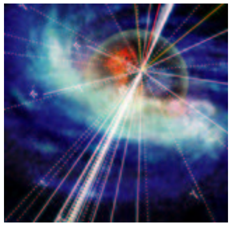
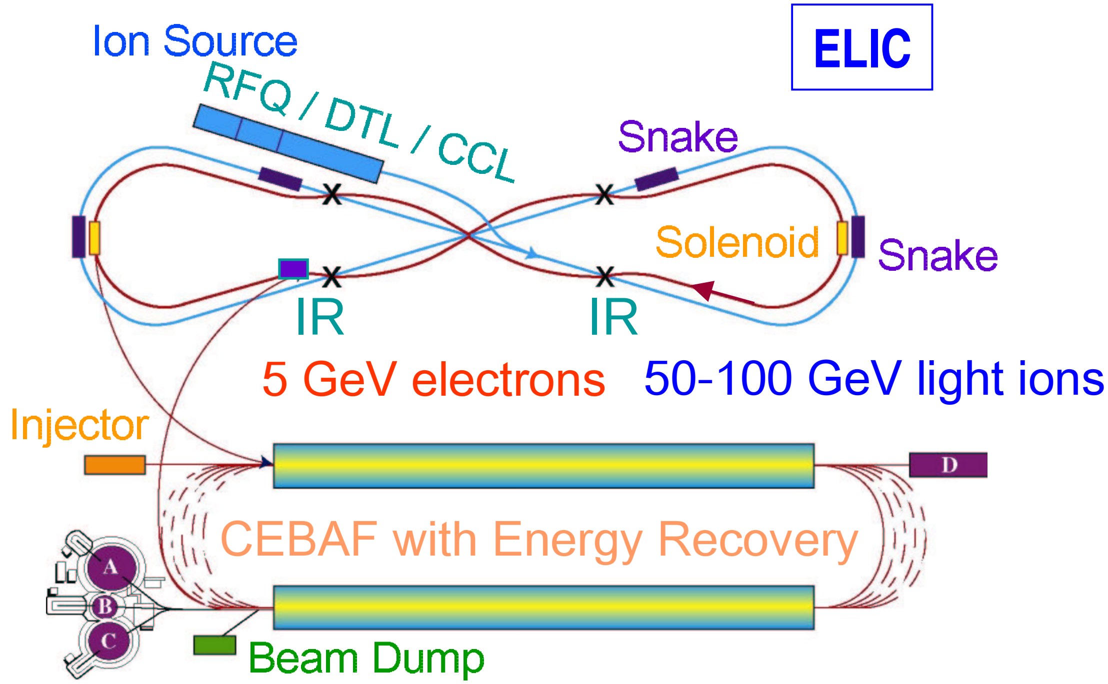


03/16/2004

Key R&D Accelerator Issues for a Linac Ring EIC

Georg Hoffstaetter (Cornell University)

5-20 GeV electrons
25-108 GeV Ag ions



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Nuclear Physics Requirements

- Energies of up to $E_e \sim 10$ GeV on $E_i \sim 100$ GeV. Higher E_e is possible.
- Luminosity above $10^{33} cm^{-2} sec^{-1}$
- Longitudinal polarization of about 90% for both beams in the IR
- Transverse polarization of ions extremely desirable
- Spin-flip of both beams extremely desirable

These could be satisfied by both designs, eRHIC and ELIC

ELIC is focused on p/D/He, eRHIC is focused on Au
But both could, with limited effort, focus on both

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Advantages of Linac Ring Options

- e-Bunches collide only once, making much larger beam-beam parameters possible
- This allows larger β^* and smaller e-beam divergence at the IP
- Reduction of synchrotron radiation load on the detectors
- Spin manipulations are simplified
- Wide range of continuous energy variability
- Feasibility studies were conducted at BNL (based on RHIC) and Jefferson Lab to determine whether the linac-ring option is viable

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Conclusions of Linac-Ring Studies

- Luminosities at or greater than 10^{33} cm^{-2} sec^{-1} appear attainable with an electron linac-on-proton ring design
- RF power and beam dump considerations require that the electron linac is an Energy Recovering Linac (ERL)
- High intensity polarized electron beams have to be produced, either in a gun or by accumulation
- Electron cooling of the protons is required for luminosity at or above 10^{33} cm^{-2} sec^{-1}. The e-beam will be provided by an ERL.

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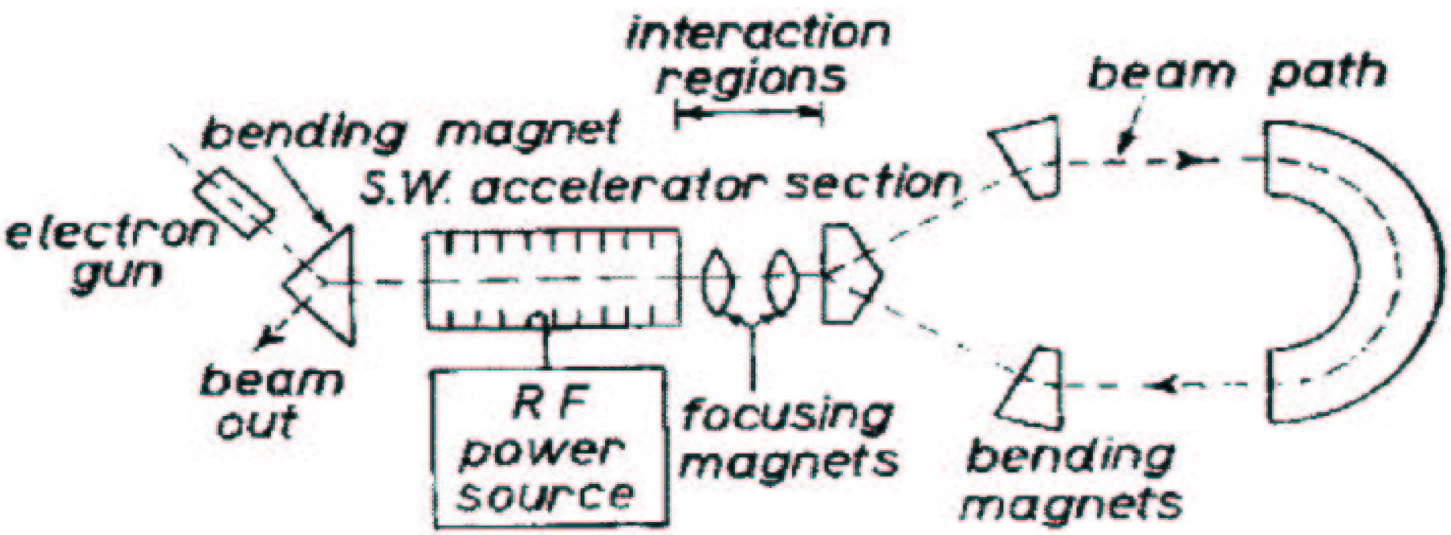
Energy Recovery & Linear Coll.

A Possible Apparatus for Electron Clashing-Beam Experiments (*).

M. TIGNER

Laboratory of Nuclear Studies, Cornell University - Ithaca, N. Y.

(ricevuto il 2 Febbraio 1965)



Energy recovery needs continuously fields in the RF structure

- Normal conducting high field cavities get too hot.
- Superconducting cavities used to have too low fields.

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ELIC Parameter Table

Parameter	Units	Point Design 1		Point Design 2		Point Design 3	
		e^-	Protons	e^-	Protons	e^-	Protons
Energy	GeV	5	50	5	50	5	50/100
Cooling	-	-	Yes	-	Yes	-	Yes
CR			No		Yes		Yes
Lumi	$cm^{-2} sec^{-1}$	1×10^{33}		1×10^{34}		$6x10^{34}$ / $1x10^{35}$	
N_{bunch}	ppb	$1x10^{10}$	$2.5x10^{10}$	$2x10^{10}$	$5x10^{9}$	$1x10^{10}$	$1x10^{10}$
f_c	MHz	150		500		1500	
I_{ave}	A	0.24	0.6	1.6	0.4	2.5	2.5
σ^*	μm	14	14	6	6	4.5/3.2	4.5/3.2
ε_n	μm	10	0.2	10	0.2	10	0.1
β^*	cm	20	5	4	1	2/1	1
σ_z	cm	0.1	5	0.1	1	0.1	1
ξ_e / ξ_i	-	0.5	0.006	0.1	0.01	0.2	0.01
$\Delta\nu_L$	-	-	0.05	-	0.05	-	0.09

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LR-eRHIC Parameter Table

Parameter	Units	e/p		e/Au	
		e^-	Protons	e^-	Ions
Energy	GeV	5	250	5	100
Cooling	-	-	At 26GeV	-	always
ν_z	-	-	0.0028	-	0.0026
Lumi	$cm^{-2} sec^{-1}$	1×10^{34}		1×10^{32}	
N_{bunch}	ppb	1×10^{11}	2×10^{11}	1×10^{11}	2.5×10^{9}
f_c	MHz	28		28	
I_{ave}	A	0.45	0.9	0.45	0.8
ε_n	μm	30	0.6	50	0.2
β^*	cm	50	26	30	25
σ_z	cm	1	20	1	20
ξ_e / ξ_i	-	0.5	0.005	0.5	0.005

At reduced luminosity, parallel running with p-p or Au-Au collisions is possible.

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ELIC Layout

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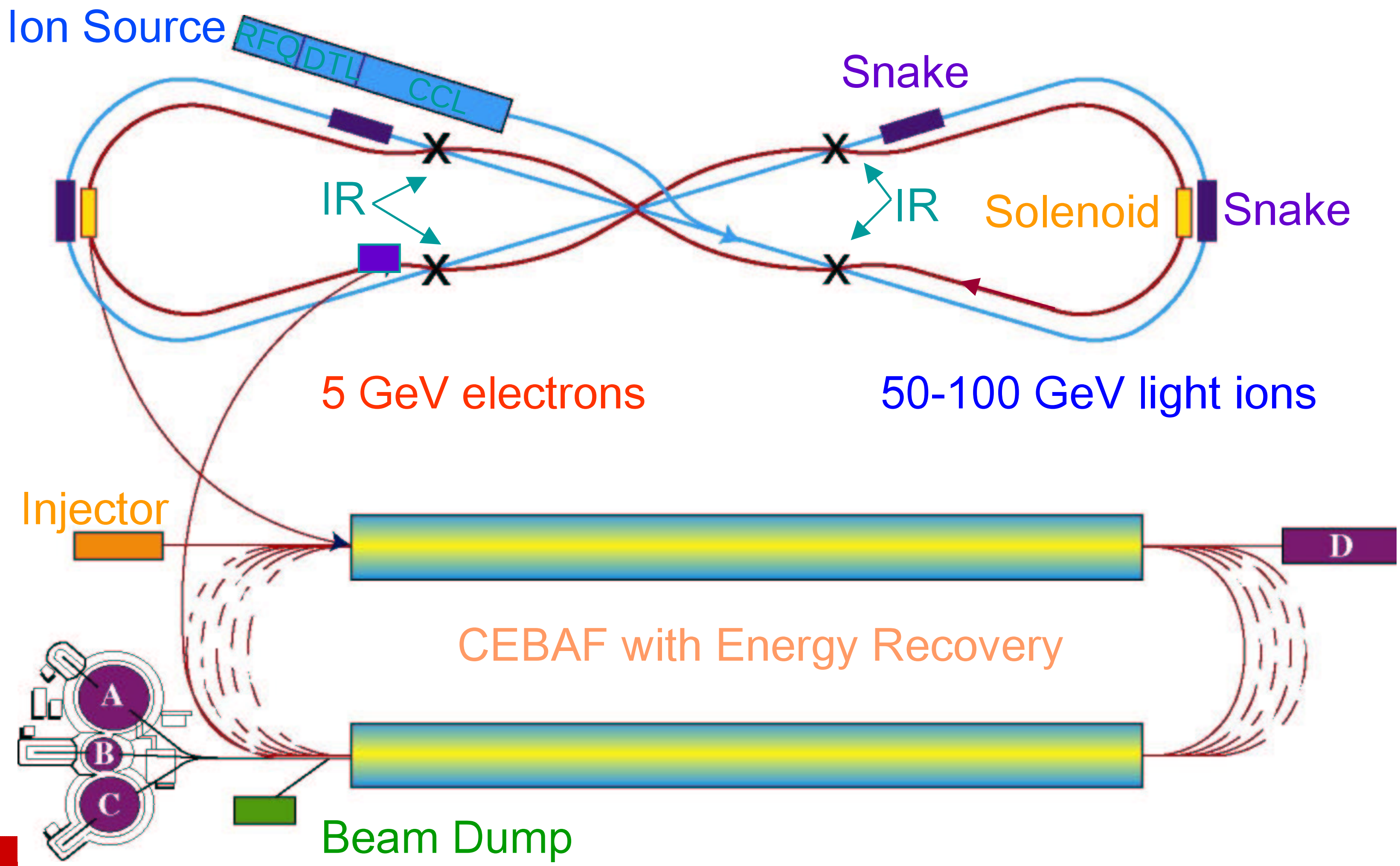
One accelerating & one decelerating pass through CEBAF



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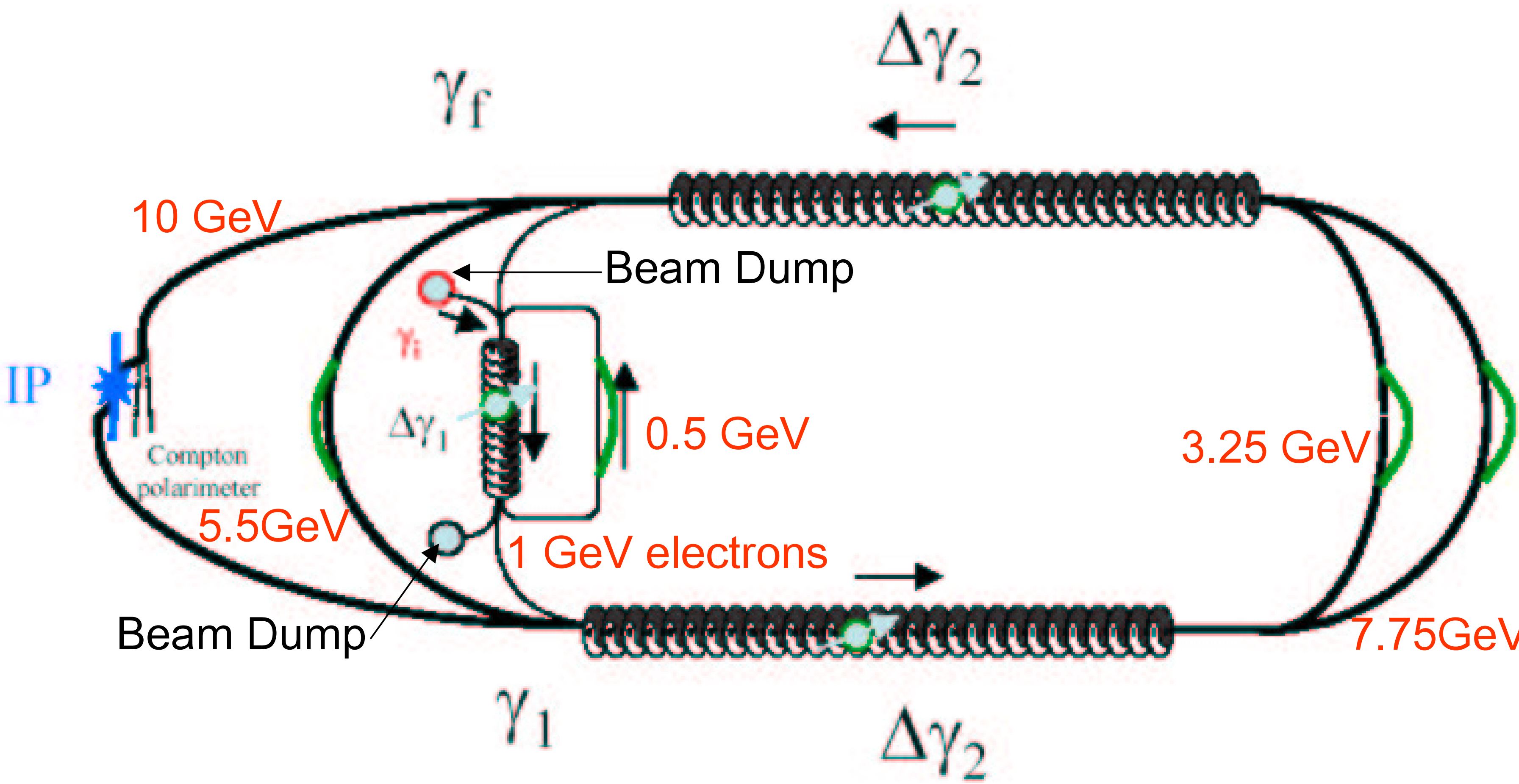
Linac Ring eRHIC Layout

Two accelerating & two decelerating pass through the two main lincas



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ELIC / LR-eRHIC Observations

- Many features are similar:
  - Reliance on electron cooling
  - Reliance on an Energy Recovery Linac
  - IR design

Comparisons would be simplified by a joined set of assumed parameters

- Some conclusions are different
  - Are flat beams (ELIC) or round beams (LR-eRHIC) favorable

Comparisons would be simplified by a common choice

- Some technology is different
  - Very high current source with an >1kW FEL (LR-eRHIC)
  - Accumulation of electrons in a 100 turn ring (ELIC)
  - Spin manipulation by an appropriate choice of energies (LR-eRHIC)

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CEBAF with Energy Recovery

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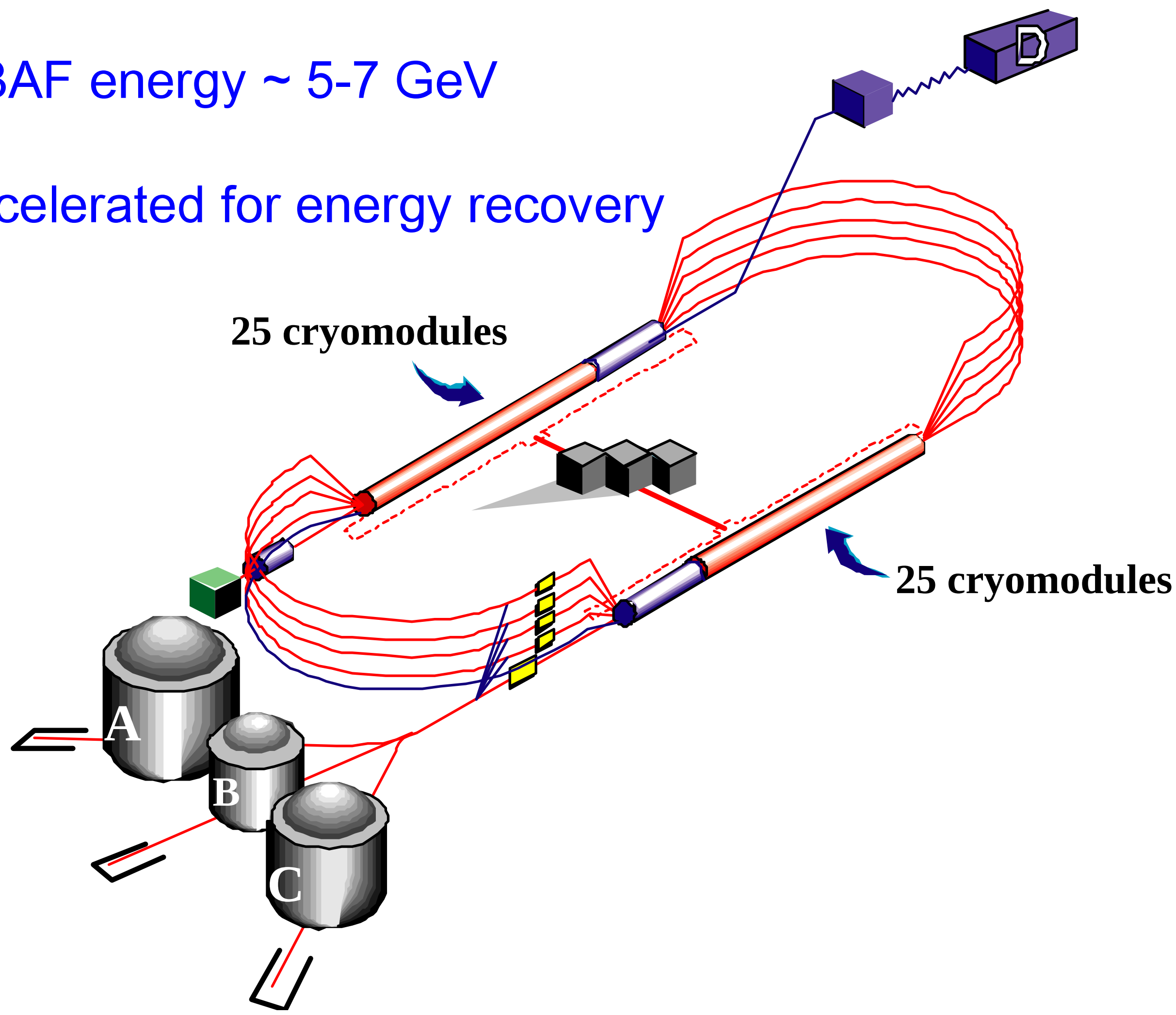
- Install 50 Upgrade CEBAF cryomodules at ~20 MV/m in both linacs
- Single-pass CEBAF energy ~ 5-7 GeV
- Electrons are decelerated for energy recovery



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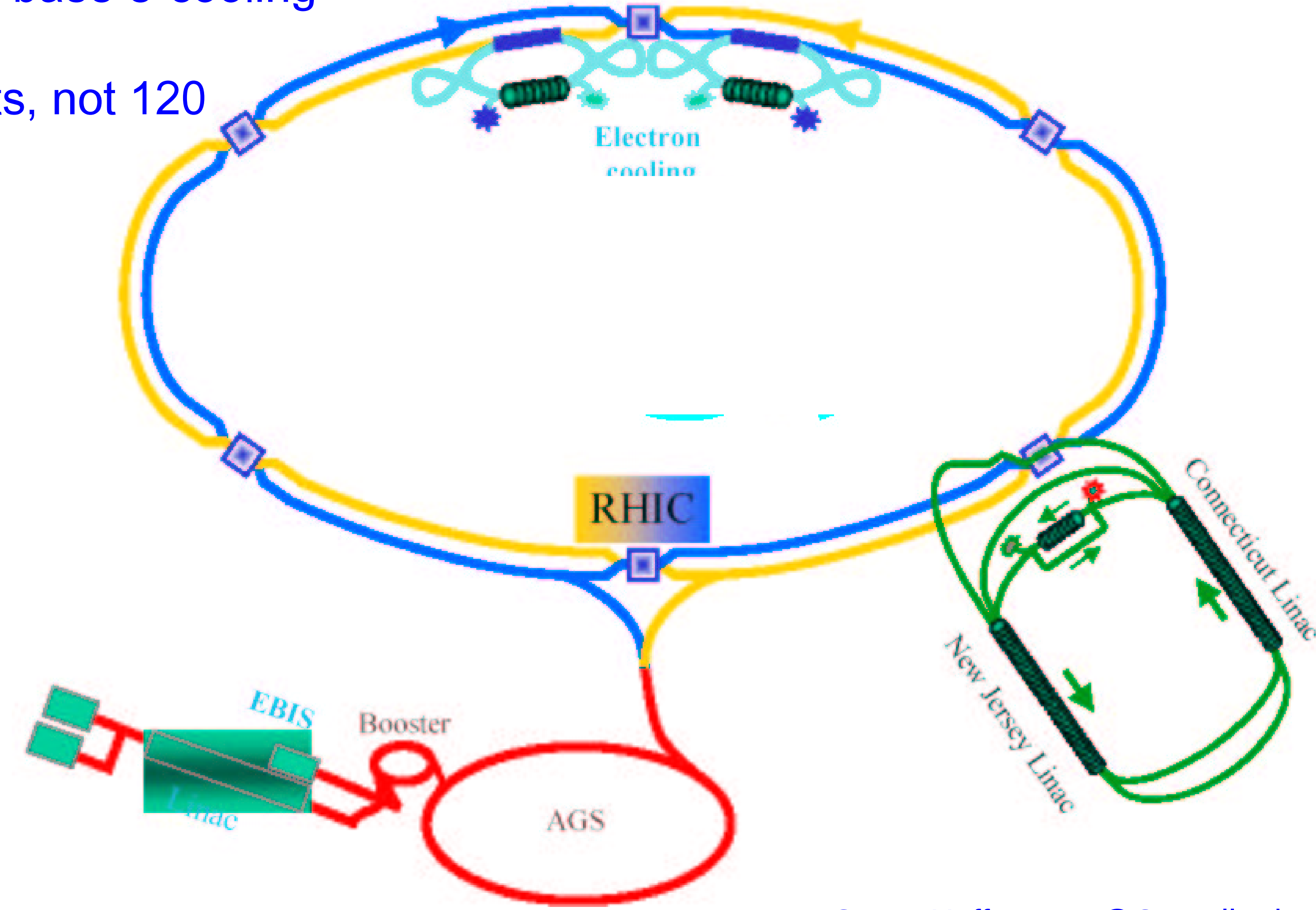
RHIC with 360 bunches and e-cooling

- Install ERL base e-cooling
- 360 buckets, not 120



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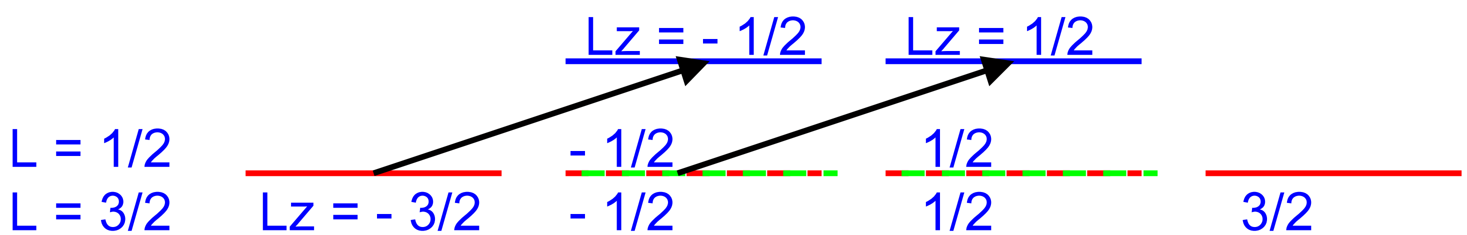
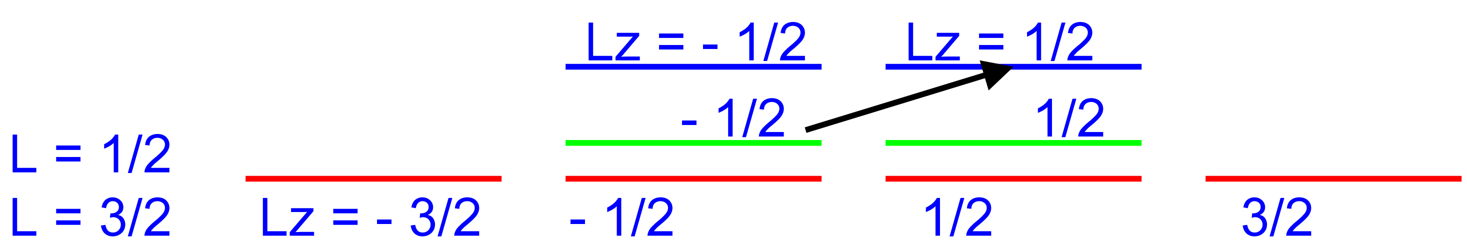
High Polarization e-gun

- Electrons are produced by photoemission from GaAs
- A Cs layer produces a dipole barrier and negative electron affinity

- Due to the symmetric crystal, degenerate energy levels limit P to 40%



- An asymmetry in the crystal can break this degeneracy, P > 80%
  - Ł alternating sections of InGaAs and AlGaAs
  - Ł strain on GaAs by growing a thin layer on GaAs + GaP (GaAsP)



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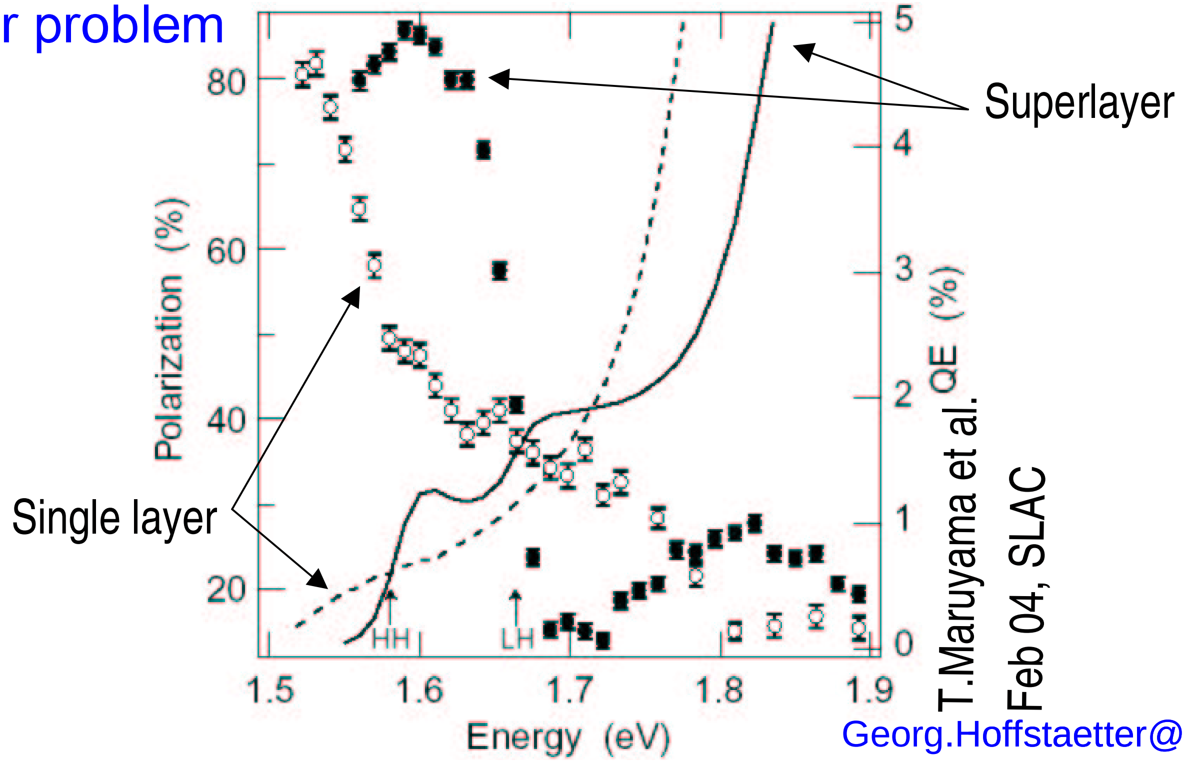
High Current polarized e-gun

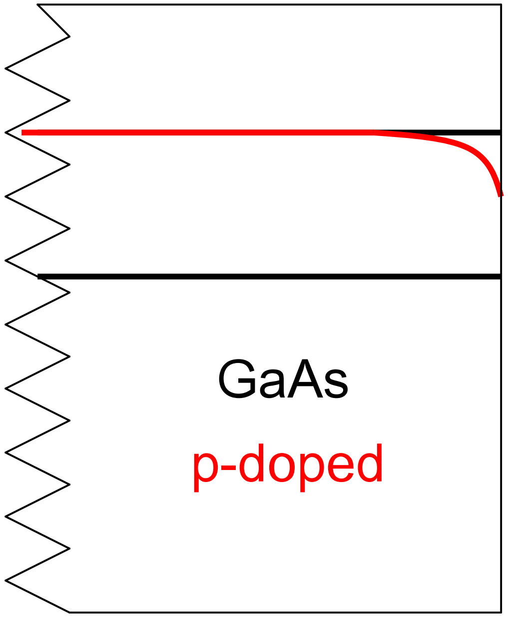
The asymmetric crystals based on GaAs have low Quantum Efficiency (QE)

- alternating sections of InGaAs and AlGaAs
  - ➔ low QE due to trapped states in potential barriers of sections
- strain on GaAs by growing a thin layer on GaAs + GaP (GaAsP)
  - ➔ low QE due to thin layer
  - ➔ Superlayers: alternating layers of GaAs and GaAsP helps, but also has the barrier problem



T.Maruyama et al.
Feb 04, SLAC

The Surface Charge Problem



Charge accumulates in the lowered potential at the surface and builds a strong barrier for the emission of electrons.

Remedies:

- Heavily p-doping the boundary section to create enough holes so that the barrier layer of electrons can be depopulated quickly.
- Increase of the surface field

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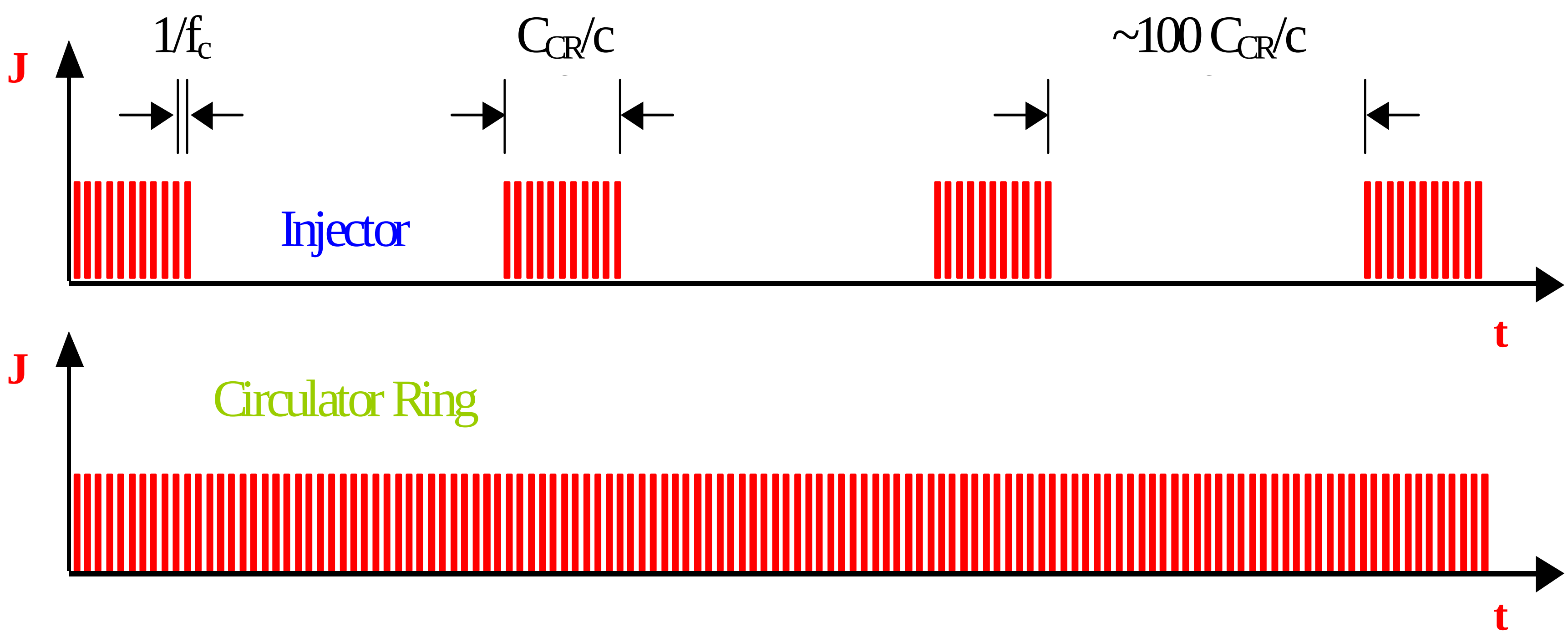
Circulator Ring (currently for ELIC)



Different filling patterns are possible.

Challenge: The beam has to be very stable immediately after injection.

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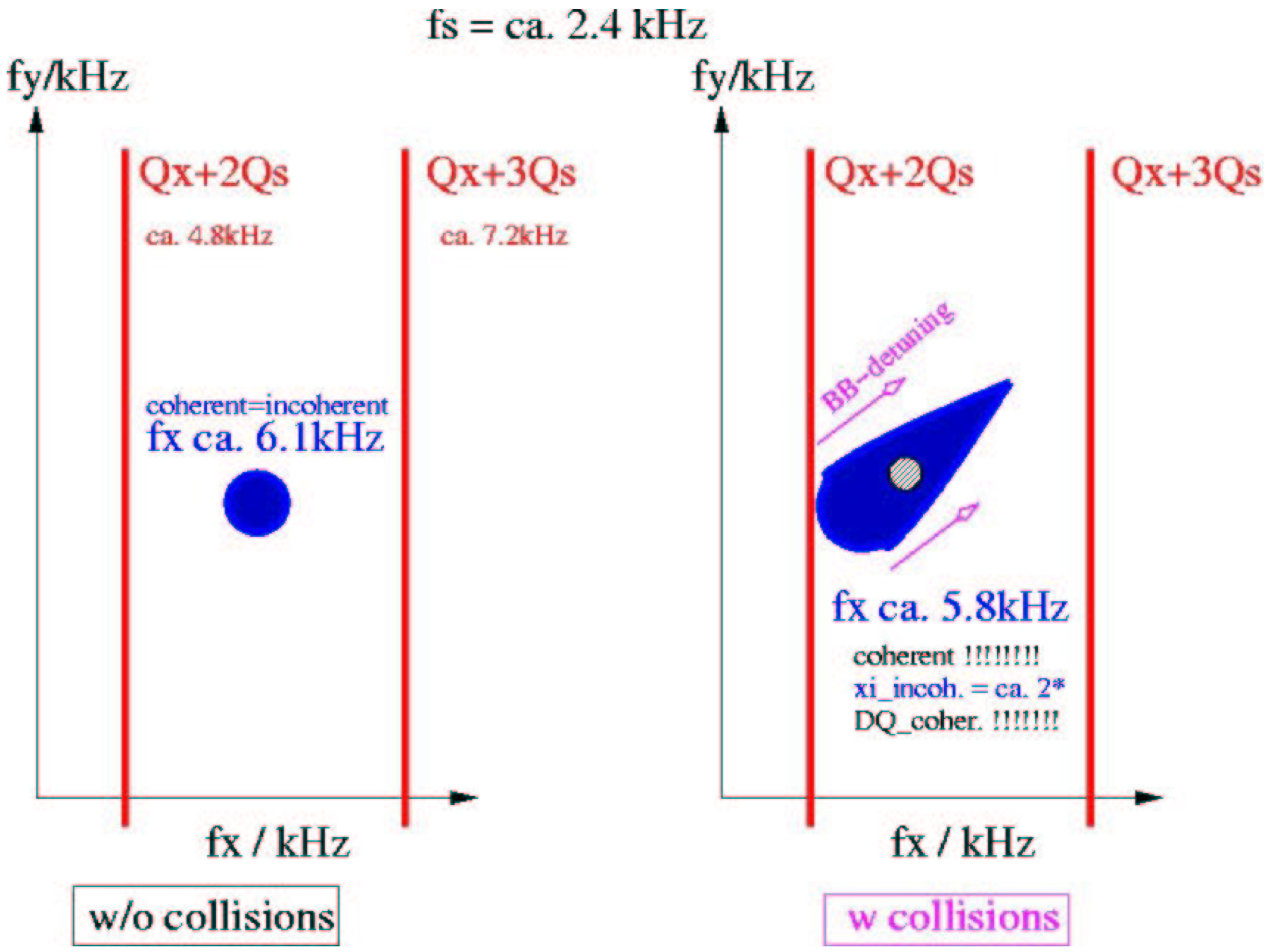
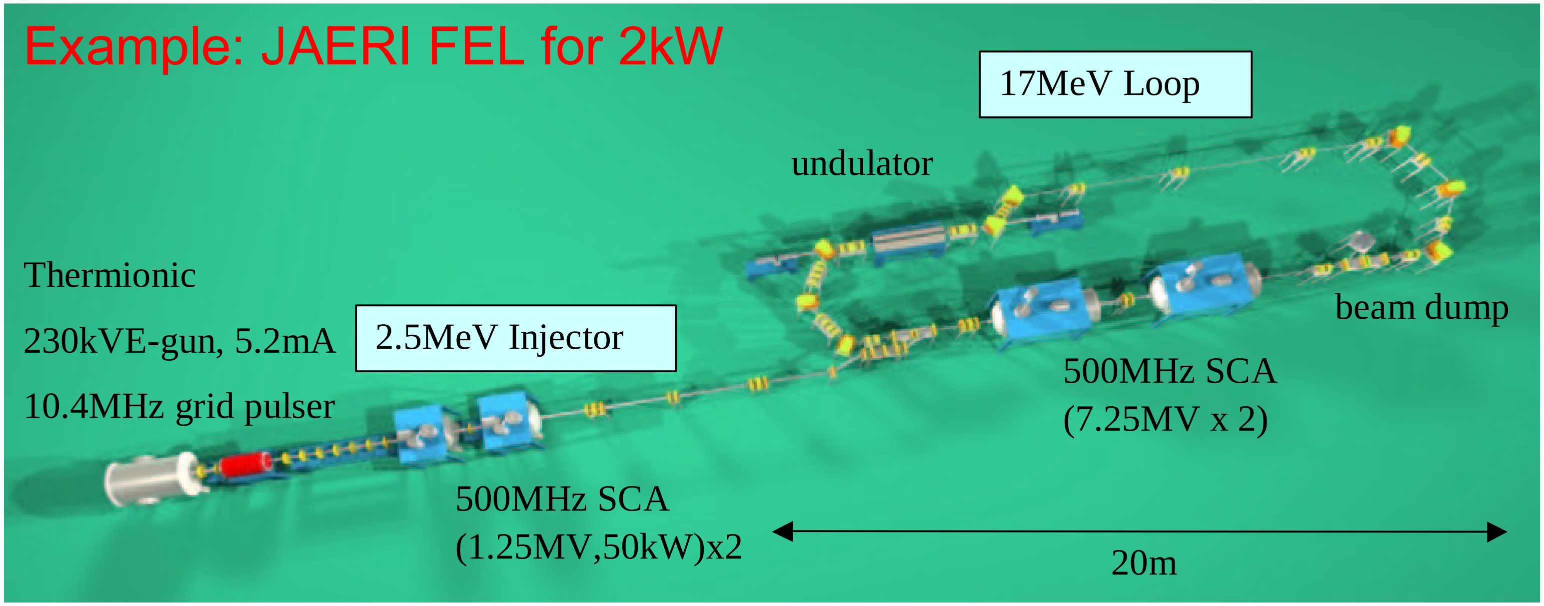
Current operation experience



- The horizontal tune has to be small for good polarization
- Tails of the e-beam on synchro beta resonance leads to proton background
- Core e-tune on synchro beta resonance leads to electron loss

Lasing for the gun at LR-eRHIC



Energy = 17MeV in 3.5m acceleration

FEL : λ = ~22µm not 840nm as needed

Bunch charge =500pC

Bunch length = ~15ps (FWHM)

Bunch rep. = 10.4MHz

Average current = 5.2mA

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R&D issues for ELIC and LR-eRHIC

- High intensity polarized and unpolarized electron gun
  - Currently a few mA
  - Up to 450 mA / 16nC
  - Currently a few 100 μA of polarized beam GaAs photo injector at 80% pol.
  - Up to 450 mA electron current at 80% pol.
  - Methods to overcome the surface charge limit for 16nC/bunch
  - Beam emittance control for 16nC/bunch and a large source diameter (14mm)
  - Test and improvement of cathode lifetimes

- Electron Cooling at high energies
  - Currently a frew 100MeV, soon 8.9GeV/c pbar at the FNAL recycler
  - For LR-EIC: Cooling of Au or light ions up to 100GeV, p at 27GeV
  - New technology: ERL cooling + cooling with bunched e-beam
  - Limits to the ion emittance with e-cooling (especially vertically) and with all noise processes.
  - Allowable beam beam parameters for ions, especially with electron cooling

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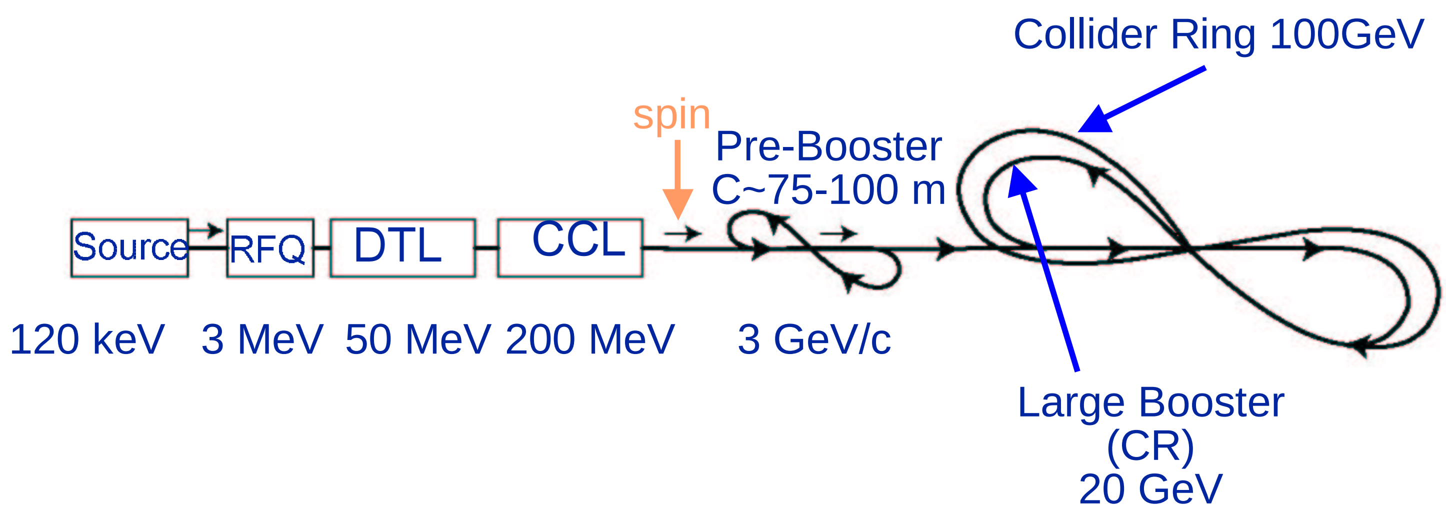
The Ion Complex of ELIC



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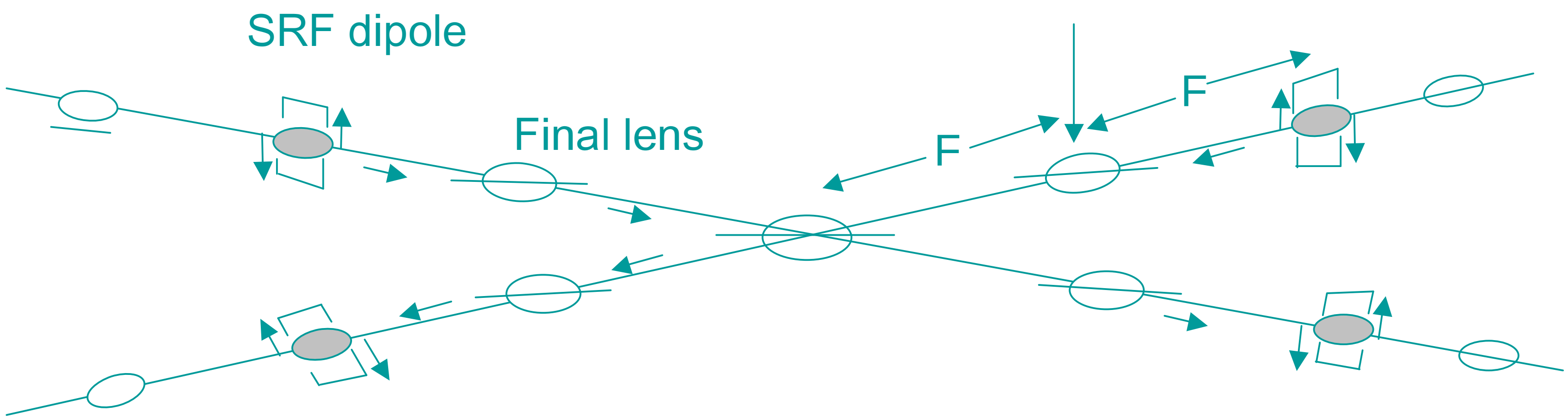
Crab Crossing for ELIC

Short bunches make feasible the Crab Crossing

SRF deflectors 1.5 GHz can be used to create a proper bunch tilt



Parasitic collisions are avoided without loss of luminosity

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R&D issues for ELIC and LR-eRHIC

- IR design, detector integration, saturation in special magnets, optimization …
  - Halo development by beam disruption, especially at low electron energies
  - Impact of beam disruption on following IRs
  - Ion-beam dynamics with crab cavities

- High current ERLs
  - Currently strong influence of small e-beam oscillations on p-emittance in HERA
  - Stabilization of the e-beam + influence on the ion beam
  - Current limits by multi-pass Beam-Breakup instability
  - CW operation of high filed cavities, stabilization, heat loss
  - Influence of HOMs with large frequencis (>2GHz)
  - R/Q and Q agreement with calculations including absorbers

R&D issues for eRHIC – LR option

- Limits to hadron beam intensity by
  - electron cloud
  - beam loss heating
  - kink hard head tail instability limits and effectiveness of a feedback system
- FEL for illuminating the cathode
- Electric helical wiggler with variable helicity
- Magnet with pole tips of various sizes
- SRF cavity with 1% tunability

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R&D specific to ELIC

- Spin resonances in Figure 8 rings
- Stability of non-vertical polarization in figure 8 rings and in the ERL
- Stable beam in a 100 turn circulator ring
- Crab cavity R&D and crab cavity beam dynamics
- Beam beam resonance enhancement when operating close to the hourglass effect
- Limits to the bunch length, since this limits the beta function

R&D specific to LR-eRHIC

- 1kW FEL at 840nm
- Heating of the cathod / problems associated with large spot size (14mm)
- Production of very high polarized e-beam

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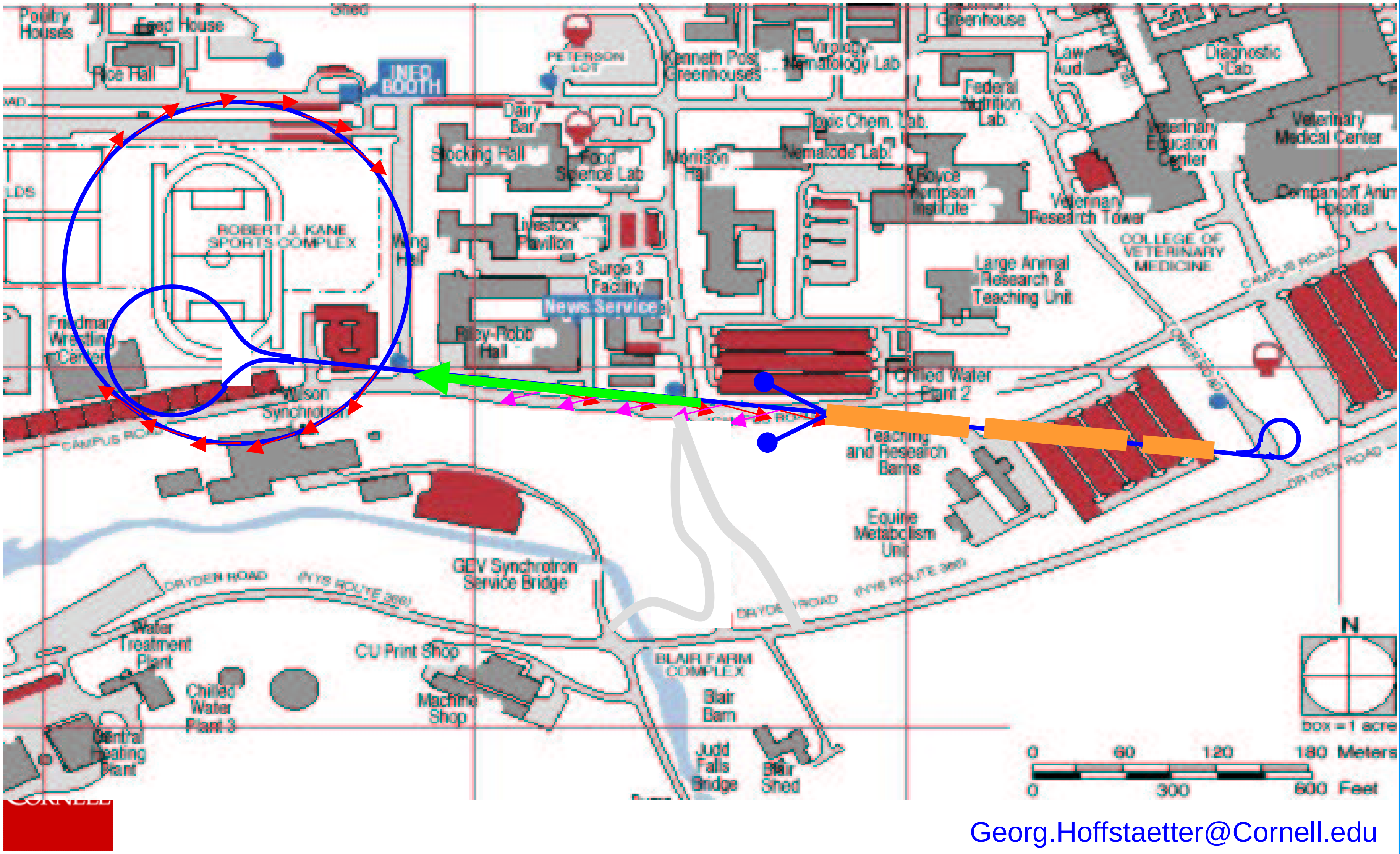
ERL@CESR being analyzed



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