H/V decomposition of beam losses

Implementation & first results

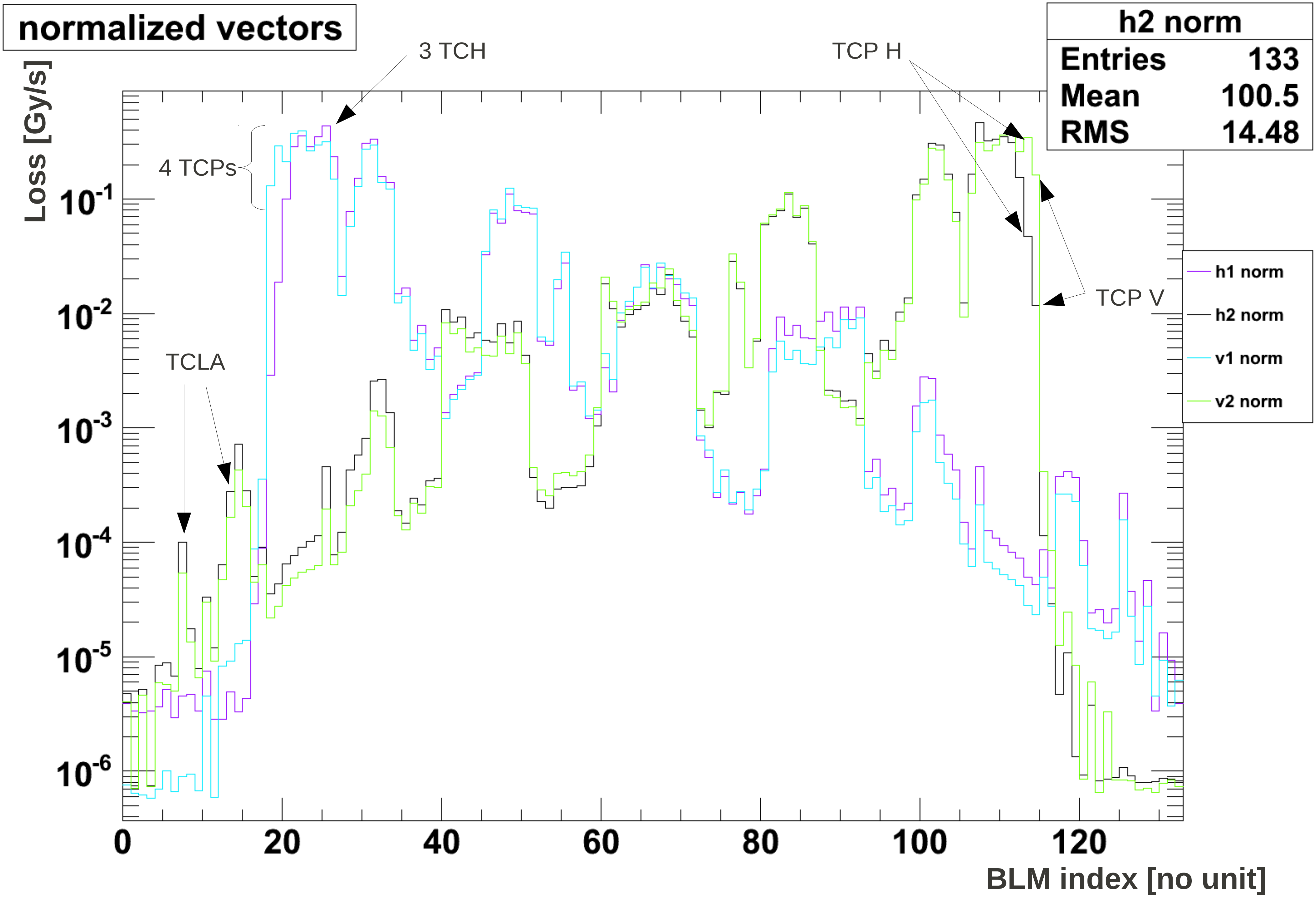
Outline

- Motivation
- Implementation
  - Matrix inversion
  - Vector projection
  - Numerical operations
- Results of numerical operations
  - Limitations
- First results on physics data
  - Evolution
- Conclusion

Motivation

- Identification of beam loss mechanism: a deterministic treatment of loss patterns.
- Try to find out if an unknown loss profile can be decomposed as a combination of well-known loss scenarios, and how precisely.
- Loss scenarios: horizontal/vertical resonance crossing for both beams.
- Implementation:
  - Matrix inversion (Singular Value Decomposition)
  - Vector projection (Gram-Schmidt process)
  - Centers of mass (only for these cases)

4 loss scenarios: reference vectors



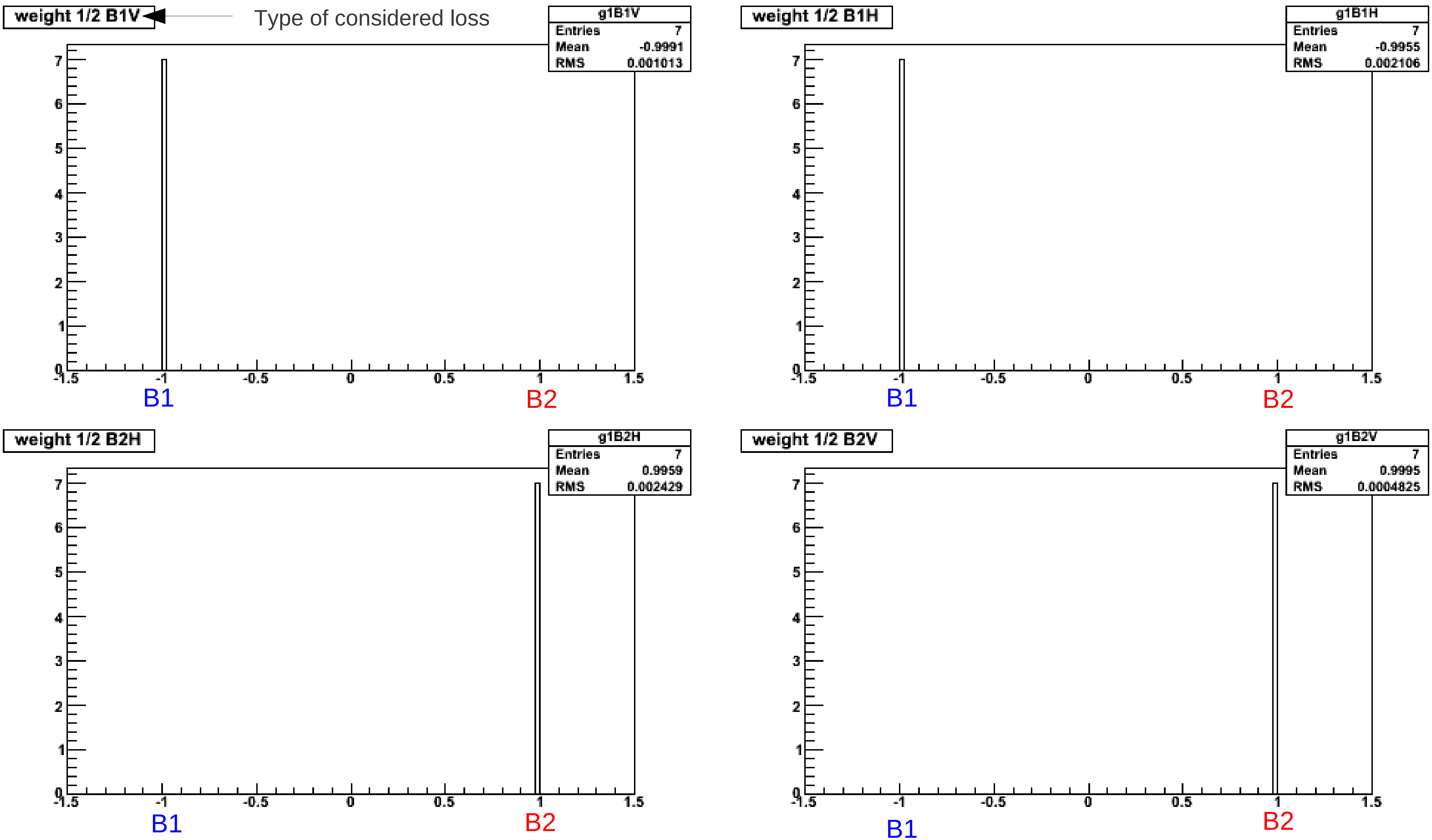
Implementations

- Numerical operations
- Matrix inversion: $X = M.F \Rightarrow F = M^{-1}.X$
  - X: unknown vector, F: factors of decomposition
  - Singular Value Decomposition ~ diagonalization
  - Pb: can give negative factors (not physical)
- Vector projection:
  - Gram-Schmidt process to create a orthogonal base
  - Order of vector matters!
  - Pb: returns mainly one vector
- Evaluate how precise decomposition is:
  - Error on recomposition: $| X – M.F |$

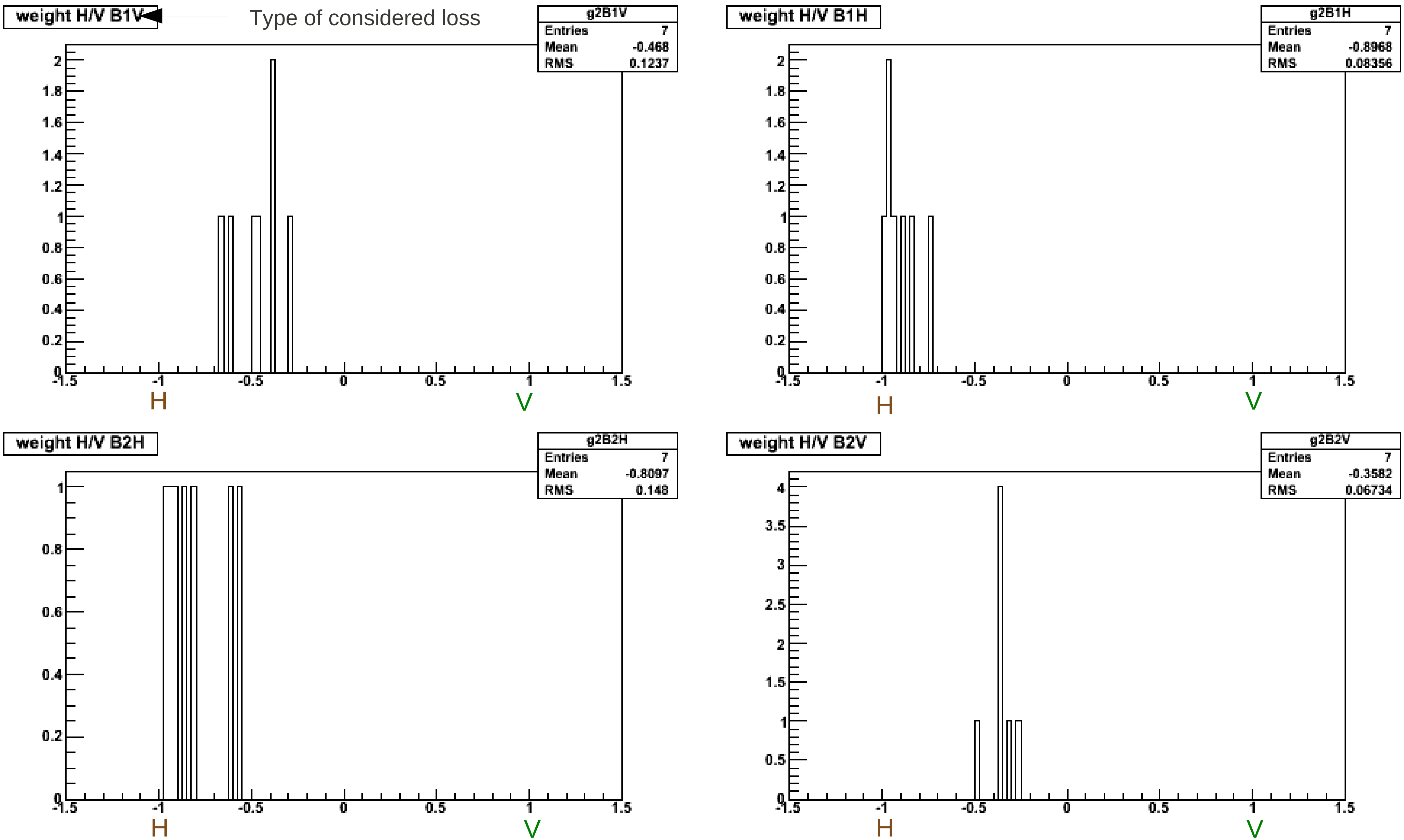
Centers of mass normalised difference

- Motivation: easy check of the type of loss scenario
- Idea: (a-b)/(a+b) ~ 1 if a >> b, -1 if a << b
- Advantages: symetric, can be combined
- Taking only signal from H and V collimators:
- $\frac{(h_2+v_2)-(h_1+v_1)}{h_1+h_2+v_1+v_2}$ = 1 for B2 and -1 for B1
- $\frac{(v_1+v_2)-(h_1+h_2)}{h_1+h_2+v_1+v_2}$ = 1 for V and -1 for H

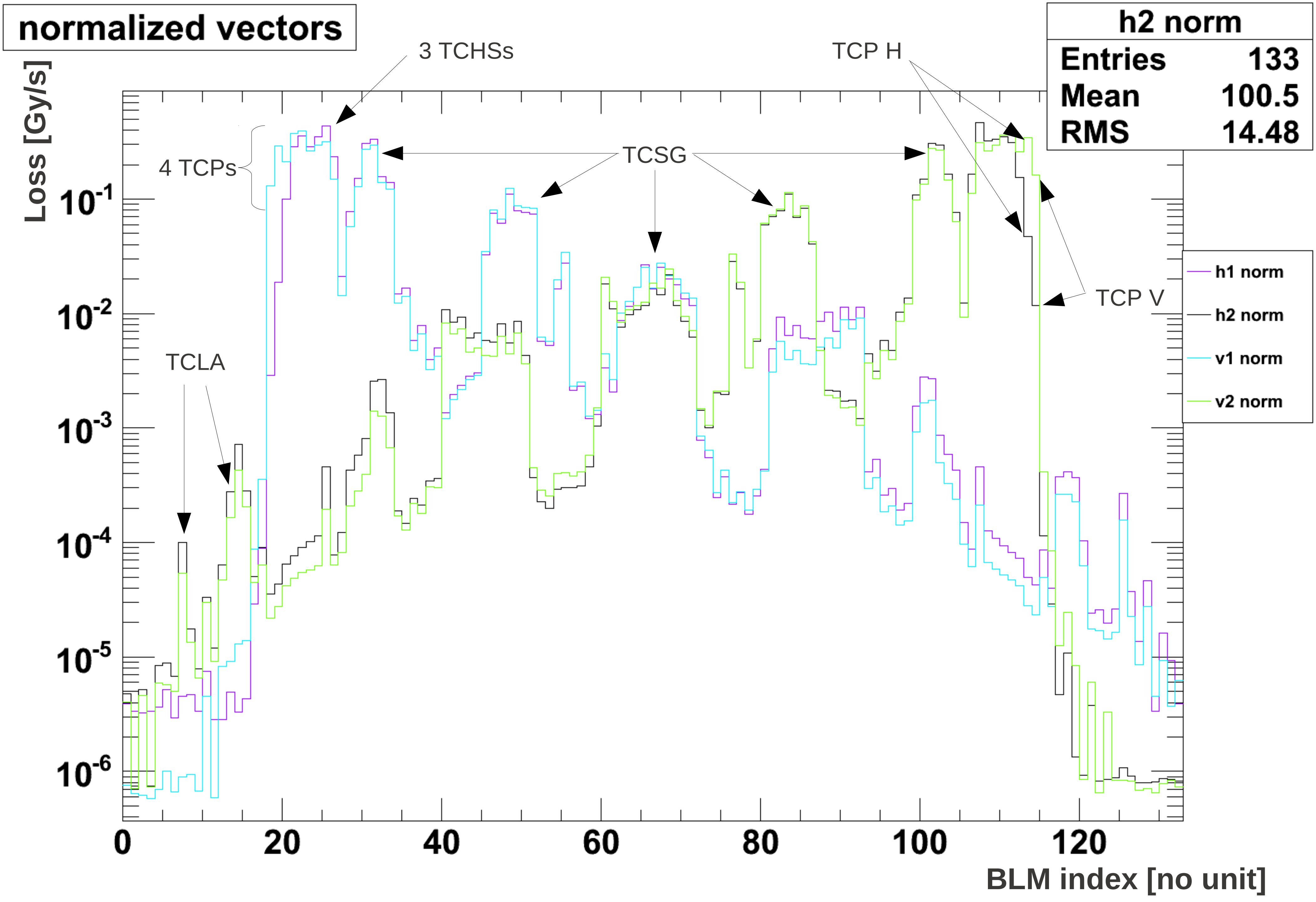
Distribution of centers of mass B1/B2 (loss maps of 2010)



Distribution of centers of mass B1/B2 (loss maps of 2010)

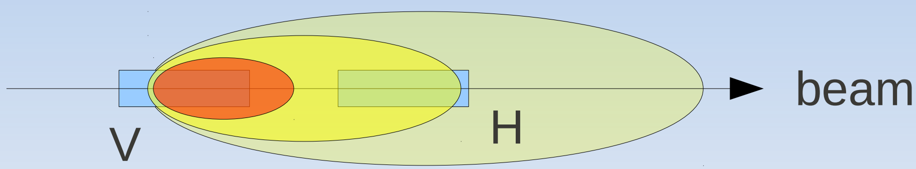


Loss scenarios :vectors of the set

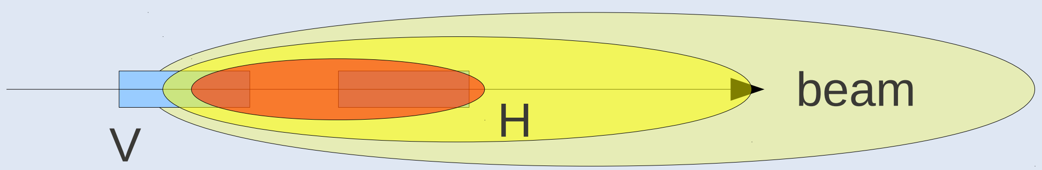


Reasons & corrections

- H is downstream from V: it ”sees” the shower from V

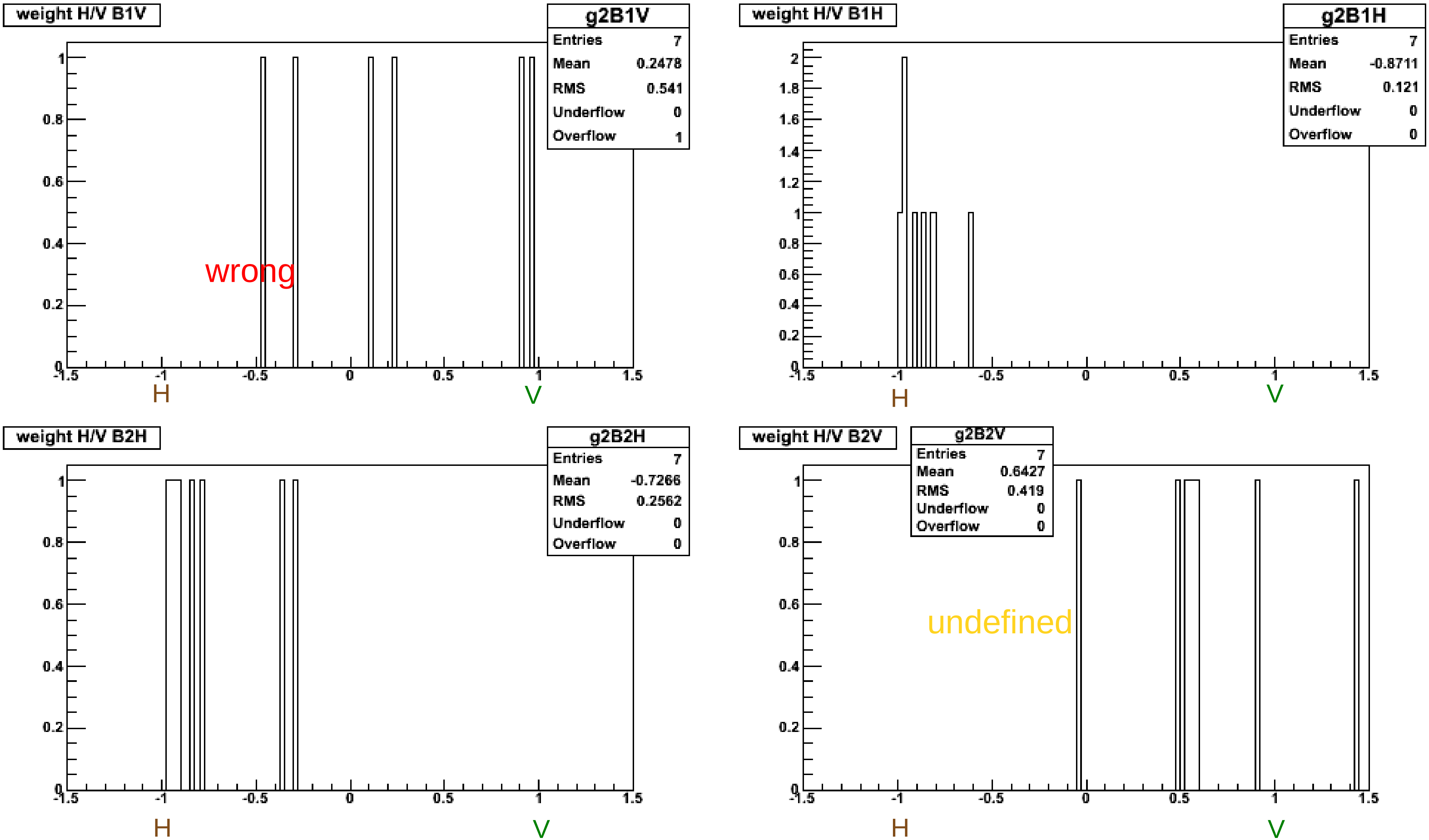


- The shower from V actually develops on H



- H sees more losses than B, even when they're only vertical
- => subtract vertical loss from horizontal signal
  (needs a factor >1 !)

After correction



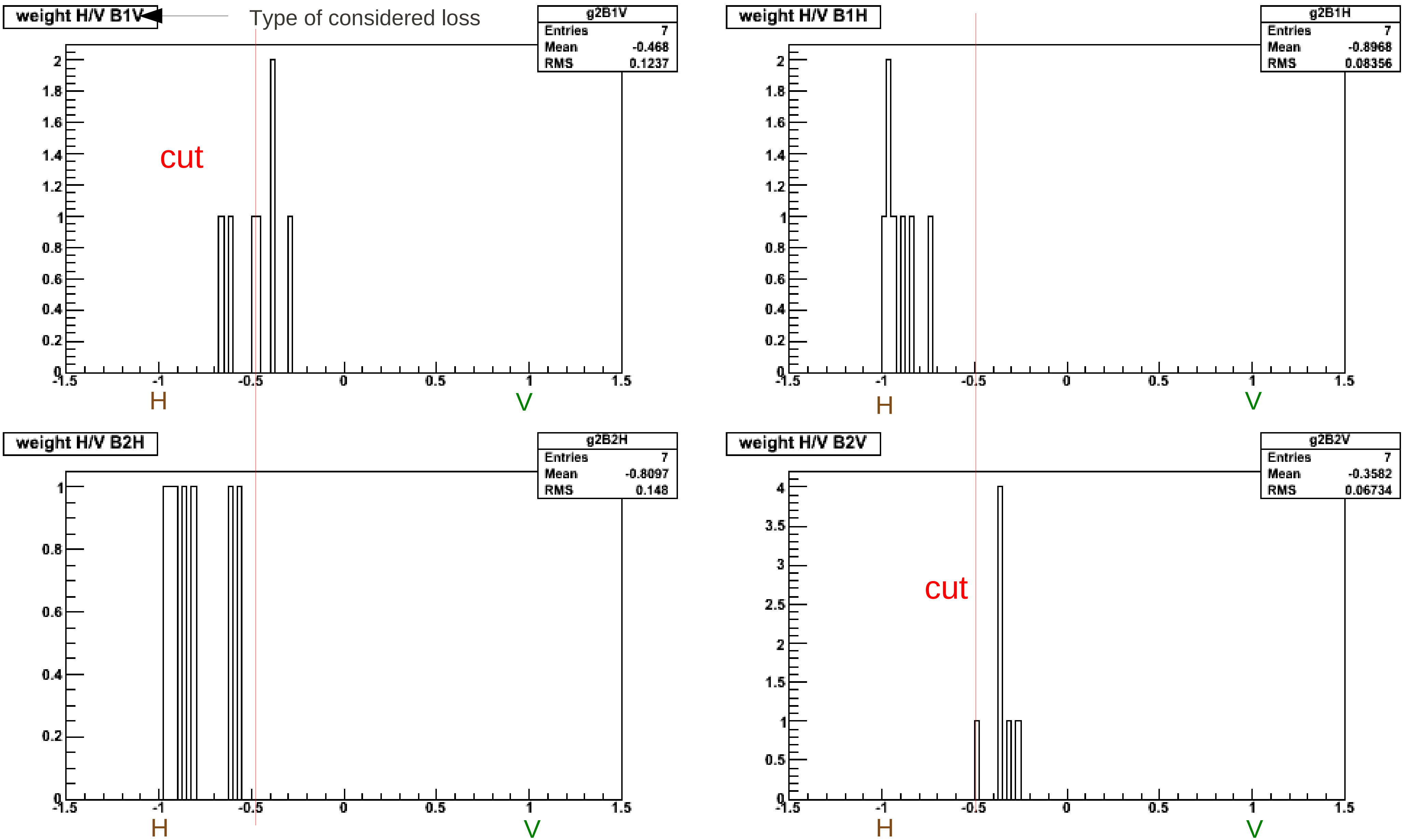
Other idea: cuts

- 1 cut: If center of mass < -0.5, it's H; else, V.
- 2 cuts: if center of mass < -0.7, it's H ;
  if center of mass > -0.4, it's V ;
  else, undefined.

- Ratio: if V/H > 0.3, it's V; else, it's H
- 2 cuts on ratio: if V/H > 0.4, it's V;
  if V/H < 0.2, it's H;
  else, undefined.

- Numerical operation can be enough to separate H/V.

Distribution of centers of mass B1/B2 (loss maps of 2010)



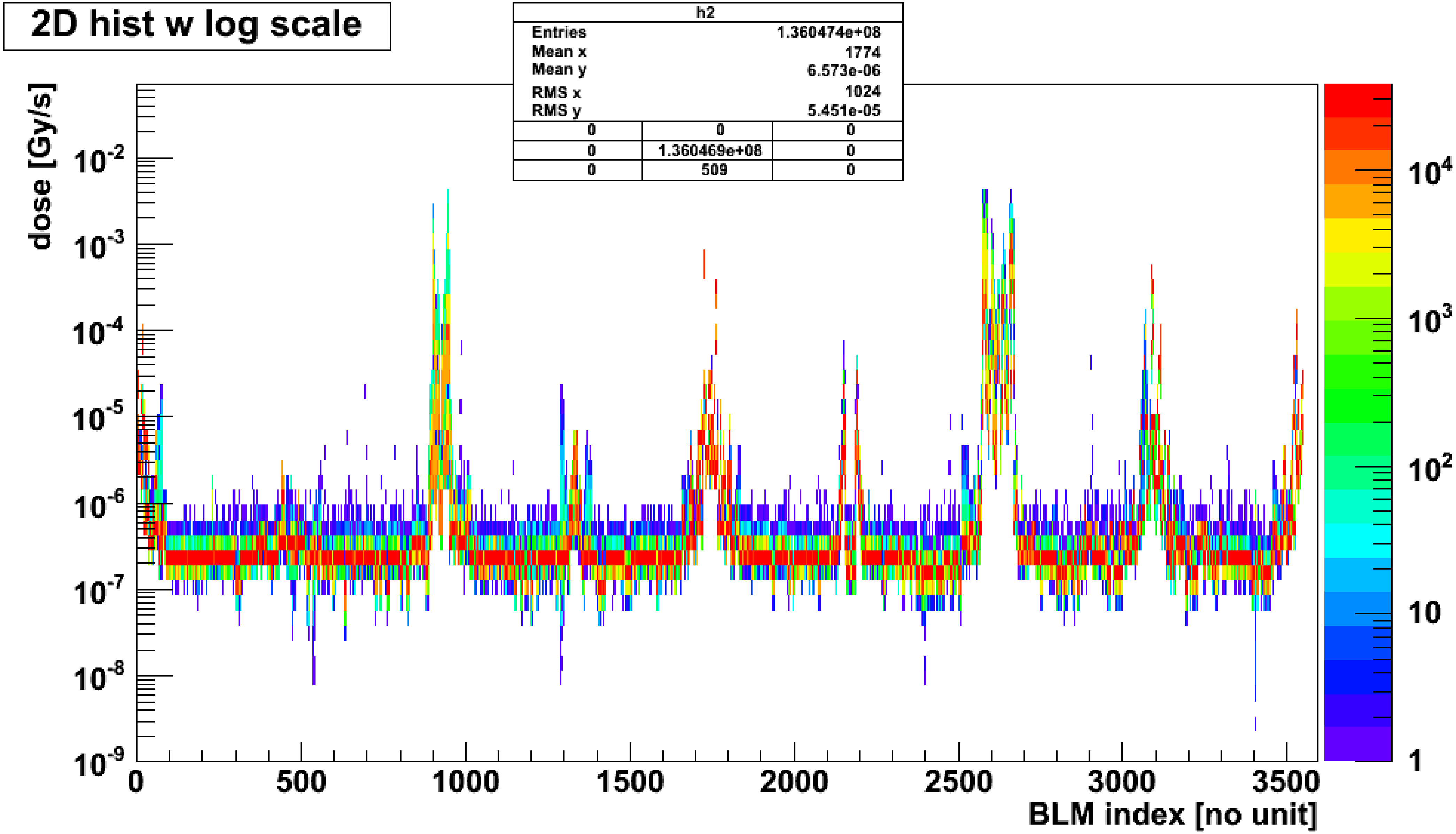
Firsts results SVD and GS

- Decomposed every vector of every loss map on every other loss map
- Not always right...
- BUT clear correlation between ”correctness” and error (norm of difference)

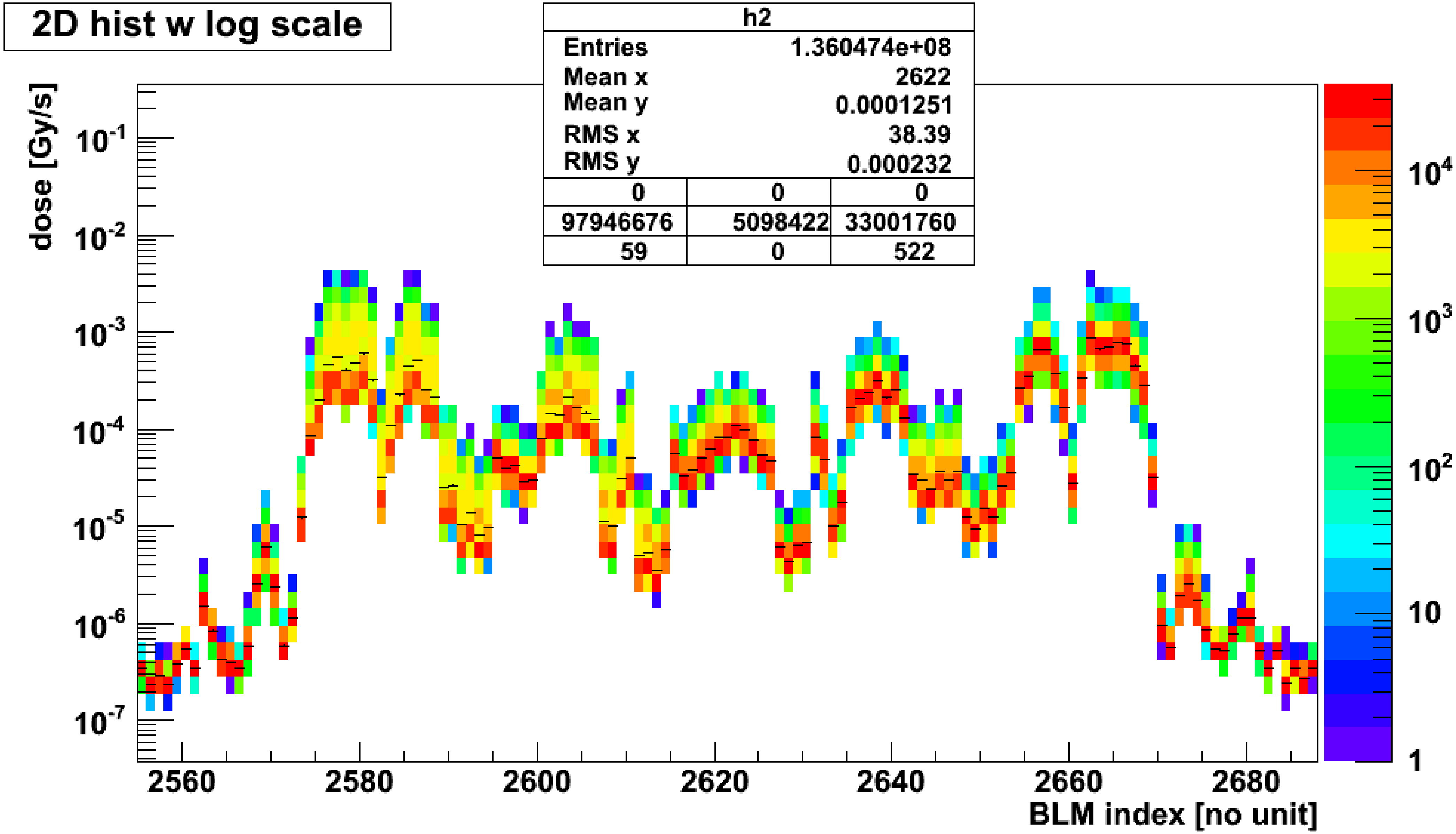
More:

- Cut on error for ”confidence”
- Use centers of mass for cross-check
- Get statistics during stable and non-stable beam.

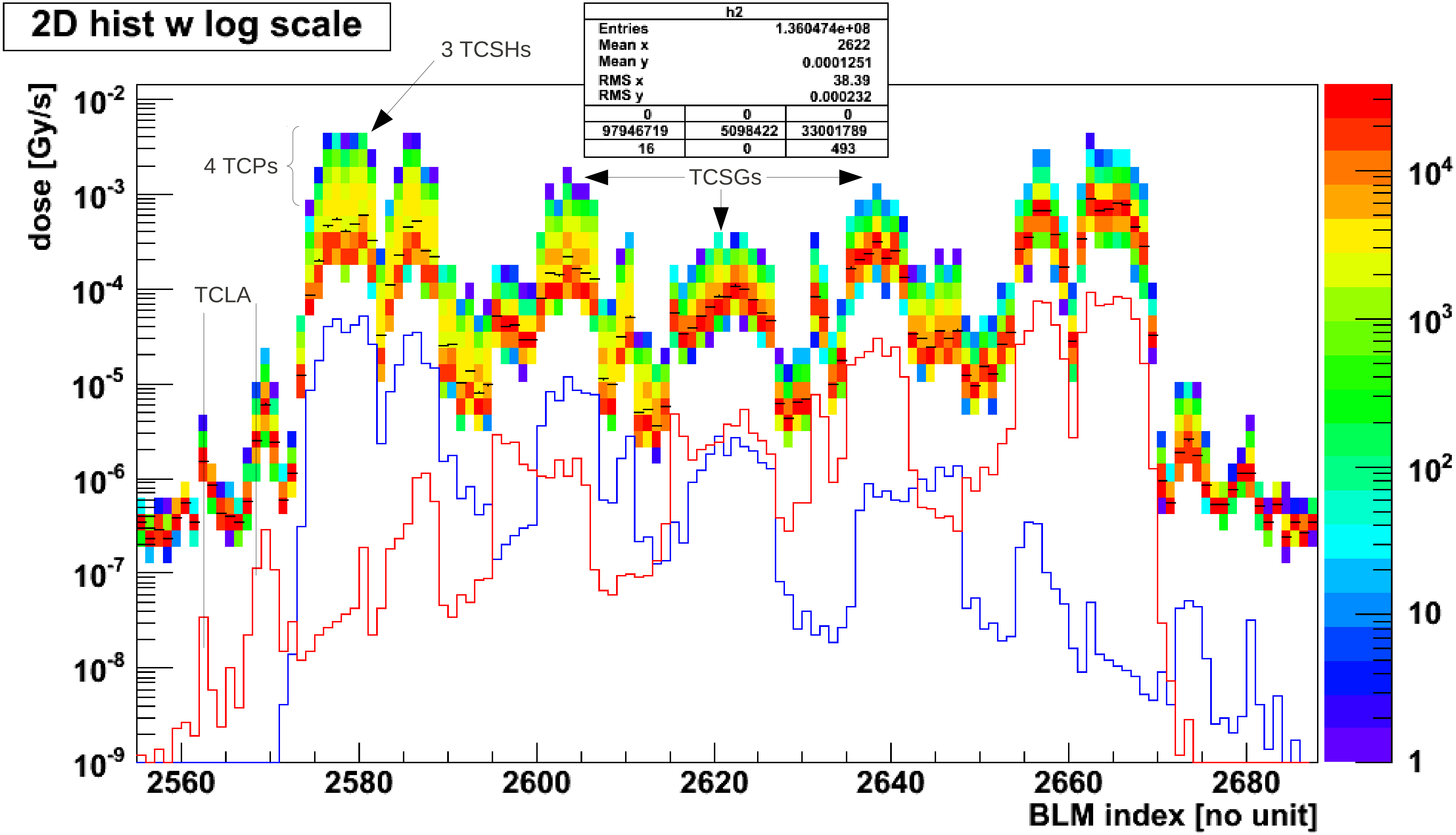
Distribution of losses in the LHC



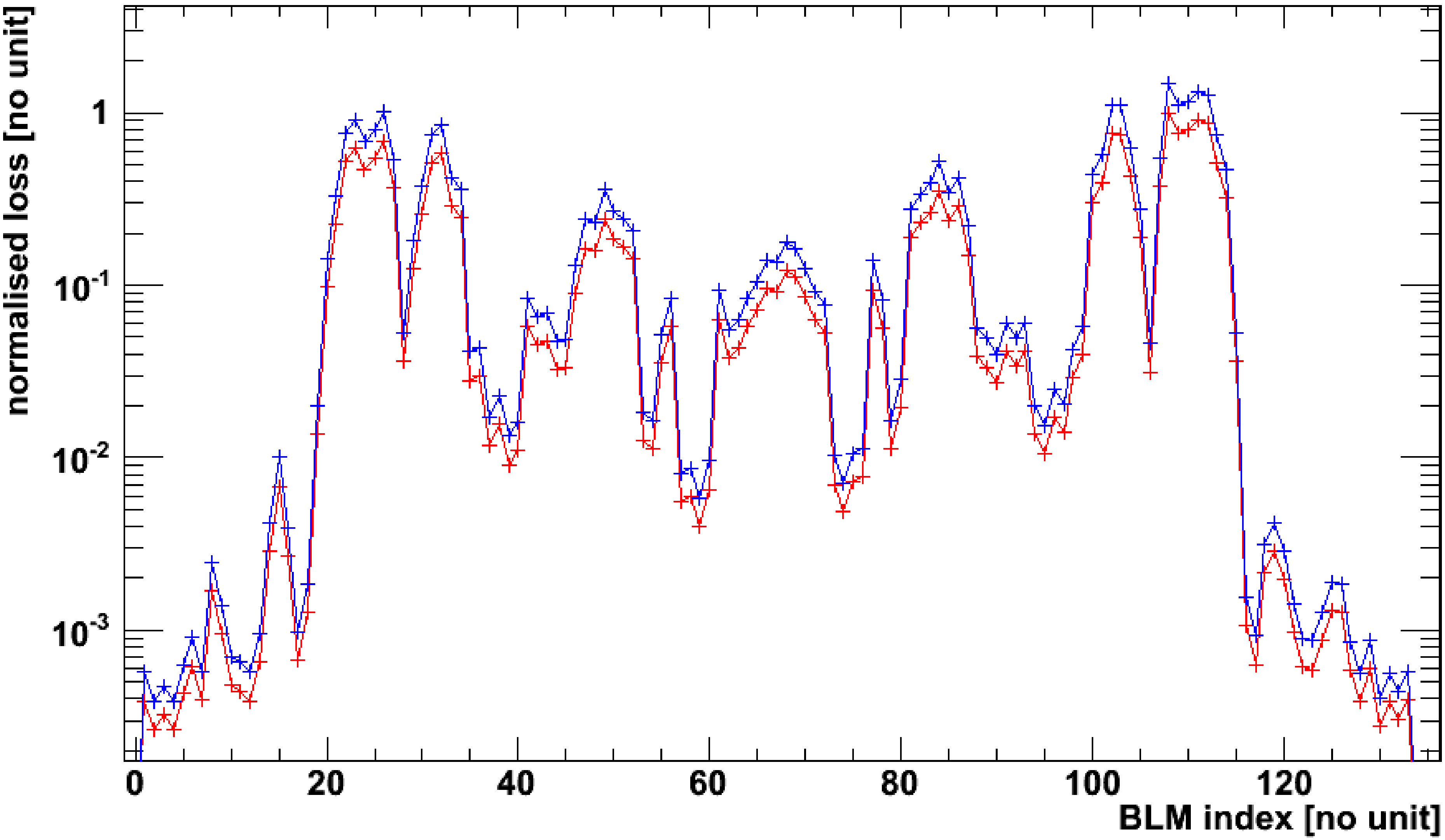
Point 7: distribution and averages



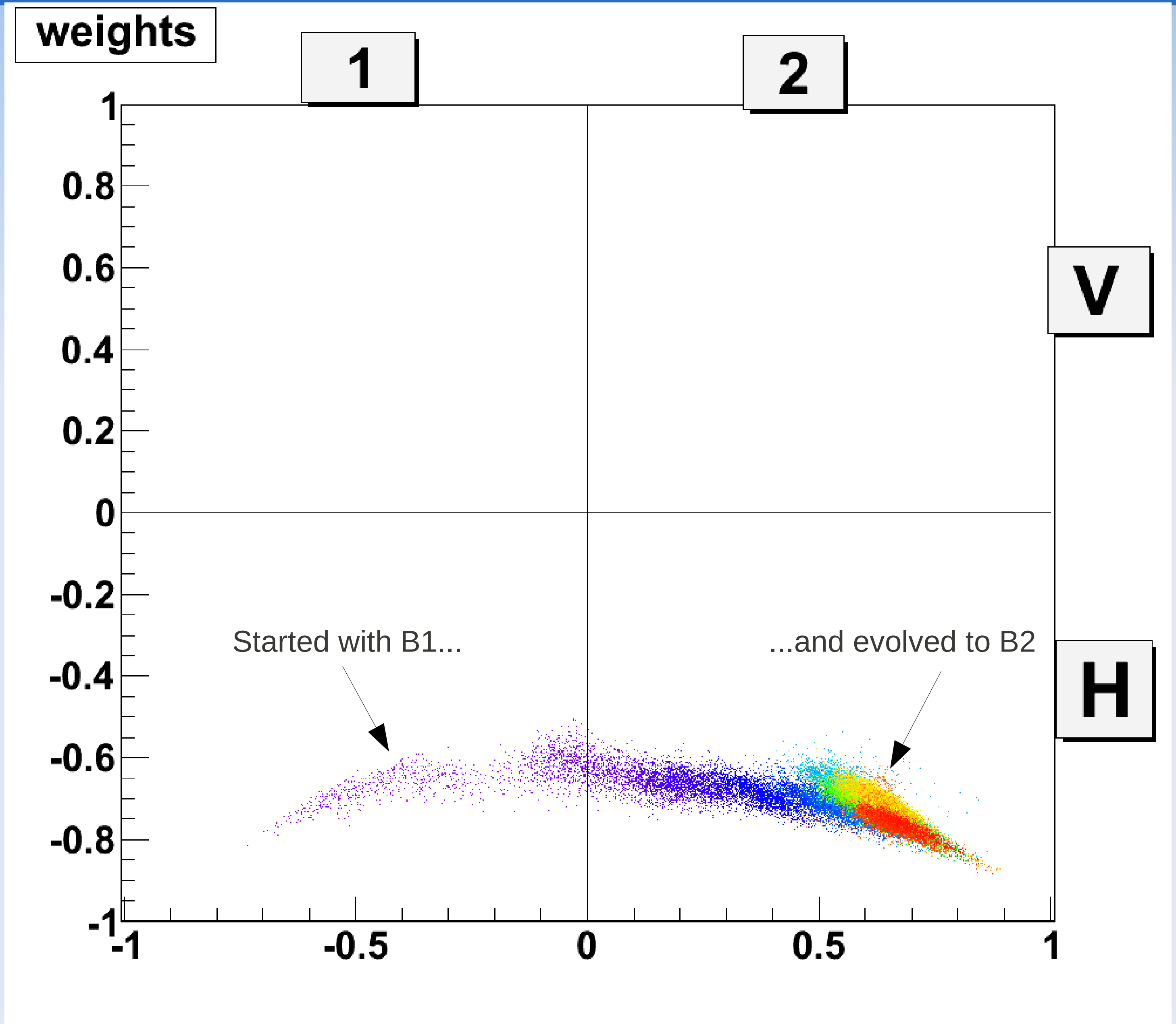
Point 7:
loss scenarios



Average losses normalised to higher monitor for both beams



Evolution of losses with time



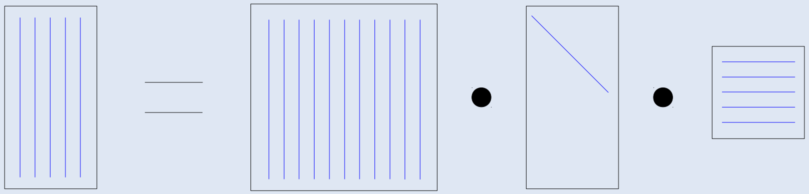
Conclusion

- Vertical and horizontal can be separated easily
- There are some undefined cases (which can correspond to reality)
- More experience is needed to select one algorithm...
- Thanks for following!

Spare slides

Matrix inversion: Singular Value Decomposition

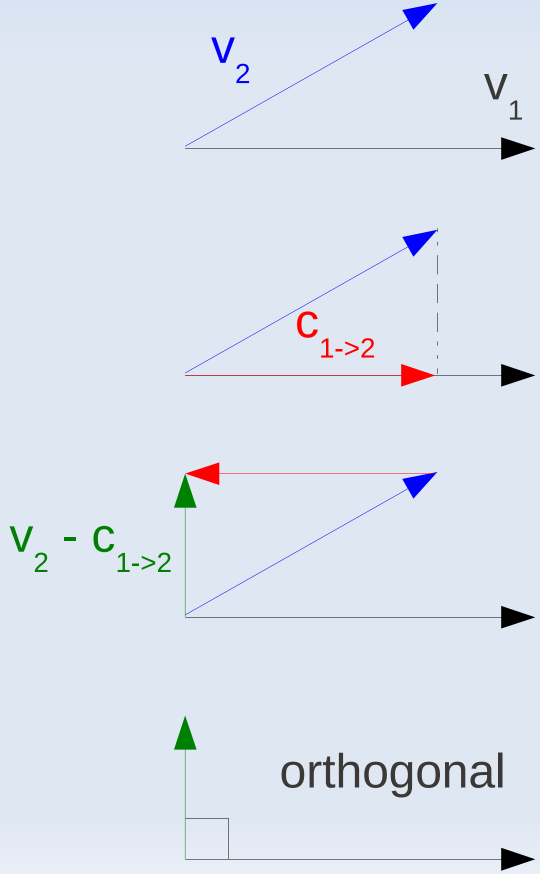
- X: unknown loss profile; M: matrix of loss scenarios; F: factors of decomposition
- $X = M.F \quad \Rightarrow \quad F = M^{-1}.X$
- M is not square (m monitors x 4 scenarios)
- SVD ~ diagonalization for a non-square matrix
- $M = U.\Sigma.V^T \quad \Rightarrow \quad M^+ = V.\Sigma^+.U^T$ (pseudoinverse)



- /!\ factors can be negative...

Projections: Gram-Schmidt process

- Vectors are not orthogonal! They are all in R^{+m}
  => decomposition is not unique
- Make the set orthogonal: Gram-Schmidt process
  - Take second vector v_2
  - Project it on first vector
  - Get contribution of v_1: $(\vec{v}_2 \cdot \vec{v}_1) \frac{\vec{v}_1}{\|\vec{v}_1\|}$
  - Substract contribution from v_2
  - Result is orthogonal to v_1
  - Carry on...



Projections: limitations

- Projection is not unique

  => Result depends on the order of the vectors
- All vectors are in R^{+m}

  => first vector has the biggest contribution

- Ordering vectors by ”closeness” to X (to the sense of the scalar product)

- Evaluate accuracy of decomposition

Error on decomposition

- Difference between X and F.M (recomposition of X)
- Vectors are normalised and ”close”: $v_i.v_j \sim 1$
- | X – F.M | gives an information on the difference of shape
- Questionable decision!
- => ”classical” scalar product is also used.