TESLA:
The Feedback System at the IP

INGRID REYZL
– DESY –

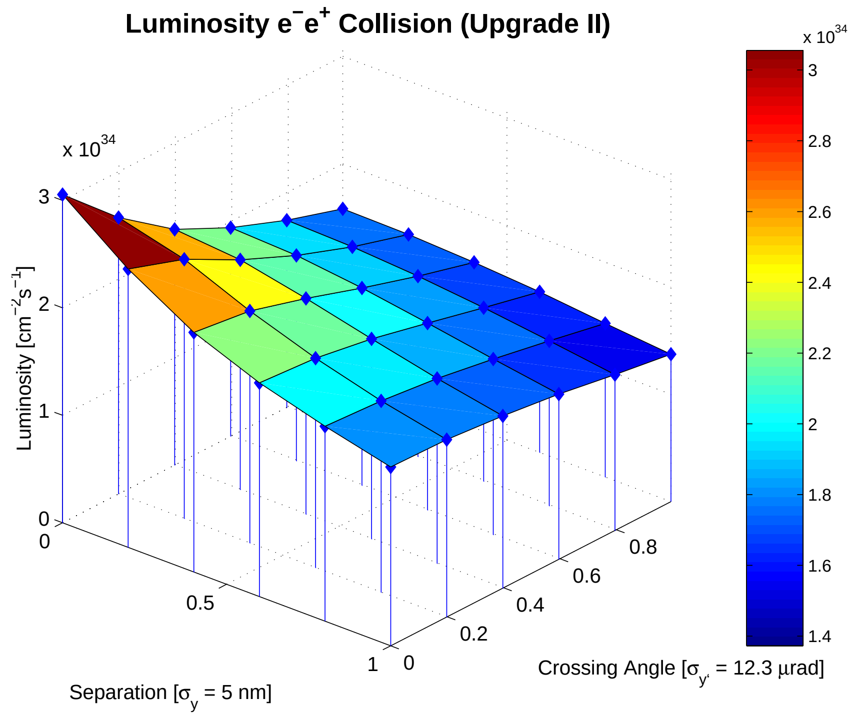
LCW 99 in Sitges 30/04/99

- Motivation:
  Luminosity vs. Beam Separation

- Feedback Loop Design:
  Its four Main Steps and its Model

- Simulation Results:
  Vibration Tolerance of the Final Doublet at 5 Hz limiting Luminosity Loss to 10 %

The Key Parameter: Luminosity

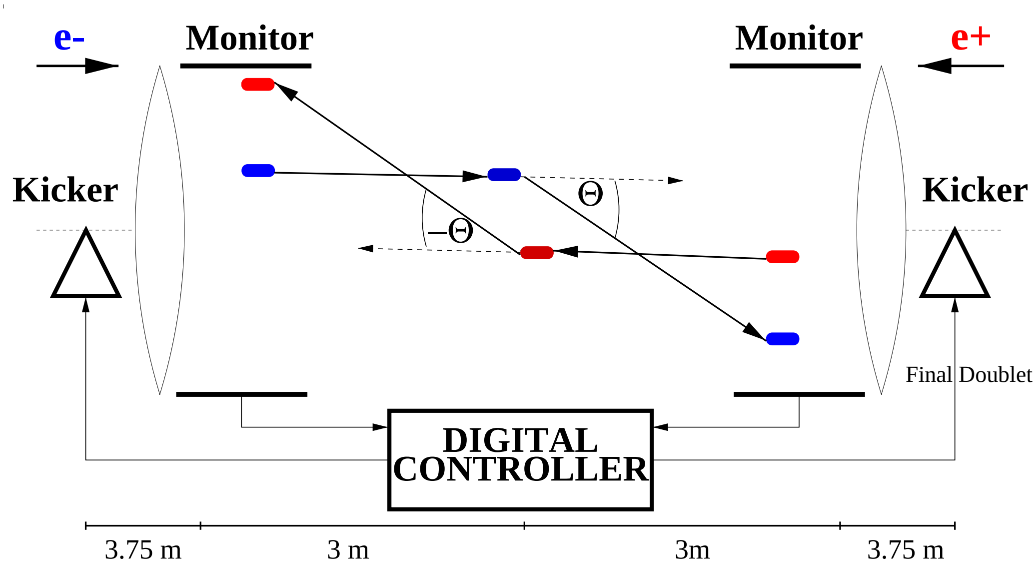


Center of mass energy	E_{cm}	500 GeV
Luminosity	$\mathcal{L}$	$3.1 \cdot 10^{34}$ cm^{-2}s^{-1}
Bunches per pulse	n_b	2820
Bunch spacing	t_{bunch}	337 ns
Length of bunch train	t_{pulse}	950 μs
Pulse repetition frequency	f_{rep}	5 Hz
Vert. r.m.s. beam size at IP	$\sigma_y^\star$	5 nm
Vertical disruption	D_y	33

Luminosity is very sensitive to Beam Separation $\triangle y^\star$
e.g. caused by Ground Motion, Final Doublet Offset.

Separation	$\triangle y^\star = 0.1\ \sigma_y^\star = 5$ Å	10 % $\mathcal{L}$-Loss/BX
	$\triangle y^\star = 1\ \sigma_y^\star = 5$ nm	46 % $\mathcal{L}$-Loss/BX

Feedback Loop Design



Expected from Ground Motion in Beam Delivery System:

$\triangle y^\star = \quad 5 \text{ nm} = \quad 1\ \sigma_y^\star$ within 1 ms (bunch train length)

$\triangle y^\star \cong 100 \text{ nm} = 20\ \sigma_y^\star$ (N. Walker) from Pulse-to-Pulse (5 Hz)

Need of Intra Bunch Train Correction! @ 3MHz

Separation detectable due to **Beam-Beam Deflection**!

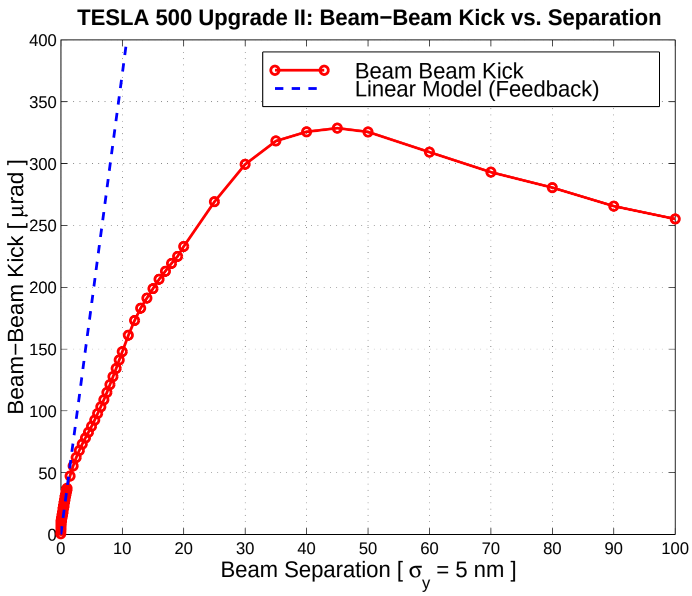
Four Steps of Feedback Loop:

1. Measurement of Bunch Position *Monitor*
2. Estimation of Bunch Separation $\triangle y^\star$ *Controller*
3. Determination of Correction Kicks *Controller*
4. Provision of Correction *Kicker*

CORRECTION FROM BUNCH TO 2nd BUNCH

Final Doublet Tolerance at 5 Hz ??? $\Longrightarrow$ Feedback Dynamic

How to model Beam-Beam Kick ?



$$\theta = -37.27 \frac{\triangle y^\star}{\sigma_y^\star} \ \mu\text{rad}$$

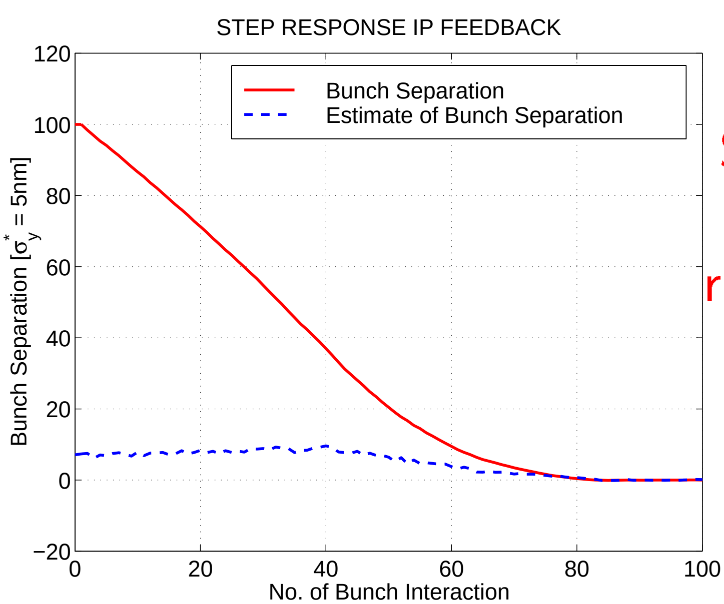
Maximum Deflection:

330μrad @ $45\,\sigma_y^\star$

Pro High Model Accuracy for small Separations & Fast Signal Processing

Contra Underestimation of large Separations:

$$|\triangle y^\star| = 100\,\sigma_y^\star \textbf{ estimated as } 7\,\sigma_y^\star$$

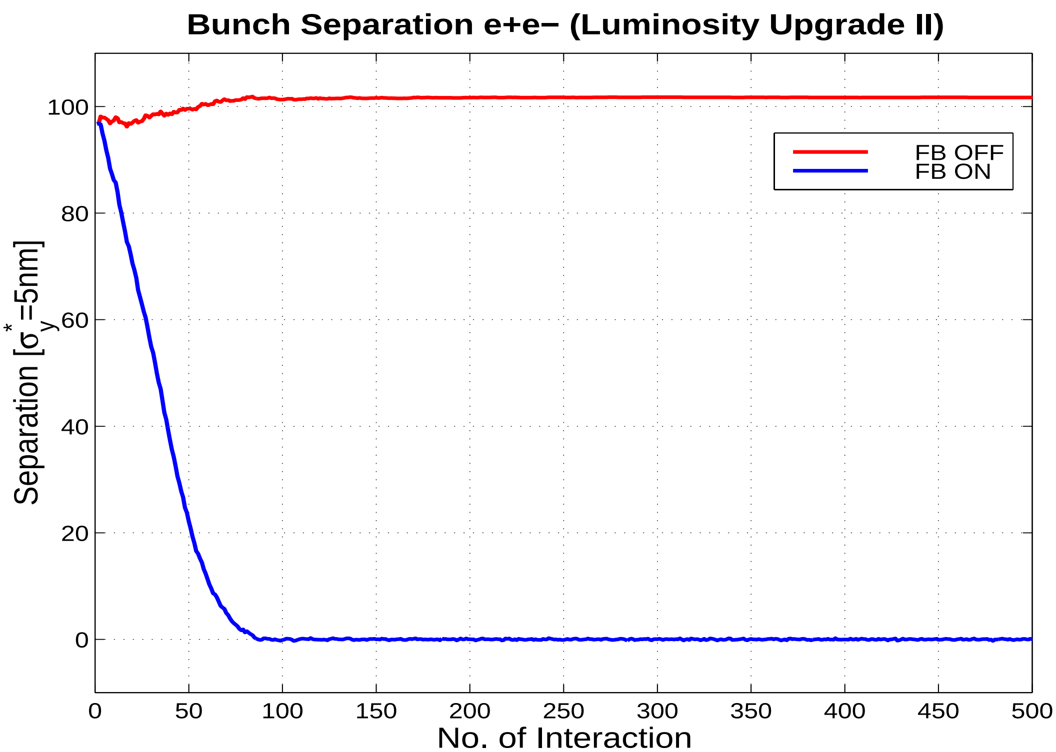


Stationary Separation of $100\,\sigma_y^\star$ reduced by 3 Orders of Magnitude after 80 Bunches!

Pulse-to-Pulse Vibration Tolerance of Final Doublet

Assumptions and Noise Sources:

Linac	Misalignment: Cavity, Quadrupole 500 μm, Monitors 100 μm
BDS	• Slow feedback removes average offset of bunch train
	• Ground motion causes $20\ \sigma_y^\star$ separation at 5 Hz
	• Offsets of final doublets σ_Q cause DC-separation
IP-Feedback	Monitor resolution $5\ \mu$m
	Beam-beam deflection Jitter $10\ \%$
	Kicker error $0.1\ \%$



To LIMIT the Luminosity Loss to 10 % $\Longleftrightarrow$
Use of Feedback System relaxes the Pulse-to-Pulse rms Vibration Tolerance of the Final Doublets to
$\boldsymbol{\sigma_Q = 200}$ **nm**.

CONCLUSION

- Due to the large Bunch Spacing of 337 ns of TESLA a
  Correction from Bunch to 2nd Bunch
  becomes feasible.

- Feedback is very robust to Model Errors.

  A stationary Separation of $100\,\sigma^\star$ is reduced by 3 Orders of Magnitude after 80 Bunches (3% of bunch train).

- **In order to limit Luminosity Loss to 10 % rms Pulse-to-Pulse Tolerance of Final Doublet Magnets is relaxed to 200 nm.**