Progress towards an evaluation of the ^{7}Be system with AZURE2

James deBoer

University of Notre Dame and JINA

R-matrix details

Using the Brune basis

Using “(light, heavy)”

- (α,^{3}He)
- (p_0,^{6}Li)
- (p_1,^{6}Li)
- Haven’t been able to successfully fit (p_2,6Li)

Step 1: Compile data sets

Ian Thompson

Pulled all $^{3}He+\alpha$, $\alpha+^{3}He$, $^{7}Li+p$ and $p+^{7}Li$ data from EXFOR

Meta data sheet

Kinematic, final state, data type, energy range, etc.

Step 2: Take a subset of data

About 50 data sets, just taking 13 representatives

Step 3: Summarize systematic uncertainties

Very important to note that several data sets obtain their absolute cross section scale by normalizing to previous measurements

Reaction	Reference	EXFOR ID	Syst. Unc. (%)	Comments
$^{3}\mathrm{He}(\alpha,\alpha)$	Barnard *et al.* [1]	A1269002	5 (total)	$d\sigma/d\Omega$, Data from Hale
$^{3}\mathrm{He}(\alpha,\alpha)$	Tombrello and Parker [2]	A1295002	5 (total)	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,p)$	McCray [3]	A1410002	5	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,p_{0,1})$	Harrison and Whitehead [4]	C1003002	N to [3]	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,\alpha)$	Elwyn *et al.* [5]	F0012002	9	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,p)$	Fasoli *et al.* [6]	D0135002	N to [2]	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,\alpha)$	Cruz *et al.* [7]	O1590003	6	σ
$^{6}\mathrm{Li}(p,\alpha)$	Tumino *et al.* [8]	O1221002	N to [5]	σ (THM)
$^{6}\mathrm{Li}(p,\alpha)$	Gemeinhardt *et al.* [9]	A1367002	5	σ
$^{6}\mathrm{Li}(p,\alpha)$	Bertrand *et al.* [10]	A1513005	unclear	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,\alpha)$	Shinozuka *et al.* [11]	F0005004	14	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,p)$	Skill *et al.* [12]	A0541002	–	$d\sigma/d\Omega$
$^{6}\mathrm{Li}(p,p)$	Soukeras *et al.* [13]	O2277002	–	$d\sigma/d\Omega$
$^{3}\mathrm{He}(\alpha,\alpha/p_{0,1})$	Spiger and Tombrello [14]	A1094007	1.5	$d\sigma/d\Omega$, Thompson revised

Step 4: Look for outliers

Spiger and Tombrello

Very small systematic uncertainty estimate of 1.5%, unrealistic.

Inconsistent data

Jeronymo *et al*., (p,α) angular distributions

Mohr *et al*., (p,p) angular distributions

etc.

Step 5: Fit as excitation functions or angular distributions

Still working this out, some preliminary decisions made

Step 6: Obtain a good R-matrix fit

Not fully achieved

Looks pretty up to about 8 or 9 MeV excitation energy

Having a hard time above the p1 threshold

Fitting some p1 data, not yet fitting p2 data

Compound Nucleus Levels

ıclude	Fix?	Level Spin	Energy [MeV]
☑	☑	3/2-	0
☑	☑	1/2-	0.429
☑	☐	7/2-	4.5636
☑	☐	5/2-	6.6545
☑	☐	5/2-	7.1573
☑	☐	1/2-	7.7667
☑	☐	5/2-	9.4709
☑	☐	7/2-	9.6768
☑	☑	1/2-	17
☑	☑	1/2-	20
☑	☑	1/2+	20
☑	☑	3/2-	20
☑	☑	3/2+	20
☑	☑	5/2-	20
☑	☑	5/2+	20
☑	☑	7/2-	20
☑	☑	7/2+	20
☑	☑	9/2-	20
☑	☑	9/2+	20

Step 7: Perform MCMC uncertainty estimation calculations

Using the Bayesian R-matrix Inference Code Kit (BRICK) developed by Daniel Odell at Ohio University (post doc of Daniel Phillips and collaborator of Carl Brune)

Give each fit parameter a prior

- Usually it is uniform (no prior uncertainty information)
- Systematic uncertainties may be given a Gaussian or Lognormal distribution if they have an independent determination of the absolute cross section

```
50 priors = [
51     stats.uniform(0,10), #1/2- FES alpha ANC
52     stats.uniform(0,10), #1/2- FES proton ANC 1
53     stats.uniform(7.7, 0.3), #1/2- unbound energy 1
54     stats.uniform(0,10000), #1/2- unbound alpha width
55     stats.uniform(-2e6,2e6), #1/2- unbound proton width 1
56     stats.uniform(0,1e6), #1/2- unbound proton width 2
57     stats.uniform(0,1e8), #1/2- BGP alpha width
58     stats.uniform(0,1e9), #1/2- BGP proton width 1
59     stats.uniform(-1e7, 1e7), #1/2- BGP proton width 2
60     stats.uniform(0,1e9), #1/2+ BGP alpha width
61     stats.uniform(0,1e9), #1/2+ BGP proton width 1
62     stats.uniform(0,1e9), #1/2+ BGP proton_1 width
63     stats.uniform(-10,10), #3/2- GS alpha ANC
64     stats.uniform(0,10), #3/2- GS proton ANC 1
```

```
105     stats.norm(1, 0.05), # Barnard
106     stats.norm(1, 0.05), # Tombrello and Parker
107     stats.norm(1, 0.05), #McCray
108     stats.uniform(0, 10), #Harrison and Whitehead
109     stats.norm(1, 0.09), #Elwyn
110     stats.uniform(0, 10), #McCray start
111     stats.uniform(0, 10),
112     stats.uniform(0, 10),
113     stats.uniform(0, 10),
114     stats.uniform(0, 10),
115     stats.uniform(0, 10), #McCray stop
116     stats.uniform(0, 10), #Fasoli start
117     stats.uniform(0, 10),
118     stats.uniform(0, 10),
119     stats.uniform(0, 10),
120     stats.uniform(0, 10),
121     stats.uniform(0, 10),
122     stats.uniform(0, 10), #Fasoli stop
```

So that’s where I’m at

Biggest problems

- Having trouble pinning down the level structure above 9 MeV excitation energy

- LOTS of data, which is good, but takes a lot of work to input into the calculations (data + meta data)

The bright side

- LOTS of data
- A large fraction are pretty consistent! (outlier data more easily identifiable)