On the measurement of $^{8}B+^{64}Zn$ to investigate the proton halo dynamics

Roberta Spartà

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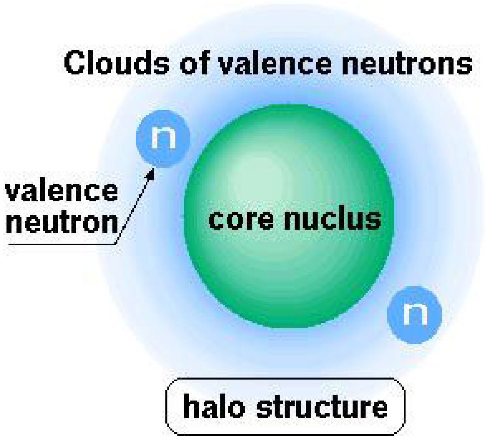
Motivation: effects of halo structure on reaction dynamics



Halo nuclei:
small binding energy, low breakup thresholds

coupling to breakup states (continuum) important → CDCC

The n-halo cases: e.g. ^{11}Li, ^{11}Be, ^{6}He

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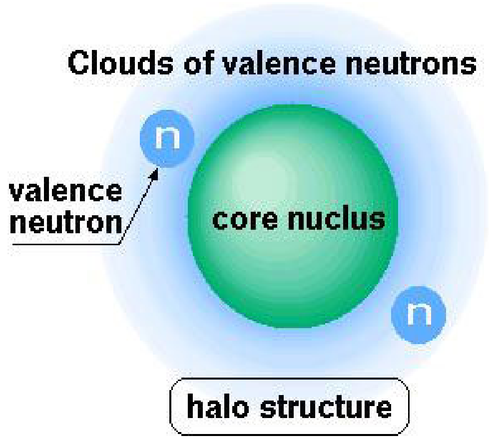

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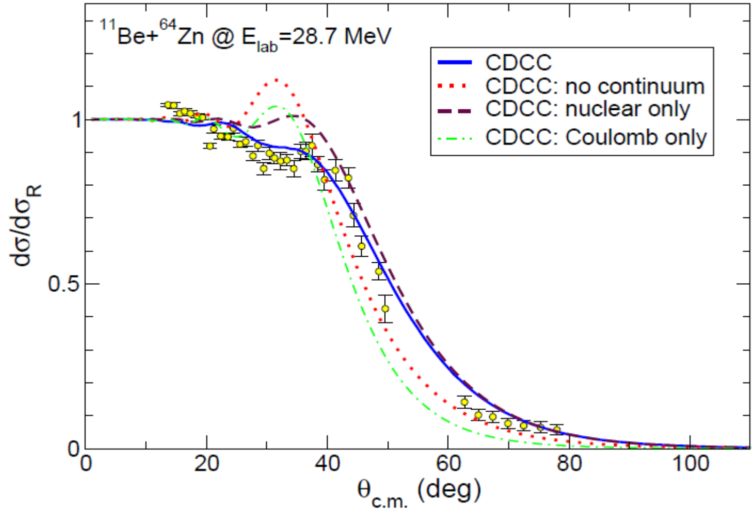
Elastic scattering

^{11}Be+^{64}Zn ISOLDE experiment

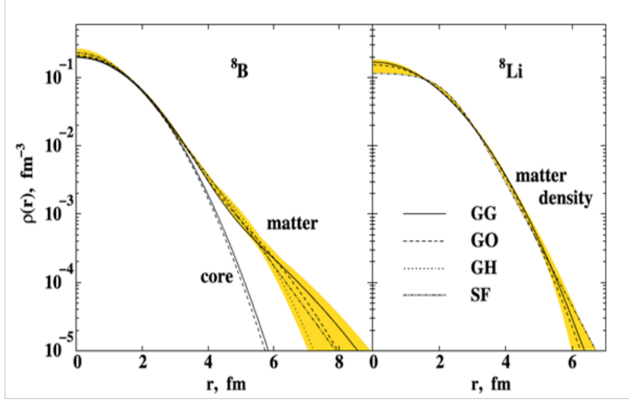


A. Di Pietro et al., PRL 105,022701(2010) & PRC 85, 054607 (2012)

Coulomb and nuclear long range absorption effects because of the halo.

The p-halo case: ^{8}B

Weakly bound Sp=0.137 MeV
(should be easy to breakup)



G.A. Korolev et al. Phys.Lett. B 780 (2018) 200

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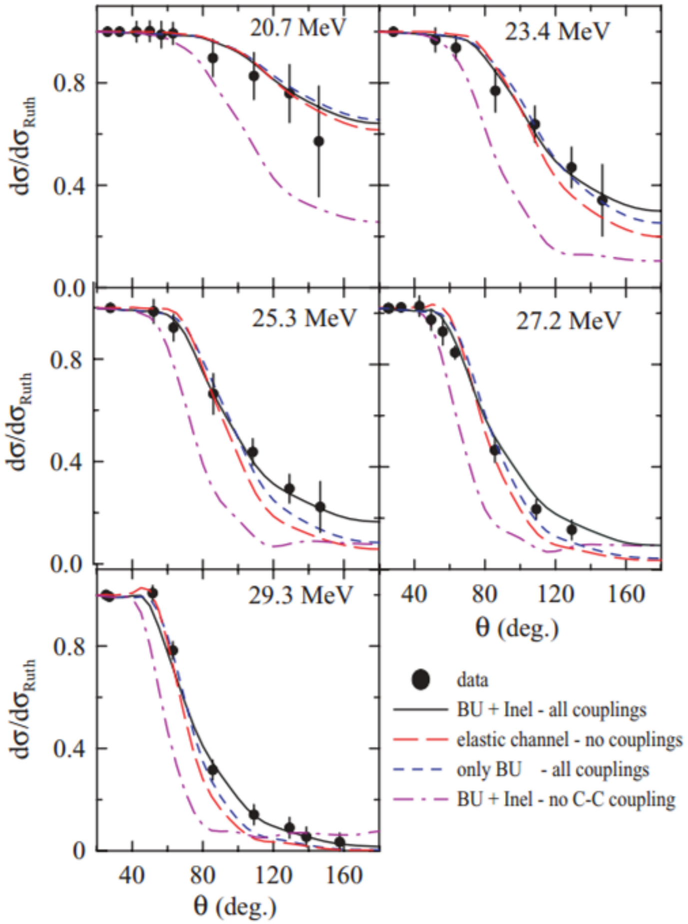
$^{8}B+^{58}Ni$ elastic scattering



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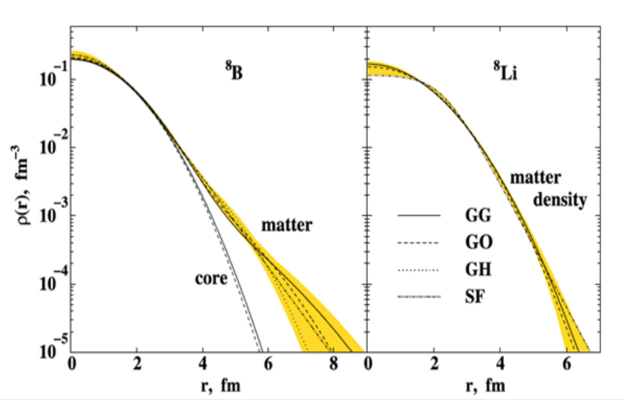

G.A. Korolev et al. Phys.Lett. B 780 (2018) 200

- ➢In-flight produced ^{8}B beam
- ➢Beam divergence = **6°**
- ➢Large angular detector opening **Δθ=12°**
- ➢No particle discrimination

J. Lubian et al PRCC 79, 064605 (2009)
data from E.F. Aguilera et al. PR C 79, 021601(R) 2009

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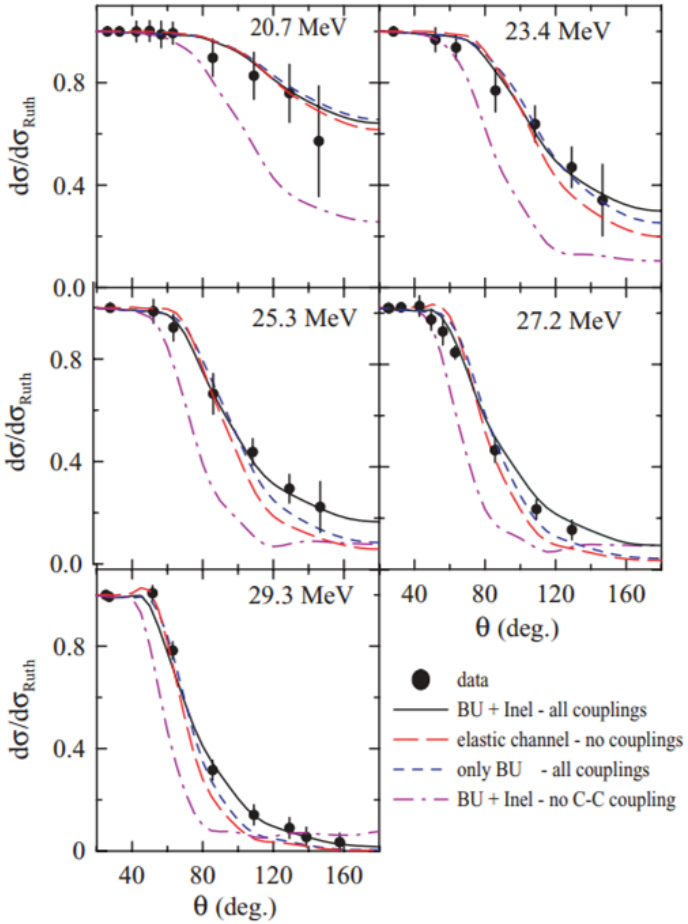

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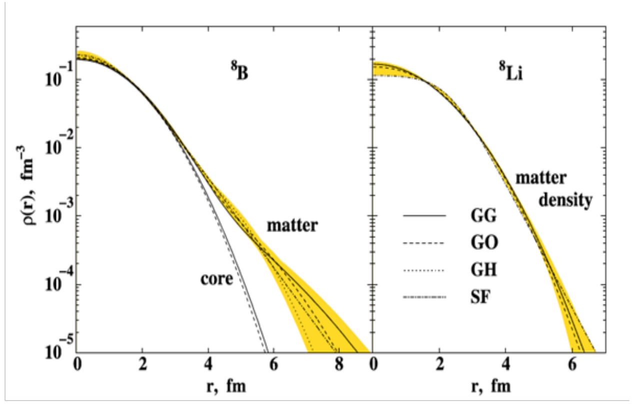

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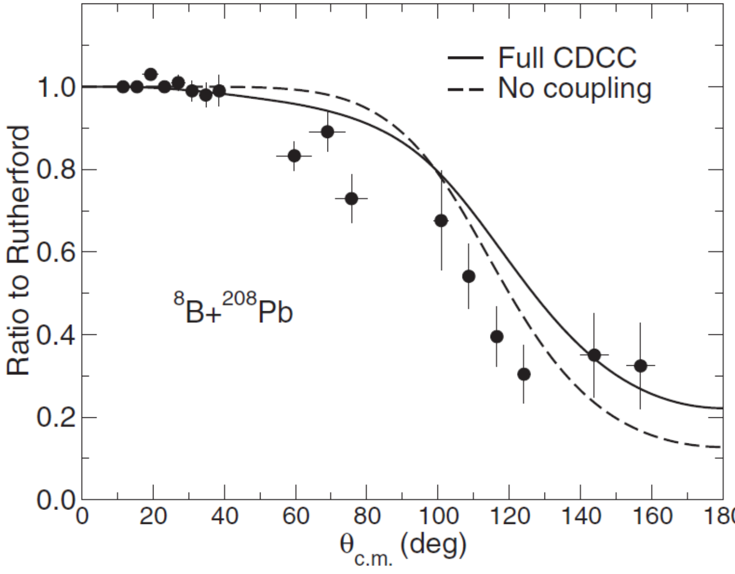


M. Mazzocco et al. PRC 100 024602 (2019)
Large σ_R with respect to other weakly bound nuclei

Scarce data in the literature.
Only in-flight beams used so far

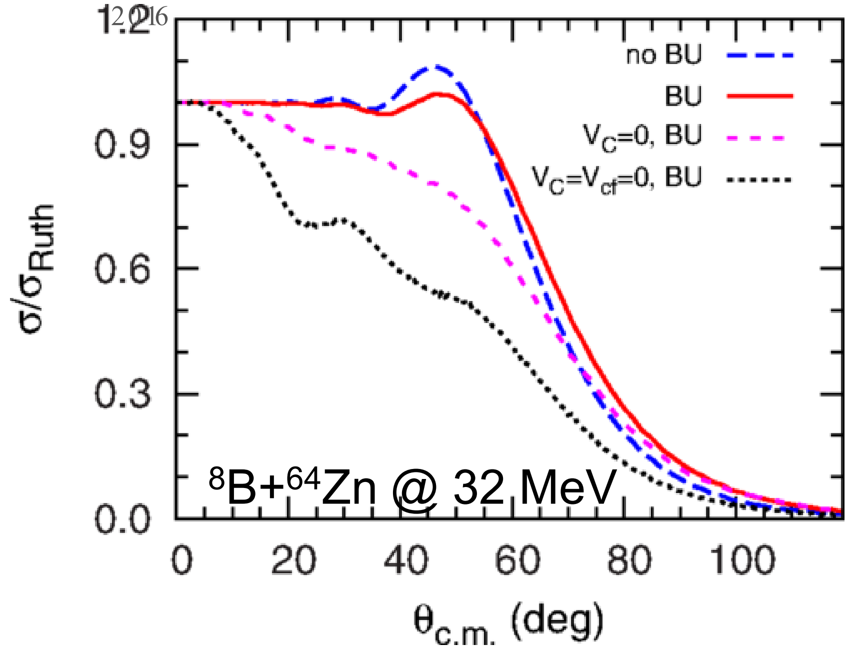
(ISOLDE has the only ISOL ^{8}B beam)

Proposed experiment

Is the total-reaction cross-section enhanced as for n-halo?

Despite of what suggested by literature,
CDCC calculations foresee small effects on the elastic cross-section.

Y. Y. Yang, X. Liu, and D. Y. Pang, Phys. Rev. C 94, 034614, 2016



barriers to overcome and undergo a BU

- *valence p of ^{8}B = p(3/2) → Coulomb (C)+ centrifugal (cf)*

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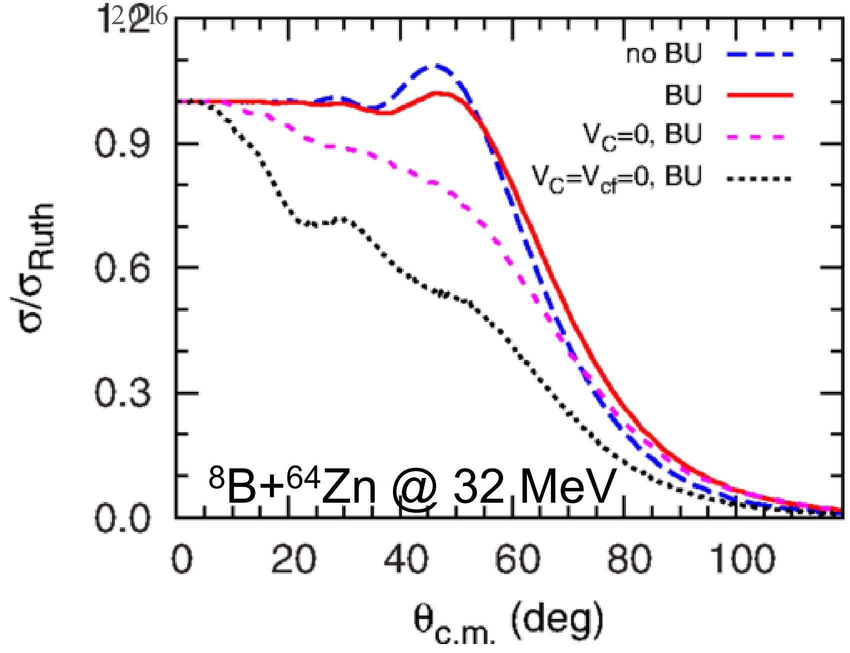

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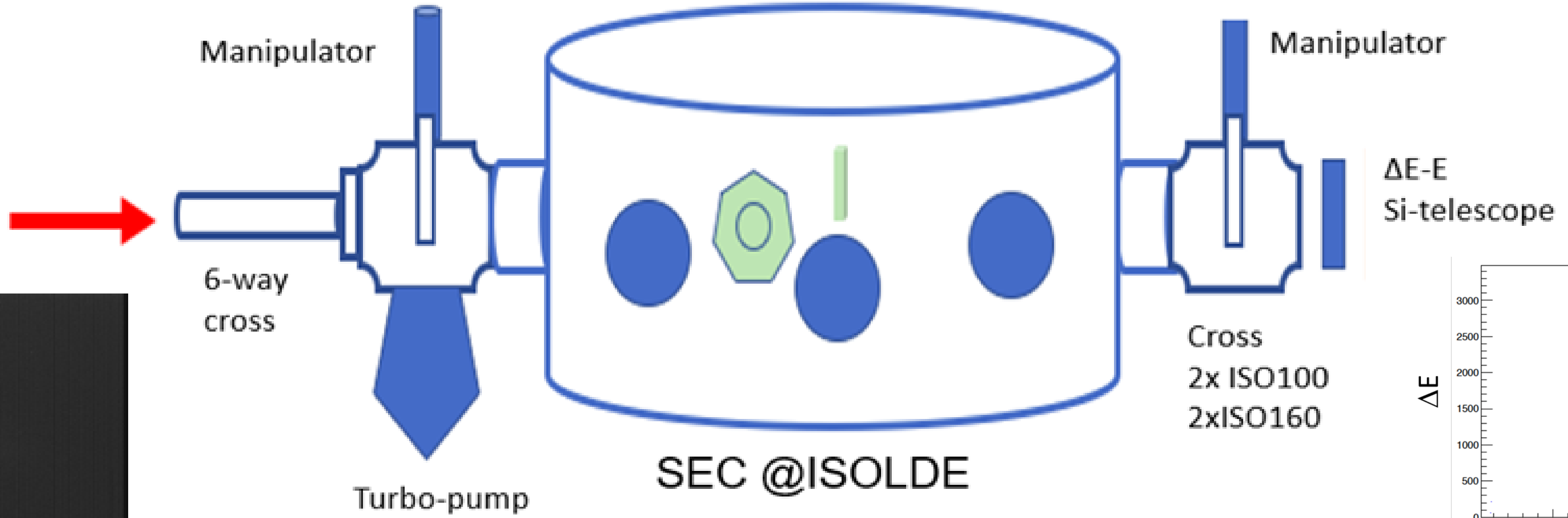
^{8}B+^{64}Zn @E_{lab}≈4.5 MeV/u @INTC 2016

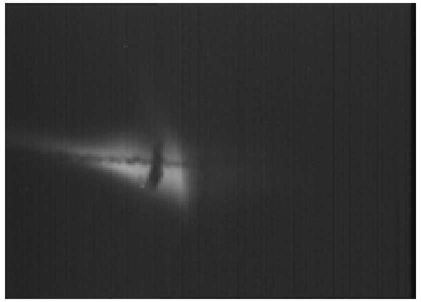
Improvements proposed:
- ^{8}B post-accelerated ISOL beam
- Large solid angle + high granularity → good angular resolution
- careful mapping of the El. Scattering angular distribution
- Be and p in singles + coincidence (first time)
→ measure and disentangle EBU/NEB (transfer, incomplete fusion….)

Entrance:
- Camera
- F-cup with current measure
- Different collimators (12,10,8 mm)

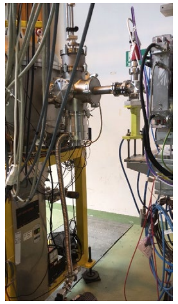
Target position:
- F-cup with current measure
- Collimators

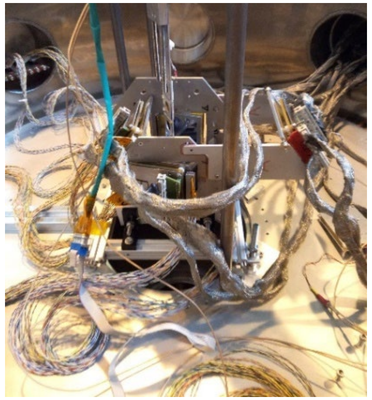
Exit:
- Pepper pots
- F-cup with current measure
- Empty

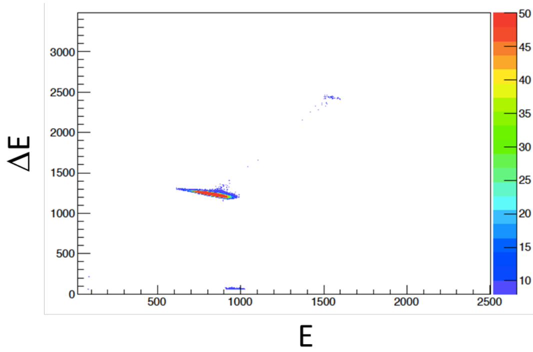




^{12}C beam







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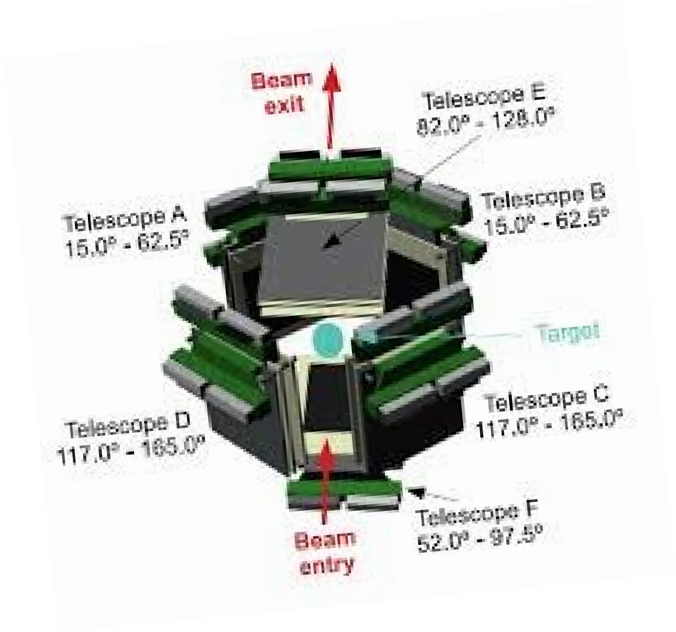
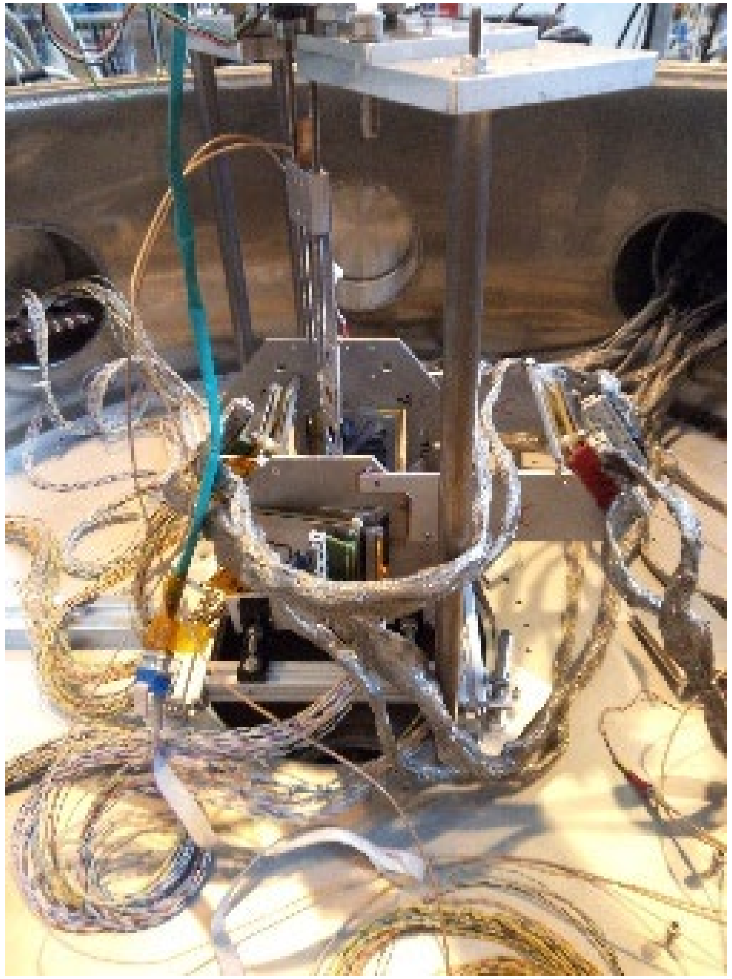
Gloria



Telescope A moved at smaller angles (5.5°<θ<23°) using an extension



Detection system:

- 2 ΔE1-ΔE2-Epad telescope θ<60°
- 4 ΔE1-E Si telescopes at θ>60°

with:

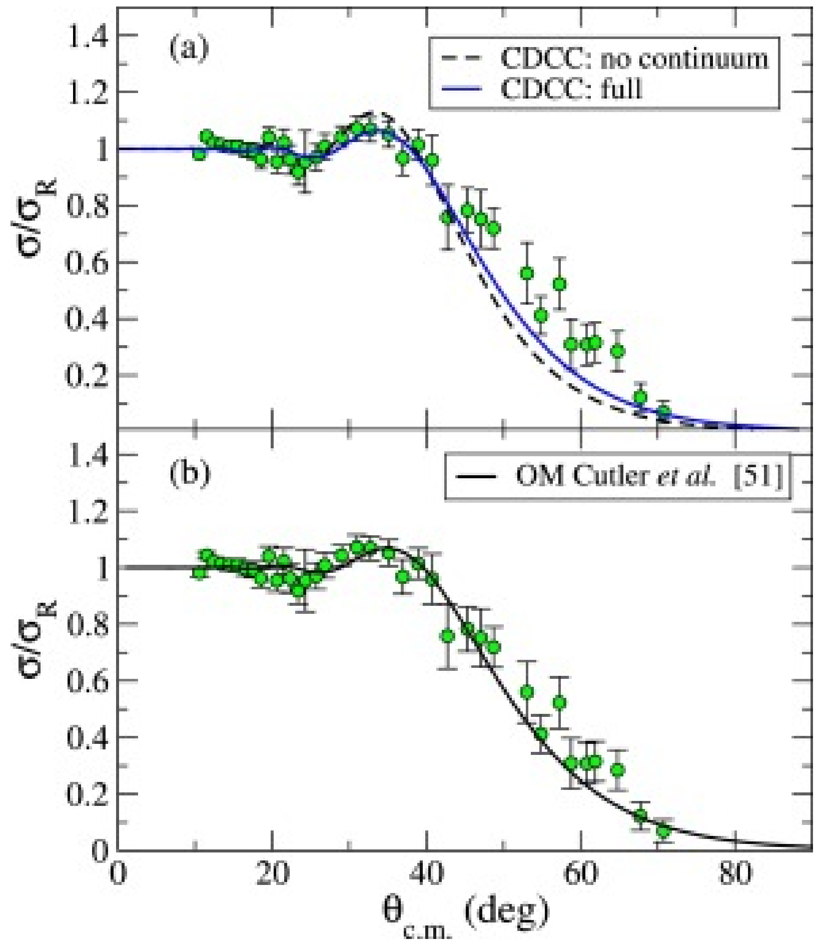
ΔE1: 40 μm DSSSD detector (16+16 strips)

ΔE2: 1000 μm DSSSD (16+16 strips)

E_{pad}: Si PAD detector 1000 μm

E: 1000 μm DSSSD (16+16 strips)

Elastic scattering results



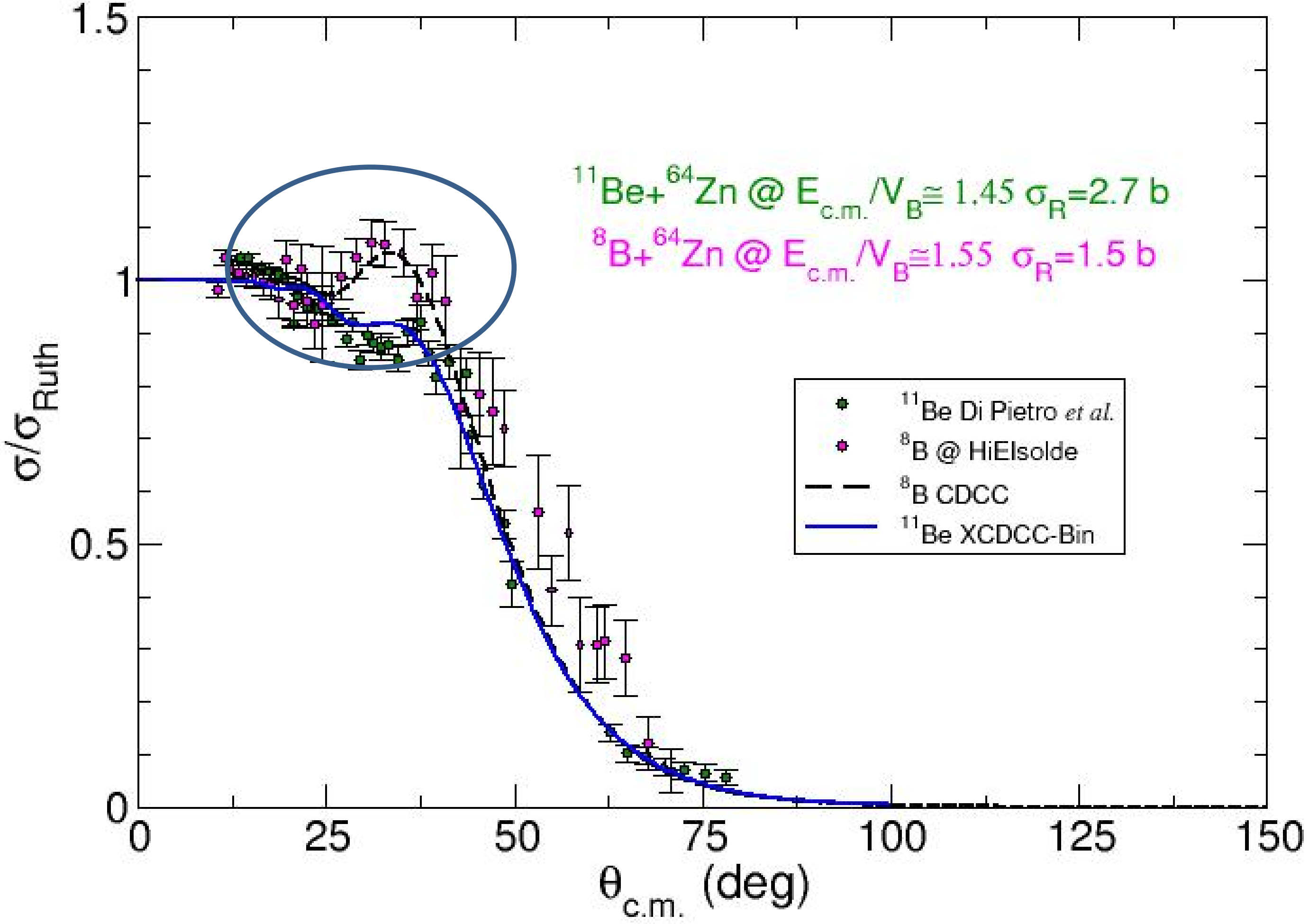
Angular distribution steps:
for θ ≤25° at steps of θ = 1°
for θ >25° at steps of θ = 2°

Anyway better than foreseen: ^{8}B 1/10 of the expected intensity (400 pps)!!

No suppression of the elastic cross section opposite to ^{11}Be
the halo effect on the rainbow peak is SMALL

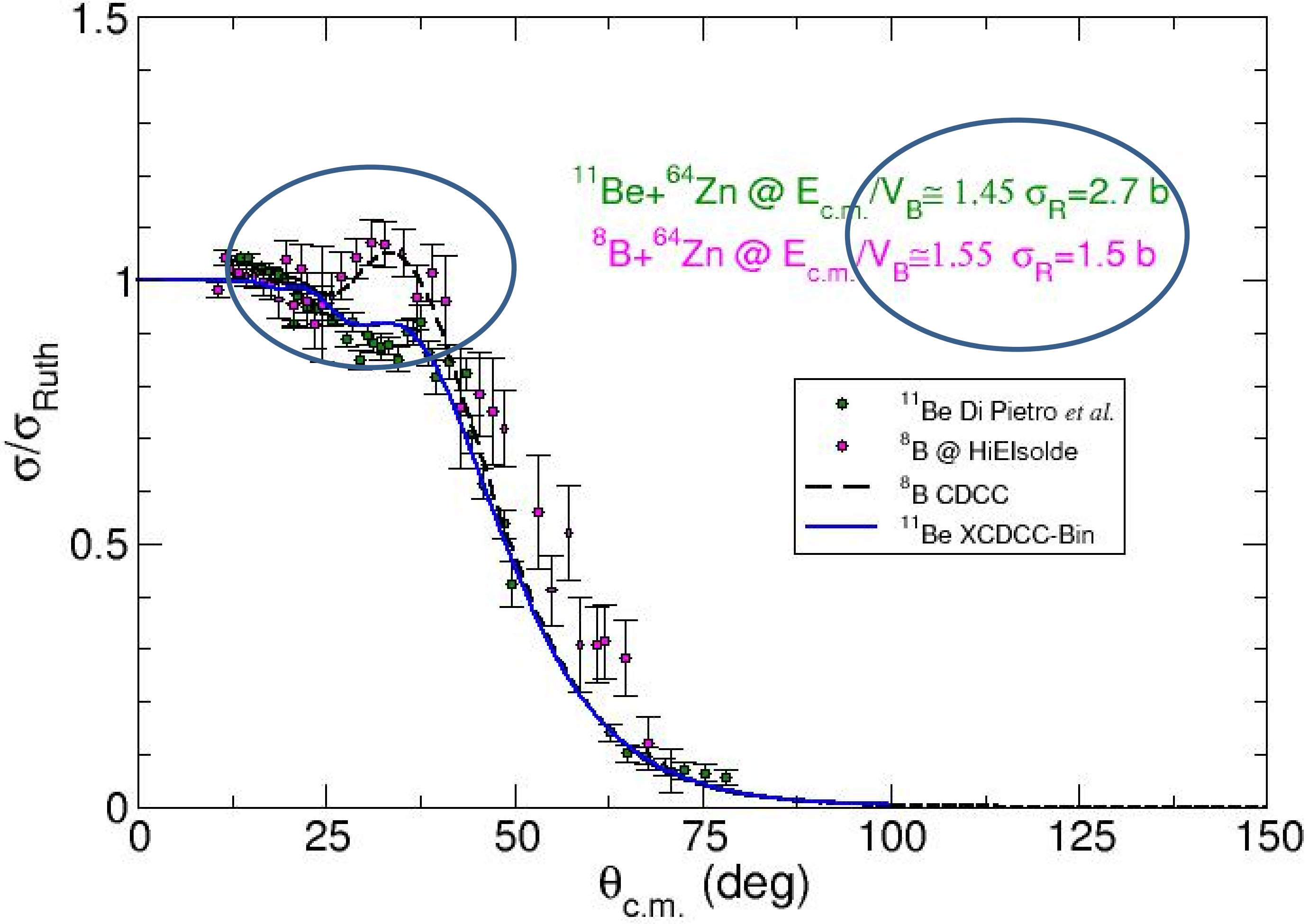
→ as foreseen by calculation
& in disagreement with previous experimental results

n- and p- halo



^{11}Be+^{64}Zn @ $E_{c.m.}/V_B \cong 1.45$ σ_R=2.7 b
^{8}B+^{64}Zn @ $E_{c.m.}/V_B \cong 1.55$ σ_R=1.5 b
^{11}Be Di Pietro *et al.*
^{8}B @ HiEIsolde
^{8}B CDCC
^{11}Be XCDCC-Bin
σ/σ_{Ruth}
$\theta_{c.m.}$ (deg)
1.5
1
0.5
0
0
25
50
75
100
125
150

n- and p- halo



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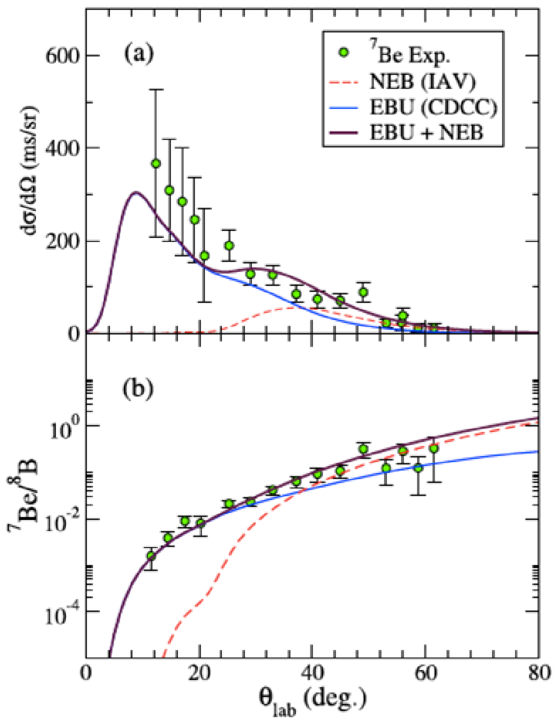
$^{8}B+^{64}Zn$:

^{7}Be angular distribution and breakup probability



R. Spartà et al. Physics Letters B 820(2021)136477

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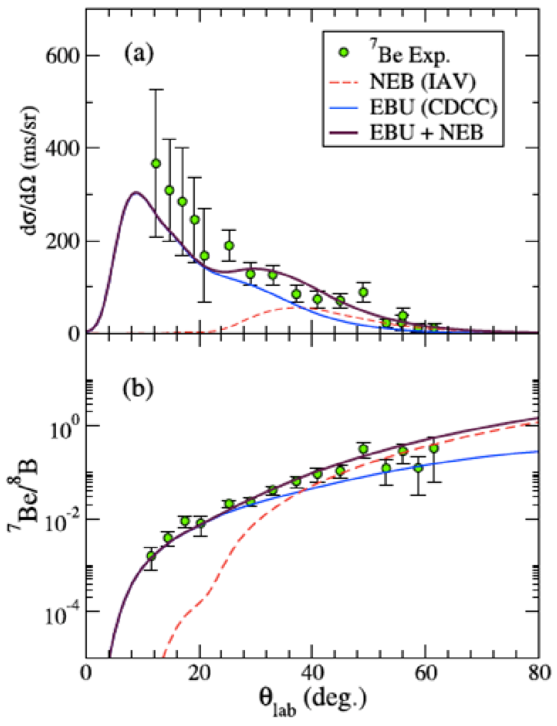

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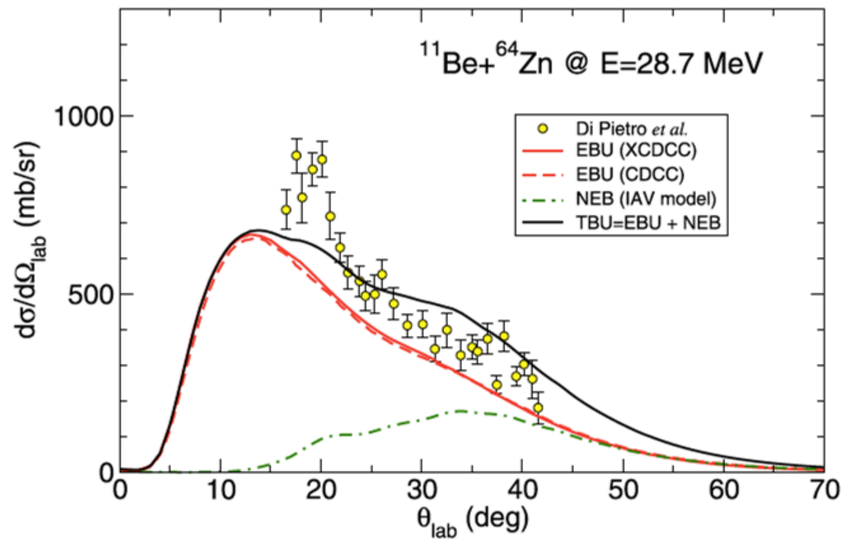
$\sigma_{BU8B} << \sigma_{BU11Be}$

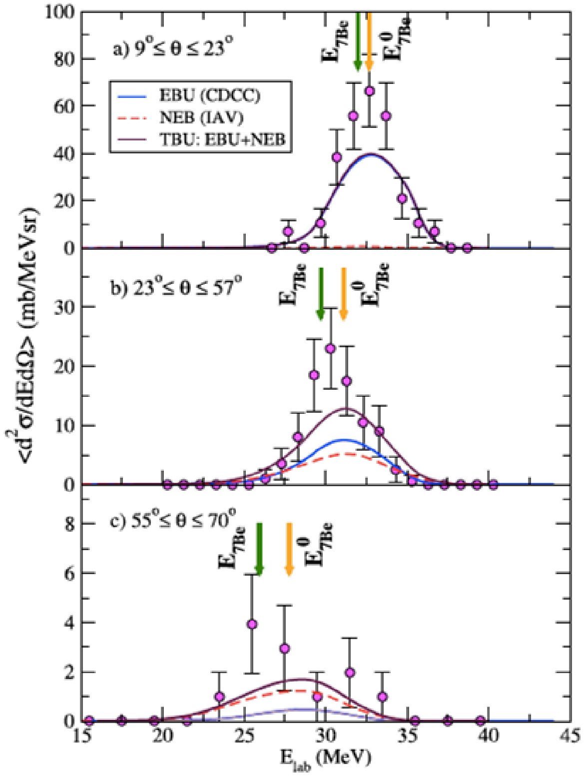
$^{11}Be+^{64}Zn$:
^{10}Be angular distribution



A. Di Pietro et al. Physics Letters B 798 (2019) 134954

^{8}B breakup: post-acceleration effects

$$E_{7\mathrm{Be}}(\theta) = E^0_{7\mathrm{Be}}(\theta) + \frac{Z_p Z_t e^2}{R_{\mathrm{bu}}}\left[\frac{Z_c m_p - m_c Z_p}{Z_p m_p}\right]$$



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→ No post-acc (far)

→ Yes post-acc (decel.) (near)

Semiclassical model predicts deceleration effect rather than acceleration as in ^{11}Be

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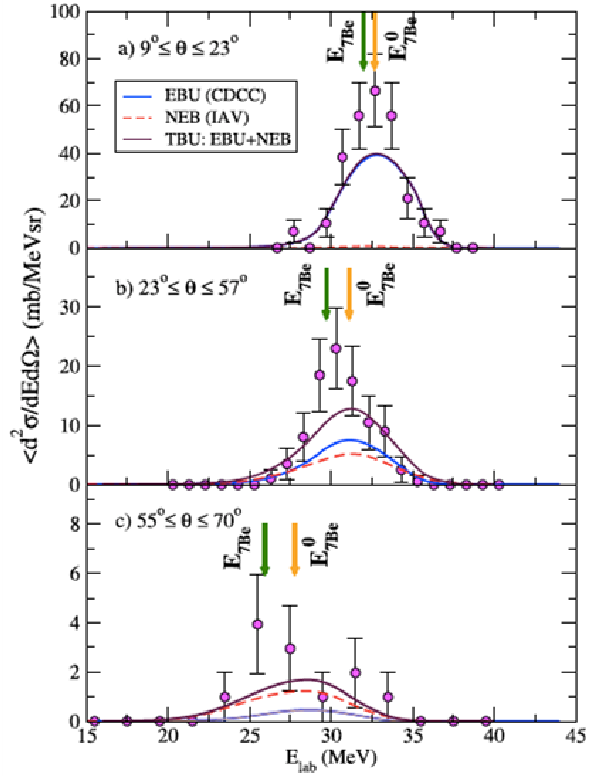

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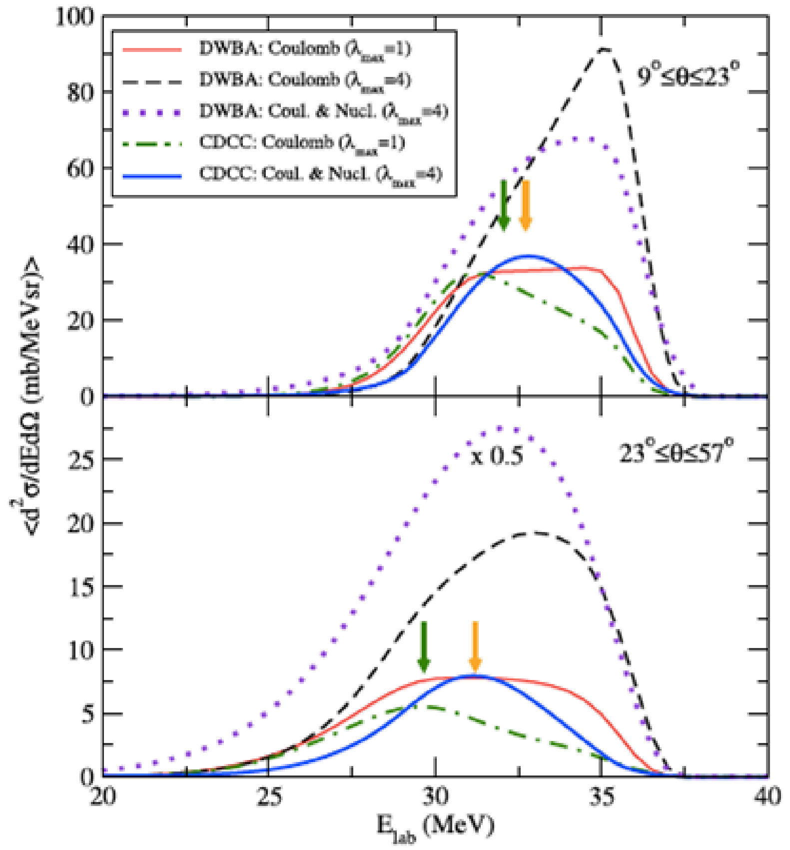

Comparison of first order (DWBA) with all-orders (CDCC) calculations including only E1 Coulomb couplings confirms the deceleration effect predicted by the classical model.
However, when higher Coulomb multipoles and nuclear couplings are considered no apparent acceleration or deceleration of the ^{7}Be fragment with respect to the ^{8}B c.m. motion is expected. (other experiments with different mass of the target? coincidences?)

→ semiclassical approximation is not enough

Conclusions

- we obtained an accurate angular distribution for elastic scattering measurement

contrary to what observed in in-flight beam measurements, we see modest effects of coupling to the continuum, no evidence of an elastic scattering peak suppression (@E≈Coul. Barrier)

& σ_{R8B}~0,5 σ_{R11Be} (like weakly bound nuclei)

- EBU dominance @ small θ, whereas NEB becomes non negligible @ larger θ

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8B reaction dynamics is very different from that of n-halo nuclei
A proper understanding of the dynamics of p-halo nuclei, including the role of post-acceleration and the dependence of the relative contribution of EBU and NEB on the target, calls for further investigations

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J. Cederkall, T. Davinson, J. Fernandez-Garcia, A.M. Moro, M.J. Garcia-Borge, O. Tengbald, J. Diaz-Ovejas, S. Vinals-Onses, L. Fraile, I. Martel-Bravo, A.M. Sanchez-Garcia, A. Perea, B. Jonson, G. Bruni, J.H. Jensen, L. Acosta, D. Galaviz, N. Soic

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