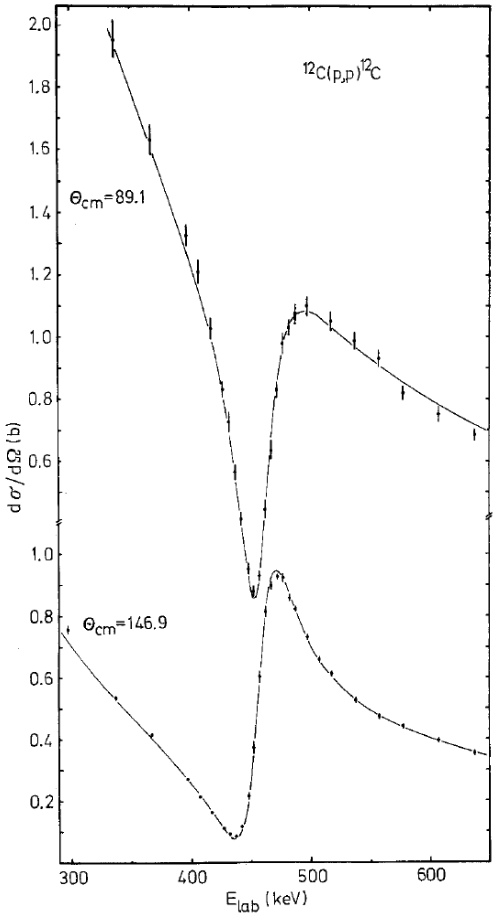
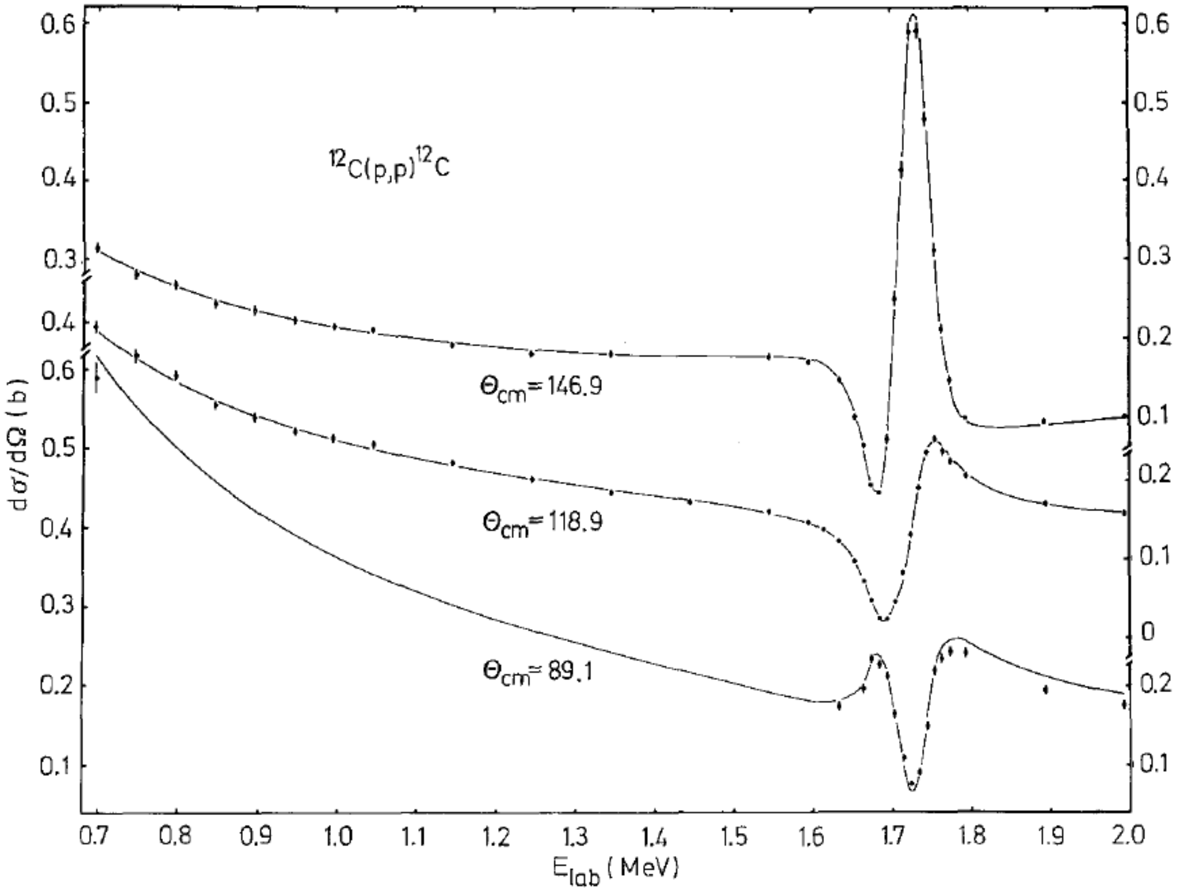
Example 2: $^{12}C(p,p_0)$, ^{13}N CN

- Charged particle scattering





$^{12}C(p,p_0)$ Summary

- The ideal case for R-matrix
- Low level density
- Isolated set of levels near threshold
- Resonances not too broad

Almost 3 MeV gap

E_{level} (keV)	XREF	Jπ	$T_{1/2}$
0.0	A DE GHIJKLM	1/2-	9.965 m 4 % ε = 100
2364.9 6	DEFGHI K	1/2+	31.7 keV 8 % IT = 0.00158 13 % p = 100
3502 2	A DEFGHIJK	3/2-	62 keV 4 % IT = 0.0011 % p = 100
3547 4	D FGHI K	5/2+	47 keV 7 % p = 100 % IT < 4.3E-6
6364 9	CD FGH KL	5/2+	11 keV % p = 100
6886 8	CD FGH K	3/2+	115 keV 5 % p = 100
7155 5	CD FGH K	7/2+	9.0 keV 5 % p = 100
7376 9	A CD FGHIJKL	5/2-	75 keV 5 % p = 100
7900	FG	3/2+	≈ 1500 keV % p = 100
8918 11	A D FG IJ L	1/2-	230 keV % p = 100
9000	C GH J	9/2+	280 keV 30
9476 8	A CD FGH J	3/2-	30 keV % p = 100
1025E+1 15	E	(1/2+)	≈ 280 keV % IT = ? % p = ?
10360	A CD FGH	5/2-	30 keV % p = 100

Quick comments on capture reactions

- Electromagnetic interaction is not included in nonrelativistic R-matrix

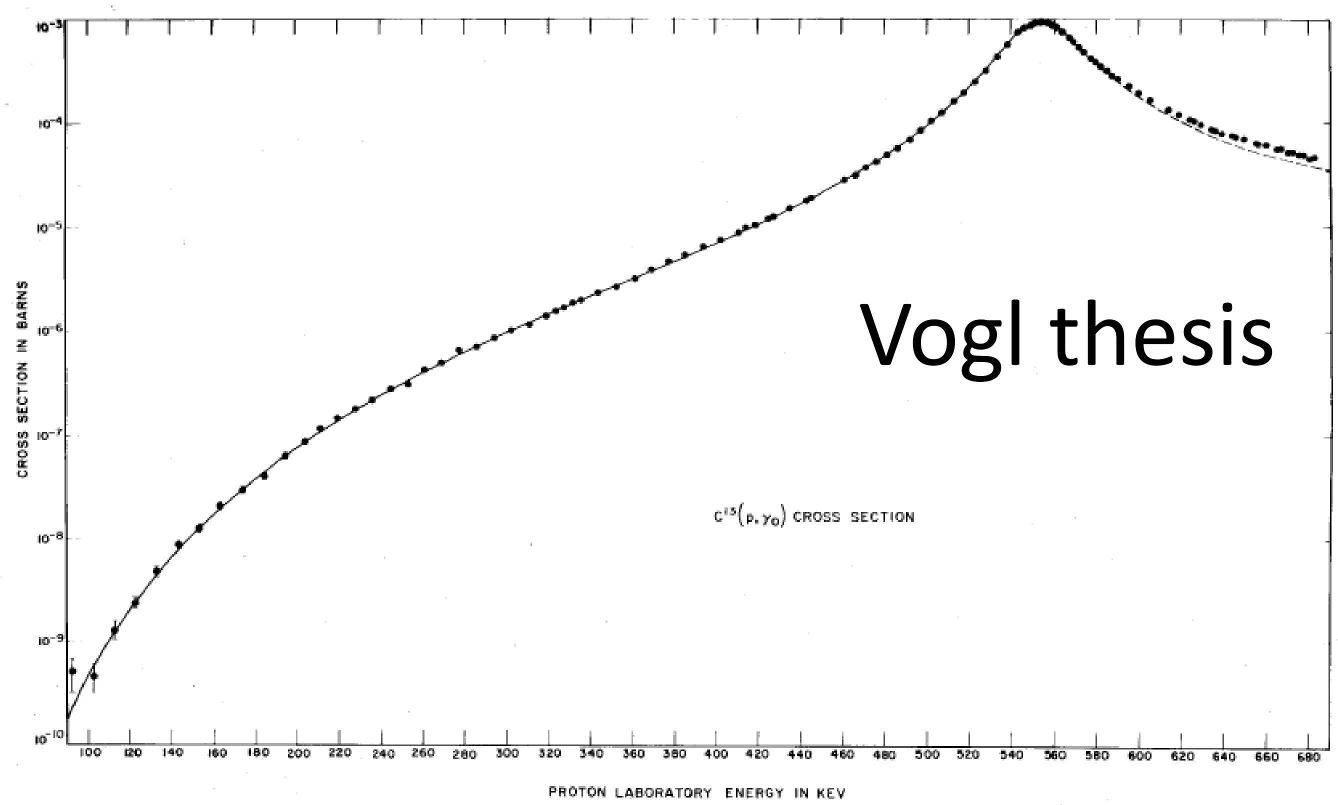
- Included using perturbation theory
  - Capture cross section (x,γ) are usually about 1000 times smaller than nuclear cross sections (e.g. mb vs ub)

- Unitarily is not conserved for capture reactions
  - i.e. capture channels are not included in S-matrix sums

- WARNING! This formalism is not applicable for low energy (n,γ) reactions where the cross section of (n,γ) can approach that of (n,n)
  - i.e. if Γ_γ > or = Γ_n
  - Must then use Reich-Moore formalism

Example 3: $^{12}C(p,\gamma)^{13}N$ --- capture reaction

- Simple capture example
- Vogle thesis (1963), Burtebaev et al. (2008), and Rolfs and Azuma (1974)
- $^{12}C(p,\gamma)$ cross section is about 1000 less than $^{12}C(p,p)$
  - Γ_p about keV, Γ_γ about eV



- Fit simultaneously with $^{12}C(p,p_0)$

- Rolfs data inconsistent at lower energies
- Just taking data above 1 MeV