Coupling control at E.S.R.F.

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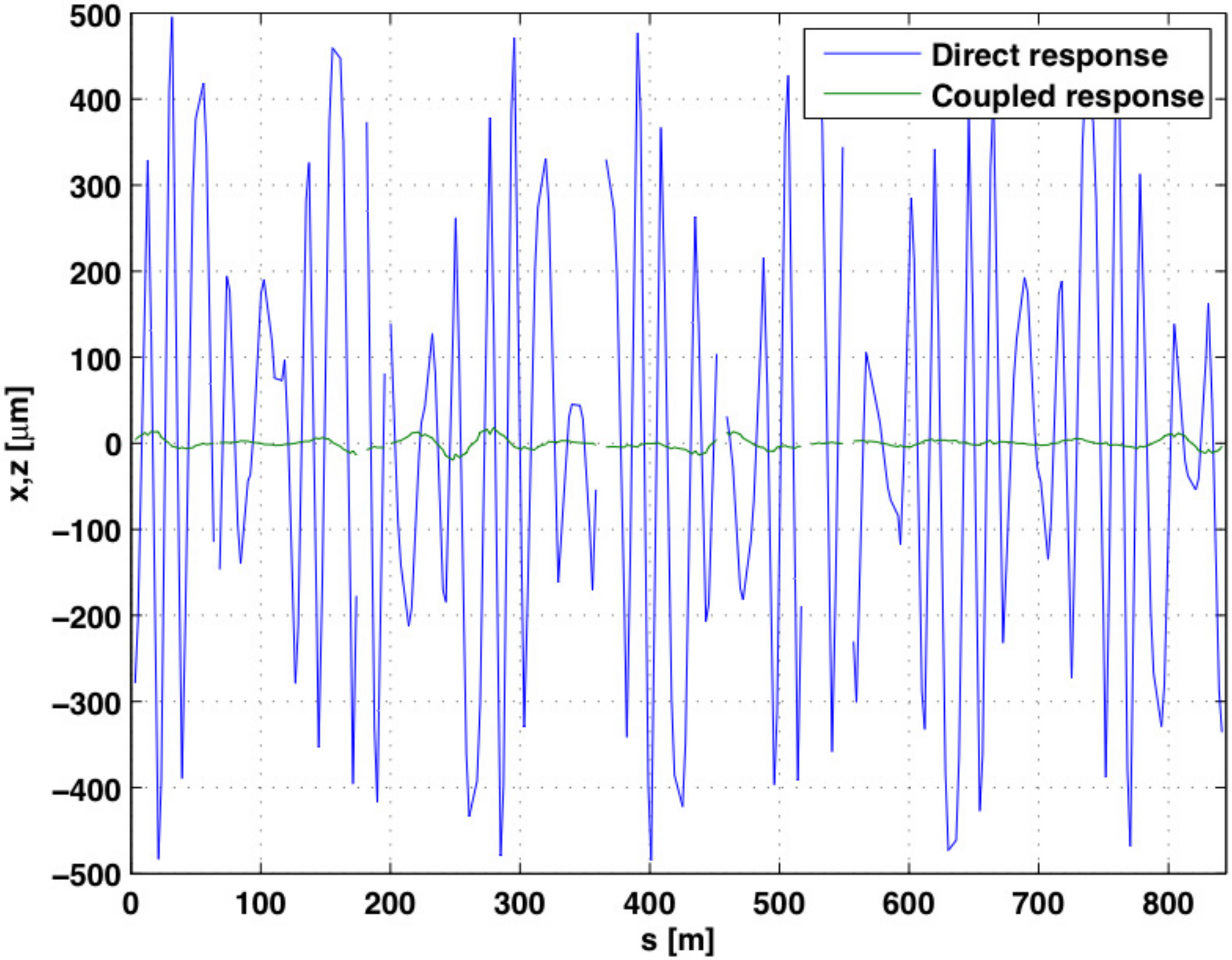
Introduction

- Correction strategy
- Analysis of results
- Effect of Insertion Devices
- Future plans

Correction strategy

- Old method
  - Empirical correction of the two nearest coupling resonances
- New method
  - Coupled response matrix fit by introducing tilt errors on the 256 quadrupole magnets (SVD)
  - Vertical dispersion fit by introducing tilt errors on the 64 dipoles
  - Fit of the 32 skew correctors to minimize either:
    - Eigen emittances,
    - Vertical beam sizes,
    - Betatron coupling coefficient γ
    - Resonance driving terms,
    - …

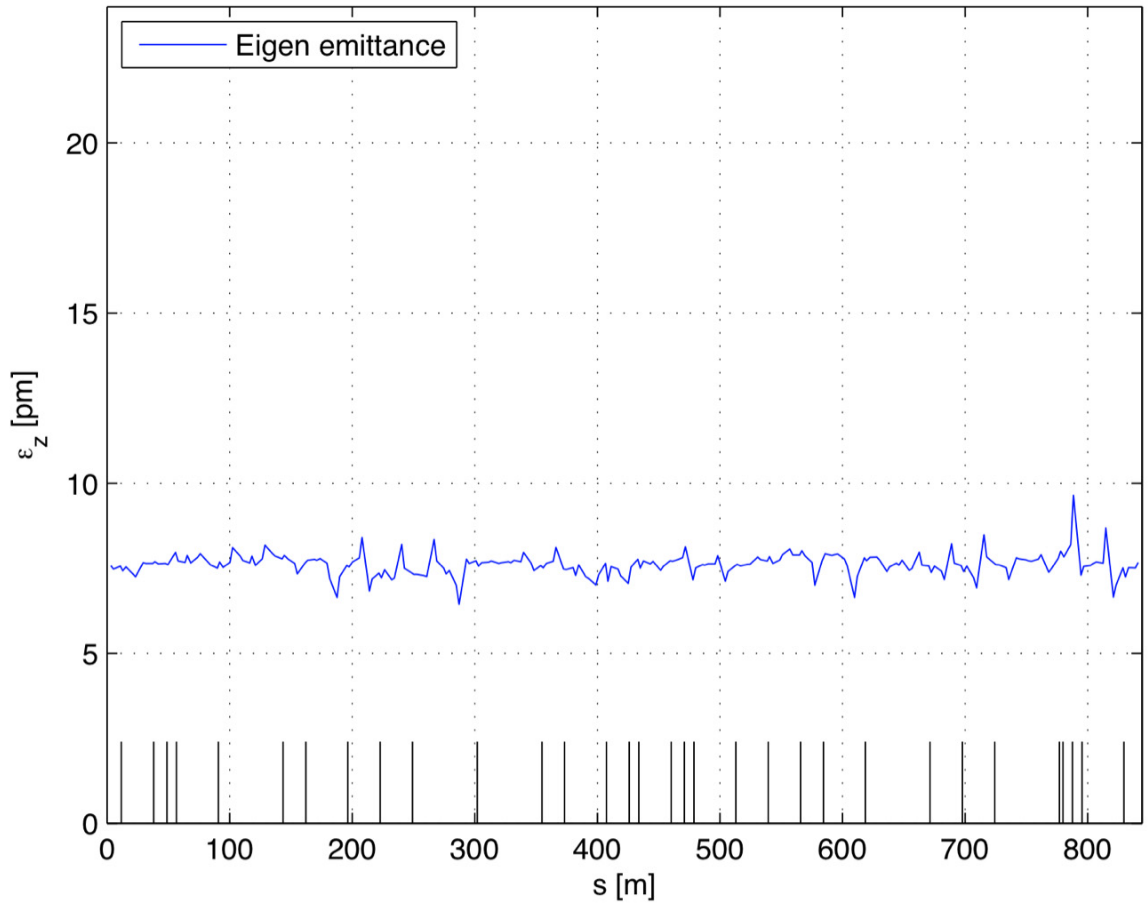
Response matrix (example)



Rms orbits:
x: 261 µm
z: 6 µm

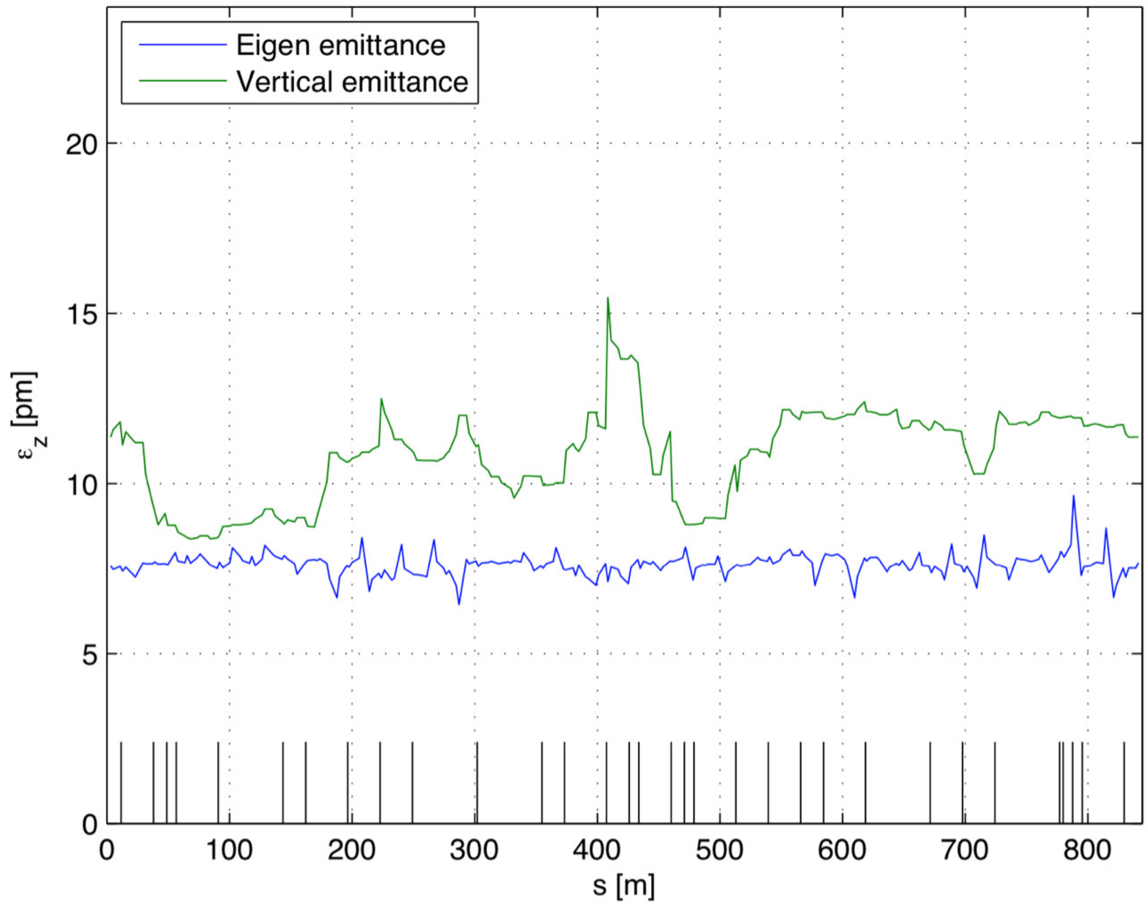
Example error model

- Focusing errors + corrections
  - rms quad. strength error of 1.2×10^{-3}
  - β-beat of 2.5%
- Coupling errors + corrections
  - rms quad. tilt error of 2.5×10^{-4}
- The smallest Eigen mode is almost vertical but its orientation varies along the circumference



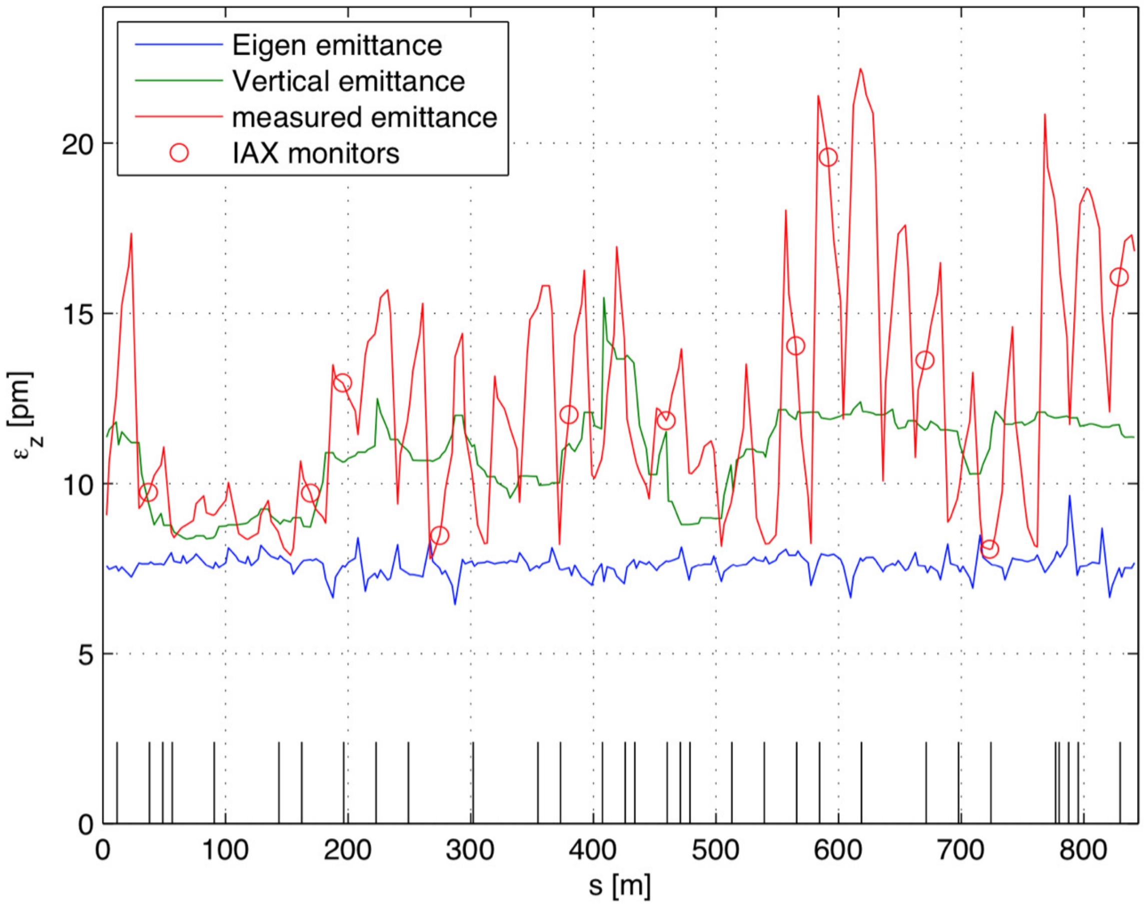
Example error model

- The vertical emittance is the projection of the two Eigen modes in the vertical plane
- It varies along the circumference but is constant in-between two skew errors
- It may be significantly higher than the Eigen emittance



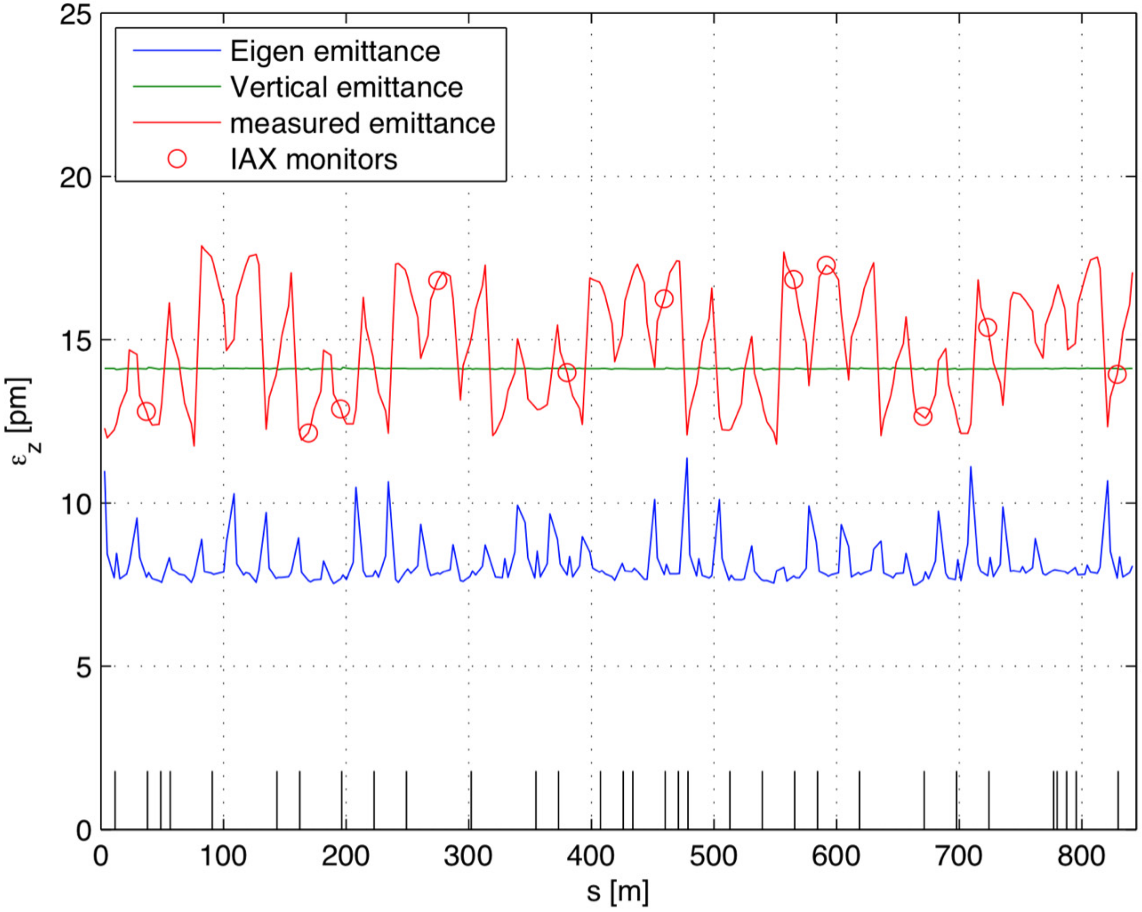
Example error model

- We only measure beam sizes:
  - 2 pinhole cameras
  - 11 In-air X-ray detectors (vertical beam size only)
- The vertical emittance is computed using the vertical β-function. For a coupled lattice, this is simplistic.
- Fluctuations are expected but are surprisingly high. They explain the large deviations between monitors



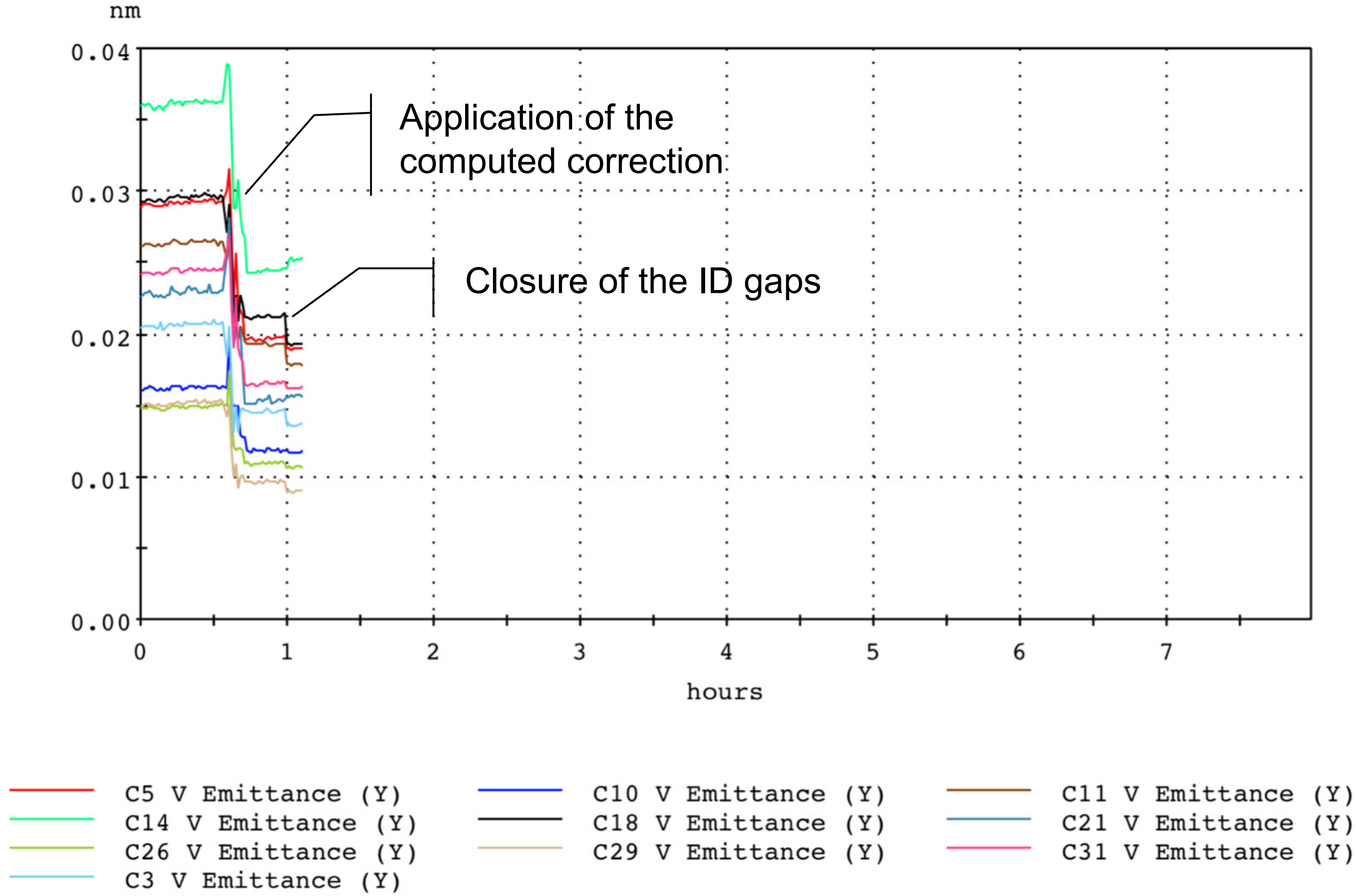
The simplest model

- No focusing errors (no β-modulation)
- A single skew error
- The beam size modulation is still large



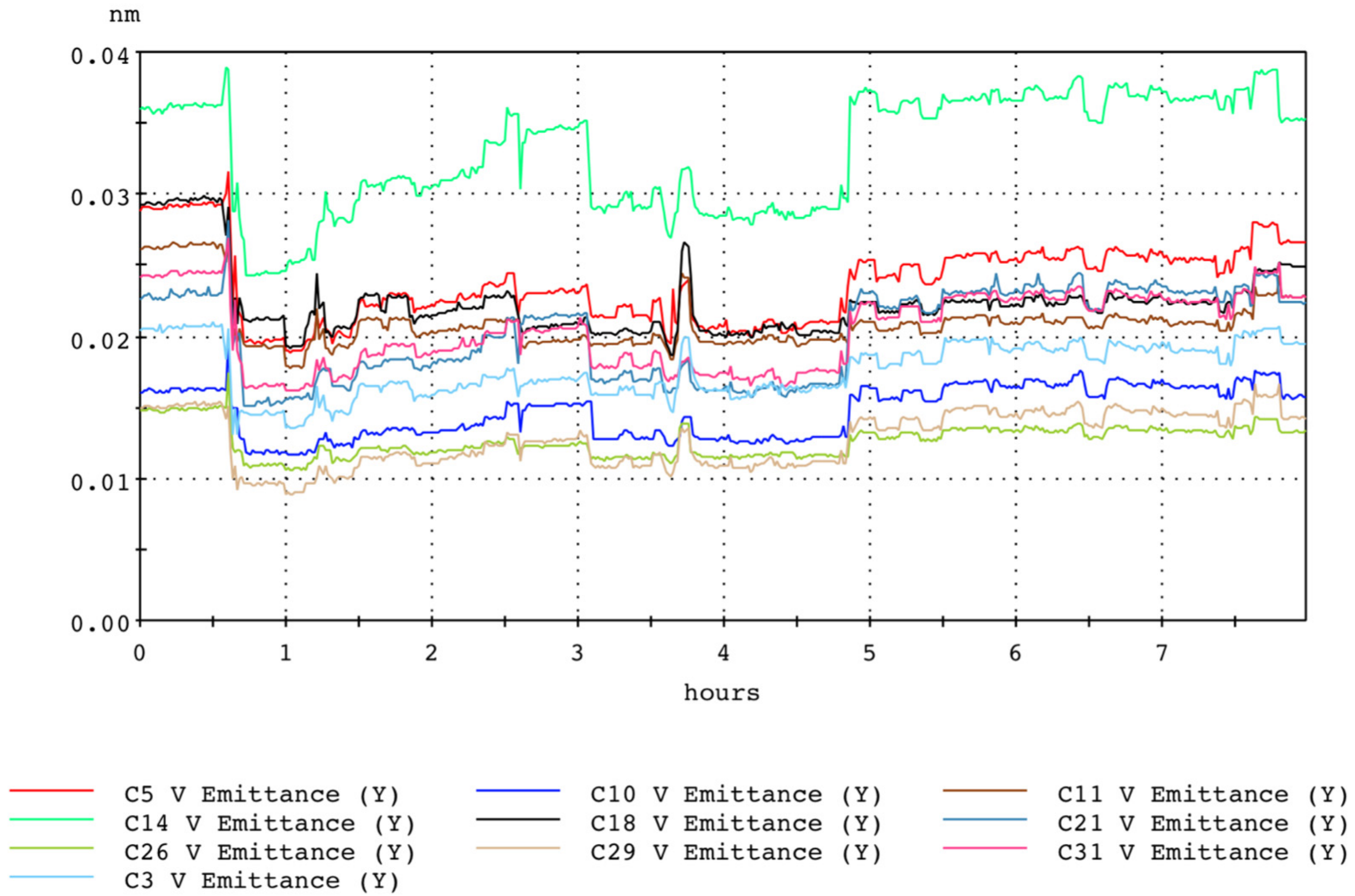
Experimental results

Start-up of beam delivery:



Experimental results

Some time later:

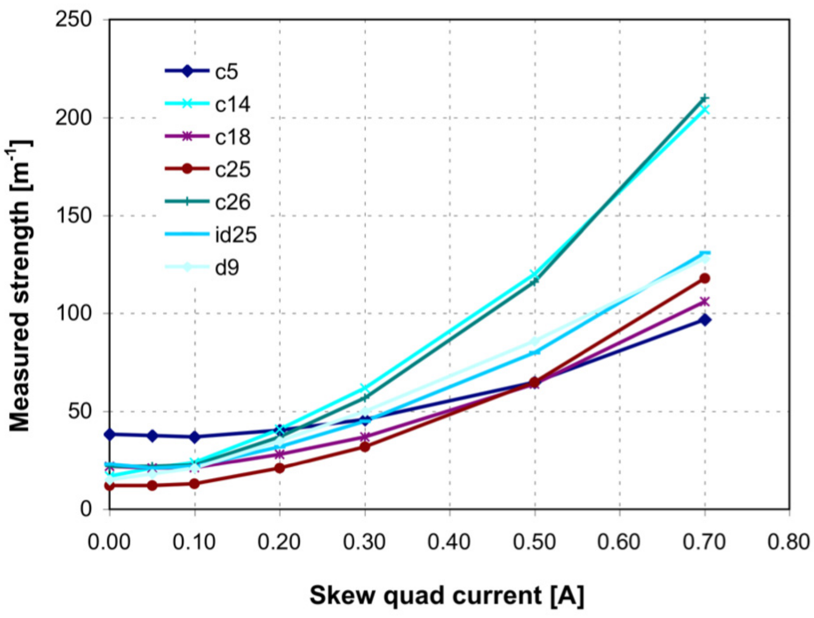


Calibration of ID effect

- The coupled orbit scales linearly with a single skew focusing error,
- So we can make the difference of 2 response matrices measured with a gap open and then closed,
- The resulting difference matrix is fitted with a single skew error located at the ID centre,
- In this analysis we ignore the residual coupling. However for better results, this is done with a well corrected machine.

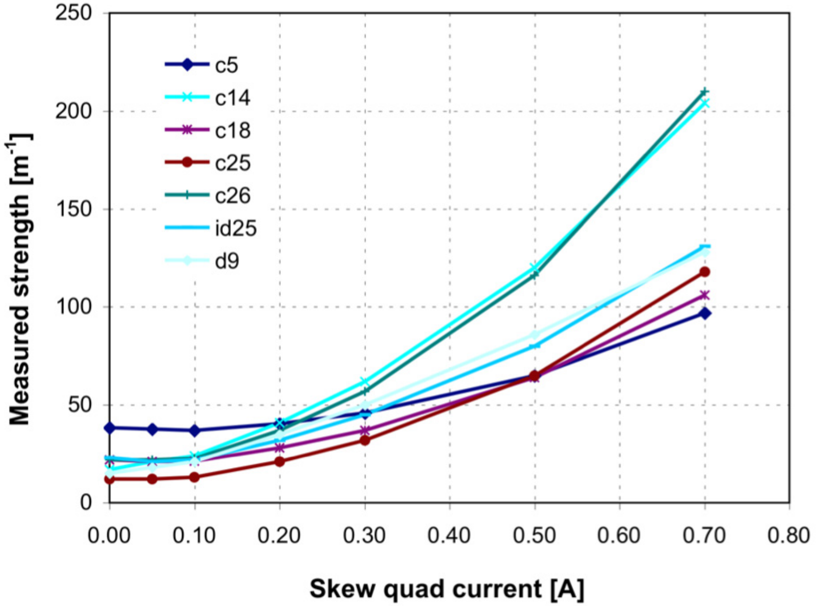
Check of the method

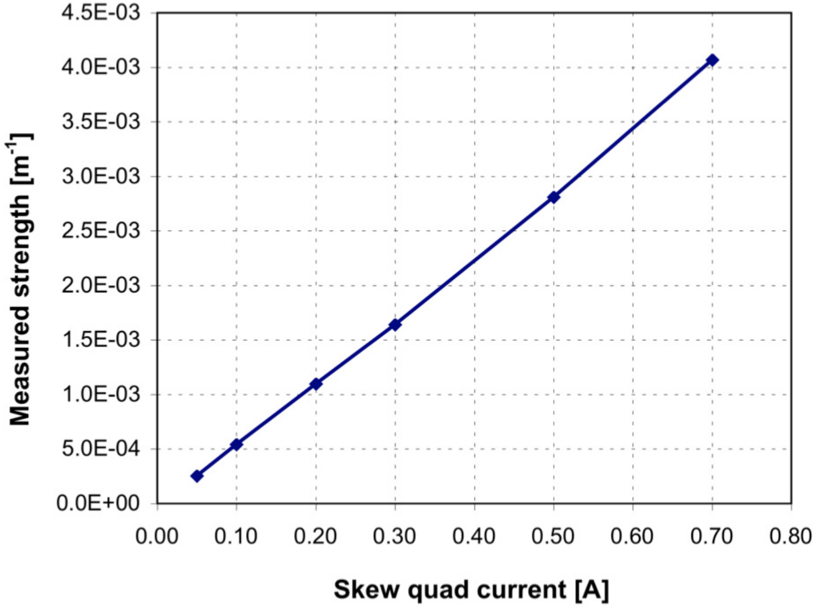
- The method is checked by modifying a single skew quad corrector



Check of the method

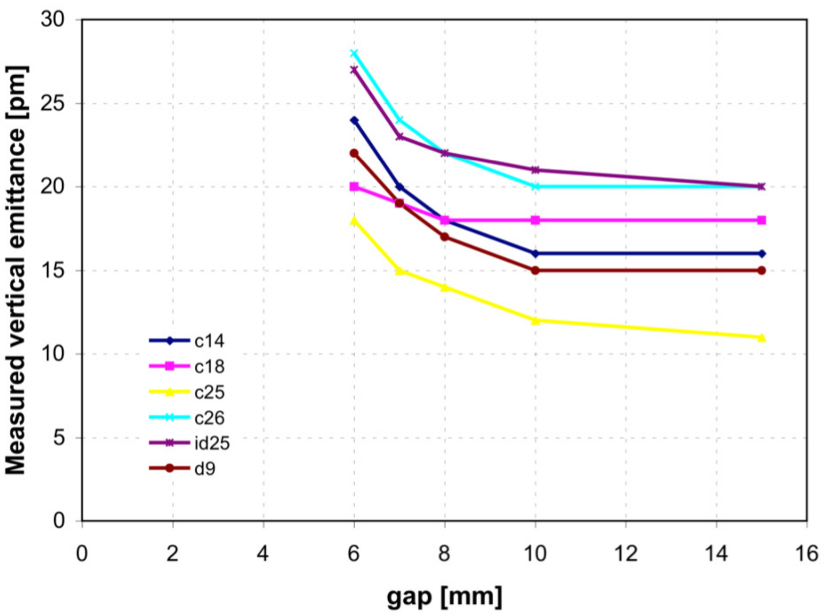
- The method is checked by modifying a single skew quad corrector
- The calibration agrees with the theoretical value
- The resolution is estimated at 1.10^{-4} m^{-1}, or 20.10^{-4} T





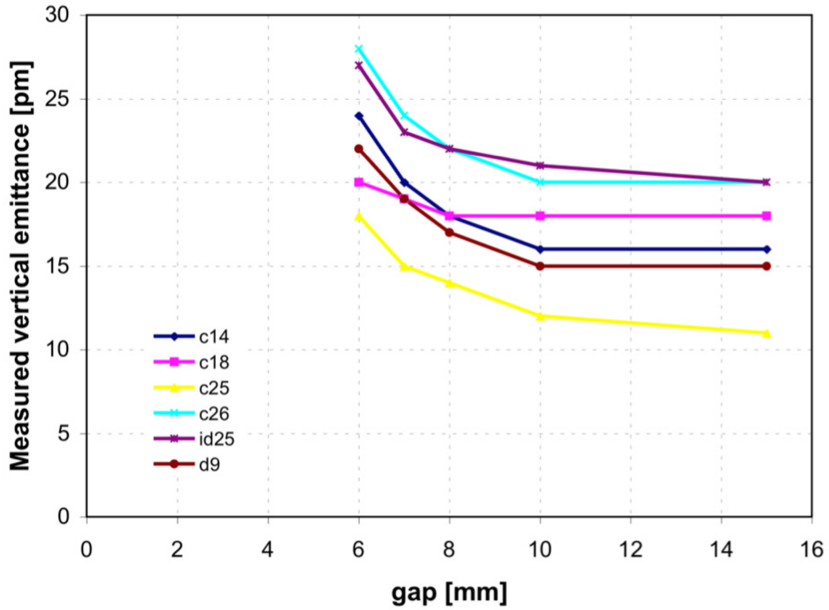
ID13 calibration

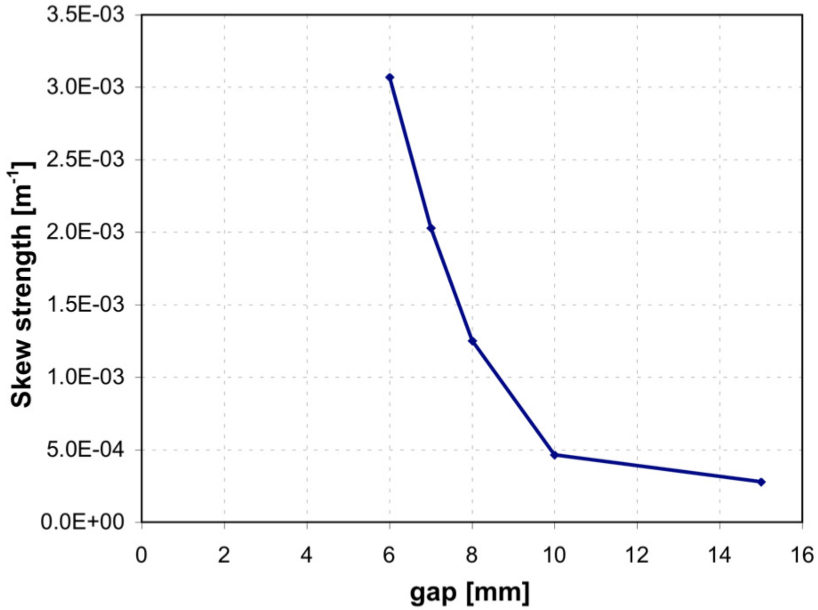
- One of the most critical IDs (in-vacuum)
  - The measured emittance vary when closing the gap



ID13 calibration

- One of the most critical IDs (in-vacuum)
  - The measured emittance vary when closing the gap
  - The corresponding skew quad strength is accurately measured





Other IDs

ID		Gap [mm]	Skew quad [m^{-1}]
ID13	IVU18d	6	$3\ 10^{-3}$
ID6	CPMU18u	6	$0.9\ 10^{-3}$
ID11	IVU23d	6	$3.6\ 10^{-3}$
ID2	U21.4m	11.5	$-4\ 10^{-5}$
ID14	U35u	11.8	$-3.5\ 10^{-4}$

Worst case (never corrected)

In air, perfect

In air

- Pending problems
  - The resulting strength is much higher than the result of magnetic measurements
  - It's already at the limit of what can be achieved at construction

$\Longrightarrow$ We need to correct dynamically

Future plans: full correction

- Long procedure (20 minutes), cannot be used during beam delivery,
- Can be accelerated by using turn-by-turn data instead of response matrix,
- Can be improved with a better skew quad scheme (more correctors, better spacing),
- Can be accelerated with better fit criteria.

Future plans: ID correction

- For the worst IDs
  - Calibration
  - Feed-forward correction
    - Either with local correctors
    - Or using the global scheme
- For all
  - Feedback on the nearest resonance
  - 2 knobs (amplitude and phase), using the IAX beam size measurements