# RHIC long-range beam-beam measurements

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Acknowledgements:
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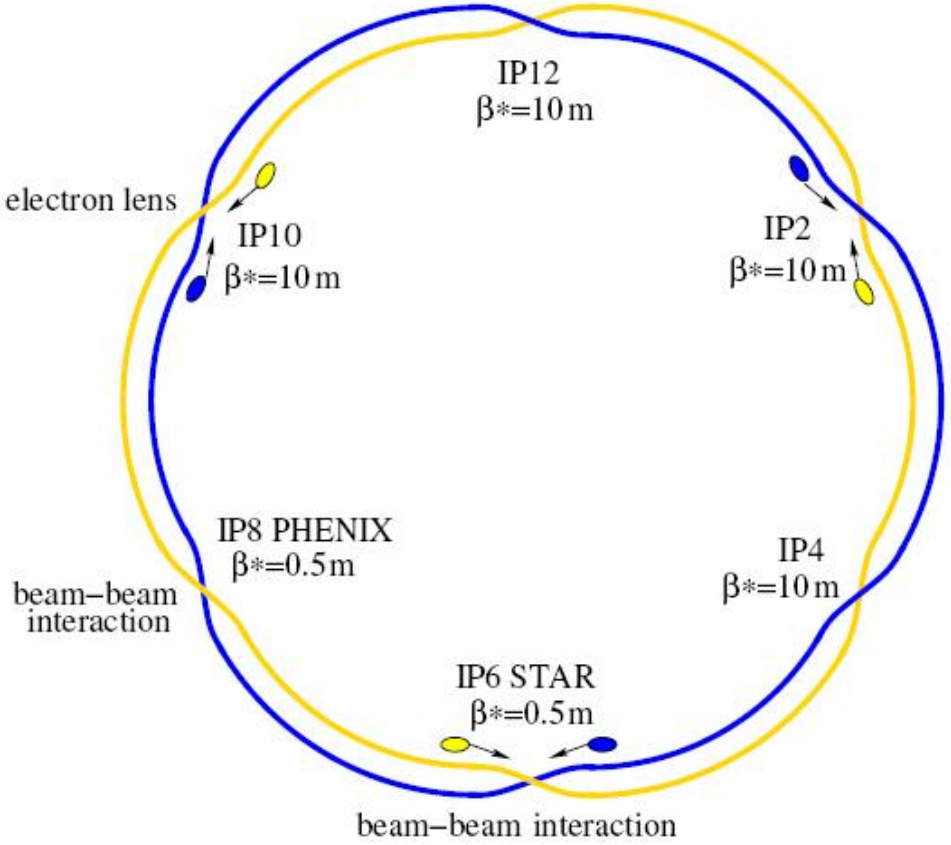
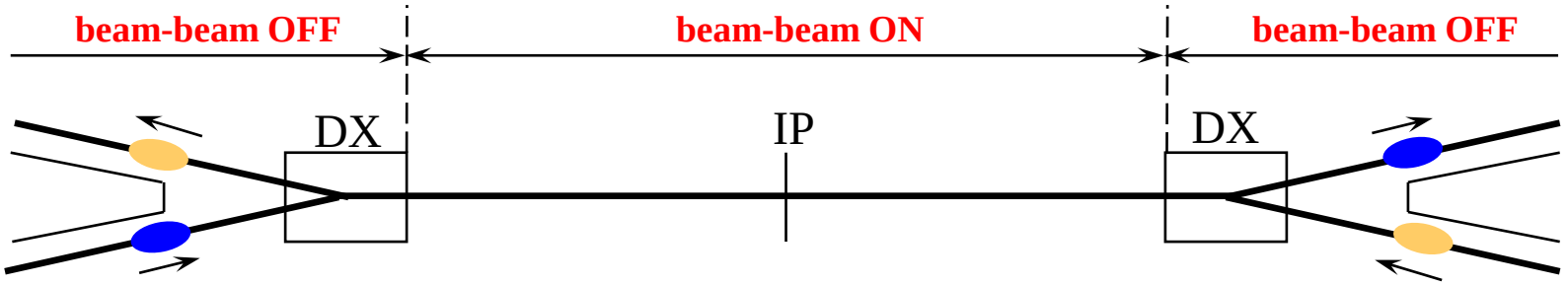
# Beam-beam effects in RHIC




- Two independent rings
- Dipole first IR
- Nominally no crossing angle
- 2 head-on collisions
- 4 long-range collisions
  (15σ vertical separation)
- Beam-beam couples 6 bunches
  (3 Blue and 3 Yellow)

**Need special setup of long-range experiments**

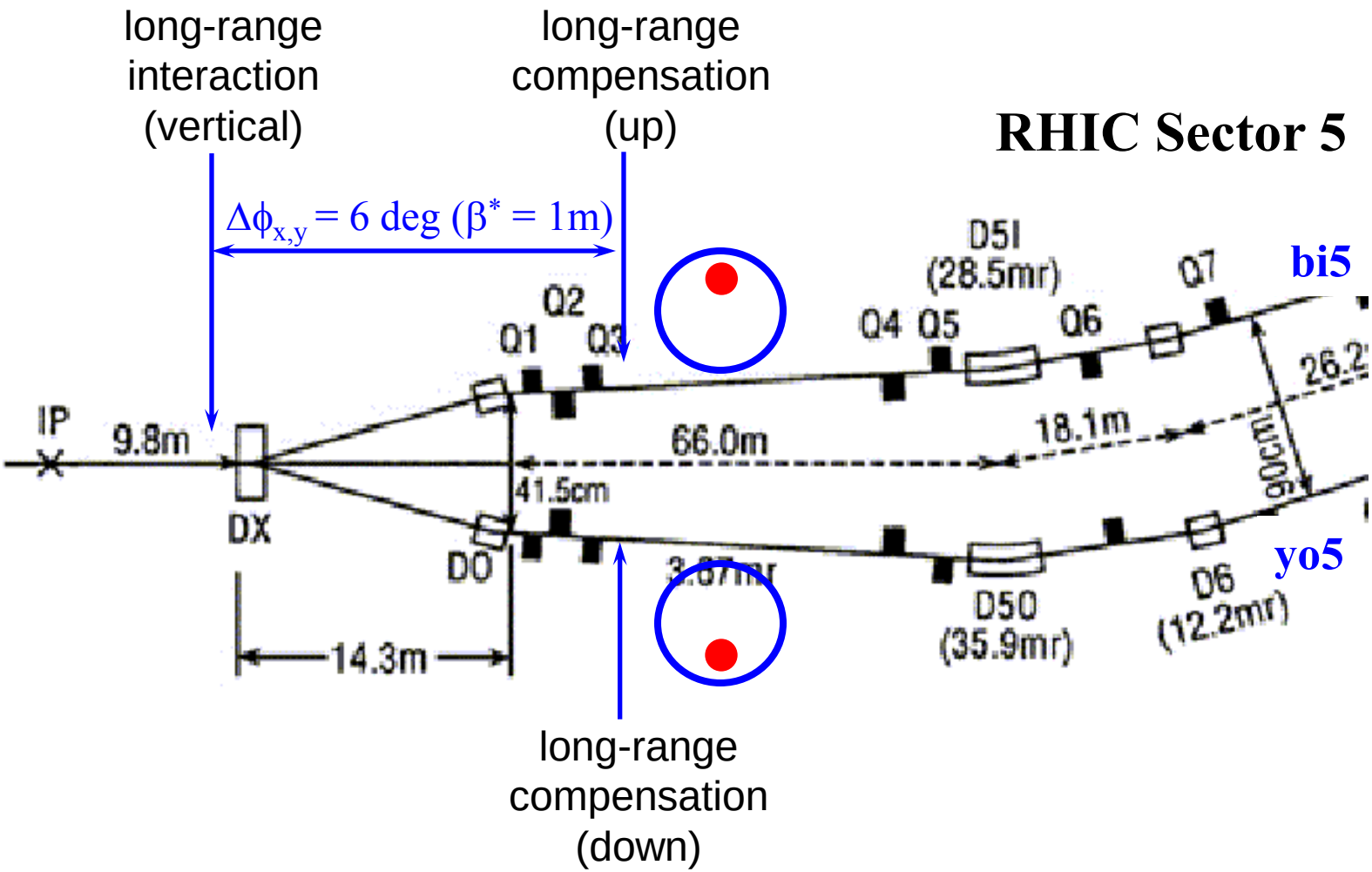


# RHIC long-range beam-beam studies for LHC

Motivation:

- RHIC with wires allows to study strong localized long-range beam-beam effect – like in LHC
  (long-range not localized in Tevatron)
- Beam lifetime in RHIC is typical for hadron collider
  (unlike SPS during wire experiments due to low beam energy)
- Head-on beam-beam effect can be added
  (not possible in SPS)
- Experimental data used to benchmark simulations, compensation of single long-range interaction possible

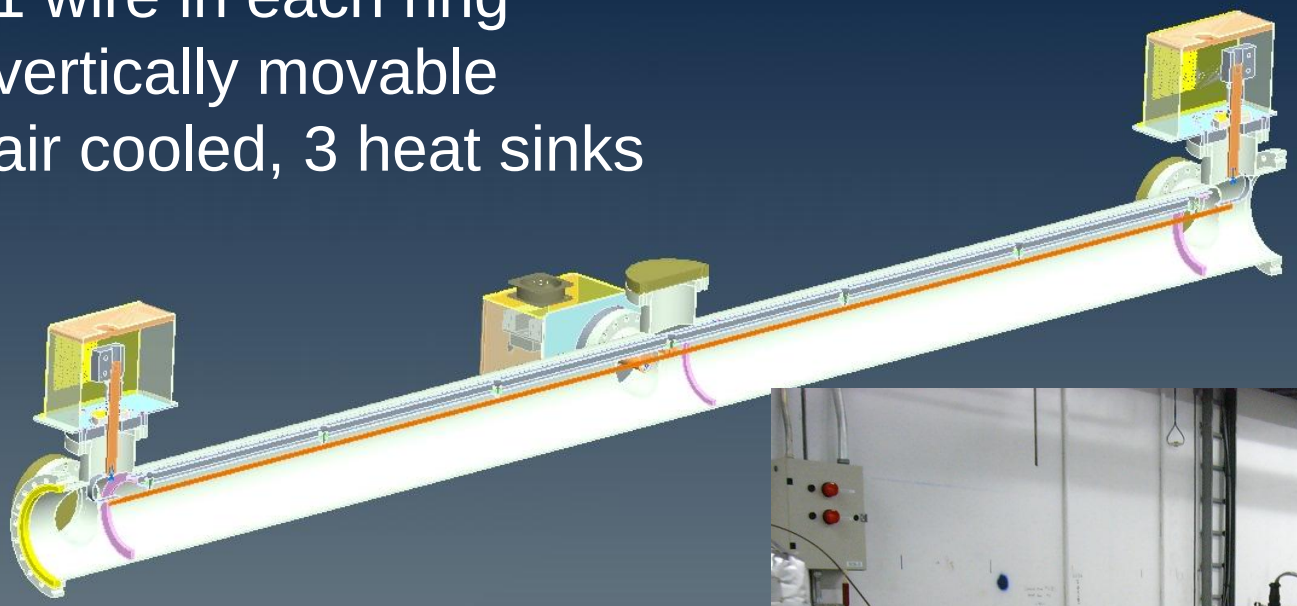
# RHIC long-range wire layout

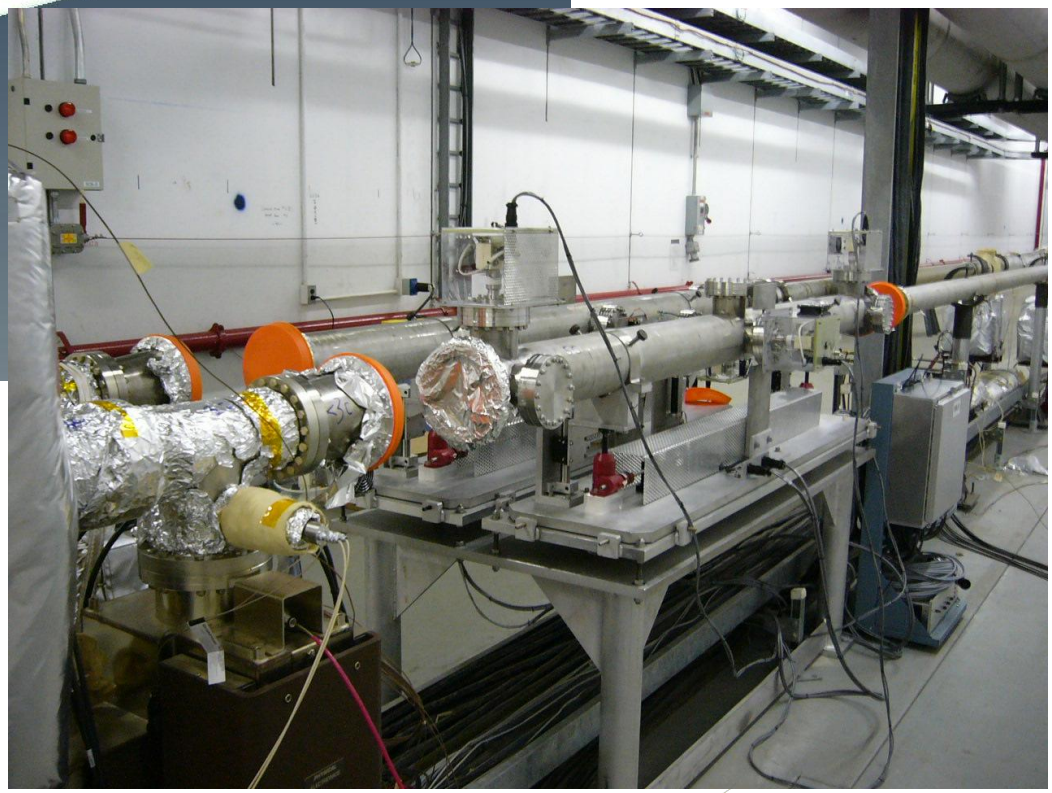



**Small phase advance between long-range beam-beam interaction and possible compensator can only be realized at store.**

# RHIC long-range wires

1 wire in each ring
vertically movable
air cooled, 3 heat sinks





2 parameters to vary:

- Distance to beam (0 – 65 mm)
- Strength (0 – 125 Am)

# RHIC long-range wire experiments

Measurements are beam lifetime observations with variations in

- Separation
- Strength (wire current)
- Other parameters (tune, chromaticity)

2005: p-beam at injection

2006: p-beam at store

2007: Au-beam & wire at store

2008: d-beam & wire at store

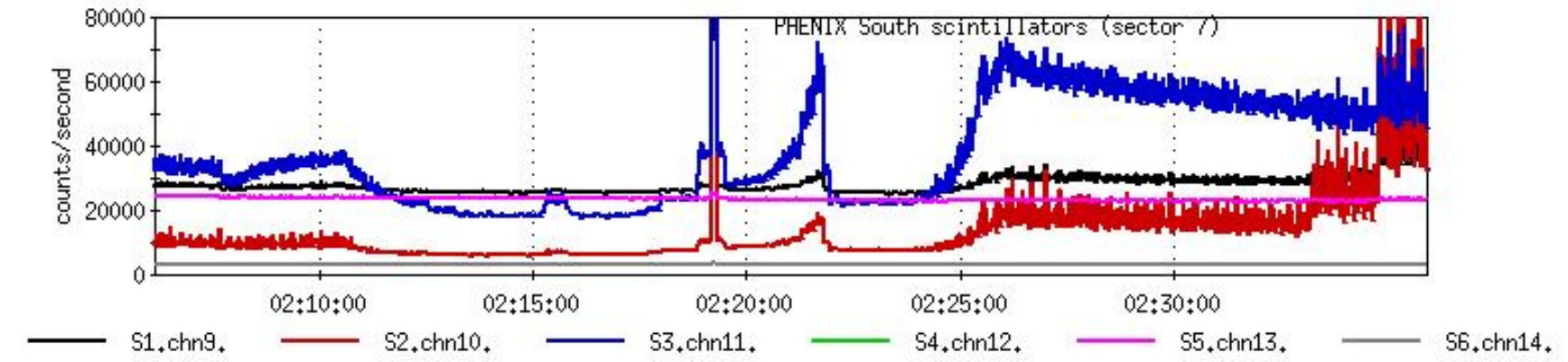
**2009: p-beam & wire at store, including head-on, compensation**

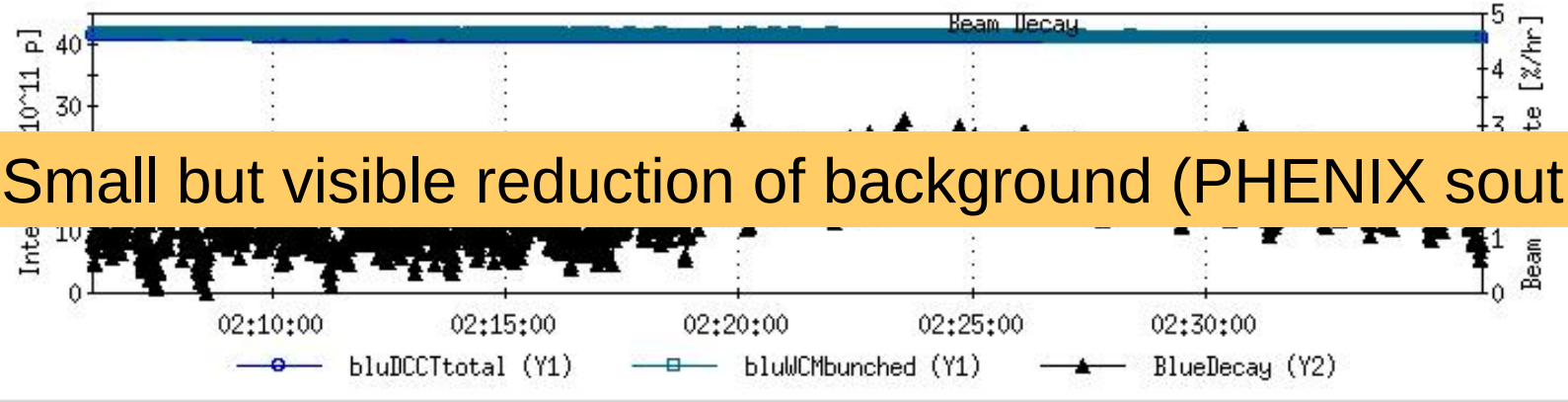
**BBLR measurements finished.**

# Run-10 measurements

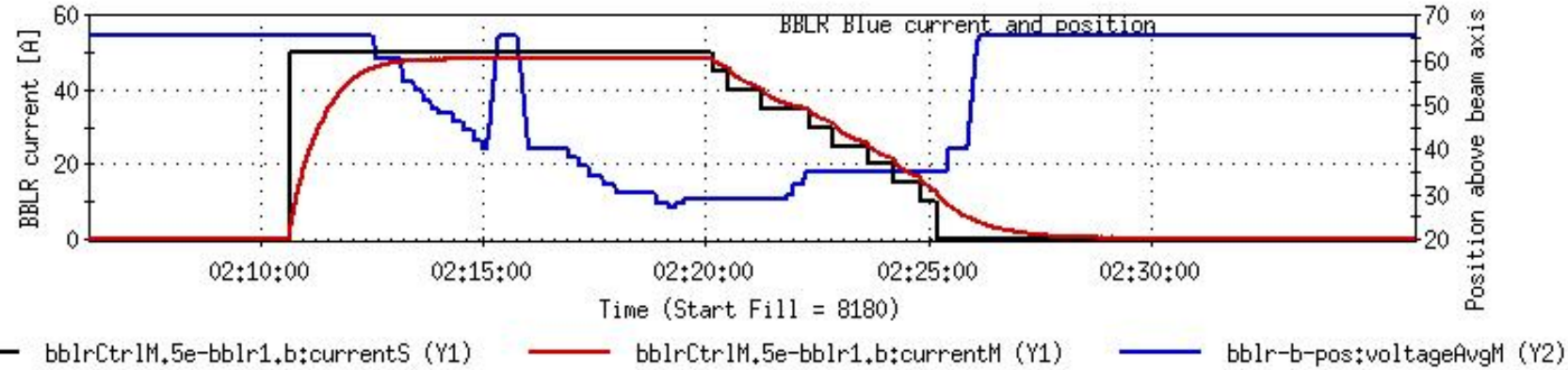
- **04/14/09 (10542 250 GeV)**
  BBLR effect on background (not APEX, parasitic)
- **04/14/09 (10554 250 GeV)**
  BBLR effect on background (not APEX, parasitic)
- **04/29/09 (10678 100 GeV)**
  5A and 50A distance scan in Blue and Yellow, including head-on beam-beam
- **05/13/09 (10739 100 GeV)**
  5A distance scan in Blue and Yellow
  Chromaticity scan in Blue
- **05/26/09 (10793 100 GeV)**
  5A distance scan in Blue and Yellow
  **Reduction of Yellow loss rate <u>with</u> BBLR**
- **07/05/09 (11055 100 GeV)**
  Attempt to reproduce compensation, failed.
  Noisy losses with 20 s period rate, cannot improve.

# 04/14/09 (10542) BBLR effect on Blue background

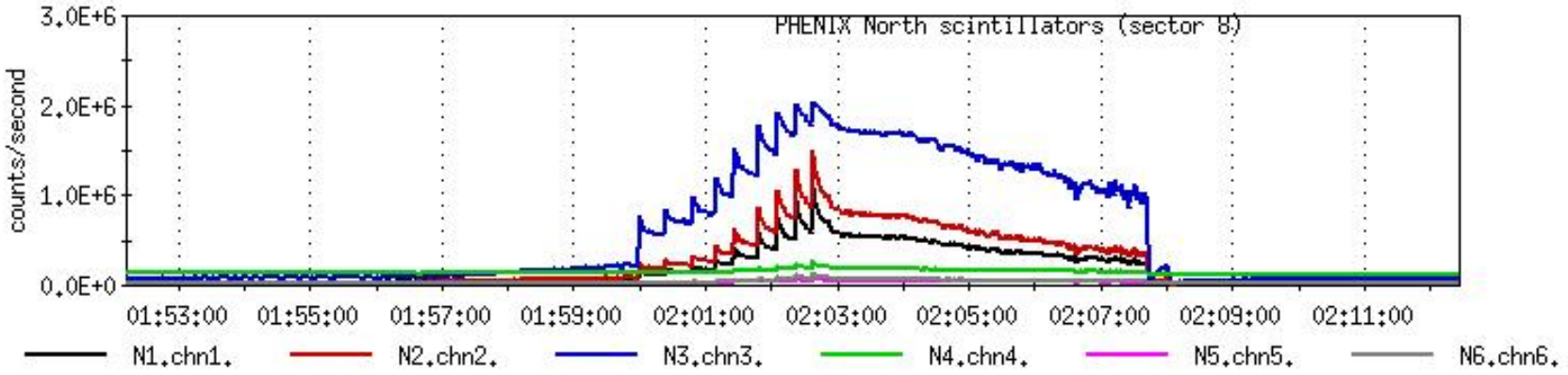


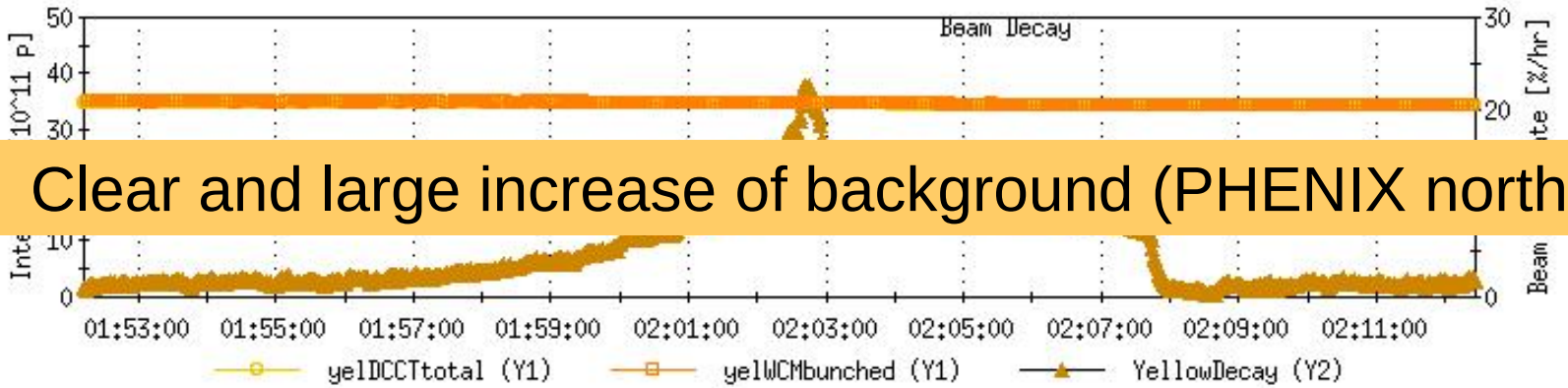




Small but visible reduction of background (PHENIX south)

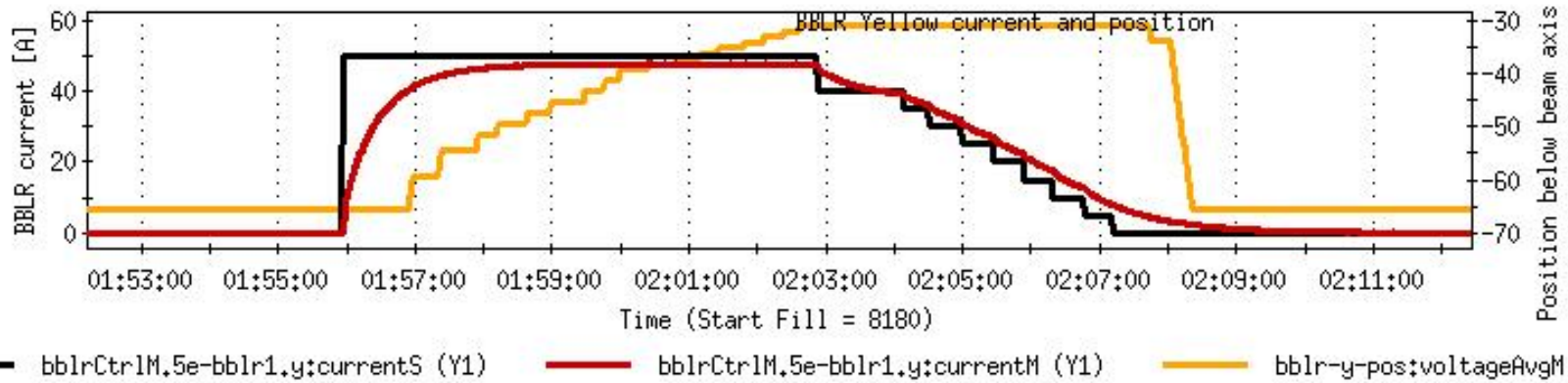


# 04/14/09 (10542) BBLR effect on Yellow background



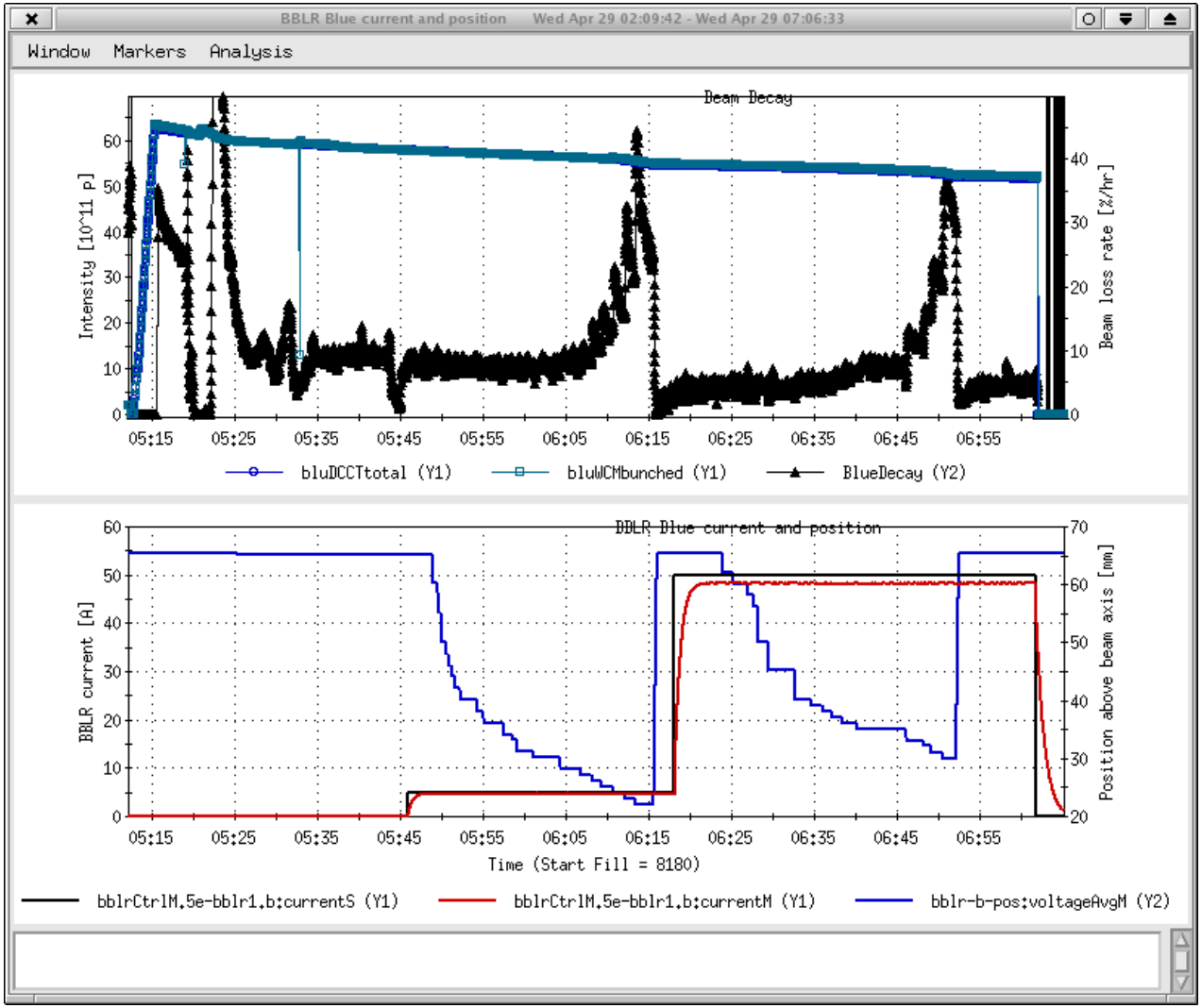




Clear and large increase of background (PHENIX north)



# 04/29/09 (10678) scan including head-on

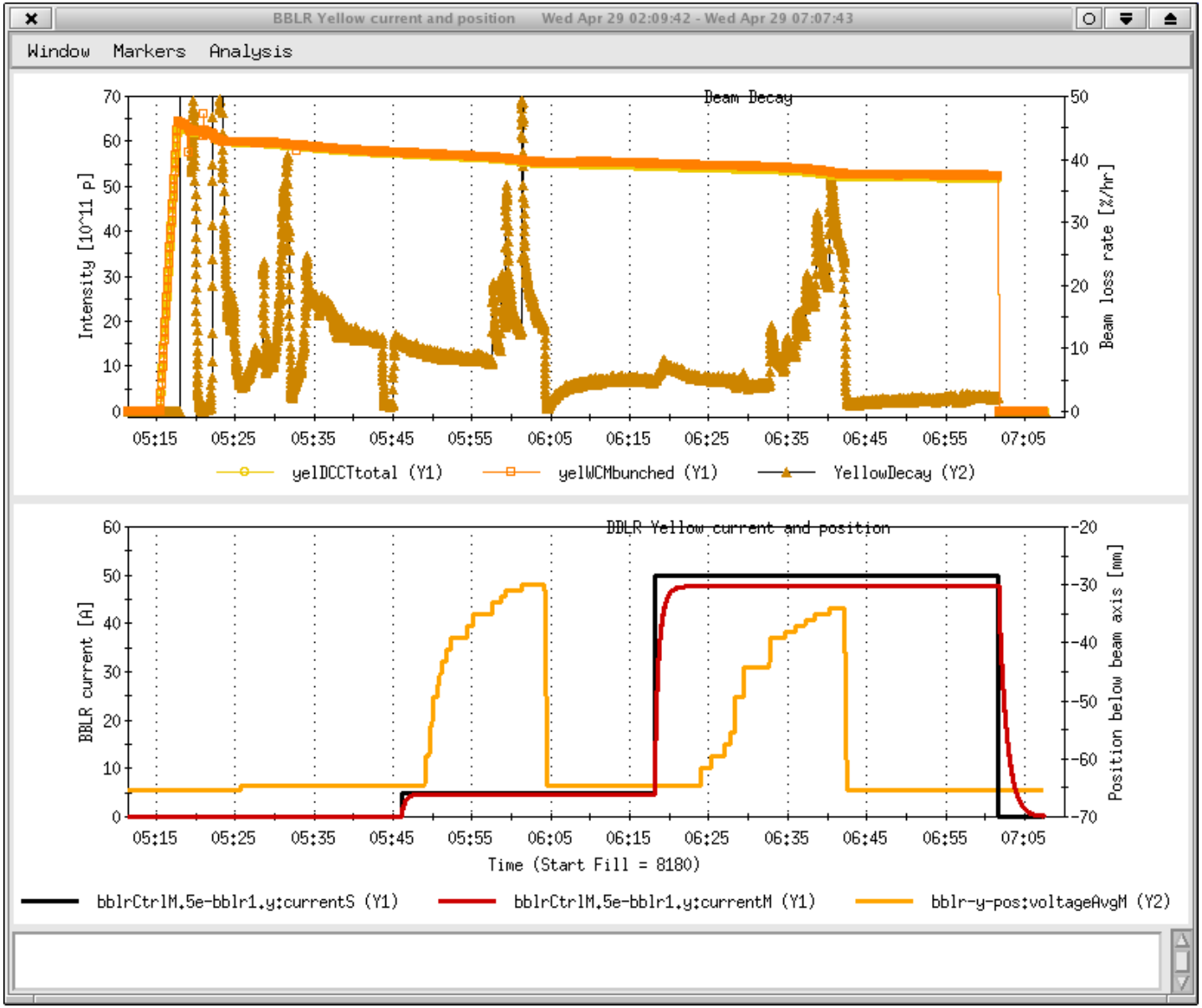
[BBQ on ramp resulting in large emittance]




Blue scan
5A and 50A

(not yet
simulated)

# 04/29/09 (10678) scan including head-on

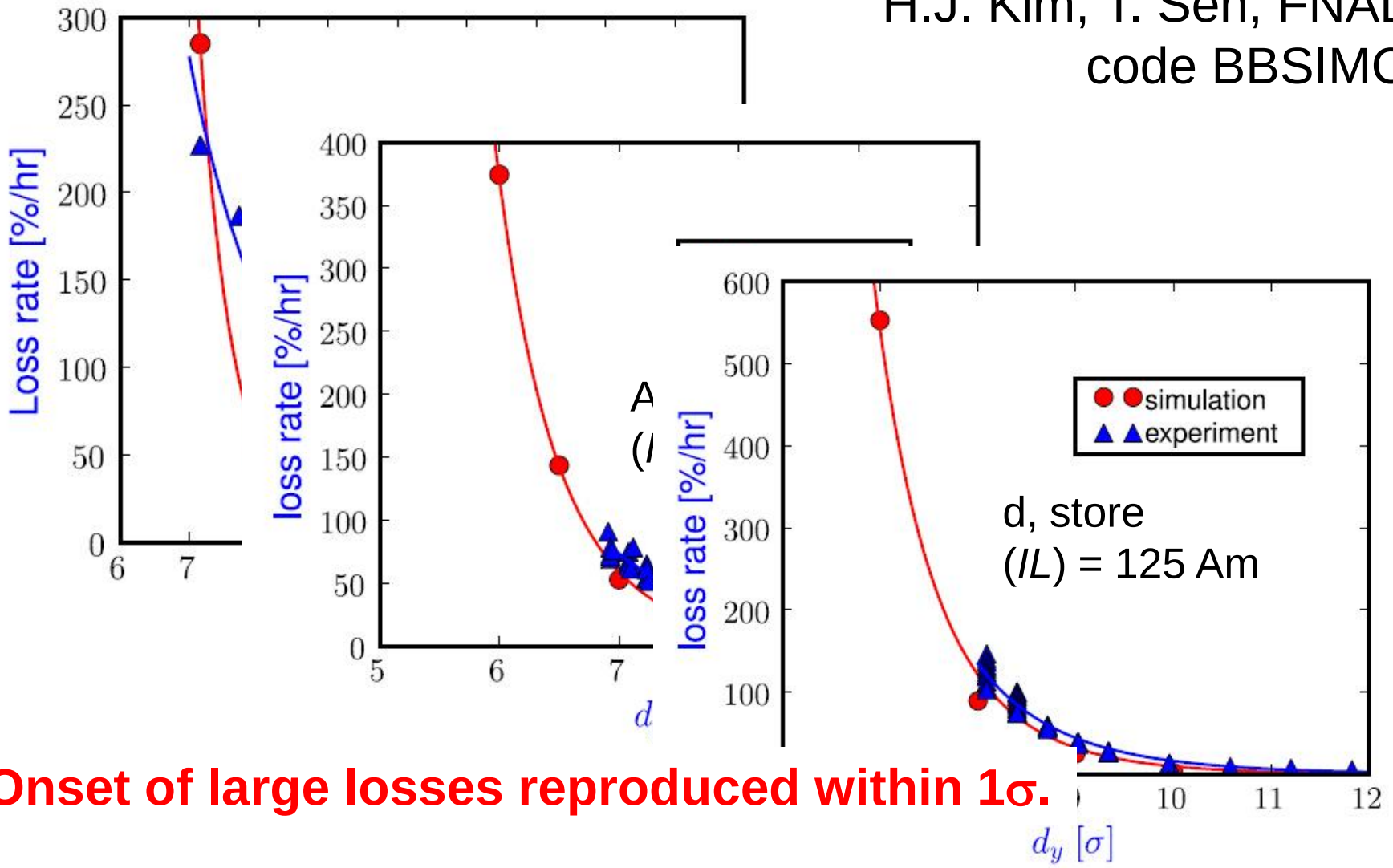



Yellow scan 5A and 50A

(not yet simulated)

# RHIC wire experiments – comparison with simulations

H.J. Kim, T. Sen, FNAL
code BBSIMC

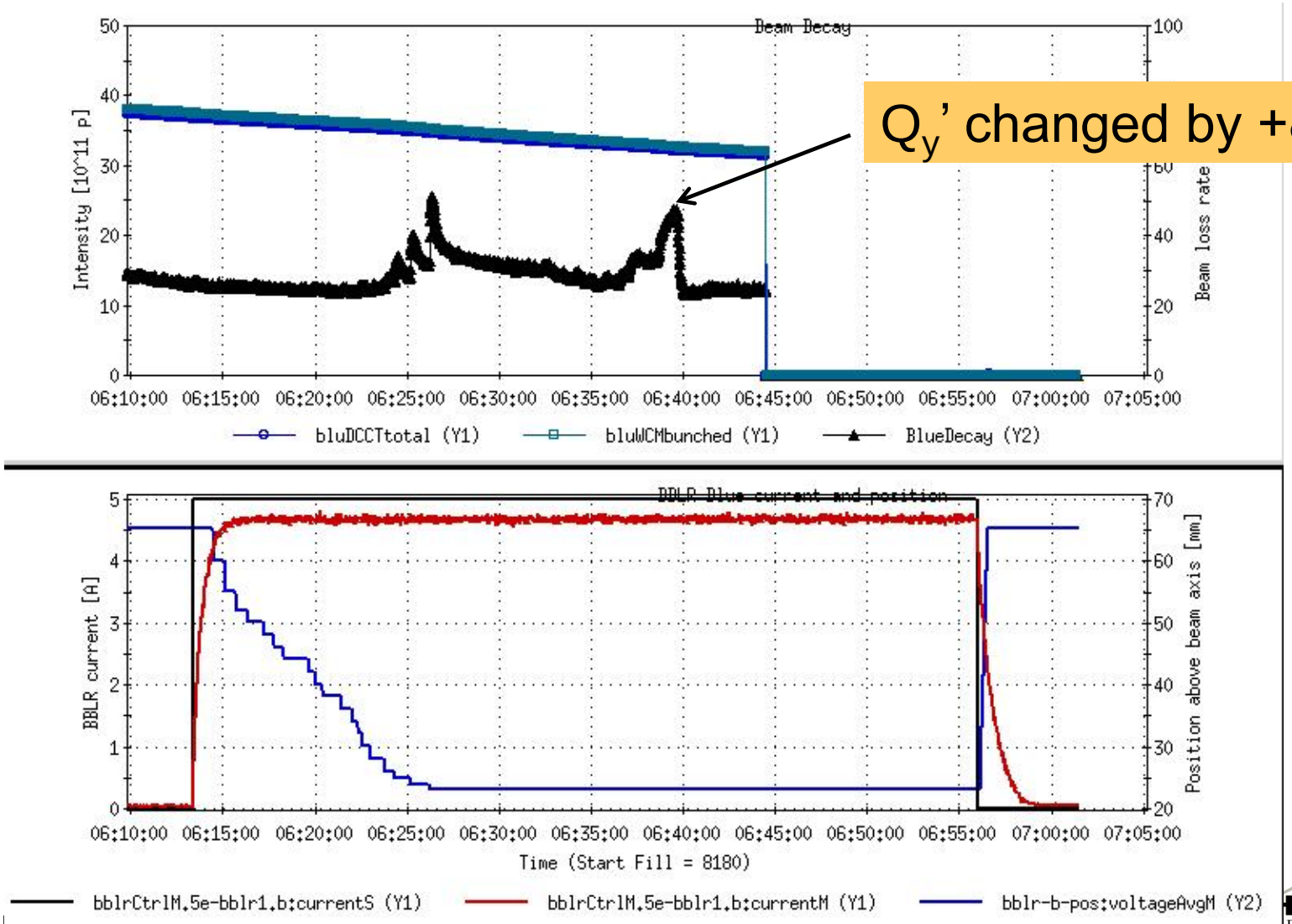



**Onset of large losses reproduced within 1σ.**

[H.-J. Kim et al., Phys. Rev. ST Accel. Beams 12, 031001 (2009).]

# 05/13/09 (10739) chromaticity scan

[lost ¼ of Blue intensity, poor Blue beam lifetime,
lost Yellow in chromaticity scan due to model problem]

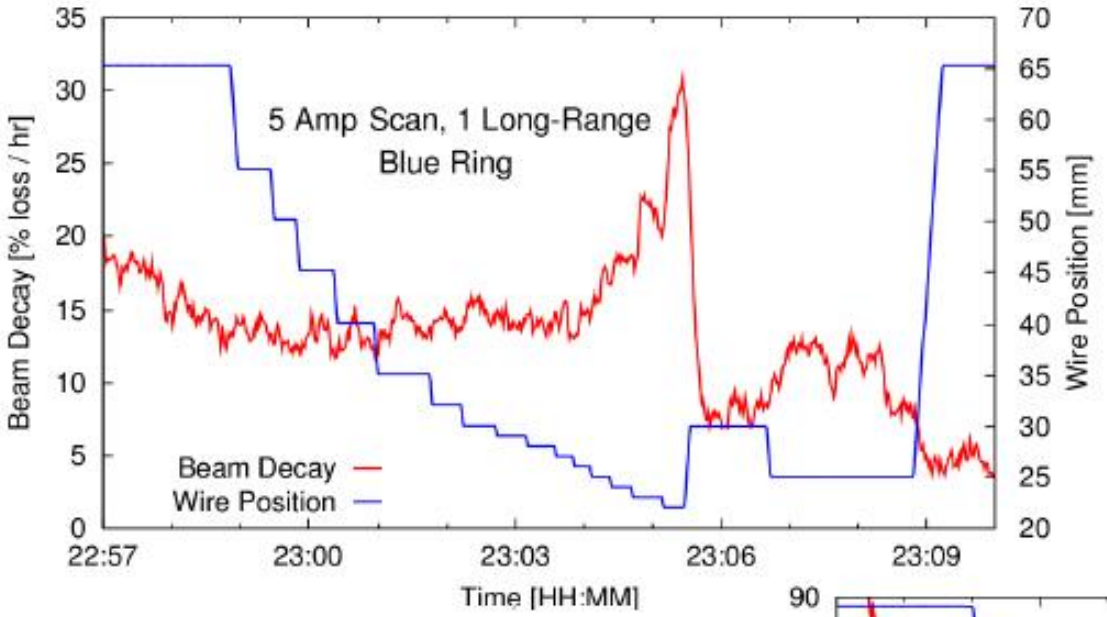


# Yellow compensation (10793)

- 34x34 bunches (6 non-colliding)
- $1.7 \times 10^{11}$ p/bunch
- Yellow
  $(Q_x,Q_y) = (0.695,0.692)$, $(Q_x',Q_y') = (-1.5,+1)$, $(\varepsilon_x,\varepsilon_y) = (49?,19)$ mm.mrad
- Blue
  $(Q_x,Q_y) = (0.691,0.688)$, $(Q_x',Q_y') = (+2.3,-1.4)$, $(\varepsilon_x,\varepsilon_y) = (?,25)$ mm.mrad

- Wire with 5A is about the same effect as 1 bunch with $2 \times 10^{11}$p

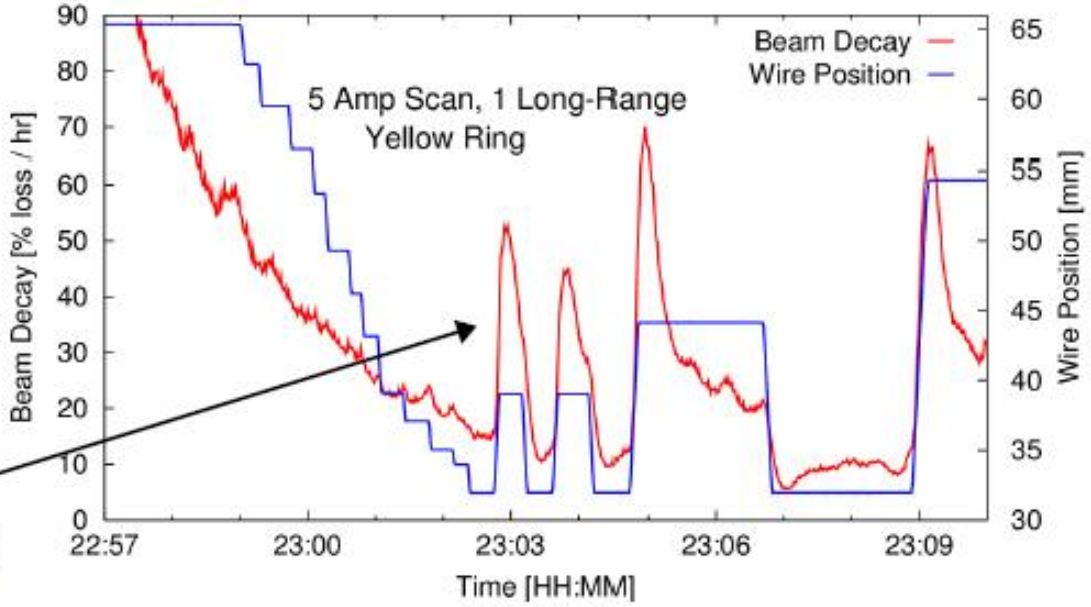
# Yellow compensation (10793)




Blue Ring

No visible effect

Yellow Ring




Losses increase when compensation is removed !!!

# Summary

- **Run-10 long-range wire measurements**
  - Measured effect on background (250 GeV p)
    *only small reduction in Blue, increase in Yellow*
  - Included head-on beam-beam
    *strong head-on effect only with protons, still needs to be simulated*
  - One case of beam lifetime improvement with BBLR
  - Simulations not yet done

- **RHIC long-range wire measurement finished**
  - Blue BBLR removed
  - Will be shipped to CERN for installation in SPS
  - Yellow to be removed next year (obstruction for pp2pp)

# Run-10 measurements

- 04/14/09 (10542, 10554) BBLR effect on background (semi-parasitic)
- 04/29/09 (10678)

  34x34, 1.8e11, BBQ on on ramp -> large emittance, about 30 mm.mrad, distance scans with both 5A and 50A in both beams, including head-on beam-beam
  Plan executed (distance scans with both 5A and 50A scans in both beams, including head-on beam-beam). Suffered from larger than usual emittance (about 30 mm.mrad). -Wolfram, Ram
- 05/13/09 (10740)

  34x34 (28x28 + 6 non-colliding), 2e11/bunch injected, chrom scan with 5A
  Filled 34x34 with more than 2e11/bunch in both rings. Lost about 1/4 of the intensity in Blue (perhaps due to some earlier APEX work), 94% transmission in Yellow (the good news).

  At store very poor Blue lifetime.

  Difficulties with BTF and Artus measurements.

  Did one 5A scan in Blue and Yellow.

  Did a vertical chromaticiy scan in Blue (max change +8 units).

  Lost beam during vertical chromaticity scan in Yellow (saw large chromaticity values in RE, store dropped by Roman Pot NMCs).
- 05/26/09 (10793)

  Accelerated 34 bunches in both ring, brought into collision (6 non-colliding bunches each).

  Adjusted store lifetime for both beam.

  Distance scan in both beams with 50 A (=max) strength.

  Retracted both BBLR, reduced strength to 5 A (= long range effect of single bunch).

  Separated beams vertically in IP6 and IP8, moved collision point towards DX (2 buckets cogging).

  Distance scan in both rings, found Yellow beam loss reduction with approaching BBLR, and small increase in beam loss rate with approaching BBLR in Blue.
- 07/05/09 (11055)

  This time no head-on collisions, only long-range. Loss rates are rather noisy, with a 20 s modulation. No obvious improvement in beam loss rate with BBLR.
  **End of BBLR experiment.** -Ram, Guillaume, Wolfram