INFN Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DEL SUD

Reaction mechanisms in collisions induced by a ^{8}B beam close to the barrier.

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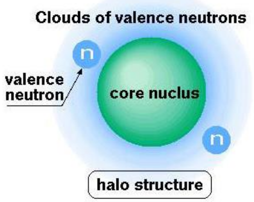
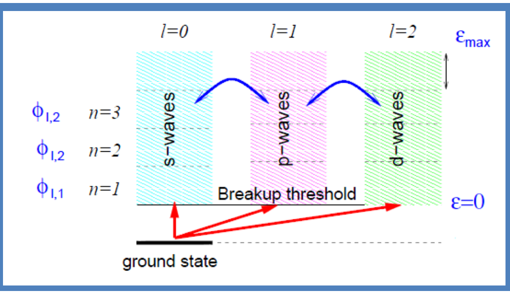
Motivation: effects of halo structure on reaction dynamics

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



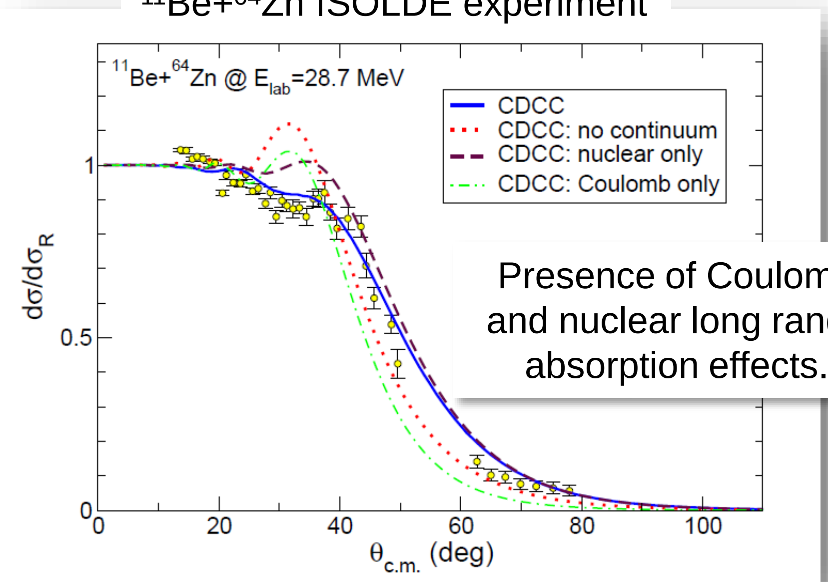
- Weakly bound (easy to break-up)
- Easy to polarise (large B(E1) low energy strenght)
- Suffer lower Coulomb barrier
- Higher transfer probability

At low bombarding energy coupling between relative motion and intrinsic excitations important.
Halo nuclei → small binding energy, low break-up thresholds → coupling to break-up states (continuum) important → CDCC.



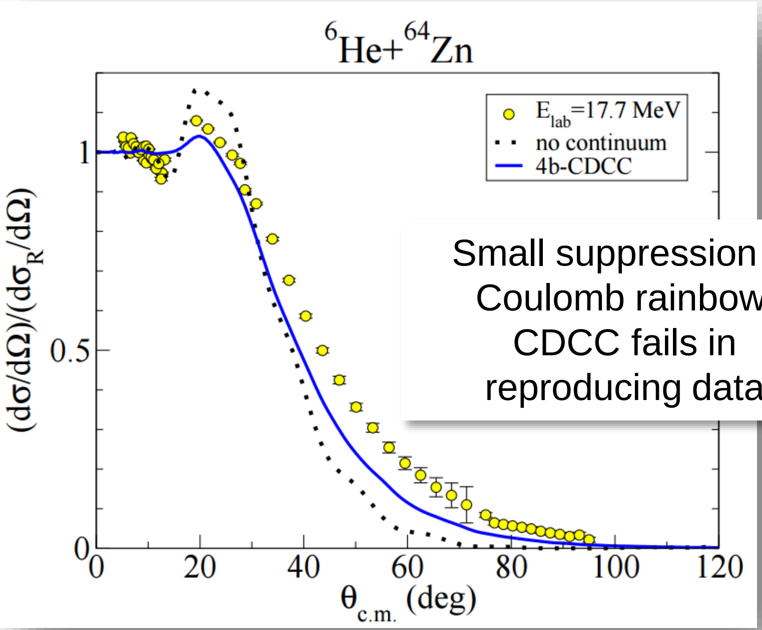
Elastic scattering

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



Presence of Coulomb and nuclear long range absorption effects.

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

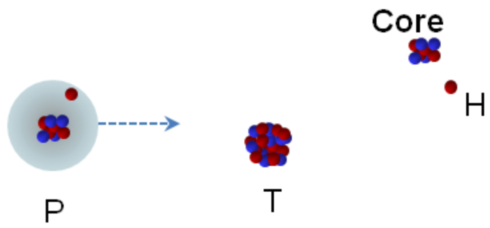


Small suppression of Coulomb rainbow. CDCC fails in reproducing data

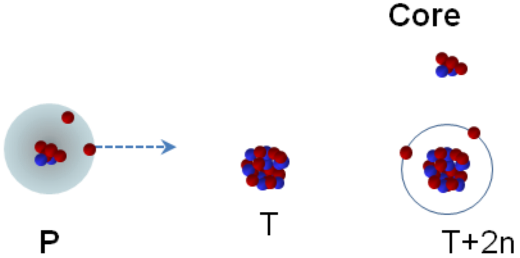
A. Di Pietro et al. to be published

The n-halo case: break-up. Inclusive detection of the core.

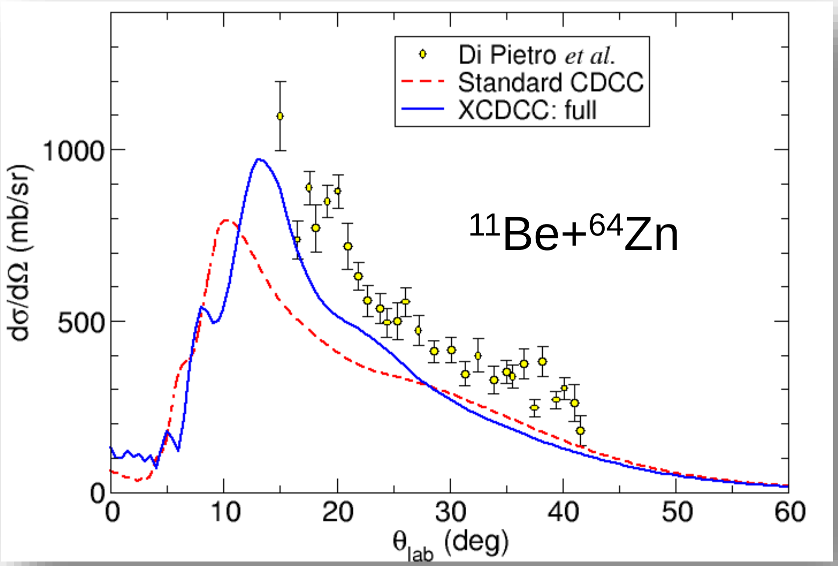
Elastic break-up



Non-elastic break-up e.g.transfer

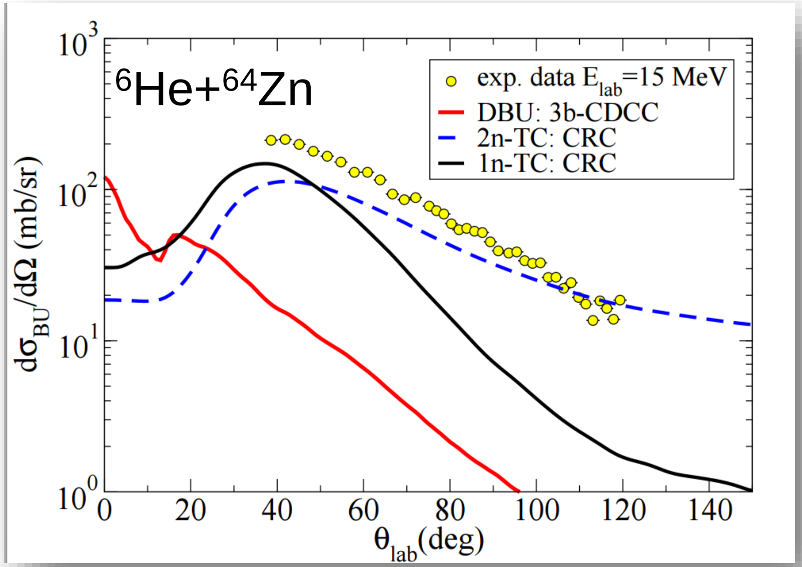


^{10}Be angular distribution



A.M. Moro et al. PRC 89, 064609 (2014)
Data from A. Di Pietro et al. PRL 105,022701(2010)

^{4}He angular distribution



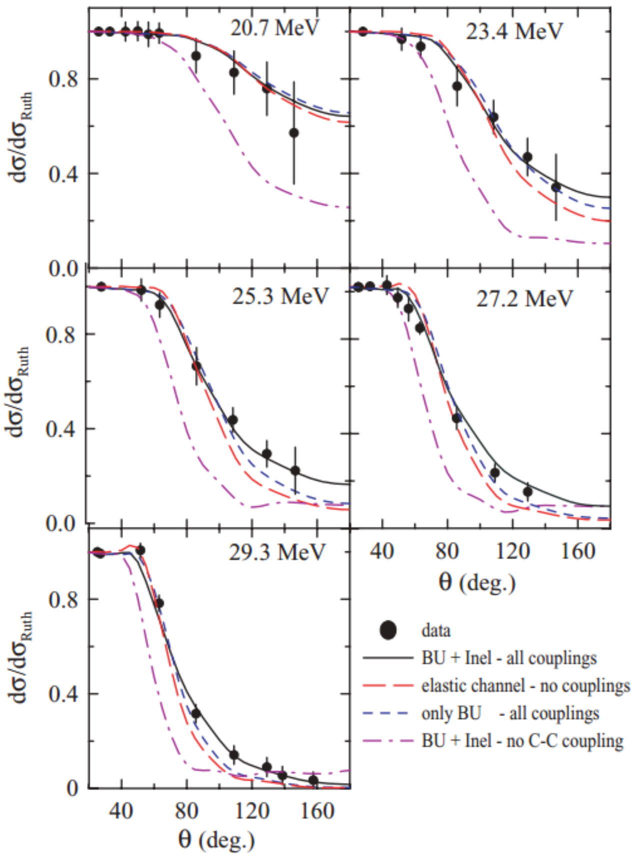
data from V. Scuderi et al. PRC 84, 064604 (2011)

Elastic-break-up is not the only process contributing to the inclusive cross-section producing the core as spectator. Non elastic-break-up contribution can be very large especially in the ^{6}He case.

Core excitaton effects important in ^{11}Be.

The p-halo case: ^{8}B

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

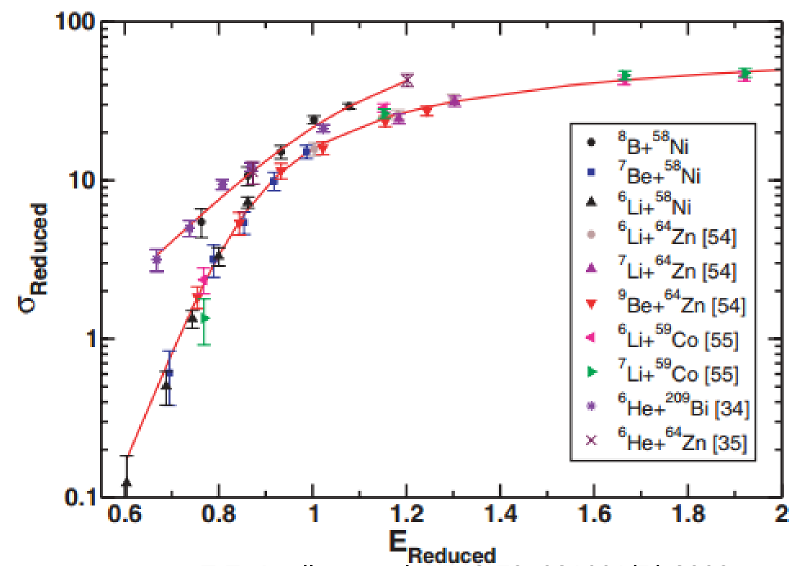


J. Lubian et al PRCC 79, 064605 (2009)
data from E.F. Aguilera et al. PR C 79, 021601(R) 2009

- Weakly bound Sp=0.137 MeV (easy to break-up)
- Small B(E1) low energy strenght
- Presence of low energy B(E2) strenght
- Transfer probability reduced by polarisation effects?

Scarce data in the literature. No ^{8}B ISOL beam so far.

Comparison of total-reaction cross-section of various systems



E.F. Aguilera et al. PR C 79, 021601(R) 2009

Some details of this experiment:

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

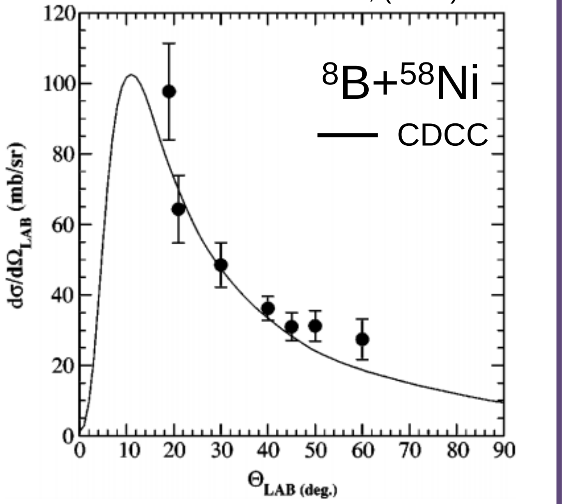
Small effects on elastic scattering however large total-reaction cross-section extracted from elastic data.

Found similar trend as for n-halo nuclei

The p-halo case: ^{8}B elastic break-up and fusion

^{7}Be angular distribution

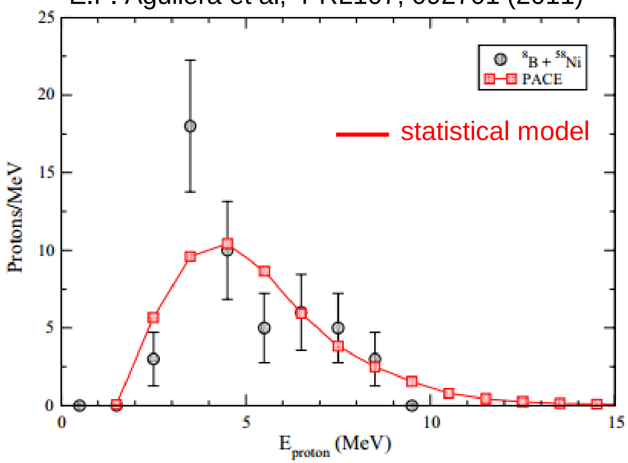
J.J.Kolata et al. PRC 63, (2001) 024616



Inclusive ^{7}Be angular distribution at forward angles consistent with elastic break-up processes.

Backward angle p-spectrum.

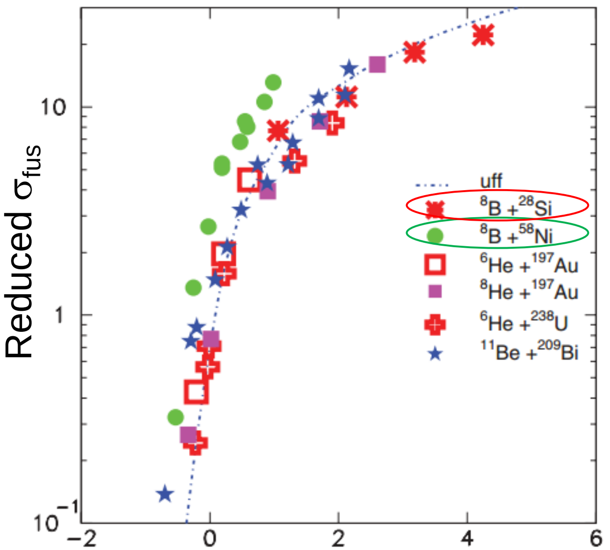
E.F. Aguilera et al, PRL107, 092701 (2011)



Fusion cross-section deduced from protons strongly enhanced. Different result found in $^{8}B+^{28}Si$ fusion deduced from α-particles. Other processes contribution?

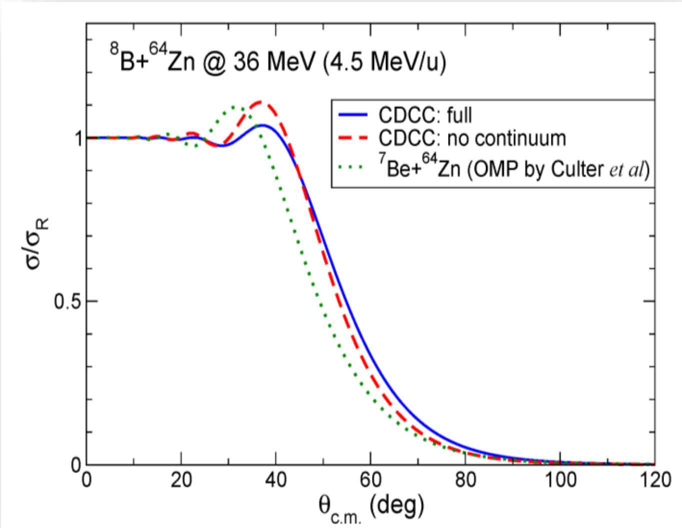
Systematics of fusion of n- and p- halo.

A.Pakou et al., PR C 87, 014619 (2013)

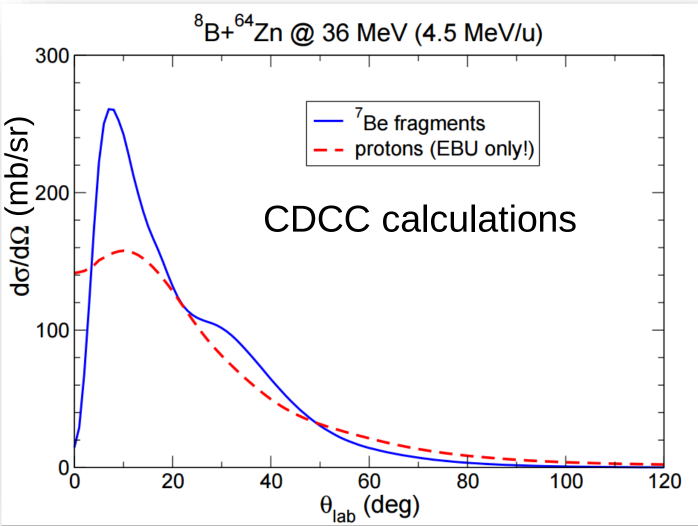


Experimental data available are of limited quality and controversy on the results

Proposed experiment:
$^{7}Be, ^{8}B + ^{64}Zn$ at $E_{lab} \approx 4.5$ MeV/u
elastic scattering, elastic and non-elastic break-up cross-sections



CDCC calculations foresee small effects on the elastic cross-section.
No core excitation effect considered (work is in progress).
Is the total-reaction cross-section enhanced as for n-halo?



Measurement of ^{7}Be and p in singles, as well as in coincidence for the first time, will help solving the puzzle. Elastic as well as non elastic break-up (transfer, incomplete fusion….) can be disentangled.

^{8}B+^{58}Ni

^{7}Be inclusive spectra measured → large cross-section found

From comparison with calculations the p-halo structure of ^{8}B is claimed

V.Guimares et al. Phys. Rev. Lett. 84,1862(2000)

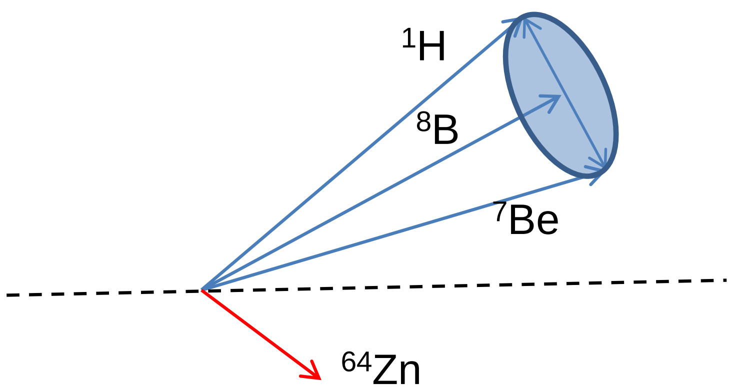
Questions:

^{7}Be coming from break-up or transfer?

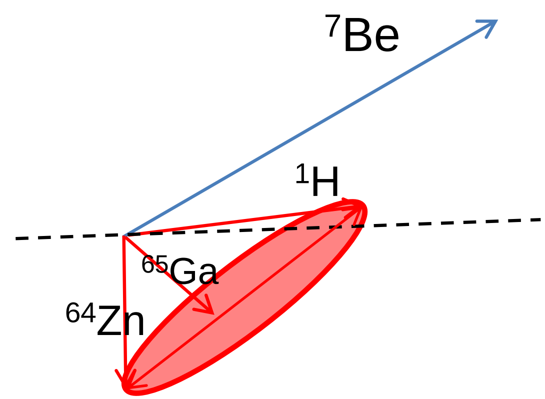
Is it possible to discriminate?

^{7}Be-proton coincidences needed.

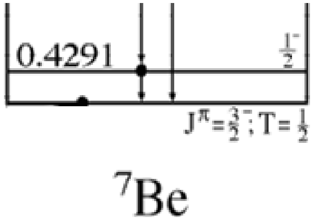
^{64}Zn(^{8}B,^{7}Be ^{1}H)
Break-up

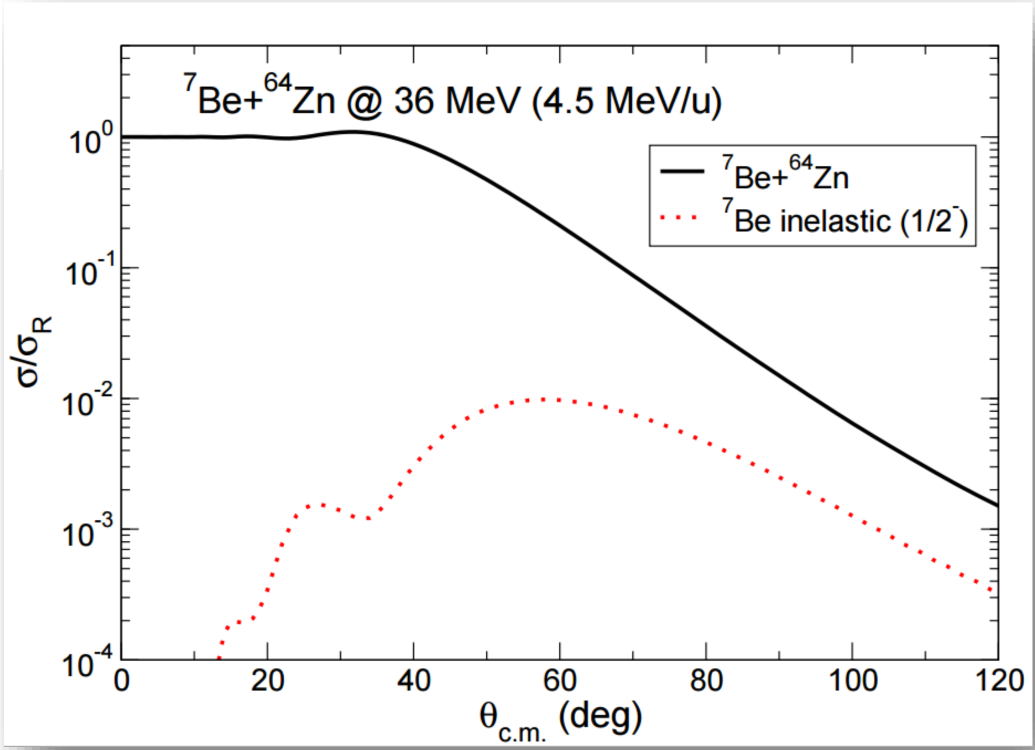


^{64}Zn(^{8}B,^{7}Be)^{65}Ga*
Transfer



$^{7}Be+^{64}Zn$ quasi-elastic scattering





Due to beam energy-resolution and target thickness the 1st excited state of ^{7}Be is not resolved (Ex≈0.43 MeV) → quasi elastic scattering will be measured. However the contribution of the inelastic cross-section is expected to be very small as we have previously found also in the case of ^{7}Li.

Proposed set-up:

Detection system:
4 ΔE-E Si telescopes at θ<100°
ΔE: 40 μm DSSSD detector (16+16 strips)
E: 1000 μm DSSSD (16+16strips)
We decided to add 2 additional telescope
at backward angles.

Angular distribution steps:
for $\theta \leq 40°$ at steps of $\theta \leq 2°$ ($\Delta\theta \leq \pm 1°$)
for $\theta > 40°$ at steps of $\theta = 3°- 5°$

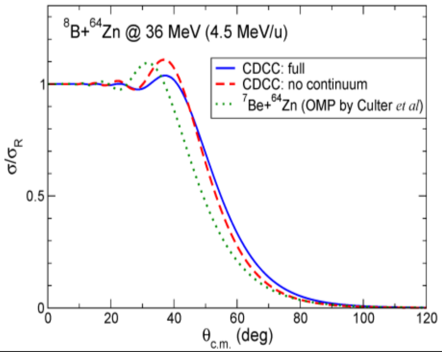
Elastic scattering of $^{7}Be + ^{64}Zn$ at the same $E_{c.m.}$ to extract core-target optical potential

Improvements:
- ^{8}B post-accelerated ISOL beam
- Large solid angle + high granularity → good angular resolution
  Complete and detailed angular distribution of ^{8}B, ^{7}Be, and p
- Coincidence measurement

Beam time requests:

21 shift to perform elastic scattering angular distribution and ^{7}Be+p coincidence measurement.

Some example of the counting statistics in 21 shifts (i ^{8}B=5x10^{3} pps)



Elastic scattering:

θ_{lab}=20° ≈ 7.8 10^{3} ($\Delta\theta \leq$±1°)

θ_{lab}=40° ≈ 800 ($\Delta\theta \leq$ ±1°)

θ_{lab}=60° ≈ 70 ($\Delta\theta \leq$±1.5°)

At backward angles wider angular bin can be used

Break-up:

^{7}Be singles ≈1500 in the angular region 10°≤ θ ≤ 90°

^{7}Be-p coincidences ≈1000 (efficiency 70%, estimate done using elastic break-up cross-section)

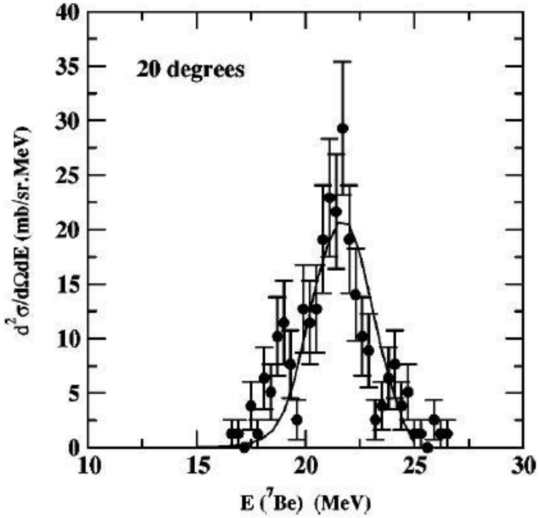
4 shifts of 7Be to measure elastic-scattering angular distribution

Additional 4 shifts of stable beam are requested for setting-up the electronics and most important for angle and solidangle determination via Rutherford scattering.

Total number of shifts 29

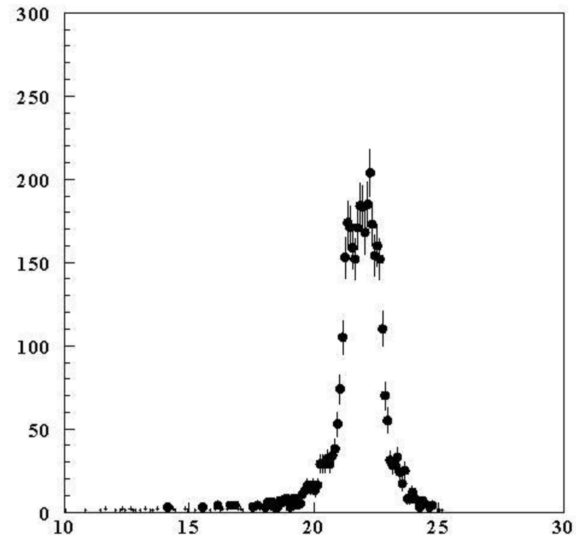
How to estimate coincidence efficiency?

Experimental ^{7}Be energy spectrum
$^{8}B+^{58}Ni$



J.J.Kolata PHYS. REV.C 63, 024616(2002)

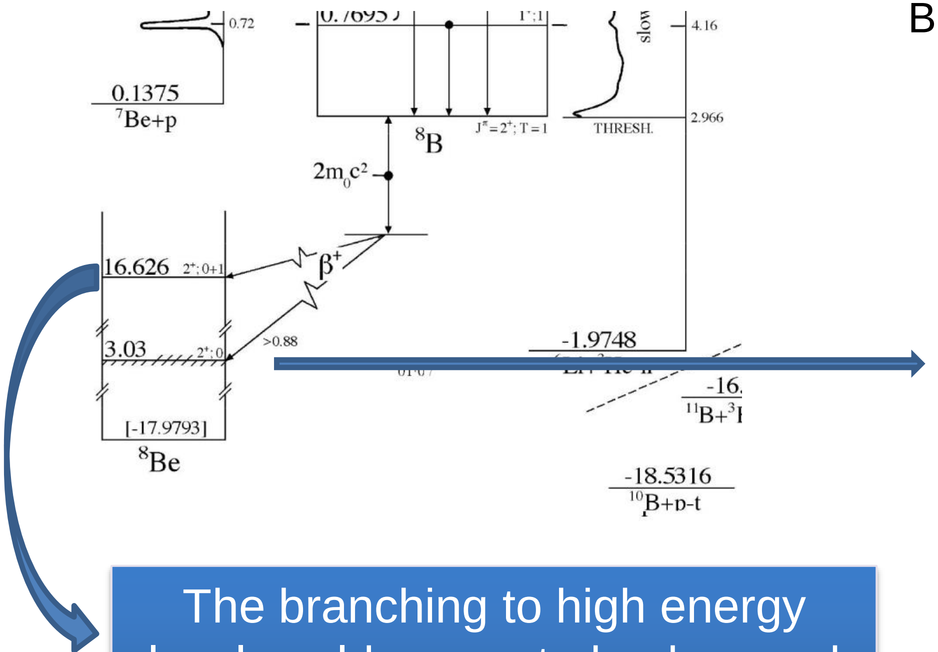
$^{8}B+^{58}Ni$ Montecarlo simulation
^{7}Be energy spectrum from break-up



E (MeV)

Starting from a Montecarlo simulation that reproduced $^{8}B+^{58}Ni$ data we estimated an efficiency to detect ^{7}Be-protons coincidences ≈ 70%

Background problems with ^{8}B beam



The branching to high energy level could generate background at backward angles where no telescope is used

Background α spectrum from $^{8}Be(2^{+})$ decay

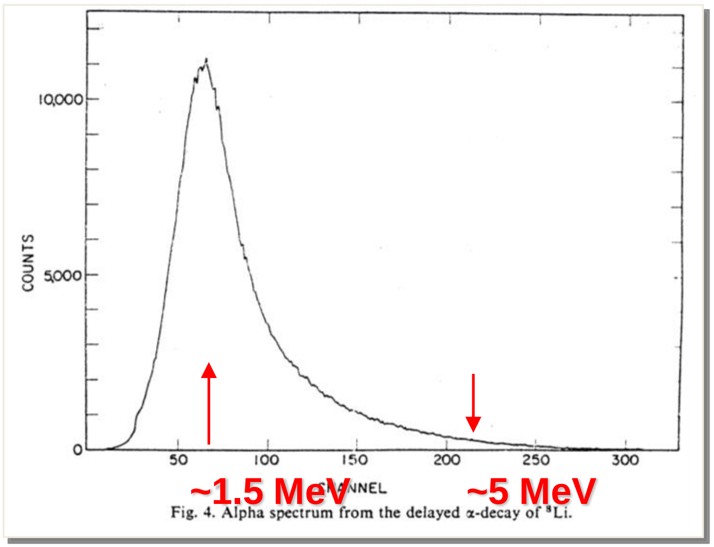


Fig. 4. Alpha spectrum from the delayed α-decay of ^{8}Li.

To dramatically reduce the background a selection on T_{ebis} time spectrum can be made (reduction factor 0.5%)