Pentaquark Search and Σ^* Results from STAR

- What is Θ^+ ? Why Σ^* ?
- How can we search for them at RHIC?
- What did we learn so far?
- What else can we do in the near future?

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STAR Collaboration

What is a Θ^+?

Quark Content: u u d d $\bar{s}$

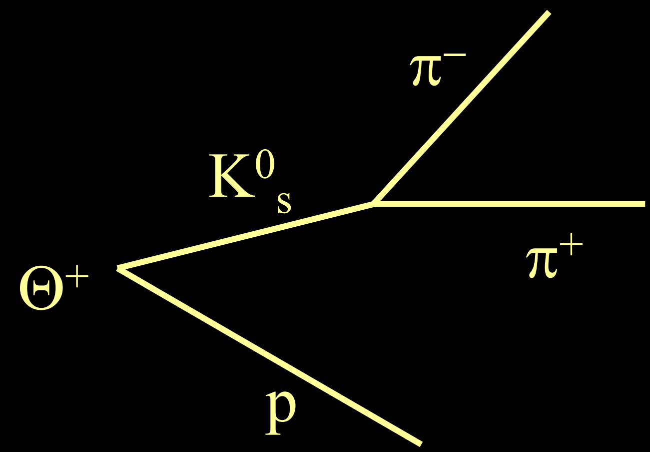
Observed Mass: ~1540 MeV

Observed Decay Channels: $p+K^0$ and $n+K^+$

Observed Width: <10 MeV

K+N Quantum Numbers: Y = 2 I_3=0

Not Yet Observed: $p+K^+$ partner → I=0



Chiral Soliton Model: Chiral dynamics generate narrow K+n resonance (partial motivation of experiments).

Uncorrelated Quark Model: $Q^4 \bar{Q}$ in the lowest orbital of a mean field. Bag, NRQM…

Correlated Diquark Description: Quarks are correlated in an antisymmetric color, flavor and spin state.

Parity → + Chiral Soliton Model, Correlated Quarks

Parity → - Uncorrelated Quarks

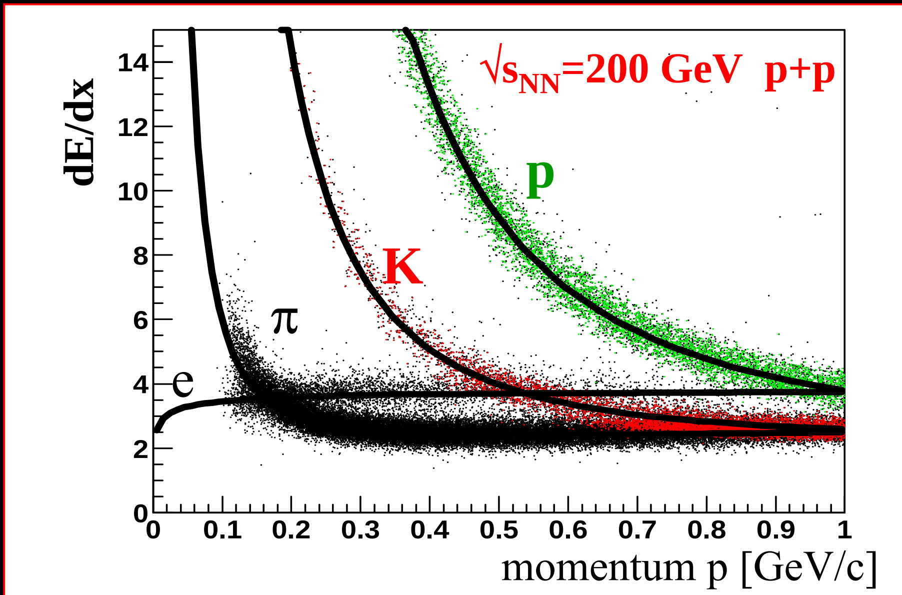
R. Jaffe and F.Wilczek, hep-ph/0307341
T. Nakano et al., AAPPS Bull.13:2-6,2003
V.V. Barmin et al, hep-ex/0304040
C. Alt et al, hep-ex/0310014

Theoretical Importance of Studying Resonances

Due to the very short lifetime ($\tau<\tau_{fireball}$) of resonances:

- Large fraction of the decays occur inside the reaction zone
- Possible change in the physical properties:
  - width broadening
  - mass shift
  - change in p_T spectra
- Determination of the hadronic expansion time between chemical and thermal freeze-out
- Due to its strange quark content and high mass, $\Sigma^*(1385)$ gives us information about strangeness production.

Particle Identification



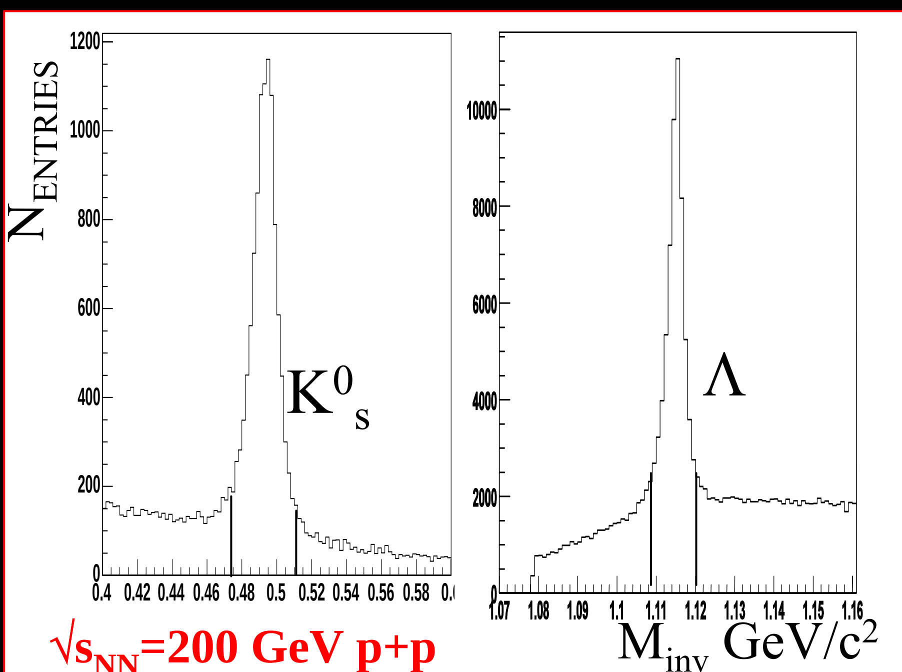
Charged daughter particles are identified by dE/dx in the TPC.

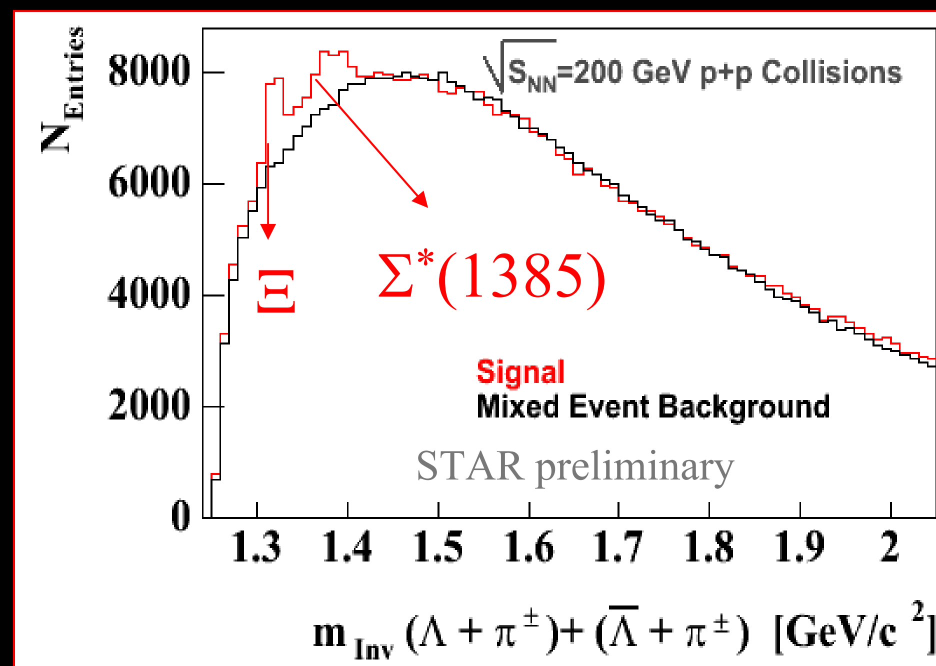
Λ's and K^0_s are reconstructed by

standard decay topology technique since they have a long lifetime

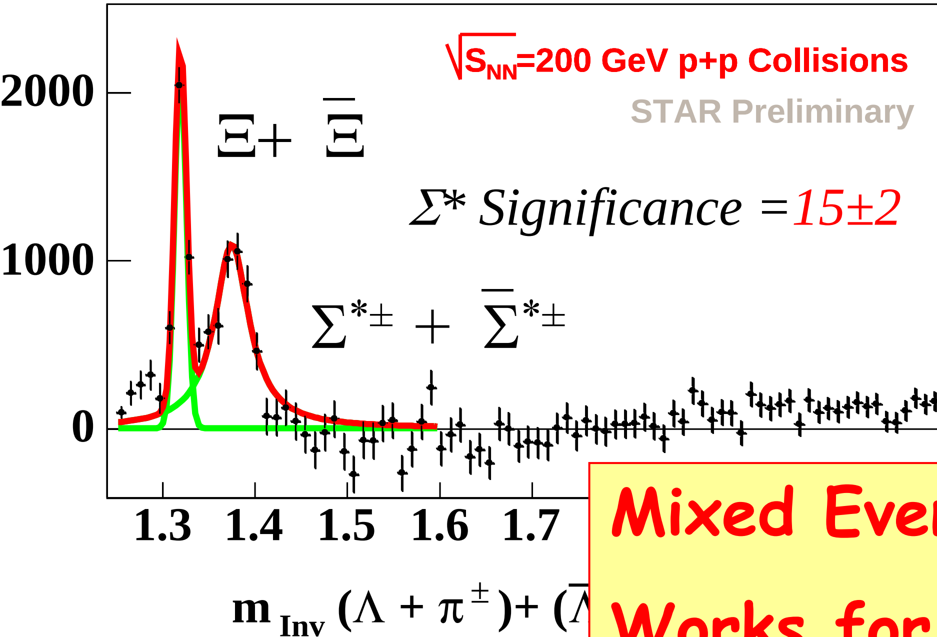
($c\tau_\Lambda$=7.89 cm and $c\tau_{K^0_s}$=2.7 cm).

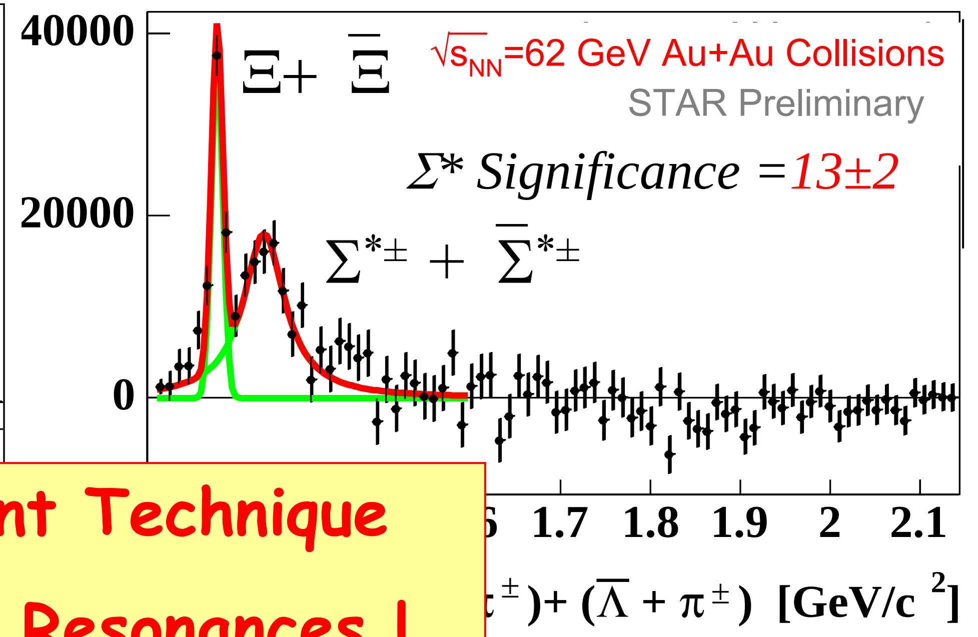
Σ^{*-} M=1387±1 [MeV] Γ=39±2 [MeV]





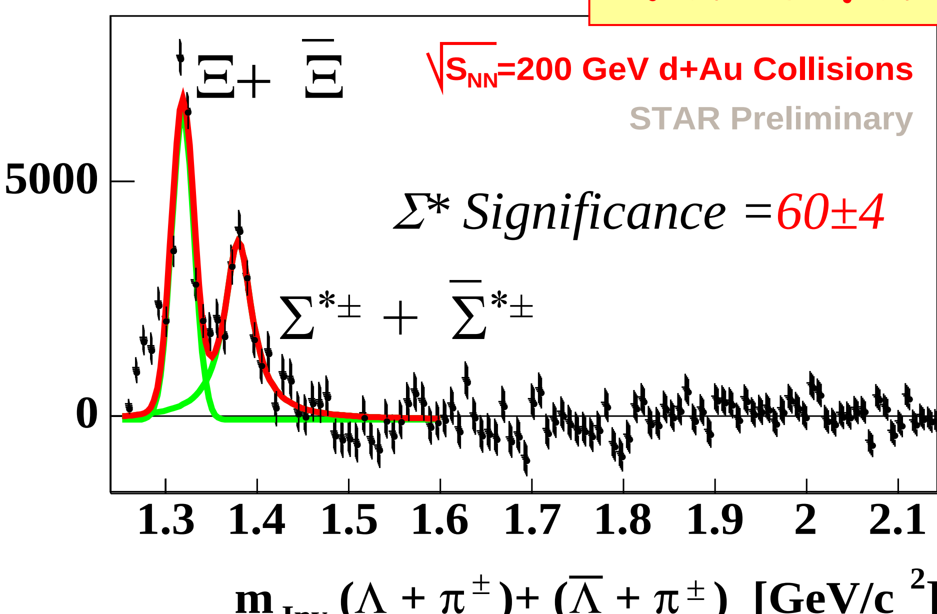
Background Subtracted Invariant Mass Spectra

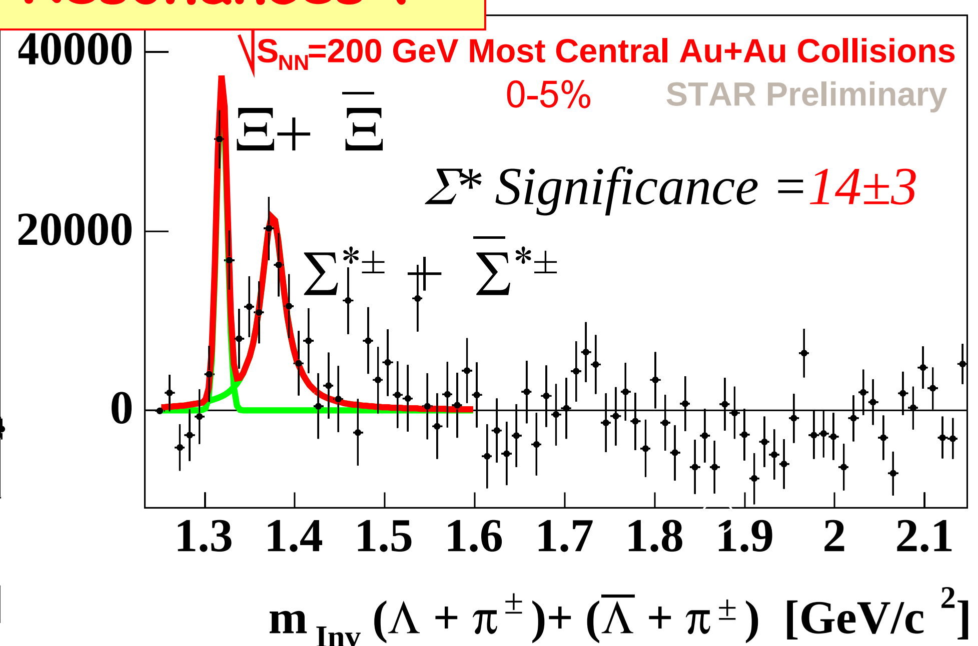




Mixed Event Technique

Works for Resonances !

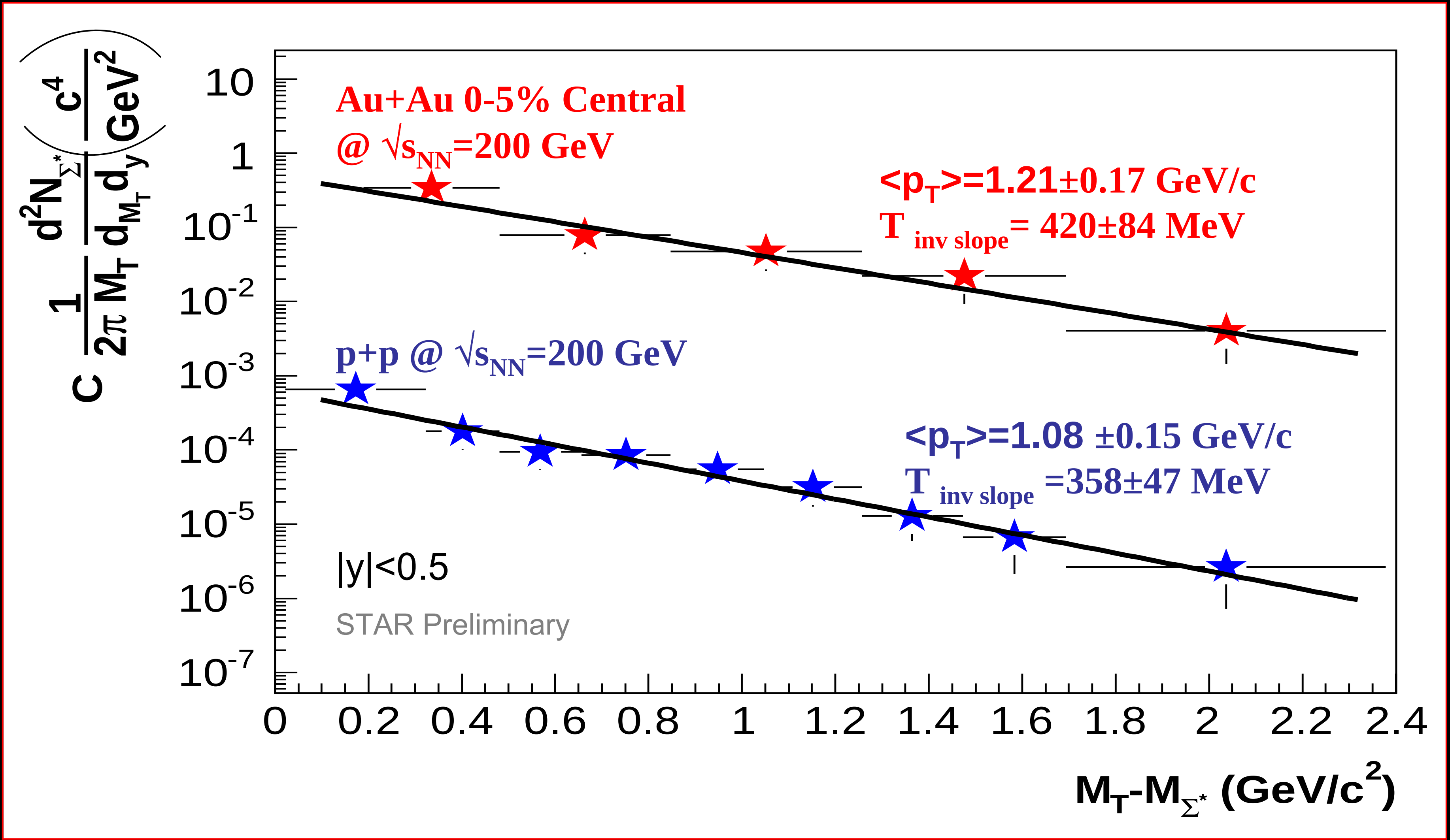




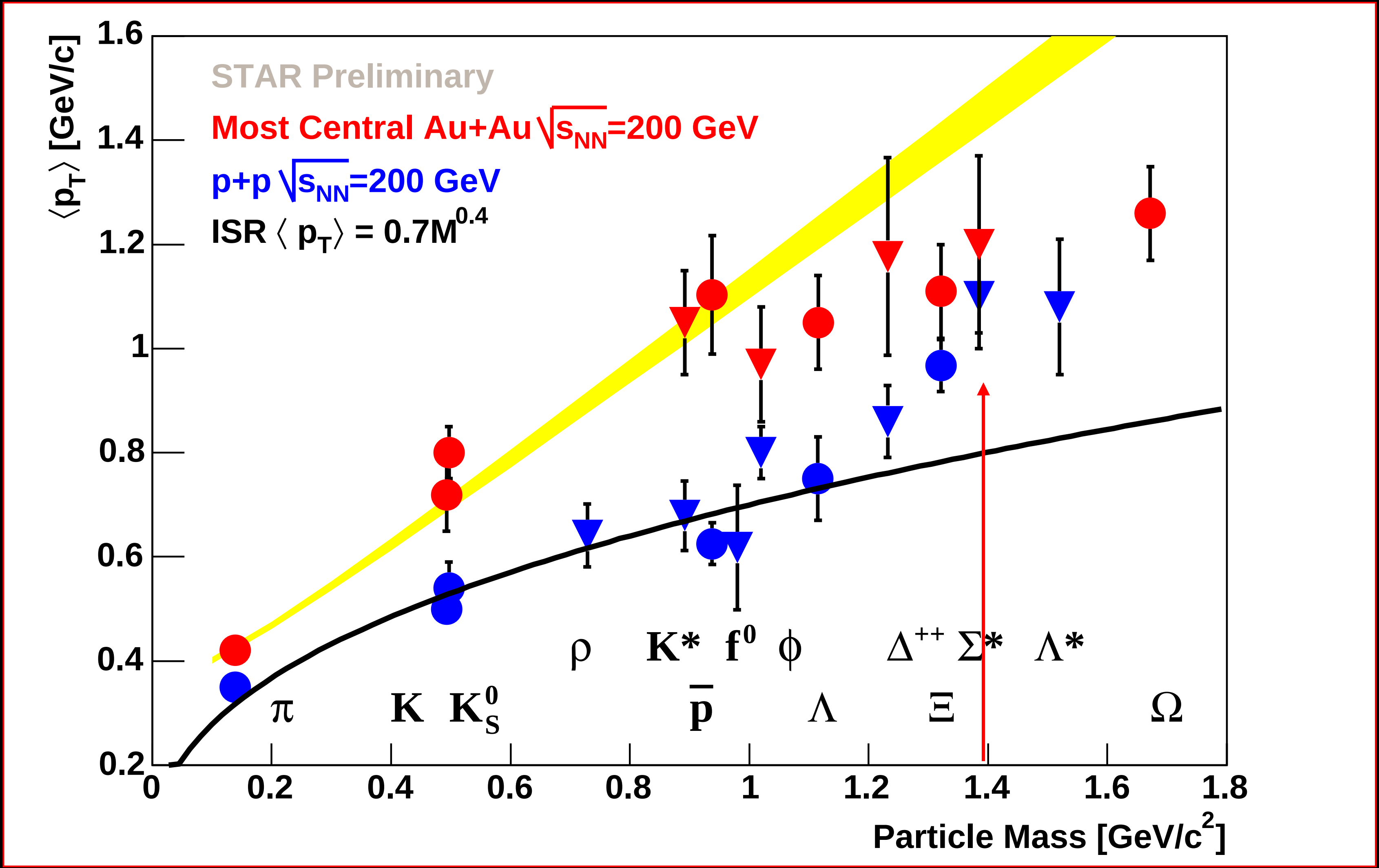
Corrected P_T Spectra

Exponential Fit Function :

$$\frac{1}{2\pi\, m_T}\frac{d^2N}{dm_T dy} = \frac{dN/dy}{2\pi\, T\,(m_0+T)}\, e^{\frac{-(m_T-m_0)}{T}}$$



Particle Mass vs <P_T>



Parameterization is from ISR data at √s=25GeV (Not correct for heavy particles.)

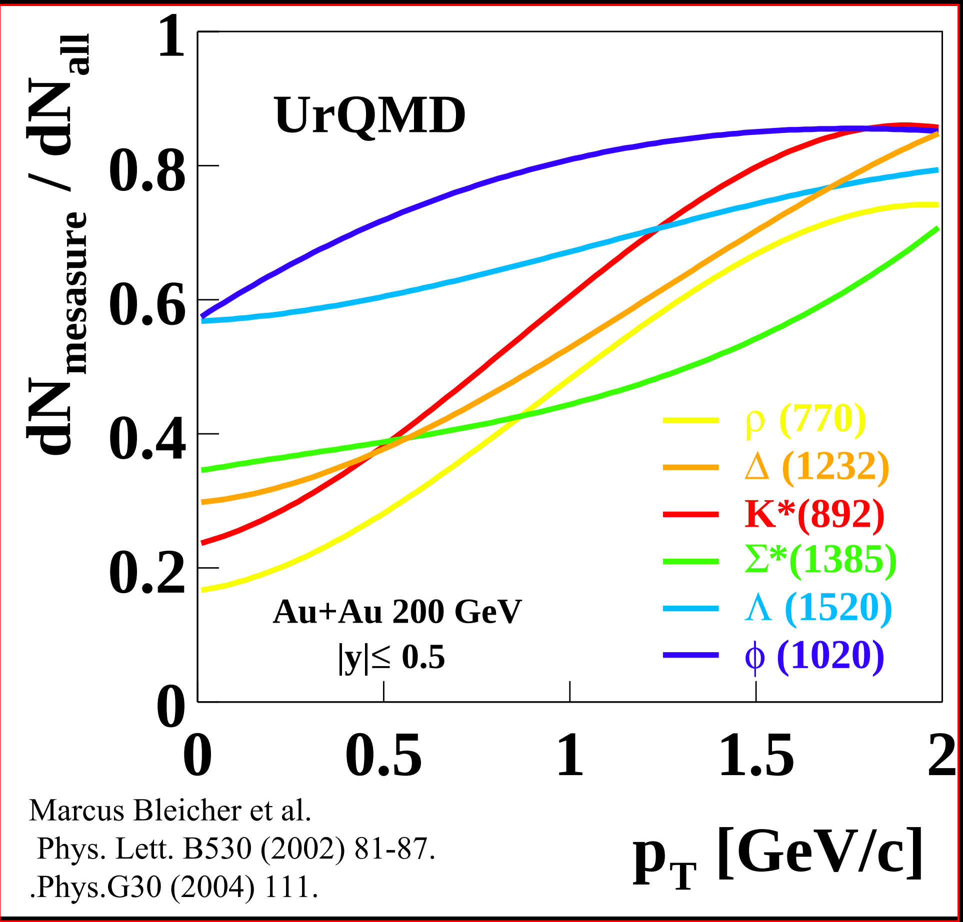
- Are heavier particles produced in more violent p+p collisions?

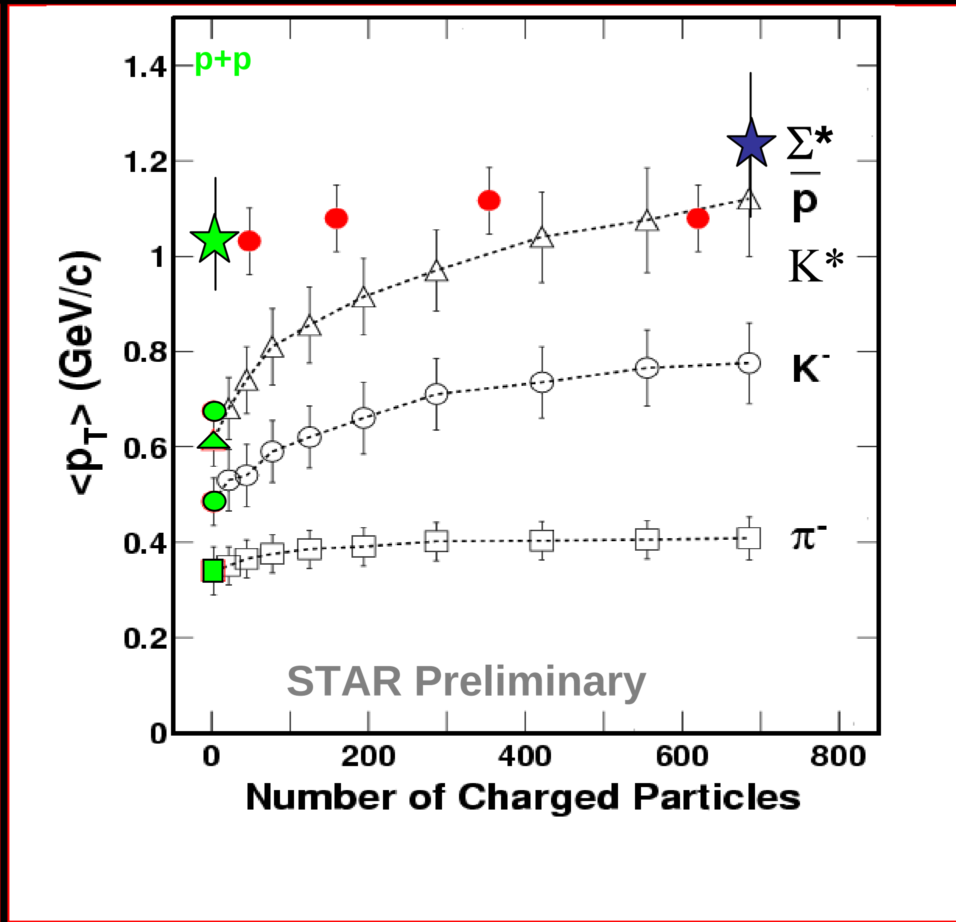
<p_T> values merge for Au+Au and p+p for heavier particles.

$<p_T>$

There is no increase within the errors in Σ^* $<p_T>$ from p+p to Au+Au.

UrQMD predicts more signal loss at low p_T due to more rescattering than regeneration → $<p_T>$ is higher.

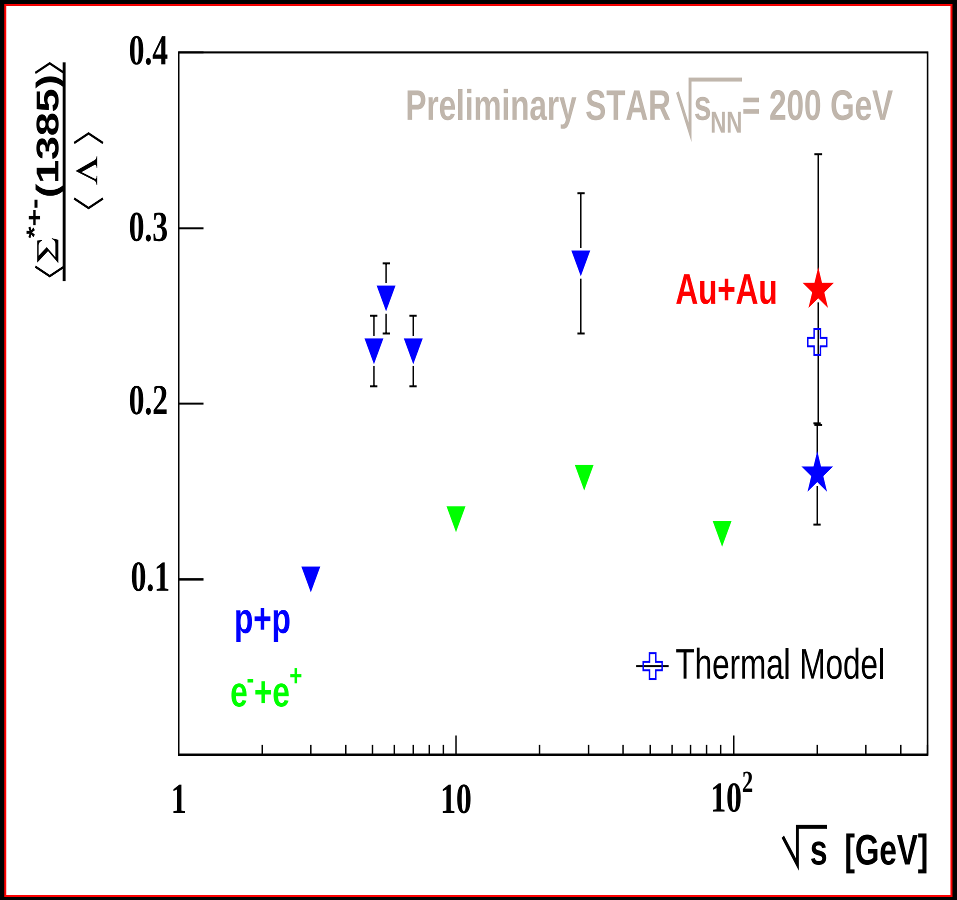


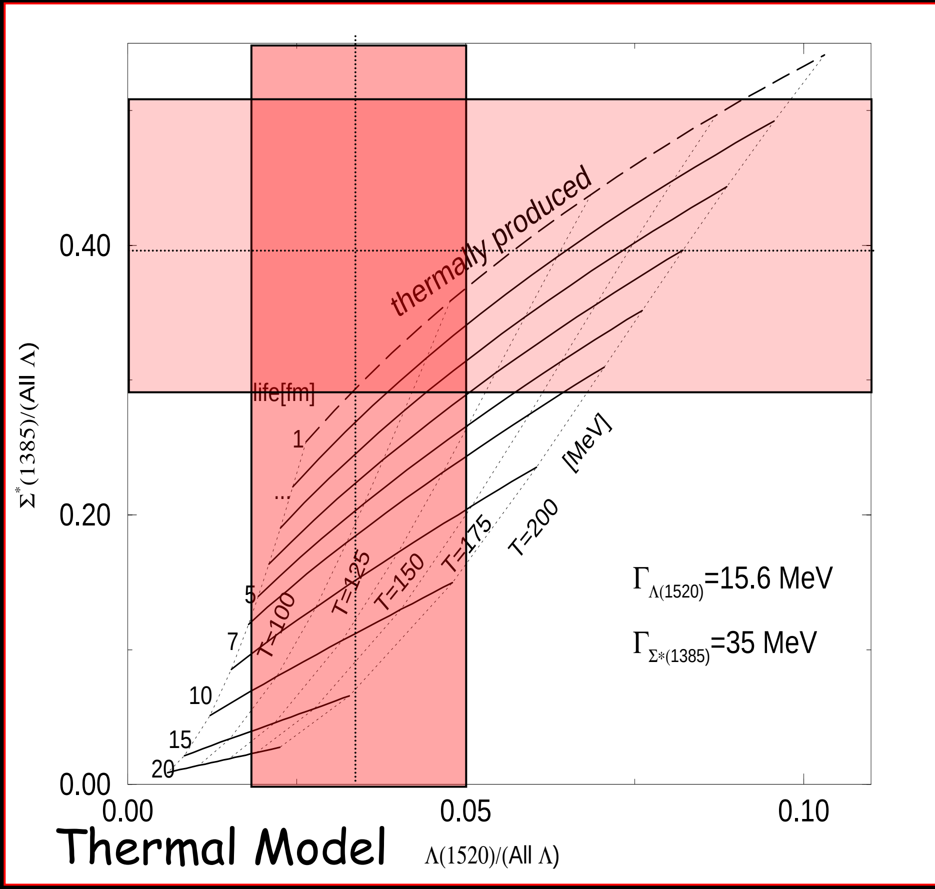


$<p_T>$ for K* shows different behavior than p,K,π vs centrality.

$\Sigma^*(1385)$ measurement in different centralities is on the way…

Σ^* Yields in p+p and Au+Au





G. Torrieri and J. Rafelski, Phys. Lett. **B509** (2001) 239

No enhancement or suppression within the errors…

Comparison of two particle ratios without regeneration gives a $\Delta\tau$ ~ 3 fm between chemical and thermal freezeout and T~ 150 MeV in thermal model.

So far from Σ^* ...

- Acceptance and efficiency corrected results are presented for the Σ^* p_T spectra in p+p and the most central Au+Au collisions.

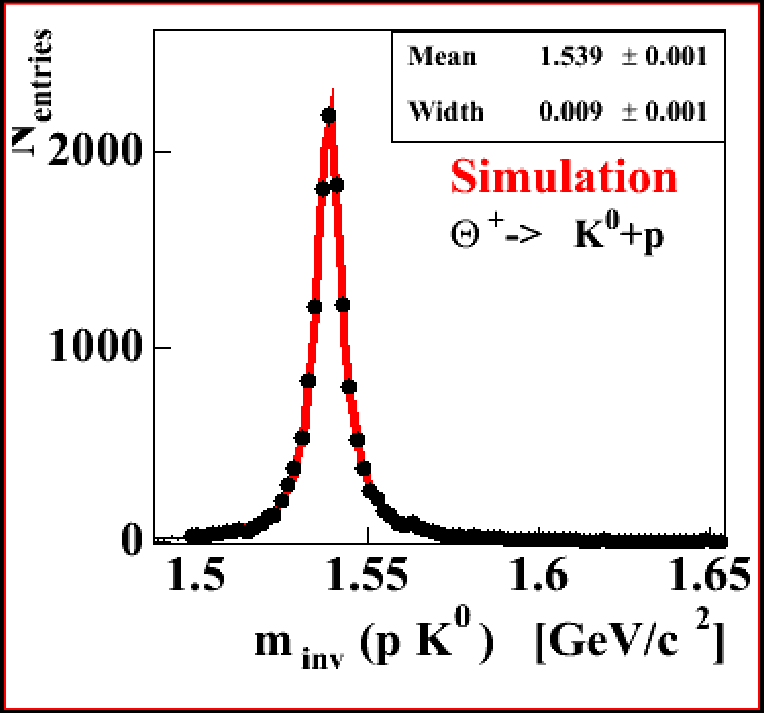
There is no strong increase of $\langle p_T \rangle$ from p+p to 0-5 % Central Au+Au. No radial flow ? Different production mechanisms (jets in p+p)? $\langle p_T \rangle$ values merge for Au+Au and p+p for heavier particles.

- There is no suppression or enhancement in the ratios of Σ^*/Λ in p+p and 0-5% Central Au+Au collisions within the errors.

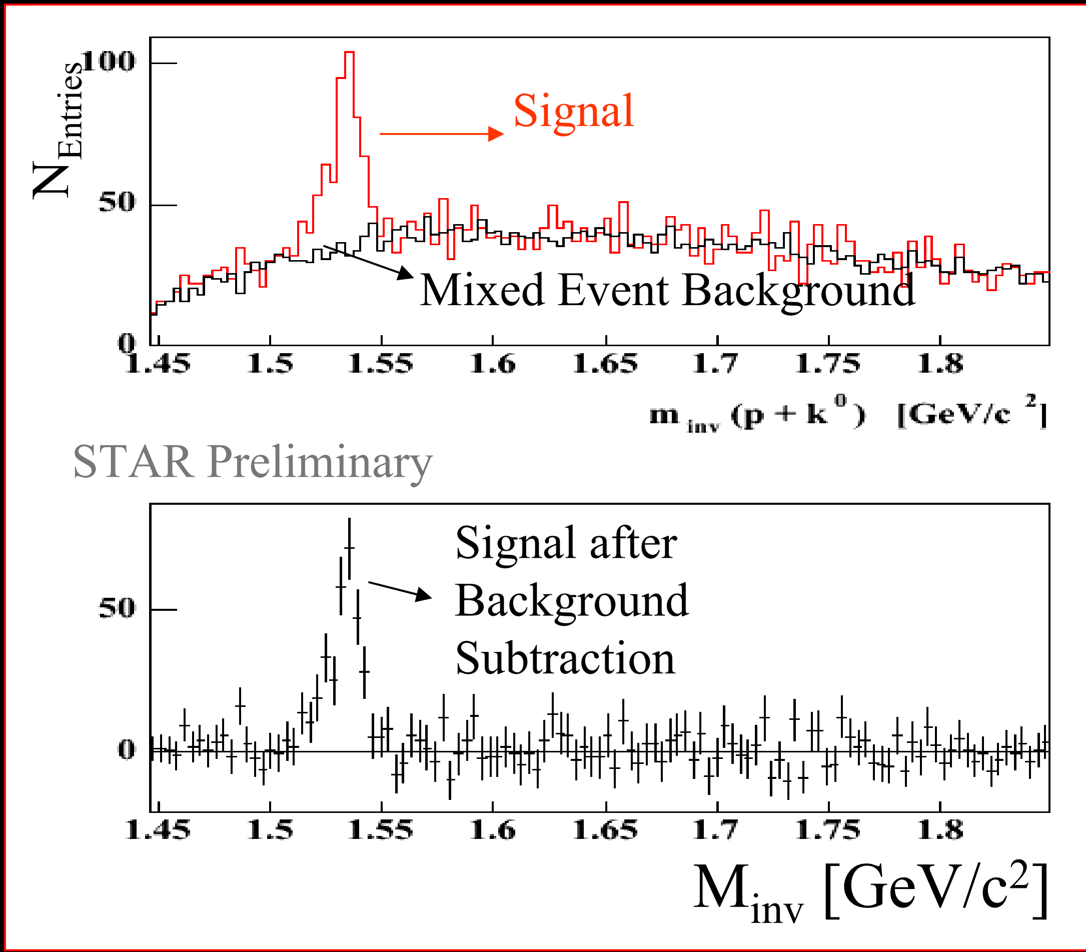
What about Θ^+ ?

Θ + Simulation Studies

Monte Carlo INPUT



Reconstruction OUTPUT



One MC Θ^+ (T_{inv} slope =250 MeV) is embedded in each real p+p event.

Only 3% of these Θ^+'s were reconstructed after cuts.

The width and the mass remain consistent with the MC input after the reconstruction. (W=10 MeV) (M=1.54 GeV/c^2)

Feasibility Studies for Θ⁺ with Current p+p Data

Assuming ~0.1-1 Θ^+ per $\Lambda(1520)$ for p+p

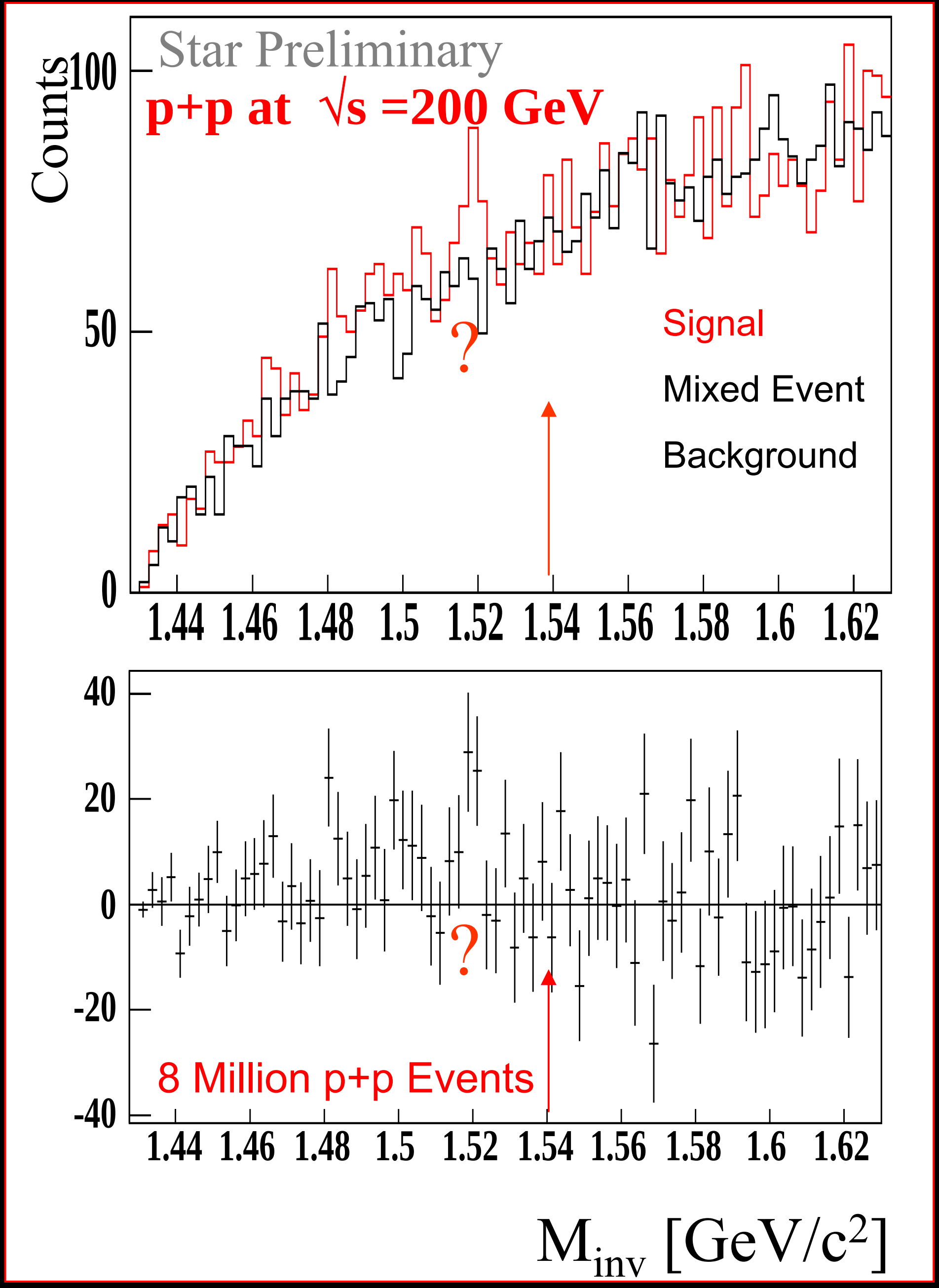
- Preliminary dN/dy of $\Lambda(1520)$ in pp → 0.004 per event
- 8 Million X 0.004 → 32 K $\Lambda(1520)$
- 0.1-1 X 32 K Θ in pp → 3-32 K
- Efficiency 3% → 90-960
- Branching Ratio 50% → 45-480
- B R 50 % from K^0s → 22-240

Background pairs per event in the mass range of Θ is 0.0004.

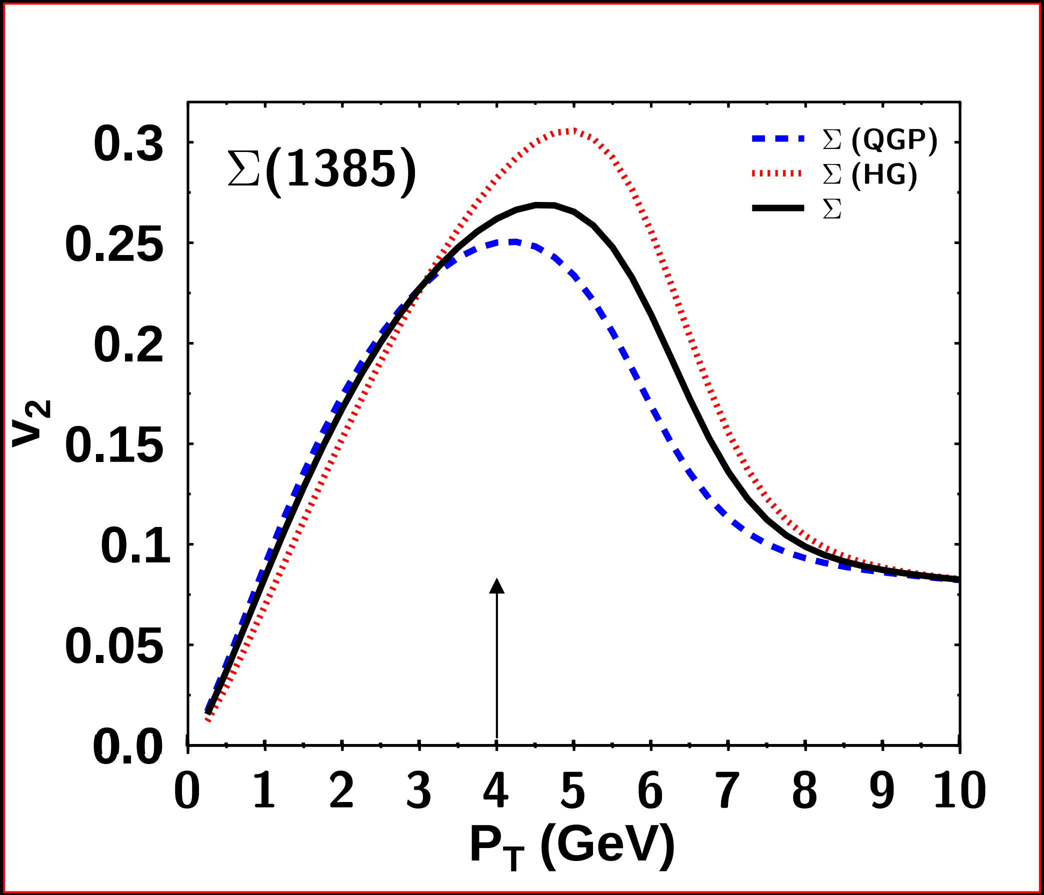
- 0.0004 X 8 Million → 3200

σ = Signal/√(2 X Background+Signal) → 0.25-3

Observation is consistent with simulation !
STILL LOOKING INTO OPTIMIZATION



Outlook - v_2 ?



Nonaka et. al. Phys.Rev. C69 (2004) 031902

Resonance contribution from

- QGP hadronization
- Coalescence in a hadron gas.

How much final state hadron-hadron recombination ?

The percentage of each v_2 as a function of p_T may answer ...

But we need high statistics at high p_T

Σ(1385) Flow Measurement with Run 4 !?

Conclusion & Near Future Plans

• Resonances can be clearly reconstructed via event mixing techniques in all collision environments with STAR at RHIC. There is no strong increase of $\langle p_T \rangle$ from p+p to 0-5 % Central Au+Au. No radial flow ? Different production mechanisms (jets in p+p)?

• There is no suppression or enhancement in the ratios of Σ^*/Λ in p+p and 0-5% Central Au+Au collisions within the errors.

• Preliminary acceptance and efficiency studies show that we should be able to find (anti) pentaquarks at the few % level. (antibaryon/baryon~1)

• No significant signal observed in d+Au and Au+Au Central collisions either.

Still Optimistically Looking !!!

• Much more data is available from Run 4 !!! Better centrality measurement for Σ^* and possible v_2 measurement.

Au+Au at $\sqrt{s_{NN}}$=200 GeV 50 Million Events taken. (35 times the current data). The significance will increase to 10 - 44 if the Θ^+ is produced with the predicted theoretical yields in RHIC and our acceptance.