The Case for Continuing RHIC Operations

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RHI Town Meeting

August 18, 2012

I. Quick Updates on RHIC Facility Status

II. Main Features of RHIC White Paper

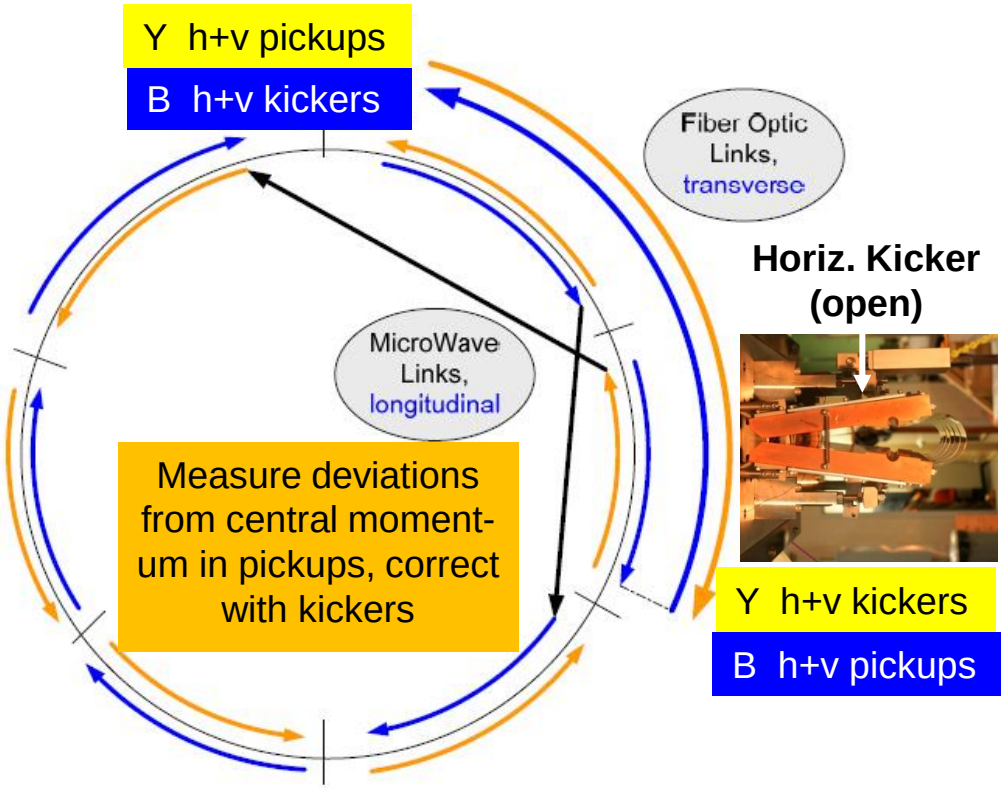
III. Types of Feedback Needed Today

BROOKHAVEN NATIONAL LABORATORY

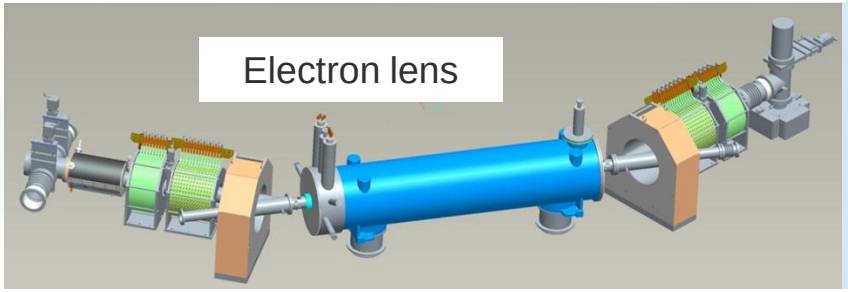
a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

RHIC-II Era is Here, Done Very Cost-Effectively !



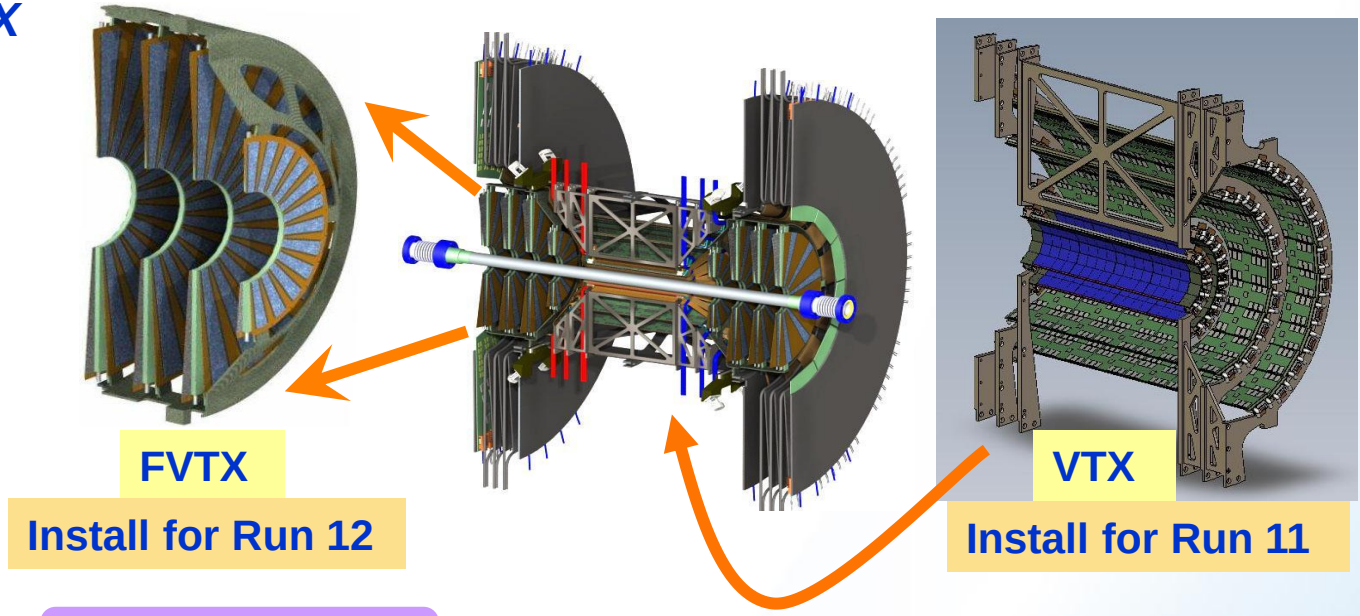
- ***RHIC breakthrough in bunched-beam stochastic cooling facilitates ~x10 improvement in heavy-ion collision rates, 5 years earlier and at ~1/7 the cost envisioned in 2007 NP Long Range Plan, saving ~$80M***
- ***All (6 planes of pickups & kickers) of the new system commissioned during 2010-12, new 56 MHz SRF cavity anticipated for 2014 run.***
- ***Electron lenses to be installed for 2013 run to improve polarized pp luminosity by factor ~2***

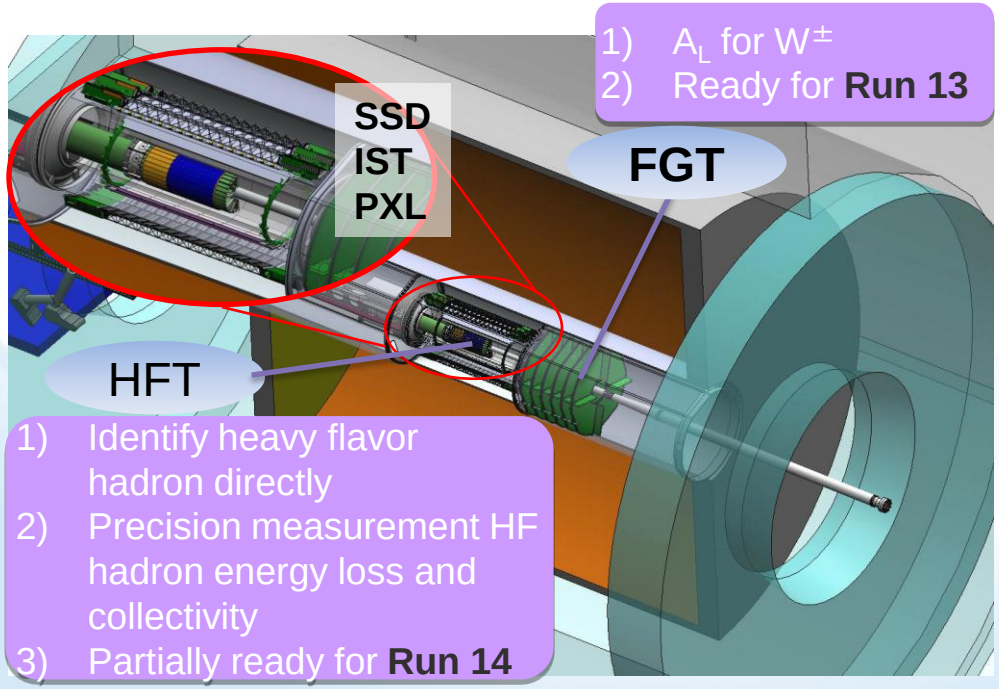


- ***New Electron Beam Ion Source (EBIS, 2012) expands range of ions available (e.g., U) and enhances cost-effectiveness of operations***

A Suite of Ongoing RHIC Detector Upgrades

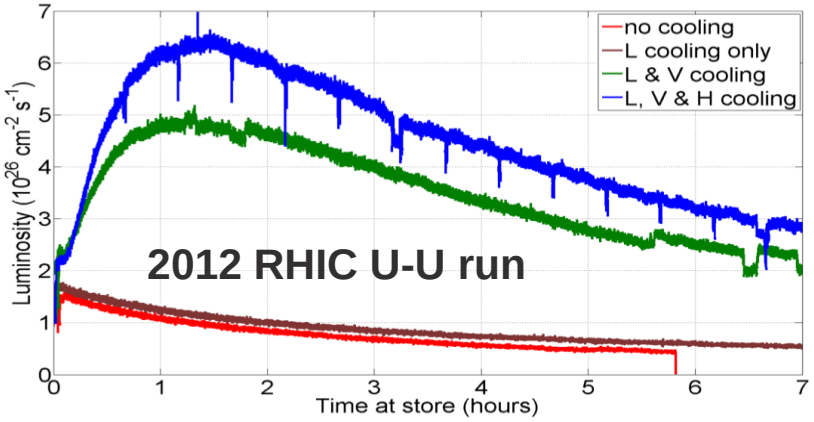
- ***PHENIX VTX & FVTX upgrades greatly improve vertex resolution, heavy flavor ID***
- ***μ trigger upgrade installed in FY10-11 enhances W prod'n triggering for spin program.***

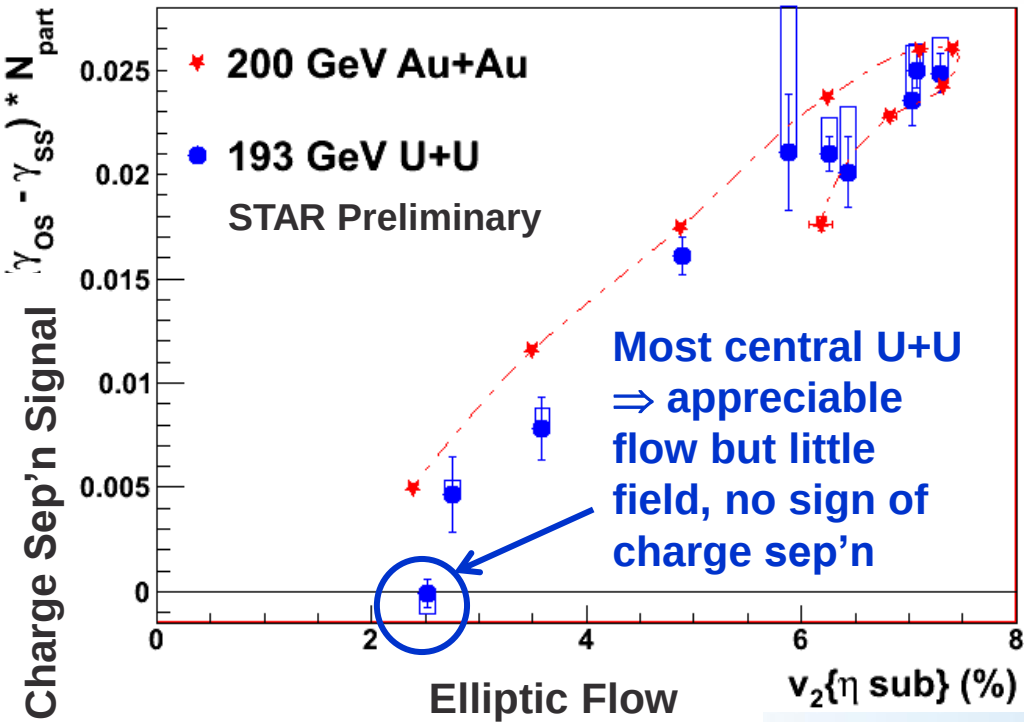




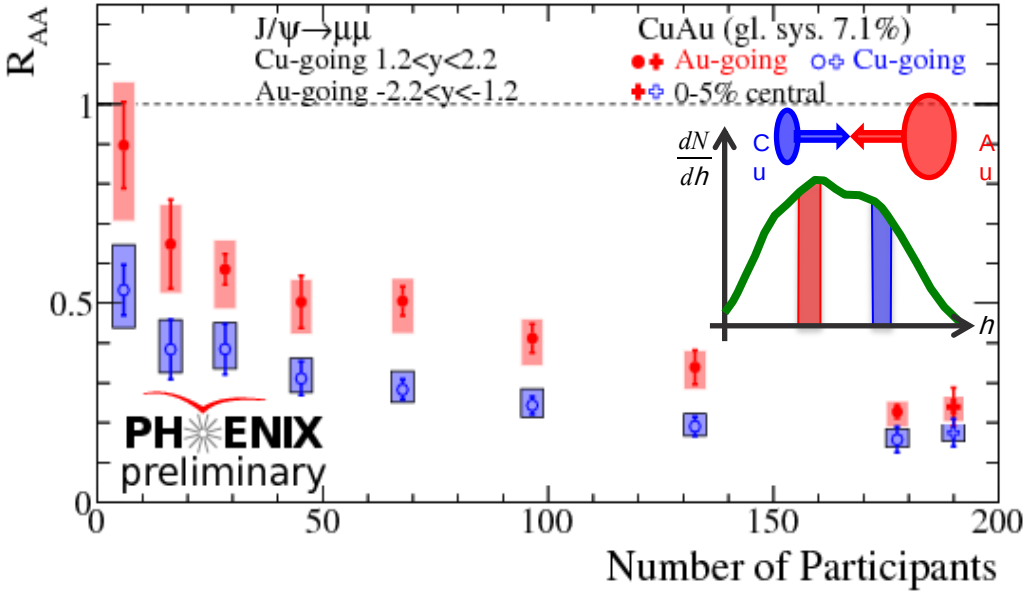
- ***STAR Heavy Flavor Tracker receives CD-2/3 review in 2011. Will permit topological recon-struction of charmed hadrons.***
- ***STAR Forward GEM Tracker to be installed for Runs 12 and 13, will enhance forward tracking, W charge sign discrimination.***
- ***STAR Muon Telescope Detector (Run 14) to improve quarkonium***

Just Completed Facility Upgrades Enable "Next Steps"





- ***Stochastic cooling dramatically increases rare event rates – full-energy HI luminosity ~15x original design***
- ***EBIS provides U beams to exploit deformation for initial geom. selection, e.g., to test signal/background for event EDM (sphaleron) correlations***
- ***EBIS simplifies asymmetric (e.g. Cu+Au) HI collisions for extra geom. control, e.g., to unravel dependences on energy density & path length***



Drafting a White Paper for Tribble-II Subpanel

The Case for Continuing RHIC Operations

Table of Contents

Reader comments welcomed from RHIC user and support community – paper will be available before Sept. 7-9 Tribble Panel meetings

The Four Most Important Reasons for Continuing RHIC

1) RHIC has pioneered a vibrant new subfield – condensed QCD matter physics – and has led the rapid climb up a steep learning curve marked by continuing S&T breakthroughs. **If RHIC operations were terminated, the U.S. would unilaterally cede leadership in this high-impact field.**

2) Discoveries and techniques at RHIC have established deep intellectual connections to other physics forefronts. **These give RHIC much broader scientific impact than other Nuclear Physics research avenues.**

3) Critical directions for future research in this subfield involve probing hot QCD matter from below to above the transition to Quark Gluon Plasma. **This transition appears to occur within the RHIC energy range, at energies not accessible at LHC. This is NOT energy frontier science!**

4) RHIC has nearly completed major performance upgrades that facilitate the next decade's science. It also provides the most cost-effective base to realize the next QCD frontier with EIC. **Short-term crisis management for U.S. NP must preserve a viable path to a vibrant long-term future.**

Terminating RHIC ops. would lead with certainty to a devastating loss of U.S. scientific leadership, and in all likelihood simultaneously to a significant loss of funding for the U.S. NP program.

10 Basic Questions Going Into the RHIC Era

	RHIC answers to date:
1) Do we reach the QGP phase?	1) Yes
2) Is it weakly coupled, with ~ideal gas behavior?	2) No
3) Can we demonstrate the transition from hadronic degrees of freedom?	3) Hints
4) Do partons lose energy rapidly in traversing QGP?	4) Yes
5) Does QGP color screening suppress quarkonium formation?	5) Hints
6) Can we find evidence of high-temp. excited QCD vacuum fluctuations (sphalerons), analogous to EW sphalerons as source of universe's baryon asymmetry?	6) Hints
7) Is there a locus of 1st-order phase transitions and a Critical Point in the QCD phase diagram?	7) Hints
8) Do we see evidence of gluon density saturation in cold nuclear matter at very low Bjorken x?	8) Hints
9) Do gluon spin preferences account for a significant part of the missing proton spin?	9) Hints
10) Is there a significant flavor-dependence in sea quark polarizations?	10) Too little data to date

It is the responsibility of RHIC and LHC to design measurements to address the more quantitative 2nd-generation questions emerging from the definitive answers above, and to resolve the hints surrounding the others.

Which Facilities Are Needed To Address Open Questions?

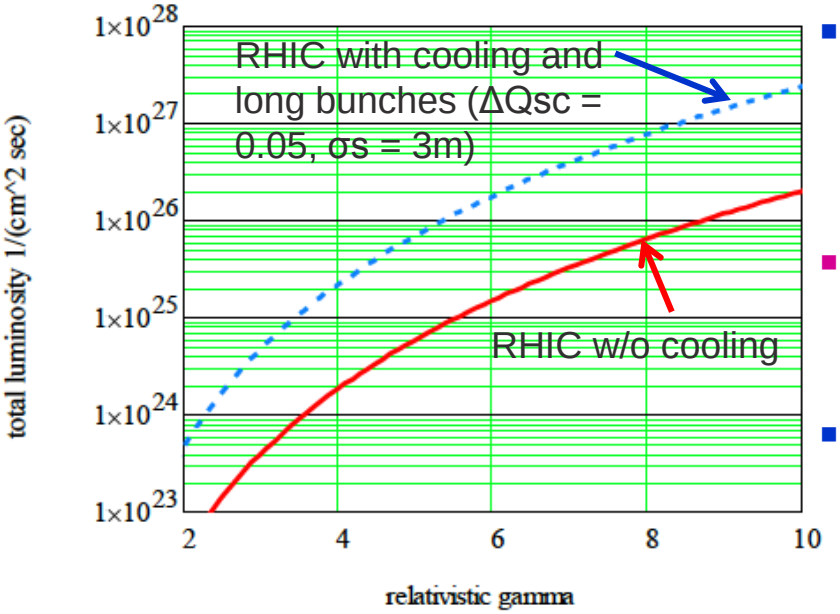
Question	Facilities	Comments	Relevant Q #'s from Table 1
1) How perfect is "near-perfect" liquid?	RHIC & LHC	Flow power spectra, next 5 yrs	1 + 2
2) How does strong coupling emerge from asymptotic freedom?	RHIC & LHC	Following 5 years @ RHIC; jets need sPHENIX upgrade	2 + 4
3) Evidence for onset of deconfine-ment and/or critical point?	RHIC; possible follow-up @ FAIR, NICA	Phase 2 E scan in following 5 years, needs low-E electron cooling	3 + 7
4) Sequential melting of quarkonia?	RHIC & LHC	LHC mass resolution a plus; RHIC det. upgrades help; $\sqrt{s}$-dependence important	5
5) Are sphaleron hints in RHIC data real?	Mostly RHIC	Exploits U+U and $\mu_B \neq 0$ reach at RHIC	6
6) Nature of initial density fluctuations?	RHIC, LHC & EIC	Benefits from asymmetric ion collisions at RHIC	2 + 8
7) Saturated gluon densities?	RHIC, LHC & EIC	Want to see onset at RHIC; need EIC to quantify	8
8) Where is missing proton spin?	RHIC & EIC	EIC will have dramatic impact	9 + 10

RHIC and LHC are complementary. Both are needed to explore temperature-dependence of QGP properties. RHIC has unique reach to QGP onset, unique ion species versatility and unique polarized capability, until EIC is realized.

Addressing these questions requires an ~10-year program of A+A (various ion species), p+p and p/d + A runs at various RHIC energies.

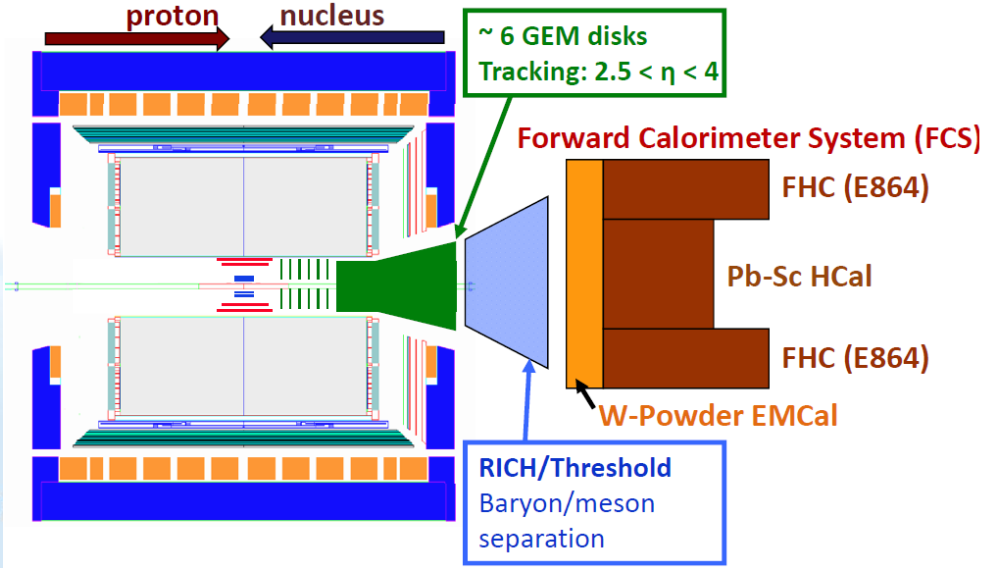
Contemplated Future Upgrades

Will likely use high brightness SRF electron gun for bunched beam electron cooling; up to ~10x L; ready after 2017 [Fermilab Pelletron (cooled 8 GeV pbar for Tevatron use) is alternative option]

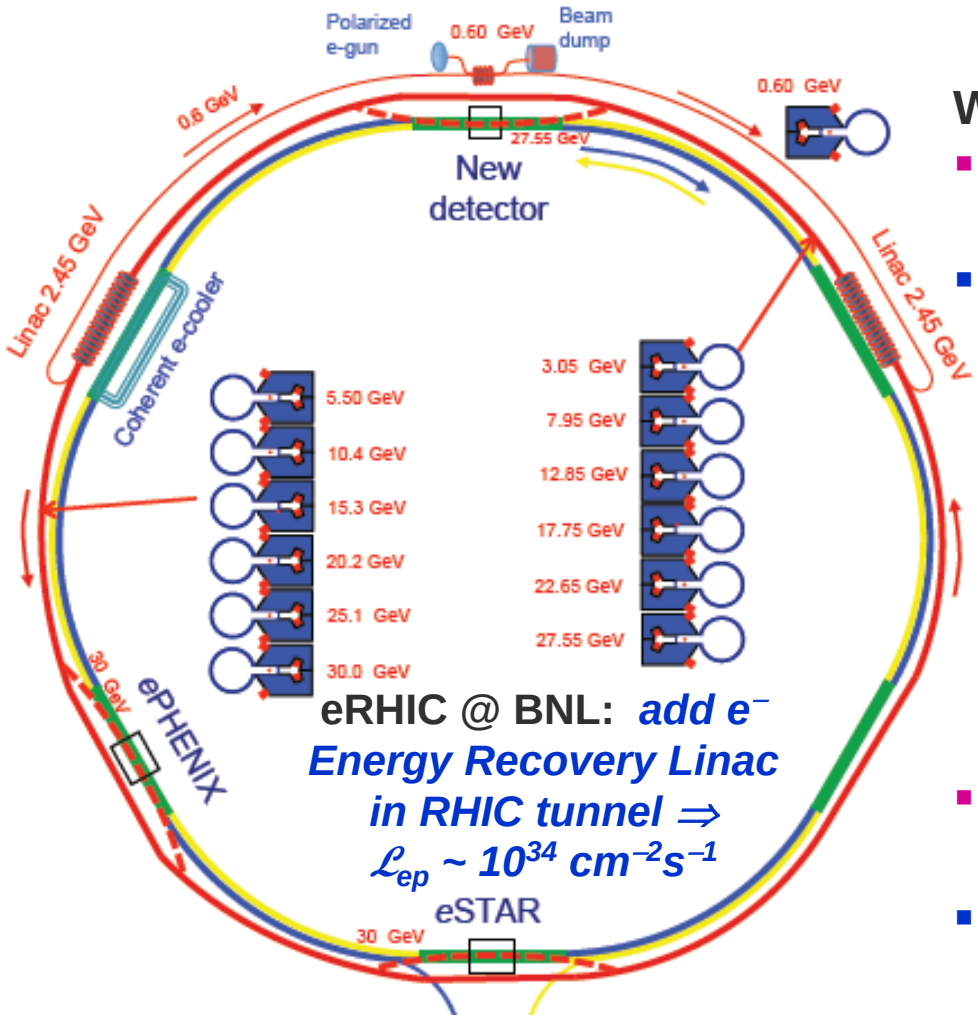


Other machine possibilities: pol'd ^{3}He; coherent e-cooling for $\mathcal{L}_{pp}$

- ***Low-E electron cooling for further pursuit of onset of deconfinement/CP***
- ***sPHENIX solenoid, EMCAL + HCAL for jet physics @ RHIC***
- ***STAR forward upgrade for p+A and transverse spin (e.g., DY) physics***
- ***PHENIX MPC-EX, STAR TPC pad rows***



RHIC's 3rd Decade: Reinvention as eRHIC ⇒ Path Forward for Cold QCD Matter



eRHIC @ BNL: ***add e⁻ Energy Recovery Linac in RHIC tunnel ⇒ $\mathcal{L}_{ep} \sim 10^{34}\ cm^{-2}s^{-1}$***

Design allows easy staging (start w/ 5-10 GeV, upgrade to ~20 GeV e⁻). Underwent successful technical design review in 2011. Bottom-up cost eval. + value engineering in progress.

Why eRHIC is a cost-effective approach:

- ***Reuses RHIC tunnel & detector halls ⇒ minimal civil construction***
- ***Reuses significant fractions of existing STAR & PHENIX detectors***
  - ***Exploits existing HI beams for precocious access to very high gluon density regime***
  - ***Polarized p beam and HI beam capabilities already exist – less costly to add e⁻ than hadron accelerator***
- ***Provides straightforward upgrade path by adding SRF linac cavities***
- ***Takes advantage of RHIC needs and other accelerator R&D @ BNL:***
  - ***E.g., coherent electron cooling can also enhance RHIC pp lumi.***
  - ***E.g., FFAG developments for muon collider considered for significant cost reductions***

What Would be Lost if RHIC Were Terminated?

- Opportunity to map QCD matter properties vs. temp., especially across QGP transition, and discover the possible Critical Point.
- Unique polarized pp access to nucleon spin structure.
- U.S. leadership in a vibrant NP subfield it pioneered.
- A major fraction of the productivity for U.S. NP over the better part of a decade – is this survivable?
- The only operating U.S. collider, hence a critical attractor for talented accelerator scientists and cutting-edge R&D.
- Quite possibly the only cost-realizable path to a future EIC.
- Home research base for >1000 domestic + foreign users.
- Strong foreign (esp. RIKEN) investment in U.S. facility.
- ~750 (direct + indirect) FTE's @ BNL.
- Many associated efforts will suffer serious collateral damage:
  - Lattice QCD thermodynamics leadership
  - Medical radioisotope production @ BNL
  - NASA Space Radiation studies @ BNL
  - Application offshoots in accelerator physics, esp. in next-generation hadron radiotherapy machine design
- Probably a sizable chunk of DOE ONP funding will be siphoned off to other agencies or program offices.

Feedback Needed on White Paper

Notes:

1) Written for audience of non-expert nuclear (+ one CM) physicists
2) Comprehensiveness less important than conveying vitality and enough compelling/answerable questions to fuel ~decade@ RHIC
3) Intend to submit to Tribble-II Panel before Sept. 7 "hearings"
4) Don't want to increase length significantly
5) Will reformat final version to include "message boxes" in each section
6) Community-wide WP can complement this one by providing more in-depth and balanced overview of recent accomplishments and goals for the entire field – this one needs to make concise case for RHIC.

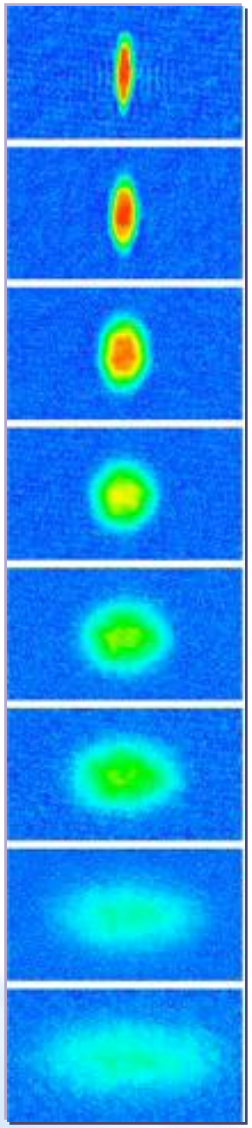
Preferred types of feedback here, in rough priority order:

1) What other things are absolutely needed to strengthen the case?
2) Are there parts of present content that damage/complicate the case?
3) Are relative emphases misjudged?
4) Should structure of document be modified?
5) Are there mistakes in the physics?
6) What missing features can help readers to get points made in the text (e.g., timeline for next-decade measurement programs)?
7) Are there better figures or results to use to make points already there?

Also welcome feedback by e-mail, including wording or detail suggestions – but please by August 24 to be considered.

Backup Slides

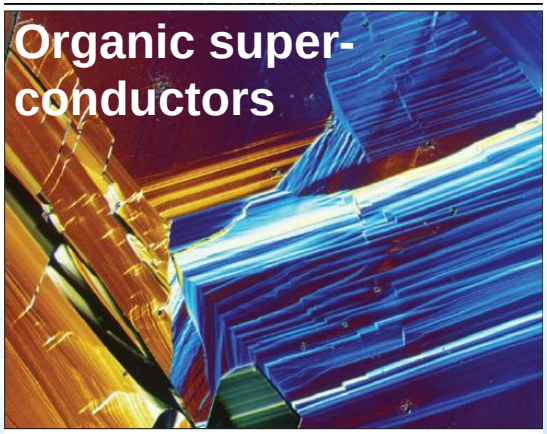
Unanticipated Intellectual Connections

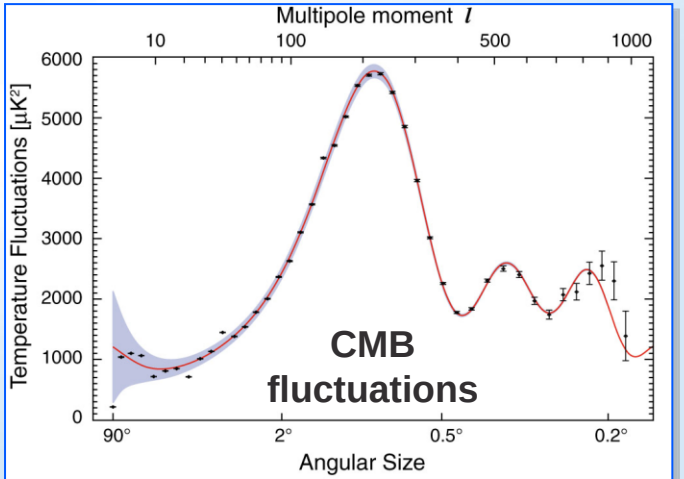


Trapped ultra-cold atom clouds

RHIC results have established ties to other forefront science:

- **String Theory studies of black hole behavior led to prediction of quantum lower bound on η/s**
- **Ultra-cold atomic gases, at temperatures 19 orders of magnitude below QGP, can also be "nearly perfect liquids"**
- **Similar liquid behavior seen and studied in a number of strongly correlated condensed matter systems**
- **Symmetry-violating bubbles in QGP analogous to speculated cosmological origin of matter-antimatter imbalance in universe**
- **Power spectrum of flow analogous to power spectrum of cosmic microwave background, used to constrain baryon acoustic oscillations & dark energy.**





Context for the NP Crisis: Quotes From the 2007 LRP

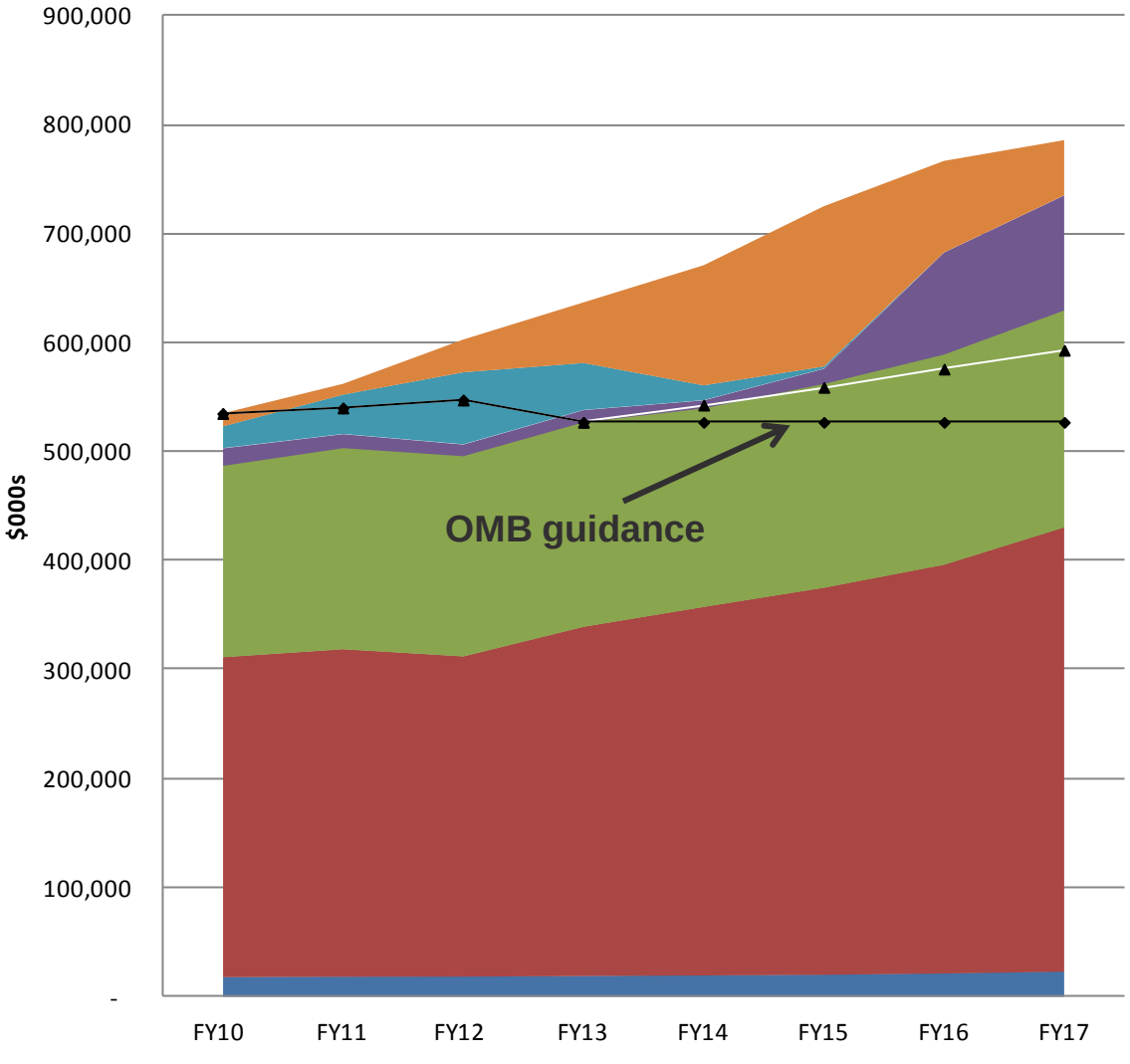
When faced with a choice of improving research funding or developing our facilities, **the consensus, as exemplified in the recommendations, was to maintain a near constant level of effort for the research program and facility operations, based on the FY2008 President's budget request, and to invest additional resources in the tools needed to make new discoveries in the future.**

Implementing the four principal recommendations of this Plan can be accomplished with a funding profile consistent with doubling the DOE's Office of Nuclear Physics budget, in actual year dollars, over the next decade, together with NSF funding for DUSEL including some of the equipment for experiments to be carried out in DUSEL.

Constant effort funding falls far below the level needed to carry out the four recommendations in the Plan. … If budgets were restricted to constant effort, proceeding with any of the new initiatives presented in this Plan would be possible only by reduced funding for operations and research, with clear adverse and potentially dire consequences for core components of the U.S. nuclear physics program. Since nuclear science, like all areas of basic research, evolves in time, it is impossible now to forecast what strategy would minimize damage to the field if future budgets dictated such stark choices.

Defining the ONP Problem

- This chart reflects the estimated funding needed to implement the majority of elements of the NSAC 2007 Long Range Plan (LRP) – not including EIC.
- The FY 2013 Congressional Request is reflected as two lines, one assuming 3% cost-of-living into the outyears and the other assuming flat funding into the outyears.



- ***FY13 shortfall ~$100M → ~$250M by FY17***
- ***Requires serious re-prioritization by NSAC***
- ***NSAC process will complete by Jan. 2013***
- ***Poses clear & present danger for RHIC ops.***

NSAC Charge to Tribble SubPanel II

We seek advice from NSAC on implementing the priorities and recommendations of the 2007 Long Range Plan in light of projected budgetary constraints and for guidance on developing a plan to implement the highest priority science in the context of likely available funding and world-wide capabilities. We request that NSAC examine the existing research capabilities and scientific efforts, assess their role and potential for scientific advancements, and advise the two agencies regarding the time and resources needed to achieve the planned programs. Your report should describe how to optimize the overall nuclear science program over the next five years (FY 2014-2018), under at least the following funding scenarios for the nuclear science budgets at the two agencies: (1) flat funding at the FY 2013 request level, and (2) modest increases over the next five years.

NSAC should submit the report by January 2013.

House and Senate E&W subcommittees, in marking up FY13 budget (both add $3-5M for RHIC ops.), call for NSAC process – e.g., Senate E&W markup says:

The Committee believes that the budget request puts at risk all major research and facility operations activities without significantly advancing nuclear physics goals. … The Committee directs the Office of Science to charge the Nuclear Physics Advisory Committee to submit a report by December 1, 2012 to the Office of Science and the Committee that proposes research and development activities for nuclear, physics under a flat budget scenario over the next 5 fiscal years. **The report should specifically identify priorities for facility construction and facility decommissioning to meet those priorities.**

Tribble-II Panel Membership & Schedule

Adam Burrows, Princeton
Joe Carlson, LANL
George Crabtree, ANL
Brad Filippone, CalTech
Stuart Freedman, UC Berkeley
Haiyan Gao, Duke
Don Geesaman, ANL (NSAC Chair)
Barbara Jacak, Stony Brook
Peter Jacobs, LBNL
David Kaplan, INT, U. Washington
Kirby Kemper, Florida State
Krishna Kumar, U. Massachusetts
Naomi Makins, U. Illinois
Curtis Meyer, Carnegie-Mellon
Jamie Nagle, U. Colorado
Witek Nazarewicz, U. Tennessee
Krishna Rajagopal, MIT
Michael Ramsey-Musolf, U. Wisconsin
Lee Sobotka, Washington U.
Bob Tribble, Texas A&M, Chair
Michael Wiescher, Notre Dame
John Wilkerson, U. North Carolina

May 15: 1st organizational meeting
Sept. 7-9: Lab and research group presentations (awaiting guidance on length and content)
Oct. 24-27: Town Meetings at DNP in Newport Beach
November, after election: Resolution/recommendation meeting of panel
December: Presentation of interim report to NSAC
January: Final report due to DOE and NSF

Many white papers being written – I'm drafting one on "Case for Continuing RHIC Operations". July-August Town Meetings being organized – thinking about one for Quark Matter 2012 in D.C. Will arrange dry run of RHIC talks.