Polarized Electron Source for eRHIC

(the ring-ring option)

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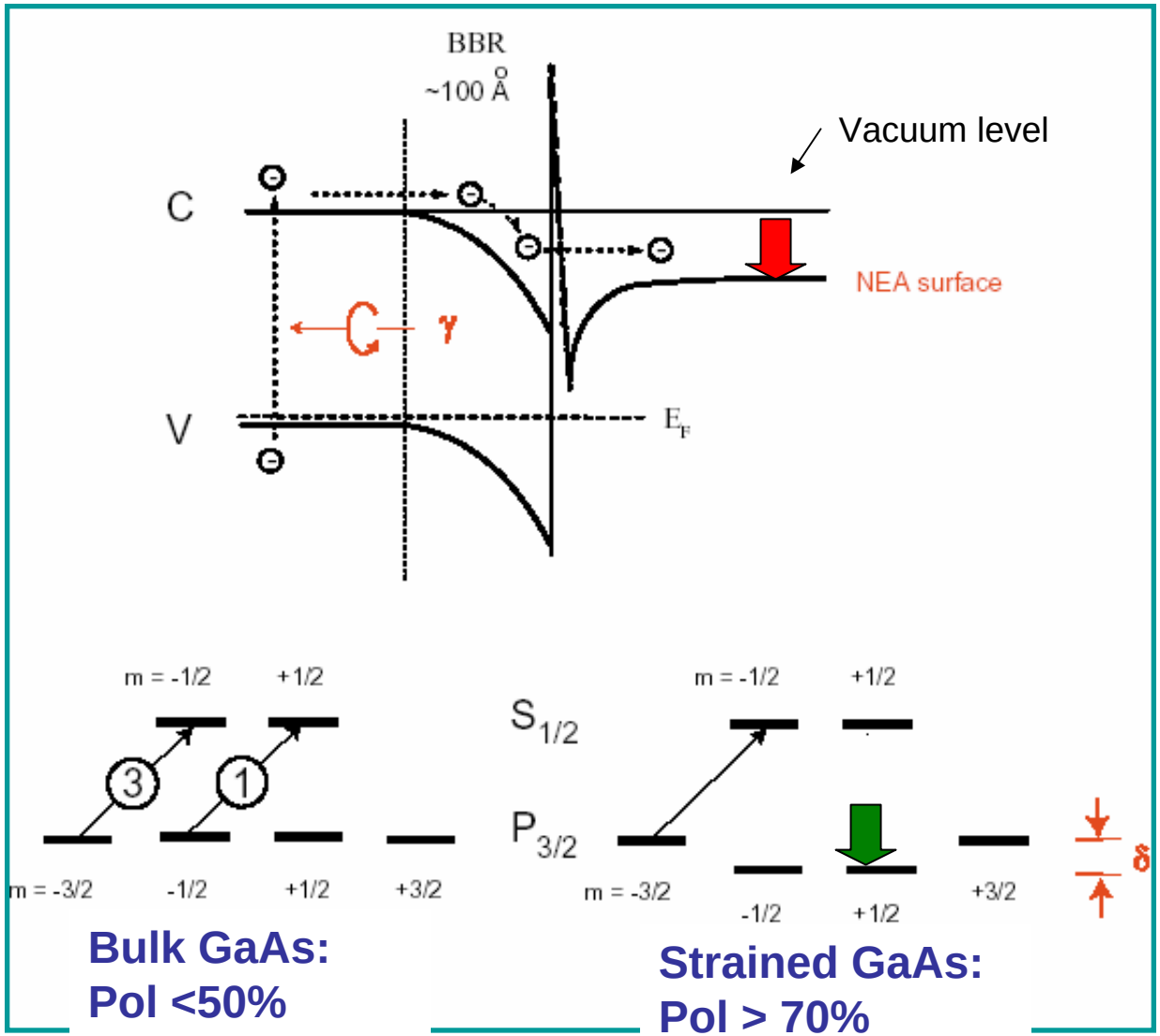
Second EIC Workshop, Jefferson Lab, March 15-17, 2004

OUTLINE

- Basics of polarized electron sources
- Polarize source requirements for a ring-ring eRHIC
- Options for the laser system and the injector
- R&D for eRHIC polarized source

Photoemission from GaAs based photocathode

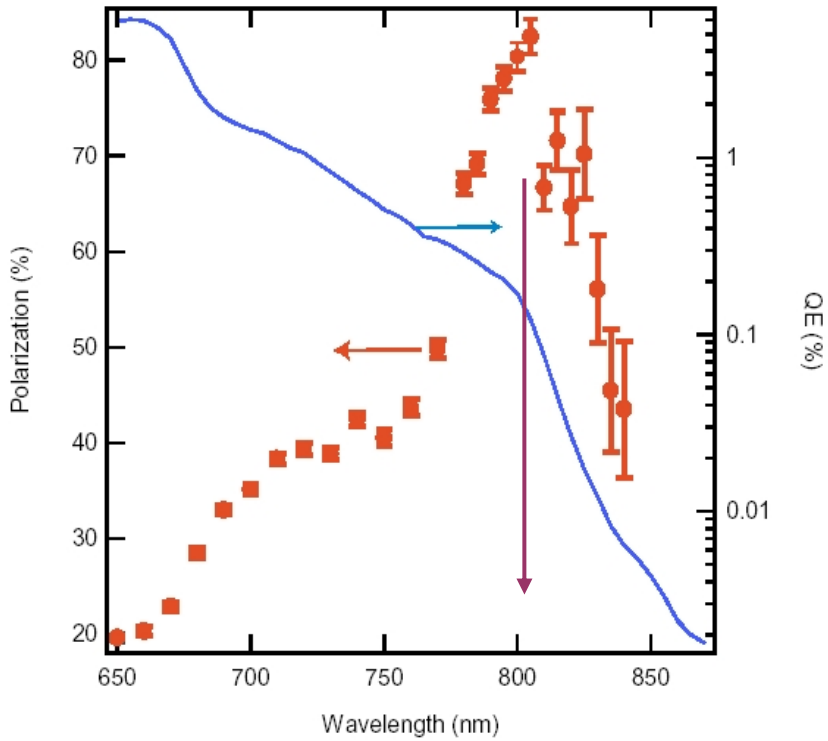


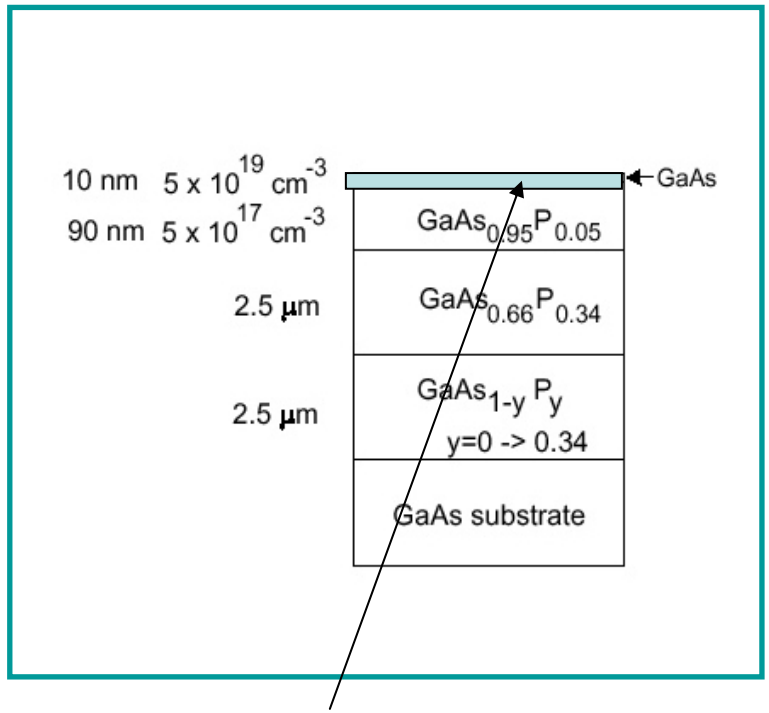
Bulk GaAs: Pol <50%

Strained GaAs: Pol > 70%

High polarization Photocathodes

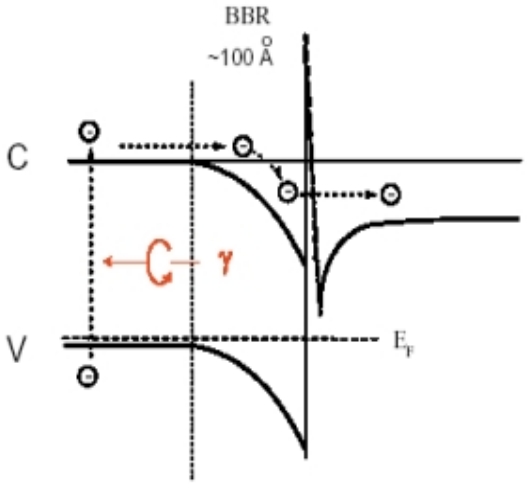
High Gradient doped GaAsP photocathode



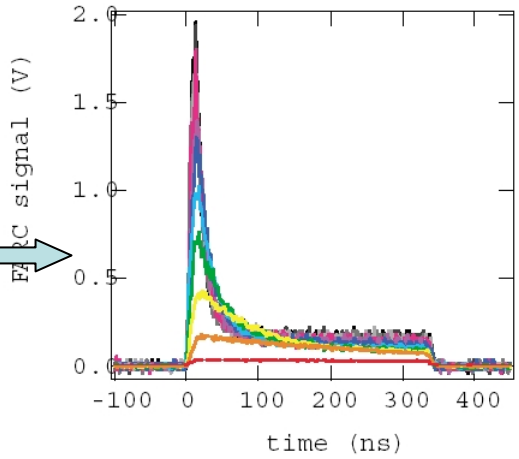


High polarization → Low QE

Surface Charge limit effect



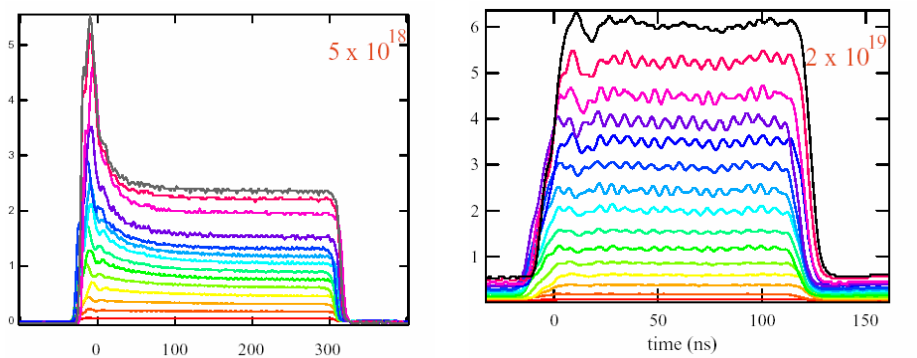
QE reduced as laser power increases



Data from SLAC

Increasing Charge limit:

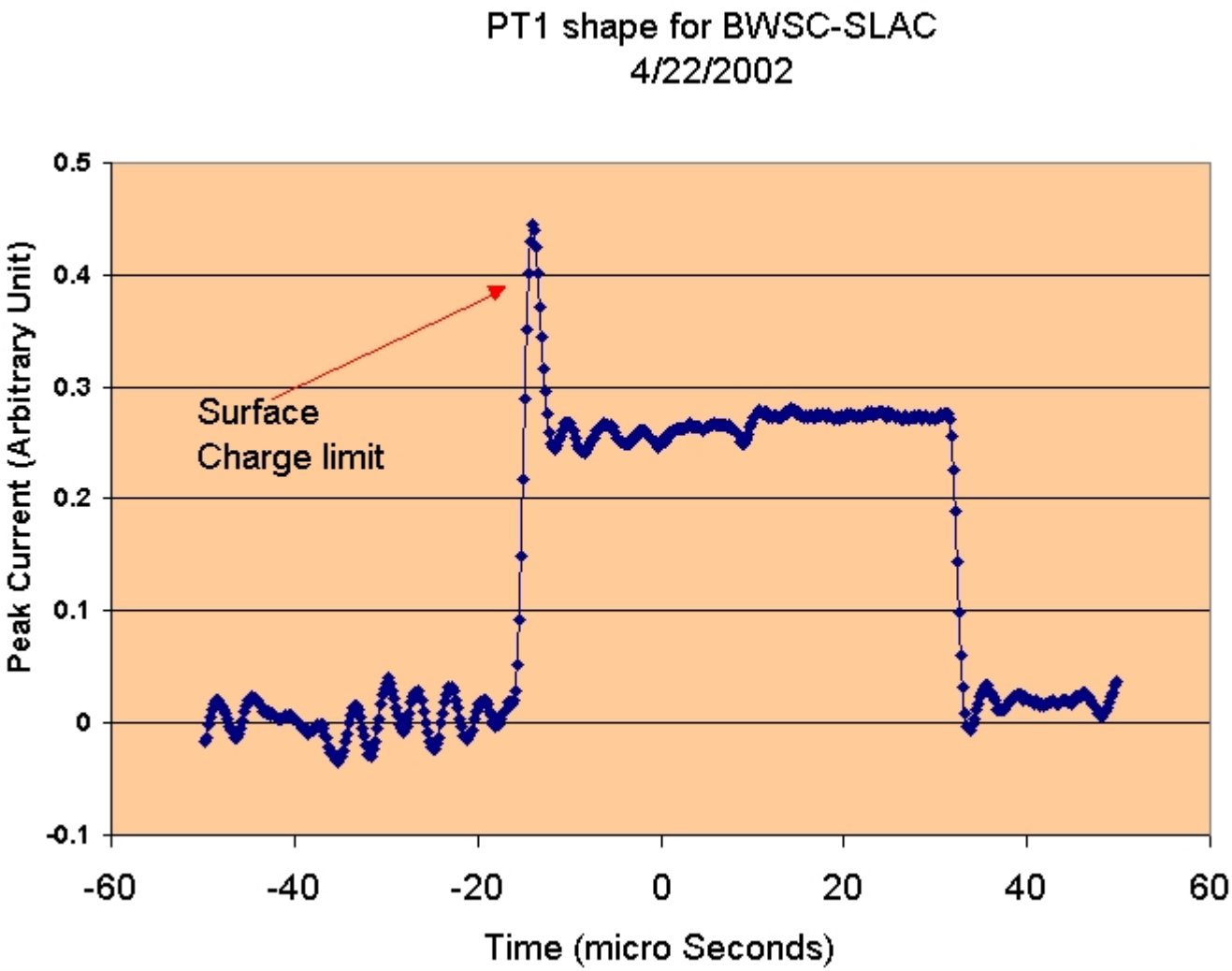
- Increase doping concentration
- superlattice structure
- large band-gap material
- larger cathode area to lower power density



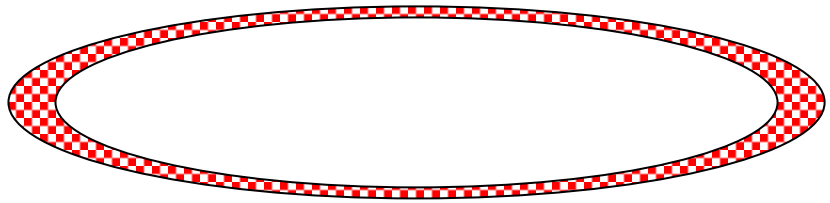
$5x10^{18}$ /cm^3 $2x10^{19}$

doping density

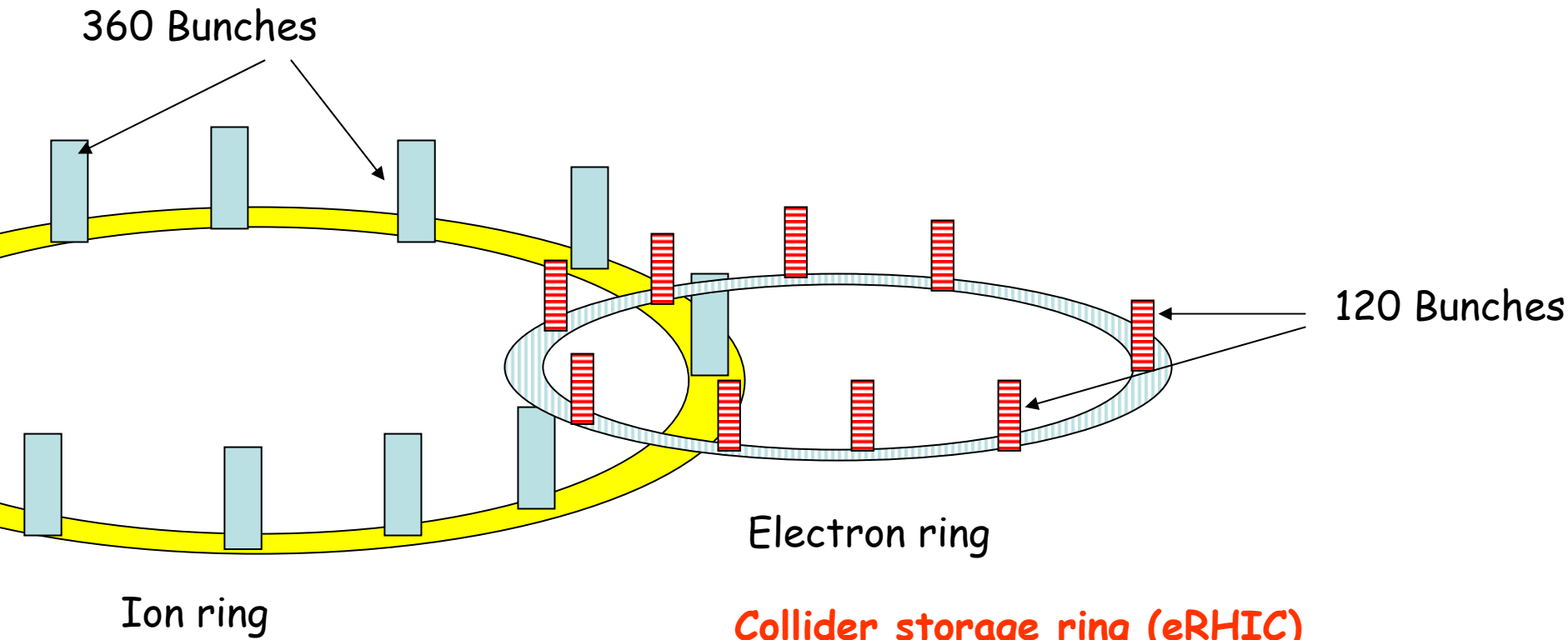
Surface Charge limit effect



Macroscopic Time structure for eRHIC



Non-collider Storage ring (Bates SHR)



Collider storage ring (eRHIC)

Time structure for eRHIC

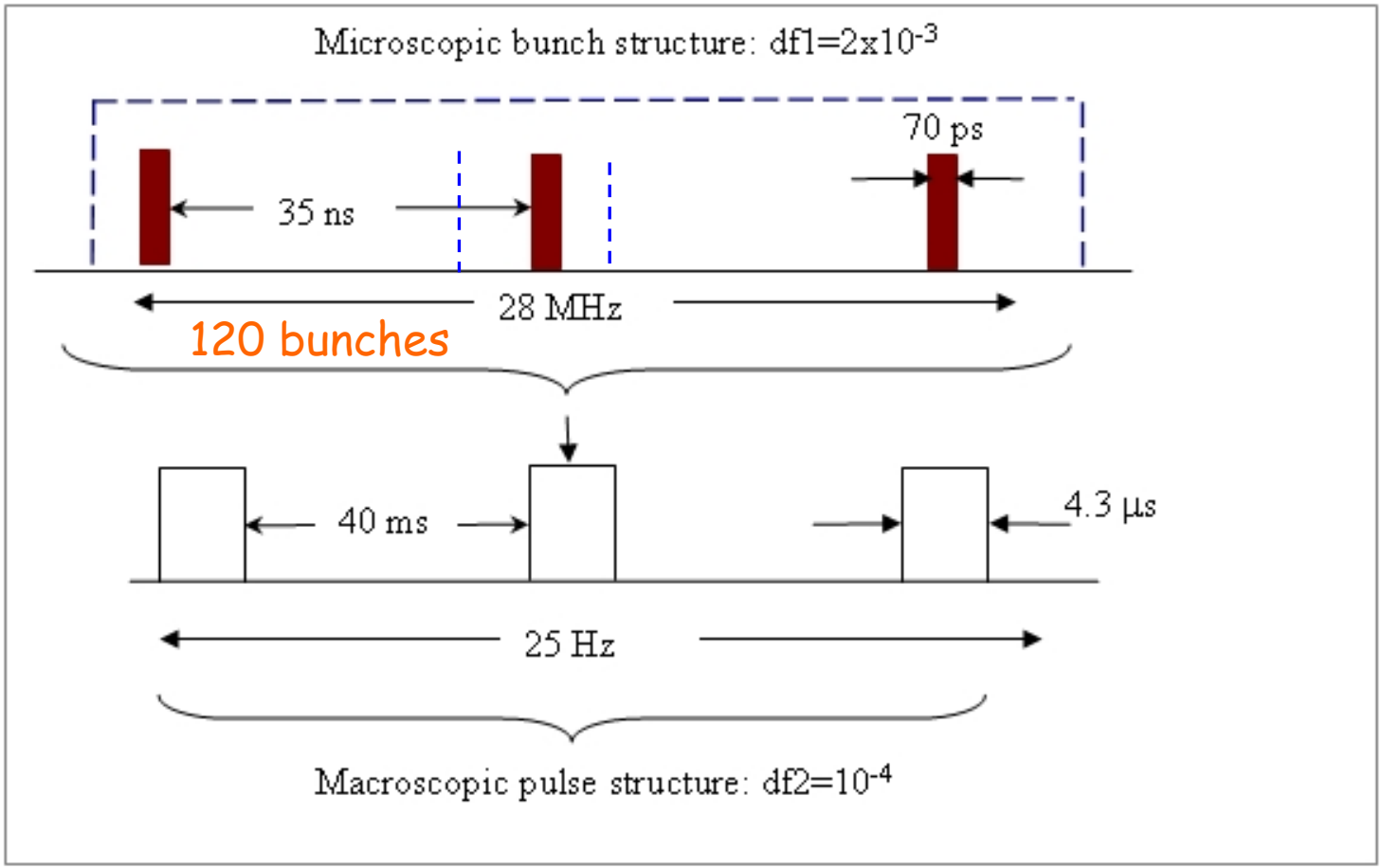


Figure 3: schematic diagrams of microscopic bunch structure (top) and the macroscopic pulse structure (bottom). The duty factors are 2×10^{-3} and 1×10^{-4} respectively. The overall duty cycle of the injector and linac is 2×10^{-7}.

Peak current requirements for eRHIC

- 450 mA average current in the ring and 120 bunches
- 10 minutes fill time at 25 Hz injection →15000 pulse trains stacked bunches from the injector each 1.3 pC and ~70-100 ps wide (I=dQ/dt)
- → 18-20 mA peak current in linac

  (instantaneous current within each bunch)

$$I(mA) = \frac{QE.P(mW)\lambda(nm)}{1240}$$

With QE of 5×10^{-4} , λ=800nm, would need

≥ 50 Watts of laser power.

Polarized injector options

Option 1 Mode locked laser:

In this option all bunch manipulations and synchronizations are made on the laser light before directed to the photocathode. No chopping and bunching of the electron beam may be necessary (J-lab, G_0 Experiment).

Option 2: CW high power diode laser

In this option, quasi CW laser light (4.3 μs long) produces photoemission of polarized electrons. All pulse manipulation, synchronizations are made on the electron beam using chopper and bunchers (MIT-Bates)

Option 1:

P_{peak}=150 W

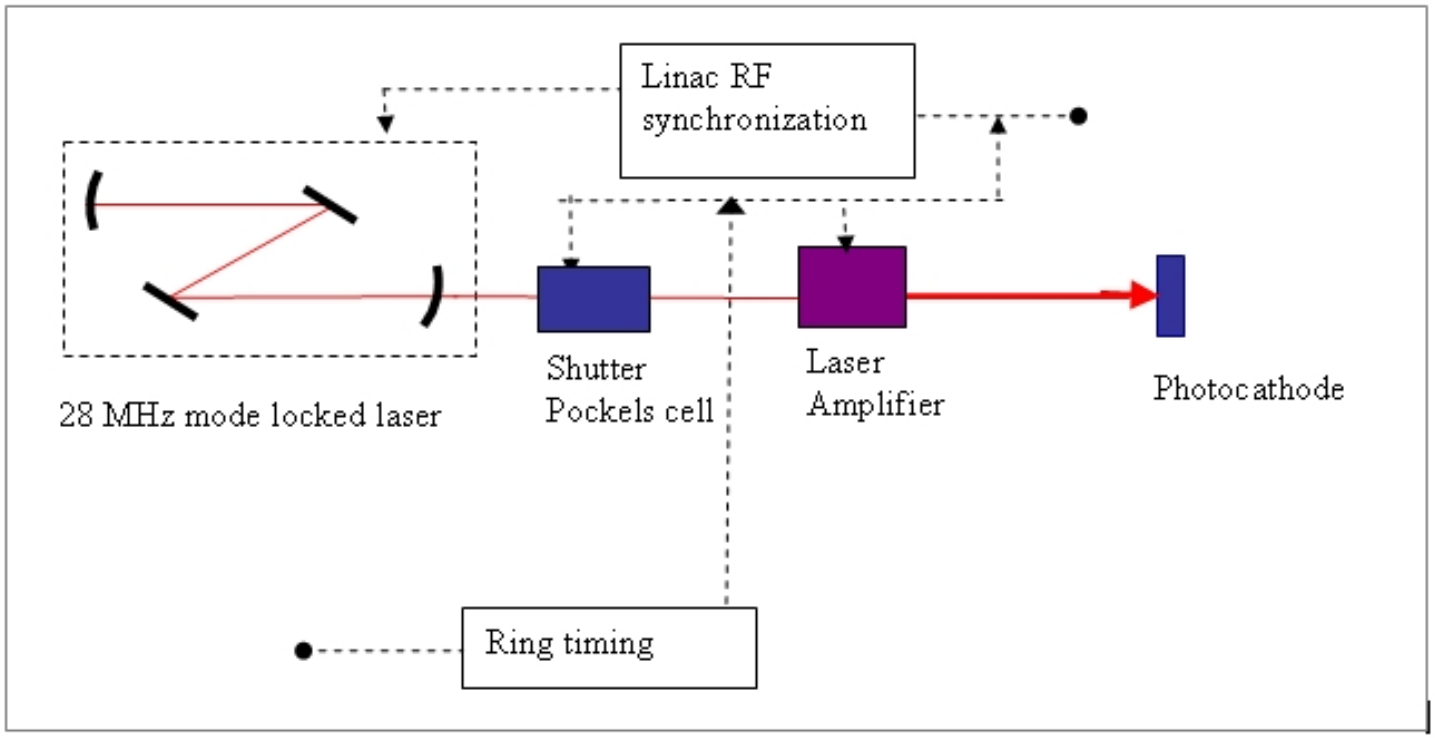


Figure 4. Schematic diagram of mode locked laser option for the eRHIC electron injector.

For ring I_{av} =450 mA, need I_{peak}=18 mA from injector

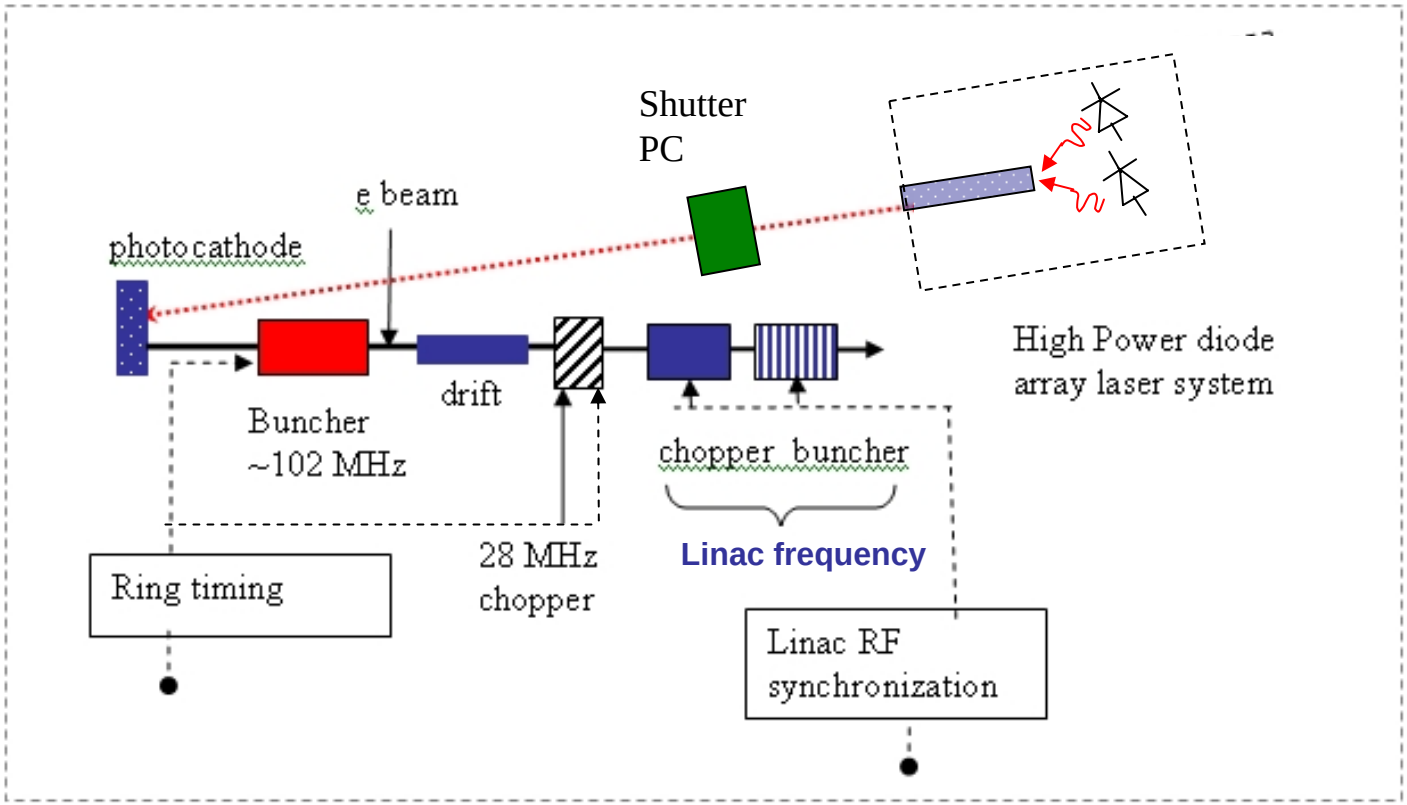
P_{peak}=50 W

Mode locked laser system at J-lab

J-lab G0 laser would produce ~150 W "equivalent" power for each bunch. Adequate power if surface charge limit effect is small.

Option 2:

P_{peak}=150 W CW-1 kHz

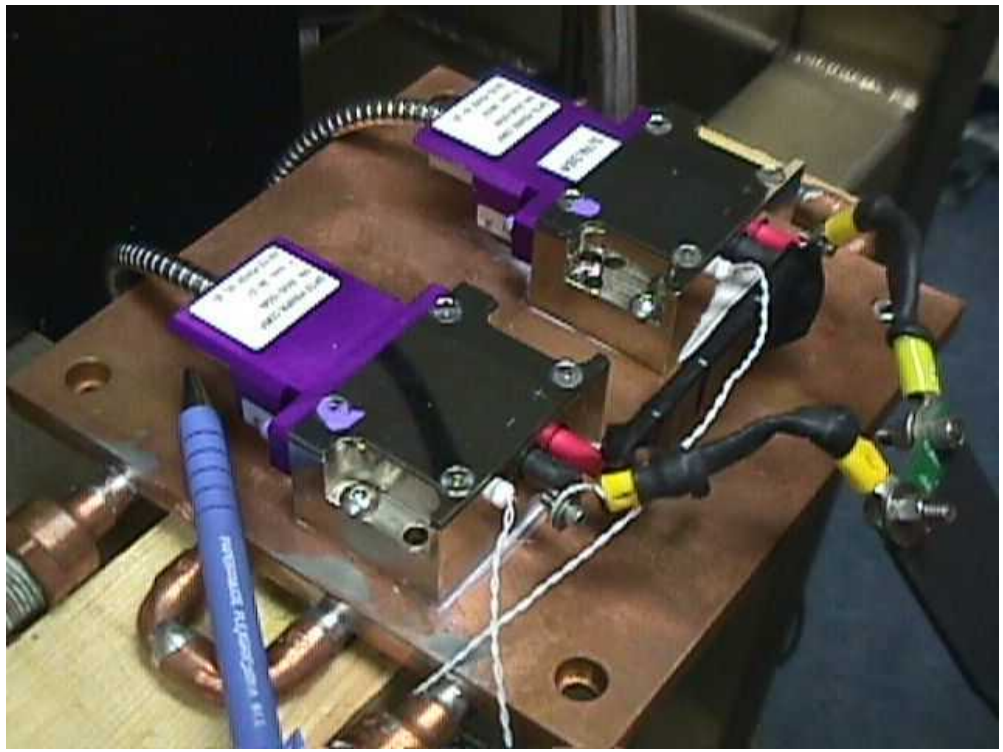


$$I_{inj} = \frac{I_{linac}}{\varepsilon_{cap}} \times F_{bunching}$$

F_bunch~2-10, ε_cap~0.5 at Linac frequency ⟹ **I_inj ~ 2-20 mA**

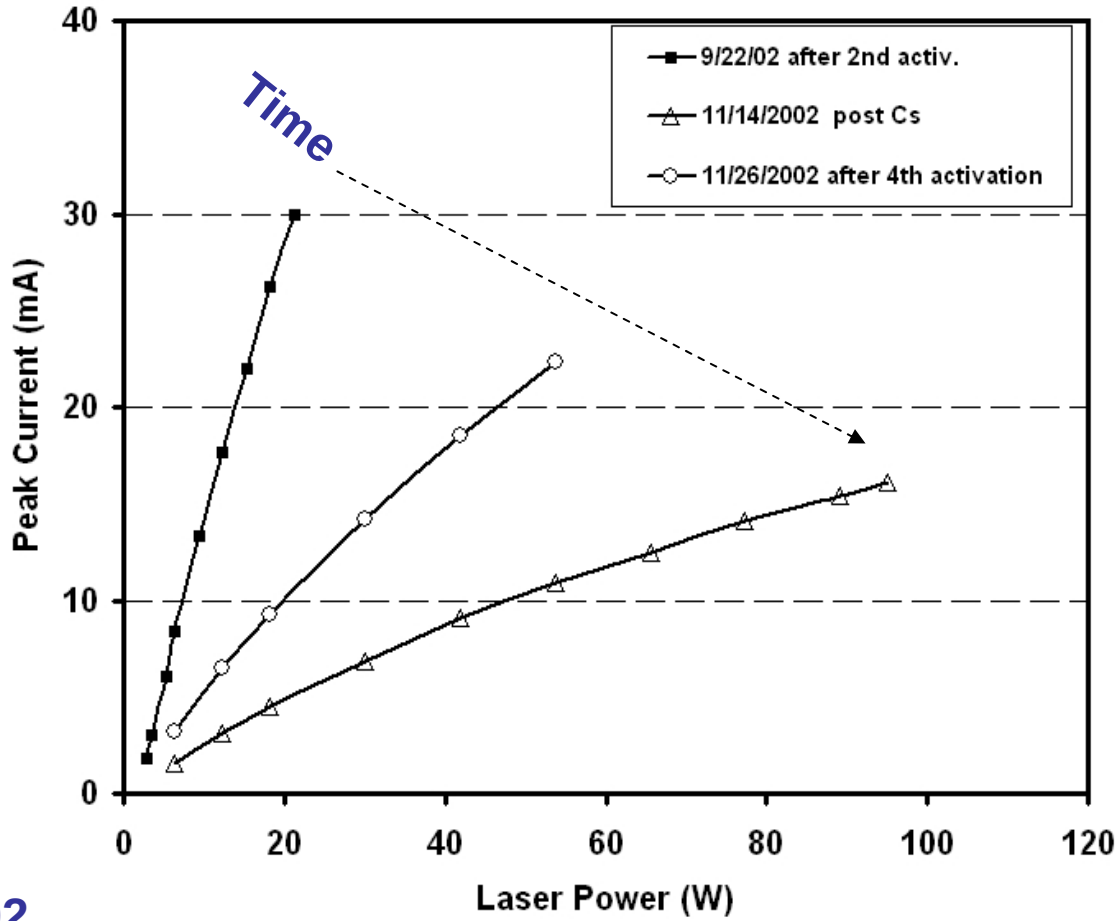
Need more work on the 102 MHz bunching.

High Power Diode array laser system at MIT-Bates



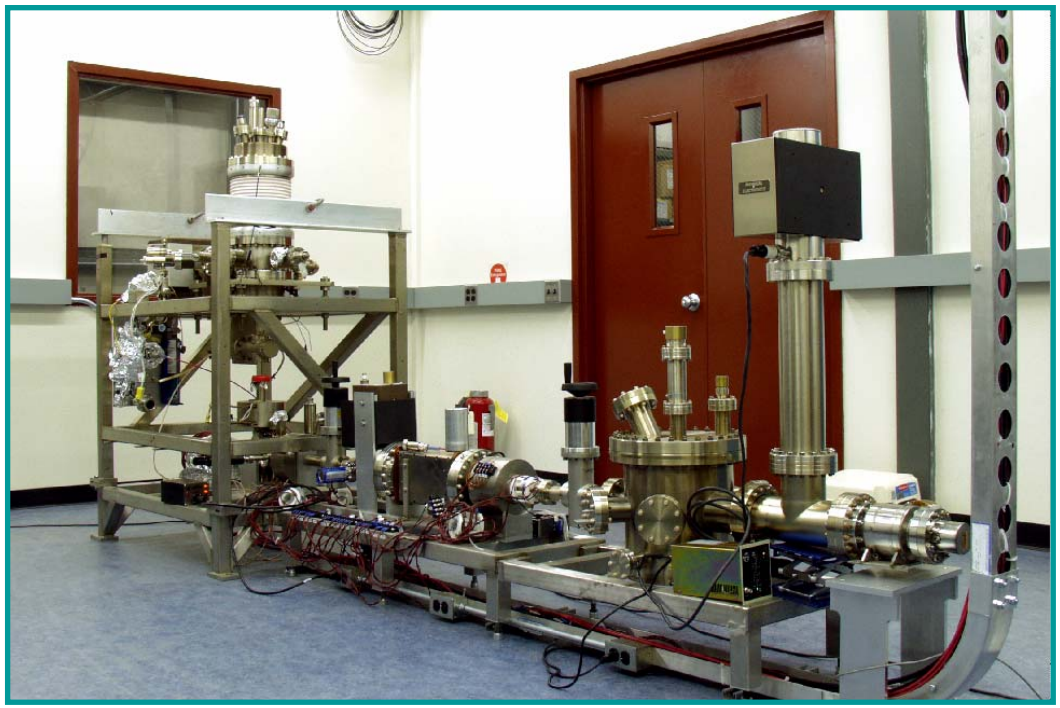
In use for several years, extremely reliable. 102 MHz bunching would further ease the requirements.

Peak current vs laser power



Bates data, 2002

Source R&D at Bates using test beam setup



MIT-Bates 60 keV test beam setup

- A Unique opportunity at Bates beyond FY05 to do R&D on the eRHIC polarized source both for the ring-ring and the linac-ring requirements.
- Both the expertise and hardware exist.

Summary

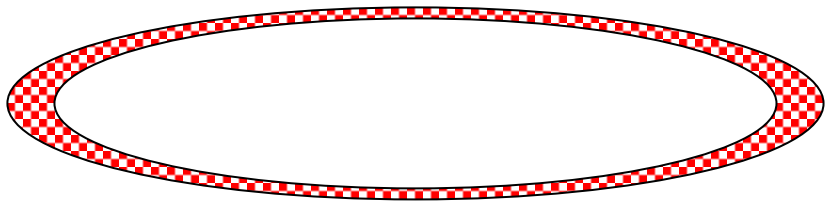
- Two options for eRHIC (ring-ring) polarized injector presented in the ZDR.
  - For option one: Precise timing synchronization of the laser is required.
  - For option two: Precise timing of the chopping/bunching of the e beam is required.
- For FY06-08 MIT-Bates is Proposing R&D related to the eRHIC polarized source requirements.
- Also proposed R&D related to the polarized source requirements for the linac-ring architecture of eRHIC that needs polarized beams at very high average currents.

End of Presentation

eRHIC electron beam parameters

	Quantity	Value	Unit
Collider Ring	**Stored current** Frequency	**480** 28.	**mA** MHz
	Ring circumference Number of bunches in the ring **Charge per macroscopic bunch**	4.3 120 **20**	μs **nC**
	stacking: pulse train rep. rate Duration Total pulse train from injector **Charge per bunch** **e per bunch**	25 10 15,000 (25x10x60) **1.3** **8xE+6**	Hz minutes **pC**
Photocathode	Bunch duration Bunch charge Peak current	~70 1.3 20	ps pC mA
Linac	Microscopic duty cycle (within 4.3 us) Macroscopic duty cycle during fill Macropulse average current Average current during fill	$2x10^{-3}$ $1x10^{-4}$ 40 4	μA nA

Macroscopic Time structure for eRHIC



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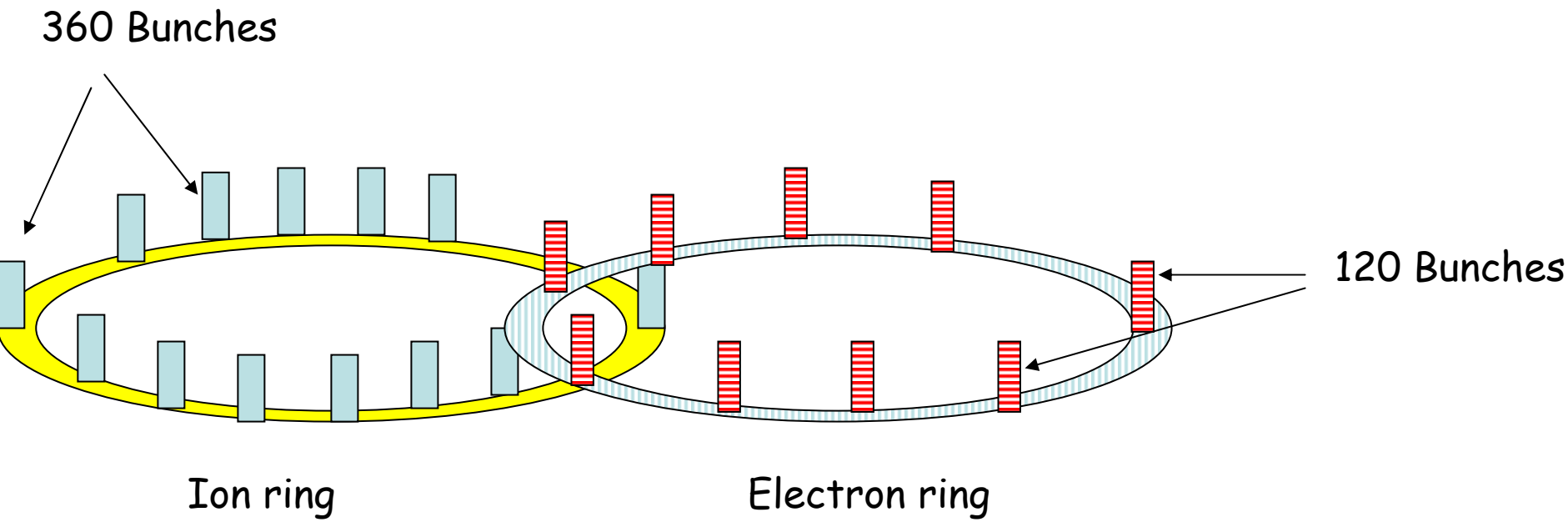


Collider storage ring (eRHIC)

- Both options are discussed in the ZDR.
- Both would work with NC or SC linacs.

- **Questions:**
  - Is there enough laser power to meet the requirements?

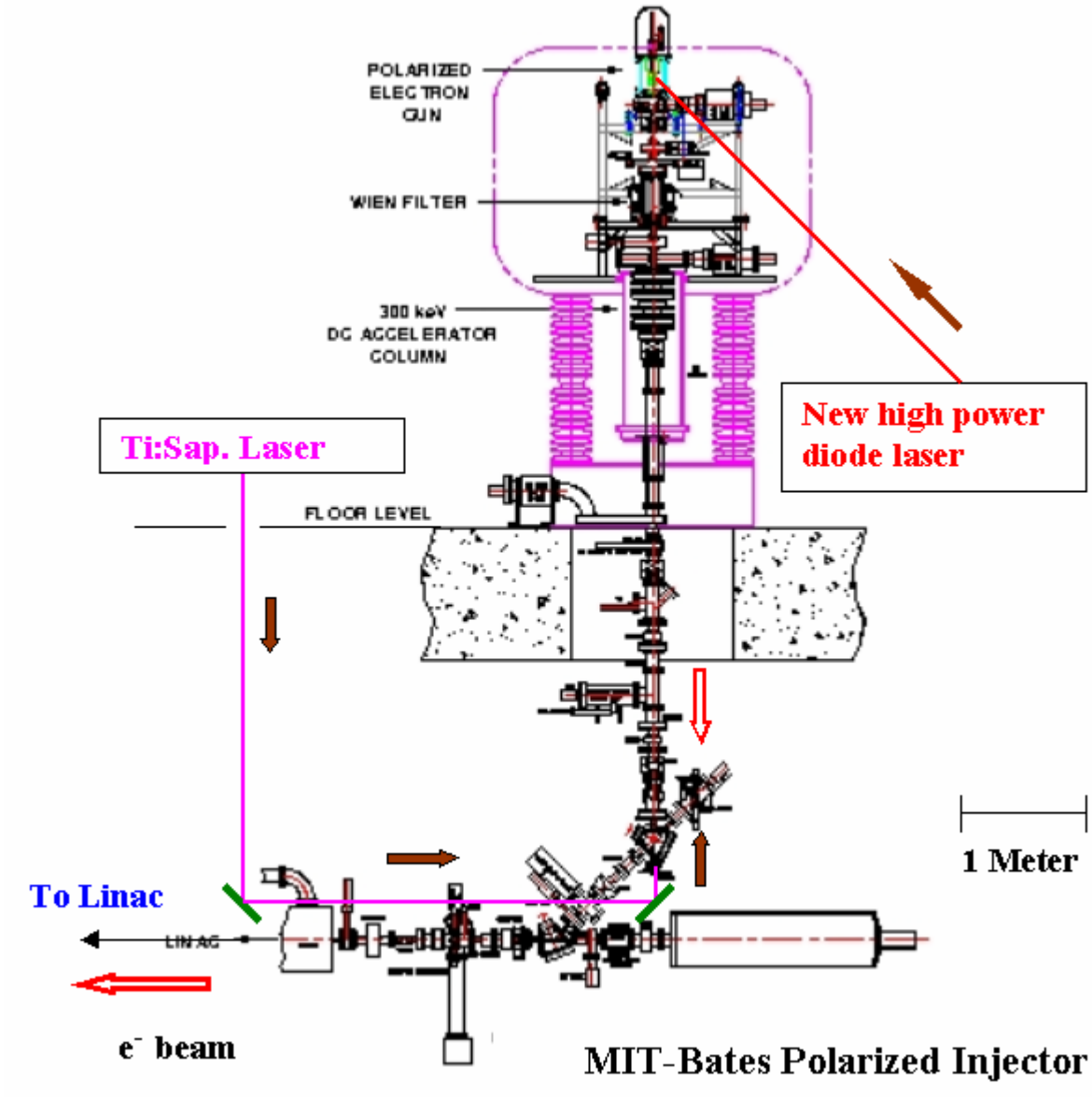
    Yes, for both options. More laser power would prolong source lifetime.

  - Does the chopping and bunching scenario in option 2 work as expected.

    Most likely it will, but need simulations and R&D

  - Is charge limit effect a major problem?

    1.3 pC charge per bunch, Not a major problem, ways to overcome


POLARIZED
ELECTRON
GUN
WIEN FILTER
300 keV
DC ACCELERATOR
COLUMN
New high power
diode laser
Ti:Sap. Laser
FLOOR LEVEL
1 Meter
To Linac
LINAC
e⁻ beam
MIT-Bates Polarized Injector