Pentaquark Search at $\sqrt{s_{NN}}$=200 GeV with STAR at RHIC

- Introduction to STAR
- Techniques and Analysis
- Simulation Studies
- Conclusions and Future Plans

Sevil Salur **Yale University STAR Collaboration**

RHIC @ Brookhaven National Laboratory

•2 concentric rings

•3.8 km circumference

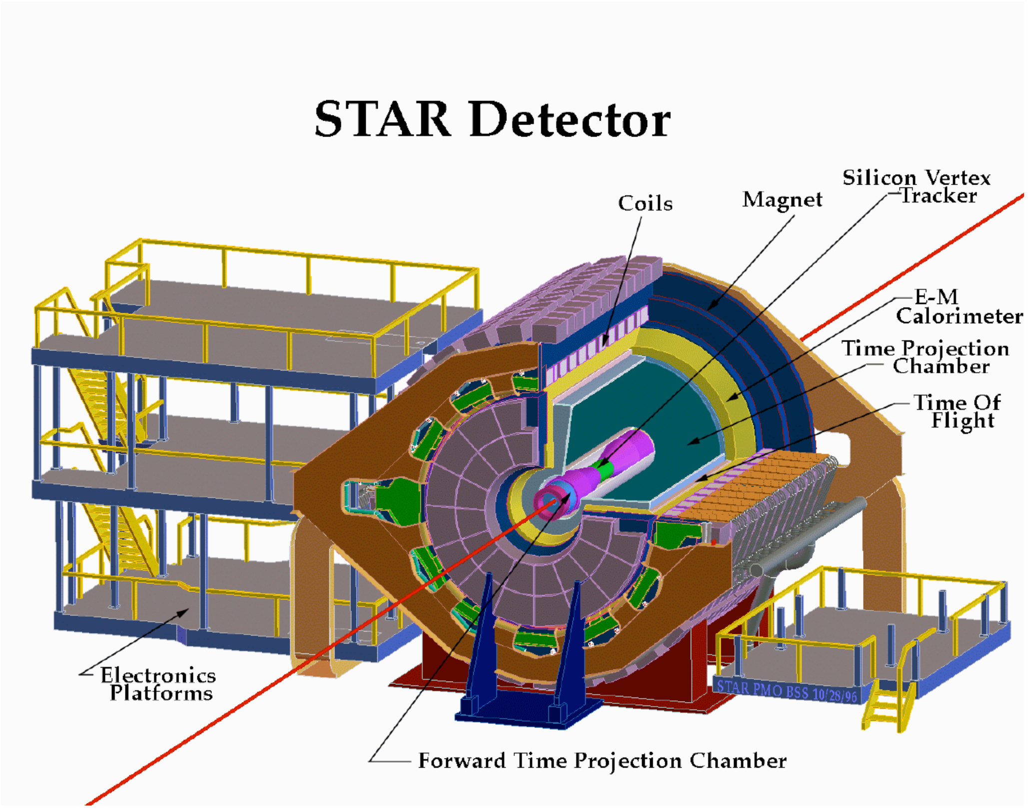
•p+p (s □500 GeV)

•d+Au(s □200 GeV)

•Au+Au(s □200 GeV)

- 2000 run: Au+Au @ s_{NN}=130 GeV
- 2001 run: Au+Au @ s_{NN}=200 GeV and p+p @ s=200 GeV
- 2003 run: d+Au @ s_{NN}=200 GeV and p+p @ s=200 GeV
- 2004 run: Au+Au@ s_{NN}=200 GeV [Starts Dec 2003]

Introduction to STAR



Solenoidal **T**racker **a**t **R**HIC is one of the two large detector systems constructed at the **R**elativistic **H**eavy **I**on **C**ollider (RHIC) at Brookhaven National Laboratory.

• Investigation of strongly interacting matter at high energy density

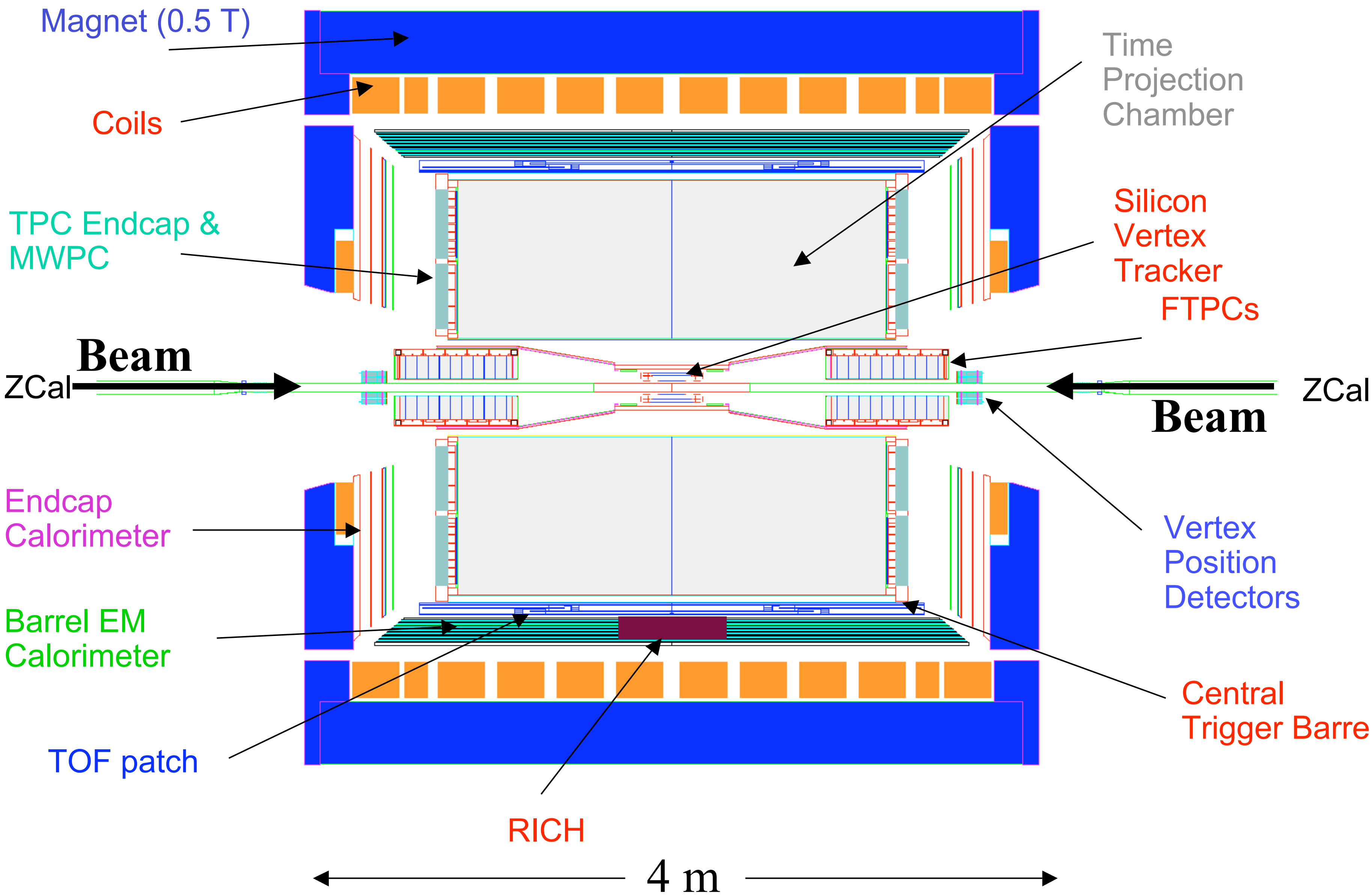
•Search for signatures of Quark-Gluon Plasma (QGP)

QGP Phase transition
Space time evolution

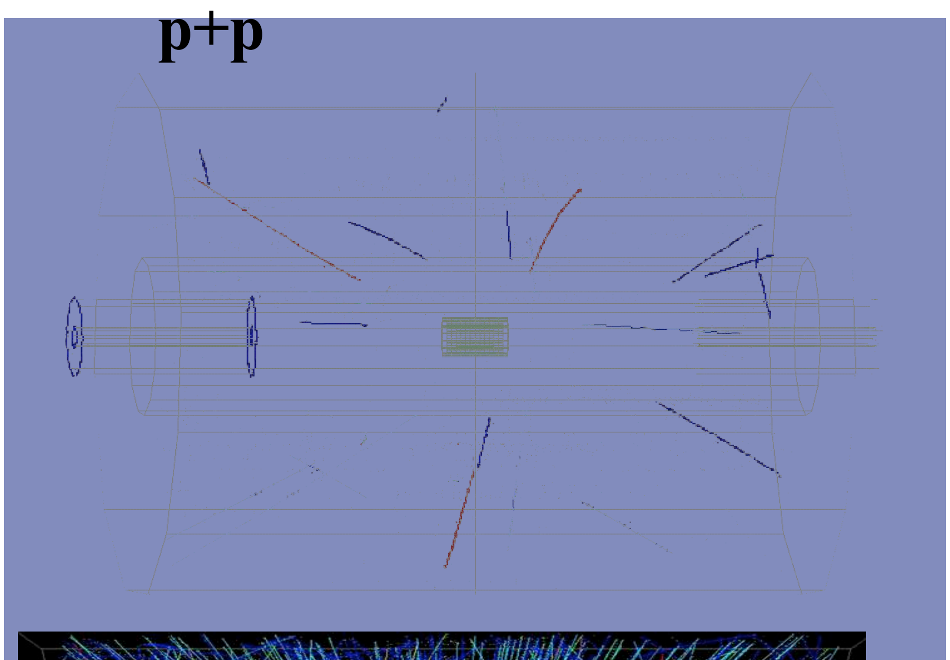
Time Projection Chamber (TPC)

1. Magnetic Field: 0.5 Tesla
2. Acceptance:
   charged particles |_|< 1.5
   dE/dx identification p<0.8 GeV/c
   V0 identifications |y| < 1.0
   □□<□<□
3. Resolutions:
   dE/dx ~ 8%
   Momentum: 1.5%-5%
   at p_t ~ 0.2-10 GeV/c

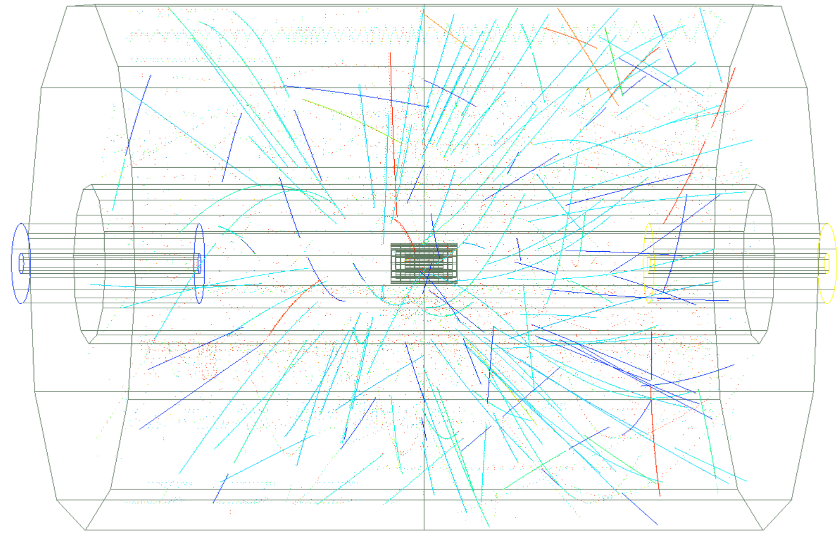
The STAR Detector

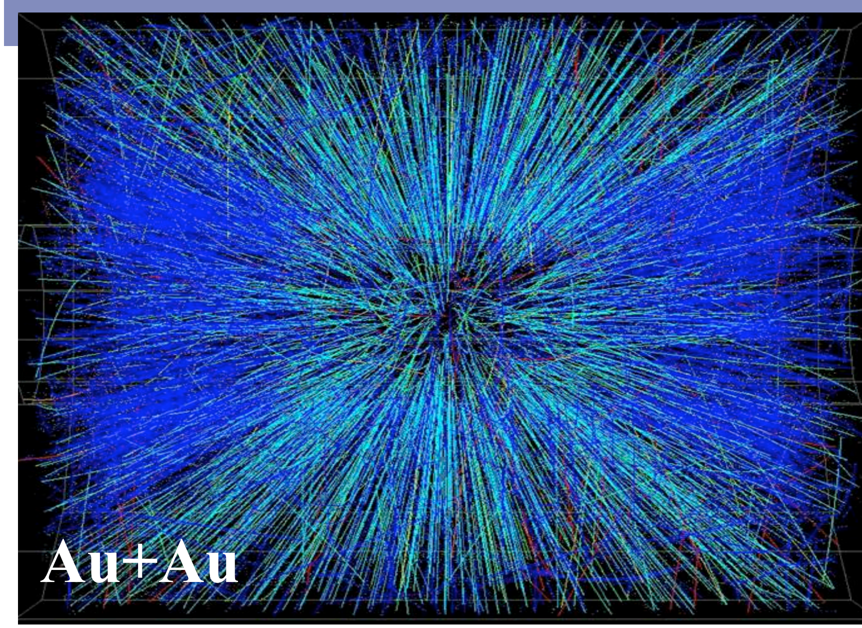


Available Data



d+Au





	# of Events	dNch/dη
p+p	8 Million	3
d+Au	14 Million	15
Au+Au	1.5 Million	800

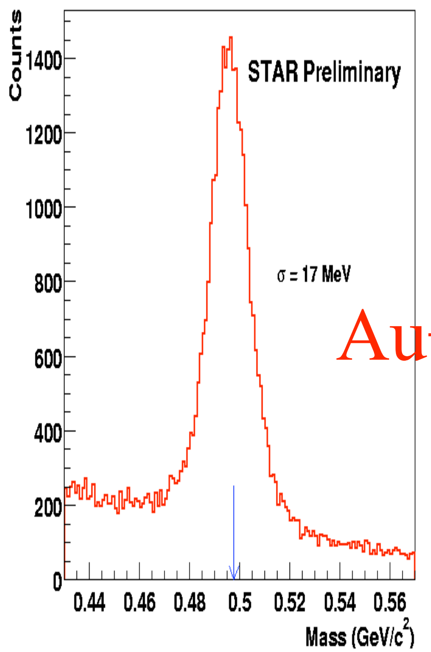
What pentaquarks are we looking for?

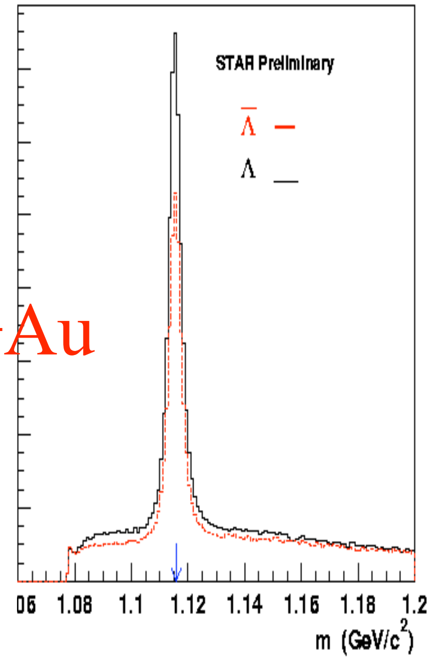
□$^{+}$→n+K^{+}	No	No id for n
□$^{+}$→p+K^{0}	Yes	
□$^{□□}$→□$^{□}$+□$^{□}$	Yes	
□$^{□□}$→□$^{□}$+□$^{□}$	No	No id for □→n+□$^{□}$
□$^{+}$→□^{0}+□+	No	No id for □^{0}→□+□^{0}
□$^{+}$→□$^{+}$+□□^{0}	No	No id for □$^{+}$→p+□^{0}
□$^{+++}$→p+□$^{+}$+□$^{+}$	Yes	
□$^{□}$→n+□$^{□}$	No	No id for n or □^{0}
□^{0}→p+□$^{□}$	Yes	
□$_{5}$→□+□	Yes	
□$_{5}$→□ + □	Yes	
□$_{5}$→p+ □□^{0}	Yes	

Good oportunity to observe **anti pentaquarks** (□p/p ~ 0.7 at RHIC)

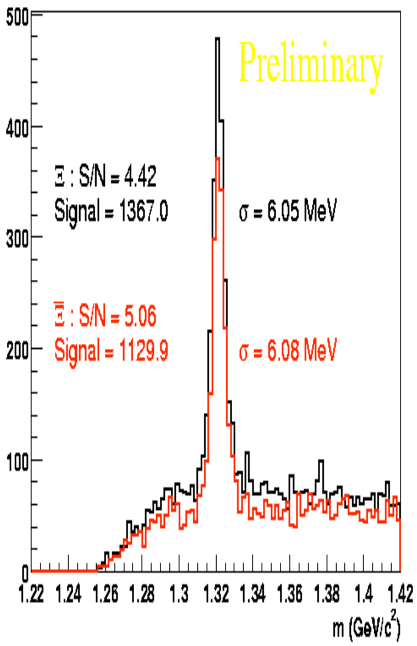
First we need to identify the decay daughters □^{0}, □, □, □ and p.

Topological Analysis Technique



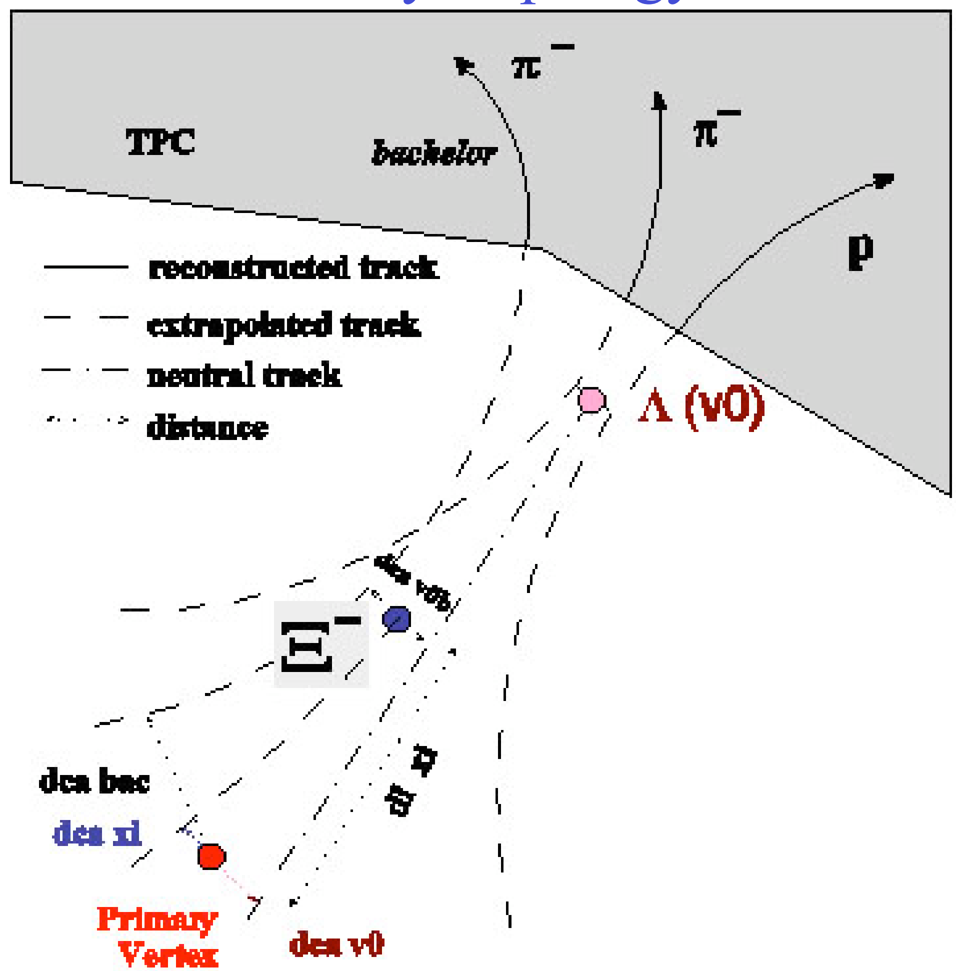


Au+Au



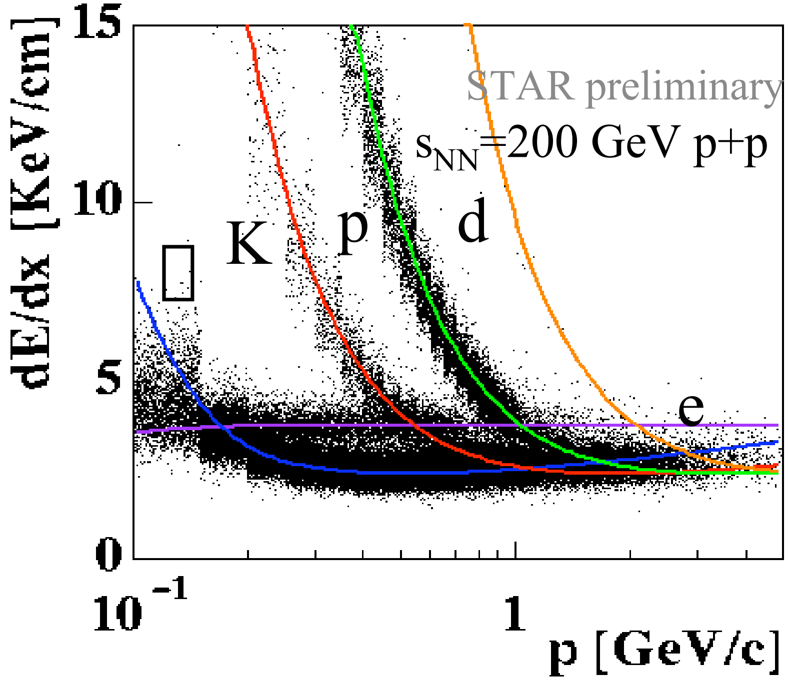
Geometrical identification of secondary decay vertex

Decay Topology



This technique is used to find long lived (~few cm) particles.

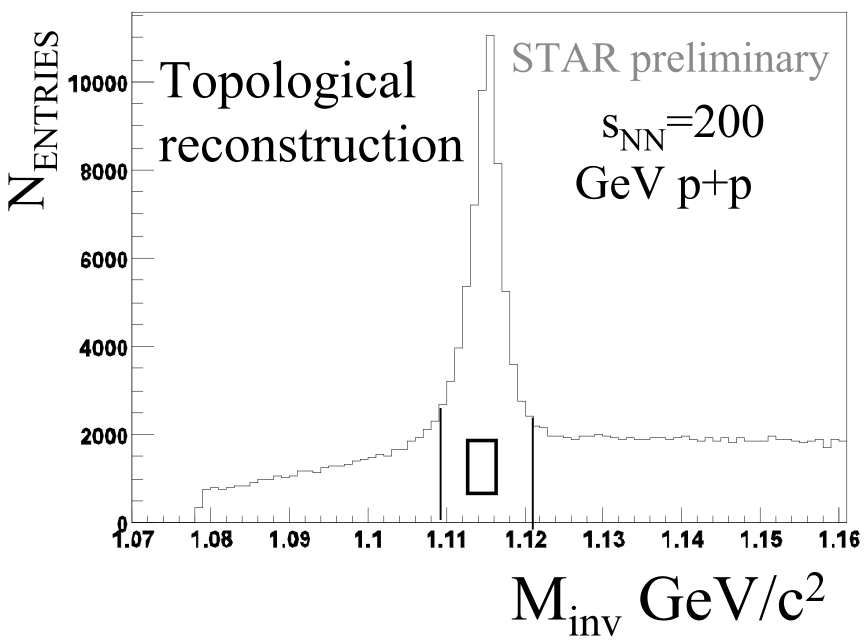
Particle Identification and Mixing Technique

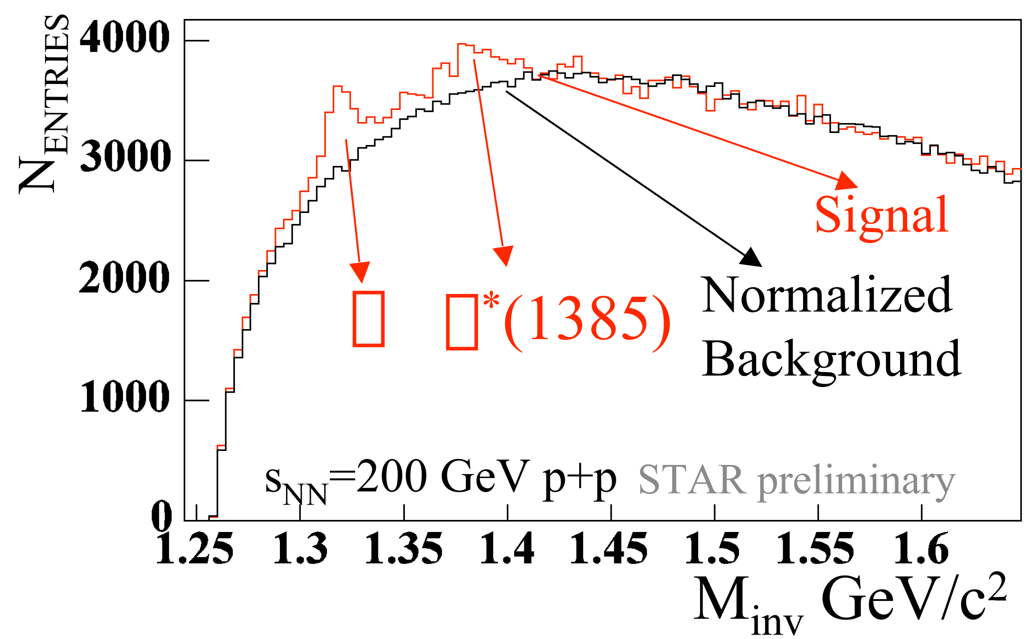


Charged daughter particles are identified by dE/dx in the TPC.

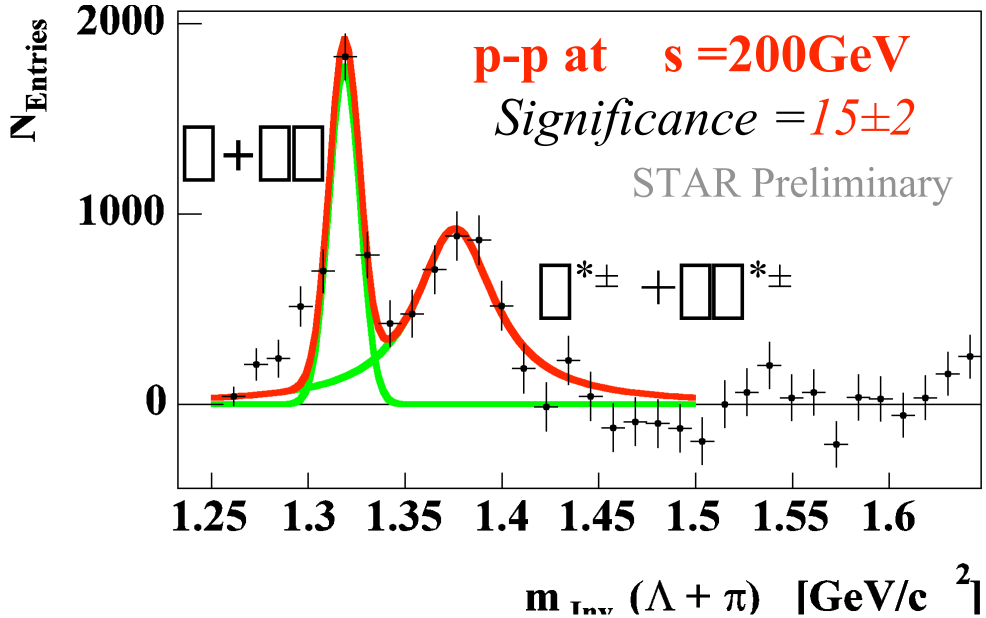
□'s are reconstructed by:

Standard decay topology technique since □'s have a long lifetime (c□=7.89 cm).





Background subtracted Invariant Mass Spectra

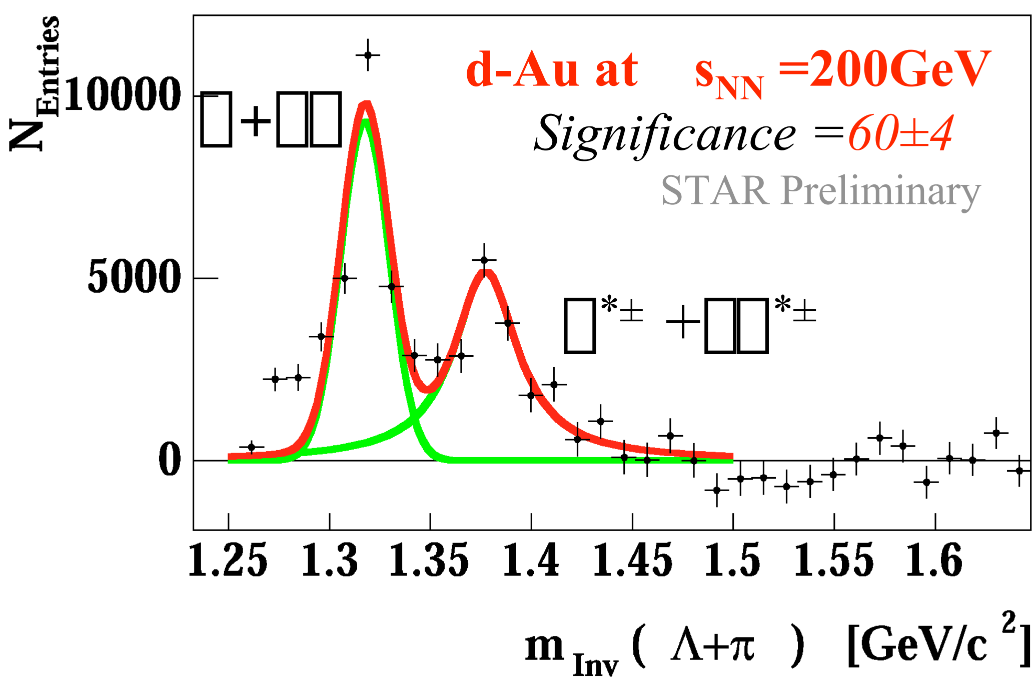


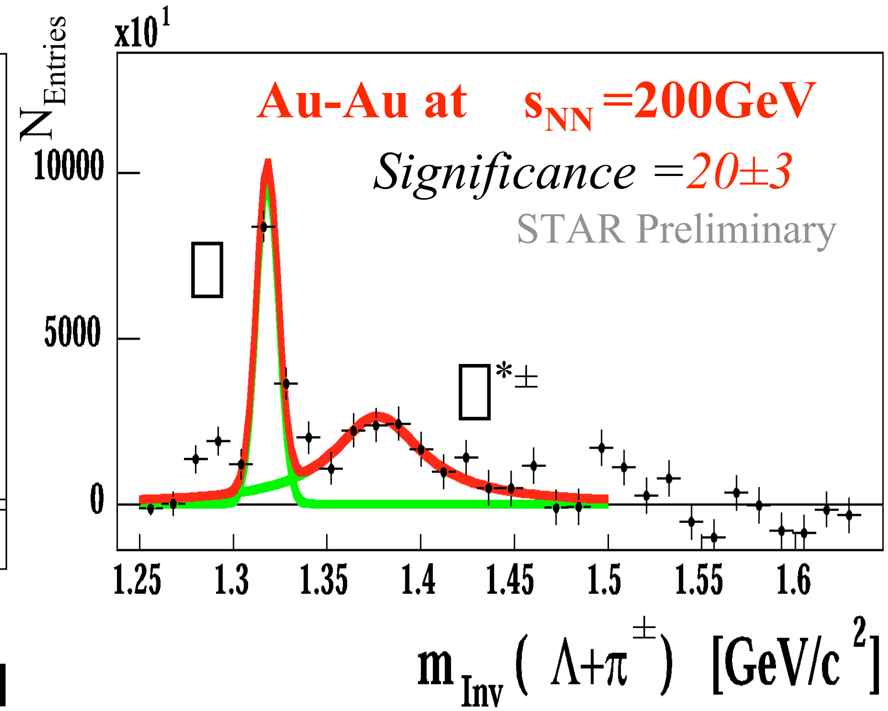
PDG values for □□

M=1387±1 MeV

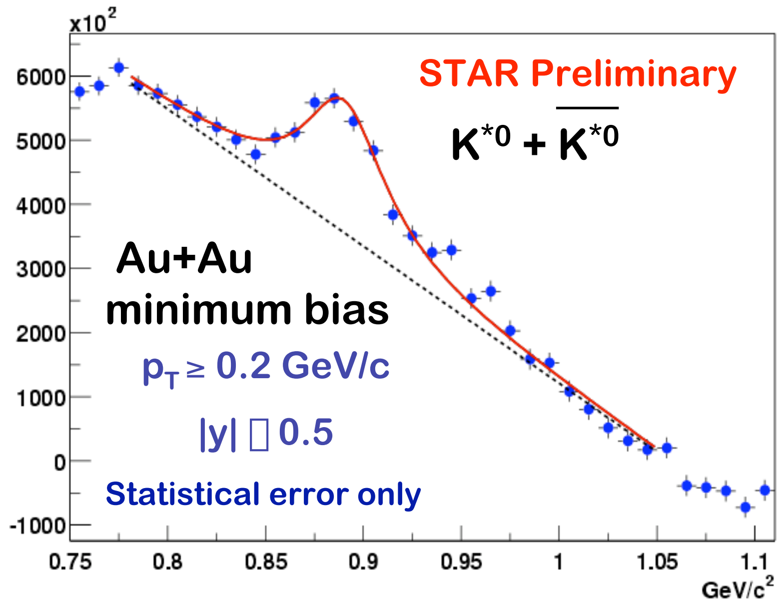
□=39±2 MeV

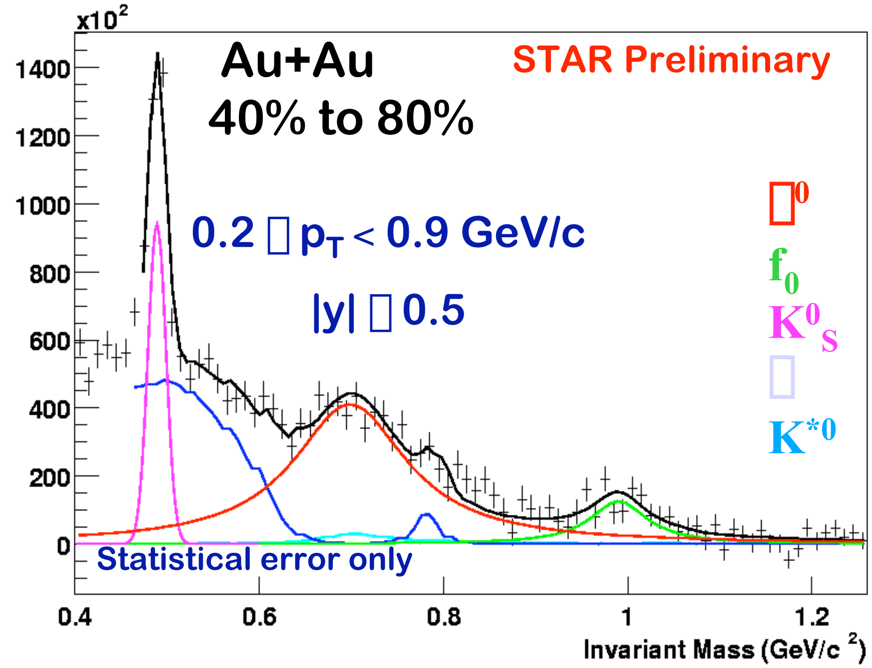
The width and the mass is consistent within the PDG and momentum resolution.

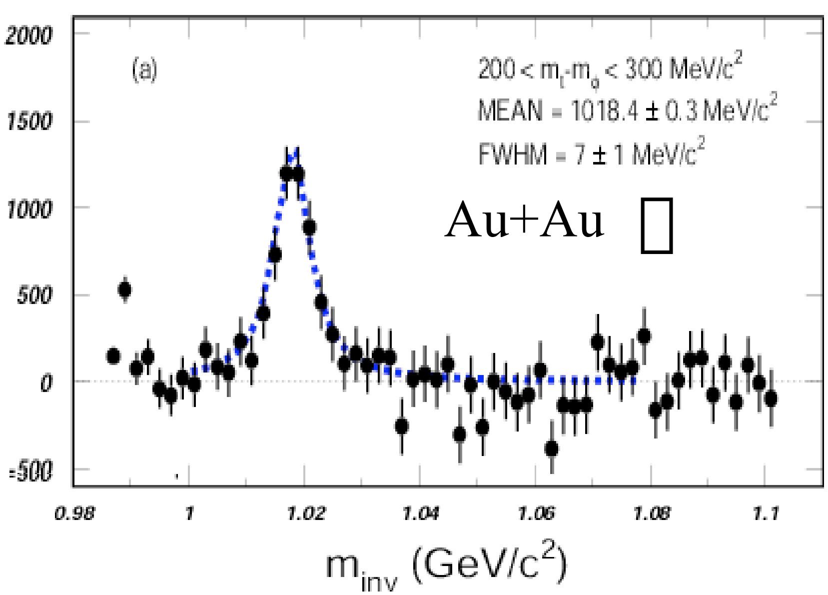


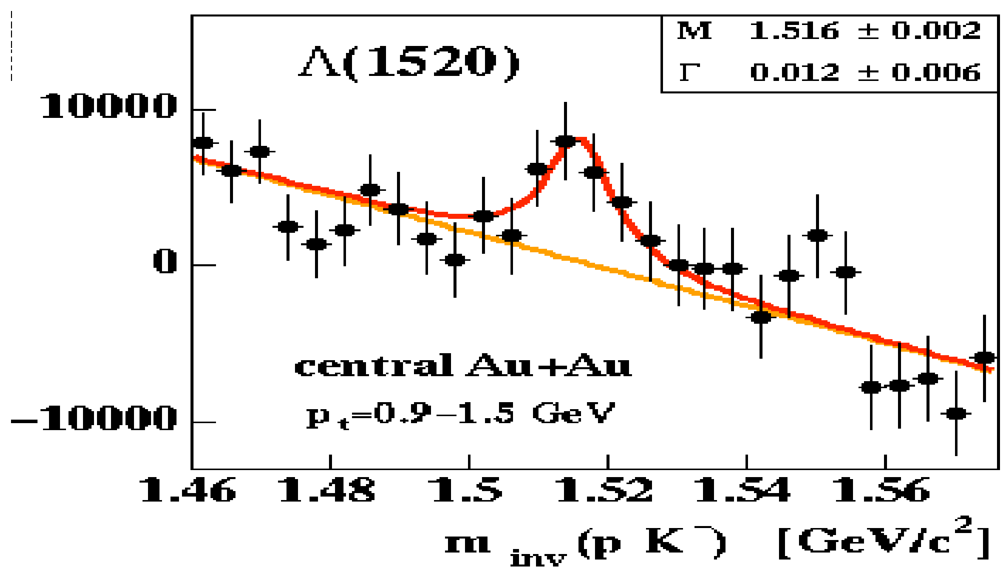


Some Other Resonance Invariant Mass Spectra

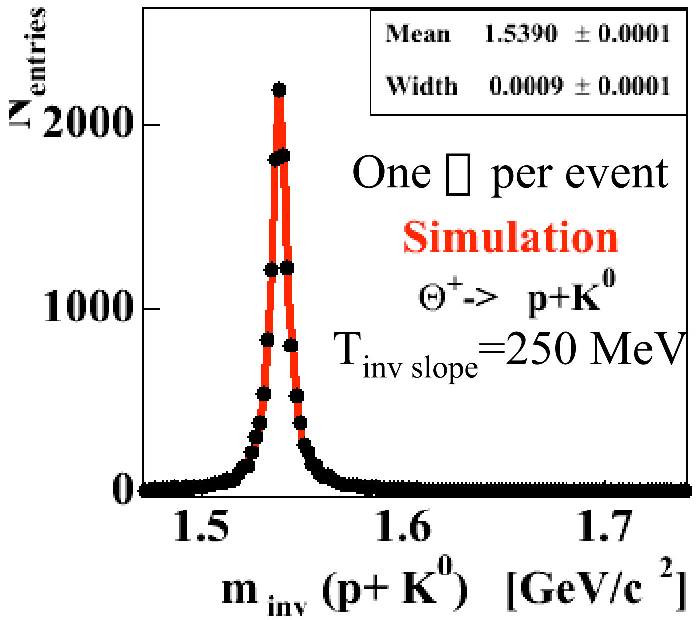


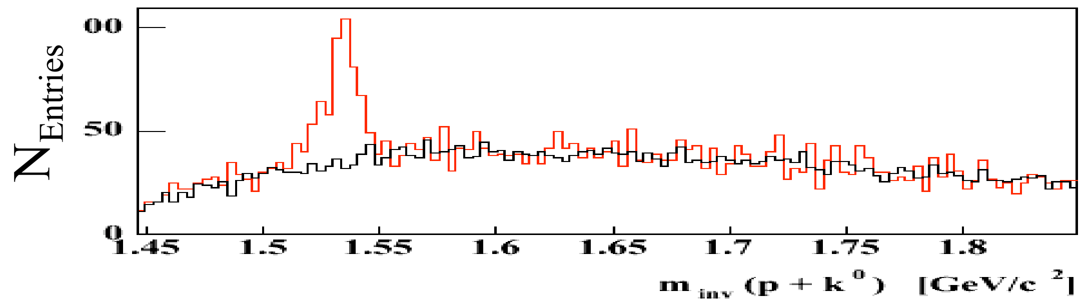


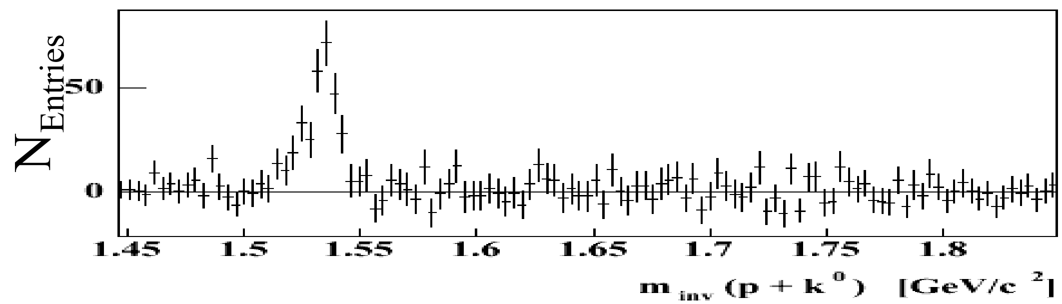


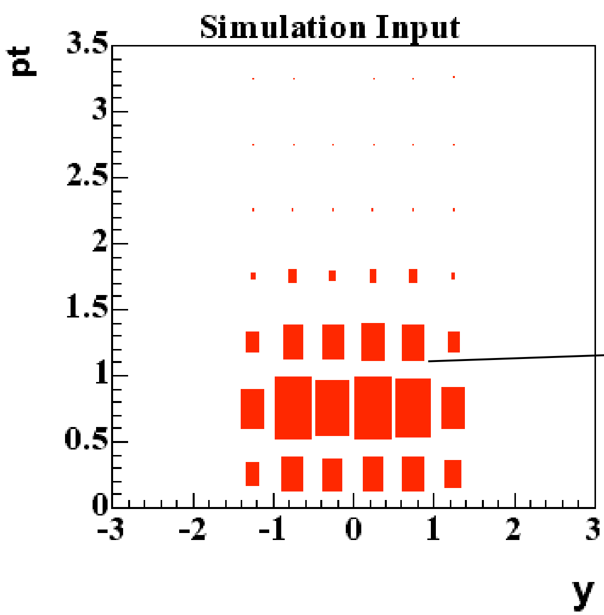


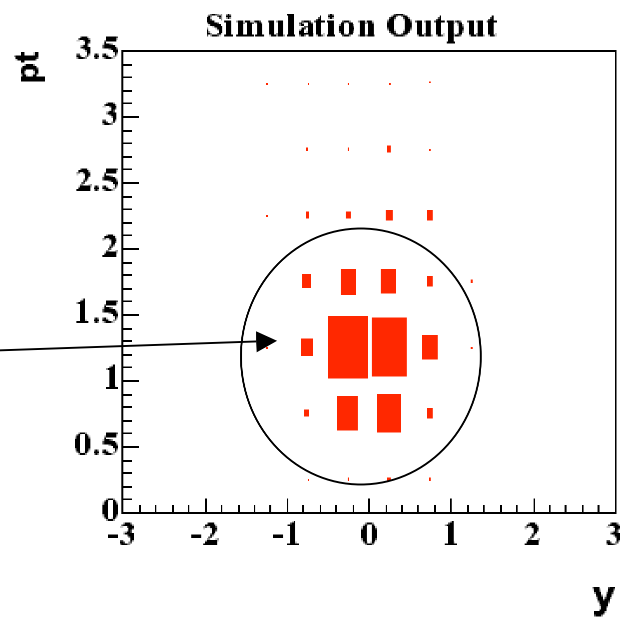
Acceptance Study for Θ^+ in p+p

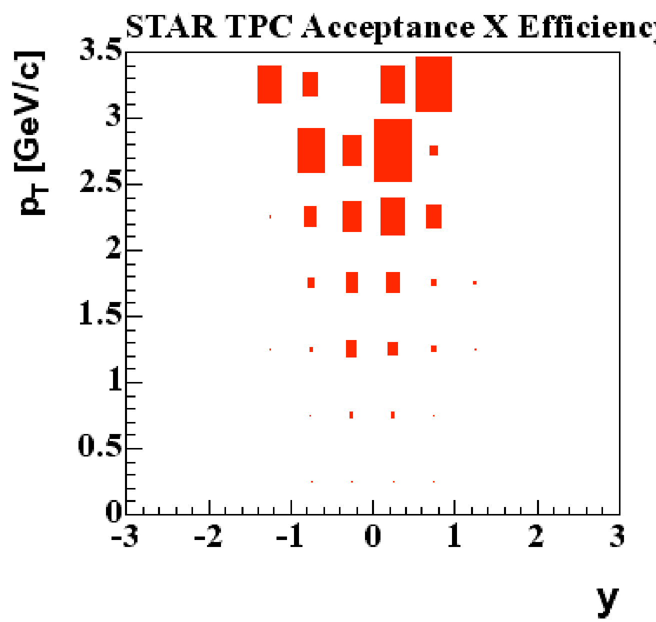






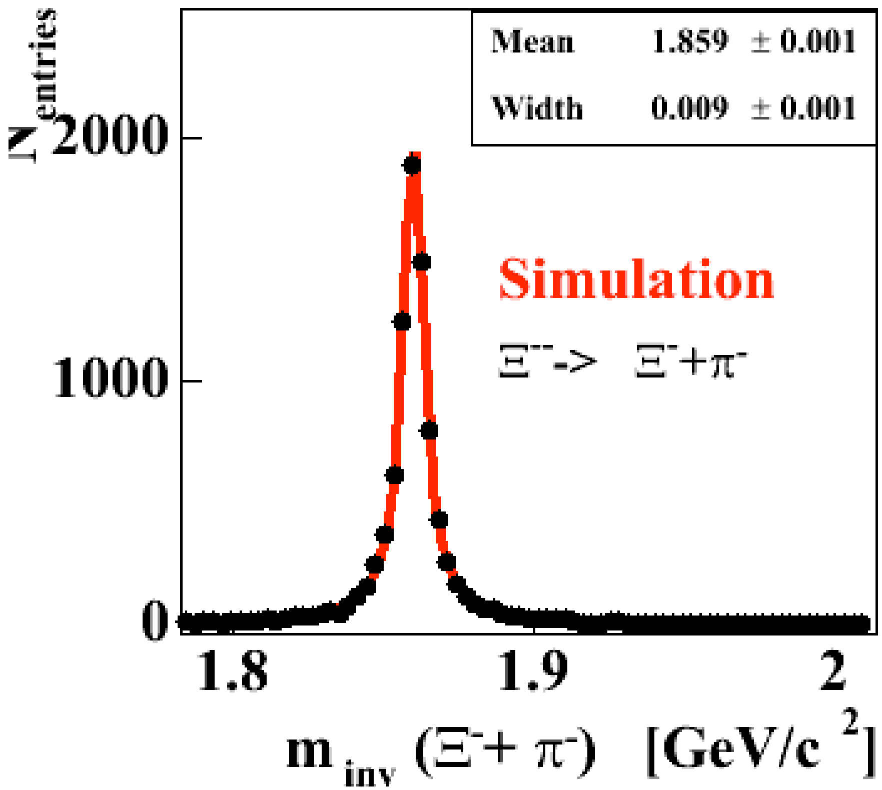


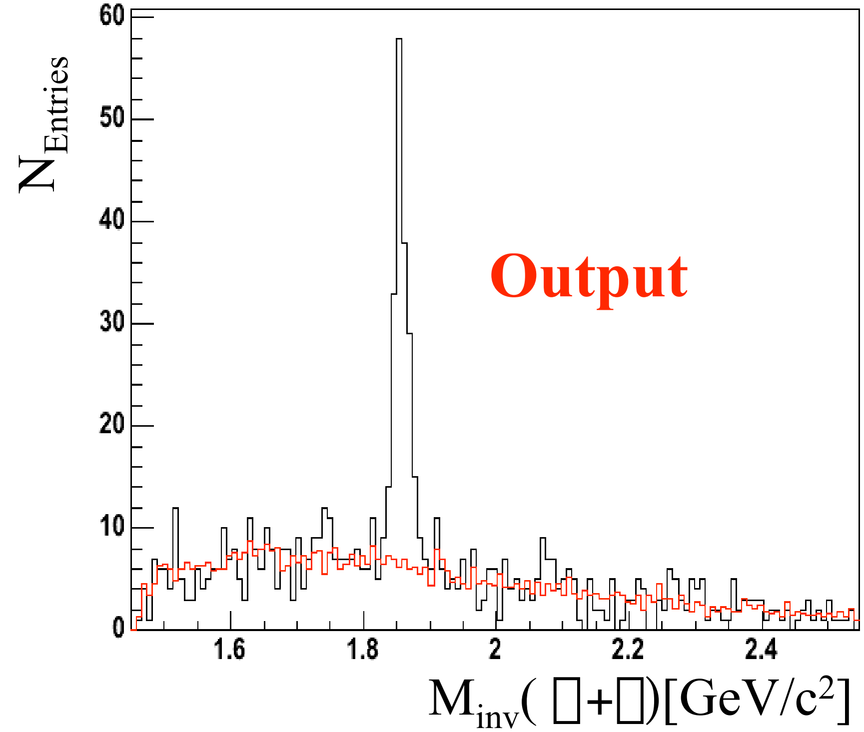


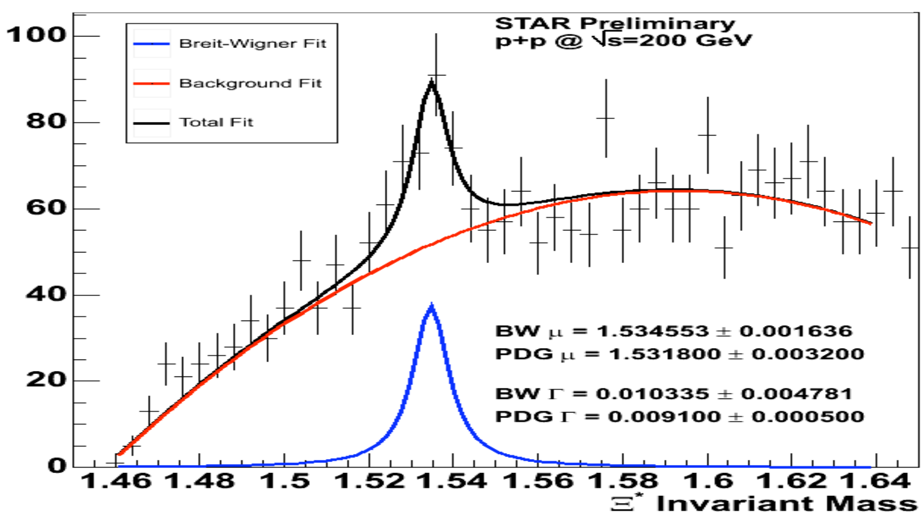


Efficiency X Acceptance ~3% .This factor depends highly on cuts applied. Investigating!

Acceptance Study for □$^{--}$ in p+p







1 □$^{□□}$'s per event embedded

Acceptance ~2.3 %

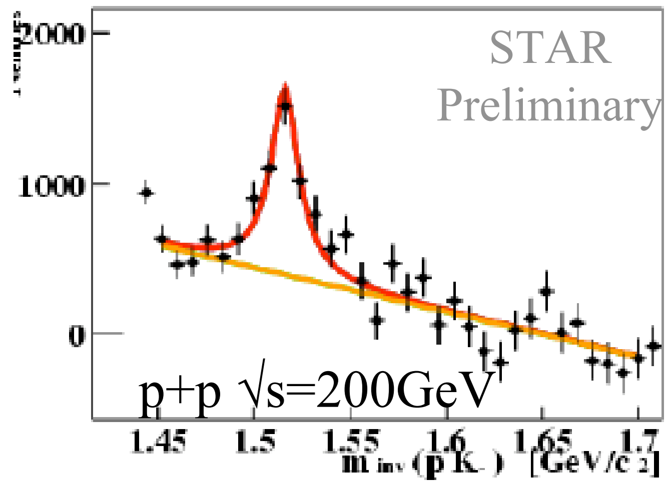
□□(1530)→□+□

Feasibility Studies with current p+p data

Ballpark Number

~0.1-1 □ per □(1520) for p+p

- Preliminary dN/dy
  of □(1520) in pp→ 0.004 per event
- 8 Million X 0.004 → 32 K □(1520)
- 0.1-1 X 32 K □ in pp → 3-32 K
- Efficiency 3% → 90-960
- Branching Ratio 50% → 45-480



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

- 0.0004 X 8 Million → 3200

Significance □ = Signal/√(2 X Background+Signal)

□ → 0.5-6

STAR

Feasibility Studies with current Au+Au data

From AuAu to pp we have a slightly smaller efficiency with a much higher background!

W. Liu, C.M. Ko **Phys.Rev.C68:045203,2003**
J.Letessier, G.Torrieri, S.Steinke and J.Rafelski **hep-ph/0310188**
Jorgen Randrup **nucl-th/0307042**

~0.5-1.5 □ per event for AuAu

- 0.5-1.5 X 1.5 Million → 0.8-2.3 Million
- Efficiency 3% → 25-70 K
- Branching Ratio 50% → 10-35 K

Background pairs per event in the mass range of □ is 2.

- 2 X 1.5 Million → 3 Million

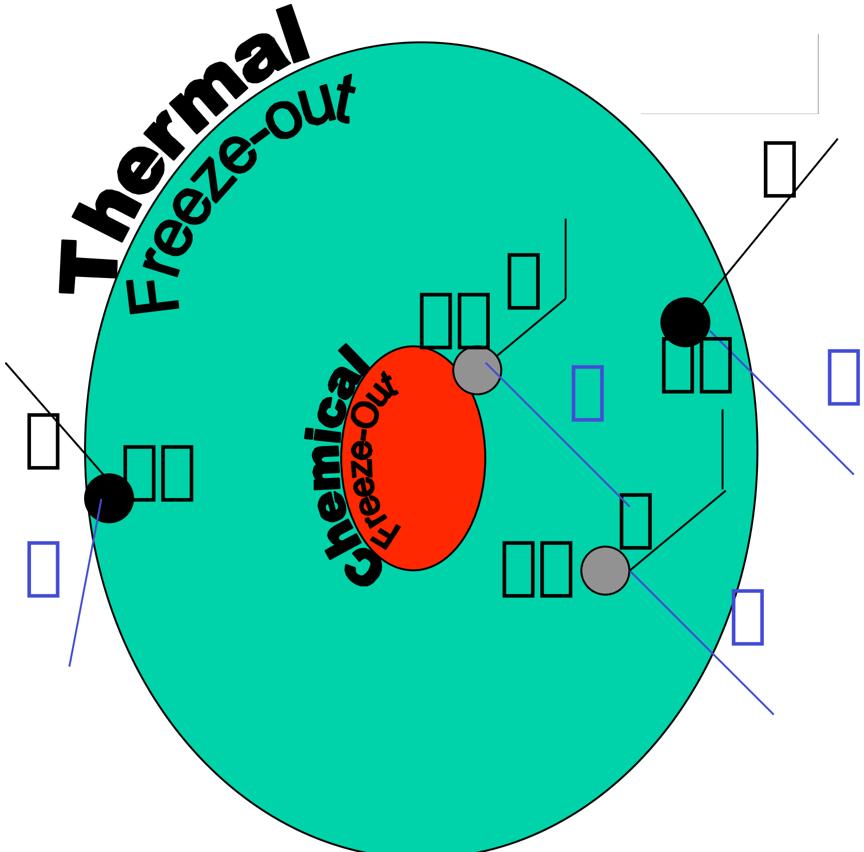
Significance □ = Signal/√(2 X Background+Signal)

□ → 4-14

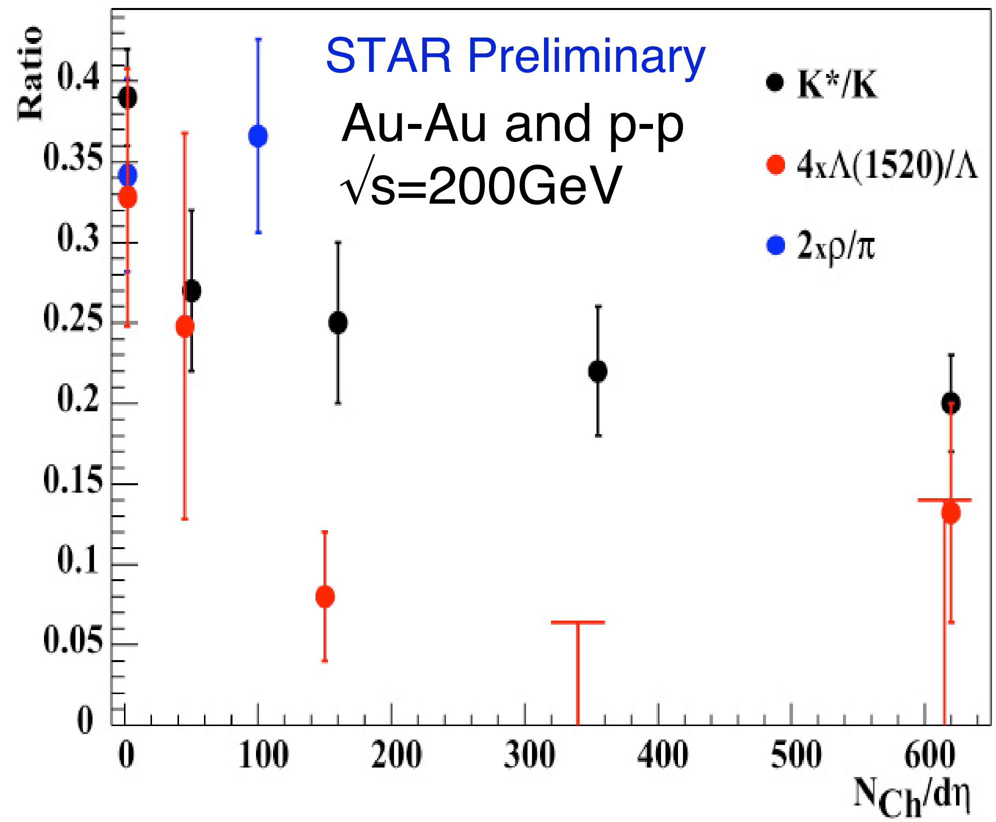
But bin by bin fluctuations …

We might be losing some of it via re-scattering of daughters.

Resonance Ratios



Lost □* due to re-scattering
Found □*



□ → □+□ (1.3 fm/c)
K* → K+□ (4 fm/c)
□(1520) → p+K (13 fm/c)

Conclusion & Near Future Plans

•Preliminary acceptance and efficiency studies shows that we should be able to find the pentaquarks at the few % level.

(Resonances can be clearly reconstructed via event mixing techniques in p-p , d-Au and Au-Au central collisions.)

•Can measure the anti pentaquarks at RHIC. (antibaryon/baryon~1)

•STAR measures particles at mid rapidity $|y|<1$and $|y_{Beam}|\sim6$.

Are the pentaquarks made away from the fragmentation region?

•Much more data from upcoming Run 4 !!!

Au+Au at $\sqrt{s_{NN}}$=200 GeV 100 Million Events planned. (70 times the Current Data)

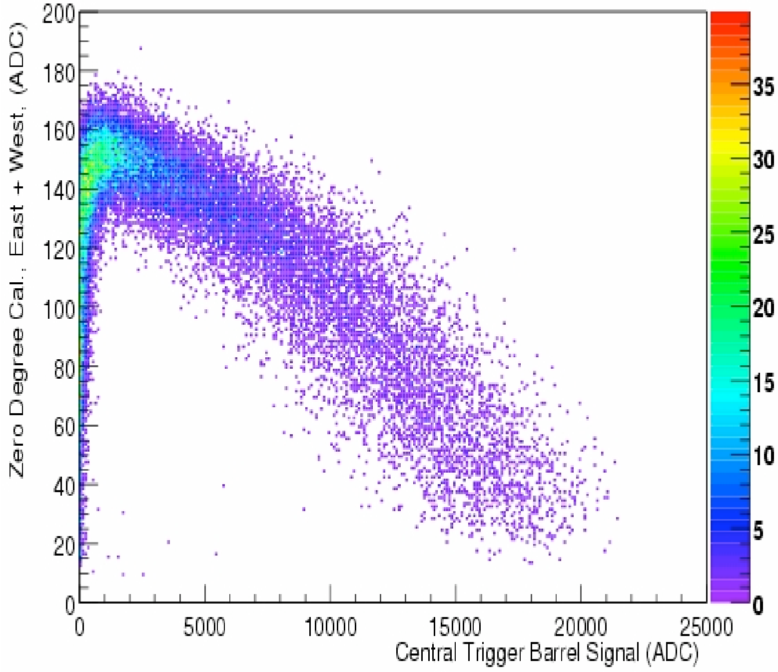
STAR continues to search pentaquarks with Bern University, UCLA, Yale University

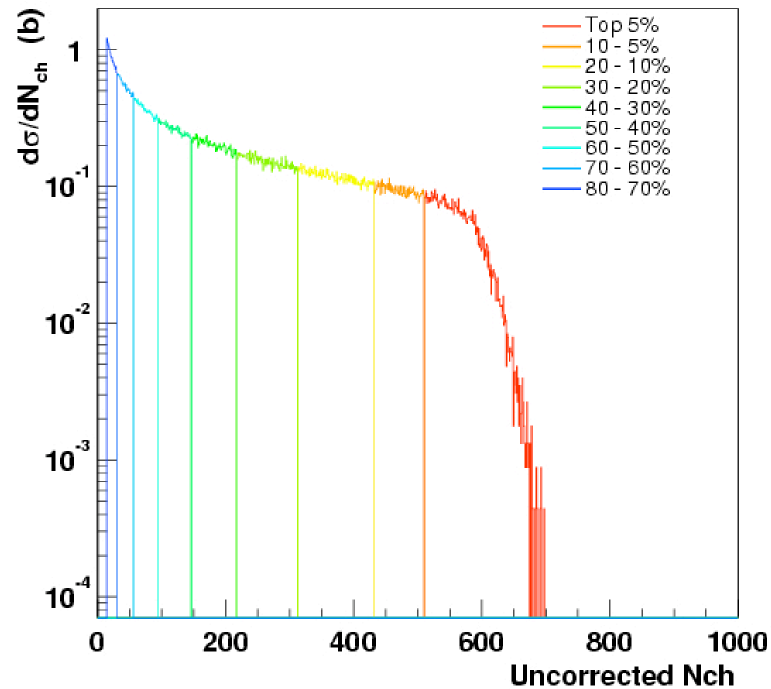
The STAR Collaboration

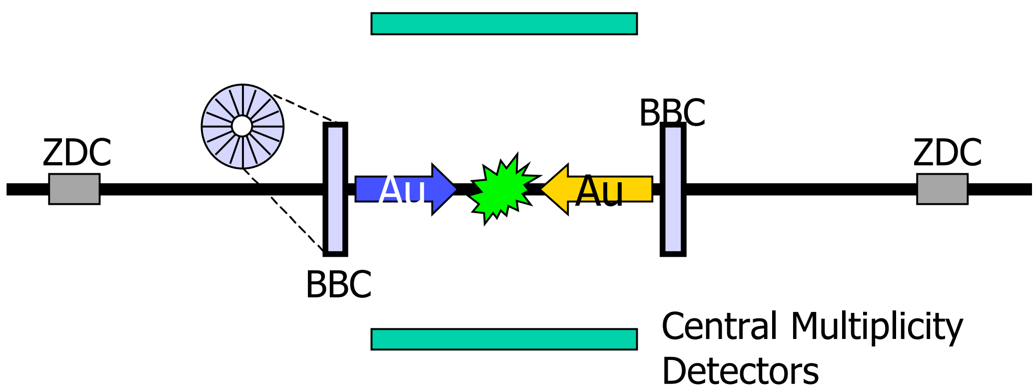
Argonne National Laboratory• Institute of High Energy Physics, Beijing• Institute of Physics, Bhubaneswar• University of Birmingham• Brookhaven National Laboratory• University of California, Berkeley• University of California, Davis• University of California, Los Angeles• Carnegie Mellon University• Creighton University• Laboratory for High Energy (JINR), Dubna• Particle Physics Laboratory (JINR), Dubna• University of Frankfurt• Indiana University, Bloomington• Institut de Recherches Subatomiques, Strasbourg• Jammu University• Kent State University• Institute of Modern Physics, Lanzhou• Lawrence Berkeley Laboratory• Max-Planck-Instit fuer Physik, Munich• Michigan State University• Moscow Engineering Physics Institute• Indian Institute of Technology, Mumbai• City College of New York• Ohio State University• Panjab University• Pennsylvania State University• Institute of High Energy Physics, Protvino• Purdue University• University of Rajasthan• Rice University• Universidade de Sao Paulo• University of Science and Technology of China (USTC)• Shanghai Institue of Nuclear Research (SINR)• SUBATECH, Nantes• Texas A & M• University of Texas, Austin• Tsinghua University• Variable Energy Cyclotron Centre, Kolkata• Warsaw University• Warsaw University of Technology• University of Washington• Wayne State University• Institute of Particle Physics, Wuhan• Yale University

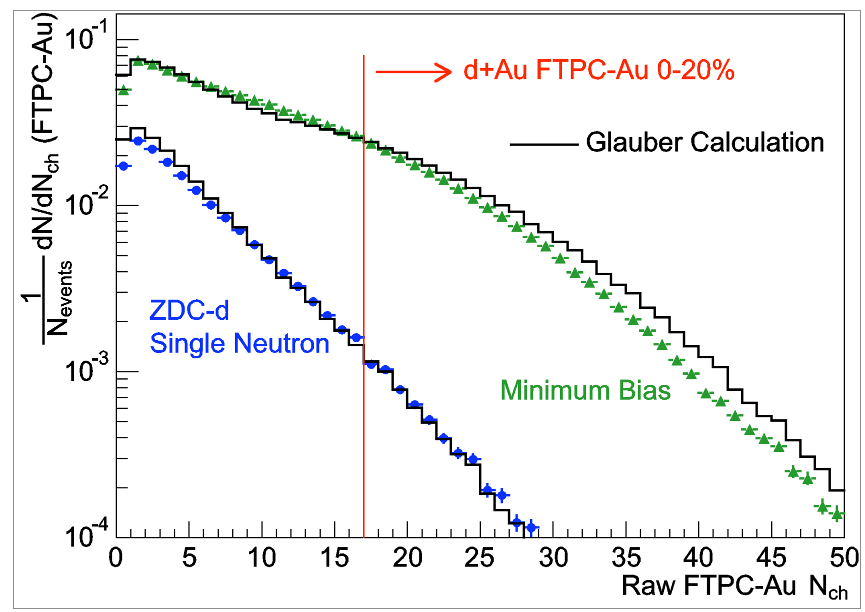
EXTRAS …..

Trigger

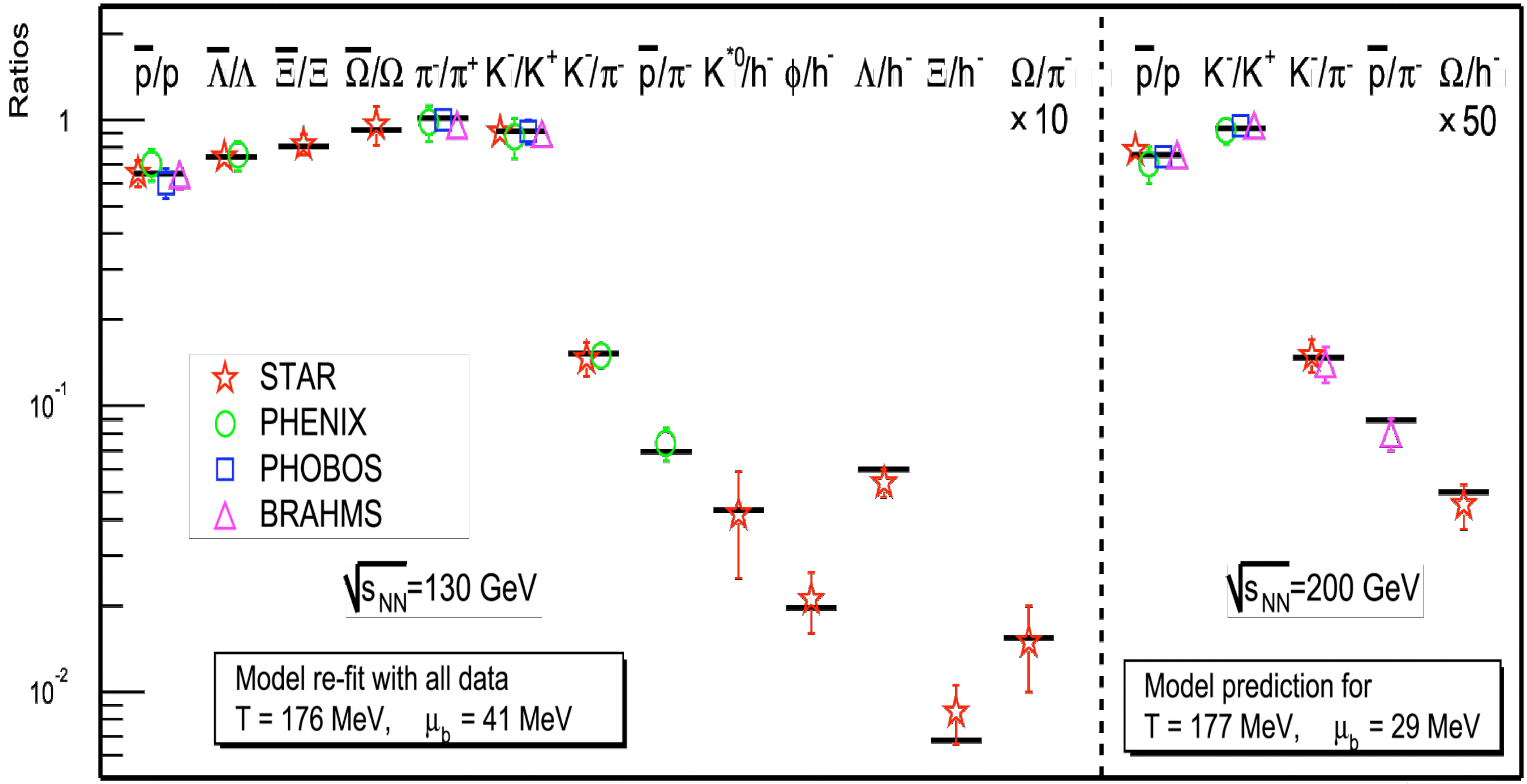

Zero Degree Cal., East + West, (ADC)
Central Trigger Barrel Signal (ADC)
0
5000
10000
15000
20000
25000
0
20
40
60
80
100
120
140
160
180
200
0
5
10
15
20
25
30
35


dσ/dN_ch (b)
Uncorrected Nch
Top 5%
10 - 5%
20 - 10%
30 - 20%
40 - 30%
50 - 40%
60 - 50%
70 - 60%
80 - 70%
0
200
400
600
800
1000


ZDC
BBC
Au
Au
BBC
ZDC
Central Multiplicity
Detectors


1/N_events dN/dN_ch (FTPC-Au)
d+Au FTPC-Au 0-20%
Glauber Calculation
ZDC-d
Single Neutron
Minimum Bias
Raw FTPC-Au N_ch

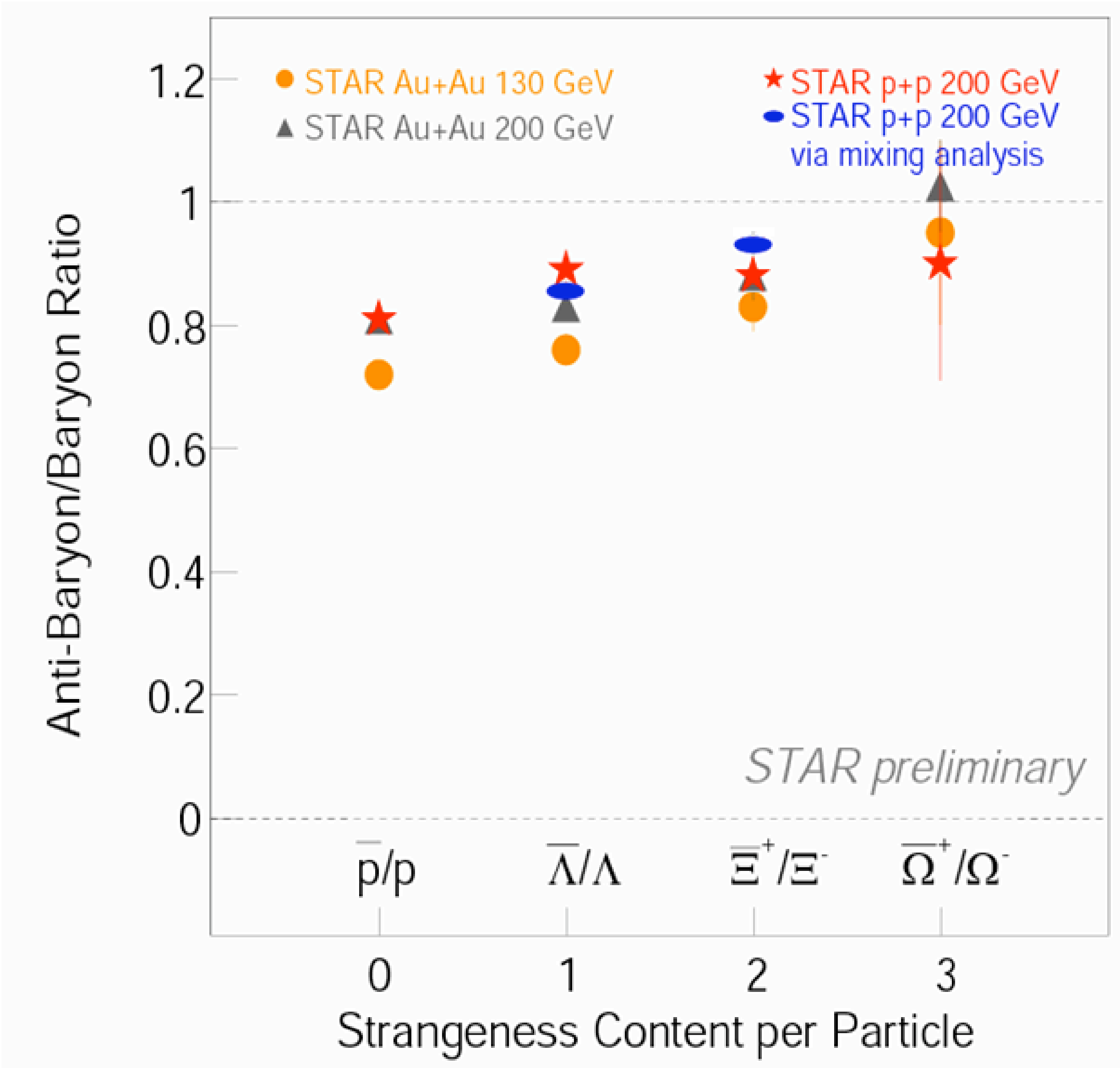
Statistical Model



Braun-Munzinger et al., PLB 518 (2001) 41

D. Magestro (updated July 22, 2002)

Anti Baryon to Baryon Ratio



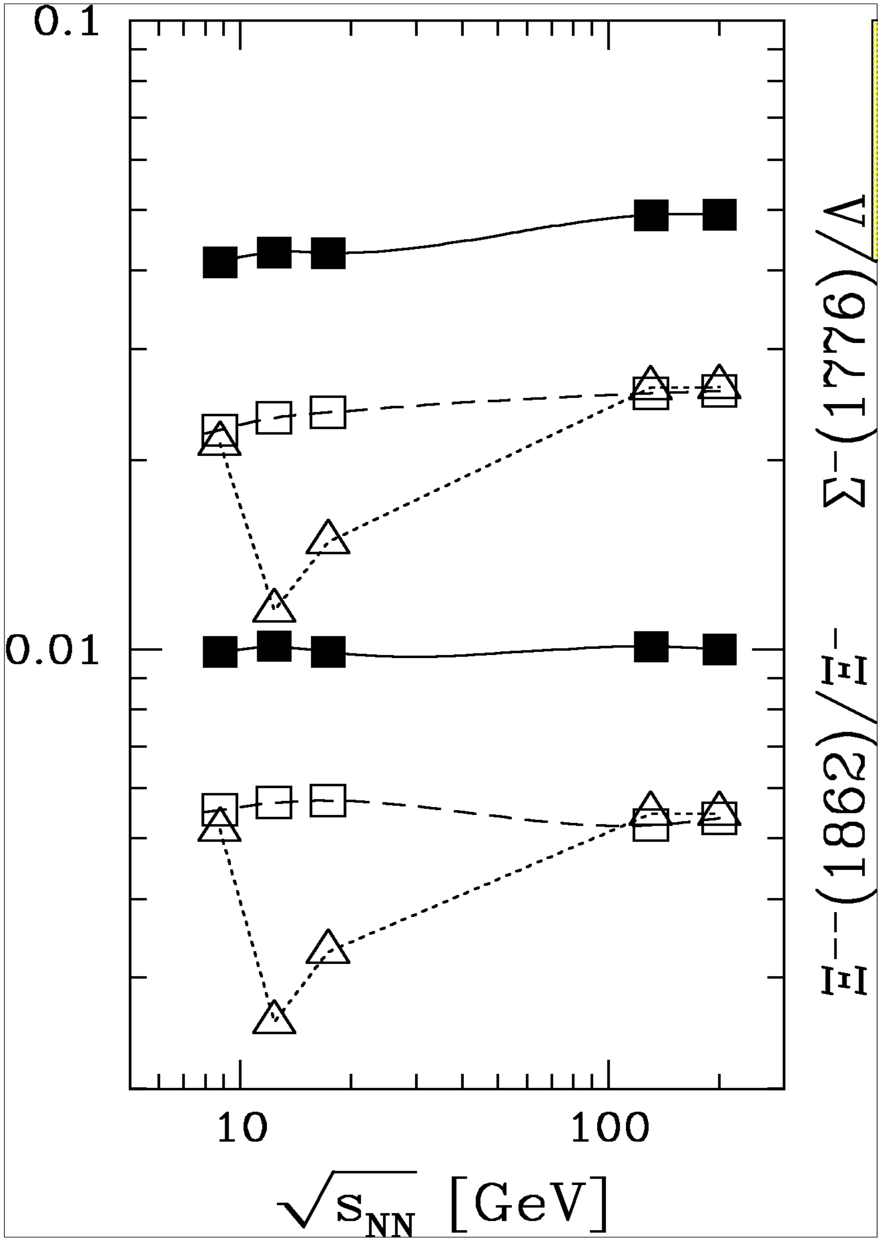


FIG. 2: Yield of $\Theta^+(1540)$ in relativistic heavy ion collisions, based on statistical hadronization fit to hadronization parameters at SPS and RHIC 40, 80, 158A GeV Pb on stationary Pb target collisions and at RHIC for 65+65 and 100+100A GeV Au–Au head on interactions. Relative yields with K_s, Λ, and $\Lambda(1520)$ are shown from bottom to top.

nances in figures 2 and 3. These yields vary strongly with collision energy for the case of $\Theta^+(1540)$ in figure 2, but are rather constant in figure 3. Certainly our result differs greatly from expectations arising from an earlier study of the statistical model production of the $\Theta^+(1540)$ resonance [23] where the decisive variation of the particle yield with chemical potentials was not explored. Moreover, the hadron yields, presented in [23], did not include the contributions from decay of short lived hadron resonances. We checked that the relative particle yields shown in [23] for zero chemical potentials and varying temperature are mathematically correct, also as a cross check of our program.

In figure 2, we show (from top to bottom) the relative yields $\Theta^+(1540)/\Lambda(1520)$, $\Theta^+(1540)/\Lambda$, $\Theta^+(1540)/K_s$ for chemical nonequilibrium (solid lines), semi-equilibrium ($\gamma_s = 1$, dashed lines) and chemical equilibrium (dotted lines). The yields of Λ used here include 50% weak interaction cascade from Ξ.

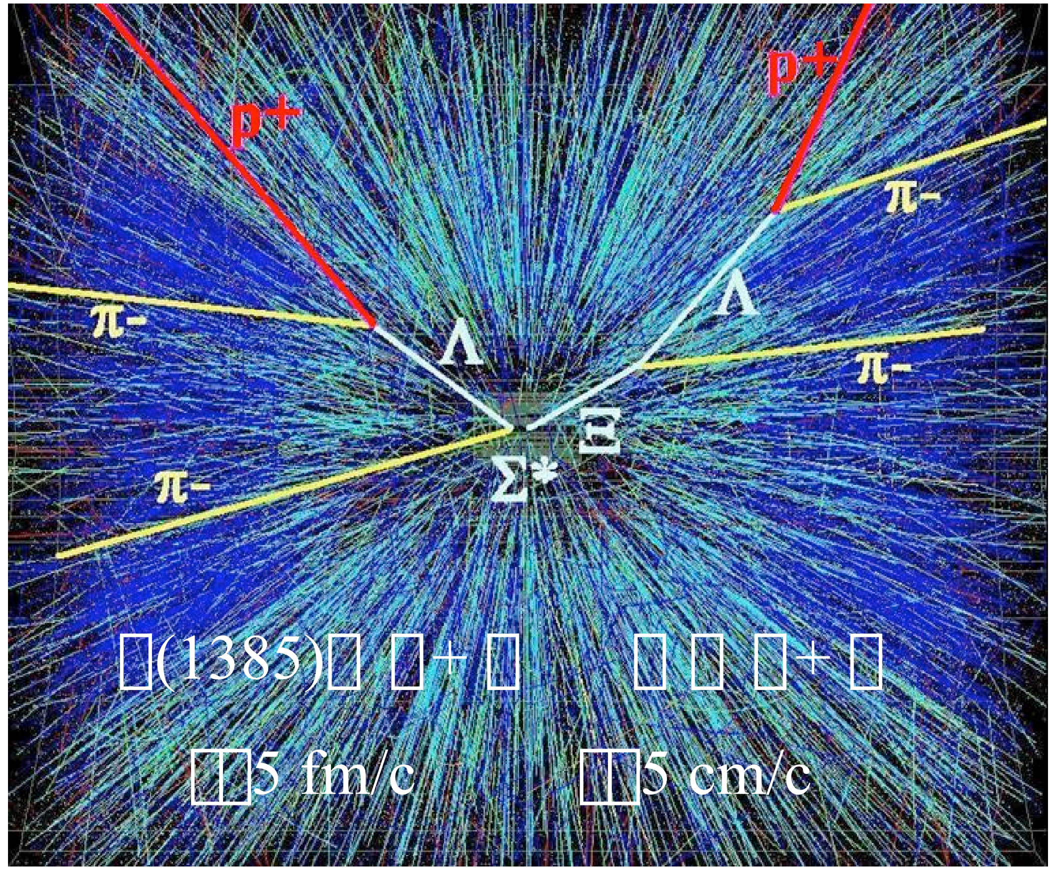
The reason that the chemical nonequilibrium is leading to greater than equilibrium yields is that the

Resonance Analysis Techniques

Resonances cannot be directly identified with the decay topology information due to their very short lifetime.

Example: Reconstructing □*

A □ candidate is mixed with a □ to get a □*(1385). The background is formed by mixing □'s from one event with the □ candidates from another event.



STAR measures charged particles with the **T**ime **P**rojection **C**hamber

This technique can be extended to identify Pentaquarks.