THE RHIC FACILITY AND THE SBIR/STTR PROGRAM

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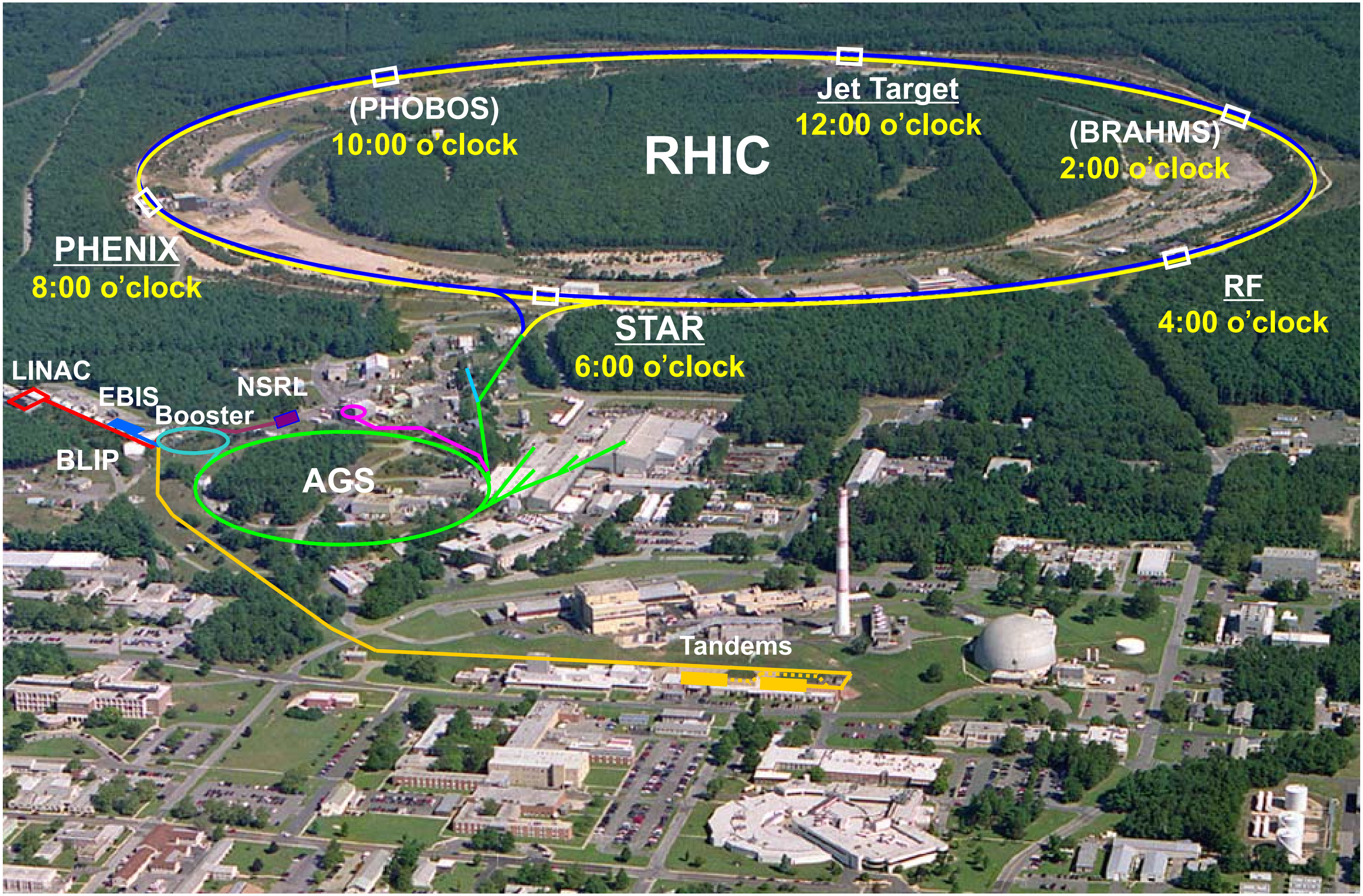
RHIC and the SBIR/STTR Program

- The RHIC complex comprises eight accelerators, including the twin 3.8 km superconducting collider rings.
- The C-AD Department has about 400 staff members which operate, maintain and upgrade the accelerator complex and do R&D on a variety of subjects.
- We consider the SBIR/STTR program as an important element in the way we do accelerator R&D.
- SBIR/STTR programs are highly encouraged and strongly supported by C-AD.

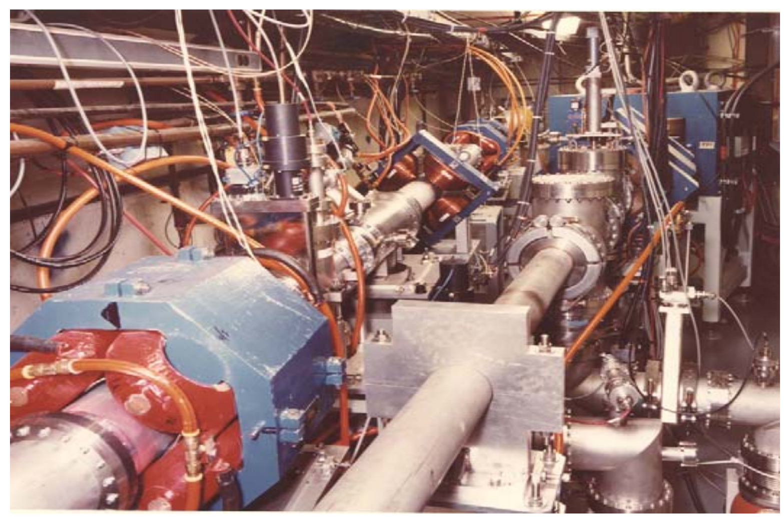
RHIC – a High Luminosity (Polarized) Hadron Collider, and much more!



Brookhaven LINAC Isotope Producer (BLIP)

The LINAC supplies protons to the Booster for nuclear physics. Excess pulses (~85-92%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV.

The BLIP beam line directs protons up to 115µA intensity to targets; parasitic operation with nuclear physics programs



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RHIC is central to carrying out the ONP science mission:

The mission of the Nuclear Physics (NP) program is to discover, explore, and understand all forms of nuclear matter. The fundamental particles that compose nuclear matter - quarks and gluons - are relatively well understood, but exactly how they fit together and interact to create different types of matter in the universe is still not fully explained. To solve this mystery, NP supports experimental and theoretical research - along with the development and operation of particle accelerators and advanced technologies – to create, detect, and describe the different forms and complexities of nuclear matter that can exist in the universe, including those that are no longer found naturally.

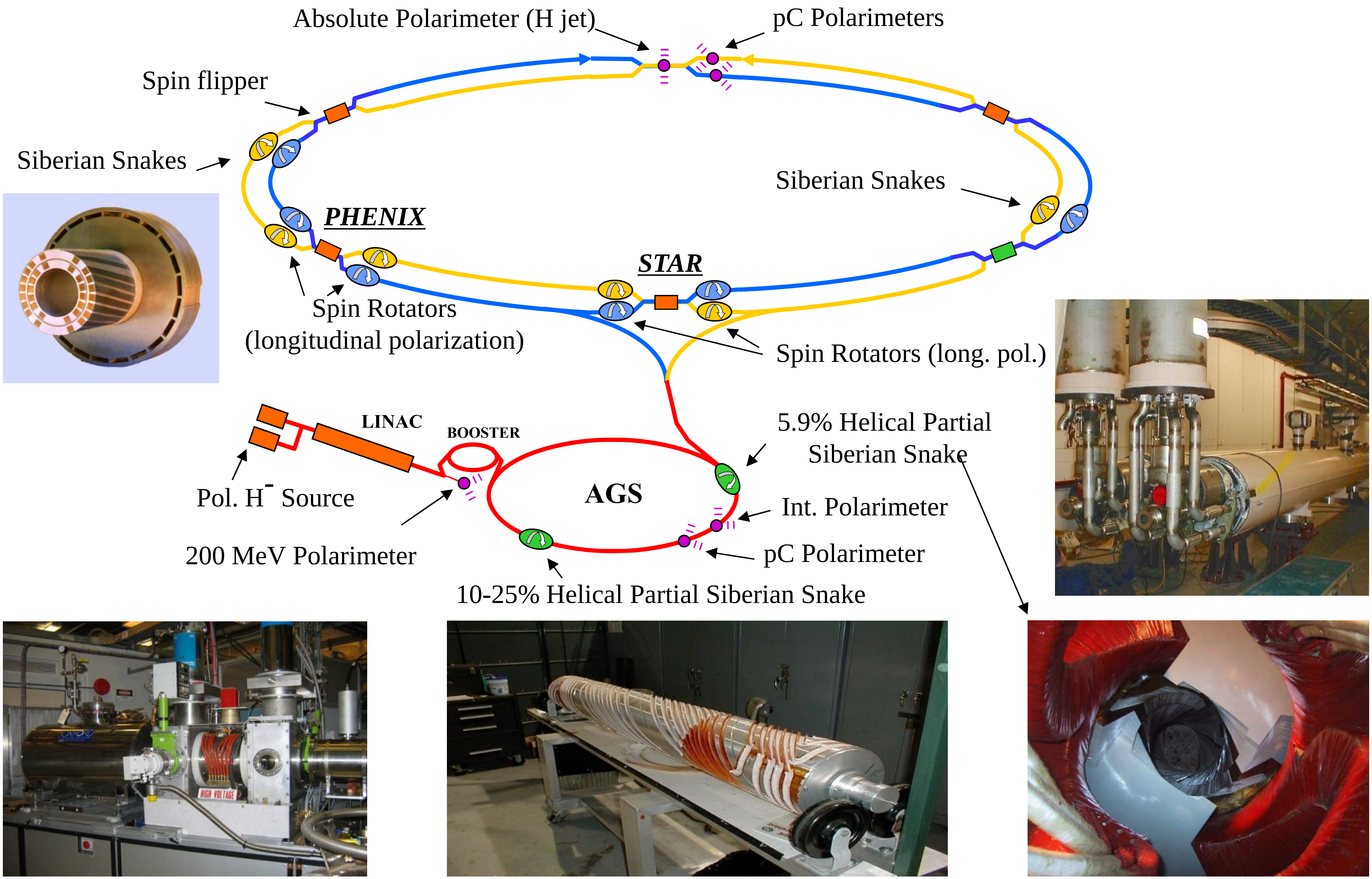
C-AD Mission Statement

The mission of the Collider-Accelerator Department is to develop, improve and operate the suite of particle / heavy ion accelerators used to carry out the program of accelerator-based experiments at BNL; to support the experimental program including design, construction and operation of the beam transports to the experiments plus support of detector and research needs of the experiments; to design and construct new accelerator facilities in support of the BNL and national missions. The C-A Department supports an international user community of over 1500 scientists. The department performs all these functions in an environmentally responsible and safe manner under a rigorous conduct of operations approach.

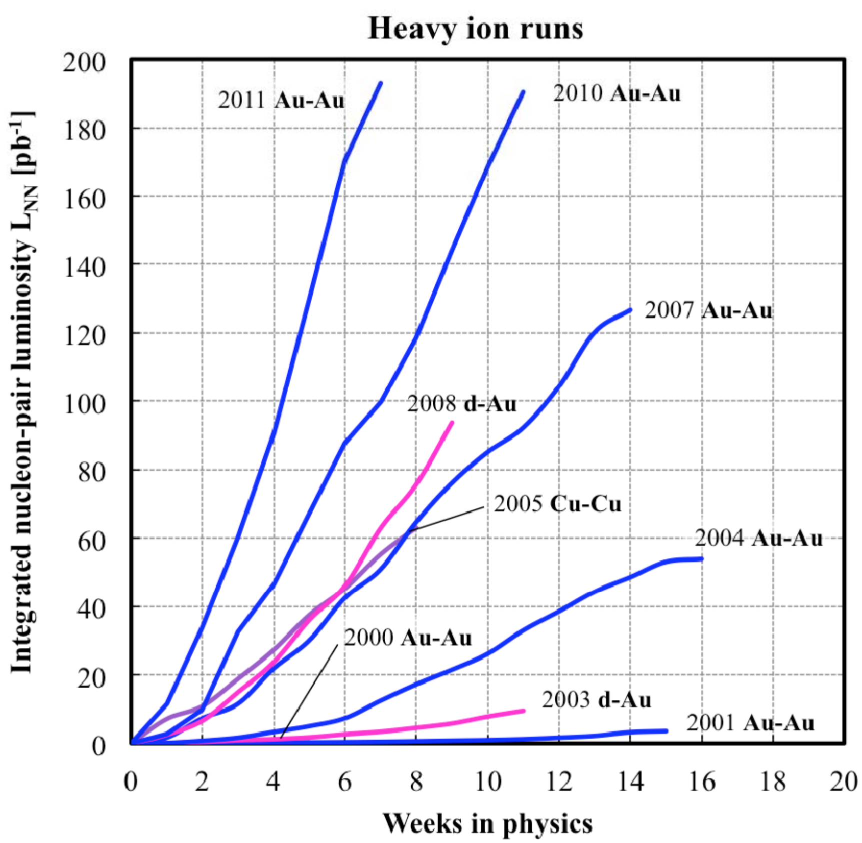
The Center for Accelerator Science and Education

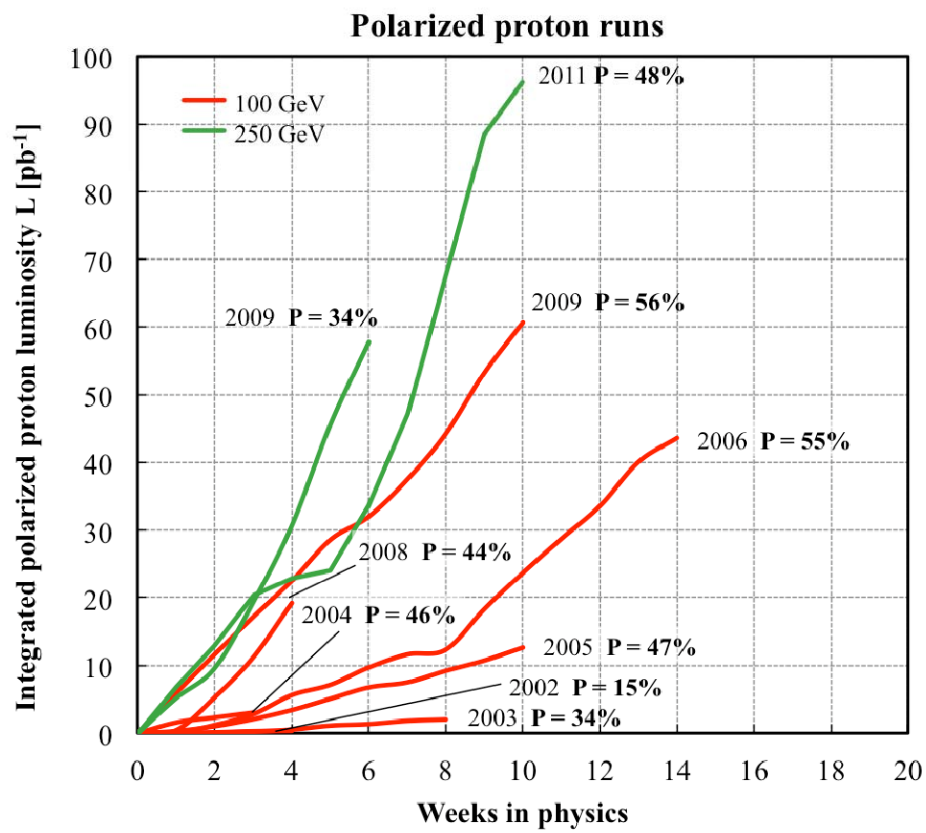
Brookhaven National Laboratory and Stony Brook University established a joint Center for Accelerator Science and Education (CASE). Research done under the aegis of CASE involves a large number of graduate students and post doctoral associates, and brings together the resources of a large National Laboratory and a large State University.

RHIC – First Polarized Hadron Collider



Delivered Integrated Luminosity and Polarization





Nucleon-pair luminosity: luminosity calculated with nucleons of nuclei treated independently; allows comparison of luminosities of different species; appropriate quantity for comparison runs.

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Excellence (as determined by NSAC Committee on Performance Measures) for RHIC's 9th year

A true surprise has been found, a new type of strongly-coupled matter with a ratio of viscosity to entropy density lower than any heretofore known. Attempts to understand this property have led to **completely unanticipated connections to theories of quantum gravity and to a postulated fundamental quantum limit on the ratio of viscosity to entropy density.** This unforeseen development implies that "viscosity" should be added as a particularly important property to be quantified.

Just last run alone:

Measured $T_{init} \gtrsim 300$ MeV ~ 4 $x10^{12}$K

Hints of local parity violation

Anti-hypertriton discovery

and much more…

S. Vigdor- RHIC's 10th Year: Quite Possibly the Best Yet

Steady stream of high-impact new science results:

$T_{init} \gtrsim 300$ MeV ~ 4×10^{12}K > T_{crit} , $T_{Hagedorn}$

Hints of local parity violation

Anti-hypertriton discovery

d+Au "mono-jet" signal for gluon saturation

First W production spin asymmetry.

Outstanding run & great progress:

Good budget ⇒ longest run in years

Commissioned 4 planes stoch. cooling

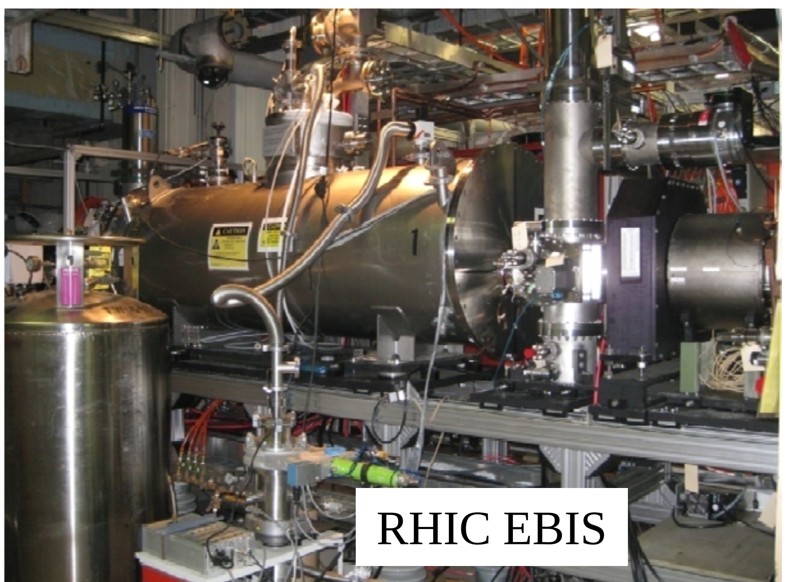
Outstanding machine/detector performance ⇒ meet/exceed all science goals

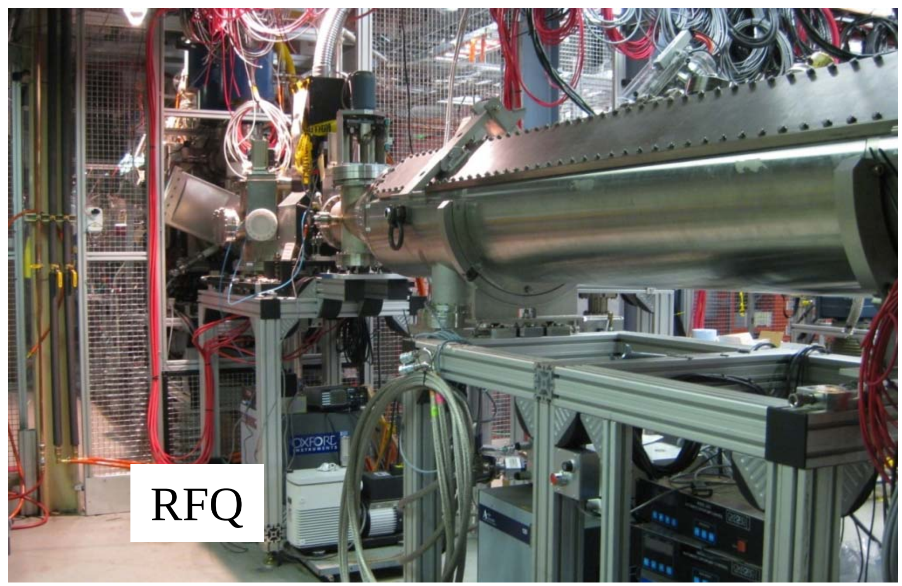
Demo stability needed to improve $P_{p\ beam}$

Run 10 again demonstrated RHIC's great versatility and steadily improving performance ! PHENIX and STAR combined to produce >2 petabytes of Run 10 data !

Electron Beam Ion Source (EBIS)

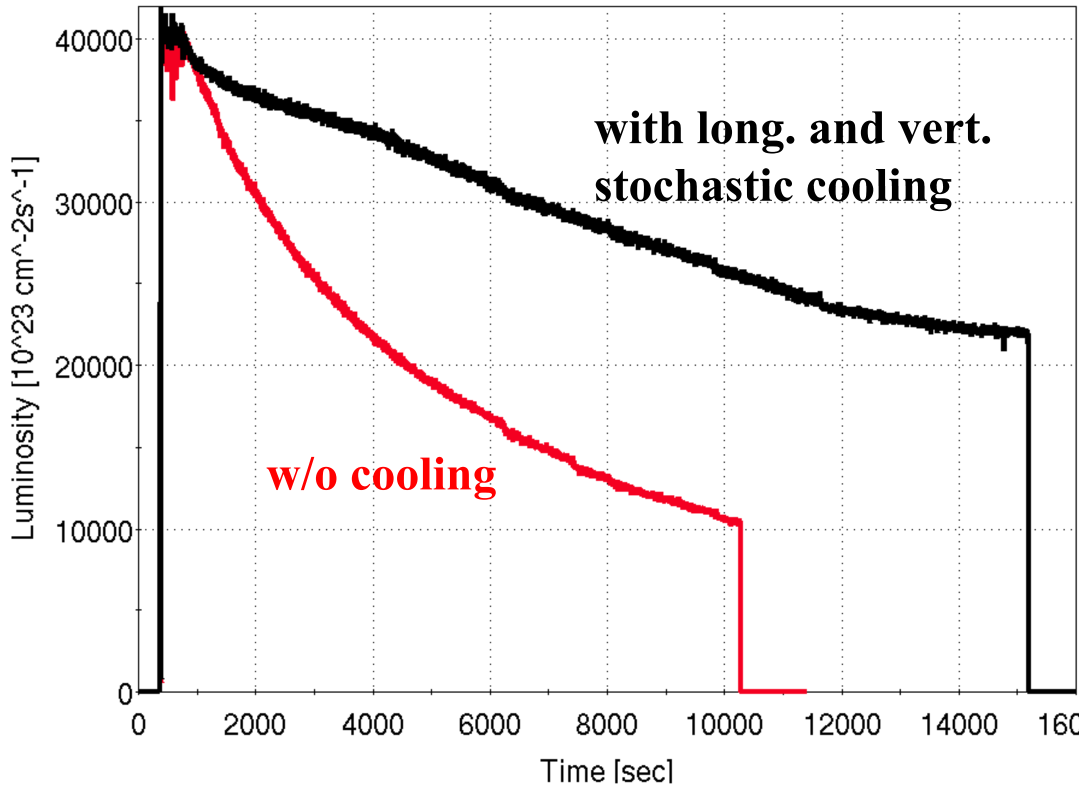
- New high brightness, high charge-state pulsed ion source, ideal as source for RHIC
- Construction completed in 2010
- Produces beams of all ion species including noble gas ions, uranium (RHIC) and polarized ^{3}He (RHIC and eRHIC)
- Operated for NASA Space Radiation Laboratory (NSRL) with
  He^{+}, He^{2+}, Ne^{5+}, Ne^{8+}, Ar^{11+}, Ti^{18+}, Fe^{20+}
- Heavy ion commissioning for RHIC under way, will use in Run-12



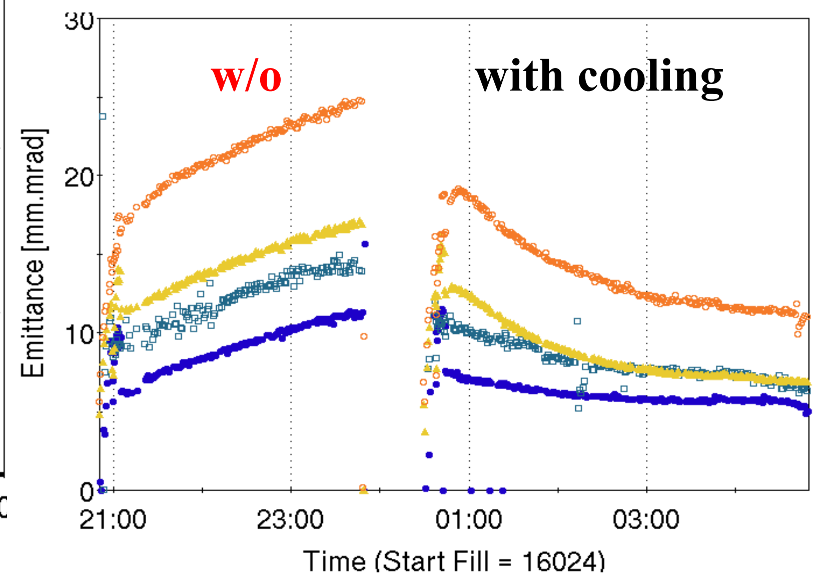


Transverse stochastic cooling

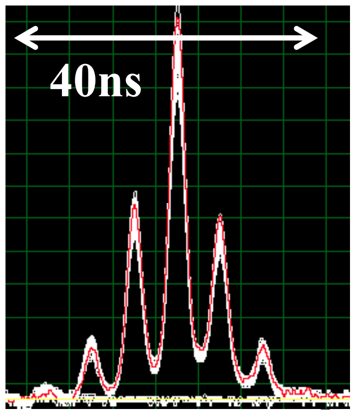
luminosity in 2 consecutive stores



Factor 2 gain in average luminosity from stochastic cooling so far (2011)



strong transverse cooling makes longitudinal cooling less efficient, i.e. these longitudinal profiles at the end of a store with be more pronounced with horizontal cooling next year



[hourglass factor 0.75 at beginning, 0.55 at end of store]

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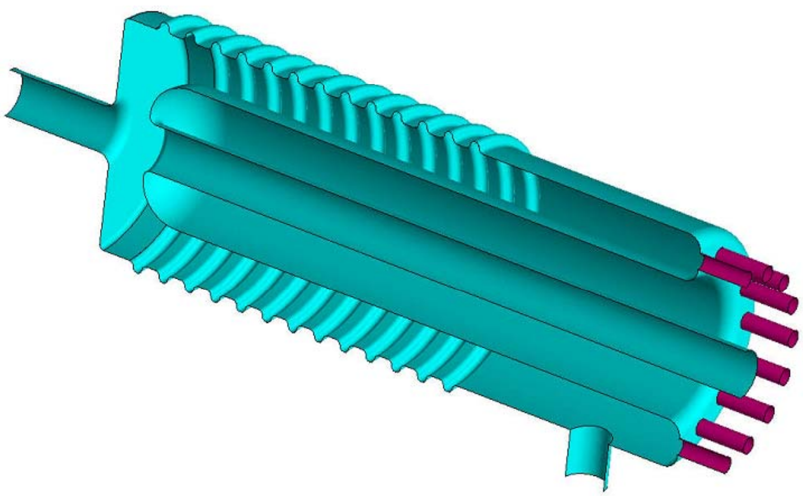
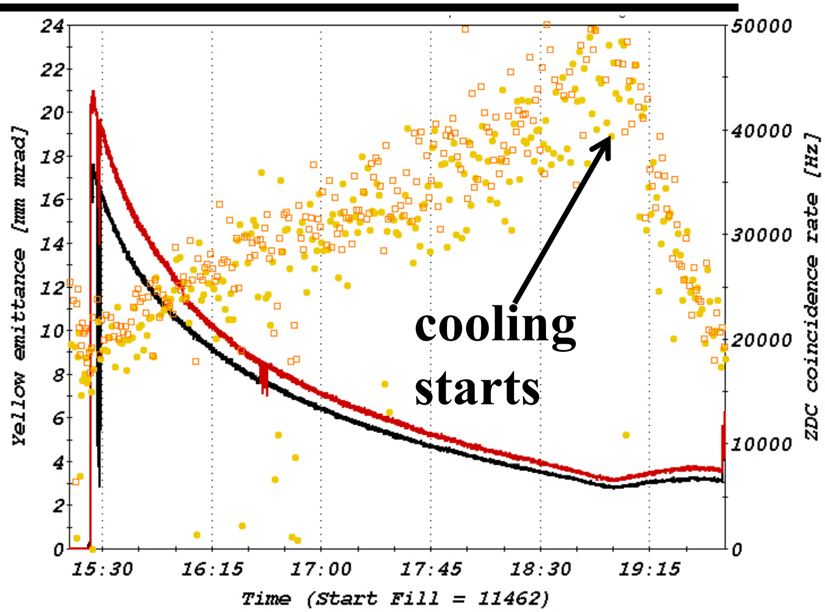
Stochastic Cooling and 56 MHz SRF cavity

- Longitudinal and transverse cooling demonstrated at 100 GeV/nucleon in RHIC, counteracting IBS.
- Longitudinal and vertical cooling installed in both rings. Horizontal cooling under construction, to be competed for Run-12.

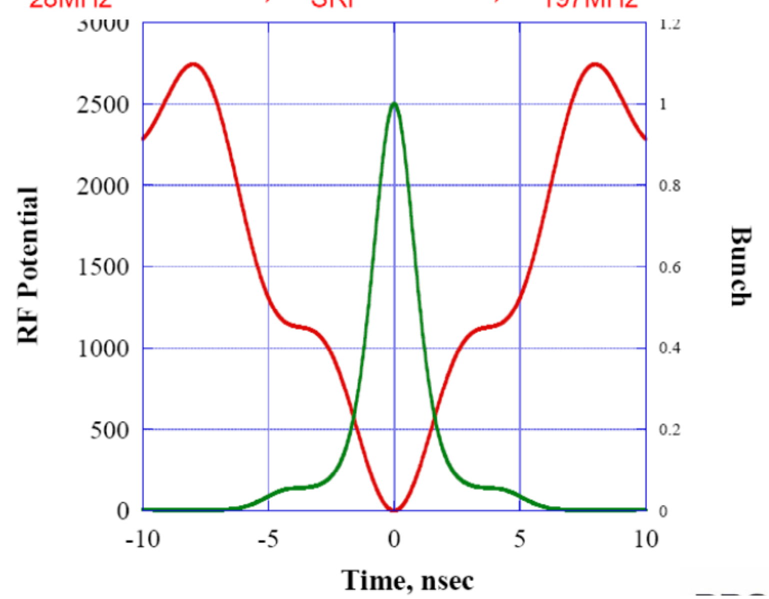
56 MHz SRF storage cavity:

- Greatly reduces satellite bunches
- Re-entrant quarter wave resonator
- Under construction, to be completed for Run-14.





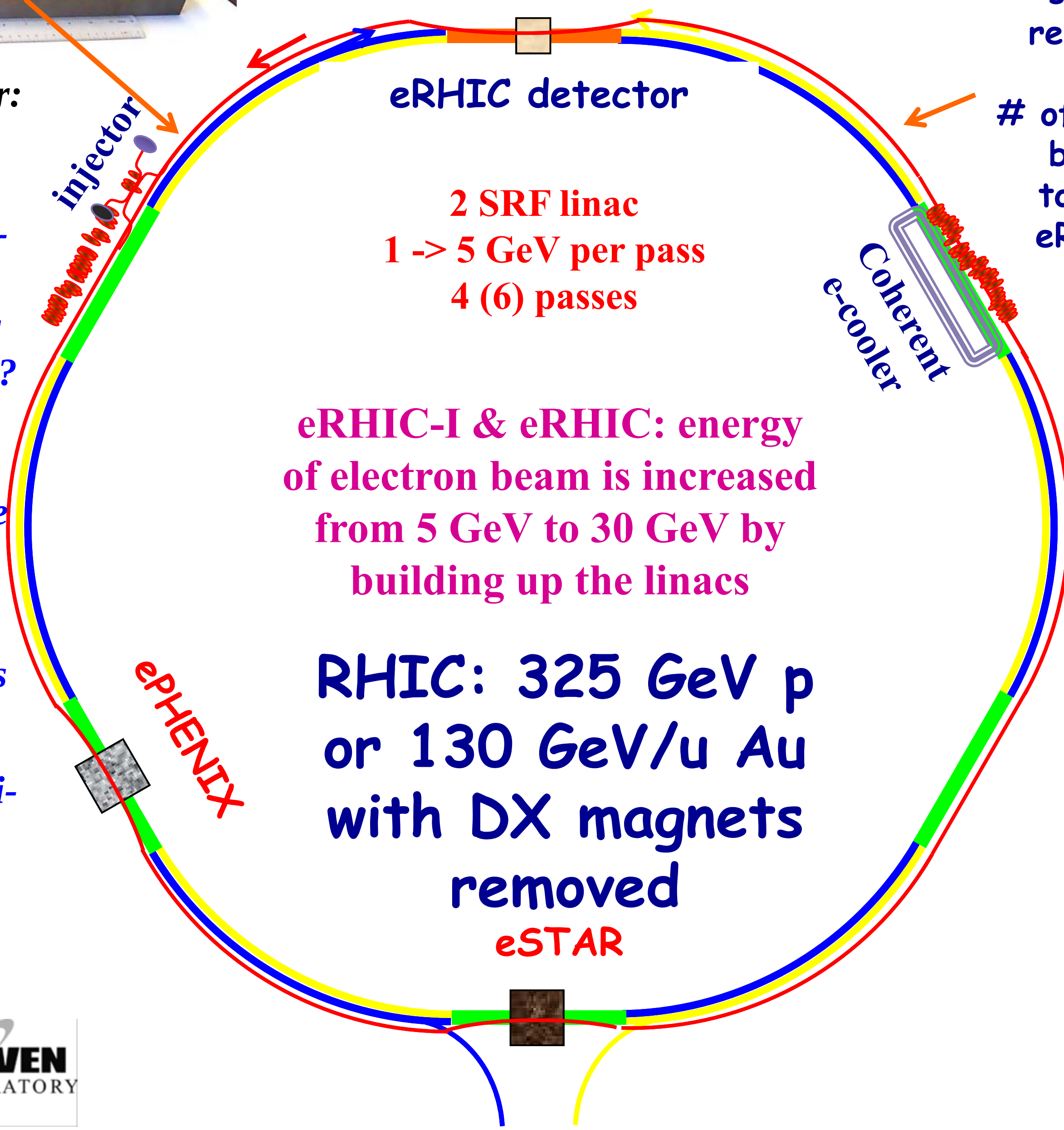
V_{28MHz}= 0.3MV; V_{SRF}= 2 MV; V_{197MHz}= 2 MV



eRHIC Design

Design allows for:

- ➢ *multiple IP's*
- ➢ *reusing infra-structure + det. components for STAR, PHENIX?*
- ➢ *low cost*
- ➢ *easy up-grade*
- ➢ *minimal environmental impact concerns*
- ➢ *IR design to reach >10^{34} luminosity*

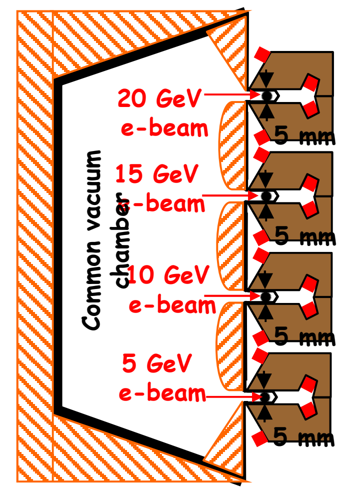


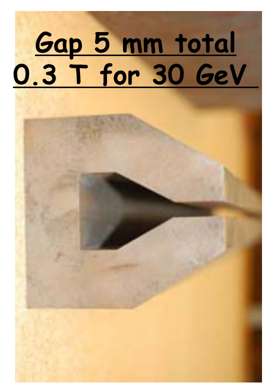
2 SRF linac
1 -> 5 GeV per pass
4 (6) passes

eRHIC-I & eRHIC: energy of electron beam is increased from 5 GeV to 30 GeV by building up the linacs

RHIC: 325 GeV p or 130 GeV/u Au with DX magnets removed

Vertically separated recirculating passes.
# of passes will be chosen to optimize eRHIC cost





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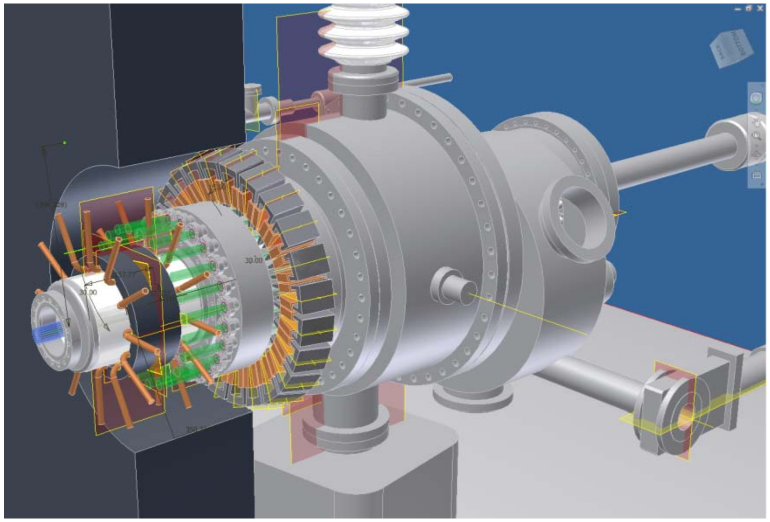
eRHIC R&D

- High current polarized electron gun.
- Polarized He^3 source.
- Coherent Electron Cooling.
- Beam-Beam simulations.
- SRF cavity development.
- High current ERL technology:
  - Non-destructive diagnostics
  - RF power and control
- Compact small-gap magnets.



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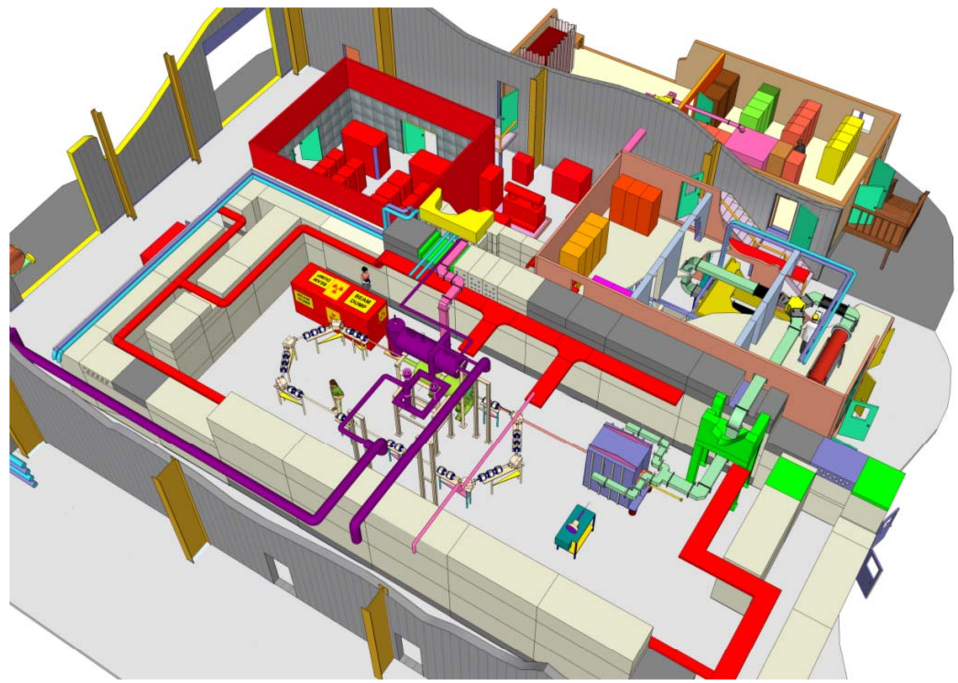
R&D on ERL

Test the key components of the High Current SRF ERL

- 703.75 MHz **SRF gun** test
  - Apply and evaluate high QE photocathodes
- high current 5-cell **SRF ERL** test with ferrite HOM absorbers
- test the beam current stability criteria for CW beam currents
- measure beam quality
- measure halo
- measure spurious radiations



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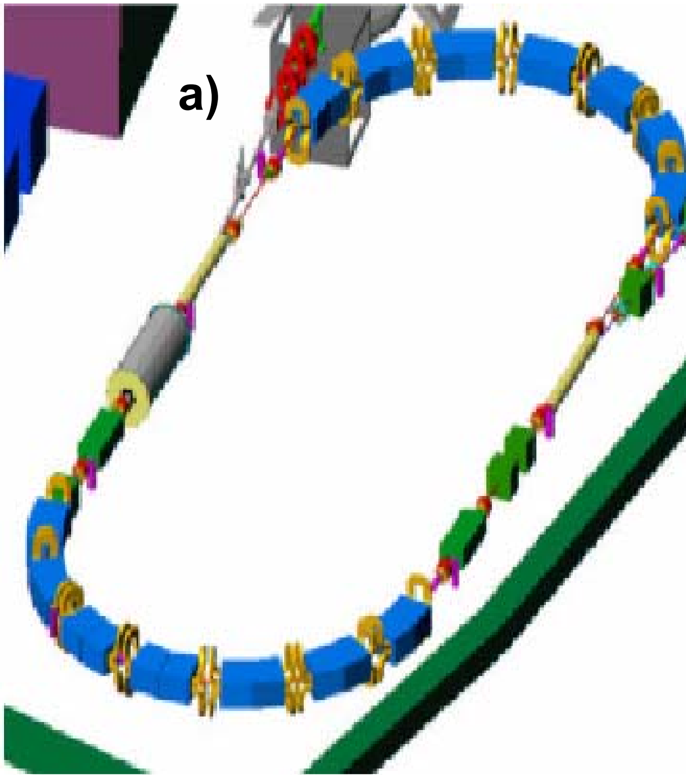
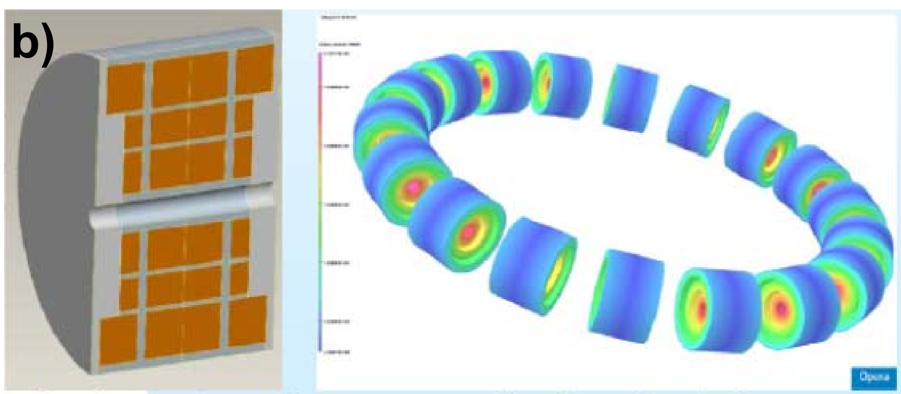
Recent Technological Impacts of BNL NP Research



a) CRADA to develop ion Rapid Cycling Medical Synchrotron (iRCMS) with BEST Medical

b) HTS magnet development expertise from BNL's work for NP accelerators critical in attracting ARPA-E grant for Superconducting Magnet Energy Storage (SMES)

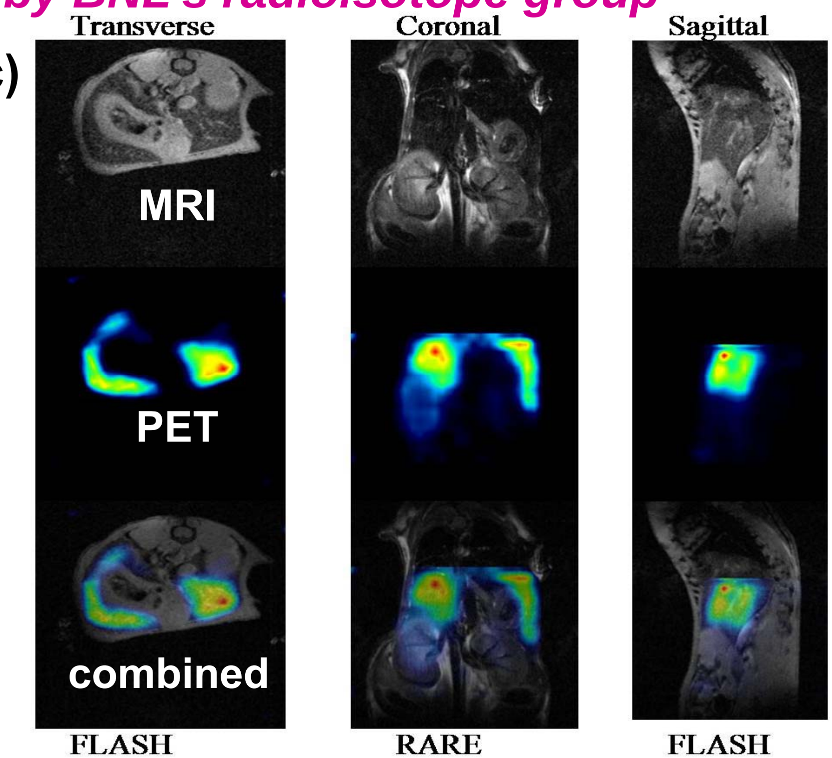
c) First combined MRI-PET imaging (on mouse liver) done with ^{52}Fe nanoparticles developed by BNL's radioisotope group



Basic structure of a single SMES Unit

Number of units in a SMES system

c)



Medical Isotope Research and Production Program

Radionuclide R&D

- **New/unique radionuclides**
- **Nuclear reactions, targetry research**
- **Processing chemistry, generator development**

Radionuclide Production and Distribution

- **Distribution of BLIP-produced isotopes**
- **Process development research: improve quality and speed, minimize waste and/or personnel exposure.**

Radiopharmaceutical R&D (on a limited basis)

- **Recombinant vehicles for targeting tumors with diagnostic/therapeutic isotopes**
- **Tin-117m chelates: imaging and treatment of bone metastases and of cardiovascular atherosclerotic disease**
- **Radiolabeled stem cells for non-invasive imaging**

View of several processing hot cells

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Examples of opportunities

Software and Data Management:

- Simulation software of beam cooling, photocathodes, SRF cavities
  - Examples: Tech-X VORPAL based simulations of electron cooling, coherent electron cooling, diamond amplified photocathodes, 3-D multipacting code
- Last run (Run 10) RHIC detectors produced >2 pewtabytes of data.

Electronics Design and Fabrication:

- RF power amplifiers
  - Example: Green Mountain Radio Research solid-state amps
  - Example: Beam Power Technology elliptic beam klystron
- Reactive power tuners
  - Example: OmegaP development of high-power, fast reactive tuners
- Materials for reactive power tuners
  - Example: Euclid Techlabs development of Nonlinear Ferroelectric

Examples of opportunities (continued)

Accelerator Technology:

SRF cavity

Example: AES development of crab cavity,

Example: Niowave development of 28 MHz fast tunable SRF cavity

HOM damping

Cryomodule

Electron guns

Example: AES 1.3 GHz SRF gun, Niowave 112 MHz SRF gun

Photocathodes

Example: AES development of preparation chambers and load-locks

Example: Nanohmics surface modifications of photocathodes

Example: AES development of polarized SRF gun load-lock

Examples of opportunities (continued)

Accelerator Technology (continues)

Surface coating:

In-situ coating technology to reduce resistivity and secondary electron yield

Specialty magnets:

HTS magnets for location with restricted power infrastructure

Instrumentation:

Non-destructive beam monitors

Example: RadiaBeam proposed Thomson scattering monitor

Example: FARTECH proposed beam profile monitors

Nuclear Physics Isotope Science and Technology:

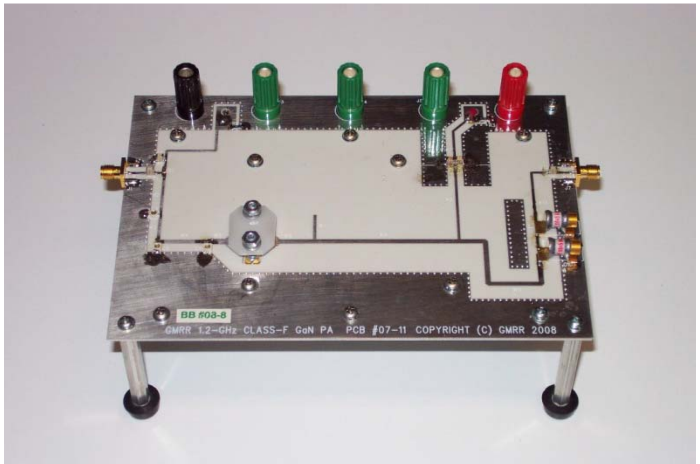
BLIP is a major producer of medical radioactive isotopes for medical and research applications. Development of raster scan beam is proposed.

HIGH-EFFICIENCY POWER AMPLIFIERS FOR 704 MHz

SBIR Grant - Phase I Completed - Phase II Just Awarded

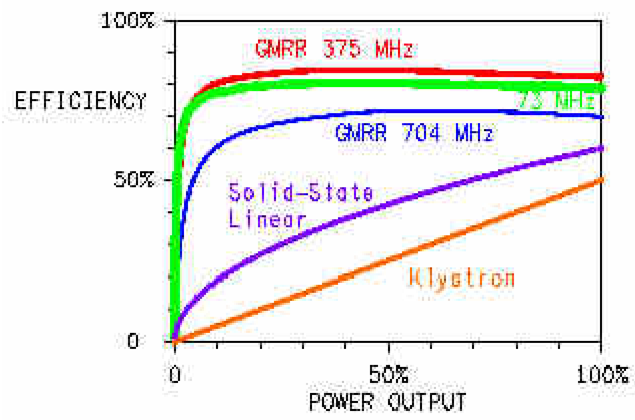
Frederick H. Raab, Ph.D. / Greem Mountain Radio Research Company

PROTOTYPE AMPLIFIER



Accelerators used for nuclear-physics research require megawatts of radio-frequency energy and are operated on a 24/7 basis. Most employ vacuum-tube power amplifiers or conventional solid-state amplifiers that are inefficient and therefore consume a great deal of prime power. One example is the new eRHIC system at Brookhaven National Laboratory that will require several hundred multi-kilowatt power amplifiers that operate at 704 MHz. This grant investigated high-efficiency power amplifiers for this application..

COMPARISON OF EFFICIENCIES



PROPOSED SOLUTION

Class-F RF power amplifier

Class-S modulators

Digital signal processor

800-W power module

Scalable to multi-kilowatt levels

High efficiency at all power outputs

Power consumption cut in half

Summary

The RHIC Complex is supporting the mission of the Office of Science in providing a thriving and highly successful service to the users' community and carrying out cutting edge accelerator R&D program.

The SBIR/STTR program is playing an important role in our R&D program.

Small business companies are encouraged to get in touch with the speaker to find a match between the R&D needs of the RHIC complex and their capabilities and ideas.