

# Repeatability of high velocity crash tests

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## Abstract

Most of time, we have only one physical test to estimate the safety capacity of a vehicle face to a crash test. Moreover, we know that the test is hardly duplicated. Unfortunately, we don't know how the response of the crash test is spread because we only have one result. And, we don't know if this only response is favorable or unfavorable.

PSA, Peugeot Citroen manage to reproduce the efficient dispersion of physical crash test with simulations tools. Indeed, we realize several tests on frontal and lateral crash on the same car in order to estimate the dispersion of the results. Then, thanks to the growth of the numerical simulations, and using the physical results, we perfect a methodology to estimate this non-repeatability for a project which is in development by using Monte Carlo on RADIOSS simulations. So, rather than to form a car using one result, now it's possible to use the distribution of the results. And so , thanks to the position of the unique numerical results on distribution of the non repeatability of the crash test, we can refine our vehicle concept.



# Repeatability of automotive crash-test - Correlation between simulation and test

# PROBLEM

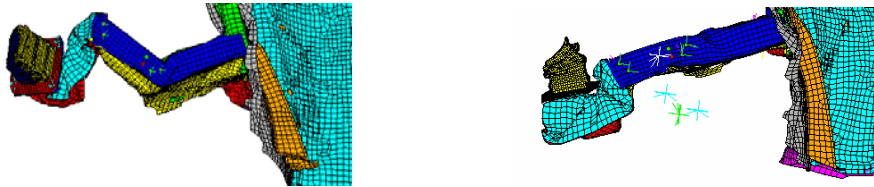
- What are the dispersions in high speed frontal and lateral crash test ?
- Is it significant ?
- Is it possible to simulate these dispersions ?

# SYNOPSIS

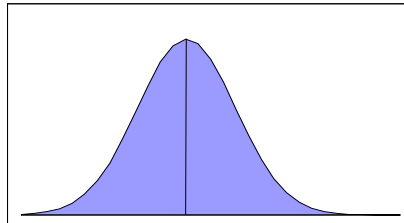
- Definition
- Repeatability
- Correlation between simulation and test
- Assessment / prospect

# DEFINITIONS

⇒ **Robustness** : repeatability of a scenario (*example : comportment of a sidemember*)



⇒ **Dispersion** : width of the response (*a robust vehicle may be more or less dispersive, a vehicle not robust will generate dispersion*)



⇒ **Numeric dispersion** : dispersion due to the solver itself (*only numeric parameters*)

# STATE OF ART

- PSA Peugeot-Citroën has made a sled campaign to evaluate the repeatability of a full car crash-test.
- 12 tests in frontal impact crash-test on a large vehicle in 5 laboratories
- 15 tests in side impact crash test on a large vehicle in 5 laboratories
- Sample satisfactory but not enough for statistic theory

# RESULTS BEFORE IMPACT

## ⇒ For frontal impact :

- ⇒ The velocity varies from + 0,6 km.h<sup>-1</sup>
- ⇒ The barrier position in width and height varies between -15 mm and + 15 mm
- ⇒ The mass of the vehicle varies from 7 kg (with a repartition between the front and the rear of 20 kg)
- ⇒ ...

## ⇒ For side impact :

- ⇒ The velocity varies from + 0,6 km.h<sup>-1</sup>
- ⇒ The barrier position in width and height varies between -10 mm and + 10 mm
- ⇒ The dummy position varies between -10 and + 20 mm (point H)
- ⇒ ...

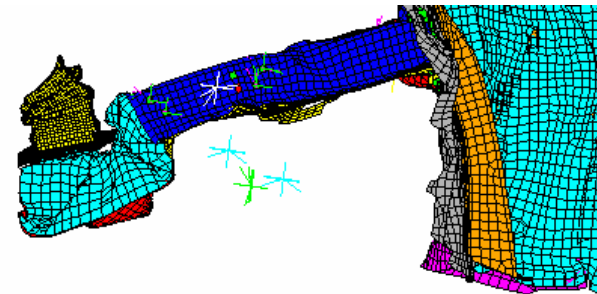
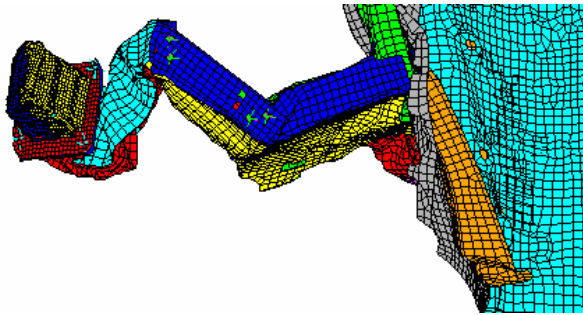
⇒ All these values are allowed by the protocol

# RESULTS AFTER IMPACT

- ⇒ For frontal impact :
  - ⇒ 2 modes of deformations of the side member and of the aperture

# RESULTS AFTER IMPACT

→ For frontal impact :



# RESULTS AFTER IMPACT

## ⇒ For frontal impact :

- ⇒ 2 modes of deformations of the side member and of the aperture
- ⇒ A variation until 40 mm of bulkhead intrusions
- ⇒ A variation until 50 ms of the rupture of the engine attachment
- ⇒ A difference of 160 mm of vehicle sinking
- ⇒ A contact moment between the wheel and the beam which varies from 30 ms
- ⇒ Chest deflection varies from 10 mm

## ⇒ For side impact :

- ⇒ Door and B-Pillar's intrusions varies from 40 mm
- ⇒ Velocities varies from 1,5 m.s-1
- ⇒ Thoracic deflection varies from 10 mm

# STATE OF ART

⇒ Significant differences are generated by repeatability.

The analysis of the database of tests show :

- ⇒ Protocol parameters are preponderant (mass, velocity, position...). These parameters are measured
- ⇒ Quid of vehicle parameters (material tolerance) which have not been measured
- ⇒ No relation between parameters couldn't be found : it is indeed a chaotic result

⇒ Need of simulate these uncertainties with the simulation tool

⇒ 2 conditions are necessary :

- ⇒ The uncertainty of the simulation itself must be lower than the physical uncertainty
- ⇒ Statistic methodology to reproduce these dispersions

# NUMERIC DISPERSION

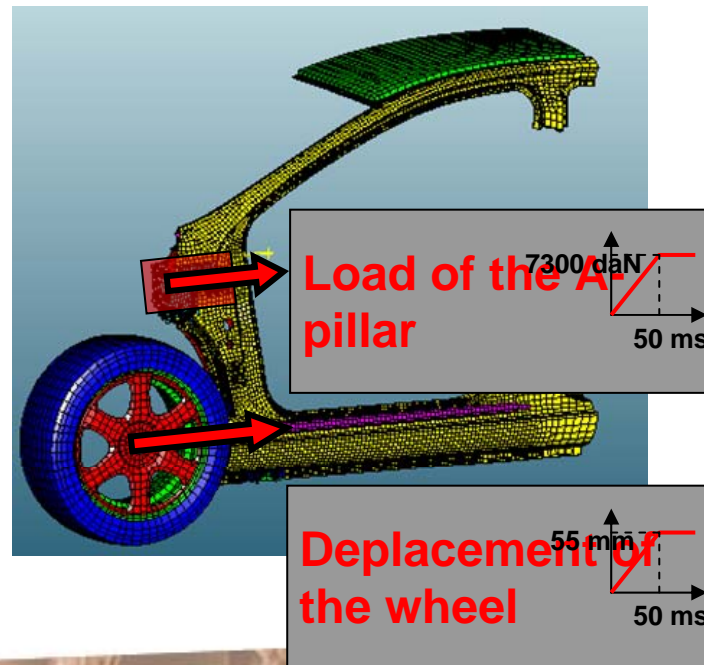
- Adjustment of some parameters of the model which are only numeric :
  - Variation from 10 % of the time step control
  - Contact rigidity factor
  - Rigidity of the end of the articulation
  - Random noise on the coordinates of the nodes of 1 micrometer
  - ...

# NUMERIC DISPERSION

- Numeric dispersion is negligible on full side impact car crash
- Numeric dispersion is weak on subsystem

# NUMERIC DISPERSION

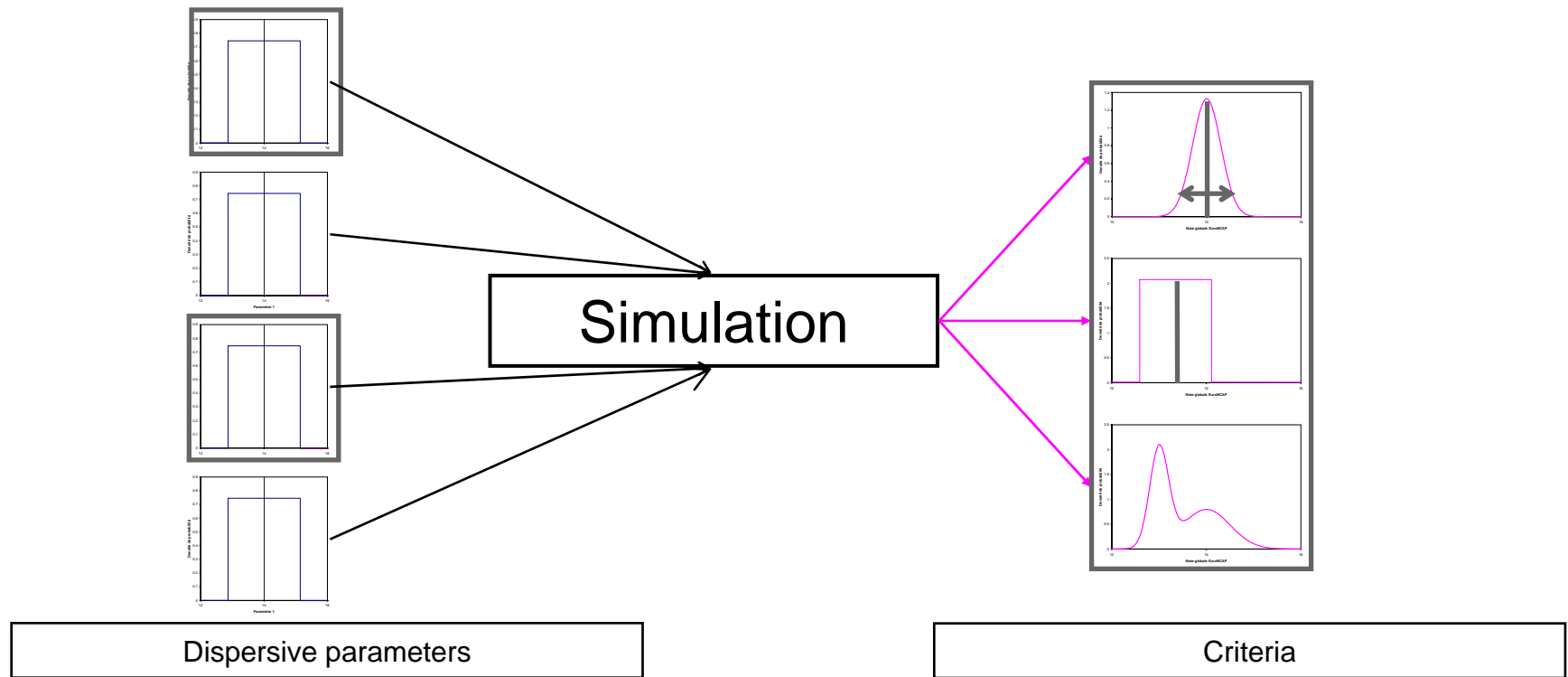
- Numeric dispersion is negligible on full side impact car crash
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# NUMERIC DISPERSION

- Numeric dispersion is negligible on full side impact car crash
- Numeric dispersion is weak on subsystem
- Numeric dispersion on full frontal car crash generates physical dispersions but lower than in tests dispersions.
- **Observed condition : the tool Radioss gives reproducible results**

# STATISTIC METHODOLOGY



- **Test conditions:**  
Velocity of the barrier or vehicle, position, mass and rigidity of the barrier
- **Structural parts :** widths, material laws, rupture of some parts
- **Cockpit :**  
pressure of the airbags, TTF  
position of the dummy and limitation of the belt load
- **Frontal impact**
  - 3 structural criteria
  - EuroNCAP cotation by segment, conductor and passenger
- **Side impact**
  - Biomechanical criteria
  - EuroNCAP cotation by segment

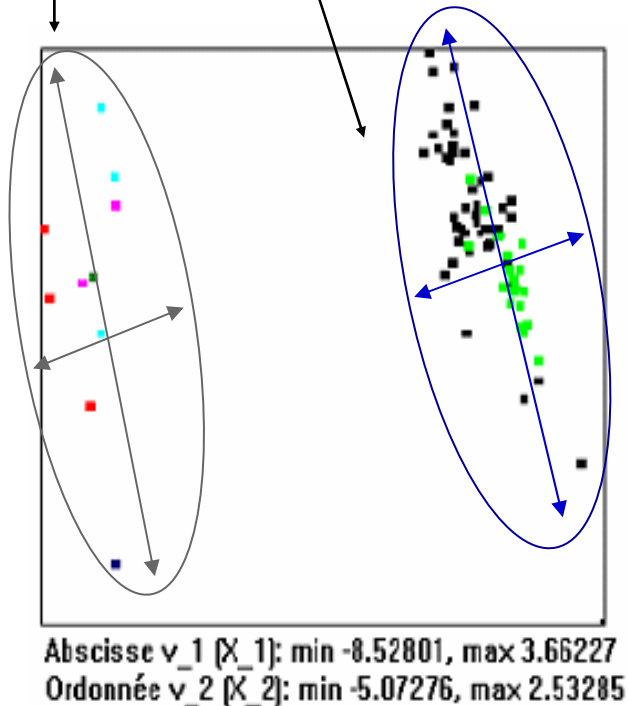
# STATISTIC METHODOLOGY

- ⇒ Monte-Carlo simulation
- ⇒ The numbers of simulation depend on the numbers of the parameters and on the numbers of output criteria
  - ⇒ In our study 100 simulations are necessary because we have almost 40 parameters and criteria
- ⇒ Hypothesis of linearity between input and output
- ⇒ All of the input law are supposed to be Gaussians
- ⇒ Possibility to re-estimate the outputs according to the input law
- ⇒ Tool of pre/post : Isight (society Engineous)

# STATISTIC METHODOLOGY

*Set of points of the test*

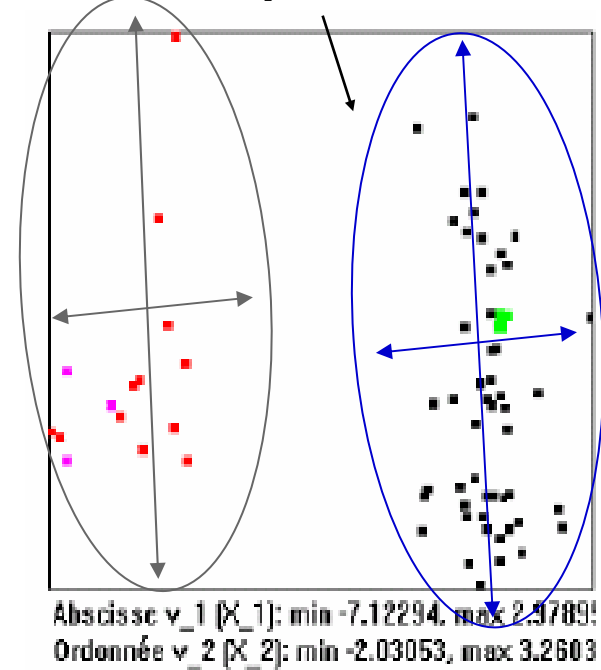
*Set of points of the simulation*



Frontal impact

*Set of points of the test*

*Set of points of the simulation*

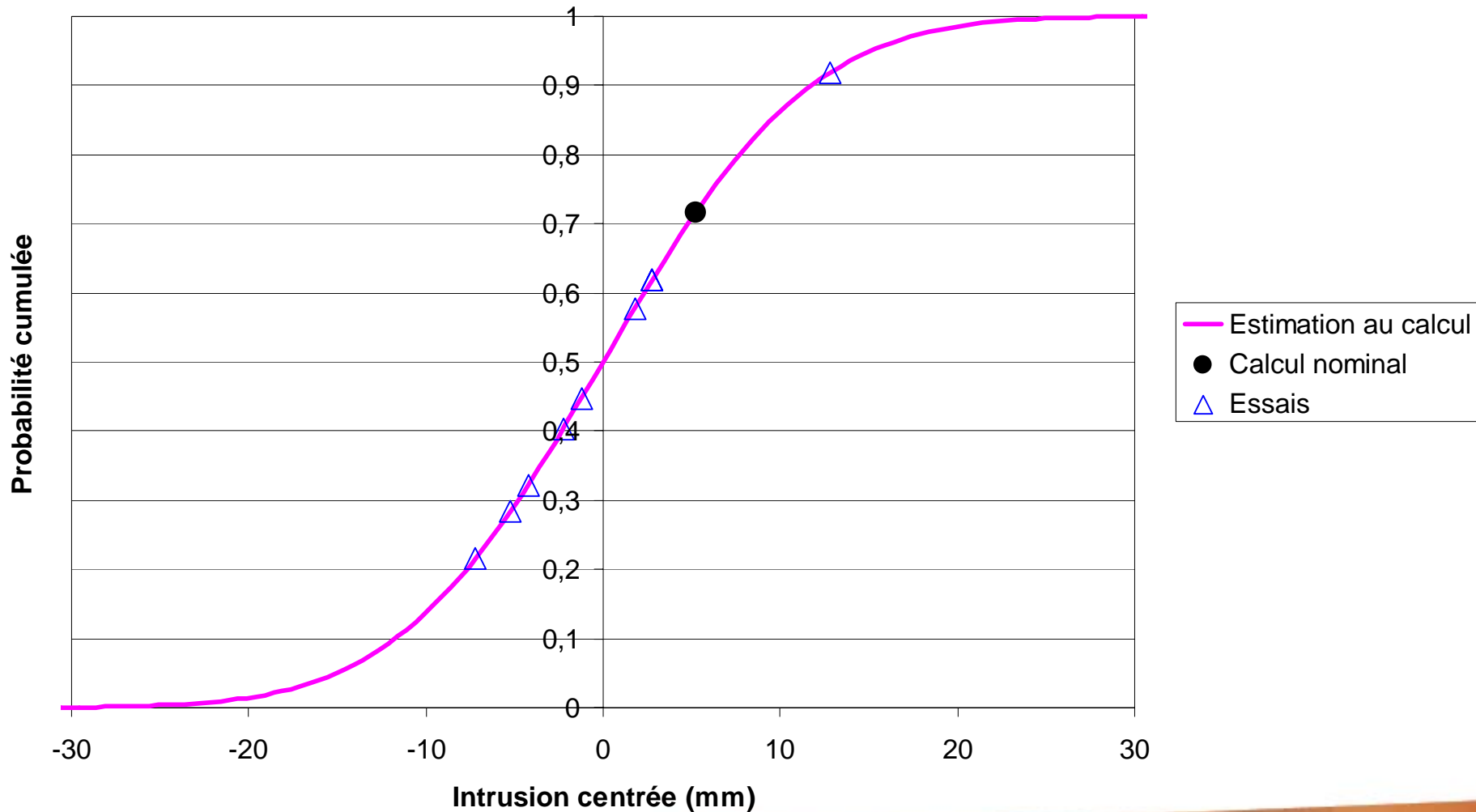


Side impact

Principal Component Analysis of all the  
output criteria

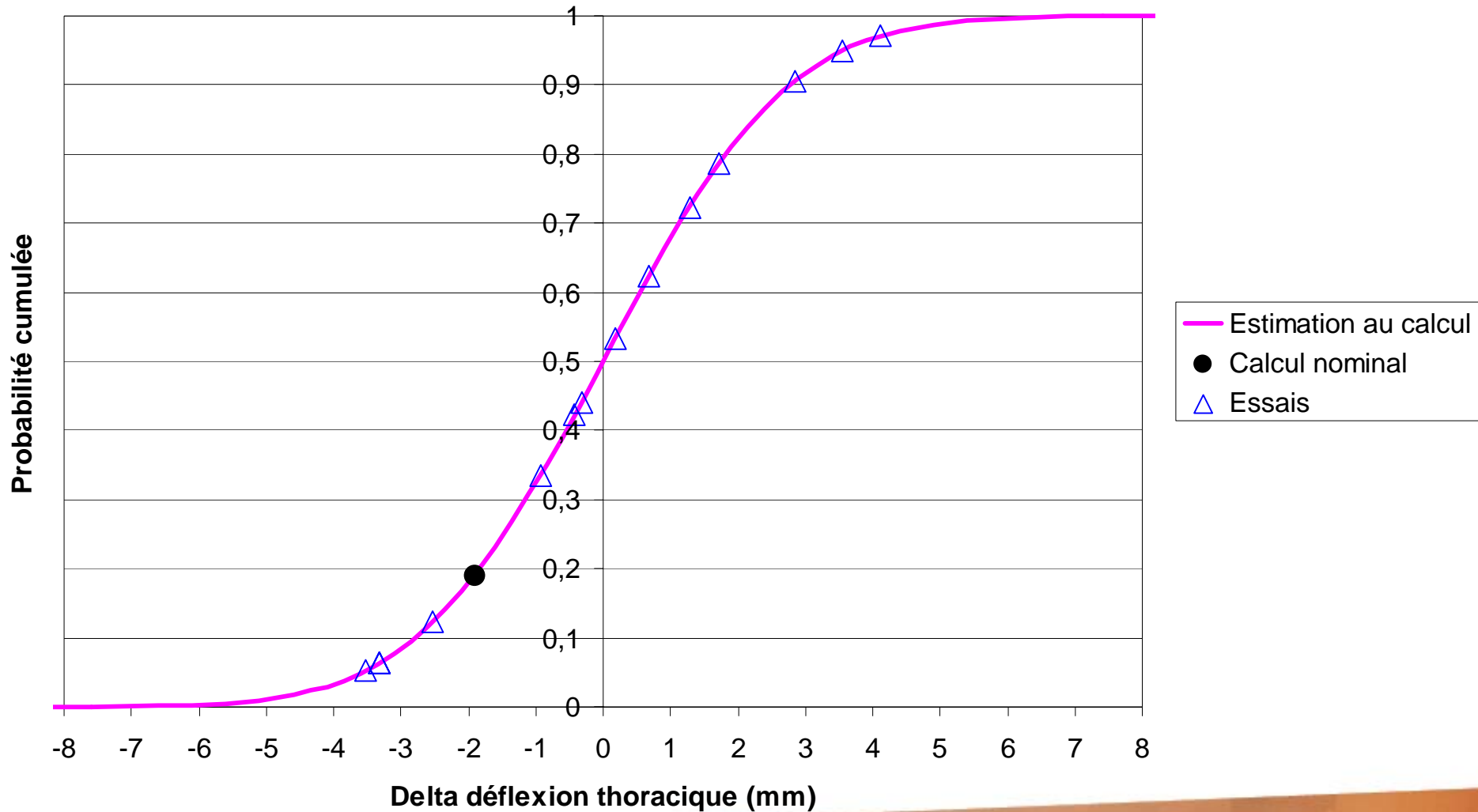
# Results on a large vehicle

Ex : intrusion of a bulkhead point for frontal impact



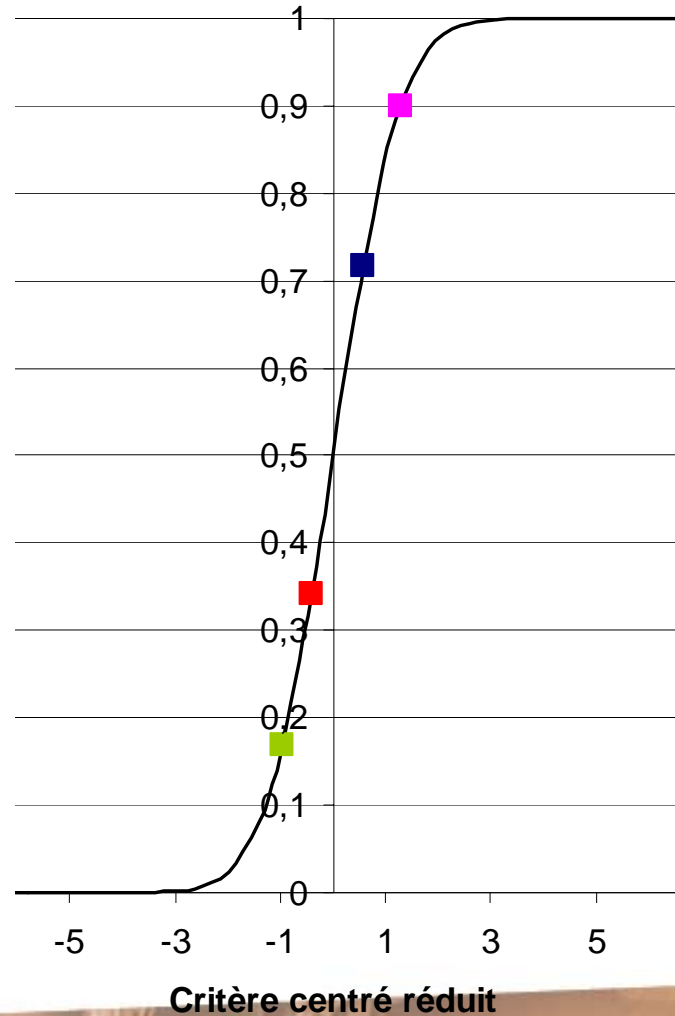
# Results on a large vehicle

Ex : Thoracic deflection for the side impact



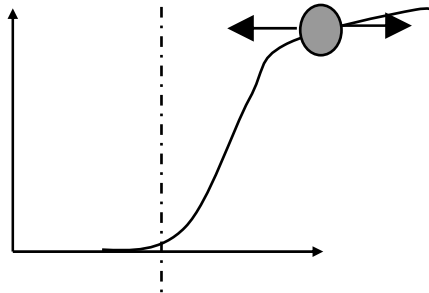
# Applications on new vehicle

Ex : intrusion of a bulkhead point for frontal impact



# SYNTHESIS

- Methodology developed able to reproduce the spread of the dispersion in side and frontal impact
- Methodology allow to know for each criteria the probability law and the position of the nominal simulation



- The limitation is in the method : difficulty to automate of the analysis

# ASSESSMENT / PROSPECT

- **PSA Peugeot Citroën has developed a tool able to reproduce by the simulation the dispersions which are noticed in the tests**
  - **For a criteria, the probability law is known (structural, biomechanical...)**
  - **For each criteria, the position of the nominal simulation is known and his rate of confidence**
  - **This methodology must be improved for another crash (reparability...)**
  
- **The reduction of the dispersions by the vehicle conception is being studied but it seems to be very difficult because of the preponderance of the protocol parameters**

# THANKS

- Frédérique Muyl, expert in optimisation at PSA Peugeot Citroën
- Richard Zeitouni, manager of safety at PSA Peugeot Citroën
- Society EUROBIOS