PHENIX Highlights

Takao Sakaguchi
Brookhaven National Laboratory
for the PHENIX Collaboration
What’s New at PHENIX and RHIC

New era of heavy flavor physics
- VTX (2011) and FVTX (2012) are installed

New Collision species and high luminosity (2012)
- U+U 193GeV
  - 3 weeks, 90/ub
- Cu+Au 200GeV
  - 5.5 weeks, 2.5/nb
  \(\rightarrow\) geometry control

PHENIX took data with high efficiency

Energy scans (2010-2012): 7.7, 19.6, 27, 39, 62, 200GeV

T. Sakaguchi, QM2012@Washington D.C.
Probing initial state with high precision d+Au data
Direct photon

- No modification in initial hard scattering and PDF compared to p+p at mid-rapidity

**Graph:**
- Data points for d+Au at $\sqrt{s_{NN}}=200$ GeV
- Fits: virtual $\gamma$, $\pi^0$-tagging, Cronin+Isospin, Cronin+Isospin+Shadowing, Cronin+Isospin+Shadowing+$\Delta E_{\text{init}}$

**Note:**
- See I. Tserruya (Thu) talk

**Reference:**
- arXiv:1208.1234
Initial state - Jet probes -

- Jets are reconstructed in d+Au up to 40 GeV/c
Initial state - Jet probes -

- Jets are reconstructed at mid-rapidity in d+Au up to 40 GeV/c
- $R_{dA}$ increases for more peripheral collisions at high $p_T$

See M. Wysocki (Mon) and B. Sahlmueller (Wed) talk
First measurement of $\psi'$ in d+Au ($y=0$)

$d+Au$ 0-88% Centrality

$\psi' / (J/\psi) = 0.8 \pm 0.2 \pm 0.3\%$

$|y| < 0.35$, $s_{NN} = 200$ GeV

Best Fit

Data

Total fit

$J/\psi$

$\psi'$

$c\bar{c} \rightarrow e^+ e^-$ (Pythia)

$b\bar{b} \rightarrow e^+ e^-$ (Pythia)

Drell Yan

$M_{e^+e^-}$ [GeV/c$^2$]
First measurement of $\psi'$ in $d+Au$ ($y=0$)

- $\psi'/(J/\psi) = 2\%$ in $p+p$, $0.8\%$ in $d+Au$

![Graph showing the measurement of $\psi'$ in $d+Au$](image)
ψ’ is strongly suppressed in dAu

- Very challenging for models!

See M. Wysocki (Mon) and D. McGlinchey (Tue) talk
Probing Hot dense matter with collision geometry control
PID’ed v2 in Au+Au and U+U

\[ V_2 = \sqrt{s_{NN}} \]

(a) Au+Au $\sqrt{s_{NN}} = 200$ GeV

(b) U+U $\sqrt{s_{NN}} = 193$ GeV

2012-08-13
T. Sakaguchi, QM2012@Washington D.C.
PID’ed v2 in Au+Au and U+U

- Flattening of $v_2$ at low $p_T$ for (anti) protons in UU

![Graph showing $v_2$ vs. $p_T$ for Au+Au and U+U collisions at different energies.](image-url)
PID’ed v2 in Au+Au and U+U

- Similar radial flow at RHIC and LHC

ALICE preliminary, Pb-Pb events at $\sqrt{s_{NN}} = 2.76$ TeV
centrality 10%-20%

LHC

U+U $\sqrt{s_{NN}} = 193$ GeV

$\pi^+$, $v_2$(SP, |$\Delta\eta$|>1)
$K^+$, $v_2$(SP, |$\Delta\eta$|>1)
$\bar{p}$, $v_2$(SP, |$\Delta\eta$|>1)

hydro LHC
(CG initial conditions)
($\eta/s=0.2$)
Strong radial flow in Tip-Tip enriched events

(a) 0–2%  
(b) 2–4%  
(c) 4–6%  
(d) 6–10%

0–2% U+U $s_{NN} = 193$ GeV
Strong radial flow in Tip-Tip

- Strong radial flow due to geometry or higher energy density?

Flattening appears only in 0-2%

See S. Huang (Thu) talk
Asymmetric Cu+Au collisions

- Asymmetric coordinate space leads to asymmetric density profile and pressure gradient
- Shower Max Detector (SMD) sees Au-spectator and defines $\Psi_1$
$v_1$ and $v_2$ in Cu+Au collisions

- SMD sees Au-spectator and defines $\Psi_1$
- Sizable $v_1$ is seen (direction opposite to AMPT)
J/ψ in Cu+Au

- J/ψ is more suppressed in Cu going direction compared to Au going direction (CNM and final state?)
J/ψ in Cu+Au, Au+Au

- J/ψ suppression in Au-going direction is same as Au+Au
- Cu-going direction stronger suppression than in Au+Au

See M. Rosati (Tue) and R. Hollis (Fri) talk
Probing the geometry evolution with HBT
Triangularity from HBT in Au+Au

Rside

Rout

\( R_{s}^{2} [\text{fm}^{2}] \)

\( R_{t}^{2} [\text{fm}^{2}] \)

Au+Au 200GeV 0-10%

See T. Niida (Tue) talk
Triangularity from HBT in Au+Au

- Large modulation of HBT radii ($R_0$) with respect to $\psi_3$ is seen for the first time.

See T. Niida (Tue) talk.
Probing hot dense matter with hard probes
$\gamma$-h correlation in Au+Au

$z_T = p_{Ta}/p_{Tt}$
$\xi = \ln(1/z_T)$

- Associated particles in three angle ranges are integrated

$|\Delta \phi| > 5\pi/6$
$|\Delta \phi| > 2\pi/3$
$|\Delta \phi| > \pi/2$

$I_{AA} \equiv \frac{(1/N_{trig}dN/d\xi)_{AA}}{(1/N_{trig}dN/d\xi)_{pp}}$
$\gamma$-h correlation in Au+Au

$$I_{AA} \equiv \frac{(1/N_{\text{trig}}dN/d\xi)_{AA}}{(1/N_{\text{trig}}dN/d\xi)_{pp}}$$

Low $z_T$ away side particles distributed over wider angle

$5 < p_T^\gamma < 9$ GeV/c x $0.5 < p_T^h < 7$ GeV/c

- $|\Delta \phi| > \pi/2$
- $|\Delta \phi| > 2\pi/3$
- $|\Delta \phi| > 5\pi/6$

0 - 40% Au + Au

See J. Frantz (Thu) talk
Single hadron $R_{AA}$ RHIC energy

- $\pi^0$ in Au+Au 200GeV 0-5%
- Rising slope in $R_{AA}$: $(1.06 \pm 0.34 -0.29) \times 10^{-2}$ (GeV/c)$^{-1}$
Single hadron $R_{AA}$ RHIC vs LHC

- Charged hadrons in Pb+Pb 2.76TeV 0-5%
- $R_{AA}$ for both systems look very similar

![Graph showing $R_{AA}$ for PHENIX and ALICE at 0-5% centrality.](image)
Fractional momentum loss

- Measure fractional mom. loss ($\delta p_T/p_T$) instead of $R_{AA}$
- Different $\delta p_T/p_T$ for same $R_{AA}$

See M. McCumber (Tue) talk

$\rho_T$ vs $p_T$ (GeV/c) for (p+p) and (p+p) x $T_{AB}$

LHC

RHIC

$\delta p_T/p_T$ vs $p_T$ (GeV/c)

- Pb+Pb 0-5%, $\delta$(global)=0.3%
- Au+Au 0-5%, $\delta$(global)=1.0%
- Pb+Pb 70-80%, $\delta$(global)=0.7%
- Au+Au 70-80%, $\delta$(global)=2.9%

arXiv:1208.2254
Energy dependence of $\delta p_T/p_T$:

- $\delta p_T/p_T$ decreases significantly going from 200GeV to 62, 39GeV.

See E. O’Brien (Fri) talk.

[Graph showing the energy dependence of $\delta p_T/p_T$ for $\pi^0$, Au+Au 0-10% at 39 GeV, 62.4 GeV, and 200 GeV.]
Energy dependence of $\delta p_T/p_T$

- $\delta p_T/p_T$ from 39GeV to 2.76TeV!

\[ \pi^0, \text{Au+Au 0-10 \%} \]

\[ R_{AA}, p_T [\text{GeV/c}] \]

\[ \delta p_T/p_T \]

\[ p_T [\text{GeV/c}] \]

\[ \text{LHC 0-5\%} \]

See E. O’Brien (Fri) talk
Single electrons

- Heavy flavor electron $R_{AA}$ is a mixture of charm and bottom contributions
- We really want $R_{AA}$ for charm and bottom
Charm and bottom decomposition

- \((b \rightarrow e)/(b \rightarrow e + c \rightarrow e)\) ratio for p+p collisions from partial reconstruction of \(D \rightarrow e^+/-K^-/+X\)

![Graph showing the ratio of charm and bottom decomposition over electron p_T (GeV/c)]
First direct c/b decomposition with new VTX detector

- New direct measurement of bottom fraction agrees with FONLL

See M. Rosati (Tue) and R. Nouicer (Fri) talk
$R_{AA}$ for $c \rightarrow e$

PHENIX Preliminary

Using FONLL shape as reference

Charm: 200 GeV Au+Au MB

See M. Rosati (Tue) and R. Nouicer (Fri) talk
$R_{AA}$ for $c \rightarrow e$ and $\pi^0$

- Charm contribution is less suppressed

**Diagram:**

- **PHENIX Preliminary**
- **Using FONLL shape as reference**
- **Charm:** 200 GeV Au+Au MB
- **$\pi^0$** PRL 101, 232301 (2008)

**Legend:**

- Red circle: Charm
- Black square: $\pi^0$

**Axes:**

- **$R_{AA}$**
- **$p_T$ (GeV/c)**

**Note:**

- See M. Rosati (Tue) and R. Nouicer (Fri) talk
$R_{AA}$ for $c \rightarrow e$, $b \rightarrow e$ and $\pi^0$

- Bottom contribution is heavily suppressed!

See M. Rosati (Tue) and R. Nouicer (Fri) talk
$R_{AA}$ for $c \to e$, $b \to e$ and HF $e$

- $R_{AA}$ for $c \to e$ is consistent with $R_{AA}$ for HF electrons

PHENIX Preliminary

Using FONLL shape as reference

- Charm: 200 GeV Au+Au MB
- $e^{HF}$: Au+Au PRC 84, 044905
- Bottom: 200 GeV Au+Au MB

Electron $p_T$ (GeV/c)

90% C.L.
PHENIX talks

- **Plenary talks**
  - M. Wysocki (Mon, *Initial state, Global & Collective Dynamics*)
  - M. McCumber (Tue, *Jets*)
  - M. Rosati (Tue, *Heavy Flavor*)
  - I. Tserruya (Thu, *Quarkonia, Real & Virtual Photons*)
  - E. O’Brien (Fri, *Exploring the QCD Phase Diagram*)

- **Parallel talks (Tue)**
  - T. Niida (*Correlations & Fluctuations, Parallel #3*)
  - Y. Gu (*Global & Collective Dynamics, Parallel #1*)
  - J. Frantz (*Jets, Parallel #2*)
  - D. McGlinchey (*Heavy Flavor & Quarkonia, Parallel #4*)

- **Parallel talks (Wed)**
  - E. Atomssa (*Electro-Weak Probes, Parallel #7*)
  - M. Kurosawa (*Global & Collective Dynamics Parallel #5*)

- **Parallel talks (Thu)**
  - B. Sahlmueller (*Pre-Equilibrium & Initial State, Parallel #8*)
  - S. Huang (*Global & Collective Dynamics Parallel #5*)

- **Parallel talks (Fri)**
  - J. Haggerty (*New Experimental Developments, Parallel #15*)
  - R. Nouicer (*Heavy Flavor & Quarkonia, Parallel #13*)
  - J. Seele (*New Experimental Developments, Parallel #15*)
  - T. Todoroki (*Correlations & Fluctuations, Parallel #16*)
  - R. Hollis (*Correlations & Fluctuations, Parallel #16*)
  - J. Mitchell (*Exploring the QCD Phase Diagram, Parallel #14*)

And, Many posters
Summary

- Understanding the baseline – d+Au -
  - Direct photons – no modification
  - Jets and high $p_T \pi^0/\eta$ – Little modification
  - $\psi'$ is very heavily suppressed

- Varying the geometry
  - U+U - Strong radial flow
  - positive $v_1$ in Cu+Au
  - $J/\psi$ suppressed in Cu-going direction more than Au+Au at same $N_{\text{part}}$

- Varying the energy
  - $\delta p_T/p_T$ for hadrons increases by a factor of 6 from 39GeV to 2.76TeV

- Know your hard probes
  - $\gamma$-h – Detail jet tomography, hints of jet broadening

- Separating heavy flavor electrons into charm and bottom
  - Strong suppression of $b$ in Au+Au for $p_T<5\text{GeV}/c$
Backup
