Not All Matrix Elements are Equal
Comparing Shell-Model Interactions

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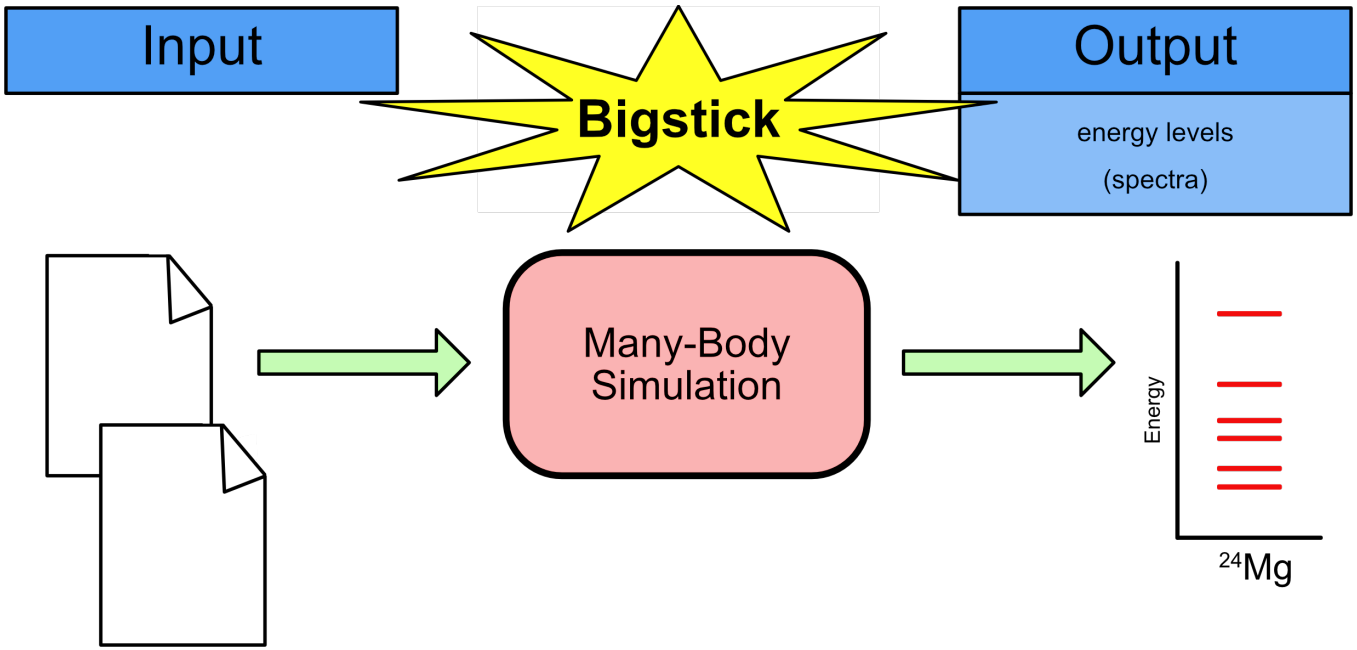
Interactions in the sd-Shell



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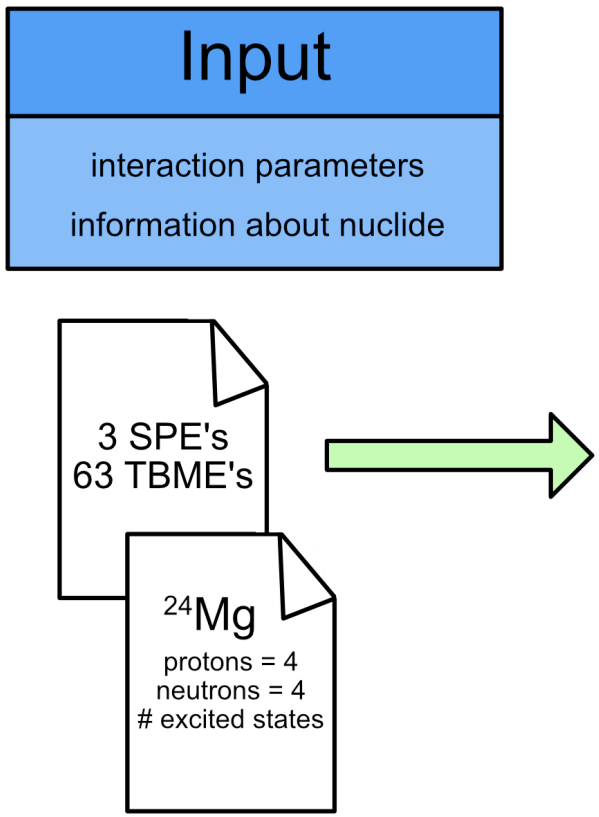


To Many-Body Simulation:

- Interaction file
  - Single Particle Energies (SPE)
  - Two-Body Matrix Elements (TBME)
- Information about nuclide
  - # of valence protons
  - # of valence neutrons
  - # of excitation states

Interactions in the sd-Shell

Single Particle Energies

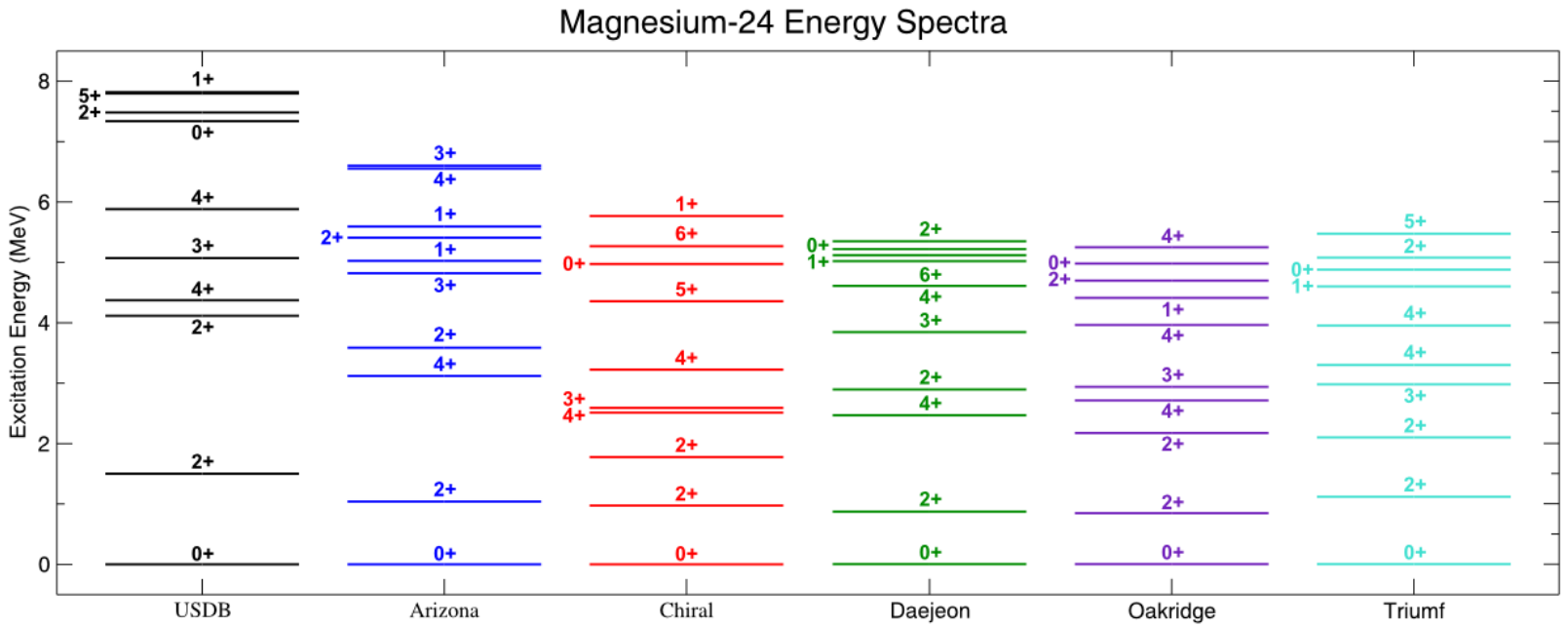
```
63      2.1117   -3.9257   -3.2079
  2   2   2   2     1   0  -1.3796
  2   2   2   1     1   0   3.4987
  2   2   1   1     1   0   1.6647
  2   2   1   3     1   0   0.0272
  2   2   3   3     1   0  -0.5344
  2   1   2   1     1   0  -6.0099
  2   1   1   1     1   0   0.1922
  2   1   1   3     1   0   1.6231
  2   1   3   3     1   0   2.0226
  1   1   1   1     1   0  -1.6582
  1   1   1   3     1   0  -0.8493
  1   1   3   3     1   0   0.1574
  1   3   1   3     1   0  -4.0460
  1   3   3   3     1   0  -0.9201
  3   3   3   3     1   0  -3.7093
  2   1   2   1     2   0  -4.2117
  2   1   2   3     2   0  -0.6464
  2   1   1   3     2   0  -0.4429
  2   3   2   3     2   0  -0.3154
  2   3   1   3     2   0  -2.5110
  :
  a   b   c   d     J   T
```

TBME

Typical Interaction Input:

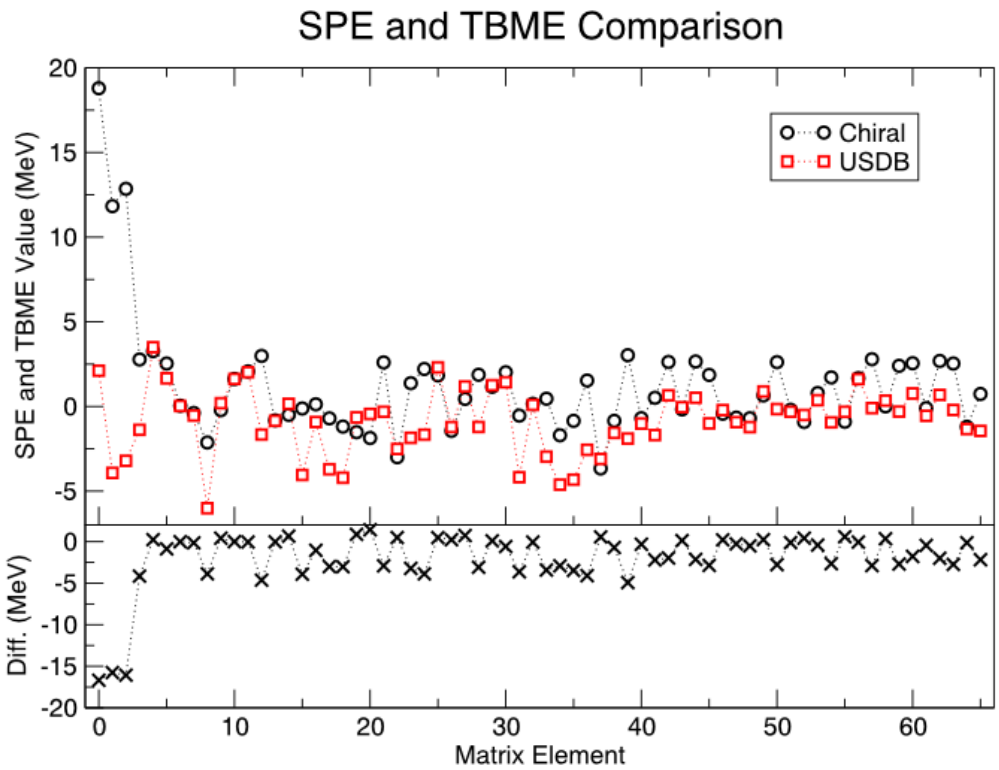
"Gold Standard" is Alex Brown's USDB interaction (a fit to many-body spectra)

Motivation



See differences in energies and order of angular momentum.

Motivation



Element by element comparison is not enlightening.

Method

We investigate the effects of perturbations of the SPEs and TBMEs on the energy spectra output by our CI code:

$$E_\alpha(\lambda_i + \delta\lambda_i) = E_\alpha(\lambda_i) + \frac{\partial E_\alpha}{\partial \lambda_i}\delta\lambda_i + \cdots$$

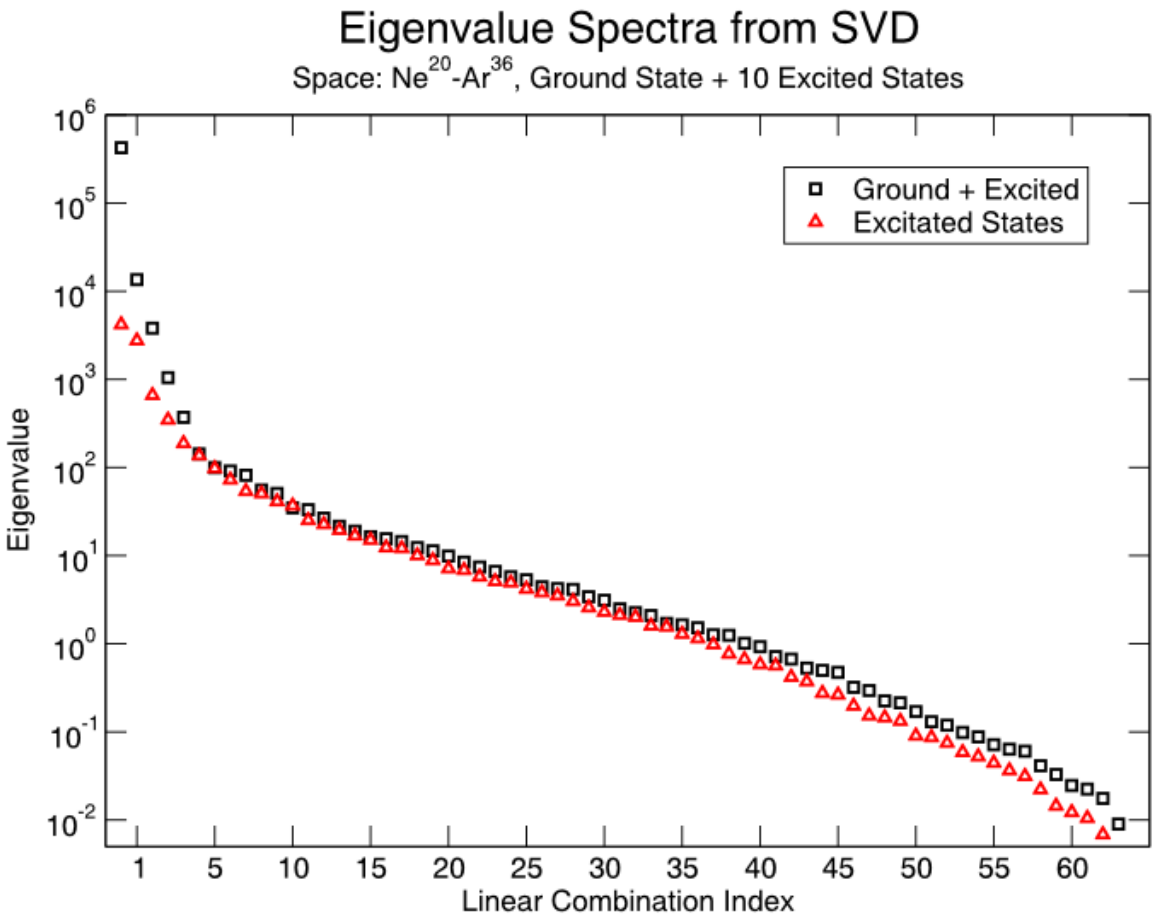
The second term can be evaluated using the Feynmann-Hellmann Theoreom:

$$\frac{\partial E_\alpha}{\partial \lambda_i} = \langle \Psi_\alpha | H_i | \Psi_\alpha \rangle$$

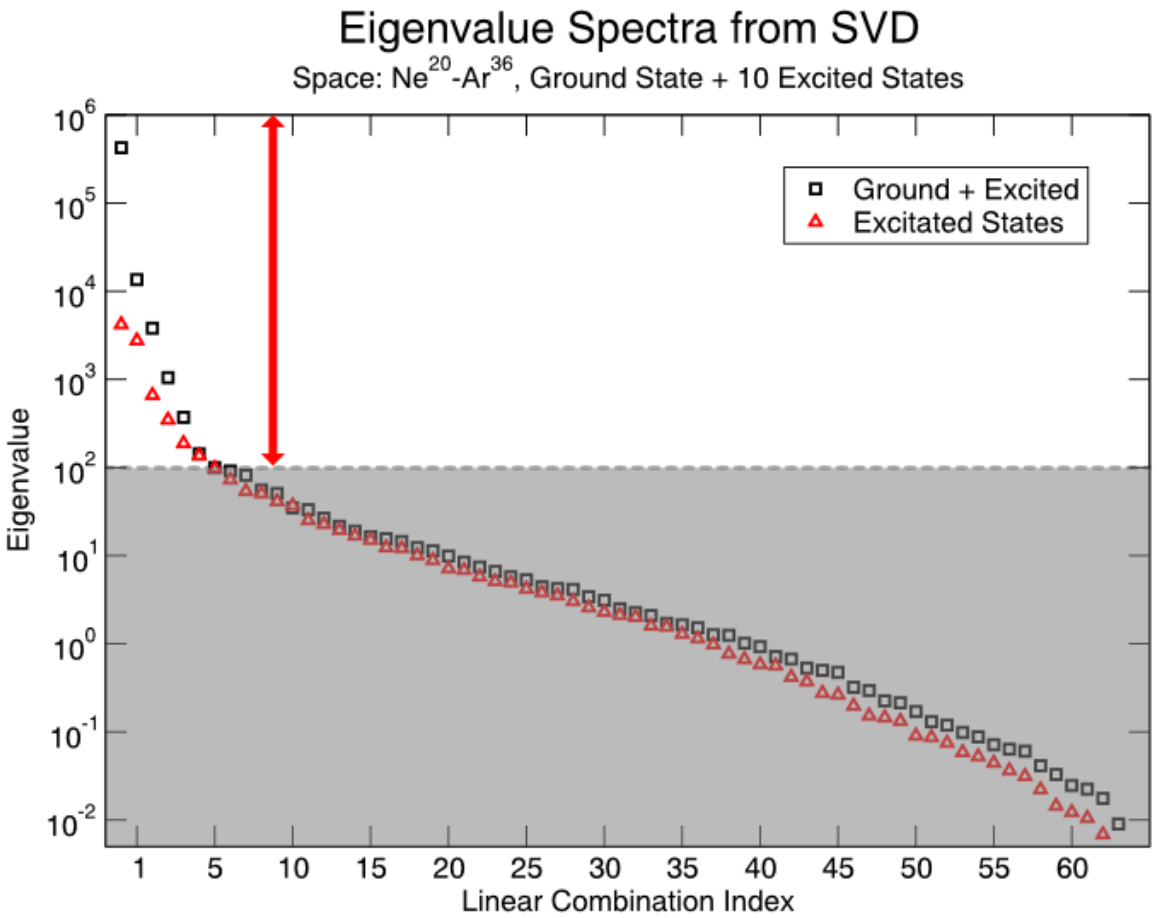
We do not expect all SPEs + TBMEs to contribute equally.

Use a Singular Value Decomposition to determine dominant linear combinations.

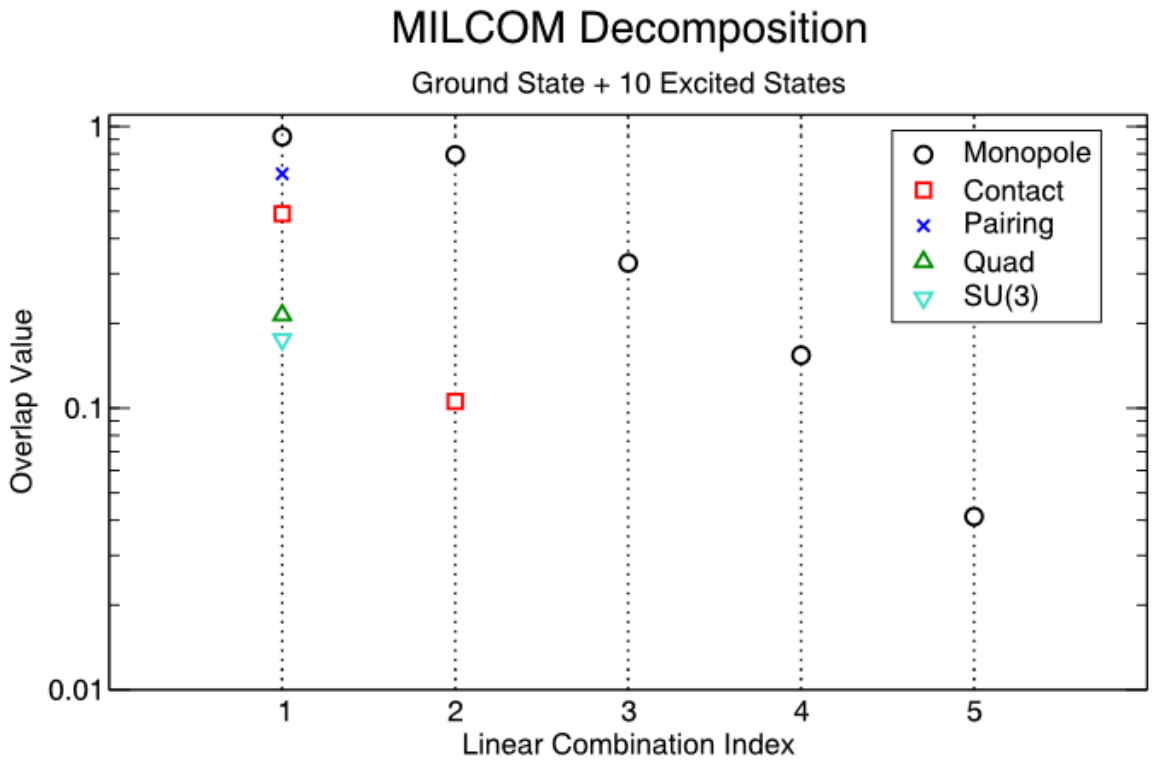
SVD of USDB Interaction



SVD of USDB Interaction

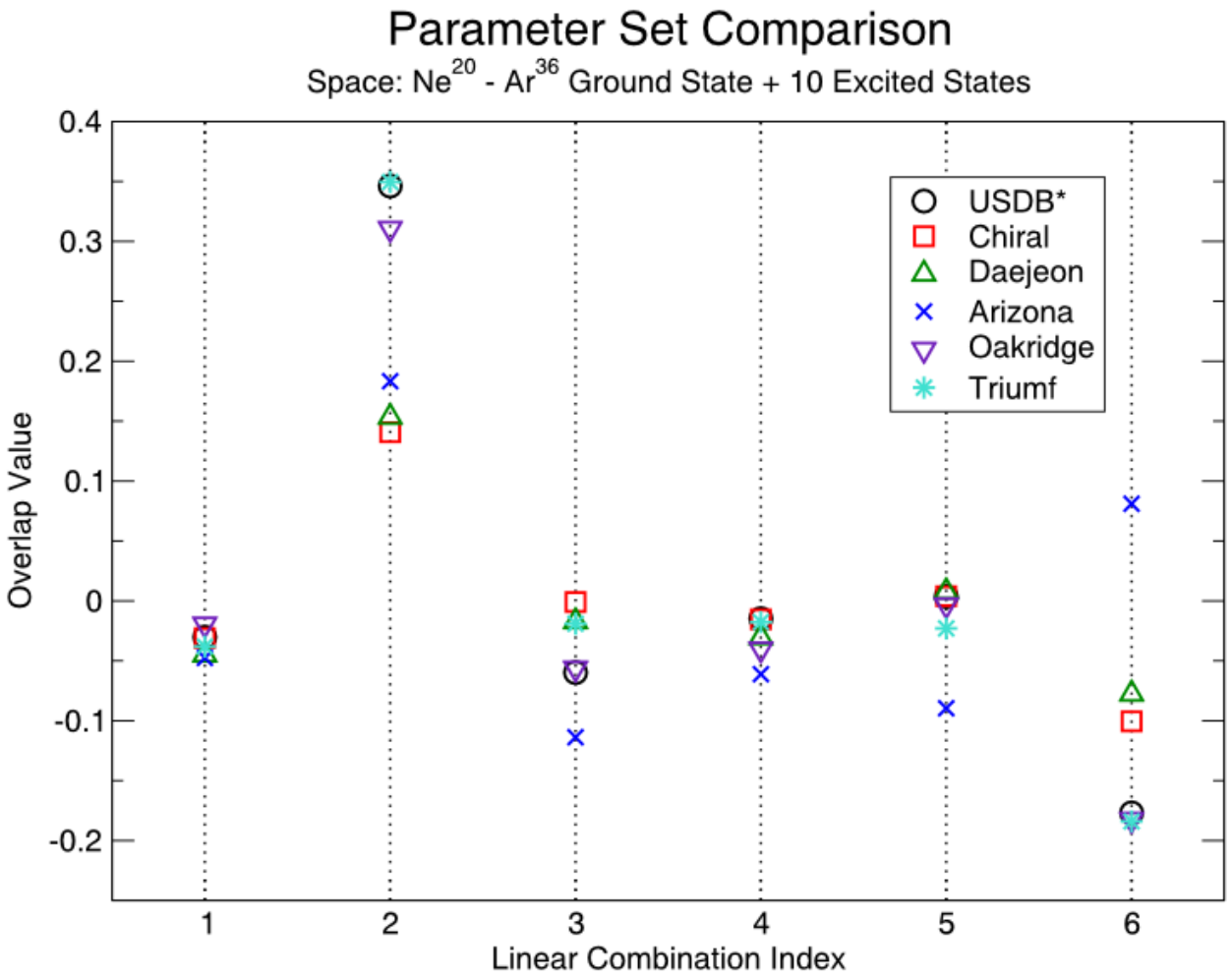


Subspace Decomposition

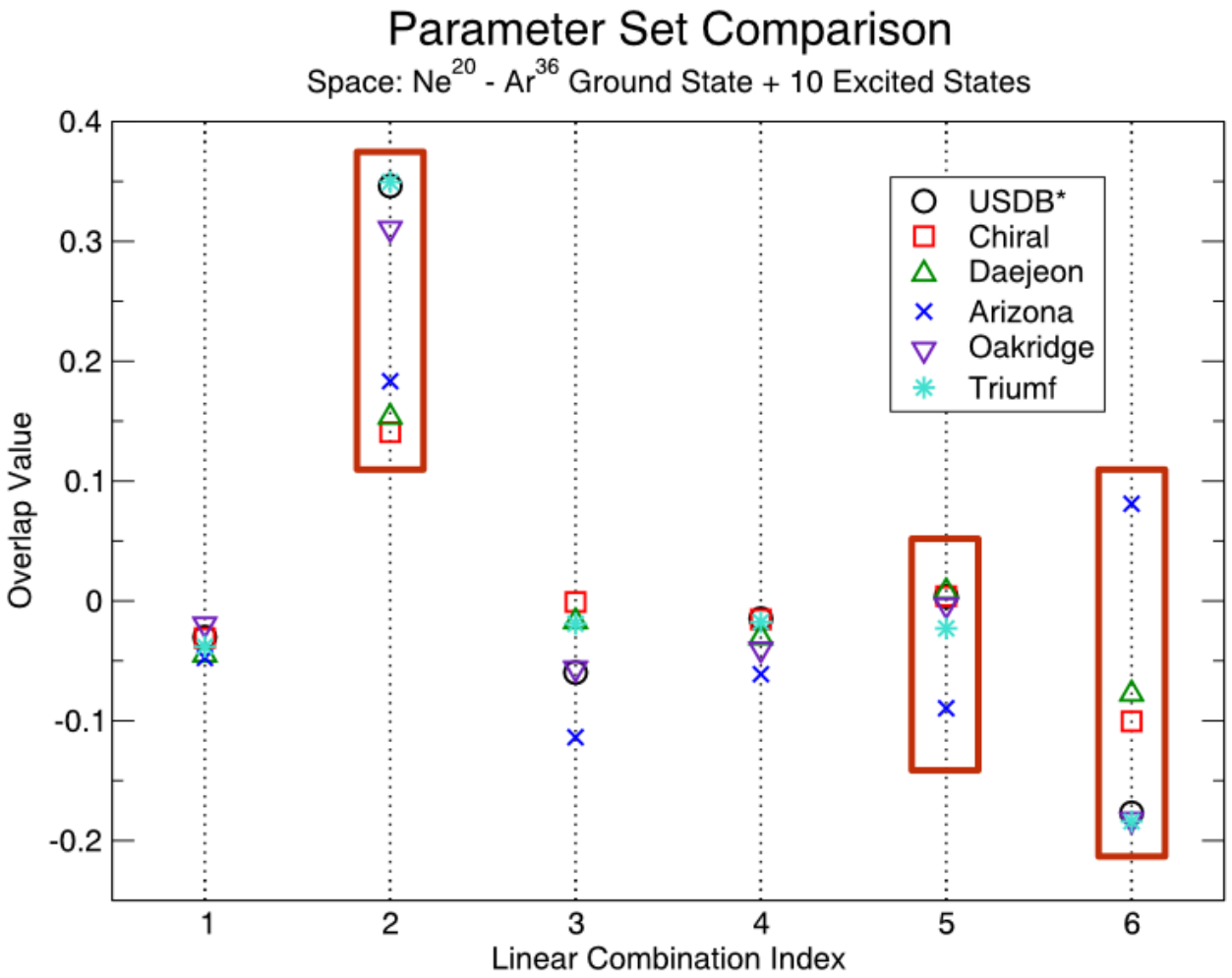


"MILCOM" = most important linear combination

Interaction Comparison



Interaction Comparison



Future Work

Currently comparing:

- Arizona
- Chiral
- Daejeon
- Oakridge
- Triumf

Open to more sd-shell interactions with similar analysis for different shells (coming soon...)

References

(1) E. Dikmen et al., Phys. Rev. C **91**, 064301 (2015)

(2) D. R. Entem and R. Machleidt, Phys. Rev. C **68**, 041001(R) (2003)

(3) A. M. Shirokov et al., Phys. Lett. B **761**, 87-91 (2016)

(4) G. R. Jansen et al., Phys. Rev. C **94**, 011301 (2016)

(5) S. R. Stroberg et al., Phys. Rev. C **93**, 051301(R) (2016)

(6) B. A. Brown and W. A. Richter, Phys. Rev. C **74**, 034315 (2006)

(7) C. W. Johnson and P. G. Krastev, Phys. Rev. C **81**, 054303 (2010)

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