SNP99, Feb. 19-22, 1999, Seoul, Korea

Λ-Λ interferometry in (K^-, K^+) and AA reactions

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1. $\Lambda\Lambda$ Interaction: How can we get it ?
2. $\Lambda\Lambda$ Inv. Mass Spec. $\rightarrow$ $\Lambda\Lambda$ Int.
   - ⋆ IntraNuclear Cascade model + Correlation
   - ⋆ Comparison with Nijmegen Models
3. Do Two Lambdas Bound ?
   - ⋆ Double-well Structure
   - ⋆ $\Lambda\Lambda$ Correlation at AGS, SPS, and RHIC
4. Summary

Refs. of Ours

(K^-, K^+)	Nara, Ohnishi, Harada, Engel, NPA614 (97), 433
AA	Nara, NPA638 ('98), 555c; nucl-th/9802016
	Nara et al., to be submitted.
Corr. to nn Int.	Slaus, Akaishi, Tanaka, PRep. 173, ('89), 257.
$\Lambda\Lambda$ Int.	Ohnishi, Hirata, Nara, Shinmura, Akaishi, in preparation
	Hirata, Ohnishi, Ohtsuka, Nara, in preparation

$\Lambda\Lambda$ Interaction: How can we get it ?

- ⋆ **IMPORTANT**

  Baryon-Baryon Int. with $SU_f(3)$,

  Double Hypernuclei, H particle, Neutron Star, . . .

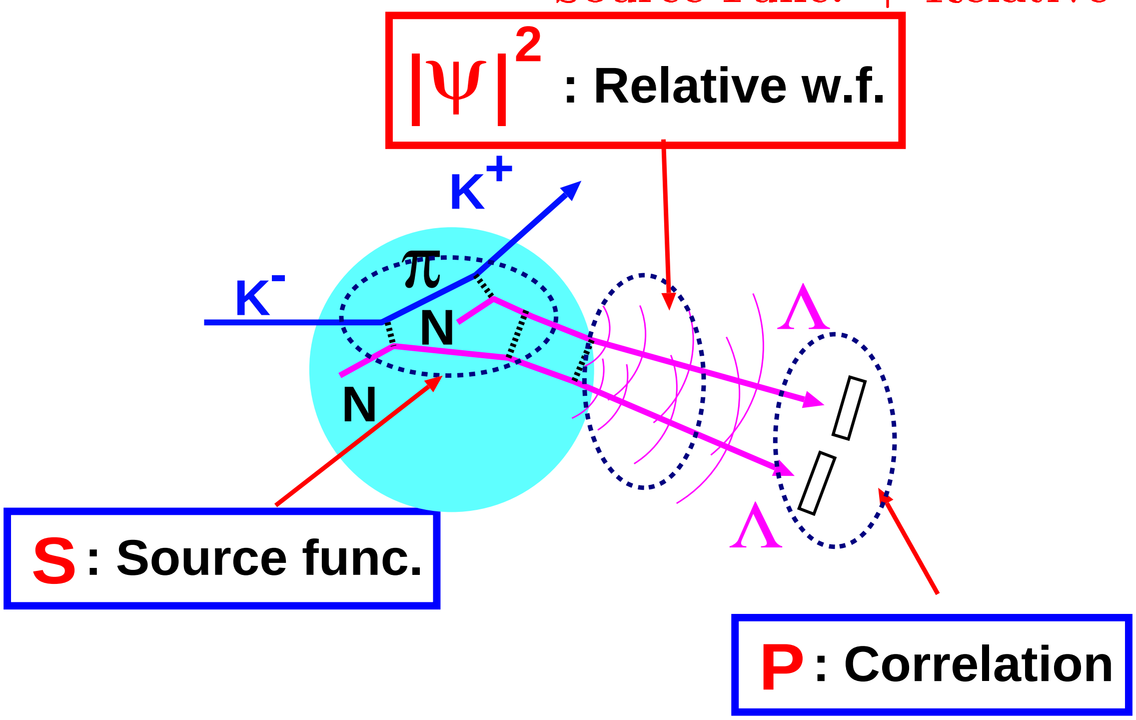
- ⋆ **but DIFFICULT to measure**
  - ∘ **Double Hypernuclei → 3 events/35 years, Only $^1S_0$**
  - ∘ **Scattering Exp. → Compact Collider**

• Enh. of Λ-Λ Inv. Mass Spec. at Low E.

Ahn et al. (KEK E224 coll.), KEK Preprint 98-24, 1998; PRL, in press

• Two-Particle Momentum Correlation

= Source Func. + Relative w.f.



$$P(p_1, p_2) = \int dx_1 dx_2 S(p_1, x_1, p_2, x_2) |\psi^{(-)}(k, r_{12})|^2$$

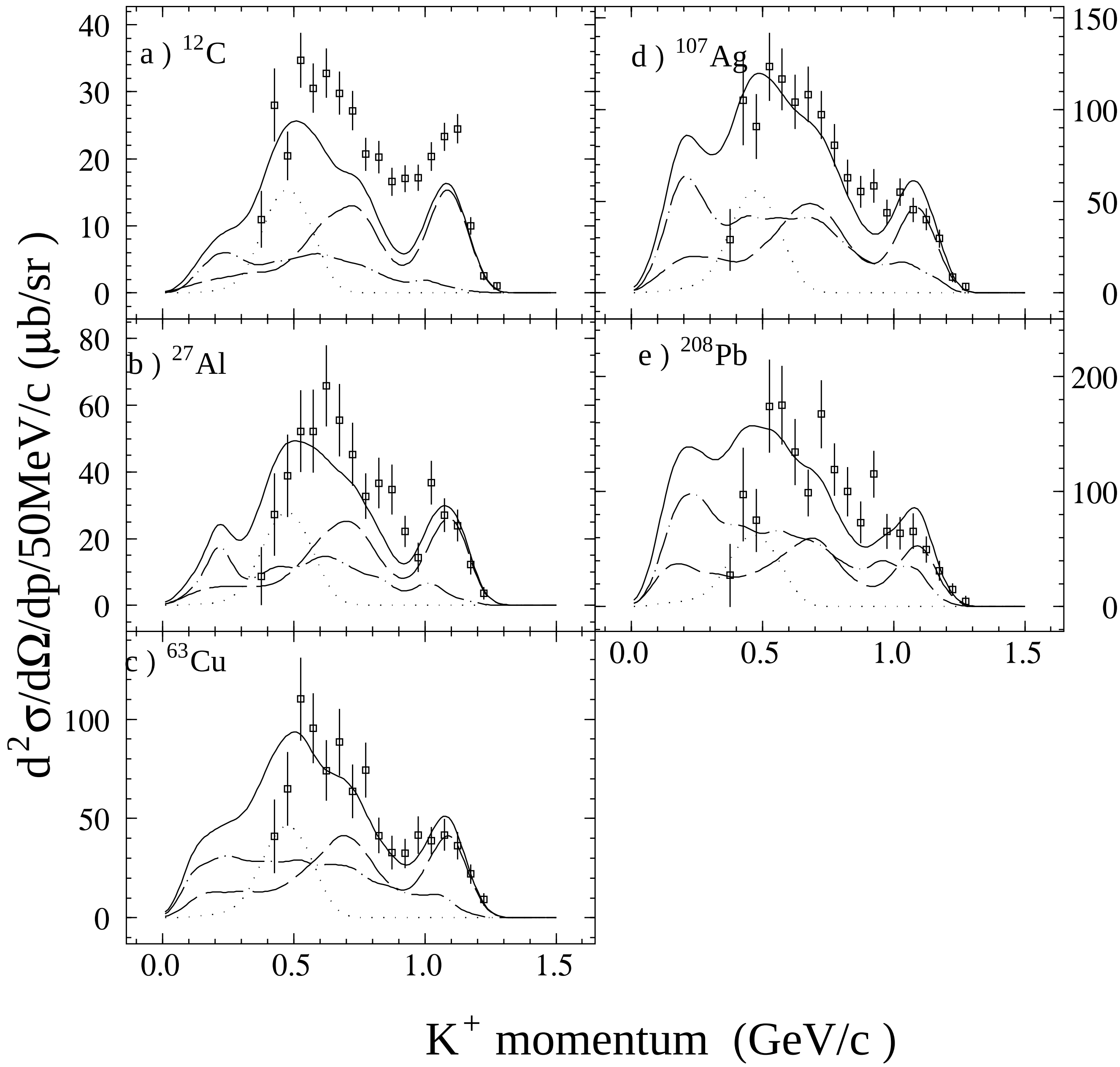
$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2 + \vec{P}(t_2 - t_1)/2m \ , \quad \vec{P} = \vec{p}_1 + \vec{p}_2 \ , \quad \vec{k} = \frac{1}{2}(\vec{p}_1 - \vec{p}_2) \ ,$$

W. G. Gong et al., PRC 43 ('91), 781.

Slaus, Akaishi, Tanaka, PRep. 173, ('89), 257.

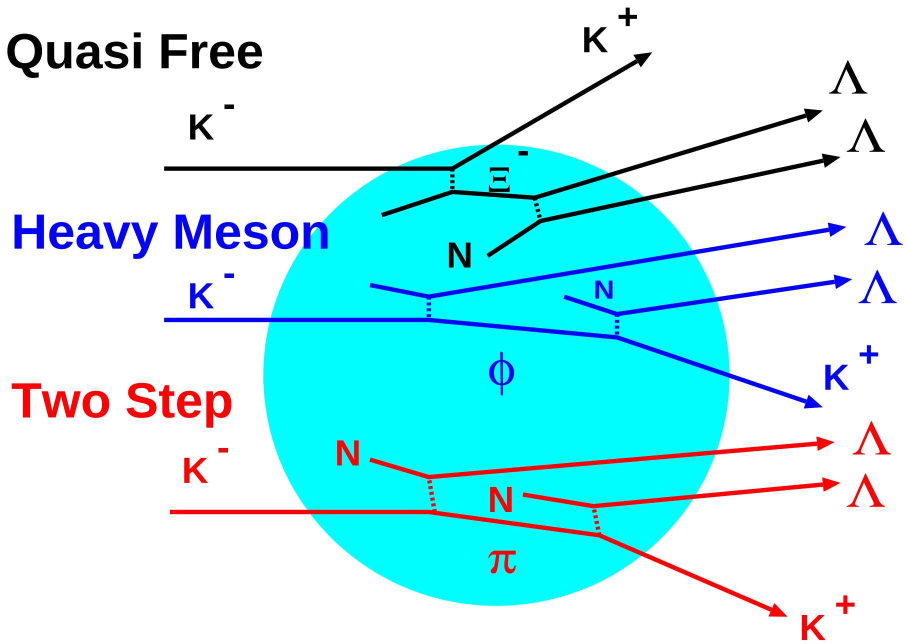
Is there any reliable source function ?

→ **INC: Nara,Ohnishi,Harada, Engel, NPA614 (97), 433.**



Source Func. = IntraNuclear Cascade

Nara,Ohnishi,Harada, Engel, NPA614 (97), 433.



- **K^+ Production Mech.**

Quasi Free	$K^-N \to K^+\Xi^{(*)}$
Heavy-Meson (Gobbi-Dover-Gal)	$K^-N \to MY, M \to K^-K^+$ $MN \to K^+\Lambda$ $(M = \phi, f_0, a_0)$
Two-Step	$K^-N \to MY^{(*)}, MN \to K^+Y^{(*)}$ $(M = \pi, \eta, \rho, \omega, \eta')$

- **Baryon-Baryon Collision**

⋆ $NN \to NN$, $NY \to NY'$ (ND)

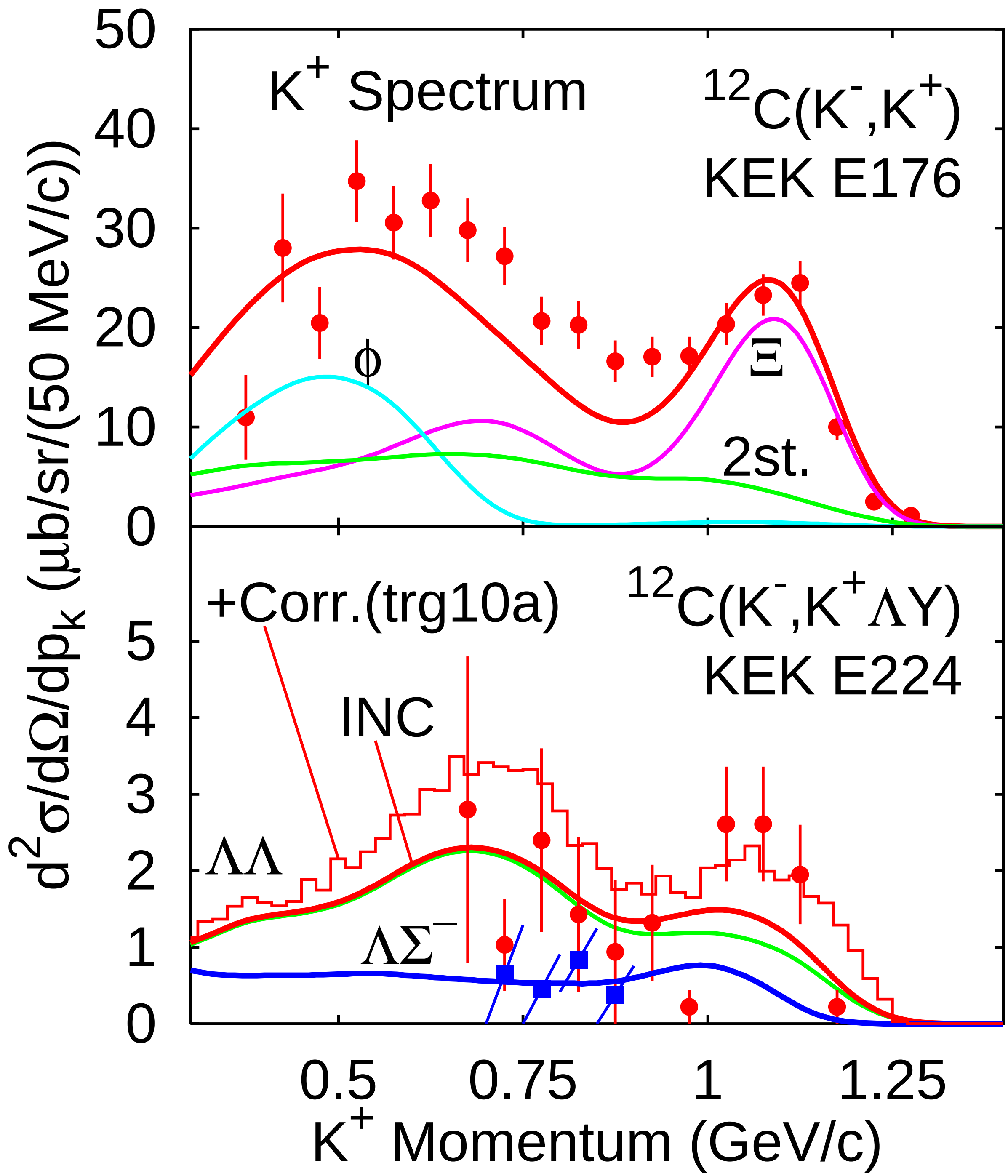
⋆ $\Xi N \to \Lambda\Lambda$ (ND, r_c=0.5 fm)

- **Mean Field Effects**

⋆ $U_\Lambda = -30$ MeV, $U_\Sigma = -10$ MeV
$U_\Xi = -16$ MeV

(Fukuda et al. PRC58 (98) 1306)

K^+ Spectrum in $^{12}C(K^-, K^+)$

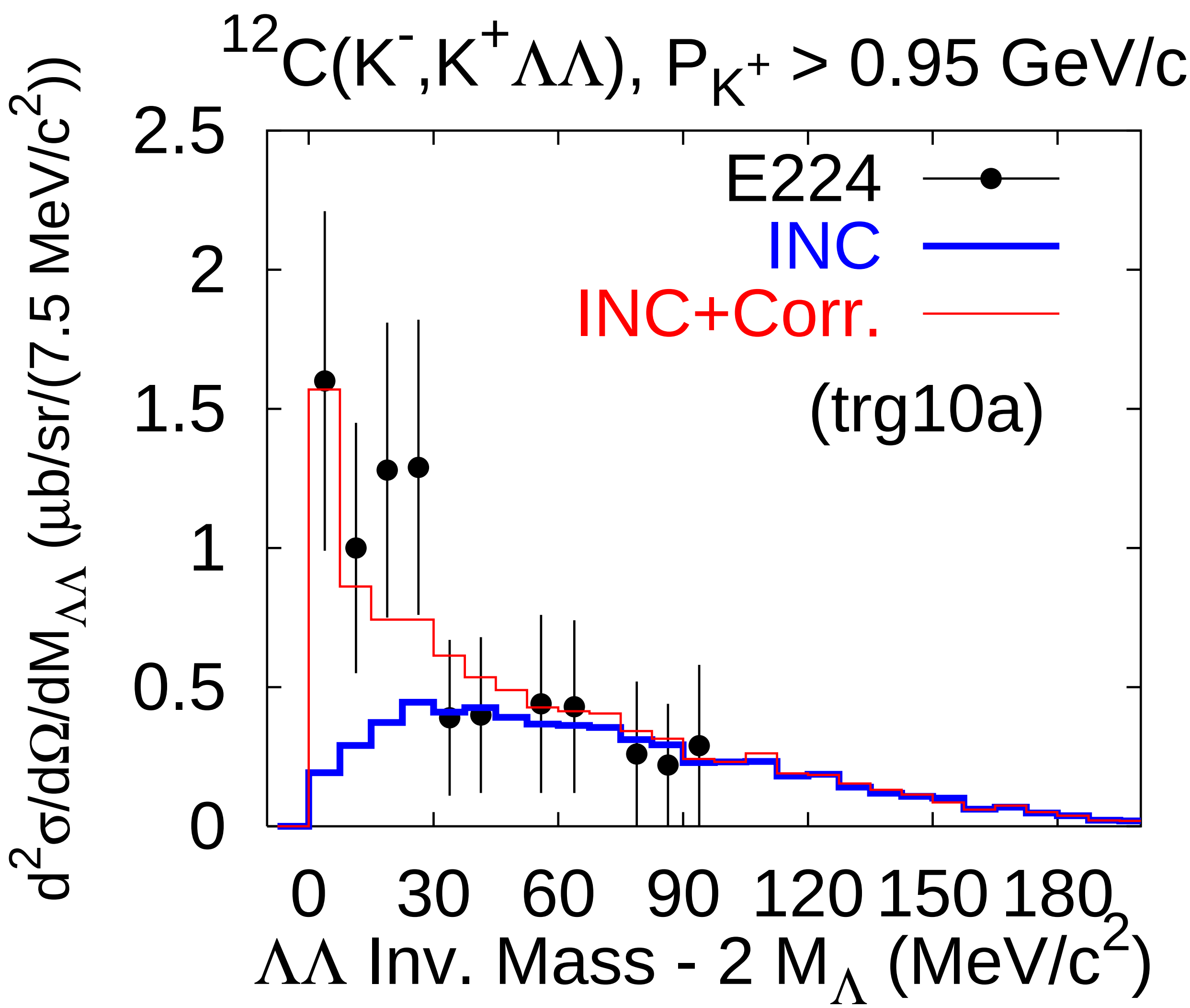


- **INC** results of $(K^-, K^+\Lambda\Lambda)$

  ⋆ **Underestimate of around 3 μb** ($P(K^+) > 0.95$ **GeV/c**)

  ⋆ **Two-Step Processes are dominant even in QF region.**

Λ-Λ Inv. Mass Spectrum

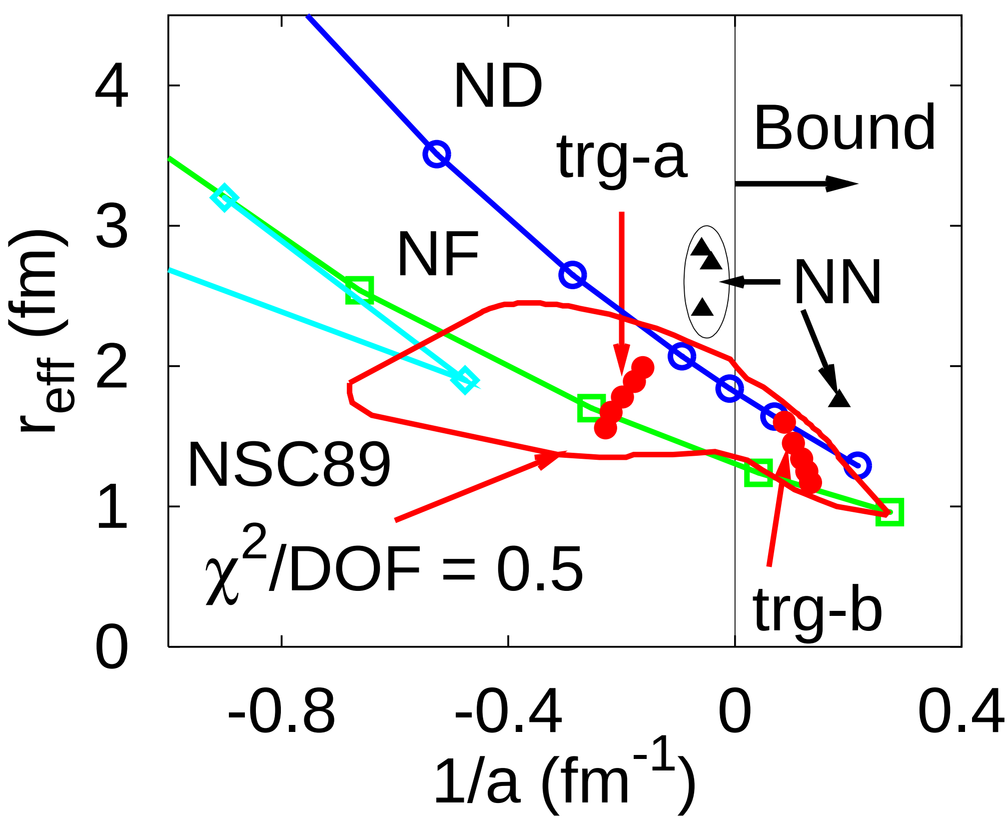


- **INC results**
  - ⋆ **Underestimate ($\sim 3\mu$b) at Low $M_{\Lambda\Lambda}$**
  - ⋆ **Reproduces at $E_{\Lambda\Lambda} > 50$ MeV $\cdots$ Source Size $\leq$ 3 fm**
- **INC+Corr. results**
  - ⋆ **Attr. ΛΛ Int. → Fast Growth of W.F.**
    → Enh. of Inv. Mass Spec.

Extracted Λ-Λ Interaction

• χ^2-Fit within Two-Range Gauss Interaction

	μ_l	μ_s	v_l	v_s	a	r_{eff}	$\tilde{\chi}^2$	B.E.
		(fm)		(MeV)		(fm)		(MeV)
trg06a	0.6	0.45	-900	1440	-4.4	1.6	0.34	U.B.
trg08a	0.8	0.45	-230	470	-5.0	1.8	0.36	U.B.
trg10a	1.0	0.45	-105	200	-6.2	2.0	0.39	U.B.
trg06b	0.6	0.45	-950	1310	7.5	1.2	0.37	0.72
trg08b	0.8	0.45	-270	410	8.5	1.3	0.40	0.56
trg10b	1.0	0.45	-135	210	11.5	1.6	0.43	0.29



Comparison with Nijmegen Models

- ⋆ **ND with** $r_c = 0.5 \sim 0.52$ **fm** $\leftrightarrow$ **trg10a**
- ⋆ **NF with** $r_c = 0.46$ **fm** $\leftrightarrow$ **trg06a**
- ⋆ **NSC98 with** $M_{cut} = 920$ **MeV**

Does Λ-Λ System Bound ?

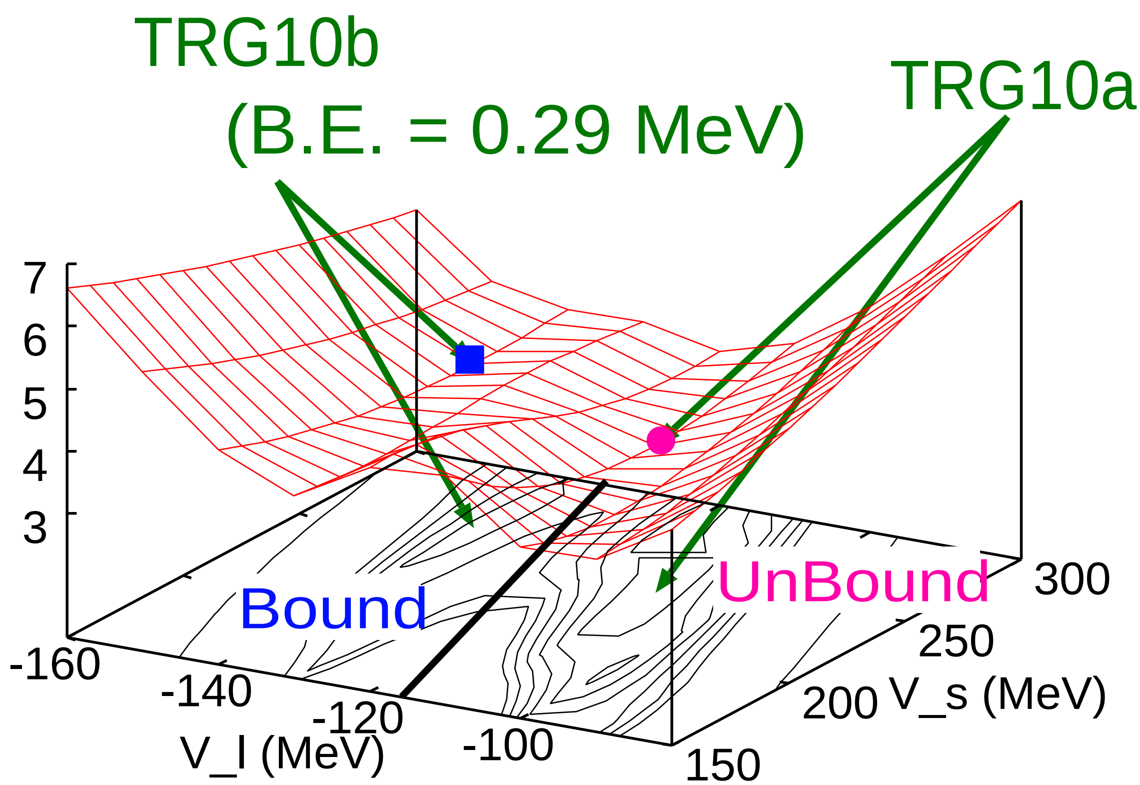
- **Corr. Formula + Long Wave Approx.**
  → Enhancement Factor

$$P(\vec{p}_1,\vec{p}_2) \;=\; 2\;F(k)\;P_c(\vec{p}_1,\vec{p}_2)\;,$$
$$P_c(\vec{p}_1,\vec{p}_2) \;=\; \int d^4x_1\,d^4x_2\,S(\vec{p}_1,x_1,\vec{p}_2,x_2)\;,$$

$$F(k) = \left|\frac{\sin(kb+\delta_0)}{\sin kb}\right|^2 \xrightarrow{k\to 0} \left(1-\frac{a}{b}\right)^2 - ck^2$$

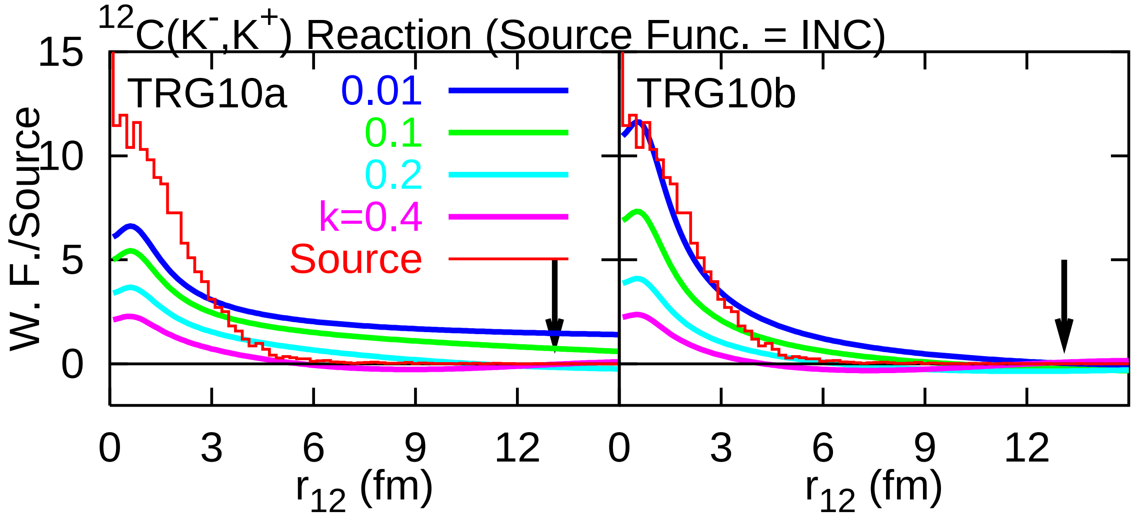
a: **scattering length,** b: **intrinsic range**

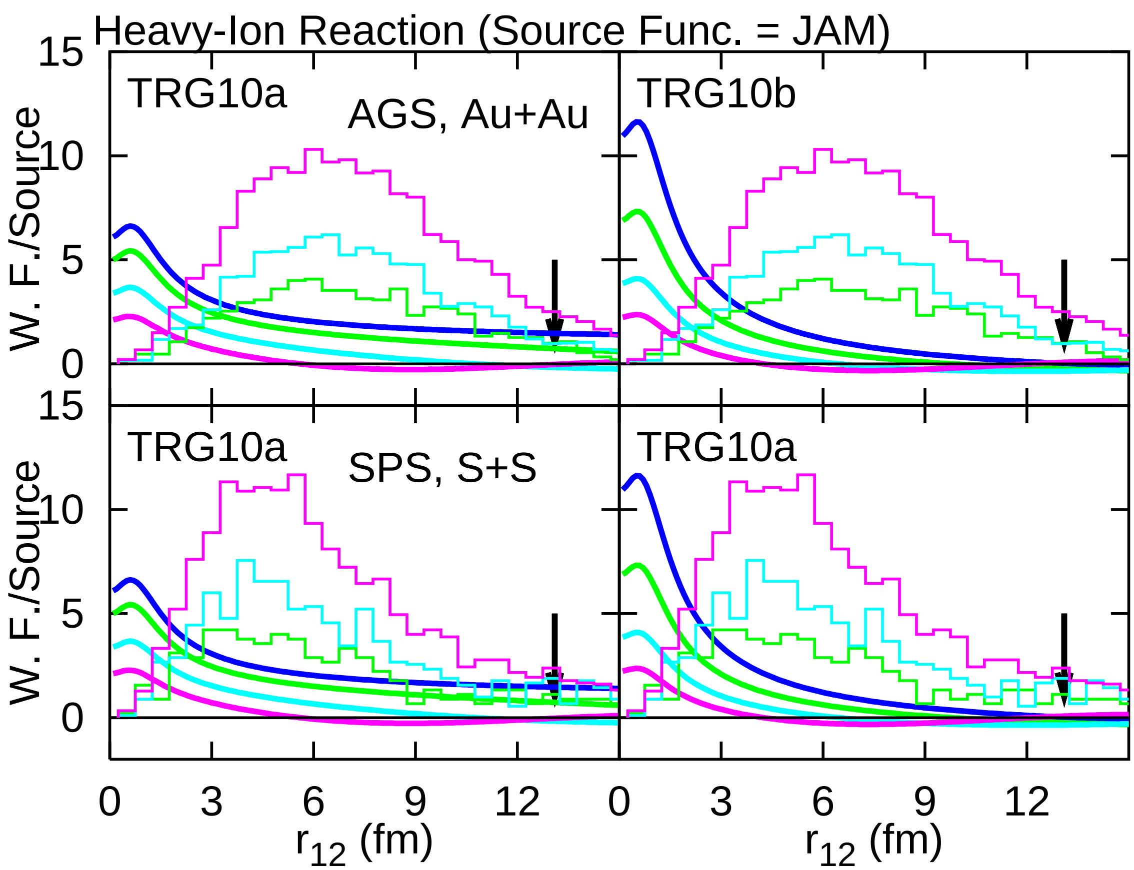
→ **Double-well structure:** $a \simeq b(1 \pm \sqrt{F(0)})$



• How to Distinguish Them ?

→ **Use Reactions with Different Source Size, covering the region around Scattering Length.**





JAM: Y.Nara, NPA638 ('98), 555c; nucl-th/9802016

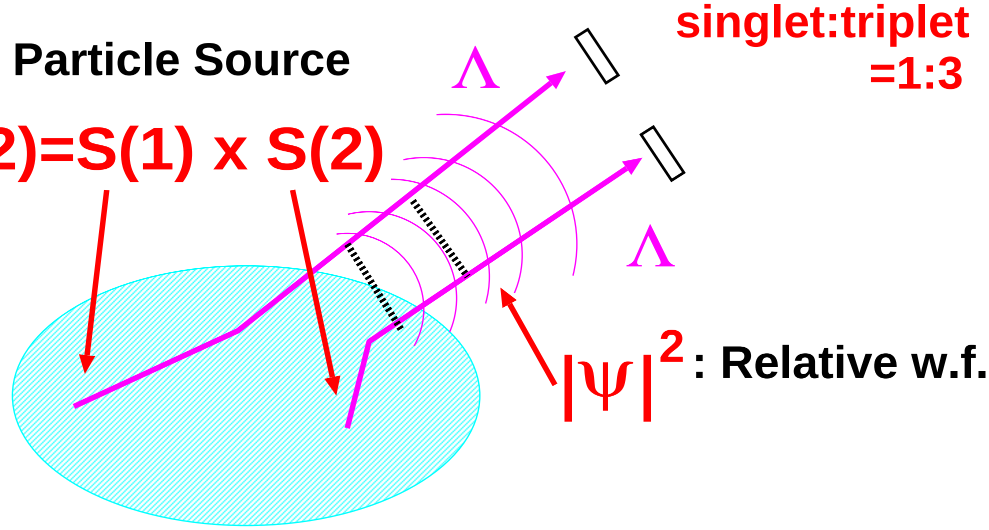
Y.Nara et al., to be submitted.

Particle Correlation in HIC

Indep. Particle Source

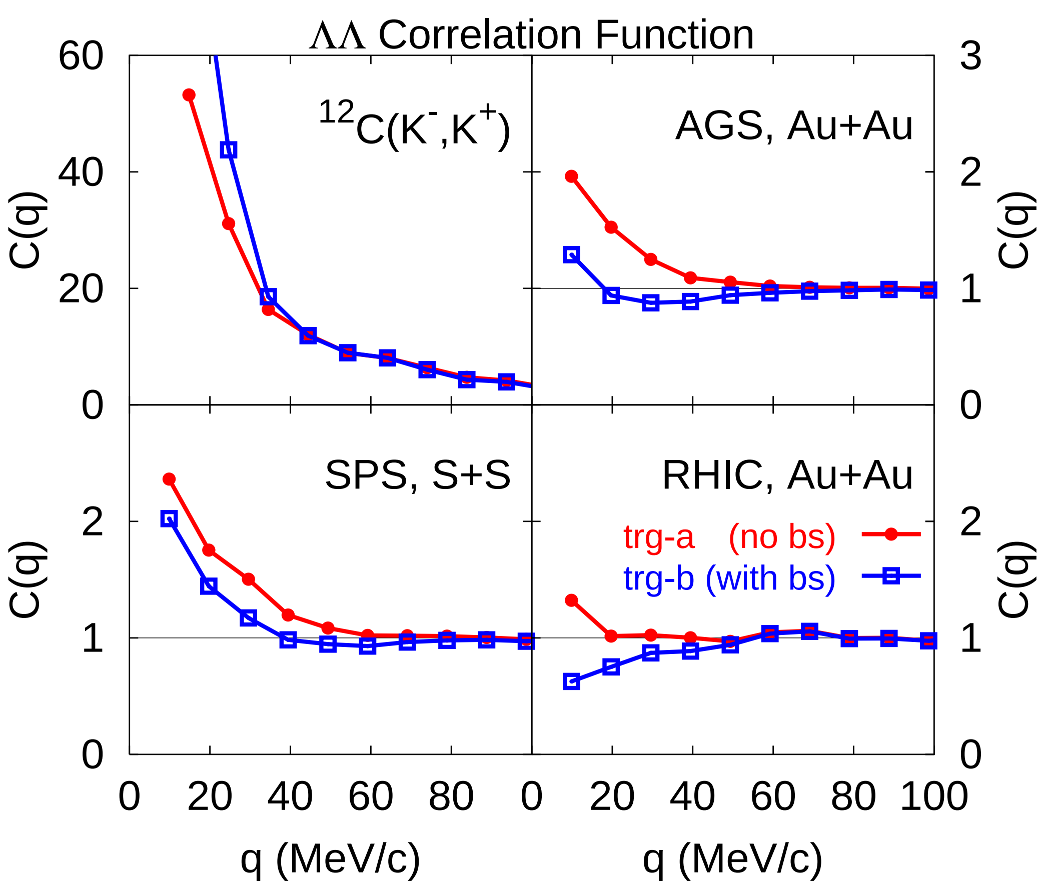
singlet:triplet =1:3

$$S(1,2)=S(1)\times S(2)$$



$$C(q)=\frac{\int dP\, dx_1 dx_2\, S(p_1,x_1,p_2,x_2)\,|\psi^{(-)}(k,r_{12})|^2}{\int dP\, dx_1 dx_2\, S(p_1,x_1,p_2,x_2)}$$

$$p_1 = P/2 + q \qquad p_2 = P/2 - q$$



Summary

1. **Source Func. (INC) + Λ-Λ Corr. (Inv. Mass Spec.)**
   → Λ-Λ Interaction
   (We can use HBT INVERSELY)

2. **Extracted Λ-Λ Int. at χ^2 Local Min.**
   - ⋆ **Best Fit Parameters: No Bound State.**
     → $a \simeq -5$ **fm**, $r_{\text{eff}} \simeq 1.8$ **fm**
   - ⋆ **Double well structure**
     → **We cannot exclude** $a > 0$ **(bound)**
   - ⋆ χ^2/**DOF** $\simeq$ **0.4: Large Error Bar of Data**

3. **Λ-Λ Interferometry in** (K^-, K^+) **and** AA **Reaction**

	Source	Corr.
(K^-, K^+)	Small, Dyn. Corr.	Large
AA	Large, Indep.	Small

   - ⋆ (K^-, K^+) **Reaction**
     - **One-Dim. Prod. Mech. + Small Source Size**
     → **Large Enh.**
   - ⋆ **Relativistic Heavy-Ion Collision**
     - **Indep. Prod. Mech. + Large Source Size**
     → **Corr. Func. is Available through Exp.**
     → **Covers Scat. Length Region of Small B.E.**

• Remaining Problems

1. Resonance of $\Lambda\Lambda$-ΞN Coupling or $^3\mathbf{P}_2(\Lambda\Lambda)$
   c.f. Oka-Yazaki '84, Shinmura et al.

2. Assumption in this work

   (a) Spin Singlet dominance

   (b) Only the $L = 0$ partial waves are distorted.

   $\cdots$ Odd partial waves $\leftarrow$ Spin dist. in ^{12}C

3. Other Hyperon-Hyperon Interaction
   $\cdots$ $\Lambda\Sigma^-$, $\Sigma^+\Sigma^-$ (BNL-E906)

4. Mean Field Effects in AA Collision
   $\cdots$ Flow at AGS and SPS energies (P.K. Sahu et al.)

5. Small Yield of Low Energy $\Lambda\Lambda$ in AA

6. Evaporation from Hypernuclei in (K^-, K^+) Reaction.

7. .....