СЕССИЯ-КОНФЕРЕНЦИЯ СЕКЦИИ ЯДЕРНОЙ ФИЗИКИ ОТДЕЛЕНИЯ ФИЗИЧЕСКИХ НАУК РАН 2009

High-p_T Spectra of Charged Hadron Production in Au+Au Collisions at $\sqrt{s_{NN}}$ = 9.2 GeV in STAR

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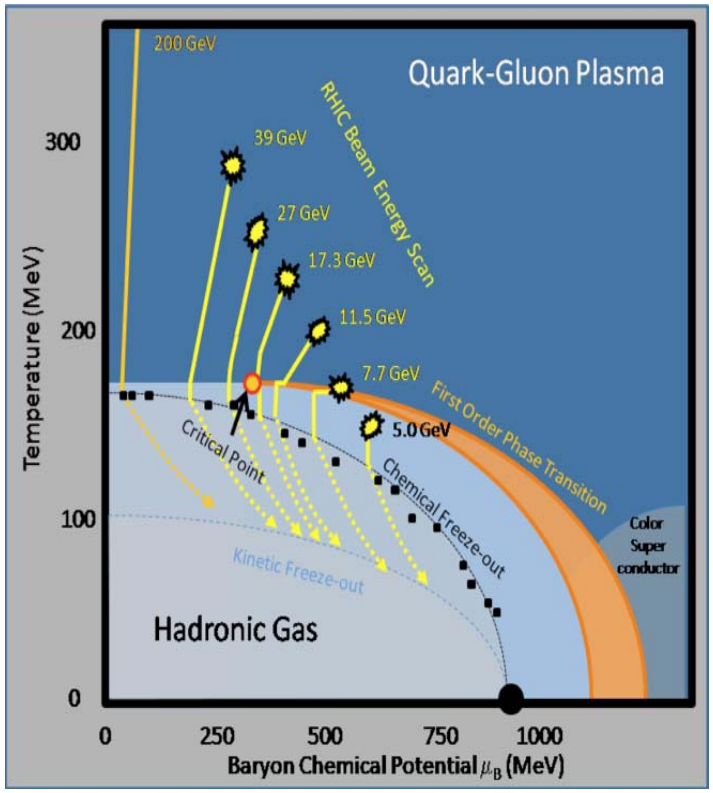
for STAR Collaboration

JINR, Dubna

Outline:

- Motivation
- STAR Experiment and Collisions at $\sqrt{s_{NN}}$ = 9.2 GeV
- Results and systematics : spectra, ratios, efficiency
- Results of analysis: energy loss vs. p_T, centrality
- Summary and Outlook (RHIC Energy Scan)

Motivation & Goal



RHIC has uncovered an exciting new state of matter

The most important questions are not fully answered

-- location of phase boundaries

-- position of critical point (CP)

-- signatures of phase transition (1^{st}, 2^{nd})

-- thermodynamic parameters near CP

T, μ_B, heat capacity, energy density,…

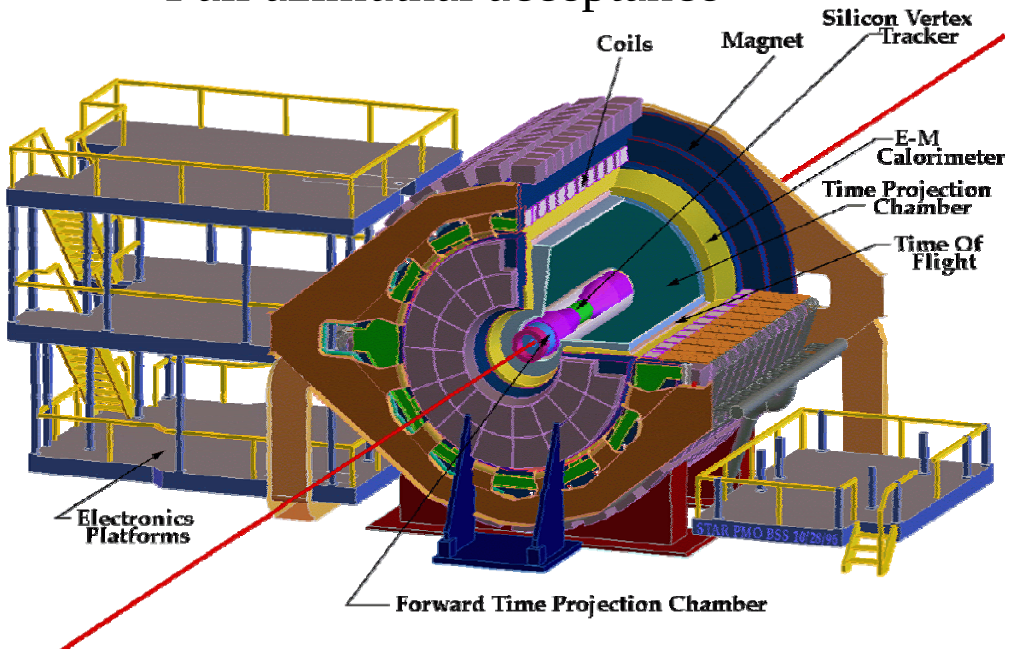
An exploration of the full region of energy $s^{1/2}$ = 5-200 GeV available at the RHIC facility is an unavoidable imperative.

To find the region where the "flagship" observables established at top RHIC energies will change or even disappear (v_2 & CQS, R_{AA} & R_{CP} suppression,…)

- To present p_T spectra of charged hadrons from data taking in STAR with the Au+Au collisions at $\sqrt{s_{NN}}$ = 9.2 GeV
- To estimate constituent energy loss vs. centrality, energy collisions and p_T
- The Beam Energy Scan at RHIC as a Program to search for CP

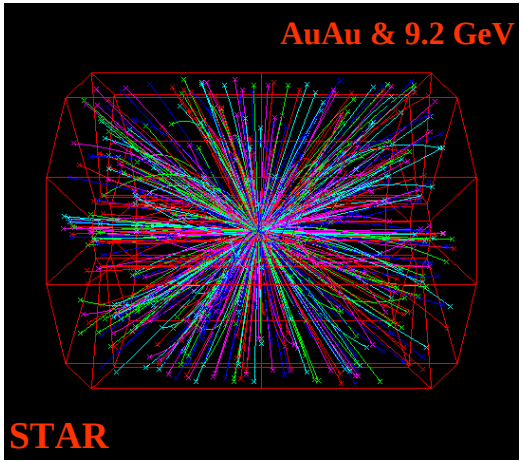
STAR Experiment

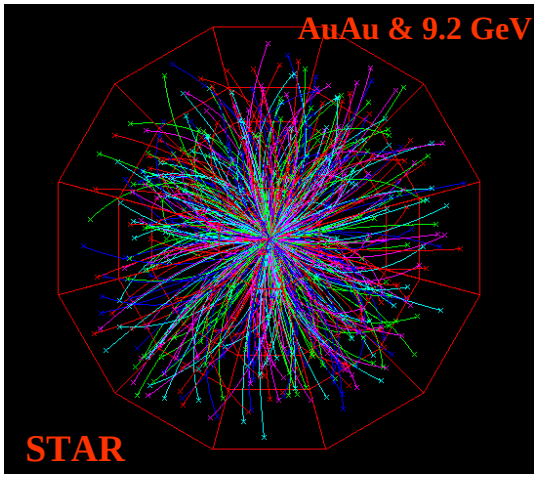
- Time Projection Chamber
  - Measures charged particle momenta and energy loss within $|\eta|<1.8$
  - Full azimuthal acceptance



Large uniform acceptance
Excellent particle ID (π,K,p,e)

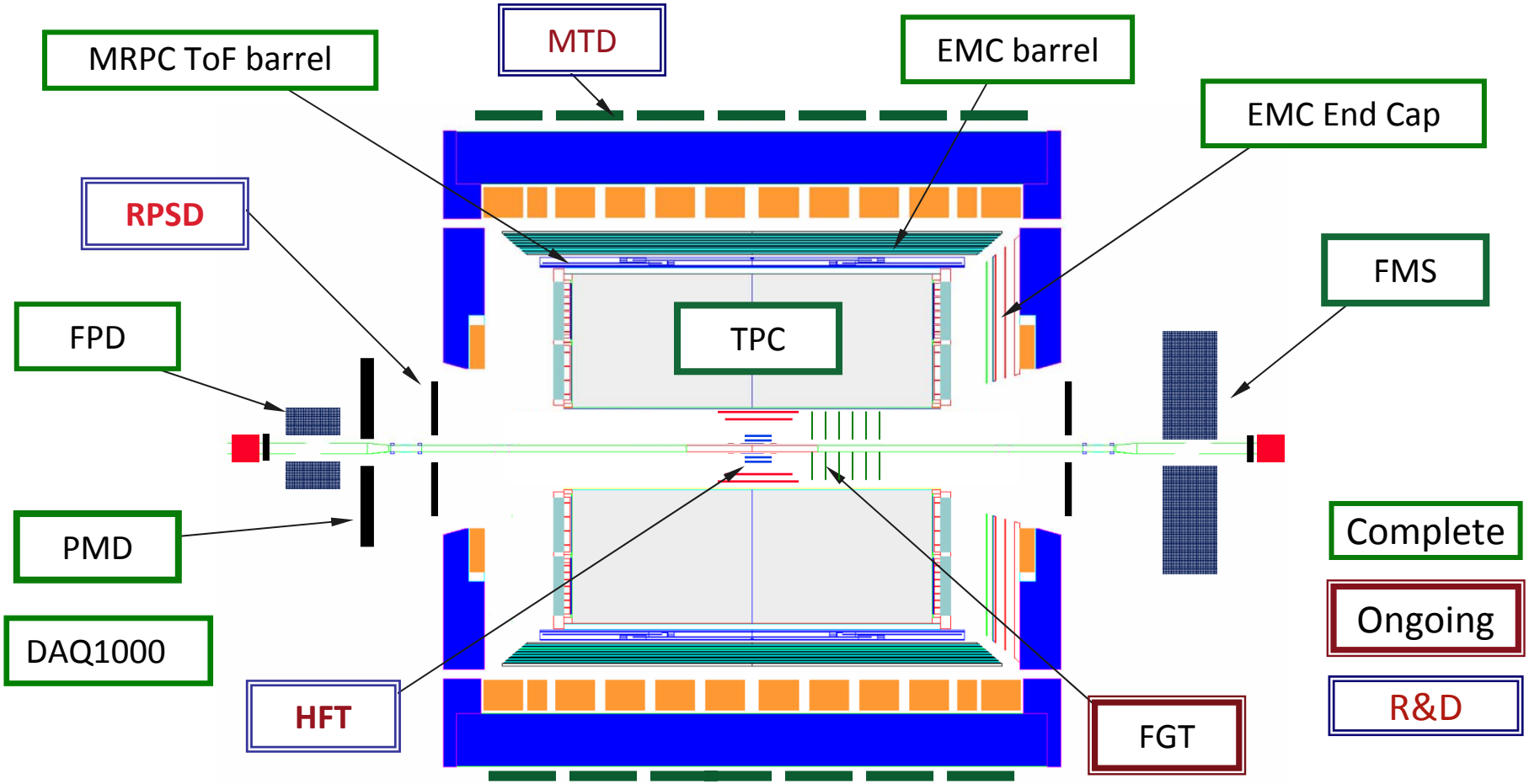
STAR TPC Event Display





central collision

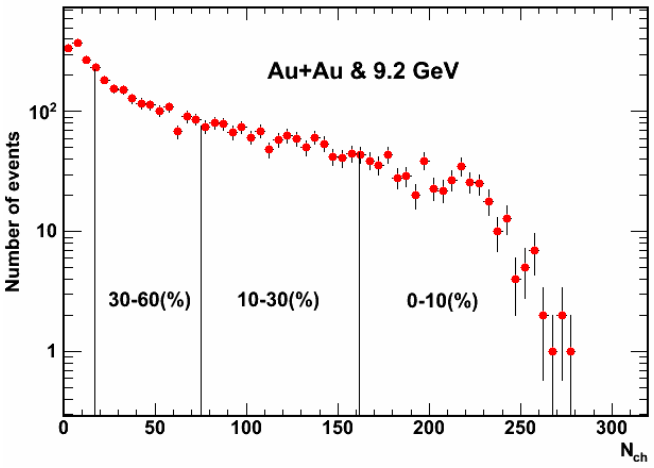
The Solenoidal Traker At RHIC



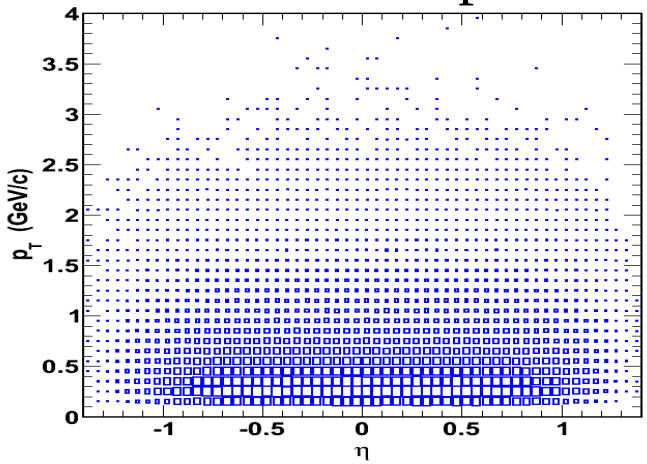
Large and uniform acceptance for all beam energies,
excellent particle identification (TPC+ToF) are significant advance
to carry out the BES program in the Critical Point search

Charged multiplicity

Collision centrality



Uniform acceptance



Data sample (2008)

$|z_{vrtx}| < 75$cm

≈ 4000 events

Tracks from TPC

DCA < 3cm

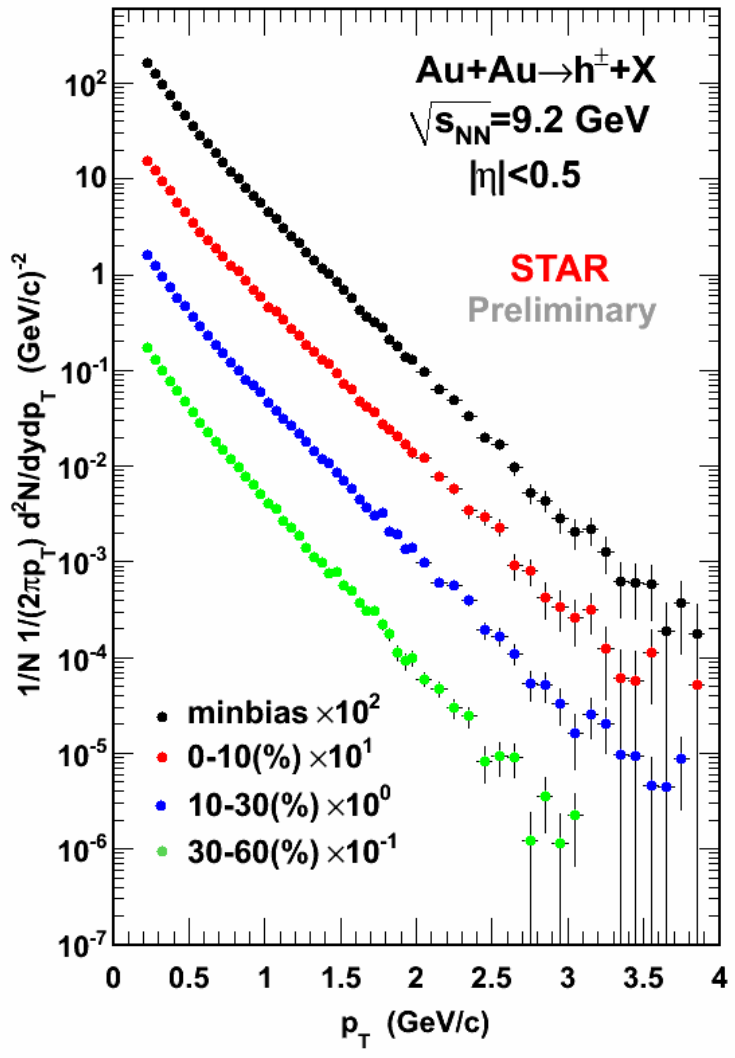
NFit>20

$|\eta|<0.5$

p_T >0.2 GeV/c

% cs	$<N_{ch}>$	N_{evnt}
0 - 10%	198.5	500
10 - 30%	115.2	1070
30 - 60%	39.6	1537
min.bias	69.6	4037

Charged hadron spectra in Au+Au & 9.2 GeV



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B.Abelev, nucl-ex/0909.4131
J.Chen, nucl-ex/0910.0556

Spectra

Corrected on the efficiency of reconstructing particle tracks

The similar shape of p_T distribution

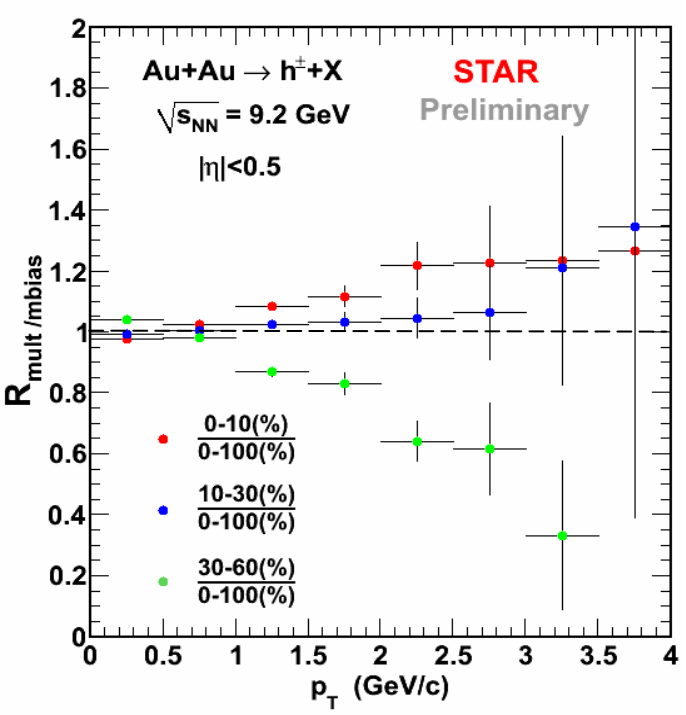
Decreases by more than 5 order of magnitude

$$< p_T >= \frac{1}{N_{hist}} \sum_{i=1}^{N_{hist}} p_T^i$$

centrality	$<p_T>$, MeV/c
0 - 10%	413.5 ± 0.5
10 - 30%	409.8 ± 0.4
30 - 60%	399.8 ± 0.5
minbias	408.7 ± 0.3

Spectra ratio vs. p_T & multiplicity

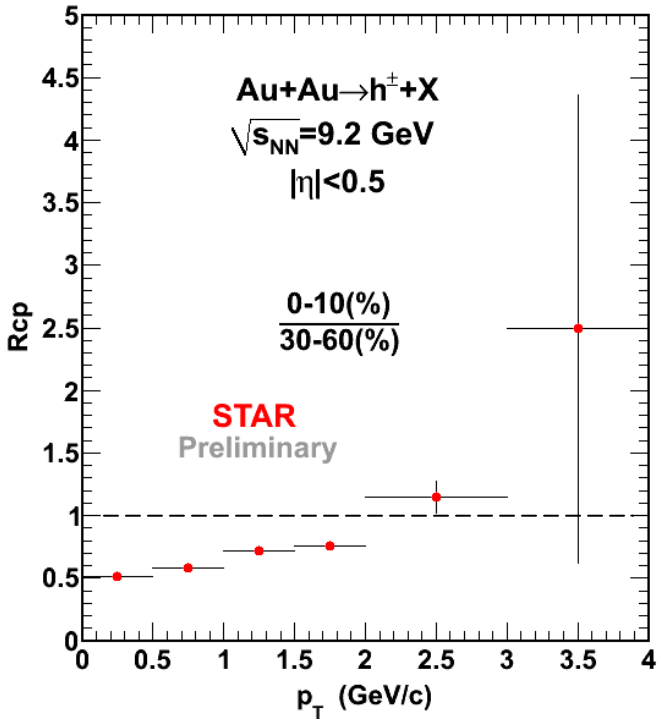
$$R_{mult/mbias} = F_{scale} \cdot \frac{d^2N^{mult}/d\eta dp_\perp}{d^2N^{mbias}/d\eta dp_\perp} \qquad F_{scale} = \frac{N_{evnt}^{mbias}}{N_{evnt}^{mult}} \cdot \frac{< N_{ch}^{mbias} >}{< N_{ch}^{mult} >}$$



The ratio of multiplicity binned p_T spectra to multiplicity-integrated spectra scaled by mean multiplicity for each bin for charged hadrons is sensitive to centrality for high p_T.

R_{CP} ratio vs. p_T

$$R_{CP} = \frac{d^2N/dp_T d\eta \,/\, \langle N_{bin} \rangle_{central}}{d^2N/dp_T d\eta \,/\, \langle N_{bin} \rangle_{peripheral}}$$



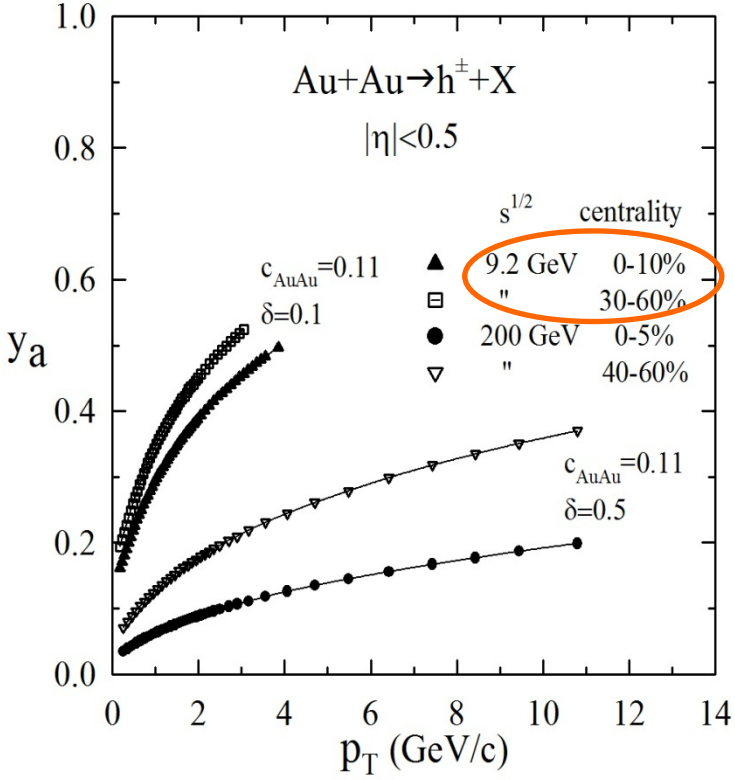
The R_{CP} ratio increases with p_T.

Constituent energy loss & z-scaling

STAR
PRL 91 (2003) 172302

z-Scaling
M.T. & I.Zborovsky
PRD75,094008(2007)
IJMPA24,1(2009)

Energy loss ~ $(1-y_a)$

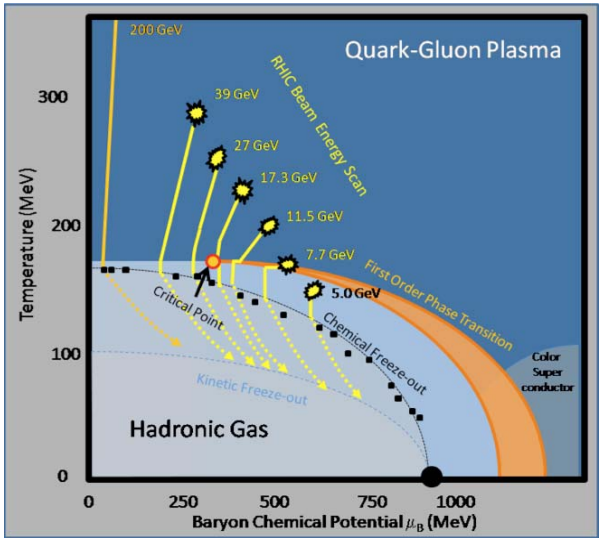


y_a – the momentum fraction of scattered constituent carried away by charged hadron

Constituent energy loss
decreases with p_T , increases with $s^{1/2}$ and centrality.

AuAu Beam Energy Scan Program at RHIC

Experimental Study of the QCD Phase Diagram and Search for the Critical Point



STAR Run 10 Plan for First Energy Scan

Beam Energy	μ_B (MeV)	Event Rate	8-hr Days/1M Events	Events proposed	8-hr days proposed
5	550	0.8	45	(100 k)	5
7.7	410	3	11	5M	56
11.5	300	10	3.7	5M	19
17.3	230	33	1.1	15M	16
27	150	92	0.4	33M	12
39	110	190	0.2	24M	5

Turn off of QGP Signatures and Other New Phenomena

- Constituent Quark Number Scaling
- High & Intermediate p_T Spectra:
- QGP Opacity and the Baryon Anomaly
- Pair Correlations in $\Delta\varphi\&\Delta\eta$
- Local P violation in Strong Interactions

Search for Phase Transition and Critical Point

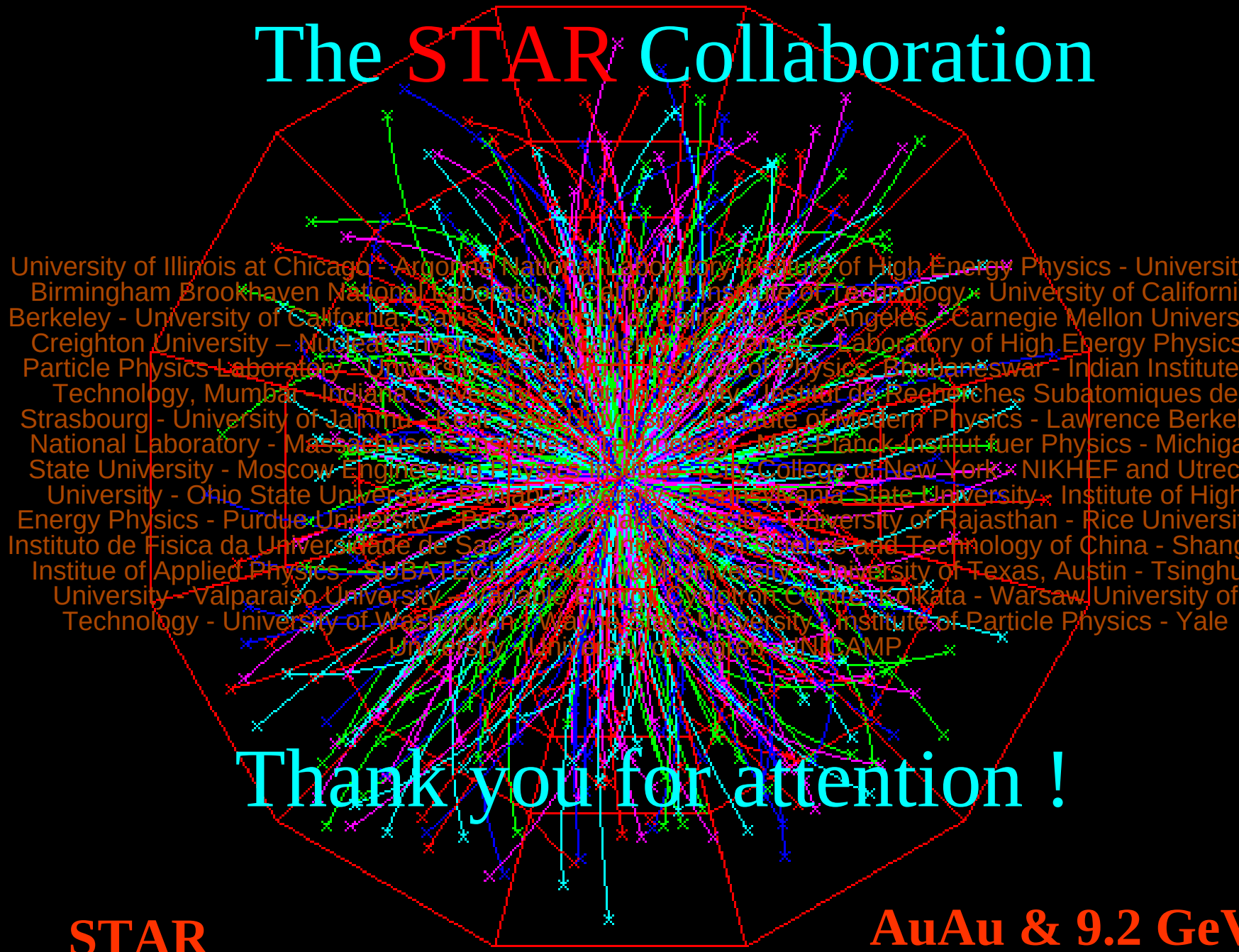
- Elliptic and Directed Flow
- Azimuthally Sensitive HBT
- Fluctuations p/π, K/π, $\langle p_T \rangle$

STAR Collaboration
B.Abelev et al., Run 10 Beam Energy Scan at RHIC
H.Crawford, AGS-RHIC Meeting, 2009
L.Kumar, SQM08
O.Barannikova, RSCM09, Dubna

Summary

- Spectra of charged hadrons produced in Au+Au collisions at 9.2 GeV and ratios of particle yields in middle rapidity at high p_T are obtained by STAR.
- Sensitivity of the ratios $R_{mult/mbais}$ & R_{CP} to centrality is enhanced with p_T.
- Hadron yields can be an estimate of a constituent energy loss as a function of energy and centrality collision, transverse momentum of hadron in the z-scaling approach.
- Large and uniform acceptance and extended particle identification (TPC, ToF, EMC) of STAR is suitable to Critical Point search at low energy $\sqrt{s}_{NN}$ = 5 - 39 GeV.

The STAR Collaboration



University of Illinois at Chicago - Argonne National Laboratory - Institute of High Energy Physics - University of Birmingham Brookhaven National Laboratory - California Institute of Technology - University of California, Berkeley - University of California, Davis - University of California, Los Angeles - Carnegie Mellon University - Creighton University – Nuclear Physics Institute AS CR, Řež - Laboratory of High Energy Physics - Particle Physics Laboratory - Universities Research Association, Inc - Department of Physics, Bhubaneswar - Indian Institute of Technology, Mumbai - Indiana University Cyclotron Facility - Institut de Recherches Subatomiques de Strasbourg - University of Jammu - Kent State University - Institute of Modern Physics - Lawrence Berkeley National Laboratory - Massachusetts Institute of Technology - Max-Planck-Institut fuer Physics - Michigan State University - Moscow Engineering Physics Institute - City College of New York - NIKHEF and Utrecht University - Ohio State University - Panjab University - Pennsylvania State University - Institute of High Energy Physics - Purdue University - Pusan National University - University of Rajasthan - Rice University - Instituto de Fisica da Universidade de Sao Paulo - University of Science and Technology of China - Shanghai Institue of Applied Physics - SUBATECH - Texas A&M University - University of Texas, Austin - Tsinghua University - Valparaiso University - Variable Energy Cyclotron Centre, Kolkata - Warsaw University of Technology - University of Washington - Wayne State University - Institute of Particle Physics - Yale University - University of Zagreb - NIKHEF/UU

Thank you for attention !

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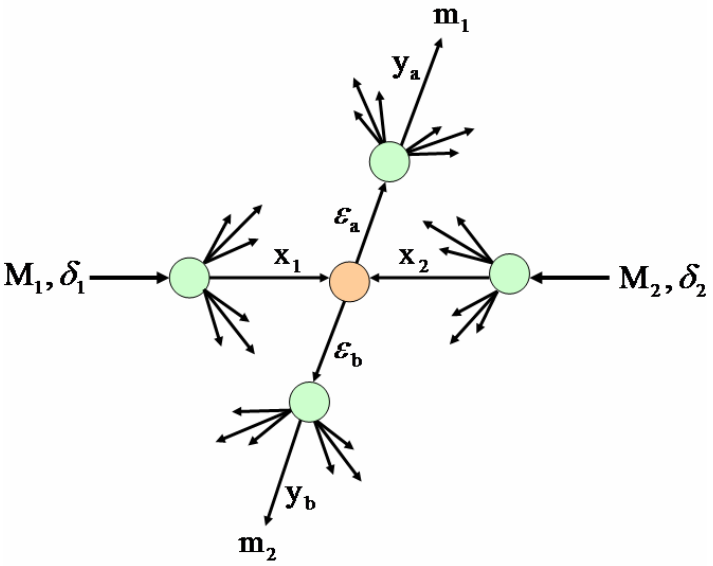
AuAu & 9.2 GeV

Backup slides

Kinematics of constituent sub-process in AA



M.T. & I.Zborovsky
PRD75,094008(2007)
IJMPA24,1(2009)

Momentum conservation law

$$(x_1P_1 + x_2P_2 - p/y_a)^2 = M_X^2$$

$$M_X = x_1M_1 + x_2M_2 + m_2/y_b$$

Principle of minimal resolution Ω^{-1} of the fractal measure z gives:

$$z = z_0\Omega^{-1}$$

$$z_0 = \frac{s_\perp^{1/2}}{(dN_{ch}/d\eta|_0)^c m_N}$$

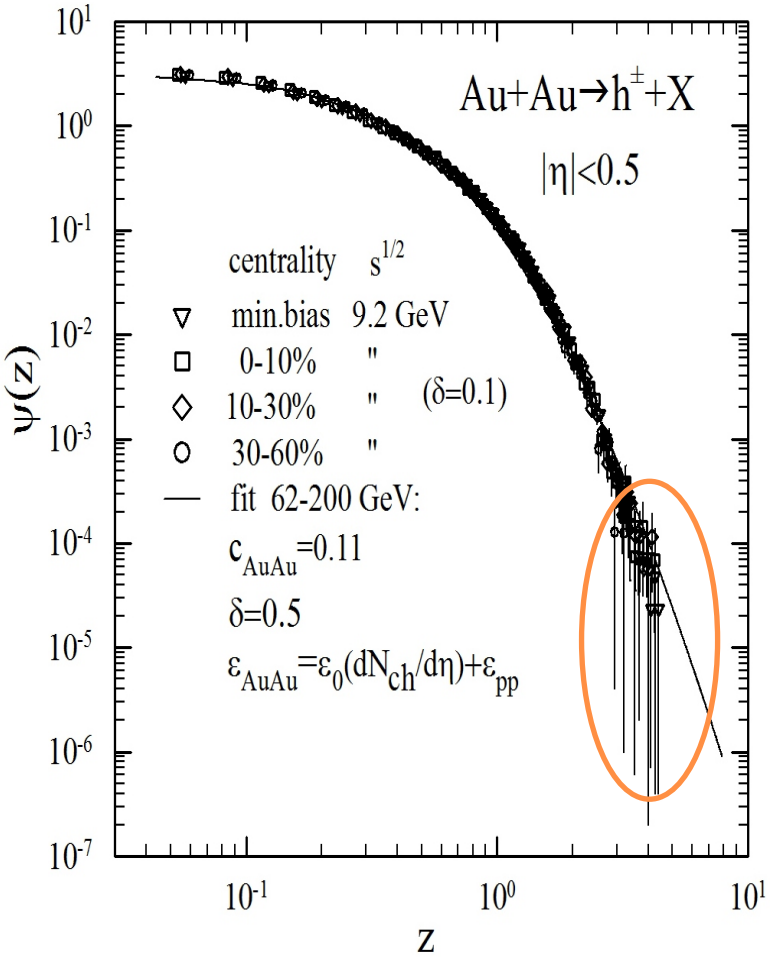
$$\Omega = (1-x_1)^{\delta_1}(1-x_2)^{\delta_2}(1-y_a)^{\varepsilon_a}(1-y_b)^{\varepsilon_b}$$

- x_1, x_2 → energy of the sub-process
- y_a → energy loss (dissipation) by production of the inclusive particle
- $M_X = x_1M_1 + x_2M_2 + m_2/y_b$ → recoil mass
- y_b → multiplicity of the recoil system

- The fractal dimensions δ, ε and "specific heat" c are parameters of the theory describing the structure of nuclei, fragmentation process and nuclear medium.
- The parameters are sensitive to energy and centrality collision at high p_T.

Charged hadron spectra in Au+Au & 9.2 GeV

z-presentation of spectra



- The same shape $\Psi(z)$ for all centralities & energies
  ε_{AuAu} depends on a multiplicity density
- Scenario of interaction: small "specific heat" & δ_{AuAu}
- Correlation of c_{AuAu}, ε_0, δ at high p_T
- Centrality dependence of the spectra constraints c_{AuAu}
- Different scenario in high-z range (p_T > 4 GeV/c)

Beam Energy Scan Program at RHIC

could help to discriminate different scenario of constituent interactions and to search for CP.