Update on eRHIC and related studies

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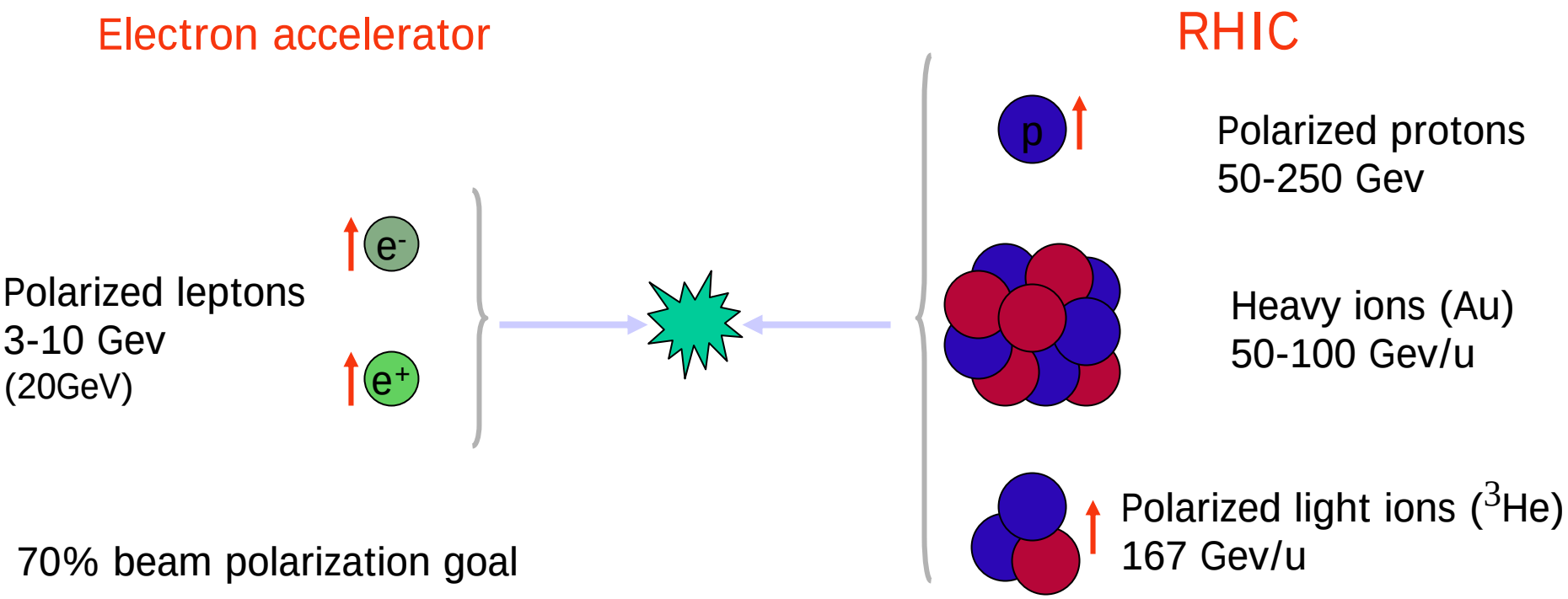
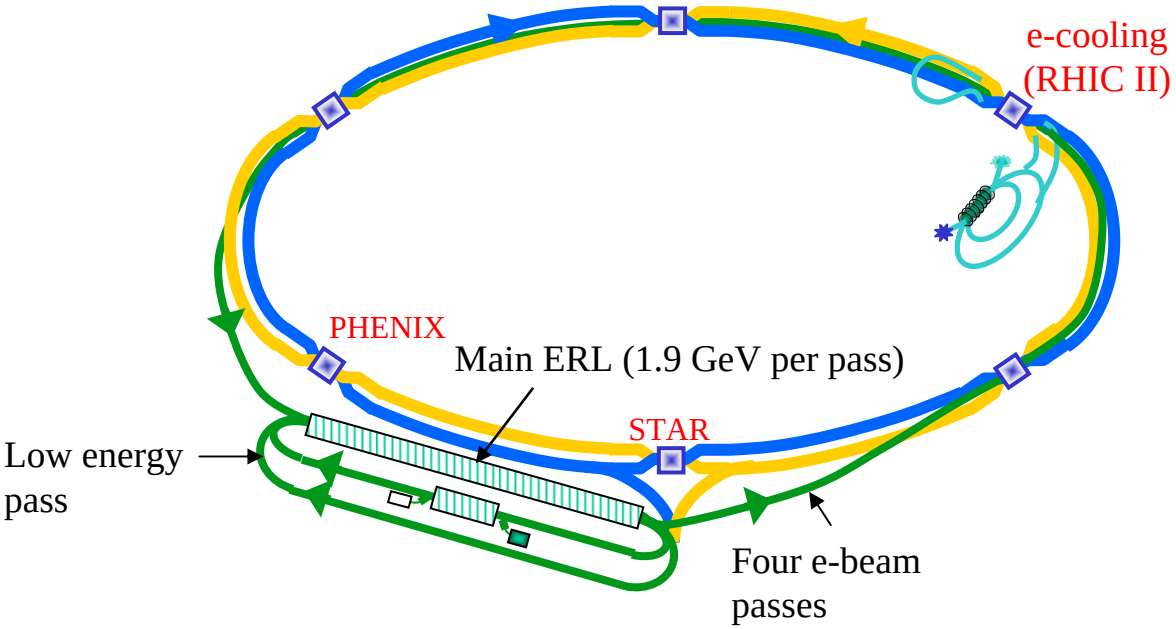
eRHIC Scope


Electron accelerator
RHIC
p
Polarized protons
50-250 Gev
e-
Polarized leptons
3-10 Gev
(20GeV)
e+
Heavy ions (Au)
50-100 Gev/u
Polarized light ions (^{3}He)
167 Gev/u
70% beam polarization goal

ERL-based eRHIC Design



- Peak luminosity of 2.6×10^{33} $cm^{-2}s^{-1}$ in electron-hadron collisions;
- high electron beam polarization (~80%) and full polarization transparency at all energies for the electron beam;
- multiple electron-hadron interaction points (IPs) and detectors;
- ± 3 meter "element-free" straight section(s) for detector(s);
- ability to take full advantage of electron cooling of the hadron beams;
- easy variation of the electron bunch frequency to match the ion bunch frequency at different ion energies.

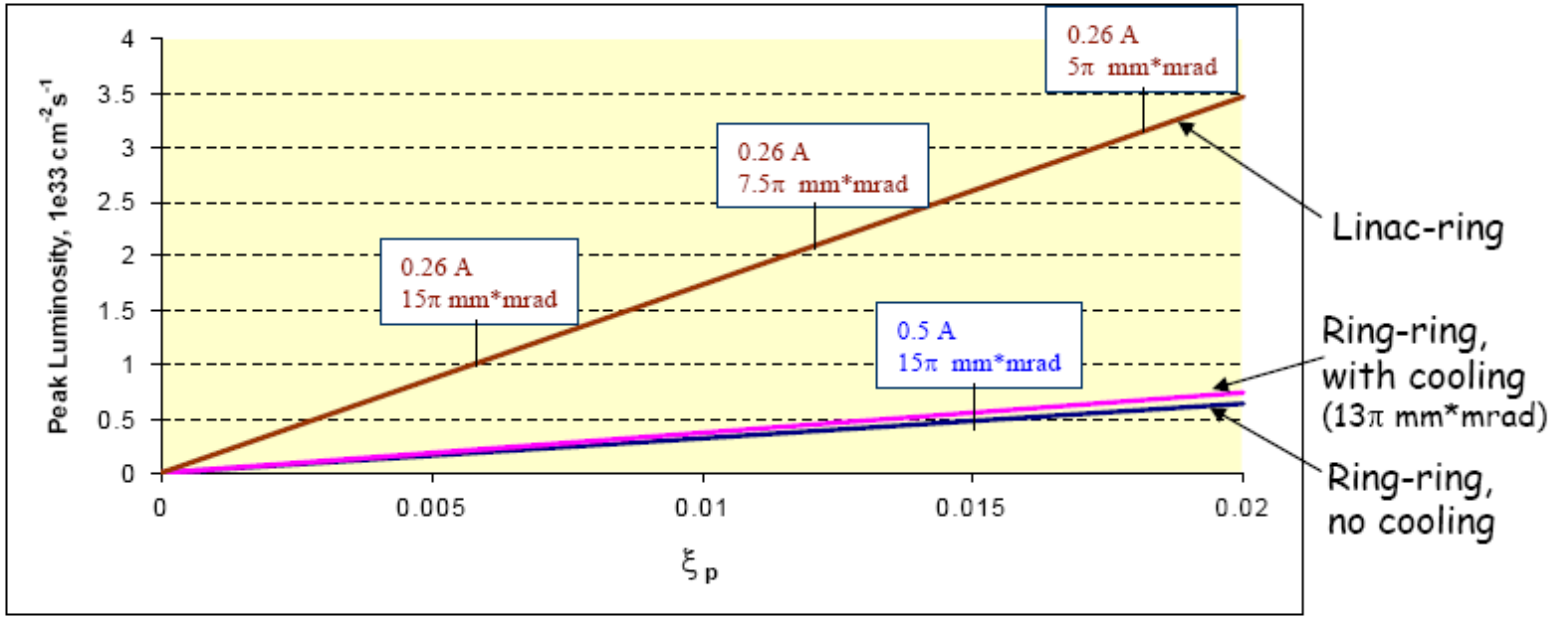
Another design version (ring-ring) serves as backup solution

ERL-based eRHIC Parameters

	High energy setup		Low energy setup	
	p	e	p	e
Energy, GeV	250	10	50	3
Number of bunches	166		166	
Bunch spacing, ns	71	71	71	71
Bunch intensity, 10^{11}	2	1.2	2.0	1.2
Beam current, mA	420	260	420	260
Normalized 95% emittance, p mm.mrad	6	115	6	115
Rms emittance, nm	3.8	1.0	19	3.3
β^*, x/y, cm	26	100	26	150
Beam-beam parameters, x/y	0.015	2.3	0.015	2.3
Rms bunch length, cm	20	1	20	1
Polarization, %	70	80	70	80
Peak Luminosity, 1.e33 $cm^{-2}s^{-1}$	2.6		0.53	
Aver.Luminosity, 1.e33 $cm^{-2}s^{-1}$	0.87		0.18	
Luminosity integral /week, pb^{-1}	530		105	

Luminosity with e-cooling

Calculations for 166 bunch mode and 250 Gev(p) x 10 Gev(e) setup;



Markers show electron current and (for linac-ring) normalized proton emittance.
In dedicated mode (only e-p collision): maximum ξ_p~0.016-0.018;

Transverse cooling can be used to improve luminosity or to ease requirements on electron source current in linac-ring option.
For proton beam only e-cooling at the injection energy is possible at reasonable time (~1h)

Coherent Electron Cooling (V.N. Litvinenko, Ya.S. Derbenev)

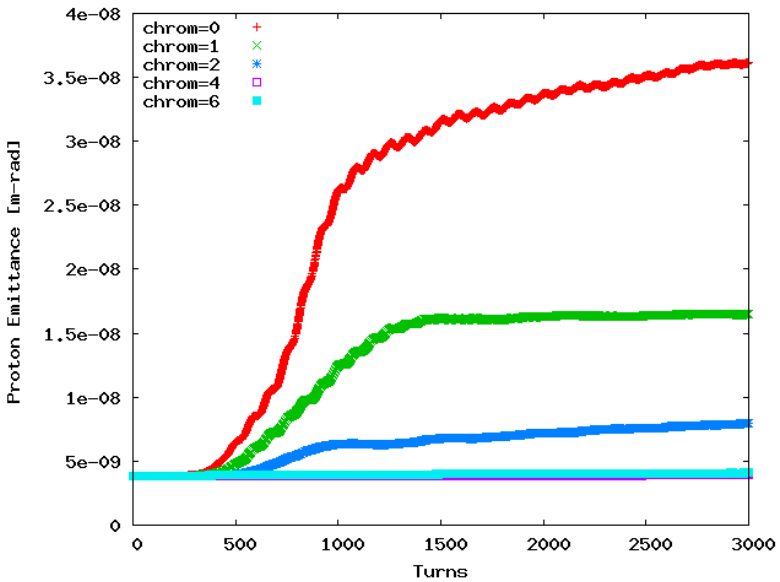
of high energy protons may be possible with present FEL and ERL technology

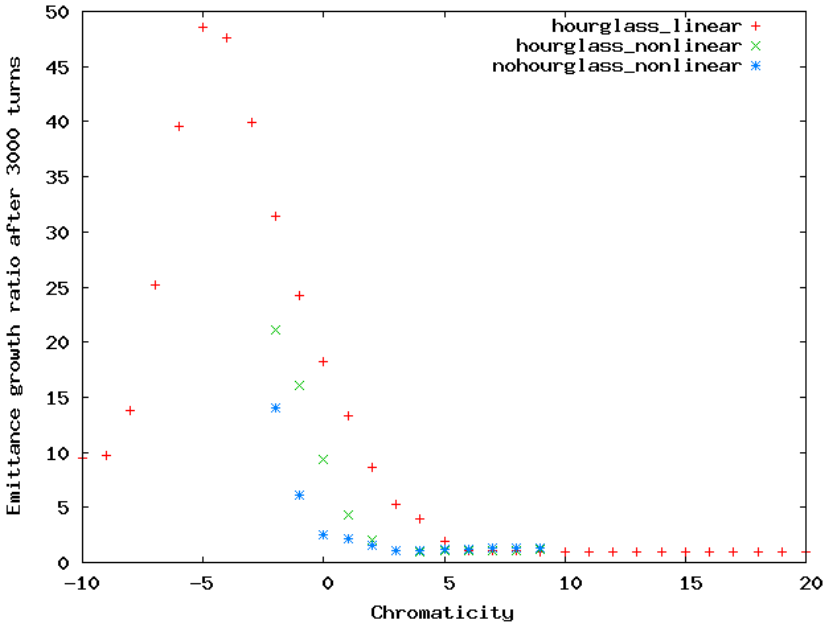
Main R&D Items

- Electron beam R&D for ERL-based design:
  - High intensity polarized electron source (for polarized beams!)
    - Development of large cathode guns with existing current densities ~ 50 mA/cm^2 with good cathode lifetime. (MIT-Bates)
  - Energy recovery technology for high power beams
    - 5-cell cavity; BNL test ERL; loss protection; instabilites.
  - Development of compact recirculation loop magnets
    - Design, build and test a prototype of a small gap magnet and its vacuum chamber.
  - Evaluation of electron-ion beam-beam effects, including the kink instability and e-beam disruption
    - Realistic beam-beam simulations.
- Main R&D items for ion beam:
  - Polarized ^{3}He production (EBIS) and acceleration
  - 166 bunches

Recent beam-beam studies: kink instability

Y.Hao





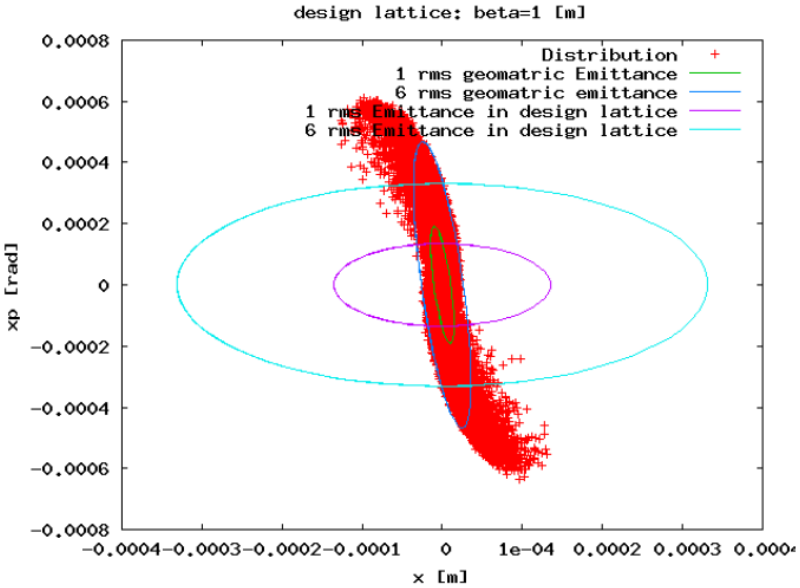
Nonlinear force model with Hourglass effect

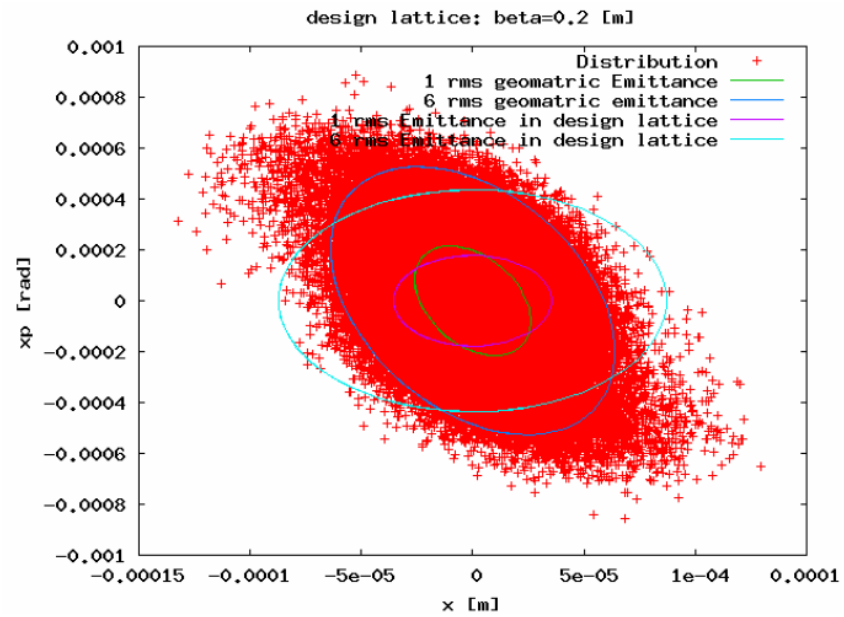
With rms proton energy spread =1e-3

The optimum chromaticity is around +4

Electron beam disruption

Y.Hao





Old IR optics

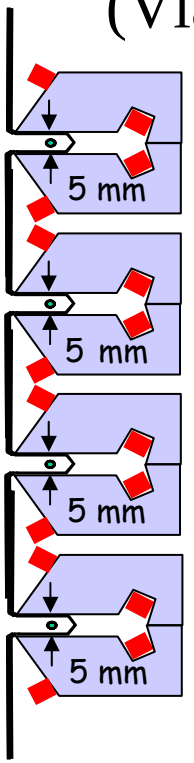
Disruption parameter ~ 5

Reoptimized electron IR optics:
β*=0.2m, s*= 0.2m

Disrupted beam has to be transported and decelerated.
Power in beam halo defines the aperture (and cost!) of magnets.

Recirculating passes

Compact magnet loops
(Vladimir)



Separate loops
Small aperture magnets

Approved LDRD

FFAG
(Dejan)

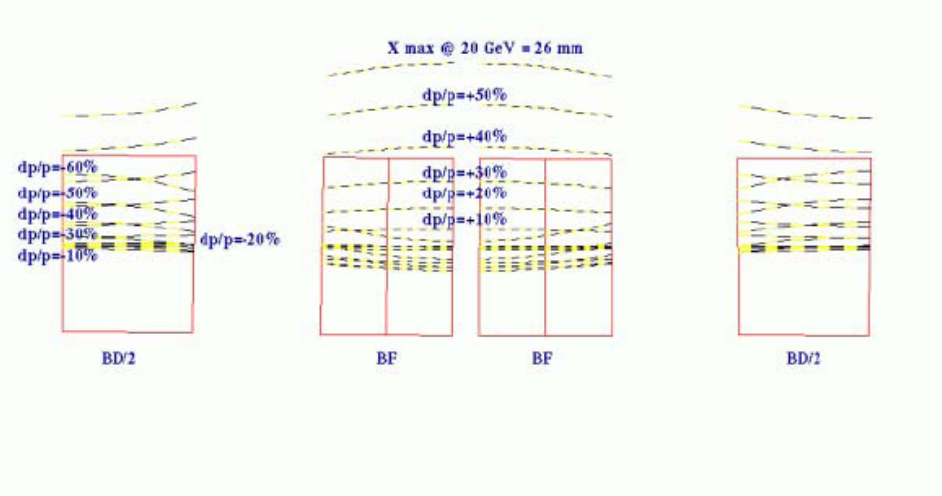
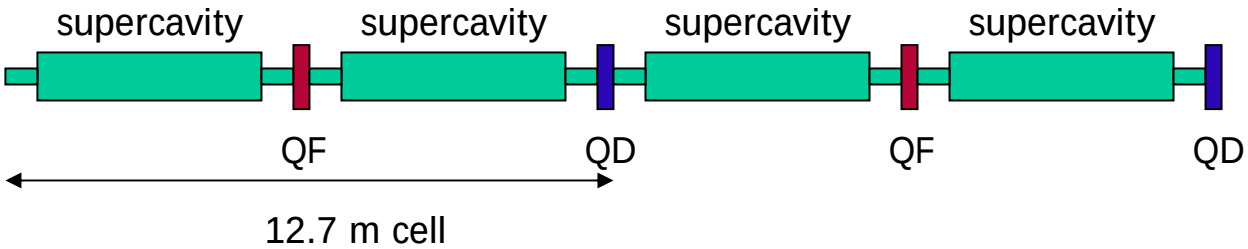


Figure 2: Magnets and orbit offsets in the "arc" cell.

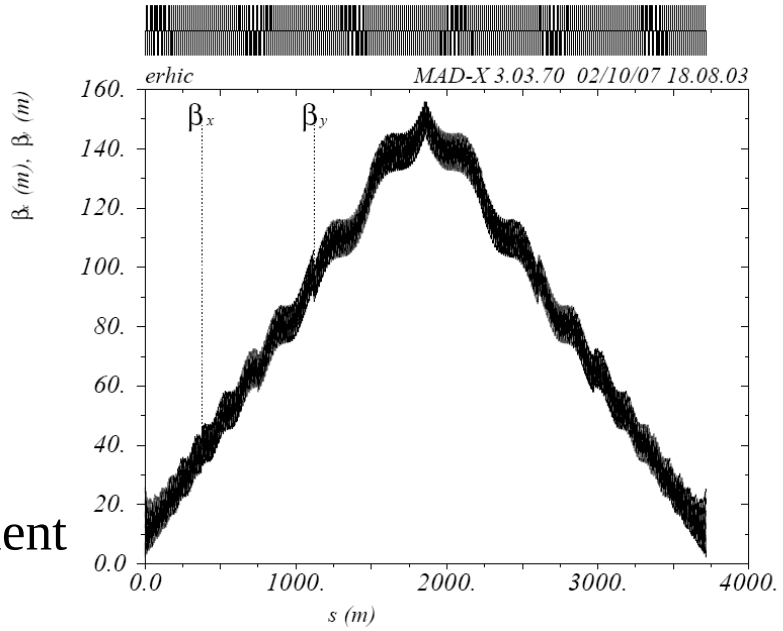
Synchrotron radiation loss problem

Linac optics development



Supercavity: two 700 MHz cavities with up to 19 Mev gain/cavity
+ 2.1 GHz cavity

Total energy gain per supercavity ~ 34 MeV



Optics solution
with constant gradient

eRHIC interests from beam studies and RHIC operation experience

- Main interest is to the effects related with increased number of bunches and higher total beam intensity.

  The present design intensity is 2e11 protons per bunch in 166 bunches.

  - Electron cloud related effects:
    - Instabilites
    - Emittance growth.

  - Studies of cryogenic load due to vacuum pipe heating .

- Also, of interest is better understanding of beam-beam limits at RHIC.

  - New working point experience
  - Beam-beam compensation scheme (electron lens).