The Future of Nuclear and High Energy Physics at Brookhaven

2004

RHIC & AGS Annual Users' Meeting

May 10 - 14, 2004

Sam Aronson Physics Department

Office of Science
U.S. DEPARTMENT OF ENERGY

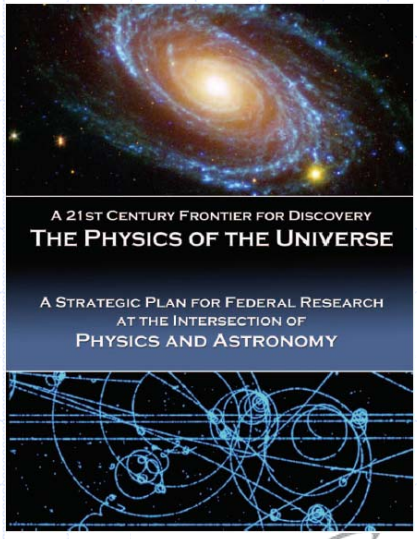
BROOKHAVEN NATIONAL LABORATORY

Introduction

- Today's summaries of RHIC & AGS past accomplishments and present status give a good basis for much of this forecast
- However, my title (The future of NP and HEP at BNL) is broader than RHIC & AGS, requiring a look also at BNL's future off-site, off-shore and even off the planet
- Try to *sample* the whole spectrum of BNL's NP and HEP vision, then see what the program could look like 15 years down the road

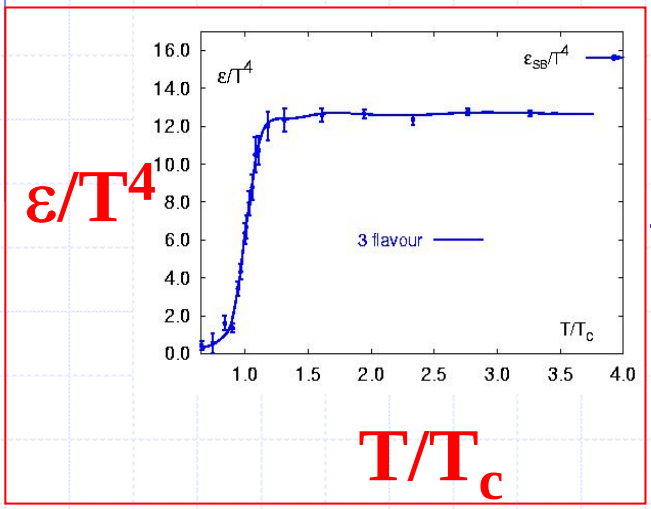
Alignment with the agencies

- Some of the biggest items in the picture find support in the DOE's Office of Science 20-year Facilities Plan (RHIC II, eRHIC, ν Superbeam)
- Others are major DOE and/or NSF projects (ATLAS, RSVP)
- Others are high-priority topics in OSTP's recently published "The Physics of the Universe" (LSST)



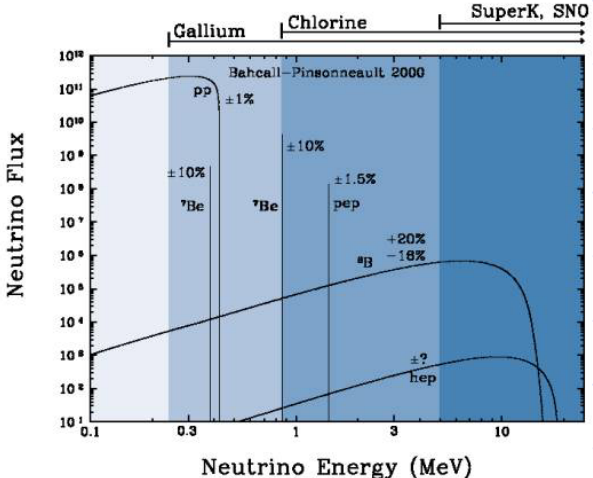
NP vision & initiatives

- RHIC II and eRHIC



- Lattice Gauge Computing

- Neutrinos (low energy)



RHIC Near Term Evolution

- Science Goals
  - Discover and characterize Quark Gluon Plasma
  - Determine the gluon's role in the spin of the proton
- RHIC Detector Goals
  - Upgrades for new capabilities (continuous path)
  - Consolidation into 2 detectors
- RHIC Machine Goals
  - Increase injector intensity
  - Achieve 70% beam polarization (recent breakthrough!)
  - RHIC II & eRHIC R&D (electron cooling)
  - EBIS
- LGC: 10 Tflops QCDOC (RBRC & "U.S." machines)

RHIC → RHIC II

- Science
  - High p_T & heavy quark studies will extend our characterization of ***QGP:*** jets & γ's; c, b energy loss in the medium; D, J/ψ, B, Υ
  - Polarized W-production →flavor dependent spin str. fns.
- Detectors
  - Upgraded STAR and PHENIX Detectors, increased rate and technical reach: coverage; PID; tracking; secondary vertices
- Machine
  - Electron cooling at *full-energy* in RHIC enables ***10X*** increase in *average Luminosity*
- Computing
  - Finite temperature Lattice Gauge Physics and supercomputing
  - Better simulations: spectral functions & survival of bound states

Detector R&D

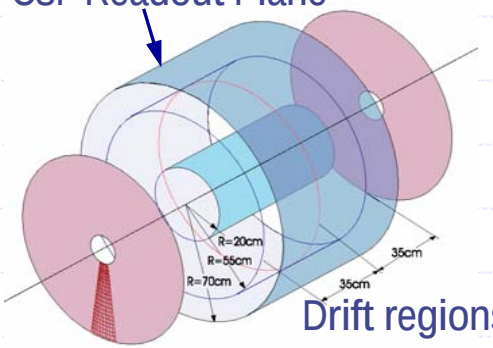
STAR Time of Flight Prototype

PHENIX Si Vertex Detector

Near term

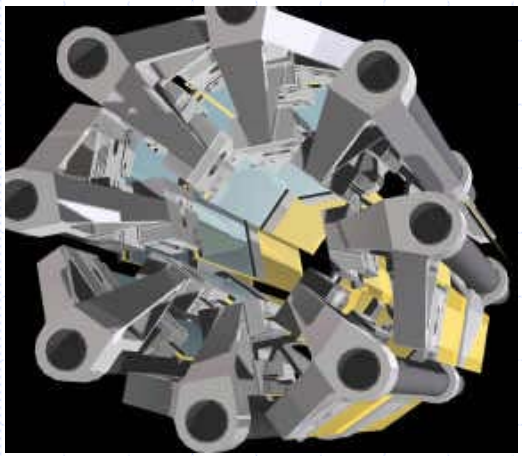
Longer term

CsI Readout Plane



Drift regions

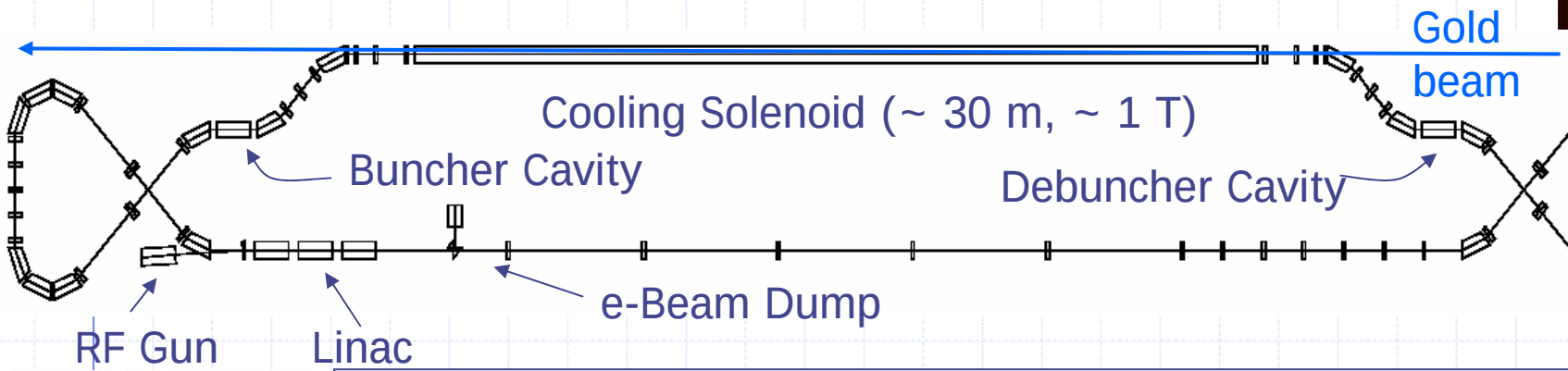
STAR Si Vertex Detector

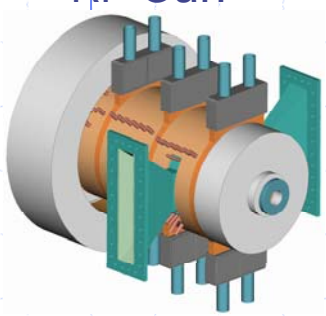


[PHENIX forward muon upgrade...]

PHENIX & STAR: Hadron-Blind Detector and/or compact TPC with GEM readout

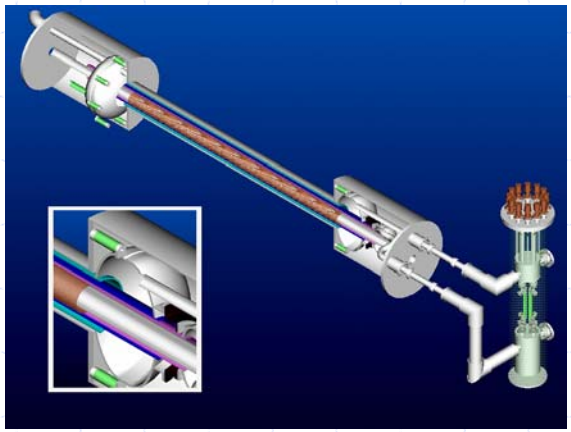
Electron Cooler R&D



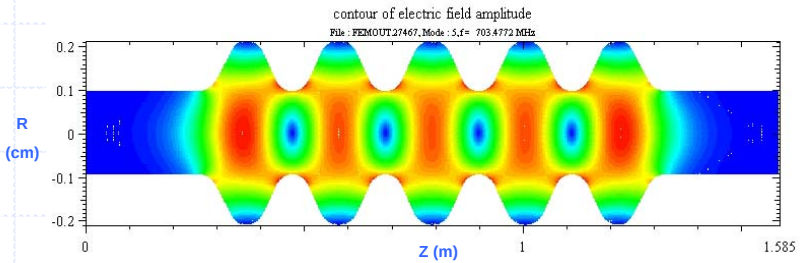


Demonstrate 10 nC, 100–300 mA CW RF photo-cathode electron gun:
High power, 700 MHz 2.5 cell cavity (collab. with LANL)

Demonstrate high precision (10 ppm) solenoid



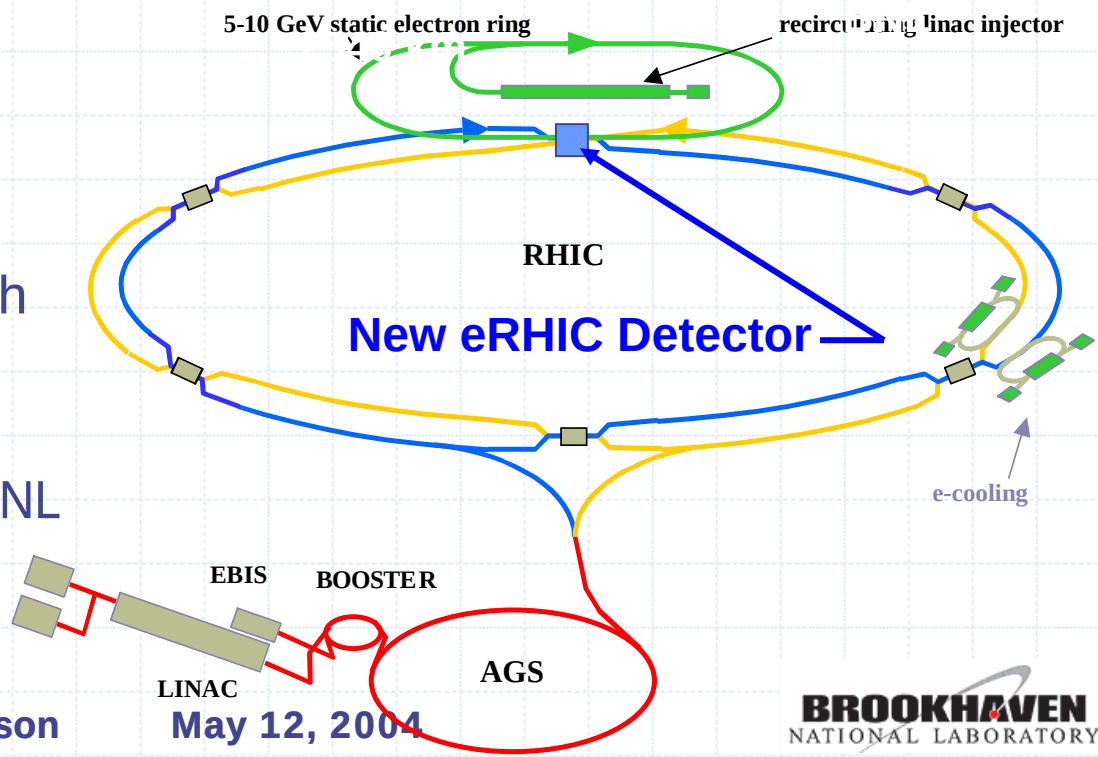
Develop CW s.c. cavity for high intensity beams:
Large bore, 700 MHz cavity with ferrite HOM samplers and high BBU threshold (collab. with JLab)



eRHIC

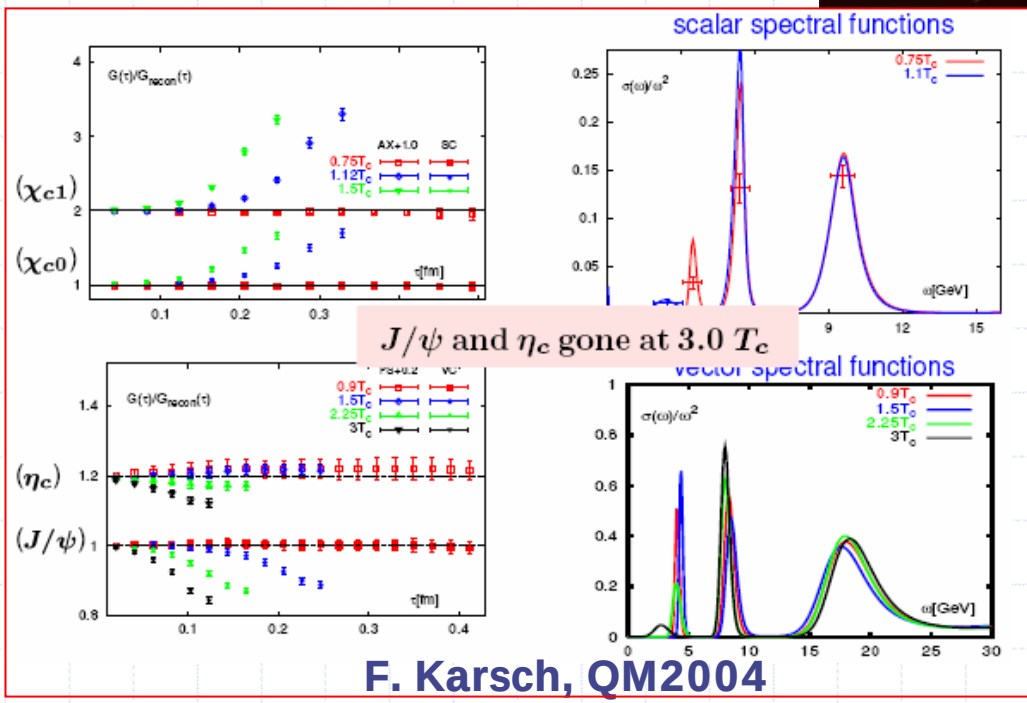
- eRHIC uniquely enables the discovery and characterization of Color Glass Condensate (*CGC*), a unique Bose condensate of *gluonic matter*, plus the extension of *gluon polarization* measurements to *small x*
- eRHIC requires upgrade of the existing RHIC facility (10 GeV e-ring plus a new experimental detector)
- a strong NP community is already well-started in both physics and machine R&D to move eRHIC forward
- MIT-Bates partners with BNL in eRHIC; HERA scientists and others will join in

eRHIC Site Plan



Lattice Gauge Computing

- Calculations of heavy quark bound states (in quenched QCD*)
  - Charmonium ground states still exist at $1.5T_c$, gone by $3T_c$
  - * Need much bigger computers to do better!



F. Karsch, QM2004

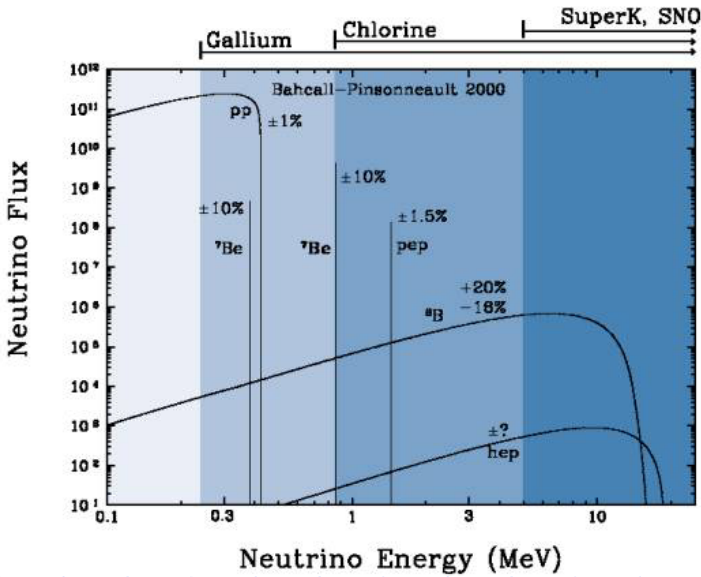
- Thanks to DOE and RBRC, BNL+Columbia building **10 Tflops QCDOC** machines this year

128 node prototype

S. Aronson

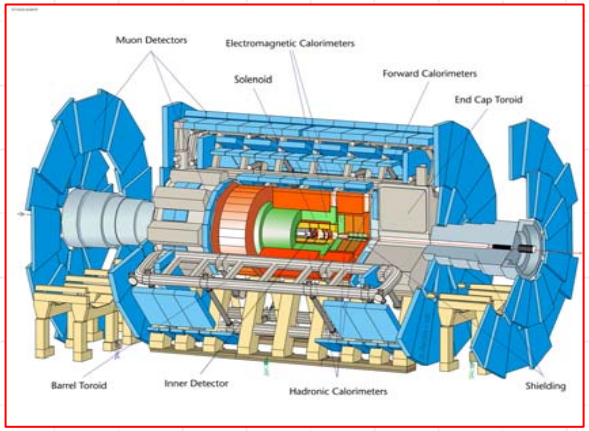
Low energy neutrinos

- Solar pp neutrinos, E_ν<1MeV
  - Very high flux, hard to detect
  - Would like to do “real time” experiment (i.e., not radio-chemical counting)
- Two R&D efforts
  - LENS experiment (Chemistry)
    - ^{176}Yb-loaded liquid scintillator → >10 Ton detector
  - Noble liquid TPC (Instrumentation/Physics)
    - LHe long drift TPC → > 5 Ton detector

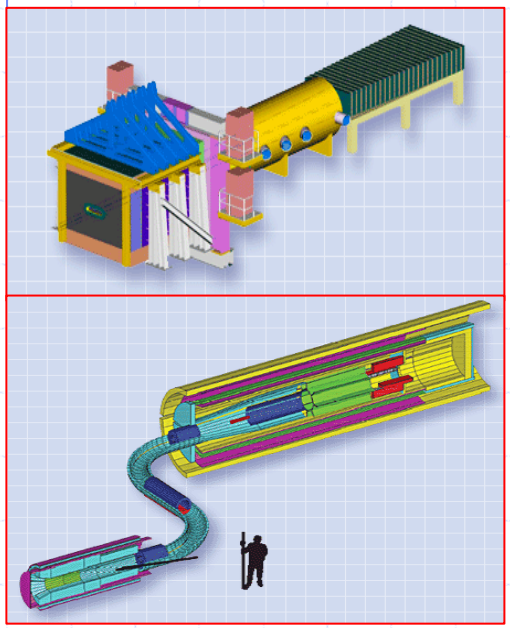


HEP vision & initiatives

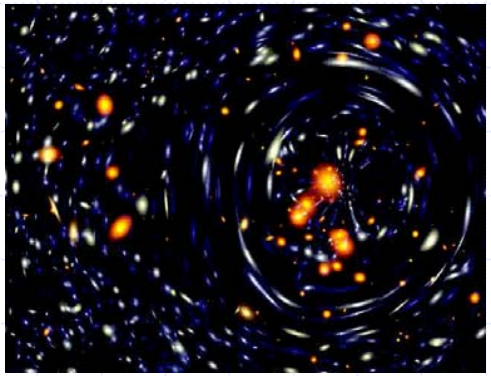
- ATLAS (Energy frontier)



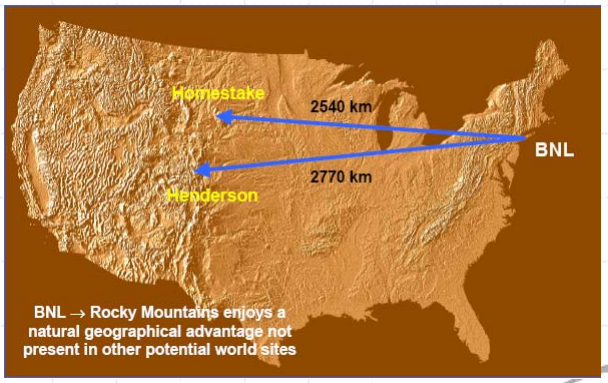
- RSVP (Sensitivity frontier)



- LSST

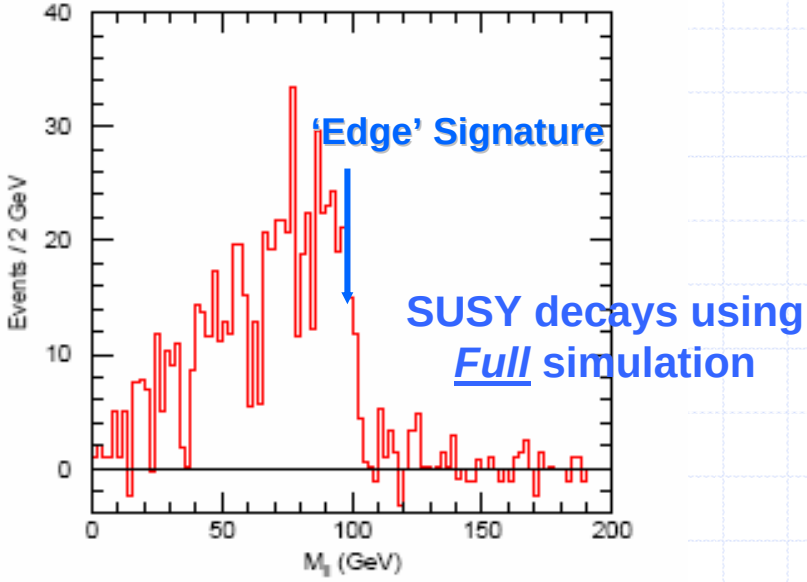


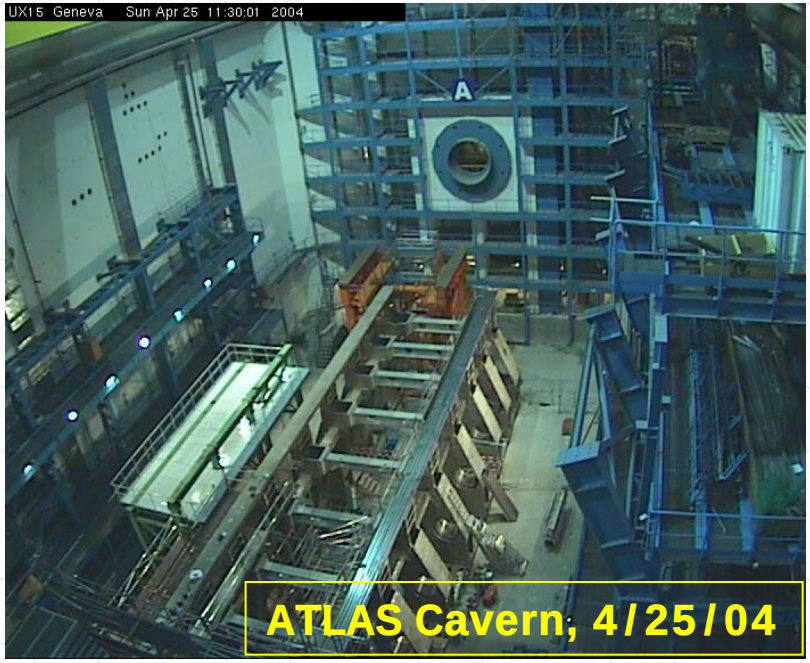
- VLB ν oscillations



ATLAS

- Construction of the ATLAS Detector & basic software creation is on track for completion on the July 2007 CERN schedule
- U.S. scientists must have the capability to perform physics analysis of ATLAS data in a rapid and cost-effective manner
- Exciting physics could emerge in the 1st year of operation – **SUSY**





US-ATLAS Physics Analysis Center

FTEs
FY04 → FY08

ATLAS BNL Physics Analysis Center
5→ 15

30 Universities, LBNL and ANL

Theory
3 → 5

ATLAS Tier 1 Computing Center
7 → 20

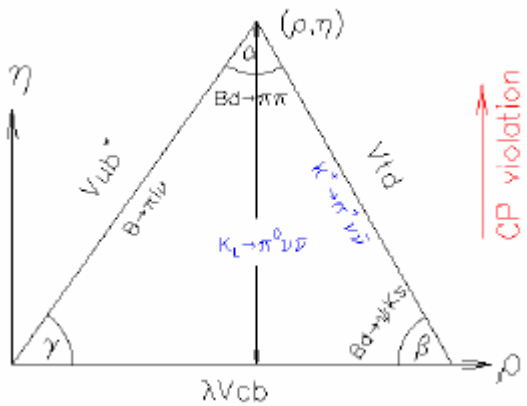
ATLAS Core Software
5 → 8

ATLAS Detector Constr. → M&O + Upgrade
8 → 8

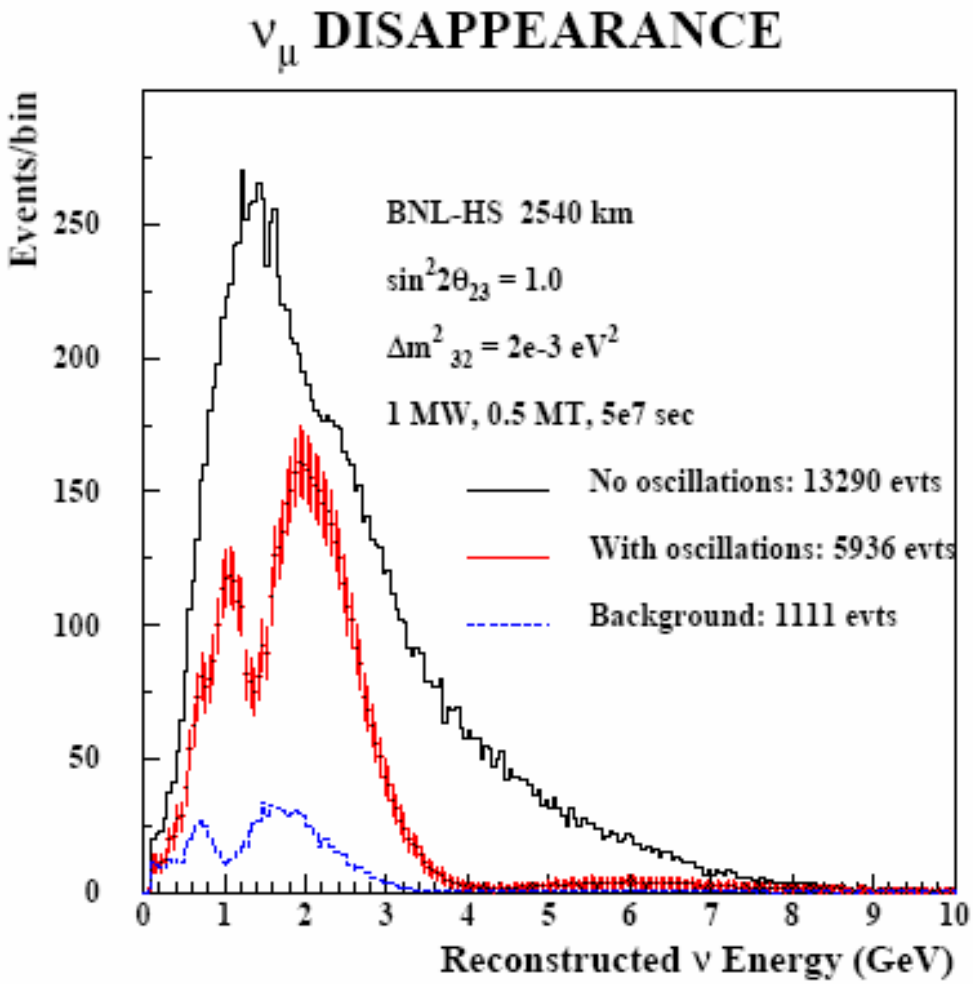
Enabling U.S. Physicists to do LHC Physics...

RSVP

- NSF Major Research Equipment project
  - Construction of two new experiments
  - Operation of AGS for these experiments
    - Opportunity for other AGS experiments to run
- KOPIO
  - $K^0 \rightarrow \pi^0 \nu \bar{\nu}$ with s.e.s. < 10^{-12}
  - Clean measurement of **CP violation** in the quark sector
- MECO
  - $\mu^- N \rightarrow e^- N$ to < 10^{-16} sensitivity
  - Charged lepton flavor violation ⇒ **BSM physics**

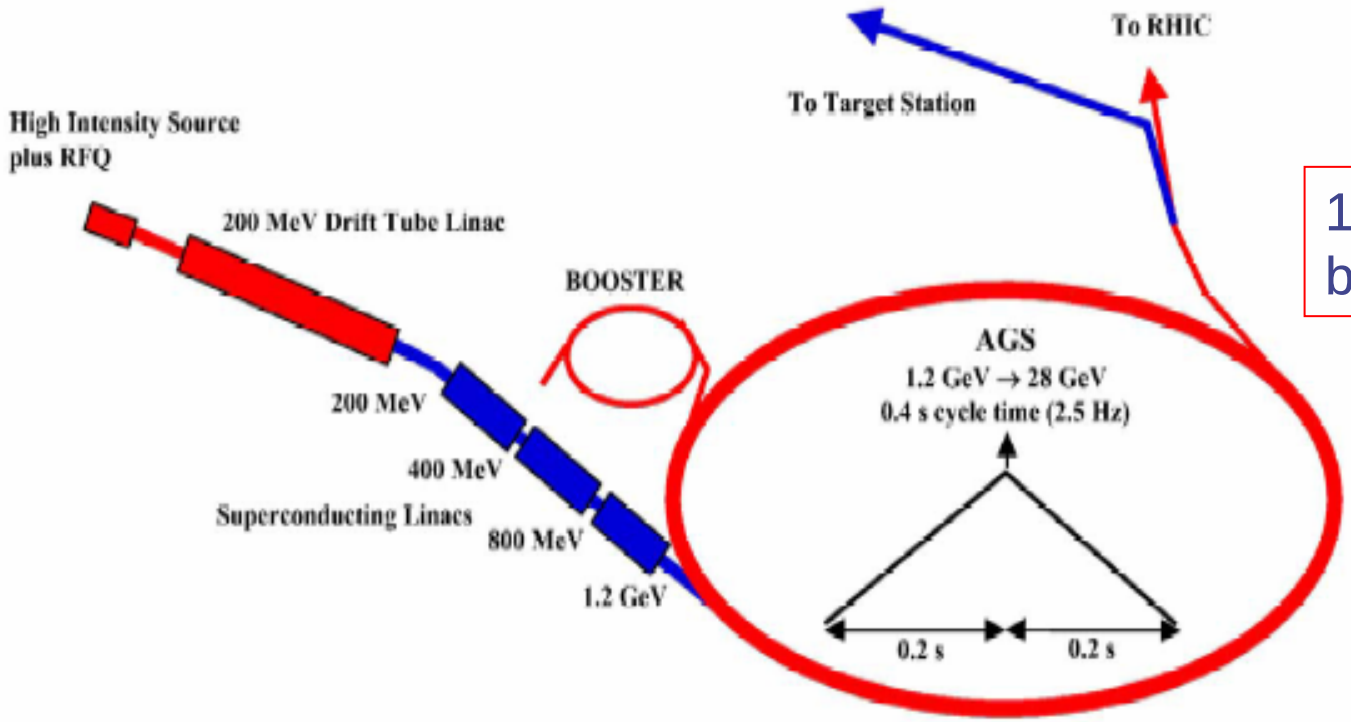


Very Long Baseline ν Osc.



- neutrino oscillations result from the factor $\sin^2(\Delta m_{32}^2 L / 4E)$ modulating the ν flux for each flavor (here ν_μ disappearance)
- the oscillation period is directly proportional to distance and inversely proportional to energy
- with a *very long baseline* actual oscillations are seen in the data as a function of energy
- the multiple-node structure of the very long baseline allows the Δm_{32}^2 to be precisely measured by a *wavelength* rather than an amplitude (reducing systematic errors)

ν Superbeam proton driver



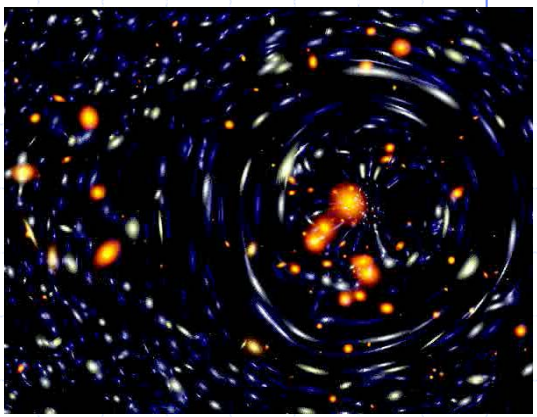
1 to 2 MW beam power

- BNL will complete in June 2004, a Conceptual Design in preparation for a proposal to DOE to upgrade the AGS to 1-2 MW target power and construct the wide-band ***Super Neutrino Beam*** as listed in the DOE's "Facilities for the Future of Science" plan of November 2003

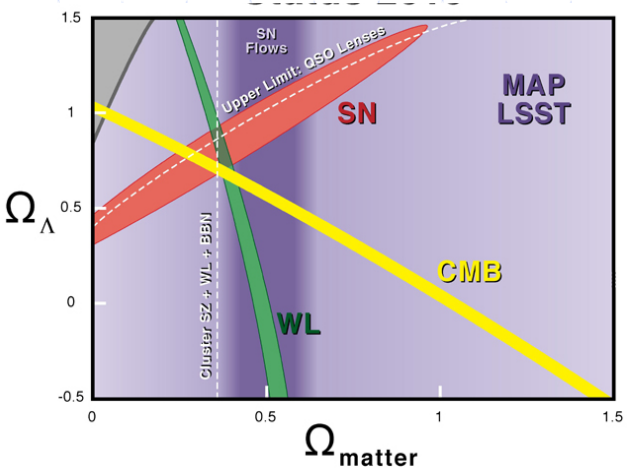
The Science of LSST

- Probe Dark Energy & Dark Matter
  - "The committee supports the Large Synoptic Survey Telescope (LSST) project, which has significant promise for shedding light on dark energy."

    "Connecting Quarks with the Cosmos"

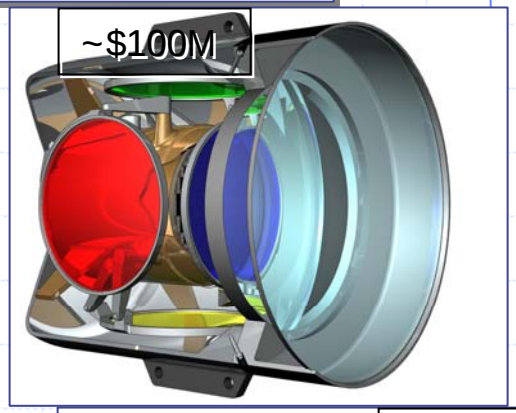


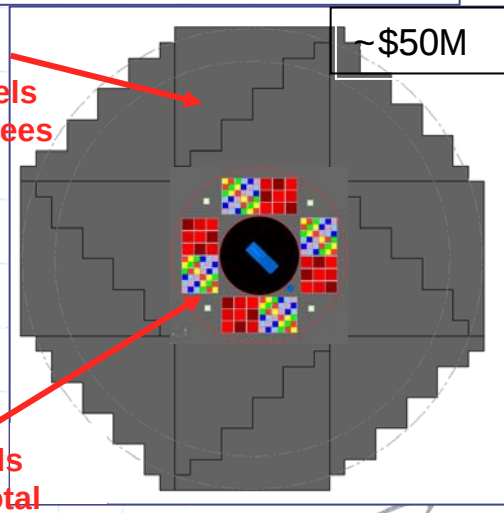
- BNL will explore the nature of Dark Energy via weak gravitational lensing
  - Wide, deep, frequent imaging of the entire visible sky → 3D map of the visible sky to redshift $z \leq 1$
  - BNL is building a group to do this science



LSST Project

- Ground-based telescope
  - 8.4m diameter f/1, 8.6° field of view
- DOE institutions propose to deliver the Camera
  - BNL, Harvard, Illinois, LLNL, SLAC
- BNL would deliver the Focal Plane Array
  - 2.8 Gigapixel CCD or CMOS array
  - BNL expertise in large Si detectors & low-noise electronics
- First light 2011-2012

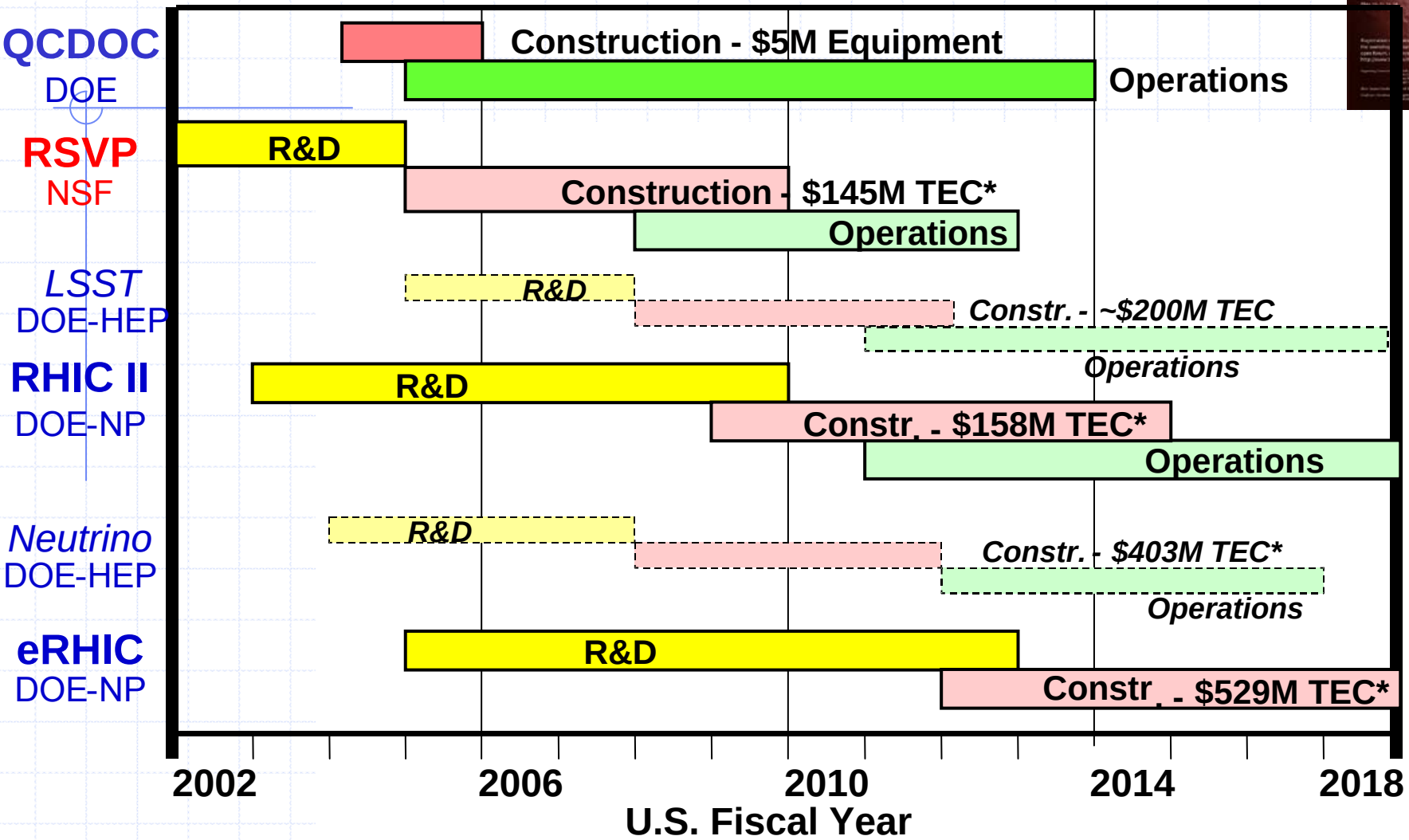




Summary: What could the BNL HENP landscape look like in the next 15 years?

- RHIC complex: the World QCD Laboratory
  - Probes: $\vec{p}$-$\vec{p}$, p-A, A-A, $\vec{e}$-$\vec{p}$ and e-A
  - LGC with QCDOC's and successors (Blue-Gene?)
- Neutrinos
  - VLB oscillations CP violation in the lepton sector (& p-decay?)
  - Solar p-p neutrinos
- ATLAS
  - US analysis effort centered at BNL
  - ATLAS upgrades
- RSVP
  - CP violation in the quark sector
  - BSM discovery reach beyond the energy frontier
- LSST
  - The nature of Dark Energy

Summary: Is all this possible?



* Estimates in FY 2004 Dollars