Future Plans at Brookhaven National Laboratory

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US-Japan Collaboration 30th Anniversary Symposium

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BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

BNL's Overall Future Plan

- Multi-program lab
  - Discovery to Deployment
- Activities
  - Nuclear & Particle Physics
  - Photon Sciences
  - Energy & Nanoscience
  - Climate & Life Sciences
  - Nuclear Nonproliferation & National Security
- A Core Capability
  - Accelerator Science & Technology

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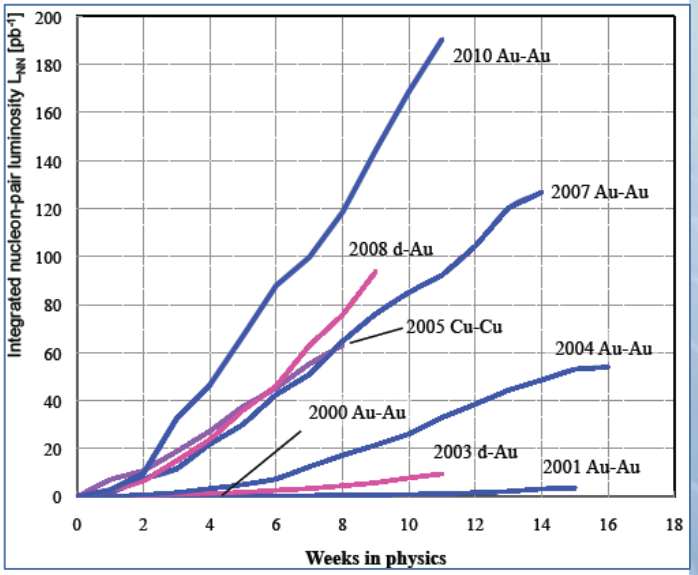
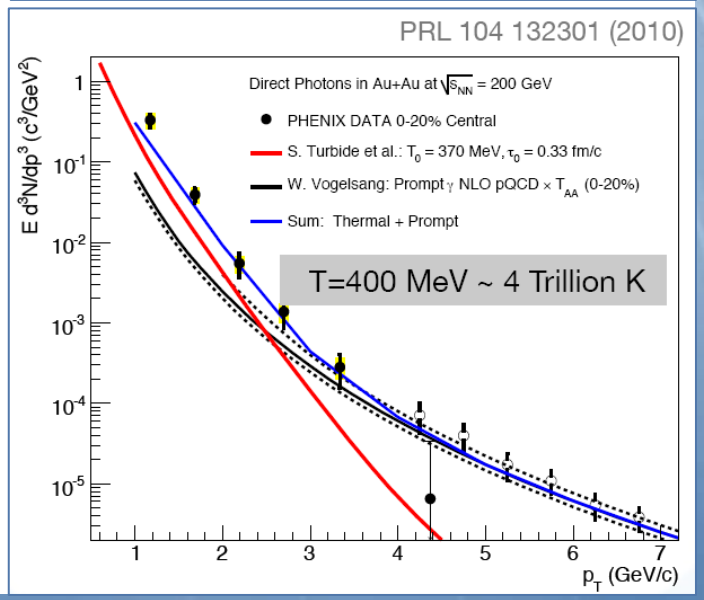
Activities in **Nuclear**, Particle and Accelerator **Physics**

- RHIC
  - 10th run completed in July
  - Au-Au, Cu-Cu, d-Au, p-p, $\sqrt{s_{NN}}$ from 7.7 to 500 GeV
  - Results (some unexpected)
    - Strongly coupled (!) QGP
      - $T > T_{crit}$
      - Collective flow → "Perfect Liquid"

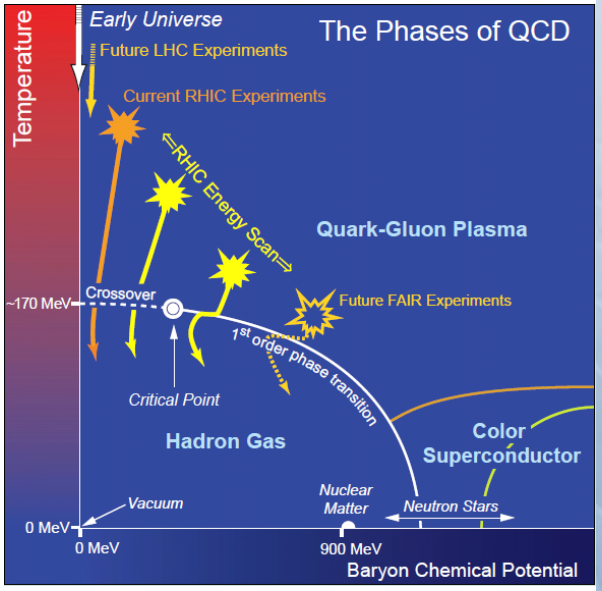
    RHIC Spin
    - Gluon contribution to nucleon spin
    - $W^{\pm}$ production to flavor-separate q, $\bar{q}$ helicity distributions

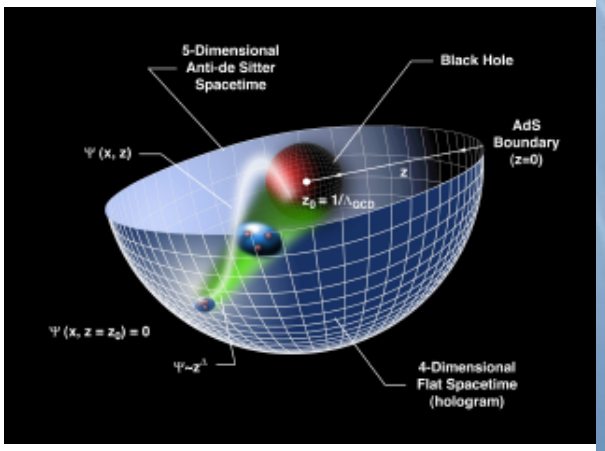




RHIC Physics, Impact

- RHIC has turned out to be a powerful and flexible tool:
  - Structure and dynamics of a non-abelian gauge theory
    - Phase diagram of QCD
    - Spin of the proton
  - Relationship to other strongly coupled systems
    - Cold atomic gases
    - Strongly correlated electron systems
  - Relationship of QCD to semi-classical gravity and black holes (AdS/CFT)

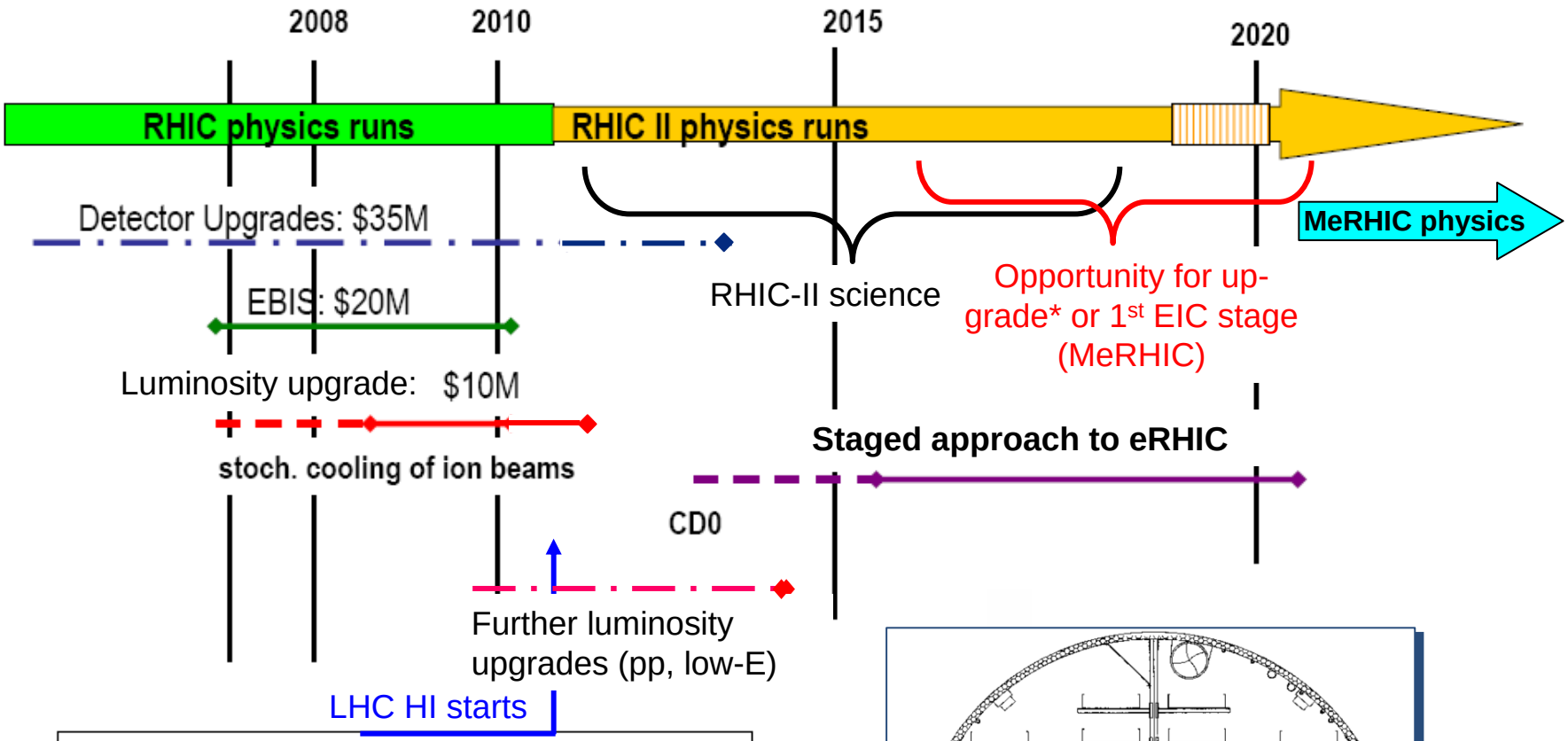


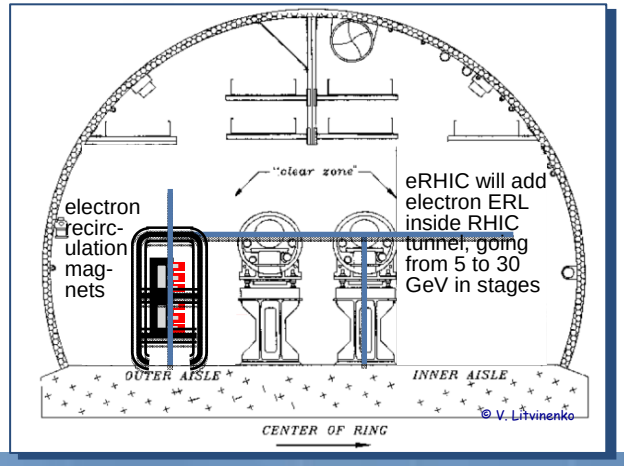


US-Japan Impact on RHIC & PHENIX

- Scientific Leadership
  - Shoji Nagamiya – founding spokesperson
  - Yasuyuki Akiba – current deputy spokesperson
  - Many Executive Council members
- Detector subsystems/leaders
  - RICH: H. Hamagaki
  - TOF, Aerogel: Y. Miake
  - Beam-Beam Counters: T. Sugitate

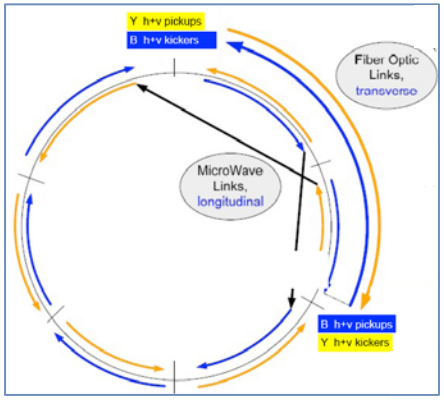
Long-Term Strategic Timeline for the RHIC Facility

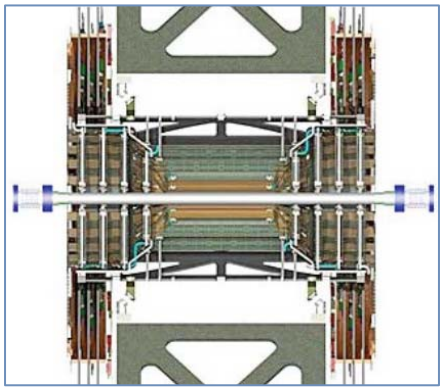


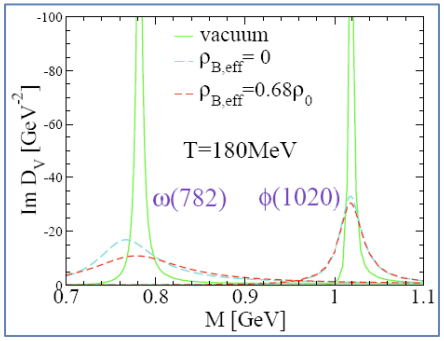


Midterm Plans in Nuclear Physics (~2015)

- RHIC-II
  - Luminosity + detector upgrades
  - Originally a separate project based on electron cooling, > 4 years, > $100M
  - Achieved much earlier at 1/7 the cost using stochastic cooling (2 transv. + long.)
  - Detector upgrade construction under way, some online in 2011
- RHIC-II Physics
  - Is there a critical point in the QCD phase diagram?
  - How are QCD jets affected by the medium?
    - Mechanisms of energy loss, light & heavy flavor jets
  - What are the properties of the sQGP?
    - Chiral symmetry restoration?

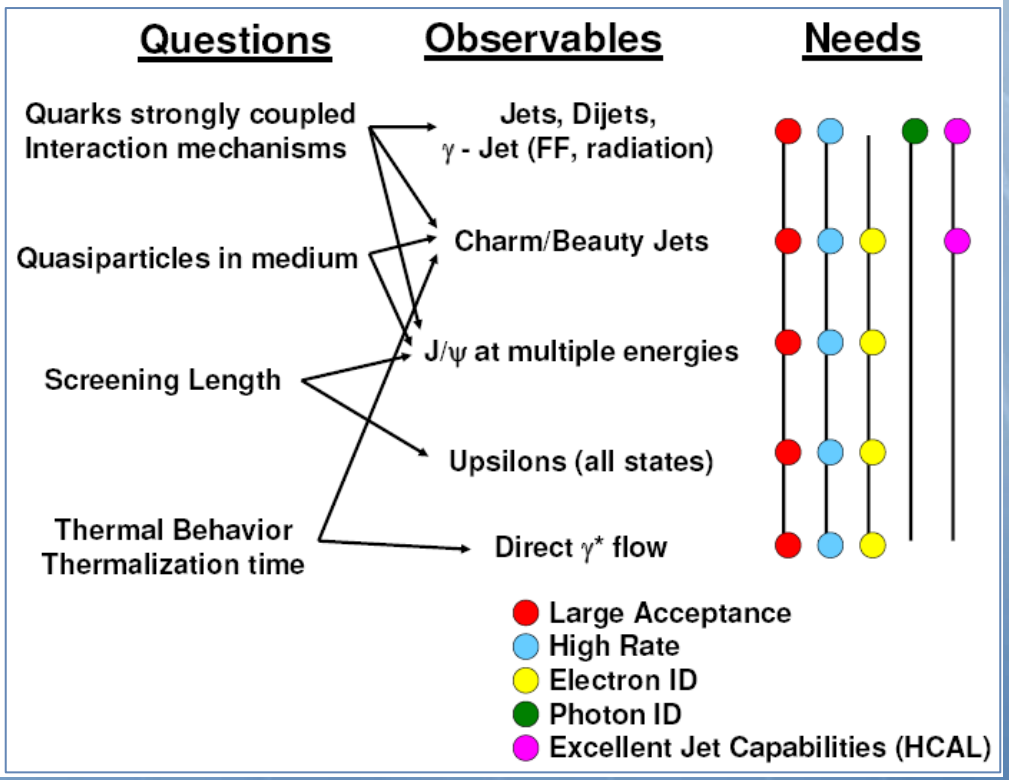






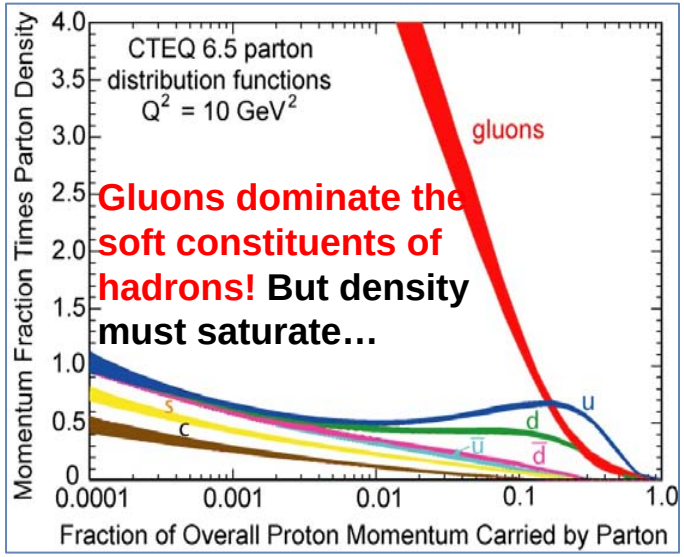
Long-term Plans in Nuclear Physics (>2015)

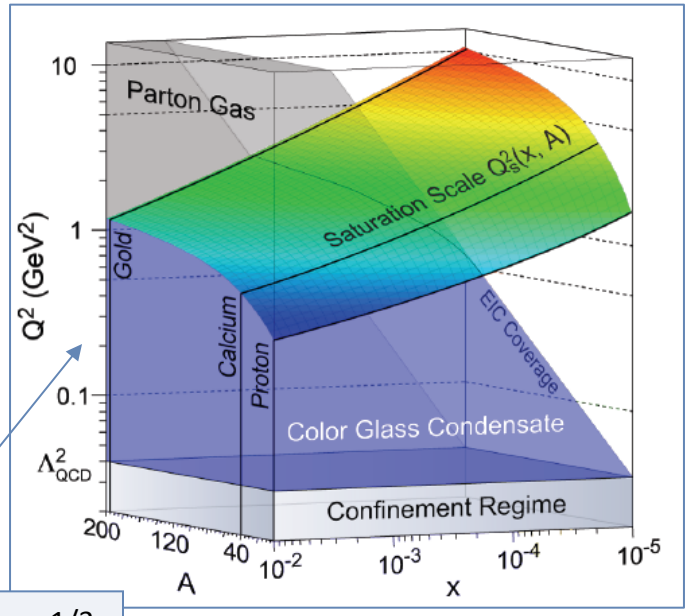
- RHIC Physics Questions
  - What are the detailed mechanisms for parton-QGP interactions?
  - Are there quasi-particles in the medium? What are m and Γ?
  - Is there a relevant color screening length in the QGP?
  - How is rapid equilibration and entropy production achieved?
  - What roles do gluon saturation and the EMC effect play in nucleus-nucleus collisions?
- RHIC Requirements
  - Further $\mathcal{L}$ enhancements
  - Significant further detector upgrades



Long-term Plans in Nuclear Physics (>2015)

- eRHIC Science (e+A)
  - Do gluon self-interactions ⇒ "universal" saturated gluonic matter?
  - eRHIC probes weak coupling regime of very high gluon density, where gauge boson occupancy >> 1 ⇒ intense, semi-classical force field
  - Can we
    - Demonstrate its universal behavior?
    - Track transition from parton gas to CGC?
    - "See"confinement reflected in soft-gluon spatial distributions inside nuclei?
- eRHIC Science ($\vec{e}+\vec{p}$)
  - Low-x helicity structure of the nucleon
  - Proton "tomography;" exclusive reactions → constrain GPDs





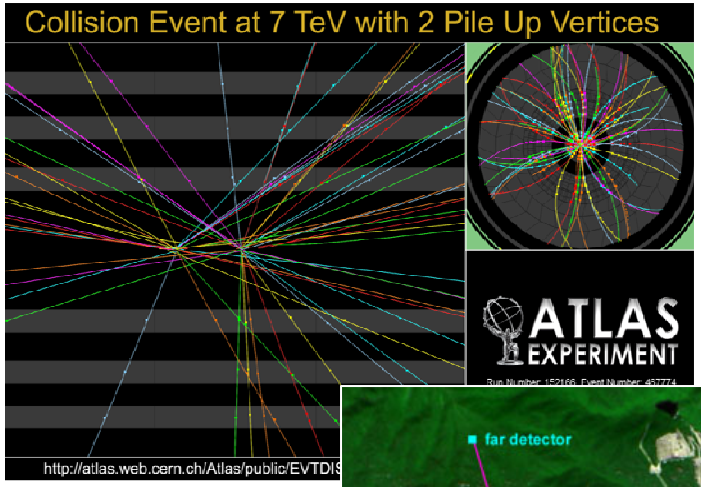
Nuclear enhancement factor ~$A^{1/3}$

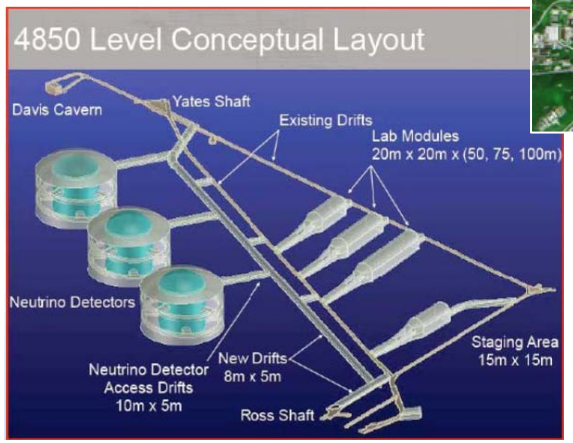
Impact of RHIC on Nuclear and Particle Physics in Japan

- The US-Japan program, and later RIKEN, contributed significantly to PHENIX and RHIC
  - Scientific leadership, hardware, computing, analysis
- ~10,000 citations to ~100 published PHENIX papers
- Scientific manpower
  - Currently 87 from Japan (out of about 500 total)
    - About half from US-Japan program
    - 37 Grad students, 12 Post-docs, 37 Faculty, 1 support
  - PHENIX and precursor AGS experiments have so far produced 37 advanced degrees in Japan (35 PhD, 2 MS)
    - 26 working in HEP and NP experiments, 11 in other fields, industry
    - 14 have tenure or equivalent positions

Activities in Nuclear, **Particle** and Accelerator **Physics**

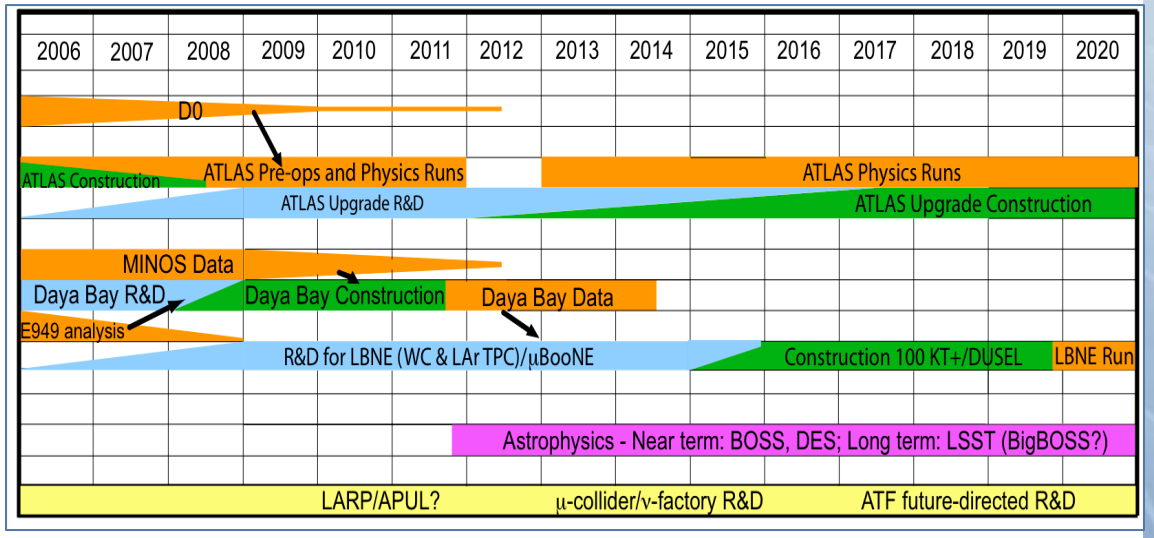
- ATLAS
  - US-ATLAS host
  - Tier-1 data center
- Daya Bay
  - Good construction progress
  - First running early 2011
- LBNE
  - Intellectual leadership
  - Detector Design, R&D
- LSST
  - Focal plane detector





Future Plans in Particle Physics

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



Long-term BNL plan presented to P5 (2008)

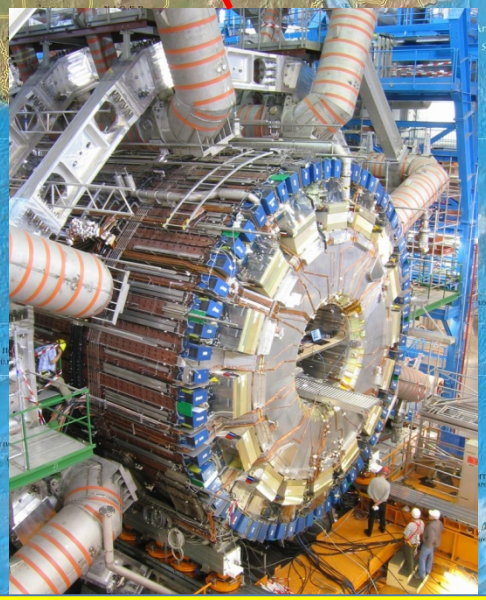
- 2010-16 physics payoff with ATLAS, Daya Bay
- LBNE and ATLAS upgrade projects fuel physics beyond ~2018
- Major ongoing roles in LARP, MAP, APUL?
- Particle astrophysics group established, with short-term roles in DES & BOSS, long-term in LSST

Major BNL Particle Physics Initiatives

Long baseline ν probes CPV, p decay, matter-antimatter asym.

μ Collider R&D ⇒ next generation energy frontier option

LSST to constrain nature of dark energy

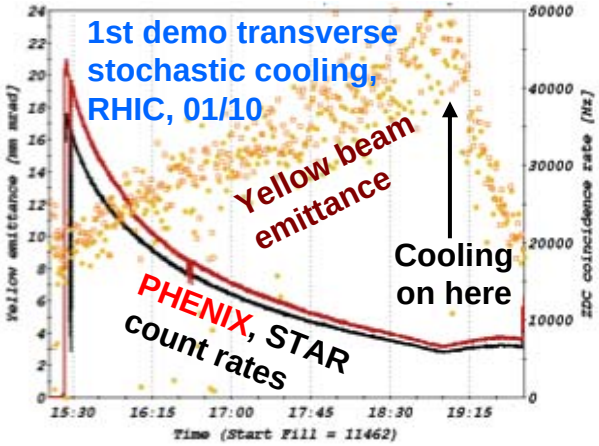


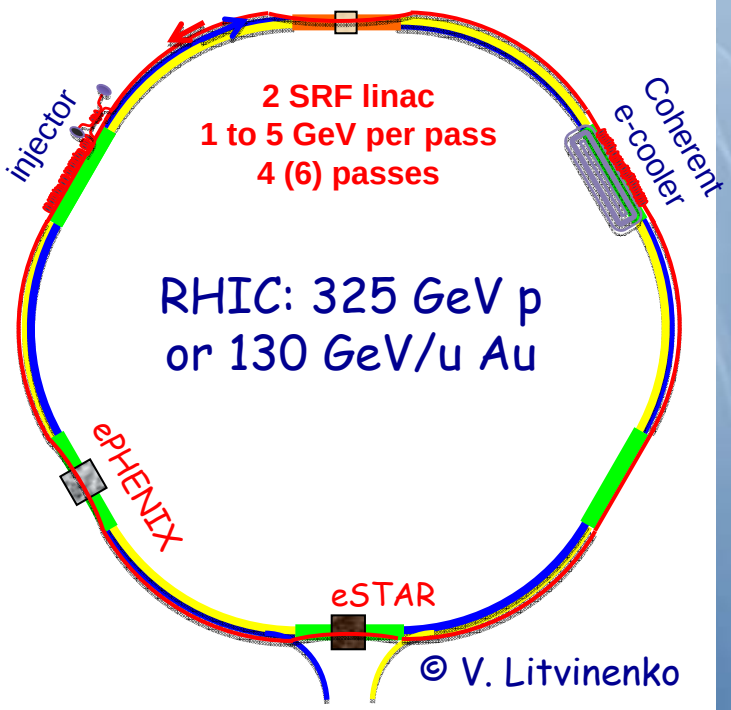
ATLAS @ LHC searches for supersymmetric partners as possible dark matter candidates, Higgs as origin of mass

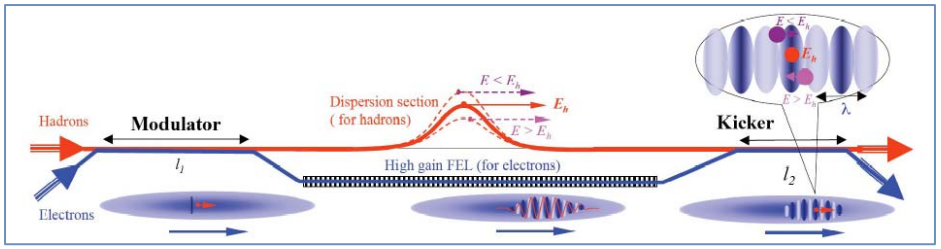
Daya Bay reactor ν exp't ⇒ best sensitivity to θ_{13}

Activities in Nuclear, Particle and **Accelerator Physics**

- Stochastic Cooling at RHIC
  - First working design for high-energy bunched beams
- EBIS – e-Beam Ion Source
- eRHIC
  - Design advancing
  - Multi-pass ERL, SRF, CeC
- Muon Collider
- XFEL
  - eRHIC ERL as driver

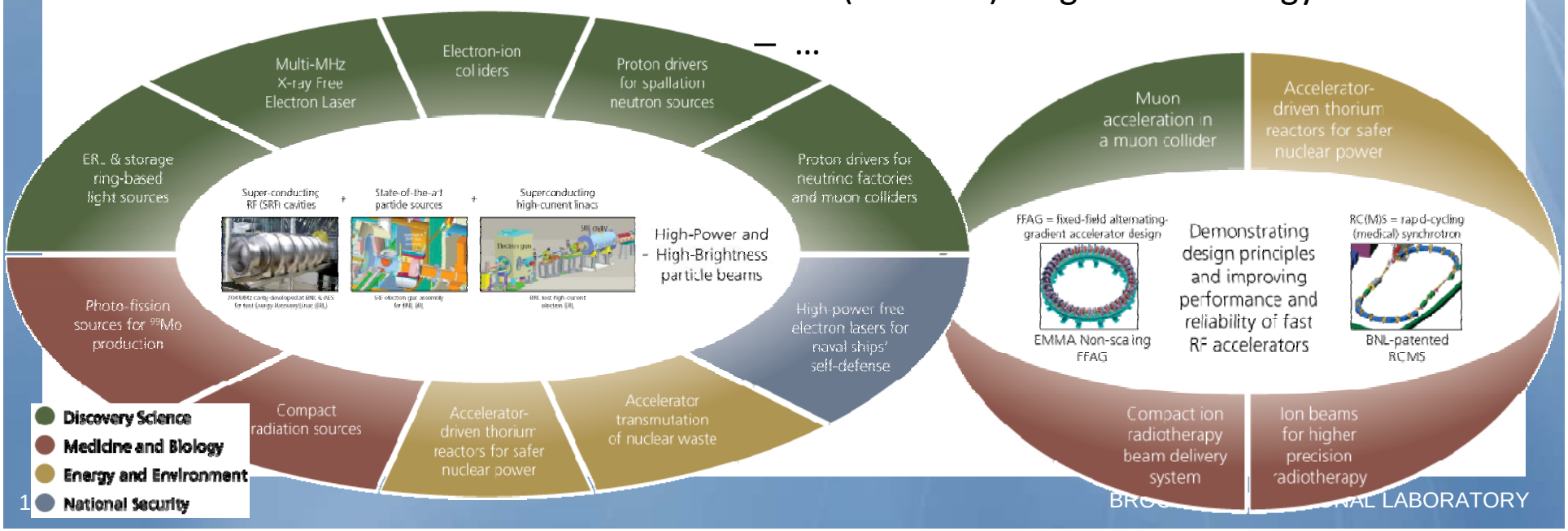






Future Plans in Accelerator S&T

- Past Developments
  - Courant-Snyder strong focusing
  - Chasman-Greene lattice
  - 2-in-1 SC magnets
  - Crab-crossing
  - Stochastic cooling
  - …
- Strengths
  - Hadron collider & light source design, construction, operation
  - High-energy polarized beams
  - High brightness electron beams
  - FELs (4 of last 6 FEL Prizes)
  - ERL, EIC designs
  - SC (incl. HTS) magnet technology
  - …

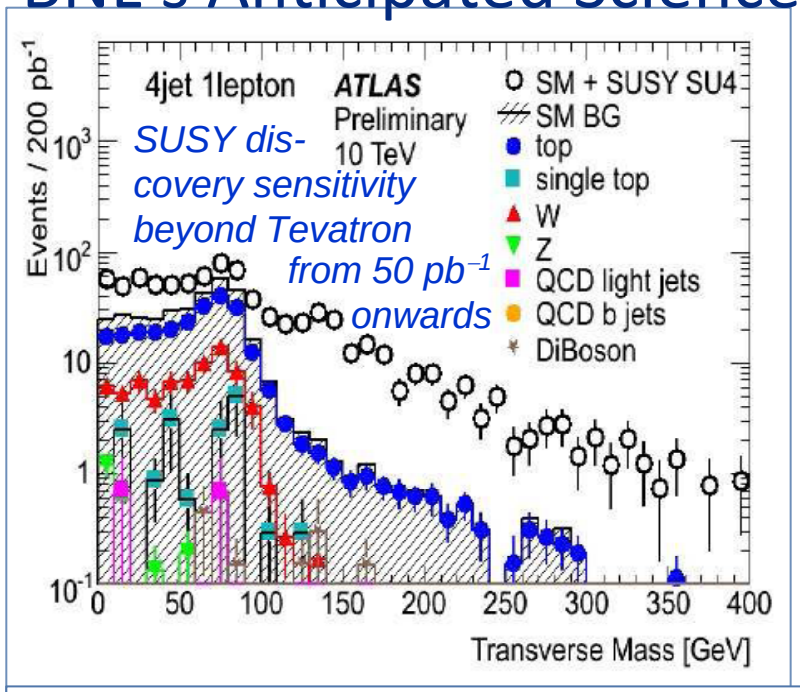


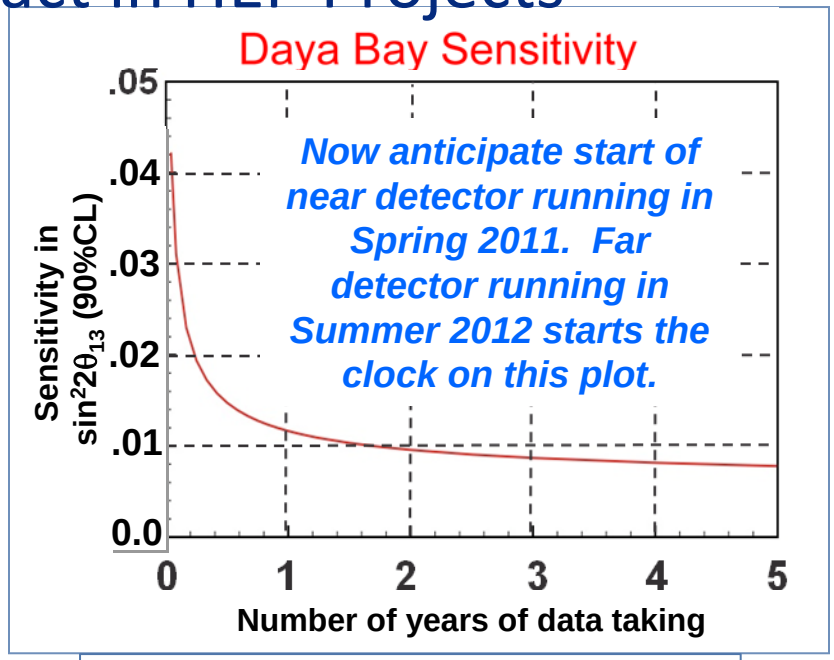
Summary

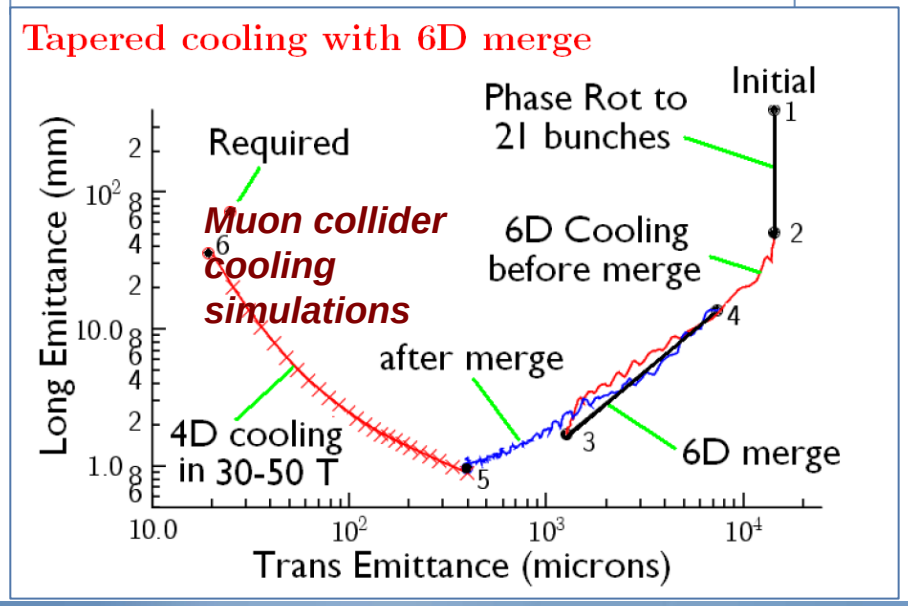
- BNL is currently active in - and has future plans in - Nuclear Physics, Particle Physics and Accelerator S&T
- BNL has benefitted from the US-Japan Collaboration in these areas and continues to do so
  - PHENIX
  - ν elastic scattering, rare K decays, relativistic heavy ions, SRF and other accelerator R&D, Detector/DAQ R&D
- Japanese Institutions have benefitted from these joint activities as well – both in scientific advance & impact and in the training of scientists
- BNL looks forward to the next 30 years of US-Japan Collaboration!

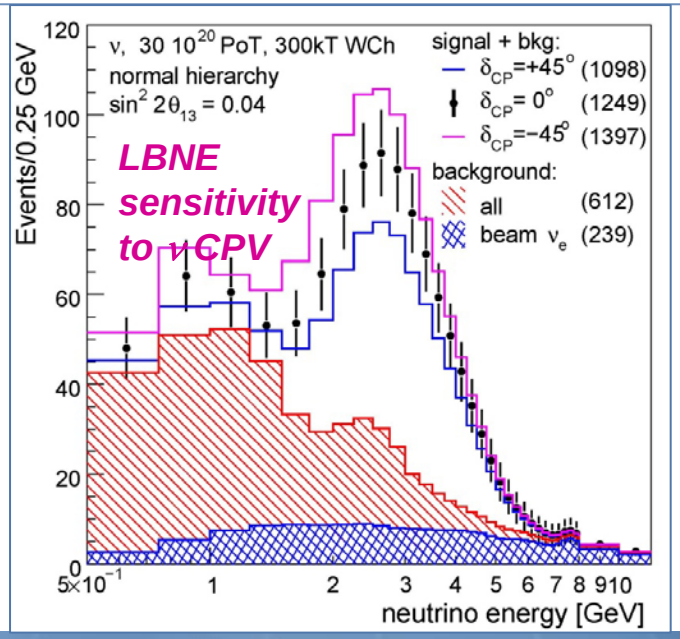
Extras

BNL's Anticipated Science Impact in HEP Projects

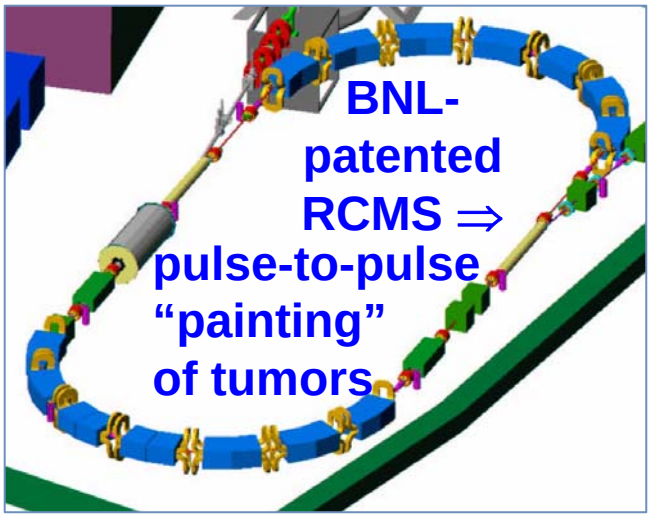




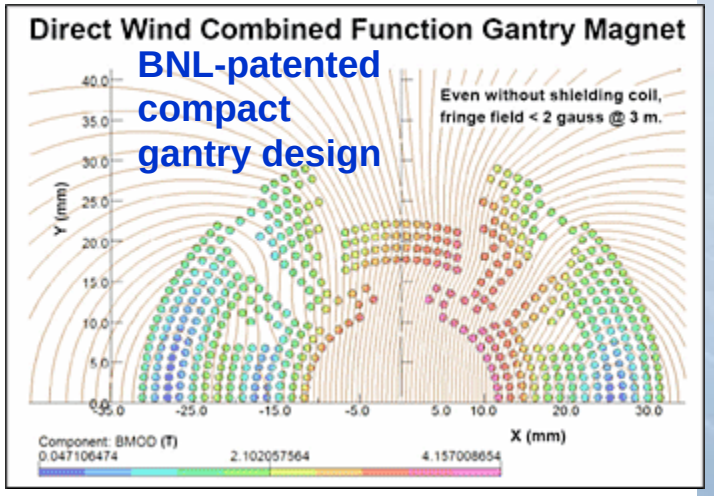




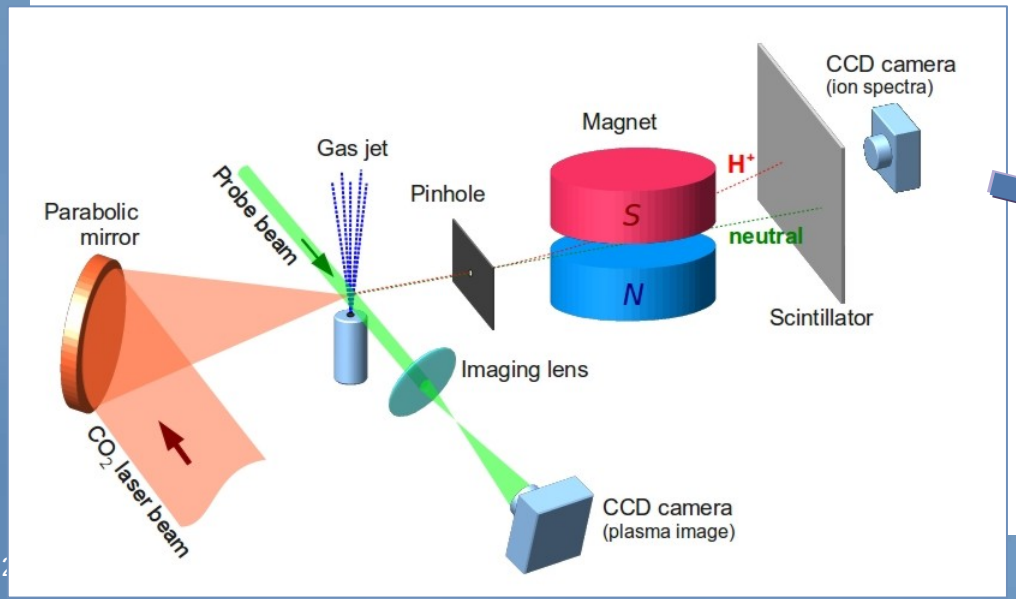
BNL AS&T Broader Impact: Hadron Therapy

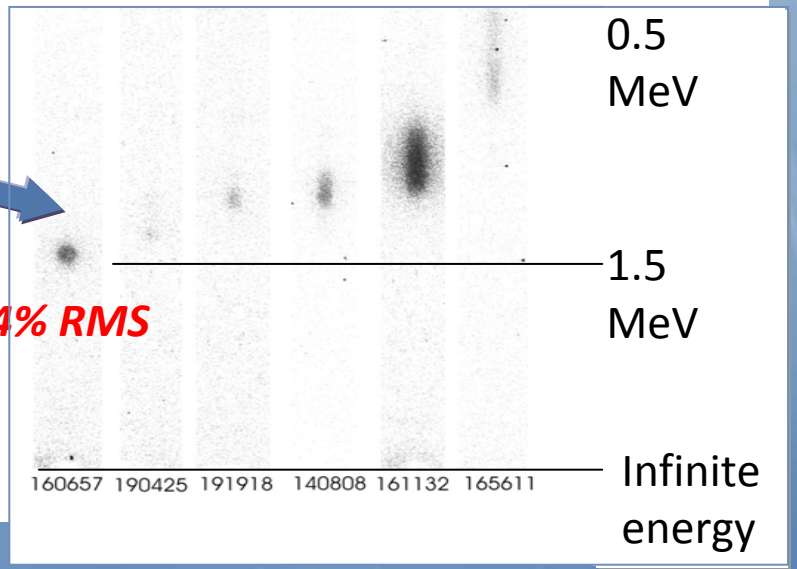


Work on state-of-the-art accelerator design has stimulated patents to improve precision + cost-effectiveness of next-generation radio-therapy devices. Very recent R&D ⇒ promising laser-driven beam technology for longer-term therapy applications.

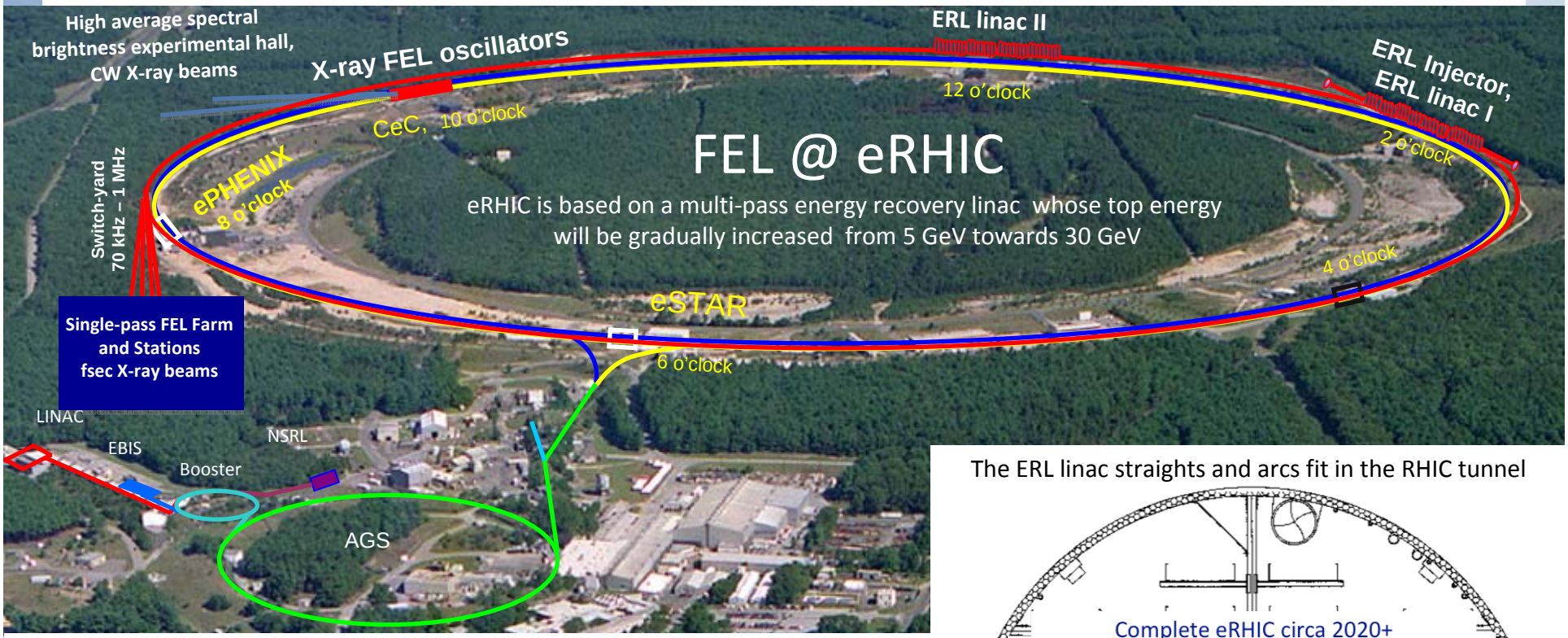


Laser-gas jet interaction @ ATF ⇒ compact low-E ion source of record brightness, energy sharpness – upgradeable to ~75 MeV

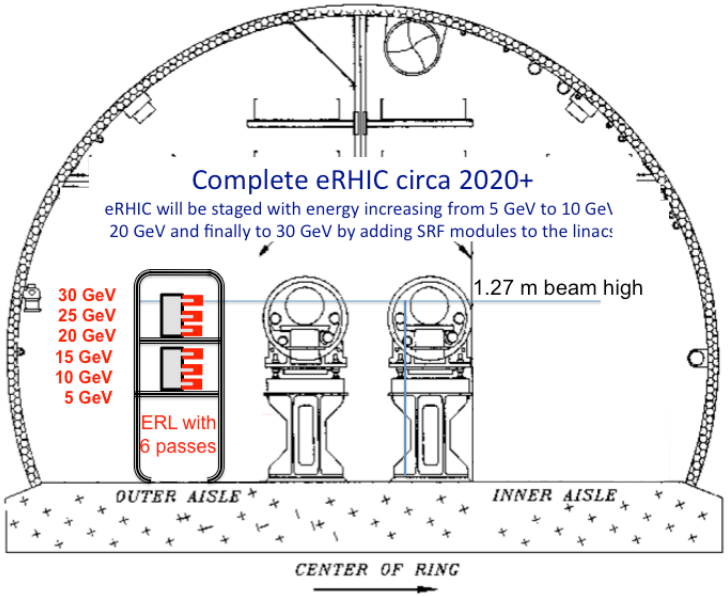




FELs and eRHIC, or LCLS at MHz Repetition Rate



The ERL linac straights and arcs fit in the RHIC tunnel



The FEL will be driven by a dedicated electron gun, capable of MHz repetition rate and sub-micron emittance to drive either single-pass or oscillator high-gain FELs

- 5.6 MeV, 1 ½ cell 704 MHz superconducting RF gun
- 10 fsec 200 pC bunches , normalized emittance 0.13 mm·mrad, δp/p of 6 10^{-4}
- 6 GeV energy is sufficient for HG FEL at 1Å

AS&T Synergy @ BNL: Exploring Use of eRHIC ERL for X-ray FEL of World-Leading Spectral Brightness

	Design Values				
http://www.xfel.eu/en/in-comparison	LCLS	SCSS	EU XFEL	eRHIC FEL farm	eRHIC OFFELO*
Location	SLAC, USA	Japan	Germany	BNL, USA	BNL, USA
Start of commissioning	2009	2011	2014		
Rep Rate [Hz], NC/SC	120, NC	60, NC	10, SC (w 3000 bunches per pulse)	10^4-10^6, SC CW	10^5-10^7, SC CW
FEL Wavelength [nm]	0.15	0.1	0.1	0.1	0.1
Electron Energy [GeV]	14.35	8	17.5	10	10
Peak Brilliance	8.5×10^{32}	5×10^{33}	5×10^{33}	5×10^{32}	1×10^{33}
Average Brilliance	2.4×10^{22}	1.5×10^{23}	1.6×10^{25}	10^{24}-10^{26}	10^{27}-10^{29}

eRHIC FEL farm would use established FEL technology, while eRHIC optics-free FEL oscillator would push it beyond the state-of-the-art, revolutionizing inelastic X-ray scattering studies