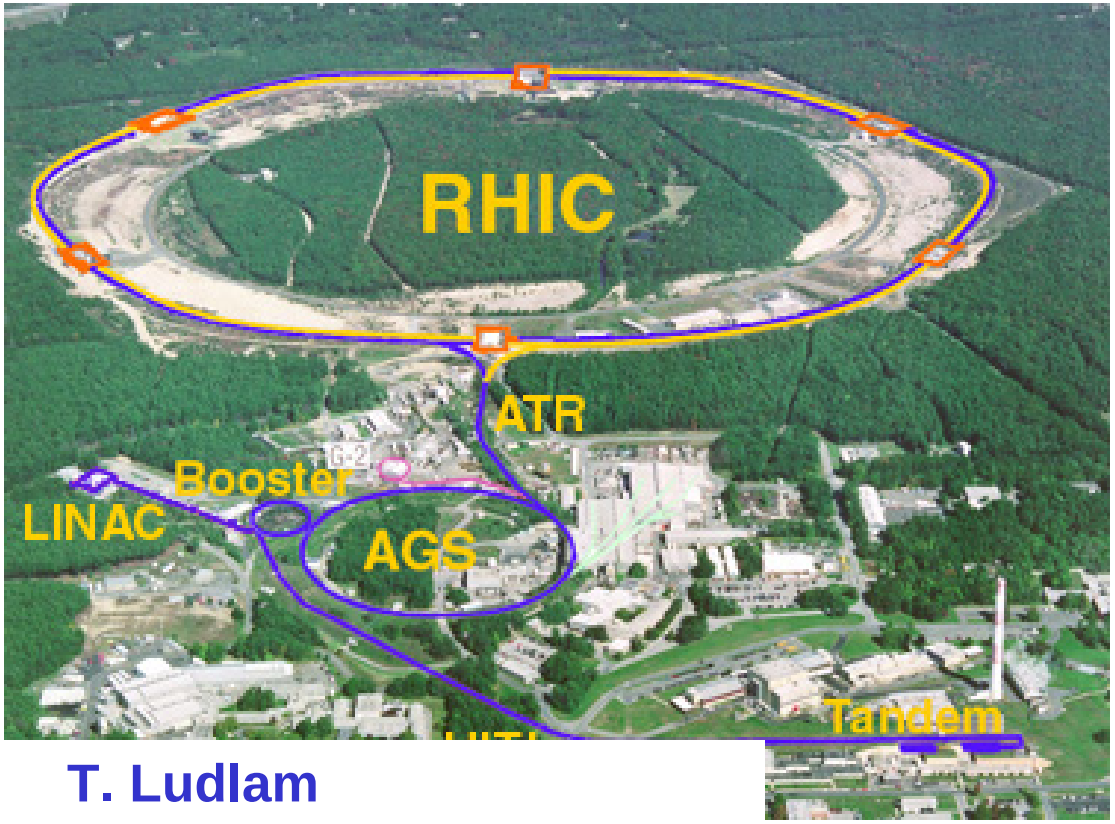
RHIC in the LHC Era

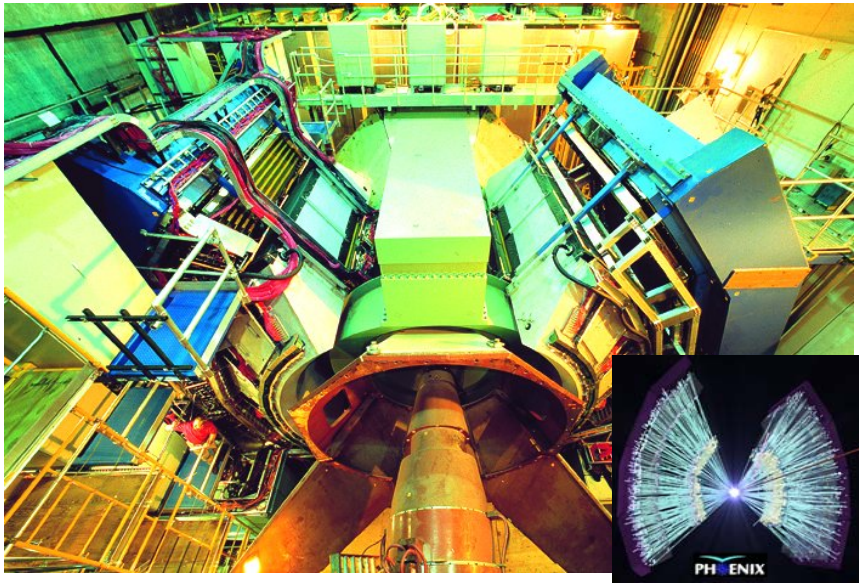


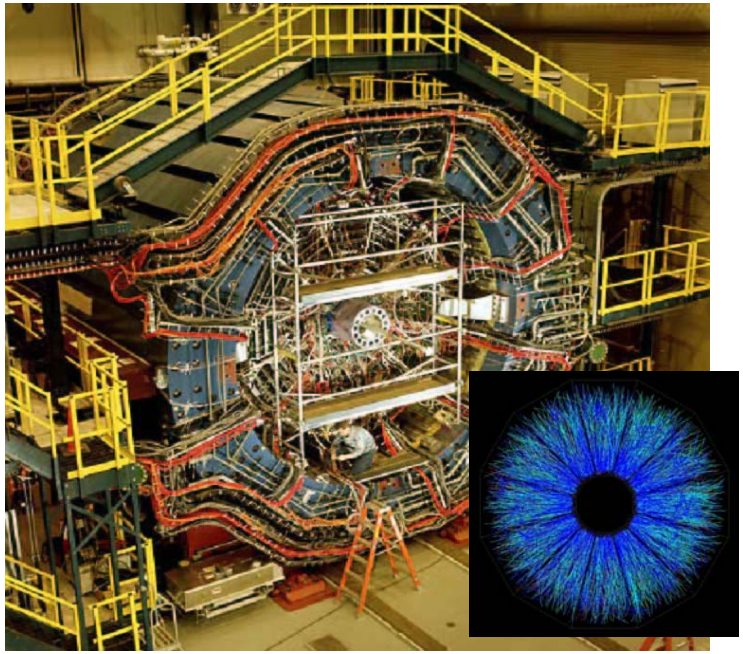
T. Ludlam

PANIC Satellite meeting on LHC Heavy Ions

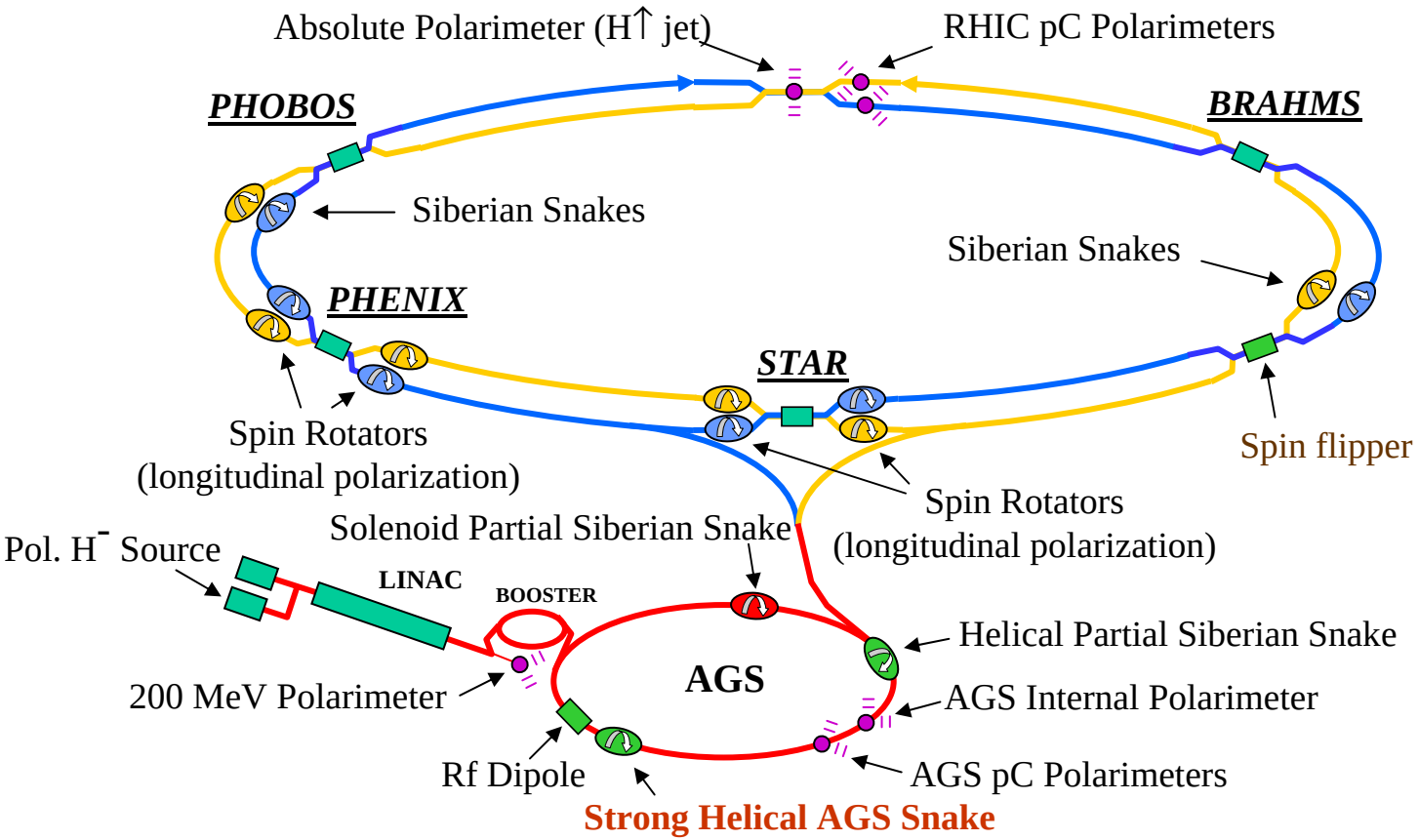
Oct. 23, 2005

The RHIC Detectors





RHIC polarized proton accelerator complex



Major Achievements with RHIC
2001 - present

4 complementary experiments: BRAHMS, PHENIX, PHOBOS, STAR

Concordance among their results is a hallmark of the program

5 Annual runs to date

Au-Au; polarized p-p; d-Au; Cu-Cu

C.M. energies range from 20 GeV/u to 200 GeV/u (410 for pp)

Tremendous scientific impact

- Hundreds of publications; thousands of citations
- 3- year retrospective "white papers" published by each of the 4 experiments
- Major discoveries have changed the view of high energy nuclear physics:

  Jet Quenching

  Gluon saturation/Color Glass Indications

  "Near-Perfect-Liquid" behavior

Significant experimental advances

- Hard Scattering → Auto-generated probes
- Fully calibrated comparison data

  p-p, d-Au, Au-Au under identical conditions
- First high energy polarized proton collider

What Have We Learned?

- We can do definitive studies of QCD at high energy density in the laboratory!

- A new form of matter produced at RHIC,
  With extraordinary and surprising properties…

  - Energy density > 5 GeV/fm^3, T ~ 200 MeV achieved
    - ✓Sufficient to induce phase transitions
    - ✓ Consistent with production from initial state with gluon saturation

  - Thermalizes very quickly; exhibits highly collective motion consistent with hydrodynamic models with near-zero viscosity
    - ✓ Near-perfect liquid

  - Extraordinary parton energy loss ~10 GeV/fm
    - ✓ Nearly opaque to high energy partons, including Charm!
    - ✓ ~transparent to leptons and photons

    A Black Body emitting hadrons!

The Big Questions

QCD at High Temperature and Density:

- What is the nature of the phase transition?
- What is the structure of quark-gluon matter above T_C?
  - Is chiral symmetry restored?
- What is the physics of superdense, strongly-interacting matter?

QCD at High Energy and low x:

- Is the initial state a Color Glass Condensate?
- What is the physics of strong color fields?

QCD and the structure of hadrons:

- What is the origin of nucleon spin?

RHIC II Science Working Groups:
www.bnl.gov/physics/rhicIIscience

RHIC II Science Workshop Nov. 11-12

Where do We Go from Here…

Key Measurements

Hard Probes: created early in the collision and propagate through the medium. Their interactions with the medium help characterize its properties

- High Pt particles and jet fragmentation
- Heavy quarkonia (J/Ψ, ψ', χ_c and Upsilon (1s, 2s, 3s)
- Open charm and bottom

Electromagnetic Probes: direct information from the medium

- Low-mass e^+e^- pairs and Thermal radiation

Polarized proton collisions:

- W-production at $s^{1/2}$ = 500 GeV for sea quark flavor selection

Facility Operation

Systematic species and energy scans *This has proved crucial!*

Balance of Running RHIC and investing in upgrades

Where Do We Stand Now?

Four Detectors ⟶ Two Large Detectors

Machine Goals for Next Few Years:

- **Enhanced Ion luminosity (112 bunches, β* = 1m):** 2x achieved

  Au – Au: 8×10^{26} cm^{-2} s^{-1} (100 GeV/nucleon)

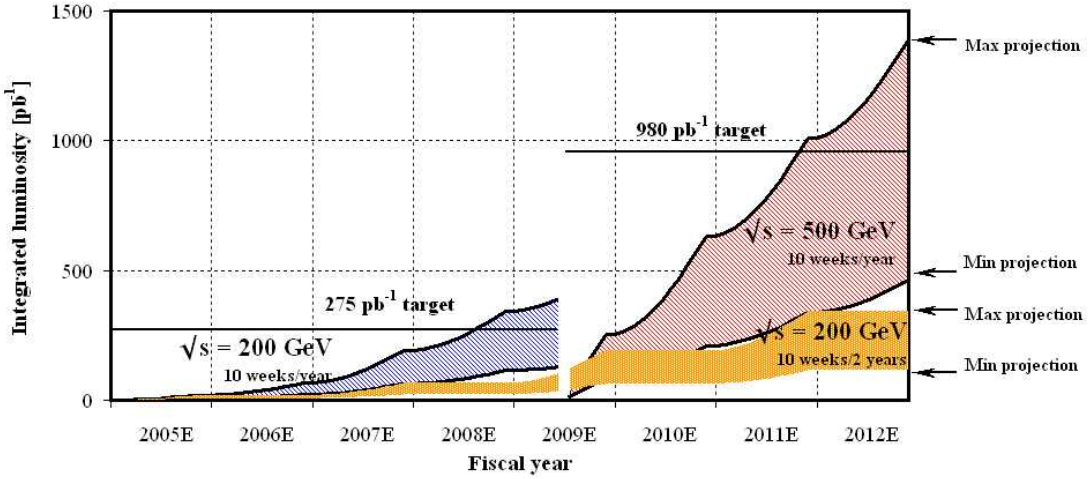
- **For protons: 2×10^{11} protons/bunch (no IBS):** 6x achieved

  150×10^{30} cm^{-2} s^{-1}; 70 % polarization (250 GeV)

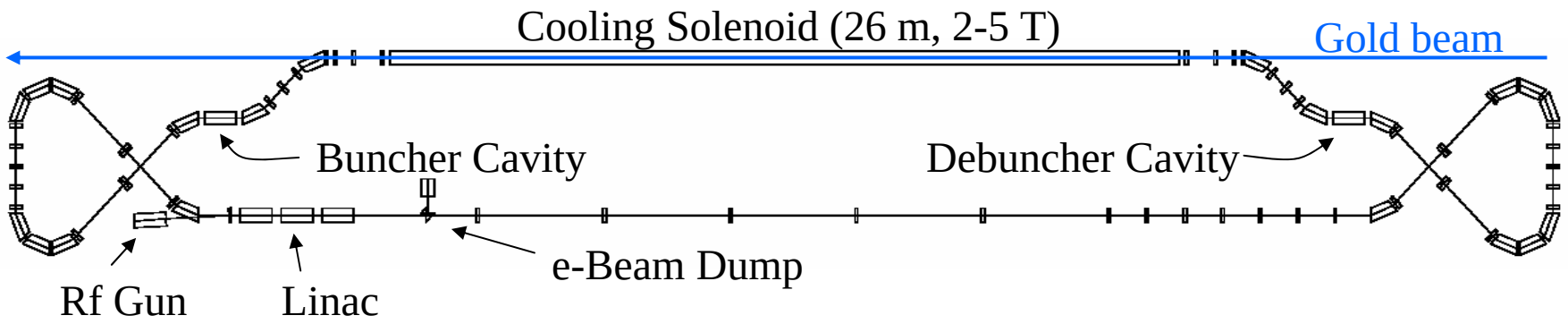
EBIS Construction funded in FY 2006. Operational in 2010

Short-term detector upgrades underway

Spin Program poised for definitive measurements:



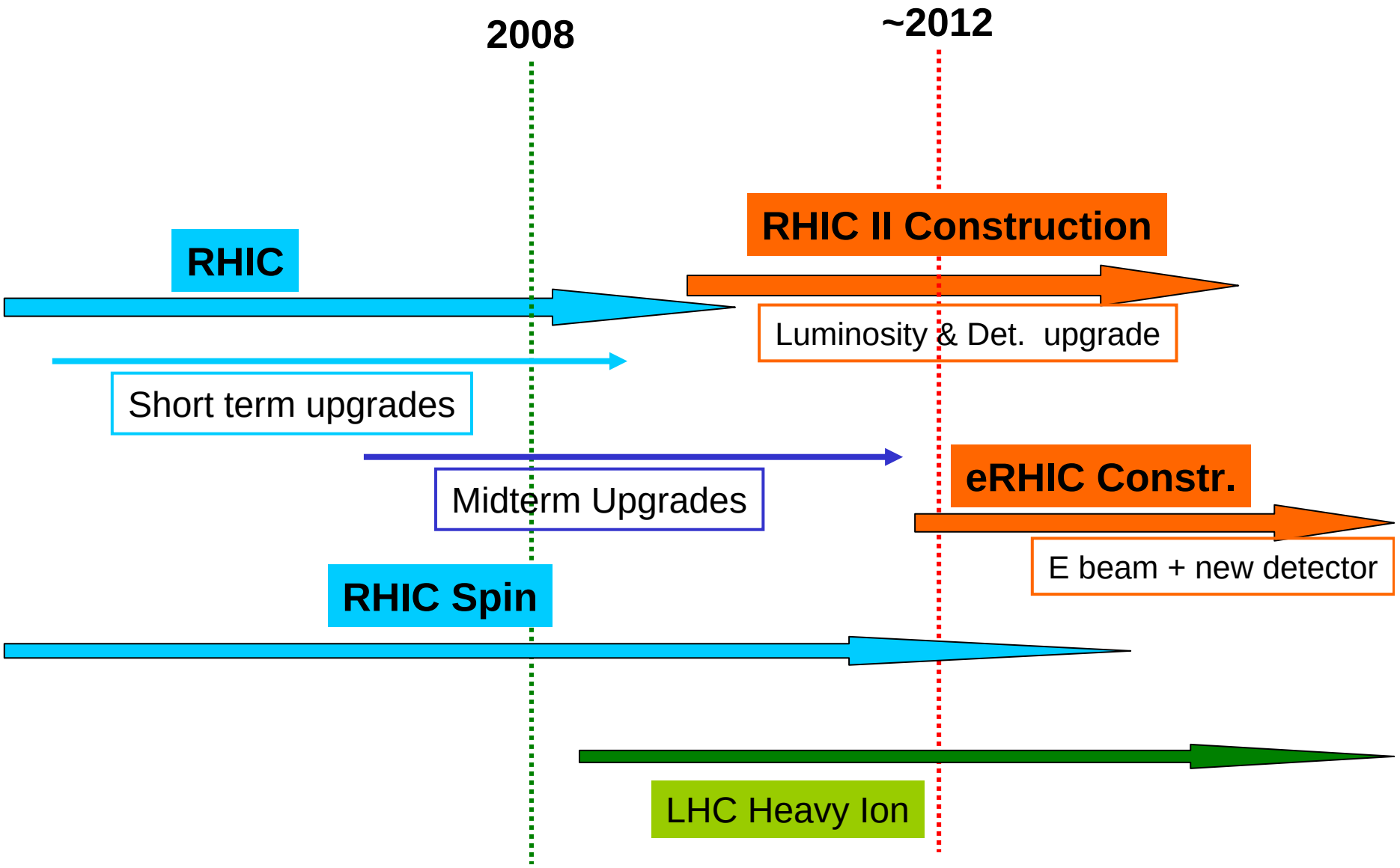
RHIC II Luminosity Upgrade with Electron Cooling



Gold collisions (100 GeV/n x 100 GeV/n):	w/o e-cooling	with e-cooling
Ave. store luminosity [10^{26} cm^{-2} s^{-1}]	8	70
Pol. Proton Collision (250 GeV x 250 GeV):		
Ave. store luminosity [10^{32} cm^{-2} s^{-1}]	1.5	5.0

R&D in Progress: proof-of-principle expected in 2006

A Long Term Strategic View



The Mid-Term Challenge

Extend the reach of the RHIC facility to address key questions in the coming 5-6 years…

Requires improved machine performance and significant running time

Requires enhanced capability for PHENIX and STAR

Complement the early results from LHC Heavy Ion running

Set the stage for RHIC II

Major Physics Measurements

Required Upgrades

Heavy Ion:

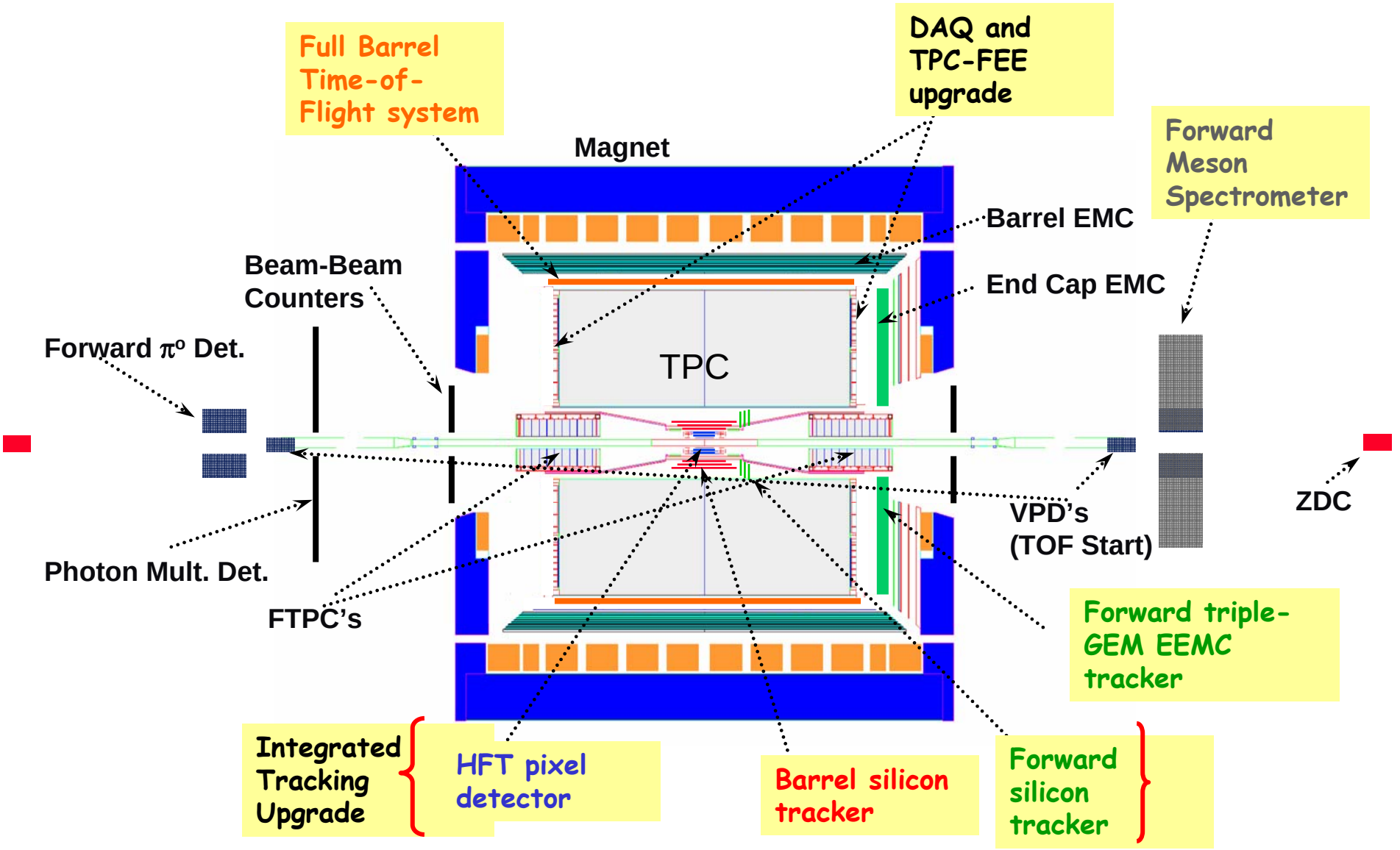
- e-pair mass spectrum PM: 2010*
  - "Hadron Blind" Dalitz pair rejection
- Open charm measurements in AA
  - High Resolution vertex detection
- Charmonium Spectroscopy PM 2010*
  - High luminosity; precision vertex, particle ID
- Jet Tomography
  - High luminosity; High-rate DAQ; particle ID
- Monojet in d-Au PM: 2012*
  - particle detection at forward rapidity

Spin:

- Complete initial $\Delta G/G$ measurement PM: 2008*
  - No upgrades needed
- Transversity measurement
  - Forward particle measurement
- W measurements at 500 GeV PM: 2013*
  - Forward tracking in PHENIX and STAR

***DOE performance milestones set by NSAC**

STAR Upgrades



The Upgraded PHENIX Detector

Charged Particle Tracking:

- Drift Chamber
- Pad Chamber
- Time Expansion Chamber/TRD
- Cathode Strip Chambers(Mu Tracking)
- Forward Muon Trigger Detector
- Si Vertex Tracking Detector- Barrel (Pixel + Strips)
- Si Vertex Endcap (mini-strips)

Particle ID:

- Time of Flight
- Ring Imaging Cerenkov Counter
- TEC/TRD
- Muon ID (PDT's)
- Aerogel Cerenkov Counter
- Multi-Resistive Plate Chamber Time of Flight
- Hadron Blind Detector

Calorimetry:

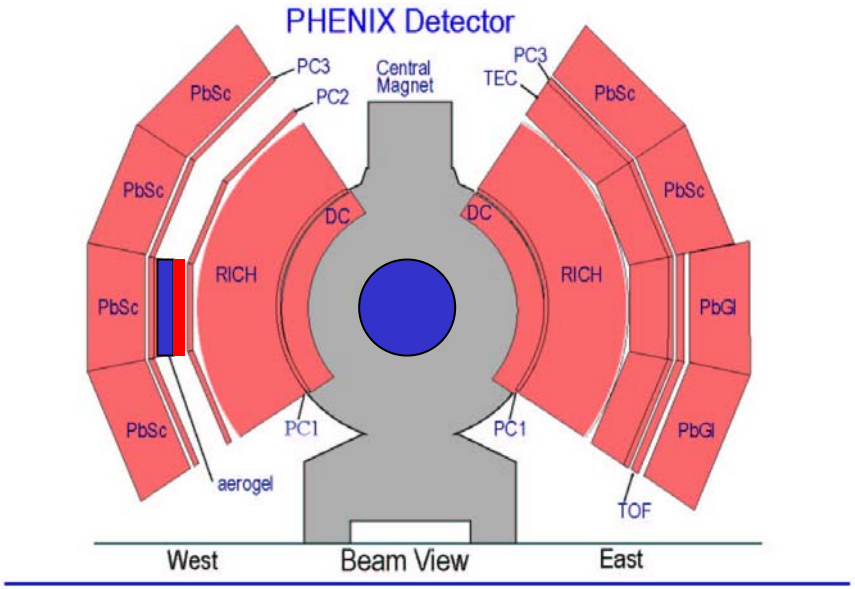
- Pb Scintillator
- Pb Glass
- Nose Cone Calorimeter

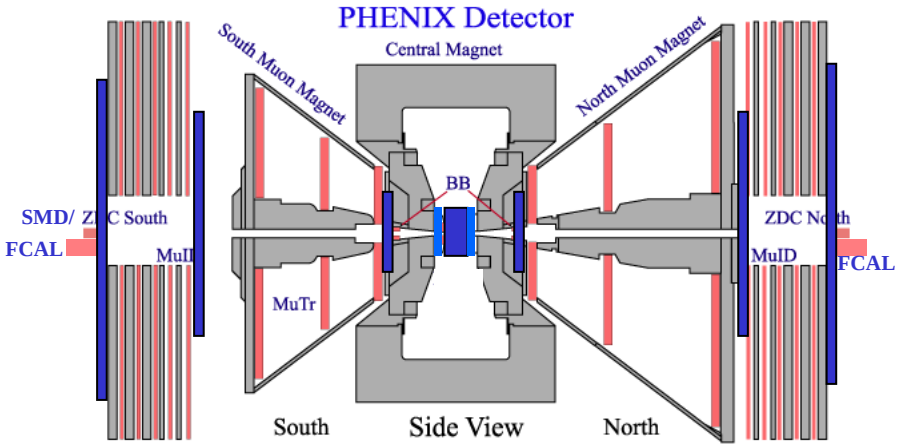
Event Characterization:

- Beam-Beam Counter
- Zero Degree Calorimeter/Shower Max Detector
- Forward Calorimeter

Data Acquisition:

- DAQ Upgrade





A timeline for physics operation, detector upgrades, machine evolution

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

pp 200
Ion Run?

Ion scan
pp 200

d-Au 200
pp 200/500

High statistics Au Au; 500 GeV Spin Runs

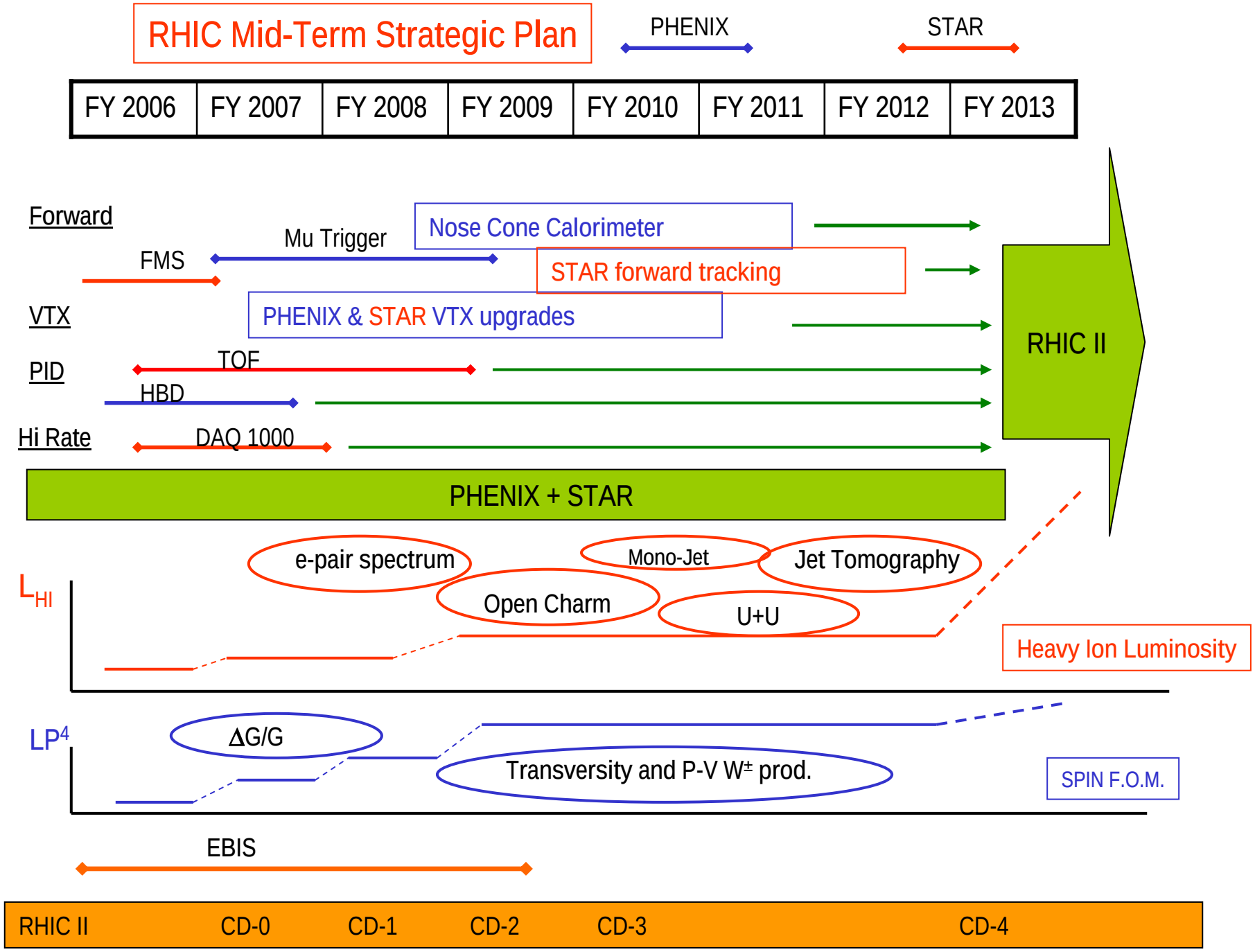
"Short-term upgrades:
HBD, TOF, DAQ, FMS, Muon Trigger

Mid-Term Upgrades

RHIC II Construction

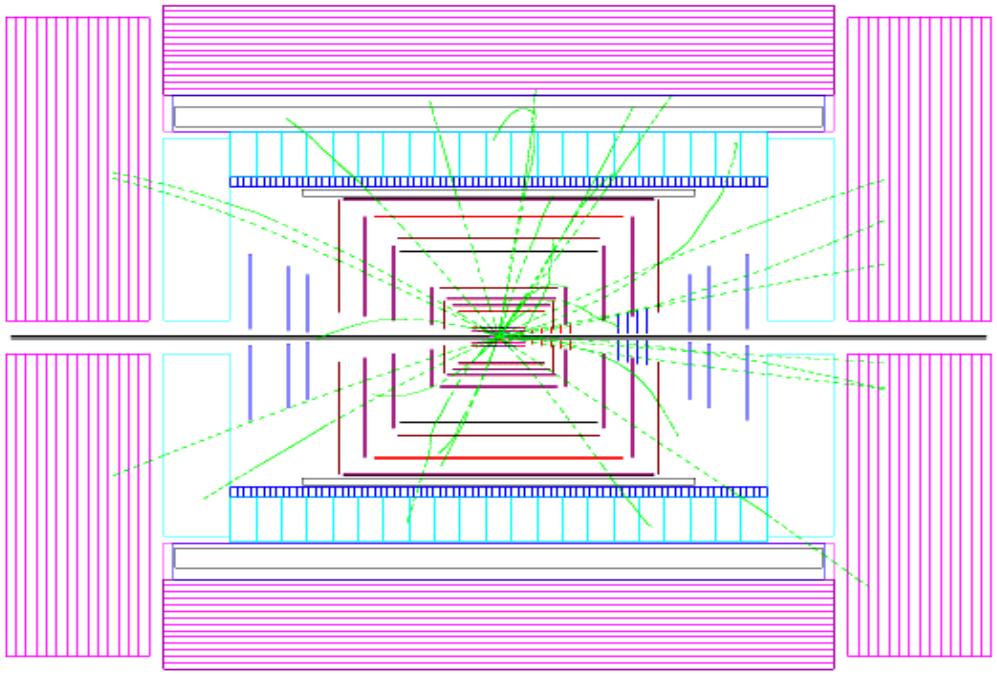
Machine and detector R&D; continued luminosity improvements

LHC Heavy Ion Program


RHIC Mid-Term Strategic Plan
PHENIX
STAR
FY 2006
FY 2007
FY 2008
FY 2009
FY 2010
FY 2011
FY 2012
FY 2013
Forward
FMS
Mu Trigger
Nose Cone Calorimeter
STAR forward tracking
VTX
PHENIX & STAR VTX upgrades
PID
TOF
HBD
Hi Rate
DAQ 1000
RHIC II
PHENIX + STAR
e-pair spectrum
Mono-Jet
Jet Tomography
Open Charm
U+U
L_{HI}
Heavy Ion Luminosity
LP^4
ΔG/G
Transversity and P-V W± prod.
SPIN F.O.M.
EBIS
RHIC II
CD-0
CD-1
CD-2
CD-3
CD-4

Will there be a major New Detector for RHIC II?

This is not part of the mid-term plan



Plans are afoot for a dedicated new detector for eRHIC

It is very possible, even likely, that the “QCD Lab” will require a new detector to exploit HI collisions in the eRHIC era.

The Future of RHIC

RHIC has opened a new realm of research in High Energy Density physics.

This has struck a deep chord not only in nuclear physics, but in the broad reach of science and society…

With RHIC II we aim to pursue this rich lode of discovery with, more powerful tools, as LHC experiments explore higher energy collisions.

RHIC and LHC

LHC is not a replacement for RHIC – they complement each other

- Collision Energy
  - o RHIC probes high energy density in the central region. The initial state (gluon saturation) is probed in the forward regions (low x)
  - o LHC's higher energies make energetic jets and heavy quarks more accessible, and may reveal unexpected new phenomena.
- Dedicated, flexible facility
  - o RHIC provides exploration vs. system size and energy in hot and cold nuclear matter, as well as p-p in the same detector. EBIS will extend A-range to U-U.
- Unique capabilities with a future
  - o Unique spin program aimed at some of the biggest problems in hadron physics. The path forward leads to a polarized DIS collider facility (eRHIC).
- U.S. Role in the Worldwide Program
  - o The U.S. taken the lead in this exciting field– great momentum, excellent teams, and a commitment to do the physics and train the next generation.
  - o The U.S. RHI community has a strong physics interest in the LHC. Worldwide involvement in forefront facilities has been a hallmark of our field. It is so at RHIC and will be so at LHC.

The Long Term Vision: *RHIC as a QCD Laboratory*

eRHIC: DIS at collider energies

e-A at 63 GeV/u

Polarized e-p at 100 GeV

L ~ 10^{33} cm^{-2} sec^{-1}

RHIC Spin: Strongly interacting probes

A-A: QGP physics at RHIC II luminosities