American Particle and Nuclear Physics Planning

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Jefferson Lab

Input to Talk

- Particle Physics 2013 -2014 -- High Energy Physics Advisory Panel (HEPAP)
  - P5 (Ritz)– not appeared yet
  - 2013 Office of High Energy Physics (OHEP) Facilities Plan
- Nuclear Physics 2012 – 2014 – Nuclear Science Advisory Committee (NSAC)
  - 2012-13 Implementation of 2001 Long Range Plan (Tribble)
  - 2013 Office of Nuclear Physics (ONP) Facilities (Redwine)
  - 2014 NSAC ν-less 2β decay (McKeown)
- DOE Office of Science Facilities Plan (Dehmer)
  - Not appeared yet
- TRIUMF
  - New 5 year plan Fall 2013
  - Reviewed and funding base approved by National Research Council (NRC)

Acknowledgements

I appreciate input and conversations with the following colleagues:

Greg Bock, Rolf Ent, Andy Lankford, Nigel Lockyer, Bob McKeown, Lia Merminga, Berndt Mueller, Steve Ritz, Brad Sherrill

I have also taken material from the presentations to P5, which can be found at:

http://www.usparticlephysics.org/p5

Particle Physics -- HEPAP

- Particle Physics 2013 -2014
  - Snowmass – community driven, lots of sub workshops
  - Particle Physics Project Prioritization Plan (P5)
    - Chair Steve Ritz, international team
    - Anticipate report within weeks

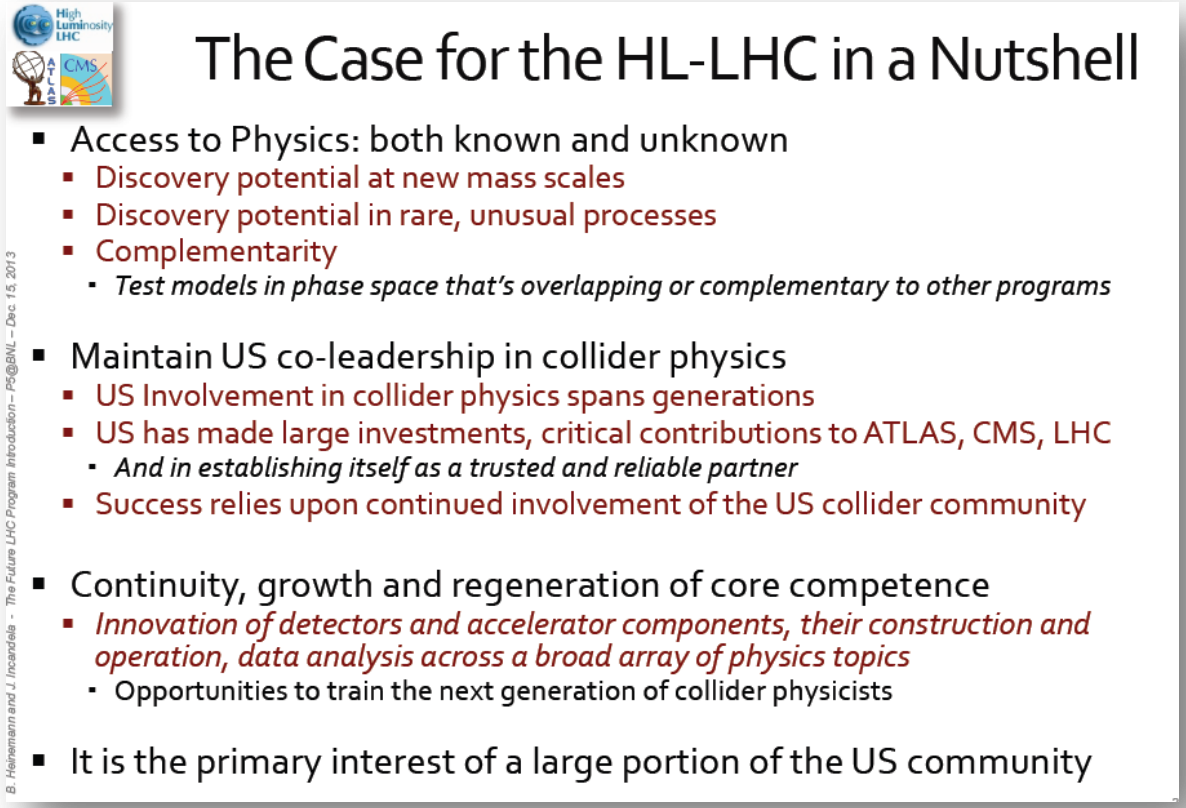
  - Physics Components
    - Energy Frontier LHC Upgrade involvement, ILC
    - Neutrino Program, existing experiments at FNAL
    - Future neutrino program,
    - Other Intensity Frontier programs
    - Direct Dark Matter Searches
    - Dark Energy probes

Not Comprehensive

Energy Frontier

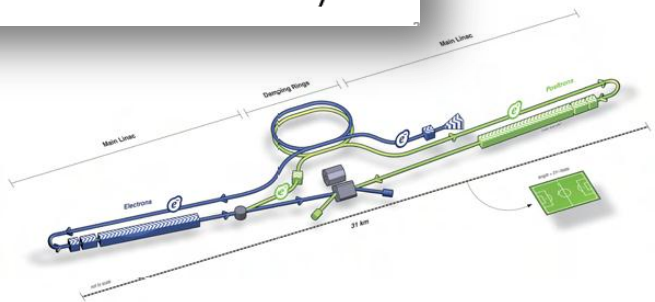
LHC Upgrades

- Machine
- Atlas
- CMS

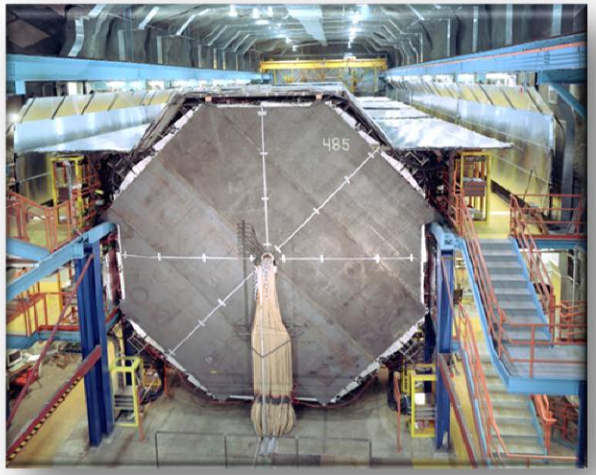


International Linear Collider

- Visits with and by members of Japanese Diet
- Japanese letter to US (inc Secretary of Energy)



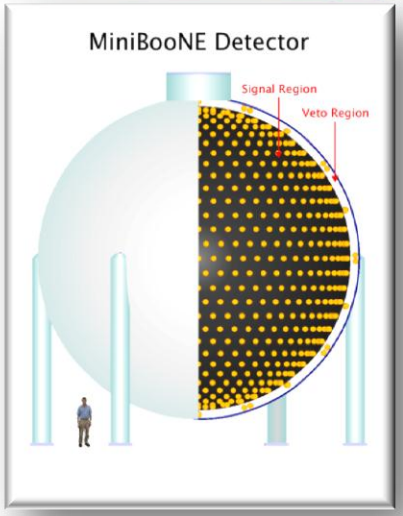
“Existing” Fermilab Neutrino Program



MINOS (Long and Short Baseline)

Main Injector (NuMI) Beam

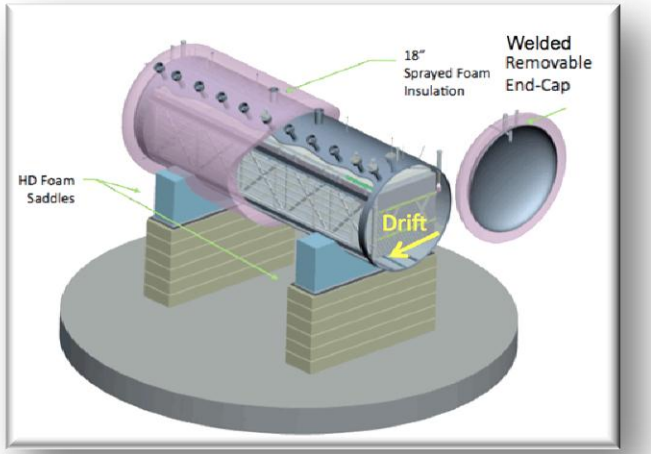
MINERvA (Short Baseline)



MiniBooNE

Booster Beam

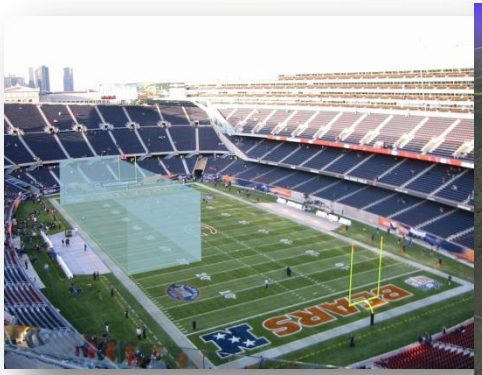
MicroBooNE

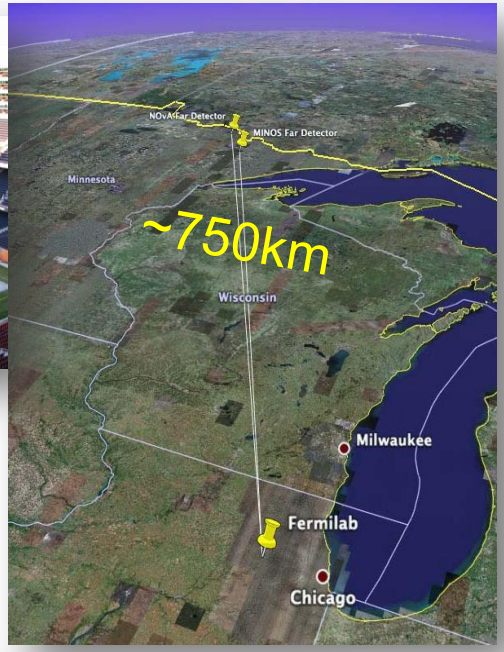


Future Fermilab Neutrino Program

NOvA

- On axis, NUMI Beam
- MI Proton Beam 700kW
- 14 kTon, liq. Scint. fine grain
- + Near Detector
- Operational 2014 …





Long Baseline Neutrino Experiment

- New Main Injector Beam
- LAr Detector
- Underground?
- Near Detector
- Beam ~1 MW+
- Operational ~2025

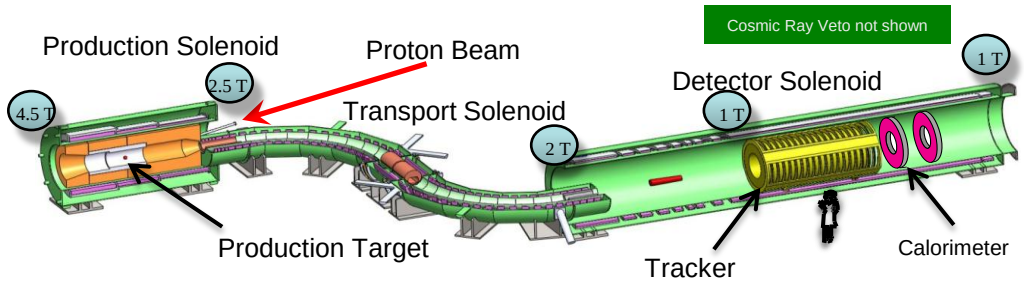
New 700kW broadband neutrino beam from Fermilab

Intensity Frontier

μ2e conversion

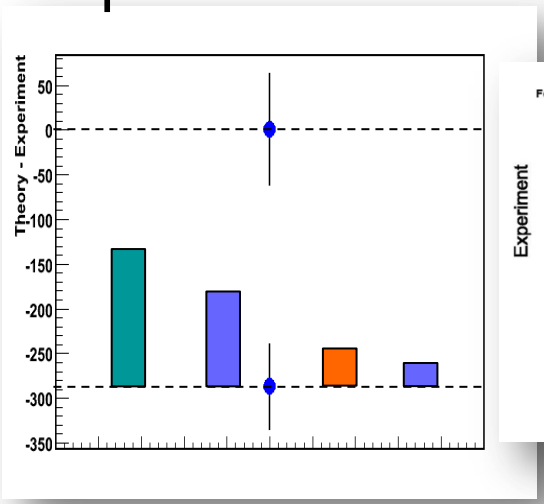
1st data 2019

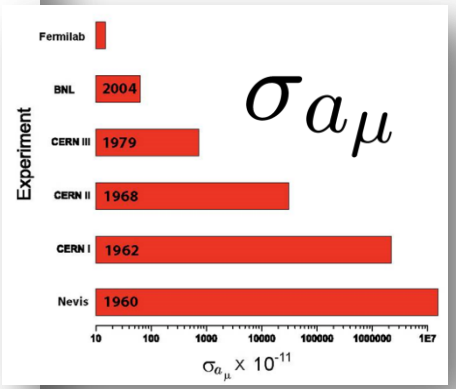
SES 3 10^{-17}



competition from COMET(JPARC) [also SES 3 10^{-17}]

$(g-2)_\mu$

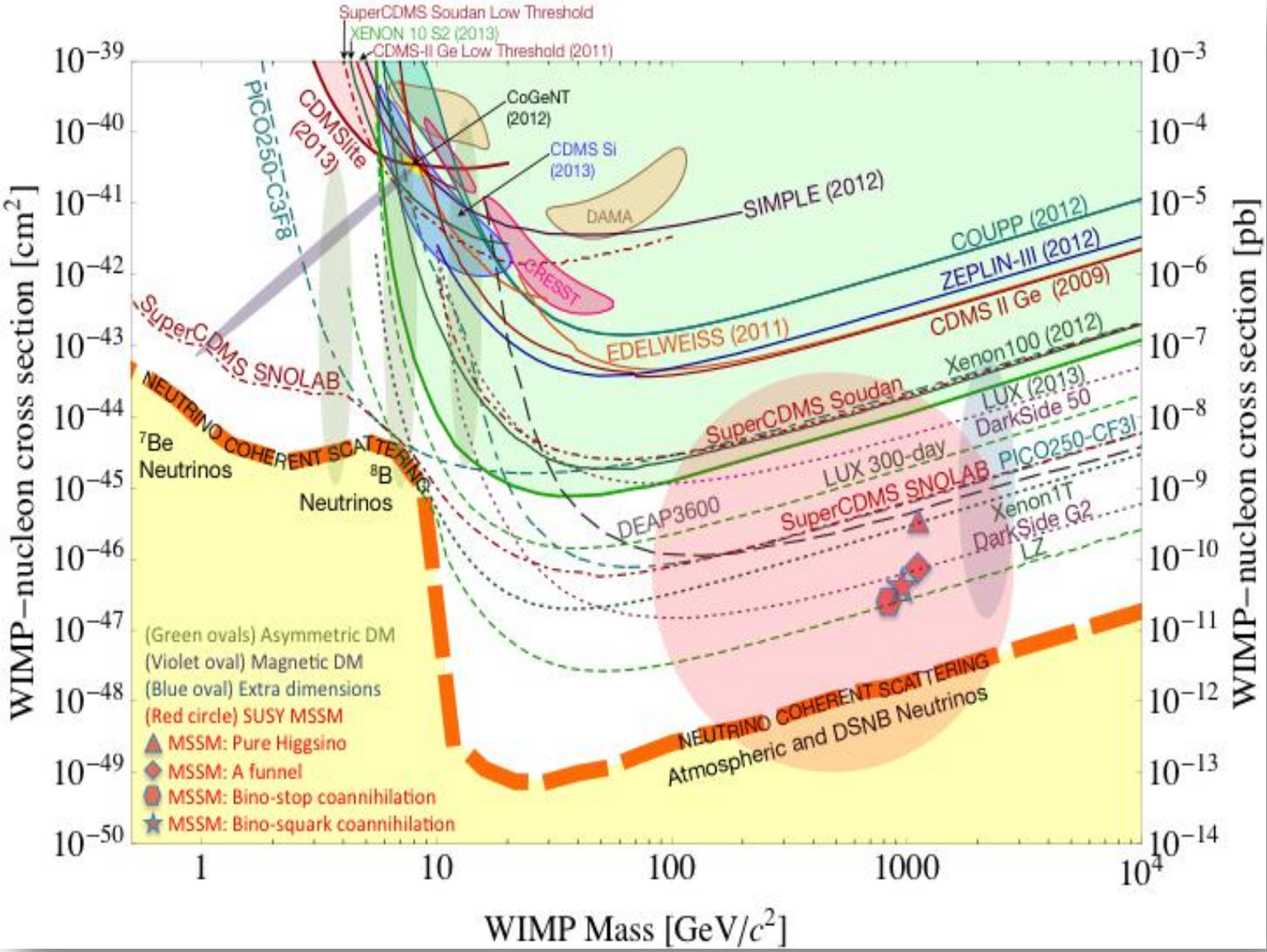




Heavy Photon Search, APEX, Darklight

Searches for A' at Jefferson Lab

Dark Matter


SuperCDMS Soudan Low Threshold
XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CDMSlite (2013)
PICO250-C3F8
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
Xenon100 (2012)
SuperCDMS SNOLAB
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
SuperCDMS Soudan
LUX (2013)
DarkSide 50
LUX 300-day
DEAP3600
SuperCDMS SNOLAB
PICO250-CF3I
Xenon1T
DarkSide G2
LZ
(Green ovals) Asymmetric DM
(Violet oval) Magnetic DM
(Blue oval) Extra dimensions
(Red circle) SUSY MSSM
MSSM: Pure Higgsino
MSSM: A funnel
MSSM: Bino-stop coannihilation
MSSM: Bino-squark coannihilation
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
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10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
1
10
100
1000
10^4

P5

P5 Identified Scientific Drivers for the Field

"Driver" = a compelling line of inquiry that shows great promise for major progress over the next 10-20 years. Each has the potential to be transformative. Expect surprises.

- Use the Higgs as a new tool for discovery.
- Explore the physics associated with neutrino mass.
- Identify the new physics of Dark Matter.
- Test the nature of Dark Energy in detail, and probe the physics of the highest energy scales that governed the very early Universe.
- Search for new particles and interactions; new physical principles.

These drivers are intertwined, possibly even more deeply than we currently understand. A selected set of different experimental approaches, which reinforce each other, is required. This effort also opens important discovery space beyond the drivers.

March 2014 8

Criteria (I): Overall Program Optimization

- Science-driven big picture: where we want to go and how to get there.
- Prioritized portfolio for discovery and exploration.
- International context and optimization:
  - Pursue the most important opportunities wherever they are, and host world-leading facilities that attract the worldwide scientific community.
  - Reliable partnerships are essential.
  - Duplication only when significant value added or when competition helps propel us in important directions. When competing, be clearly leading in key ways.
- Health of the field, sustained productivity:
  - Maintain a stream of results while investing in facilities and future capabilities => a balance of project scales.
  - Maintain and develop critical technical and scientific expertise and infrastructure to enable future discoveries.
  - a guideline: total expenditures on projects around 20-25% of total budget; research fraction >~40% for both project data analysis and blue-sky research to explore unplanned new directions.

March 2014

Particle Physics is Global

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Criteria (II): Projects

- Science first: how does it address key questions in particle physics?
- Discovery space. How might it change the direction of the field, and what is the value of null results?
- When is it absolutely needed, and how does it fit into the larger picture? What does the experiment add that is unique, is it definitive, and/or where might it lead? Are there alternatives?
- Cost vs value.
  - Is the scope well defined and does it match the physics case? For multi-disciplinary/agency projects, does the support match the distribution of science?
  - One main measurement or a preponderance of interesting possible results? Solid result(s) expected or possibly marginal?
  - At what cost/schedule/capability changes does the priority change?
- Take into account previous prioritization and existing commitments. What are the impacts of changes in direction?
- Is the project feasible as proposed? Technical, cost, schedule risks.
- Is U.S.particle physics leadership, or participation, critical, and how?
- What are the other benefits of the project?

March 2014

In final deliberations now

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Nuclear Physics – NSAC

- Nuclear Physics 2012 – 2014 -- NSAC
  - Long Range Plan (2007) Implementation 2012-2013(Tribble)
  - Facilities Subcommittee (Redwine)
  - **$0\nu\beta\beta$ McKeown Sub-Committee**
  - New Long Range Plan -- Charge to NSAC April 24, 2014
    Sub committee, report October 2015

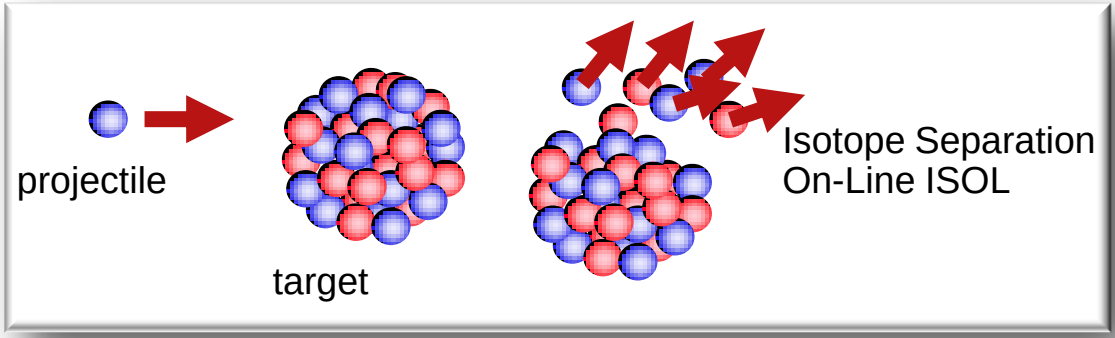
  - Essential components
    - Low Energy Nuclear Structure
    - Heavy Ion Physics
    - Medium Energy Physics
    - Fundamental Symmetries

    - Future facilities - Electron Ion Collider, $0\nu\beta\beta$

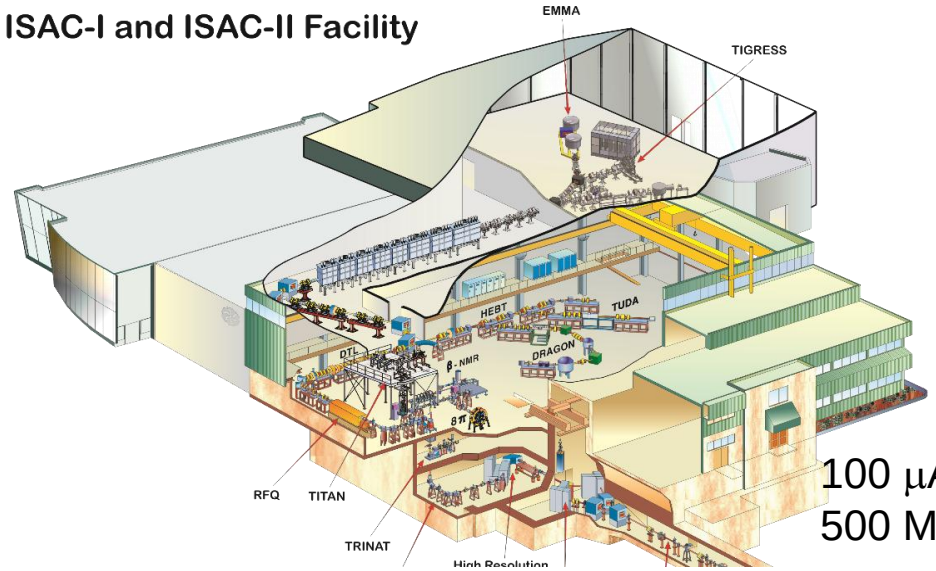
Current US Nuclear Structure Facilities

- ANL ATLAS Accelerator Facility – DOE SC Supported user facility
  - Superconducting linear accelerator
  - Approximately 300 users/year
  - Intense beams of nearly all stable isotopes
  - Rare isotopes from CARIBU (based on ^{252}Cf fission)
  - In-flight produced rare isotopes
- National Superconducting Cyclotron Laboratory – NSF Supported Rare isotope beam facility
  - Coupled Superconducting Cyclotrons
  - Approximately 300 users/year
  - Nearly 1000 different rare isotope beams delivered for experiments
  - Rare isotope experiments with stopped (Laser spectroscopy, Traps), reaccelerated at 1-5 MeV/u
  - Fast – from 30 to 150 MeV/u
- University Centers of Excellence: TAMU (DOE), LBL (DOE), Notre Dame (NSF), Florida State (NSF), Seattle (DOE), Kentucky (DOE)

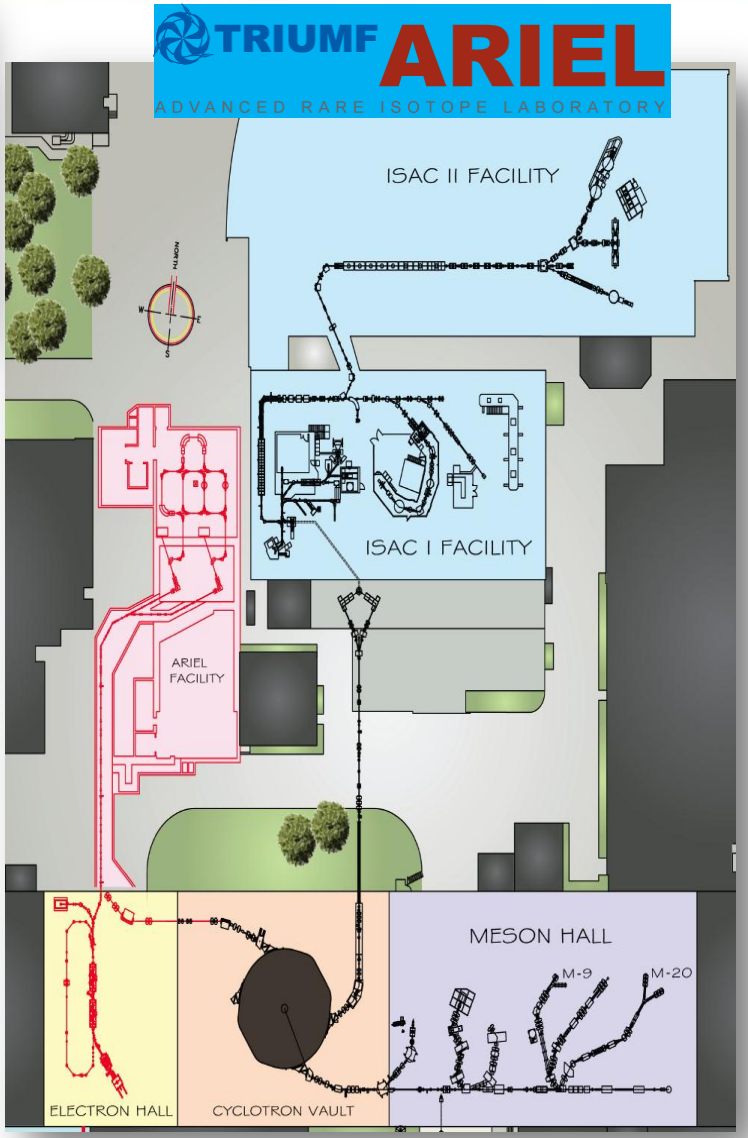
Major Canadian Facility – TRIUMF ISAC and ARIEL



- Highest power ISOL facility - >50 kW
- Programs in nuclei, astrophysics, symmetry tests, condensed matter, medical isotopes

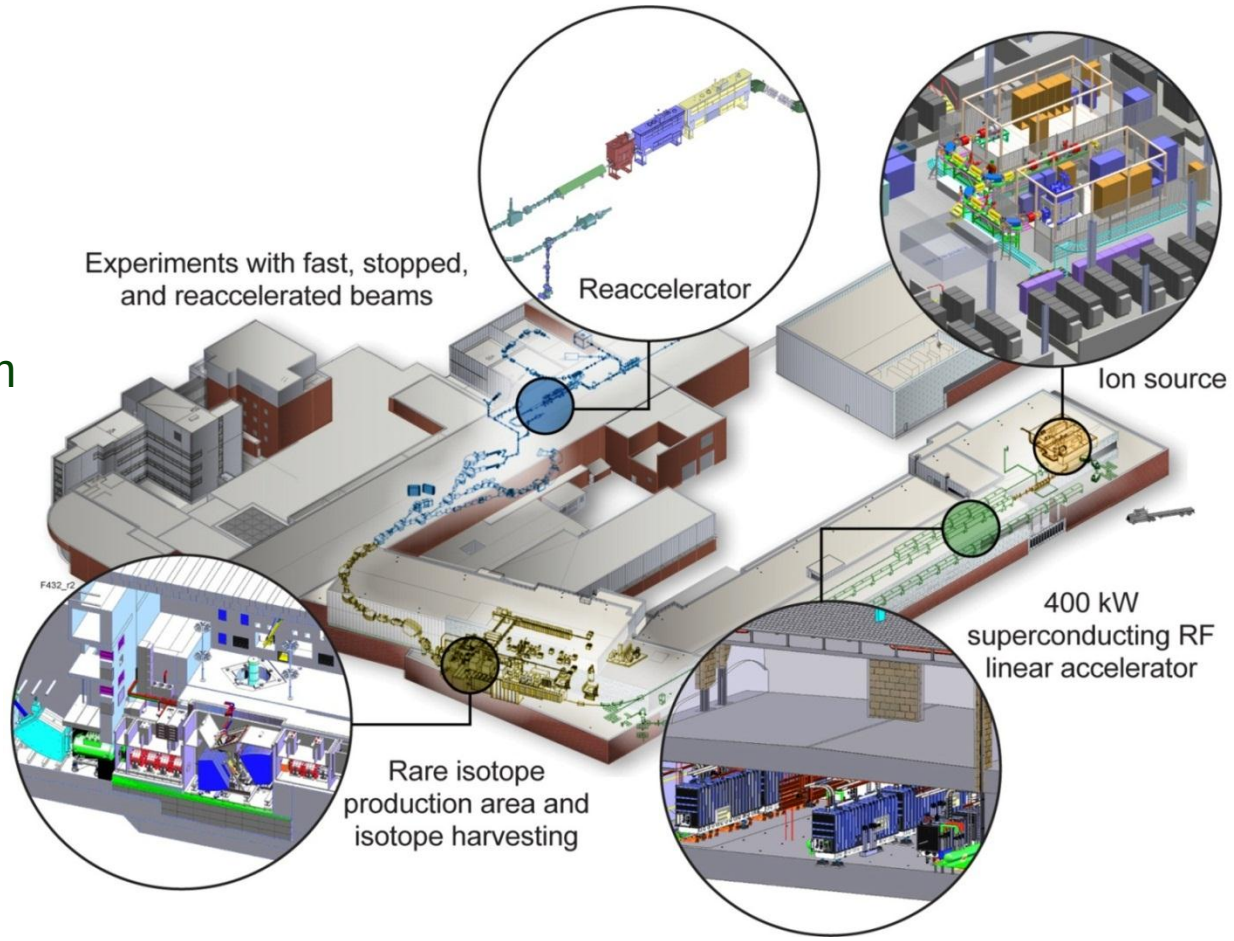


100 μA,
500 MeV, p

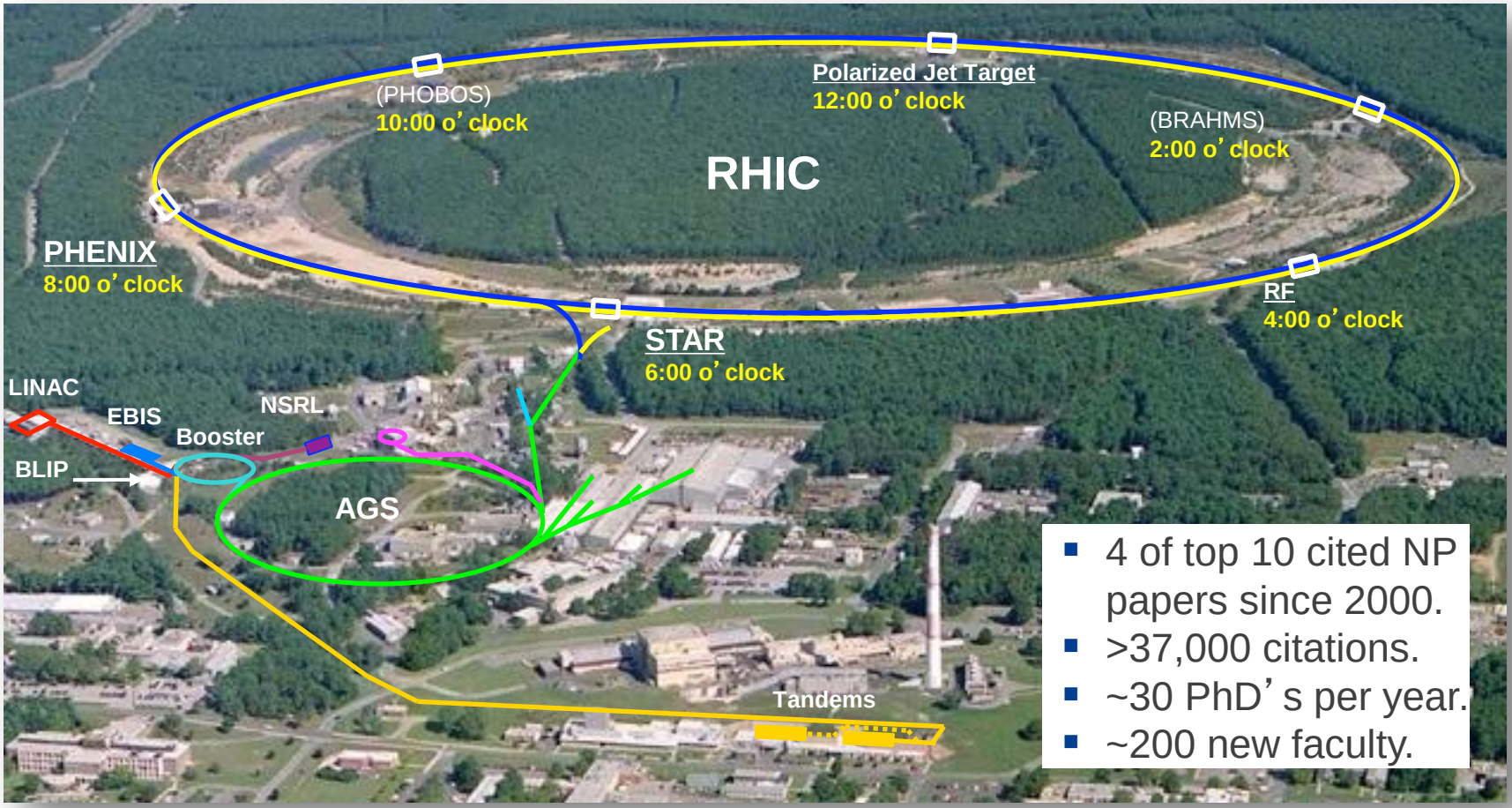


Facility for Rare Isotope Beams, FRIB

- Funded by DOE Office of Science, Office of Nuclear Physics at National Superconducting Cyclotron Lab, Michigan State U.
- Key Feature is 400kW beam power (5 x10^{13} ^{238}U/s)
- Separation of isotopes in-flight
  - Fast development time for any isotope
  - Suited for all elements and short half-lives
  - Fast, stopped, and reaccelerated beams



Relativistic Heavy Ion Collider



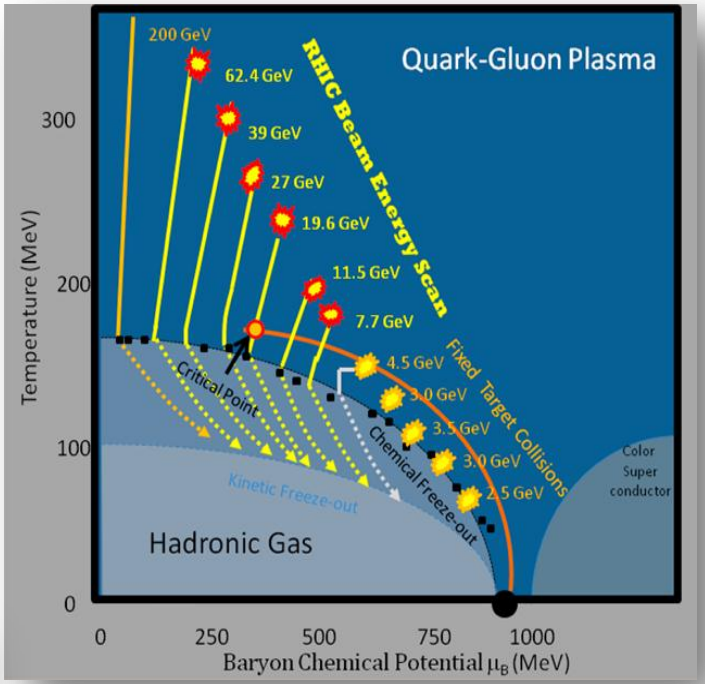
- 4 of top 10 cited NP papers since 2000.
- >37,000 citations.
- ~30 PhD's per year.
- ~200 new faculty.

Completing the RHIC science mission

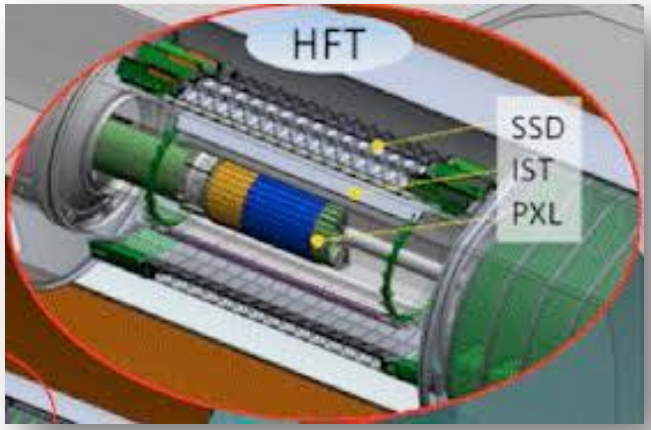
RHIC II Science Program

- RHIC-II upgrade complete
  - Luminosity upgrade via 3-D stochastic cooling
  - EBIS, 56MHz cavity, e-lenses, etc.
  - Si vertex detectors in STAR and PHENIX
- Install low energy e-cooling in 2017
- Install sPHENIX upgrade in 2020
- Complete the RHIC Mission in 3 campaigns:
  - 2014/15/16: Heavy flavor probes of the QGP
  - 2018/19: High intensity Beam Energy Scan II
  - 2021/22: Precision jet and quarkonium physics

Beam Energy Scan II



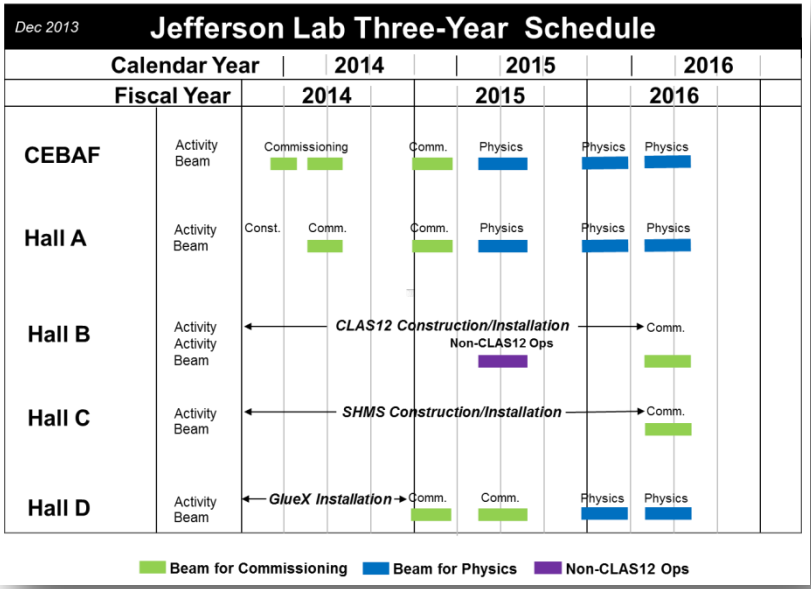
Heavy Flavor Tracker enables precision measurements of interactions of heavy quarks in the quark-gluon plasma



Low-energy e-cooling will improve statistics at $\sqrt{s} < 20$ GeV for high quality measurements of fluctuation properties in search of critical point in QCD phase diagram

Jefferson Lab CEBAF 12 GeV Upgrade

- Civil Construction essentially complete
- Accelerator in commissioning
  - 5 passes this week, >10 GeV?
- Physics Sub-Project
  - Hall A operational
  - Hall D/GlueX in advanced installation
    - Commissioning starts Fall this year
  - Hall B – detector installation, magnet construction
  - Hall C – infrastructure installation, detectors ready, magnet construction



Jefferson Lab CEBAF 12 GeV Physics

- The Hadron spectra as probes of QCD (GluEx and heavy baryon and meson spectroscopy)
- The transverse structure of the hadrons (Elastic and transition Form Factors)
- The longitudinal structure of the hadrons (Unpolarized and polarized parton distribution functions)
- The 3D structure of the hadrons (Generalized Parton Distributions and Transverse Momentum Distributions)
- Hadrons and cold nuclear matter (Medium modification of the nucleons, quark hadronization, N-N correlations, hypernuclear spectroscopy, few-body experiments)
- Low-energy tests of the Standard Model and Fundamental Symmetries

More than 5 years of approved program!

Fundamental Symmetries

2013 NSAC LRP Implementation Report

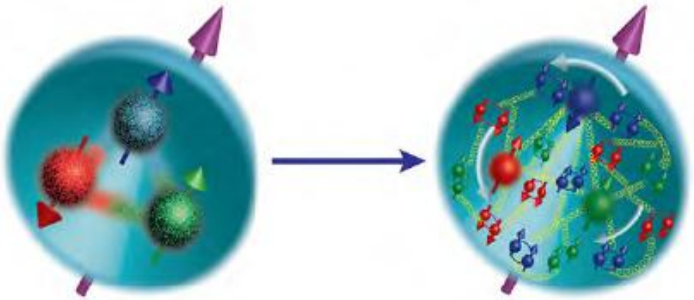
Electric Dipole Moment Searches • *Origin of Matter* • *New Forces* Exp'ts: nEDM	**Neutrinoless Double β-decay Searches** • *Nature of the Neutrino* • *Origin of Matter* Exp'ts: CUORE, EXO, MAJORANA → Tonne
Electron & Muon Properties & Interactions • *New Forces* • *New subatomic particles* Exp'ts: MOLLER, SoLID, Muon g-2	**Radioactive Decays & Other Tests** • *New Forces* • *Neutrino mass* Exp'ts: KATRIN, Nab

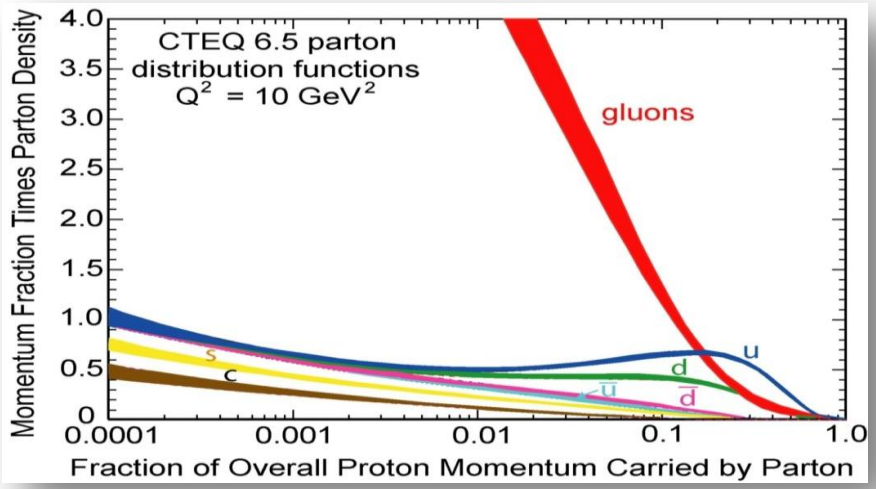
Table II-1. Four broad components of the nuclear physics program of fundamental symmetry and neutrino studies. The primary scientific questions addressed by each are given in italics. The proposed and on-going flagship experiments in each area are listed. The tonne scale neutrinoless double β-decay experiment would follow the current generation of measurements.

$0\nu\beta\beta$ McKeown Sub-Committee; April 2014

It is the assessment of this Subcommittee that the pursuit of neutrinoless double beta decay addresses urgent scientific questions of the highest importance, and that sufficiently sensitive second generation experiments would have excellent prospects for a major discovery. Furthermore, we recommend that DOE and NSF support this subject at a level appropriate to ensure a leadership position for the US in this next phase of discovery-caliber research.

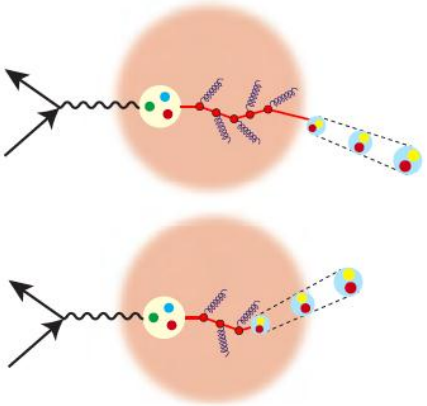
Electron Ion Collider: A QCD Laboratory

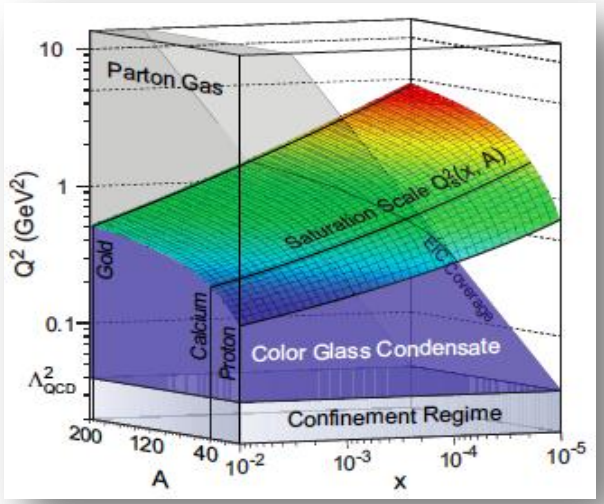




Understanding the "99%", the glue that binds us

- Tomography of the nucleus
- Gluon spin
- QCD at high gluon density
- Quark hadronization in depth





Electron Ion Collider

Energy 20 – ~100 GeV

High Luminosity → 10^{33} - 10^{34} cm^2s^{-1}

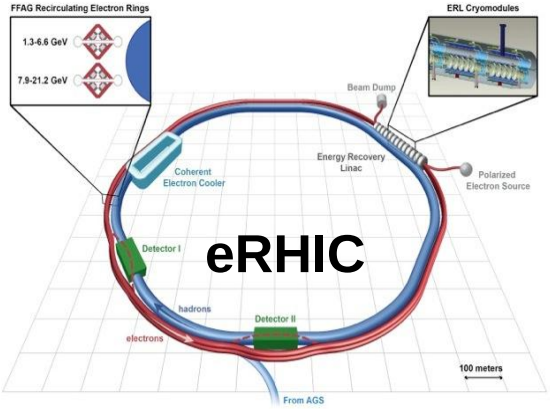
Low x regime x → 0.0001

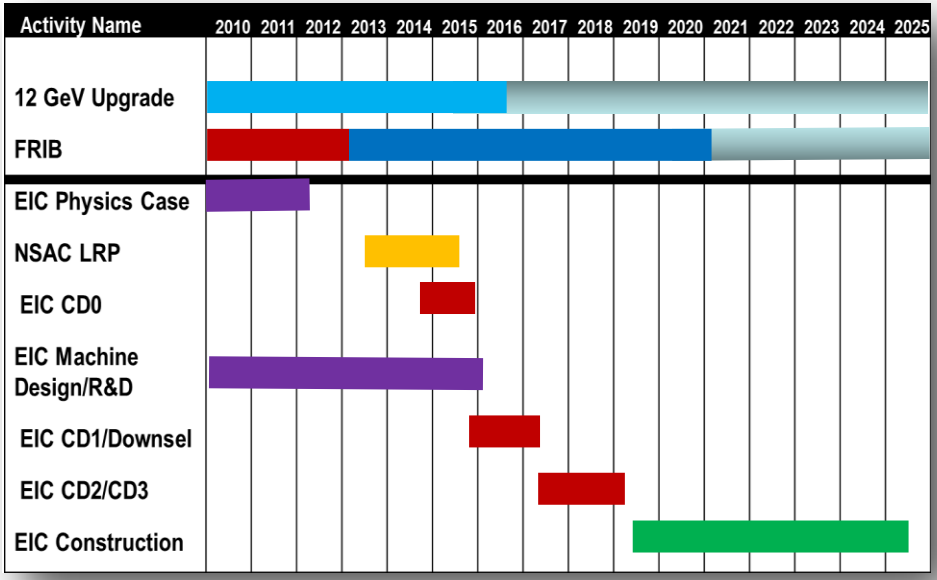
High polarizations 70%

Ion beams up to U or PB

eRHIC ERL + FFAG ring design @ $10^{33}/cm^2s$

15.9 GeV e^- + 255 GeV p or 100 GeV/u Au.





CEBAF-based 3-12 GeV on 20-100 GeV ep/eA collider

Conclusions

- Budget Constraints force us to make choices in Particle Physics and constrain Nuclear Physics
- In particle physics, the P5 process is close to conclusion
- In nuclear physics, while the field provided guidance on execution of the 2007 Long Range Plan, we are about to embark on the new edition. This will set the scene for developments from FY2015 onwards.
- There is also a DOE Office of Science Facilities document which may appear.