BNL Plans in Nuclear and Particle Physics: How dEDM Might Fit In

Steve Vigdor

RHIC/AGS PAC Meeting

May 8, 2008

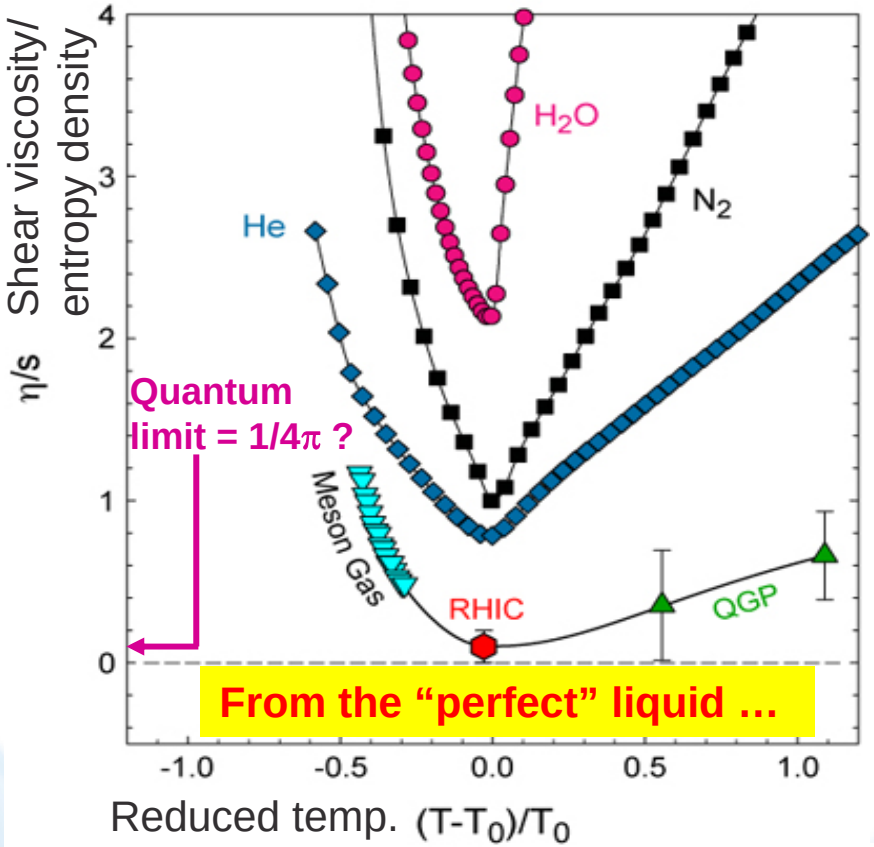
BROOKHAVEN NATIONAL LABORATORY

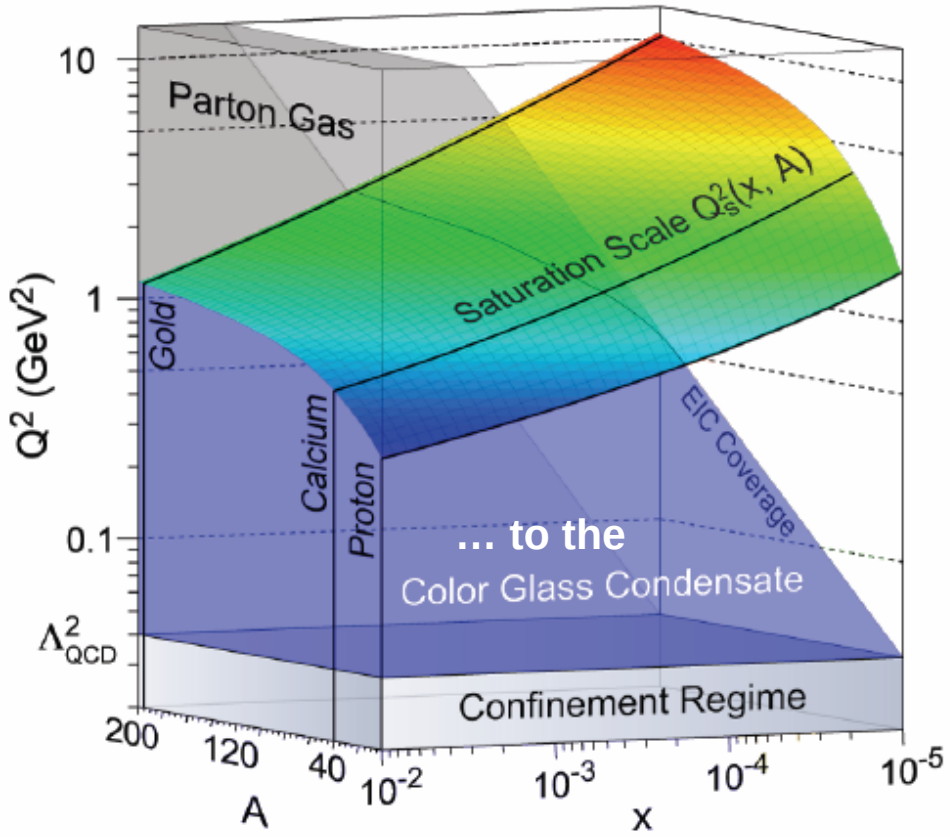
a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

RHIC Science: Condensed Matter Physics with a Force of a Different Color

What are the unique quantum many-body manifestations of a non-Abelian gauge theory? Are there lessons for other fundamental theories? How do we pump/probe partonic matter in 10^{-23} s?





RHIC, RHIC-II probe very strong coupling limit: LQCD ⇒ quantitative theory for static properties; AdS/CFT ⇒ qualitative insight + gravity connection.

e-RHIC probes weak coupling regime of very high gluon density, where gauge boson occupancy >> 1 & semi-classical field theory apply.

NP Overview: Shifting the LRP "Problem" from Short to Intermediate Term

- Short-term (~2008-2016):
  - RHIC-II luminosity via stochastic cooling + other modest upgrades (much sooner than NP LRP timeline!)
  - Ongoing detector upgrades as per "Mid-Term Plan" – see T. Ludlam talk
  - Vibrant physics program quantifying properties of "perfect liquid", searching for QCD critical point, solving nucleon spin puzzle

- Long-term (beyond ~2021):
  - eRHIC extends study of condensed strongly interacting matter to high gluon density, weak coupling regime and of nucleon spin structure to region dominated by soft gluons
  - Much work still to do on deepening and broadening the science case and developing the accelerator technology
  - Aim for "complete" case by next NP LRP (2012-13?)

Strawman eRHIC Construction Profile ($M FY07)

	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
Pre-R&D										
1) R&D	5	7	5							**17**
2) CDR	3									**3**
3) PED/ EDIA		31	62	23						**115**
4) Cons *				62	103	144	144	111		**564**
5) Preops							16	35		**72**
TEC (3+4)	8	7	5				16	35		**72**
TPC (Sum of 1 thru 5)	8	38	67	84	103	144	161	146		**752**

* includes ~ $130M for detector

RHIC-II Savings ⇒ DOE "Receptivity" to Intermediate-Term (~2016-21) Opportunities

- **Continuing RHIC upgrades?**

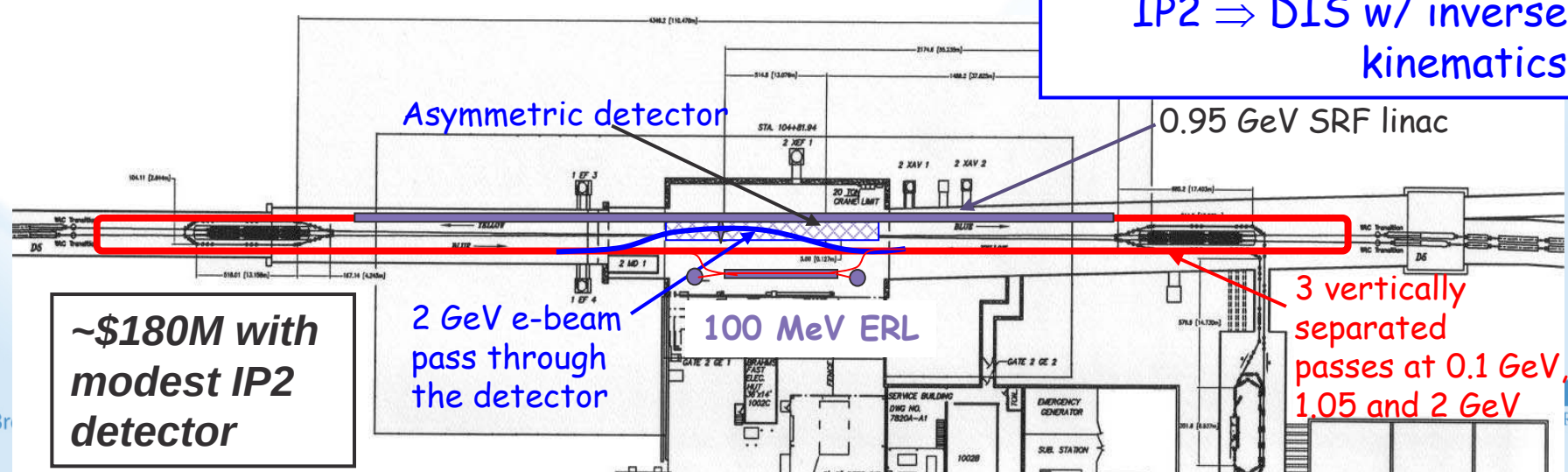
  e.g., low-E e-cooling; electron lens; 12 GHz stochastic cooling upgrade (~$10 -15 M more) plus additional STAR and PHENIX upgrades ($?? M)

- **Deuteron EDM and/or upgraded muon g-2?**

  ~$50M apiece? DOE ONP more likely to fund dEDM project

- **1st (Medium Energy) stage of eRHIC?**

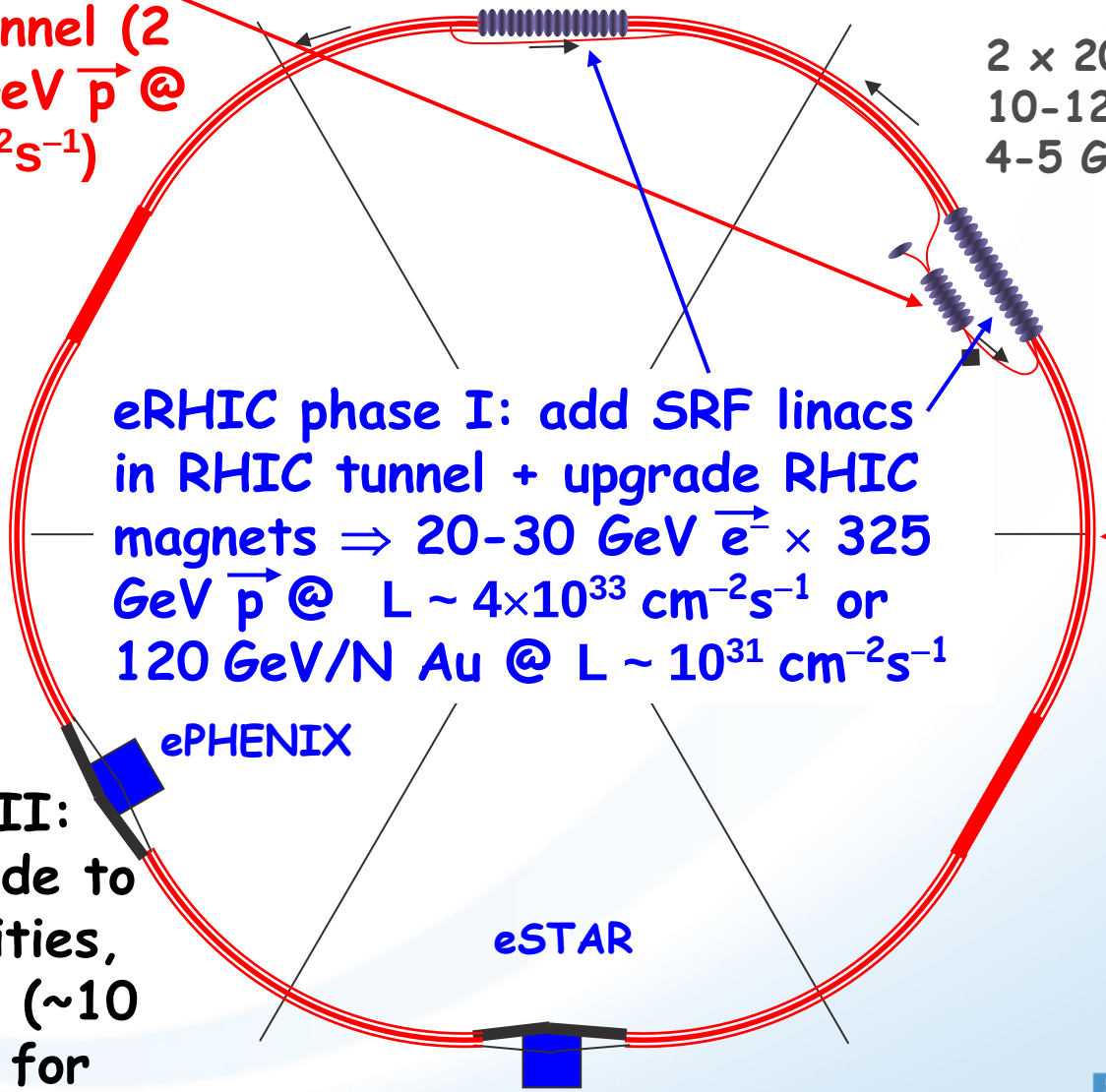
MEIC with 2 GeV ERL @ IP2 ⇒ DIS w/ inverse kinematics



~$180M with modest IP2 detector

Possible eRHIC Staging

MEIC - RHIC + ERL inside RHIC tunnel (2 GeV $\vec{e}$ × 250 GeV $\vec{p}$ @ L ~ 10^{32} $cm^{-2}s^{-1}$)



eRHIC phase II: Luminosity upgrade to ~10^{35} (crab cavities, etc.) at reduced (~10 GeV e) energy for exclusive reactions

BNL Philosophy Going Forward in Particle Physics

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*

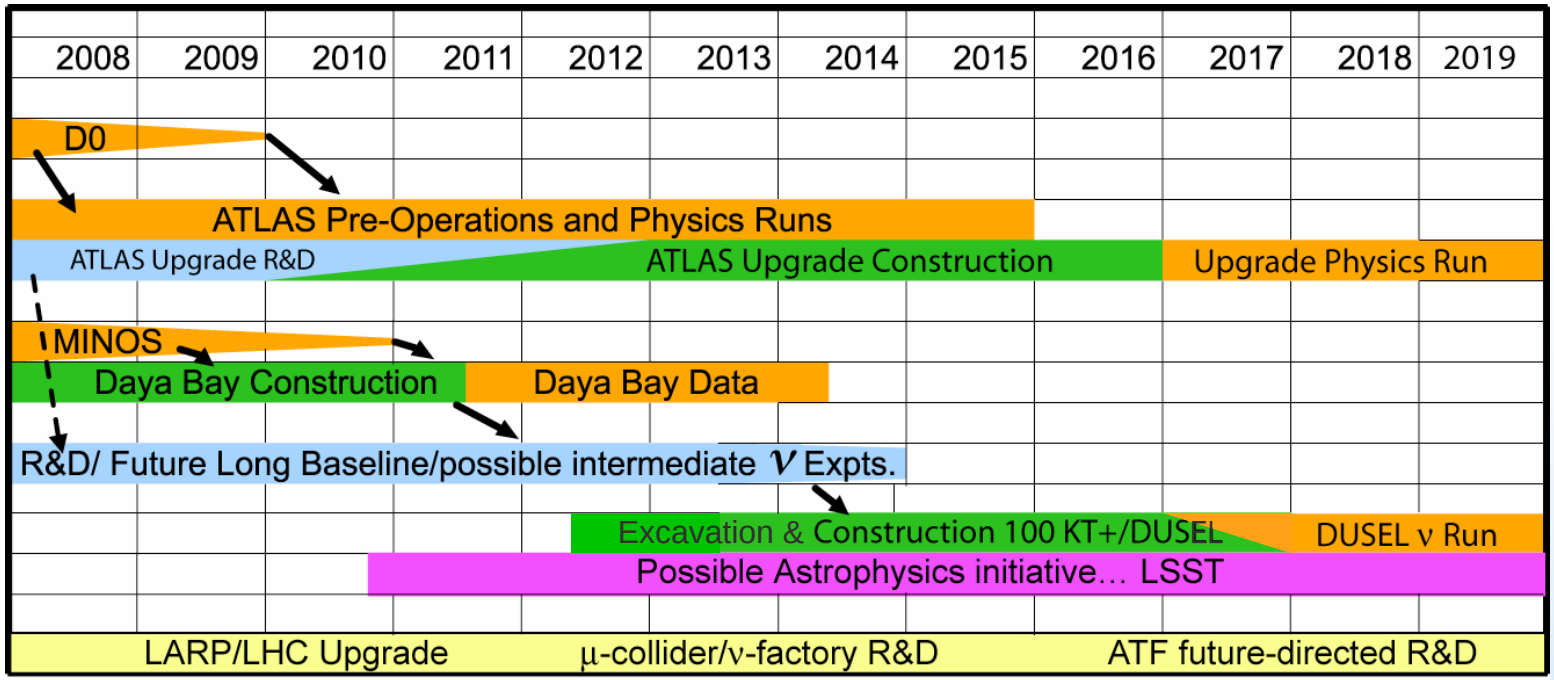
Cosmology *-- nature of dark matter, dark energy*

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

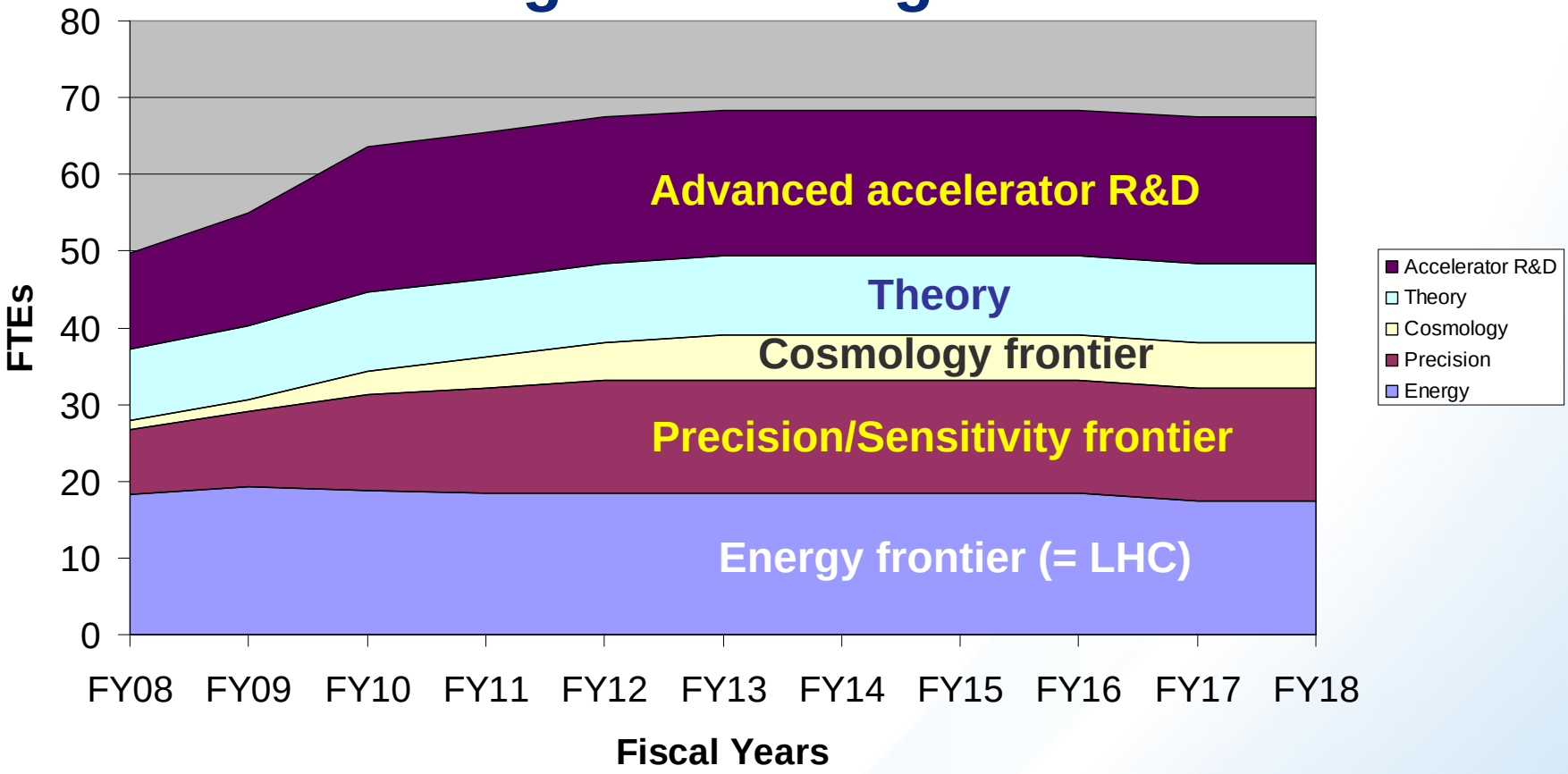
Goal: ***technical + intellectual leadership in key experiments at 3 frontiers (energy, precision, cosmology), supported by theory and by critical advanced accelerator and detector R&D.***



- **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

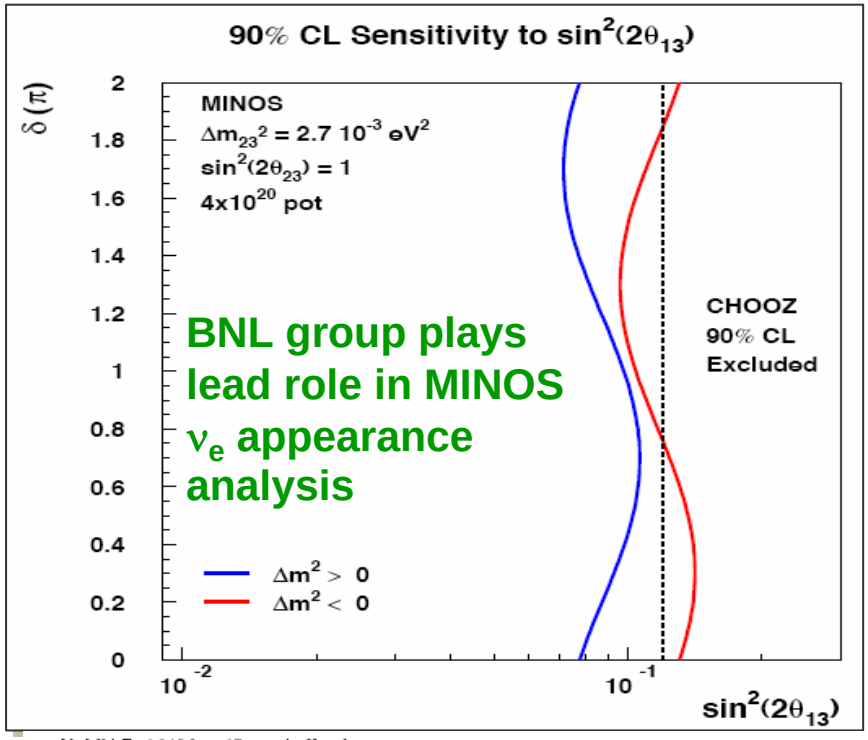
Under Budget-Doubling Scenario…



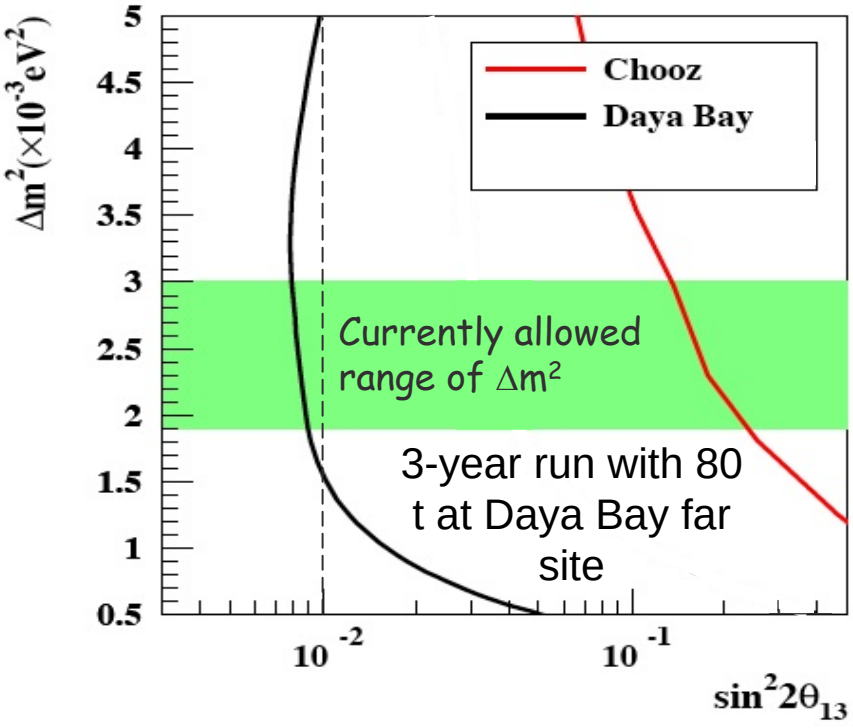
➢ ***Short-term AARD growth ⇒ viability in meeting ATF user demand, and 2012 goal for ν Factory Design and μ Collider Feasibility Reports***

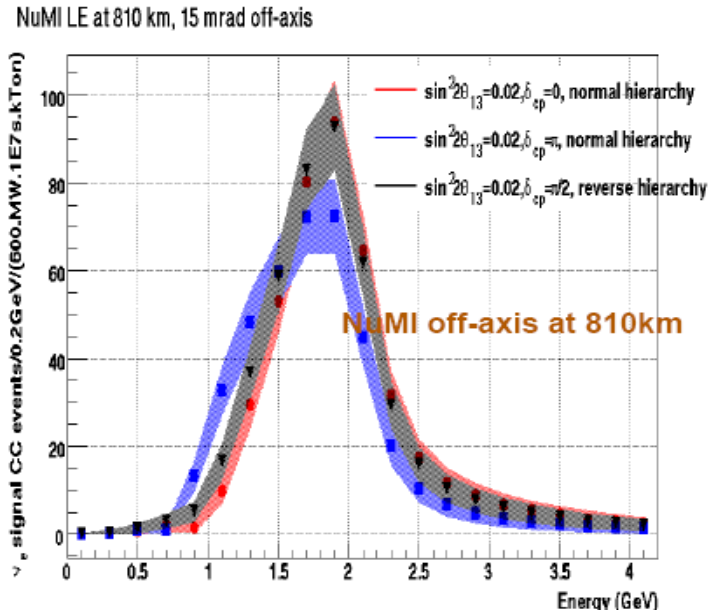
➢ ***Growth at precision frontier fuels Daya Bay and LAr development ramp-ups + significant role in one among: μ2e or rare K @ FNAL, or μ g-2 or deuteron EDM @ AGS.***

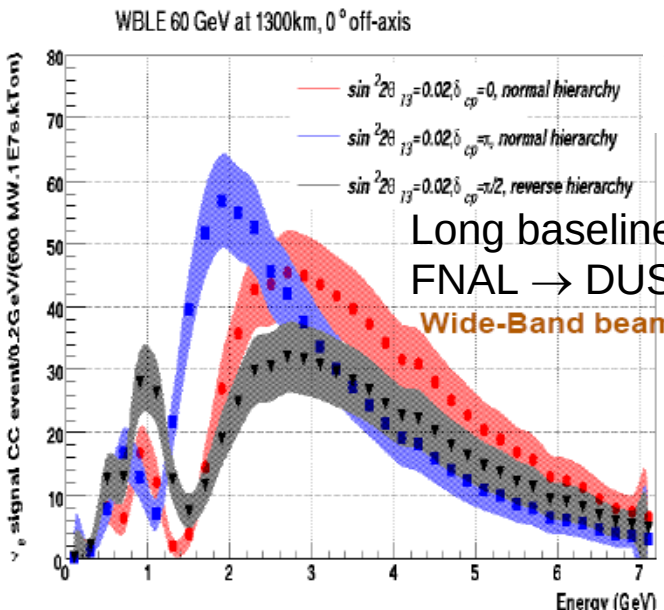
BNL Roles at the Precision/Sensitivity Frontier:



BNL group plays lead role in MINOS ν_e appearance analysis







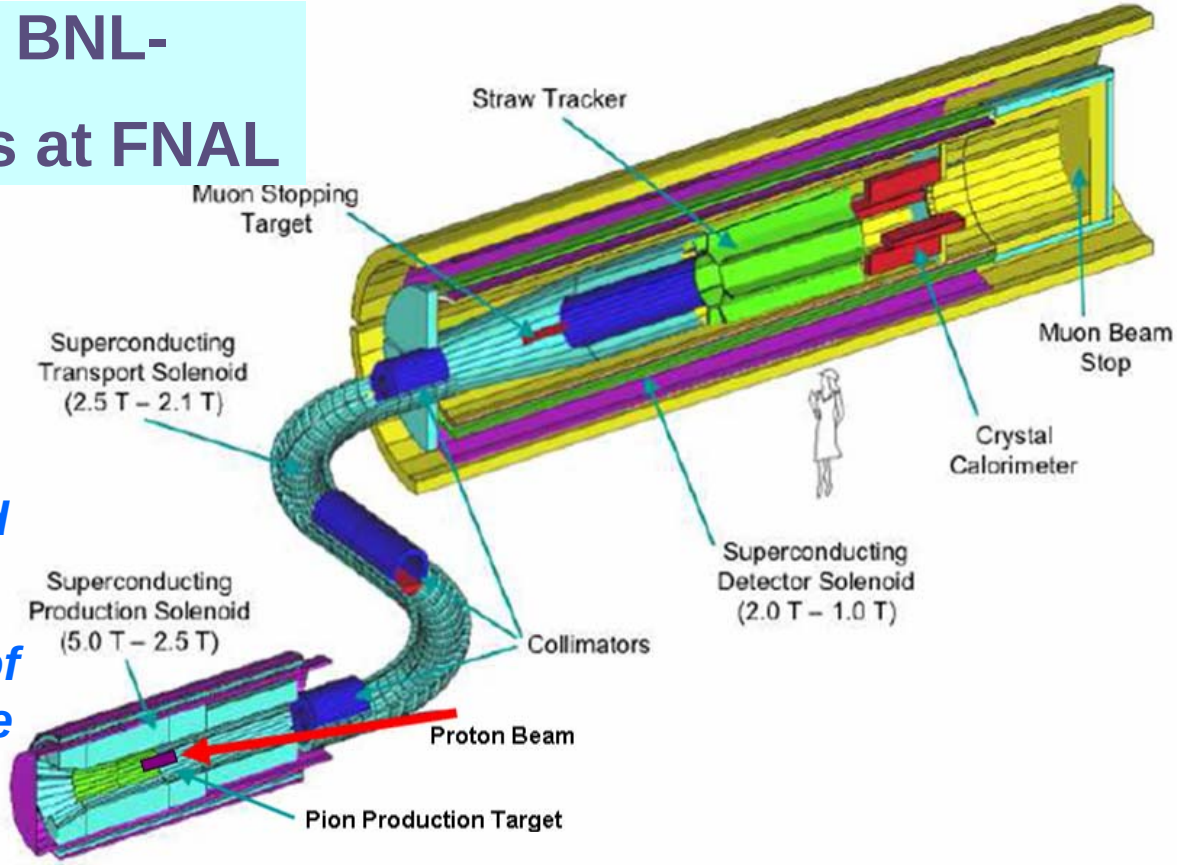
350 kT·MW·yr
$P(\nu_\mu \rightarrow \nu_e) \sim 1\%$

Long baseline exp't
FNAL → DUSEL
Wide-Band beam at 1300km

Precision Options: BNL-Inspired Flavor Physics at FNAL

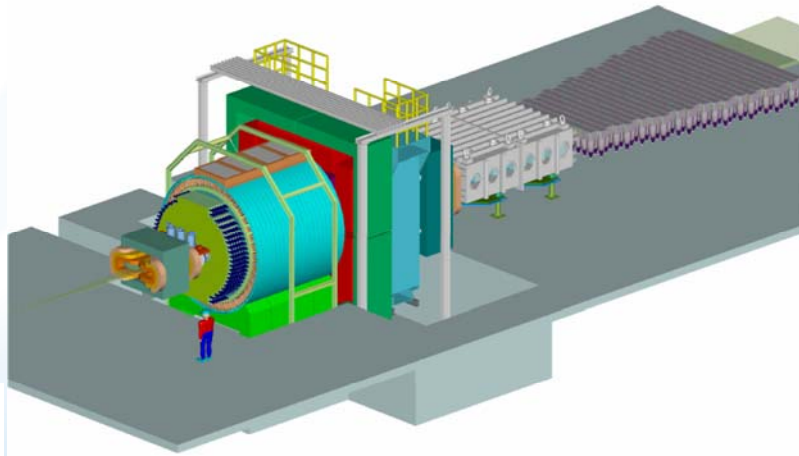
***Mu2e** would search for conversion in nuclear field, with sensitivity to $R_{\mu e} \sim 10^{-16}$ and beyond (with Project X)*

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



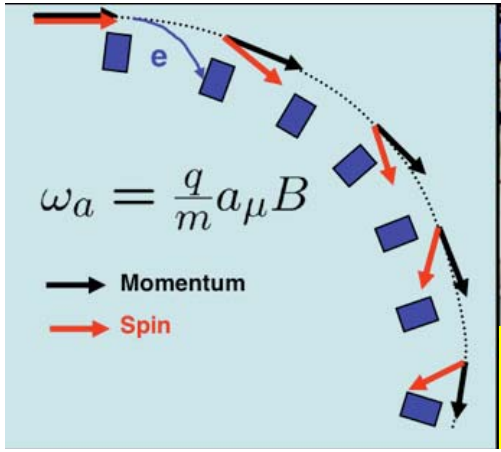
***Rare K decay exp'ts** would measure $K \to \pi \nu \bar{\nu}$ branching ratios to ±3% ⇒ unique probe of BSM flavor structure*

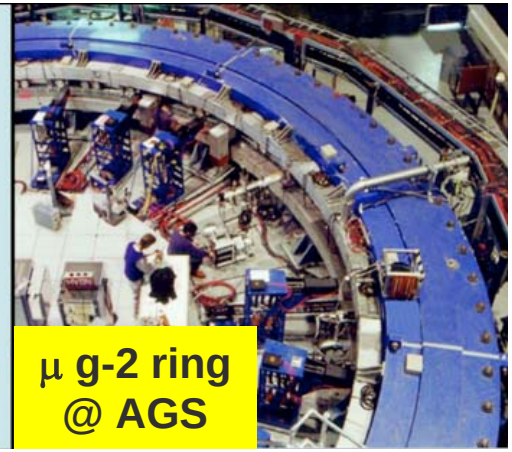
- *inspired by & using similar techniques to BNL predecessors E787/949 & KOPIO*
- *would really benefit from Project X !*

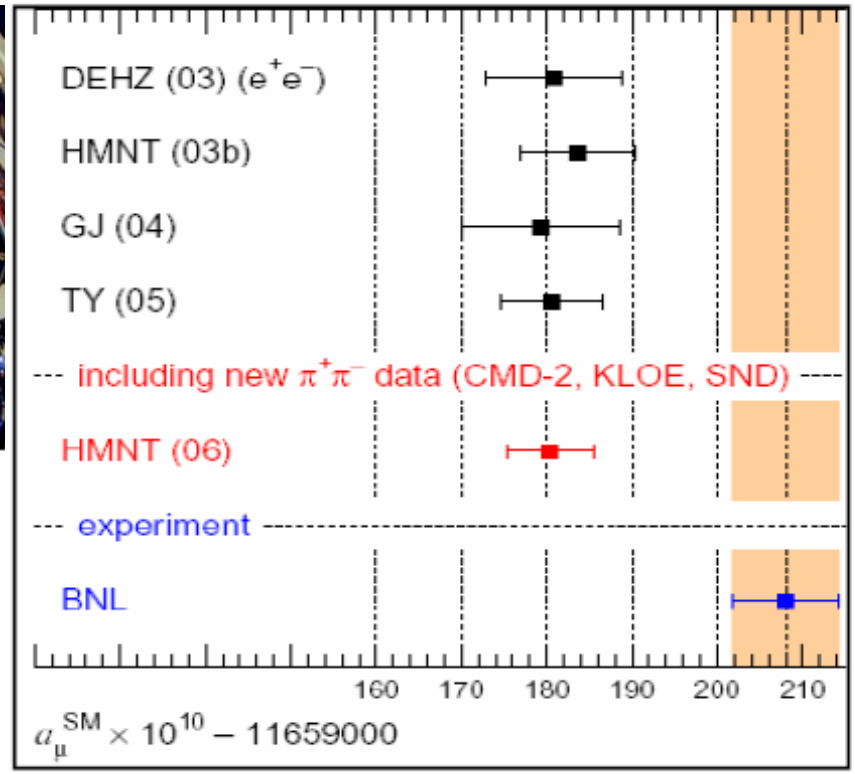


We have contributed to discussions, EOI's & could participate in one exp't if budgets allow

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***

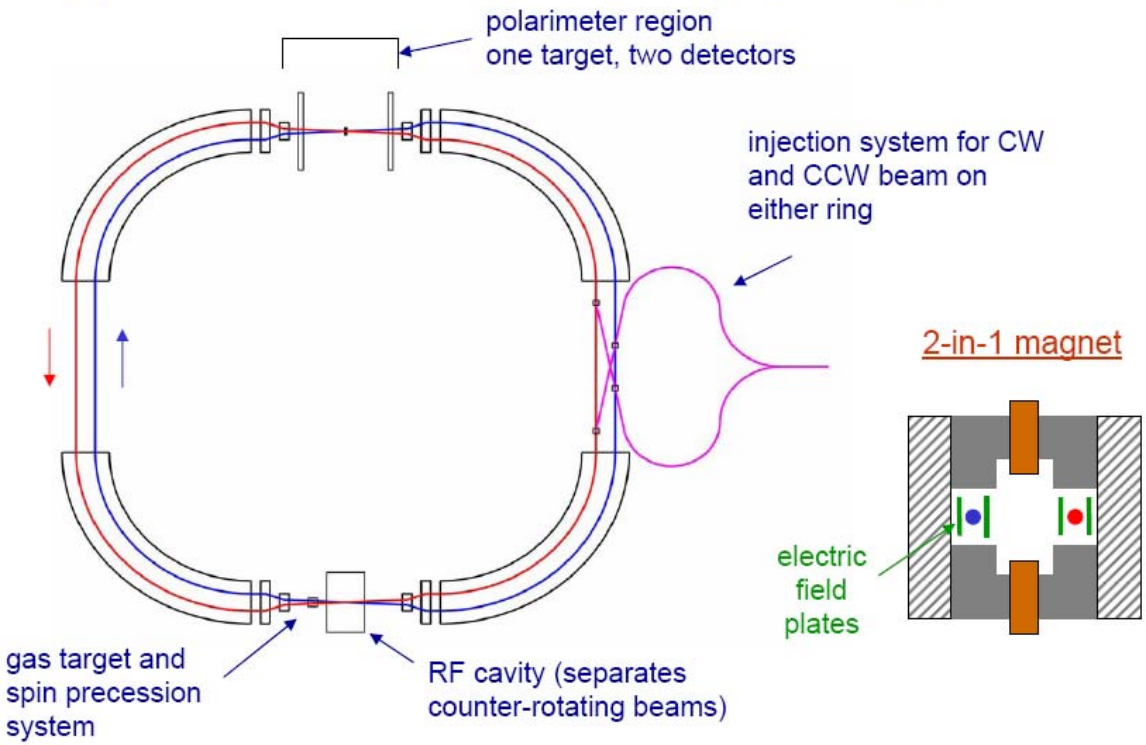
Precision Options: Deuteron EDM @ AGS

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 ~10^3 s ~ spin coherence time.***
- ***E*-field = v × B (0.5 T ⇒ 150 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:



Necessary Conditions for dEDM to Proceed

1) PAC rates science as "must do" for ~2020 time scale, technical challenges as not "showstoppers"
2) ACI-fueled budgets in NP and HEP (to fund BNL physicists on dEDM)
3) CD-0 in 2009-10, with first R&D funds in FY11
4) Carefully chosen R&D milestones to demonstrate technical feasibility, ~2011-13
5) Construction funding profile ~2013-17
6) Run experiment behind RHIC stores ~2017-20
7) Strong collaboration committed for the "long haul"

Realization Challenges are Well-Matched to Technical Challenges of the Experiment!

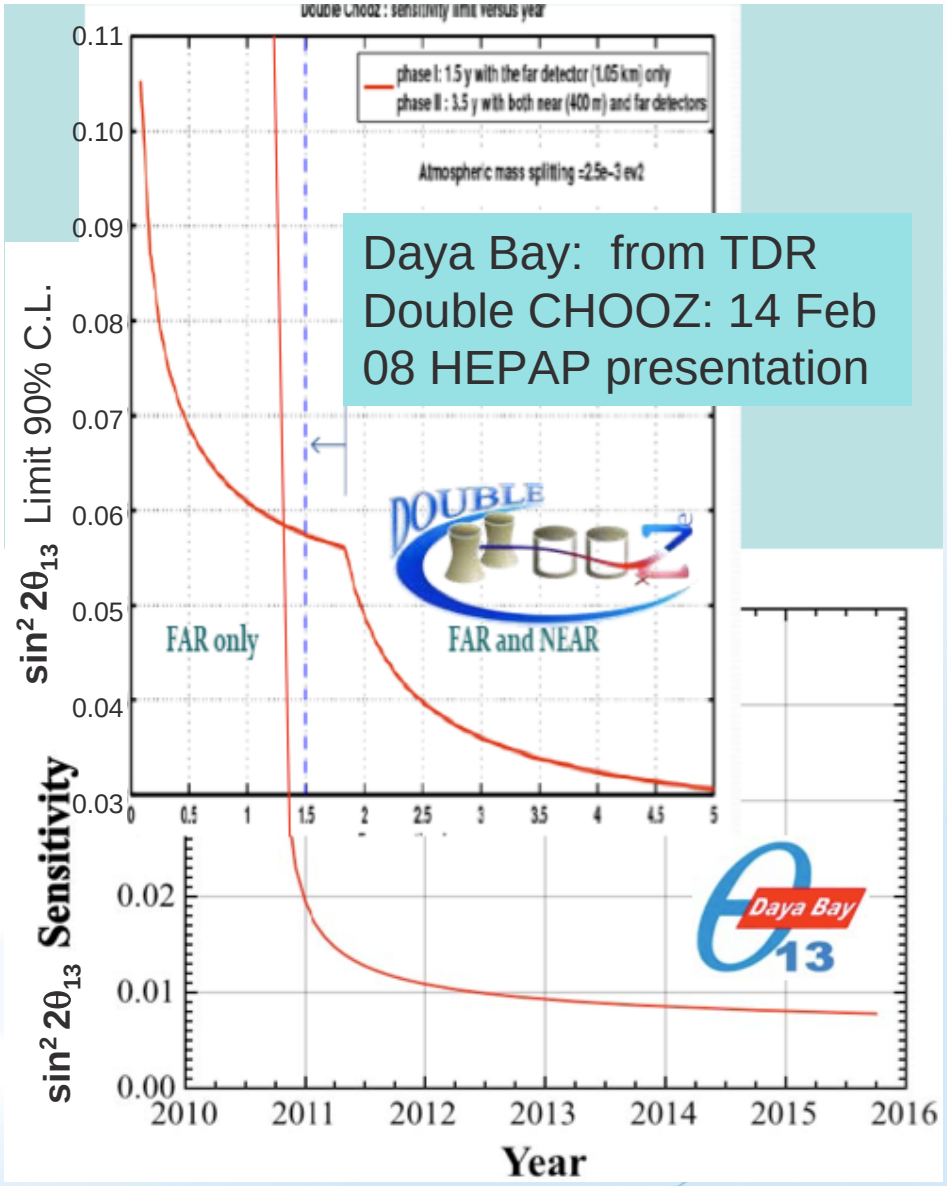
Backup Slides

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

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

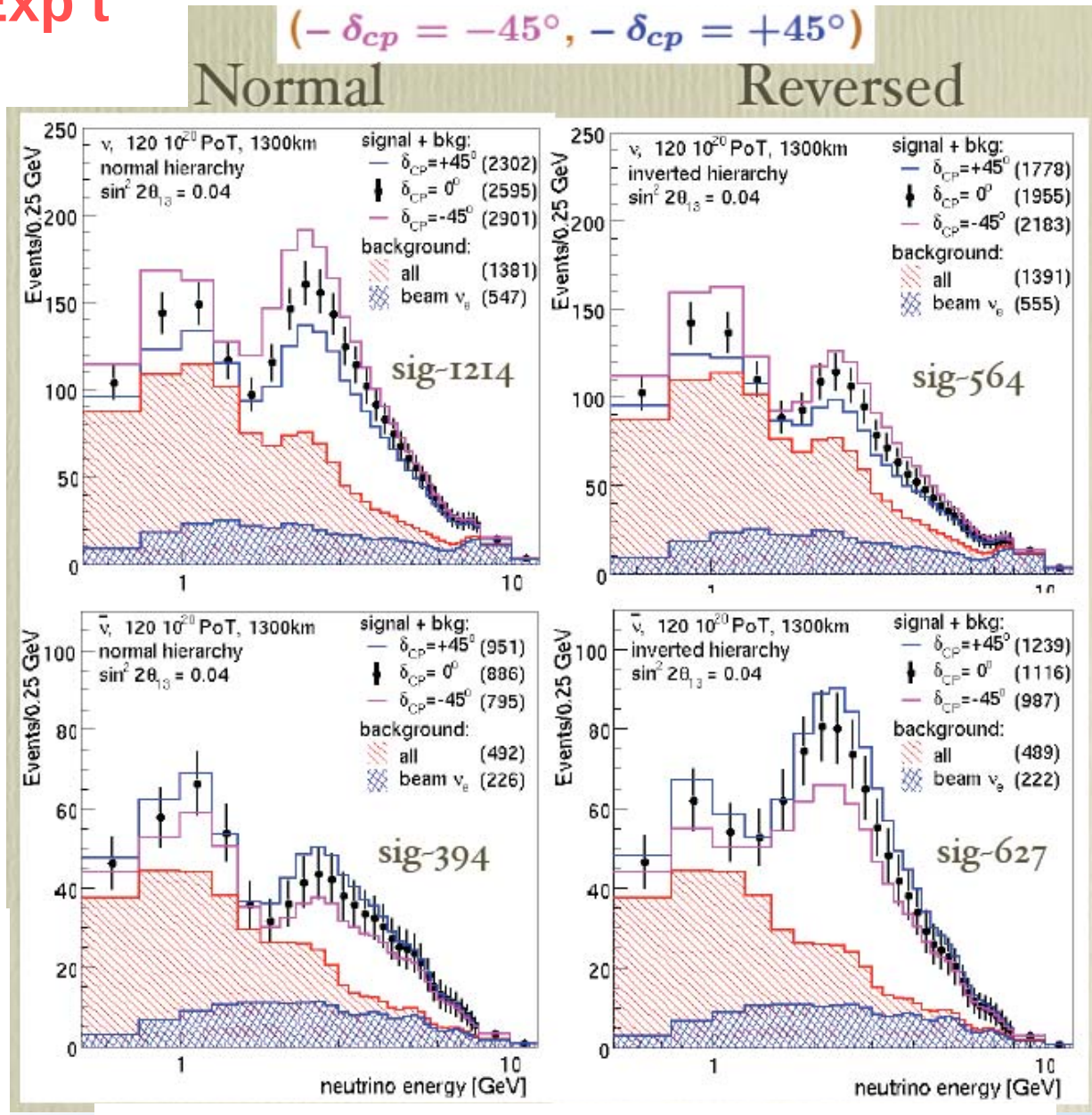
$(-\delta_{cp} = -45°, -\delta_{cp} = +45°)$

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***



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!