

RHIC Run 11 Actual vs. PAC & Guidelines for Runs 12/13

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RHIC/AGS PAC Meeting

June 6, 2011

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NATIONAL LABORATORY
a passion for discovery



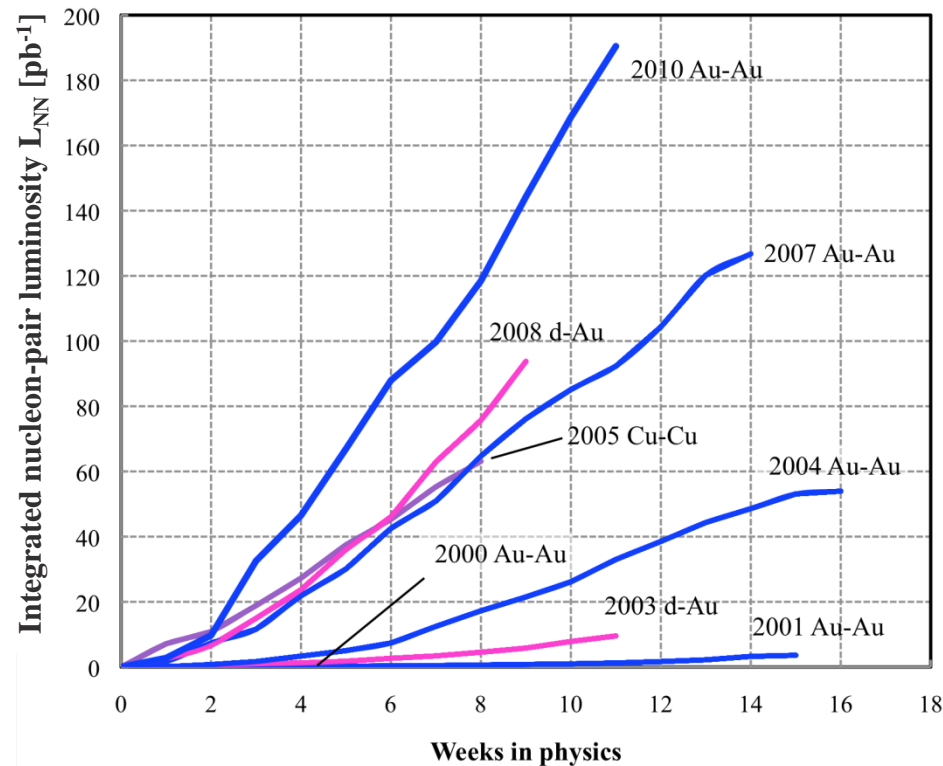
Improvements in Recent RHIC Operations Budgets and Efficiency - Shown 6/2010

	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011P	FY2011A
RHIC Ops. \$M	116.4	135.5	137.0	149.8	158.7	164.8	159.4
# cryoweek ops.	21	20	19	22	27	28-30	~26
Comments	Supple- mented by Renaiss- ance Technol- ogies to facilitate pp run	Budget arrived late, other- wise could have supported more weeks	Unexpect- ed Omnibus bill causes early run termina- tion	Budget could have support- ed 25 weeks, but long CR led to very late	Robust run, should maintain carryover for early start on Run 11 even with CR	Could be even better if power costs remain moderate, Congress doesn't slash	Long run possible due to carryover from FY10. Will finish end of June 2011

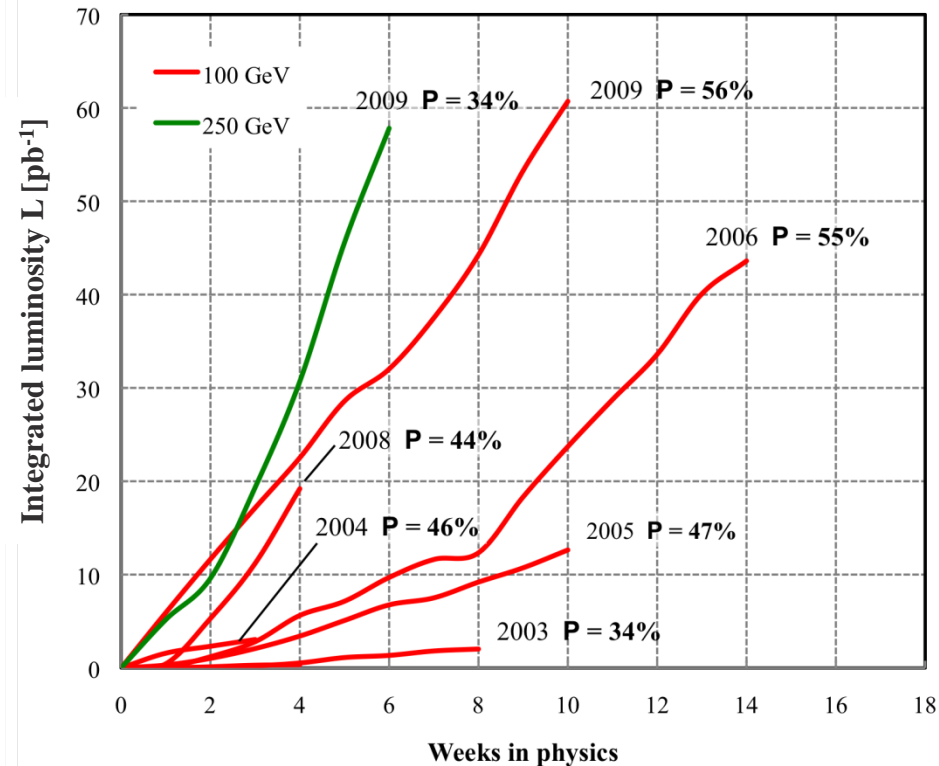
- 1) **“RHIC Ops”= (collider + det.) [Ops. + R&D + CE] + AIP**
- 2) **“Optimal” RHIC run ≈ 33 cryoweeks; 22 = minimum for healthy 2-species run**
- 3) **Run 10 outstanding, President’s FY11 budget very encouraging, but anticipate LONG Continuing Resolution – budget not finalized till May!**

RHIC Machine Performance History

Heavy ion runs



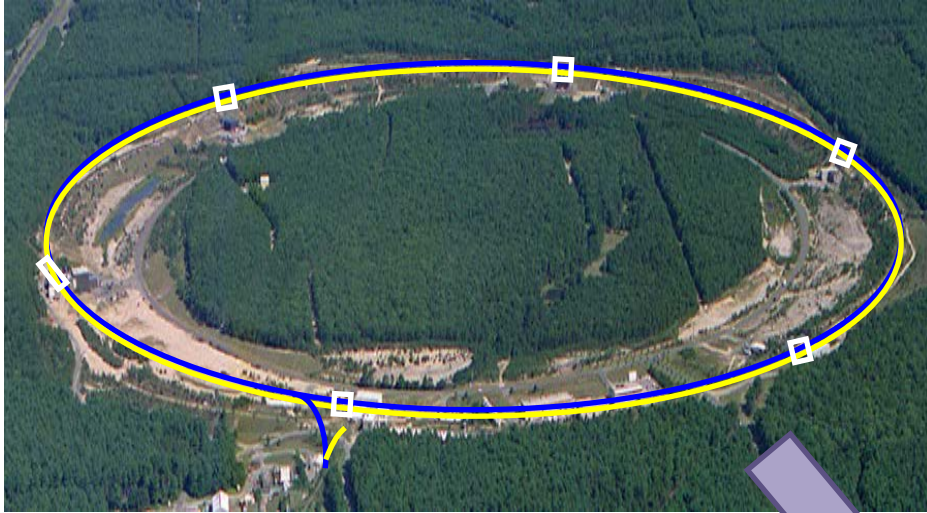
Polarized proton runs



New systems and conditions installed for Run 11:

- **New pp 500 GeV working point**
- **9 MHz RF system for pp**
- **Full suite of AGS tune-jump quads**
- **Full orbit feedback**
- **10 Hz vibration feedback control**
- **Upgraded RHIC pol'mtr electronics**
- **RHIC spin flipper**
- **AnDY setup in IP2**
- **4 refurbished stochastic cooling systems**
- **EBIS for commissioning and NSRL**
- **PHENIX VTX upgrade**

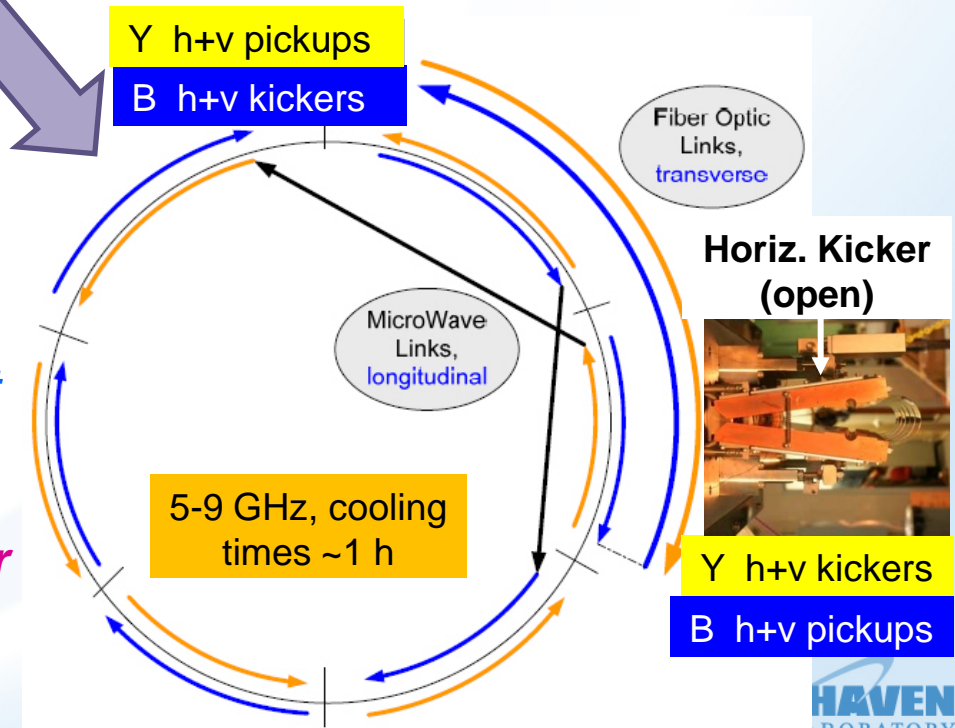
Ongoing Transition to RHIC-II Era



- ❑ Order of magnitude luminosity increase for heavy-ion collisions
- ❑ Fueled by accelerator technology breakthrough (bunched-beam stochastic cooling) **achieved @ RHIC**
- ❑ Completed ~2014 at ~1/7 the cost and ~4 years sooner than envisioned in 2007 NP Long Range Plan


With ongoing detector upgrades, facilitates:

- ❑ quantitative characterization of early-universe matter
- ❑ confirm/refute symmetry-violating bubble prediction
- ❑ search for unique critical endpoint in QCD phase diagram
- ❑ study how force between quarks changes in dense quark-gluon matter
- ❑ search for even rarer exotica like recent anti-hypertriton and anti- α



Updated RHIC 5-Year Run Plan

Assumes sufficient ops. funding for healthy 2-species run each year; aimed at meeting NP Performance Milestones on schedule; will be updated as we have definitive information about upgrade schedule and/or budget changes

Year	Likely Beam Species	Science Goals	New Detector Sub-systems	New Machine Upgrades	Gain from Machine Upgrades	Comments
FY10 	Au+Au at 200, 62.4 GeV + assorted lower E	Low-mass dilepton spectrum; early collision temp.; improved jet quenching studies (especially e^- from heavy quarks); begin energy scan for critical pt.	STAR TOF completed; PHENIX HBD for heavy ions	Blue ring longitudinal + yellow and blue vertical stochastic cooling; yellow longitudinal cooling (μ wave link) upgrade	Factor >2 increase in average store luminosity for full-energy Au+Au	Need 4-8 weeks early in run to (re)commission all 4 stoch. cooling systems, demonstrate gain in lumi. lifetime
FY11	200 GeV Au+Au; 500 GeV p+p; short 200 GeV U+U; continue low-E Au+Au scan	Bottom vs. charm suppression, flow; antiquark pol'n from W production; 1 st characterization of deformation effects in U+U centrality distrib'ns; continue critical pt. search	PHENIX VTX engineering run; AnDY installed, commissioned in IP2	EBIS commissioning; 9 MHz cavity; RHIC beam dump; AGS tune jump quads (comm'd in Run 10); RHIC spin flipper	U beam capability; improved pp vertex distrib'n; improved pol'n from AGS; reduced syst. errors	9MHz requires upgrade to main PS + "bouncer" cavity for both rings + longitudinal damper or Landau cavity for each ring.

Year	Likely Beam Species	Science Goals	New Detector Sub-systems	New Machine Upgrades	Gain from Machine Upgrades	Comments
FY12	Au+Au and U+U at 200 GeV; 500 GeV p+p	RHIC-II HI goals: heavy flavor, γ -jet, quarkonium, multi-particle correlations; anti-quark and low-x gluon polarizations in proton	PHENIX FVTX and μ trigger ; PHENIX DAQ/trig upgrades; STAR FGT	Full yellow + blue horiz. stoch. cooling (6 planes in all);	Further heavy-ion luminosity improvements + improved proton polarization	“Proton cannon” increases pol. source current, to allow scraping to improve polarization
FY13	200 + 500 GeV p+p ; further heavy-ion running to complement earlier runs	Continue RHIC-II heavy-ion goals; transverse spin asymmetry for Drell-Yan (2015 spin milestone) ; pp reference data for new subsystems	STAR HFT prototype	Polarized source upgrade ; Electron lenses	improved pp luminosity	Electron lens commissioning \Rightarrow Run 13 gains possible ; detailed collimator upgrade plans still to be developed
FY14	200 GeV Au+Au; low-E Au+Au dictated by Run 10+11 results	Continue pursuit of γ + jet, energy scan and identified heavy flavor (DM10-12) milestones; quarkonium prodn	STAR HFT pixel det. (full HFT in Run 15); 50% STAR MTD ?	RHIC collimator upgrade; 56 MHz SRF ; coherent e-cooling install starts in IP2	Full RHIC-II heavy-ion luminosity + improved vertex & store length	

Plans and Upgrades for Coming ~5 Years Address All New RHIC-Related Performance Milestones...

Year	#	Milestone
2013	HP8	Measure flavor-identified q and \bar{q} contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12 (update of HP1)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering
2014	DM9 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
2014	DM10 (new)	Measure jet and photon production and their correlations in $A \approx 200$ ion+ion collisions at energies from medium RHIC energies to the highest achievable energies at LHC.
2015	DM11 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ between 5 and 60 GeV to search for evidence of a critical point in the QCD matter phase diagram.
2016	DM12 (new)	Measure production rates, high p_T spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}} = 200$ GeV.

spin

Heavy ion

Making clear progress toward all the above!

Not all the exciting physics is yet incorporated in existing milestones...

For example:

- 1) *Does explanation of Local Parity Violating bubbles (and close analogy to speculated origin of baryon-antibaryon asymmetry at EW phase transition) hold up under more detailed scrutiny?***
- 2) *Can we observe predicted sequential melting of different quarkonium species in QGP?***
- 3) *Are gluon densities saturated in RHIC's colliding (cold) nuclei?***
- 4) *Can we produce even heavier anti-hypernuclei?***

PAC Recommendations from June 2010

Assuming 30 cryoweeks:

For Run 11 the PAC recommends the following (*in order of priority*):

1. 8 weeks Au+Au heavy ion running at 200 GeV
2. 10 weeks p+p polarized proton running at 500 GeV
3. 1.5 weeks Au+Au heavy ion running at 18 GeV
4. 1.5 weeks U+U heavy ion running at 192 GeV (Au rigidity)
5. 1 week Au+Au heavy ion running at 27 GeV

Should roughly match # weeks in each case, but fall short of pp lumi goal

Would not fit in 26-week run

With following recommended strategy:

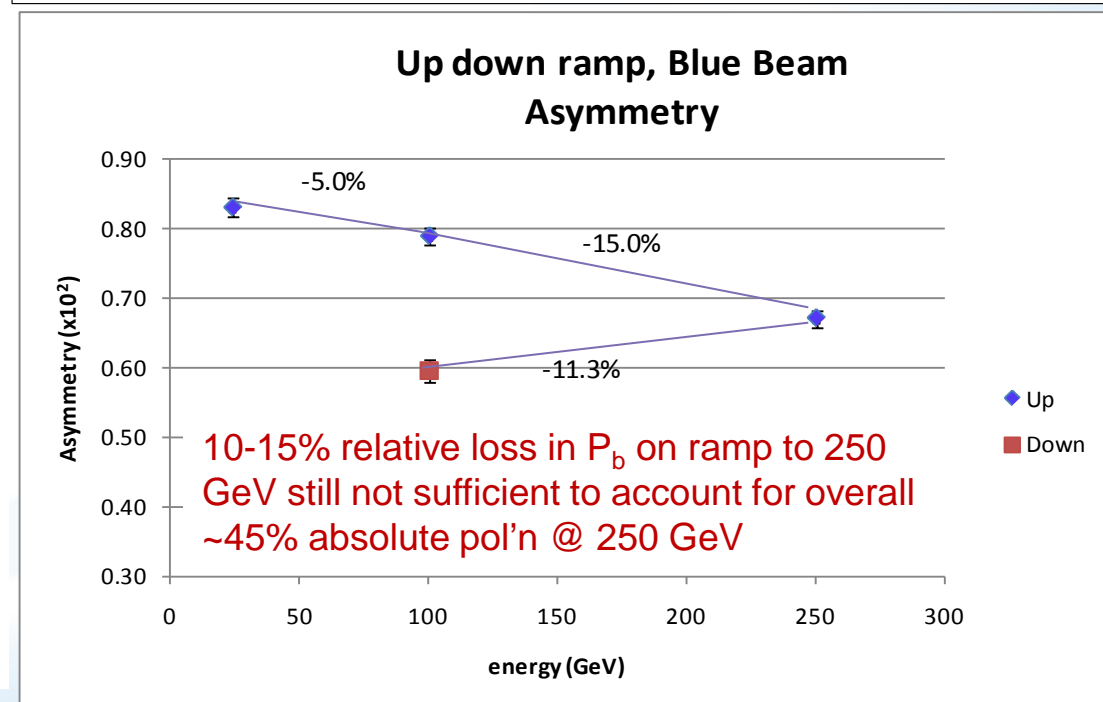
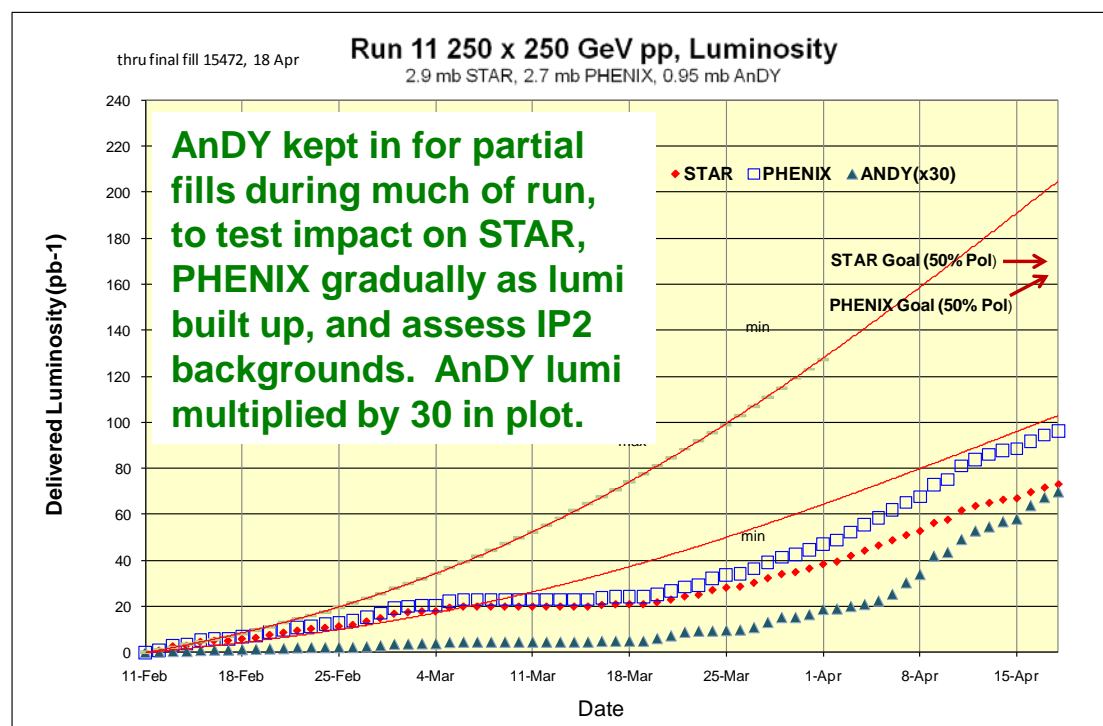
1. Run 11 should start with proton-proton collisions to allow low-multiplicity commissioning of the PHENIX VTX.
2. PHENIX must demonstrate during this commissioning period that successful operation of the VTX during full-energy Au+Au operation is likely.
- 3. If the likelihood of successful VTX operation in full energy Au+Au running is not demonstrated, the PAC recommends full energy Au+Au running be postponed until Run 12.**

With regard to DY asymmetry test (AnDY) in IP2:

The PAC encourages the collaboration to prepare a full proposal for the next PAC. As the first stage is less than a year away, we also endorse the commitment of 2-3 machine shifts in 2011 for testing the impact on PHENIX and STAR of collisions at IP2.

RHIC Run 11 Problems

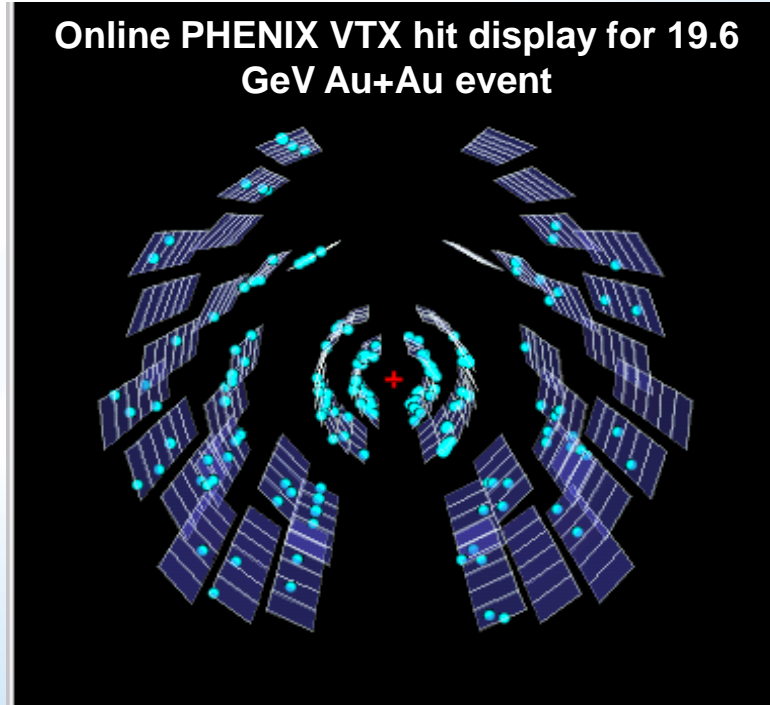
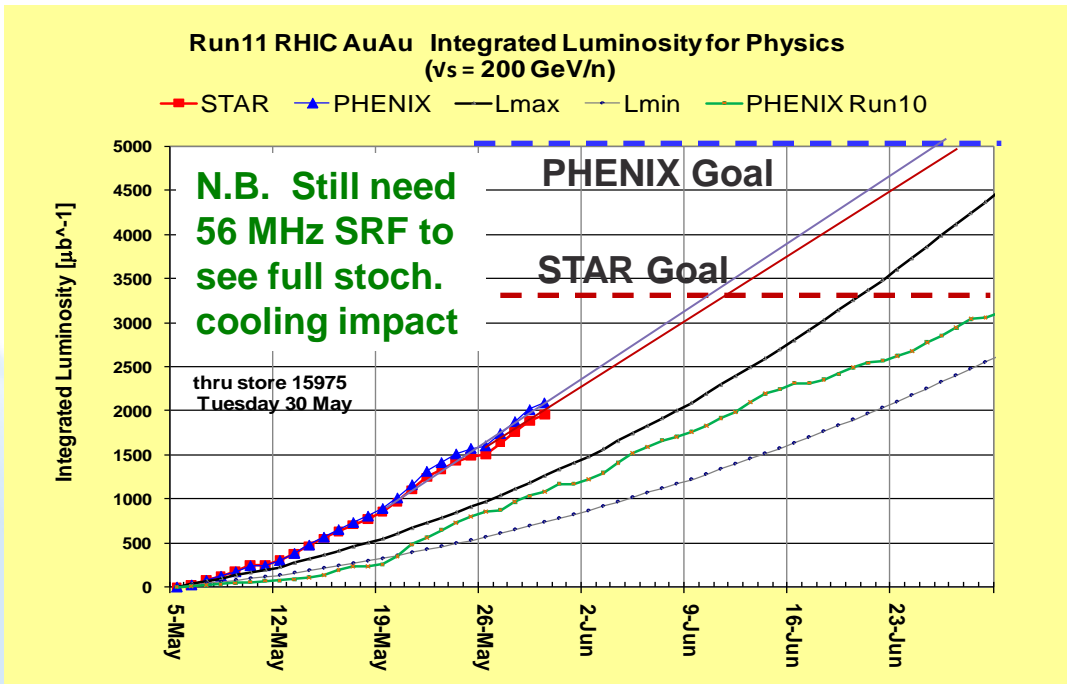
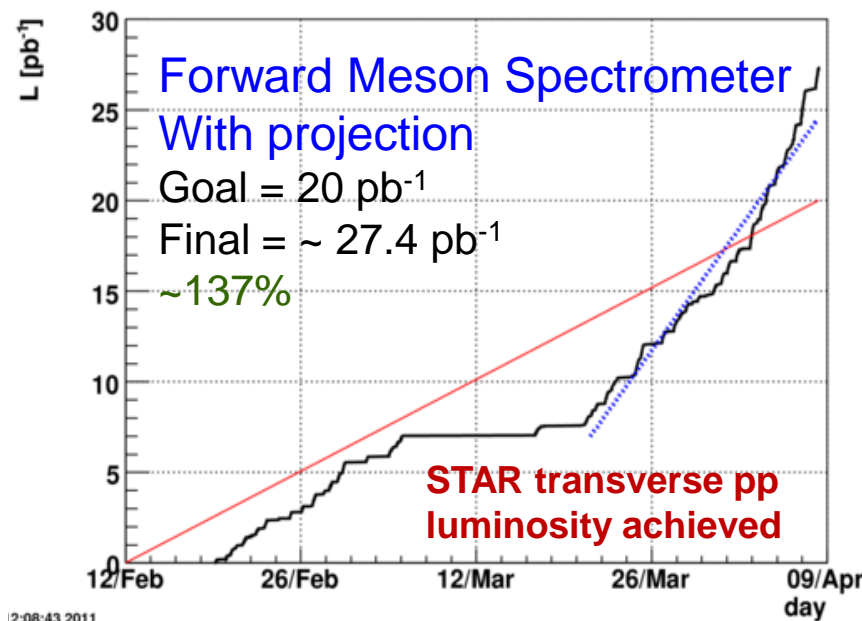
- *FY11 budget negotiations required continual reassessment of priorities, but finally supports 26 cryoweeks, thru end of June*
- *Start of run was delayed 1 month by VTX installation and AGS Access Controls relay fire*
- *10 days lost in March to failures in cryosystem power (breaker trip) and 13.8 kV power for AGS (underground cable damage)*
- *pp luminosity buildup slowed by hardware failures, leaving exp'ts far short of lumi goals*
- *Beam polarization was improved from Run 9, but still suffered from loss on ramp from 100 to 250 GeV*



RHIC Run 11 Achievements

- Improved P_b ~33% relative to Run 9, incl. better pol'n from AGS + orbit feedback in RHIC
- Achieved ~75% of peak enhanced design lumi for 500 GeV pp, late in run with 9 MHz
- Achieved STAR transverse and PHENIX & STAR *minimal* longitudinal spin physics goals
- Commissioned 9 MHz RF for pp and 4 retrofitted stochastic cooling planes for Au+Au
- Successful first use of PHENIX VTX detector
- Highly efficient Au+Au operation at 19.6 GeV and start at 200 GeV (ongoing)

FMSJP2



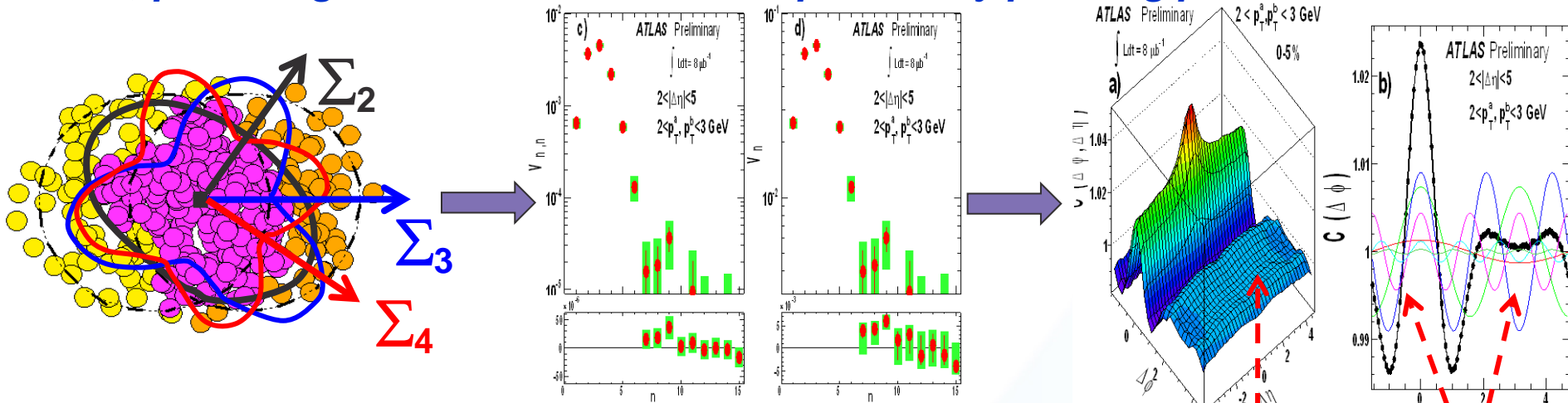
PAC/Experiment Guidance for Run 12/13 Plans

- *Clear priorities within 26 cryoweeks Run 12, 30 cryoweeks Run 13*
 - *President's FY12 request + const. effort would support 26 + 30 weeks, but anticipate Congressional cuts & long Continuing Resolution*
 - *2 weeks cooldown/warmup overhead + 2 weeks commissioning per colliding beam species run (~1-2 days for energy change)*
- *EBIS available for heavy ions, with tandem as backup in Run 12 only (still working to get EBIS beam intensity for Au to tandem level)*
- *Anticipate 6 stochastic cooling planes installed for Run 12, but not yet 56 MHz SRF system for ultimate Au+Au full-energy luminosity gain*
- *Use 50% as 250 GeV proton polarization goal for Run 12, until we understand better the remaining sources of polarization loss*
- *Electron lenses should be installed for commissioning in Run 13, but should not yet be counted on to improve pp luminosities*
- *AnDY impact on STAR & PHENIX luminosities, and improvements still needed to achieve useful AnDY luminosity, will be described in later talks. Remaining AnDY detector needs not yet funded. Coherent electron cooling exp't anticipated for IP2 starting in Run 14, but could be delayed by funding*
- *PHENIX FVTX and STAR FGT schedules both very tight for Run 12!*

Quark Matter 2011 (May 22-28) a Watershed:

Impressions and lessons learned:

1) Field is maturing – e.g., initial characterization of collective flow of matter via elliptic multipole only now replaced by full Fourier decomposition, providing natural account for two previously puzzling phenomena:



Similar results shown by all collaborations, should \Rightarrow better characterization of initial-state geometry fluctuations, hence quantification of fluid's "perfection."

But they reopen another question: does the medium respond collectively to the energy lost by quarks & gluons passing through it?

2) No fundamental new discoveries, but interesting, unanticipated results on \sqrt{s} -dependence of behavior from RHIC and on medium effect on jets from LHC

Quark Matter 2011 (May 22-28) a Watershed:

Impressions and lessons learned, continued:

3) RHIC's importance substantiated – the nature of the matter produced does not change much from RHIC to LHC collisions; LHC analyses very rapid since based on techniques already perfected over years at RHIC.

4) The power and scope of the LHC exp'ts is very clear! The broader momentum range and higher multiplicity of outgoing particles, the higher-energy emerging jets, the finer granularity of some subsystems – all allow prolific characterization of QGP matter very similar to that at RHIC. On the other hand, probably only one more Pb+Pb run at LHC before 2015.

5) Watch out especially for CMS, which may well dominate future jet and quarkonium analyses (without DOE support for ATLAS heavy ions)!

6) Excellent presentations by 5 strong collaborations, with mostly corroborative results ⇒ a heady, but not long-term sustainable, experience!

7) Challenge for RHIC: give greatest emphasis in future plans to exploiting those capabilities that are unique or world-leading at RHIC !

Today's Agenda:

Room 2-160, Bldg. 510 (physics)

8:30 PAC Executive Session

Large Seminar Room, Bldg. 510 (physics)

9:00 Run 11 as achieved, plus guidance for Runs 12+13 (S. Vigdor, 25+5)

9:30 Machine performance and projections (W. Fischer, 30+10)

10:10 Coffee break

10:30 PHENIX Beam Use Proposal (B. Jacak, 40+20)

11:30 STAR Beam Use Proposal (N. Xu, 40+20)

Room 2-160, Bldg. 510 (physics)

12:30 Lunch + PAC Executive Session

Large Seminar Room, Bldg. 510 (physics)

14:00 AnDY Beam Use Proposal (L. Bland, 25+15)

14:40 Summary of Drell-Yan spin workshop (E. Aschenauer, 25+5)

15:10 Status report on proton EDM proposal (Y. Semertzidis, 30+10)

*For PAC info
– comments
welcome, but
no action
needed*

Room 2-160, Bldg. 510 (physics)

15:50 PAC Executive Session

More on Decadal Plan evaluations and context tomorrow morning...

Backup Slides

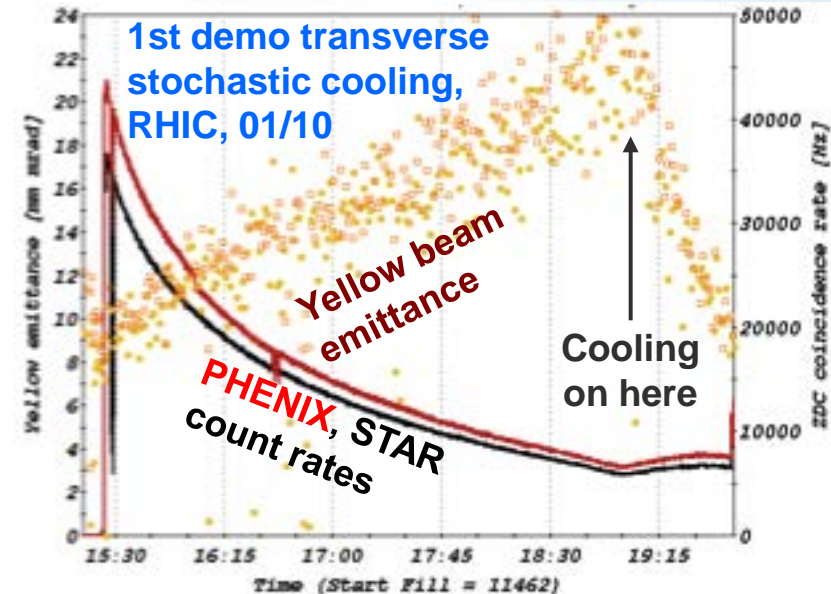
Charge for June 6-8 PAC Review of Decadal Plans

- 1) Are the science goals in each Plan well-posed and compelling? Are there important questions addressable with RHIC's capabilities (perhaps after minor upgrades) that you find missing from the Collaboration's list?
- 2) How well do the suggested measurement programs answer the highlighted science questions? Are there additional simulations or theoretical work that would strengthen the case for making those measurements?
- 3) Are the suggested measurement techniques and upgrades essential for answering these questions? (For example, can some questions be adequately answered by high- p_T hadron detection without full jet reconstruction?)
- 4) Is the complementarity of the proposed RHIC program and of LHC heavy-ion capabilities clearly defined and convincing? If not, what would it take to clarify complementarity?
- 5) Do the measurements proposed with polarized beams constitute a compelling extension of the RHIC Spin Program, achievable with anticipated integrated luminosities?
- 6) Do the plans and proposed detector upgrades provide the basis for a useful transition of each Collaboration to an era with substantial focus on ep and eA collisions at an eRHIC?
- 7) How would you rank the priority (high, medium or low) of each proposed upgrade, taking into account both scientific and technical merit and rough estimates of cost?
- 8) Does the suite of proposed measurements justify RHIC operations beyond ~2017, assuming RHIC-II luminosities? If not yet, how can the case be strengthened?

FY10 RHIC Run Plan (as of 11/25/2009)

$\sqrt{s_{NN}}$ (GeV)	Physics prod'n/beam studies weeks		Weeks achieved / science goals met?
	25-cryoweek run	27-cryoweek run	
200	10	10	10.5 / ✓
62.4	4	4	2.9 / ✓+
39	1.5	1.5	1.9 / ✓++
27	0	0	Outstanding collider & detector performance!
18	0	0	
11.5 @ STAR	0	2	1.5 / ✓+
7.7	4	4	4.7 / ✓
Beam studies @ 5 GeV and @ $v \approx 0.67$	0.5	0.5	0.5 / ✓

- *Improve high-E Au+Au statistics, esp. for e^+e^- studies with PHENIX Hadron Blind Det.*
- *Launch low-energy scan searching for evidence of QCD critical endpoint*
- *Commission 4 planes stochastic cooling*
- *Carry out beam tests relevant to improve polarized pp performance in FY11*



Upcoming and Recent Planning Exercises and Milestones

April 10, 2011: **3rd EIC International Advisory Committee meeting**

May 9-10, 2011: **Detector Advisory Committee review of first round of submitted EIC detector R&D proposals**

June 6-8, 2011: **PAC review of PHENIX & STAR Decadal Plans**

June 21-24, 2011: **RHIC user workshop to develop optimal RHIC strategy going into LRP**

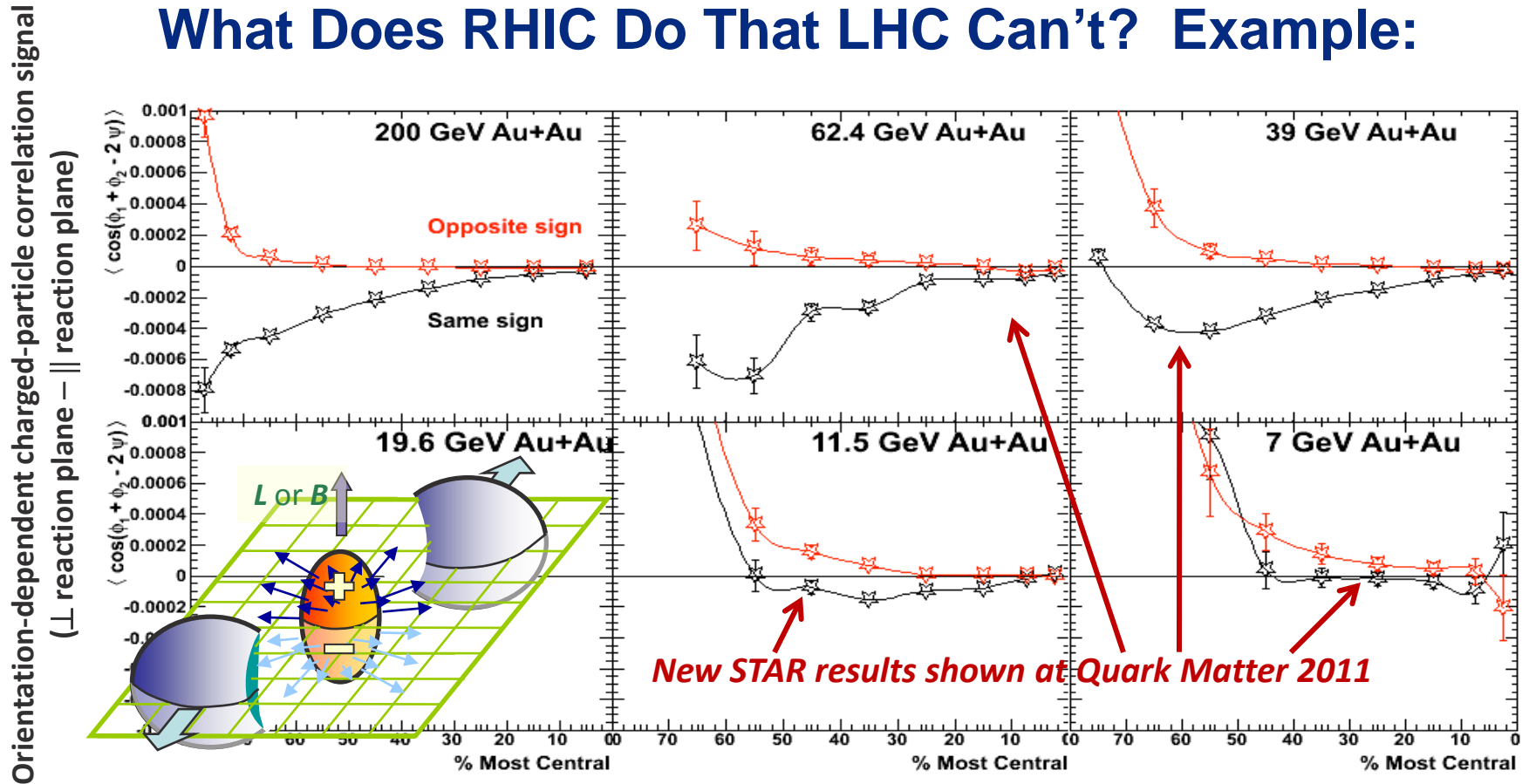
June 27-29, 2011: **RHIC annual S&T review with 'all-star' panel**

August 1-3, 2011: **eRHIC technical design review**

Fall 2011: **EIC science White Paper (Steering Committee appointed and charged, with BNL-JLab-EICC agreement); eRHIC cost review**

Fall 2012 (??): **Town Meetings for next Nuclear Physics LRP? ⇒ Formulate RHIC strategy clearly by Summer 2012, presumably by time of August 2012 Quark Matter in Washington, D.C.**

What Does RHIC Do That LHC Can't? Example:



- P -, CP -violating “bubbles” should \Rightarrow “EDM”-like correlation, with characteristic orientation, charge, E -dependence; \cong signals @ 2.76 TeV & 200 GeV
- New E -dep. results above \sim consistent with predictions, suggest onset of deconfinement within RHIC energy range; test further with EBIS U beams
- Analogous to speculated B -violation in “bubbles” at EW phase transition, possible origin of matter-antimatter asymmetry in infant universe
- Bottom line (also supported by other observations): RHIC in “sweet spot” in energy, able to test early-universe behavior due to machine’s versatility

What are RHIC's Unique Capabilities?

- *Beam energies spanning apparent onset of deconfinement and chiral symmetry restoration*
- *Polarized proton beams*
- *d+A, possibly p+A, collisions; other asymmetric combinations?*
- *Uranium beams, ability to explore deformation effects on behavior*
- *Low-mass di-electron detection for temperature measurement and chiral symmetry studies*
- *Reconstruction of jets below ~50 GeV, where effect of lost energy on the medium may become more revealing than just heating the plasma*
- *Transition to eRHIC -- but on what time scale?*

