Hadron Intensity Upgrade

Wolfram Fischer

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Upgrade parameters

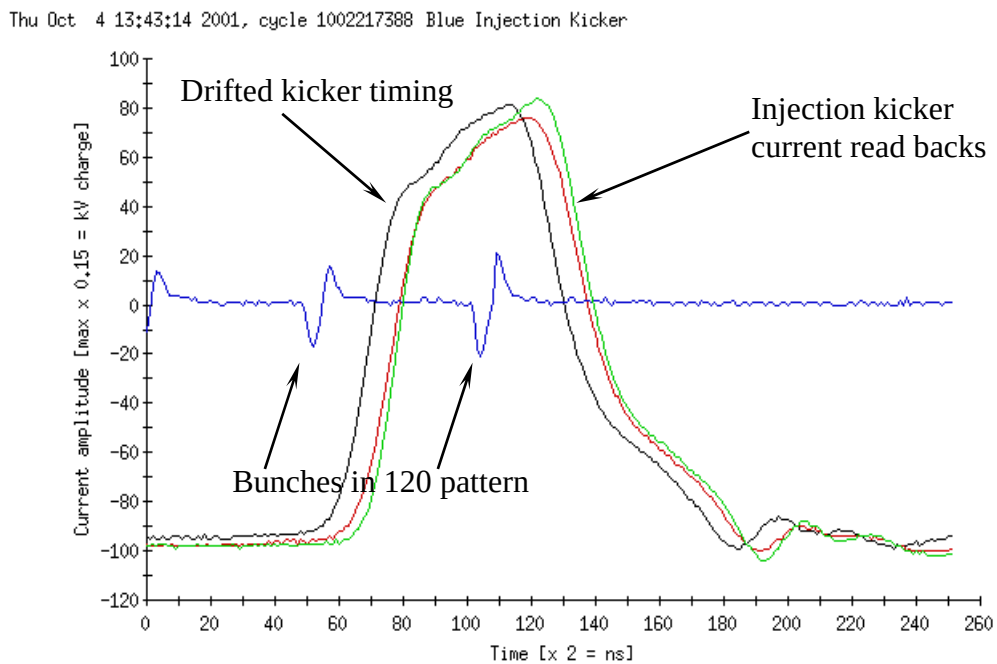
	RHIC Enhanced Luminosity (2008)		eRHIC Ring-Ring	eRHIC Linac-Ring
Bunch intensity Au [10^9]	1	→	1	1–2.5
Bunch intensity p [10^{11}]	2	→	1	1–2
Bunch number (no abort gap)	120	→	360	up to 360
Bunch spacing [ns]	108	→	36	up to 36

Hadron intensity upgrade issues

- Injection
- Vacuum breakdown
- Increased heat load
- Instabilities
- Long-rang beam-beam interactions
- Beam abort and radiation safety

Injection

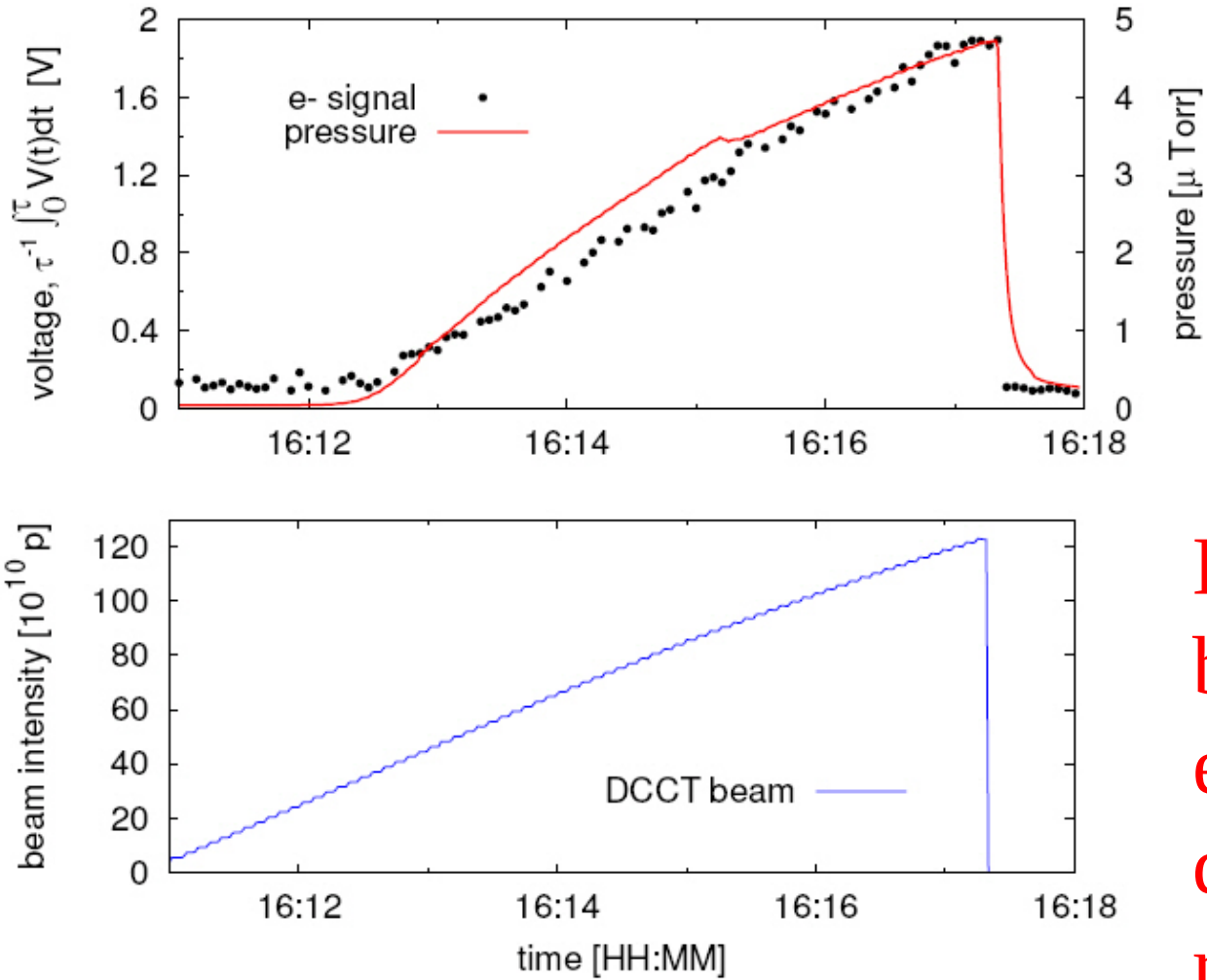
- Current injection scheme bunch-by-bunch, bunch spacing limited by injection kicker rise time
- Consider 3 options:
  - **Very fast injection kickers**
  - **Long flattop injection kickers**
  - **Barrier rf stacking**



Injection

- Very fast injection kickers
  - 57ns (→180 bunches) rise time may be possible
  - 20ns (→360 bunches) rise time requirements are extreme
- Long flattop injection kickers ← Most conventional approach
  - Transfer whole AGS fill into RHIC
    → need 28 MHz rf system in AGS
    → need ~10x more Booster cycles per AGS fill than now
- Barrier rf stacking
  - Use barriers to maintain increasingly long bunch, inject into a bucket that is then merged into the long bunch

Vacuum break down



Due to shorter bunch spacing electron-cloud driven pressure rise is enhanced

[Example from Run-3 pp, unbaked stainless steel bo2.]

Vacuum break down

- Currently warm beam pipe upgrade (NEG), and cold beam pipe upgrade (pre-pumping)
- May need to treat some elements further
  - → NEG coating of instrumentation elements
  - → Reconditioning of NEG at lower pressure
  - → Solenoids on NEG pipes or other elements
  - → Scrubbing with beam
- At this point uncertain if full 360 bunches can be stored

Vacuum breakdown

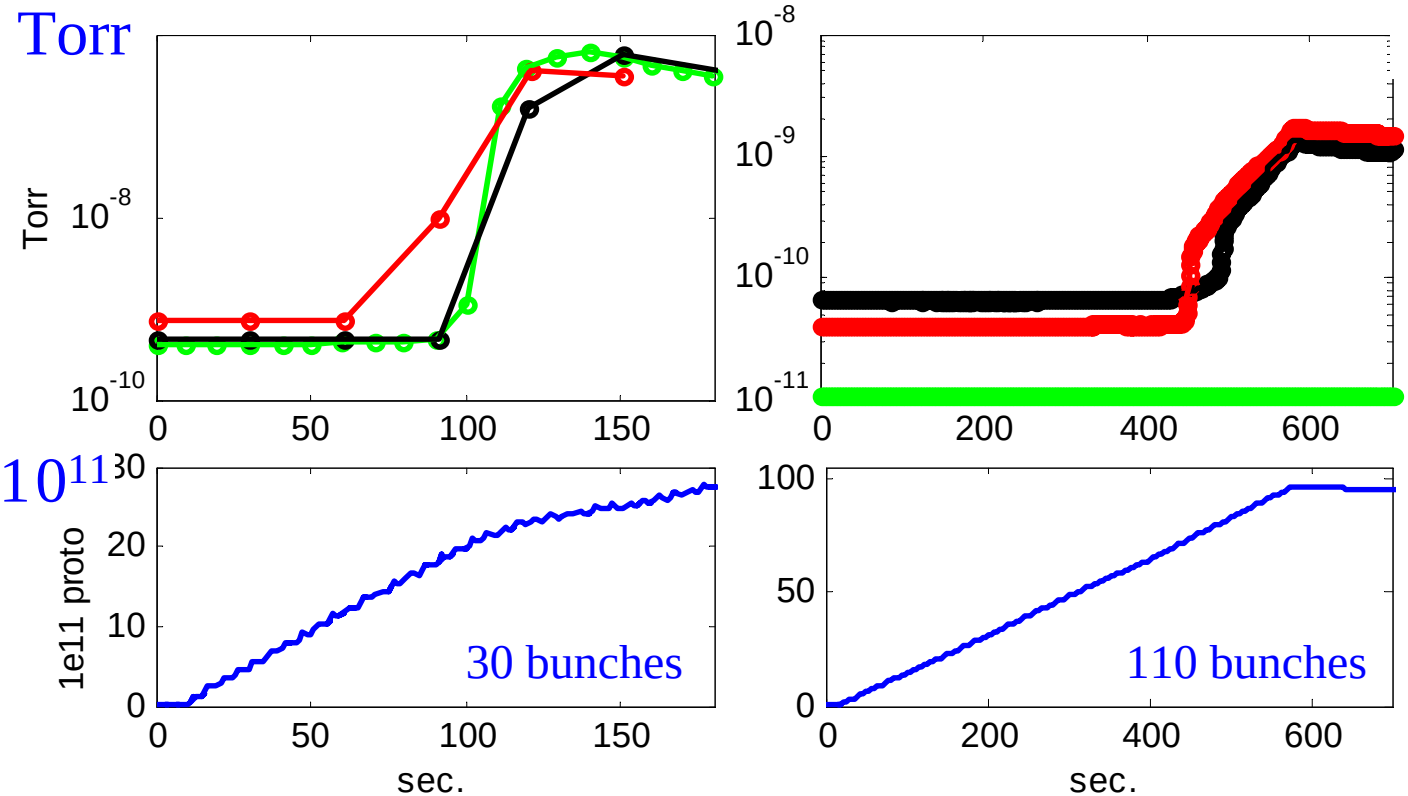
Injection of 1×10^{11} proton bunches, 3 buckets spacing, same location

2002

2005

1e-6 Torr

1e-8 Torr



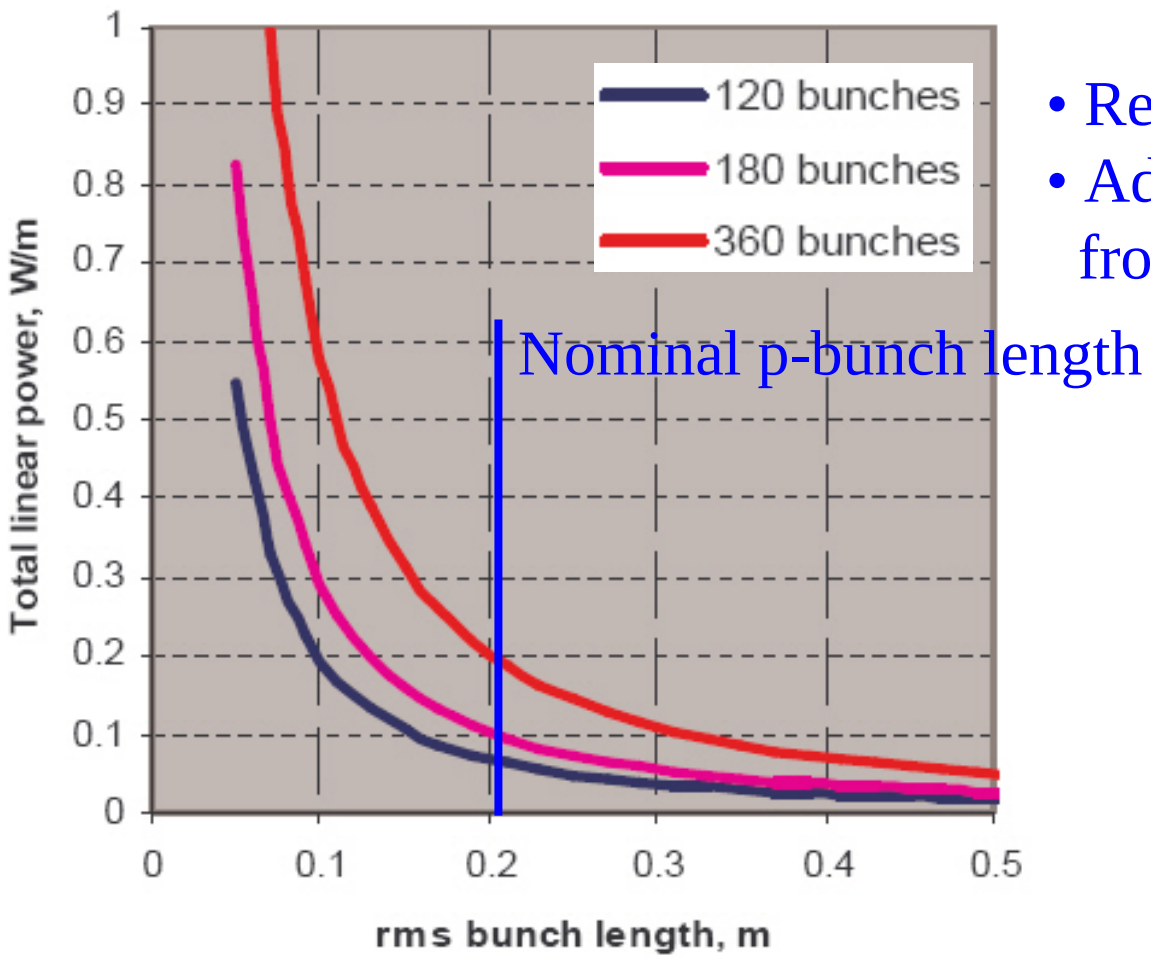
30×10^{11}

100×10^{11}

S.Y. Zhang

Heat load

- 0.5-1.0 W/m of heat load tolerable



- Resistive wall heat load
- Additional contribution from electron clouds likely

Instabilities – single-bunch

- So far all instabilities were single bunch, most vulnerable at transition
  (although enhancement observed with e-clouds)

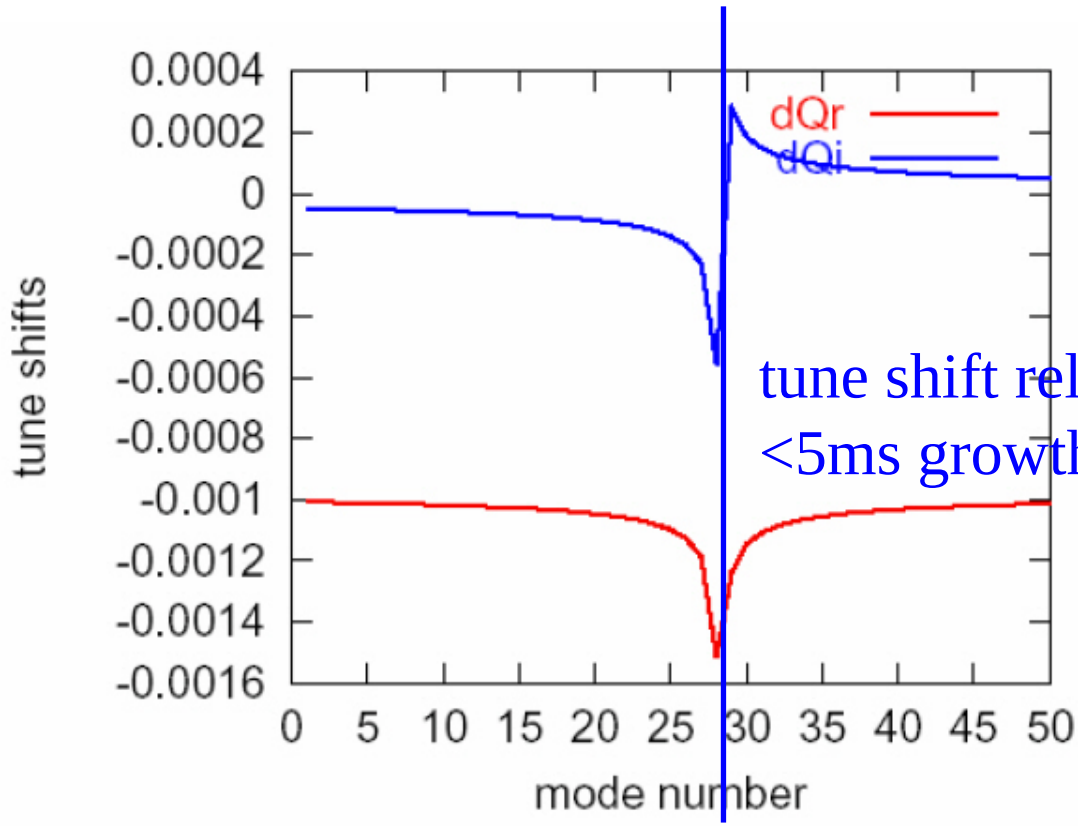
- Had stored 1.7×10^{11}p/bunch at $\gamma = 100$ (eRHIC 1.0×10^{11})
- Had stored 1.1×10^{9}Au/bunch at $\gamma = 100$ (eRHIC 1.0×10^{9})

→No problems expected from single-bunch instabilities in eRHIC.

(May need to increase transverse tune spread with lower emittance – octupoles or beam-beam.)

Instabilities – multi-bunch

M. Blaskiewicz

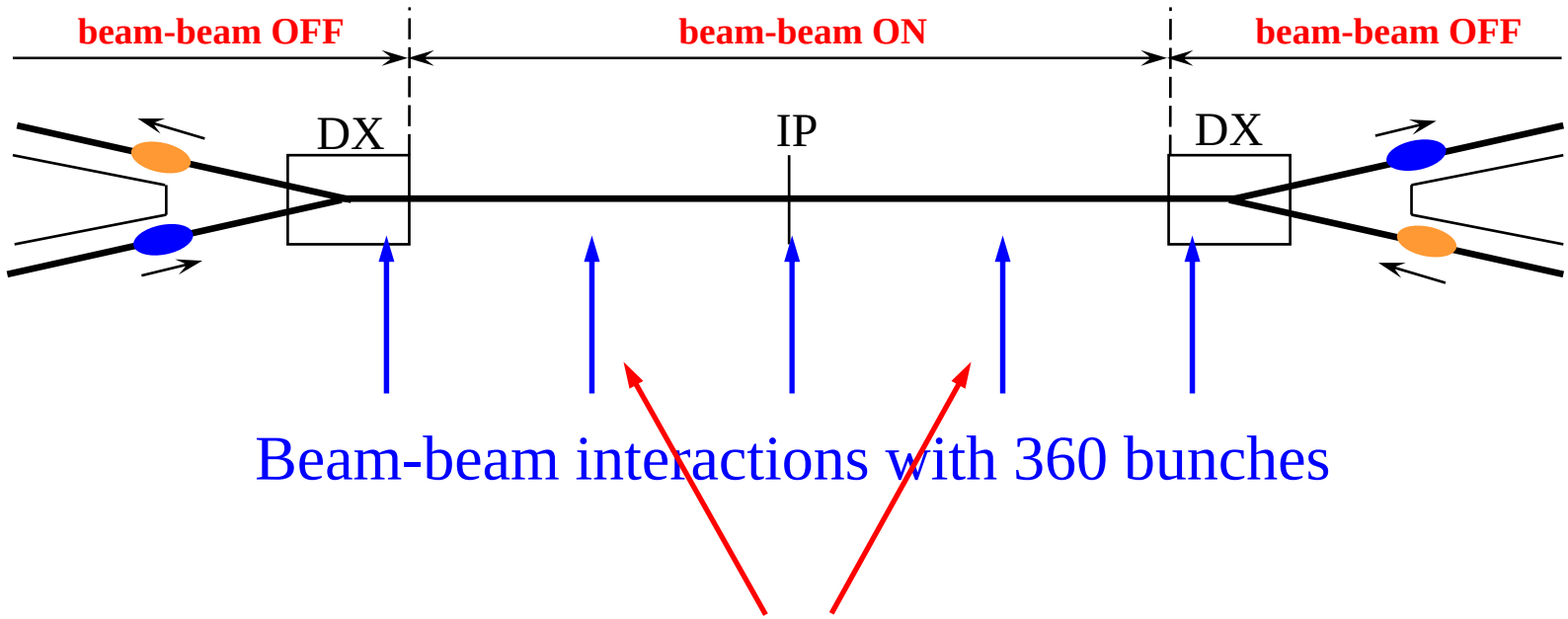


tune shift relatively flat
<5ms growth time, could be damped

- Impedance model includes resistive wall, abort kickers, and unshielded bellows.
- May be too low by up to a factor 3
- Calculation for injection (worst case)

Long-range beam-beam interactions

No long-range beam-beam interactions with 120 bunches apart from nominal IP



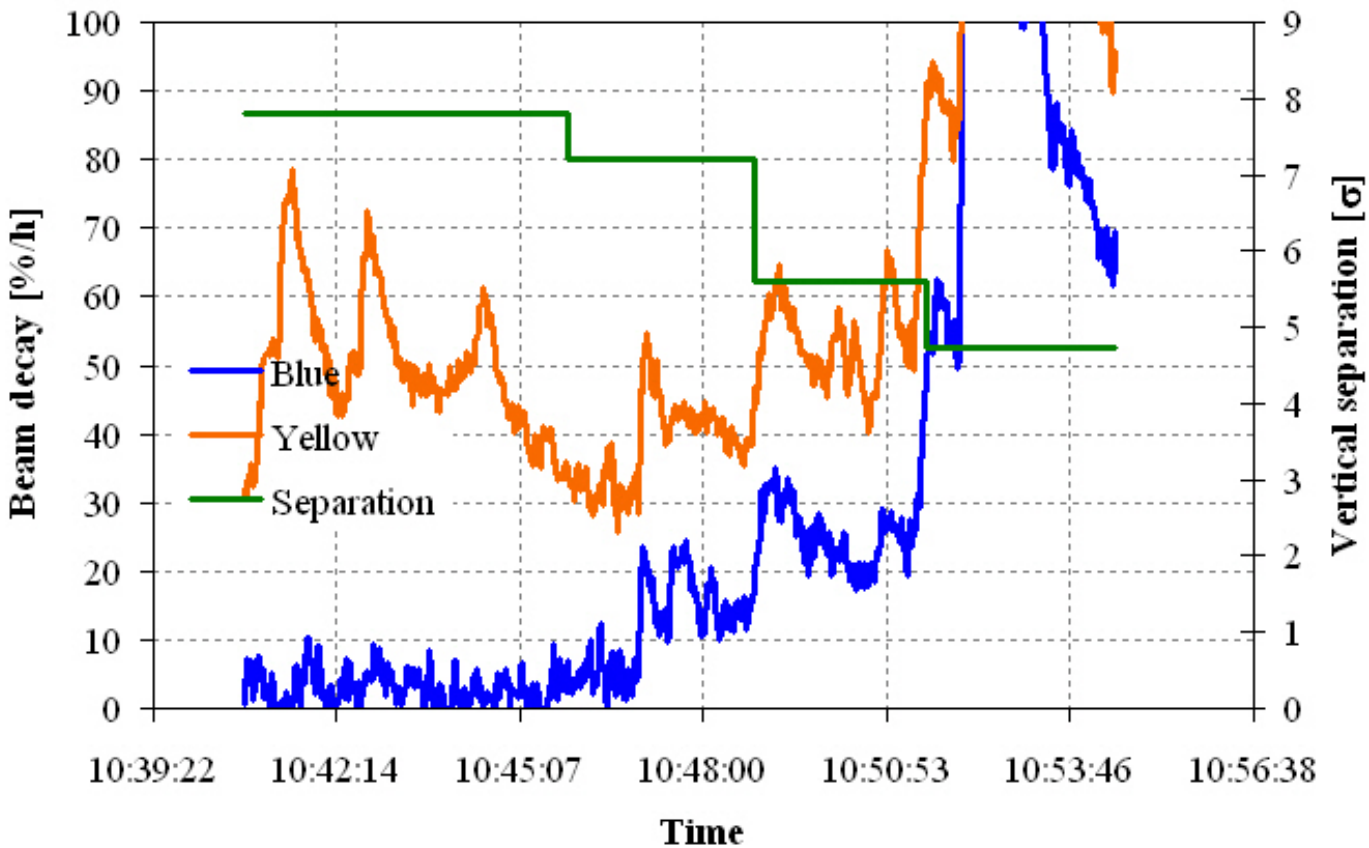
Beam-beam interactions with 360 bunches

8 σ separation for γ =100 and 0.5mrad crossing angle in store

Expect problems during ramp

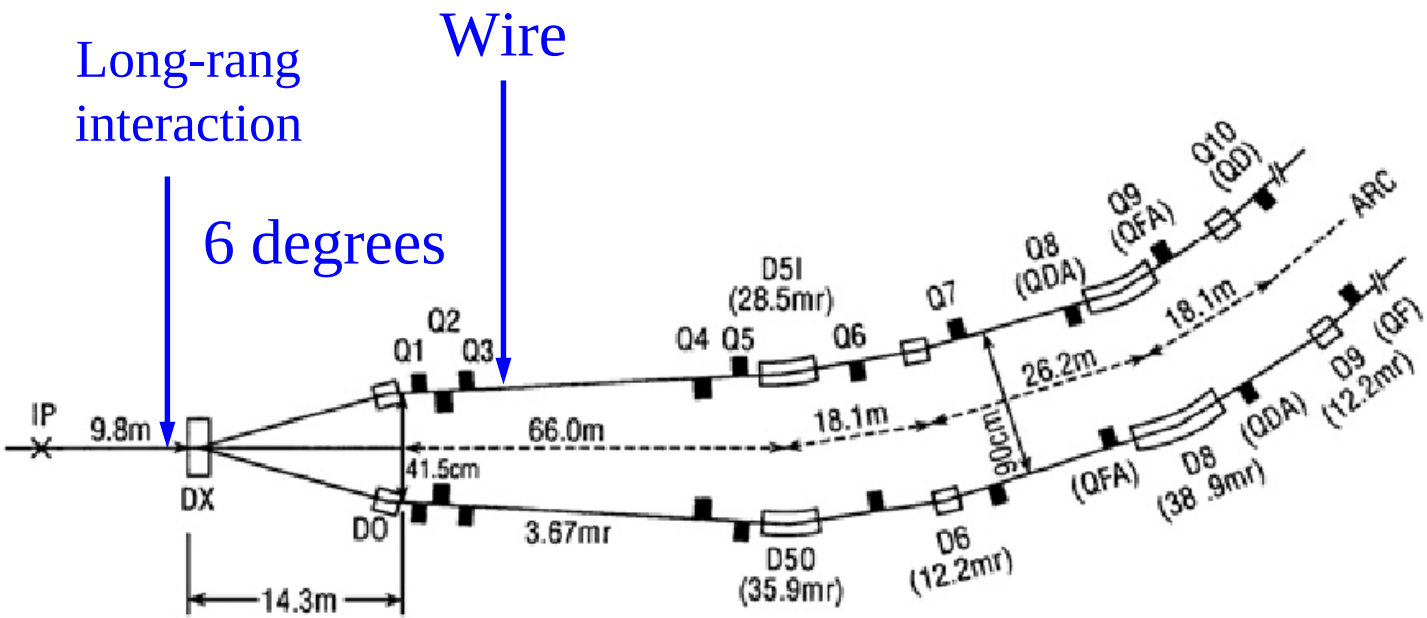
Long-range beam-beam interactions

- Study long-range compensation with wire as an option
  (collaboration with CERN and FNAL within LARP)
- Confirmed measurable effect on long-rang interaction



Long-range beam-beam interactions

- Plan to install an SPS-like compensating wire for test
  Initial compensation of single long-range interaction



- Compensation of several interactions still needs study

Beam abort issues

- Need to increase Accelerator Safety Envelope (ASE) for eRHIC by 50% (total intensity limit)
- Early RHIC notes show concern for
  - absorber heating (→may need cooling)
  - Quench in Q4
- Existing experience not sufficient to safely extrapolate

Summary

- Most severe limitations are expected from electron clouds
- Significant changes in the injection system needed
- Radiation safety, abort system and long-range beam-beam interactions are also of concern
- Linac-Ring option less demanding on ion beam upgrade for same luminosity as Ring-Ring option