eRHIC/MeRHIC and related beam studies

Vadim Ptitsyn

Staging of eRHIC

eRHIC

- **MeRHIC**: Medium Energy eRHIC
  - Both Accelerator and Detector are located at IP2 of RHIC
  - 4 GeV e^- x 250 GeV p (63 GeV c.m.), L ~ 10^{32}-10^{33} cm^{-2} sec^{-1}
  - 90% of hardware will be used for HE eRHIC (ERLs, injector)
- **eRHIC, High energy and luminosity phase,** inside RHIC tunnel

  Full energy, nominal luminosity
  - Polarized 20 GeV e^- x 325 GeV p (160 GeV c.m), L ~ 10^{33}-10^{34} cm^{-2} sec^{-1}
  - 30 GeV e x 120 GeV/n Au (120 GeV c.m.), ~1/5 of full luminosity (10mA I_e)
  - 20 GeV e x 120 GeV/n Au (120 GeV c.m.), full liminosity (50mA I_e)
- **eRHIC up-grades – if needed**
  - **Higher luminosity with decreased beta**
  - **Higher hadron energy**
  - **Additional detectors**

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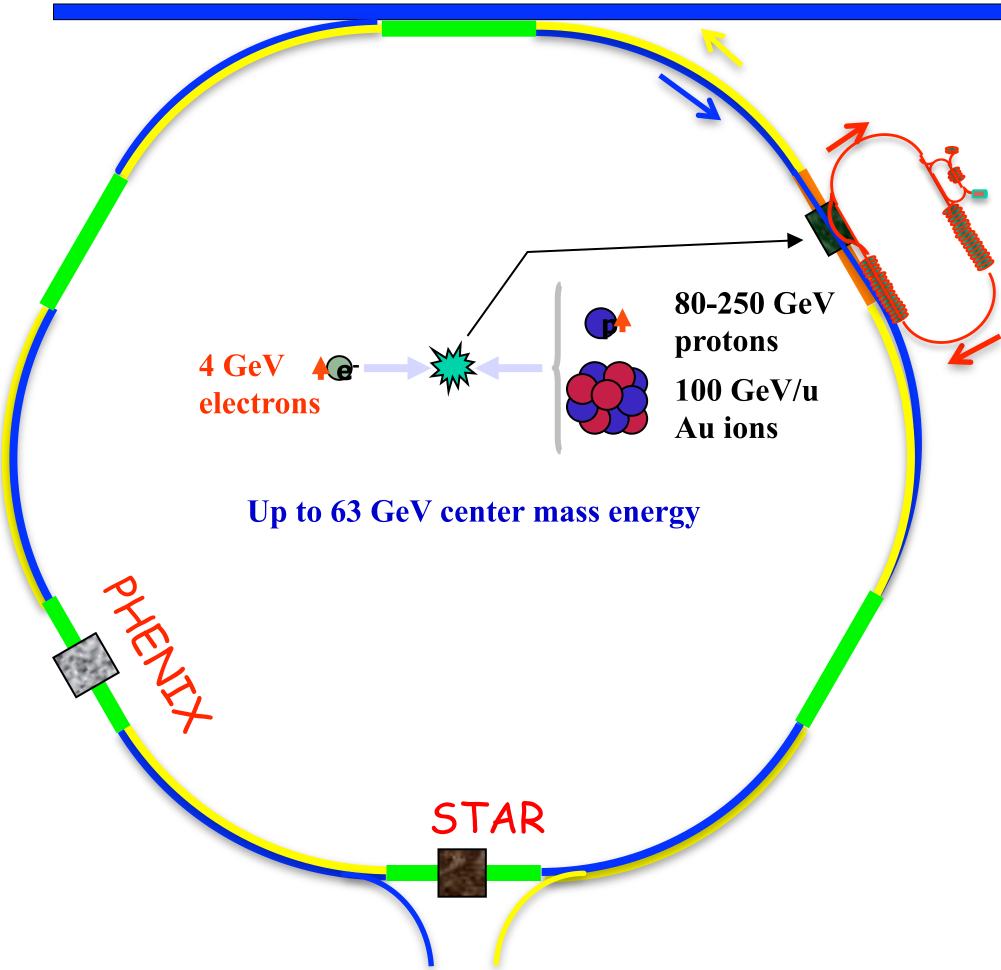
First stage: MeRHIC

eRHIC



- MeRHIC – Medium energy eRHIC. First stage of the electron-ion collider at BNL.
- Electrons collide with protons and ions from RHIC Blue ring.
- Polarized electron and proton beams. Longitudinal polarization orientation at the collision point for both beams.
- Parallel operation with the p-p (or ion-ion) collisions at PHENIX and STAR detectors.
- Electron acceleration is based on energy-recovery linacs.

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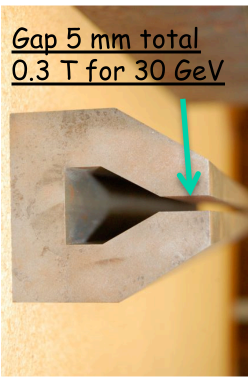
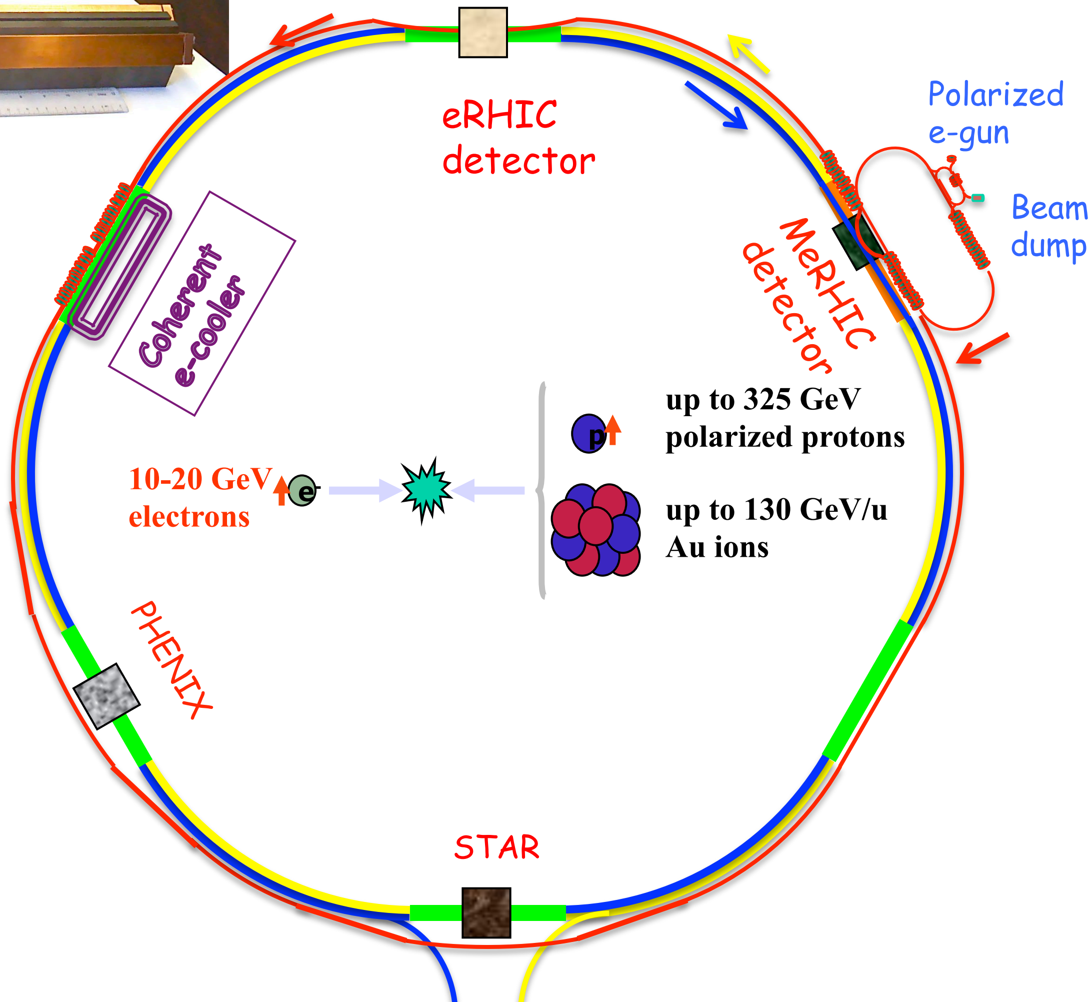
High E, High L Stage: eRHIC

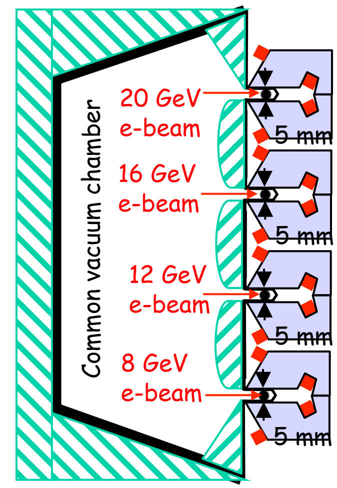
eRHIC



Possibility of 30 GeV low current operation



2 x 200 m SRF linac
4 (5) GeV per pass
5 (4) passes



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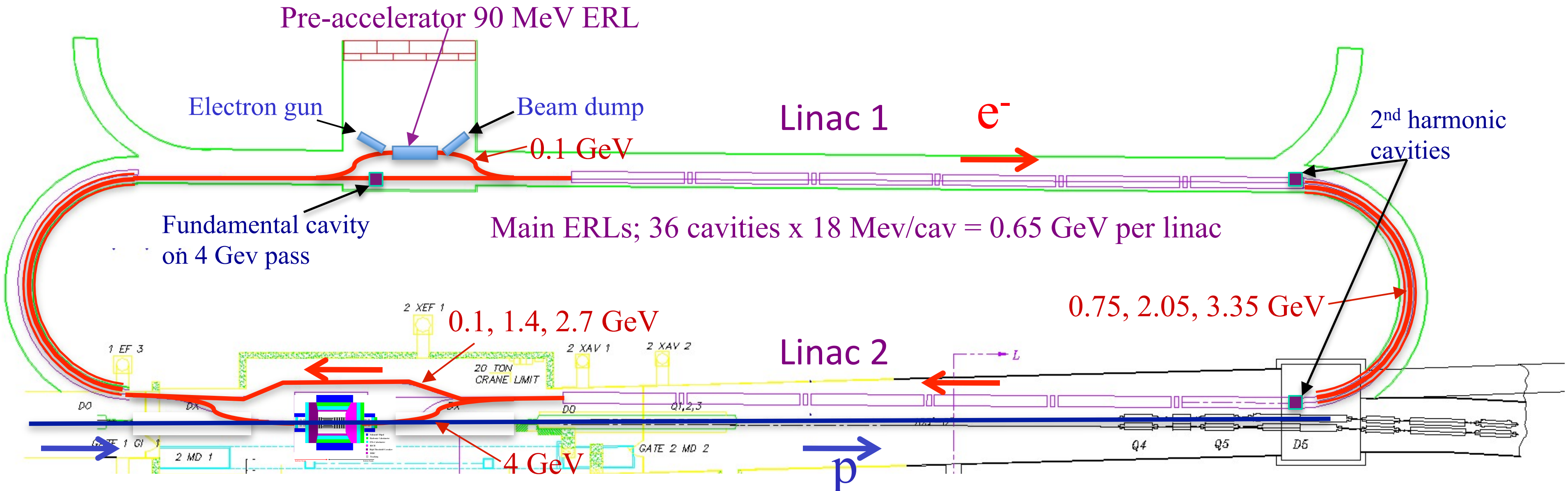
MeRHIC at IR2 region

eRHIC



IR2 region features:

- asymmetric detector hall (appropriate for asymmetric detector for e-p collisions)
- long wide (7.3m) tunnel on one side from the IR (enough space to place energy recovery linac(s))

Main components:

-A 100 MeV injector with a 50 mA polarized electron gun and pre-accelerator ERL
-Two main SRF linacs (one in the RHIC tunnel) with 0.65 GeV energy gain per linac
-Recirculation passes: room-temperature magnets, acceptable synchrotron radiation power (<2 kW/m)

MeRHIC and eRHIC parameters

	MeRHIC		eRHIC with CeC	
	p (A)	e	p (A)	e
Energy, GeV	250 (100)	4	325 (125)	20
Number of bunches	111		166	
Bunch intensity (u) , 10^{11}	2.0	0.31	2.0 (3)	0.24
Bunch charge, nC	32	5	32	4
Beam current, mA	320	50	420	50
Normalized emittance, 1e-6 m, 95% for p / rms for e	15	73	1.2	25
Polarization, %	70	80	70	80
rms bunch length, cm	20	0.2	4.9	0.2
β*, cm	50	50	25	25
Luminosity, x 10^{33}, $cm^{-2}s^{-1}$	0.1 -> 1 with CeC		2.8	

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Machine luminosity

eRHIC

Limiting factors for the luminosity:

- Maximum average electron current can be limited by the polarized source, SR losses or instabilities.
- Electron charge/bunch (or peak current): EM wake fields
- Allowable beam-beam tune shift on hadron beam
- Electron beam disruption
- β* limits from the detector design (no quads in the detector).
- Maximum proton current: electron cloud, radiation limits

MeRHIC baseline design: L~ 10^{32}, no cooling assumed for the proton beam, parallel operation with PHENIX and STAR experiments.
MeRHIC upgrade with Coherent Electron Cooling (CEC) -> higher luminosity (10^{33})

eRHIC: L=2.8 10^{33} assumes Coherent Electron Cooling and dedicated operation mode (no p-p collisions). Required average electron current =50mA.

eRHIC upgrades: copper-covered beam pipe, lower β*;
higher beam energy; more detectors

Proton beam parameters

eRHIC

	For MeRHIC	Presently achieved
Energy, GeV	250	Several runs at 100 GeV. Recent 250 GeV run.
Number of bunches	111	111
Bunch intensity, 10^{11}	2.0	1.7 (at store)
Normalized 95% emittance, 1e-6 m	15	<10 mm*mrad at the injection ~15-20 mm*mrad at the store
beta*, cm	50	70
rms bunch length, cm	20	50 cm with 28 MHz system In future, shorter bunches with combination of 9 MHz RF (ramp) + 56 MHz SRF (store)
Average Polarization	70%	~55% at 100 GeV, ~35% at 250 GeV

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Beam studies

eRHIC

- Most of beam studies to improve the performance of present RHIC will be useful for eRHIC too: increased beam intensity, higher polarization …

- Specific studies for better understanding of the achievable luminosity and beam energy at eRHIC:

  ❖ Bunch length limits. How short can be bunch in RHIC
  Cryoload due to resistive wall and electron cloud, instabilties

  ❖ Maximum achievable beam energy with DX magnets.

09-21 Study of bunch length limits

eRHIC

V.Ptitsyn, V.N.Litvinenko, C.Montag, S.Y.Zhang

- Two possible techniques:
  - At the proton injection energy use gammaT quadrupoles to approach the transition energy to shorten the bunch length.

    It was tried in last proton run (next slides). Difficulties found.

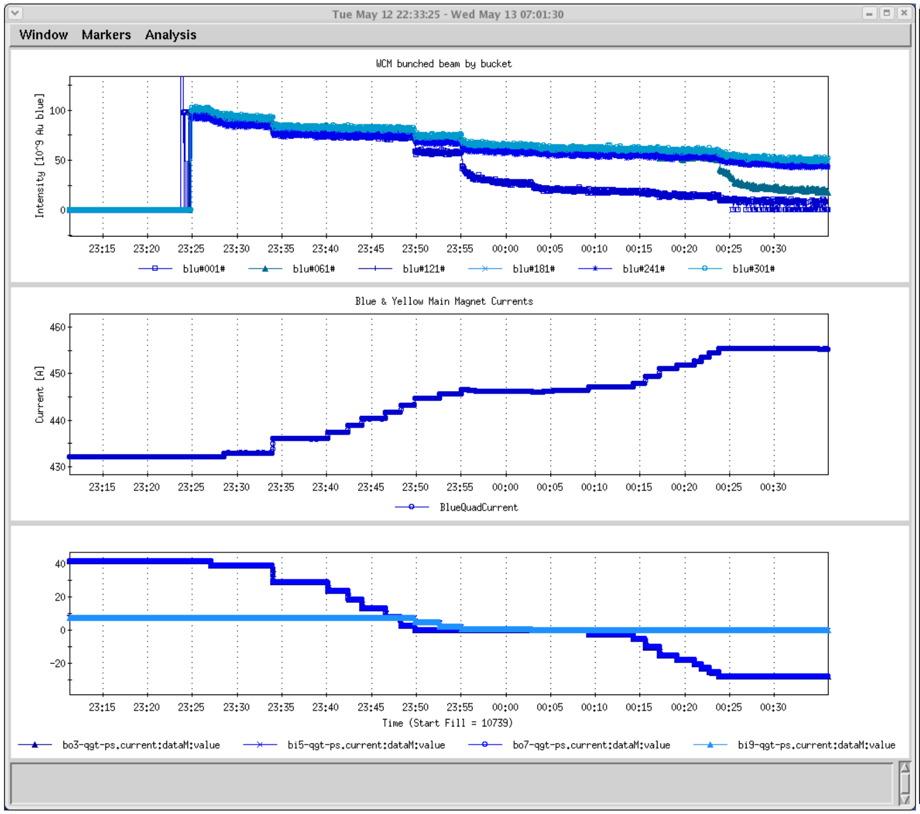
  - Use dedicated energy ramp to approach the transition energy either with protons or ions.

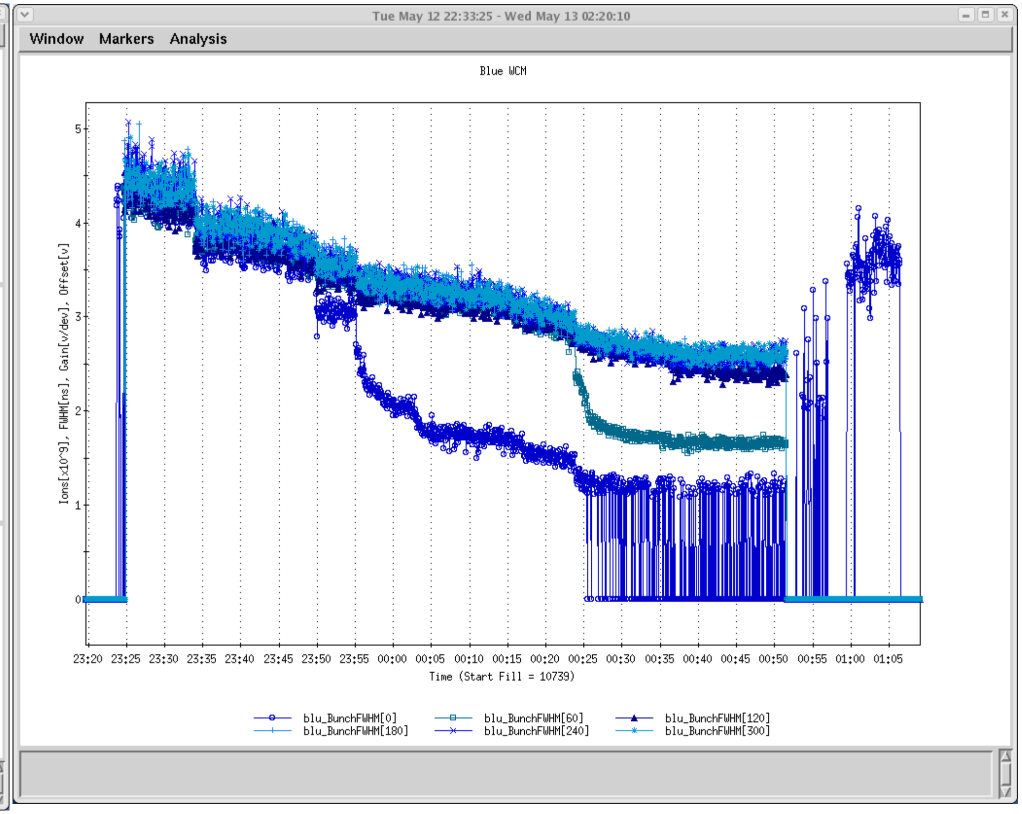
Approaching transition using gammaT quads

eRHIC

Bunch intensities, main quad and gammaT quad currents

Bunch length





Data from Run-9 measurements

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Approaching transition study

eRHIC

- Difficulties identified during the use of gammaT to approach the transition:
  - Beam losses when large step of gammaT quad change was used
  - Some model problems when trying to calculate the required tune correction.
  - Considerable closed orbit change.
- To address these problems a dedicated ramp is needed for correction tunes and orbit when ramping gammaT quads.
- Better alternative would be the use of dedicated energy ramp to approach the transition. (It can be done with ions too.)

Maximum achievable beam energy

eRHIC

- Goal: to find out a maximum beam energy which can be achieved in RHIC with DX magnets.
- Study items:
  - Explore what maximum crossing angle can be allowed by beam lifetime at the top energy.

    Defines minimum achievable DX field and, correspondingly, maximum possible increase in arc magnet field.

    ~4 mrad crossing angle will be needed for 325 GeV energy.
  - Explore magnet ramp to higher beam energy (without beam).
  - Explore the ramp to higher energy with the beam.