Direct reactions and spectrometers: a few random thoughts

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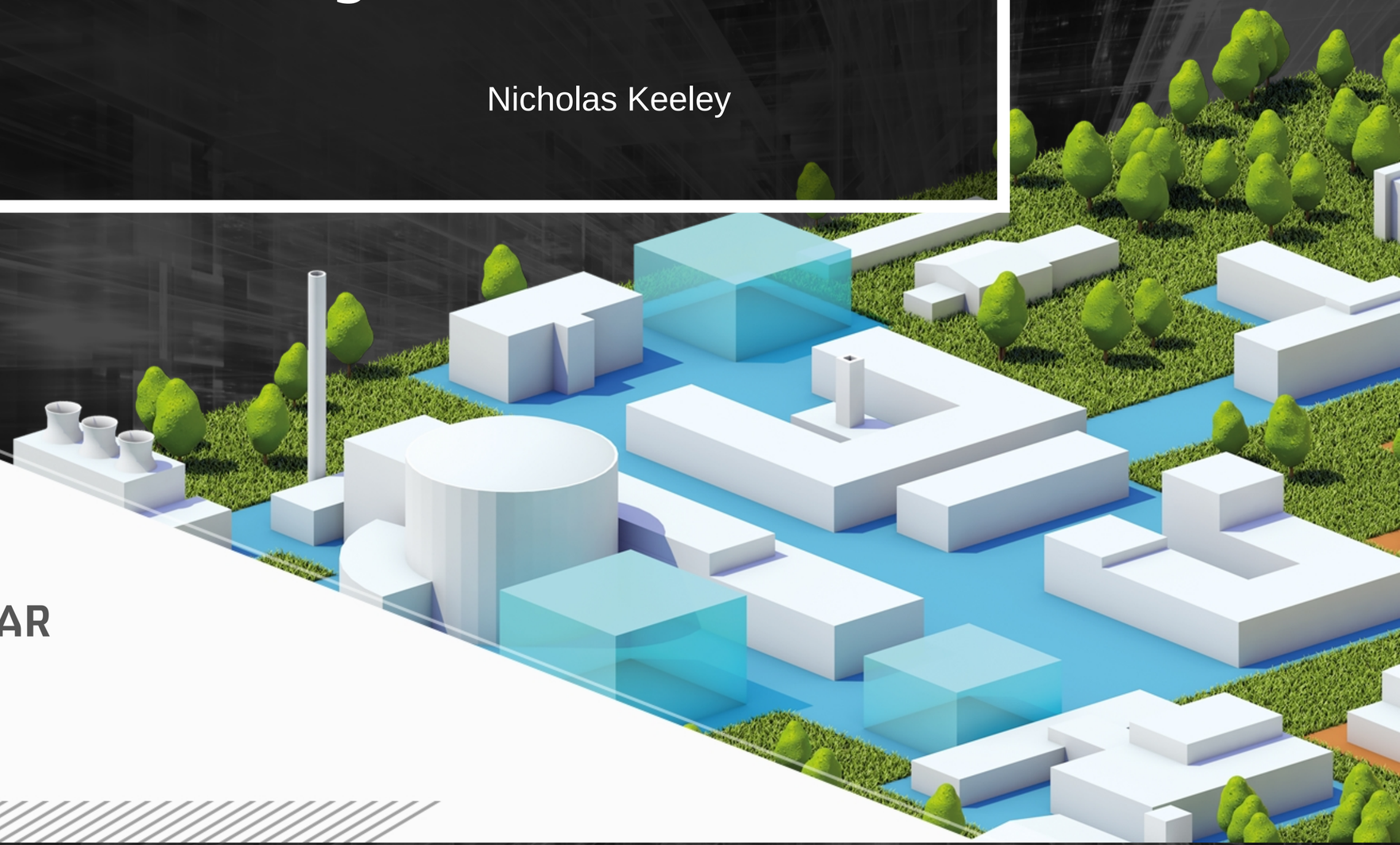

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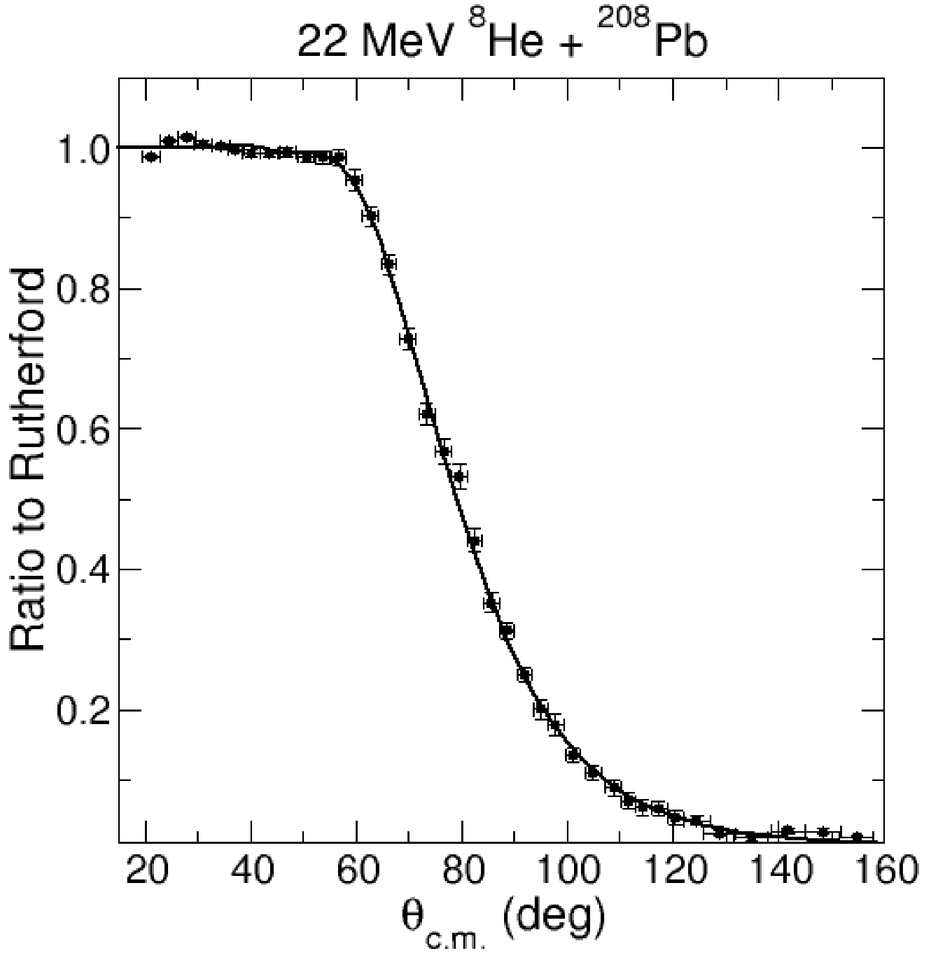
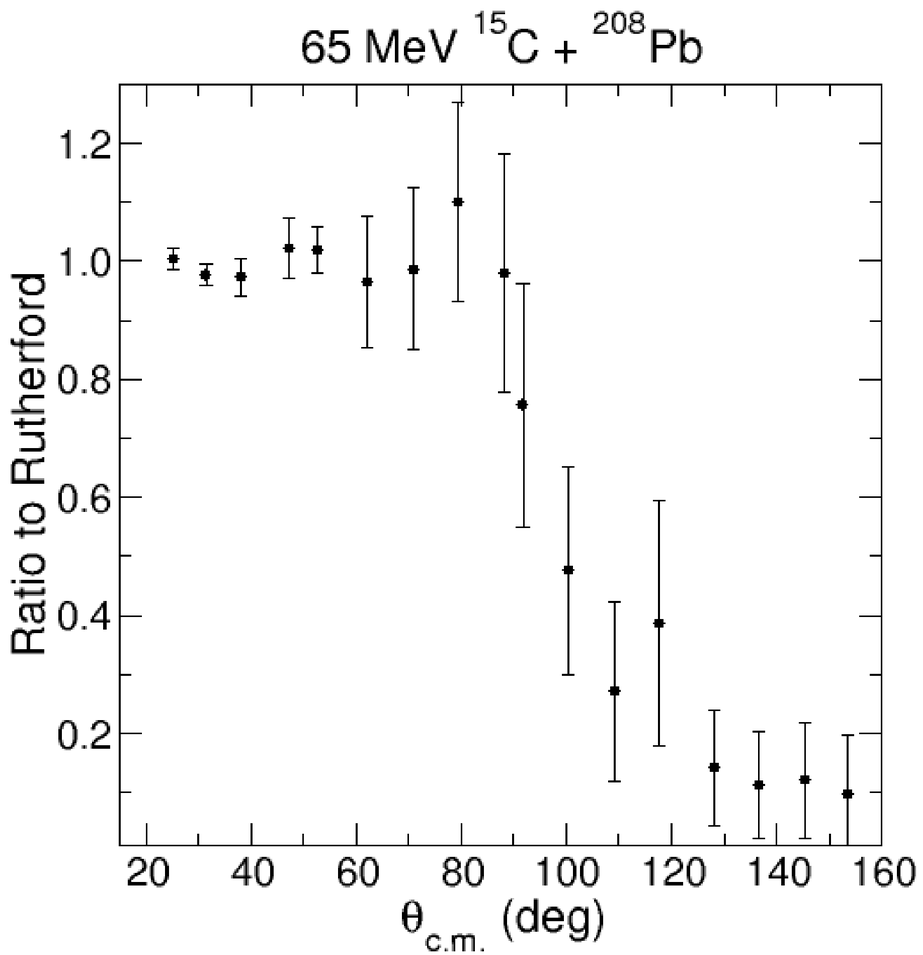
Perhaps the main concern when performing direct reaction measurements with radioactive beams is the question of beam intensity, closely followed by beam quality (i.e. purity and optical properties such as beam spot size etc.).

Direct reaction experiments impose heavy demands on both these aspects, since they usually involve angular distribution measurements – small cross sections – and require good scattering angle definition – small beam spot size.

Most such experiments need 10^4 pps as a bare minimum if worthwhile results are to be obtained; ~10^5 pps is better …

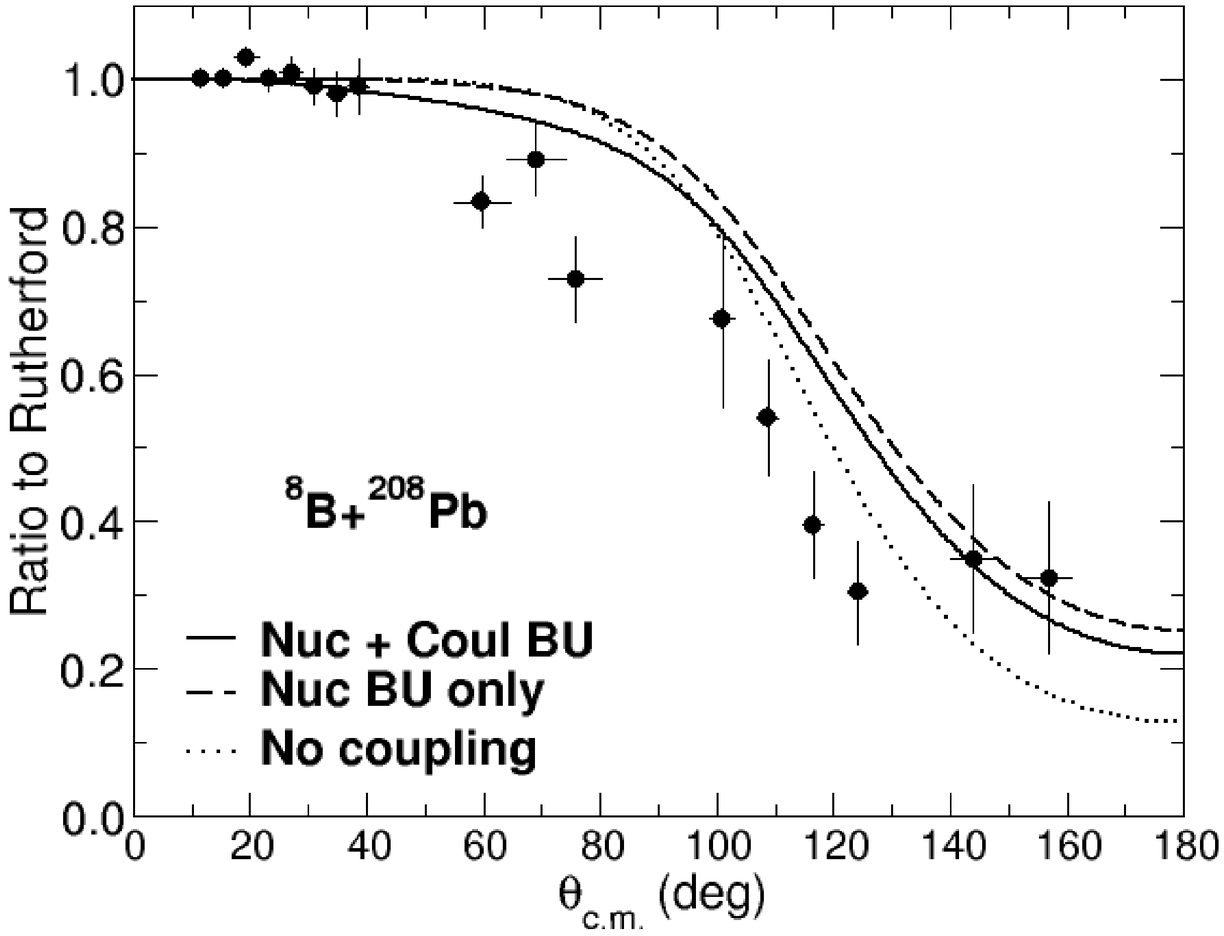




^{8}He: 10^{5} pps on target at GANIL, pure beam, beam spot ø ~ 3.5 mm

^{15}C: 1.5 x 10^{3} pps on target at ISOLDE, heavy ^{15}N contamination

Of course, this problem is not unique to ISOLDE; there were similar problems with a low-energy (50 MeV) ^{8}B beam at RIKEN:



We can and must do better if we wish to progress in our understanding of direct reactions induced by radioactive beams

These comments also apply to direct reactions as spectroscopic tools; we should be thinking in terms of data that approach those obtainable with stable beams

This is not a pipe dream, as the data from GANIL show; it can be done (and for reactions such as (d,p), (p,d), (d,t), (d,^{3}He) etc. too).

However, the range of available beams at GANIL is limited, so any possibility of a significant increase in usable beam intensity at ISOLDE would be of great interest to the direct reaction community.

Experimentalists (almost) always want more beam; I hope I have answered the “why?” as far as direct reactions are concerned, so the real question now is “how?”

The ISRS could be used as a storage ring: thin internal targets could be employed and the effective beam current would be increased. Beam purity would also be improved.

Beam half-life would pose a limitation, but this should not be a problem for many of the isotopes of interest.

I have rather put the cart before the horse in this diversion concerning beam current, but this is really the fundamental issue with ISOLDE as far as direct reactions are concerned.

Now for some physics arguments in favour of spectrometers *per se* …

The main use of a spectrometer is in transfer reactions where they address two important issues: energy resolution and accessible angular range.

Energy levels in nuclei of interest can be only 100 keV or less apart. In radioactive beam work the thick(er) targets and poorer beam quality can make it impossible to resolve such levels with solid state detectors.

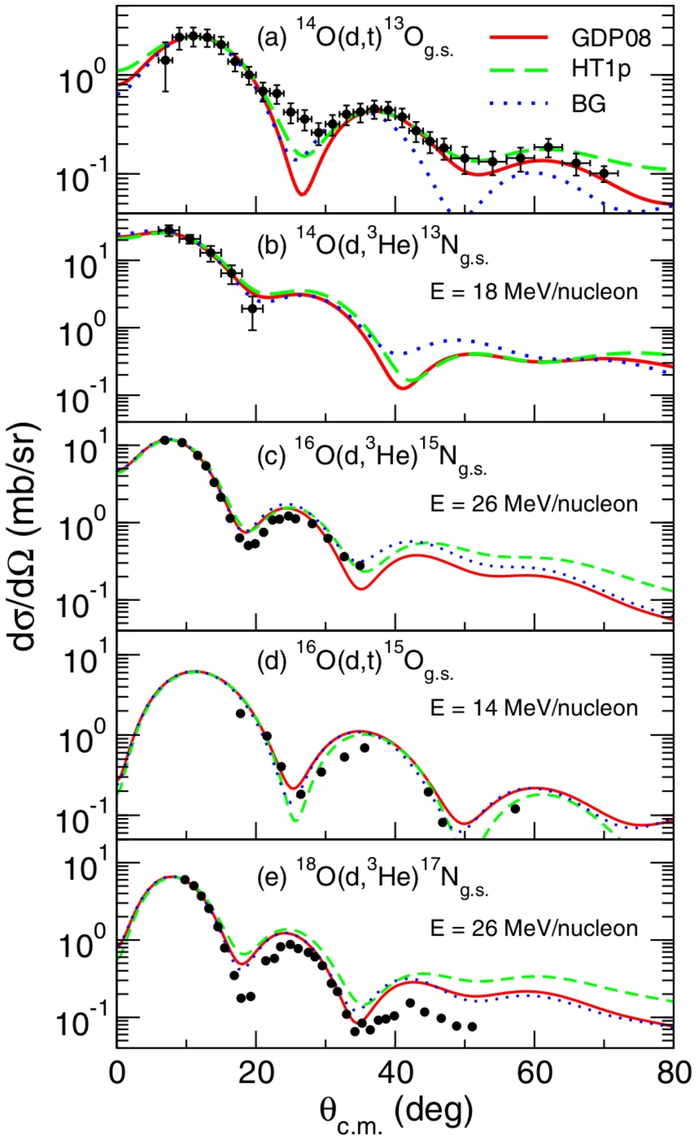
A magnetic spectrometer will give much improved resolution.

A magnetic spectrometer will also help extend measurements of transfer angular distributions to forward angles (in the centre of mass frame).

Why is this important?

When extracting spectroscopic factors, it can be crucial to define the position of the first cross section peak if the least uncertain result is to be obtained. This can involve angles as small as 5° or less in the centre of mass frame

^{14}O(d,t) and (d,^{3}He) data taken at GANIL; MUST2 array to detect light recoils (inverse kinematics) and VAMOS to detect the heavy ejectiles (^{13}O, ^{13}N).



Inverse kinematics means that reaction products are focused at forward angles in the laboratory frame, very close to the beam. A spectrometer such as the ISRS can be critical in measuring the centre of mass forward angles in these circumstances.

It also gives the mass (as well as charge) resolution needed for unambiguous identification of the heavy “ejectiles”.

The availability of the ISRS at ISOLDE could represent a real turning point in the direct reaction programme at the facility

To sum up, the ISRS could make a vital contribution to increasing the attractiveness of ISOLDE as a facility for direct reactions with radioactive beams.

The current (very) low beam intensities severely limit its usefulness. If a direct reaction programme at HIE-ISOLDE is to realise its potential then this problem must be addressed.

The ISRS would be a good way to do this, and at the same time provide a true state of the art detection system

Thank you for your attention

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