BNL 20-Year Plan, Cost and Schedule

NSAC Subcommittee on Heavy Ion Physics

BNL

June 2-6, 2004

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Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN
NATIONAL LABORATORY

Introduction

The Lab's planning for the next 20 years at RHIC

- Near term (2004 – 2008): Detailed run plan for RHIC
- Mid term: RHIC II
- Long term: eRHIC
- Leadership in RHI sustainable with Constant Effort funding through end of this decade
  - Big increase in productivity would result from a modest operations funding increase above the "constant effort" level
- New capabilities in A-A, p-A, $\vec{p}$-$\vec{p}$, $\vec{e}$-$\vec{p}$, e-A
  - Continued leadership in critical aspects of phase transition study
  - Broad-spectrum QCD facility

RHIC and National Planning

- RHIC is recognized in numerous government planning efforts
  - "Connecting Quarks with the Cosmos," National Academy Press (2003)
  - "Facilities for the Future of Science," DOE-OS (2003)
  - "Office of Science Strategic Plan," DOE-OS (2004)
  - "Physics of the Universe," OSTP (2004)

* DOE and NSF will develop a scientific roadmap for the luminosity upgrade of the The Relativistic Heavy Ion Collider (RHIC) in order to maximize the scientific impact of RHIC on High Energy Density (HED) physics.

The Planning Process

- Ongoing process
- Focused planning effort in 2003 by BNL in concert with the RHIC user community
  - The resulting report was delivered to DOE-NP 12/31/03:

*"Twenty-Year Planning Study for the Relativistic Heavy Ion Collider Facility at Brookhaven National Laboratory"**

* *http://www.bnl.gov/henp/docs/20year_BNL71881.pdf*

  - The planning group:

Convenors: T. Kirk, T. Ludlam

PHENIX	STAR	PHOBOS	BRAHMS
G. Bunce A. Drees E. O'Brien W. Zajc	W. Christie T. Hallman R. Majka S. Vigdor	M. Baker G. Roland P. Steinberg	F. Videbaek J.H. Lee
Accelerator	**Theory**	**Computing**	**PAC/DAC Invited**
J. Alessi I. Ben Zvi W. Fischer P. Pile V. Ptitsyn T. Roser	D. Kharzeev W. Vogelsang	B. Gibbard T. Throwe	R. Betts P. Jacobs S.-Y. Lee J. Nagle

Ex Officio: S. Aronson, D. Lowenstein, P. Paul

The Near Term: 2004-2008

- Critical science goals for RHIC
  - Follow up on the watershed results of the first RHIC runs by making **definitive experimental statements** on the **existence of the quark gluon plasma and determining its essential properties**
  - Obtain spin-polarized p-p data samples of sufficient sensitivity to **address the core physics questions** of the **RHIC spin** program, including direct determination of the **spin-dependent gluon structure functions**

Minimal program to meet the critical goals

- The Planning Group put forth the following run plan to address these two goals:

Heavy Ions	Physics Data Goals for Experiments
1.	A 200 GeV Au Au run (>300 μb^{-1}) in 2004 to follow-up on high p_T results, and get the first sizeable sample of J/ψ. ✓
2.	Energy dependence: Au Au at 1 or 2 lower energies. 50-100 μb^{-1} total ✓
3.	Species dependence: 1 – 2 lighter ions at 200 GeV. 3-6 nb^{-1} total
4.	A long Au Au run at 200 GeV in 2007 or 2008, with upgraded detector capability for open charm and particle i.d. at high p_T (≥2000 μb^{-1})
Polarized Protons	
1.	15-20 weeks of "development" in 2004 – 2005 (this would include physics data, but is required primarily to get the luminosity and polarization up to required levels). ✓
2.	Full-capability spin data at 200 GeV. ≥150 pb^{-1}

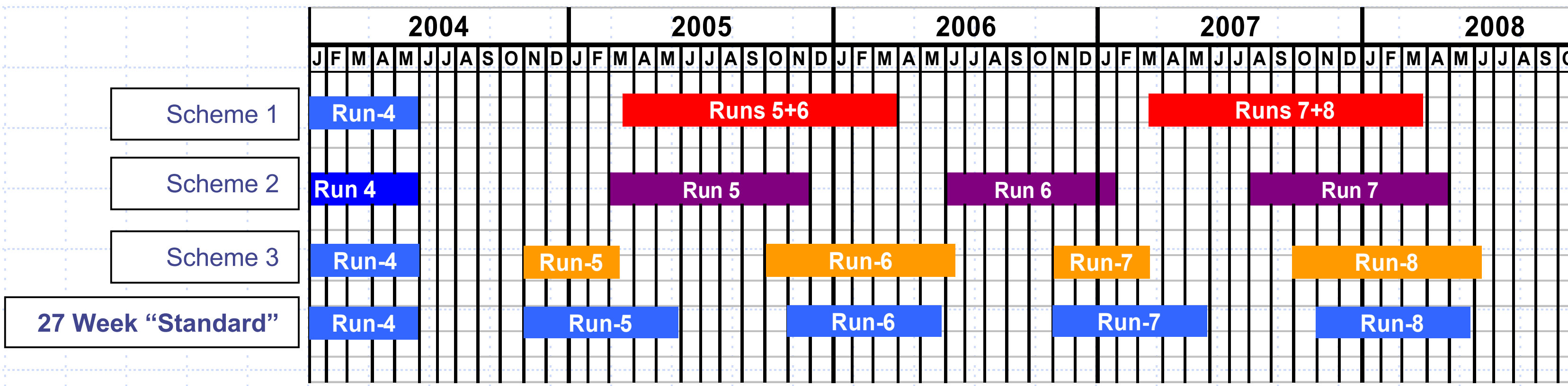
- Some important measurements didn't make minimal list
  - e.g., more d-Au, more species and energy dependence, p-p @ 500GeV

Planning to meet the near term goals

- The President's FY 2004 budget and constant effort in the future → 27 weeks of cryo-operations/year
  - 3 weeks of cool-down & warm-up
  - 5 weeks of set-up & tuning per configuration
    - Example: 1 configuration (e.g., Au-Au@$\sqrt{s}$=200) → 19 weeks of stable physics operation
    - Example: 2 configurations (e.g., Au-Au and $\vec{p}$-$\vec{p}$) → 14 weeks of stable physics operation, split between the two configurations
  - Projected luminosity ranges based on experience
- The planning group considered how to optimize the productivity of the program under these constraints

The Near Term Run Plan - conclusions

- Cadence: no gain from departing from the standard plan



- 27-week runs are inefficient
  - 2 configurations: 14 of 27 wks available for stable physics runs
  - Hard to integrate A-A luminosity ***and*** develop the Spin program
- The corollary is that a little extra goes a long way
  - 32-week runs are a dramatic improvement over 27-week runs

Revising the Run Plan

- Annual implementation of the plan responds to
  - Physics drivers
    - Previous accomplishments, new physics directions, new detector capabilities
    - Experiments' Beam Use Proposals
  - Evolution of machine performance expectations
  - Funding
    - Operations costs = large base cost + somewhat non-linear incremental costs
    - Small funding changes = significant operations changes
      - Example 1: +3% funding → + 5 weeks running
      - Example 2: flat-flat –5% funding → switch to back-to-back runs across FY boundaries (~30 weeks every other year) → productivity of the program cut ~ in half

Near Term Upgrades

- The constant effort near term plan also includes
  - R&D for machine and detector upgrades (on all time scales)
    - Included in the Operations budget
    - Inclusion can have important consequences
  - Partial funding for near term upgrades
    - Annual Operations Equipment funds used to
      - Build “modest” (<$3M) upgrades (e.g., PHENIX aerogel)
      - Supplement Research (a.k.a. Competitive) Capital to start upgrades when technically ready (e.g., EBIS, VTX, TOF)

Detector R&D and Upgrades

Detector Advisory Committee

- Standing committee with a strong scientific and technical membership to evaluate new initiatives and progress in evolving the detectors and advise BNL management

  Peter Braun-Munzinger (chair) - GSI

  Russell Betts – UIC

  Carl Haber – LBL

  Rick Van Berg – Penn

  Don Geesaman – ANL

  Berndt Mueller – Duke

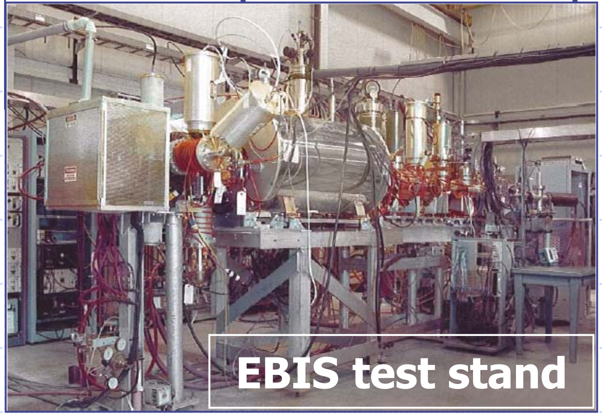
  Jerry Va'vra – SLAC

Near Term R&D and Upgrades

- Detectors
  - R&D: $1 to 2M/year through FY 07
    - FY03: $700k → 0 → $200k at year end
    - $1M in FY04, at least $1M in FY05
  - Fabrication: $4M/yr Operations Equipment funds
    - Aerogel Cherenkov counter + TOF; HBD (PHENIX)
    - New TPC FEE (STAR)
    - Trigger, DAQ and Computing upgrades (all + RCF)
  - Proposed MIE projects: STAR TOF, MVTX PHENIX VTX, FVTX
- Machine
  - AIP: $2M/year →E-cooling R&D
  - Proposed MIE project: EBIS

Electron Beam Ion Source

- Linac-based pre-injector for RHIC – replaces tandems
  - Simple, modern, low maintenance → Lower operating cost
  - Can produce any ions (U, He3↑)
  - Fast switching between species
  - Expect future improvements to lead to higher intensities



EBIS test stand

	RHIC Requirements	Achieved
E-beam current	10 A	10 A
E-beam energy	20 keV	20 keV
Yield of pos. charges	5.5×10^{11} (Au, 10 A, 1.5m)	3.2×10^{11} (Au, 8 A, 0.7m)
Pulse length	$\leq 40\ \mu s$	$20\ \mu s$
Yield of Au^{33+}	3.4×10^{9}	$> 1.5 \times 10^{9}$

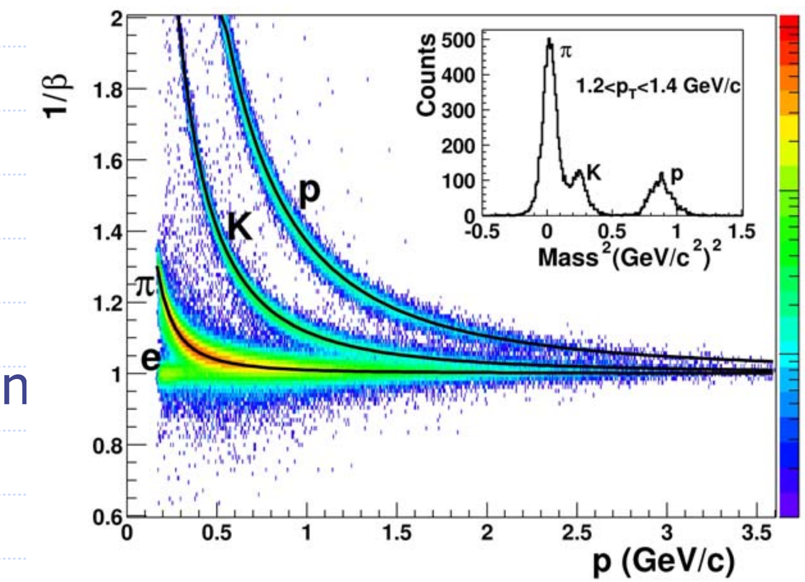
  - Could be built for $17.5M over 3 years, starting in '05/06
  - Recent positive developments
    - Working with DOE on CD0
    - NASA planning 25% contribution to construction cost

Subcommittee questions on EBIS

- The C-AD R&D line is funded at $2.0M per year. Our understanding is that this primarily is to fund the electron cooling R&D program. Is that correct? Is it sufficient, in light of the issues raised in the recent review? Are there other accelerator-related R&D needs before 2010 that are not included in the constant effort budget?
- There are BNL LDRD and US Navy JTO funds that are also being applied (Total = $750K per year over the past 2 years). There are no other R&D areas that are not included.
- This budget proposes to fund the EBIS project with $7.5M in MIE funds, and the rest (~$10M) through AIP. The latter nearly exhausts the additional anticipated C-AD equipment funds over the next three years. Are all other planned accelerator improvements during this period, e.g. to improve proton beam polarization and/or luminosity, included within the constant effort budget?
- There are some AIP funds and staff that are supported by operating funds that will be applied. We expect at least ~$7-8M of new DOE funds and ~$5M of NASA funding for EBIS. The plan previously presented to DOE is in a state of flux because of the new NASA funding initiative.

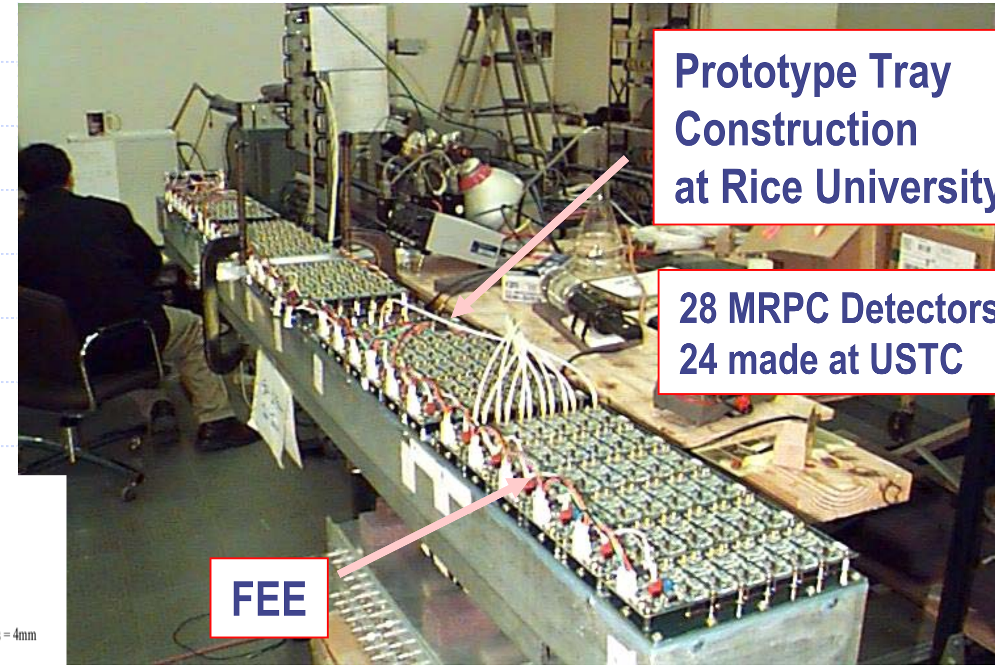
STAR Barrel Time of Flight Detector

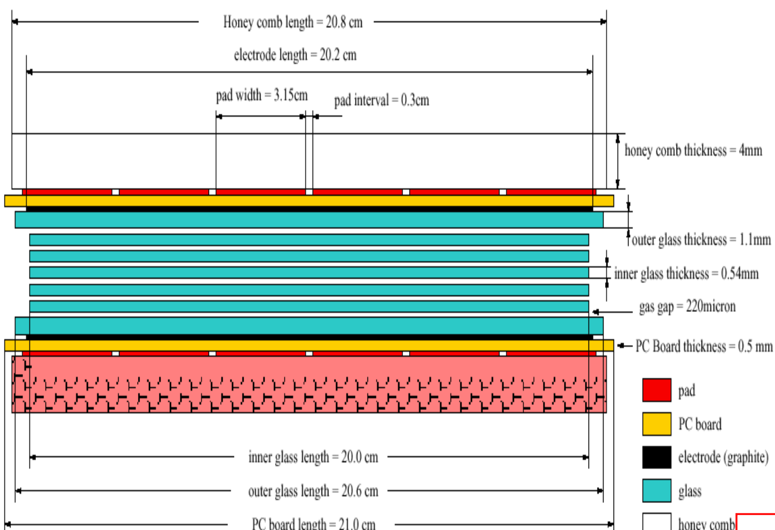
- Full barrel coverage of hadronic PID to higher p
  - Extend the p_t reach to for measuring resonances to 1-2 GeV/c
  - Improve the rate of measuring open charm and heavy baryon flow by factors of 5 to 10
- Prototyping and Construction
  - MRPC technology has been well tested
  - A full prototype was used to take data in STAR last year
  - Three year construction period could start in FY 2005
  - $5M DOE cost (+ $2M contribution from China)



STAR Barrel TOF MRPC prototype

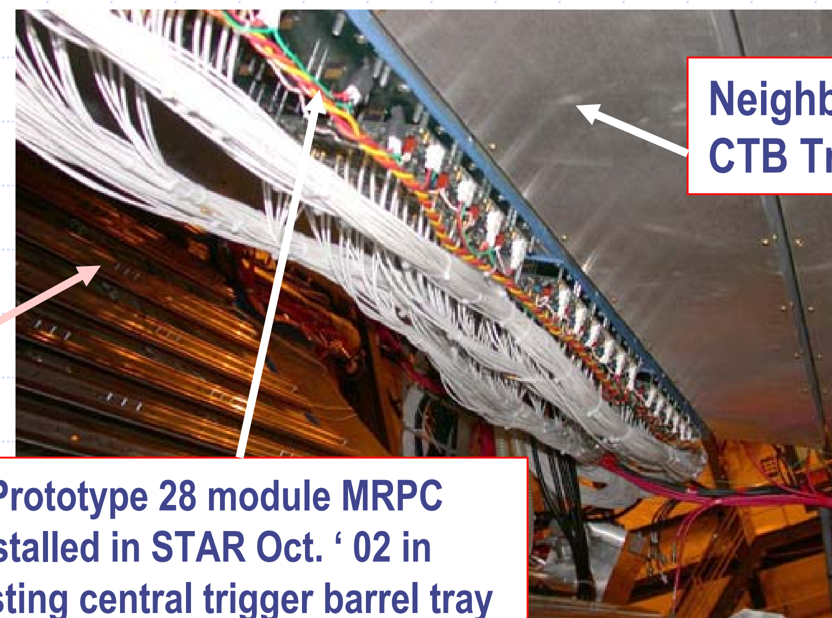
- MRPC design developed at CERN, built in China





σ ~ 70 ps, 2 meter path

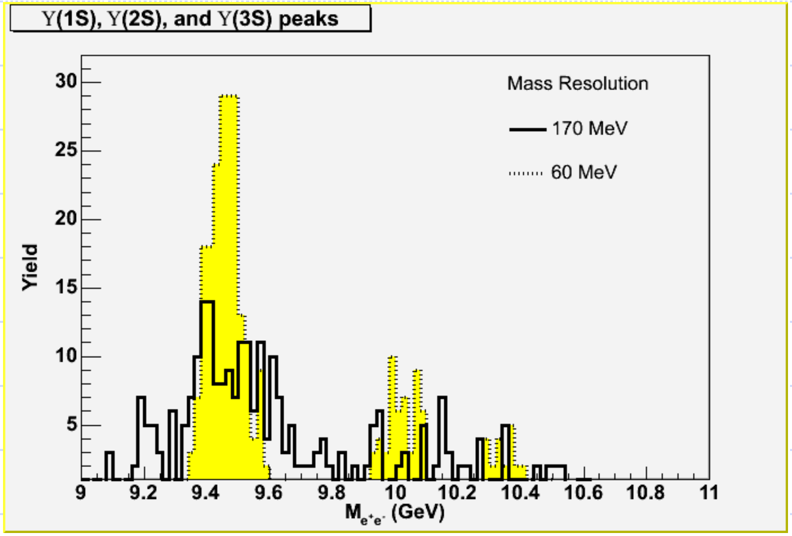
Strong team including 6 Chinese Institutions in place



Completed Prototype 28 module MRPC TOF Tray installed in STAR Oct. ' 02 in place of existing central trigger barrel tray

PHENIX Barrel Si Vertex Tracker

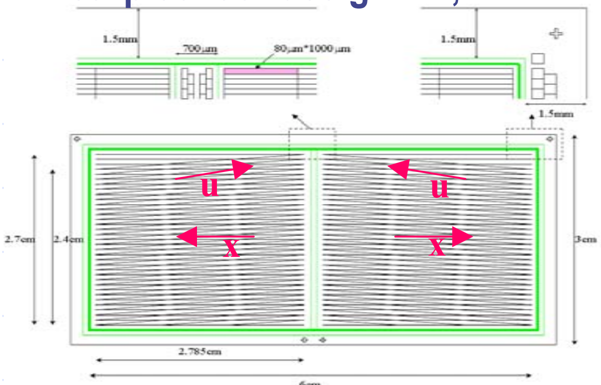
- Si pixels + stripixels (4 layers) covering ($|\eta| < 1.2$) with vertex tracking at a resolution of <50 μm
  - provide precision measurements of heavy-quark production (charm and beauty) in *A+A*, *p(d)+A*, and polarized *p+p* collisions
- R&D and design
  - A large PHENIX sub-collaboration is vigorously pursuing R&D
- Construction
  - A three-year construction period could start in FY05-06
  - $6M DOE cost (+$3M contribution from Japan)



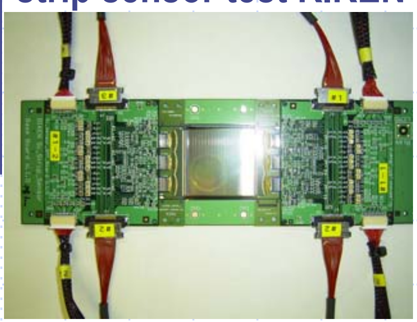
1/nb Upsilon spectrum w/ and w/o VTX

PHENIX VTX R&D Program

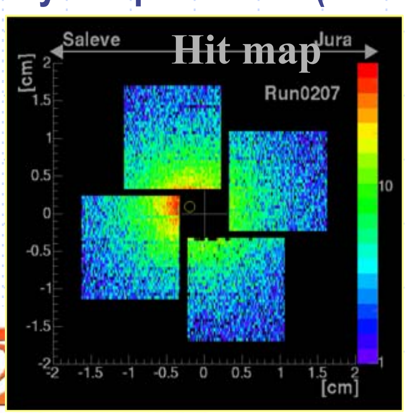
strip sensor design Z.li, BNL



strip sensor test RIKEN



NA60 hybrid pixel tests (RIKEN,SB)



- Ongoing or started R&D
  - Silicon strip sensor development
  - Hybrid pixels (with ALICE and NA60)
  - design of support structure
- Critical contributions supported by R&D proposal
  - silicon strip readout & integration into PHENIX
  - hybrid pixel integration, thinning & bump bonding
  - development of monolithic active pixel sensors
  - design of support structure including cooling etc
- Participating institutions
  - BNL, ISU, Kyoto U., LANL, ORNL, RIKEN, SBU

Near Term Summary Table

Fiscal Year	2003	2004	2005	2006	2007	2008
PHENIX						
Ops Costs	$6.0M (24K/wk)	5.85M (27K/wk)	5.85M (42K/wk)	5.85M (42K/wk)	5.85M (42K/wk)	5.85M (42K/wk)
R&D	$0.12M	0.5M	0.95M	0.6M	0.3M	---
Ops Equip.	$0.5M	0.89M	0.89M	0.89M	0.89M	0.89M
Res. Equ.			2.5M VTXb	2.5M VTXb	4.2M VTXb/e	4.5M VTXe
STAR						
Ops Costs	$5.9M (38K/wk)	5.75M (40K/wk)	5.75M (40K/wk)	5.75M (40K/wk)	5.75M (40K/wk)	5.75M (40K/wk)
R&D	$0.12M	0.5M	1.0M	1.28M	0.3M	---
Ops Equip.	$0.49M	0.99M	0.99M	0.99M	0.99M	0.99M
Res. Equ.	$3.0M BEMC [$1.5M EEMC]	1.95M BEMC	2.0M TOF	4.0M TOF, MVTX	4.5M MVTX	3.0M MVTX
PHOBOS						
Ops Costs	$0.86M (10K/wk)	0.75M (10K/wk)	0.75M (10K/wk)	0.75M (10K/wk)	.75M (10K/wk)	-------------
Ops Equ.		0.185M	0.185M	0.185M	----	
BRAHMS						
Ops Costs	$0.78M (10K/wk)	0.7M (10K/wk)	0.7M (10K/wk)	0.7M (10K/wk)	-----------	-------------
Ops Equ.		0.11M	0.1M	0.1M		
RCF						
Ops Costs	$5.18M	5.31M	5.6M	5.6M	5.6M	5.6M
Ops Equ.	$2.0M	2.0M	3.4M	2.0M	2.0M	2.0M
C-AD						
Ops Costs	$90.3M (350K/w)	90.7 (350K/wk)	90.9M (350K/wk)	94.9M (500K/w)	94.9M (500K)	92.8M (500K)
R&D	$0.9M	2.0M	2.0M	2.0M	2.0M	2.0M
Ops Equip.	$4.4M	3.9M	3.8M	3.8M	3.8M	3.8M
Res. Equ.	---	---	2.5M EBIS	2.5M EBIS	2.5M EBIS	---
Users/CAP	$0.86M	0.90M	0.90M	0.90M	0.90M	0.90M
Totals						
Ops costs	$109.8M (432K)	$110.1M (437K)	$110.4M (452K)	$114.4M (602K)	$113.8M (592K)	$110.9M (582K)
R&D	$1.1M	$3.0M	$4.0M	$3.9M	$2.6M	$2.0M
Ops Equip.	$7.4M	$8.0M	$9.4M	$8.0M	$7.9M	$7.7M
Ops Total	**$118.4M**	**$121.0M**	**$123.8M**	**$126.3M**	**$124.3M**	**$120.6M**
	Actual: $118.0M	Pres: $121.1M				
Res. Equ.	$3.0M	$1.95M	$7.0M	$9.1M	$11.4M	$7.5M

Near Term Summary Table

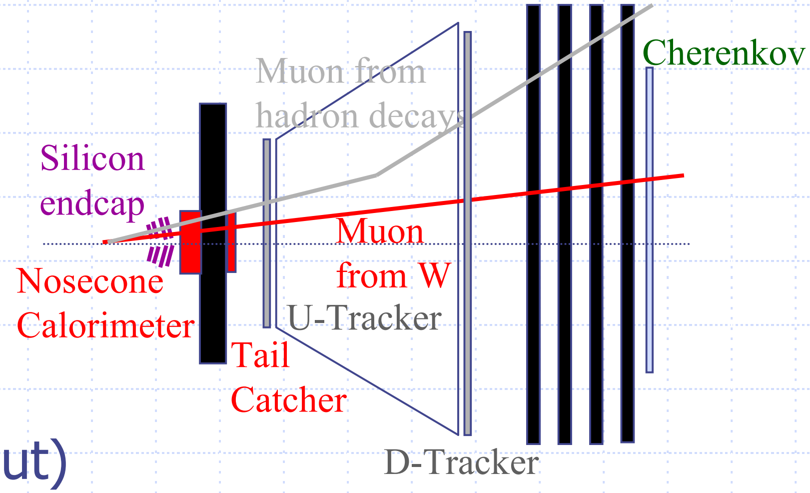
- Points of note
  - The plan as tabulated misses the Constant Effort target by a few percent in the middle years
    - Bump in RCF EQU costs (FY 05 – one year)
    - Bump in power cost (FY 06 start – estimated)
  - Returns to the constant effort line by FY08
    - Small experiments cease operations
    - EBIS → operational cost savings
  - FY 2005 – 2008 Research Equipment: $35M
    - Not part of the Constant Effort budget
    - Near term Major Items of Equipment as mentioned above
      - EBIS, VTX, FVTX, TOF, MVTX

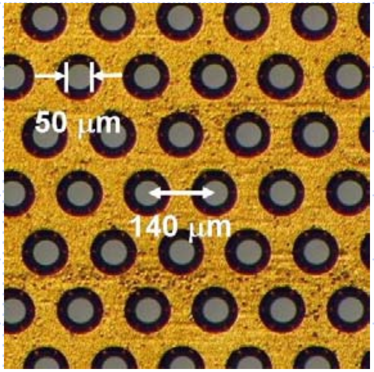
Mid Term: RHIC II

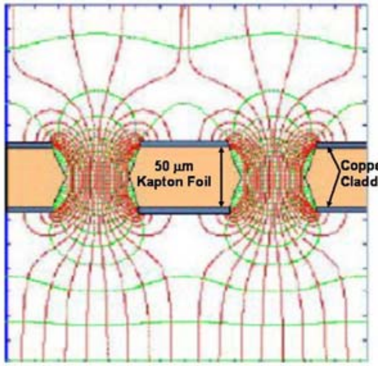
- Physics goals of RHIC II have been clearly laid out today
- These translate into the need for higher integrated luminosity and enhanced detector capabilities
- R&D is required for both, in particular electron cooling of the ion beams
  - Discussed by Thomas Roser in the next presentation
- Without additional funding or administrative limits, RHIC II could start construction in FY2008 and could start operating in FY2010
  - Completion of construction, full upgraded luminosity in FY2013, but phased operations with partially upgraded detectors could start earlier

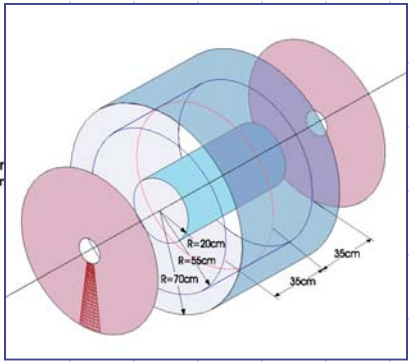
RHIC II Detector Upgrades

- PHENIX
  - Compact TPC (GEM readout)
  - Forward Upgrade (Si-W cal.)
  - DAQ
- STAR
  - TPC replacement (GEM readout)
  - Forward Tracking Upgrade
  - DAQ

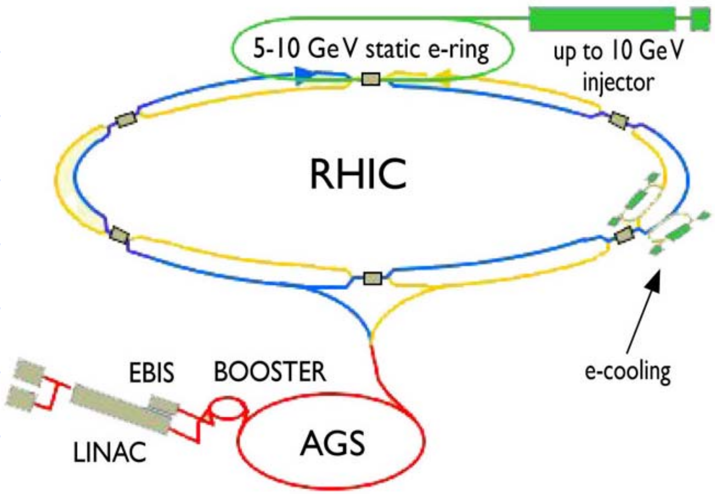






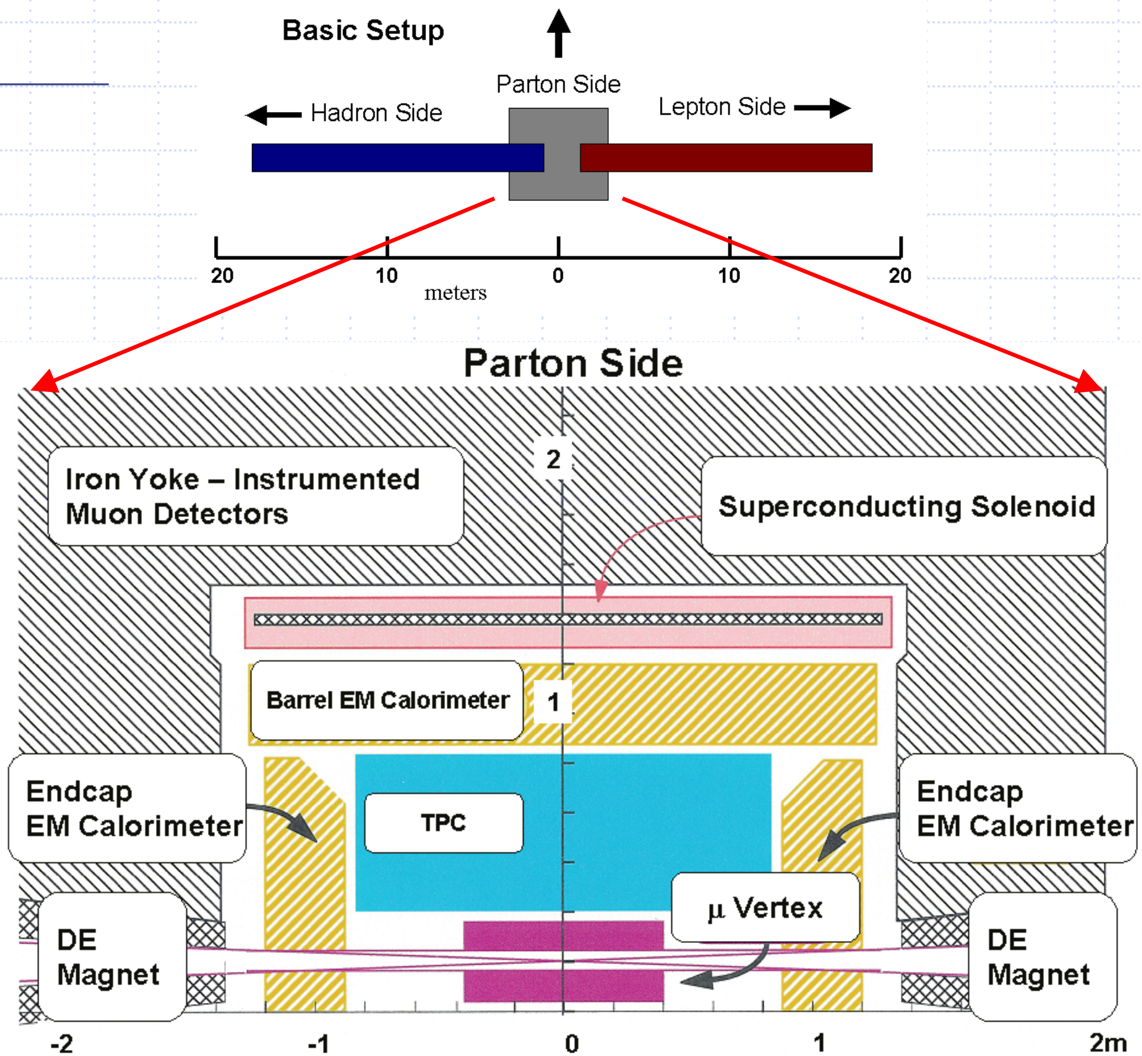


Long Term: eRHIC

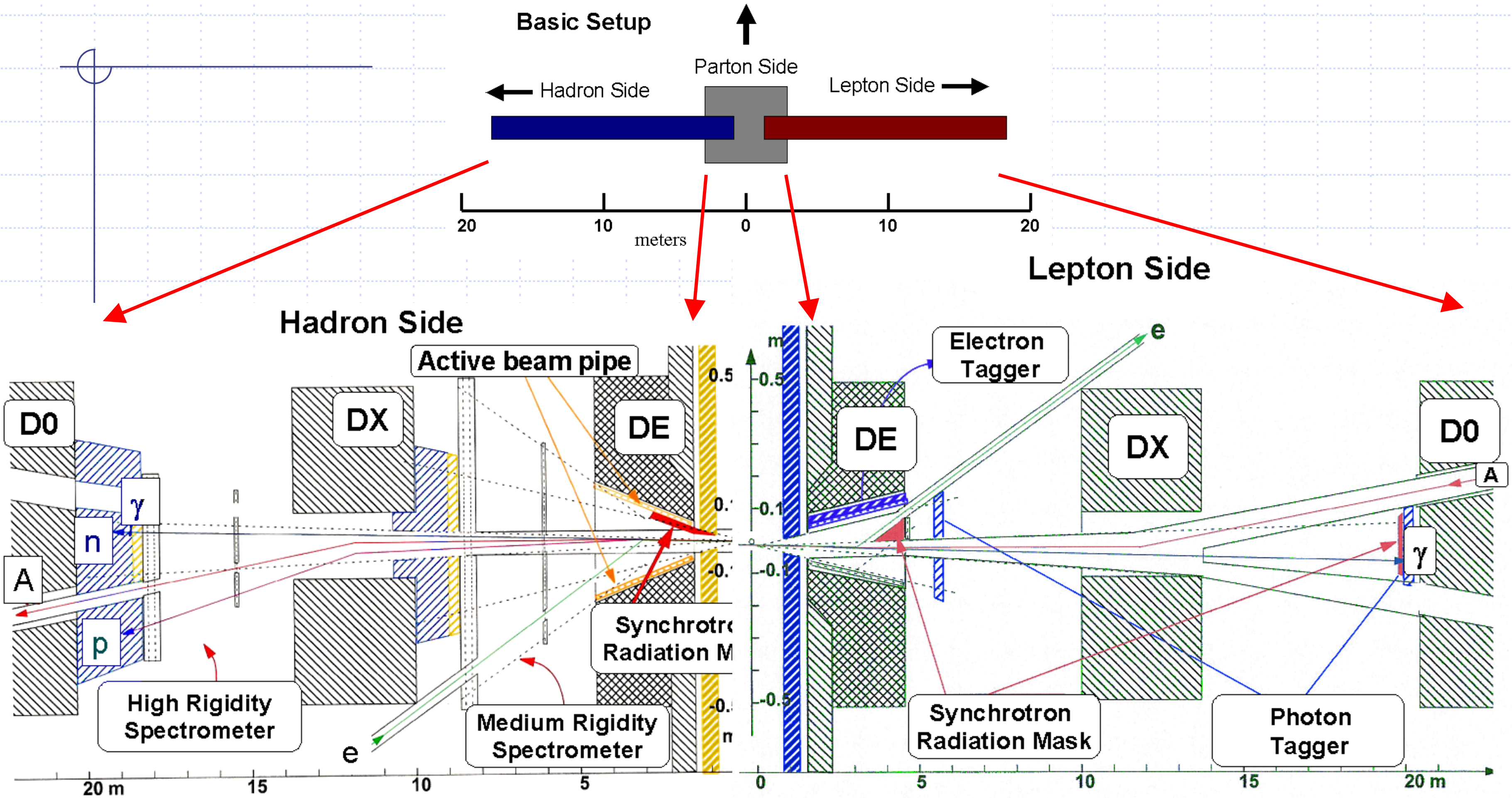


- A high energy, high intensity polarized electron beam facility at BNL to collide with the existing RHIC heavy ion and polarized proton beam will significantly enhance RHIC's ability to probe fundamental, universal aspects of QCD
- Builds on the RHIC II accelerator enhancements (e.g., e-cooling)
  - New 10 GeV electron ring; new IR and detector (@ 12 o'clock)
  - MIT/Bates, BINP-Novosibirsk
- eRHIC Steering Committee
  - ANL, BNL, Kyoto, MIT/Bates, UIUC, IU
  - Contact person – A. Deshpande, SBU

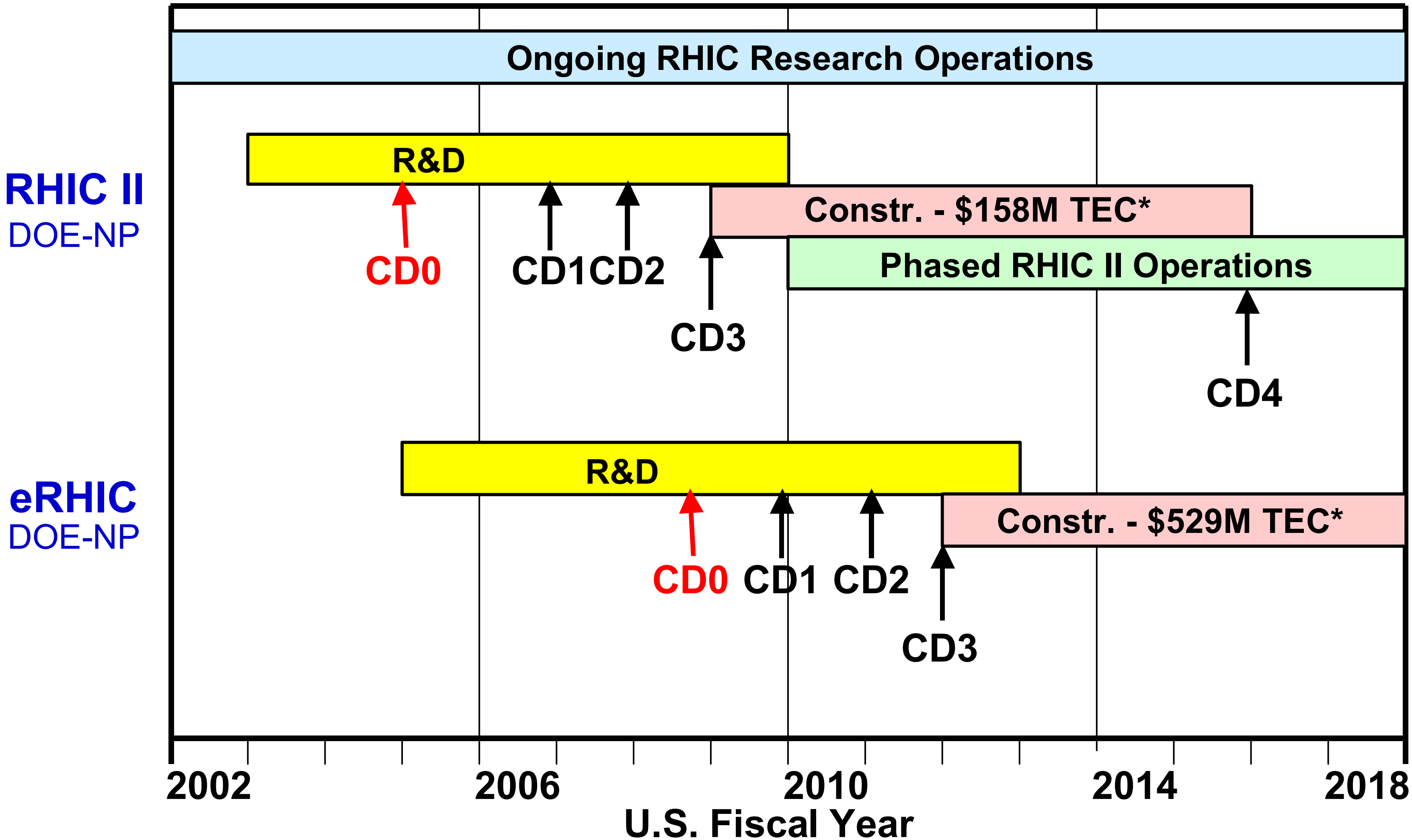
Possible eRHIC Detector Design



Possible eRHIC Detector Design

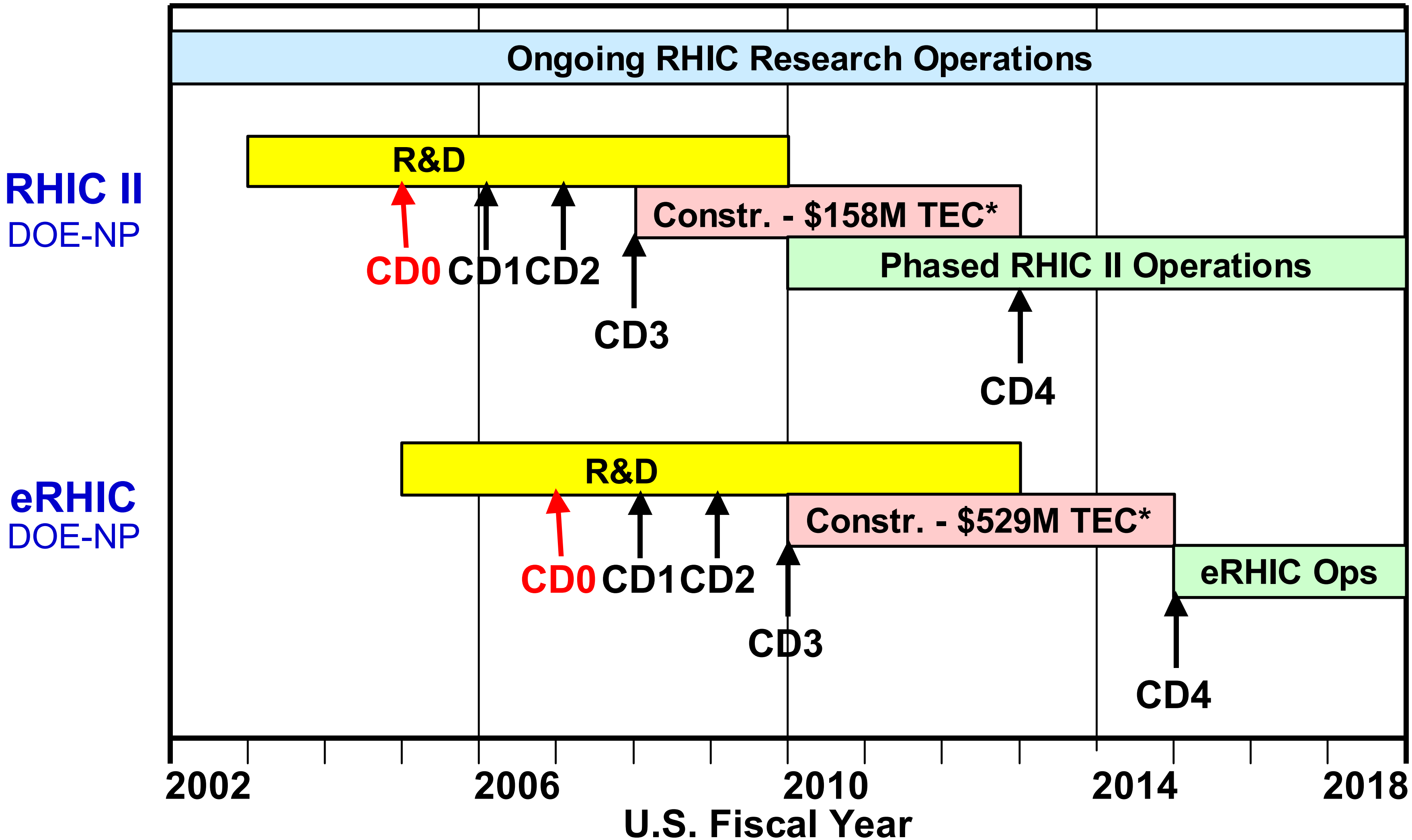


RHIC Upgrade Schedules (2004 Inst. Plan)



* Estimates in FY 2004 Dollars

RHIC Upgrade Schedules (technical limit)



* Estimates in FY 2004 Dollars

Summary

- RHIC is *the* engine for advancing RHI physics
  - Will remain unchallenged for about 5 years
- In the LHC era, evolution of RHIC will keep it at the forefront of RHI (and more generally QCD) research
  - At the right energy to explore strongly interacting q - g matter
  - A dedicated facility capable of running 37 weeks/year
  - Unique QCD capabilities: polarized protons & (future) electrons
- RHIC II
  - $158M; construction could start in 2008, operations in 2010
- eRHIC
  - $529M; construction could start in 2010, operations in 2015
- Can deliver competitive, unique data from a full menu of probes on ions and polarized protons for the next 20 yrs