Extraction of ANC via Coulomb breakup

[A]Kazuyuki Ogata

[A]K. Minomo, [A]T. Fukui, [B]C. A. Bertulani, and [A]M. Yahiro

[A]*Department of Physics, Kyushu University*

[B]*Texas A&M, Commerce*

1) Brief introduction to CDCC

—— *M. Kamimura, Yahiro, Iseri, Sakuragi, Kameyama and Kawai, PTP Suppl.* ***89****, 1 (1986);*
N. Austern, Iseri, Kamimura, Kawai, Rawitscher and Yahiro, Phys. Rep. ***154*** *(1987) 126.*

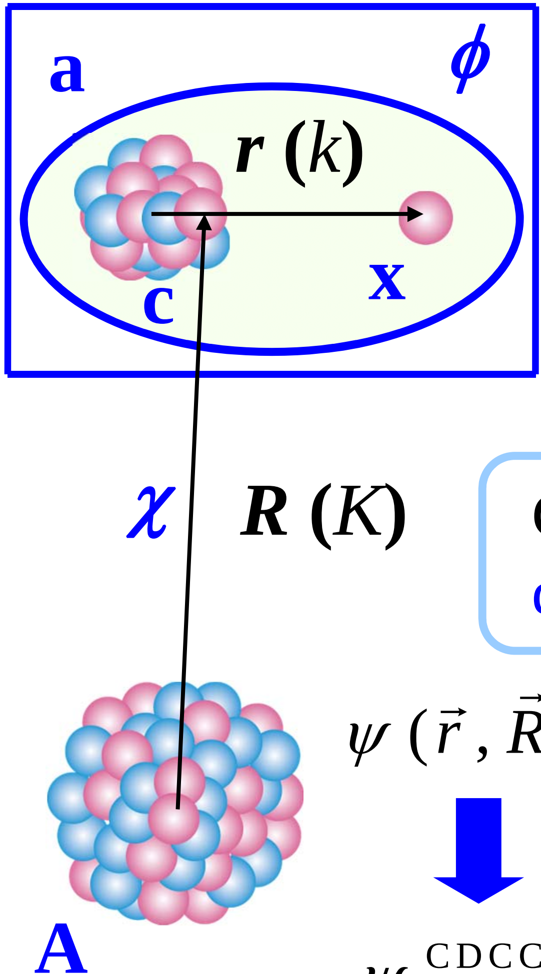
2) Some “new” aspects of our paper on $S_{17}(0)$

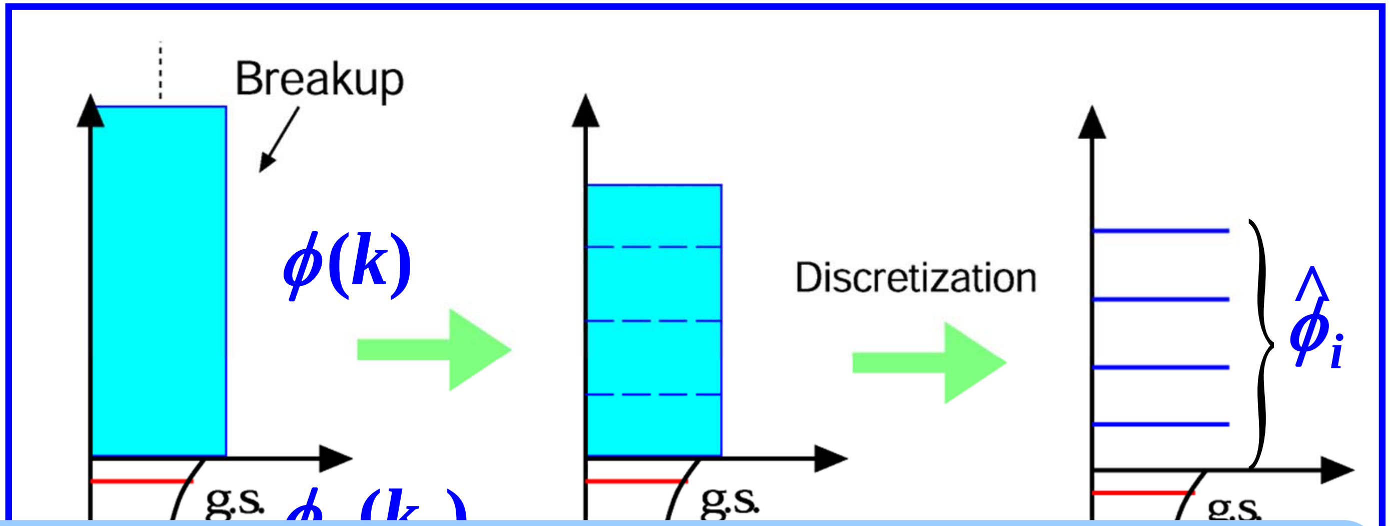
—— *KO, Hashimoto, Iseri, Kamimura, and Yahiro, PRC****73****, 024605 (2006).*

3) Some results on breakup of ^{9}C

—— *KO, Minomo, Bertulani, and Yahiro, in preparation*

The Continuum-Discretized Coupled Channels method (CDCC)





CDCC is just a usual CC calculation with truncation and discretization of the continuum.

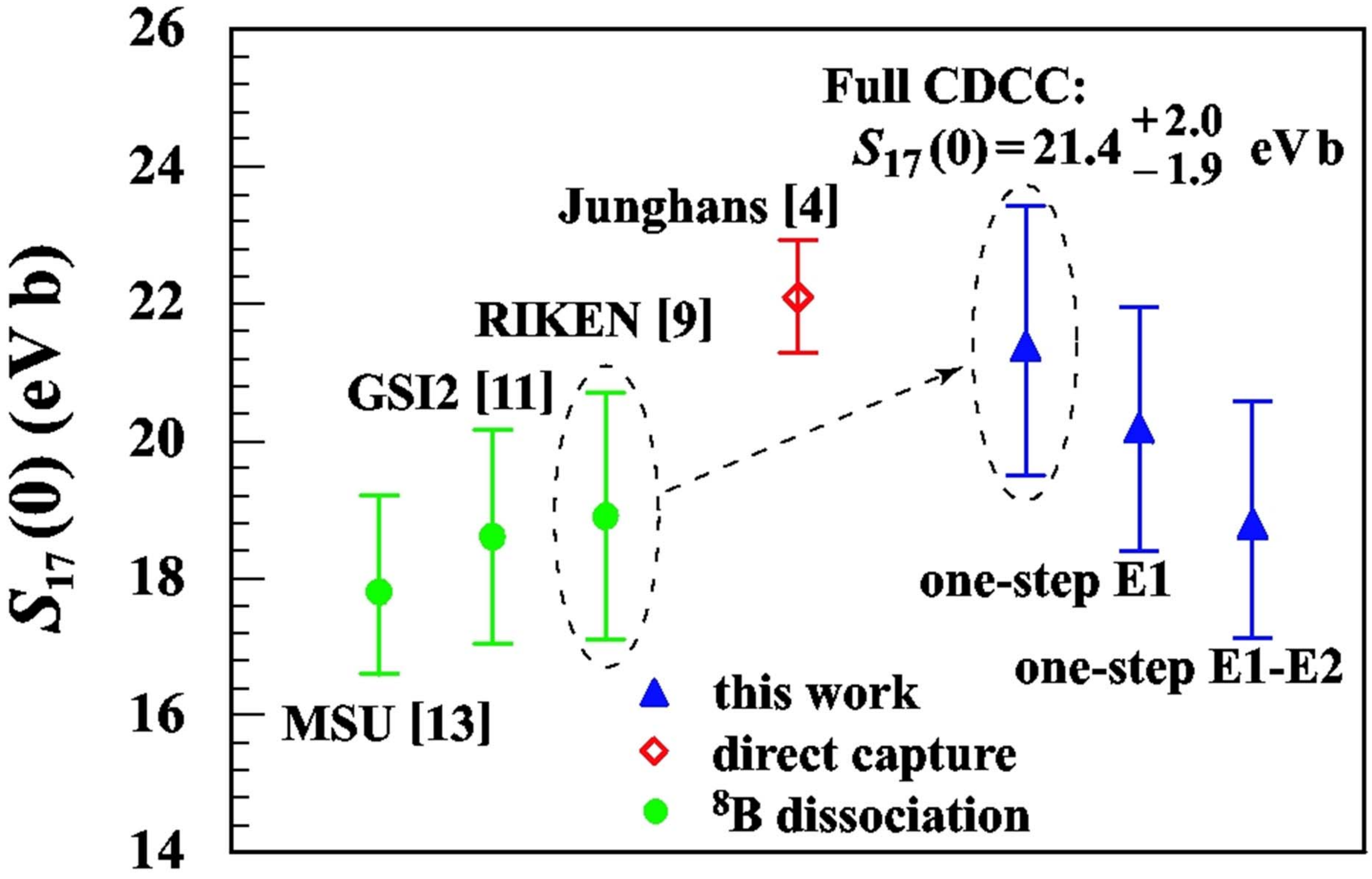
$$\psi(\vec{r},\vec{R}) \cong \phi_0(k_0,\vec{r})\chi_0(K_0,\vec{R}) + \underline{\sum_{i=1}^{i_{max}} \hat{\chi}(\hat{K}_i,\vec{R})\int_{k_{i-1}}^{k_i}\phi(k,\vec{r})dk}$$

Truncation and Discretization

$$\psi^{CDCC}(\vec{r},\vec{R}) = \sum_{i=0}^{i_{max}} \hat{\phi}_i(\vec{r})\hat{\chi}_i(\hat{K}_i,\vec{R})$$

$S_{17}(0)$ extracted from ^{8}B breakup with CDCC

—— *KO, Hashimoto, Iseri, Kamimura, and Yahiro, PRC**73**, 024605 (2006).*



Three "new" aspects of our S_{17} paper

—— *KO, Hashimoto, Iseri, Kamimura, and Yahiro, PRC**73**, 024605 (2006).*

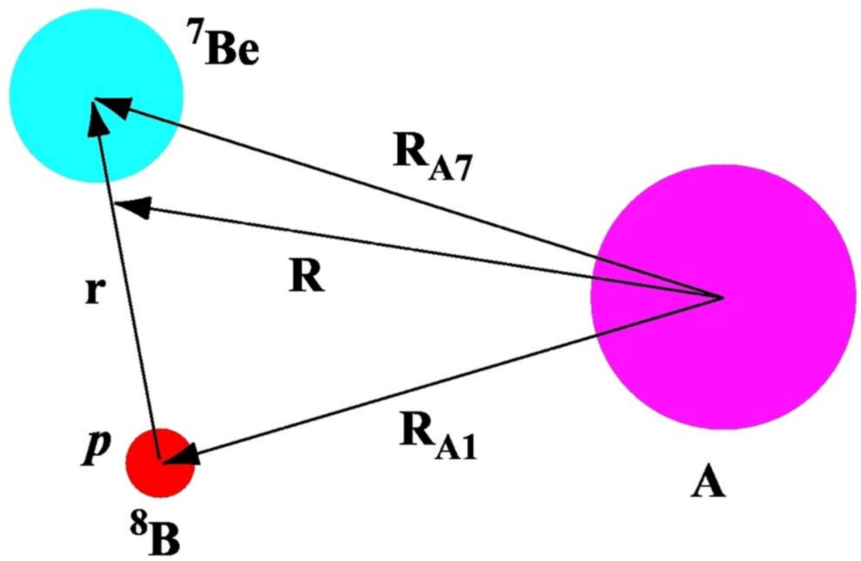
1) The first work to determine ANC from exclusive Coulomb breakup (showing peripherality of Coulomb breakup reaction)

- **Peripherality with respect to *R*:**

$$R \geq R_{\min}$$

- **Property of the E1 operator:**

$$\frac{R}{(wr)^2}\theta(wr - R) + \frac{wr}{R^2}\theta(R - wr)$$



Coulomb-dominated breakup is peripheral with respect to *r*.

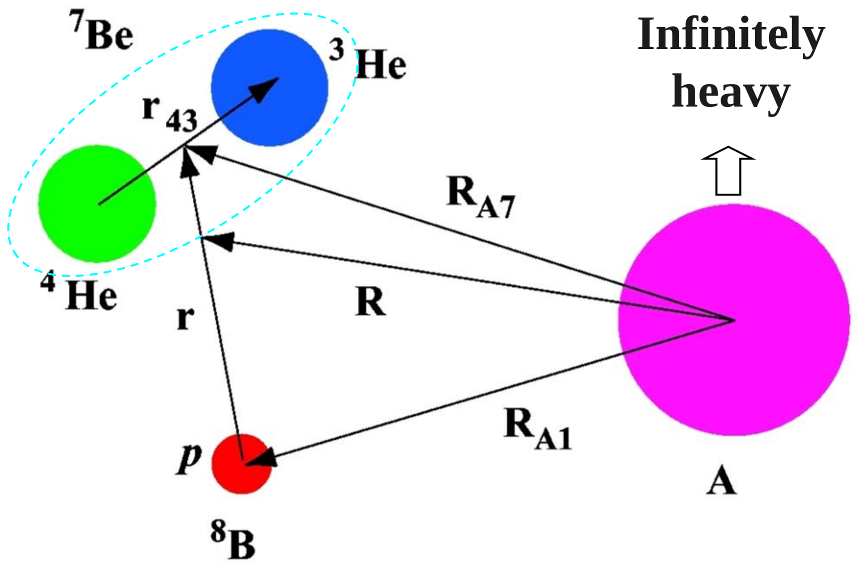
Coulomb breakup ANC method!

*c.f. L. Trache, Carstoiu, Gagliardi, and Tribble, PRL**87**, 271102 (2001).*

Three "new" aspects of our S_{17} paper

—— *KO, Hashimoto, Iseri, Kamimura, and Yahiro, PRC**73**, 024605 (2006).*

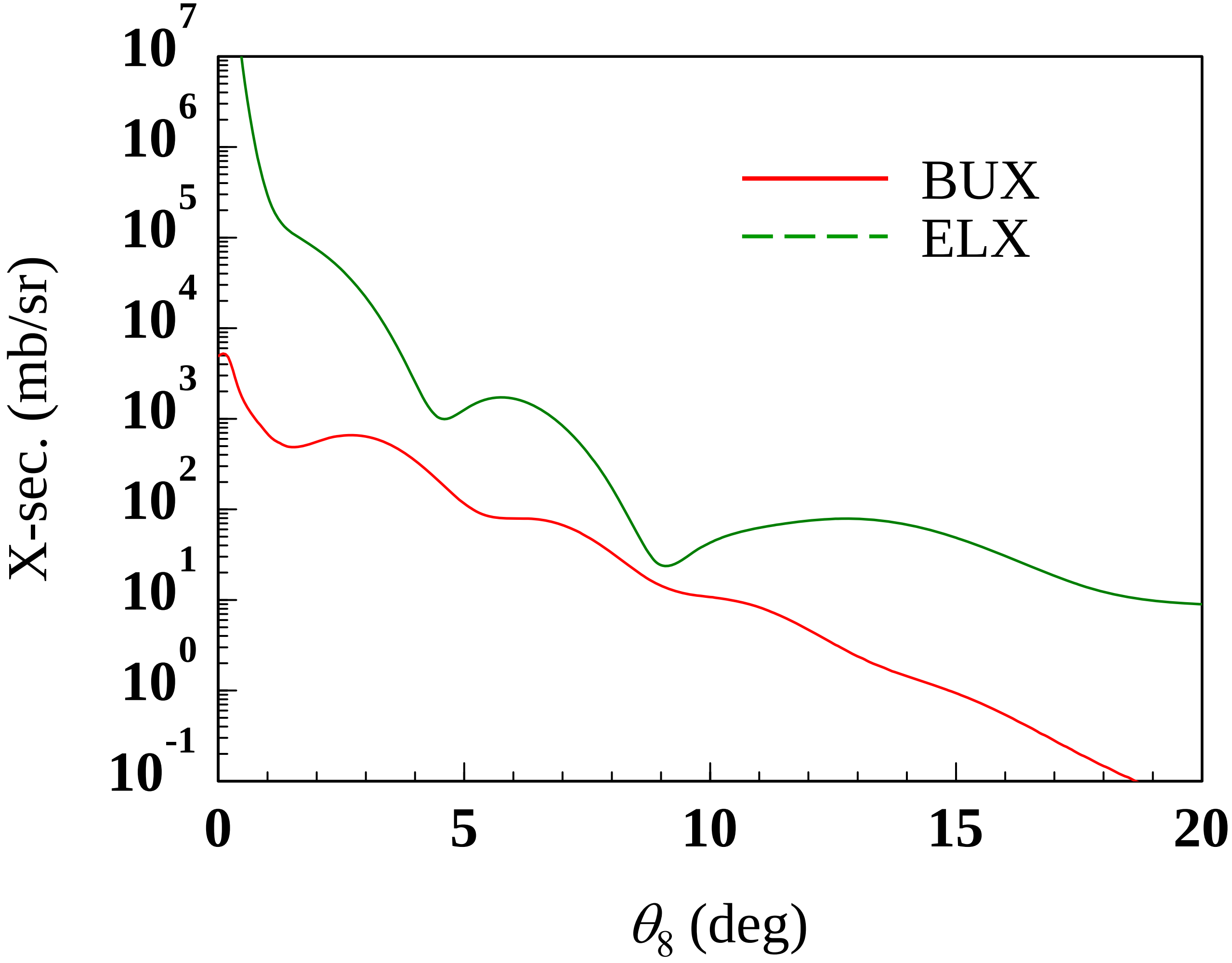
2) Reduction from 4-body breakup to 3-body breakup



- **The triple-differential cross section for (^{8}B, ^{7}Be+p) is obtained by** $C\,\rho\,|\mathfrak{T}|^2$ **with** $\mathfrak{T} = \langle \chi_1 \chi_7 \phi_7^{(0)} | U_{A3} + U_{A4} + U_{A1} + V_{13} + V_{14} | \Psi_{\text{4-body}} \rangle$
- **^{7}Be breakup cross section by ^{208}Pb turned out to be negligibly small for forward-scattering.**

$$\Rightarrow \begin{cases} U_{A3} + U_{A4} \approx \langle \phi_7^{(0)} | U_{A3} + U_{A4} | \phi_7^{(0)} \rangle \\ V_{13} + V_{14} \approx \langle \phi_7^{(0)} | V_{13} + V_{14} | \phi_7^{(0)} \rangle \end{cases}$$

^{8}B scattering from ^{9}Be at 100 A MeV



Three “new” aspects of our S_{17} paper

—— *KO, Hashimoto, Iseri, Kamimura, and Yahiro, PRC**73**, 024605 (2006).*

3) CDCC cross section is proportional to ANC

$$\langle \phi_7^{(0)} | \Psi_{4\text{-body}} \rangle = \langle \phi_7^{(0)} | \frac{i\varepsilon}{E - H_{4\text{-body}} + i\varepsilon} | \phi_8^{(0)} e^{i\mathbf{P}\cdot\mathbf{R}} \rangle$$

$$\approx \frac{i\varepsilon}{E - e_7 - H_{3\text{-body}} + i\varepsilon} | \mathfrak{S}_{\text{exp}}^{1/2} \psi_{17}(\mathbf{r}) e^{i\mathbf{P}\cdot\mathbf{R}} \rangle$$

with

$$\mathfrak{S}_{\text{exp}}^{1/2} \psi_{17}(\mathbf{r}) \equiv \langle \phi_7^{(0)}(\mathbf{r}_{43}) | \phi_8^{(0)}(\mathbf{r}_{43}, \mathbf{r}) \rangle$$

Normalization factor

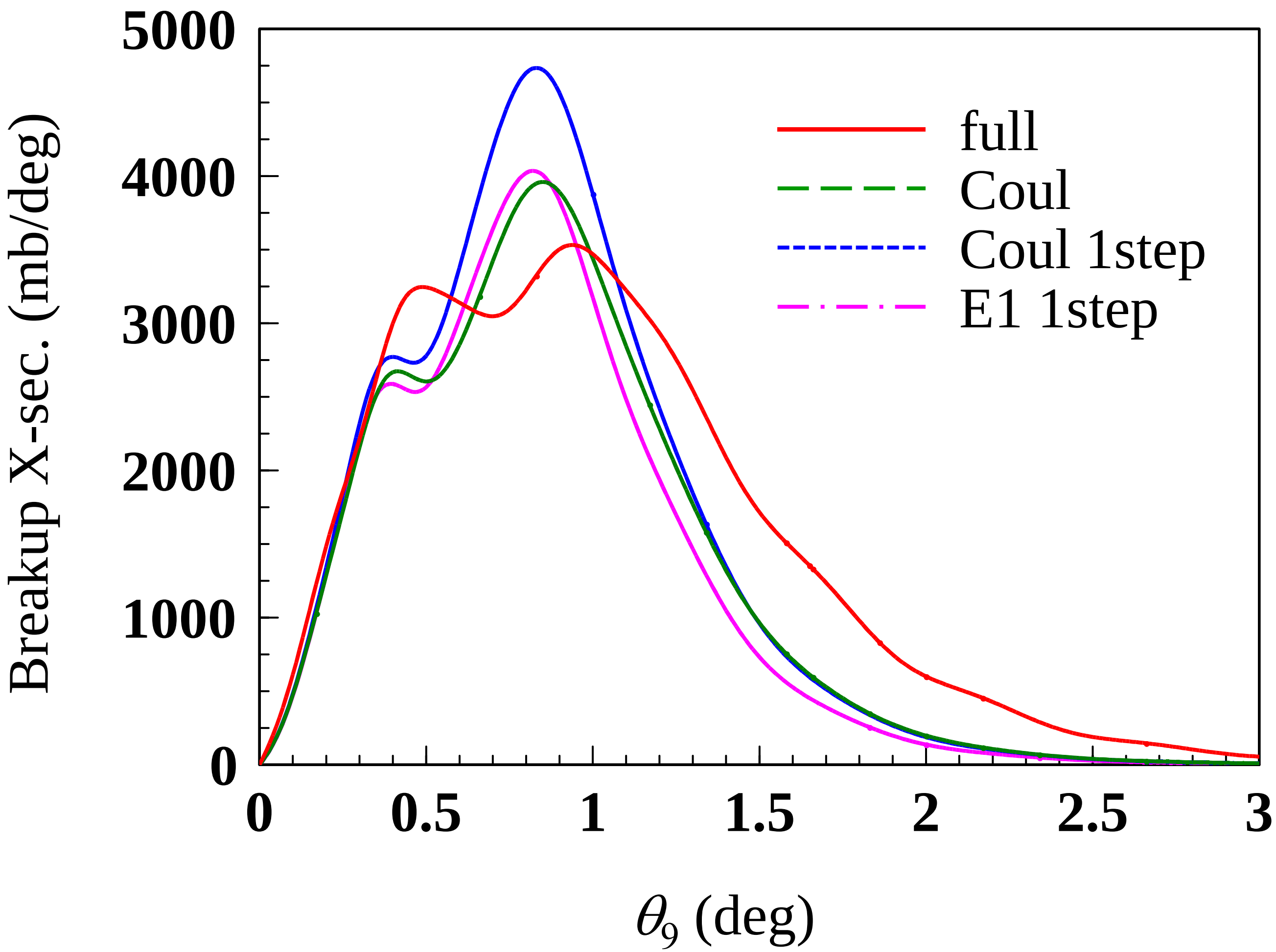
$$H_{3\text{-body}} = T_r + T_R + V_{17}(\mathbf{r}) + U_{\text{A7}}(\mathbf{R}_{\text{A7}}) + U_{\text{A1}}(\mathbf{R}_{\text{A1}})$$

$$\mathfrak{T} \approx \mathfrak{S}_{\text{exp}}^{1/2} \mathfrak{T}_{3\text{-body}},$$

$$\mathfrak{T}_{3\text{-body}} \equiv \langle \chi_1 \chi_7 | U_{\text{A7}} + U_{\text{A1}} + V_{17} | \Psi_{3\text{-body}} \rangle,$$

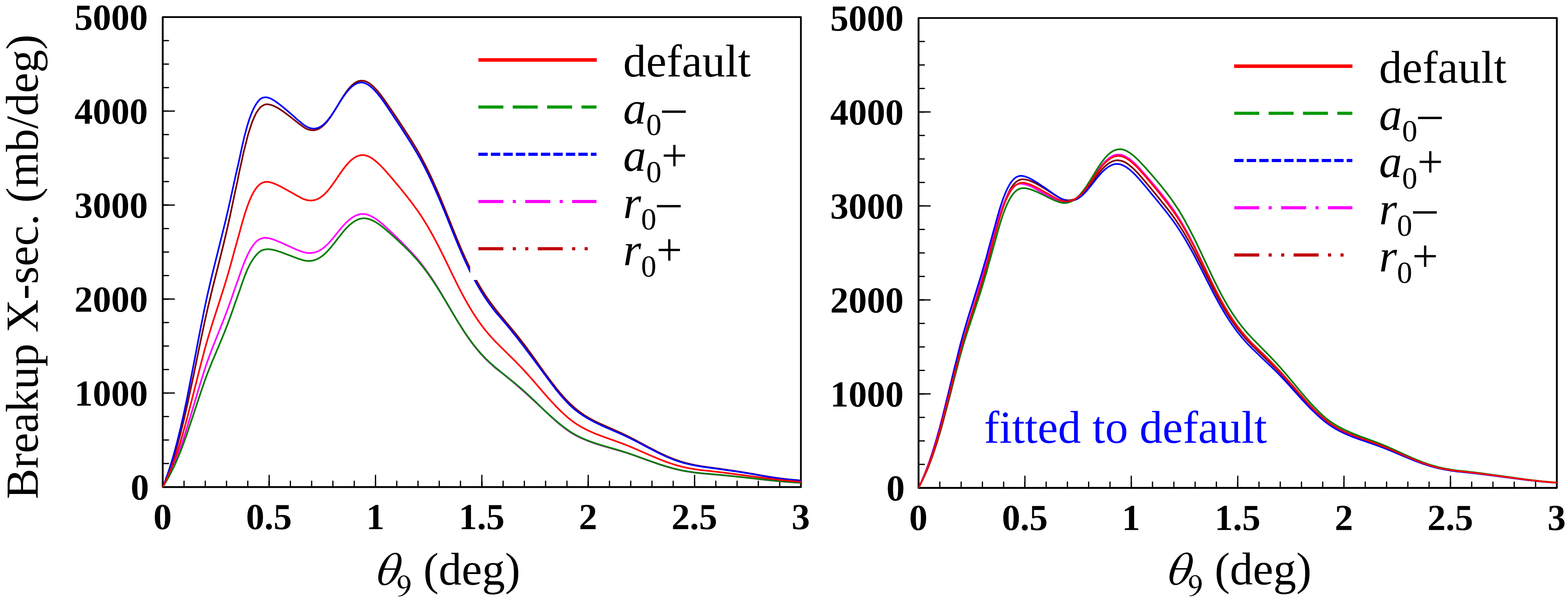
^{9}C breakup by ^{208}Pb at 300 MeV/nucleon

(nuclear and higher-order effects)



^{9}C breakup by ^{208}Pb at 300 A MeV

(check of peripherality)



	default	a_0^-	a_0^+	r_0^-	r_0^+
S	1.00	1.26	0.80	1.22	0.81
$(C_{sp})^2$	1.63	1.30	2.05	1.28	2.10
C^2	1.63	1.64	1.64	1.57	1.69

Summary

1) ***CDCC*** **is a powerful tool to describe projectile breakup processes non-perturbatively.**

2) ***Coulomb-breakup ANC method*** **is proposed.**

- ✓ Coulomb-dominated breakup is peripheral.
- ✓ Three-body description of ^{8}B and ^{9}C breakup processes is justified.
- ✓ CDCC cross section is proportional to the ANC^2.

3) **Some results on** ***^{9}C breakup*** **are discussed**

- ✓ Nuclear and higher-order contributions are important.
- ✓ ^{9}C breakup by ^{208}Pb at (100 and) 300 MeV/nucleon is peripheral.
  - ⇨ Application to ^{9}C breakup at 65MeV/A (Fukui)
- ✓ Eikonal CDCC is valid.
  - ⇨ Eikonal Reaction Theory (Minomo)