PHENIX Overview:
Physics, Experiment, Collaboration

W.A. Zajc

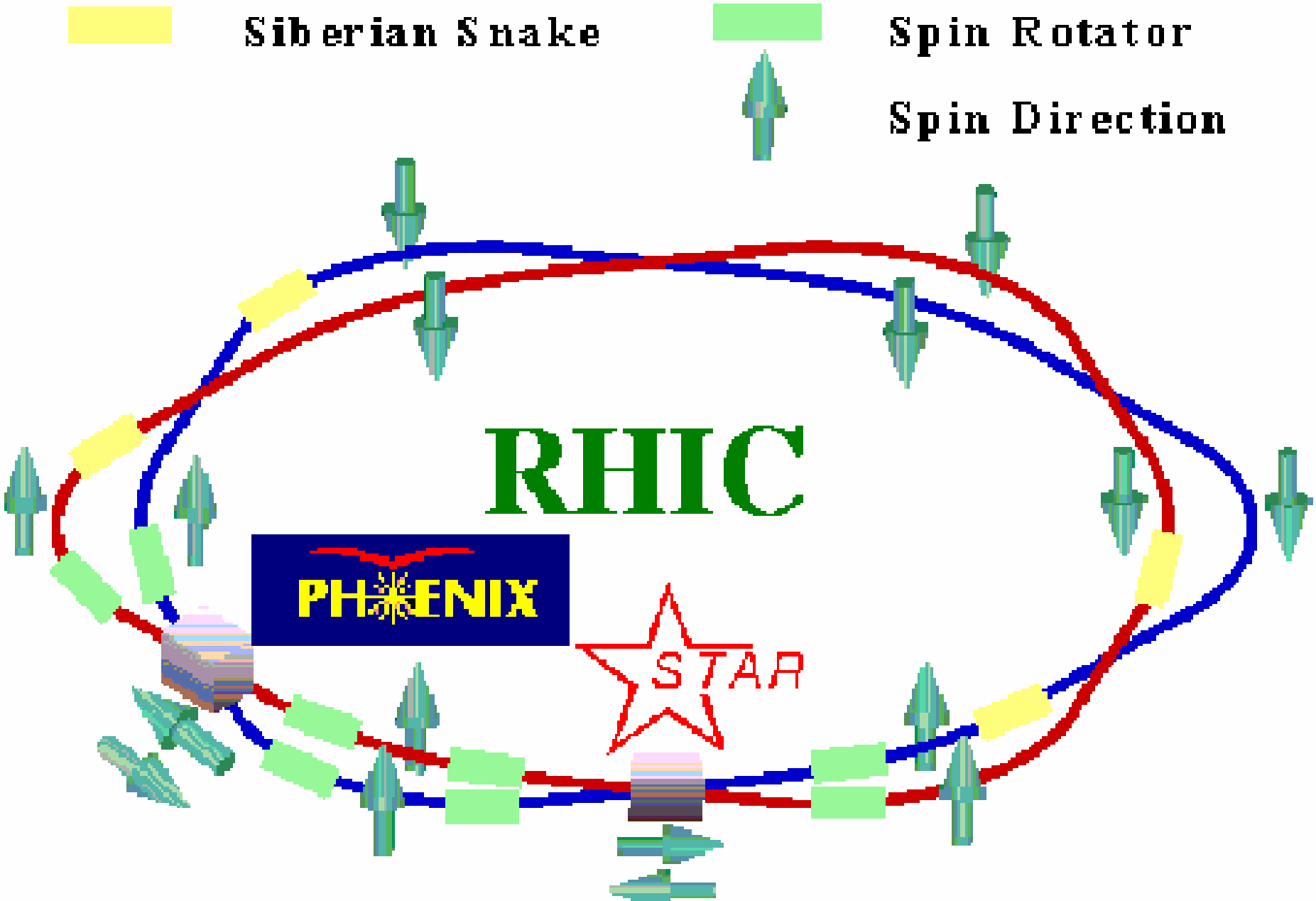
for the PHENIX Collaboration

Summary

- PHENIX is a
  - unique collaboration
  - pursuing unique physics
  - at a unique experimental facility

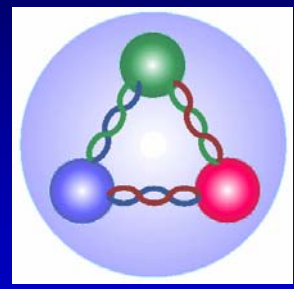
PHENIX

RHIC- the unique facility

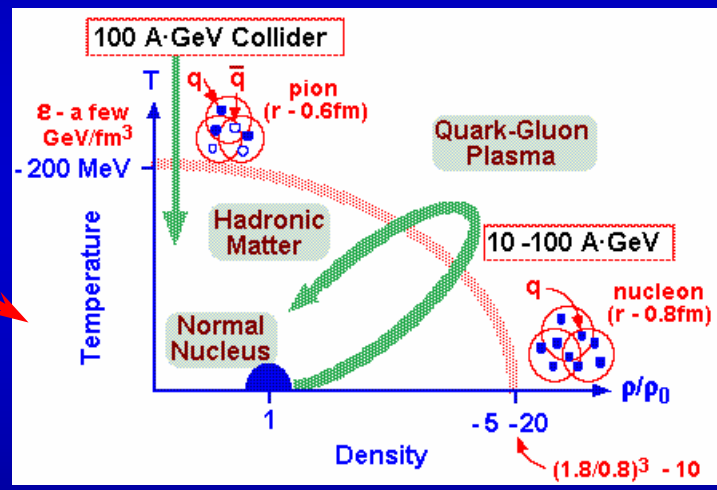


Why is RHIC?

- To understand fundamental aspects of the strong interaction:
  - Where does the proton get its spin?



  - How does nuclear matter "melt"?



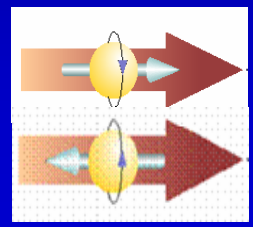
- We have a theory of the strong interaction:

$$L = i\bar{\psi} D \psi - \frac{1}{4} \tilde{F}_a^{\mu\nu} F^a{}_{\mu\nu} - \bar{\psi} \hat{M} \psi$$

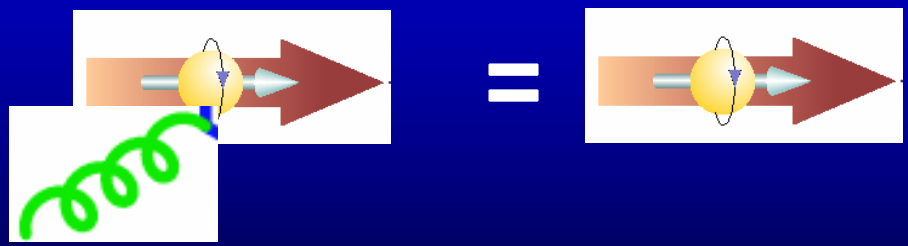
It works well except when the interaction is strong!

The Fascinating Connection

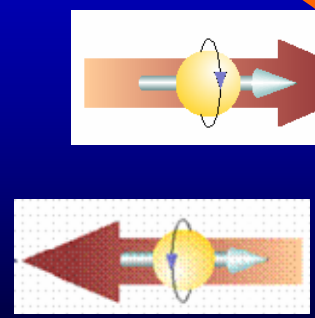
- These two aspects of the RHIC program are closely related
- The unifying concept: *CHIRALITY*
  - In particle physics, *chirality* refers to the orientation between the spin and momentum of a particle
  - In QCD,
    - right-handed quarks
    - and
    - left-handed quarks



  - are independent degrees of freedom
  - However, confinement necessarily mixes this degrees of freedom:
- A gluon can not change a quark's chirality:



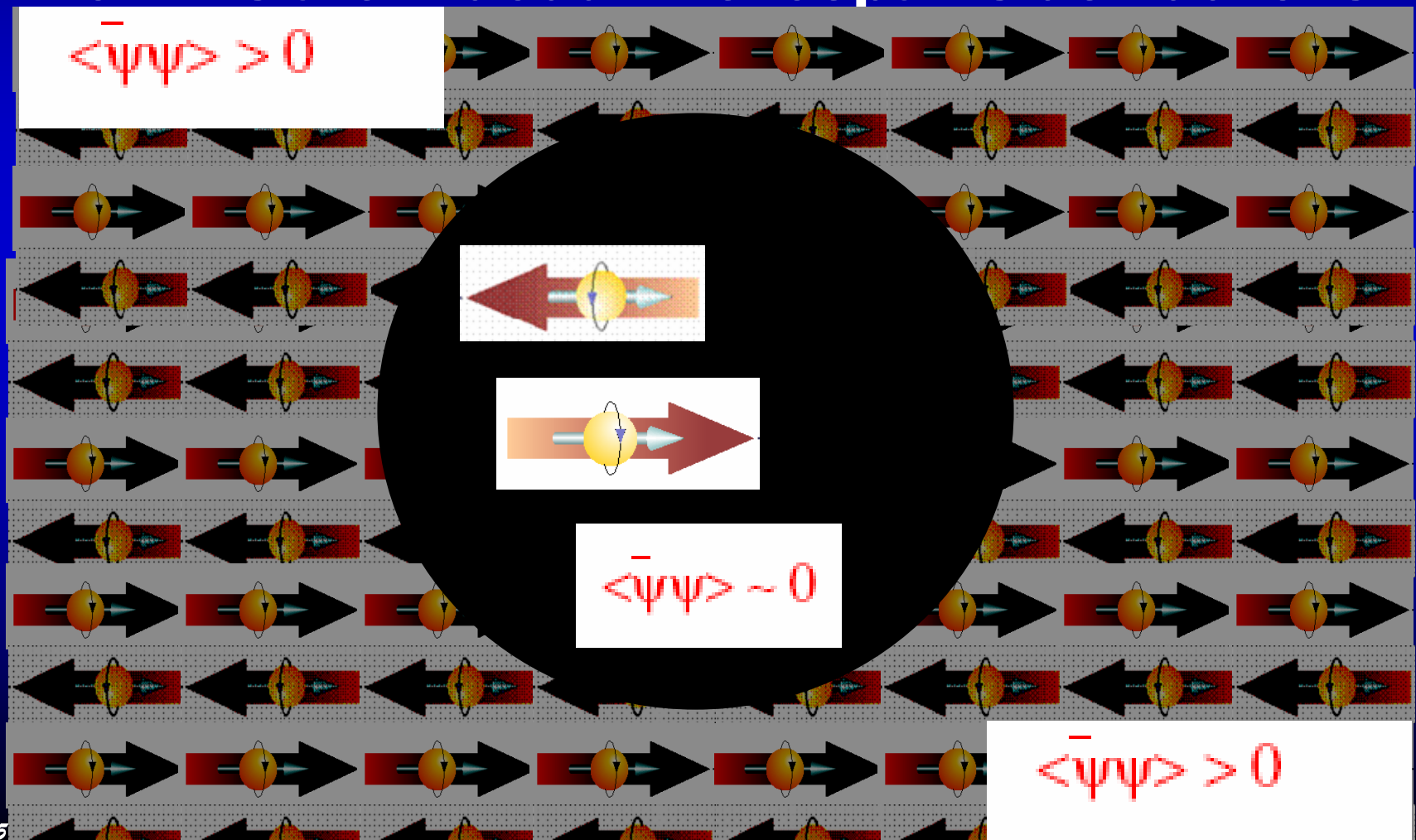
- But confinement requires chirality change:



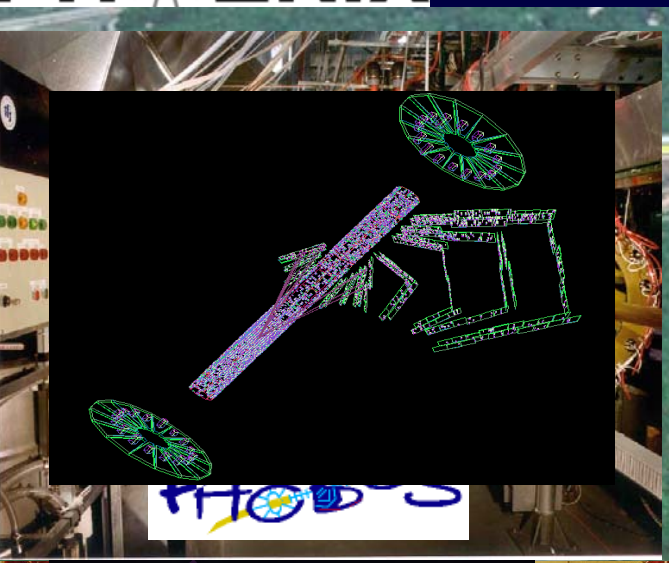
Bag Wall

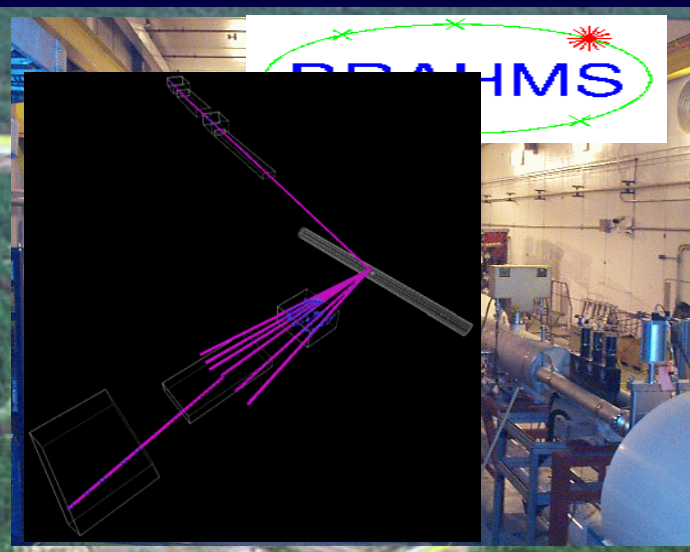
A Better Picture

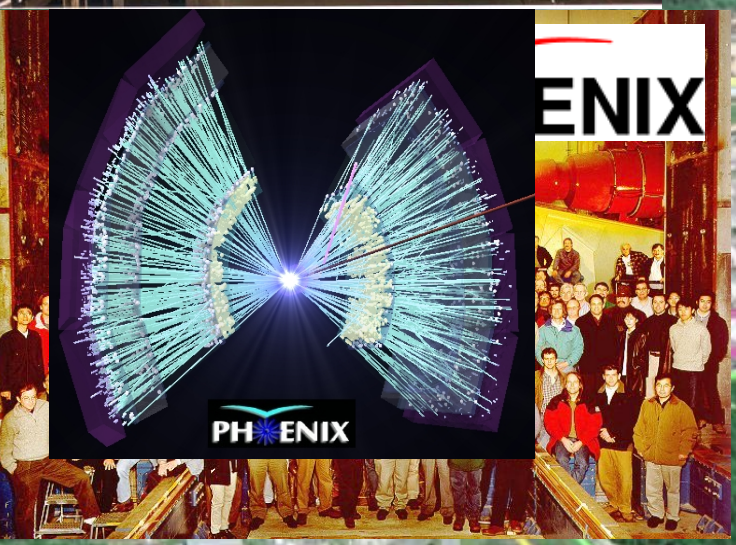
- The chirality changes required by confinement are mediated by the "chiral condensat $\langle\bar{\psi}\psi\rangle$ which fills the "vacuum" except inside hadrons:

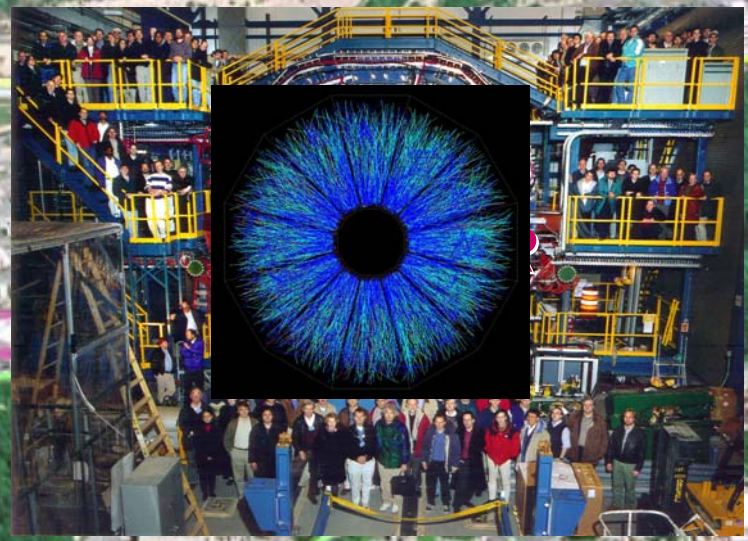


RHIC's Experiments

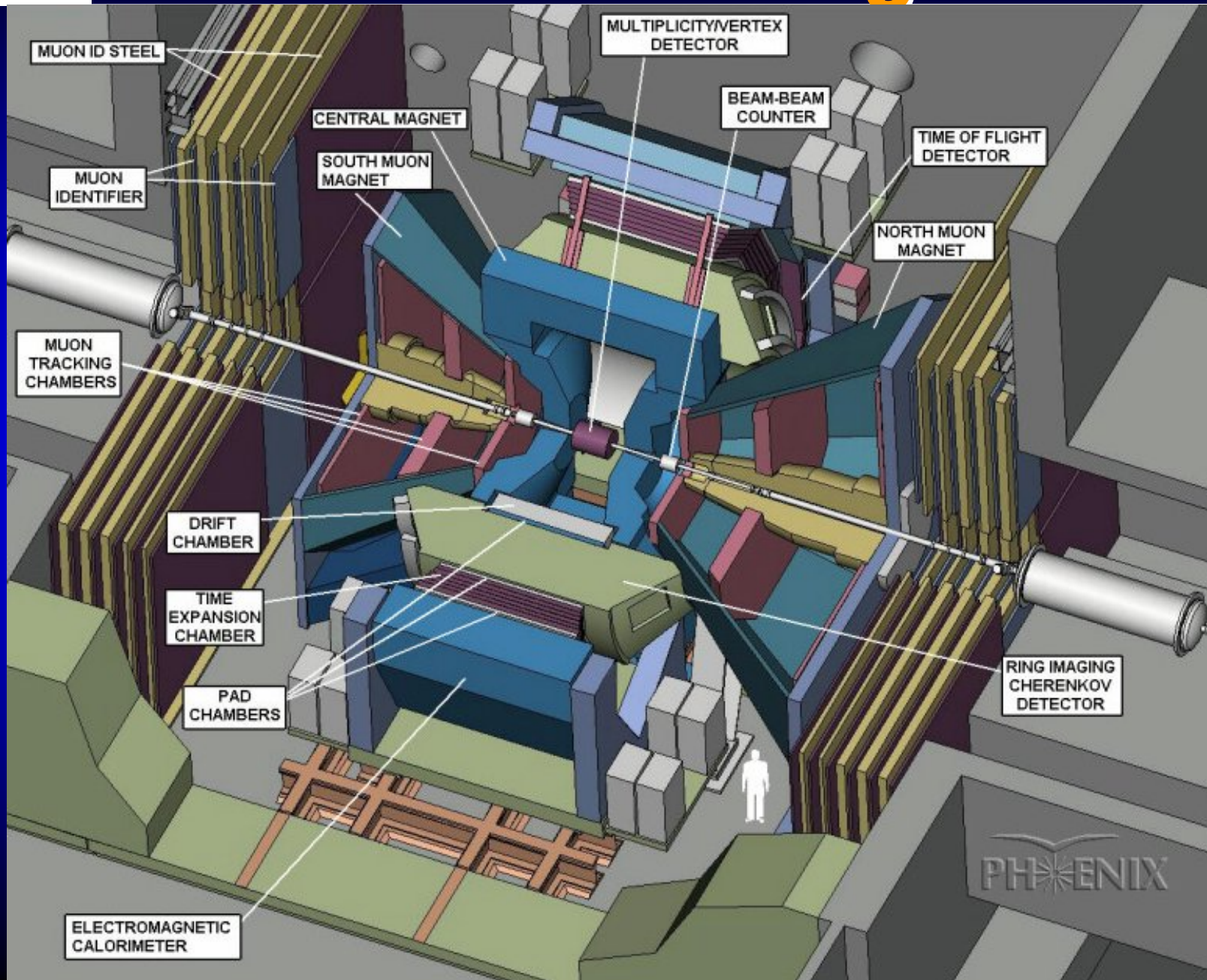








PHENIX Design



PHENIX

Collaboration, 2005

13 Countries; 62 Institutions; 550 Participants*

- University of São Paulo, São Paulo, Brazil
- Academia Sinica, Taipei 11529, China
- China Institute of Atomic Energy (CIAE), Beijing, P. R. China
- Peking University, Beijing, P. R. China
- Charles University, Faculty of Mathematics and Physics, Ke Karlovu 3, 12116 Prague, Czech Republic
- Czech Technical University, Faculty of Nuclear Sciences and Physical Engineering, Brehova 7, 11519 Prague, Czech Republic
- Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague, Czech Republic
- Laboratoire de Physique Corpusculaire (LPC), Universite de Clermont-Ferrand, 63 170 Aubiere, Clermont-Ferrand, France
- Dapnia, CEA Saclay, Bat. 703, F-91191 Gif-sur-Yvette, France
- IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406 Orsay, France
- Laboratoire Leprince-Ringuet, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128 Palaiseau, France
- SUBATECH, Ecòle des Mines at Nantes, F-44307 Nantes France
- University of Muenster, Muenster, Germany
- KFKI Research Institute for Particle and Nuclear Physics at the Hungarian Academy of Sciences (MTA KFKI RMKI), Budapest, Hungary
- Debrecen University, Debrecen, Hungary
- Eövös Loránd University (ELTE), Budapest, Hungary
- Banaras Hindu University, Banaras, India
- Bhabha Atomic Research Centre (BARC), Bombay, India
- Weizmann Institute, Rehovot, 76100, Israel
- Center for Nuclear Study (CNS-Tokyo), University of Tokyo, Tanashi, Tokyo 188, Japan
- Hiroshima University, Higashi-Hiroshima 739, Japan
- KEK - High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
- Kyoto University, Kyoto, Japan
- Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki, Japan
- RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 35 0198, Japan
- RIKEN – BNL Research Center, Japan, located at BNL
- Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
- Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japa
- University of Tsukuba, 1-1-1 Tennodai, Tsukuba-shi Ibaraki-ken 305-8577, Japan
- Waseda University, Tokyo, Japan
- Cyclotron Application Laboratory, KAERI, Seoul, South Korea
- Kangnung National University, Kangnung 210-702, South Korea
- Korea University, Seoul, 136-701, Korea
- Myong Ji University, Yongin City 449-728, Korea
- System Electronics Laboratory, Seoul National University, Seoul, South Korea
- Yonsei University, Seoul 120-749, Korea
- IHEP (Protvino), State Research Center of Russian Federation "Institute fo High Energy Physics", Protvino 142281, Russia
- Joint Institute for Nuclear Research (JINR-Dubna), Dubna, Russia
- Kurchatov Institute, Moscow, Russia
- PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
- Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119992, Russia
- Saint-Petersburg State Polytechnical Univiversity, Politechnicheskayastr, 2
- Lund University, Lund, Sweden
- Abilene Christian University, Abilene, Texas, USA
- Brookhaven National Laboratory (BNL), Upton, NY 11973, USA
- University of California - Riverside (UCR), Riverside, CA 92521, USA
- University of Colorado, Boulder, CO, USA
- Columbia University, Nevis Laboratories, Irvington, NY 10533, USA
- Florida Institute of Technology, Melbourne, FL 32901, USA
- Florida State University (FSU), Tallahassee, FL 32306, USA
- Georgia State University (GSU), Atlanta, GA, 30303, USA
- University of Illinois Urbana-Champaign, Urbana-Champaign, IL, USA
- Iowa State University (ISU) and Ames Laboratory, Ames, IA 50011, USA
- Los Alamos National Laboratory (LANL), Los Alamos, NM 87545, USA
- Lawrence Livermore National Laboratory (LLNL), Livermore, CA 94550, USA
- University of New Mexico, Albuquerque, New Mexico, USA
- New Mexico State University, Las Cruces, New Mexico, USA
- Department of Chemistry, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Department of Physics and Astronomy, State University of New York at Stony Brook (USB), Stony Brook, NY 11794, USA
- Oak Ridge National Laboratory (ORNL), Oak Ridge, TN 37831, USA
- University of Tennessee (UT), Knoxville, TN 37996, USA
- Vanderbilt University, Nashville, TN 37235, USA

Collaboration Status

- Healthy
  - Wide-ranging participation in
    - Data analysis
    - Shift support (309 individuals in Run-5 !)
    - Upgrades program

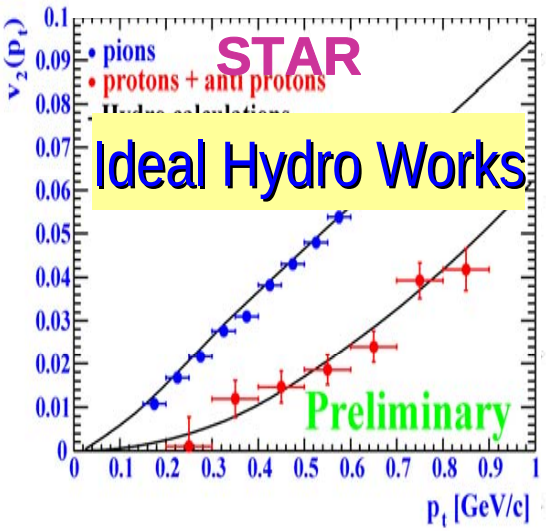
- Continued growth:

Year	Institutions	Nations	Participants
2001	53	11	420
2003	57	12	460
2005	62	13	550

PHENIX Scientific Impact

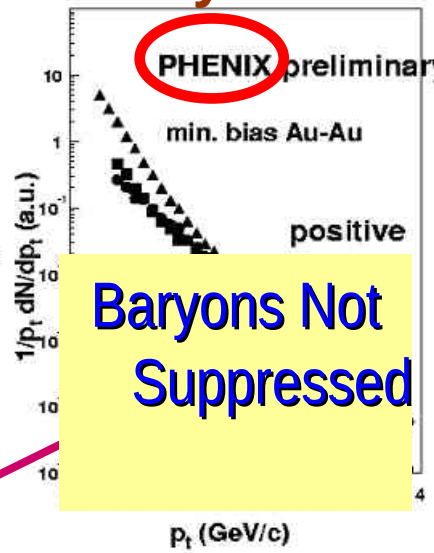
Four major "day 1" discoveries

Collective Flow



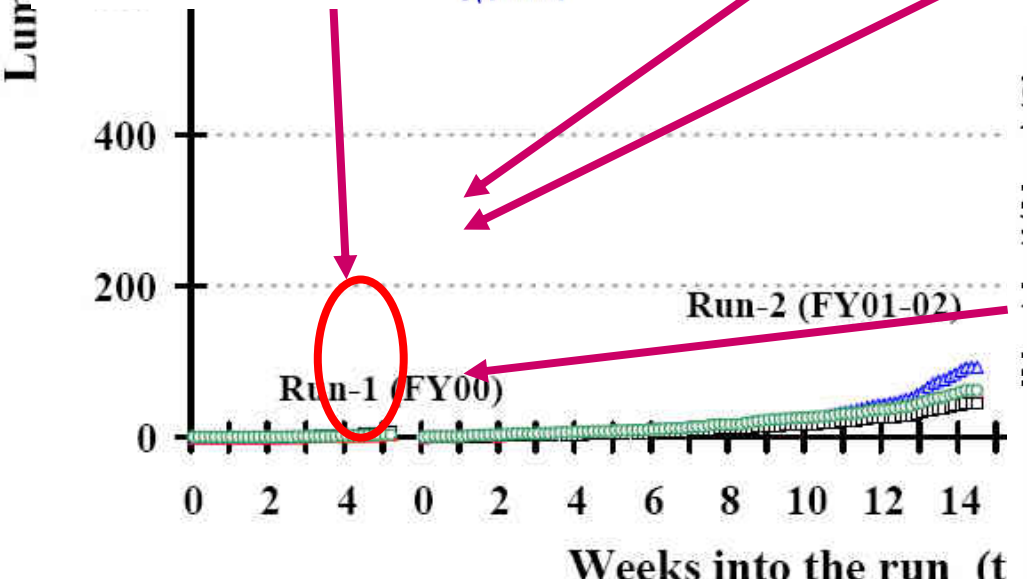
Jet Quenching

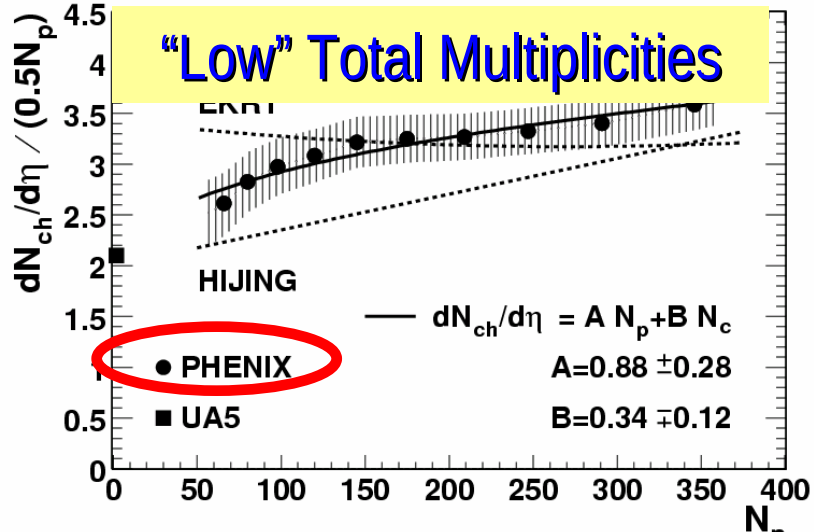
Baryon anomaly



As presented by M. Gyulassy in June, 2004 to Nuclear Science Advisory Committee

CGC Saturation





Accomplishments and Discoveries

- First measurement of the dependence of the charged particle pseudo-rapidity density and the transverse energy on the number of participants in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV; systamatic study of same versus energy.
- Discovery of high p_T suppression in π^0 and charged particle production in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and a systematic study of the scaling properties of the suppression; extension of these results to much higher transverse momenta in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV
- (Co)-Discovery of absence of high p_T suppression in d+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Discovery of the anomalously large proton and anti-proton yields at high transverse momentum in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV through the systematic study of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$ spectra; measurement of Λ and anti-Λ in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV ; study of the scaling properties of the proton and anti-proton yields , of Φ production and d and dbar production n Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Measurement of HBT correlations in $\pi^+\pi^+$ and $\pi^-\pi^-$ pairs in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV , establishing the ``HBT puzzle" of $R_{OUT} \sim R_{SIDE}$ extends to high pair momentum; extension of these results to $\sqrt{s_{NN}}$ = 200 GeV
- First measurement of single electron spectra in Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV, suggesting that charm production scales with the number of binary collisions.
- Sensitive measures of charge fluctuations and fluctuations in mean p_T and transverse energy per particle in Au+Au collisions at at $\sqrt{s_{NN}}$ =130~GeV; role of jets in p_T fluctuations at 200 GeV
- Measurements of elliptic flow for charged particles from Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and identified charged hadrons from Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV along with study of the saturation of the azimuthal flow.
- Extensive study of hydrodynamic flow, particle yields, ratios and spectra from Au+Au collisions at $\sqrt{s_{NN}}$ =130 GeV and 200 GeV.
- First observation of J/Ψ production in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV.
- Measurement of crucial baseline data on π^0 spectra , J/ Ψ production and direct photon production in p+p collisions at $\sqrt{s_{NN}}$ =200~GeV.
- First measurement of direct photon production in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV, demonstrating that photon yields scaleswith the number of binary collisions.
- First observation of heavy flavor flow in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- First measurement of $A_{LL}(\pi^0)$ in p+p collisions at $\sqrt{s_{NN}}$ =200 GeV
- First study of jet structure of baryon excess in Au+Au collisions at $\sqrt{s_{NN}}$ =200 GeV
- First study of nuclear modification factor in d+Au collisions in forward *and* backward region at $\sqrt{s_{NN}}$ =200 GeV

PHOENIX

Public Recognition

BBC NEWS UK EDITION — Big Bang experiment strikes gold

The New York Times ON THE WEB — Scientists Report Hottest, Densest Matter Ever Observed

Newsday.com Thursday, June — A Matter of Accomplishment

AMERICAN INSTITUTE OF PHYSICS — Intriguing Oddities In High-Energy Nuclear Collisions.

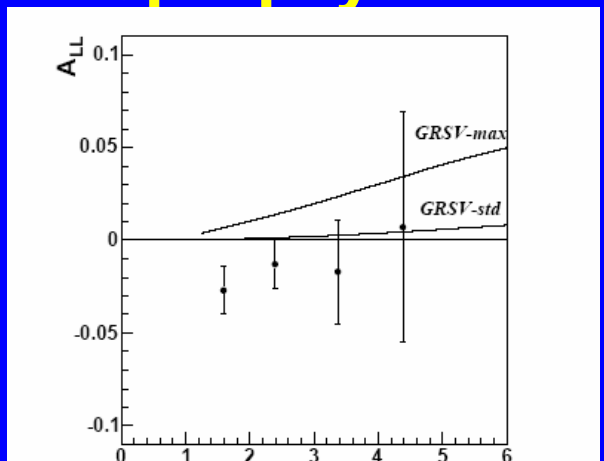
AP Associated Press — Quark-gluon plasma discovery key in examining universe, scientists say

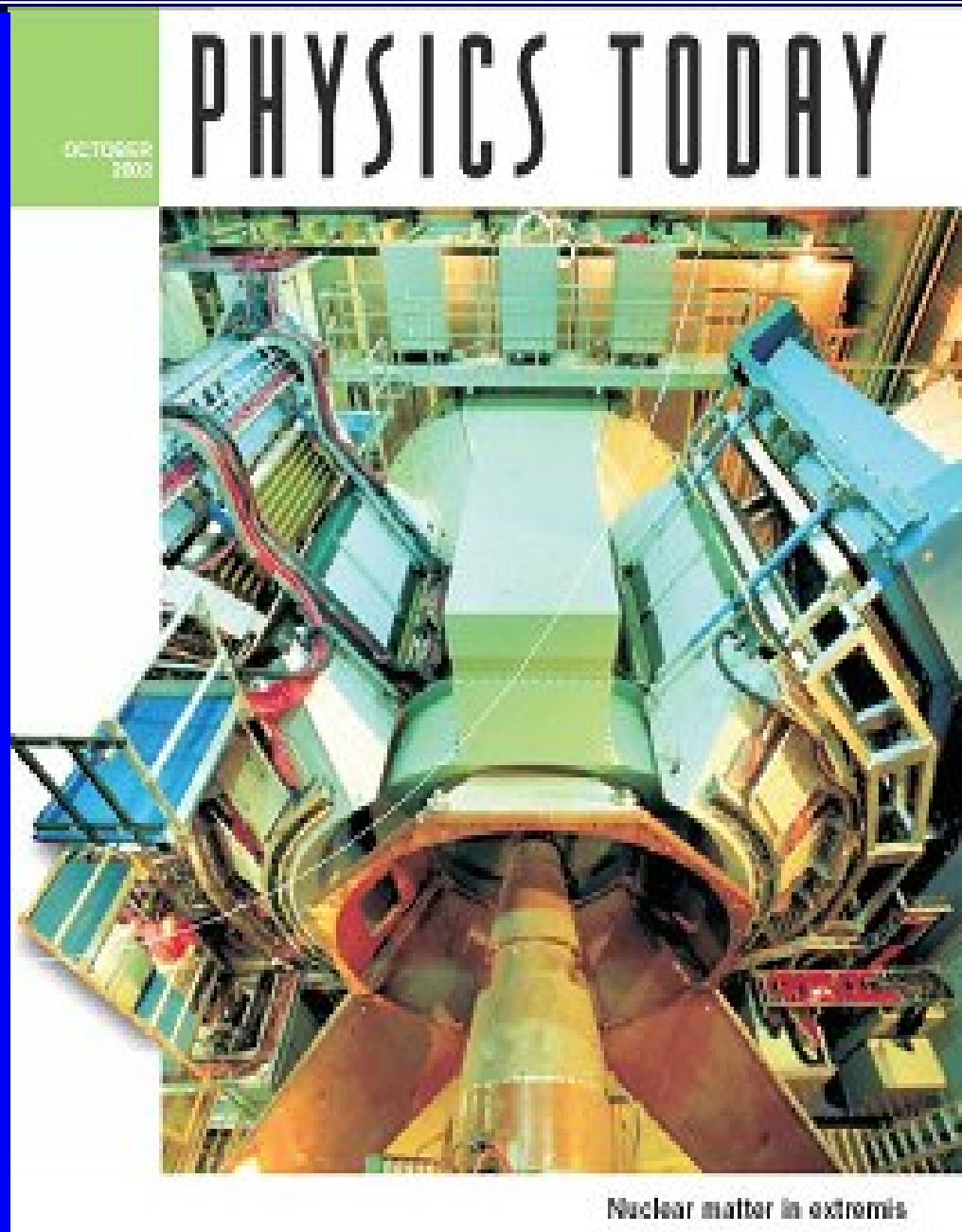
Science magazine — Has RHIC Set Quarks Free at Last? Physicists Don't Quite Say So

- along with *National Public Radio, WCBS, Times of India, Nature, New Scientist, Science News, Public Radio International, Physics Today, Swedish National Radio, The Chronicle of Higher Education, San Francisco Chronicle, Dallas Morning News, Slashdot, Der Spiegel, AOL, Cern Courier, CNN, Discover, Bild der Wissenschaft, Die Welt, Times of London, Yahoo, Fox News, Hungarian National Press, …*

PHENIX Recognition

- Currently the world's most sophisticated nuclear physics experiment
- World-class discoveries and measurements in
  - Heavy ion physics
  - Spin physics





Data Analysis at Wako

Data transfer between RCF (BNL) and CC-J (RIKEN):

data sample: 260 TB
rate : 60MB/sec.
duration : ~11 weeks

RIKEN/CCJ: *Yasuhi Watanabe*, Satoshi Yokkaichi, Takashi Ichihara
PHENIX : Martin Purschke, *Mickey Chiu*, Hiro Hiejima
RCF : Dantong Yu, Shigeki Misawa, Terry Healy, Razvan Popescu, John Riordan

PHENIX Leadership

- Present
  - Y. Akiba (RIKEN), Deputy Spokesperson
  - N. Saito (Kyoto), Executive Council
- Past
  - S. Nagamiya (then Columbia), Spokesperson
  - H. En'yo (then Kyoto), Executive Council
  - H. Hamagaki (CNS), Executive Council
  - K. Imai (Kyoto), Executive Council

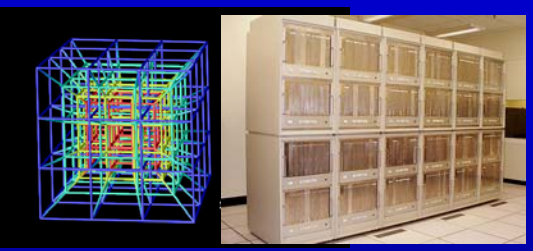
RIKEN/RHIC/BNL Physics

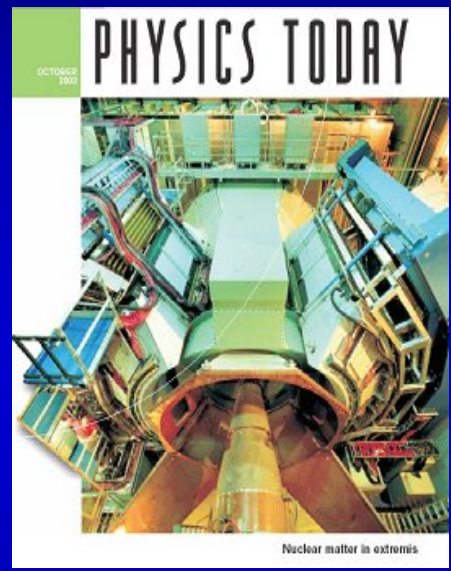
The "wave-function" of the proton

Spin Dynamics

BNL

QCD





Weak matrix elements ←

Lattice Studies

RIKEN

Heavy Ion Collisions

→ Astro-physics