RHIC long-range beam-beam studies

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Content

- Long-range beam-beam effect

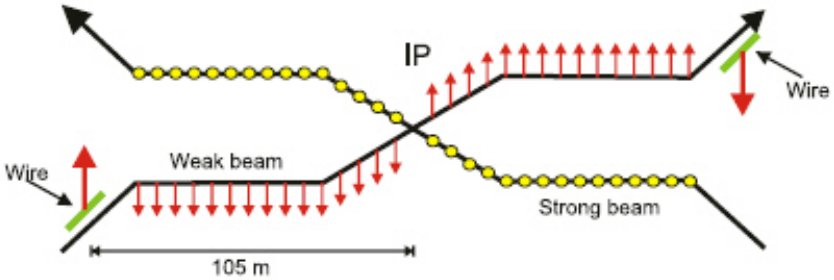
- Related beam-beam topics (not covered here)
  - New working point (C. Montag et al.)
  - Beam Transfer Function
  - Resonance compensation (Y. Luo et al.)
  - Electron lens (Y. Luo et al.)
  - 10 Hz triplet vibration (C. Montag et al.)
  - Beam lifetime calculations (J. Beebe-Wang)

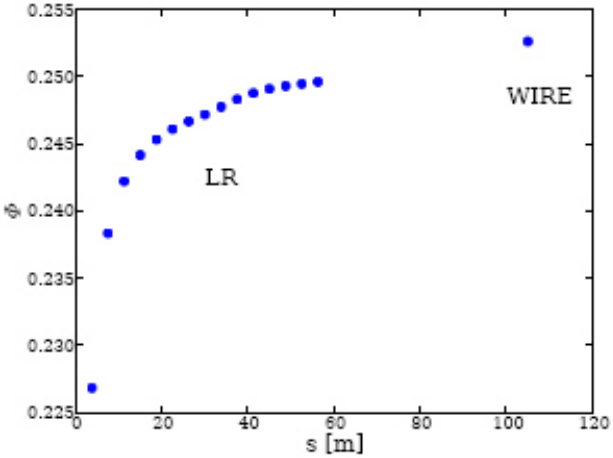
BBLR motivation (LHC)

NOMINAL LHC I

- Position: 104m from IP (reserved), defined by equal β functions (or ratio corresponding to the average beam-beam encounter).

Wire compensators
proposed by J.-P. Koutchouk





- Required wire - current: 81Am
- Average beam-beam separation: $9.5\sigma \rightarrow$ enough for the compensation to work and for the wire to be in the shade of the collimators.
- $\beta_{wire} \approx 1800 \rightarrow$ enough to place a wire with finite extensions.

BBLR motivation (RHIC)

- Nominally only weak long-range beam-beam in store
  (long-range interactions at IP2/4/10/12 with 20 σ separation for 100 GeV protons and 10 mm vertical orbit separation)
- Incidental long-range on ramp and during cogging
  (from orbit errors in IR, loose frequency lock near transition)
- Long-range with electron lens
  (2 lenses near IP10 commons to both beams,
  beams see one lens head-on, one long-range)
- Increasing pp-energy by 30% from 250 GeV increases number of Ws by 80%, long-range separation in store then reduced by 30%
- Path to eRHIC in flux, new options may be affected by long-range beam-beam effects

Long-rang beam-beam compensation efforts

- Proposals for long-range compensation with e-lens (V. Shiltsev, FNAL) and wire (J.-P. Koutchouk, CERN)
- Simulations for long-range effects and compensation
- SPS experiments with wires
- DAΦNE operating experience with partial wire compensation
- <u>RHIC experiments with wires</u>

  → first experiments with strong localized long-range beam-beam effect in hadron collider

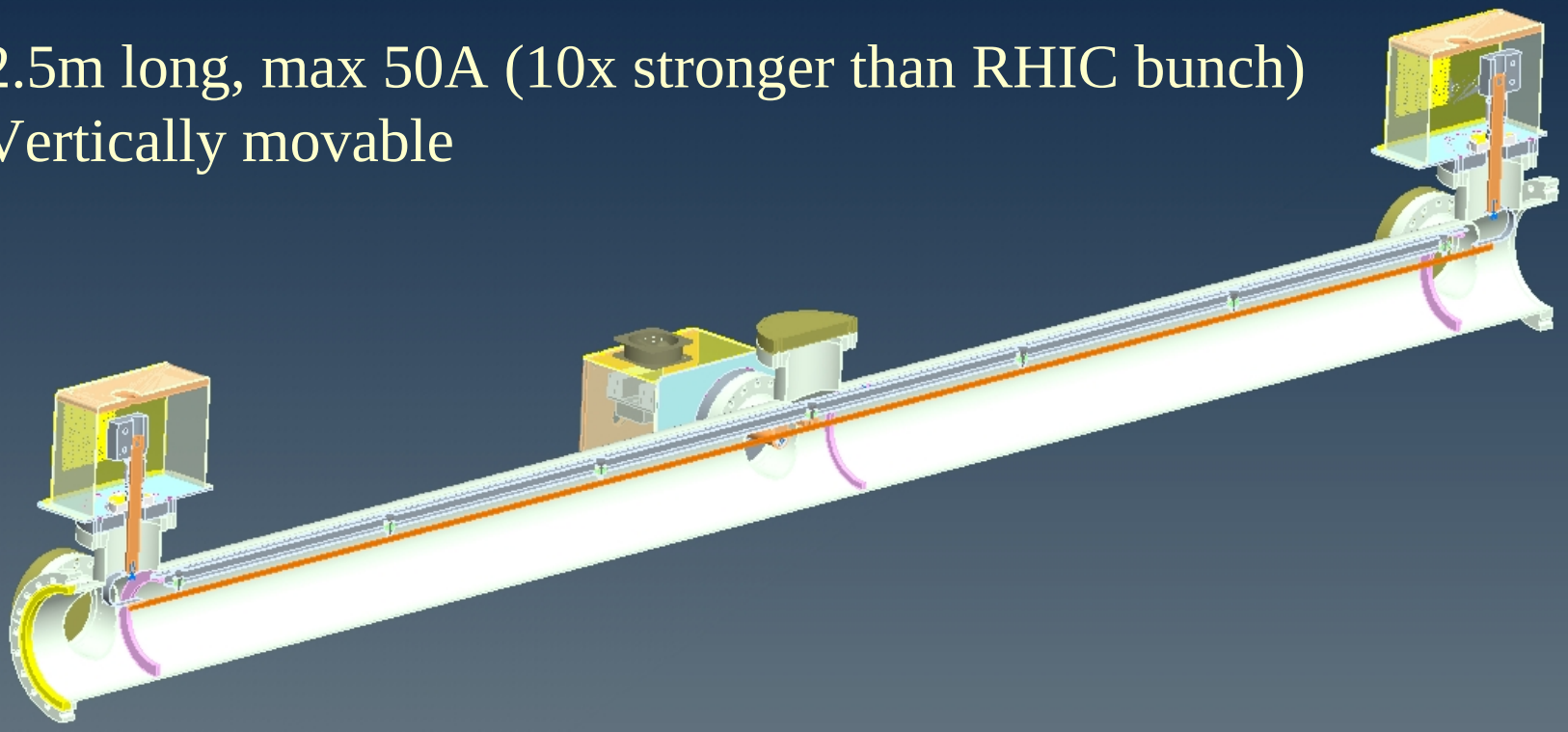
  → much better beam lifetime lifetime than SPS

  → addition of head-on effect possible
- Benchmarking of all experiments
- Design work for pulsed LHC wire

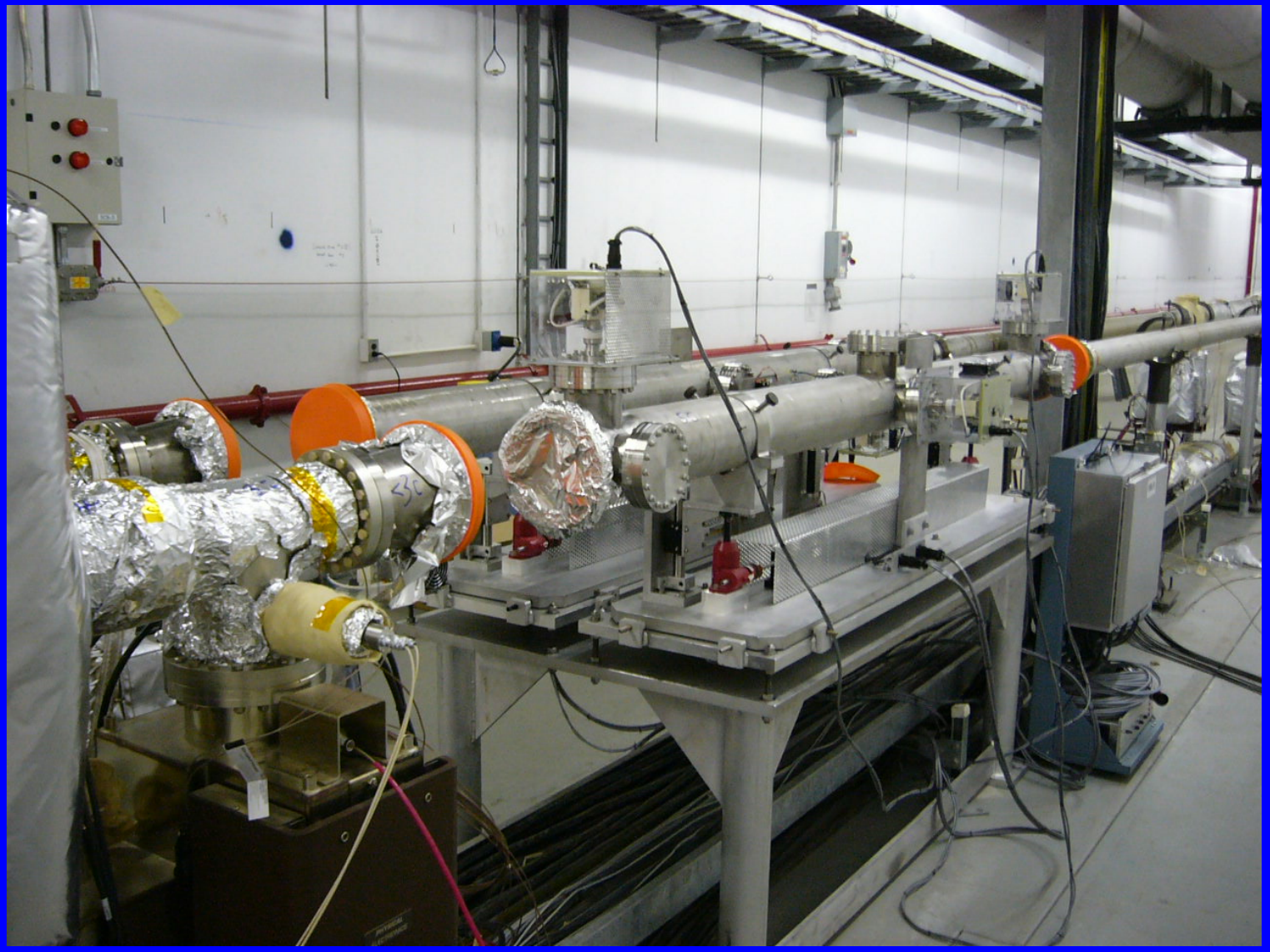
RHIC BBLR wire design

Magnetic field of wire looks like magnetic field of other beam

2.5m long, max 50A (10x stronger than RHIC bunch)
Vertically movable



RHIC BBLR wires in tunnel

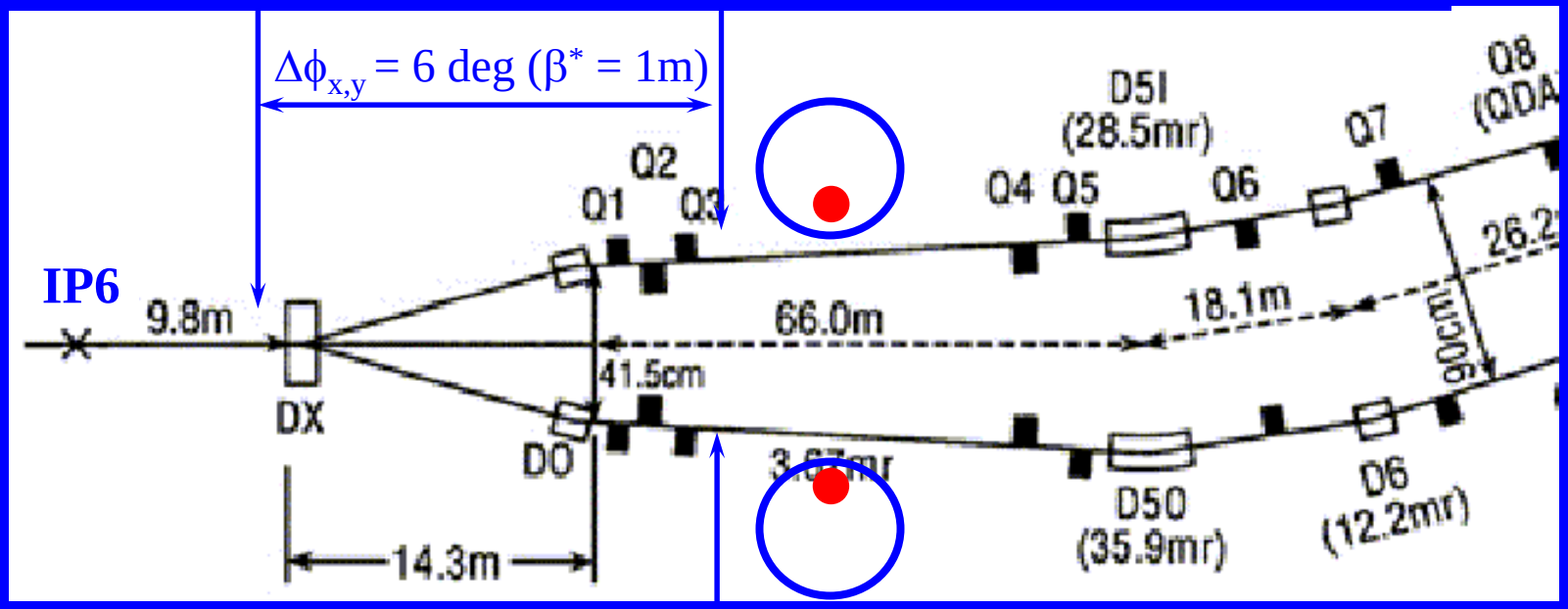


RHIC – location for compensation

long-range interaction (vertical)

long-range compensation (up)

RHIC Sector 5



long-range compensation (down)

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

Wire operation

Two degrees of freedom:

- Current (0 – 50 A)
- Vertical position (0 – 65 mm)

- Local PIN diodes
  (middle of BBLR and downstream end of BBLR)
- Temperature sensors

Experiments in RHIC Run-7 (2007)

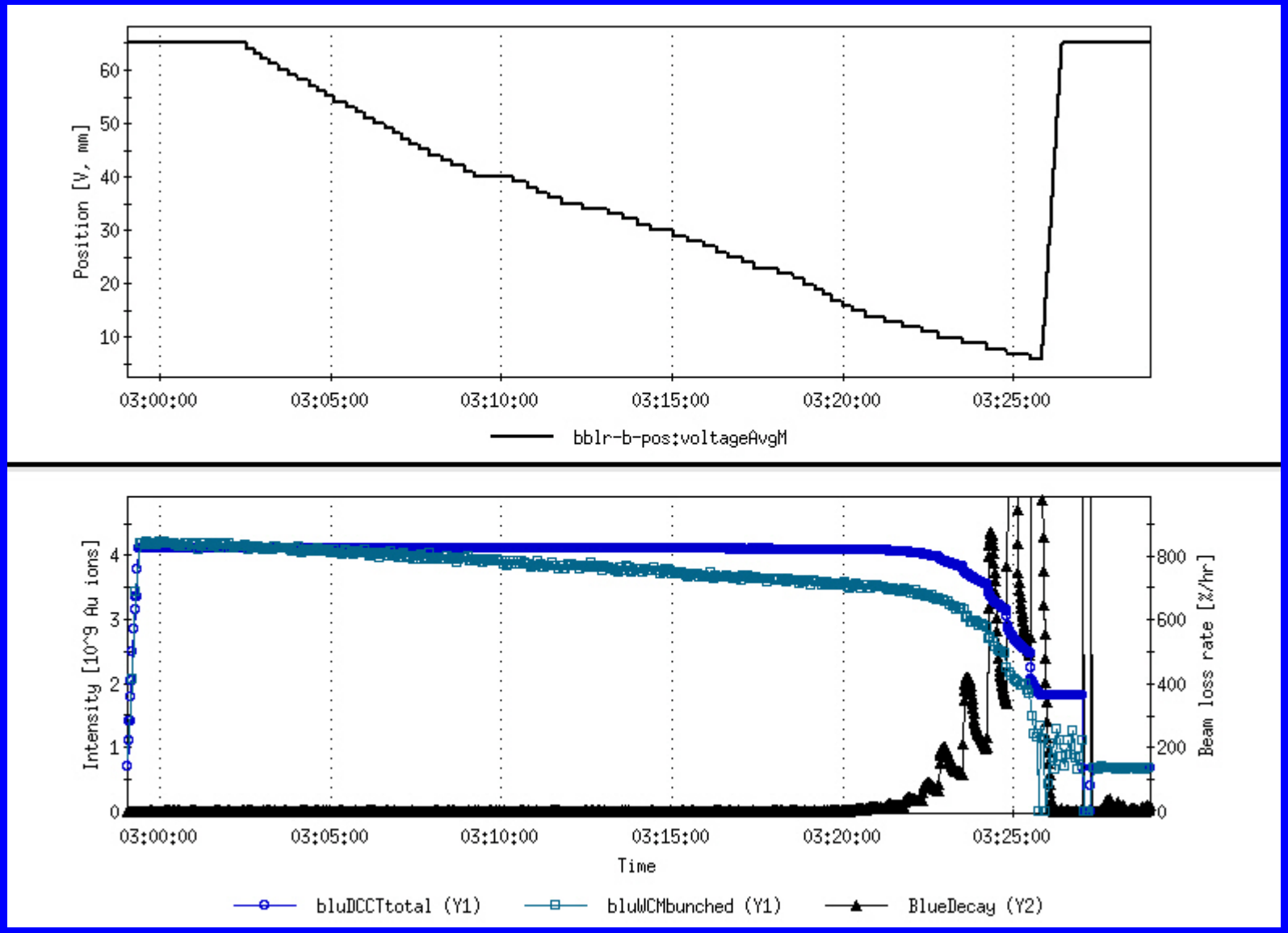
- No actual long-range compensation
  - Beam-beam effect too small with Au (3x stronger with p)
- Test effect of wire (= strong long-range beam-beam effect) on Au beam, to benchmark simulation
  - At injection (10 GeV/nucleon Au beam)
  - At store (100 GeV/nucleon Au beam)
- Test effect of wire on collimation efficiency

Experiments in RHIC Run-7 (2007)

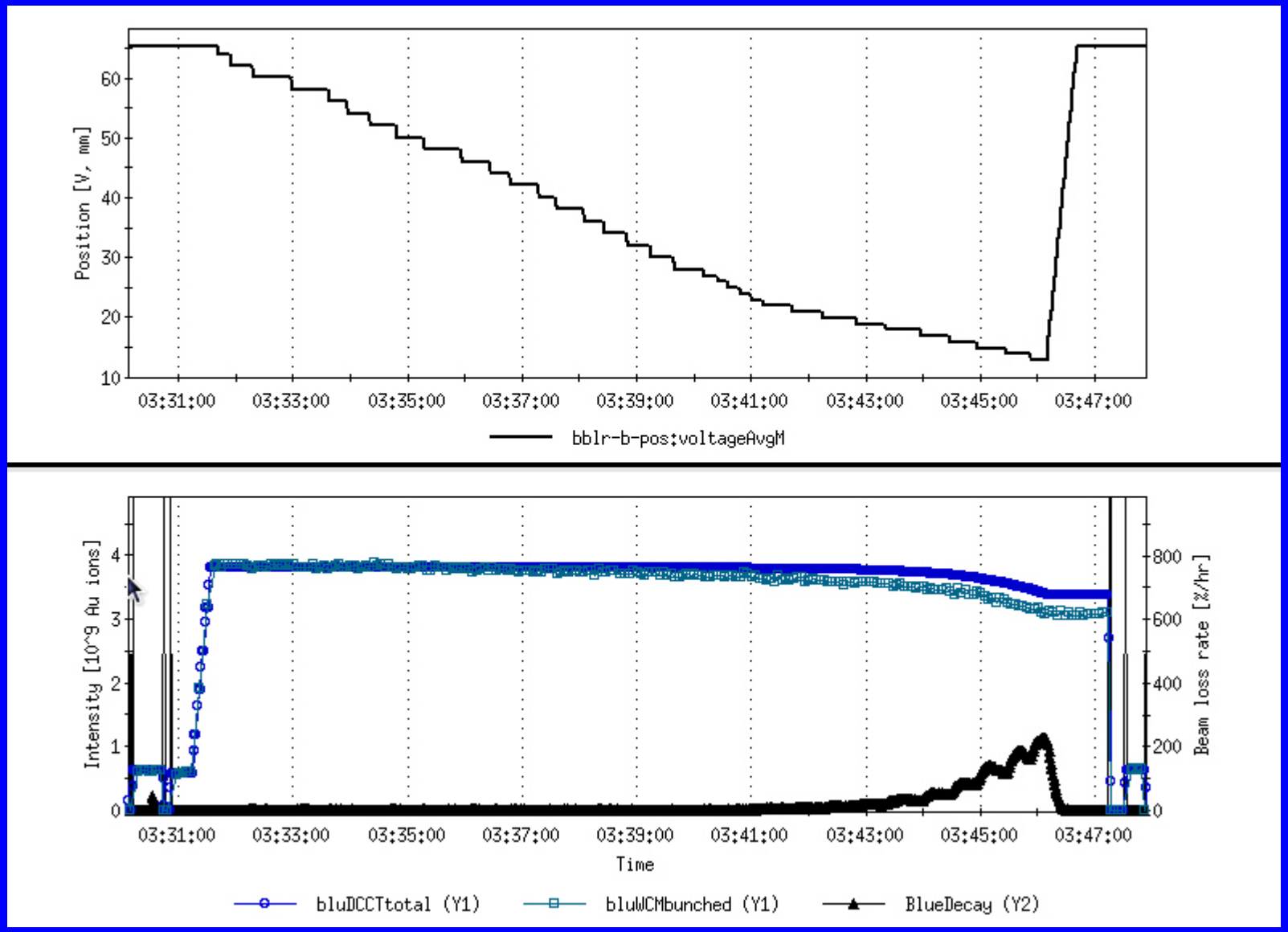
- Parasitic time
  - 03/13 0-4am during setup at injection (Blue)
  - 03/27 2:30-3pm during store in collision (Blue), for background observation

- Scheduled time
  - 04/11 5:30-8am (permit dropped after BBLR movement)
  - 04/25 5-8am (Blue+Yellow)
  - 05/09 5-8am (Blue+Yellow)
  - 06/20 5-8am (Blue+Yellow, lost after 1 h due to abort kicker problem – undetected drop of voltage)

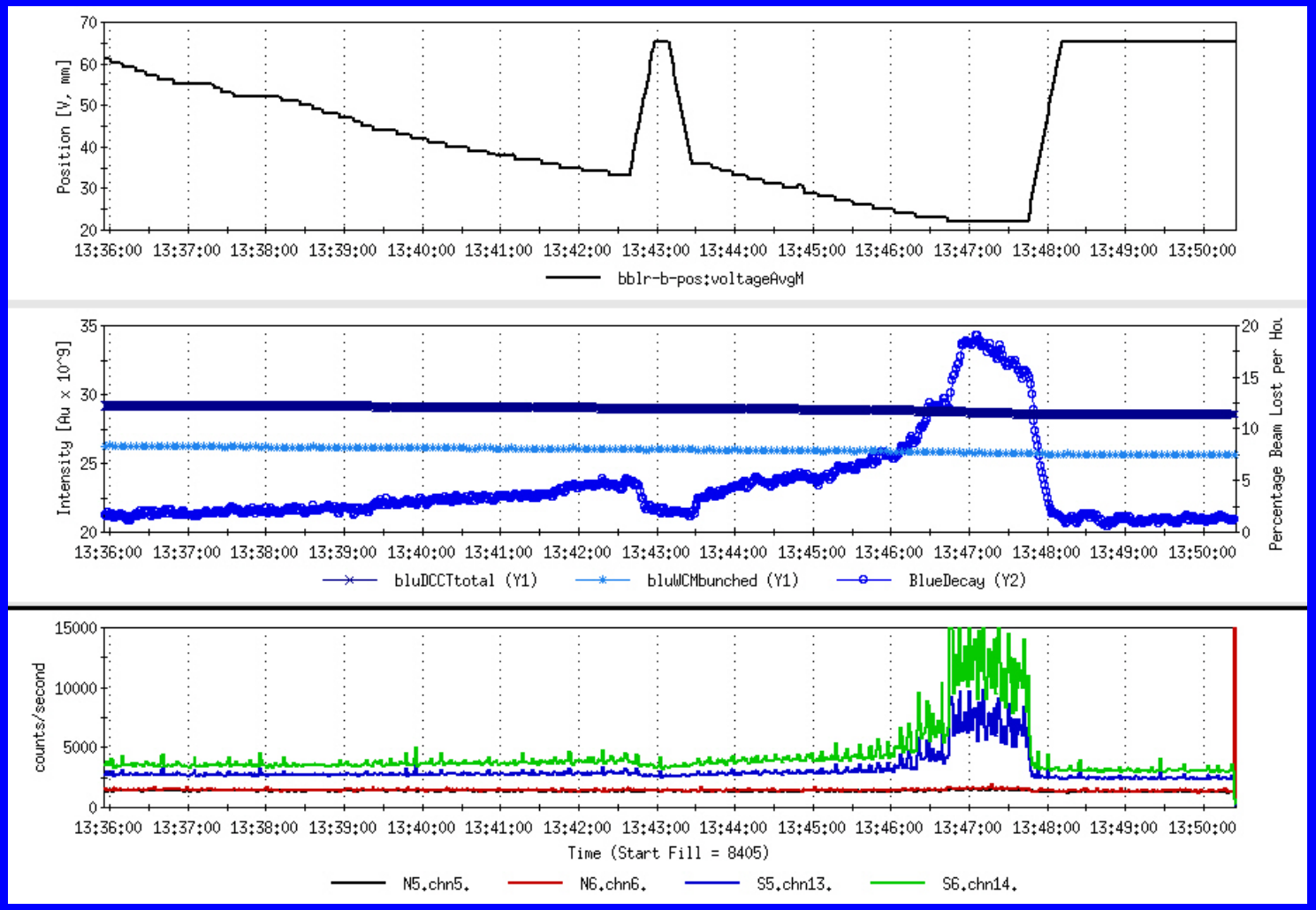
Distance scan at injection – 5A current, Au beam



Distance scan at injection – 50 A current, Au beam

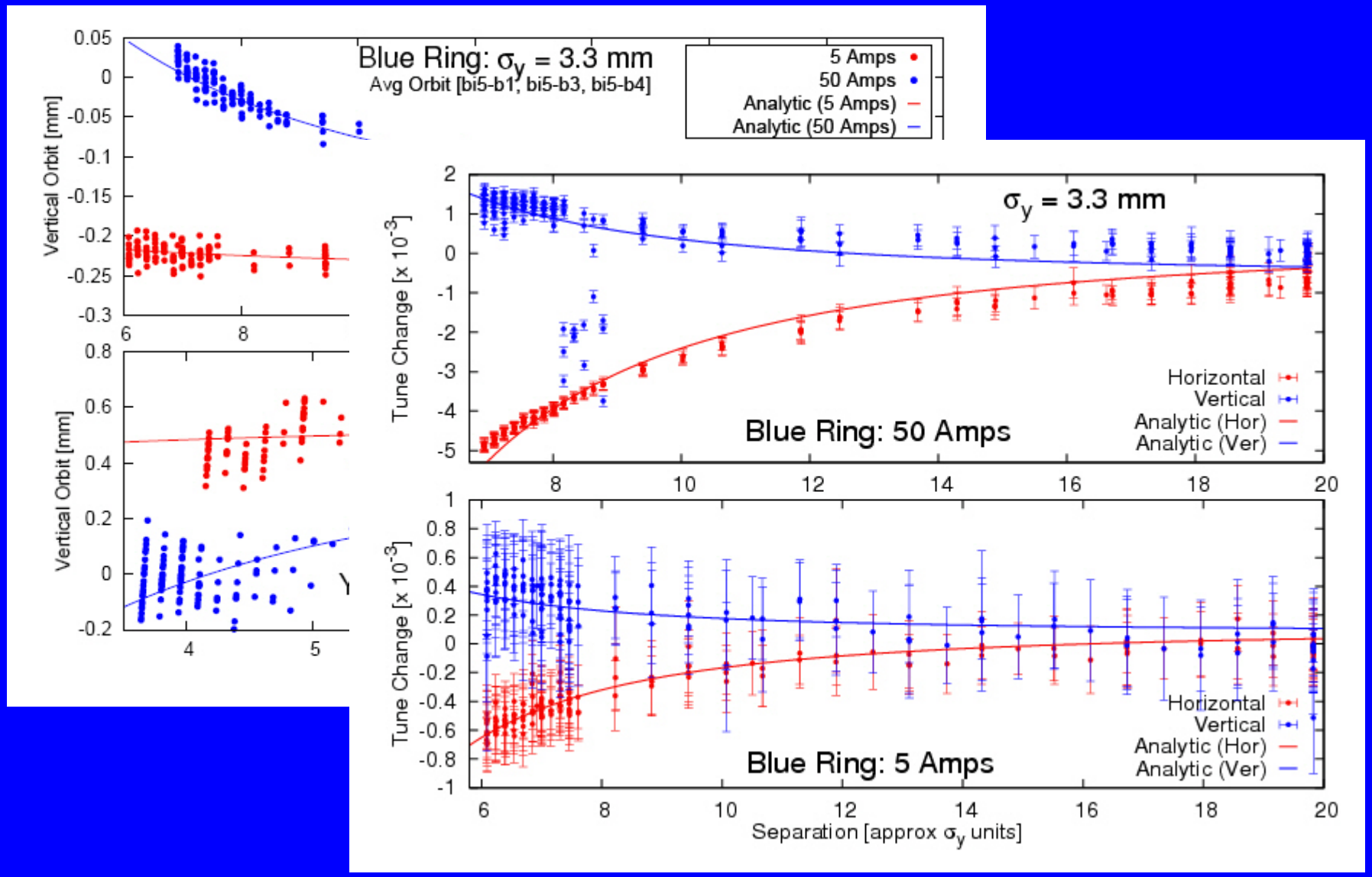


Distance scan at store – 50 A, Au beam

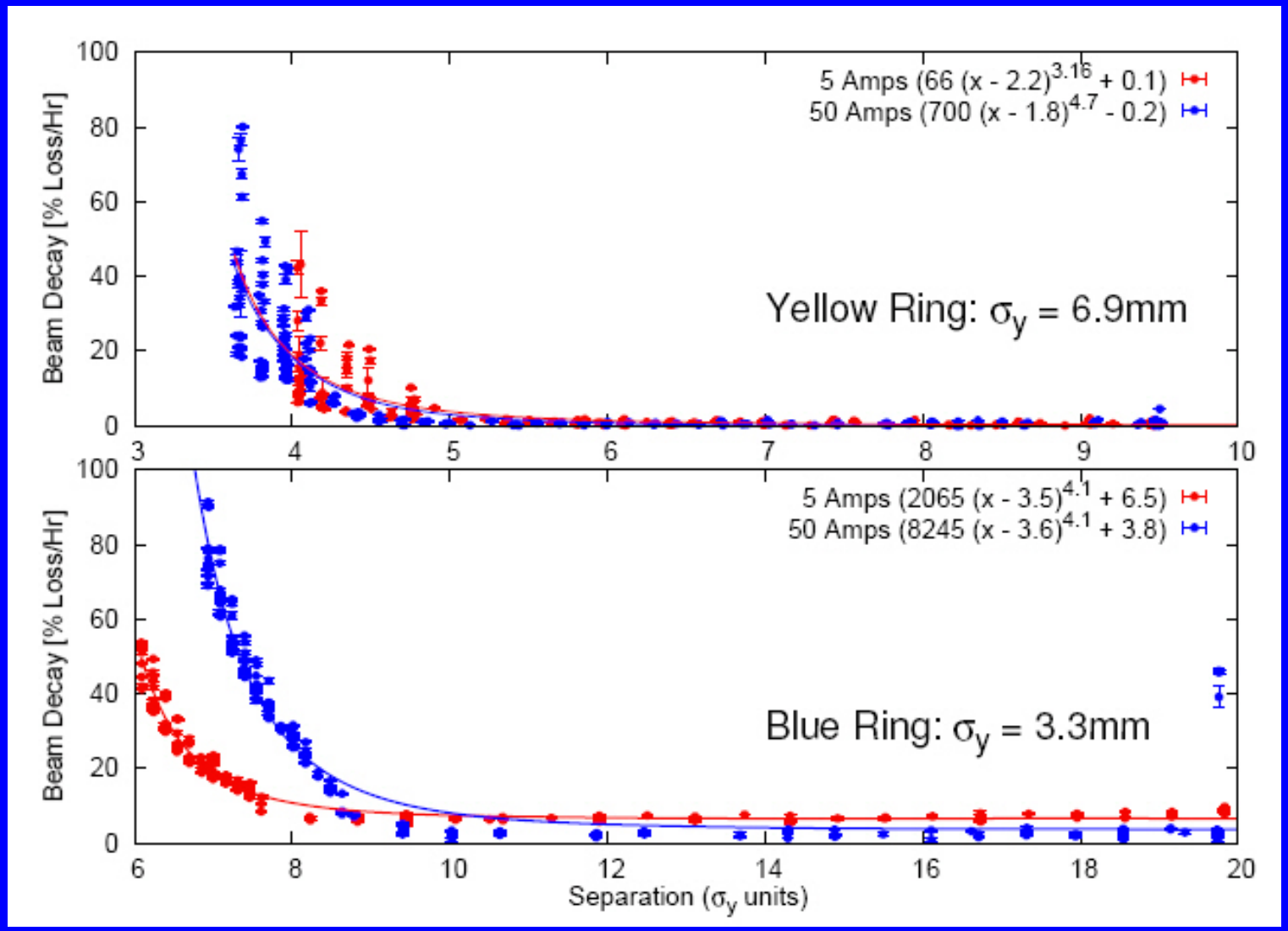


See increase in experimental background – no help for collimation.

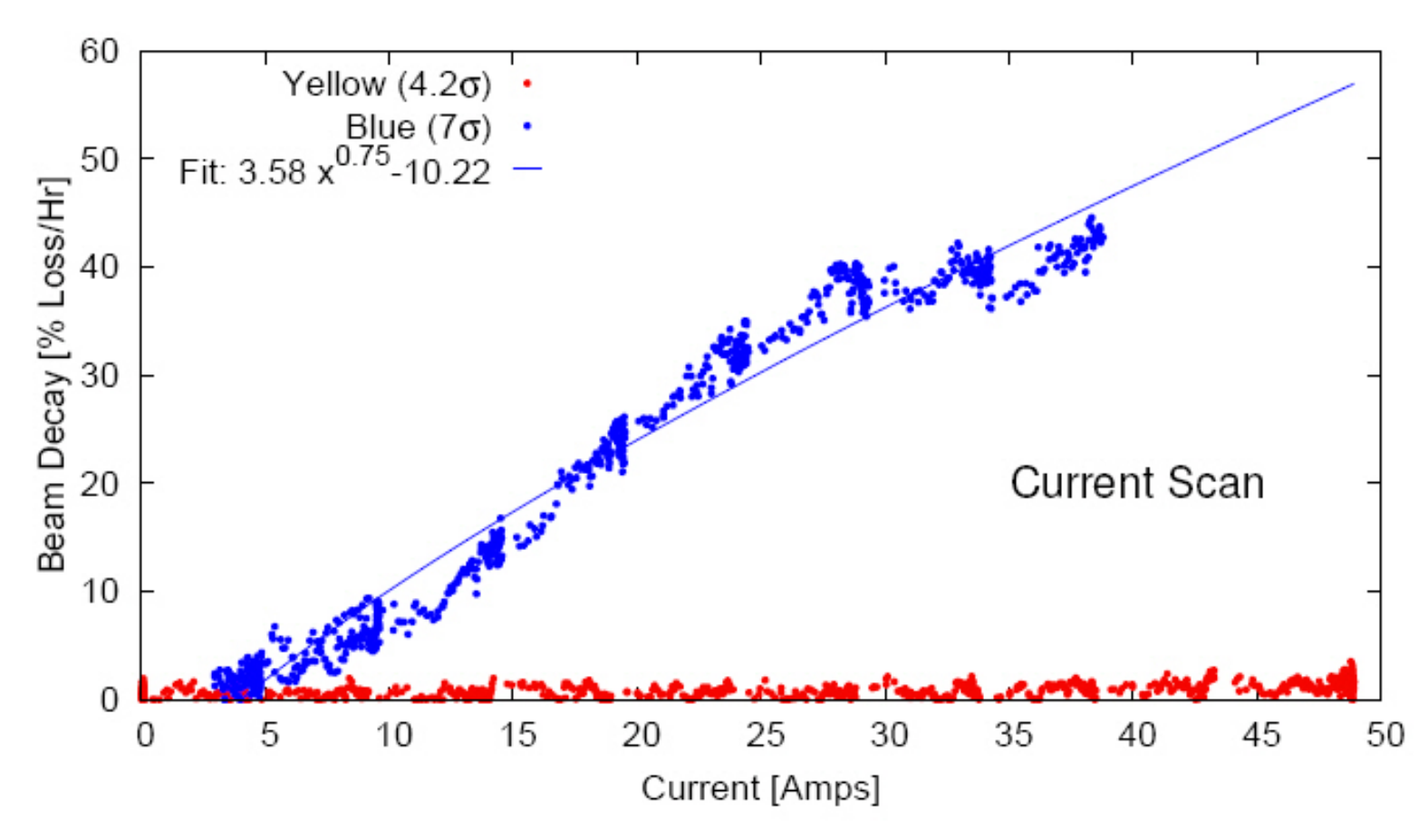
Check tune and orbit response



Distance scans: 5, 50 A, Blue, Yellow

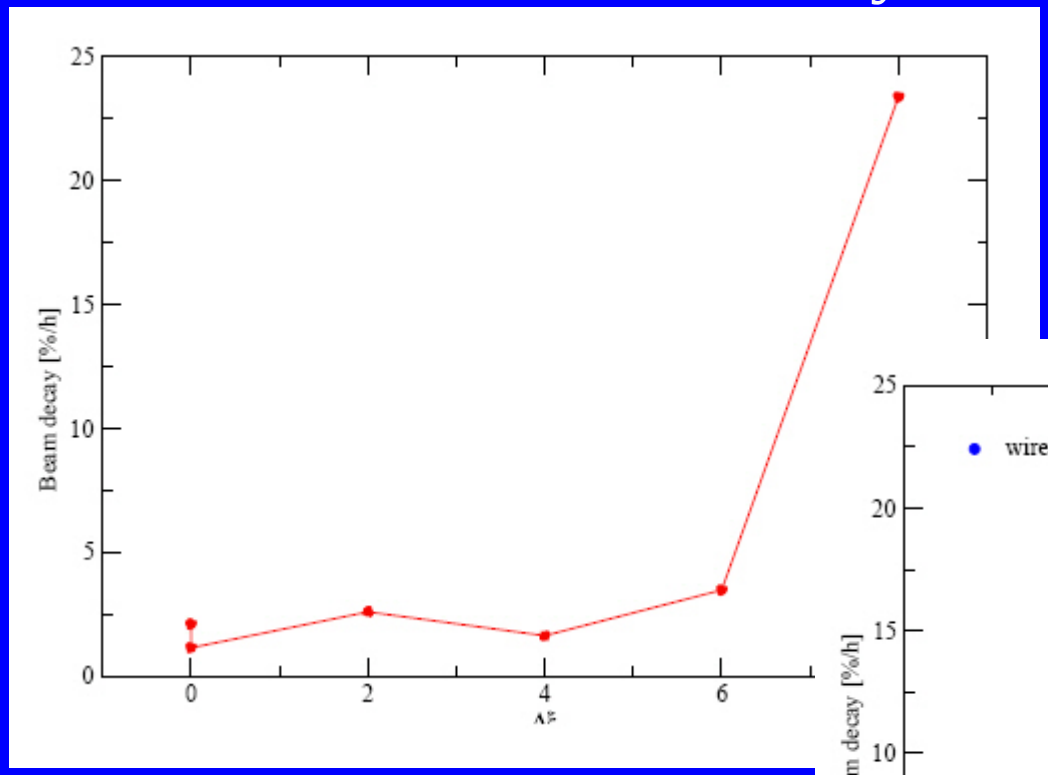


Current scan: Blue, Yellow

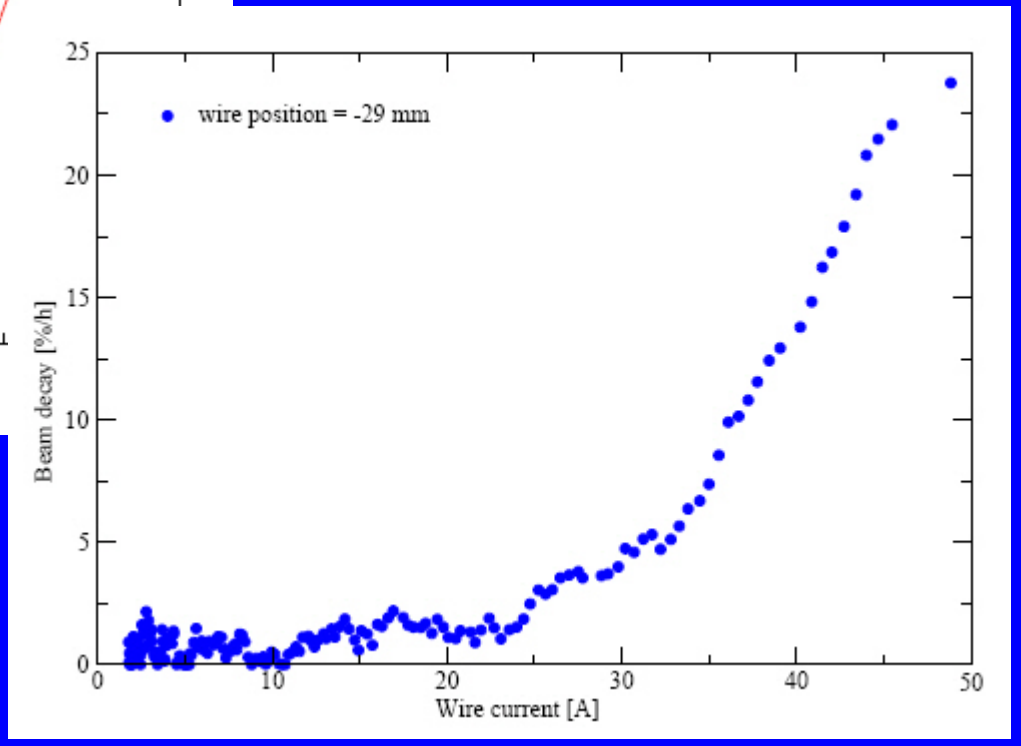


Chromaticity scan: Yellow

Loss vs. vertical chromaticity



Current scan at largest ξ



Benchmark simulations

RHIC detailed model includes:

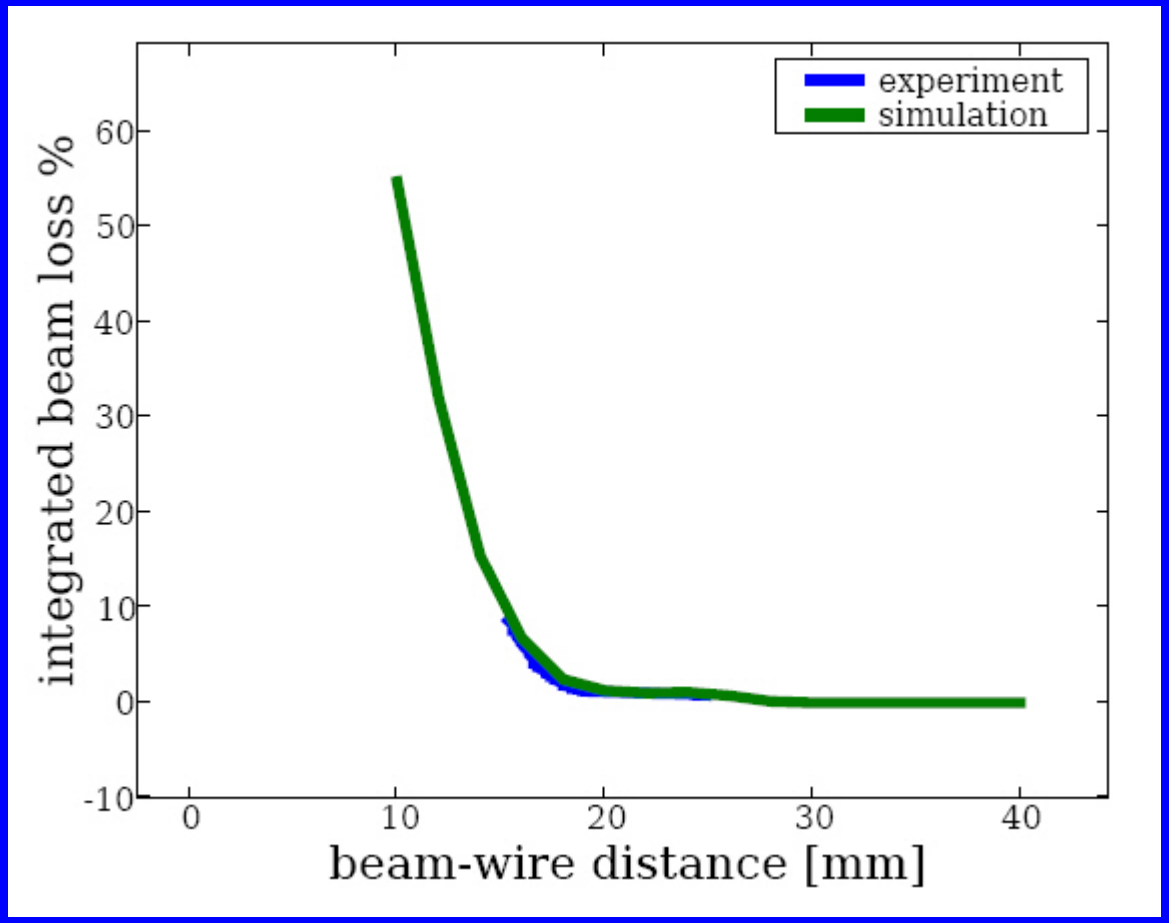
- Magnetic field errors in DX,D0,Q1,Q2,Q3
- Randomized sextupole errors in arc dipoles
- Tune ripple

Simulations by

- U. Dorda, CERN
- H.J. Kim, T. Sen, FNAL
- A. Kabel, SLAC
- J. Qiang, LBNL

Benchmark simulations

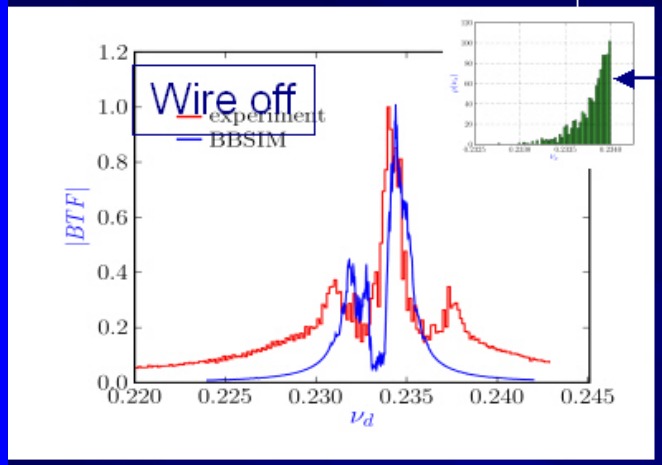
Blue beam at store (Exp. 1, 12.5 Am), U. Dorda



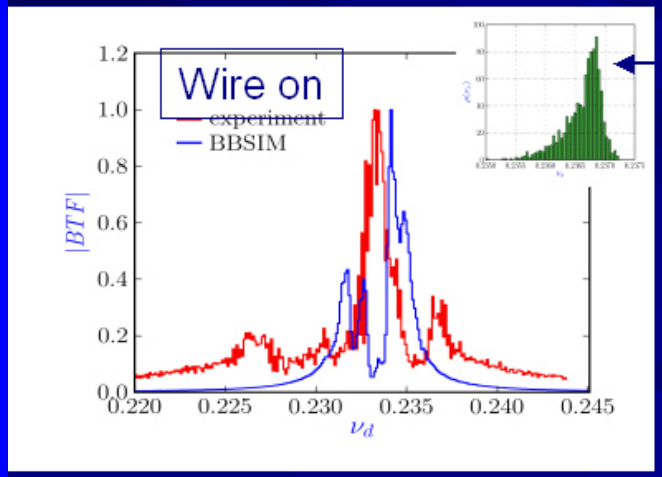
Benchmark simulations

FNAL – RHIC BTF, losses

BTF comparison at 100 GeV



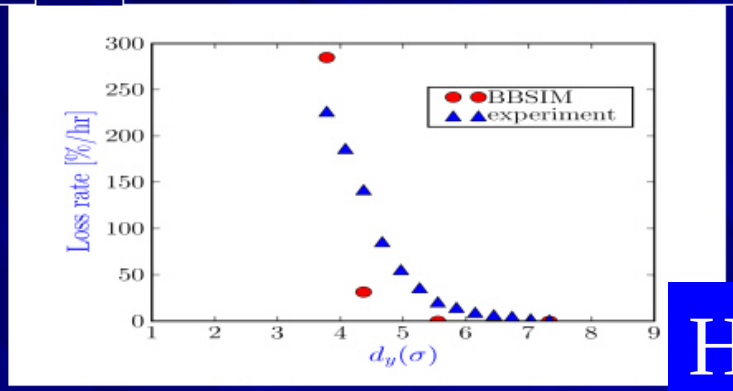
ρ(ν)



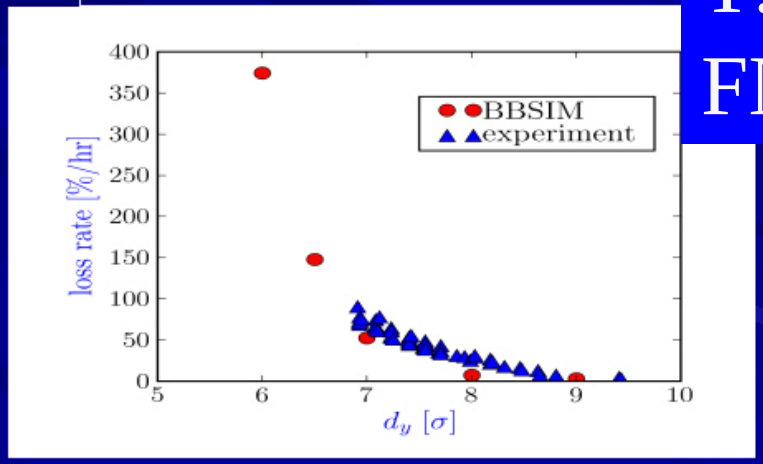
ρ(ν)

BBSIM

Loss rates with wire at Injection



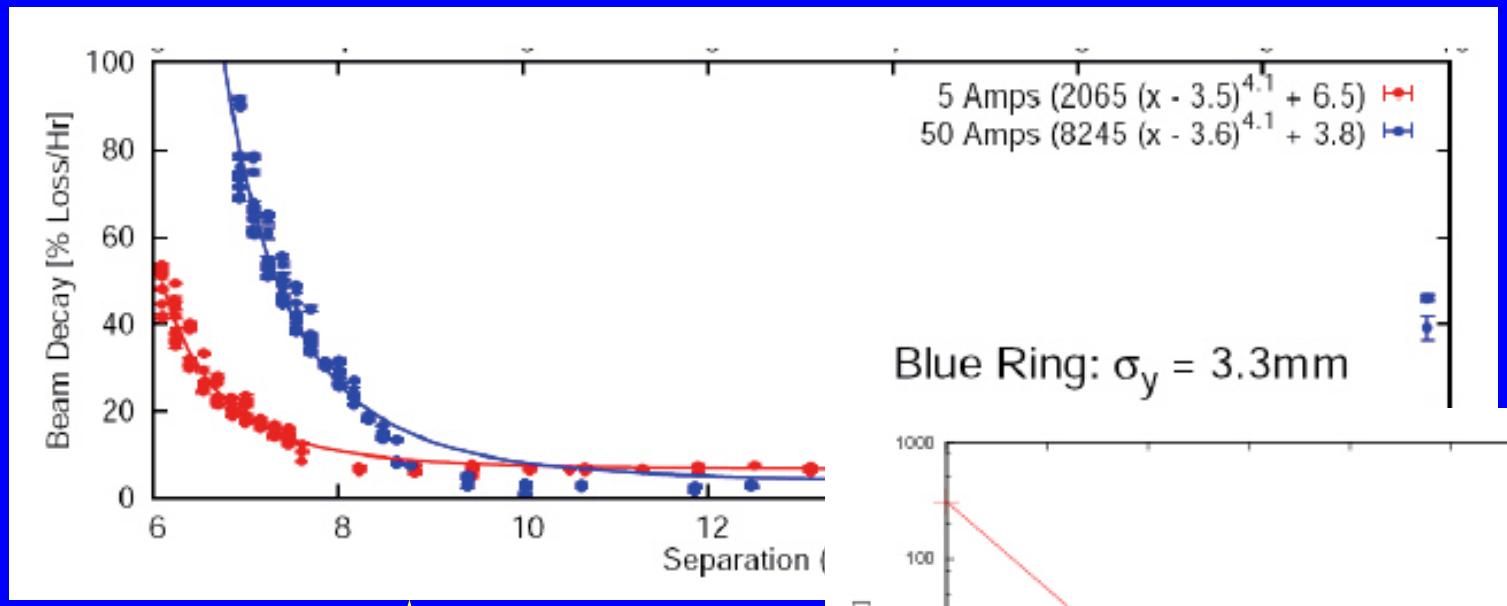
Loss rates with wire at 100 GeV



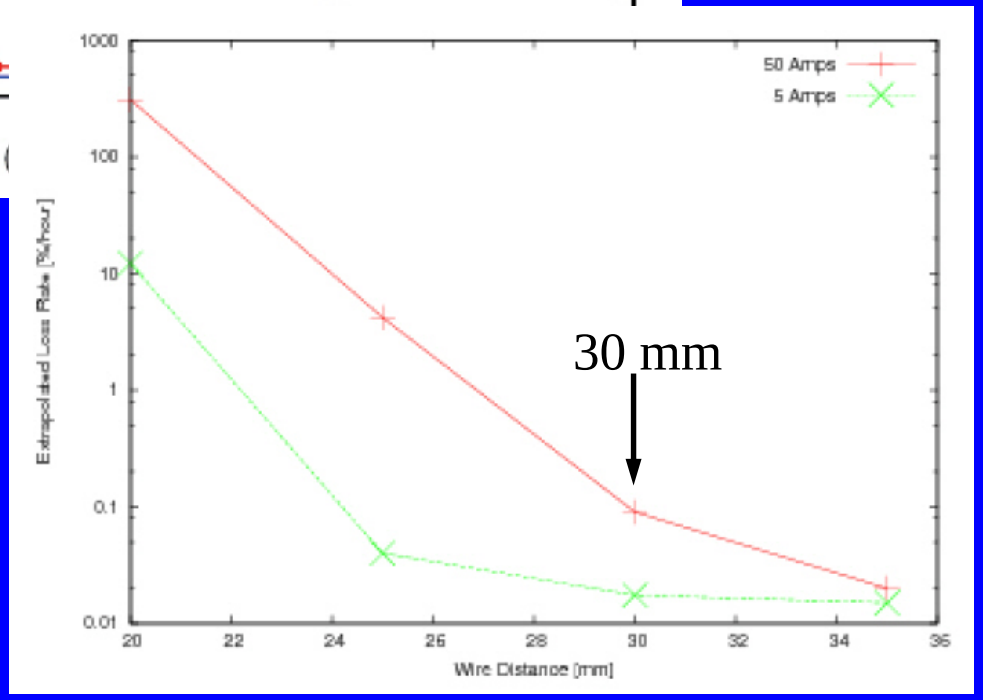
H.J. Kim,
T. Sen
FNAL

- RHIC simulations appear to be approaching reality

Benchmark simulations



30 mm



Blue at store, A. Kabel

Open items in experiments

- Only Au beams tested with BBLR, proton beams have 2-3× larger beam-beam parameter, and different tunes
- No head-on collisions included in scan
- No attempt to compensate for single head-on interaction
- No pulsed wire tested (under study by U. Dorda)

Planned test with RHIC BBLR wires in 2008

- Will ask for 3×3 hr dedicated time again
- Would like to test effect on background with protons too (parasitic)
- Parameter scans (distance, strength) with protons
  - Including head-on
  - Different working points
- Attempt to compensate one long-range interaction

Summary – long-range beam-beam in RHIC

- Parasitic measurements done with Au beams in 2007:
  - At injection
  - At store with colliding beams
- Dedicated experiments with Au beams at store (100 GeV/n):
  - Loss rate vs. distance
  - Loss rate vs. wire strength
  - Loss rate vs. chromaticity
- Simulations for 2007 experiments coming to conclusion
- Experimental plans for 2008:
  - Parameter scans with p-beam (including head-on, new tunes)
  - Attempt to compensate single long-range interaction