B(E1) distributions from Coulomb-dominated break-up cross sections with XCDCC

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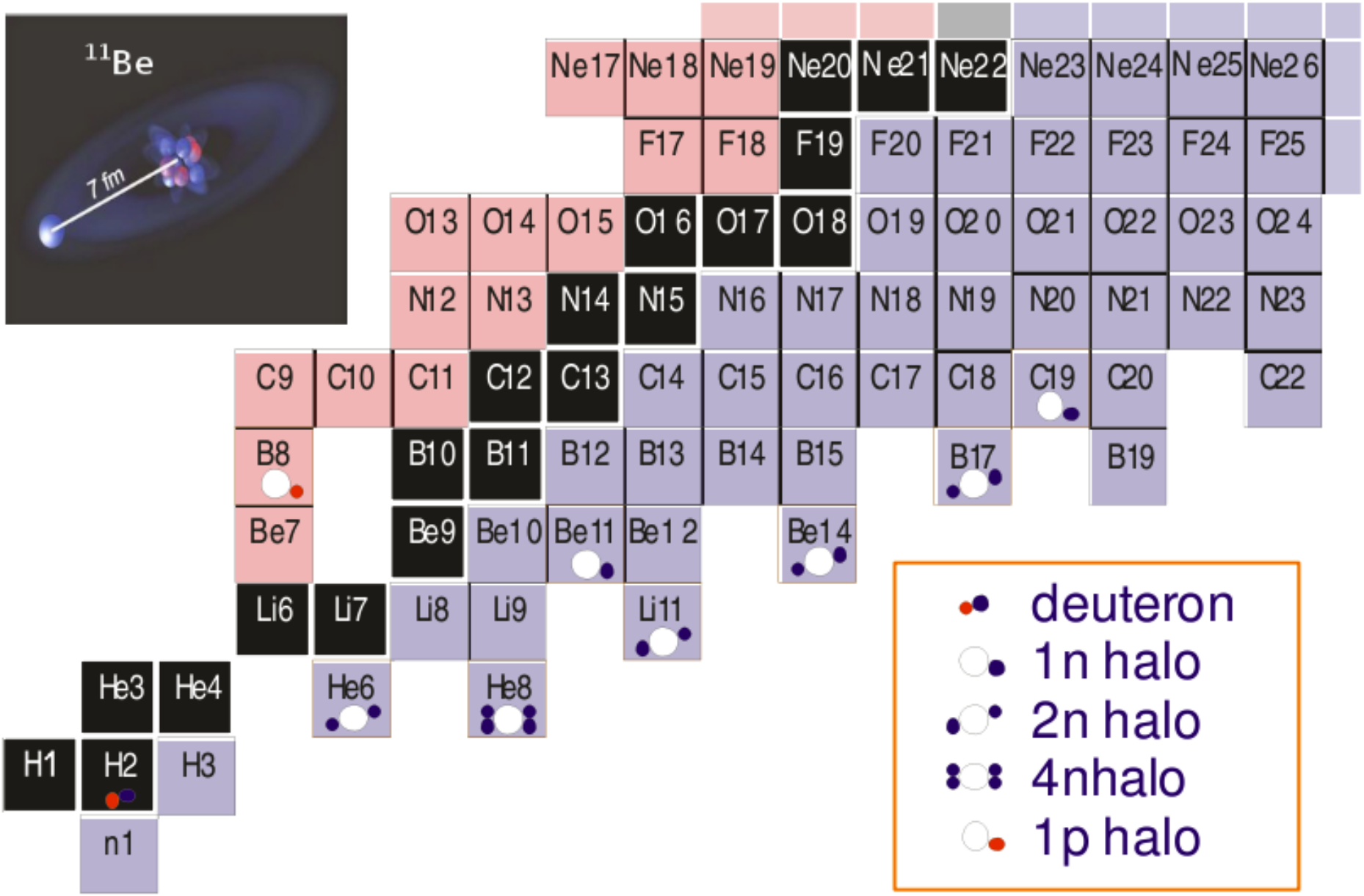
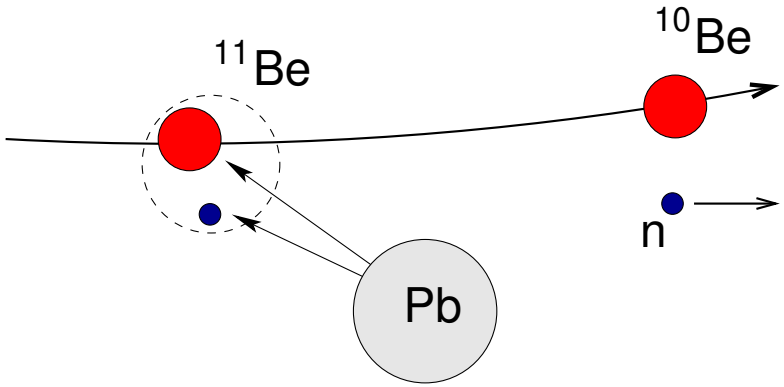
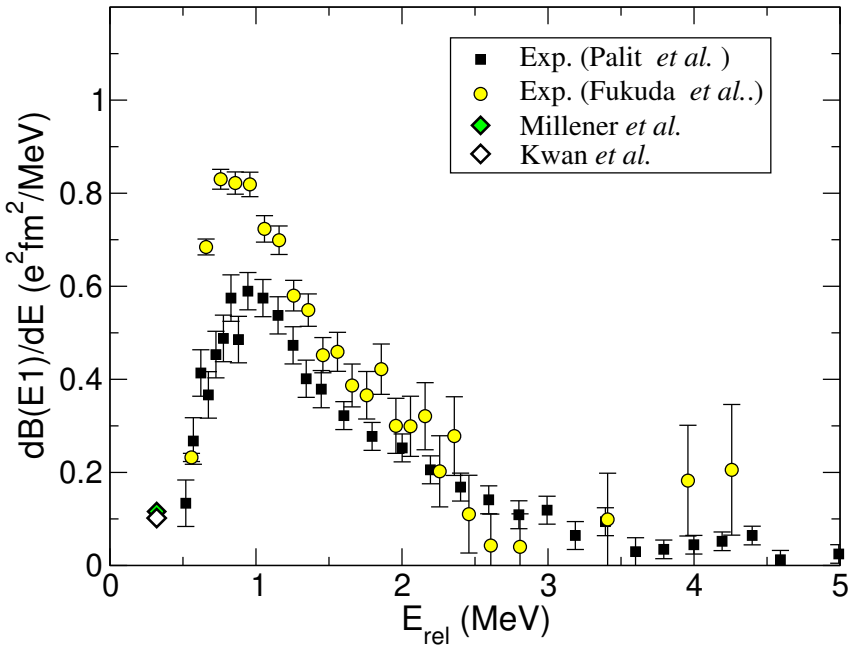
1. Motivation
2. Dipole polarizability in Halo Nuclei
3. Applications
   - ^{11}Be
   - ^{19}C - Work in progress
4. Conclusions


11Be
7 fm
Ne17 Ne18 Ne19 Ne20 Ne21 Ne22 Ne23 Ne24 Ne25 Ne26
F17 F18 F19 F20 F21 F22 F23 F24 F25
O13 O14 O15 O16 O17 O18 O19 O20 O21 O22 O23 O24
N12 N13 N14 N15 N16 N17 N18 N19 N20 N21 N22 N23
C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C22
B8 B10 B11 B12 B13 B14 B15 B17 B19
Be7 Be9 Be10 Be11 Be12 Be14
Li6 Li7 Li8 Li9 Li11
He3 He4 He6 He8
H1 H2 H3
n1
deuteron
1n halo
2n halo
4nhalo
1p halo

A long-standing problem...



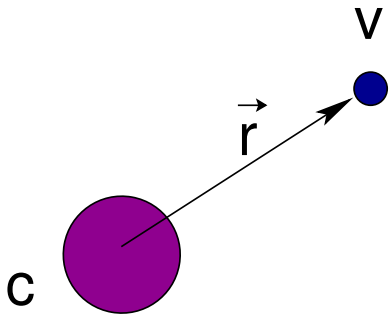


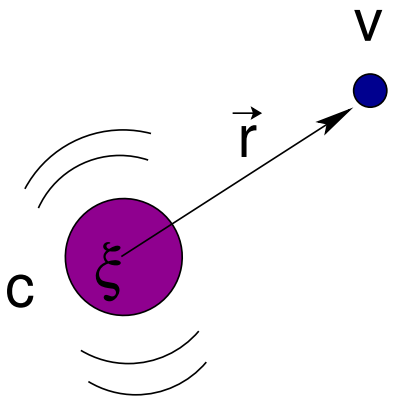
Palit *et al* PRC68 (2003) 034318
Fukuda *et al* PRC70 (2004) 054606

Equivalent Photon Method

⇒ Only includes first order Coulomb excitation.

$$\left.\frac{d\sigma_\lambda}{d\Omega\, dE}\right|_{bu} = \frac{4\pi^3}{9}\frac{d\mathcal{B}(E1)}{dE}\frac{dN_{E1}}{d\Omega}$$





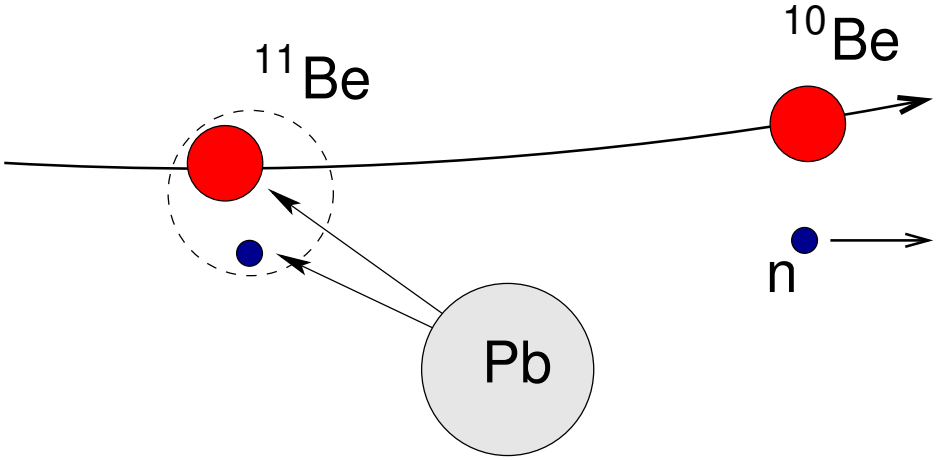
x No core excitations

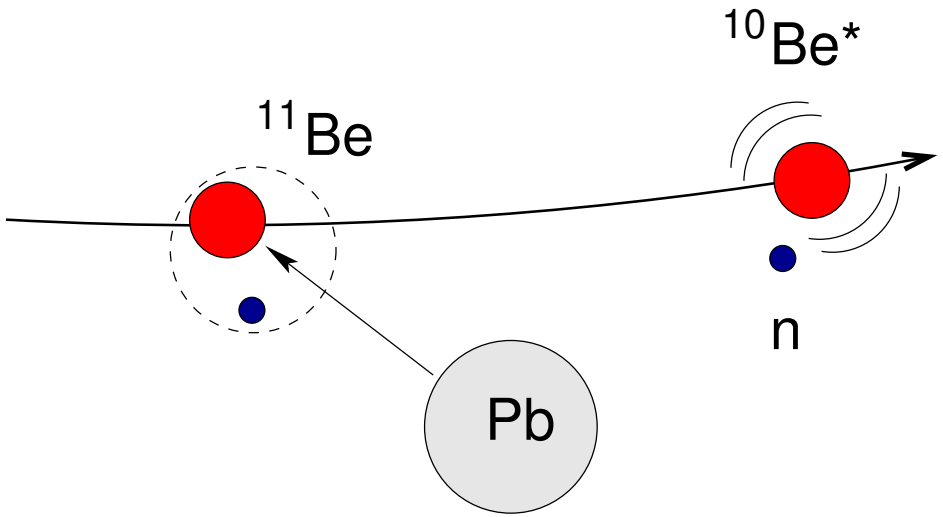
$$1/2^+ = |^{10}\text{Be}(0^+ \text{ g.s.}) \otimes \nu\, s_{1/2}\rangle$$

✓ Core excitations

$$1/2^+ = \alpha|^{10}\text{Be}(0^+ \text{ g.s.}) \otimes \nu s_{1/2}\rangle + \beta|^{10}\text{Be}(2^+) \otimes \nu d_{5/2}\rangle + \ldots$$

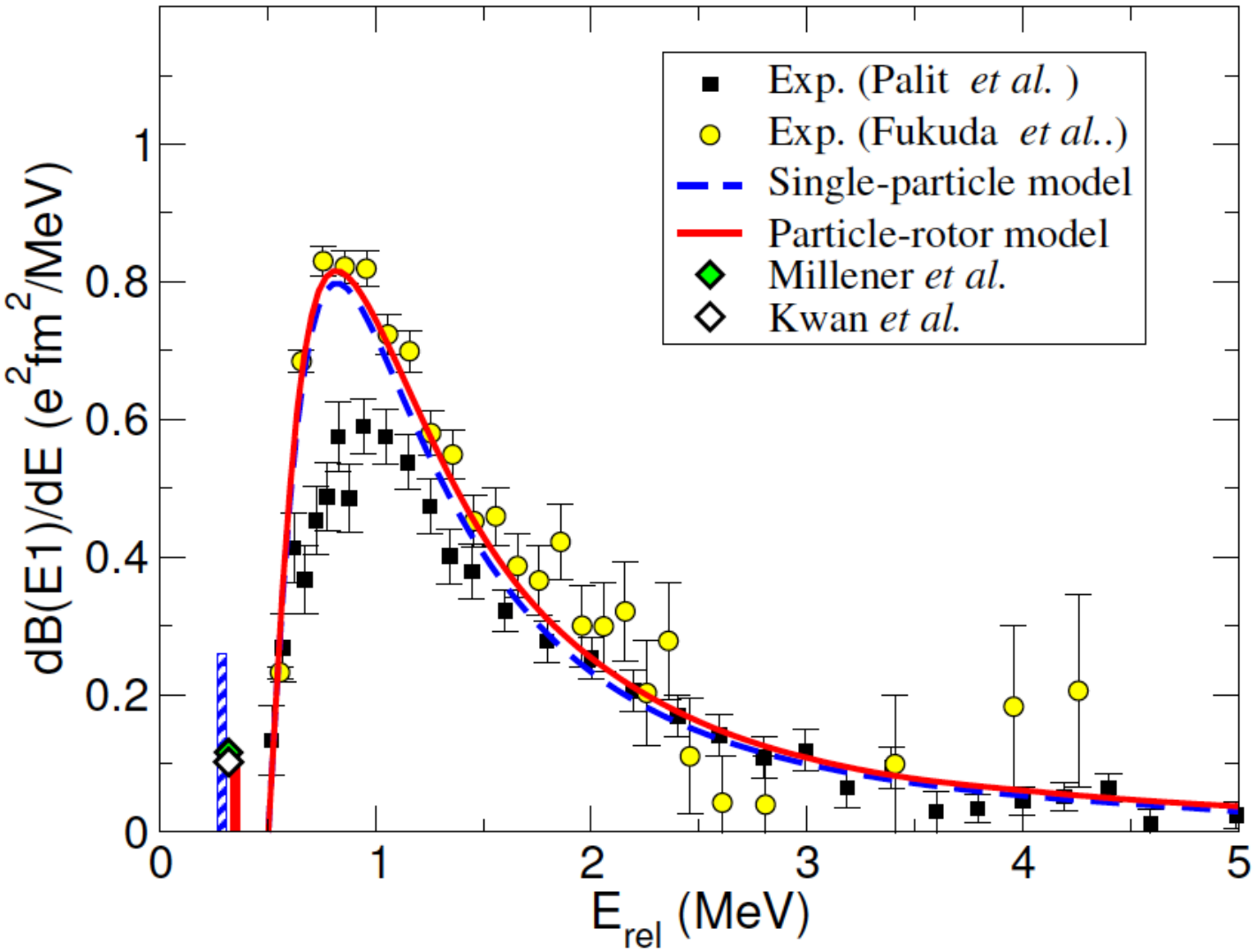
α^2, β^2 = spectroscopic factors

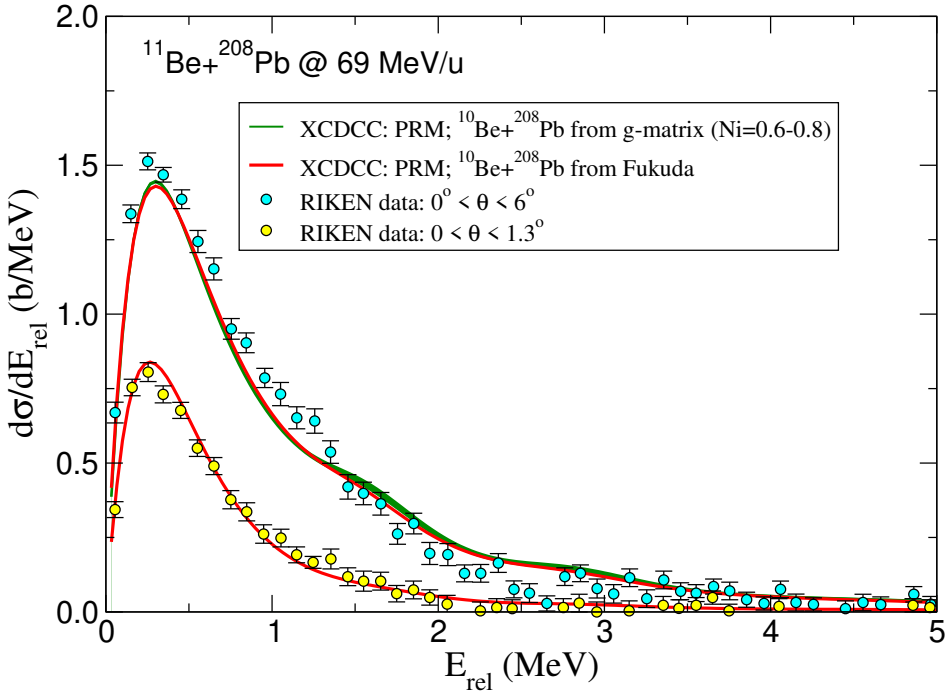


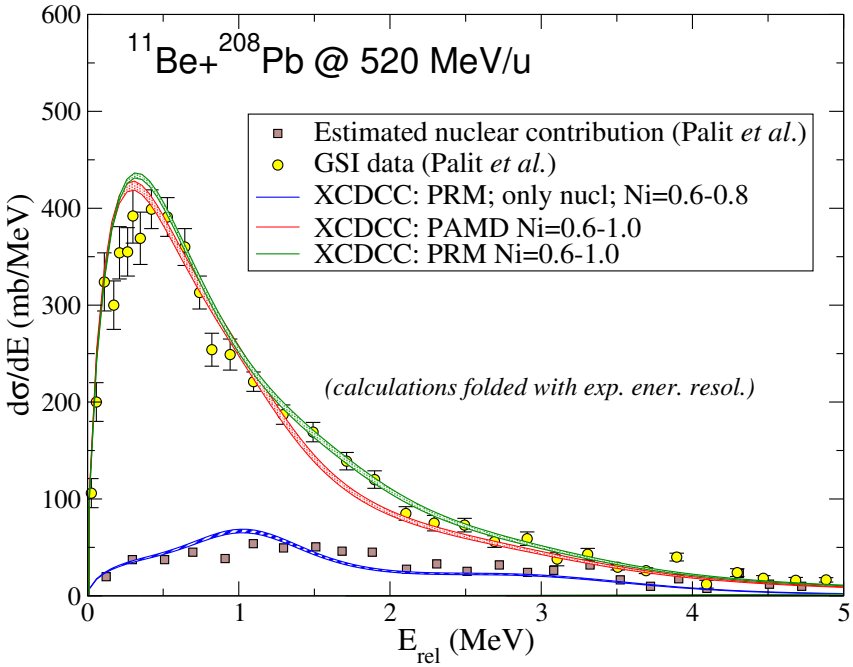


✗ Pure valence excitation
CDCC

✓ Core-excitation mechanism
XCDCC

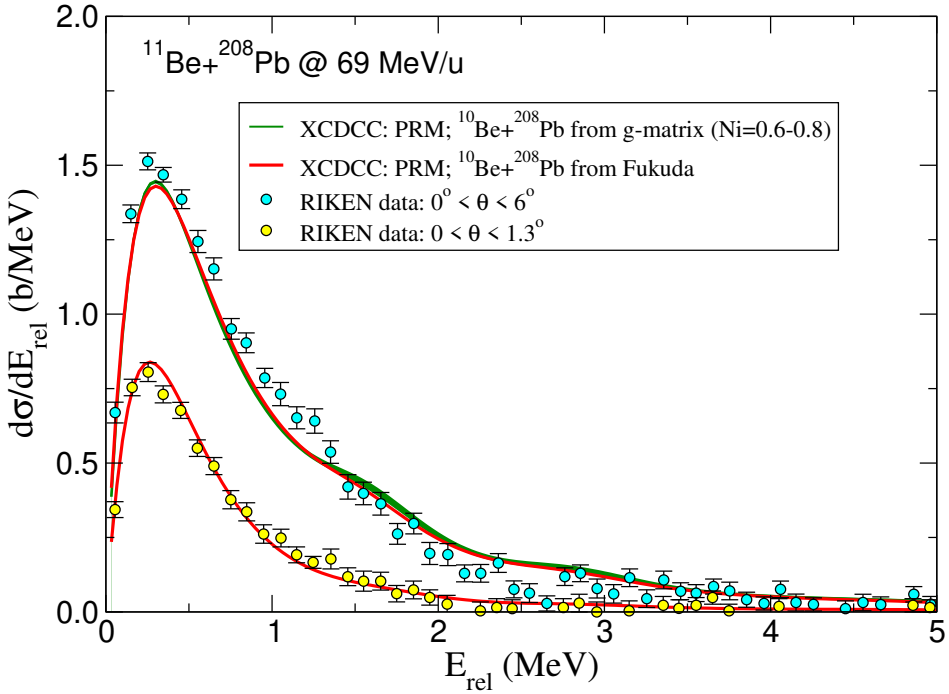

Exp. (Palit et al.)
Exp. (Fukuda et al..)
Single-particle model
Particle-rotor model
Millener et al.
Kwan et al.
dB(E1)/dE (e2fm2/MeV)
Erel (MeV)
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5

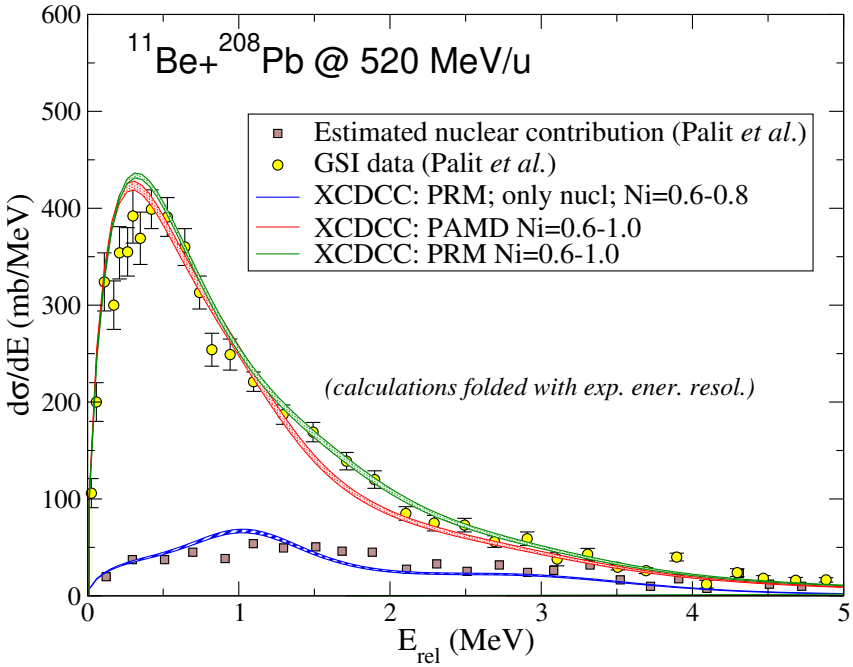




⇒ XCDCC includes:

- full order Coul.+Nucl.
- Both Valence + Core excitations



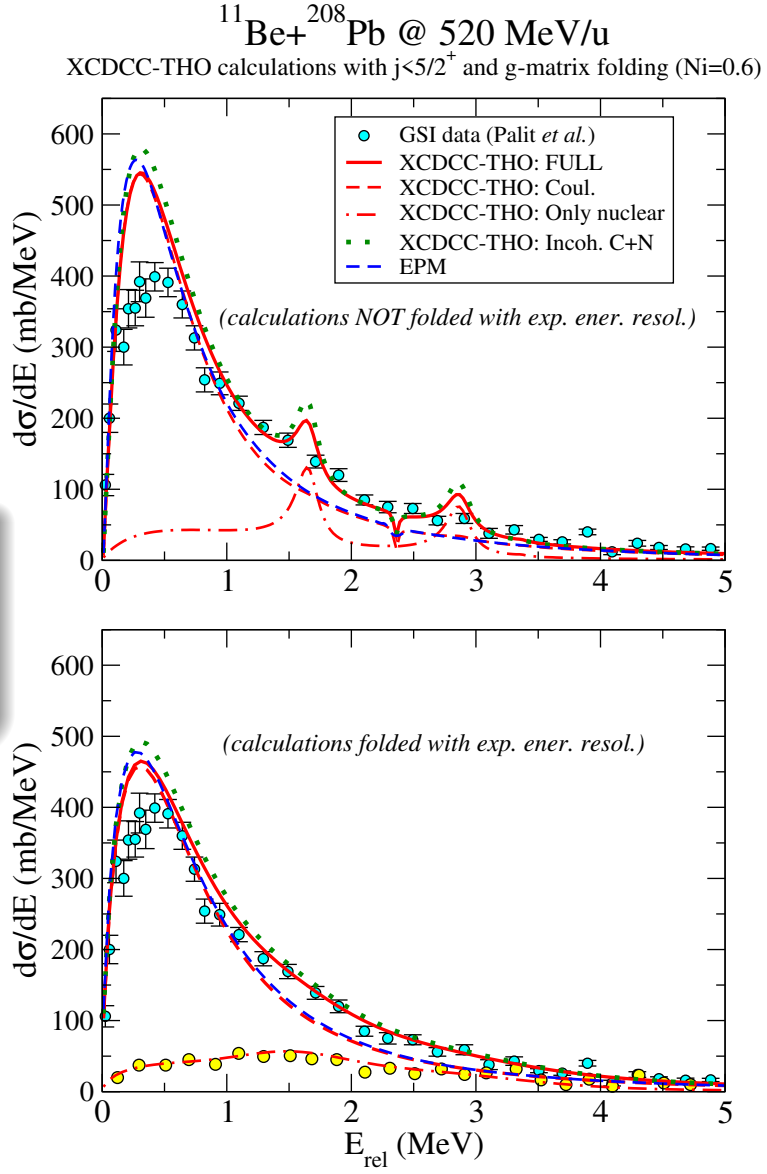


⇒ XCDCC includes:

- full order Coul.+Nucl.
- Both Valence + Core excitations

Different source of deviation:

- Convolution with exp. resolution
- Nucl. contributions
- Coul-Nucl interference
- Second order processes



Larger deviation from:

- Convolution with exp. resolution
- Coul-Nucl interference

? Can we extract the B(E1) better?

$$M^m(E1,\varepsilon_i) \simeq M^0(E1,_i)(1+\delta(\varepsilon_i)),$$

$$B^m(E1,\varepsilon_i) \simeq B^0(E1,\varepsilon_i)(1+2\delta(\varepsilon_i)),$$

$$\sigma_i^m \simeq \sigma_i^0 + \delta(\varepsilon_i)\,\sigma'_i.$$

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$$\sigma_i^m \simeq \sigma_i^0 + \delta(\varepsilon_i)\,\sigma'_i.$$

I can invert the relation:

$$B^m(E1,\varepsilon_i) \simeq B^0(E1,\varepsilon_i)\left(1+2\frac{\sigma_i^m-\sigma_i^0}{\sigma'_i}\right).$$

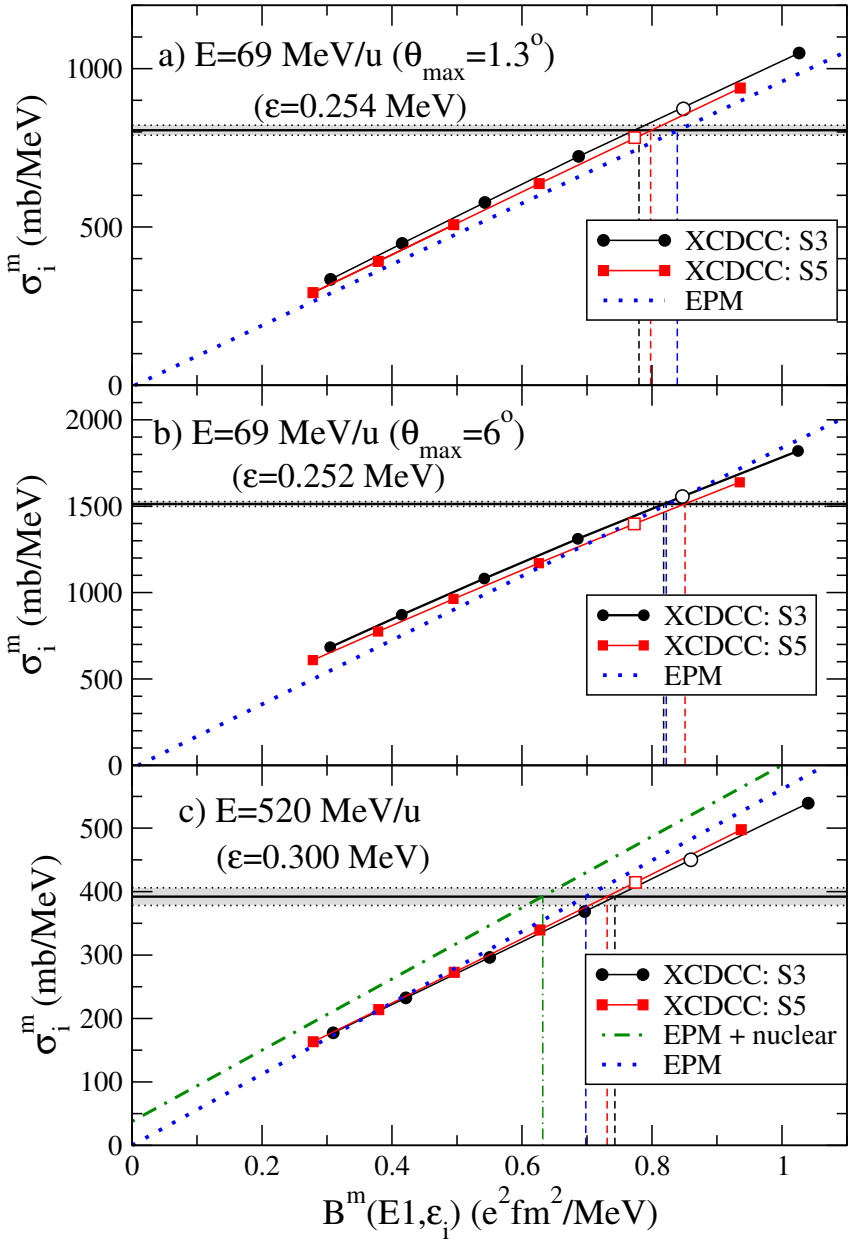
And if you want to arrive to the experimental cross section:

$$B^e(E1,\varepsilon_i) \simeq B^0(E1,\varepsilon_i)\left(1+2\frac{\sigma_i^e-\sigma_i^0}{\sigma'_i}\right).$$

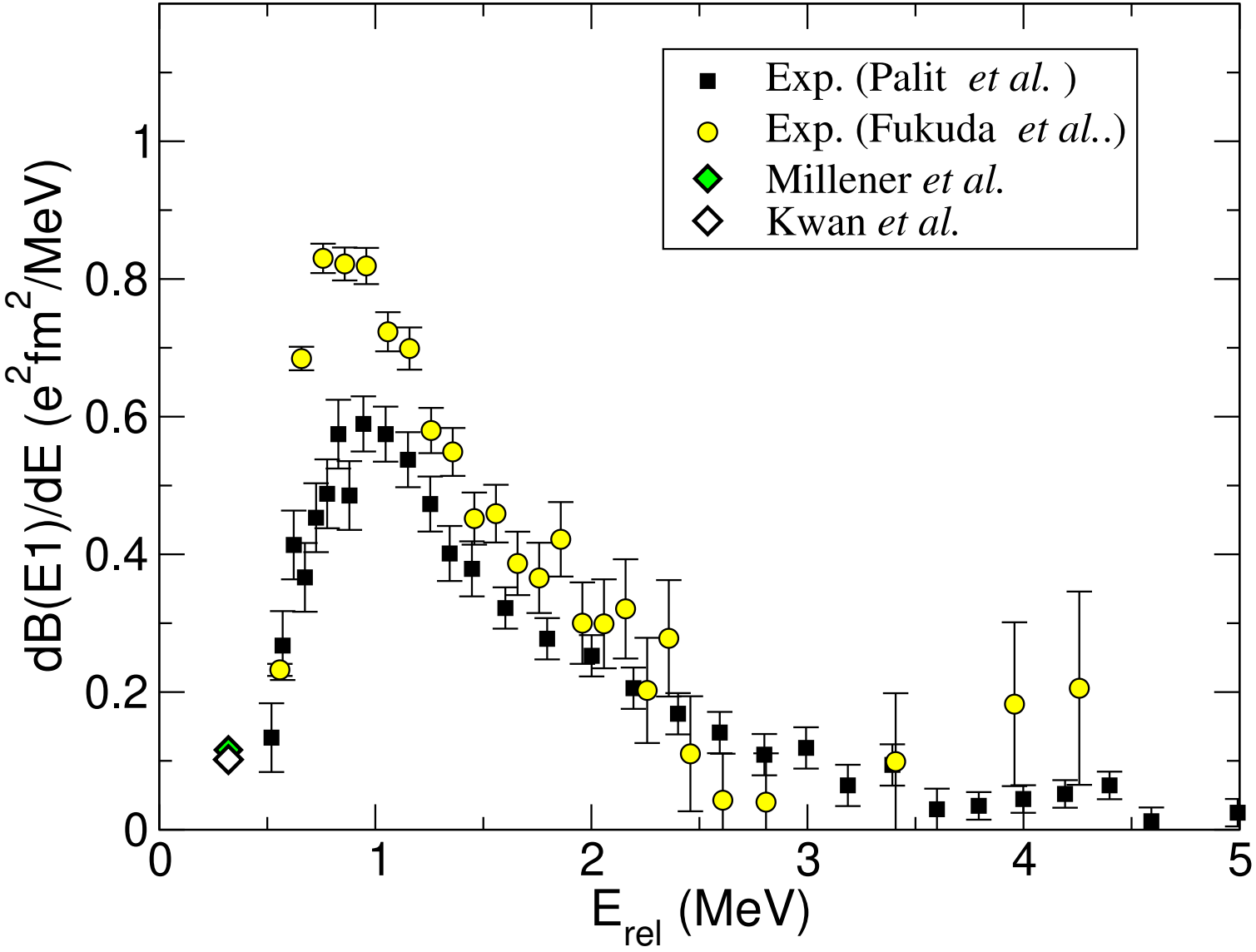
? Is it really linear?

$$B^m(E1,\varepsilon_i) \simeq B^0(E1,\varepsilon_i)\,(1+2\delta(\varepsilon_i))\,.$$

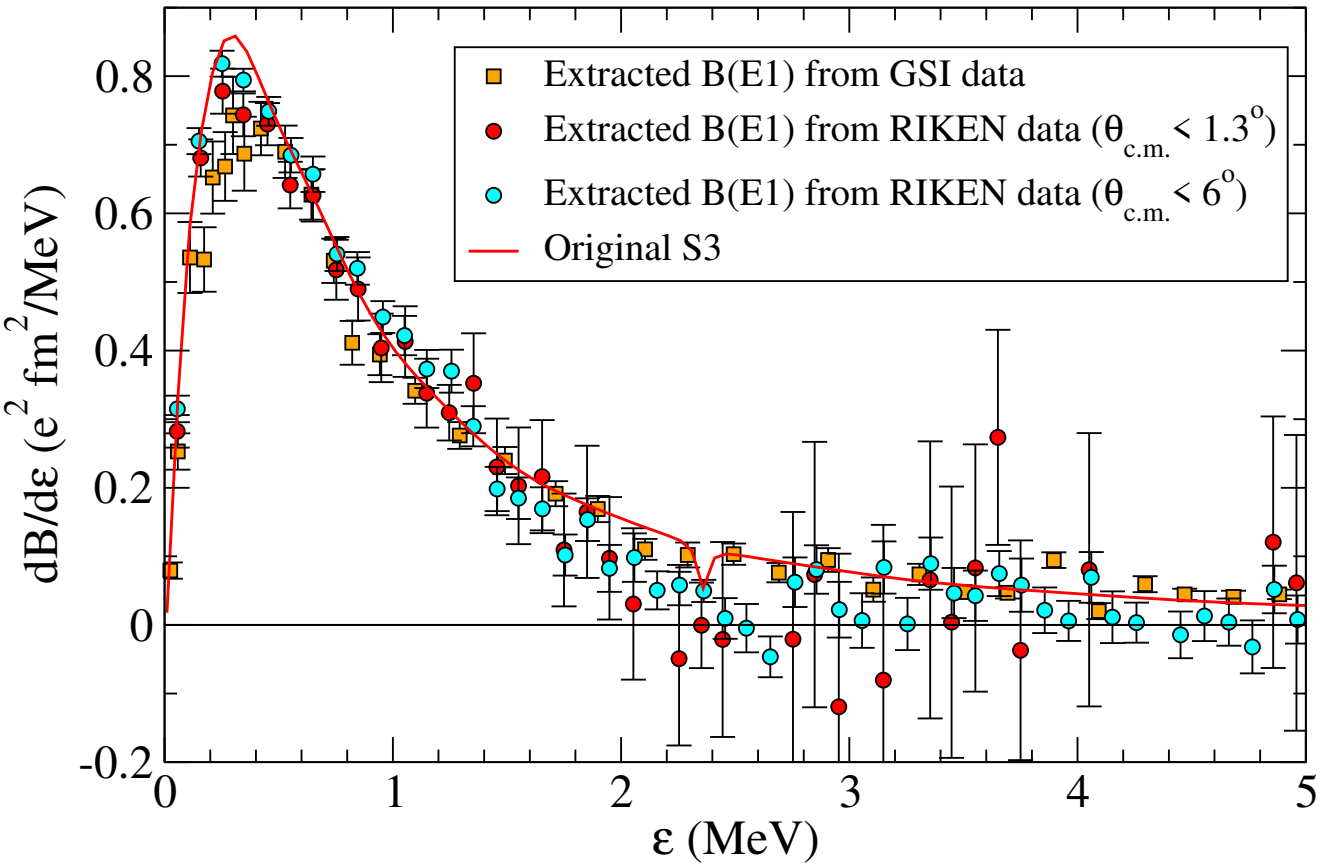
$$\sigma_i^m \simeq \sigma_i^0 + \delta(\varepsilon_i)\,\sigma'_i.$$



A long-standing problem...



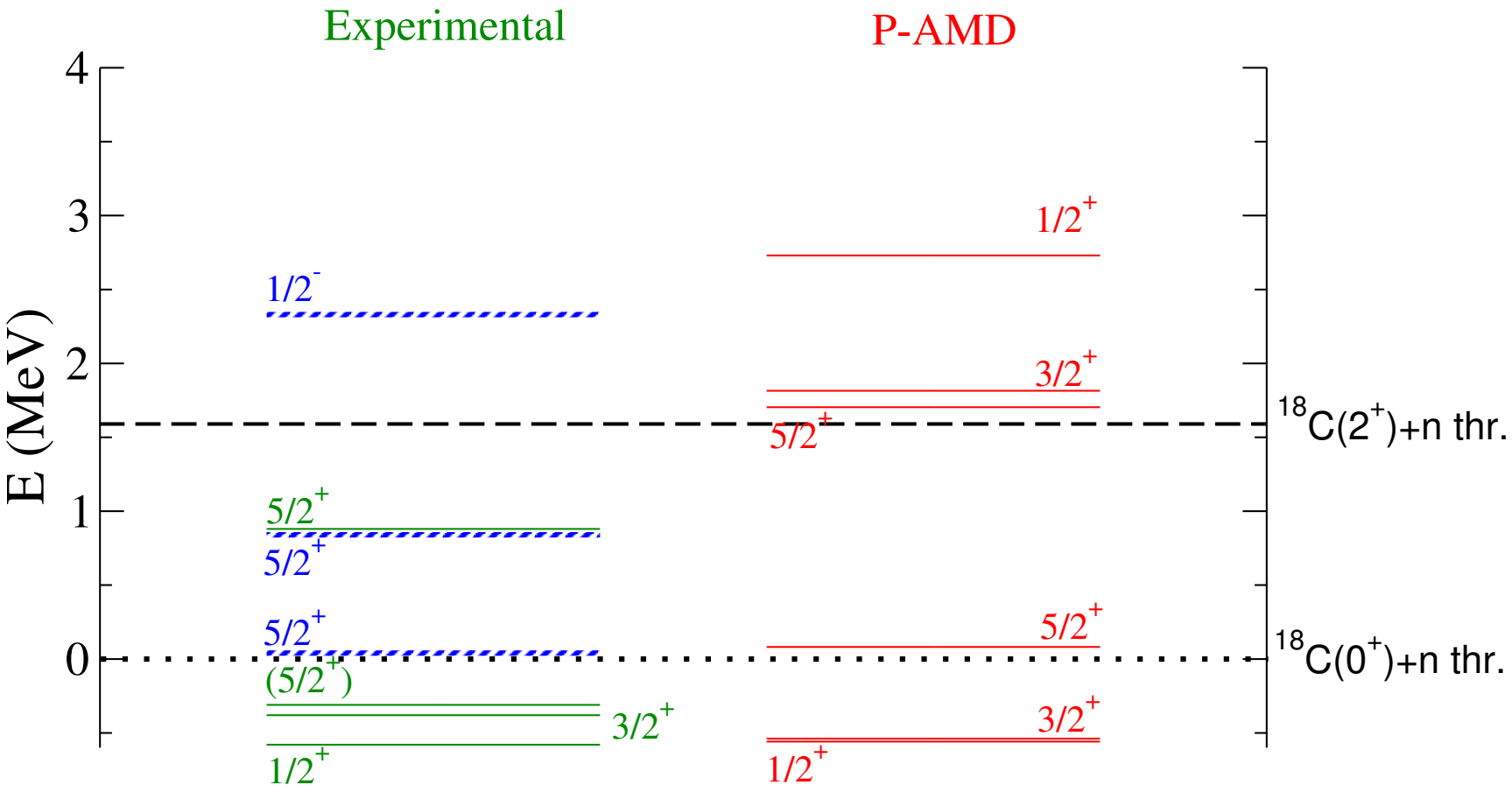
A long-standing problem... No more.



⇒ And it does not depend on experimental resolution (up to a point)

A. M. Moro, J. A. Lay, J. Gómez-Camacho PLB811, 135959 (2020)

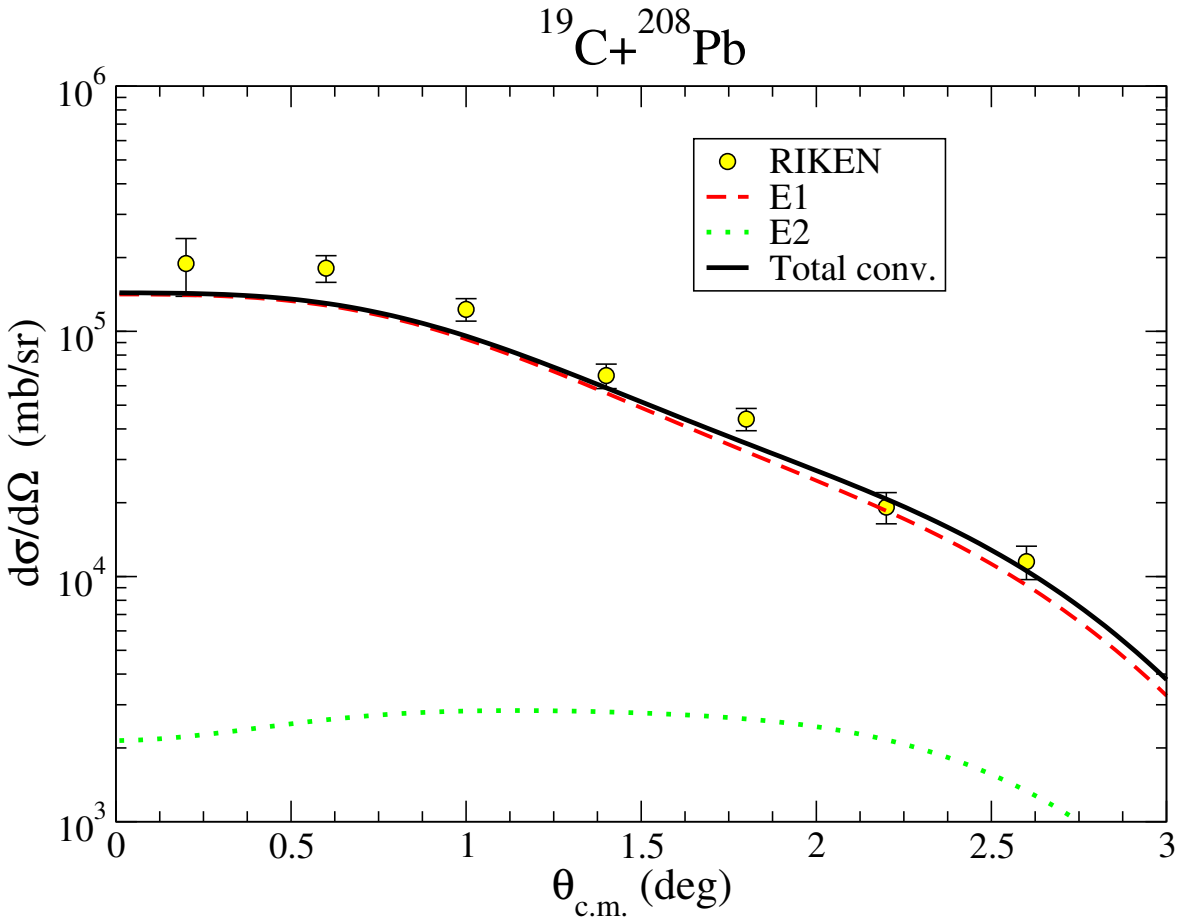
^{19}C Spectrum



PLB660, 320 (2008); PLB 614, 174 (2005); PLB 769, 503 (2017)
J. A. Lay *et al* PRC89, 014333 (2014)

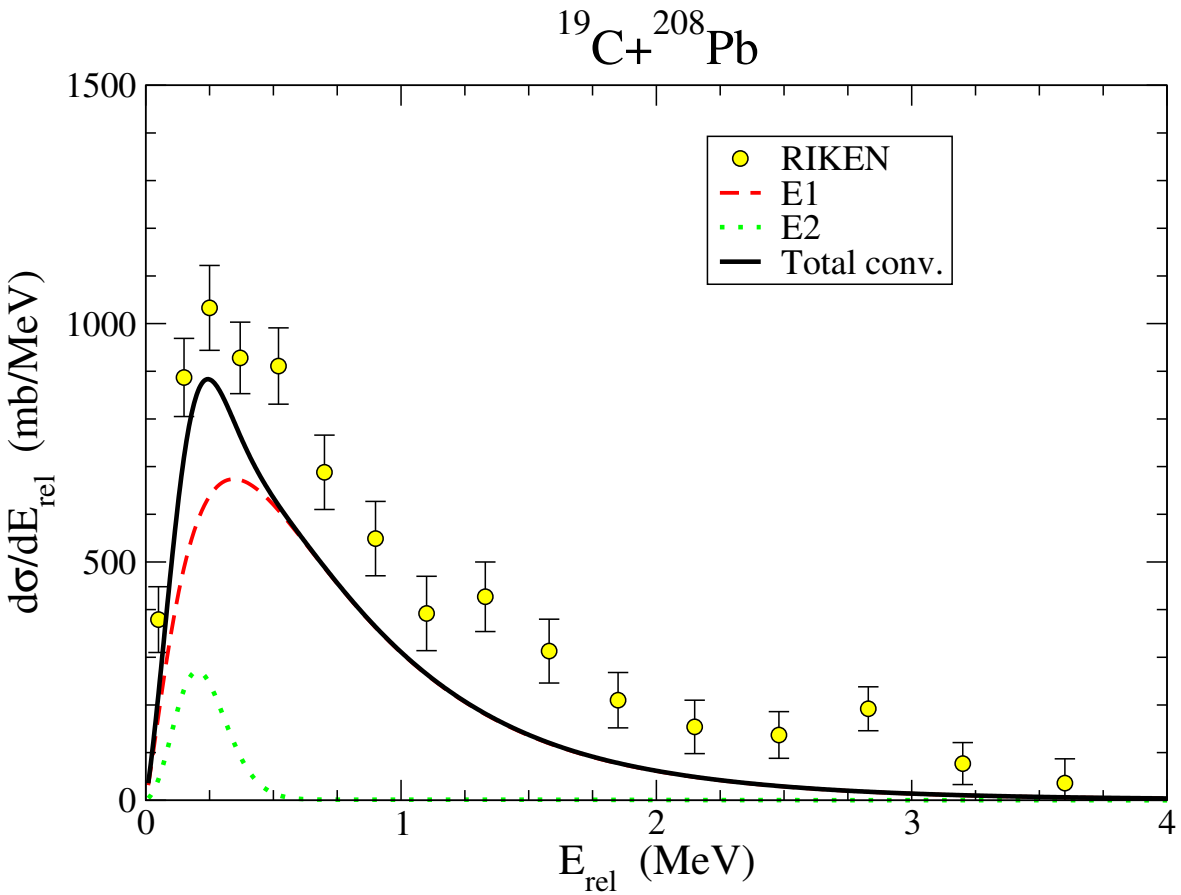
^{19}C+^{208}Pb @ 67 MeV/u

T. Nakamura *et al.*, Phys. Rev. Lett. 83, 1112 (1999).



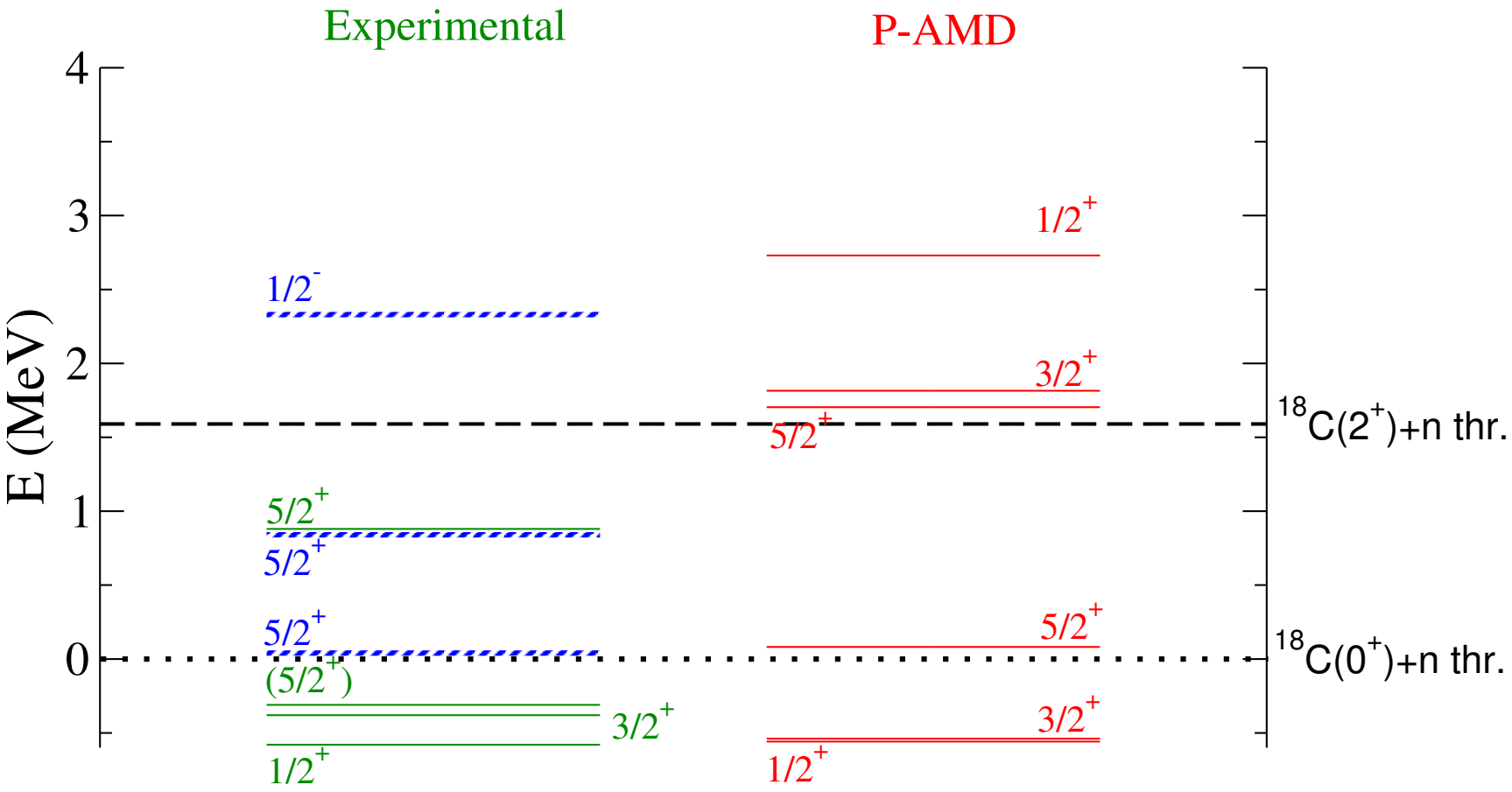
- The reaction is dominated by E1 first order Coulomb excitation as expected

^{19}C+^{208}Pb @ 67 MeV/u



- Resonant E2 contribution more important due to its low excitation energy

^{19}C Spectrum



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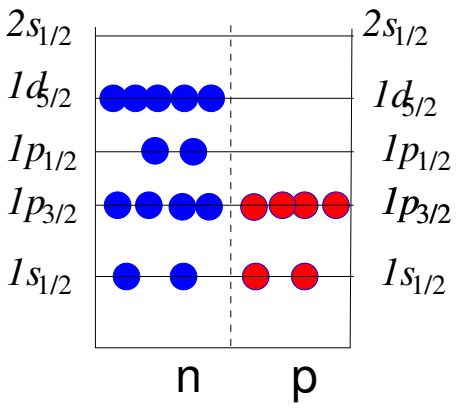
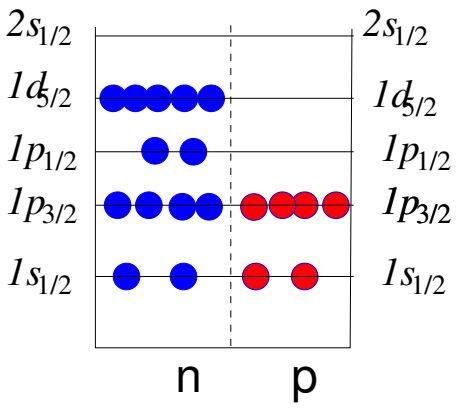
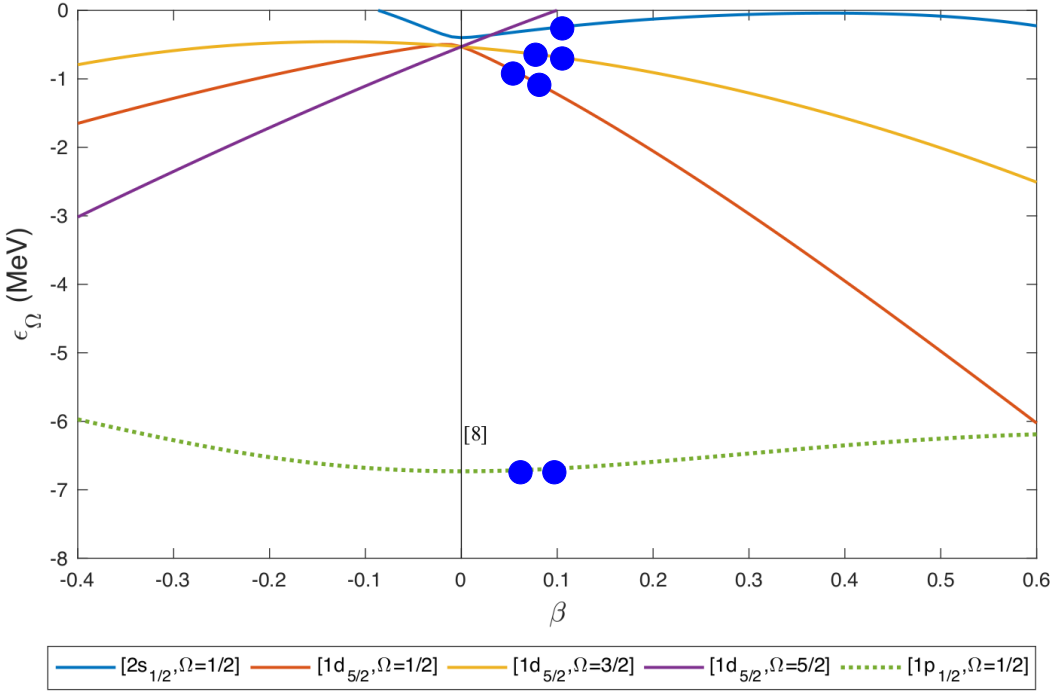
J. A. Lay *et al* PRC89, 014333 (2014)

Level scheme for ^{19}C



Level scheme for ^{19}C





$$H_{sp}|\phi_{i\Omega}\rangle = \varepsilon_{i\Omega}|\phi_{i\Omega}\rangle$$

$$|\phi_{i\Omega}\rangle = \sum_{nj} C^{i\Omega}_{nj}|n(ls)j\rangle$$

⇒ See poster by P. Punta

Conclusions

- ⇒ The proposed method allows the extraction of B(E1) by using XCDCC
- ⇒ It allows to handle Coulomb-Nuclear interference
- ⇒ it does not depend on experimental resolution (up to a point)

- ⇒ Quadrupole resonances will play a role in the Coulomb excitation of halo nuclei through core excitations

Thank you!!

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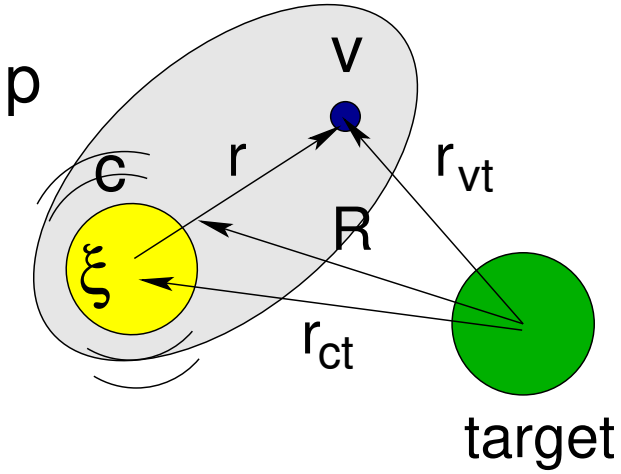
Coupling potentials: CDCC vs. XCDCC



- Standard CDCC. ⇒ uses coupling potentials:

$$V_{\alpha;\alpha'}(\vec{R}) = \langle \Psi^{\alpha'}_{J'M'}(\vec{r}) | V_{vt}(r_{vt}) + V_{ct}(r_{ct}) | \Psi^{\alpha}_{JM}(\vec{r}) \rangle$$

- Extended CDCC ⇒ uses generalized coupling potentials

$$V_{\alpha;\alpha'}(\vec{R}) = \langle \Psi^{\alpha'}_{J'M'}(\vec{r},\xi) | V_{vt}(\vec{r}_{vt}) + V_{ct}(\vec{r}_{ct},\xi) | \Psi^{\alpha}_{JM}(\vec{r},\xi) \rangle$$

R. de Diego *et al*, PRC89 (2014) 064609 (PS discretization)
also for binning Summers *et al*, PRC74 (2006) 014606