Overview of Wire Compensation for the LHC

Jean-Pierre Koutchouk

CARE-HHH Meeting on beam-beam effects and beam-beam compensation
CERN 08/28/2008

Outline

1. **Motivation for wire compensation in the nominal LHC**

2. **Motivation for wire compensation for the LHC Upgrade(s)**

3. **Principle of wire compensation (LHC)**

4. **Compensation efficiency: simulations, experiments, operations**

5. **Conclusions**

1- Motivations for nominal LHC

1. The nominal machine performance is limited by the long-range beam-beam effect, with constraints on the Xing planes.
2. The crossing angle had already once to be increased from 200 to 300 μrad (footprint to dynamic aperture); its margin seems small (tight control necessary during operations).
3. chaotic particle trajectories at 4-6σ due to long-range; beam-beam effect: lifetime? background? collimation?

- ❖ (modest) recovery of some of the ~15% geometric luminosity loss from crossing angle
- ❖ Investigations of the beam-beam effect severity well before the nominal beam current is reached.

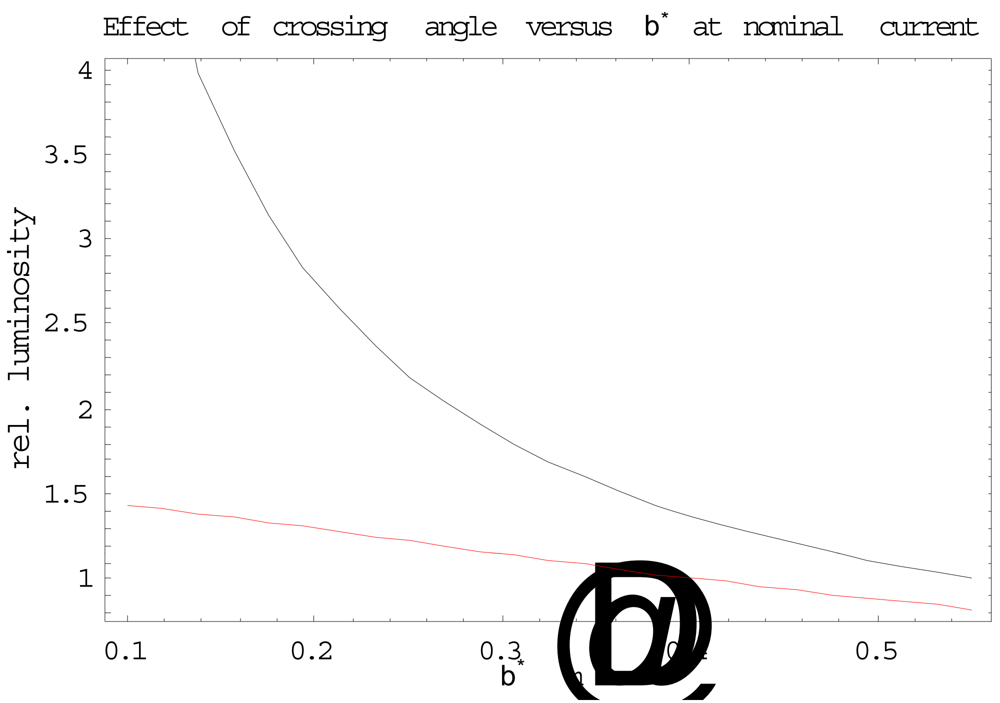
2- Motivation for the LHC Upgrade

- **The crossing angle has to be significantly increased with a large loss of luminosity**
  - the reduction of β*
  - the increased bunch current and number of bunches
  - the possibly increased interaction length (longer quadrupoles)

Luminosity increase vs beta*:

1. no Xing angle,

2. nominal Xing and bunch length,



Motivation for the LHC Upgrade

Wire compensation has the potential to:

- minimize the required increase in crossing angle (and quad aperture) and corresponding rapid loss in luminosity.
- compensate all LRBB's at large enough separation, leaving more freedom to keep a few at reduced separation (D0 scheme; cf Guido's talk).

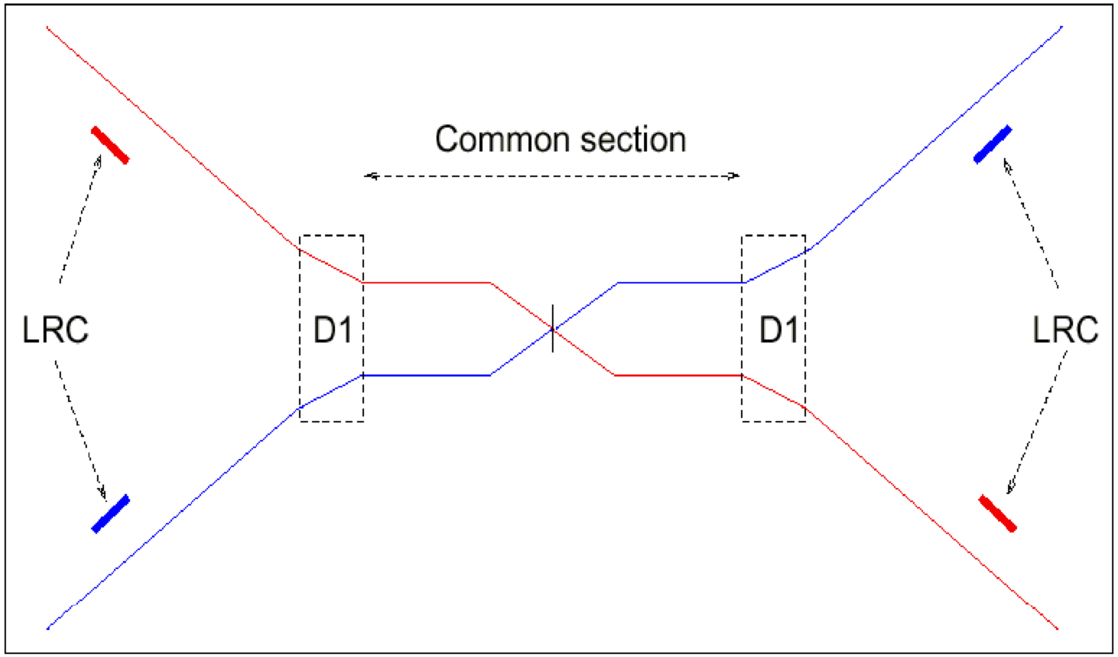
3- Principle of Wire Compensation

Proposed in 2000.

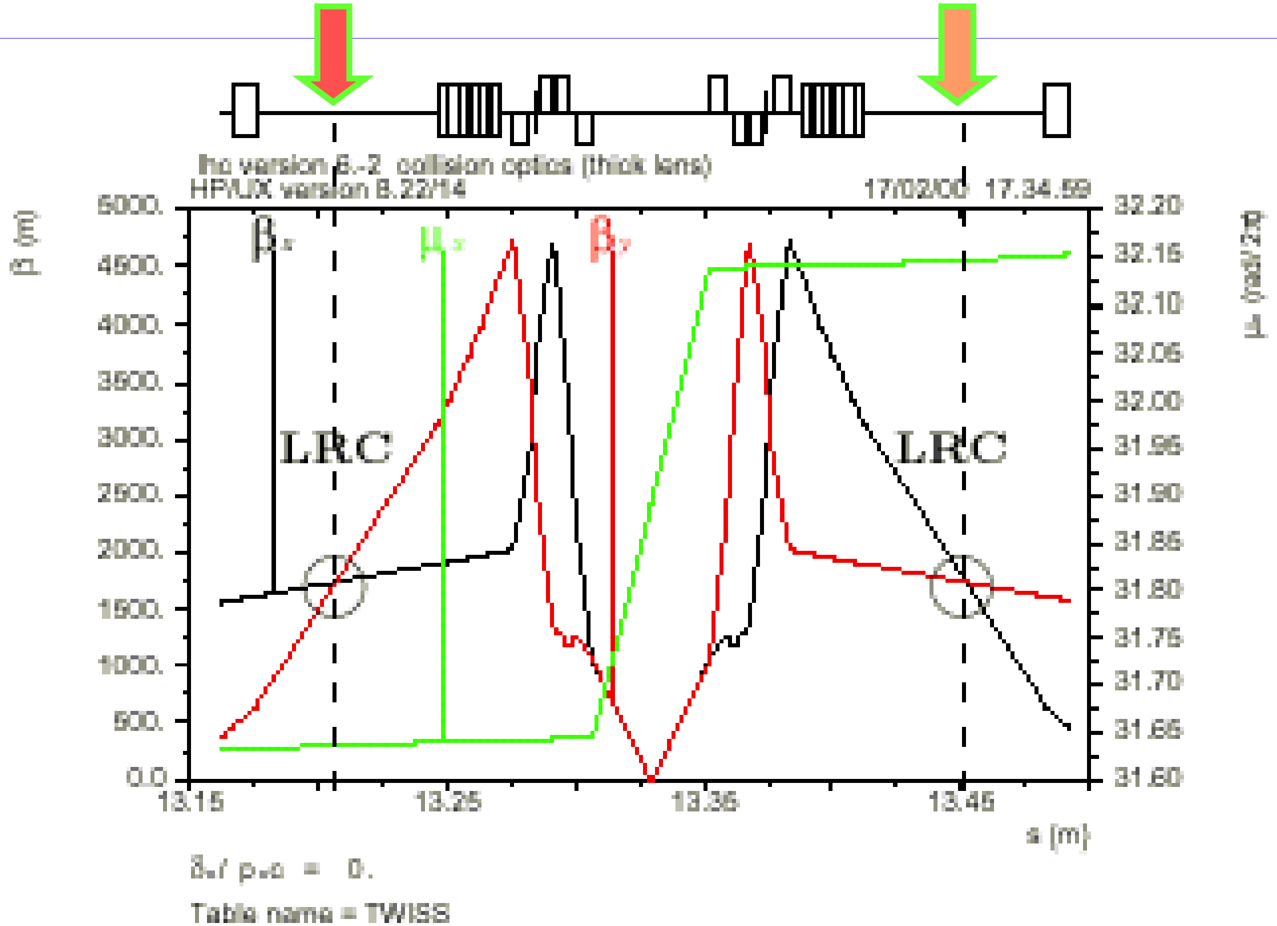
Either side of IP1 and IP5.

H crossing: wires BETWEEN the beams

V crossings: wires above or below the beams



Location of the Correctors



104.931m from the IP’s, in front of the TAN absorber.

ECR: LHC-BBC-EC-0001, EDMS503722, Oct. 2004

CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-BBC-EC-0001
EDMS Document No.
503722
Engineering Change requested by (Name & Div./Grp.) :
C.Fischer AB/BDI

Date: 2004-10-27

Engineering Change Order – Class I

RESERVATIONS FOR BEAM-BEAM COMPENSATORS IN IR1 AND IR5

Brief description of the proposed change(s) :

Reservations on the vacuum chamber in IR1 and IR5 for beam-beam compensator monitors.
We propose to include these modifications in the next v.6.5 machine layout version.

Equipment concerned :	***Drawings concerned :***	***Documents concerned :***
BBC	**LHCLSX—0001** **LHCLSX—0002** **LHCLSX—0009** **LHCLSX—0010**	

PE in charge of the item :	***PE in charge of parent item in PBS :***
J.P. Koutchouk AT/MAS	**C. Rathjen AT/VAC**
Decision of the Project Engineer :	***Decision of the PLO for Class I changes :***
☐ Rejected. ☐ Accepted by Project Engineer, no impact on other items. *Actions identified by Project Engineer* ☑ Accepted by Project Engineer, but impact on other items. *Comments from other Project Engineers required* *Final decision & actions by Project Management*	☐ Not requested. ☐ Rejected. ☑ Accepted by the Project Leader Office. *Actions identified by Project Leader Office*
Date of Approval : 2004-10-27	***Date of Approval :*** 2004-10-27

Actions to be undertaken :

Modify the drawings and Equipment codes concerned to reflect the changes described in this ECO.

Date of Completion : 2004-10-27	***Visa of QA Officer :***

*Note : when approved, an **Engineering Change Request** becomes an **Engineering Change Order/Notification**.*

for future wire beam-beam compensators - "BBLRs" -, 3-m long sections have been reserved in LHC at 104.93 m (center position) on either side of IP1 & IP5 in 2004

4 Compensation Efficiency

4a Simulations

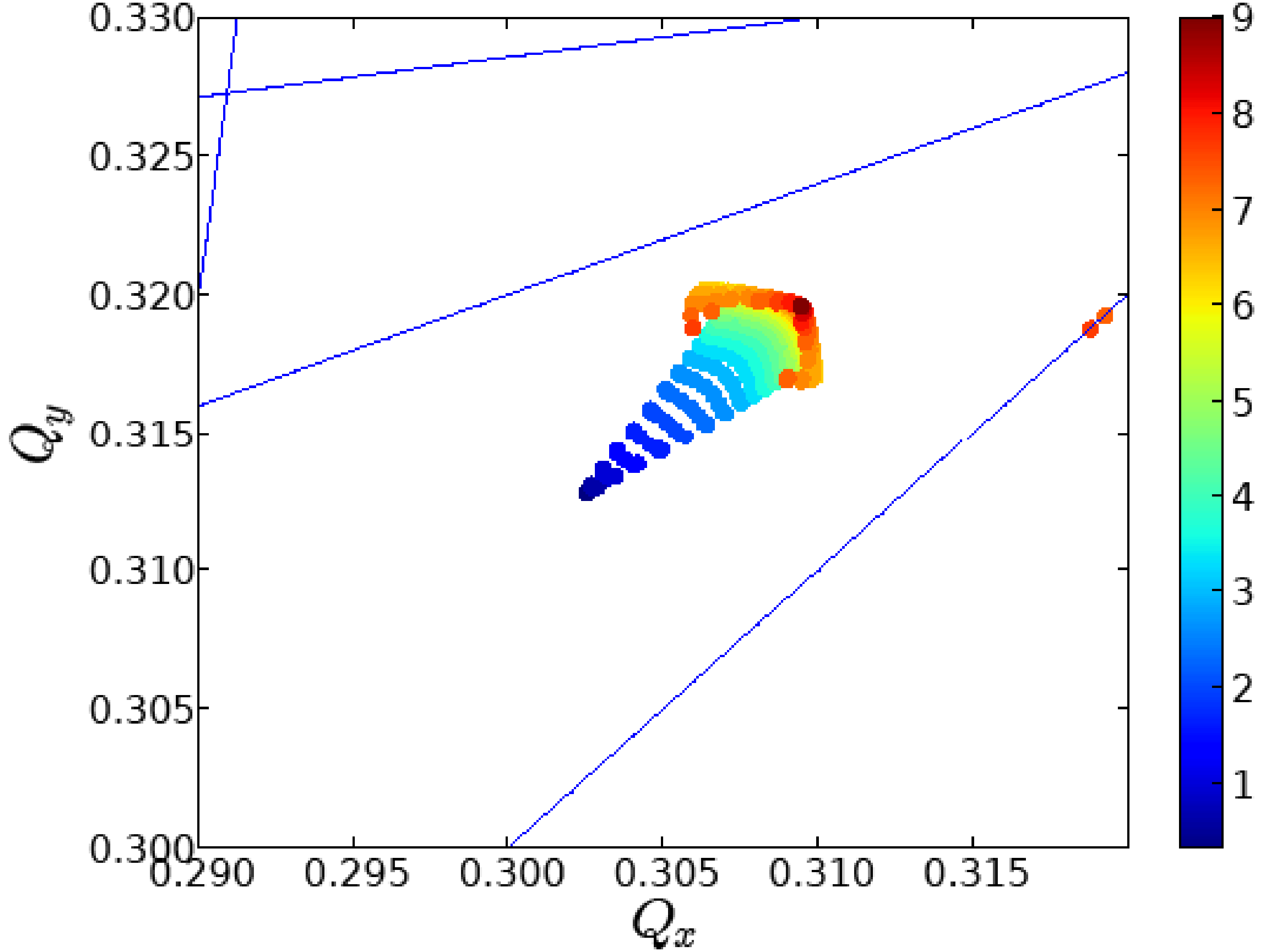
Several generation of mostly weak-strong, but as well strong-strong simulations since 2000:

- JPK
- Zimmermann
- Shi, Jin & Herr (strong-strong)
- Dorda

With consistent conclusions:

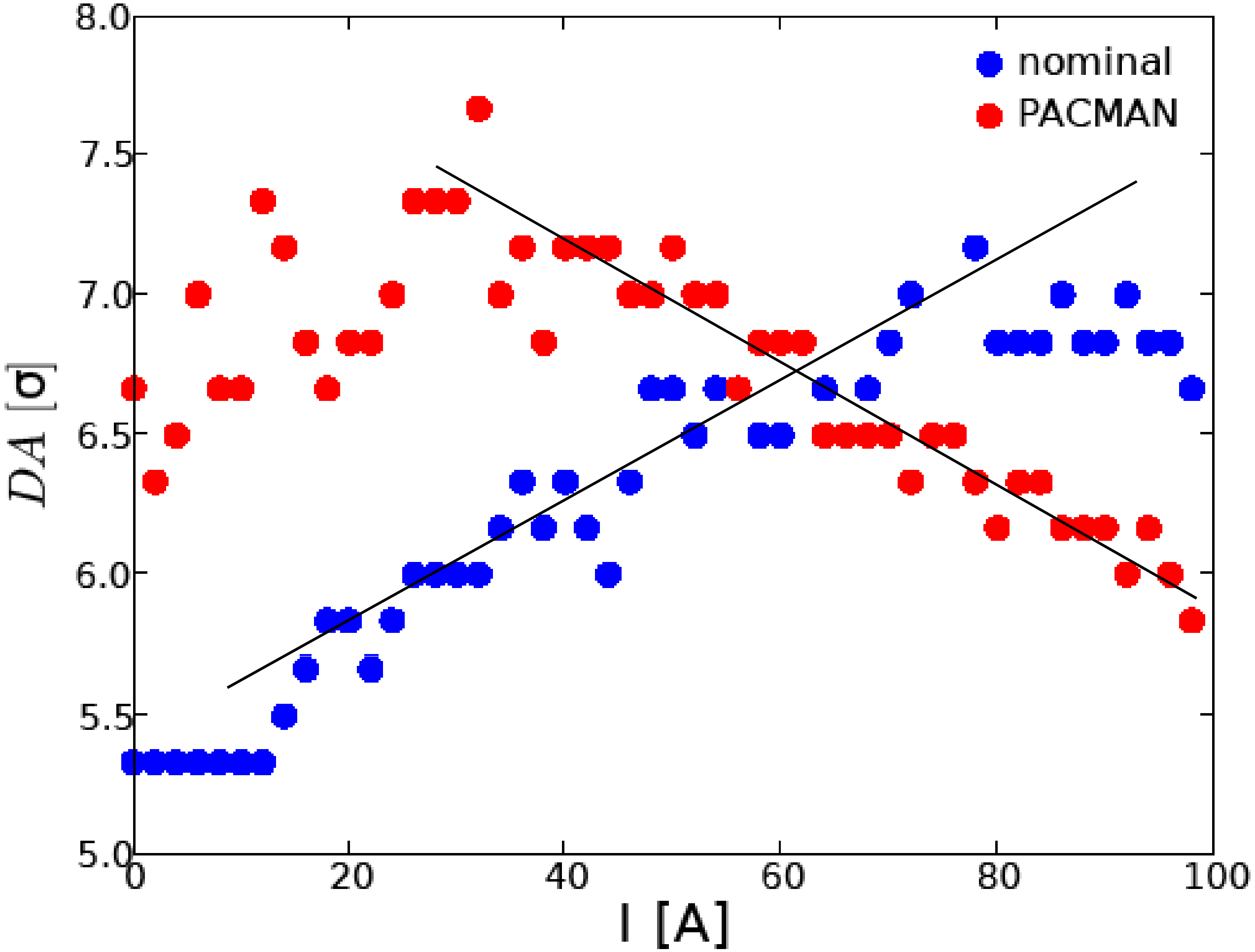
- compensation very “efficient” (footprint, dynap)
- compensation robust (need not be exact)
- intensity noise shall be under control (FZ: <0.1%; J. Shi: <0.5%; TEV elens < 1% in practice, with less current but less distance)

1- Footprint compression (U. Dorda):



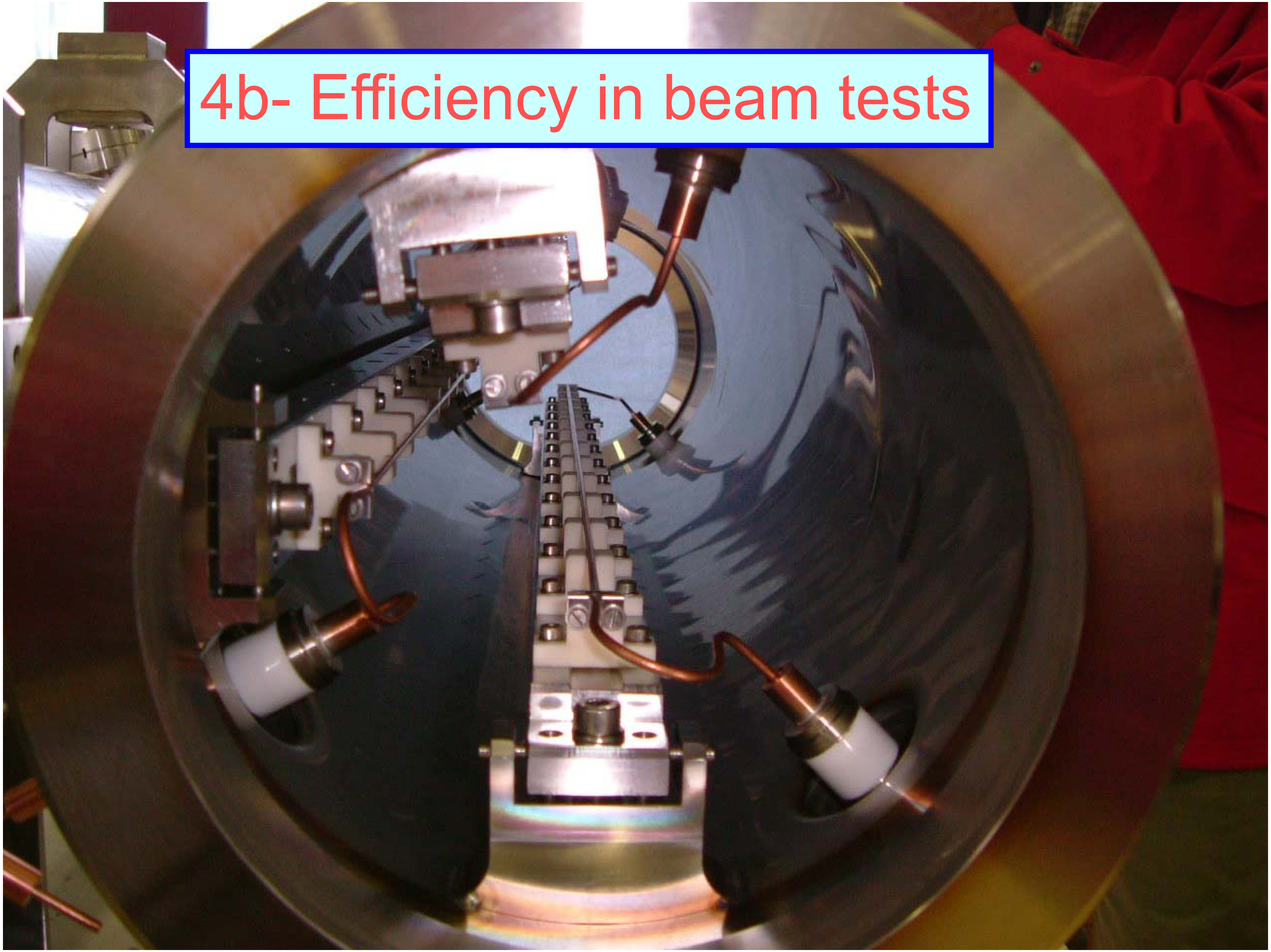
2- Dynap gain: 1.5 to 2 sigma (U. Dorda)

U. Dorda: dynap versus compensating current for nominal and extreme pacman.



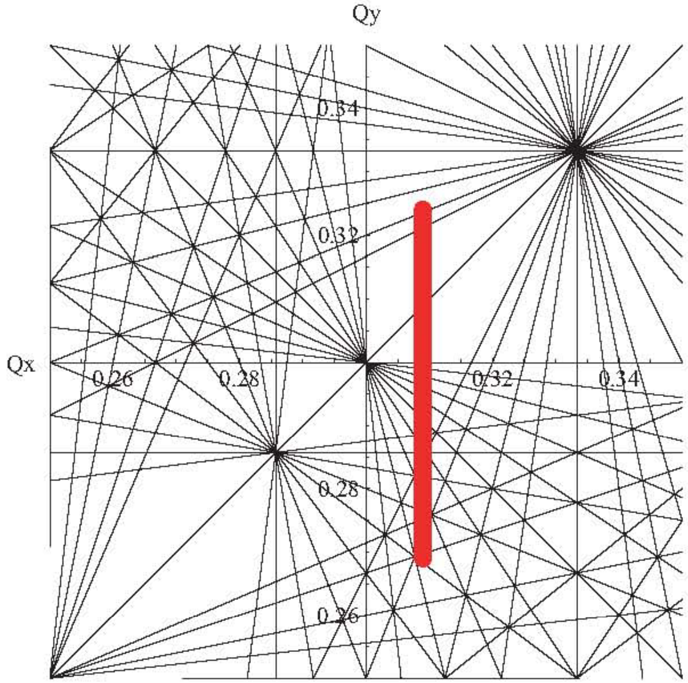
Even though a pulsed wire compensation should be the final goal, a first generation of simple dc wire compensation is worth considering.

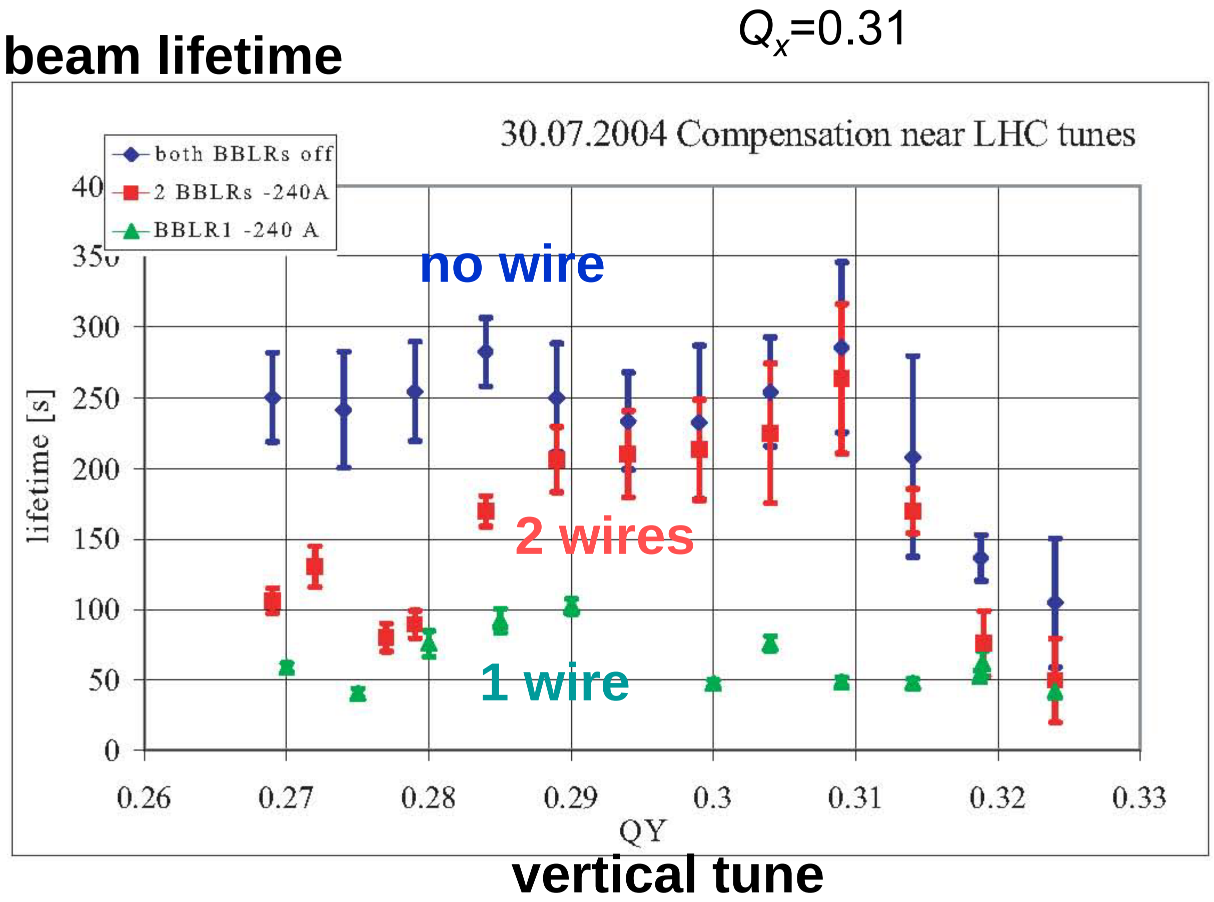
4b- Efficiency in beam tests



SPS experiment 2004:

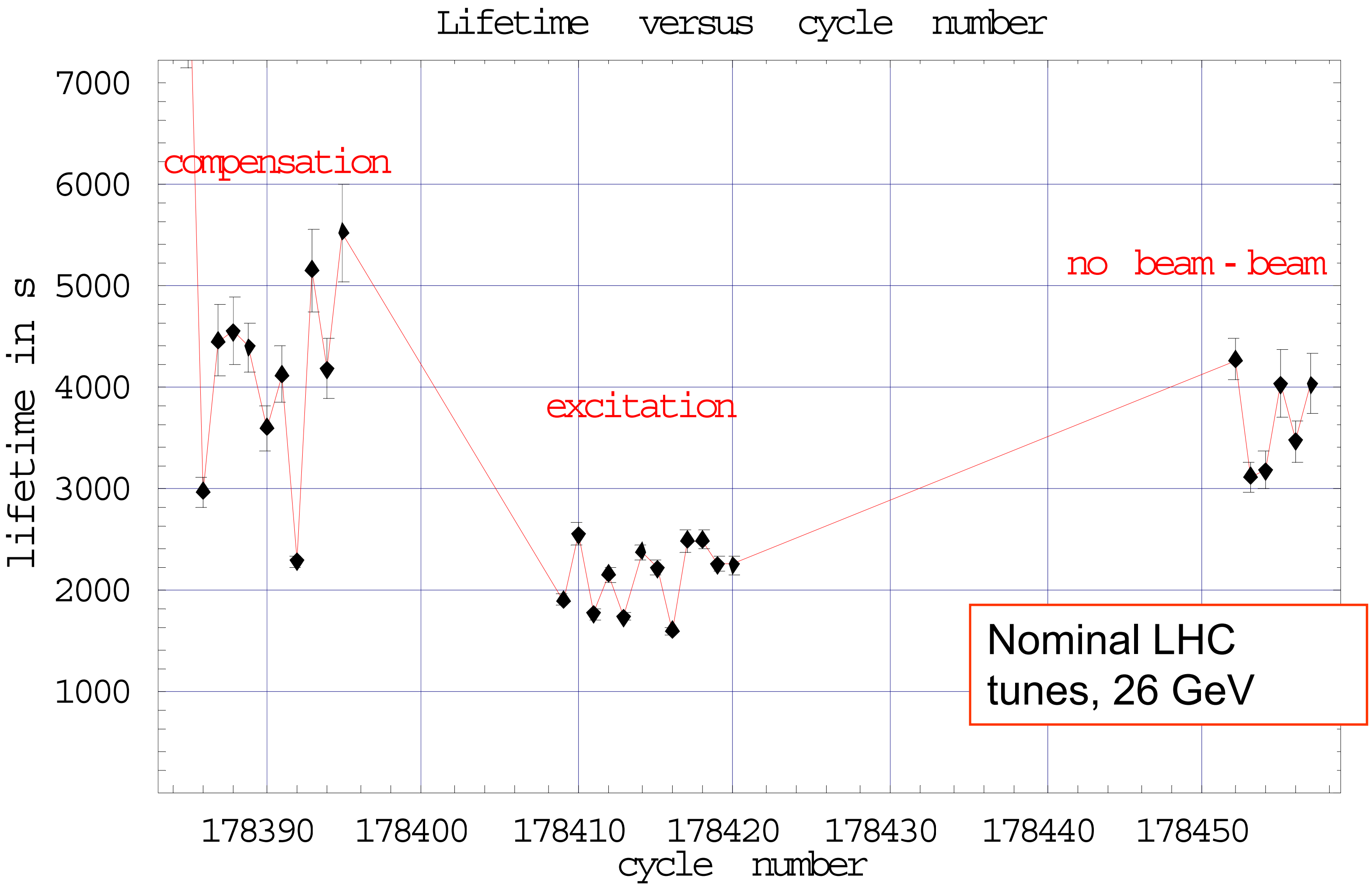
two wires model beam-beam compensation
2.6 degree phase shift





lifetime is recovered over a large tune range, except for Qy<0.285

MD 02.09.2004


Lifetime versus cycle number
lifetime in s
7000
6000
5000
4000
3000
2000
1000
compensation
excitation
no beam - beam
Nominal LHC tunes, 26 GeV
178390
178400
178410
178420
178430
178440
178450
cycle number

Other SPS and RHIC experiments & studies

Several other experiments have been carried out at the SPS and at RHIC, since wires were installed. Their goal has been to investigate the strength of the long-range beam-beam interaction rather than the compensation (so far in RHIC).
A good understanding of the perturbation is indeed a key step towards its compensation.
They have as well demonstrated the required reliability of the instrument.

Clearly, RHIC has a high potential to advance the understanding of (simulated) long-range beam-beam encounters , given its long beam lifetime, observation time and precision instrumentation…
More MD time would be very useful.

4c- Efficiency in Operations

A wire was installed "in" Dafne to compensate the long-range beam-beam interaction.

<u>C. Milardi et al, 2008.</u>

Long-range beam-beam interactions (parasitic crossings) were one of the main luminosity performance limitations for the lepton Φ-factory DAΦNE in its original configuration. In particular, the parasitic crossings led to a substantial lifetime reduction of both beams in collision. The wires installed in the DAΦNE IRs proved to be effective in reducing the impact of BBLR interactions and improving the lifetime of the positron beam especially during the KLOE run.

Conclusions

1. By beam-beam standards, the efficiency of the compensation of the long-range beam-beam effect appears well established.
2. It has given concrete improvement in Dafne.
3. The compensation has a potential both for the nominal and upgraded LHC. In addition, it would allow early and efficient studies of one of the most difficult and limiting phenomenon in the LHC.
4. The implementation of a first dc solution should be relatively simple and of limited cost.
5. It appears timely to consider an implementation plan.