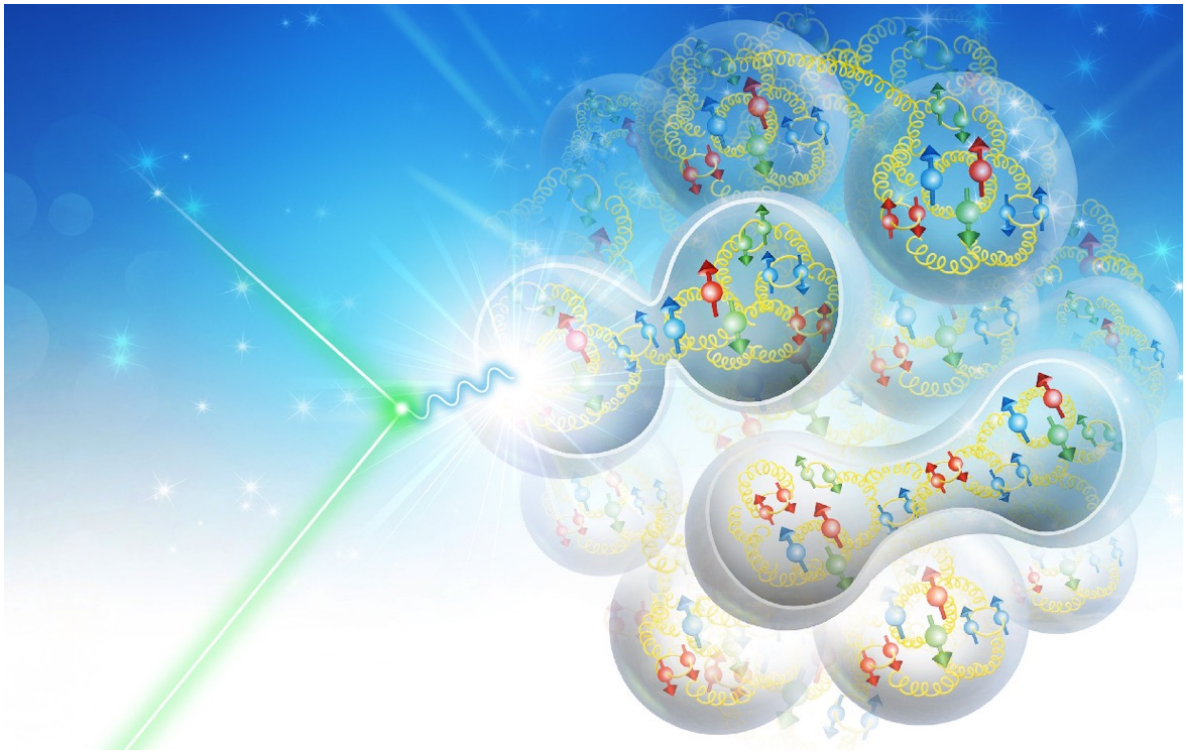
R&D for JLEIC

Todd Satogata

on behalf of JLEIC collaboration

Warning: This talk is intended to generate workshop-like discussion



EIC Accelerator Collaboration Meeting, ANL, Lemont, IL
October 11, 2019

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

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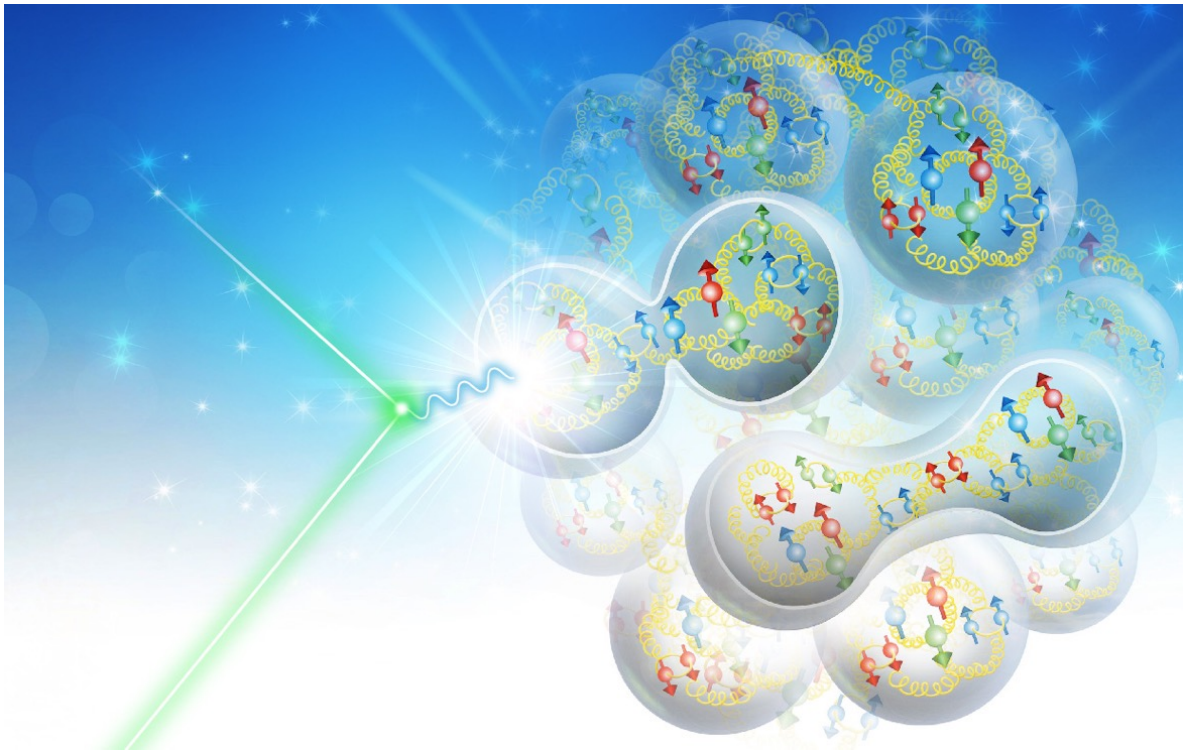

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Past and Current R&D discussed by Yuhong Zhang on Wednesday

EIC R&D at Jefferson Lab with Collaborations

- High-Priority EIC R&D topics defined by a community review panel (Jones panel)

- **Accelerator R&D funded by NP – FY17, *completed***
  - Crab system design and experimental test
  - Electron cooler design
  - IR magnet design
  - Simulation software development

Jones panel report

Report of the Community Review of EIC Accelerator R&D for the Office of Nuclear Physics

February 13, 2017

2017

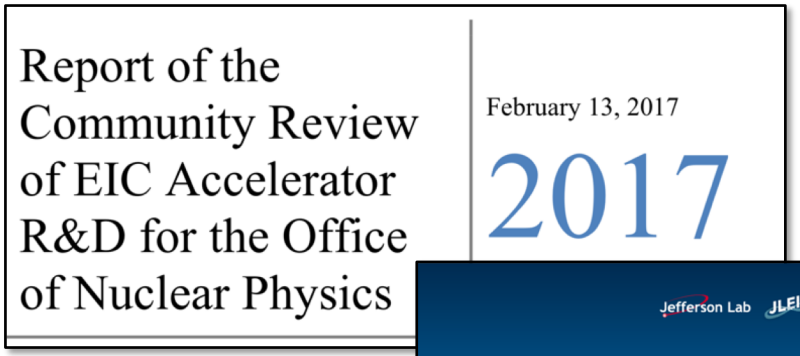
- **Accelerator R&D fund by FY18-19**
  - Crab cavity operation in a hadron ring (BNL, JLab, ODU)
  - Strong hadron cooling
    - Development of innovative high-energy magnetized electron cooling for an EIC (BNL, FNAL, JLab, ODU)
    - Strong hadron cooling with micro-bunched electron beams (ANL, BNL, JLab, SLAC)
  - Magnet design
    - High Gradient Actively Shielded Quadrupole (BNL, JLab, LBNL)
    - Validation of EIC IR magnet parameters and requirements using existing magnet results (JLAB, LBNL, SLAC)
  - Benchmarking of EIC simulations
    - Development & test of simulation tools for EIC beam-beam interaction (BNL, JLab, LBNL MSU)
    - Experimental verification of spin transparency mode in an EIC (BNL, JLab)
  - Electron complex
    - High Bandwidth Beam Feedback Systems for a High Luminosity EIC (ANL, JLab)

Y. Zhang

23 Jefferson Lab

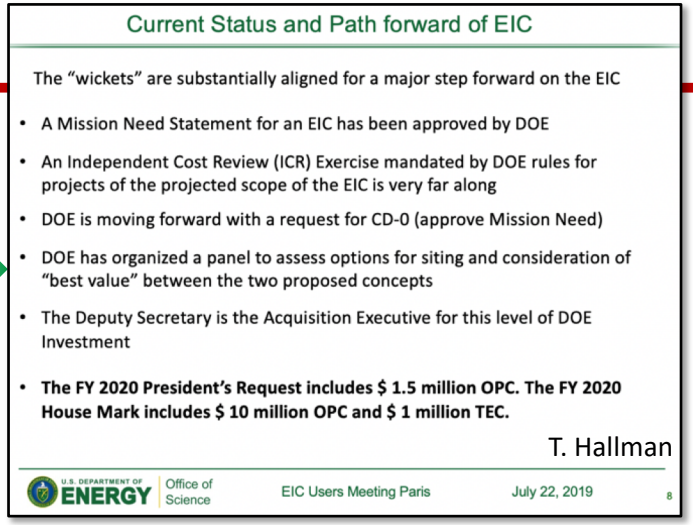
Outline: R&D 32 Months After and Beyond the Jones Report

- **Jefferson Lab EIC R&D discussions**
  - An exciting (and delicate) time
- **Continuing R&D from the Jones Report (~2y)**
  - Strong electron cooling
  - Everything else
- **JLEIC 140 GeV Upgrade R&D (~10y)**
  - 12T Nb_3Sn superconducting dipoles
  - IR spectrometer dipole upgrades
- **R&D Beyond 140 GeV Upgrade (long-term)**
  - Polarized positrons at the EIC
  - EIC luminosity approaching 10^{35} cm^{-2} s^{-1}



Jefferson Lab EIC R&D Discussions

- **Ground rules**
  - EIC CD0 is coming in FY20 (CY19?)
    - Tim Hallman, 2019 EIC User Group Meeting
  - R&D for baseline scope must have horizon consistent with anticipated project planning
    - Clarifies and sharpens priorities
  - Lay groundwork for organized, rapid ramp-up
- **Assess R&D portfolio**
  - Identify R&D associated with retired risk
  - Discussed with all system owners
  - Prioritize R&D necessary for baseline scope
    - Early engineering prototyping
    - Address remaining performance risk
  - Prioritize high-impact cost/performance tradeoffs
    - e.g. electron cooling



Current Status and Path forward of EIC

The "wickets" are substantially aligned for a major step forward on the EIC

- A Mission Need Statement for an EIC has been approved by DOE
- An Independent Cost Review (ICR) Exercise mandated by DOE rules for projects of the projected scope of the EIC is very far along
- DOE is moving forward with a request for CD-0 (approve Mission Need)
- DOE has organized a panel to assess options for siting and consideration of "best value" between the two proposed concepts
- The Deputy Secretary is the Acquisition Executive for this level of DOE Investment
- **The FY 2020 President's Request includes $ 1.5 million OPC. The FY 2020 House Mark includes $ 10 million OPC and $ 1 million TEC.**

T. Hallman

U.S. DEPARTMENT OF ENERGY | Office of Science | EIC Users Meeting Paris | July 22, 2019 | 8

M. Farkhondeh

Row No.	Proponent	Concept / Proponent Identifier	Title of R&D Element	Panel Priority	Panel Sub-Priority	Still relevant	No longer needed	Still in progress
1	PANEL	ALL	Crab cavity operation in a hadron ring	High	A	x		x
2	PANEL	ALL	High current single-pass ERL for hadron cooling	High	A		x	
3	PANEL	ALL	Strong hadron cooling	High	A	x		x
4	PANEL	ALL	Benchmarking of realist EIC simulation tools against available data	High	A	x		x
5	PANEL	ALL	Validation of magnet designs associated with high- acceptance interaction points by prototyping	High	A	x		x
6	PANEL	ALL	Polarized 3He Source	High	A	x		
17	PANEL	JLEIC	Complete and test a full scale suitable superferric magnet	High	B		x	
18	PANEL	JLEIC	Develop a high current magnetized electron injector	High	B	x		
19	PANEL	JLEIC	High power fast kickers for high bandwidth (2ns bunch spacing) feedback	High	B	x		x
20	PANEL	JLEIC	Complete the design of the gear change synchronizations and assess its impact on beam dynamics	High	B		x	
21	PANEL	JLEIC	Integrated magnetized beam/kicker circulation test using the existing ERL infrastructure	High	B	x		
22	PANEL	JLEIC	Operate the JLAB Continuous Electron Beam Accelerator Facility in the JLEIC injector mode	High	B	x		x
37	JLAB	BDD1	Spin tracking in ion and electron rings	High			x	
38	JLAB	BDD2	Beam-beam simulation with gear changing	High	C		x	
39	JLAB	ECL1	Electron cooling simulations	High		x		x
40	JLAB	ECL3	ERL Cooler design for single and multi turn operations	High	C		x	
41	JLAB	ECL4	Magnetized source for the e-cooler 36mA	High	C		x	
42	JLAB	ECL5	Fast kicker prototype for multi turn cooler	High	C	x		x
43	JLAB	INJ6	Test of CEBAF electron injection mode	High	C	x		x
44	JLAB	IRS1	IR design and detector integration	High		x		x
45	JLAB	MAG1	Super-ferric 3T fast ramping short prototype	High	C		x	
46	JLAB	MAG4	IR compact large aperture, high radiation magnets	High	C	x		x
47	JLAB	SRF1	SRF cavity systems	High			x	
48	JLAB	SRF2	Crab cavity design, simulations, and prototype	High	C		x	

Continuing R&D: Strong Electron Cooling

- **ERL-based conventional electron cooling**
  - Magnetized beam transport
  - Lead: Steve Benson
  - EIC Cooling workshop talk and discussions

- **Continuing R&D**
  - Master plan with several funding sources
  - Cooling solenoid design and prototype
    - Alignment tolerance
  - CCR arc design
    - Magnetized beam transport
  - Injector design maturity
    - Gun cathode lifetime
    - Bunch distribution optimization
    - Harmonic RF correction strategy
  - CBeta addresses some R&D needs

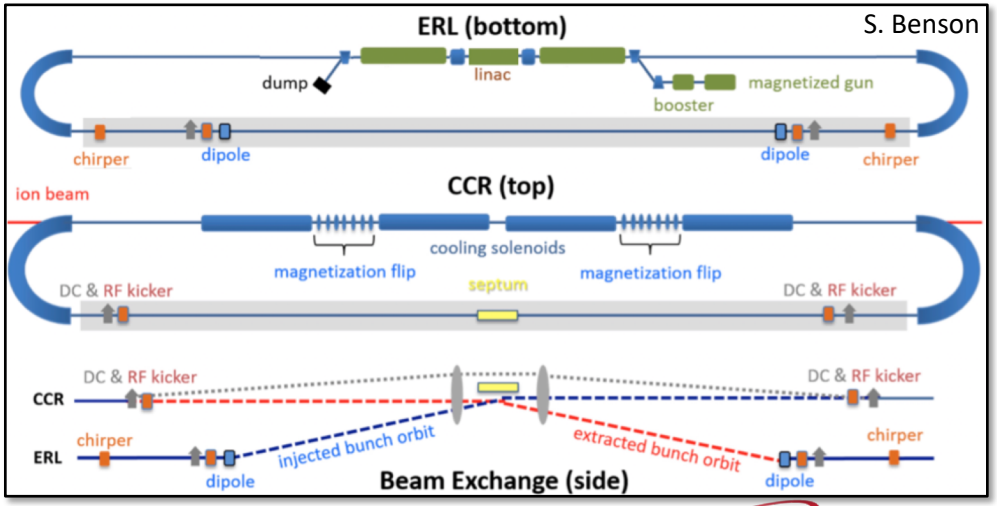
Research Needs for ERLs for EICs

What research do we still have to do?

- Need high current tests of injectors
- Still much design work to do (CCR arcs e.g.)
- Prototyping is ongoing.
- Definitely need ERL testbed facility for high current beams to test:
  - Halo
  - Beam loading
  - BBU
  - Transients
- Full scale tests are expensive

S. Nagaitsev I EIC Cooling Workshop

S. Benson



Continuing R&D: Everything Else ☺

- **Other R&D** from Jones report is in various stages of development
  - Not retired, still relevant to baseline design
  - No fundamental project technical risk
    - Most address cost/performance optimization
  - Reasonable-sized list for pre-CD0 stage
  - Active (some very active) R&D areas
  - Multiple funding sources
- **R&D deliverables achievable** on timescale of...
  - ... early on-project R&D, prototyping
  - ... 1y or 2y POP FY20-FY21 FOA
- Ongoing opportunities for collaboration

Topic	JLab Lead(s)
DC cooling	Y. Zhang
Vacuum chamber design/impedance/heating	R. Li, T. Michalski
Gap transient analysis / feedback	R. Rimmer, J. Fox
Fast feedback kicker prototyping	R. Rimmer
Ion beam diagnostics (LDR BPM)	T. Satogata
ECR damping wiggler	J. Guo
Hadron polarimetry	D. Gaskell
IR FFQ energy range optimization	T. Michalski
IR ion corrector coil integration	T. Michalski
IR fully integrated engineering design	T. Michalski

JLEIC 140 GeV Upgrade R&D

- **A shift in timescale and scope**
  - Upgrade of ion collider ring from 6T to 12T dipoles: 200 GeV to 400 GeV (protons)
  - Leverage long-term Nb_3Sn magnet R&D
  - Large long-term effort/expertise exists
  - Long timescale (10+ years)
  - DOE application of magnet R&D investment

- **12T Nb_3Sn SC dipoles**
  - Bespoke demonstrator prototypes exist
  - Near-term plans for 15T and beyond
  - Industrialization and cost optimization R&D

- **IR spectrometer dipole upgrades**
  - Large-aperture high field Nb_3Sn R&D

CERN 5.5m 11T Nb_3Sn Prototype Dipole (2017)

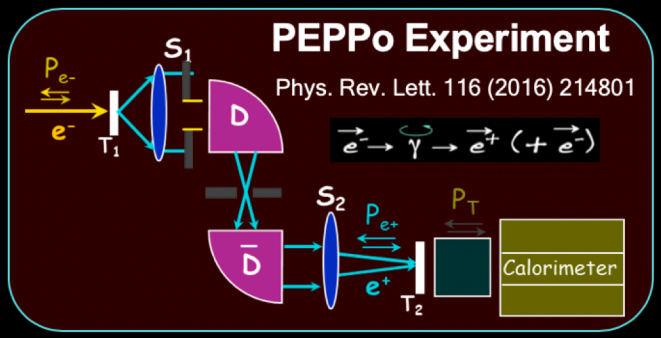

DOE Magnet Development Program: 14.1T 4.5K Nb_3Sn dipole

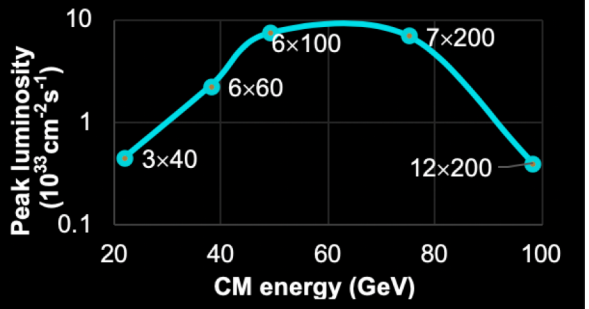
Antimatter Matters: Polarized Positrons for EIC

- Important science remains beyond the EIC White Paper program
- Reduced performance requirements: luminosity of a few 10^{33} cm^{-2} s^{-1}, ~40% positron polarization

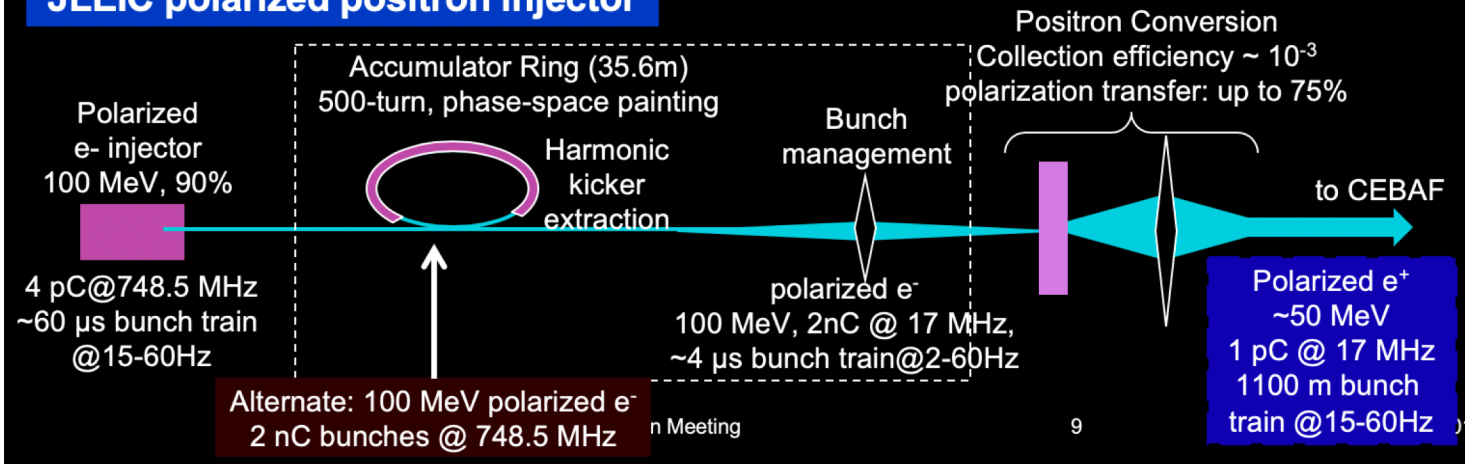
- Polarized positrons generated with PEPPo (from the CEBAF polarized positron program)
- 50-100 MeV accumulator ring (500-turn) for high polarized electron current
- 2017 polarized positron workshop

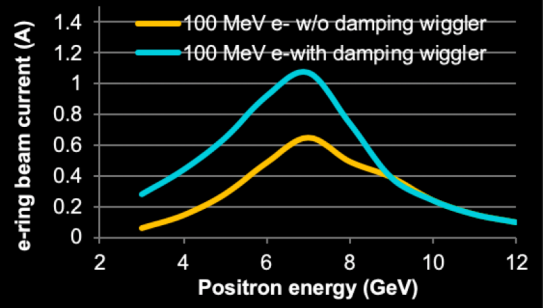
  https://www.jlab.org/conferences/JPos2017/





JLEIC polarized positron injector





J. Guo, F. Lin, Y. Zhang, J. Grames

Jefferson Lab

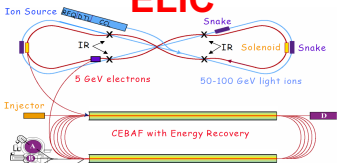
On Beyond Z: EIC luminosity approaching 10^{35} cm^{-2} s^{-1}

- Present JLEIC design is optimized for full acceptance detection
- There are luminosity-hungry experiments (eg. Double Deep Virtual Compton Scattering, DDVCS)
- Ironically, ELIC (the early version of JLEIC) was designed for very high luminosity, up to ~8x10^{34} cm^{-2} s^{-1}

Proceedings of EPAC 2002

ELIC: AN ELECTRON-LIGHT ION COLLIDER BASED AT CEBAF*

L. Merminga†, K. Beard, L. Cardman, Y. Chao, S. Chattopadhyay, K. de Jager, J. Delayen, Y. Derbenev, J. Grames, A. Hutton, G. Krafft, R. Li, M. Poelker, B. Yunn and Y. Zhang, Jefferson Lab,



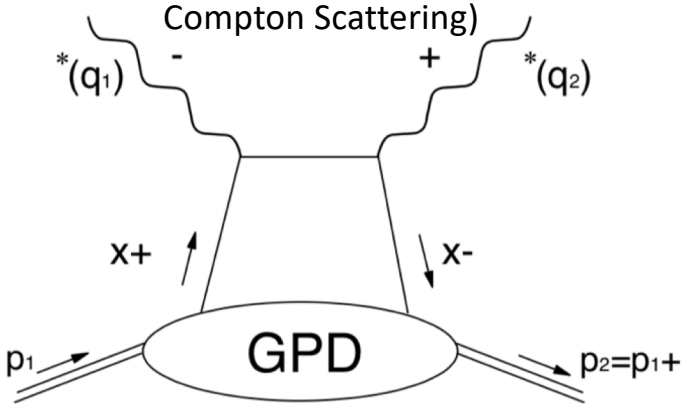
Parameter	Unit	ERL	Ring-Ring		
Beam energy	**GeV**	150/7	150/7	100/5	30/3
Bunch collision rate	**GHz**	1.5			
Number of particles/bunch	10^{10}	.4/1.0	.4/1.0	.4/1.1	.12/1.7
Beam current	**A**	1/2.4	1/2.4	1/2.7	.3/4.1
Cooling beam energy	**MeV**	75	75	50	15
Cooling beam current	**A**	2	2	2	.6
Energy spread, rms	10^{-4}	3/3			
Bunch length, rms	**mm**	5/5			
Beta-star	**mm**	5/5			
Horizontal emittance, norm	**μm**	1/86	1/86	.7/70	.2/43
Vertical emittance, norm	**μm**	.04/3.4	.04/3.4	.06/6	.2/43
Beam-beam tune shift (vertical) per IP		.01/.086	.01/.086	.01/.073	.01/.007
Laslett tune shift (p-beam)		.015	.015	.03	.06
Luminosity per IP, 10^{34}	cm^{-2} s^{-1}	7.7	7.7	5.6	.8
Number of interaction points		4			
Core & luminosity IBS lifetime	**h**	24	24	24	> 24

2006 parameter set

- Concept: trade full acceptance for very high luminosity but still large acceptance
  - Short bunch length: 2.5 cm ➔ 1.25 cm
  - Doubling proton beam current: 0.75 A ➔ 1.25 A
  - Ultra small vertical beta-star: 1.3 cm ➔ 0.5 cm
  - Magnet-free detector space: **7 m ➔ ~ 4.5 m**
- Need even stronger HE cooling: 1.6 nC ➔ 3.2+ nC

DDVCS (Double Deep Virtual Compton Scattering)

eN -> e' e$^+$e$^-$ N'



A. Camsonne

Y. Zhang

Conclusions and Thoughts

- **EIC quite possibly achieving CD0 soon**
  - FY20 (CY19?)
  - Requires shift in attitude towards R&D
- **JLEIC team R&D approach: 3 stages**
  - Near-term R&D: ~2y
    - Retire some risk items from Jones report R&D
    - Complete existing near-term project R&D
    - Provide recommendations for FY20 FOA thrust
  - Upgrade R&D: ~10y
    - 12T dipoles for ion collider ring energy upgrade
    - Technology maturation and industrialization
  - Horizon R&D: potential new capabilities
    - Polarized positrons as EIC nuclear probe
    - Higher luminosity for second IR
- **Discussion**
  - Identify Near-Term Site-Neutral R&D for FOA