UNIL | Université de Lausanne

Nederlands Forensisch Instituut
Ministerie van Veiligheid en Justitie

Measurement Science & Standards in Forensic Firearms Analysis

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Comparison and Interpretation of Impressed Marks Left by a Firearm on Cartridge Cases

| le savoir vivant |

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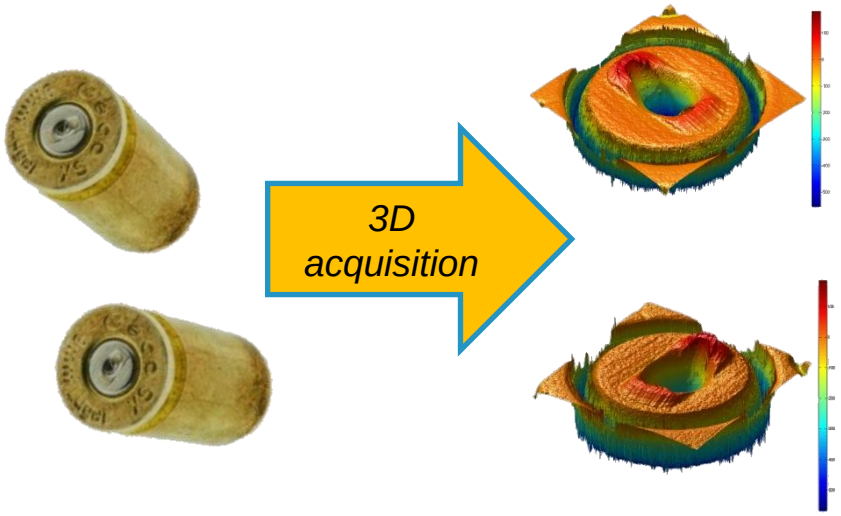
Objective

- To bring an objective measure of the weight associated with comparison results between impressed marks (breech face and firing pin) on cartridge cases.



3D acquisition

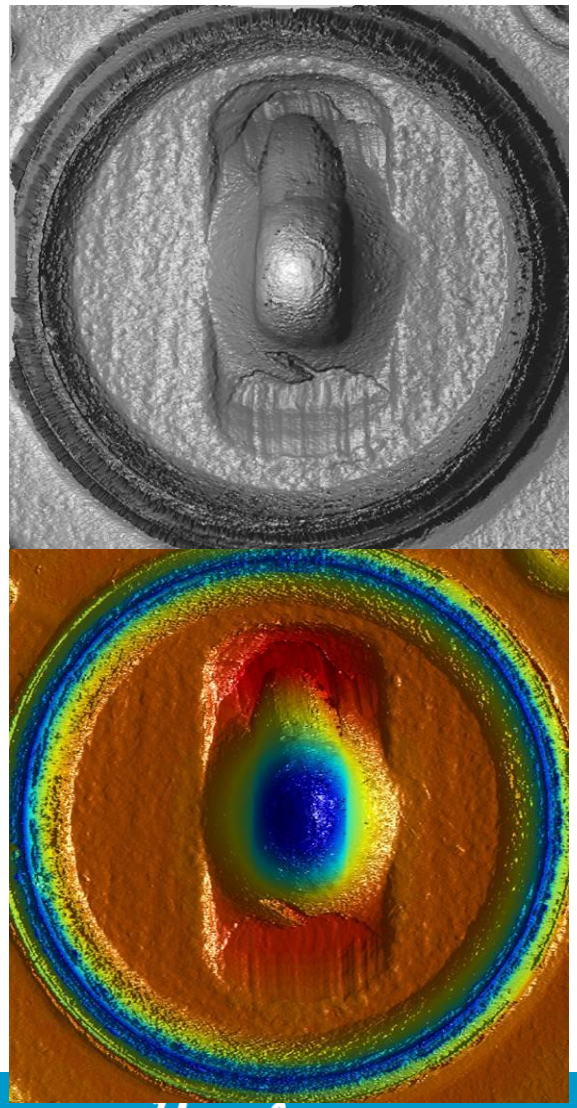
FP and BF comparison

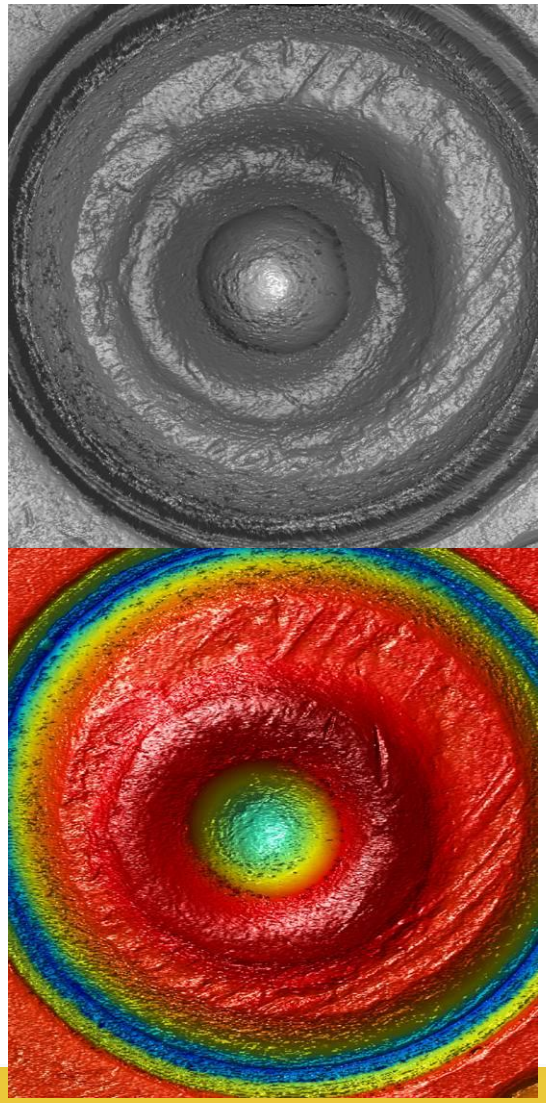
Similarity scores

Interpretative model

Likelihood Ratio (LR)

3D measurement



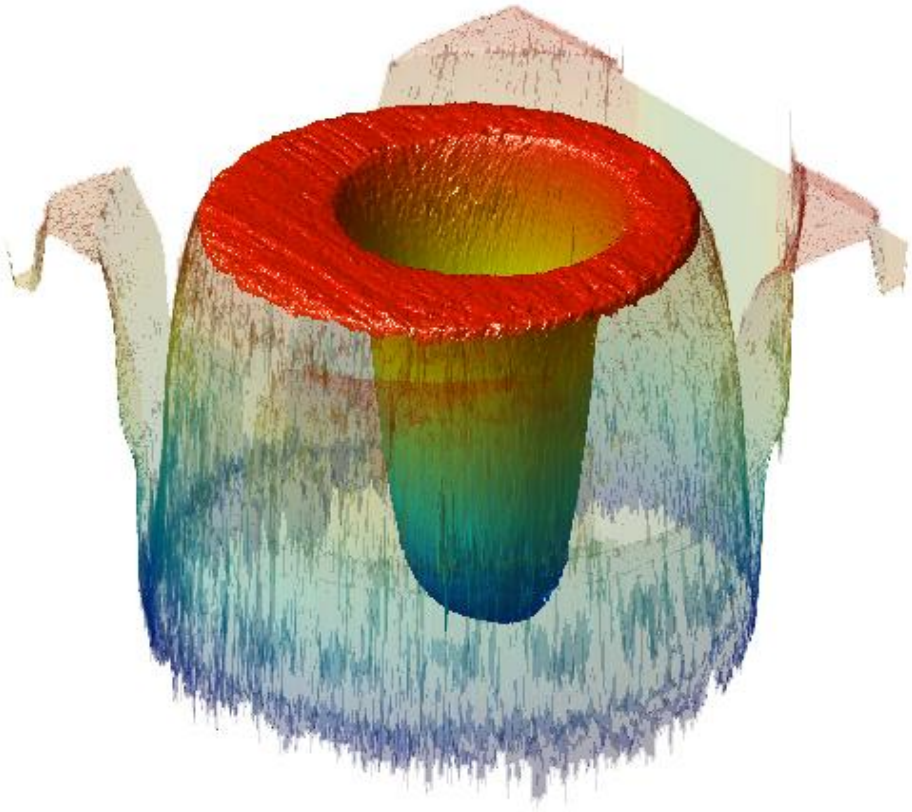


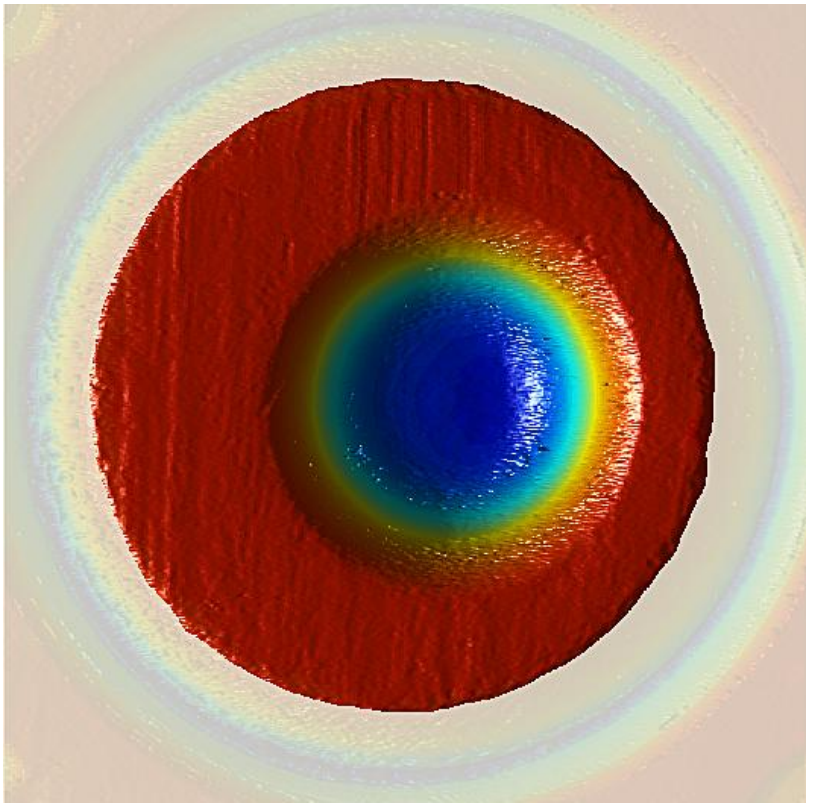
Confocal detection profiler

µscan of Nanofocus®

Resolution: 2 µm

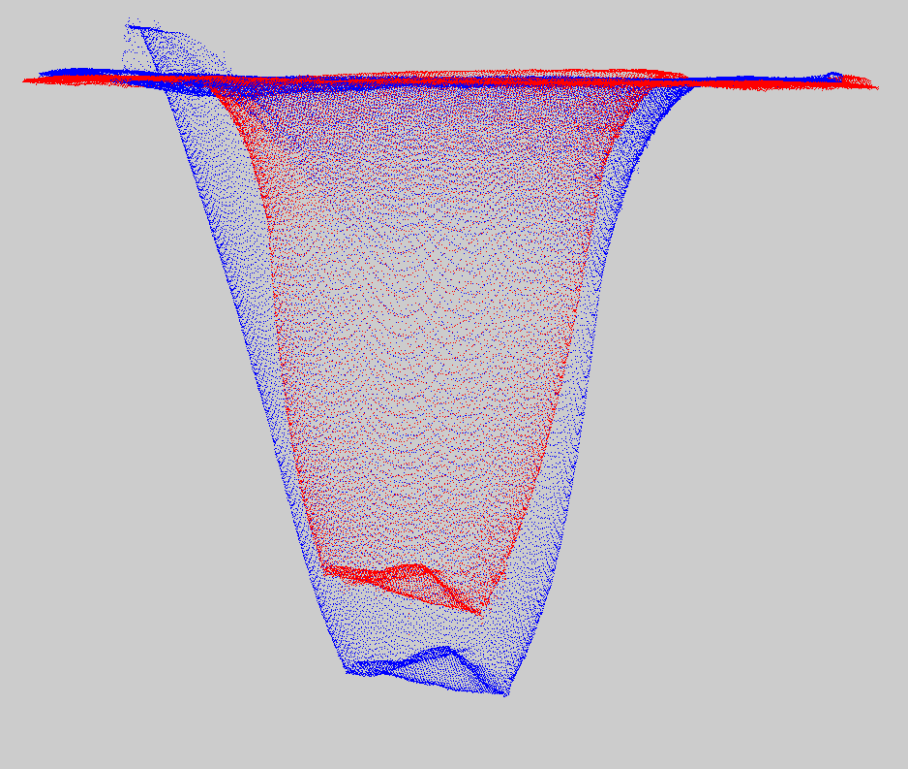
Primer Cup Cutting

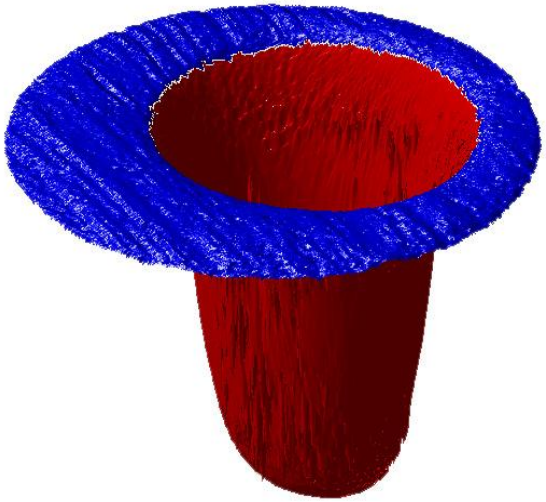




Automatic segmentation of the primer cup taking advantage of normal vectors

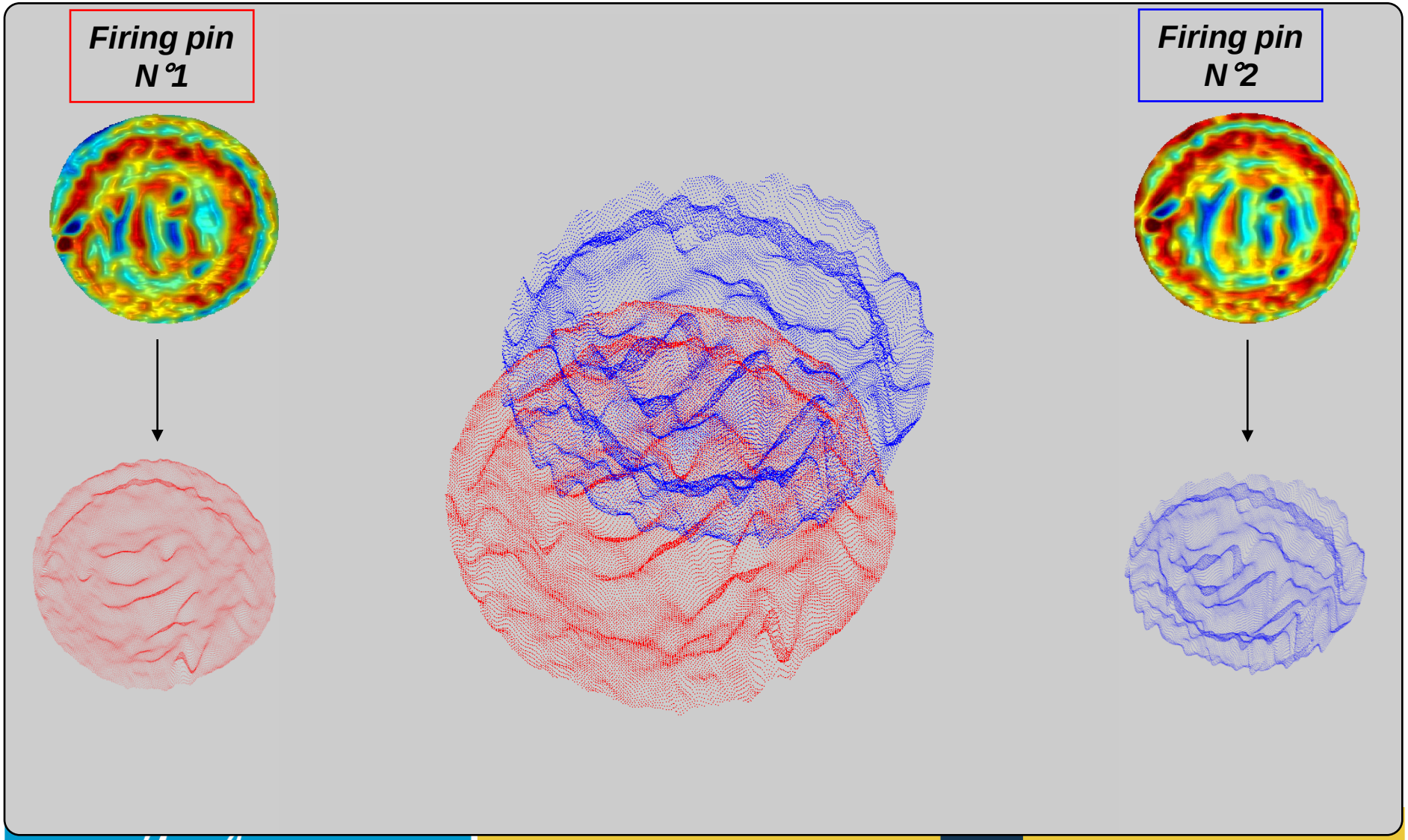
Marks separation





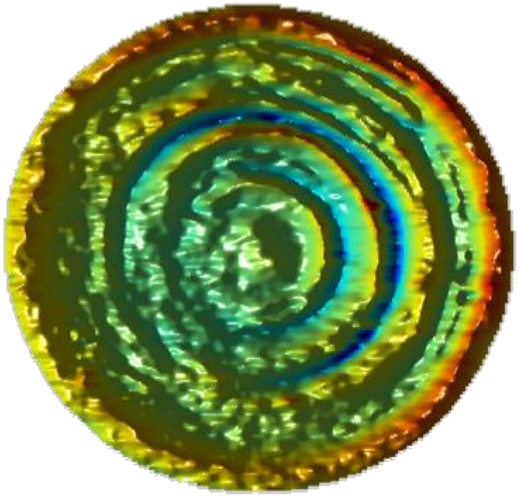
Automatic separation of the marks taking advantage of normal vectors

Firing pin alignment using ICP

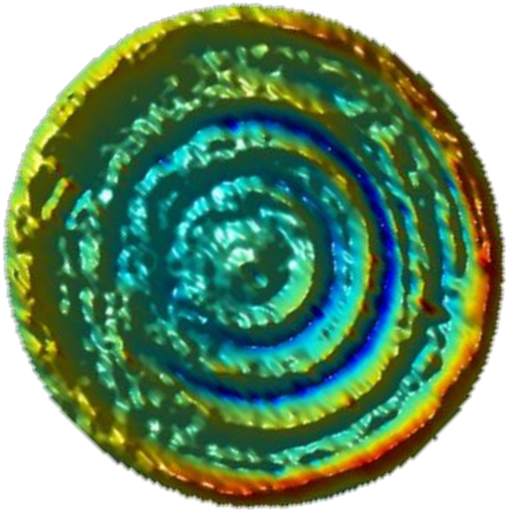


Firing pin alignment using ICP

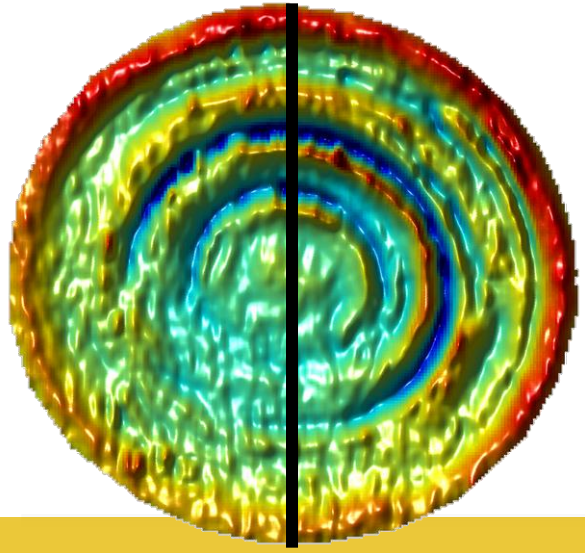
Ceska Zebrojovka
Sample A



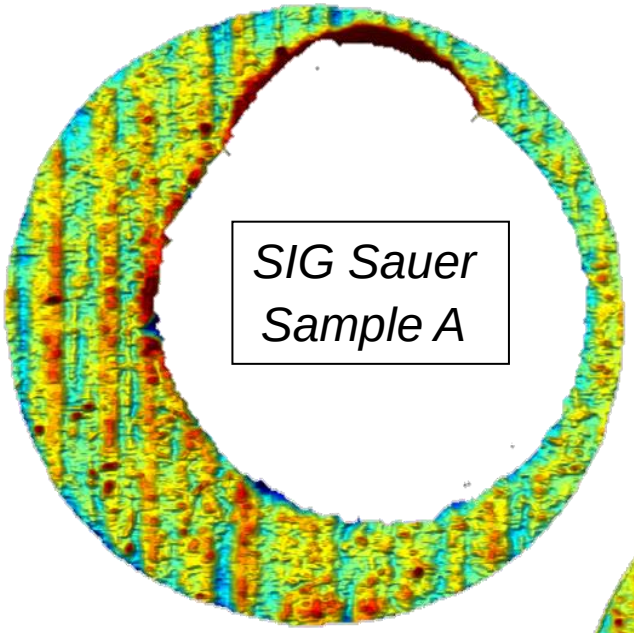
Ceska Zebrojovka
Sample B



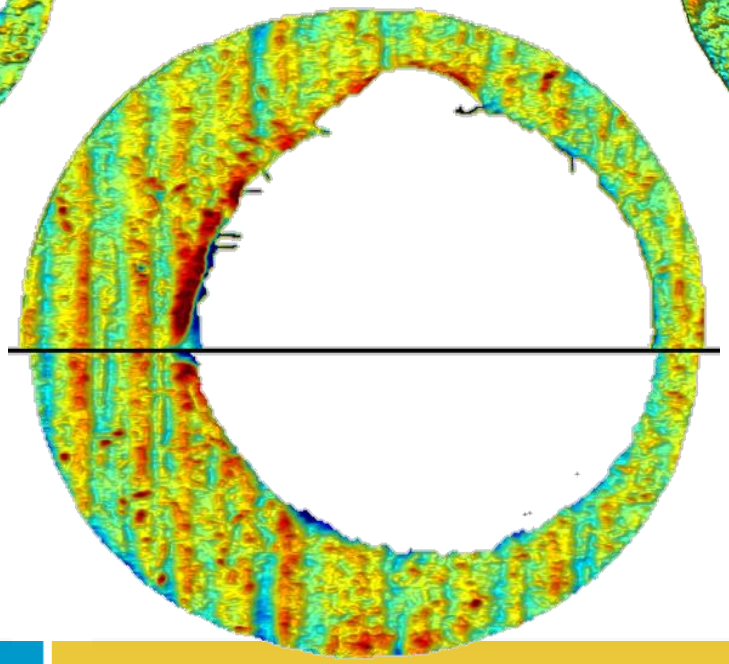
Alignment

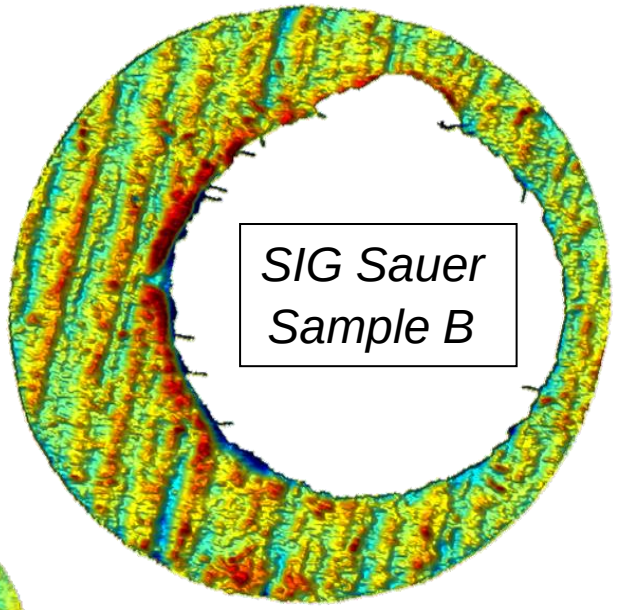


Breech face alignment



Alignment



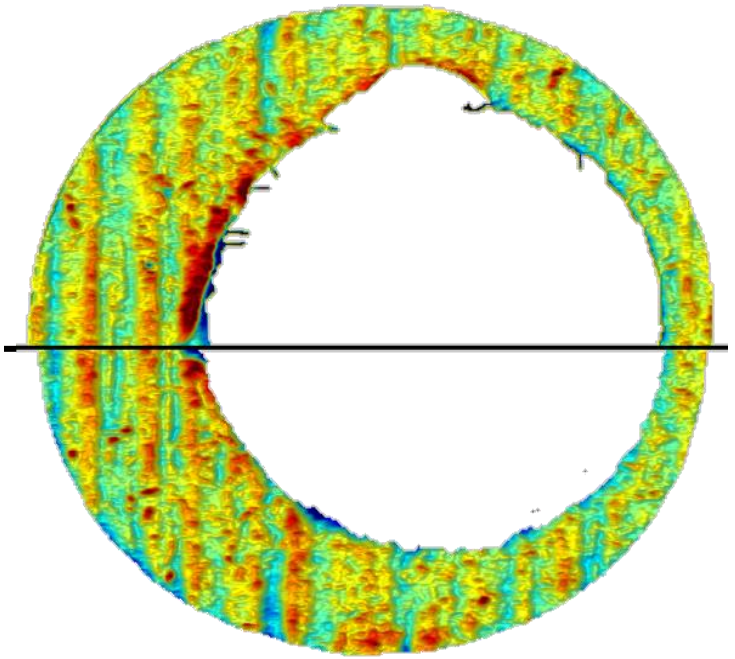


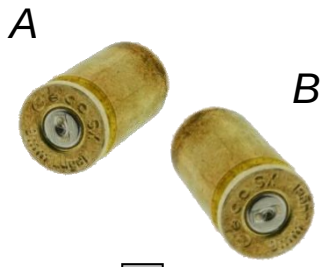
Similarity metrics (scores)

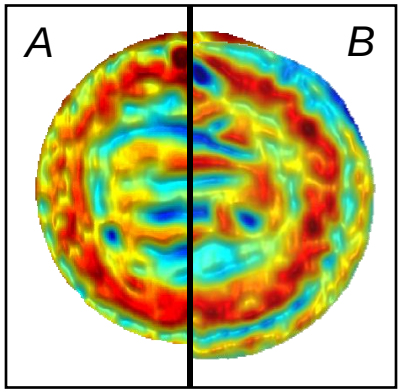
Similarities quantification

Correlation index
Euclidean distance
Normal vectors difference

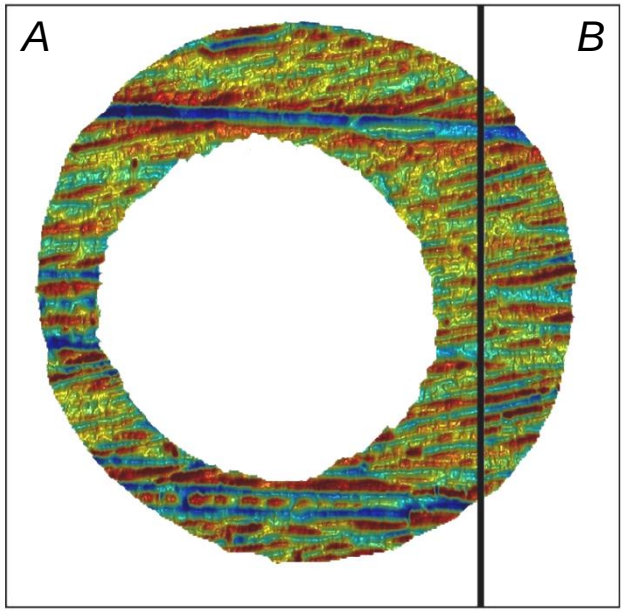
3 Scores







3x Scores FPM



3x Scores BFM

Towards a likelihood ratio (LR)

The LR represents the ratio between the probability to observe the comparison results (*E*) under two different hypothesis: H_1 : The cartridge cases are fired by the same firearm *versus* H_2 : The cartridge cases are fired by different* firearms

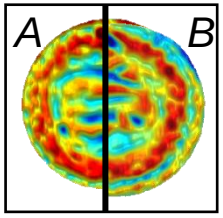
$$LR = \frac{\Pr\left(E \middle| H_1, I\right)}{\Pr\left(E \middle| H_2, I\right)}$$

Within distribution: Results of comparisons between cartridge cases fired by the same firearms

Between distribution: Results of comparisons between cartridge cases fired by different* firearms

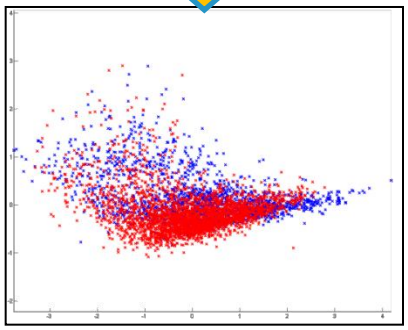
Evaluate the results (E) of a comparison as a ratio of the likelihoods under both propositions invoking the *within* and the *between* distributions.

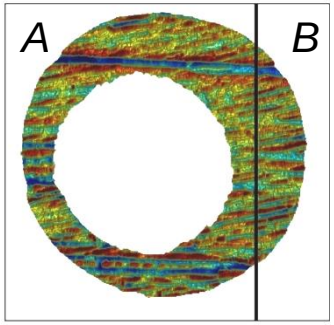
Reduction to two dimensions by PCA



within + *between*
using 3 scores

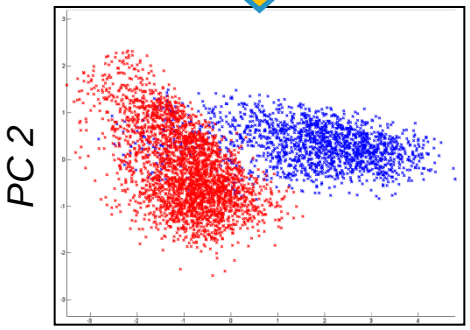
PCA

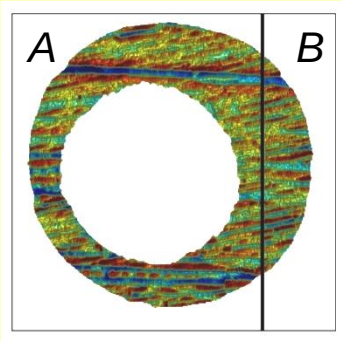




within + *between*
using 3 scores

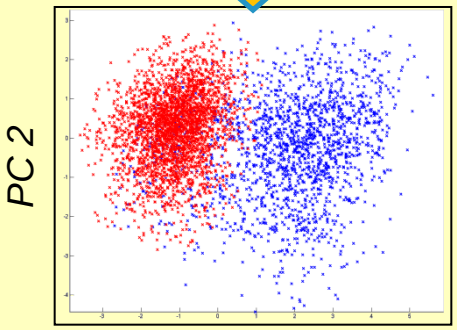
PCA



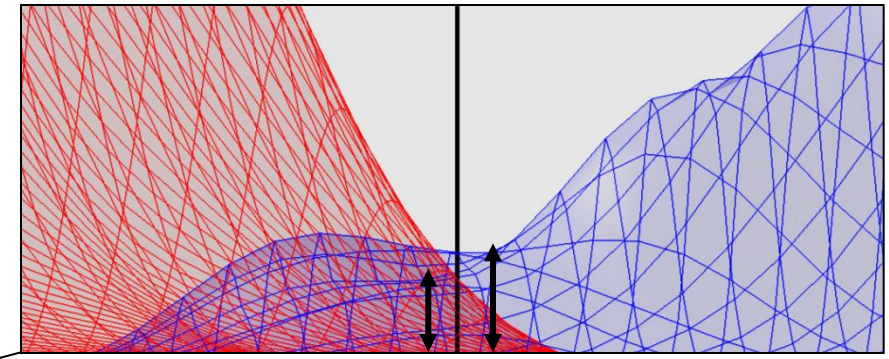


within + *between*
using 6 scores (3xFPM + 3xBFM)

PCA

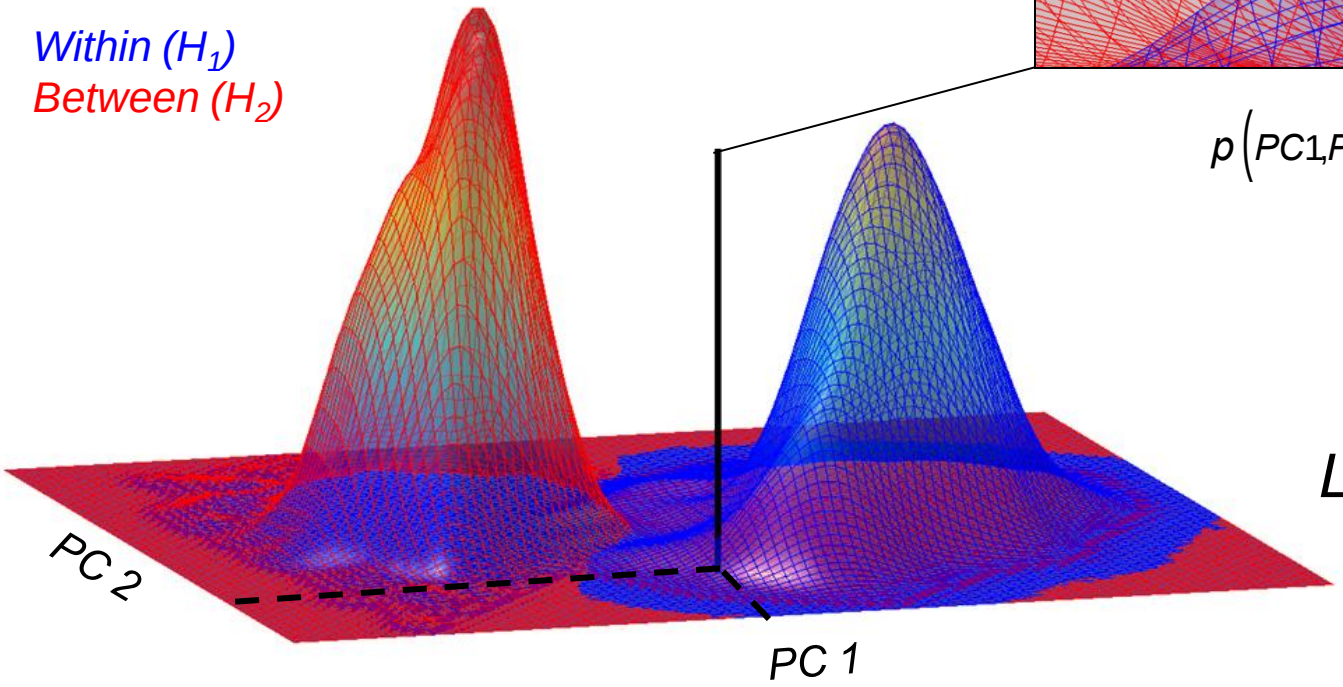


Bi-dimensional case



$p\left(PC1,PC2\middle|H_2\right)$ $p\left(PC1,PC2\middle|H_1\right)$

Within (H_1)
Between (H_2)

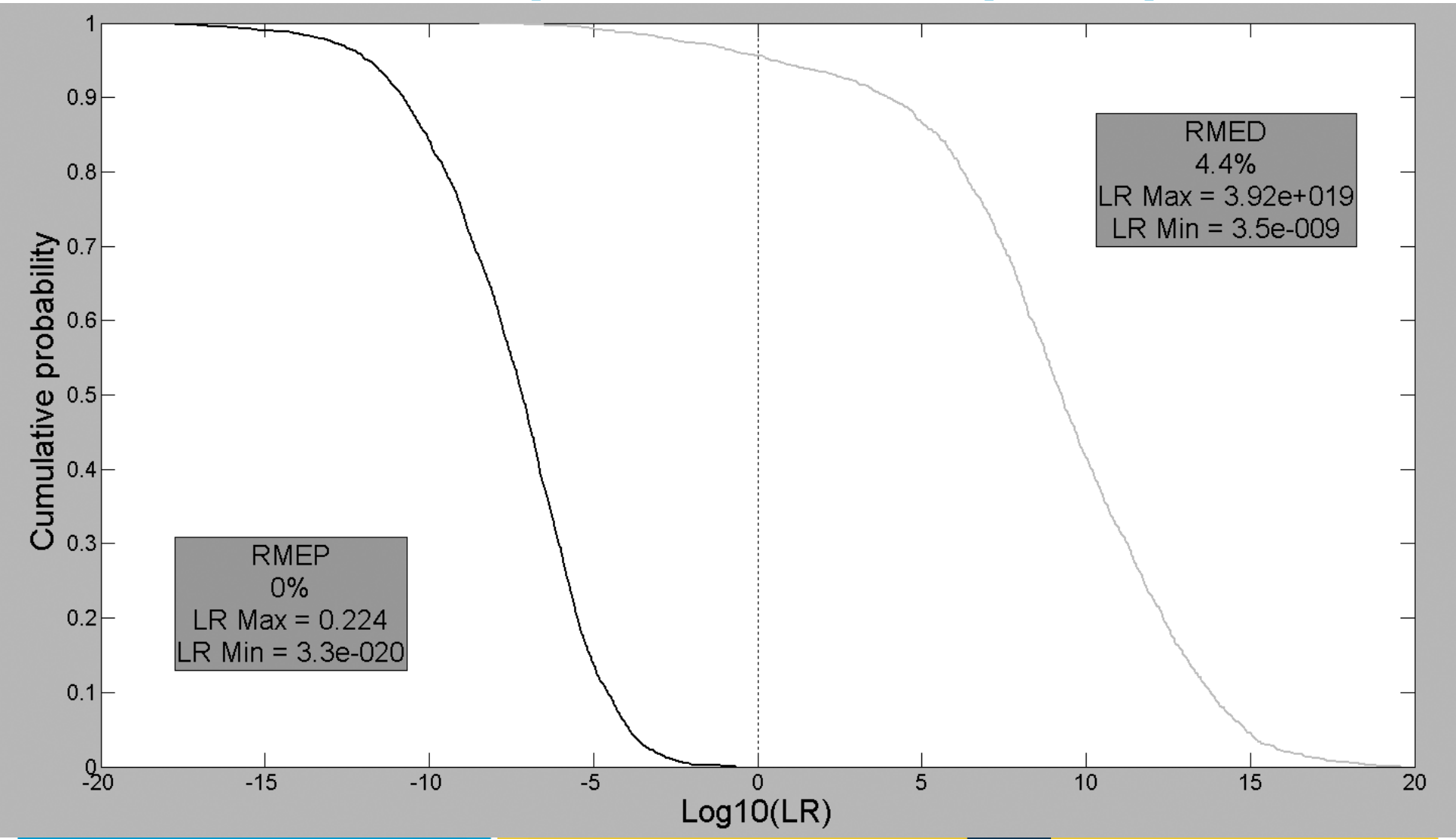


$$LR = \frac{p\left(PC1,PC2\middle|H_1\right)}{p\left(PC1,PC2\middle|H_2\right)}$$

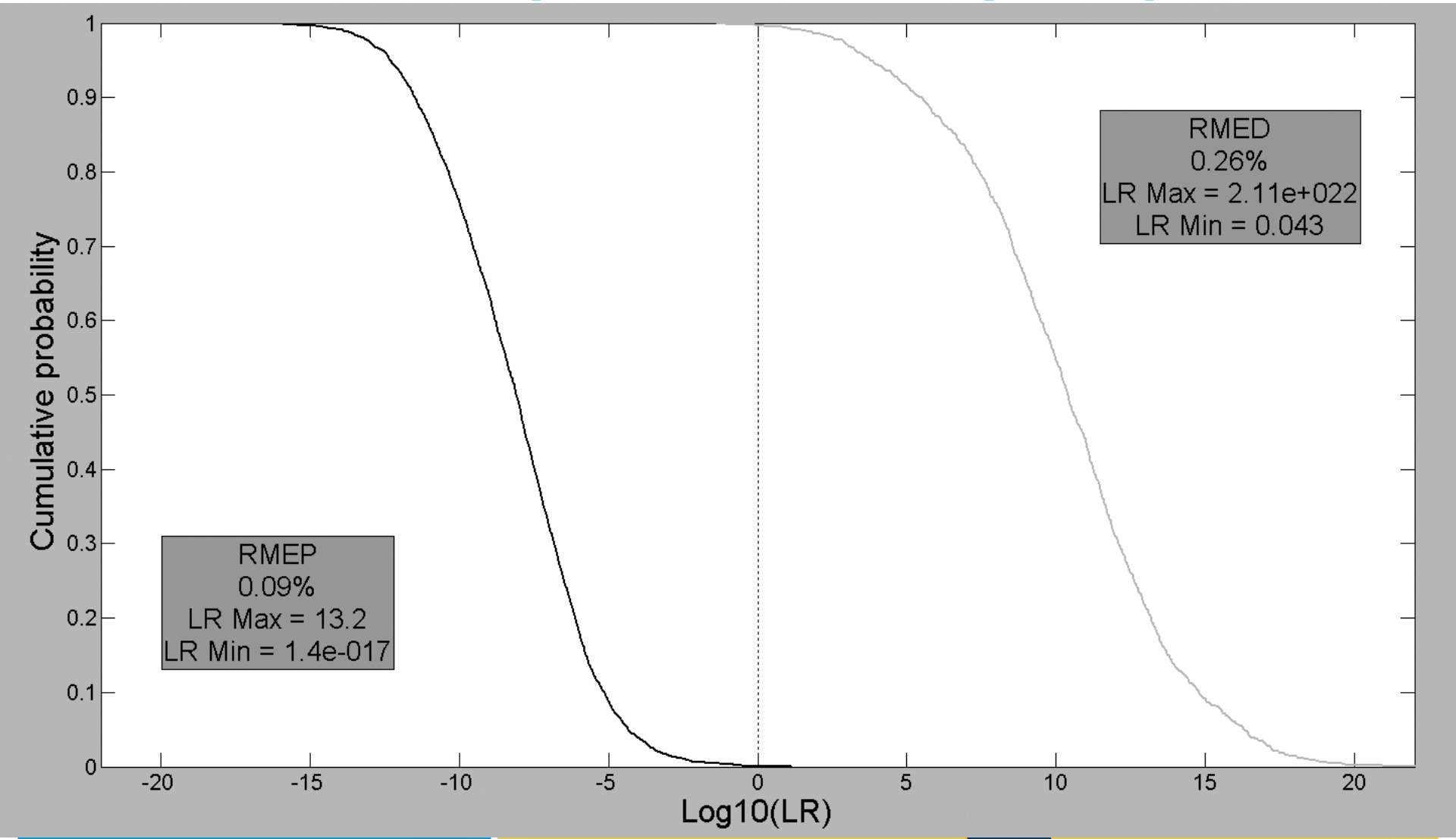
Samples used initially

Firearms	Manufacturer	Model	Ammunition Type	Quantity of cartridge cases
Within N°1 (firearm W1)	SIG Sauer	P228	Geco Sintox 9 mm Luger	60 from one firearm
Within N°2 (firearm W2)	SIG Sauer	P226	Geco Sintox 9 mm Luger	60 from one firearm
Between	SIG Sauer	P226 (42), P228 (14), and Sig Pro (23)	Geco Sintox 9 mm Luger	79 from 79 firearms

Overall performances (P228)

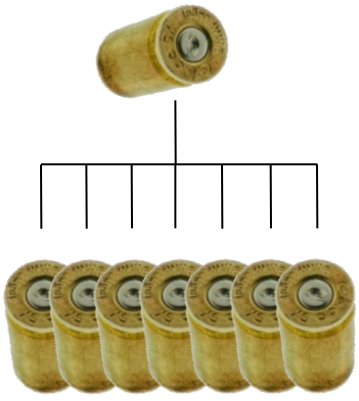


Overall performances (P226)



Methodology for an operational application

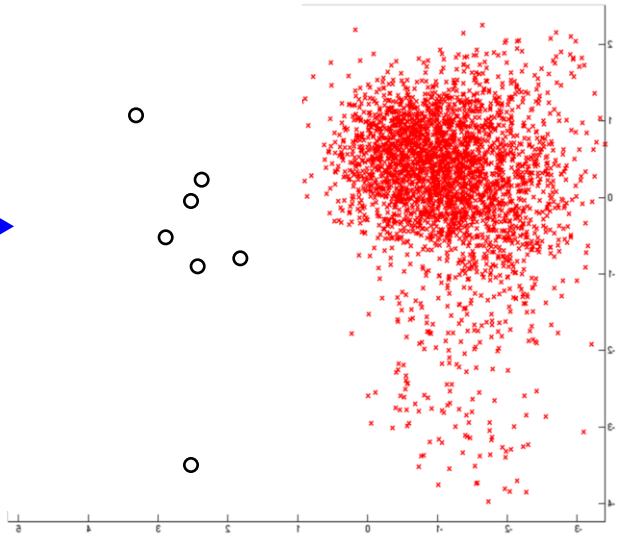
Questioned cartridge case



Suspected firearms

Within

Between



Towards an operational application

- ***Ammunition influence***: Is it possible to make abstraction of the type of ammunition?

- ***Faster establishment of the within distribution***: Can we use a limited number of samples to establish the *within* distribution?

- ***Generalization of the between distribution***: Has the *between distribution* to be re-established for each case?

Additional data to test the different options

- *Within* distribution
  - Firearm W1 (SIG Sauer P228)
    - **60 Geco**, 60 Geco SX, **60 Winchester, 60 Fiocchi**
  - Firearm W2 (SIG Sauer P226)
    - **60 Geco**, 60 Geco SX, **60 Winchester, 60 Fiocchi**

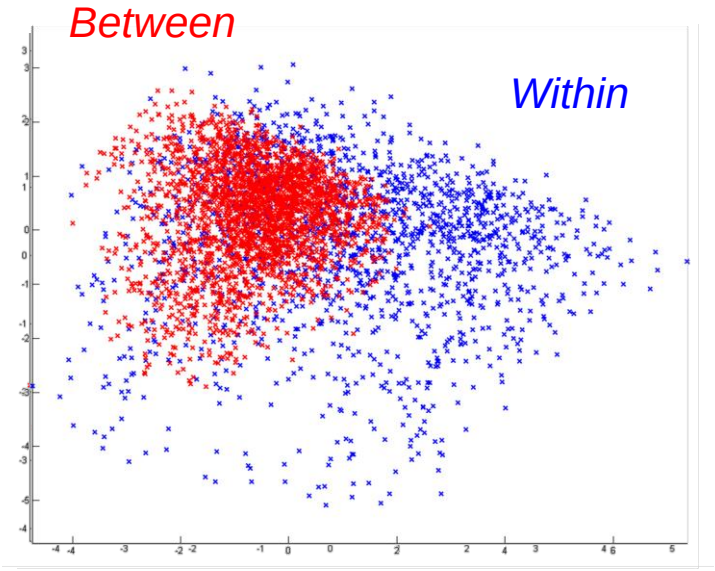
8x Within of 1770 comparisons

- *Between* distribution
  - 79 firearms (SIG Sauer P226,P228,Pro)
    - **79 Geco**, 79 Geco SX, **79 Winchester**, **79 Fiocchi**

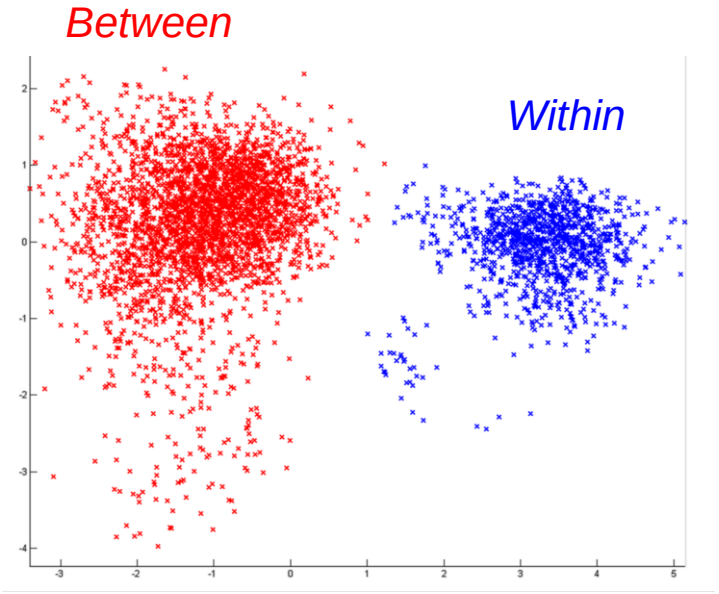
4x Between of 3081 comparisons

Effect of Ammunition

Examples: Geco vs Geco SX and Winchester vs Geco SX



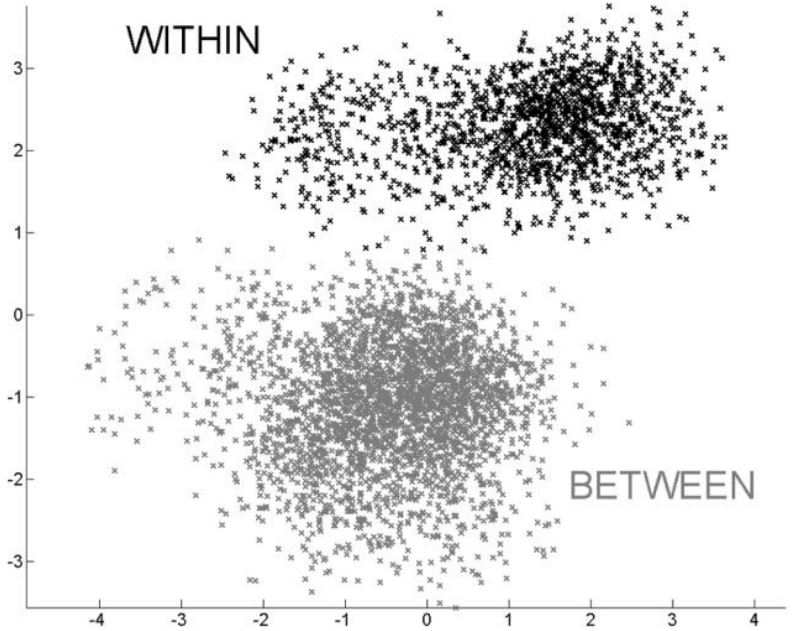
Winchester vs Geco SX



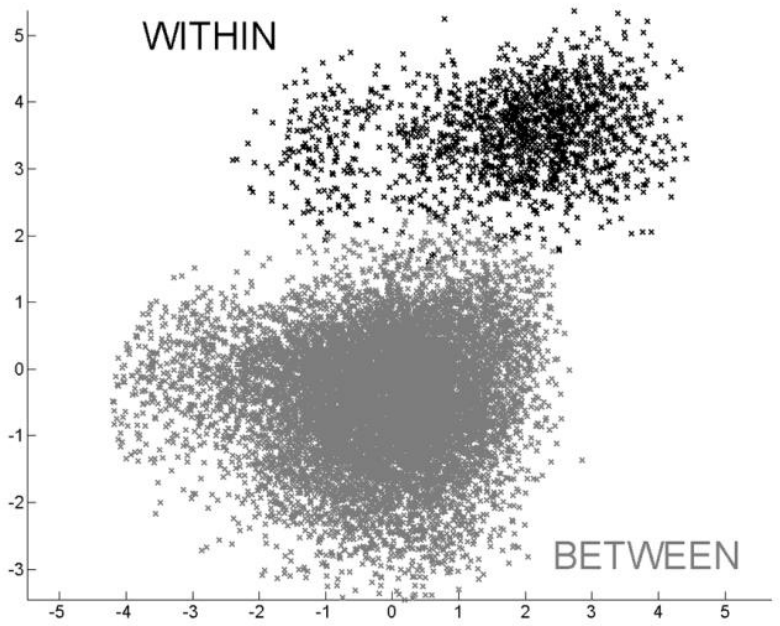
Geco SX

Generalization of the *between* distribution

- Comparison between the LRs calculated using the *between* distribution established with one ammunition (A) and with four ammunition types (A+B+C+D) .



(A)

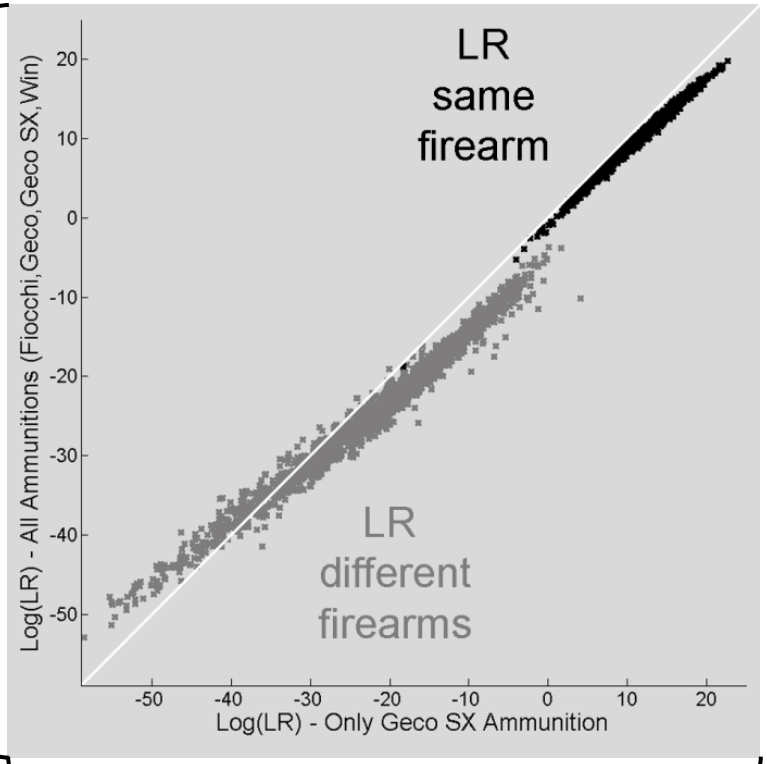


(A+B+C+D)

Generalization of the between distribution

High correlation supports the use of a ”general *between* distribution”

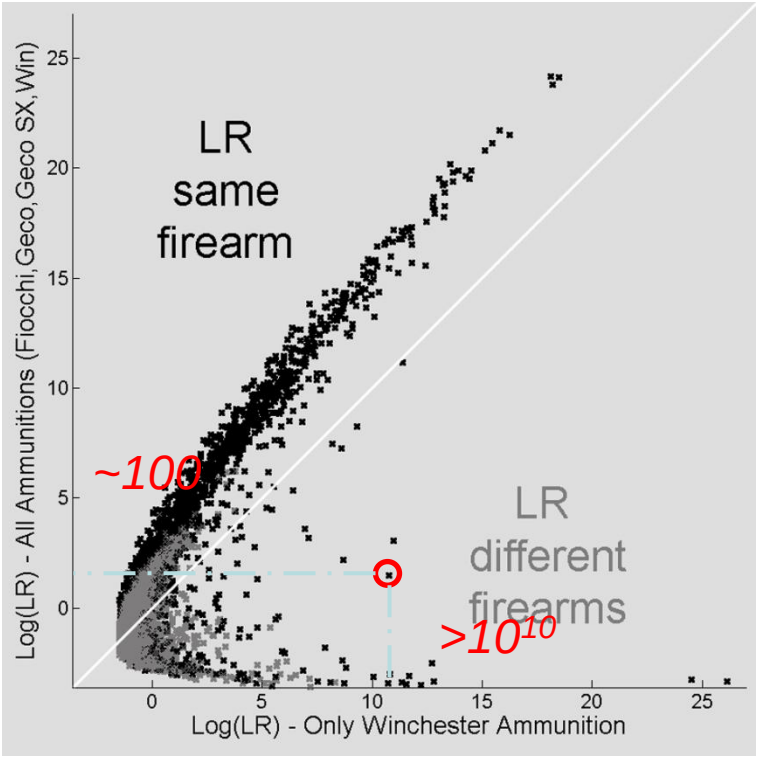
LRs calculated using the Between established with 4 ammo types



LRs calculated using only the Between established with Geco SX

Generalization of the between distribution

Low correlation leads to an under- or – overestimation of the LRs



Conclusions

- This system offers an objective measure of the weight of evidence (LR). It is characterized by low rates of misleading evidence (RMED and RMEP).
- The LRs that it provides are very indicative of the true state.
- From an **operational perspective**:
  - The *within* distribution can be established using a limited number of samples (7 cases) without adverse consequences (stable RMEP and RMED).
  - If available, the *between* distribution has to be established using the same type of ammunition.