HYP2000 @ Trino, Italy

Lambda-Lambda correlation in (K^-, K^+) reaction — Is there a virtual pole ?

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1. Introduction
   — From $\Lambda\Lambda$ Corr. to $\Lambda\Lambda$ Int.
2. Hyperon Dist. and Corr. in (K^-, K^+) Reaction
   — INC + Λ Evaporation + FSI Correlaton
3. Is there a Pole ?
   — Virtual Pole in $\Lambda\Lambda$
4. Summary

Refs. of Ours:

INC for (K^-, K^+): Nara et al., NPA614('97),433.

Λ Evap.: Nara et al., PLB346('95),217. (${}^{4}_{\Lambda}$H formation)

Hirata et al., PTP102('99),89. ($\Lambda\Lambda$ Hyp.)

Corr. → Int. in Few-Body: Slaus,Akaishi,Tanaka, Phys.Rep.173('89)

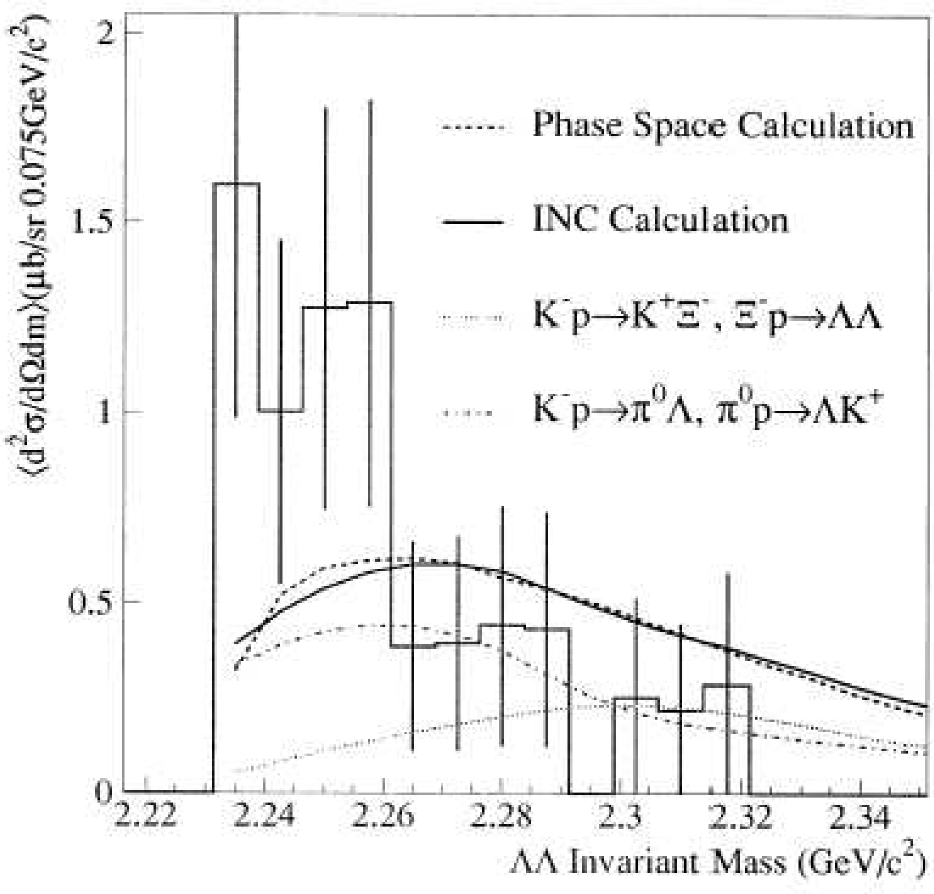
Prel. Results on $\Lambda\Lambda$ Corr.: Ohnishi et al., NPA670('00),297.

From ΛΛ Corr. to ΛΛ Interaction

- ΛΛ Int.: Important but No Scattering Data
  - ⋆ Threshold Channel in SU(3) Singlet BB (BB Int.)
  - ⋆ Related to the Existence of H-particle (QCD)
  - ⋆ Abundant in Neutron Star Core (Mass, Supernova)
- ΛΛ Inv. Mass Spec.

KEK-E224 Exp., Ahn et al.,PLB444('98)267

$K^- + {}^{12}\mathrm{C} \to K^+\Lambda\Lambda \to$ Strong Enh. at Low-E



Why is it Enhanced ? → HBT

What Does Corr. Tell ?

→ Source Size + ΛΛ Int.

- Symm. → Coulomb → Strong Int.

H.-B. & T ··· $\gamma\gamma$ → Star (Symmetry)

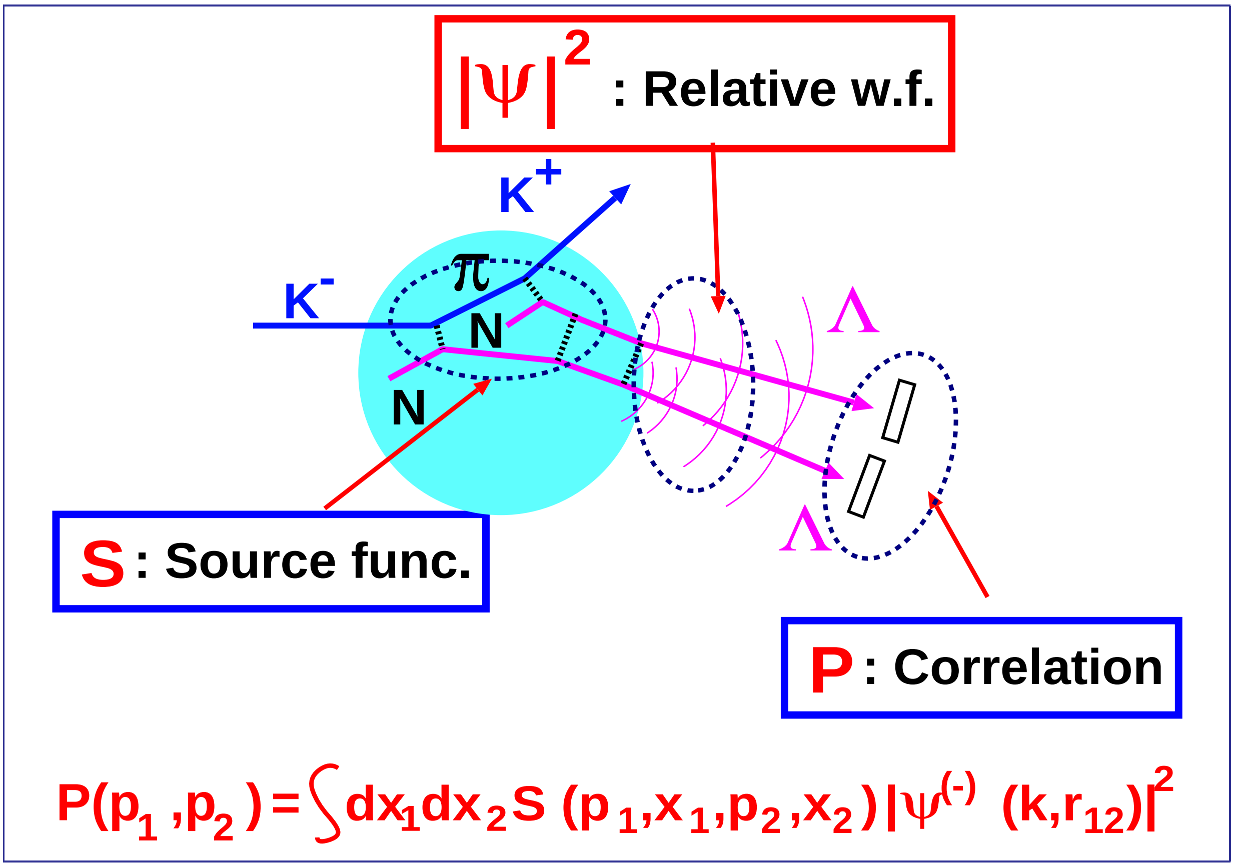
Goldhaber/Shuryak ··· $\pi\pi$ → HIC (+Coulomb)

Pratt/Koonin ··· NN, AA → HIC (+Strong)

Bauer et al. ··· BUU Source → HIC (+Dyn.)

This Work ··· INC & Corr. & Data → ΛΛ Int.

Ohnishi et al., NPA670('99)297; Slaus, Akaishi, Tanaka, Phys.Rep.173(1989)



$|\psi|^2$: Relative w.f.

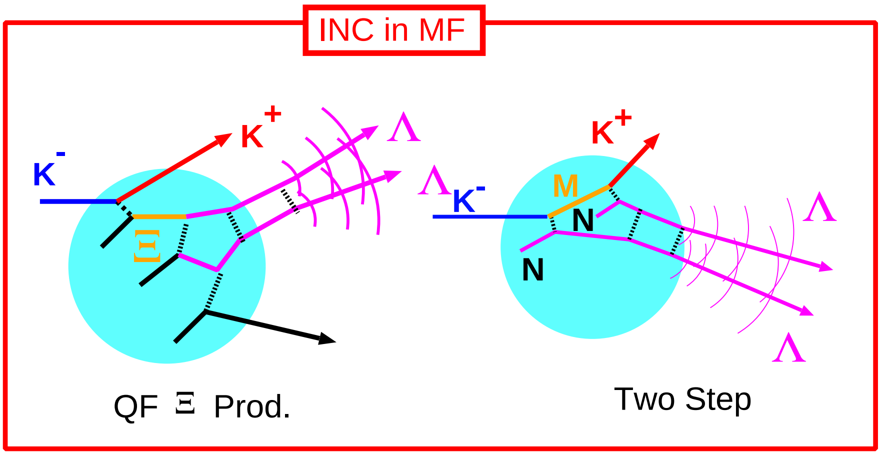
S : Source func.

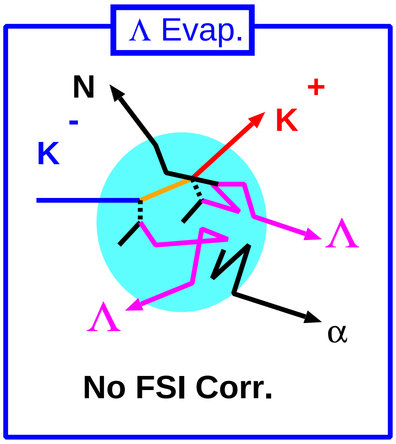
P : Correlation

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

Good Corr. Data + Reliable Source → ΛΛ Int.

Model Source Func.: INC + Λ Evap.





Is the Source Reliable ?

Check List

1. $MB \to M'B'$ Cross Sections $\leftarrow$ K^+ Spectra, HIC Data
   - $\star$ Breit-Wigner (s-channel, Res. Region)
     $+$ Reggeon Exchange (t, u- chan.)
2. $BB \to B'B'$ Cross Sections $\leftarrow$ Y Spectra
   - $\star$ $N, \Delta, N^* ...$ ($S = 0$ Sector): Exclusive Data Fit
   - $\star$ YN ($S = -1$): Nijmegen Model D
   - $\star$ $\Xi N \to \Lambda\Lambda$ ($S = -2$): ND, $R_c = 0.5$ fm (assumed)
3. Mean Field for Baryons $\leftarrow$ K^+ tail, Y Spectra
   - $\star$ $U_N = -40$ MeV, $U_\Lambda = -30$ MeV, $U_\Sigma = -10$ MeV,
   - $\star$ $U_\Xi = -16$ MeV (Twin, KEK-E224, BNL-E885)
4. Evaporation of Λ $\leftarrow$ Λ Spectra
   - $\star$ Statistical Evaporation (assumed)

K^+ Spectrum:

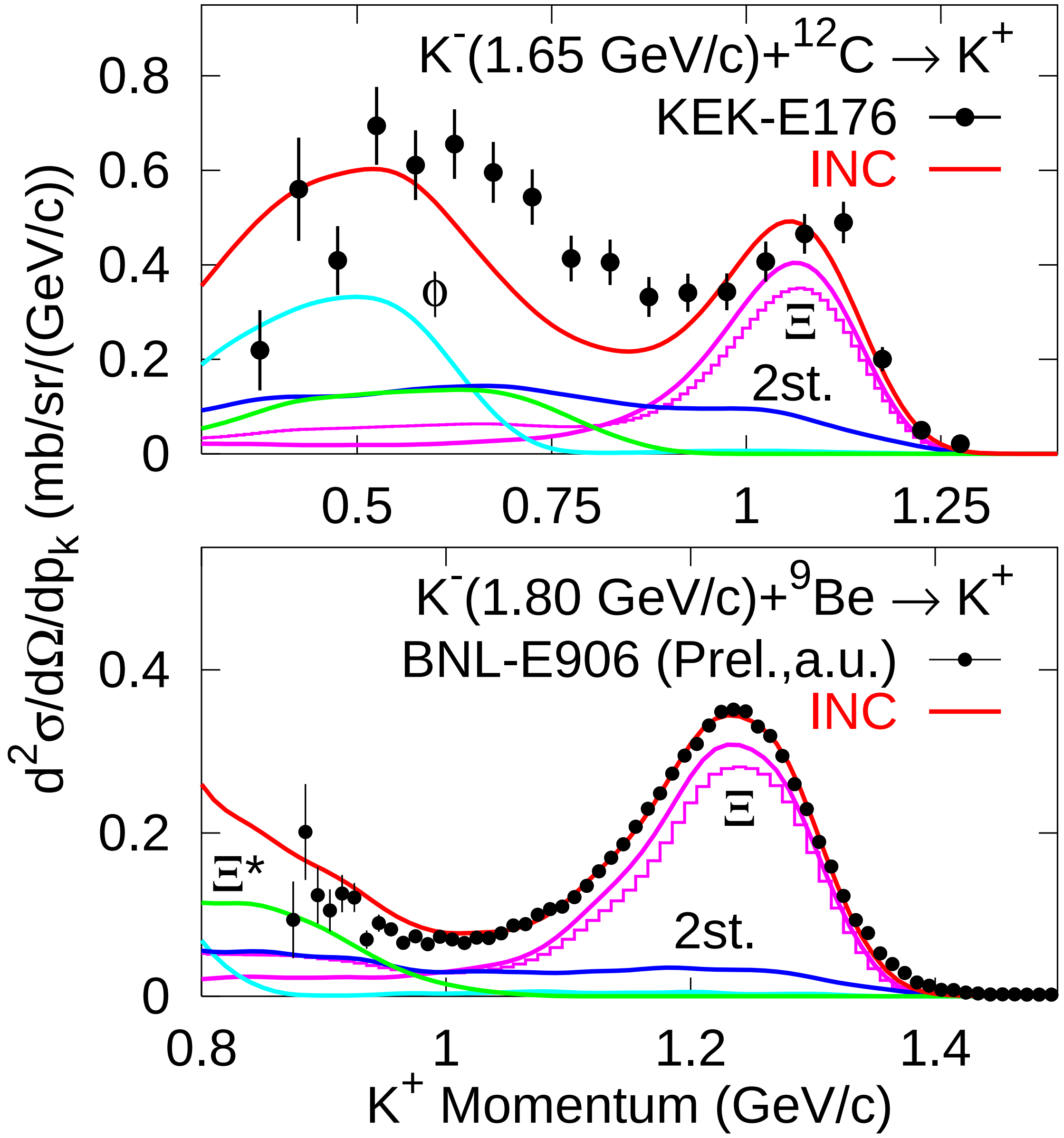
Test of MB Cross Sections and Prod. Mech.

... Breit-Wigner (s-channel, Res. Region)

$+$ Reggeon Exchange (t, u- chan.)

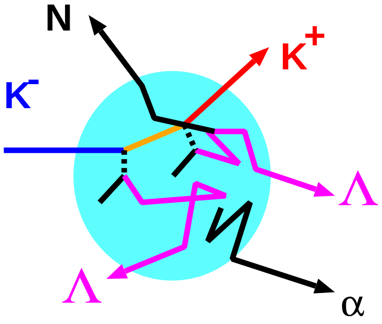
- KEK-E176 (Iijima et al.) / BNL-E906 (Tamagawa et al.)

KEK-E176:Iijima et al., NPA546('92),588; BNL-E906: Tamagawa's Talk



Good at P(K^+) > 0.95 GeV !

Stat. Decay of Hyperon Compound Nucleus

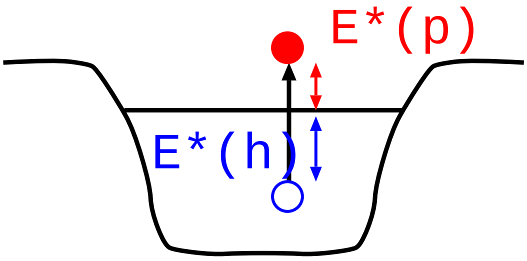


⋆ Idea: Yamazaki (NC103A('89),78)

⋆ Stopped $K^- \to {}^4_\Lambda$H
Tamura, Wakai, Yamamoto et al.
(PRC40('89)R483)
Nara et al. (AMD + Stat. Dec.)
(PLB346('95)217; HYP94)

⋆ Stopped $\Xi^- \to$ Single, Double, Twin Hyp.
Hirata et al. (AMD-QL + Stat. Dec.)
(PTP102('99)89; HYP97)

- Theoretical Inputs of Statistical Decay



⋆ Compound Nuclei: $A, Z, S \ldots$ INC results
⋆ Excitation Energy:
Exciton Model Estimate
⋯ Hole Energy
+ Trapped Particle Energy

⋆ Level Density Parameter: $a = A/8$ (assumed)
$\cdots E^* = aT^2 \;\leftrightarrow\; S = 2\sqrt{aE^*} \;\leftrightarrow\; \rho \propto \exp(2\sqrt{aE^*})$

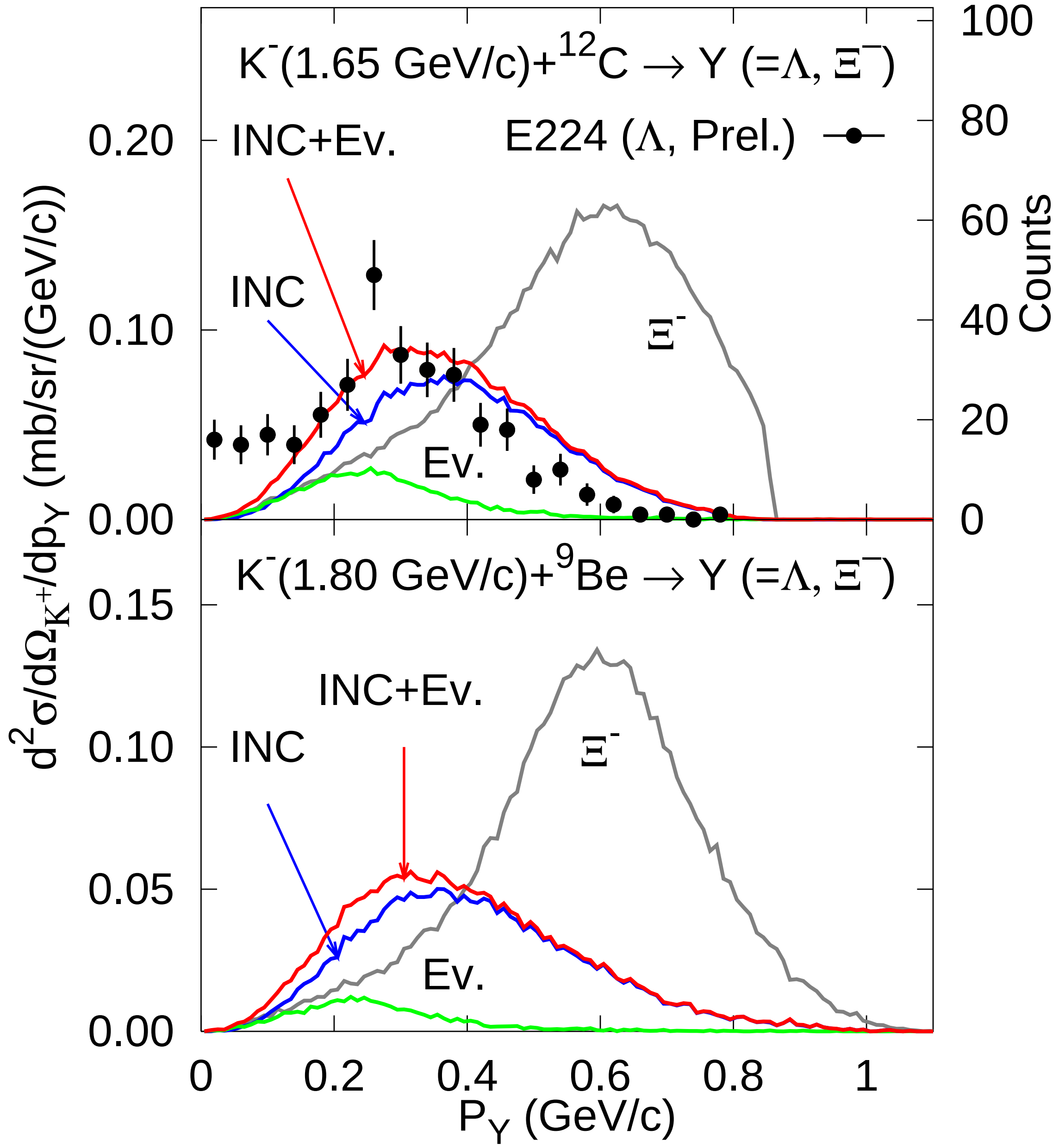
- Statistical Decay Model

⋆ Simplified Multistep Evaporation model (Weiskopf)
⋯ Successive Evaporation of p, n, Λ, α
↔ Simultaneous Multifragmentation Model
(Berlin, NBI, Yamamoto-Wakai-Sano)

Hyperon Spectrum:

Test of $\sigma(YN)$, Mean Fields, and Reac. Mech.

- KEK-E224 (SCIFI) / BNL-E906 (CDS)



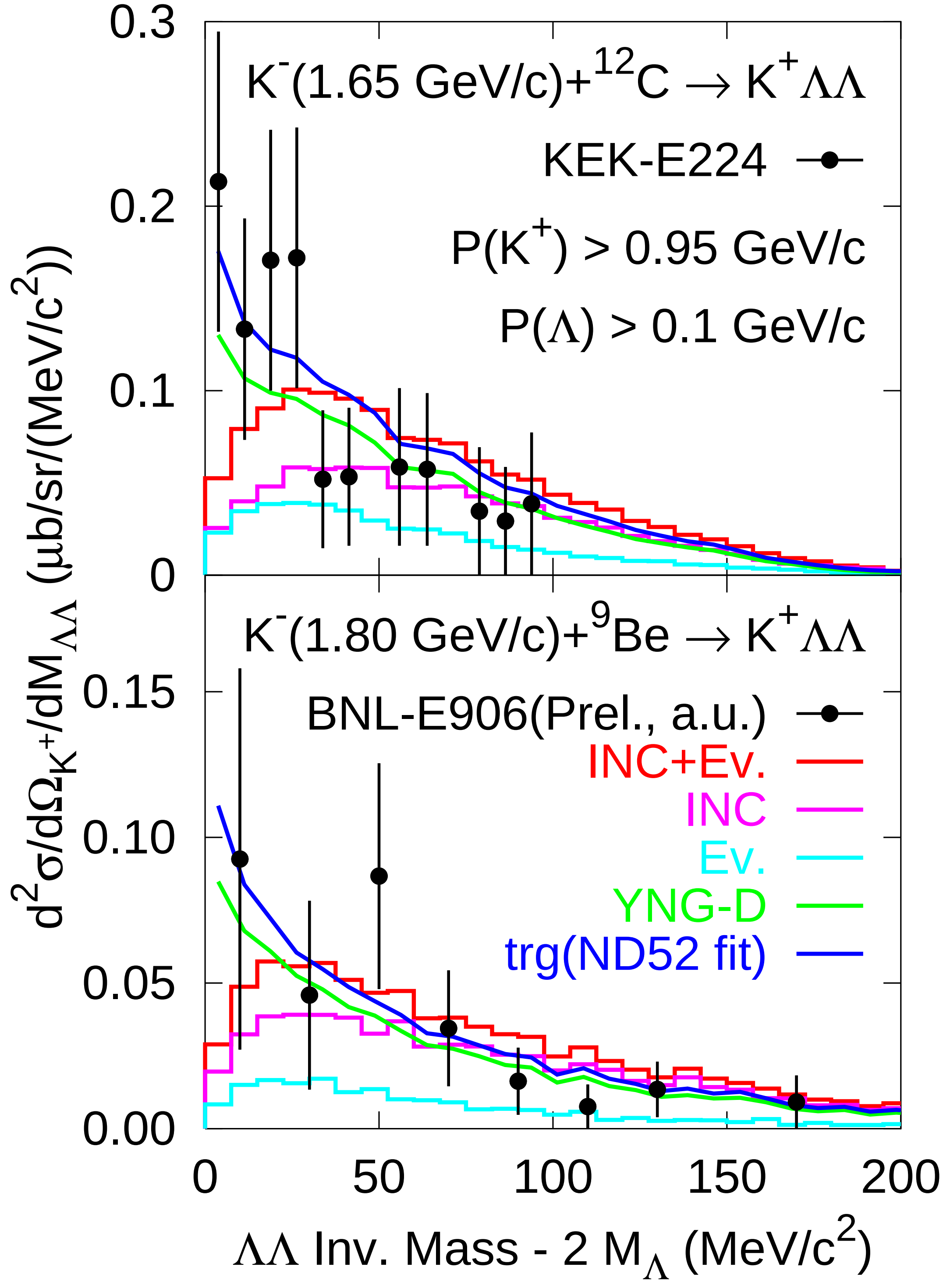
Λ Mom. Spec.: J.K.Ahn, private Comm.

☞ Λ Evap. Enhance Low Mom. Spec.

Λ-Λ Inv. Mass Spectrum: Test of ΛΛ Interaction

- KEK-E224 (SCIFI) / BNL-E906 (CDS)

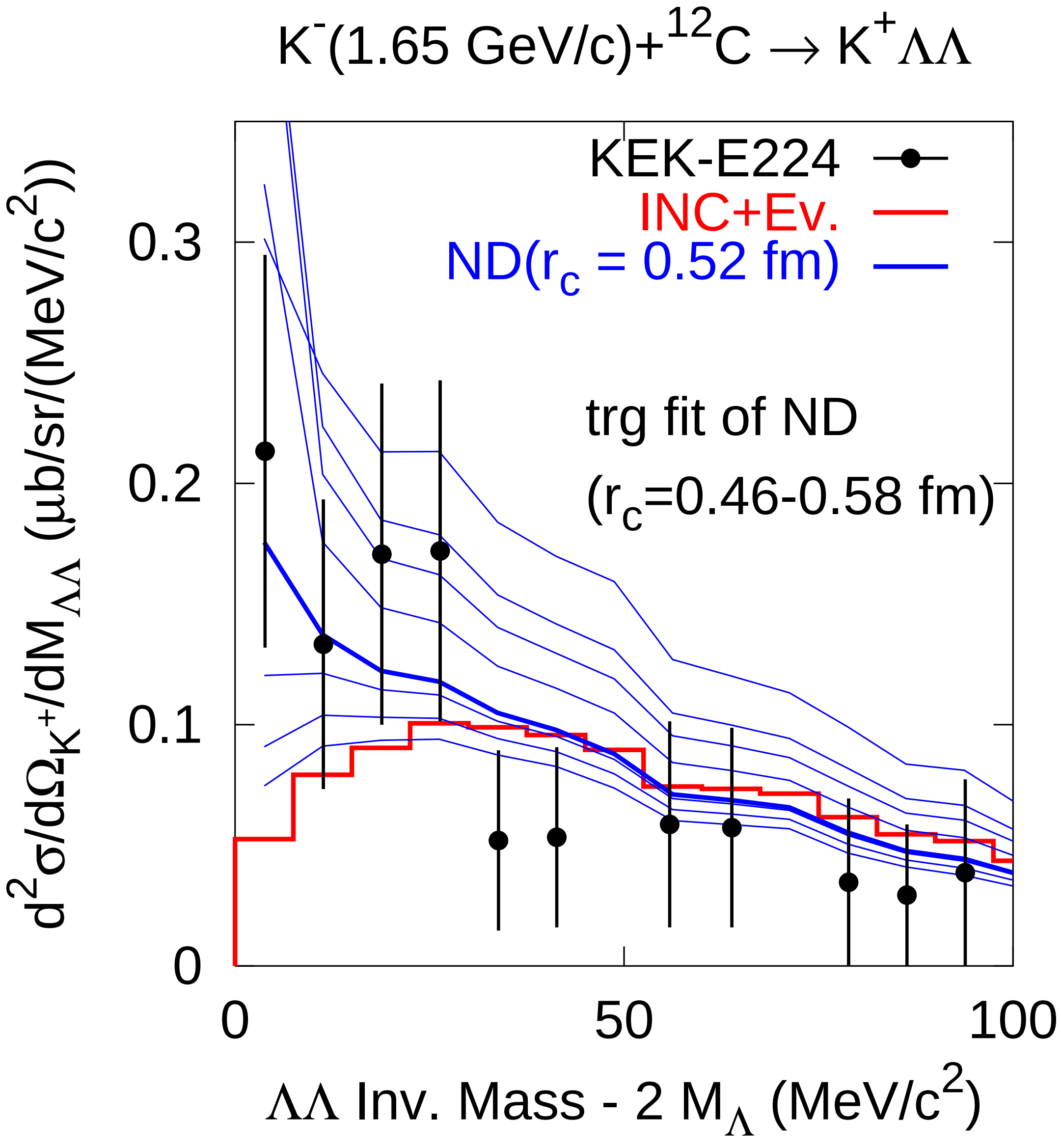
E224: Ahn et al., PLB444('98)267; E906: Tamagawa, priv. comm.



☞ Low-E. Enh. is well reproduced with Reasonable Int.

Is the Corr. Sensitive to ΛΛ Int. ?

☞ Yes, IT IS !



ND simulating TRG: $(\mu_l, \mu_s) = (1.0, 0.45)$ fm, a, r_{eff} fit.

- Favorable ΛΛ Int.
  - ⋆ Strong Enh. of $|\psi(r)|^2 (r < 1.5$ fm) at Low E.
    $\cdots$ large $|a|$
  - ⋆ Small Effective Range $(1.5 < r_{eff} < 3.5$ fm)

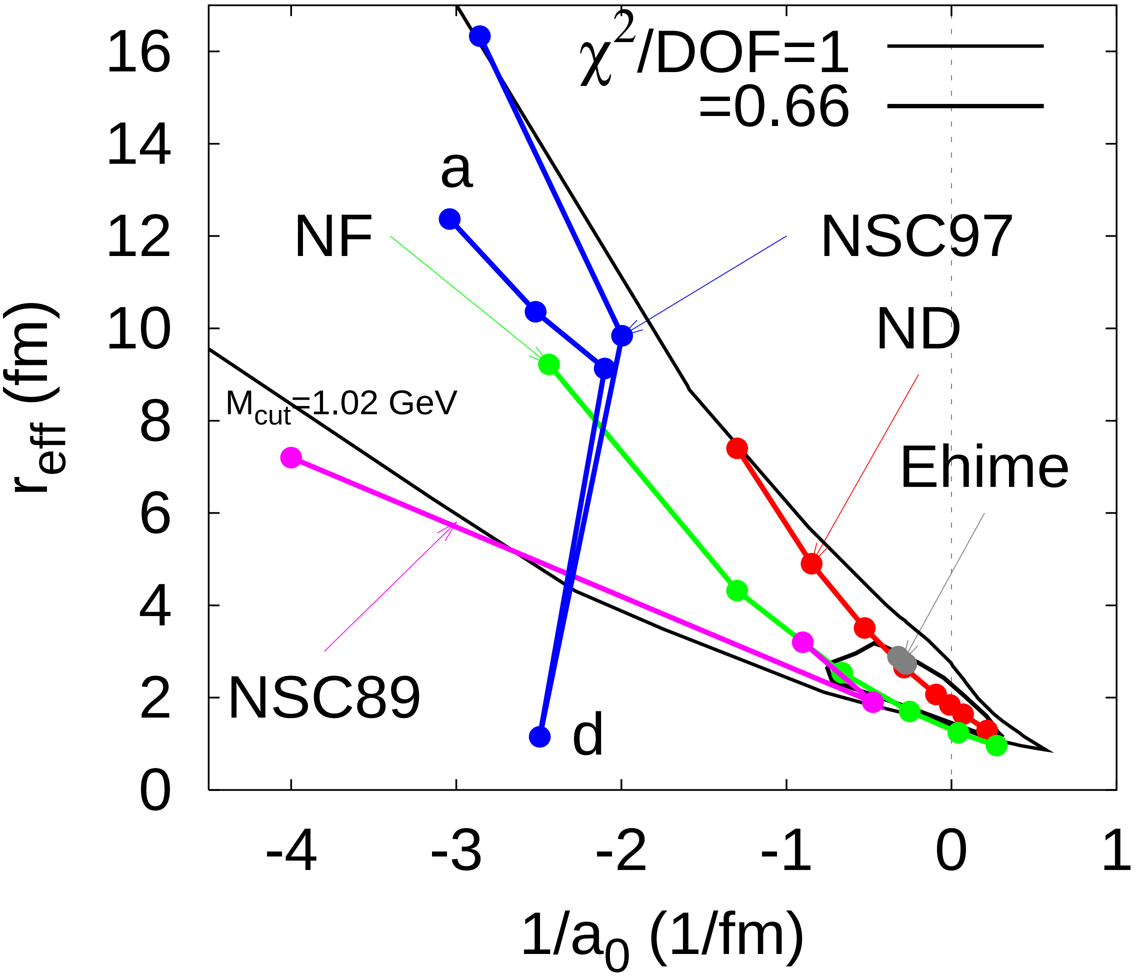
χ^2 Contour in Two Range Gaussian Int.

Scattering Length a and Effective Range r_{eff}

$\cdots \quad k\cot\delta = -1/a + r_{eff}k^2/2$

- ⋆ trg: (μ_l, μ_s) = (1.0-0.6, 0.45) fm
- ⋆ Nijmegen Models:
  ND ($r_c = 0.46 - 0.58$ fm), NF ($r_c = 0.42 - 0.52$ fm),
  NSC89 ($M_{cut} = 0.82 - 1.02$ GeV), NSC97 (a-f),
- ⋆ Ehime Potential (Set 2,A,B)

  (Tominaga et al.,NPA642('98)483)

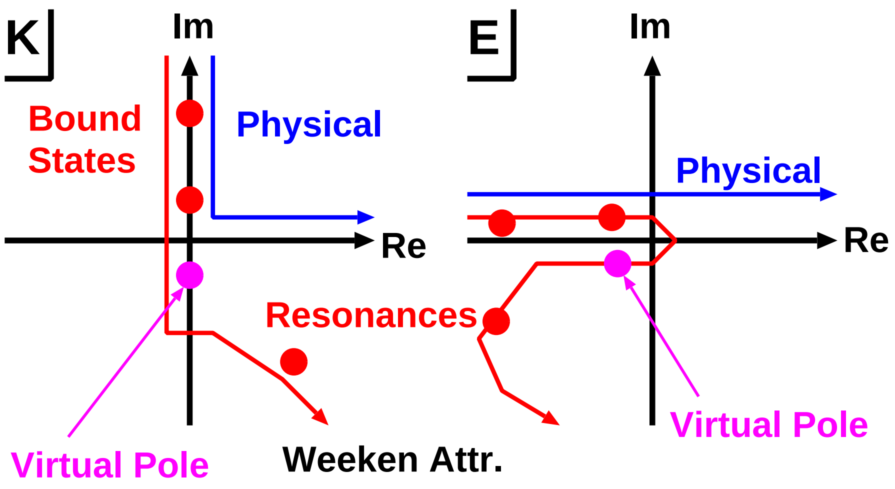


Is there any Pole ?

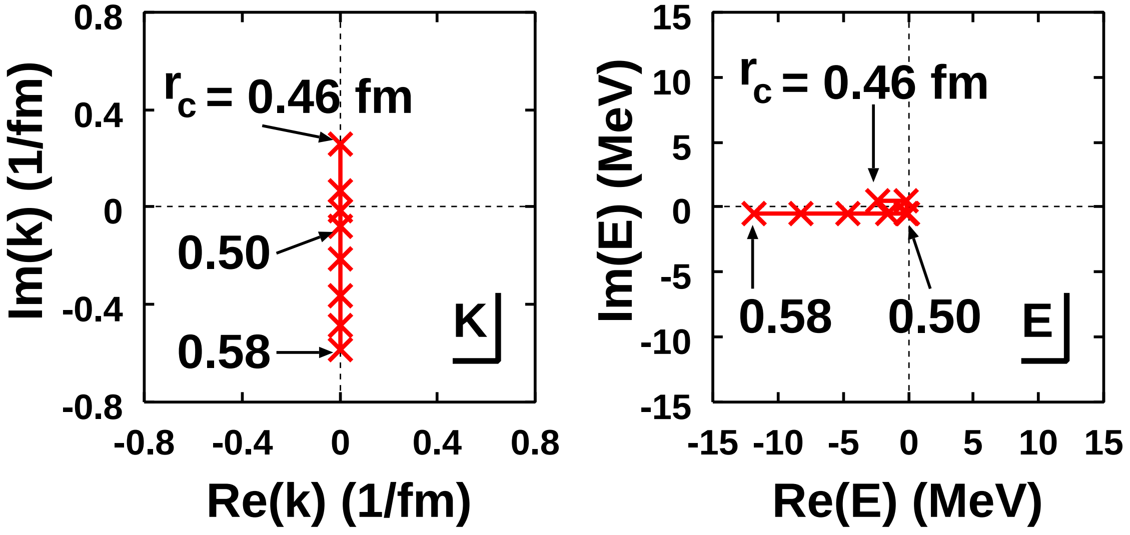
$\Lambda\Lambda$ Inv. Mass Spec. $\sim$ ^{9}Li-n IMS in ^{11}Li Breakup
$\sim$ nn IMS in HIC

Virtual Pole Effect ?

Behavior of s-wave Pole



ND simulating TRG

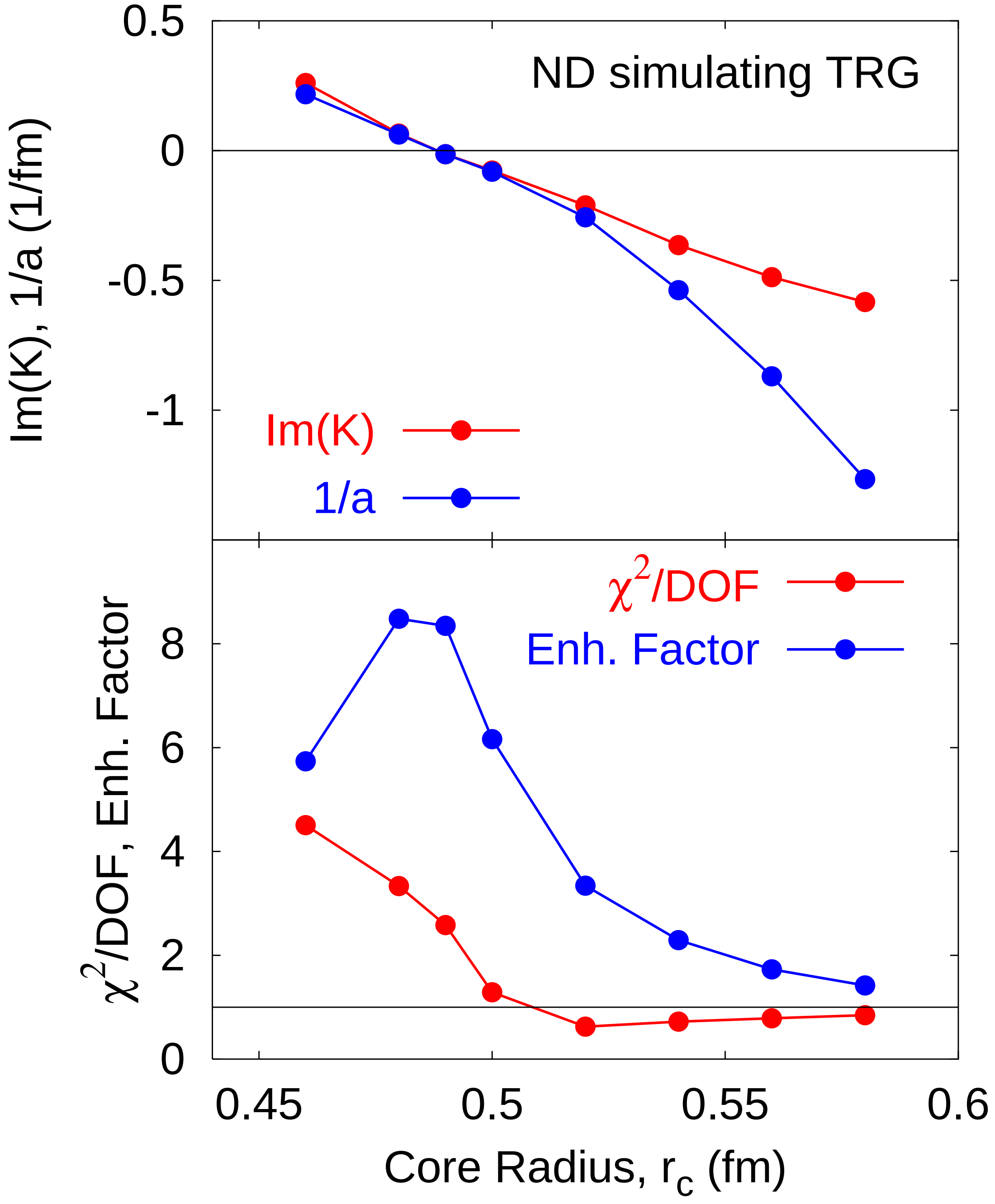


Solved by using Jost Function Method:

Rakityansky and Sofianos, J.Phys.A31('98),5149.

Masui,Aoyama,Myo,Kato,Ikeda, NPA673('00),207.

Effects of Virtual Pole



☞ Virtual Pole near threshold
Enhances Strength at Low E.

Summary

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

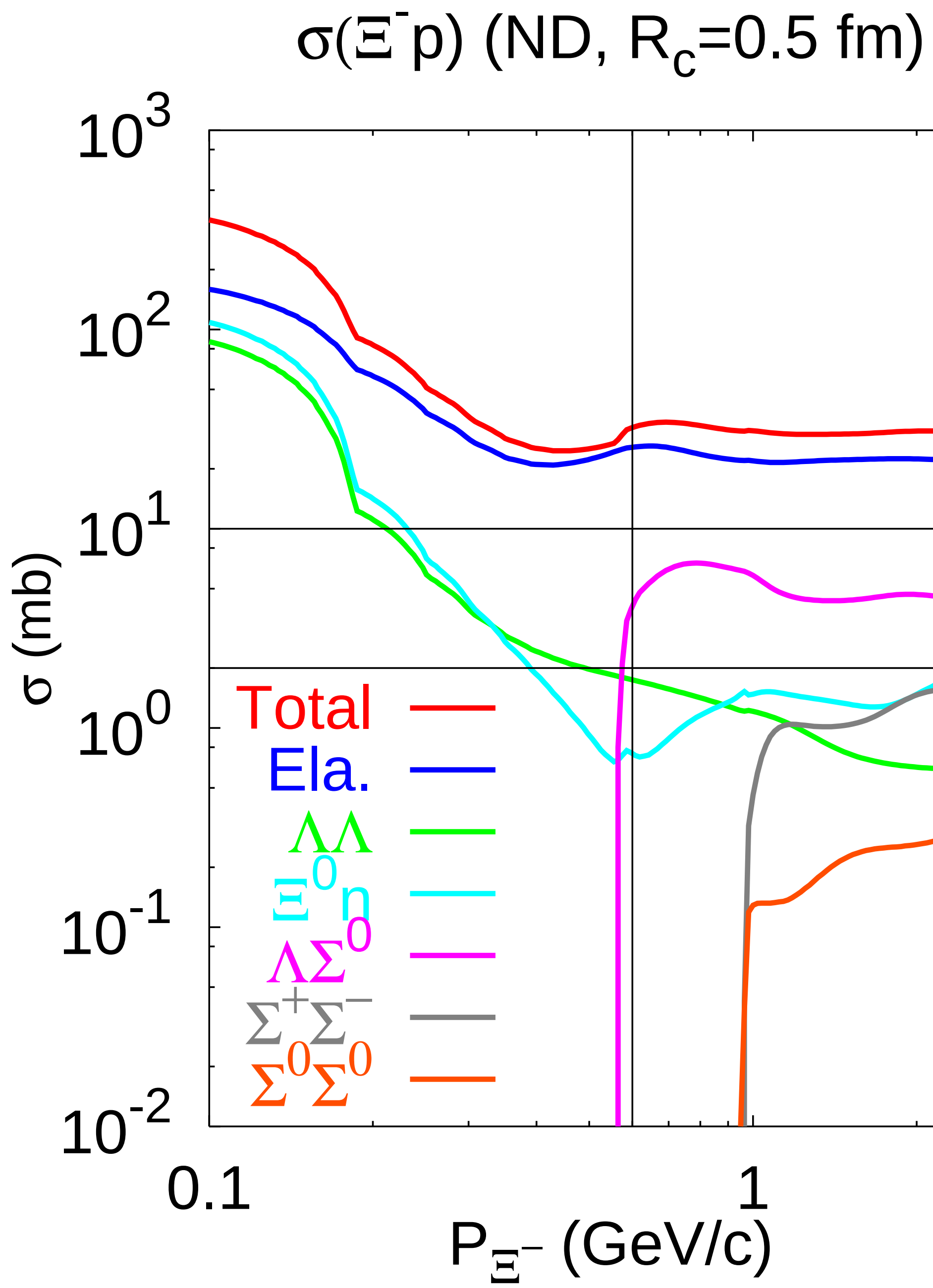
2. INC + Ev. Source Function is verified through
   - ⋆ K^+ Spectrum (MB, BB Cross Sections)
   - ⋆ Λ Momentum Spectrum
   - ⋆ $(K^-, K^+\Lambda\Lambda)$ Coinc. Spec.

3. $\Lambda\Lambda$ Inv. Mass Spectrum is well Reproduced
   with Reasonably Attractive $\Lambda\Lambda$ Int.
   $\cdots$ ND ($r_c = 0.50 - 0.52$ fm), Ehime

4. Low-E. Enh. of Inv. Mass Spectrum
   might come from Virtual Pole near threshold

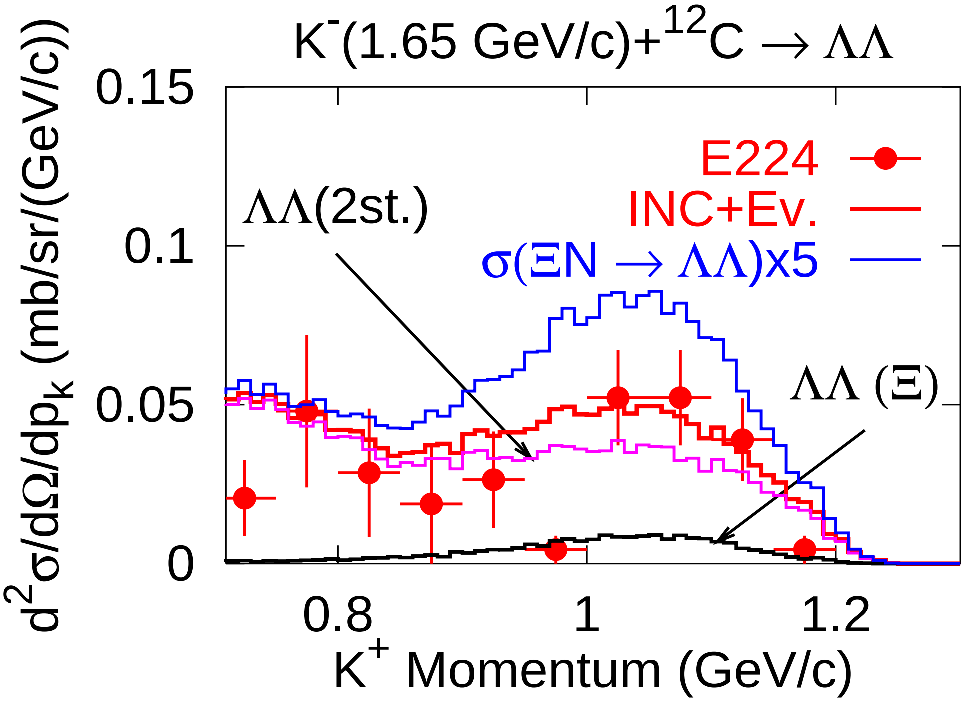
5. Todo
   - ⋆ YN Cross Section,
     Especially $\Xi N \to \Lambda\Lambda$ (Tamagawa's Talk)
   - ⋆ Fully Quantum Mechanical Two-Step calculation
   - ⋆ Getting Precise Data with High Statistics → JHF

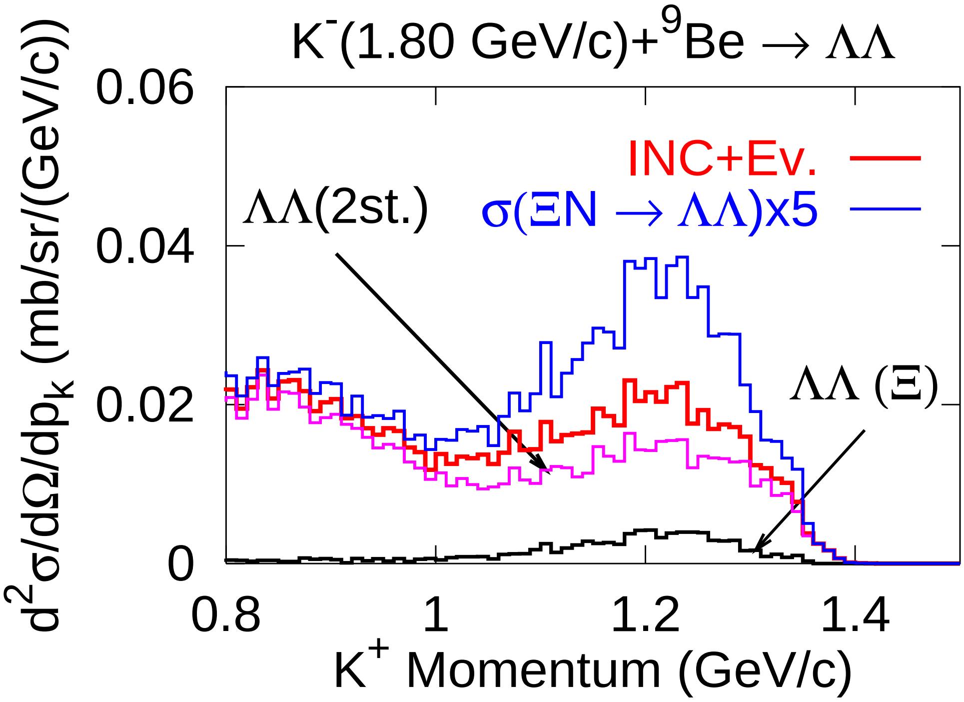
$\Xi^- p \rightarrow \Lambda\Lambda$: Cross Sections



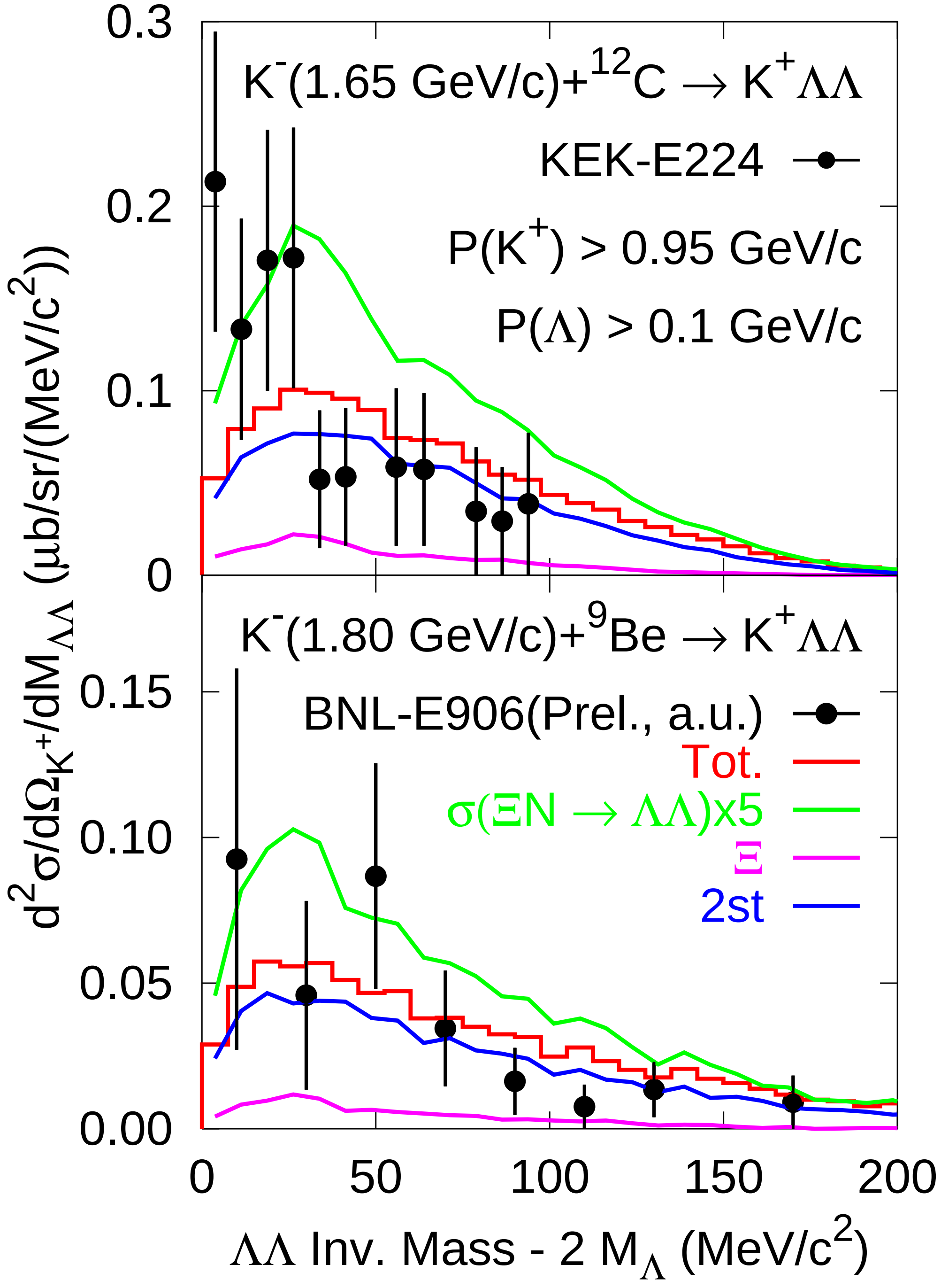
Ξ or Two-Step ?

- $\Lambda\Lambda$ Emission Prob.

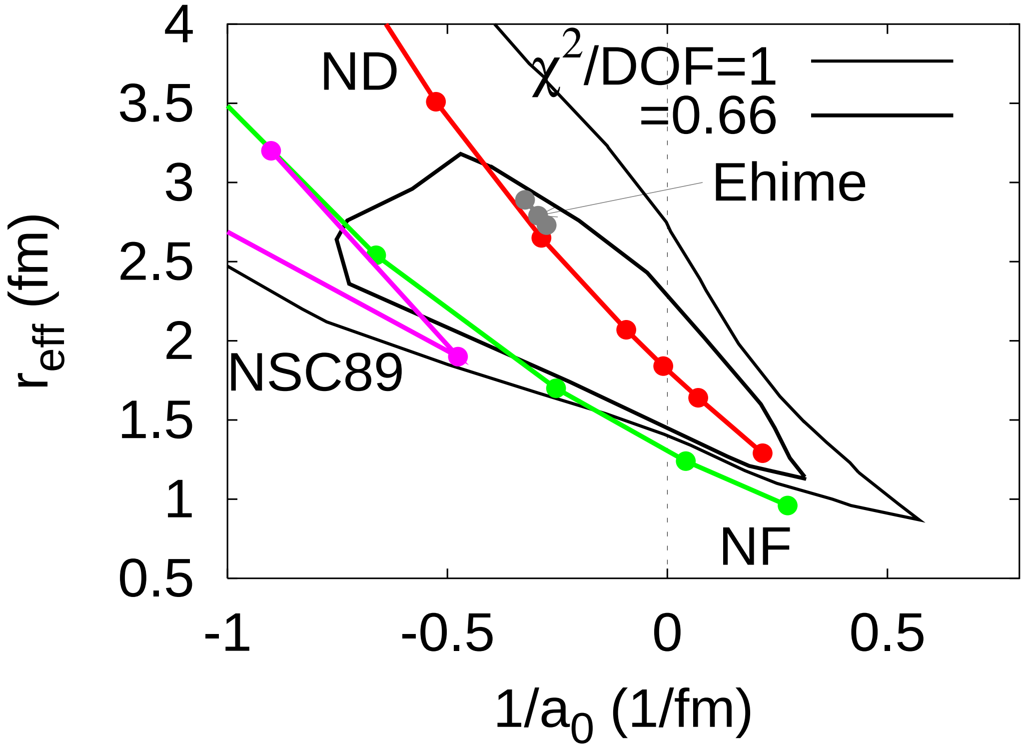




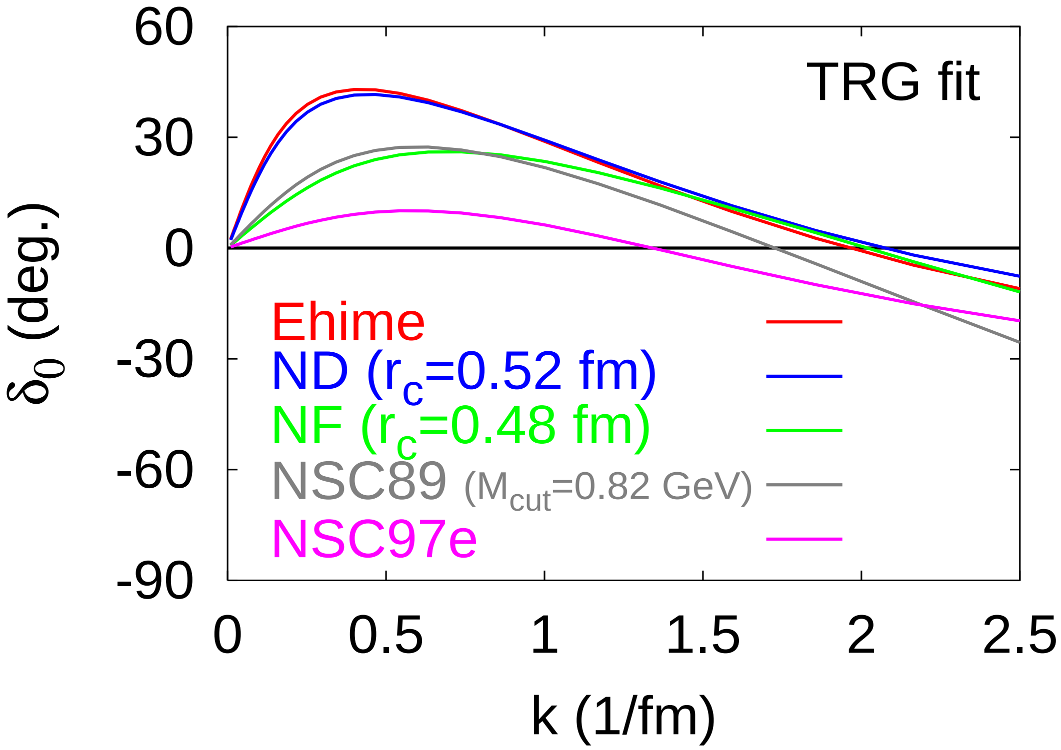
- Invariant Mass Spec.



- χ^2 Surface (Enlarged)



- Phase Shifts



Relation of a and r$_{eff}$ to Enh. Factor

Corr. Formula + Long Wave Approx.

→ Enhancement Factor

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

Wave Function

$$\begin{aligned} \psi^{(-)}(\vec{k},\vec{r}) &\simeq \sqrt{2}\left[\cos(kr\cos\theta) - j_0(kr) + e^{-i\delta_0}u_0(r)\right] \\ &\to \sqrt{2}e^{-i\delta_0}\sin(kr+\delta_0)/kr \end{aligned}$$

Phase Shift

$$\frac{k}{\tan\delta_0(k)} = -\frac{1}{a} + \frac{1}{2}\,\mathrm{r}_{eff}\ k^2 \cdots \delta_0 \simeq -ak + \mathcal{O}(k^3)$$

Enh. Factor

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

a: scattering length, b: intrinsic range

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