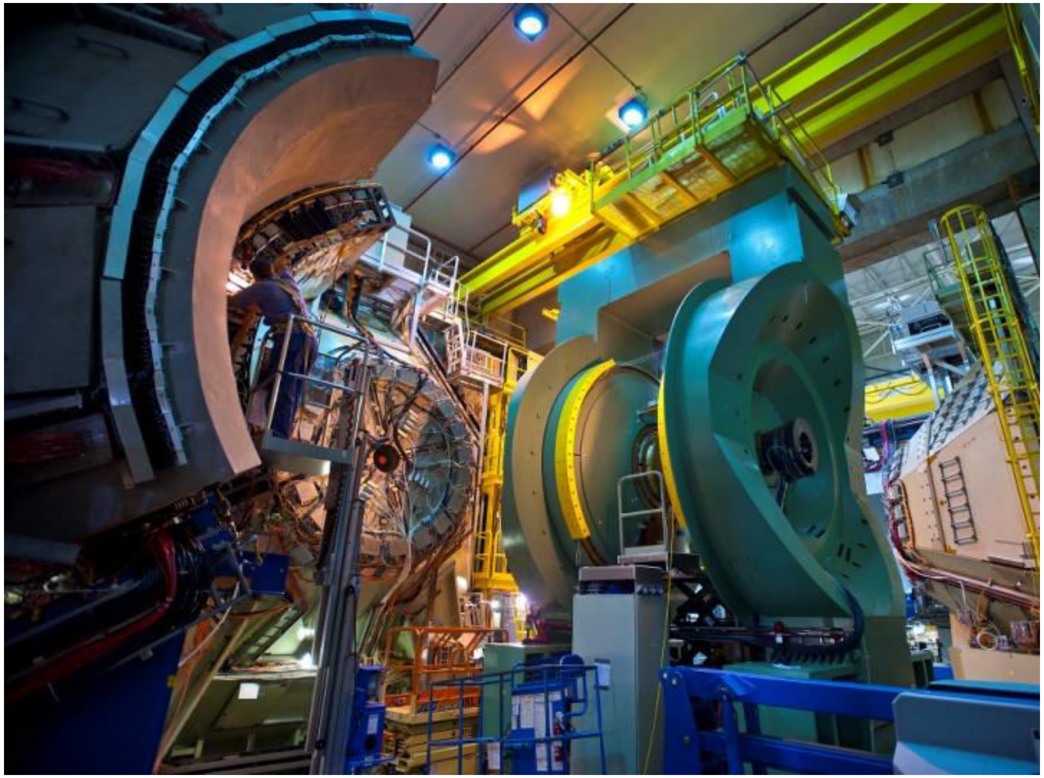
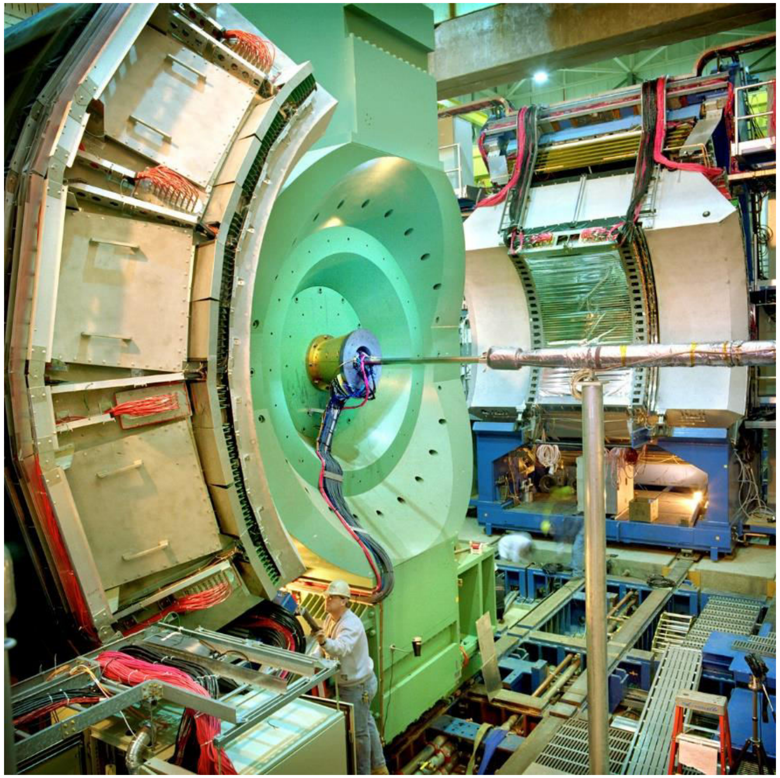
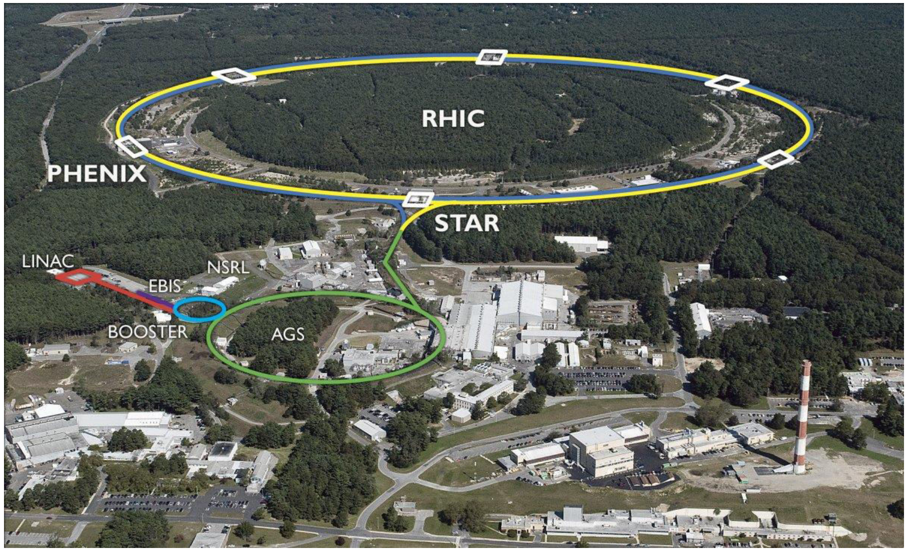
Эксперименте ФЕНИКС

В. Рябов, ЛРЯФ ОФВЭ





Relativistic Heavy-Ion Collided (RHIC)



√s [GeV]	p+p	p+Al	p+Au	d+Au	^{3}He+Au	Cu+Cu	Cu+Au	Au+Au	U+U
510	✓								
200	✓	✓	✓	✓	✓	✓	✓	✓	✓
130								✓	
62.4	✓			✓		✓		✓	
39				✓				✓	
27								✓	
20				✓		✓		✓	
14.5								✓	
7.7								✓	

- 2000-2016, обширная физическая программа:
  - ✓ p+p, p+A, A+A при максимальной энергии $\sqrt{s_{NN}}$ = 200 ГэВ (9 комбинаций)
  - ✓ программа сканирования по энергии взаимодействия (13 энергий)
  - ✓ единственный коллайдер пучков поляризованных протонов, P ~ 70%

14 countries, 75 institutions, Jan 2015

Universidade de São Paulo, Instituto de Física, Caixa Postal 66318, São Paulo CEP05315-970, Brazil
China Institute of Atomic Energy (CIAE), Beijing, People's Republic of China
Peking University, Beijing, People's Republic of China
University of Zagreb, Faculty of Science, Horvatovac 102a, HR-10000 Zagreb, Croatia
Charles University, Ovocnytrh 5, Praha 1, 116 36, Prague, Czech Republic
Czech Technical University, Zikova 4, 166 36 Prague 6, Czech Republic
Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague 8, Czech Republic
Helsinki Institute of Physics and University of Jyväskylä, P.O.Box 35, FI-40014 Jyväskylä, Finland
Dapnia, CEA Saclay, F-91191, Gif-sur-Yvette, France
Laboratoire Leprince-Ringuet, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128, Palaiseau, France
Laboratoire de Physique Corpusculaire (LPC), Université Blaise Pascal, CNRS-IN2P3,
Clermont-Fd, 63177 Aubiere Cedex, France
IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406, Orsay, France
Debrecen University, H-4010 Debrecen, Egyetem tér 1, Hungary
ELTE, Eötvös Loránd University, H - 1117 Budapest, Pázmány P. s. 1/A, Hungary
KFKI Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Sciences (MTA KFKI RMKI), H-1525 Budapest 114, POBox 49, Budapest, Hungary
Department of Physics, Banaras Hindu University, Varanasi 221005, India
Bhabha Atomic Research Centre, Bombay 400 085, India
Weizmann Institute, Rehovot 76100, Israel
Center for Nuclear Study, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan
Hiroshima University, Kagamiyama, Higashi-Hiroshima 739-8526, Japan
Advanced Science Research Center, Japan Atomic Energy Agency, 2-4 Shirakata Shirane, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan
KEK, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan
Kyoto University, Kyoto 606-8502, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki 851-0193, Japan
RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 351-0198, Japan
Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
Department of Physics, Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japan
Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan
IHEP Protvino, State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, 142281, Russia
INR_RAS, Institute for Nuclear Research of the Russian Academy of Sciences, prospekt 60-letiya Oktyabrya 7a, Moscow 117312, Russia
Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
National Research Nuclear University, MEPhI, Moscow Engineering Physics Institute, Moscow, 115409, Russia
Russian Research Center "Kurchatov Institute", Moscow, Russia
PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
Saint Petersburg State Polytechnic University, St. Petersburg, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119992, Russia
Chonbuk National University, Jeonju, South Korea
Ewha Womans University, Seoul 120-750, South Korea
Hanyang University, Seoul 133-792, South Korea
Korea University, Seoul, 136-701, South Korea
Accelerator and Medical Instrumentation Engineering Lab, SungKyunKwan University, 53 Myeongnyun-dong, 3-ga, Jongno-gu, Seoul, South Korea
Myongji University, Yongin, Kyonggido 449-728, Korea
Department of Physocs and Astronomy, Seoul National University, Seoul, South Korea
Yonsei University, IPAP, Seoul 120-749, South Korea
Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden

Abilene Christian University, Abilene, TX 79699, U.S.
Department of Physics, Augustana College, Sioux Falls, SD 57197
Baruch College, CUNY, New York City, NY 10010-5518, U.S.
Collider-Accelerator Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
University of California - Riverside, Riverside, CA 92521, U.S.
University of Colorado, Boulder, CO 80309, U.S.
Columbia University, New York, NY 10027 and Nevis Laboratories, Irvington, NY 10533, U.S.
Florida Institute of Technology, Melbourne, FL 32901, U.S.
Florida State University, Tallahassee, FL 32306, U.S.
Georgia State University, Atlanta, GA 30303, U.S.
University of Illinois at Urbana-Champaign, Urbana, IL 61801, U.S.
Iowa State University, Ames, IA 50011, U.S.
Lawrence Livermore National Laboratory, Livermore, CA 94550, U.S.
Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.
University of Maryland, College Park, MD 20742, U.S.
Department of Physics, University of Massachusetts, Amherst, MA 01003-9337, U.S.
Department of Physics, University of Michigan, Ann Arbor, MI 48109-1040
Morgan State University, Baltimore, MD 21251, U.S.
Muhlenberg College, Allentown, PA 18104-5586, U.S.
University of New Mexico, Albuquerque, NM 87131, U.S.
New Mexico State University, Las Cruces, NM 88003, U.S.
Oak Ridge National Laboratory, Oak Ridge, TN 37831, U.S.
Department of Physics and Astronomy, Ohio University, Athens, OH 45701, U.S.
RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
Chemistry Department, Stony Brook University,SUNY, Stony Brook, NY 11794-3400, U.S.
Department of Physics and Astronomy, Stony Brook University, SUNY, Stony Brook, NY 11794, U.S.
University of Tennessee, Knoxville, TN 37996, U.S.
Vanderbilt University, Nashville, TN 37235, U.S.
Department of Physics and Astronomy, Howard University, 2355 6th St. NW, Washington, DC 20059, U.S.

Участие ПИЯФ, 2018

- ✓ В. Самсонов, д.ф.-м.н., зав. ЛРЯФ
- ✓ Д. Иванищев, к.ф.-м.н.нс
- ✓ Д. Котаов, к.ф.-м.н., снс
- ✓ В. Рябов, д.ф.-м.н., внс
- ✓ Ю. Рябов, к.ф.-м.н., снс
- ✓ А. Ханзадеев, д.ф.-м.н., внс

- ❖ Участие в работе международной физической группы PWG-LF-HF
- ❖ Участие в PSB (PHENIX Speaker Bureau)
- ❖ Участие во многочисленных PPG, IRC
- ❖ Физический анализ экспериментальных данных (легкие адроны)

Конференции

❖ XXIV International Baldin Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics , September 17-22, Dubna, Russia

V. Riabov for the PHENIX Collaboration, “Recent results from PHENIX at RHIC“

❖ HSQCD-2018, August 6-10, Gatchina, Russia

V. Riabov for the PHENIX Collaboration,, “Recent results from PHENIX”

Публикации

1. Pseudorapidity dependence of particle production and elliptic flow in asymmetric nuclear collisions of p+Al, p+Au, d+Au, and 3He+Au at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev.Lett. 121 (2018) no.22, 222301

2. Production of π0 and η mesons in Cu+Au collisions at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev. C98 (2018) no.5, 054903

3. Low-momentum direct photon measurement in Cu+Cu collisions at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev. C98 (2018) no.5, 054902

4. Nonperturbative transverse-momentum-dependent effects in dihadron and direct photon-hadron angular correlations in p+p collisions at $\sqrt{s}$=200 GeV, Published in Phys.Rev. D98 (2018) no.7, 072004

5. Single-spin asymmetry of J/ψ production in p+p, p+Al, and p+Au collisions with transversely polarized proton beams at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev. D98 (2018) no.1, 012006

6. Cross section and longitudinal single-spin asymmetry AL for forward W±→μ±ν production in polarized p+p collisions at $\sqrt{s}$=510 GeV, Published in Phys.Rev. D98 (2018) no.3, 032007

7. Measurement of emission angle anisotropy via long-range angular correlations with high pT hadrons in d+Au and p+p collisions at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev. C98 (2018) no.1, 014912

8. Measurements of mass-dependent azimuthal anisotropy in central p+Au, d+Au, and 3He+Au collisions at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev. C97 (2018) 064904

9. Measurement of ϕ-meson production at forward rapidity in p+p collisions at s√=510 GeV and its energy dependence from $\sqrt{s}$=200 GeV to 7 TeV, Published in Phys.Rev. D98 (2018) no.9, 092006

10. Lévy-stable two-pion Bose-Einstein correlations in $\sqrt{s_{NN}}$=200 GeV Au+Au collisions, Published in Phys.Rev. C97 (2018) no.6, 064911

11. Measurements of Multiparticle Correlations in d+Au Collisions at 200, 62.4, 39, and 19.6 GeV and p+Au Collisions at 200 GeV and Implications for Collective Behavior, Published in Phys.Rev.Lett. 120 (2018) no.6, 062302

12. Nuclear Dependence of the Transverse-Single-Spin Asymmetry for Forward Neutron Production in Polarized p+A Collisions at $\sqrt{s_{NN}}$=200 GeV, Published in Phys.Rev.Lett. 120 (2018) no.2, 022001

Основные результаты

QGP droplets in small systems

nature physics

LETTERS

https://doi.org/10.1038/s41567-018-0360-0

Creation of quark–gluon plasma droplets with three distinct geometries

PHENIX Collaboration*

Experimental studies of the collisions of heavy nuclei at relativistic energies have established the properties of the quark-gluon plasma (QGP), a state of hot, dense nuclear matter in which quarks and gluons are not bound into hadrons[1-4]. In this state, matter behaves as a nearly inviscid fluid[5] that efficiently translates initial spatial anisotropies into correlated momentum anisotropies among the particles produced, creating a common velocity field pattern known as collective flow. In recent years, comparable momentum anisotropies have been measured in small-system proton–proton (p+p) and proton–nucleus (p+A) collisions, despite expectations that the volume and lifetime of the medium produced would be too small to form a QGP. Here we report on the observation of elliptic and triangular flow patterns of charged particles produced in proton–gold (p+Au), deuteron–gold (d+Au) and helium–gold (^{3}He+Au) collisions at a nucleon–nucleon centre-of-mass energy $\sqrt{s_{NN}} = 200$ GeV. The unique combination of three distinct initial geometries and two flow patterns provides unprecedented model discrimination. Hydrodynamical models, which include the formation of a short-lived QGP droplet, provide the best simultaneous description of these measurements.

anisotropy to
stages of the co
correlation mo
A projectile
the RHIC was
namical model
momentum co
system from p-
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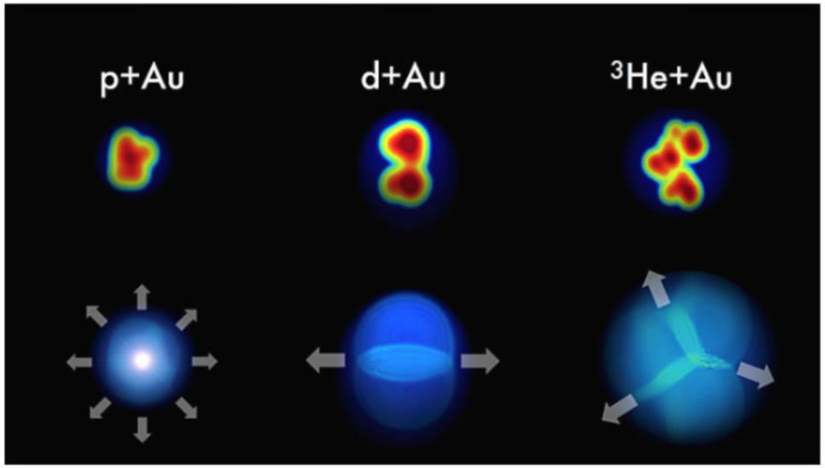
Contact: Karen McNulty Walsh, (631) 344-8350, or Peter Genzer, (631) 344-3174 share:

Compelling Evidence for Small Drops of Perfect Fluid

PHENIX publishes new particle-flow measurements to support their case that tiny projectiles create specks of quark-gluon plasma.

December 10, 2018

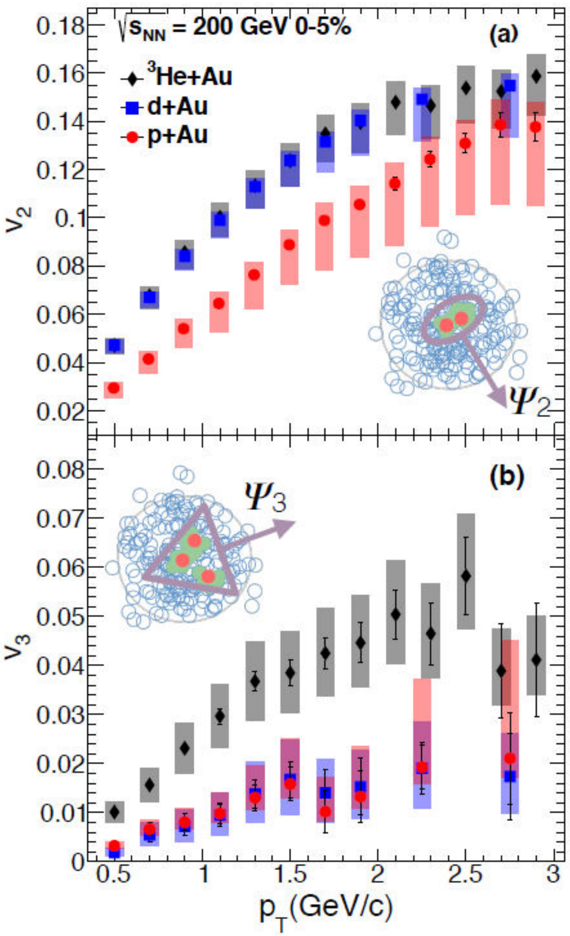


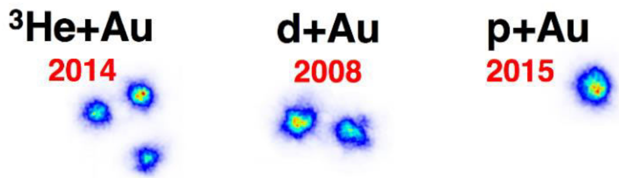
+ENLARGE

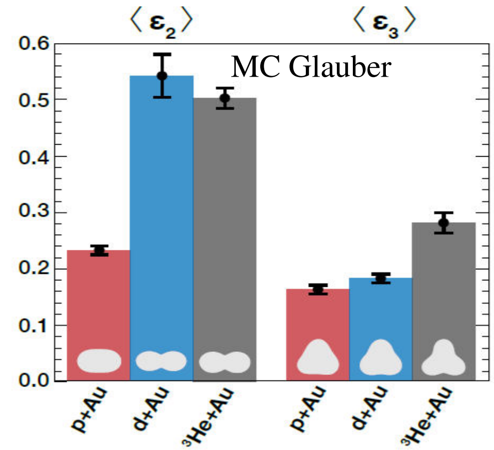
If collisions between small projectiles—protons (p), deuterons (d), and helium-3 nuclei (3He)—and gold nuclei (Au) create tiny hot spots of quark-gluon plasma, the pattern of particles picked up by the detector should retain some "memory" of each projectile's initial shape. Measurements from the PHENIX experiment match these predictions with very strong correlations between the initial geometry and the final flow patterns. *Credit: Javier Orjuela Koop, University of Colorado, Boulder*

Geometry engineering – v_2, v_3 of charged hadrons

❖ Geometry engineering is a unique capability of RHIC







$$\varepsilon_n = \frac{\sqrt{\langle r^n \cos(n\phi)\rangle^2 + \langle r^n \sin(n\phi)\rangle^2}}{\langle r^n \rangle}$$

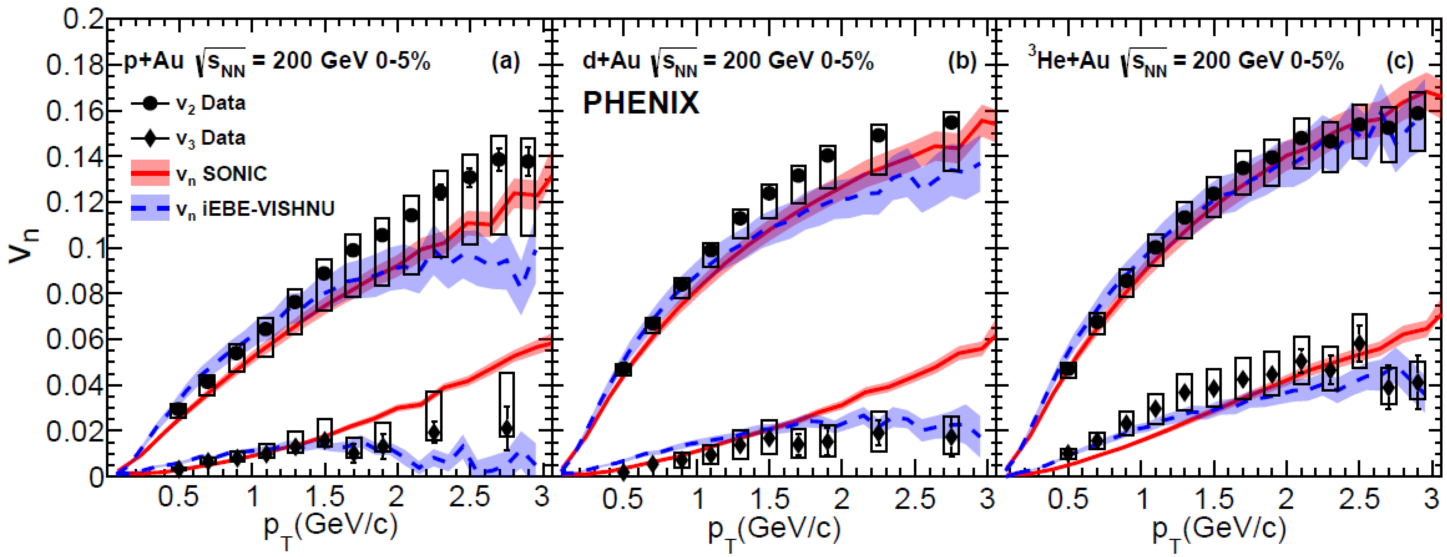
❖ v_2 (^{3}He+Au) ~ v_2 (d+Au) > v_2 (p+Au)

❖ v_3 (^{3}He+Au) > v_3 (d+Au)

→ initial geoametry transforms in the final state momentum anisotropy

→ what is the mechanism of the transformation?

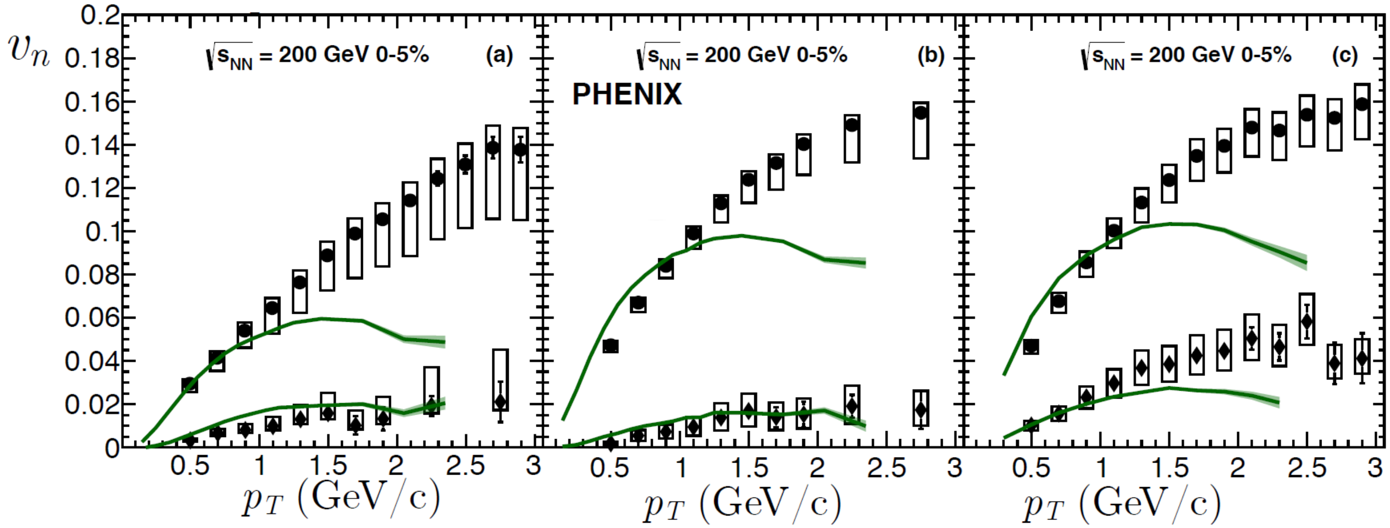
v_2, v_3 of charged hadrons – model comparison (hydro)



- v_2 and v_3 in three systems are simultaneously described by hydrodynamic models:
  - ✓ both models use η/s=0.08, MC Glauber initial conditions, 2+1D viscous hydrodynamic evolution
  - ✓ different hadronic rescattering packages: B3D(SONIC), UrQMD(iEBE-VISHNU)
- Same models describe the production spectra

→ strong evidence for QGP droplets in high-multiplicity collisions of small systems

v_2, v_3 of charged hadrons – model comparison (AMPT)

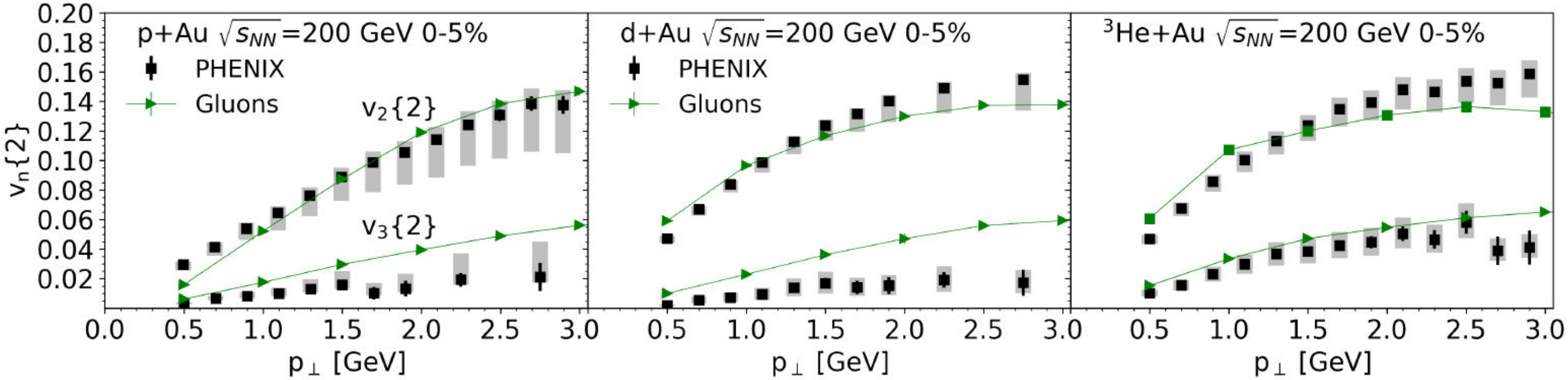


- AMPT:
  - ✓ MC Glauber initial conditions
  - ✓ Strings melt to partons
  - ✓ Partonic transport (partonic cross section σpart = 1.5 mb)
  - ✓ Haronization - parton coalescence
  - ✓ Hadronic rescattering (ART package)

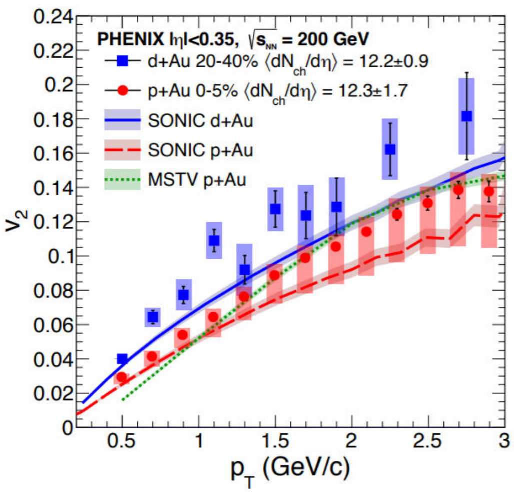
- Decent consistency with v_2 and v_3 in three systems, but only at low momentum

- AMPT calculations do not describe large and small systems with a consistent set of parameters

v_2, v_3 of charged hadrons – model comparison (CGC)

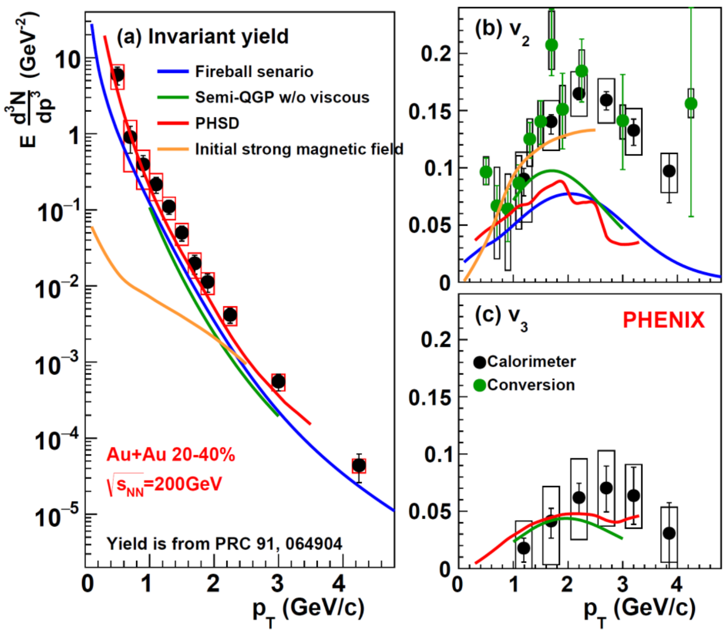


- Model explains data via initial state color correlations computed in the Color Glass Condensate effective field theory (CGC EFT)
- Provides a competitive explanation for the v_2 data
- Describes v_3 in ^{3}He+Au, but overestimates that in d+Au and p+Au
- Predicts that v_2 will be identical between systems when selecting on the same event multiplicity → not supported by data



Direct photon puzzle

Phys.Rev. C94 (2016) no.6, 064901



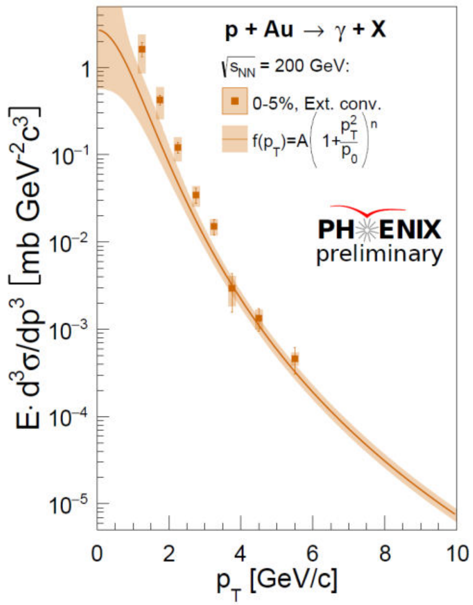
❖ Simultaneous description of the large photon yields and flow is a challenge for theoretical models

❖ Similar situation at the LHC

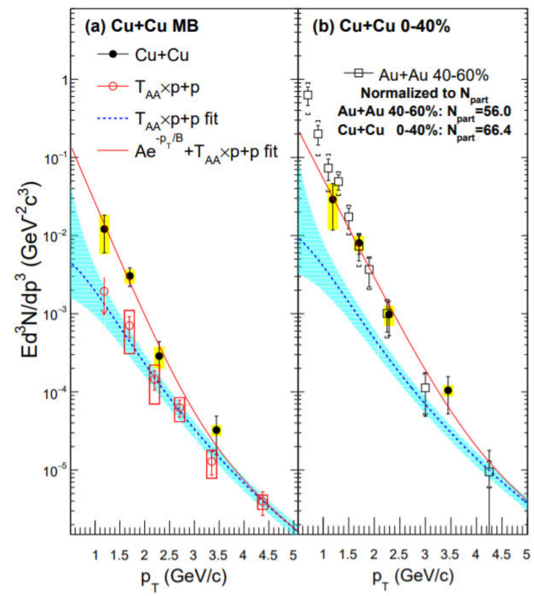
❖ Systematic studies vs. collision system and energy are required

Direct photons, pp@200 & pAu@200 & CuCu@200

pAu@200, 0-5%



arXiv:1805.04066



- New pp@200 reference & fit

- Clear enhancement of the photon yield in central pAu@200 with respect to N_{coll}-scaled pp@200
  → consistent with formation of the QGP droplets in hydro evolution

- Cu+Cu: p_T spectra and dN/dy are consistent with Au+Au data at similar N_{part}

- Exponential fits:

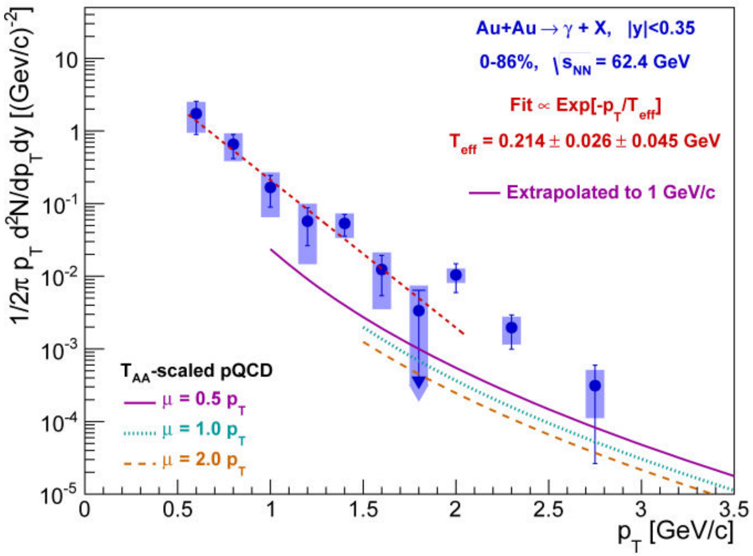
T = 285 ± 53(stat) ± 57(syst) MeV (MB)

T = 333 ± 72(stat) ± 45(syst) MeV (0-40%)

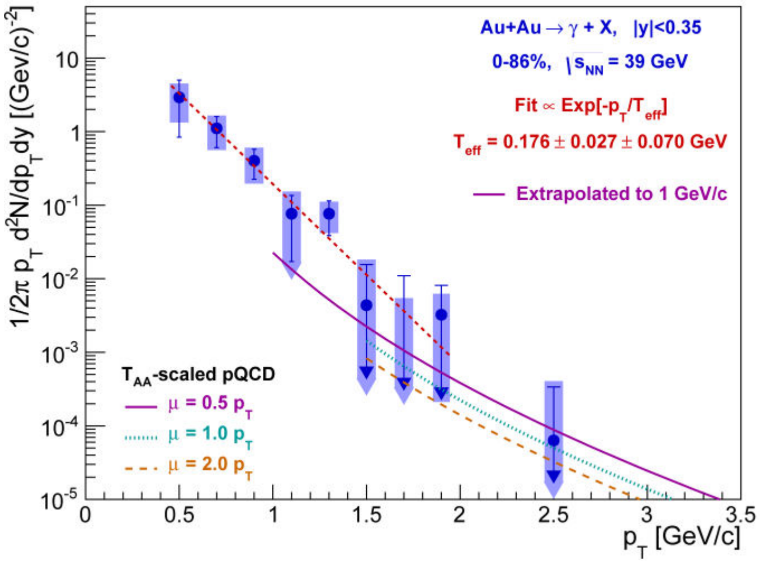
Direct photons, AuAu@62 & AuAu@39

arXiv:1805.04084

AuAu@62, 0-86%



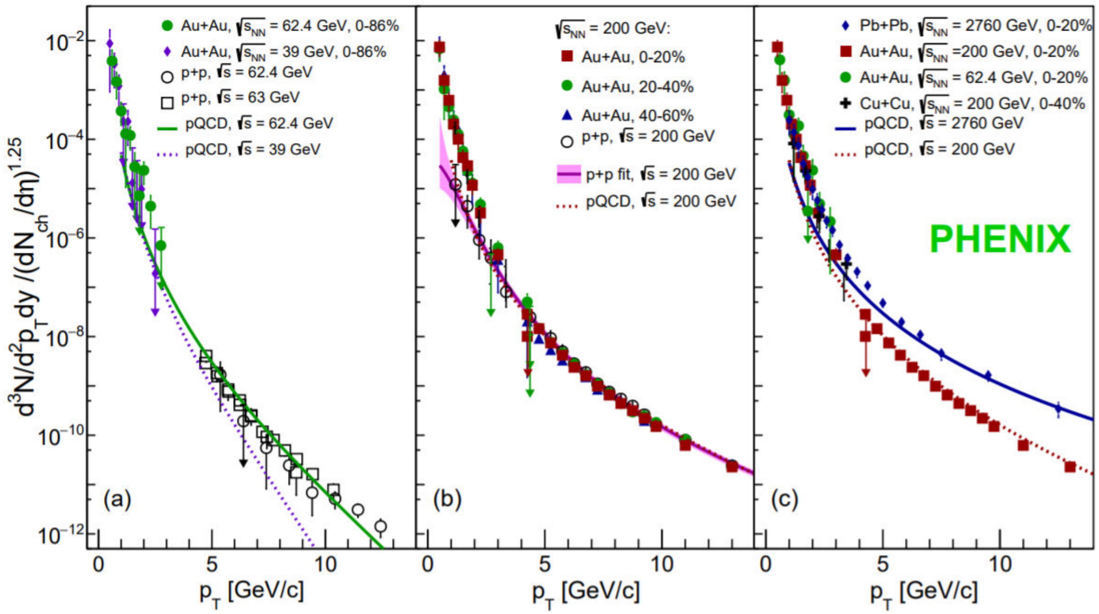
AuAu@39, 0-86%



- Substantial direct photon yield at p_T < 3 GeV/c at both energies
- In AuAu@62 observe increase of the photon yields with centrality
- Exponential fits:
  T = 214±26(stat)±45(syst) MeV (62 GeV);
  T = 176±27(stat)±70(syst) MeV/c (39 GeV)

Spectra normalized by $(dN_{ch}/d\eta)^{1.25}$

arXiv:1805.04084

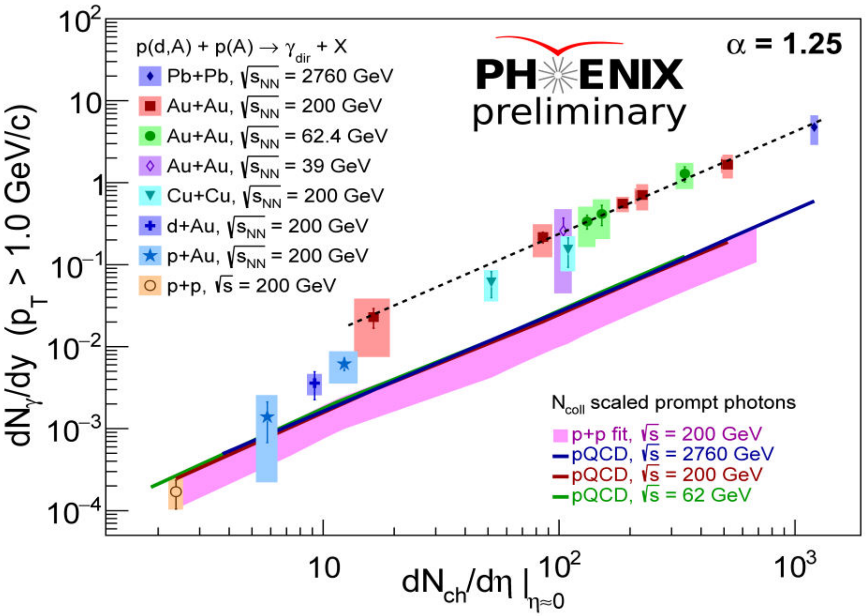


❖ Spectra in A+A collisions at different energies and centralities as well as pQCD curves are normalized by $(dN_{ch}/d\eta)^{1.25}$:

- ✓ separation by energy at high momentum
- ✓ nearly perfect scaling at low momentum

Scaling of low-p_T photon yields

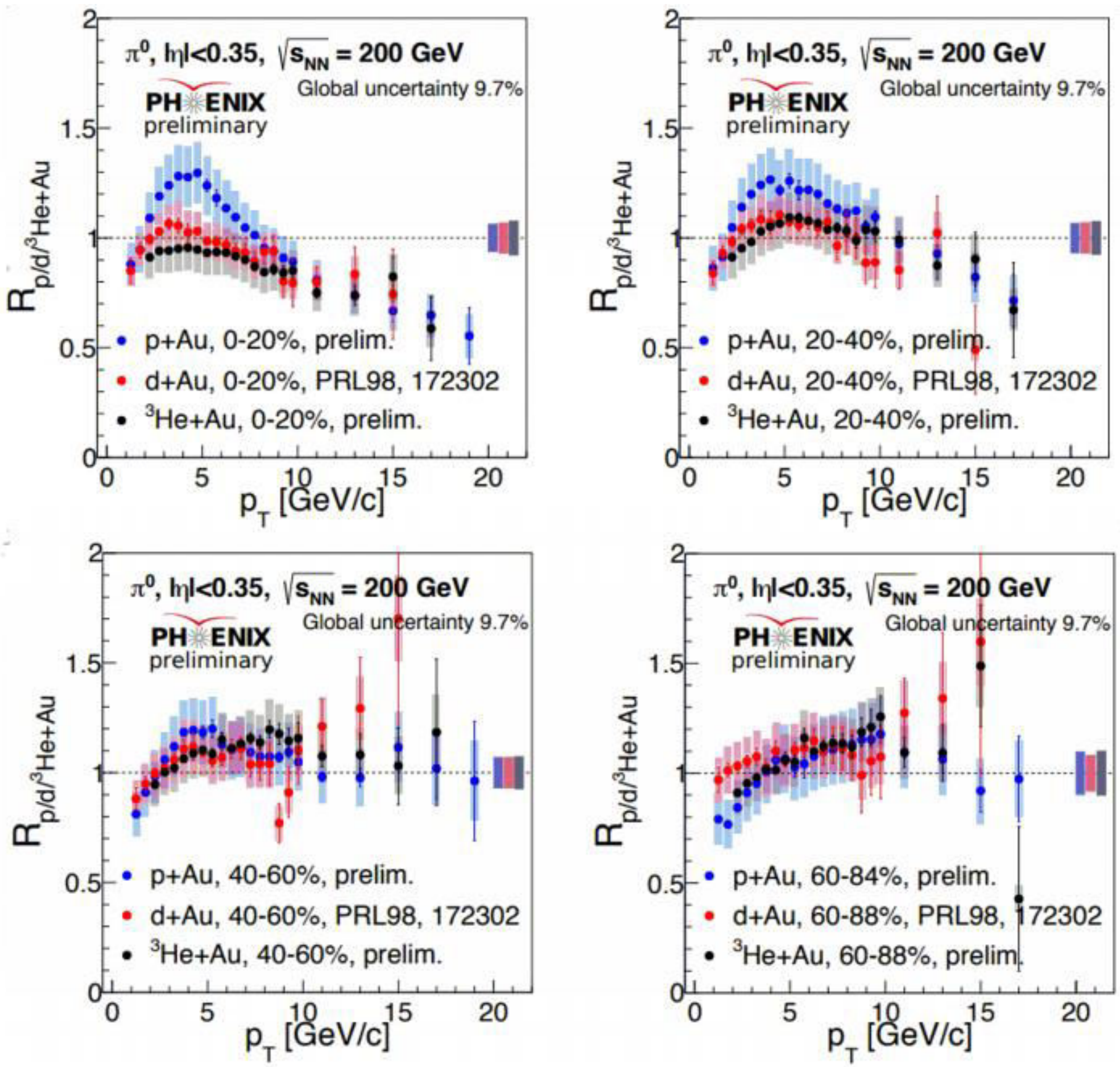
arXiv:1805.04084



- Photon yields are integrated at $p_T > 1$ GeV/c
  → dominated by thermal photons
- A+A:
  - ✓ common trend for integrated yields with $dN_{ch}/d\eta$ at different centralities and energies
  - ✓ integrated photon yields grow faster than multiplicity, $\alpha = 1.25$

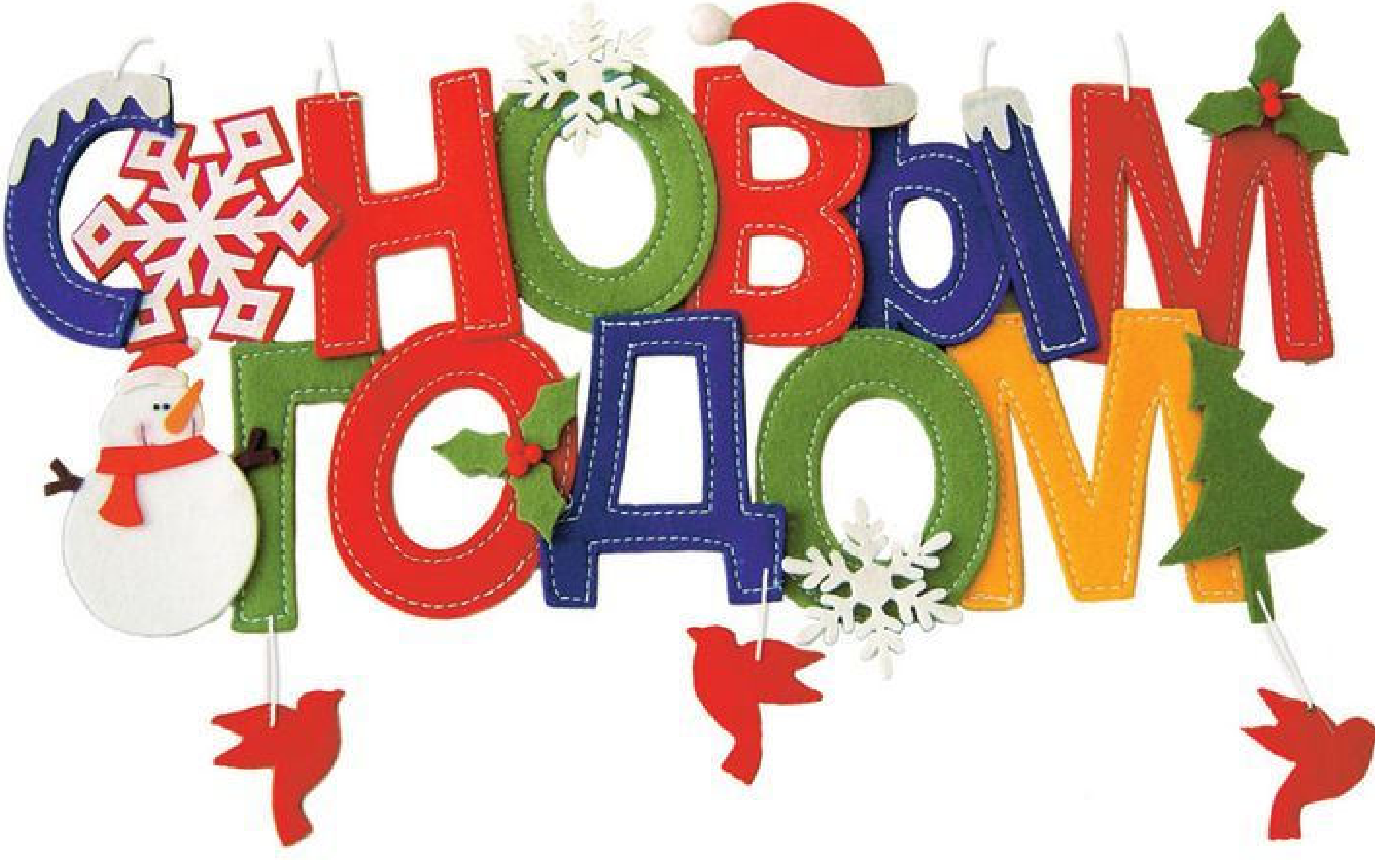
  → large photon production near the phase transition to hadronic phase?
- p+p:
  - ✓ integrated pQCD curves have similar slope
- p/d+Au:
  - ✓ another trend for small systems, suggests the possible turn on of thermal radiation

R_{AA}, p/d/^{3}He+Au@200



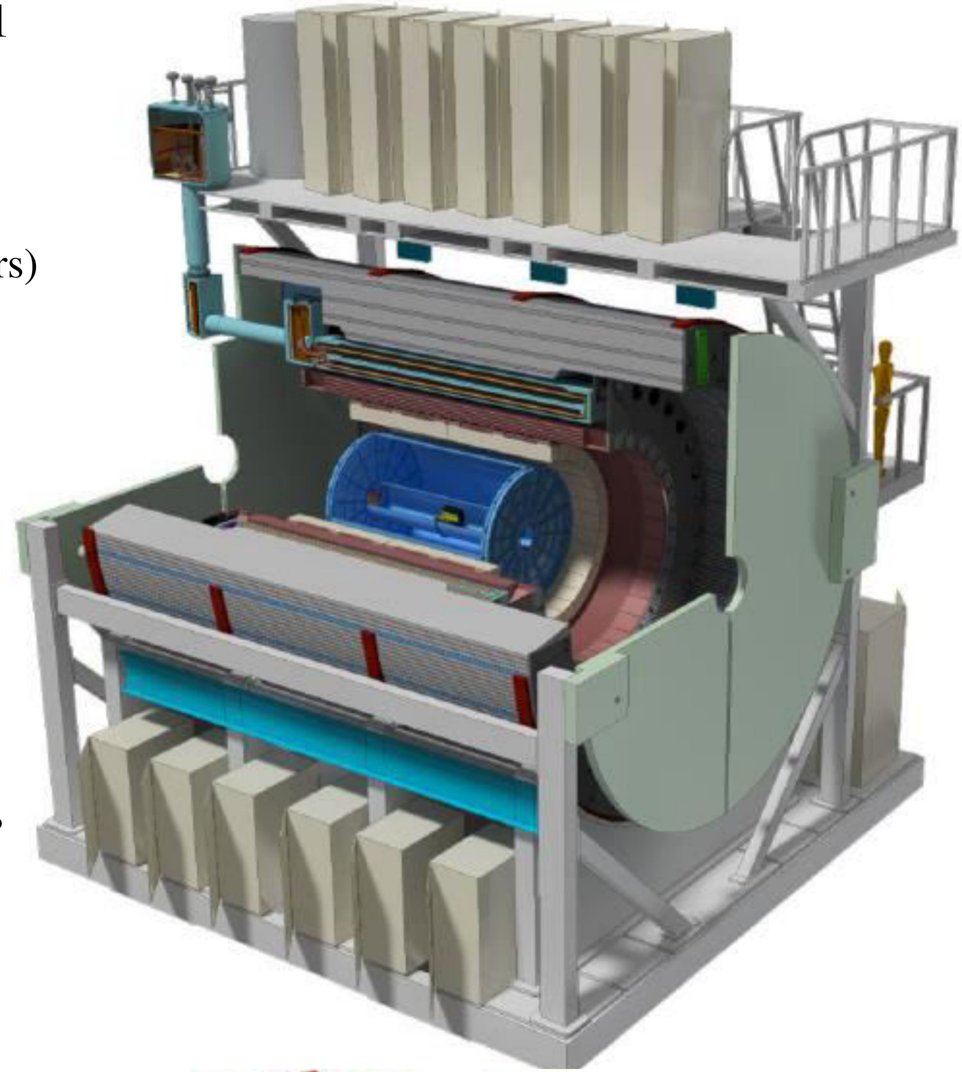
Заключение

- Обработка данных продолжается
- Новые экспериментальные результаты и публикации
- Участие в sPHENIX проблематично


С Новым Годом

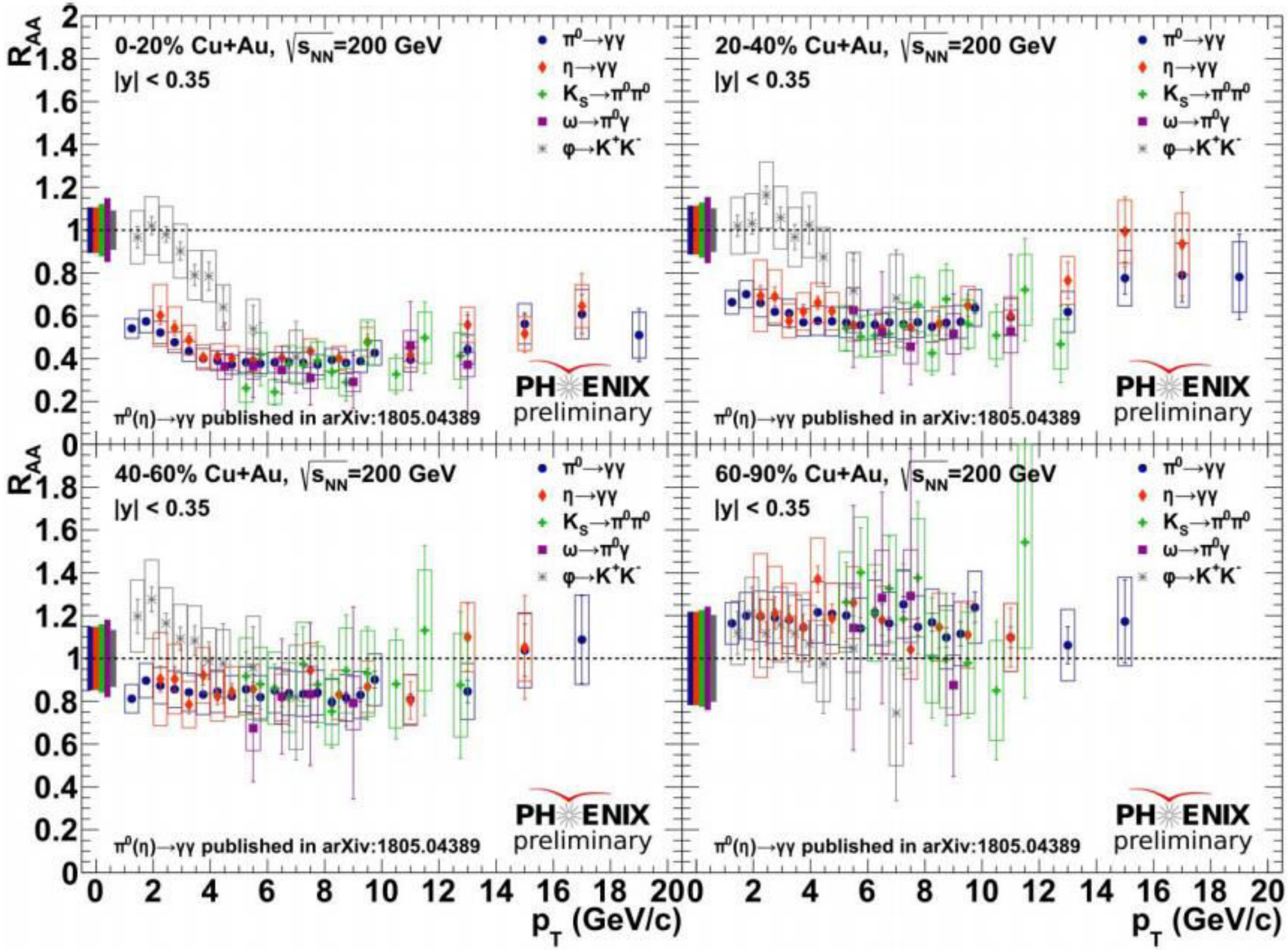
Концепция sPHENIX

- Однородный аксептанс: $0 < \phi < 2\pi$; $|\eta| < 1.1$
- 1.5 Т сверхпроводящий соленоид (BaBar)
- Трекинг (0.2 - 40 ГэВ/c):
  - ✓ VTX: MAPS (Monolithic Active Pixel Sensors)
  - ✓ Промежуточный трекер: silicon strips
  - ✓ Внешний трекер: TPC
- Калориметрия:
  - ✓ EMCal: tungsten-scintillating fiber (W/ScFi)
  - ✓ Внутренний адронный калориметр
  - ✓ Внешний адронный калориметр; также используется как возвратное ярмо
- Возможность добавления мюонного плеча, fsPHENIX
- Коллаборация sPHENIX создана на основе коллаборации PHENIX, большой опыт и поддержка
- Первые данные ожидаются в 2022 году



sPHENIX

R_{AA}, Cu+Au@200



R_{AA}
0-20% Cu+Au, $\sqrt{s_{NN}}$=200 GeV
|y| < 0.35
20-40% Cu+Au, $\sqrt{s_{NN}}$=200 GeV
|y| < 0.35
40-60% Cu+Au, $\sqrt{s_{NN}}$=200 GeV
|y| < 0.35
60-90% Cu+Au, $\sqrt{s_{NN}}$=200 GeV
|y| < 0.35
$\pi^0\to\gamma\gamma$
$\eta\to\gamma\gamma$
$K_S\to\pi^0\pi^0$
$\omega\to\pi^0\gamma$
$\varphi\to K^+K^-$
PHENIX
preliminary
$\pi^0(\eta)\to\gamma\gamma$ published in arXiv:1805.04389
p_T (GeV/c)