

# 25 Years of PHENIX

W.A. Zajc  
Physics Department  
Columbia University, New York, NY

Thanks to  
John Haggerty, Hubert van Hecke, Dave Morrison, Jamie Nagle, Ilya Ravinovich,  
Baldo Sahlmueller, Walter Sondheim, Ralf Seidl

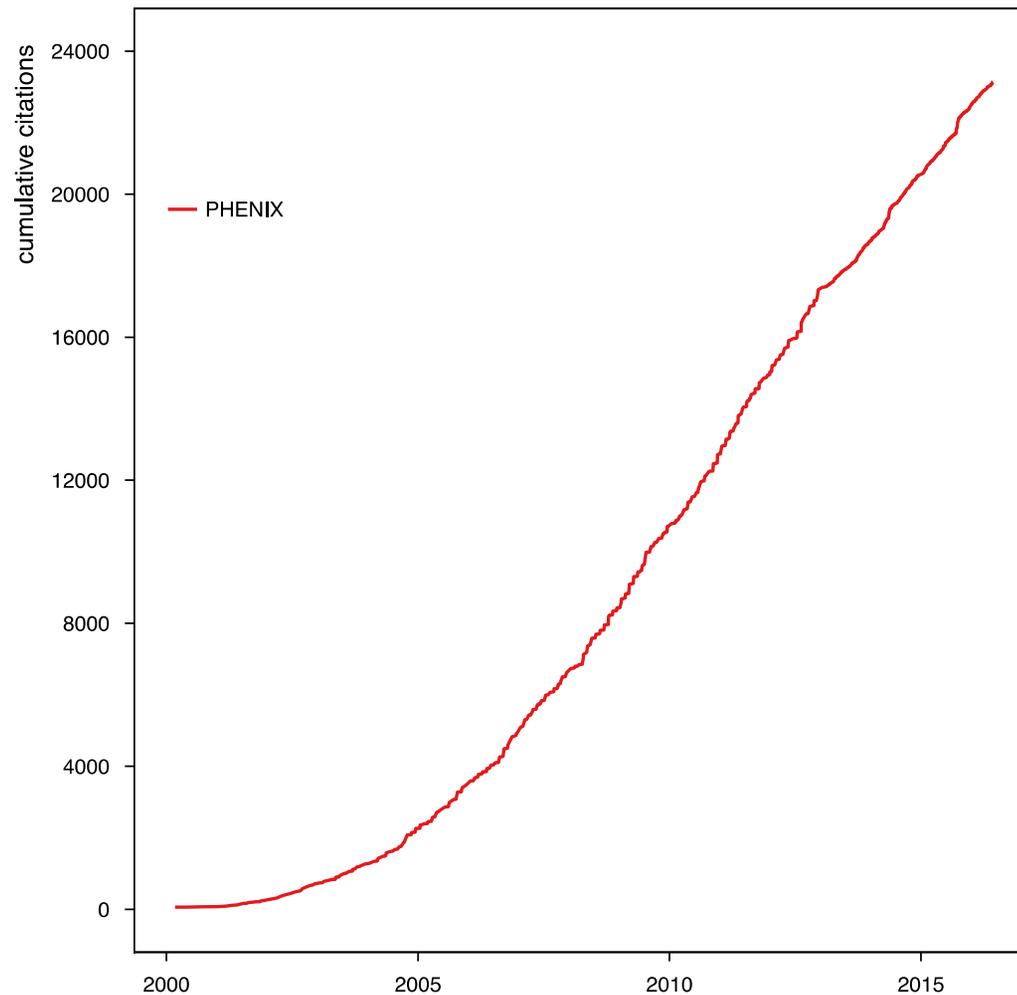


## An Important Number

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- 525,948.766

- **525,948.766** =  $\frac{25 \text{ Years}}{25 \text{ Minutes}}$





BROOKHAVEN NATIONAL LABORATORY  
ASSOCIATED UNIVERSITIES, INC.

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(516) 282-7711  
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Office of the Director

September 9, 1991

Prof. P. Braun-Munzinger Department of Physics SUNY-Stony Brook Stony Brook, NY 11794-3800	Prof. S. Nagamiya Department of Physics Columbia University 538 West 120th Street New York, NY 10027	Dr. G. Young MS 373 Oak Ridge National Laboratory P.O. Box X, Bldg. 6003 Oak Ridge, TN 37830
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Dear Peter, Shoji and Glenn:

This is to confirm the discussion we had on Tuesday, September 3, 1991 regarding the decisions made by the Program Advisory Committee with respect to your RHIC Letters of Intent.

1. The Committee decided to reject all three of the Letters of Intent because of what were felt to be major deficiencies in each of these.
2. The Committee decided to place the emphasis on a detector designed to study electrons and photons emerging from the QGP. In this regard, it will address some of the basic physics interests of each of your groups.
3. The Laboratory has appointed Sam Aronson as Spokesman and Project Director with the charge of developing a new collaboration to design and build such a detector. We strongly urge each of you and your current respective collaborators to join in this effort. Those of you who are primarily interested in hadron physics will be welcomed by the STAR collaboration which has been empowered to build a large TPC detector.
4. The Laboratory is prepared to contribute at most \$50 million to the design and construction of this detector. Hopefully, you can find resources outside of the Laboratory to augment this sum.
5. It is hoped that the new collaboration can present a conceptual design to the Technical Advisory Committee in mid December. Sam Aronson will have final authority as to the technical and scientific content of the proposal. He is in the process of forming an advisory committee composed primarily of the leadership of the three former collaborations to assist in the conceptual design.

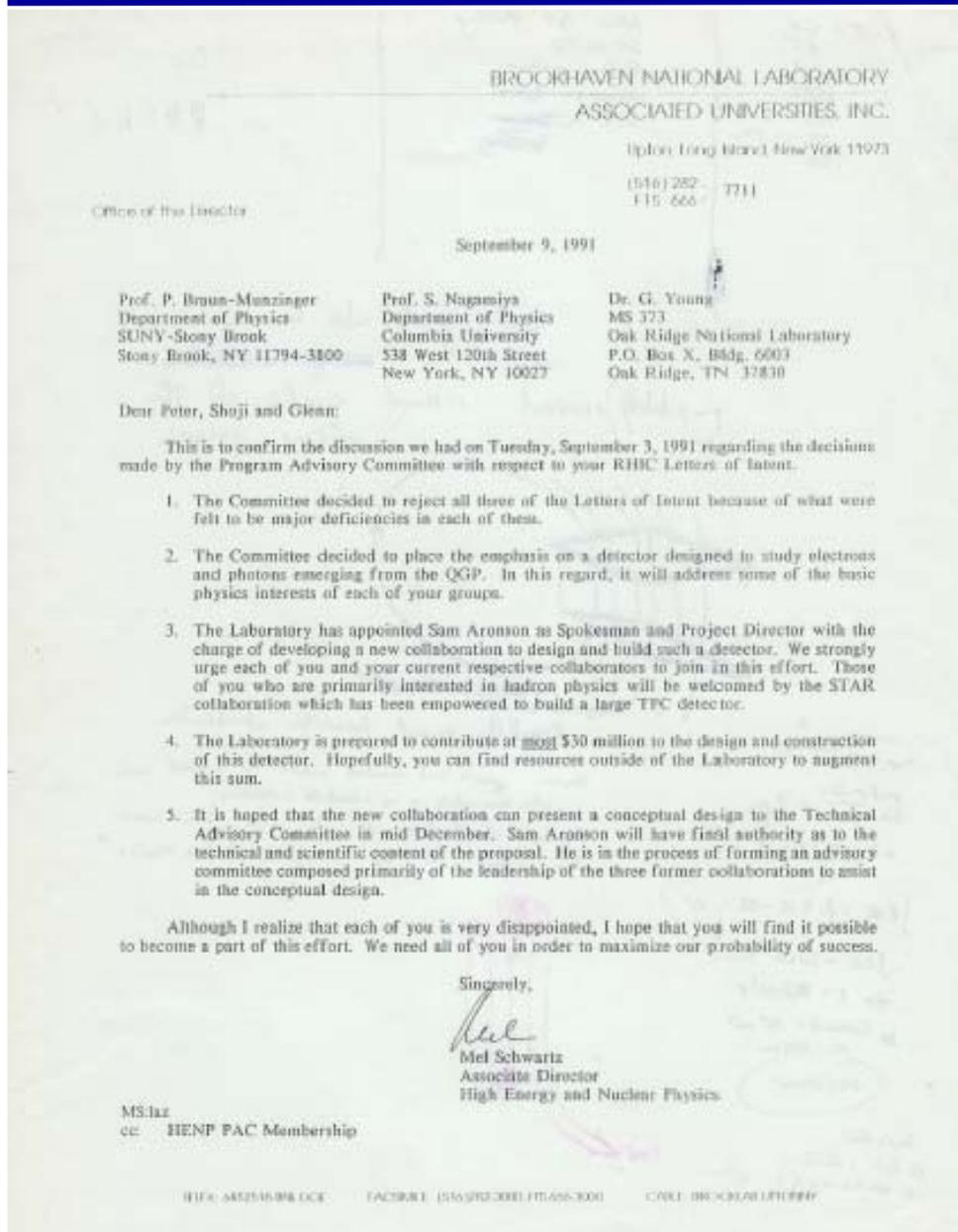
Although I realize that each of you is very disappointed, I hope that you will find it possible to become a part of this effort. We need all of you in order to maximize our probability of success.

Sincerely,  
  
Mel Schwartz  
Associate Director  
High Energy and Nuclear Physics

MS:lax  
cc: HENP PAC Membership

BIFC: 0452516/04 DCE    FACSOLE: (516) 282-3000/PT/ASG-1000    CABLE: BROOKLAB1@PTTBBF





- RIP:

- Dimuon
- TALES/SPARC
- OASIS

- Née

- RE2
- “RHIC Experiment 2”

# 1991 Labor Day Massacre

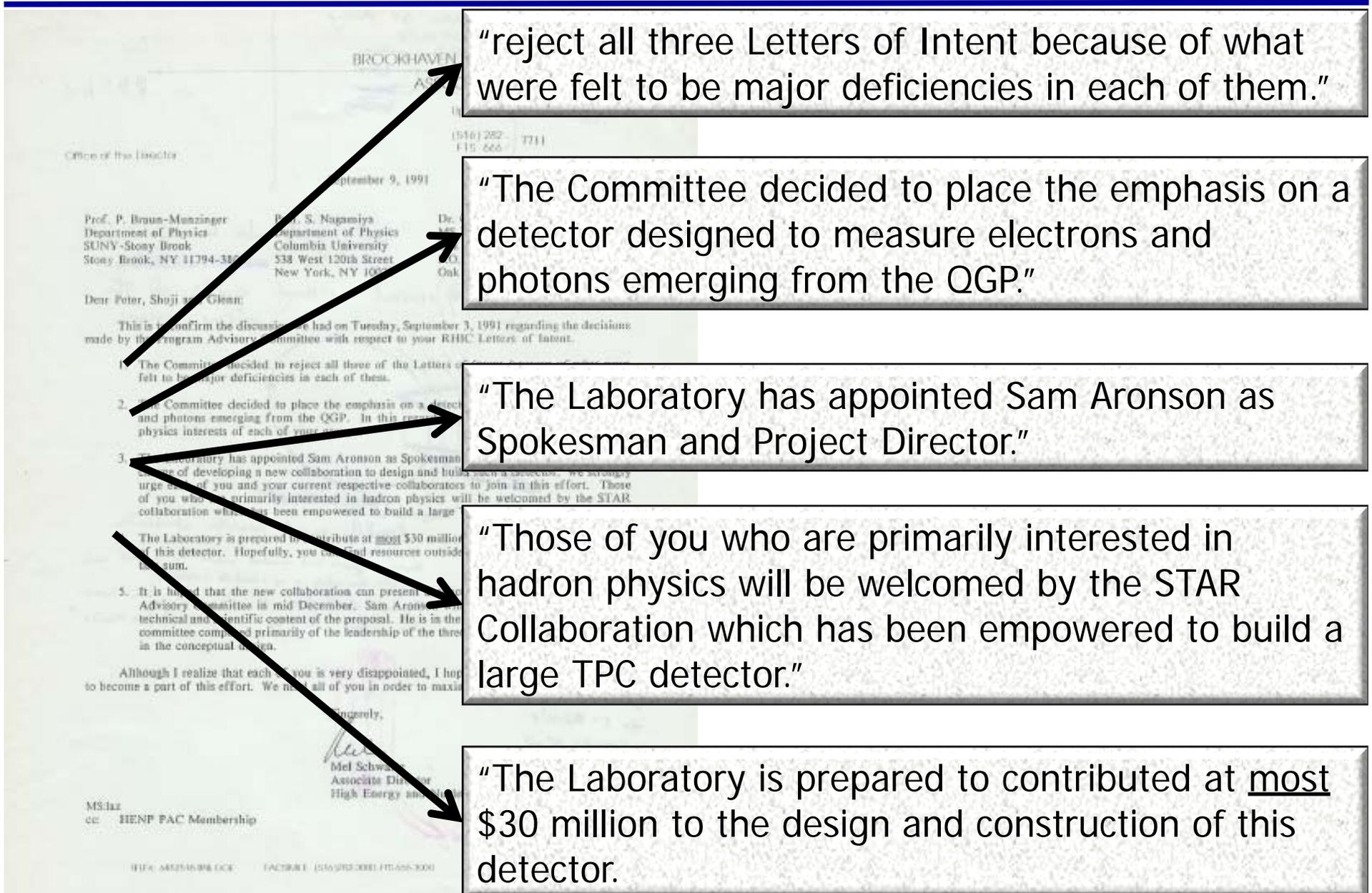
"reject all three Letters of Intent because of what were felt to be major deficiencies in each of them."

"The Committee decided to place the emphasis on a detector designed to measure electrons and photons emerging from the QGP."

"The Laboratory has appointed Sam Aronson as Spokesman and Project Director."

"Those of you who are primarily interested in hadron physics will be welcomed by the STAR Collaboration which has been empowered to build a large TPC detector."

"The Laboratory is prepared to contribute at most \$30 million to the design and construction of this detector."



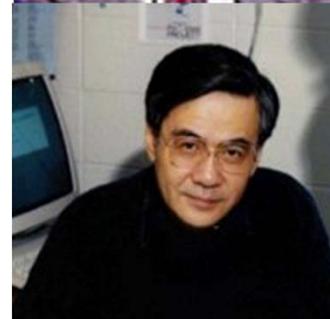


## A Long Interregnum...

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dominated by the struggles you can easily imagine that follow from forced marriage of three major experiments...

most significant event: Profoundly wise decision by Sam Aronson to separate Project Director and spokesperson → *Shoji Nagamiya*





# PHENIX Is Born

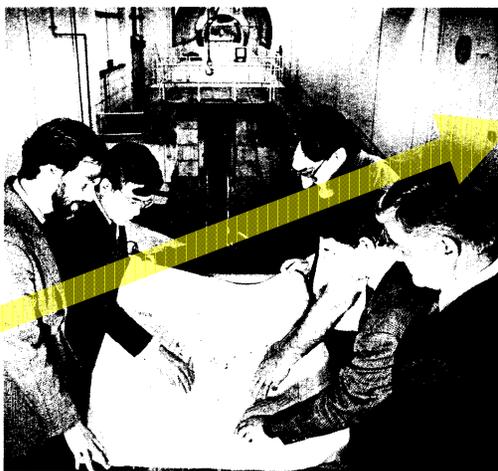
# PHENIX

PHENIX: 10-Mar-94  
(STAR: Jan-93)

## PHENIX Has Risen: Second Major RHIC Experiment Approved

Successful two-day re-  
vised schedule proposed  
for the High Energy  
Ion Experiment, the  
short as PHENIX  
on March 10 as the  
experiment for BNL's  
Ion Collider (RHIC).  
PHENIX will be com-  
pared, which is short for  
cracker at RHIC and  
approved in January 1993.

PHENIX's lead time for  
detectors are expected to  
RHIC physics on the  
turns on in 1999,"  
Ludlam, RHIC Associ-  
ates & Experiments.  
of the physics we  
doing, our detector is  
we now understand  
within budget and on  
Shoji Nagamiya,  
Ludlam and a professor  
Columbia University.  
approval to PHENIX,  
Advisory Committee  
satisfied that all the  
design and management  
were raised last No-  
vember answered," contin-  
ues. "It convenes this com-  
mittee has allowed us to  
physics for our dollar,



estimate to Ludlam's TAC last  
November. At that time, however, the  
committee gave the experimenters five  
more months to reduce the cost of  
their detector by \$4.5 million.

"Instead of turning off any of the  
major subsystems, we tightened every-  
thing, especially the electronics and  
data-acquisition system," comments  
Sam Aronson, PHENIX Project Direc-  
tor, Physics Department. "While we  
won't be able to install as much of the

physics that RHIC  
day one until the re-  
design intensity. It  
is expected, we will  
additional funds to  
components."

While some \$36.7 million is now  
available from RHIC construction  
funds to build PHENIX, the actual cost  
of the detector is approximately \$70  
million. To cover the other half of the  
bill, PHENIX management enlisted

Despite nearly (sic) a year's lead time for  
STAR, both detectors are expected to be  
ready to "do RHIC physics on the day the  
machine turns on in 1999".

up of 12 heads of the detector's major subsystems,  
which is chaired by Aronson and meets every month  
or two. In addition, the entire collaboration gathers  
twice a year to review its progress, with the next  
meeting scheduled for this August at BNL.

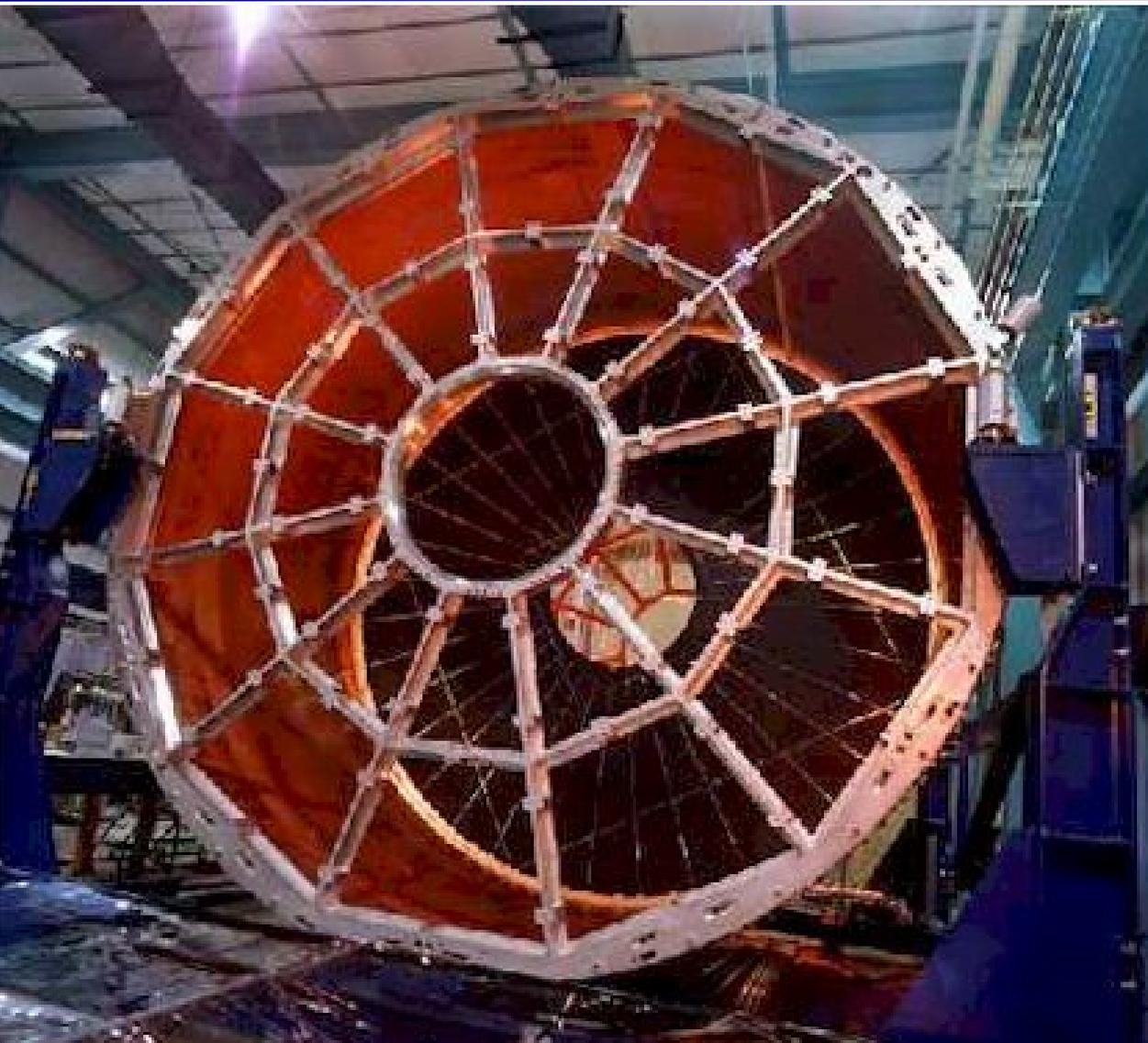
(To reduce costs) "Instead of turning off any  
of the major subsystems, we tightened  
everything, especially the electronics and  
data acquisition system".

**Chemist F. Sherwood  
Rowland, of the University of  
California, Irvine, will give an  
AUI Distinguished Lecture on  
Tuesday, March 29. His talk  
on "The Depletion of Strato-  
spheric Ozone by Chlorofluo-**



# STAR TPC circa 1997

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PHENIX 25-Jun-97





# Doing Triage

1997, Costa Mesa  
Workshop: Abandon all  
reckoning, just measure  
neutral mesons in  
perimeter??

No !

1998: Ames meeting  
Too much experiment  
at the end of the  
tuesday...

## PHENIX Guidance

**"That which does not kill us, makes us stronger."**

**(Friedrich Nietzsche)**

**"A man's got to know his limitations."**



**You can't always get what you want**

**But if you try sometime**

**Yeah, you just might find**

**You get what you need**

**(Jagger/Richard)**



**Well, less is more, Lucrezia...**

**Ah, but a man's reach should exceed his grasp,**

**Or what's a heaven for? ...**



# Doing Triage

1997, Costa Mesa  
Workshop: Abandon all  
checking, just measure  
neutral mesons in  
perimeter??

No !

1998: Ames meeting  
Too much experiment  
at the end of the  
money...

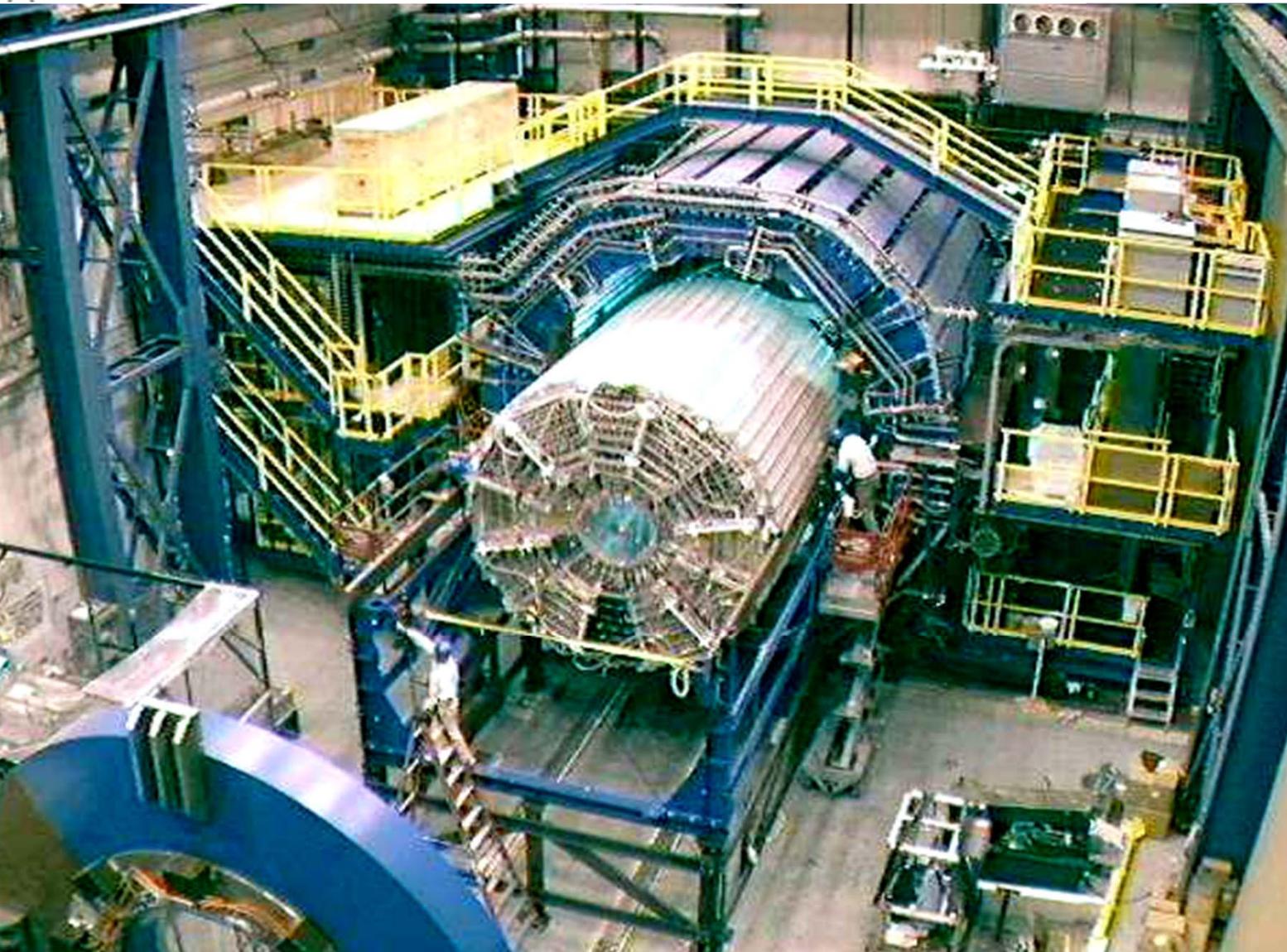


## Real Guidance

- Our reach has exceeded our grasp
- We can count on funds only up to our grasp
- We must have a clear set of principles from which to prioritize:
  - We must have a Year-1 physics capability
  - That physics must be matched to (expected) machine ramp-up
  - That physics should (ideally) be
    - ◆ of maximal impact
    - ◆ unique
  - We must not make decisions now that later cripple completion of PHENIX



# STAR Circa Nov-98





# PHENIX Nov-98

me assembly required ....





## 1999: A Strange Morale Booster

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Several month RHIC schedule delay

(Mechanically unstable vacuum pipe support  
inside cryostat for short corrector magnet...)

-Oct-99: (Public) **“The recently announced  
delay of the RHIC schedule provides us with  
an opportunity to make ready a significant  
portion of the Baseline detector for the very  
start of RHIC operations.”**

(Private): **“should be a call to arms to come  
and help in this last ditch effort to even the**



# First Event 15-Jun-00 !

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## Just a Few Months Later





# Data Debut at QM01



## PHENIX OVERVIEW

W.A. Zajc

Columbia University  
for the PHENIX Collaboration

# PHENIX QM01: 1<sup>st</sup> Jet Quenching Result

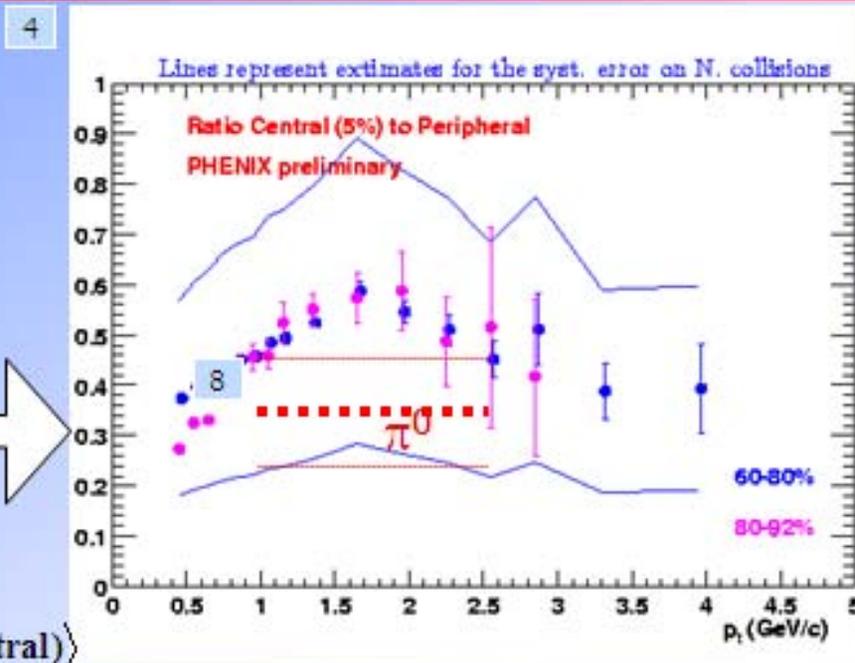
## PHENIX Central vs. Peripheral Yields

- Can study relative yields within the data set:

- Compare central to peripheral spectra vs.  $p_T$
- Scale by the average number of collisions

$$\text{Ratio} = \frac{\text{Yield(Central)} / \langle N_{\text{COLL}}(\text{Central}) \rangle}{\text{Yield(Peripheral)} / \langle N_{\text{COLL}}(\text{Peripheral}) \rangle}$$

- Ratio unity if yields scale as number of collisions
- Ratio found to be less than 1, decreasing for  $p_T > 2$  GeV/c
- Same is observed in  $\pi^0$  analysis (very different systematics)



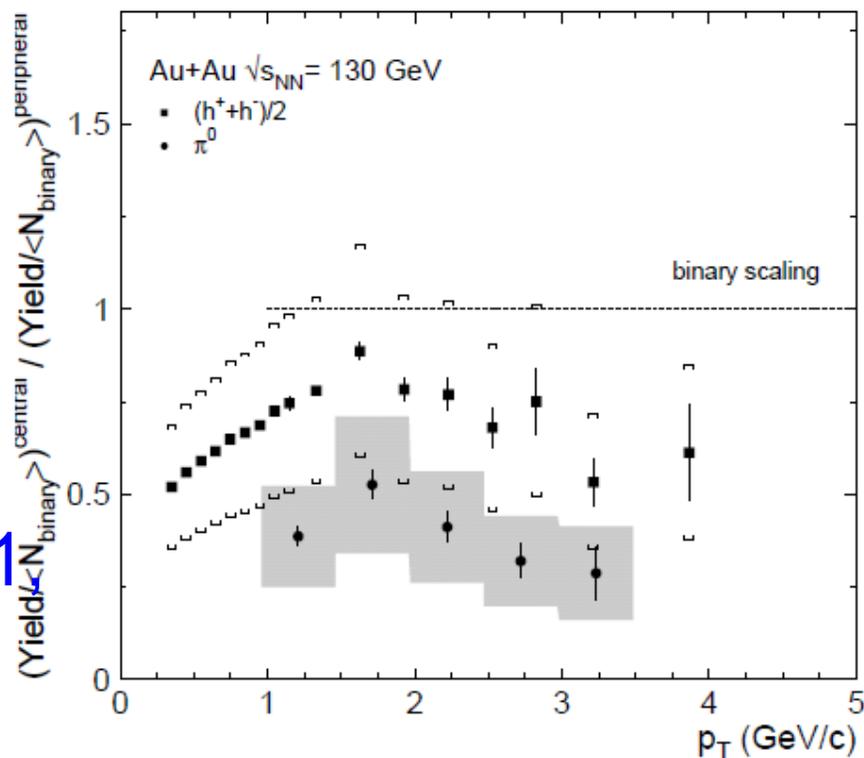


# First Jet Quenching Paper

Suppression of hadrons  
with large transverse  
momentum in central  
Au+Au collisions at  
 $\sqrt{s_{NN}} = 130$  GeV.  
([K. Adcox et al.](#)).

Phys.Rev.Lett.88:022301  
2002.

e-Print: [nucl-ex/0109003](#)



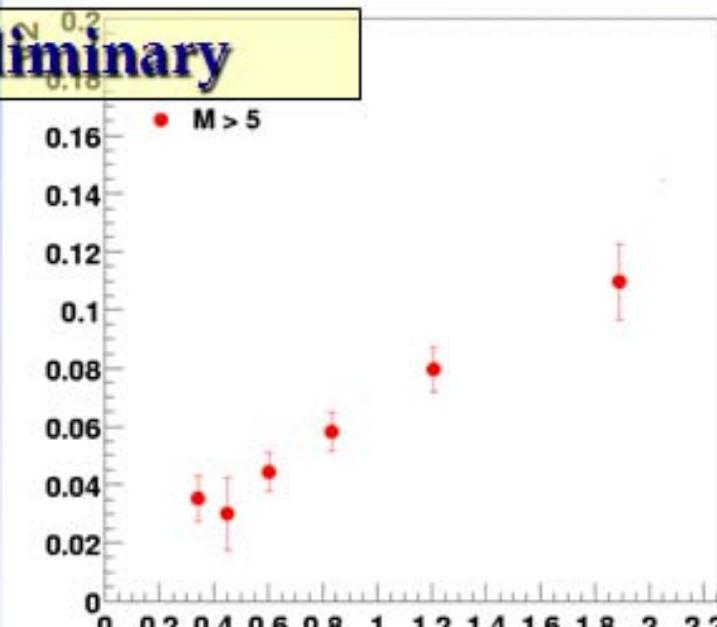
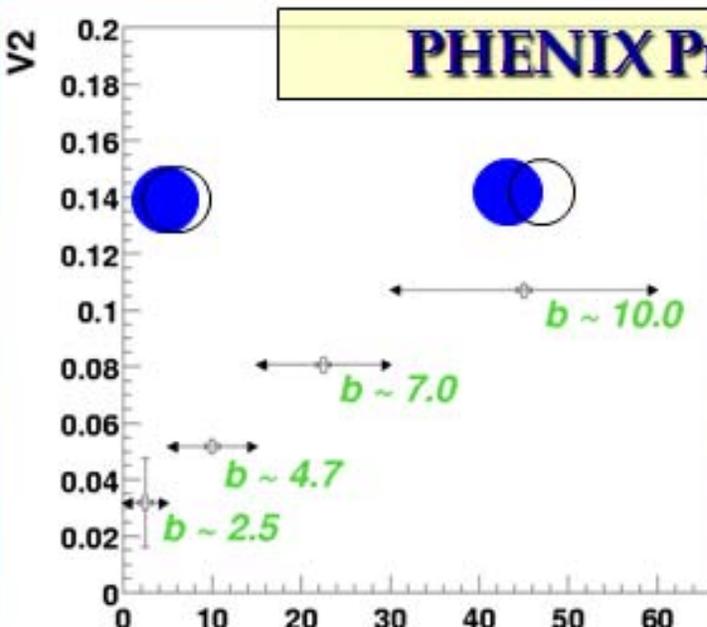
922 citations

## Elliptic Flow

- Extract  $v_2$ 's from  $C(\Delta\phi)$
- Qualitative trends consistent with STAR results

Wednesday, Parallel Session II

R. Lacey: *Elliptic Flow Measurements with the PHENIX Detector System*



## Summary

- PHENIX detector has provided outstanding data in first year of RHIC operations
  - Measured
    - ◆ Charged multiplicity
    - ◆ Transverse energy
    - ◆ Elliptic flow
    - ◆ Identified particle spectra
    - ◆ HBT parameters
    - ◆ High  $p_T$  spectra
    - ◆ Inclusive electron spectrum
    - ◆ (more)
  - Observed
    - ◆ Role of hard scattering
    - ◆ Intriguing systematics in high  $p_T$  particle yield
- *Ideally positioned to dramatically extend*

# ENIX “Hadrons in RE2” 10 year later

Elliptic flow of identified hadrons in Au+Au collisions

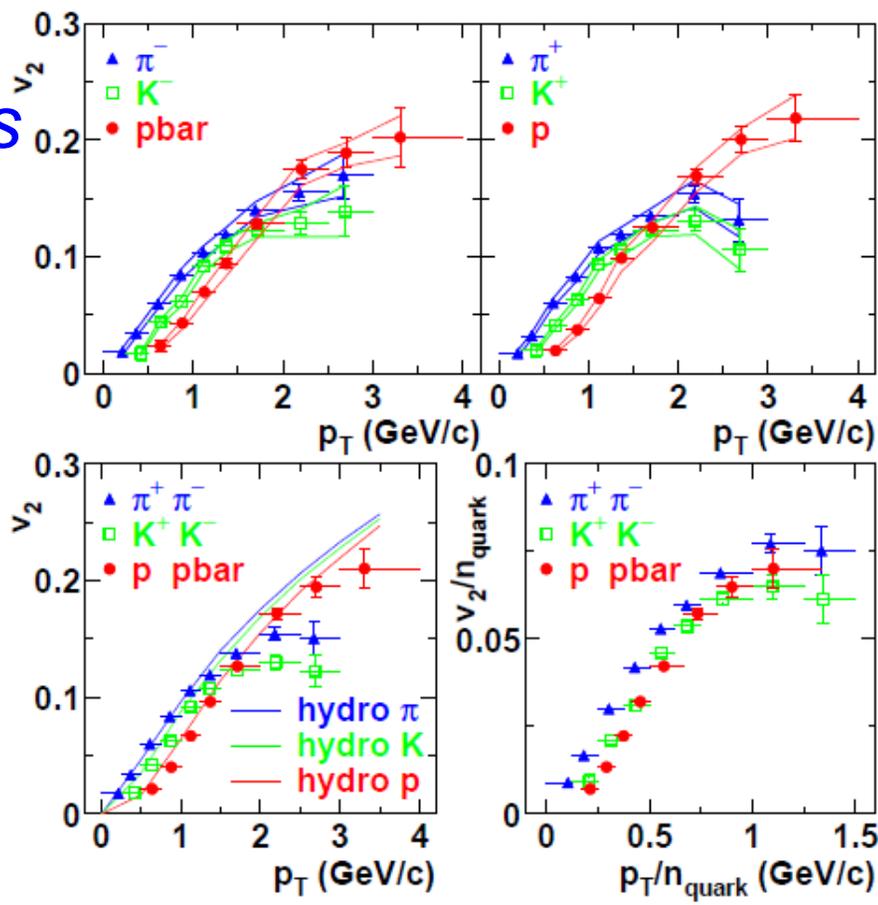
$\sqrt{s_{NN}} = 200 \text{ GeV}$ .

(Stephen Scott Adler et al.).

Phys.Rev.Lett.**91**:182301,2003.

arXiv:hep-ex/0305013

5 citations



“Those of you who are primarily interested in hadron physics will be welcomed by the STAR Collaboration which has been empowered to build a



# RHIC Success

firefox

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http://www.bnl.gov/bnlweb/pubaf/pr/PR\_print.asp?prID=05-38

Lifetime Columbia University ...

Close Window

PHENIX LABORATORY

...sh, (631) 344-8350 or Mona S. Rowe, (631) 344-5056

## Hunting the Quark Gluon Plasma

RESULTS FROM THE FIRST 3 YEARS AT RHIC

ASSESSMENTS BY THE EXPERIMENTAL COLLABORATIONS

April 18, 2005

### Physicists Serve Up "Perfect" Liquid

...er more remarkable than predicted -- raising many new questions

...our detector groups conducting research at the [Relativistic Heavy Ion Collider](#) (RHIC) -- a giant atom...  
...t the U.S. Department of Energy's Brookhaven National Laboratory -- say they've created a new state...  
...r out of the quarks and gluons that are the basic particles of atomic nuclei, but it is a state quite...  
...ore remarkable than had been predicted. In [peer-reviewed papers](#) summarizing the first three years of...  
...cientists say that instead of behaving like a gas of free quarks and gluons, as was expected, the...  
...RHIC's heavy ion collisions appears to be more like a *liquid*.

...ysics research sponsored by the Department of Energy is producing historic...  
...ary of Energy Samuel Bodman, a trained chemical engineer. "The DOE is the...  
...der of basic research in the physical sciences, including nuclear and...  
... With today's announcement we see that investment paying off."



Secretary of Energy  
Samuel Bodman

...finding at RHIC that the new state of matter created in the collisions of gold...  
...iquid than a gas gives us a profound insight into the earliest moments of the...  
...Raymond L. Orbach, Director of the DOE Office of Science.

...t to many following progress at RHIC is the emerging connection between the...  
...calculations using the methods of string theory, an approach that attempts to...  
...properties of the universe using 10 dimensions instead of the usual three...  
...us time.

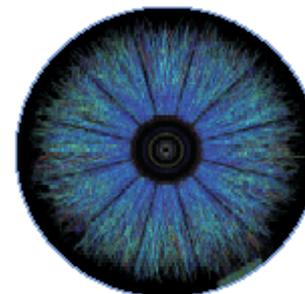
...connection between string theory and RHIC collisions is unexpected and...  
...Orbach said. "String theory seeks to unify the two great intellectual...  
...twentieth-century physics, general relativity and quantum mechanics, and it may...  
...d impact on the physics of the twenty-first century."



...the four RHIC collaborations ([BRAHMS](#), [PHENIX](#), [PHOBOS](#), and [STAR](#)) have been...  
...y a year, will be published simultaneously by the journal *Nuclear Physics A*, and...  
...in a [special Brookhaven report](#), the Lab announced at the April 2005 meeting.



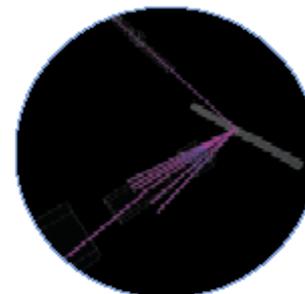
PHOBOS



STAR



PHENIX



BRAHMS



# “White Paper”

Summary of PHENIX  
Results from RHIC  
Years 1-3

126 pages

56 figures

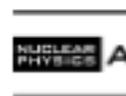
267 references

Part of “First Three  
Years of Experiments  
at RHIC” special  
Volume in Nuclear  
Physics A.

90 citations and  
counting...



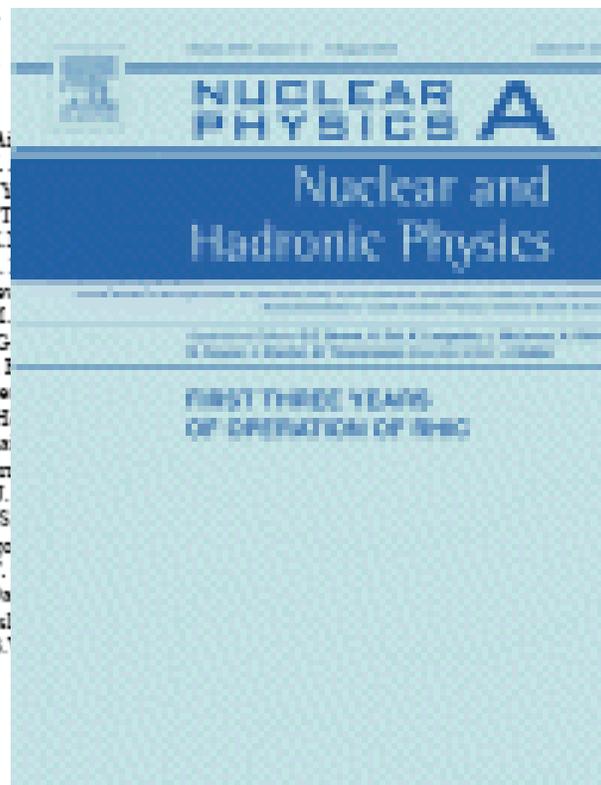
Available online at [www.sciencedirect.com](http://www.sciencedirect.com)  
SCIENCE @ DIRECT®  
Nuclear Physics A 757 (2005) 184–189



Formation of dense partonic matter in relativistic  
nucleus–nucleus collisions at RHIC:  
Experimental evaluation by  
the PHENIX Collaboration

PHENIX Collaboration

K. Adcox<sup>1a</sup>, S.S. Adler<sup>1</sup>, S. Afanasiev<sup>1</sup>, C. A. J. N.N. Ajitanand<sup>2a</sup>, Y. Akiba<sup>3a,b</sup>, A. Al-Jamal<sup>4d</sup>, J. R. Amirkhanov<sup>5</sup>, K. Aoki<sup>6a,b</sup>, L. Aphecetche<sup>7a</sup>, Y. R. Armendariz<sup>8</sup>, S.H. Aronson<sup>9</sup>, R. Averbeck<sup>10</sup>, T. R. Armouni<sup>11a</sup>, V. Babitskiy<sup>12</sup>, A. Baldissari<sup>13</sup>, K. P.D. Barnes<sup>14</sup>, J. Barrette<sup>15</sup>, B. Bassalleck<sup>16</sup>, S. S. Batsooli<sup>17</sup>, V. Baublis<sup>18</sup>, F. Bauer<sup>19</sup>, A. Bazilevsky<sup>20</sup>, S. Belikov<sup>21a</sup>, F.G. Bellaiche<sup>22</sup>, S.T. Belyaev<sup>23</sup>, M. Y. Berdnikov<sup>24</sup>, S. Bhagavatlala<sup>25</sup>, M.T. Bjornedal<sup>26</sup>, J.G. H. Borel<sup>27</sup>, S. Borenstein<sup>28</sup>, S. Botelho<sup>29</sup>, M.L. J. D.S. Brown<sup>30</sup>, N. Bruner<sup>31</sup>, D. Bucher<sup>32</sup>, H. Buehler<sup>33</sup>, V. Bumazhnikov<sup>34</sup>, G. Bunce<sup>35</sup>, J.M. Burward-Hens<sup>36</sup>, S. Butryk<sup>37a</sup>, X. Casmard<sup>38</sup>, T.A. Carey<sup>39</sup>, J.-S. Chen<sup>40</sup>, J. Chang<sup>41</sup>, W.C. Chang<sup>42</sup>, L.L. Chavez<sup>43</sup>, S. Chen<sup>44</sup>, C.Y. Chi<sup>45</sup>, J. Chiba<sup>46</sup>, M. Chin<sup>47</sup>, J.J. Choi<sup>48</sup>, J. R.K. Choudhury<sup>49</sup>, T. Christ<sup>50</sup>, T. Chujo<sup>51a,b</sup>, M.S. P. Chung<sup>52</sup>, V. Cianciolo<sup>53</sup>, C.R. Cleverson<sup>54</sup>, Y. Cobice<sup>55</sup>, M.P. Comets<sup>56</sup>, P. Constantin<sup>57</sup>, M. Csanad<sup>58</sup>, T. J.P. Cussoneaux<sup>59</sup>, D. d’Enterria<sup>60</sup>, T. Dahms<sup>61</sup>, K. De Groot<sup>62</sup>, F. Deak<sup>63</sup>, H. Delagrèze<sup>64</sup>, A. Denisov<sup>65</sup>, A. Deschamps<sup>66</sup>, E.J. Desmond<sup>67</sup>, A. Derives<sup>68</sup>, O. Dietzsch<sup>69</sup>, B.





# A Nice Surprise

The screenshot shows a web browser window with the address bar containing the URL `blog.inspirebeta.net/2011/06/topcited-hep-paper-of-all-time.html`. The browser's toolbar includes various icons for navigation and utility. The page content features the INSPIRE logo at the top, followed by the text "News and updates from INSPIRE - the information management system for High Energy Physics". The main article is dated "WEDNESDAY, JULY 13, 2011" and titled "The topcited HEP paper of all time." The article text discusses the history of topcited papers in HEP, mentioning Weinberg's "A model of leptons" and Maldacena's work on superconformal field theories and supergravity. A blue circle highlights the phrase "heavy ion results from Brookhaven" in the text. The article is posted by Heath O'Connell at 12:50 AM and has 2 people +1'd it. On the right side, there are sections for "ABOUT INSPIRE" and "BLOG ARCHIVE". The "ABOUT INSPIRE" section provides information about the service and its partners (CERN, DESY, Fermilab, and SLAC). The "BLOG ARCHIVE" section lists the number of posts for each month from July to November 2011.

blog.inspirebeta.net/2011/06/topcited-hep-paper-of-all-time.html

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# INSPIRE

News and updates from INSPIRE - the information management system for High Energy Physics

WEDNESDAY, JULY 13, 2011

## The topcited HEP paper of all time.

For as long as the annual [topcited papers](#) lists have been around, the all-time champion has been Weinberg's "A model of leptons", the 1967 paper that laid the foundation stone for the Standard Model. 30 years later, in November of 1997, the paper [The Large N limit of superconformal field theories and supergravity](#) by Maldacena appeared that established a connection between string theory and quantum field theory. It immediately set of a revolution in HEP and was the most highly cited paper ever since. Remarkably, its [highest citation count](#) was in 2010, where it received over 1,000 citations in a single year! One reason for this is [the heavy ion results from Brookhaven](#) that drew people to conclude that, based on Maldacena's work, the quark-gluon plasma can be modeled using string theory techniques.

Posted by Heath O'Connell at 12:50 AM

M t f +1 2 people +1'd this

0 comments:

#### ABOUT INSPIRE

INSPIRE is the place for HEP information. It is run by CERN, DESY, Fermilab, and SLAC. For more information: [www.projecthepinpire.net](http://www.projecthepinpire.net)

This blog will contain occasional updates about the service and information about our future plans. For rapid service notifications, follow [INSPIREhep on twitter](#).

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  - ▶ November (1)
  - ▶ October (2)
  - ▶ September (1)
  - ▶ August (1)
  - ▼ July (3)



# A Nice Surprise

inspirehep.net/record/731668?ln=en

LexisNexis A More Particle phys Phenix link SPIRES-HEP F Services Suggested Sites Web Slice Gallery [hep-ph 04124] columbia ~zaj Other bookmarks

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References (40) Citations (325) Files Plots

## Energy Loss and Flow of Heavy Quarks in Au+Au Collisions at $\sqrt{s_{NN}} = 200$ -GeV.

PHENIX Collaboration (A. Adare (Colorado U.) *et al.*) [Show all 421 authors.](#)

Nov 2006  
6 pp.

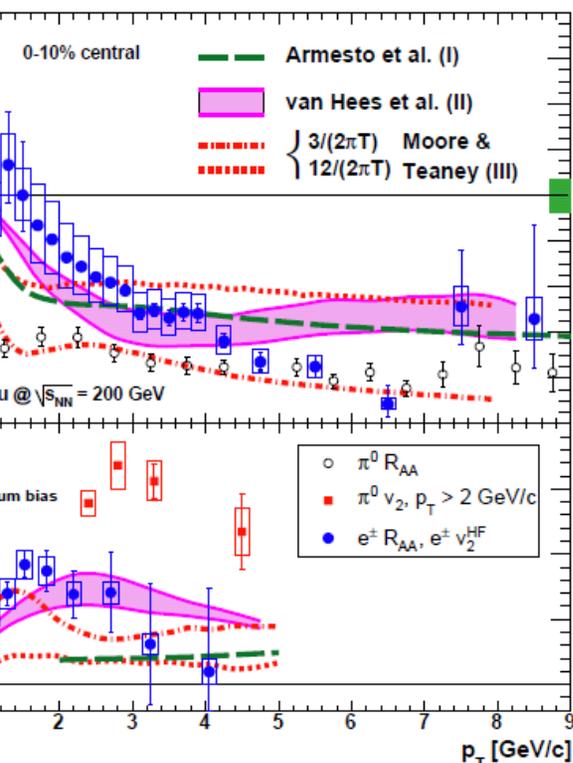
**Phys.Rev.Lett. 98 (2007) 172301**  
e-Print: [nucl-ex/0611018](#)

**Abstract:** The PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) has measured electrons from heavy flavor (charm and bottom) decays for  $0.3 < p_T < 9$  GeV/c at midrapidity ( $|\eta| < 0.35$ ) in Au+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV. The nuclear modification factor  $R_{AA}$  relative to p+p collisions shows a strong suppression in central Au+Au collisions, indicating substantial energy loss of heavy quarks in the medium produced at RHIC. A large azimuthal anisotropy,  $v_2$ , with respect to the reaction plane is observed for  $0.5 < p_T < 5$  GeV/c indicating non-zero heavy flavor elliptic flow. Both  $R_{AA}$  and  $v_2$  show a  $p_T$  dependence different from those of neutral pions. A comparison to transport models which simultaneously describe  $R_{AA}(p_T)$  and  $v_2(p_T)$  suggests that the viscosity to entropy density ratio is close to the conjectured quantum lower bound, i.e., near a perfect fluid.

**Keyword(s):** INSPIRE: [nucleus nucleus: colliding beams](#) | [scattering: heavy ion](#) | [gold](#) | [charm](#) | [bottom](#) | [quark: hadroproduction](#) | [quark: decay](#) | [electron: yield](#) | [elliptic flow](#) | [multiple scattering](#) | [quark: energy loss](#) | [nuclear matter: effect](#) | [viscosity](#) | [entropy](#) | [model: fluid](#) | PHENIX | [experimental results](#) | [Brookhaven RHIC Coll](#) | [200 GeV-cms/nucleon](#)

created 2006-11-13, last modified 2011-07-26 [Similar records](#)

# The Real Surprise



- Heavy quark

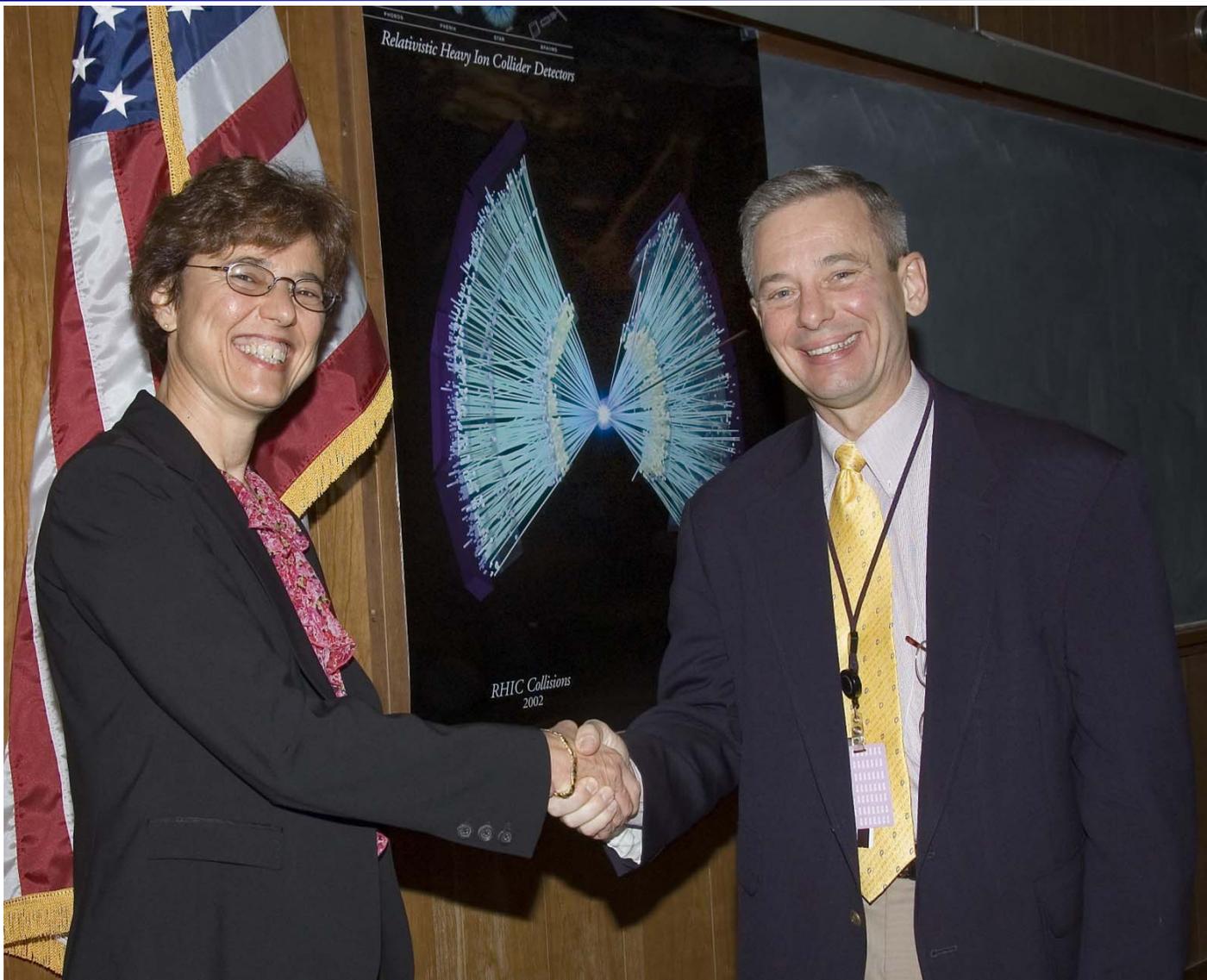
- Energy loss

- Flow

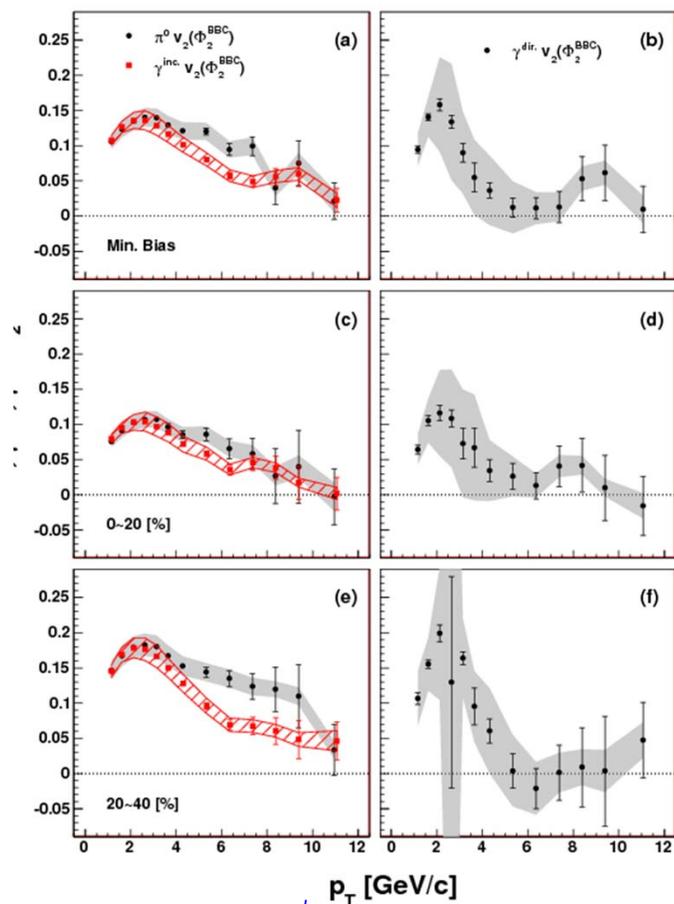
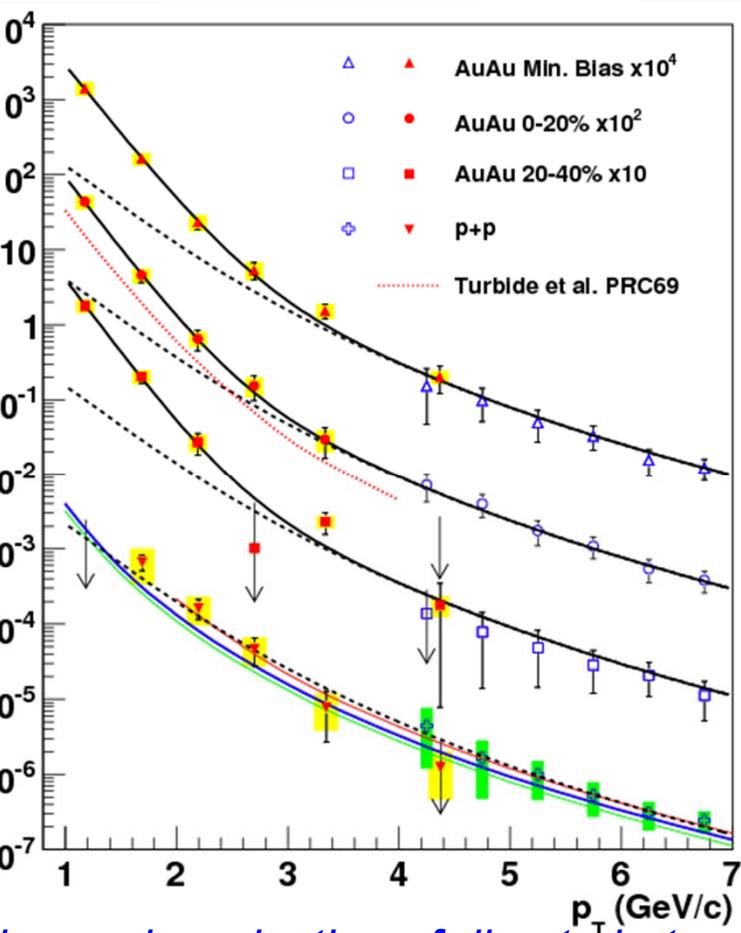
along with

quark's diffusion coefficient  $D$ . Using the observation [32] that  $D \approx 6 \times \eta / (\epsilon + p)$  with  $\epsilon + p = Ts$  at  $\mu_B = 0$  provides an estimate for the viscosity to entropy ratio  $\eta/s \approx (2 - 2)/4\pi$ , intriguingly close to the conjectured quantum

# Era III



# Direct Photons (and Flow!)



Enhanced production of direct photons in Au+Au collisions at  $\sqrt{s_{NN}}=200$  GeV and implications for the initial temperature, A. Adare et al., Phys.Rev.Lett. 104,132301, [arXiv:0804.4168](https://arxiv.org/abs/0804.4168)

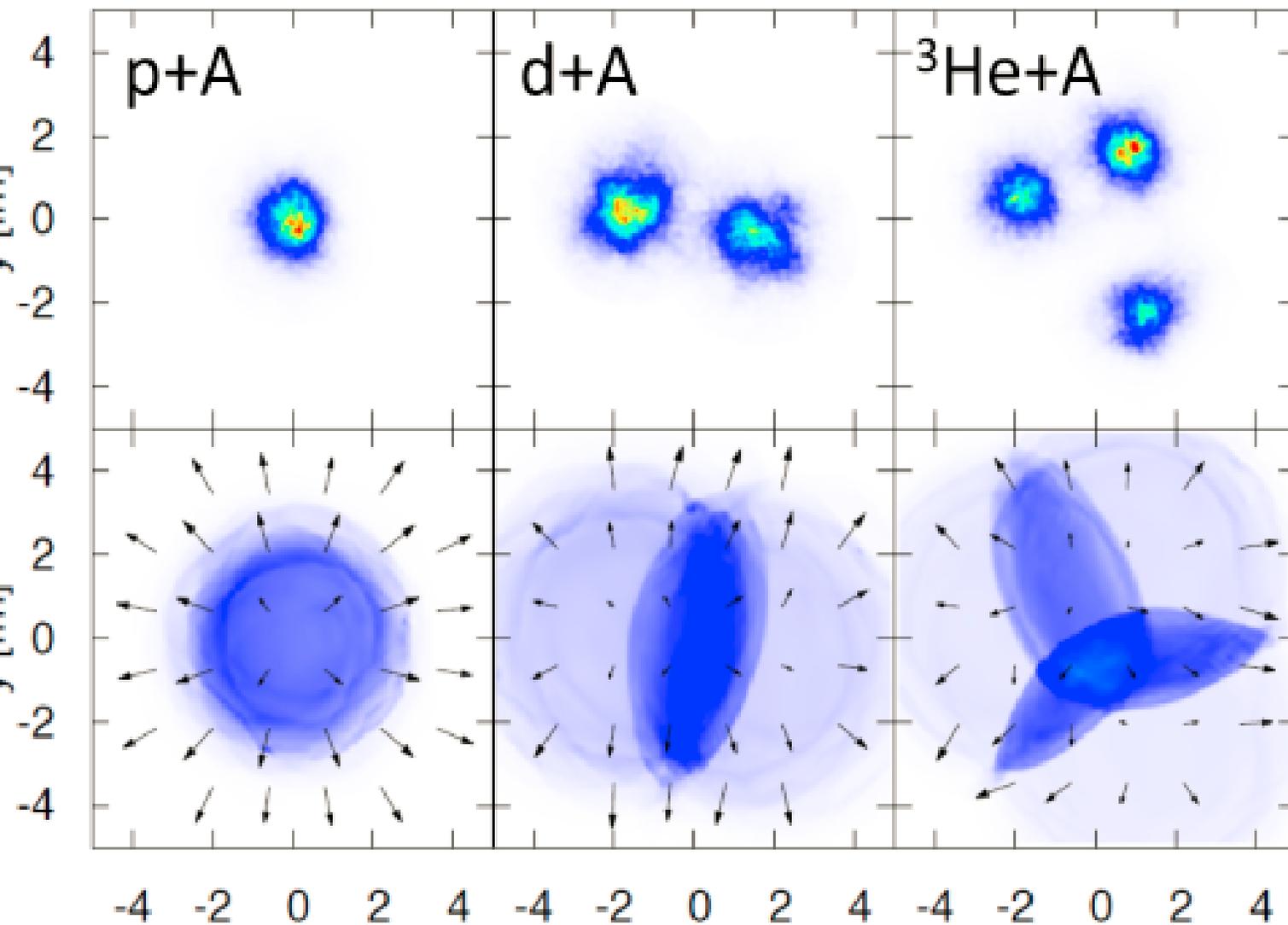
Observation of direct-photon collective flow in  $\sqrt{s_{NN}}=200$  GeV Au+Au collisions



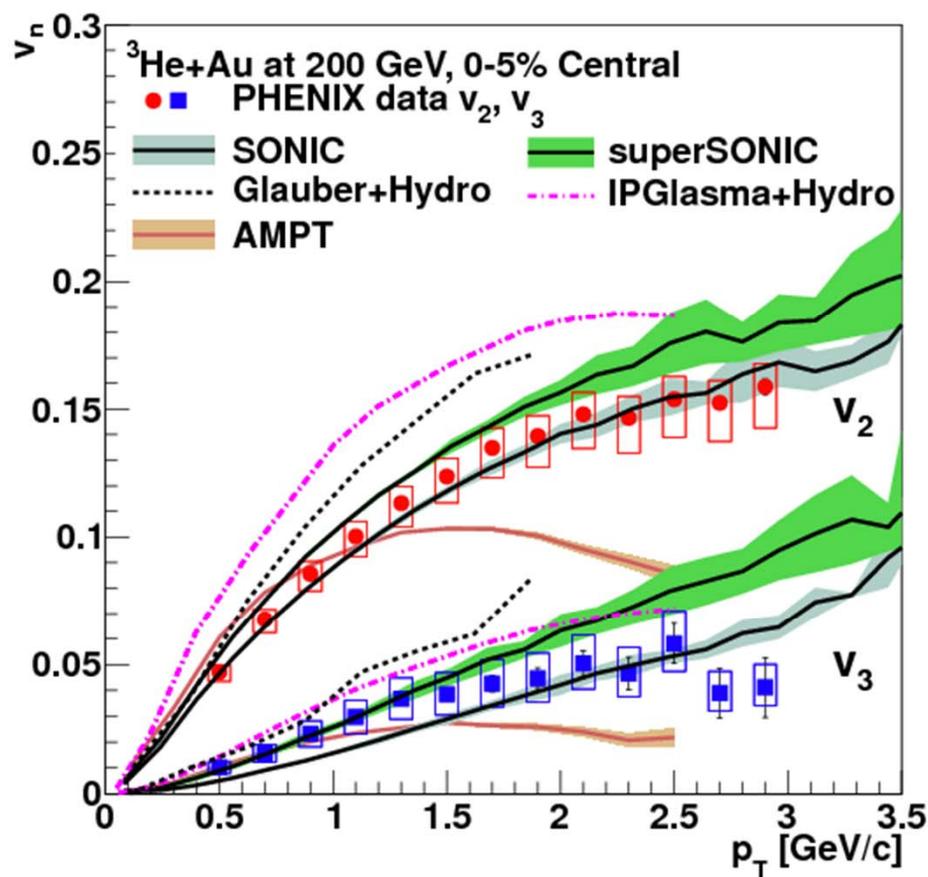
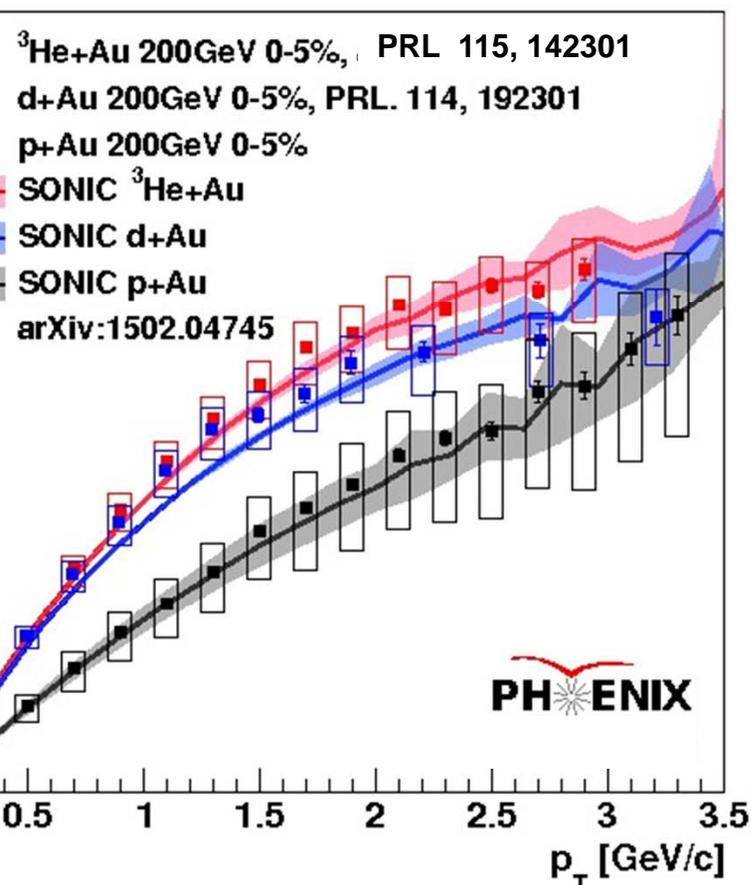
## Era IV



# Systematic Investigation of Flow in Small Systems



# Systematic Investigation of Flow in Small Systems

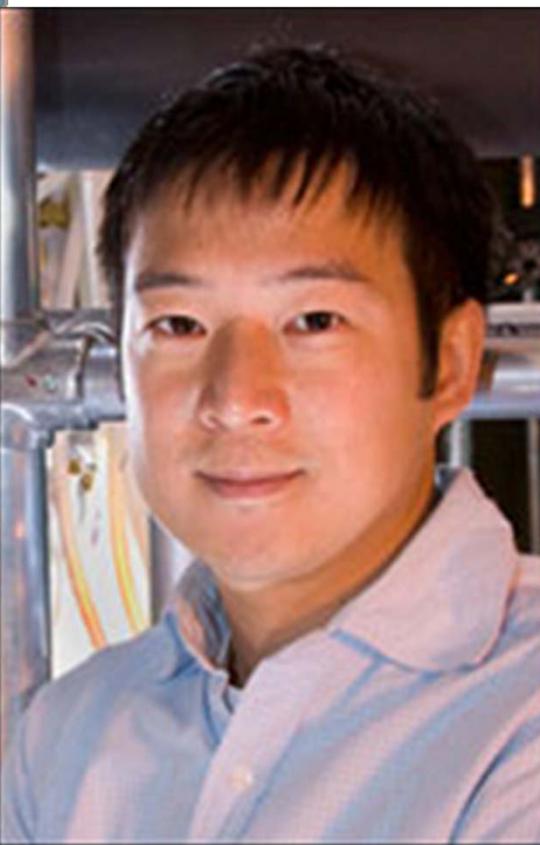
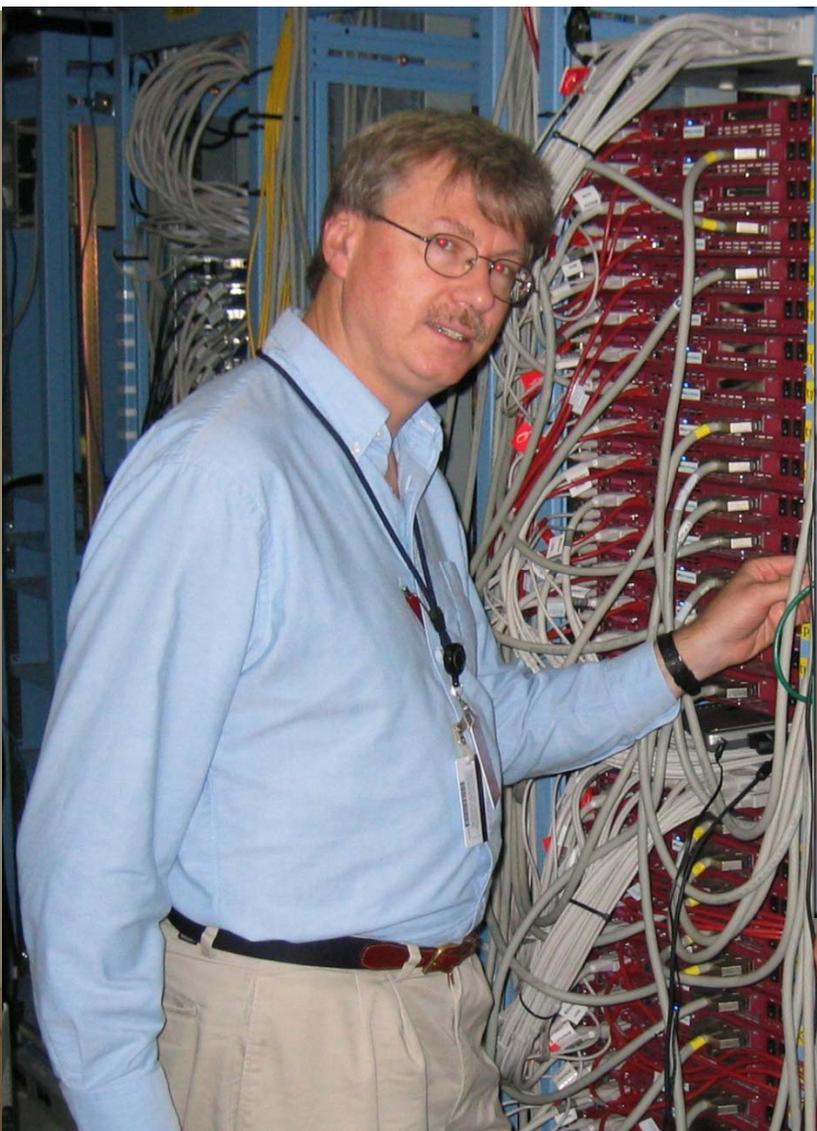


Measurement of long-range angular correlation and quadrupole anisotropy of pions (anti)protons in central  $d+\text{Au}$  collisions  $\sqrt{s_{NN}}=200$  GeV, A. Adare et al., Phys.Rev.Lett. 114,192301, [arXiv:1404.7461](https://arxiv.org/abs/1404.7461)

Measurements of elliptic and triangular flow in high-multiplicity  $^3\text{He}+\text{Au}$  collisions at



# Secrets to Success





# Eras I through IV

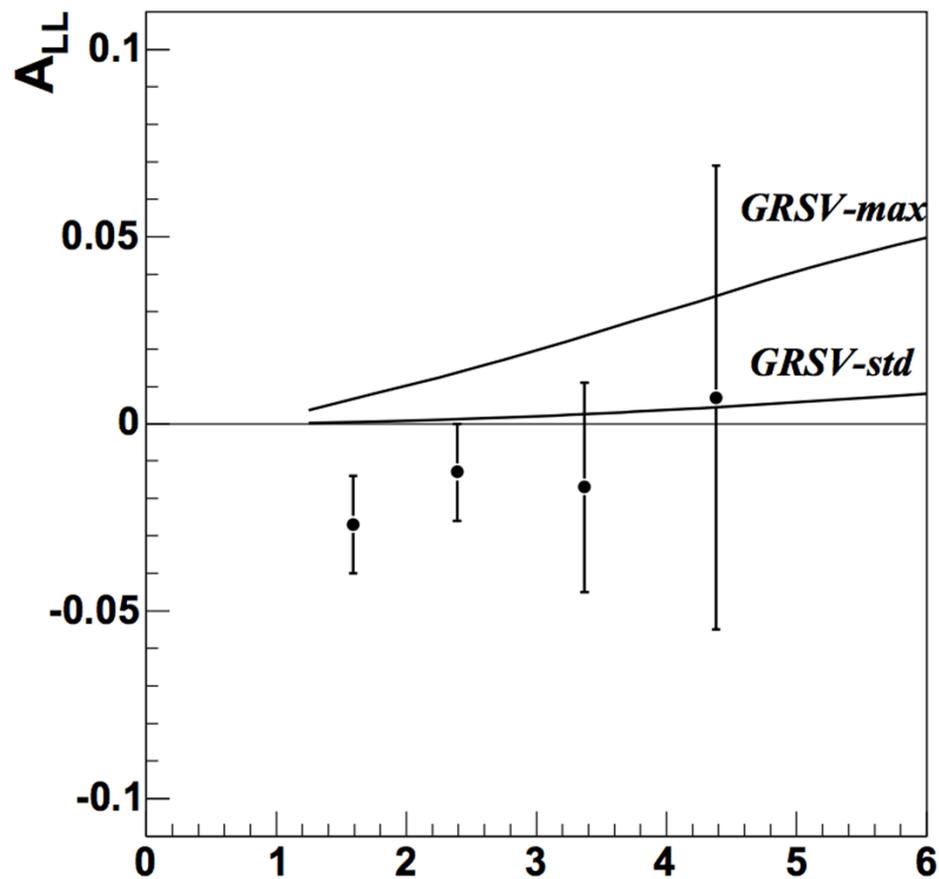


# Era V



# ENIX Integral Spin Program

Double helicity asymmetry in inclusive mid-rapidity  $\pi^0$   
production for polarized p+p collisions at  $\sqrt{s} = 200$  GeV,  
J. Adler *et al.*, Phys.Rev.Lett. **93** (2004) 202002,  
[hep-ex/0404027](https://arxiv.org/abs/hep-ex/0404027)



# ENIX Integral Spin Program+12y

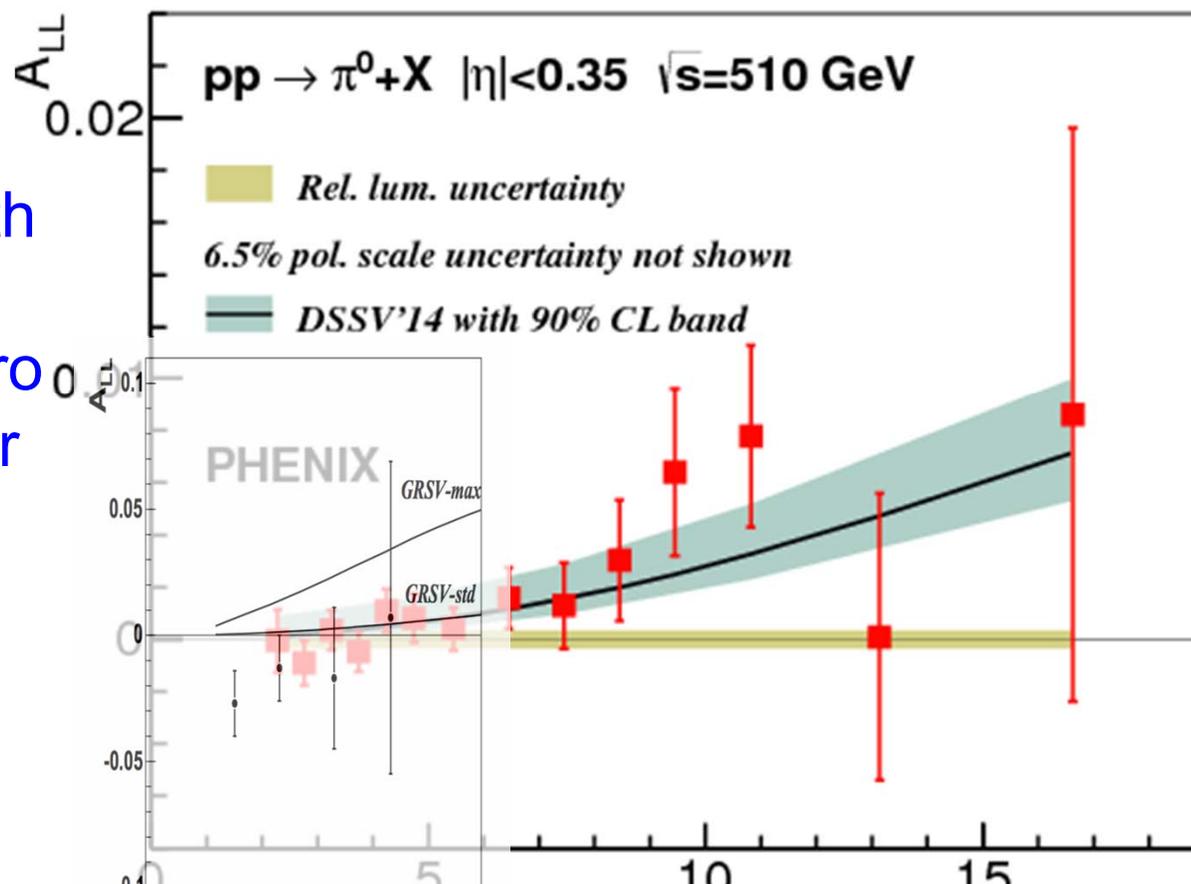
Inclusive cross section and double-helicity asymmetry for  $\pi^0$  production at mid-rapidity in p+p collisions at  $\sqrt{s} = 510$  GeV

V. A. Adare *et al.*, Phys.Rev. **D93** (2016) 011501,

[arXiv:1510.02317](https://arxiv.org/abs/1510.02317)

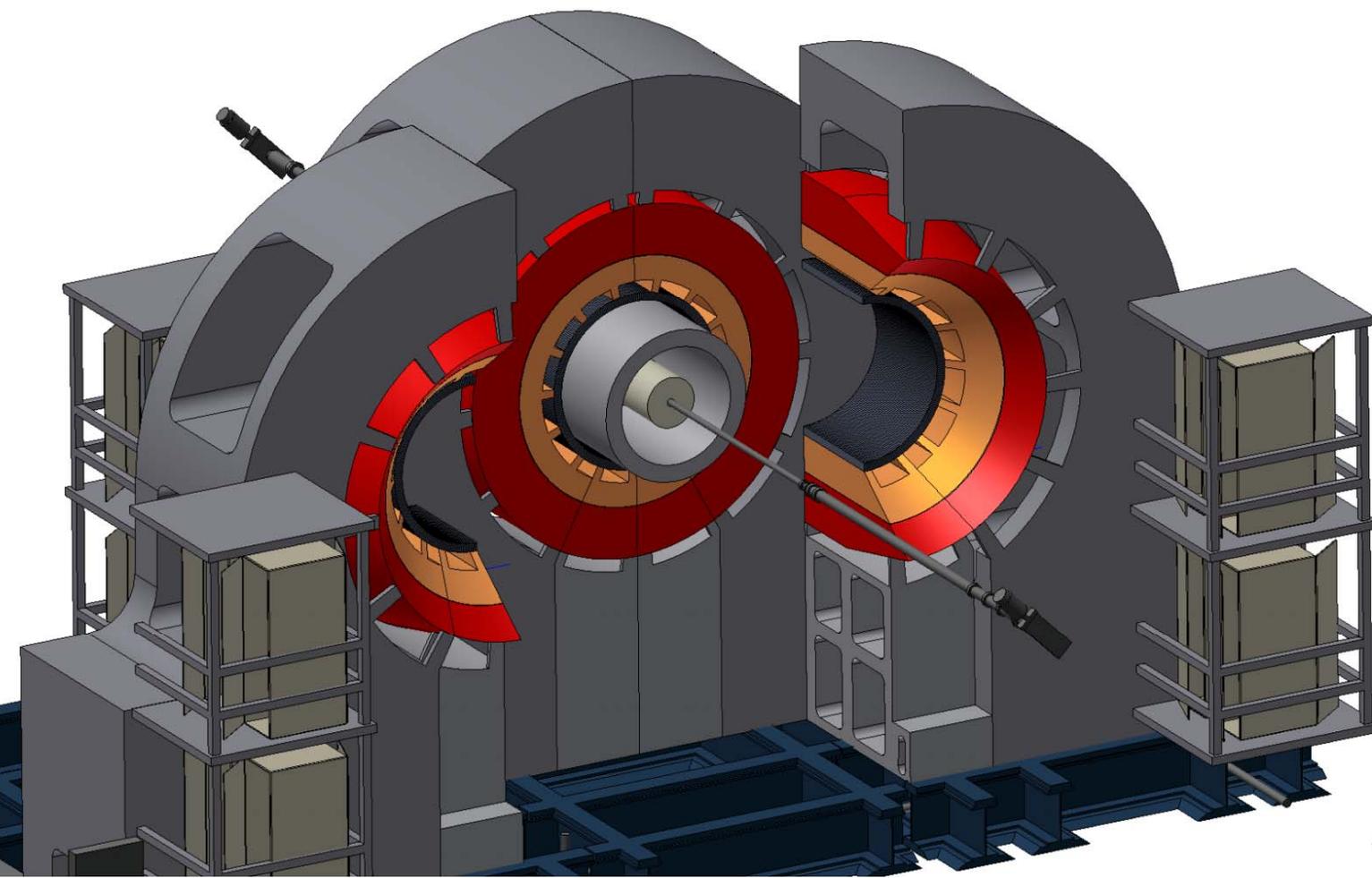
Good agreement with pQCD fits

Incorporating nonzero polarization for  $A_{LL} > 0.05$





# The Next Generation



See sPHENIX talk by Megan Connors this



# Secrets to Success





# Special Thanks to

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# Special Special Thanks to

75 articles

2,500 citations

