The RHIC and RHIC Pre-Injectors Controls Systems: Status and Plans*

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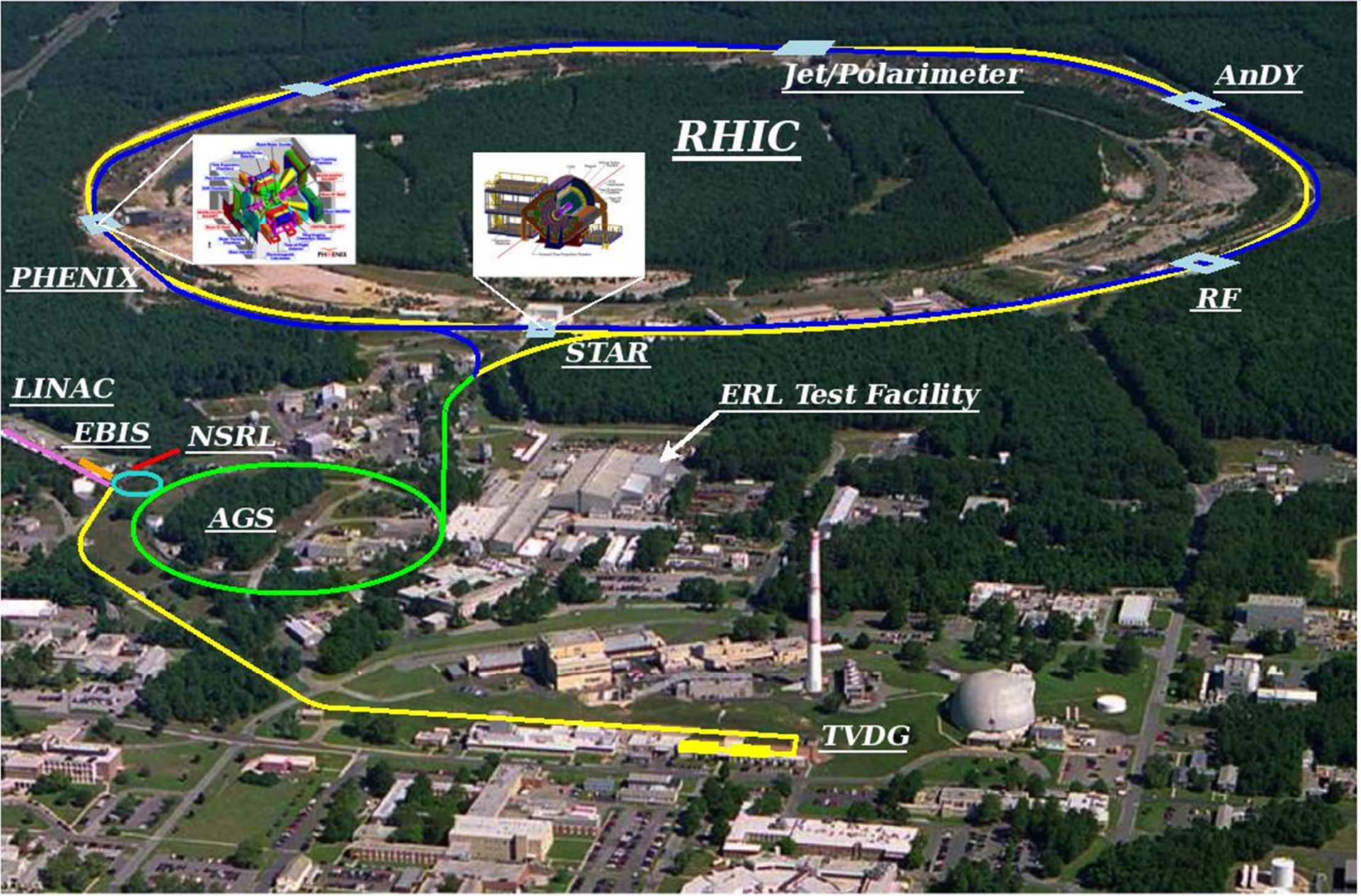
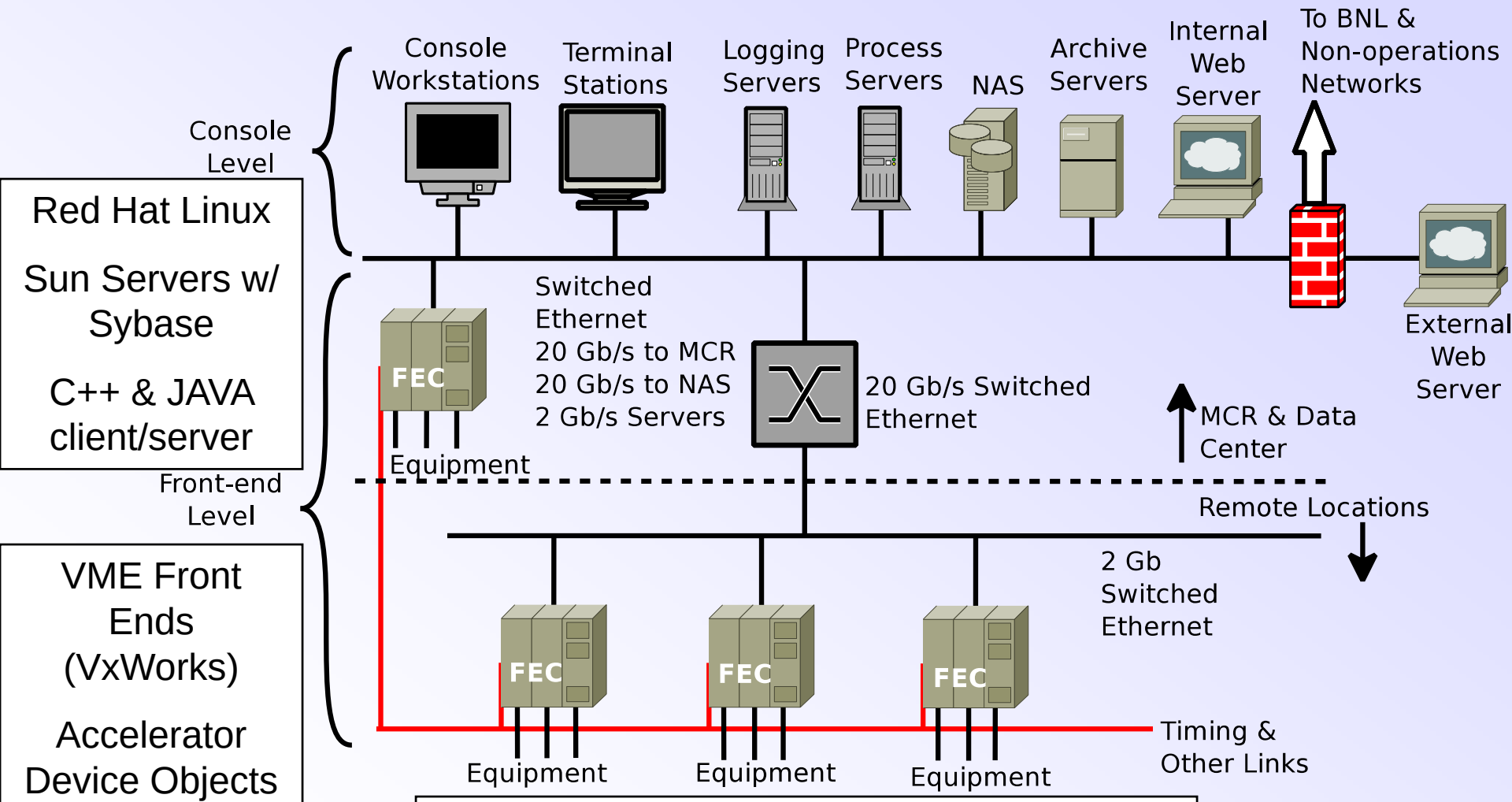
* Relativistic Heavy Ion Collider

Outline

- Quick Tour of C-AD
- C-AD Controls Systems
- What RHIC has Achieved
- Future Directions at RHIC
- EBIS = Electron Beam Ion Source
- Bunched Beam Stochastic Cooling
- Feedback in RHIC
- eRHIC = Electron-Ion Collider


Jet/Polarimeter
AnDY
RHIC
PHENIX
RF
STAR
LINAC
ERL Test Facility
EBIS
NSRL
AGS
TVDG

System Hardware Architecture



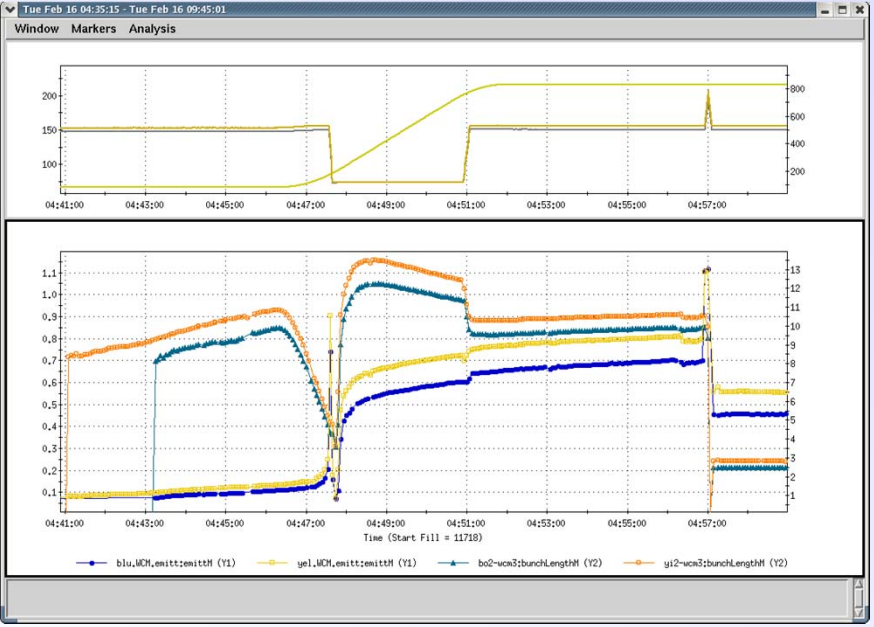
Some Reference Parameters

	2011
Number of front-end VME chassis	315
Number of read/write parameters (settings)	403,000
Number of read-only parameters (measurements)	502,000
Number of name server entries (devices & servers)	52,600
Total archive capacity	75 GB/day
Number of Named Items Archived	260,000
Total Amount of Data written to disk *	~15 TB/run
Trigger resolution of event system	100 ns
Time jitter of beam synchronous event clock	< 0.5 ns
Real-Time Data Link and time-of-day clock rate	720 Hz
Maximum time: loss-of-permit to beam abort	60 μs (5 turns)

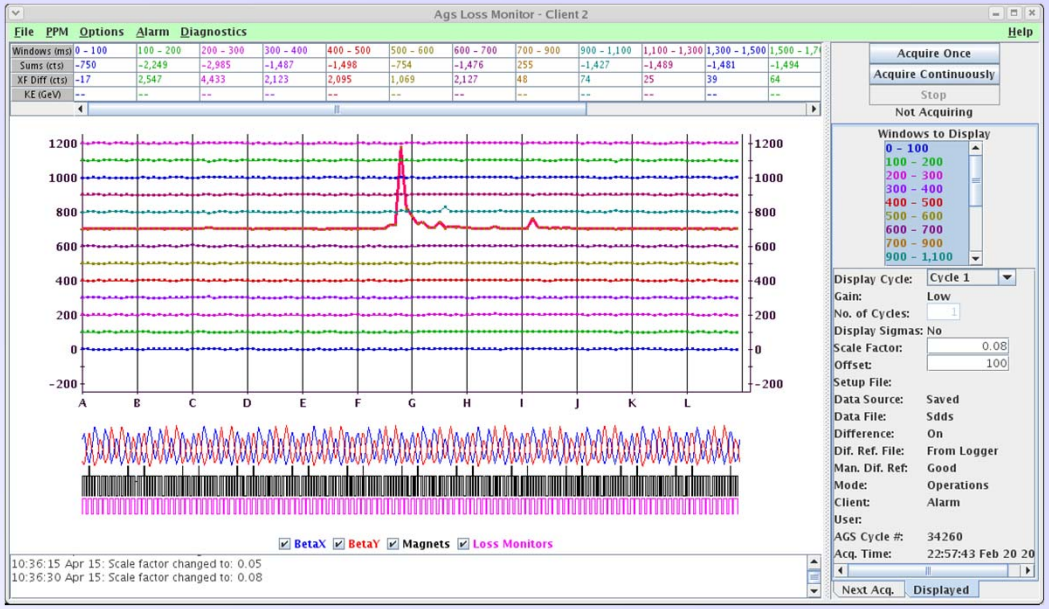
* MOMAU002 Improving Data Retrieval Rates Using Remote Data Servers
presenter: Bart Frak

Current Focus & Future Directions

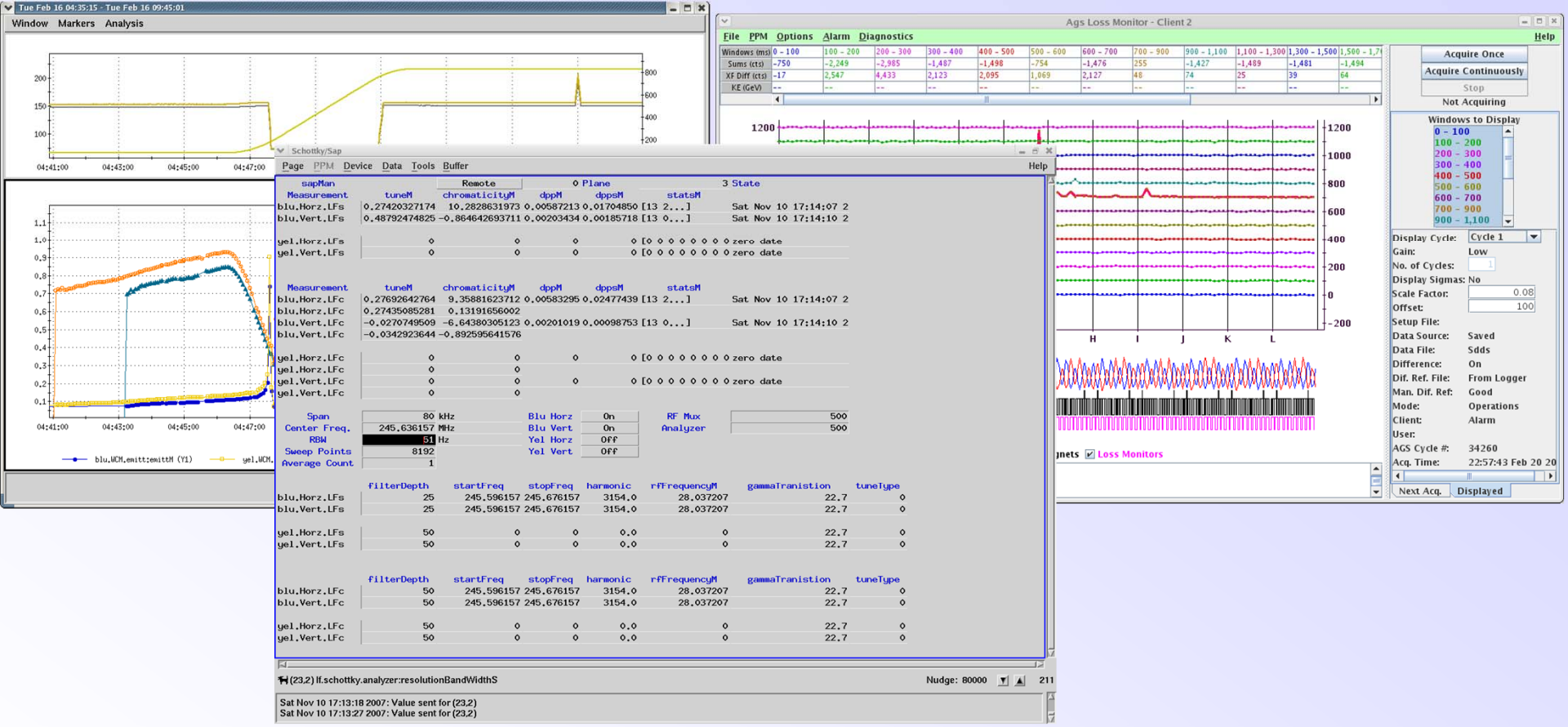
- Cyber Security
  - our sophistication must grow to (even) match sophistication of new threats
  - Threats now reach deeper into the layers of the controls (Stuxnet)
- Operations (*see MOPKN021 Asynchronous Data Notification …)*
  - All digital MCR (no oscilloscopes) – greater demand on software & reliability
  - Better data mining tools and improved access to large volumes of data
- Machine Protection (*see: WEPMUO15 MPS for ERL*)
  - reliability analysis
  - improved quench detection reliability
  - synchrotron radiation from high energy electron beams
  - high power electron beams
  - SRF systems
- Accelerator Physics
  - more compute intensive online models
  - more sophisticated online analysis
  - larger data volumes and bandwidth utilization
  - ORM & online optics measurements (as operations tools)
  - more beam physics based control (parametric, auto-correction, model based corrections)
- All digital controls
  - LLRF and instrumentation for feedback
- Feedback and new controls paradigms



LogView: log (archive) data viewer

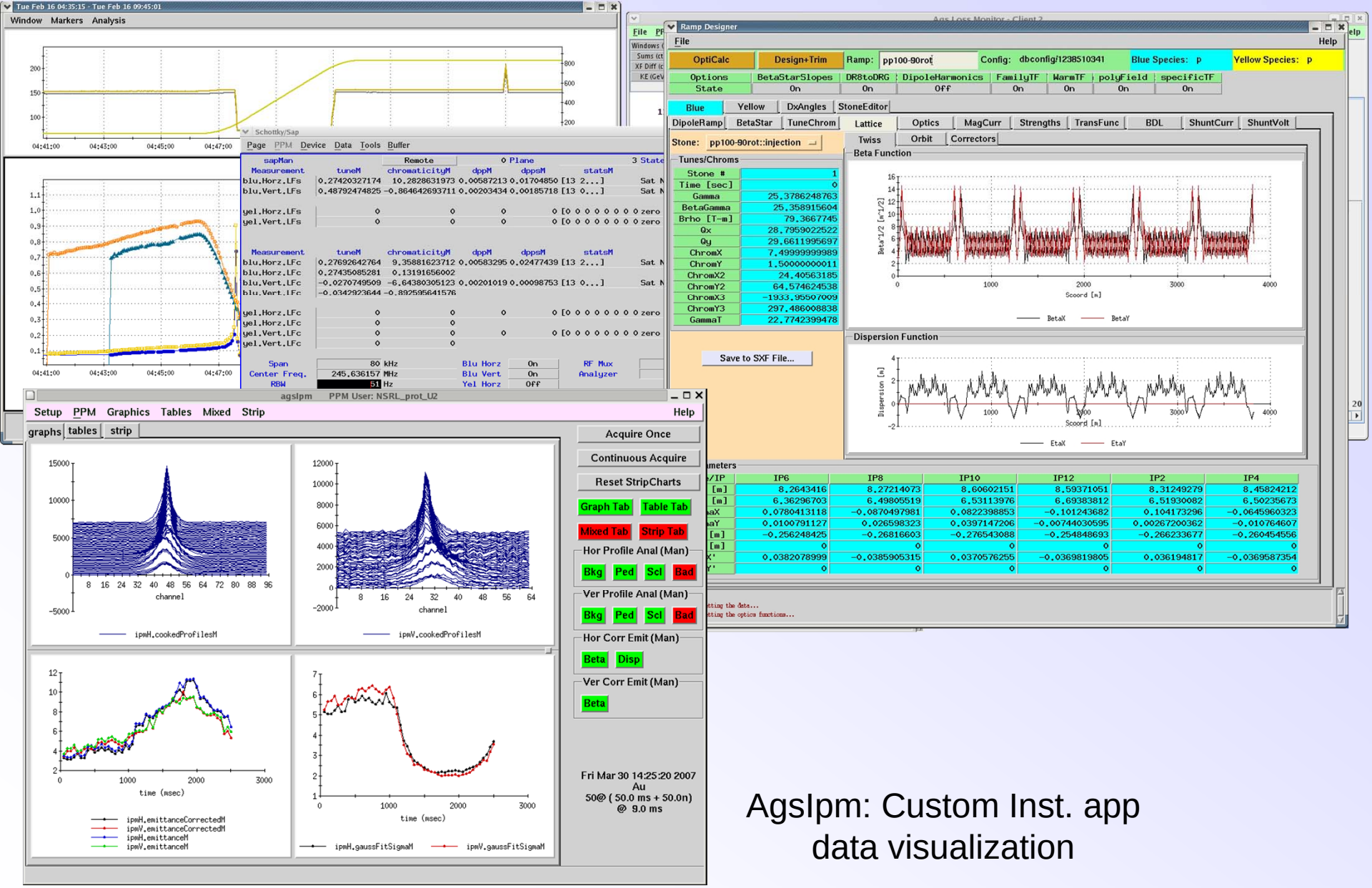


AgsLossMonitor: Custom app example



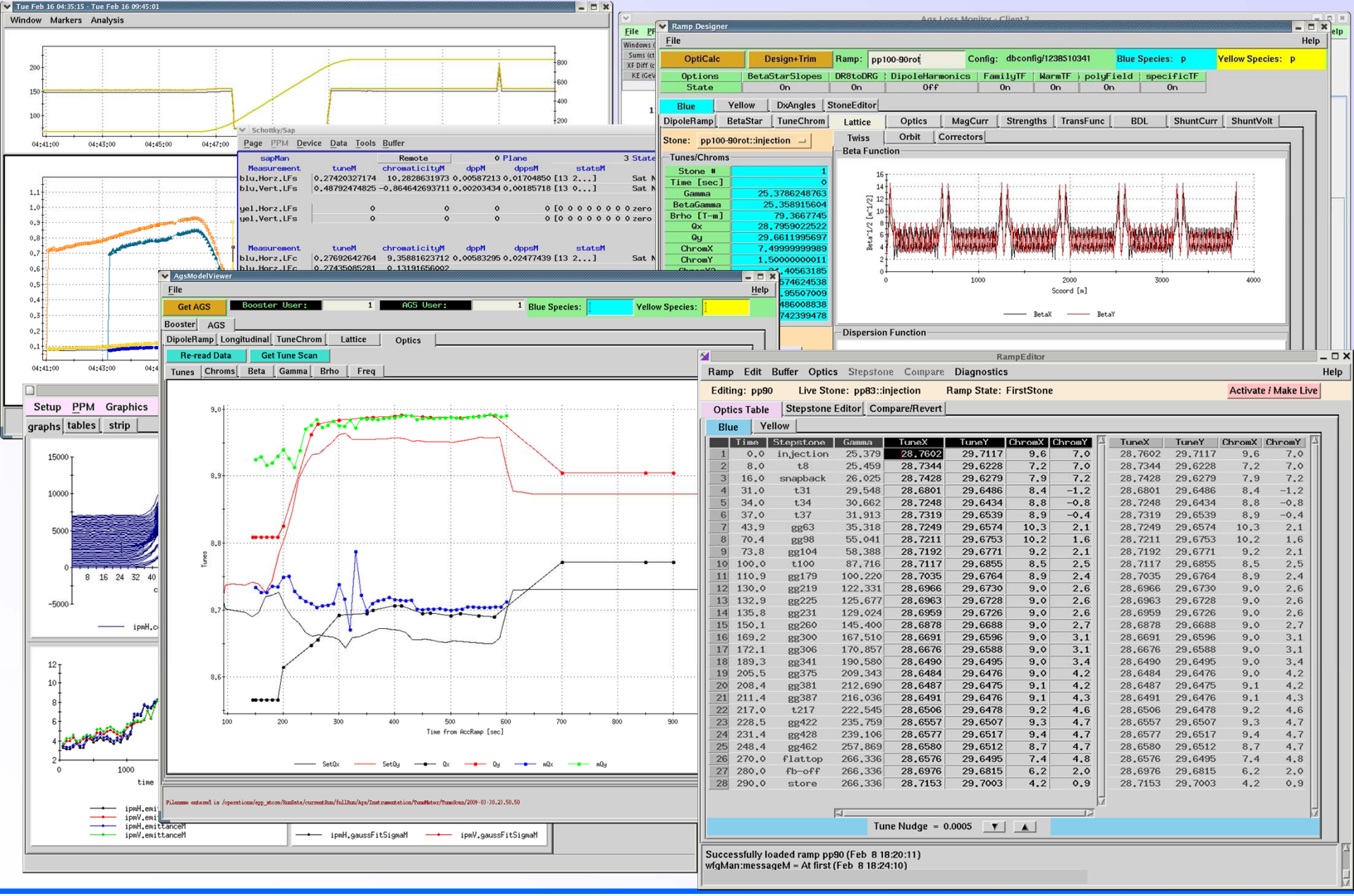
"pet" parameter Page
(contains ADO parameters)

RHIC Ramp Designer: Custom app



AgsIpm: Custom Inst. app data visualization

AgsModelViewer: combines model and measurement data


Ramp Designer
AgsModelViewer
RampEditor
Schottky/Sap
Beta Function
Dispersion Function
Tunes/Chroms
Optics Table
Blue
Yellow
Tune Nudge = 0.0005
Successfully loaded ramp pp90 (Feb 8 18:20:11)
wfgMan:messageM = At first (Feb 8 18:24:10)

Remote Windows based Scope control and display.

What RHIC has Achieved?

- RHIC is the first machine capable of colliding ions as heavy as gold.
  - RHIC has created a new state of hot, dense matter out of the quarks and gluons, called a "perfect" liquid, because it can be explained by the equations of hydrodynamics for a fluid with virtually no viscosity
  - RHIC's quark-gluon plasma exhibits other unusual properties
    - symmetry-altering bubbles speculated to have played important roles in the evolution of the infant universe
    - the heaviest antimatter nucleus yet discovered
  - RHIC Energy Range Appears to be a "Sweet Spot," allowing exploration of the onset of deconfinement and the search for the QCD critical point
- RHIC is the world's only machine capable of colliding beams of polarized protons to investigate the 'missing' spin of the proton
  - the spins of the proton's constituent quarks (and antiquarks), in some cases accounts for only about 30% of its total spin
  - RHIC spin experiments are providing the first information on how much the spin of gluons contributes to the proton's spin
  - measurements of the spin substructure of the proton may lead us beyond our current, still rudimentary understanding of how quarks move inside protons and other particles

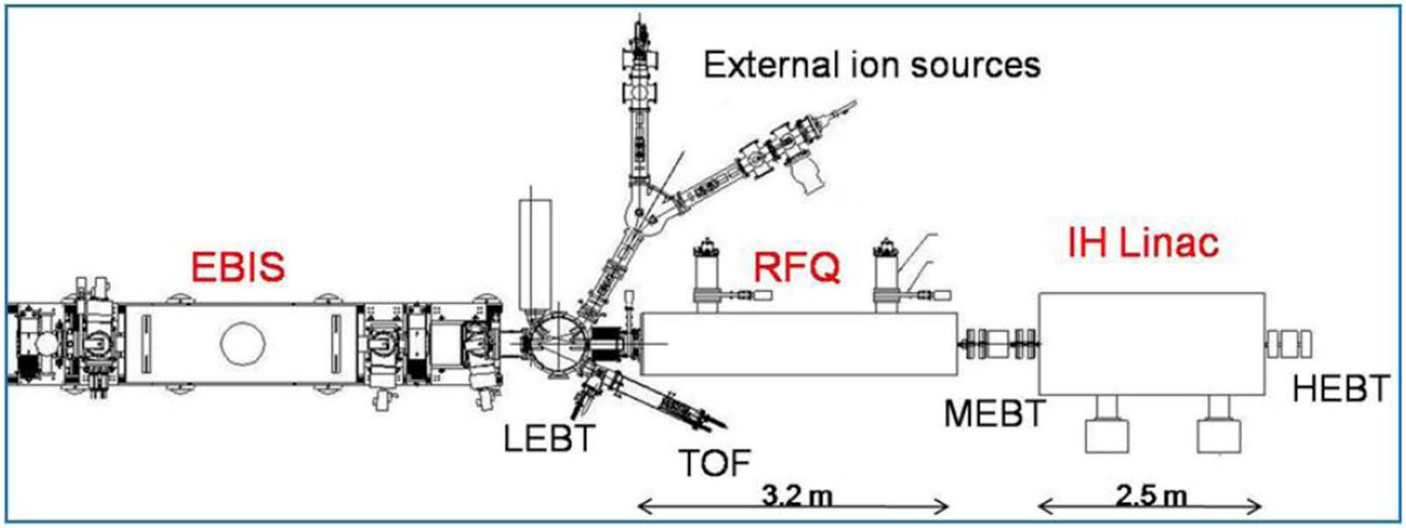
Three Stages of RHIC's Future

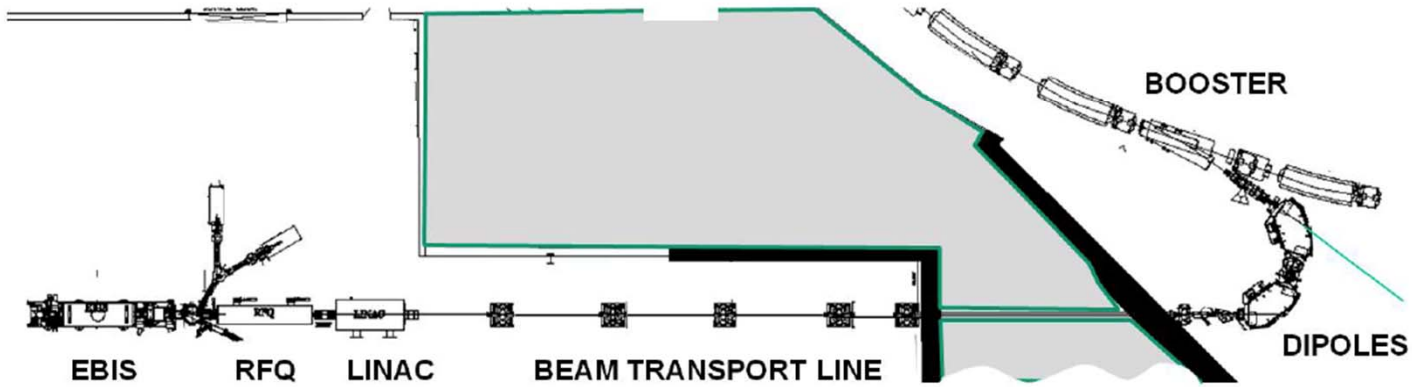
Short-term (2011-2016): ***ongoing upgrades to RHIC $\mathcal{L}$, PHENIX & STAR fuel well-defined program addressing key open questions, most encoded in NP performance milestones for dense matter and spin***

Medium-term (2017-2022): ***further upgrades selected from PHENIX, STAR and collider Decadal Plans, as needed for quantitative pursuit of long-term questions outlined above for A+A, d(p)+A, and $\vec{p}$+$\vec{p}$ (including refinement/resolution of issues from short-term results)***

Long-term (> 2022): ***eRHIC – add ~5 GeV (upgradable to 30 GeV) electron Energy Recovery Linac inside RHIC tunnel to facilitate e+A, $\vec{e}$+$\vec{p}$ ($\vec{^3He}$) studies of gluon-dominated cold matter***

EBIS – Electron Beam Ion Source



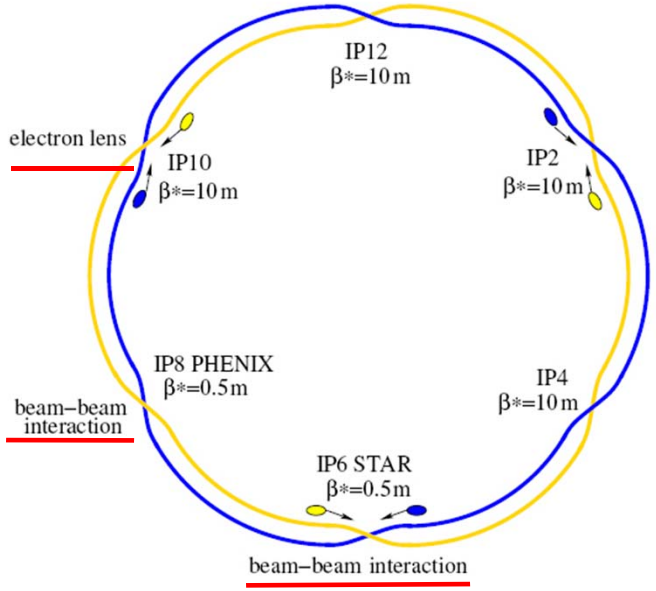


EBIS

- Replaces the Tandem Van de Graaff's as the source of heavy ions
- All ion species including noble gas ions (NSRL*), uranium (RHIC) and polarized He^3 (eRHIC) (~ 1-2 x 10^{11} charges/bunch with $\varepsilon_{N,rms}$ = 1-2 μm)
- Operated reliably for NSRL with He^{+}, He^{2+}, Ne^{5+}, Ne^{8+}, Ar^{11+}, Ti^{18+}, Fe^{20+}
- Expect to provide *Au* and *U* for RHIC in 2012
- For Controls (a modest project):
  - 5 Hz PPM Operation (Capability to switch ion species at 5 Hz)
  - Standard hardware interfaces
  - New applications for project specific controls

* NASA Space Radiation Laboratory

Electron lenses – partial head-on beam-beam compensation



Polarized proton luminosity limited by head-on beam-beam effect ($\Delta Q_{bb,max} \sim 0.02$)

Basic idea:

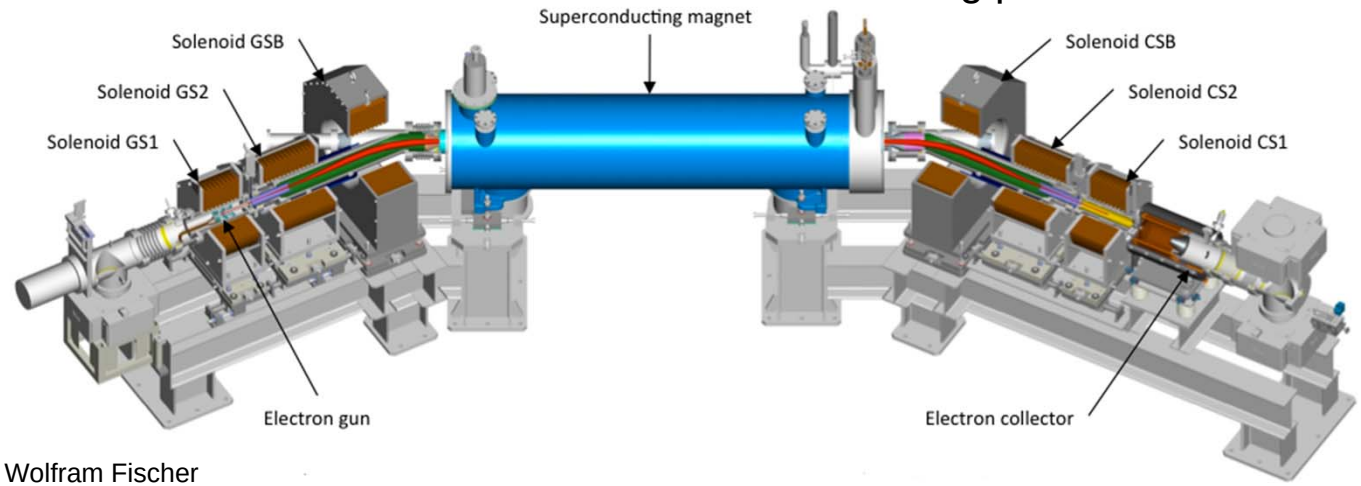
In addition to 2(3) beam-beam collisions with **positively** charged beam have another collision with a **negatively** charged beam with the same amplitude dependence.

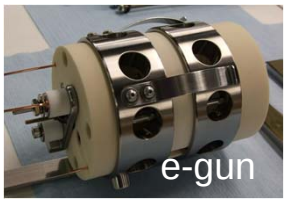
Exact compensation for:

- short bunches
- $\Delta\psi_{x,y} = k\pi$ between p-p and p-e collision
- no nonlinearities between p-p and p-e
- same amplitude dependent kick from p-p, p-e
- only approximate realization possible

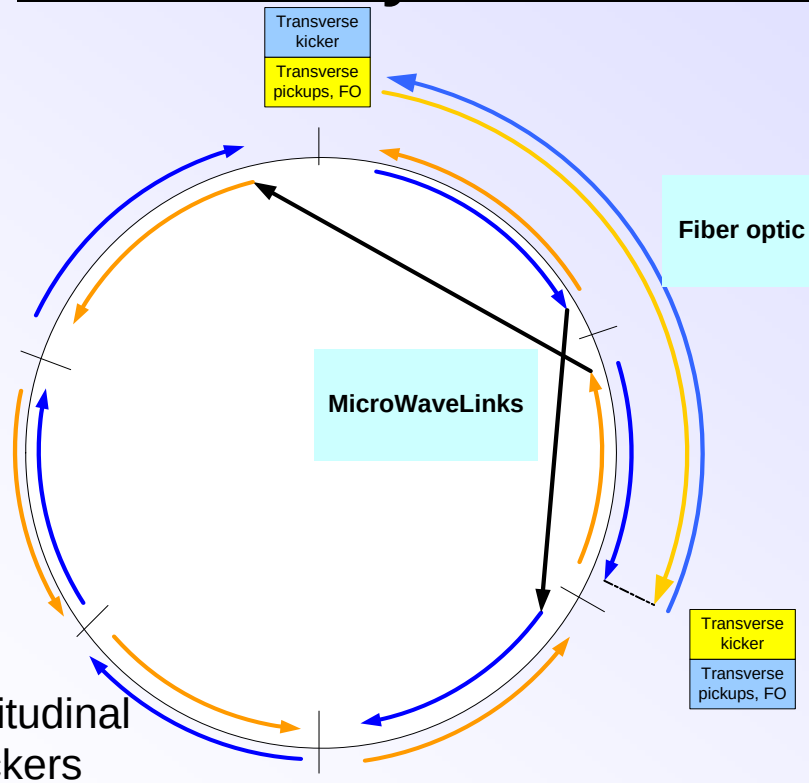
Expect up to 2x more luminosity with OPPIS upgrade

Commissioning planned for Run-13



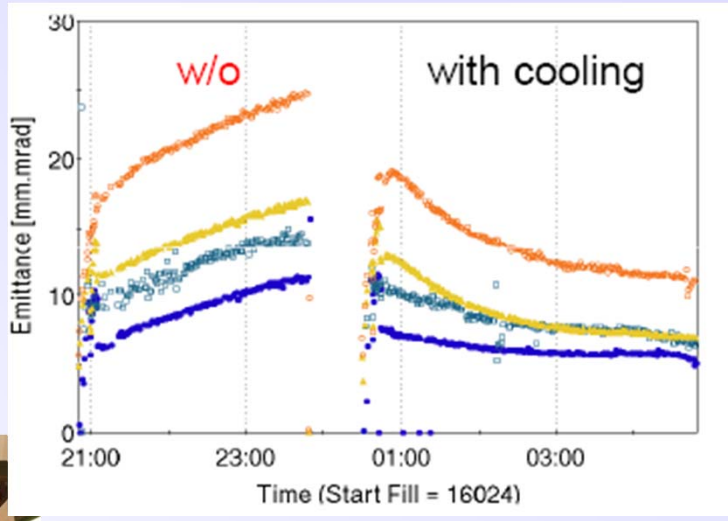


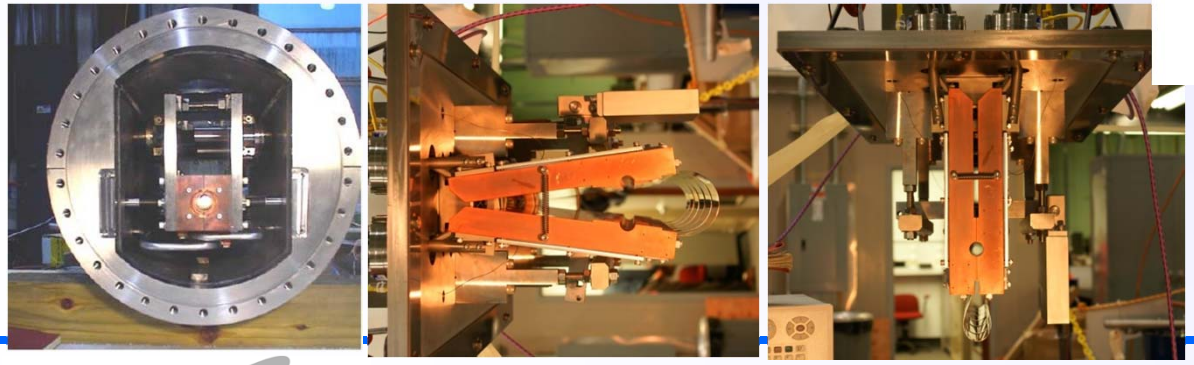
Luminosity Increase with Stochastic Cooling



Longitudinal kickers

- 5 – 8 GHz bandwidth split up into 16 frequency bands with each frequency having its own cavity kicker
- 6 – 9 GHz bandwidth for longitudinal stochastic cooling using microwave link



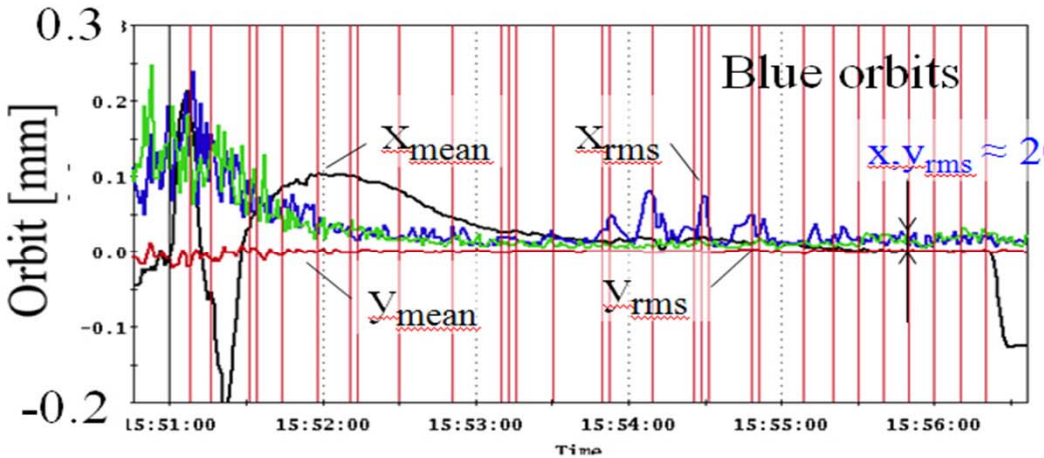


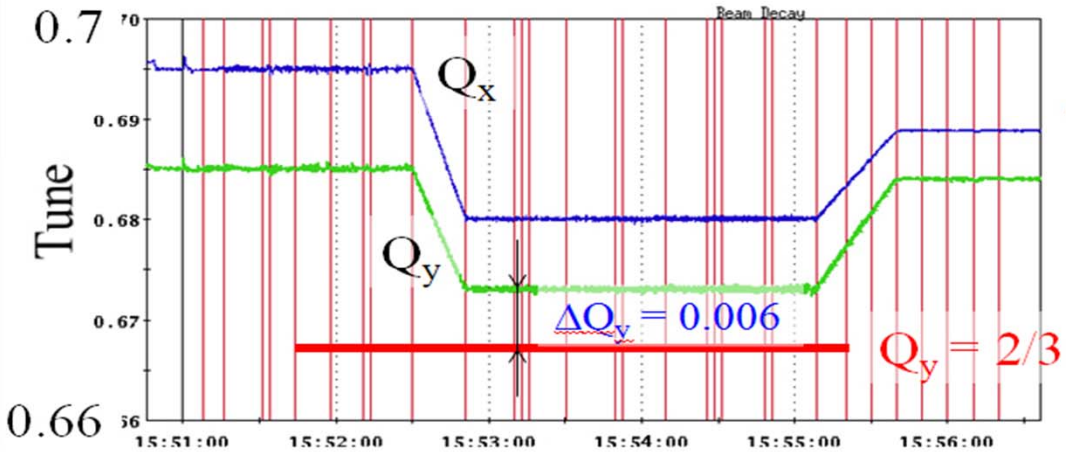
Transverse kickers

Feedback Systems

- In RHIC
  - Tune/Coupling using Base Band Tune (BBQ) measurement system
  - Orbit Feedback using existing orbit system (>400 bpm measurements) and correctors (through the controls system at 1 Hz)
  - Chromaticity feedback using BBQ measurement system
  - Feedback system to correct ~10 Hz beam position oscillations using turn by turn bpm's and dedicated corrector magnets (BPM data @ 10kHz for 36 signals)
- Other systems
  - Injection dampers (injection coherence correction)
  - AGS orbit feedforward for polarized protons (with near integer tune)
  - Longitudinal quad mode damper (under development)

Beam control improvement – feedbacks on ramp



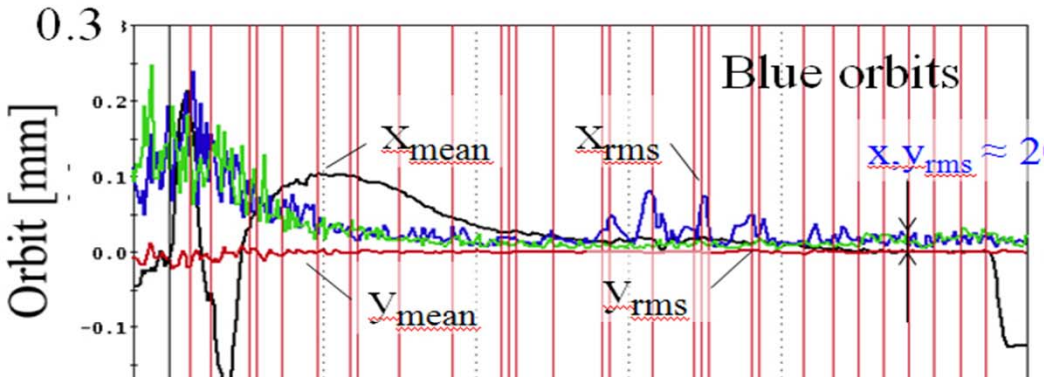


M. Minty, A. Marusic et al.

- Orbit feedback on every ramp allows for
  - Smaller y_{rms} (smaller imperfection resonance strength)
  - Ramp reproducibility (have 24 h orbit variation)
- Tune/coupling feedback on every ramp allows for
  - acceleration near $Q_y = ⅔$ (better P transmission compared to higher tune)

R. Michnoff et al

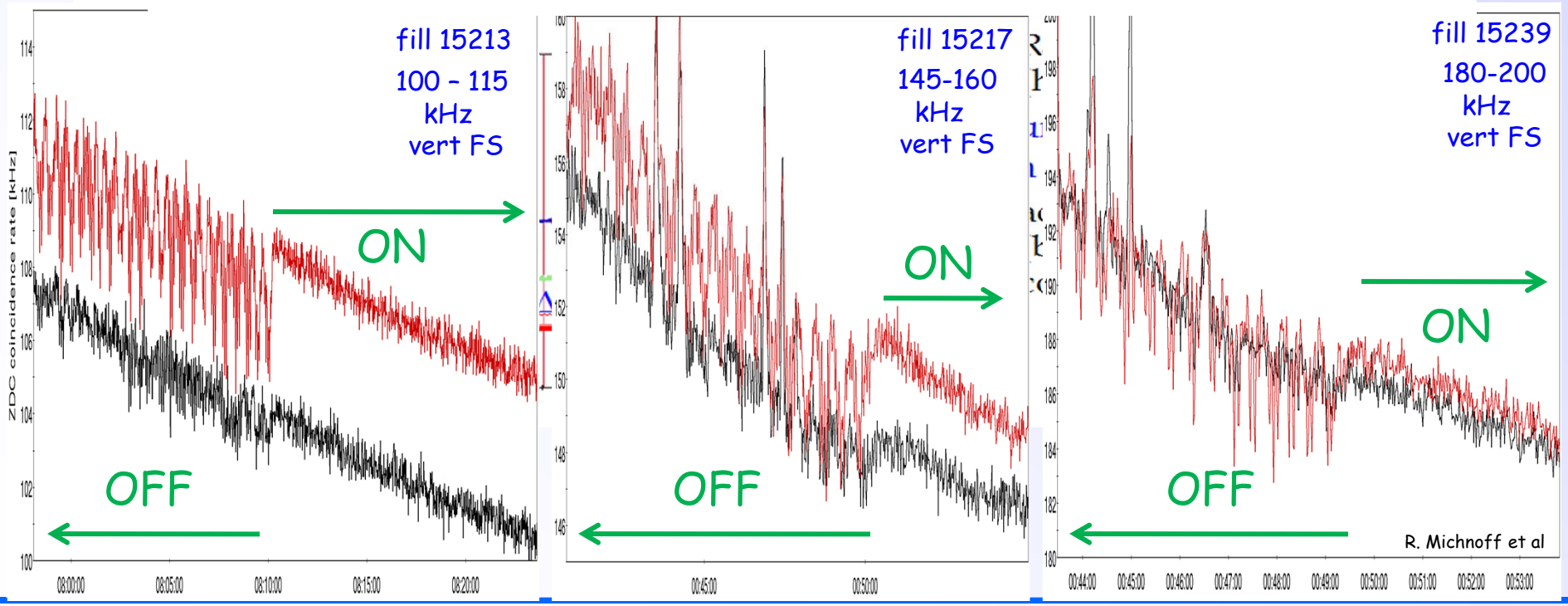
Beam control improvement – feedbacks on ramp



M. Minty, A. Marusic et al.

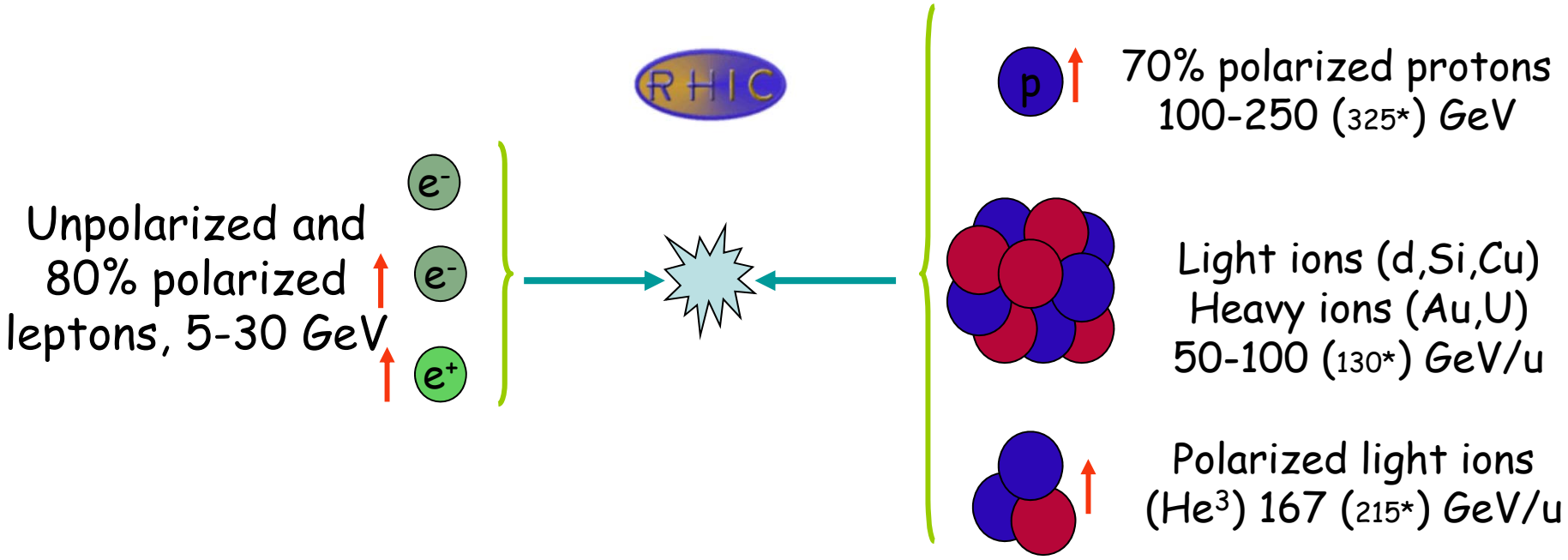
- Orbit feedback on every ramp allows for
  - Smaller y_{rms} (smaller

10 Hz Feedback: ZDC rates at PHENIX and STAR versus time



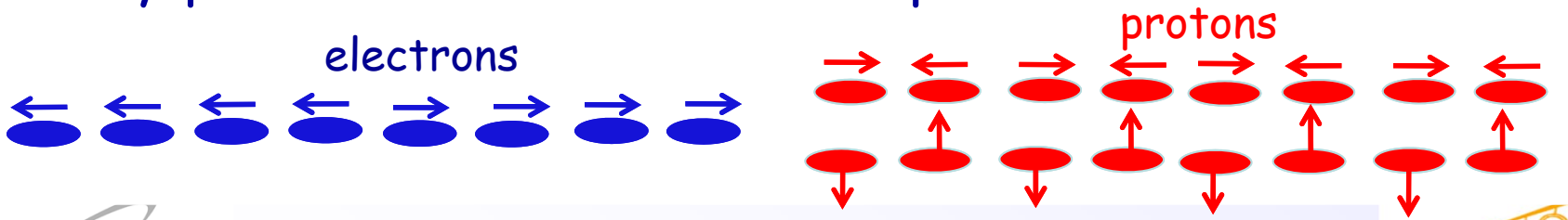
eRHIC – Electron-Ion Collider

Add electron accelerator to the existing $2B RHIC



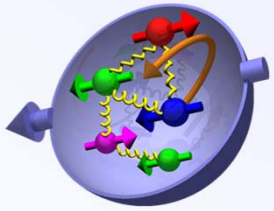
Center of mass energy range: 30-175 GeV

Any polarization direction in lepton-hadrons collisions

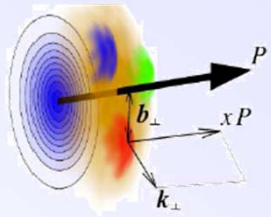


Why an Electron-Ion Collider?

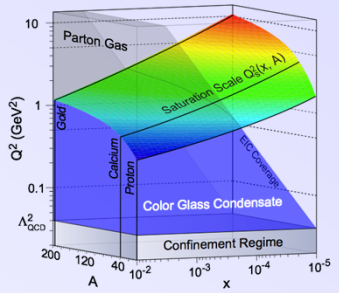
- Precision imaging of the sea-quarks and gluons to determine the spin, flavor and spatial structure of the nucleon
- Definitive study of the universal nature of strong gluon fields in nuclei.
- Improve our understanding of the strong force and the properties of gluons



quark and gluon contributions to the proton spin

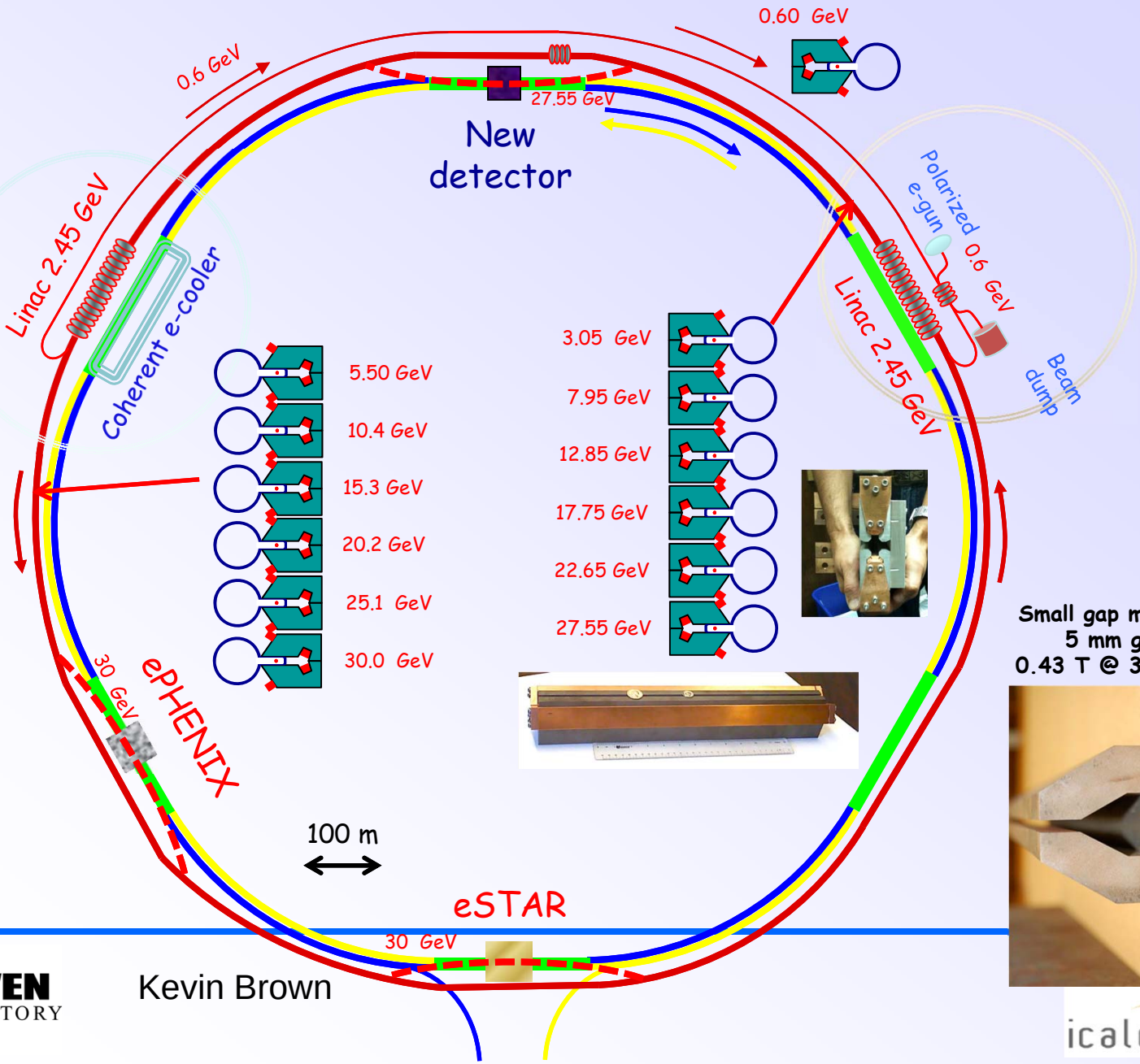


spatial distribution of quarks and gluons in nucleons/nuclei



strong color fields in AA, pA, and eA

eRHIC: polarized electrons with $E_e \leq 30$ GeV will collide with either polarized protons with $E_e \leq 250^*$ GeV or heavy ions $E_A \leq 100^*$ GeV/u



Small gap magnets
5 mm gap
0.43 T @ 30 GeV

Thank You!

Please see:

- MOMAU002 *Improving Data Retrieval Rates Using Remote Data Servers* presenter: Bart Frak
- MOPKN021 *Asynchronous Data Notification between Database Server and Accelerator Control Systems* presenter: Seth Nemesure
- WEPMU015 *The Machine Protection System for the R&D Energy Recovery LINAC* presenter: Jim Jamilkowski
- MOPMU027 *Controls System Developments for the ERL Facility* presenter: Jim Jamilkowski