BNL Plans and Views in High Energy Physics

Steve Vigdor

P5 Meeting, March 7, 2008

I. *BNL's Vision for the Next Decade in HEP*

II. *BNL's Leadership Roles in Ongoing and Proposed Experiments*

III. *Advanced Accelerator R&D at BNL*

IV. *Synergy with RHIC*

V. *Possible AGS Experiments at the Precision Frontier*

SIXTY YEARS
OF DISCOVERY
1947-2007

BROOKHAVEN
NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

BNL Philosophy Going Forward

Structural Problem I: *Δt(design, fund, construct major new facility) $\gtrsim$ Δt(science program @ present generation facilities)*

$\therefore$ single-minded pursuit of single (i.e., energy) frontier $\Rightarrow$ need to design before physics results tell you what you need!

$\Rightarrow$ *Unsustainable funding model*

Structural Problem II: *U.S. HEP would shrink, change dramatically without major operating U.S. accelerator facility*

Intellectual excitement migrates; *funds from facility closure seldom return*

Solutions:

1) Diversity & improved balance among 3 "must-do" frontiers: *Energy;*

Precision/sensitivity (incl. non-accelerator-based) *-- origin of matter-antimatter asymmetry; new particles via symmetry or SM violations*

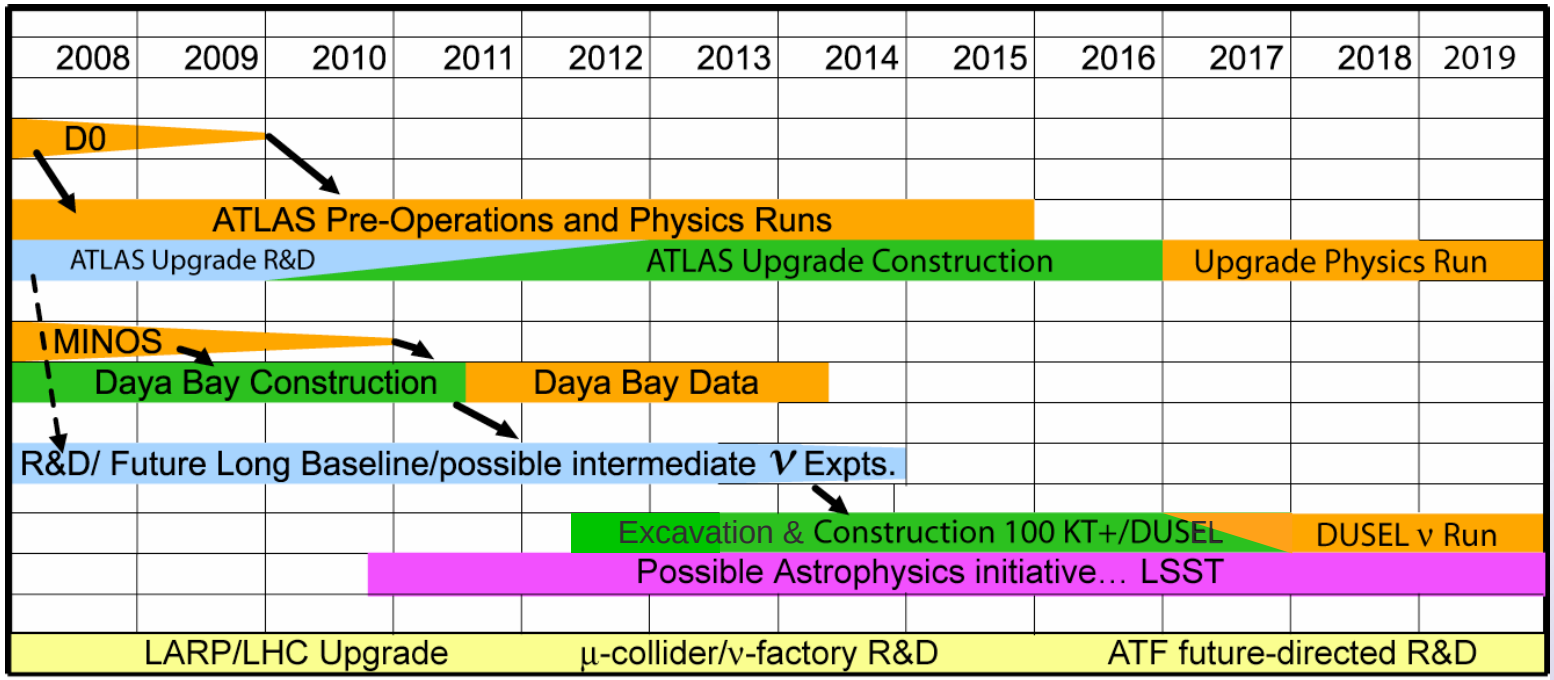
Cosmology *-- nature of dark matter, dark energy*

2) Support the most decisive precision experiments -- e.g., a very long baseline ν exp't -- and FNAL upgrade as needed to carry them out

3) Aggressively pursue advanced accel. R&D to improve reach, cost-effectiveness of *next*-generation facilities at energy frontier

Long-Term Vision for BNL HEP

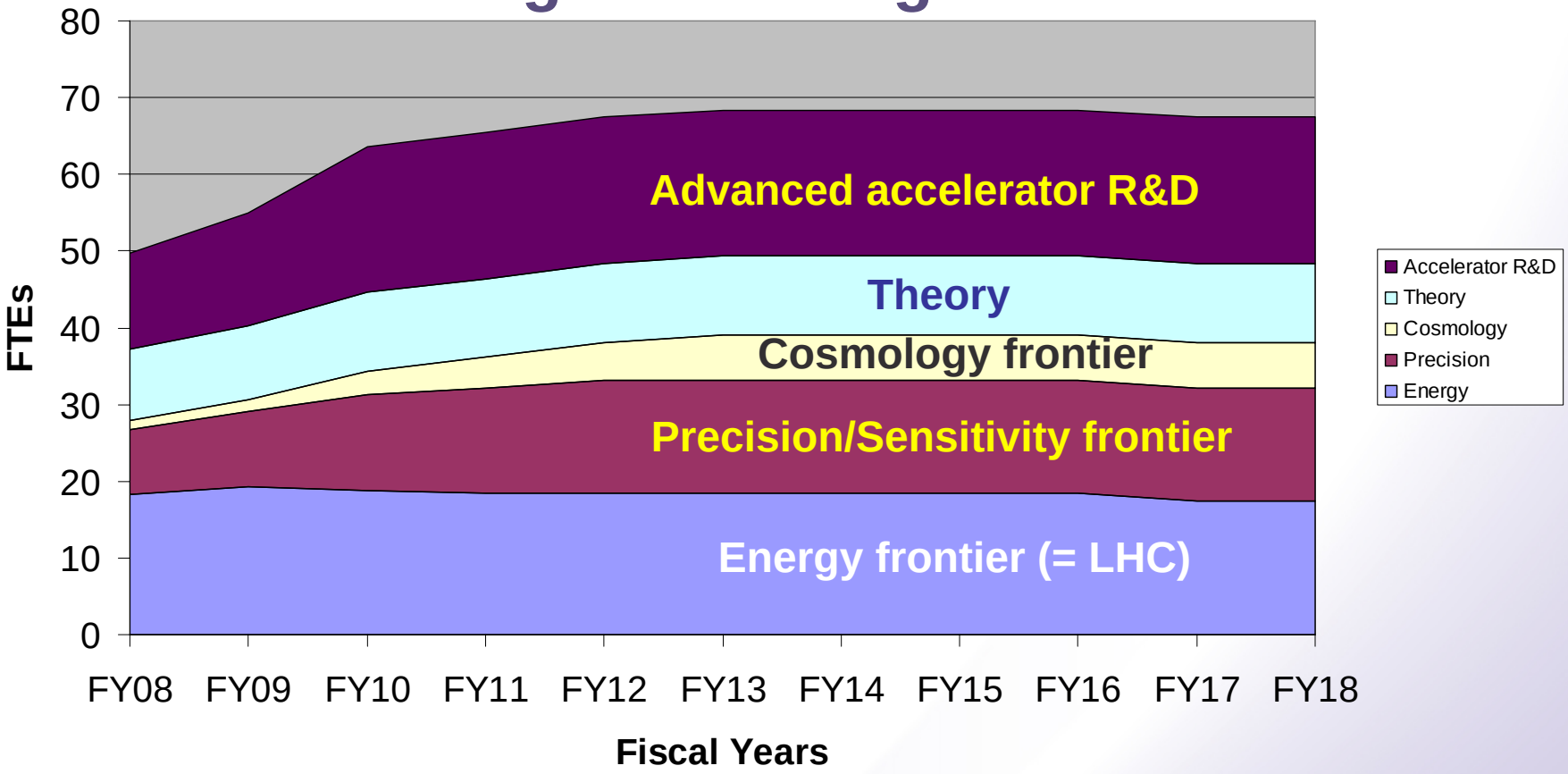
Goal: ***technical + intellectual leadership in key experiments at 3 frontiers (energy, precision, cosmology), supported by theory and by critical advanced accelerator and detector R&D.***



- **2010-15 physics payoff with ATLAS, Daya Bay**
- **Large new construction projects fuel physics beyond 2015**
- **Modest-scale complementary precision exp't at FNAL or AGS can fill in physics gap**
- **Cosmology a growth area for BNL Physics**

"Frontiers" of BNL Physicists

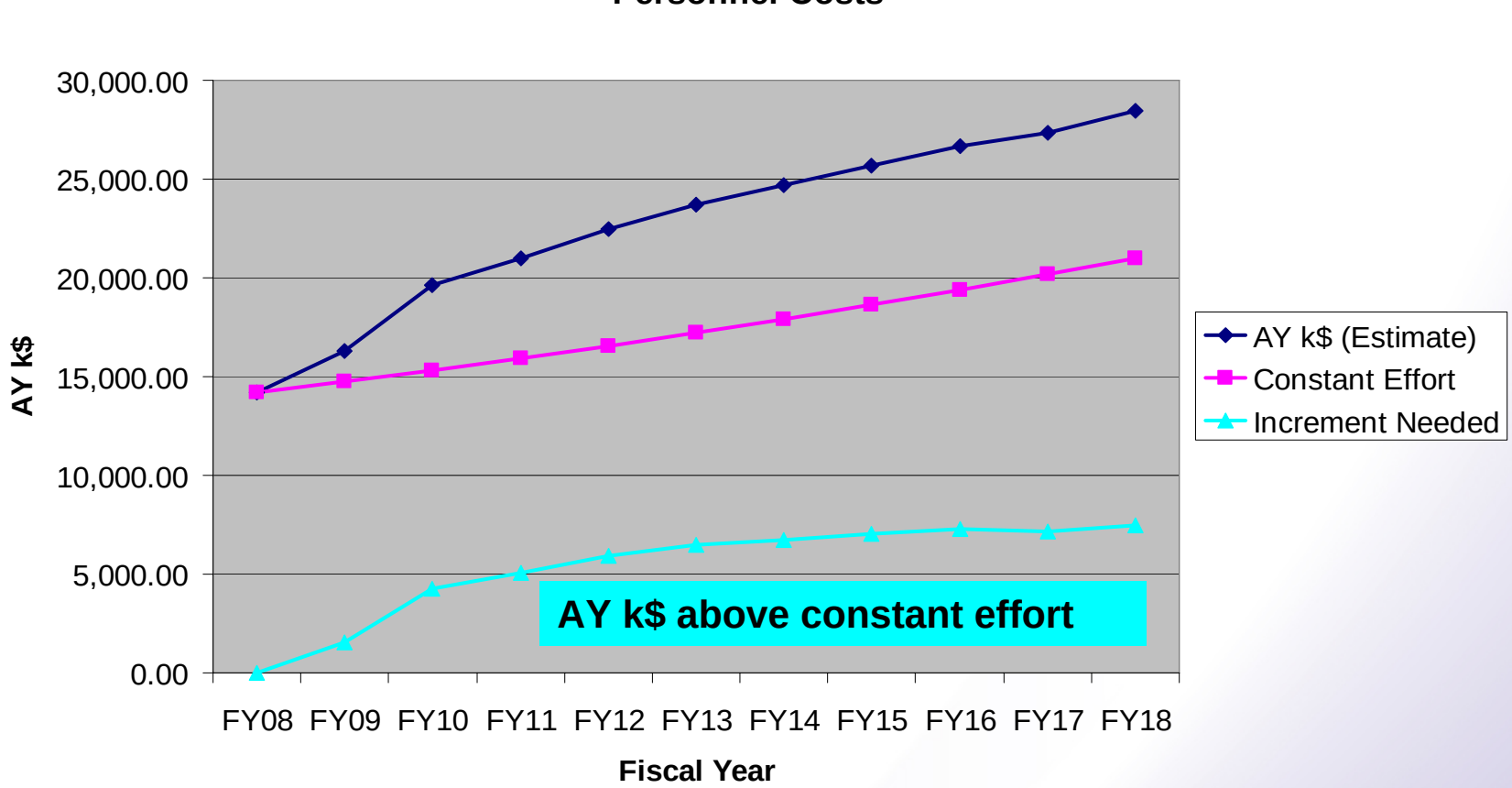
Under Budget-Doubling Scenario…



➢ ***Short-term AARD growth ⇒ viability in meeting ATF user demand, and 2012 goal for ν Factory Design and μ Collider Feasibility Reports***

➢ ***Growth at precision frontier fuels Daya Bay and LAr development ramp-ups + significant role in one among: μ2e or rare K @ FNAL, or μ g-2 or deuteron EDM @ AGS.***

Budget Implications of "Vision"



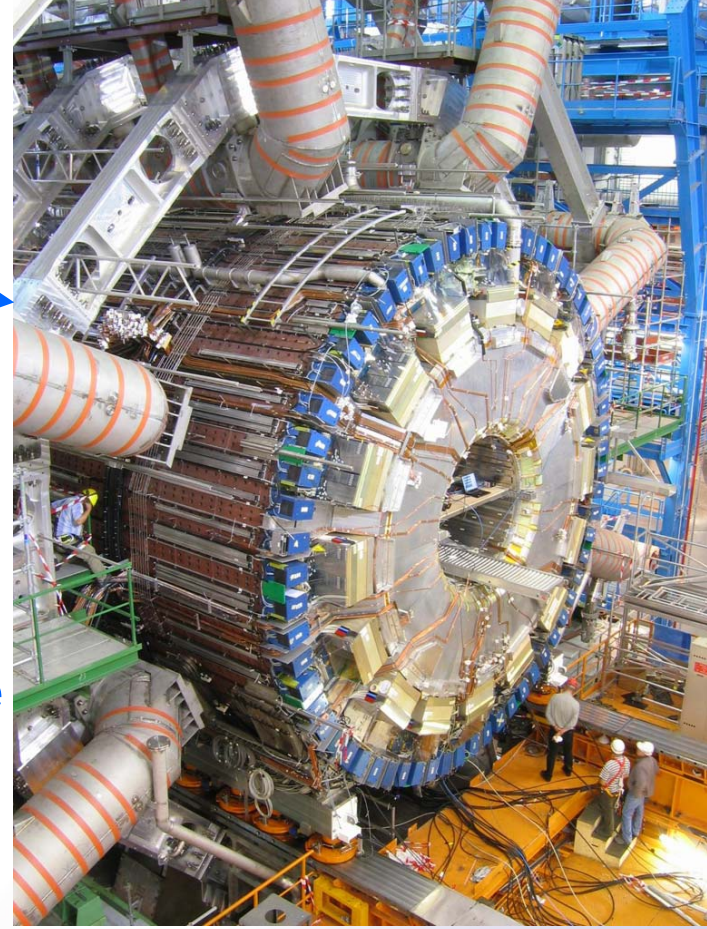
With constant effort budgets, we cannot afford the growth indicated above. In that scenario we protect our present core programs, and their natural evolution, in ATLAS, neutrinos, theory and advanced accelerator R&D.

Unique Capabilities BNL Brings to HEP Projects

- *Extensive experience planning/managing large HEP projects*
- *Strong engineering leadership*
- *Close collaboration with BNL HE theorists in developing physics programs*
- *Strong Instrumentation Division supporting state-of-the-art technology development*
- *Expertise in specific technologies -- e.g., LAr calorimetry, superconducting magnets, semiconductor detectors, low-noise electronics, high-power lasers for acceleration*
- *Extensive experience and strong ongoing efforts in advanced accelerator design*
- *Accelerator Test Facility*
- *High-performance computing capabilities (RHIC-ATLAS Computing Facility, New York Blue, LQCD work)*
- *Synergy with large NP-funded collider efforts, with strong overlap on experiment, theory, accelerator and computing fronts*
- *NP funding for AGS/RHIC base ops. and RACF space expansion*

BNL Roles at the Energy Frontier in ATLAS: Construction

- **LAr calorimeter**
- **Trigger**
- **Cathode Strip Chambers in muon spectrometer**
- **Technical Coordination in ATLAS**



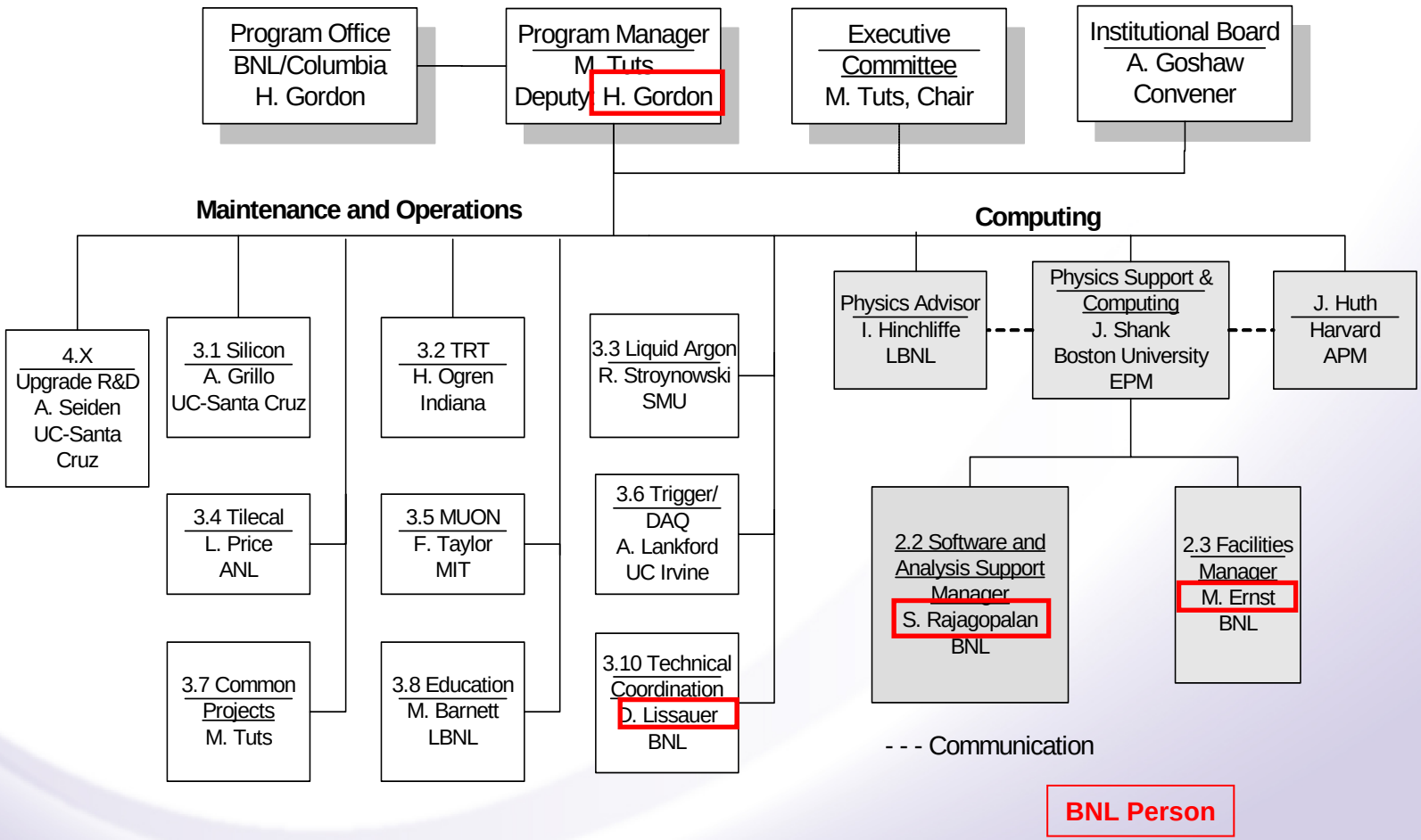
2nd Small Wheel before lowering into ATLAS Hall on 2/29/08

- **Upgrade Project office** (Lissauer)
- **LAr Calorimeter upgrade** (Lanni)
- **Si tracker upgrade** (Lynn)
- **μ–Mega muon chambers for forward region** (Polychronakos)

Silicon Multi-Channel Readout Probe Card

BNL Roles at the Energy Frontier in ATLAS: Management

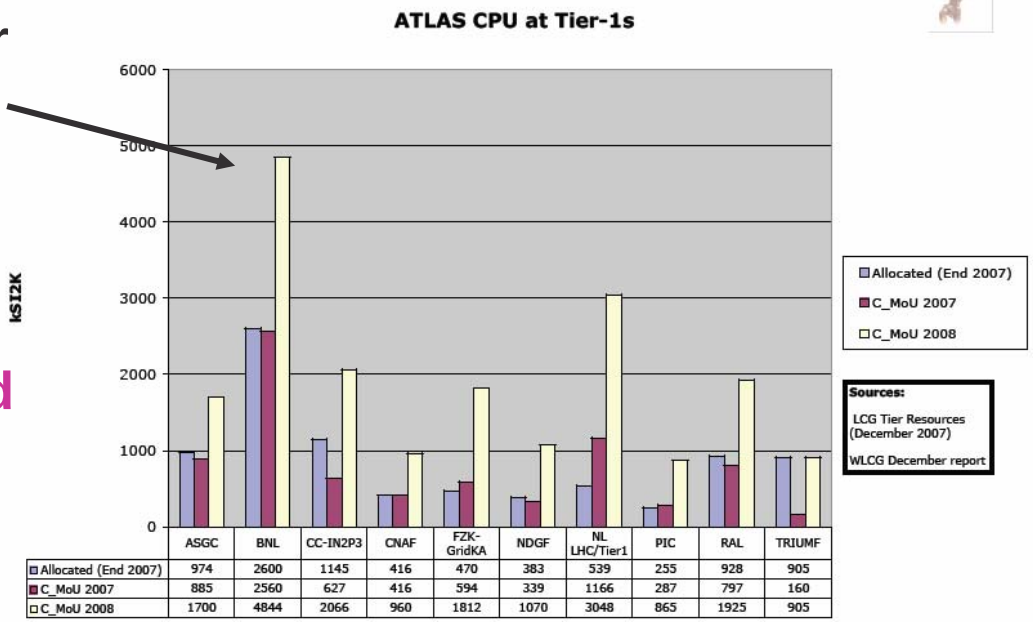
U.S. ATLAS Research Program Organization as of January 15, 2008



BNL Roles at the Energy Frontier in ATLAS: Software, Computing & Analysis Support

- **BNL hosts largest, and so far most successful, ATLAS Tier 1 Computing Center (M. Ernst)**

- **Workload management system adopted by ATLAS for distributed data production and analysis (PanDA) was developed under BNL leadership (Wenaus)**



	ASGC	BNL	CC-IN2P3	CNAF	FZK-GridKA	NDGF	NL LHC/Tier1	PIC	RAL	TRIUMF
Allocated (End 2007)	974	2600	1145	416	470	383	539	255	928	905
C_MoU 2007	885	2560	627	416	594	339	1166	287	797	160
C_MoU 2008	1700	4844	2066	960	1812	1070	3048	865	1925	905

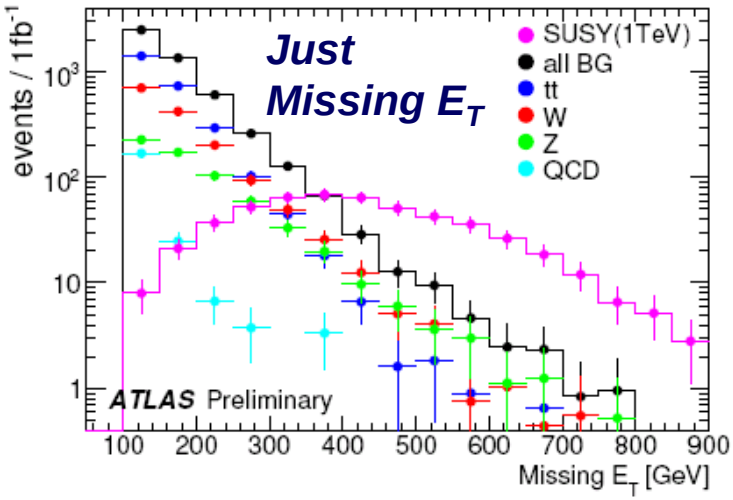
Analysis jamboree at BNL, 12/07

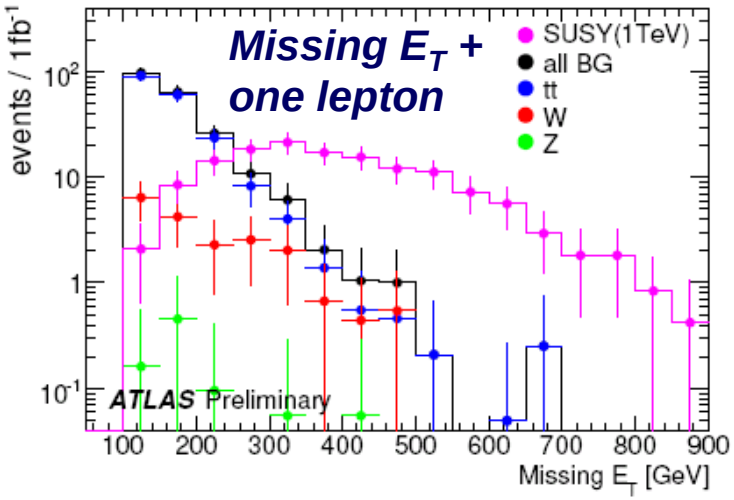
- **A. Klimentov leads ATLAS Distributed Computing effort**

- **BNL Analysis Support Center is resource for all U.S. ATLAS members: runs "jamborees" for users; maintains expertise in all aspects of ATLAS analysis software & computing; works with university users on analysis topics**

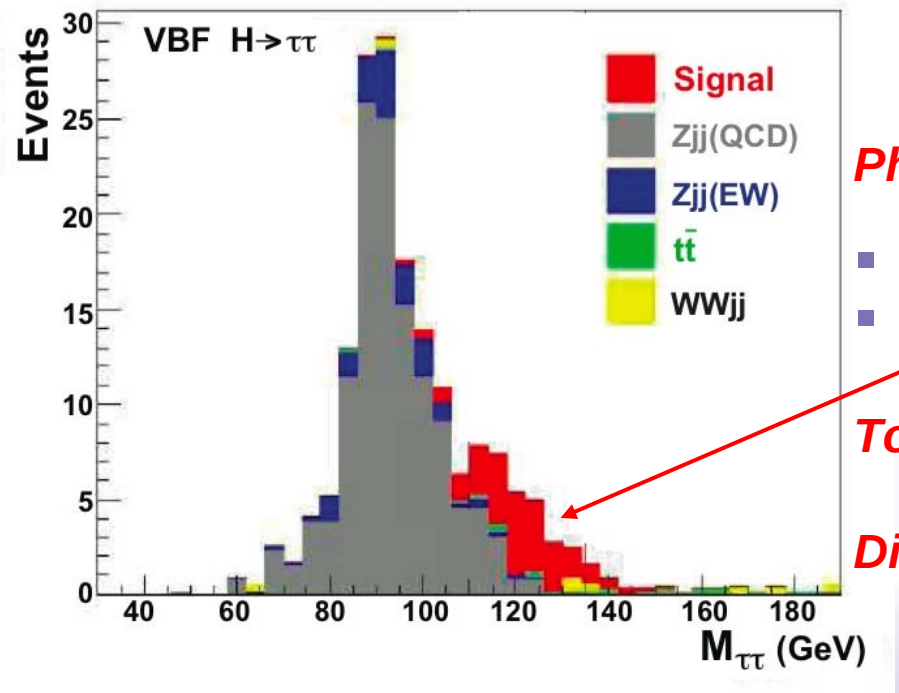
BNL Roles at the Energy Frontier in ATLAS: Physics Analysis

F. Paige leads efforts to evaluate SUSY early discovery potential with ATLAS @ LHC





SUSY ($M_{\tilde{g}} \approx M_{\tilde{q}} \approx 1$ TeV) S/B improves although lower # events



Physics with tau lepton (Protopopescu, Patwa, Tarrade)

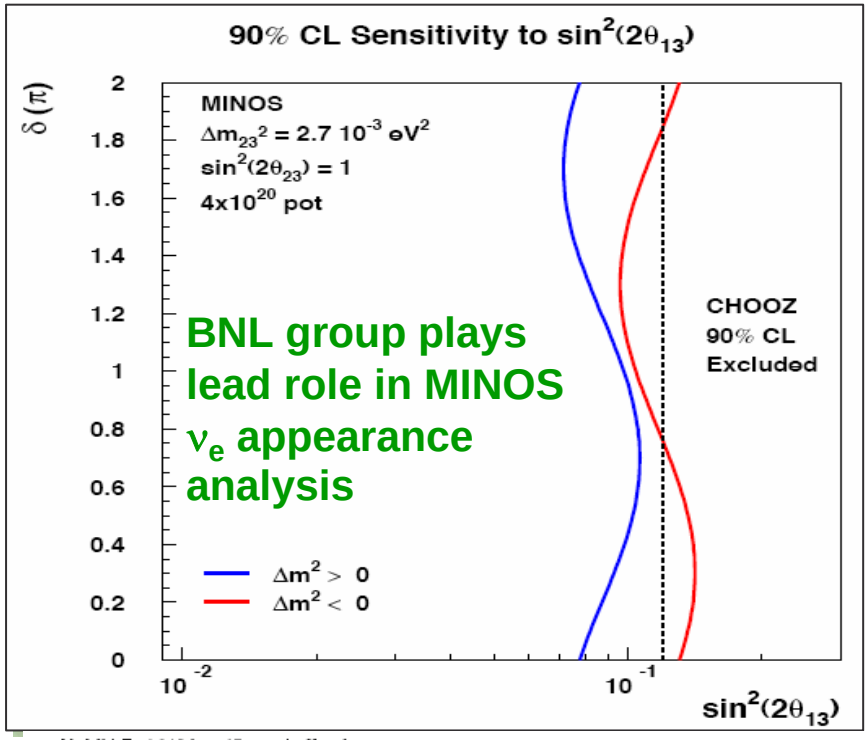
- ***Strong D0 experience***
- ***$H \rightarrow \tau\tau$ in Vector Boson Fusion***

Top physics (Snyder, Assamagan)

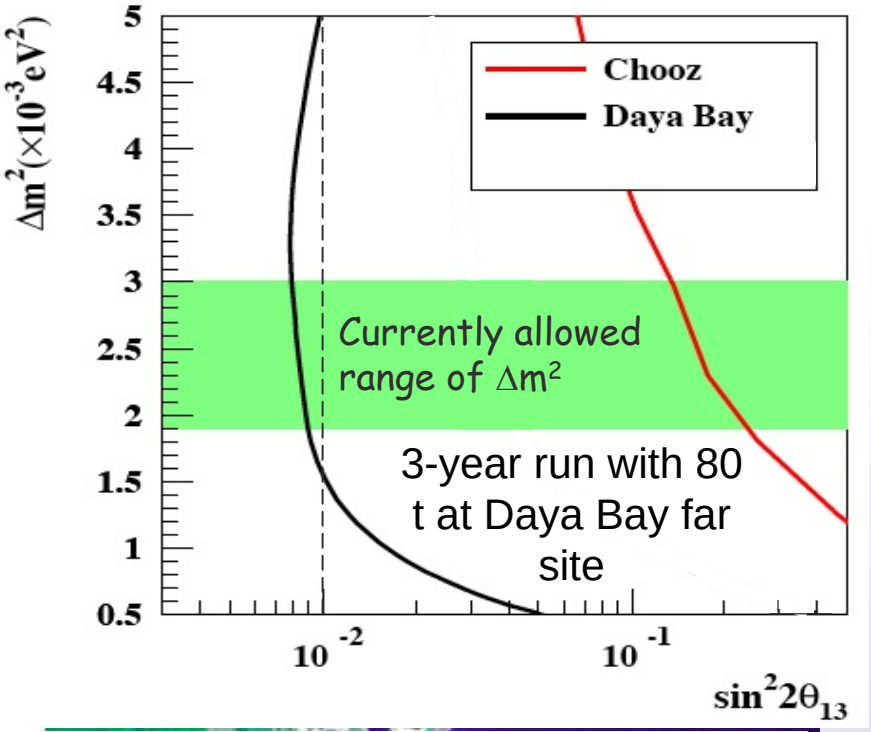
Di-boson physics (WW, WZ, ZZ, Zγ, Wγ) (Ma)

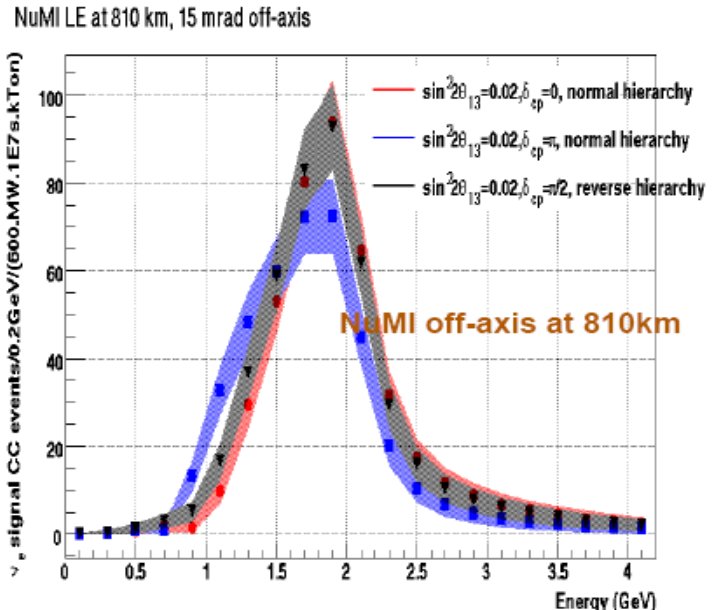
~50 FTE total @ BNL, mostly on U.S. ATLAS Research Program support

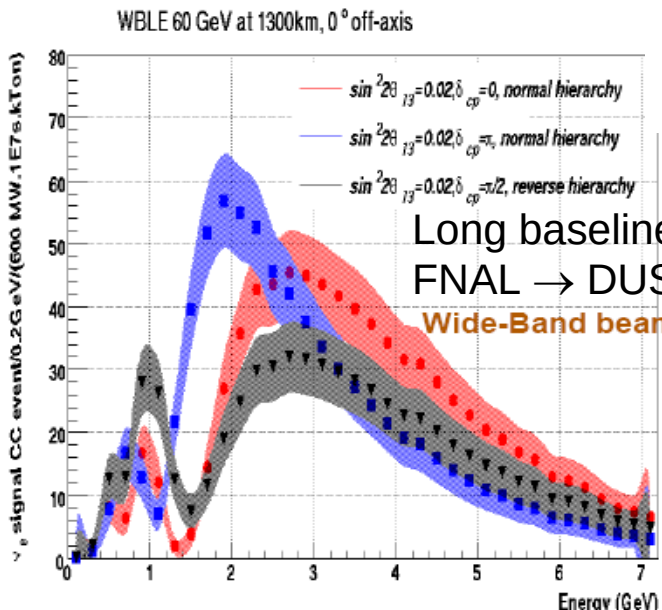
BNL Roles at the Precision/Sensitivity Frontier:



BNL group plays lead role in MINOS ν_e appearance analysis







350 kT·MW·yr
$P(\nu_\mu \rightarrow \nu_e) \sim 1\%$

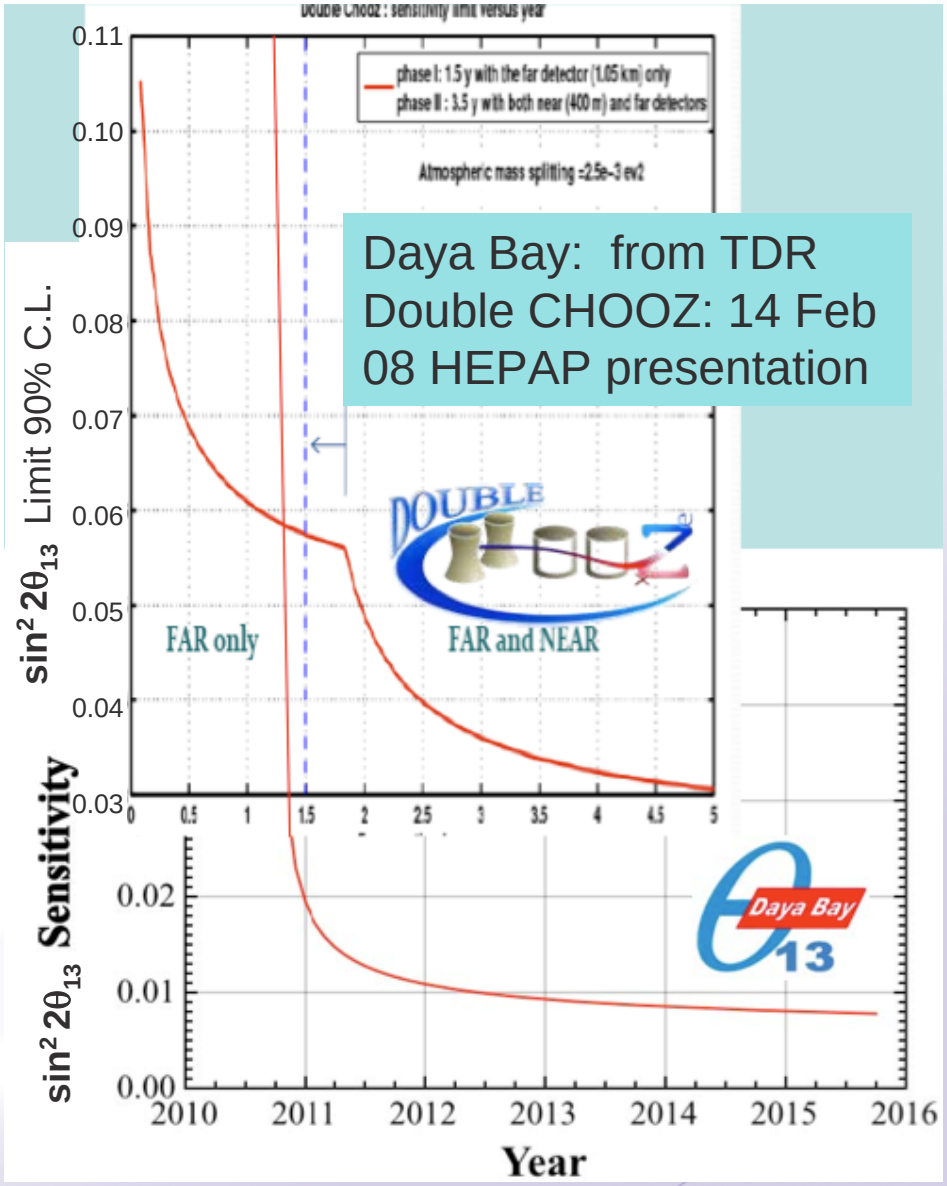
Long baseline exp't
FNAL → DUSEL

BNL Roles in Daya Bay

BNL & LBNL host labs for US Project; Joint leadership structure with Chinese

- Steve Kettell: US Chief Scientist; Ralph Brown: US Chief Engineer; Dana Beavis: US Safety Officer
- BNL leadership of Muon System & Installation/Integration, liquid scintillator, simulation, etc.

❑ CD-2/3A Review January 8-10, 2008 – anticipate imminent approval



BNL Paper Trail for Very Long Baseline Exp't

Extra Long Baseline Neutrino Oscillations and CP Violation
Author: William J. Marciano
hep-ph/0108181

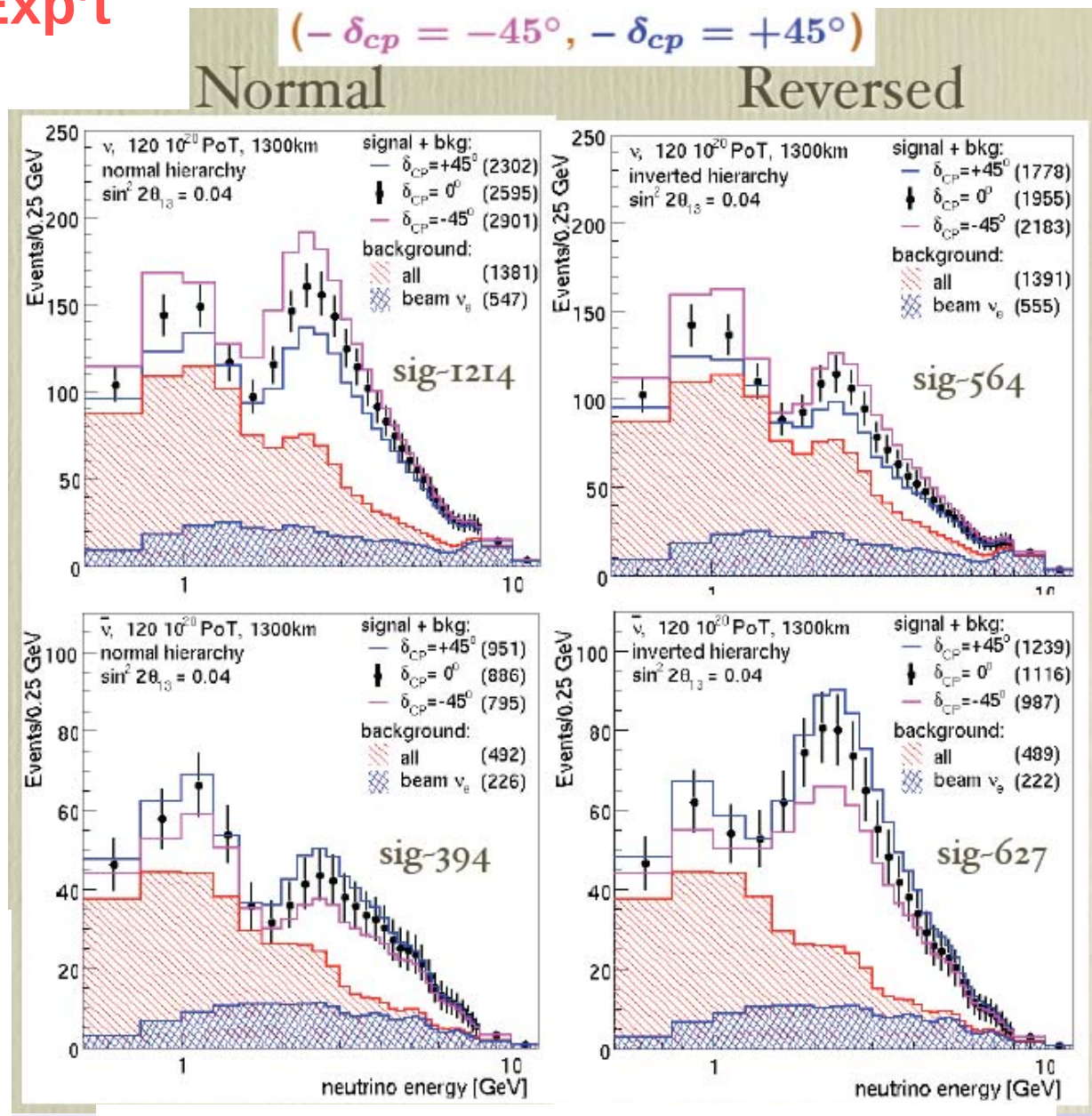
Very Long Baseline Neutrino Oscillation Experiment for Precise Measurements of Mixing Parameters and CP Violating Effects
Phys.Rev.D68:012002,2003.
Authors: M.V. Diwan, *et al.*

Proposal for an Experimental Program in Neutrino Physics and Proton Decay in the Homestake Laboratory
hep-ex/0608023
Authors: M. Diwan, *et al.*

U.S. Long Baseline Neutrino Study, launched by S. Dawson & H. Montgomery; chaired by M. Diwan & G. Rameika → ***NuSAG recommendations***

$\sin^2 2\theta_{13}$ = 0.04, 300 kT, 1300 km, ~2 MW @ 60 GeV 3 yrs ν + 3 yrs $\bar{\nu}$

$(-\delta_{cp} = -45°, -\delta_{cp} = +45°)$



Mark Dierckxsens (UChicago) & Mary Bishai (BNL)

Detector R&D for Future ν Experiments

Make effective use of the unique physics and engineering capabilities at BNL

- Water Cerenkov detector at 100 kT scale
  - Phototubes under pressure; optimization of photocathode
  - Water conditioning systems (common with Daya Bay)
  - Support systems

- Long-drift Liquid Argon Detector
  - BNL has well-established capability in this technology
  - Original work of Radeka & Willis (1974)
  - R-806 (ISR); D0 (Tevatron); ATLAS (LHC)

Present → MicroBooNE → Intermediate detector → Large ν dectector

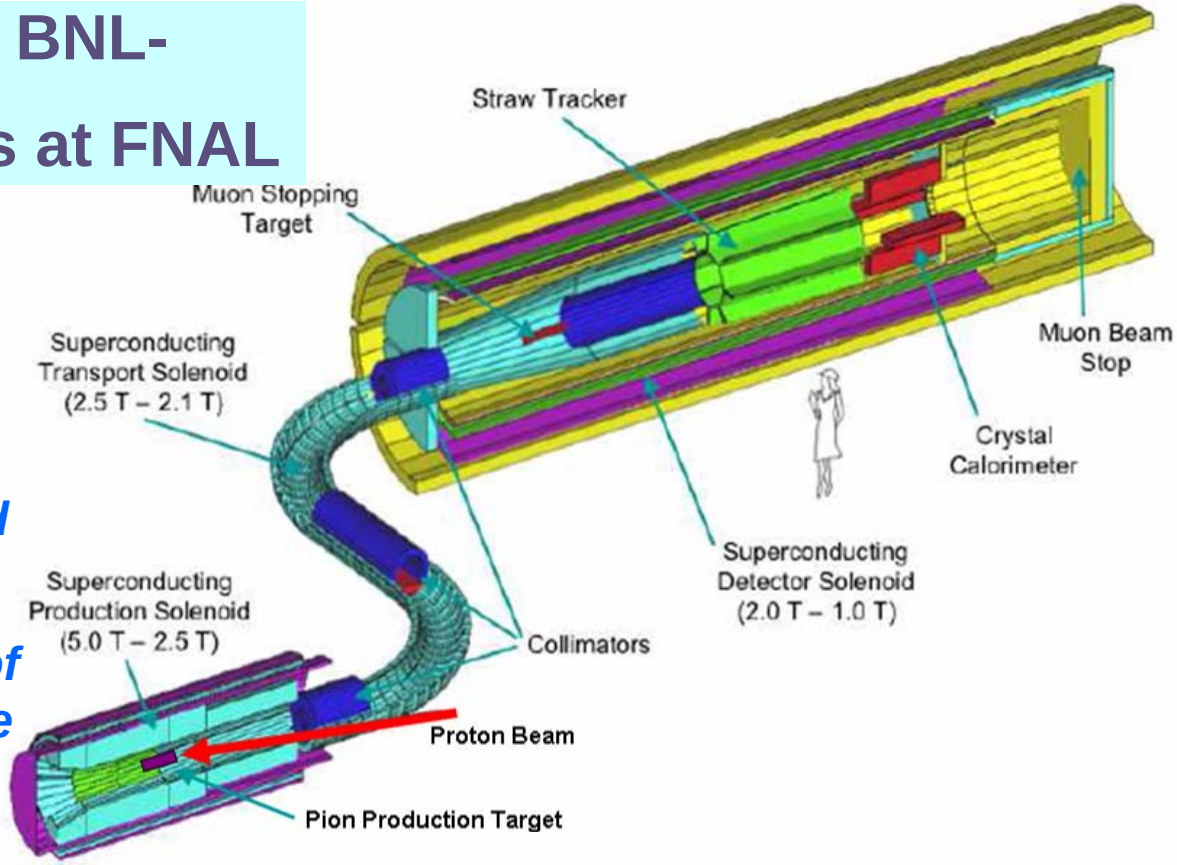
Development | 170 tons | 5ktons | ~50-100 ktons

Note - Our focus is the physics: water Cerenkov, LAr , or even a mix of detector technologies, would be fine. But, start of data-taking early during 2nd half of next decade, as allowed by DUSEL ISE for 1st ~100 kT detector, highly desirable!

Precision Options: BNL-Inspired Flavor Physics at FNAL

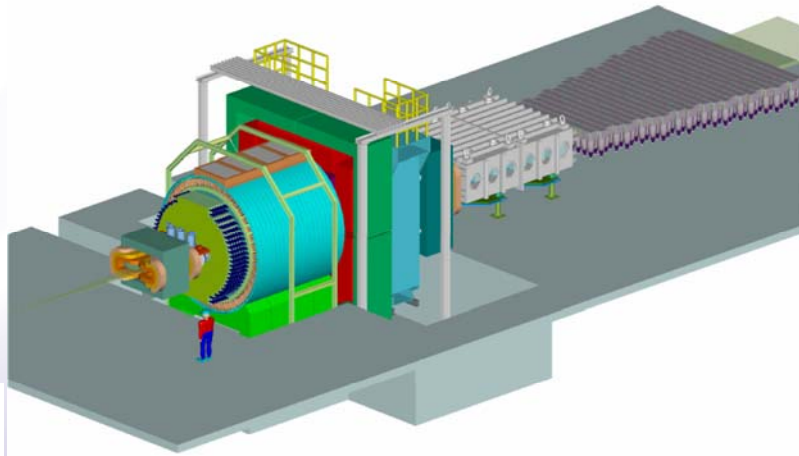
***Mu2e** would search for conversion in nuclear field, with sensitivity to $R_{\mu e} \sim 10^{-16}$ and beyond (with Project X)*

- *keen probe of BSM charged lepton flavor violation*
- *very similar to MECO part of RSVP ⇒ strong BNL expertise*



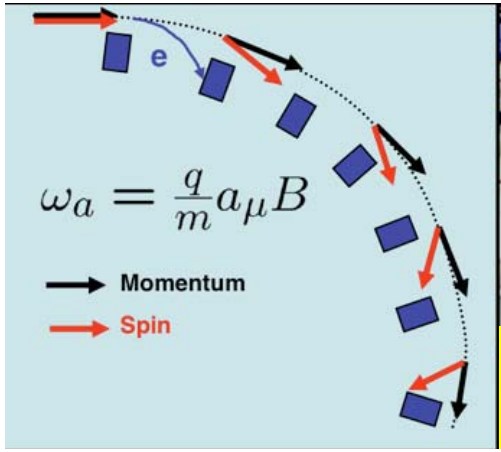
***Rare K decay exp'ts** would measure $K \to \pi \nu \bar{\nu}$ branching ratios to ±3% ⇒ unique probe of BSM flavor structure*

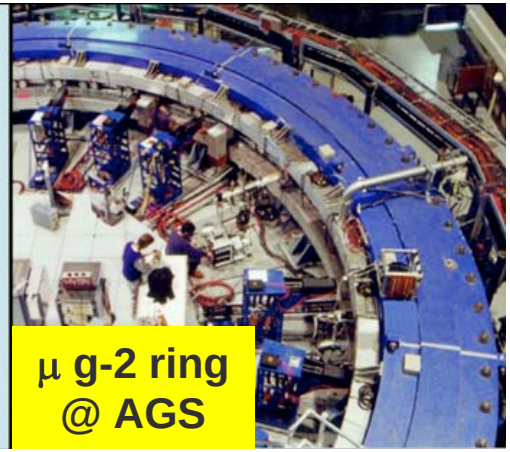
- *inspired by & using similar techniques to BNL predecessors E787/949 & KOPIO*
- *would really benefit from Project X !*

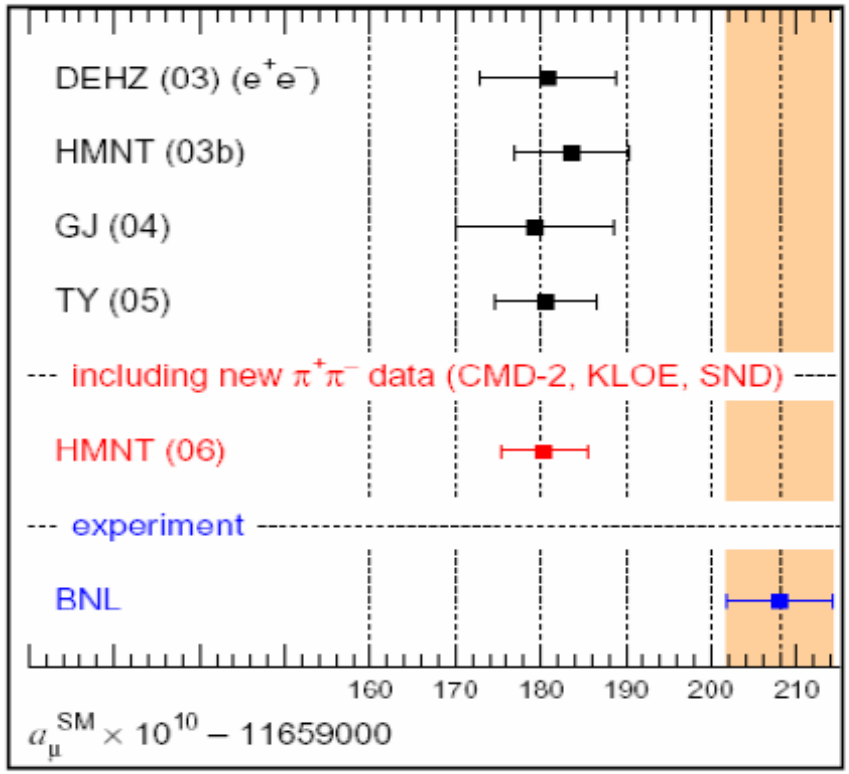


We have contributed to discussions, EOI's & could participate in one exp't if budgets allow

Precision Options: Muon g-2







Physics Beyond the Standard Model: Supersymmetry

SUSY working group report: Les Houches 2007 (Feb 08 archive)

"The strongest hint for a TeV-scale modification of the Standard Model originates from the anomalous magnetic moment of the muon."

$\Delta a_\mu(\text{expt-thy}) = (29.5 \pm 8.8) \times 10^{-10}$ $(3.4\ \sigma)$

Based on de Rafael's theory summary (2007), using inputs from Davier (2006) and HMNT (2006). Rep.Prog.Phys. **70**, 795 (2007).

- ***Proposed new exp't to 0.1 ppm $\Rightarrow 6\sigma$ sensitivity would need ~$55M (0.25 ppm "fast" version ~$30M)***
- ***Ring and expertise exist at BNL (AGS ops costs shared with NP?); FNAL version offers some technical advantages in muon accumulation; J-PARC?***
- ***BNL wants to see the physics done: will support regardless of location***

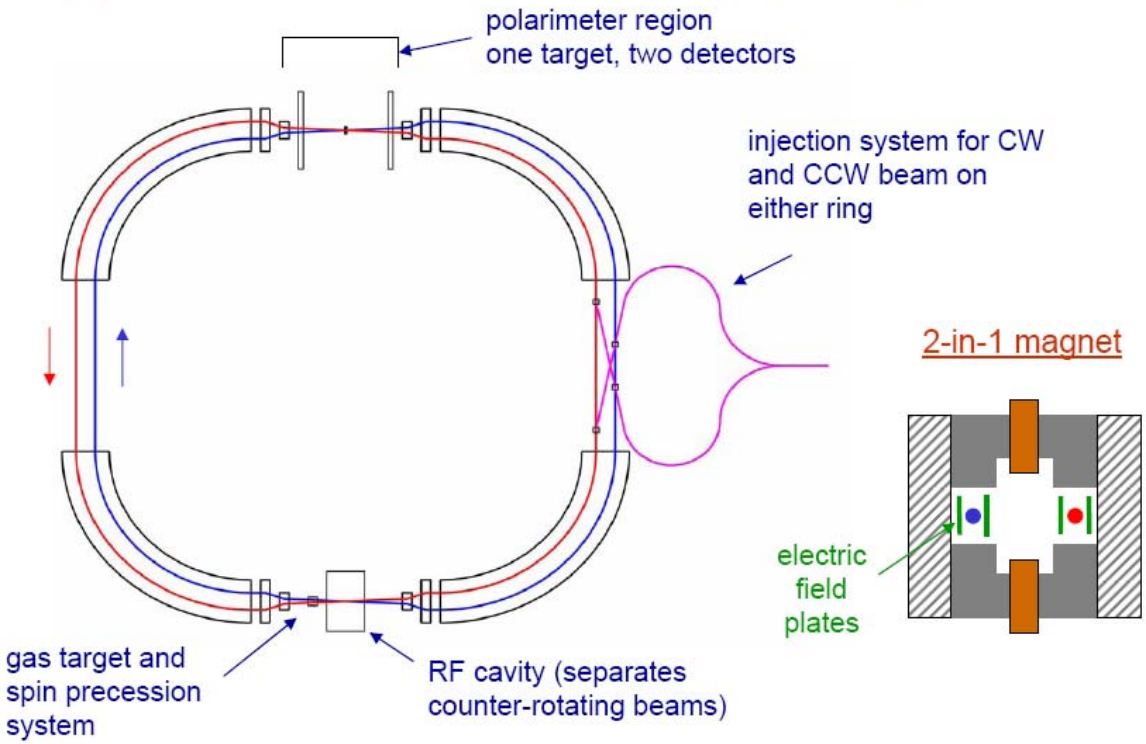
Precision Options: Deuteron EDM @ AGS

I. $dEDM \simeq 10^{-24}\,\mathrm{e}\cdot\mathrm{cm}\times\sin\delta\times\left(\frac{1\ \mathrm{TeV}}{M_{SUSY}}\right)^2$

- Deuteron EDM at 10^{-29}e·cm has a reach of $>10^2$ TeV or, if new physics exist at the LHC scale, 10^{-5} rad CP-violating phase. Both are much beyond the design sensitivity of LHC.

- ***Longitudinally pol'd d beam from AGS into ring.***
- ***Store beam for ~10^2 s ~ spin coherence time.***
- ***E*-field = v × B (1 T ⇒ 300 MV/m) precesses d spin out of plane if dEDM ≠ 0.***
- ***CW and CCW beams with 2-in-1 magnet design cancels many syst. errors.***
- ***Sensitivity ≳ nEDM @ SNS attainable.***
- ***Another opportunity for NP-HEP funding sharing?***

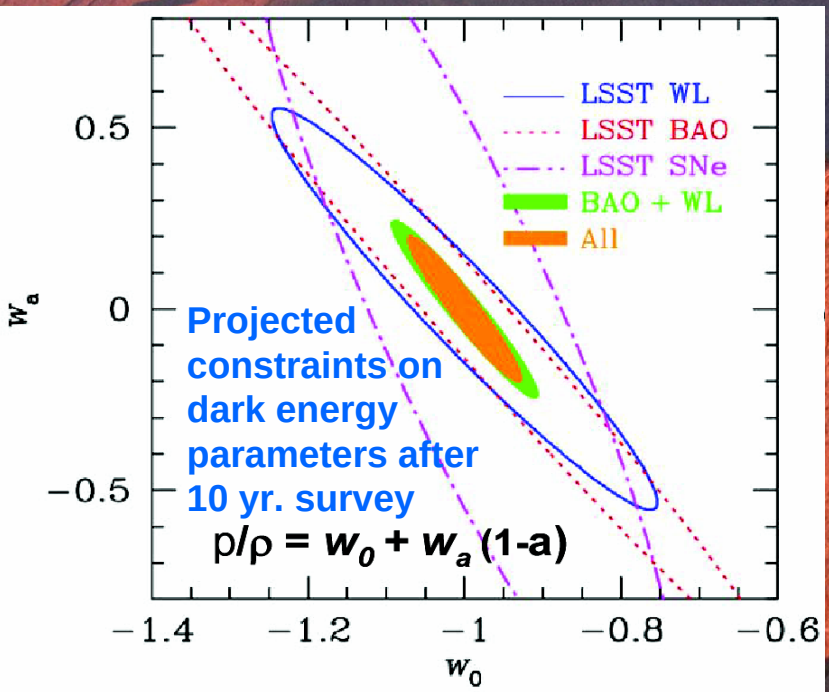
2-in-1 magnets in two intersecting storage rings geometry:

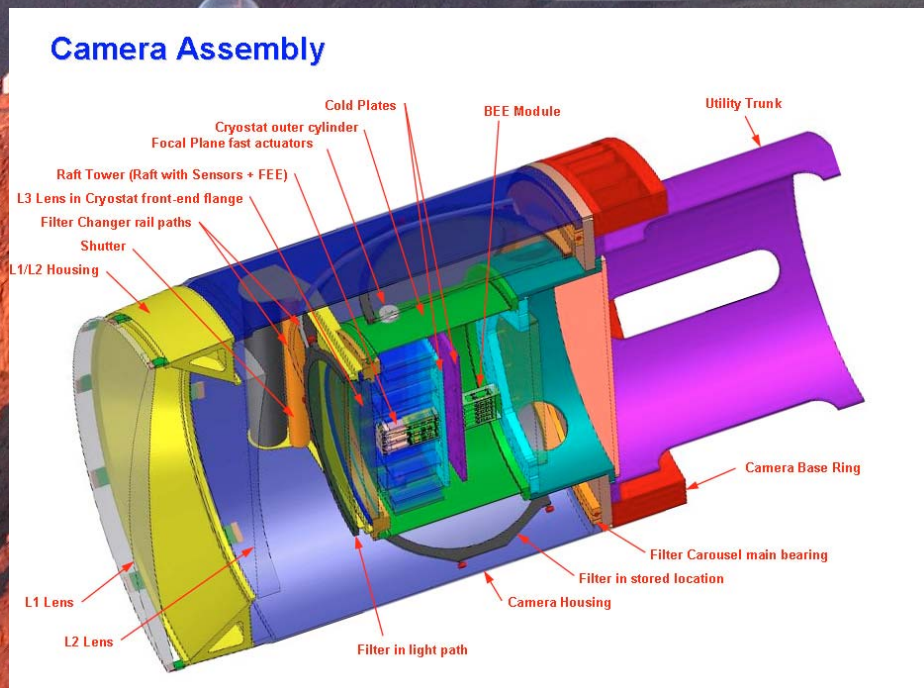


BNL Growth at the Cosmology Frontier

Proposed LSST facility: stage IV dark energy exp't based on 8.4 m telescope with unique 3 Gpixel camera

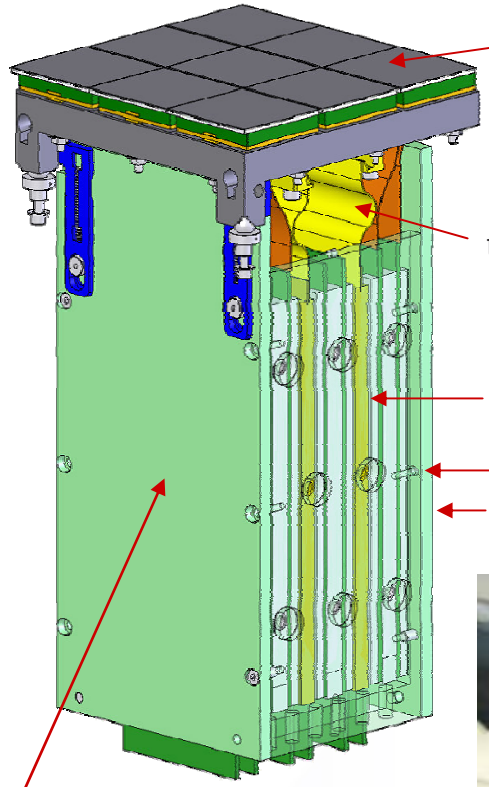
Pachón



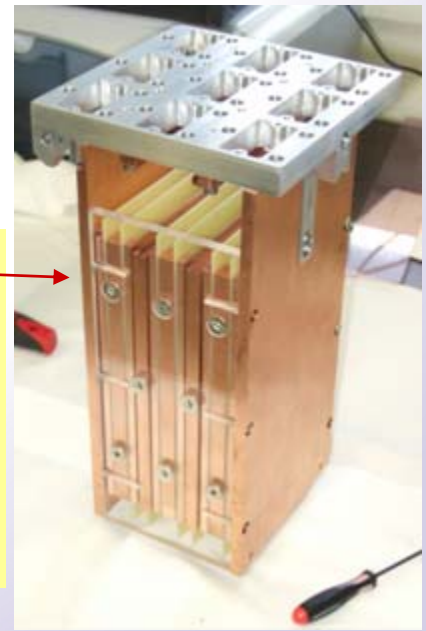


BNL Roles in LSST

- **Focal plane:**
  - 200 over-depleted thick silicon CCDs
  - highly parallel fast readout
  - integrated front-end electronics
  - ultra-flat mosaic assembly
- **BNL (Instrumentation Div.) role:**
  - ***Lead institution for sensor development***
  - CCD modeling and characterization
  - optical metrology
  - integration of key focal plane building block
  - a natural outgrowth of BNL detector R&D
- **Nascent Physics research effort funded by HEP core research funds**
- **Search for 2 junior scientists under way, BNL Program Development funds for early support**

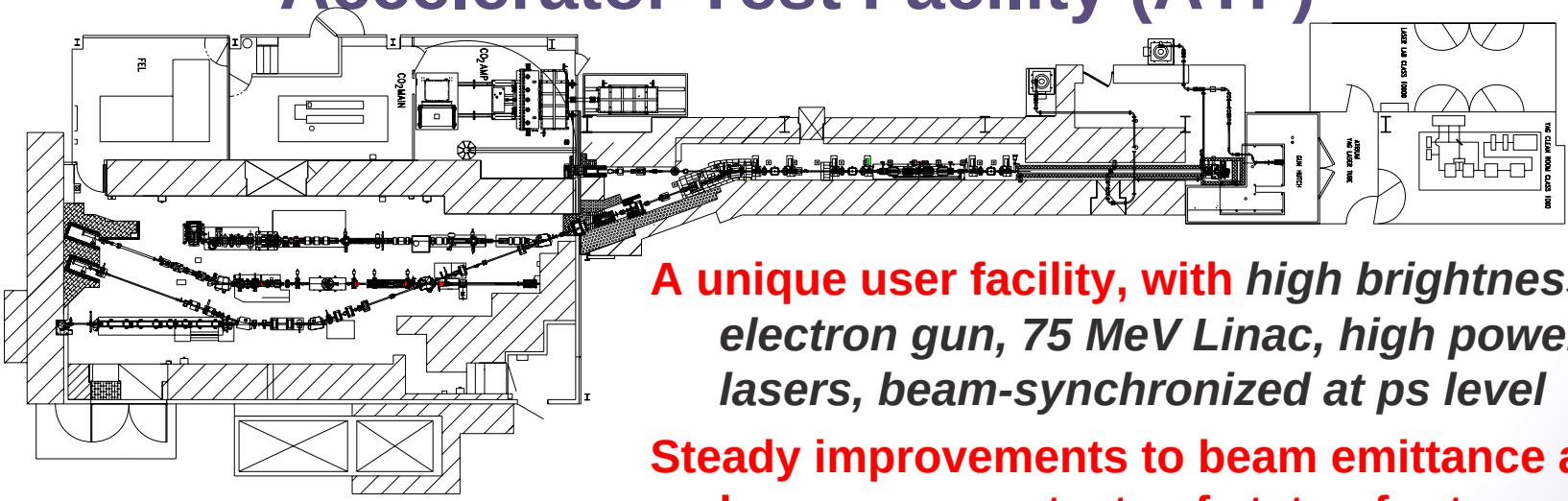


TOWER
- 3x3 CCDs + front end electronics
- 180K operation
- ***An autonomous 144 Mpixel camera***
- ***A BNL DELIVERABLE***



⇒ **Strong potential BNL contributions on instrumentation + simulation/ analysis computing (also for nearer-term digital sky survey exp'ts)**

BNL Roles in Advanced Accelerator R&D: Accelerator Test Facility (ATF)

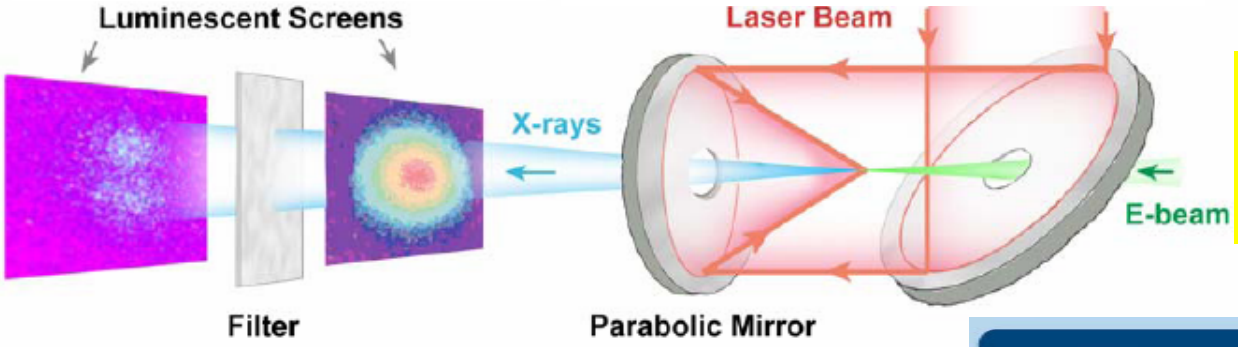


A unique user facility, with *high brightness electron gun, 75 MeV Linac, high power lasers, beam-synchronized at ps level*

Steady improvements to beam emittance and laser power ⇒ tests of state-of-art concepts

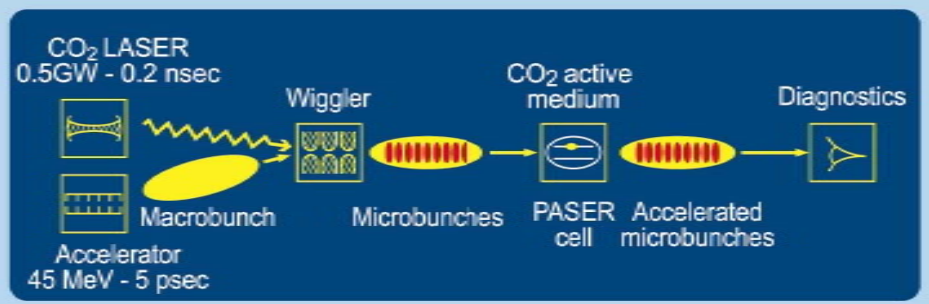
Real CCD images
Nonlinear and linear x-rays

2-3 orders of magnitude intensity increase from 'normal' method



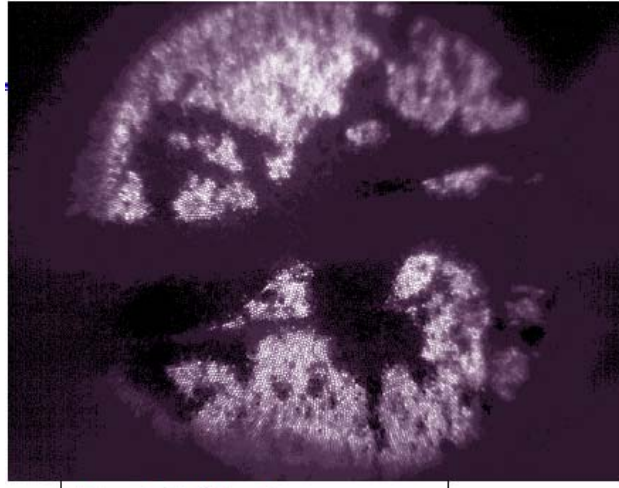
Compton scattering within 10 μm laser cavity ⇒ > 10^8 X-rays! (N_X/N_{e-} ~0.3)

Particle Acceleration by Stimulated Emission of Radiation (for e beam with CO_2-laser-induced microbunching in CO_2 cell)



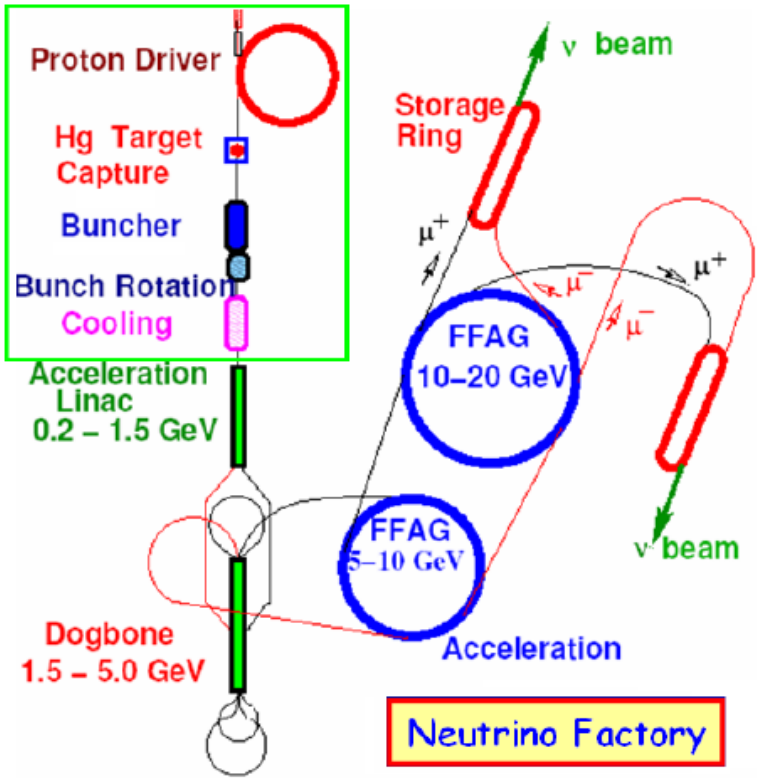
BNL Advanced Accelerator Group: Neutrino Factory/Muon Collider R&D

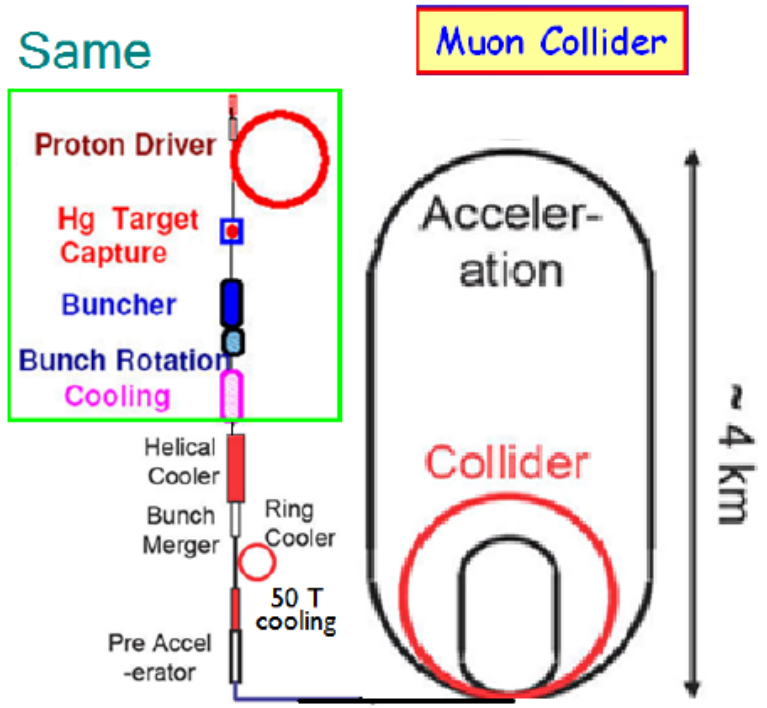
- $\mu^+\mu^- \Rightarrow$ *same physics as e^+e^- with 40,000 x less radiation $\Rightarrow$ smaller rings replace huge linacs*
- μ *storage ring/neutrino factory may be needed to explore ν-sector CP violation if $\theta_{13} < 0.01$*
- *BNL group provides leadership in overall design, in FFAG's & in liquid Hg target test @ CERN*



Hg Jet 15m/s
Solenoid Field 5T
Proton Intensity 10TP

Aim for 2012 Reports on Multi-TeV Muon Collider technical feasibility and Internat'l Neutrino Factory design

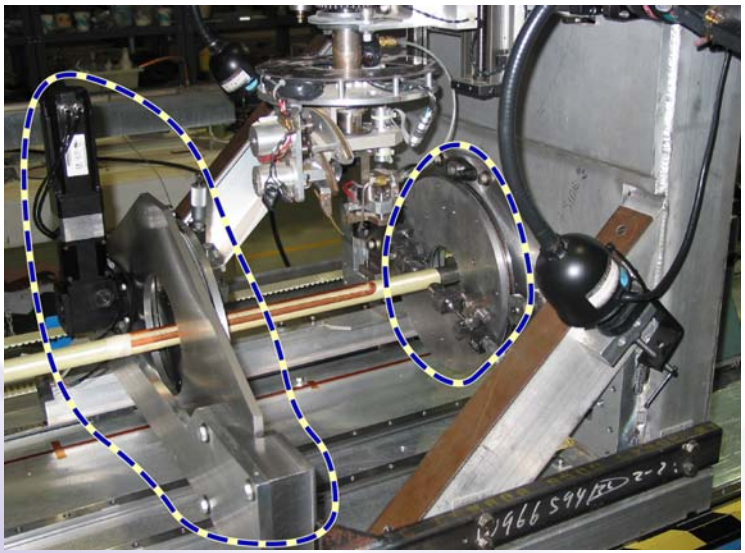




BNL Magnet Division Roles in Advanced Accelerator R&D and Construction

LHC:

- ***Leadership roles in LARP (S. Peggs, P. Wanderer, A. Ghosh)***
- ***4 m Nb_3Sn superconducting coils***
- ***Hope to contribute SC magnets for LHC Accelerator Upgrade Construction (LAUC)***

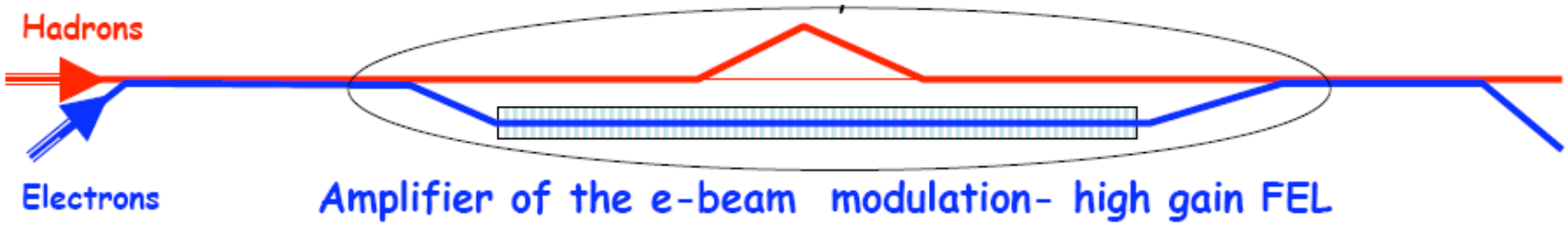


ILC Final Focus R&D:

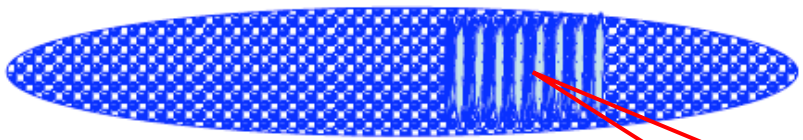
- ***BNL ultra-compact "direct wind" SC magnet technology now baseline for all ILC Final Focus magnets***
- ***Significant increase in Machine-Detector interface activities (B. Parker heads GDE IR Integration Group)***

Synergy with Accelerator R&D @ RHIC (NP Funding)

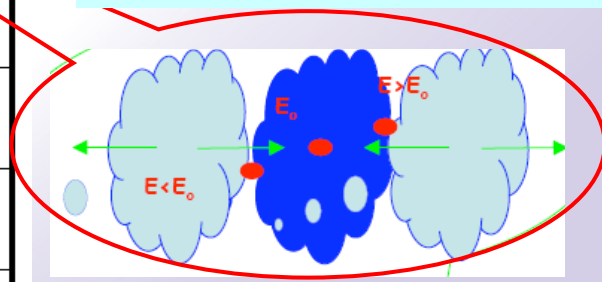
RHIC has become hotbed of beam cooling! E.g., V. Litvinenko & Y. Derbenev aim to test concept of Coherent Electron Cooling of high-energy hadron beams with high-gain FEL based on high-brightness ERL:



$$\lambda = \frac{\lambda_w}{2\gamma^2}(1 + a_w^2) \qquad L_{Go} = \frac{\lambda_w}{4\pi\rho\sqrt{3}} \qquad L_G = L_{Go}(1 + \Lambda)$$



FEL-amplified e-beam density modulation ⇒ E field that reduces energy spread in co-moving (same β) ion beam



Ion beam dispersion allows coupling to give transverse cooling also

Machine	Species	Energy GeV/n	SC, hrs	Synchrotron radiation, hrs	Electron cooling, hrs	CEC, hrs
RHIC	Au	100	~1	20,961 ∞	~ 1	0.03
RHIC	p	250	~100	40,246 ∞	> 30	0.8
LHC	p	450	?	48,489 ∞	> 1,600	0.95
LHC	p	7,000	?	13/26	∞ ∞	< 2

High Energy Theory Group

Important roles in core activities and plans

LHC Collider physics
Paige, Dawson, Kilgore, Soni, Davoudiasl

Electroweak Physics:
Neutrinos, Fundamental Symmetries
Marciano

Lattice Gauge theory
Creutz, Soni

Astroparticle-cosmology
Davoudiasl

Central players in USQCD Collaboration, LQCD-II proposal for next-generation hardware at few labs, including BNL

Working in concert with a unique BNL environment:

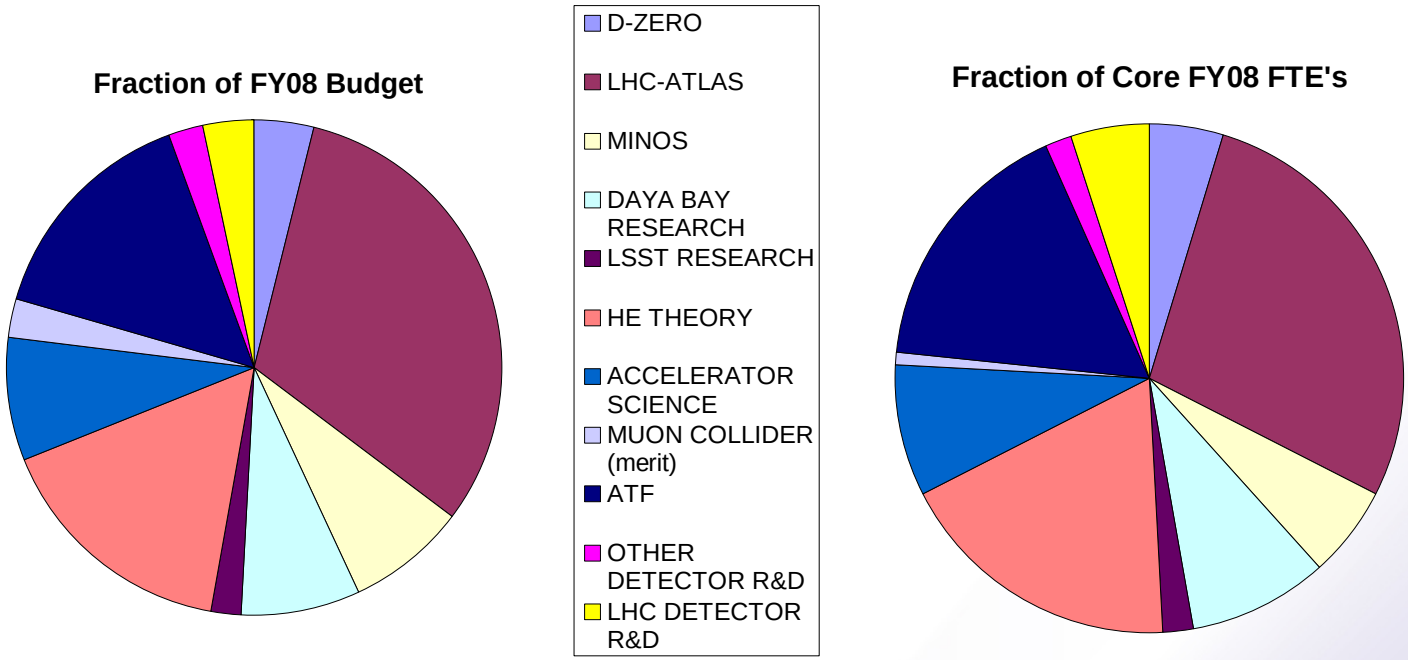
- Nuclear Theory Kharzeev et al
- RBRC Theory group
- Lattice Gauge Theory group Karsch et al

Bottom-Line Messages

- **Nobel-class physics at precision & cosmology, as well as energy, frontiers. Diversity/balance healthy for field and for BNL.**
- **Take advantage of win-win opportunities to support and attract NSF funding for DUSEL exp'ts and LSST.**
- **BNL work on LHC, continuing as host lab & analysis support center for U.S. ATLAS, can proceed at ~constant effort. Modest growth needed for more robust efforts in AARD, cosmology and expanded precision exp't involvement.**
- **BNL plans at precision frontier would benefit from Project X, but can be profitably launched earlier. A long baseline exp't should be launched as soon as practicable to enhance ν-sector CPV discovery potential.**
- **BNL's unique scientific, technical and management capabilities $\Rightarrow$ critical contributions to broad research.**
- **Synergy with high-energy NP also unique. With modest project funding from HEP, AGS (as part of the RHIC complex) can be a resource for mid-term precision exp'ts.**

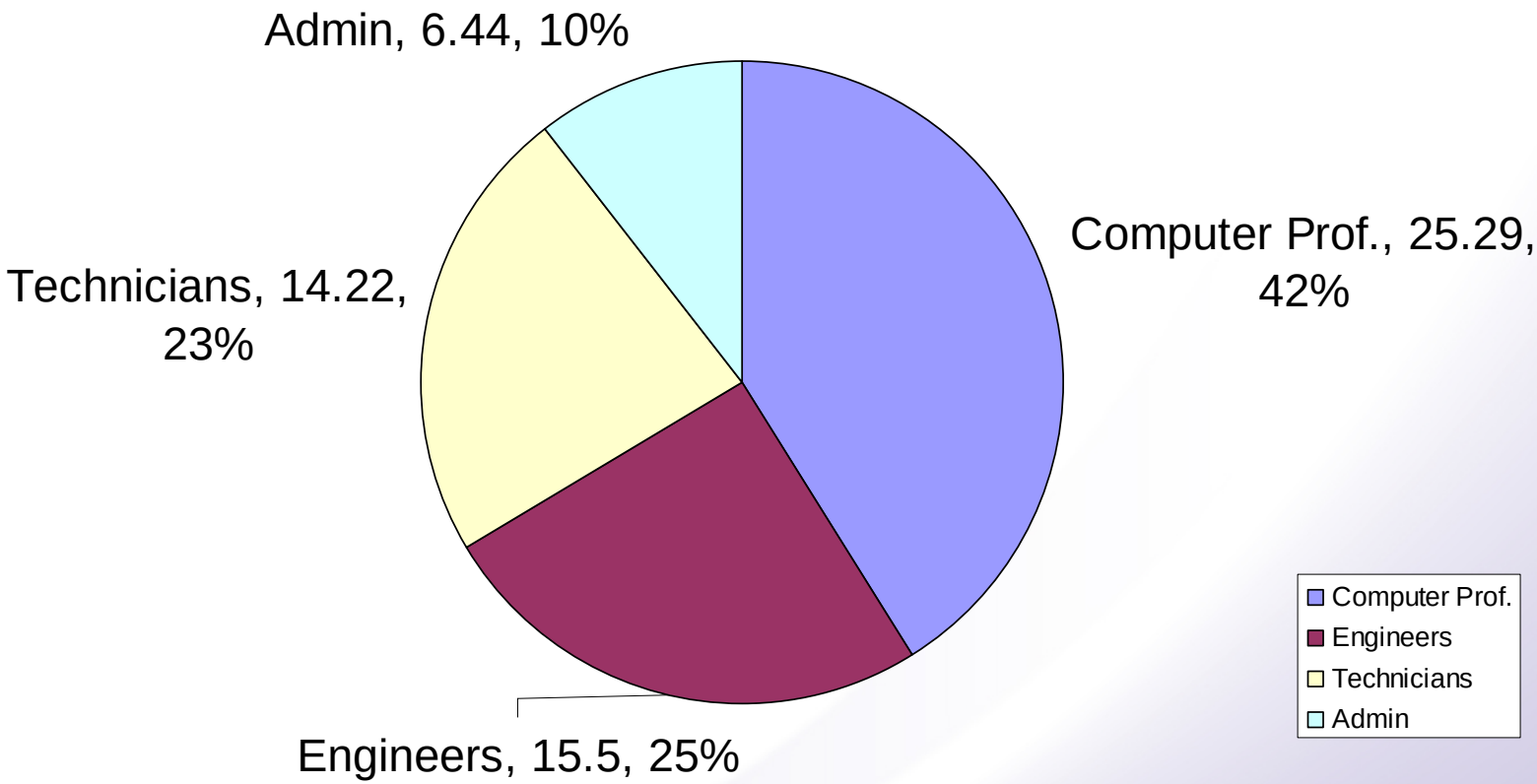
Backup Slides

Present Division of Effort in BNL's Core HEP Programs



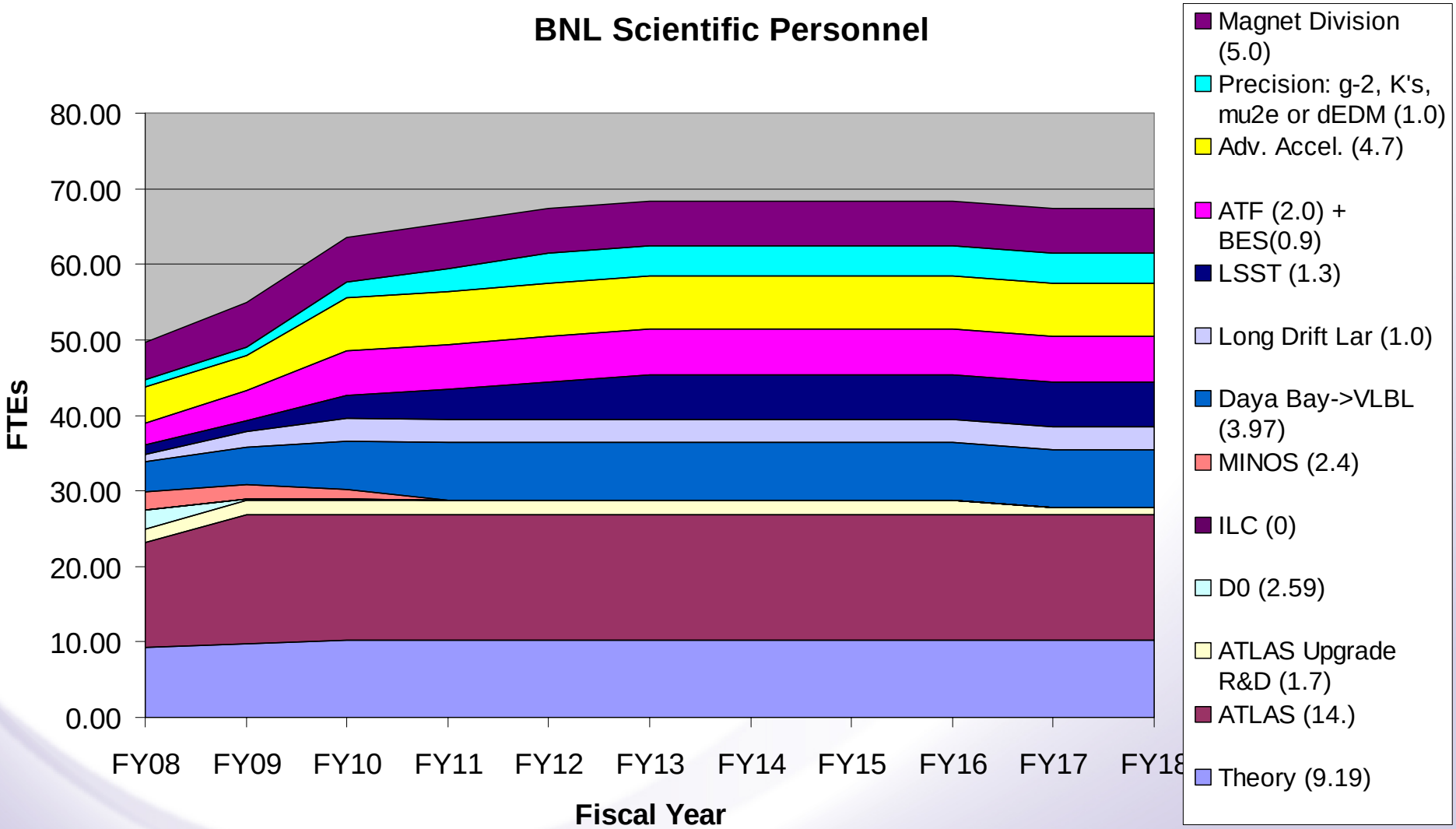
- Mainly staff salaries + modest Materials, Supplies & Travel
- 54.8 FTE total on core program; additional support staff on projects; Magnet Div. support (~$700K, ~2 FTE) not included
- 4 dominant pieces: ATLAS; Neutrinos; Theory; Adv. Accel. R&D

BNLHEP funded non-Scientist FTEs FY08



Snapshot of support personnel, mostly project-funded

A More Microscopic View, By Project



Instrumentation Division

Core Competencies ↔ Program Areas Roadmap

BROOKHAVEN NATIONAL LABORATORY

Mission:
"To develop state-of-the art instrumentation required for experimental research programs at BNL."

Staff (43)

Scientific:	16
Professional:	12
Technical:	11
Administrative:	4

Publications

Annual: ~50
Cumulative: 1370

LEGS TPC Detector

Semiconductor Detectors
- Si : X-ray
- Si : Tracking
- Si : CCDs
- Ge: X-ray

Gas & Noble Liquid Detectors
- Gaseous X-ray and neutron
- μ - TPCs
- LAr TPCs
- He, Ne TPCs

Electronics
- Low noise ASICs
- Radhard electronics
- Digital Signal Processing
- SQUID based amplifiers
- Special Printed Circuits

Lasers & Optics
- Ultra-short photon & electron sources and measurements
- Photocathodes
- Optics & Optical metrology

Micro/Nano Technology
- Sensors & Microstructures

Nuclear & High Energy Physics
- RHIC Detector Upgrades, NP Exps.
- ATLAS Detector (+Upgrades)
- Neutrino & Special Detectors
- LSST

Accelerator Development
- Photocathodes for e-cooling
- Photocathodes for e-RHIC
- Polarimetry at RHIC
- Beam diagnostics

Basic Energy Sciences
- X-ray detectors for NSLS-II, LCLS
- Optical metrology for NSLS-II
- CFN Support
- Detectors for electron microscopy
- Ultra fast techniques

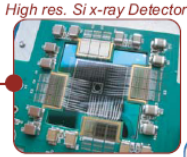
Biology & Medicine
- PET Imaging
- MRI at 9T
- PET/MRI Imaging
- Detectors for e-microscopy

EENS
- Neutron and gamma ray detectors for Homeland Security

Other Labs.
- X-ray detectors for LCLS
- X-ray detectors for NRL
- Microelectronics for NASA
- Neutron detectors for SNS, LANCE

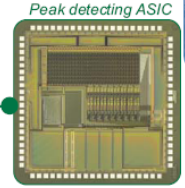
Transfer to Industries
- Microelectronics for CZT detectors
- Optical metrology

High res. Si x-ray Detector



120° neutron detector

Peak detecting ASIC



Lighthouse-style Fresnel lenses

Future Research areas: nano-electronics, Si - detectors integrated with microelectronics.

2008/Rev 1.0/AK

Recent Highlights and Milestones

BNL leadership in ATLAS readiness for 1st LHC collisions:

e.g., from Feb. 4-7, 2008 DOE-NSF US-LHC S&C + M&O Review:

- Current costs and projections for readiness are consistent with funding guidance. Painful but judicious choices are being made and we commend the process.
- Plans for U.S. access to data and ability to do analysis are adequate. User feedback was very positive… Demonstrated capability in the facilities and tools…
- Estimate of personnel needs for commissioning and running is credible…They are making good use of a very talented team of people.
- U.S. contribution and quality [are] significant and excellent.
- The recommendations from last year have been addressed in commendable ways.

BNL leadership toward successful CD-2 review for Daya Bay:

The project has made excellent and rapid progress since CD-1, Approve Alternative Selection and Cost Range. The technical elements have each reached a level of development sufficient for CD-2 approval. All procurement items being requested for CD-3a approval have a well-established need. The design status is at or very near the point (approximately zero to six weeks) for proceeding with acquisition. The major CD-3a items include phototubes, acrylic vessels, and a transporter. In all, the CD-3a items are valued at approximately $5 million. The Committee concluded that there are no major issues with the CD-3a items requiring further committee review, and final readiness can be confirmed by the FPD and Program Manager.

Scientific Leadership Roles

- Creutz: US Lattice Gauge Theory Executive Committee
- Dawson: EPP2010, Chair, Fermilab PAC, AAAS Section Board, KITP Advisory Board, FNAL Steering Group for Accelerator Futures
- Diwan: Homestake DUSEL Executive Board, co-chair BNL/FNAL long baseline study
- Ernst: ATLAS International Computing Board; WLCG Management Board
- Gordon: ATLAS Construction Project Manager; Deputy US ATLAS Research Program Manager; Member Open Science Grid Council, Ice Cube Project Advisory Panel, NSF Review of NEON; DOE SLAC operations review
- Harrison: Regional director for ILC GDE, LHC Machine Advisory Cmte, LHC Cost & Schedule Cmte, DESY Machine Advisory Cmte, ILC Executive Cmte
- Kettell: U.S. Project Chief scientist Daya Bay experiment
- H. Kirk: Co-spokesperson for Neutrino Factory and Muon Collider Collaboration; co-spokesperson CERN MERIT experiment
- Lanni: ATLAS Liquid Argon Upgrade Coordinator

Scientific Leadership Roles- 2

- Lissauer: Leader of ATLAS Technical Coordination Project Office; Head of Upgrade Project Office
- Littenberg: Particle Data Group
- Ma: U.S. ATLAS Analysis Support Center leader
- Marciano: Homestake DUSEL PAC, Particle Data Group, Coordinator fundamental symmetries group for NSAC long range plan
- Morse: Coordinator for very forward calorimeter for ILC SiD detector
- Ozaki: HEPAP, International Linear Collider Steering Group, Deputy Chair LCSGA, Chair LCSGA regional interest panel
- Palmer: Executive Board member for Neutrino Factory and Muon Collider
- Peggs: LARP program manager, FNAL Fermilab AAC, Chair APS Wilson Prize Cmte, Chair SciDAC Advisory Cmte
- Rajagopalan: ATLAS Trigger Menu Coordinator – interacts with all physics groups
- Samios: HEPAP, Director RIKEN BNL Research Center
- Semertzidis: BNL PAC, Working group leader for Flavor in the LHC Era
- Yakimenko: ORNL Machine Advisory Committee