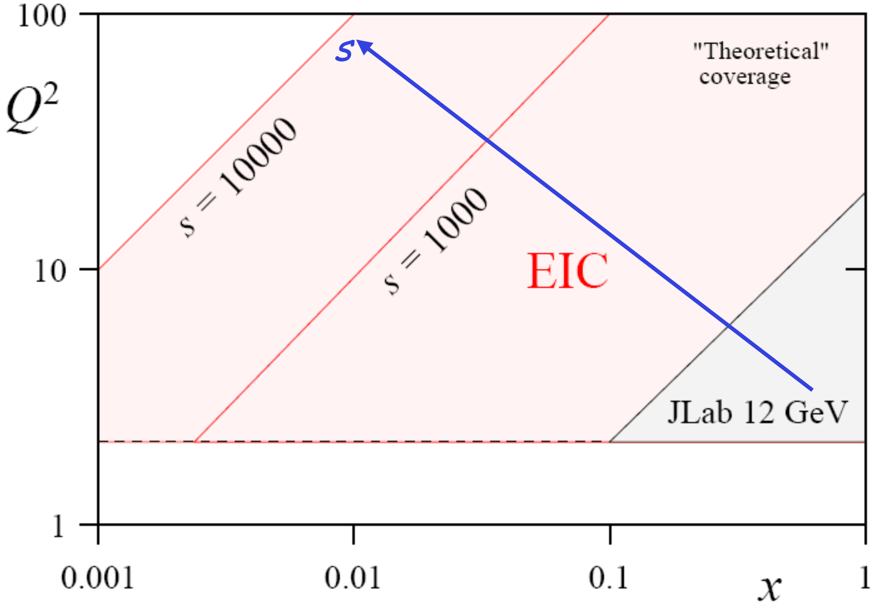
MEIC/ELIC Accelerator Design

Rolf Ent – Jefferson Lab

EIC Generic Detector R&D Advisory Committee Meeting
Brookhaven National Lab, May 9th 2011

MEIC assumptions



$x = Q^2/ys$

(x,Q^2) phase space directly correlated with s $(=4E_eE_p)$:

@ $Q^2 = 1$ lowest x scales like s^{-1}

@ $Q^2 = 10$ lowest x scales as $10s^{-1}$

- Detecting only the electron $y_{max} / y_{min} \sim 10$
- Also detecting all hadrons $y_{max} / y_{min} \sim 100$

("Medium-Energy") EIC@JLab option driven by:

access to sea quarks (x > 0.01 (0.001?) or so)
deep exclusive scattering at $Q^2 > 10$ (?)
any QCD machine needs range in Q^2

→ s = few 100 - 1000 seems right ballpark
→ s = few 1000 allows access to gluons, shadowing

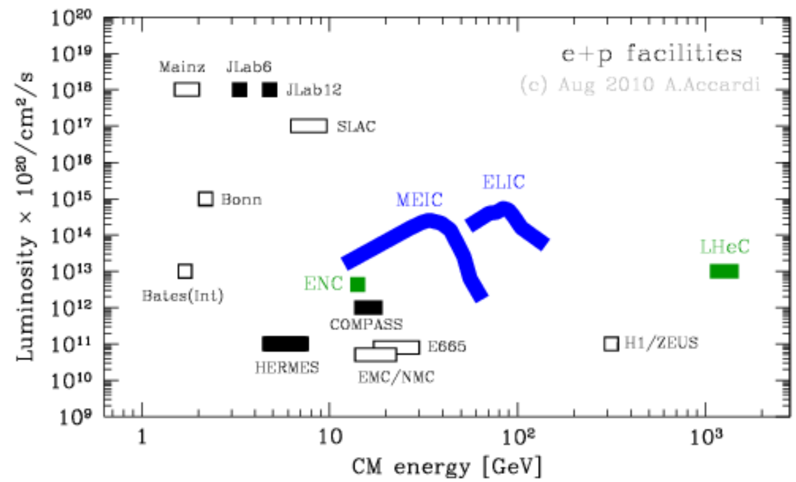
Requirements for deep exclusive and high-Q^2 semi-inclusive reactions also drives request for (lower &) more symmetric beam energies.
Requirements for very-forward angle detection folded in IR design

MEIC Design Goal

- Energy
  - Full coverage in *s* from a few hundreds to a few thousands
    Bridging the gap of 12 GeV CEBAF and HERA/LHeC
  - Electron 3 to 11 GeV, proton 20 to 100 GeV, ion 12 to 40 GeV/u
  - s = 300-4500 GeV^2
  - Design point: 60 GeV proton on 5 GeV electron
- Ion species
  - Polarized light ion: p, d, ^{3}He and possibly Li
  - Un-polarized ions up to A=200 or so (Au, Pb)
- Detectors
  - Up to three interaction points, two for medium energy (20 to 100 GeV)
  - One *full-acceptance* detector (primary), *7 m* between IP & 1st final focusing quad
  - One *high luminosity* detector (secondary), *4.5 m* between IP and 1st final focusing quad

MEIC Design Goal (cont.)

- Luminosity
  - About 10^{34} cm^{-2} s^{-1} (e-nucleon) per interaction point (IP)
  - Maximum luminosity should optimally be around s = 1000-2000 GeV^2



- Polarization
  - Longitudinal at the IP for both beams, transverse at IP for ions only
  - Spin-flip of both beams (at least 0.1 Hz)
  - All polarizations >70% desirable

- Upgradeable to higher energy & luminosity
  - 20 GeV electron, 250 GeV proton and 100 GeV/u ion

- Positron beam highly *desirable*
  - Positron-ion collisions with reasonable (reduced/similar?) luminosity

Technical Design Strategy

Limit as many design parameters as we can to *within or close to* the present state-of-art in order to *minimize technical uncertainty and R&D tasks*

- Stored electron current should not be larger than 3 A
- Stored proton/ion current should be less than 1 A (better below 0.5 A)
- Maximum synchrotron radiation power density is 20 kW/m
- Maximum peak field of warm electron magnet is 1.7 T
- Maximum peak field of ion superconducting dipole magnet is 6 T
- Maximum betatron value at FF quad is 2.5 km

- New beta-star, appropriate to the detector requirements

2.5 km β^{max} + 7 m	➔	β_y^*= 2 cm	Full acceptance
2.5 km β^{max} + 4.5 m	➔	β_y^*=0.8 cm	

- This design will form a base for *future optimization* guided by
  - Evolution of the science program
  - Technology innovation and R&D advances

Luminosity Concept: *Following the Leader*

Luminosity of KEKB and PEP II follow from

- Very small β* (~6 mm)
- Very short bunch length (σ_z~ β*)
- Very small bunch charge (5.3 nC)
- High bunch repetition rate (509 MHz)

Low Charge Intensity

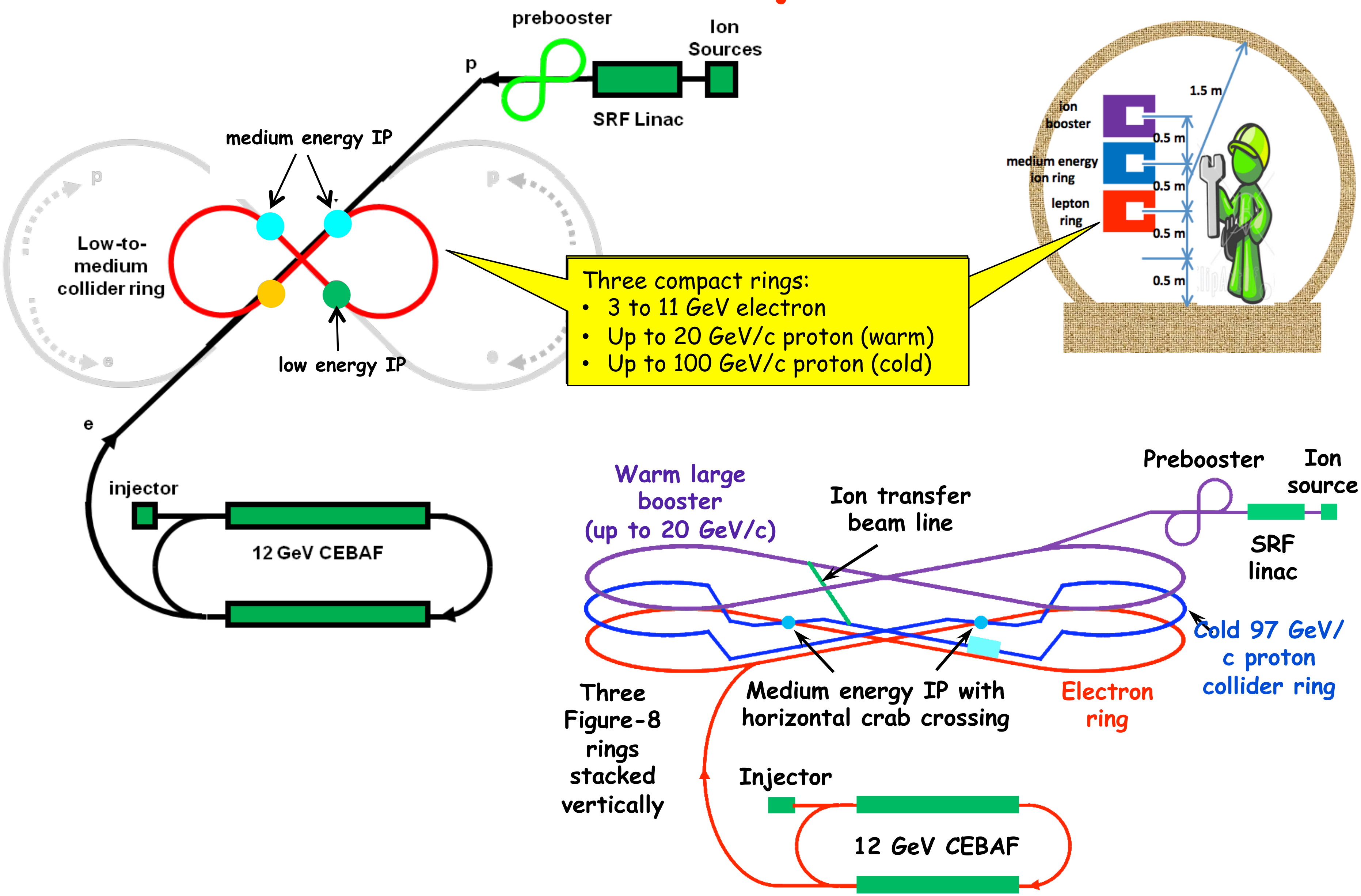
➔ KEK-B already over 2x10^{34} /cm^2/s

JLab is poised to replicate same success in electron-ion collider:

- **A high repetition rate electron beam from CEBAF**
- **A green-field ion complex (so can match e-beam)**

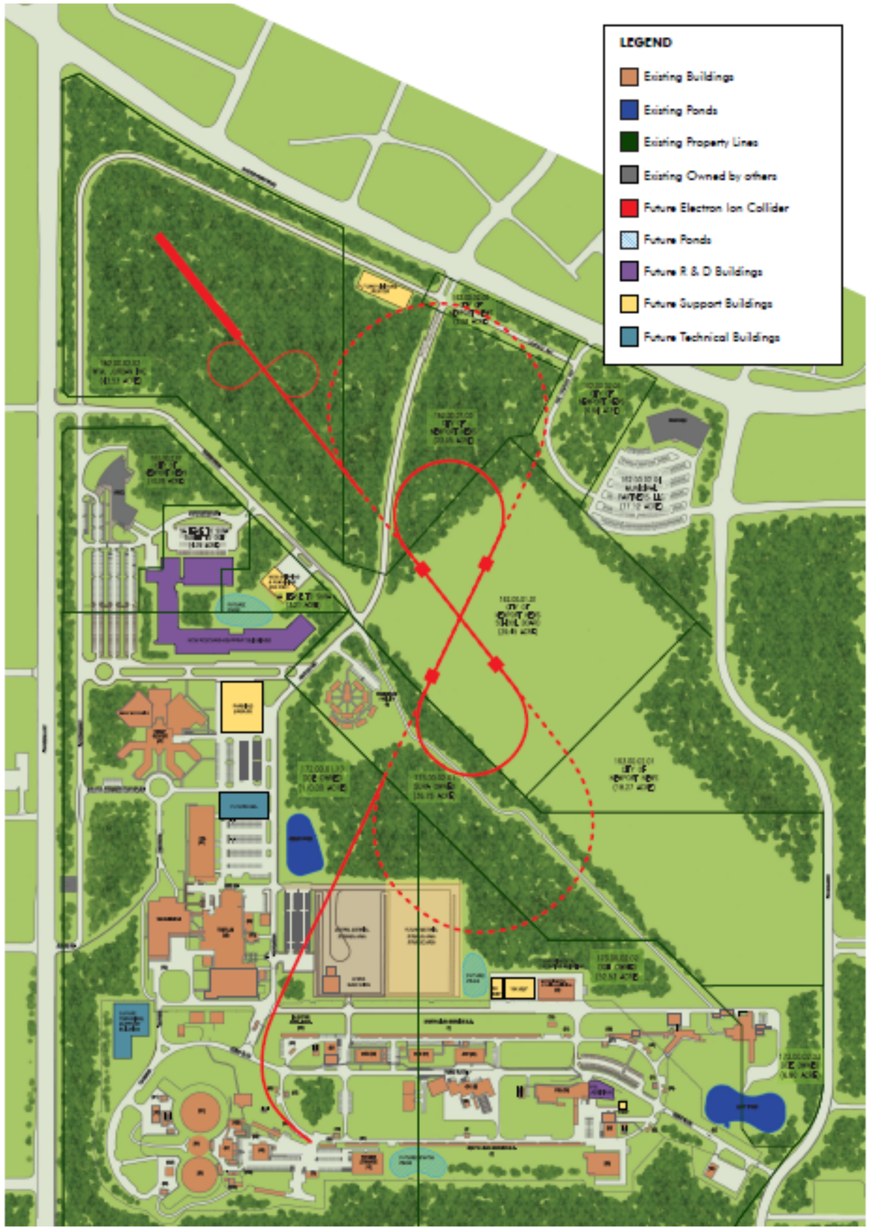
		KEK B	MEIC
Repetition rate	MHz	509	750
Particles per bunch	10^{10}	3.3 / 1.4	0.42 / 2.5
Beam current	A	1.2 / 1.8	0.5 / 3
Bunch length	cm	0.6	1 / 0.75
Horizontal & vertical β*	cm	56/0.56	10 / 2
Luminosity per IP, 10^{33}	cm^{-2}s^{-1}	20	5.6 ~ 14

MEIC Layout



prebooster
Ion Sources
p
SRF Linac
medium energy IP
Low-to-medium collider ring
low energy IP
e
injector
12 GeV CEBAF
Three compact rings:
• 3 to 11 GeV electron
• Up to 20 GeV/c proton (warm)
• Up to 100 GeV/c proton (cold)
1.5 m
ion booster
medium energy ion ring
lepton ring
0.5 m
0.5 m
0.5 m
0.5 m
Warm large booster (up to 20 GeV/c)
Ion transfer beam line
Prebooster
Ion source
SRF linac
Cold 97 GeV/c proton collider ring
Three Figure-8 rings stacked vertically
Medium energy IP with horizontal crab crossing
Electron ring
Injector
12 GeV CEBAF

MEIC and Upgrade on JLab Site Map



Parameters for A *Full Acceptance* Detector

		Proton	Electron
Beam energy	GeV	60	5
Collision frequency	MHz	750	750
Particles per bunch	10^{10}	0.416	2.5
Beam Current	A	0.5	3
Polarization	%	> 70	~ 80
Energy spread	10^{-4}	~ 3	7.1
RMS bunch length	cm	10	7.5
Horizontal emittance, normalized	µm rad	0.35	54
Vertical emittance, normalized	µm rad	0.07	11
Horizontal β*	cm	10	10
Vertical β*	cm	2	2
Vertical beam-beam tune shift		0.014	0.03
Laslett tune shift		0.06	Very small
Distance from IP to 1st FF quad	m	7	3.5
Luminosity per IP, 10^{33}	$cm^{-2}s^{-1}$	5.6	

Parameters for A *High Luminosity* Detector

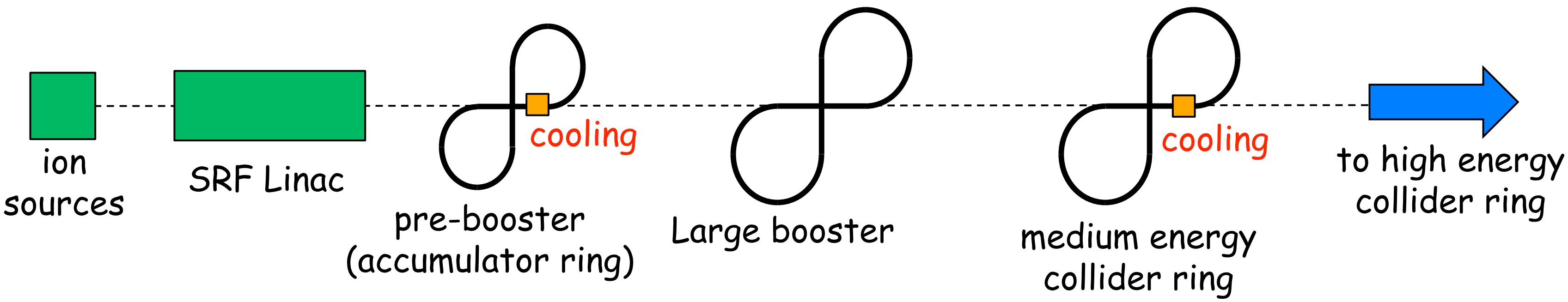
		Proton	Electron
Beam energy	GeV	60	5
Collision frequency	MHz	750	750
Particles per bunch	10^{10}	0.416	2.5
Beam current	A	0.5	3
Polarization	%	> 70	~ 80
Energy spread	10^{-4}	~ 3	7.1
RMS bunch length	cm	10	7.5
Horizontal emittance, normalized	µm rad	0.35	54
Vertical emittance, normalized	µm rad	0.07	11
Horizontal β*	cm	4	4
Vertical β*	cm	0.8	0.8
Vertical beam-beam tune shift		0.014	0.03
Laslett tune shift		0.06	Very small
Distance from IP to 1st FF quad	m	4.5	3.5
Luminosity per IP, 10^{33}	$cm^{-2}s^{-1}$	14.2	

A Green Field Ion Complex

MEIC ion complex design goal

- Be able to generate/accumulate and accelerate ion beams for collisions
- Covering all required varieties of ion species
- Matching the time, spatial and phase space structure of the electron beam (bunch length, transverse emittance and repetition

Schematic layout



	Length (m)	Max. energy (GeV/c)	Electron Cooling	Process
SRF linac		0.2 (0.08)		
Pre-booster	~300	3 (1.2)	DC	accumulating
booster	~1300	20 (8 to 15)		
collider ring	~1300	96 (40)	Staged/ERL	

* Numbers in parentheses represent energies per nucleon for heavy ions

Ion Pre-booster

Purpose of pre-booster

- Accumulating ions injected from linac
- Accelerating ions
- Extracting/sending ions to the large booster

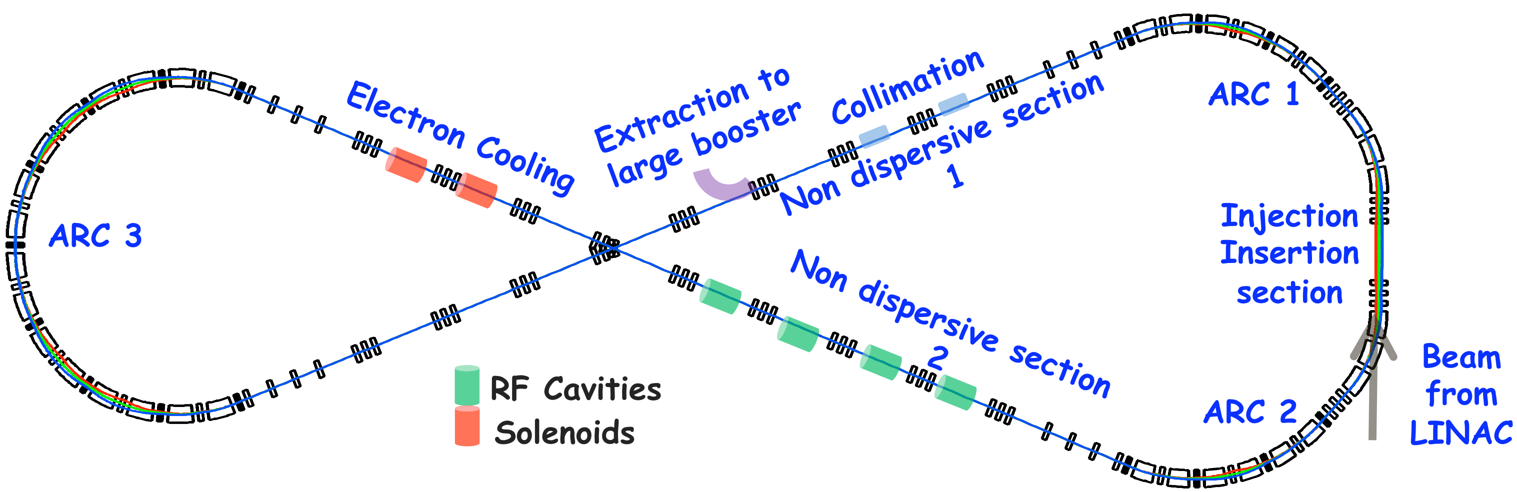
Design concepts

- Figure-8 shape
- (Quasi-independent) modular design
- FODO arcs for simplicity and ease optics corrections

Design constraints

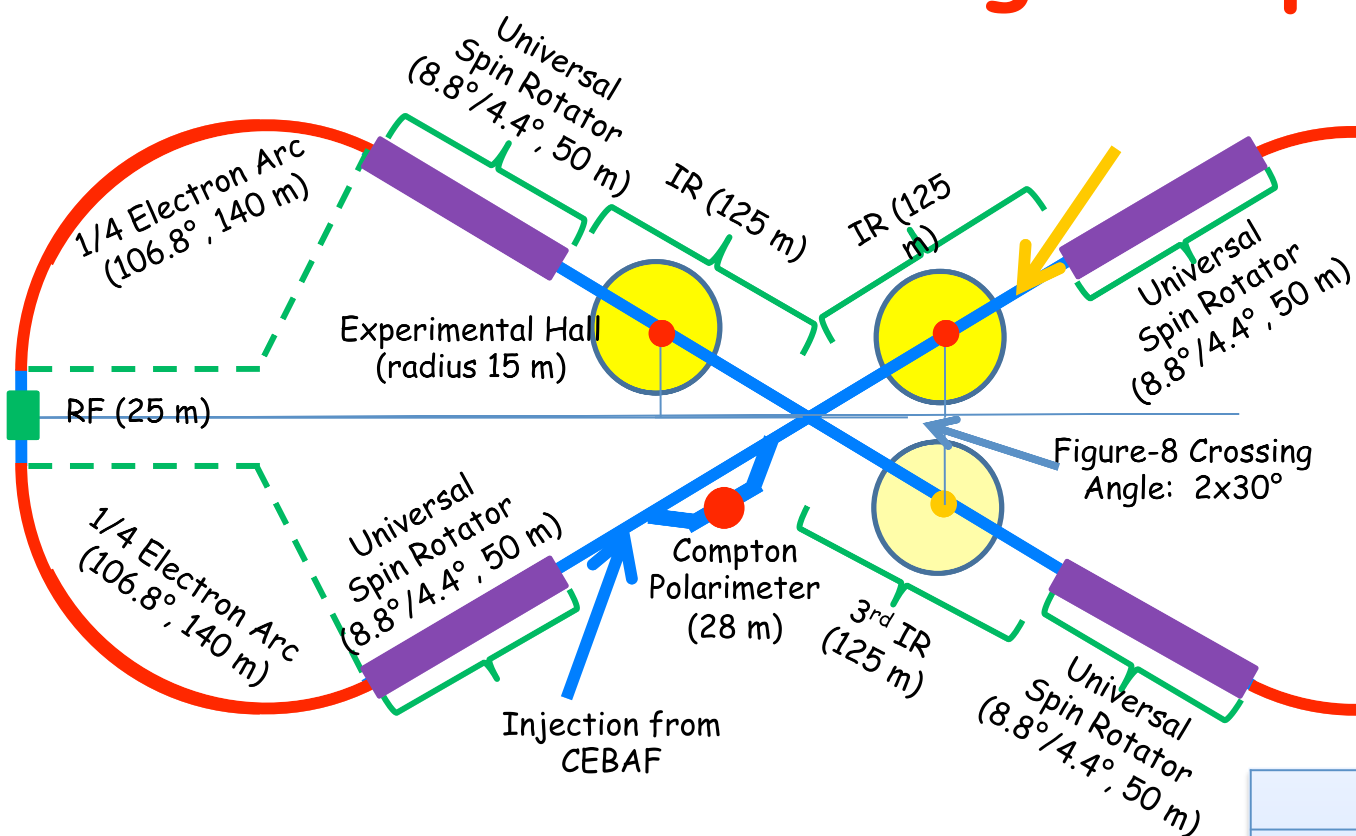
- Maximum bending field: 1.5 T
- Maximum quad field gradient: 20 T/m
- Momentum compaction smaller than 1/25
- Maximum beta functions less than 35 m
- Maximum full beam size less than 2.5 cm
- 5m dispersion-free sections for RF, cooling, collimation and extraction.

Layout



B. Erdelyi

MEIC Collider Ring Footprint



Ring design is a balance between

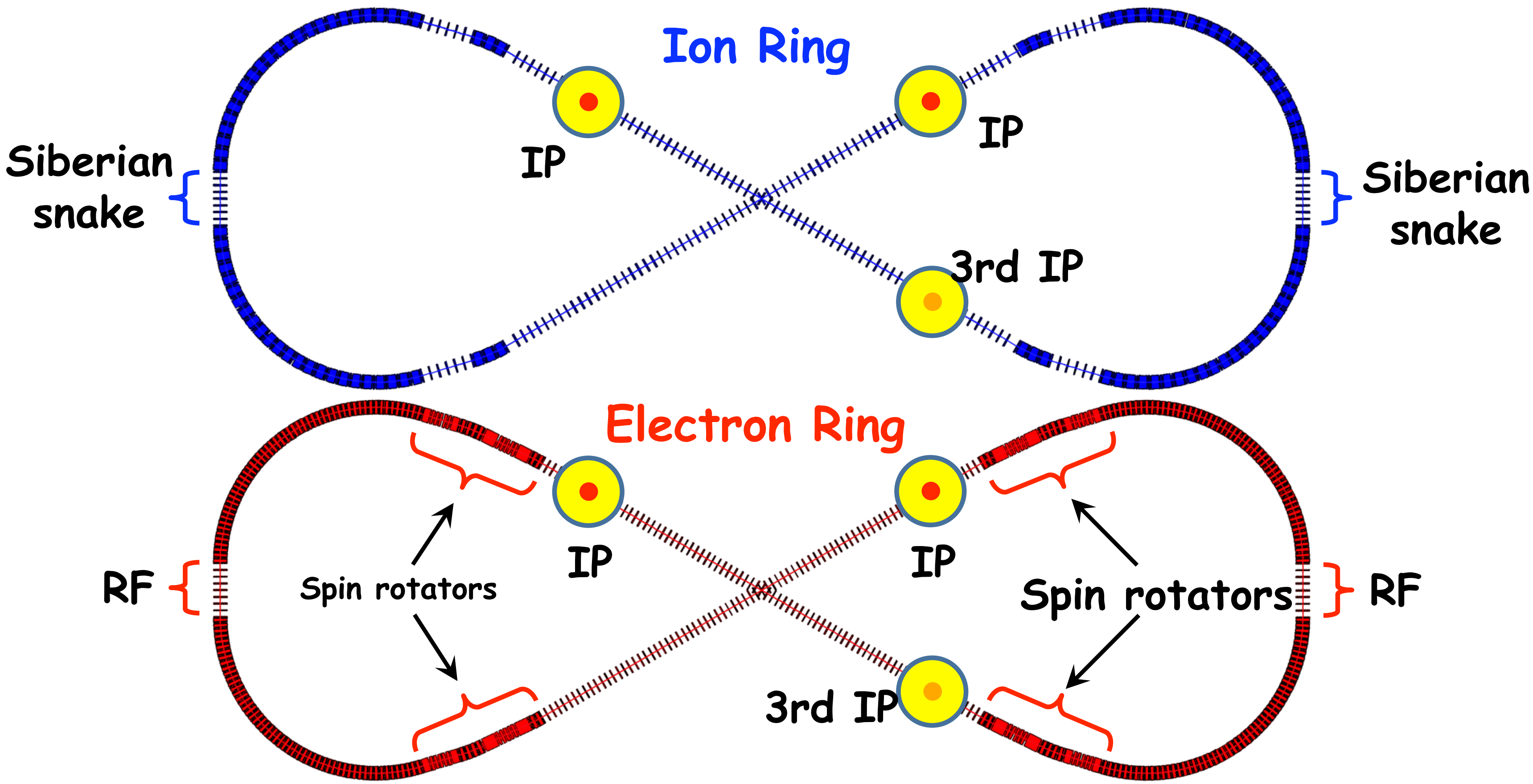
- Synchrotron radiation ➔ prefers a large ring (arc) length
- Ion space charge ➔ prefers a small ring circumference

Multiple IPs require long straight sections

Straights also hold required service components
(cooling, injection and ejection, etc.)

	m
Quarter arc	140
Universal spin rotator	50
IR insertion	125
Figure-8 straight	140 x 2
RF short straight	25
Circumference	~ 1300

Vertically Stacked & Horizontal Crossing

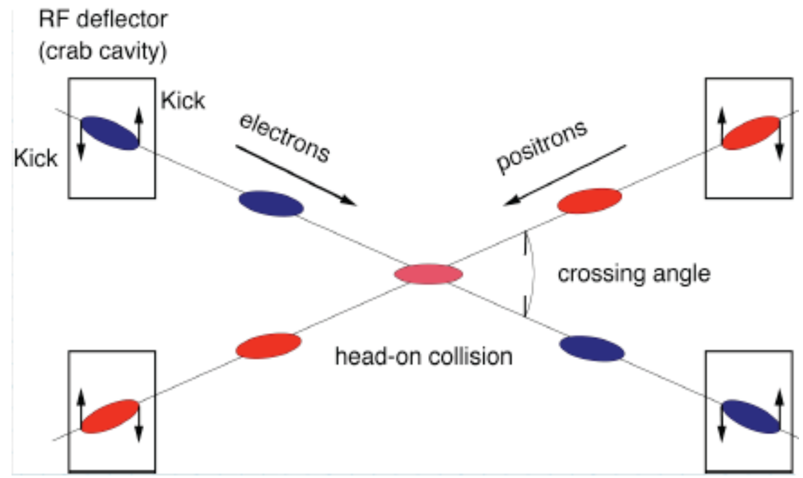


- Vertical stacking for identical ring circumferences
- Horizontal crab crossing at IPs due to flat colliding beams
- Ion beams execute vertical excursion to the plane of the electron orbit for enabling a horizontal crossing

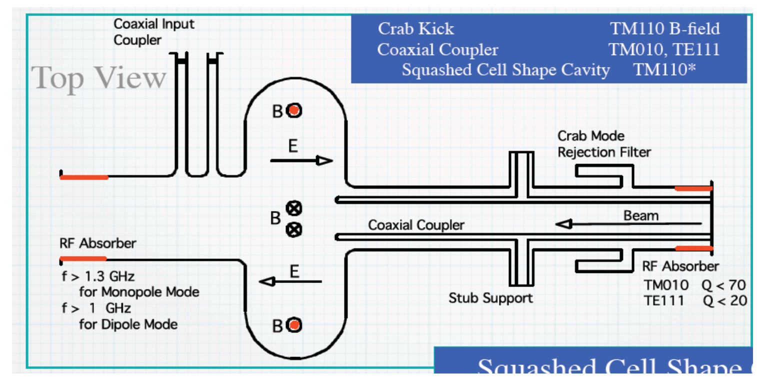
- Ring circumference: 1340 m
- Maximum ring separation: 4 m
- Figure-8 crossing angle: 60 deg.

Crab Crossing

- High bunch repetition rate requires crab crossing of colliding beams to avoid parasitic beam-beam collisions
- Present baseline: 50 mrad crab crossing angle
- Schemes to restore head-on collisions
  - SRF crab cavity (Like KEK-B)
    ← using transverse RF kicking
  - Dispersive crabbing (J. Jackson)
    ← introducing high dispersion in regular accelerating/bunching cavities



Crab Cavity	Energy (GeV/c)	Kicking Voltage (MV)	R&D
electron	5	1.35	State-of-art
Proton	60	8	**Factor of six**

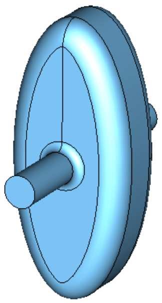


Dispersive crab	Energy (GeV/c)	RF Voltage (MV)
electron	5	34
Proton	60	51

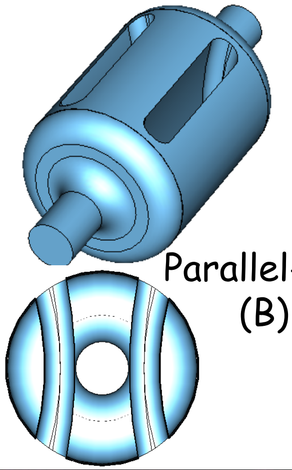
Crab cavity State-of-the-art:
KEKB Squashed cell@TM110 Mode
V_{kick}=1.4 MV, E_{sp}= 21 MV/m

New type SRF crab cavity currently under development at ODU/JLab

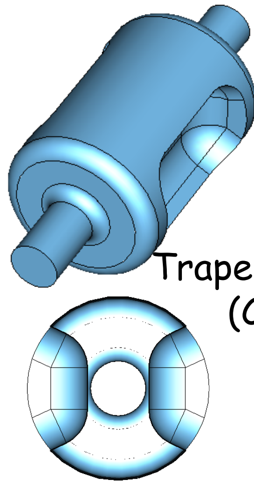
750 MHz SRF Crab Cavity



Elliptical (A)

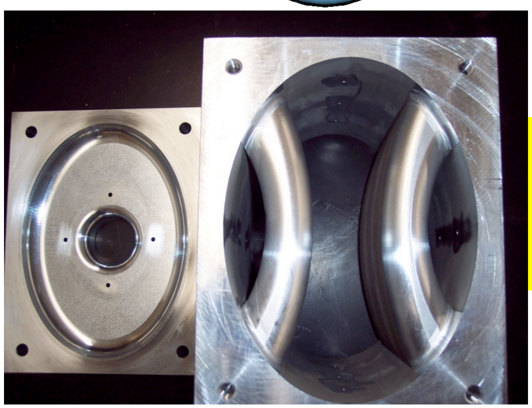


Parallel-Bar (B)



Trapezoidal (C)

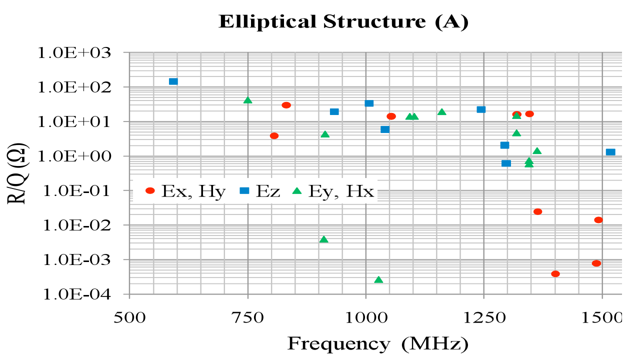
Parameter	Elliptical (A)	Par. Bar. (B)	Trapezoidal (C)	Units
Freq. of π mode	749.93	750.07	750.28	MHz
λ/2 of π mode	199.7	199.8	199.8	mm
Freq. of 0 mode		1047.7	1252.8	MHz
Freq nearest mode to Pi	806.19	1024	1111.7	MHz
Freq. Lower order modes	592.7	--	--	MHz
Cavity length	200	280	281	mm
Cavity width	309.3	214	196.3	mm
Cavity height	698.8	--	--	mm
Bars width	--	33.8	--	mm
Bars length	--	200	200	mm
Aperture diameter	80	60	60	mm
Deflecting voltage (V_T*)	0.2	0.2	0.2	MV
Electric field (E_P/E_T)	2.32	3.95	4.2	MV/m
Magnetic field (B_P/E_T)	7.72	8.66	10.14	mT
B_P/E_P	3.32	2.19	2.41	mT/(MV/m)
Geometrical factor	281.00	118.92	128.92	Ω
$[R/Q]_T$	41.31	166.53	120.91	Ω
$R_T R_S$	1.18 e4	1.95 e4	1.55 e4	$Ω^2$

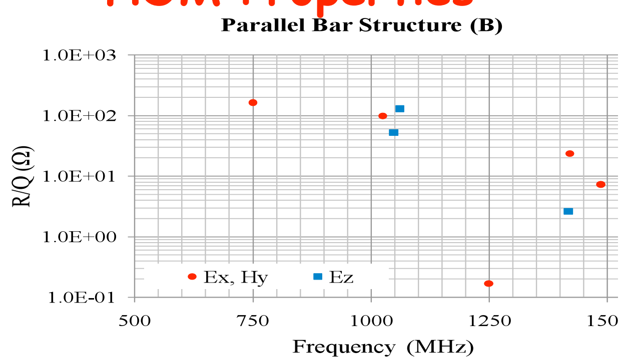


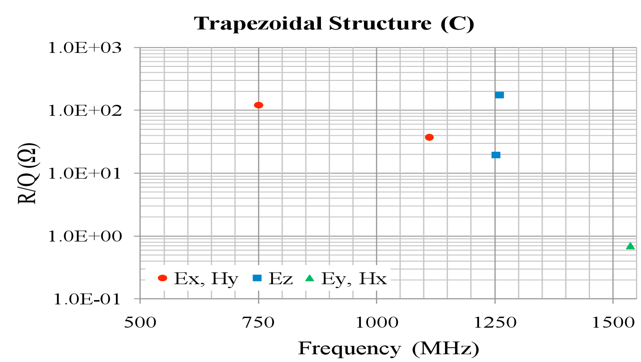
Work performed by graduate students at ODU under a DOE STTR with Niowave Inc.

J. Delayen

HOM Properties







Ion Polarization

Design Requirements

- High (>70%) polarization of stored electron beam
- Preservation of polarization during acceleration (in boosters and collider ring)
- *Longitudinal and transverse* polarization at interaction points
- *Polarized deuteron*

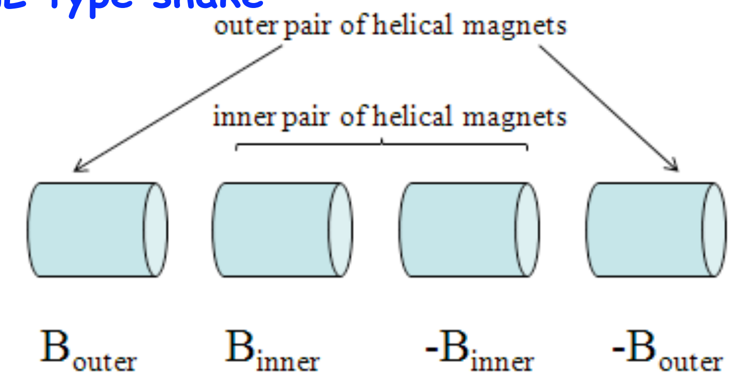
Design Choices

* Polarized ion sources   * Figure-8 ring   * Siberian snakes

Polarization schemes we have worked out

- Proton: longitudinal, transverse and combined polarizations at IPs
- Deuteron: longitudinal and transverse polarization at IPs

BNL type snake



P. Chevtsov, A. Kondratenko

Snake parameters for longitudinal scheme

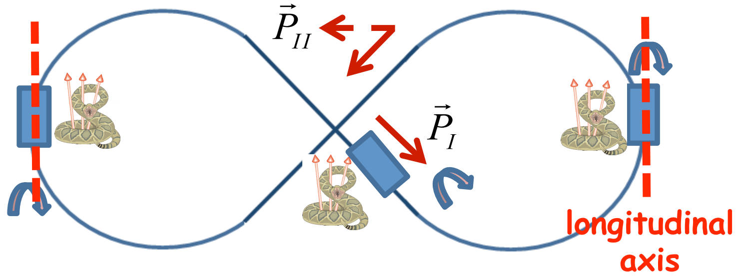
E (GeV)	20	40	60	100	150
B_{outer} (T)	-2.13	-2.16	-2.173	-2.177	-2.184
B_{inner} (T)	2.83	2.86	2.88	2.89	2.894

Snake parameters for transverse scheme

E (GeV)	20	40	60	100	150
B_{outer} (T)	-1.225	-1.241	-1.247	-1.251	-1.253
B_{inner} (T)	3.943	3.994	4.012	4.026	4.033

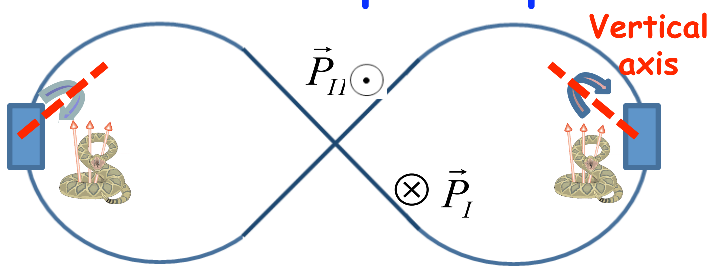
Proton Polarization at IPs

Case 1: Longitudinal Proton Polarization at IP's



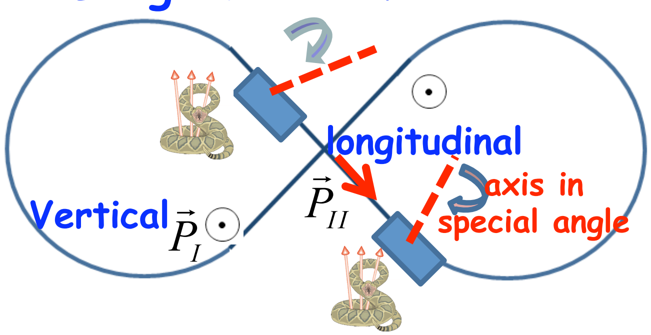
- Three Siberian snakes, all longitudinal-axis
- Third snake in straight is for spin tune
- Spin tune: 1/2

Case 2: Transverse proton polarization at IP's



- Three Siberian snakes, both in horizontal-axis
- Vertical polarization direction periodic
- Spin tune: 1/2

Case 3: Longitudinal & transverse proton polarization on two straights



- Two Siberian snake, with their parameters satisfying certain requirements
- Spin tune: 1/2

Staged Electron Cooling In Collider Ring

Not Coherent Electron Cooling. Regular electron cooling

(FNAL, 8 GeV/4 MeV)

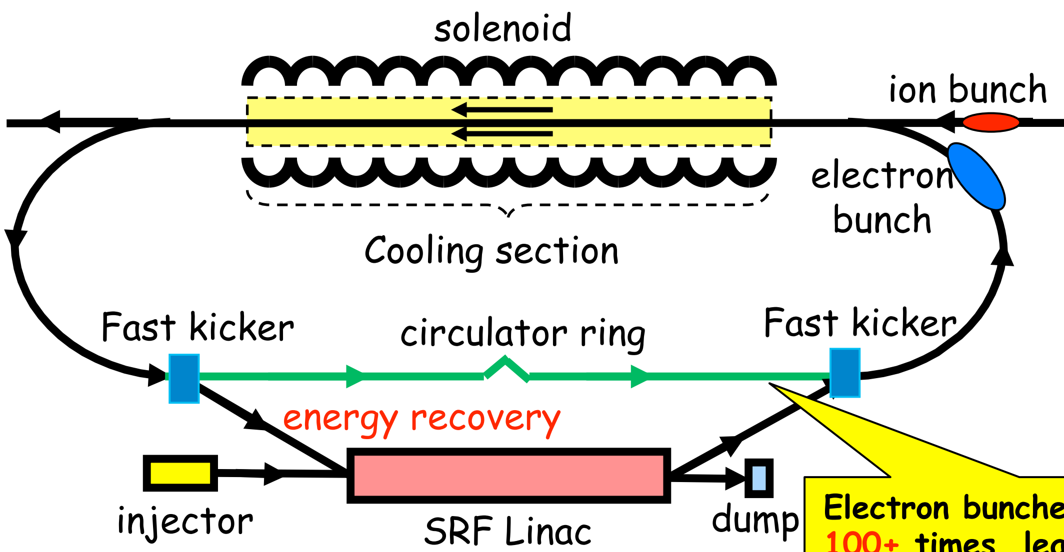
- **Initial cooling:** after injection for reduction of longitudinal emittance < acceleration
- **Final cooling:** after boost & rebunching, for reaching design values of beam parameters
- **Continuous cooling:** during collision for suppressing IBS & preserving luminosity lifetime

		Initial Cooling	after boost & bunching	Colliding Mode
Energy	GeV/MeV	20 / 8.15	60 / 32.67	60 / 32.67
Beam current	A	0.5 / 3	0.5 / 3	0.5 / 3
Particles/Bunch	10^{10}	0.42 / 3.75	0.42 / 3.75	0.42 / 3.75
Ion and electron bunch length	Cm	(coasted)	1 / 2~3	1 / 2~3
Momentum spread	10^{-4}	10 / 2	5 / 2	3 / 2
Horiz. and vert. emitt, norm.	µm	4 / 4		0.35 / 0.07
Laslett's tune shift	(proton)	0.002	0.006	0.07
Cooling length /circumference	m/m	15 / 1000	15 / 1000	15 / 1000

	formula		Longitudinal	Horizontal	Vertical
IBS	Piwinski	s	66	86	
IBS	Martini (BetaCool)	s	50	100	1923
Cooling	Derbenev	s	~7.9		

* Assuming I_e=3 A, 60 GeV/32.67 MeV

ERL Based Circulator Electron Cooler



Electron bunches circulates 100+ times, leads to a factor of 100+ reduction of current from a photo-injector/ERL

Design choice

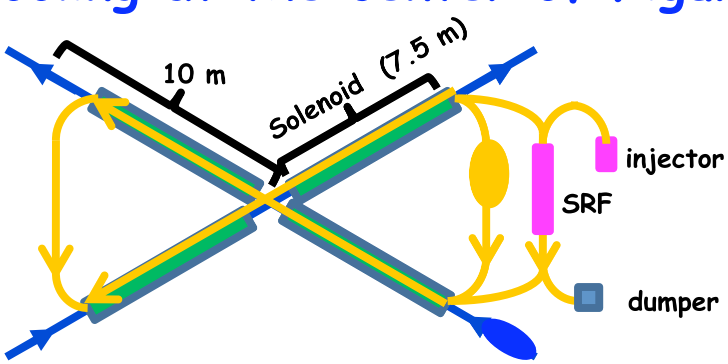
to meet design challenges

- RF power (up to 50 MW)
- Cathode lifetime (130 kC/day)

Required technology

- High bunch charge gun (ok)
- ERL (50 MeV, 15 mA) (ok)
- Ultra fast kicker

Cooling at the center of Figure-8

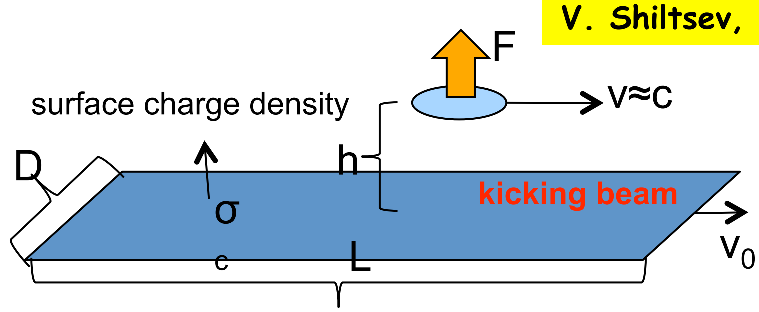


Eliminating a long return path could

- cut cooling time by half, or
- reduce the cooling electron current by half, or
- reduce the number of circulating by half

Beam-beam fast kicker

V. Shiltsev, 1996



Where do particles go - general

Several processes in e-p:

1) "DIS" (electron-quark scattering)	e + p → e′ + X
2) "Semi-Inclusive DIS (SIDIS)"	e + p → e′ + meson + X
3) "Deep Exclusive Scattering (DES)"	e + p → e′ + photon/meson + baryon
4) Diffractive Scattering	e + p → e′ + p + X
5) Target fragmentation	e + p → e′ + many mesons + baryons

Even more processes in e-A:

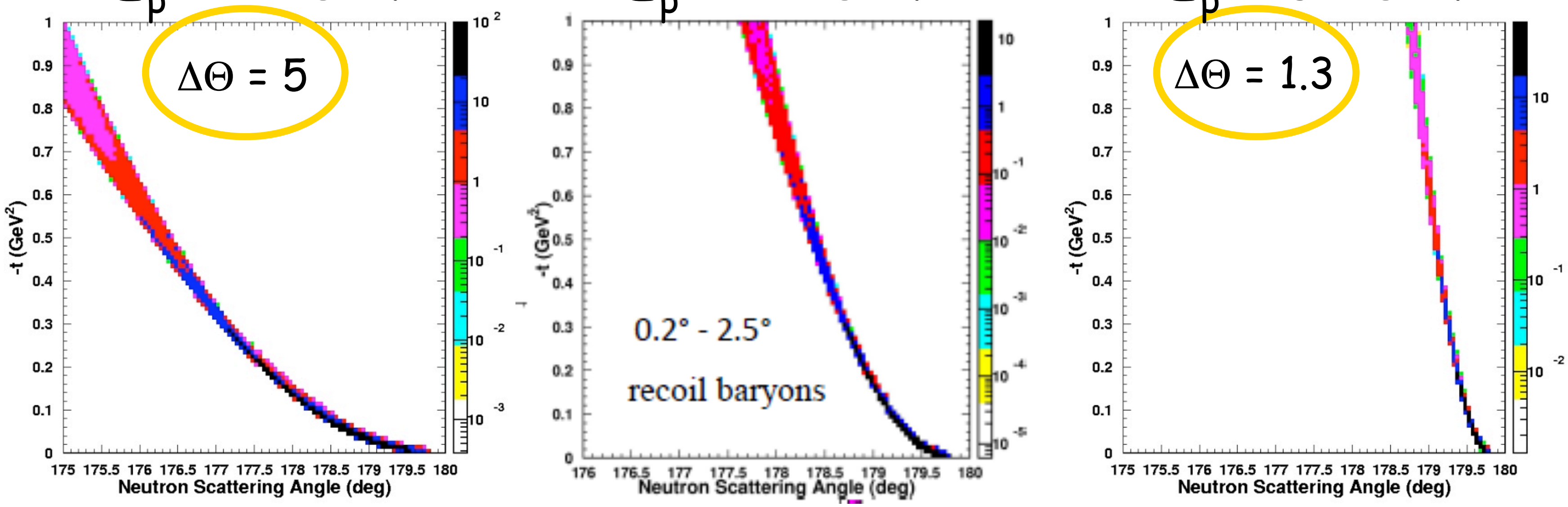
1) "DIS"	e + A → e′ + X
2) "SIDIS"	e + A → e′ + meson + X
3) "Coherent DES"	e + A → e′ + photon/meson + nucleus
4) Diffractive Scattering	e + A → e′ + A + X
5) Target fragmentation	e + A → e′ + many mesons + baryons
6) Evaporation processes	e + A → e′ + A′ + neutrons

In general, e-p and even more e-A colliders have a large fraction of their science related to the detection of what happens to the ion beams. The struck quark remnants can be guided to go to the central detector region with Q^2 cuts, but the spectator quark or struck nucleus remnants will go in the forward (ion) direction.

Detector/IR – Forward Angles

$t \sim E_p^2\Theta^2 \rightarrow$ Angle recoil baryons = $t^{\frac{1}{2}}/E_p$

E_p = 12 GeV $\quad$ E_p = 30 GeV $\quad$ E_p = 60 GeV



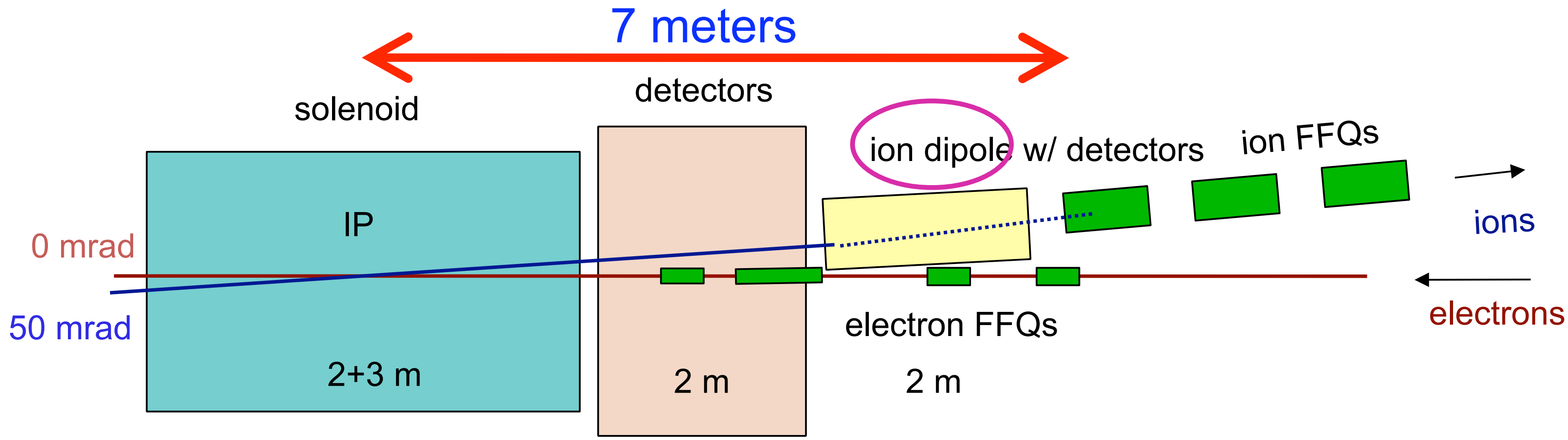
Nuclear Science: Map t between t_{min} and 1 (2?) GeV

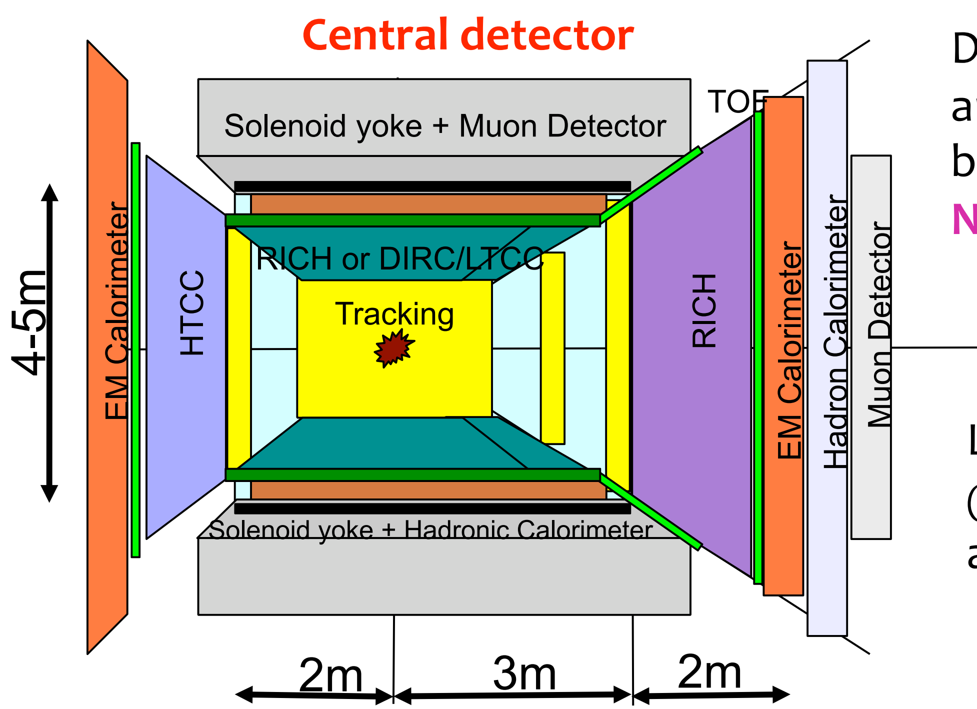
→ Must cover between 1 and 5 degrees

→ Should cover between 0.5 and 5 degrees

→ Like to cover between 0.2 and 7 degrees

Full Acceptance 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

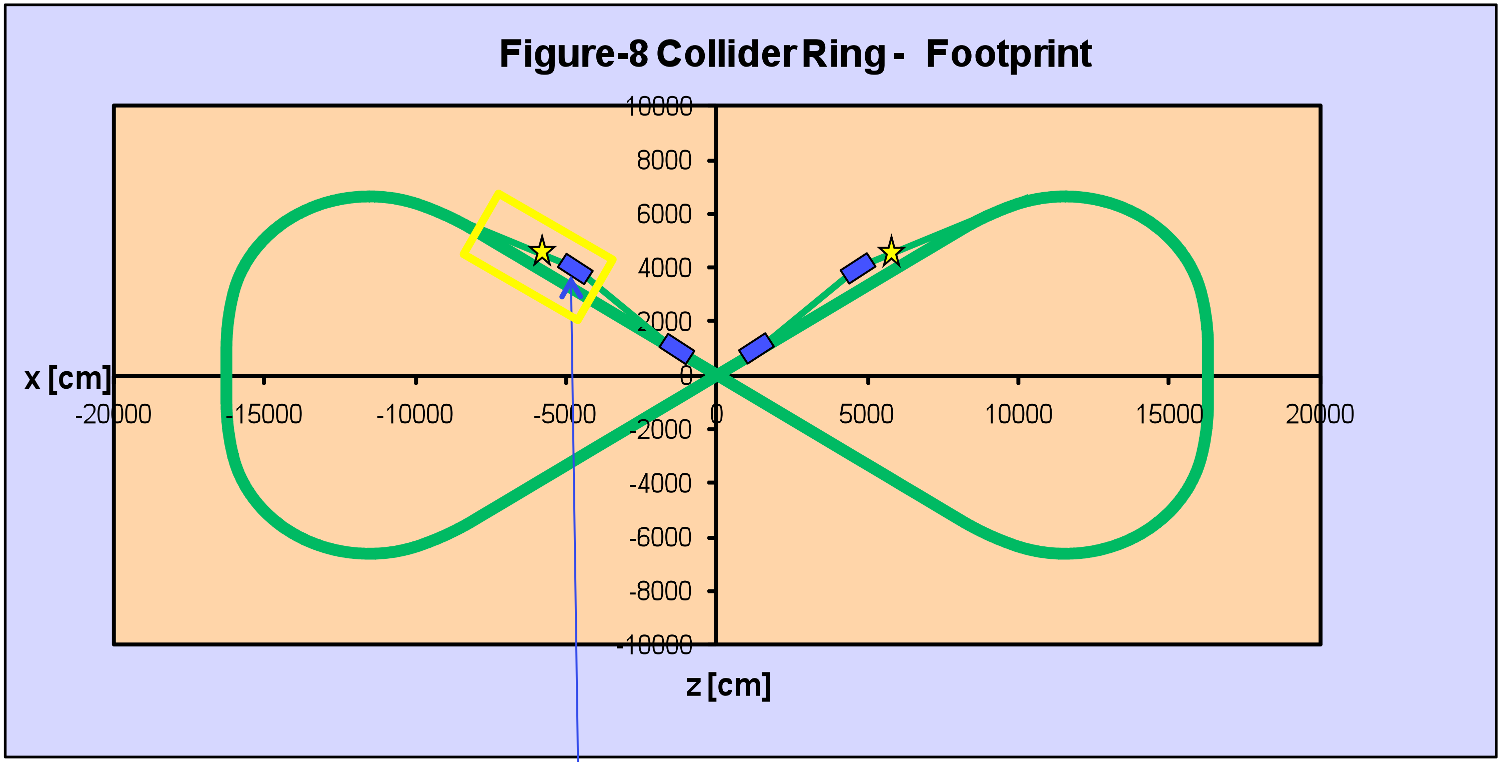
(to correct the 50 mr ion horizontal crossing angle)

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

Use Crab Crossing for Very-Forward Detection too!

(Reminder: MEIC/ELIC scheme uses 50 mr crab crossing)

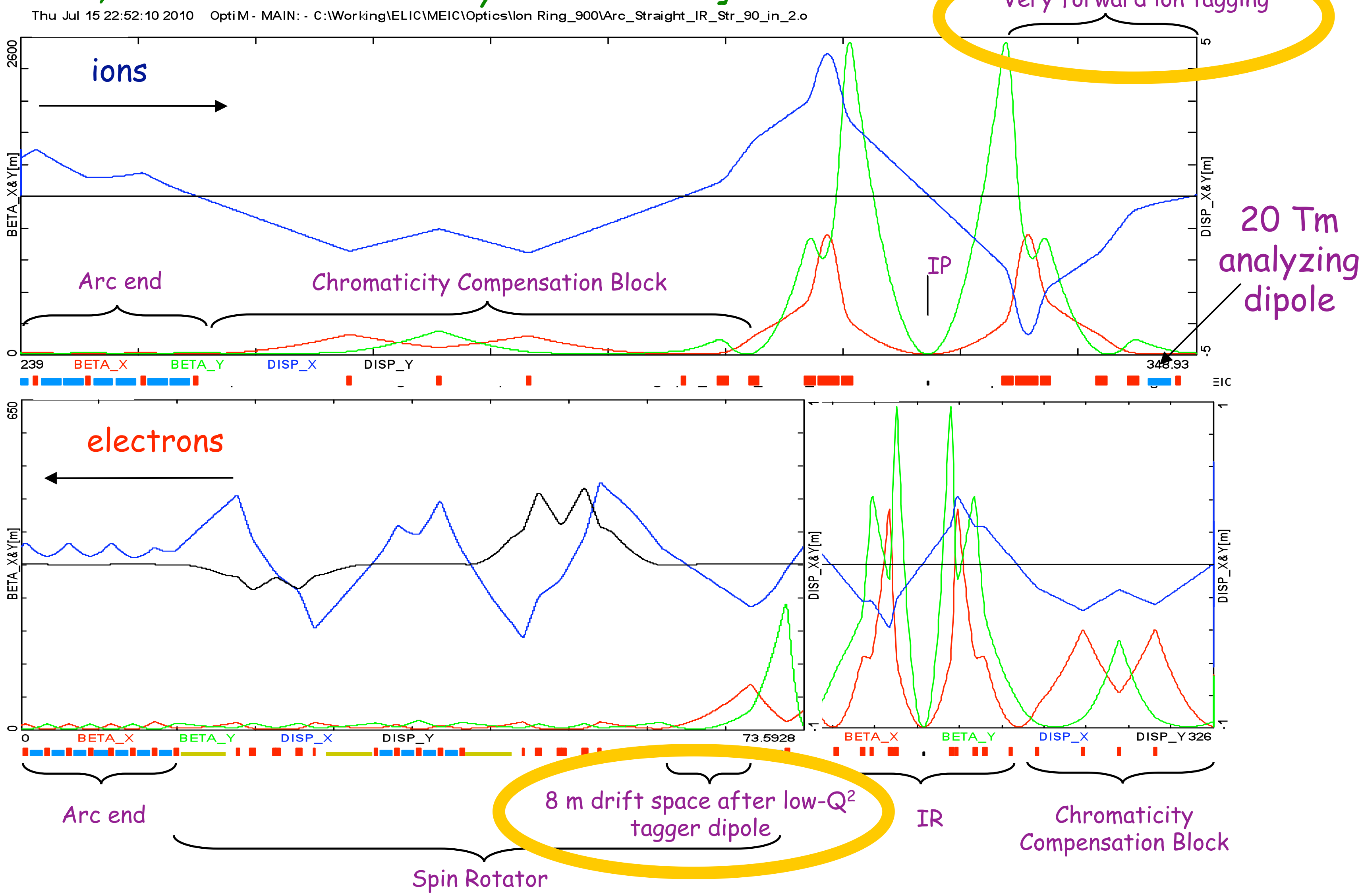
Present thinking: ion beam has 50 mr horizontal crossing angle
Renders good advantages for **very-forward particle detection**



100 mr bend would need 20 Tm dipole @ ~20 m from IP

MEIC Interaction Region – forward tagging

[Bogacz 10, new version underway: Morozov 11]



2011 design: Maximum quad strength at 100 GeV/c: 64.5 T/m at Final Focusing Block

Detector/IR – Forward & Very Forward

- Ion Final Focusing Quads (FFQs) at 7 meter, allowing ion detection **down to 0.5° *before* the FFQs** (BSC area only 0.2°)

- Use large-aperture (10 cm radius) FFQs to detect particles **between 0.3 and 0.5° (or so) in few meters after ion FFQ triplet**

$\sigma_{x\text{-}y}$ @ 12 meters from IP = 2 mm
12 σ beam-stay-clear → 2.5 cm
0.3° (0.5°) after 12 meter is 6 (10) cm
→ enough space for Roman Pots & "Zero"-Degree Calorimeters

- Large dipole bend @ 20 meter from IP (to correct the 50 mr ion horizontal crossing angle) allows for **very-small angle detection (< 0.3°)**

$\sigma_{x\text{-}y}$ @ 20 meters from IP = 0.2 mm
10 σ beam-stay-clear → 2 mm
2 mm at 20 meter is only 0.1 mr… ($\Delta\Theta_{min}$ ~ 0.01° @ 60 GeV)

Δ(bend) of 29.9 and 30 GeV spectators is 0.7 mr = 2.7 mm @ 4 m
Situation for zero-angle neutron detection very similar as at RHIC!

Backgrounds and detector placement

Synchrotron radiation

- From arc where electrons exit and magnets on straight section

Random hadronic background

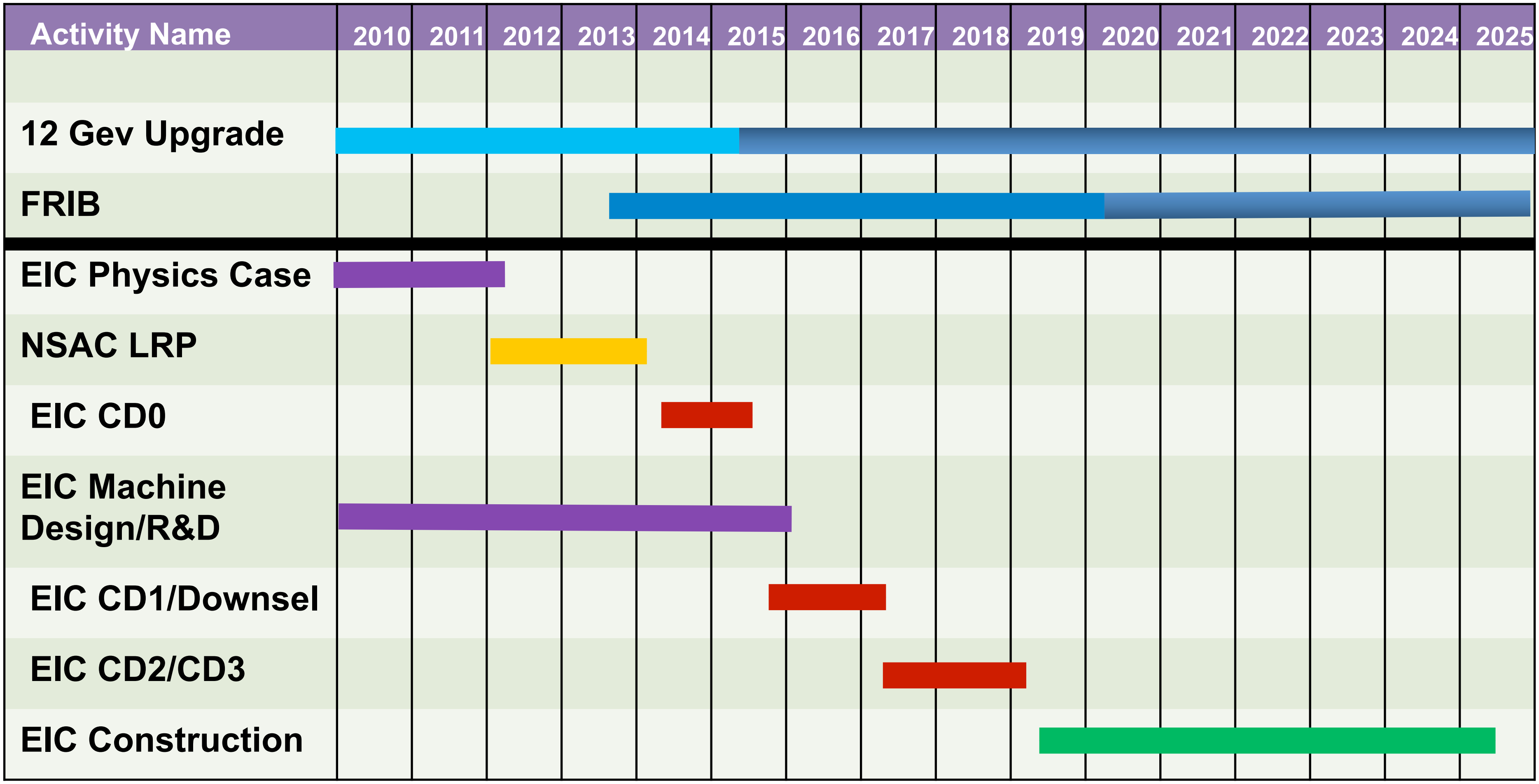
- Dominated by interaction of beam ions with residual gas in beam pipe between arc and IP
- **Comparison of MEIC (at s = 4,000) and HERA (at s = 100,000)**
  - Distance from ion exit arc to detector: 50 m / 120 m = 0.4
  - Average hadron multiplicity: $(4000 / 100000)^{1/4} = 0.4$
  - p-p cross section (fixed target): $\sigma(90\ \text{GeV}) / \sigma(920\ \text{GeV}) = 0.7$
  - At the same ion current and vacuum, MEIC background should be about 10% of HERA
    - Can run higher ion currents (0.1 A at HERA)
    - Good vacuum is easier to maintain in a shorter section of the ring

- **Backgrounds do not seem to be a major problem for the MEIC**
  - Placing high-luminosity detectors closer to ion exit arc helps with both background types
  - Signal-to-background will be considerably better at the MEIC than HERA
    - MEIC luminosity is more than 100 times higher (depending on kinematics)

JLab Accelerator Team's Roadmap Toward the Next NSAC LRP

Nov. 2009	2nd EIC Advisory Committee Meeting *("Finish the MEIC design!")*
Feb. 2010	1st design "contract": MEIC 1.0
Sept. 2010	1st MEIC Internal Accelerator Design Review
April. 2011	3rd EIC Advisory Committee Meeting
➡ May 2011	Complete the remaining tasks of MEIC 1.0 and the intermediate design report
Aug. 2011	2nd design "contract": MEIC 1.1
➡ Dec. 2011	Complete MEIC 1.1 design
	2nd MEIC Internal Accelerator Design Review and 1st Cost Review
2012	Focusing on accelerator R&D (electron cooler, polarization and IR)
March 2013	Completion of a full *MEIC ZDR*
??? 2013	Next NSAC LRP

EIC Realization Imagined (Mont@INT10)



Assumes endorsement for an EIC at the next ~2012/13 NSAC Long Range Plan

Note: 12 GeV LRP recommendation in 2002 – CD3 in 2008

Summary

- Close and frequent collaboration with our nuclear physics colleagues regarding the machine, interaction region and detector requirements has taken place. This has led to our agreed-upon baseline parameters.

- Potential ring layouts for MEIC, including integrated interaction regions, have been made. Chromatic compensation for the baseline parameters has been achieved in the design. A remaining task is to quantify the dynamic aperture of the designs.

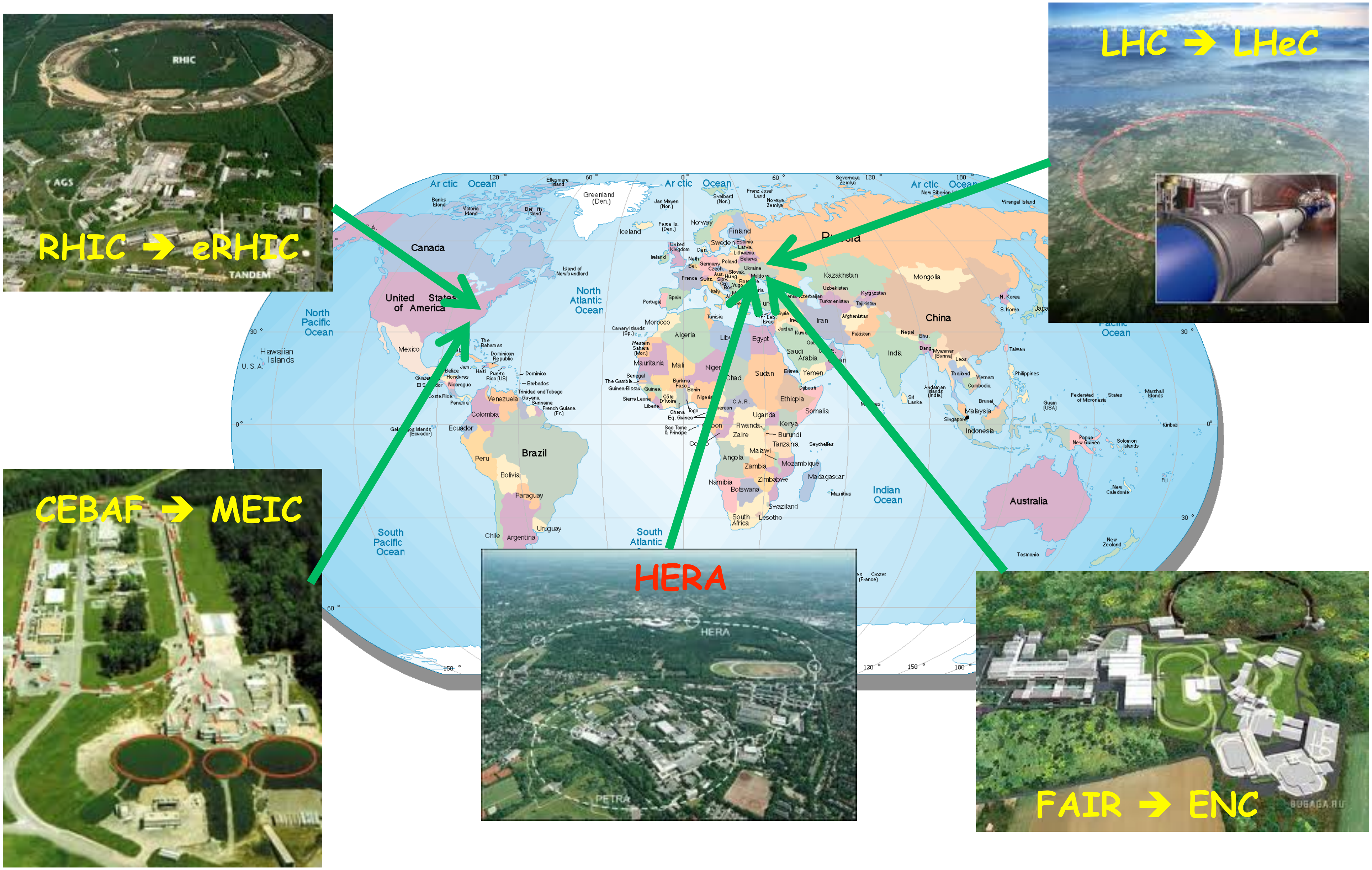
- Suitable electron and ion polarization schemes for MEIC have been worked out and integrated into the designs.

- The detector/IR design has concentrated on *maximizing acceptance* for deep exclusive processes and processes associated with very-forward going particles

- A draft design document has been assembled specifying in great detail an electron-ion collider with luminosity in the range 10^{34} $cm^{-2}s^{-1}$. Editing, completing, and issuing the design report are our highest priority near-term goals.

- We plan to initiate a cost review process soon

Electron Ion Colliders on the World Map



Science Goals

The High-Energy/Nuclear Science of LHeC

Overarching Goal: lepton-proton at the TeV Scale

Hunt for quark substructure & high-density matter (saturation)

High precision QCD & EW studies and possible implications for GUT

The Nuclear Science of eRHIC/MEIC

Overarching Goal: Explore and Understand QCD:

Map the spin and spatial structure of quarks and gluons in nucleons

Discover the collective effects of gluons in atomic nuclei

(role of gluons in nuclei & onset of saturation)

Emerging Themes:

Understand the emergence of hadronic matter from quarks and gluons & EW

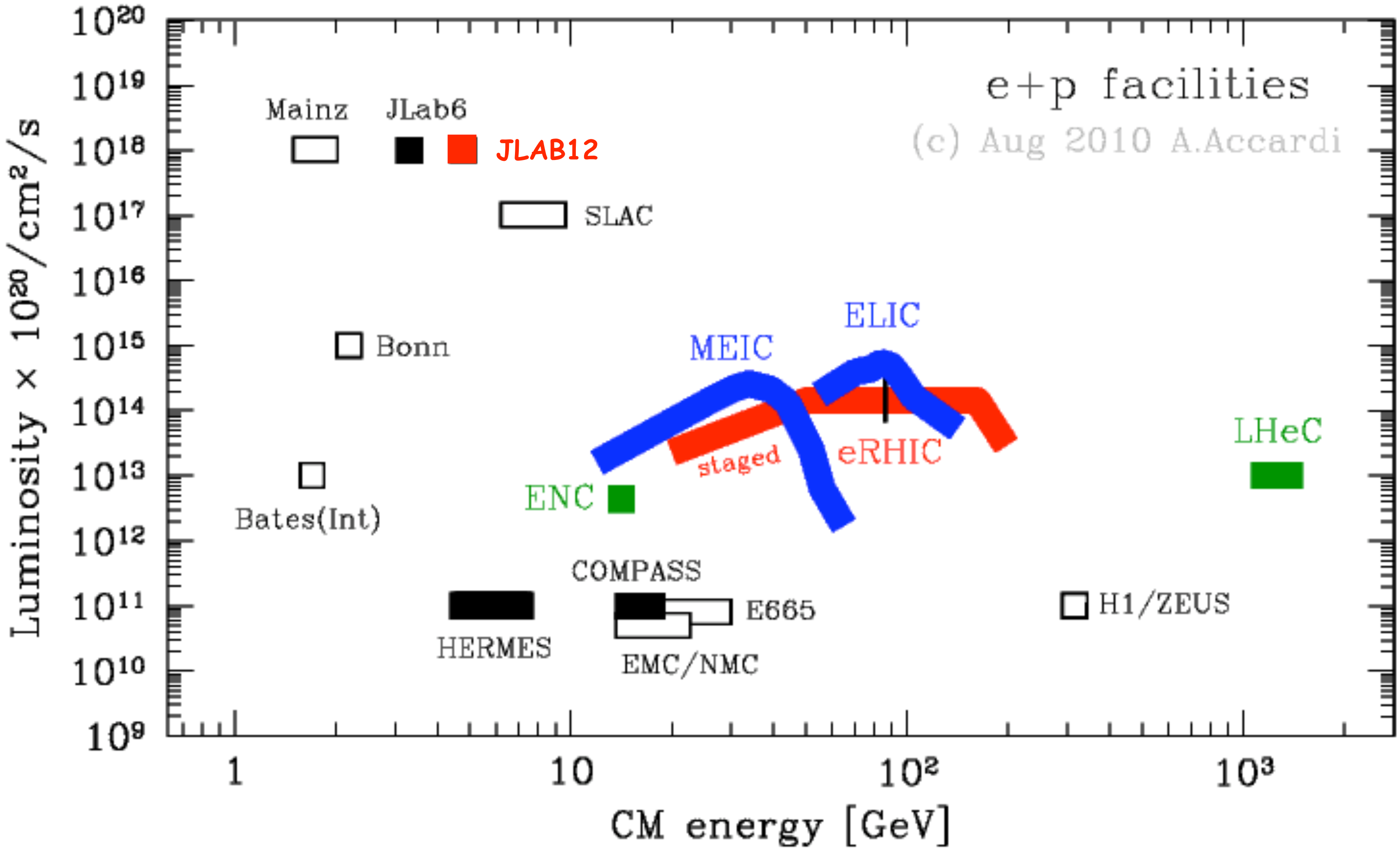
The Nuclear Science of ENC

Overarching Goal: Explore Hadron Structure

Map the spin and spatial structure of valence & sea quarks in nucleons

The Facilities

E_{CM} vs. L_{int}-plane for ep [μp]:

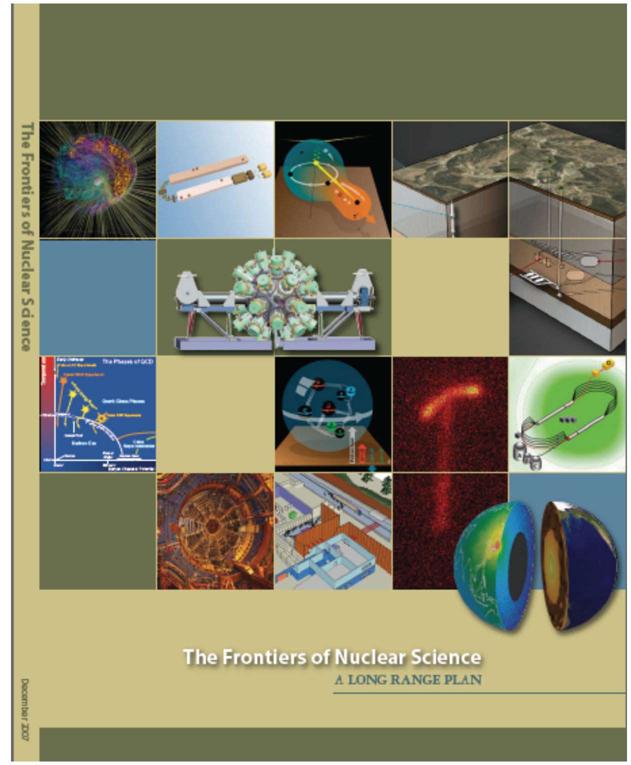


A.Accardi

A High-Luminosity Electron Ion Collider

NSAC 2007 Long-Range Plan:

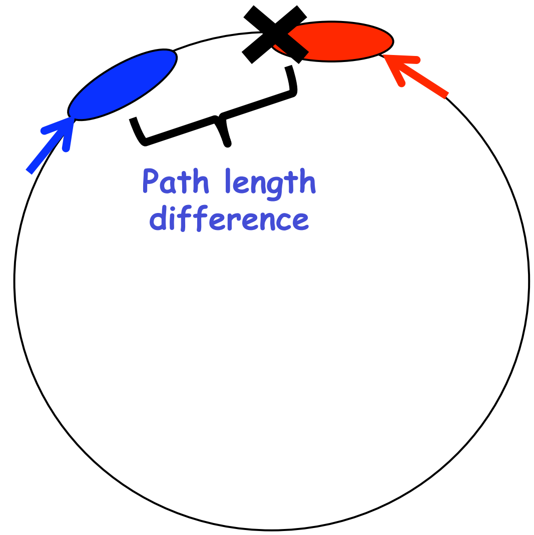
"An **Electron-Ion Collider (EIC)** with **polarized** beams has been **embraced by the U.S. nuclear science community** as embodying the vision for **reaching the next QCD frontier**. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia."



- Base EIC Requirements:
  - range in energies from s = few 100 to s = few 1000 & variable
  - fully-polarized (>70%), longitudinal and transverse
  - ion species up to A = 200 or so
  - high luminosity: about 10^{34} e-nucleons cm^{-2} s^{-1}
  - upgradable to higher energies

Beam Synchronization

- Problem
  - Electrons travel at the speed of light, protons/ions are slower
  - Slower ion bunches will not meet the electron bunch again at the *collision point* after one revolution
  - Synchronization condition must be achieved at *every collision point* in the collider ring *simultaneously*



- Path length difference in collider rings

Assuming: (*nominal*) collider ring circumference ~1000 m

proton:	60 GeV		design point				
	20 GeV	→	-979 cm	→	2.44 bunch spacing	→	2 unit of HN
Lead:	23.8 GeV/u	→	-65.7 cm	→	1.64 bunch spacing	→	2 unit of HN
	7.9 GeV/u	→	-692 cm	→	17.3 bunch spacing	→	17 unit of HN

- Present conceptual solutions
  - Low energy (up to 30 GeV proton & all energies for ions): change bunch number in ion ring
  - Medium energy (proton only, 30 GeV & up): change orbit or orbit and RF frequency together
    - Option 1: change Ion orbit ➔ mounting SC magnets on movers, unpleasant but affordable
    - Option 2: change electron orbit and RF frequency (less than 0.01%) ➔ large magnet bore

A. Hutton, Ya, Derbenev

Beam-Beam Simulations

Simulation code: BeamBeam3D code (LBNL)

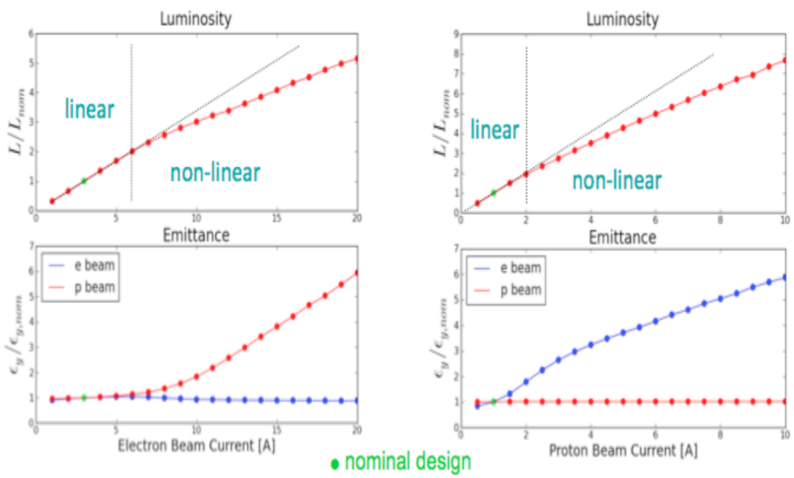
- Self-consistent, particle-in-cell
- Strong-strong or weak-strong mode

Scope and model:

- One IP, head-on collision
- Linear transfer map in the ring
- Radiation damping & quantum excitations
- Chromatic optics effects not included

Results

- Beam stability and luminosity verified



B. Terzic

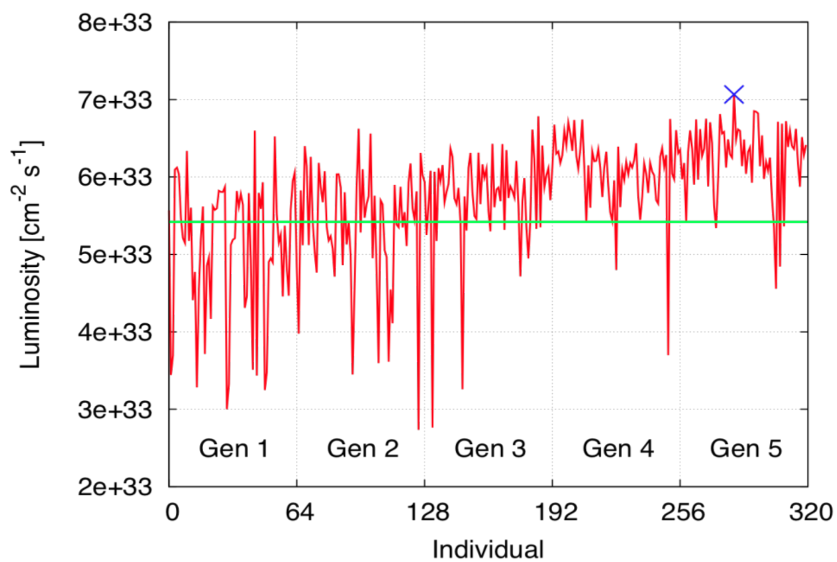
Evolutionary algorithm:

natural selection, mutation and recombination

- Objective function: collider's luminosity
- Independent variables.: betatron tunes (synchrotron tunes fixed for now; 4D problem)

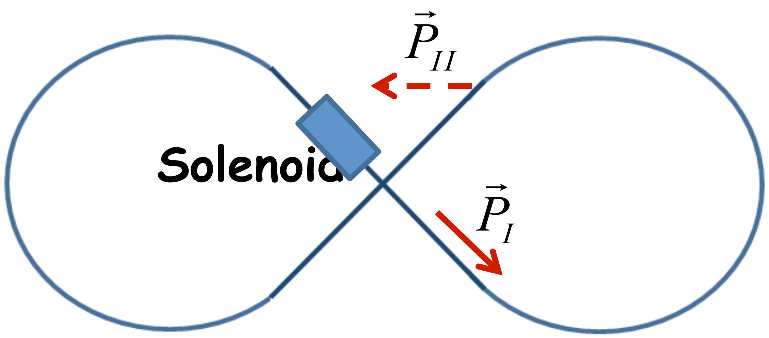
- Found an optimized working point
  - e-beam: $\nu_x = 0.53$, $\nu_y = 0.548456$,
  - p-beam: $\nu_x = 0.501184$, $\nu_y = 0.526639$,

  in only **300** simulations



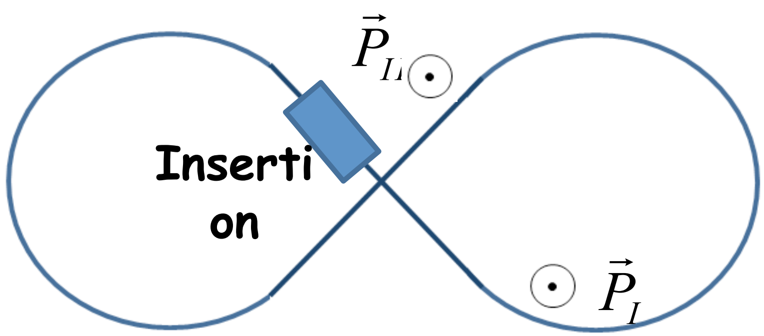
Deuteron Polarizations at IPs

Case 1: Longitudinal Deuteron Polarization at IP's



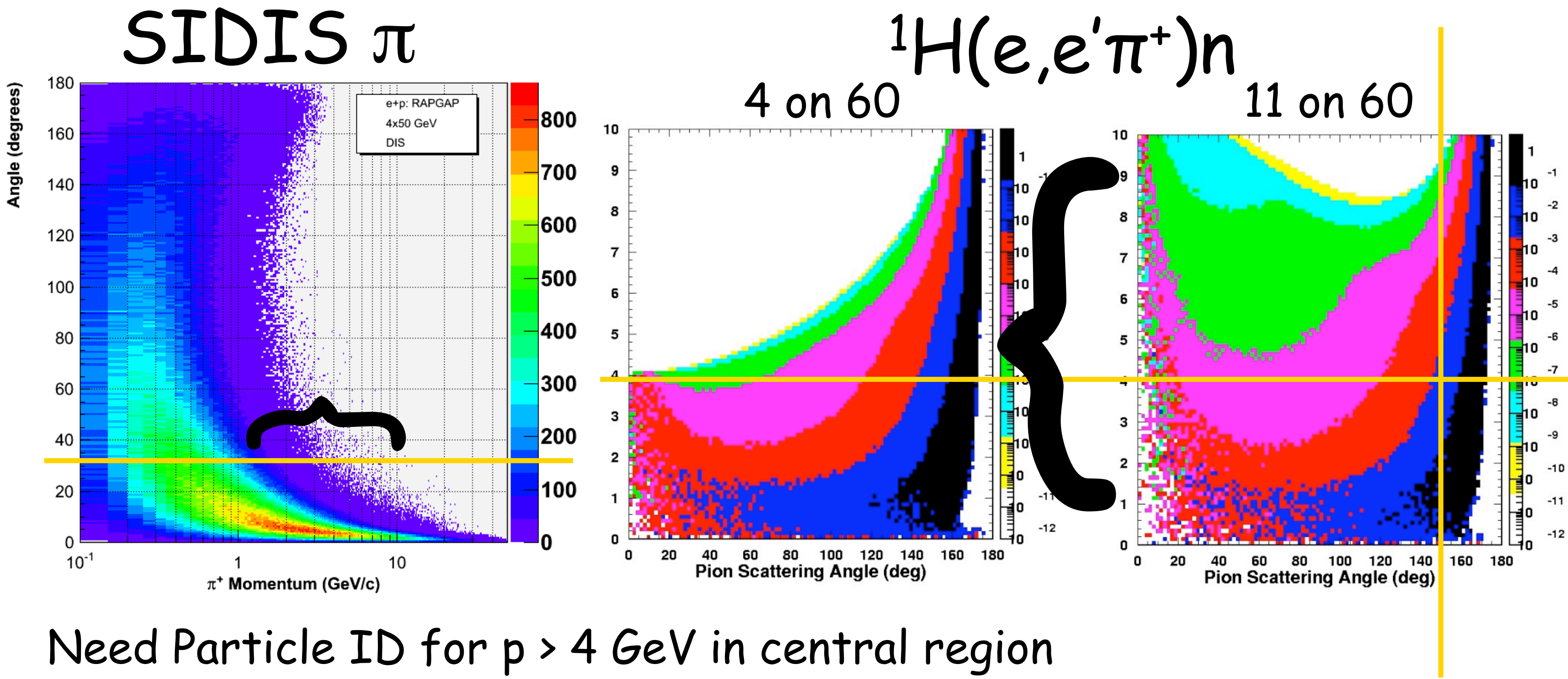
- Sable spin orientation can be controlled by magnetic inserts providing small spin rotation around certain axis and shifting spin tune sufficiently away from 0
- Polarization is stable as long as additional spin rotation exceeds perturbations of spin motion
- Polarization direction controlled in one of two straights
- Longitudinal polarization in a straight by inserting solenoid(s) in that straight

Case 2: Transverse Deuteron Polarization at IP's



- Magnetic insert(s) in straight(s) rotating spin by relatively small angle around vertical axis (Prof. A. Kondratenko)

Where do particles go - mesons



Need Particle ID for p > 4 GeV in central region

→ existing DIRC not sufficient

Need Particle ID for well above 4 GeV in forward region (< 30°?)

→ needs RICH, determines bore of solenoid

In general: Region of interest up to ~10 GeV/c mesons

Momentum ~ space needed for detection