New results on the “Early Separation” scheme

J.-P. Koutchouk,

G. Sterbini

CERN/AT/MCS

Outline

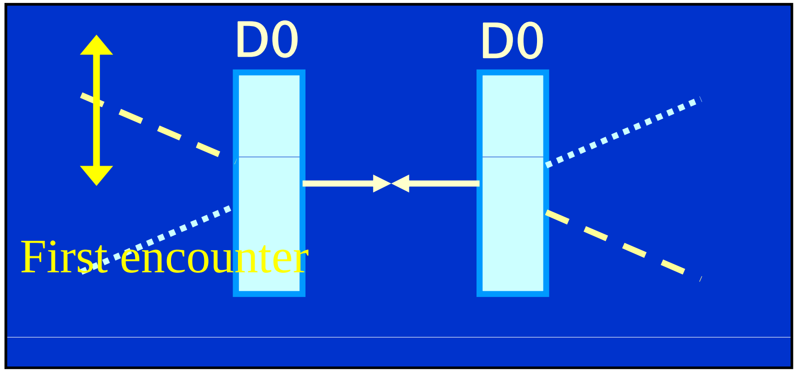
This first talk set the perspectives, the second talk by Guido Sterbini will go in more details in the analysis of experiments, hypotheses and magnet issues.

1. **Recall principle & possible dipole layouts**
2. **Beam-beam studies**
3. **Magnet studies**
4. **Integration issues**
5. **Improvement of performance**
6. **Conclusions**

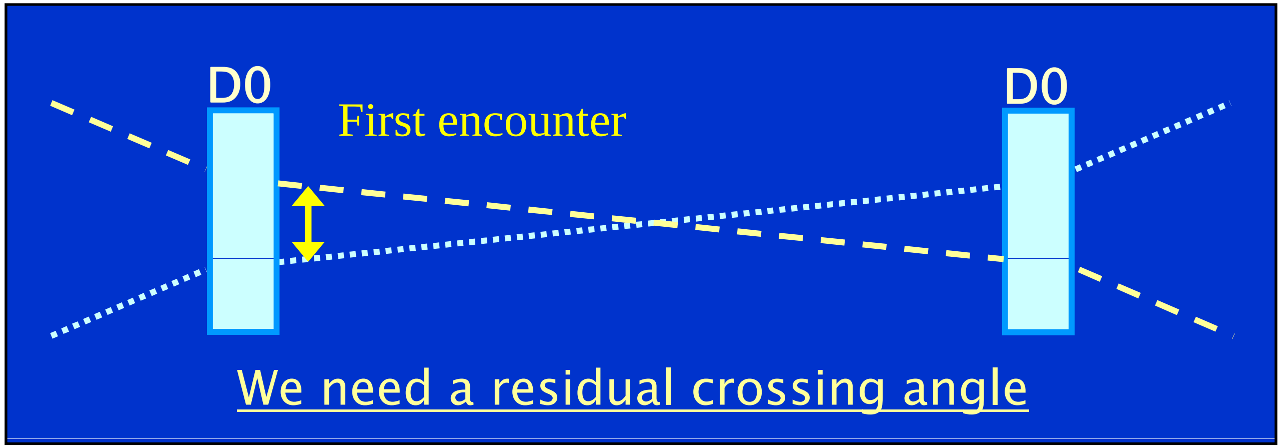
1- Principle of Early separation

Stronger focusing with cancellation of the geometrical luminosity loss

***F**ull **E**arly **S**eparation (50 ns only if D0 not in inner detector)*



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



1- Possible Layouts

1. Field integral of each dipole:

Depends on beta* and position: ~ 5 to 8 Tm for present scheme (positions 3 to 6 m)

2. Position of dipole center from IP

		25 ns	*50 ns*
Full early separation		~~1.9 m~~	3.8 m
Partial Early Sep.	1LR @ 5σ	5.6 m	11.25 m
	2LRs @ 5σ	9.4 m	~~18.8 m~~

2- Beam-beam studies

A dipole deep in the detectors is a very difficult challenge for the detectors, deemed to be "maybe not impossible":

"…Provisionally, our gut preference is for "50 ns"*…"

Or, more specific: the higher multiplicity (400 vs 300) is less of an issue than the forward calorimetry (pseudorapidity 4.1 to 4.8 for the D0). **last POFPA**

* *The bunch spacing does not qualify the upgrade options: better use* **higher intensities** *vs* **lower beta*** *to prevent misunderstandings.*

This hard fact motivated beam-beam studies to investigate the possibility of moving the D0 from 3 m to 6 m or even more

2-Outcome of beam-beam studies

Experiments with wire excitation were carried out at RHIC (US-LARP) and SPS in 2007. The next one is this Friday in the SPS.

They were summarized in the October BEAM07 Meeting:

"***Experiments have shown that a certain number of long-range encounters at a reduced distance (5 σ) can be tolerated. However, their exact number is not yet clear:*** 1 LR on each side (RHIC) or 2 (SPS)?

Even though these results are rather clean, experimental beam-beam studies are notably difficult. A confirmation in both SPS and especially RHIC is critically needed to be confident.

We can nevertheless start considering the other positions if they make a big difference for the detectors.

3- Dipole design

1. *It was verified so far that a design is feasible with NbTi (Sterbini, Tommasini) for a position 3 to 6 m from IP (memo to the experiments).*

2. *The energy deposition was calculated and proper protection added.*

3. *A more compact Nb3Sn version will be investigated.*

4. *There is much interest for the design of this "small" dipole from several places, including using HTS.*

More information in Guido's talk

4- Integration

1. *Discussions were carried out for the D0 and Q0 integration, led by P. Limon and E. Tsesmelis.*
2. *In addition, we have direct contacts with ATLAS and now CMS.*

A number of talks will address these issues.

5- Evolution of Performance prospects

We realized (June) that the early separation scheme includes a **<u>built-in method of luminosity leveling</u>** compatible with leaving the detectors ON (even technically simpler than luminosity maximization)

We realized (October) that this leveling can be made **'smart': instead of loosing integrated luminosity by leveling, it appears possible to increase it very significantly** *if the beam current can exceed the "ultimate".*

Thus, the practical performance index should become the **<u>leveled luminosity</u>** for this scheme. For completeness, we shall recall the peak performance as well…

5-Peak luminosity estimates

***Ultimate bunch current**, l*=23 m, beta*=14 cm*

	25 ns	50 ns
No early sep., beta*=25 cm	3.1	1.7
Full early sep. Beta*=14 cm	9.8	4.9
Partial early sep., Beta*=14 cm	5.8	3.1

With weak global crabbing

~7 , with electron lens & separation of 3 sig

~+30% for l*=13m

5- Performance with leveling

APD07 workshop, from Summary by V. Shiltsev

The best way to level luminosity -?

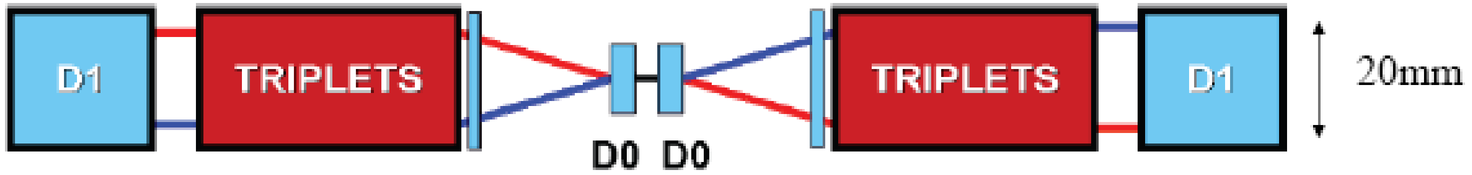
V.Lebedev summarized Tevatron's thinking on the leveling:

Luminosity Leveling in Tevatron

- Any luminosity leveling results in reduced luminosity integral
- (1) Smooth (multi-step) beta-function changes during the store is close to impossible to implement in operations
- (2) Single step beta-function change looks promising
  - Significant time for commissioning
  - More complicated operations - larger probability to lose the store. ~1 min stop for data acquisition beta-function change

Leveling by variation of crossing angle

G.Serbini and J.P.Koutchouk:



Pros

- Increase of integrated luminosity with a reduced peak luminosity increase
- Clean to implement
  - NO chromaticity correction variation
  - NO closed orbit variation around the machine
  - NO sextupoles feed-down
  - NO spurious dispersion at the IP.
- With flexibility: reduced separation when the beam current is decreased.

Cons

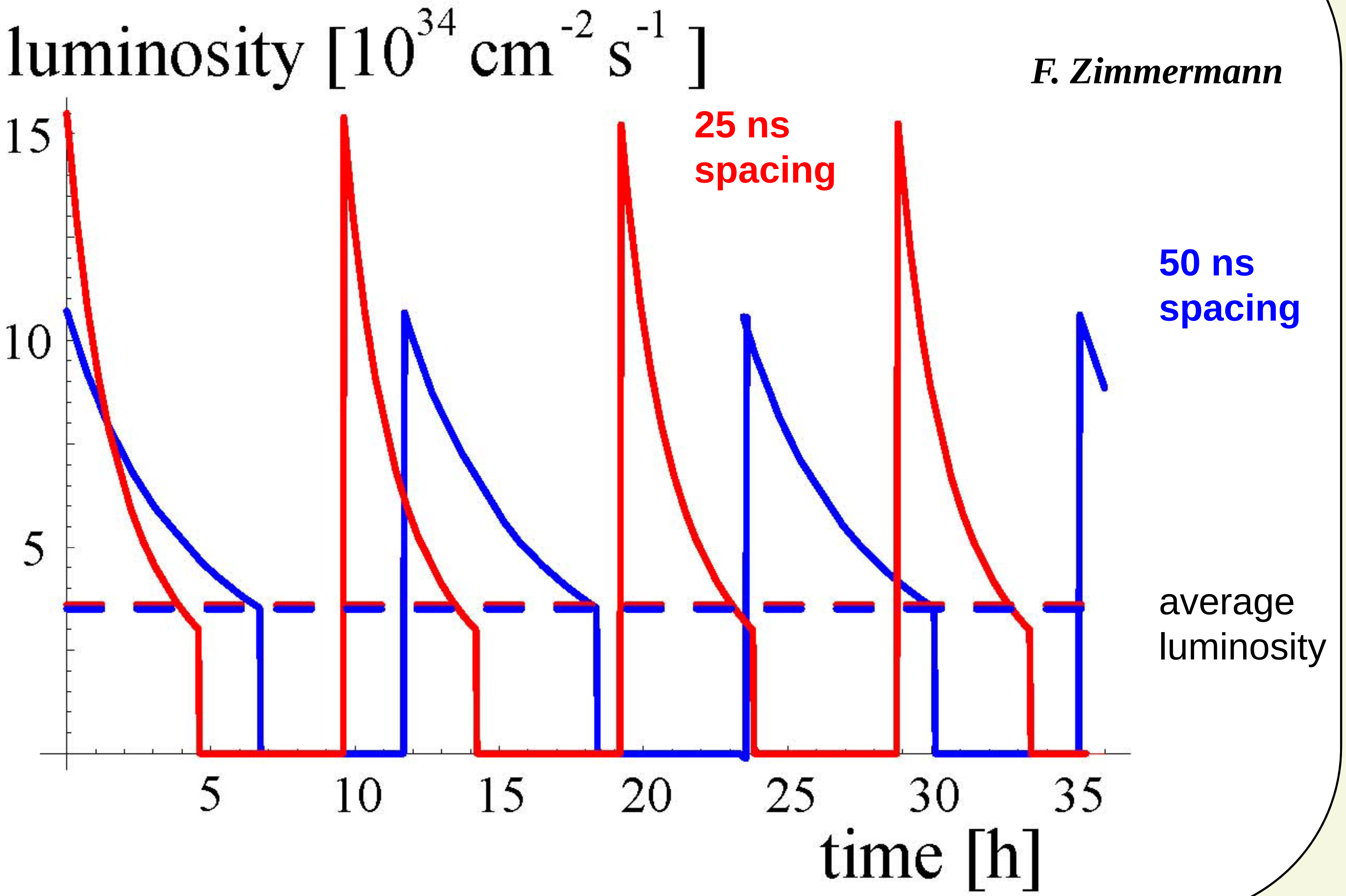
- Dipoles in the detectors
- Variation in the luminous region longitudinal size
  - synchro-betatron coupling
- BB effect to understand better.

* head-on/LR beam-beam dQ reduced

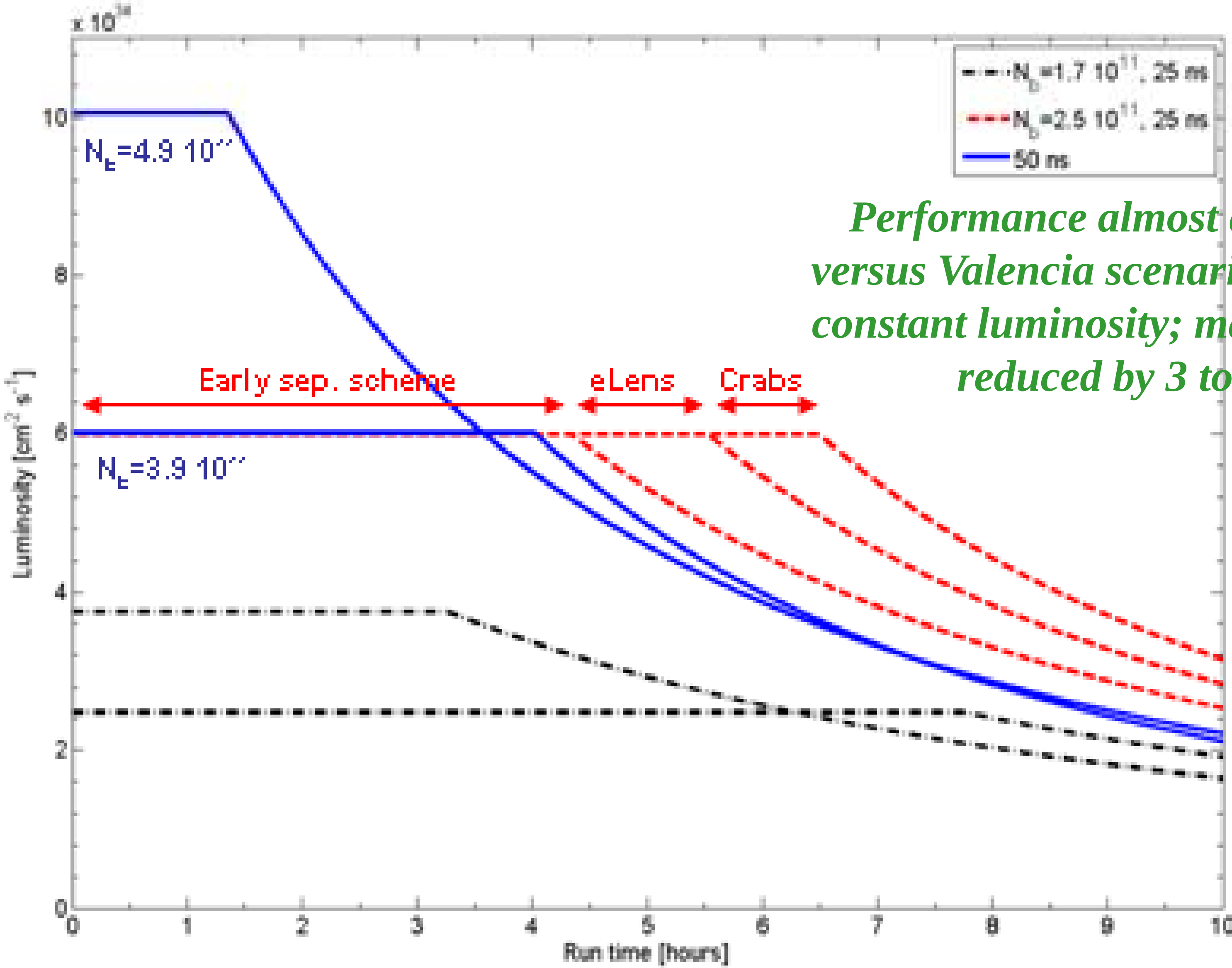
Piwinski angle up to 3 or 3.5

5- Valencia scenarios

F. Zimmermann



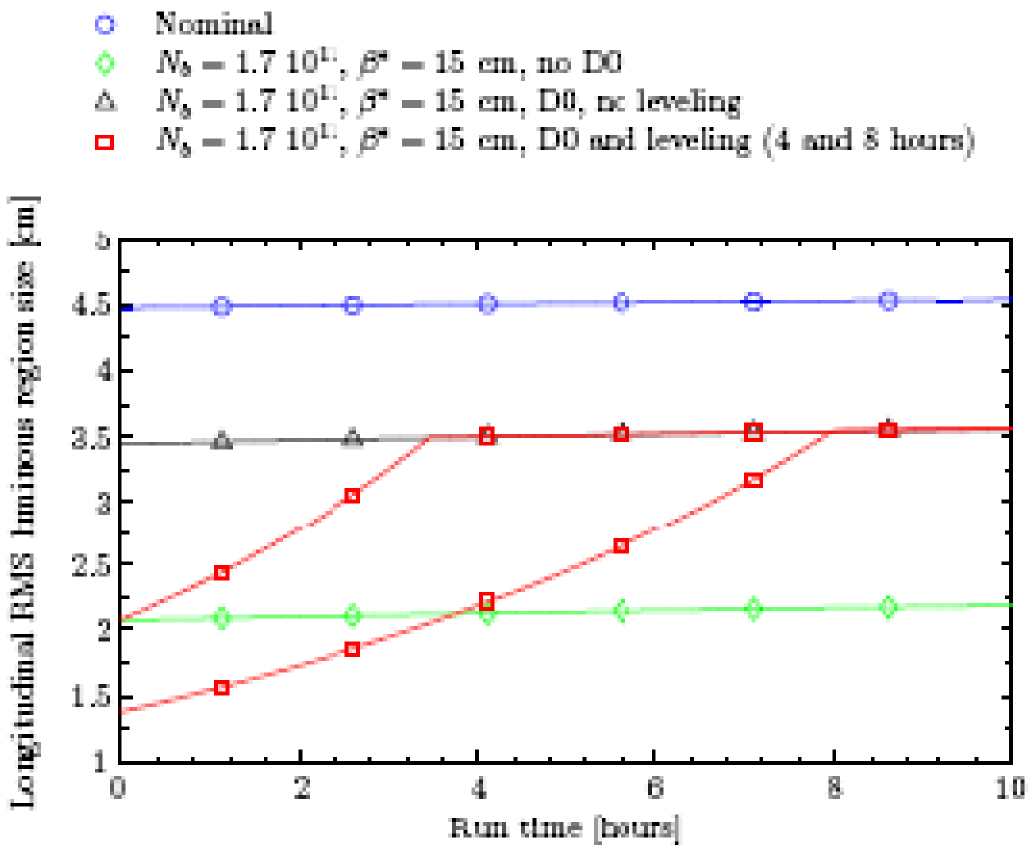
5- Performance with leveling



Performance almost doubled versus Valencia scenarios & with constant luminosity; max pile-up reduced by 3 to 4

Variation of the luminous region with dynamic θc

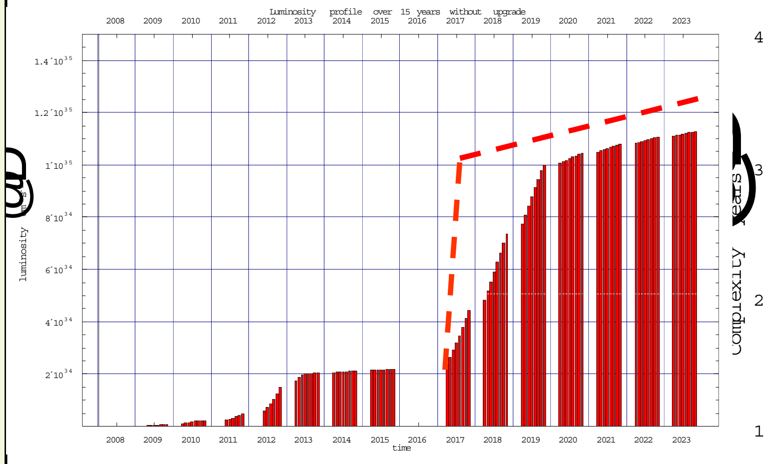
$$\frac{1}{\sigma_{lum}} \approx \sqrt{\frac{2}{\sigma_z^2} + \frac{\theta_c^2}{2\,\sigma^{*2}}} \qquad \sigma_{lum} \approx \frac{\sigma_z}{\sqrt{2}} F.$$



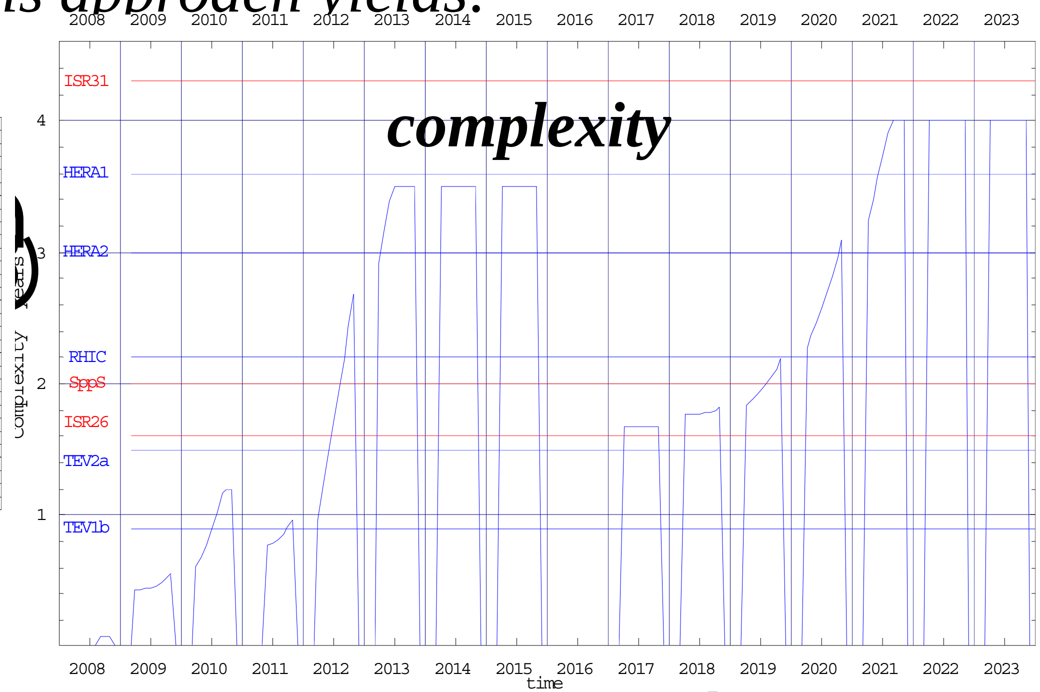
Sterbini

Rise time of performance

Performance rise depends on ***complexity.*** *Statistical law by V. Shiltsev. Using/extending his approach yields:*



luminosity



The strategy with beam current increase requires about <u>3 years</u> after Phase I (4 years without).

In the ISR, a comparable beta decrease (/7) took a few weeks* ***at reduced current****; <u>one year for the LHC at full current?</u>*

Conclusion

If the **modulation of the length of the luminous region** is acceptable, the “native” luminosity leveling of the early separation scheme can suppress the fast luminosity decay with a small loss of integrated luminosity.

When combined with a beam current increase beyond “ultimate” and below or equal to the LPA scenario, the integrated luminosity can be boosted by almost a factor of two with respect to the present parameter lists with a significant decrease of peak pile-up (3 to 4).

The scheme offers similar performance for 25 or 50 ns spacing. Of course the pile-up and bunch charge increase at 50 ns spacing.

The electron lens and/or global crabbing are very useful both to extend the duration of constant luminosity and mitigate risks.

Conclusion

In this way, "smart" leveling **makes the link between the two upgrade options**. With a common beta*=~11 to 14 cm triplet, all options should become possible and complementary like a lego (including flat beams?), with various ways of mitigating unexpected phenomena or planning/performance issues (e.g. injector upgrade) at any time.

All the results obtained with early separation can be obtained as well with **local crabbing** and *nothing inside* the detectors…However one method is robust and the other not yet successful on a "forgiving" electron machine. Crab Xing for hadron machines is to be given strong support. Demonstration will require years and, if successful, risks will persist until it is in operation. If D0's can be acceptable to the detectors, the best strategy is to start with D0's, add a global crab Xing to extend the duration of the luminosity plateau; if successful, the D0's can then be removed to be replaced by local crab Xing.