LHC Beam Loss Pattern recognition application

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Content

Introduction: motivation and methodology

Motivation

- Finding the contribution of known loss scenarios in an unknown loss profile.
- Loss scenarios: horizontal/vertical resonance crossing for both beams (loss maps).

Approach

Every loss profile is treated as a vector where each component is the signal of one BLM.

- The loss under investigation is referred as $\vec{x}$
- The known loss scenarios are used as the reference vectors $\vec{r_i}$

The contribution of each loss scenario (f_i) can be calculated by

- Linear combination of known losses (vector decomposition)
- Similarity to known loss scenarios (cross-correlation)

Reference data

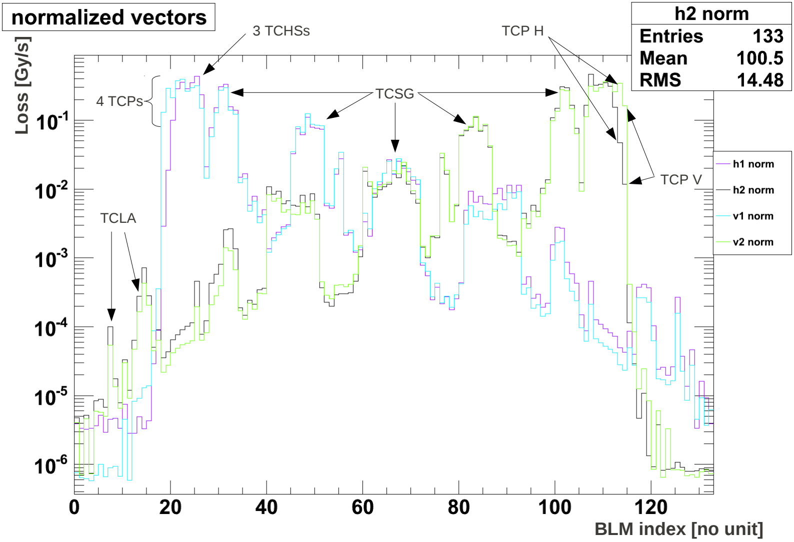


Figure: Courtesy of A. Marsili

Vector decomposition (SVD)

Approximate the unknown loss as a linear combination of the loss scenarios that:

$$\sum_{i=1}^{n} f_i \cdot \vec{r_i} \approx \vec{x} \tag{1}$$

Rewrite as matrix equation:

$$M_{m\times n} \cdot \vec{f_n} \approx \vec{x}_m \tag{2}$$

Calculating the factor by inverting the matrix (pseudo inverse):

$$\vec{f_n} \approx M^{+}_{n\times m} \cdot \vec{x}_m \tag{3}$$

Error estimation:

$$\|\vec{e}\| = \|\vec{x} - M_{m\times n} \cdot \vec{f_n}\| \tag{4}$$

Cross-correlation

Measurement of the similarity based on the dot product:

$$corr(\vec{r}, \vec{x}) = \frac{\langle \vec{r}, \vec{x} \rangle}{\|\vec{r}\| \cdot \|\vec{x}\|} \in [0, 1] \tag{5}$$

The factors (f_i) are the proportion of the similarity:

$$f_i(\vec{x}) = prop_{\vec{x}}(\vec{r_i}) = \frac{corr(\vec{r_i}, \vec{x})}{\sum_{j=1}^{n} corr(\vec{r_j}, \vec{x})} \tag{6}$$

Error estimation:

$$e(\vec{x}) = \sum_{i=1}^{n} (1 - corr(\vec{r_i}, \vec{x})) \cdot f(i) \tag{7}$$

Emittance blow up using the transverse damper

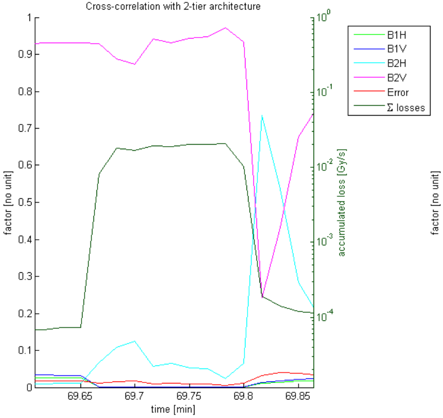
Analysed data from MD on the 26th August 2011:

- Transverse damper excite the beam 2
- Energy: $450 GeV$

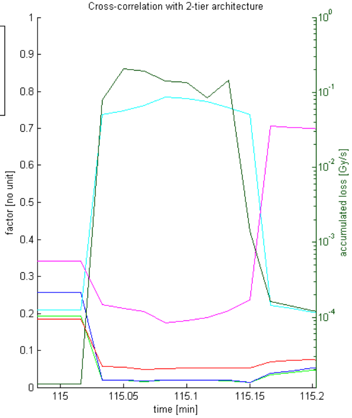
Num.	Time	Plane	Method	Nb	Amplitude
(1)	05:54	H	Blow-up	12	Full excitation
(2)	06:08	V	Blow-up	12	Full excitation
(3)	06:10	V	Blow-up	12	Full excitation
(4)	06:45	H	Resonance	1	No excitation
(5)	06:56	H	Blow-up	1	Full excitation, FB on
(6)	07:12	H	Blow-up	1	Half excitation, FB on
(7)	07:17	H	Blow-up	1	Full excitation, FB off
(8)	07:29	H	Blow-up	1	Half excitation, FB off

Results: cross-correlation

vertical blow up (3)



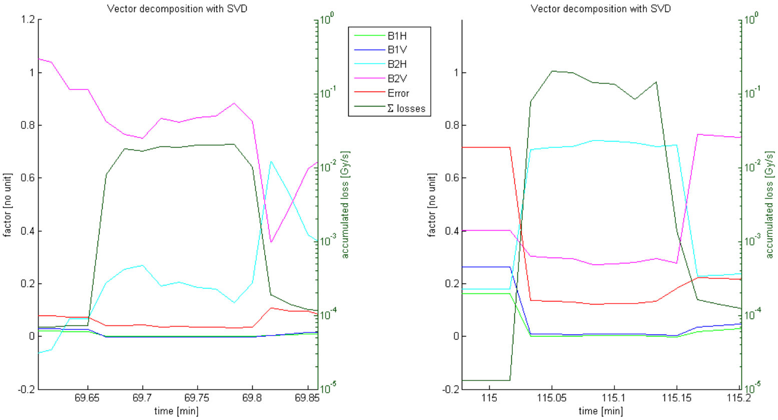
horizontal blow up (5)



- Method responds well in all 8 test cases
- No difference found for different conditions

Results: vector decomposition

vertical blow up (3) — horizontal blow up (5)



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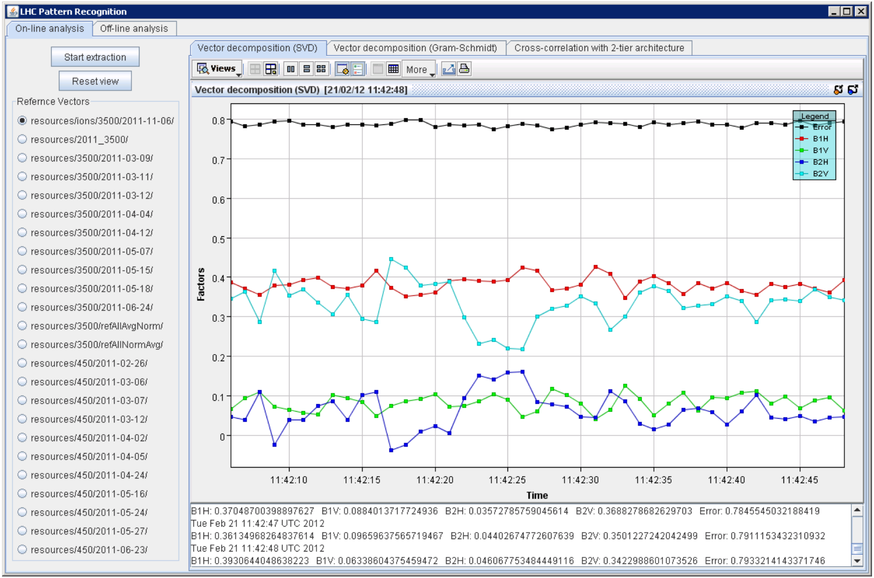
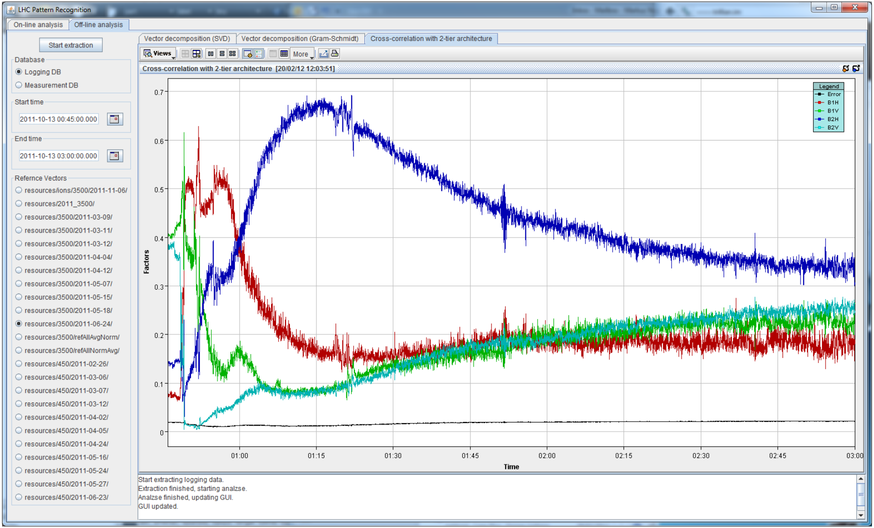
The Java Application



The Java Application



Conclusions and outstanding issues

- Pattern recognition methods based on several techniques have been developed and implemented for analysis of the LHC beam losses.
- Qualitative agreement of the different methods has been tested in controlled cases. Pending quantitative verification.
- Error estimation of the coefficients and study of the sensitivity of the recognition tool.
- Application for collimation inefficiency under development.
  - Collimation inefficiency vs time (Signal cold element / Signal primary collimator)
  - Algorithm for collimation hierarchy

References

[1] H/V decomposition of beam losses; A, Marsili; MPP meeting 27-05-2011

[2] LHC Beam patters recognition; A, Marsili; IPAC'11 , TUPC141

[3] Pattern recognition with the LHC Beam Loss Monitoring system; M. Nagel; Bachelor thesis