Beam-beam compensation in RHIC

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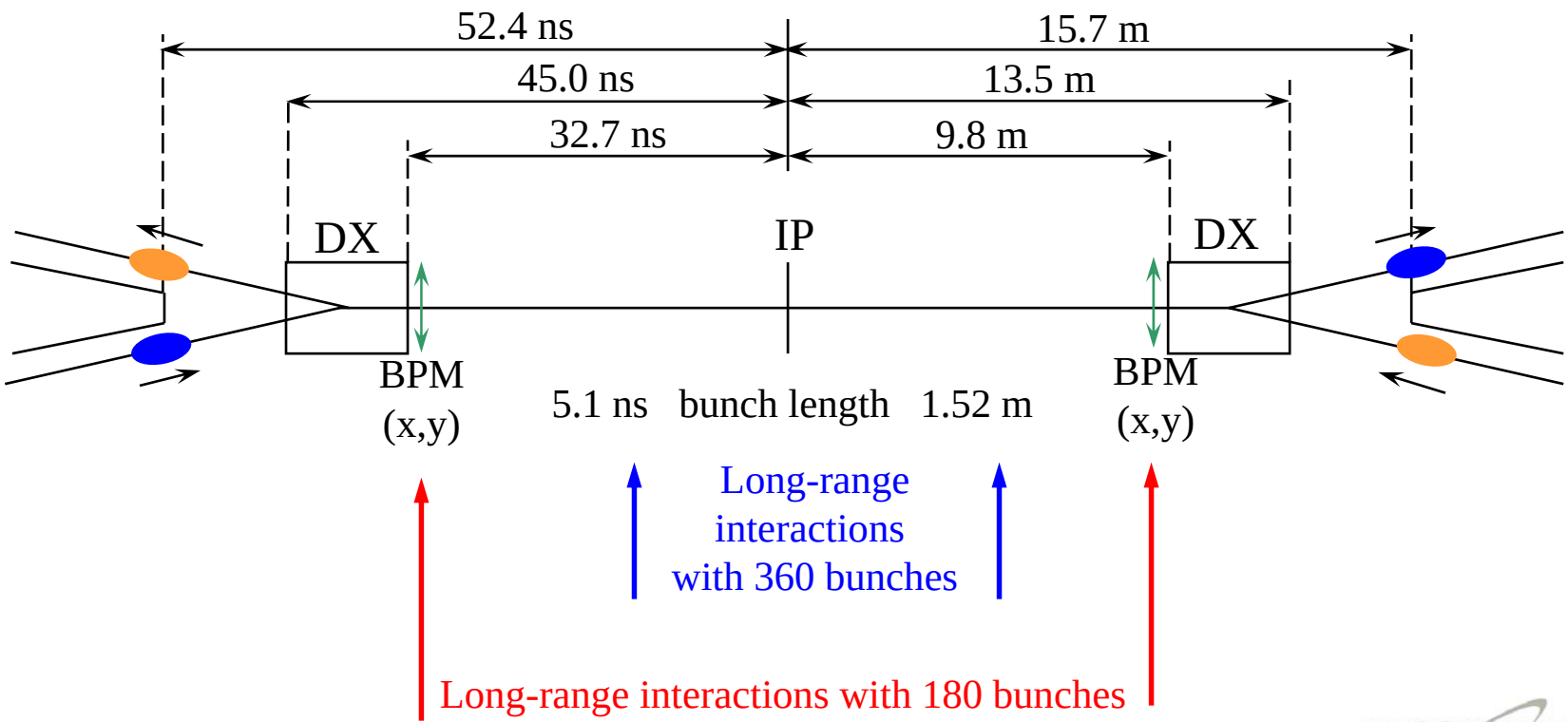
RHIC Interaction Region

- With >120 bunches cannot avoid long-range beam-beam interactions (eRHIC)
- LRBB important effect in LHC, under investigation in LARP
- RHIC is a good test bed for a wire compensator (more difficult in Tevatron)



RHIC long-range beam-beam scans 2005

Observation of beam lifetime as function of

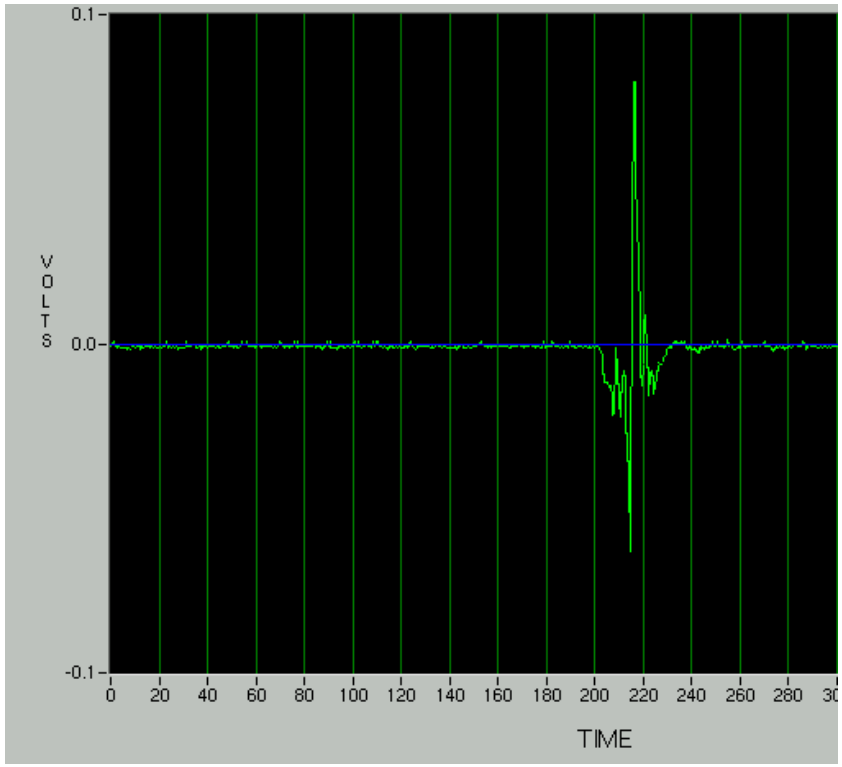
- **Transverse tunes**
- **Vertical separation**

Quantity	Unit	value
Proton energy E	GeV	24.3
Bunches per beam *N*	…	1
Bunch intensity N_b	10^{11}	1-2
Norm. emittances ε_x, ε_y (95%)	mm.mrad	20, 13
Long-range interaction location	m from IP	0.0, 10.6
Transverse tunes (Q_x,Q_y)	…	B(.733,.722) Y (.727,.723) B(.735,.722) Y(.728,.723) B(.738,.725) Y(.727,.722) B(.739,.727) Y(.726,.739)
Vertical separation	mm	10 – 0
	σ	11 – 0

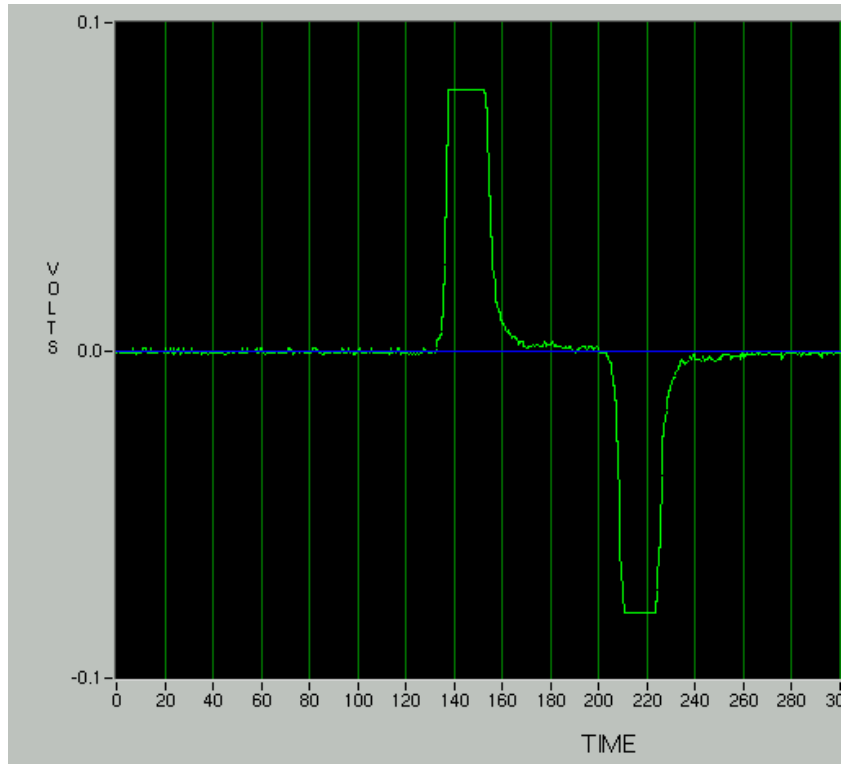
RHIC experiment – control of interaction location

Wall current monitor at IP4 (sees both beams)

Interaction at nominal IP

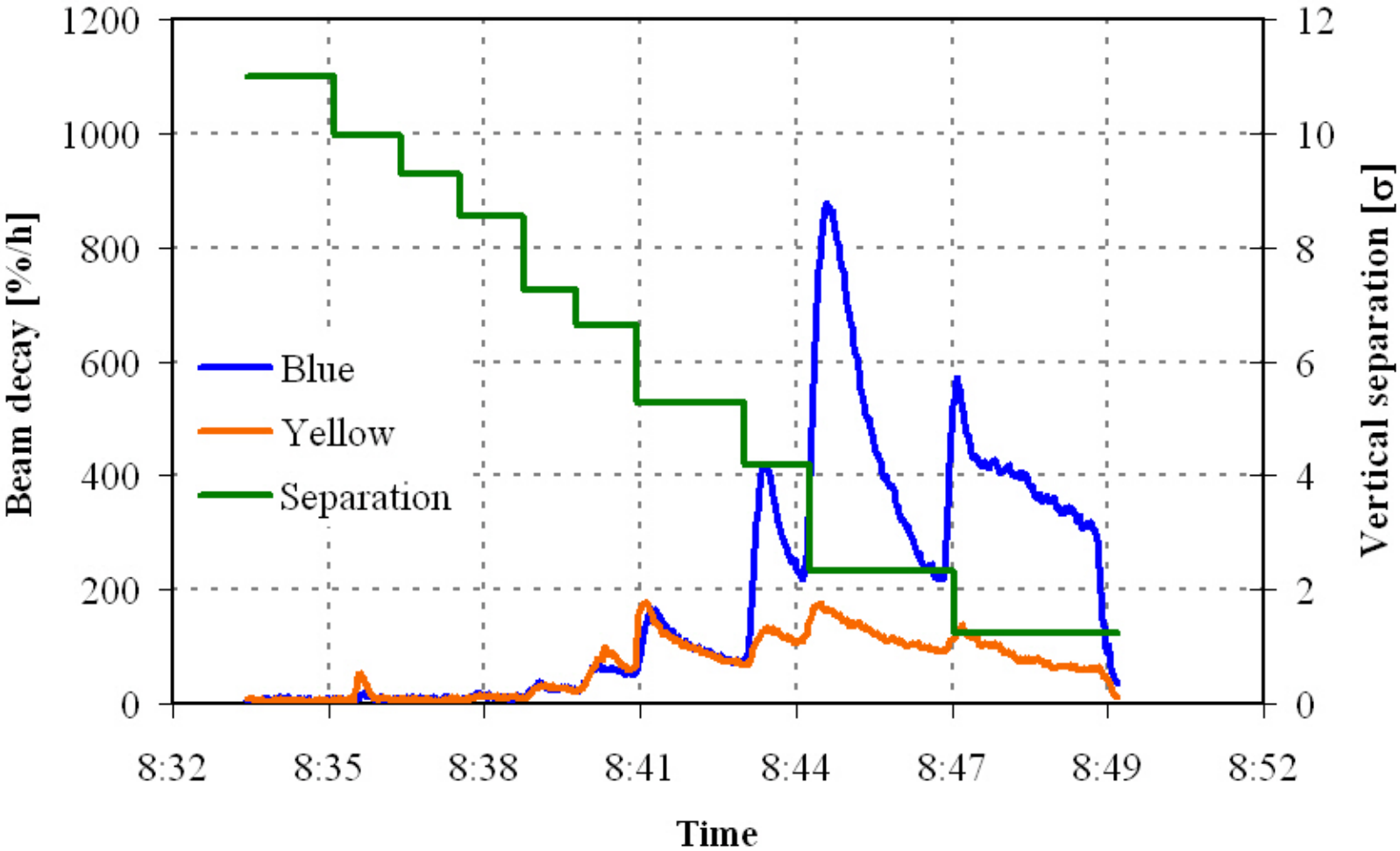


Interaction moved by 10m



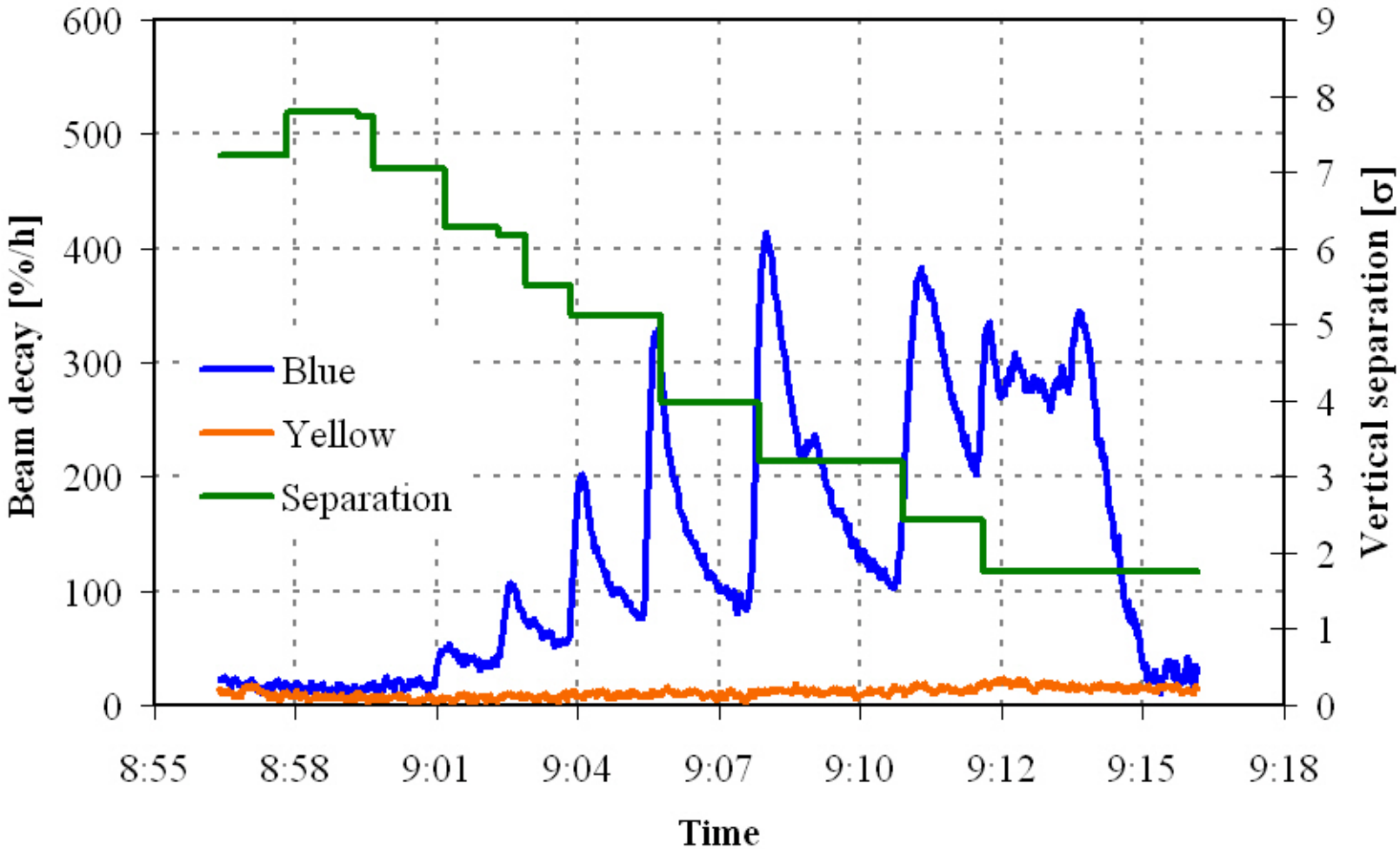
Experiment – scan 1

Collision at s = 0 m, Blue beam moved vertically
Tunes B (0.733,0.722) Y (0.727,0.723)



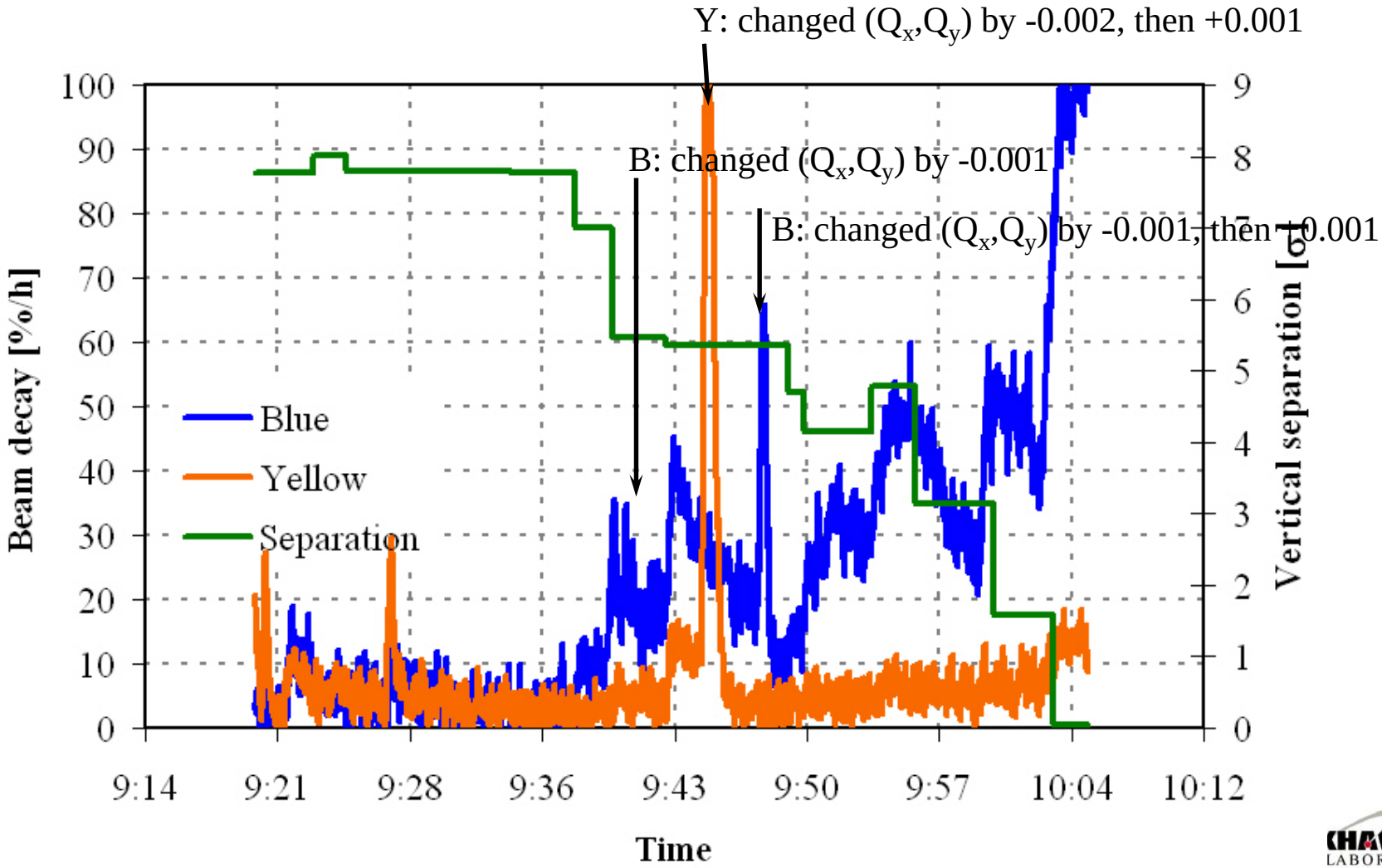
Experiment – scan 2

Collision at s = 10.6 m, Blue beam moved vertically
Tunes B (0.735,0.722) Y (0.728,0.723)



Experiment – scan 3

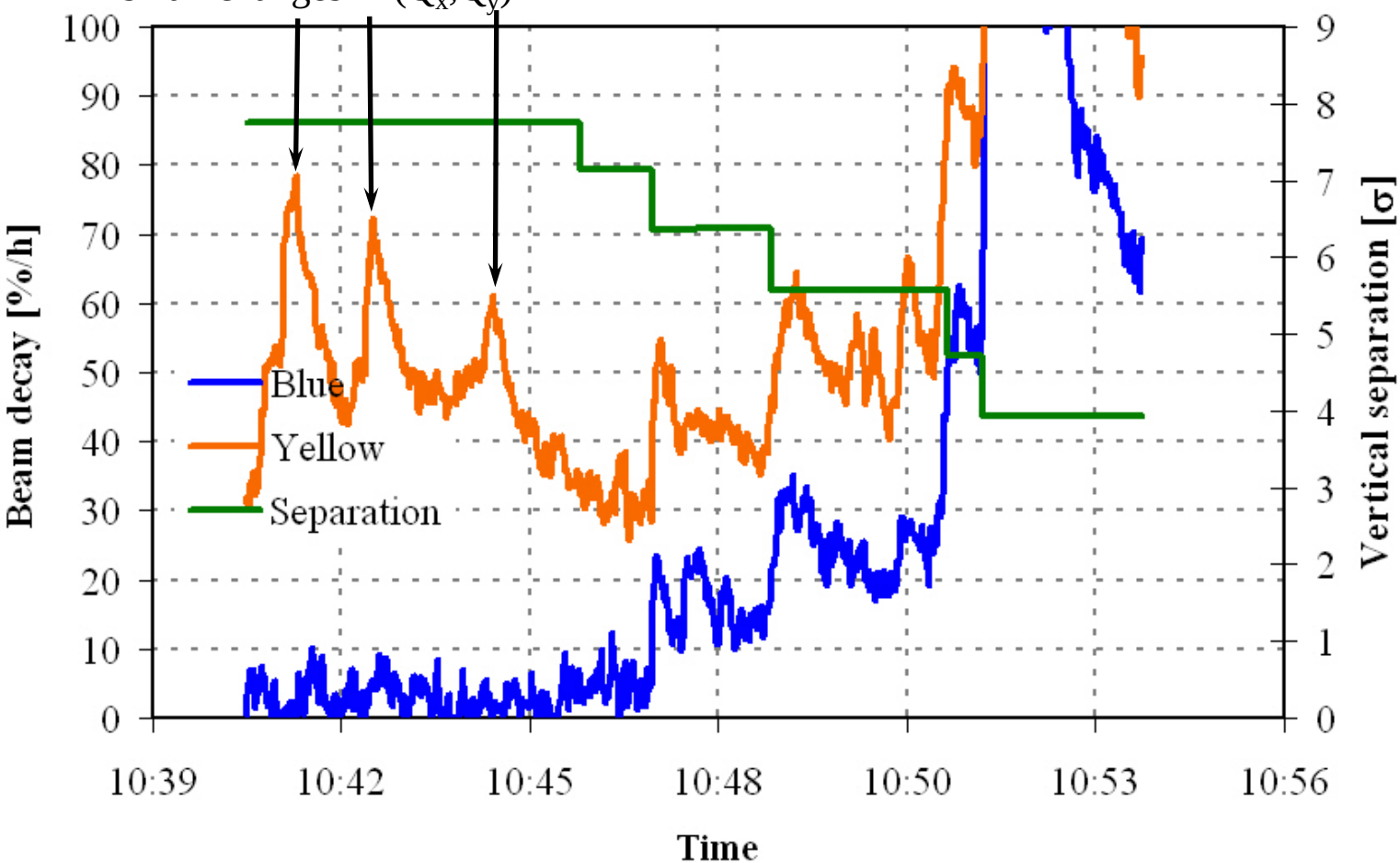
Collision at s = 10.6 m, Yellow beam moved vertically
Tunes B (0.738,0.725) Y (0.727,0.722)



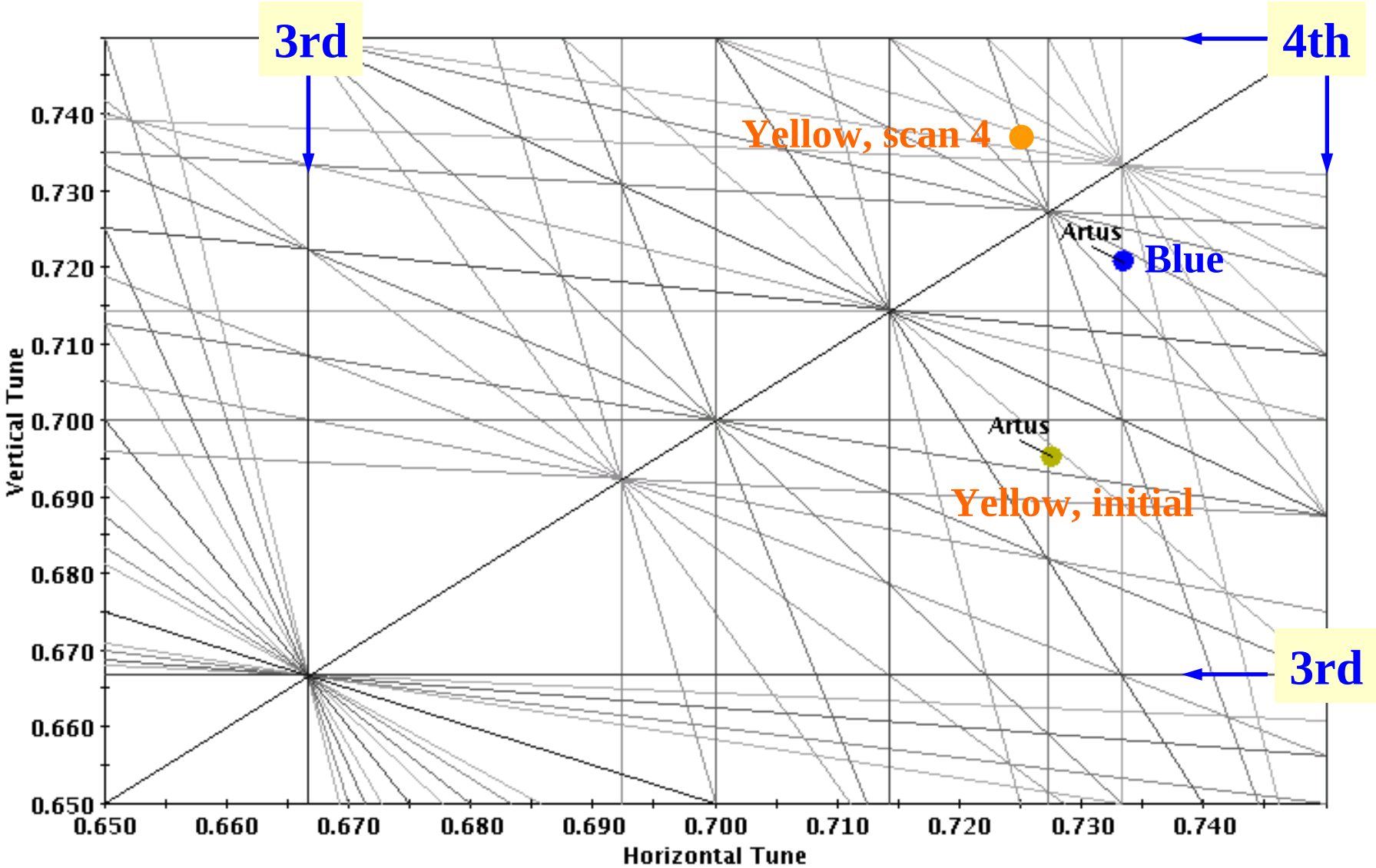
Experiment – scan 4

Collision at s = 10.6 m, Blue beam moved vertically
Tunes B (0.739,0.727) Y (0.727,0.738)

Y: attempt to improve lifetime,
small changes in (Q_x,Q_y)



Experiment – tune diagram



RHIC experiment

- Did not correct tunes and orbits for each new separation change
- Beam lifetime clearly dependent on vertical separation
- Found strong tune dependence of lifetime,
  ruled out tune change due to orbit change as dominating effect
- With mirrored tunes beam lifetime of both beam comparable

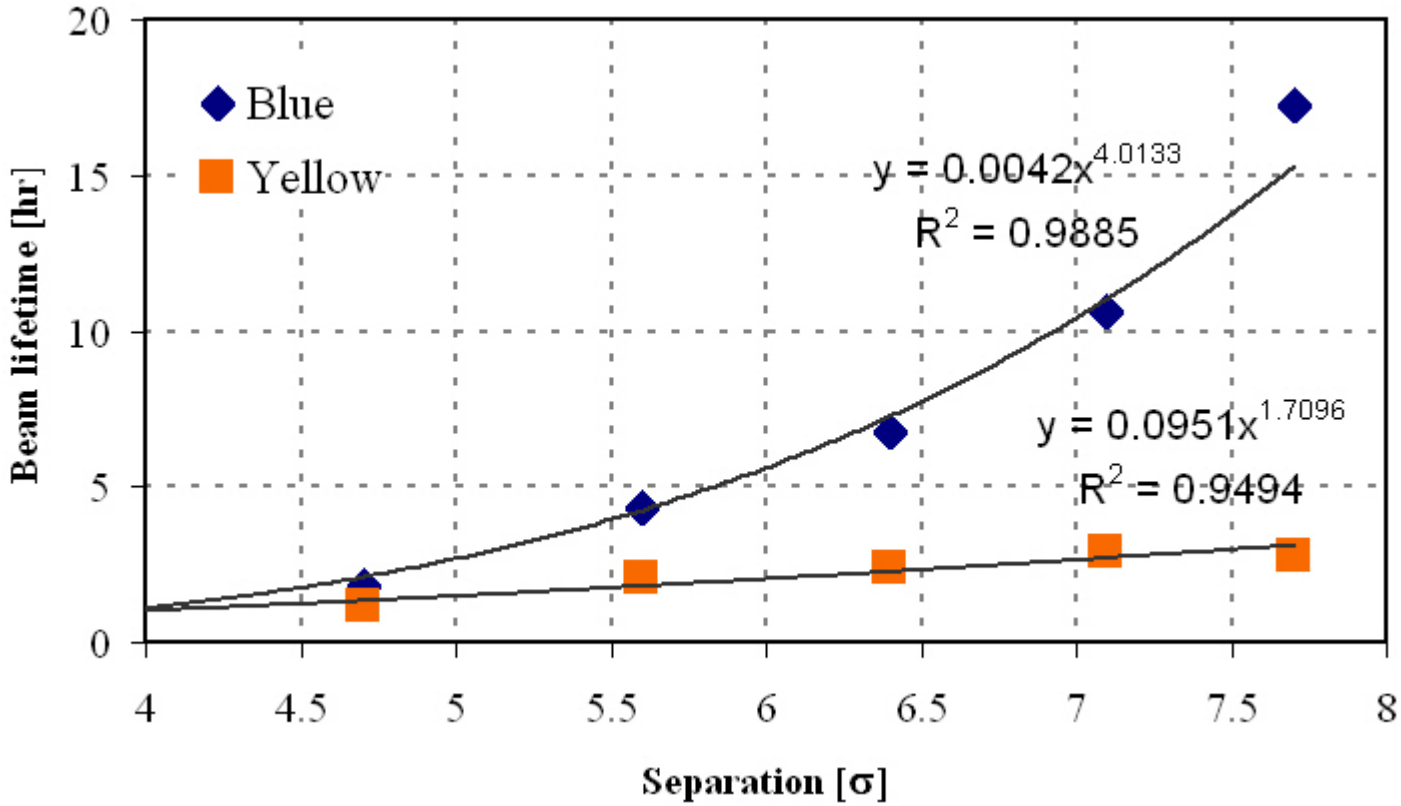
Effects of long-range beam-beam interaction observable at RHIC injection with a single bunch.

Lifetime versus separation

SPS : $\tau \approx 5\text{ms}\ (d/\sigma)^5$ [measured 11/09/04]

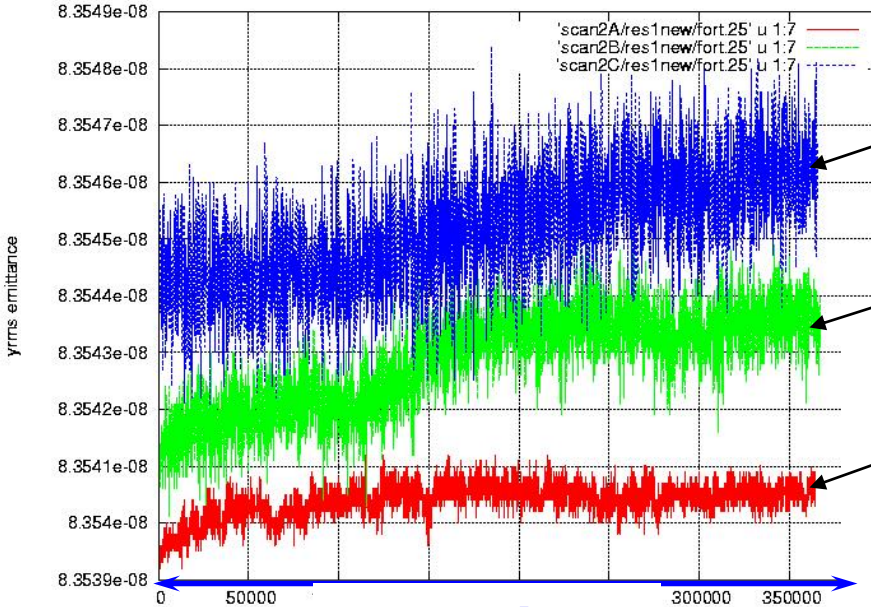
Tevatron: $\tau \sim d^3$ [reported in F. Zimmermann, LTC 11/24/04]

RHIC : $\tau \sim d^4$ or d^2 [measured 04/28/05, scan 4]



Simulation – Ji Qiang, LBNL

Scan 2 – rms emittance vs. time



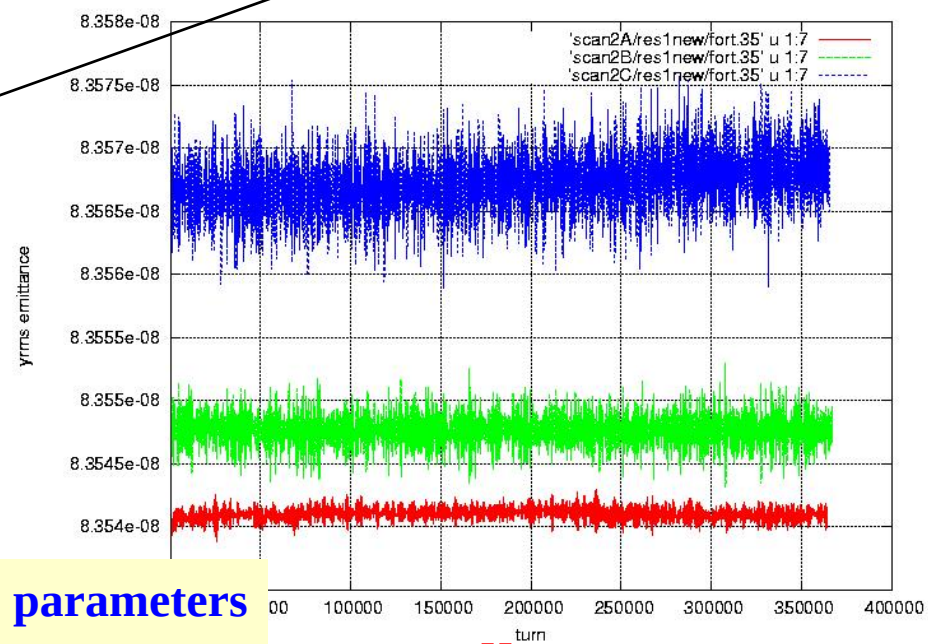
4.7σ separation

5.54σ

7.1σ

5 sec real time

Blue



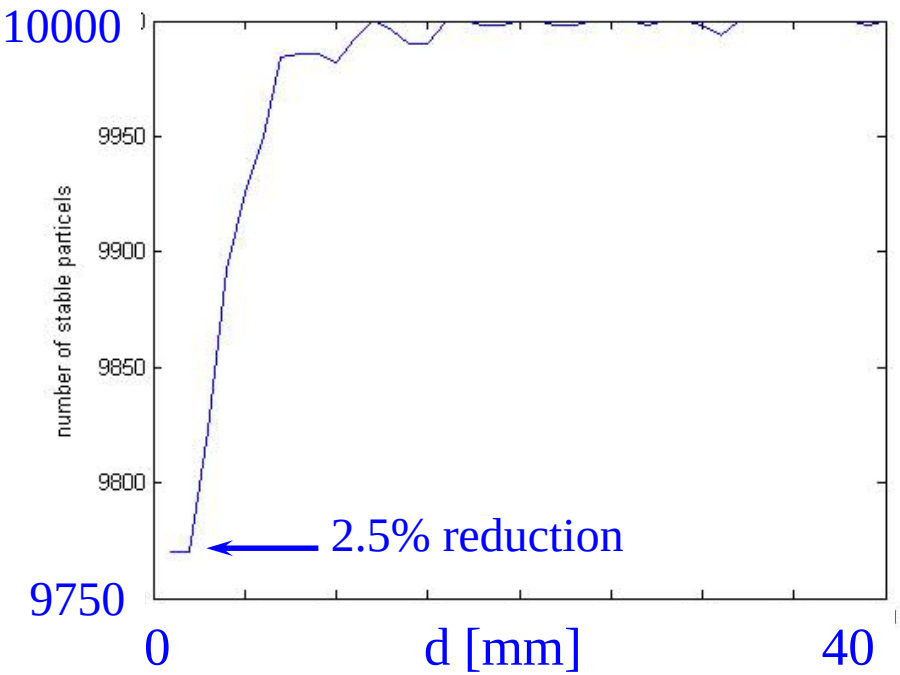
Yellow

Difference between beams visible for scan 2 parameters
Little effect seen for scan 4 parameters

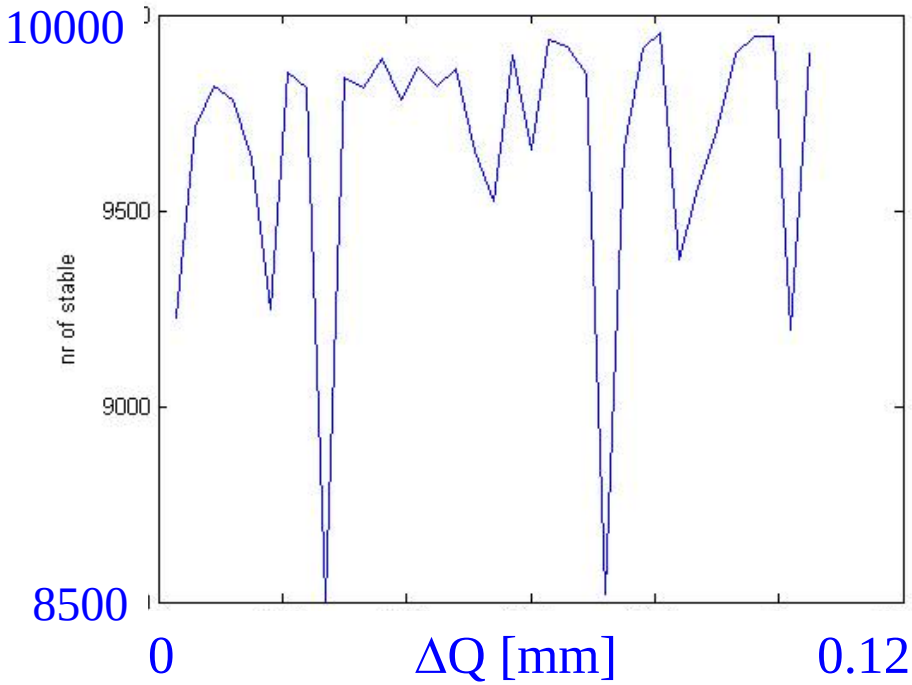
Simulation – Ulrich Dorda, CERN

Scan 1 parameters for Blue, 4 sec real time

No of stable particles vs. distance

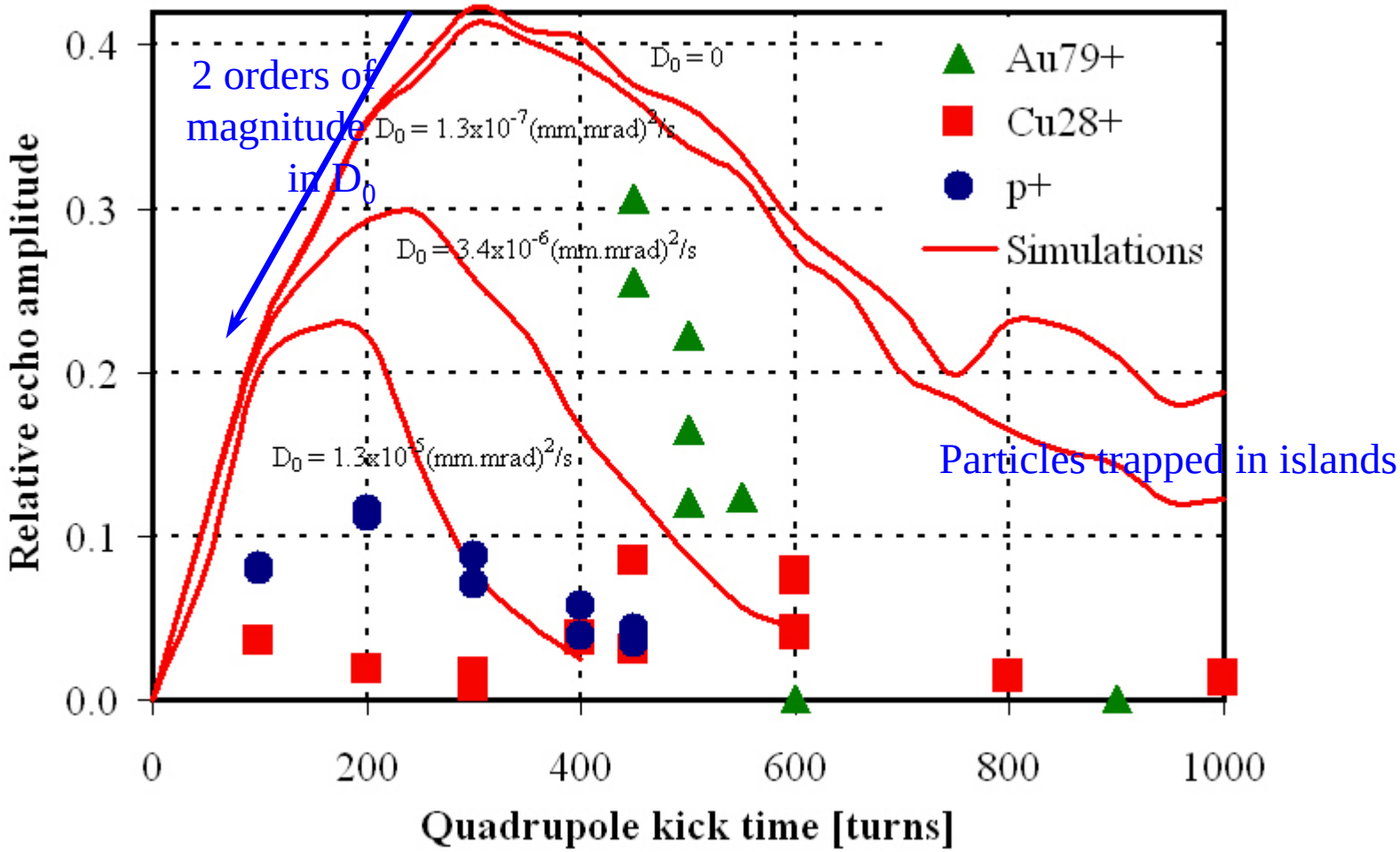


No of stable particles vs. tune



Code: BBTRACK (weak-strong, multi-particle, bb is the only nonlinearity)

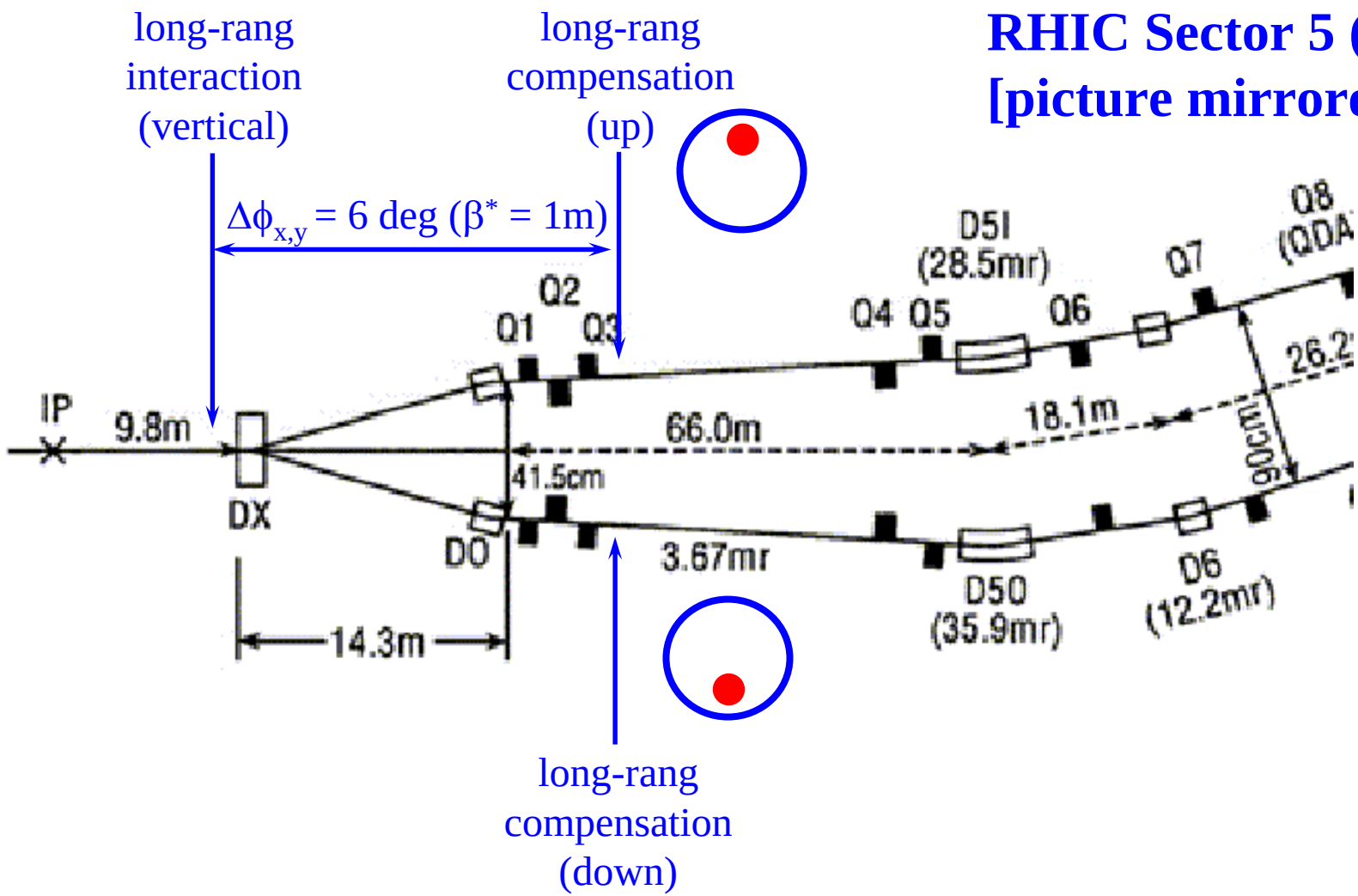
Simulations – are we missing something?



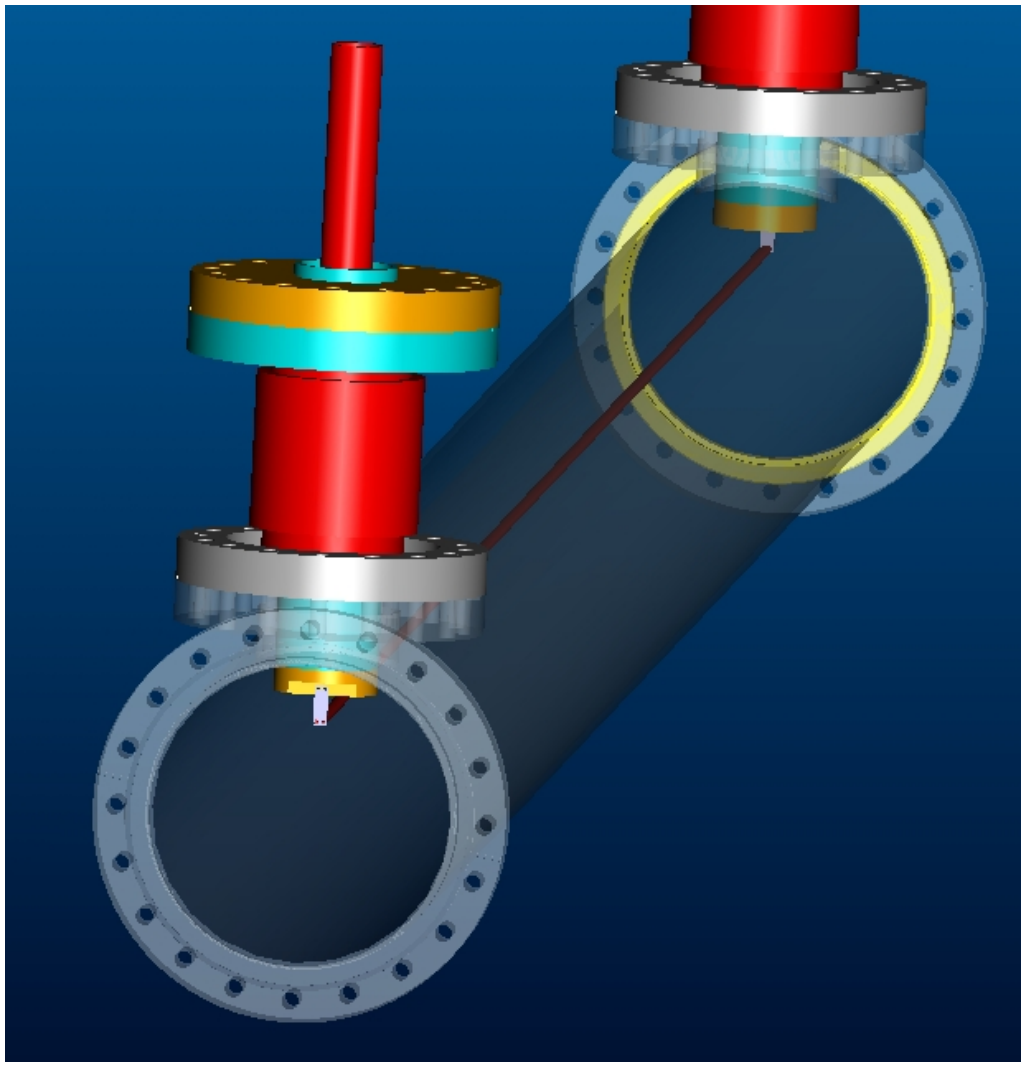
Transverse echoes measurements show stronger diffusion for protons than for heavier ions (without BB)

RHIC BBLR design – locations

RHIC Sector 5 (IR6)
[picture mirrored]



RHIC BBLR design – drawing



Main features:

- round copper bar
- air cooled heat sinks
- on vertically movable stand (60mm movement)

RHIC BBLR design – parameters

Integrated strength per long-range collision	Am	9.6
Integrated strength of compensator *IL*	Am	125
Length of wire *L*	m	1.5
Major half axis of elliptic bus bar *a*	mm	4.0
Minor half axis of elliptic bus bar *b*	mm	2.4
Output parameters		
Current in wire *I*	A	83
Electric resistance *R*	mΩ	0.87
Voltage *U*	mV	72.8
Electric power *P*	W	6.1
Max temperature change ΔT_{max}	K	100
Change in length due to ΔT	mm	1.7

~10x single bunch will have smaller power supply initially

RHIC BBLR experimental program proposal

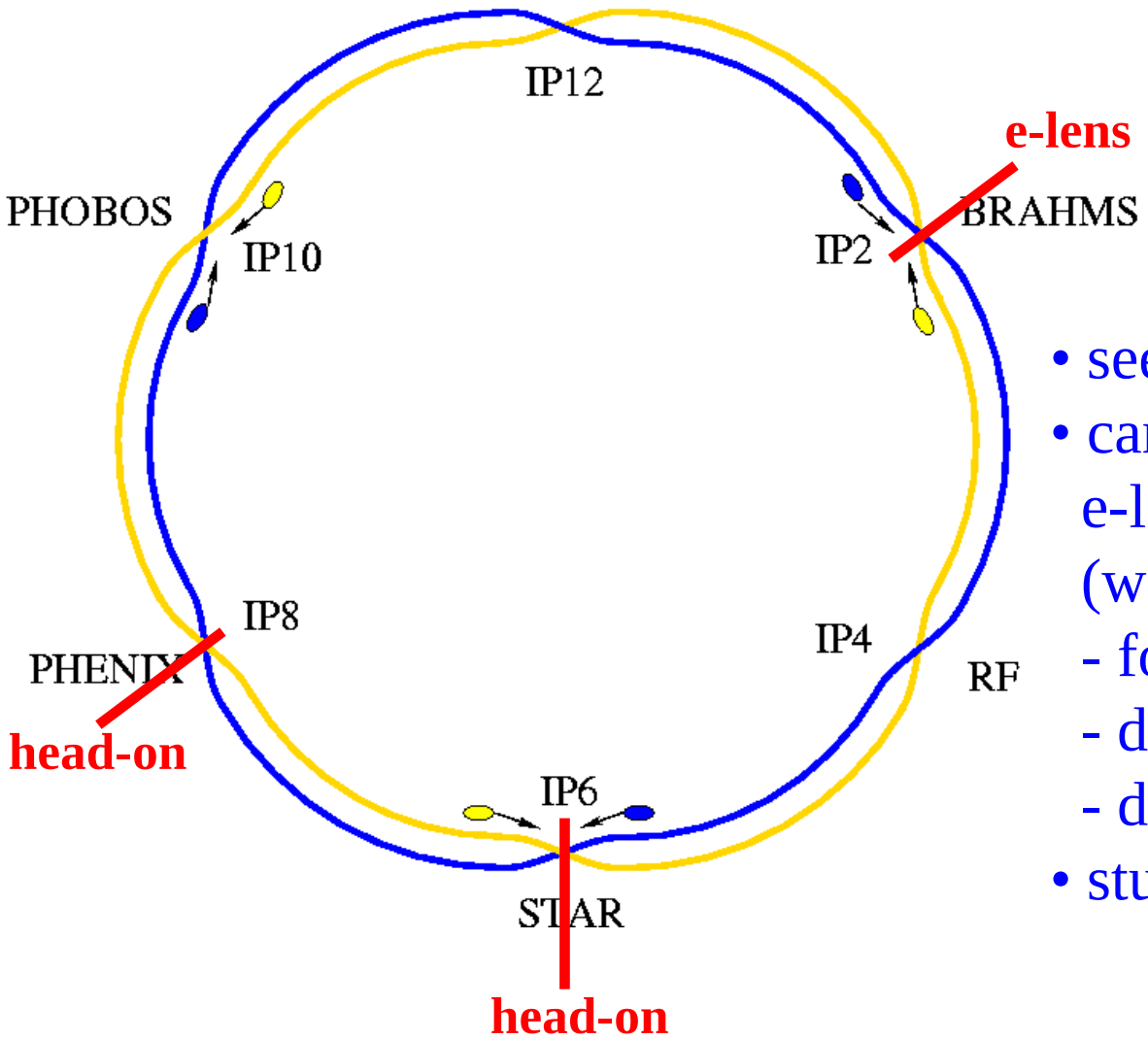
- (d,Q_y) scan at 100 GeV
- Single and multiple long-range interactions

Run-6 (2006) w/o BBLR (ask for 2x3hrs)

Run-7 (2007) with 1 or 2 dc BBLR

Run-8 (2008) with ac BBLR

RHIC head-on beam-beam compensation (Y. Luo)



- see last talk by V. Shiltsev
- can study effect of e-lenses in simulation (weak-strong)
  - footprints
  - dynamic aperture
  - diffusive aperture
- study started by Y. Luo

Summary

1. Long-range beam-beam compensation (wire)

- Measurable long-range beam-beam effect at injection
- Some features reproduced in simulation (not yes satisfying)
- Basis parameter range and design for BBLR established
- Study plan evolving

2. Head-on beam-beam compensation (e-lens)

- See previous talk by V. Shiltsev
- Simulation study started by Y. Luo