Polarized Electron Beams in the MEIC at JLab

Fanglei Lin for MEIC Study Group

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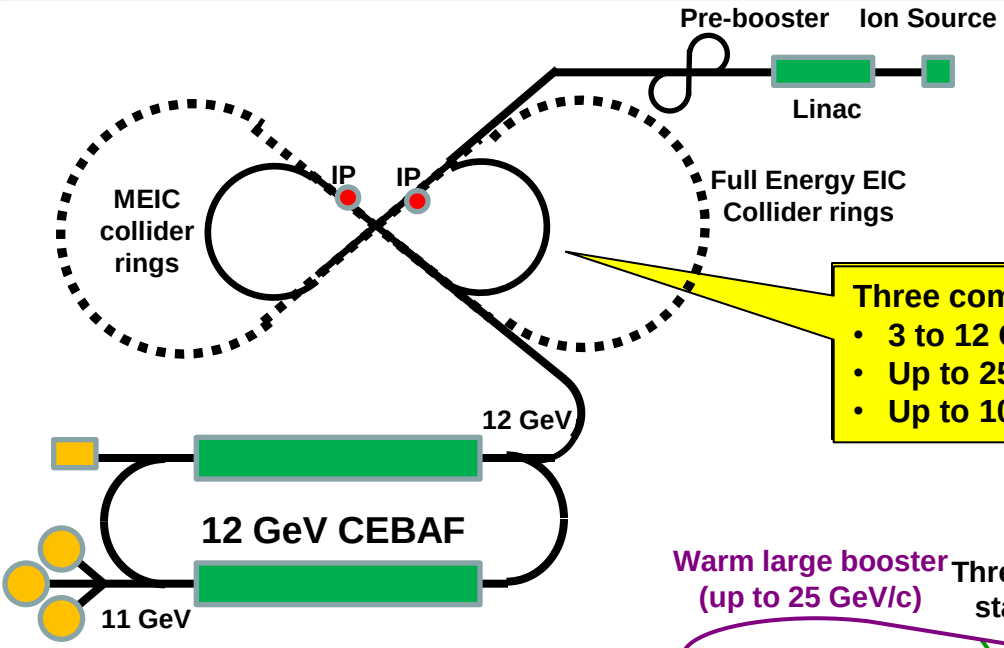
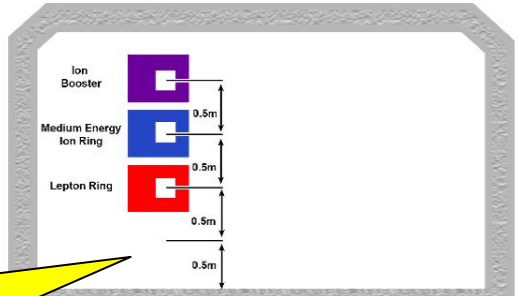
Outline

- Medium-energy Electron Ion Collider (MEIC) at Jefferson Lab
- MEIC electron complex: Polarized CEBAF + electron collider ring
- MEIC electron polarization design
  - Overview of strategies
  - Universal spin rotator
  - Polarization configuration
  - Optimization of average polarization
  - Continuous injection option
  - Polarization measurement
- Conclusions & Outlook

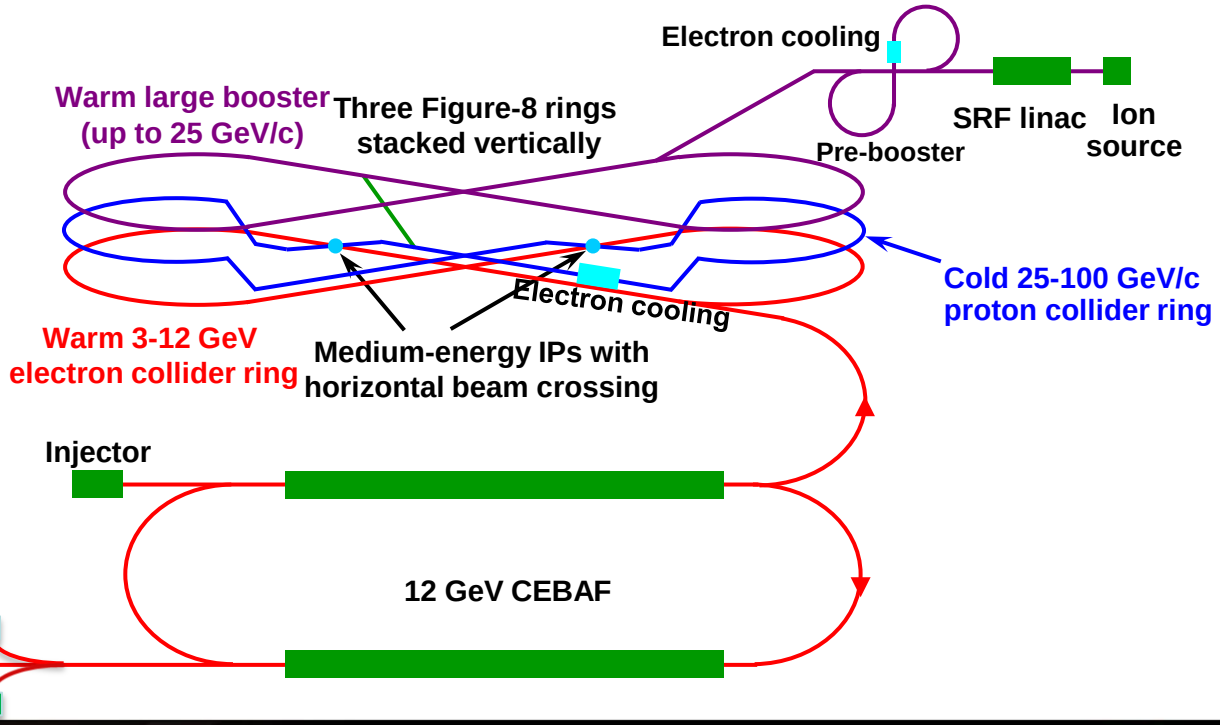
MEIC at Jefferson Lab



Three compact rings:
- 3 to 12 GeV electron
- Up to 25 GeV/c proton (warm)
- Up to 100 GeV/c proton (cold)

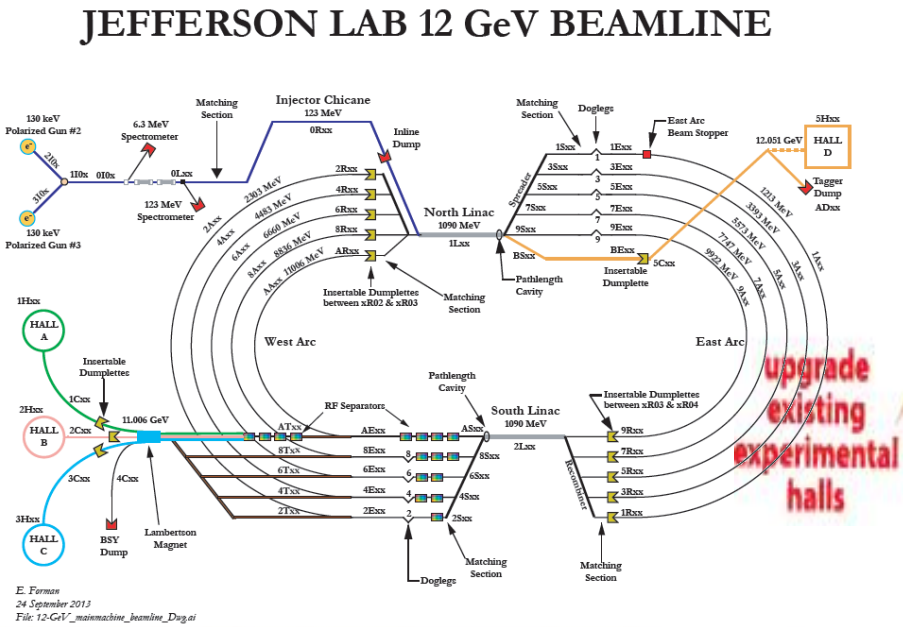


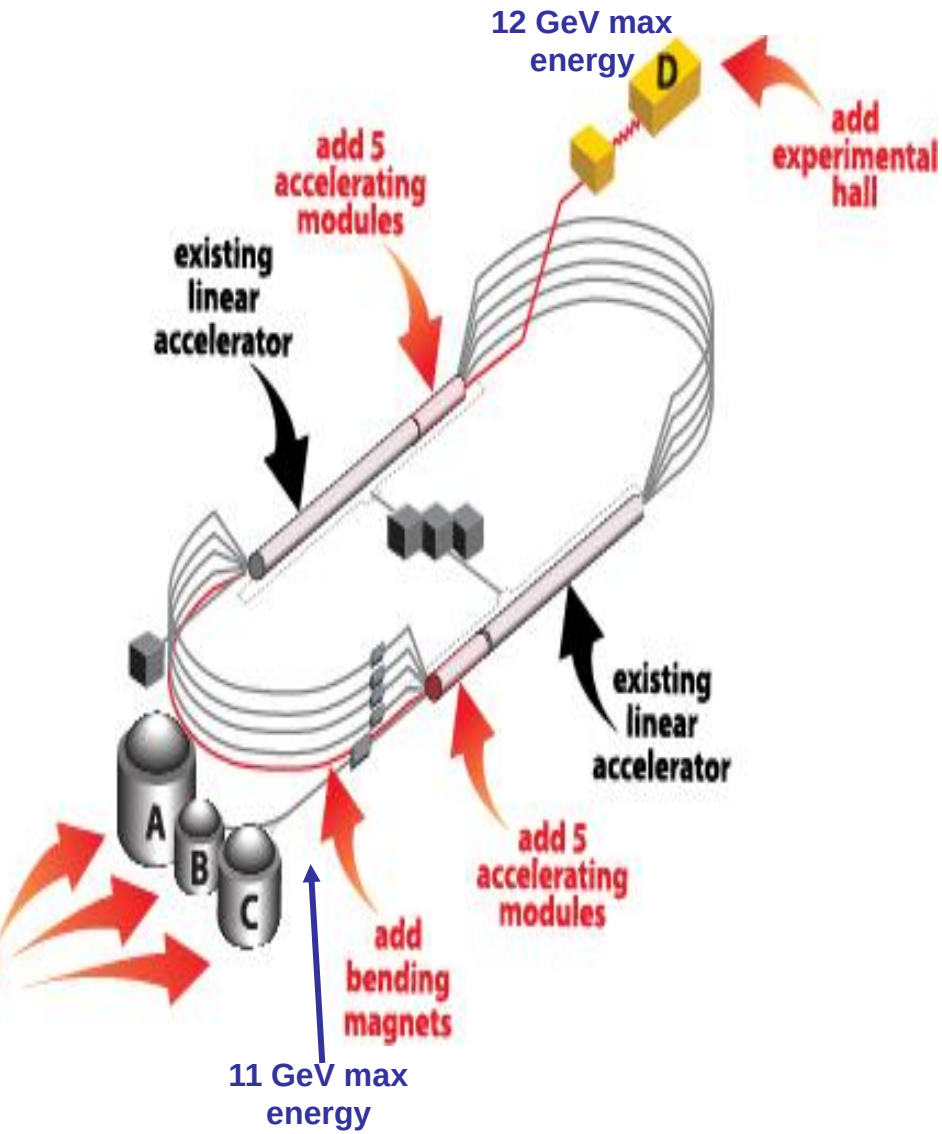
Cross sections of tunnels for MEIC



12 GeV CEBAF

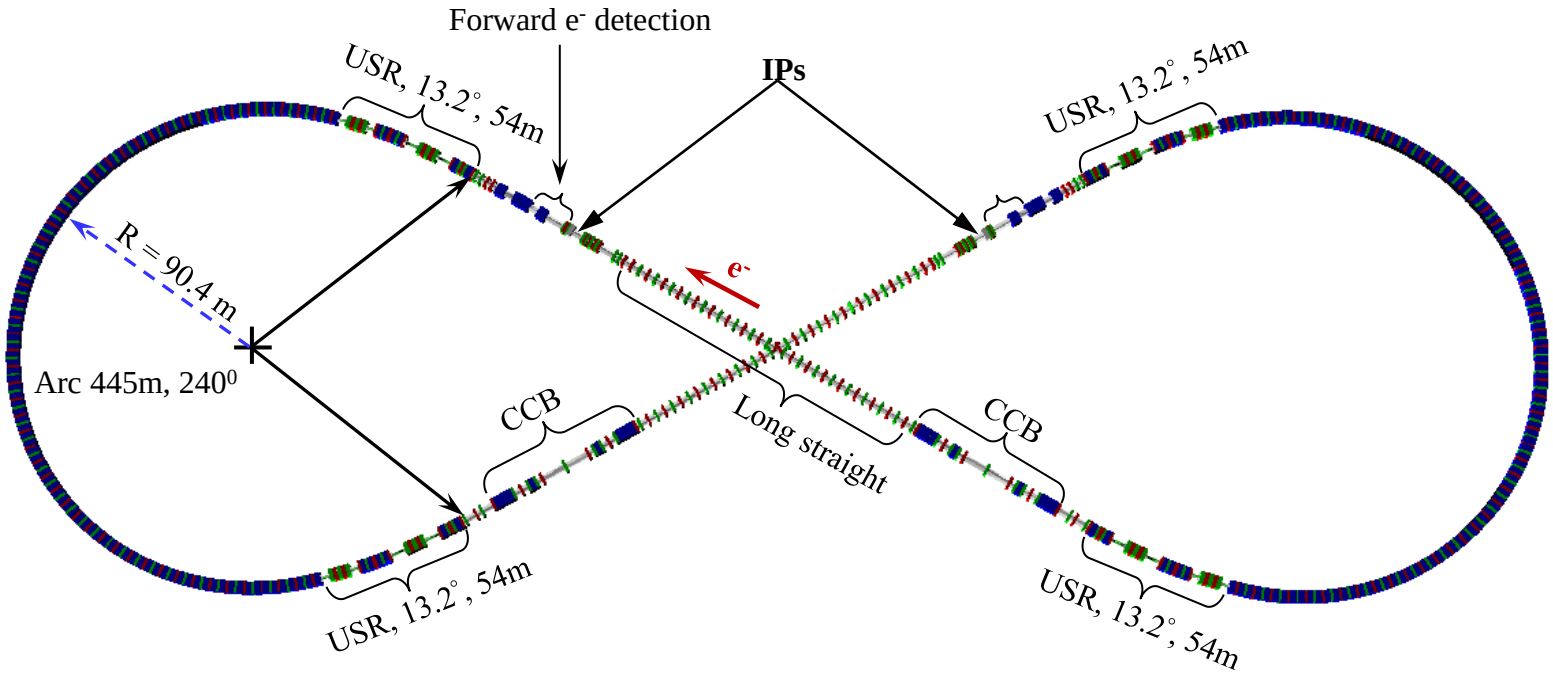
- CEBAF fixed target program
  - 5-pass recirculating SRF linac
  - Exciting science program beyond 2025
  - Can be continued parallel to MEIC
- CEBAF will provide for MEIC
  - Up to 12 GeV CW electron beam
  - High repetition rate (750 MHz)
  - High polarization (>85%)
  - Good beam quality up to mA level





MEIC Electron Collider Ring

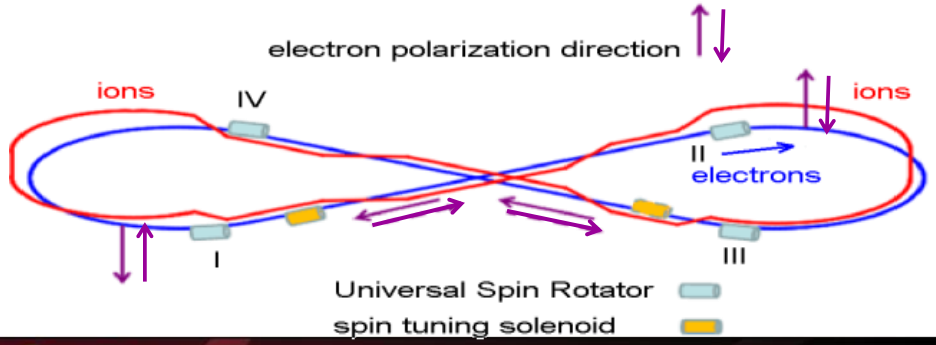
- Electron collider ring geometry
  - Figure-8 shape electron collider ring with a crossing angle of 60˚
  - Each of two arcs bends 240˚
  - Integrated interaction region with forward electron detection

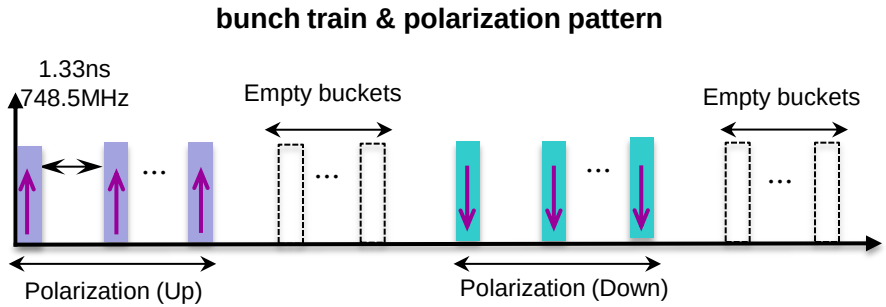


- **Electron polarization requirements**
  - Electron polarization of 70% or above
  - Longitudinal electron polarization at collision points
  - Spin flipping

Overview of e⁻ Polarization Strategies

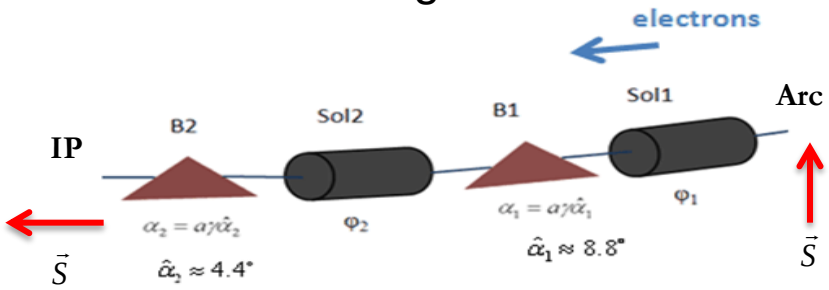
- Highly vertically polarized electron beams are injected from CEBAF
  - avoid spin decoherence, simplify spin transport from CEBAF to MEIC, alleviate the detector background
- Polarization is designed to be vertical in the MEIC arc to avoid spin diffusion and longitudinal at collision points using spin rotators
- Universal spin rotator (fixed orbit) rotates the electron polarization from 3 to 12GeV
- Desired spin flipping is implemented by changing the source polarization
- Compton polarimeter is considered to measure the electron polarization
  - Two long opposite polarized bunch trains (instead of alternate polarization between bunches) simplify the Compton polarimetry
- Polarization configuration with figure-8 geometry removes electron spin tune energy dependence
  - Such configuration has a net radiative Sokolov-Ternov depolarization effect
- Continuous injection of electron bunch trains from the CEBAF is considered to
  - preserve and/or replenish the electron polarization, especially at higher energies
- Spin matching in some key regions is considered to further improve polarization lifetime





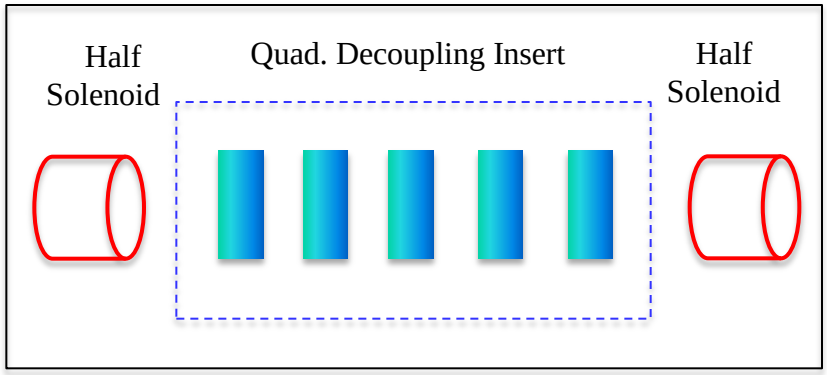
Universal Spin Rotator (USR)

- Schematic drawing of USR



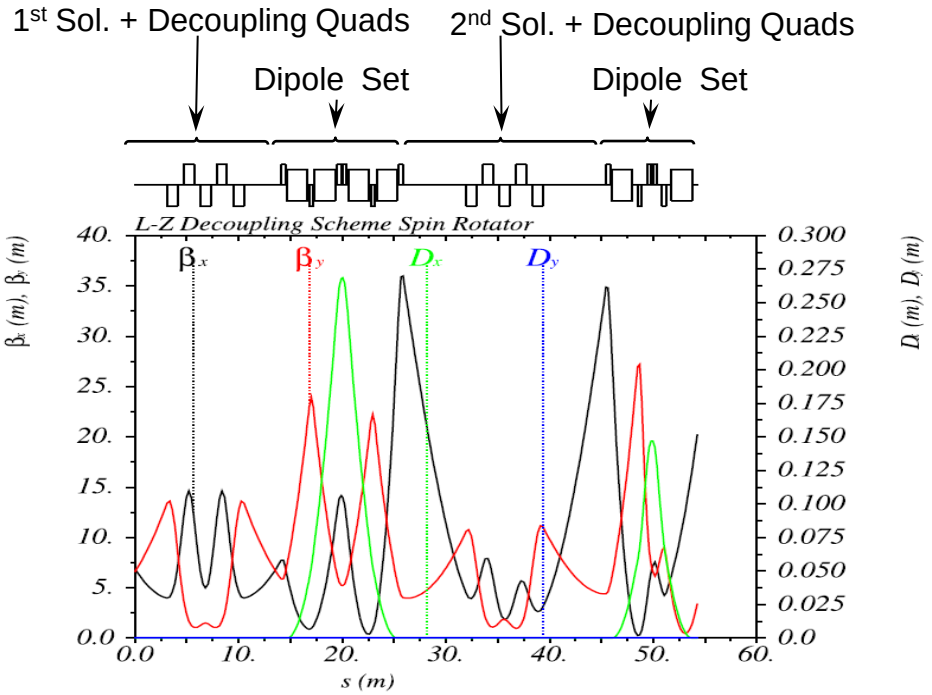
P. Chevtsov et al., Jlab-TN-10-026

- Solenoid decoupling & Lattice function



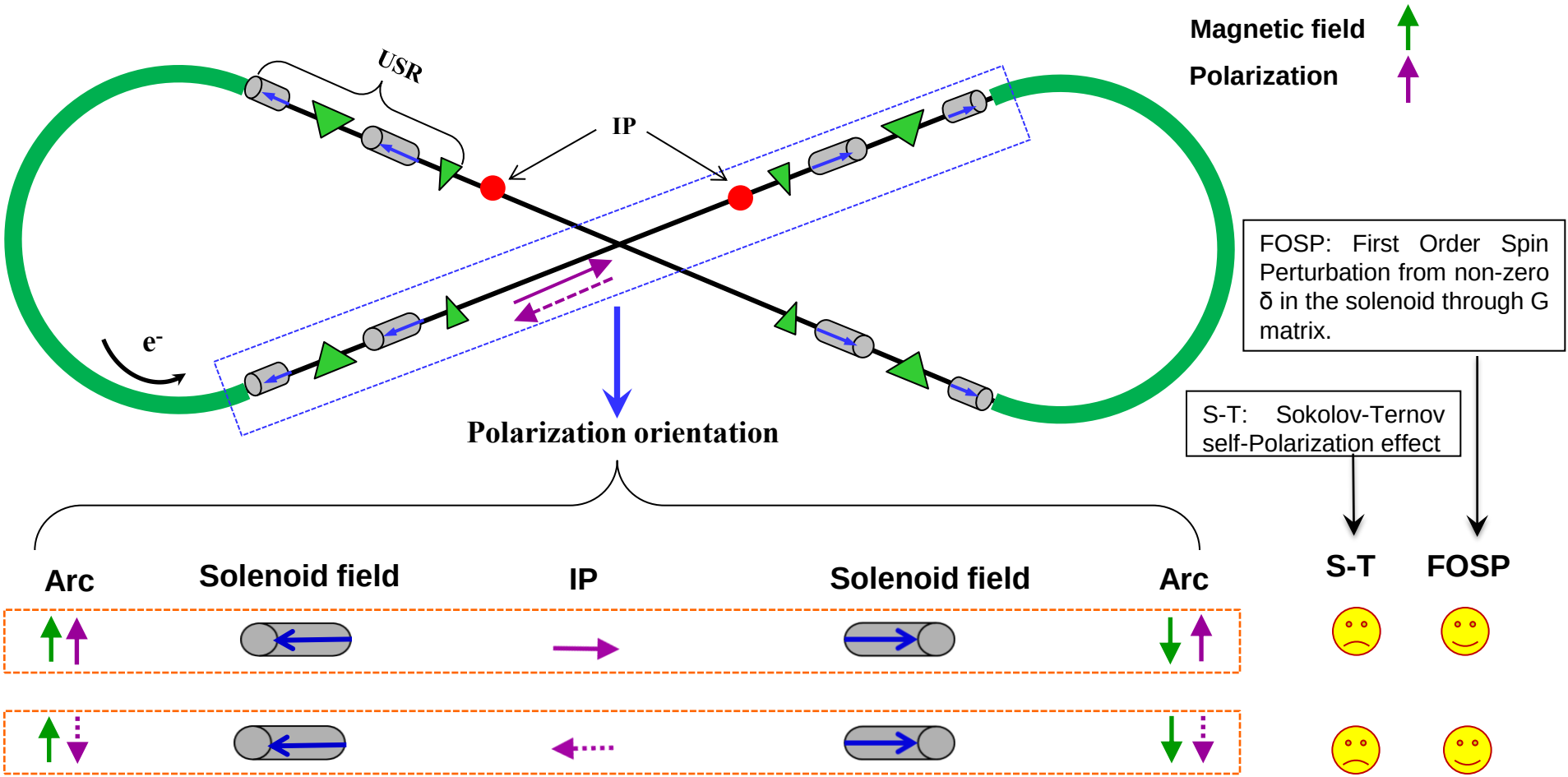
- Parameters of USR for MEIC

E	Solenoid 1		Arc Dipole 1	Solenoid 2		Arc Dipole 2
	Spin Rotation	BDL	Spin Rotation	Spin Rotation	BDL	Spin Rotation
GeV	rad	T·m	rad	rad	T·m	rad
3	π/2	15.7	π/3	0	0	π/6
4.5	π/4	11.8	π/2	π/2	23.6	π/4
6	0.62	12.3	2π/3	1.91	38.2	π/3
9	π/6	15.7	π	2π/3	62.8	π/2
12	0.62	24.6	4π/3	1.91	76.4	2π/3

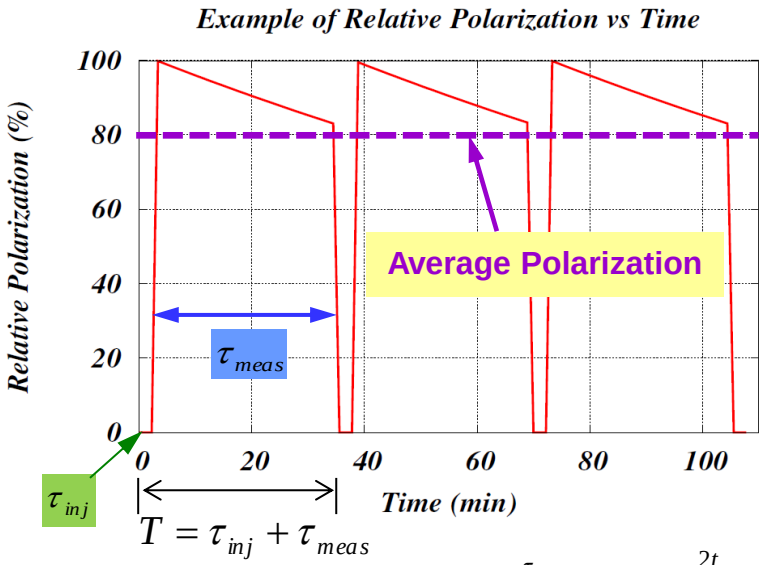


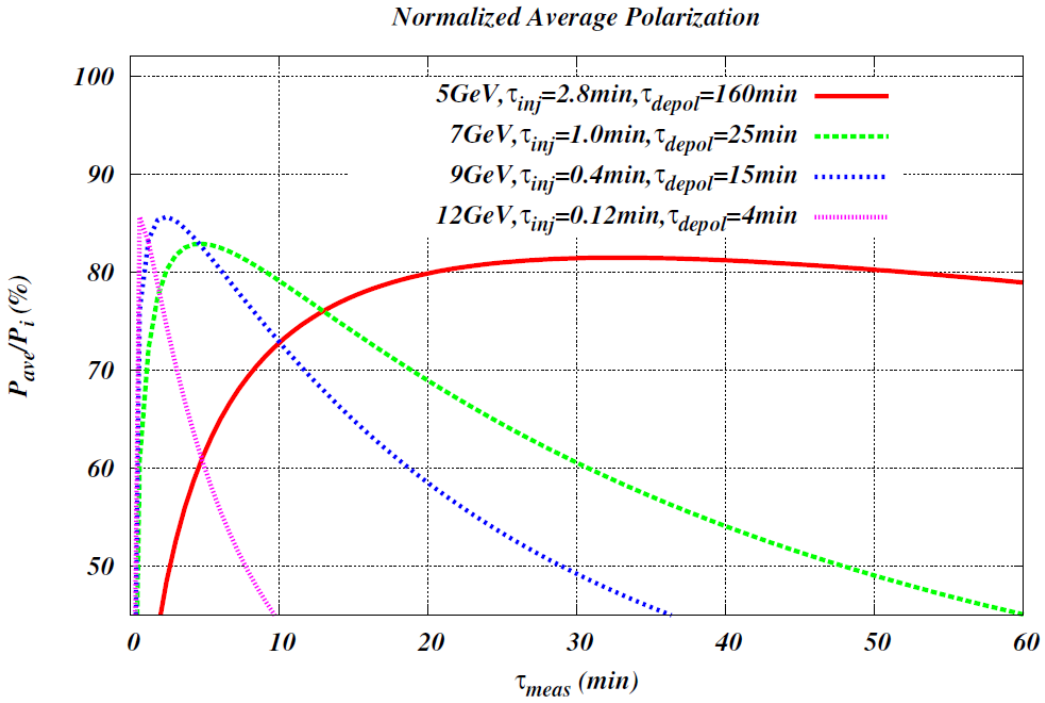
Polarization Configuration

- Unchanged polarization in two arcs by having opposite solenoid field directions in two spin rotators in the same long straight section
  - figure-8 removes spin tune energy dependence



Optimization of Average Polarization





$$FOM \propto \langle P^2 \rangle_T = \frac{\int P^2(t)dt}{T} = \frac{\int_0^{\tau_{meas}} P_i^2 \cdot e^{-\frac{2t}{\tau_{depol}}} dt}{\tau_{inj} + \tau_{meas}}$$

$$\Rightarrow \frac{P_{ave}}{P_i} = \sqrt{\frac{(1 - e^{-\frac{2\tau_{meas}}{\tau_{depol}}})}{2 \cdot (\frac{\tau_{inj}}{\tau_{depol}} + \frac{\tau_{meas}}{\tau_{depol}})}}$$

Energy (GeV)	τ_{inj} (min)	τ_{opt_meas} (min)	$(P_{ave}/P_i)_{max}$ *
5	2.8	32	**0.82**
7	1	5	**0.83**
9	0.4	2.3	**0.85**
12	0.12	0.6	**0.85**

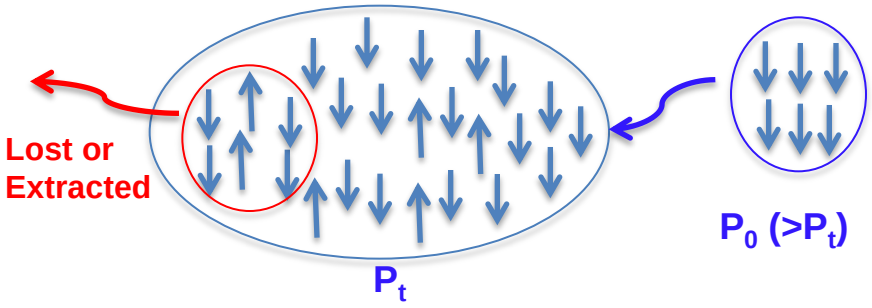
*** Includes duty factor**

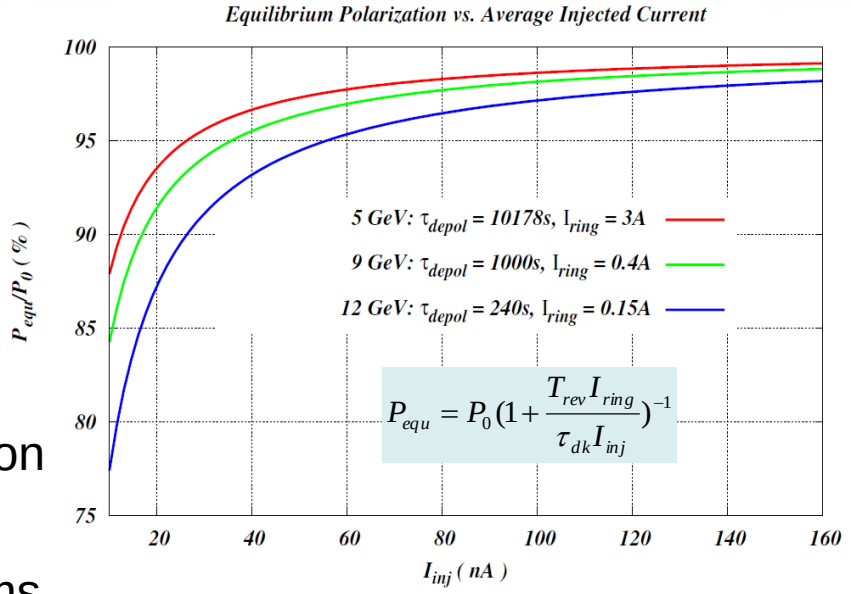
P_i : Initial polarization τ_{inj} : Injection time

τ_{depol} : Depolarization time τ_{meas} : Measurement time

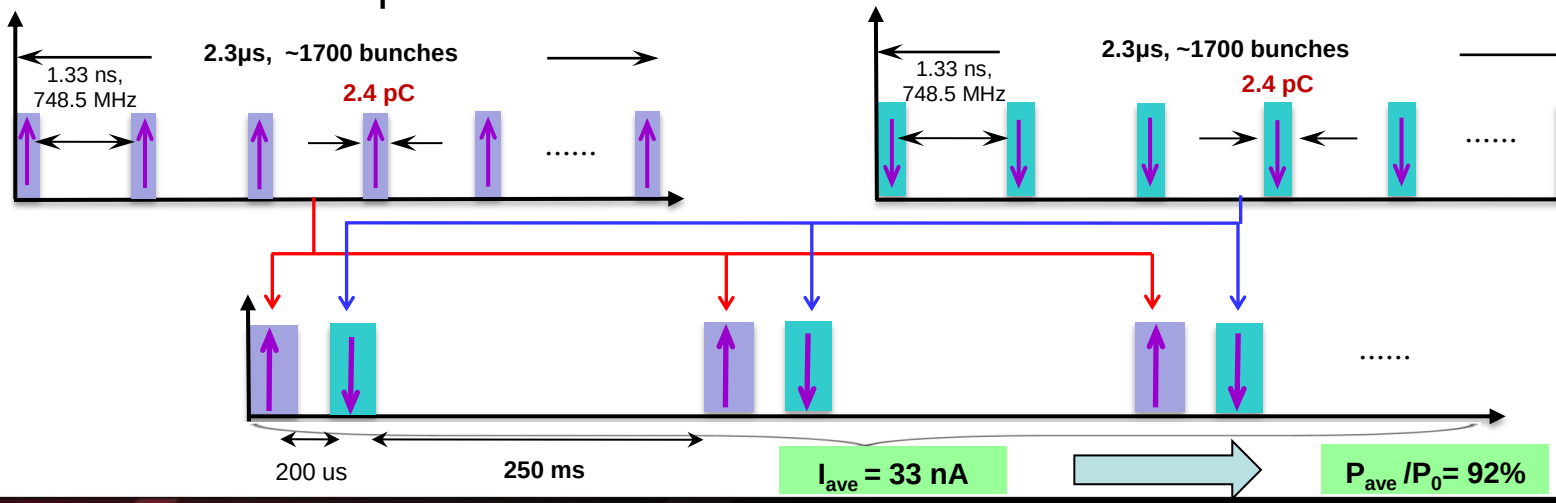
Continuous Injection Option

- Continuous injection principle



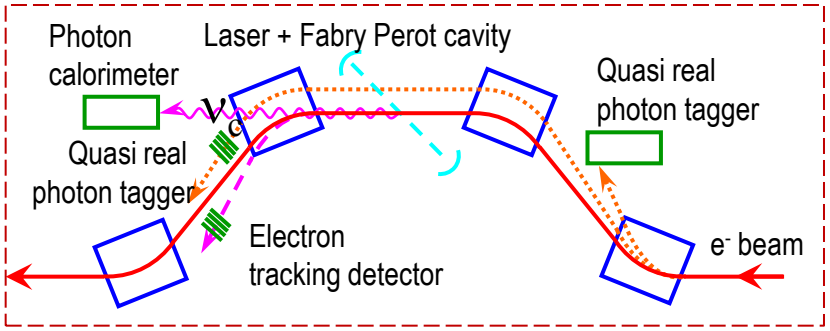


- Low injected current preserves high polarization
- One possible injection bunch pattern
  - Damping time at energy > 5 GeV << 250ms
  - No beam dump needed

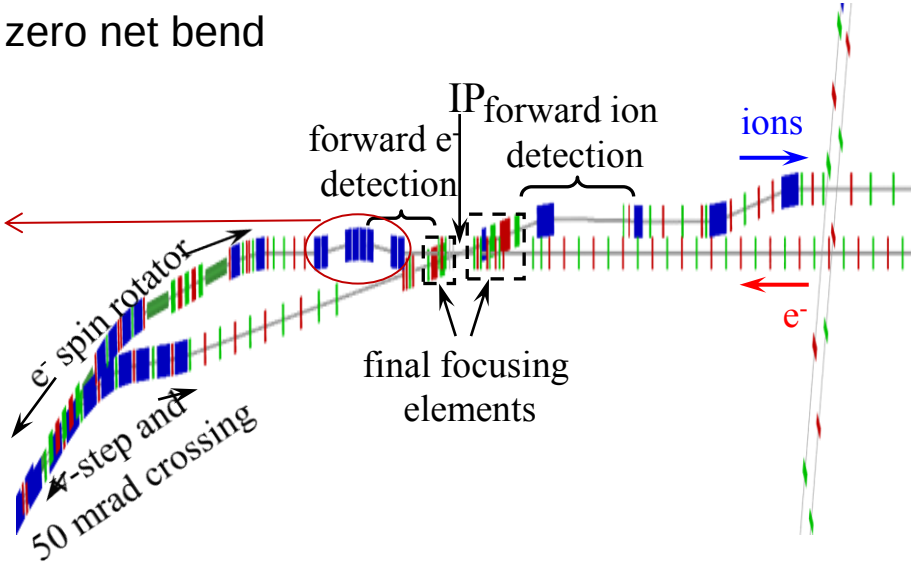


Polarization Measurement

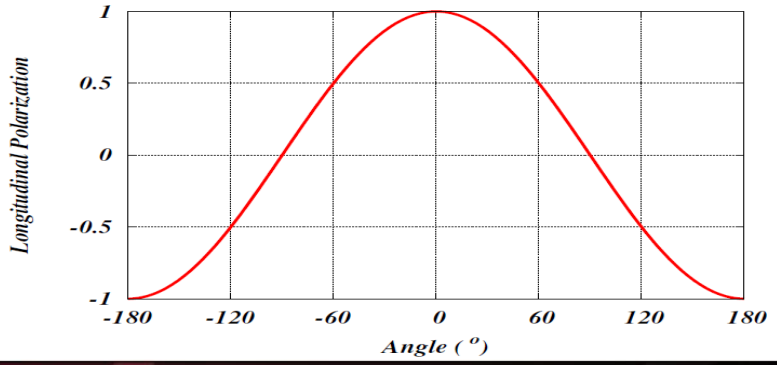
- Compton polarimetry
  - same polarization at laser as at IP due to zero net bend



Courtesy of Alexandre Camsonne



- Spin dancing (using spin rotators):
  - Experimentally optimize (calibrate) longitudinal polarization at IP



Schematic drawing of USR

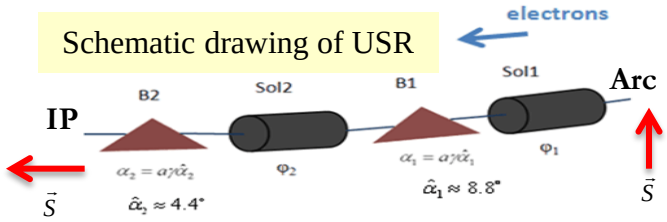
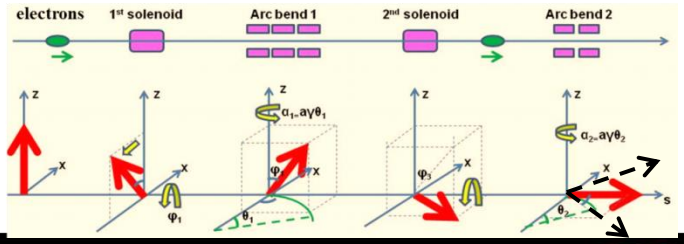


Illustration of spin rotation by a USR



Conclusion and Outlook

- Electron polarization schemes have been developed
  - Comprehensive polarization strategies
    - Polarized CEBAF + figure-8 shape ring + universal spin rotator + polarization configuration (+ continuous injection)
  - Optimization of average polarization
  - Polarization measurement
- Outlook
  - Scheme or technique optimization
  - Spin matching through the optics to improve polarization lifetime
  - Spin tracking with realistic errors using SLICKTRACK

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Thank You for Your Attention !

谢谢 !

Спасибо !