Progress Toward RHIC's Future

Steve Vigdor

RHIC/AGS Users Meeting

June 5, 2009

I. *Long-Term Vision: establishing an intellectual theme and connections to other fields + other facilities*

II. *Toward RHIC-II Science: machine + detector upgrades; funding outlook; ~5-year run plan*

III. *Progress Toward eRHIC*

IV. *Complementary AGS Program?*

But First a Word About the Past: High-Profile RHIC-Related Awards During the Past Year

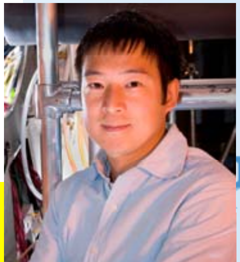
2009 APS George E. Valley Jr. Prize to Paul Sorensen, BNL
"For … quark number scaling in elliptic flow…"

2009 Maria Goeppert Mayer Award to Saskia Mioduszewski, TAMU
"For…contributions to… jet quenching [at RHIC]…"

2009 APS Robert R. Wilson Prize to Satoshi Ozaki, BNL
"For…realization of major machines for fundamental science on two continents…"

2009 Gian Carlo Wick Gold Medal Award (World Federation of Scientists) to Nick Samios, BNL *"For his visionary role in… RHIC and…intellectual leadership in… discoveries which established the existence of …QGP…"*

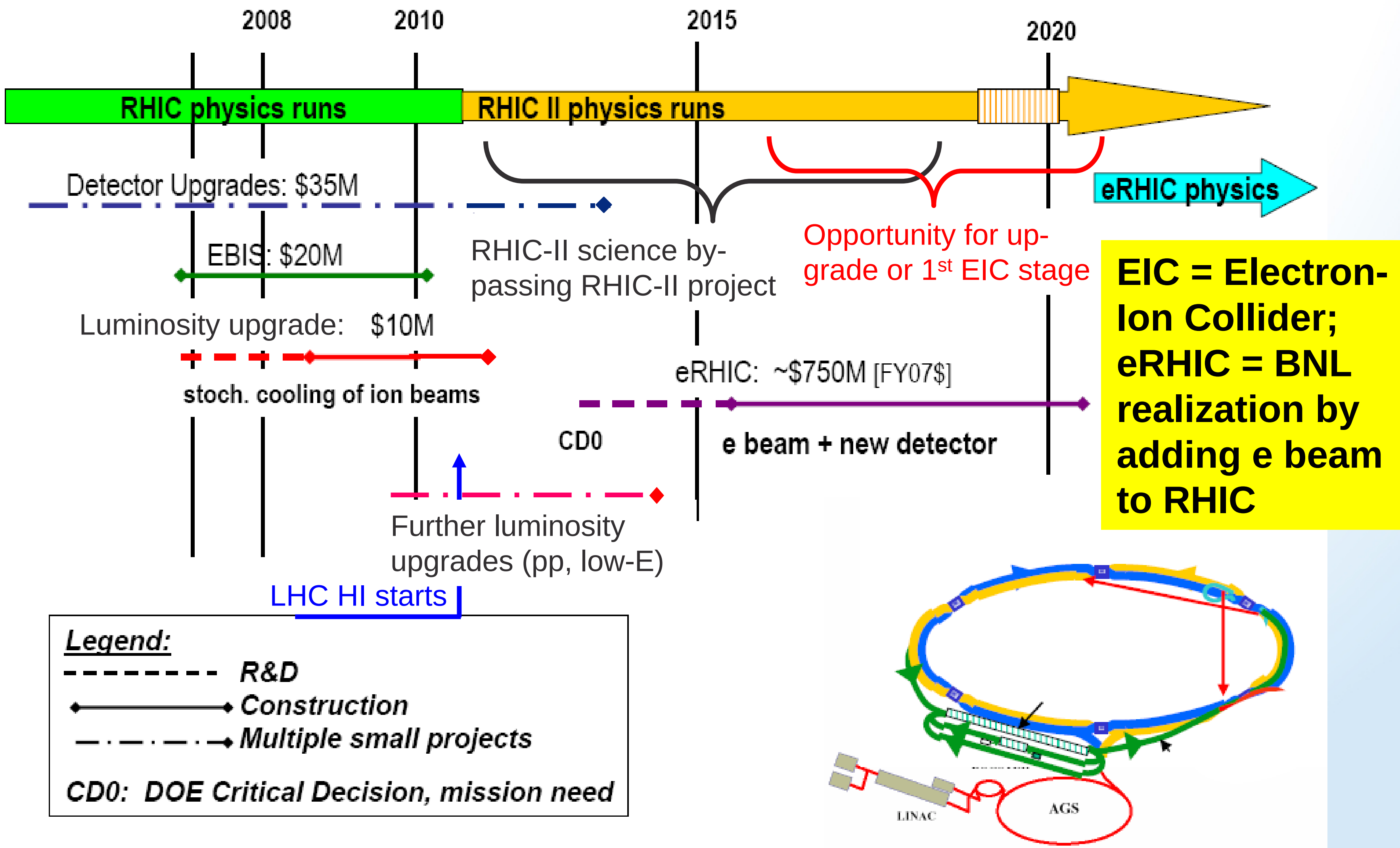
Election to National Academy of Sciences for Barbara Jacak, Stony Brook



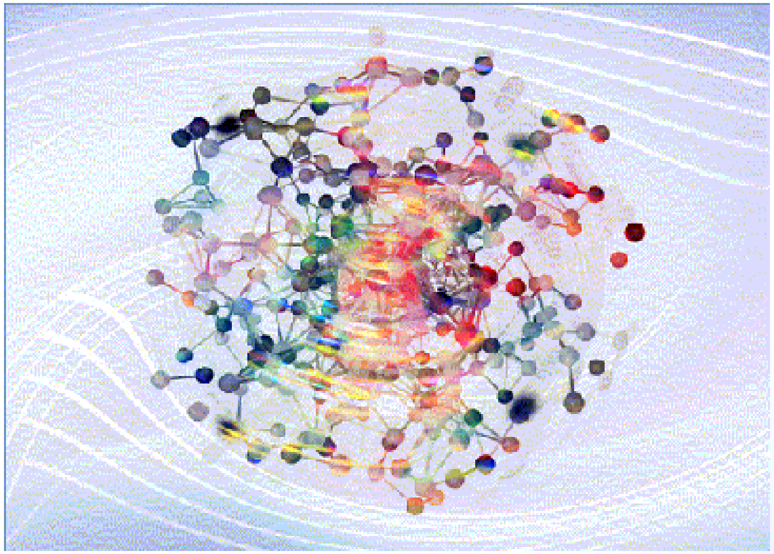
DOE Presidential Early Career Award to Mickey Chiu, BNL

Congratulations for making RHIC such a success!

A Long Term (Evolving) Strategic View for RHIC



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 and self-interacting force carriers? Are there lessons for other fundamental (e.g., EW) theories, that are harder to subject to laboratory investigation? How do we pump/probe fleeting partonic matter in 10^{-23} s?

Apply to

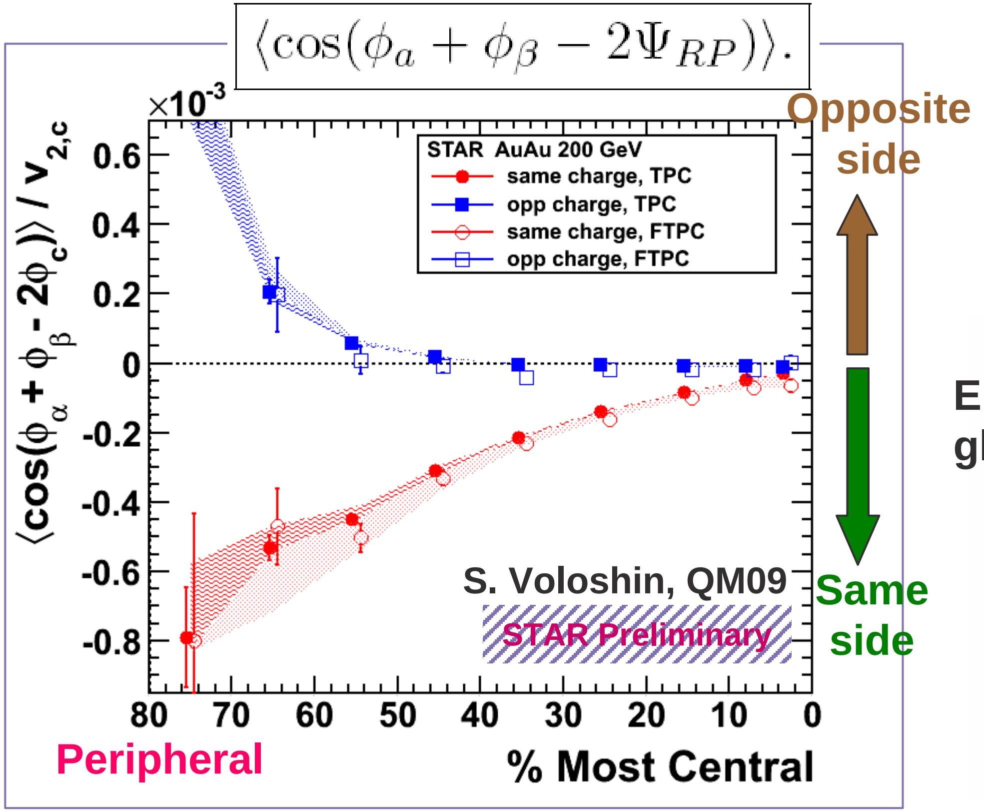
new matter: ***quantify properties of "near-perfect liquid" seen @ RHIC***

old matter: ***determine partonic decomposition of p spin @ RHIC & eRHIC***

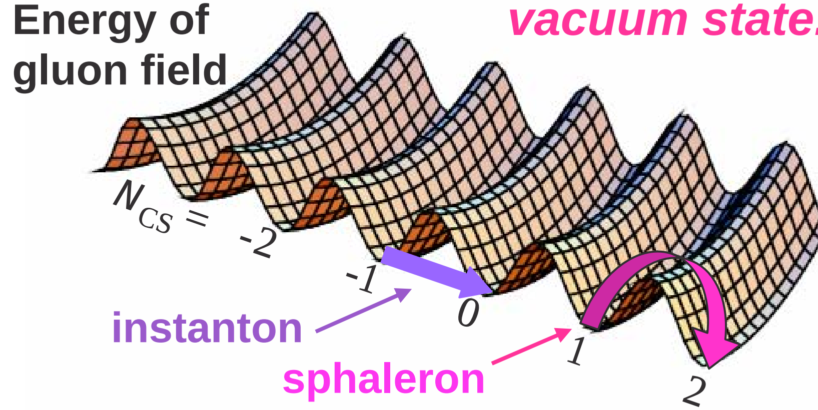
hot matter: ***search for critical point in QCD phase diagram in RHIC E-scan & for correlations signalling symmetry-violating local vacuum fluctuations***

cold matter: ***expose & map intense force field (Color Glass Condensate) at heart of all ordinary matter, using eRHIC***

Do Charge Correlations Observed by STAR Signal Non-Abelian Vacuum Fluctuations?



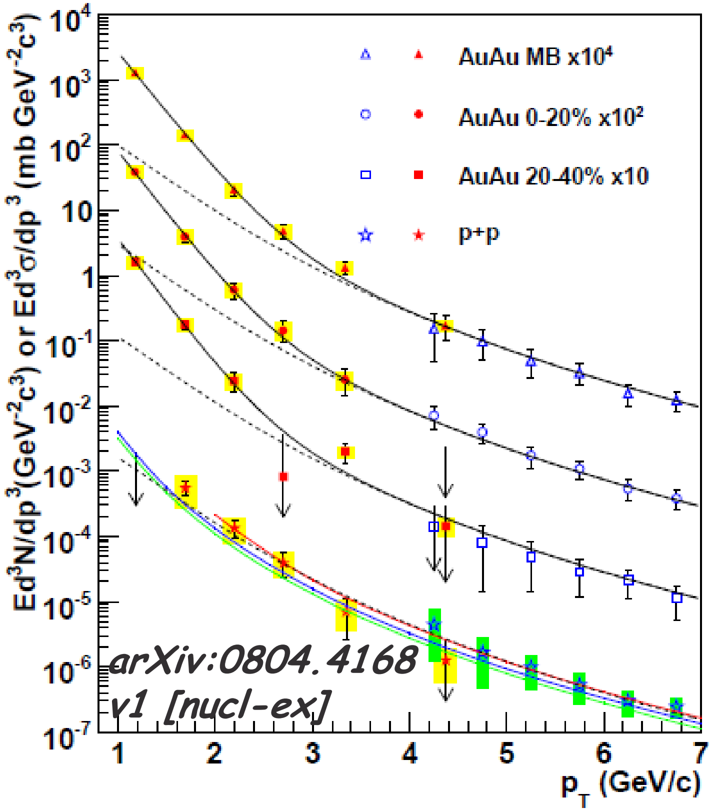
STAR reports "EDM-like" charge correlations in non-central HI collisions, similar to Kharzeev et al. predicted behavior resulting from high-T P- and CP-violating local fluctuations in QCD vacuum state.



Statistically significant signal must average over many events and local "bubbles" with possibly opposite signs of CPV and chiral imbalance ⇒ signal is P- and CP-even, subject to contamination by mundane effects.

Pursue at RHIC, since all non-Abelian gauge theories admit such non-trivial vacuum fluctuations – e.g., B- and CP-violating sphalerons frozen in at EW phase transition are (one) speculated origin of BAU!

PHENIX Measurement of Early Collision Temperature Helps to Establish Context for LHC-RHIC Complementarity

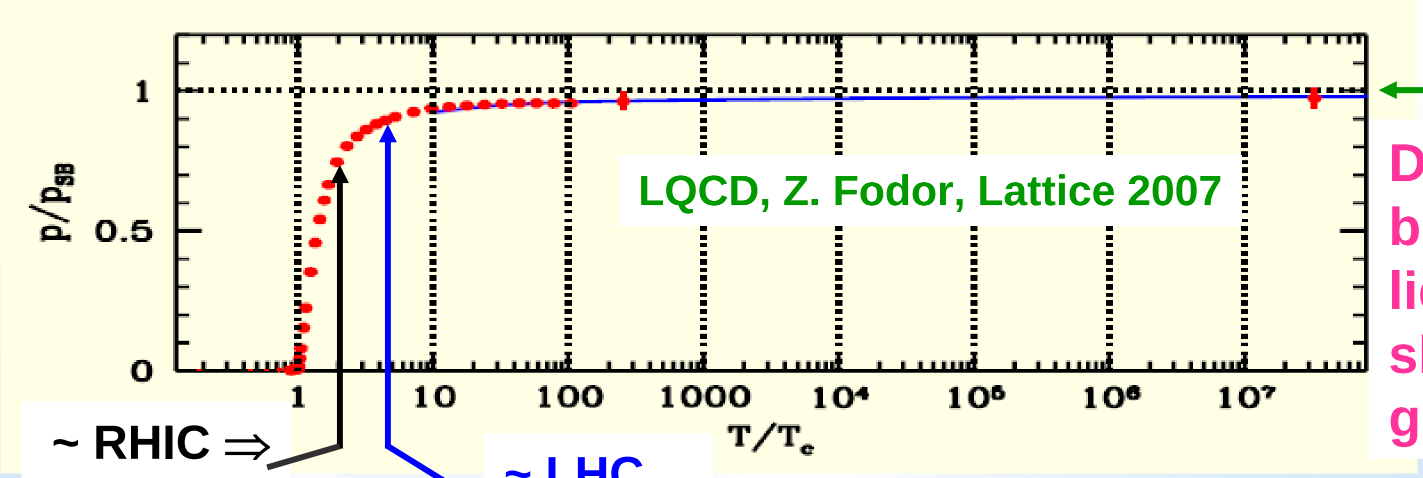


Low-mass di-electron yield (⇒ nearly real photons) shows low-p_T enhancement vis-à-vis p+p. Thermal fit to p_T slope ⇒

$$T_{avg} = 221 \pm 23 \pm 18 \text{ MeV}$$

from which hydrodynamics models ⇒

$$T_{init} > 300 \text{ MeV} >> T_{LQCD\ transition} \approx T_{Hagedorn}$$



Does matter still behave as an ideal liquid, or does shear viscosity grow from RHIC?

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Equally Important to Establish Connections to Other Fields

AAAS Annual Meeting

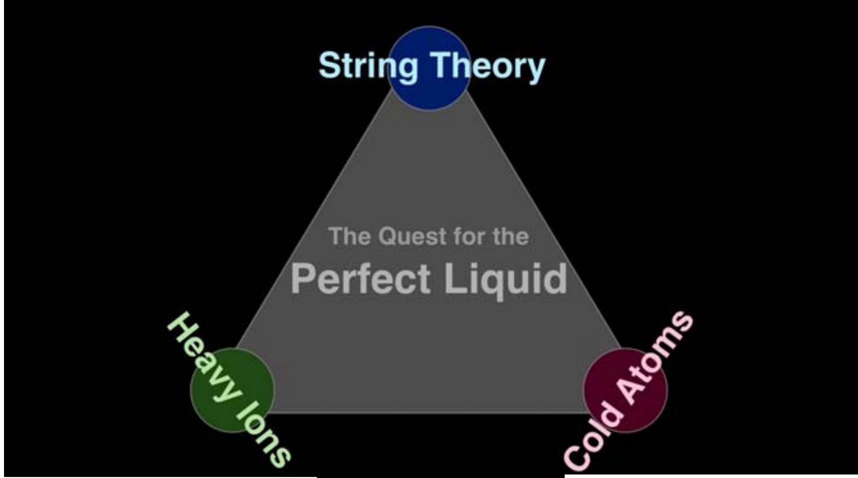
12–16 February 2009 • Chicago

Quest for the Perfect Liquid: Connections Between RHIC, String Theory and Cold Atoms

Organizers: Peter Steinberg & Bill Zajc, with support from BNL's CEGPA

Discussants: Bill Zajc & Glennda Chui (Deputy Editor, Symmetry Magazine)

Clifford Johnson, USC



Barbara Jacak
Stony Brook U.

John Thomas
Duke Univ.

February 16, 2009

4:49 pm

At a AAAS session on Sunday, physicists said string theory is making important contributions to the study of two extreme forms of matter –one heated to trillions of degrees, the other chilled to near-absolute zero. In both cases the matter became a "perfect liquid" that ripples and flows freely, like water. String theorists analyzed the results by applying what they had learned from pondering how a black hole might behave in five dimensions. Then they went on to calculate just how free-flowing these liquids might be, predictions that the experimenters are using to guide the next stage of their work.

Spin Symposium Proposal for AAAS 2010

AAAS "designated theme": **Bridging Science and Society**

Proposed Mini-symposium: **Particle Spin: From Quarks and Gluons to Medical Imaging and Quantum Computers**

Organizer and Moderator: Elke Aschenauer, BNL

Co-Organizer: Karen McNulty Walsh, BNL

Proposed Talks:

1. Werner Vogelsang, BNL

The Puzzle of Proton Spin: More than the Sum of its Quarks

2. Charles Springer, Director, Advanced Imaging Research Center, Oregon Health & Science University

Magnetic Resonance Imaging: Using Proton Spin to Diagnose Breast Cancer

3. David Awschalom, Director, Center for Spintronics and Quantum Computation, UCSB

Putting Electron Spin to Work: The Future of Quantum Computing and Spintronics

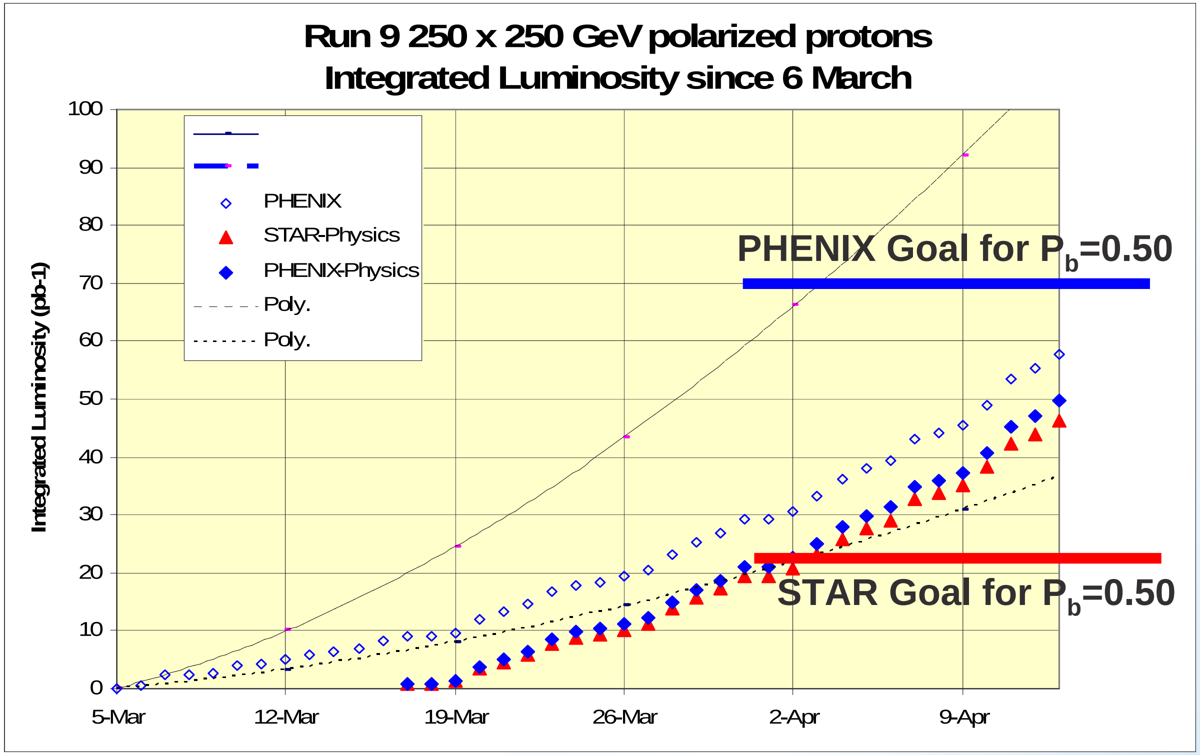
Discussant: Adrian Cho, staff writer, Science Magazine

Progress Toward RHIC-II Science: Run 9

- ***Administration + Congressional recognition of role of science research in short- and long-term economic recovery***

- ***Good FY09 budget would have supported 25 cryo-week RHIC ops***

- ***Continuing Resolution ⇒ late start, summer truncation at ~22 weeks***



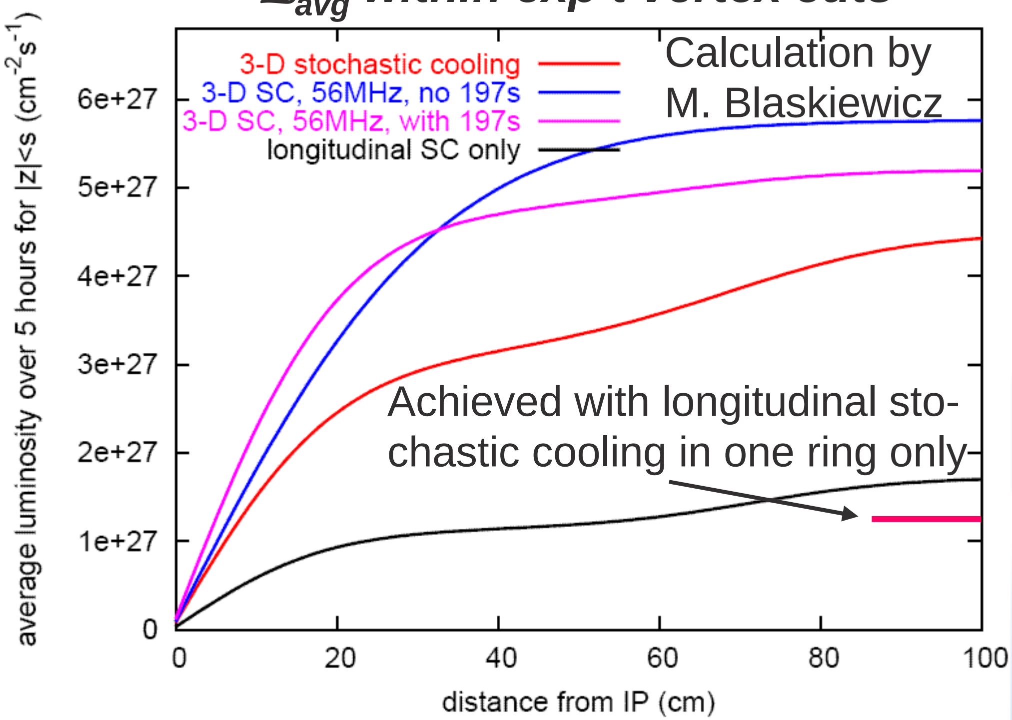
Milestones:

- ***First 500 GeV pp collision run ⇒ 1st observation of W signals above bkgd?***
- ***~10-week 200 GeV pp run allows progress toward ΔG constraint goals***
- ***First plane of transverse stochastic cooling installed, functionality tested***
- ***RHIC spin flipper commissioned toward end of run***
- ***Identified numerous remaining issues for $\mathcal{L}$, P_{beam} , CNI pol'm'ter rate-dependence, rate capability of experiments***

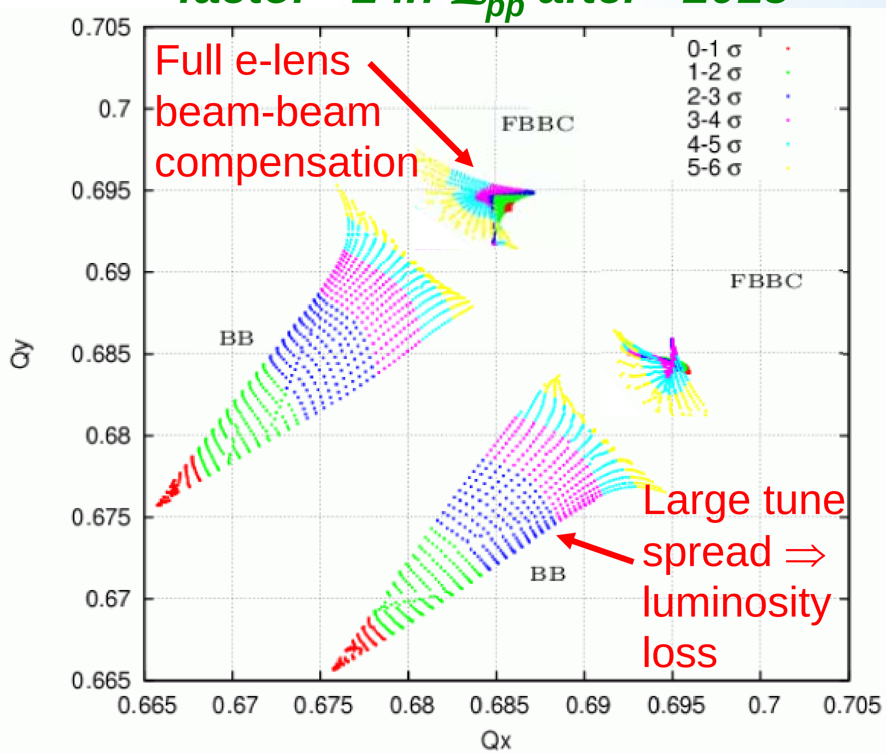
Progress Toward RHIC-II Science: Machine Upgrades

- EBIS on track for scheduled Q4 FY2010 completion; superconducting trap solenoid passed acceptance test 5/21/09
- FY09 ARRA (stimulus) funds for 2 additional planes transverse stochastic cooling + electron lenses to improve pp luminosity

2 planes transverse stochastic cooling + longitudinal cooling in each ring + 56 MHz SRF rebunching by 2012 run should ⇒ ~ order of magnitude enhancement in $\mathcal{L}_{avg}$ within exp't vertex cuts

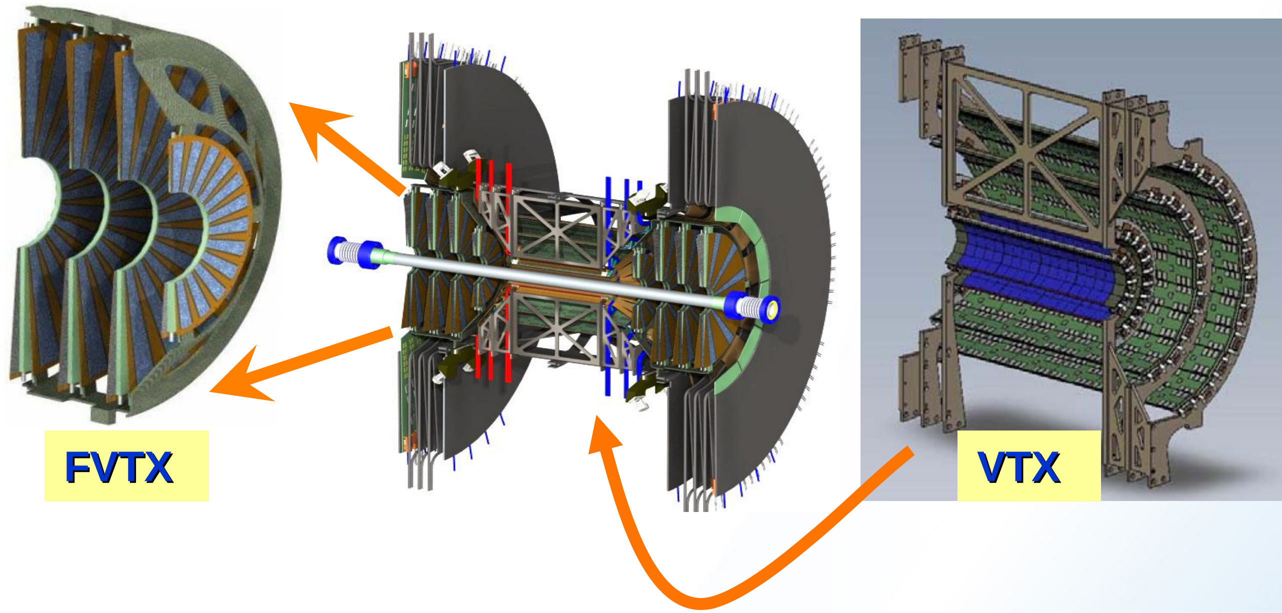


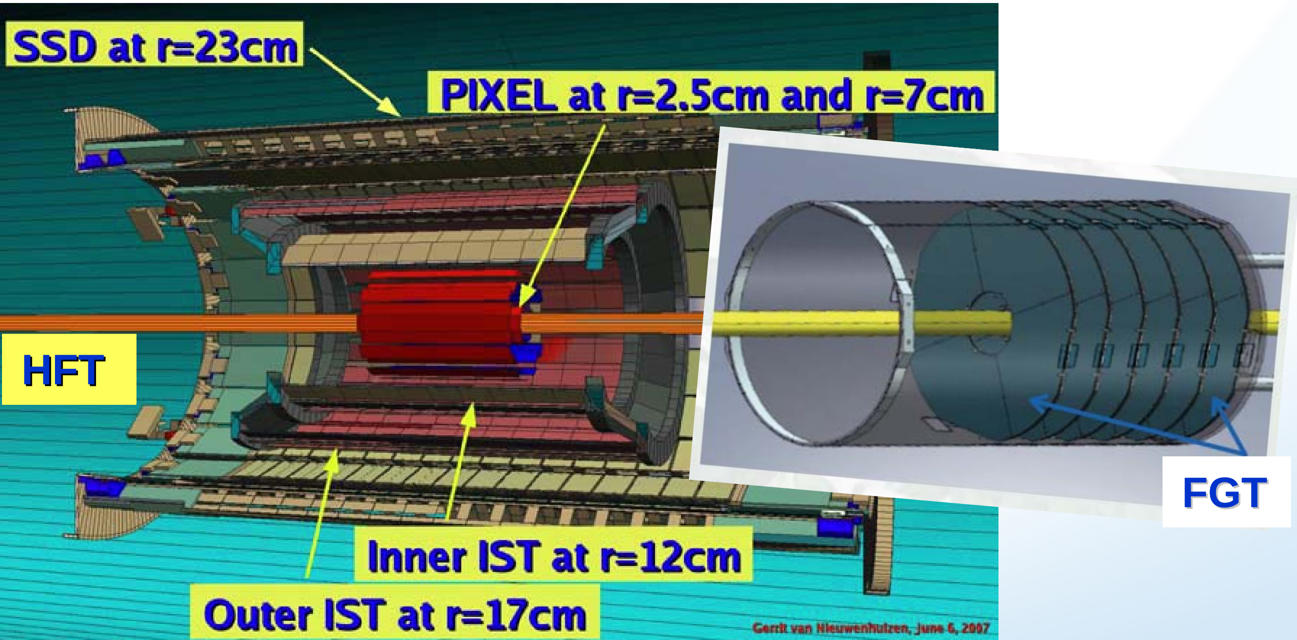
Interaction with ~5 keV e⁻ beam to compensate pp head-on beam-beam tune spread ⇒ (?) factor ~2 in $\mathcal{L}_{pp}$ after ~2013



Progress Toward RHIC-II Science: Detector Upgrades

- ***FY09 ARRA funds ensure timely completion of PHENIX VTX & FVTX upgrades***
- ***Awaiting updated plan, sharpened physics focus, for forward calorimetry in PHENIX***





- ***STAR Heavy Flavor Tracker receives CD-0 in FY09; CD-1 review anticipated for Fall '09***
- ***STAR Forward GEM Tracker launched as Capital Equipment project***

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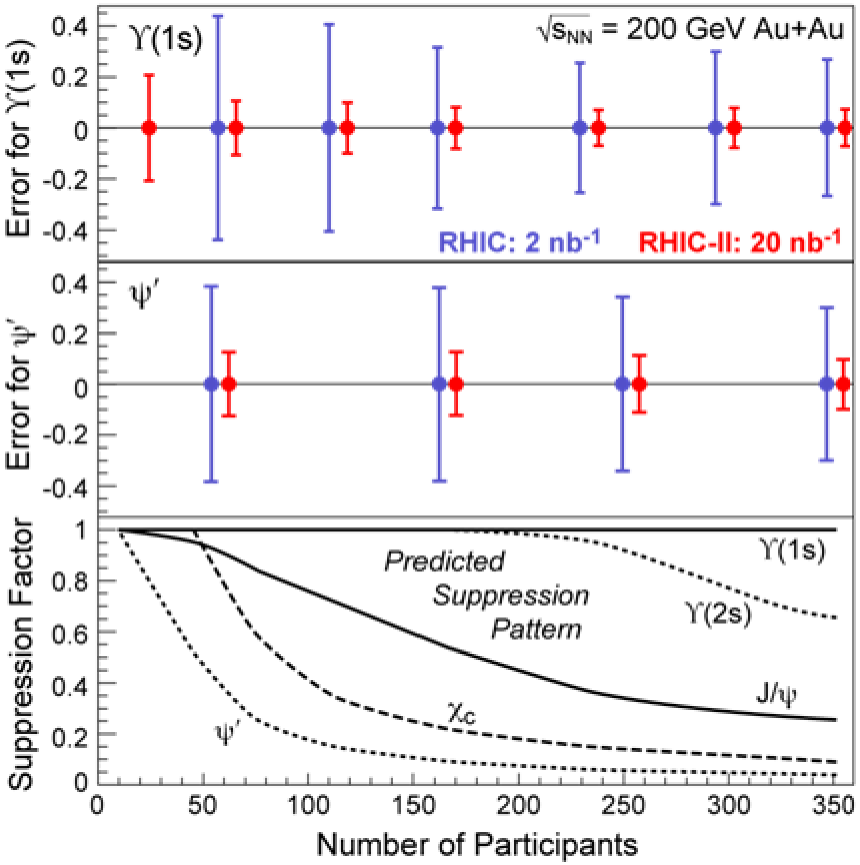
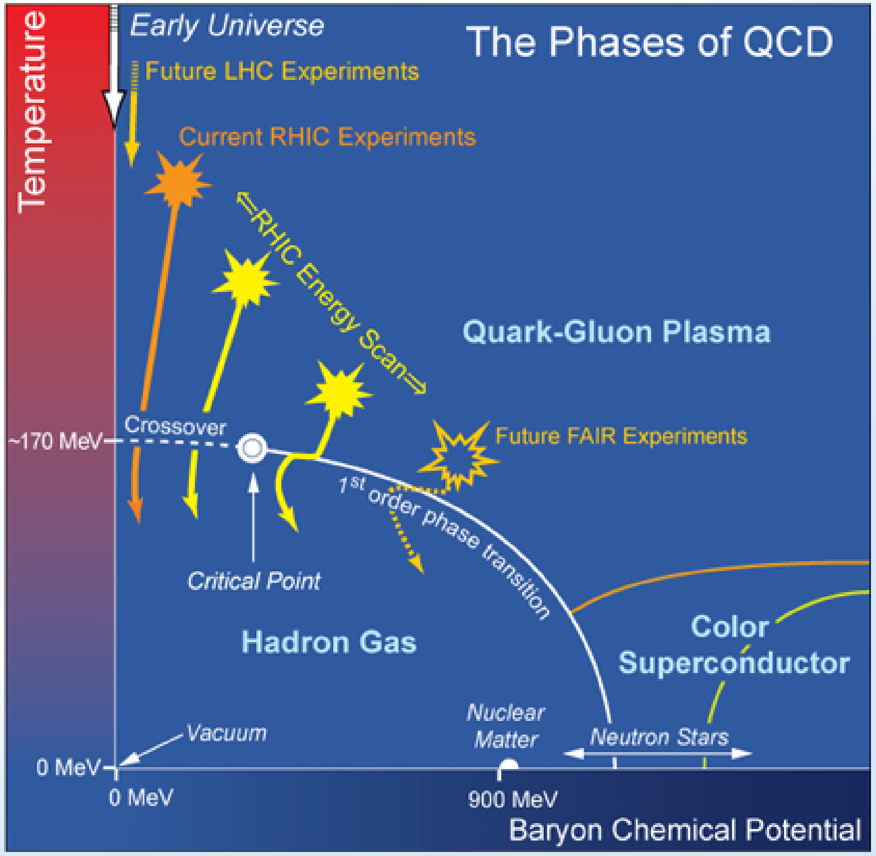
RHIC-II Science Goals



Utilize enhanced luminosity & detectors to:

- ***Quantify properties (viscosity/entropy, transport coeffs., speed of sound?...) of near-perfect liquid matter formed @ RHIC***
- ***Explore signatures of deconfinement and in-medium q-q interaction via yield & flow of quarkonia and open heavy flavor***
- ***Search for evidence of symmetry-violating QCD vacuum fluctuations***
- ***Scan for QCD critical point, onset of deconfinement*** ***(N.B. CPOD, 6/8-12/2009)***
- ***Probe mechanism of transverse spin asymmetries & sensitivity to L_{parton}***



Tentative RHIC Run Plan Following 2008 PAC Recommendations

(assumes 6-month FY09 CR, 2-species runs in FY10-14 & best info on detector upgrade schedules)

Fiscal Year	Colliding Beam Species/Energy	Comments
2009	500 GeV p+p	~5-6 physics weeks to commission collisions, work on polarization & luminosity, obtain first W prod'n signal to meet 2011 RIKEN milestone; STAR DAQ1000 fully operational
2010	200 GeV p+p	10-12 physics weeks to complete 200 GeV A_{LL} measurements – could be moved to Run 9 if FY09 Omnibus Funding Bill supports 21 cryoweeks
	200 GeV Au+Au	9-10 physics weeks with PHENIX HBD, STAR DAQ1000 & TOF permits low-mass dilepton response map and 1st HI collision test of transverse stochastic cooling (one ring)
2011	Au+Au at assorted low E	1st energy scan for critical point search, using top-off mode for luminosity improvement – energies and focus signals to be decided; commission PHENIX VTX (at least prototype)
	200 GeV U+U	1st U+U run with EBIS, to increase energy density coverage
2012	500 GeV p+p	1st long 500 GeV p+p run, with PHENIX muon trigger and STAR FGT upgrades, to reach ~100 pb^{-1} recorded for substantial statistics on W production and ΔG measurements
	200 GeV Au+Au	Long run with full stochastic cooling, PHENIX VTX and prototype STAR HFT installed; focus on RHIC-II goals: heavy flavor, γ-jet, quarkonium, multi-particle correlations
2013	500 GeV p+p	Reach ~300 pb^{-1} to address 2013 DOE performance milestone on W production
	200 GeV Au+Au or 2nd low-E scan	To be determined from 1st low-E scan and 1st upgraded luminosity runs, progress on low-E e-cooling, and on installation of PHENIX FVTX and full STAR HFT
2014	200 GeV Au+Au or 2nd low-E scan	Run option not chosen for 2013 run – low-E scan addresses 2015 DOE milestone on critical point, full-E run addresses 2014 (γ-jet) and 2016 (identified heavy flavor) milestones. Proof of principle test of coherent electron cooling.
	200 GeV p+p	Address 2015 DOE performance milestone on transverse SSA for γ-jet; reference data with new detector subsystems; test e-lenses for p+p beam-beam tune spread reduction

Run Plan, Detector & Luminosity Upgrades Address All New RHIC-Related Performance Milestones

	Year	#	Milestone
spin	2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
spin	2013	HP12 (update of HP1)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
spin	2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering
Heavy ion	2014	DM9 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
Heavy ion	2014	DM10 (new)	Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies from medium RHIC energies to the highest achievable energies at LHC.
Heavy ion	2015	DM11 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ between 5 and 60 GeV to search for evidence of a critical point in the QCD matter phase diagram.
Heavy ion	2016	DM12 (new)	Measure production rates, high pT spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}}$ = 200 GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
Heavy ion	2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}}$ = 200 GeV.

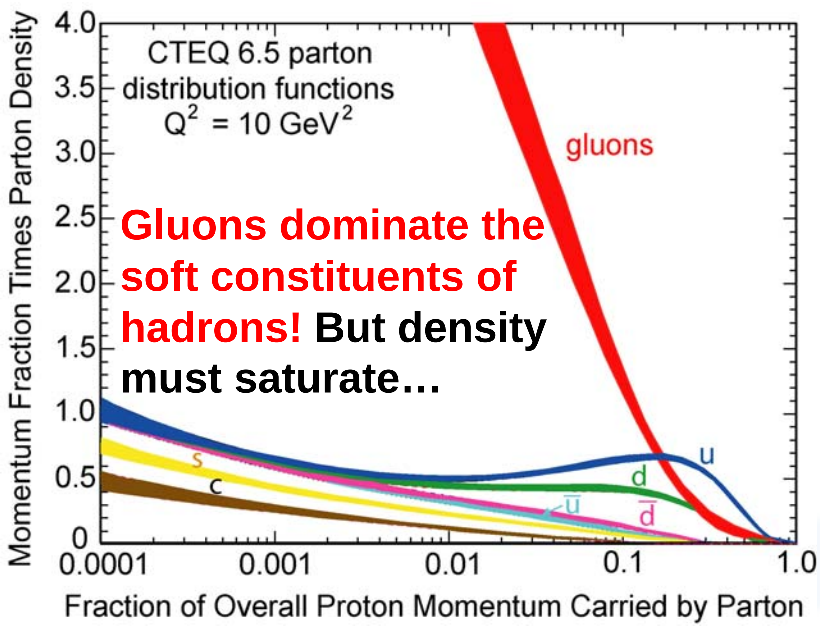
N.B. Some will be missed if budgets do not permit 2 species/year runs in FY10-14, but FY09 and President's FY10 budgets encouraging!

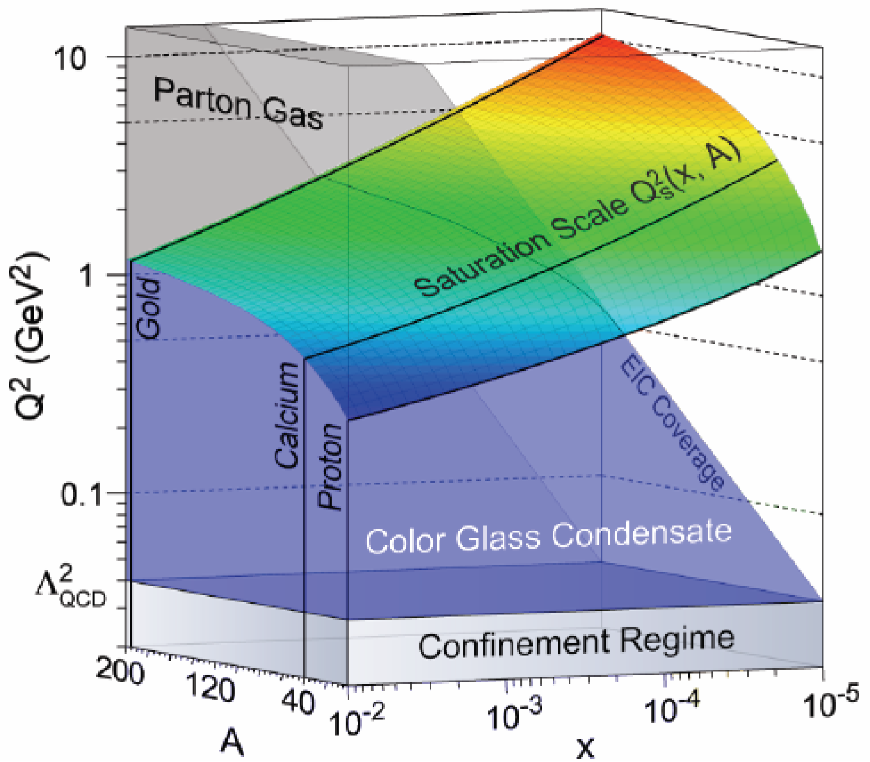
EIC Science: Gluon-Dominated Cold Matter

Search for supersymmetry @ LHC, ILC (?): ***seeking to unify matter and forces***

Electron-Ion Collider: ***reveal that Nature blurs the distinction***

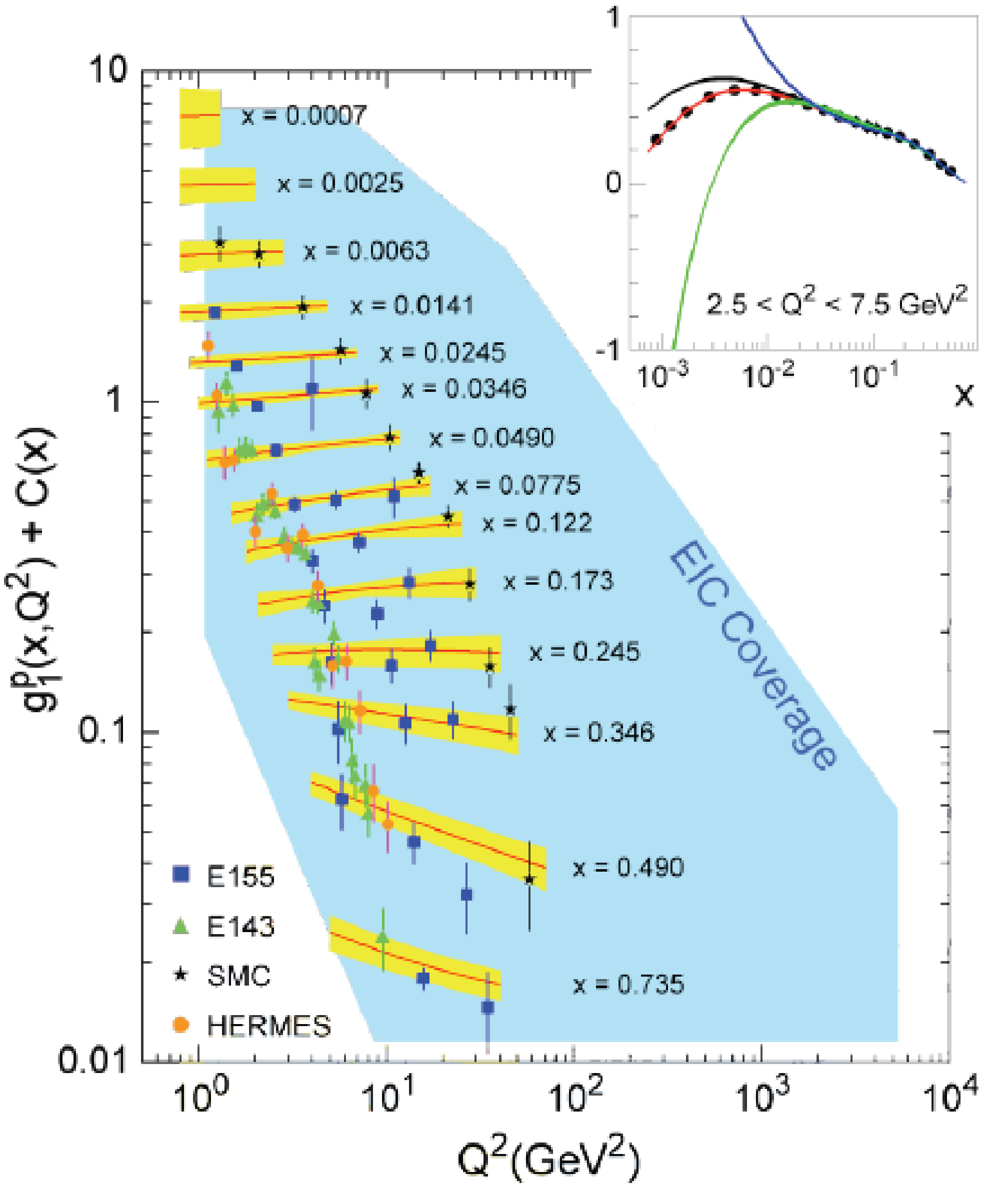
Deep inelastic scattering @ HERA ⇒





EIC probes *weak* coupling regime of very high gluon density, where gauge boson occupancy >> 1. *All ordinary matter has at its heart an intense, semi-classical force field* -- can we demonstrate its universal behavior? Track the transition from dilute parton gas to CGC? "See" confinement reflected in soft-gluon spatial distributions inside nuclei?

Polarized $\vec{e} + \vec{N}$ at EIC

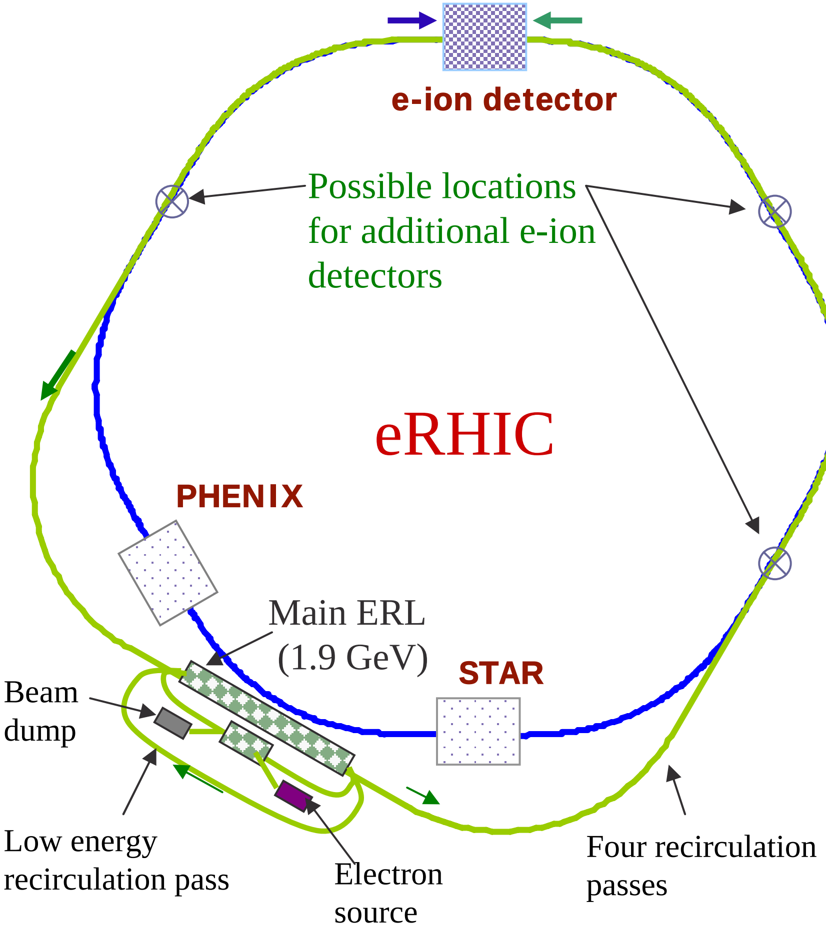


- *Polarized DIS, γ-gluon fusion to determine gluon polarization down to x ~ few $\times 10^{-4}$*
- *Bjorken sum rule test to $\lesssim$2% precision*
- *SIDIS for low-x sea-quark polarization and transverse spin studies*

More luminosity-hungry:

- *Polarized DVCS, exclusive reactions + LQCD $\Rightarrow$ GPD's $\Rightarrow$ map low-x transverse position-dep. PDF's; J_q from Ji sum rule*
- *Parity violation in $\vec{e}$+p,d at high Q^2 to study running of weak coupling below Z-pole*

Note INT workshops on EIC science, Fall '09 and '10.



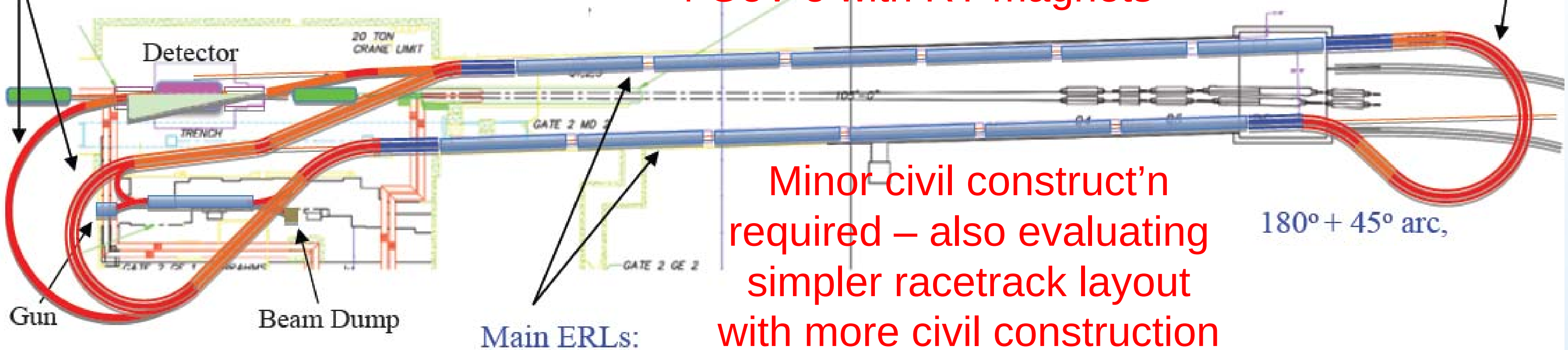
Long-Term (>2020) Future Built on Adding 10-20 GeV Electron Linac ⇒ eRHIC

Add ERL injector with polarized e^- source to enable $\vec{e}+\vec{p}$, $^3\vec{He}$ and e+A (up to Uranium) to study matter in gluon-dominated regime

- 10 GeV electron design energy. Possible upgrade to 20 GeV by doubling main linac length.
- 5 recirculation passes (4 in RHIC tunnel)
- Multiple electron-hadron interaction points (IPs) permit multiple detectors;
- Full polarization transparency at all energies for the electron beam;
- Ability to take full advantage of transverse cooling of the hadron beams;
- Possible options to include polarized positrons at lower luminosity: compact storage ring or ILC-type $\vec{e}^+$ source
- R&D already under way on various accelerator issues; more to come.

- ***Subsequent stages/ alternative layouts could increase e-beam & ion-beam energies and L from nominal 10 $\times$ 250 GeV, ~3 $\times 10^{33}$ cm^{-2}s^{-1} $\vec{e}+\vec{p}$***

Considerable FY09 Progress on Design of Possible 1st (Medium Energy, MeRHIC) Stage



- ***Would enable 4 GeV $\vec{e}^-$ on 100 GeV/N heavy ions and 250 GeV $\vec{p}$, with most equipment to be reused later in full EIC***
- ***1st look at saturation surface for nuclei in e+A DIS: confirm nuclear "oomph" factor & measure gluon densities relevant to RHIC initial state; e+A diffraction tests of high gluon occupancy***
- ***$\vec{e}$-$\vec{p}$ program extending $\overrightarrow{DIS}$, adding: transverse-spin SIDIS over broad Q^2-range ⇒ TMD evolution; detection of boosted target fragments to probe spin-dependent correlations in nucleon.***
- ***Developing science case, detector design, cost estimate.***

Progress Toward EIC: Other FY09 Milestones

- ***Set up BNL EIC Task Force led by Elke Aschenauer & Thomas Ullrich, comprising ~15 nuclear/particle physicists in addition to accelerator team***

- ***Hold 1st joint BNL-JLab EIC International Advisory Committee meeting 2/16/09 ⇒ many "comments, suggestions and (cautious) recommendations" + more pointed individual remarks:***

  EICAC requested next meeting on Fall '09 schedule, for 2 days to allow deeper discussion, and with following major deliverables:

  - ***Coherent R&D plan, timeline, milestones & resource needs***
  - ***Initial cost-performance-science reach matrix***
  - ***Short list of "golden measurements" & what will be learned***
  - ***Implications of golden exp'ts for detector requirements + R&D***

  - Further develop the schedule including approximate resource-loading, to provide a timeline for major decisions (including, if at all possible, site decision), technical developments, and (staged) realization
  - In particular, strive for a timeline (under reasonable assumptions) that provides for data taking before 2020

- ***DIS09 (April 2009, Madrid) panel discussion of eRHIC, ELIC (JLab), & LHeC (CERN) with community of potential users***

- ***Launch EIC-targeted LDRD-funded R&D program at BNL***

eRHIC LDRD Proposals Under Consideration

Accelerator-related:

I. Ben-Zvi *et al.*, EIC Polarized Electron Gun

T. Rao and T. Tsang, Development of a laser system for driving the photocathode of the polarized electron source for the EIC

V. Litvinenko *et al.*, Simulation, design and prototyping of an FEL for proof-of-principle of Coherent Electron Cooling

A. Zelenski *et al.*, Feasibility studies of new polarization techniques for $^3He^{++}$ ion beams

Experimental issues:

T. Ullrich and R. Venugopalan, Realization of an e+A Physics Event Generator for the EIC

W. Guryn *et al.*, Developing Methods at RHIC to Tag Coherent Diffraction in eA at eRHIC

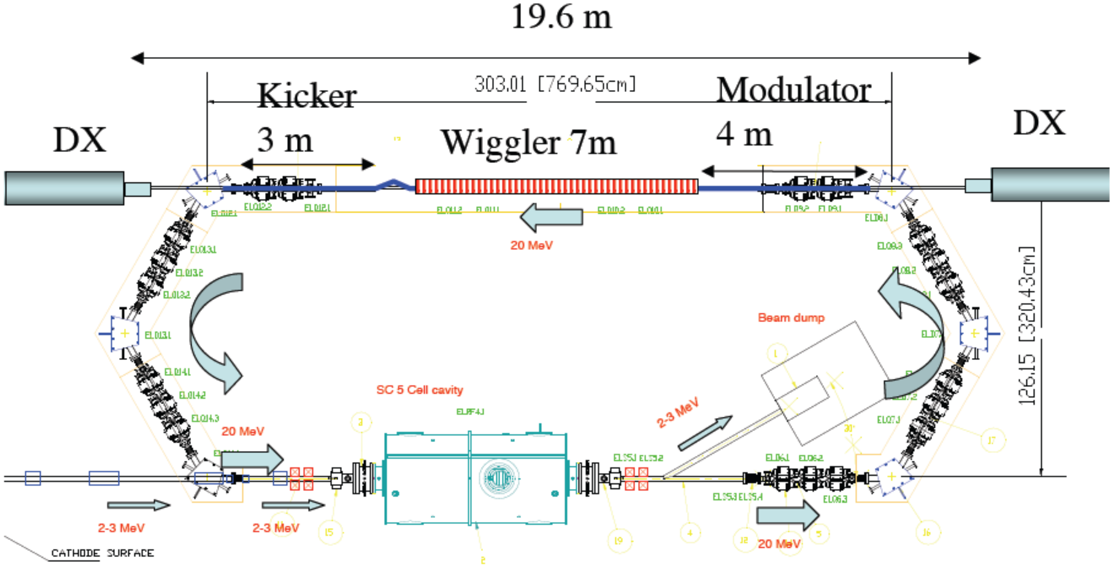
E. Kistenev *et al.*, Development of hybrid strip-pad silicon sensors for high resolving power silicon-tungsten electromagnetic calorimetry for eRHIC

Theoretical issues:

R. Venugopalan *et al.*, Exploring signatures of saturation and universality in e+A collisions at eRHIC

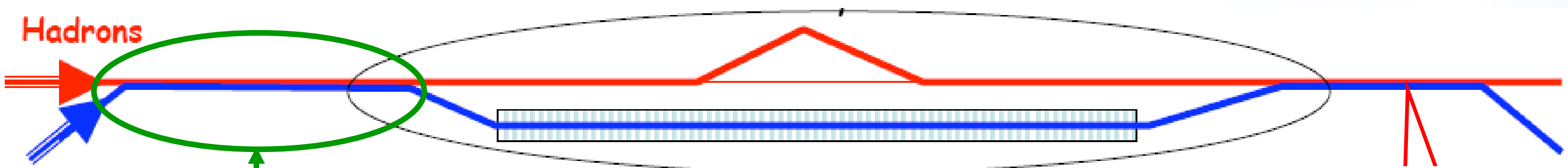
W. Marciano *et al.*, Electroweak Physics with an Electron Ion Collider

Longer-Term EIC-Aimed Accelerator R&D @ BNL



Develop high-current Energy Recovery Linac (ERL) technology with 20-MeV R&D ERL

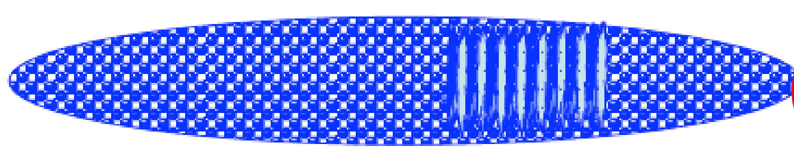
Install R&D ERL in RHIC ring for proof-of-principle test (~2014) of Derbenev & Litvinenko concept of Coherent Electron Cooling

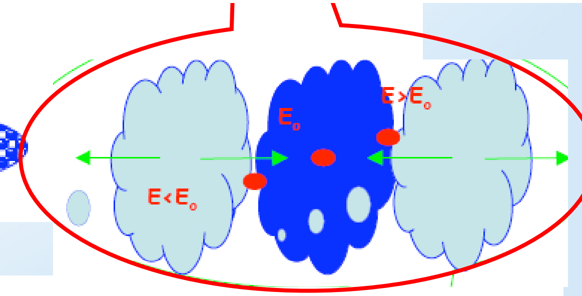


Modulator: hadron beam structure introduces density modulation in e-beam

Wiggler: FEL amplification (x $10^{2\text{-}3}$) of e-beam modulations, while chicane adds dispersion to h beam

Kicker: attraction to e-beam density peak reduces ion-beam E spread.

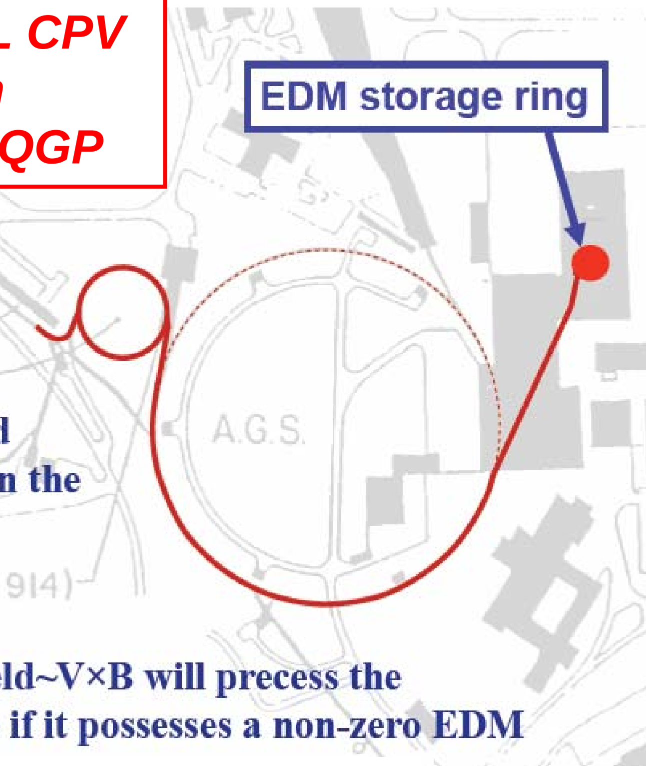




***CeC** of high-energy hadron beams: high-gain FEL based on high-brightness ERL ⇒ potential to boost EIC (and LHC? RHIC p+p?) luminosities.*

Novel Storage Ring EDM Exp'ts @ AGS ?

Complements BNL CPV searches in lepton sector (DUSEL) & QGP



A longitudinally polarized deuteron beam is stored in the EDM ring, for ~10^3 s.

The strong effective E*-field~V×B will precess the deuteron spin out of plane if it possesses a non-zero EDM

- ***Inject longitudinally pol'd $\vec{p}$ or $\vec{d}$ beam, via AGS, into dedicated storage ring***
- ***Choose magic momentum + static $\vec{E}$, $\vec{B}$ combination (B=0 for protons) to ~cancel (g-2) horizontal spin precession***
- ***Search for EDM signature of vertical polarization build-up due to precession in strong $\vec{E}$-field (static for p, $\vec{v} \times \vec{B}$ for d)***
- ***Sensitivity goal ~ 10^{-29} e·cm***
- ***Cancel many syst. errors via simultaneous counter-rotating (vertically separated) beams.***
- ***If EDM $\neq 0$ observed for n, p and/or d, combination powerfully constrains the source. E.g., the three systems have quite different sensitivities to θ_{QCD} vs. SUSY (latter strongly enhanced in d).***

System	Current limit [e-cm]	Future goal [e-cm]	n-equivalent [e-cm]
n	$<1.6\times10^{-26}$	10^{-28}	10^{-28}
^{199}Hg	$<3\times10^{-29}$		10^{-25}-10^{-26}
^{129}Xe	$<6\times10^{-27}$	10^{-30}-10^{-33}	10^{-26}-10^{-29}
d		10^{-29}	3×10^{-29}-5×10^{-31}
p	$<7\times10^{-25}$	10^{-29}	4×10^{-29}-25×10^{-31}

Charge for EDM Technical Review (Fall '09)

1) Are there technical showstoppers evident at this stage that would seriously imperil attainment of interesting sensitivity levels in the eventual experiments? If there is no single showstopper, are there nonetheless too many high-risk performance goals to maintain a significant probability of payoff?

2) Is the proposed R&D plan sensible and achievable on a timeline suited to mount a competitive experiment? Has the collaboration properly identified the highest risk assumptions and proposed an appropriate set of R&D milestones to manage the risk?

3) Are the collaboration's considerations of systematic errors and approaches to mitigate them unduly optimistic?

4) Are you aware of competitive plans or proposals for charged-particle (other than electron) EDM measurements? Is the need for proton and/or deuteron EDM measurements to complement neutron EDM experiments sufficiently strong to merit proceeding?

5) Do the cost estimates and timelines presented for the R&D stages and for the EDM measurements themselves seem reasonable? (A detailed cost review would be premature at this point.) Is the proposed sequence for the proton and deuteron EDM measurement optimal? Are both measurements worth doing?

6) How much time do you estimate the collaboration needs to develop the proposal to a stage suitable for a DOE Critical Decision 0 ("mission need") review?

If technical review positive, then proceed to seek funding (EDM not yet included in NP budget spreadsheets). Recommend DOE or NSAC panel advice on optimal national suite of EDM measurements.

Conclusions

1) FY09 has been a good year for external recognition of RHIC's accomplishments and for funding upgrades and operations. Funding outlook is upbeat!

2) ∃ a coherent vision, fueled by vibrant theory development, to continue RHIC's exploration of QCD's unique implications for hot and cold strongly interacting matter, in both short and long term.

3) Science vision is matched by innovative concepts for advancing accelerator state-of-the-art.

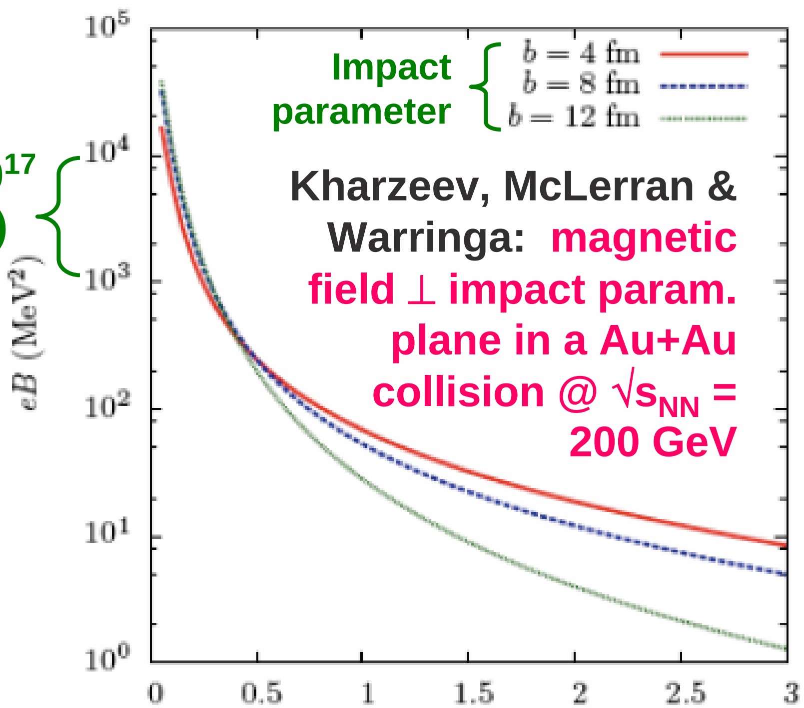
4) Much work remains to demonstrate scientific need, technical feasibility and achievable realization plan for eRHIC. Greater user involvement, e.g., in detector R&D, is critical.

5) BNL is strongly committed to maintaining RHIC's success through another generation.

Backup Slides

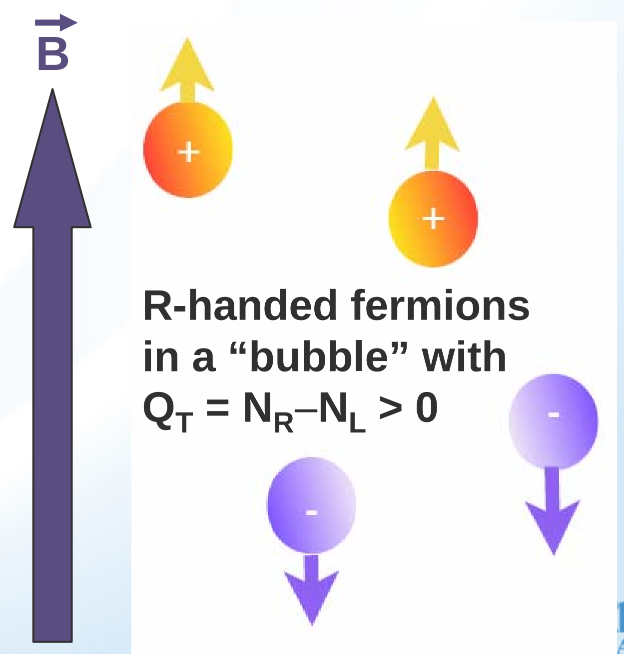
The Chiral Magnetic Effect (D. Kharzeev et al.)

~ 10^{17} G (!)



Time during collision (fm/c)

- *The strong magnetic field in a non-central HI collision orients spins for + and – quarks oppositely.*
- *In a "bubble" with non-zero topo-logical charge (⇒ chiral imbalance), this leads to a net electric current and P- and CP-violating EDM.*
- *Charge separation can become "macroscopic" in deconfined matter.*



The sign of the EDM can differ from bubble to bubble, and event to event ⇒ no global CPV ! But can look for particle correlations indicative of local parity and CP violation.

Next Steps

➢ Think more about physics backgrounds and try to simulate them. Make theoretical calculations more realistic.

➢ Collect / analyze larger data sets with improved RHIC luminosity, STAR DAQ, and new TOF detector for improved particle ID:

- compare different methods to extract event reaction plane
- does effect show up in all quark flavor sectors?
- seek evidence of reduced correlation in most peripheral events, where energy density reduced, QGP phase not reached

➢ Measure charge correlations for lower Au+Au energies, lighter systems: does effect vanish below onset of deconfinement?

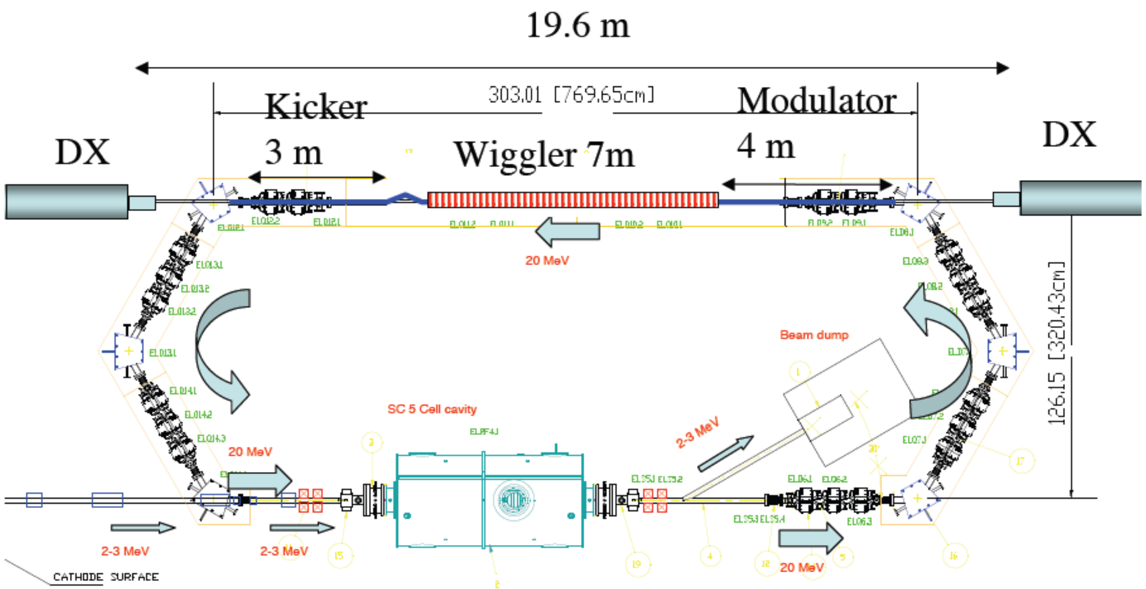
➢ Consider in more depth whether there are any explicitly P-odd or CP-odd correlations signatures one can explore. Since different bubbles can have different signs of topological charge, simple helicity correlations will vanish when we average over events.

➢ Try to vary magnetic field strength ($\propto Z_1 Z_2$) independently of centrality by comparing isobaric nuclei, e.g., ${}^{96}_{40}Zr + {}^{96}_{40}Zr$ vs. ${}^{96}_{44}Ru + {}^{96}_{44}Ru$

⇒ Important program for the RHIC-II era !

Intermediate-Term Possibilities: CeC-Fueled Upgrade in p+p Luminosity?

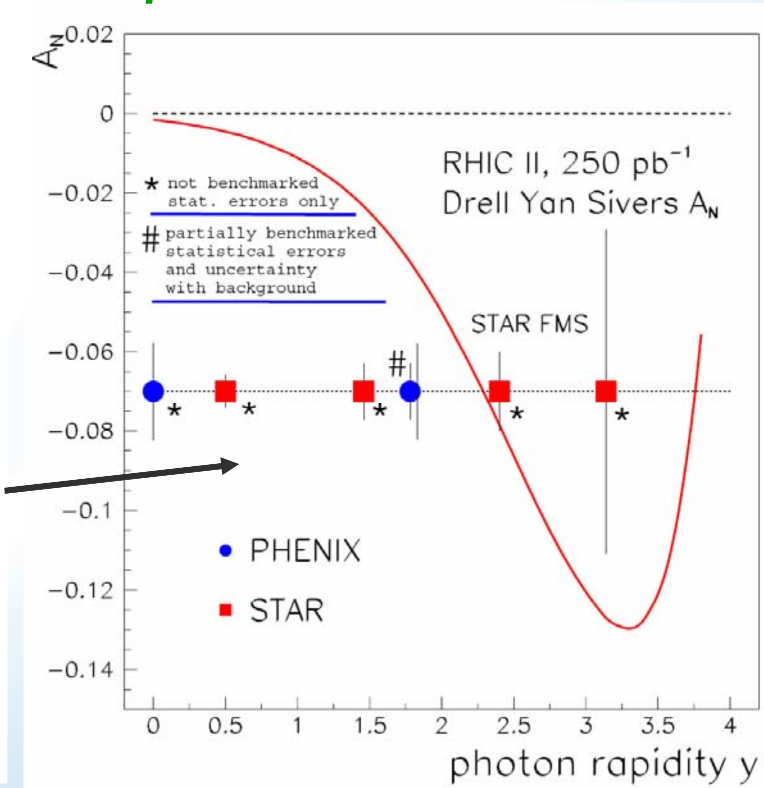
IR-2 layout for Coherent Electron Cooling proof-of-principle experiment



Planning proof of principle demo of coherent e-cooling in RHIC, using ~20 MeV e from ERL already being developed + 40 GeV/N Au beams.

If successful, consider CeC for $\vec{p}$ beams at RHIC → EIC.

- ***Cooling time for p @ RHIC ~ 0.1-0.3 hours***
- ***Enhanced $\mathcal{L}$ facilitates contemplated measurements, e.g.: Drell-Yan test of QCD for transverse spin asym.; parity violation in hard jet prod'n; W-charm coincidences to probe strangeness contribution to proton spin.***
- ***Can detectors handle higher rates, pileup?***



Suggested Framing Questions for EIC Science Case

1) ***Is main goal of EIC “discovery” or “characterization”? If latter, what is transformational (as opposed to incremental)? How are we likely to fundamentally alter understanding of QCD and/or QCD matter? Are there likely to be implications beyond QCD? What facility features not available at HERA ($\vec{N}$, A-beams, higher L) enable transformational measurements? Not doable in p-A?***

2) ***Why should scientists not directly involved in QCD studies care about dense gluonic matter? If we find, or don’t find, clear evidence that gluon field strength saturates, what do we conclude about QCD or nuclei? Are there general implications of transition from dilute parton gas to high gauge boson occupancy?***

3) ***Are gluon degrees of freedom important for understanding nuclear structure? Should soft gluon distributions in nuclei exhibit evidence of confinement, or should saturated gluonic matter look identical in nucleons and nuclei? Can we measure gluon spatial distributions in nuclei with sufficient resolution to see nucleon-scale “clumps”?***

Suggested Framing Questions, continued…

4) If we can't solve the nucleon spin puzzle without EIC, can we solve the puzzle with EIC? Do we have a clear strategy for completing a full measurement of the spin sum rule in either target rest frame (Ji sum rule) or on light front (ΔG sum rule)?

5) What features do we hope to unravel with 3D maps from GPDs at low x (more than x-dependence of overall transverse size)? Do we have the transverse spatial resolution to see "fine" structure? Is there a viable strategy to J_q by combining DES with LQCD constraints on moments of GPD's?

6) Will the running of $\sin^2\theta_W$ below the Z-pole, at sensitivity levels accessible with PVES @ EIC still be a significant question on the timescale of EIC measurements? Are there other unique EW symmetry opportunities with EIC?

7) What fraction of above science goals could be accomplished, or at least started, with 1st lower-energy stage of EIC? In what ways can experience gained at 1st stage inform accelerator / detector design and cost-effectiveness for a full EIC?

EICAC's "Comments, Suggestions and Cautious Recommendations"

- Work out a clear and well-defined matrix of science goals vs. accelerator performance parameters (and cost). If possible identify in such a matrix (or perhaps in two separate matrices) the potential approach(es) to realizing key objectives in stages

- Distill and appropriately formulate from the range of research opportunities that the EIC provides a short list of the most compelling science objectives (and possibly "golden experiments") that can convince, and generate support from, the broader science community as represented by NSAC

- As a principal approach to a concise list of science objectives and facility parameters (including detectors), aggressively pursue the planned series of structured workshops

- Further develop the schedule including approximate resource-loading, to provide a timeline for major decisions (including, if at all possible, site decision), technical developments, and (staged) realization

EICAC's "Comments, Suggestions and Cautious Recommendations" -- continued

- In particular, strive for a timeline (under reasonable assumptions) that provides for data taking before 2020

- An obvious important near-term activity is to work out a detailed and comprehensive R&D plan. The proposed common effort between BNL and JLab should focus, to a substantial extent, on R&D for technologies needed for both facility concepts

- It would be desirable for the EICAC to see a detailed common plan at the next meeting with deliverables & resources needed to reach a buildable design for the LRP. This might also help to reduce the considerable range of possibilities being discussed to a more concrete set of scenarios for the next meeting.

EICAC requested next meeting on ~ Sept. '09 schedule, for 2 days to allow deeper discussion, and with following major deliverables:

- ***Coherent R&D plan, timeline, milestones & resource needs***
- ***Initial cost-performance-science reach matrix***
- ***Short list of "golden measure-ments" & what will be learned***
- ***Implications of golden exp'ts for detector requirements + R&D***

More Pointed Remarks from Individual EICAC Members

"If the Collaboration is truly interested in expediting the approval process – in time for the Long Range Plan in 2012, and DOE Critical Decisions (CD's) steps afterwards – then it would be prudent to converge on a site decision and machine plan as early as at all possible."

"Time scales beyond 2020 for a start of data taking are de-motivating, and unjustified it seems to me…The cost of the staged project is at the 10% level of what has been invested in RHIC, and comparable to the cost of many single purpose projects planned or envisaged in the nuclear and particle physics communities, so it is not obvious why the lead time should be so long. The laboratory(s) (in this example BNL) should investigate possibilities to have a more aggressive time scale, while the EIC collaboration should present a clear and straightforward case for a project of this scope, keeping in mind that the staged project does not already need to reach all the final project goals."

"Of the two alternatives presented, the JLAB concept is in essence a new facility even though built around the existent CEBAF. As such, a lot of (basic) accelerator design work has to be done. The ion ring has a number of challenging beam parameters (e.g. the ultra-short ion bunches, beam lifetimes, figure-8 rings etc.). This is not to ignore the challenges for eRHIC."