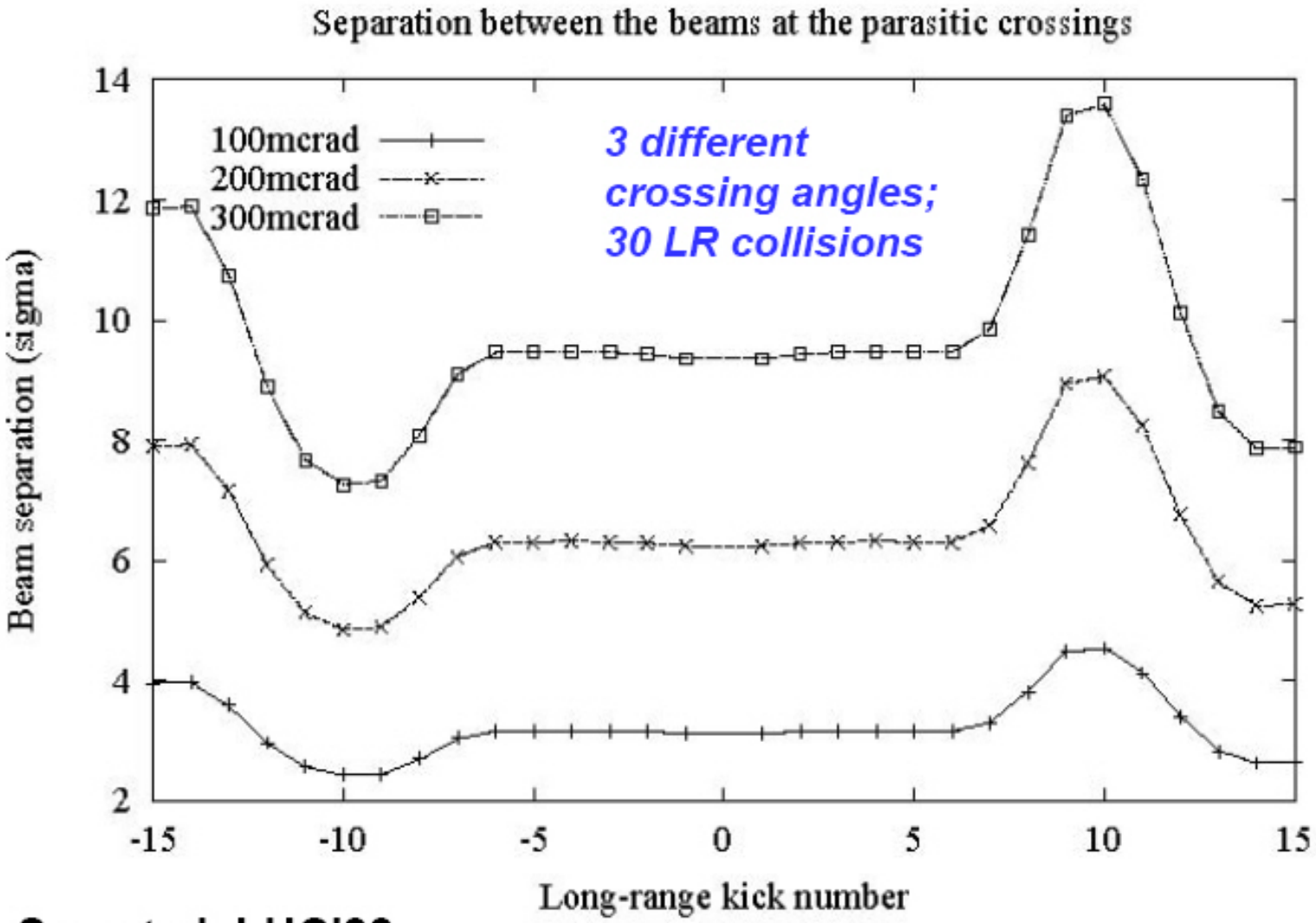
Results and tests for the beam-beam wires

W. Fischer, N. Abreu, R. Calaga, G. Robert-Demolaize
and collaborators from CERN and LARP

APEX08 BNL
4 December 2008

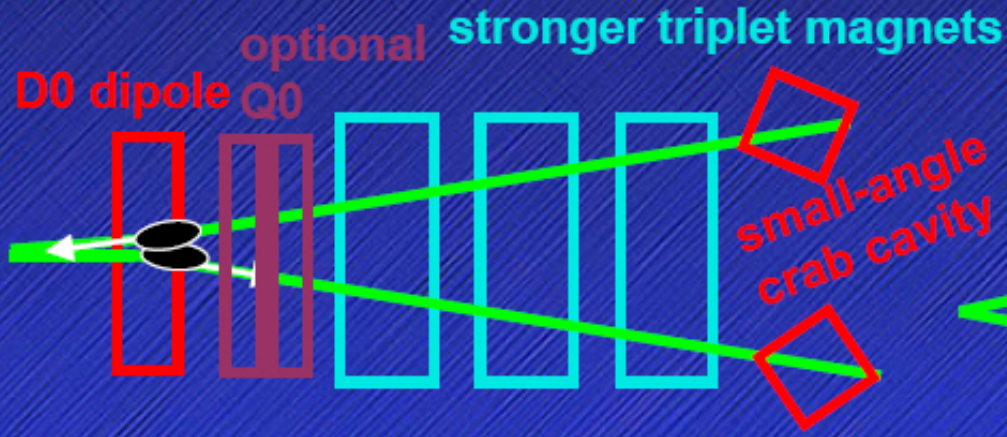
long-range separation at IP1 & 5



T. Sen et al, LHC'99

early separation (ES)

- stay with ultimate LHC beam (1.7×10^{11} protons/bunch, 25 spacing)
- squeeze β^* to ~10 cm in ATLAS & CMS
- add early-separation dipoles in detectors starting at ~ 3 m from IP; accept 4 long-range collisions at 4-5σ separation
- possibly also add quadrupole-doublet inside detector at ~13 m from IP
- and add crab cavities

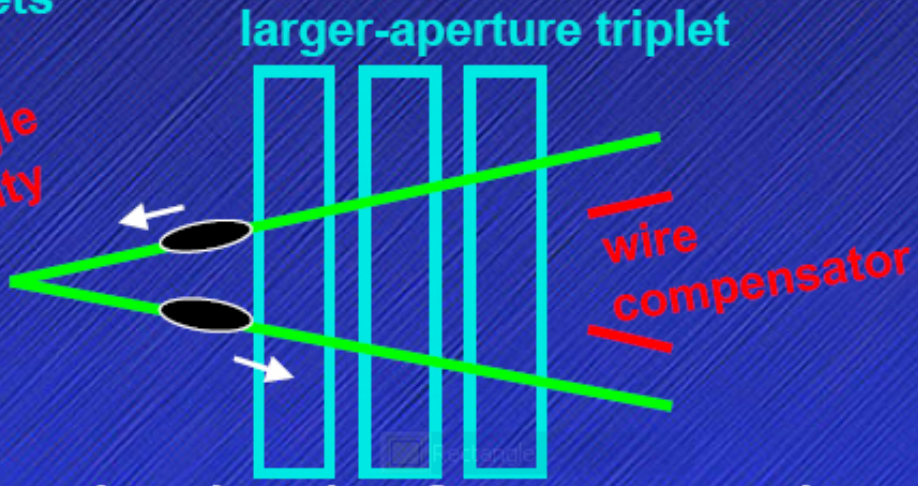


ultimate bunches & near head-on collision

large Piwinski angle (LPA)

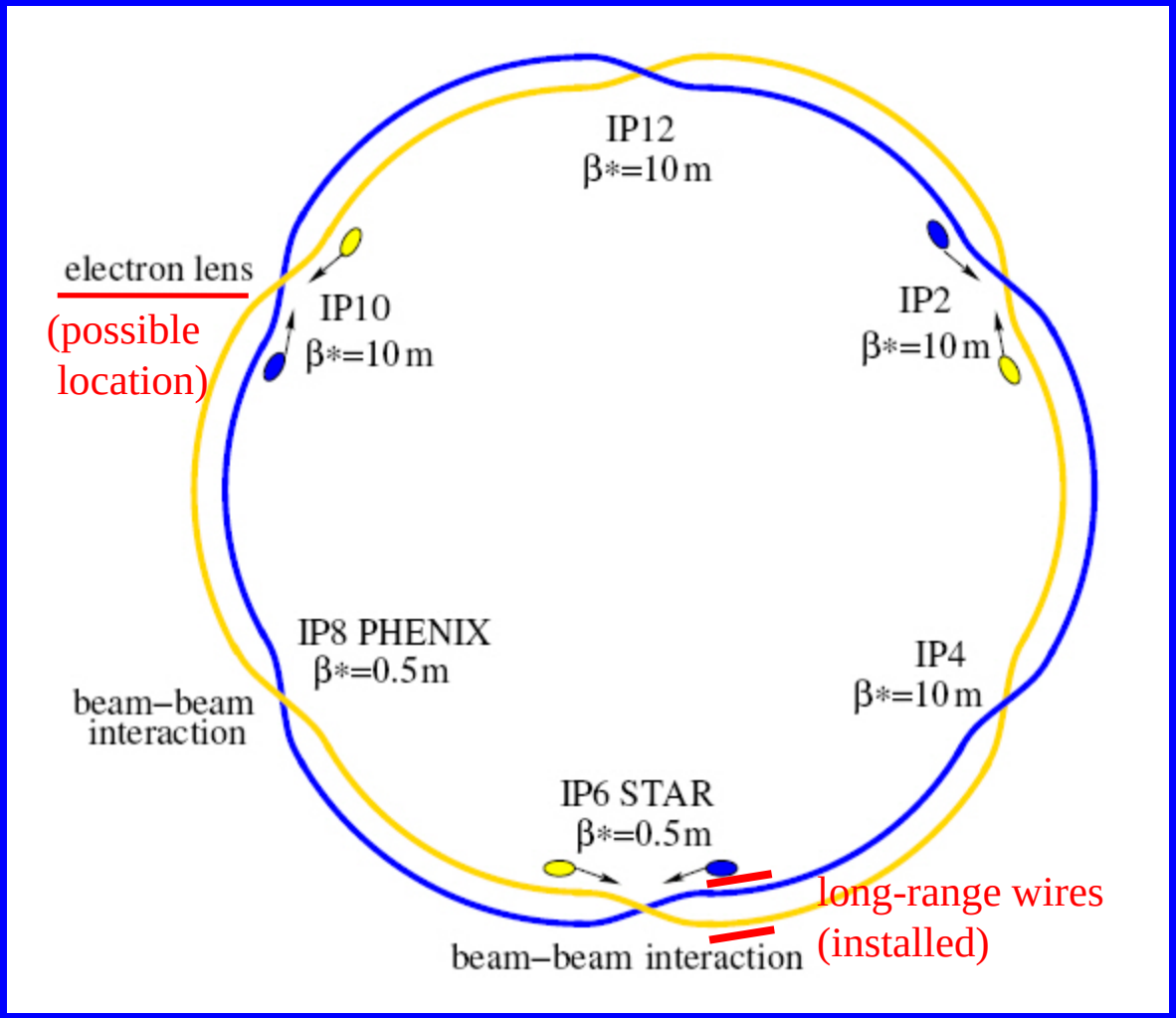
- double bunch spacing
- longer & more intense bunches with $\phi_{Piwinski} \sim 2$
- $\beta^* \sim 25$ cm
- no elements inside detectors
- long-range beam-beam wire compensation

→ novel operating regime for hadron colliders



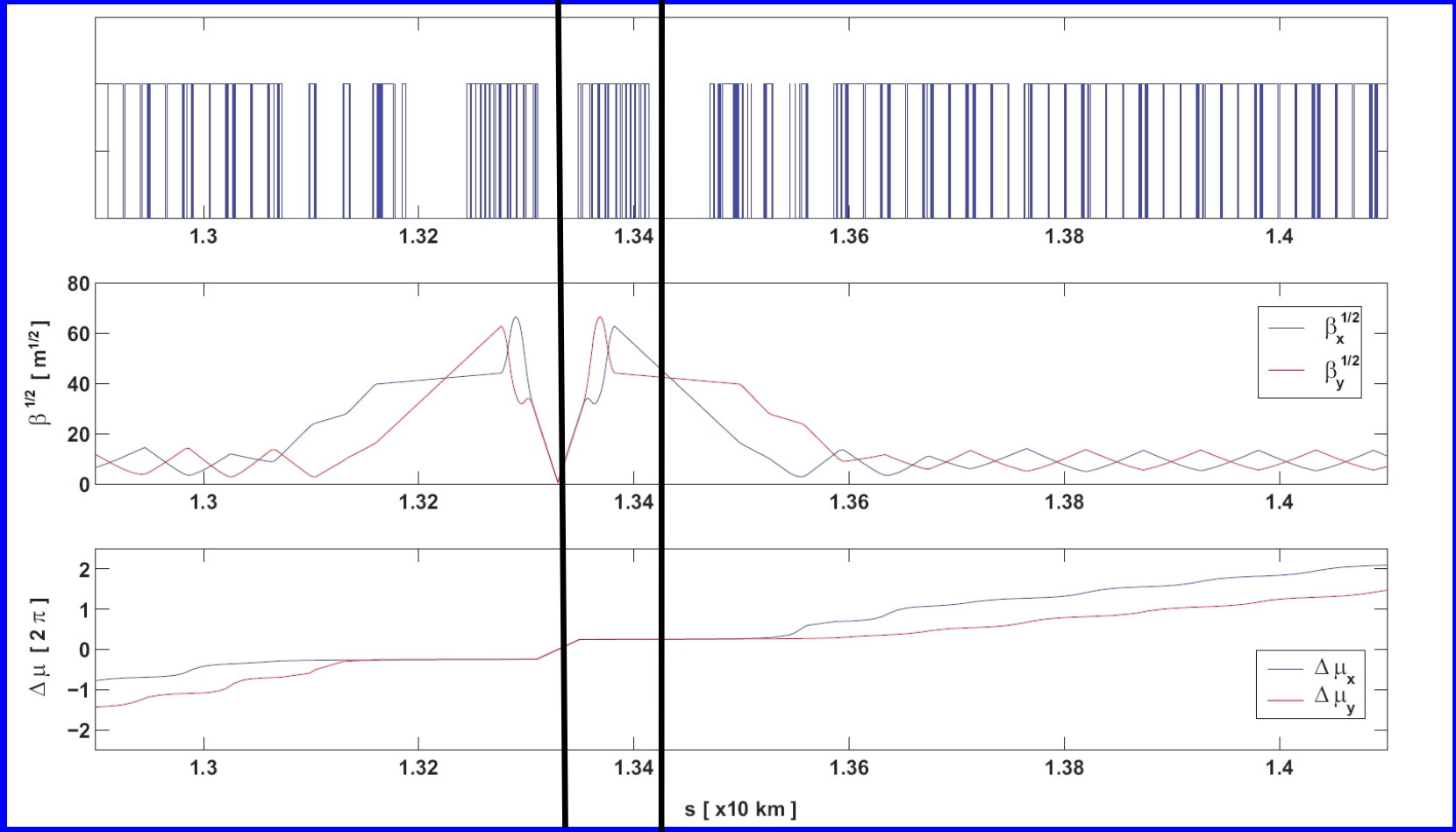
long bunches & nonzero crossing angle & wire compensation

RHIC beam-beam devices



Nominally no long-range beam-beam interactions (dipole first IR).

Beam-beam compensators in LHC



IP

s = 13329 m

β_x = 0.55 m μ_x = 32.049 [2π]

β_y = 0.55 m μ_y = 29.604 [2π]

BBLR or e-lens

s = 13433 m

β_x = 1925 m μ_x = 32.303 [2π]

β_y = 1784 m μ_y = 29.857 [2π]

$\Delta\mu_x$ = 91°

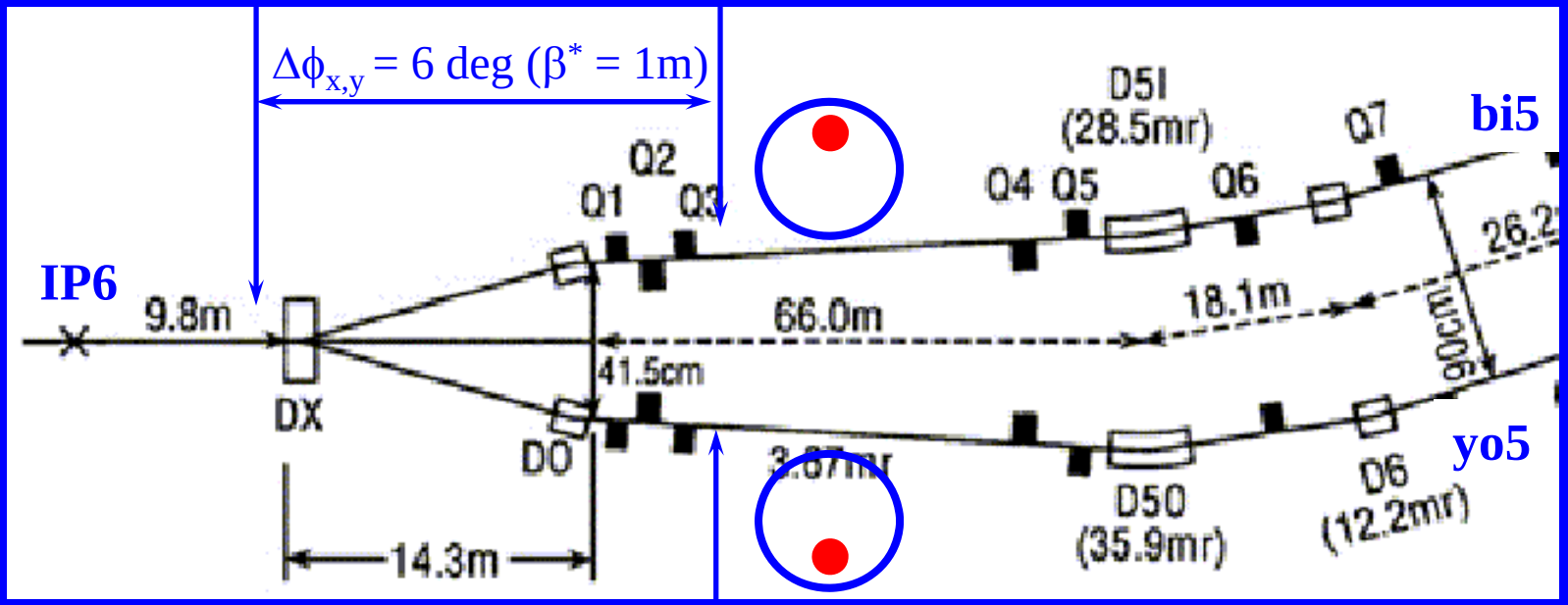
$\Delta\mu_y$ = 91°

Long-range beam-beam studies in RHIC

long-range interaction (vertical)

long-range compensation (up)

RHIC Sector 5

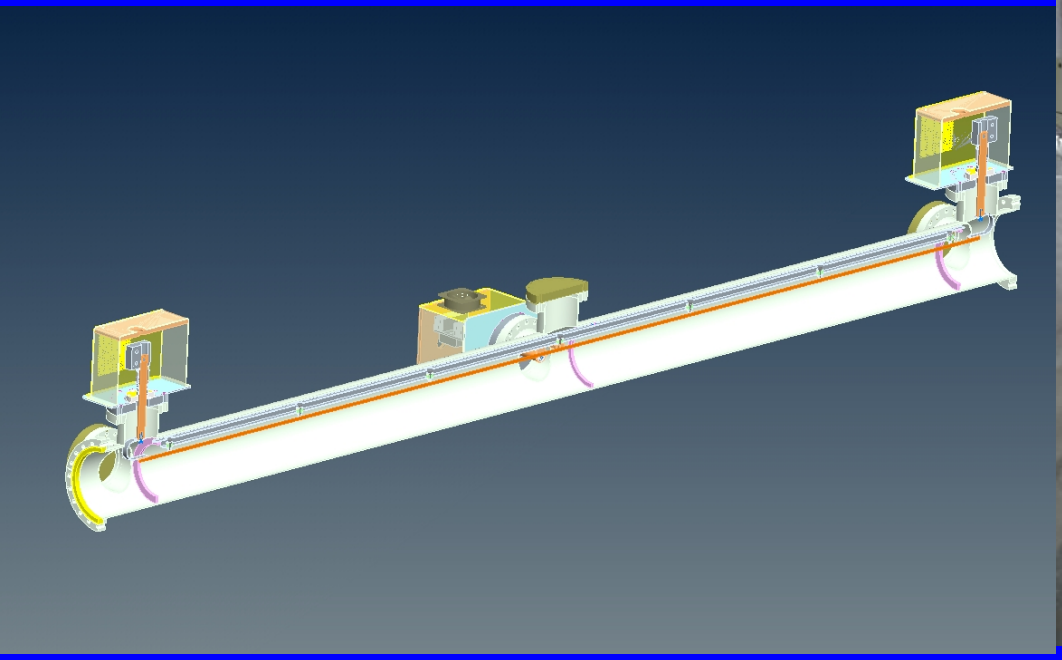


long-range compensation (down)

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

Long-range experiments with wire

- Long-range beam-beam effects in RHIC only on ramp, possibly with upgrades
- 2 wires installed to study long-range effect
  (collaboration within U.S. LHC Accelerator Research Program)



Vertically movable wires, maximum integrated strength of 125Am
(~13 LR interactions with N_b=2×10^{11}).

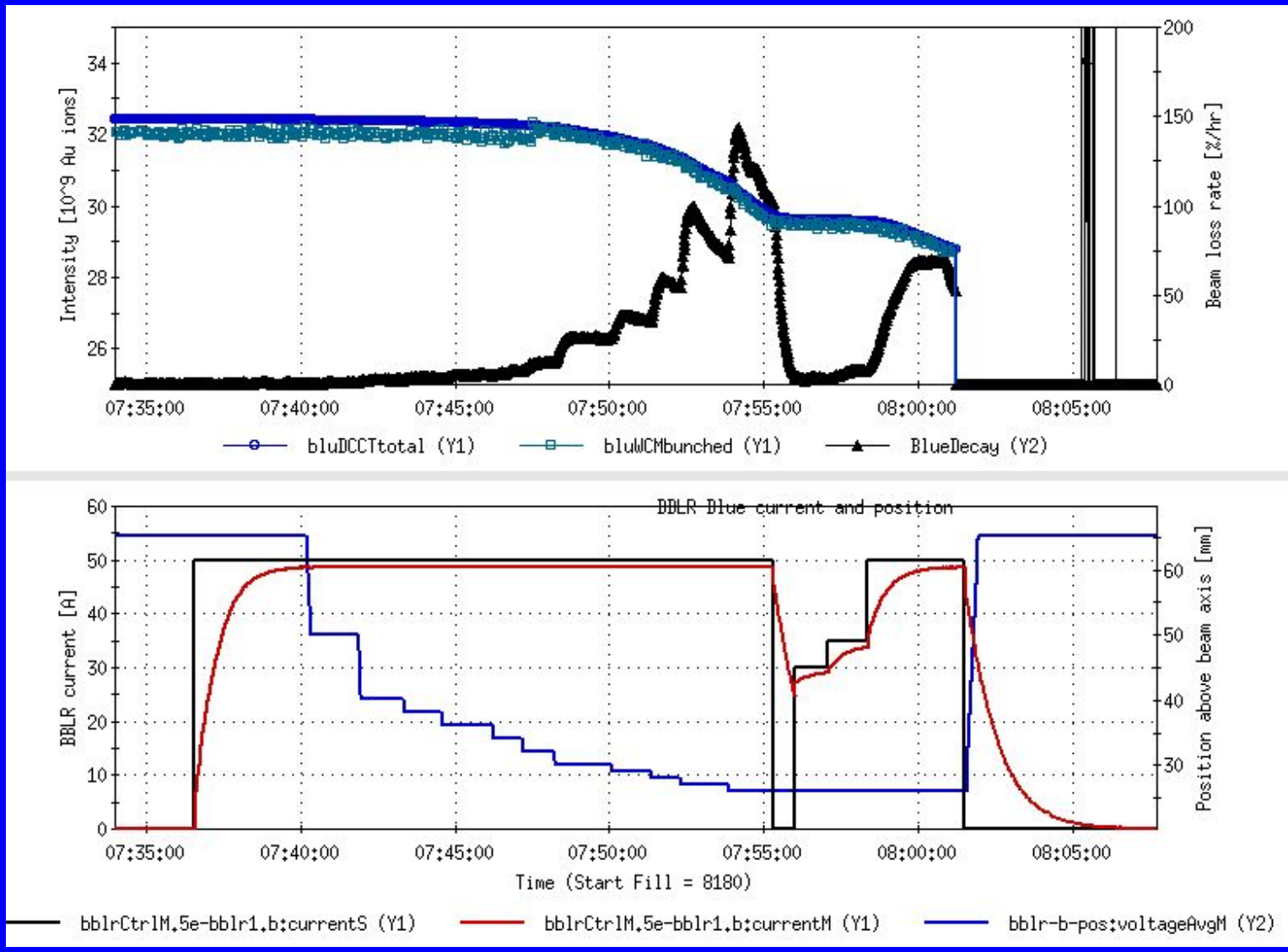
Long-range beam-beam experiments in RHIC

Measurements are beam lifetime observations with variations in

- separation
- strength (wire current)
- other parameters (tune, chromaticity)

- 2005: long-range with p-beam at injection
- 2006: long-range with p-beam at store
- 2007: long-range with Au-beam & wire at store
- 2008: only (parasitic) test d-beam & wire (short p-run)
- 2009: p-beam available (short p-run again)

Scan with d-beam in 2008 (01/28/08, fill 9664)



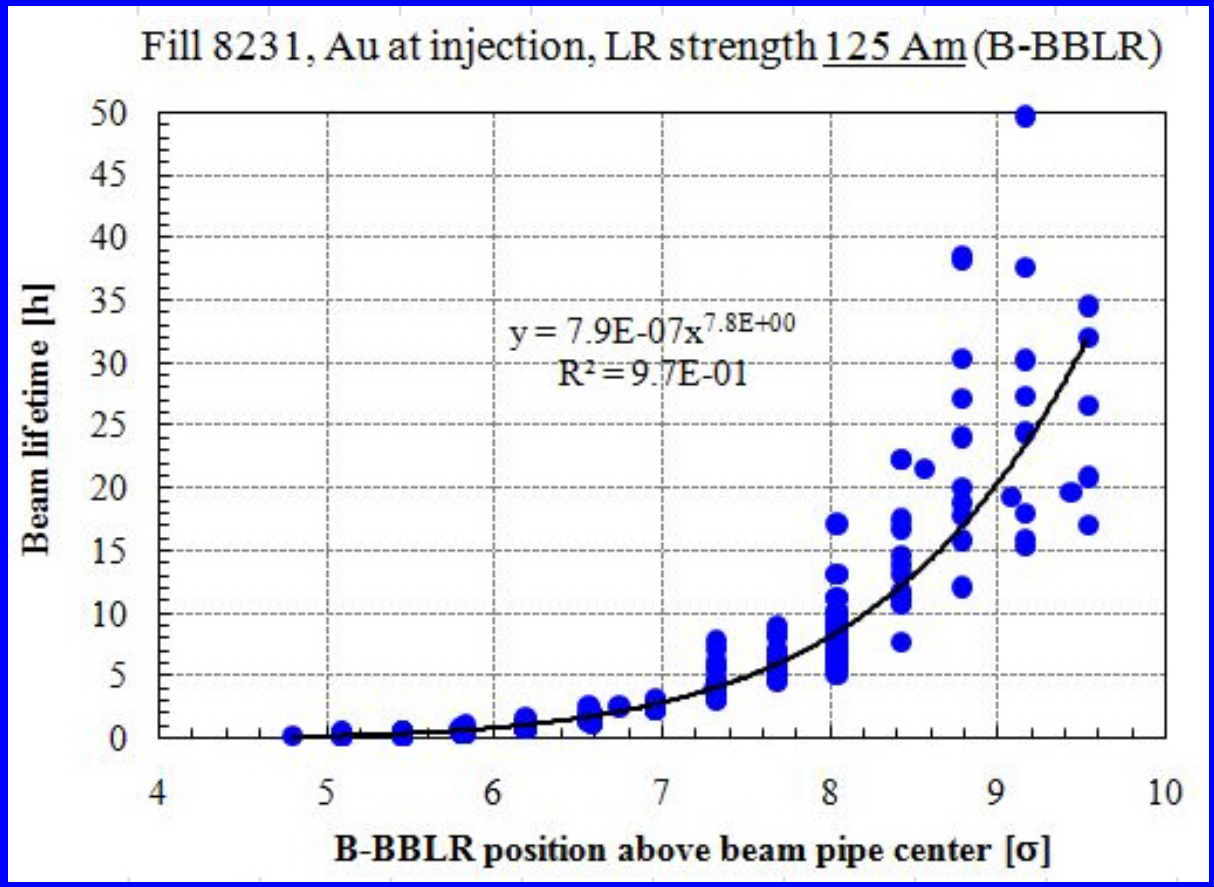
Long-range beam-beam studies at RHIC

Summary of long-range beam-beam measurements in RHIC							Blue		Yellow				
							hor tune	ver tune	hor tune	ver tune			
date	fillno	ring	scan	species	elativistic	no of bunches	[...]	[...]	[...]	[...]	LR location	LR strength [Am]	LR separation [mm]
04/28/05	6981	B & Y	1	p	25.963	1/ring	0.7331	0.7223	0.7267	0.7234		5.3	B beam position scanned
04/28/05	6981	B & Y	2	p	25.963	1/ring	0.7351	0.7223	0.7282	0.7233	IP4	5.8	B beam position scanned
04/28/05	6981	B & Y	3	p	25.963	1/ring	0.7383	0.7247	0.7271		IR4 DX	8.6	Y beam position scanned
04/28/05	6981	B & Y	4	p	25.963	1/ring	0.7394	0.7271	0.726	0.7388	IR4 DX	8.9	Y beam position scanned
04/05/06	7707	B & Y	1	p	106.597	10/ring					IR6 DX (sector 5)	6.7	B beam position scanned
04/05/06	7707	B & Y	2	p	106.597	10/ring					IR6 DX (sector 5)	6.7	Y beam position scanned
04/12/06	7747	B & Y	1	p	106.597	8 B/10 Y					IR6 DX (sector 5)	7.9	B beam position scanned
04/12/06	7747	B & Y	2	p	106.597	8 B/10 Y					IR6 DX (sector 5)	7.0	Y beam position scanned
05/03/06	7807	B & Y	1	p	106.597	12/ring	0.692	0.695	0.692	0.6966	IR6 DX (sector 5)	8.2	Y beam position scanned
03/13/07	8231	B	1	Au	10.520	6	0.2327	0.2140			B-BBLR	12.5	B-BBLR position scanned
03/13/07	8231	B	1	Au	10.520	6	0.2322	0.2140			B-BBLR	125.0	B-BBLR position scanned
03/27/07	8405	B	1	Au	107.369	56	0.2200	0.2320			B-BBLR	125.0	B-BBLR position scanned
04/25/07	8609	B	1	Au	107.369	23	0.2340	0.2140			B-BBLR	12.5	B-BBLR position scanned
04/25/07	8609	B	2	Au	107.369	23	0.2340	0.2140			B-BBLR	125.0	B-BBLR position scanned
04/25/07	8609	Y	1	Au	107.369	23			0.2280	0.2350	Y-BBLR	12.5	Y-BBLR position scanned
04/24/07	8609	Y	2	Au	107.369	23			0.2280	0.2350	Y-BBLR	125.0	Y-BBLR position scanned
05/09/07	8727	B	1	Au	107.369	23	0.2200	0.2320			B-BBLR	12.5	B-BBLR position scanned
05/09/07	8727	B	2	Au	107.369	23	0.2200	0.2320			B-BBLR	125.0	B-BBLR position scanned
05/09/07	8727	Y	1	Au	107.369	23			0.2320	0.2280	Y-BBLR	12.5	Y-BBLR position scanned
05/09/07	8727	Y	2	Au	107.369	23			0.2320	0.2280	Y-BBLR	125.0	Y-BBLR position scanned
05/09/07	8727	Y	3	Au	107.369	23			0.2320	0.2280	Y-BBLR	125 - 0	-29
05/09/07	8727	Y	4	Au	107.369	23			0.2320	0.2280	Y-BBLR	125.0	-29
05/09/07	8727	Y	5	Au	107.369	23			0.2320	0.2280	Y-BBLR	125 - 0	-29
01/28/08	9664	B	1	d	107.369	12	0.2288	0.2348			B-BBLR	125.0	B-BBLR position scanned
01/28/08	9664	B	2	d	107.369	12	0.2288	0.2348			B-BBLR	75 - 125	26

25 long-range measurements (scans)
- 2 strengths (12.5 and 125 Am)
- 3 species (p, Au, d)
- 2 energies
- 2 tune ranges
- chromaticity scan

RHIC long-range measurements

Beam lifetimes τ fitted to $\tau = A\, d^{\,p}$. Fitted exponents p varies from 1.5 to 16.

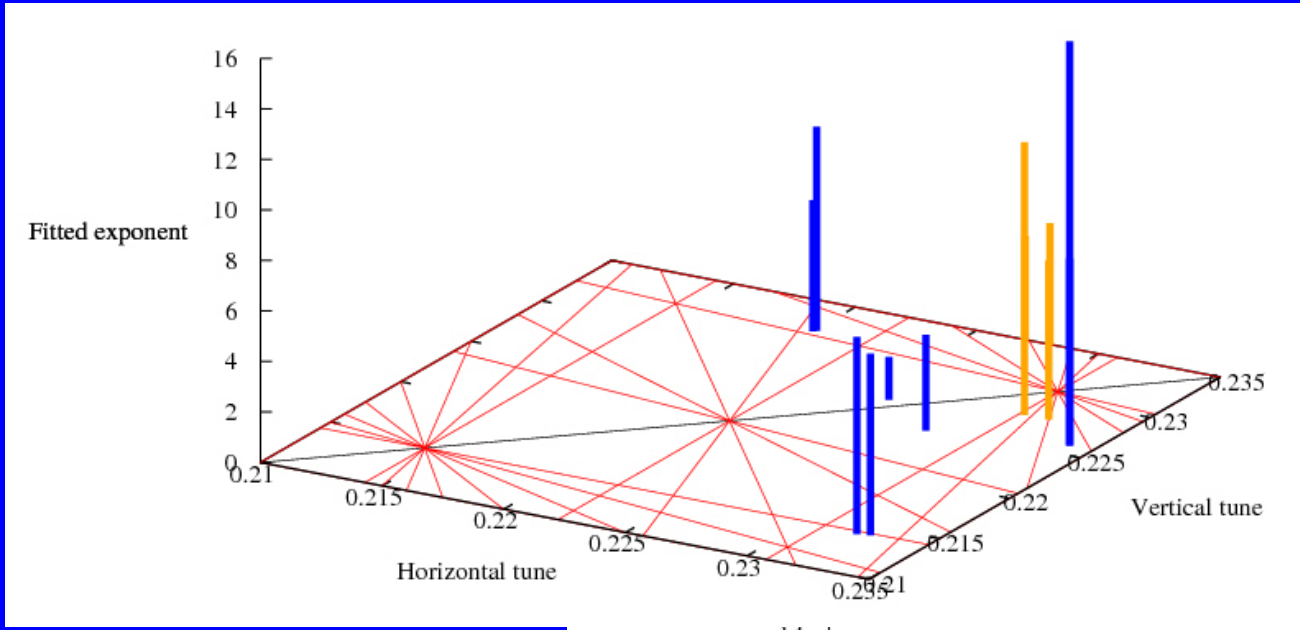


SPS found $\tau \propto d^5$ [measurement 11/09/04]

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

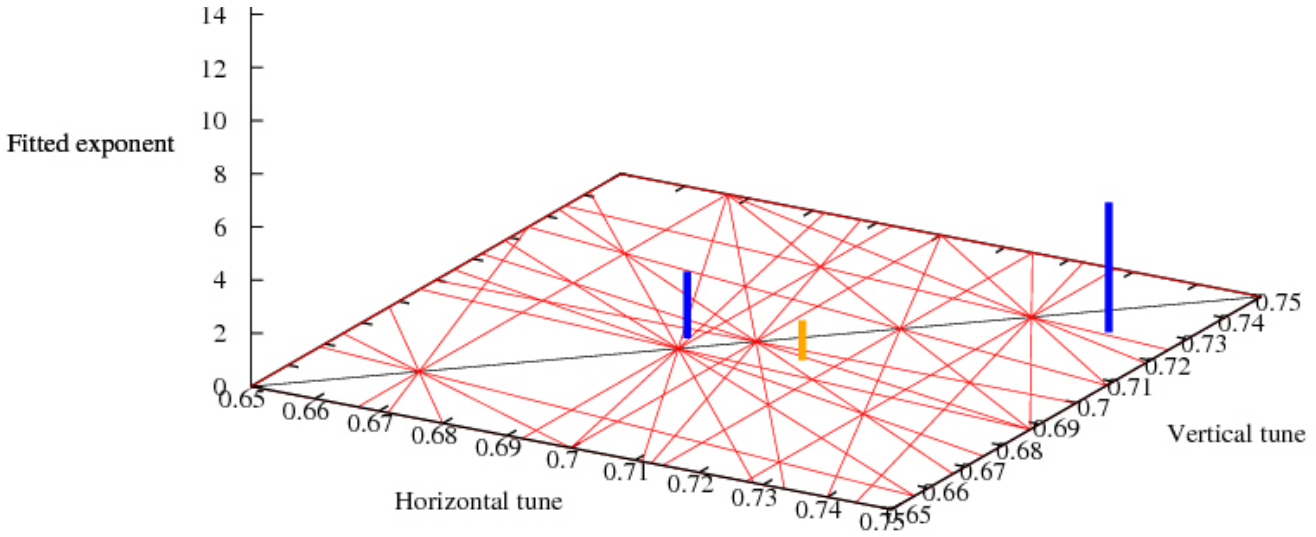
Long-range beam-beam studies at RHIC

Beam lifetimes τ fitted to $\tau = A\, d^{\,p}$. Fitted exponents p varies from 1.5 to 16.



← Tune range [0.21,0.235] (heavy ions)

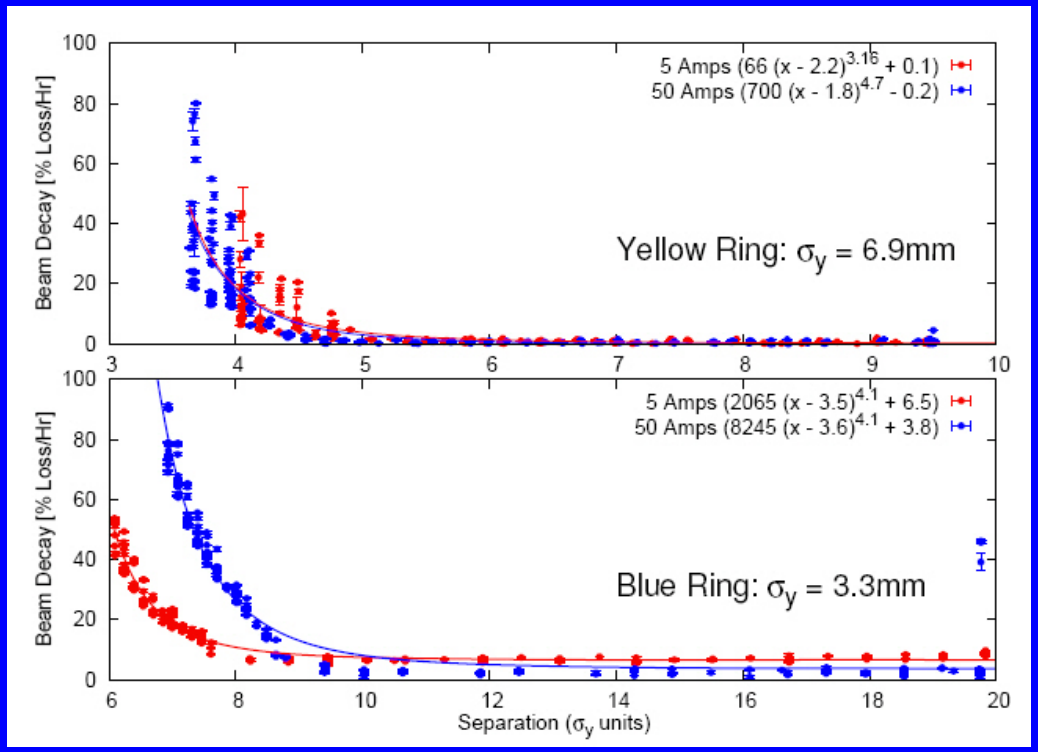
Tune range [0.65,0.75] → (protons)

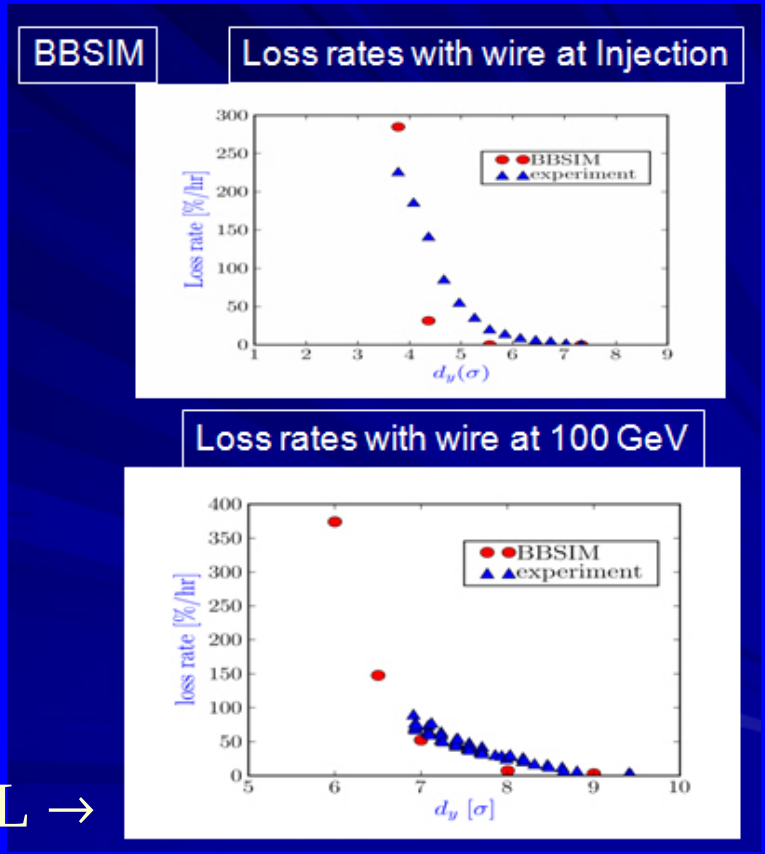


Wolfram Fischer

Long-range measurement and simulation

Experiments so far: distance, current and chromaticity scans with Au,
for comparison with simulations



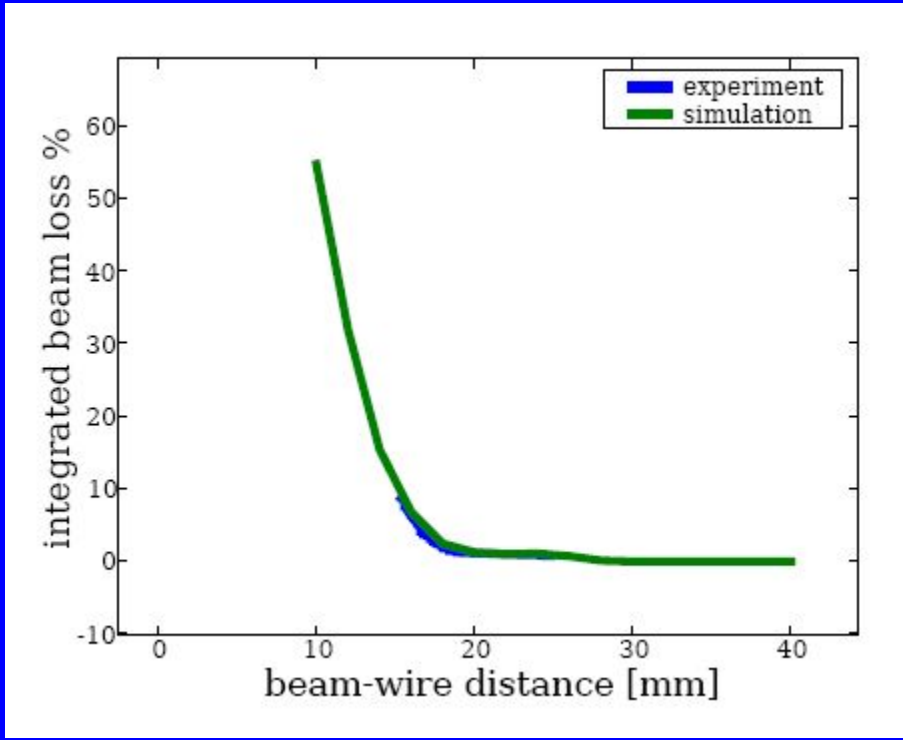


H.J. Kim, T. Sen, FNAL →

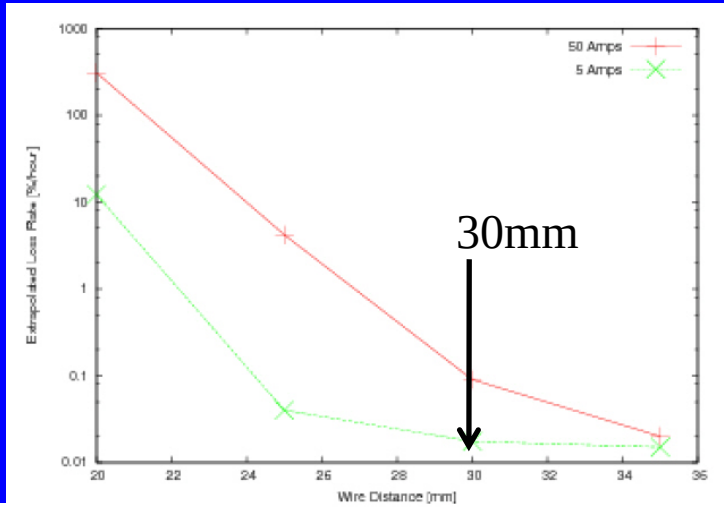
Onset of large losses reproduced within 1σ.

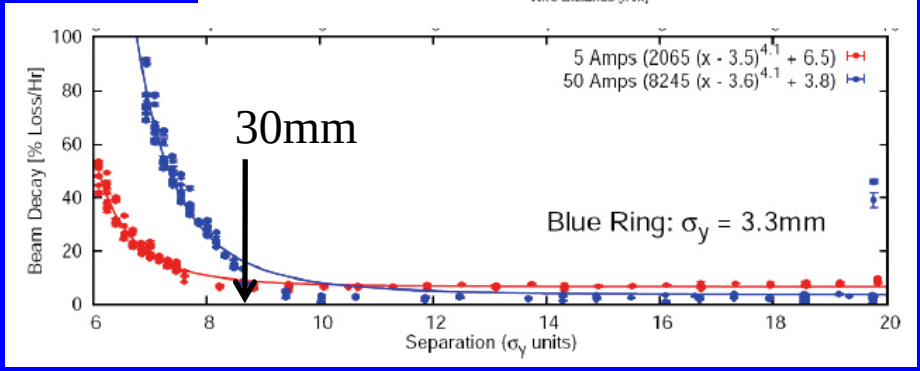
Long-range measurement and simulation

Simulation by U. Dorda for Au beam with wire 12.5Am



Simulation by A. Kabel for Au beam with wire 12.5 & 125Am

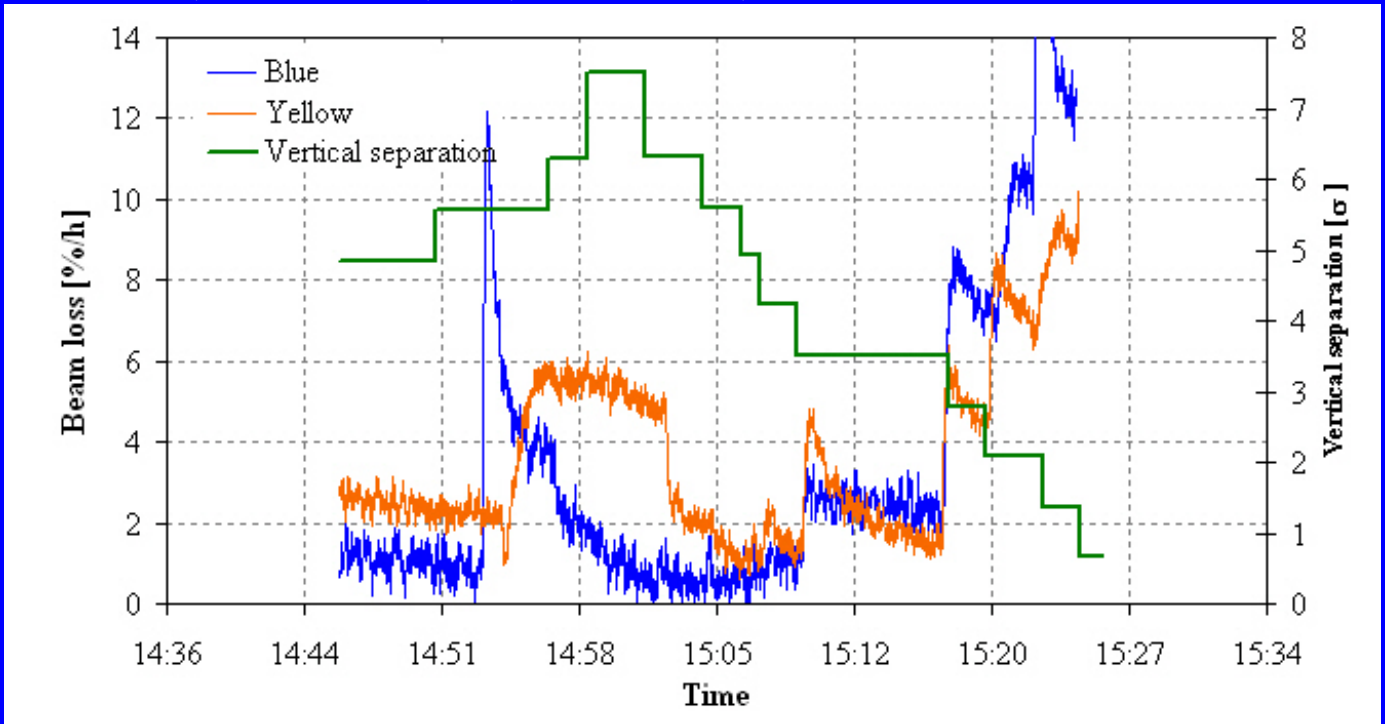




Onset of large losses reproduced within 1σ.

Minimum beam separation

Collision at s = 10.6 m, Yellow beam moved vertically (after 15:00)
Tunes B (0.739,0.727) Y (0.727,0.738)



Onset of losses from long-range interaction seen in experiments:

- at 4σ for single beam LR interaction (picture above)
- between 5-9σ with wire (strong dependence on WP and chromaticity)

[N. Abreu, "Beam-beam with a few long-range encounters at long distance", BEAM'07.]

Planned test with RHIC BBLR wires in 2009

- Would like to ask for 3×3 hr dedicated time again
- Would like to test effect on background with protons too (semi-parasitic)
- Parameter scans (distance, strength) with protons
  - Including head-on
  - Different working points than for Au (LHC working point mirrored at 0.5)
- Attempt to compensate one long-range interaction (need increased chromaticity for this measurement)

LRBBC studies at RHIC – summary

1. Strong long-range beam-beam effect confirmed with RHIC data
   - Experimental conditions in RHIC closer to LHC than Tevatron
   - 125 Am ≈ one side of one LHC IR, but beam rigidity is ≈ 30× smaller)
2. Lifetime fit to $\tau = A\, d^{\,p}$ shows large range of fitted exponent p (1.5 to 16)
   - Found $p \approx 5$ in SPS and $p \approx 3$ in Tevatron
3. Distance with onset of large losses can be reproduced in simulations within 1σ
4. Distance smaller than 5σ appear problematic

Acknowledgements

- J. Beebe-Wang, S. Tepikian (BNL)
- U. Dorda, J.-P. Koutchouk, G. Sterbini, F. Zimmermann (CERN)
- H.-J. Kim, T. Sen (FNAL)
- J. Qiang (LBNL)
- A. Kabel (SLAC)