Electromagnetic Dipole Strength distribution in $^{124,128,134}$Xe below the neutron separation energy

Ralph Massarczyk

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29.05.2013
Outlook

my original idea

- introduction
- experiment
- my results
- other results
Outlook

Oh oh I got 40 minutes talk...

- introduction
- experiment
- my results
- other results
Outlook
new idea

My Hitchhiker’s Guide to a PhD in nuclear physics ...
...trails and off the beaten track
new idea
My Hitchhiker’s Guide to a PhD in nuclear physics ...
...trails and off the beaten track

How would such a book look like?
Part I - Maps and Overview
How effects nuclear deformation nuclear reactions?

R. Massarczyk (HZDR)  dipole strength in $^{124,128,134}$Xe  29.05.2013
Part Ib - A closer view

- deformation changes shape of the Giant Dipole Resonance
- different parameterizations available
deformation changes shape of the Giant Dipole Resonance

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Part Ib - A closer view

- deformation changes shape of the Giant Dipole Resonance
- different parameterizations available
Part Ic - some background

**photo-absorption cross-section vs. strength function**

\[ f_{0\lambda XL}^J = 26 \cdot 10^{-8} \frac{\sigma_{0\alpha XL}^J (E_\gamma)}{g_J E_\gamma^{2L-1}} (MeV)^{- (2L+1)} \]

<table>
<thead>
<tr>
<th>( \sigma )</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>• is what we can measure</td>
<td>• is needed to describe deexcitations of excited states</td>
</tr>
<tr>
<td>• starts from ground state</td>
<td>• splits up in E1, M1, E2 ...</td>
</tr>
<tr>
<td>• often includes E1, M1, E2 transitions as well as ((\gamma, \gamma')), ((\gamma, n)) and other reactions ((\gamma, X))</td>
<td>• should be independent from excitation energy, spin, parity, excitation mechanism</td>
</tr>
<tr>
<td>• an idea based on statistical assumptions</td>
<td></td>
</tr>
</tbody>
</table>

R. Massarczyk (HZDR) dipole strength in \(^{124, 128, 134}\)Xe 29.05.2013 5 / 22
A short why-to-visit the energy region below the threshold

- interesting for a lot of nuclear reactions
- cross-over from a system dominated to a statistical dominated system
- new resonances (pygmy, M1, soft pole), new picture of nuclear matter?
- fascinating how small scale effects can change big things
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\[^1]\text{figure by D. Savran}\]

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My personal walking tour

- measure the photo-absorption cross section in a chain of stable isotopes
- recently published results of chain with neutron number $N = 50$
- What happens if neutron excess and nuclear deformation go in different directions?
- measurements of Xenon isotopes $\leftrightarrow$ learn something about the general behavior
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$^1$R. Schwengner PRC 87 (2013) 024306
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1. R. Schwengner PRC 87 (2013) 024306

R. Massarczyk (HZDR) dipole strength in $^{124,128,134}$Xe 29.05.2013 7 / 22
pro and cons of Xenon

Pro and Contra

- noble gas
- interesting for reactor physics
- acts as the most important reactor poison - $^{135}\text{Xe}(n,\gamma)$
- $^{129}\text{Xe}/^{130}\text{Xe}$, $^{136}\text{Xe}/^{130}\text{Xe}$ ratios important in solar system studies and planetary differentiation
- rarest not radioactive element on earth
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$^1$ J. Kunz Science 280 (1998) 877
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\[ \text{dipole strength in } ^{124,128,134}\text{Xe} \]

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Part II - Sites

The (new) **ELBE** at Dresden

Electron Linac for secondary radiation purposes
*(neutrons, positrons, FEL, activation experiments, bremsstrahlung)*
Part II - Sites

- Photon excitation at the bremsstrahlung setup at the electron accelerator ELBE
- Electron energies from 5 to 20 MeV with up to 1 mA
- Electron beam on thin niobium foil produces bremsstrahlung
- Setup contains high purity Germanium detectors with BGO shielding
- Empty target measurements necessary
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Part III - A walk through the analysis

- subtraction of the background from target container
- correction for efficiency and deconvolution of detector response (GEANT4)
- subtraction of atomic background

![Graph showing photon energy distribution with peaks and valleys, labeled with $S_n = 8.5$ MeV and $pc = 12$ MeV.](image)
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\(^1\)R. Massarczyk PRC 86 (2012) 014319
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\(^1\) R. Massarczyk PRC 86 (2012) 014319
beaten track and an alternative way to go
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![Graph showing level spacing or FWHM (keV) vs. $E_\gamma$ (keV).]

- Level spacing or FWHM (keV)
- $E_\gamma$ (keV)

- Plot with data points and curves.
- Logarithmic scale.

- Diagram with energy and strength axes.
- Notation: neutron skin, p, n.

- Text: R. Massarczyk (HZDR)
- Date: 29.05.2013
- Page: 12/22

- Comment: dipole strength in $^{124,128,134}$Xe
beaten track and an alternative way to go

continuum analysis...
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... standard tool in $(n,\gamma)$ analysis (e.g. Two-Step-Cascades)
beaten track and an alternative way to go

continuum analysis...

... standard tool in \((n,\gamma)\) analysis (e.g. Two-Step-Cascades)
... but not in nuclear resonance fluorescence experiments

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beaten track and an alternative way to go

In this continuum of unresolvable states ...
beaten track and an alternative way to go

In this continuum of unresolvable (not overlapping) states ...
beaten track and an alternative way to go

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... we have distributions for strength and level densities, their means, their deviations ...
beaten track and an alternative way to go

In this continuum of unresolvable (not overlapping) states ...

... we have distributions for strength and level densities, their means, their deviations ...

... Why do we still use random numbers and waste computational power?
Based on the idea of DICEBOX\(^1\)

- First step: scheme of levels $\rightarrow$ scheme of energy bins\(^2\), \(^3\)
- Second step: remove the random numbers, by distributions, mean values, deviations and covariances

\(^1\) F. Bečvář NIM A 417 (1998) 434
based on the idea of DICEBOX

first step: scheme of levels $\rightarrow$ scheme of energy bins

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DEX 2.0 - off the beaten path

change computer time to computer power!

new calculation method:
γDEX 2.0 - off the beaten path

change computer time to computer power!

new calculation method:
- define Histogram of 1st bin:

\[ H_1 = \delta(E_1) \]
γDEX 2.0 - off the beaten path

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- define Histogram of 2nd bin:

\[ H_2 = \frac{\Gamma_{2\rightarrow 0}}{\Gamma_{tot}} \delta(E_2) + \frac{\Gamma_{2\rightarrow 1}}{\Gamma_{tot}} H_1 \]
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- define Histogram of nth bin:

\[ H_n = \frac{\Gamma_{n\rightarrow0}}{\Gamma_{tot}} \delta(E_n) + \sum_{i=1}^{n-1} \frac{\Gamma_{n\rightarrow i}}{\Gamma_{tot}} H_n \]
new calculation method:

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Problems

- Uncertainty propagation much more complicated
- Statistical assumption not true for low energies
γDEX 2.0 - off the beaten path

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Solutions

- Uncertainty by error propagation
- Use discrete level scheme for low energies
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Advantages

- TIME...TIME...TIME, calculation within a minute
- Test with different model combinations
Correction of inelastic scattered events and branching

Calculation and subtraction with γDEX $^{1, 2}$

Self-consistent: Input PSF is equal to Output PSF
Back to the experiment

- Correction of inelastic scattered events and branching
- Calculation and subtraction with $\gamma$DEX $^{1,2}$
- Self-consistent:
  Input PSF is
  Output PSF

$^{1}$G. Schramm PRC 85 (2012) 014311
$^{2}$R. Massarczyk PRC 87 (2013) 044306
Back to the experiment

- Correction of inelastic scattered events and branching
- Calculation and subtraction with $\gamma_{DEX}$\textsuperscript{1, 2}
- Self-consistent: Input PSF is Output PSF

\textsuperscript{1}G. Schramm PRC 85 (2012) 014311
\textsuperscript{2}R. Massarczyk PRC 87 (2013) 044306
last chapter - results

- Complete dipole strength below the neutron separation energy in gas targets
- QRPA calculations performed \(^1\)
last chapter - results

- Complete dipole strength below the neutron separation energy in gas targets
- QRPA calculations performed \(^1\)
results and theory

- Deviation to other results \(^1\)
- Follows the trend of theory in N/Z plot, extra strength observed

\[
\sum BE_{\ell,\text{eV}} \text{ (e}^2\text{fm}^2) = \text{this work }(^{124,128,134}\text{Xe} + ^{136}\text{Ba})
\]
results and theory

- Deviation to other results\(^1\)
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\[^1\] D. Savran PRL 100 (2008) 232501
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extra strength (pygmy resonance ? )...

... seems to be more dependent on (triaxial) deformation than known so far.

\(^1\)D. Savran PRL 100 (2008) 232501
Conclusions

- determination of dipole strength functions below the neutron separation energy
- we are able to measure gaseous targets
- fast reaction code $\gamma$DEX for correction
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Outlook

- additional measurement on $^{130}$Xe
- analysis of HI$\gamma$S Data
- additional work with $\gamma$DEX in (n,$\gamma$) experiments at GEELINA
Thank you for your attention.
Announcement

The 15\textsuperscript{th} International Symposium on Capture Gamma-Ray Spectroscopy and Related Topics (CGS15) will take place in Dresden, Germany, from \textbf{August 25 to August 29, 2014}.

We are looking forward to seeing you there.