{128}\text{Te}\)
$\gamma$-$\gamma$ coincidence on $^{128}\text{Te}$

LaBr Sum
Projection on x-axis
$E_{\text{beam}} = 6.9$ MeV
\( \gamma-\gamma \) coincidence on \(^{128}\text{Te}\)
$\gamma$-$\gamma$ coincidence on $^{128}$Te

$743$ keV

$0^+_1$

$2^+_1$

$1^\pm$

$^{128}$Te

Counts / 30 keV

LaBr Sum (cut on 743 keV)
$E_{\text{beam}} = 6.9$ MeV

preliminary

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22
$\gamma$-$\gamma$ coincidence on $^{128}$Te

LaBr Sum (cut on 743 keV)  
$E_{\text{beam}} = 6.9$ MeV

preliminary
$\gamma$-$\gamma$ coincidence on $^{128}$Te

$1^\pm \rightarrow 2_1^+$

LaBr Sum (cut on 743 keV)
LaBr deconvoluted
$E_{\text{beam}} = 6.9$ MeV

preliminary
γ-γ coincidence on $^{128}$Te
$\gamma-\gamma$ coincidence on $^{128}\text{Te}$

**Preliminary**

**No coincidence**

Energy (MeV)

**Preliminary**

**Coincidence**

Energy (MeV)
$\gamma-\gamma$ coincidence on $^{128}\text{Te}$

$$\langle b_1 \rangle = \frac{I_{1^\pm \rightarrow 2_1^+}}{I_{\text{elast}}}$$

![Graph showing $^{128}\text{Te}$ data with $\langle b_1 \rangle$ and energy distribution.](image)

**Preliminary**

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γ-γ coincidence on $^{140}\text{Ce}$

V. Yu. Ponomarev, private communication
B. Löher, doctoral thesis (2014)

$^{140}\text{Ce}$

\[
\langle b_1 \rangle = \frac{I_{1^+} \rightarrow 2_{1^+}}{I_{\text{elast}}} \text{ extracted from LaBr Sum}
\]

\[
\langle b_1 \rangle (\%)
\]

Energy (MeV)

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$\gamma-\gamma$ coincidence on $^{140}\text{Ce}$

V. Yu. Ponomarev, private communication  
B. Löher, doctoral thesis (2014)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{gamma-gamma_coincidence.png}
\end{figure}

\[
\langle b_1 \rangle = \frac{I_1^+ \rightarrow 2^+_1}{I_{\text{clast}}}
\]

extracted from LaBr Sum

Energy (MeV)
$\gamma-\gamma$ coincidence on $^{140}\text{Ce}$

V. Yu. Ponomarev, private communication
B. Löher, doctoral thesis (2014)
γ-γ coincidence on $^{140}\text{Ce}$

V. Yu. Ponomarev, private communication
B. Löher, doctoral thesis (2014)

$^{140}\text{Ce}$

\[ \langle b_1 \rangle = \frac{I_{r}^{+} - I_{\text{clast}}}{I_{\text{clast}}} \]

extracted from LaBr Sum

\[ \langle b_2 \rangle \]

extracted from LaBr Sum

coupling between PDR and low-lying states well described
Thank you for your attention!

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Commissioning with $^{32}\text{S}$

Singles

Coincidence

2230 keV  Singles:  0.197(3)

5894 keV  Singles:  1.03(2)

peak to background

Counts / 5 keV x 20

Energy [MeV]
Commissioning with $^{32}$S

\begin{align*}
\text{counts / 5 keV} & \quad \text{Energy [MeV]} \\
0 & \quad 0 \quad 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9 \\
0 & \quad 10 \quad 20 \quad 30 \quad 40 \quad 50 \quad 60 \quad 70 \quad 80 \quad 90 \quad 100
\end{align*}

- 2230 keV: Singles: 0.197(3), Energy Cut: 9.6(15)
- 5894 keV: Singles: 1.03(2), Energy Cut: 11.7(13)

### Peak to Background Ratio

- 2230 keV: $\frac{1}{300}$
- 5894 keV: $\frac{1}{20}$
Experimental campaigns using the $\gamma^3$-setup

beam time 2012:

$^{40}\text{Ca}, ^{76}\text{Ge}, ^{124}\text{Sn}, ^{140}\text{Ce}, ^{156}\text{Gd}$

- Pygmy Dipole Resonance
- Scissors mode
- Mixed-symmetry state
- Two-phonon state

beam time 2013:

$^{92,94}\text{Zr}, ^{128}\text{Te}, ^{152,156}\text{Gd}, ^{162,164}\text{Dy}, ^{206}\text{Pb}$

beam time 2014/2015:

$^{150}\text{Sm}, ^{54}\text{Fe}, ^{50}\text{Ti}, ^{52}\text{Cr}$
Single $\gamma$-ray spectroscopy on $^{128}$Te

$R = \frac{I_{M1}}{I_{E1}}$ extracted from LaBr
Single $\gamma$-ray spectroscopy on $^{128}\text{Te}$

\[ \text{asymmetry} = \frac{N_\parallel - N_\perp}{N_\parallel + N_\perp} \]

extracted from LaBr

\[ ^{128}\text{Te} \quad ^{32}\text{S} \]
Single $\gamma$-ray spectroscopy on $^{128}$Te

... with linearly polarized photons

- distinguish between E1 & M1 transition

N. Pietralla et al., PRL (2001) 012502