Beam-beam with a few long-range encounters at short distance

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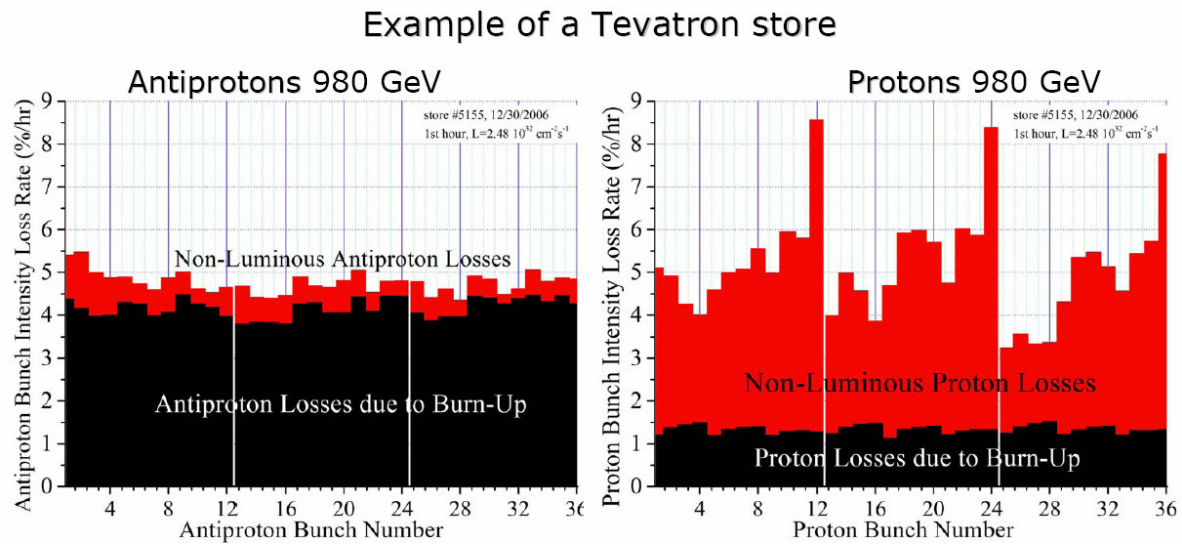
Overview

- Long-range interactions at:
  - Tevatron
  - SPS+LHC
  - RHIC
- Experiments with a few long rang encounters;
- BBLR experiments at RHIC;
- Comparison with simulation and
- Conclusions

Tevatron

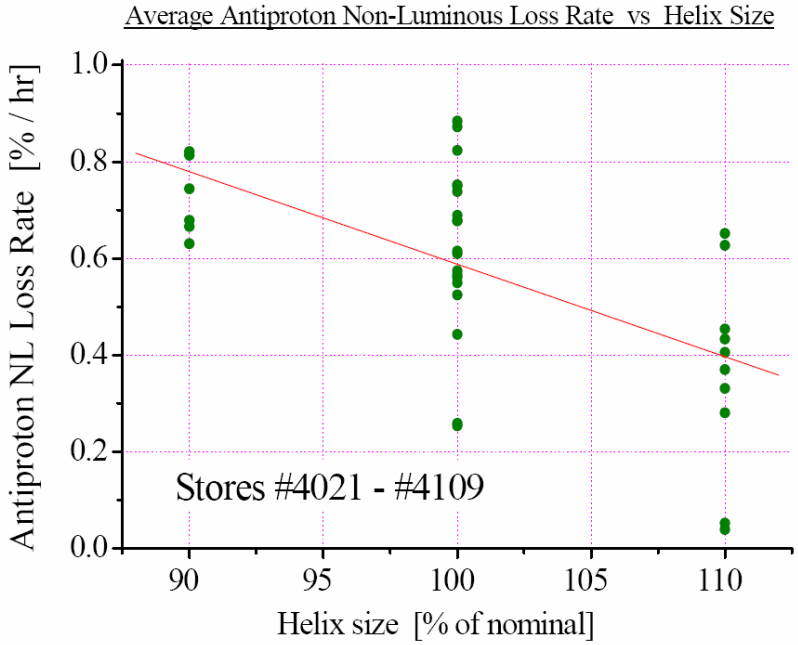
- Each bunch experiences 70 LR and 2 HO collisions / turn;
- There are 138 locations around the machine where LR interaction can take place and the sequence of 72 out of 138 is different for each bunch, hence the effects change from bunch to bunch
- This parasitic collisions limit the DA and also the beam lifetime and thus also affects the luminosity.

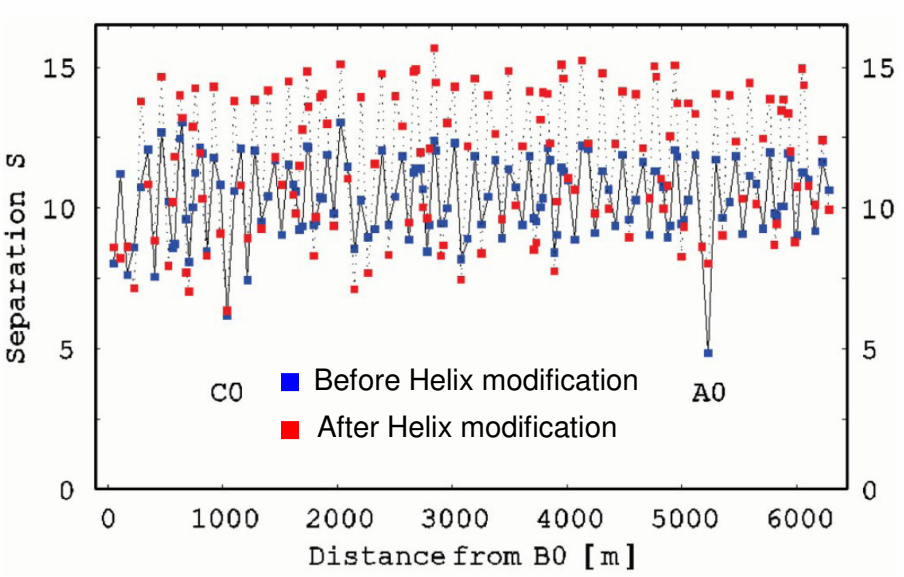


V. Kamerdzhiev
BB Compensation with Tevatron Electron Lenses
LARP Mini-workshop at SLAC

Tevatron

- Experience shows that less then 5-6 σ separation causes losses
- Change of the helix separation (mean separation: ~10 σ and minimum separation: from 4 σ to 6 σ) and use of electron lenses to compensate the emittance blow-up (emittance "scallops")



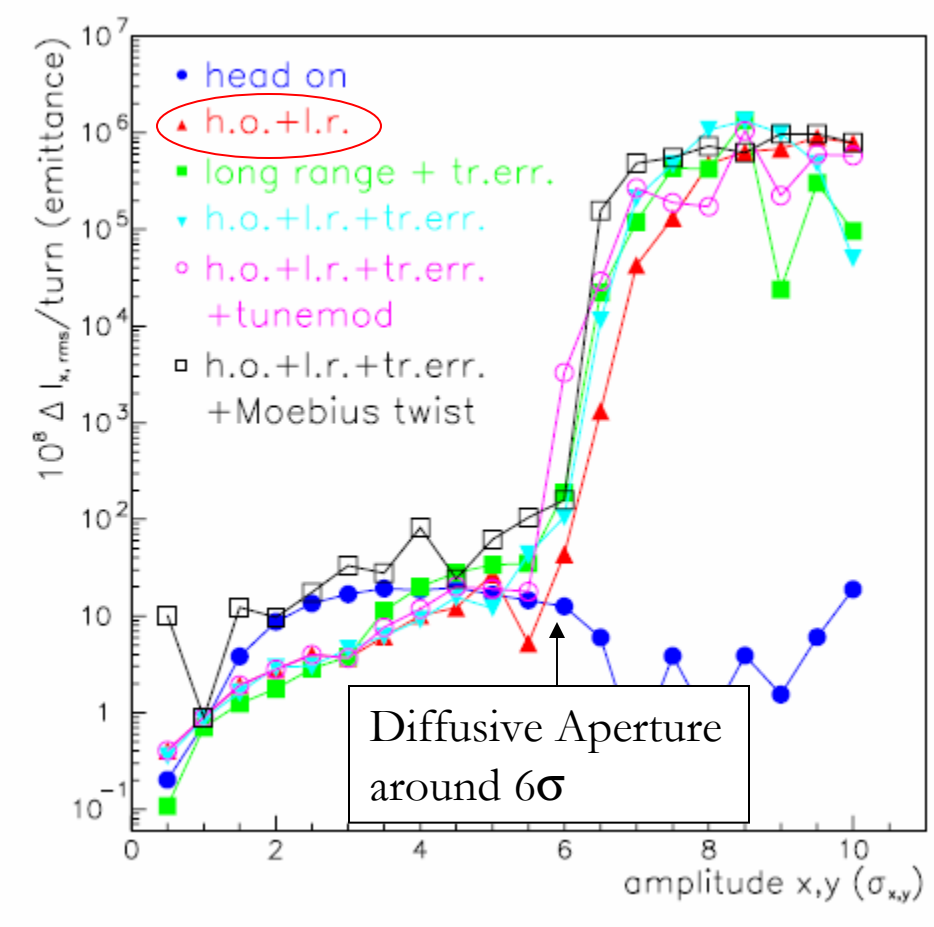


A. Valishev
Tevatron BB Phenomena and Counter Measures
LARP Mini-workshop at SLAC

V. Shiltsev, *et al.*
Beam-beam effects in Tevatron
PSRT-AB vol.8 101001 (2005)

LHC

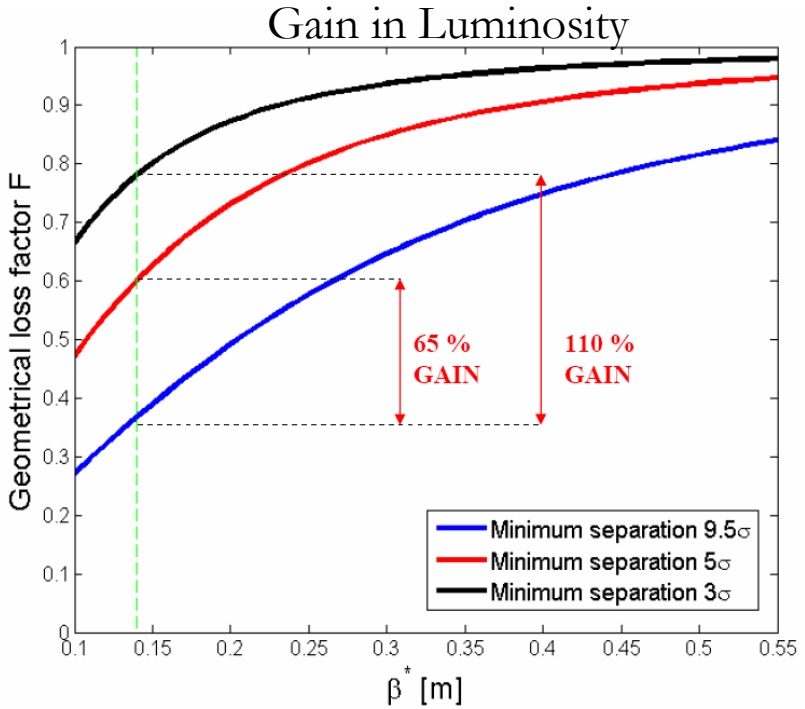
- There are around 120 LR interactions / turn all concentrated around the interaction regions;
- The LR interactions at the high luminosity IPs create a diffusive aperture around 6σ and can be potentially harmful for the beam dynamics and a limiting effect to achieve higher luminosities;
- Possible solutions:
  - Early separation schemes;
  - Use of wires to compensate for the LR interactions.

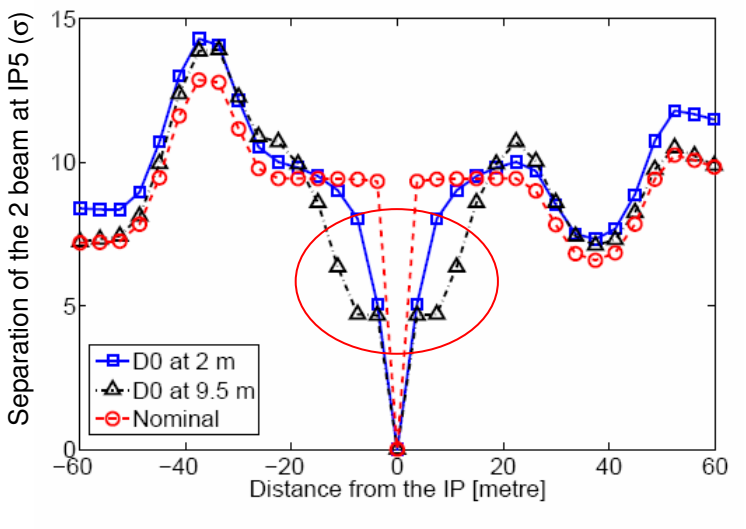


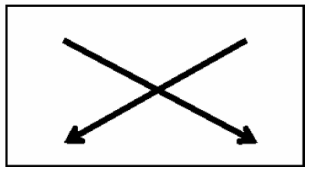
Y. Papaphilippou and F. Zimmermann
PRST-AB vol.2 1999

LHC : Early separation scheme

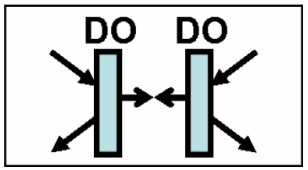
- Motivation: Luminosity improvements by changing the crossing scheme
- This new setup reduces the minimum separation from 9.5 σ to 5-4 σ
- How harmful this few close encounters could be regarding the stability of the beam?



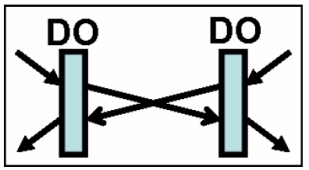




Nominal



D0 at 2 m

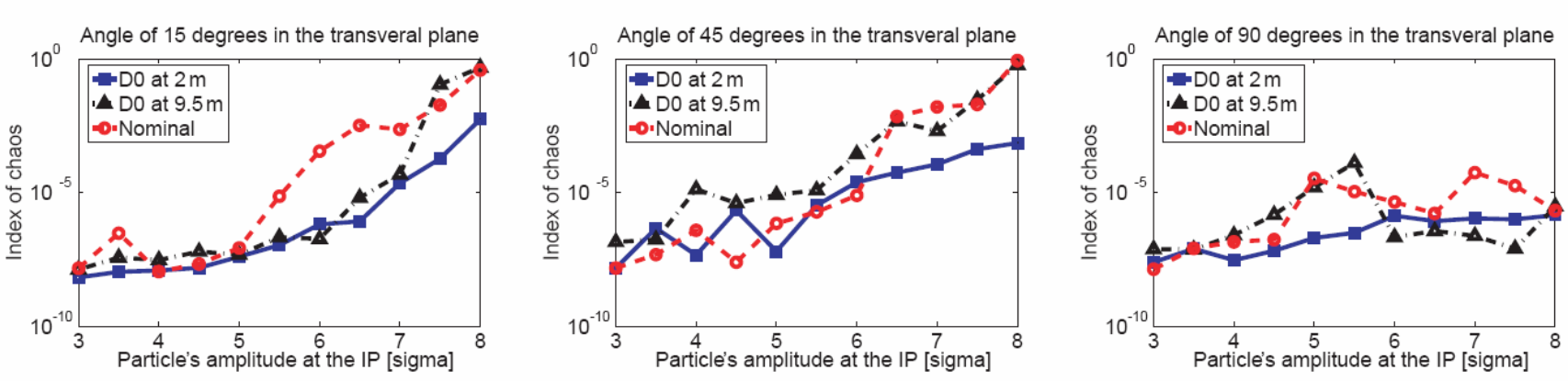


D0 at 9.5 m

J.-P. Koutchouk, G. Sterbini
PAC07

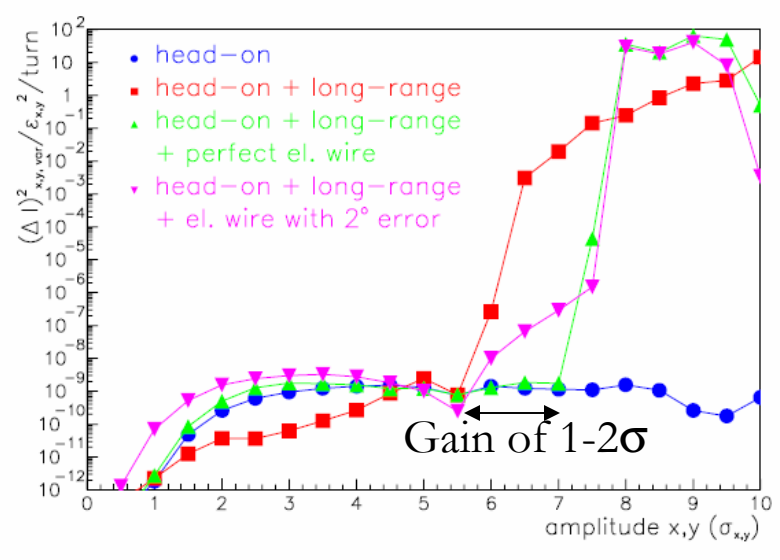
LHC : Early separation scheme

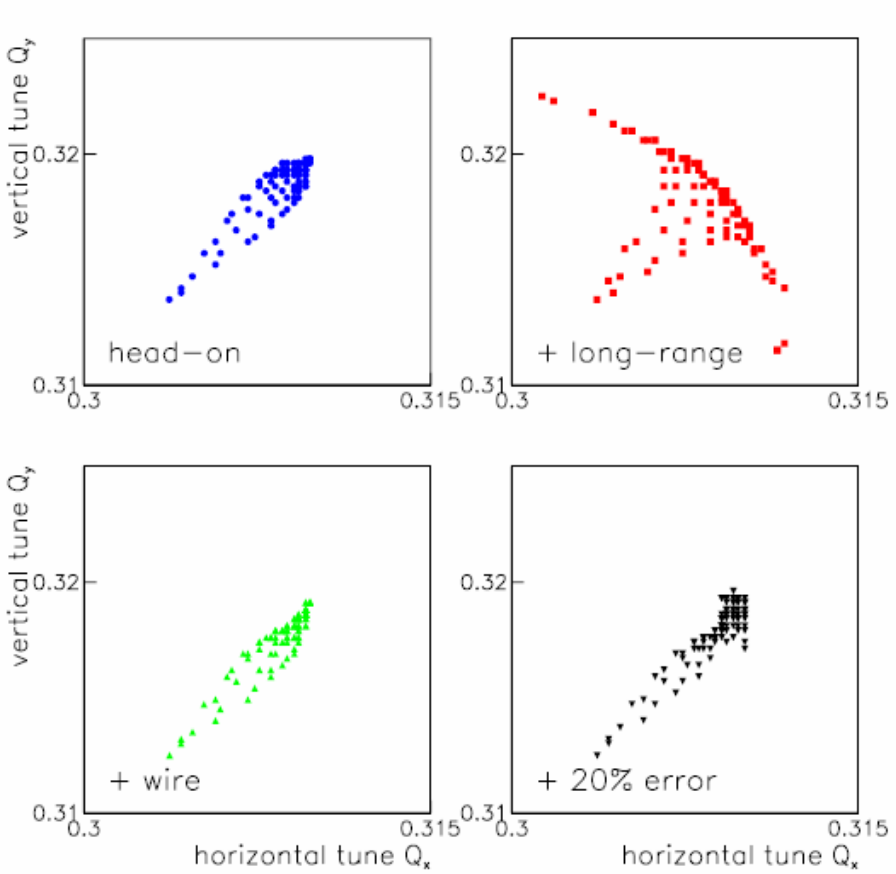
- 4 encounters at 5.5 σ (blue curve) does not indicate that diffusion due to this LR interaction is worse than in the nominal case.



LHC: Wires

- A compensator can increase the diffusive aperture by 1 to 2σ
- It is also able to compensate for the tune changes due to LR interactions.





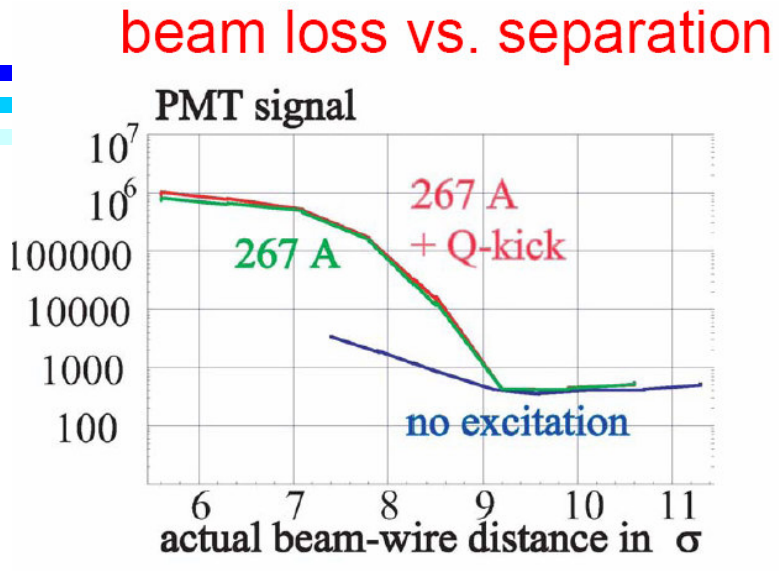
F. Zimmermann
LHC Project Report

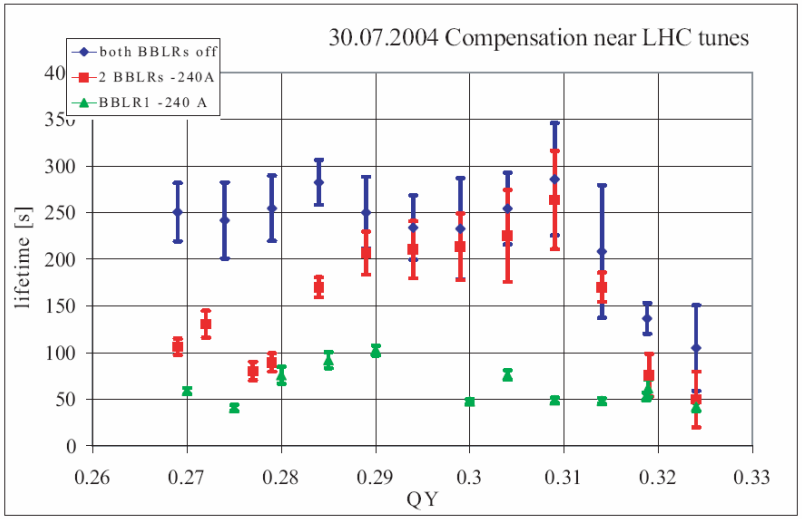
SPS

F. Zimmermann. LARP Workshop 2007

- Experiments with wire also show that for all 120 LR (I_{wire}=276 A) losses start at 8-9σ;
- BBLR experiments at SPS may indicate that 2 LR interactions at 5 σ can create losses that can not be tolerated at LHC. (?)
- There are two sets of wires installed at the SPS that can be used to create LR-like interactions;
- It is also possible to correct the effect of one set of wires with the second set, indicating the ability to compensate for LR interactions.

BBLR logbook 4 July 2003





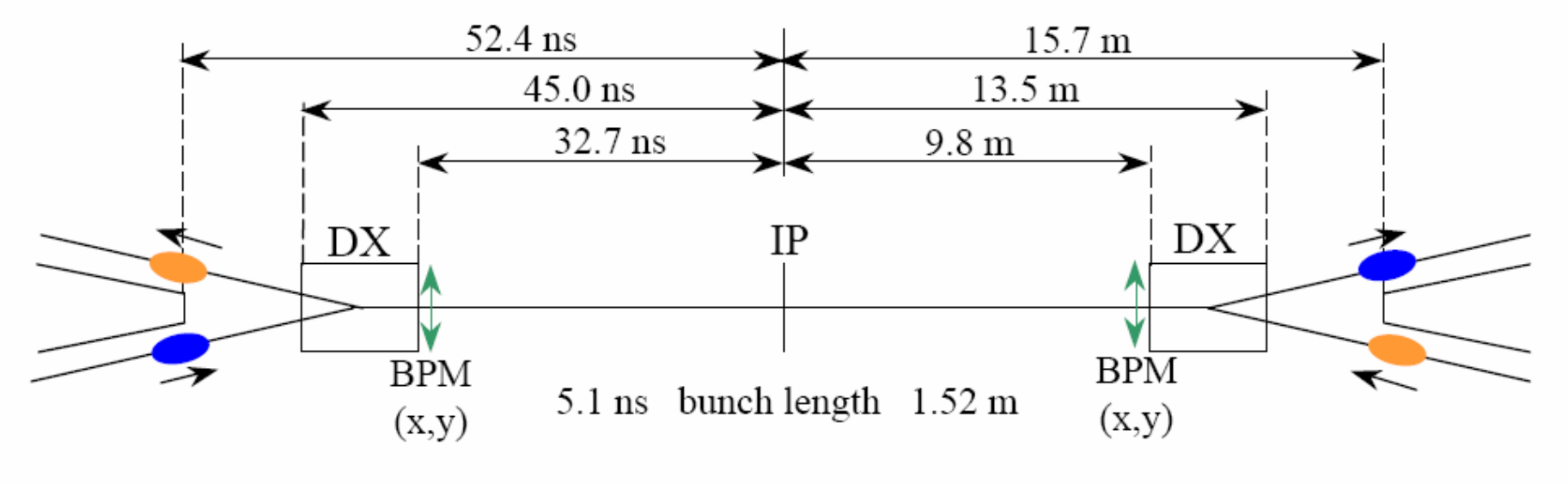
F. Zimmermann, J.-P. Koutchouk, F. Roncarolo, J. Wenninger, T. Sen, V. Shiltsev and Y. Papaphilippou. PAC05

RHIC

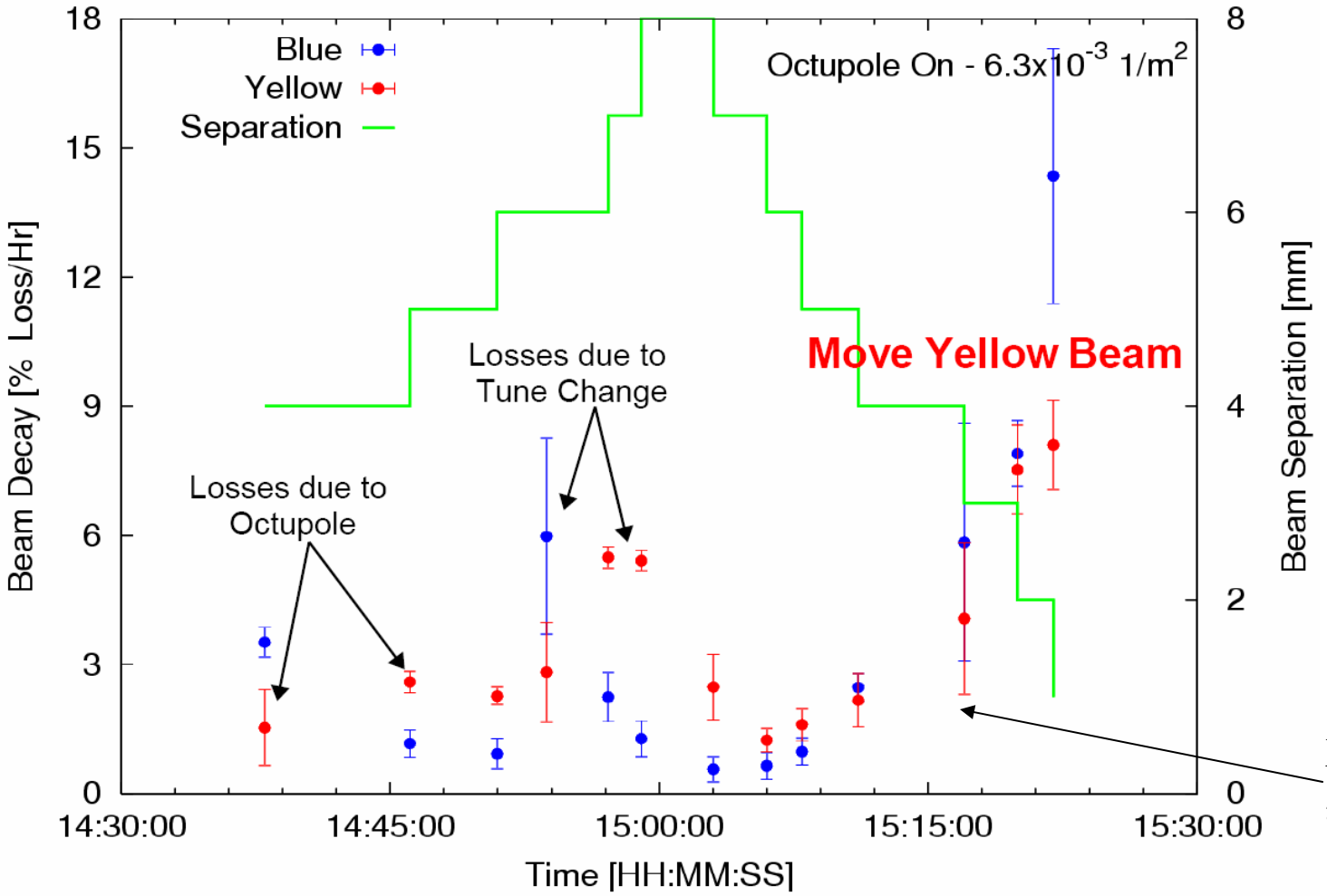
- Like in the LHC, LR interactions are localized at the IPs
- With a bunch spacing of 108 ns (currently nominal operation) there is no LR interactions
- For eRHIC a bunch spacing of 72 ns is considered which would lead to 2 LR interactions per IP

RHIC interaction region

- Layout of one of the IPs at RHIC
- Bunch length and bunch spacing for the RF storage system (2520 buckets)



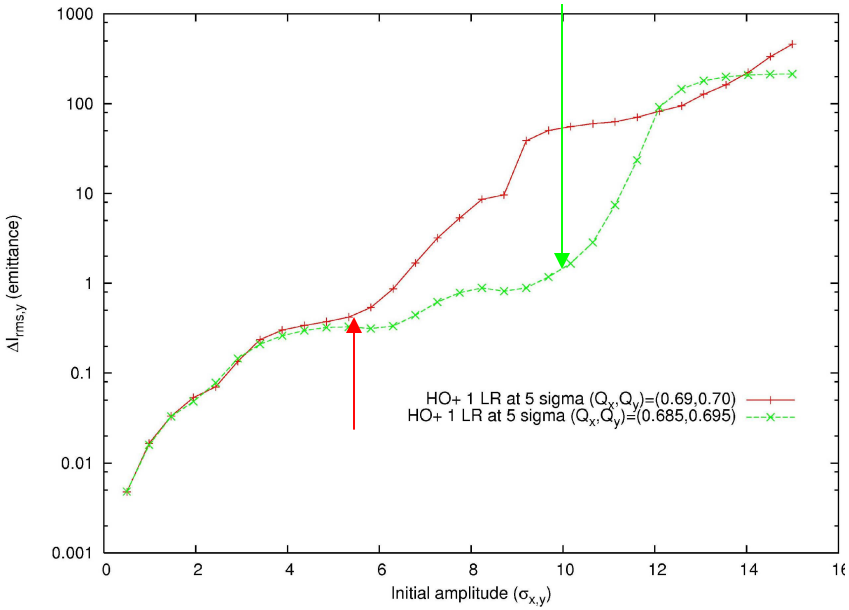
Experiments with a single LR encounter (100 GeV and Q_{xy}=(0.69,0.7))

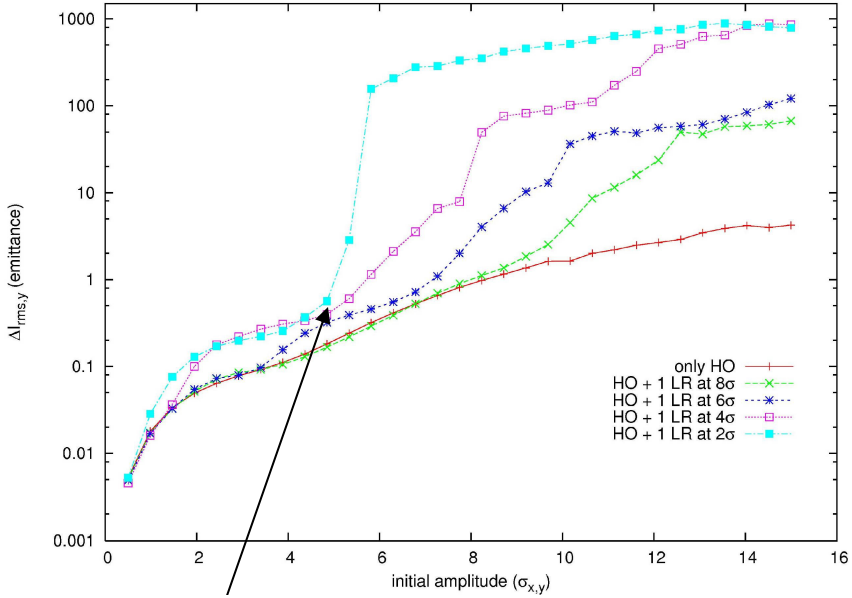


Simulations Results

- Using the tunes: (Qx,Qy)=(0.7,0.69) and 1 LR encounter at IP6 with Nb=1.7x10^{11};

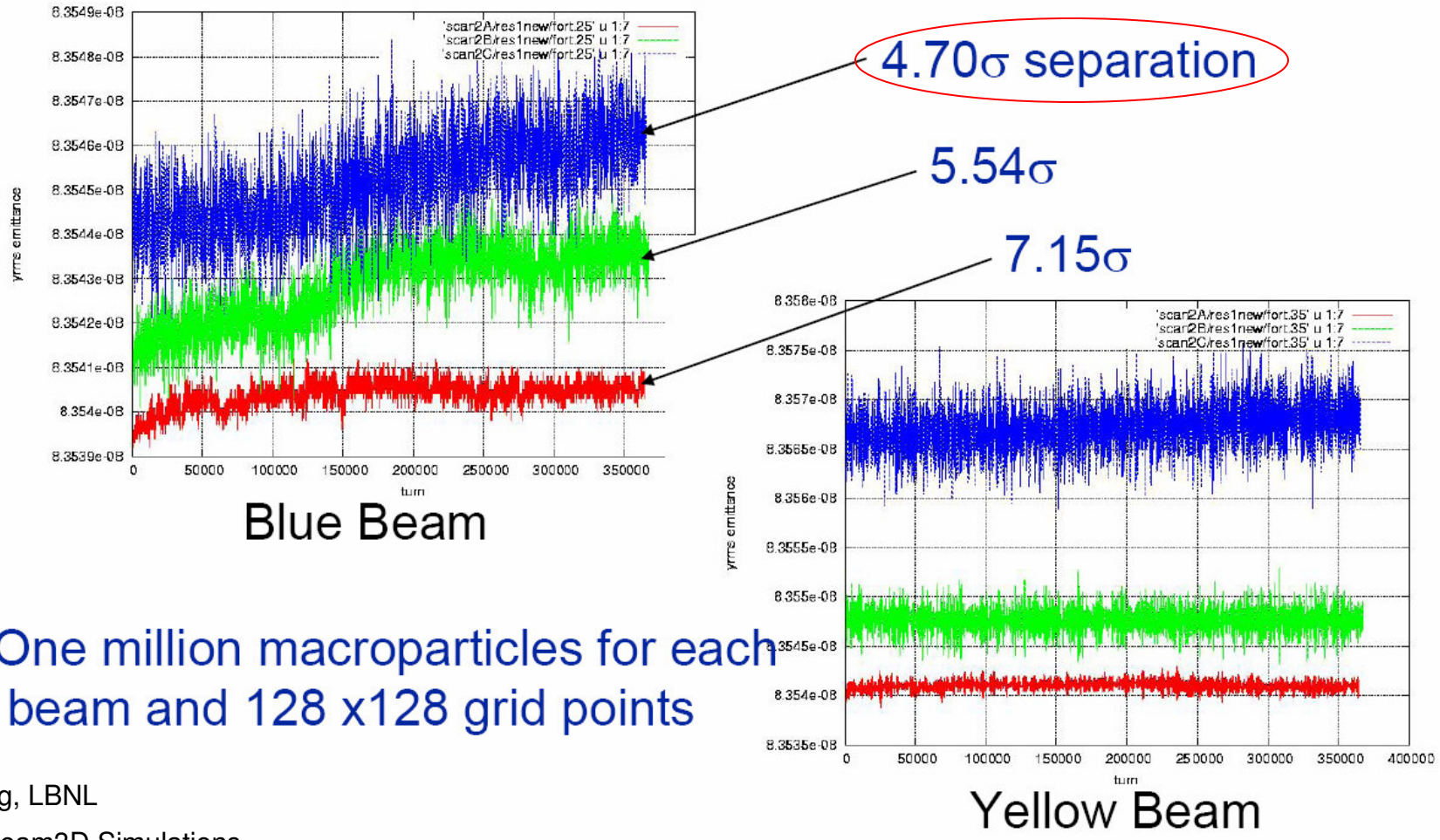
Diffusive aperture around 10σ for 5σ separation and nominal tunes





Diffusive aperture around 5σ for 2σ separation

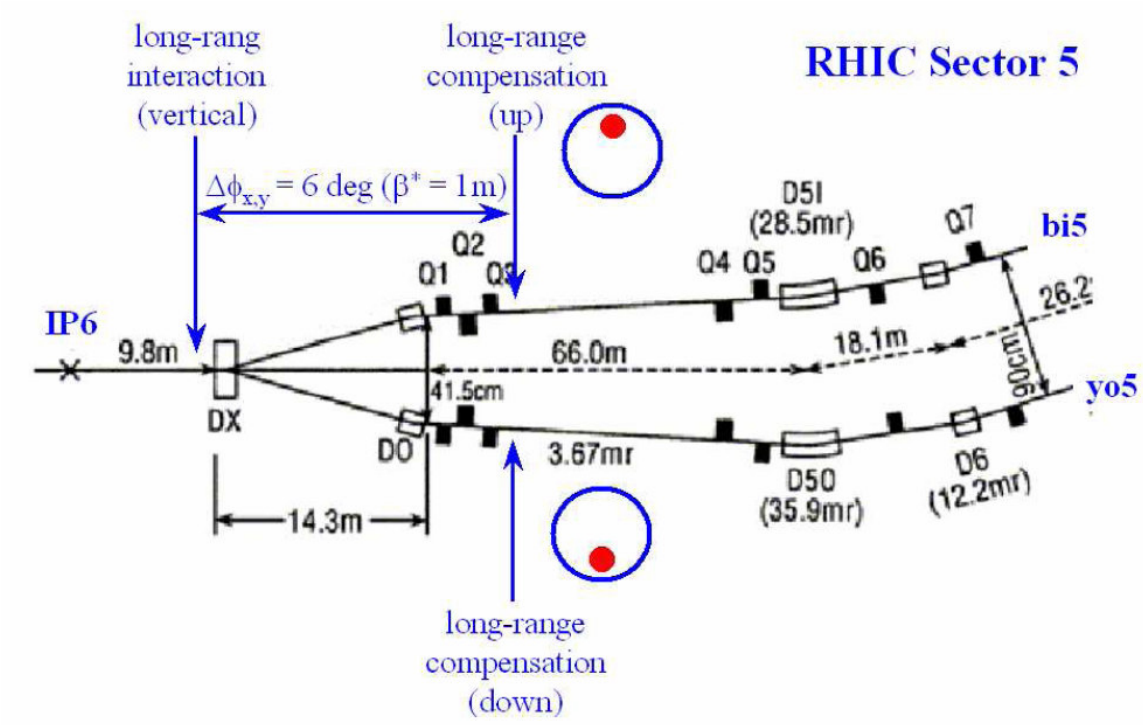
Simulation with a few long range encounters



One million macroparticles for each beam and 128 x128 grid points

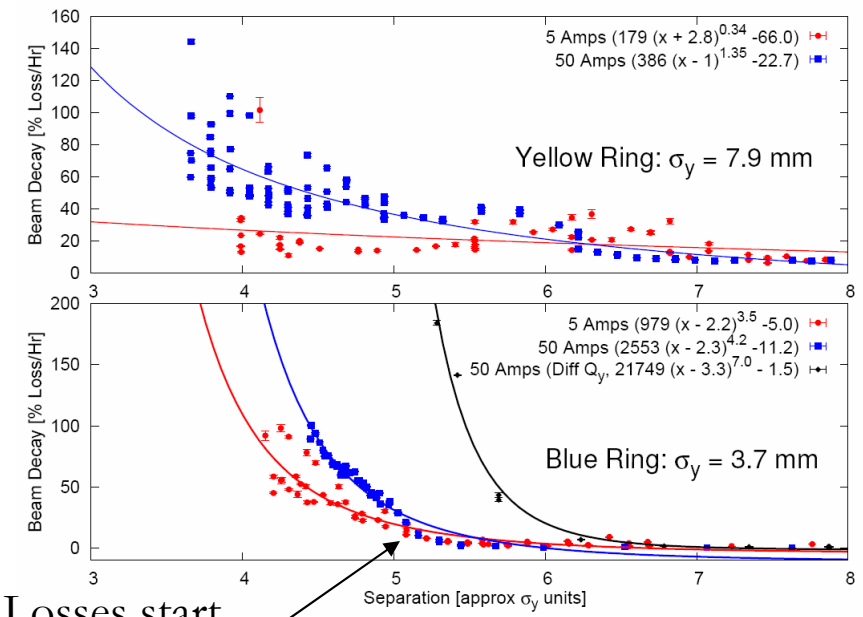
BBLR experiments at RHIC

- In 2006 a set of compensators was installed at RHIC
- The experiments were carried out at the Au 2007 run at top energy (100 GeV/nucleon);
- Integrated strength: 12.5 Am (=1 LR) and 125 Am (=10 LR).



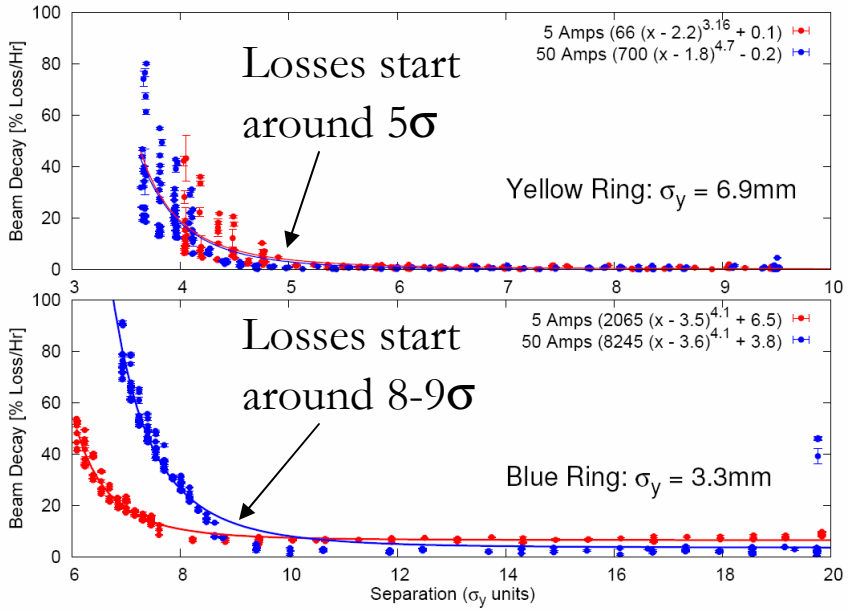
BBLR experiments at RHIC

Experiment I: Nominal Tunes



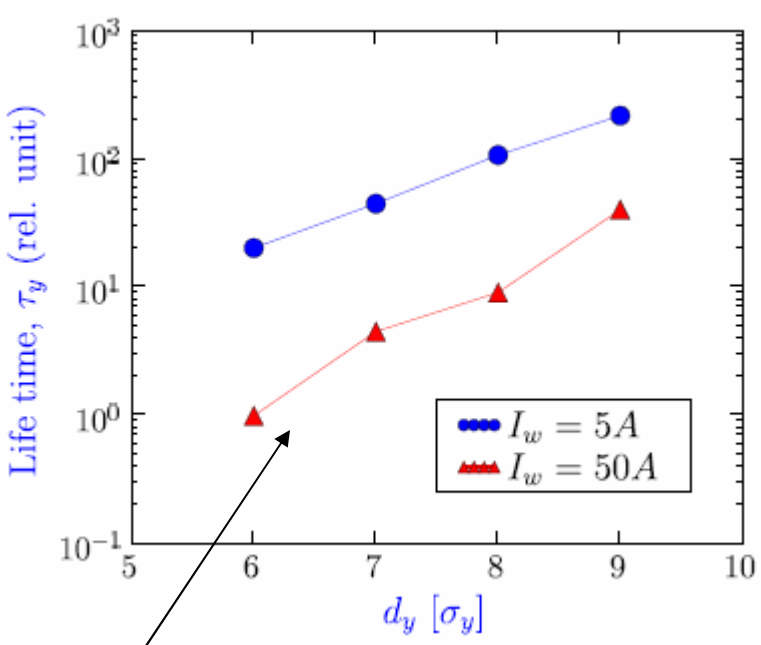
Losses start around 5σ

Experiment II: Tunes Swapped

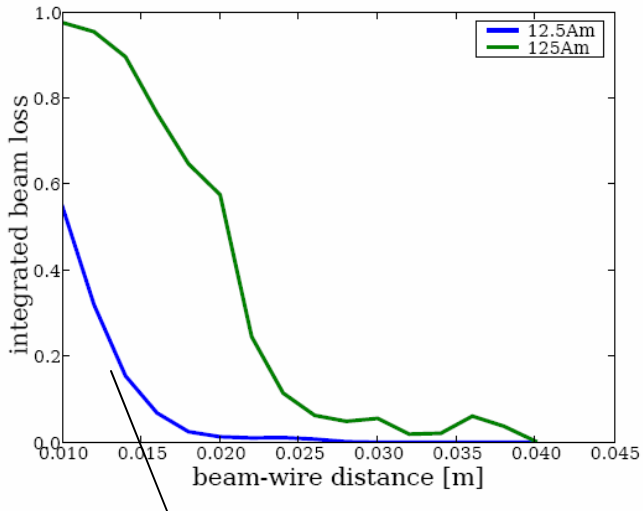


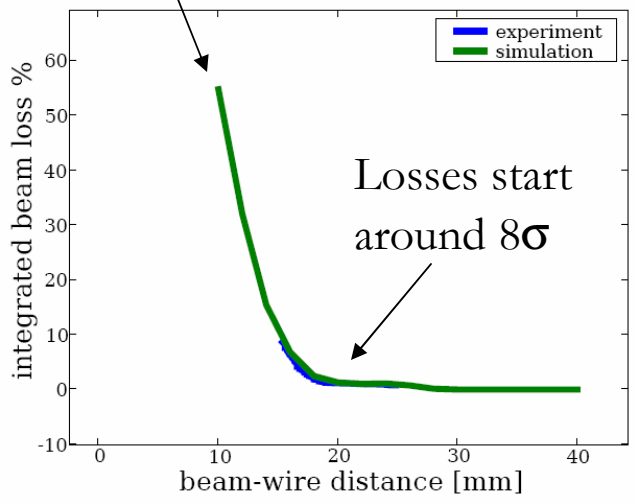
Beam loss rate as a function of vertical distance, in Yellow and Blue ring for experiments I (left) and II (right). The solid lines are power law fits to the respective data.

Comparison with simulation



The lifetime depends exponentially on the beam wire separation and show a strong correlation with the wire current.





W. Fischer , R. Calaga, N. Abreu, G. Robert-Demolaize, H.-J. Kim, T. Sen, J. Qiang, A. Kabel, U. Dorda, J.P.-Koutchouk and F. Zimmermann
PAC07

Conclusions

- LHC with early separation scheme has between 1 and 3 LR encounters at 4-5σ;
  - Tevatron: 70 LR encounters at a mean separation of 9-10σ. Losses start for minimum separation smaller than 5-6σ;
  - SPS:
    - Wire experiments indicates that 2 LR interactions at 5σ can create losses that can not be tolerated at LHC;
    - Experiments with wire also show that for all 120 LR (I_{wire}=276 A) losses start at 8-9σ;
  - RHIC:
    - experiments with 1 LR (100 GeV/n) show onset of losses at 4σ;
    - BBLR experiment with 1-10 LR (I_{wire}=5-50 A) show onset of losses at 5-9σ (very sensitive to working point);

Conclusions

- Simulations for RHIC show that a 1 long range encounter at 5σ imposes a diffusive aperture at 10σ (for the nominal working point);
- Simulations with the wire at RHIC can reproduce the onset of losses around 9σ for Experiment II;
- Simulations for the LHC shows that the wire compensator can increase the diffusive aperture by almost 2σ and also that a few LR encounters at 5.5σ (while the mean separation is kept constant at 9.5σ) does not affect the diffusive aperture;