Electroexcitation of the first $1/2^+$ state in ^{9}Be *
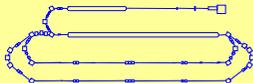
O. Burda, C. Forssén, P. von Neumann-Cosel, A. Richter

Institut für Kernphysik, TU Darmstadt

- Motivation

- Experiments
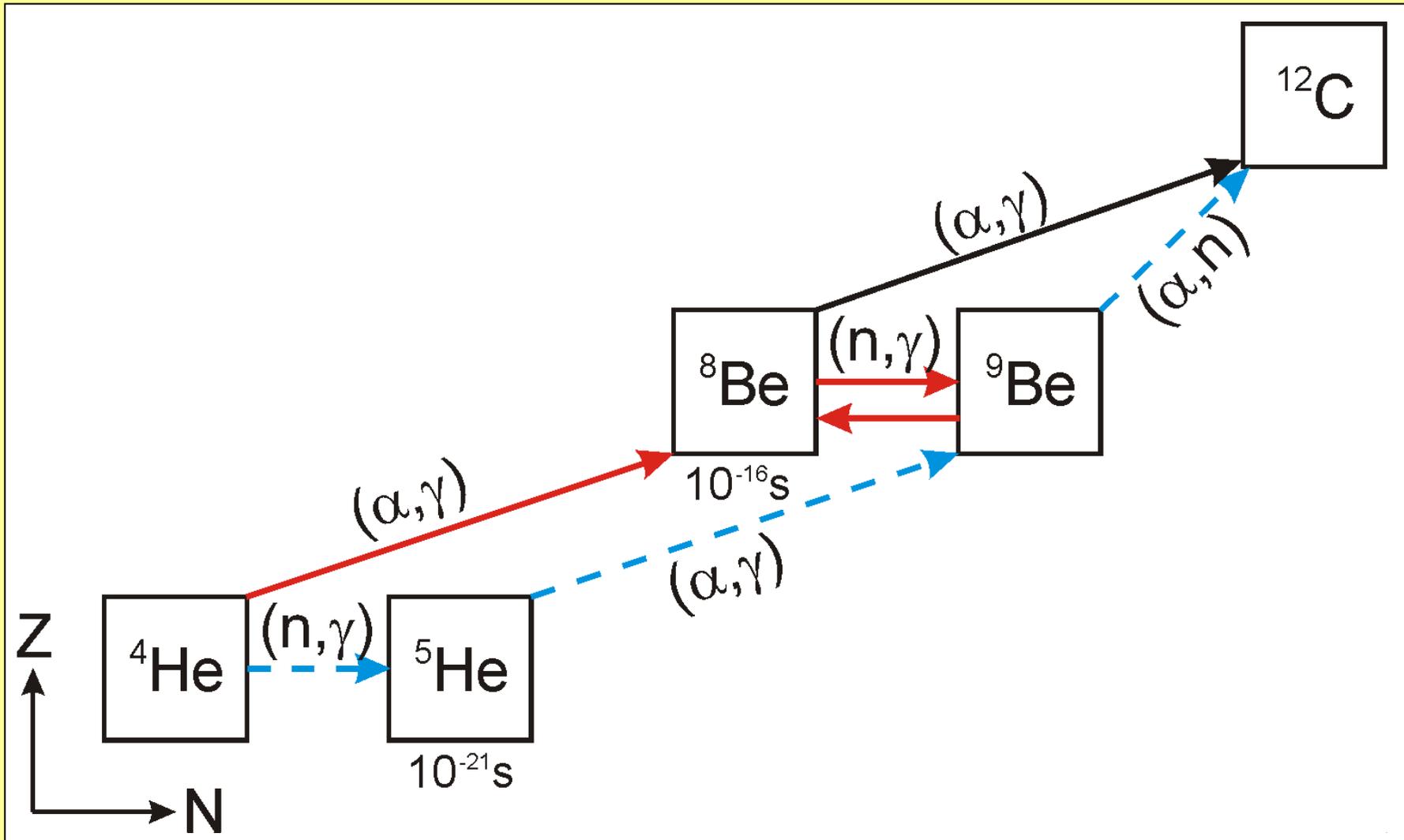
- Results

- Summary and outlook

Motivation
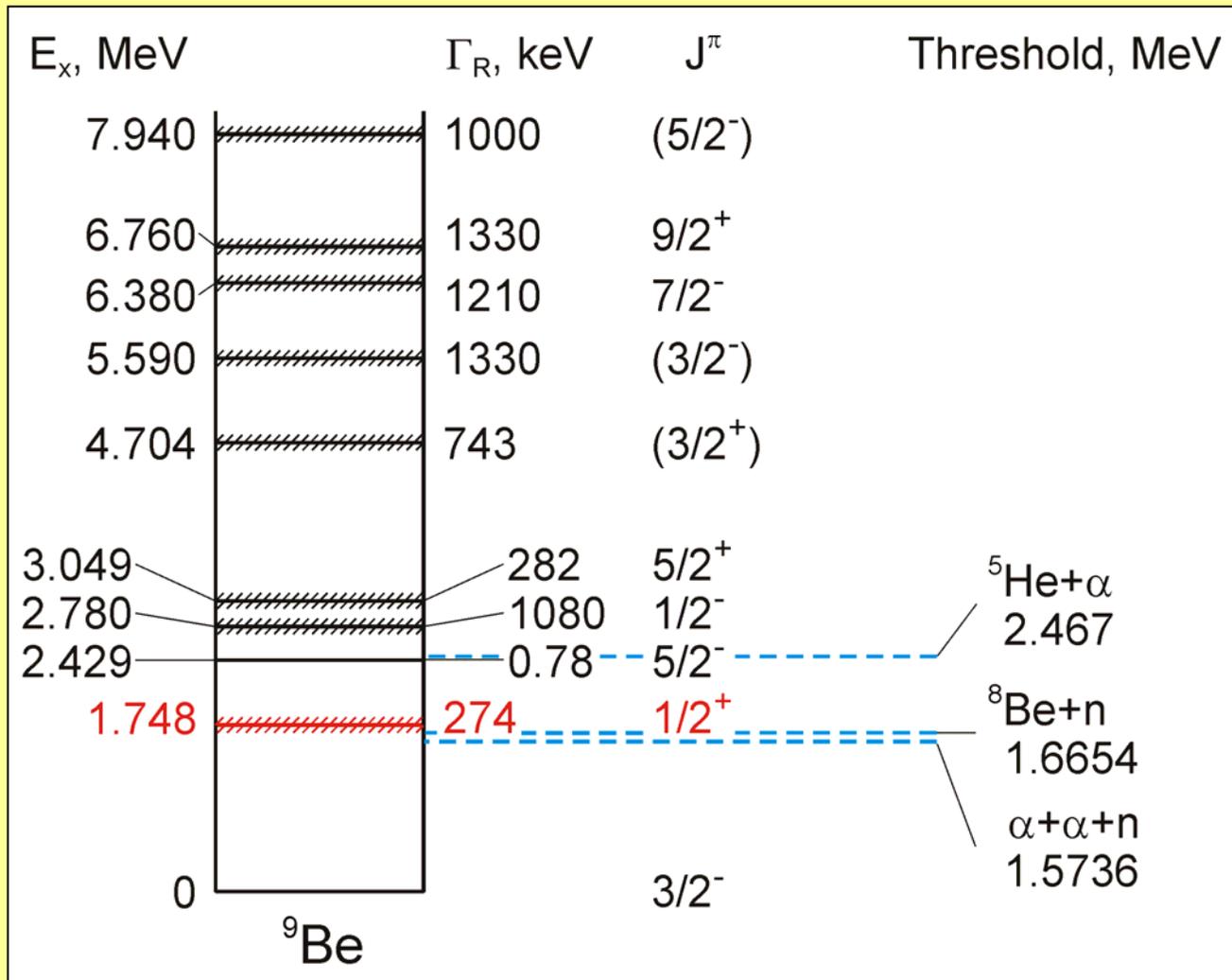
- ^{9}Be is a loosely bound nuclear system consisting of 2α and a neutron

- ^{9}Be has the lowest neutron threshold (S_n= 1.665 MeV) of all stable nuclei

  $\rightarrow$ first excited state lies some tens of keV above S_n

  $\rightarrow$ all excited states are unstable with respect to neutron decay

Possible role of ⁹Be in the production of ¹²C

- In *n*-rich environment (core-collapse supernovae) this reaction path may provide an alternative route for building up the heavy elements and triggering the *r* process

$J^\pi = 1/2^+$ state at threshold

E_x, MeV	Γ_R, keV	J^π	Threshold, MeV
7.940	1000	$(5/2^-)$	
6.760	1330	$9/2^+$	
6.380	1210	$7/2^-$	
5.590	1330	$(3/2^-)$	
4.704	743	$(3/2^+)$	
3.049	282	$5/2^+$	$^5He+\alpha$
2.780	1080	$1/2^-$	2.467
2.429	0.78	$5/2^-$	
1.748	274	$1/2^+$	^8Be+n 1.6654
			$\alpha+\alpha+n$ 1.5736
0		$3/2^-$	

^9Be

- The photodisintegration cross section at low energies is given by the properties of $1/2^+$ resonance

- Strongly asymmetric line shape

Parameters of the first $J^\pi = 1/2^+$ state in ^{9}Be

	(γ, n) [1]	(e,e') [2]	[3]	Reanalysis of [2] by Barker [4]
E_R, MeV	1.75(1)	1.684(7)	1.68(15)	1.7316
Γ_R, keV	283(42)	217(10)	200(20)	280
$B(E1)\uparrow$, $e^2 fm^2$	0.0535(35)	0.027(2)	0.034(3)	0.0685

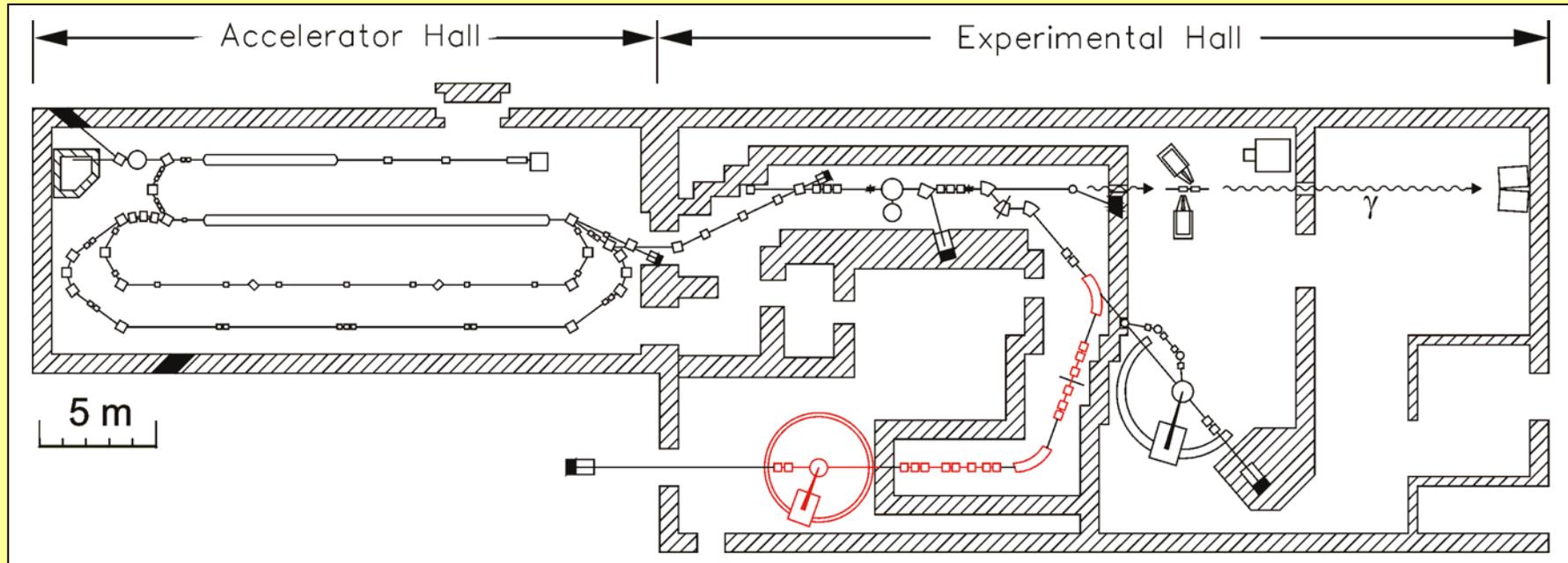[1] H. Utsunomiya et al., Phys. Rev. C63 (2001) 018801
[2] G. Küchler et al., Z. Phys. A326 (1987) 447
[3] J. P. Glickman et al., Phys. Rev. C43 (1991) 1740
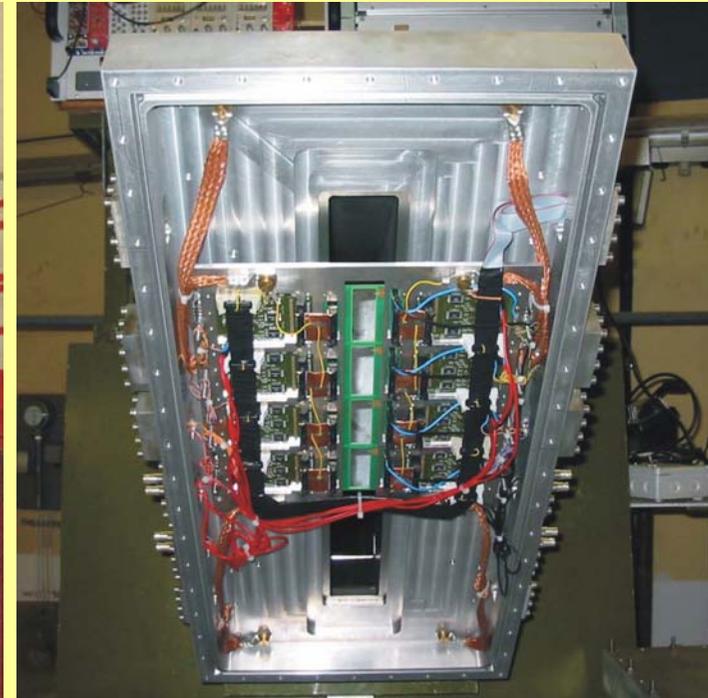[4] F. C. Barker, Aust. J. Phys. 53 (2000) 247

🔴 Resonance parameters from different experiments and analysis are not in mutual agreement

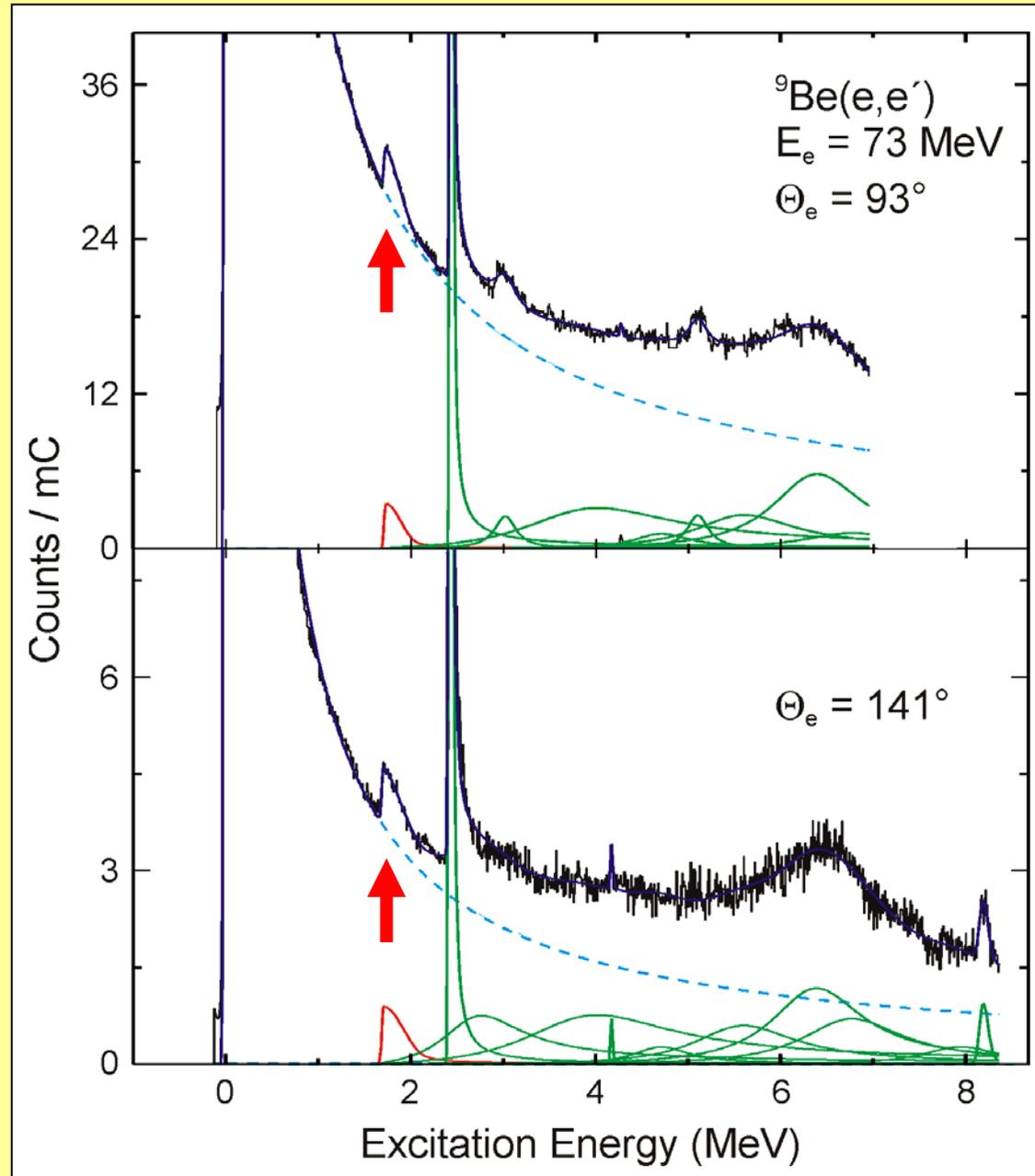# S-DALINAC and its Experimental Facilities

High-resolution (e,e´) experiments at 169° spectrometer
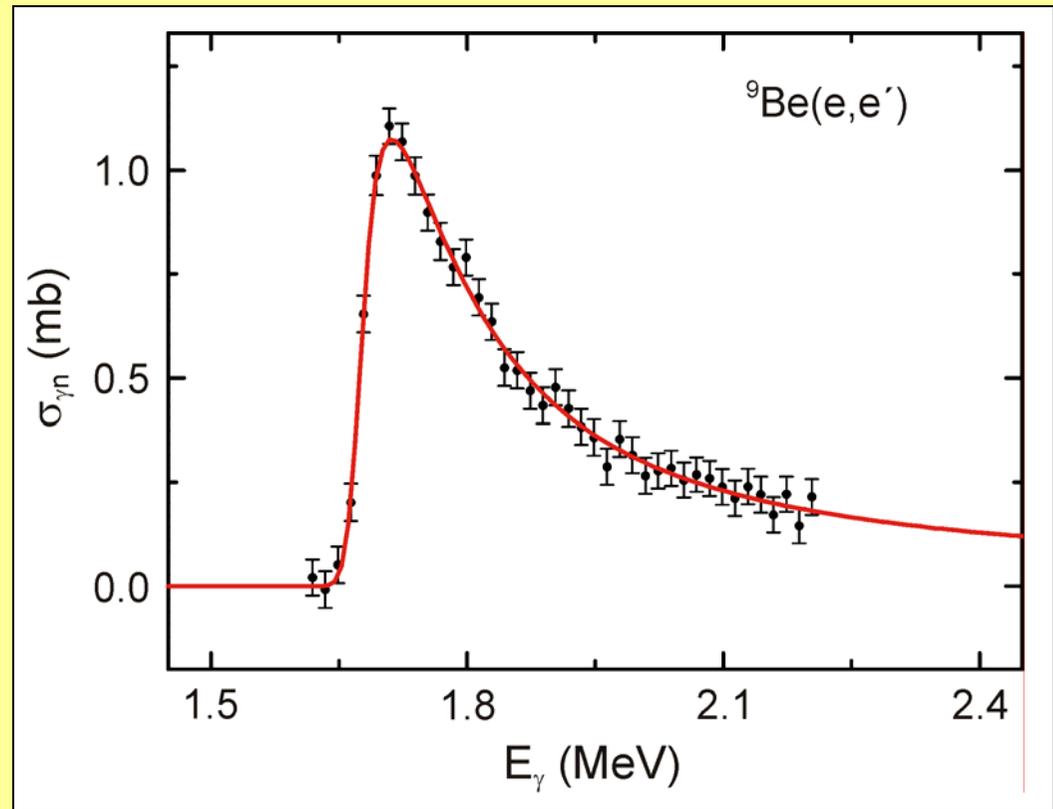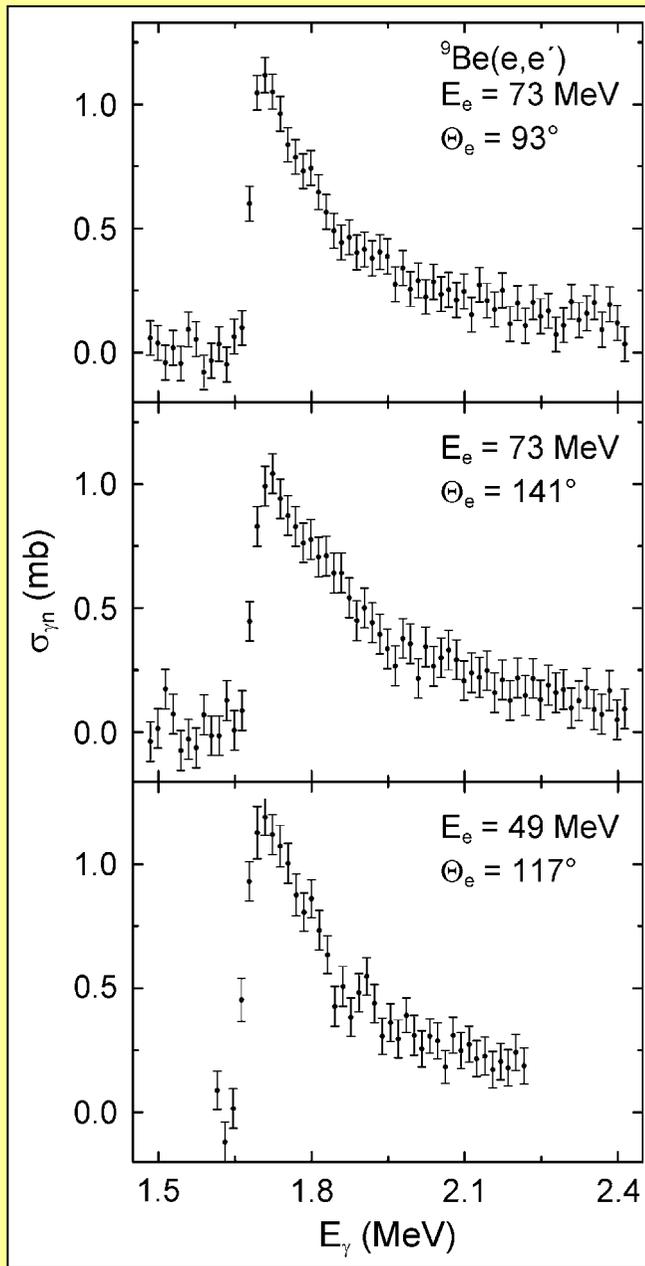
169° Spectrometer and Focal Plane Detector System

- Si microstrip detector system: 4 modules, each 96 strips with pitch of 650 μm

- Count rate up to 100 kHz

- High spatial resolution 1.5×10^{-4}
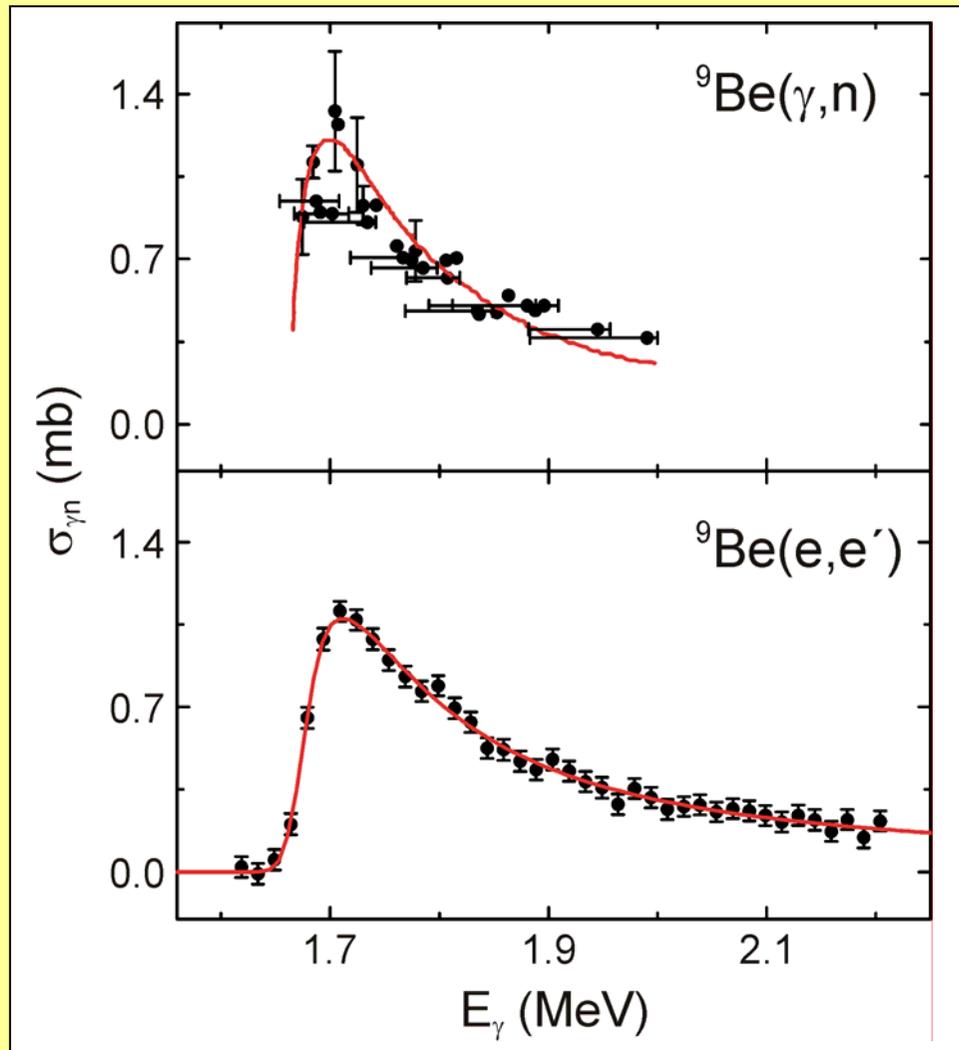
Deconvolution of the spectrum

⁹Be(γ,n) extracted from ⁹Be(e,e´)

$E_R = 1.737(10)$ MeV
$\Gamma_R = 275(14)$ keV

Comparison: ^{9}Be(γ,n) and ^{9}Be(e,e´)

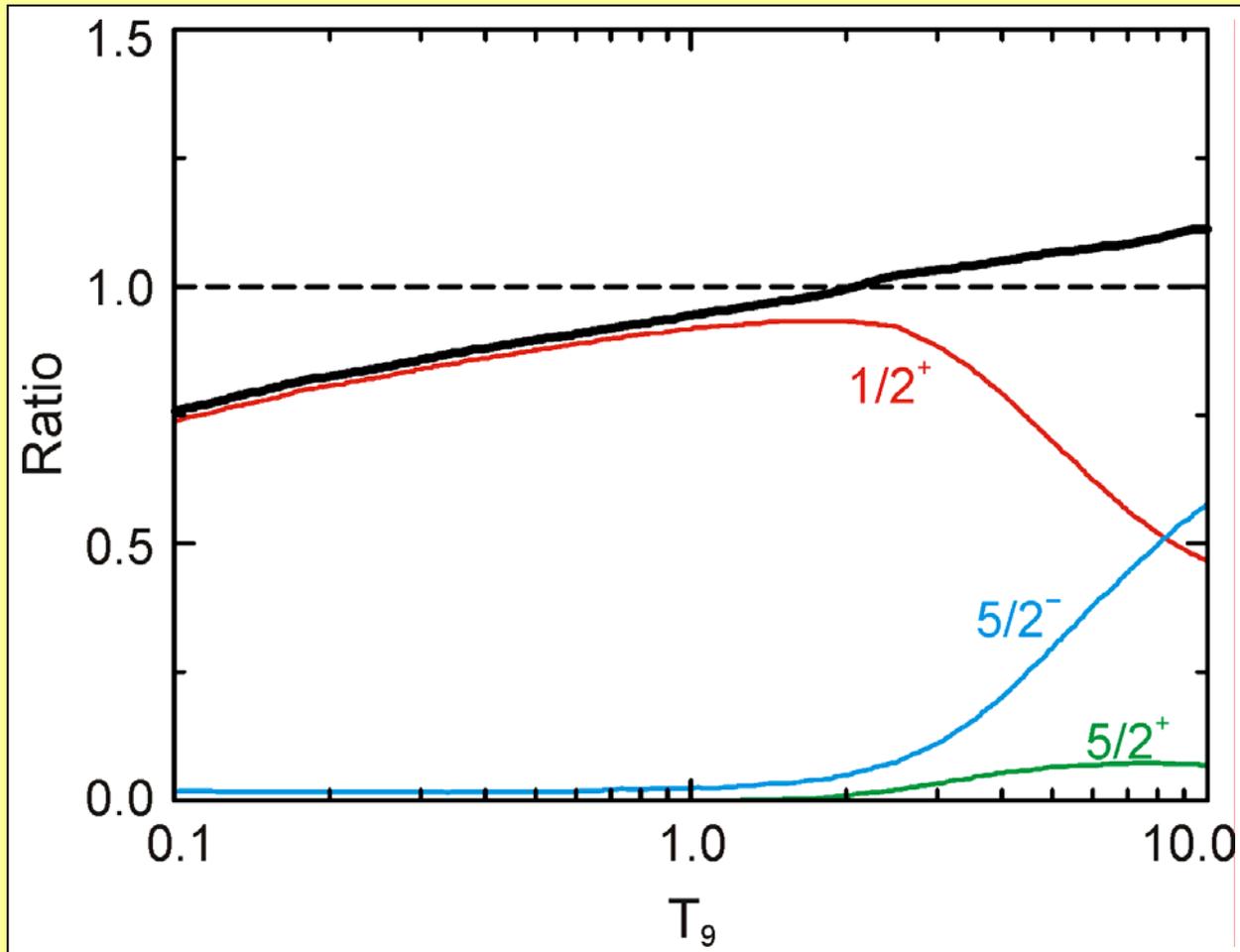

H. Utsonomiya et al.,
PRC 63, 018801

E_R = 1.75(1) MeV
Γ_R = 283(42) keV

Present

E_R = 1.737(10) MeV
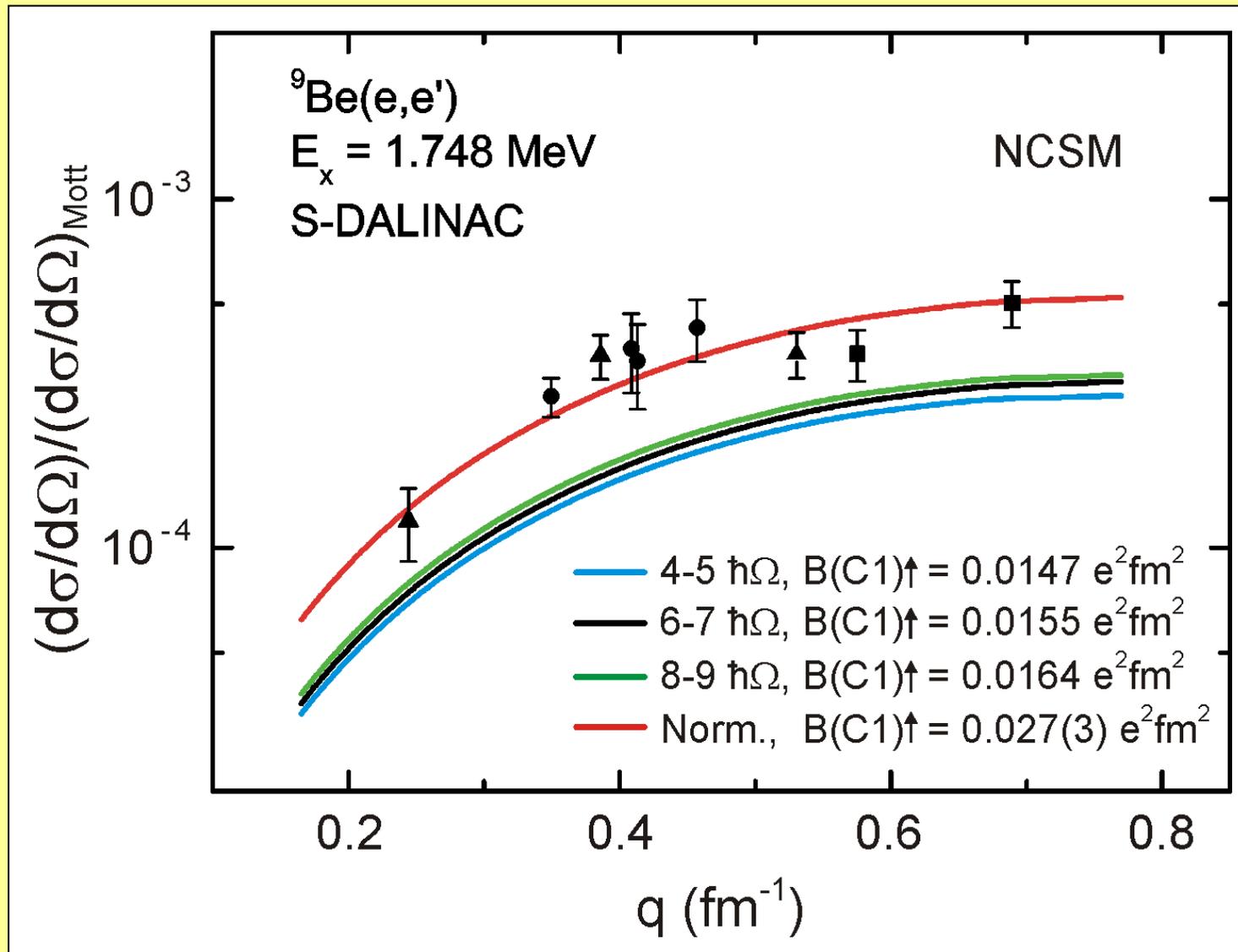Γ_R = 275(14) keV

● Resonance parameters agree well

Reaction rate of $\alpha\alpha n \rightarrow {}^9Be$

1999 compilation:
C. Angulo et al.,
NPA 656 (1999) 3

- Deviation ranges from -25% to +11% from adopted values

- For $T_9 = 0.1 - 3$ the $1/2^+$ resonance determines exclusively $^4He(\alpha,\gamma)^8Be(n,\gamma)^9Be$ chain

Form factor of the $J^\pi = 1/2^+$ state

NCSM: correct q dependence but difference in magnitude compared to the data (C. Forssén)

B(E1,k) strength

Siegert´s theorem: $\qquad$ $B(E1,q) = (k/q)^2 B(C1,q)$

at photon point $(q = k = E_x/\hbar c)$ $\qquad$ $B(E1,k) = B(C1,k)$

$(e,e´)$ $\qquad$ $B(C1,k) = 0.027(3)\ e^2 fm^2 = B(E1,k)$

(γ,n) $\qquad$ $B(E1,k) = 0.0535(35)\ e^2 fm^2$

⦿ $B(C1) \neq B(E1)$ at photon point $k = q \rightarrow$ violation of Siegert´s theorem ?

Summary and outlook

- Final values of line shape parameters of $J^\pi = 1/2^+$ resonance:
  $E_R = 1.748(6)$ MeV and $\Gamma_R = 274(8)$ keV

- B(C1) ≠ B(E1) at photon point $k = q$
  $\rightarrow$ violation of Siegert´s theorem ?

- Theoretical calculations in NCSM and FMD

- E1 operator needs to be renormalized $\rightarrow$ effective charges

- Investigate also the transverse E1 response to search for possible
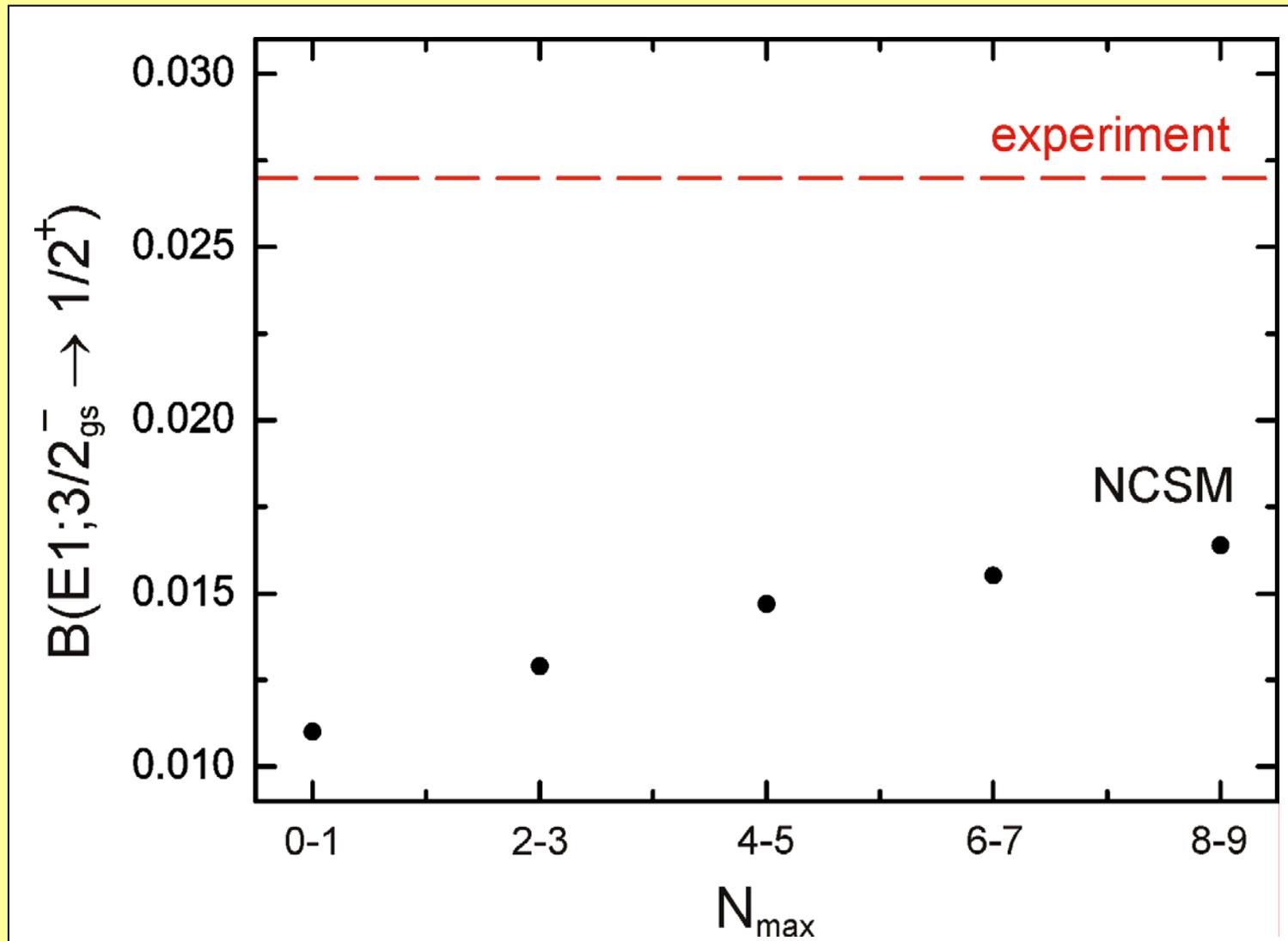 sources of the violation of Siegert´s theorem

PWBA model independent analysis: B(C1,k)

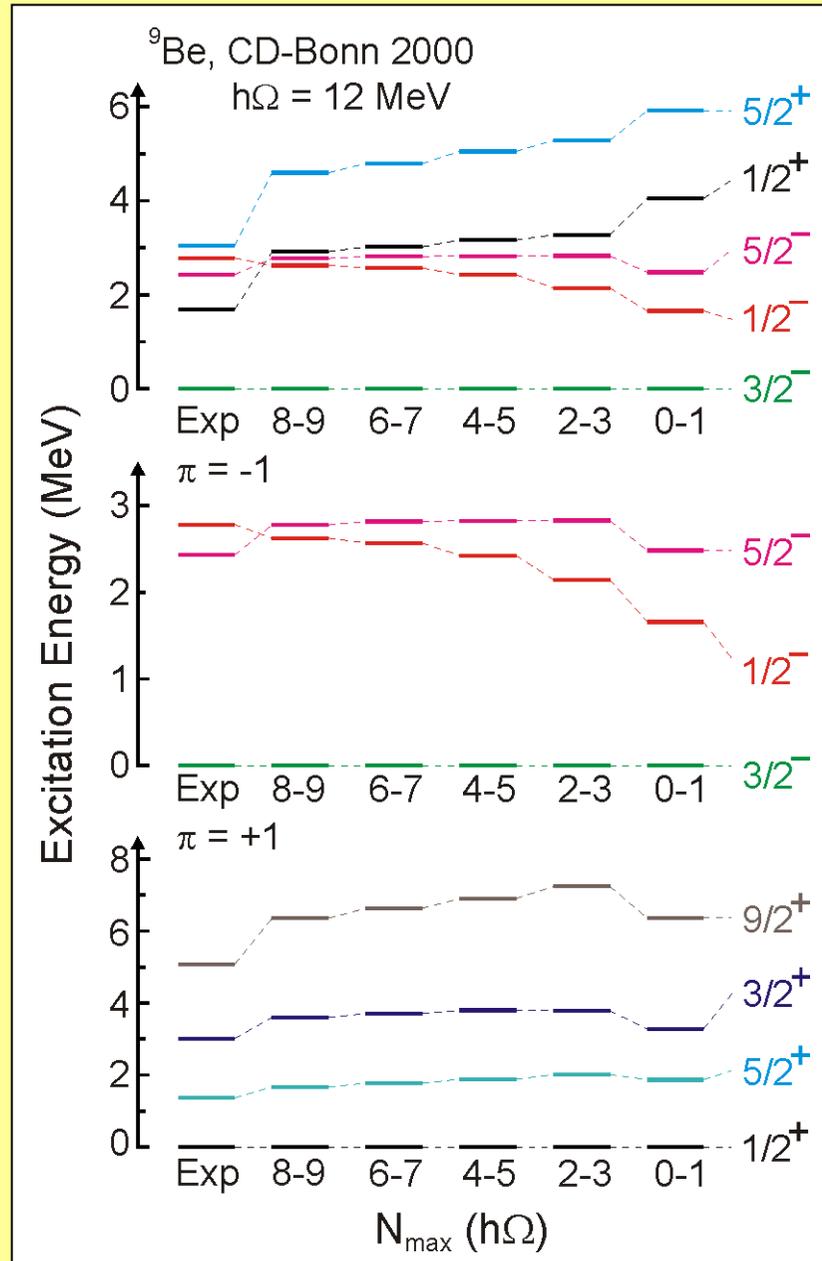$$\sqrt{B(C1,q)} = \sqrt{B(C1,0)} \left(1 - q^2 \frac{R_{tr}^2}{10} + q^4 \frac{R_{tr}^4}{280} - \ldots\right)$$
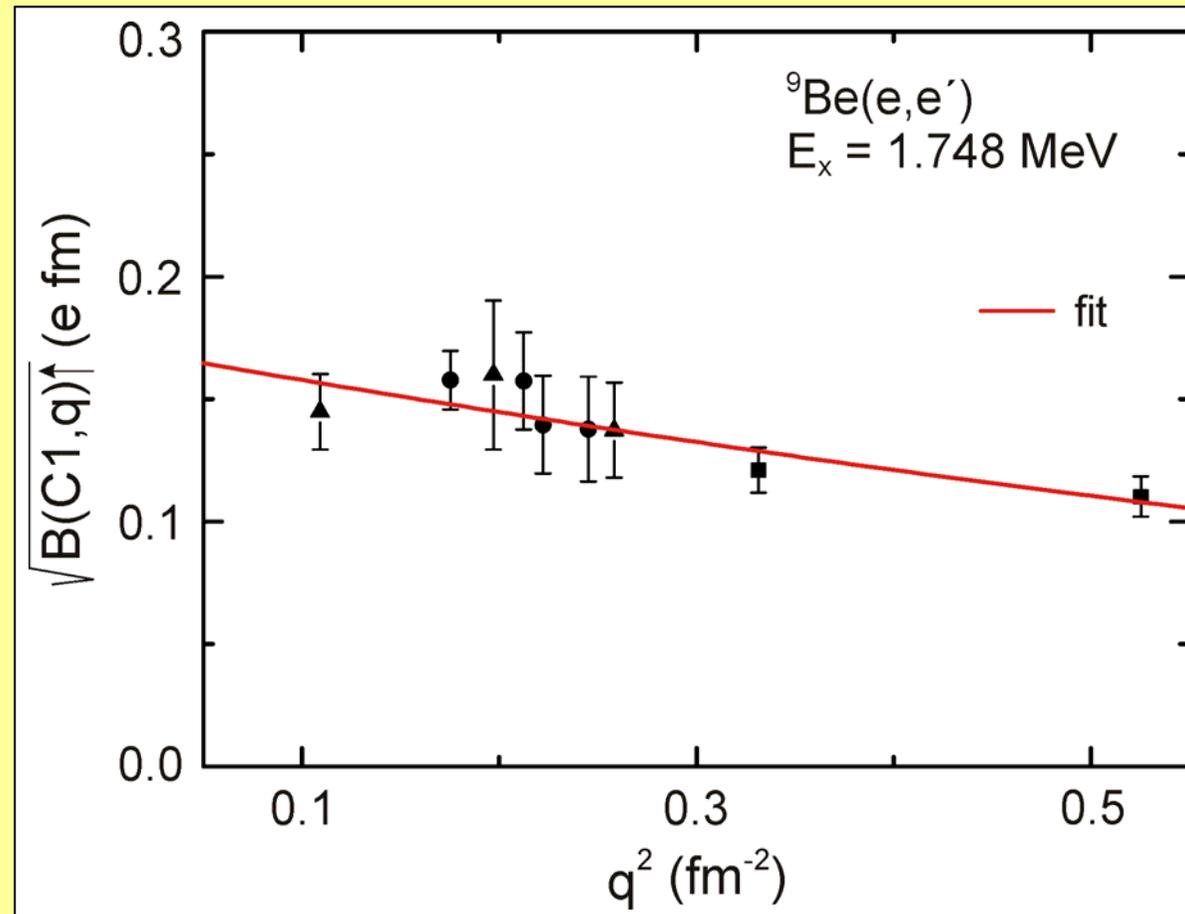
$B(C1, k = E_x/hc) = 0.027(4)\ e^2\text{fm}^2$

Convergence behavior of NCSM results

Convergence behavior of NCSM results

Radial transition densities from NCSM