Recent Result on Pentaquark Searches from STAR @RHIC

Huan Z. Huang
Department of Physics and Astronomy
University of California, Los Angeles

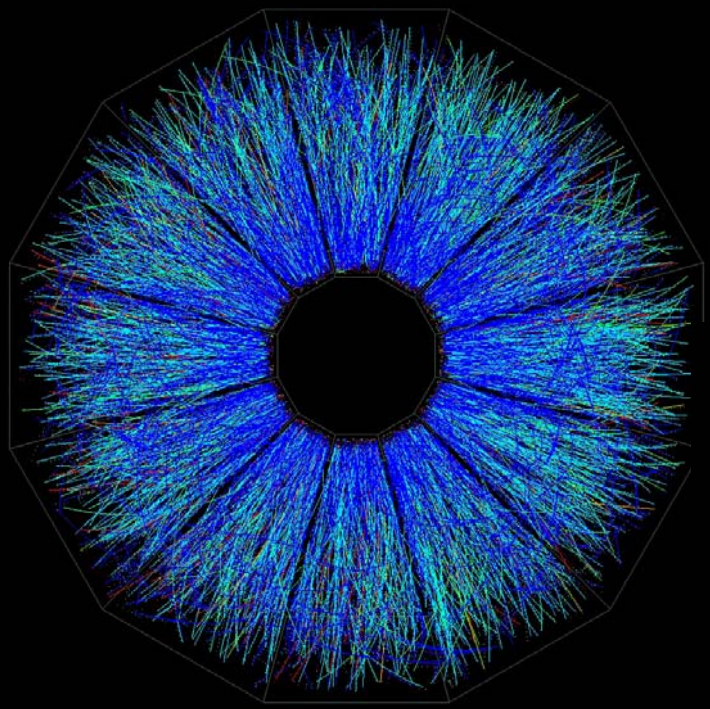
The STAR Collaboration

Pentaquark Workshop @JLab, Oct. 2005

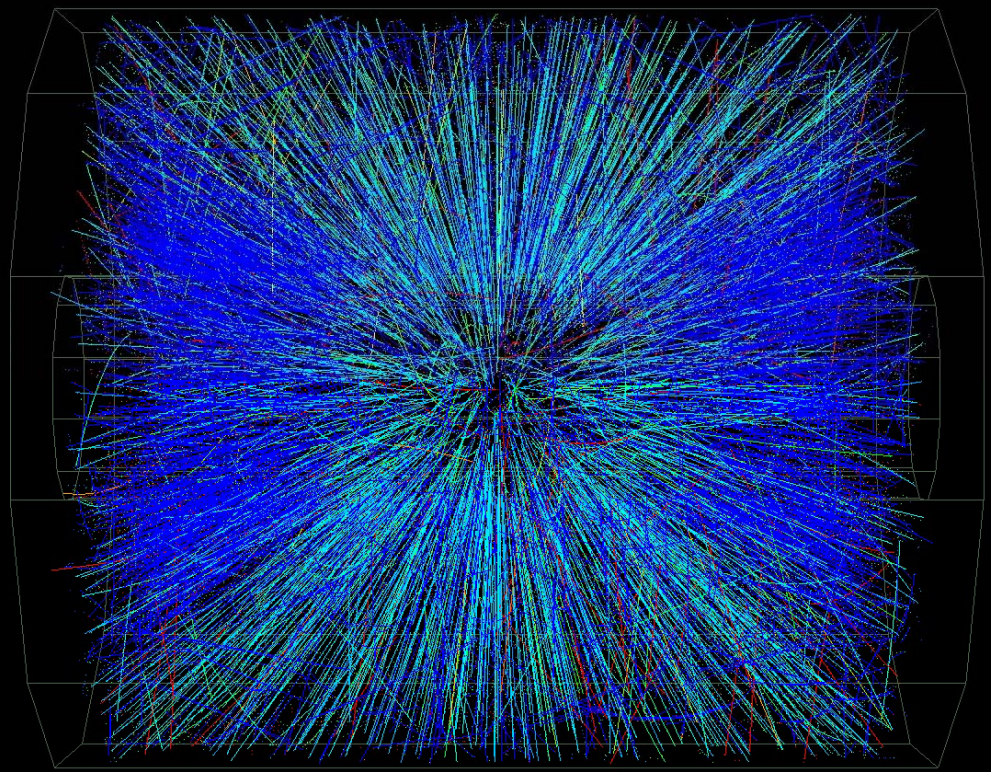
Outline

- **Pentaquark Searches in STAR**
- **The Puzzle Continues**
- **RHIC – as an Exotic Particle Factory**

Au + Au Collisions at RHIC



Central Event



STAR

(real-time Level 3)

STAR Pentaquark Searches

$\Theta^{+} \rightarrow p + K_S$

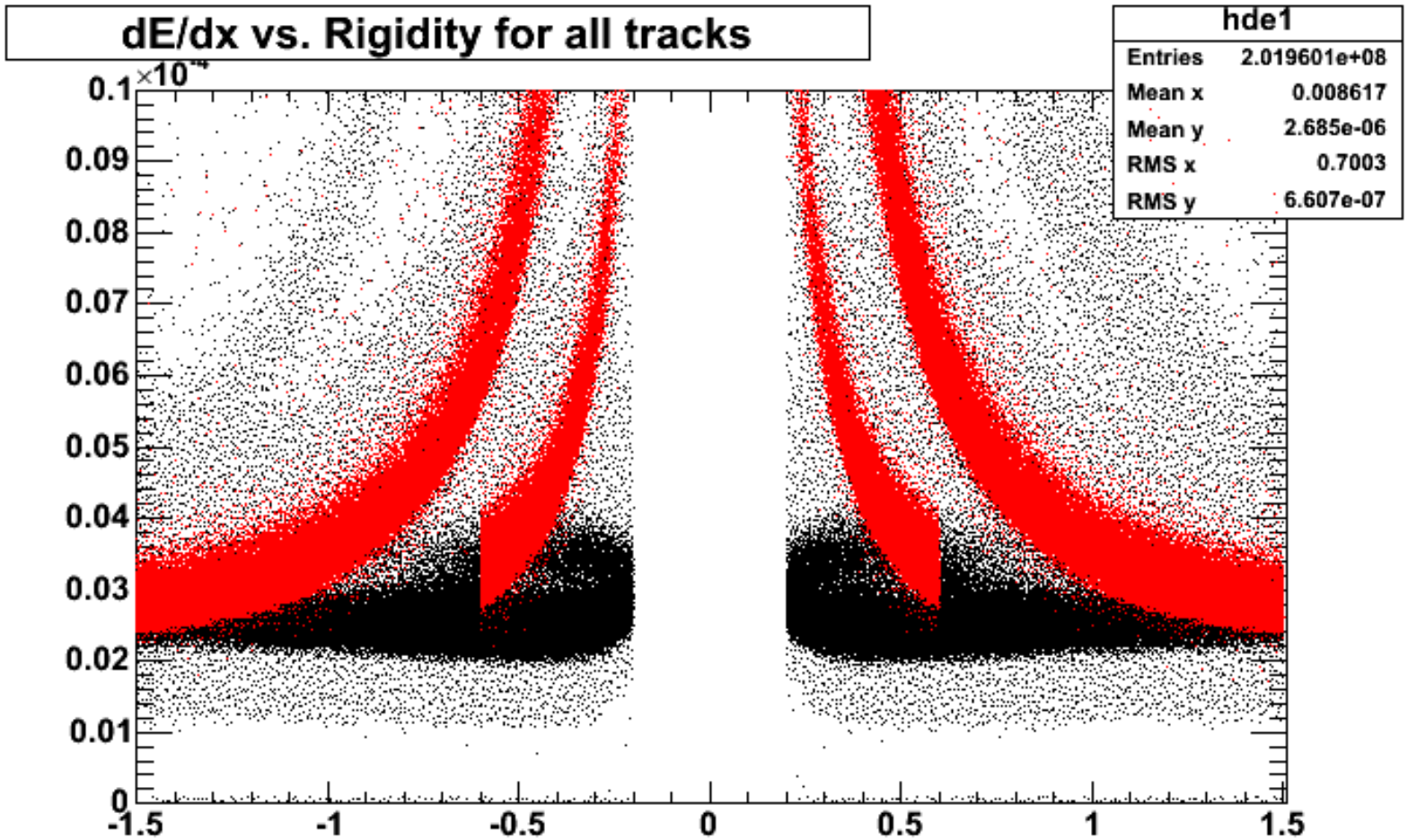
$\Theta^{++} \rightarrow p + K^{+}$

Data Set:

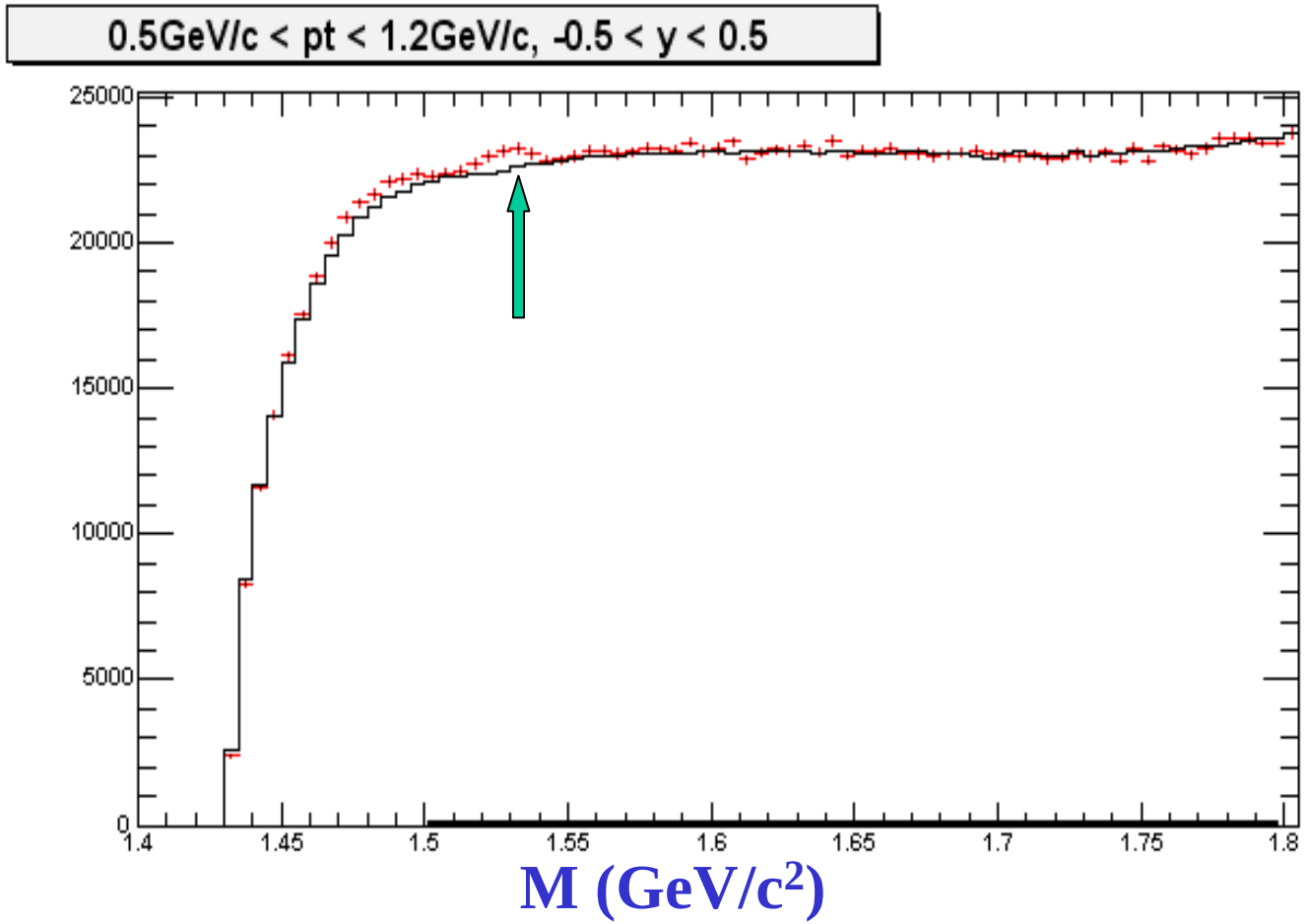
Au + Au 200 GeV run 2 (~1.7 M, 30-80%)
p + p data 200 GeV run 2 (~6.5 M)
d + Au 200 GeV run 3 (18.6 M)
Au + Au 63 GeV run 4 (5.6 M)
Cu + Cu 63 GeV run 5 (16.5 M)
Au + Au 200 GeV Run 4 (10.7 M, 20-80%)

Particle identification

Particle Identification: dE/dx from TPC



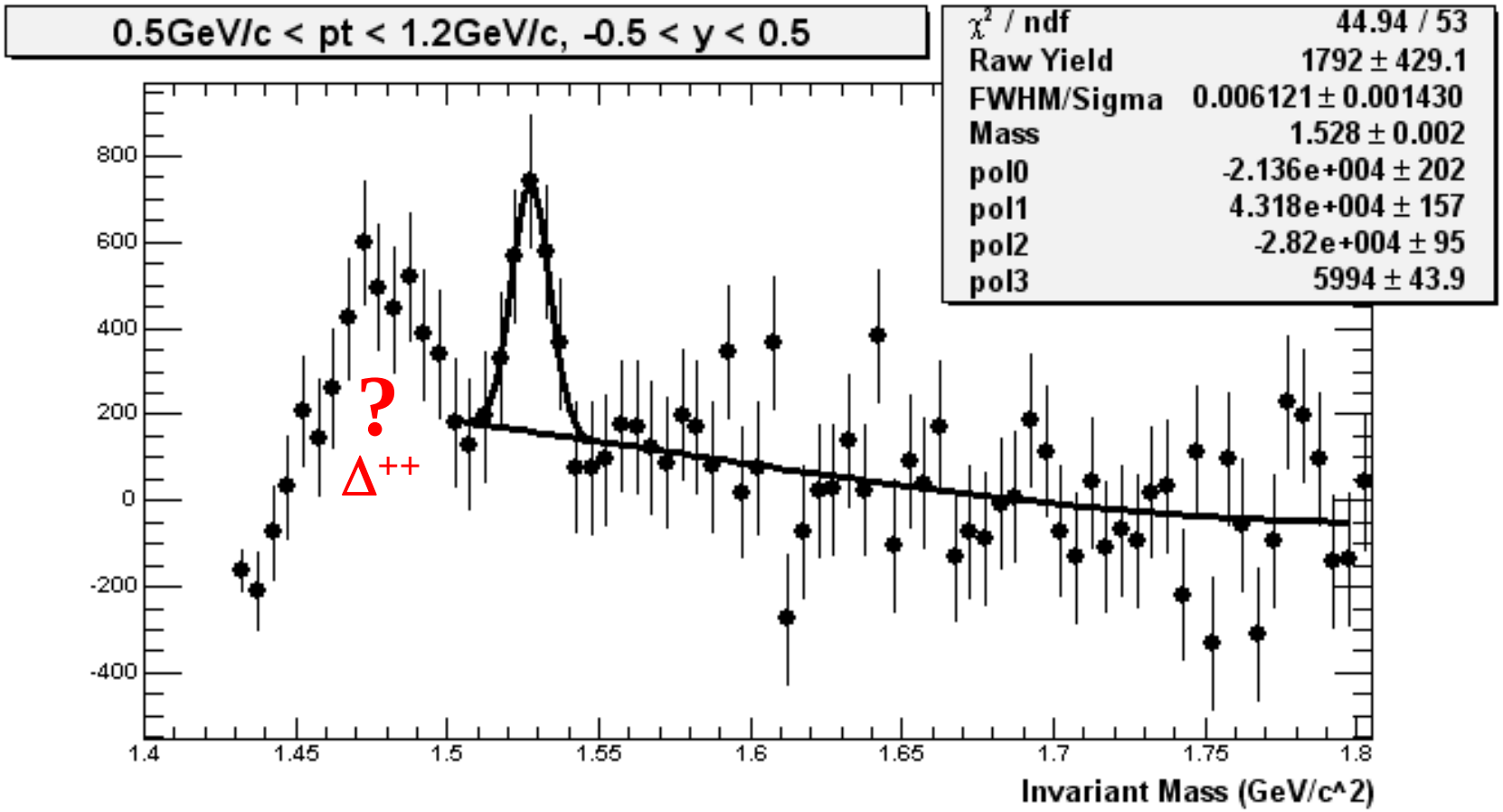
dAu results



pK^+ and $\bar{p}K^-$ from 18.6 M d+Au at 200 GeV

Background – Combinatorial and Correlated Pairs

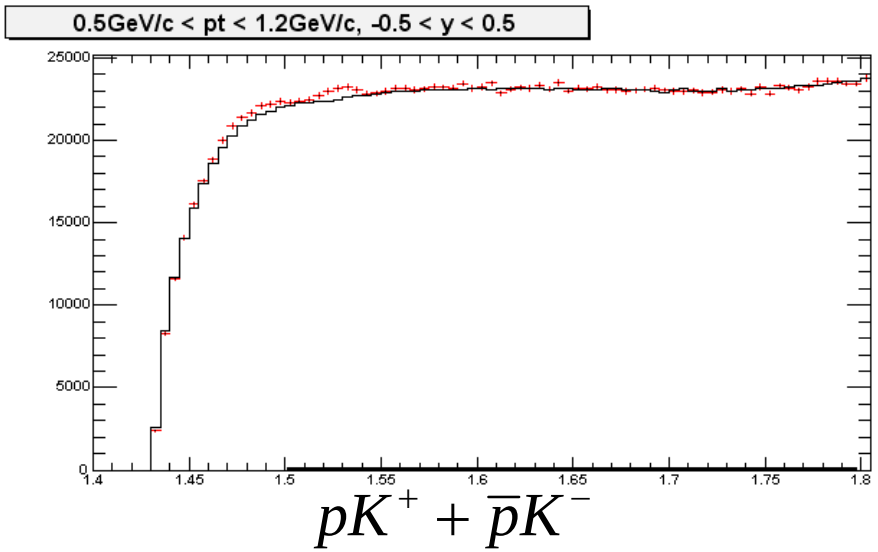
dAu results

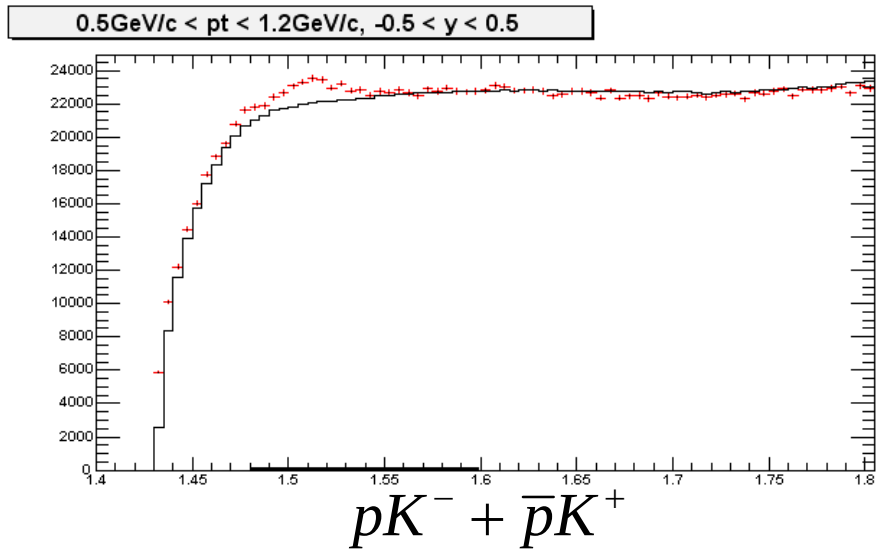


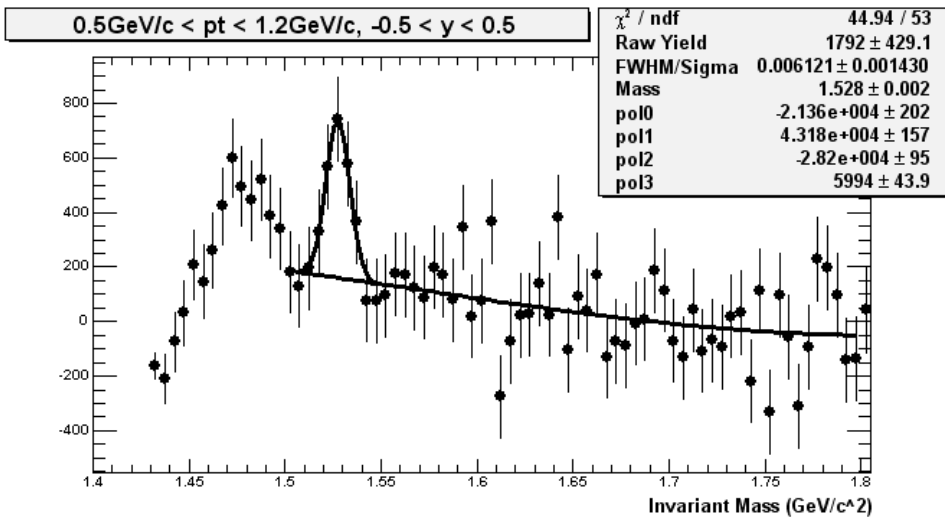
The invariant mass distribution is fitted to a Gaussian plus a linear function. A 3.5-5.0 sigma signal is seen

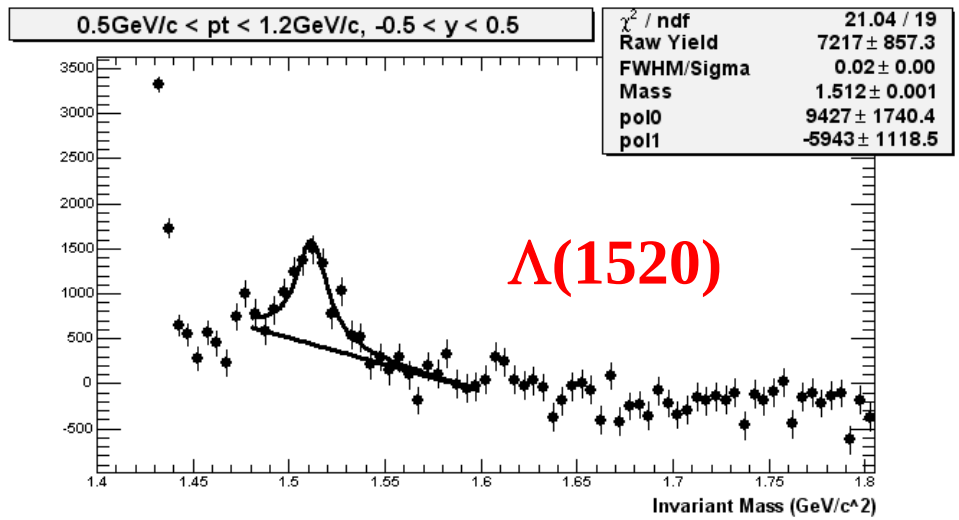
Measured mass is about 1.53 GeV/c^2. Full width is about 15 MeV

Θ^{++} and $\Lambda(1520)$ Using the Same Analysis Procedure



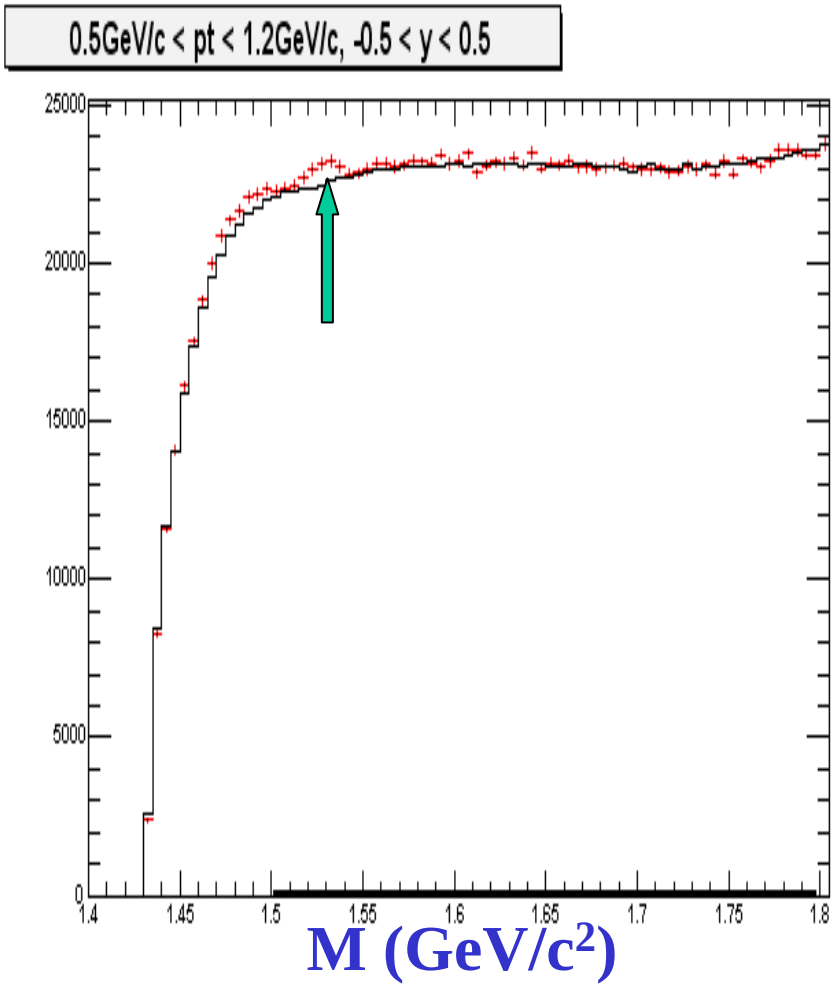




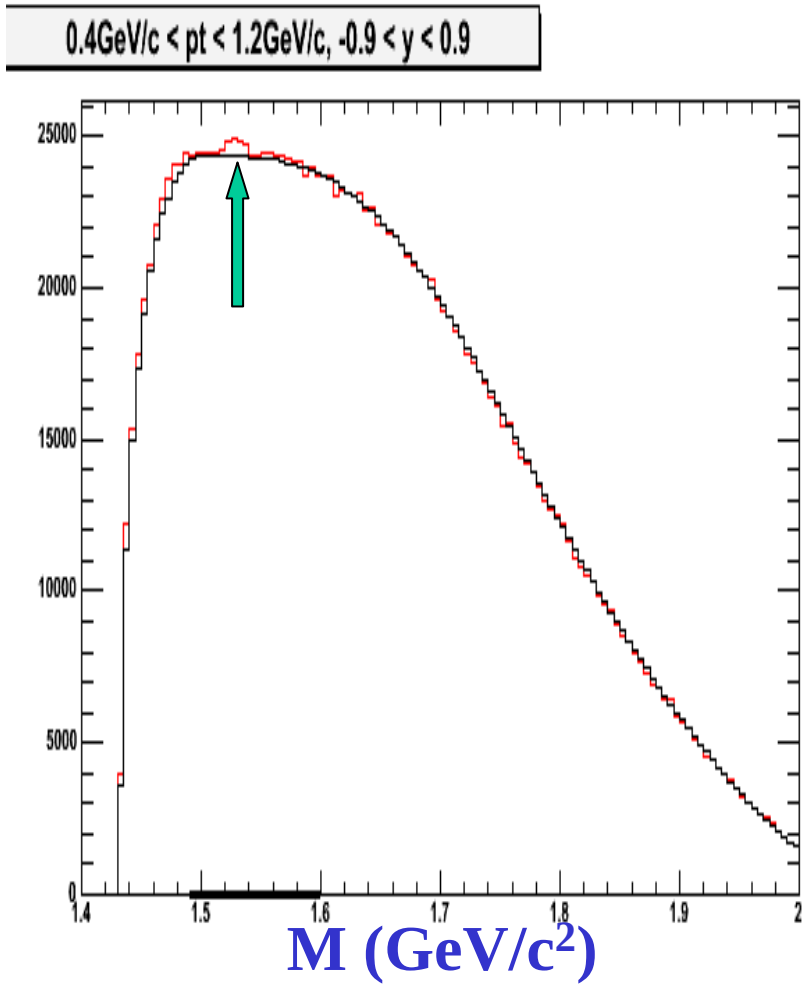


Same charge Sign (SS) and Opposite Sign (OS) background different

Background Shape Depends on Cuts



K [0.2-0.6] GeV/c
P [0.3-1.5] GeV/c



K [0.2-0.6] GeV/c
P [0.3-1.0] GeV/c

Possible Sources of Background

Double Conversion of π^0 photons

$\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^- e^+e^-$

Same-sign e's within the K and p bands

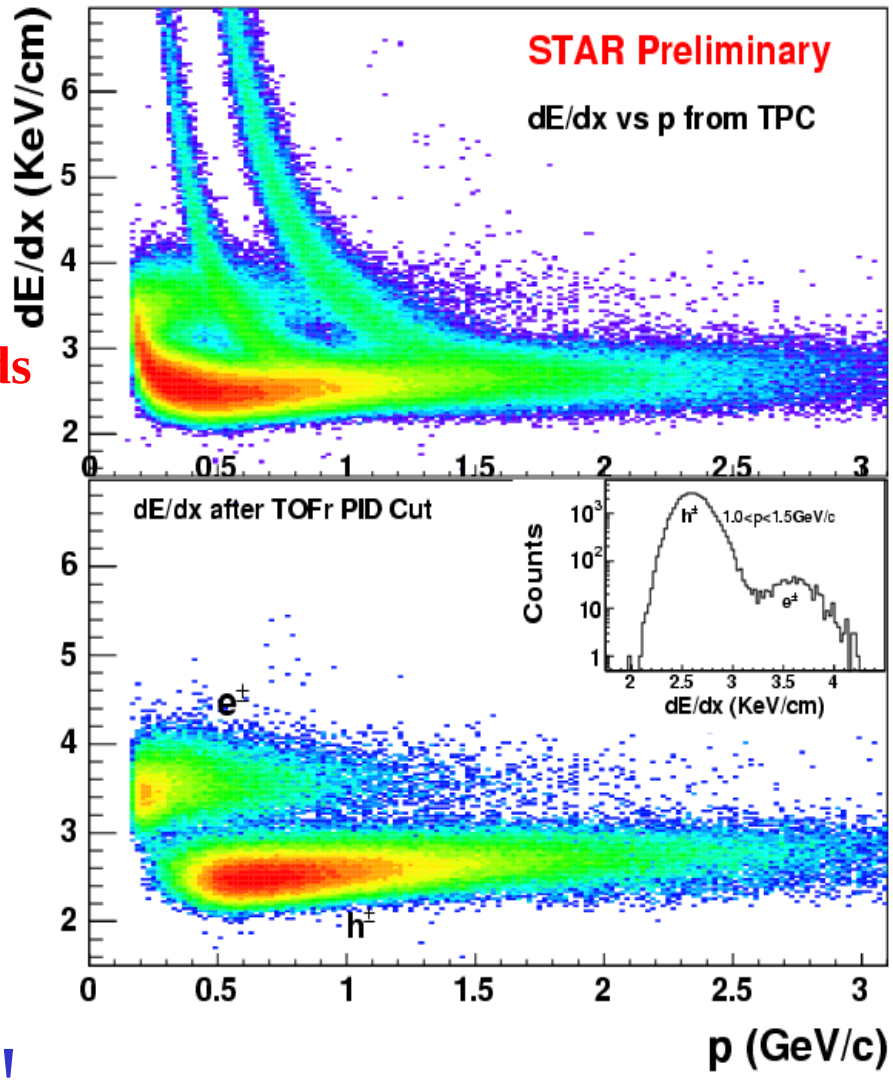
mostly in the low mass region

opening angle cut → very effective

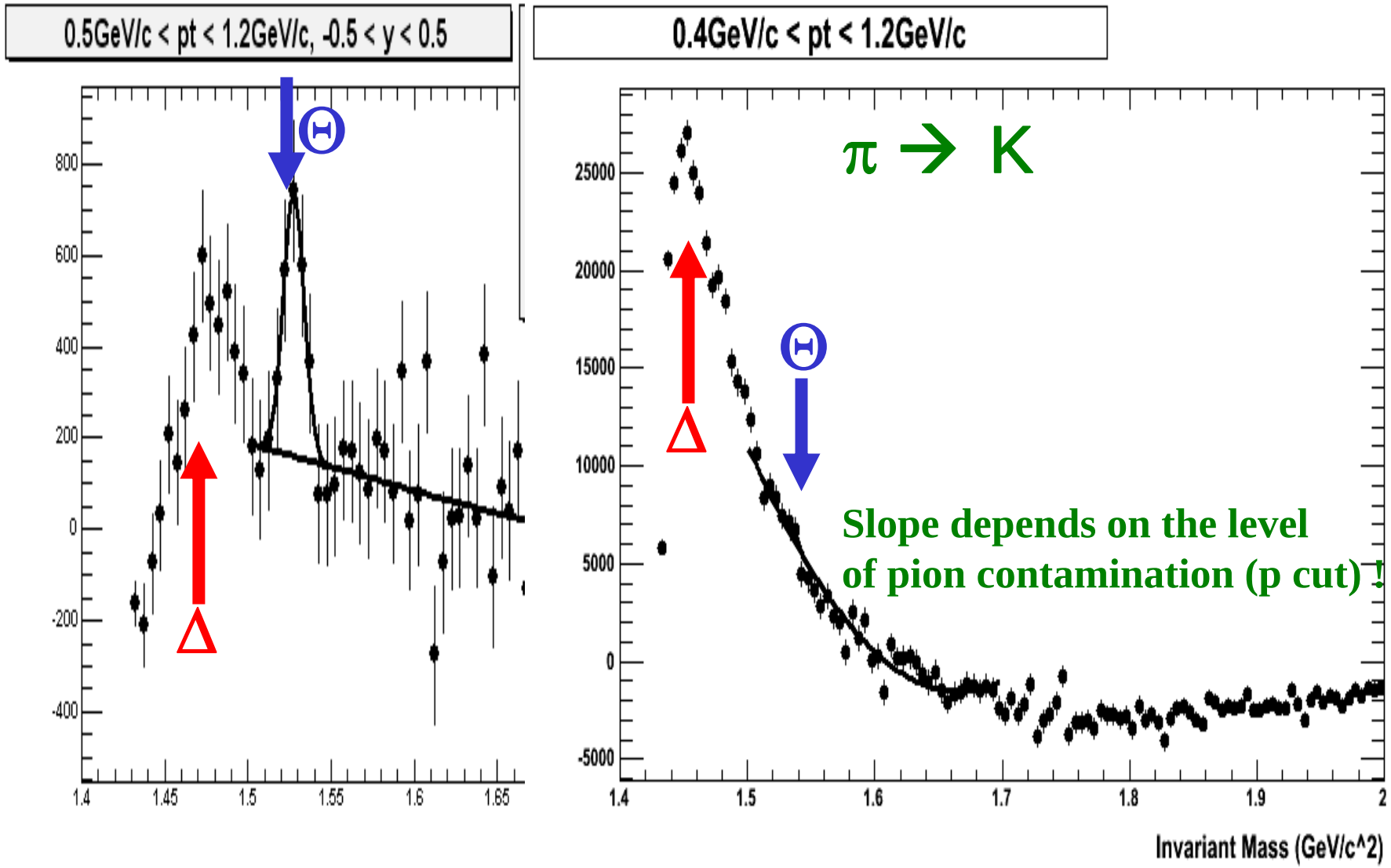
Associated production

$\Lambda K^+ \rightarrow p\pi^- + K^+$

These background sources contribute to the residuals in the event-mixing. But they do not produce a narrow peak !

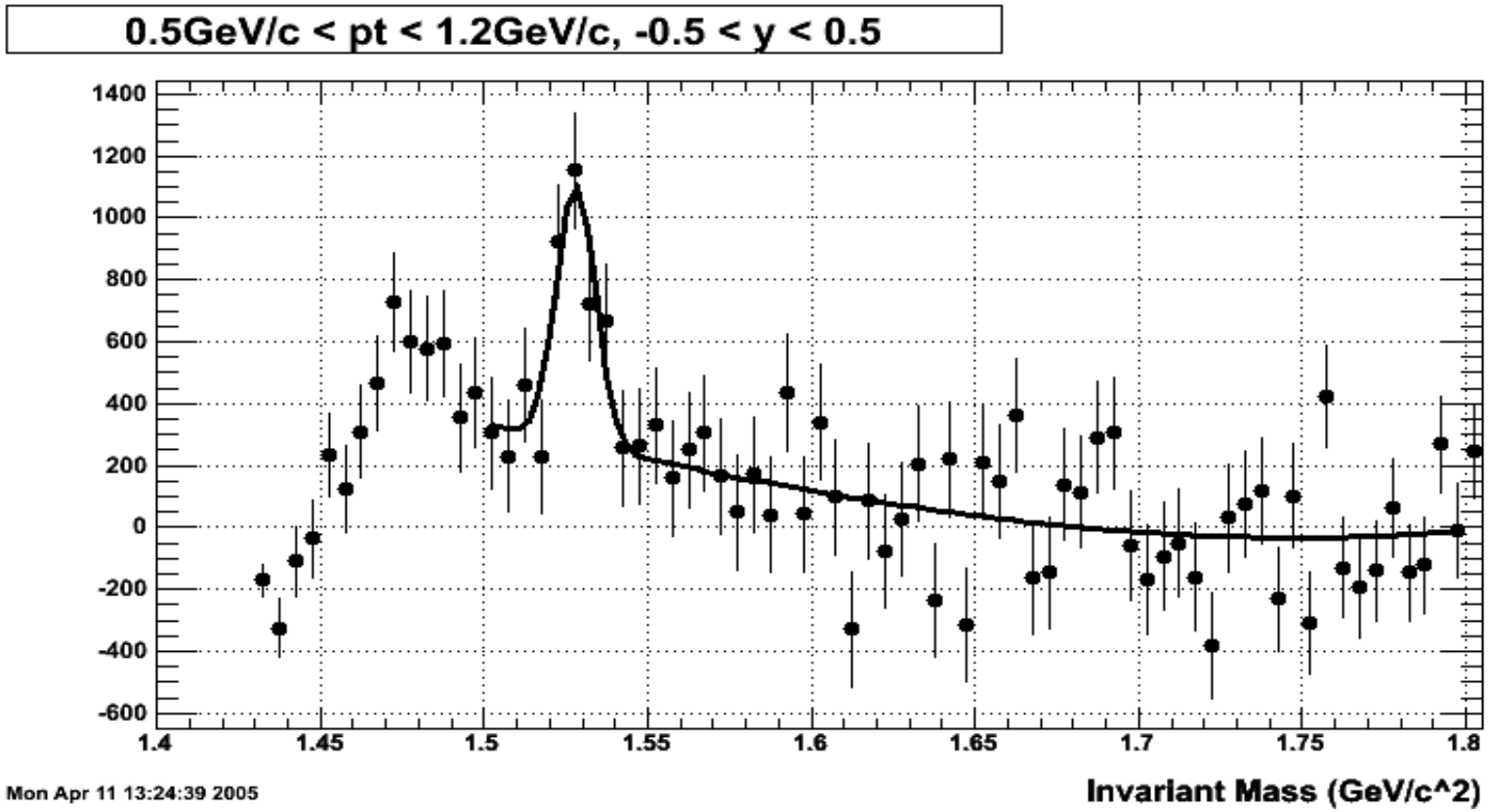


$\Delta^{++} \rightarrow \pi + p$ and using π as K



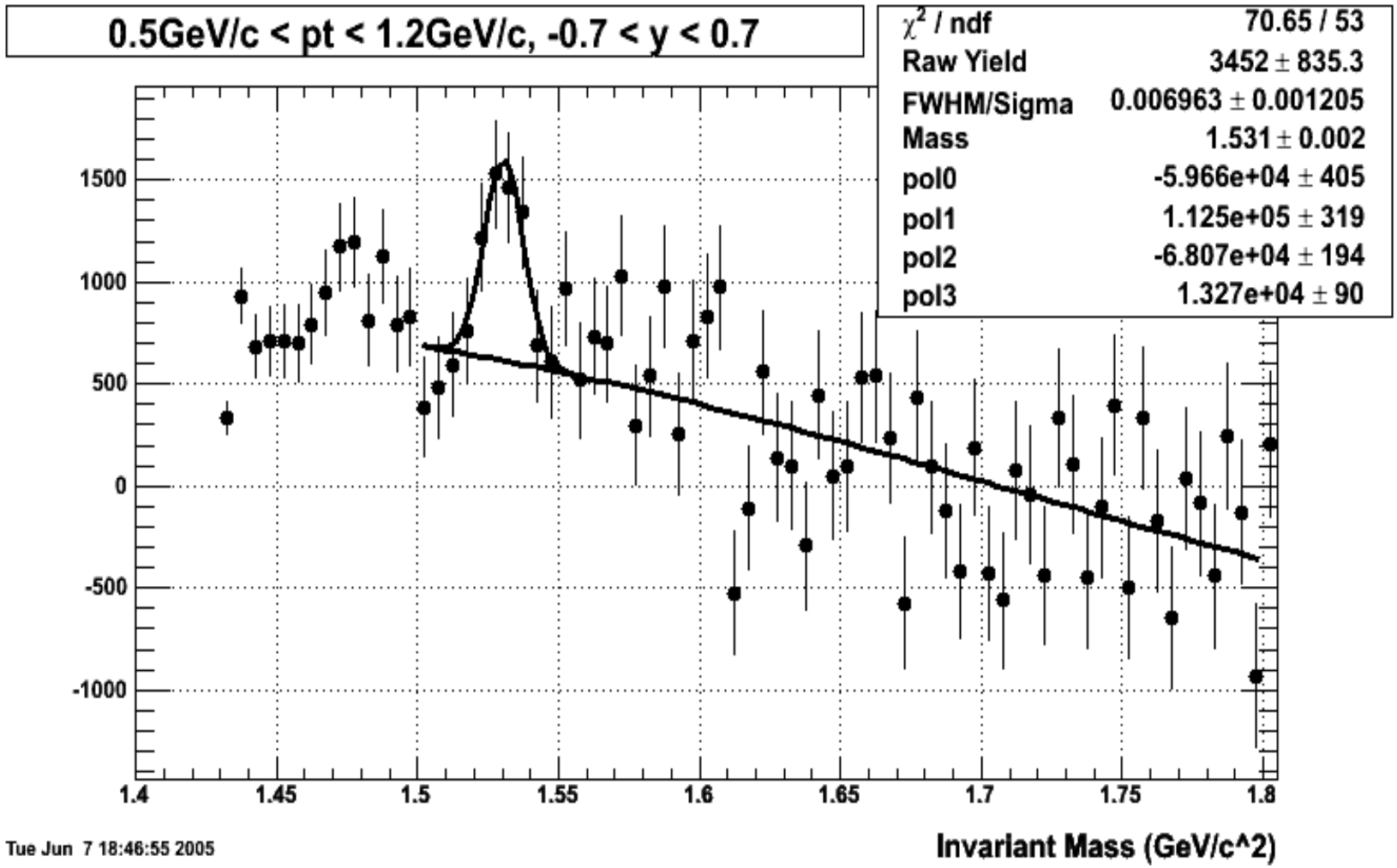
Other PID Cuts

Kaon 0.2<p&pt<0.7, Proton 0.3<p&pt<1.0, no opening angle cut

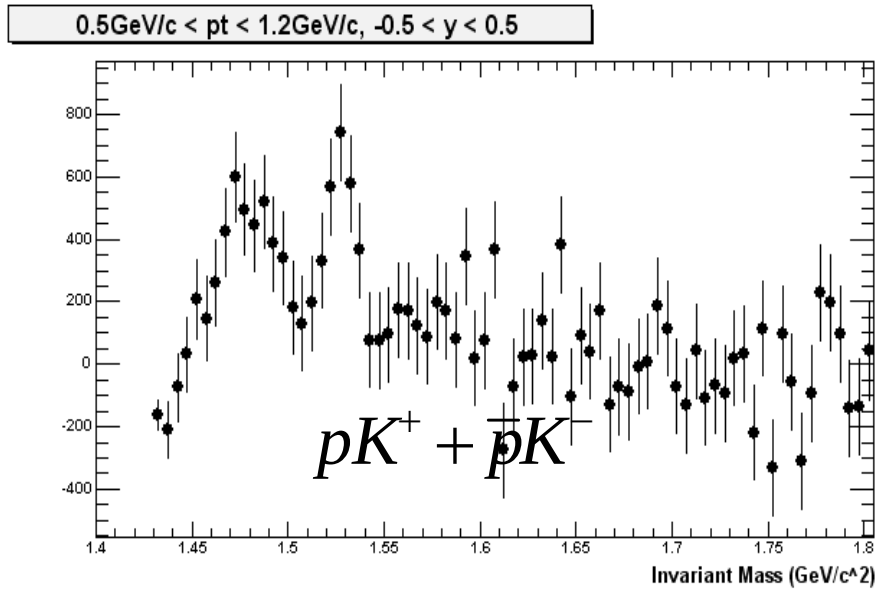


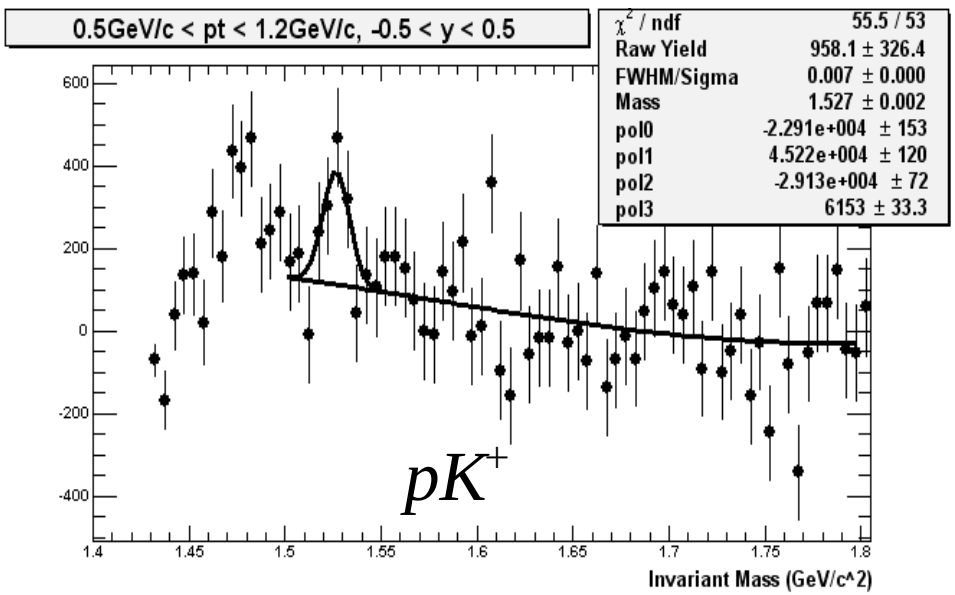
Other PID Cuts

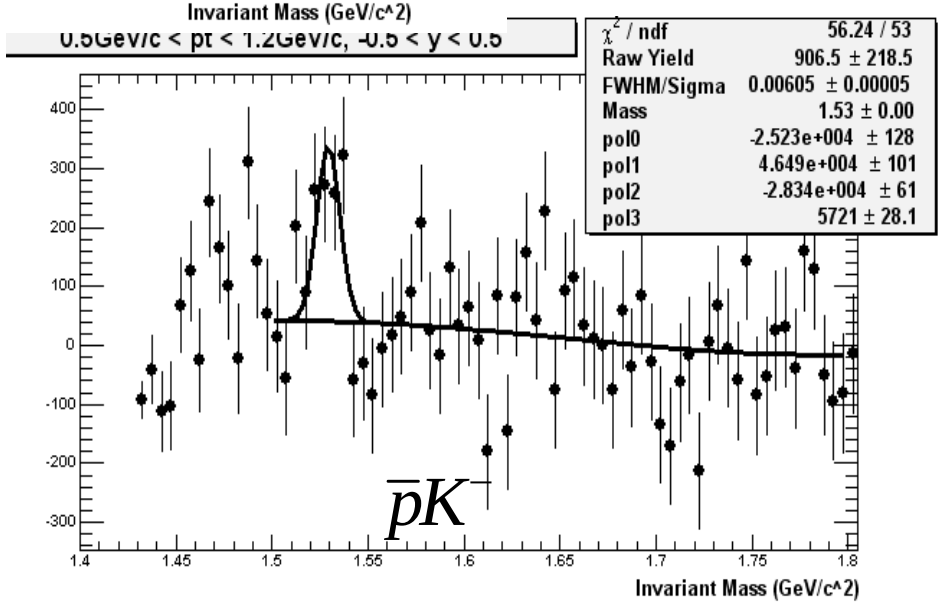
Kaon 0.2<p&pt<1.0, Proton 0.3<p&pt<1.5, no opening angle cut



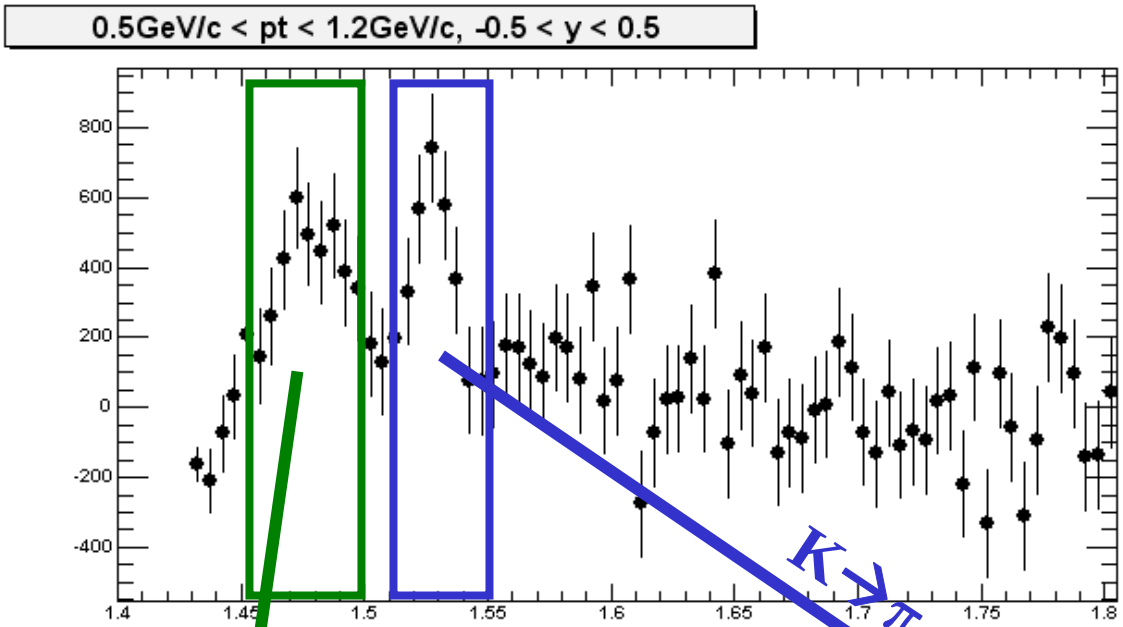
Can the Peak Be Real ??



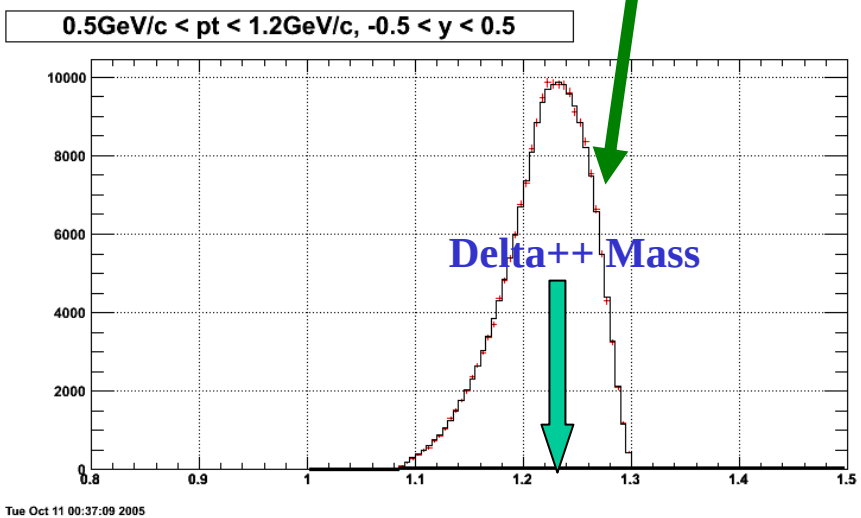


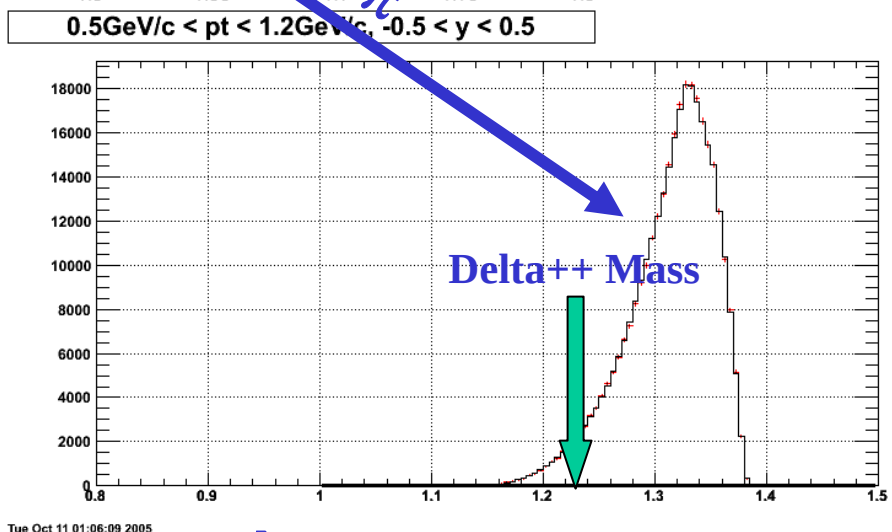


$\Delta/N^*(1535)$ decay and $\pi \rightarrow K$ does not make the peak



$K \rightarrow \pi$





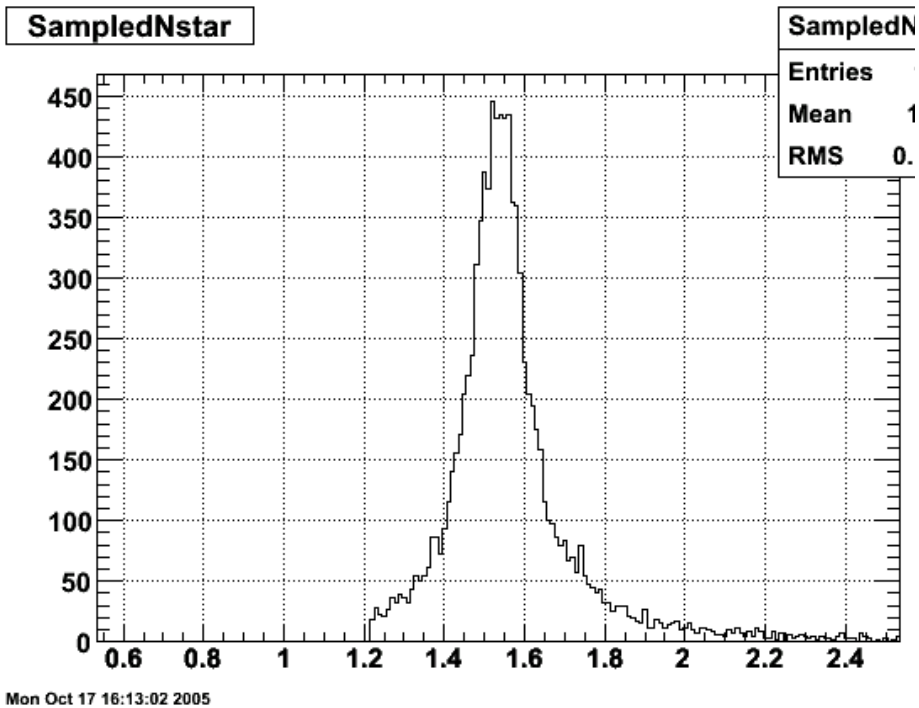
$N^*(1535) \rightarrow p\pi$ wrong charge for θ^{++}!

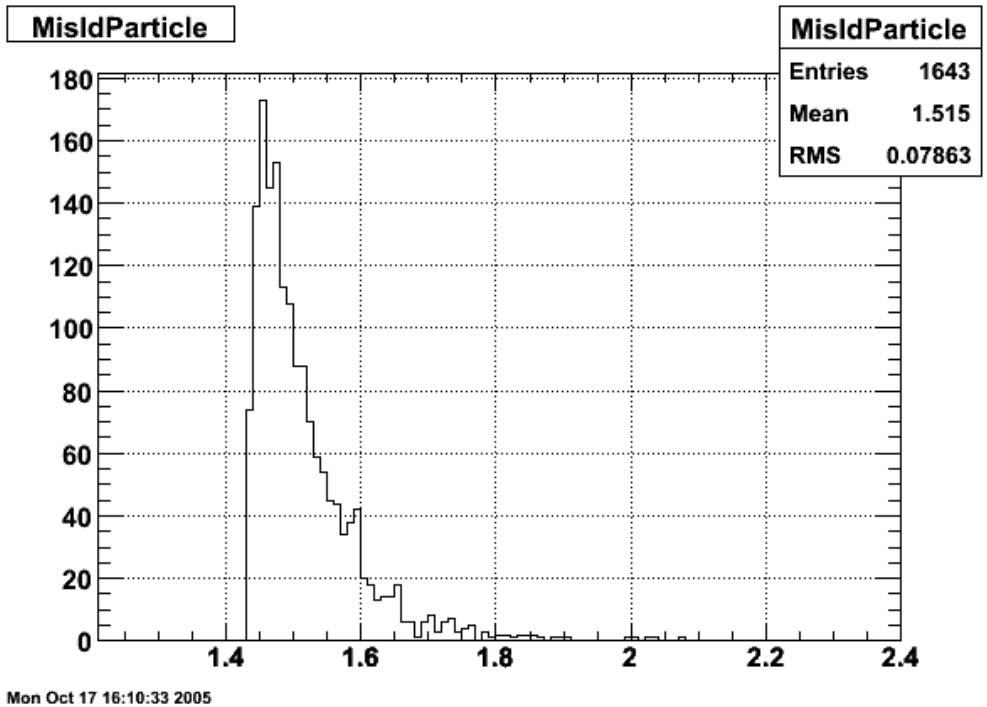
$N^*(1535) \rightarrow N\pi\pi$ and $\pi \rightarrow K$ cannot make the peak either

Nstar Mass: 1535 MeV

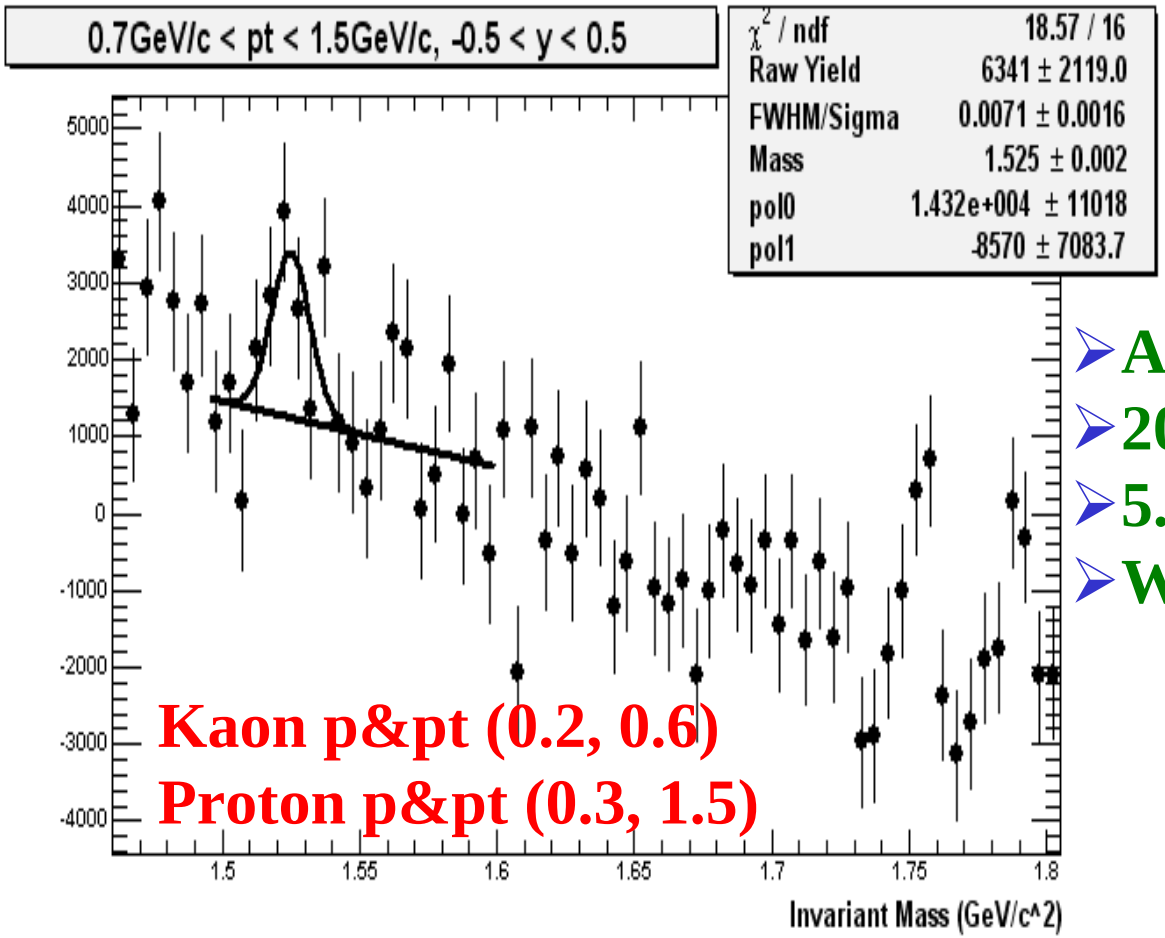
Nstar FWHM: 150 MeV

Peak at ~1460 MeV



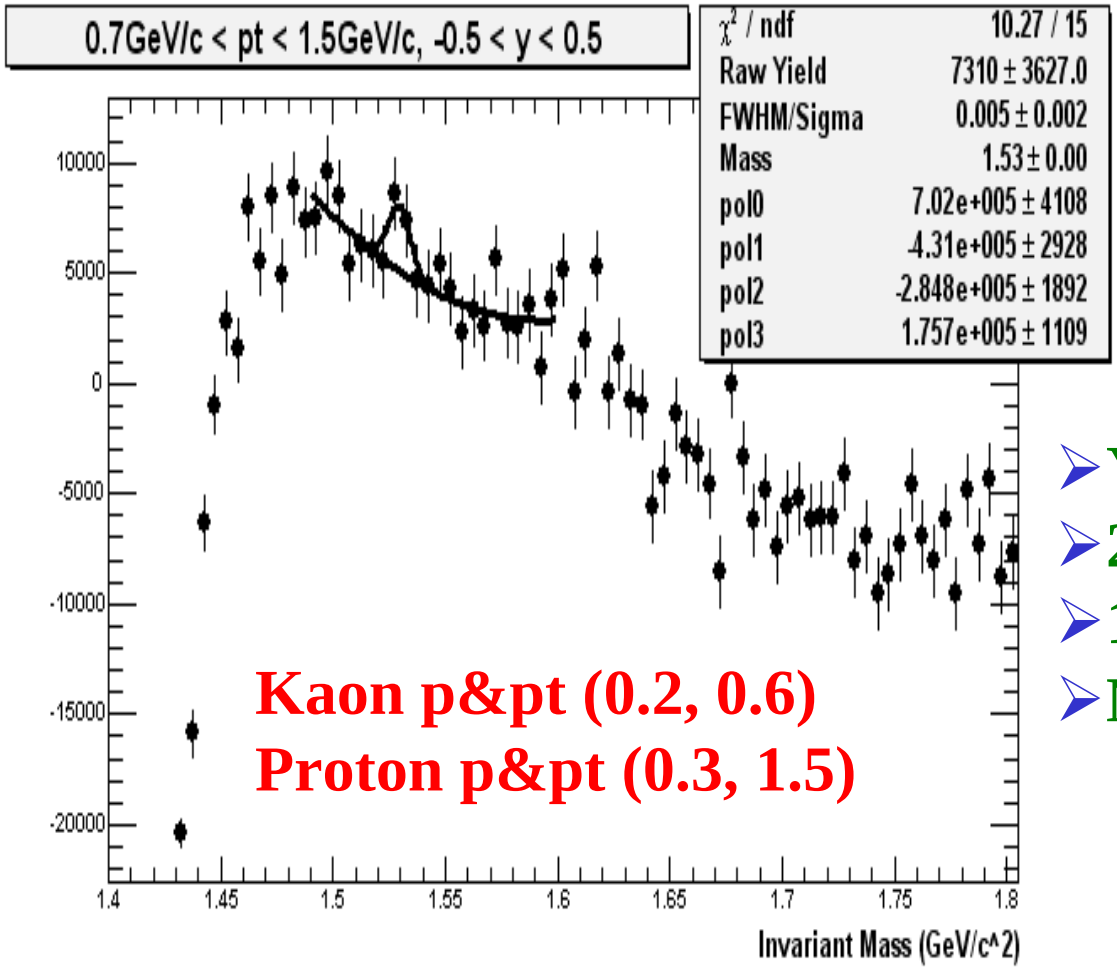


AuAu 62.4 GeV Results



- AuAu 62 GeV data
- 20-80% centrality bin
- 5.6 M events
- Weak Signal (3sigma) if any

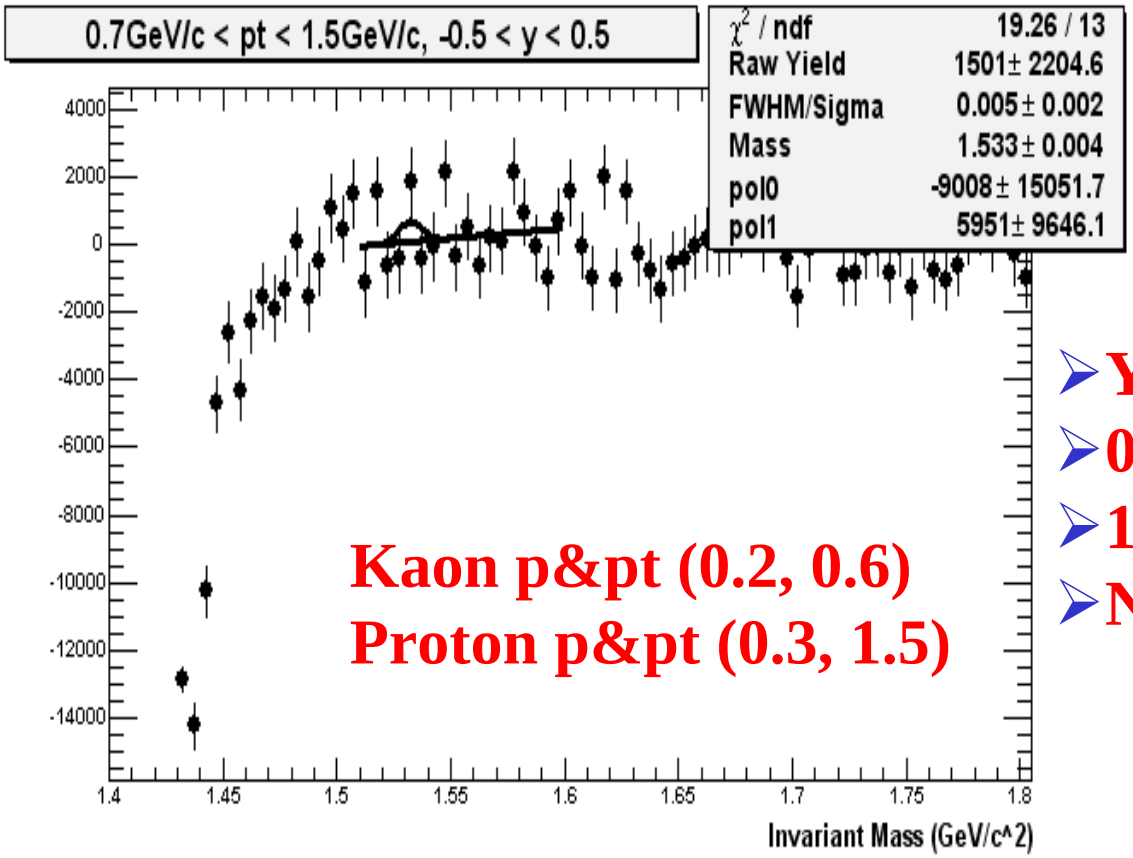
AuAu 200 GeV Run 4 Results



Kaon p&pt (0.2, 0.6)
Proton p&pt (0.3, 1.5)

- **Year 4 AuAu 200 GeV data**
- **20-80% centrality bin**
- **10.7 M events**
- **No Significant Signal (2σ)**

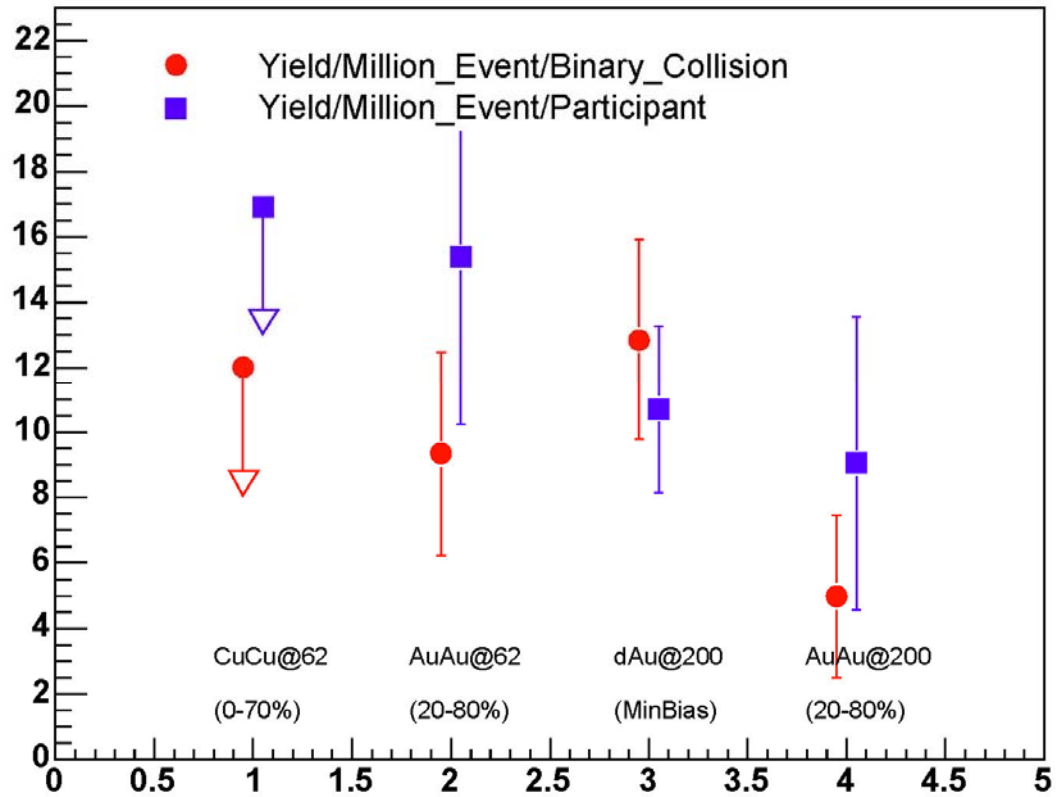
Cu+Cu 62.4 GeV Run 5 Data



Kaon p&pt (0.2, 0.6)
Proton p&pt (0.3, 1.5)

- **Year 5 CuCu 62 GeV data**
- **0-70% centrality bin**
- **16.5 M events**
- **No signal at all !!**

Is There an Obvious Contradiction ?



The signal is not significant in Au+Au systems !

d+Au is indeed a favored system:

signal strength and combinatorial background !!

RHIC should have another long d+Au run !!

A Stringent Limit from HERA-B

HERA-B	**hep-ex/0408048**
sqrt(s)	**42 GeV**
pA (C,Ti,W)	**200 M inelastic events**
θ^+/Λ	**<0.92%; 95%CL**
$\theta^+/\Lambda(1520)$	**<2.7%; 95% CL**

Does this imply $\Lambda(1520)/\Lambda \sim 34\%$?

Our Estimate in STAR	
d+Au	**sqrt(s) 200 GeV**
θ^{++}/Λ	**~ 0.35%**

STAR $\Lambda(1520)/\Lambda \sim 10\%$ (corrected for branching ratio) !

The Puzzle Continues

1) If pK^+ peak at 1530 MeV/c^2 is a real pentaquark, then I = 1 likely, there must be a θ^+. But the recent JLab null result on θ^+ casts serious doubt on the observation of θ^+.

2) The STAR observed yield is so small such that many experiments would not have the sensitivity to see it.

3) Within the STAR data we have not seen any significant peak signal in p+p data and Au+Au at 200 GeV and Cu+Cu 62 GeV.
   What do these null observations mean?
   Production dynamics or data set bias unknown to us?
   What is so special about d+Au 200 GeV (18.6 M events)?

4) Can the formation is such that photo-production is not favored?

An Intriguing Production Mechanism

If θ is a real particle, the production is different from normal hadrons which can be described by thermal statistical model.

Coalescence Mechanism --

pK^+ Interaction – Repulsive (not favored)

ΔK^+ Interaction – Attractive !!

ΔK Coalescence → Θ → pK^+

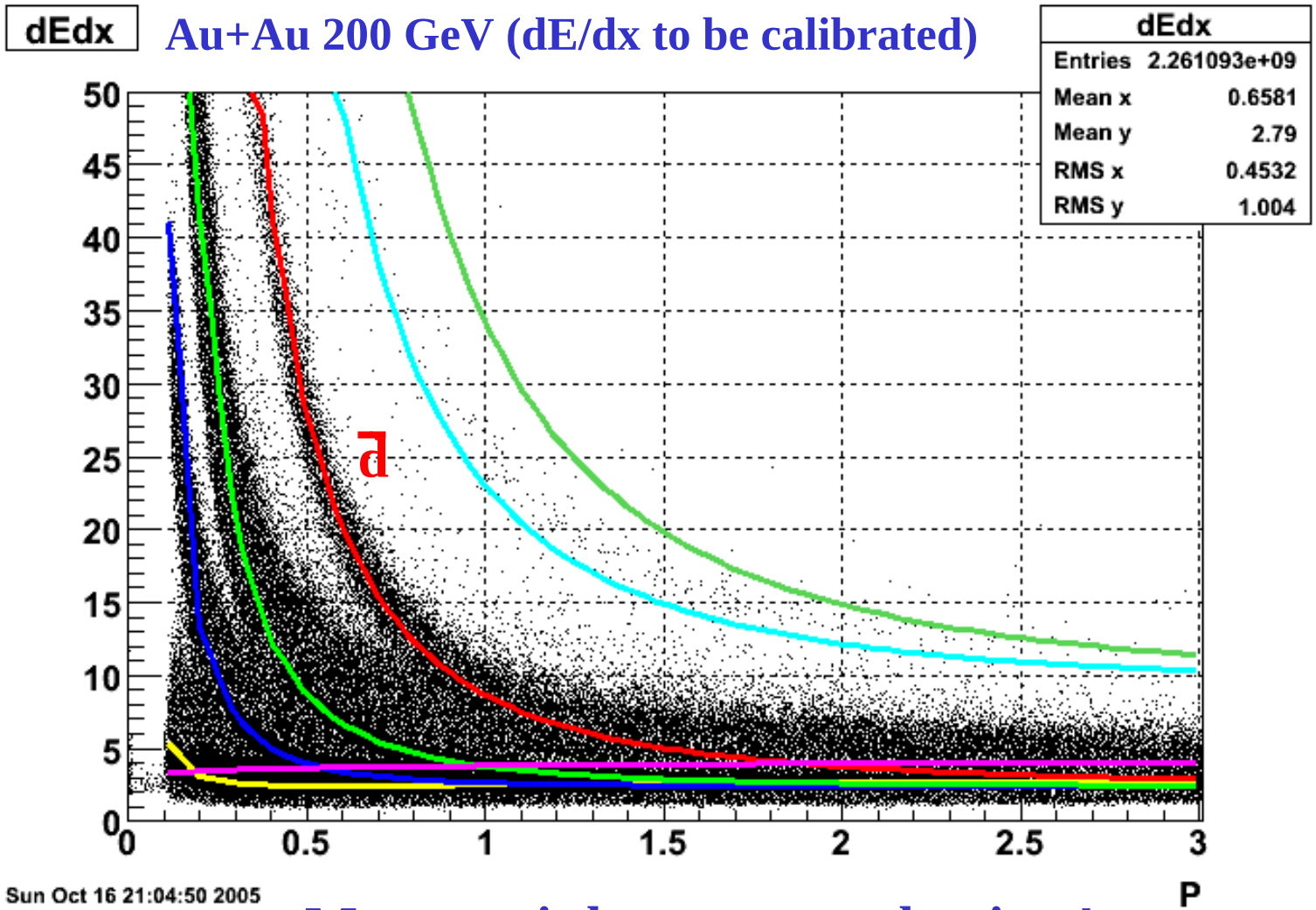
($N\pi K$ = 1575 MeV; $\Delta K > N\pi K$; but Δ is very wide !)

Δ lifetime ~ 1 fm → not easy for the coalescence process in e+e, photo-production and p+p collisions.

Θ spin 3/2, parity -1; pK d-wave decay → narrow width (KN formation scattering may not be so sensitive?!)

p+A collisions favored !

Coalescence Production Abundant @RHIC



Many anti-deuteron production !

Combinatorial Background killer for θ in A+A!

RHIC – Exotic Particle Factory

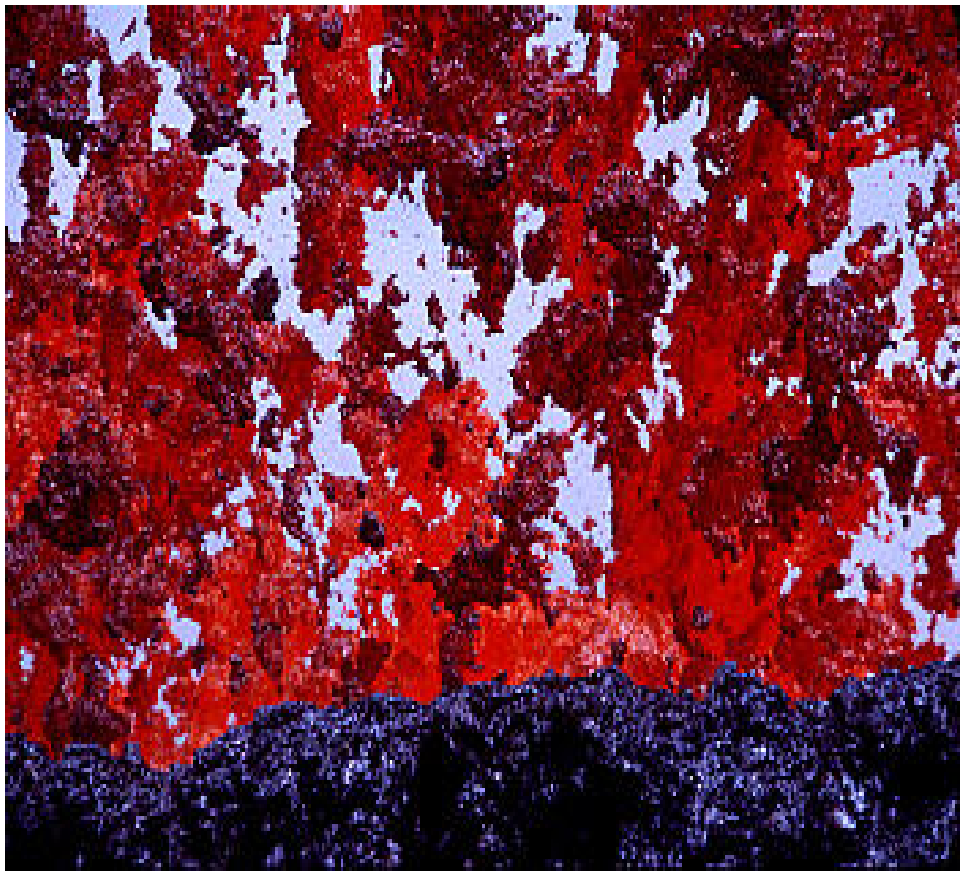
RHIC – Very Dense Partonic Matter and Rapid Hadronization

-- Hadron Formation Through Parton Clustering (coalescence/recomb.)

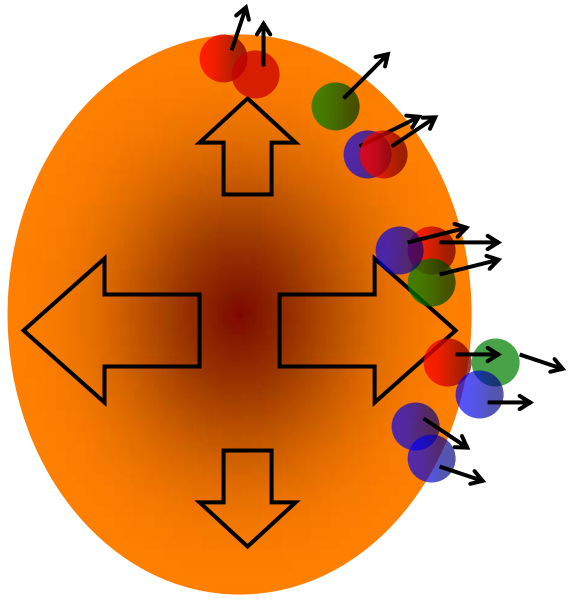
→Unique Collision Environment for Possible Exotic Particles Formation

→Exotic Mesons, Pentaquarks, Di-baryons [ΩΩ] and Strangelets

Clustering and Surface Emission



Volcanic mediate p_T – Spatter (clumps)



Enhancement of Clusters at intermediate p_T ! (baryons and hyperons)

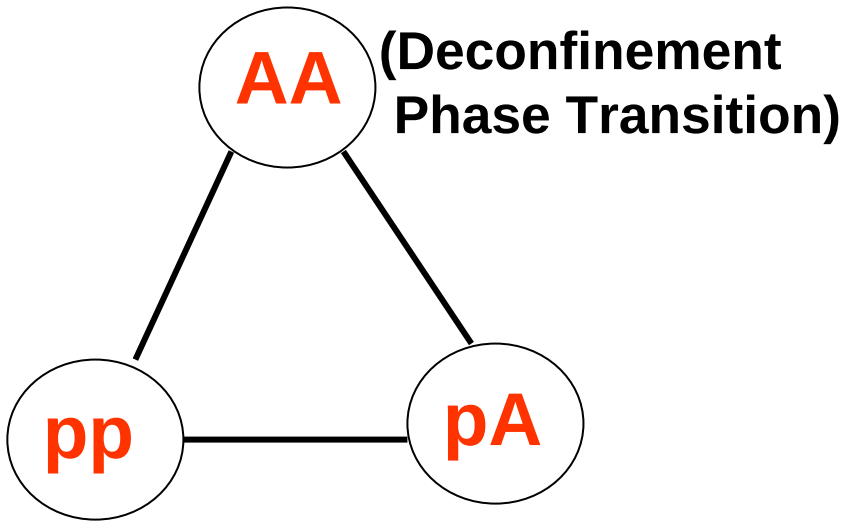
Search for Multi-quark (>3) Cluster State at RHIC !

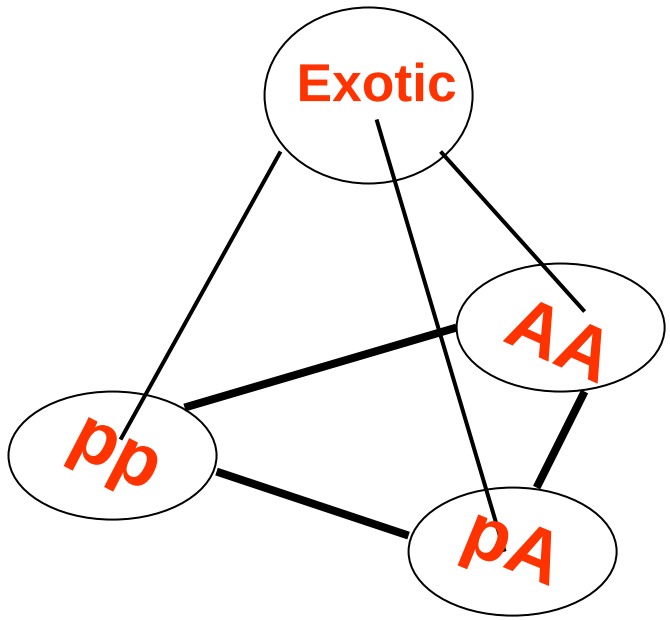
Exotic Particles

Hadrons with internal structure beyond existing QCD qqq and q-qbar framework !!

RHIC –

Dedicated QCD Machine & Beyond





(spin) **(CGC,EMC)**

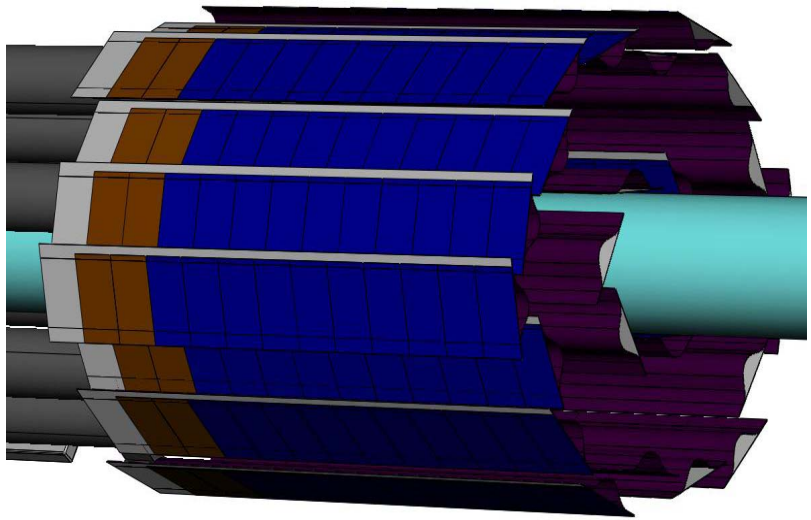
The End

RHIC – Exotic Particle Factory

STAR – Exciting Physics Program

A full TOF and Heavy Flavor Tracker upgrade will greatly enhance STAR's capability !!

Full Barrel TOF Using MRPC



Heavy Flavor Tracker

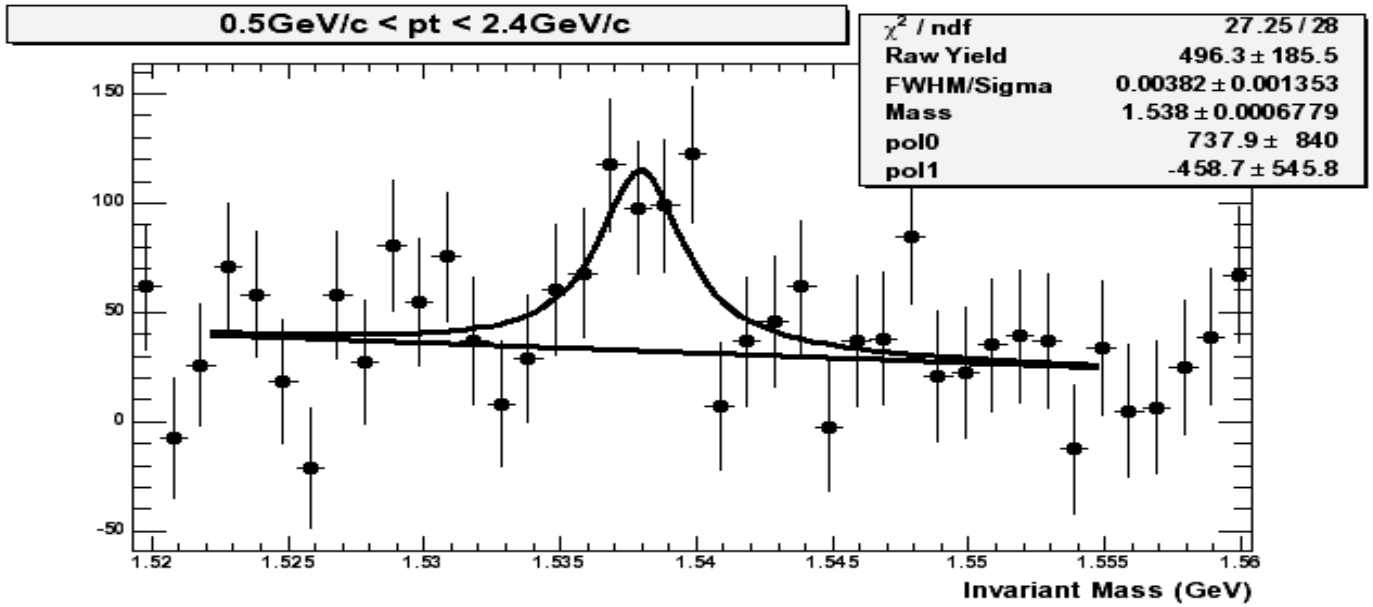
Using Active Pixel Sensor

two layers of thin silicon detector

1.5 cm and 4 cm radius

Charmed Exotics?!

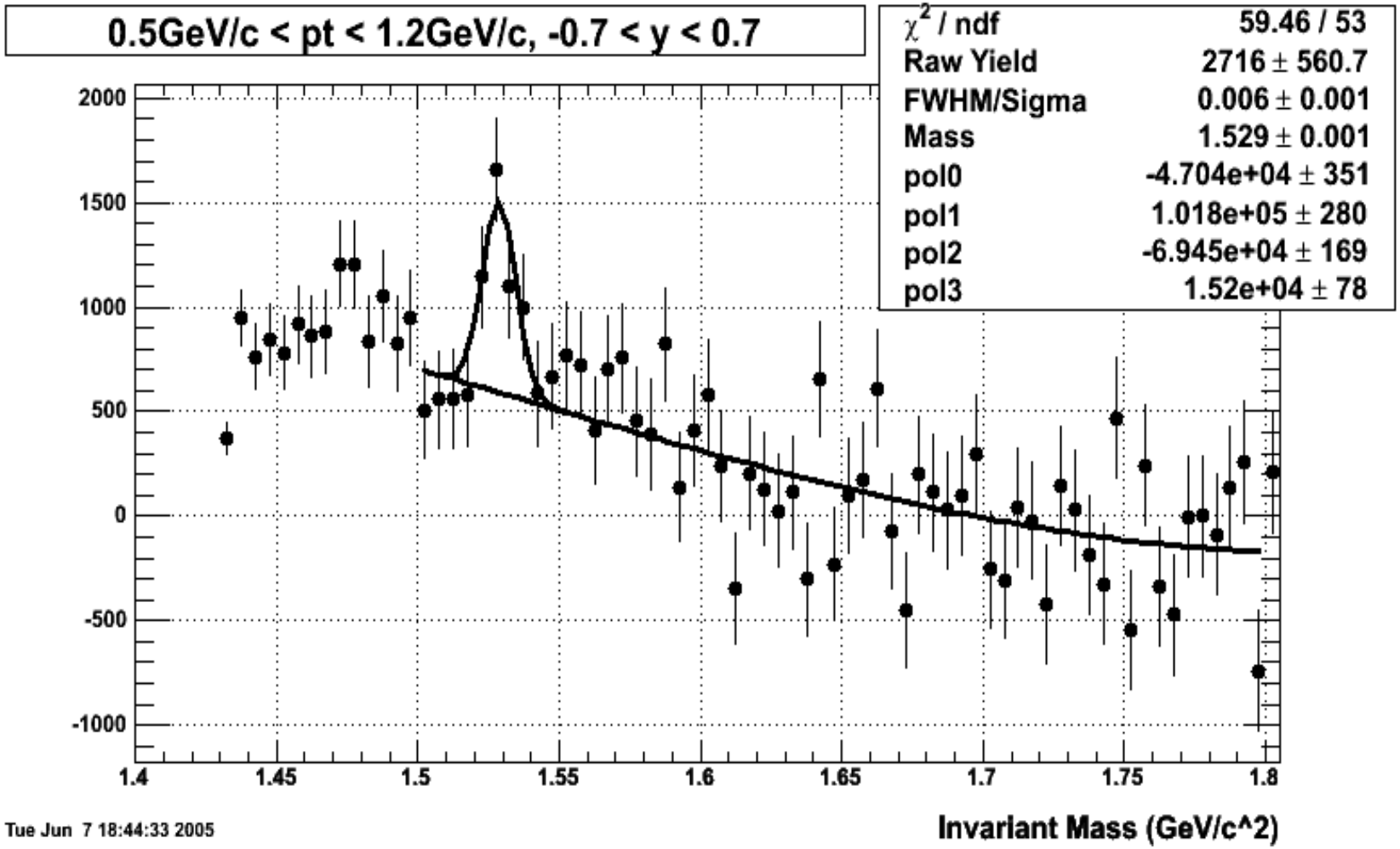
$\Theta^+ \rightarrow KsP$



- dAu data, Ks was identified by topological method
- The Θ^+ is probably there, several reasons may be responsible for the less significant signal:
  - Smaller branching ratios
  - Half of the Ks will become K_L
  - Efficiency for finding Ks at low pt is low
- This year's AuAu data may give us an answer?

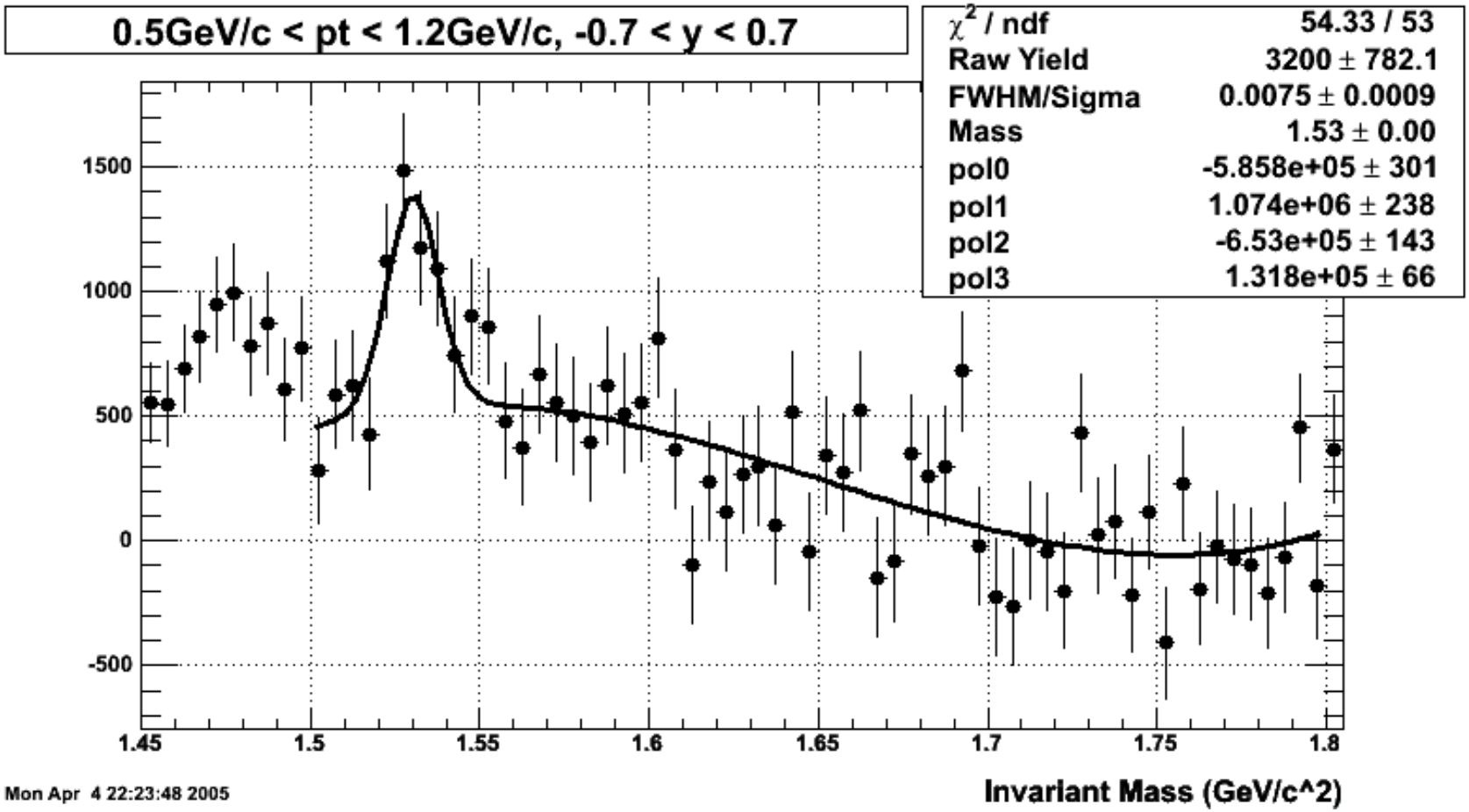
Other PID Cuts

Kaon 0.2<p&pt<0.8, Proton 0.3<p&pt<1.5, no opening angle cut

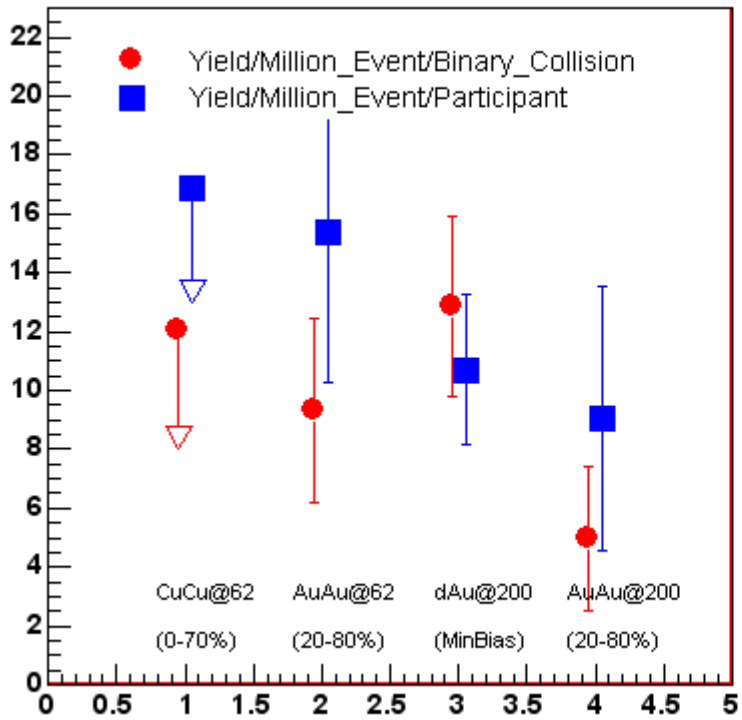


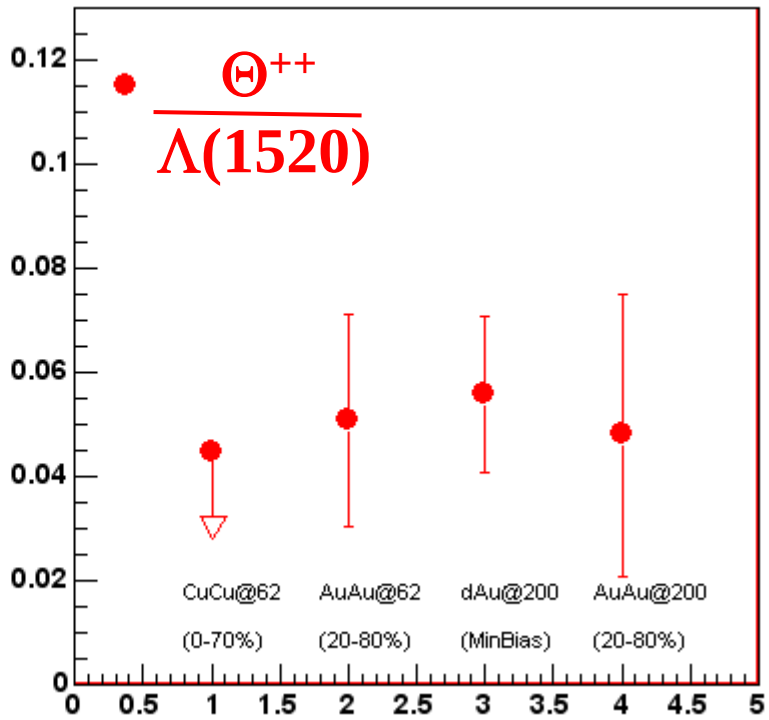
Other PID Cuts

Kaon 0.2<p&pt<0.8, Proton 0.3<p&pt<1.0, no opening angle cut



Is There an Obvious Contradiction ?





The signal is not significant in Au+Au systems !

$\Lambda(1520) \rightarrow pK^-$ branching ratio ~ 22%, corrected for the ratio.

d+Au is indeed a favored system:

signal strength and combinatorial background !!

RHIC should have another long d+Au run !!