Los Alamos NATIONAL LABORATORY

Recent Light-Element Standards-Related Work at Los Alamos

TM on Neutron Data Standards 2023
IAEA, Vienna, Austria

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LA-UR-XXXXX

Updated R-matrix Analyses/Evaluations

- n-p [N-N system] scattering up to 250 MeV
- n+^{3}He cross sections up to 20 MeV
- n+^{12}C [^{13}C system] scattering up to 8 MeV

Charge-Independent Analysis of N-N System up to 100 MeV

Channel	a_c (fm)	l_{max}
p+p	3.26	3
n+n	3.26	3
n+p	3.26	3
γ+d	84.6	1

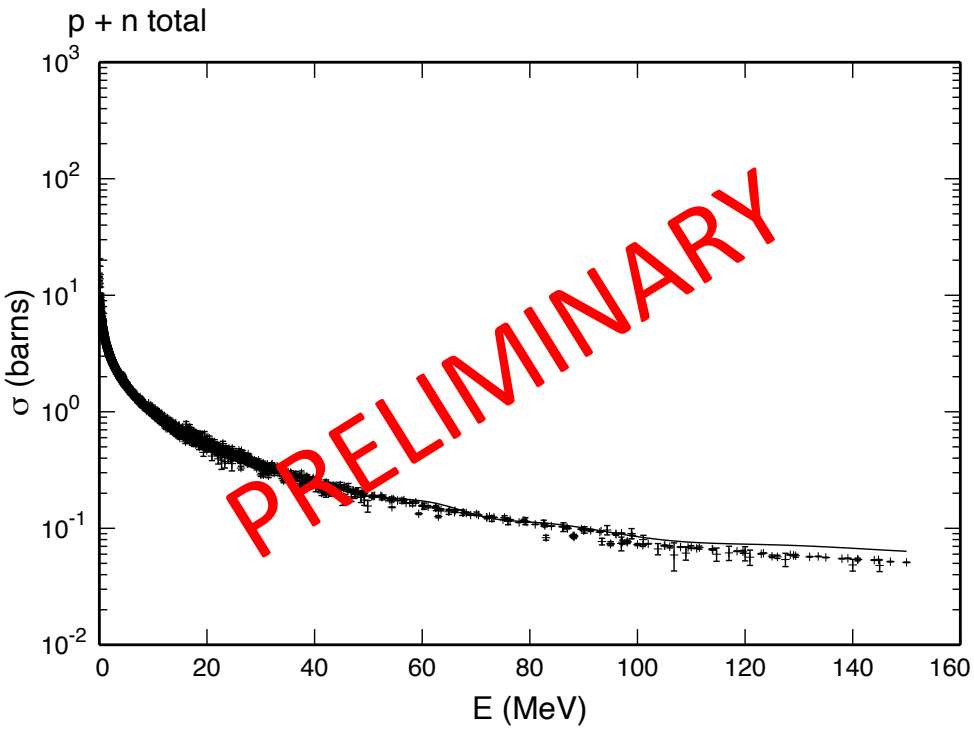
Reaction	# Pts.	χ^2	Observable Types
p(p,p)p	667	1218	$\sigma(\theta)$, $A_y(p)$, $C_{x,x}$, $C_{y,y}$, $K_x^{x'}$, $K_y^{y'}$, $K_z^{x'}$
n(n,n)n	1	0	σ_{int} (a_0)
p(n,n)p	5260	4687	σ_T, $\sigma(\theta)$, $A_y(n)$, $C_{y,y}$, $K_y^{y'}$
p(n,γ)d	82	133	σ_{int}, $\sigma(\theta)$, $A_y(n)$
d(γ,n)p	84	106	σ_{int}, $\sigma(\theta)$, $\Sigma(\gamma)$, $P_y(n)$
Total	6094	6144	19

free parameters = 50 $\Rightarrow$ χ^2/degree of freedom = 1.0165

Additional NN data to 250 MeV

Preliminary

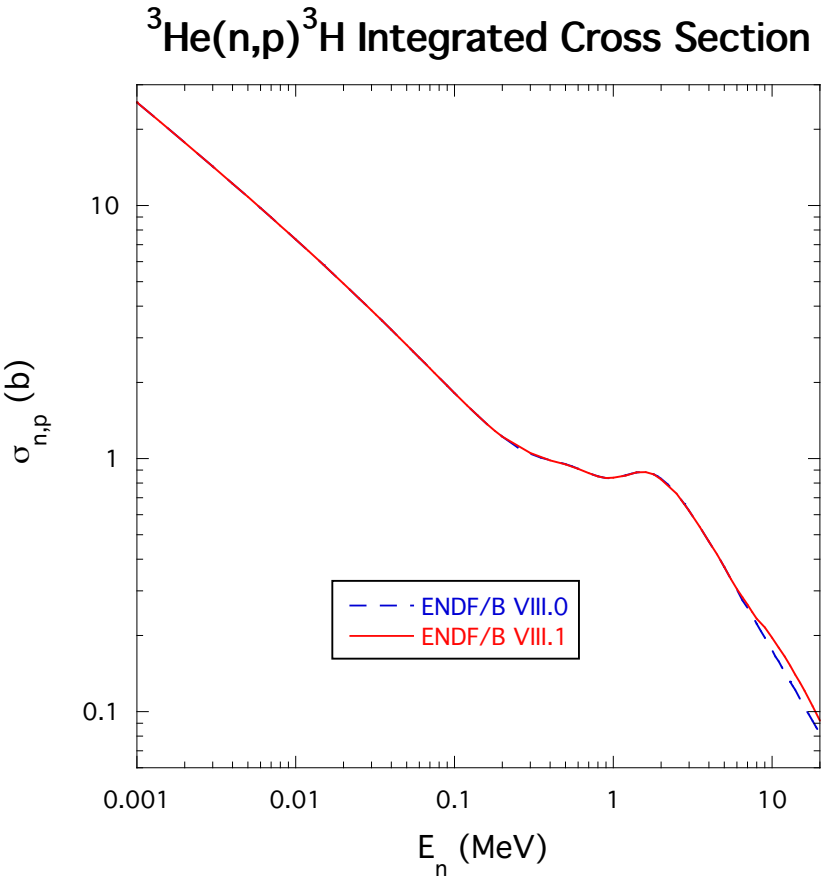
- pp
  - Angular dists. to 250 MeV
- np
  - Integrated to 250 MeV
  - *Snapshot* of current fit status (to 150 MeV)

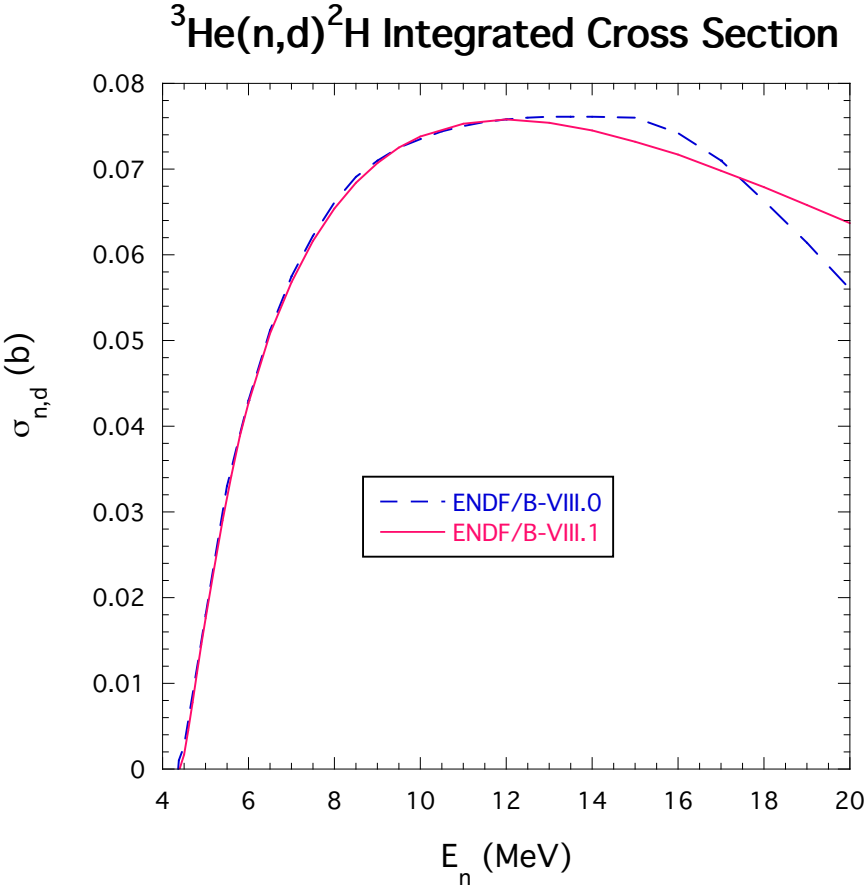


New Evaluation of n+^{3}He Reactions Submitted for ENDF/B-VIII.1

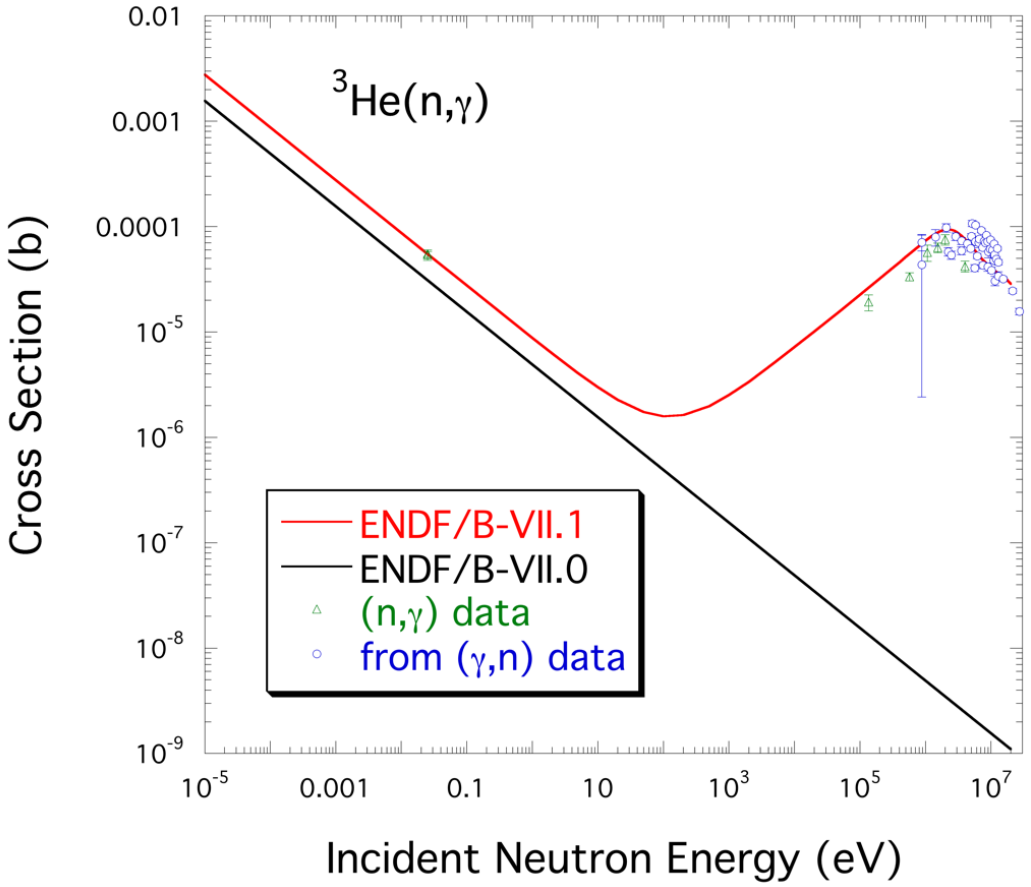
- Evaluation was essentially ENDF/B-VII.1 carried over to ENDF/B-VIII.0.
- Angular distributions existed only for for elastic scattering (MT=2).
- Added angular distributions and modified integrated cross sections for the ^{3}He(n,p)^{3}H and ^{3}He(n,d)^{2}H reactions.
- Added angular distributions for the ^{3}He(n,γ)^{4}He reaction consistent with the integrated cross section that had been revised in ENDF/B-VII.1.

Changes in the n+^{3}He Reaction Cross Sections

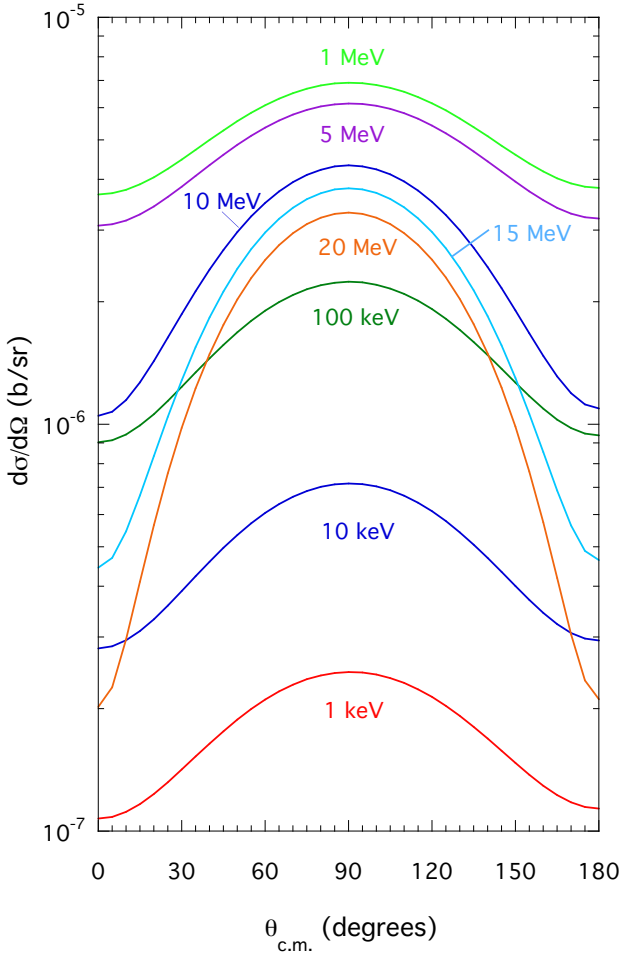




$^{3}He(n,\gamma)^{4}He$ Cross Section



Differential Cross Section



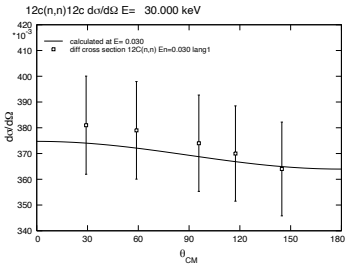
^{13}C System Analysis

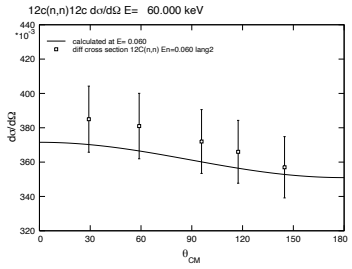
channel	a_c (fm)	l_{max}
n+^{12}C(0$^+$)	4.47	4
n+^{12}C*(2$^+$)	6.10	1
α+^{9}Be	5.00	3
γ+^{13}C	50.	1

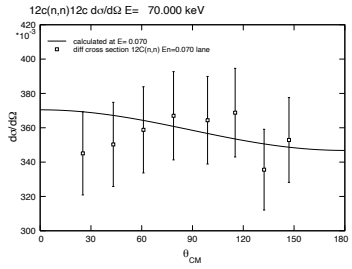
Reaction	Energies (MeV)	# data points	Data types
^{12}C(n,n)^{12}C	E_n = 0 – 8.0	7618	σ_T, $\sigma(\theta)$, $A_n(\theta)$
^{12}C(n,n')^{12}C	E_n = 4.8 – 7.0	950	σ_{int}, $\sigma(\theta)$
^{12}C(n,α)^{9}Be	En = th – 8.5	19	σ_{int}
^{12}C(n,γ)^{13}C	E_n = E_{thml} – 0.2	7	σ_{int}
total	5556	8594	4

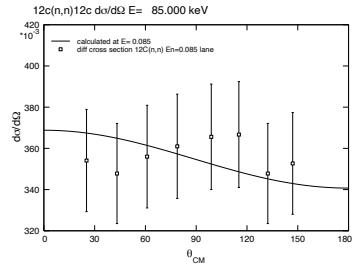
χ^2 per degree of freedom = 1.40

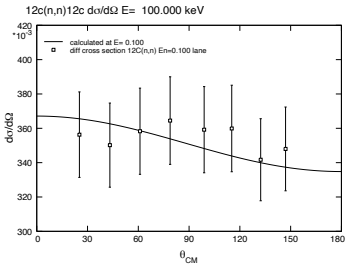
n+^{12}C Elastic Scattering

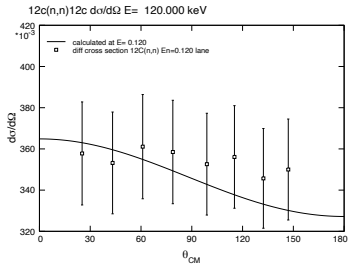


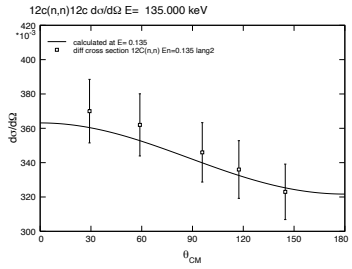


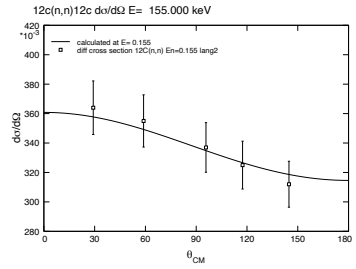


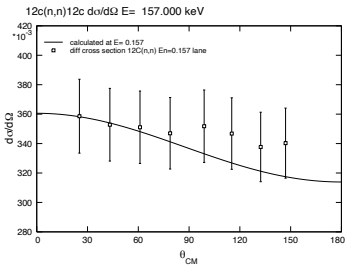


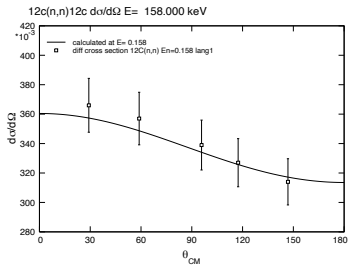


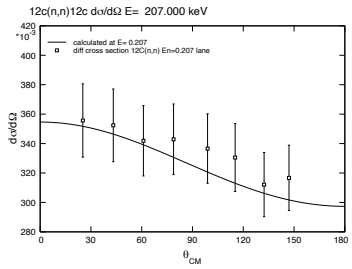


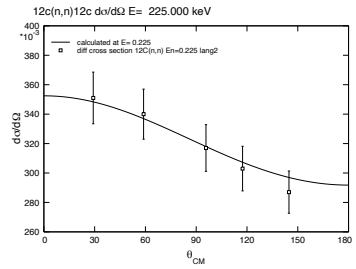




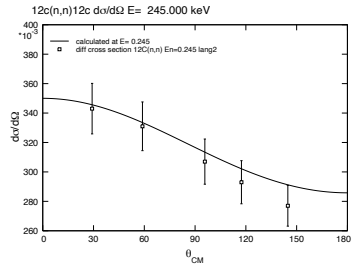


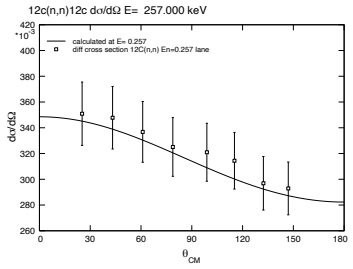


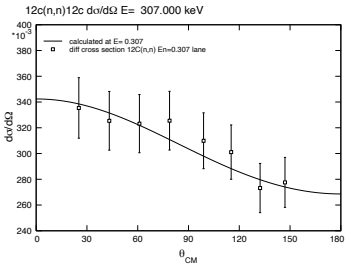


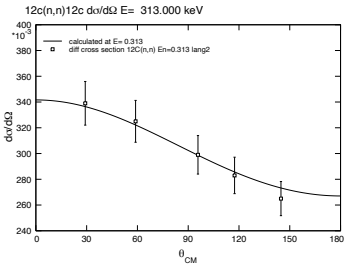


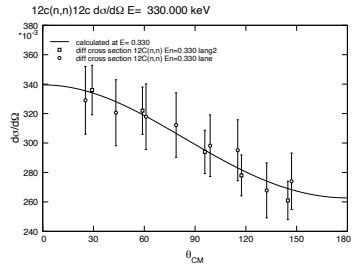
n+^{12}C Elastic Scattering, cont.

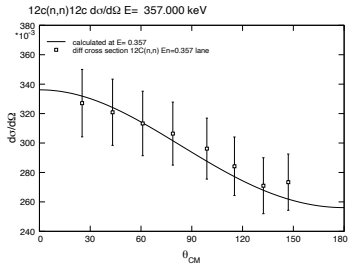


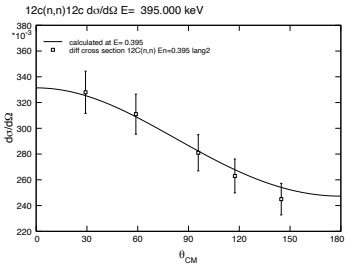


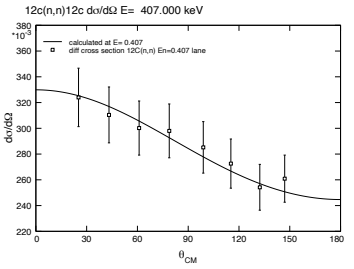


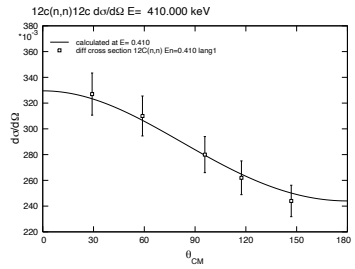


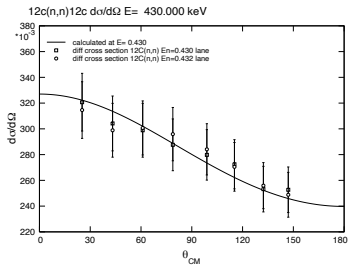


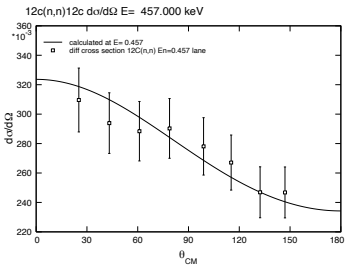


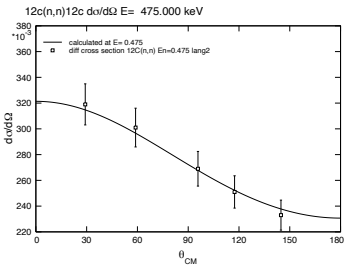




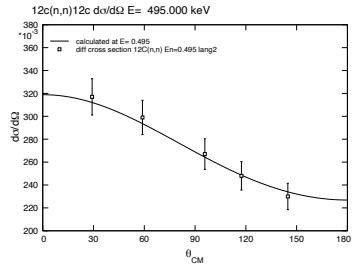


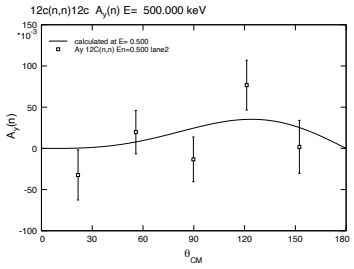


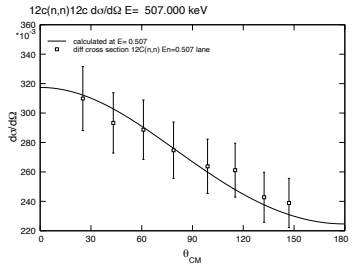


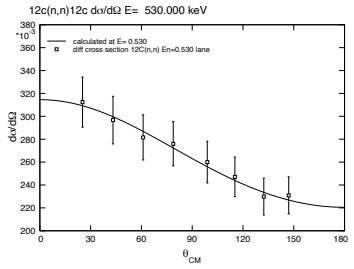


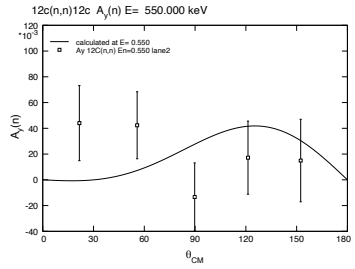
n+^{12}C Elastic Scattering, cont.

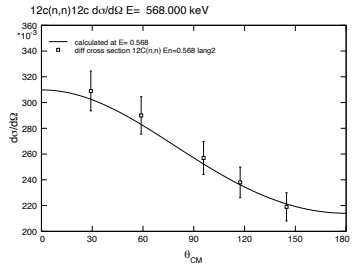


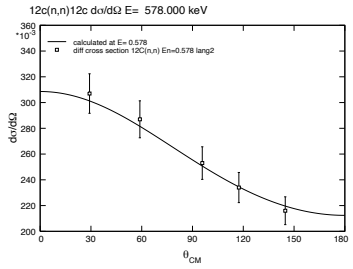


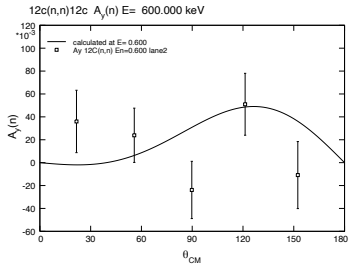


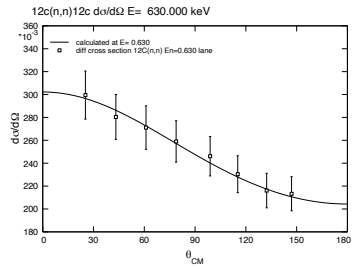


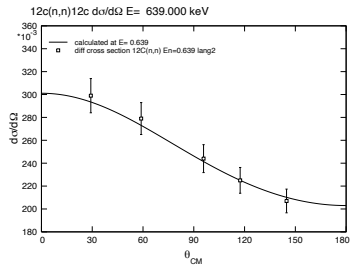


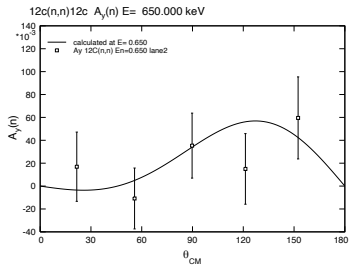


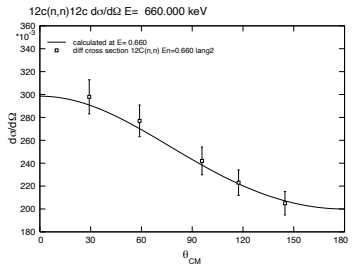




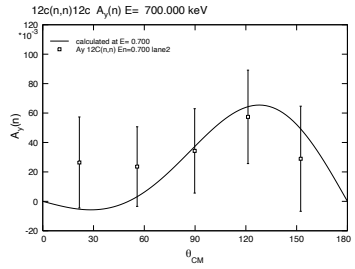


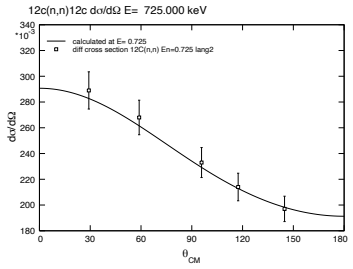


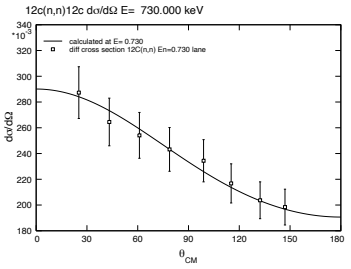


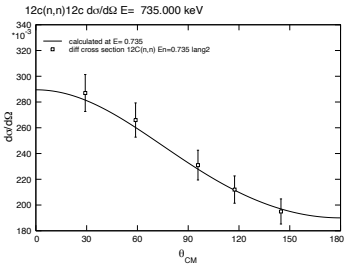


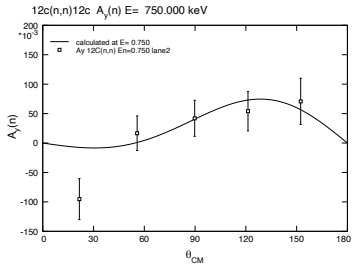
n+^{12}C Elastic Scattering, cont.

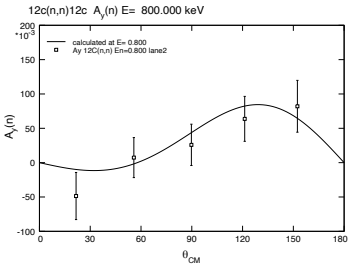


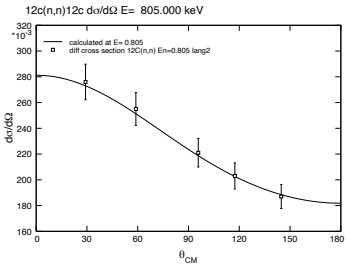


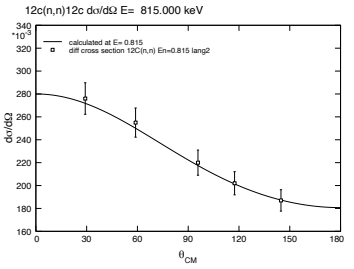


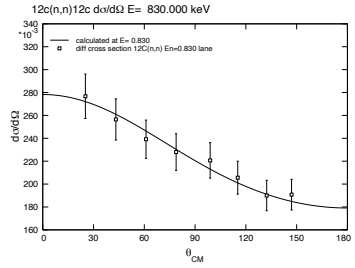


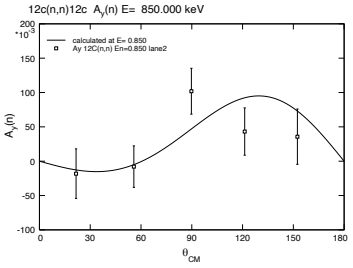


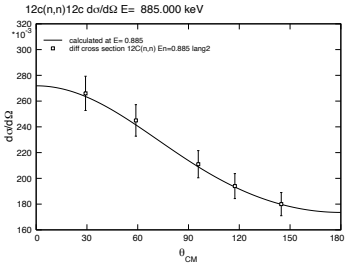


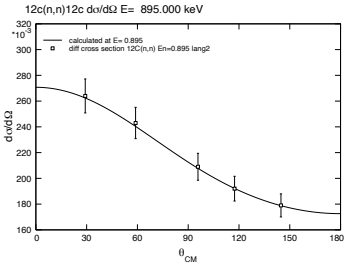




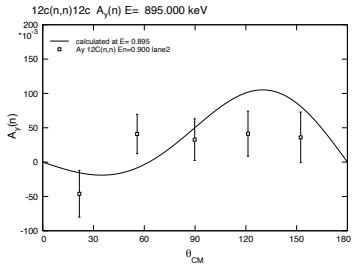


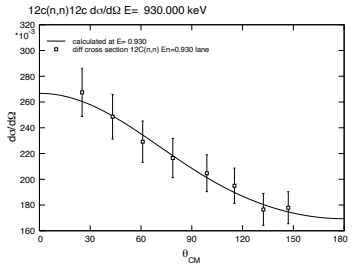


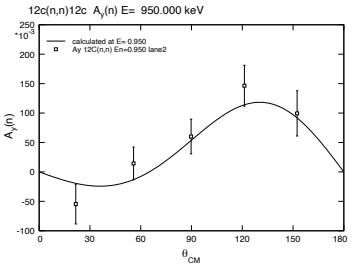


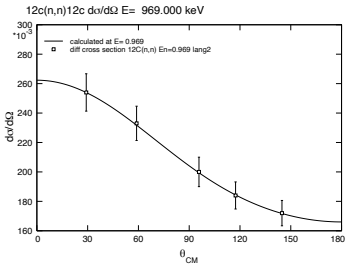


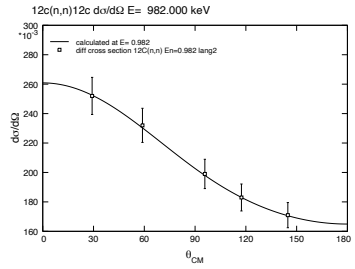
n+^{12}C Elastic Scattering, cont.

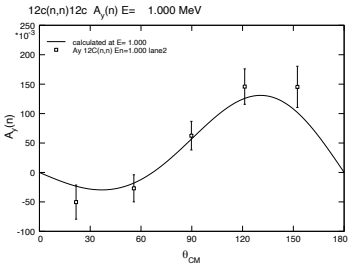


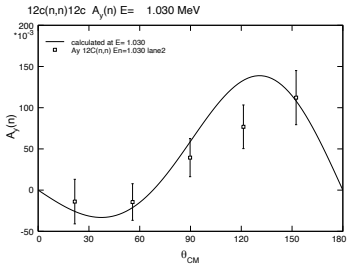


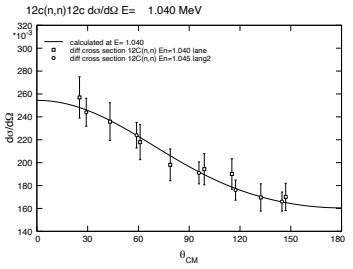


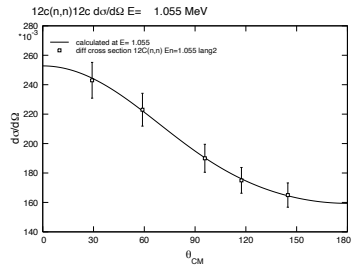


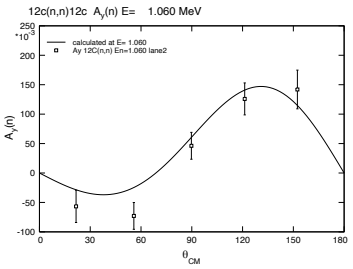


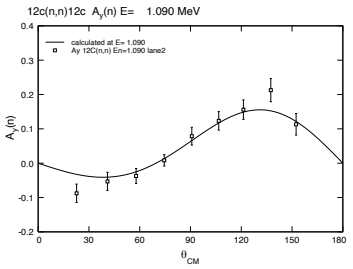


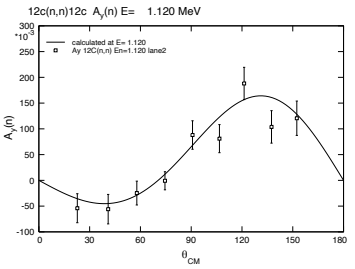




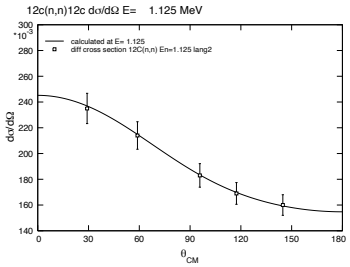


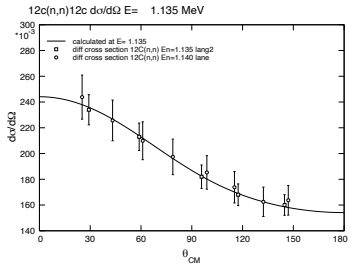


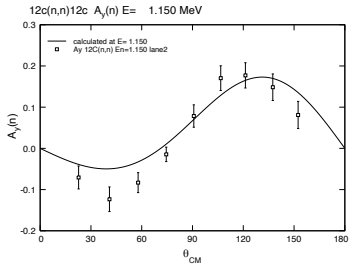


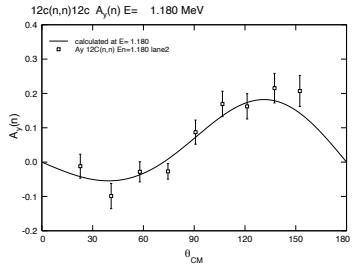


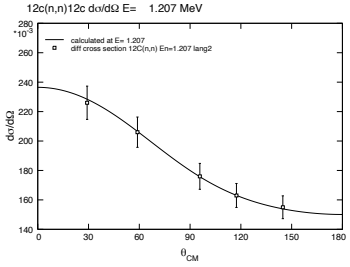
n+^{12}C Elastic Scattering, cont.

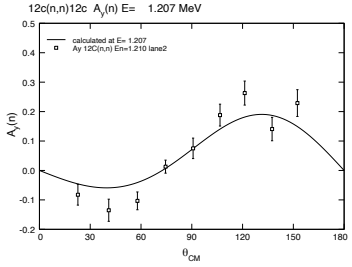


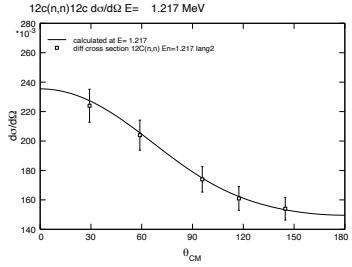


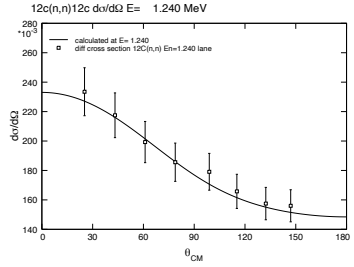


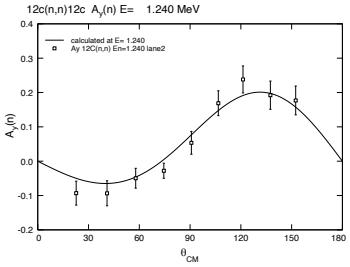


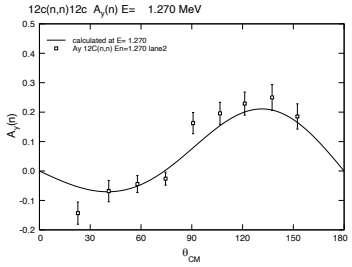


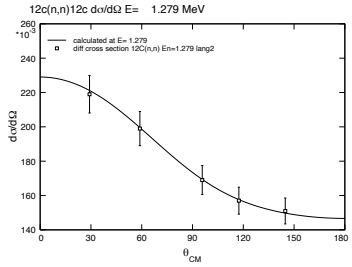


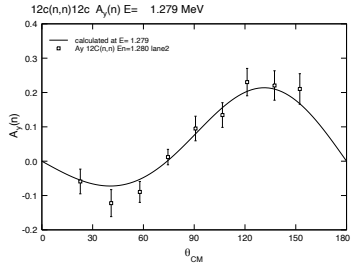




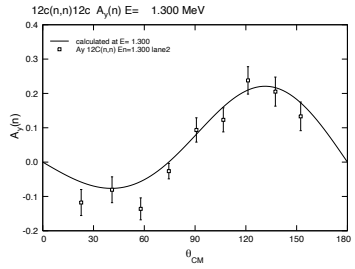


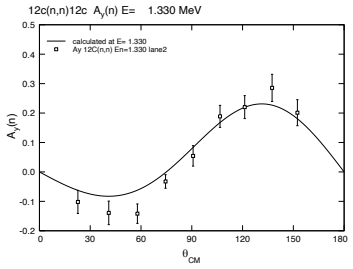


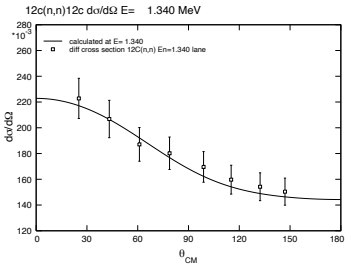


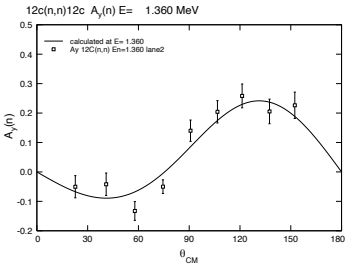


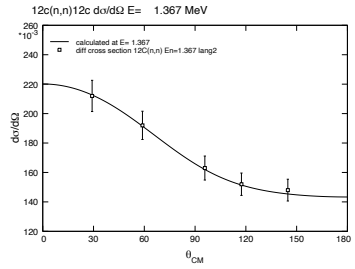
n+^{12}C Elastic Scattering, cont.

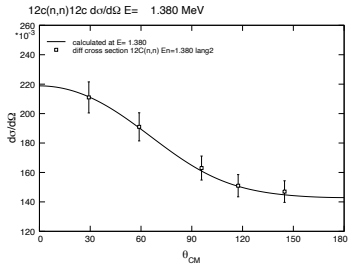


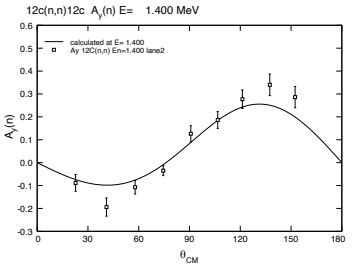


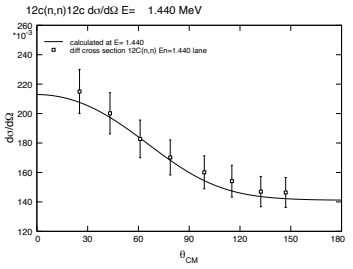


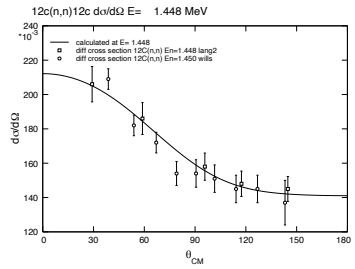


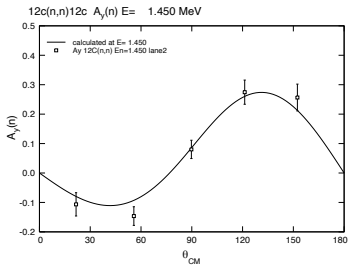


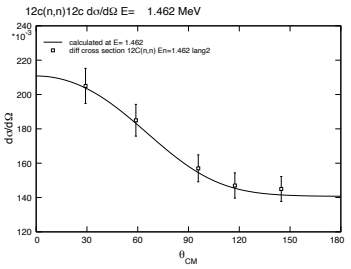


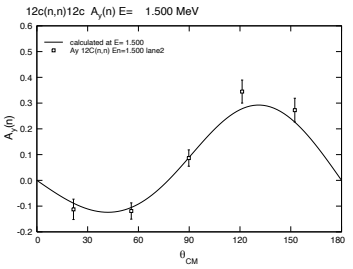




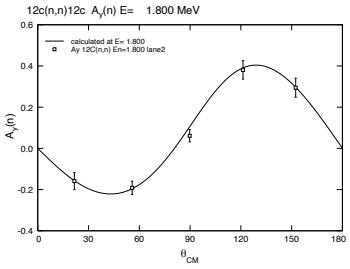


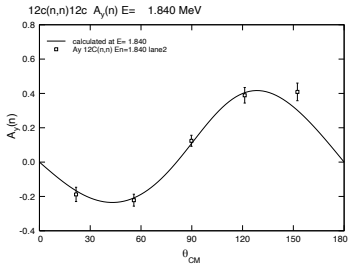


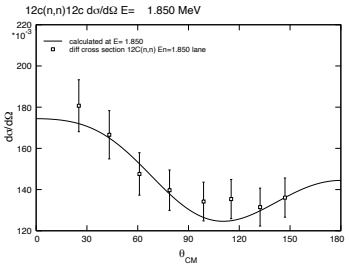


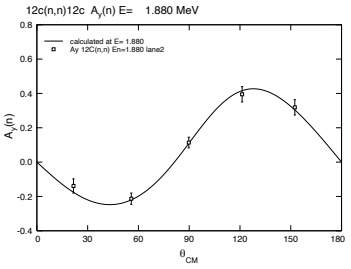


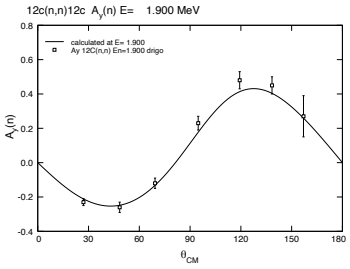
n+^{12}C Elastic Scattering, cont.

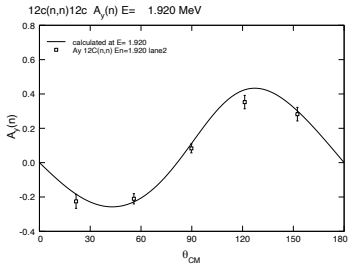


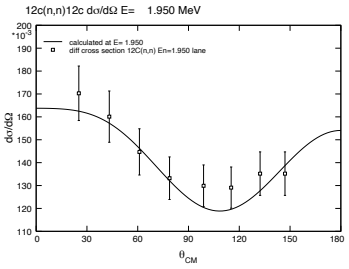


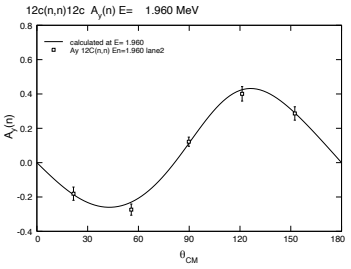


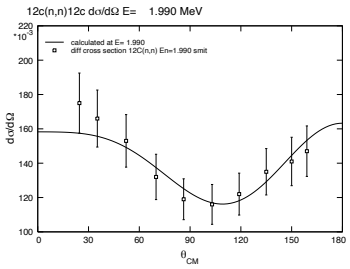


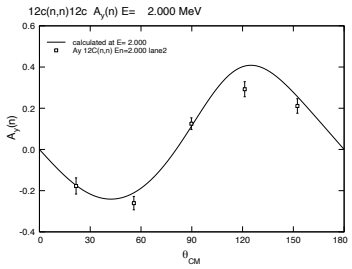


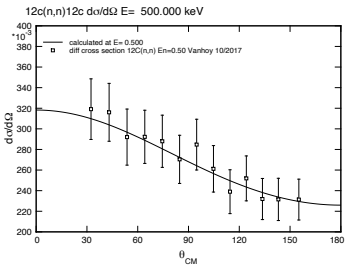


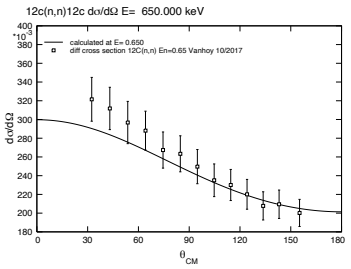




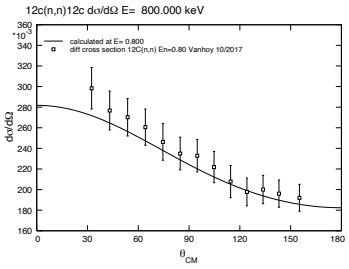


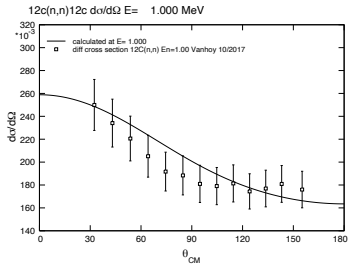


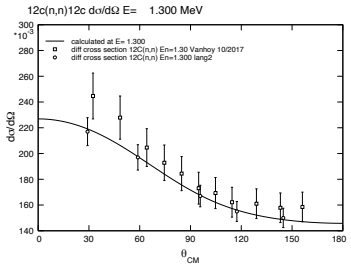


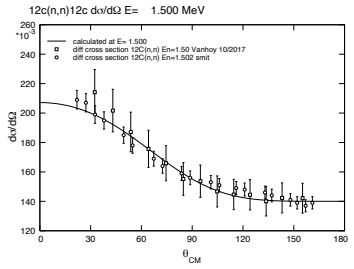


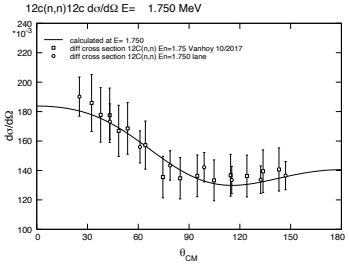
n+^{12}C Elastic Scattering, cont.

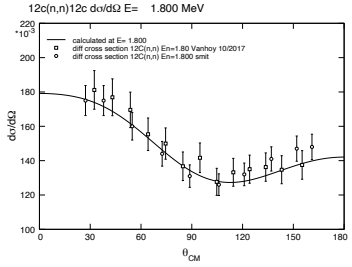


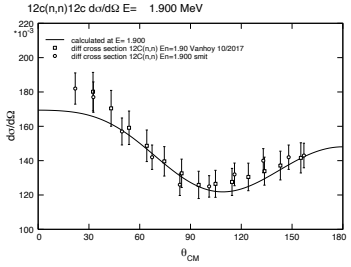


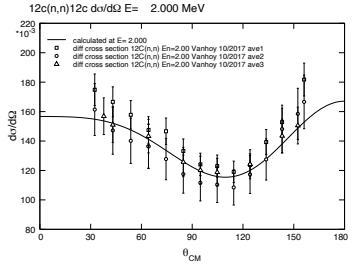


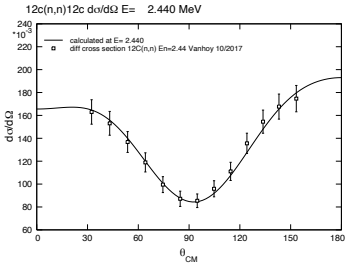


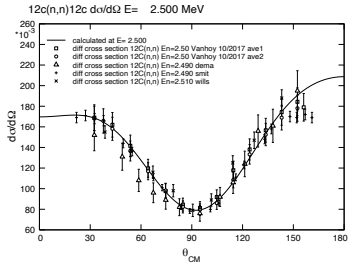


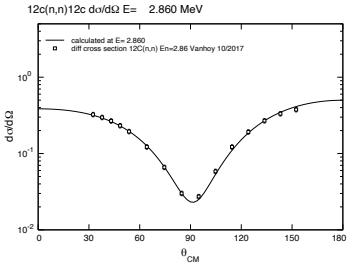


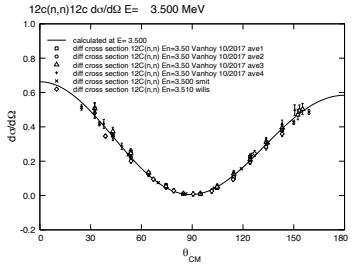




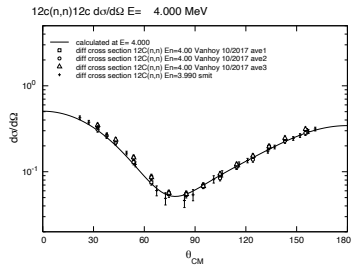


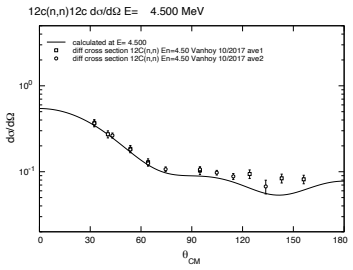


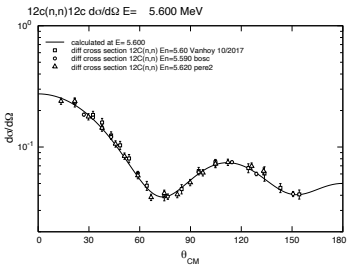


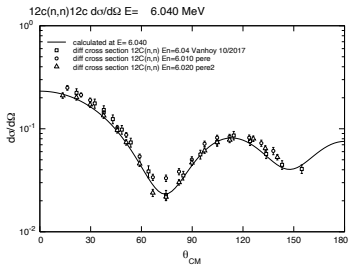


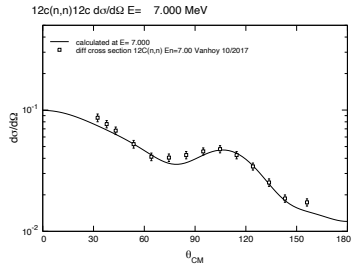
n+^{12}C Elastic and Inelastic Scattering

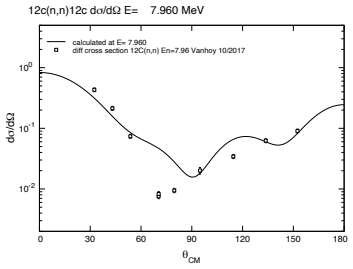


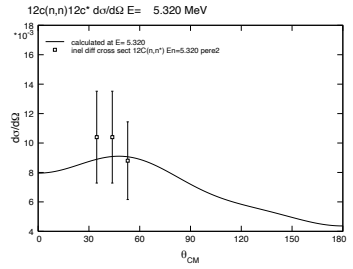


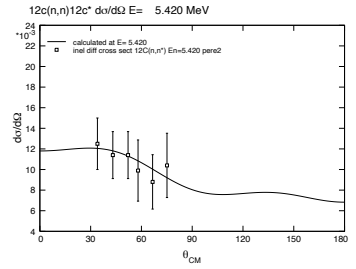


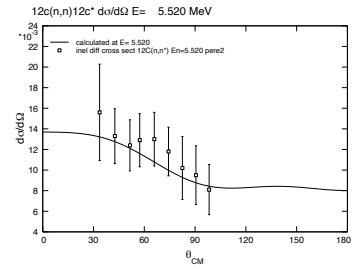


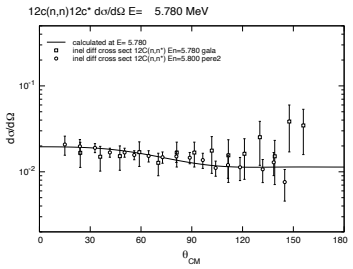


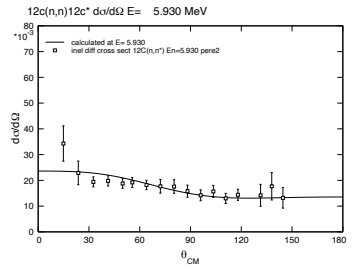


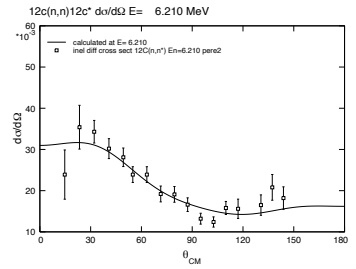




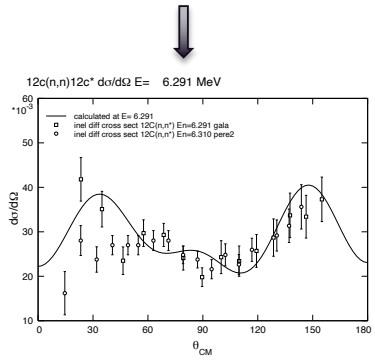


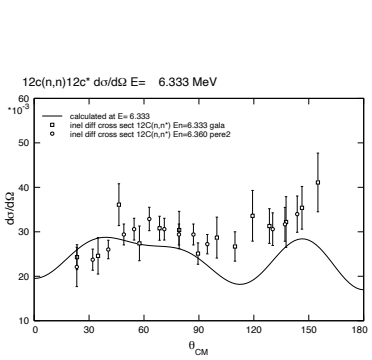


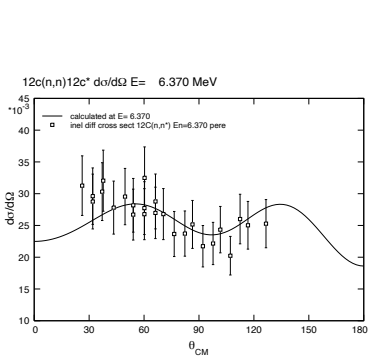


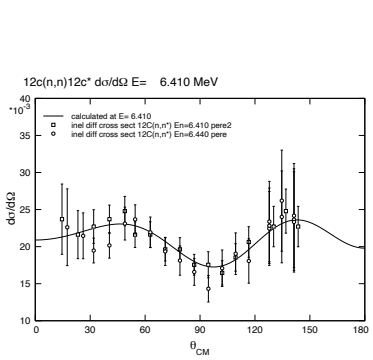


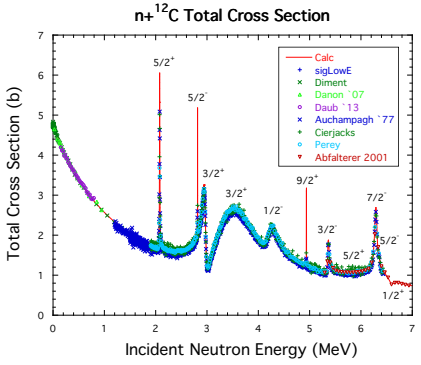
$^{12}C(n,n_1)^{12}C^*$ and Integrated Cross Sections

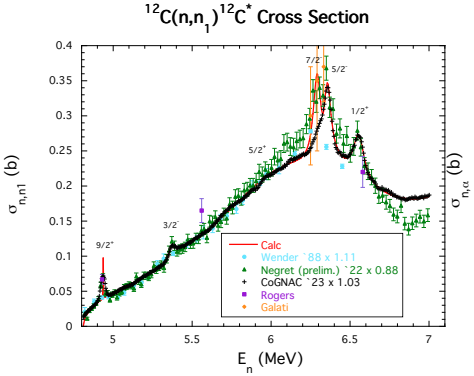


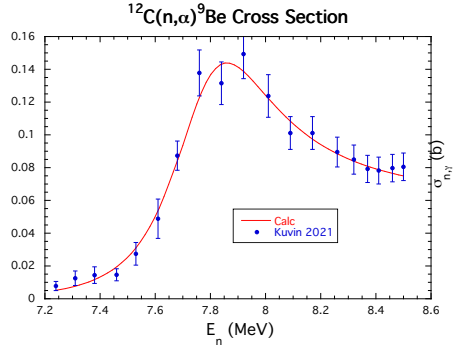


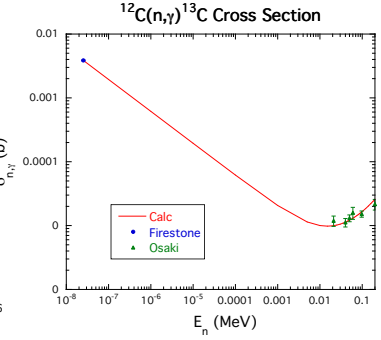












Status of the Light-Element Standards

- Extension of N-N scattering analysis to 250 MeV is in progress. New data are being added even in the energy range up to 100 MeV. Mark has Dick Arndt's NN data base, and will add any data from it we are missing.
- n-^{3}He: A rather extensive update of the n+^{3}He evaluation was submitted for ENDF/B-VIII.1. It is based at low energies on our ^{4}He R-matrix analysis, and at higher energies on an experimental evaluation done by Drosg and Otuka. Since that evaluation agrees so well with our R-matrix results in the region of overlap, it was decided to use it at all but the lowest energies. No changes were made in the ^{3}He(n,p) cross section below 200 keV (standard up to 50 keV). Angular distributions calculated from the R-matrix analysis were added for the ^{3}He(n,γ)^{4}He reaction.
- n-^{6}Li: Still working to get a reasonable fit to all data up to E_n = 8 MeV. The presence of several broad resonances in the MeV region hinders the determination of the ^{6}Li(n,t) cross section to standards accuracy (~1%), even at energies as low as 1 MeV. We need better data up to at least 5 MeV.

Status of the Light-Element Standards, cont.

- n-^{10}B: New work on the ^{11}B system has not yet been started. There is a lot of new data to add for the n+^{10}B and α+^{7}Li reactions, but the proliferation of excited-state n+^{10}B* channels will probably limit the upper range of the R-matrix analysis to a few MeV.
- n-^{12}C: New elastic and inelastic scattering data from Vanhoy support the results of the present analysis. New ^{12}C(n,n')^{12}C* data from the CoGNAC detector system is well described except in the region of a 7/2^{-} resonance around 6.3 MeV. An attempt to resolve this difference by adding the α+^{9}Be channel to the analysis has thus far not been successful.