Detecting Doubly Strange Dibaryon Resonances with the STAR Detector

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Introduction and Motivation:

- QCD based models predict 6-quark doubly strange (Y=0) dibaryons (udsuds) – Jaffe, MIT Bag Model, 1977.

- Searches have been done for "stable" Y=0 SU(3)-flavor singlet H_0 via weak decay modes – none observed so far.

- If H_0 mass $\gtrsim M_{\Lambda\Lambda}$, it could appear as narrow resonance:
– P-matrix model, Bashinsky and Jaffe, NP A**625**, 167 (1997).
– ϕ, D^* and D_{S1} mesons

- Dibaryon production in A+A collisions could occur thru:
– Copious strange baryon production
– Coalescence of co-moving baryons

- Dibaryon production might be increased in RHIC collisions as a result of:
  - Further increased strange particle production
  - QGP formation and population via color octet components

$$|\mathrm{H}\rangle \;=\; \sqrt{\frac{1}{5}}\,|\,\mathbf{1}_c \otimes \mathbf{1}_c\rangle + \sqrt{\frac{4}{5}}\,|\,\mathbf{8}_c \otimes \mathbf{8}_c\rangle \quad \text{(Dover)}$$

- If dibaryons are observed at RHIC, they could provide an independent QGP signal.

- If any of these are resonant, they could decay to $\Lambda\Lambda$, $N\Xi$ or other higher mass final states.

- We initially study the detection sensitivity of STAR for a hypothetical Dibaryon $\rightarrow p\Xi^-$ resonance decay; we expect the $p\Xi^-$ combinatoric background to be less than that for $\Lambda\Lambda$.

- STAR is well suited for this exploratory program because of its:
  - Large acceptance
  - Precision vertex tracking with the Silicon Vertex Tracker (SVT) and Silicon Strip Detector (SSD).
  - Large data handling capacity

Possible Dibaryons and Decay Modes:

- SU(3)-flavor representation of baryon octet $\otimes$ baryon octet:

$$\mathbf{8} \otimes \mathbf{8} \quad = \quad \mathbf{1} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{10} \oplus \bar{\mathbf{10}} \oplus \mathbf{27}$$

- Y ranges from +2 (NN) to −2 ($\Xi\Xi$)

- Many possible Y=0 dibaryons with components $\Lambda\Lambda$, NΞ, $\Lambda\Sigma$, $\Sigma\Sigma$; Dibaryon searches in A+A are best suited to the Y=0 states.

- First, we examine all of the Y=0, $J^{\pi} = 0^{+}$,1^{+} dibaryons and their possible decay modes for a wide range of masses.

- Then, because STAR can only reconstruct p, Λ and Ξ^{-} among the possible decay products, we will focus on just the I_3=0 states.

- And in particular we explore STAR's detection sensitivity to one specific dibaryon, the $H^{27}(0^{+},1,0)$:
  - Member of 27-flavor multiplet, $J^{\pi} = 0^{+}$, I=1, I_3=0
  - It is the lowest angular momentum state that cannot strong decay to $\Lambda\Lambda$ but which can decay to a detectable final state, $p\Xi^{-}$.

- The Y=0 dibaryons, their possible decay modes, and the states and mass ranges relevant for STAR are summarized on the following chart.

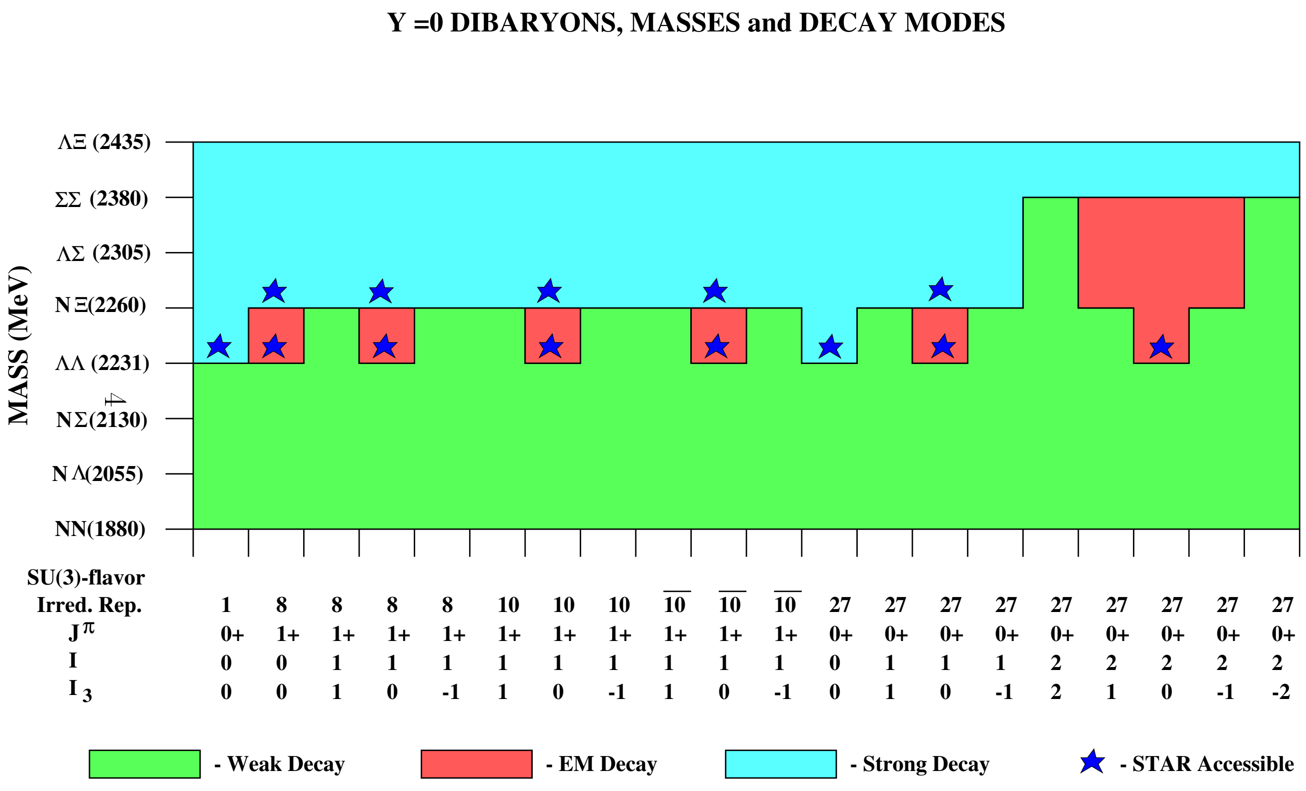

Figure 1: Y=0 dibaryons and decay modes

Simulation Results:

- Determine STAR detection sensitivity with respect to the assumed number of H^{27} decays per event and the assumed resonance width.

- Embed $H^{27} \rightarrow p\Xi^-$ decays in Au+Au HIJET central events.

- For convenience and economy use standalone code, Fast Simulation Detector Response (FSDR), for this feasibility study:
  - Propagates and decays Λ, Ξ^-, etc.
  - Applies acceptance cuts, tracking efficiencies, momentum resolution smearing
  - Reconstructs Λ, Ξ^- decays as in real STAR reconstruction software

- Assume STAR SVT-SSD-TPC global tracks are used with:
  - Full ϕ, $|\eta| \leq 1$ acceptance
  - 2% momentum resolution
  - 70% tracking efficiency
  - few 10's micron track position accuracy near vertices

- For Λ, Ξ^- vertex reconstruction:
  - Primary/secondary track cuts
  - DCA cuts for daughter tracks
  - Mass cuts for Λ, Ξ^- candidates
  - Results are similar to that with full STAR software

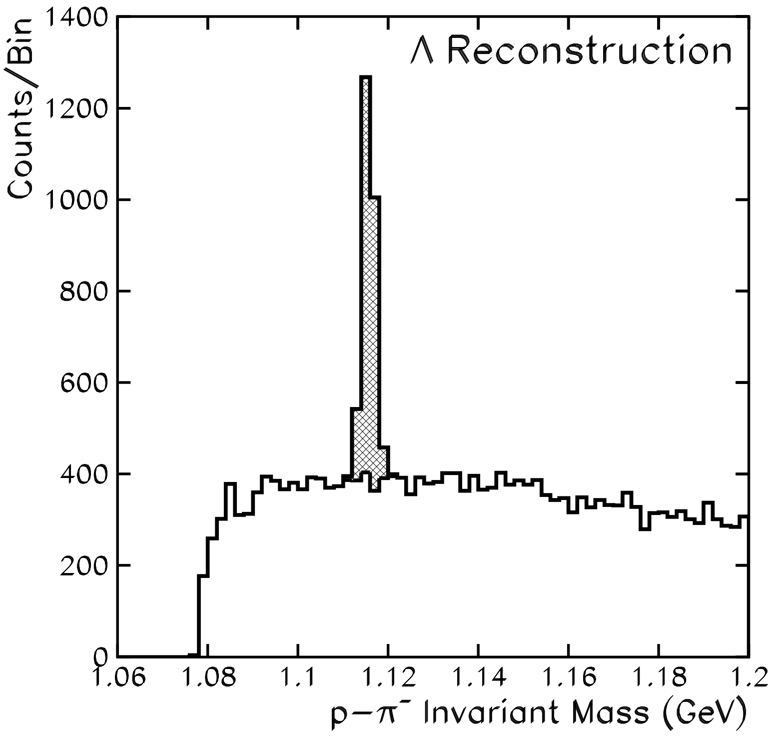

Figure 2: FSDR $p\pi^-$ invariant mass spectrum for $\Lambda \rightarrow p\pi^-$ reconstruction for 600 central Au+Au HIJET events with embedded H^{27} resonances at a collision energy of 200 A·GeV. Bin size is 2 MeV.

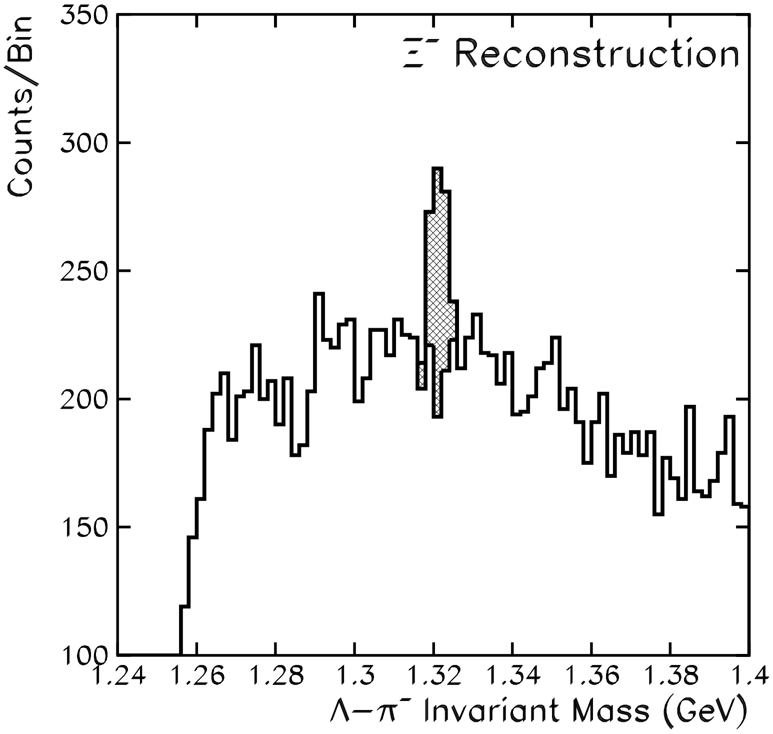

Figure 3: FSDR $\Lambda\pi^-$ invariant mass spectrum for $\Xi^- \rightarrow \Lambda\pi^-$ reconstruction for 600 central Au+Au HIJET events with embedded H^{27} resonances at a collision energy of 200 A·GeV. Bin size is 2 MeV.

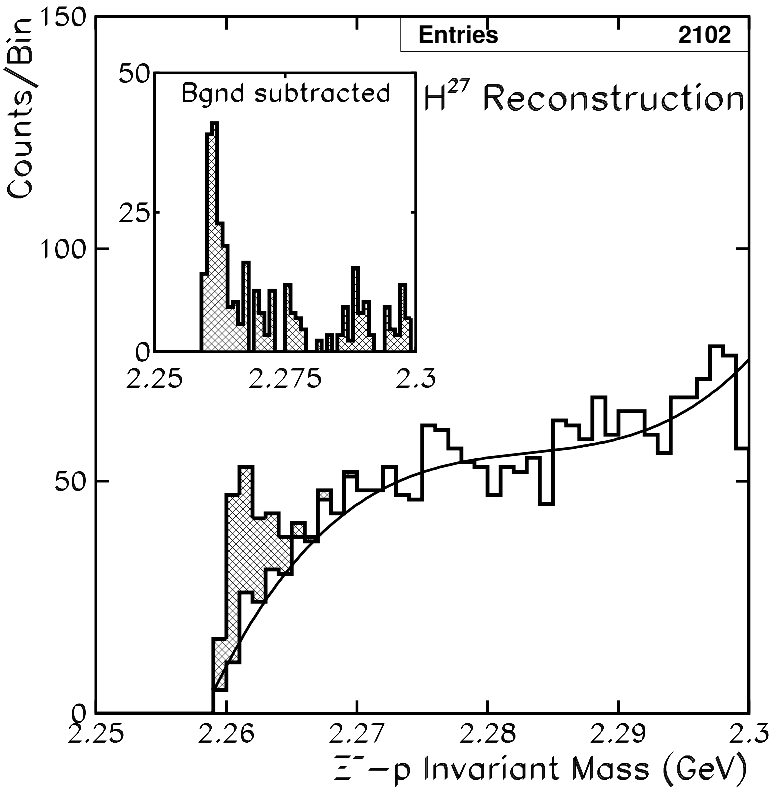

Figure 4: FSDR $p\Xi^-$ invariant mass spectrum for $H^{27} \rightarrow p\Xi^-$ reconstruction for 600 central Au+Au HIJET events at a collision energy of 200 A·GeV, assuming an average of 2.6 $H^{27} \rightarrow p\Xi^-$ resonance decays per event into the acceptance with resonance energy 1 MeV above threshold and Gaussian width parameter (σ) of 2 MeV. Bin size is 1 MeV. Background subtracted peak is shown in the insert. Background was fit with a polynomial.

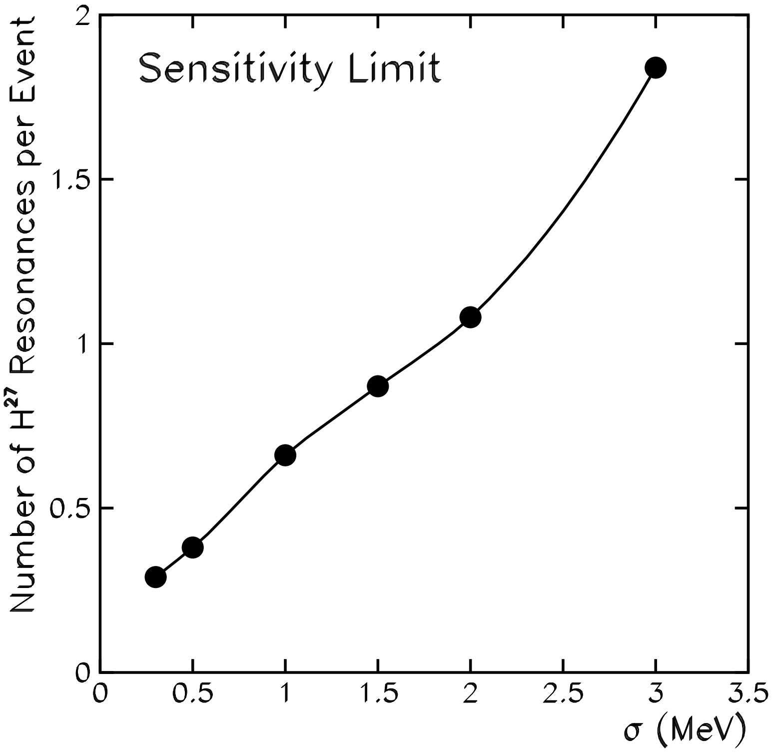

Figure 5: STAR's detection limit for $H^{27} \rightarrow p\Xi^-$ resonance decays in terms of production rate (number per event into STAR's acceptance) as a function of assumed Gaussian width parameter. Detection criteria: signal to subtracted background must be at least 3:1.

Summary and Conclusions:

1. Dibaryons might exist as narrow resonances in the B-B invariant mass continuum.

2. Production could be enhanced at RHIC; possible QGP signal.

3. Eight Y=0, I_3=0 dibaryon states are suitable for experimental search at STAR in the $\Lambda\Lambda$ and $p\Xi^-$ invariant mass spectra.

4. We studied $H^{27} \rightarrow p\Xi^-$; STAR detection sensitivity is $\sim$1 per event, which is comparable to coalescence model predictions (Dover *et al.,* PRC **40**, 115 (1989)) for bound dibaryons produced in Au+Au collisions at AGS energies.

5. STAR with SVT-SSD vertex tracking can obtain enough data in just a few days to allow statistically accurate $p\Xi^-$ invariant mass spectra to be constructed.