Hungary in the PHENIX Collaboration

ECFA Meeting, October 4, 2013

Máté Csanád (Eötvös University)
for the PHENIX Hungary group

PHENIX @ RHIC

- Au+Au, Cu+Cu, p↑+p↓, d+Au
- 7 to 200 (500) GeV
- Upgrade to eRHIC
- BRAHMS, STAR, PHENIX, PHOBOS
- PHENIX: few 100 participants from 14 countries
- Official Hungarian participation
The PHENIX-Hungary group

- Current member institutions
  - Wigner Research Center for Physics, Institute for Particle and Nuclear Physics
  - Eötvös University, Department of Atomic Physics

- Earlier: Debrecen University, Dep’t of Exp. Physics (P. Tarján, J. Imrek, V. Veszprémi)

- Tamás Csörgő (Wigner RCP), group leader, member since 2003
- Márton Nagy (Eötvös U.), member since 2005
- András Ster (Wigner RCP), member since 2001
- Márton Vargyas (Wigner RCP), member since 2010
- Máté Csanád (Eötvös U.), member since 2003
- Róbert Vértesi (Wigner RCP), member 2004-2012
- János Sziklai (Wigner RCP), member since 2005
- Ádám Kiss (Eötvös U.), member since 2003
- József Zimányi†2006, (Wigner RCP), member 2003-2006

October 4, 2013  ECFA Meeting 2013
The PHENIX detector

- Charged hadrons ($\pi^\pm, K^\pm, \text{etc.}$)
- Photons: direct or decay ($\eta, \pi_0$)
- Light mesons: $\phi, \omega, \eta, \eta'$
- Single leptons (flavor tagged)
- Di-leptons (flavor tagged)
PHENIX Milestones

• Jet suppression: new phenomenon of missing high energy jets

• No jet suppression in d+Au: new form of matter

• Collective dynamics (thermal spectra, flow): it is a liquid!

• Scaling properties of the ell. flow: valence quarks

• Energy loss of heavy quarks: nearly perfect liquid

• Thermal photons: very high initial temperature
ZDC and SMD monitoring

• ZDC: neutron detector at $\eta = \pm \infty$
  • Shower generating and scintillating layers, analog sum equals $E_{\text{neutron}}$
  • Vertex position from timing

• SMD: transverse mapping of neutrons before ZDC
  • Slabs in x and y direction
  • Shower maximum indicates neutron distribution
  • Spread is larger than beam size (due to Fermi motion)

• Primary goal: trigger, centrality determination, beam monitoring

• Creation of the ZDC and SMD online monitoring
  • tn419

• Simulations for the operation
  • tn418, an935, an936
EMCal time of flight calibration

- **EMCal**: two different detectors for the same purpose (PbSc and PbGl)
- **Lead scintillator**: 66 absorber and scintillator layers
  - Excels in timing, linearity of response
- **Lead glass**: Cherenkov photon produced in the material
  - Accurate energy measurement, already used in WA98
- **Primary goal**: electrons and photons
- **ID via shower shape**
  - an330
- **Hadron energy**: much smaller deposition
- **Hadron PID**: via Time of Flight
- **Needs calibrations (corrections)**
  - Tower-by-tower, sector-by-sector effects
  - Energy dependence
  - tn400, tn428
Scaling of the elliptic flow

- Hydrodynamics: transverse kinetic energy is a scaling variable
- Scaling breaks at medium energy
- Elliptic flow of mesons & baryons may originate from a quark-gluon medium
- Can be restored if both axes rescaled by valence quark number
- Appearance of quark degrees of freedom?
- PRL98, 162301(2007)
**J/ψ** in ultra-peripheral collisions

- Nonlinear QCD dynamics at small x and $Q^2$ is in focus of theoretical activity
- Vector meson production cross-sections: sensitive to gluon distribution at small x
- $\gamma\gamma$ processes tested at HERA
- Ultra-peripheral collisions @ high E: complementary to conventional studies
- Di-electron production probable:
  - $A + \gamma + \gamma \rightarrow A^* + e^+ + e^-$
- Coherent meson production:
  - $A + \gamma \rightarrow A^* + J/\Psi$
- Incoherent meson production:
  - $A + \gamma \rightarrow A' + xN + J/\Psi$
- Experimentally challenging to ID them
- PLB 679, 321 (2009), an756, an593

---

PHENIX AuAu UPC $s_{NN}^{1/2} = 200$ GeV

- $e^+e^-$ (unlike-sign pairs)
- $J/\Psi$
- $e^+e^-$ coherent continuum
- max/min $e^+e^-$ continuum

---

Hungarian contributions
Two-particle sources and heavy tails

- Identical two-particle momentum correlations: affected by quantum-stat. eff.
- Due to symmetric two-pion wave-function, $C(q) - 1 \propto |\tilde{S}(q)|^2$
- Source function moments can be reconstructed: imaging technique
- Non-Gaussian sources discovered, may be due to anomalous diffusion?
- Lévy-shaped tail to be analyzed
- PRL98,132301(2007), PRL100,232301(2008), an527, an920
Two-pion correlations and the $U_A(1)$ symmetry

- In hot and dense matter: partial UA(1) restoration, $\eta'$ mass reduction
- Enhanced $\eta'$ content, decay:
  \[ \eta' \rightarrow \eta + \pi^+ + \pi^- \rightarrow \pi^0 + \pi^+ + \pi^- + \pi^+ + \pi^- \]
- Long lifetime, creating pion pairs quite far from the vertex: resonance halo
- Correlation function:
  \[ C(q) - 1 = \left| \tilde{S}(q) \right|^2 = \left| \tilde{S}_{\text{core}}(q) + \tilde{S}_{\text{halo}}(q) \right|^2 \]
- At small relative momentum:
  \[ C(0) - 1 \rightarrow \lambda = \text{relative core fraction} \]
- Enhanced $\eta'$ content $\Rightarrow$ large halo $\Rightarrow$ decreased $\lambda$
Low mass dilepton enhancement

- The $\eta'$ mass reduction and production enhancement apparent in $\ell^+ \ell^-$ spectra
- Enhancement in A+A dilepton spectra, compared to cocktail based on p+p
- Cocktail simulation: EXODUS
- $\eta'$ spectra replaced based on hydrodynamic calculations
Three-pion correlations and coherent sources

• Three-particle correlations: also sensitive to quantum-statistics
• If core/halo model is valid
  • $C_2(q \to 0) \rightarrow 1 + \lambda_2$, $C_3(q \to 0) \rightarrow 1 + \lambda_3$, and
  • $\lambda_2 = f_c^2$ while $\lambda_3 = 3f_c^2 + 2f_c^3$ with $f_c$ being the core fraction
• In case of partially coherent particle production (à la pion-laser):
  • $\lambda_2 = f_c^2((1 - p_c)^2 + 2p_c(1 - p_c))$
  • $\lambda_3 = 3f_c^2((1 - p_c)^2 + 2p_c(1 - p_c)) + 2f_c^3((1 - p_c)^3 + 3p_c(1 - p_c)^2)$
• If both measured: coherent part to be revealed
• Measurement ongoing, but also
Other contributions

• Direct photon measurement with PbSc (an490)
• Identified charged hadron spectra in p+p (an640, PRC83,064903(2011))
• Squeezed back-to-back correlations (an846)
• Identical kaon correlations (an609, PRL103,142301(2009))
• Low-energy task force (an824)
• Search for the critical point via Lévy-exponents (an920)
• Quark Matter Card Game
• Zimányi School
• >20 official PHENIX talks and internal notes (some mentioned above)
• More details at http://phenix.kfki.hu/ or http://phenix.elte.hu/
• Thank you for your attention!