How PHENIX and STAR Decadal Plans Fit Into Overall RHIC Future Strategy

Steve Vigdor

RHIC 2011 PAC Meeting

BNL, June 7, 2011

I. **Broad science themes to frame the issues**
II. **Plans for the next ~5 years**
III. **Decadal plans**
IV. **Long-term future and eRHIC**
V. **Upcoming users workshop on future RHIC strategy**

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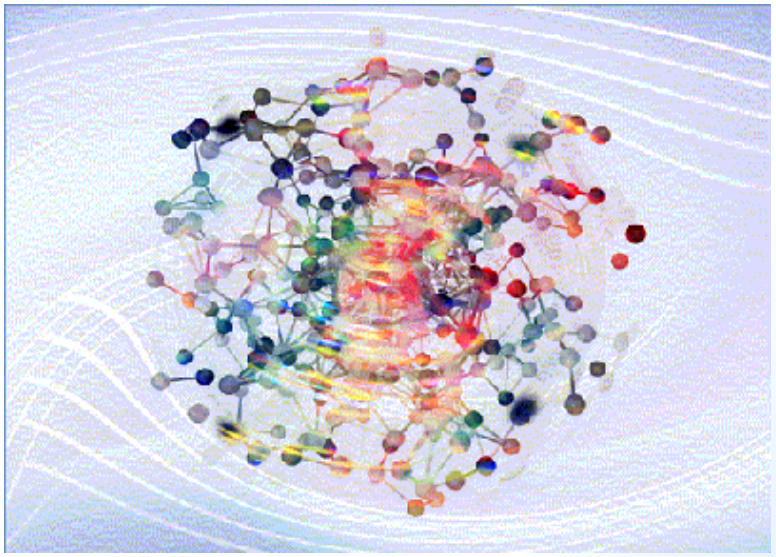
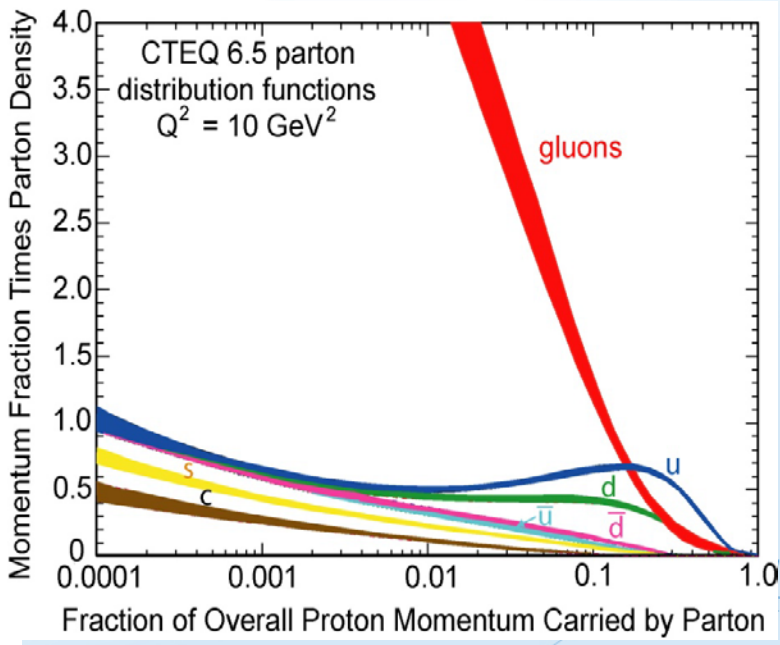
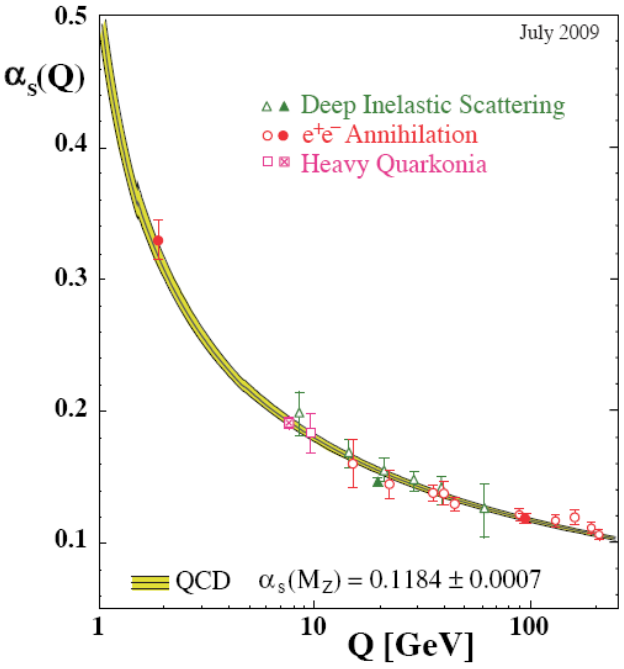
RHIC and eRHIC Science: Condensed Matter Physics with a Force of a Different Color



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., electroweak) theories, that are harder to subject to laboratory investigation? How do we pump/probe fleeting ultrahot quark-gluon matter that lives only 10^{-23} s? How do we take freeze-frame snapshots of gluons that move in cold matter on time scales ~ 10^{-23} s?



3 Examples of Basic Questions for QCD Matter at RHIC



1) *Does asymptotic freedom ⇒ high-density (of color charge) ideal Quark-Gluon Plasma gas?*

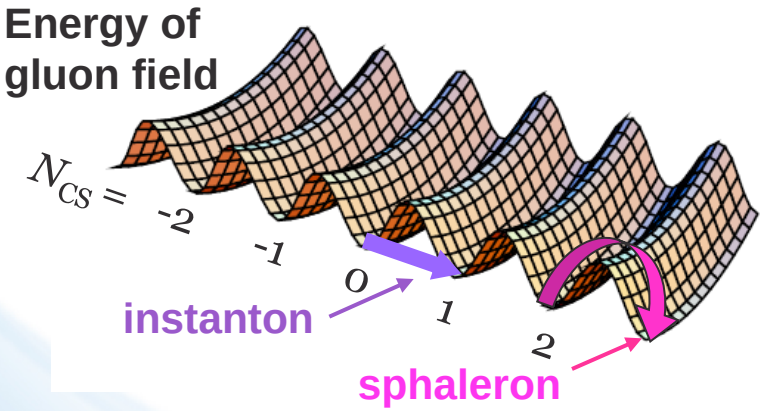
D. Gross
H.D. Politzer
F. Wilczek

American

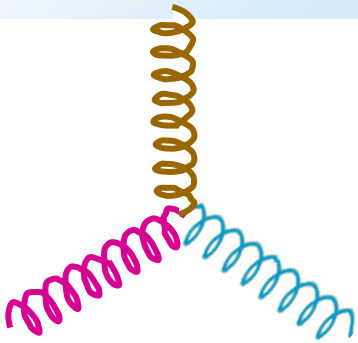
QCD Asymptotic Freedom (1973)

Nobel Prize, Physics, 2004

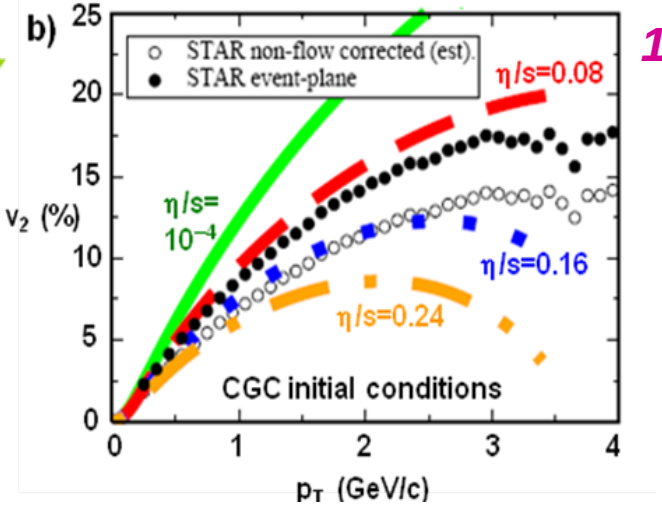
2) *Does rich topological structure of QCD vacuum ⇒ local symmetry violation from high-temperature "sphalerons" near QGP transition, analogous to ones speculated to contribute to matter-antimatter asymmetry in early universe?*



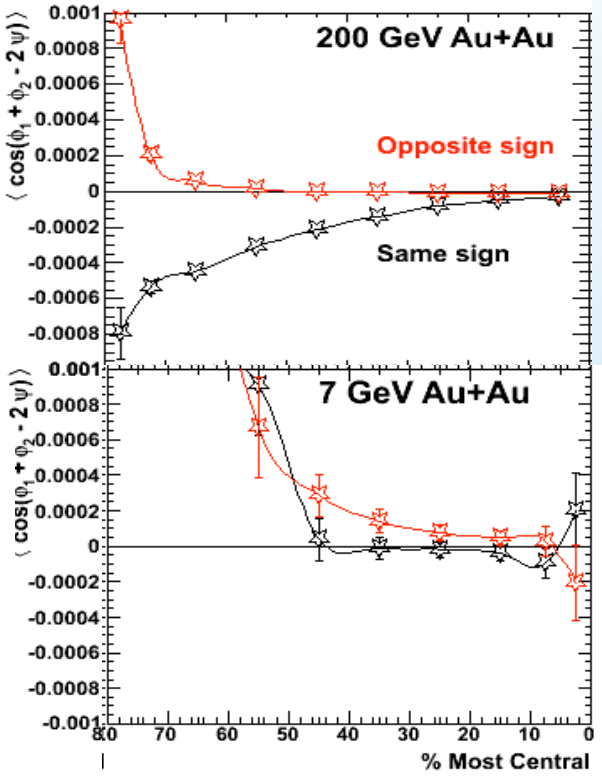
3) *Do gluon self-interactions ⇒ "universal" saturated gluonic matter at the heart of all hadrons/nuclei ? Significant gluon contributions to proton spin?*



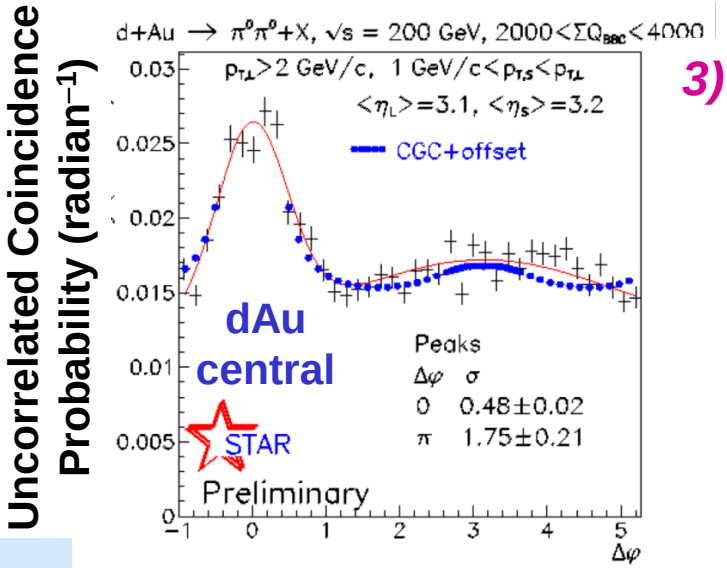
RHIC Answers to Date for Basic QCD Matter Questions



1) *From earliest elliptic flow results, QGP @ RHIC ≅ perfect relativistic quantum fluid ≠ ideal gas. Similar results from LHC. n_q scaling ⇒ sub-hadronic degrees of freedom. Viscous hydro + v_n results + other systems to alter initial geometry ⇒ path to quantify η/s vs. quantum limit.*



2) *Correlations among particles consistent with event-by-event charge separation allowed by Local P- & CP-violation. Signal ~vanishes at lower √s. Looking for further evidence…*



3) *Various RHIC observations, especially in d+Au, hint at effects of gluon saturation. No evidence yet for significant Δg. Electron-Ion Collider (EIC) needed to settle both questions.*

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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:***

- ***How perfect is the near-perfect liquid?***
- ***Is the nature of QCD vacuum transformed at RHIC T? (e.g., are LPV "bubbles" real effect? Chiral symmetry restored?)***
- ***Is there a critical endpoint in QCD phase diagram?***
- ***How is force between q and $\overline{q}$ modified in QGP?***
- ***How do partons lose energy in traversing QGP?***
- ***Does the QGP respond collectively to the lost energy?***
- ***How do nucleons get their spin from q, g constituents?***
- ***…***

Issue: ***Define complementarity to LHC HI clearly & compellingly!***

Medium-term (2017-2022): ***PHENIX, STAR Decadal Plans aimed at pursuing compelling long-term questions in A+A, d(p)+A, and $\vec{p}+\vec{p}$ that require further detector upgrades***

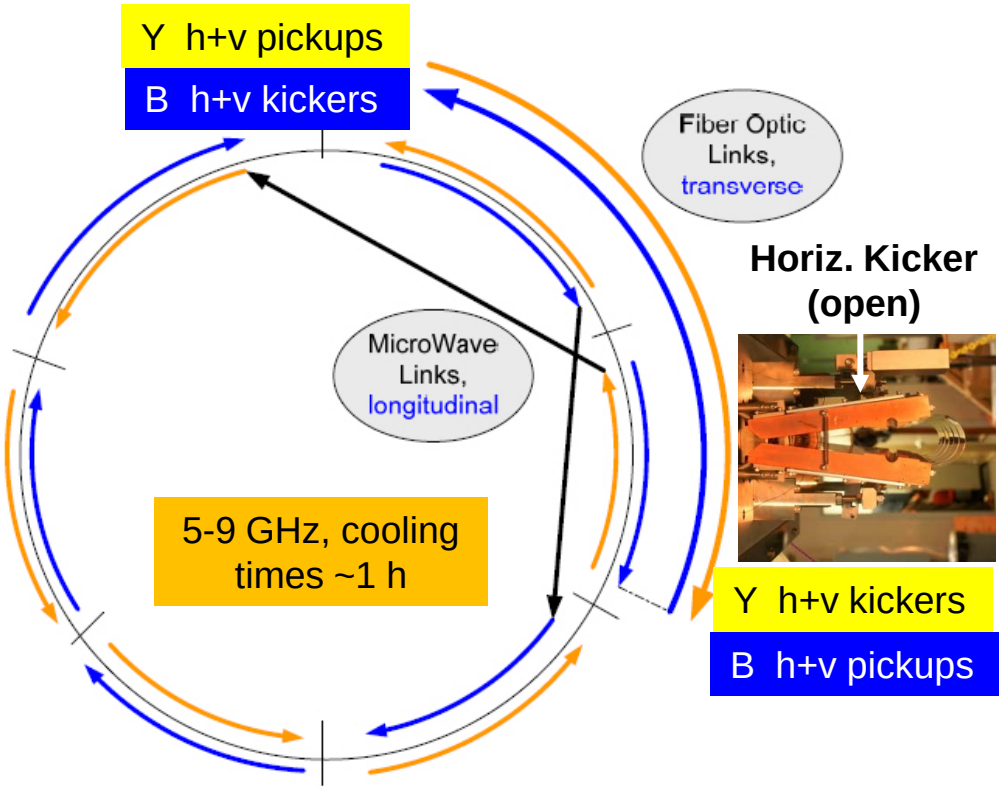
Issues: ***Why are RHIC HI collisions still needed? Can national NP budget support operations at CEBAF, RHIC and FRIB, plus construction of EIC? What is optimal strategy for RHIC going into next NP Long Range Plan?***

Three Stages of RHIC's Future

Long-term (> 2022): ***eRHIC – add ~5 GeV (upgradable to 30 GeV) electron Energy Recovery Linac inside RHIC tunnel to facilitate e+A, $\vec{e}+\vec{p}$ ($^3\vec{He}$) experiments aimed at studying gluon-dominated cold matter. Fall 2010 INT Workshop progressed in defining golden experiments, core science program.***

Issues: ***Can we match compelling science program to realizable project cost? How do we transition from RHIC to eRHIC – can we accommodate continuing A+A and p+p programs in parallel with e+A and e+p? Will we have to sacrifice some years of RHIC operations to support eRHIC construction?***

RHIC Luminosity Upgrades Under Way



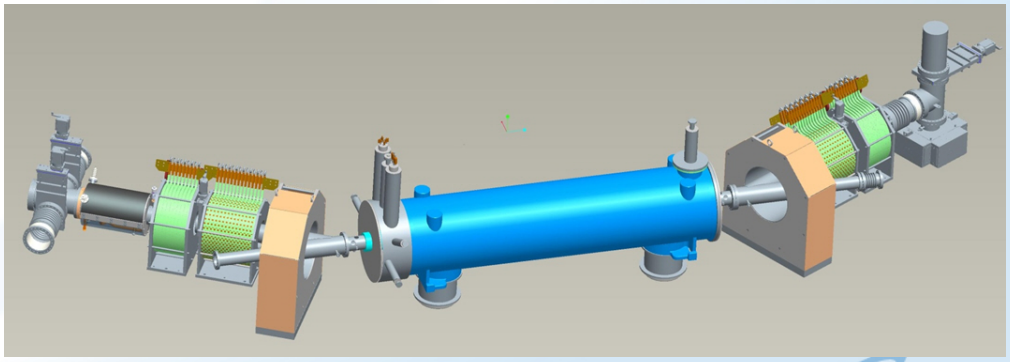
Horiz. Kicker (open)

- ***RHIC breakthrough in bunched-beam stochastic cooling overcomes intrabeam scattering limits, facilitates ~x10 improvement in heavy-ion collision rates, 4 years earlier and at ~1/7 the cost envisioned in 2007 NP Long Range Plan.***

- ***Much of the new system commissioned during 2010, rest anticipated for 2012-2014 runs (aided by ARRA funds).***

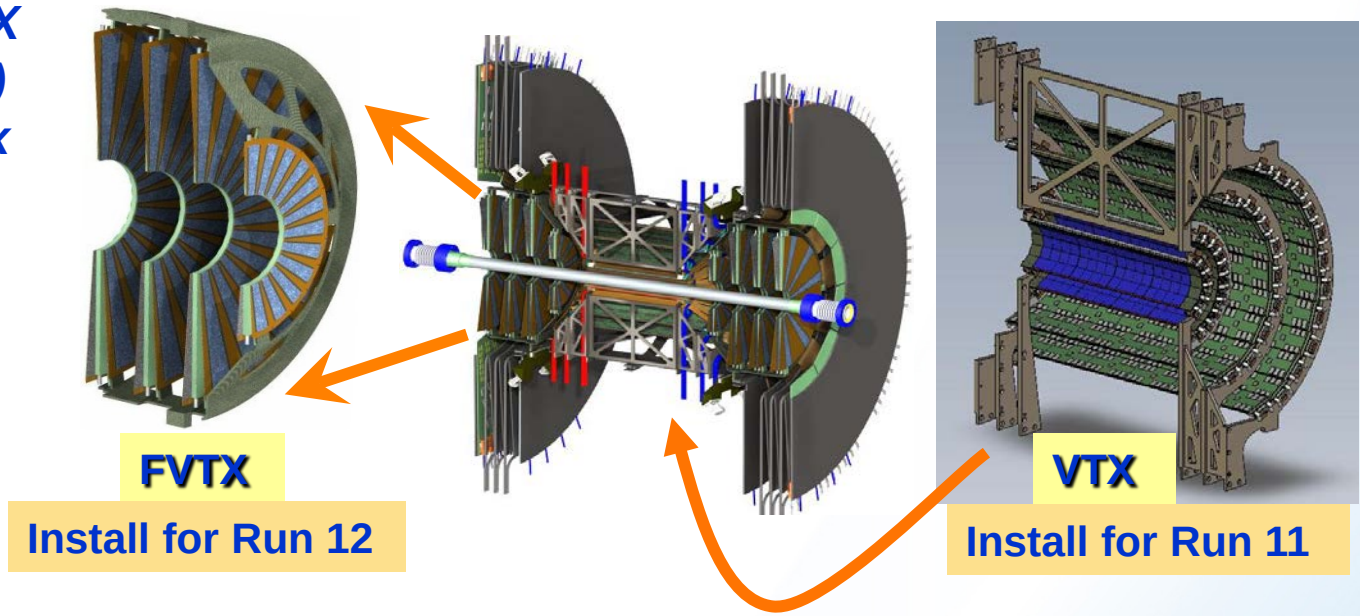
- ***Electron lenses (with ARRA + AIP support) to be installed for 2013 run will use few keV e+p collisions to compensate partially for p+p beam-beam betatron tune shift/spread***

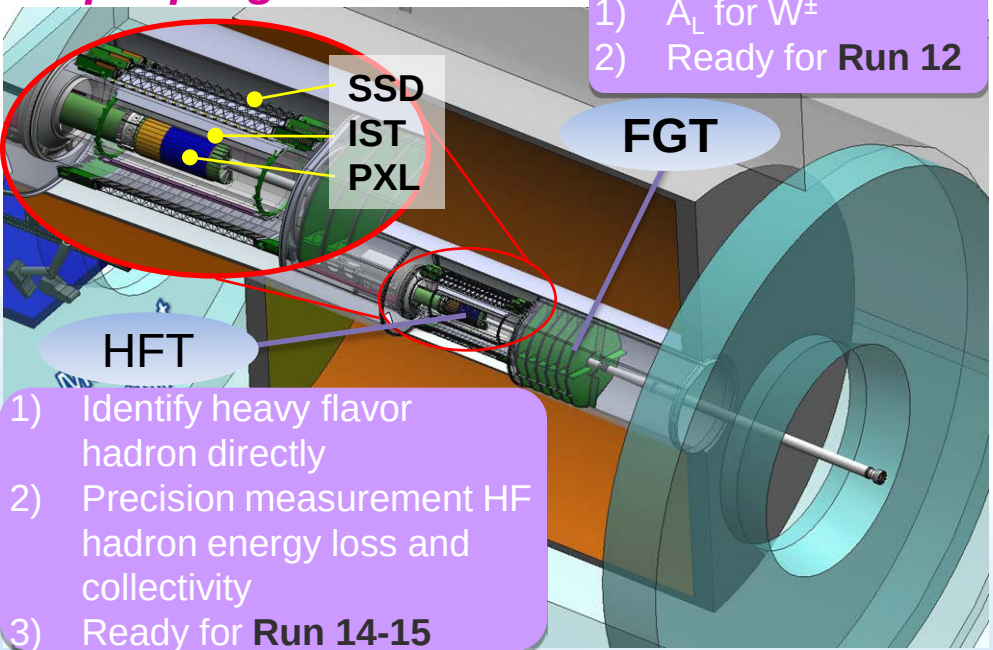
- ***Hope to improve polarized p+p luminosities by factor ~2***



RHIC Detector Upgrades Under Way

- ***PHENIX VTX & FVTX upgrades (ONP funds) greatly improve vertex resolution, heavy flavor ID***
- ***μ trigger upgrade (NSF + Japanese funds) installed in FY10-11 enhances W prod'n triggering for spin program.***





1) A_L for $W^{\pm}$
2) Ready for **Run 12**

1) Identify heavy flavor hadron directly
2) Precision measurement HF hadron energy loss and collectivity
3) Ready for **Run 14-15**

- ***STAR Heavy Flavor Tracker receives CD-1 in FY10; CD-2/3 review in July 2011. Will permit topological reconstruction of charmed hadrons.***
- ***STAR Forward GEM Tracker (RHIC capital equipment project) to be installed for Run 12, will enhance forward tracking, W charge sign discrimination.***

Plans and Upgrades for Coming ~5 Years Address All New RHIC-Related NP 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 √sNN 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 √sNN = 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 √sNN = 200 GeV.

Making clear progress toward all the above! New "small" exp't AnDY under consideration to address HP13 via Drell-Yan spin asymmetries.

Not all the exciting physics from RHIC is yet incorporated in existing milestones…

For example:

1) ***Does explanation of Local Parity Violating bubbles (and close analogy to speculated origin of baryon-antibaryon asymmetry at EW phase transition) hold up under more detailed scrutiny (energy dependence, U+U collisions)?***

2) ***Can we observe predicted sequential melting of different quarkonium species in QGP?***

3) ***Are gluon densities saturated in RHIC's colliding (cold) nuclei?***

4) ***Can we produce even heavier anti-hypernuclei?***

Updated RHIC 5-Year Run Plan

Assumes sufficient ops. funding for healthy 2-species run each year; aimed at meeting NP Performance Milestones on schedule; will be updated as we have definitive information about upgrade schedule and/or budget changes

Year	Likely Beam Species	Science Goals	New Detector Sub-systems	New Machine Upgrades	Gain from Machine Upgrades	Comments
FY10 ✓	Au+Au at 200, 62.4 GeV + assorted lower E	Low-mass dilepton spectrum; early collision temp.; improved jet quenching studies (especially e^- from heavy quarks); begin energy scan for critical pt.	STAR TOF completed; PHENIX HBD for heavy ions	Blue ring longitudinal + yellow and blue vertical stochastic cooling; yellow longitudinal cooling (μwave link) upgrade	Factor >2 increase in average store luminosity for full-energy Au+Au	Need 4-8 weeks early in run to (re)com-mission all 4 stoch. cooling systems, demonstrate gain in lumi. lifetime
FY11	200 GeV Au+Au; 500 GeV p+p; short 200 GeV U+U; continue low-E Au+Au scan	Bottom vs. charm suppression, flow; antiquark pol'n from W production; 1st characterization of deformation effects in U+U centrality distrib'ns; continue critical pt. search	PHENIX VTX engineer-ing run; AnDY installed, commis-sioned in IP2	EBIS commis-sioning; 9 MHz cavity; RHIC beam dump; AGS tune jump quads (comm'd in Run 10); RHIC spin flipper	U beam capability; improved pp vertex distrib'n; improved pol'n from AGS; reduced syst. errors	9MHz requires upgrade to main PS + "bouncer" cavity for both rings + longitudinal damper or Landau cavity for each ring.

Year	Likely Beam Species	Science Goals	New Detector Sub-systems	New Machine Upgrades	Gain from Machine Upgrades	Comments
FY12	Au+Au and U+U at 200 GeV; 500 GeV p+p	RHIC-II HI goals: heavy flavor, γ-jet, quarkonium, multi-particle correlations; anti-quark and low-x gluon polariza-tions in proton	PHENIX FVTX and μ trigger; PHENIX DAQ/trig upgrades; STAR FGT	Full yellow + blue horiz. stoch. cooling (6 planes in all);	Further heavy-ion luminosity improve-ments + improved proton polarization	"Proton cannon" increases pol. source current, to allow scraping to improve polarization
FY13	200 + 500 GeV p+p; further heavy-ion running to comple-ment earlier runs	Continue RHIC-II heavy-ion goals; transverse spin asymmetry for Drell-Yan (2015 spin milestone); pp reference data for new subsystems	STAR HFT prototype	Polarized source upgrade; Electron lenses	improved pp luminos-ity	Electron lens commission-ing $\Rightarrow$ Run 13 gains possible; detailed collimator upgrade plans still to be developed
FY14	200 GeV Au+Au; low-E Au+ Au dictated by Run 10+ 11 results	Continue pursuit of γ + jet, energy scan and identified heavy flavor (DM10-12) milestones; quarkonium prodn	STAR HFT pixel det. (full HFT in Run 15); 50% STAR MTD ?	RHIC collimator upgrade; 56 MHz SRF; coherent e-cooling install starts in IP2	Full RHIC-II heavy-ion luminosity + improved vertex & store length	

Short-Term Take-Away Message:

1) There are a good number of exciting physics questions to pursue for next ~5 years, fueled by recent and ongoing upgrades.

2) RHIC operations are likely to be funded reasonably for next ~5 years, barring federal budget disasters (which could well occur!).

3) We will get asked repeatedly why RHIC funding should continue, when there is a newer machine that can address similar issues, and budgets are very tight. Early LHC HI results + emerging results from RHIC beam energy scan ⇒ RHIC is in a "sweet spot" in energy range & can exploit beam species versatility.

4) We need to develop a coherent strategy for RHIC's long-term future during the next two years. The user community must be actively engaged in this process.

The Different Approaches of PHENIX & STAR Decadal Plans

Questions for PHENIX Plan:

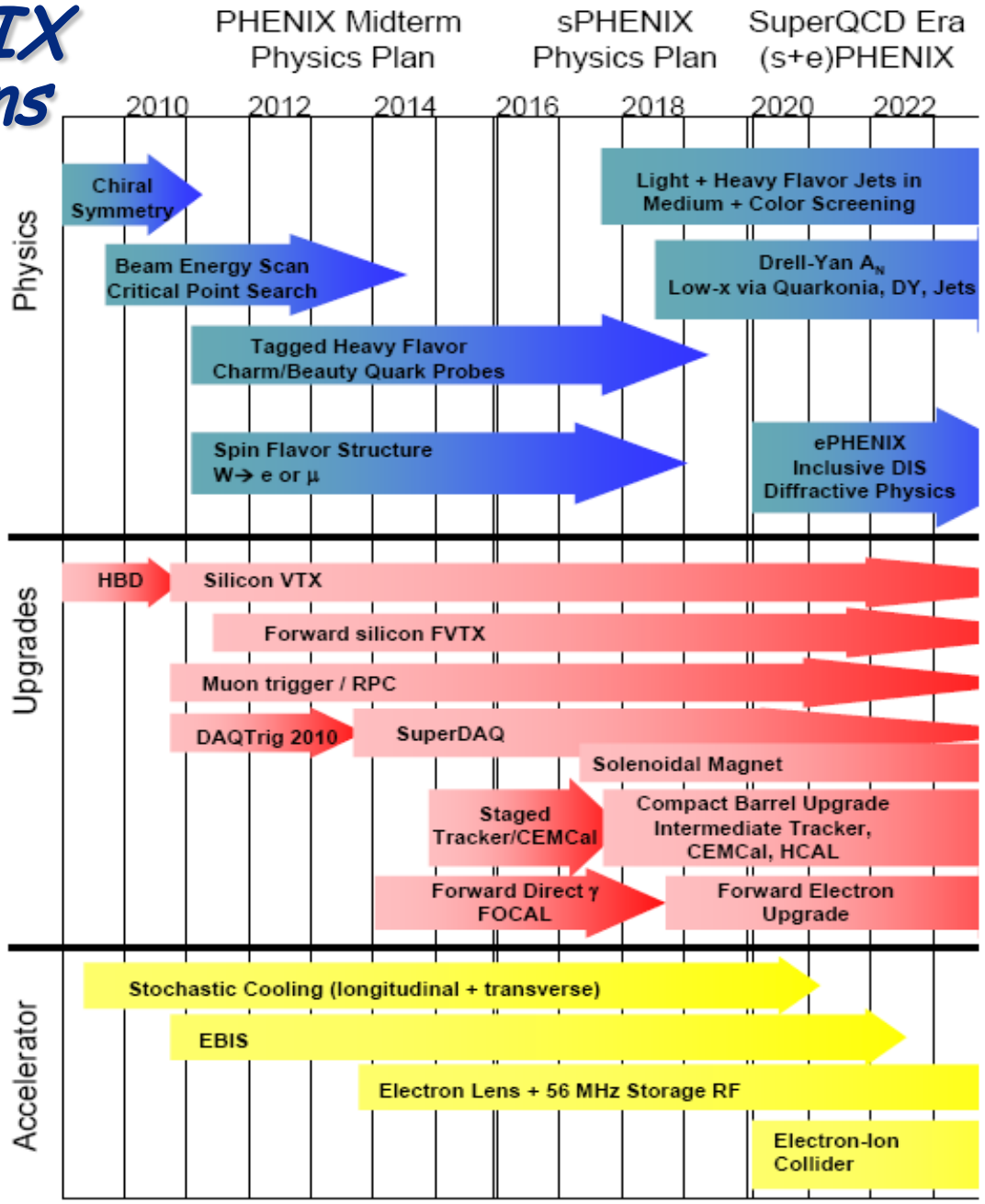
1) ***Does science case justify major overhaul $$$?***

2) ***Does jet focus play too much into LHC strengths?***

3) ***Can we understand parton interactions in QGP well enough for jets to quanti-tatively probe degrees of freedom vs. length scale?***

4) ***Can we supplement DOE $ by foreign investments? Stage barrel upgrades?***

5) ***Is ePHENIX well enough integrated into Plan?***



The Different Approaches of PHENIX & STAR Decadal Plans

Questions for STAR Plan:

1) *What is the need for A+A beyond 2017? Are collaborators primarily interested in HI collisions on board with Plan?*

2) *Is science plan strong enough to support RHIC operations beyond ~2017?*

3) *Will TPC remain robust throughout another decade?*

4) *What is time scale for fleshing out what eSTAR comprises?*

	Near term (Runs 11–13)	Mid-decade (Runs 14–16)	Long term (Runs 17–)
Colliding systems	p+p, A+A	p+p, A+A	p+p, p+A, A+A, e+p, e+A
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	Υ, $J/\psi \to ee$, m_{ee}, v_2	Υ, $J/\psi \to \mu\mu$, Charm v_2, R_{CP}, Charm corr, Λ_c/D ratio, μ-atoms	p+A comparison
(2) Mechanism of energy loss	Jets, γ-jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, c/b in CNM
(3) QCD critical point	Fluctuations, correlations, particle ratios	Focused study of critical point region	
(4) Novel symmetries	Azimuthal corr, spectral function	$e-\mu$ corr, $\mu-\mu$ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	W A_L, jet and di-jet A_{LL}, intra-jet corr, $(\Lambda+\bar{\Lambda})$ D_{LL}/D_{TT}		$\bar{\Lambda}$ D_{LL}/D_{TT}, polarized DIS, polarized SIDIS
(7) QCD beyond collinear factorization	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, J/ψ, F-F corr, Λ, DIS, SIDIS

Charge for June 6-8 PAC Review of Decadal Plans

1) Are the science goals in each Plan well-posed and compelling? Are there important questions addressable with RHIC's capabilities (perhaps after minor upgrades) that you find missing from the Collaboration's list?

2) How well do the suggested measurement programs answer the highlighted science questions? Are there additional simulations or theoretical work that would strengthen the case for making those measurements?

3) Are the suggested measurement techniques and upgrades essential for answering these questions? (For example, can some questions be adequately answered by high-p_T hadron detection without full jet reconstruction?)

4) Is the complementarity of the proposed RHIC program and of LHC heavy-ion capabilities clearly defined and convincing? If not, what would it take to clarify complementarity?

5) Do the measurements proposed with polarized beams constitute a compelling extension of the RHIC Spin Program, achievable with anticipated integrated luminosities?

6) Do the plans and proposed detector upgrades provide the basis for a useful transition of each Collaboration to an era with substantial focus on ep and eA collisions at an eRHIC?

7) How would you rank the priority (high, medium or low) of each proposed upgrade, taking into account both scientific and technical merit and rough estimates of cost?

8) Does the suite of proposed measurements justify RHIC operations beyond ~2017, assuming RHIC-II luminosities? If not yet, how can the case be strengthened?

Possible Decadal Machine Upgrades

Among possible collider upgrades under discussion beyond ~2017 are:

- ***Low-energy electron cooling if beam energy scan results make compelling case for higher luminosity running below HI injection energy***

- ***12 GHz upgrade of stochastic cooling systems for further luminosity increase of high-energy HI collisions***

- ***Removal of DX magnets and IR rebuild to allow higher beam energy (especially useful for pp) and lower β^*, thus higher luminosity***

- ***Coherent electron Cooling (CeC) to boost pp luminosities. CeC is needed for eRHIC, and proof-of-principle demonstration is BNL-JLab-Tech X R&D collaboration with ONP funding.***

Possible layout in RHIC IP of CeC driven by a single linac – **to boost polarized pp-luminosity**

Medium-Term Take-Away Message:

1) Need PAC feedback mostly on basic question: do Decadal Plans provide compelling basis for developing RHIC operations case beyond ~2017? How could they be sharpened to do so better?

2) The argument of complementarity with LHC HI needs to be sharpened: what are the unique and critical strengths RHIC brings to the investigation of QCD matter?

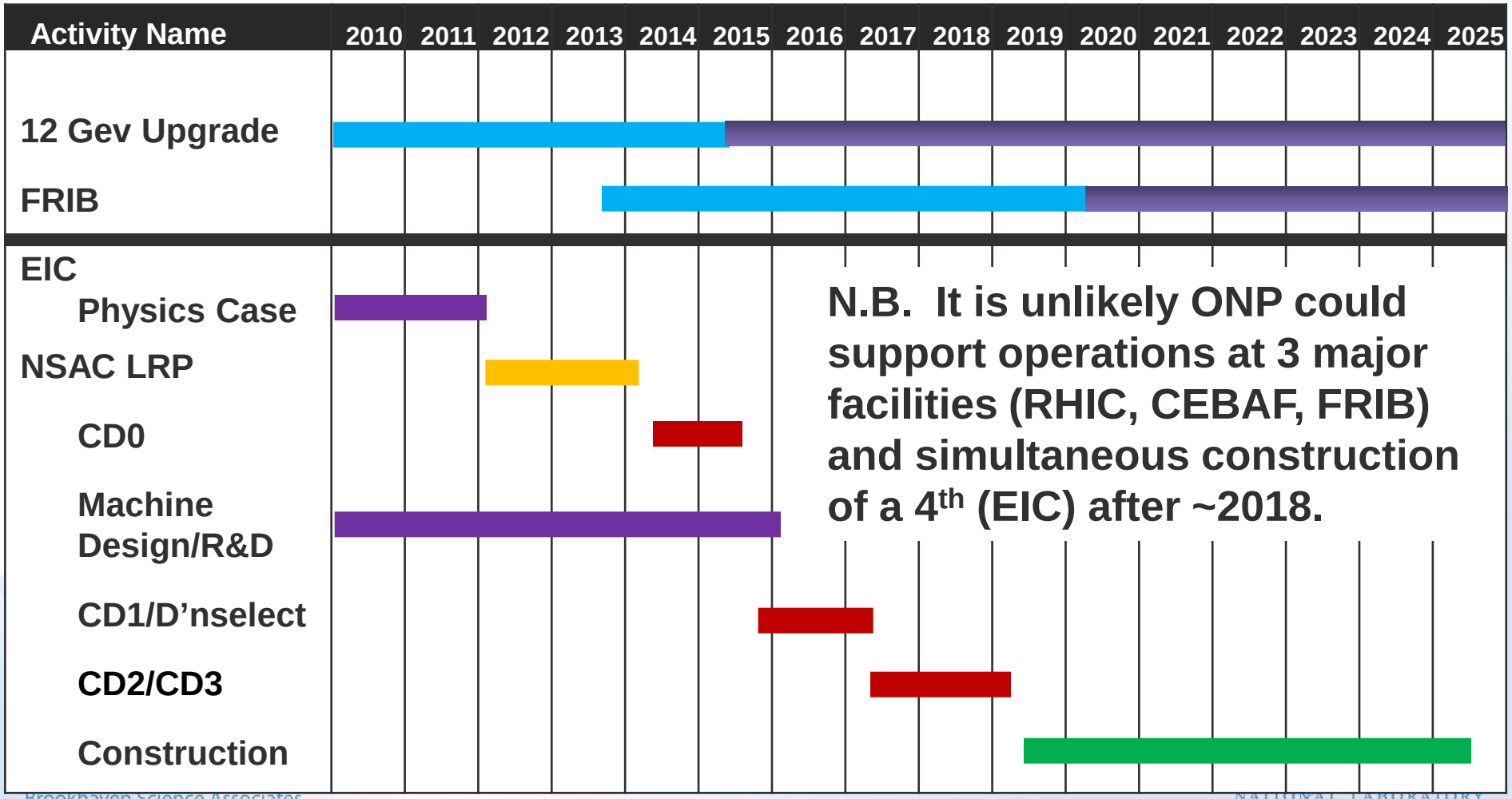
2) All detector and machine upgrade plans for this period need to be clearly connected to a long-term strategy for the facility.

3) The PHENIX and STAR Decadal Plans are the **beginning** of a process of defining the long-term strategy. There are significant questions for both, and both are likely to evolve as we develop the long-term strategy.

4) It will be extremely challenging to attract DOE funding at levels > ~ $20M for machine and detector upgrades in this period, unless they are part of a larger project, such as eRHIC, or can be shown to save costs for a later eRHIC. Foreign and NSF contributions can certainly help.

Potential Electron-Ion Collider Timeline Shown by Hugh Montgomery at INT Workshop, Sept. 2010

EIC Realization Imagined



EIC ⇒ High-Resolution, Ultra-Fast Imaging of Gluon-Dominated Matter

Twin central themes:

1) ***Probing the momentum-dependence of gluon densities and the onset of saturation in nucleons and nuclei***
2) ***Mapping the transverse spatial and spin distributions of quarks and gluons in the gluon-dominated regime***

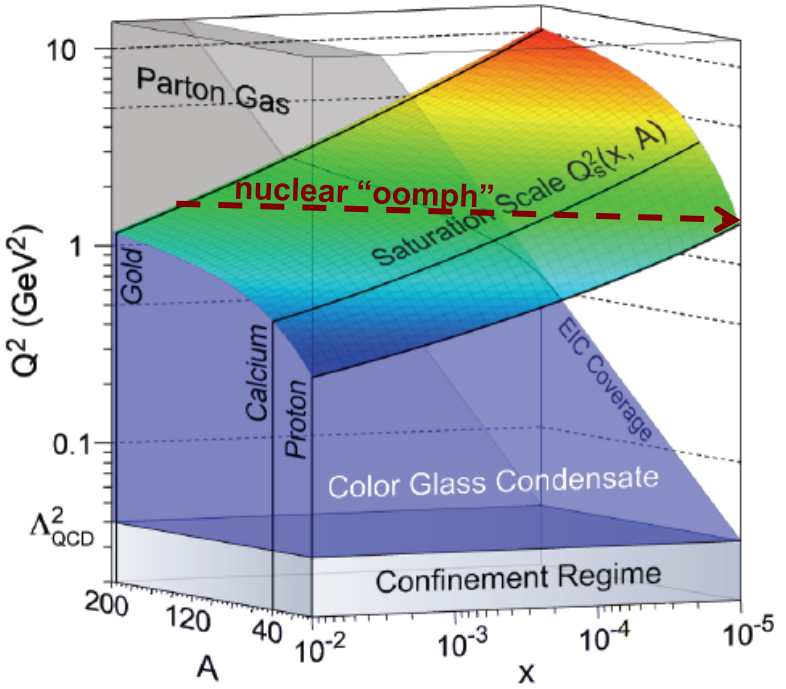
Real questions from Galveston LRP 2007:

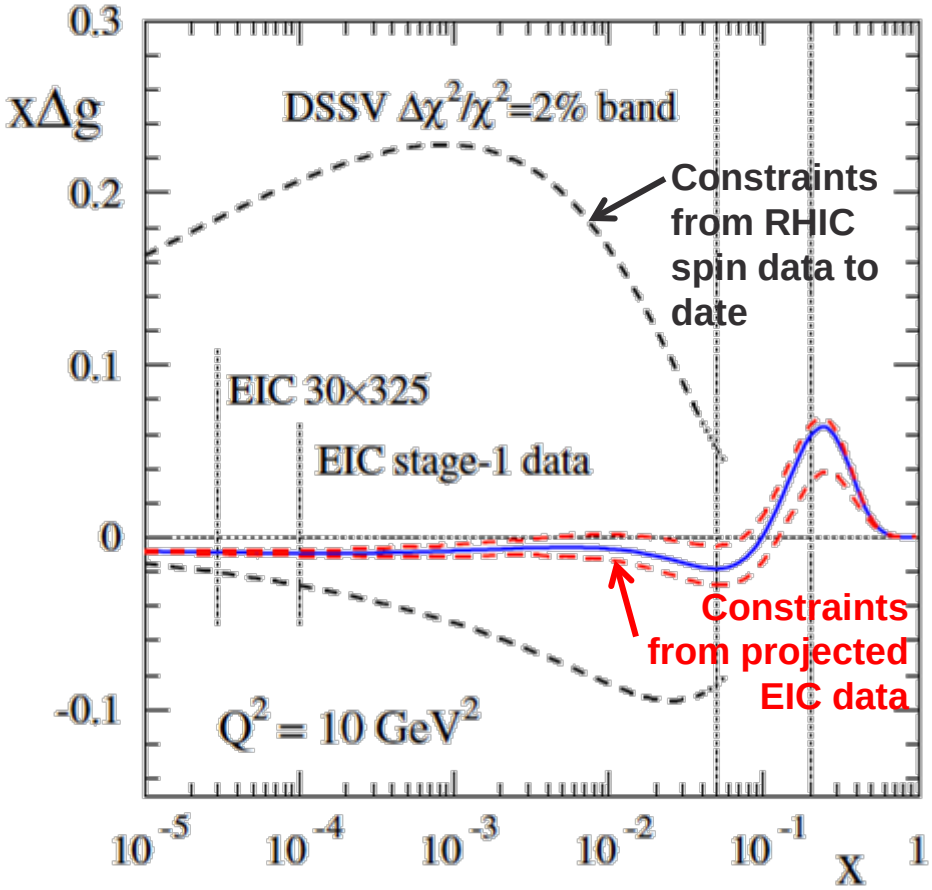
1) ***Why should we care about gluon-dominated matter? How do goals connect to other physics goals? Why of interest to nuclear physicists?***
2) ***Is an electron machine necessary? Why not just p+A @ RHIC, LHC?***
3) ***What will EIC do that HERA couldn't?***
4) ***If we haven't solved the nucleon spin puzzle yet, why do we need a new expensive facility to pursue it further?***

At next LRP, need to answer these questions crisply! Non-linear QCD regime of high gluon density is critical to understanding high-energy scattering and hadron mass generation. EIC would probe it in theoretically tractable region.

What Will EIC Have That HERA Didn't?

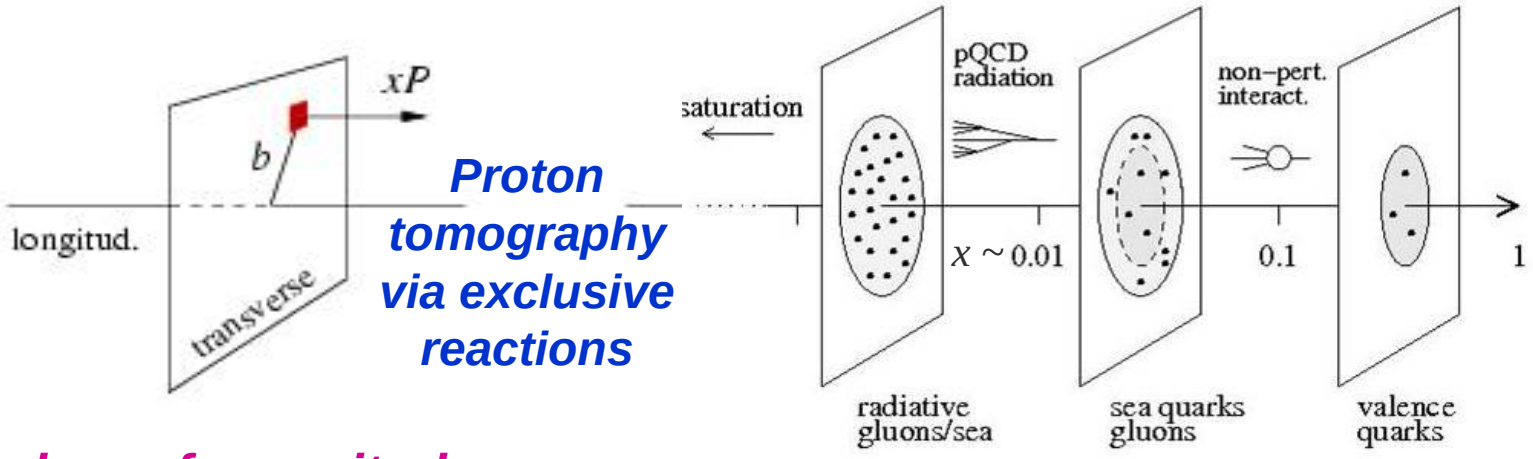
1) *Heavy-ion beams to take advantage of coherent contributions of many nucleons to gluon density, provide more cost-effective reach into gluon saturation regime when QCD coupling is still weak.*





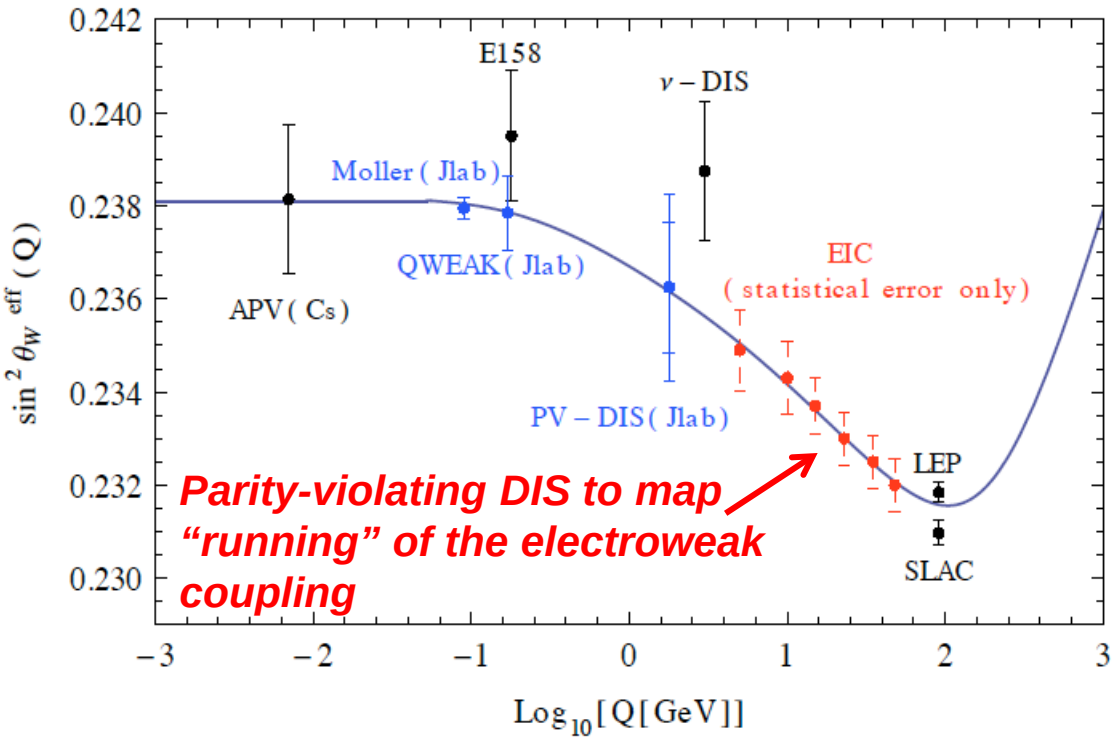
2) *Polarized proton and ^{3}He (for neutron), as well as electron, beams to pursue search for gluon contributions to nucleon spin down to very soft gluons, and map spin-momentum correlations of quarks and gluons inside nucleons.*

What Will EIC Have That HERA Didn't?



Proton tomography via exclusive reactions

3) 3 orders of magnitude higher collision luminosity to facilitate exclusive reaction studies yielding 2+1-dim'l maps of internal nucleon wave function, and symmetry violation studies of fundamental electroweak interaction properties.



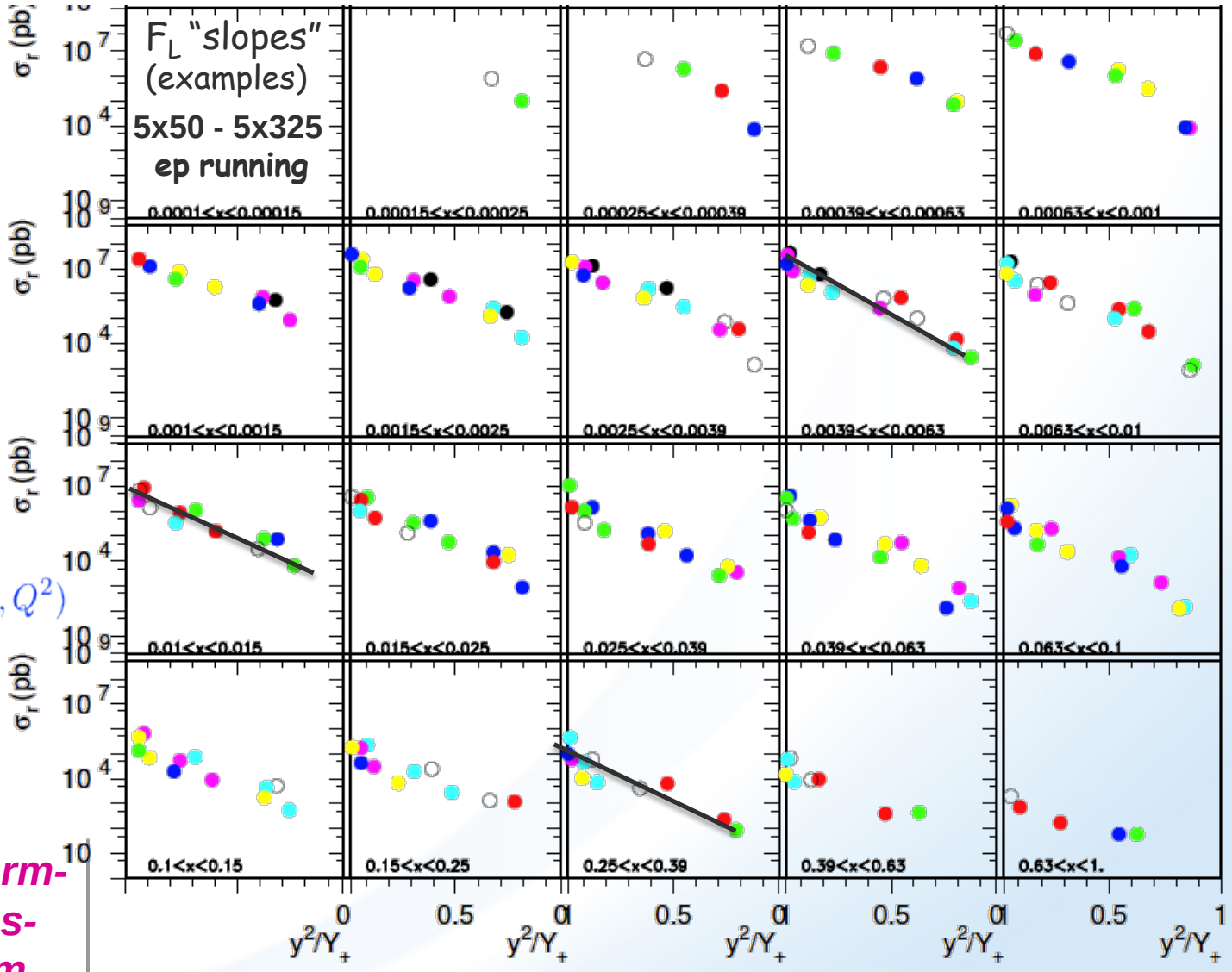
What Will EIC Have That HERA Didn't?

4) Wide variability in both electron and hadron energy, permitting separation of longitudinal from transverse structure functions.

$$\sigma_r = F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)$$

$$y = Q^2/xS$$

$$Y_+ = 1 + (1-y)^2$$



F_L gives direct information on gluon density, determined from slope of y^2/Y_+ for different S at fixed x,Q^2

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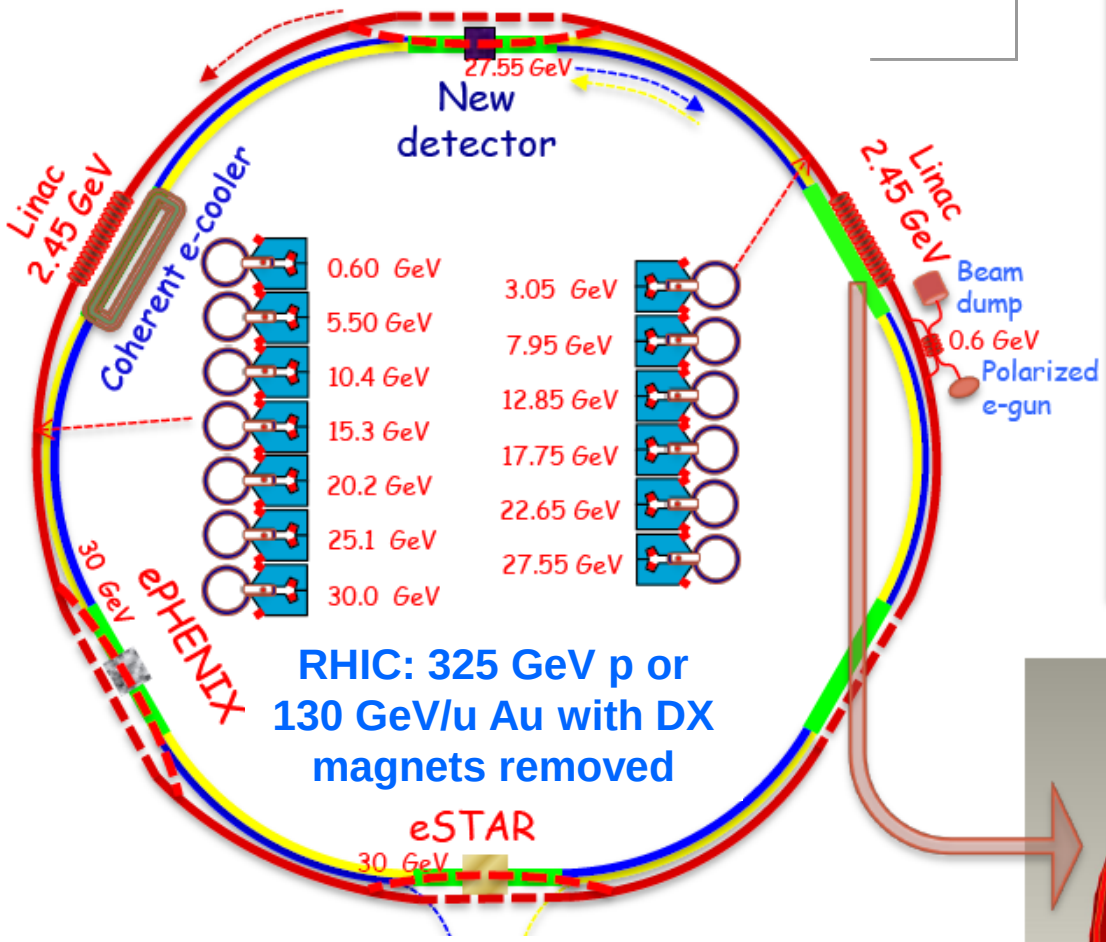
e+A Golden Science Matrix

Primary new science deliverables	What we hope to fundamentally learn	Basic measurements	Typical required precision	Special requirements on accelerator/ detector	What can be done in phase I	Alternatives in absence of an EIC	Gain/Loss compared with other relevant facilities	Comments
integrated nuclear gluon distribution	The nuclear wave function throughout x-Q^2 plane	F_L, F_2, F_L^c, F_2^c	What HERA reached for F2 with combined data	displaced vertex detector for charm	stage I: large-x & large-Q^2 need full EIC, for F_L and F_2^c	p+A at LHC (not as precise though) & LHeC	First experiment with good x, Q^2 & A range	This is fundamental input for A+A collisions
k_T dependence of gluon distribution and correlations	The non-linear QCD evolution - Qs	SIDIS & di-hadron correlations with light and heavy flavours		Need low-pt particle ID	SIDIS for sure TBD: saturation signal in di-hadron p_T imbalance	I) p+A at RHIC/LHC, although e+A needed to check universality 2) LHeC	Cleaner than p+A: reduced background	
b dependence of gluon distribution and correlations	Interplay between small-x evolution and confinement	Diffractive VM production and DVCS, coherent and incoherent parts	50 MeV resolution on momentum transfer	hermetic detector with 4pi coverage low-t: need to detect nuclear break-up	Moderate x with light and heavy nuclei	LHeC	Never been measured before	Initial conditions for HI collisions – eccentricity fluctuations

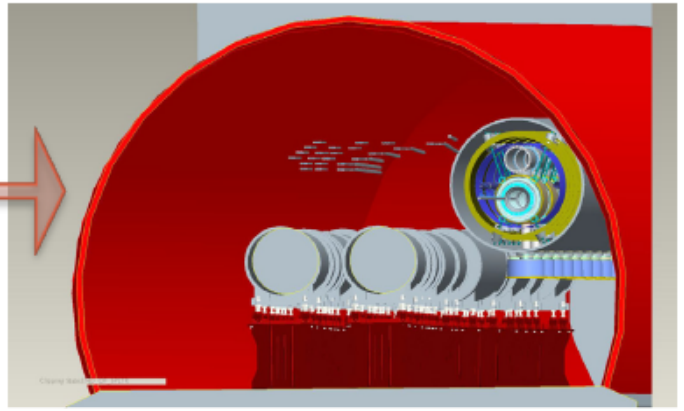
eRHIC Design Under Active Consideration



✓All-in tunnel staging approach uses two energy recovery linacs and 6 recirculation passes to accelerate the electron beam.

✓Staging: the electron energy will be increased in stages, from 5 to 30 GeV, by increasing the linac lengths .

✓Up to 3 experimental locations



Vis-à-vis earlier MeRHIC design, this allows for:

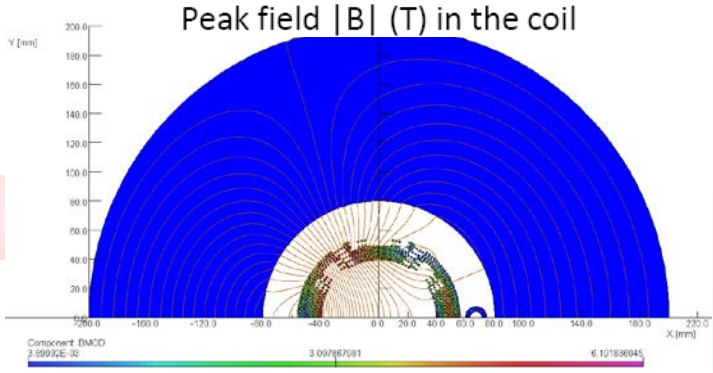
- ***more IP's***
- ***reduced cost***
- ***reusing infrastructure + det. components for STAR, PHENIX***
- ***easier upgrade path from 5 GeV eRHIC-I***
- ***minimal environmental impact concerns***
- ***IR design to reach 10^{34} luminosity***

eRHIC IRs, β*=5cm, l*=4.5 m

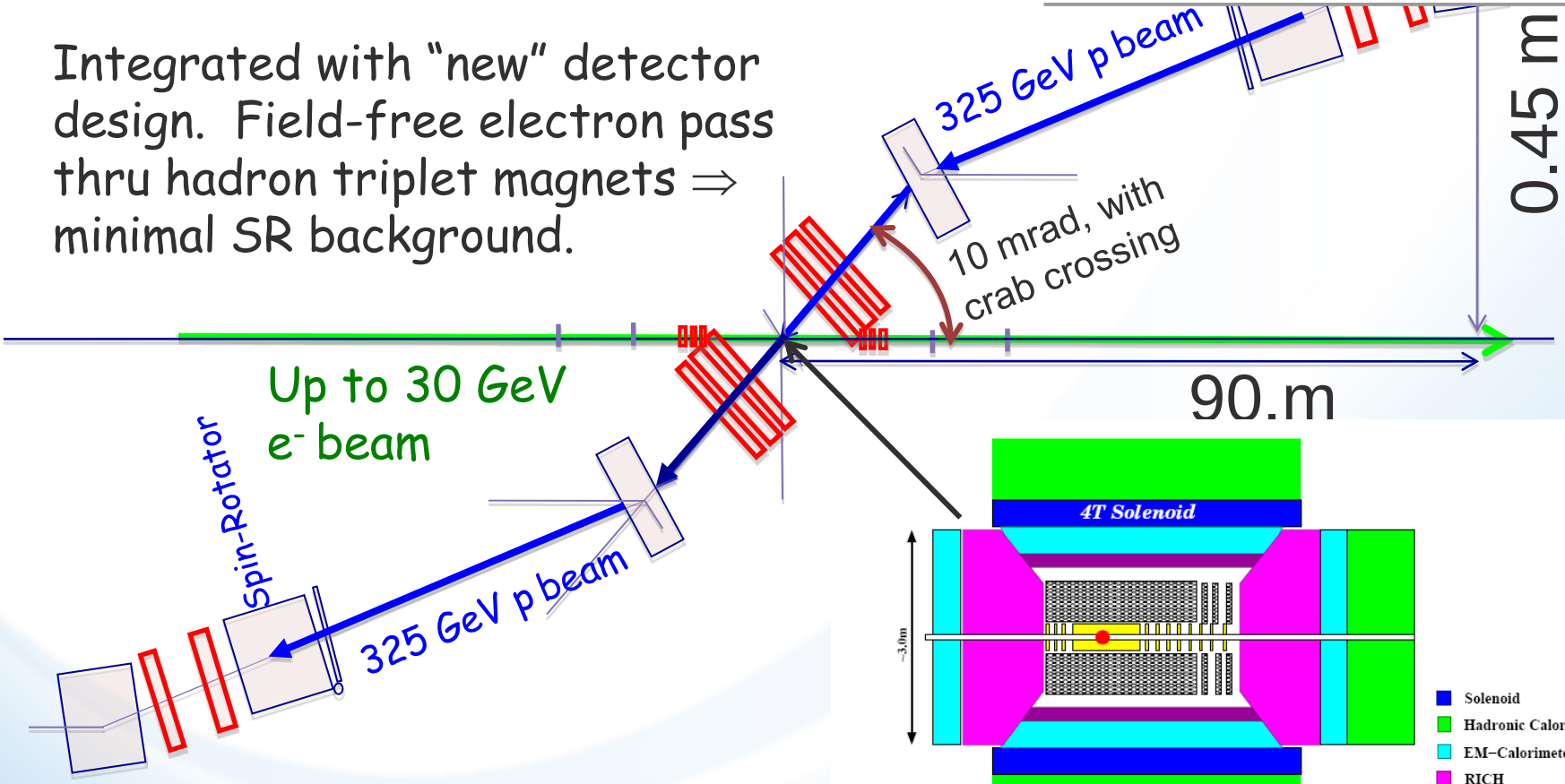
L=1.4x10^{34}cm^{-2}s^{-1}, 200 T/m gradient

Exploit LARP development of Nb_3Sn SC quads with 200 T/m gradient

Integrated with "new" detector design. Field-free electron pass thru hadron triplet magnets ⇒ minimal SR background.



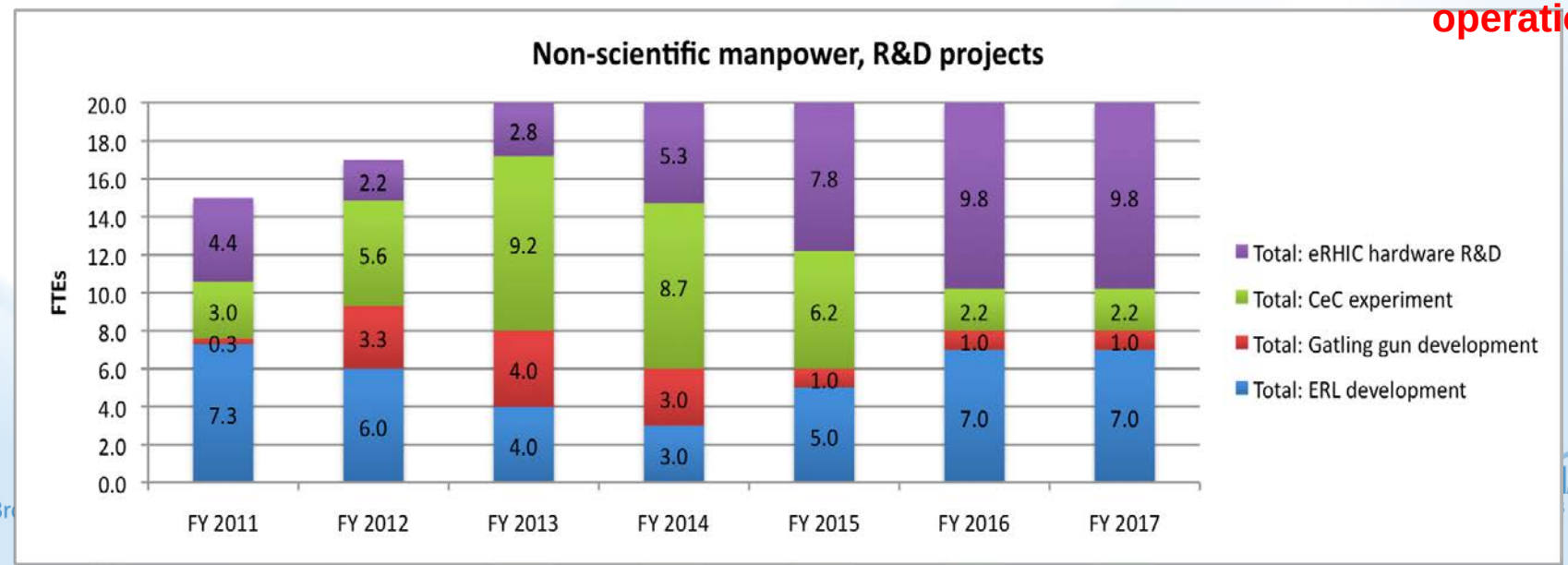
IR combined function magnet design



eRHIC Accelerator R&D is a Major Long-Term Commitment

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
ERL constr./commissioning	7.3	6.0	4.0	1.0	1.0	1.0	1.0
Second return loop				2.0	4.0	6.0	6.0
Total: ERL development	**7.3**	**6.0**	**4.0**	**3.0**	**5.0**	**7.0**	**7.0**
Gatling Gun	0.3	3.3	4.0	3.0	1.0	1.0	1.0
Total: Gatling gun development	**0.3**	**3.3**	**4.0**	**3.0**	**1.0**	**1.0**	**1.0**
CeC POP	2.0	2.2	6.2	8.7	6.2	2.2	2.2
112 MHz Gun / Cryomodule		1.0	1.0				
BNL-3 "eRHIC" Cavity & Cryomodule	1.0	2.4	2.0				
Total: CeC experiment	**3.0**	**5.6**	**9.2**	**8.7**	**6.2**	**2.2**	**2.2**
eRHIC Design / cost estimate	3.9	1.3	2.3	2.3	2.3	2.3	2.3
Small gap magnets	0.5	0.9	0.5				
Crab cavities				2.0	2.5	4.5	4.5
eRHIC RF power & control				1.0	3.0	3.0	3.0
Total: eRHIC hardware R&D	**4.4**	**2.2**	**2.8**	**5.3**	**7.8**	**9.8**	**9.8**
Total non-scientific:	**15.0**	**17.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**
Total scientific:	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**

30 FTE supported from RHIC operations



Upcoming and Recent Planning Exercises and Milestones

April 10, 2011: *3rd EIC International Advisory Committee meeting*

May 9-10, 2011: *Detector Advisory Committee review of first round of submitted EIC detector R&D proposals*

June 6-8, 2011: *PAC review of PHENIX & STAR Decadal Plans*

June 21-24, 2011: *RHIC user workshop to develop optimal RHIC strategy going into LRP*

June 27-29, 2011: *RHIC annual S&T review with 'all-star' panel*

August 1-3, 2011: *eRHIC technical design review*

Fall 2011: *EIC science White Paper (Steering Committee appointed and charged, with BNL-JLab-EICC agreement); eRHIC cost review*

Fall 2012 (??): *Town Meetings for next Nuclear Physics LRP?* ⇒ *Formulate RHIC strategy clearly by Summer 2012, presumably by time of August 2012 Quark Matter in Washington, D.C.*

Agenda for Users' Workshop on RHIC Future Strategy (June 21-24, 2011)

Session I: Long-Term Options and Near-Term Plans

Session II: The Role of Heavy Ion Collisions at RHIC Beyond ~2017

Session III: PHENIX and STAR Decadal Plans

Session IV: eRHIC S&T

Session V: Panel and Community Discussion Toward Developing a RHIC Strategy to Present at Next Long Range Plan

Among the critical questions to be discussed:

1) Since LHC HI results very similar to RHIC's, are both facilities needed? Which critical QCD matter questions are best answered at RHIC?

2) Will 2-3 year cessation of RHIC ops. be essential to fund eRHIC? If so, what is optimal timing?

3) Is it crucial to maintain AA & pp capability into eRHIC era? If so, can we reconfigure IR's annually, or do we separate HI from eA in different IR's?

4) What eRHIC science is realizable within $500M total project cost limit?

5) What is optimal path for detectors and collaborations to evolve from RHIC to eRHIC?

Aim for EIC Science White Paper by End of CY2011

- *2010 INT Workshop "yellow book" – anticipated ~500 pages, available Spring 2011 – should serve as starting point, but…*
- *White Paper should be ~100 pages, aimed at non-experts, useful for "champions" within DOE, suitable for rest of NP community*
- *Needs ~5-page general intro ("elevator speech" amplified) to lay out goals, importance and uniqueness, answer basic questions raised at last Long Range Plan in clear, concise, compelling fashion*
- *~10-page science sections to flesh out "golden experiment matrices" for several areas, with simulated "money plots," light on technical detail*
- *~10-15 pages on basic machine parameters, design options, challenges + ~10 pages on detector design features and challenges*
- *Steering Committee comprising experimentalist / theorist pairs, broadly representative of interested institutions, in scientific focus areas listed below:*

Overall editors: A. Deshpande (Stony Brook), J. Qiu (BNL) and Z.-E. Meziani (Temple)
Gluon saturation in e+A: T. Ullrich (BNL) and Y. Kovchegov (Ohio State U.)
Nucleon spin structure (mostly inclusive e+N): E. Sichtermann (LBNL) and W. Vogelsang (Tubingen)
GPD's and exclusive reactions: F. Sabatie (Saclay) and M. Diehl (DESY)
TMD's, hadronization and SIDIS: H. Gao (Duke) and F. Yuan (LBNL)
Electroweak physics: K. Kumar (U. Mass.) and M. Ramsey-Musolf (Wisconsin)
Accelerator designs and challenges: T. Roser (BNL) and A. Hutton (JLab)
Detector design and challenges: E. Aschenauer (BNL) and T. Horn (CUA)
Senior advisors: R. Holt (ANL) and A. Mueller (Columbia)

Long-Term Take-Away Message:

1) The immediate eRHIC focus should be on defining the science program clearly, crisply, compellingly and on doing reasonable facility cost estimates. Let BNL management and DOE worry about (healthy) competition with JLab.

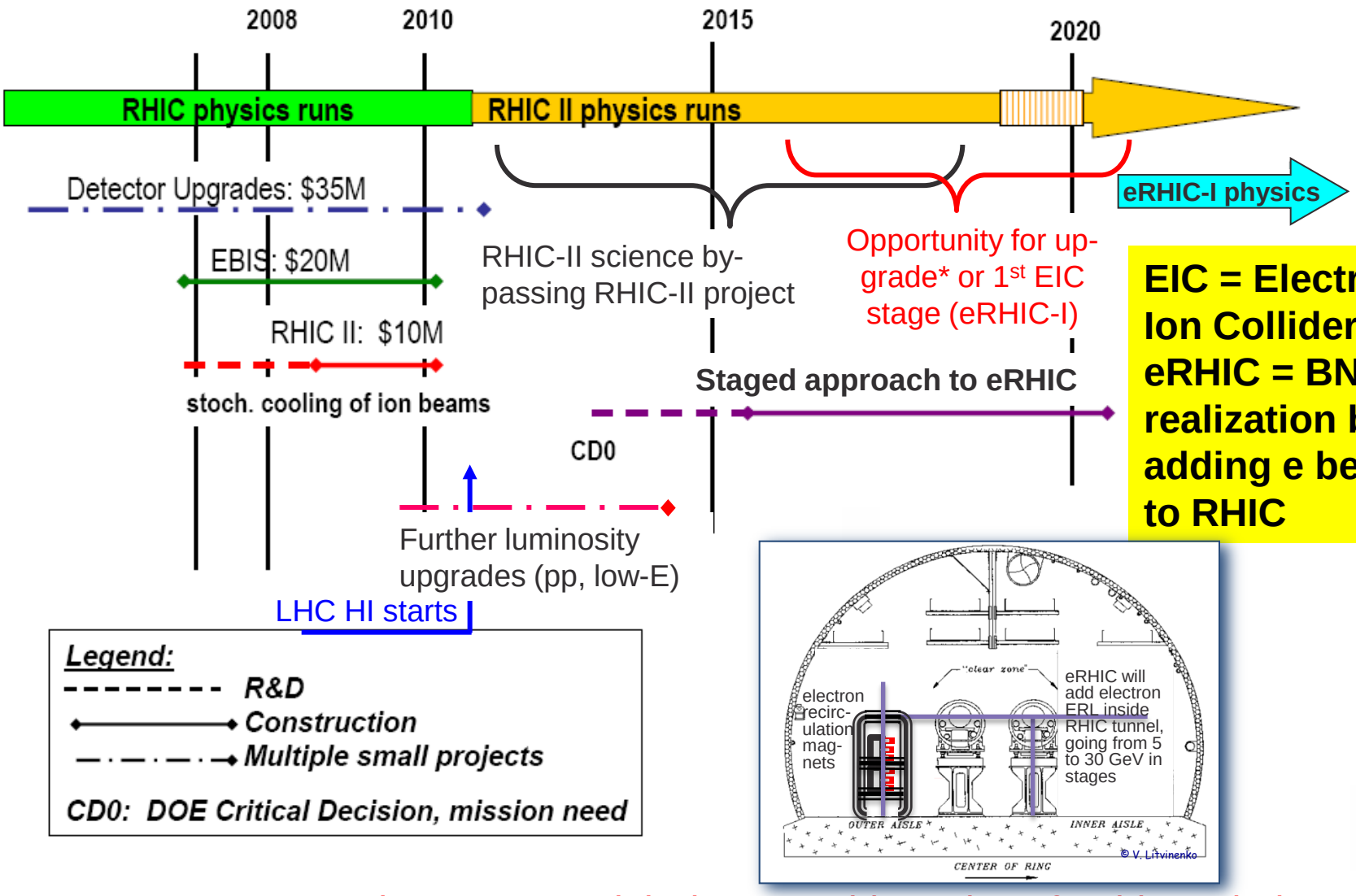
2) A full, new collider detector with new exp'tal hall is not likely to fit within cost cap for a 1st stage eRHIC ⇒ must incorporate STAR and PHENIX upgrade plans to make them viable ep/eA detectors, while also pursuing foreign contributions to a new detector.

3) Work on eSTAR, ePHENIX needs to be coordinated with work already done and ongoing for generic EIC detector, and needs to be integrated (non-trivial!) with machine lattice in IR regions

4) RHIC user community needs to participate actively in defining a path to eRHIC, as well as its detailed configuration. The process must take into account realistic constraints imposed by federal budgets, other developments in the field, and the need to have champions for the project within DOE.

Backup Slides

A Long Term (Evolving) Strategic View for RHIC



EIC = Electron-Ion Collider; eRHIC = BNL realization by adding e beam to RHIC

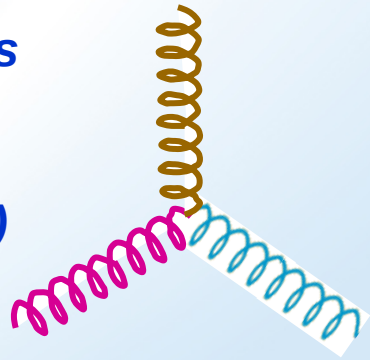
* New PHENIX and STAR Decadal Plans provide options for this period.
Dedicated storage ring for novel charged-particle EDM measurements another option.

Why Should We Care About Gluon-Dominated Matter? Gluons and Mass Without Mass…

F. Wilczek, in "The Origin of Mass":

"Its enhanced coupling to soft radiation…means that…a 'bare' color charge, inserted into empty space, will start to surround itself with a cloud of virtual color gluons. These color gluon fields themselves carry color charge, so they are sources of additional soft radiation. The result is a self-catalyzing enhancement that leads to runaway growth. A small color charge, in isolation, builds up a big color thundercloud… theoretically the energy for a quark in isolation is infinite… Having only a finite amount of energy to work with, Nature always finds a way to short-circuit the ultimate thundercloud."

Confinement of color-coordinated quarks inside hadrons cancels the "thundercloud" at long distances from the hadron. But the short-circuit mechanism also needs saturation of gluon densities (via gg → g recombination) to limit the growth of gluon fields inside the hadron.



⇒ Need to probe gluons in non-linear QCD regime of high gluon density
⇒ Need high energies for "soft" glue, but can use heavy nuclei to boost reach, lower cost, probe onset of gluon saturation inside nuclear matter

Why An Electron Machine?

Electron accelerators have traditionally been used for quantitative characterization of phenomena discovered at hadron machines:

Example table from C. Baltay talk at June 2010 NUFO Meeting

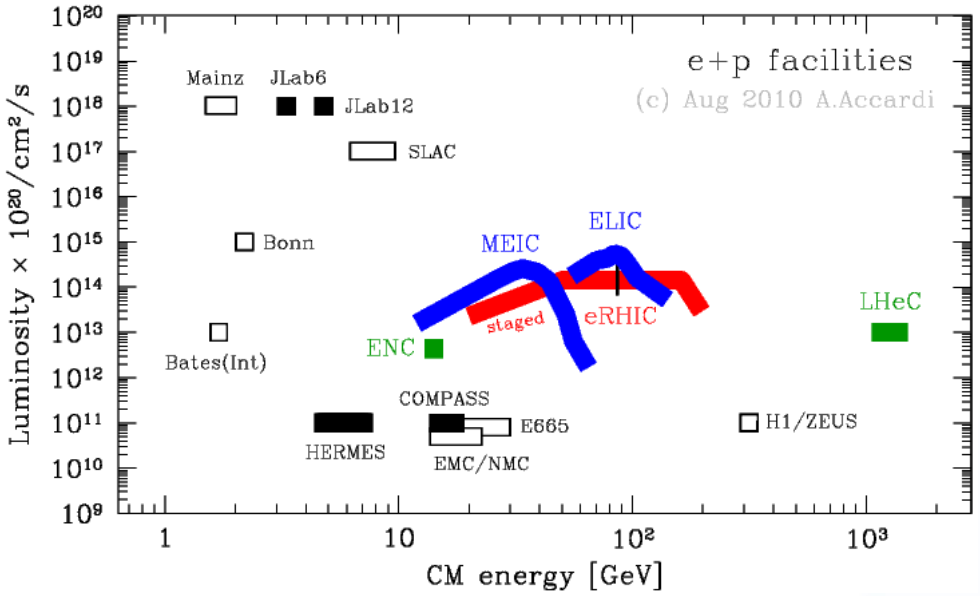
Proton Accelerators	Electron Accelerators
AGS(30 Gev p) discovered bump J	SPEAR(3 Gev e+e-) interpretation as charm charmed particle spectroscopy
FNAL(400 Gev p) discovered bump Υ	CESR (10 Gev e+e-) interpretation as b quark particles with b quarks
CERN SppS(800 Gev pp) discovered W, Z	LEP, SLC (100 Gev e+e-) detailed precision electroweak
LHC (14 Tev pp) discovery of X…	ILC (0.5 - 1.0 Tev e+e-) detailed understanding of new physics

RHIC, LHC may $\Rightarrow$ hints of gluon saturation, but need eA to probe quantitatively, despite primary EM sensitivity to quarks, rather than gluons.

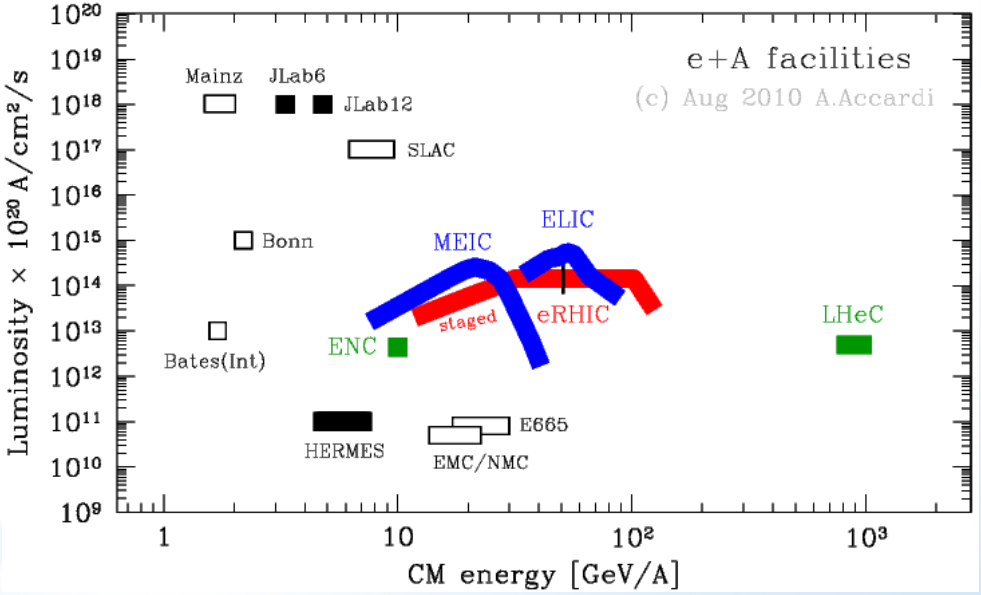
Electron Deep Inelastic Scattering (DIS) is the best demonstrated method to provide time-dilated "freeze-frame" imaging of partons in matter.

Collider Performance Parameters for RHIC vs. JLab Designs Have Converged in Past Year

e + p facilities



e + A facilities



https://eic.jlab.org/wiki/index.php/Machine_designs

Science Deliverable	Basic Measurement	Uniqueness and Feasibility	Requirements
spin structure at small x contribution of Δg, $\Delta\Sigma$ to spin sum rule	inclusive DIS	✓ 	minimal large x, Q^2 coverage about $10 fb^{-1}$
full flavor separation in large x, Q^2 range strangeness, $s(x)-\bar{s}(x)$	semi-inclusive DIS	✓ 	very similar to DIS particle ID improved FFs (Belle, LHC)
electroweak probes of proton structure flavor separation electroweak parameters	inclusive DIS at high Q^2	✓  some unp. results from HERA	20x250 to 30x325 positron beam polarized ^{3}He beam
treatment of heavy flavors in pQCD	DIS (g_1, F_2, and F_L) with tagged charm	✓  some results from HERA	large x, Q^2 coverage charm tag
(un)polarized γ PDFs relevant for γγ physics at an ILC	photoproduction of inclusive hadrons, charm, jets	✓  unp. not completely unknown	tag low Q^2 events about 10 fb^{-1}

Agenda for Users' Workshop on RHIC Future Strategy (June 21-24, 2011)

Tuesday, June 21 Session I: Long-Term Options and Near-Term Plans Chair: T. Ludlam		
8:30-9:10 am*	**S. Vigdor**, BNL	Purpose and scope of workshop; long-term strategy options and constraints
9:10-9:50 am	**W. Fischer**, BNL	Ongoing RHIC machine upgrades and performance projections
9:50-10:20 am	**Coffee Break and Poster Session**	
10:20-11:00 am	**M. Leitch,** LANL	Ongoing PHENIX upgrades + science strategy (HI and spin) for coming ~5 years
11:00-11:40 am	**J. Dunlop,** BNL	Ongoing STAR upgrades + science strategy (HI and spin) for coming ~5 years
11:40 am-12:25 pm	**J. Harris,** Yale	Early results and future prospects for LHC heavy-ion program
Tuesday, June 21 Session II: Decadal Planning for Heavy-Ion Collisions Chair: L. McLerran		
2:00-2:45 pm	**D. Morrison,** BNL	PHENIX heavy-ion science goals and upgrade strategies beyond 2015
2:45-3:30 pm	**Z. Xu,** BNL	STAR heavy-ion science goals and upgrade strategies beyond 2015
3:30-4:00 pm	**K. Rajagopal,** MIT	PAC feedback on PHENIX and STAR decadal plans
4:00-4:30 pm	**Coffee Break and Poster Session**	
4:30-5:15 pm	**B. Mueller,** Duke	Compelling open and quantifiably addressable questions that require next generation of RHIC – Take 1
5:15-6:00 pm	**D. Kharzeev,** BNL/Stony Brook	Compelling open and quantifiably addressable questions that require next generation of RHIC – Take 2
6:00-7:00 pm	**Cocktail Hour, Berkner Hall Lobby** (compliments of BSA)	
Wednesday, June 22 Session III: Decadal Planning, Continued Chair: L. Bland		
8:30-9:15 am	**P. Steinberg,** BNL	Experimentalist's view of the science case for RHIC HI beyond 2015
9:15-10:00 am	**C. Gagliardi,** Texas A&M U.	STAR spin program goals and upgrades beyond 2015, including possible migration toward eRHIC capabilities
10:00-10:30 am	**Coffee Break and Poster Session**	
10:30-11:15 am	**M. Grosse-Perdekamp,** U. Illinois	PHENIX spin program goals and upgrades beyond 2015, including possible migration toward eRHIC capabilities
11:15 am - noon	**M. Stratmann,** BNL	Theorist's priorities for RHIC spin and p/d+A programs beyond 2015

Agenda for Users' Workshop on RHIC Future Strategy (June 21-24, 2011)

Wednesday, June 22 Session IV: eRHIC		**Chair: J. Qiu**
1:30-2:15 pm	**R. Venugopalan,** BNL	Why is an Electron-Ion Collider needed?
2:15-3:00 pm	**M. Lamont,** BNL	EIC eA science program, including 1st stage goals
3:00-3:45 pm	**E. Sichtermann,** LBNL	EIC spin science program, including 1st stage goals
3:45-4:15 pm	**Coffee Break and Poster Session**	
4:15-5:00 pm	**V. Litvinenko,** BNL	eRHIC design and R&D
5:00-5:45 pm	**E. Aschenauer,** BNL	eRHIC detectors: ideal vs. eSTAR and ePHENIX possibilities
6:30-8:30 pm	**Optional Dinner at the Beach Hut**	
Friday, June 24 Session V: Developing a RHIC Strategy to Present at Plan		**Chair: S. Vigdor**
8:45-9:00 am	**H. Caines,** Yale	Poster Award & UEC Election Results
9:00-9:40 am	**V. Ptitsyn,** BNL	Possibilities for maintaining AA and pp capabilities in parallel with eRHIC
9:40 am-12:30 pm	**Y. Akiba,** RIKEN/RBRC **H. Caines,** Yale **A. Deshpande,** Stony Brook **U. Heinz,** Ohio State **T. Roser,** BNL **T.J. Symons,** LBNL Moderator: **S. Vigdor,** BNL	Panel and Community Discussion of RHIC Future Strategy Among the issues: *1) What is the optimal trajectory for RHIC? What are critical decisions and branch points?* *2) Since LHC HI results seem very similar to RHIC's, are both facilities needed? Which critical QCD matter science questions are best answered at RHIC?* *3) Will 2-3 year cessation of RHIC operations be essential to fund eRHIC? If so, what is optimal timing?* *4) Is it crucial to maintain AA & pp capability into eRHIC era? If so, can we reconfigure IR's annually, or do we separate HI from eA in different IR's?* *5) What eRHIC science is realizable within a reasonable total project cost limit?* *6) How do STAR and PHENIX Collaborations evolve smoothly from RHIC to eRHIC?*