RHIC Experimental Program And Detector Upgrades

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RHIC S&T Review

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Office of Science
U.S. DEPARTMENT OF ENERGY

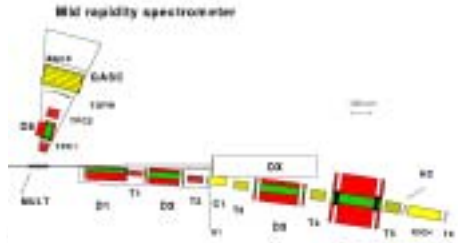
BROOKHAVEN NATIONAL LABORATORY

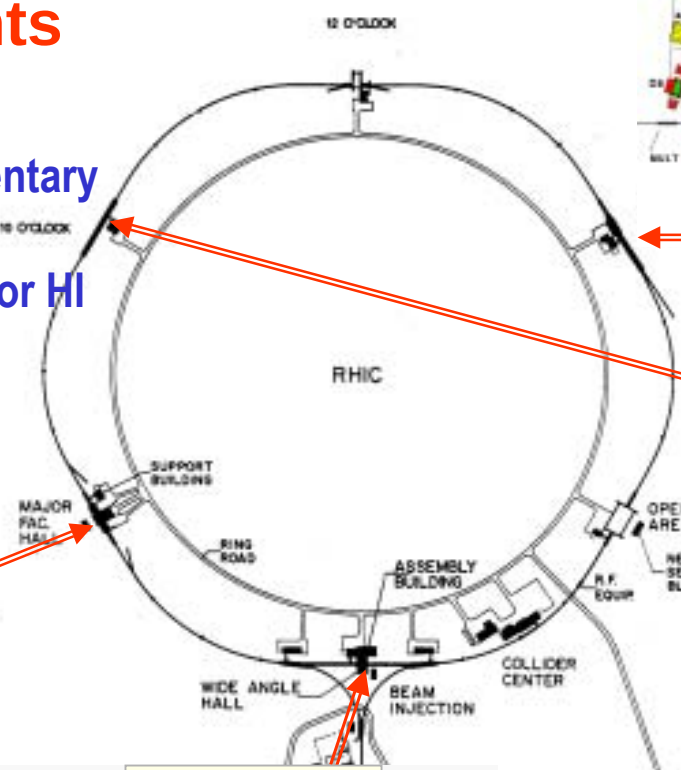
Brookhaven Science Associates
U.S. Department of Energy

The RHIC Experiments

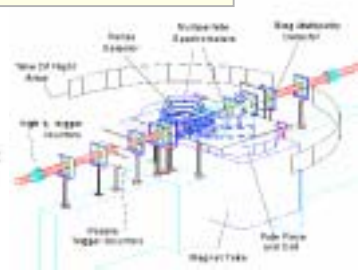
Overall strategy:

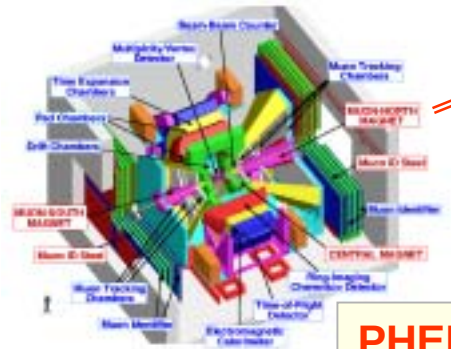
- 2 Large, general purpose, complementary
- 2 Small, focused, quick response
- Same detectors and collaborations for HI and spin measurements





PHOBOS





PHENIX

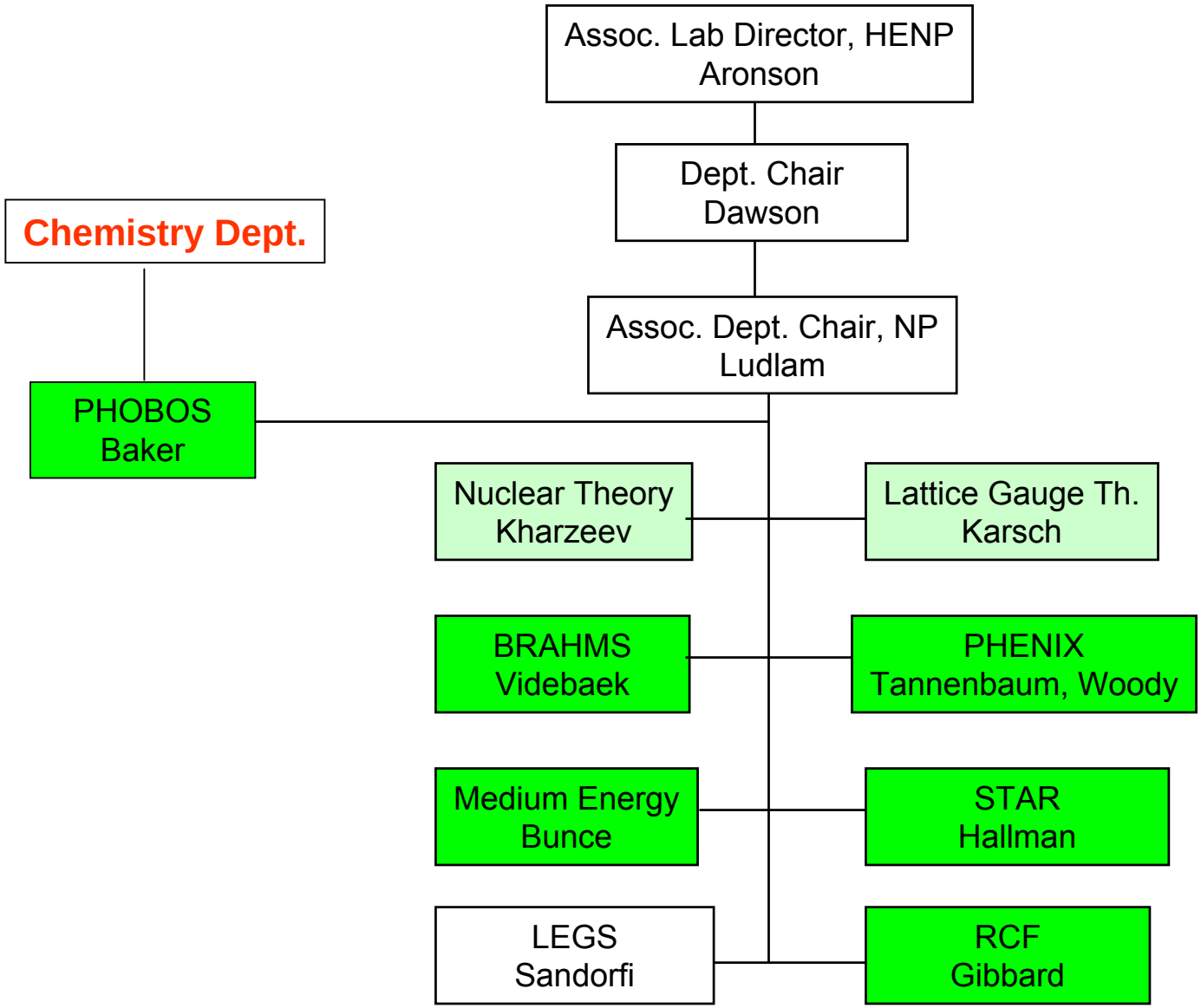
STAR

Initial investment:

- ~$120M US DOE
- ~$45M non-US collaborators

>1000 users
57 Institutions
20 Countries

BNL Physics Department: Nuclear Physics Organization



Summary of RHIC Runs 1-5

Delivered Luminosity; Physics Weeks

Year	Run Plan	Sample	Physics
2001	Au-Au at 130 GeV/A	20 μb^{-1} (6 wks)	First look at RHIC collisions
2001 – 2002	Au-Au at 200 GeV/A Commission/run pp at 200 GeV Au-Au at inj. E: 19 GeV/A	260 μb^{-1} (16wks) 1.4 pb^{-1} (5 wks) 0.4 μb^{-1} (1 day)	Global properties; particle spectra; first look at hard scattering. Comparison data and first spin run Global connection to SPS energy range
2003	d-Au at 200 GeV/A pp at 200 GeV	74 nb^{-1} (10wks) 5 pb^{-1} (6 wks)	Comparison data for Au-Au analysis; low-x physics in cold nuclear matter Spin Development & Comparison data
2004	Au-Au at 200 GeV/A Au-Au at 62 GeV/A pp at 200 GeV	3740 μb^{-1} 12wks 67 μb^{-1} (3wks) 100 pb^{-1} (7wks)	"Long Run" for high statistics, rare events Energy Scan Spin Development: Commission jet target First measurements with longitudinal spin pol.
2005	Cu-Cu at 200 GeV/A Cu-Cu at 62 GeV/A Cu-Cu at 22 GeV/A pp at 200 GeV pp at 410 GeV	42 nb^{-1} 8wks 1.5 nb^{-1} 12 days 18 μb^{-1} 39 hrs 30 pb^{-1} 10 wks 0.1 pb^{-1} 1 day	Comparison studies: surface/volume & impact parameter effects; Energy Scan Spin Development: Lum., Polarization First long data run for spin

RHIC Computing Facility...

Data Transfer and processing from all four experiments.

FY 2005 capacity

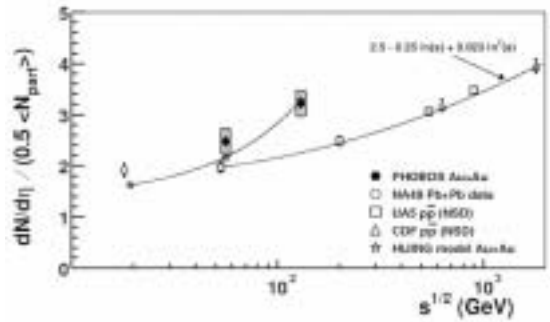
- Mass Storage System:
  - 4 StorageTek robotic tape silos **~4.3 PBytes**
  - 37 StorageTek 9940b tape drives **~ 1.1 GB/Sec**
- CPU:
  - 3400 CPU Intel/Linux processor farm
    ~2700 kSPECint2000 (~4 Tflops)
- Central Disk:
  - 220 Tbytes RAID 5 storage
  - 1.0 Gbyte/sec disk I/O capacity
  - 500 Tbytes distributed disk

Initial investment: ~$8M
Annual equip. funds of ~$2M for upgrades

Rapid Pace of Data Analysis and Discovery

Significant Contributions from each of the 4 experiments

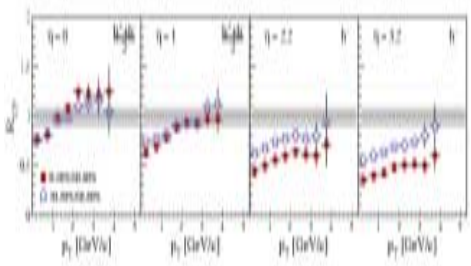
2000 First RHIC collision, June 12, 2000
Multiplicity data (PHOBOS) rule out most models



2001 High p_T suppression observed (PHENIX, STAR)
Observation of strong flow effects (STAR)

2003 Jet quenching confirmed, with d-Au control data
(PHENIX, STAR, PHOBOS, BRAHMS)

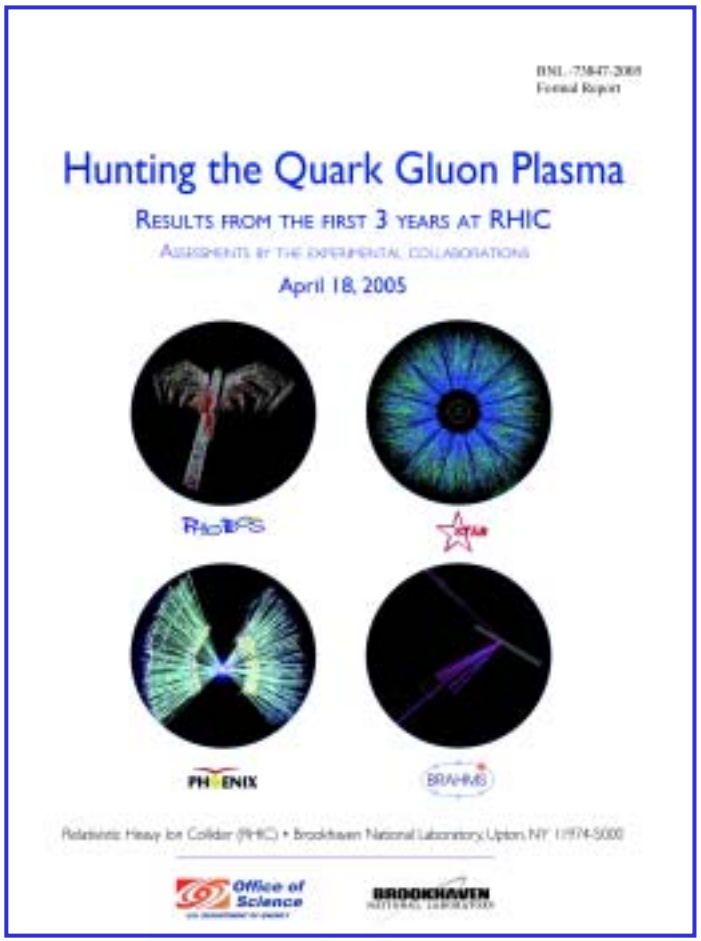
2004 Evidence for Color Glass Condensate effects at large y
(BRAHMS)

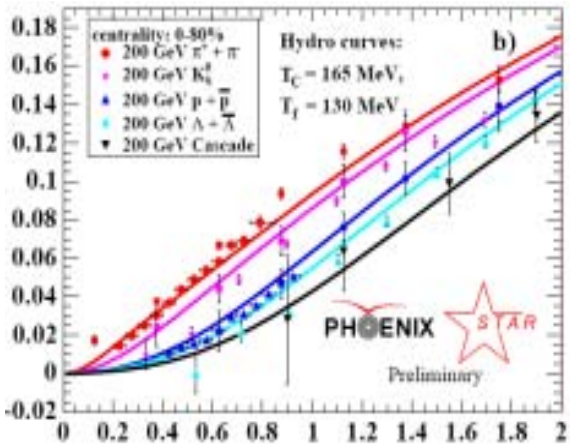


Summarizing 3 years of data and anlysis: The White Papers

Joint publication: Nuclear Physics A, August, 2005

Press Event: Tampa APS Meeting in April





A new view of high-temperature matter:
"Ideal" Hydrodynamics

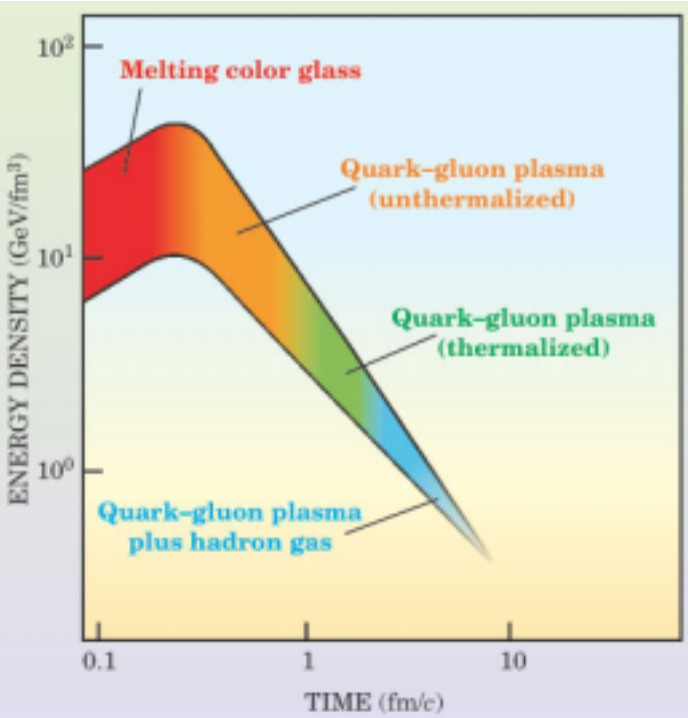
- Near-zero viscosity
- Very quick thermalization

"Perfect Liquid"

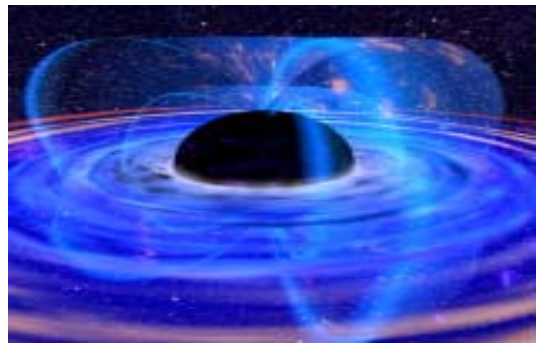
Strongly-coupled QGP = "sQGP"

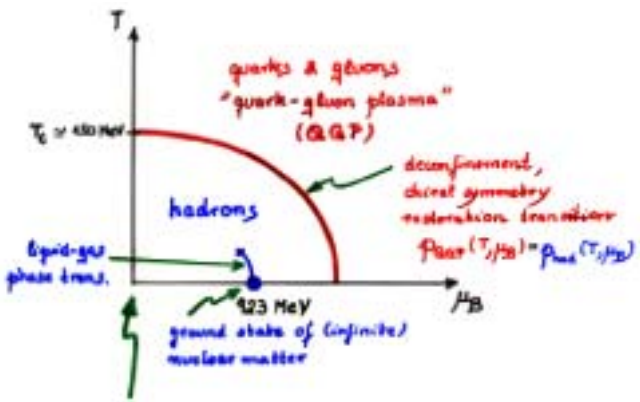
What, exactly, does this mean?
Vigorous debate among theorists and experimenters

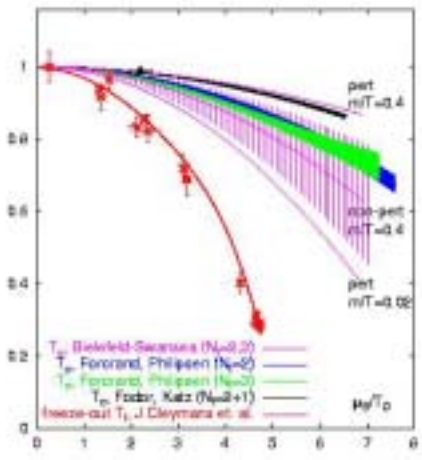
New Understanding of High Energy Density Matter at RHIC



We are beginning to get a quantitative picture of rich new phenomena in previously unexplored territory.







Scientific Planning for RHIC:

Physics priorities, Run planning, Upgrades

Major Planning Documents:

Decadal Plans: PHENIX, STAR, PHOBOS, BRAHMS

Submitted to BNL September, 2003

RHIC Twenty-Year Planning Study

Experiments, machine, RCF, Theory

Submitted to DOE January, 2004

Research Plan for Spin Physics at RHIC

Science Goals; Collider and Detector requirements

Submitted to DOE January, 2005

Documents on web at www.bnl.gov/henp

Annual Beam Operations Scenarios:

- Beam Use Proposals from Experiments
- Recommendations from Program Advisory Committee

Long Range Planning:

RHIC II Science Workshops: 7 on-going working groups; summary document ~Jan. 2006

www.bnl.gov/physics/rhicIIscience

eRHIC Workshops

Experimental Program: The Present Status

Heavy Ion Program:

Beginning detailed exploration of new forms of matter, with high statistics and improved sensitivity in STAR and PHENIX…

PHOBOS experiment has ended its run:

Local group initiating activity in PHENIX, ATLAS HI

BRAHMS may propose limited additional running:

Improved low-x measurements in d-Au collisions.

Add ALICE PHOS module for forward/backward photon detection.

Spin Program:

Nearing full capability for high-energy, high-luminosity, high-polarization Proton-proton collisions.

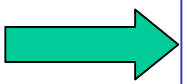
Many specific measurements require detector and luminosity upgrades

The Science Driving RHIC Upgrades

- **QCD at high temperature and density: What is the physics of superdense, strongly-interacting matter? QGP… sQGP**

- **QCD at high energy and low x: What is the physics of strong color fields? Color Glass Condensate**

- **QCD and the structure of hadrons: What is the origin of nucleon spin?**



Fundamental questions for experiment:

- Properties of QGP…sQGP
- Thermalization
- Deconfinement
- Connections with E-M plasma properties
- Properties of gluonic matter…Color Glass Condensate
- Gluon spin in the nucleon
- Polarization of the quark sea
- Transverse spin in QCD

Key Measurements Driving RHIC Upgrades

- High T QCD (AA, pA, and pp):
  - Electro magnetic radiation (e^+e^- pair continuum)
  - Heavy flavor (c- and b-production)
  - Jet tomography (jet-jet and photon-jet)
  - Quarkonium (J/ψ, ψ' , χ_c and $\Upsilon(1s), \Upsilon(2s), \Upsilon(3s)$)

requires highest AA luminosity

- Spin structure of the nucleon:
  - Quark spin structure $\Delta q/q$ (W-production)
  - Gluon spin structure $\Delta G/G$ (heavy flavor and γ-jet correlations)

- Low x phenomena
  - gluon saturation in nuclei (particle production at forward rapidity)

All measurements require upgrades of detectors and/or RHIC luminosity

Upgrading the detectors

Near-term goals (~next 5 years)

Heavy Ion Program:

- Particle ID over extended p_T range– Jet tomography; early-time hydro
- Extended EM calorimeter coverage – e, γ, π^0, jet– Quarkonium; Jet tomography
  Including forward physics: $1 < \eta < 3$ in A-A Low-x: $.001 < x < 0.1$ Color Glass
- High-resolution vertex tracking for charm– Test hydro properties of sQGP
- Dalitz rejection for low-mass e-pair spectrum-- Chiral transition; thermal radiation

Spin Program:

- Unambiguous I.D. for forward $W^{\pm}$ decay leptons
  PHENIX: high p_T single muon trigger
  STAR: forward tracking upgrade covering endcap cal.

Implementing a Detector Upgrade Program

Priorities set through major planning exercises: RHIC users & BNL

Evaluation by: Program Advisory Committee
Detector Advisory Committee

Construction Technical/Cost/Schedule monitored by:
BNL/DOE Technical Advisory Committees

On-going Detector R&D Effort: ~$1M/year

- GEM Development: Hadron blind detector; future tracking in STAR and PHENIX **BNL, Yale**
- HBD Development: Windowless, proximity-focused Cherenkov detector **BNL, Weizmann**
- Active pixel sensor: Next generation pixel technology **LBNL**
- Electronics Development: Vtx detectors, Si Cal; GEM **BNL, Iowa St., ORNL, Nevis, Stony Brook**
- Compact Si-tungsten calorimetry: nose cone calorimeter **BNL**
- MRPC detectors and readout: time of flight **Rice**

Proposed/Reviewed projects for the near term

PHENIX Hadron Blind Detector	~1.5M + NSF
STAR TOF Barrel	~$4.6M + China
PHENIX Si VTX Tracker	~$4.5M + Japan
STAR DAQ 1000	~$2M
STAR FMS Forward EM Calorimeter	~$0.8M NSF
PHENIX Forward Muon Trigger W boson decays	~$2M NSF

Planned Projects for the Longer Term

PHENIX Inner Tracker+FVTX	~$10-15M
PHENIX Nosecone Calorimeter Forward EM calorimeter	~$5-10M
STAR Microvertex Detector Heavy Flavor tracker	~$8-10M
STAR Forward Tracking Upgrade W boson decays	~$10-15M

RHIC Upgrades Overview

Upgrades	High T QCD…. QGP				Spin		Low-x
PHENIX	e+e-	heavy flavor	jet tomog.	quarkonia	W	ΔG/G	
Hadron blind detector	X						
Vertex Tracker	X	X	O	O		X	O
Muon Trigger				O	X		
Forward cal. (NCC)			O	O	O		X
STAR							
Time of Flight (TOF)		O	X	O			
MicroVtx (HFT)		X		X			
Forward Tracker		O			X	O	
Forward Cal (FMS)						O	X
DAQ 1000		O	X	X	O	O	O
RHIC Luminosity	O	O	X	X	O	O	O

X upgrade critical for success

O upgrade significantly enhances program

A. Drees 4/4/05

How to Realize these Upgrades?

Under reasonable budget scenarios, BNL's plan calls for continued detector R&D, as well as initiation of 1 or 2 MIE projects for both PHENIX and STAR in the period '06 – '08.

Consistent with June 2004 NSAC Subpanel, "Barnes Report", recommendations.

Important contributions from non-US collaborators, and National Science Foundation.

~30 new groups have joined PHENIX and STAR over the past four years, 11 from Europe, many involved with upgrades.

Staged implementation of upgrades over several years.

Detector Upgrades Timeline

Funding for RHIC operations at FY 2005 level

FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012

High statistics Au Au; 500 GeV Spin Runs

TOF and VTX construction; Muon trigger
+ “Small” upgrades: HBD, FMD, DAQ

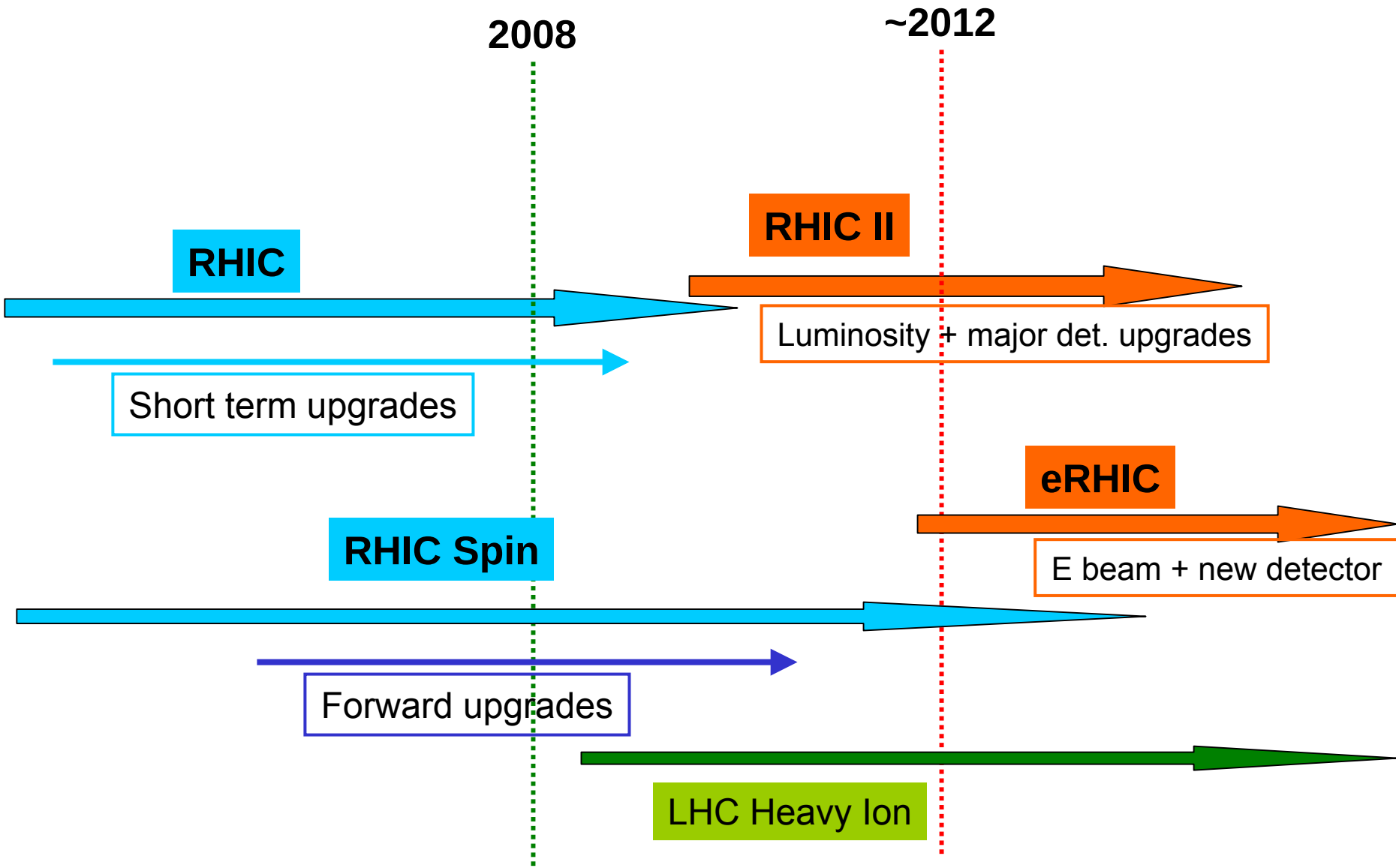
STAR HFT & PHENIX FVTX

Next Generation, RHIC II Upgrades
STAR Forward/Inner Tracker System
PHENIX Inner Tracker and Nosecone Cal
Other approaches?

RHIC Detector R&D

LHC Heavy Ion Program

A Long Term Strategic View



Summary

- The RHIC experiments have made important discoveries:
The landscape of high temperature, high density nuclear matter is no longer *Terra Incognita.*

- Further exploration will address fundamental questions in QCD:
  - The physics of high energy density matter… the Quark Gluon Plasma
  - The physics of strong color fields… the Color Glass Condensate
  - The spin structure of nucleons

- Upgrading the machine and detectors to address these questions is central to the planning and execution of the RHIC program…

Evolving from near-term upgrades to RHIC II and eRHIC