

# BNL RHIC Experimental Program

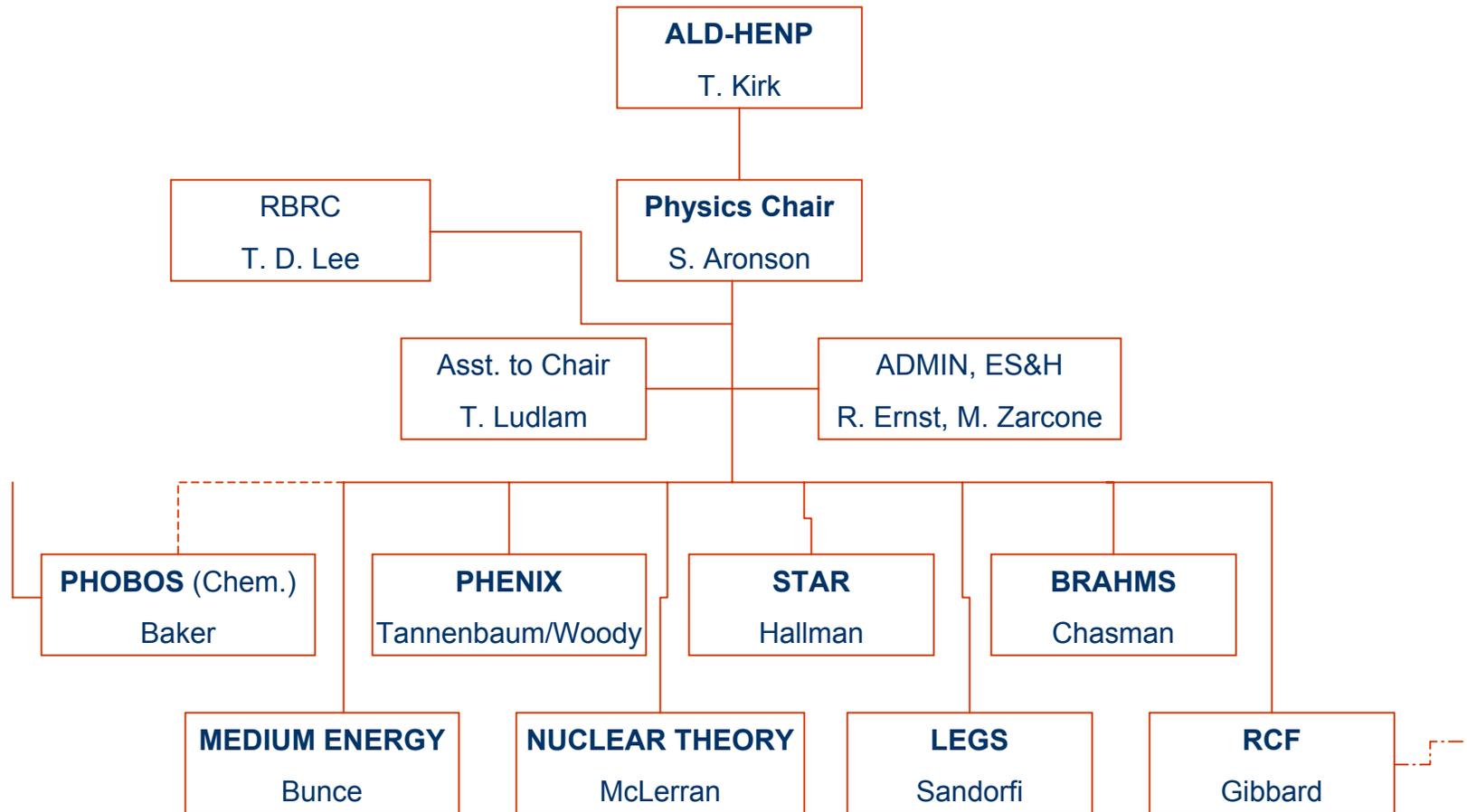
- Physics Department role in the research program
- Groups' demographics, physics output, operations roles, plans
- Impact of the President's FY'04 budget
- Future: R&D, Detector Upgrades

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BNL Physics Dept.  
July 9, 2003

# BNL RHIC Research: Executive Summary

- **Run 3:** The experimental groups in Physics and Chemistry have rapidly extracted new and important RHI results and made great strides in learning how to do collider spin physics
- The FY'04Pres budget will support less **experimental operations** than in FY'03 plus limited detector upgrade R&D
- **Experimental research** funding was flat-flat in FY'03 and is up 4% in FY'04Pres; we are not keeping up with the cost of supporting a constant level of effort on the experimental side
- Scientific staff reductions in **research** have occurred in FY'03 and will continue under FY'04Pres
- We need funding at the FY'04Rev level to fully exploit the scientific opportunities at RHIC

# Nuclear Physics Organization



# Physics head counts, NP FTEs

(as of March '03)	NP*	HEP	CM	Dept	Total
Staff Scientist	55	43	21	4	123
Post-Docs & Fellows	24	10	13		55
Engineer & Professional	33	25	2	1	61
Designer & Technician	14	13	4	1	32
Asministrator & Clerical	11	9	2	15	40
<b>Staff Total</b>	<b>137</b>	<b>100</b>	<b>42</b>	<b>21</b>	<b>311</b>
Approx. DOE budgets (\$M)	36	21	9		66
* NP includes RBRC					

NP Staffing levels from '03 → '04  
~flat, except

- Research: -3.5 (PhD term)
- Operations: +2. (PhD)

NP- supported FTEs	FY 2003	Pres FY 2004
<b>Staff Levels (FTEs) RESEARCH</b>		
PhD Permanent	24.4	24.1
PhD Temporary	25.5	22.3
Professional	4.2	4.06
Tech/Admin	7.58	7.57
Graduate Students		
<b>Sub Total</b>	<b>61.68</b>	<b>58.03</b>
<b>Staff Levels (FTEs) OPERATIONS</b>		
PhD Permanent	12.1	13.9
PhD Temporary	12.4	13
Professional	32.44	32.27
Tech/Admin	16.13	15.97
Graduate Students		
<b>Sub Total</b>	<b>73.07</b>	<b>75.14</b>
<b>Staff Levels (FTEs) TOTAL</b>		
PhD Permanent	36.5	38
PhD Temporary	37.9	35.3
Professional	36.64	36.33
Tech/Admin	23.71	23.54
Graduate Students	0	0
<b>Total</b>	<b>134.75</b>	<b>133.17</b>

# BNL RHIC physics group roles

- The model for BNL groups
  - Physicists should split their time  $\approx 50/50$  between Operations and Research
    - Research is predominantly on the RHIC experiments but there are minor exceptions
      - Role in Heavy Ion physics at CERN (in ATLAS) and connection with HEP groups remains to be defined
      - RHIC Research at present is predominantly physics analysis but R&D for detector upgrades has started and must increase (discussed in Tom Ludlam's talk tomorrow)
  - In the big experiments physicists' support is similarly split between Research and Operations budgets

# PHENIX

- 16 staff scientists
  - Group leaders: Mike Tannenbaum & Craig Woody
  - 12 permanent, 4 term
    - Will go down 1 in FY04 by attrition
  - 2+1 post-docs
    - Will go down 1 in FY04 by attrition
  - 20 prof/tech/admin staff
- Research interests and activities
  - High  $p_T$ ,  $E_T$ ,  $\pi^0$ s,  $\gamma$ s and  $e^\pm$
  - Identified hadron spectra and ratios
  - Fluctuations

# PHENIX Research

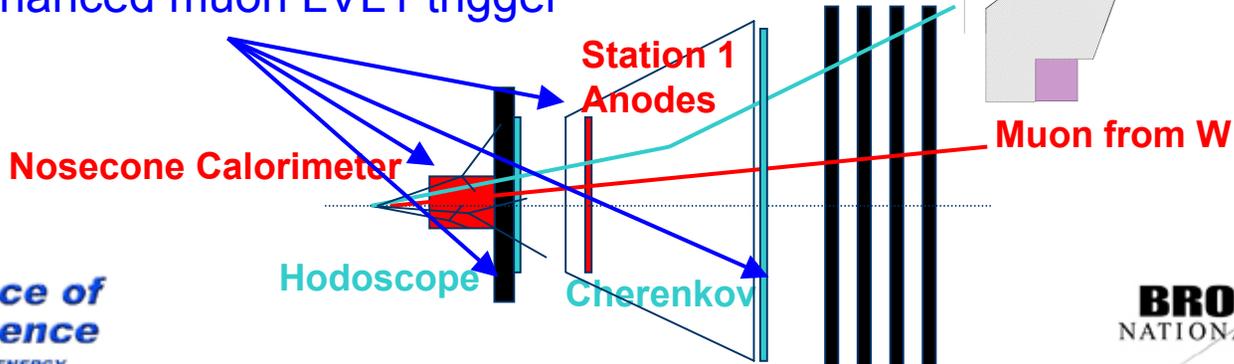
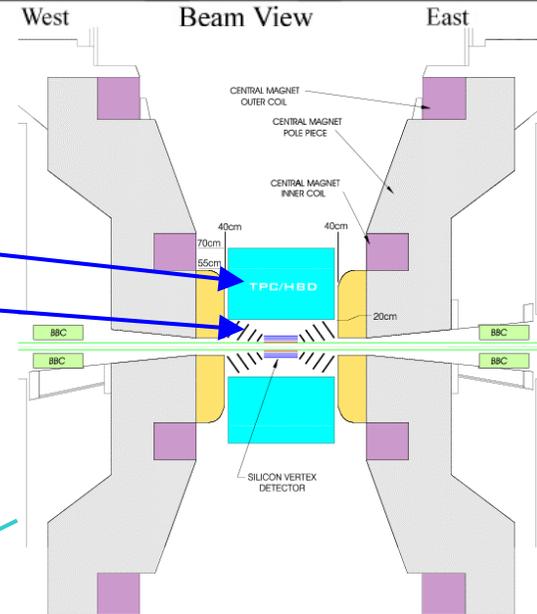
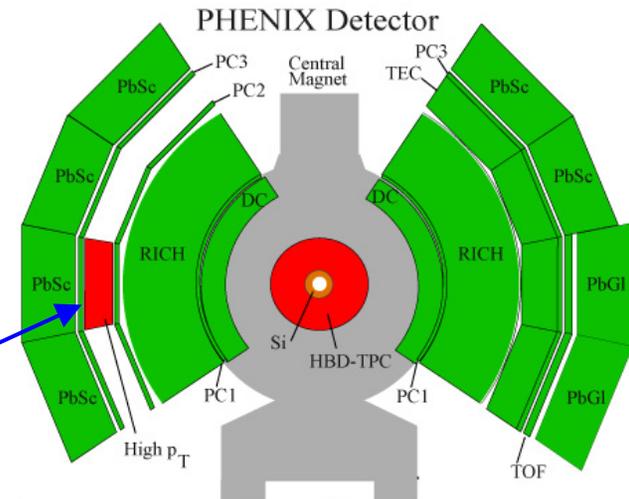
- 3 group members are currently physics working group conveners
- Recent PHENIX publications with significant BNL group roles:
  - Suppressed  $\pi^0$  Production at Large  $p_T$  in Central Au-Au Collisions at  $\sqrt{s_{NN}}=200$  GeV", submitted to PRL, Preprint nucl-ex/0304022
  - Midrapidity  $\pi^0$  Production in p-p Collisions at  $\sqrt{s_{NN}} = 200$  GeV, submitted to PRL, Preprint hep-ex/0304038
  - Scaling properties of p and pbar production in  $\sqrt{s_{NN}} = 200$  GeV Au-Au collisions" submitted to PRL, Preprint nucl-ex/0305036
  - Absence of Suppression in Particle Production at Large  $p_T$  in  $\sqrt{s_{NN}} = 200$  GeV d-Au Collisions, submitted to PRL, Preprint nucl-ex/0306021
  - $J/\psi$  Production in Au-Au Collisions at  $\sqrt{s_{NN}} = 200$  GeV at RHIC, submitted to PRC, Preprint nucl-ex/0305030.

# PHENIX R&D

The PHENIX Upgrade program implements a set of new subsystems that extend and enhance our physics reach.

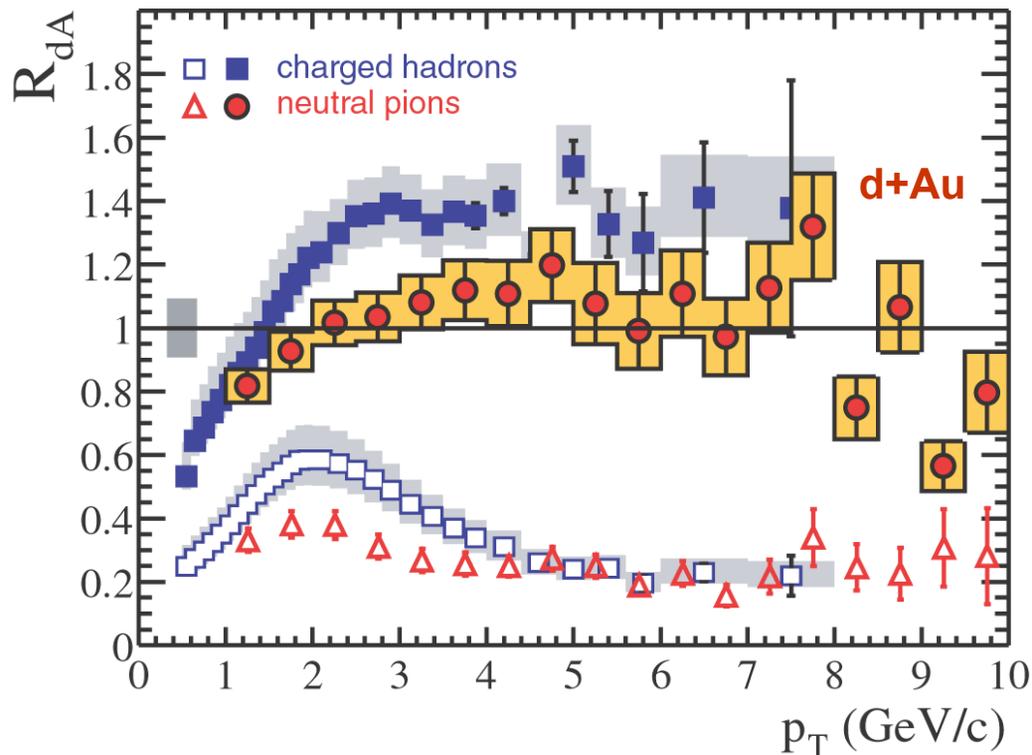
**R&D must come first!**

- High  $p_T$  particle Identification
  - Aerogel/TOF (west)
- Low mass di-leptons
  - TPC/HBD
- High  $p_T$  and jets
  - TPC/Silicon Vertex Tracker
- Charm/Beauty measurement
  - Silicon Vertex Tracker
- High  $p_T$  muons (W, Upsilon)
  - Enhanced muon LVL1 trigger



# PHENIX Science

## $R_{AA}$ in d-Au ( $R_{dA}$ )

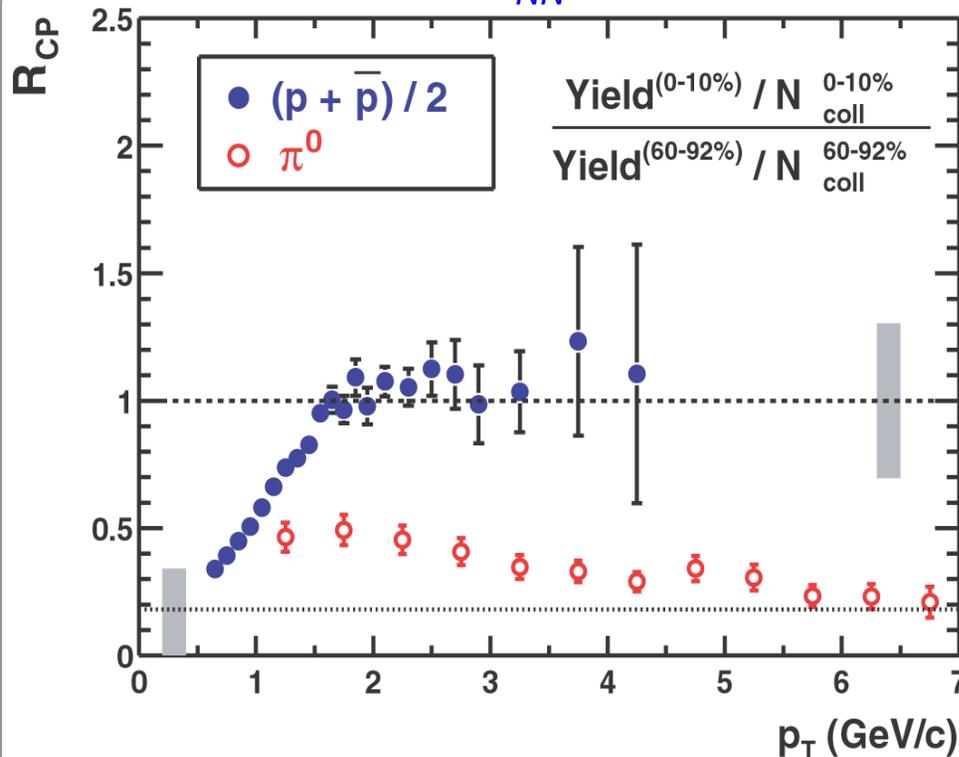


- Final state effects minimal in d-Au
- No suppression in d-Au
- Initial state effects ruled out as explanation for suppression in Au-Au

# PHENIX Science

## Proton-Scaling

Au+Au at  $\sqrt{s_{NN}} = 200$  GeV



- Proton/anti-proton-yield **scales with  $N_{coll}$**  in the range  $2 \text{ GeV} < p_T < 4.5 \text{ GeV}$

- Possible explanations
  - Collective expansion (*hydrodynamic flow*)
  - Quark recombination in quark-gluon plasma

# PHENIX Operations Roles

- PHENIX Experiment/Collaboration Management
  - PHENIX Operations Manager
  - DAQ, Computing Coordinators
  - 2 of 12 members Executive Council, 7 of 22 members Detector Council
  - Admin. of Budgets, Publications, Visitors, Data Processing, PHENIX Office
  - Run Support
- Data Acquisition, Online and Offline Computing
- Detector Subsystems
  - EM Calorimeter
  - Time Expansion Chamber
  - Zero Degree Calorimeter
  - Magnets
- Infrastructure and Common Systems
  - General Computing
  - Electronics Timing and Control
  - Gas and Safety Systems
  - High Voltage and Low Voltage

Responsibilities  
covered by 9.1  
FTEs on the BNL  
Scientific Staff

# STAR

- 11 staff scientists (10.5 FTE, down 2.5 from last year)
  - Group leader & Spokesperson is Tim Hallman
  - 6 permanent, 5 term
  - 5 post-docs
  - 19 prof/tech/admin staff
- Research interests and activities
  - high  $p_T$
  - spectra and multiplicity
  - strange and multi-strange particles and resonances
  - heavy flavor & charmonium
  - Flow & HBT
  - Two particle (non-HBT) correlations

# STAR Research

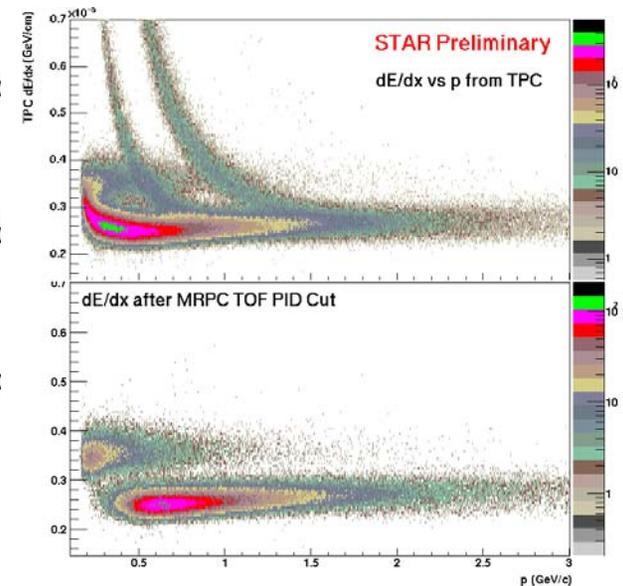
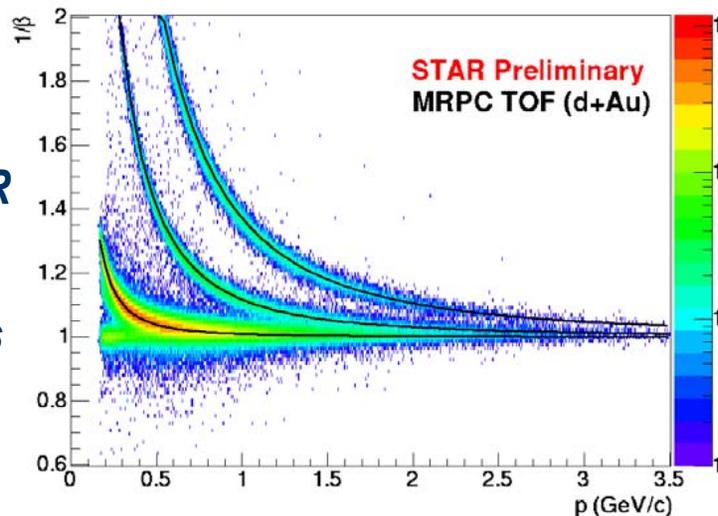
- BNL physicists co-convene three of 9 Physics Working Groups
- BNL group members have given 12 invited talks, and 2 parallel since the last review (at SQM, CIPANP, NN2003, 40th Erice Summer School, Trieste (Summary of Recent Results from RHIC), Rencontres de Moriond, etc.
- BNL physicists made significant contributions to 4 of 17 papers published or submitted since last year's review:
  - Centrality dependence of high  $p_T$  hadron suppression in Au-Au collisions at  $\sqrt{s_{NN}} = 130$  GeV (PRL **89**, 202301-1, 2002)
  - $K^*(892)$  Production in Relativistic Heavy Ion Collisions at  $\sqrt{s_{NN}} = 130$  GeV (Phys. Rev C66, 061901-1, 2002)
  - Transverse momentum and collision energy dependence of high  $p_T$  hadron suppression in Au-Au collisions at ultra-relativistic energies
  - Evidence from d-Au measurements for final state suppression of high  $p_T$  hadrons in Au-Au collisions at RHIC

# STAR Upgrades R&D

- A micro-vertex detector    precise (3  $\mu\text{m}$ ) hit position close to the primary vtx  $\rightarrow$  D's , flavor- tagged jets
- ★ A DAQ/ TPC FEE Upgrade    new architecture / FEE  $\rightarrow$  1 kHz of events sampled at Level 3; effective integration of 10 x more data
- ★ A Barrel MRPC TOF    4-vector information for an additional 60% of the hadrons in final state; greater science reach for key observables
- GEM Development    Preparation for a compact, fast, next generation TPC needed for 40 x L (LDRD and other BNL group support)

(★ = direct involvement of BNL STAR staff)

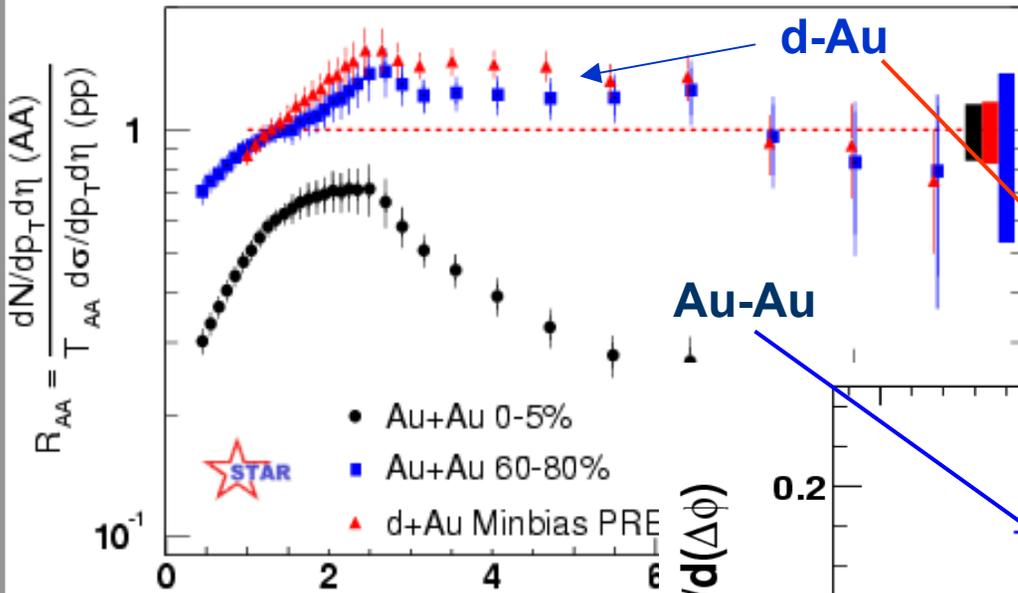
*Prototype TOF modules met all performance specs in the STAR environment and has produced important physics*



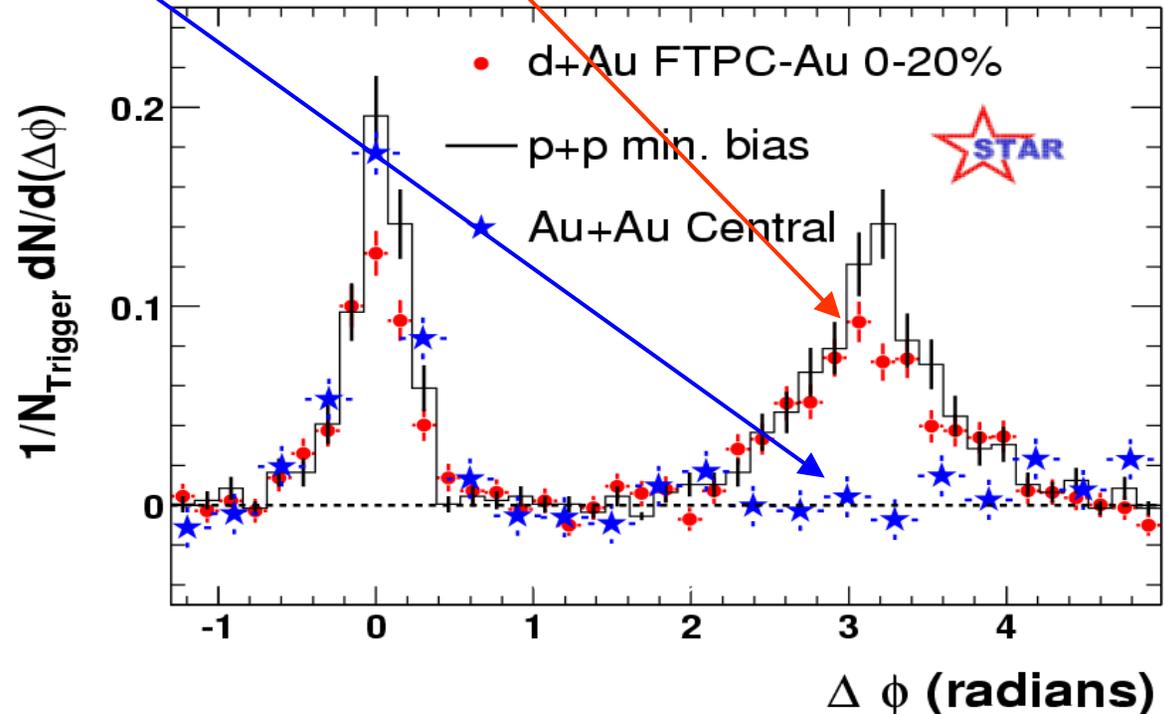
# STAR Science

Run II Au-Au results at full energy show strong suppression !

d-Au "control" data needed to distinguish between competing interpretations



**Results indicate:  
Observed suppression in Au-Au is due to nature of (new) produced matter**

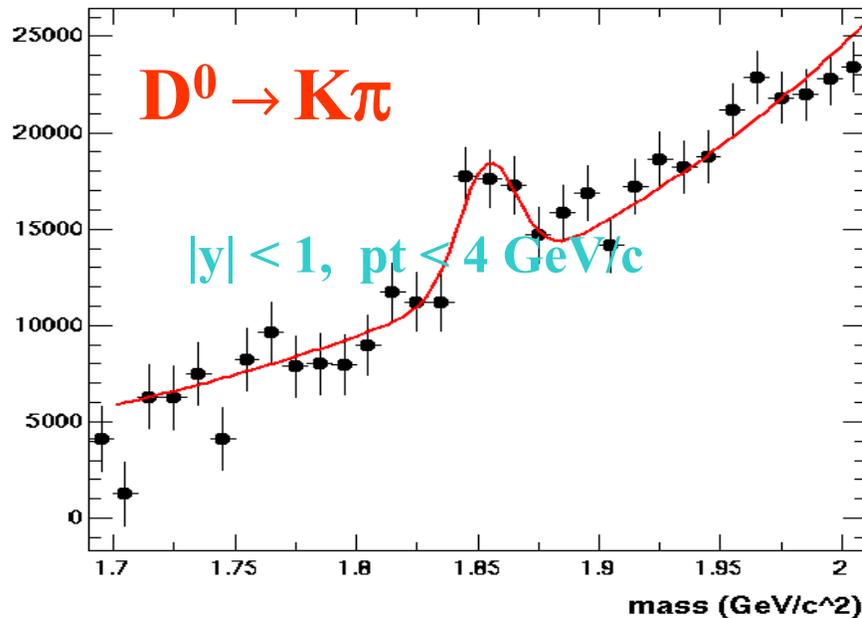


# STAR Science

First direct observation at RHIC of open charm in d-Au collisions

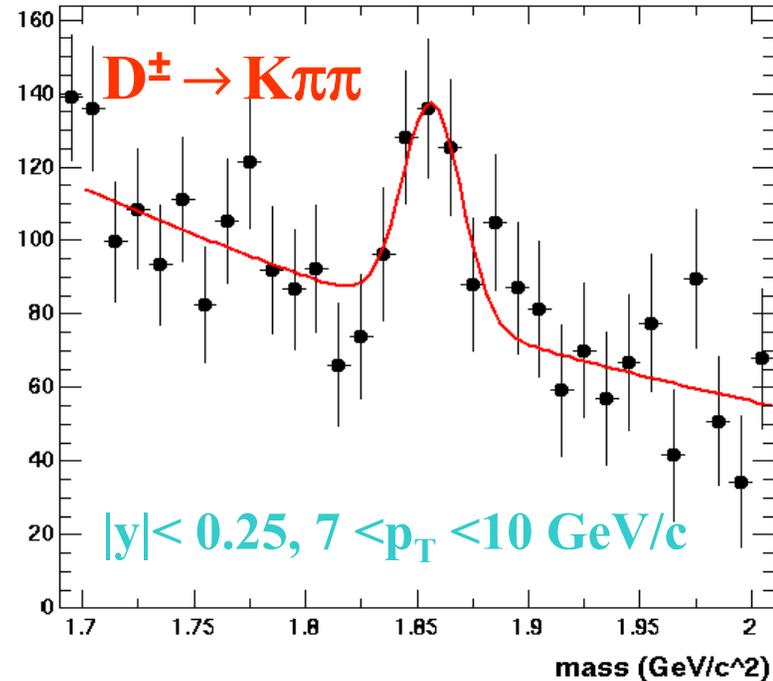
Open Charm: a sensitive probe of initial conditions, and possible equilibration at early times

D0, dAu minbias,  $|y| < 1.0, 0 < p_T < 4$  GeV/c



Star Preliminary

D±, dAu minbias,  $|y| < 0.25, 7 < p_T < 10.0$  GeV/c



# STAR Operations roles

- STAR Experiment/Collaboration Management
  - Operations Leader
  - Technical Support Group Leader, Chief Electronics Engineer
  - Software and Computing Leader, Data Acquisition Leader
  - Physics Analysis Coordinator, Simulations Leader, Data Production Manager
  - SVT, FTPC and Magnet Sub-system experts
  - Admin. of Budgets, Publications, Visitors, Data Processing, STAR Office
  - Run Support
- Responsibilities in the following infrastructure and subsystems
  - DAQ, Run Control
  - SVT, Magnet
  - Online and Offline software
  - Conventional\* systems, STAR Global Interlock System

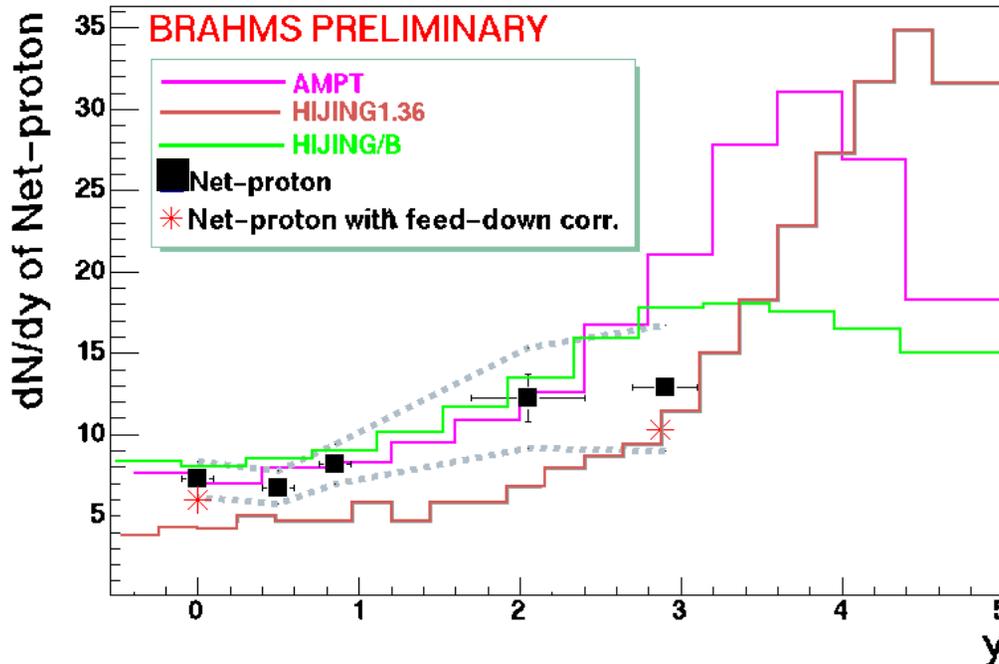
\* *In collaboration with C-AD EF&S*

# BRAHMS

- 5 staff scientists
  - Group leader is Chellis Chasman
  - BRAHMS spokesperson is Flemming Videbaek
  - 4 permanent, 1 term
  - 2 post-docs
  - 3.5 prof/tech/admin staff
- Research interests and activities
  - Spectroscopy in mid-rapidity, multiplicity measurements, d-Au at large rapidity
  - Major Contributions to analysis in Au-Au:
    - net baryons vs.  $y$ ,
    - momentum spectra of identified hadrons,
    - $dN/dy$  for identified particles vs. centrality, rapidity
    - $R_{aa}$  &  $R_{cp}$  vs. rapidity

# BRAHMS Science

dN/dy of Net-proton and Models for 0-10% central Au+Au Collisions at  $\sqrt{s_{NN}}=200$  GeV



- “Plateau” at  $|y| < 1$
- Net-baryon at  $y = 0$ :  $\sim 16$   
[if  $N(\text{proton})/N(\text{neutron}) \approx 1$   
 $N(\text{net-}\Lambda) = 0.9 \cdot N(\text{net-proton})$ ]
- Hyperon feed down correction decreases yields by 18% and 20% at  $y=0$  and 2.9

# BRAHMS Science

## High- $p_T$ Measurements in Au-Au and d-Au

- **Au-Au at  $\sqrt{s_{NN}}=200$  GeV,  $\eta=0$ :**
  - ⇒ Strong high  $p_T$  suppression in central collisions
  - ⇒ Suppression not observed in semi-peripheral collision (40-60%)

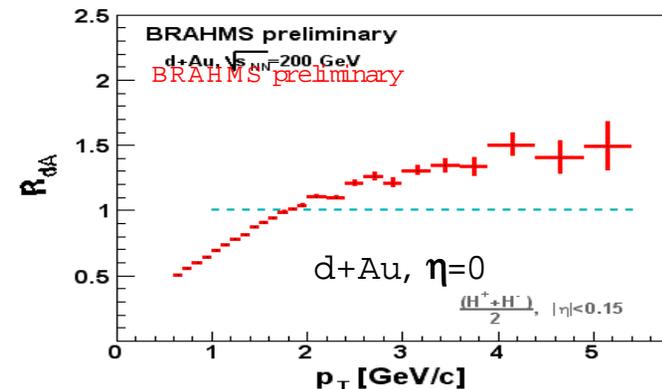
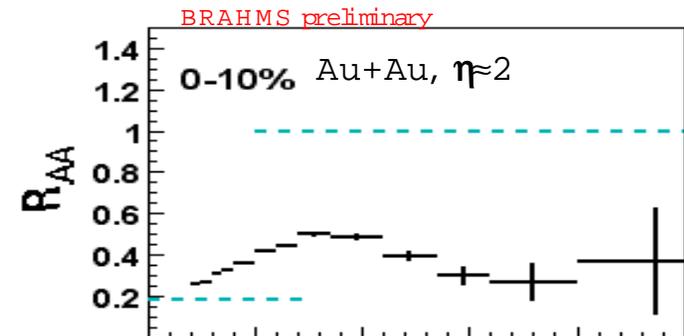
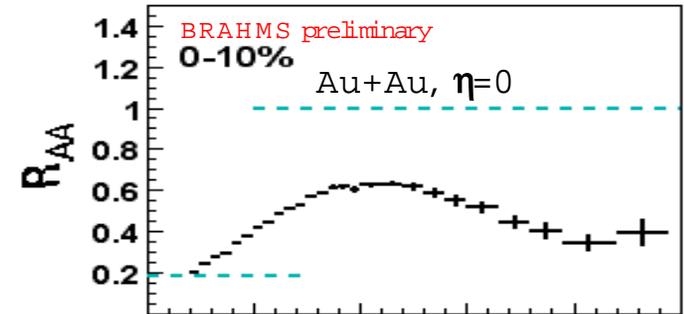
## Strong effect of dense medium

- **Au-Au at  $\sqrt{s_{NN}}=200$  GeV,  $\eta \approx 2$ :**
  - ⇒ Similar behavior as observed at  $\eta=0$  (calls for additional theoretical work)

## Medium extends to $\eta=2$

- **d-Au at  $\sqrt{s_{NN}}=200$  GeV,  $\eta=0$ :**
  - ⇒ “Cronin” like enhancement

## Medium not present in d+Au



# BRAHMS

- **New Capability for Next Run**
  - Flow detector for use with Spectrometers
  - New Mid-rapidity and Forward Spectrometer triggers
  - New Mid-rapidity TOF for improved PID (Commissioned this year)
  - New Mid-rapidity Cherenkov (Commissioned this year)
  - New Beam-Beam detector for improved efficiency (esp. in pp)
  - New Shielding from beam background in tunnel
- **R&D plans**
  - Because of recent RHIC results, the Collaboration is considering various new detector systems for physics in the forward region
- **Operations roles of BNL scientists**
  - Spokesperson: Liaison to RHIC
  - Project manager: Run Coordinator
  - Operation of Cherenkov, TPC, Mid-rapidity TOF, DAQ
  - Overall detector management

# PHOBOS

- 4 staff scientists
  - Group leader is M. Baker (Chemistry)
  - 1 permanent, 3 term
  - 1 post-doc (+1 opening) → 2 post-docs
  - 1.5 prof/tech/admin staff
- Research interests and activities
  - Co-conveners of Multiplicity Working Group
    - Source of 7 out of 12 PHOBOS publications
  - Group played a key role in 11 out of 12 PHOBOS publications submitted to date
    - Analysis, lead authorship, internal review committees, etc.
    - Lead ("corresponding") authorship of recently accepted PRL

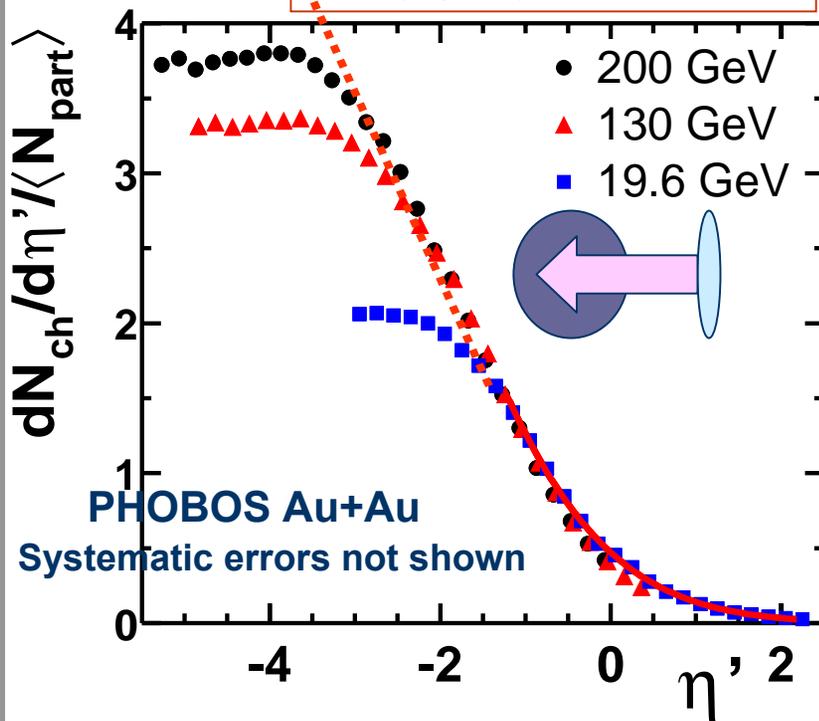
# PHOBOS

- Recent PHOBOS pubs with significant BNL roles
  - Hadron  $p_T$  spectra from 200 GeV d-Au collisions submitted to PRL
  - Hadron  $p_T$  spectra from 200 GeV Au-Au collisions subm. to PLB
  - Total multiplicity compared to  $e^+e^-$  collisions submitted to PRL
  - 20 – 200 GeV limiting fragmentation accepted by PRL
  - 200 GeV identified particle ratios                      PRC **67** (2003) 021901R
  - 130 GeV elliptic flow vs.  $\eta$                                       PRL **89** (2002) 222301
- R&D plans
  - Developing physics goal & case for PHOBOS upgrade plan
  - In discussion with PHENIX (silicon vertex tracking)
- Operations roles
  - Deputy Spokesperson
  - Project Manager, Operations Coordinator
  - Computing Coordinator
  - DAQ, Online, Slow Controls, Magnet

# PHOBOS Science

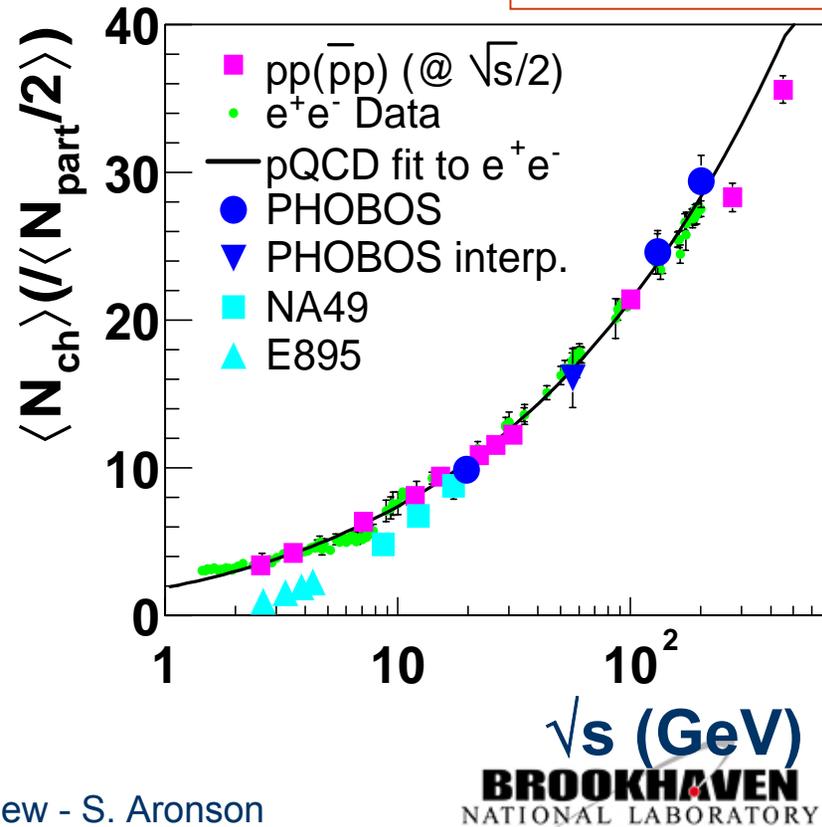
## Shape in Projectile rest frame

PRL (in press), nucl-ex/0210015



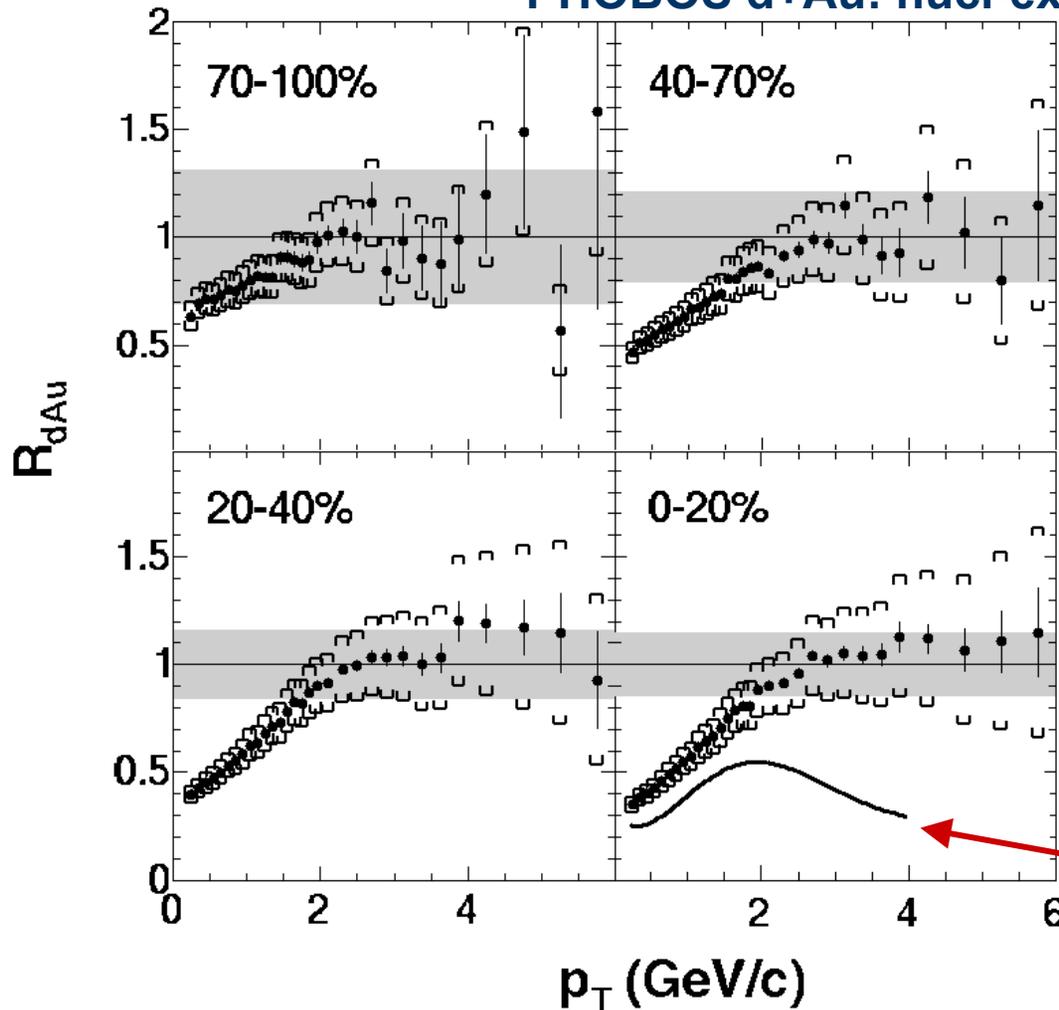
## Total Charged Multiplicity Universal at RHIC Energies?

nucl-ex/0301017



# PHOBOS Science

PHOBOS d+Au: nucl-ex/0306025



- No suppression even for CENTRAL d-Au
- Initial state effects are ruled out as an explanation for suppression in Au-Au.

# Medium Energy Group

- The RHIC effort will eventually have 4-5 physicists each for spin in STAR and PHENIX, and 3 for pp2pp. Total of about 12-13.
  - Group leader is G. Bunce
  - At present
    - STAR: 4, with 1 permanent, 2 term, 1 Goldhaber Fellow
      - expect 1 term to replace Goldhaber Fellow this fall
    - PHENIX: 2, 1 permanent; 1 term.
    - pp2pp: 3, 2 permanent, 1 post doc
    - 0.7 prof/tech/admin staff

# Medium Energy

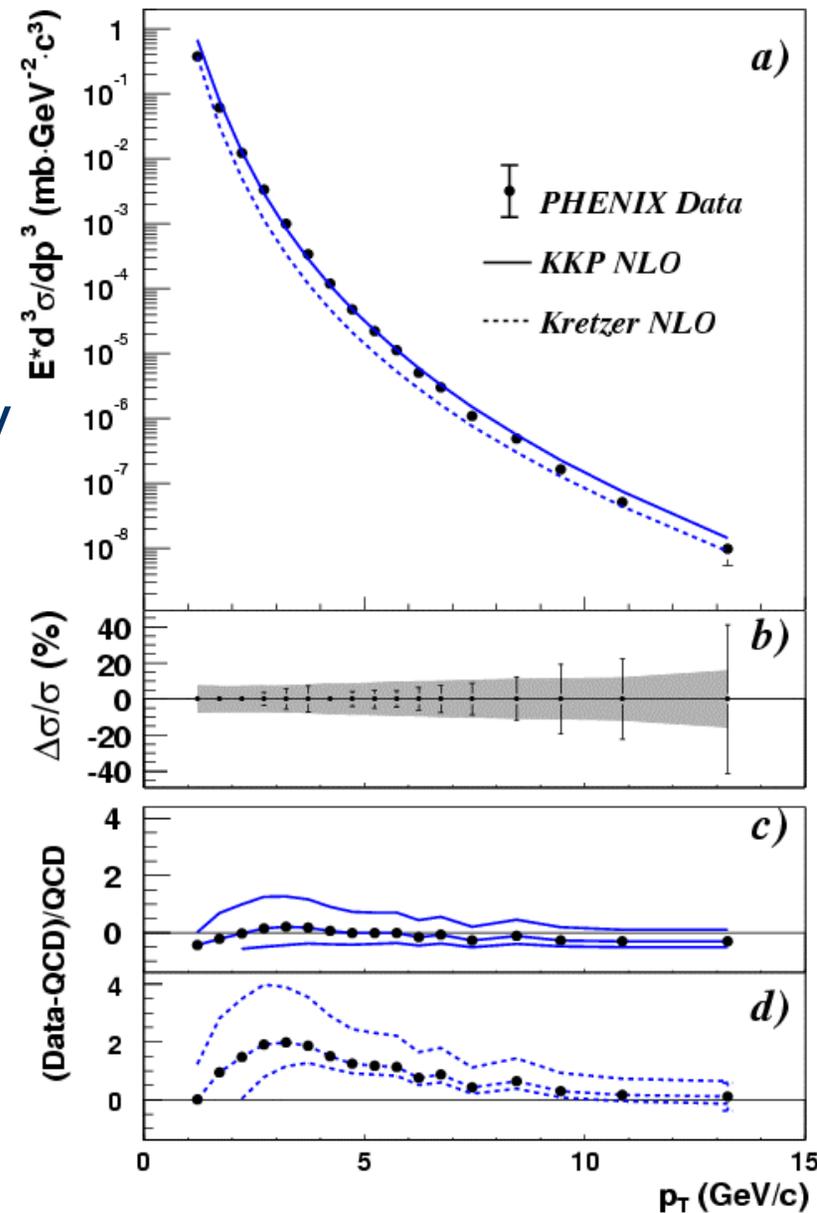
- This group is the primary focus within the department for RHIC-Spin efforts
  - Activities
    - Polarimetry (AGS, RHIC, jet)
    - Jet target and Si detectors for absolute beam polarization.
    - Forward  $\pi^0$  detectors and beam-beam counters (STAR)
    - The group is currently also responsible for all major tasks in pp2pp
  - RBRC and RIKEN groups at BNL work on spin in PHENIX now, but are not permanent staff
  - The experimental collaborations (STAR, PHENIX) are fully engaged in the spin program, produce the data. Analysis is carried out within the collaborations
- R&D plans
  - Methods to handle high luminosity (particularly STAR)

# RBRC Experimental Group

- Part of the RIKEN BNL Research Center, led by T.D. Lee
  - Group leader is H. En'yo (RIKEN)
  - 4 Fellows (2 shared: UNM, Illinois), 3 post-docs, expect +1 Fellow in fall
  - 1 prof/tech/admin
- All on PHENIX, emphasis on spin program
  - Triggers, DAQ issues for spin (GL1P, etc.)
  - New probes for spin
  - Polarimetry, luminosity (NTC)
  - Spin data analysis
- R&D plans
  - Inner tracker for jets and heavy quark physics
  - Jet tagger for trigger for muon arms

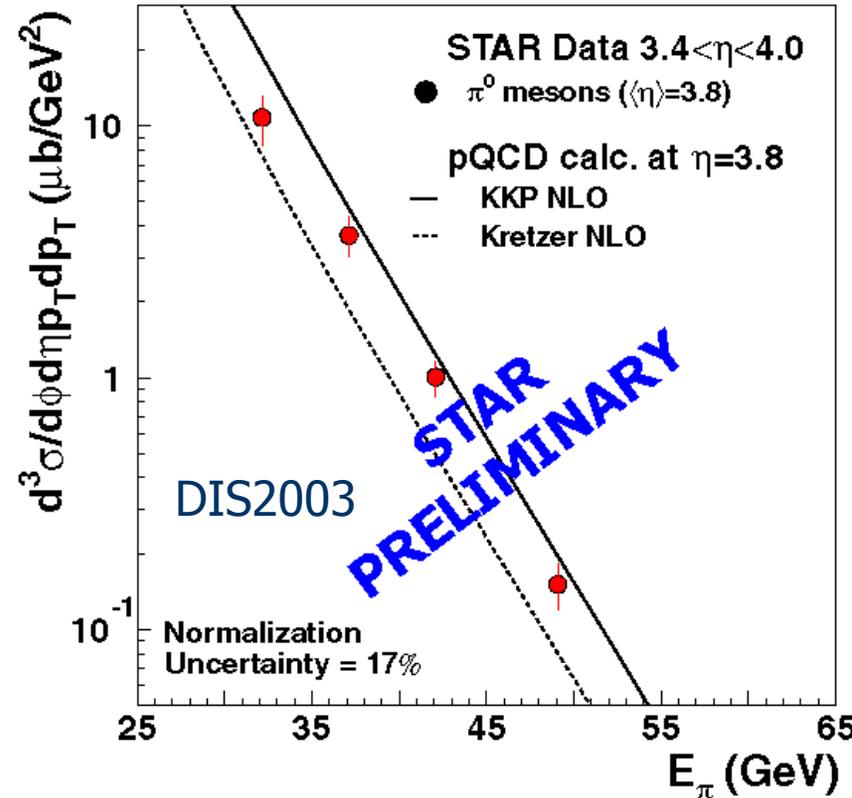
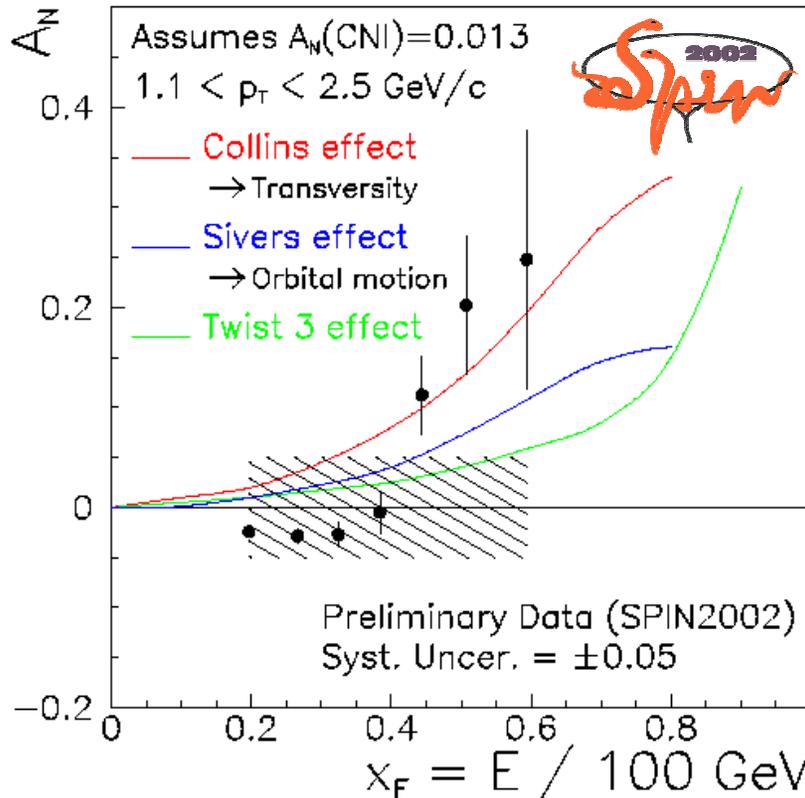
# Recent Spin results

- $p+p \rightarrow \pi^0 + X$  at  $\sqrt{s} = 200$  GeV
  - vs. next-to-leading-order QCD
  - High quality data to high  $p_T$
- RBRC and RHIC Spin group (i.e., Sasha Bazilevsky)



# RHIC Spin Results from Run 2

$$p\uparrow + p \rightarrow \pi^0 + X, \sqrt{s} = 200 \text{ GeV}$$



- Large spin effects observed for  $\sqrt{s} = 200 \text{ GeV}$   $pp$  collisions
- Measured cross sections consistent with pQCD calculations

# Experimental budgets: the bottom line

(see following slides)

- Experimental groups operated the program longer in '03 than in '02, with funding between **flat** and **flat-flat** relative to '02
  - Carry-over '02→'03 (~\$.75M) now ~gone going into '04
  - R&D funds (expected to support some of the staff) in '03 was late and much less than planned
- Research budgets cannot support the present staff in '04
  - So far, reduction has been by attrition

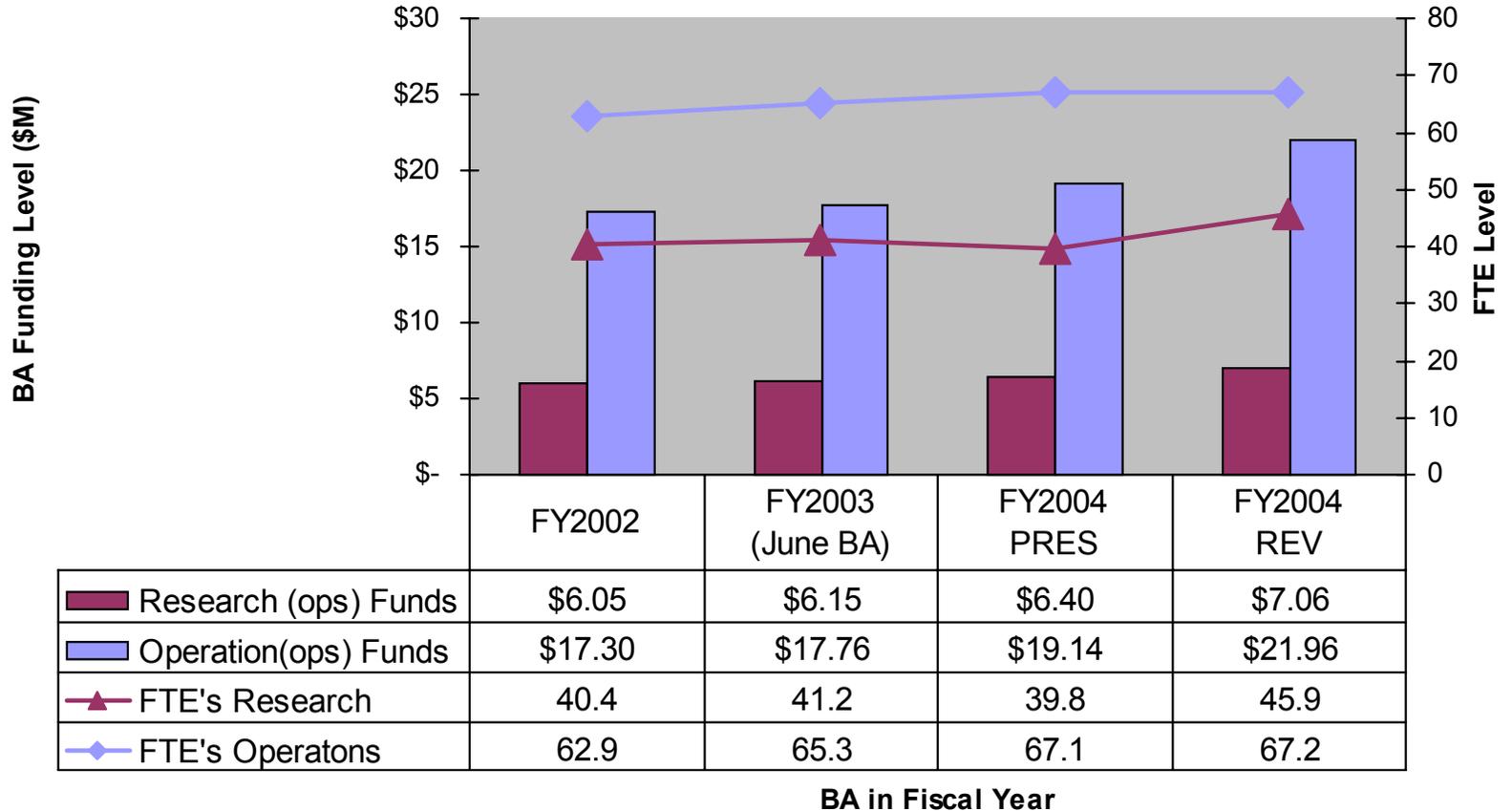
# President's FY04 budget and its impact

## Brookhaven National Laboratory- Physics Department DOE Nuclear Physics Program Summary- FY2005 Budget Submission Funding in Millions of Dollars

B&R Classification	FWP	(June BA)		PRES	REV
		<u>FY2002</u>	<u>FY2003</u>	<u>FY2004</u>	<u>FY2004</u>
KB010102-2	(SPIN) PO-001	1.28	1.71	1.75	2.19
KB010102-2	(LEGS) PO-002	1.77	1.77	1.78	1.78
KB010102-2 EQU	(LEGS) PO-002	0.16	0.06	0.10	0.10
<b>Sub Total KB01</b>		<b>3.21</b>	<b>3.54</b>	<b>3.63</b>	<b>4.07</b>
KB020102-1	(Research) PO-003	6.05	6.15	6.40	7.06
KB020102-1 EQU	(Research) PO-033	3.10	2.36	1.95	1.95
<b>Sub Total KB020102-1</b>		<b>9.15</b>	<b>8.51</b>	<b>8.35</b>	<b>9.01</b>
KB020201-2	(Operations) PO-004	17.30	17.76	19.14	21.96
KB020201-2 EQU	(Operations) PO-004	2.81	3.39	3.83	4.10
<b>Sub Total KB020201-2</b>		<b>20.11</b>	<b>21.15</b>	<b>22.97</b>	<b>26.06</b>
<b>Subtotal KB02</b>		<b>29.26</b>	<b>29.66</b>	<b>31.32</b>	<b>35.07</b>
KB030102-0	(NT) PO-006	2.33	2.03	2.05	2.32
KB030102-0	(SciDAC) PO-006	0.04	0.27	0.00	0.32
<b>Sub Total KB03</b>		<b>2.37</b>	<b>2.30</b>	<b>2.05</b>	<b>2.64</b>

# President's FY04 budget and its impact

KB020 NP Research and Operations (RHIC Exp. Program)  
BA Funding \$M



Research (ops) Funds
  Operation(ops) Funds
  FTE's Research
  FTE's Operators

# FY 2004 Budget Summary

- Presidential FY04 Request compared to June FY03 BA
  - RHIC Research is +4% and Nuclear Theory +1%
  - RHIC Research Capital is -17% (expected profile)
  - RHIC Experimental Operations is +7.8% (\$1M restored)
  - RHIC Experimental Capital is +11%
  - ME Research is +2.5%
- FY04 Funding at these levels
  - RHIC Experiment Operations throughout [shortened] Run 4
    - Need to deal with detector R&D as well
  - RHIC Research would reduce by 1.5 FTE
  - Theory would reduce by 1 post-doc, cut back visitor programs
  - ME Research less than constant effort
    - Spin Physics Group growth stalled

# FY 2004 Budget Summary

- Summary of Contractor's Revised FY 2004 request (\$000)
    - H.I. Research 660 to add post docs and staff
    - RHIC Spin 450 to support new 03 staff for full year & resume growth
    - Theory 270 to add post docs
    - H.I. Exp. Ops 2820 for full operations & detector R&D
    - H.I. Exp. Ops Equip. 270 for PHENIX & PHOBOS enhancements
- ➔ ~13% increase in KB02+Theory, of which half is detector R&D

# FY 2004 Budget Summary

- Experimental Program Issues & Concerns
  - Decline in exp. groups' research staff (especially post-docs)
    - Increasing tilt of groups toward operations at expense of research
  - Operations – gradual increase in scope for the local groups
  - International user community support
    - Foreign visit & assignment issues (~1/2 exp. ops personnel)
    - Financial support (~1/3 of visitors get support from exp. ops funds)
  - Detector R&D support
  - Growth in Spin
  - Theory visitor programs

# Summary and outlook

- Three runs at RHIC have brought us far into the discovery phase of the RHI program and data for first measurements of  $A_{LL}$  for pions and jets
- Further progress in the experimental programs requires
  - Long, stable runs with high integrated luminosity and polarization
  - Enhanced detectors
- These requirements imply strong DOE support for operations and for upgrades both to machines and to detectors
  - The FY'04 funding guidance does not allow for fully funding both operations and upgrade R&D
  - Careful optimization by BNL and the Collaborations will be required