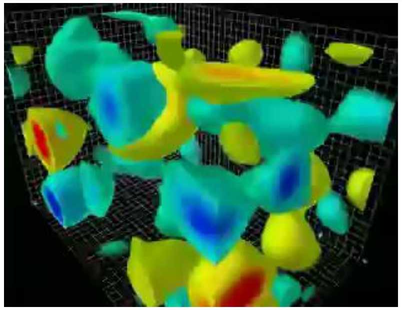
Electron Ion Collider

(An Overview)

Precision study & understanding the role of gluons (& sea quarks) in QCD

http://arxiv.org/pdf/1108.1713v1



Abhay Deshpande

October 21, 2011

Future Directions in High Energy QCD

QCD: The SM of Strong Interactions

"Folks, we need to stop "testing" QCD

and start understanding it"

Yuri Dokshitzer

1998, ICHEP Vancouver, BC , Conference Summary Talk

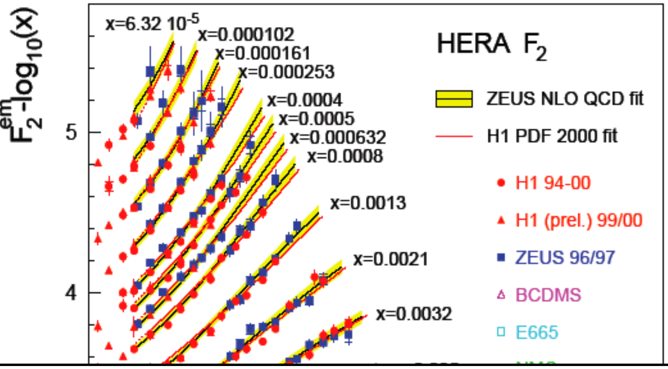
2004 For the discovery of asymptotic freedom in QCD

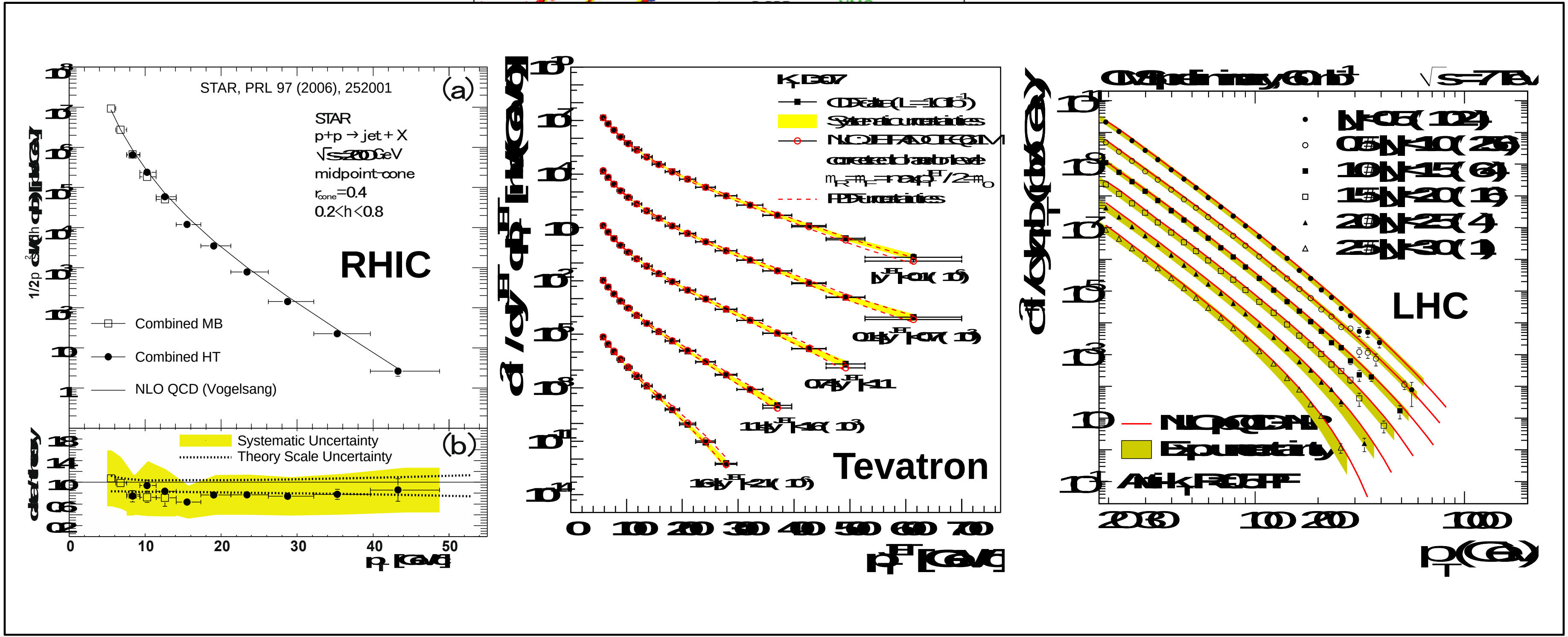




Success of pQCD at High Q: Jet Cross section

- Input:
  - $F_2(x,Q^2)$ RA
  - Next to I QCD



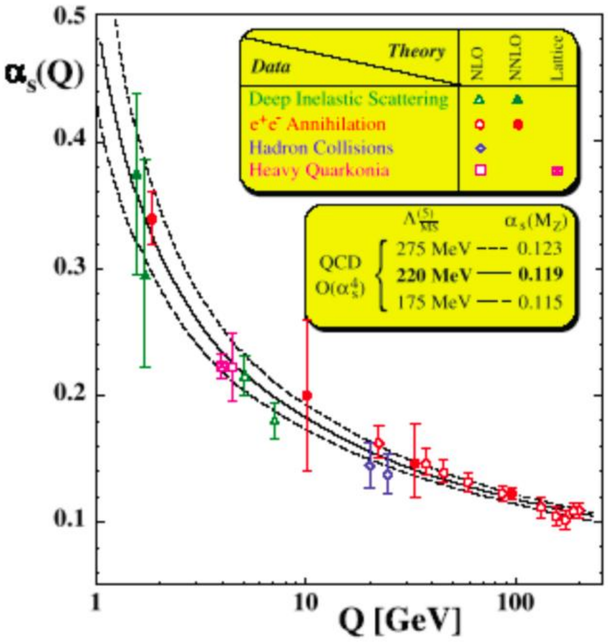


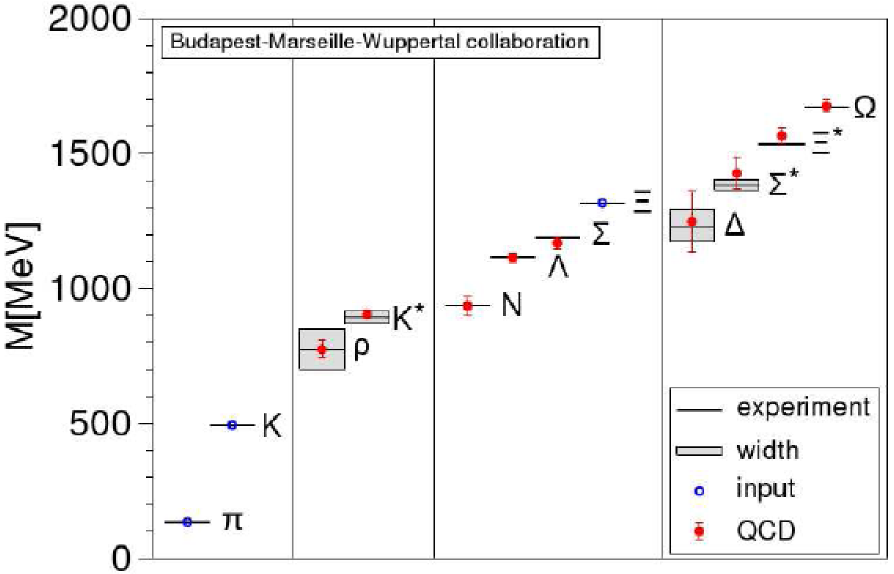
QCD definitely correct, but…

Lattice QCD

- Starting from QCD lagrangian → Static properties of hadrons: hadron mass spectrum

No guidance on partonic dynamics





Durr et al '08

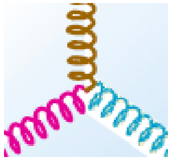
Perturbative QCD

- Calculations possible in ***when*** coupling is small, at high Q

Problematic at low Q → fast rise of α_S(Q)

Generation of Mass – Gluons in QCD

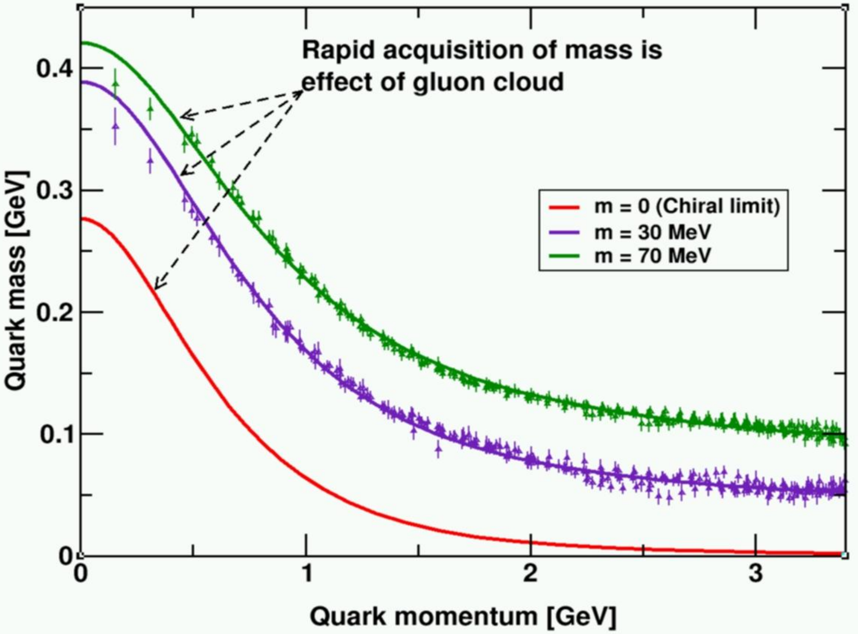
- Protons and neutrons form most of the mass of the **visible universe**
- 99% of the nucleon mass is due to **self generated gluon fields**
  - **Similarity** between p, n mass indicates that **gluon dynamics is identical** & overwhelmingly important

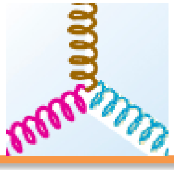


- Lattice QCD supports this

Higgs Mechanism, often credited with mass generation, is of no consequence

Bhagwat et al.





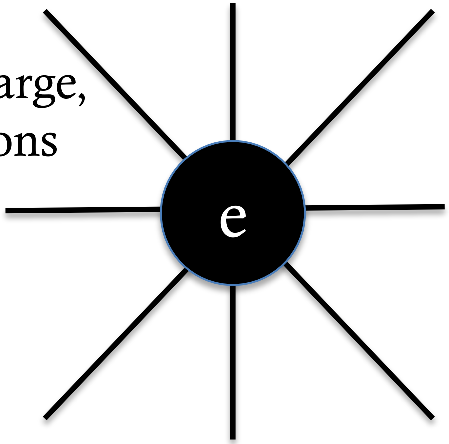
Gluon self-interaction in QCD

Dynamical generation & self-regulation of hadron masses

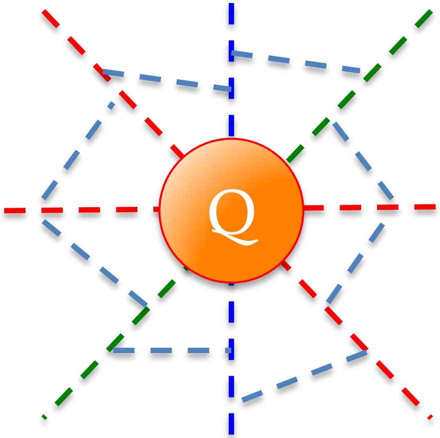
F. Wilczek in "Origin of Mass"

Its enhanced coupling to soft radiation… means that a 'bare" color charge, inserted in to 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 a ***runaway growth****. A small color charge, in isolation builds up a big color thundercloud….****theoretically the energy of the quark in isolation is infinite…*** ***having only a finite amount of energy to work with, nature always finds a way to short cut the ultimate thundercloud"***

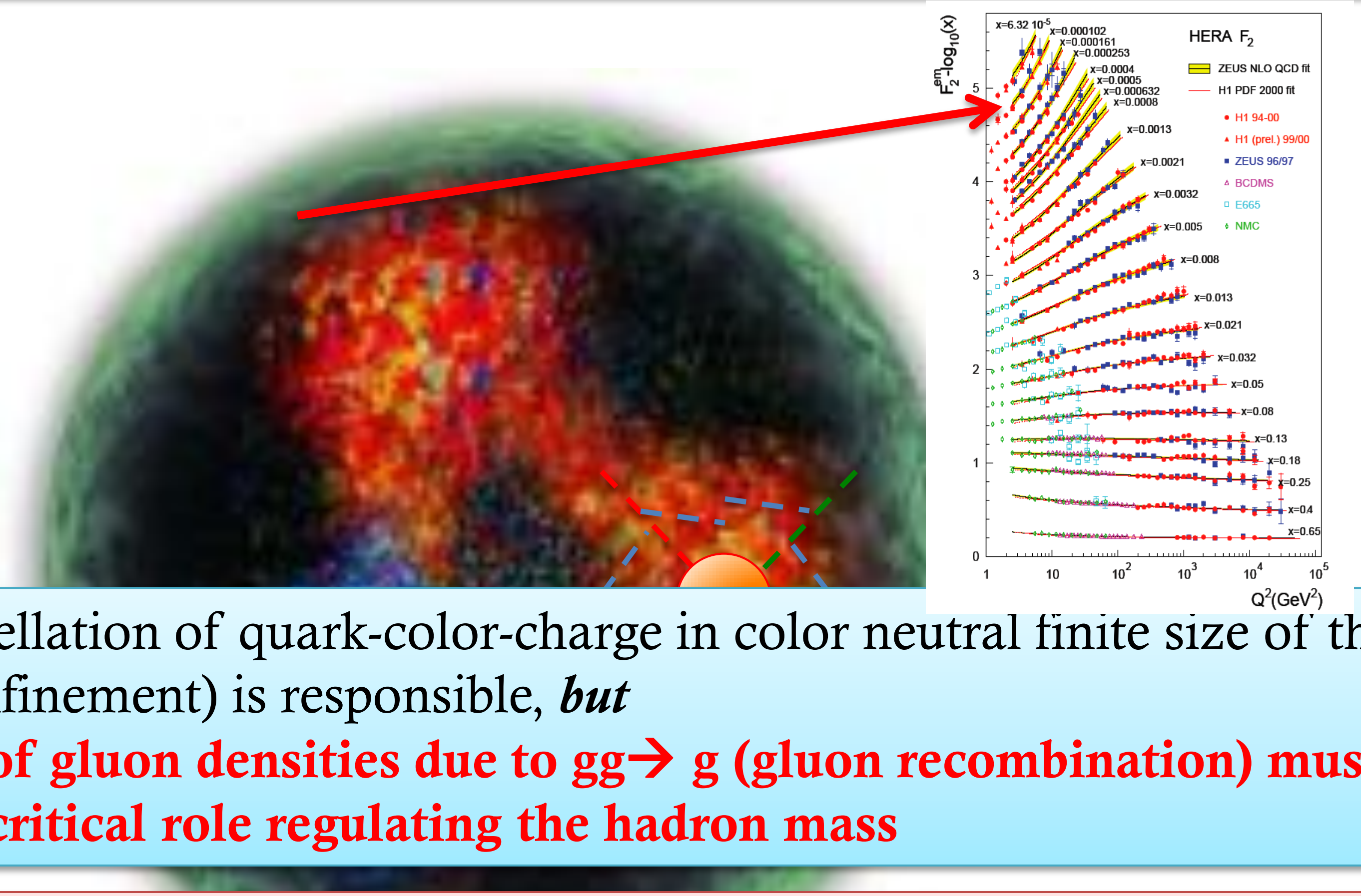
Electric charge, lines: photons



Color charge gluons



What limits the "thundercloud"?



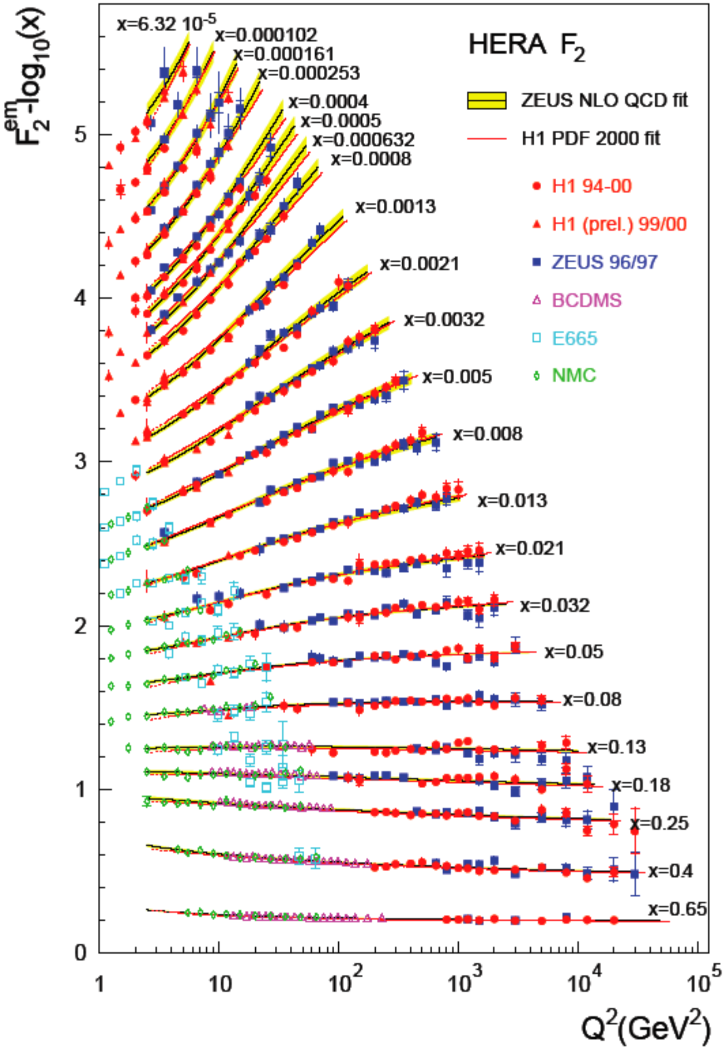
- Partial cancellation of quark-color-charge in color neutral finite size of the hadron (confinement) is responsible, ***but***
- **Saturation of gluon densities due to gg→ g (gluon recombination) must also play a critical role regulating the hadron mass**

Need to experimentally explore and study ***many body dynamics***
a) regions of ***quark-hadron transition*** and
b) non-linear QCD regions of extreme ***high gluon density***

What is the role of gluons at high energy?

HOW WELL DO WE UNDERSTAND GLUONS?

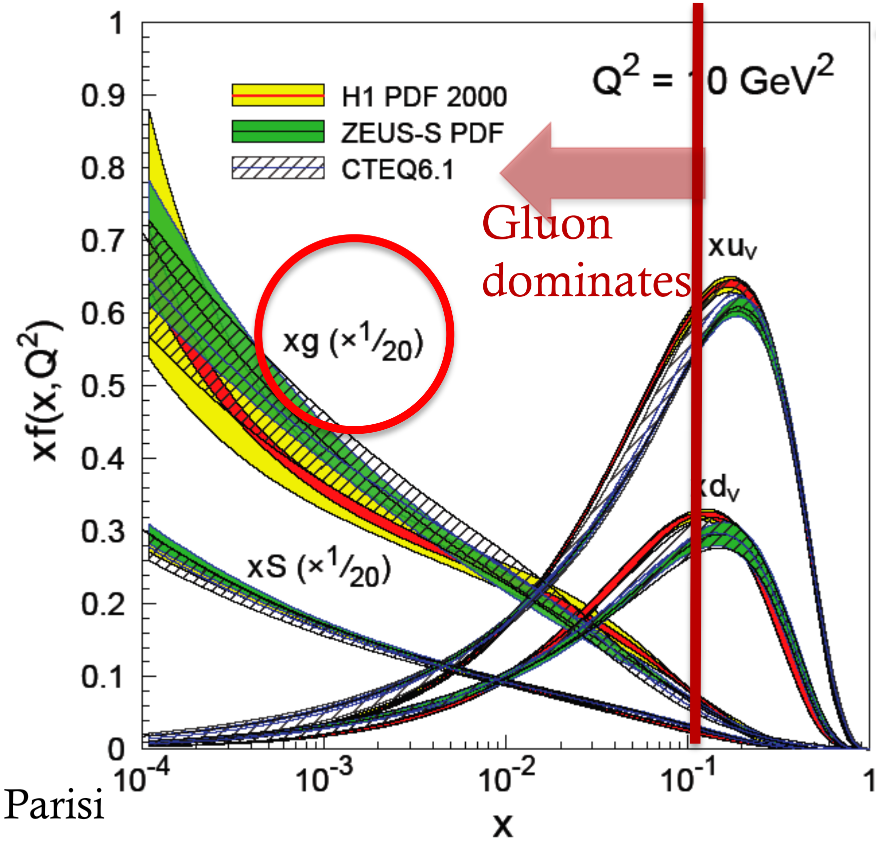
Measurement of Glue at HERA



- Scaling violations of $F_2(x,Q^2)$

$$\frac{\partial F_2(x,Q^2)}{\partial \ln Q^2} \propto G(x,Q^2)$$

- NLO pQCD analyses: fits with **linear** DGLAP* equations



Gluon dominates

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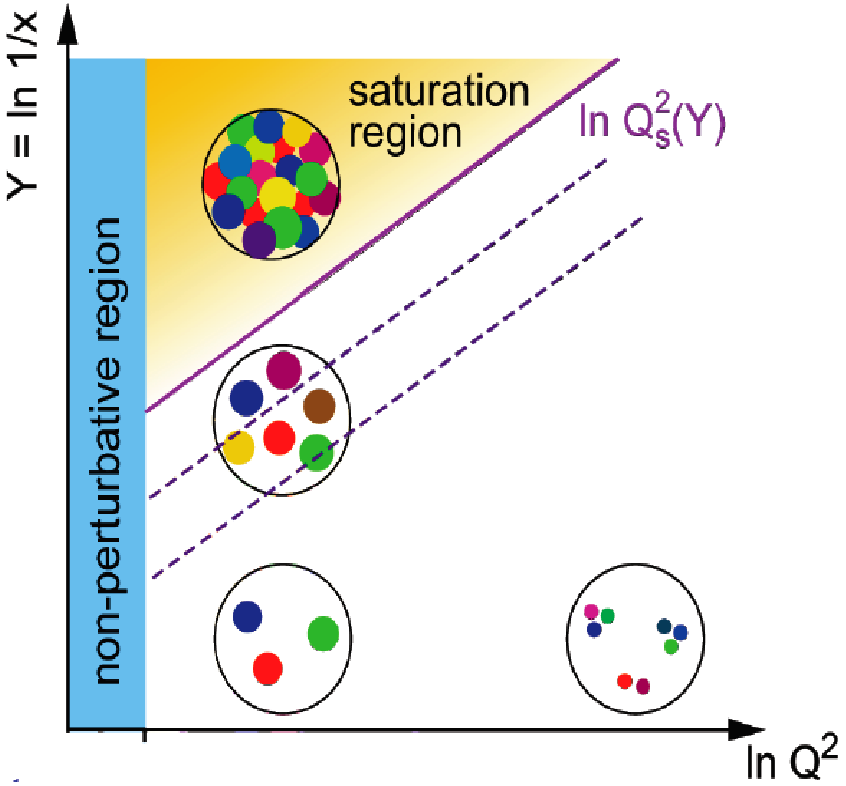
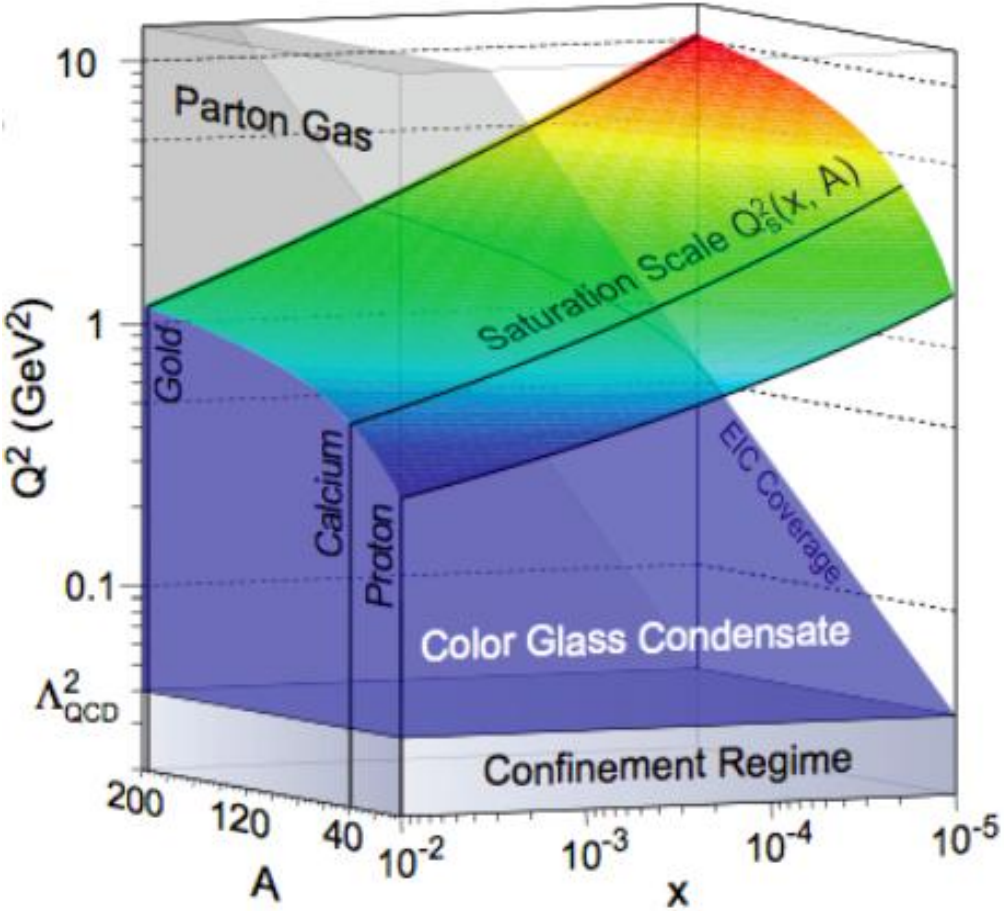
*Dokshitzer, Gribov, Lipatov, Altarelli, Parisi

Low-x, higher twist & Color Glass Condensate

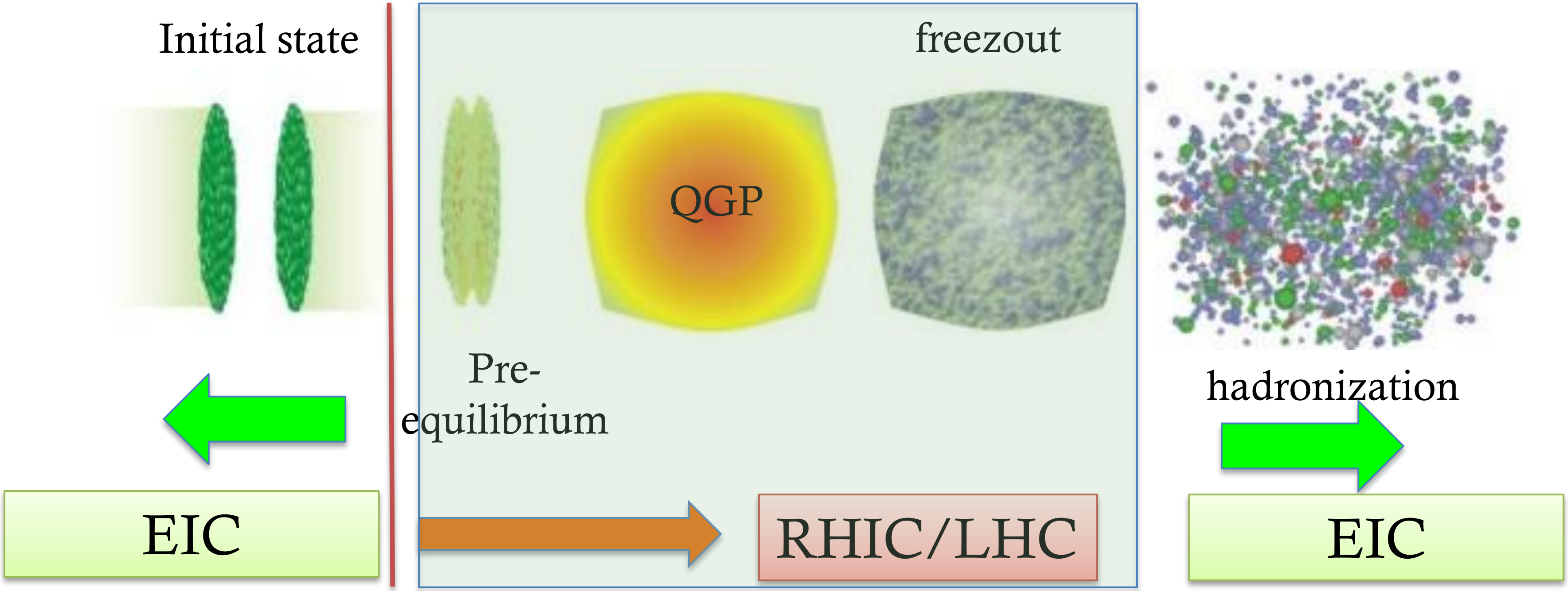
McLerran, Venugopalan… See Review: F. Gelis et al., , arXiv:1002.0333)





Could be explored cleanly in future with a high energy electron-Nucleus Collider

EIC and RHIC/LHC (Heavy Ion)

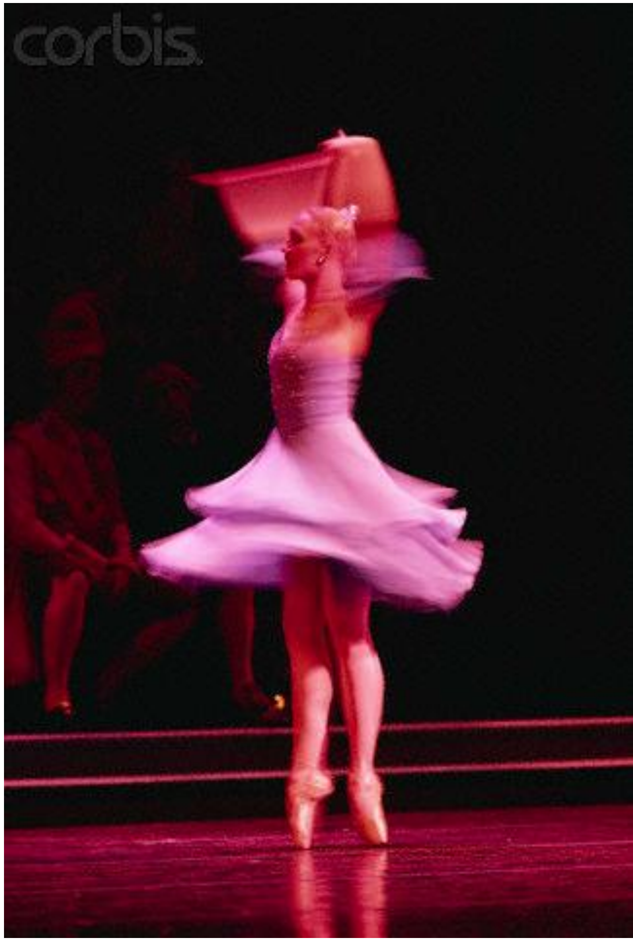


A decadal plan is being launched to characterize the “QGP”

To understand “QGP” fully, we need to understand:

The initial state i.e. the nucleus & hadronization

Deeper Connection: many body interactions of parton in QC



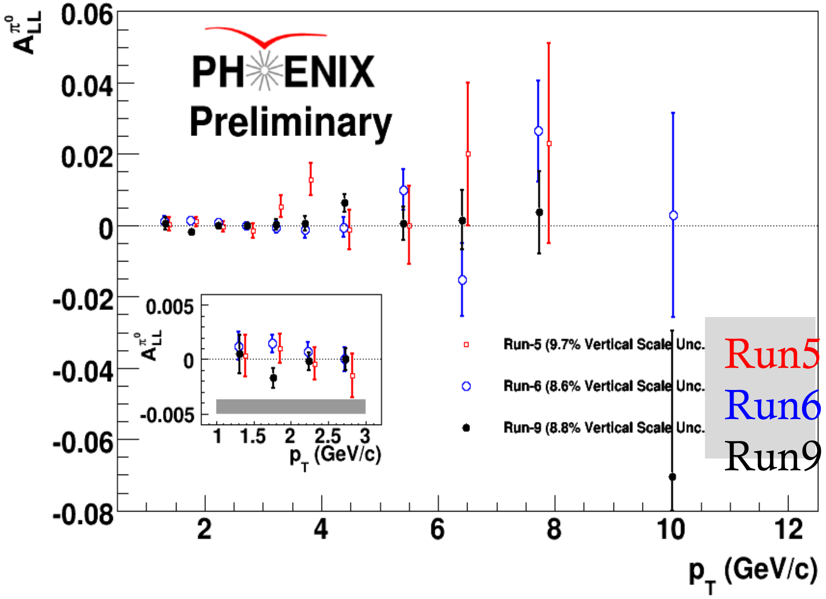
UNDERSTANDING NUCLEON SPIN:

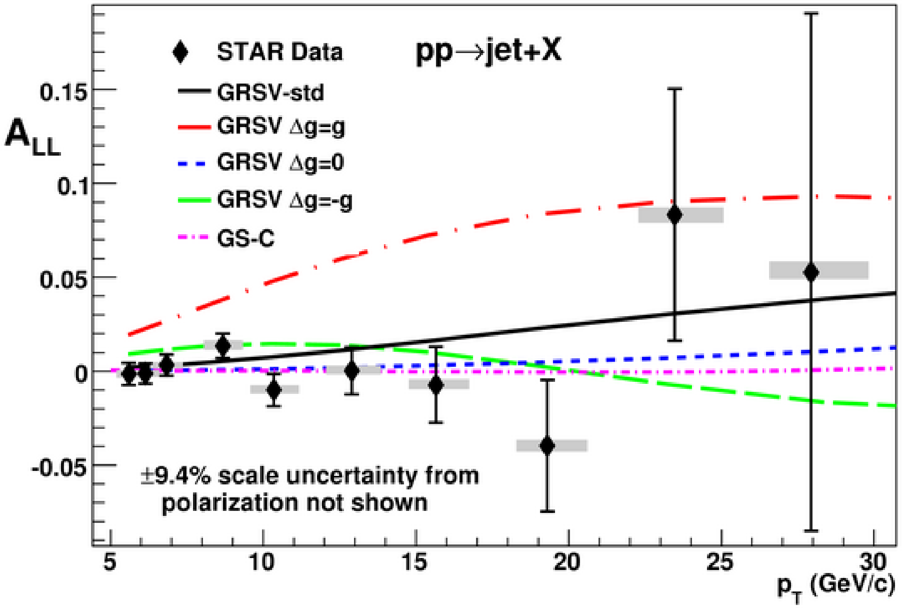
WHAT ROLE DO GLUONS PLAY?

Status of “Nucleon Spin ~~Crisis~~ Puzzle”

$$\frac{1}{2} = \boxed{\frac{1}{2}\Delta\Sigma + L_q} + \boxed{\Delta g + L_g}$$

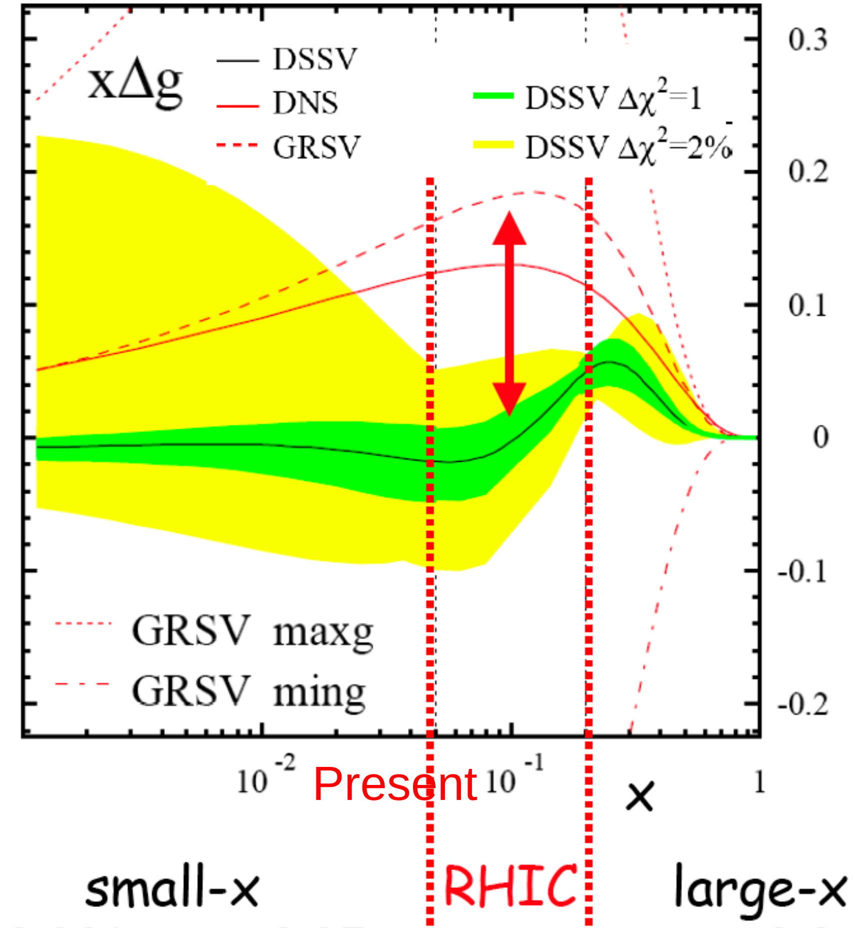
- We know how to determine ΔΣ and Δg precisely: data+pQCD
  - ½ (ΔΣ) ~ 0.15 : From fixed target pol. DIS experiments
  - RHIC-Spin: Δg *not large* as anticipated in the 1990s, but *measurements & precision needed at low & high x*





$\Delta g(x)$ @ Q^2=10 GeV^2

de Florian, Sassot, Stratmann & Vogelsang



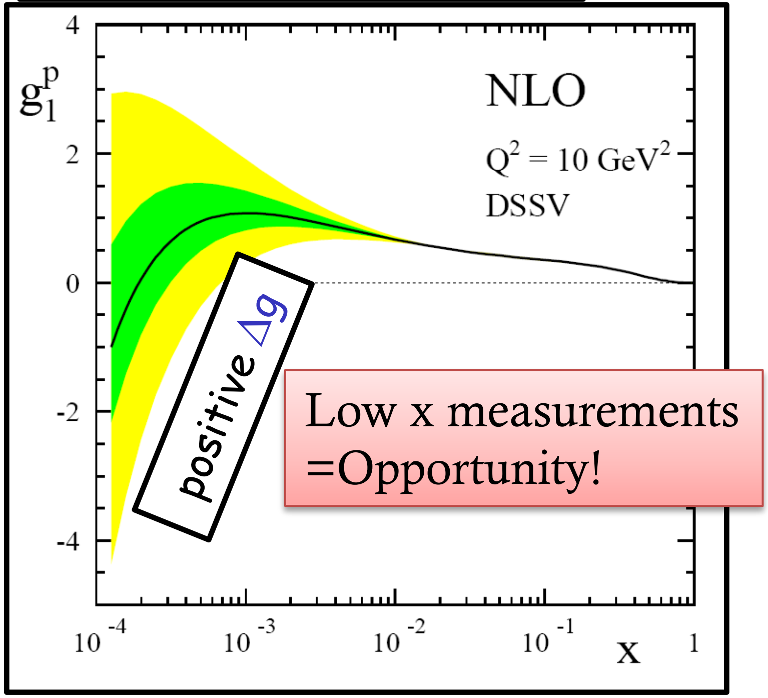
small-x
$0.001 \leq x \leq 0.05$

RHIC range
$0.05 \leq x \leq 0.2$

large-x
$x \geq 0.2$

- **Global analysis: DIS, SIDIS, RHIC-Spin**
- **Uncertainly on ΔG large at low x**

$$\frac{dg_1}{d\log(Q^2)} \propto -\Delta g(x,Q^2)$$



Low x measurements =Opportunity!

Status of "Nucleon Spin ~~Crisis~~ Puzzle"

$$\frac{1}{2} = \boxed{J_q} + J_g = \boxed{\frac{1}{2}\Delta\Sigma + L_q} + \Delta g + L_g$$

- We know how to measure ΔΣ and ΔG precisely using pQCD
  - ½ (ΔΣ) ~ 0.15 : From fixed target pol. DIS experiments
  - RHIC-Spin: ΔG *not large* as anticipated in the 1990s, but *measurements & precision needed at low & high x*

- Generalized Parton Distributions: H,E,E',H' → Connection to partonic OAM
  - Quark GPDs → $\boldsymbol{J_q}$: 12GeV@JLab & COMPASS@CERN
  - Gluons @ low x → $\boldsymbol{J_g}$ → will need the future EIC!
- (2+1)D tomographic image of the proton…. Transverse Mom. Distributions
  - **2: x,y position and +1:momentum in z direction**

Towards Full understanding of transverse and longitudinal hadron structure including spin!

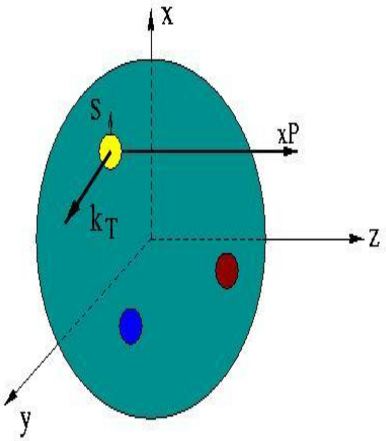
Unified View of Nucleon Structure

6D Dist.

$W_p^u(x,k_T,\boldsymbol{r})$ Wigner distributions

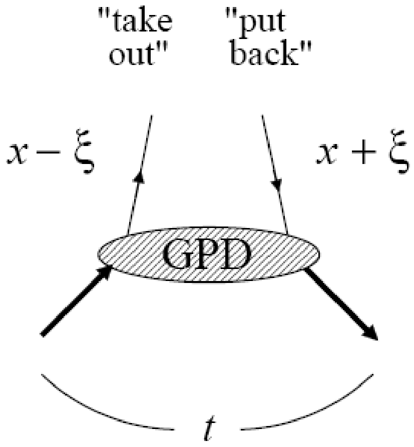
$d^3\boldsymbol{r}$

$d^2k_T\, dr_z$



TMD PDFs
$f_1^u(x,k_T)$, .. $h_1^u(x,k_T)$

GPDs/IPDs

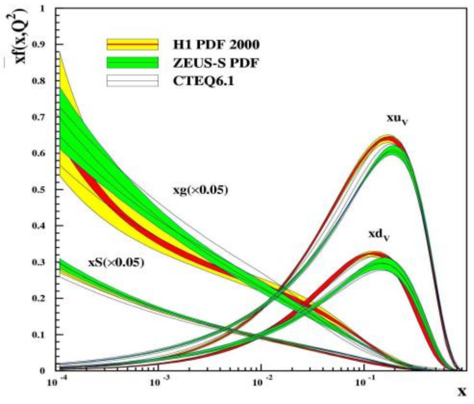


3D imaging

d^2k_T

d^2r_T

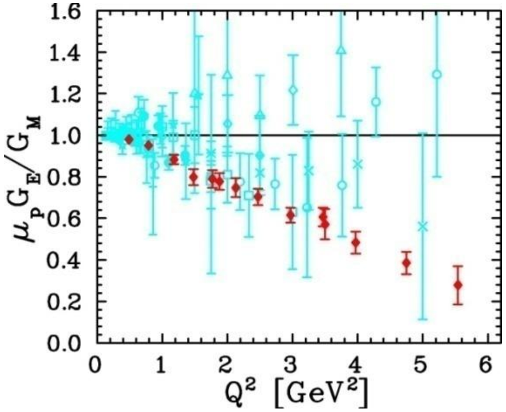
dx &
Fourier Transformation



PDFs
$f_1^u(x)$, .. $h_1^u(x)$

1D

Form Factors
$G_E(Q^2)$,
$G_M(Q^2)$



Do we really "understand" QCD?

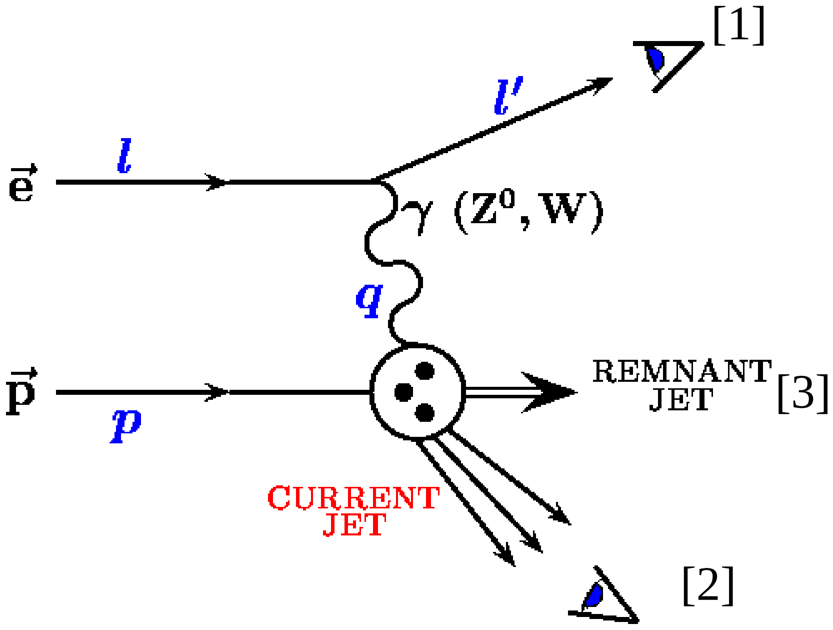
While there is no reason to doubt QCD, our level of understanding of QCD remains extremely unsatisfactory: both at low & high energy

- Can we explain basic properties of hadrons such as mass and spin from the QCD degrees of freedom at low energy?
- What ***are*** the effective degrees of freedom at high energy?
- How do these degrees of freedom interact with each other and with other hard probes?
- What can we learn from them about confinement & universal features of the theory of QCD?

After ~20+ yrs of experimental & theoretical progress, we are only *beginning to understand* the many body dynamics of QCD

The Proposal:

Future DIS experiment at an Electron Ion Collider: A high energy, high luminosity (polarized) *ep* and eA collider and a suitably designed detector

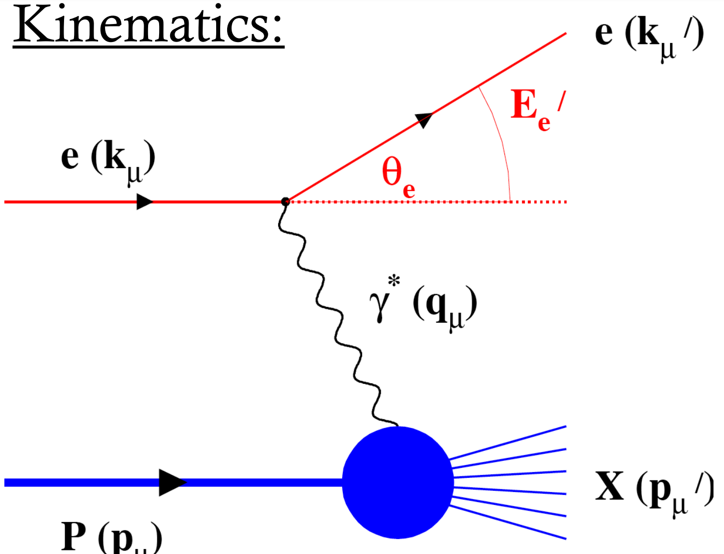


Measurements:
[1] → Inclusive
[1] and [2] **<u>or</u>** [3] →Semi-Inclusiv
[1] and [2] **<u>and</u>** [3] →Exclusive

Inclusive → Exclusive
Low → High Luminosity
Demanding Detector capabilities

Inclusive & Semi-Inclusive DIS

Kinematics:



$$Q^2 = -q^2 = -(k_\mu - k'_\mu)^2$$

$$Q^2 = 2E_e E'_e (1 - \cos\Theta_{e'})$$

Measure of resolution power

$$y = \frac{pq}{pk} = 1 - \frac{E'_e}{E_e}\cos^2\left(\frac{\theta'_e}{2}\right)$$

Measure of inelasticity

$$x = \frac{Q^2}{2pq} = \frac{Q^2}{sy}$$

Measure of momentum fraction of struck quark

Hadron :

$$z = \frac{E_h}{\nu};\ p_t^{\text{with respect to } \gamma}$$

Inclusive events:

e+p/A → e'+X

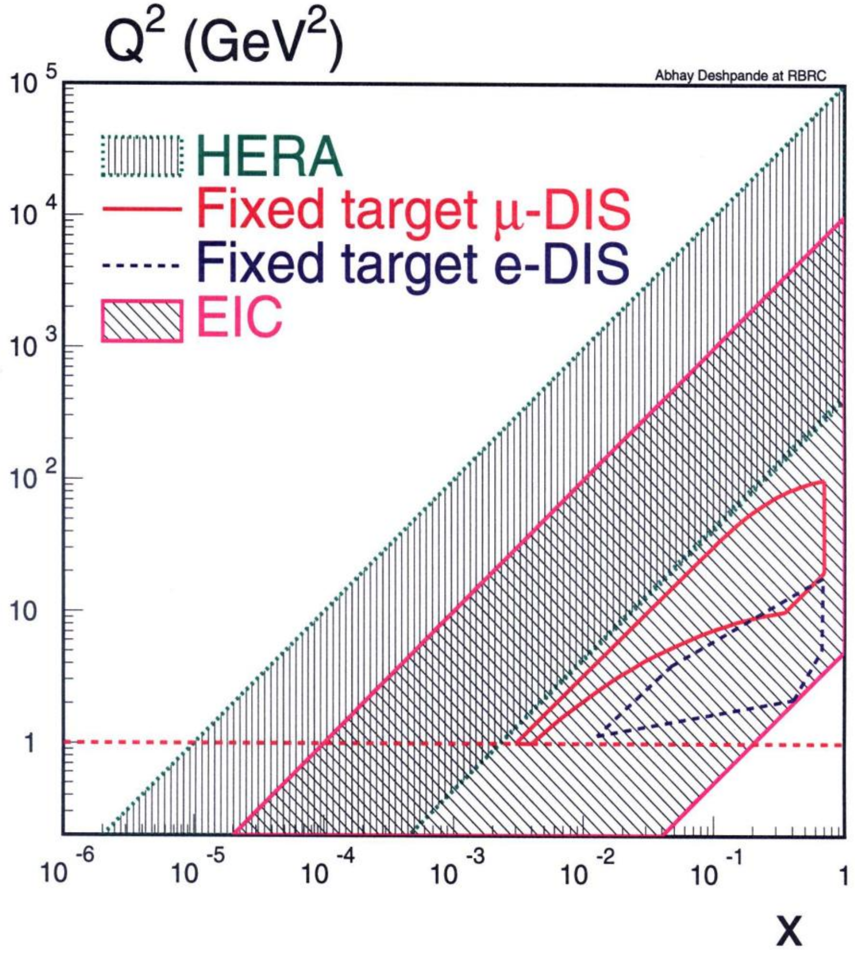
detect only the scattered lepton in the detector

Semi-inclusive events:

e+p/A → e'+h(π,K,p,jet)+X

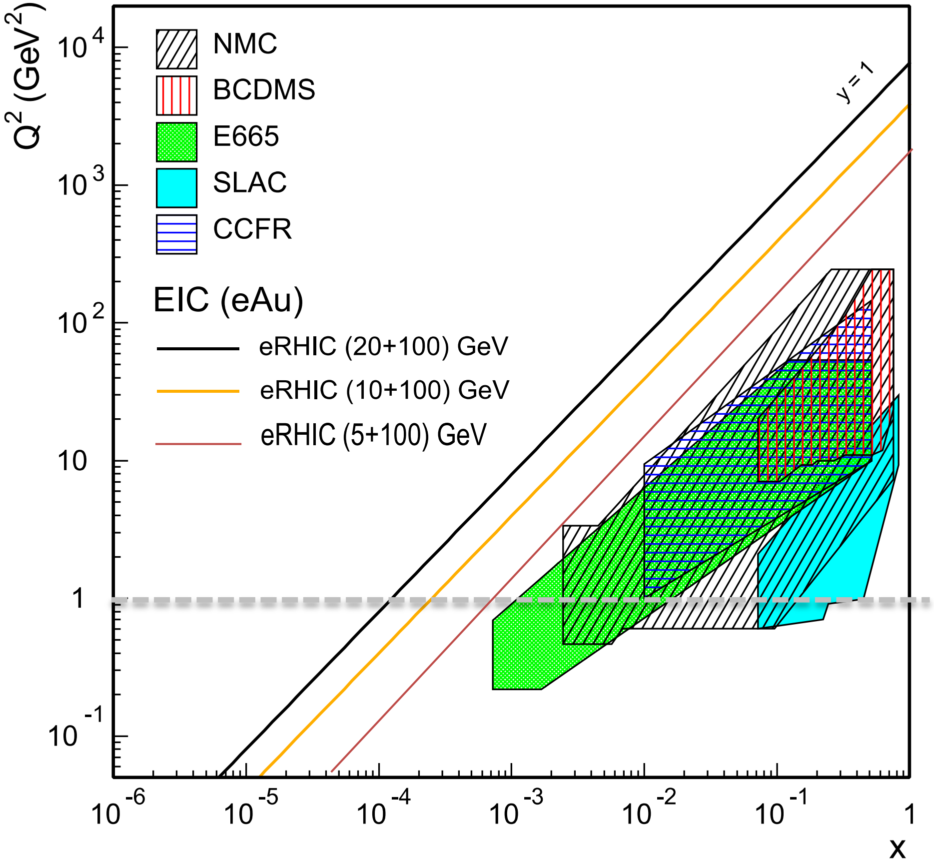
detect the scattered lepton in coincidence with identified hadrons/jets in the detector

EIC : Basic Parameters (e-p)



- E_e=10 GeV (5-30 GeV variable)
- E_p=250 GeV (50-275 GeV Variable)
- Sqrt(S_{ep}) = 100 (30-180) GeV
- x_{min} ~ 10^{-4} ; $Q^2{}_{max}$~ 10^4 GeV
- Polarization ~ 70%: e,p, D/^{3}He
- Luminosity L_{ep} = 10^{33-34} cm^{-2}s^{-1}
- Minimum Integrated luminosity:
  - 50 fb^{-1} in 10 yrs (100 x HERA
  - Possible with 10^{33} cm^{-2}s^{-1}
  - Recent projections *much higher*

EIC : Basic Parameters (e-A)



- E_e=10 GeV (5-30 GeV variable)
- E_A=100 GeV (20-110 GeV Variable)
- Sqrt(S_{eA}) = 63 (20-115) GeV
- x_{min} ~10^{-4} ;
- Q^2_{max} ~ 8 x10^3 GeV

Nuclei:

- **Proton → Uranium**
- **L_{eA}/N = $10^{33\text{-}34}$ cm^{-2}s^{-1}**

Machine Designs

eRHIC at Brookhaven National Laboratory using the existing RHIC complex

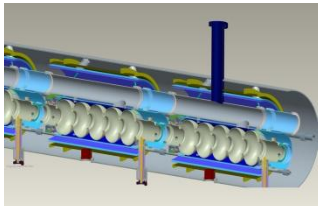
ELIC at Jefferson Laboratory using the Upgraded 12GeV CEBAF

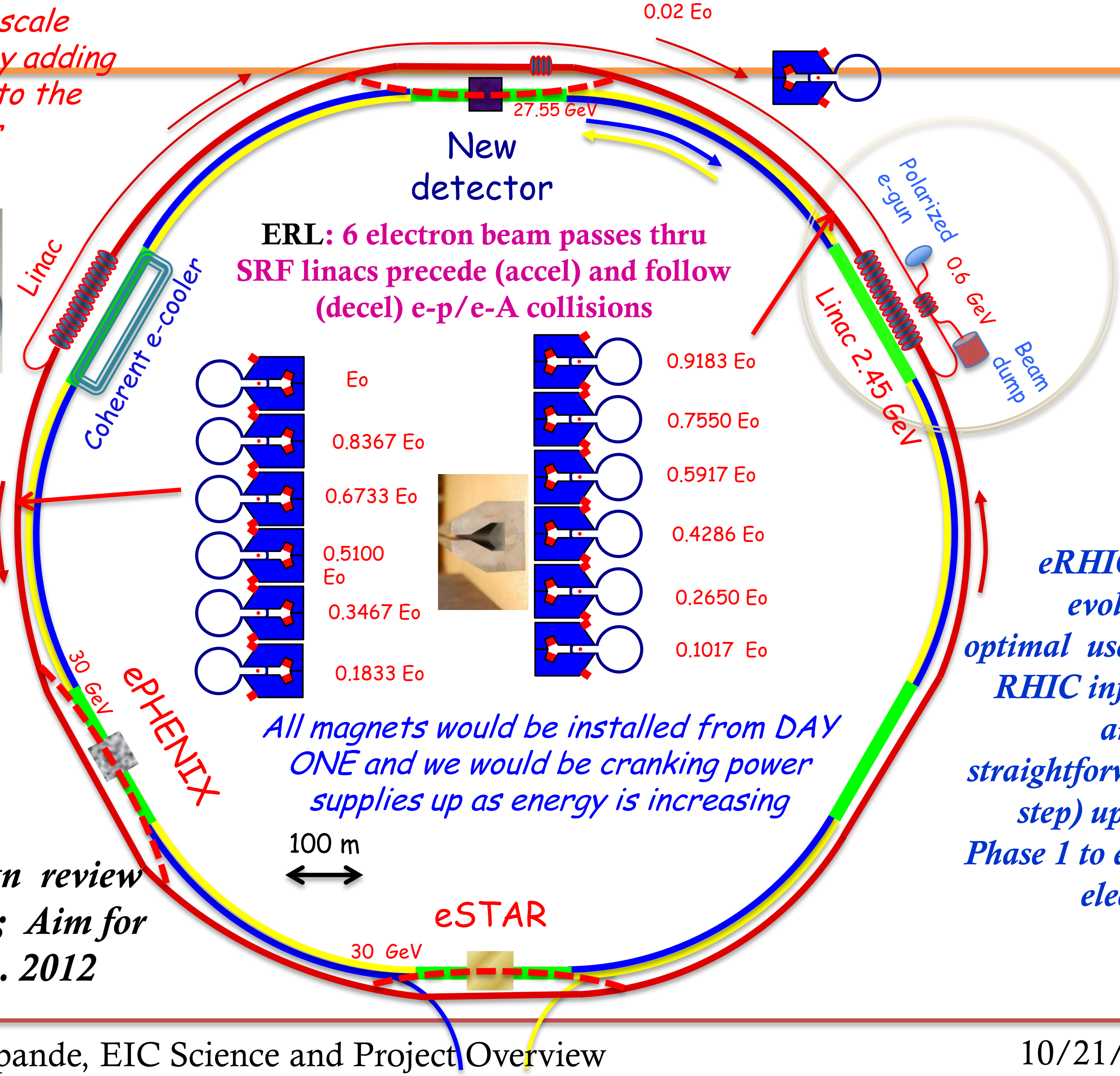
Both planned to be STAGED

Staging of eRHIC: E$_o$: 5 -> 30 GeV

E/Eo
0.0200
0.1017
0.1833
0.2650
0.3467
0.4283
0.5100
0.5917
0.6733
0.7550
0.8367
0.9183
1.0000

All energies scale proportionally by adding SRF cavities to the injector





ERL: 6 electron beam passes thru SRF linacs precede (accel) and follow (decel) e-p/e-A collisions

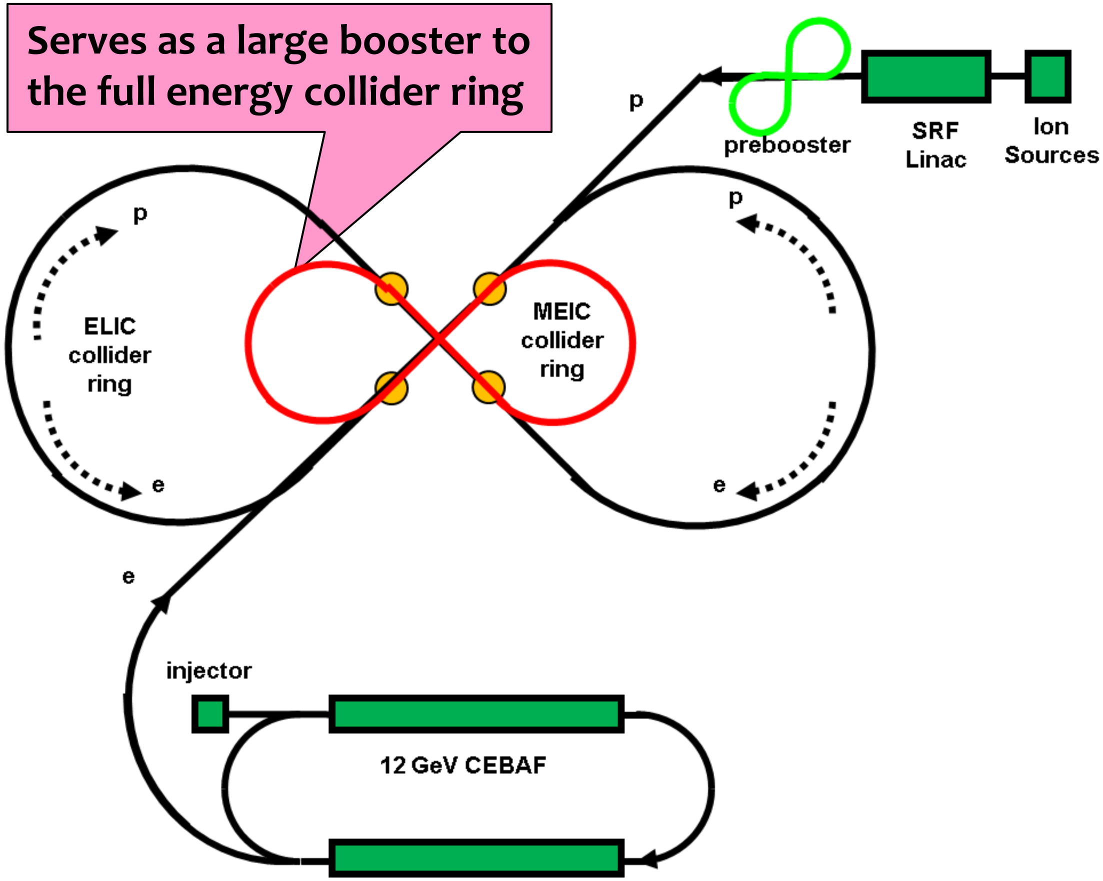
All magnets would be installed from DAY ONE and we would be cranking power supplies up as energy is increasing

Roser's talk

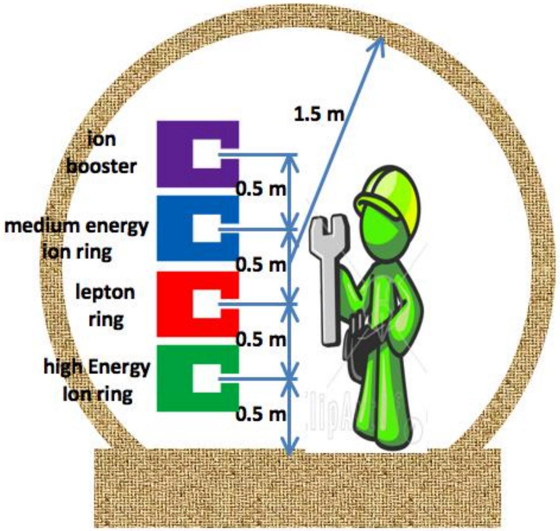
Technical design review Aug. 1-3, 2011; Aim for cost review Jan. 2012

eRHIC design has evolved to make optimal use of existing RHIC infrastructure, and to permit straightforward (multi-step) upgrades from Phase 1 to eventual full electron energy

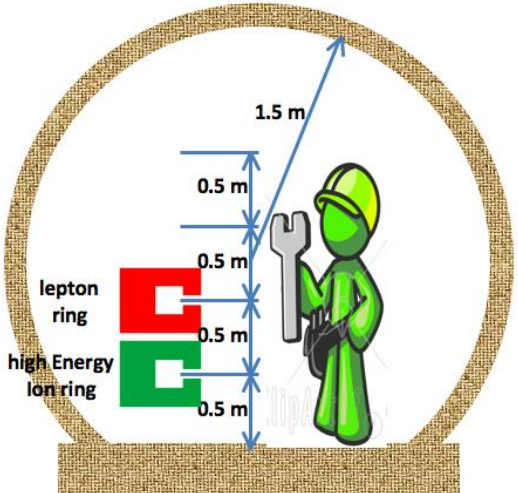
ELIC: High Energy & Staging


Serves as a large booster to the full energy collider ring

Straight section



Arc

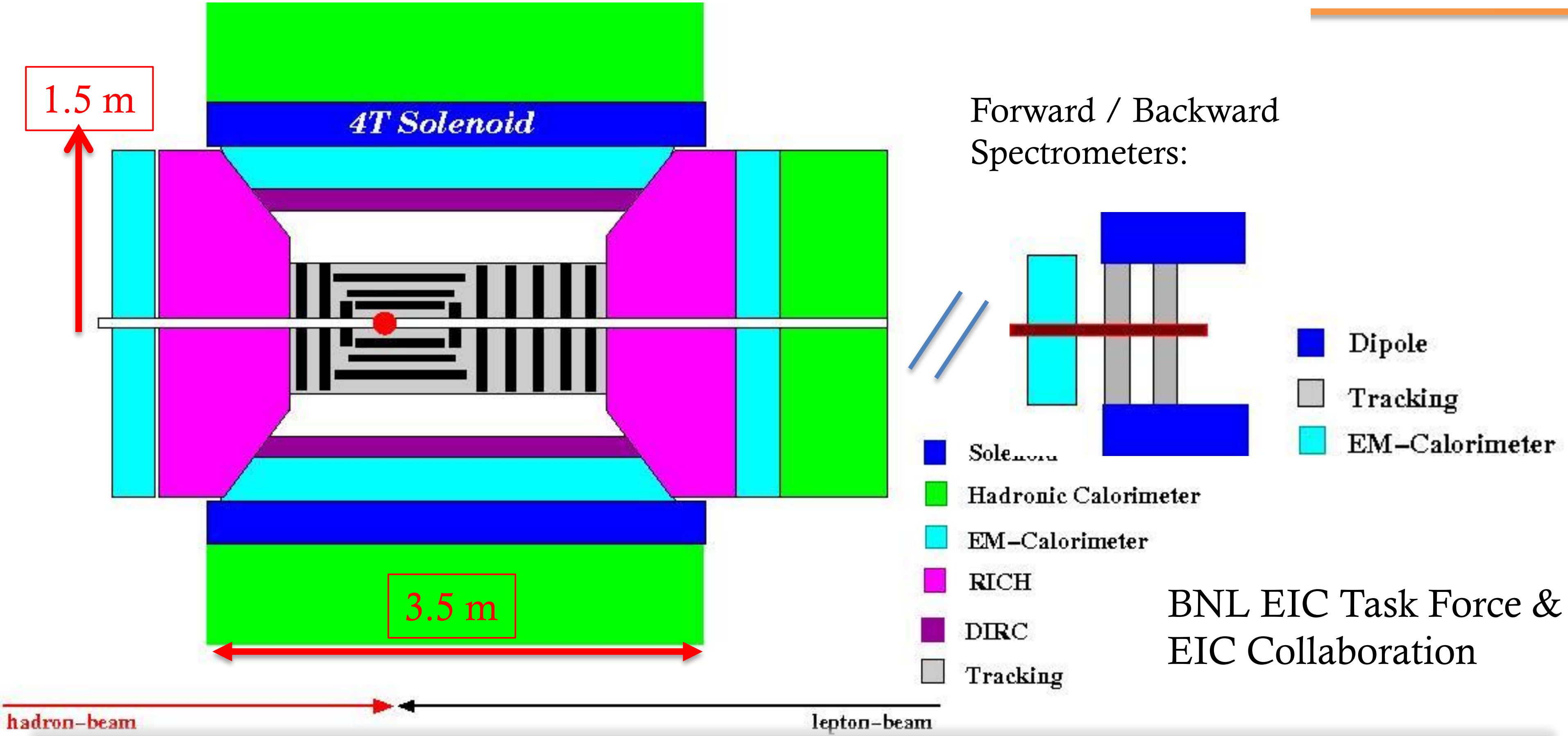


Stage	Max. Energy (GeV/c)		Ring Size (m)	Ring Type		IP #
	p	e		p	e	
Medium	96	11	1000	Cold	Warm	3
High	250	20	2500	Cold	Warm	4

Hutton

R. Ent's Talk

Emerging eRHIC Detector Concept



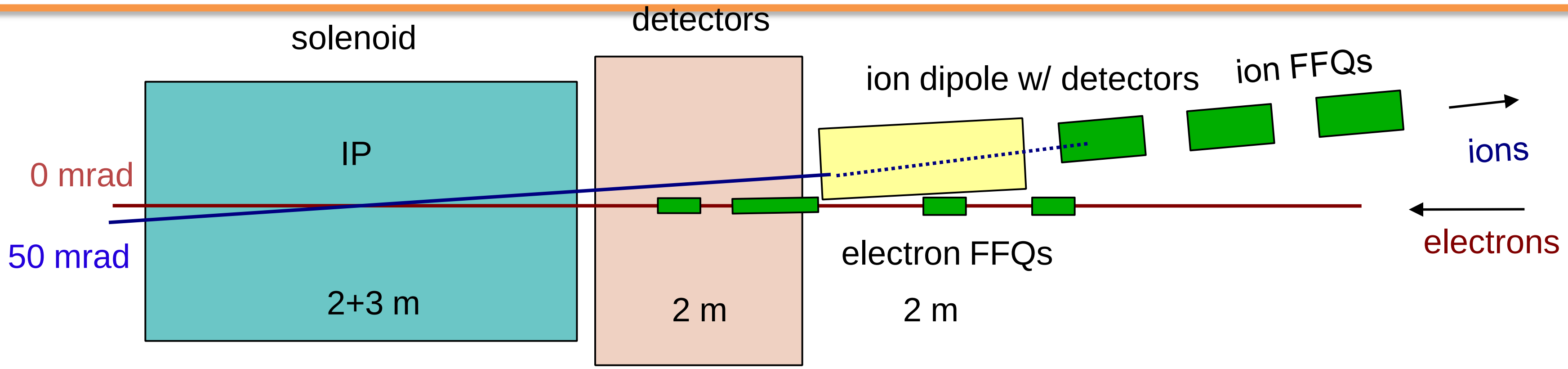
Forward / Backward Spectrometers:

BNL EIC Task Force & EIC Collaboration

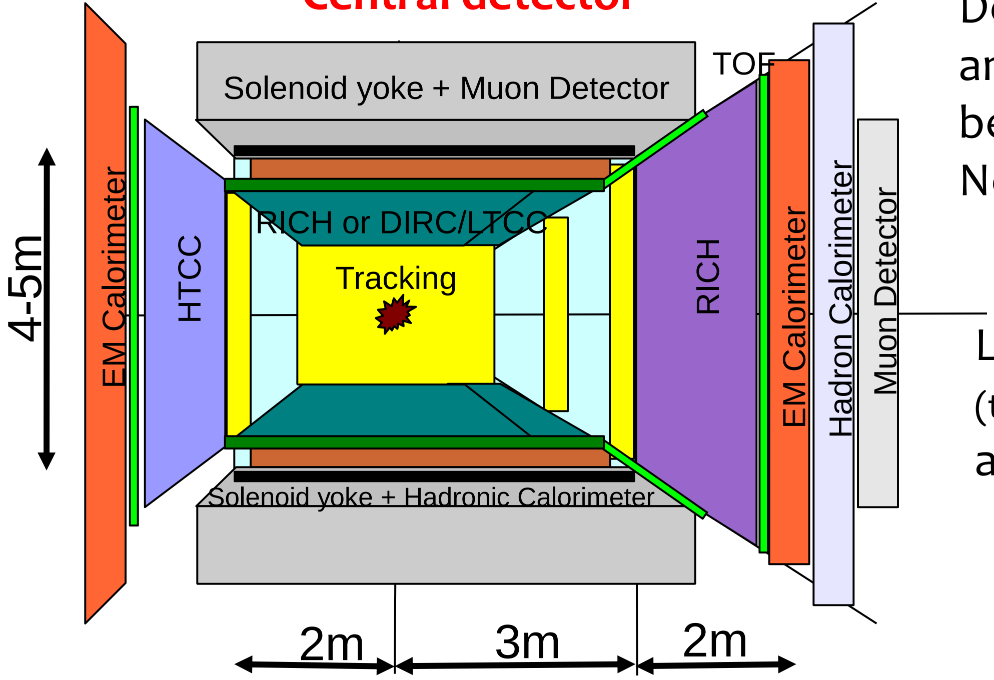
high acceptance $-5 < \eta < 5$ central detector
good PID and vertex resolution ($< 5\mu m$)
tracking and calorimeter coverage the same → good momentum resolution, lepton PID
low material density → minimal multiple scattering and brems-strahlung
very forward electron and proton detection → maybe dipole spectrometers

R. Ent's Talk

Detector & IR Design: ELIC



Central detector



Detect particles with angles down to 0.5° before ion FFQs. Need 1-2 Tm dipole.

Detect particles with angles below 0.5° beyond ion FFQs and in arcs.

Very-forward detector

Large dipole bend @ 20 meter from IP

(to correct the 50 mr ion horizontal crossing angle)

allows for **very-small angle detection (<0.3°)**

JLab EIC WG and EIC Collaboration

EIC: the Machines, IR and Detector

Both BNL and JLab machine designs have progressed significantly.

In spite of very different starting points for collider concepts:

- Both designs are now converging to similar luminosities:
  - Few x $10^{33\text{-}34}$ cm^{-2} sec^{-1} for high energy
  - ~5 x $10^{32\text{-}34}$ cm^{-2} sec^{-1} for low energy
  - Exchange of ideas over the last year very useful
- Both plan a staged realization
- Both designs have settled on more than one IR point
- Both machine designs integrate detector design in to the machine lattice
- Detectors concepts include a central solenoid and forward dipole, extensive low mass tracking for low x and good particle ID

A set of meetings on the Physics of EIC: 1999-2010

http://web.mit.edu/eicc/Meetings.html

A series of Users Workshops at Jefferson Lab in 2010:

Users Workshops Organizer by the Users of Jeff Lab:

httpp://michael.tunl.duke.edu/workshop

httpp://www.physics.rutgers.edu/np/2010rueic-home.html

http://www.phy.anl.gov/mep/EIC-NUC2010/

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

An International Group met at the INT September – December 2010 to define: The Science of EIC "Golden Measurements"

Institute of Nuclear Theory (INT) at U. of Washington: Sep-Nov 2010

Organizers: D. Boer, M. Diehl, R. Milner, R. Venugopalan, W. Vogelsang

See the INT WebPage for details of all studies:

http://www.int.washington.edu/PROGRAMS/10-3/

INT Workshop Write-up: http://arxiv.org/abs/1108.1713

Science of EIC:
Precise Investigations of the "Glue & Sea Quarks"

- Precision measurements of Sea Quarks and Gluon's Spin via inclusive and semi-inclusive DIS including EW probes of the hadron structure

Burkardt, Prokudin, Yuan

- Measurement of **(gluon)** GPDs & TMDs: via semi-inclusive and exclusive DIS → **wide range in x and Q^2**
  - 3D momentum and position (correlations) of the nucleon → Possibly leading to orbital angular momentum

M. Burkardt, Prokudin

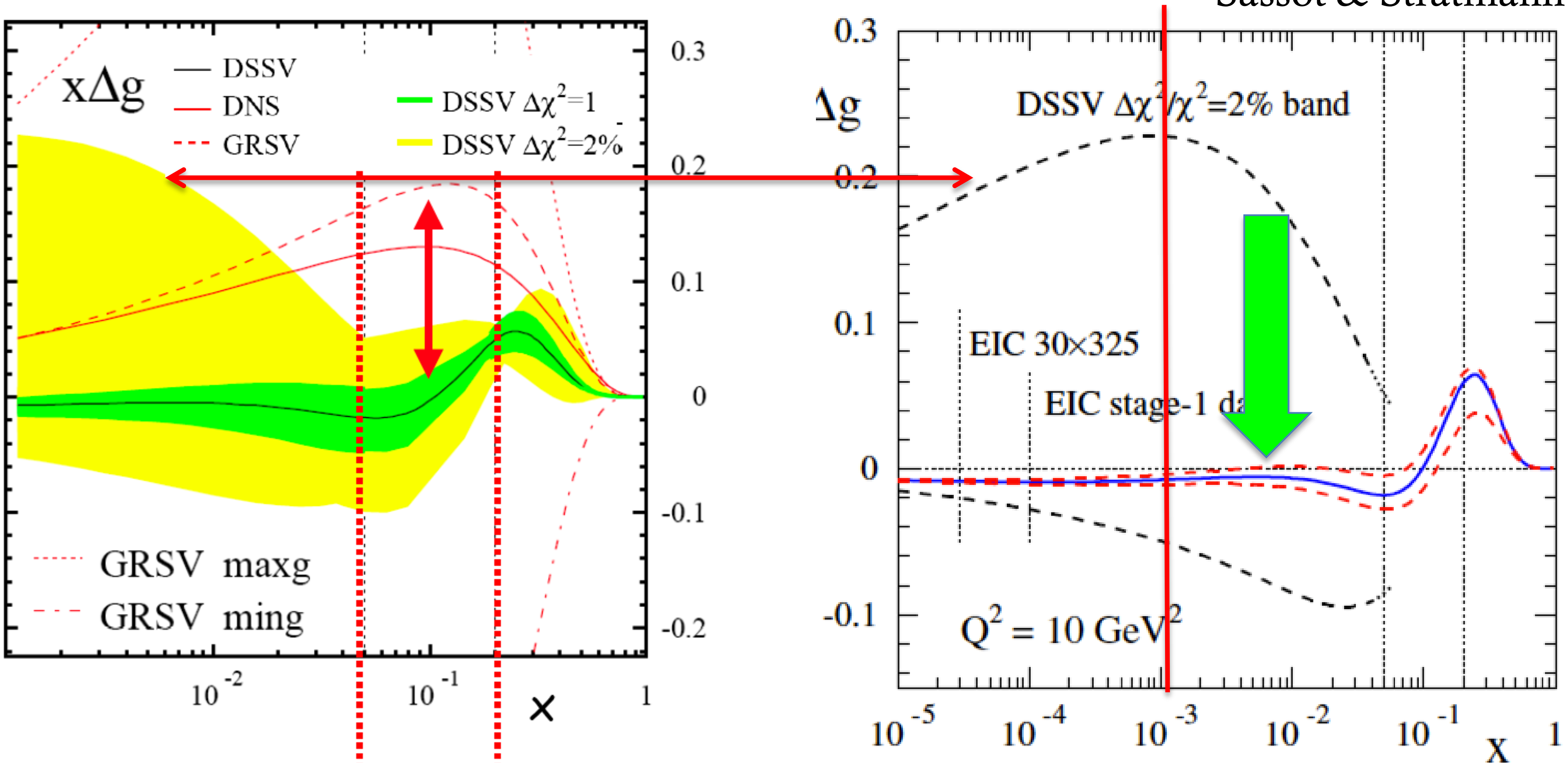
- Study **of extreme high gluon densities** via inclusive and sem-inclusive DIS off a wide range of nuclei and energies

K. Itakura, T. Ullrich, J. Qiu

- High energy, beam polarization, and a full acceptance detector: why not explore precision electroweak physics and EW (spin) structure functions

Nucleon Spin: Precision measurement of ΔG

Sassot & Stratmann



small-x
$0.001 \leq x \leq 0.05$

RHIC
range
$0.05 \leq x \leq 0.2$

large-x
$x \geq 0.2$

Yellow band (left) reduces to the band shown with **red dashed line** (right)

Science of EIC: Precise Investigations of the "Glue & Sea Quarks"

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  - 3D momentum and position (correlations) of the nucleon → Possibly leading to orbital angular momentum

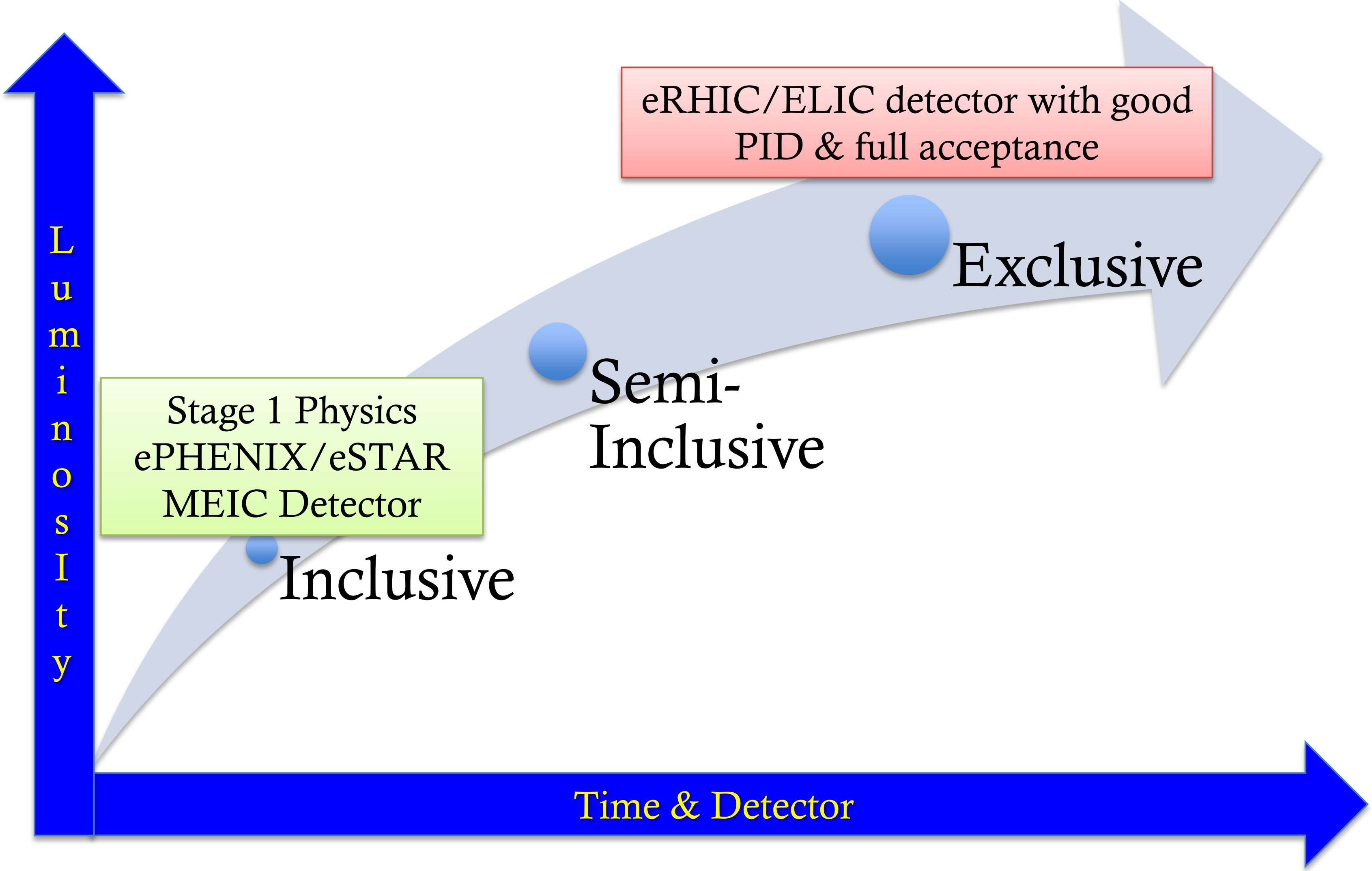
M. Burkardt, Prokudin

- Study **of extreme high gluon densities** via inclusive and sem-inclusive DIS off a wide range of nuclei and energies

K. Itakura, T. Ullrich, J. Qiu

- High energy, beam polarization, and a full acceptance detector: why not explore precision electroweak physics and EW (spin) structure functions

EIC Luminosity vs. Time (Detector)



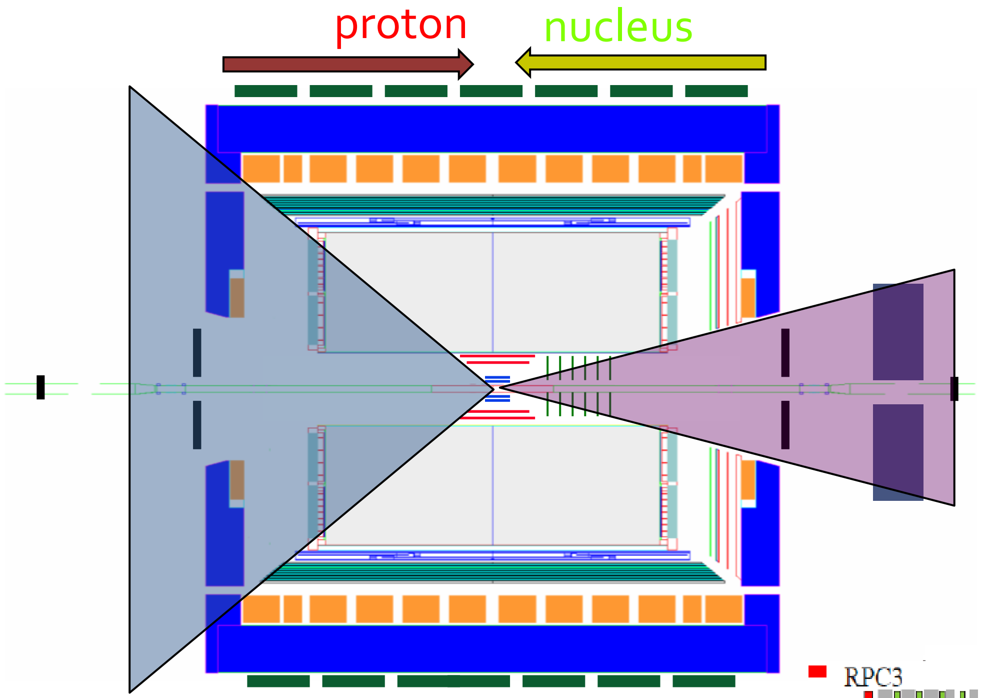
eRHIC/ELIC detector with good PID & full acceptance

Exclusive

Semi-Inclusive

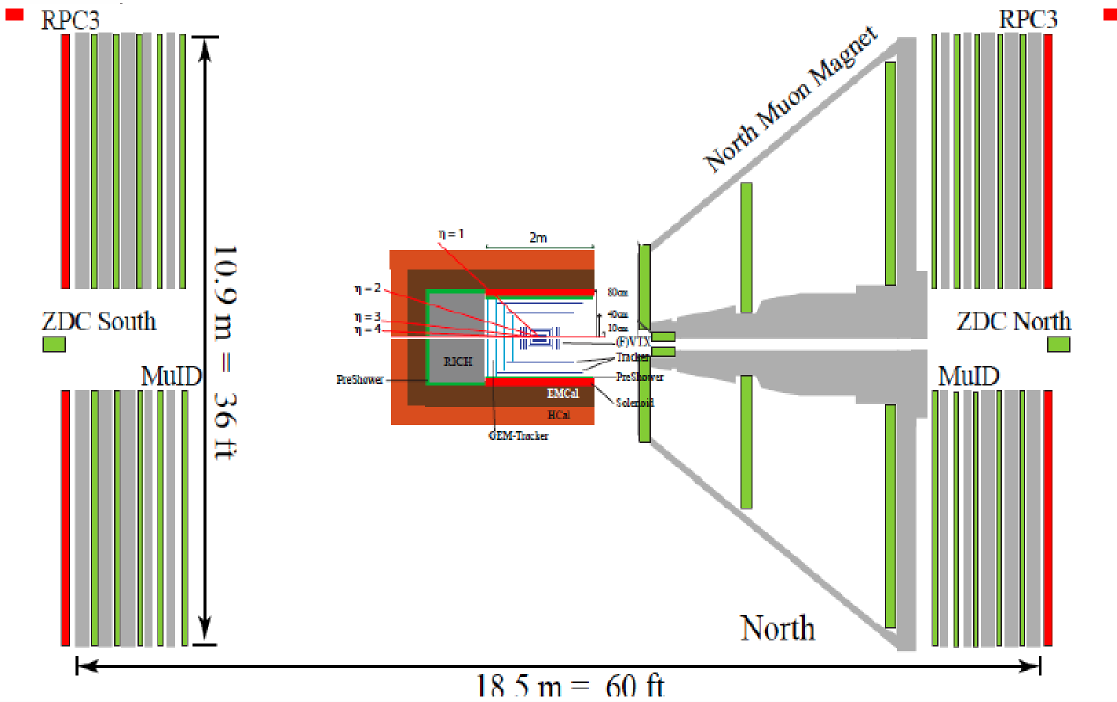
Stage 1 Physics
ePHENIX/eSTAR
MEIC Detector

Inclusive



eSTAR
J. H. Lee

s/ePHENIX
B. Jacak



Science of EIC: Stage 1

- Nucleon (spin) structure
  - Precision measurements of ΔQ, ΔQbar and ΔG via inclusive and semi-inclusive DIS

- Start the measurement of (gluon) GPDs & TMDs: 3D momentum and position (correlations) of the nucleon, possibly leading to orbital angular momentum(?)

- Start the study of extreme high gluon densities via inclusive and sem-inclusive DIS off a wide range of nuclei

- High energy, beam polarization, and a full acceptance detector: why not explore precision electroweak physics and EW (spin) structure functions?

EIC Project status and plans

- A “collaboration” of highly motivated people:
  - EIC Collaboration **Web Page:** **http://web.mit.edu/eicc/**
  - 100+ dedicated physicists from 20+ institutes
  - Task Forces at BNL (Aschenauer & Ullrich) and at Jefferson Laboratory (Ent)
  - Steering Committee (co-ordinators: A. Deshpande & R. Milner)
- **EIC International Advisory Committee** formed by the BNL & Jlab Management to steer this project to realization: ***W. Henning (ANL/RIKEN, Chair)***, *J. Bartels (DESY),A. Caldwell (MPI, Munich) A. De Roeck (CERN), R. Gerig (ANL), D. Hetrzog (U of W), X. Ji (Maryland), R. Klanner (Hamburg), A. Mueller (Columbia), S. Nagaitsev (FNAL), N. Saito (J-PARC), Robert Tribble (Texas A&M), U. Wienands (SLAC), V. Shiltev (FNAL)*

A White for NSAC Long Range Plan 2012/2013 to be produced by early 2012

Writing Group: E; Aschenauer, M. Diehl, H. Gao, A. Hutton, T. Horn, K. Kumar, Y. Kovchegov, M. Ramsey-Musolf, T. Roser, F. Sabatie, E. Sichtermann, T. Ullrich, W. Vogelsang, F. Yuan

Senior Advisors: A. Mueller, R. Holt

Co-Chairs/Editors: A. Deshpande, J. Qiu, Z.E. Meziani

Generic Detector R&D for an EIC

- Community wide call for R&D Detector proposals for EIC
- Program run from BNL (RHIC R&D funds), NOT site specific

New detector technology for fiber sampling calorimetry for EIC and STAR.
UCLA, Texas A&M, Penn State
Front end readout modules for data acquisition and trigger system.
Jefferson Lab
DIRC based PID for EIC Central Detector**.**
Catholic U. of America, Old Dominion U., JLab, GSI (Darmstadt)
Liquid scintillator calorimeter for the EIC.
Ohio State U.
Test of improved radiation tolerant silicon PMTs.
Jefferson Lab
Letter of Intent for detector R&D towards an EIC detector **(Low mass tracking and PID)**.
BNL, Florida Inst. Tech., Iowa State, LBNL, LANL, MIT, RBRC, Stony Brook, U. of Virginia, Yale U.

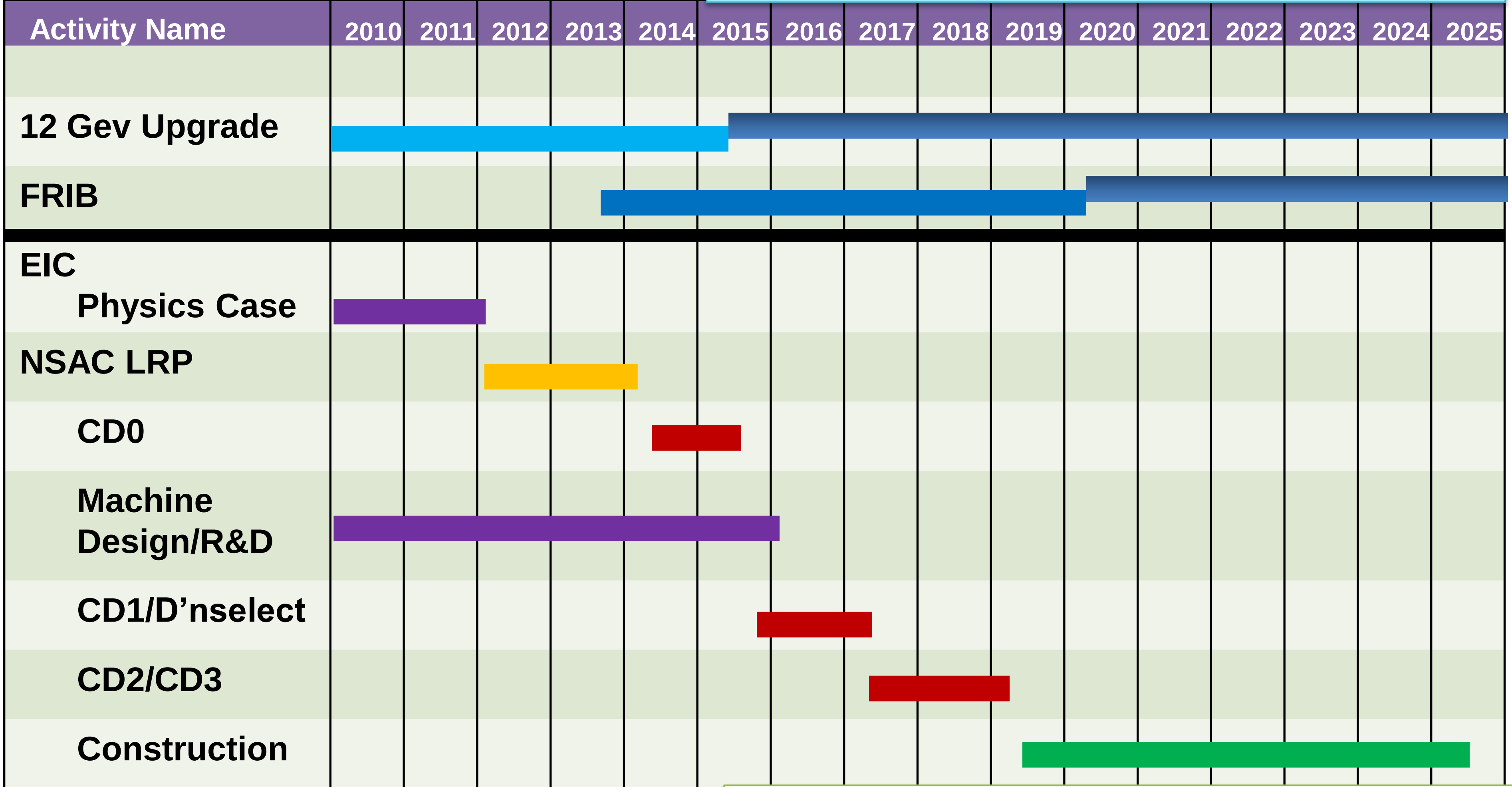
Seeds for possible future experimental collaboration…. Attracting new collaborators….

Next round of applications and updates requested in November, 2011

H. Montgomery, Jeff. Laboratory Director

EIC Realization Possible Time Line

eRHIC, Vigdor's time line similar



Construction Schedule Highly Site Dependent

Summary

Science Case for EIC: → "Understand QCD" via

"Precision study of the role of gluons & sea quarks in QCD"

The Collaboration & the BNL+Jlab managements are moving **(*together*)** towards realization: ***Milestoe: NSAC approval 2013***

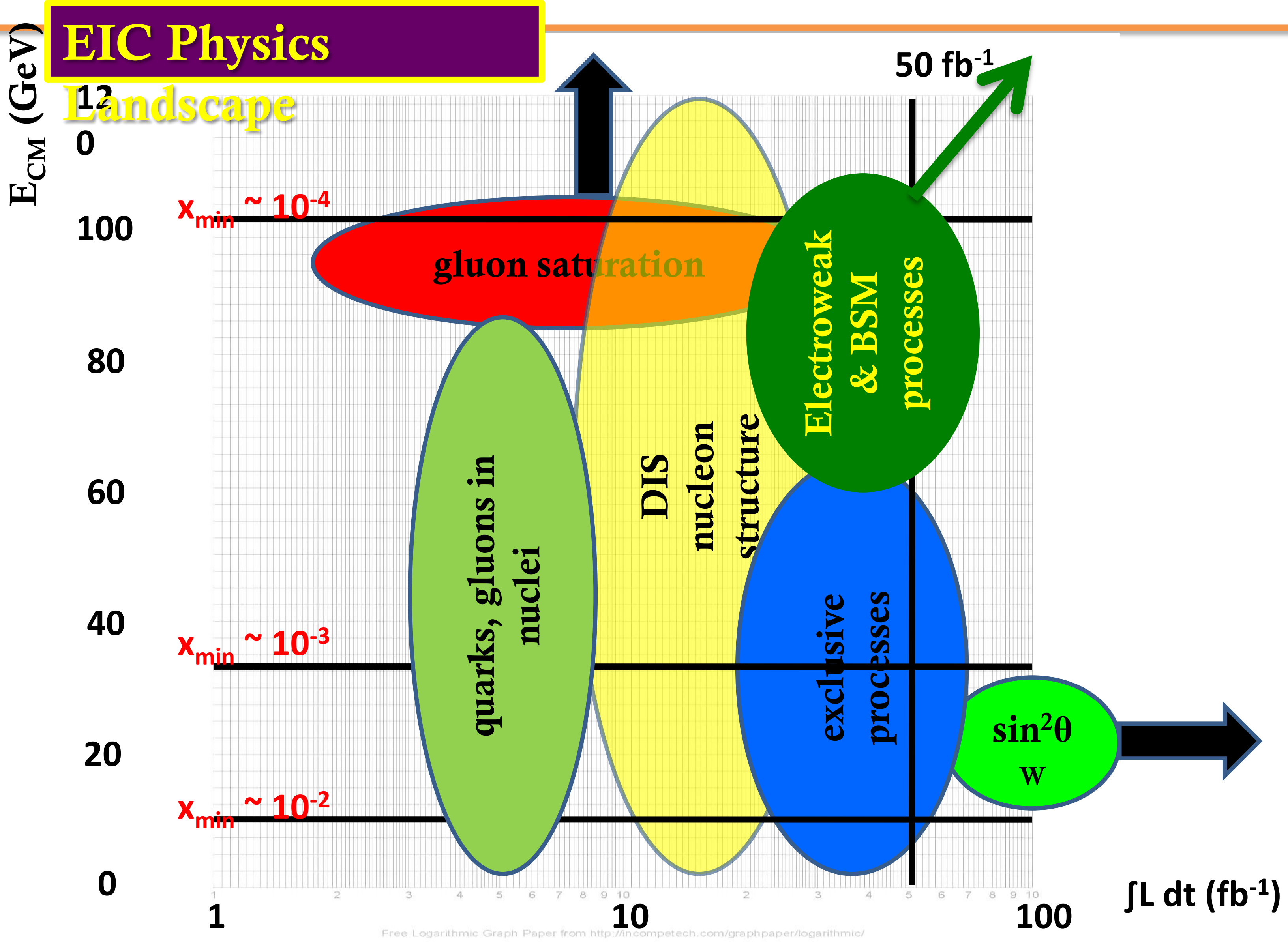
- Machine R&D, detector discussions, simulation studies towards making the final case including detailed detector design and cost considerations

INVITATION: Ample opportunities to ***get involved and influence*** this exciting quest for understanding of QCD!

RIKEN's investment in RHIC has had a DISPROPORTIONATELY LARGE IMPACT on ~~RHIC science~~: Understanding QCD: Experiment, Theory & Lattice QCD

EIC is the opportunity to do the same or better in the next decade

Physics Opportunities at the EIC



Electroweak & beyond….(?)

BNL LDRD: Deshpande, Marciano, Kumar & Vogelsang

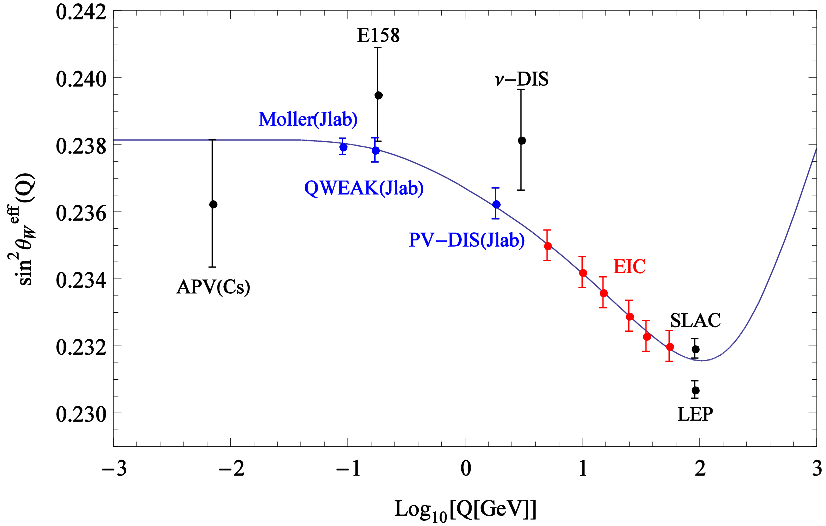
- High energy collisions of polarized electrons and protons and nuclei afford a unique opportunity to study electro-weak deep inelastic scattering
  - **Electroweak structure functions (including spin)**
  - Significant contributions from W and Z bosons which have different couplings with ***quarks and anti-quarks***

- **Parity violating DIS**: a probe of beyond TeV scale physics
  - Measurements at higher Q^2 than the PV DIS 12 GeV at Jlab
  - Precision measurement of $\mathrm{Sin}^2\Theta_W$

arXiv: 006.5063v1 [hep-ph]
M. Gonderinger et al.

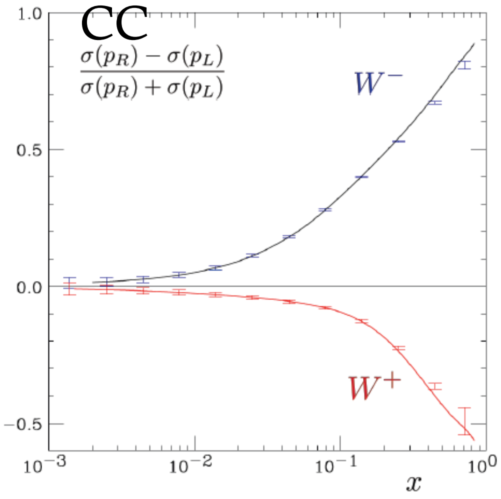
- **New window for physics beyond SM?**
  - Lepton flavor violation search $e^- + p \rightarrow \tau^- + X$

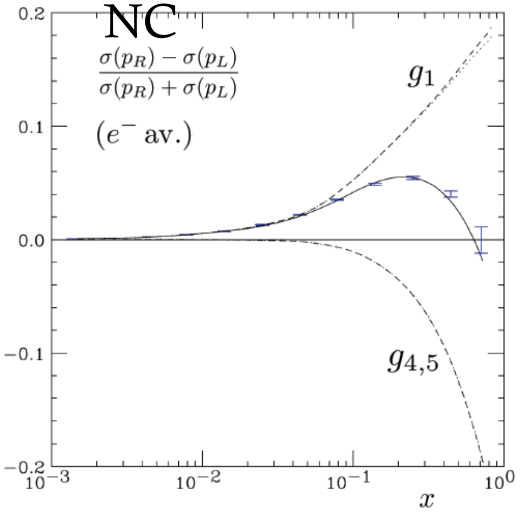
EW Physics Highlights



Deviations from the curve may hint at existence of BSM scenarios including: Lepto-Quarks, RPV SUSY extensions, E_6/Z' based extensions of the SM

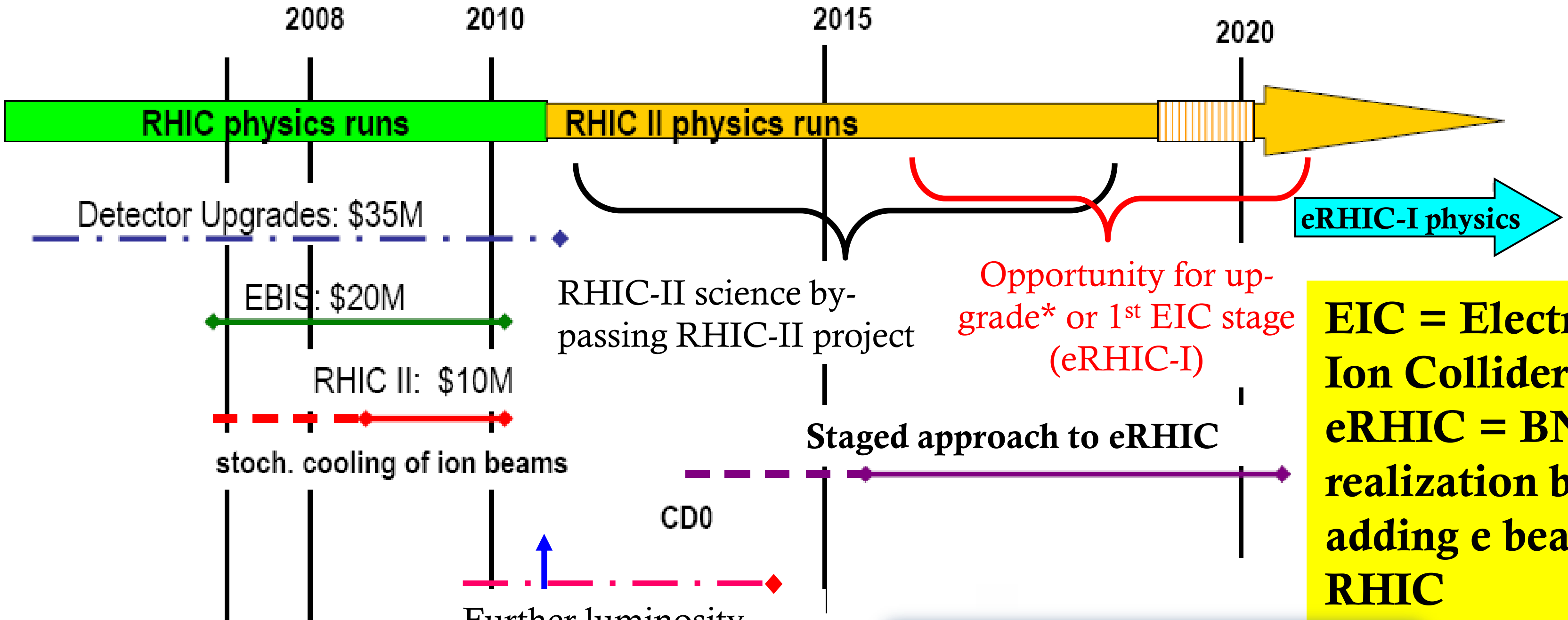
Electroweak CC and NC structure functions: access to spin properties of quarks and anti-quarks over a wide x, Q^2 range.





S. Vigdor, BNL Associate Director

A Long Term (Evolving) Strategic View for RHIC



RHIC physics runs

RHIC II physics runs

eRHIC-I physics

Detector Upgrades: $35M

EBIS: $20M

RHIC II: $10M

stoch. cooling of ion beams

RHIC-II science by-passing RHIC-II project

Opportunity for up-grade* or 1st EIC stage (eRHIC-I)

Staged approach to eRHIC

CD0

Further luminosity upgrades (pp, low-E)

LHC HI starts

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

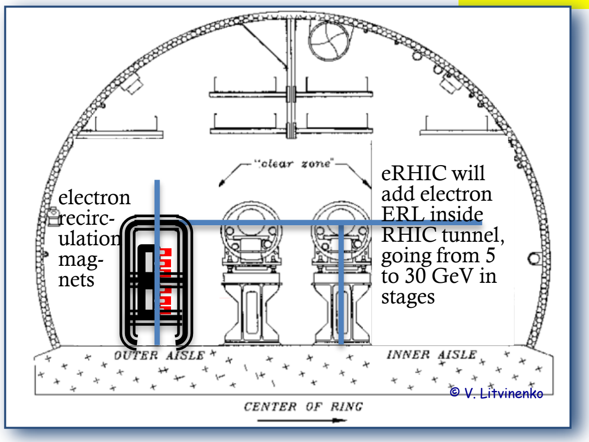
Legend:

R&D

Construction

Multiple small projects

CD0: DOE Critical Decision, mission need



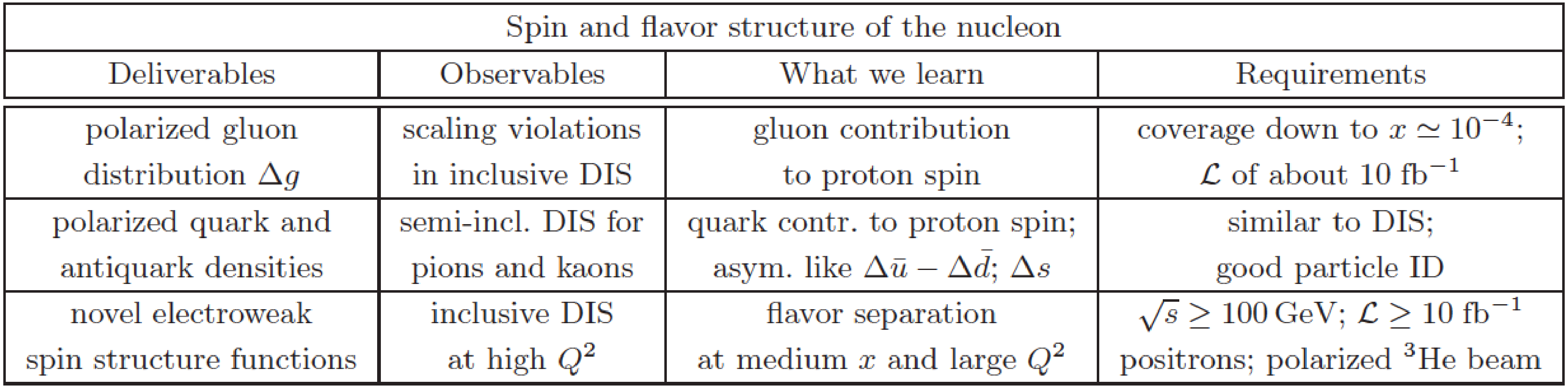
electron recirc-ulation mag-nets

eRHIC will add electron ERL inside RHIC tunnel, going from 5 to 30 GeV in stages

* New PHENIX and STAR Decadal Plans provide options for this period.

Golden Measurements (1)

Spin & flavor structure of the nucleon



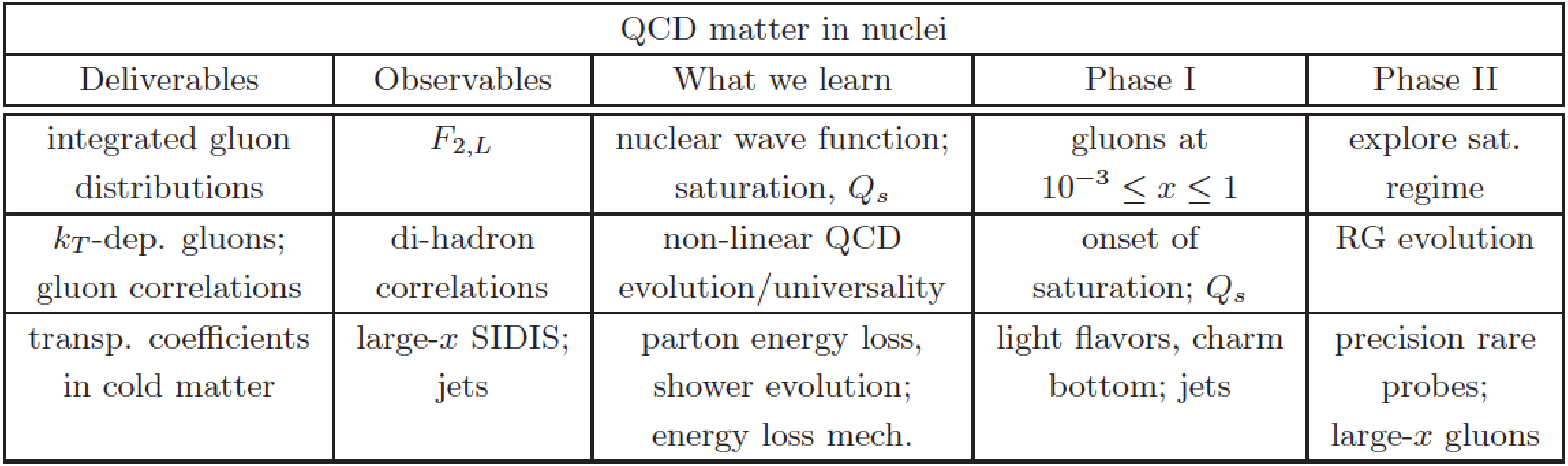
Spin and flavor structure of the nucleon			
Deliverables	Observables	What we learn	Requirements
polarized gluon distribution Δg	scaling violations in inclusive DIS	gluon contribution to proton spin	coverage down to $x \simeq 10^{-4}$; $\mathcal{L}$ of about 10 fb^{-1}
polarized quark and antiquark densities	semi-incl. DIS for pions and kaons	quark contr. to proton spin; asym. like $\Delta\bar{u} - \Delta\bar{d}$; Δs	similar to DIS; good particle ID
novel electroweak spin structure functions	inclusive DIS at high Q^2	flavor separation at medium x and large Q^2	$\sqrt{s} \geq 100$ GeV; $\mathcal{L} \geq 10$ fb^{-1} positrons; polarized ^{3}He beam

Golden Measurements (2): TMDs & GPDs of nucleons & nuclei

Three-dimensional structure of the nucleon and nuclei: transverse momentum dependence				
Deliverables	Observables	What we learn	Phase I	Phase II
Sivers and unpolarized TMDs for quarks and gluon	SIDIS with transv. polarization/ions; di-hadron (di-jet) heavy flavors	quantum interference multi-parton and spin-orbit correlations	valence+sea quarks, overlap with fixed target experiments	3D Imaging of quarks and gluon; Q^2 $(P_\perp)$ range QCD dynamics

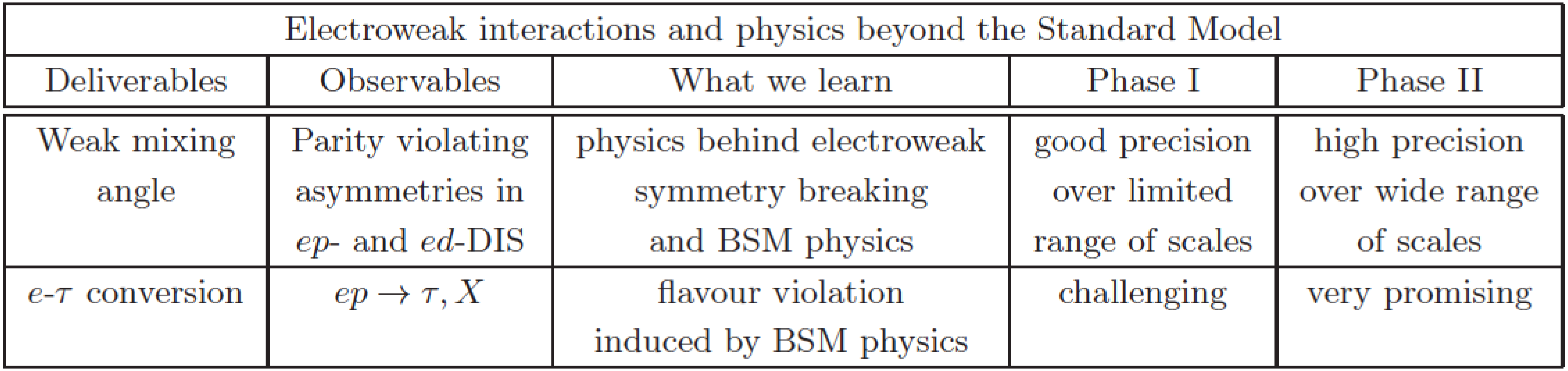
Three-dimensional structure of the nucleon and nuclei: spatial imaging			
Deliverables	Observables	What we learn	Requirements
sea quark and gluon GPDs	DVCS and $J/\psi, \rho, \phi$ production cross sect. and asymmetries	transverse images of sea quarks and gluons in nucleon and nuclei; total angular momentum; onset of saturation	$\mathcal{L} \geq 10^{34}$ cm^{-2}s^{-1}, Roman Pots wide range of x_B and Q^2 polarized e^- and p beams e^+ beam for DVCS

Golden Measurement (3): QCD matter in Nuclei



QCD matter in nuclei				
Deliverables	Observables	What we learn	Phase I	Phase II
integrated gluon distributions	$F_{2,L}$	nuclear wave function; saturation, Q_s	gluons at $10^{-3} \leq x \leq 1$	explore sat. regime
k_T-dep. gluons; gluon correlations	di-hadron correlations	non-linear QCD evolution/universality	onset of saturation; Q_s	RG evolution
transp. coefficients in cold matter	large-x SIDIS; jets	parton energy loss, shower evolution; energy loss mech.	light flavors, charm bottom; jets	precision rare probes; large-x gluons

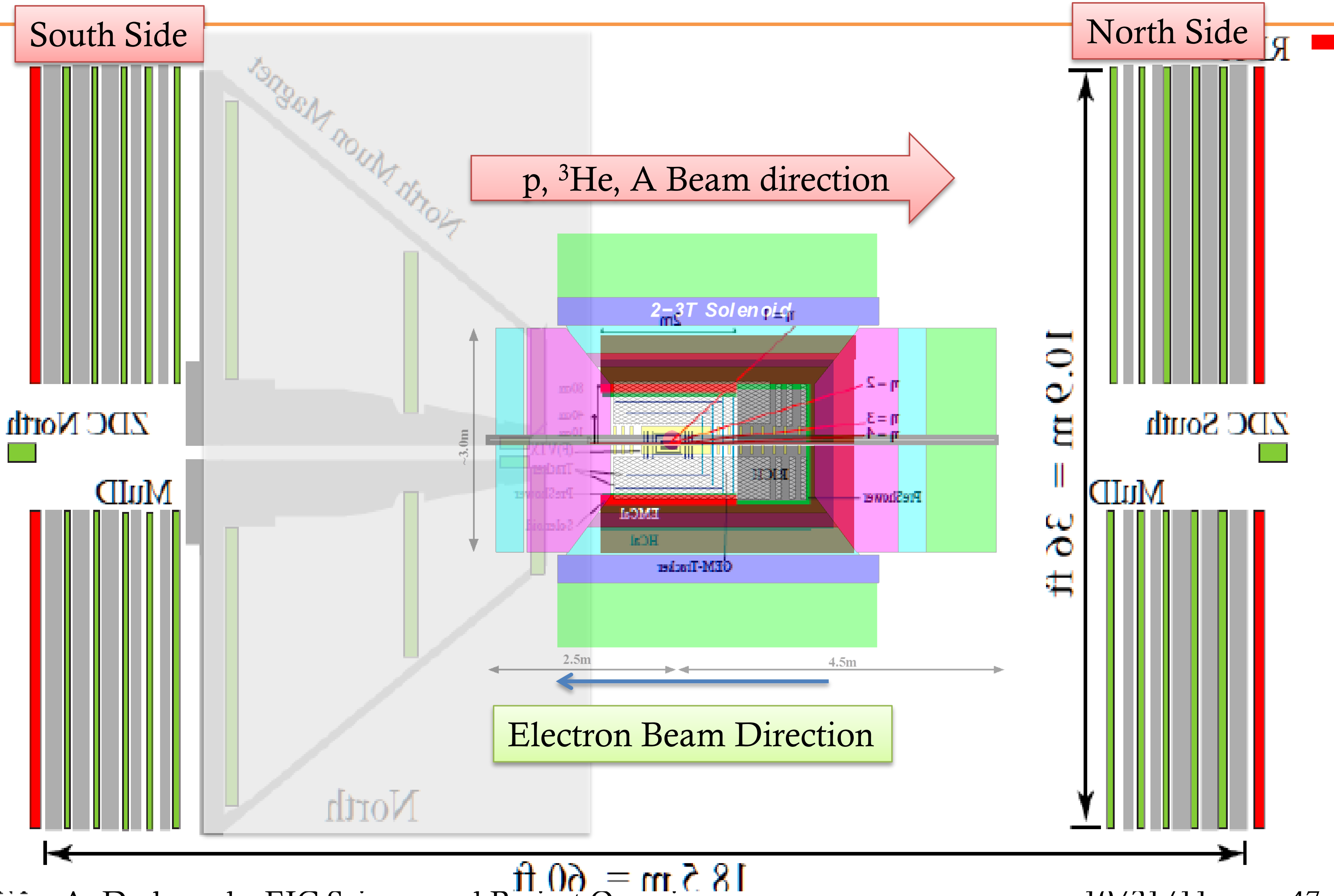
Golden Measurements (4): EW interactions & BSM



Electroweak interactions and physics beyond the Standard Model				
Deliverables	Observables	What we learn	Phase I	Phase II
Weak mixing angle	Parity violating asymmetries in ep- and ed-DIS	physics behind electroweak symmetry breaking and BSM physics	good precision over limited range of scales	high precision over wide range of scales
e-τ conversion	$ep \to \tau, X$	flavour violation induced by BSM physics	challenging	very promising

My Cartoon !

sPHENIX → ePHENIX → eRHIC



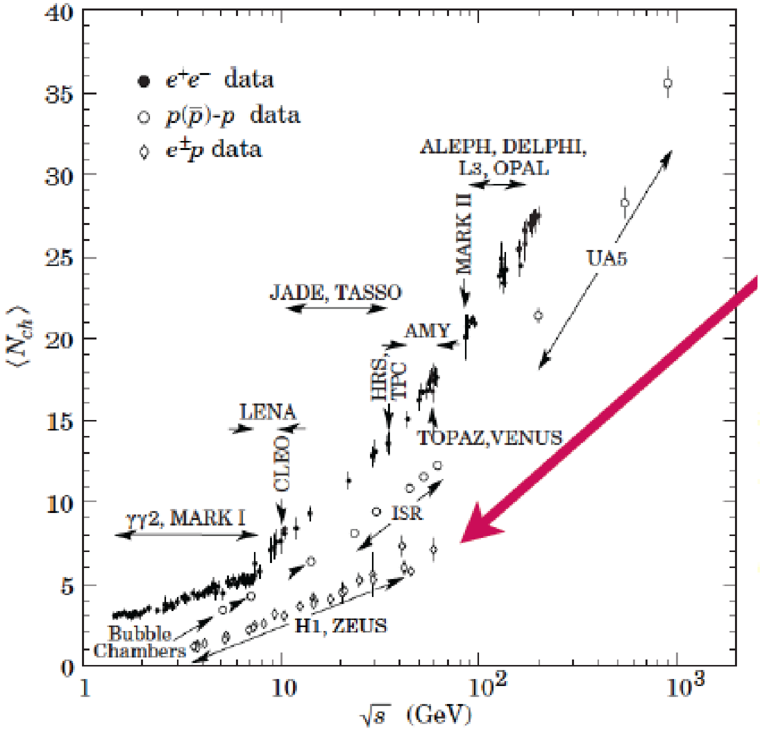
South Side

North Side

p, ^{3}He, A Beam direction

Electron Beam Direction

Some thought about rates

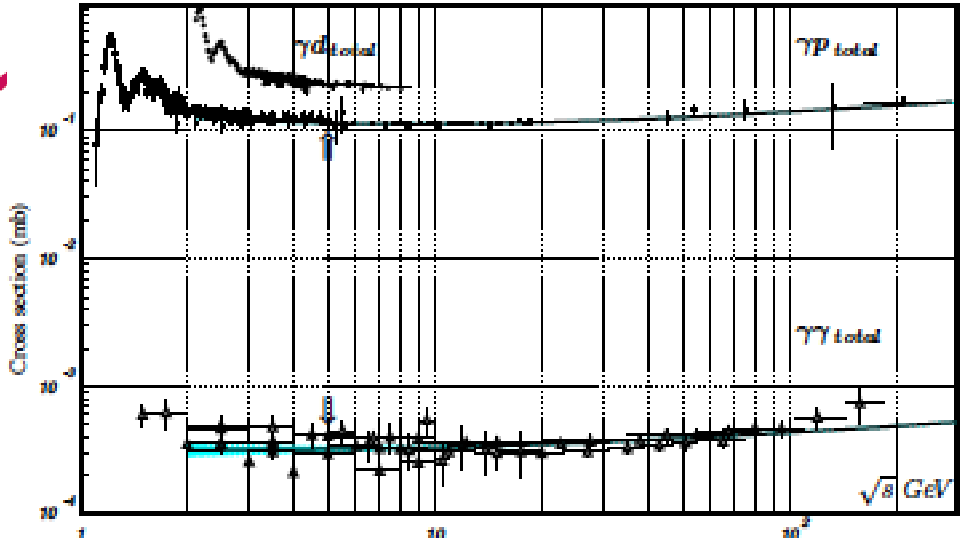


low multiplicity

4-6 √s = 40-65 GeV

N_{ch} (ep) ~ N_{ch} (eA) < N_{ch}(pA)

→ no occupancy problem



Cross section: $\sigma_{ep} < \sigma_{\gamma^* p} < \sigma_{\gamma p}$

Pythia σ_{ep}: 0.030 – 0.060 mb

Luminosity: 10^{34} cm^{-1} s^{-1} = 10^7 mb^{-1} s^{-1}

Interaction rate:
300 -600 kHz