STAR Near Future Physics Program

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Outline

(1) Introduction

(2) Recent Results from STAR

(3) Near Future Physics Program
Physics Goals at RHIC

- Identify and study the property of matter (EOS) with partonic degrees of freedom.

- Explore the QCD phase diagram.

- Study the origin of spin in $p$.

- Investigate the physics at small-$x$, gluon-rich region.

RHIC

- Au+Au, Cu+Cu, d+Au, p+p collisions at 200 – 5 GeV

- Polarized p+p collisions at 200 & 500 GeV

- p+p, d+Au pp2pp
STAR Physics Focus

1) At 200 GeV top energy
   - Study *medium properties, EoS*
   - pQCD in hot and dense medium

2) RHIC beam energy scan
   - Search for *critical point*
   - Chiral symmetry restoration

Polarized spin program
   - Study *proton intrinsic properties*

Forward program
   - Study low-x properties, search for *CGC*
   - Study elastic (inelastic) processes (pp2pp)
   - Investigate *gluonic exchanges*
STAR Detector (current)

Full azimuthal particle identification!
\( \gamma, e, \pi, \rho, K, K^*, p, \varphi, \Lambda, \Delta, \Xi, \Omega, D, \Lambda_C, J/\psi, Y \ldots \)
Reconstruct particles in full azimuthal acceptance of STAR!
Search for Parity Violation …

The separation between the same-charge and opposite-charge correlations.

- Strong EM fields
- De-confinement and Chiral symmetry restoration

Sergei Voloshin, QM09
New $v_2$ Results (Run7)

Run7 data, strangeness flow =>

**Final word on partonic collectivity at RHIC!**

*Shusu Shi, QM09*
Event Anisotropy for $\rho^0$-meson

- First measurement of $\rho^0$: $v_2 \sim 13 \pm 4\%$ ($p_T > 1.2$ GeV/c).
- Physics discussion will depends on future results with ToF.

Particia Fachni, QM09
First Observation of \( \Lambda \bar{H} \rightarrow \Lambda \bar{He} + \pi^+ \)

**STAR Preliminary**

- **200 GeV Au+Au collisions at RHIC**

**New!**  
More data with full ToF needed!

*Jinhui Chen, QM09*
From pp to dAu collisions, the width is increased – de-correlation => qualitatively consistent with CGC!

Chris Perkins, QM09
In 500 GeV p+p collisions, ZDC has been used for the polarization measurements.
In 200 GeV Au+Au collisions at RHIC, strongly interacting matter formed:
- Jet energy loss: $R_{AA}$
- Strong collectivity: $v_0$, $v_1$, $v_2$
- Hadronization via coalescence: $n_q$-scaling

Questions:

*Is thermalization reached at RHIC?*
- Systematic analysis with $dN/dp_T$ and $dv_2/dp_T$ results…
- *Heavy quark measurements*

*When (at which energy) does this transition happen? What does the QCD phase diagram look like?*
- *RHIC Beam Energy Scan*
High-Energy Nuclear Collisions

Energy Frontier
LHC, RHIC

Density Frontier
RHIC, FAIR

Baryon Density
1st order p.b.
FAIR, NICA, CSR

Explore the QCD landscape, structure of the matter with partonic degrees of freedom.

Critical Point?

quark-gluon plasma

hadron gas

nuclei

CSC

Baryon Chemical Potential

Temperature

Early Universe

Density Frontier

1st order p.b.
FAIR, NICA, CSR

Energy Frontier
LHC, RHIC

Baryon Density

High-Energy Nuclear Collisions:

High-Energy Nuclear Collisions:
STAR Mission

STAR collaboration physics program:

- Best positioned for Exploring the QCD phase diagram
- Excellent for precision measurements
- Great potential for new discoveries

Complementary to ALICE at LHC at higher energy
Complementary to CBM at FAIR at lower energy

Physics focuses:

1. Light quark thermalization:
   heavy quark collectivity

2. QCD critical point and phase boundary:
   \( n_q \) scaling in \( v_2 \), net-\( p \) Kurtosis

3. Chiral physics:
   di-electron (mass, width), continuum, \( \sigma \), \( v_2 \), \( R_{AA} \)
Quark Masses

1) Higgs mass: electro-weak symmetry breaking. (current quark mass)
2) QCD mass: Chiral symmetry breaking. (constituent quark mass)

⇒ New mass scale compared to the excitation of the system.
⇒ Important tool for studying properties of the hot/dense medium at RHIC.
⇒ Test pQCD predictions at RHIC.
Charm Hadron $v_2$ and $R_{AA}$

- 200 GeV Au+Au m.b. collisions (500M events).
- Charm hadron collectivity $\Rightarrow$ drag/diffusion constants $\Rightarrow$

Medium properties!

- 200 GeV Au+Au m.b. collisions ($|y|<0.5$ 500M events)
- Charm hadron $R_{AA}$ $\Rightarrow$

- Energy loss mechanism!
- QCD in dense medium!
The QCD Phase Diagram

- LGT prediction on the transition temperature, $T_c \sim 170$ MeV.

- LGT calculation, universality, and models point to the existence of the critical point on the QCD phase diagram* at finite baryon chemical potential.

- Experimental evidence for either the critical point or 1st order transition is important for our knowledge of the QCD phase diagram*.

* Thermalization is assumed

STAR’s plan:

run10: RHIC Beam Energy Scan
run11: Heavy Quark measurements

Stephanov, Rajagopal, and Shuryak, PRL 81, 4816(98)
Rajagopal, PR D61, 105017 (00)
Collider Acceptance

$\sqrt{s_{NN}} = 9.2$ GeV Au+Au Collisions at RHIC

Fix-target Mode NA49

Collider Mode STAR

$\sqrt{s_{NN}} = 6$ GeV

$\sqrt{s_{NN}} = 17$ GeV
Particle Identification at STAR

Neutral particles
Strange hyperons
Jets
Heavy Quark Hadrons

Multiple-fold correlations among the identified particles!
**STAR Detectors:** Full $2\pi$ particle identification!
Direct Radiation

Di-leptons allow us to measure the direct radiation from the matter with partonic degrees of freedom, no hadronization!

- Low mass region:
  \[ \rho, \omega, \phi \Rightarrow e^-e^+ \]
  \[ m_{\text{inv}} \Rightarrow e^-e^+ \]

  *medium effect*

  *Chiral symmetry*

- High mass region:
  \[ J/\psi \Rightarrow e^-e^+ \]
  \[ m_{\text{inv}} \Rightarrow e^-e^+ \]

  *Direct radiation*
The di-Lepton Program

- (1) $\sigma$
- (2) $V_2$
- (3) $R_{AA}$

$\rho \phi$

 DY, charm Bk

$J/\psi$

 min. bias Au+Au at $\sqrt{s_{NN}} = 200$ GeV

- DATA
- $l|y| < 0.35$
- $p_T > 0.2$ GeV/c

$\pi^0 \rightarrow \gamma e e$
- $J/\Psi \rightarrow e e$
- $\eta \rightarrow \gamma e e$
- $\Psi' \rightarrow e e$
- $\eta' \rightarrow \gamma e e$
- $c \bar{c} \rightarrow e e$ (PYTHIA)
- $\rho \rightarrow e e$
- $\omega \rightarrow e e & \pi^0 e e$
- $J/\Psi \rightarrow e e$
- $c \bar{c} \rightarrow e e$ (random correlation)

$\rho_T$ (GeV/c)

Mass (GeV/c$^2$)

✓ Chiral Symmetry Restoration

✓ Direct Radiation from The Hot/Dense Medium

* ToF Crucial for the physics.
STAR Physics Focus (HI)

1) Heavy Quark Distributions
   - heavy flavor collectivity, light flavor thermalization

2) Beam Energy Scan
   - Search for QCD critical point and phase boundary

3) Di-lepton (electrons)
   - Search for signature of Chiral transition

4) U+U Collisions
   - test of thermalization

*ToF will play crucial role for STAR physics program!*