Electric dipole response of ^{52}Ca

- low-lying dipole strength -

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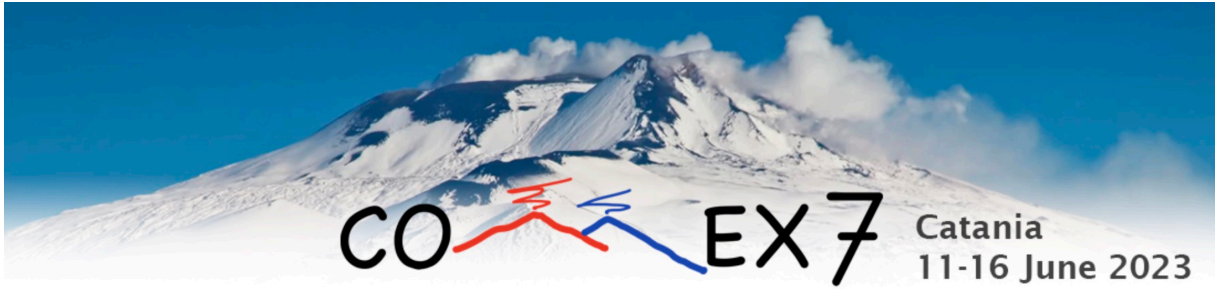
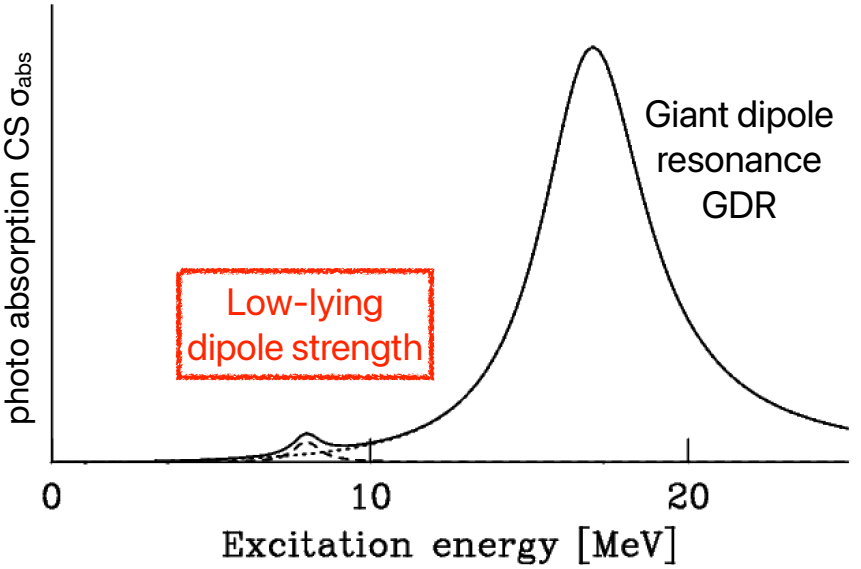


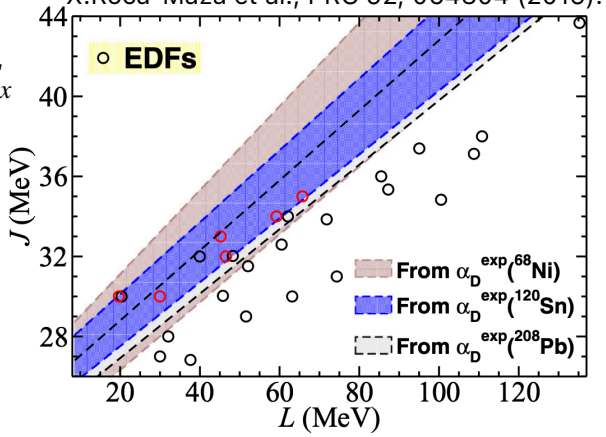
Electric dipole response of neutron-rich nuclei



Constraint on symmetry energy

$$\alpha_D = \frac{\hbar c}{2\pi}\int \frac{\sigma_{abs}}{E_x^2} dE_x$$

X.Roca-Maza et al., PRC 92, 064304 (2015).



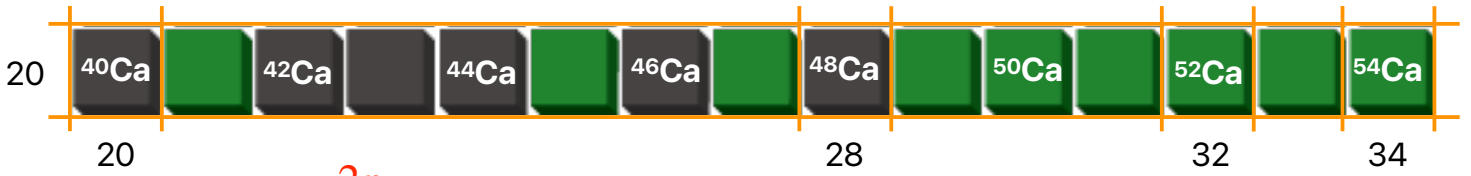
Low-E dipole strength = PDR

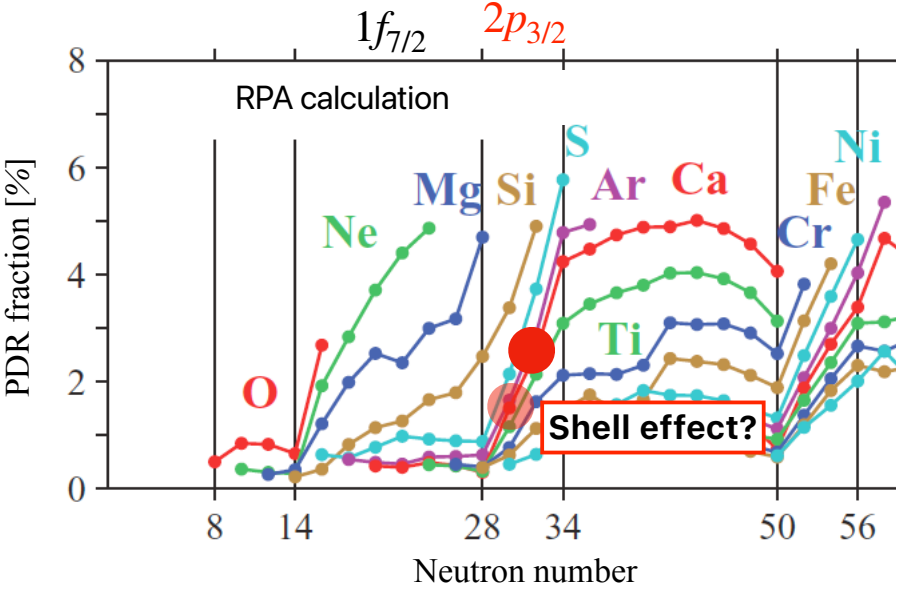
Ex: ~ neutron separation energy S_n (6~10 MeV)
Strength: ~5% of TRK sum
Isoscalar & isovector

Structure: unknown

Oscillation of n-skin, toroidal mode…
Single particle?

Is there sudden change on PDR in Ca isotope chain?





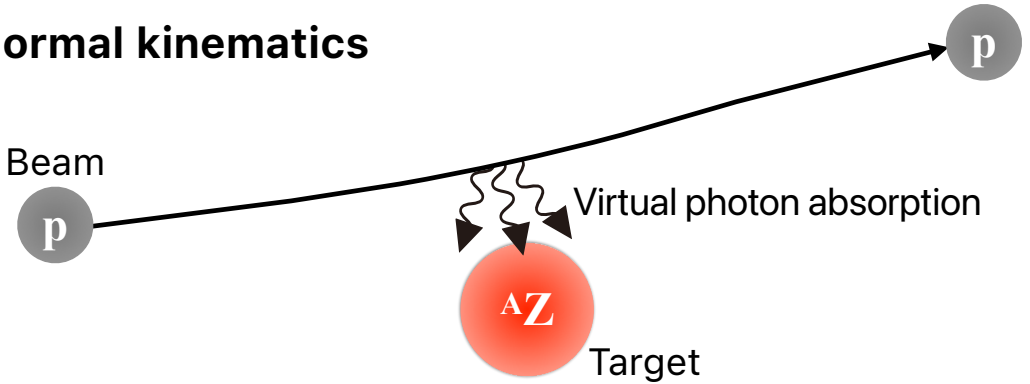
T. Inakura et al., PRC 84, 021302 (2011).

Evolution of PDR/dipole strength at N=28~34

Coulomb excitation of $^{(50),52}$Ca

Method: Relativistic Coulomb excitation

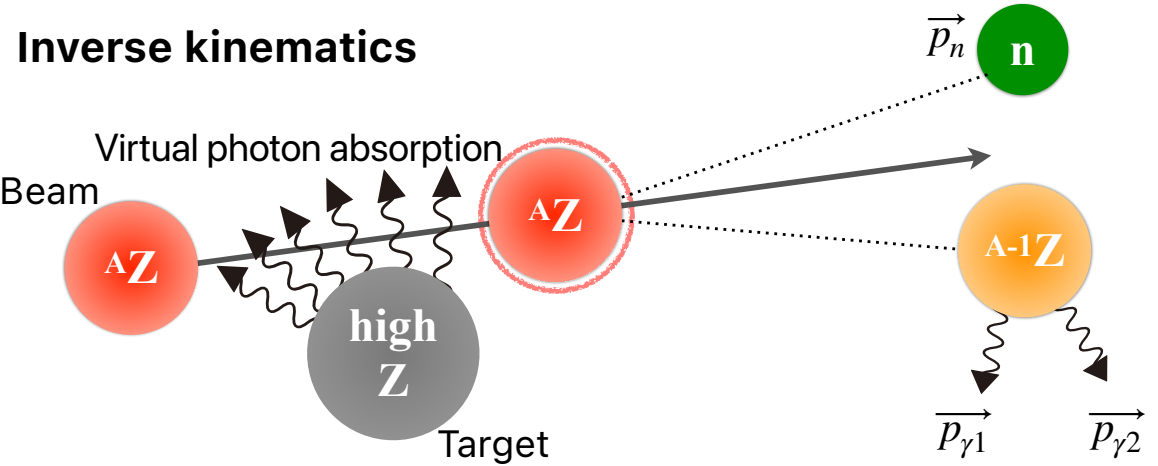
Normal kinematics



Momentum of scattered protons

E_x **of** ^{A}Z

Inverse kinematics



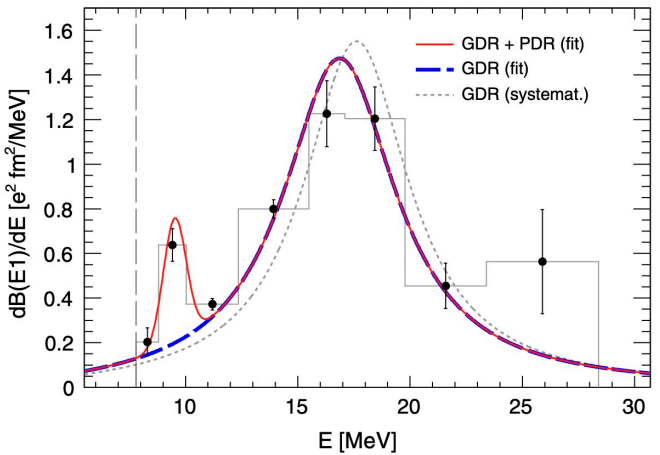
In Projectile rest frame

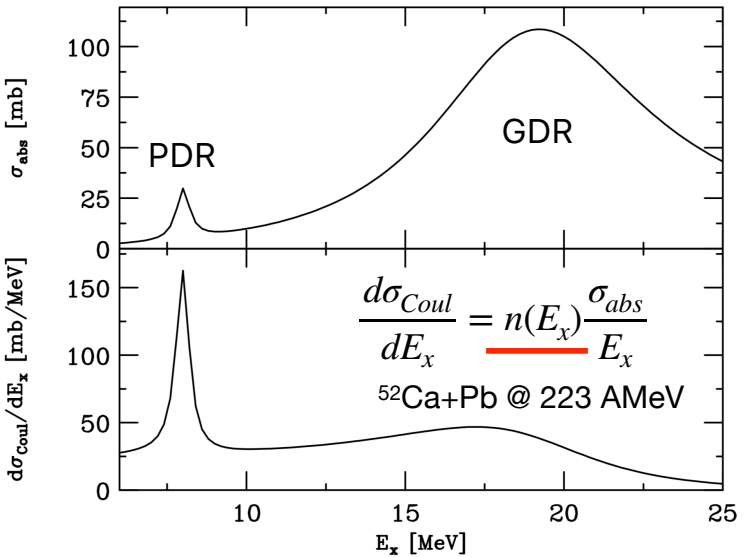
$$E_x(^{52}\mathrm{Ca}) = \sum^{N} E_{n_i} + \sum E_{\gamma_j} + S_{Nn}$$

Momenta of all fragments

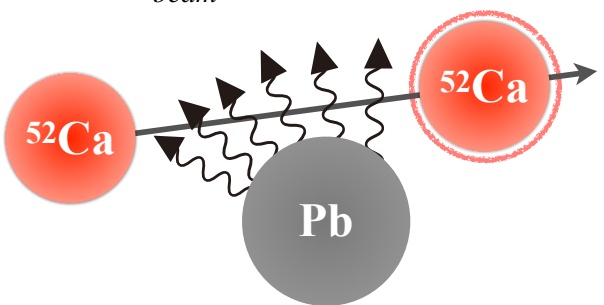
Relativistic Coulomb excitation in inverse kinematics

^{68}Ni B(E1) at GSI (D. Rossi et al., 500 AMeV)





$$E_{beam} = 223\ A\text{MeV}$$



High sensitivity to PDR region

Sensitive up to Ex =25 MeV

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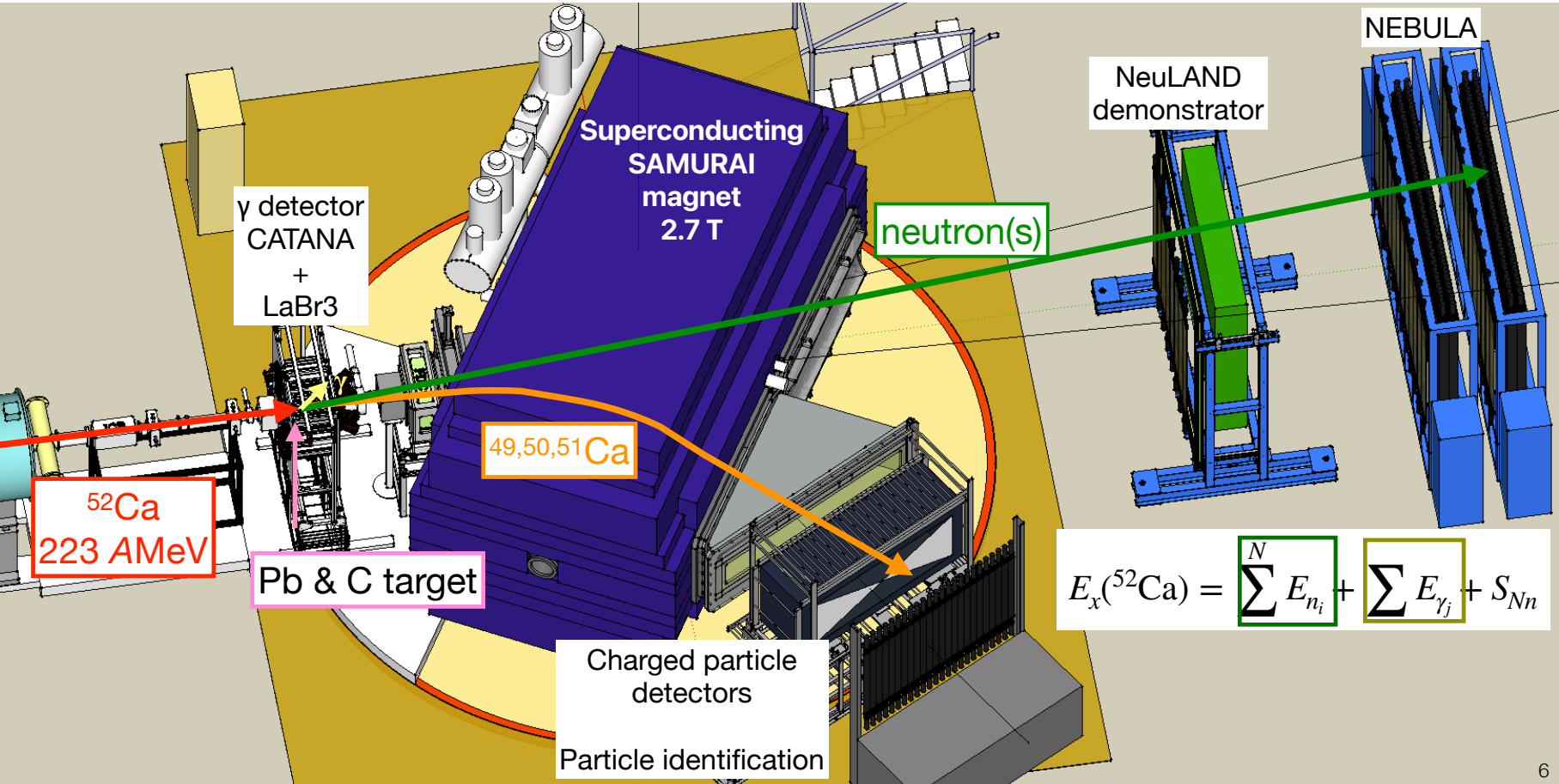
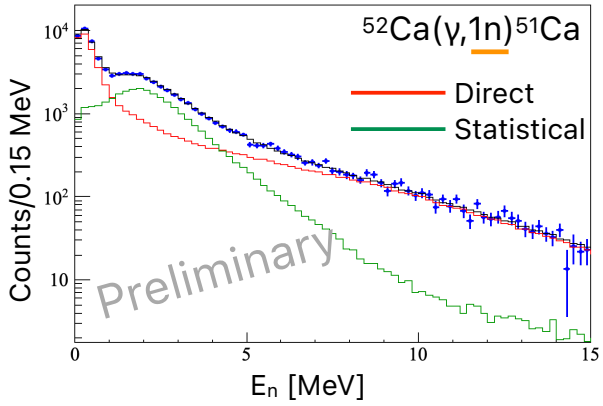
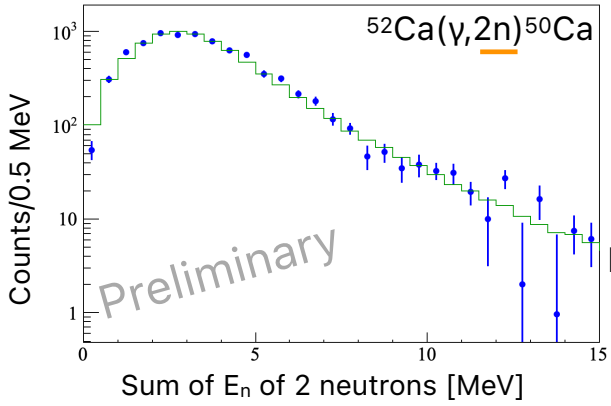


$$E_x(^{52}\mathrm{Ca}) = \sum^{N} E_{n_i} + \sum E_{\gamma_j} + S_{Nn}$$

Neutron and γ-ray energy spectra





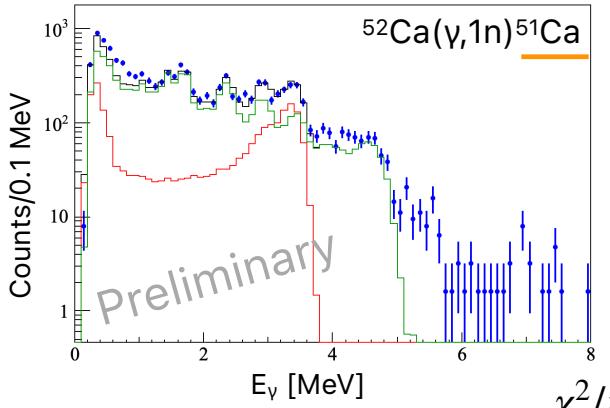
$$E_x(^{52}\mathrm{Ca}) = \sum^{N} E_{n_i} + \sum E_{\gamma_j} + S_{Nn}$$

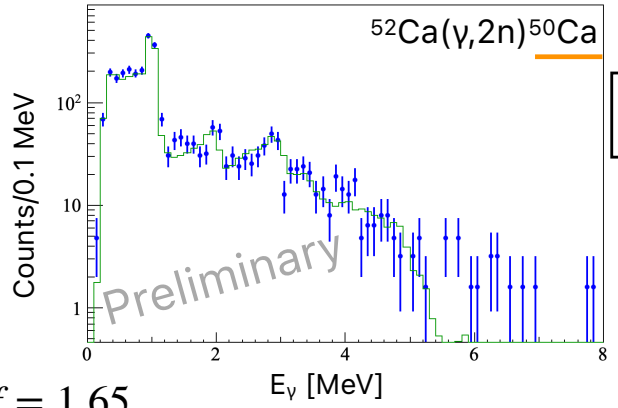
Detector inefficiency & response

Response functions
from 12 E_x bins

Response functions

Decay: direct + statistical
Detector : Monte-Carlo simulation





Simultaneous fit of spectra
(E_n, sum of E_n, E_γ, E_γ+E_n)

$$\chi^2/ndf = 1.65$$

Coulex cross section and B(E1) distribution

$$\sigma_{Coul} = \sigma_{Pb} - \Gamma\sigma_C$$

$$\Gamma = \frac{r_0(A_{beam}^{1/3} + A_{Pb}^{1/3})}{r_0(A_{beam}^{1/3} + A_C^{1/3})} \sim 1.6$$

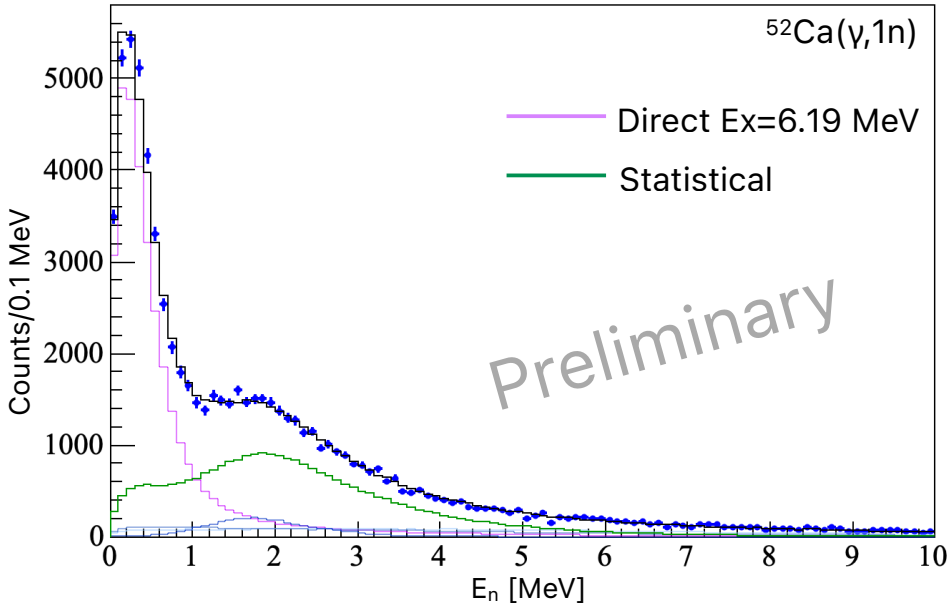
K. Boretzky et al., PRC 68, 024317 (2003).

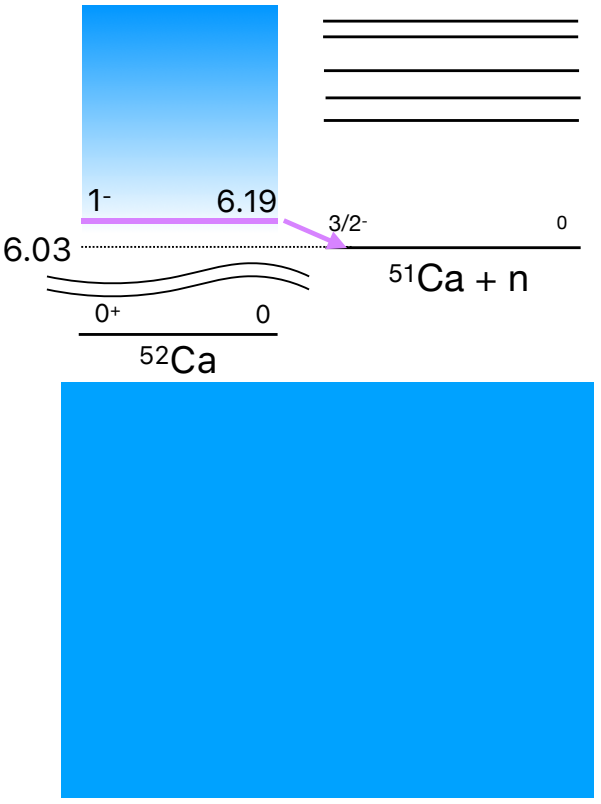
Equivalent photon method

$$\frac{d\sigma_{Coul}}{dE_x} = \frac{16\pi^3}{9\hbar c} N_{E1}(E_x) \frac{dB(E1)}{dE_x}$$

N_{E1}: virtual photon number

Detailed analysis of peak



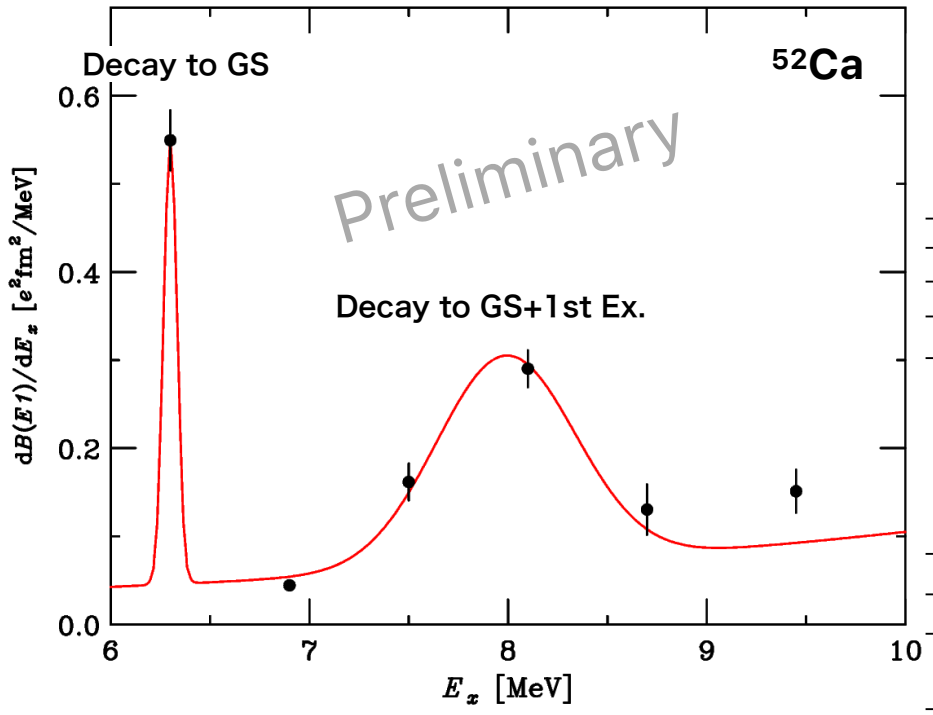


Energy-dependent Breit-Wigner A.M.Lane et al., Rev. Mod. Phys. 30, 257 (1958)

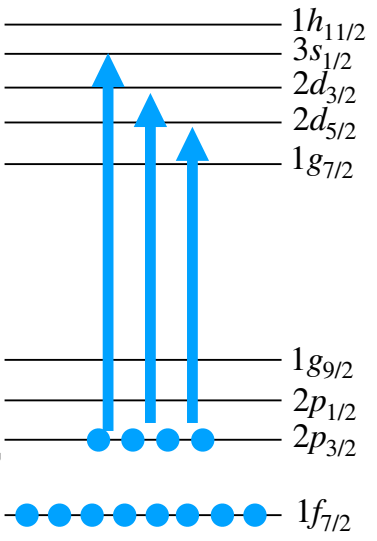
$$f_\ell\left(E_\mathrm{n};E_r,\Gamma_\mathrm{r}\right) \propto \frac{\Gamma_\ell\left(E_\mathrm{n}\right)}{\left(E_r+\Delta_\ell-E_\mathrm{n}\right)^2+\Gamma_\ell\left(E_\mathrm{n}\right)^2/4}$$

$$\Gamma_\ell\left(E_\mathrm{n}\right)=\Gamma_\mathrm{r}\times\frac{P_\ell\left(E_\mathrm{n}\right)}{P_\ell\left(E_r\right)}$$ (assume l=2 in this analysis)

Two different peaks at low excitation energy



	Ex [MeV]	Width [MeV]
PDR1	6.19(1)	<0.02
PDR2	8.0(1)	0.8(2)

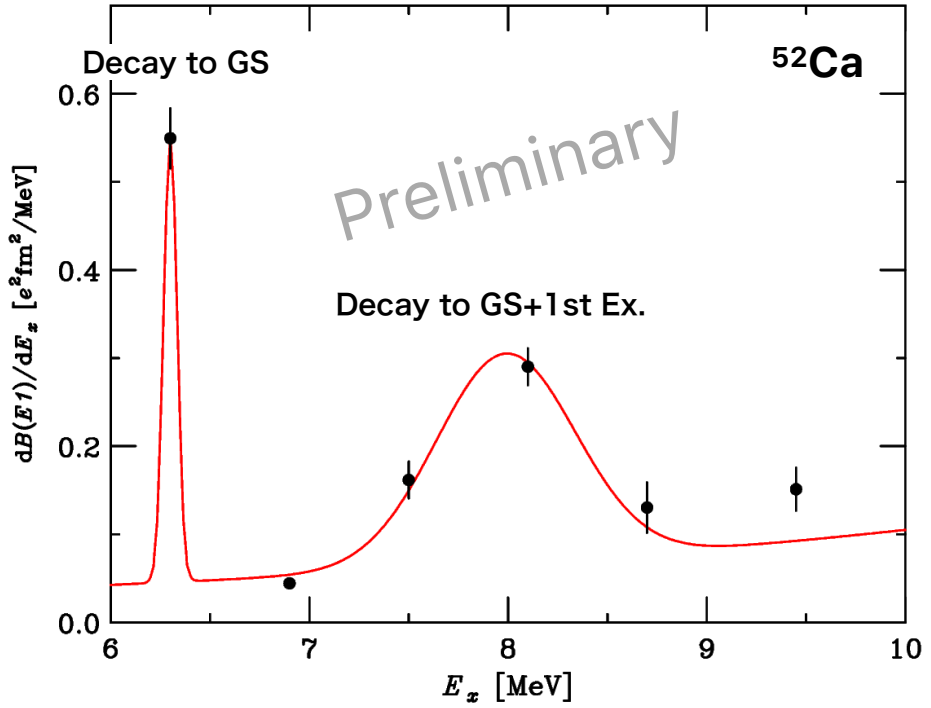


PDR1: single particle like

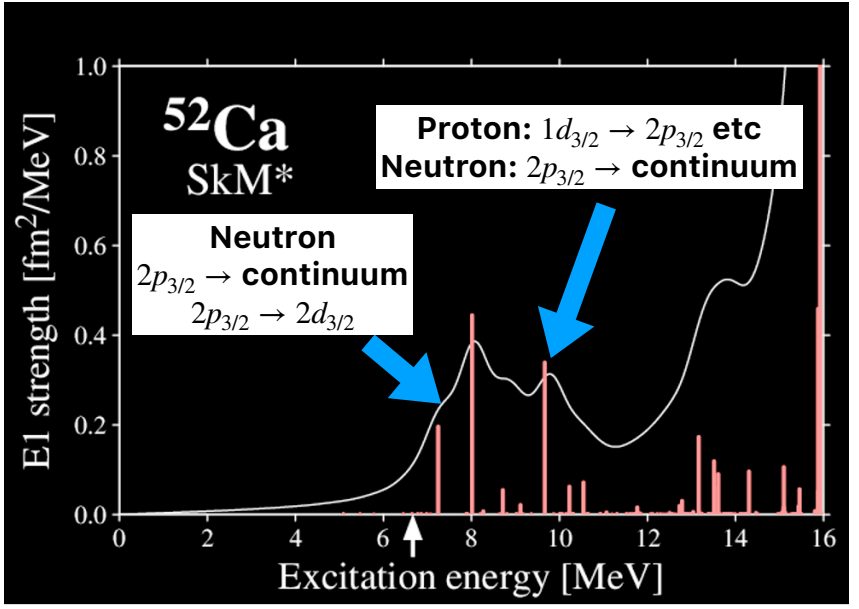
$2p_{3/2} \rightarrow 2d_{3/2}$ or $2d_{5/2}$

PDR2: many components

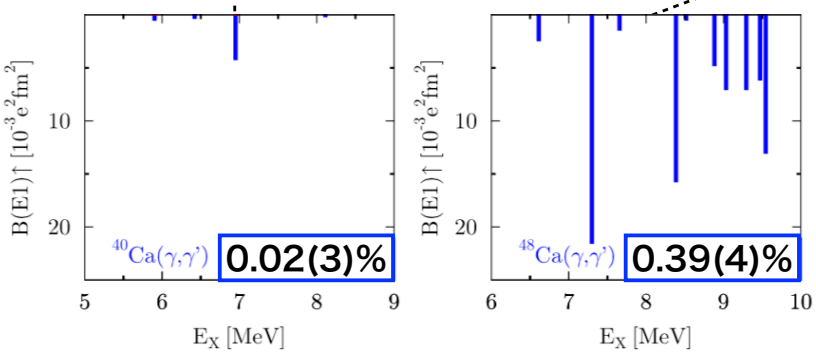
Two different peaks at low excitation energy



RPA calculation (Courtesy of Inakura-san)



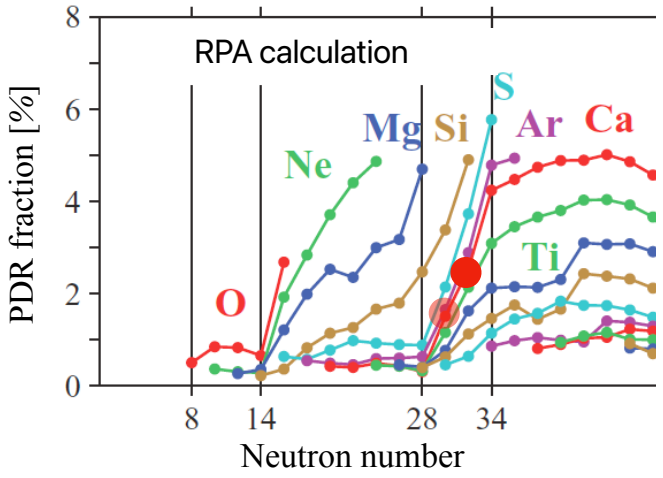
Is there sudden change on PDR in Ca isotope chain?



V. Derya et al., PLB 730, 288 (2014).

Summary and outlook

- Relativistic Coulomb excitation of ^{52}Ca → dipole response of ^{52}Ca.
  - 2 peaks at low Ex above Sn: Candidates of PDR.
    - Different widths → different structures.
  - GDR parameters: to be extracted ← analyzing ^{52}Ca(γ,3n) channel.
- ^{50}Ca data: analysis in progress.



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