2004 BBLR MD Results

- 2002/03 MDs & new BBLRs
- preliminary results of 3 parasitic MDs in 2004
- proposal for additional MD

for the BBLR team

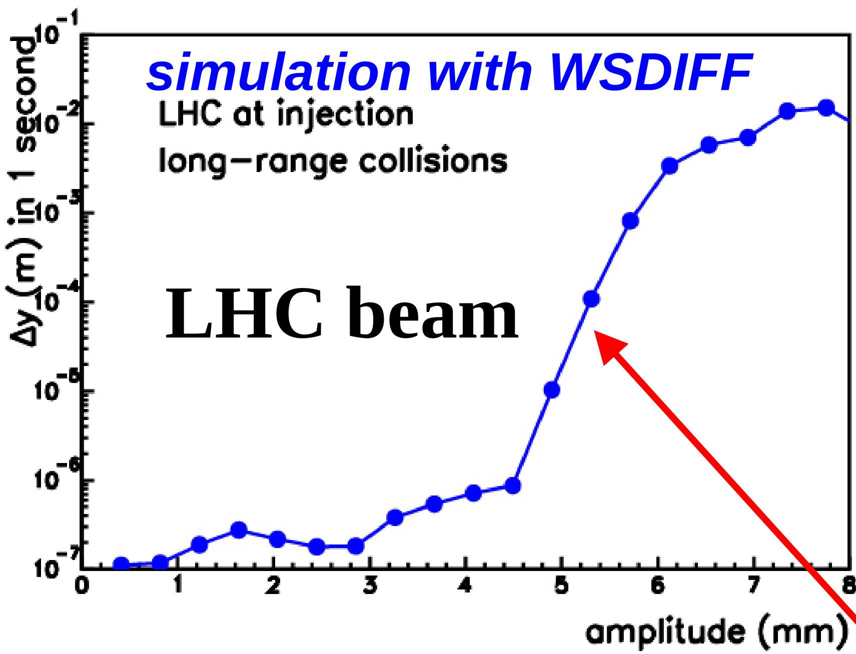
LHC BBLR

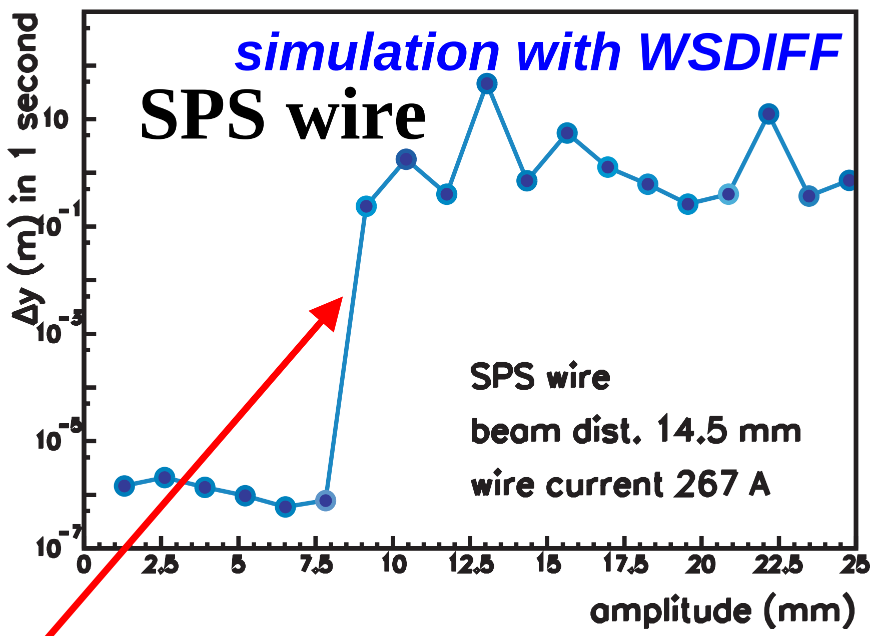
many people contributing

J.Albertone, G.Arduini, S.Baird, F.Billard, C.Benvenuti, G.Burtin, F.Caspers, A.Cherif,G.Ferioli, C.Fischer, J.-M.Geisser, J.-J.Gras, A.Grudiev, R.Jones, J.Koopman, J.-P.Koutchouk, L.Jensen, Y.L'Aminot, S.Mathot, S.Myers, J.-L.Pasquet, R.Perret, J.-P.Riunaud, F.Roncarolo, M.Royer, H.Schmickler, J.Wenninger, …, CERN; Y. Papaphilippou, ESRF; B.Erdelyi, T.Sen, V.Shiltsev, FNAL

motivation

long-range collisions cause a **large diffusion** and **proton losses -**
effect of SPS BBLR wire resembles LHC long-range collisions -
hence we can study LHC long-range collisions and their compensation in the SPS

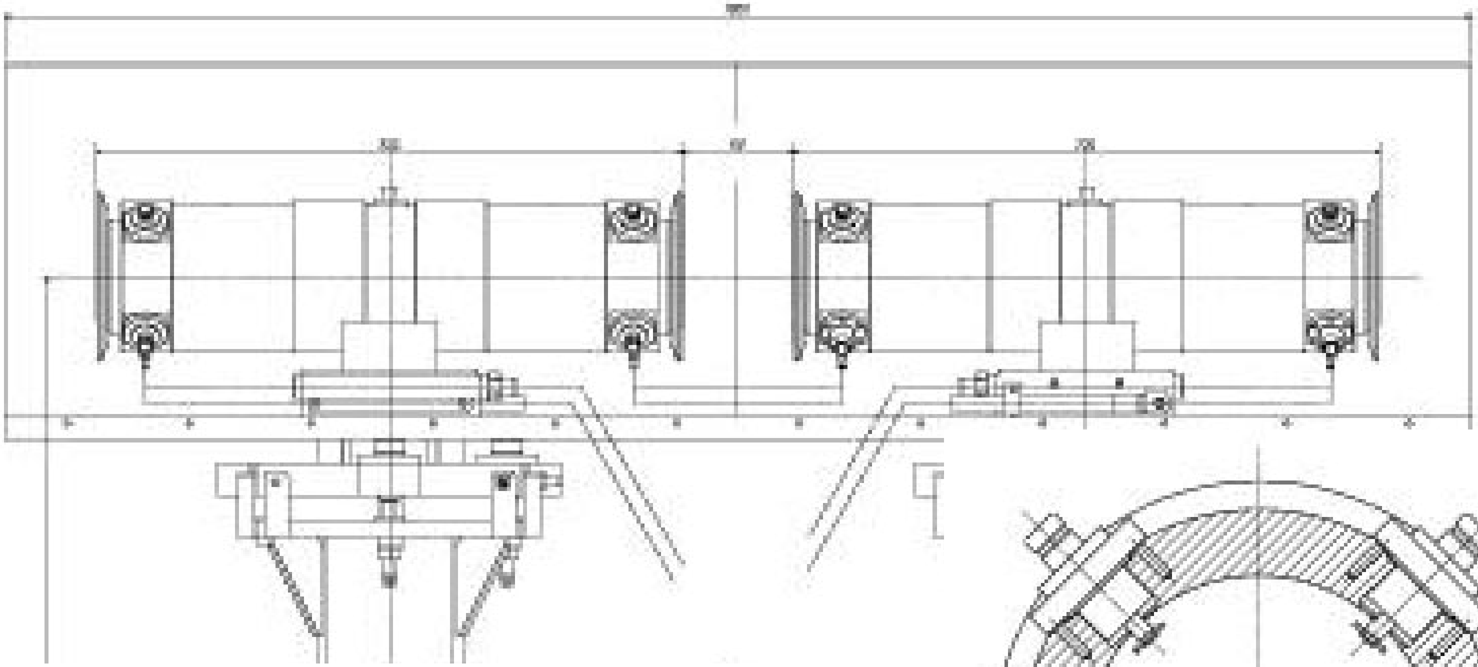




diffusive aperture

F. Zimmermann, 2004 BBLR MD Results, APC 15.10.2004

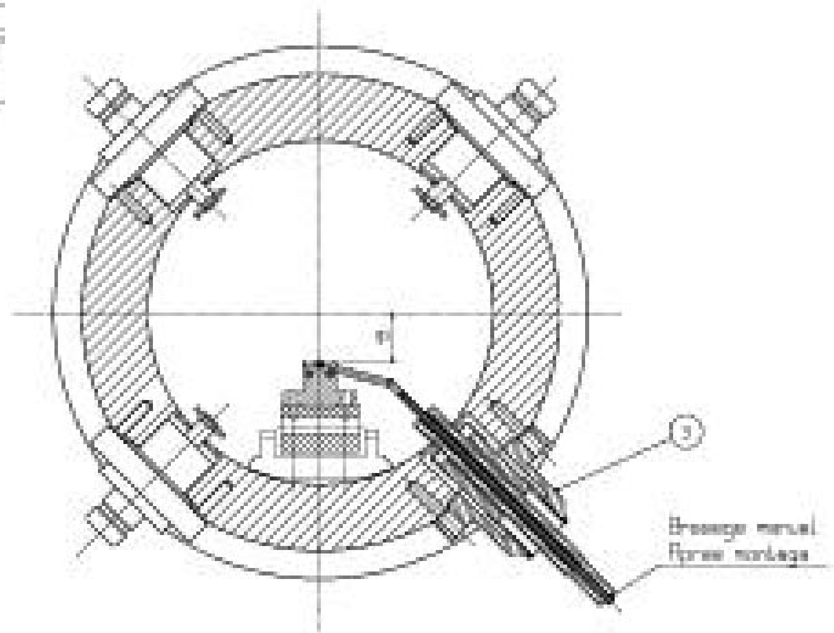
early in 2002 a single 1-wire BBLR was installed in the SPS



each BBLR consists

of 2 units, total length:

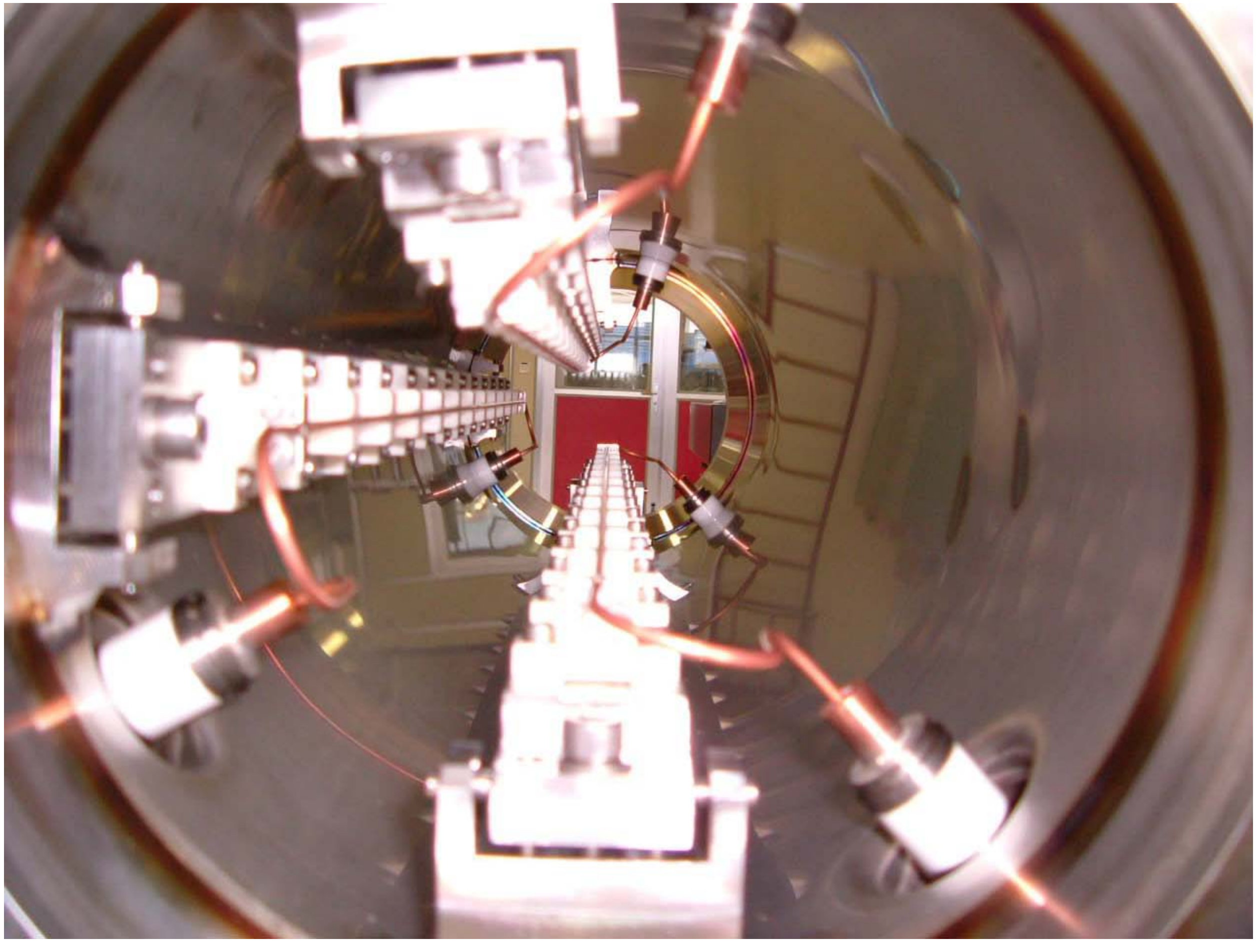
2x0.8+0.25=1.85 m



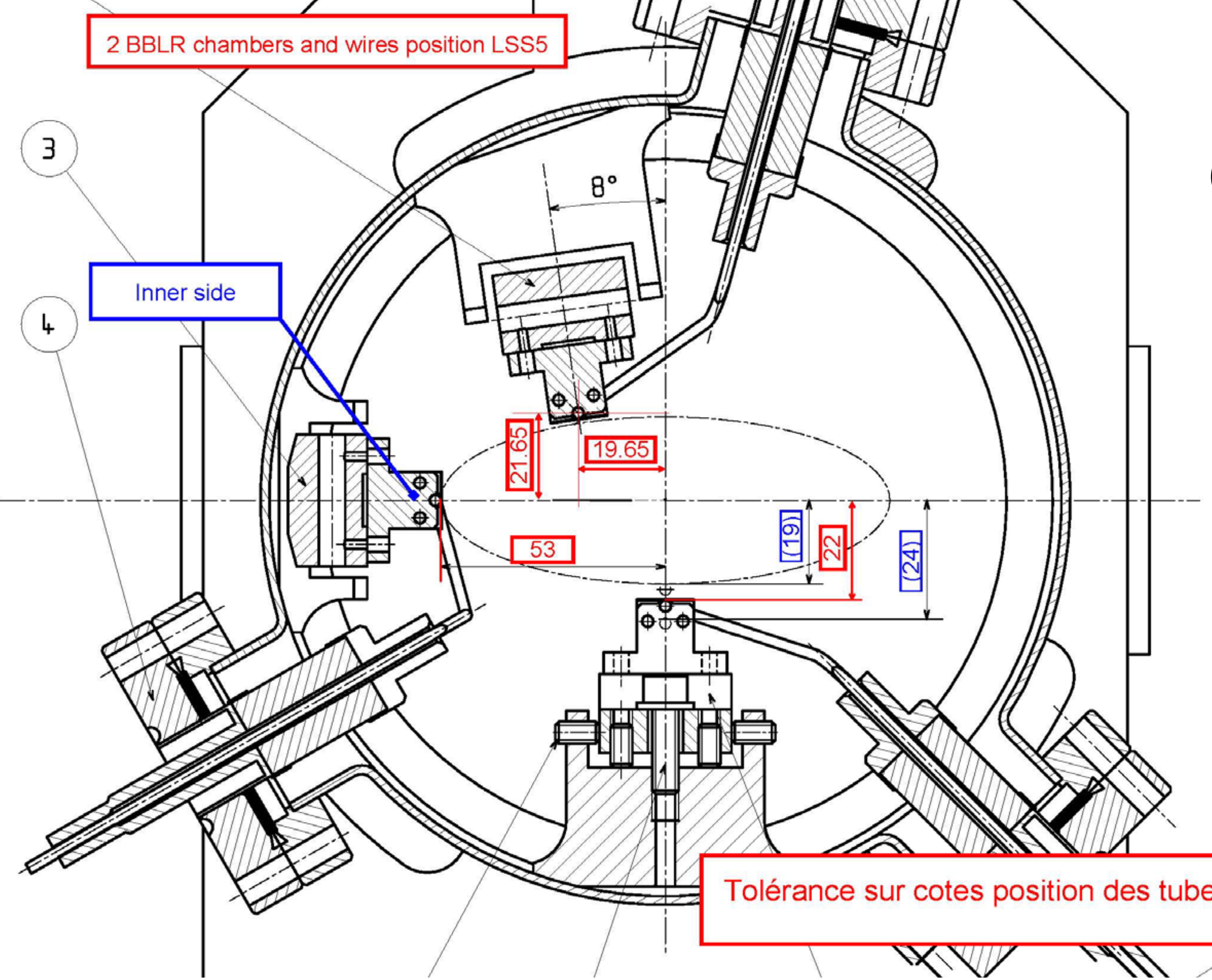
2002/2003 MDs

- the first BBLR allowed us to model the effect of SPS long-range collisions in the SPS and to benchmark the simulations
- 6 MDs were performed in 2002 and 2003
- we observed lifetime reduction, beam losses, and emittance shrinkage, tune shift, orbit distortion, enhanced decoherence; we scanned both the beam-wire distance and the wire current,…
- results were presented to the APC on 19.10.2003 and published in two reports: CERN-AB-2004011-ABP and LHC-Project-Report-777

for 2004 two novel 3-wire BBLRs were built; one of these is installed in LSS5 close to the 1st BBLR; the 2nd new device is being refurbished, after a vacuum leak, for installation in LSS2



LHC BBLR

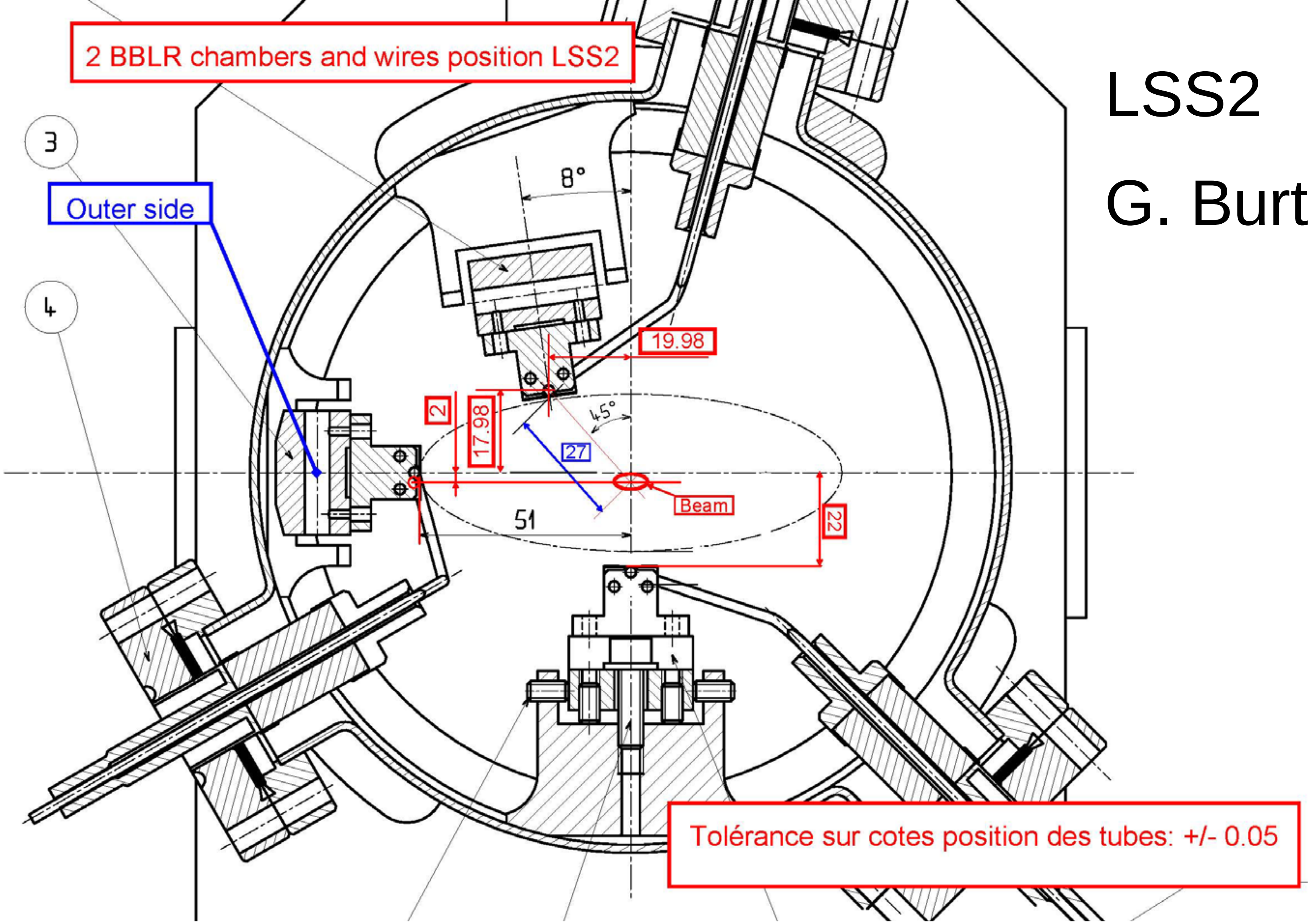


LSS5

G. Burtin

remotely movable in Y by 5 mm!

installed since July



LSS2

G. Burtin

to be installed

MDs in 2004

29./30.07.04 compensation of BBLR1 by BBLR2, mismatched emittance to 4-6 μm, scan compensator current and position, tune scans around SPS & LHC tunes

26.08.04 test of crossing schemes HH, VV, and “pseudo-VH”, tune scan around LHC tunes

02.09.04 compensation of BBLR1 by BBLR2, “scaled” with original emittance at smaller distance

diagnostics signals

for all experiments we have recorded

BCT, PMT loss signals, tunes, emittance & wire scans at different times in the cycle, orbits, 1000-turn data,…

1.4 Gbytes on disk – analysis in progress at CERN (J.-P.K., F.R., F.Z.), FNAL (T.S.), and ESRF (Y.P.)

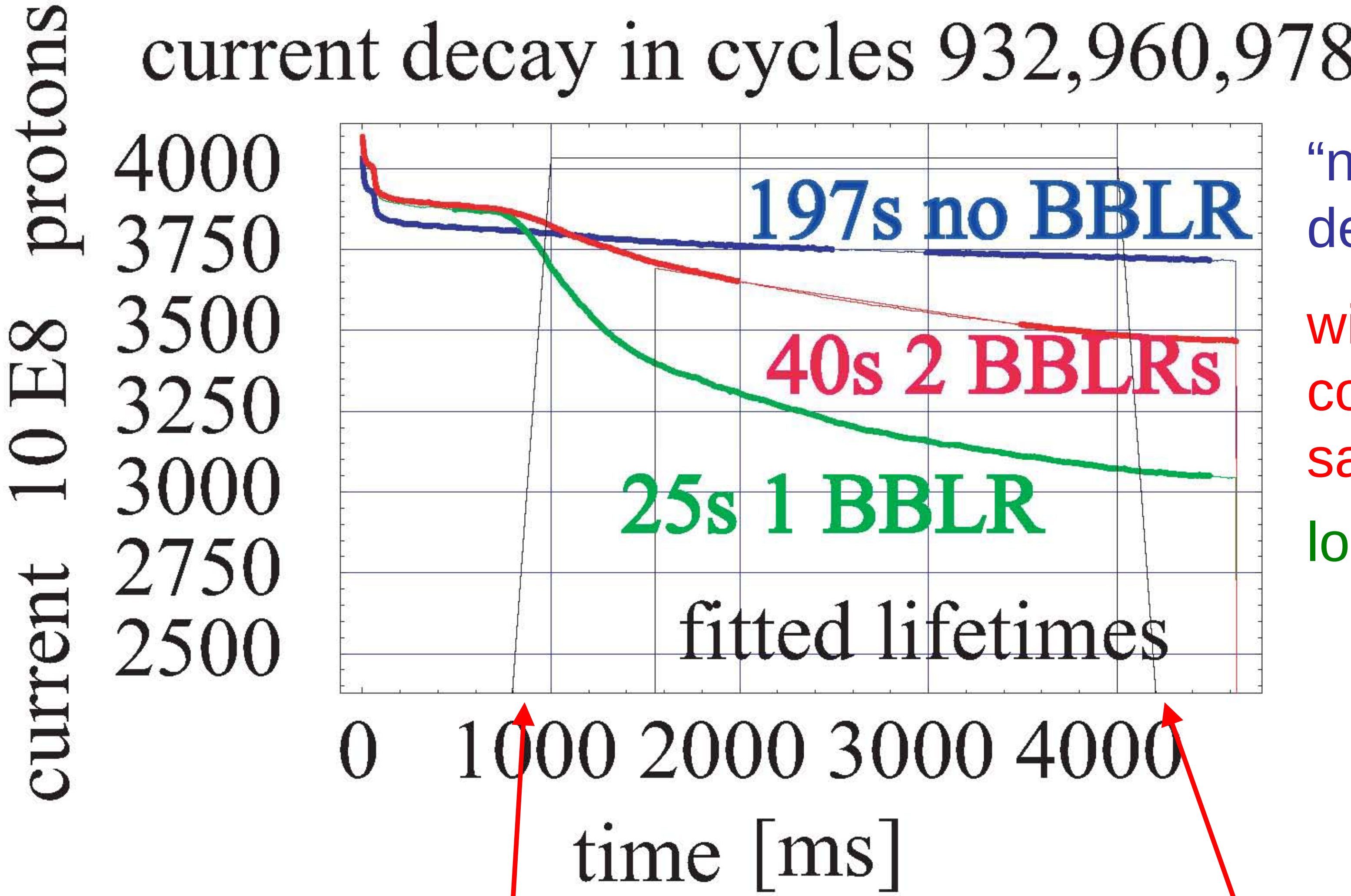
we use new BDI ROSALI* beta version for BCT and PMT analysis (J.P. Koutchouk)

*Rapid Online Software Algorithm Implementation

29.07.04

SPS tunes

example BCT data



"natural decay"

with compen-sation

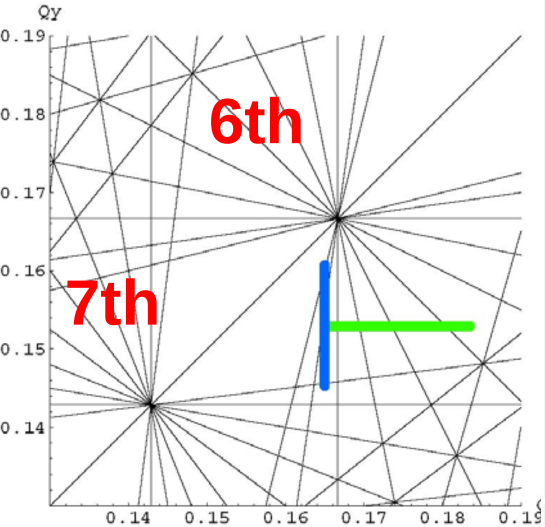
long-range effect

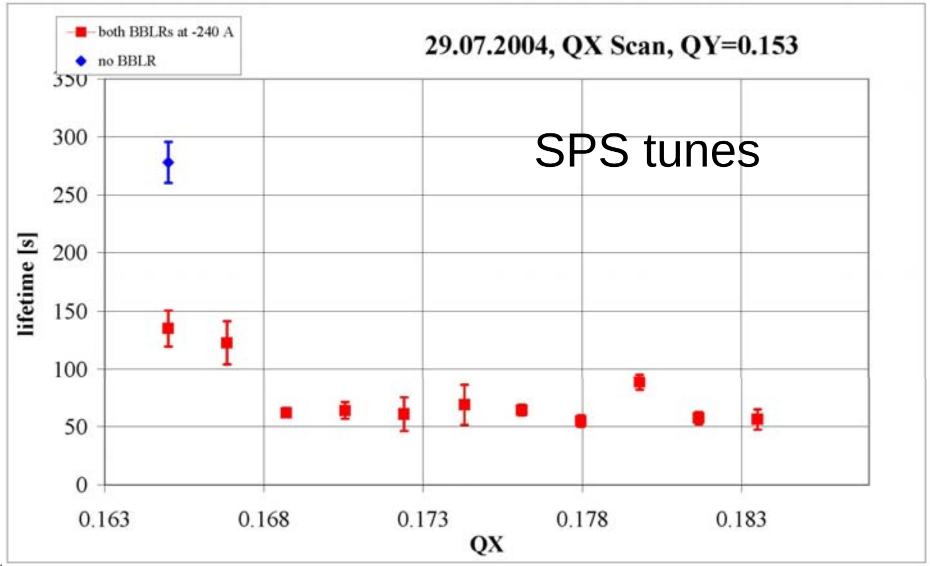
wire up ramp 0.5-1 s

wire down ramp 4-4.5 s

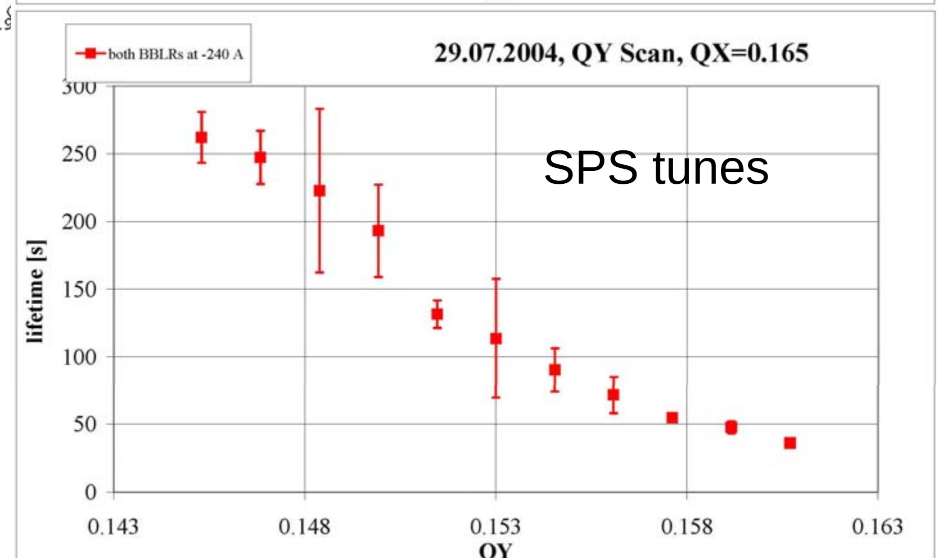
measured BBLR compensation efficiency vs. working point - scan around SPS tunes (proposal V. Shiltsev)

29.07.04





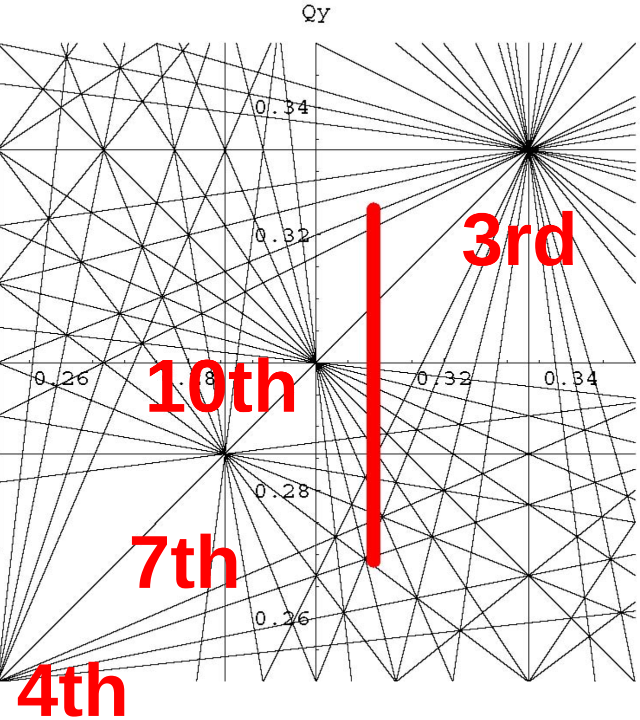
first we optimized QX, lifetime with compensation was ~2x lifetime with 1 BBLR, and ~1/2 lifetime w/o BBLR



then at optimum QX, we scanned QY, lifetime increased more a few times (note starting point value different!)

LHC BBLR

measured BBLR compensation efficiency vs. working point - scan around LHC tunes



we scanned QY w/o BBLRs, with BBLR1 only, and with BBLR1 & BBLR2

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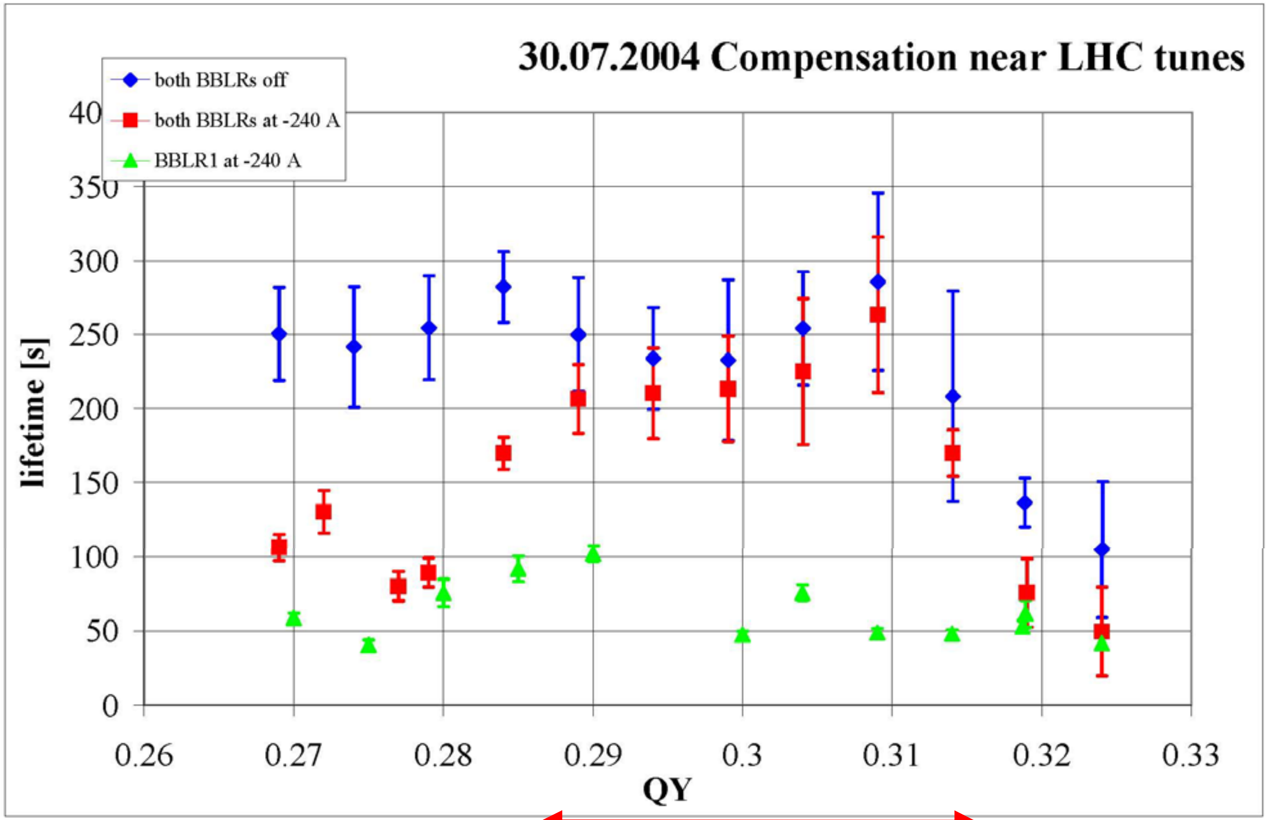


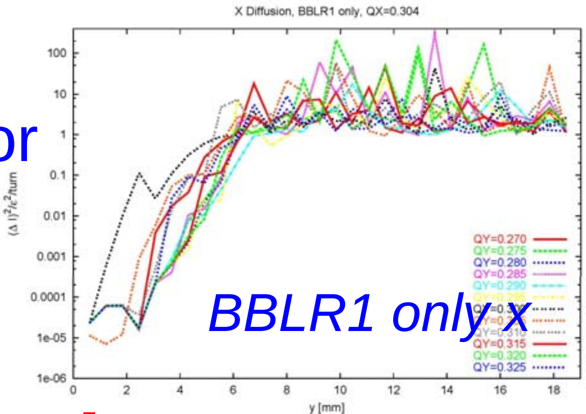
what happens here?

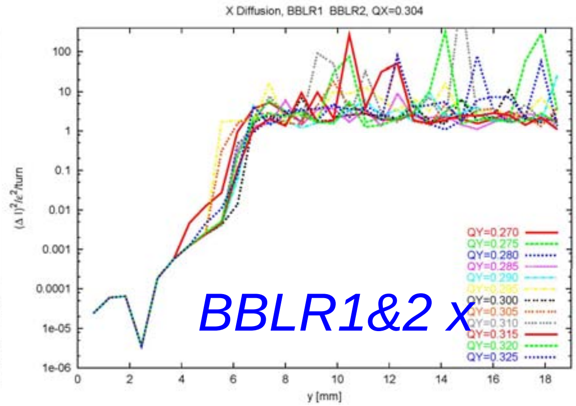
nearly perfect compensation

Twiss parameters at the two BBLRs

	BBLR1	BBLR2
β_x	47.66 m	54.14 m
α_x	-1.39	-1.53
μ_x	0.6045	0.611
β_y	50.83 m	44.69 m
α_y	1.46	1.32
μ_y	0.5215 (2π)	0.5285 (2π)

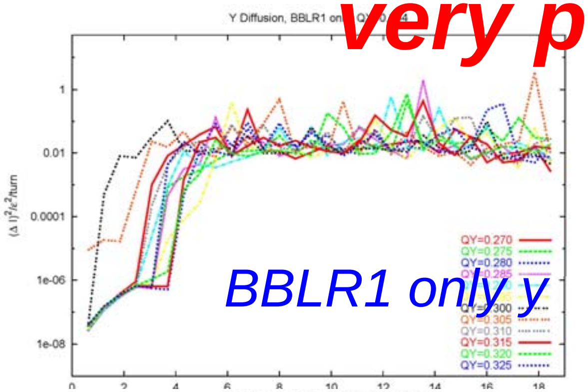
$\Delta\phi_x = 2.3^o$, $\Delta\phi_y = 2.5^o$ (as in LHC) *simulated* diffusion rates (WSDIFF) vs. amplitude for different tunes, assuming model Twiss parameters

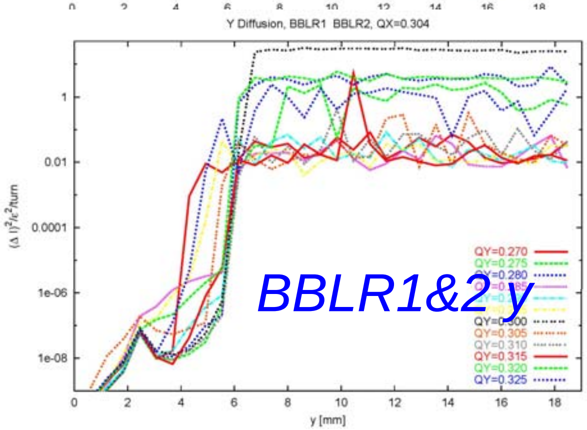


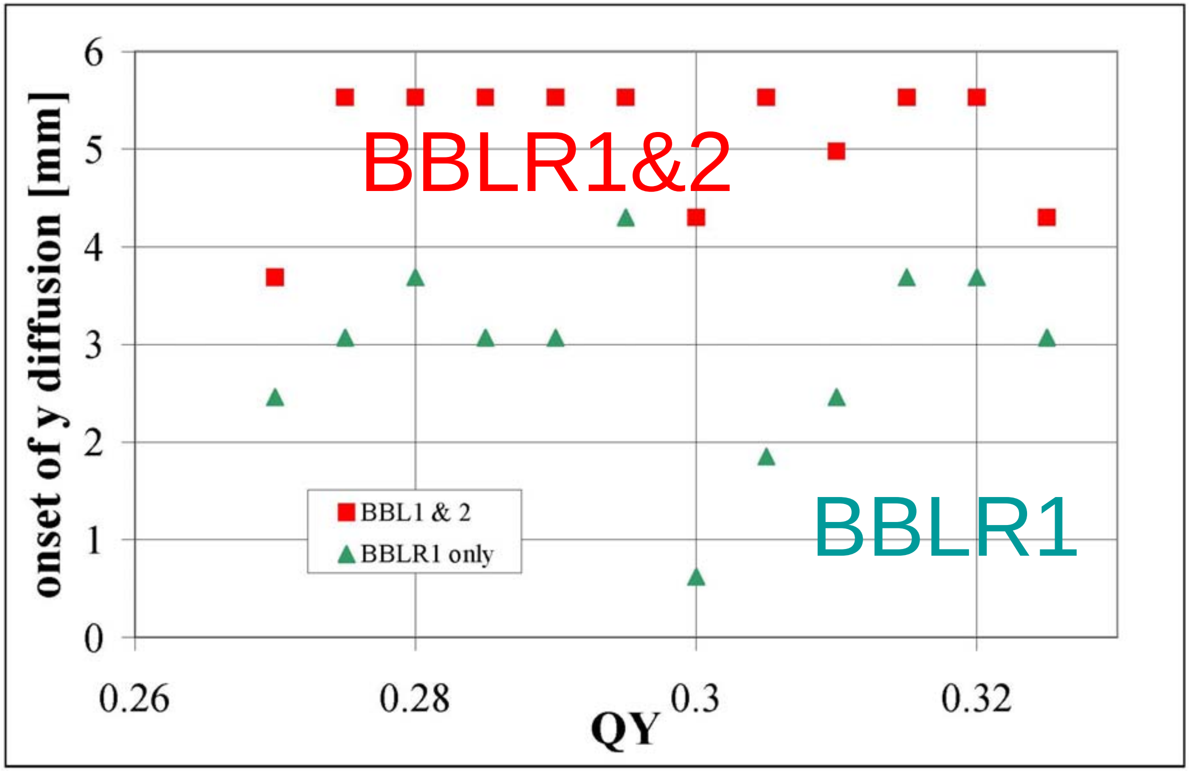


very preliminary!

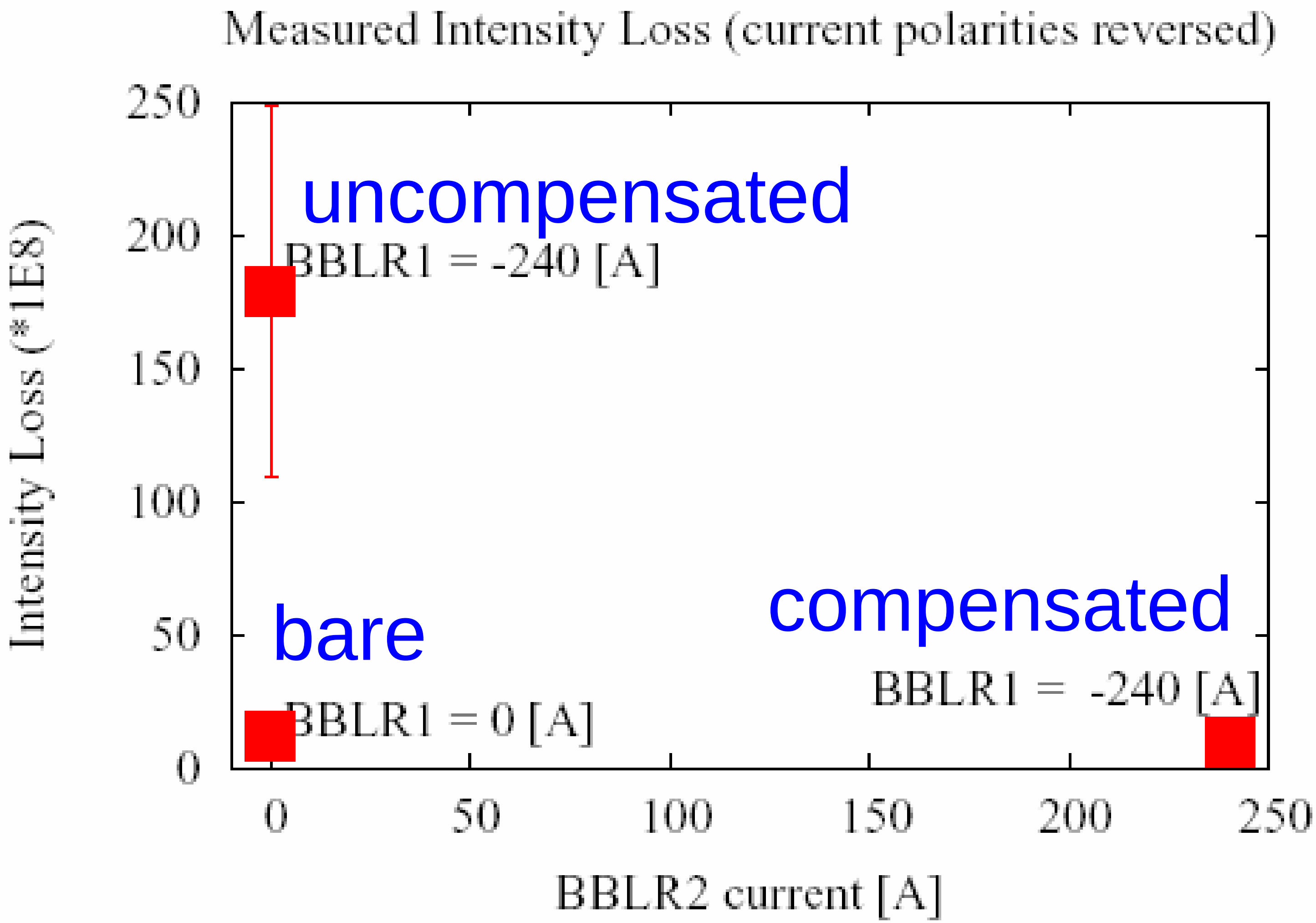
more diffusion in x?







measured intensity loss on flat top



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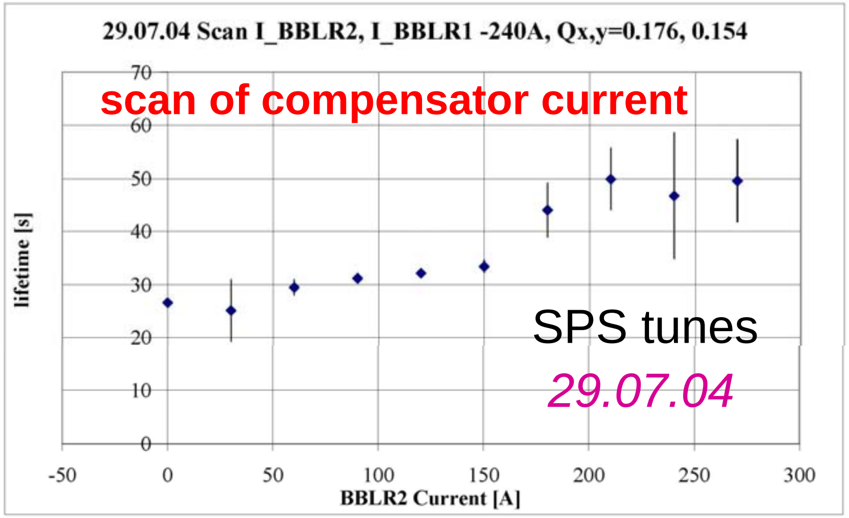
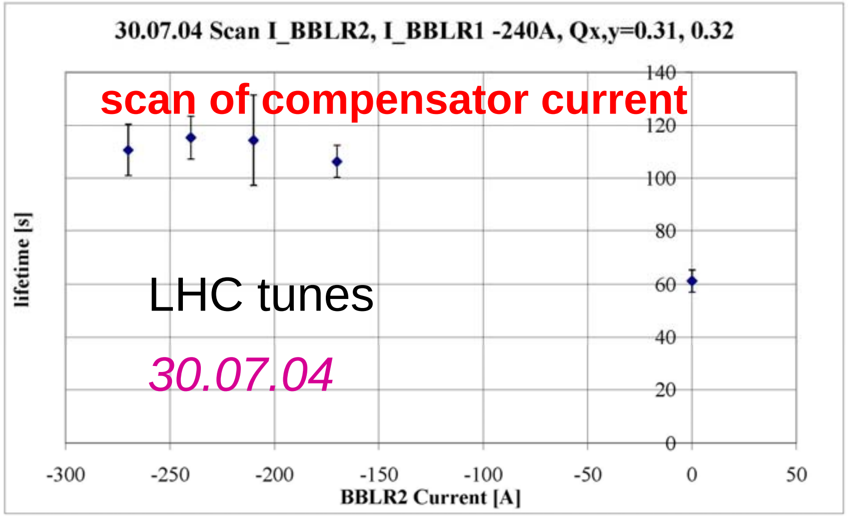
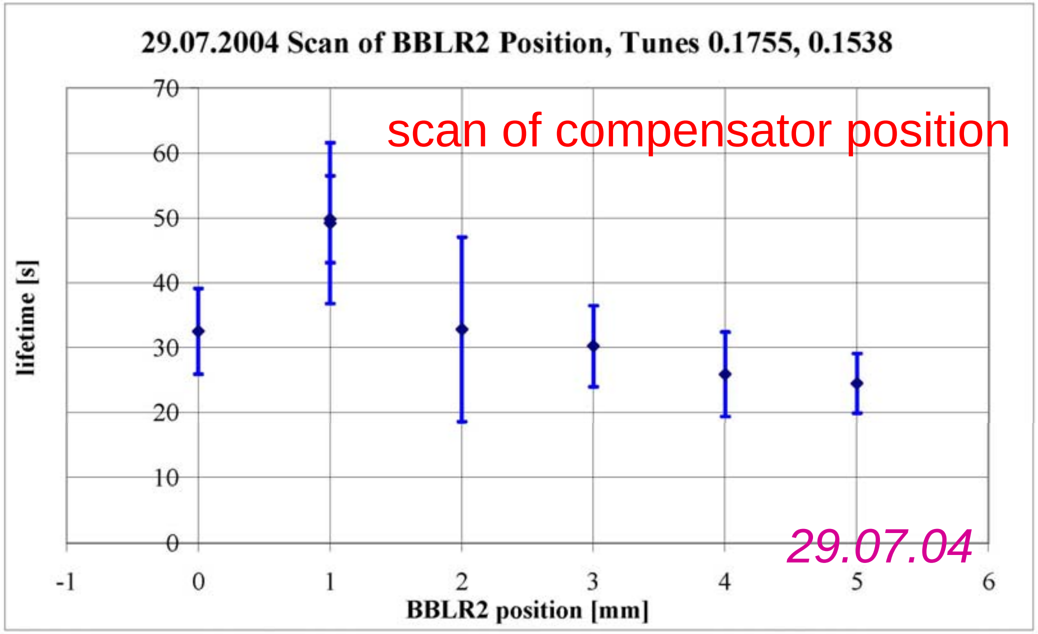
T. Sen

measured BBLR compensation efficiency vs. current & position





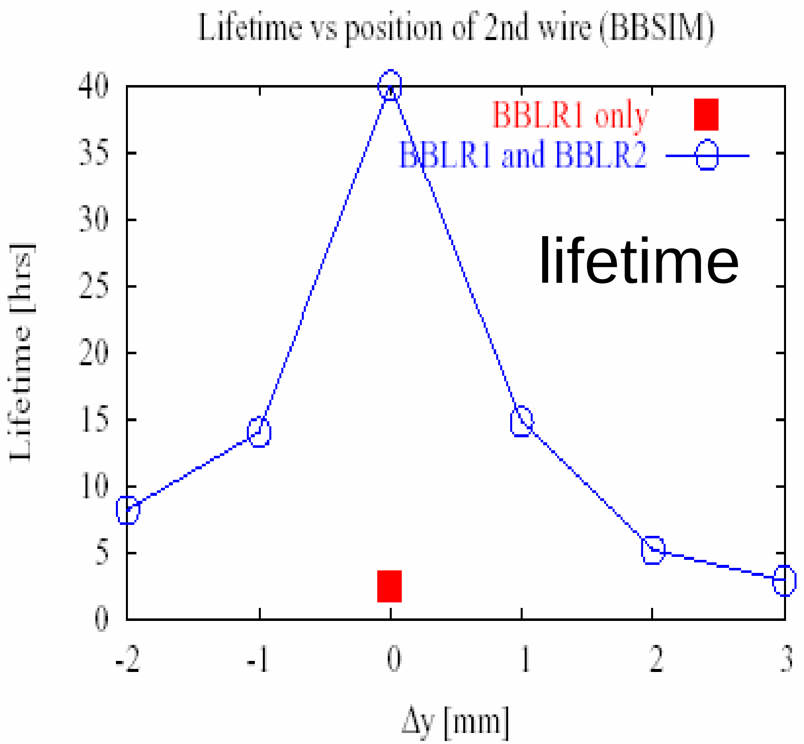
current tolerance +/- 10% (BBLR1 at 240 A)

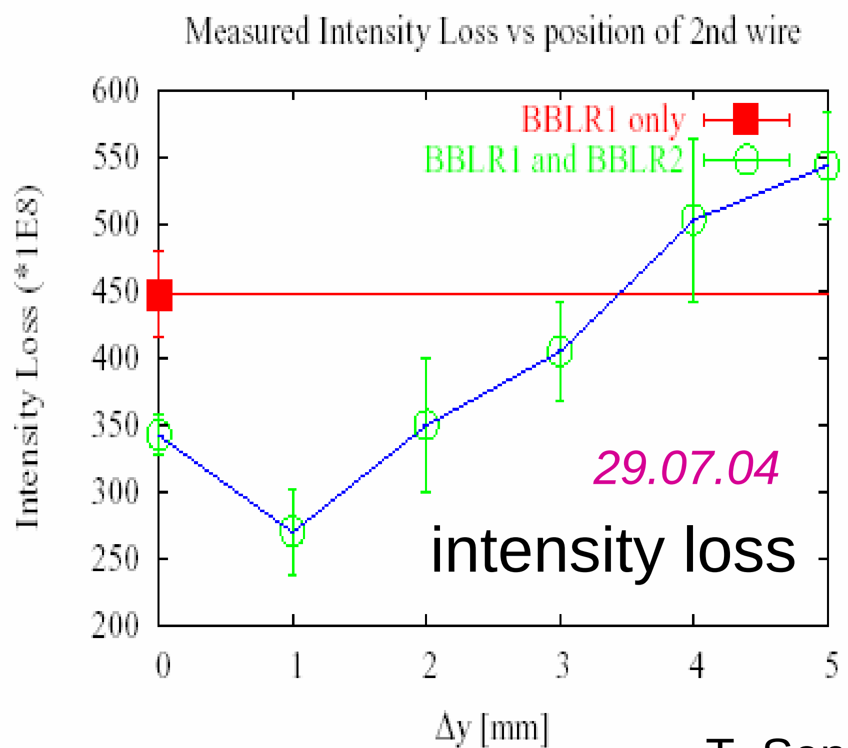


optimum position differs by 1 mm from expectation, tolerance <5% (total distance ~20 mm)

LHC BBLR

position sensitivity:
prediction & measurement





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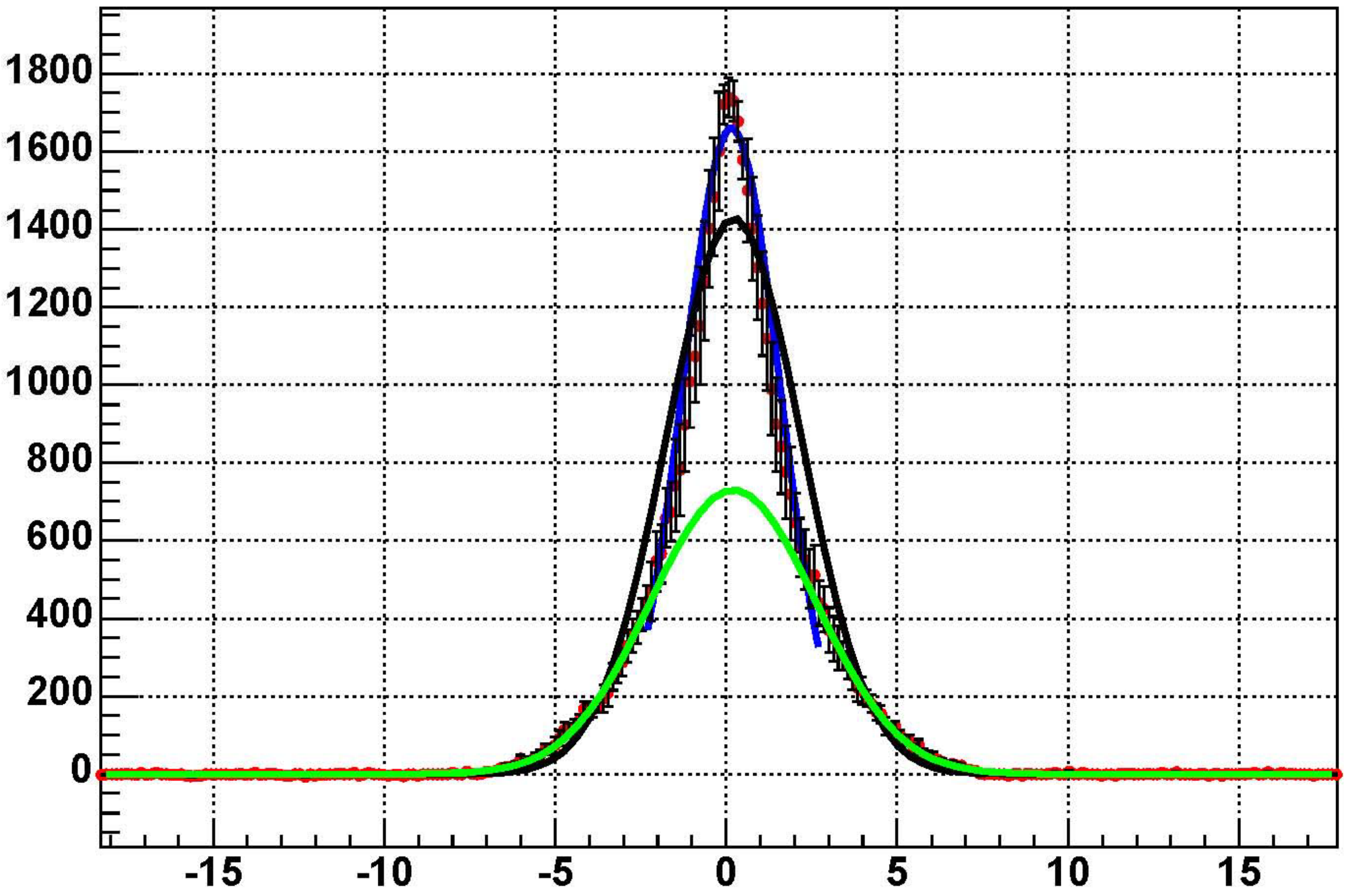
BBSIM: No compensation beyond ~3mm

Measurement: Compensation lost beyond ~2.5mm from optimum

consistent!

wire scans - taken at various times in the cycle



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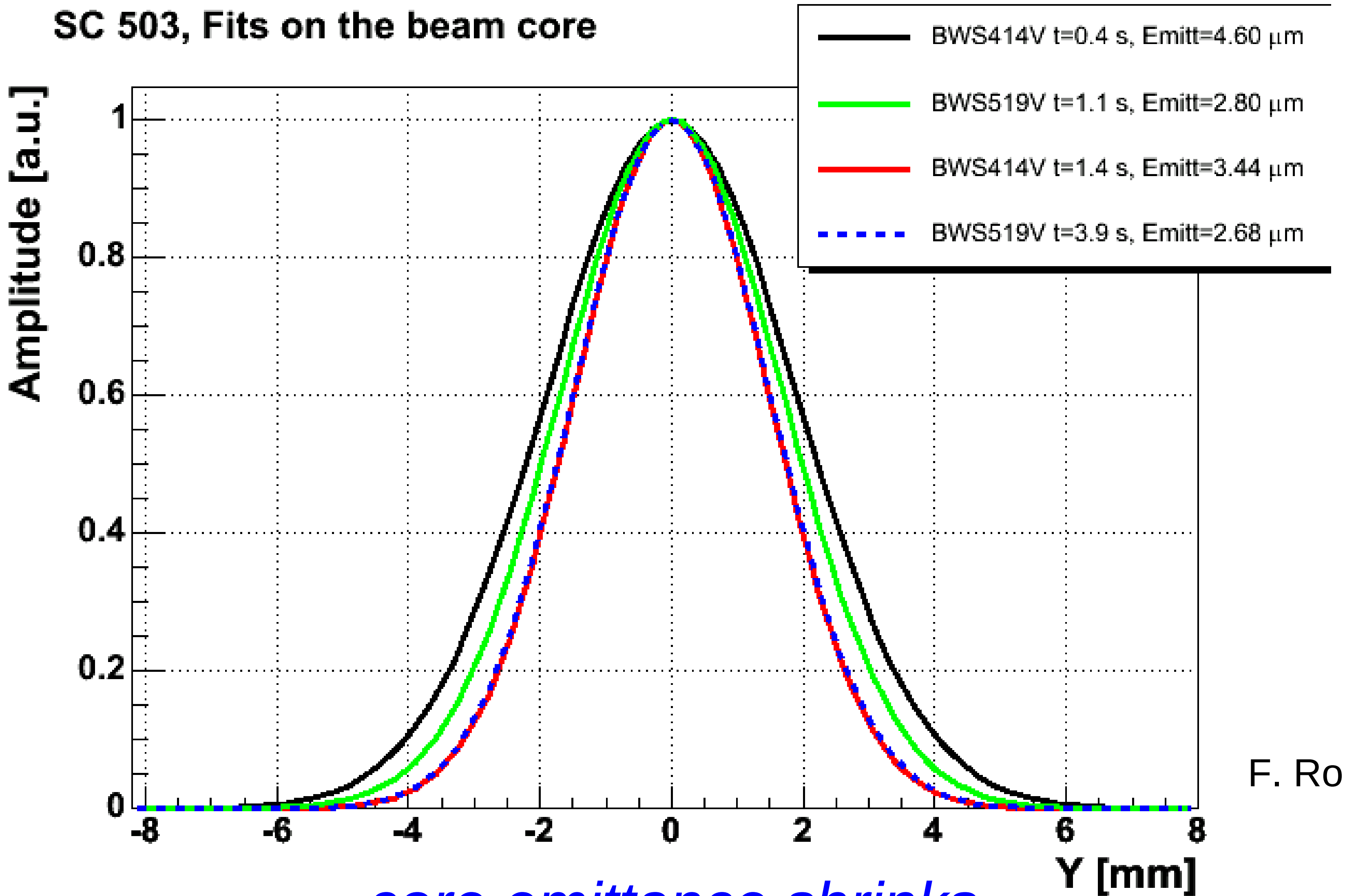
distribution is fitted as sum of 2 Gaussians representing core & tail

systematic differences between IN & OUT scans are corrected for; BWS519 and 414 agree within +/-2%

F. Roncarolo

BBLR1 only

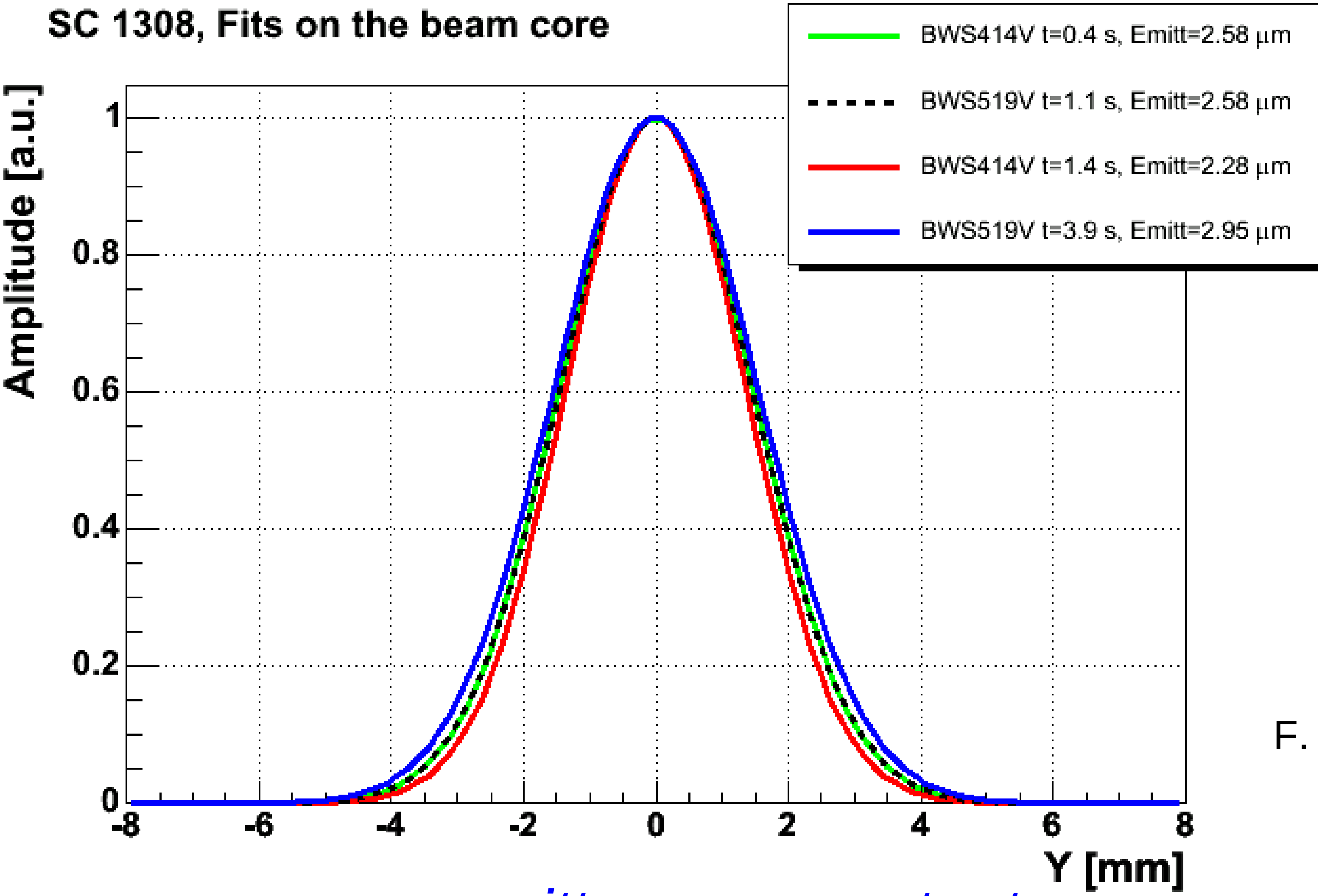


F. Roncarolo

core emittance shrinks

LHC BBLR

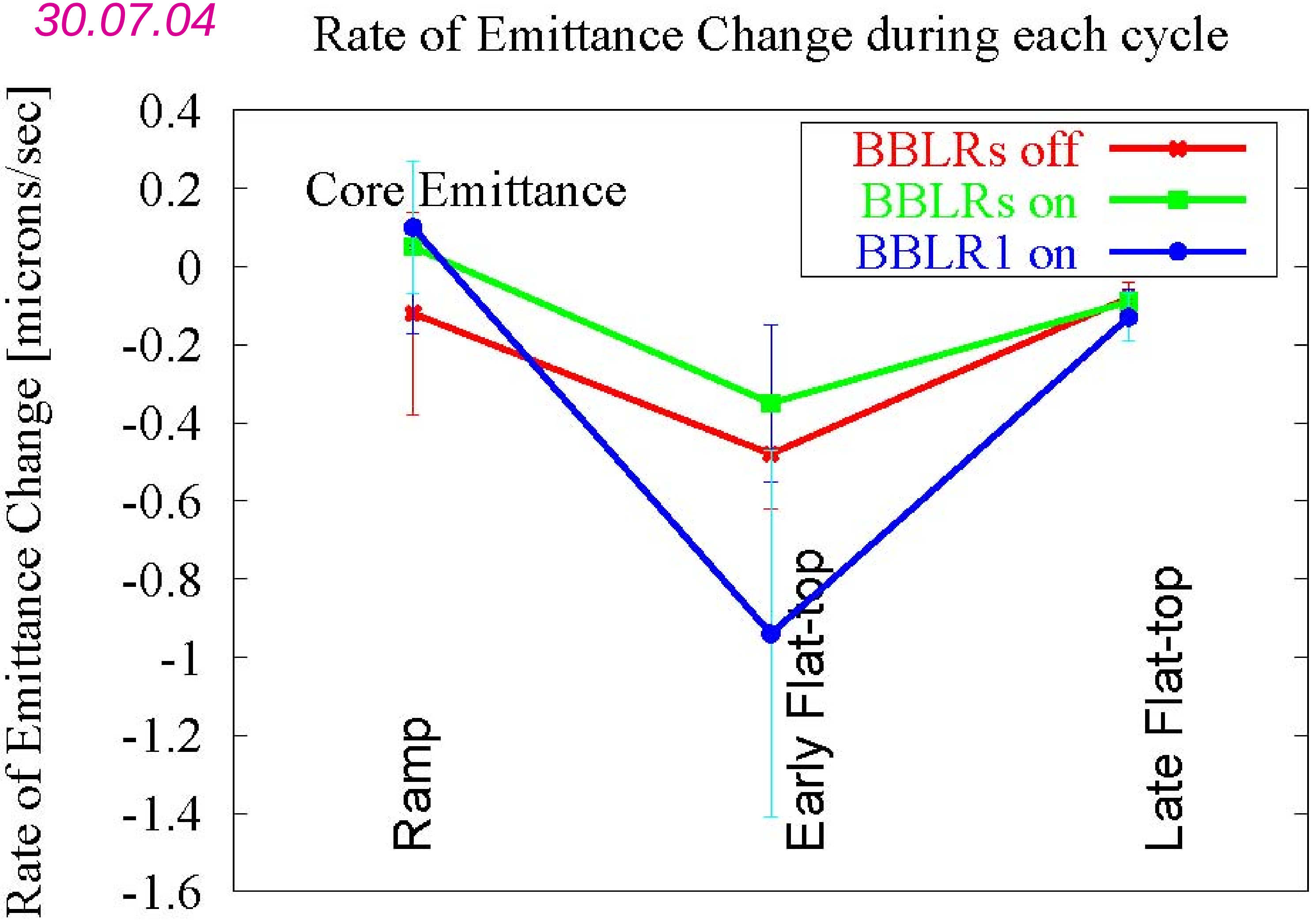
BBLR1&2 (compensation)



F. Roncarolo

core emittance ~constant

30.07.04



0.4-1.1 s 1.1-1.4 s 1.4-3.9 s

emittance decrease

"core emittance does get shaved with BBLR1; turning on BBLR2 reduces this shaving"

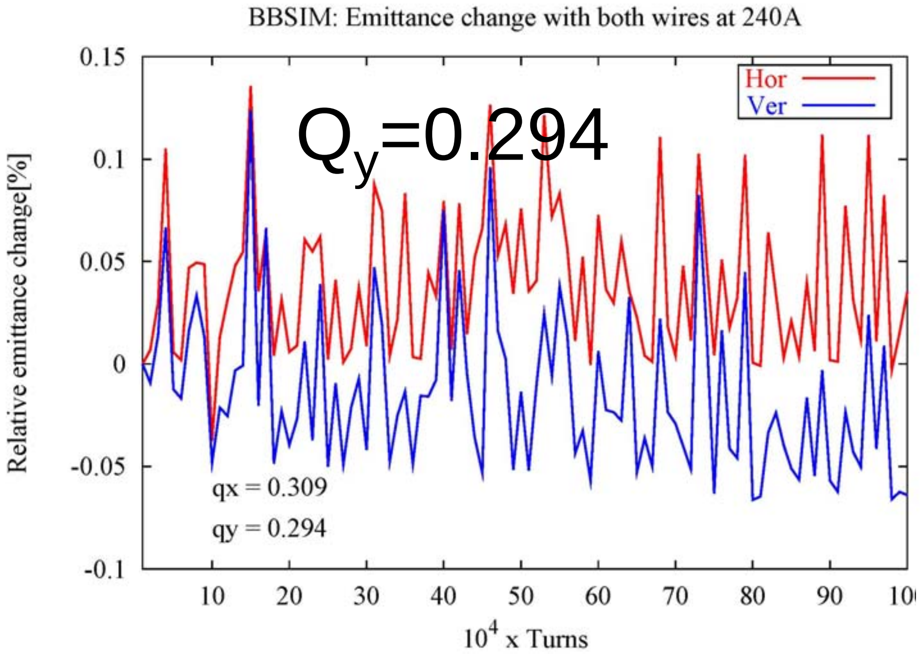
T. Sen

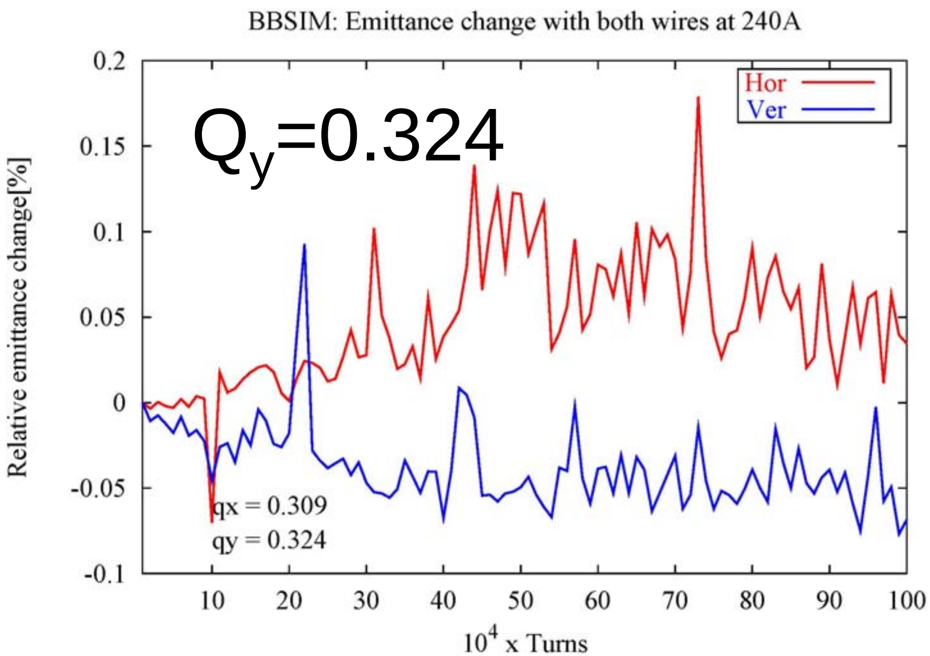
T. Sen

F. Roncarolo

LHC BBLR

simulation (BBSIM) of x&y emittance evolution with time - horizontal emittance grows, vertical shrinks





T. Sen

LHC BBLR

assessment after 1st compensation MD:

parameters not under control or whose control is critical, e.g., beam emittance (sudden jump from 6 to 2.5 μm!?) , aperture limits, BBLR ramp

new strategy for 2nd compensating MD:

BBLR switched on before injection

Q-meter kick near end of cycle → monitor tune, and tail measurement

incoming emittance not blown up, adjust beam-wire distance & current → increased effective aperture

Nominal conditions: ϵ_N=3.75 10^{-6} m; I_W= 267 A;
d_y=9.5σ=21.42 mm (BBLR1), 21.10 mm (BBLR2)

Scaling:

$$I_w = 267 \frac{\varepsilon_N}{3.75\times 10^{-6}\,\mu\mathrm{m}}\,\mathrm{A}$$

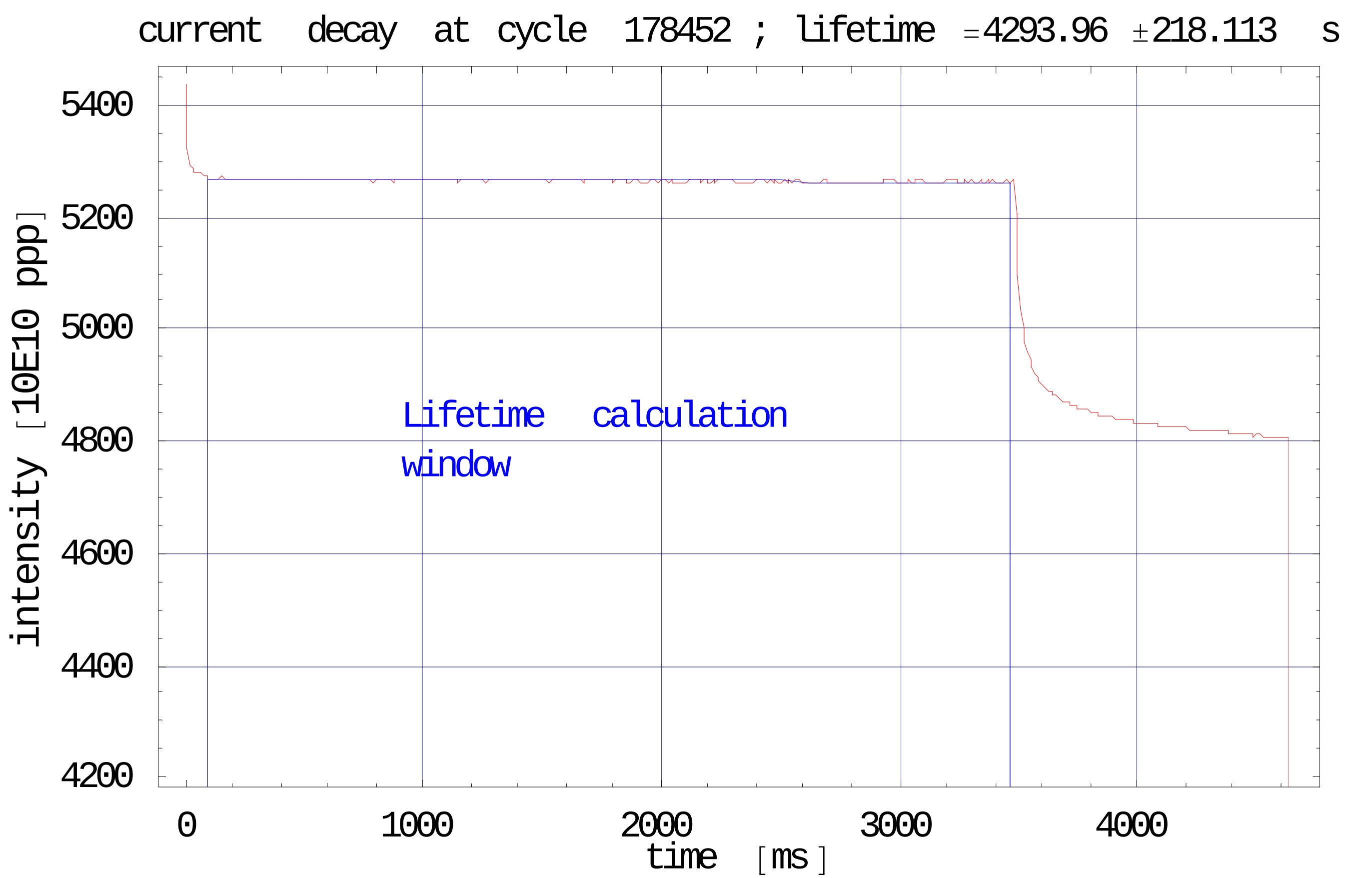
BBLR current

$$d_y = 21.42\sqrt{\frac{\varepsilon_N}{3.75\times 10^{-6}\,\mu\mathrm{m}}}\,\mathrm{mm}$$

beam-wire distance

in MD: ε_N=1.72x10^{-6} μm, I_w=122.5 A, d_w=14.5 mm

'scaled' experiment: - emittance not increased, distance reduced by scaling, BBLR ramped prior to injection



02.09.04

injection losses:

0-100 ms

steady BBLR losses:

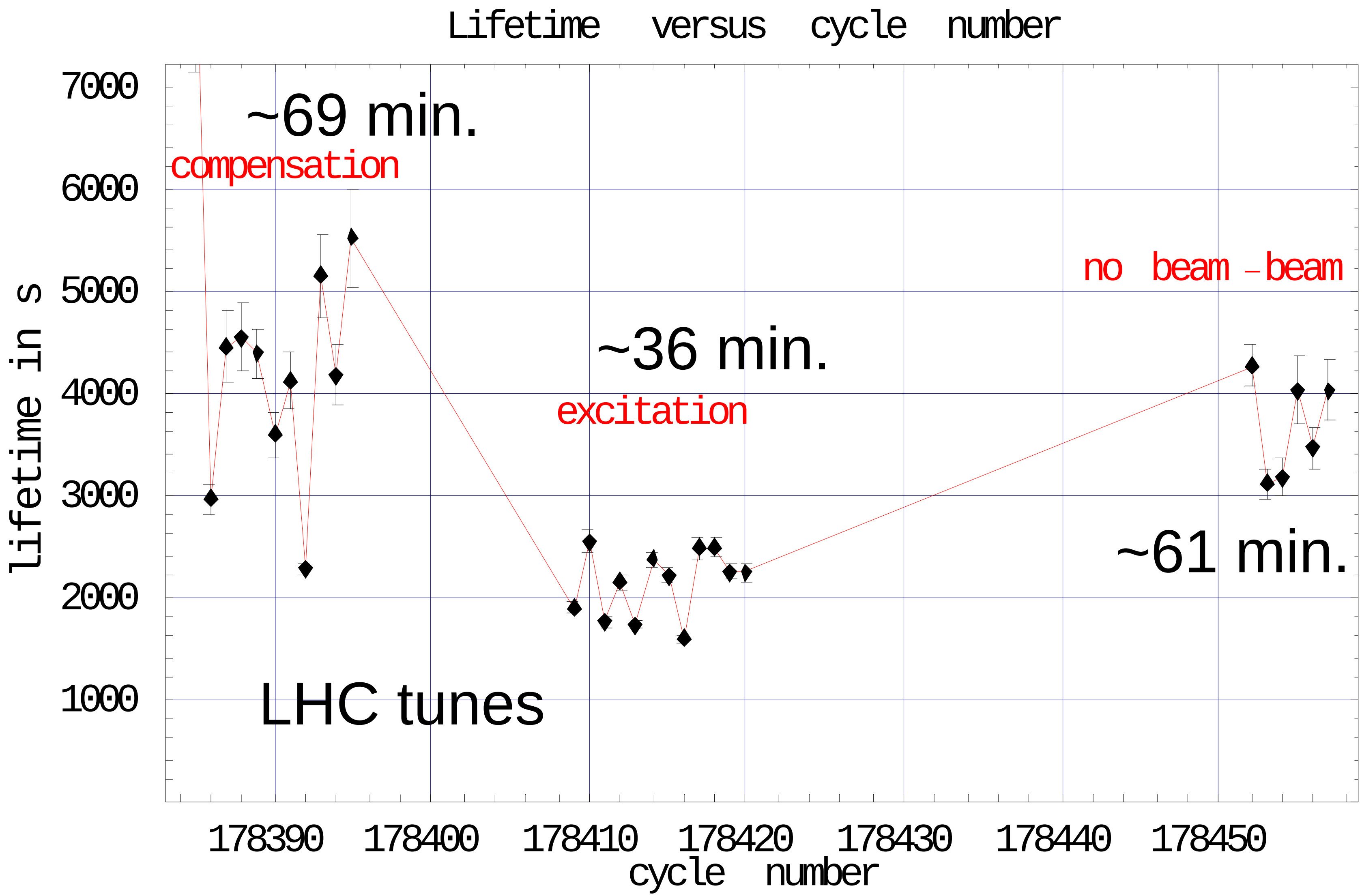
100-3450 ms

kick losses:

3450-3670 ms

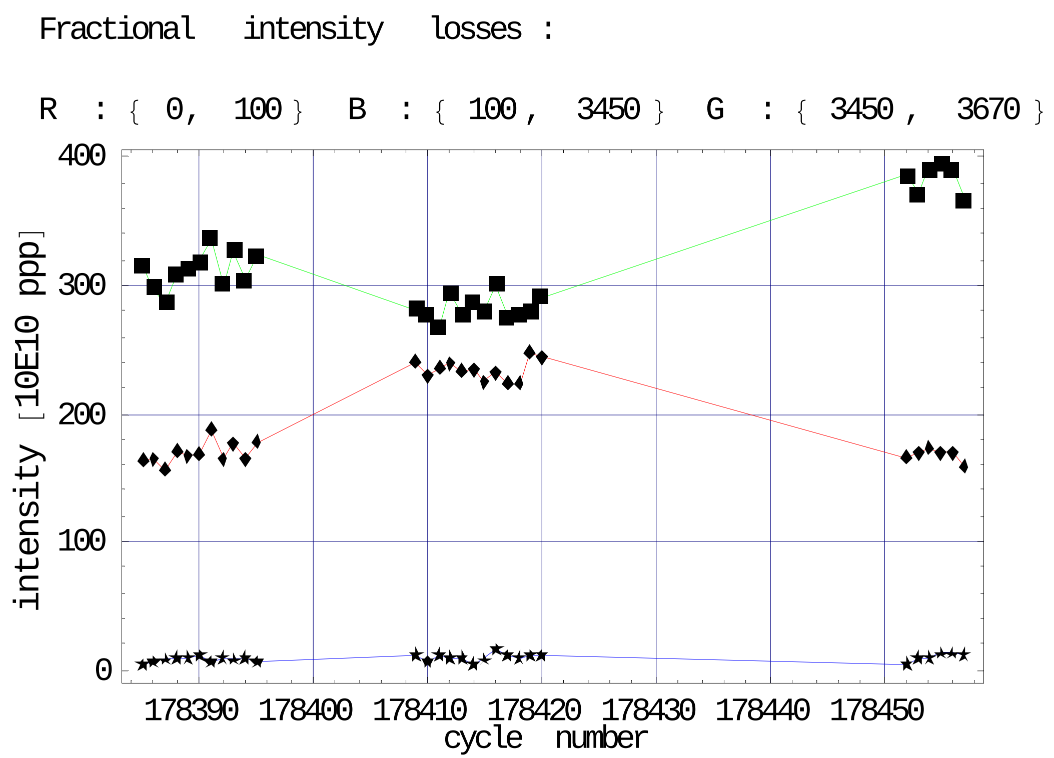
LHC BBLR

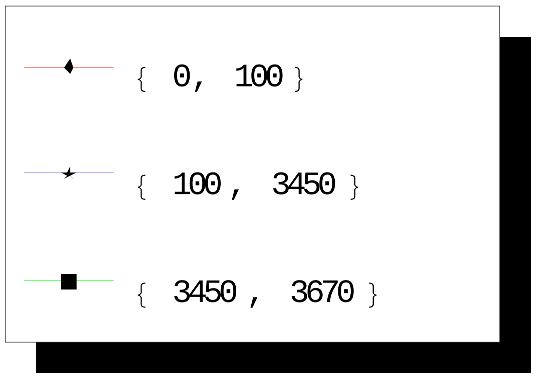
02.09.04 'scaled' experiment: measured beam lifetime



J.-P. Koutchouk

02.09.04 ‘scaled’ experiment: measured losses





lifetime	Total current	Loss at injection 0 to 100 ms	Loss during plateau: 100 to 3450 ms	Loss after kick: 3450 to 3670 ms	Scenario
4111±966	5309±167	170±9	8.3±1.8	312±15	2 BBLR’s (compensation)
2131±325	5911±114	234±8	10.0±2.9	282±9	1 BBLR (excitation)
3666±494	5319±91	168±5	10.3±3.1	383±12	No BBLR

LHC BBLR

J.-P. Koutchouk

interpretations & observations for “scaled” compensation

- 36 min. correct estimate of uncompensated LHC lifetime? or effect enhanced by SPS tune ripple?
- lifetime improved with compensation – stabilizing effect of residual nonlinearity?
- beam intensity varied by 10%, drift in the PS, change of closed orbit at the dump?
- losses after kick reduced by presence of single BBLR,

  → tails are partly cut by the BBLR

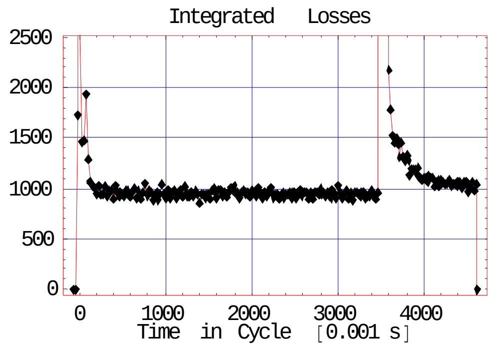
  interesting extension: repeat for different kick amplitudes; with 2 BBLRs kicks intermediate losses → imperfect compensation

PMT signals

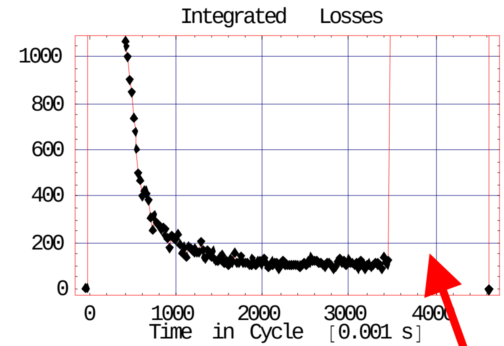
PMT down | PMT out

02.09.04

no BBLR

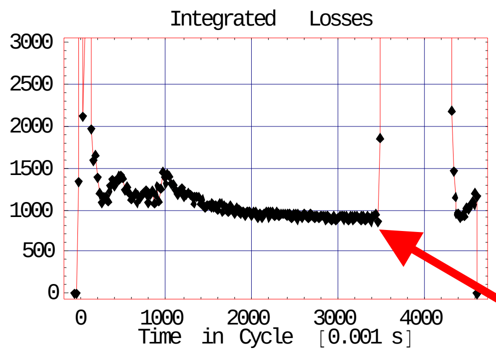


Ctr1 [no_unit

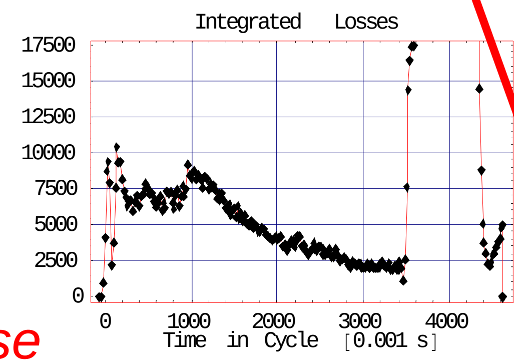


Ctr1 [no_unit

BBLR1



Ctr1 [no_unit

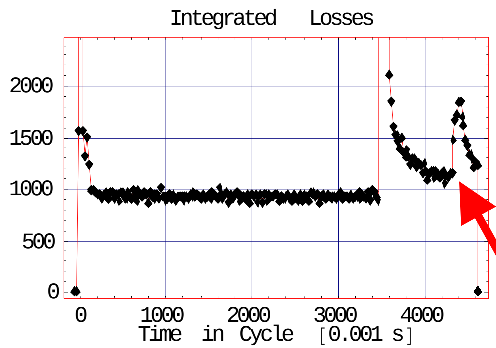


Ctr1 [no_unit

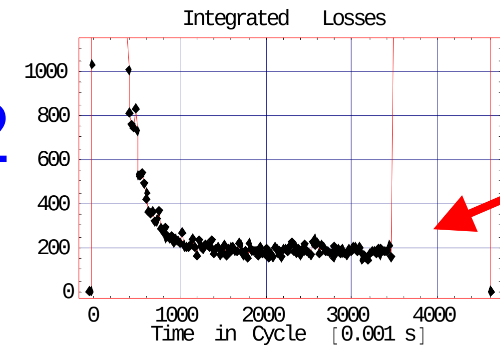
much larger loss rate

losses increase after kick

BBLR1 & 2



Ctr1 [no_unit



Ctr1 [no_unit

similar rate

BBLR ramp

'PMT down' less sensitive

kicking earlier may allow accurate measurement of rise time ?!

LHC BBLR

J.-P. Koutchouk

how could we model the XY crossing without the LSS2 BBLR?

(where we would have had independent orbit control)

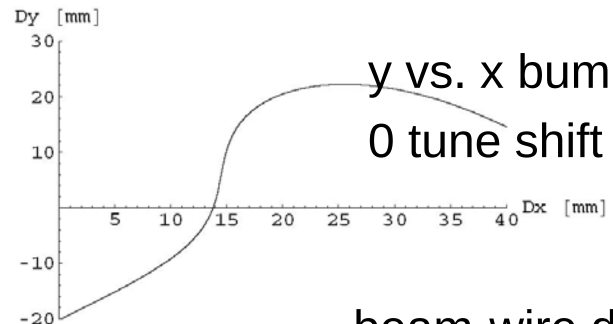
idea: cancel linear tune shift between the two BBLRs

$$\Delta Q_{x,y} = \pm \frac{r_p I_w l_w}{2\pi\gamma e c} \beta_{x,y} \frac{d_y^2 - d_x^2}{\left(d_x^2 + d_y^2\right)^2}$$

to achieve tune shift cancellation in both planes we must have equal β_x/β_y ratio at both BBLRs (only approximately fullfilled)

denote
$$d_{x,1} = D_x, \qquad d_{x,2} = A_{x2} - D_x$$
$$d_{y,1} = A_{y1} + D_y, \qquad d_{y,2} = D_y$$

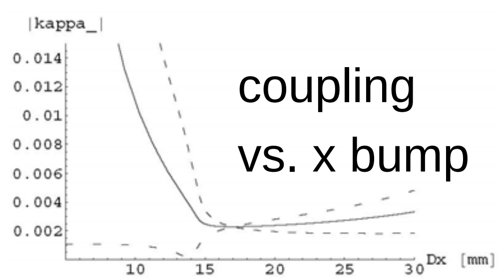
[capital Ds are bump amplitudes]



y vs. x bump for 0 tune shift

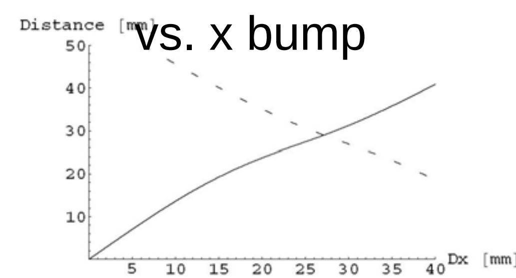
conditions for zero tune shift in X and Y

$$\left(\left(A_{y1} + D_y\right)^2 - D_x^2\right)\left(\left(A_{x2} - D_x\right)^2 + D_y^2\right)^2 =$$
$$-\left(D_y^2 - \left(A_{x2} - D_x\right)^2\right)\left(D_x^2 + \left(A_{y1} + D_y\right)^2\right)^2$$

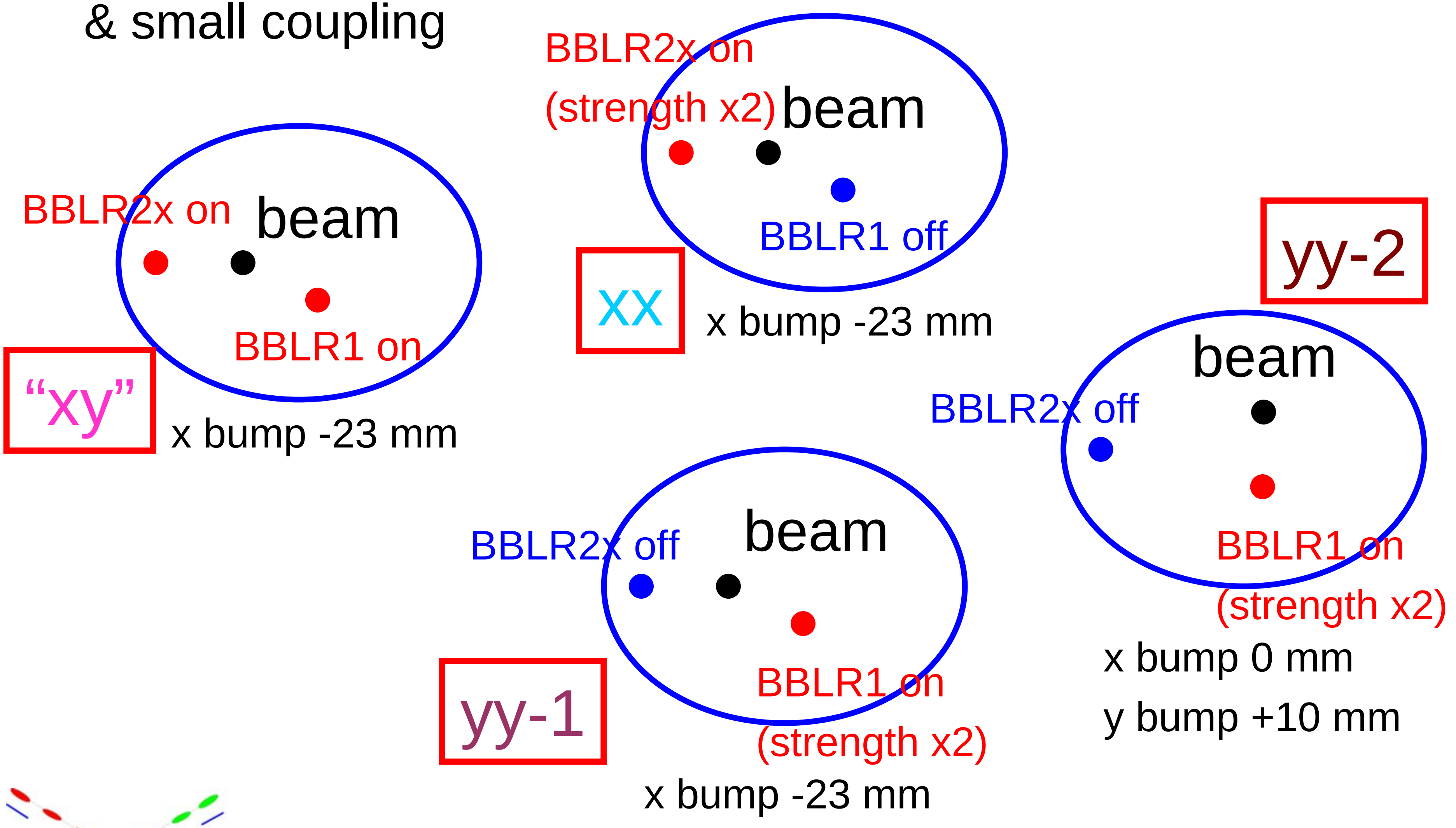


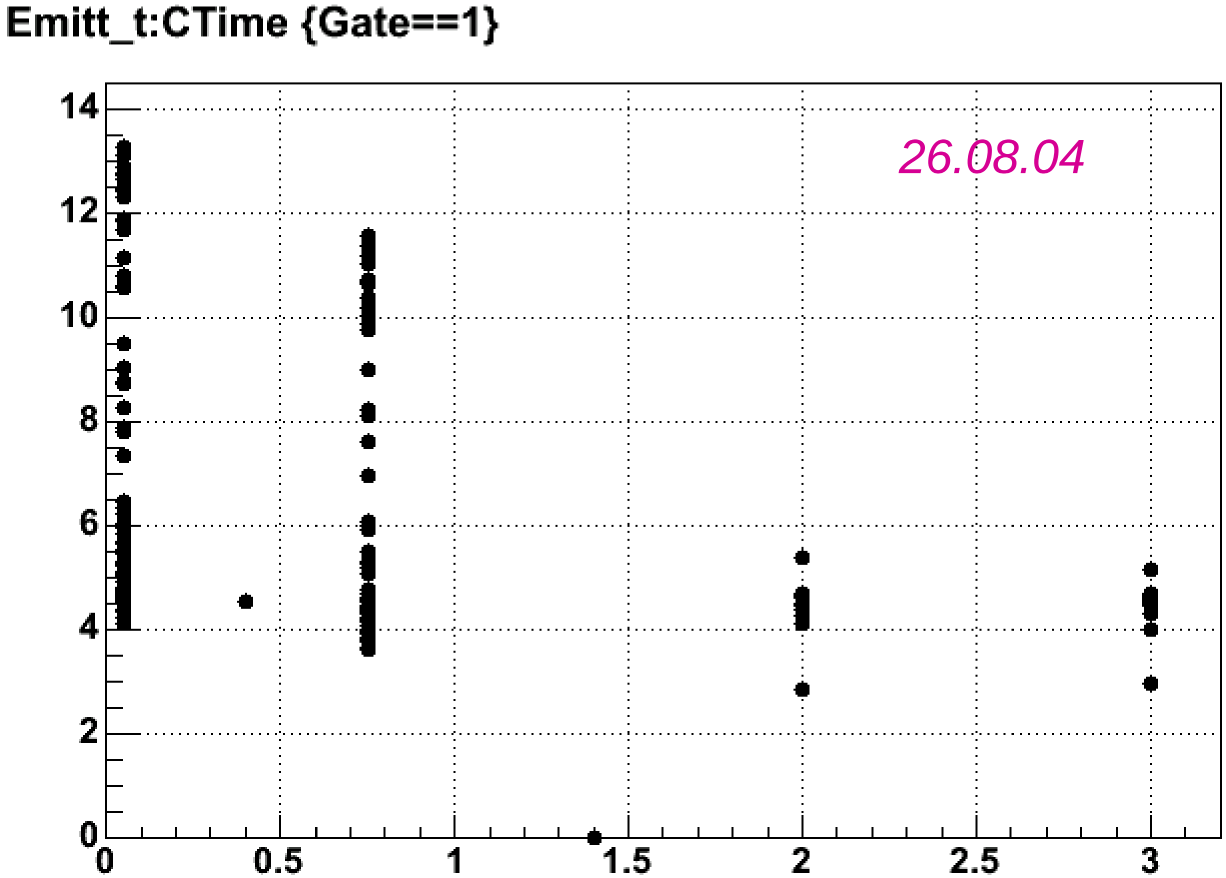
coupling vs. x bump

beam-wire distances vs. x bump



we compromised between different constraints so at to achieve equal beam-wire distances, small tune shifts, & small coupling





vertical core emittance for all cycles vs. time in s – shrinking

F. Roncarolo

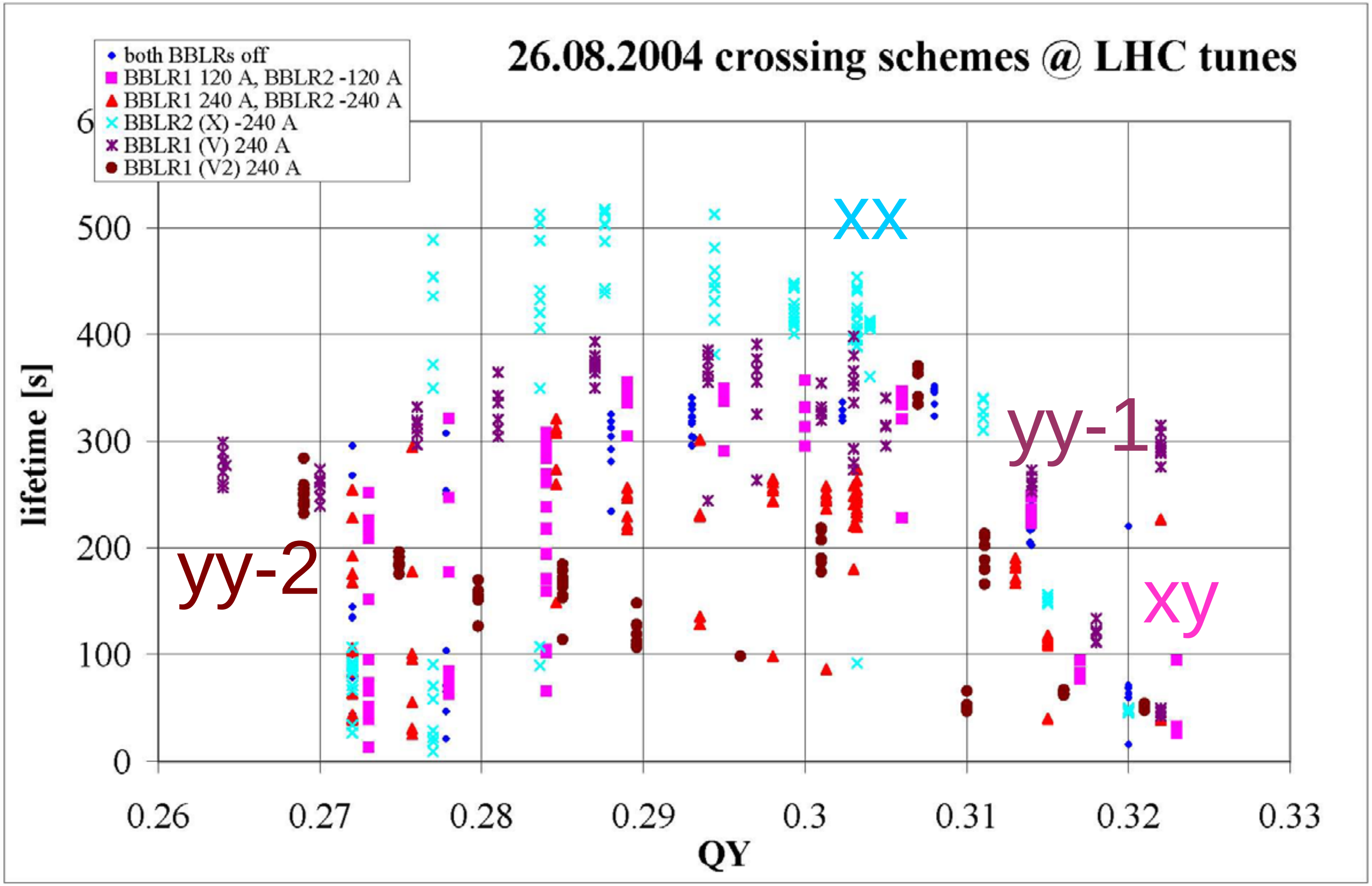
on the other hand: between 0.5 and 3 s:

horizontal core emittance grows from ~3 to ~4 μm

LHC BBLR

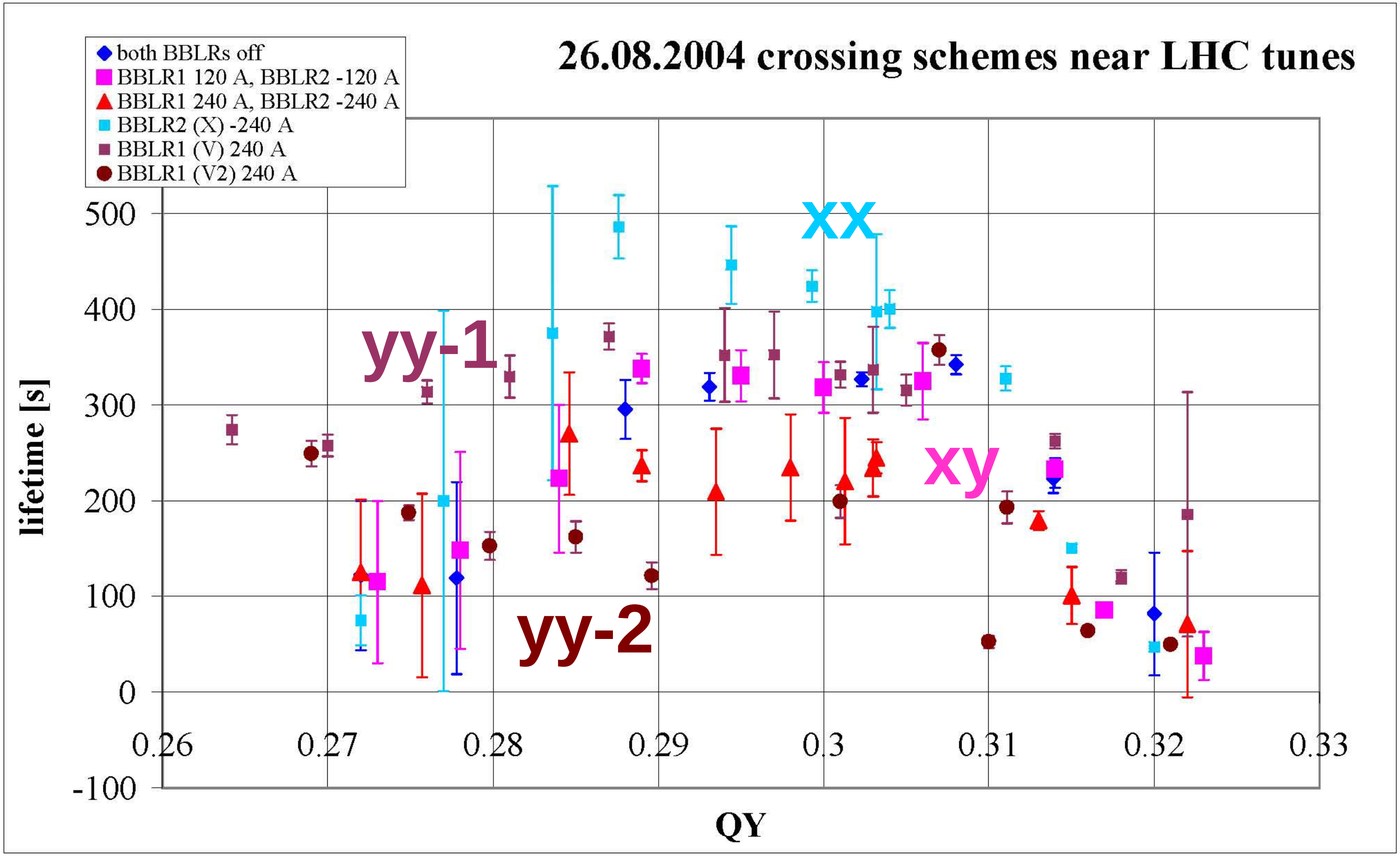
probing the LHC crossing scheme: raw lifetime data

26.08.04

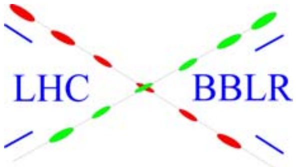


y tune scan

probing the LHC crossing scheme: mean & rms τ



y tune scan



interpretations & observations of crossing study

- we found best lifetime for XX crossing, followed by YY-1 crossing
- 3rd best lifetime for pseudo “XY” crossing
- YY-2 lifetime worst; this could be

  due to vertical aperture reduction by

  y bump at the BBLR
- lifetime less sensitive because beam-wire distance larger than in other BBLR studies

  (x wire far out)

several studies still ongoing

emittances & profiles (F. Roncarolo, T. Sen)

1000-turn data (Y.Papaphilippou)

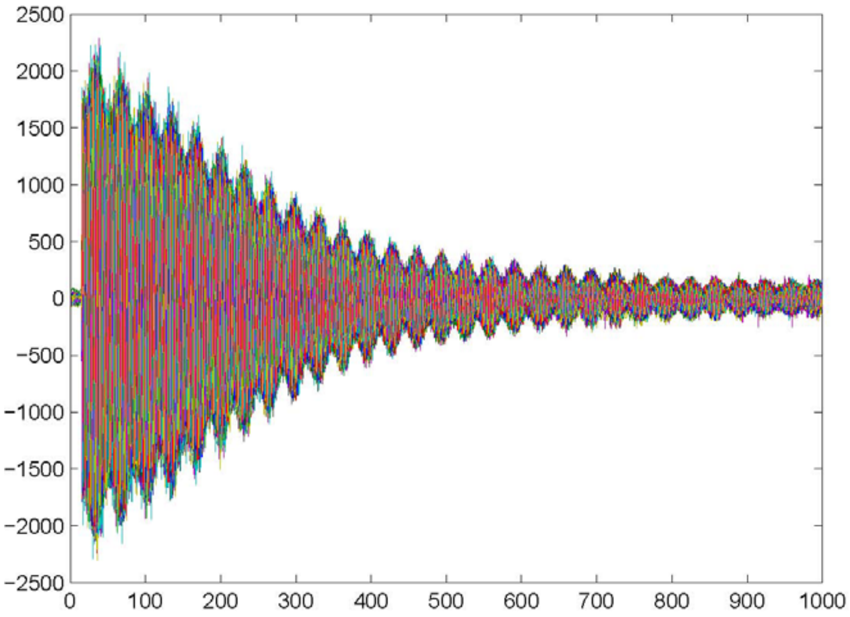
PMT, lifetime & losses (J.-P. Koutchouk, F.Z.)

simulations with FNAL BBSIM code (T. Sen)

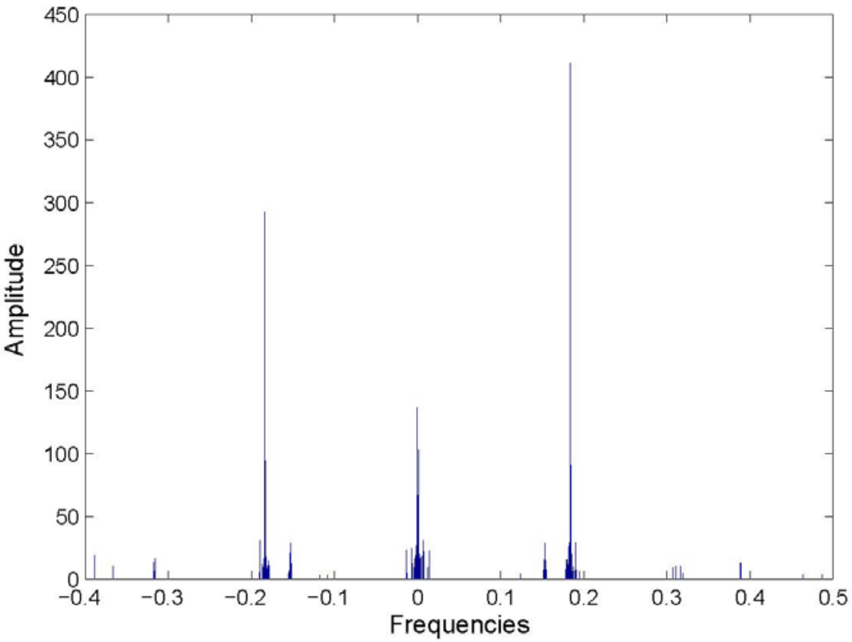
more simulations with WSDIFF (F.Z.)

example of turn-by-turn data

raw data



spectrum



2mm kicks in both planes, both BBLRs excited

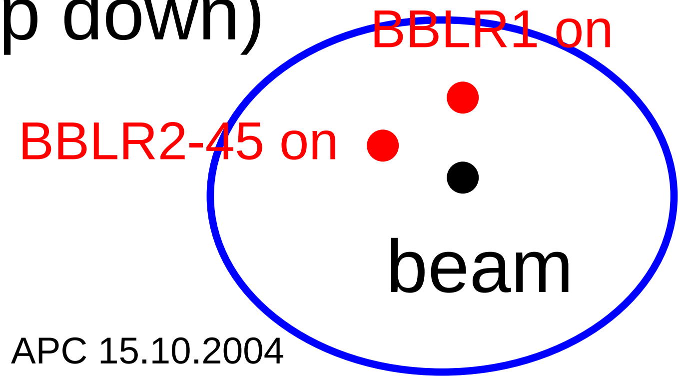
Y. Papaphilippou

→ *indications of coupling, 3rd and 4th order resonances*

LHC BBLR

proposal for additional MD

- results from end of last MD promising (better control of beam parameters, improved stability, optimized procedure, 'static BBLRs', precise BCT)
- new technique for measuring tail populations by kicking to various amplitudes after wire excitation; we would like to do systematic measurements
- tune scan not yet done for these stable conditions
- could create a closer 'XY crossing' by rotating BBLR1 (1 hr access, ~3 hr pump down)

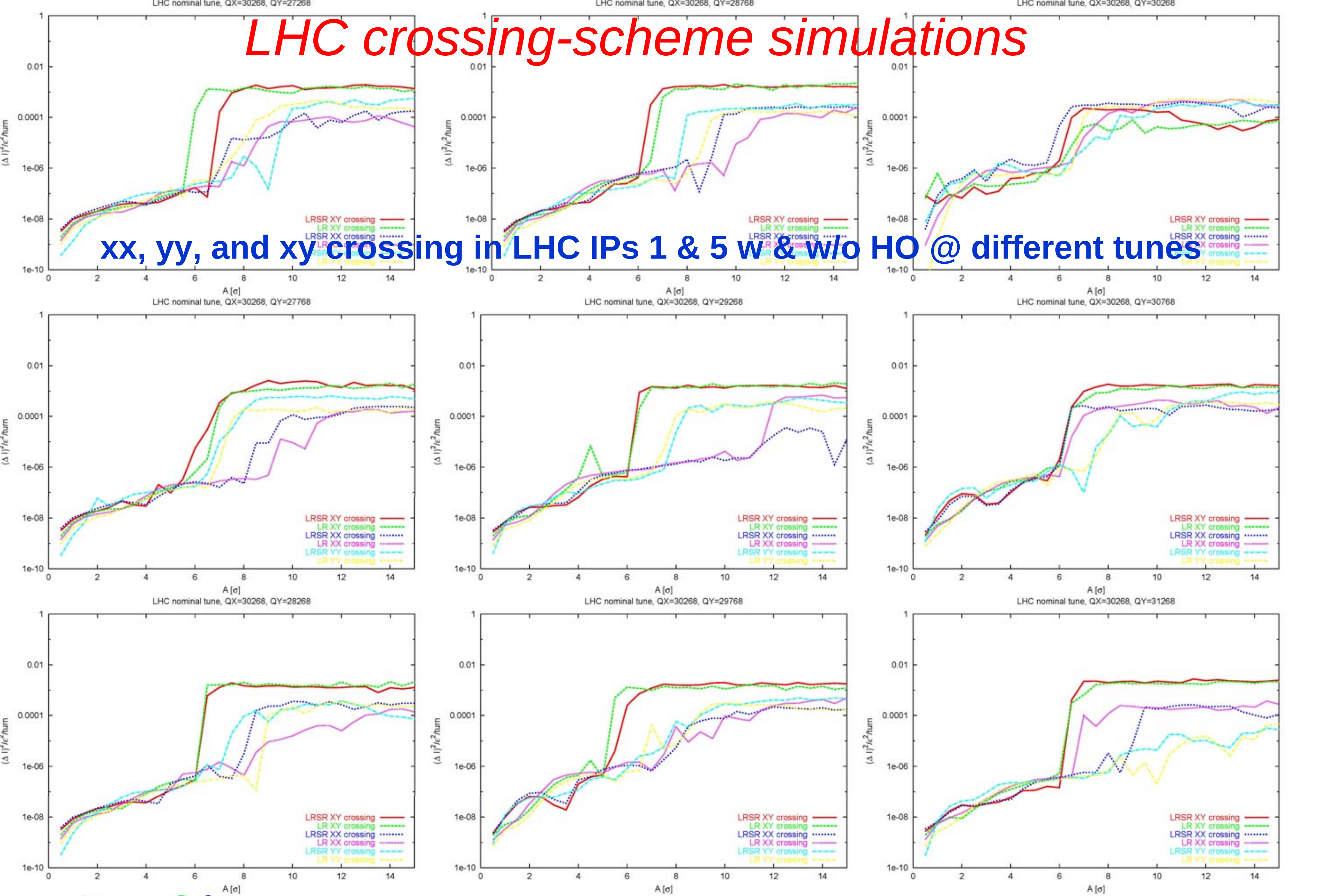


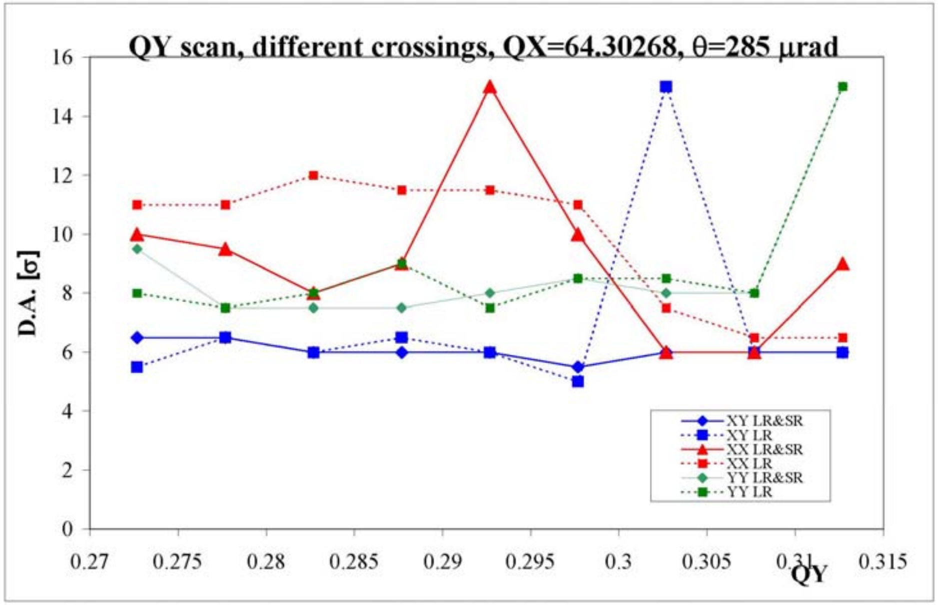
thank you for your attention!

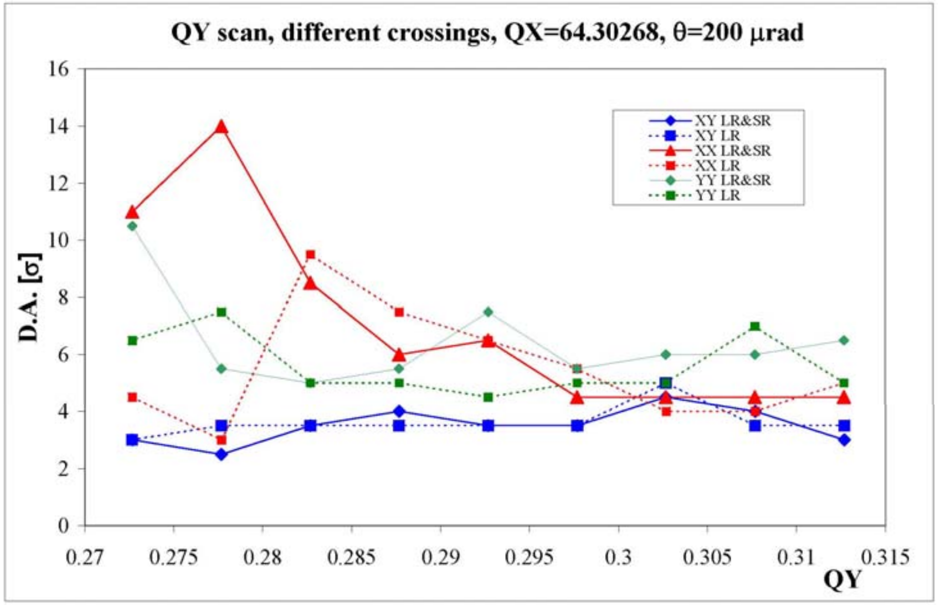
back-up slides

LHC crossing-scheme simulations

xx, yy, and xy crossing in LHC IPs 1 & 5 w & w/o HO @ different tunes







simulated LHC diffusive aperture for nominal & reduced crossing angle vs. Q_y