Beam-beam aspect of a possible LHC Early Separation Scheme

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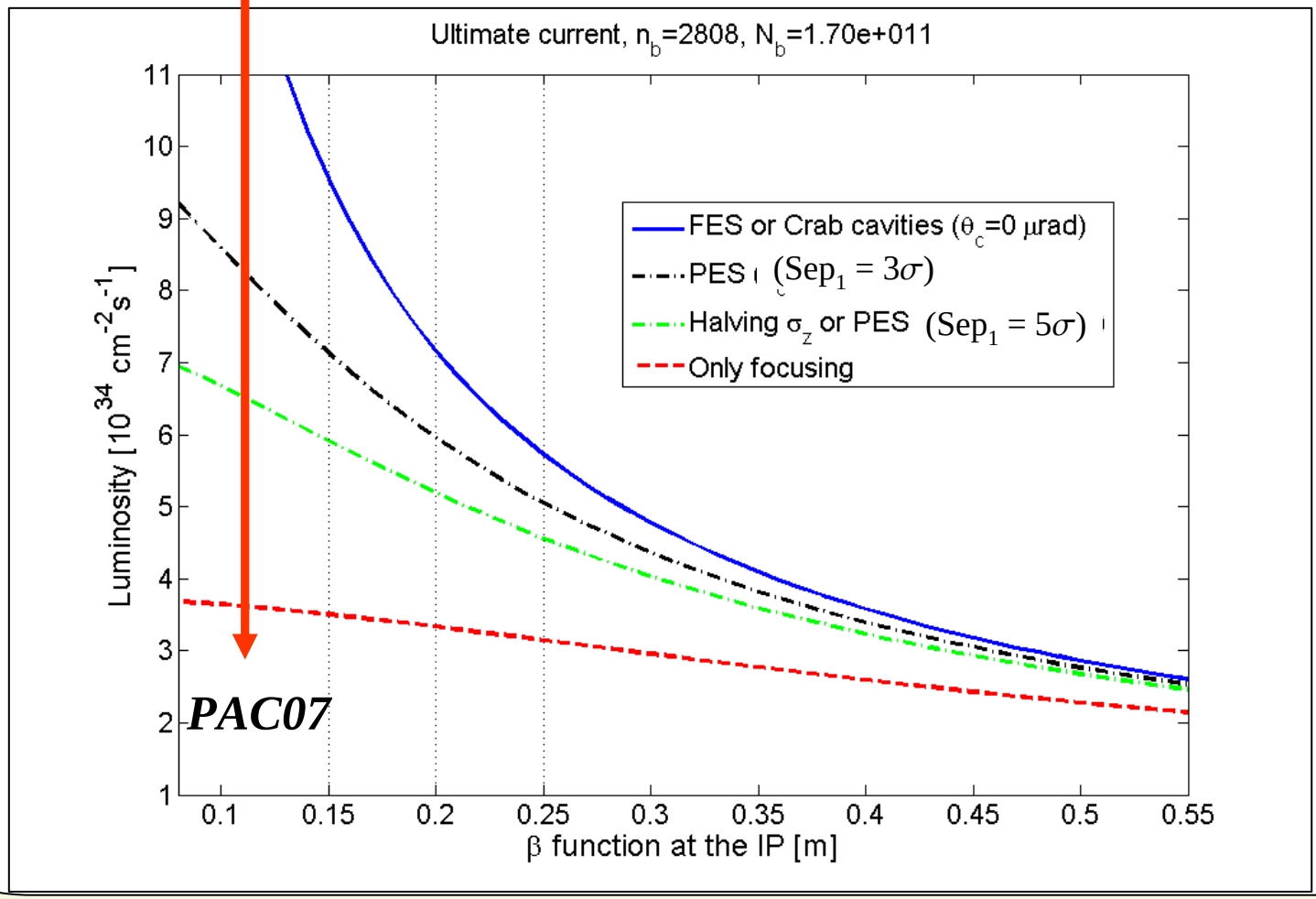
Outline

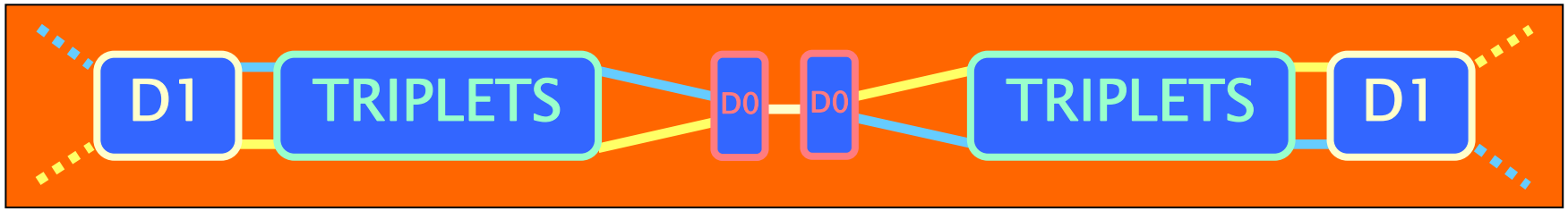
1. Motivation for the early separation scheme & principle
2. Detector constraints and partial scheme
3. Relative loss of performance of the partial scheme
4. Minimum beam-beam separation
5. Experiment at RHIC to decide on minimum separation
6. How to gain back what was lost: crab crossing and electron-lens

1a- Motivation

To improve significantly the luminosity by a β* reduction, a modification of the crossing scheme or parameters is mandatory



1b- Principle



Allow a vanishing crossing angle at the IP using a dipole on each sides of the IP, the "D0", while maintaining the separation elsewhere. For 25 ns spacing, it should be placed at 1.75m from the IP!

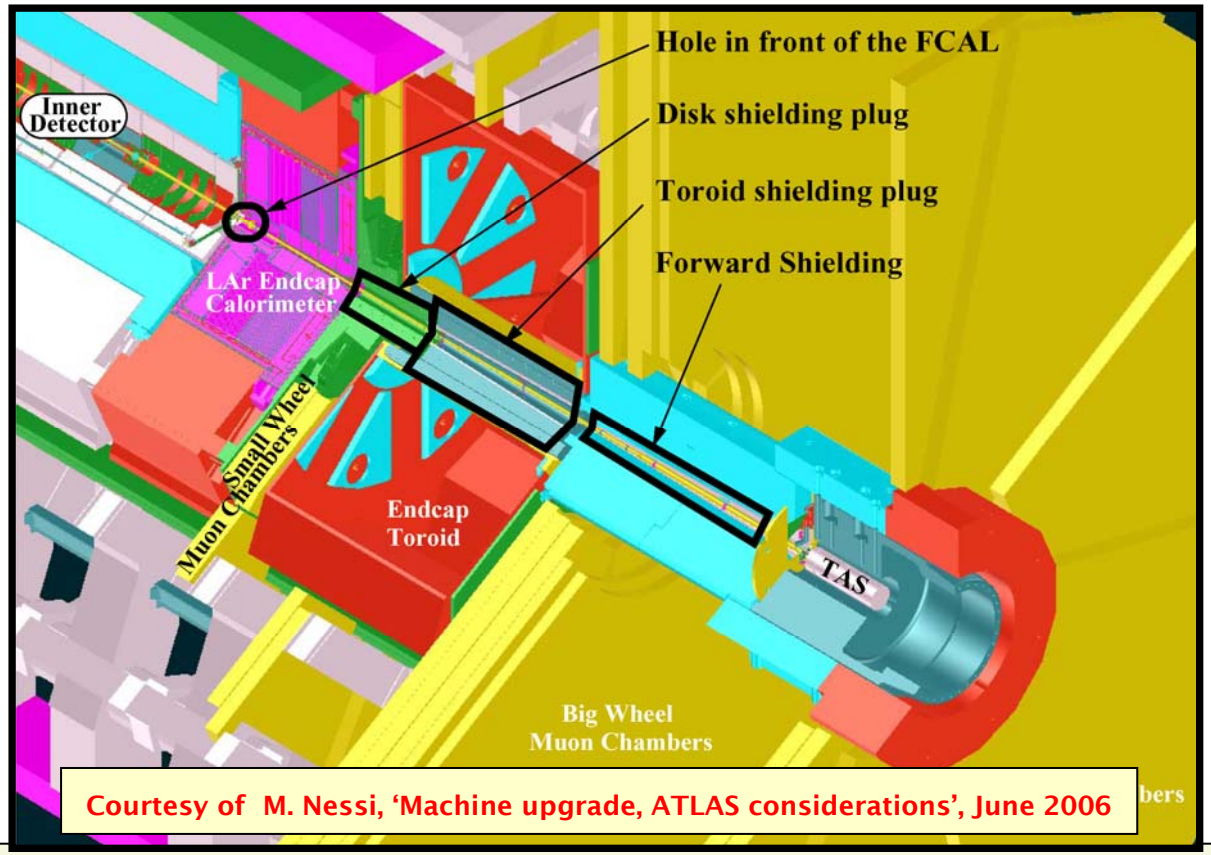
- **PROS** : simple, cheap, local change, transparent to the rest of the machine, possibility of 'easy' luminosity leveling
- **CONS** : intrusion of materials and magnetic fields in the detectors

2- Detector constraints & partial scheme

We cannot put the D0 in the inner detector

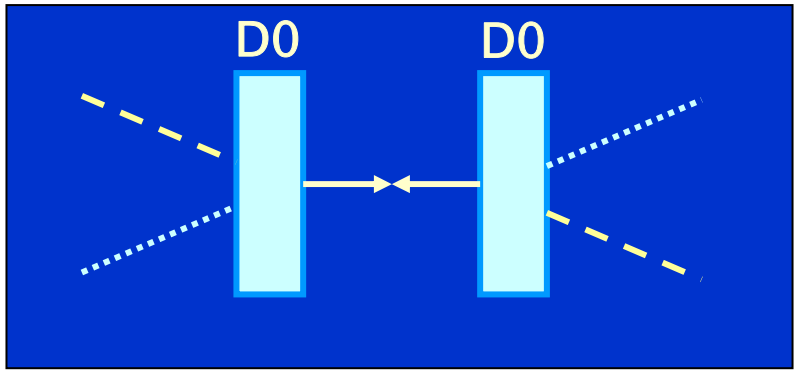
BUT there are potential slots starting at 3.5 m and 6.8 m (ATLAS).

A “partial” early separation should be considered

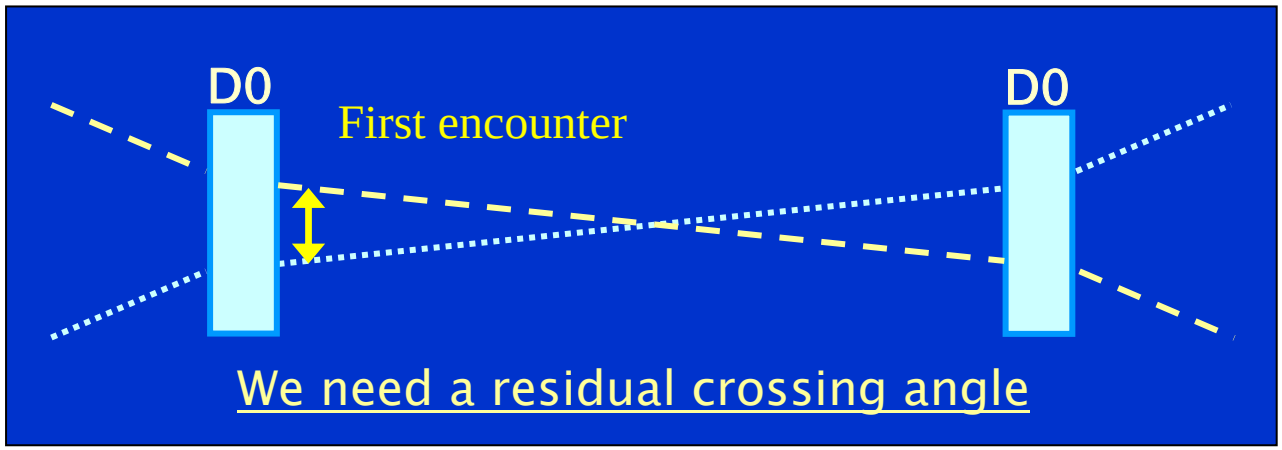


2- Partial early separation

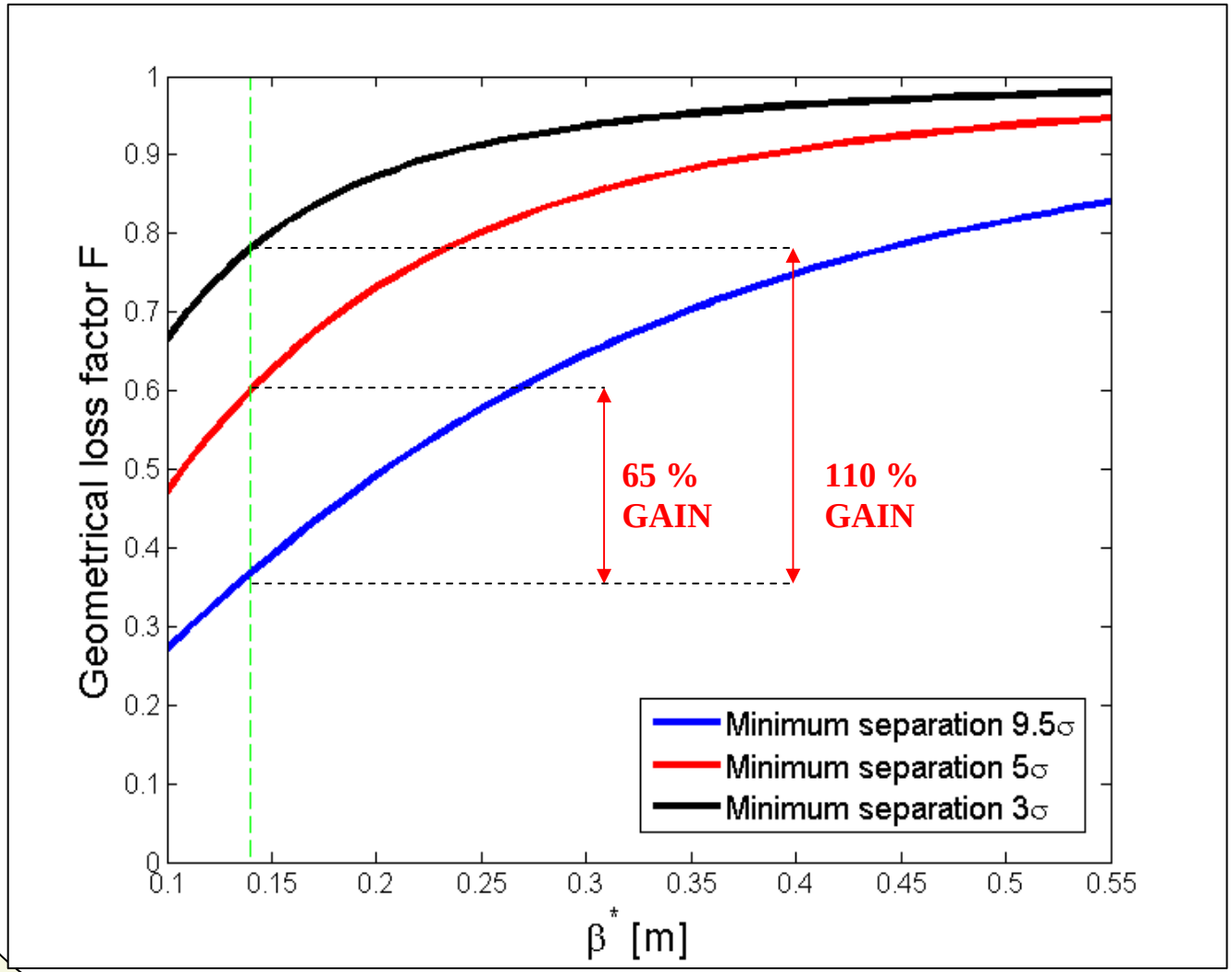
***F**ull **E**arly **S**eparation (50 ns)*



***P**artial **E**arly **S**eparation (25 or 50 ns)*



3- Performance loss of a partial scheme



Hence, the beam separation shall be minimized for 4 encounters in ~60.

What is the lowest limit??

4a- What minimum separation ?

- ***SppS:*** Operations with one encounter at 3.5σ and 7 at 6σ (~2×10^{11}p); studies with 8 encounters at 3σ showed tune – dependent increased background (× 2 to 4), *Cornelis/LHC99*.

- ***LHC studies:***

  - *Papaphilippou, Zimmermann, LHC99*: the semi-empirical law would leave little chance to reduce the separation ***but a threshold effect*** is noted. $d_\sigma \propto \left(6 + 3.5\sqrt{k_b N_b}\right)$

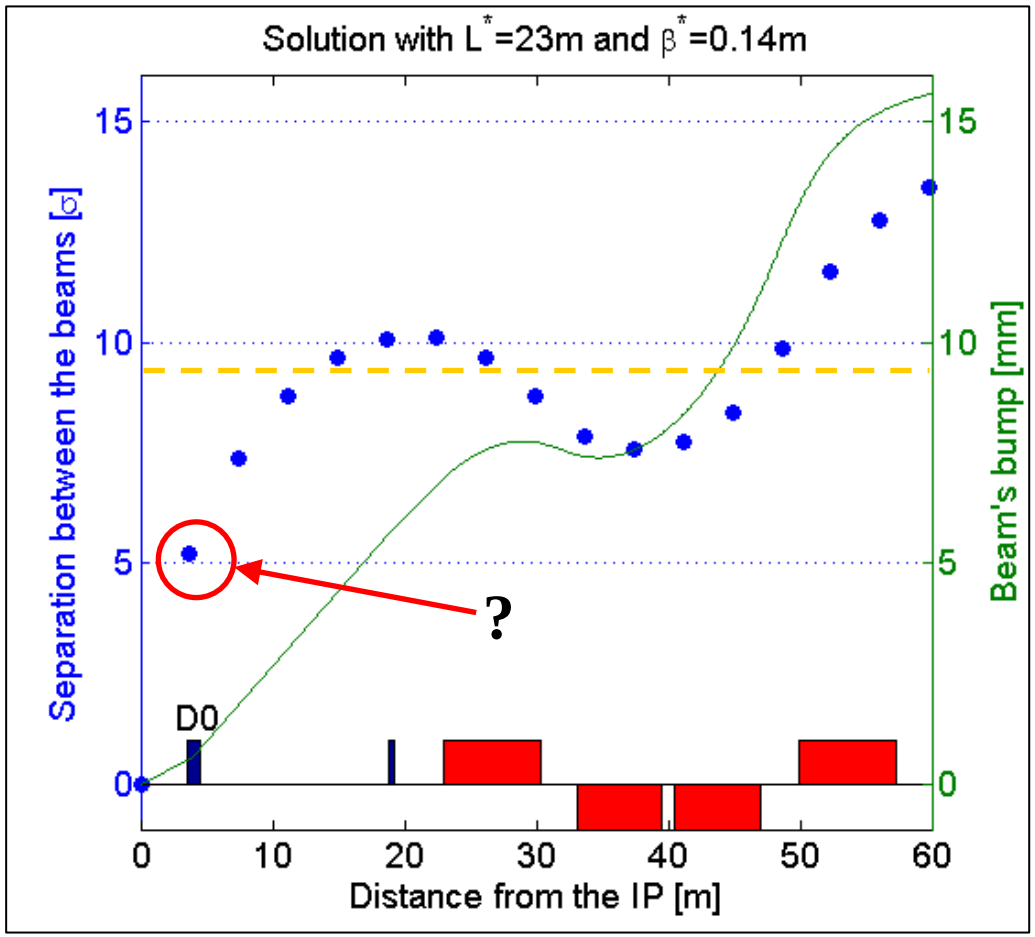
  - *Herr:* one halo collision at 5σ is acceptable for nominal LHC operations

4a- What minimum separation?

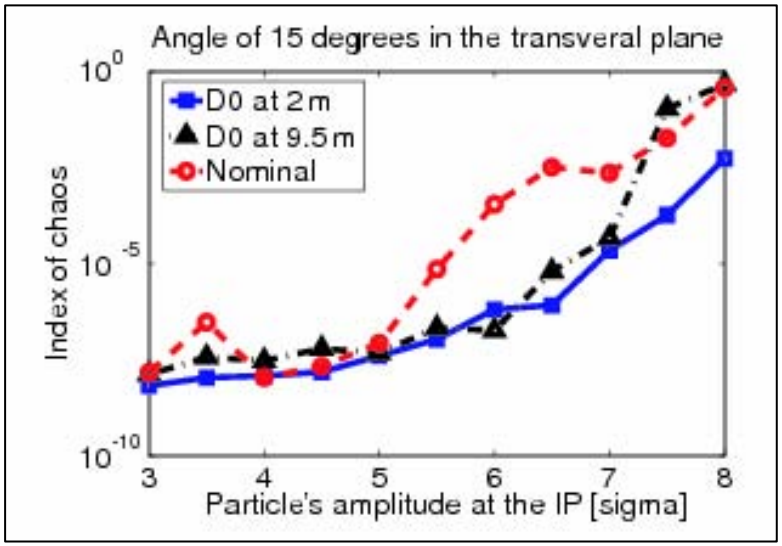
- ***TeV***: - Zhang et al., PAC 2003: 80% of helix OK, i.e. a few encounters at 5σ are OK
  - Info from FZ (V. Shiltsev): Removing 4×6.2σ encounters increased the int. L by 30%

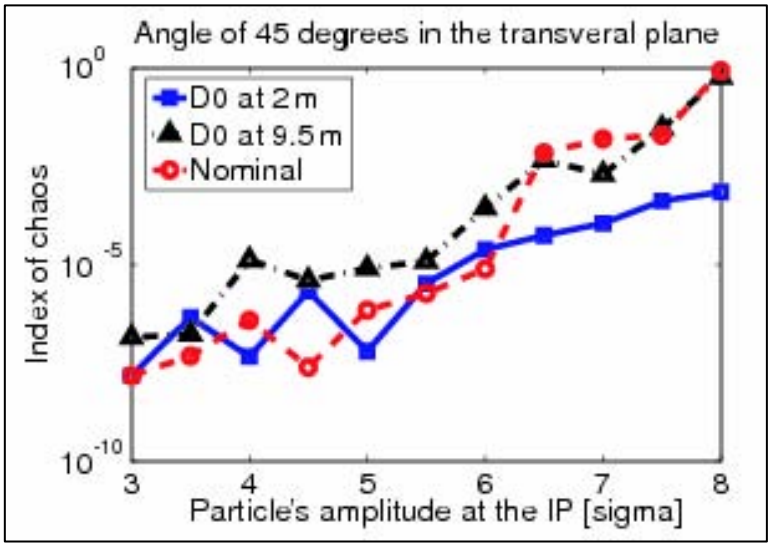
- ***RHIC***: At 100 GeV, there was no effect for a beam-wire separation of 5σ, while at 24 GeV the 5σ separation caused a large increase of the beam decay. Later results from 2007 show the presence of an effect of a beam separation of 5σ ***depending on the physical size of a sigma.*** This needs interpretation.

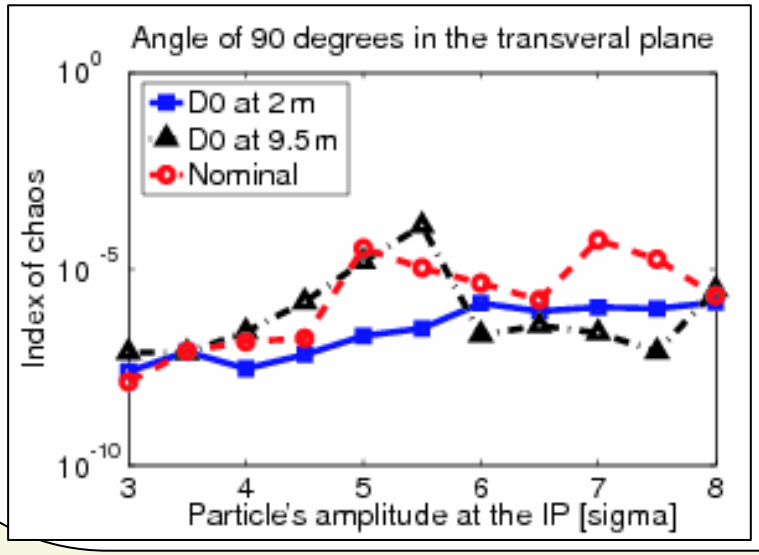
4b- Minimum separation of PES



4c- Minimum separation







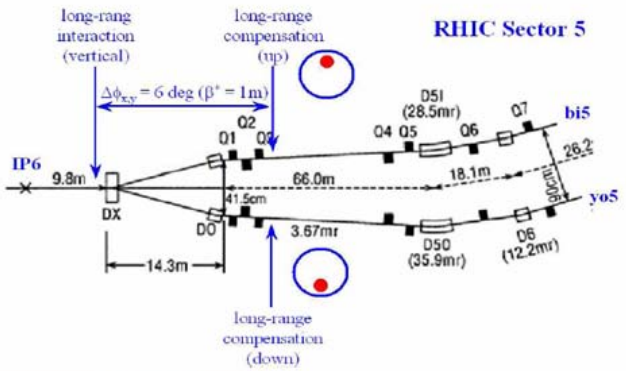
Tracking by *G. Sterbini*, using bbtrack (*U. Dorda & F. Zimmermann*); vertical axis is variance of diffusion in amplitude:

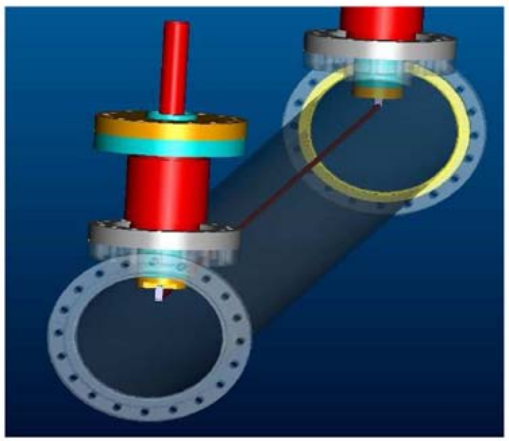
4×1 encounter at 5.5σ (blue) looks OK

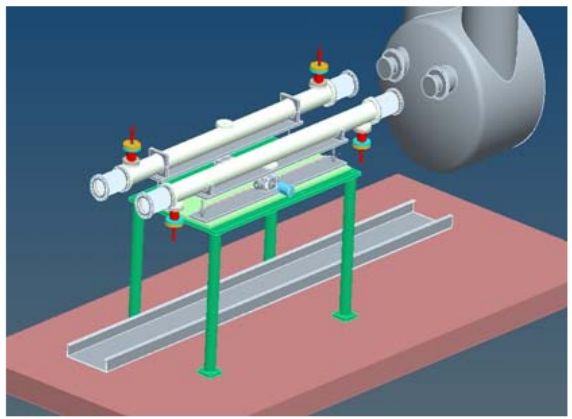
5- Minimum separation

The experimental setup with a wire at RHIC is an unique opportunity to do very clean measurements on lifetime versus beam separation (weak-strong) until we have a consistent set of results. Scaling laws to be investigated further.

Wire compensation at RHIC







New fresh results from RHIC:

6- Back-up for PES

If an early separation scheme can be implemented, it will be partial, with one or more encounters on each side of each IP at a reduced separation. ***A residual crossing angle is unavoidable.***

Complementary means to reduce it (or its effect) are:

- **Crab crossing** with a small angle (~300μrad)
- **E-lens** to compensate the few encounters at reduced distance.

For a challenging LHC upgrade, the combination of several schemes is certainly an advantage to mitigate the risks and maximize the integrated luminosity.

Conclusion

There is a strong case for an early separation scheme (higher luminosity with LHC beam current as anticipated).

Two issues:

- Acceptability to the detectors (*can be a show-stopper*)
- ***Long-range beam-beam effect***

The present experimental knowledge is insufficient. It does not seem to rule out a few encounters at 5σ or less. ***New experimental data from RHIC are essential .***

There is a strong case to complement the system with crab crossing and e-lens L-R compensation.

Independently, wire compensation should help lifetime and background issues in all cases.