Estimating Nuclear Effects With FRESCO

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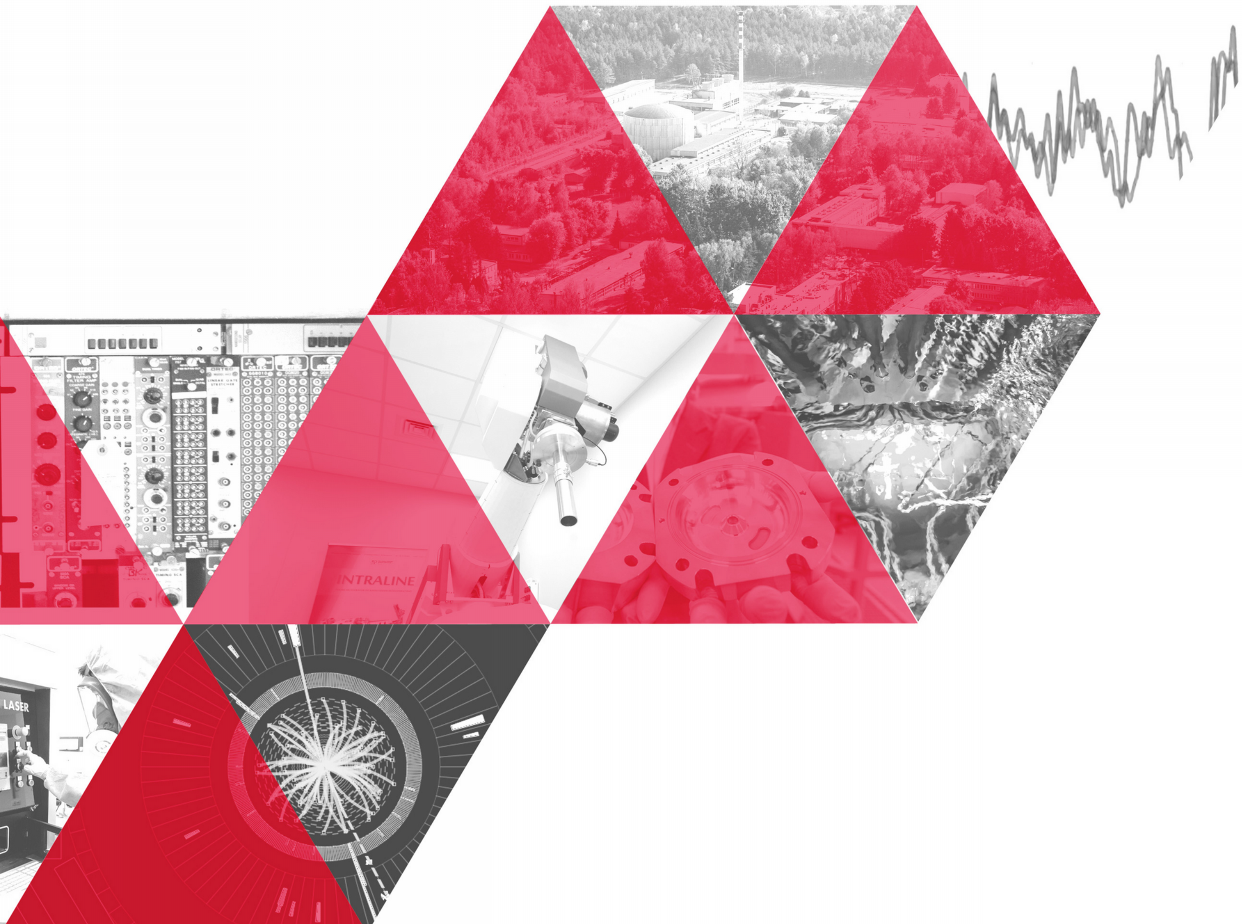


Coulomb excitation experiments are usually performed below the “safe energy” to avoid “contamination” from nuclear effects.

Cross sections are often low – could be a problem with low intensity RIBs – but increase rapidly with energy in this region.

We would like to estimate how far above the safe energy we can go before nuclear effects are too large to tolerate.

We can calculate the angular distribution of the inelastic scattering differential cross section.

This should be related to the probability of detecting the relevant γ ray at a given angle.

Reaction codes allow us to “switch off” the nuclear excitation so we can attempt to estimate at what point it becomes unacceptably large.

How can we do this?

Take as our test case the ^{32}S nucleus. We want to extract the B(E2) and Q for its 2.23 MeV 2^{+} state using Coulomb excitation with a ^{197}Au target.

Cline's safe energy for this system is 130 MeV, so take this as our starting point.

Use the FRESCO code [I.J. Thompson, Comput. Phys. Rep. **7**, 167 (1988)] to calculate inelastic scattering with and without nuclear contribution.

What ingredients do we need?

First of all, the $B(E2; 0^+ \rightarrow 2^+)$ and Q for the ^{32}S 2^+

Secondly, we need a (complex) nuclear potential

Finally, we need *nuclear* deformation parameters since we also wish to include nuclear excitation processes (we do this by deforming the complex diagonal nuclear potential)

Where do we get all these and what do we do with them?

B(E2; $0^+ \rightarrow 2^+$) and Q for the ^{32}S 2^+ are known experimentally; in general they won't be, but we can just as easily take theoretical values.

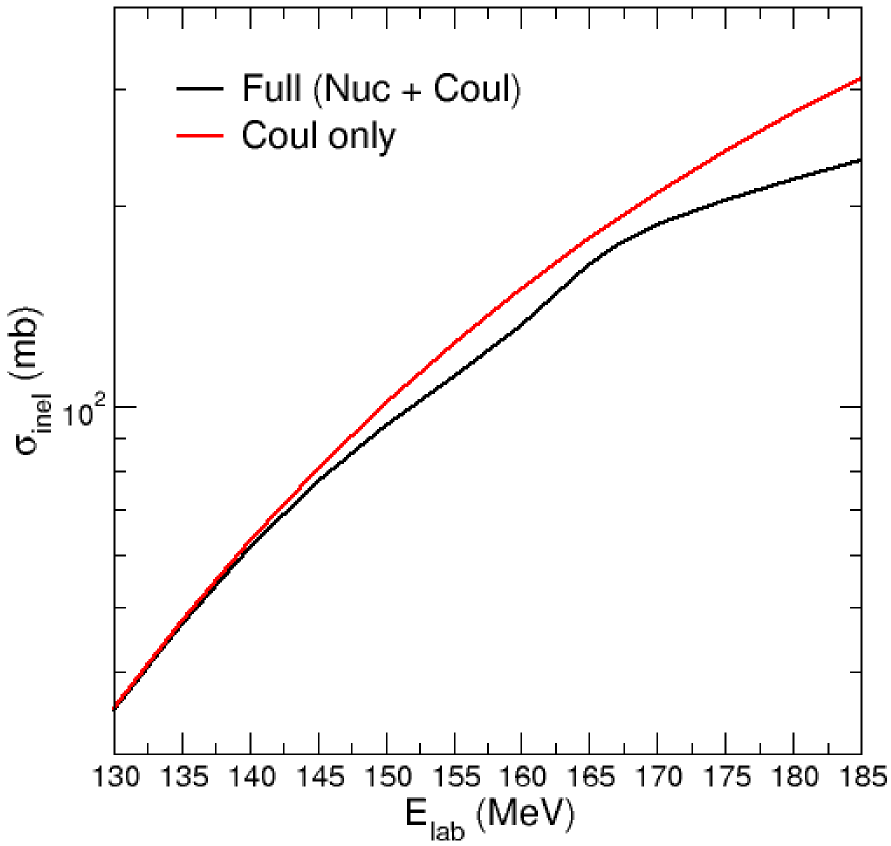
Attention: FRESCO uses B(E2↑) not B(E2↓).
Intrinsic or spectroscopic Q?
Convert to M(E2) for use in code.

Nuclear potential: systematics of Broglia and Winther, *Heavy Ion Reactions*, Lecture Notes vol. 1. Real part only: imaginary same but well depth multiplied by 0.25. Nuclear deformations from M(E2) assuming collective model expressions.

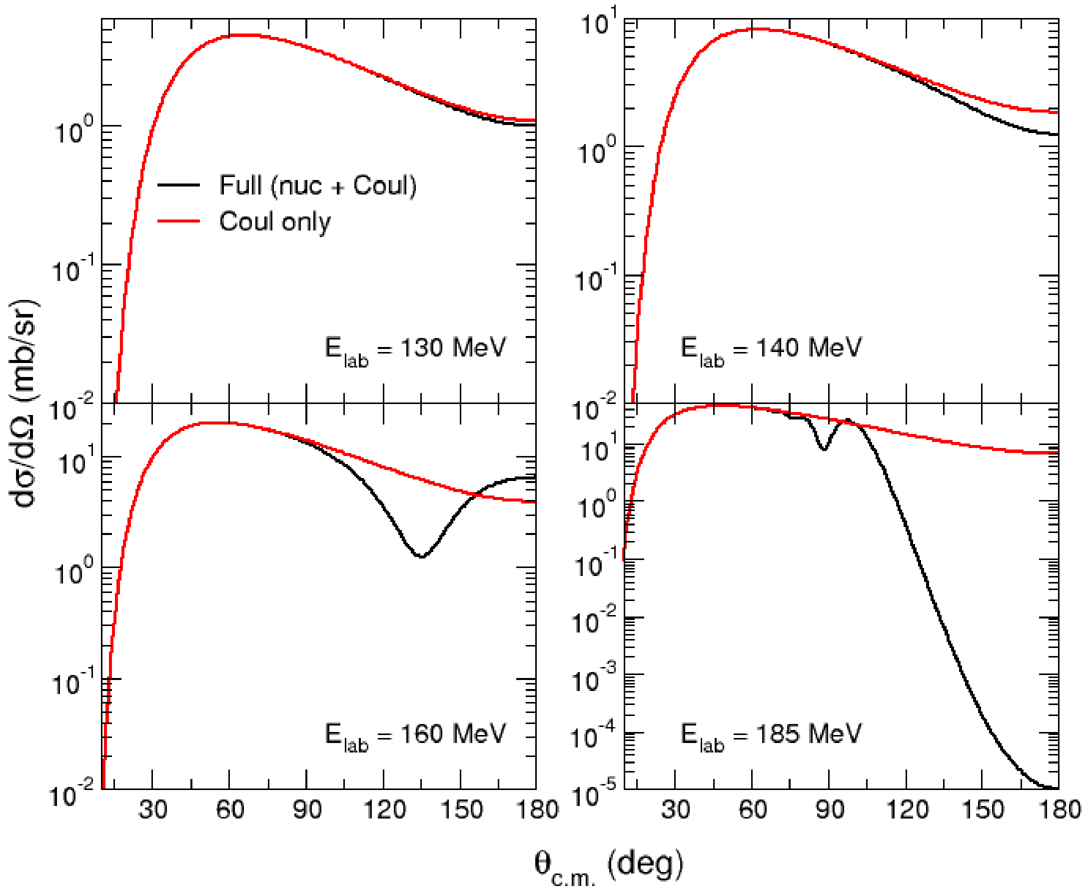
What does the input look like?

```
32S+197Au at 130 MeV
0.015   400.0   0.3
 00.1000  +.00   F F
0  0.     180.    1.0
0.0        0 2 0  48
 1 1 0 0 1 3 0 0 0 1 0 0 1
32S     31.9721 16.0       2  197Au   196.9666 79.0
0.0   +1 0.0               1  0.0   +1 0.0             F F
2.0   +1 2.2306            1       1

  1 0  0   197.0    32.0     1.2
  112 10         16.8523
       2   1   2 16.8523
       1   2   2 16.8523
      -2   2   2-20.3184
  1 1  0   71.62  1.2122    0.63   17.91  1.2122    0.63
  112 11          1.1581
       2   1   2 1.1581
       1   2   2 1.1581
      -2   2   2-1.3962
0

   0   1   1
130.0
```

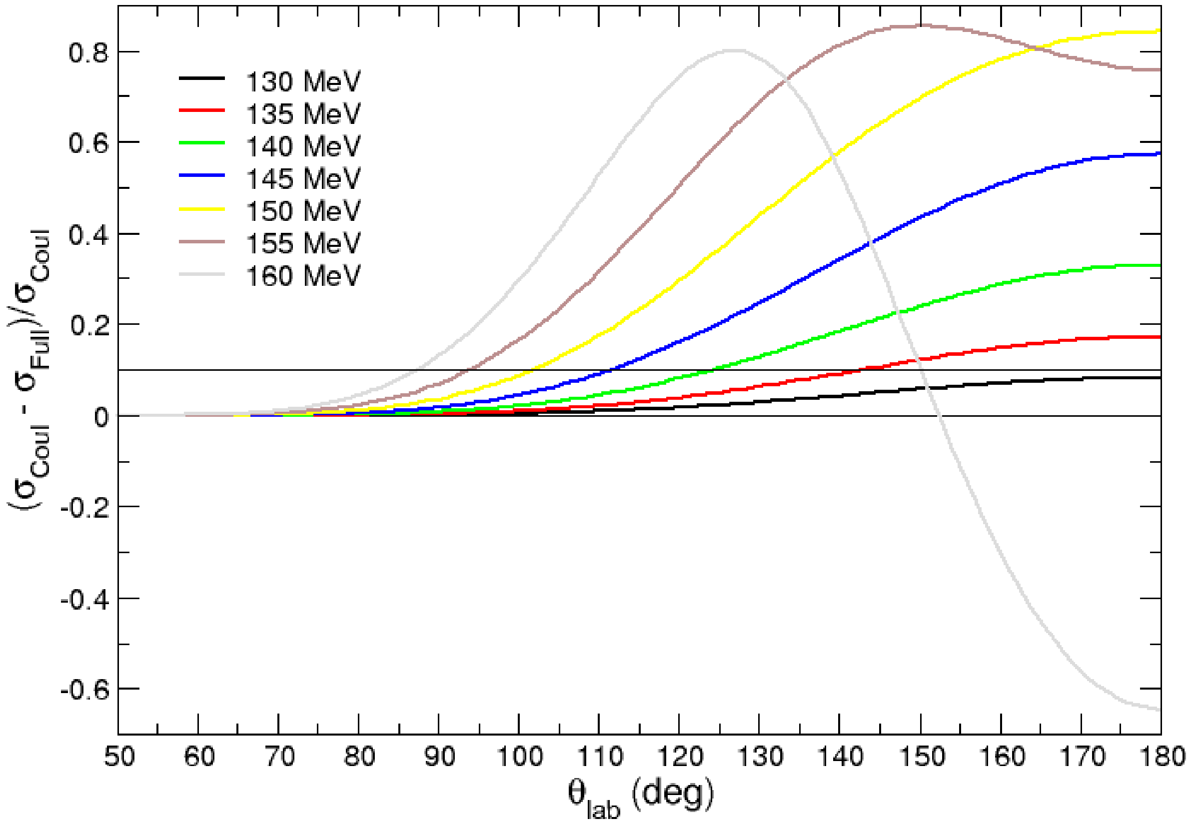
What does this input file predict? First, excitation function of total cross section for exciting $^{32}S\ 2^+$



Angular distributions of differential cross section for exciting $^{32}S\ 2^+$



Difficult to interpret; would like to quantify deviation from pure Coulex as a function of laboratory angle:

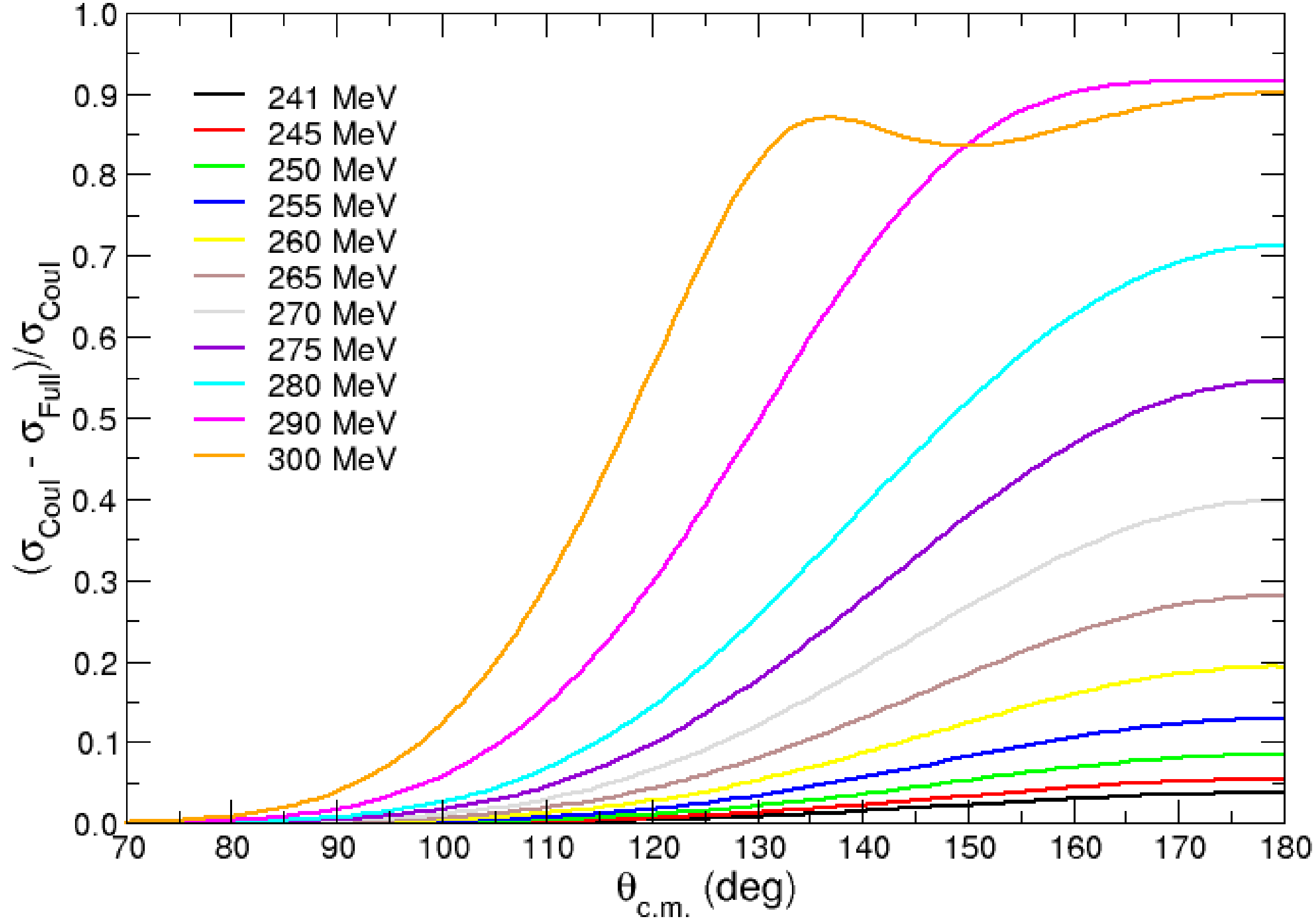


To sum up, this exercise perhaps does not tell us much more than Cline's criterion but does allow us to quantify the nuclear “contamination” (one may pick the level to be tolerated: 10%, 20% etc.)

Results for ^{32}S + ^{197}Au system not encouraging; if we wish to keep level of nuclear effects reasonable at most we will gain about a factor of 2 in cross section

However, nuclear deformation lengths are likely to be upper limits, so represent maximum nuclear influence (nuclear part always model dependent)

Not quite so discouraging for heavier systems: $^{58}Ni + ^{197}Au$



Cross section increases from 400 mb to 1100 mb