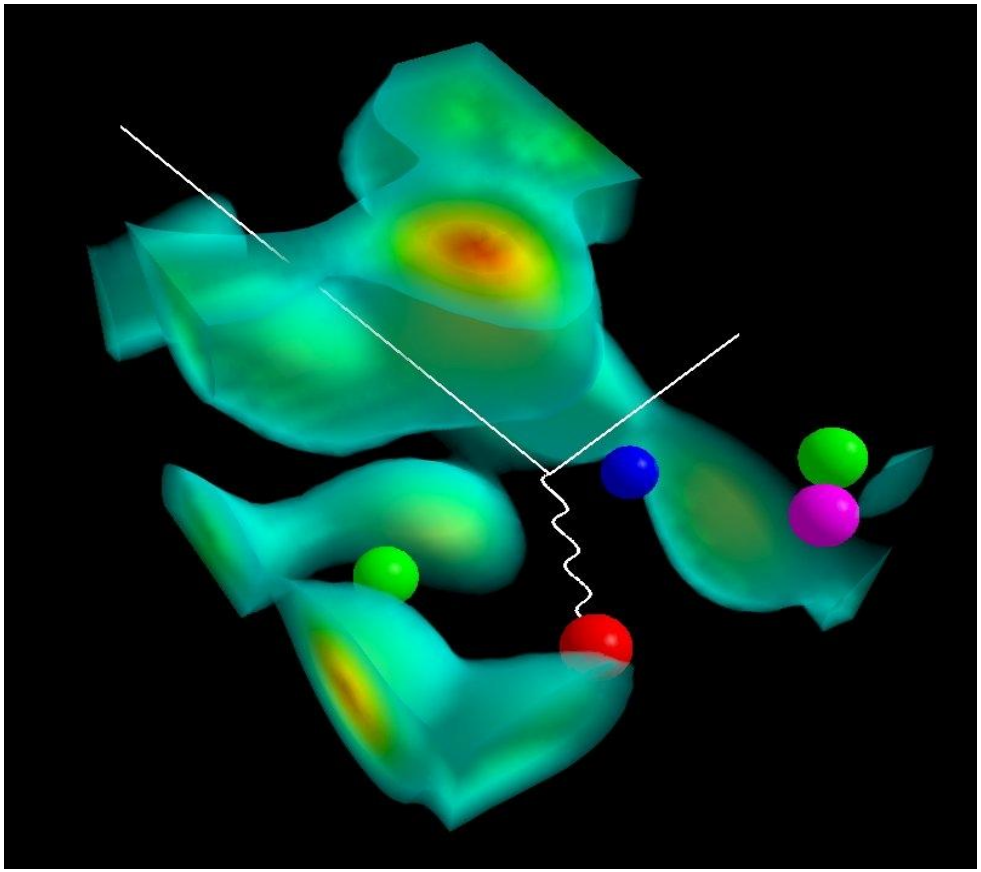
An Electron-Ion Collider at JLab

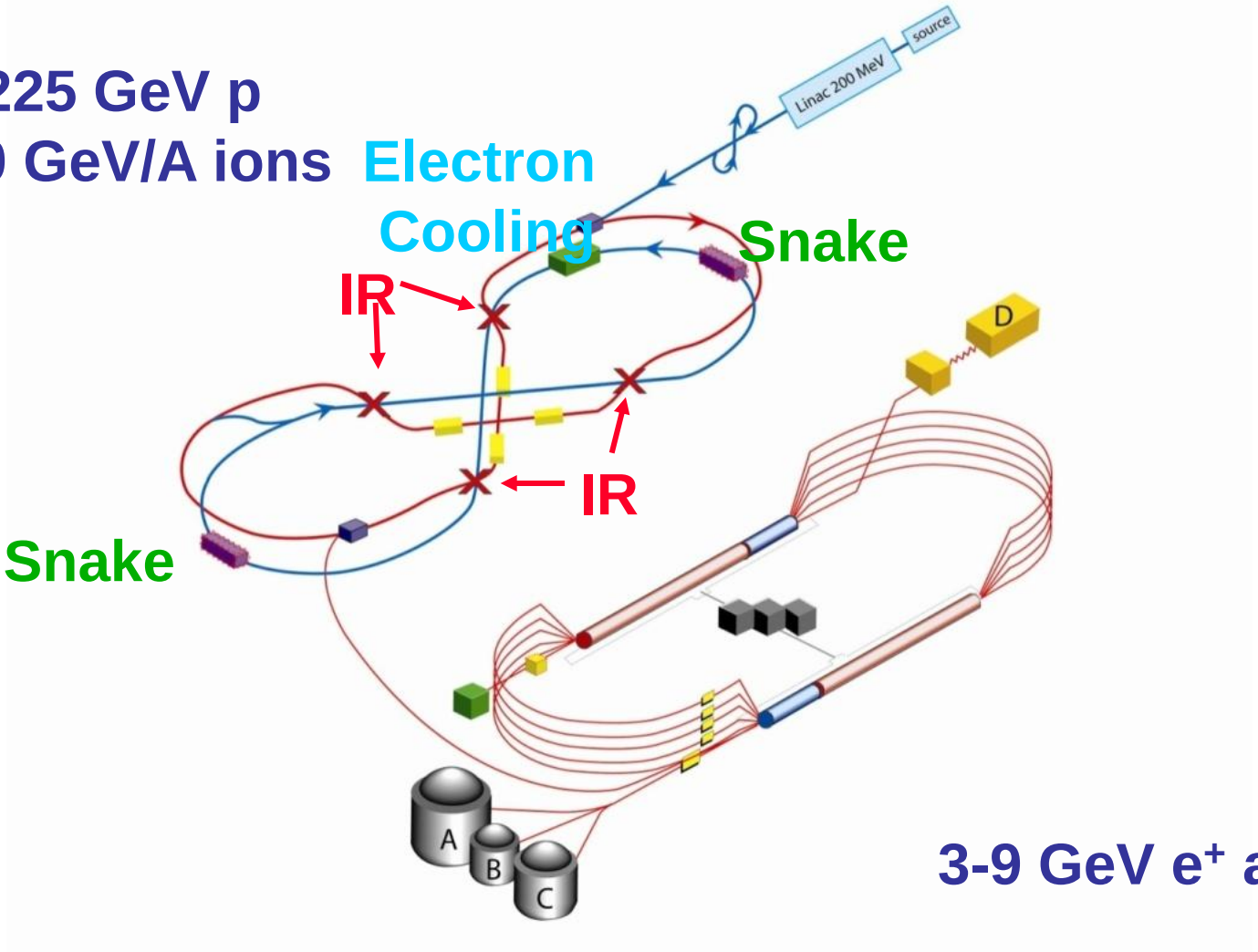


Anthony W. Thomas

DIS09 Madrid : April30th 2009

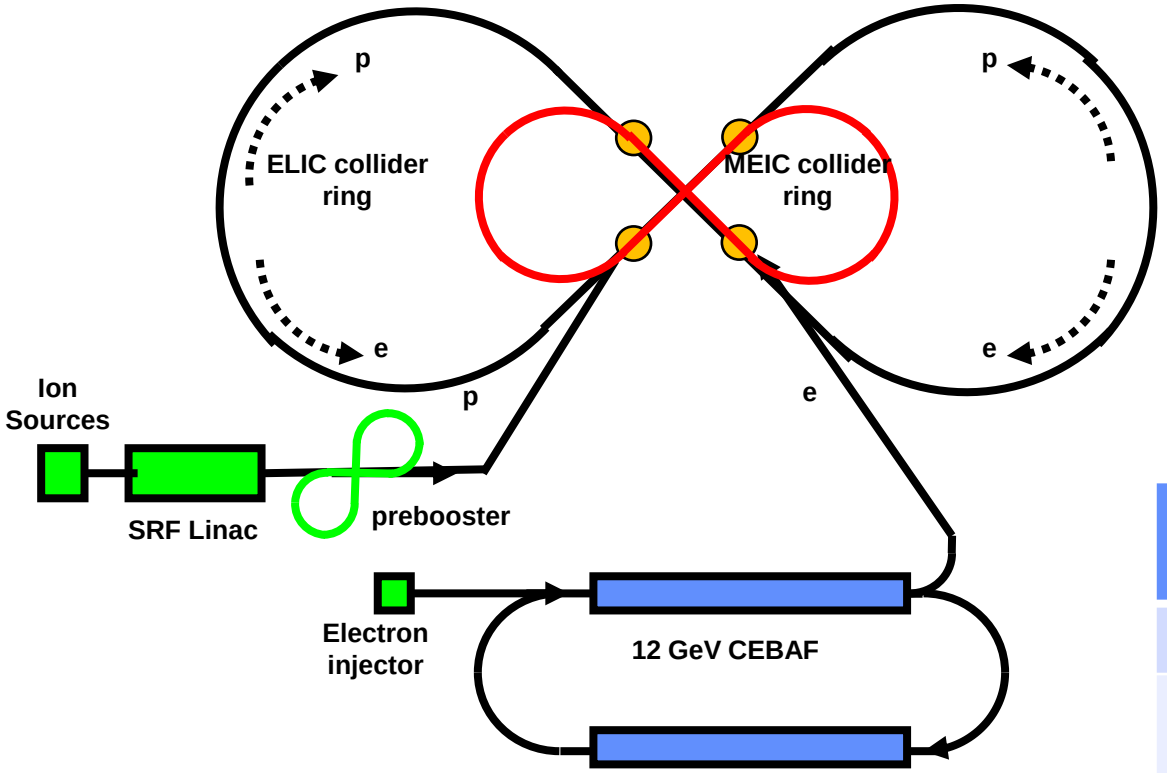
Long-term Landscape : ELIC

30-225 GeV p
30-100 GeV/A ions



3-9 GeV e^+ and e^-

Consideration of Staging – Medium Energy



MEIC parameters	Length (m)
Arc	157
Straight section	150
Insertion section	10
Circumference	634

A High-Luminosity Medium-Energy Collider (MEIC) for Nuclear Physics at JLab

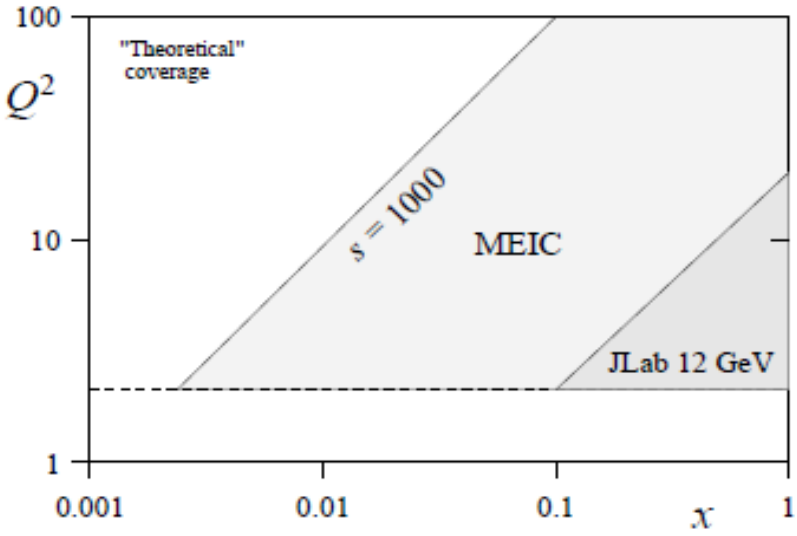
- **Ring-ring collider with**
  - **electron energies ranging from 3 to 11 GeV**
  - **proton energies ranging from 12 to 60 GeV**

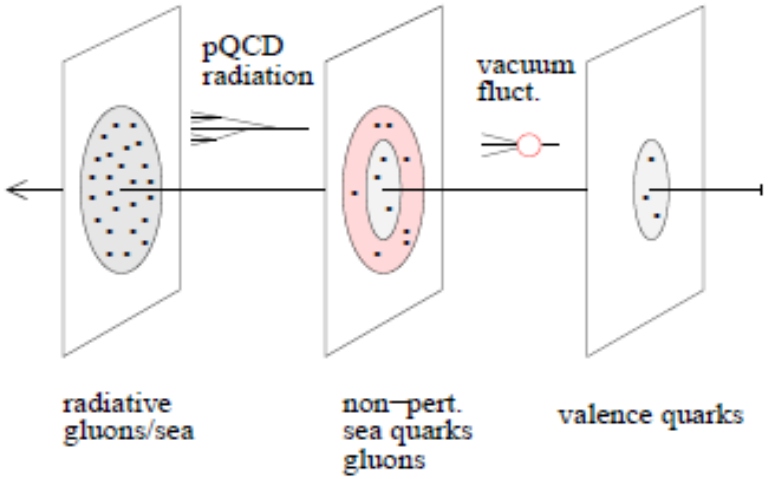
- **Luminosity L ~ few x 10^{34}, approaching 10^{35} cm^{-2} s^{-1}**

- **Requires less R&D, parameters within reach**

- **Physics: Nucleon/nuclear structure in QCD**
  (Gluon and sea quark imaging of the nucleon, nucleon spin, nuclei in QCD, QCD vacuum and hadronic structure)
  - **Natural extension of 12 GeV**
  - **Consistent with NSAC Long-Range Plan**

Scientific Opportunities with Medium Energy EIC



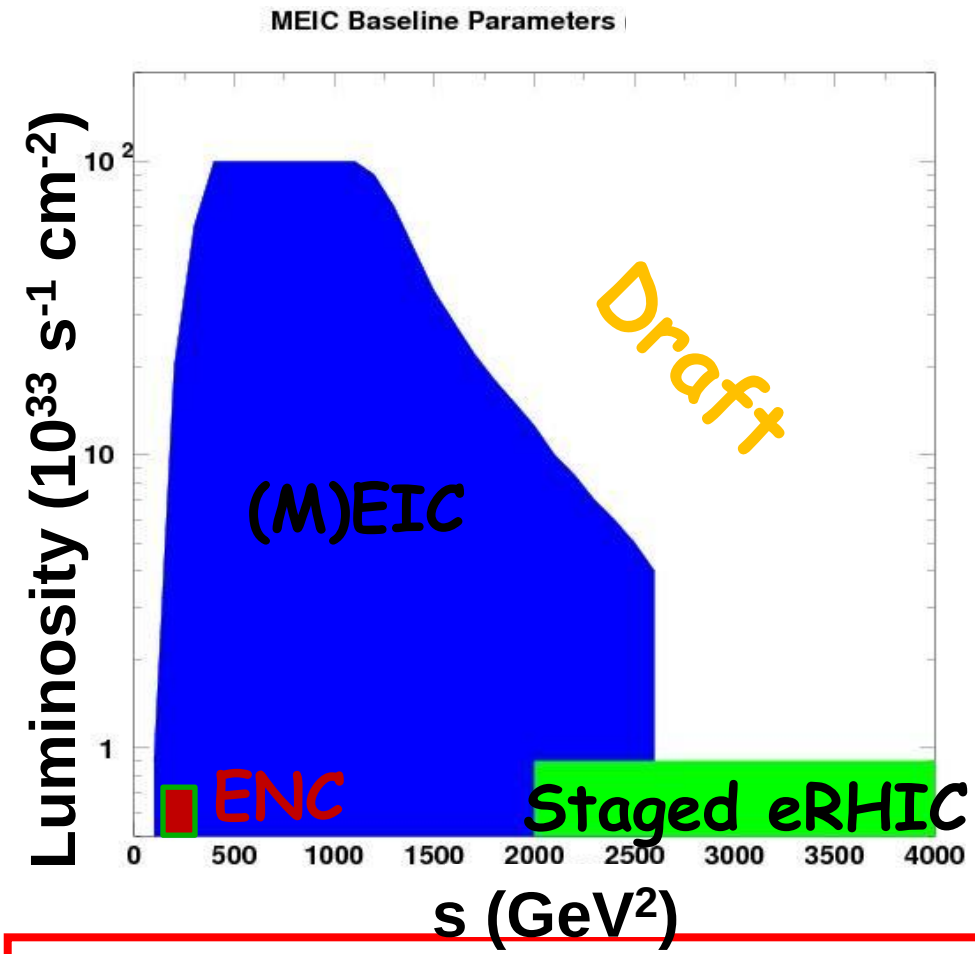


- 12 GeV upgrade will map the spin and flavor dependence of pdfs in valence region

Medium Energy Collider

- Precise exploration of spin and flavor dependence in sea
- GPDs &transverse spin to investigate orbital angular momentum of quarks and gluons & spatial distribution
- Quark and gluon structure of nuclei (flavor & spin too) through the shadowing region
- J/Ψ production, fragmentation….

(M)EIC@JLab: Present Status



Plot assumptions:

1) **Detector/DAQ/electronics limits the luminosity to 10^{35}**
2) **Scale to higher electron beam energies (up to 11 GeV) at fixed synchrotron limit**
3) **Luminosity for staged eRHIC at 2 on 250 is similar as for 4 GeV on 250 GeV (from EICAC meeting)**

- **Design provides excellent luminosity for $200 < s < 1200$ ($x = 0.0008$ @ $Q^2 = 1$) ($x = 0.01$ @ $Q^2 = 12$)**
- **Good luminosity (10^{33} or more) down to $s = 100$ and up to $s = 2640$ (can access gluons down to $x = 0.001$ or so)**

MEIC Parameter Table: Medium Energy

Beam energy	GeV	60/5	60/4	60/3	45/5	45/4	45/3	30/5	30/4	30/3
Circumference	m	560	560	560	560	560	560	560	560	560
Beam current	A	0.6/2	1.2/3.2	2.7/5	0.5/2	0.6/2.3	2.1/5	0.7/2	0.5/3.5	0.6/4
Repetition	GHz	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Particles/bunch	10^{10}	0.7/2.5	1.5/4	3.4/6.3	0.6/2.5	0.7/2.9	2.6/6.25	0.9/2.5	0.7/4.4	0.8/5
Bunch Length	mm	5	5	5	5	5	5	5	5	5/5
Norm. hori. emit.	μm	1/147	1/120	0.8/75	0.7/147	0.5/85	0.6/75	0.5/147	0.4/85	0.4/75
Norm. vert. emit.	μm	0.1/15	0.2/24	0.8/75	0.14/29	0.17/28	0.6/7.5	0.5/147	0.4/85	0.4/75
Horizontal β^*	mm	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5
Vertical β^*	mm	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5
Size at IP (x/y)	μm	8.7/2.7	8.8/3.9	8	8.7/3.9	7.4/4.3	8	8.7	7.4	8
Hori. Beam-beam		.005/.002	.007/.04	.009/.1	.006/.01	.009/.02	.012/.08	.006/.01	.015/.02	.015/.02
Vert. beam-beam		.015/.05	.015/.09	.009/.1	.013/.03	.015/.04	.012/.08	.006/.01	.0`5/.02	.015/.02
Laslett tune shift	proton	0.1	0.1	0.055	0.1	0.1	0.1	0.1	0.1	0.1
Luminosity (10^{34})	$cm^{-2}s^{-1}$	3	6.8	13	1.8	2.7	10	1.2	2.1	3.1

- Luminosity is given as a peak value per IP, may be reduced by other beam dynamics effects. We assume maximum allowable synchrotron radiation (SR) power density is 20 kW/m.
- We can allow 60x11 GeV/c (CM energy up to 51 GeV) with a luminosity of 1.3×10^{34} $cm^{-2}s^{-1}$.
- Case of 60x3 GeV/c provides highest luminosity (above 10^{35}) due to optimization of low electron energy (low SR power) and high proton energy (low space charge effect)
- Studies of new ideas/concepts for increasing luminosity for low proton energy are in progress

MEIC Accelerator R&D

- Key R&D for MEIC are
  - electron cooling for delivering low emittance/ultra short ion bunches
  - Traveling focusing for suppressing space charge effect & boosting luminosity
  - Crab cavity required for colliding high repetition beams
  - Forming high intensity low energy ion beam
  - Beam-beam effect
- There are other less critical/challenging R&D topics but required by ZDR

Level of R&D	MEIC	ELIC
Nearly impossible		
Very challenging		Electron cooling
Challenging	Electron cooling Traveling focusing	Crab crossing/crab cavity
Likely	Crab crossing/crab cavity High intensity low energy *i* beam Beam-beam	High intensity low energy *i* beam Beam-beam
Know-how	Spin tracking IP design/chromaticity	Spin tracking IP design/chromaticity

Back-up

MEIC Design Features

- An ultra high luminosity collider, up to above 10^{35} $cm^{-2}s^{-1}$ per detector
- CM energy from 8 GeV (4x4 GeV/c) up to 51 GeV (60x11 GEV/c)
- Up to 4 IPs (1 for low proton energy, 3 for medium proton energy)
- High polarization for both electron and light ion beams (due to Figure-8 ring)
- Natural staging path to high energy ELIC (250x10 GeV)
- Can also be staged (1^{st} stage with warm ion ring, up to 12 GeV/c)
- Possibility of polarized positron-ion collider in the same low to medium energy region with same high luminosity.
- Significant lower cost comparing full ELIC