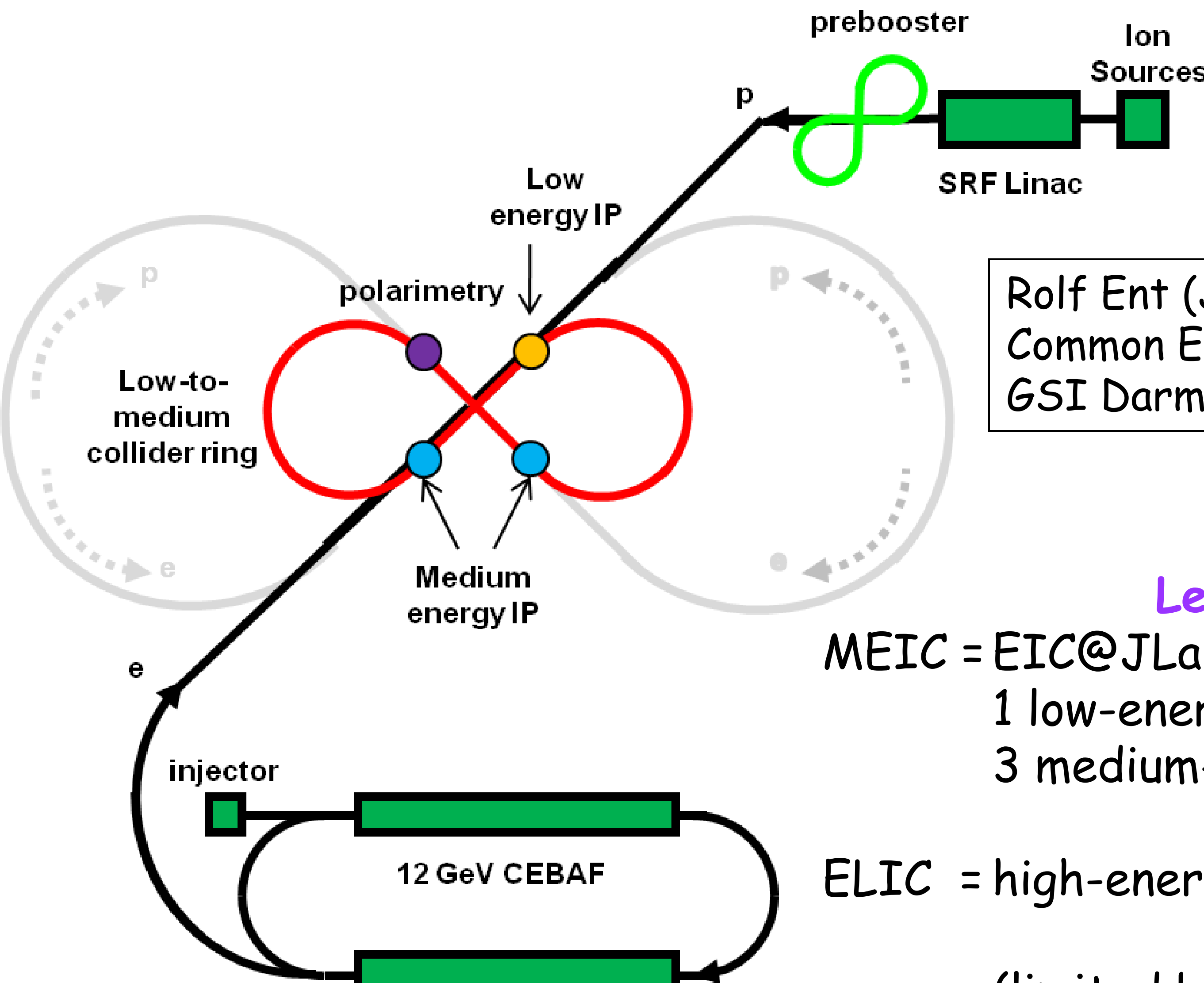
Interaction Region at ELIC



Rolf Ent (JLab)
Common ENC/EIC Workshop
GSI Darmstadt, May 30 2009

Legend:

MEIC = EIC@JLab
1 low-energy IR (s ~ 200)
3 medium-energy IRs
(s < 2600)
ELIC = high-energy EIC@JLab
(s = 10000)
(limited by JLab site)

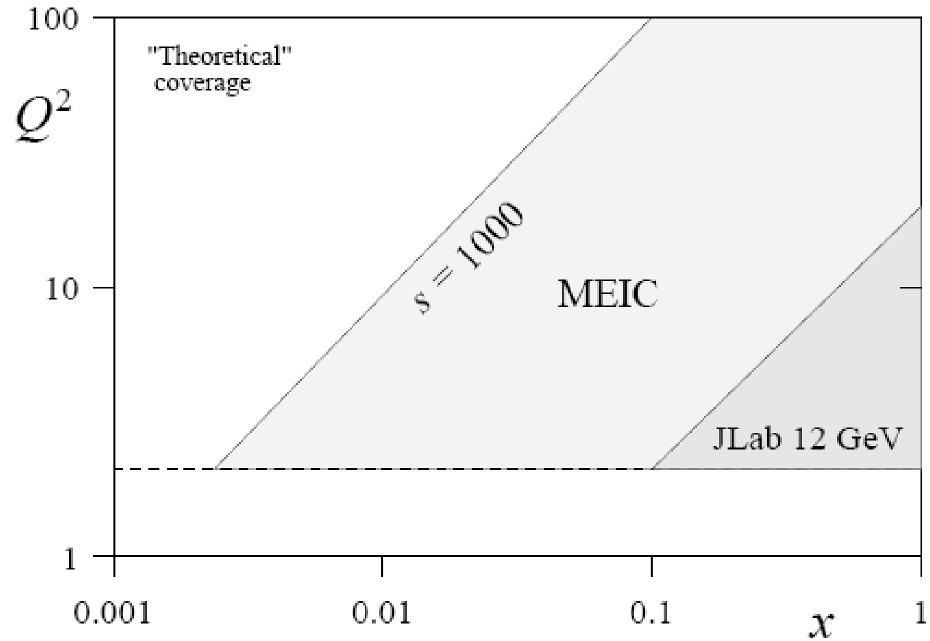
Use CEBAF "as-is" after 12-GeV Upgrade

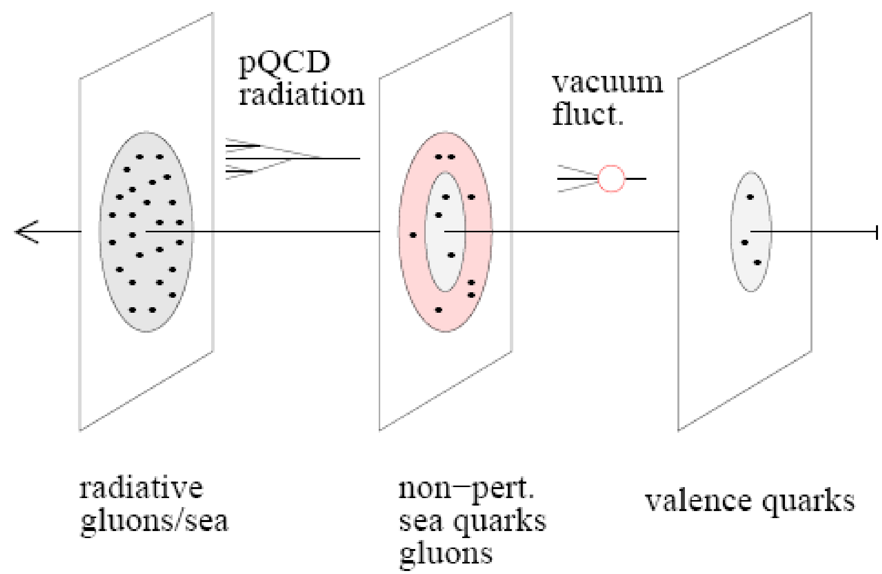
EIC@JLab High-Level Overview

• Hadrons in QCD are relativistic many-body systems, with a fluctuating number of elementary quark/gluon constituents and a very rich structure of the wave function.

• With 12 GeV we study mostly the valence quark component, which can be described with methods of nuclear physics (fixed number of particles).

• With an (M)EIC we enter the region where the many-body nature of hadrons, coupling to vacuum excitations, etc., become manifest and the theoretical methods are those of quantum field theory.





EIC@JLab High-Level Summary

What science goals are accessed/appropriate?

1) Gluon and sea quark (transverse) imaging of the nucleon
2) Nucleon Spin (ΔG vs. $\ln(Q^2)$, transverse momentum)
3) Nuclei in QCD (gluons in nuclei, quark/gluon energy loss)
4) QCD Vacuum and Hadron Structure and Creation

	Energies	s	luminosity
(M)EIC@Jlab	Up to 11 x 60	150-2650	Few x 10^{34}
Future option	Up to 11 x 250	11000	10^{35}

- Energies and figure-8 ring shape and size chosen to optimize polarization and luminosity
- Try to minimize headaches due to synchrotron and large leaps in state-of-the-art through R&D
- 4 Interaction Regions, with function and size optimized to "decouple" detector from accelerator – can optimize later to increase luminosity

(M)EIC@JLab: Basic Considerations

- Optimize for nucleon/nuclear structure in QCD
  - **access to sea quarks/gluons (x > 0.01 or so)**
  - **deep exclusive scattering at Q^2 > 10**
  - **any QCD machine needs range in Q^2**

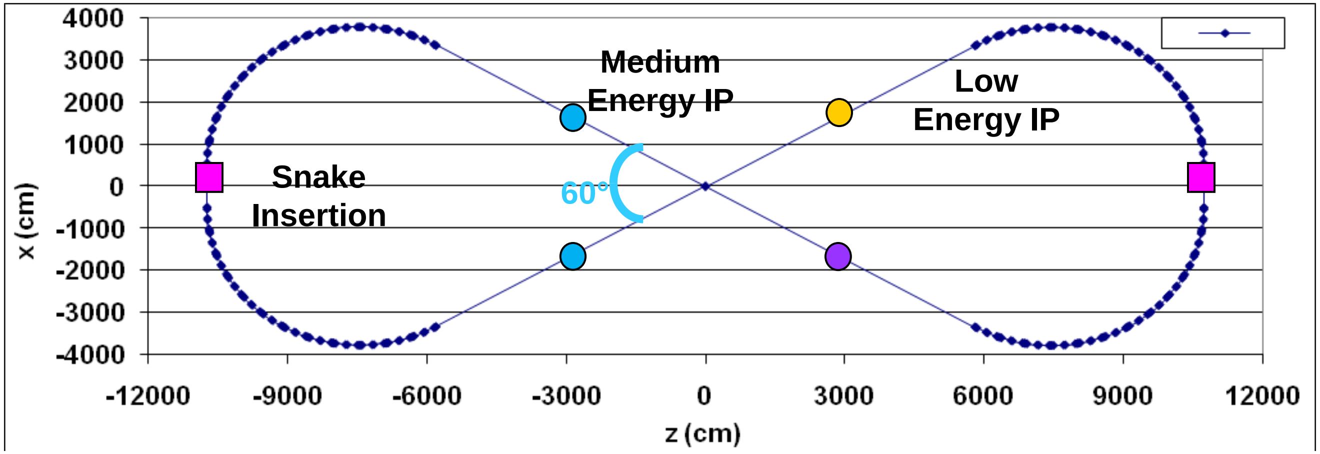
  → s = 1000 or so to reach decade in Q^2
  → high luminosity, >10^{34} and approaching 10^{35}, essential
  → lower, more symmetric energies for resolution & PID

- **Not** driven by gluon saturation (small-x physics) …

- "Sweet spot" for
  - electron energies from 3 to 5 GeV (minimize synchrotron)
  - proton energies ranging from 30 to 60 GeV
  - but larger range of s accessible (E_e = 11 GeV, E_p = 12 GeV)

- **Decrease R&D needs**, while maintaining **high luminosities**
  - Potential future upgrade to high-energy collider, but no compromising of nucleon structure capabilities

MEIC/ELIC Figure-8 Collider Ring Footprint



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

- MEIC luminosity is limited by
  - Synchrotron radiation power of e-beam
    ➔ requires large ring (arc) length
  - Space charge effect of p-beam
    ➔ requires small ring length
- Multiple IRs require long straight sections. Recent thinking: start with 18 meter detector space for all IRs to make life easier (?)
- Straight sections also hold other required components (electron cooling, injection & ejections, etc.)

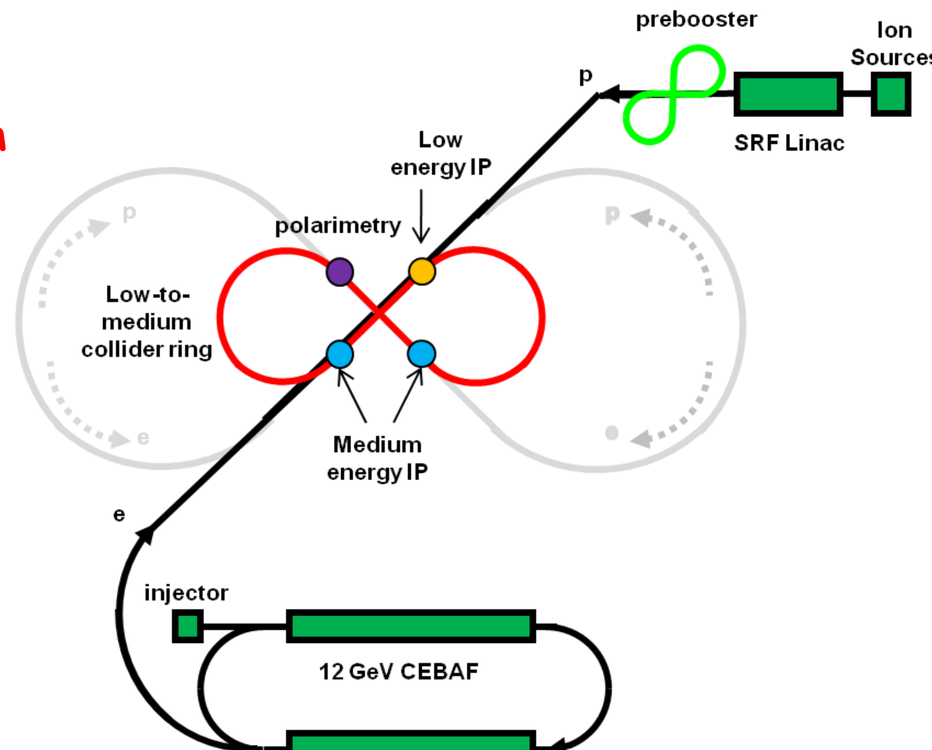
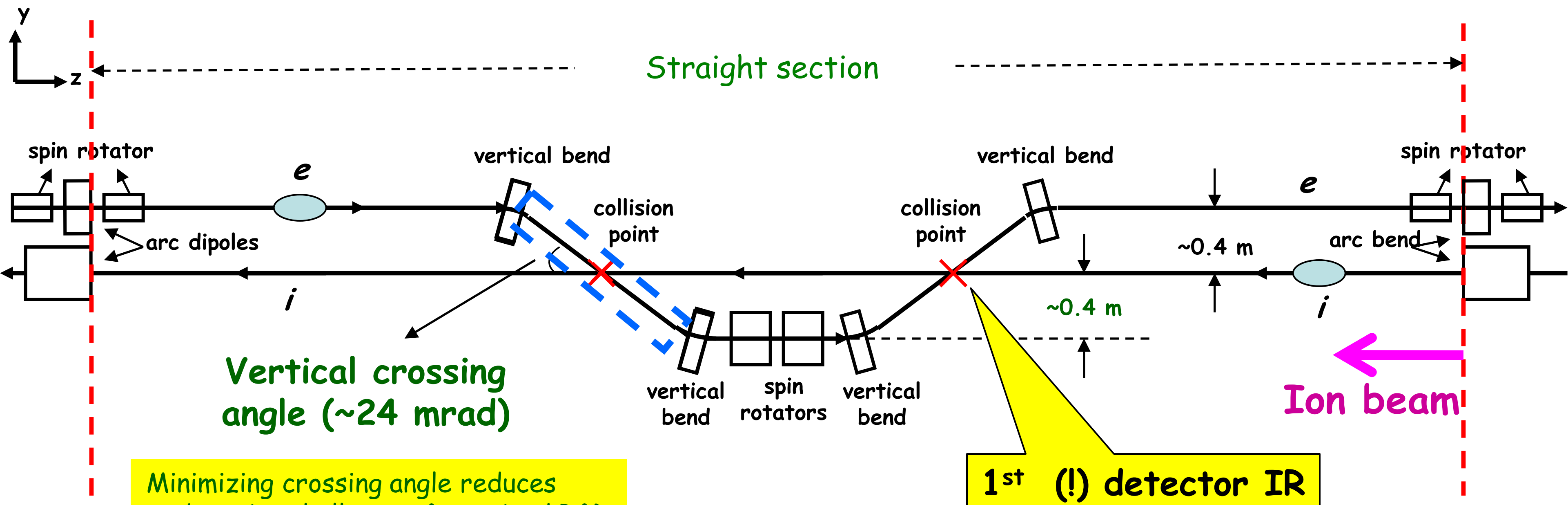


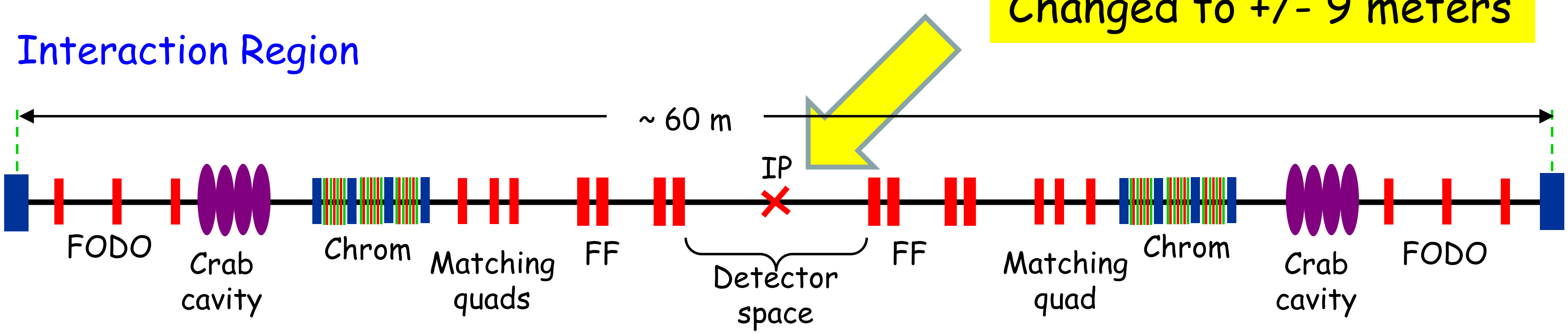
Figure-8 (half) Straight Sections & Interaction Regions



Minimizing crossing angle reduces crab cavity challenges & required R&D

Changed to +/- 9 meters

Interaction Region

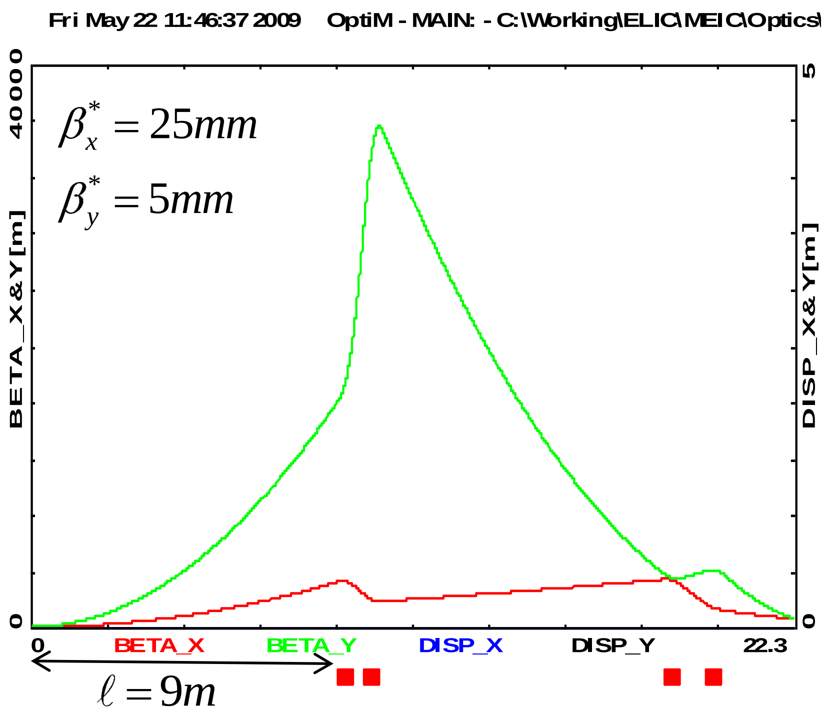


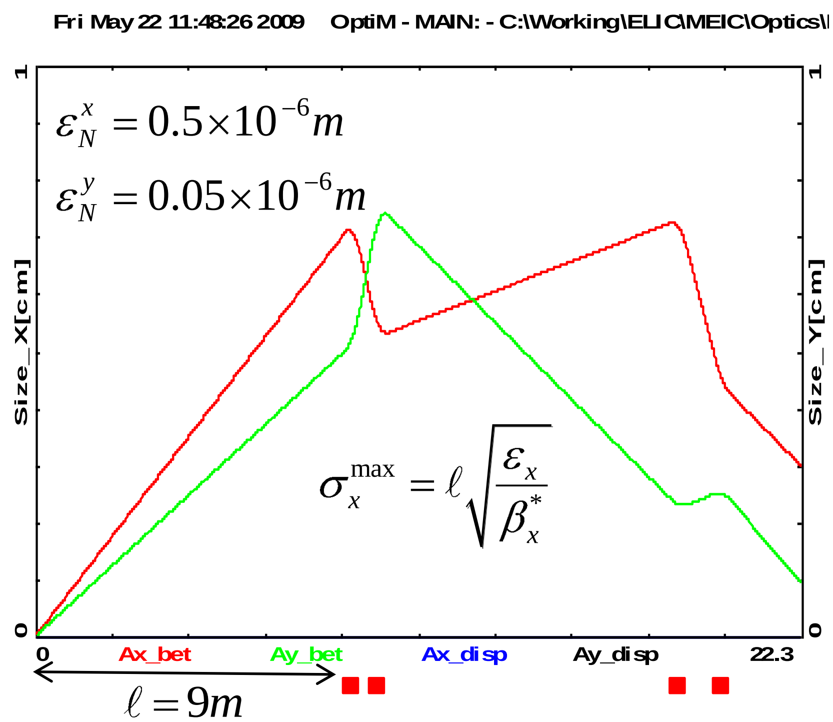
β chrom.

Asymmetric IR with large 'magnet free' region IR (9m + 9m)

final focus asymmetry (β*), $\beta_x/\beta_y \sim 5$

emittance asymmetry - 'flat beams', $\varepsilon_x/\varepsilon_y \sim 10$





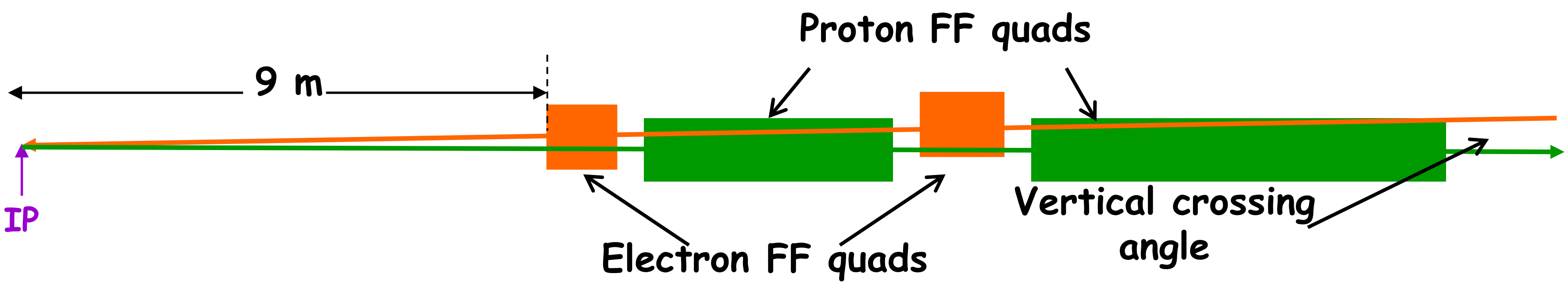
(Alex Bogacz)

- Manageable beam sizes at the FF quads ($\sigma_{RMS} \sim 5$ mm)
  - The longest distance between the IP and the first quad is critical for FF quad apertures
  - Initial focusing of larger emittance plane results in minimized beam sizes in both planes
- IR design consistent with the luminosity of 10^{34}

(Longitudinal) Asymmetric IR - Findings

- Longitudinally asymmetric IR has no advantage
  - The longest distance between the IP and the first quad is critical for FF quad apertures
  - (9m + 3m) IR as challenging as **(9m + 9m) IR**
- Triplet vs Doublet FF Optics
  - Same magnet apertures required
  - Triplet focusing more compact
  - Doublet focusing more suitable for **'interleaved' FFs for smaller beam crossing**
- **Flat beams** favorable, $\varepsilon_x/\varepsilon_y \sim 10$
  - Beam-beam interaction
  - Luminosity optimization
- Asymmetric focusing (β^*) for flat beams desirable, $\beta_x/\beta_y \sim 5$
  - Initial focusing of larger emittance plane results in minimized beam sizes in both planes
  - **Manageable beam sizes on FF quads**, $\sigma_{RMS} \sim 5mm$

IR Magnet Layout

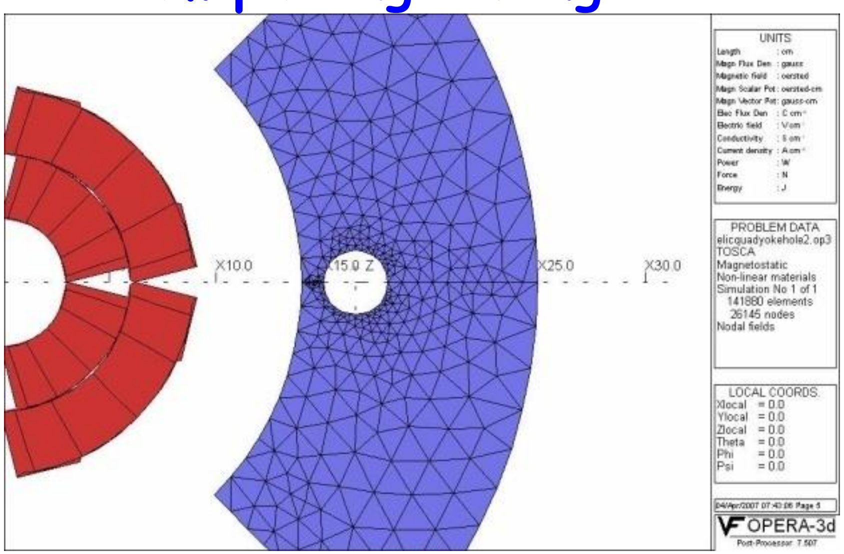


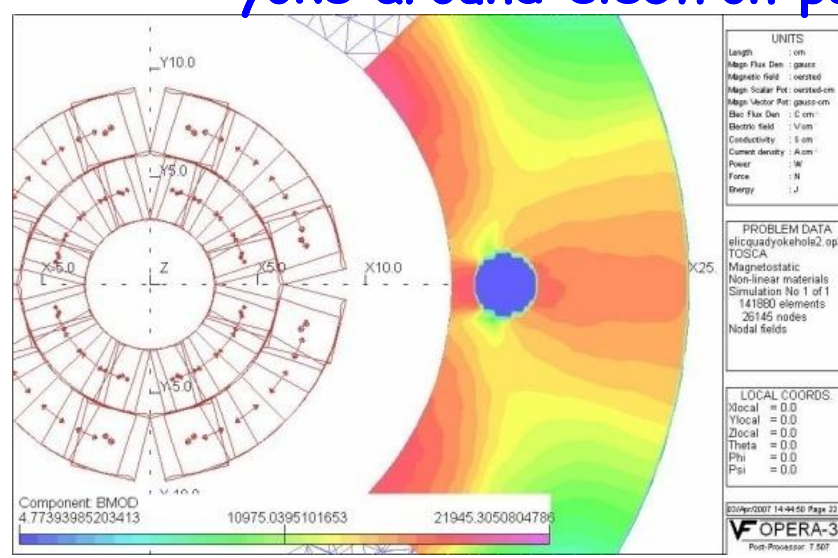
If ELIC w. 8 m IR space → Proton FF quads of 1.8 (3.0) m with 20.8 (12.0) kG/cm

Cross section of quad with beam passing through

(Paul Brindza)

Magnetic field in cold yoke around electron pass

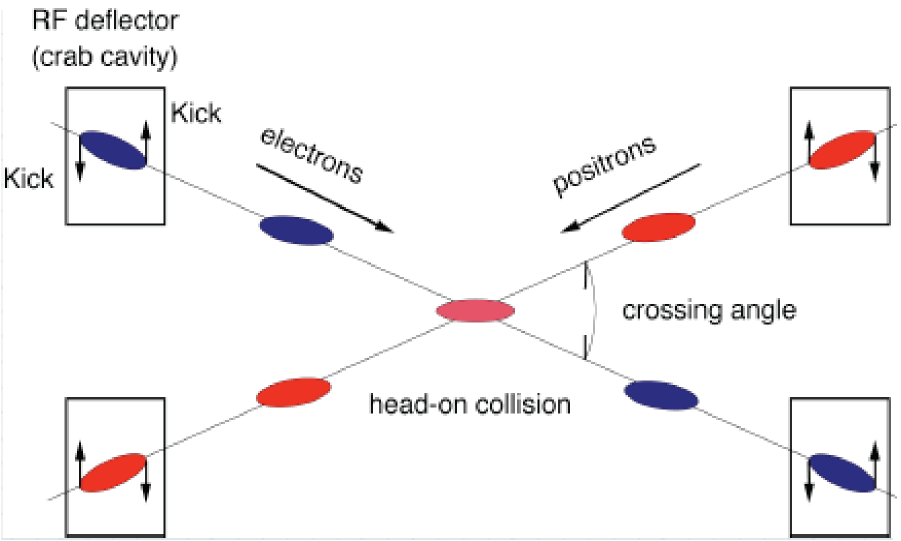




No need for such Lambertson-type quads with MEIC (18 m IR space)

Crab Crossing

- High repetition rate requires crab crossing to avoid parasitic beam-beam interaction
- Crab cavities needed to restore head-on collision & avoid luminosity reduction
- Minimizing crossing angle reduces crab cavity challenges & required R&D



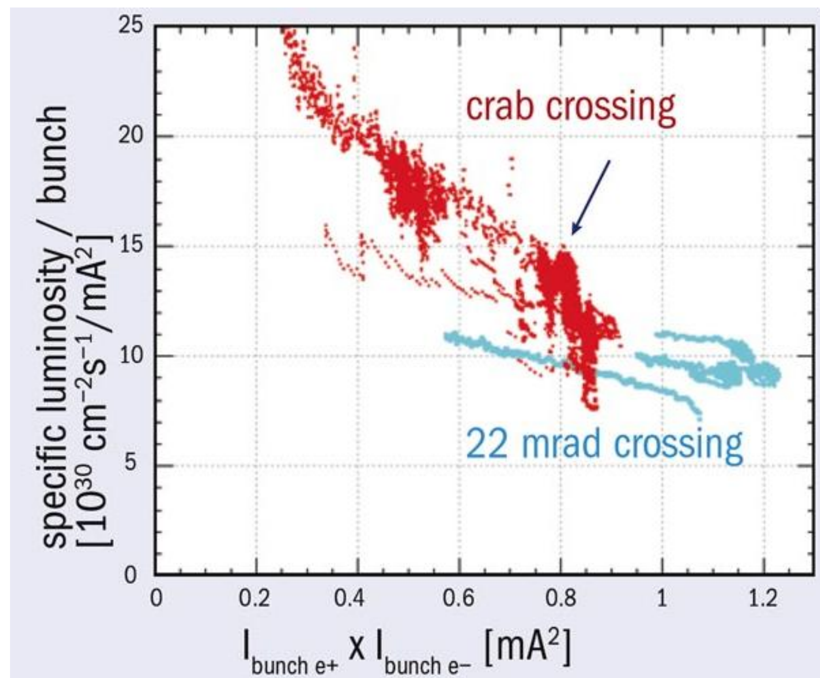
Symmetry *Breaking* (05/11/09)

"Record luminosity collisions due to "crab" crossing,

State-of-art:
KEKB Squashed cell@TM110 Mode
- Crossing angle = 2 x 11 mrad

V_{kick}=1.4 MV

E_{sp}= 21 MV/m



MEIC R&D: Crab Crossing

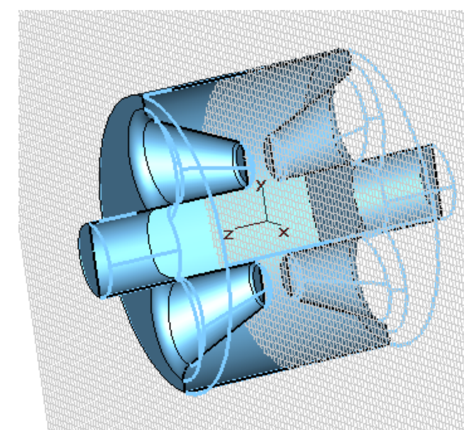
Crab cavity development (~24 mrad crossing angle for 5 GeV electrons and 60 GeV ions, 18 meter IR space)

Electron: 1 MV - within state of art (KEK)

Ion: 5 MV (Integrated B field on axis 38G/4m)

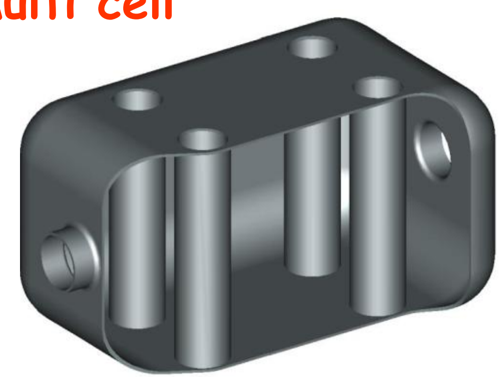
Crab Crossing R&D program

- Understand gradient limit and packing factor
- Multi-cell SRF crab cavity design capable for high current operation.
- Phase and amplitude stability requirements
- Beam dynamics study with crab crossing



Single cell

Multi cell



(top) Multi-cell TM110 and Loaded Structure of Crabbing Cavity (JLab/Cockcroft/Lancaster)

(left) Compact TEM-type, parallel-bar

Single cell: 37x50cm, 4MV@500 MHz

Multi cell: nx37 cm, nx4MV

J. Delayen, H. Wang, PRST 2009

J. Delayen, JLab seminar, 02/19/09

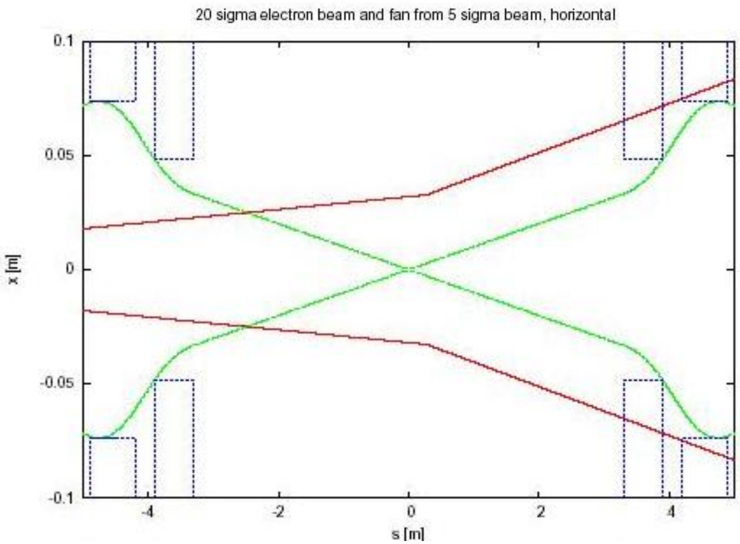
Synchroton Power/Backgrounds

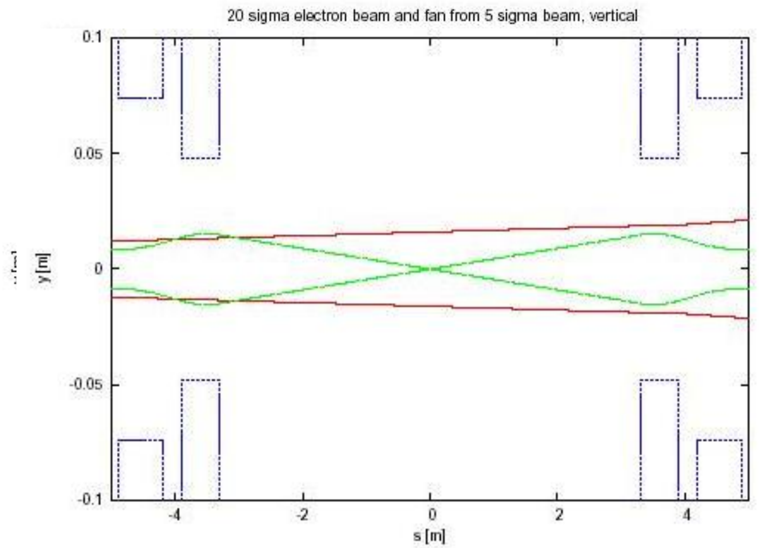
- Synchrotron radiation in IR : lower electron energy than HERA!
  - Synchrotron Power ~ I E^4 / R
  - ELIC / HERA II current ratio: ~ 0.55 A / 45 mA = 12
  - Electron energy ratio: (10 GeV / 27.5 GeV)^4 = 0.017
  - ELIC / HERA radius: (0.18/1.0) = 0.18 → 1/R = 5.6
  - Use of crab crossing makes this **simpler** for IR:

    Confirmed for (old) ELIC 100 mr crab crossing case

} **Same!**

Alex Bogacz, Slava Derbenev, Lia Merminga (JLab) and Christoph Montag (BNL)





Synchroton Power/Backgrounds

- Synchrotron radiation in IR : simplified as electron energy low!
  - Synchrotron Power ~ I E^4 / R
  - EIC@JLab / HERA II current ratio: 2000 mA / 45 mA = 44
  - Electron energy ratio: (**5 GeV** / 27.5 GeV)^4 = 0.001
  - Same power if bending radius at detector is **20 times smaller**
  - Use of (24 mr) crab crossing makes this even simpler
  - Such simplification was earlier confirmed for an (old) ELIC 10 GeV electron beam energy and 100 mr crab crossing angle case (where synchrotron power estimate is similar to HERA)

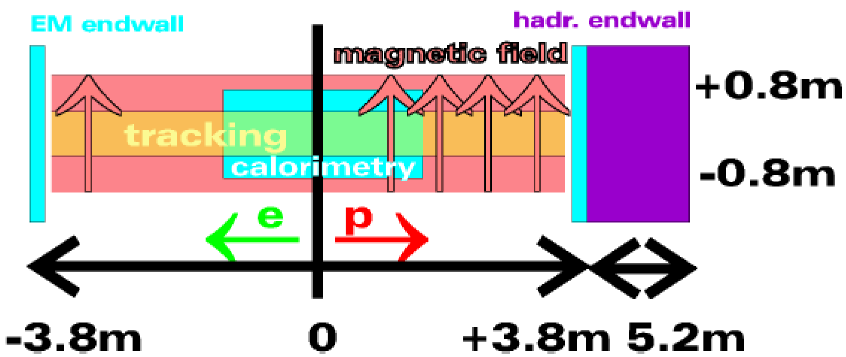
Again Detailed IR design needed,
but no obvious problems @ 5 GeV

EIC@JLab – IR Assumptions

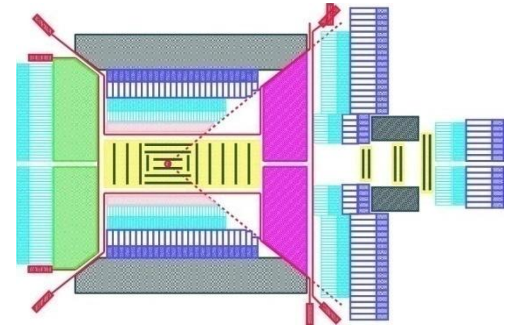
Can one use pluses of green field MEIC in IR design?
- Four Interaction Regions available
- novel design ideas promise high luminosity
- more symmetric beam energies → "central" angles
- figure-8 design optimized for spin (no impact on IR design)

Main IR assumptions:
- concentrate on one IR as main-purpose detector
- separate diffractive/low-Q^2 "Caldwell-type" detector from this main-purpose detector
- define relatively long (18 meter) fixed detector space (albeit with loss in luminosity – this 18 meter space is what Yuhong used in his presentation on MEIC/ELIC design)
- use flexibility in RF frequency to advantage (high RF for main detector physics?, low for eA etc.)

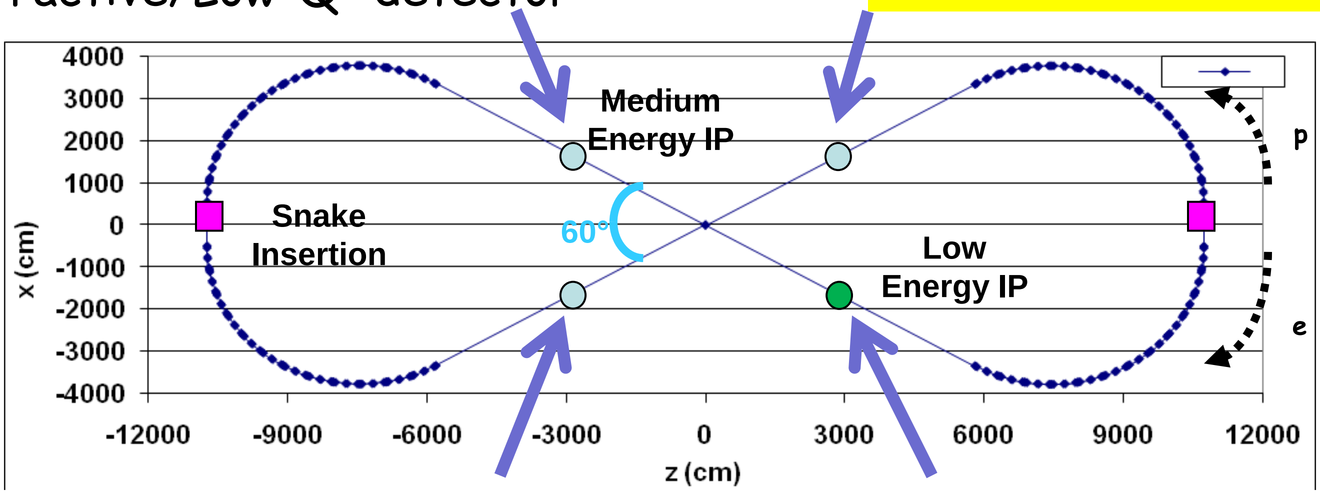
EIC@JLab IR Assumptions



IR3: Diffractive/Low-Q^2 detector



IR1: General Purpose detector (but not diffractive/low-Q^2)



IR2: Polarimetry etc.

IR4: Low Energy detector

IR Regions: +/- 9 meter

Medium Energy:
30-60 on 3-5 (11)

Low Energy:
12 on 3-5
[sqrt(s) only factor of three higher than 12-GeV program]

$^1H(e,e'\pi^+)n$ - Kinematics

MEIC@JLab
4 on 12 GeV^2
~ ENC@GSI

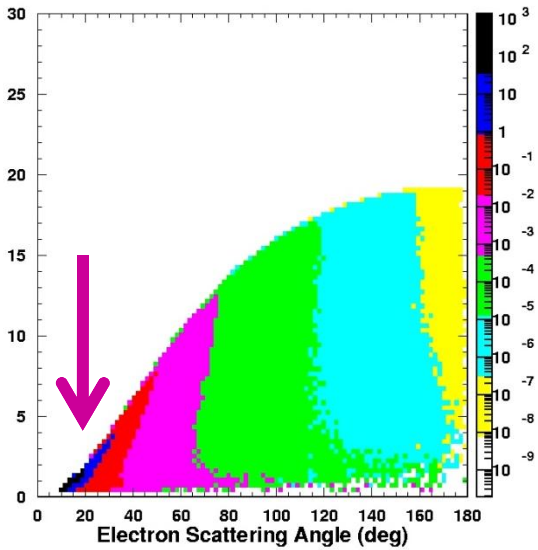
MEIC@JLab
4 on 60 GeV^2

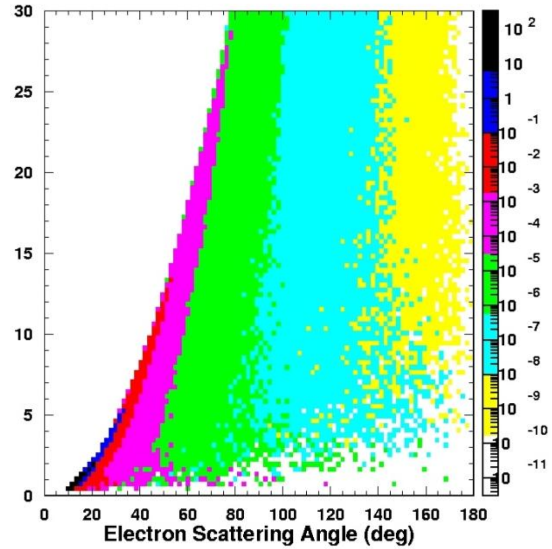
MEIC@JLab
11 on 60 GeV^2

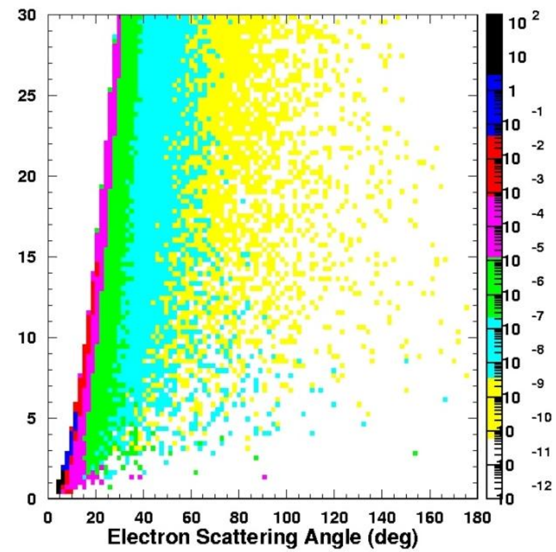
Staged eRHIC
4 on 250 GeV^2

Staged eRHIC
2 on 250 GeV^2

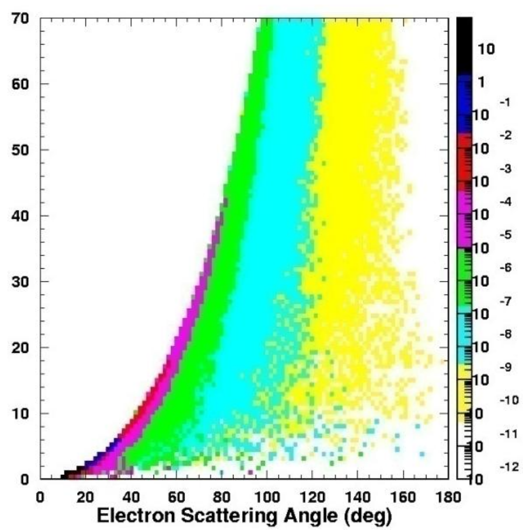
$^{1}H(e,e'\pi^{+})n$ – Electron Kinematics – Q^2

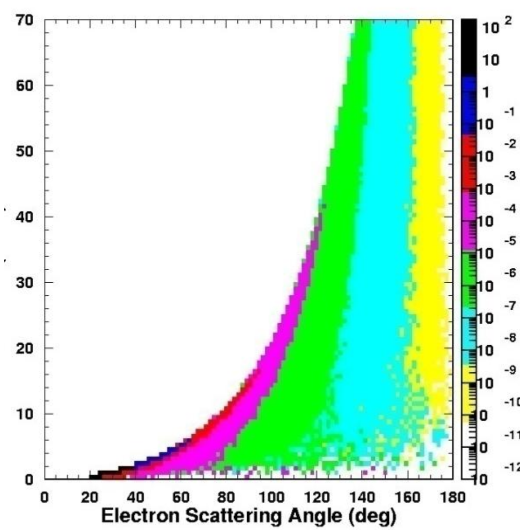






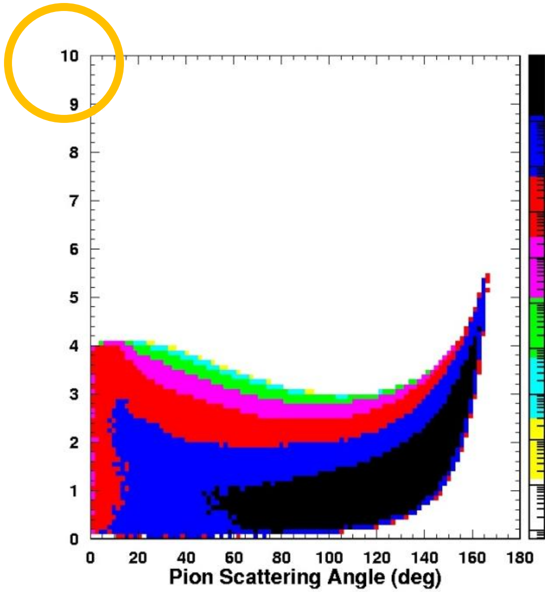
(Tanja Horn)

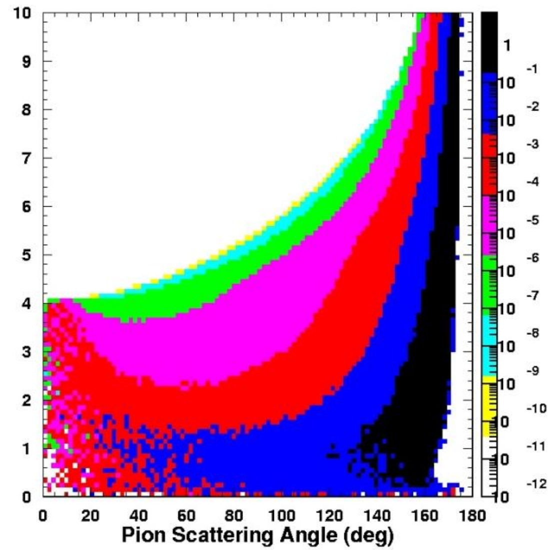


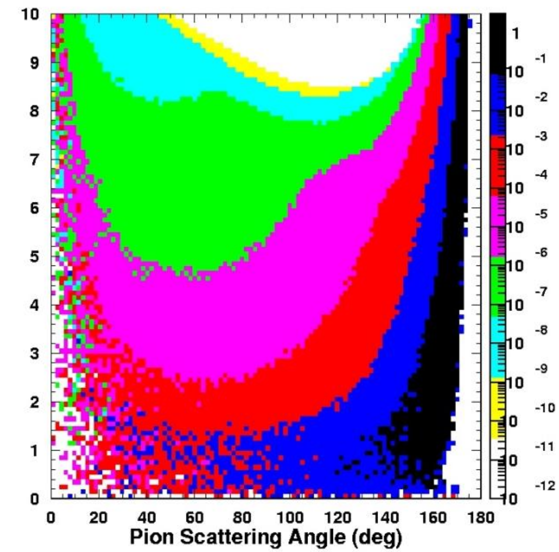


No need for very low Θ_e, or at least not with very good energy resolution.

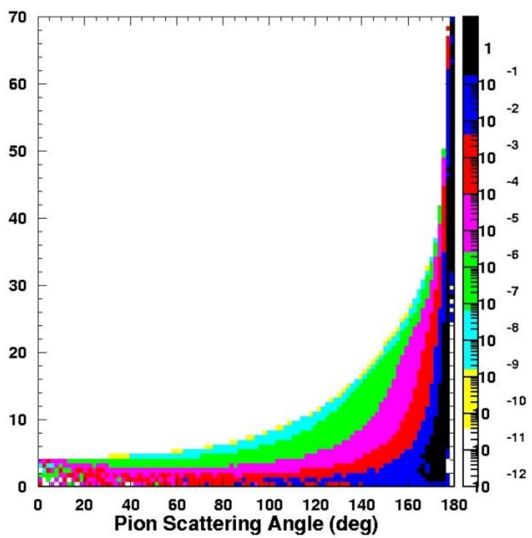
$^{1}H(e,e'\pi^{+})n$ – Pion Kinematics – P

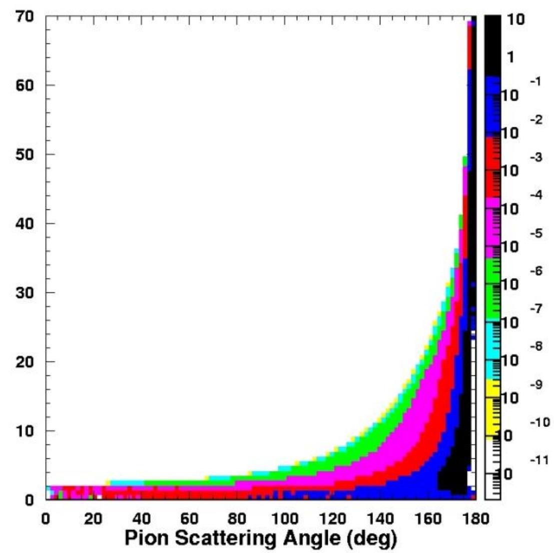






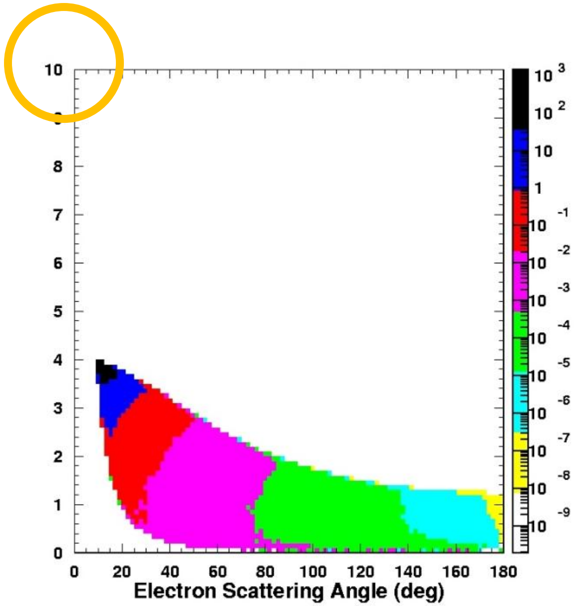
(Tanja Horn)

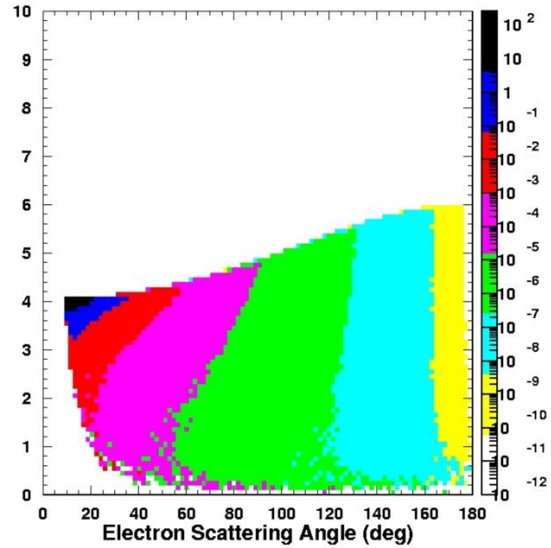


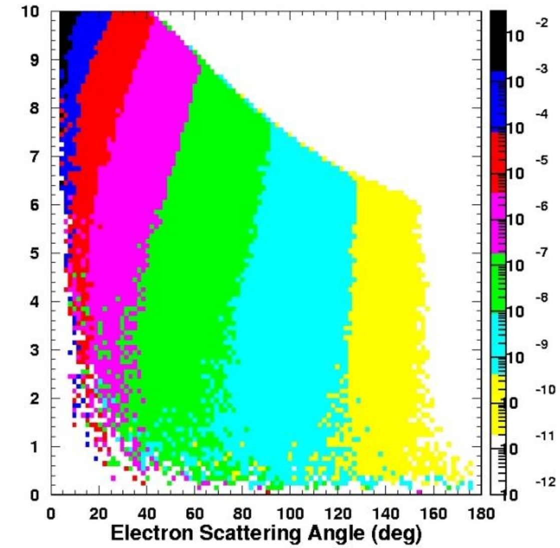


Lower proton energies better to map cones around hadrons for deep exclusive and SIDIS

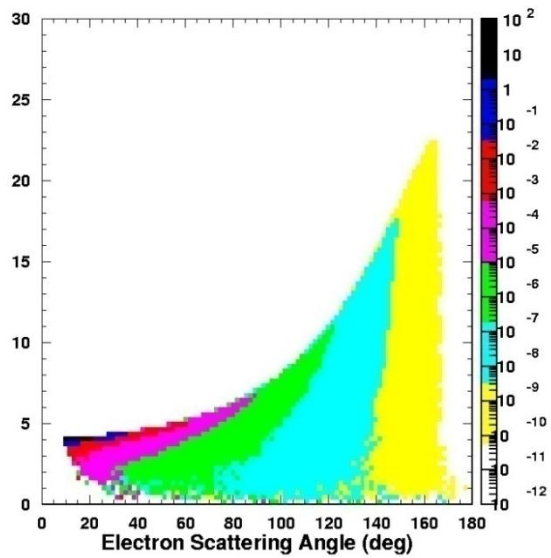
$^1H(e,e'\pi^+)n$ – Electron Kinematics – P

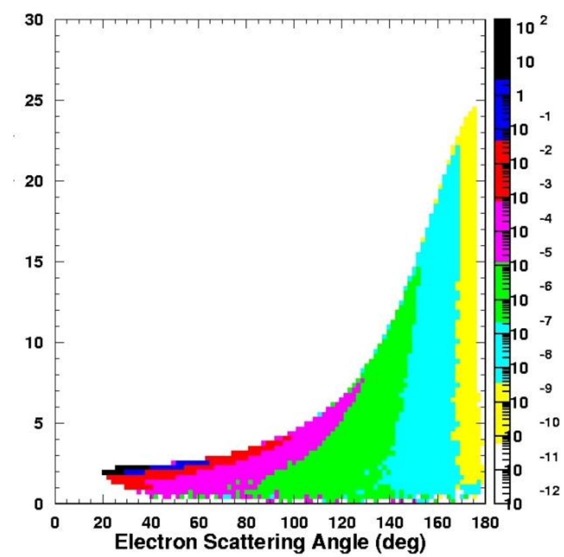






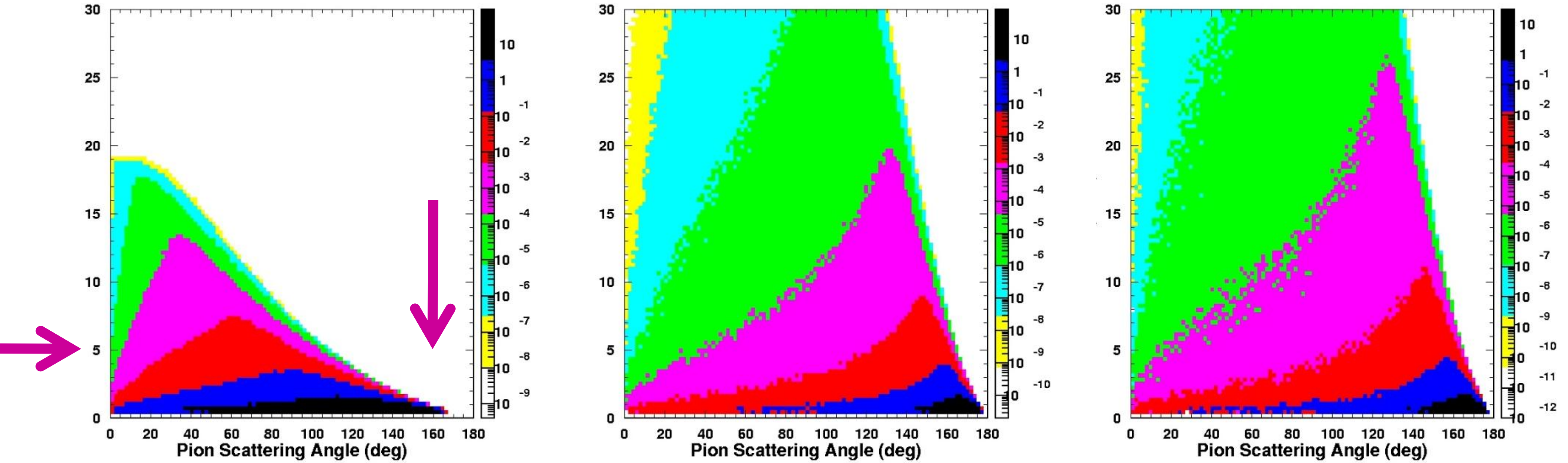
(Tanja Horn)



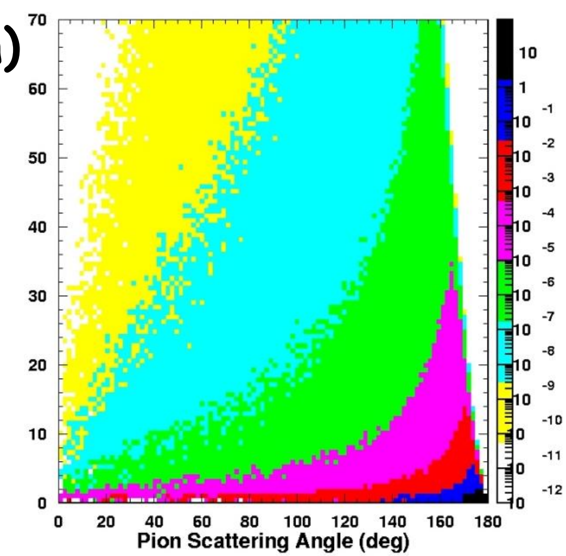


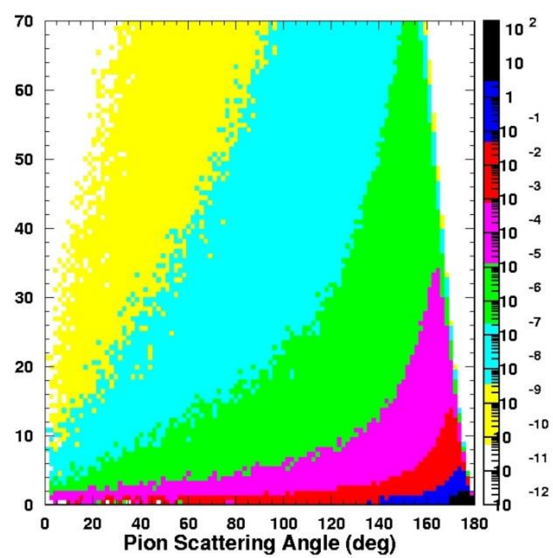
More symmetric and lower energies are better for energy resolution

$^1H(e,e'\pi^+)n$ – Pion Kinematics – Q^2



(Tanja Horn)

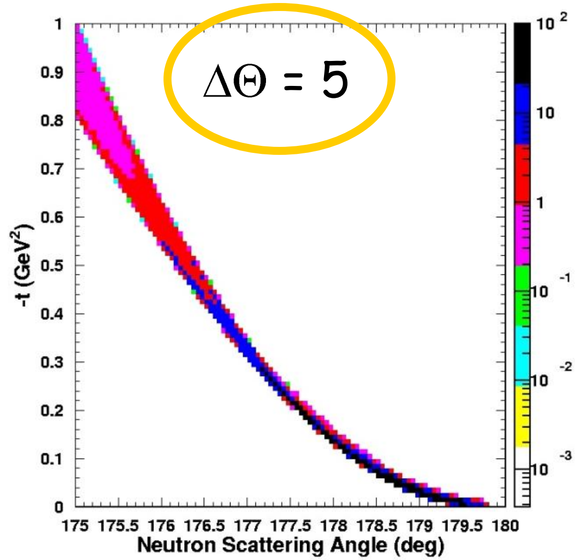


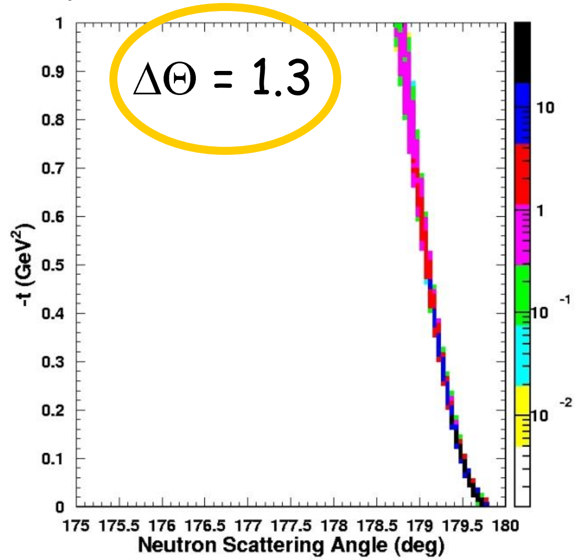


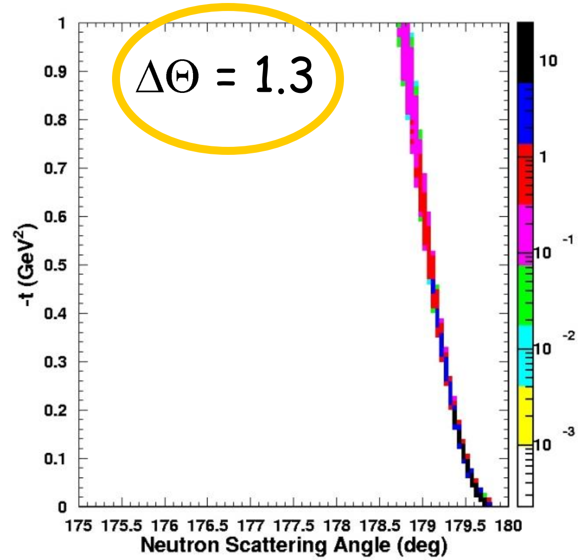
No need to push to most forward hadron angles for reasonable Q^2 in DES + SIDIS

$^1H(e,e'\pi^+)n$ – Neutron Kinematics – t

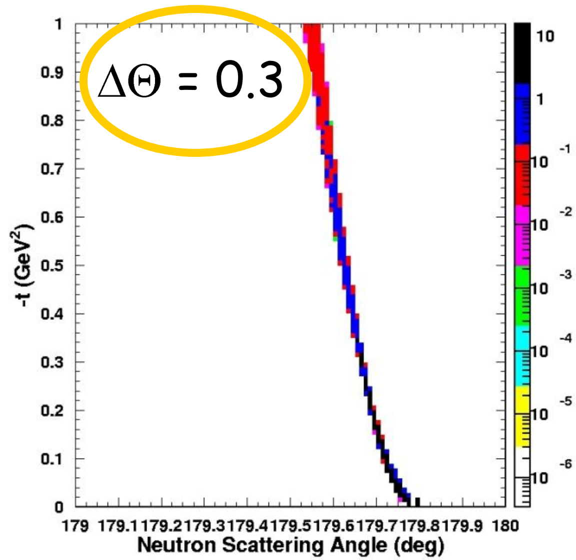
Want 0 < t < 1 GeV!

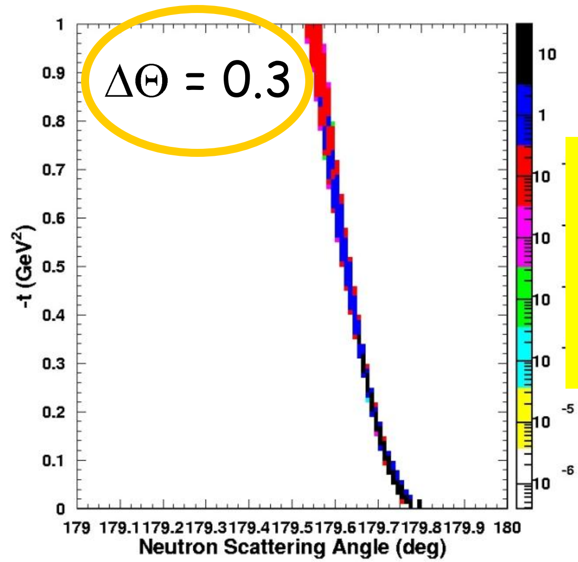






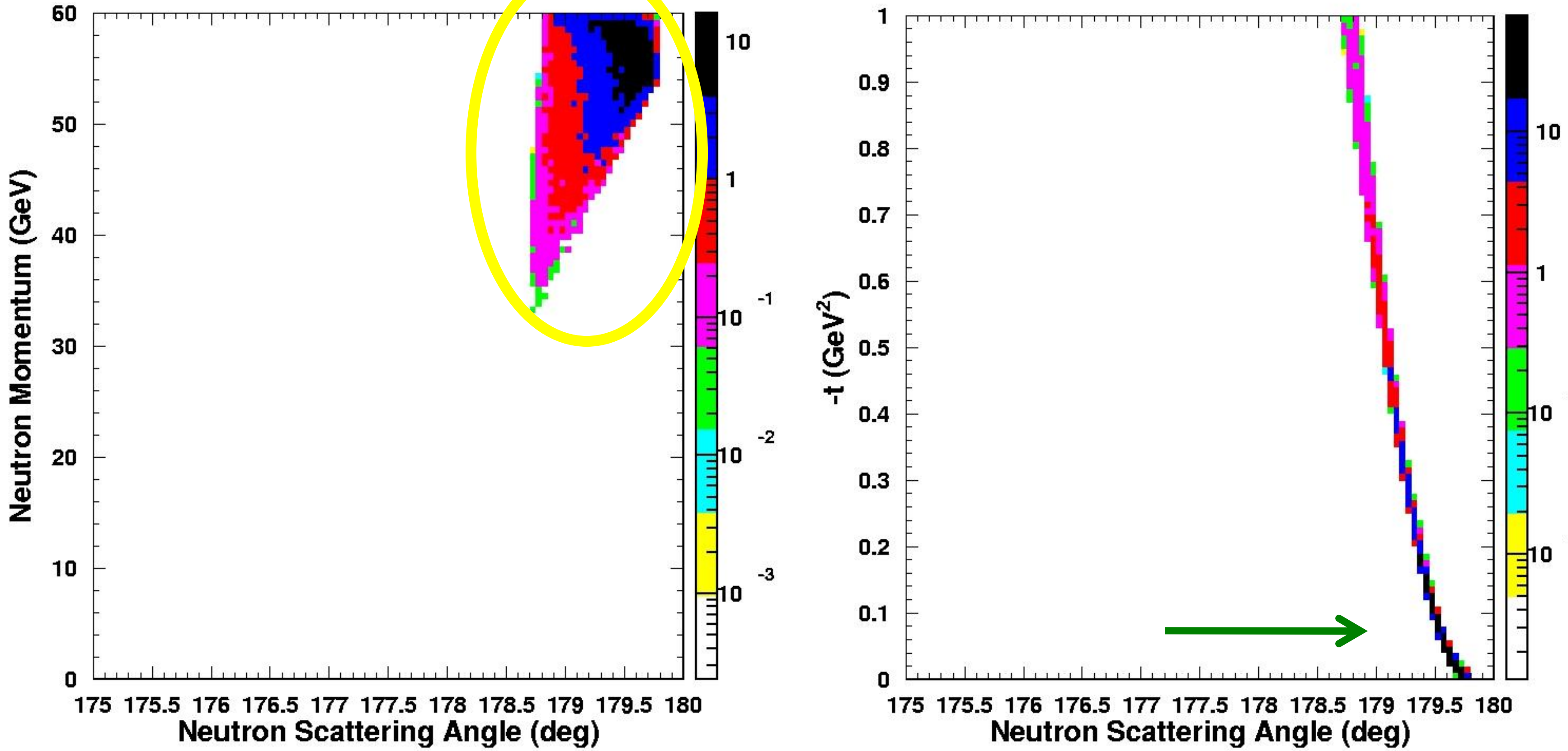
(Tanja Horn)





$\delta t/t \sim t/E_p$
$\rightarrow$ lower E_p better

$^1H(e,e'\pi^+)n$ – Scattered Neutron, 4 on 60



- Low –t neutrons (or protons) are emitted at very small angles with respect to the beam line, outside the main detector acceptance
  - **Between 0.2 and 1.5 degrees, or 3 and 25 mrad**
  - <u>If first IR magnet element 9 m away</u> → 2.7 to 22.5 cm
  - Better to assume all detection before 1st IR magnet?
- A separate detector placed tangent to the proton beam line away from the intersection region is required – not clear how to do yet

General Considerations for Magnetic Fields

- Solenoid is "easy" field, but not much field at small scattering angles

- Toroid would give better field at small angles but with an asymmetric acceptance
  - Improves acceptance for positive hadrons (outbending)
  - Improves detection of high Q^2 electrons (inbending)
  - Limits acceptance at very small angles (~3^o?) due to coils (want 1^o or so: resolved with $$ barrel toroid? Other tricks?
  - May limit acceptance for π+π- detection

- Vary Solenoid field to see how far one can push and compare with toroidal field
  - But … also need runs with lower central solenoid field to access low-momentum reaction products from e.g. open charm production (~0.5 GeV/c)

- Could also add central toroidal or dipole field(s) to solenoid
  - Small dipole component may be useful for lattice design (~0.3-0.5 Tm?)
  - goal of dipole field on electron side to optimize resolutions
  - goal of dipole field on hadron side to "peel" charged particles away from beam

Formulas - used in parametric MC

(Tanja Horn, Richard Milner, Rolf Ent)

Multiple scattering contribution:

$$\left(\frac{\delta p}{p}\right)_{msc} = \frac{1}{0.3B_T}\frac{0.0136\,z}{L\beta\cos^2\gamma}\sqrt{n_{r.l.}}$$

- z = charge of particle
- L = total track length through detector (m)
- γ= angle of incidence w.r.t. normal of detector plane
- $n_{r.l.}$ = number of radiation lengths in detector

Intrinsic contribution (first term):

$$\left(\frac{\delta p}{p}\right)_{intr} = \frac{p}{0.3B_T}\frac{\sigma_{r\phi}}{L'^2}\sqrt{\frac{720}{n+4}}$$

- B=central field (T)
- $\sigma_{r\varphi}$=position resolution (m)
- L'=length of transverse path through field (m)
- N=number of measurements

Assumptions:

- circular detectors around interaction point
- $n_{r.l.}$ = 0.03 (from Hall D CDC)
- simulations only done for pions (for now)

Solenoid Fields - Overview

Experiment	Central Field	Length	Inner Diameter
ZEUS	1.8 T	2.8 m	0.86 m
H1	1.2T	5.0 m	5.8 m
BABAR	1.5T	3.46 m	2.8 m
BELLE	1.5T	3.0 m	1.7 m
GlueX	2.0T	3.5 m	1.85 m
ATLAS	2.0T	5.3 m	2.44 m
CMS	4.0T	13.0 m	5.9 m
PANDA(*design)	2.0T	2.75m	1.62 m
CLAS12(*design)	5.0T	1.19 m	0.96 m

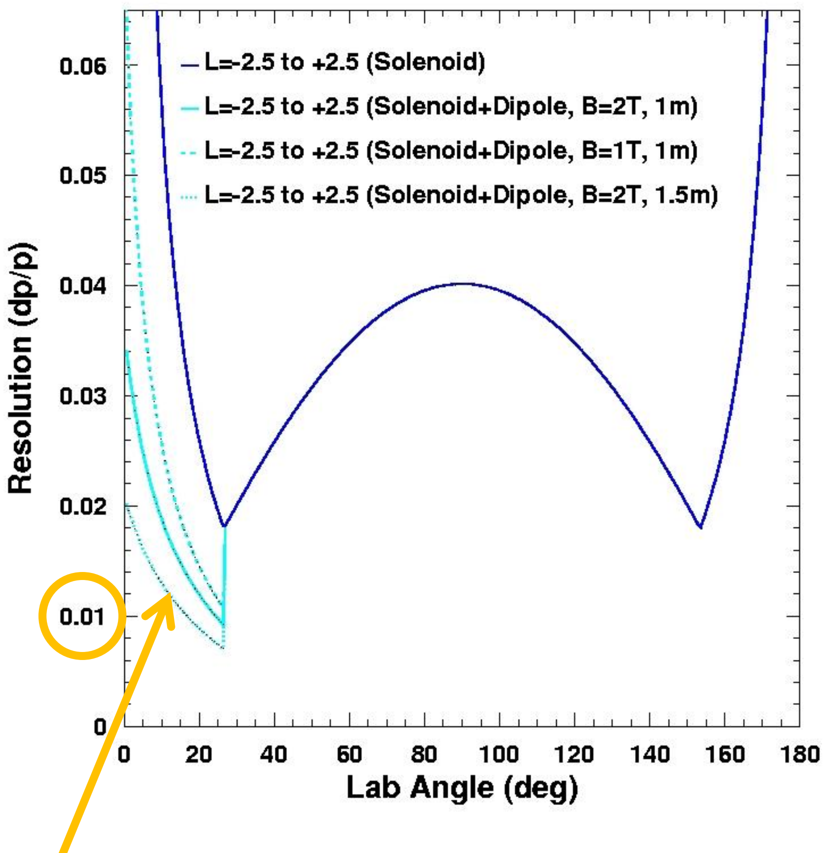
Conclusion: ~4-5 Tesla fields, with length scale ~ inner diameter scale o.k.

Simulations showed we would need some 5-10 (?) Tm on central ion side, AND some additional 2 Tm magnetic field in the ion (< 20 deg?) direction to improve resolutions. Field needs are not too far off from CLAS12!

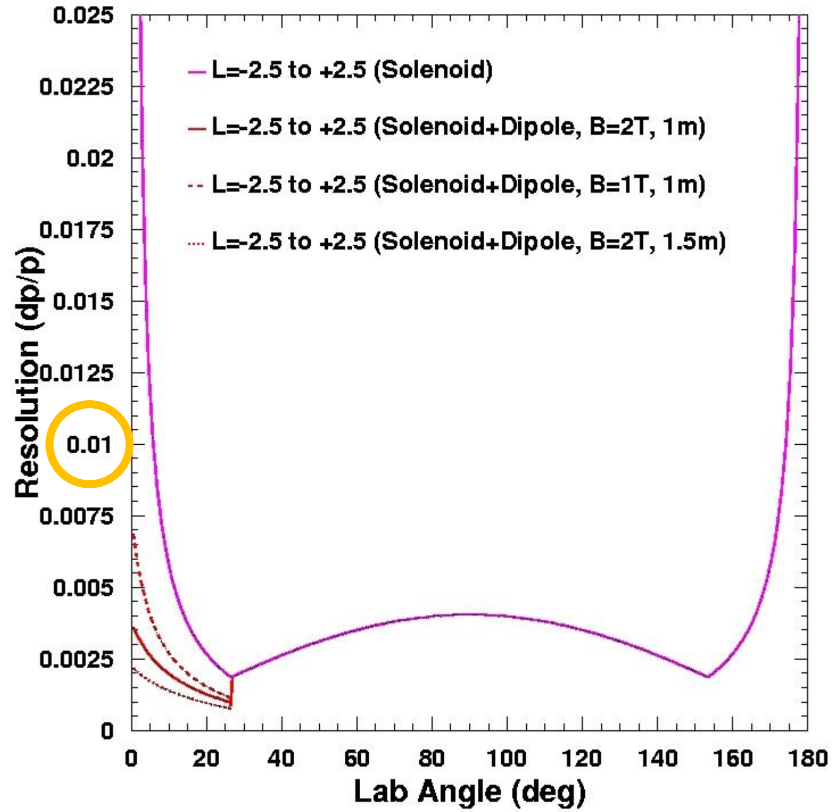
ID ~ length solenoid → likely scenario is some 3-4 meter long and 3-4 m ID

Solenoid and dipole field

p = 50 GeV

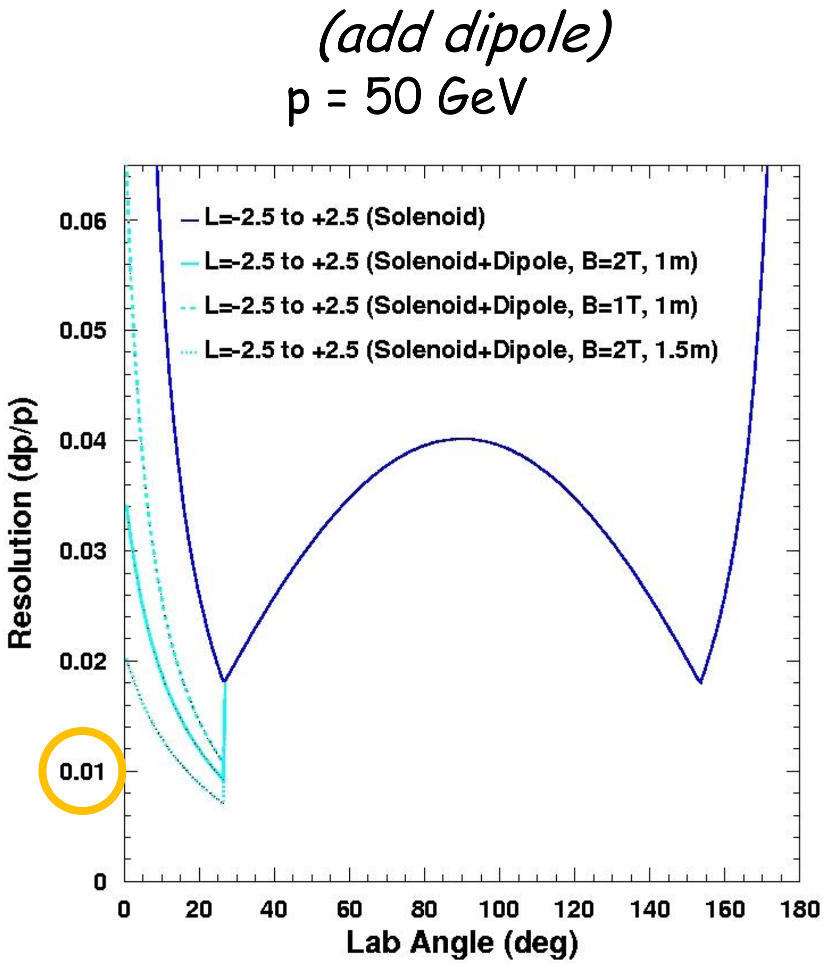


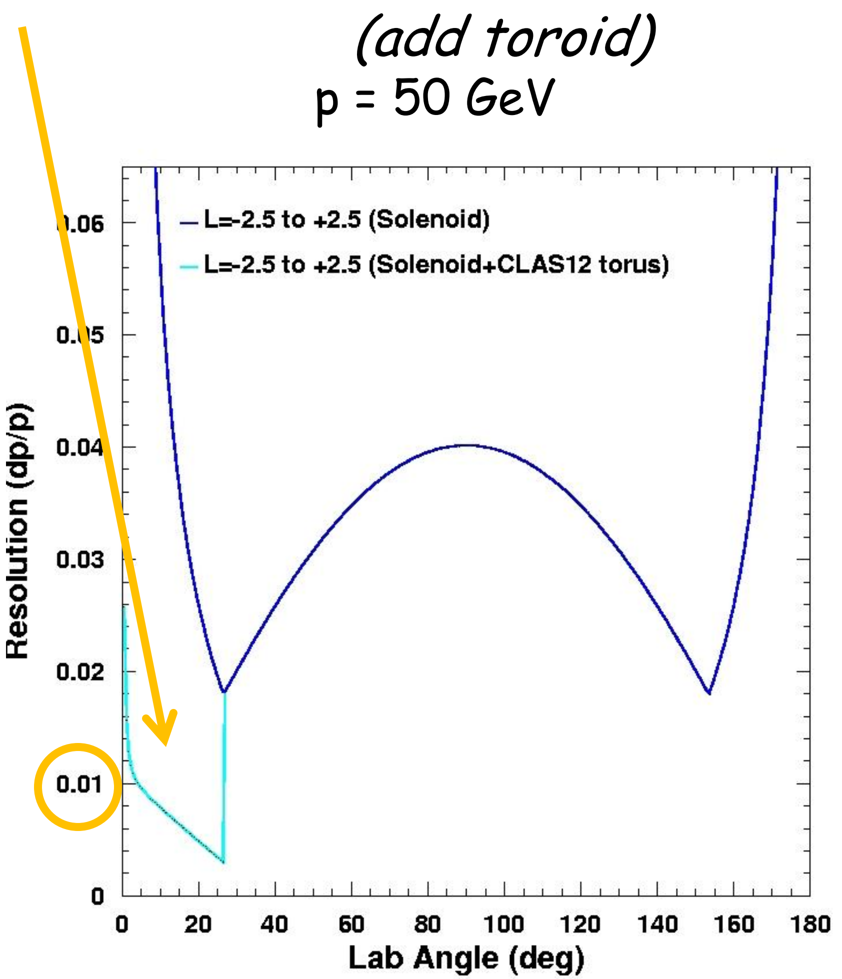
p = 5 GeV



As expected, substantially improves resolutions at small angles

Solenoid and CLAS12 toroidal field

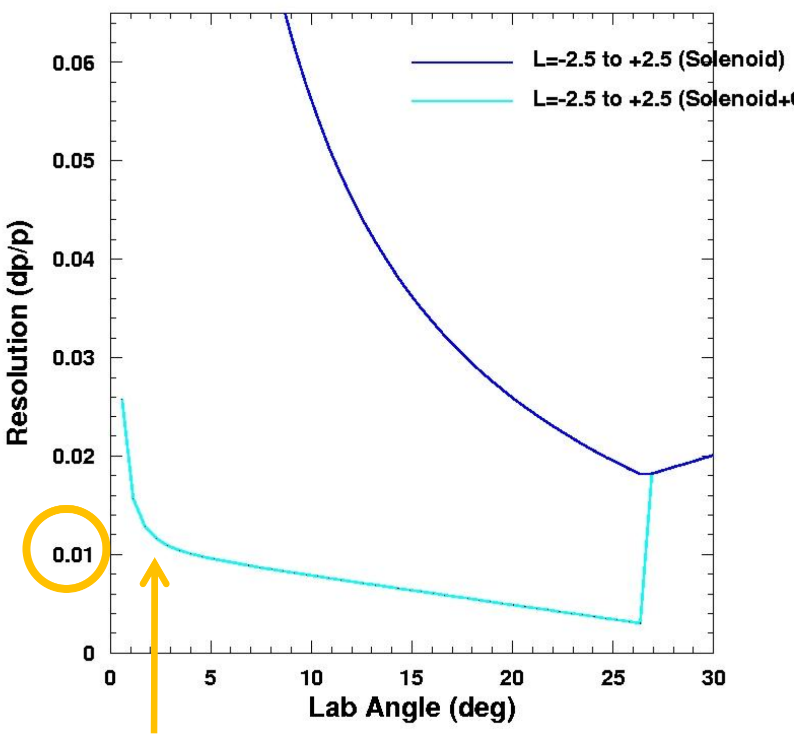




Does the same trick, but would get acceptance loss at small angles (~3°?)
Not likely to push this to 1°, but we are still looking at it.

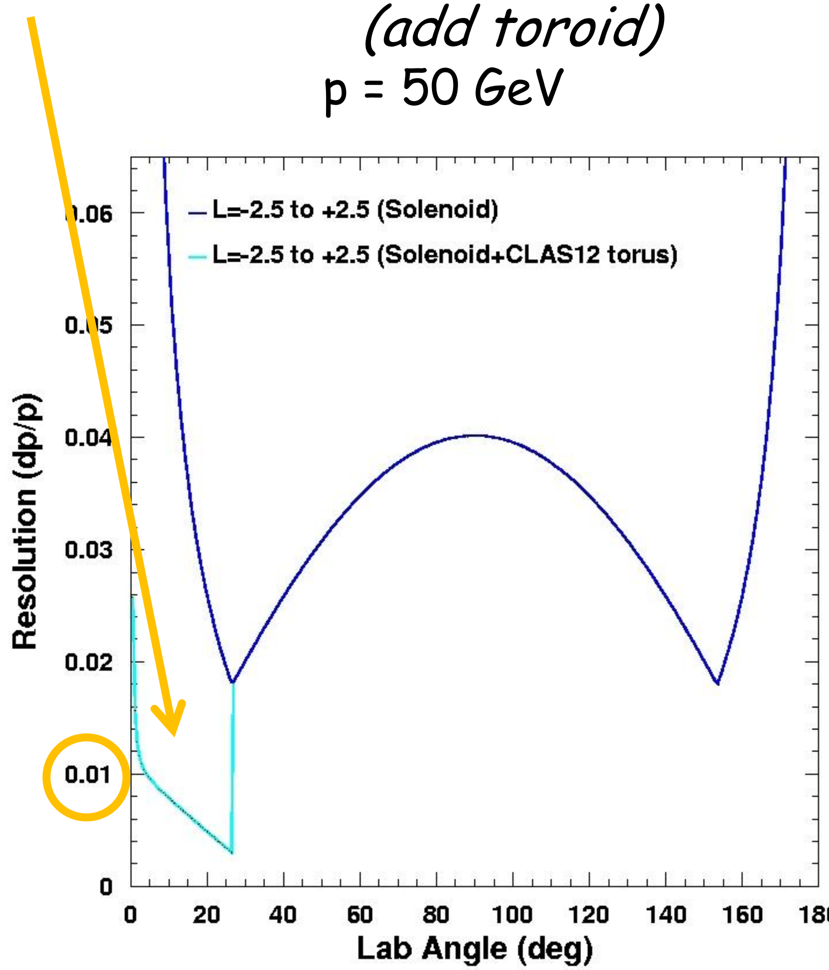
Solenoid and CLAS12 toroidal field

(add toroid, zoom)
p = 50 GeV



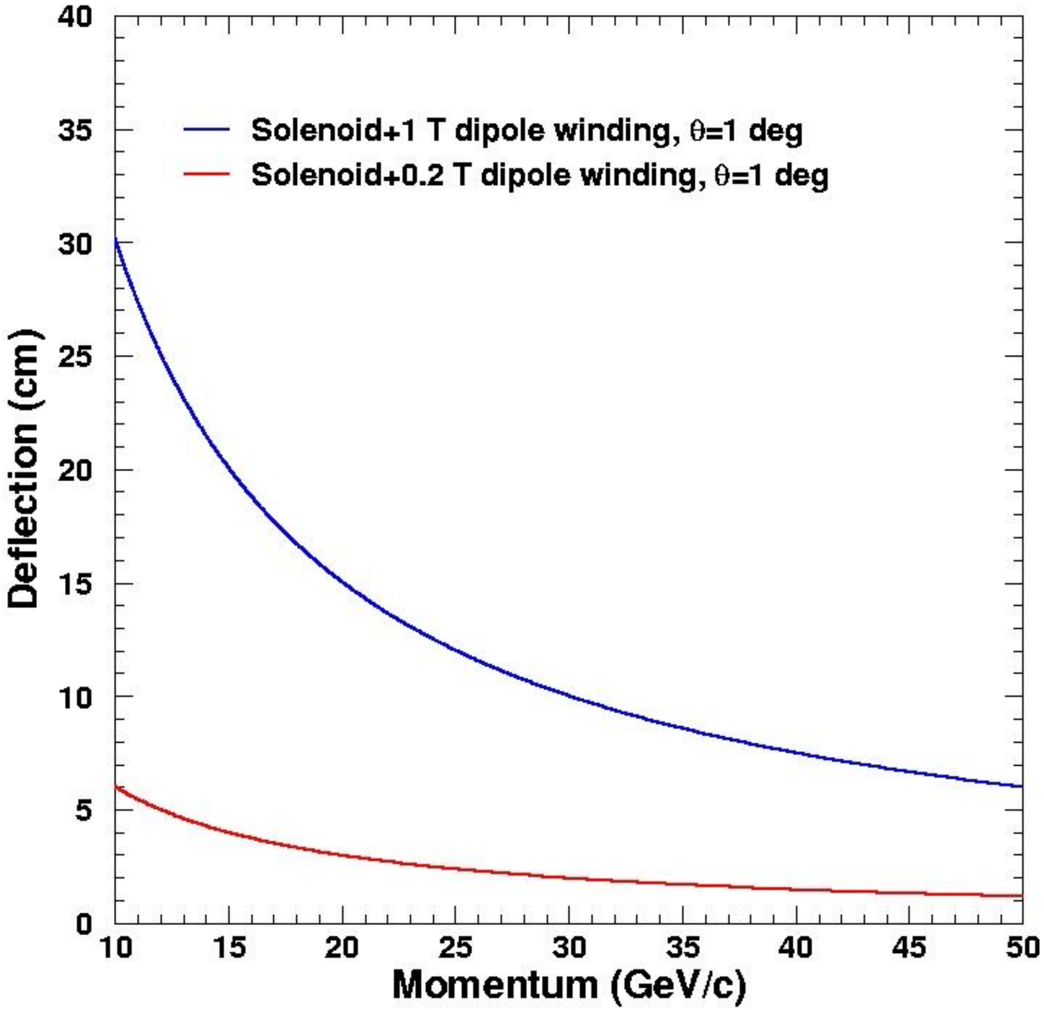
>1% for angles <2deg

(add toroid)
p = 50 GeV



Initial solenoid: B=4T, L=5m, D=2.5m

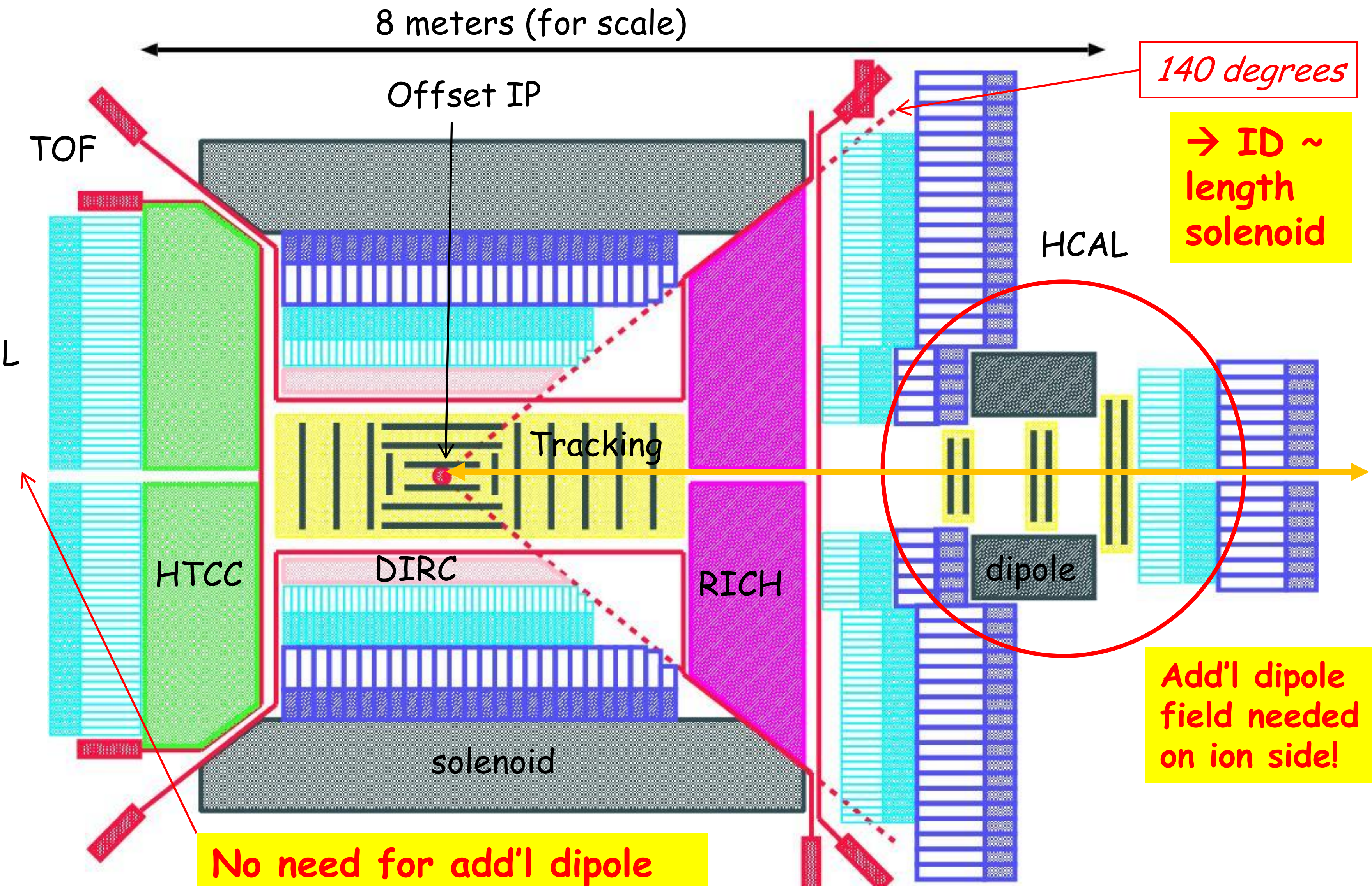
Dipole field requirement on hadron side



Deflection @ 5 meters

- 0.5-1 Tm dipole component, or 2 Tm separate dipole sufficient on hadron side to peel the charged particles away from beam line and allow for tagging/vetoing?
- Need to fold in map of angle vs. momentum of particles of interest to better constrain.
- Of course, such options also need to be checked for resolutions required for SIDIS and DES reactions.

ELIC detector cartoon - ~May. 09



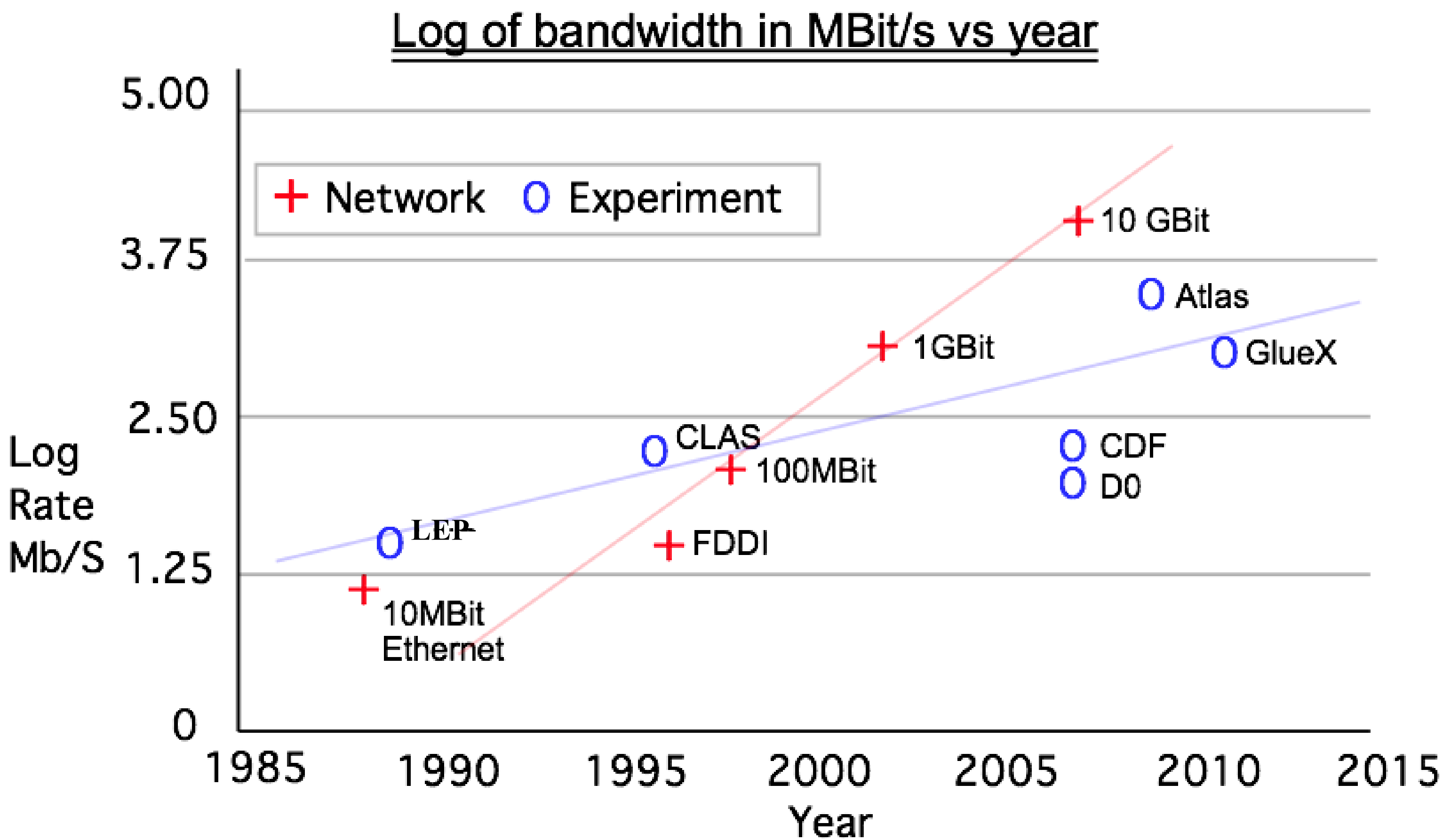
No need for add'l dipole if non-diffractive, non-low-Q^2 detector: Θ > 10^o

But, 9 m space exists → add dipole, HCAL?

Ion beam

e beam

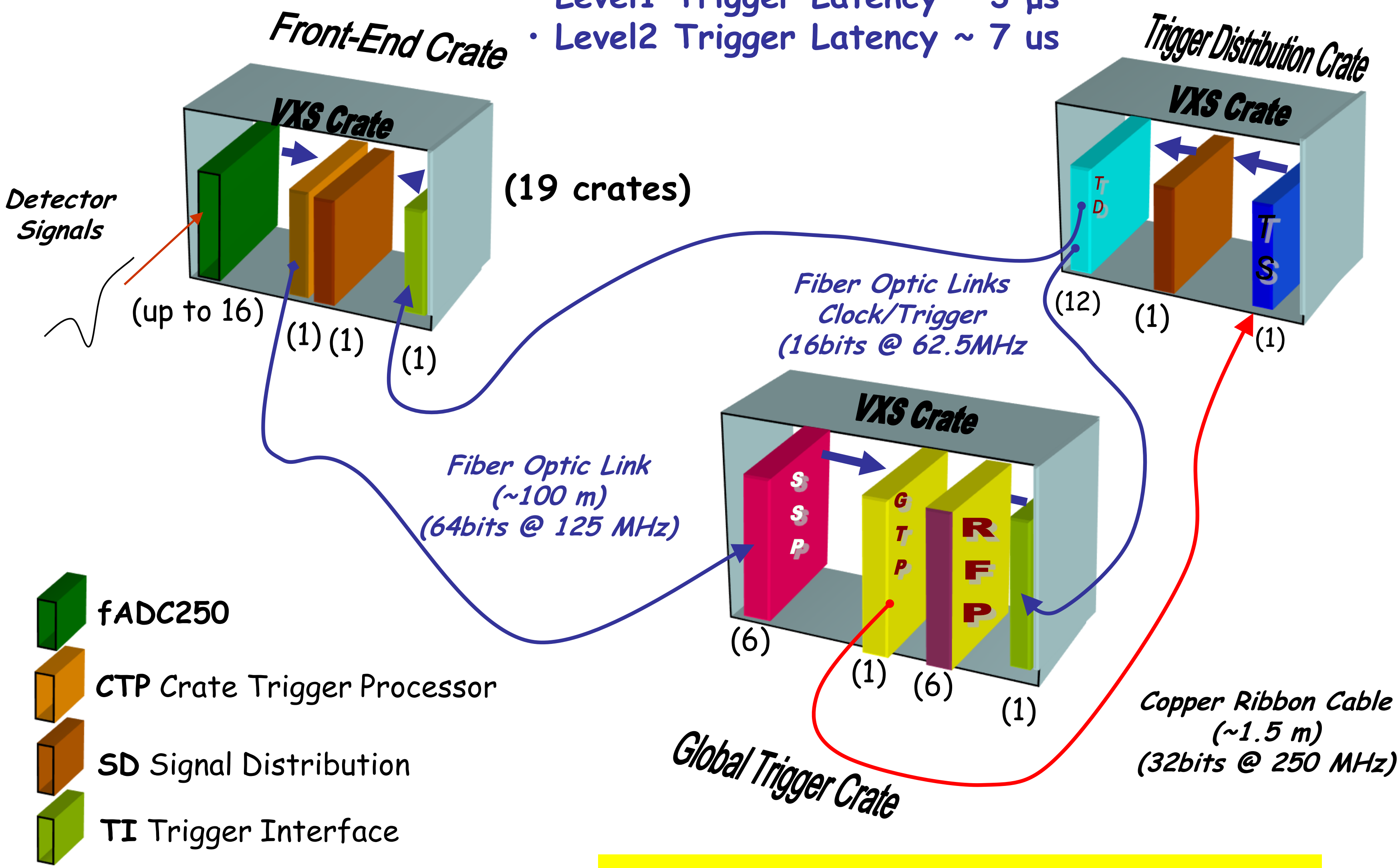
Benefit from data transport



[CLAS12 DAQ/Fast electronics will be able to meet event rates of up to 10,000 kHz, 100 MB/s data rates, at <15% dead time]

CLAS12 Trigger System

- Level1 Trigger Latency ~ 3 μs
- Level2 Trigger Latency ~ 7 us



Not a synchronized trigger!

Numerical Example at High Luminosity

At a luminosity of 10^{35} $cm^{-2}s^{-1}$, the total hadronic production rate is about 1×10^7 s^{-1}

Assume a data-acquisition capability of 5,000 s^{-1}
[CLAS @ Moment, at dead times of 15%, has achieved an event rate of up to 8,000 s^{-1} (10,000 peak), and a data rate of 35 MB/s, using pipeline TDCs, dual-CPU ROCs, and multiprocessing in Event Builder]

→Trigger would need to provide a factor of 2,000 rejection of hadronic events: seems challenging but near reality (CLAS12 assumes >2,000).

[CLAS12 DAQ/Fast electronics will be able to meet event rates of up to 10,000 kHz, 100 MB/s data rates, at <15% dead time, by using all pipelined electronics, VXS, + increased data transport]

Bunch Spacing from Detector Point of View

CLAS operates at a 500 MHz bunch frequency. The e^- can be traced back to the specific bunch, which is then used as "RF time tag" to calibrate the detectors for the hadrons.

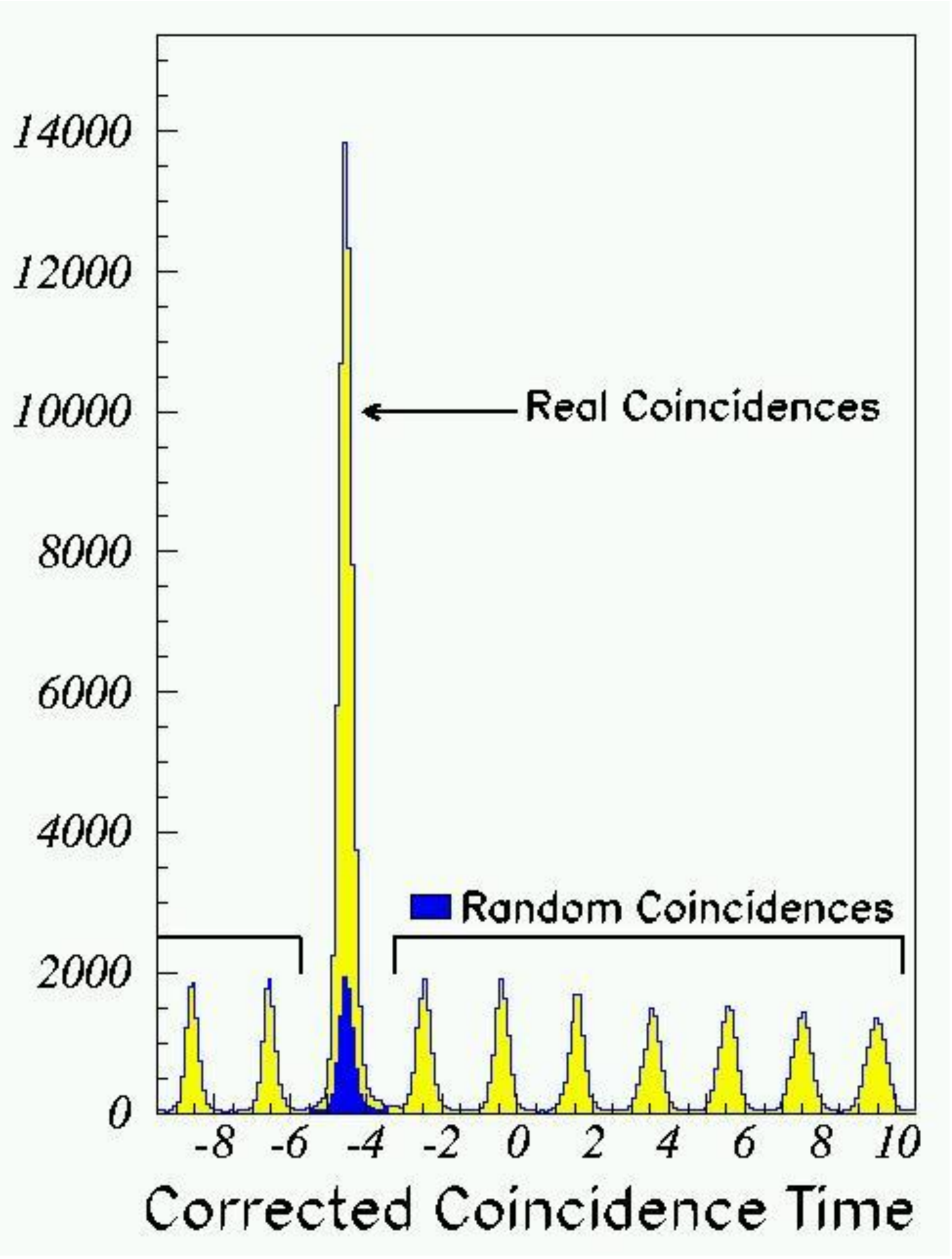
Question: What are the implications in collider mode?

1. For the specific e-ion process, you still have the e^- tag
2. Collection times for (fast) detection devices is 10-20 ns
   (e.g., silicon, scintillator, and PMT's, but not for e.g. Ar calorimetry)
3. Use a pipelined ultrafast DAQ/electronics system, but **NO NEED to synchronize with RF bunch frequency – we don't do it now either.**
4. Digitization allows determination of time less than the resolving time of the specific detector (now, calibration becomes the main issue)
5. The multiplicity w.r.t. CLAS12 only increases by a factor of 2-4, and the luminosity is close to the same → hadronic rates not dissimilar.
6. Hence, can one untangle the interactions separated in time by less than the resolving time of the detector in the face of pileup?
7. **Yes. If CLAS and CLAS12 can, so can MEIC. (backgrounds expected to be low with proper choice of IR location).**

"Proof of Principle"

"Easy" at a fixed-target facility with a 500 MHz beam structure

2/3 ns spacing may be too short to "pick bucket", but that simply means three random peaks are under the coincidence one. Similar as a DC background, **RF frequency in principle does not matter**. But, the real/random ratio does matter!



Hadronic Background – scaling w. HERA

(Pawel Nadel-Turonski)

- Hadronic Random Background:
  - assumed to be governed by ion-residual vacuum gas (mainly H) interactions
  - σ(pp) nearly independent of energy
- EIC@JLab background rates comparable to HERA II
  - Distance between dipoles and detector: 40 m / 120 m = 0.3
  - Average hadron multiplicity: ~ (60 GeV / 920 GeV)$^{1/4}$ = 0.5
  - Ion beam current: 0.7 A / 0.1 A = 7
  - Vacuum (10^{-9} torr?) easier to maintain in smaller ring
- Signal-to-(beam-related) background is 10^3 times better
  - EIC@JLab luminosity: ~5 x 10^{34} cm^{-2} s^{-1}
  - HERA luminosity: ~5 x 10^{31} cm^{-2} s^{-1}

Conclusion on IR/detector studies

- Great advantage by separating diffractive/low-Q^2 "Caldwell-type" detector from main DIS/SIDIS/DES detector! **Is this o.k.?**
- Since luminosity requirements for eA and polarized ep are vastly different, this does not seem a big issue.
- Life also simplified by first starting with large detector space and avoiding complicated detector/accelerator interfaces **(if we can…).**
- Lower beam energies (than 250 GeV) make SIDIS and DES experiments simpler (but they are still difficult). For DES, it may be mandatory if one needs to optimize t-resolution.
- More symmetric energies is advantageous for good resolutions and easier particle Id.
- Need a field beyond a solenoid field to "peel" charged particles off beam for such deep exclusive processes.
- Studies ongoing on whether solenoid + dipole, solenoid + barrel or end-cap toroid, or other magnet configurations are optimal.
- Initial studies show coherent nuclear processes also accessible by angle measurements after magnetic field (need good dispersion).
- Have started thinking how to handle high luminosity from detector/electronics/DAQ point of view. Short straight section before IR is a plus in terms of background.

Recent Progress towards a High-Luminosity EIC at JLab

Large effort by the MEIC/ELIC Study Group

Nuclear Physics	(exp.)	Tanja Horn
		Charles Hyde
		Franz Klein
		Pawel Nadel-Turonski
	(thy)	Vadim Guzey
		Christian Weiss
CASA		Alex Bogacz
		Slava Derbenev
		Geoff Krafft
		Yuhong Zhang
		(+ help from many others)
With input from		Larry Cardman
		Andrew Hutton
		Hugh Montgomery
		Tony Thomas

Multiplicity for High-Energy Hadron Interactions

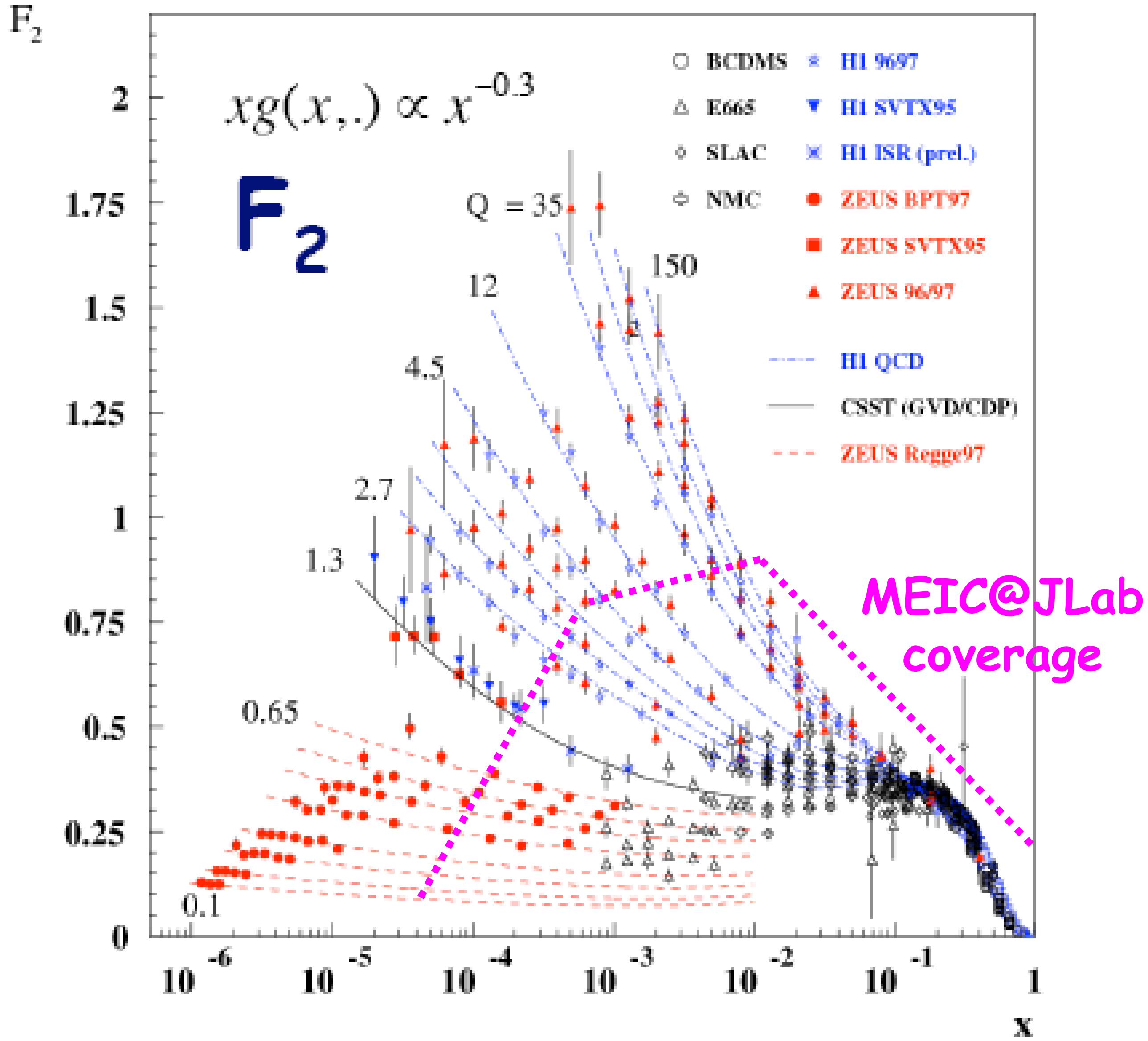
F. Braccella and L. Popova, J. Phys. G 21 (1995) 1379

My Simple Estimate: Total Multiplicity ~ $s^{1/4}$

$s^{1/2}$ (GeV)	n (article)	$2s^{1/4}$
20 (ISR/FNAL)	9	9
540 (SPS)	45	46
1800	82	86

CLAS	($L = 2 \times 10^{34}$)	n = 3.7	(close to empirical observation in CLAS)
CLAS12	($L = 1 \times 10^{35}$)	n = 4.2	
EIC E_{cm} =	12 (MEIC-Low E)	7	
	51 (MEIC-Hi E)	14	
	100 (ELIC)	20	

Factor of 2-4



F2
$xg(x,.) \propto x^{-0.3}$
F2
Q = 35
150
12
4.5
2.7
1.3
0.65
0.1
BCDMS
E665
SLAC
NMC
H1 9697
H1 SVTX95
H1 ISR (prel.)
ZEUS BPT97
ZEUS SVTX95
ZEUS 96/97
H1 QCD
CSST (GVD/CDP)
ZEUS Regge97
MEIC@JLab coverage
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
x

Appendix: MEIC Physics Most Critical R&D

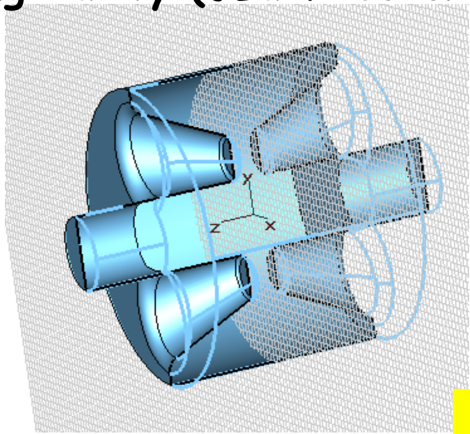
Activity	Detailed Description
Flash ADC	Explore the development of higher channel density per module. ADC available at higher sampling rates but power consumption is a significant challenge. New multichannel, low power devices with serial outputs are attractive.
FADC FPGA	Continue development of on board high speed FPGA using the latest FPGA devices. Development includes algorithm development work, timing simulation, and board layout techniques
Gigabit FPGA	Continue development with FPGA that contain the latest high speed Gigabit Serial I/O for transporting readout and trigger data. Development includes firmware, timing simulation, and board layout analysis tools
Event Readout (DATA Path)	Build on the existing success of our VXS trigger data transmission. Begin R&D for a VXS 'Switch' path for the event readout data from each crate that easily exceeds the present VME readout data rate.
Global Trigger FPGA Processing	Continue R&D with the latest FPGA devices and develop global trigger algorithms for use with pipeline front end modules and large scale, complex detector geometries
Computer Aided Design Computer Aided Engineering CAD/CAE	This is not R&D, but the manpower associated with the R&D efforts will require Designers with expertise in high speed, multi-layer circuit boards, schematic capture, and circuit board modeling tools.

Appendix: MEIC Physics Most Critical R&D

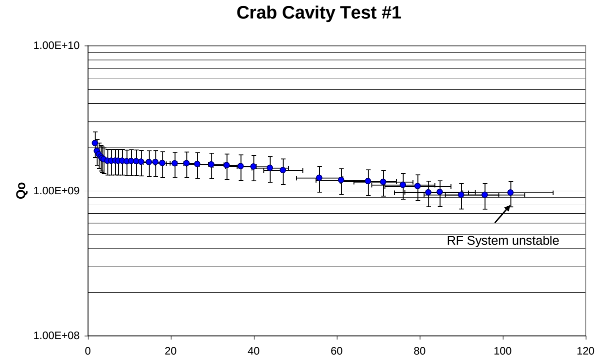
Procurements	
FPGA Tools	Xilinx or Altera full development tools (2 Licenses)
Schematic capture; Board Layout	"Altium" design suite or equal (2 Licenses)
VHDL Synthesis and Simulation Tools	Aldec, MicroSim, or other tools from FPGA vendors (2 Licenses)
FPGA Evaluation Modules	Latest versions of FPGA devices available from vendors for testing and algorithm simulation (2 eval kits)
Oscilloscope	Digital Serial Analyzer (DSA) for high speed multi-Gigabit serial devices and circuit designs
Test crates	VXS full crate with power supply
Peripherals	Board extenders, fiber optic devices, test equipment, cabling

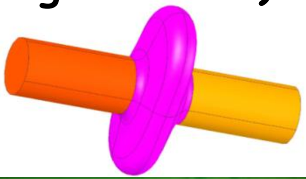
JLab Crab Cavity Development

Multi-cell TM110 and Loaded Structure of Crabbing Cavity (JLab/Cockcroft/Lancaster)



Elliptical squashed SRF cavity R&D for APS (JLab/LBNL/AL/Tsinghua Univ.)





H. Wang, R. Rimmer, 12/10/2008
Muon Collider Design Workshop

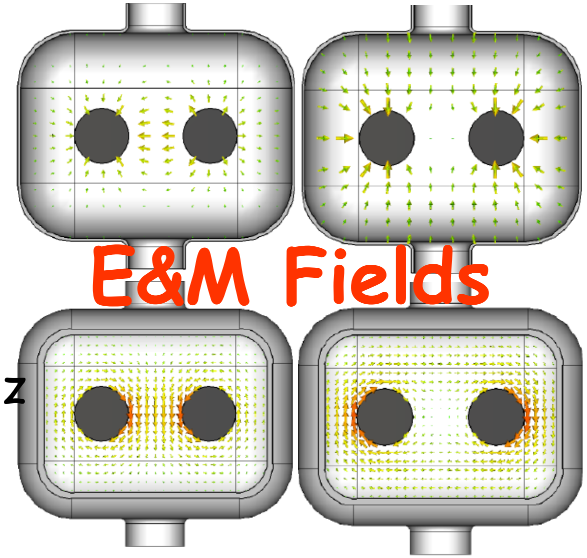
J. Delayen, H. Wang, PRST 2009
J. Delayen, JLab seminar, 02/19/09

New (Innovative) Program

- Compact TEM-type, parallel-bar
- Deflecting ➔ 12 GeV CEBAF
- Crabbing ➔ ELIC
- Providing high transverse kinking

Single cell: 37x50cm, 4 MV@500MHz

Multi-cell: ~ n x (37 cm), n x (4 MV)



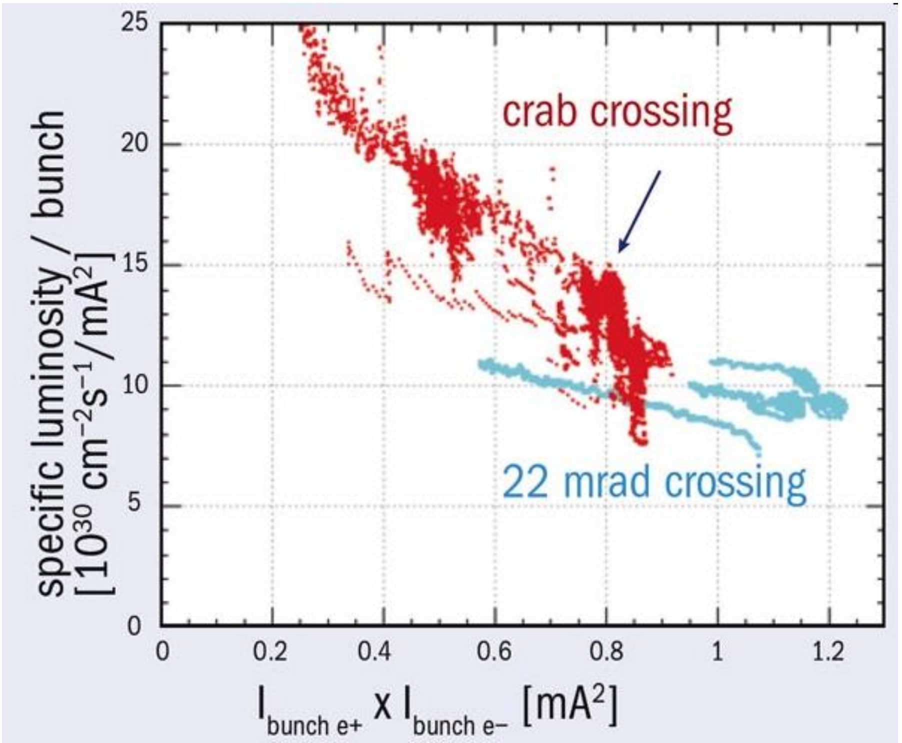
Great News From KEK

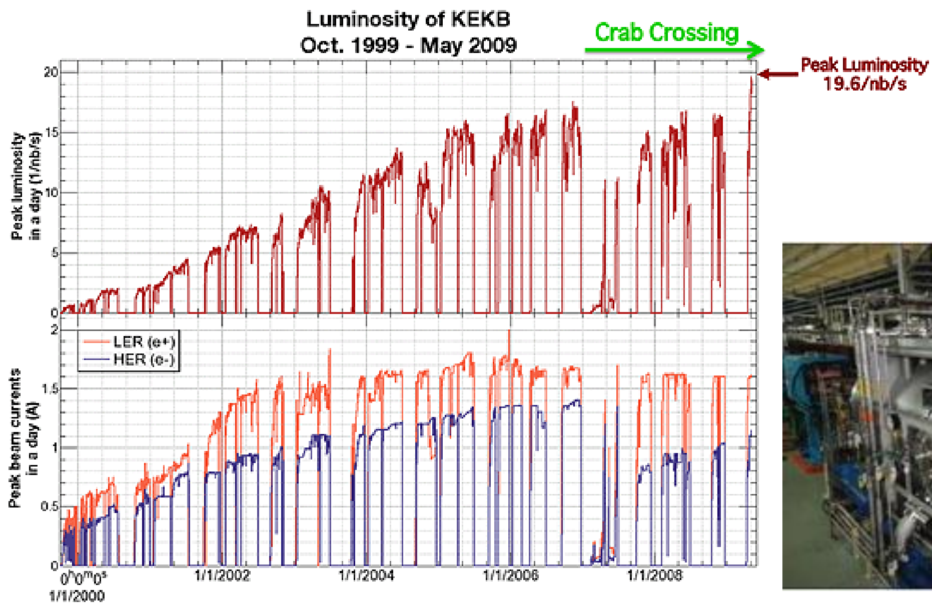
KEK Press Release (05/11/09)

"Using Crab Cavities, KEKB Breaks Luminosity World Record"

Symmetry Breaking (05/11/09)

"Record luminosity collisions due to "crab" crossing,





Trick: 28 skew sextupoles

Maximum Synchrotron Radiation Line Density

Y. Suetsugu, *et.al,* PAC2003

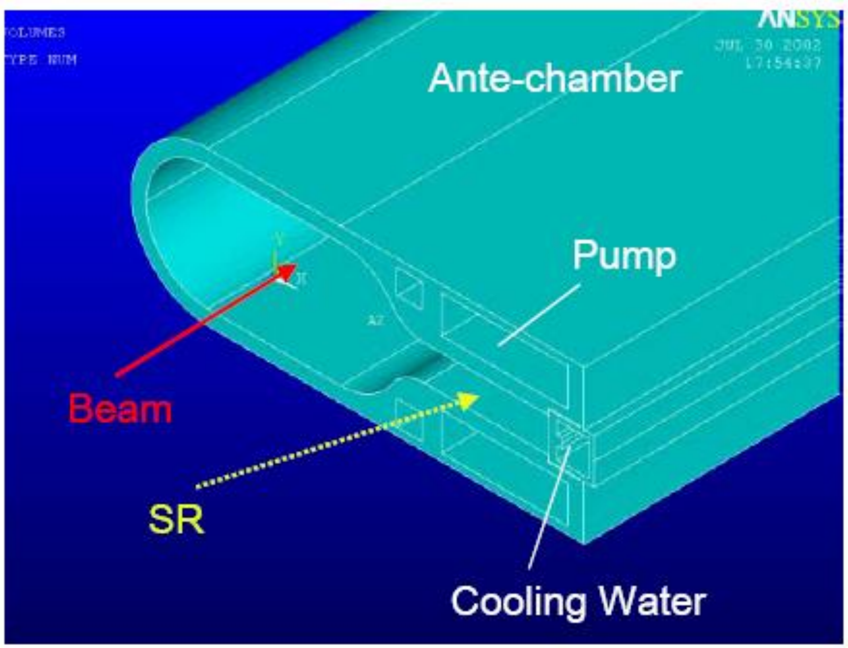


Table 1: Vacuum related main parameters of Super KEKB. The parentheses are those for the KEKB.

	LER (e^-)	HER (e^+)
Goal Luminosity [nb^{-1} s^{-1}]	100	
Energy [GeV]	3.5	8.0
Beam Current [A]	9.4	4.1
Bunch Length [mm]	3	3
Bunch Number	5018	5018
Bending Radius [m]	16.31	104.46
Aperture [mm]	ϕ94	104×50
Total SR Power without Wigglers [MW]	7.64 (2.11)	14.21 (3.81)
Max. Line Power Density of SR* [kW m^{-1}]{present chamber}	53.50 (14.8)	21.64 (5.8)
Critical Energy of SR [keV]	5.84	10.88
Ave. Photon Density [photons $m^{-1}s^{-1}$] {C = 2200 m}	1.21E19	1.20E19
Ave. Gas Load [Pa $m^3s^{-1}m^{-1}$] {η =1E-6 molecules $photon^{-1}$}	4.56E-8 (1.35E-8)	4.52E-8 (1.31E-8)

* Using present single beam chamber.

- ELIC sets maximum line power density to 10kW/m ➔ 18MW total power
- MEIC can assume a more aggressive power line density, **~20 kW/m**, since this special beam pipe still keeps the total power under 10 MW total power (cost: $2/W), due to the smaller ring size