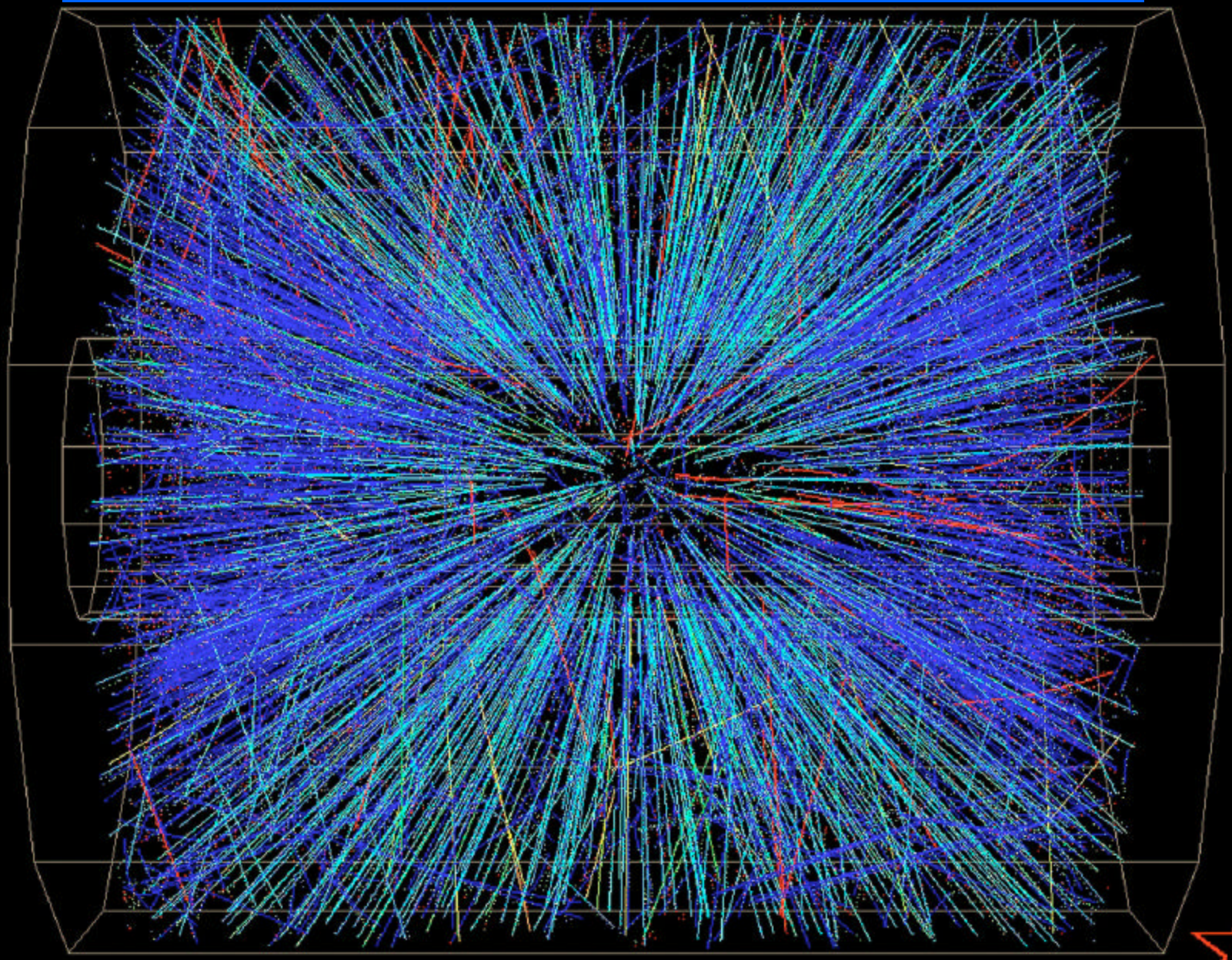
Overview of First Results from STAR

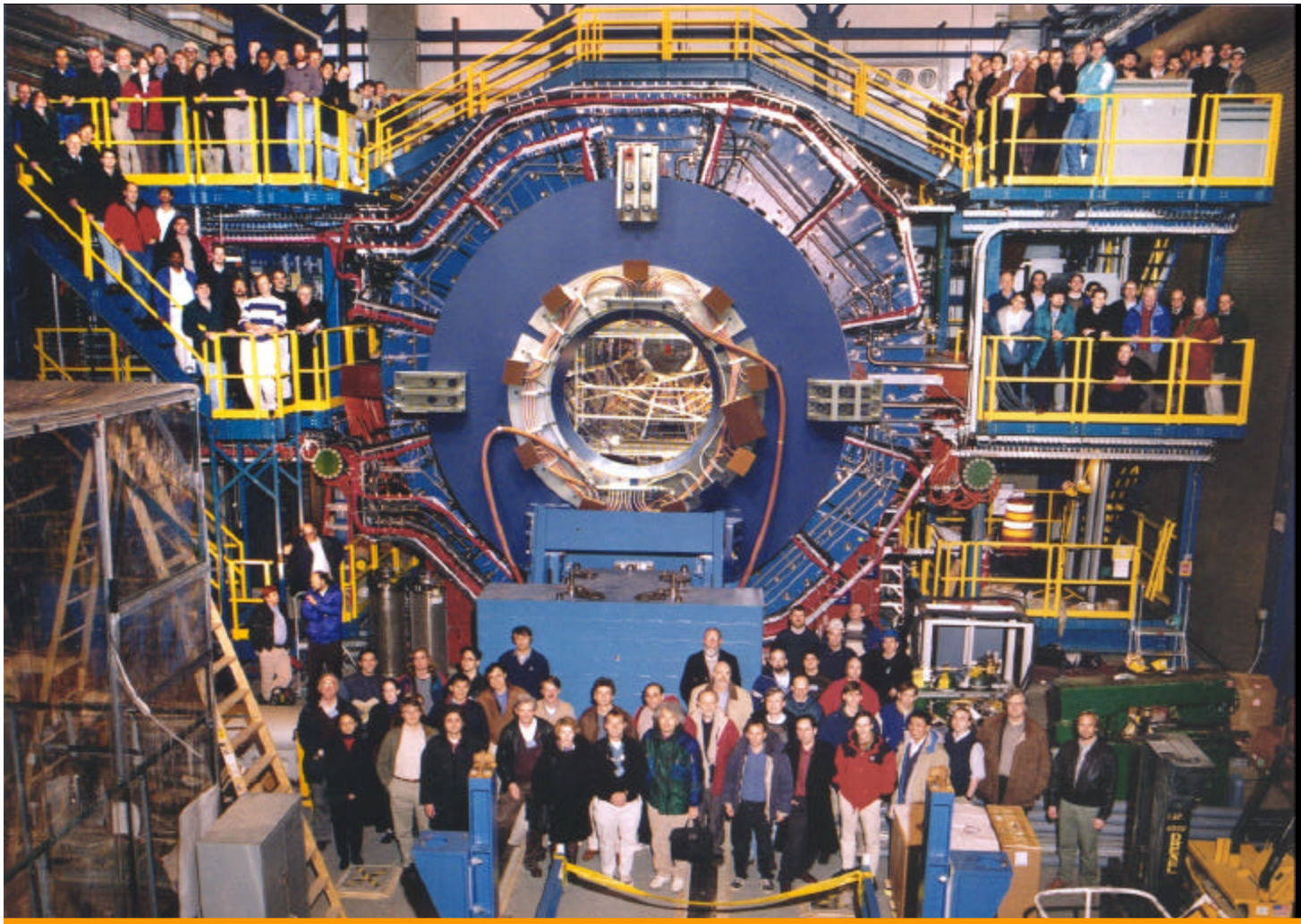
John Harris
(Yale University)

for the STAR Collaboration

Quark Matter 2001

First Au + Au Collision in STAR at RHIC





The STAR Collaboration

~ 400 collaborators
34 institutions
8 countries

Brazil: Sao Paolo

England: Birmingham

Germany: Frankfurt, MPI - Munich

China: IHEP - Beijing, IPP - Wuhan

France: IReS - Strasbourg, SUBATECH-Nantes

Poland: Warsaw University, Warsaw U. of Technology

Russia: MEPHI - Moscow, JINR - Dubna, IHEP - Protvino

U.S.: Argonne, Berkeley, Brookhaven National Laboratories
UC Berkeley, UC Davis, UCLA, Creighton, Carnegie-Mellon, Indiana, Kent State, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas, Texas A&M, Washington, Wayne, Yale Universities

STAR Detector (year-by-year)

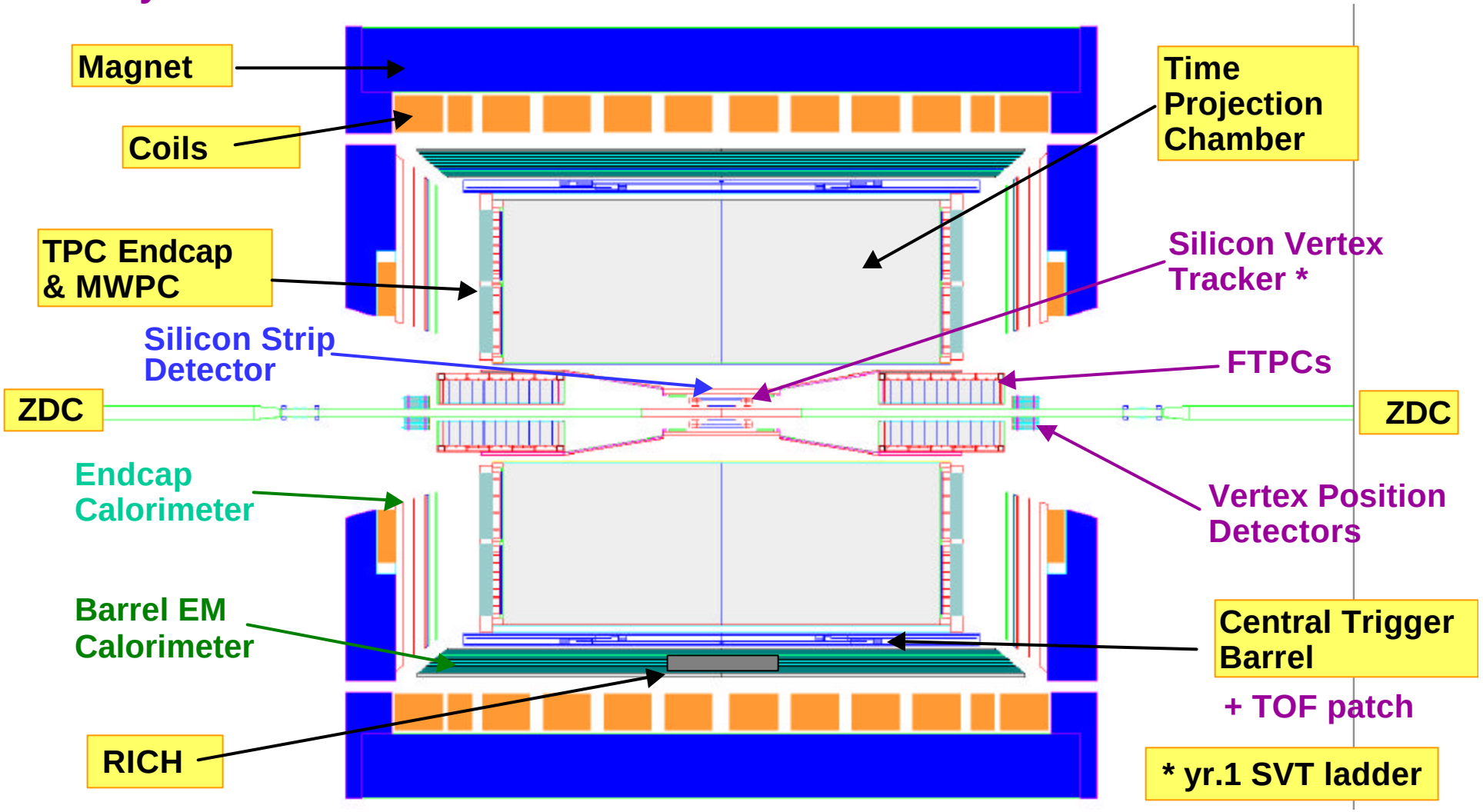
1st year detectors

2nd year detectors

year-by-year implementation until 2003

installation in 2002

installation in 2003



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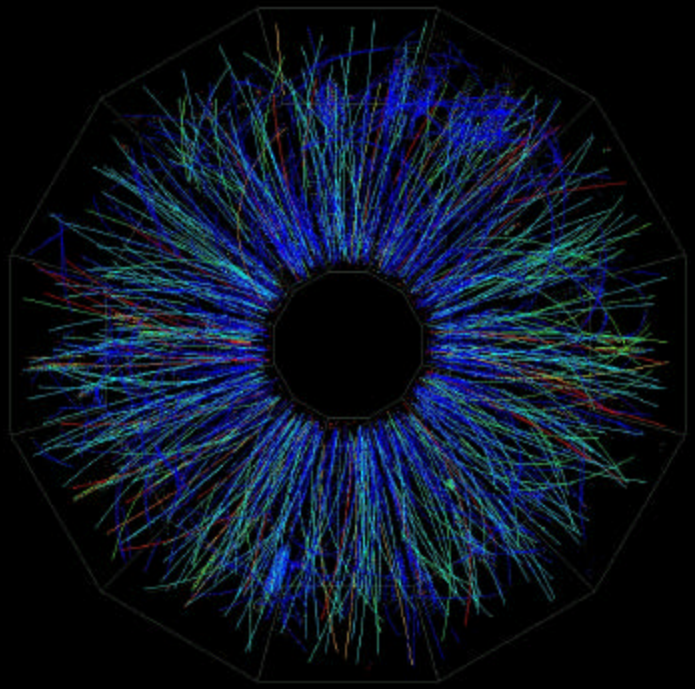
Detector Performance

See talks:

"The STAR Time Projection Chamber"
F. Retiere for STAR

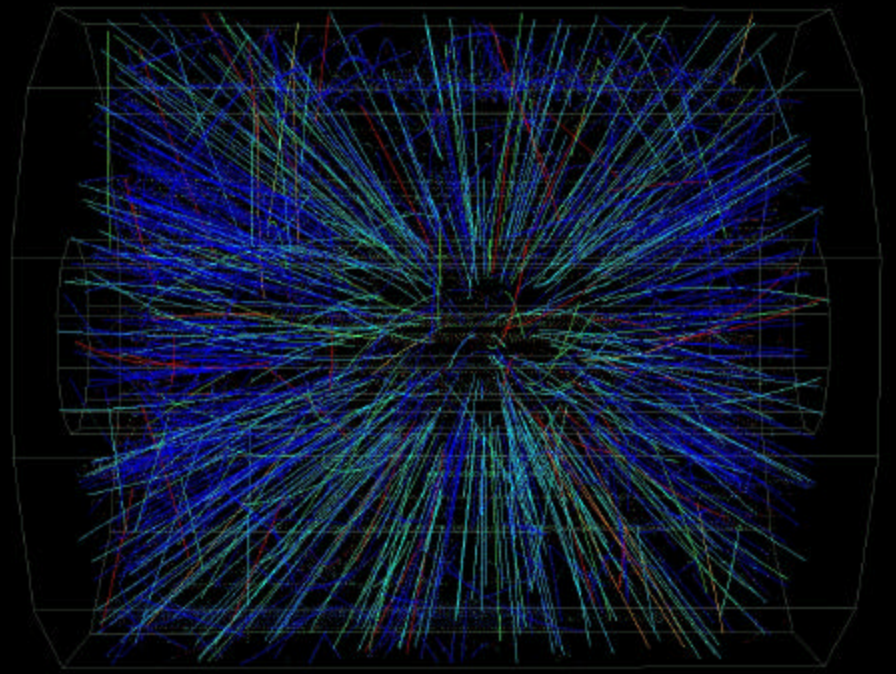
"The STAR RICH Detector"
B. Lasiuk for STAR

Au on Au Event at CM Energy ~ 130 A-GeV



Peripheral Event

From real-time Level 3 display.



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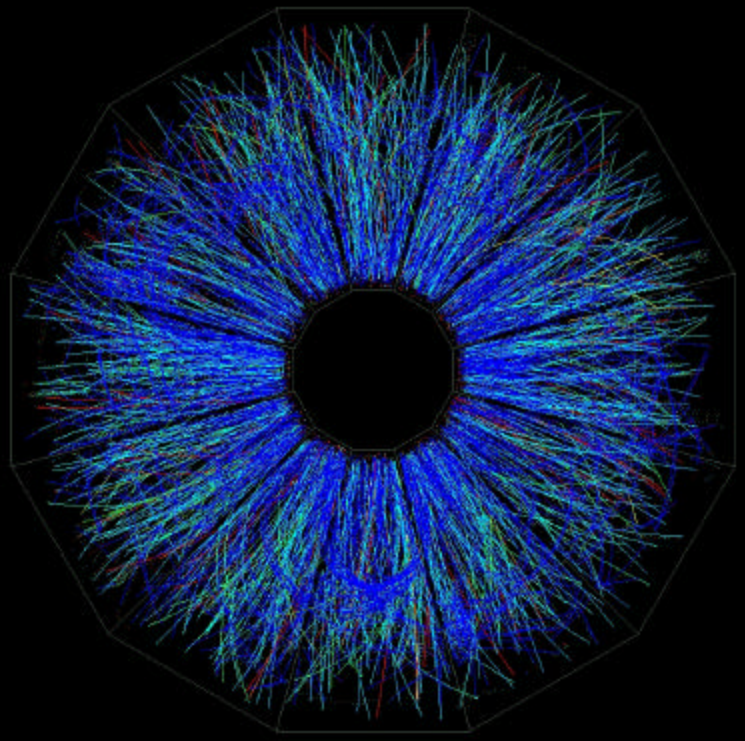
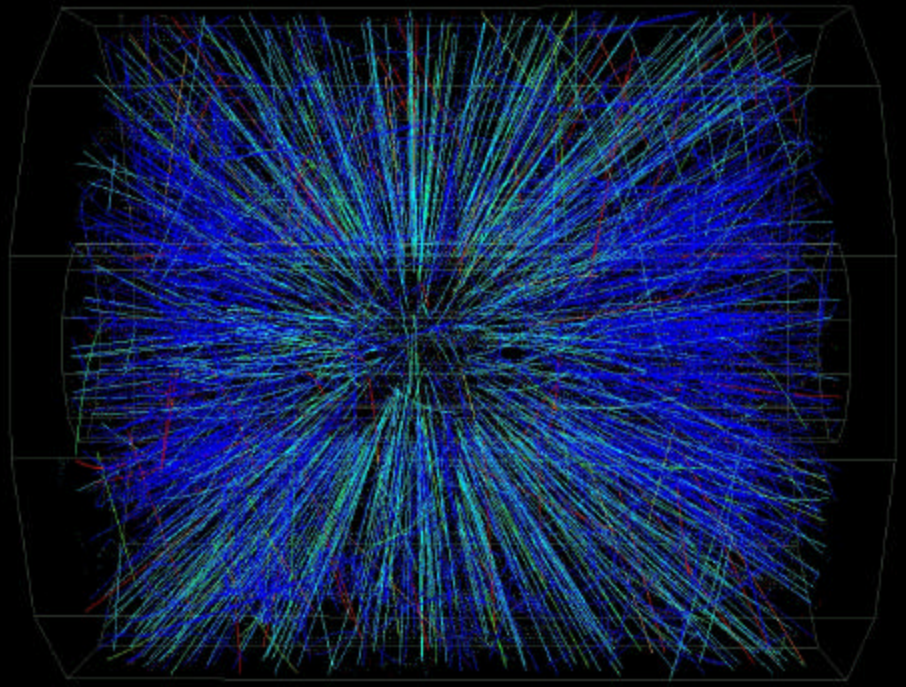
Au on Au Event at CM Energy ~ 130 A-GeV



Mid-Central Event

From real-time Level 3 display.



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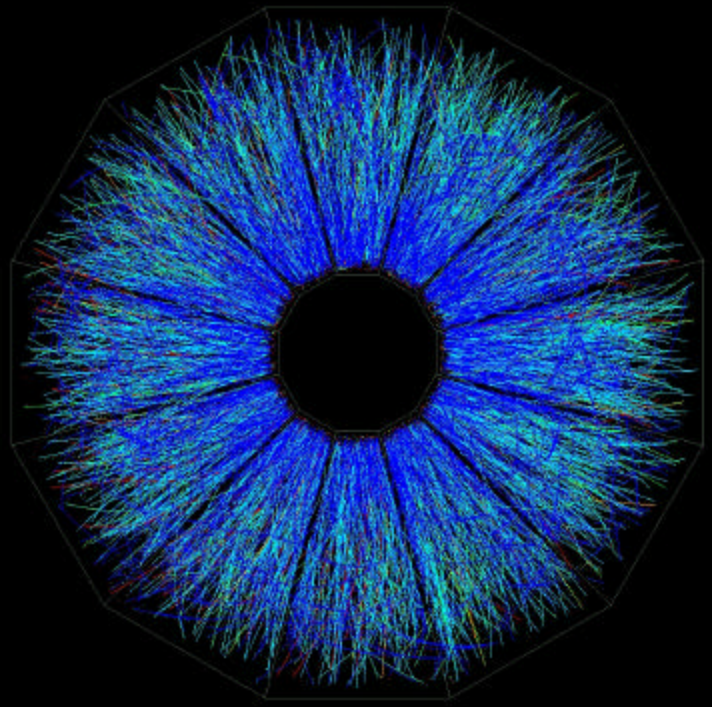
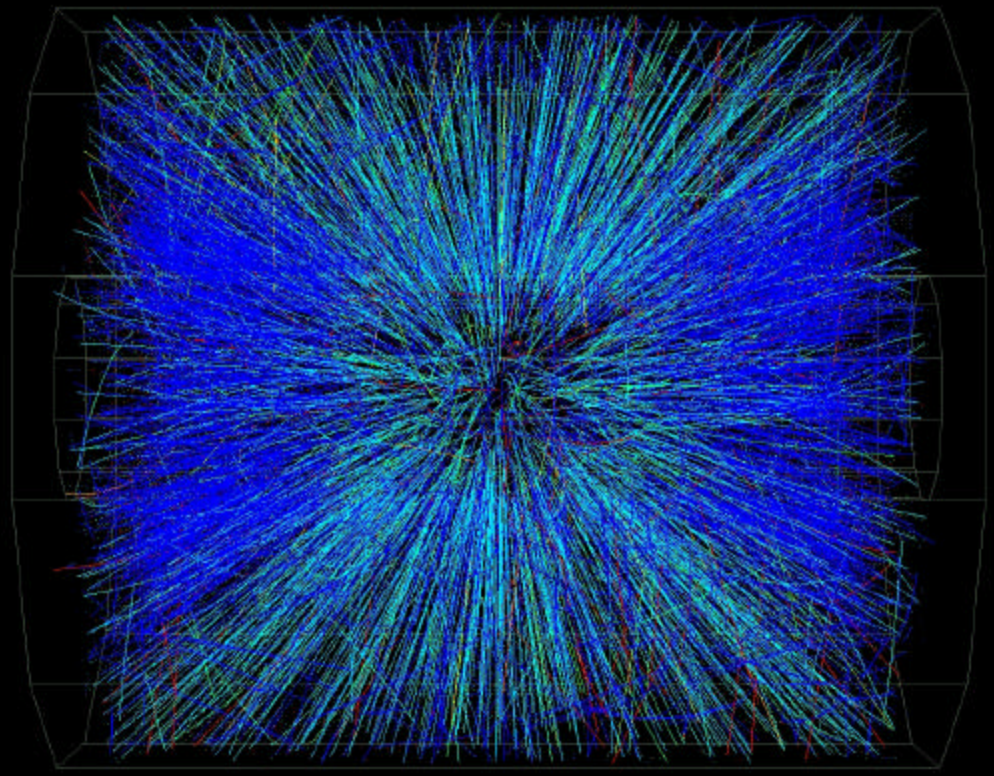
Au on Au Event at CM Energy ~ 130 A-GeV



Central Event

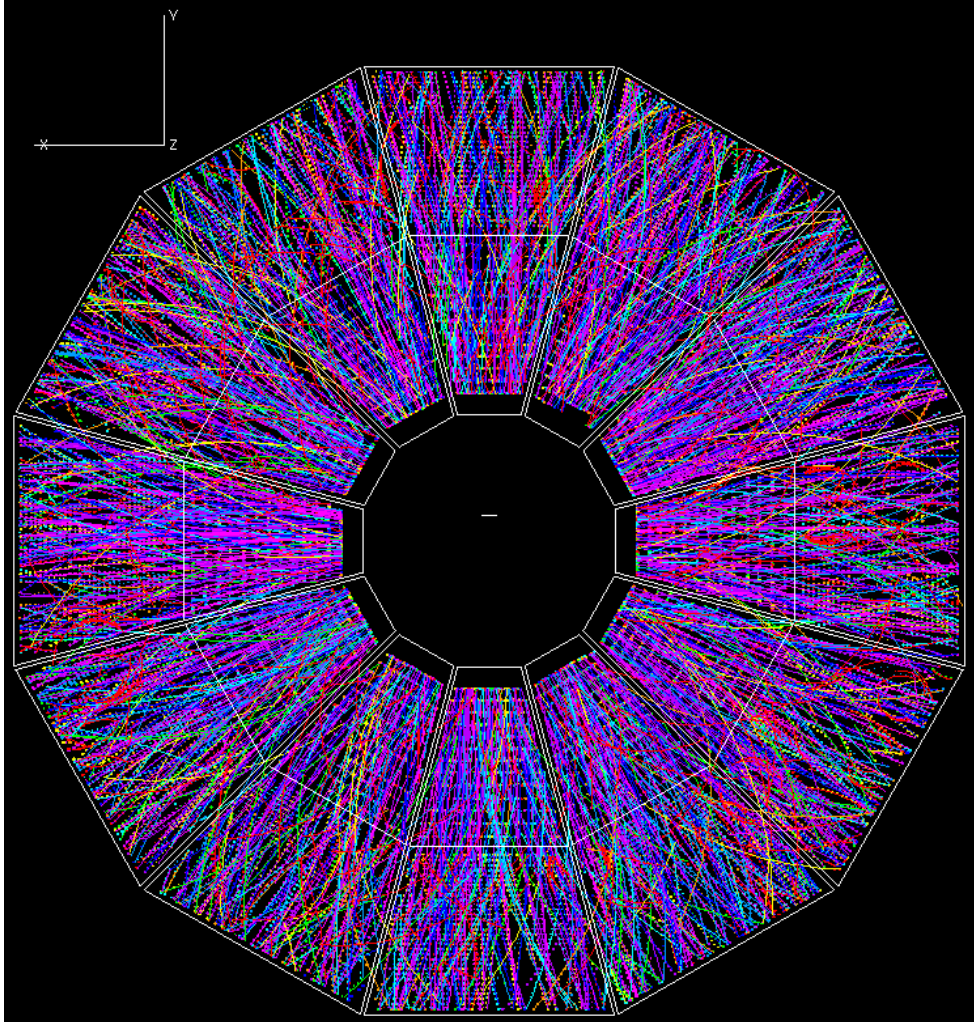
From real-time Level 3 display.



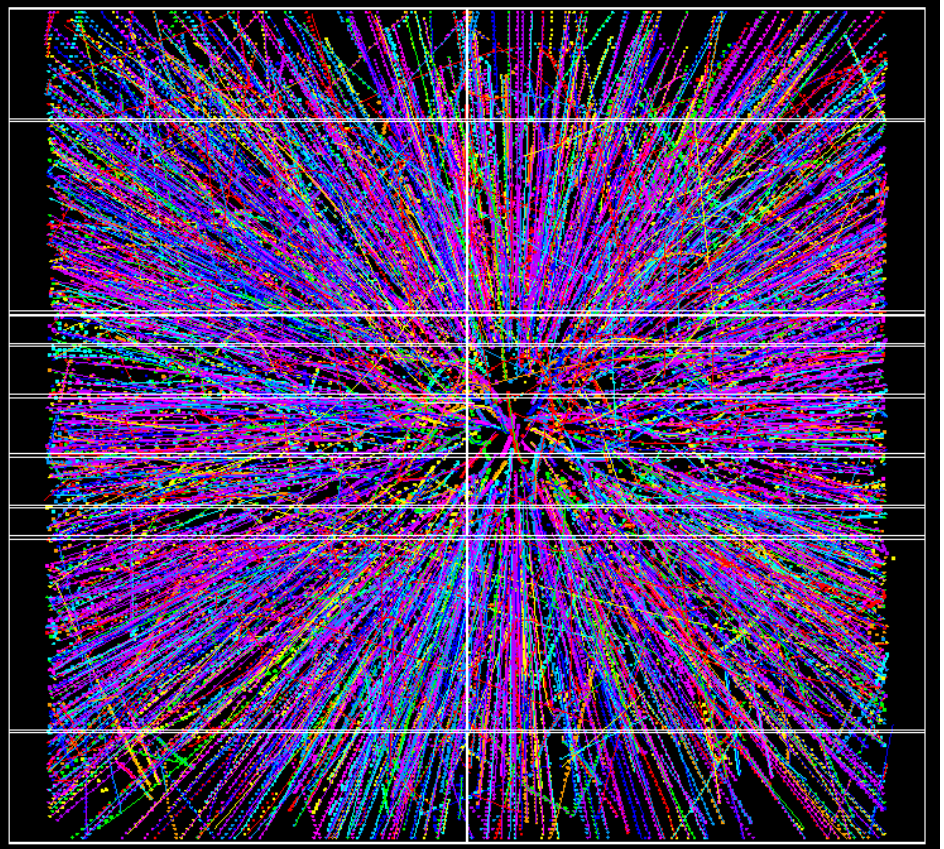
STAR

STAR

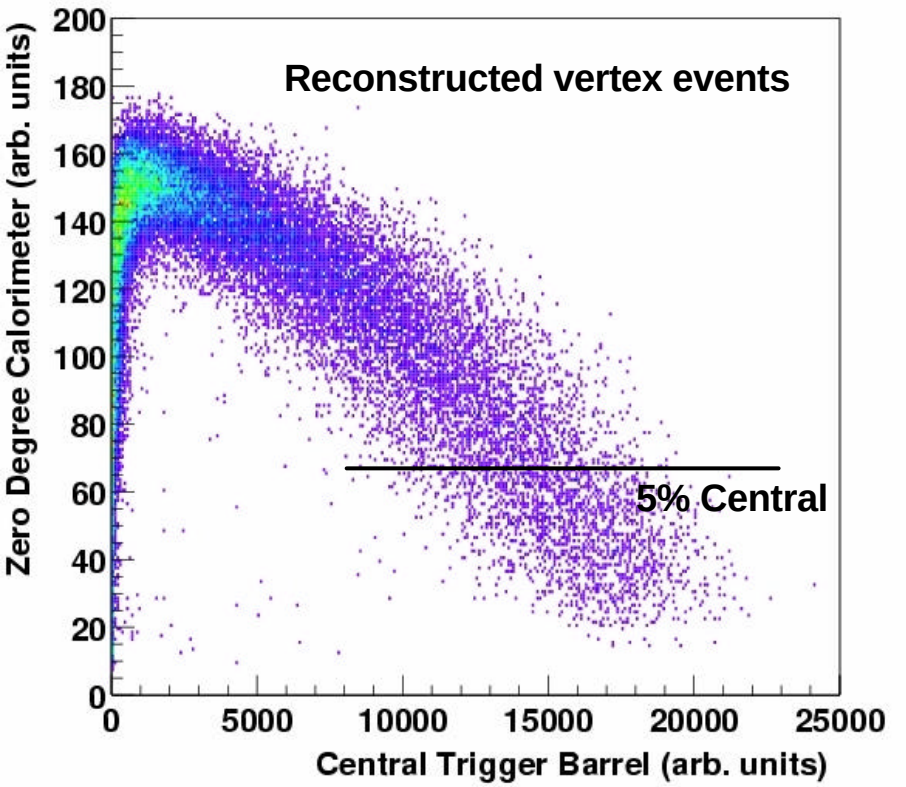
TPC Performance



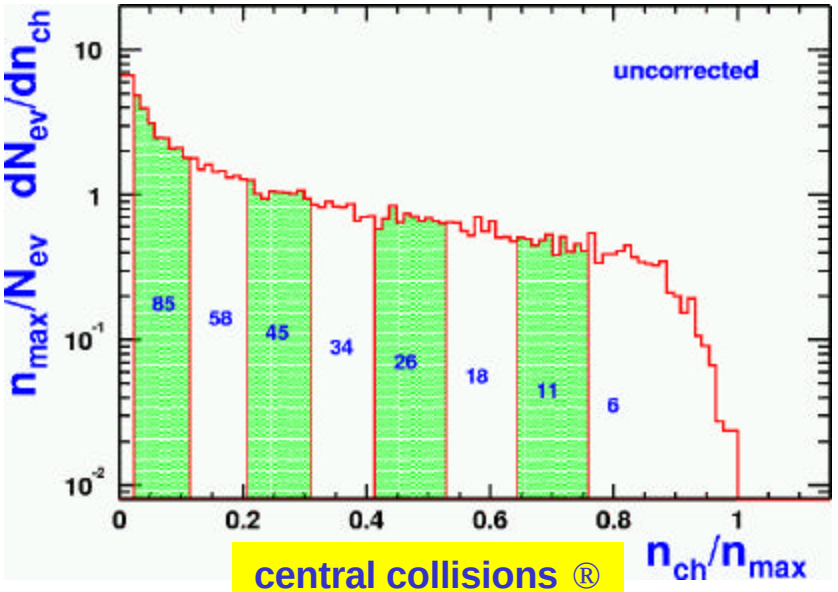
colors ~ momentum: low - - - high



STAR Geometry Trigger and Multiplicity Cuts



n_{ch} - number of primary tracks in $|\eta| < 0.75$
~ 90% of all hadronic Au+Au interactions



central collisions ®

Data Summer 2000 ® 2.0 M total trigger events taken, 844 K central (top 15%)
® 331 K good (top 5%) central for physics analysis
® 458 K good min bias events for physics analysis

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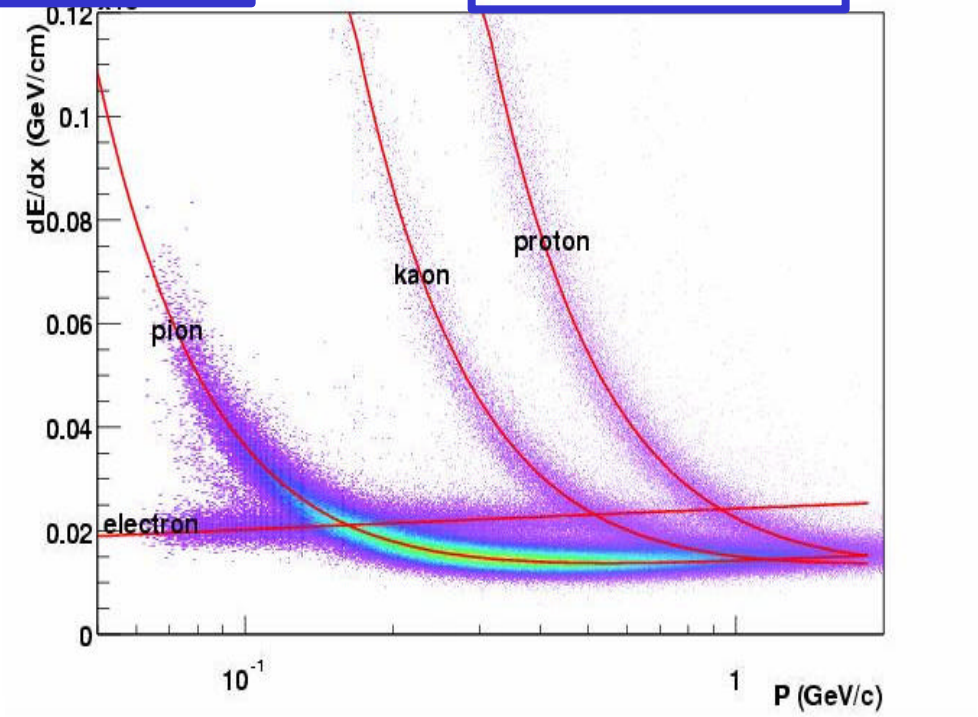
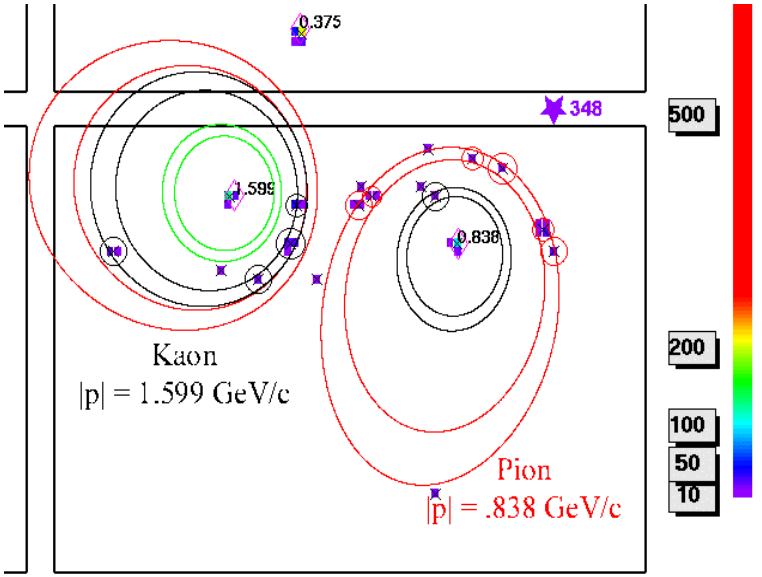
STAR Particle ID Techniques - dE/dx & RICH

dE/dx

s (dE/dx) = .08



RICH



dE/dx PID range:

p ® ~ 0.7 GeV/c for K/p

® ~ 1.0 GeV/c for `p/p

RICH PID range for K/p/p

1 - 3 GeV/c for K/p

1.5 - 5 GeV/c for `p/p

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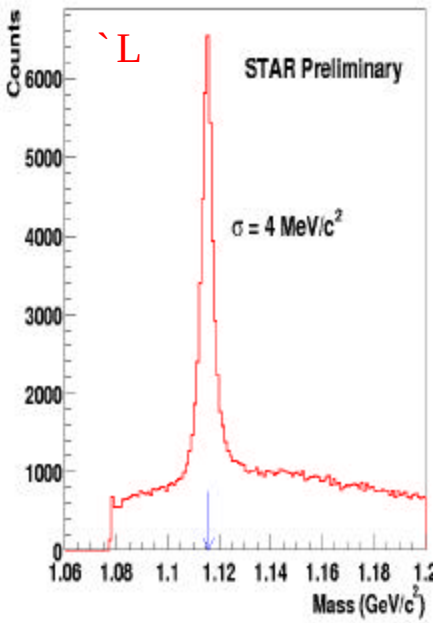
Particle ID Techniques - Topology

topology



Decay vertices

K_s ® $p^+ + p^-$

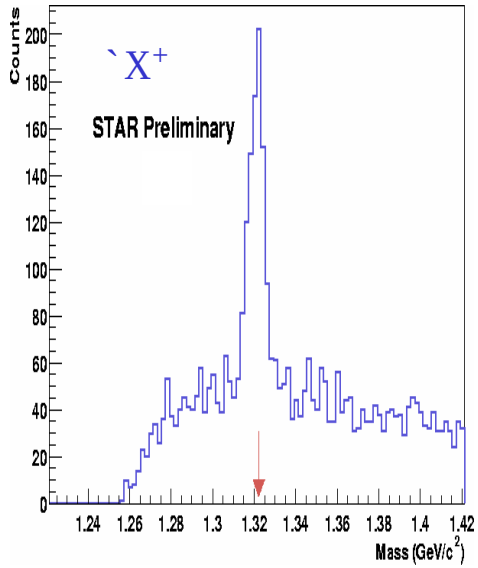
L ® p + p^-

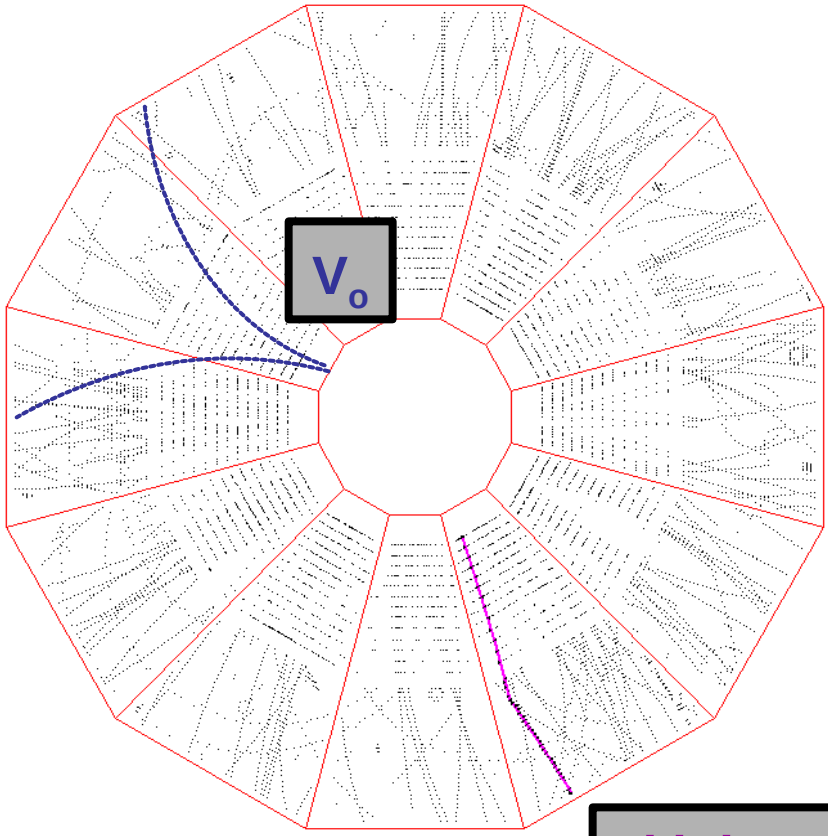
`L ® `p + p^+

X^- ® L + p^-

`$X^+$ ® `L + p^+

W ® L + K^-





"kinks":

$K^{\pm}$ ® $m^{\pm}$ + n

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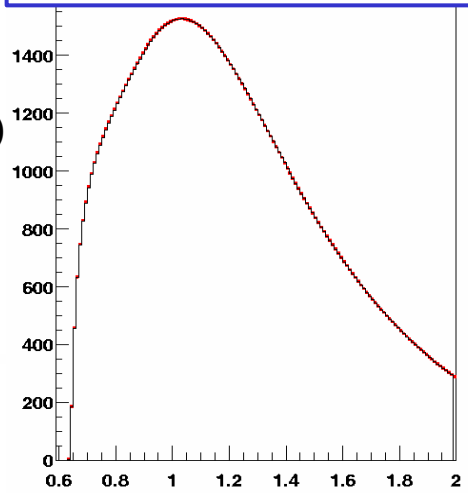
Particle ID Techniques Combinatorics

Combinatorics

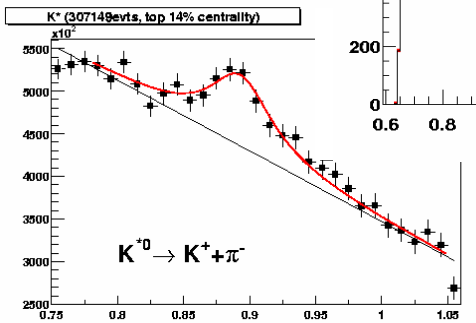
$K_s \rightarrow p^+ + p^-$	$f \rightarrow K^+ + K^-$
$L \rightarrow p + p^-$	$\bar{L} \rightarrow \bar{p} + p^+$
$[r \rightarrow p^+ + p^-]$	$[D \rightarrow p + p^-]$

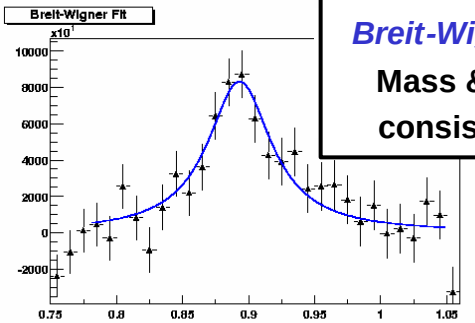
K* combine all K^+ and p^-

pairs (x 10^{-5})

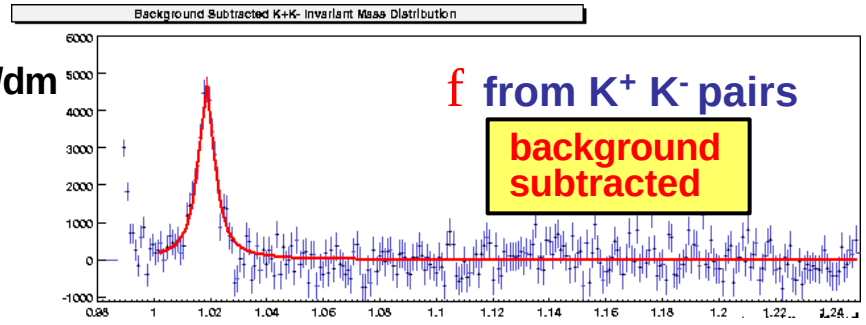


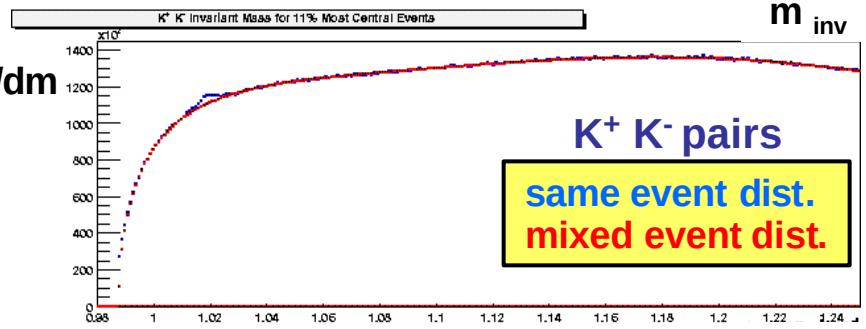
m_{inv} (GeV)





Breit-Wigner fit
Mass & width consistent w. PDG





central collisions

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Negative Hadron Multiplicities & Spectra

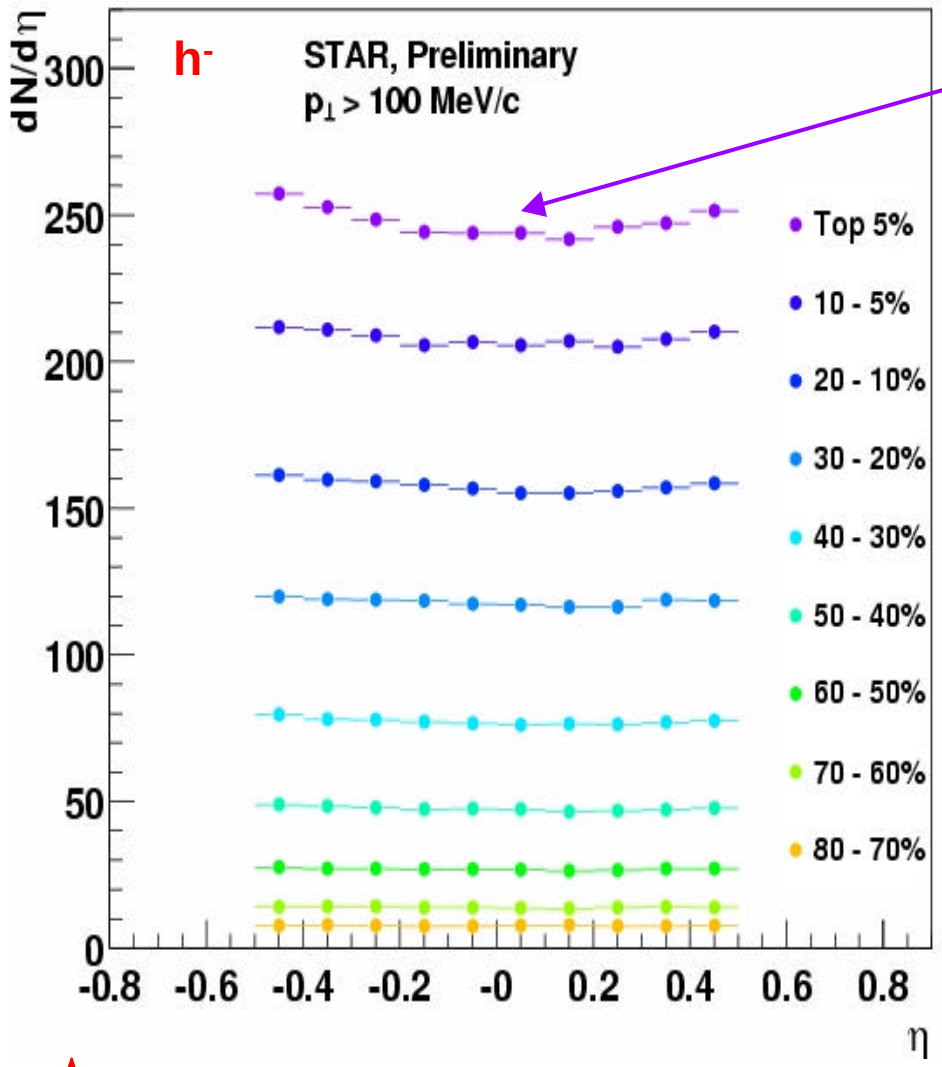
See talks:

"Charged Particle Spectra in Au + Au Collisions.."
M. Calderon for STAR

"High Pt Spectra from STAR"
J. Dunlop for STAR

[all data presented in present talk is for Ös$_{nn}$ = 130 GeV Au + Au]

Negative Hadrons: h - distribution vs Centrality

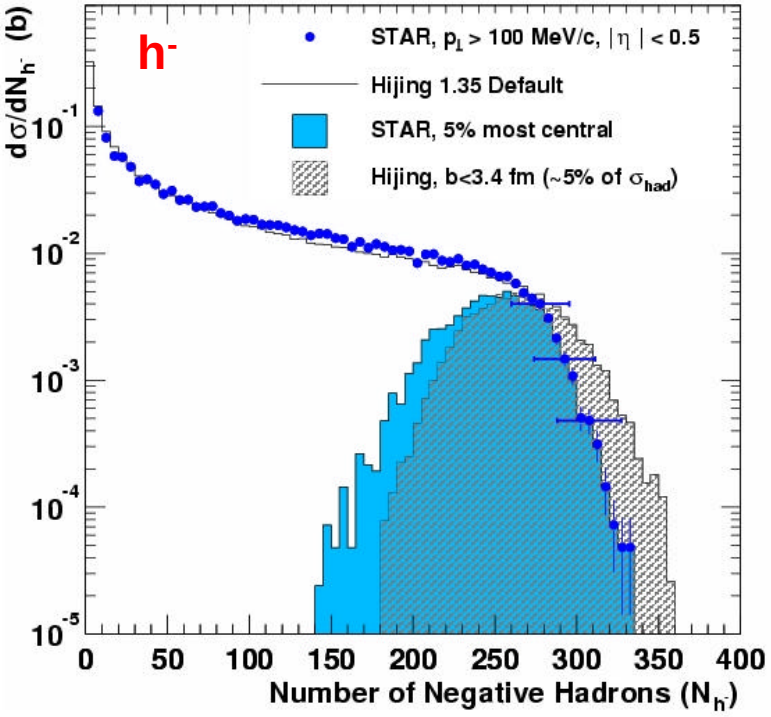


dN(h-)/dh = 244 ± 1 ± 16 (p_t > 100 MeV/c)

dN(h-)/dh = 264 ± 1 ± 18 (extrap. to all p_t)

Increased particle production:

43% compared to Pb+Pb @ 17.2 GeV



Full efficiency corrections

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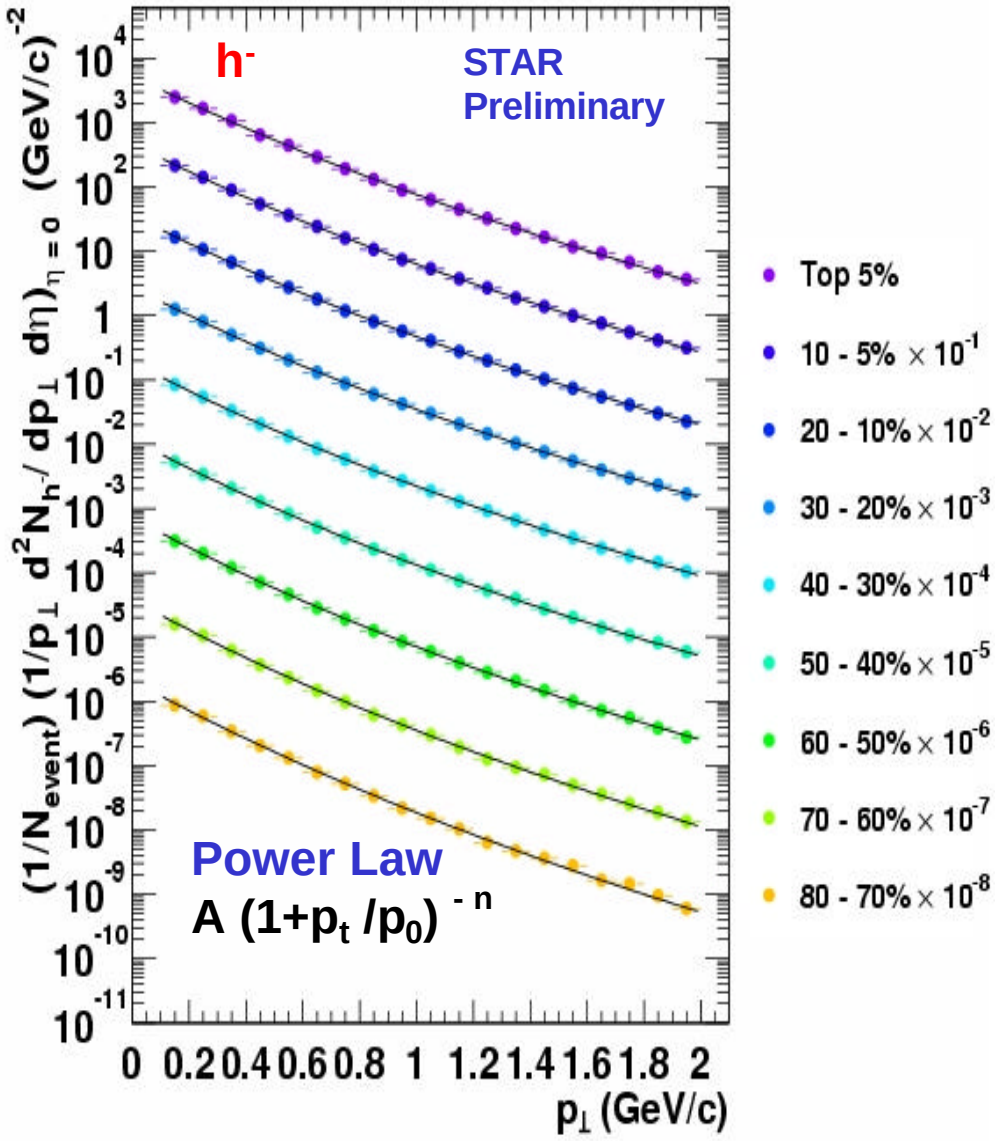
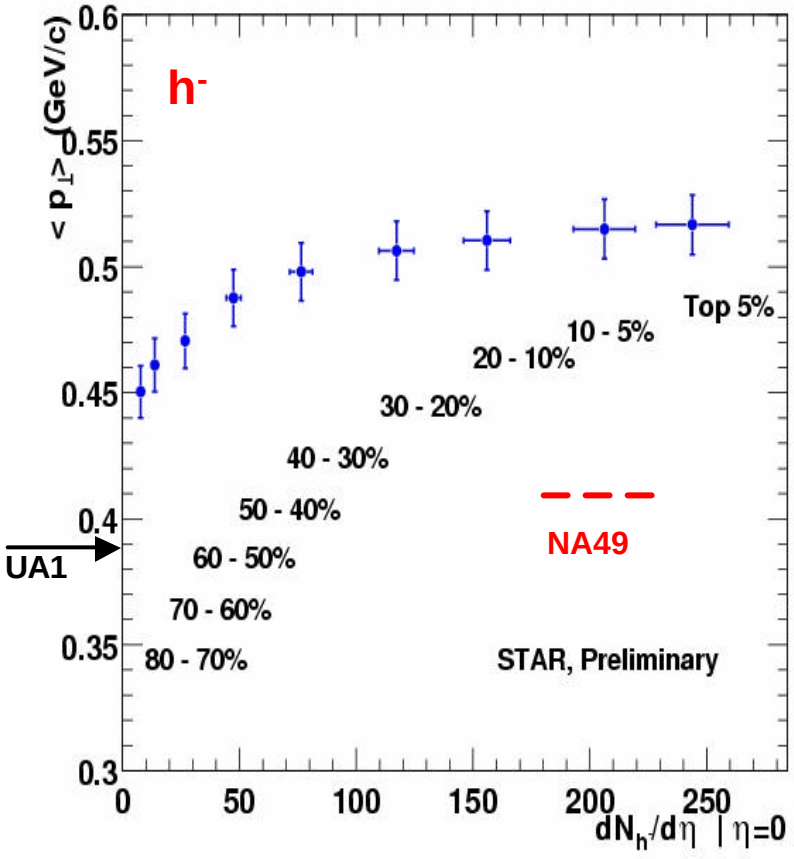
STAR h^- : p_t distributions and á p_t ñ vs centrality





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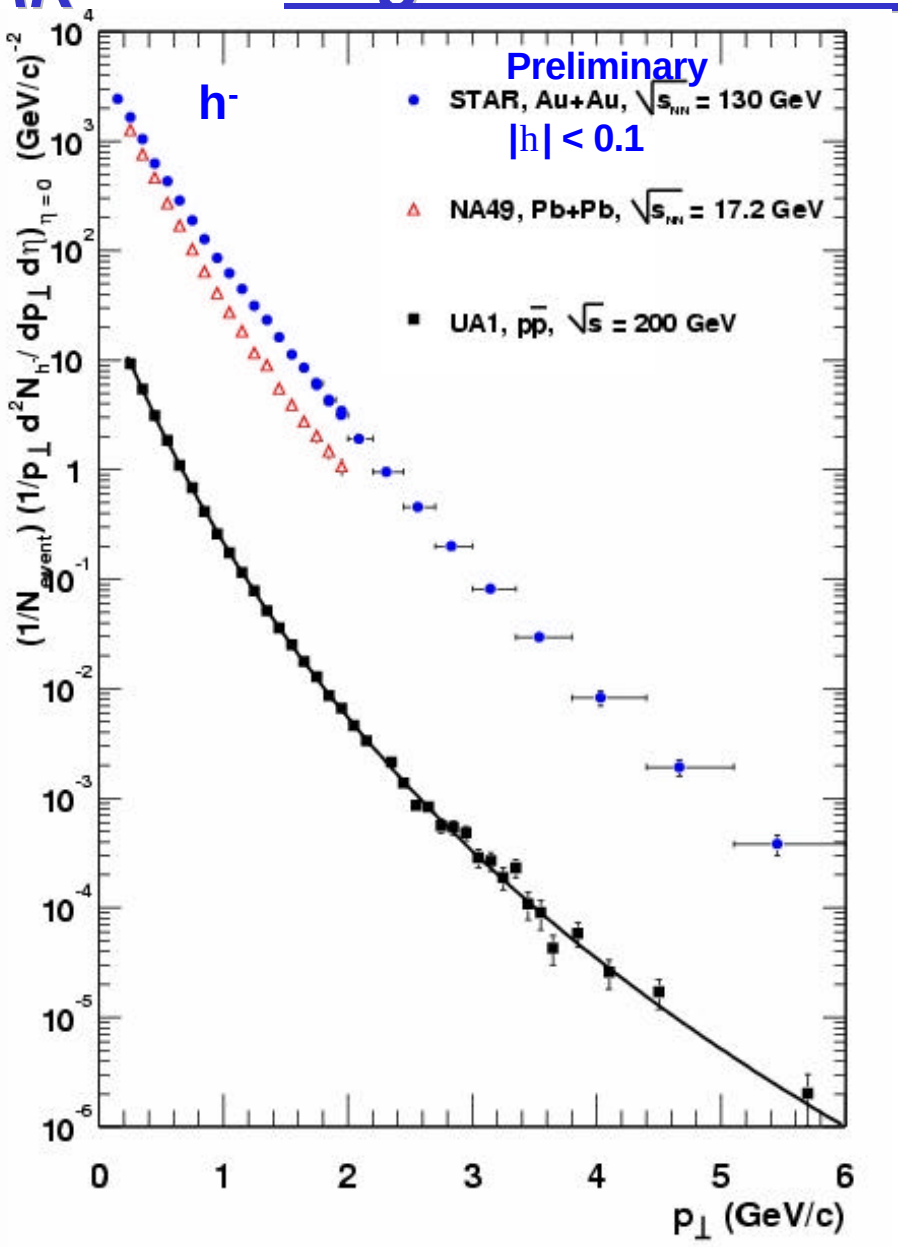
Negative Hadrons: p_t - distributions



Power Law

$A (1 + p_t / p_0)^{-n}$

$p_0 = 2.74 \pm 0.11$ GeV/c

$n = 13.65 \pm 0.42$

STAR

$\langle p_t \rangle = 0.514 \pm 0.012$ GeV/c

NA49

$\langle p_t \rangle = 0.414 \pm 0.004$ GeV/c

UA1

$\langle p_t \rangle = 0.392 \pm 0.003$ GeV/c

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Negative Hadrons: Compare with `pp p_t - distributions

UA1 Ös = 200

Þ R (130/200)

From power law scaling

R = 0.92 at 0.2 GeV/c

R = 0.70 at 2 GeV/c

"Hard" Scaling

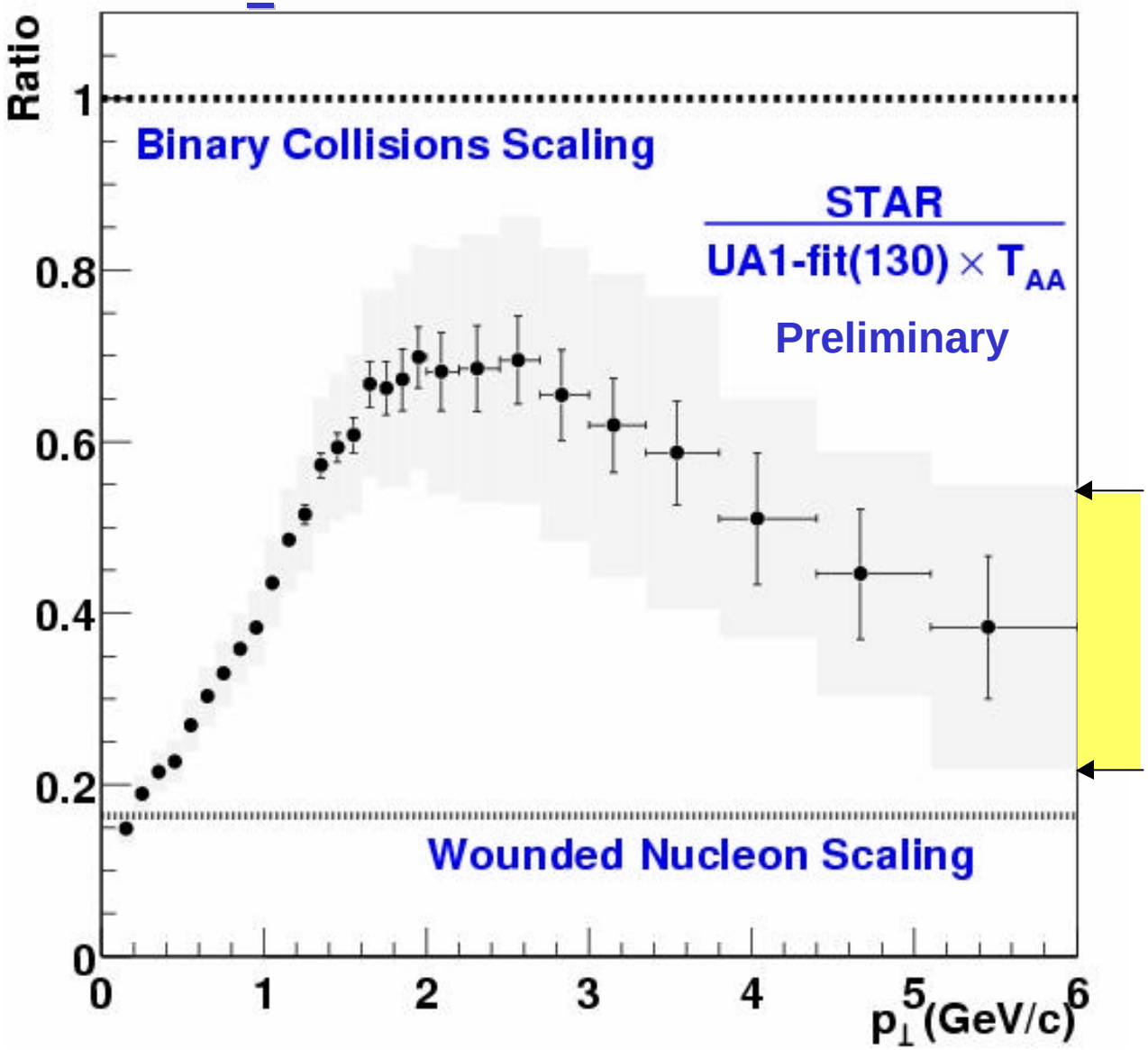
Nuclear Overlap Integral

T_{AA} = 26 mb^{-1} for 5% most central

$N_{AA} / N_{pp} = N_{bin\ coll} = 1050$

"Soft" Scaling

$N_{AA} / N_{pp} = (344 / 2)$



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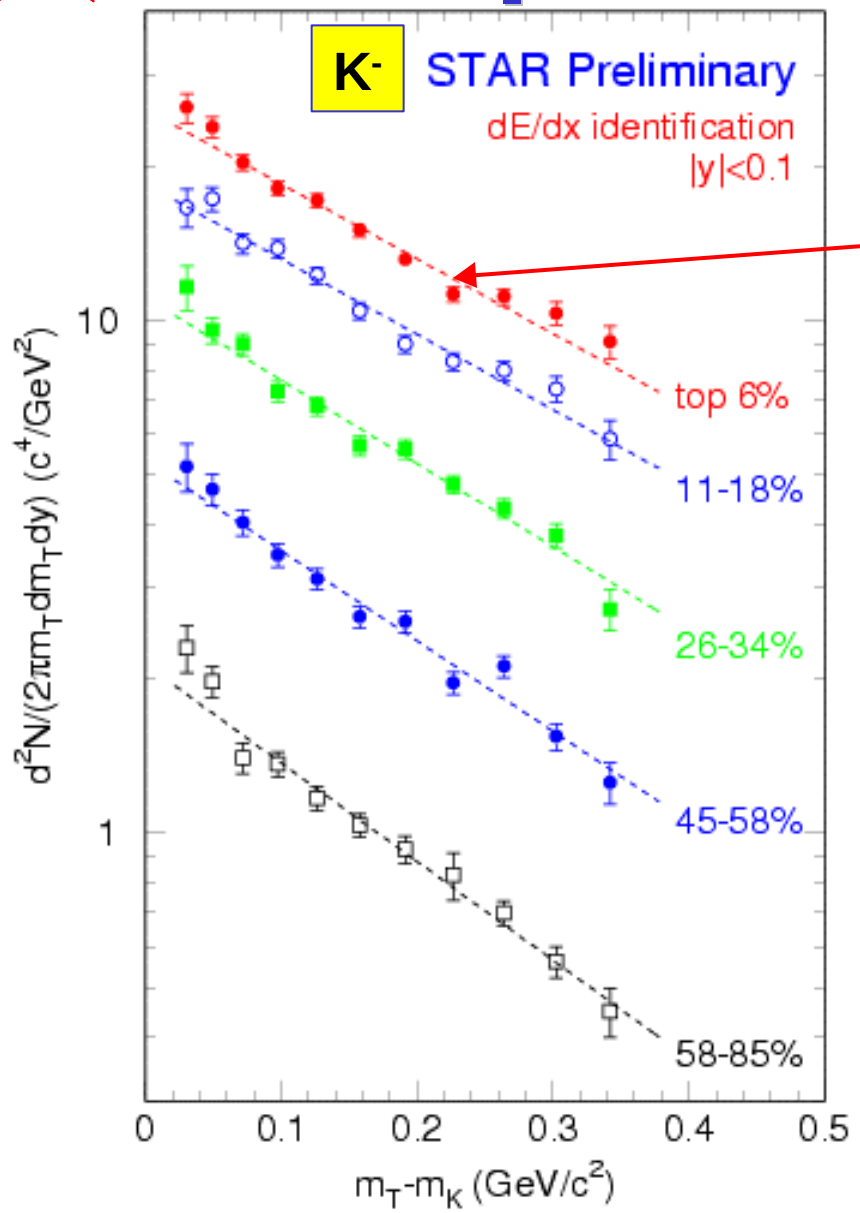
Identified Particle Spectra

See talks:

"Strangeness Production at RHIC"
H. Caines for STAR

"Resonance Studies at STAR"
Z. Xu for STAR

STAR K^- m_t - distributions vs Centrality



T = 300 ± 15 ± 30 MeV

peripheral ® central

- **Lines are fits to m_T exponential**
- **Fully corrected**

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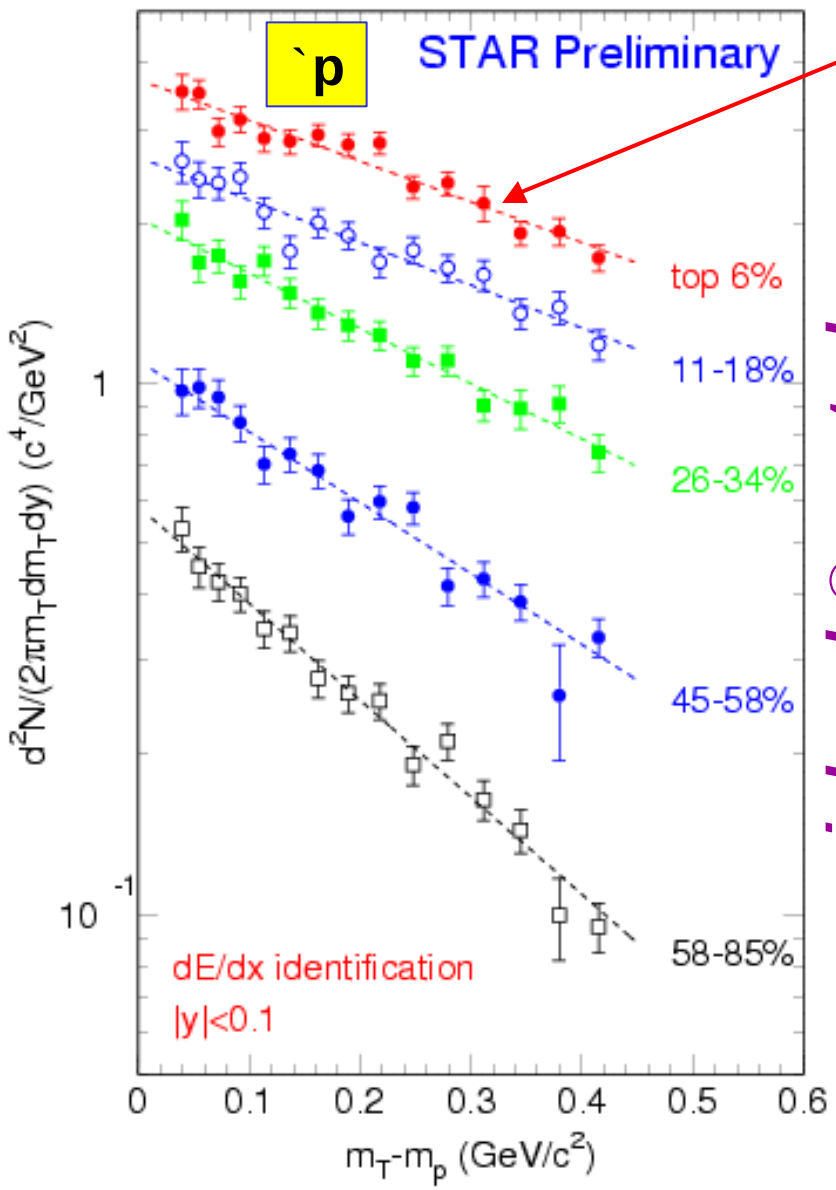
STAR `p : m_t - distributions vs Centrality



- **Large increase in T:**
  from peripheral (~ 200 MeV) to central collisions (~ 565 MeV).
- **Fully corrected**

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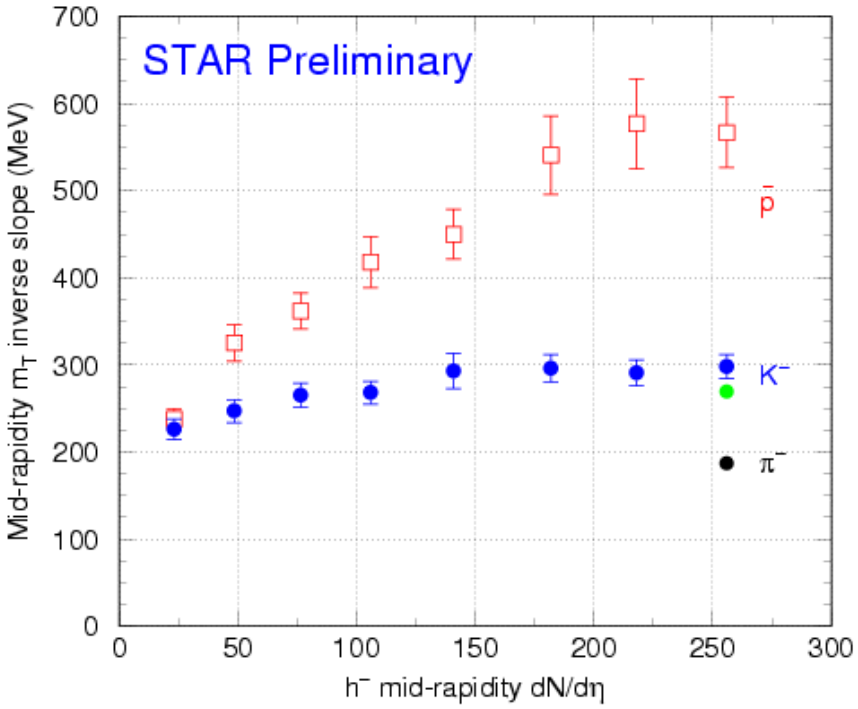
STAR `p , K^-, $\bar{p}$ Spectra

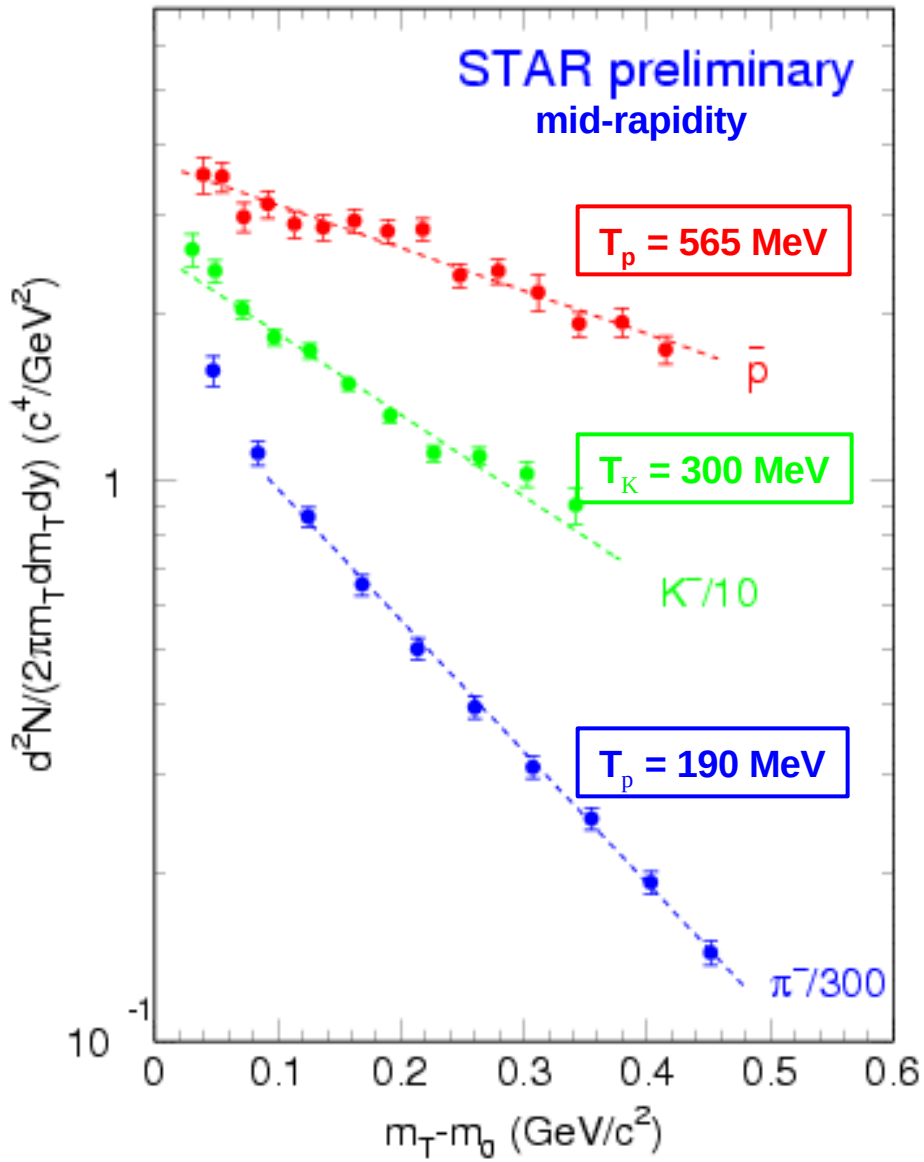
m_t - slopes vs. Centrality



Increase with collision centrality

® consistent with radial flow.

Au+Au central collisions



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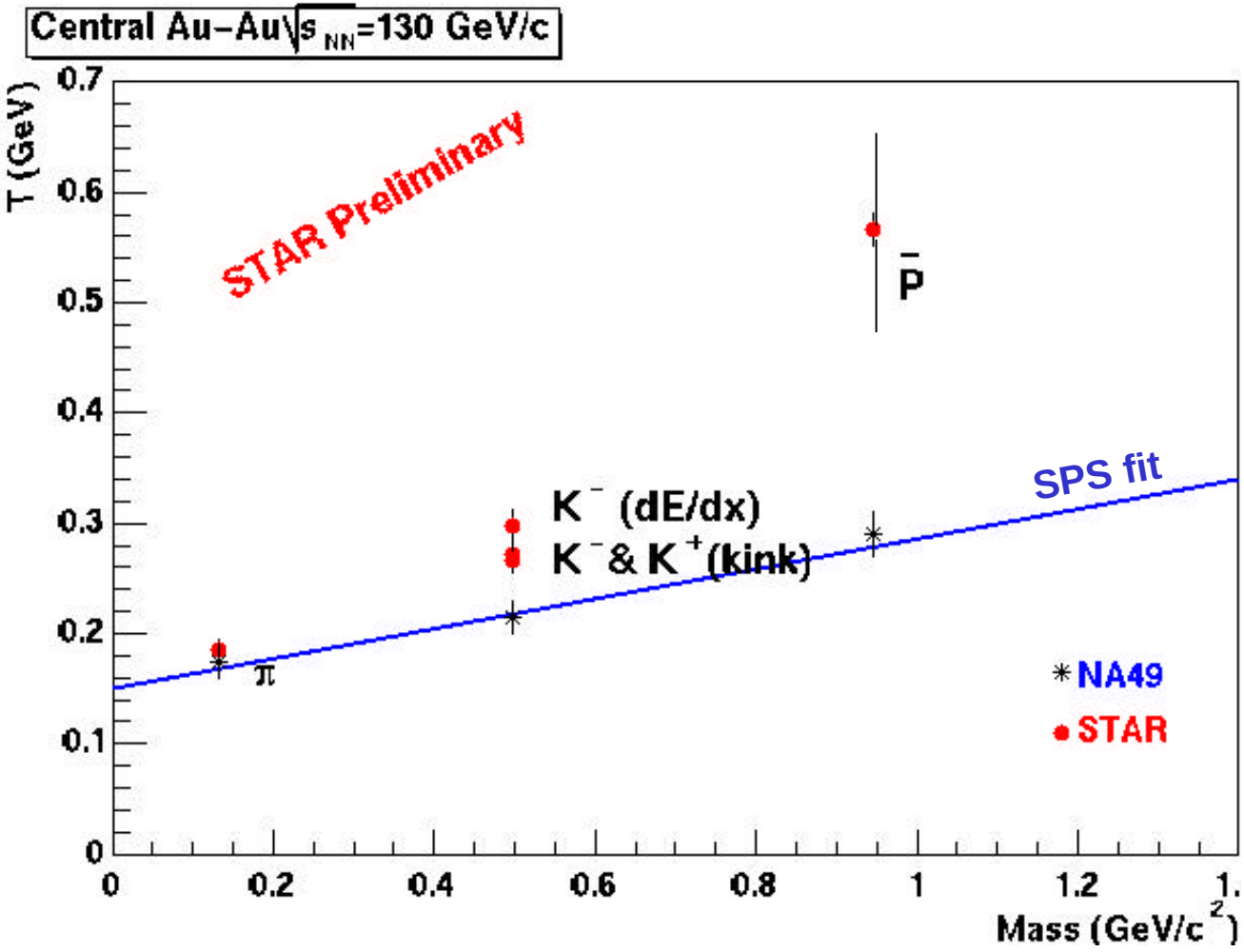
m_t - slopes vs mass



Increased transverse flow at RHIC?

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Particle Ratios

See talks:

"Strangeness Production at RHIC"
H. Caines for STAR

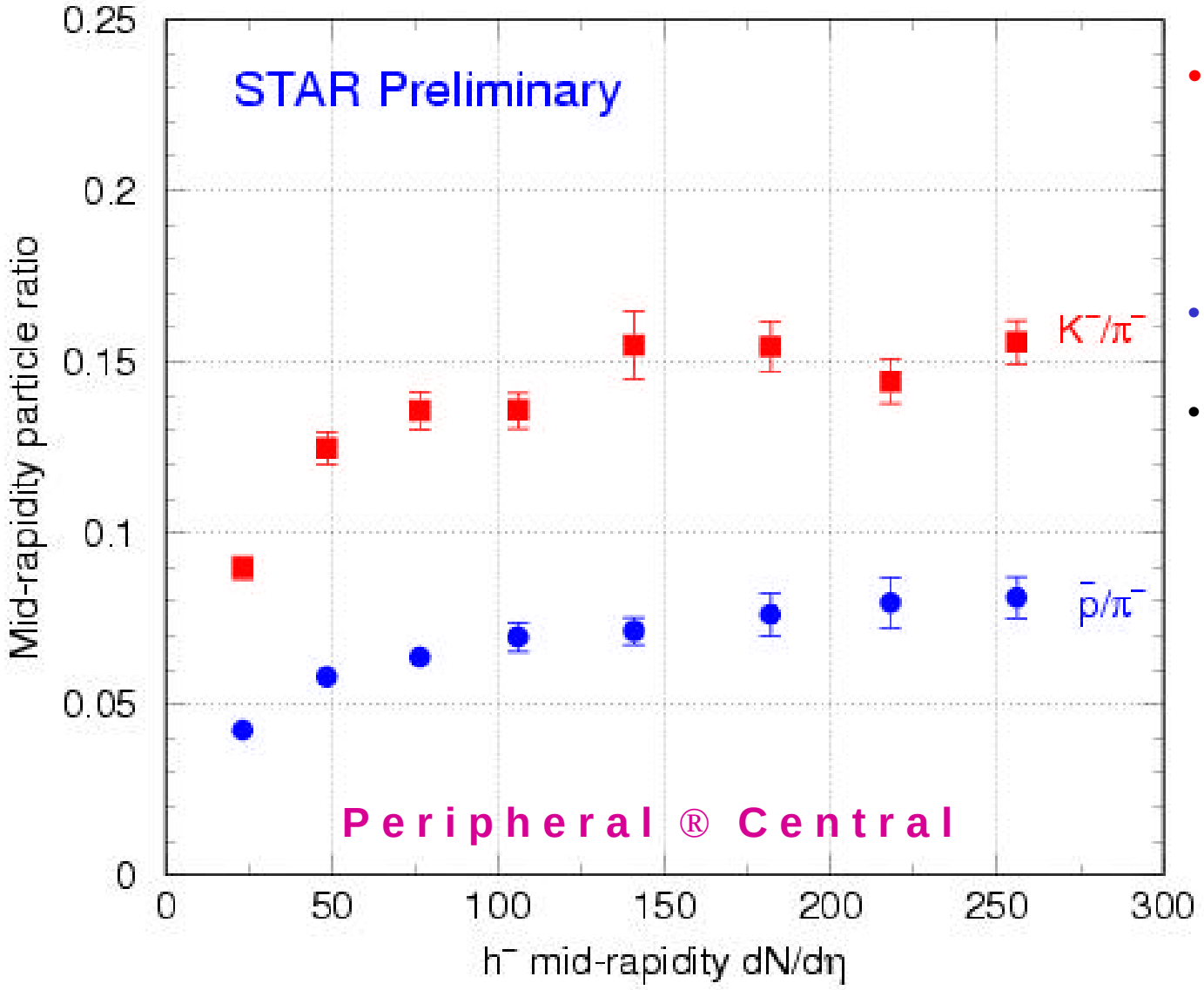
"Particle Ratios from Au + Au Collisions.."
H. Huang for STAR

"High Pt Spectra from STAR"
J. Dunlop for STAR

"Resonance Studies at STAR "
Z. Xu for STAR

"Anti-Nucleus Production at RHIC"
D. Hardtke for STAR

STAR Mid-rapidity $\bar{p}/p^-$, K^-/p^- vs Centrality



- K^-/p^-, $\bar{p}/p^-$ enhanced by ~2 in central vs. peripheral collisions
- $\bar{p}/K^-$ ~ constant
- In central collisions:
  K^-/p^- = 15%
  $\bar{p}/p^-$ = 8%

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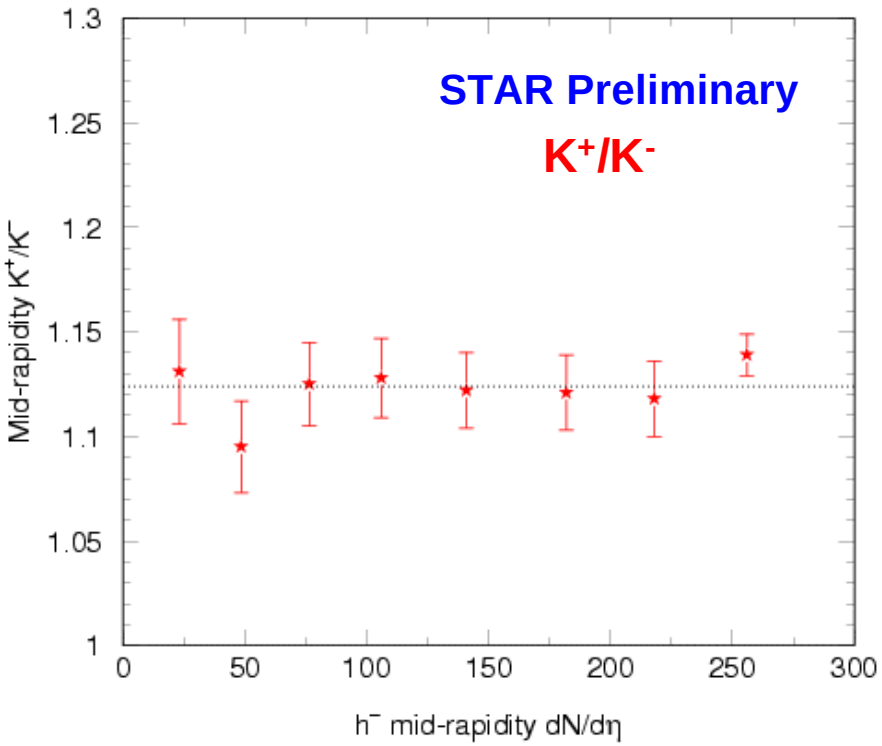
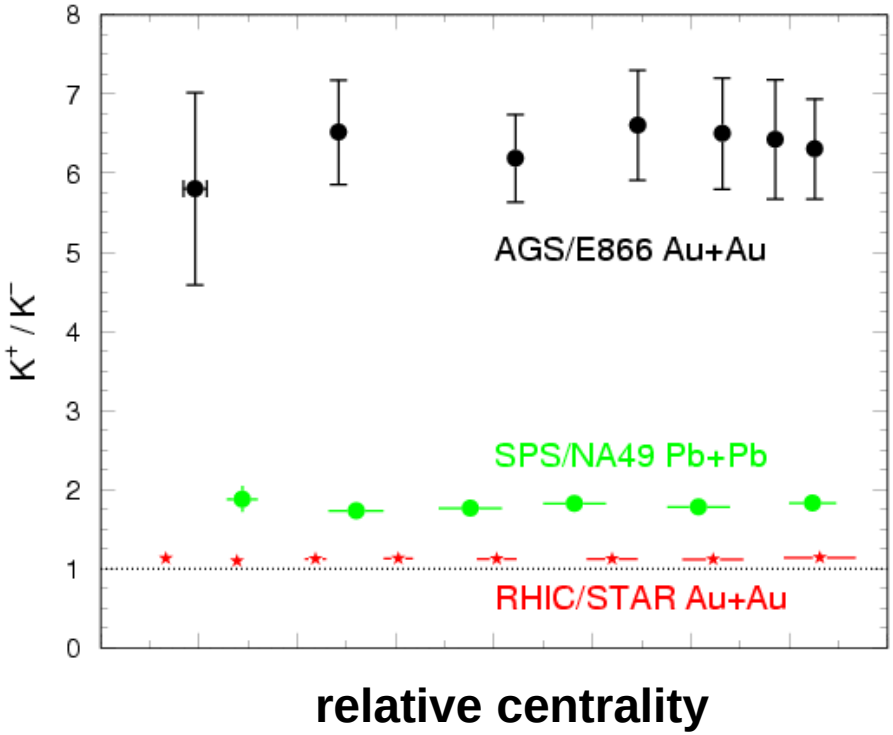
Mid-rapidity K^+ / K^- vs Centrality





relative centrality

- **Results from STAR:**
  - **K^+/K^- = 1.12+-0.01+-0.06**
  - **K^+/K^- constant vs. centrality.**
- **K^+/K^- constant at GSI, AGS, SPS. [production/physics different….]**
- **K^+/K^- decreases with $\sqrt{s_{nn}}$, near 1 at RHIC.**

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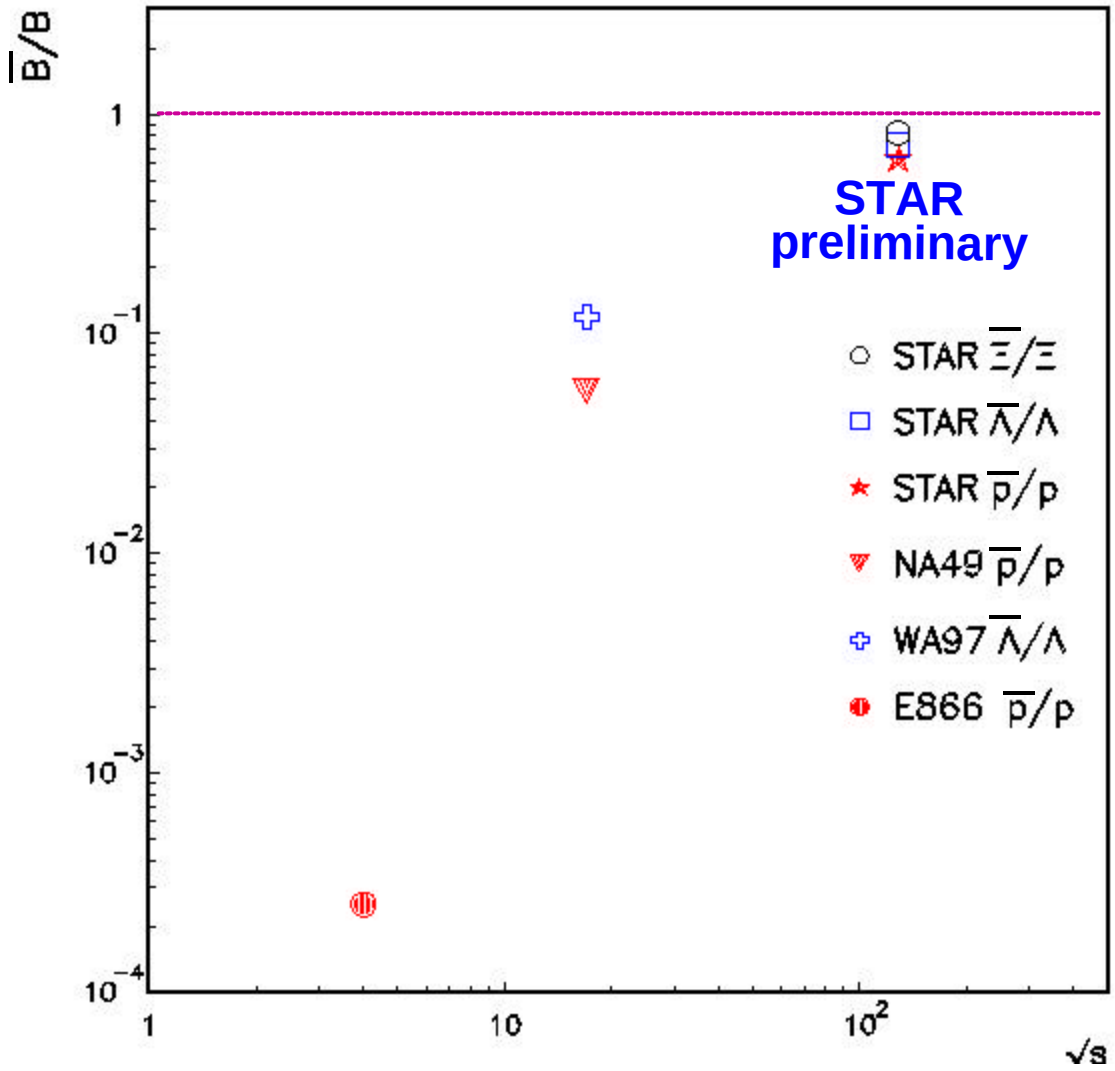
STAR Anti-baryon/Baryon Ratios versus Ös



Baryon-pair production increases with Ös

Mid-rapidity region not yet baryon-free!

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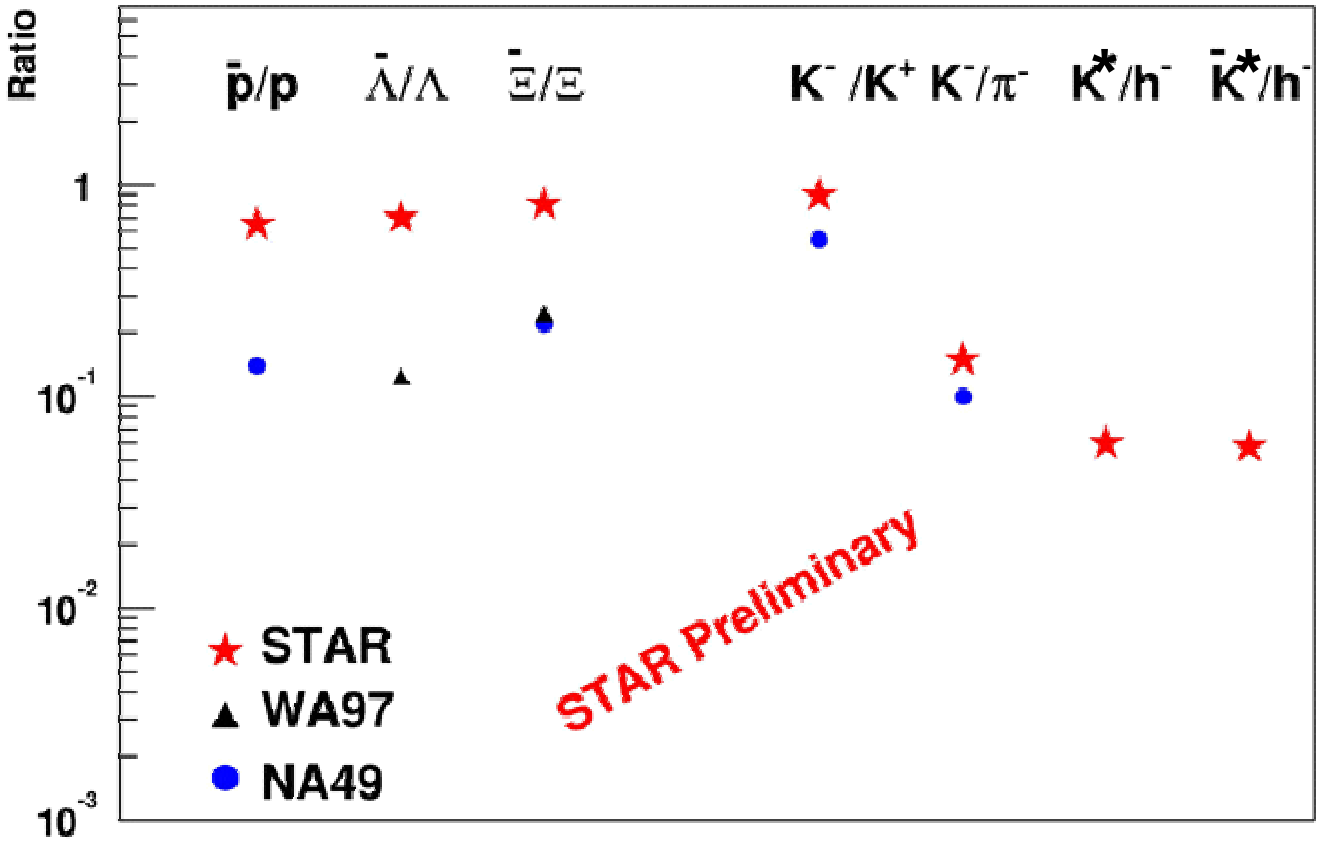
Ratios Compared to SPS



`p /p = 0.61 ± 0.03 (stat.) ± 0.06 (sys.)

`L/L = 0.73 ± 0.03 (stat.)

`X/X = 0.82 ± 0.08 (stat.)

$K^+/K^- = 1.12 \pm 0.01 \pm 0.06$

® Quark Coalescence

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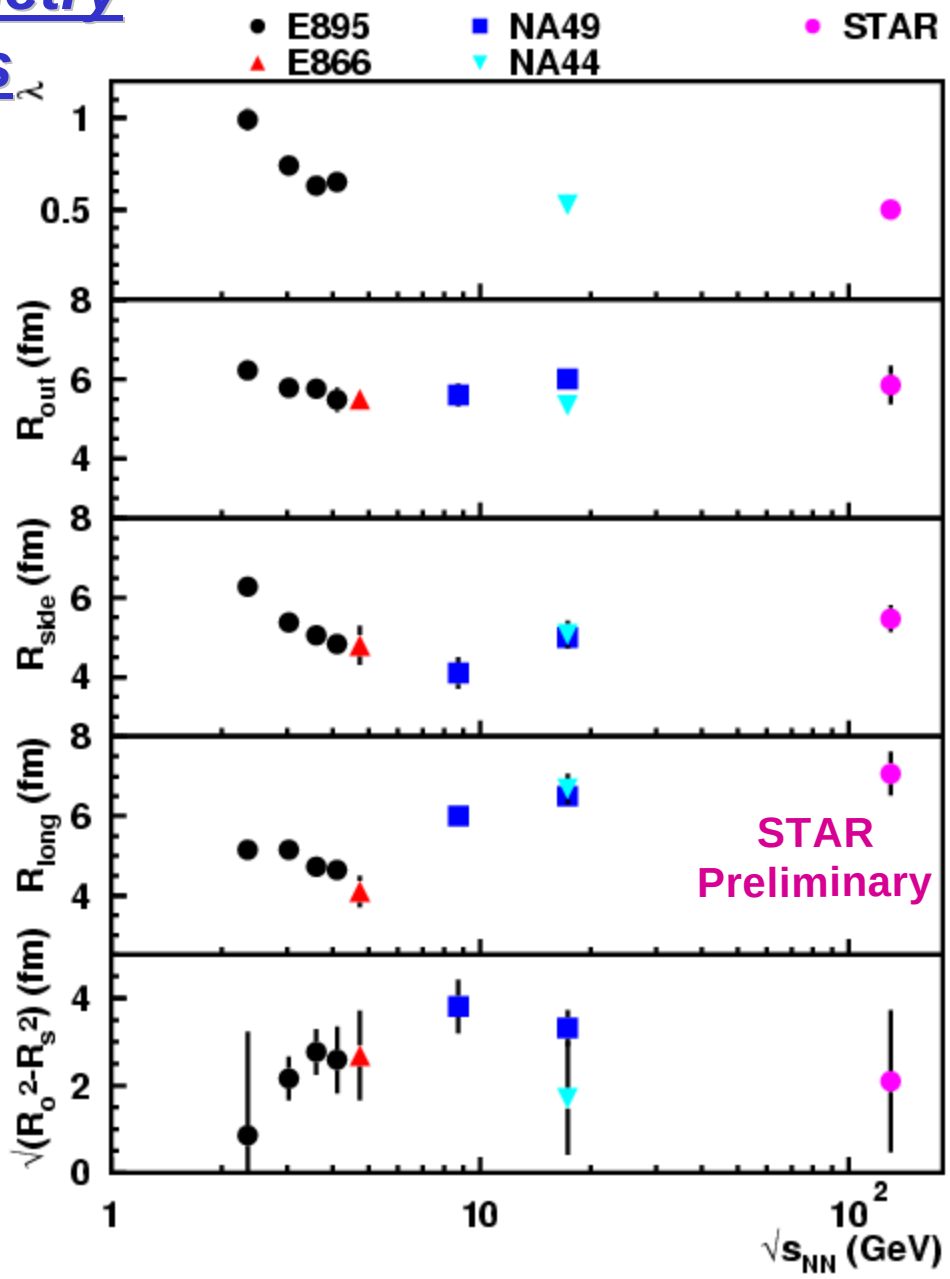
STAR Two-Particle Interferometry

See talk:

"HBT at RHIC"
F. Laue for STAR

Pion interferometry systematics

- Central AuAu (PbPb)
- decreasing λ parameter
- saturation in radii
  - geometric or dynamic (thermal/flow) saturation
  - no jump in effective lifetime
- no significant rise in spatio-temporal size of the π emitting source
- **Lower energy running needed!**



(STAR results include systematic uncertainty)

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STAR Elliptic Flow Measurements

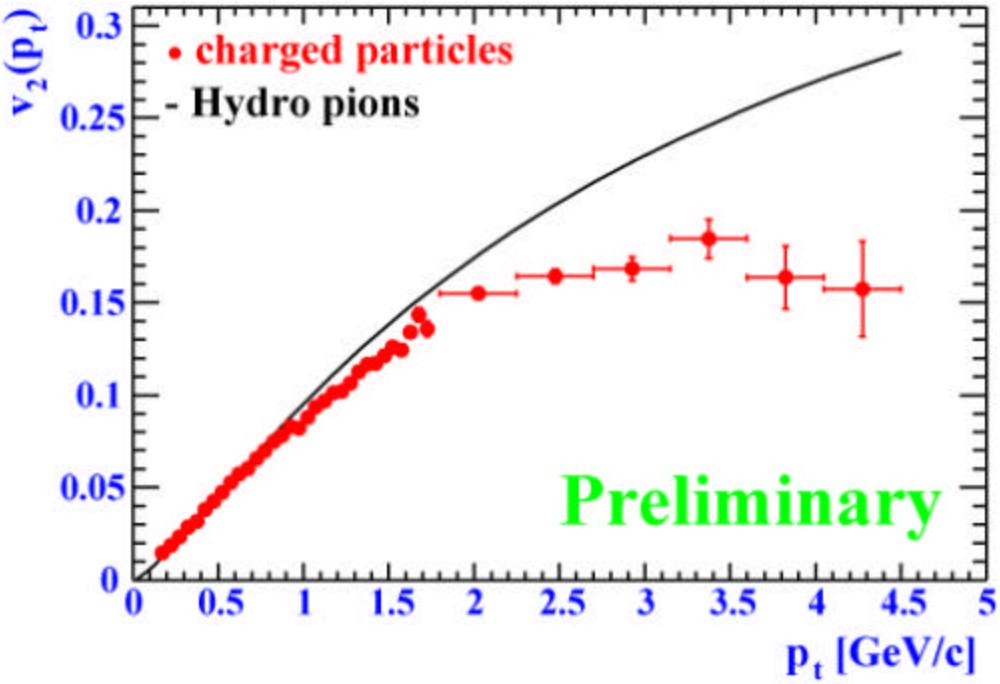
See talk:

"Flow at RHIC"

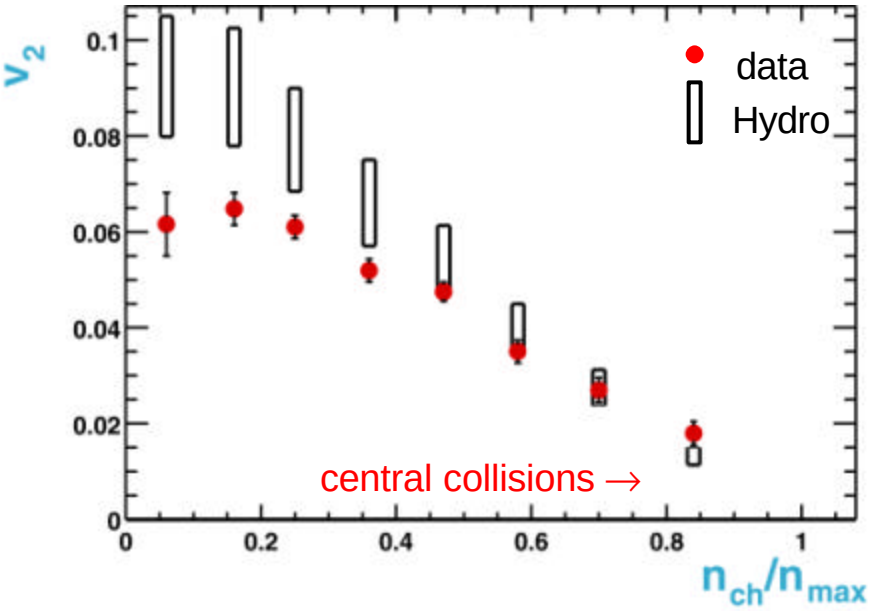
R. Snellings for STAR

Elliptic Flow - Centrality Dependence

v_2: 2nd Fourier harmonic coefficient of azimuthal distribution of particles with respect to the reaction plane



STAR, PRL 86 (2001) 402



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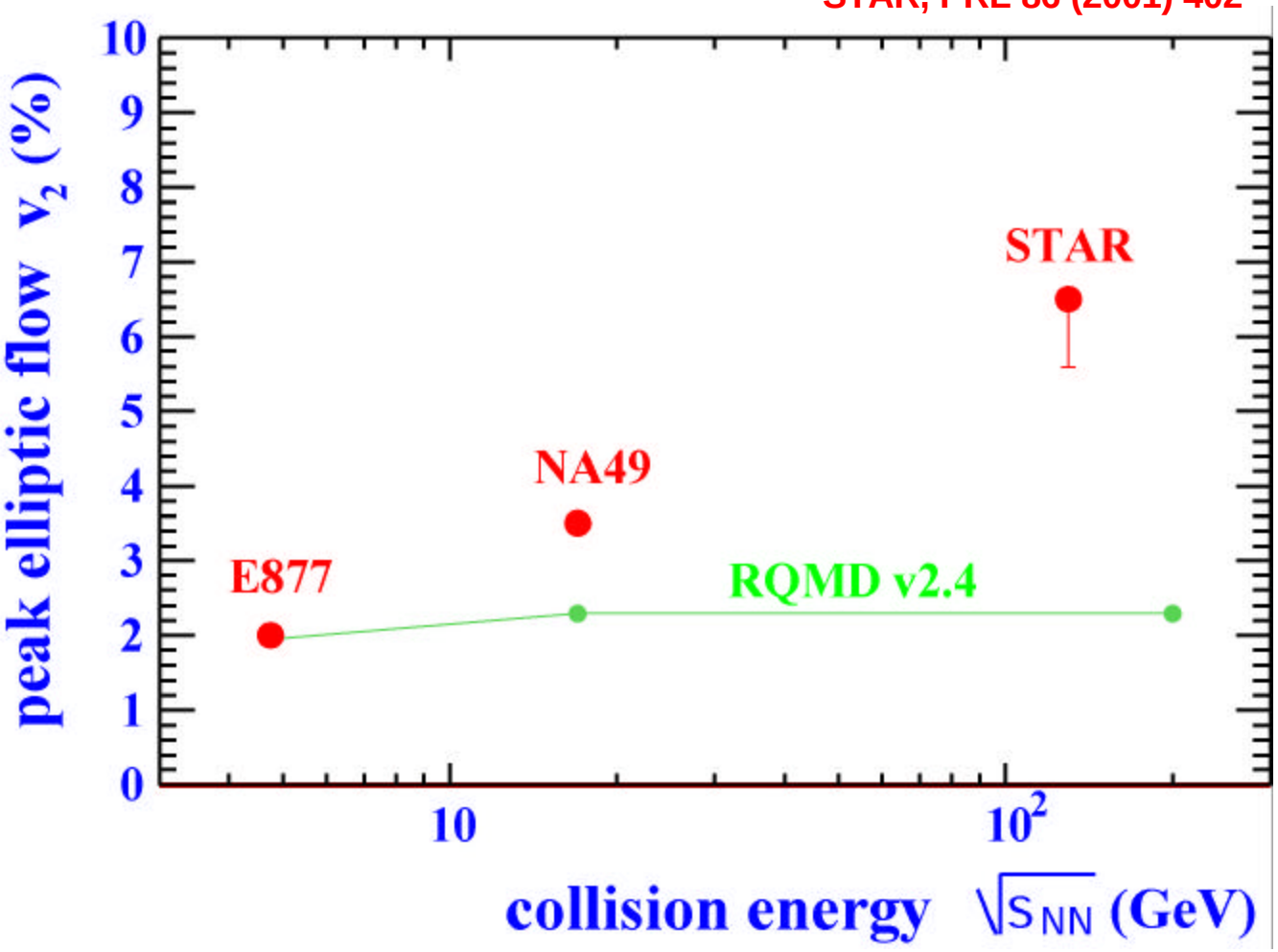
Elliptic Flow Excitation function

STAR, PRL 86 (2001) 402



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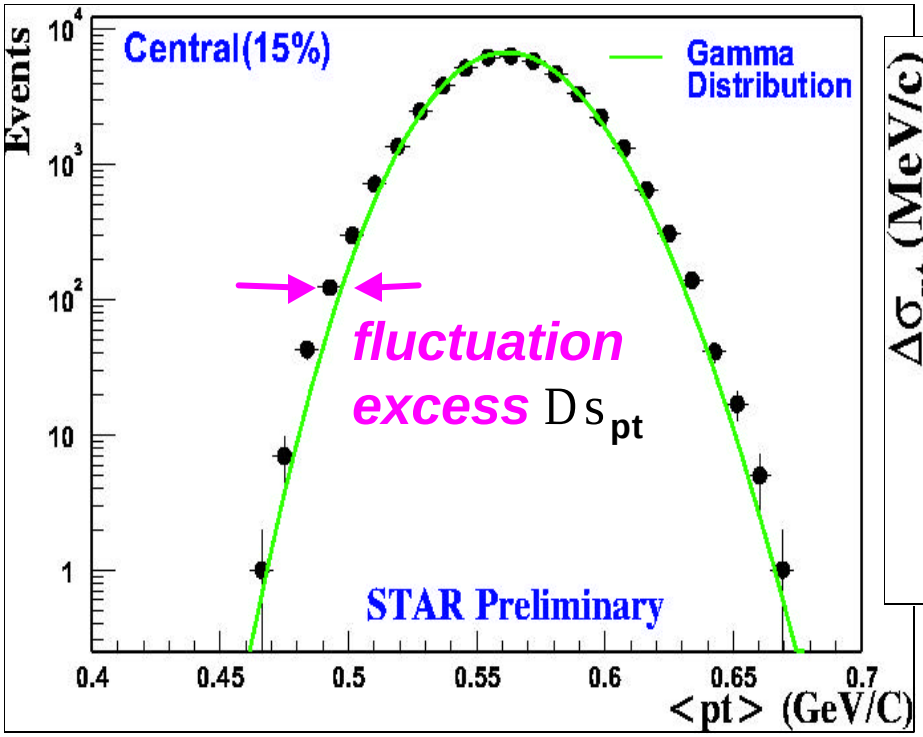
Event by Event Measurements

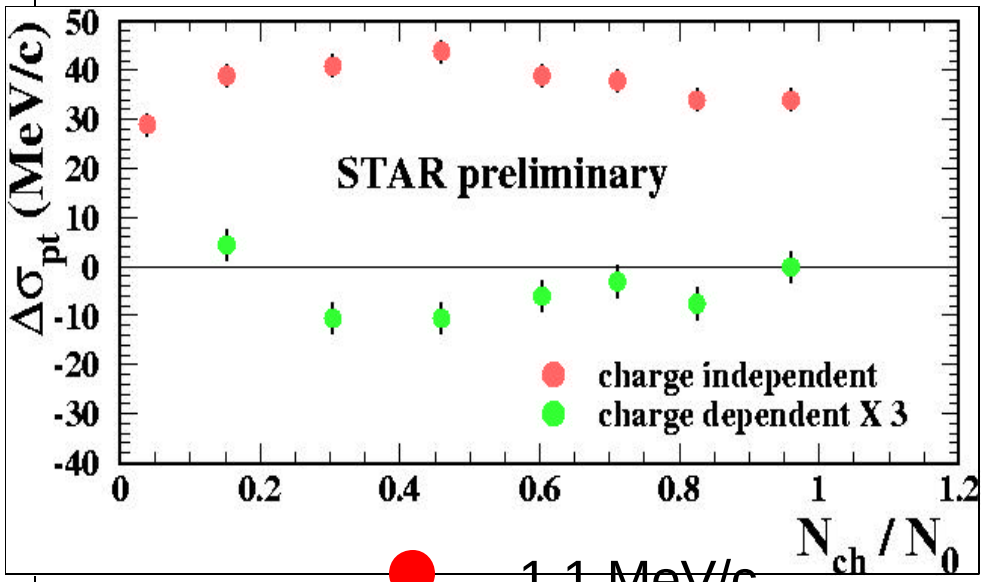
- **See Talk :**

  "STAR Event-by-Event Fluctuations"

  J.R. Reid

á p_t ñ Fluctuations





NA49: 1.1 MeV/c

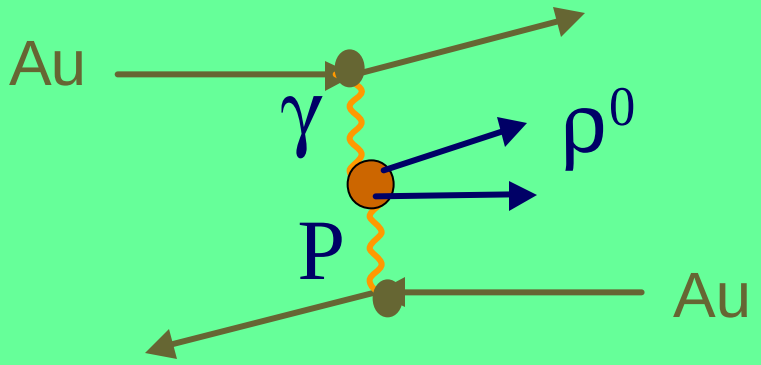
–8.5 MeV/c

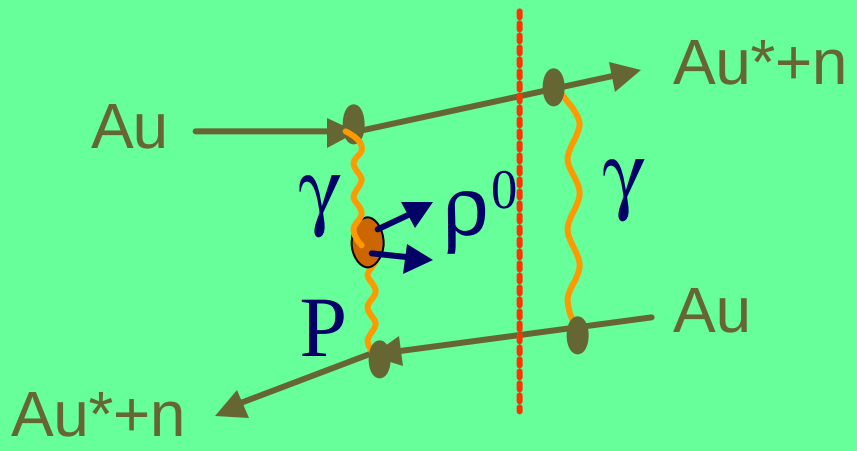
- **Substantial <p_t> fluctuation excess is observed over a range of collision centralities**
- **Centrality dependence differs for charge-dependent (●) and charge-independent (●) excess**

● [(++) + (– –)] / [(+–) + (–+)] ● [(++) + (– –)] * [(+ –) + (– +)]

J.W. Harris for STAR at QM2001

Ultra-Peripheral Collisions



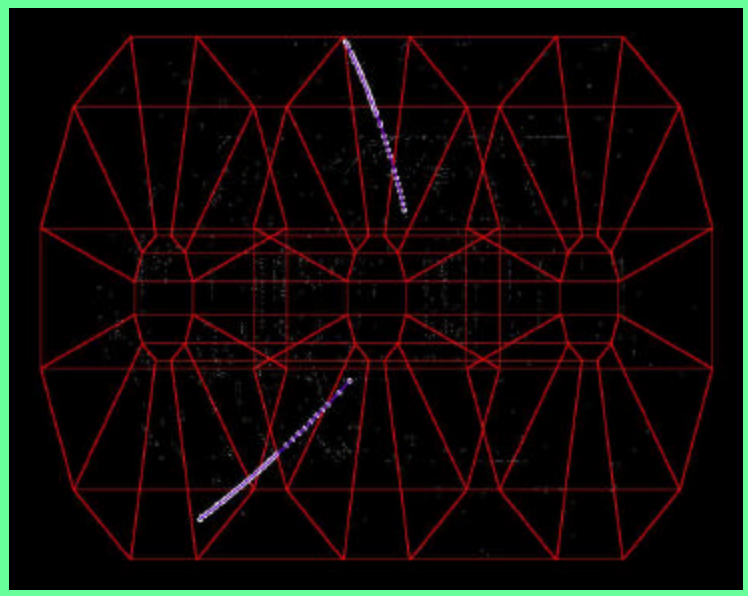


- *Coherent Coupling* **to both nuclei:**
  photon~z^2,Pomeron~$a^{4/3}$

Signature: back-to-back opposite charges

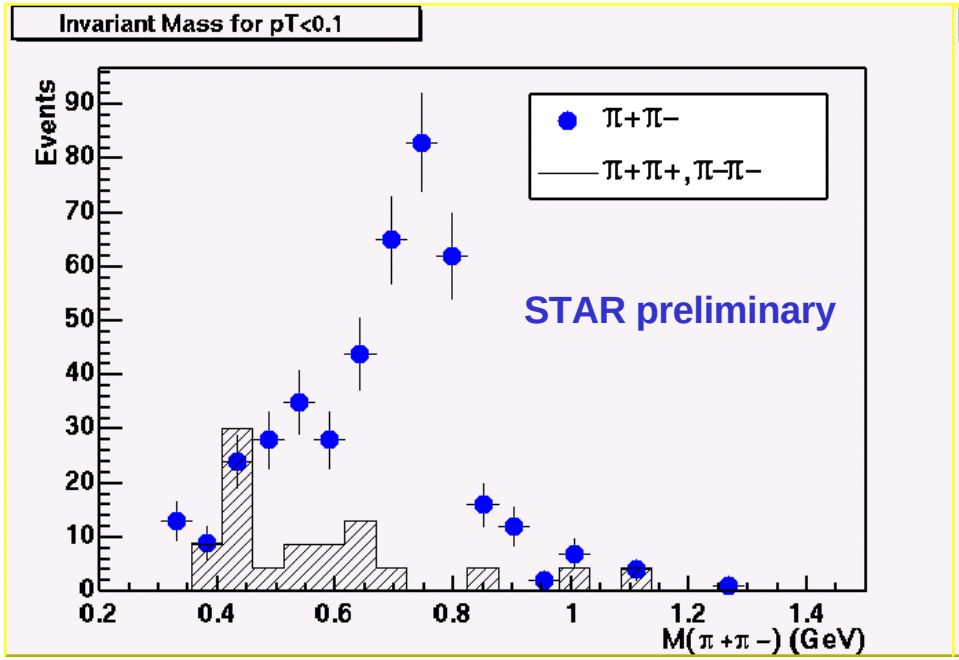
Au+Au --> Au+Au + r^0

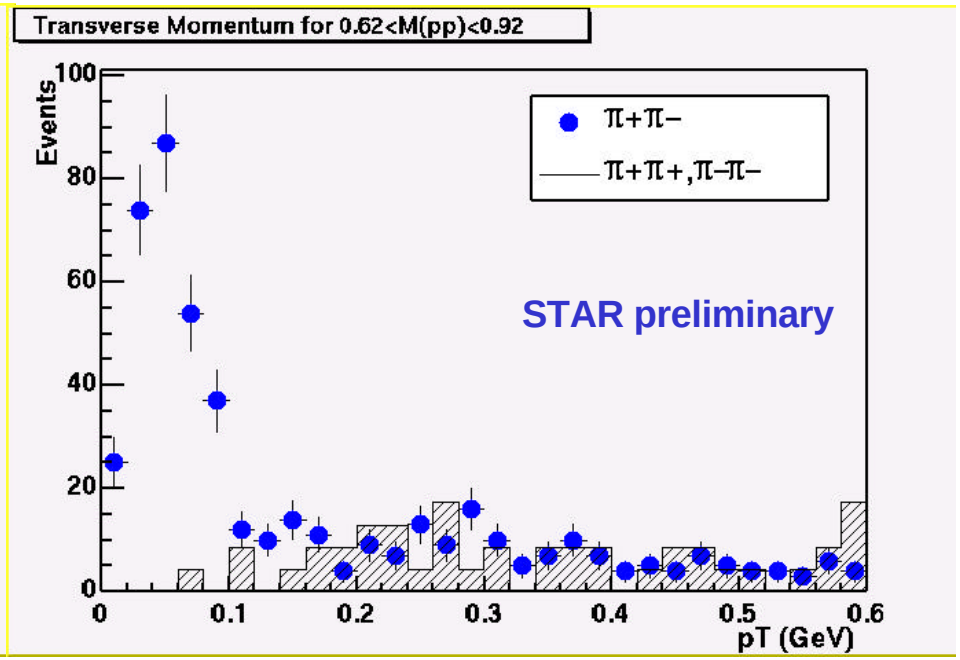
Au+Au --> Au*+Au* + r^0



M_{pp} and p_t Spectra

All events with only two tracks





First measurement of

Coherent EM Production (gP)

in heavy ion interactions

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STAR Conclusions

Conclusions

- STAR Detectors (TPC, RICH, Triggers) and Collaboration

  "working well ® to (better than) specifications!"

- Mapped out "Soft Physics" Regime
  - Particle production increased by 43% relative to SPS
  - Midrapidity spectral slopes increase with centrality & particle mass

    ® Strong transverse flow
  - Strong elliptic flow measured to high p_t (4.5 GeV/c)
  - Anti-particle and strange particle production increase rel. to SPS

    ® low net baryon density (but mid-rapidity not yet baryon free)

    ® consistent with quark coalescence
  - HBT (freeze-out) sizes similar to SPS
  - Substantial excess in mean p_t fluctuations
- "Hard Physics"
  - h- spectra never reach hard-scattering limit,

    diverge from it at $2 < p_t < 6$ GeV/c

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STAR Talks at Quark Matter

- **PHYSICS**
  - **“Anisotropic Flow …….”, R. Snellings**
  - **“First Results on Strangeness Production ……”, H. Caines**
  - **“HBT Interferometry ….. ”, F. Laue**
  - **“Charged Particle Spectra ……”, Manuel Calderon**
  - **“Particle Ratios ……”, H. Huang**
  - **“Anti-Nucleus Production …. ”, D. Hardtke**
  - **“Resonance Studies ….. ”, Z. Xu**
  - **“High Pt Spectra …… ”, J. Dunlop**
  - **“Two-particle Transverse Mass Correlation Analysis ……”, J. Reid**

- **INSTRUMENTATION**
  - **“The STAR Time Projection Chamber”, F. Retiere**
  - **“The STAR RICH Detector”, B. Lasiuk**

STAR Poster Presentations at Quark Matter

- **STRANGENESS**
  - **"Calculating the Efficiency of Singly-Strange Hadrons in the STAR TPC" - M. Lamont**
  - **"Strange Particle Correlation Studies with the STAR Detector" - T. Humanic**
  - **"Kaon Reconstruction via One-Prong Decays in the STAR TPC" - W. Deng**
  - **"Multiply-Strange Baryon Production in Au + Au…" - C. Lansdell**
- **HBT**
  - **"HBT Event-by-Event" - D. Flierl**
  - **"Results from Three Particle Interferometry at STAR" - R. Willson**
  - **"Correlations of Non-identical Particles in Au + Au..." - A. Kisiel**
  - **"Pion Interferometry Relative to the Reaction Plane" - R. Wells**
  - **"Proton-proton and Anti-proton-Anti-proton Correlations" - M. Lopez-Noriega**
  - **"Pion Phase Space Density from STAR HBT Analysis" - J. Cramer**
- **SPECTRA**
  - **"Photon Production in Au + Au Collisions" - I. Johnson**
  - **"Parity and CP Violation Studies at RHIC" - E. Finch**
  - **"Systematic Studies of Numbers of Participants in Au + Au Collisions at RHIC Using STAR Data" - Y. Chen**
- **EVENT-BY-EVENT**
  - **Azimuthal and pseudo-rapidity correlations of high p_t particles - S. Chattopadhyay**
  - **Event-by-Event fluctuations of mean p_t - Z. Ahammed**
- **PERIPHERAL**
  - **Peripheral collisions with STAR - F. Meissner**
- **INSTRUMENTATION**
  - **"The Hardware Controls System for the STAR Experiment"**
  - **"Laser Calibration System for the STAR TPC"**
  - **"Performance of the Partial STAR SVT in the RHIC 2000 Run"**
  - **The STAR Trigger System - Z. Milosevich**
  - **The Hardware Controls System for the STAR Experiment - Dennis Reichhold**