Study of ΛΛ correlations and search for the H^0-dibaryon with the STAR detector at RHIC

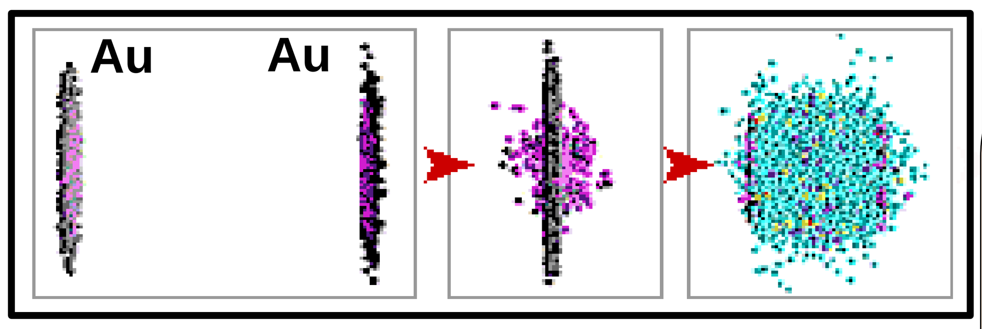
Neha Shah* *for the STAR Collaboration*

Department of Physics and Astronomy, UCLA

Abstract

The production of large number of multi-strange hyperons per central nucleus-nucleus collision at RHIC allows us to study hyperon-hyperon interactions through measurement of particle correlations and search for exotic particles like dihyperons. In 1977 Jaffe [1] predicted a six quark state, H^0-dibaryon, with hypercharge (Y) = 0 and Strangeness (S) = -2 to be stable against strong decay, but not to weak decay. It has been proposed that the H^0 would appear as a bump in the ΛΛ invariant mass spectra if the H^0 is a resonance state, or it would lead to a depletion of the ΛΛ correlation near the threshold if the H^0 is weakly bound, which can be used to probe whether there is a stable H^0 or resonance. Considerable experimental efforts have been devoted to search for H^0. However there is no conclusive experimental evidence for a bound H^0. In addition to H^0, many other dihyperon states have been predicted theoretically. However, very few measurements are available due to low multiplicity of hyperon production in early nuclear collisions. Recently STAR has collected unprecedented high statistics data for Au+Au collision at RHIC, which provides a unique opportunity to look for the exotic particles and hyperon-hyperon correlations. Here we present the measurement of ΛΛ correlations for $\sqrt{s_{NN}}$ = 39-200 GeV in Au+Au collisions using the STAR experiment at RHIC.

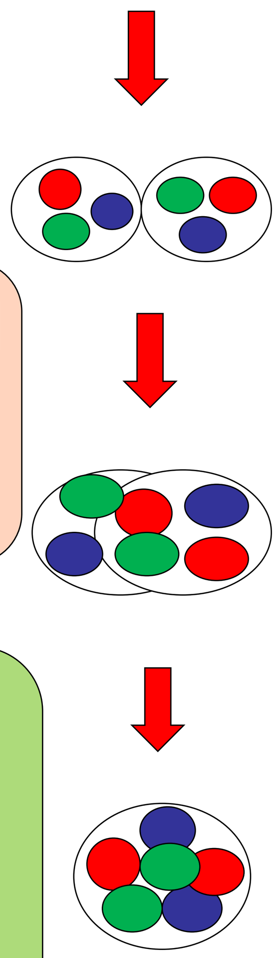
Motivation



Two co-moving hyperons/ nonstrange baryons

Production of H^0 dibaryon [1] (6 quark state) through coalescence or scattering through resonance

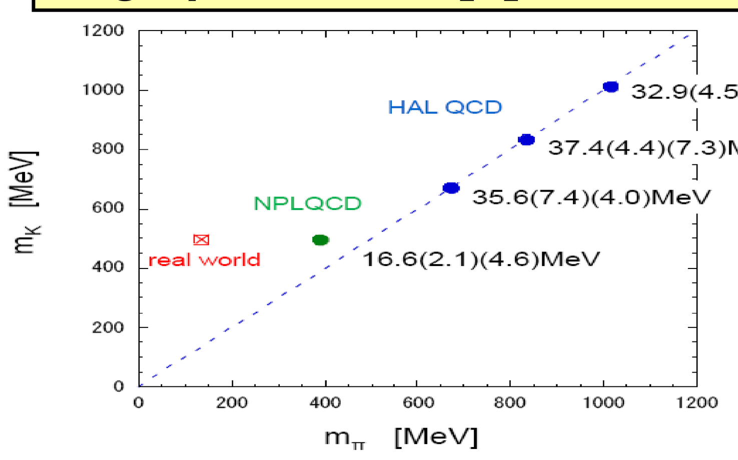
Properties of H^0 ($J^\pi=0^+$):
Mass – (1.9 – 2.8) GeV/c^2
$H^0 \to \Lambda\Lambda$, $\Lambda N\pi$, $NN\pi\pi$
Rates: 10^{-3}–10^{-5} per central Au+Au collisions



❖ Two particle correlation measurement with Λ, which are also sensitive to size of emitting region
❖ Advantages :
- no Coulomb interactions
- sensitive to hyperon-hyperon interactions

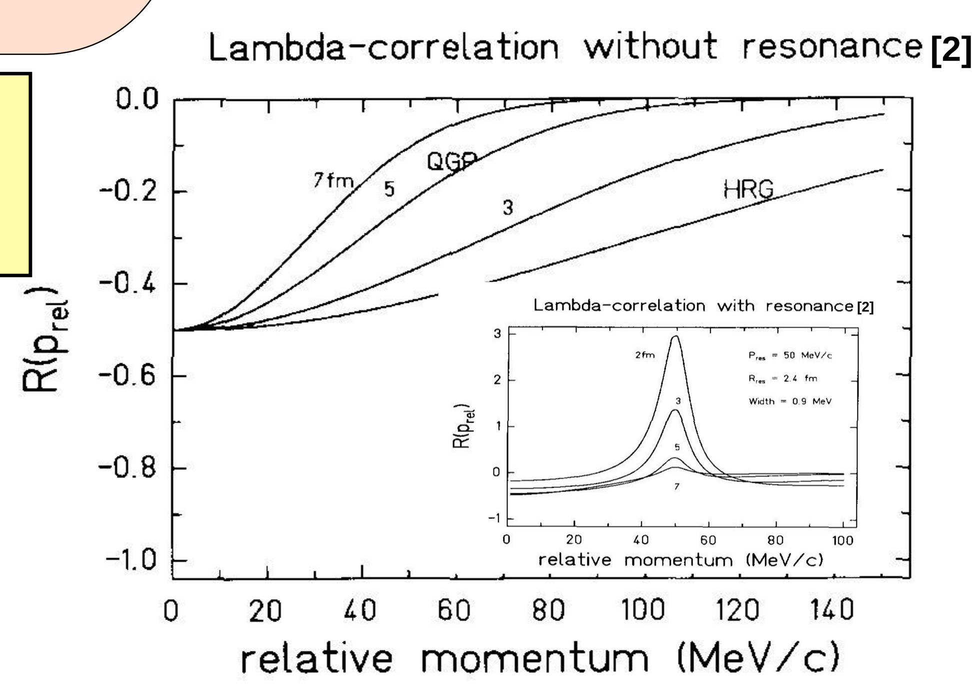
❖ Depletion of phase space due to bound state formation of H^0 ⇒ inclusive measurement, sensitive to total yield

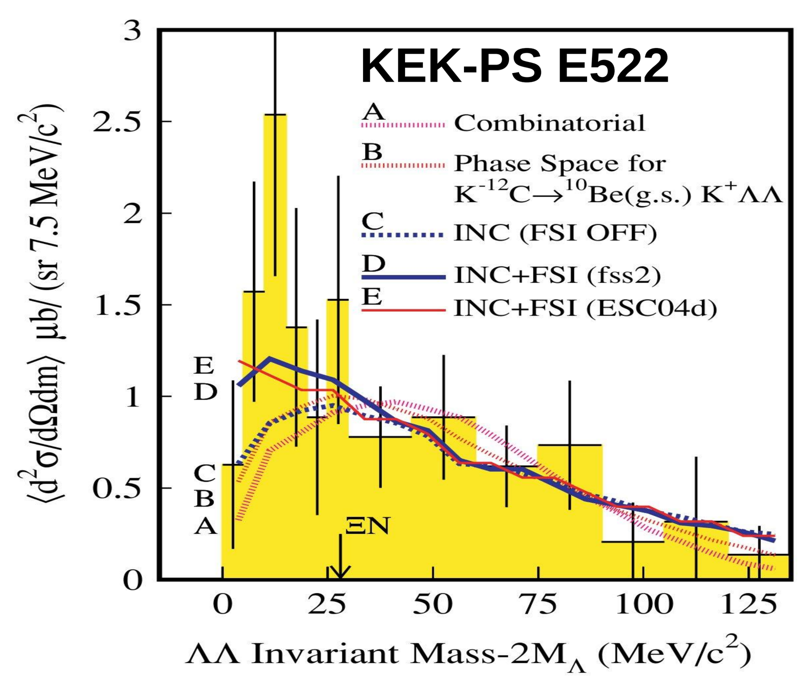
Lattice QCD predicts bound H^0 with binding energy B ≥ 16 MeV at large pion mass [3]



Experimental searches for stable H^0:
- Double strangeness exchange reactions (e.g. A(K^-,K^0)X)
- Ξ^-A capture on nuclear targets with A ≥ 2
- p-N and NN collisions

What have we learned so far?
- Nagara event ⇒ no deeply bound H^0
- ΛΛ invariant mass analysis :
  scattering length (f_0) = $-0.10^{+0.45}_{-2.37} \pm 0.04$ fm [4]
  ⮑ No/ weakly bound state [4,5]





Analysis

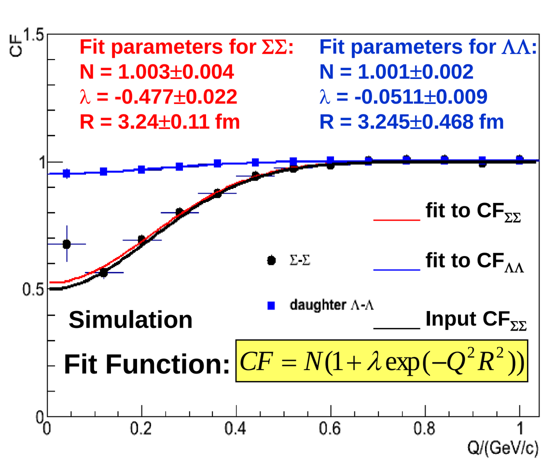
- Correlation function : $CF(Q) = \frac{A(Q)}{B(Q)}$

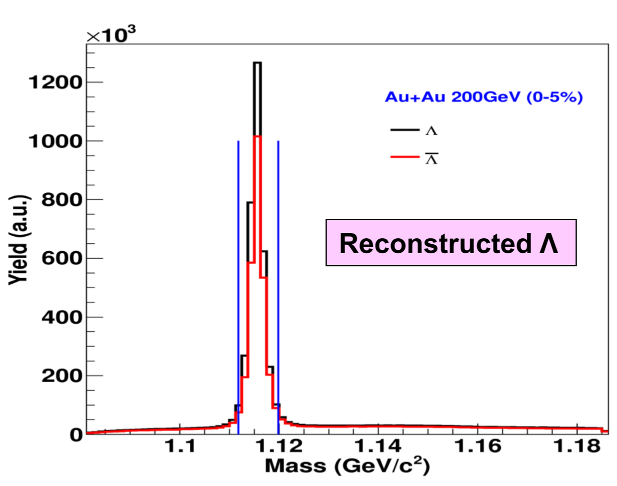
where Q relative momentum between 2Λ, A(Q) is relative momentum from same event and B(Q) is reference distribution from mixed event

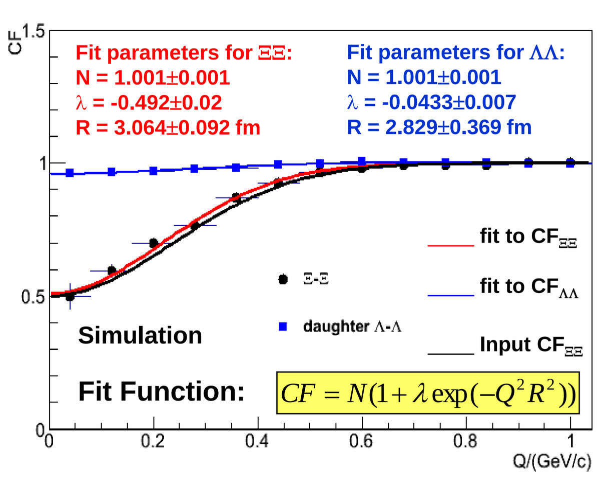
$$CF_{corrected}(Q) = \frac{CF_{measured}(Q)-1}{PP(Q)} + 1 \qquad PP(Q) = \frac{S}{S+B}(P_{t_i}) \times \frac{S}{S+B}(P_{t_j})$$

where PP(Q) is pair purity, S is signal, B is background and P_t is transverse momentum for Λ_i and Λ_j

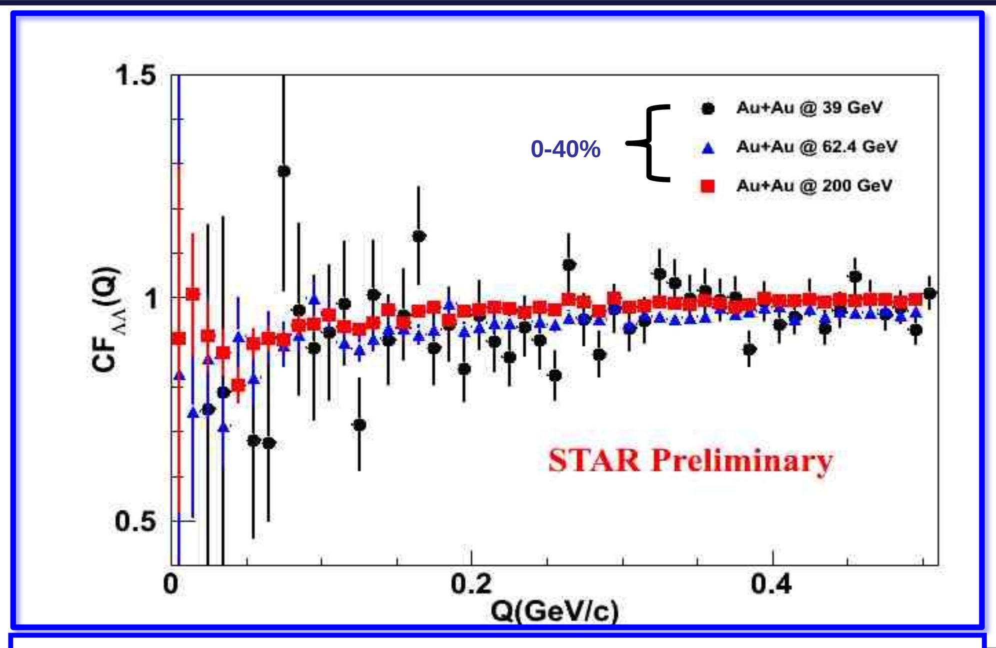
- Pair purity : 90-95%
- Toy model simulation for ΣΣ and ΞΞ feed-down contribution:
• Generate spectra : Boltzmann fit (T=335 MeV)
• Assign weight to each pair using HBT correlation: (1-0.5*exp($-Q^2R^2$)), R = 3.83/$\sqrt{m_t}$

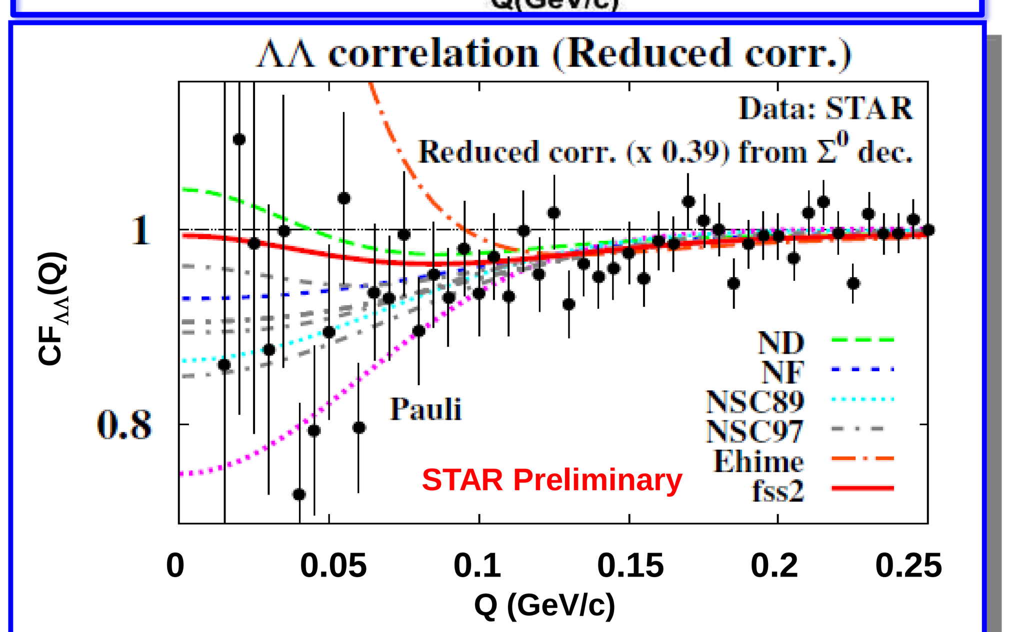


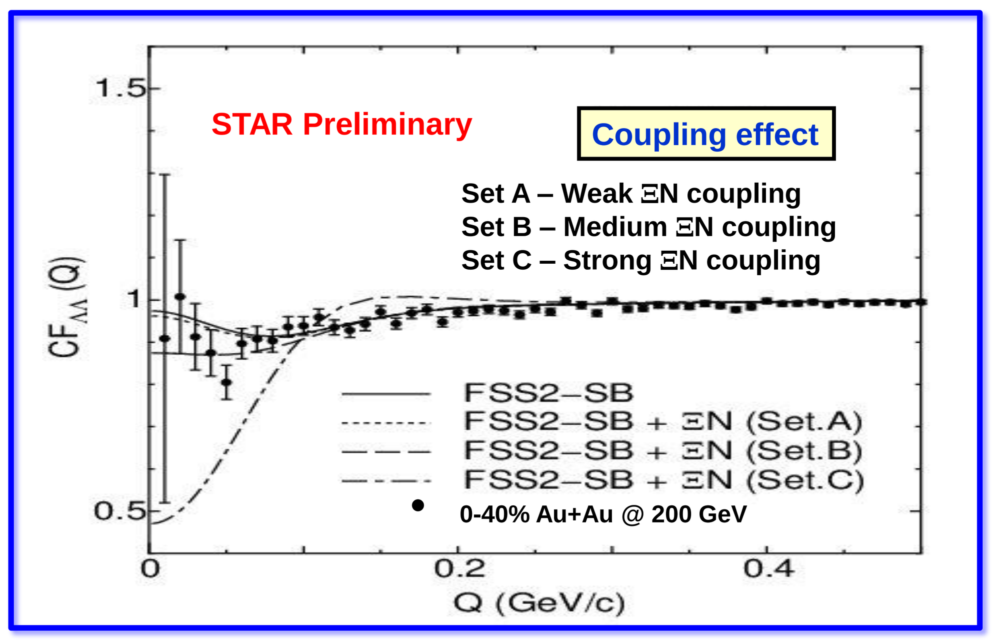




Results







- Type of ΛΛ interaction:

❖ Meson exchange models: Nijmegen model D, F, Soft Core (89, 97) [6]
❖ Quark cluster model interaction: fss2 [6]
❖ Phenomenological model: Ehime [6]

- Inclusive ΛΛ correlations: Feed down contributions included in theoretical models.
- Statistical errors only

Summary

- The Λ-Λ interaction is attractive
- Quark model interaction (FSS2) [6] describes the data fairly well for small ΞN coupling as well as without ΞN coupling ⇒ consistent with Nagara event [8].
- Current fit to the data for scattering length (f_0) and effective range (d_0) gives indication towards non-existence of strong bound state of ΛΛ.

References:
[1] Jaffe, Phys. Rev. Lett. 38 (1977) 195
[2] Greiner and Mueller, Phys. Lett. B 219 (1989) 199
[3] HAL QCD Collab., Phys. Rev. Lett. 106 (2011) 162002 , NPLQCD Collab., Phys. Rev. Lett. 106 (2011) 162001
[4] Yoon et al, Phys. Rev. C 75 (2007) 022201
[5] Yoon et al, Int. J. Mod. Phys. E 19 (2010) 2448
[6] Phys. Rev. C64 (2001) 054001, Phys. Rev. C 40 (1989) 2226, Phys. Rev. C 59 (1999) 21
[7] Lednicky and Lyuboshitz, Sov. J. Nucl. Phys. 35 (1982) 770
[8] Takahashi et.al., Phys. Rev. Lett. 87 (2001) 212502

*e-mail: neha@physics.ucla.edu