Systematic Study of α-Optical Potential via Elastic Scattering for p-Process

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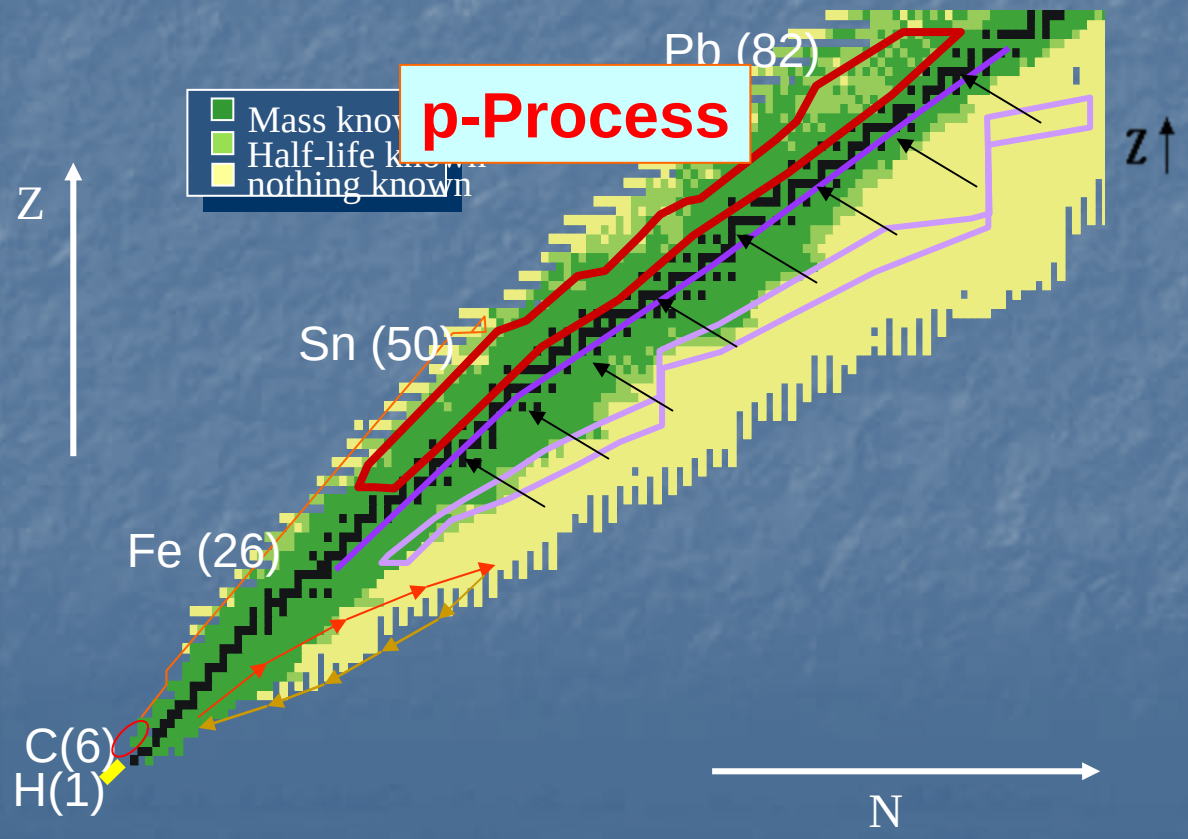
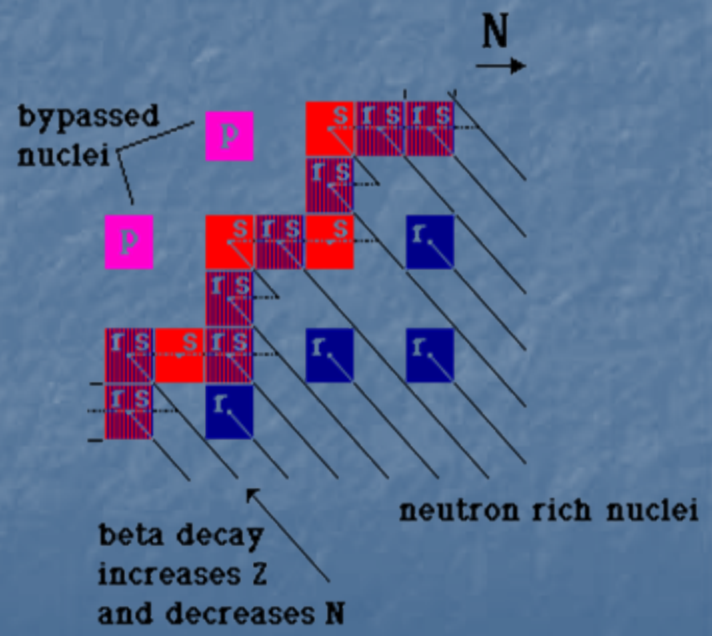
Production of p-Nuclei

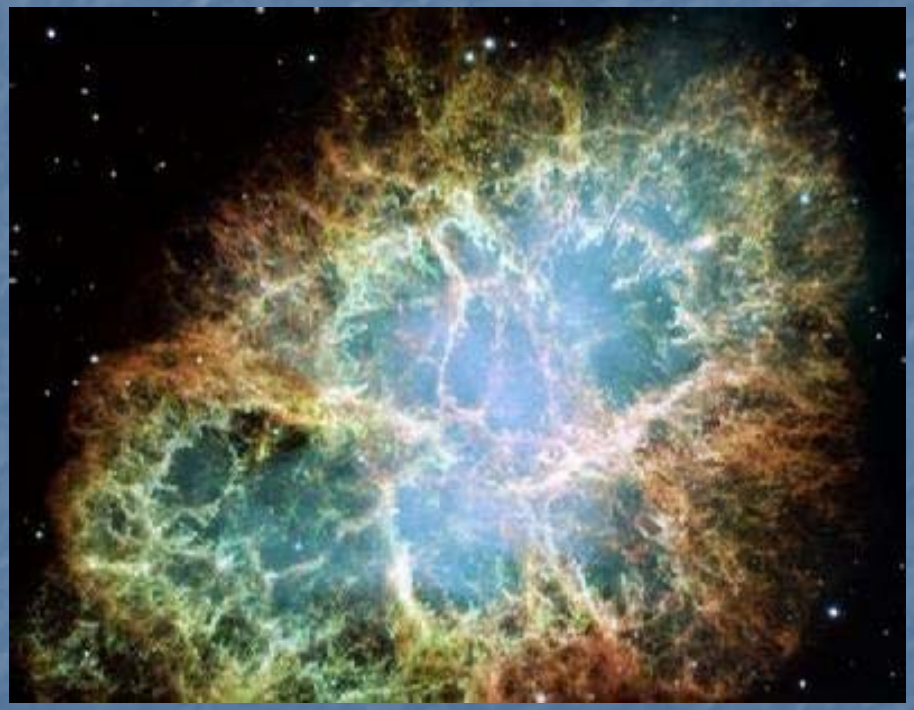
- Production of p-nuclei, lying on the proton rich side of the valley of stability and shielded from s- and r-processes, proceeds most likely via the so-called p-process or photo-disintegration process.

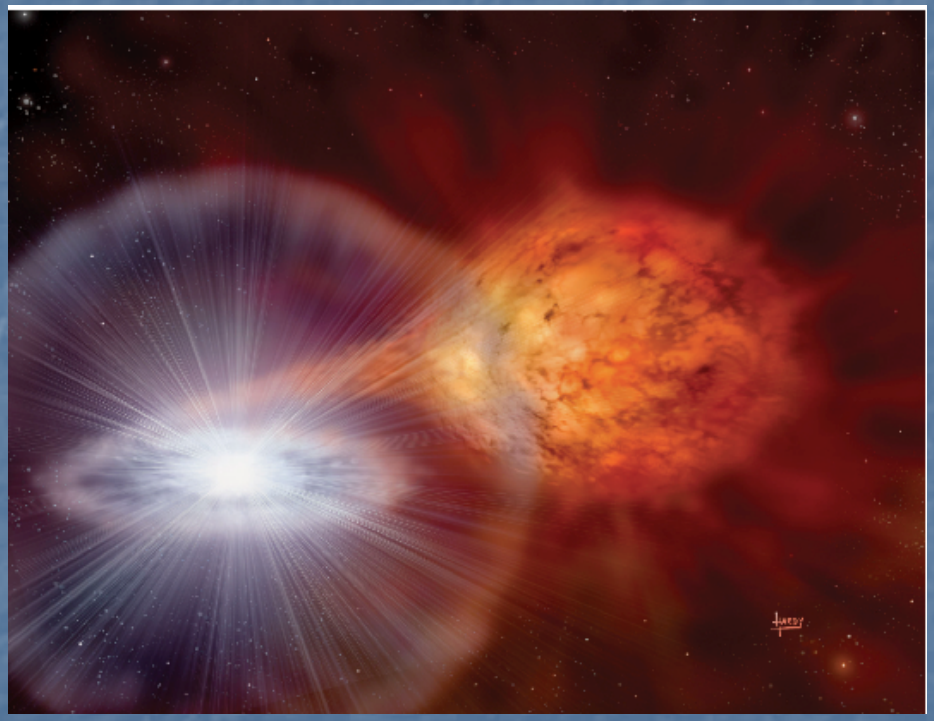




Possible Astrophysical Sites

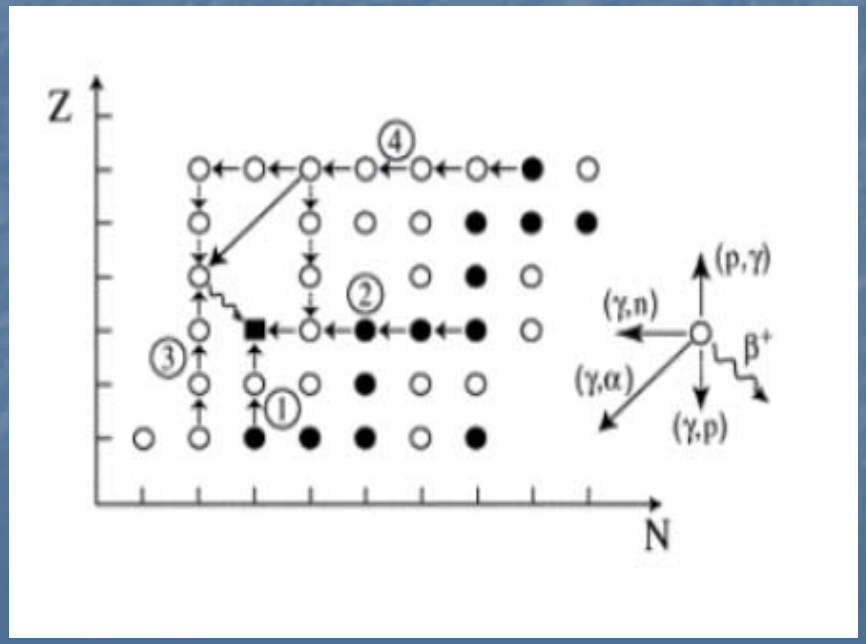
- Possible p-process sites: Ne-O layers of Type II Supernova; Type Ia Supernova explosions

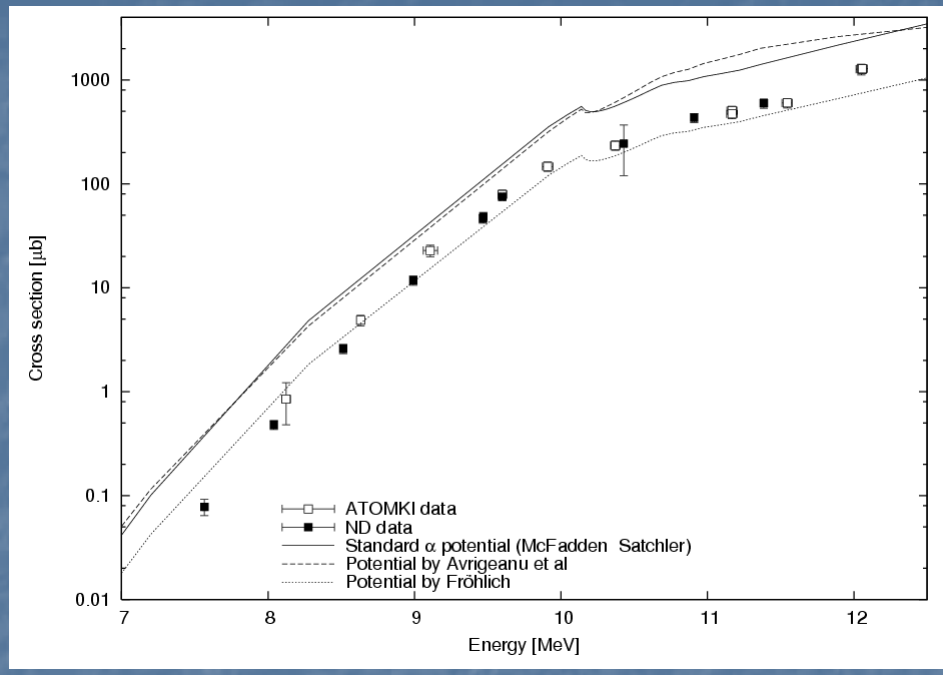




Uncertainties of p-Process

- The p-nuclei are synthesized via a series of (g,n) (g,a) and (g,p) reactions on heavy seed nuclei. These reaction rates are calculated with the statistical Hauser Feshbach Model (HF-Model) which may carry large uncertainties.

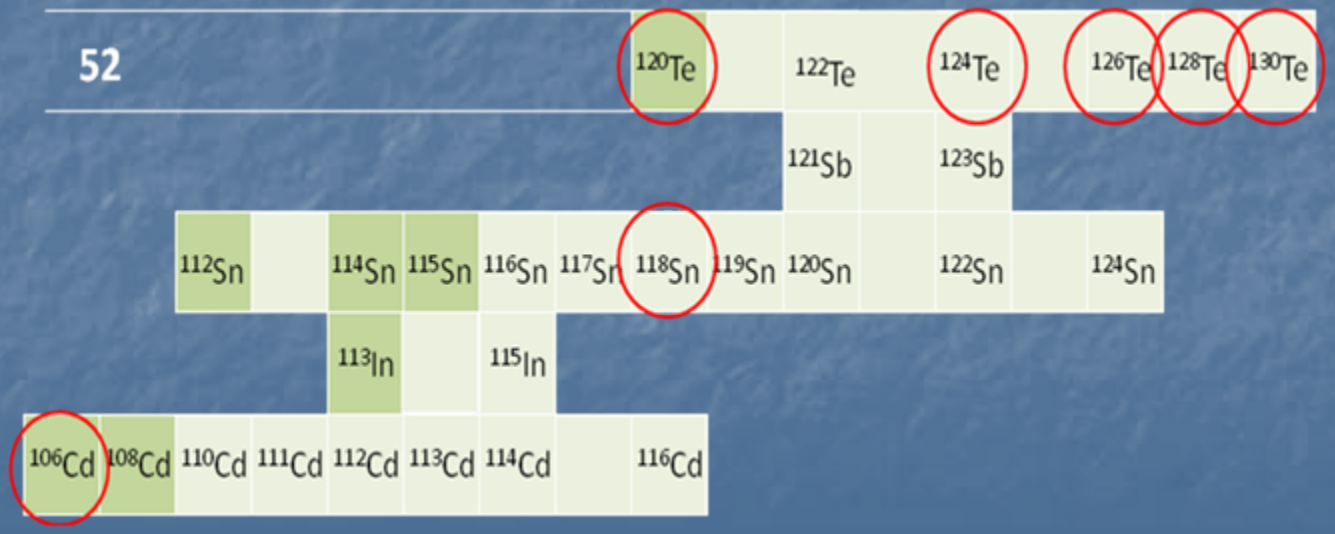




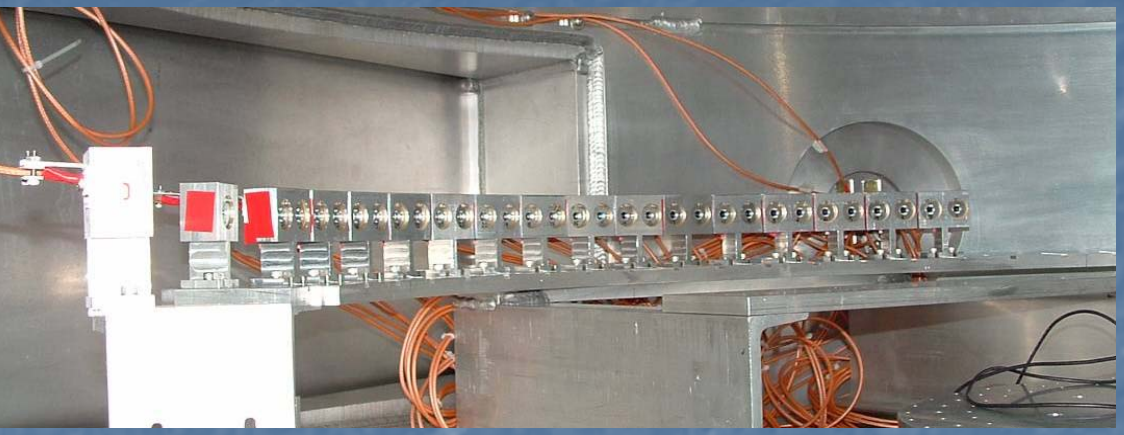
Large discrepancies between experimental data and theoretical HF predictions for α-capture rates have indicated a necessity of improving the current α-potential models.

α-Elastic Scattering

- To test the reliability of the HF calculations for p-process and provide a systematic understanding of the alpha optical potential at energies of astrophysical interest, a series of precision alpha scattering measurements were carried out at the Notre Dame FN tandem accelerator: 120,124,126,128,130Te / 106Cd / 118Sn (a, a) at energies of 17, 19, 22, 24.5, 27 MeV

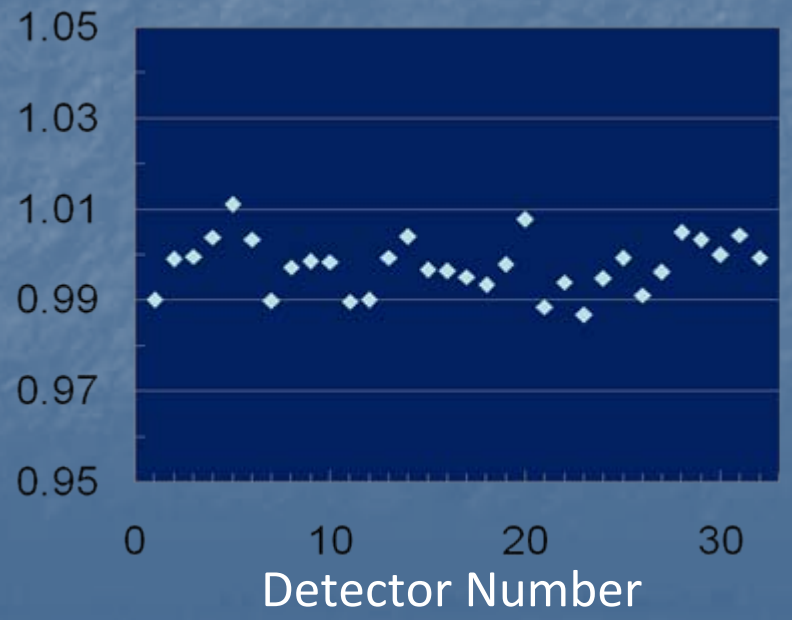


Experimental Setup



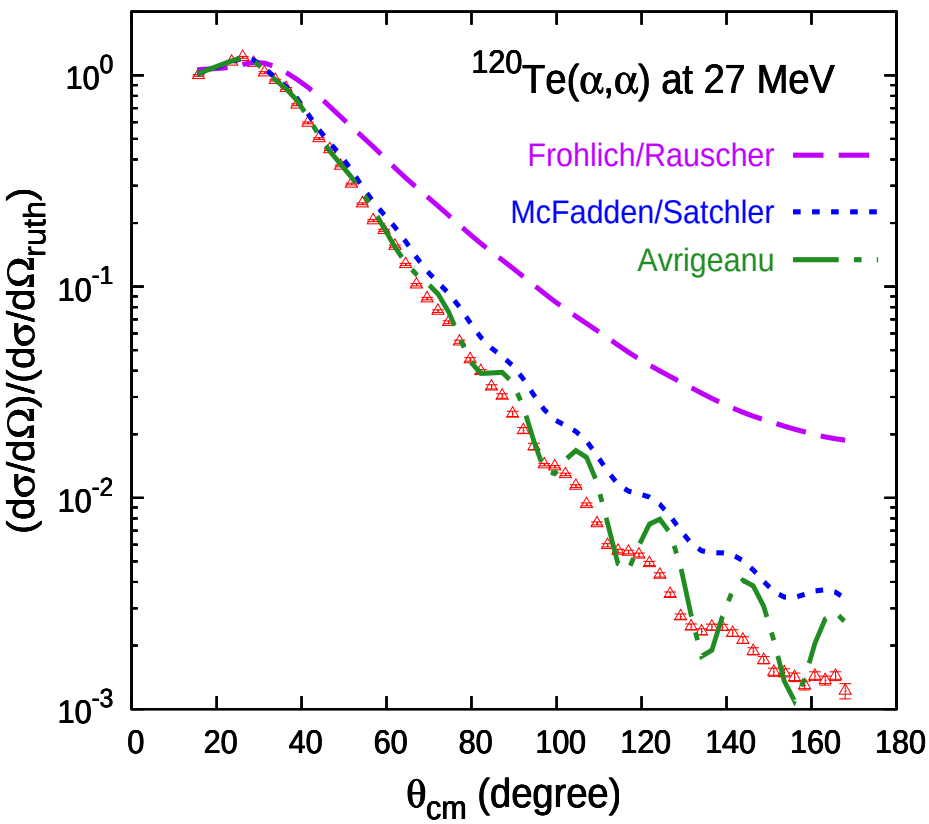
An array of 32 photo-diode detectors were used to cover alpha scattering angles between 15 and 167.5 degrees.

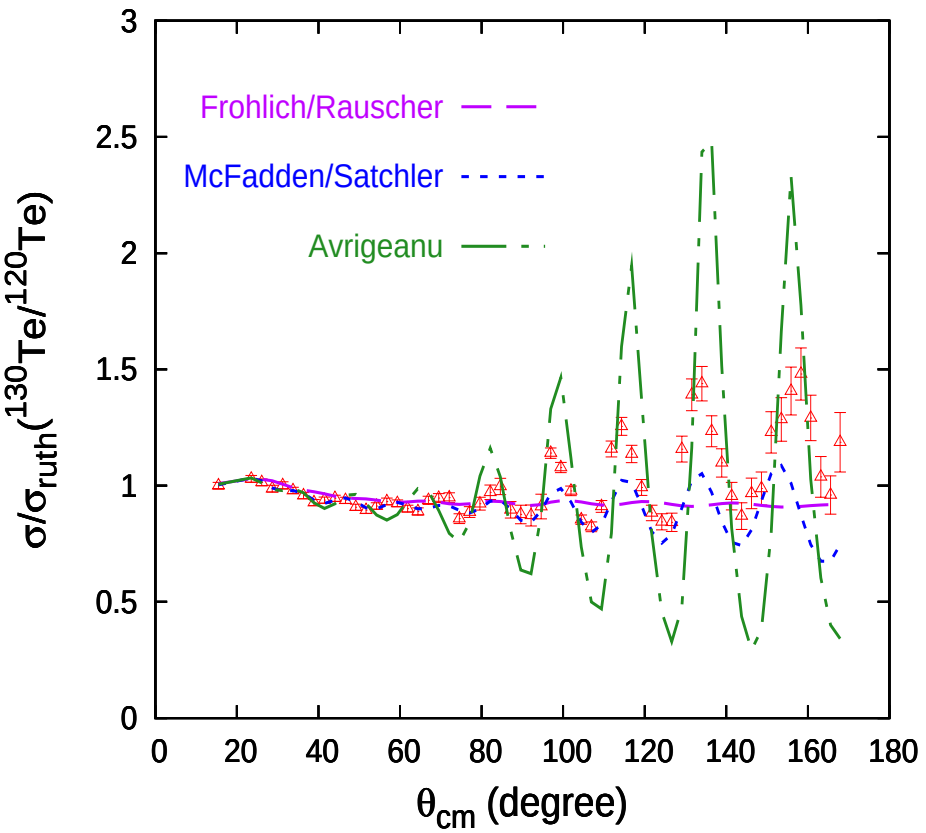
Solid angle uncertainties from two independent measurements



Global Potential Models

- Experimental cross sections (normalized to Rutherford cross sections) are compared to the calculations of various alpha optical potential models used in Non-Smoker calculations of reaction rates.





Develop new models

- Introduce mass and energy dependeces in optical potential model parameters:

$$V = Vc + Vr + i\,(Vv+Vs)$$

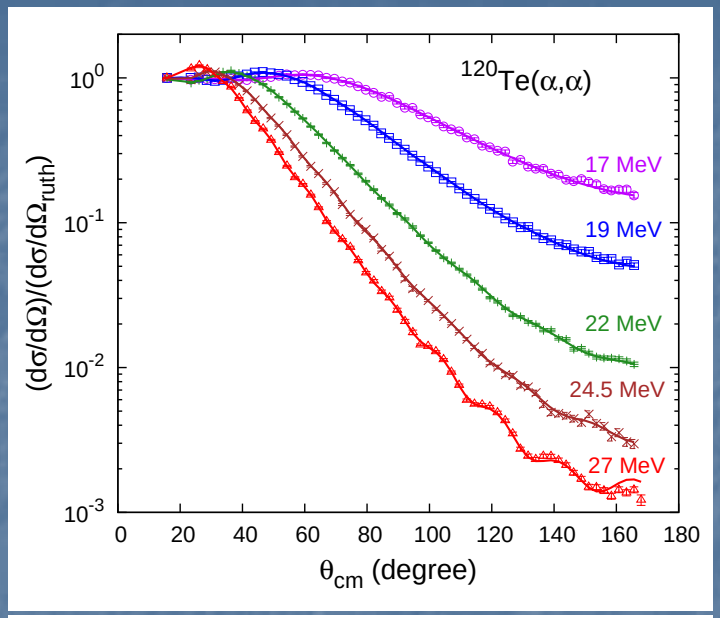
$$Vv = Wv \left(1+\exp\left(\frac{r-R_V}{a_V}\right)\right)^{-1}$$

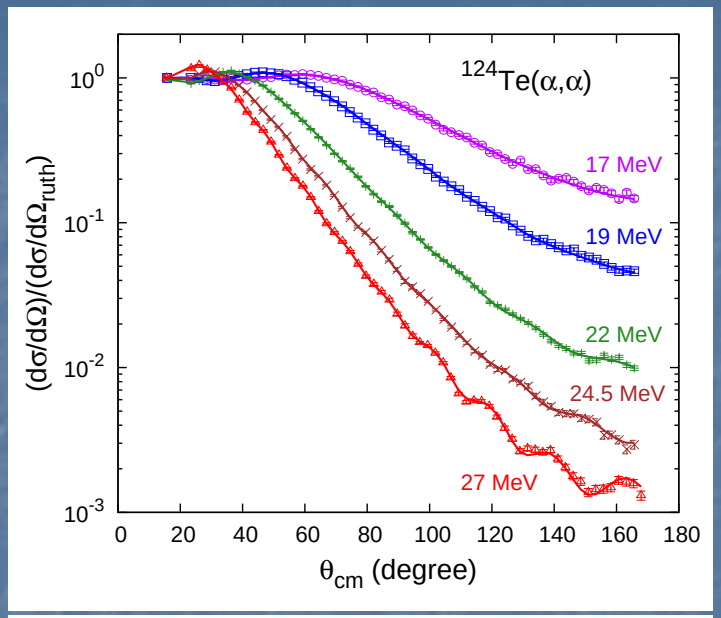
$$Vs = Ws \exp\left(\frac{r-R_S}{a_S}\right)\left(1+\exp\left(\frac{r-R_S}{a_S}\right)\right)^{-2}$$

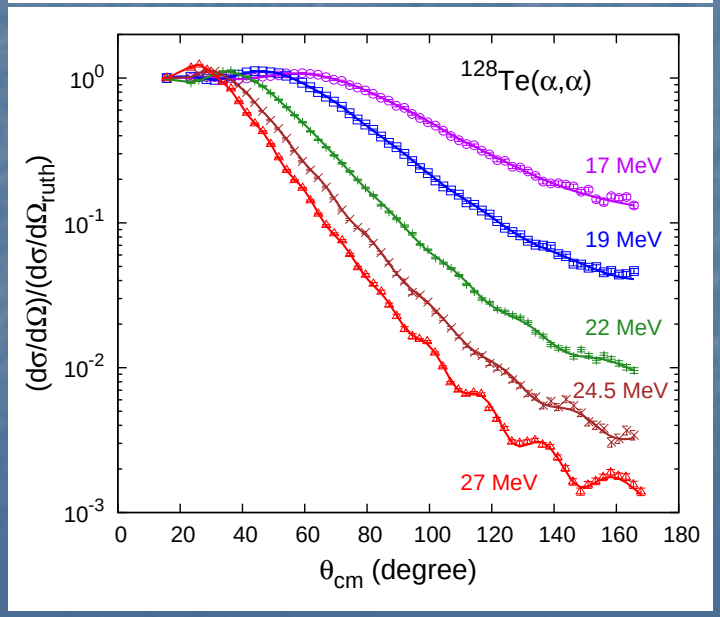
$Wv = 14.848 - 0.1066\,A + 0.189\,E\alpha$
$Rv = 1.690 - 0.23479\,A^{(1/3)}$
$a_V = 1.5811$

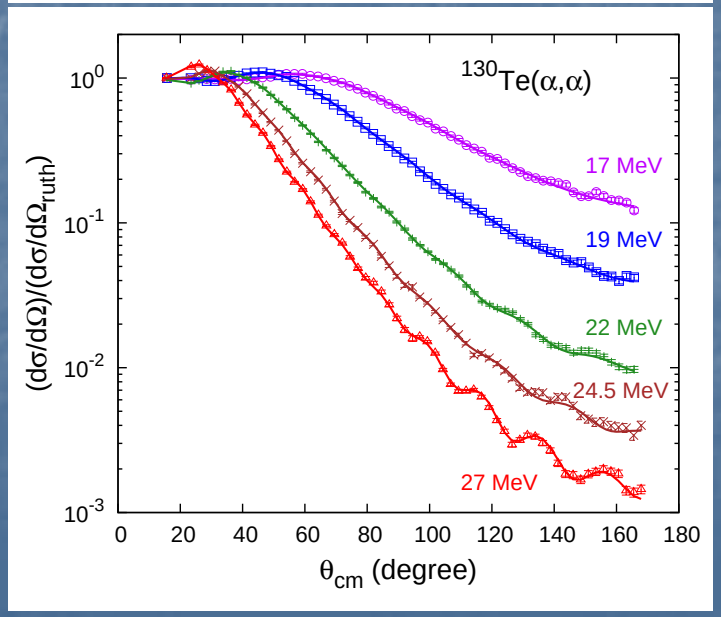
$Ws = 772.196 - 4.5464\,A + 3.48\,E\alpha$
$Rs = 1.270$
$a_S = 0.19$

Comparisons with Data

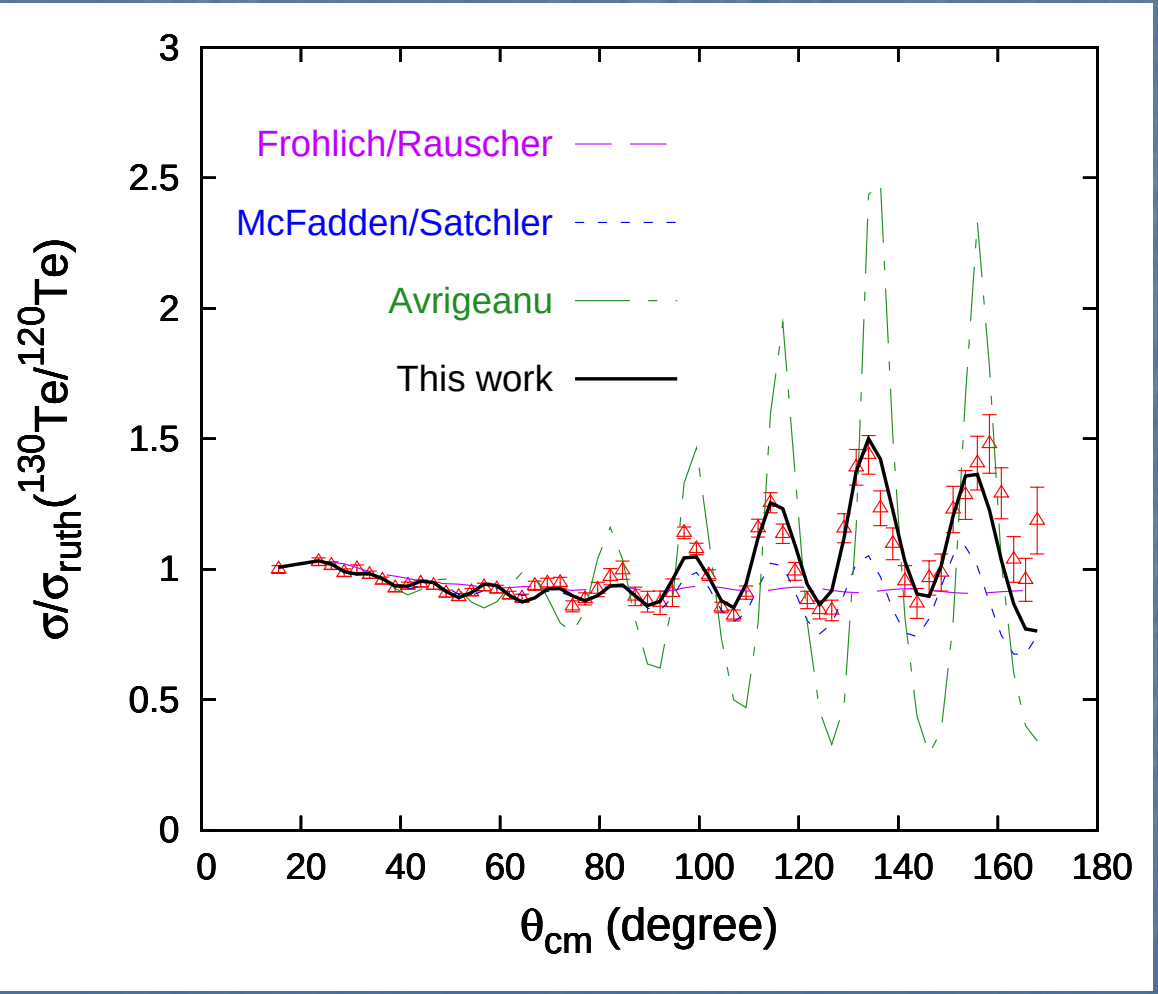




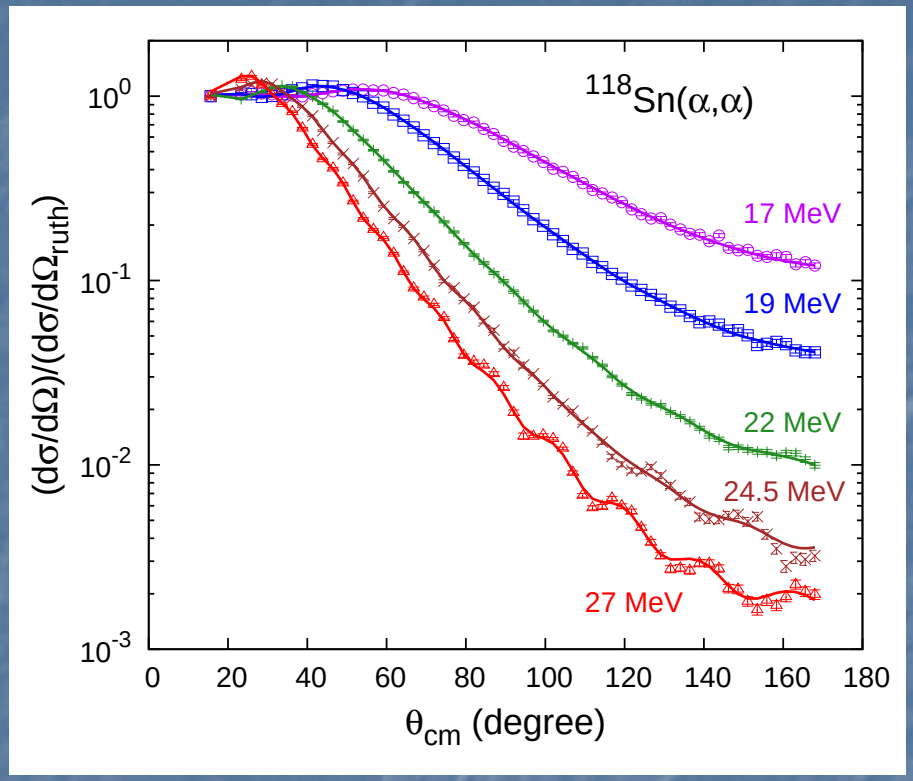


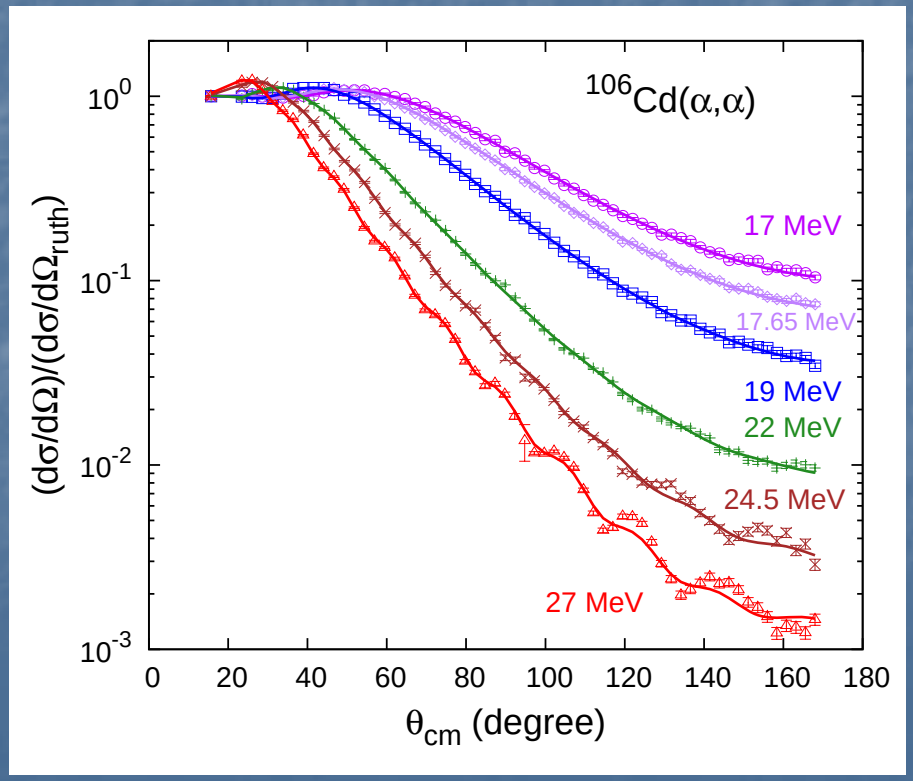


Mass Dependence



Charge / Isospin Dependence?





Summary

- Precision alpha elastic measurements were conducted to better constrain the model parameters of alpha-optical potentials for reaction rate calculations
- The extended energy range helps probe the energy dependence of the potential parameters and guide the extrapolation down to the astrophysical energy range.
- The systematic study of almost all stable Te isotopes helps determine the isotopic dependence of the potential and therefore extend the application to the unstable p-rich nuclei away from the stability valley.
- Additional measurements with 106Cd and 118Sn provide a test on the charge/isospin dependence. Further detailed analysis is in process.

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