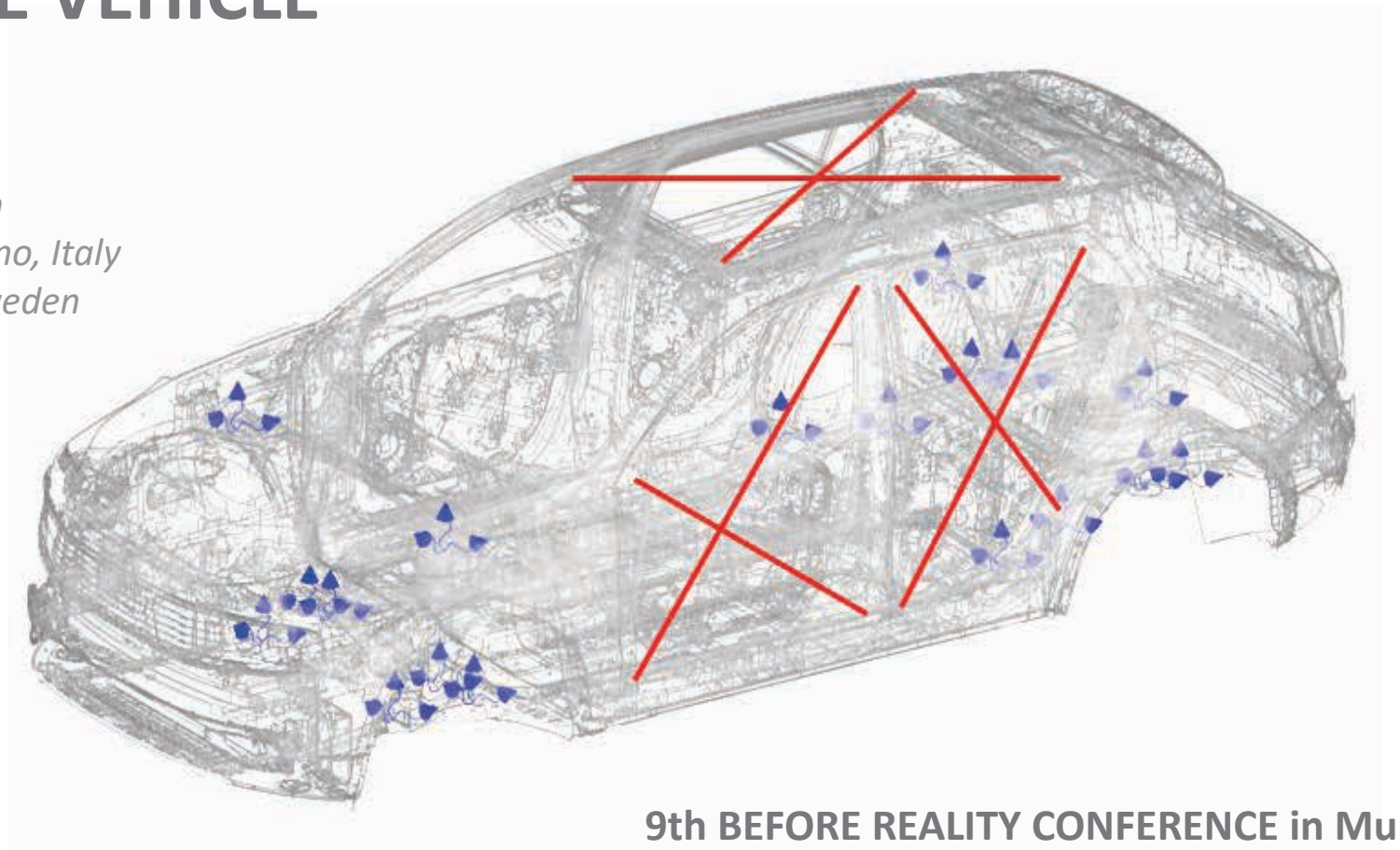
NEW EQUIVALENT STATIC LOAD (ESL) CREATION PROCEDURE FOR COMPLETE VEHICLE

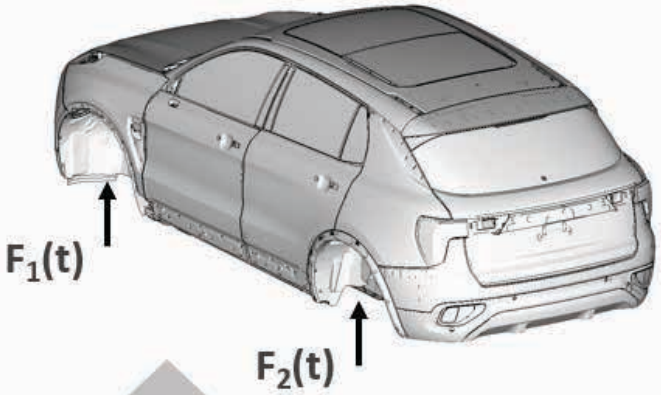
Jens Weber, CEVT AB, Sweden
Luiz Ricardo, Politecnico Milano, Italy
Jesper Bäcklund, CEVT AB, Sweden



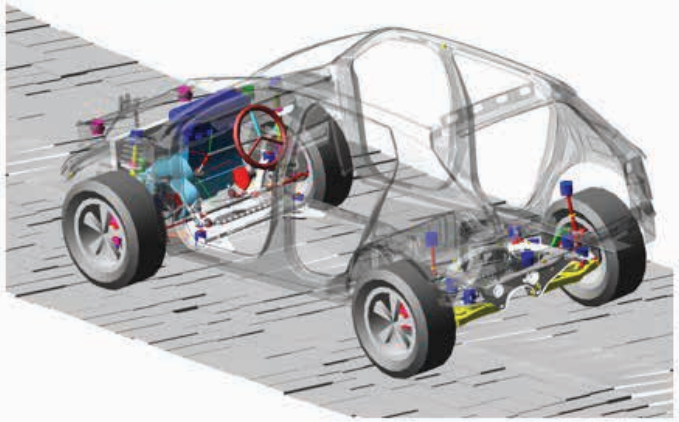
9th BEFORE REALITY CONFERENCE in Munich, Germany
Science Congress Center
June 14 - 16, 2023

CEVT

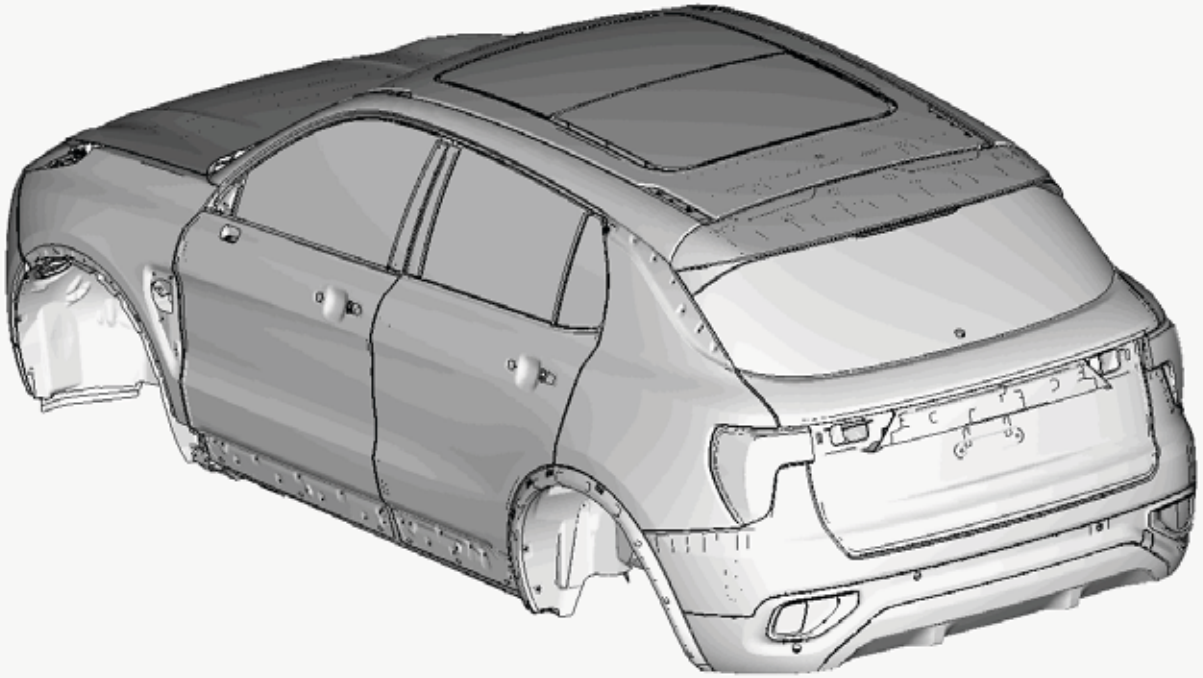
FEM modal transient



MBD



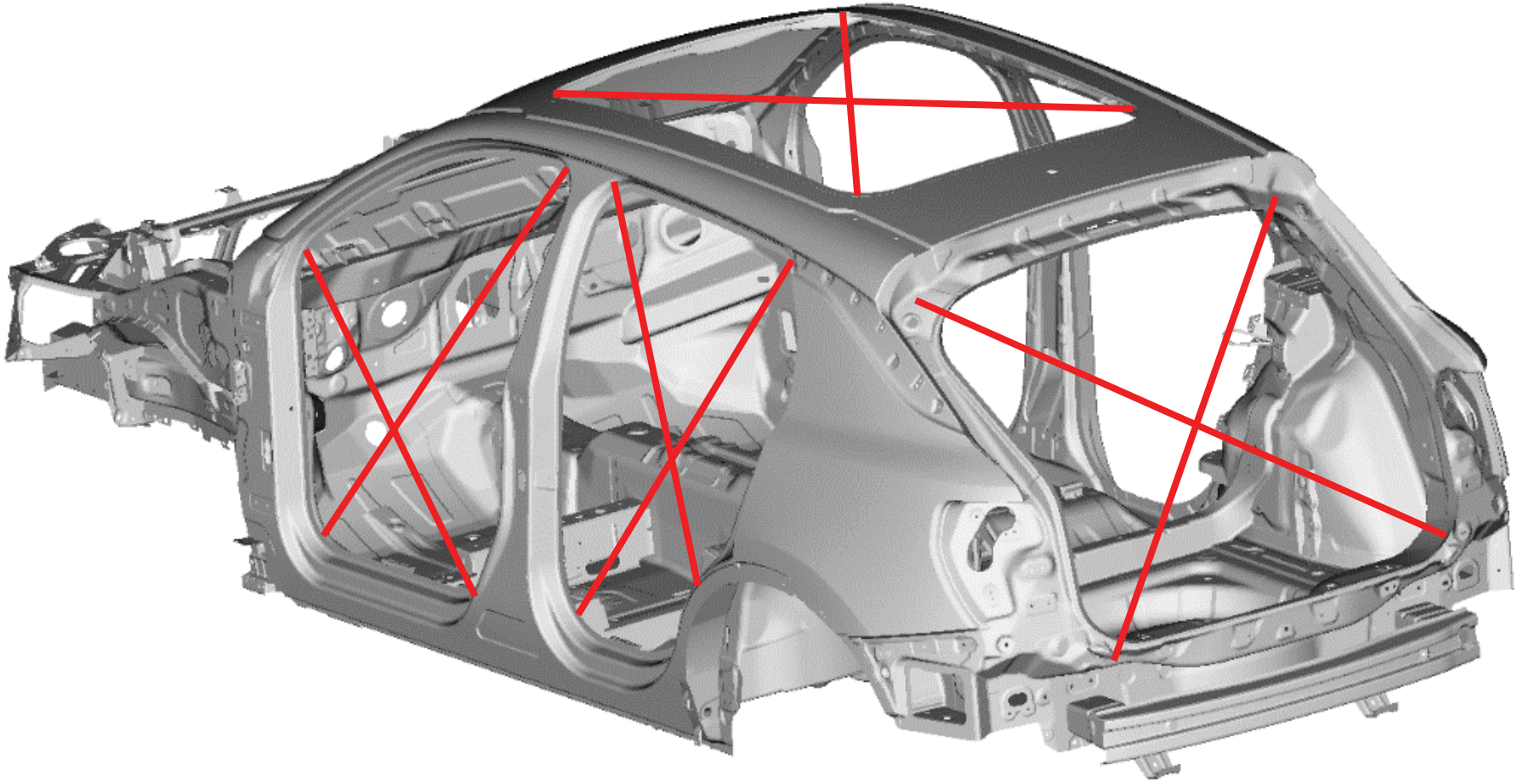
Pavé 30 km/h



Deformation scale factor 50 !

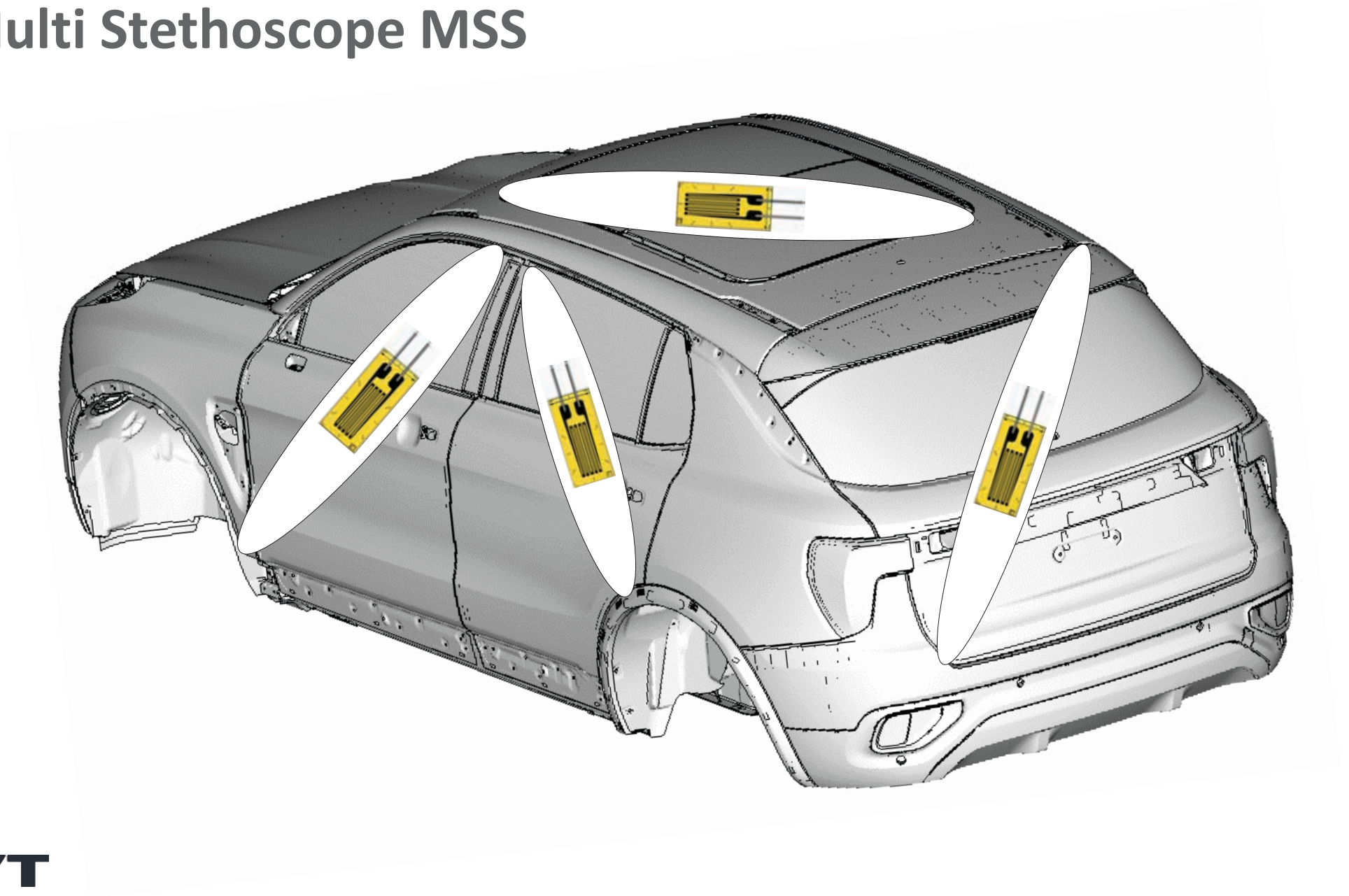
CEVT

Multi Stethoscope MSS



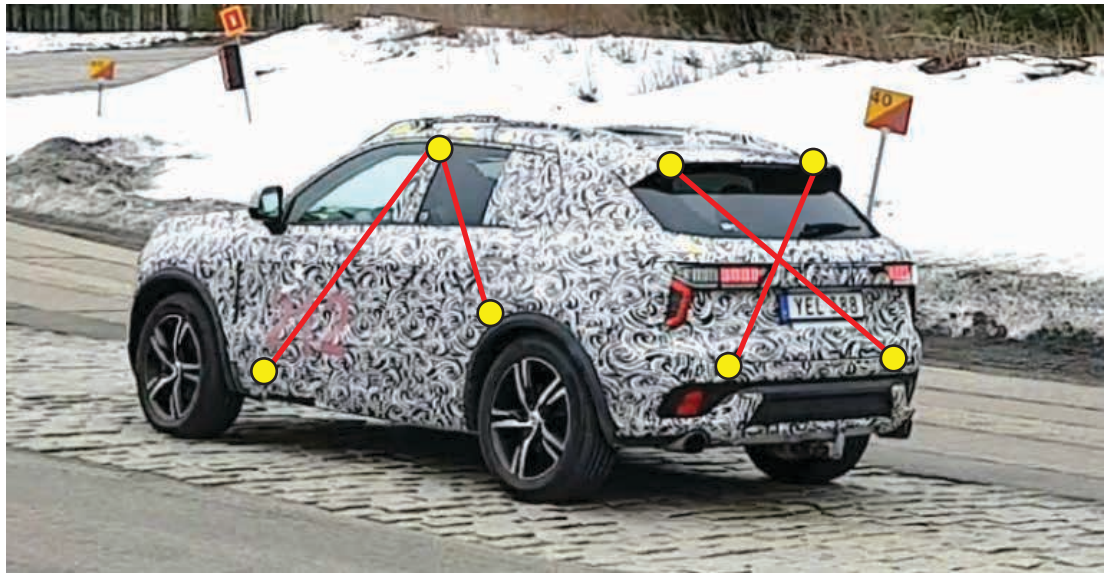
CEVT

Multi Stethoscope MSS



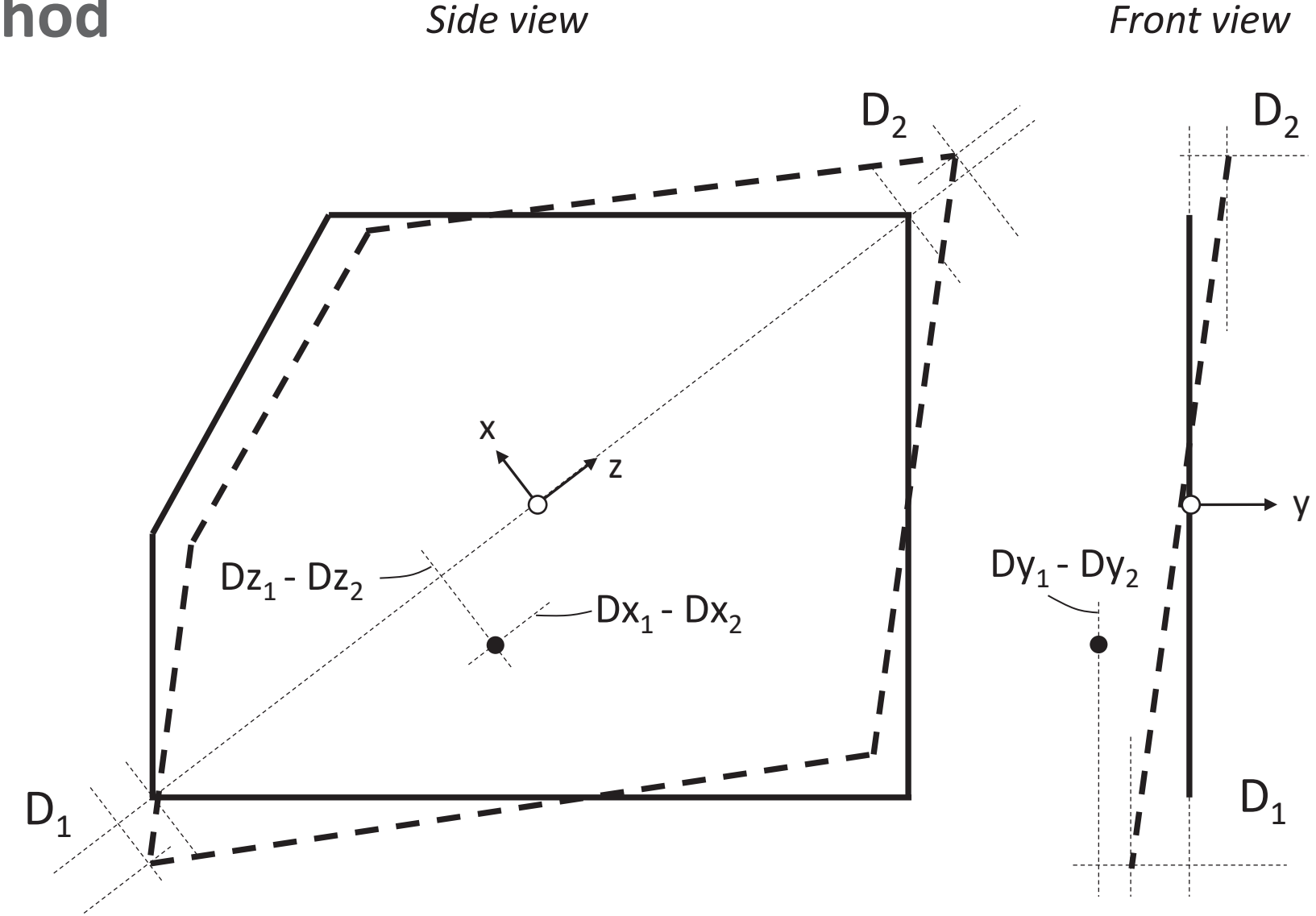
CEVT

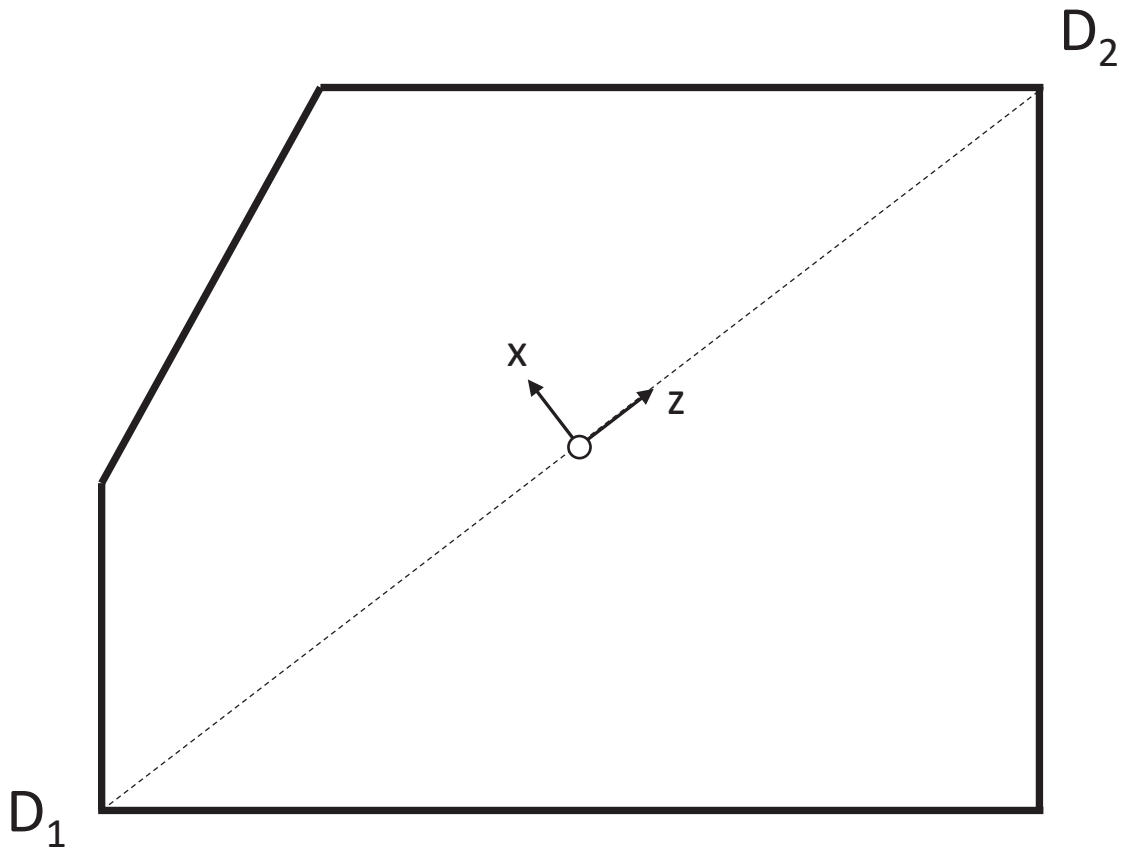
Multi Stethoscope MSS

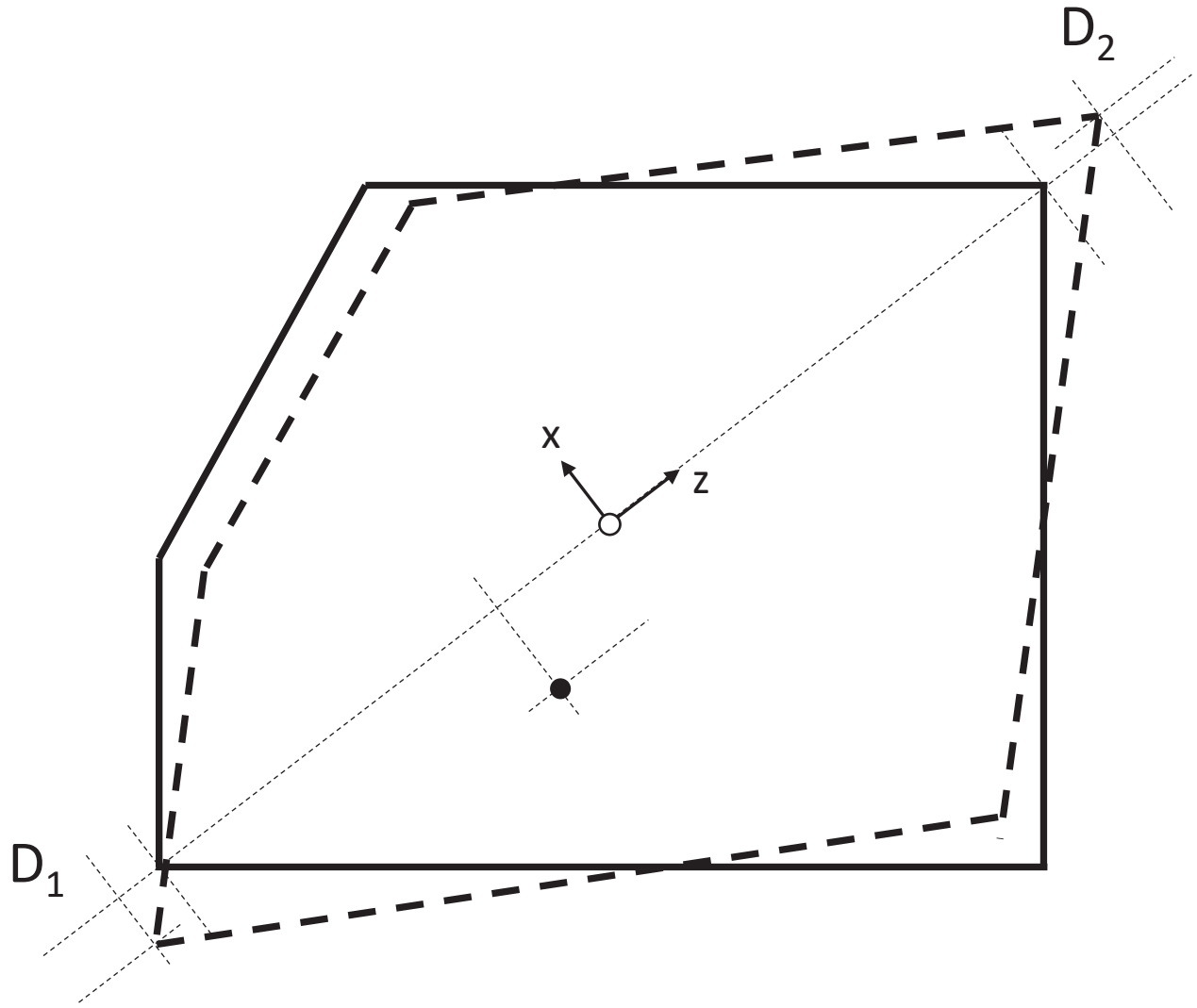


CEVT

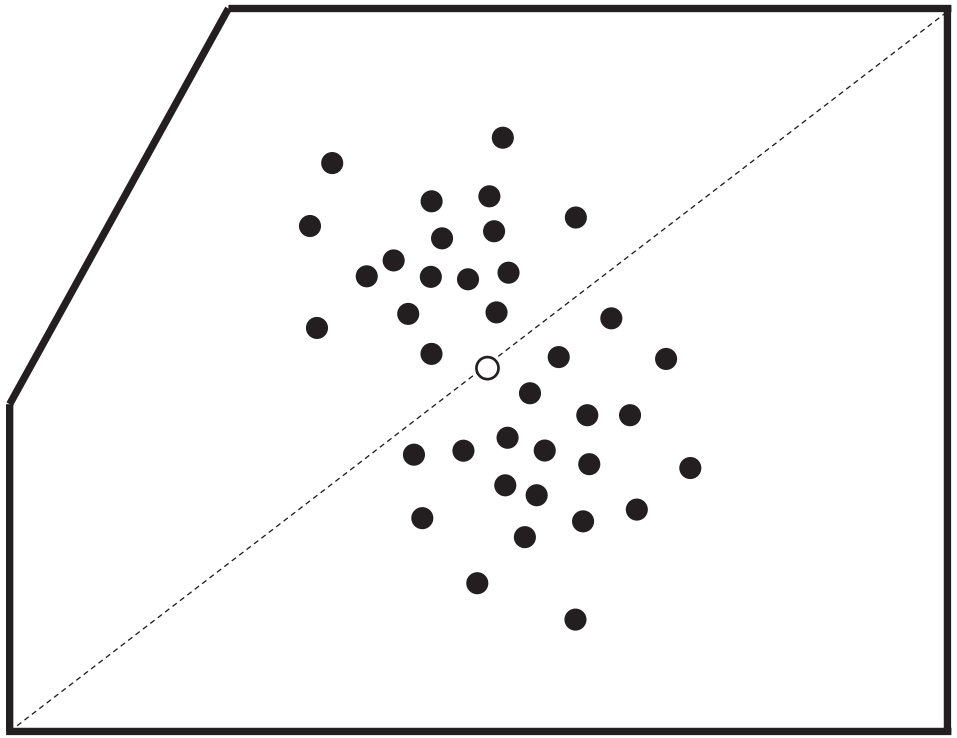
E-line Method

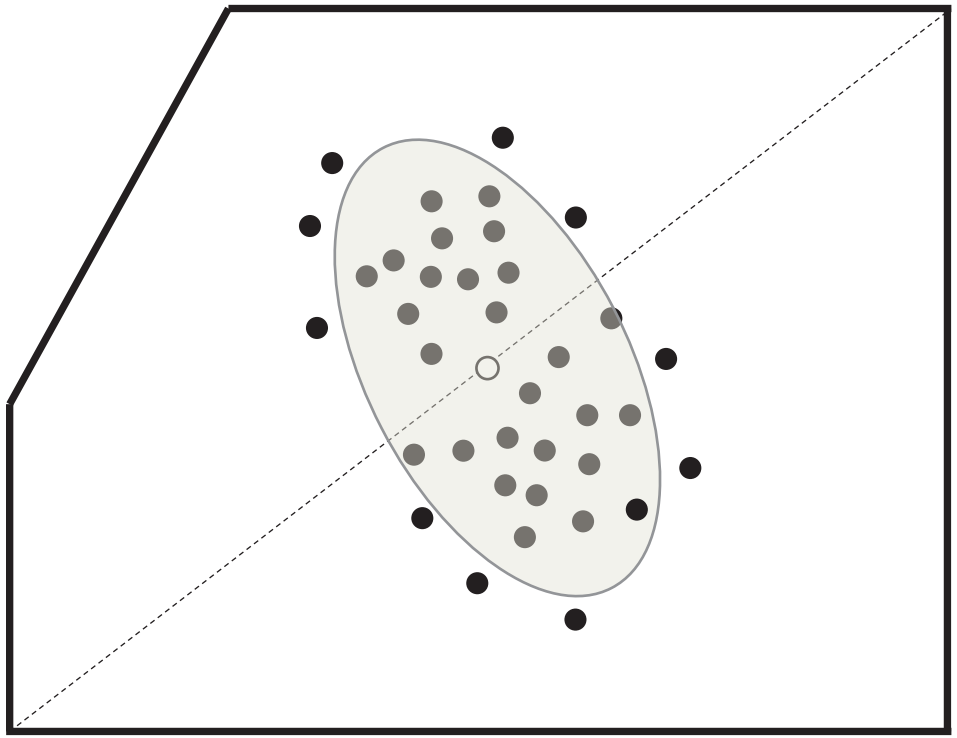


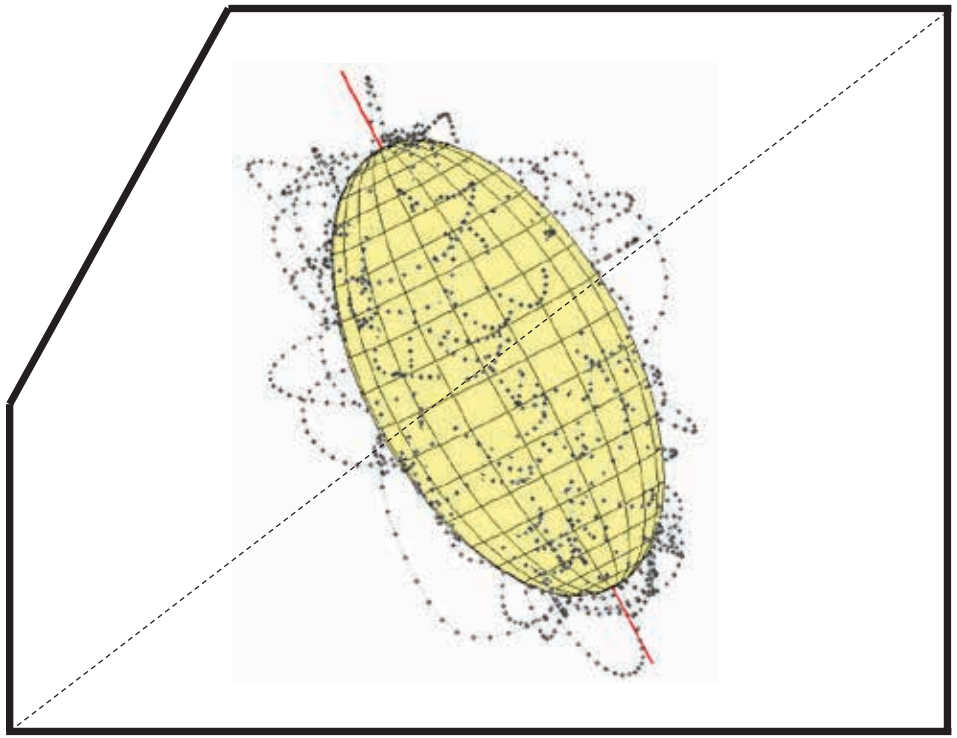

D_2
x
z
D_1

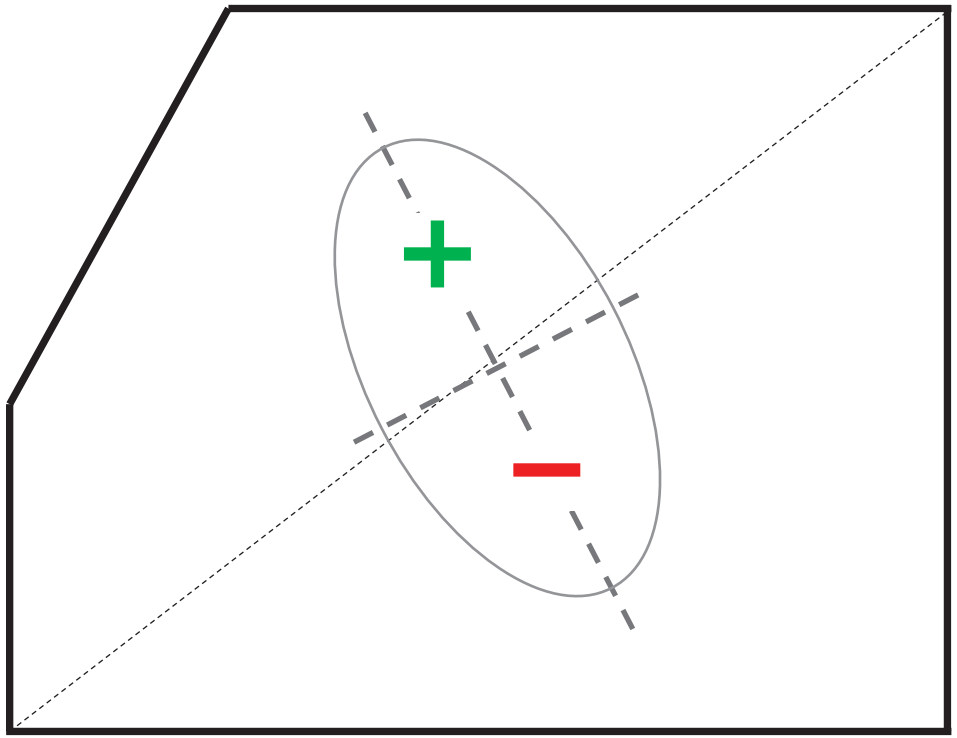


CEVT



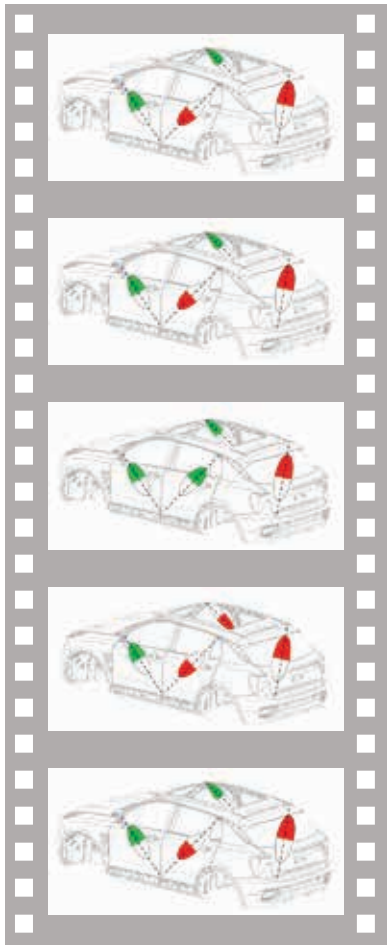






Max Principal Response Vector

MRV

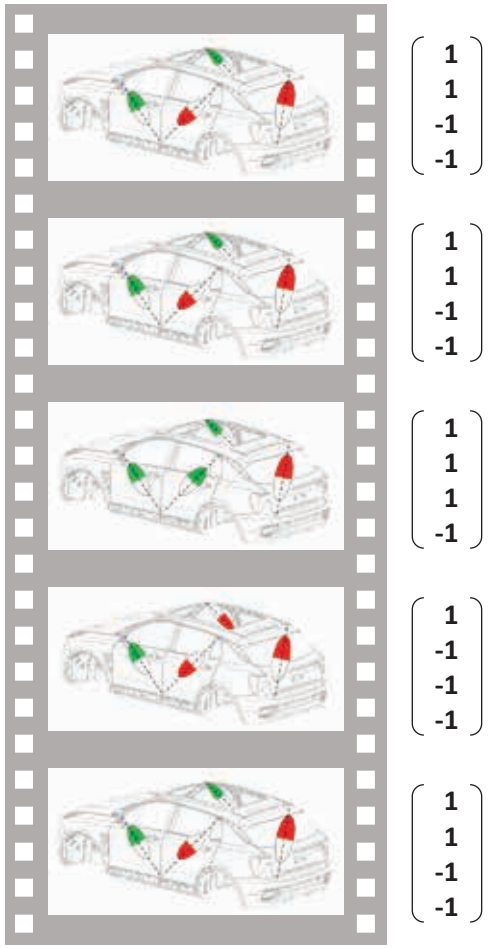


$$\begin{pmatrix} 1 \\ 1 \\ -1 \\ -1 \end{pmatrix} \quad \begin{pmatrix} 1 \\ 1 \\ -1 \\ -1 \end{pmatrix} \quad \begin{pmatrix} 1 \\ 1 \\ 1 \\ -1 \end{pmatrix} \quad \begin{pmatrix} 1 \\ -1 \\ -1 \\ -1 \end{pmatrix} \quad \begin{pmatrix} 1 \\ 1 \\ -1 \\ -1 \end{pmatrix}$$

CEVT

Max Principal Response Vector

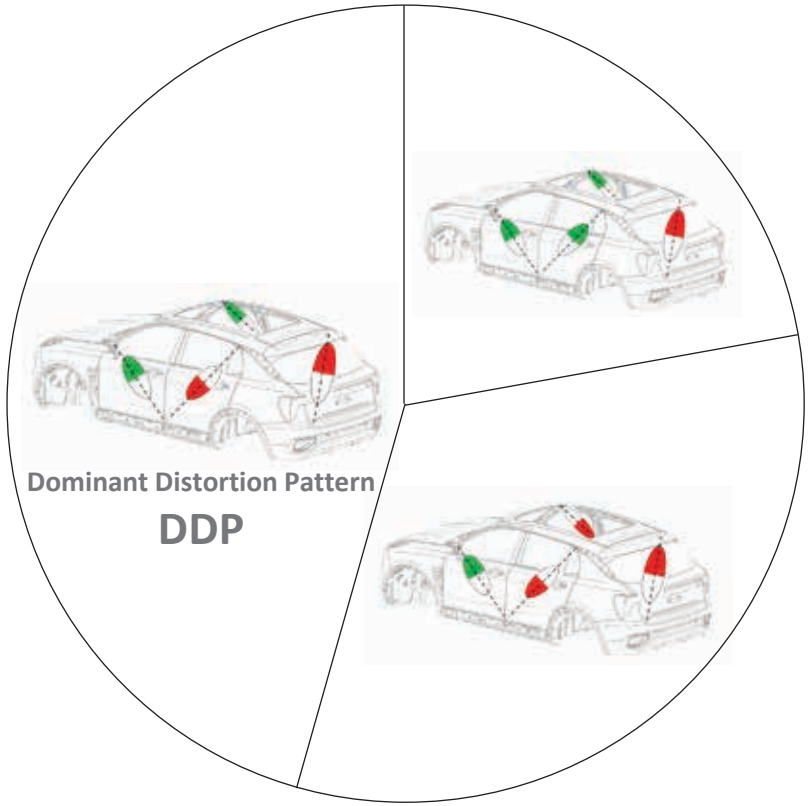
MRV



1	1	1	1	1
1	1	1	1	1
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1

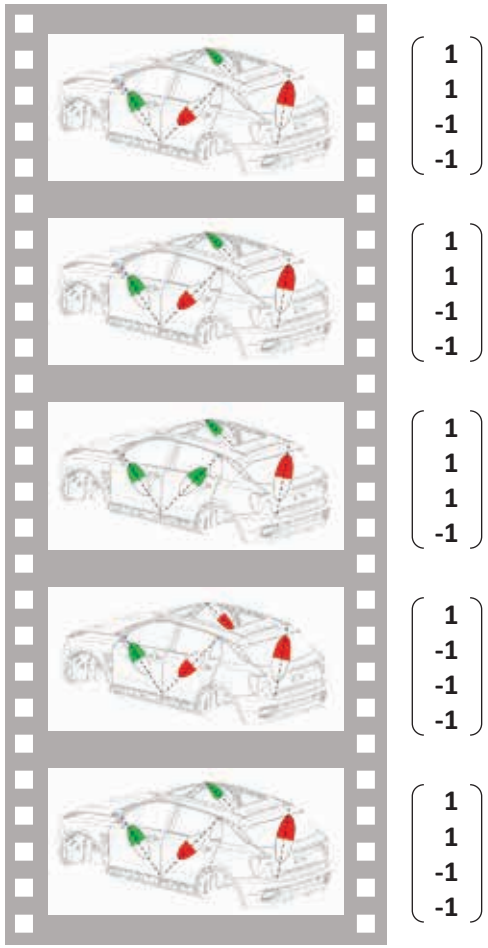
Vector Participation Plot

VPA



Max Principal Response Vector

MRV



1
1
-1
-1

1
1
-1
-1

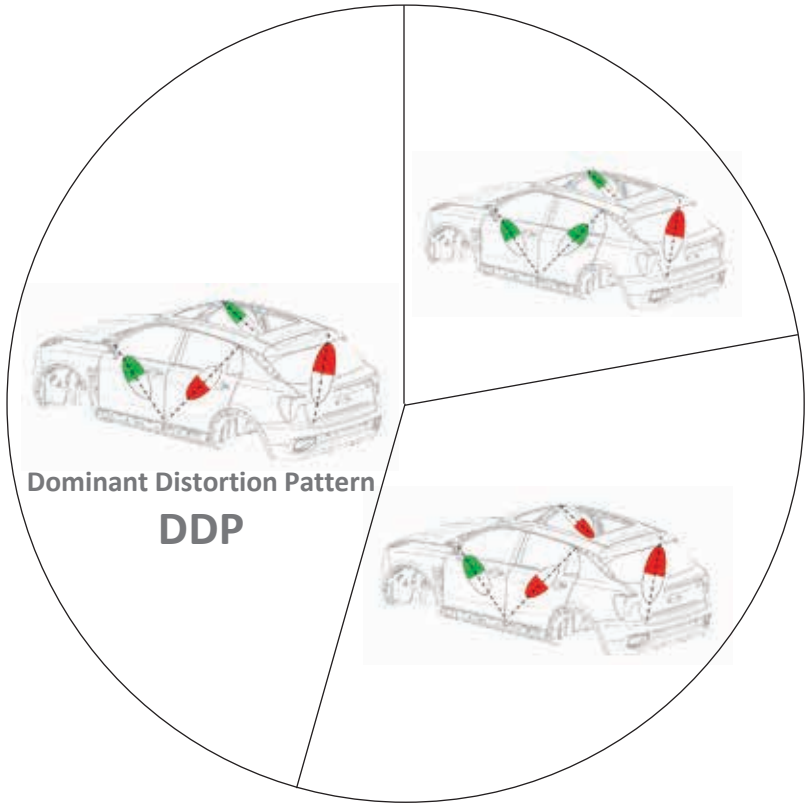
1
1
1
-1

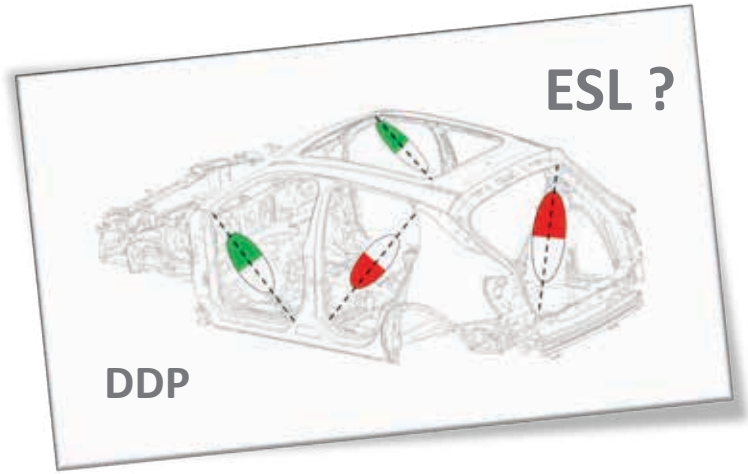
1
-1
-1
-1

1
1
-1
-1

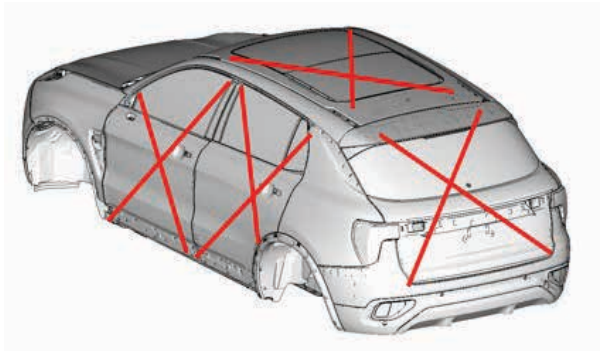
Vector Participation Plot

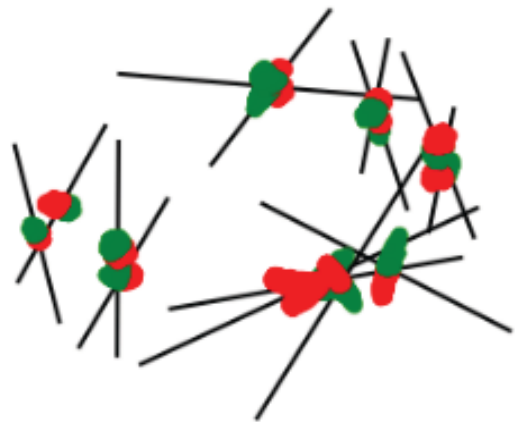
VPA

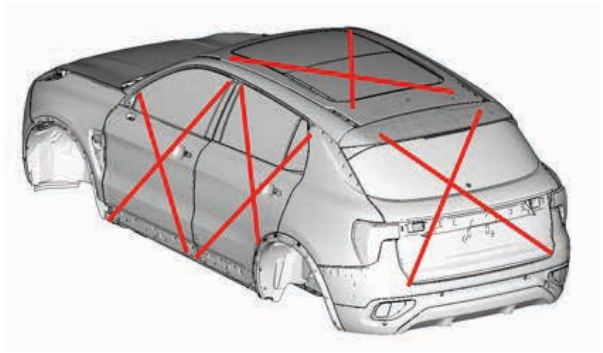


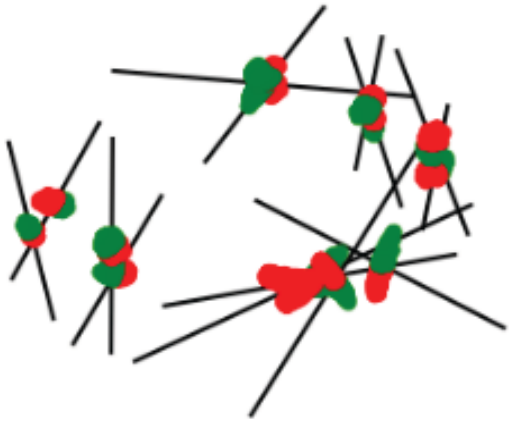


CEVT

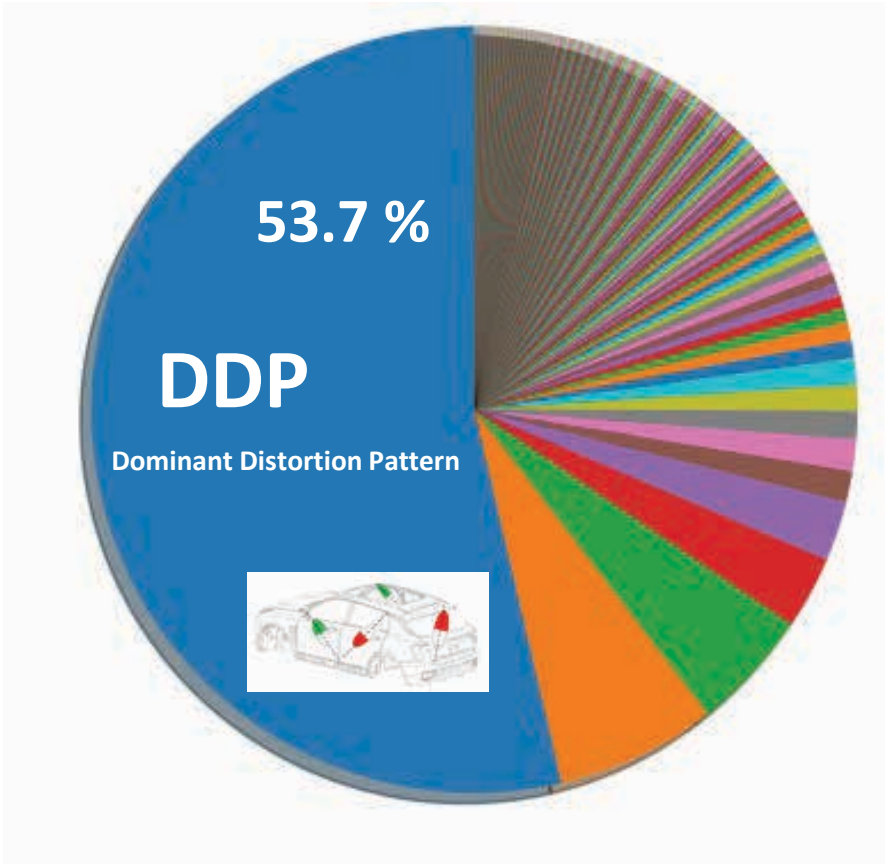








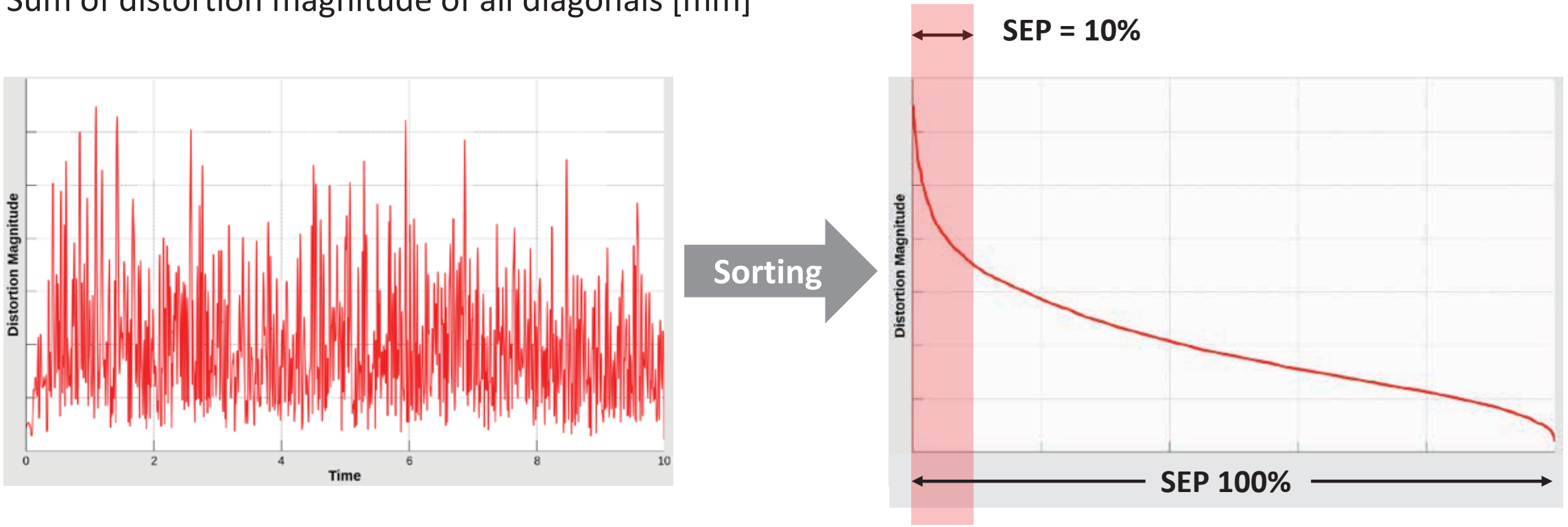
VPA



CEVT

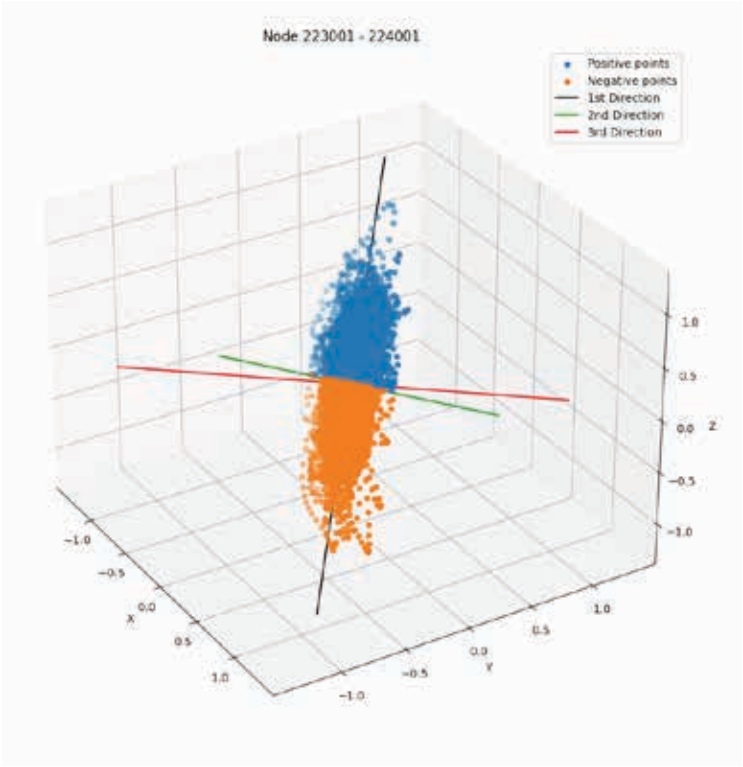
Statistical Evaluation Parameter SEP

Sum of distortion magnitude of all diagonals [mm]



CEVT

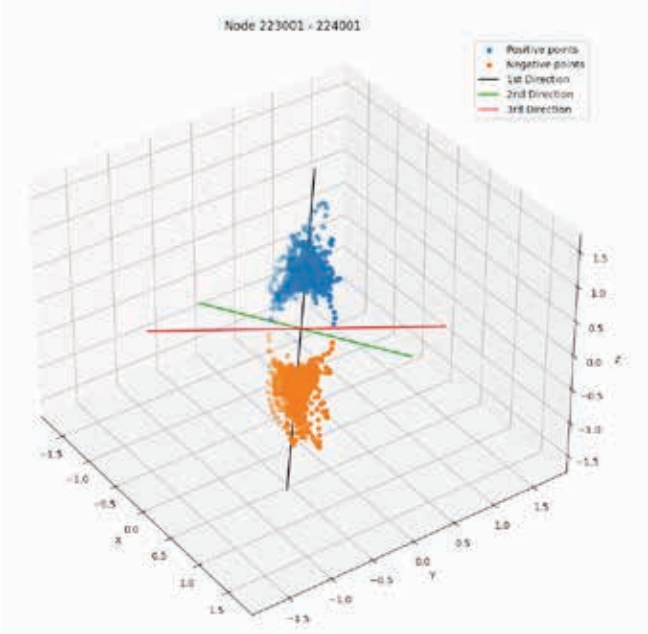
Statistical Evaluation Parameter SEP



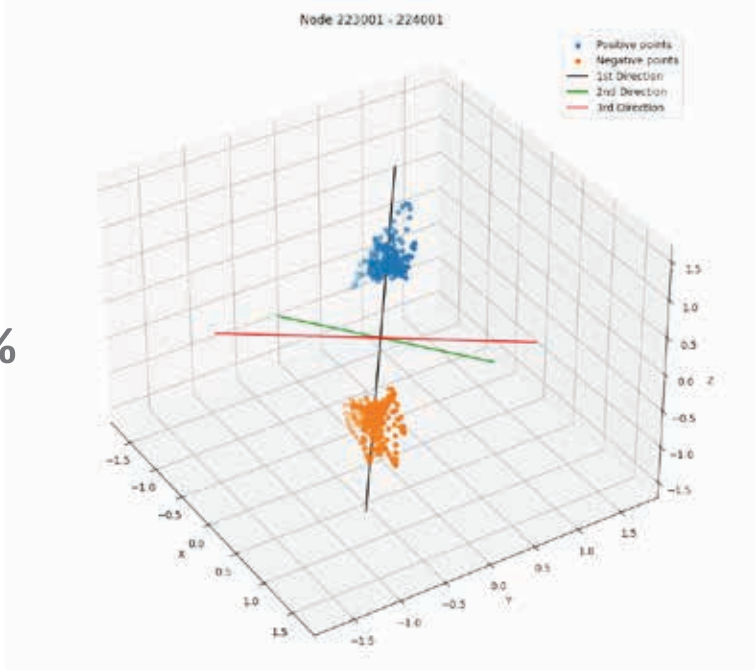
SEP = 100 %

SEP

SEP = 30 %

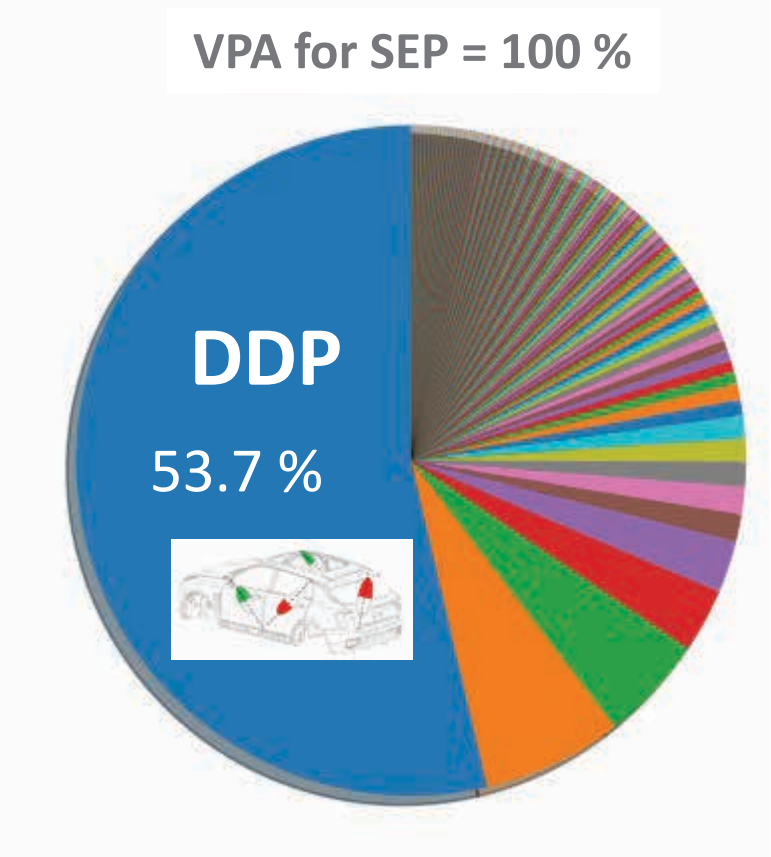


SEP = 10 %



CEVT

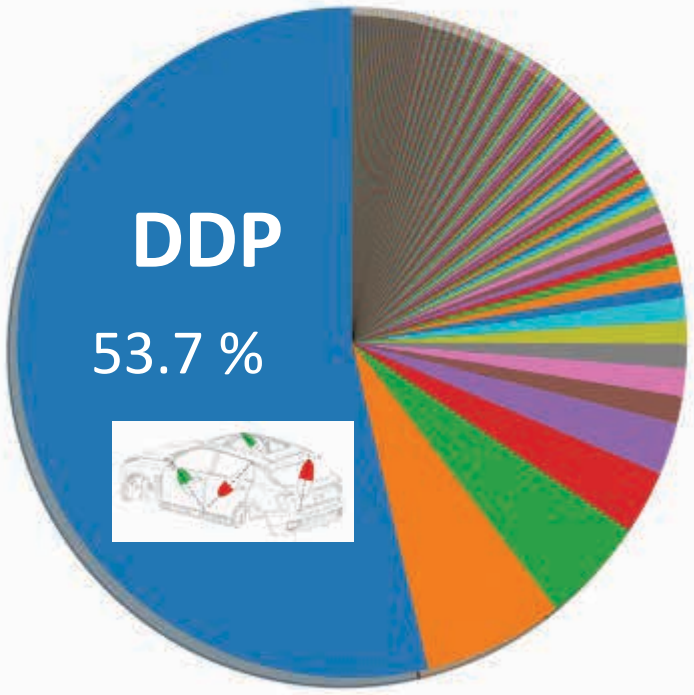
Dominant Distortion Pattern DDP = f(SEP)



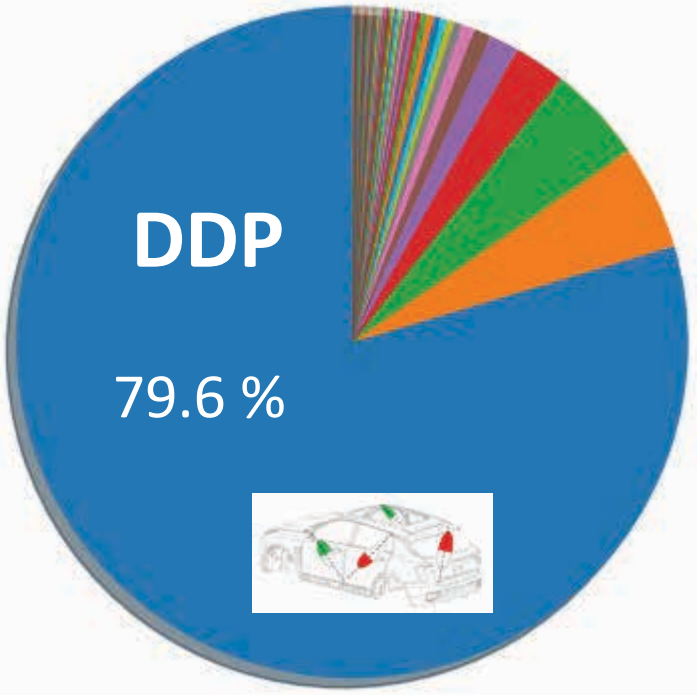
CEVT

Dominant Distortion Pattern DDP = f(SEP)

VPA for SEP = 100 %



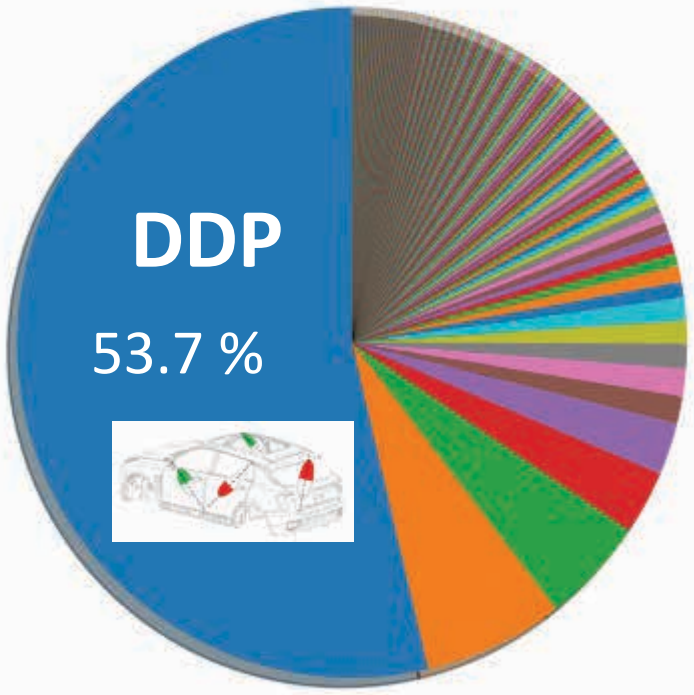
VPA for SEP = 50 %



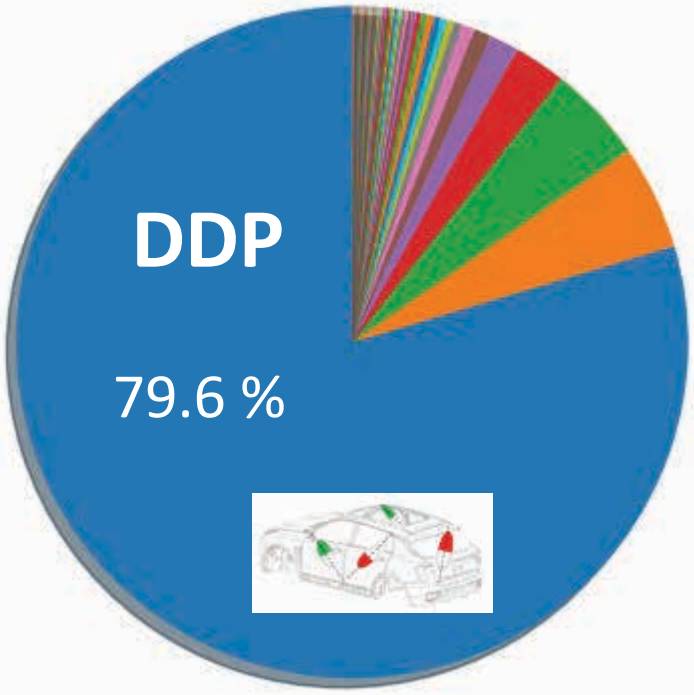
CEVT

Dominant Distortion Pattern DDP = f(SEP)

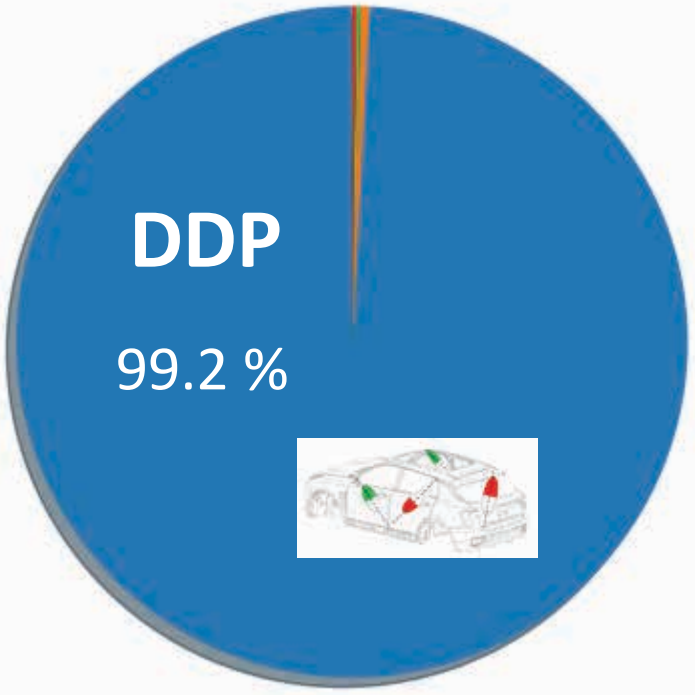
VPA for SEP = 100 %



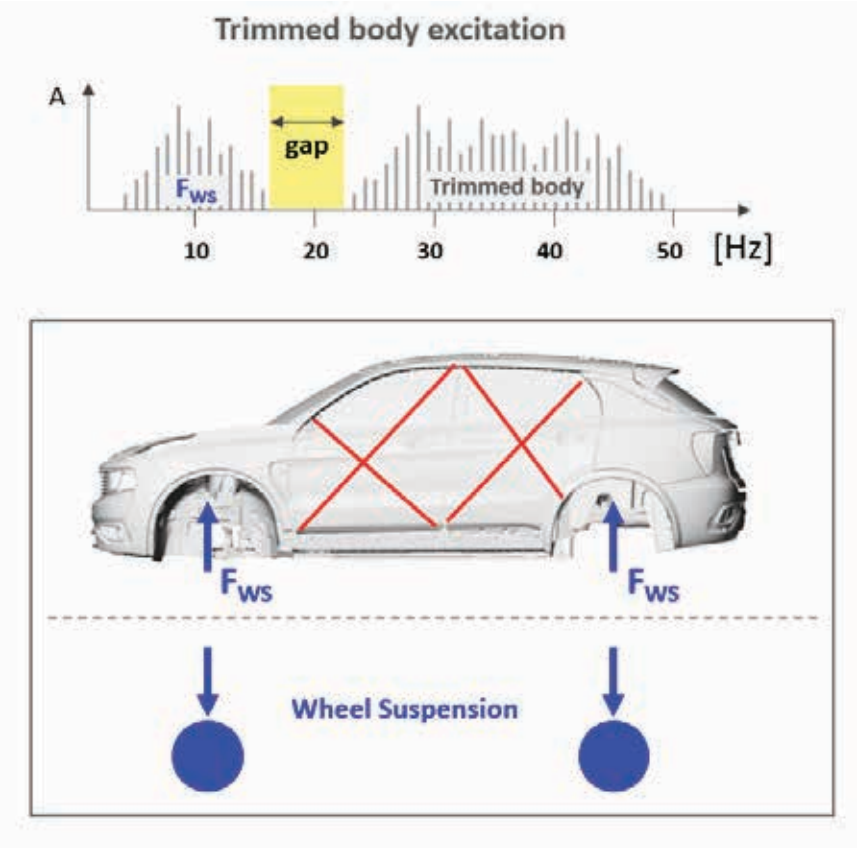
VPA for SEP = 50 %

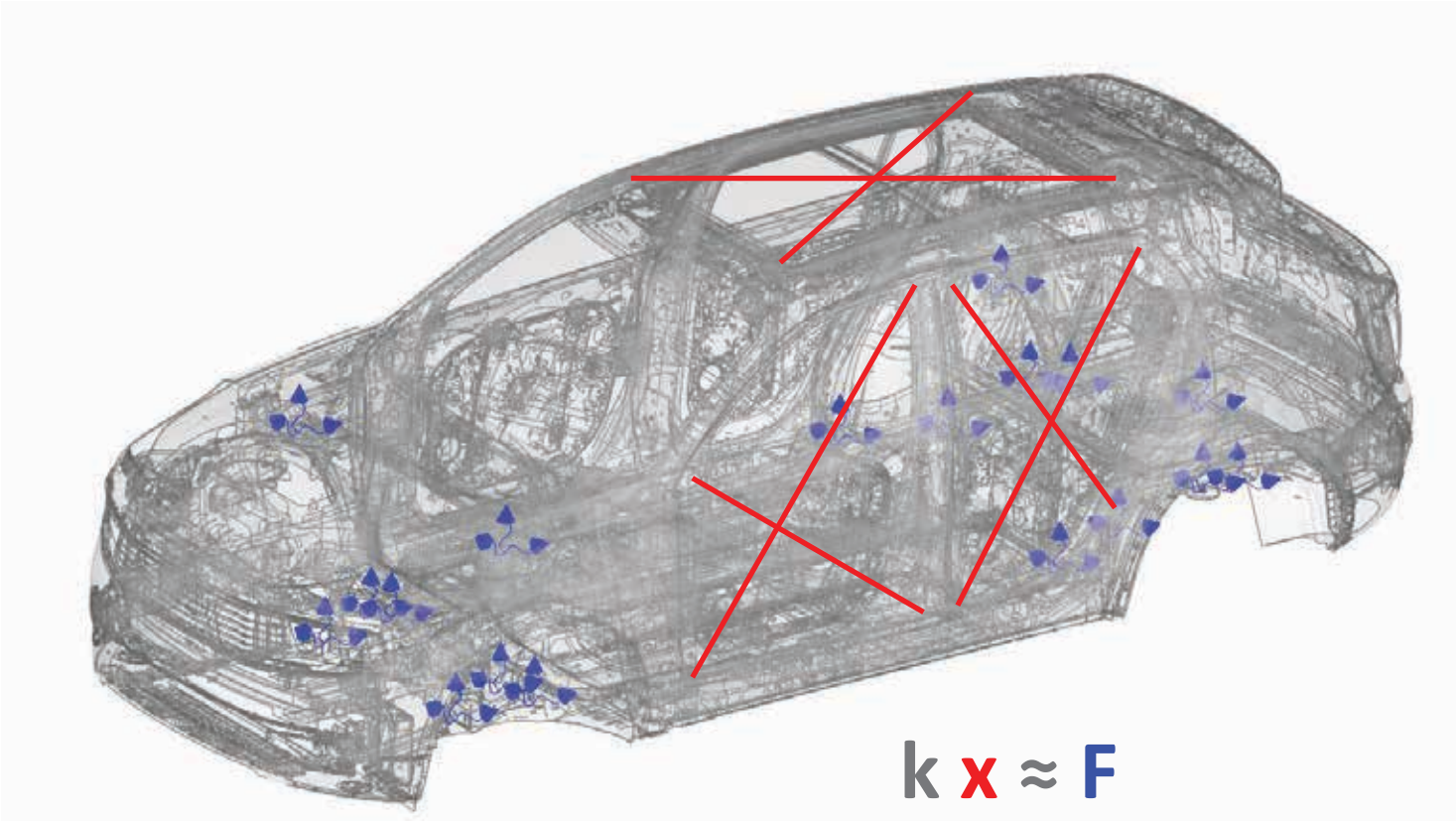


VPA for SEP = 10 %

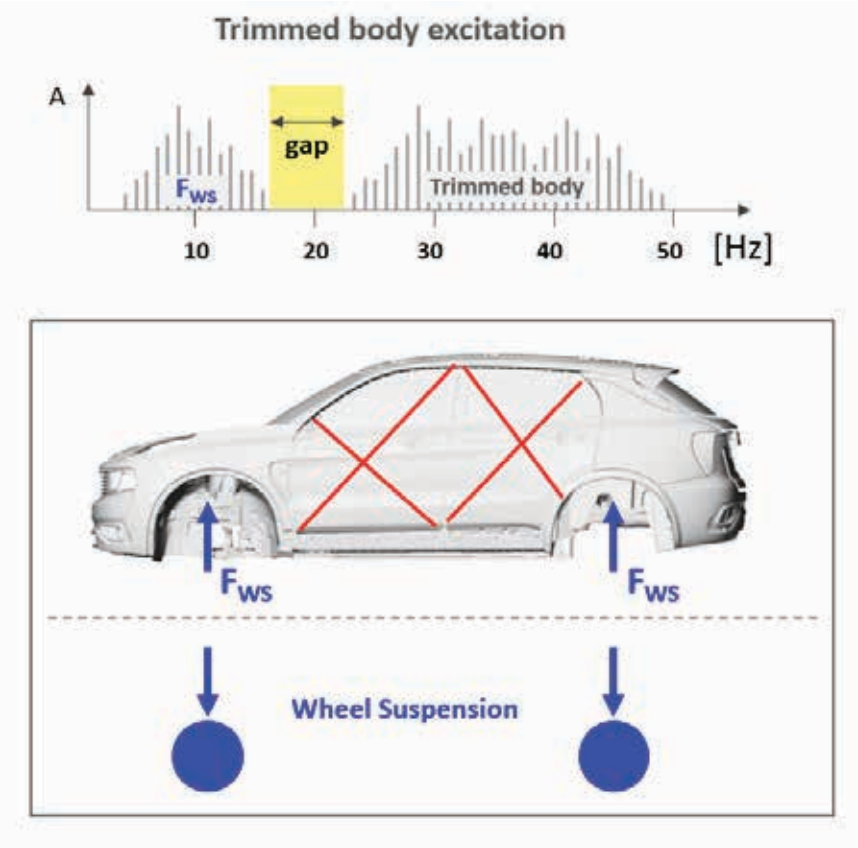


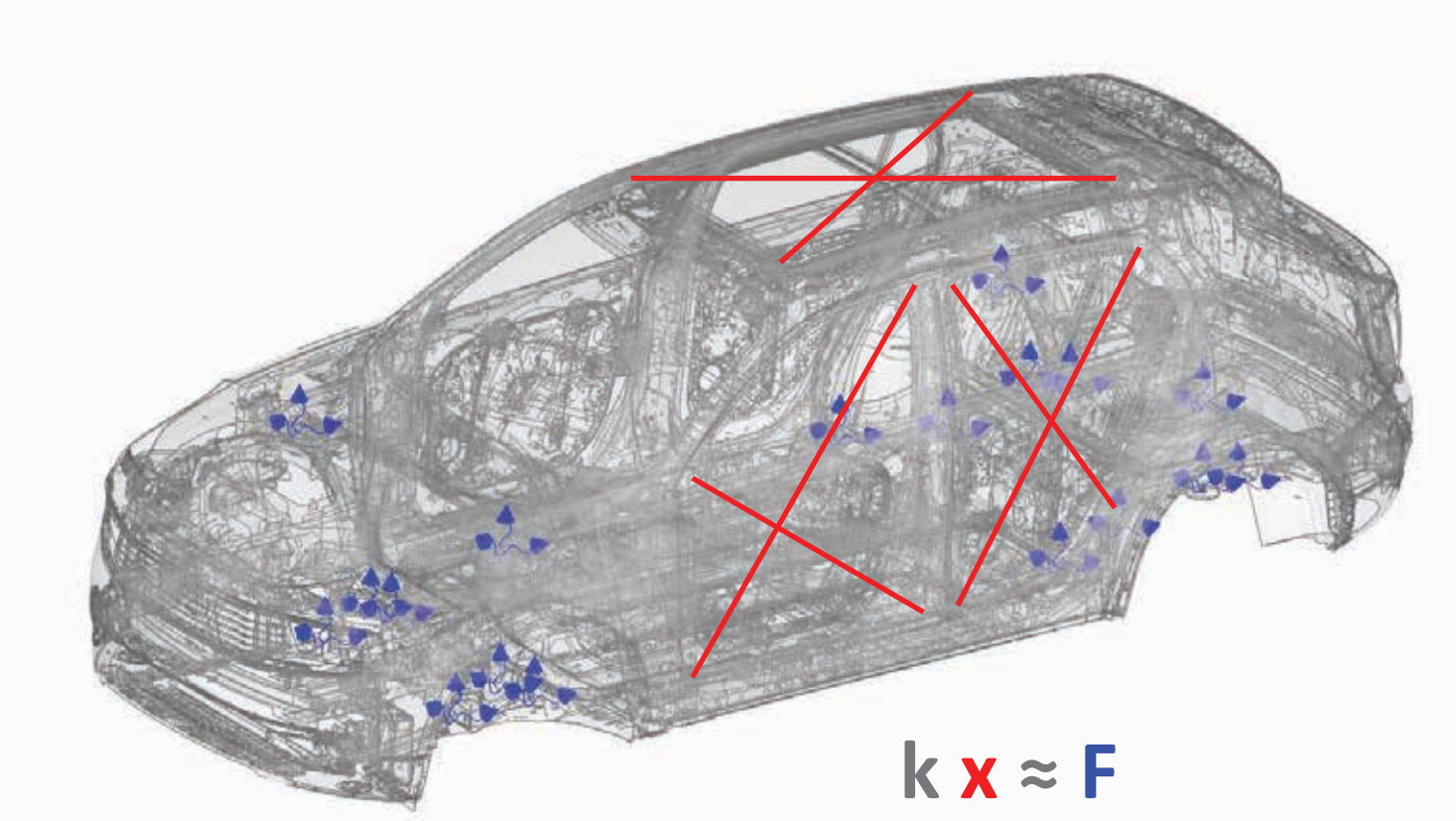
CEVT


Trimmed body excitation
A
gap
F_{WS}
Trimmed body
10
20
30
40
50
[Hz]
F_{WS}
F_{WS}
Wheel Suspension


k x ≈ F

CEVT





Distortion

!

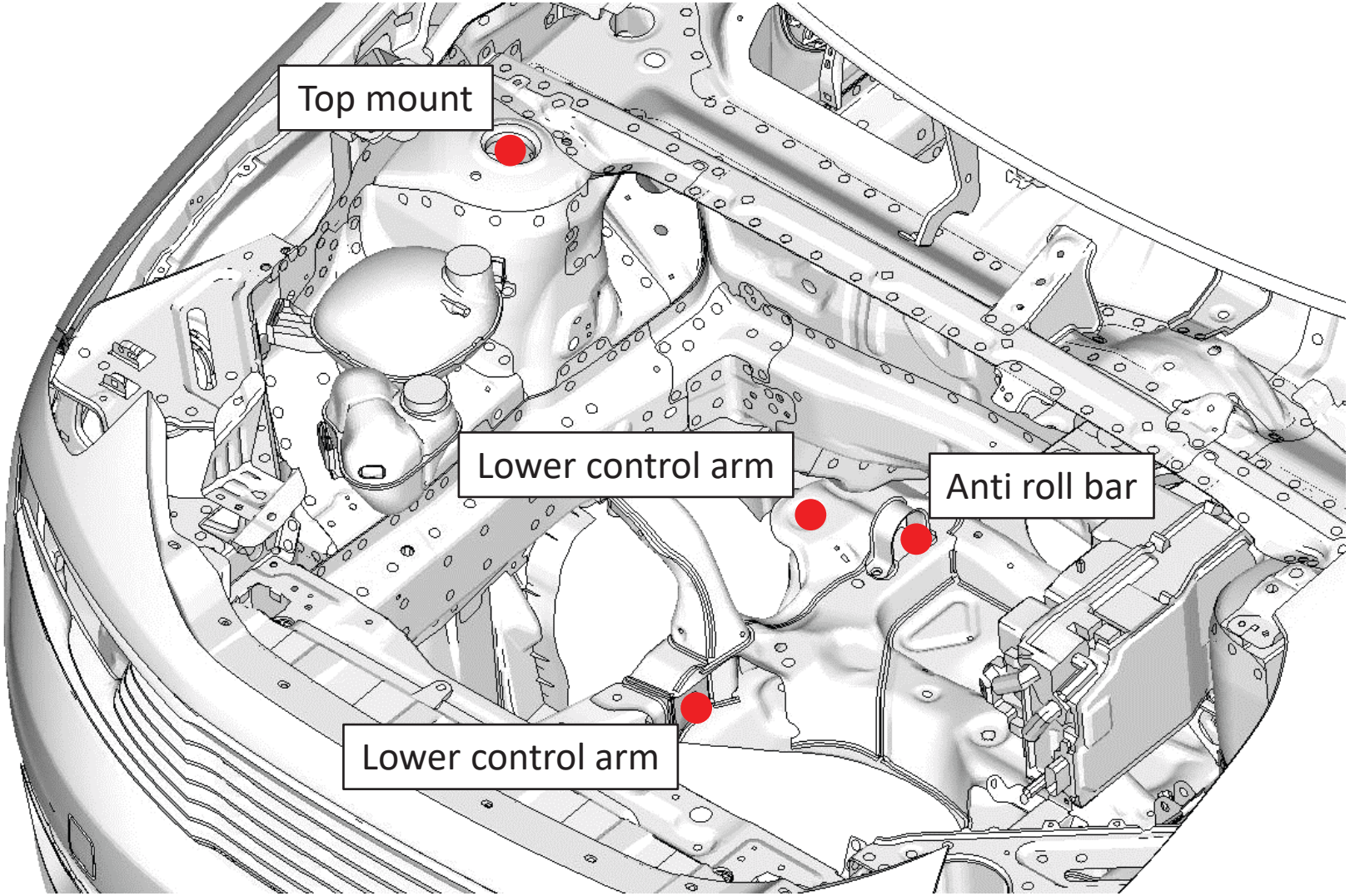
Forces

Dominant Force Pattern

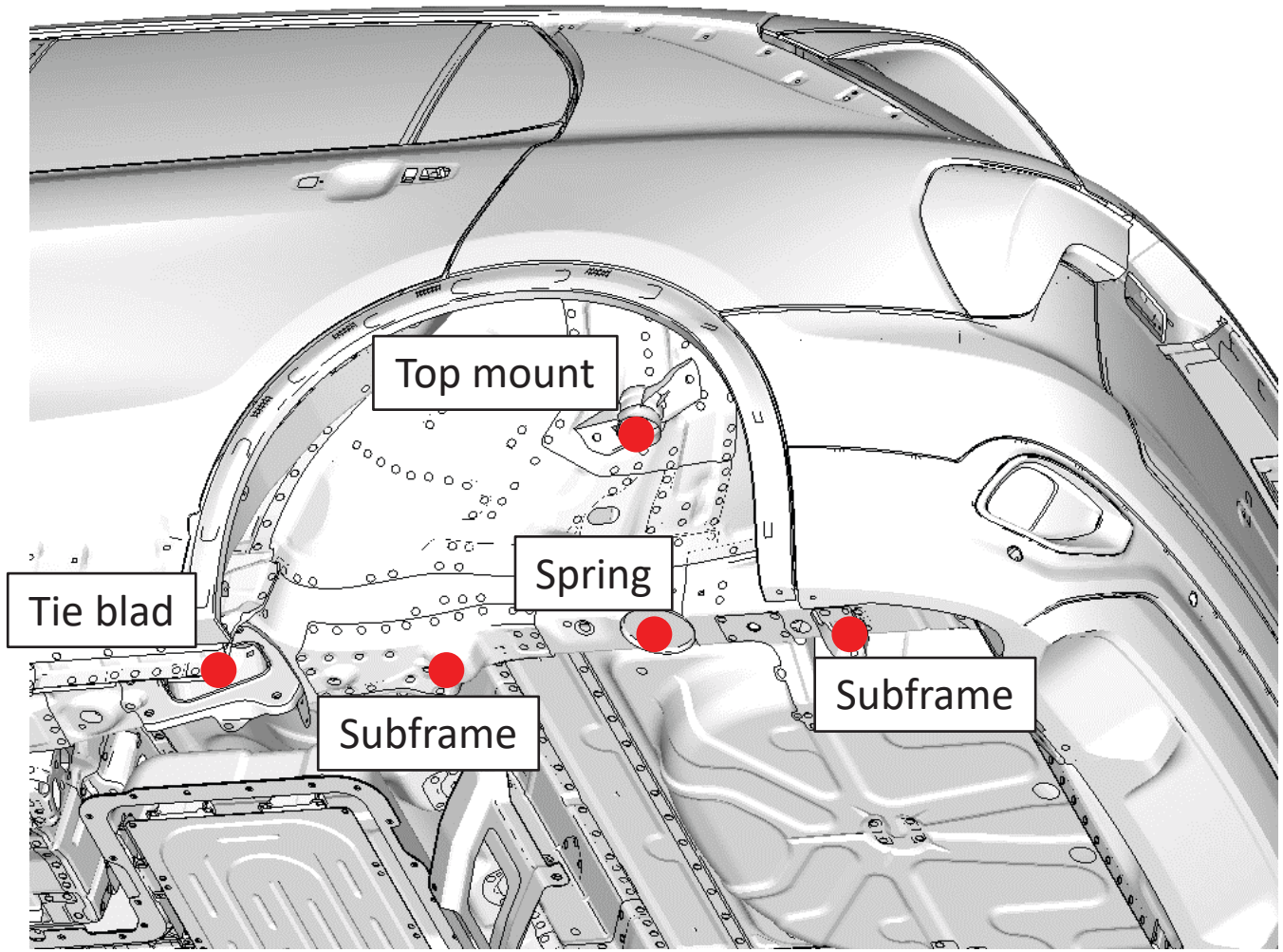
?

CEVT

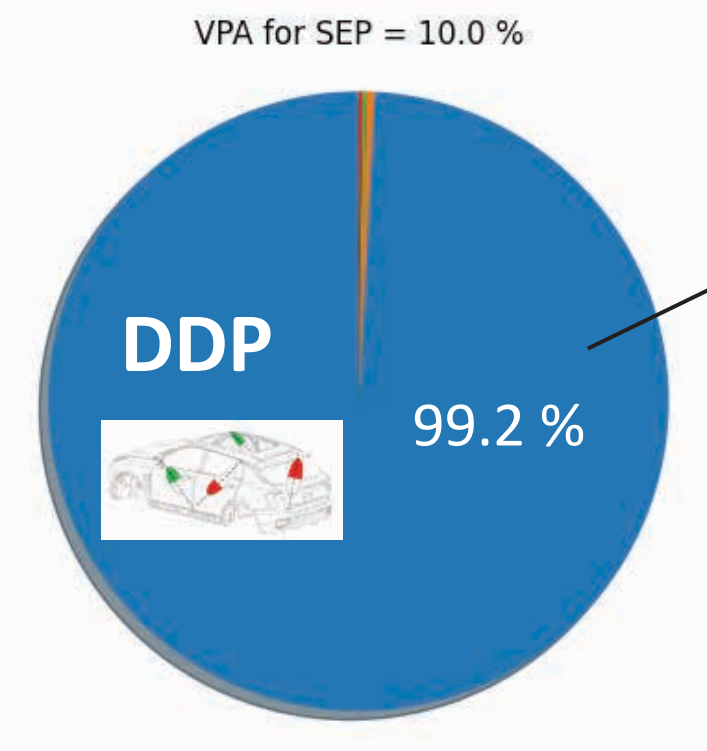
Force locations



Force locations



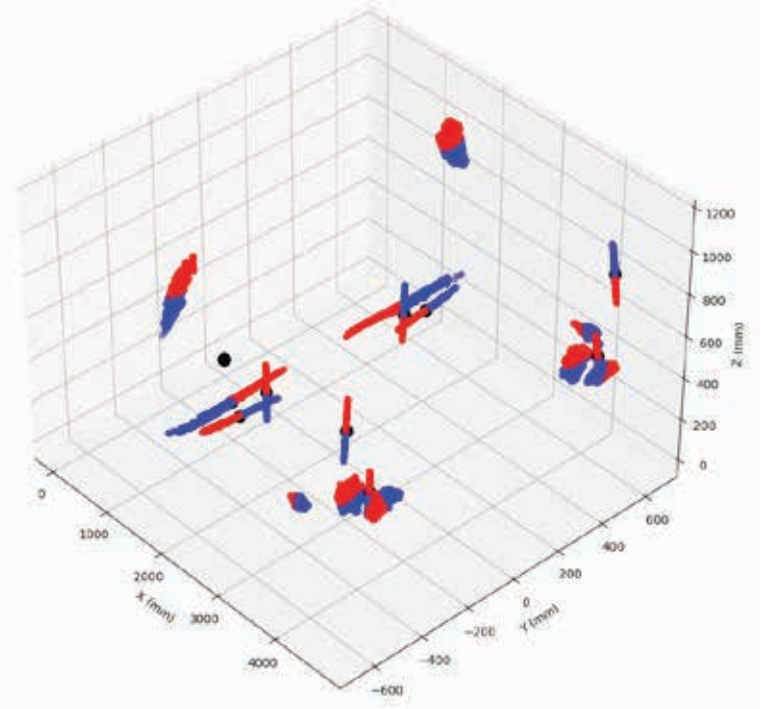
Force VPA



Time Steps associated with DDP

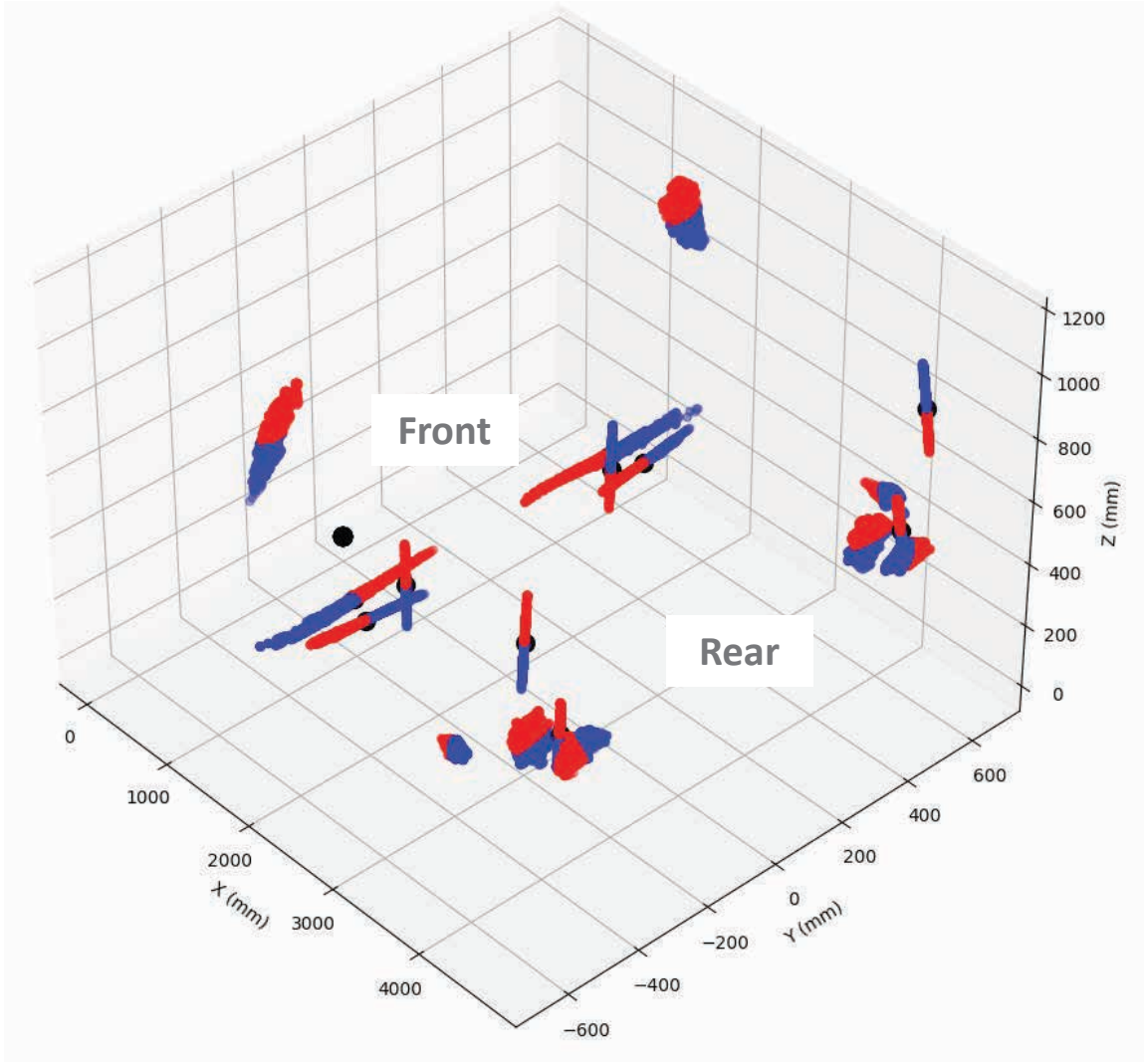
Forces associated with those time steps

PCA on those forces

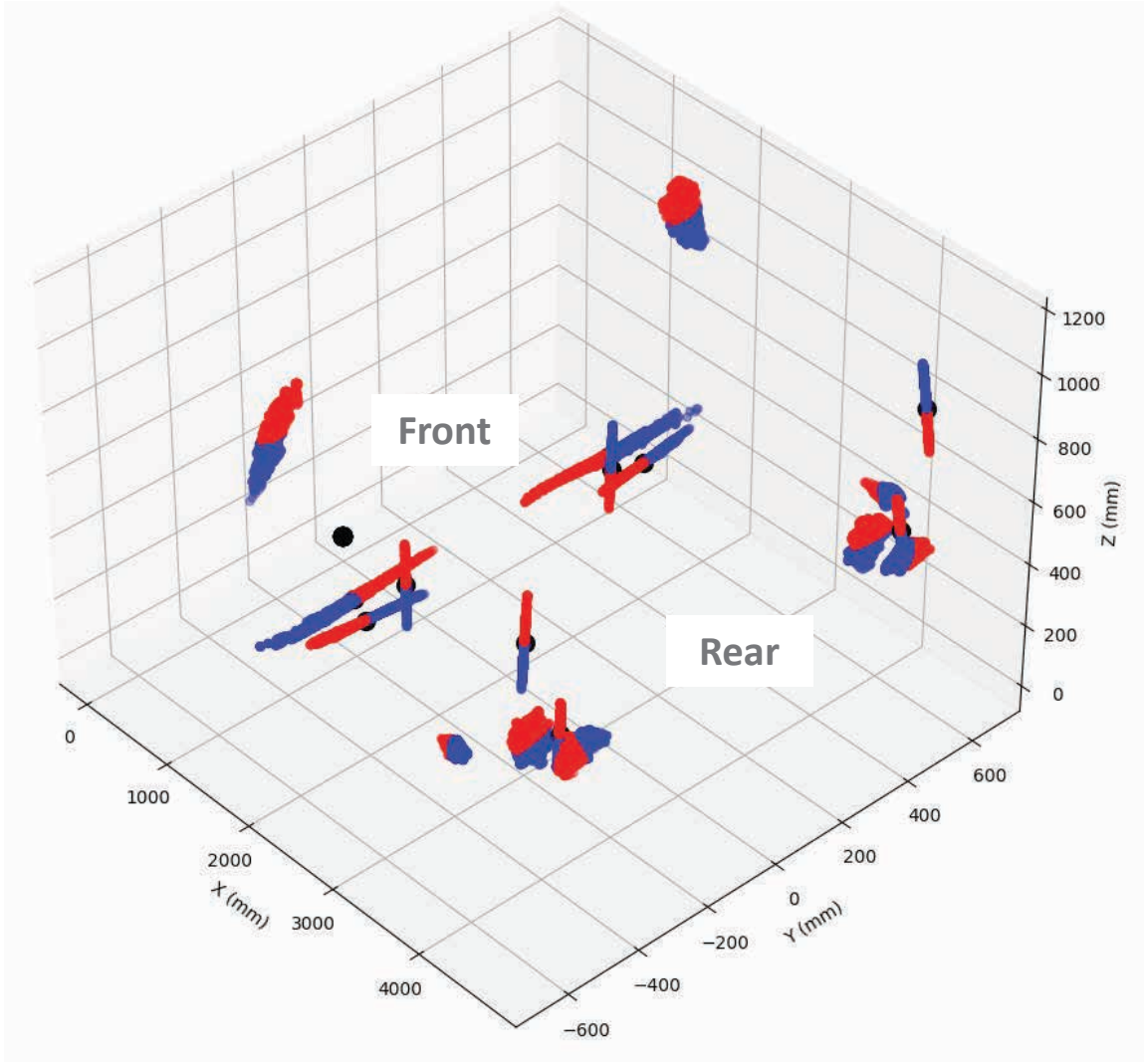


CEVT

Wheel suspension forces

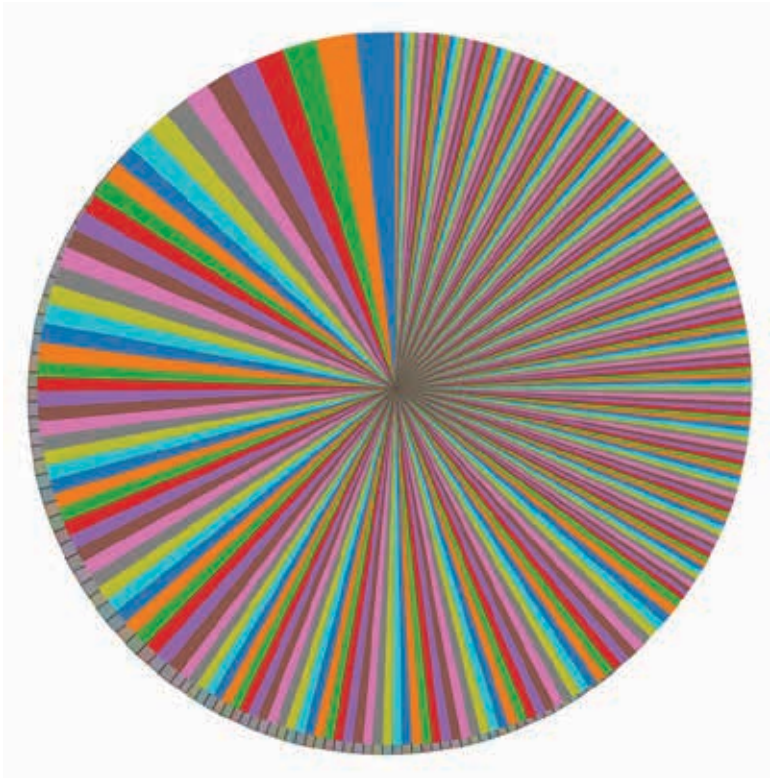


Wheel suspension forces

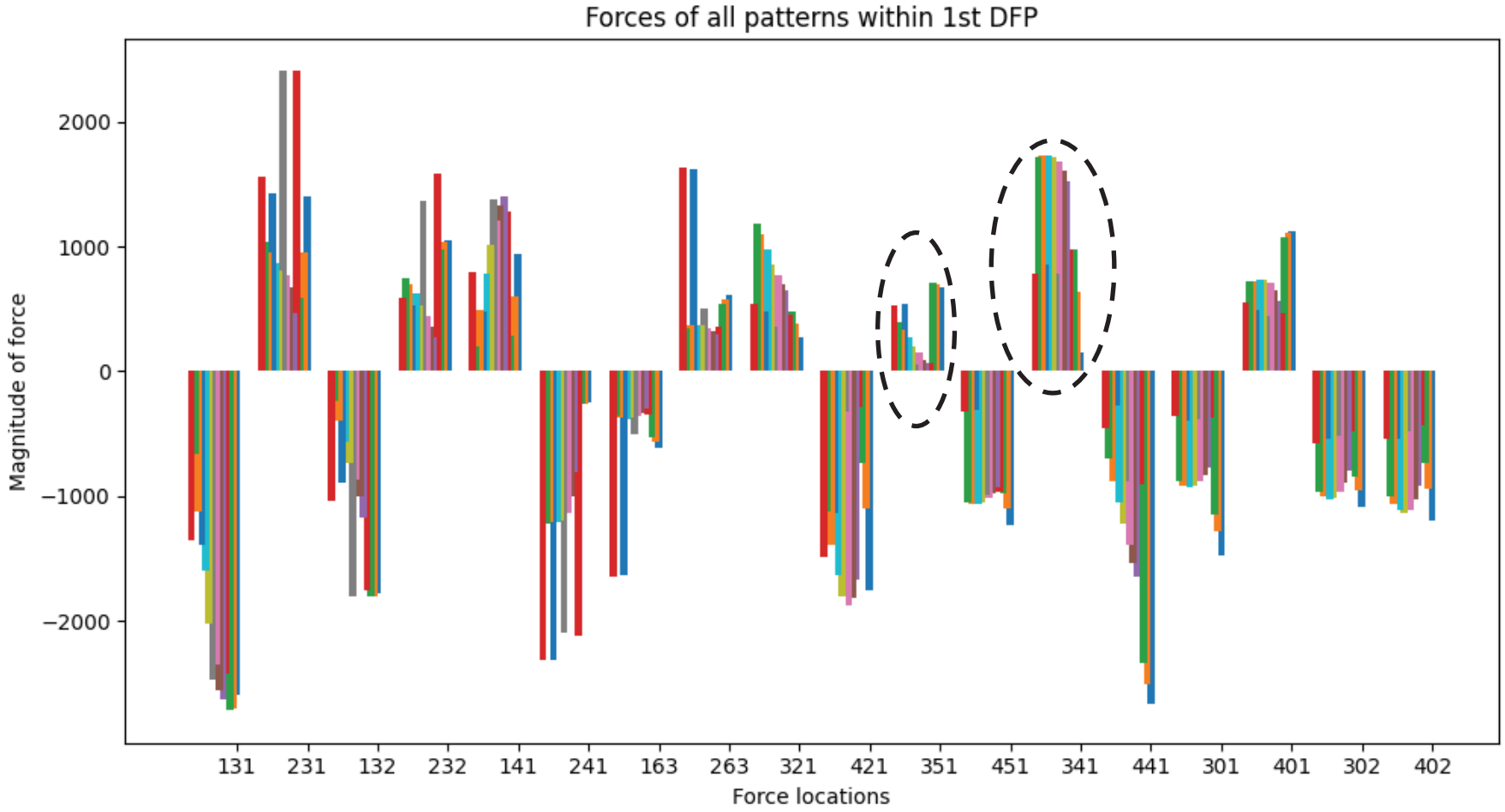


VPA

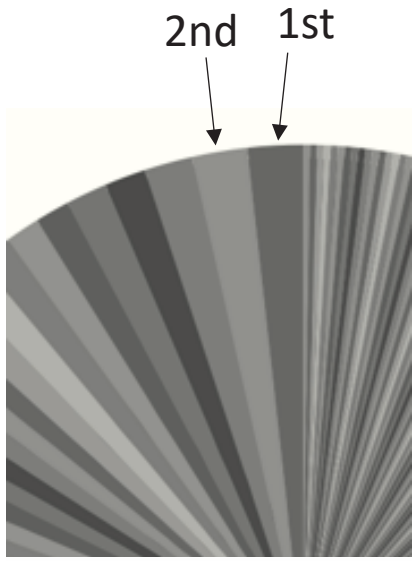
All forces for SEP 10 %

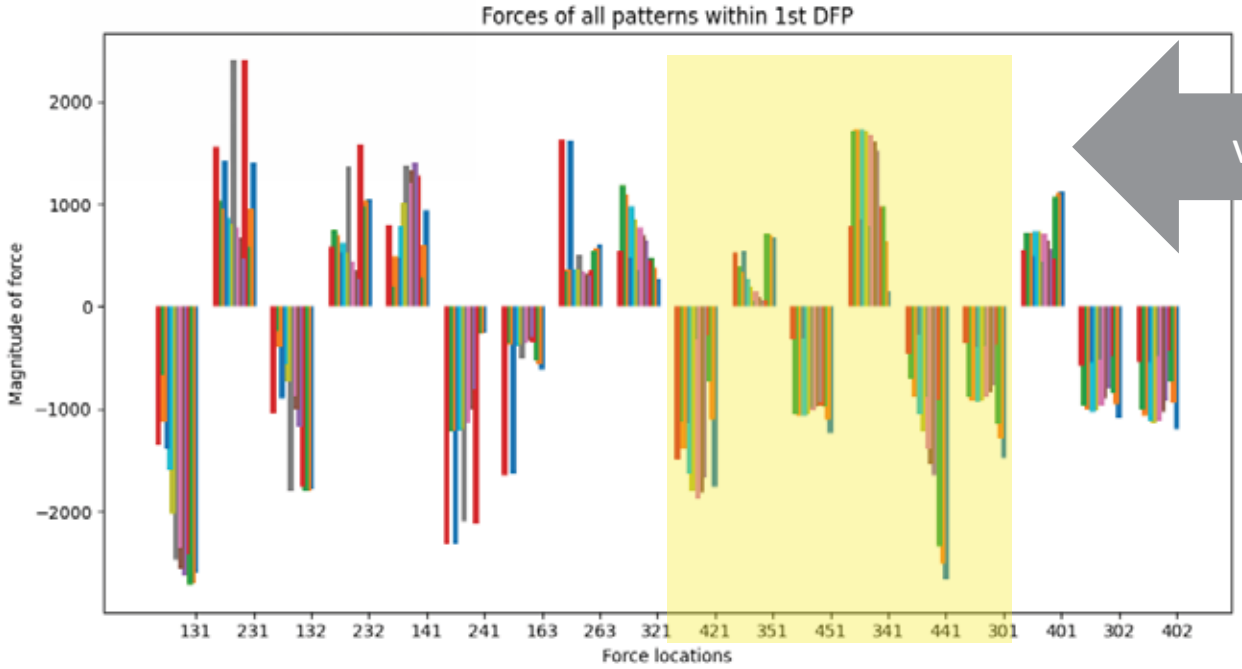


Forces analysis

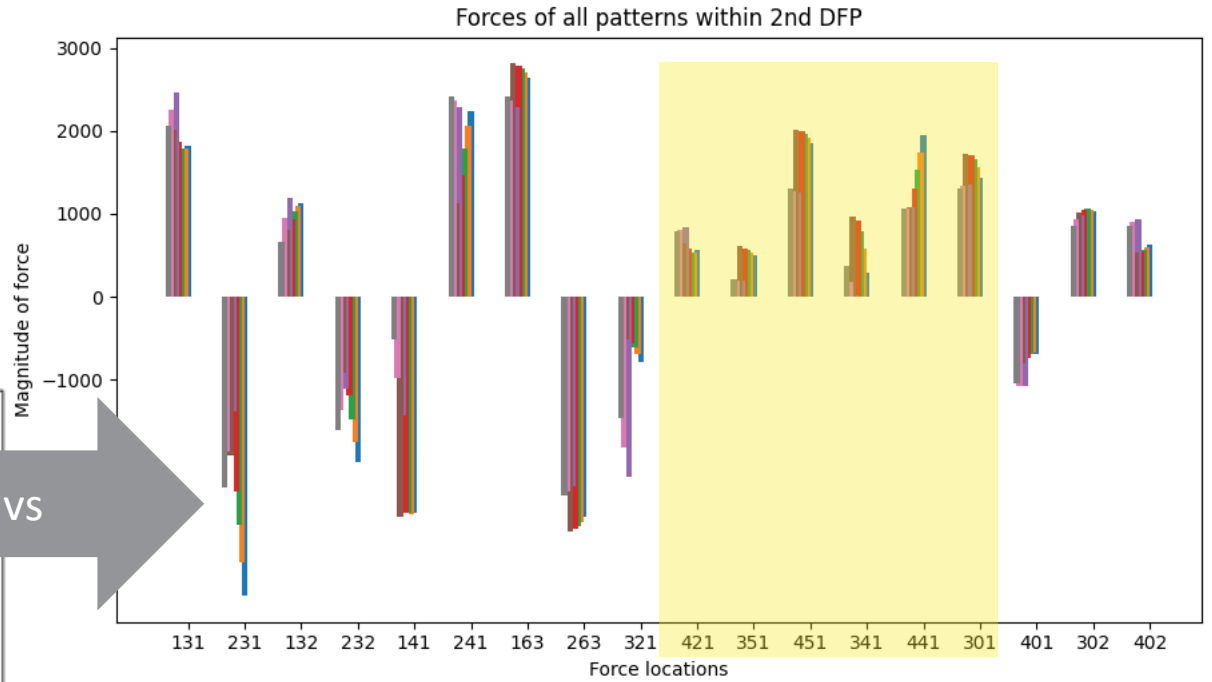


Forces analysis



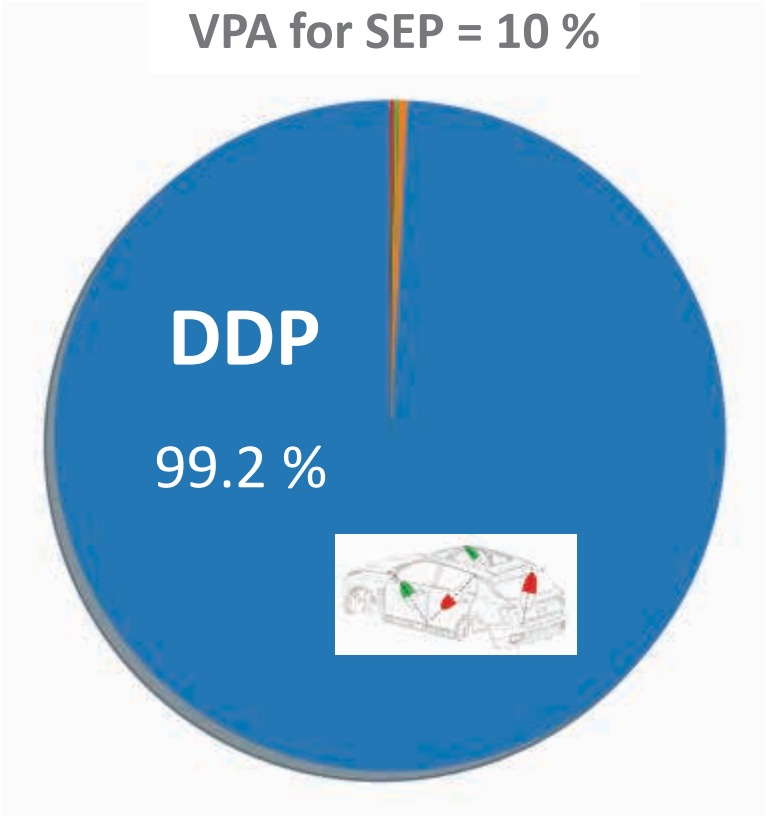


VS

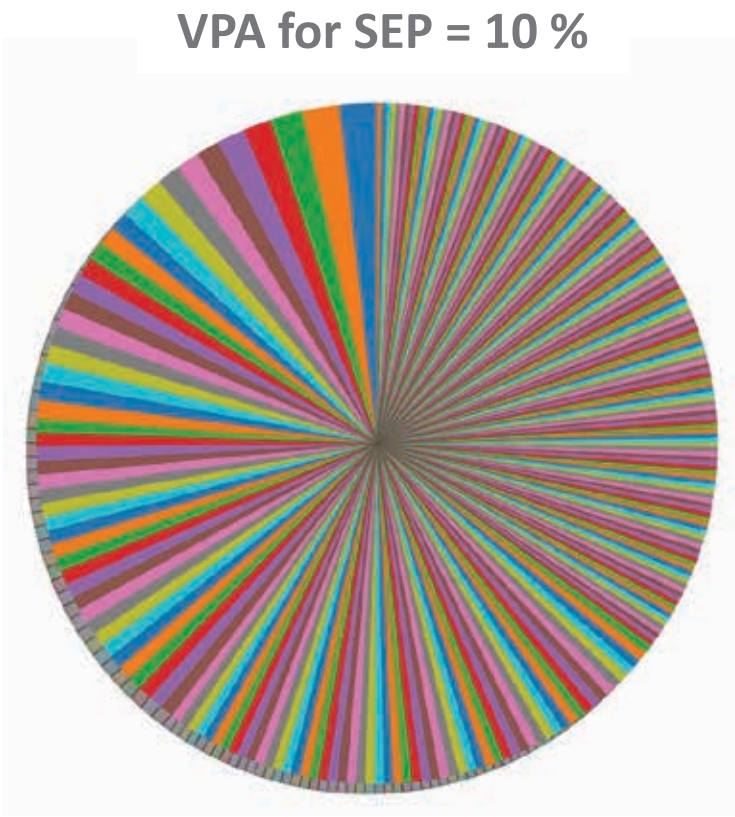


Dominant Distortion Pattern

Force Pattern



?



CEVT

SOL 101 using inertia relief

3rd

```
$$ DLOAD index  : 1291
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORCE           155000131       -100.732    1.0     0.0     0.0
FORCE           155000131       -616.837    0.0     1.0     0.0
FORCE           155000131       -106.204    0.0     0.0     1.0
```

...

2nd

```
$$ DLOAD index  : 713
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORCE           155000131       -228.128    1.0     0.0     0.0
FORCE           155000131       1409.032    0.0     1.0     0.0
FORCE           155000131       24.94774    0.0     0.0     1.0
```

...

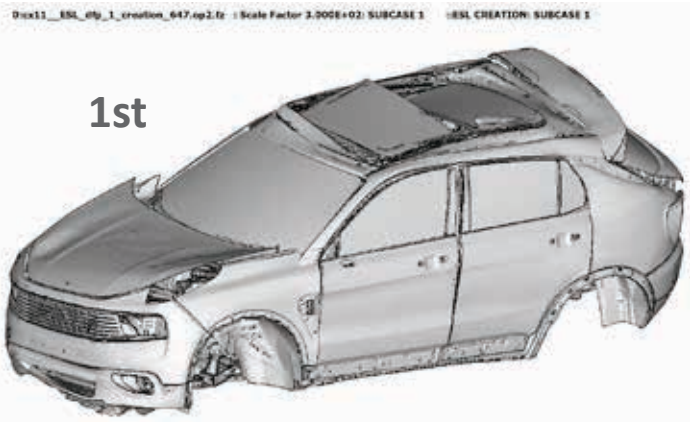
1st

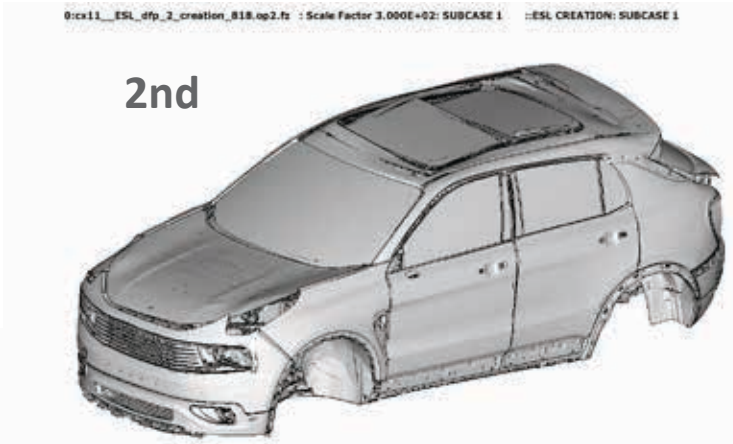
```
$$ DLOAD index  : 547
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORCE           155000131       452.0457    1.0     0.0     0.0
FORCE           155000131       -2362.20    0.0     1.0     0.0
FORCE           155000131       -2.90363    0.0     0.0     1.0
```

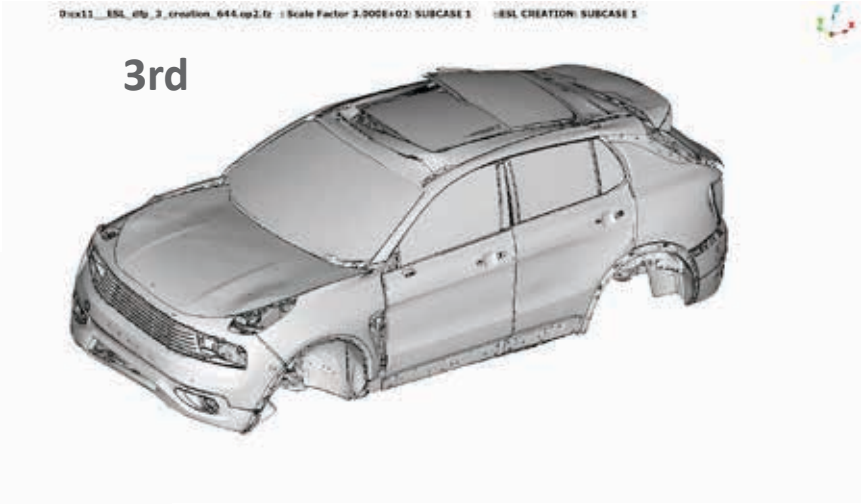
...

CEVT

SOL 101 using inertia relief







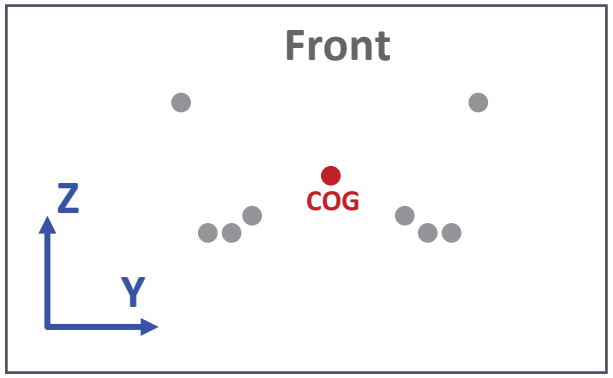
Animation from 0 to max

Scale factor 300 !

CEVT

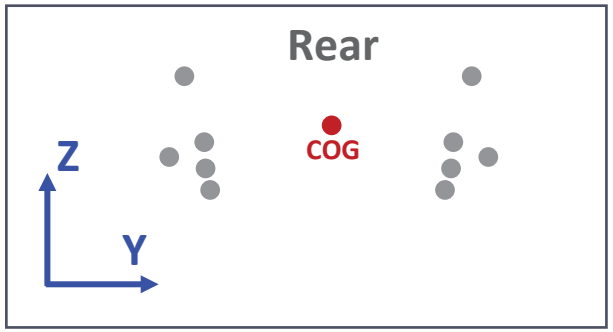
Moment around X (COG)

Y & Z Forces



$$M_{front} = \sum F_y \cdot z + F_z \cdot y$$

Moment Front



$$M_{rear} = \sum F_y \cdot z + F_z \cdot y$$

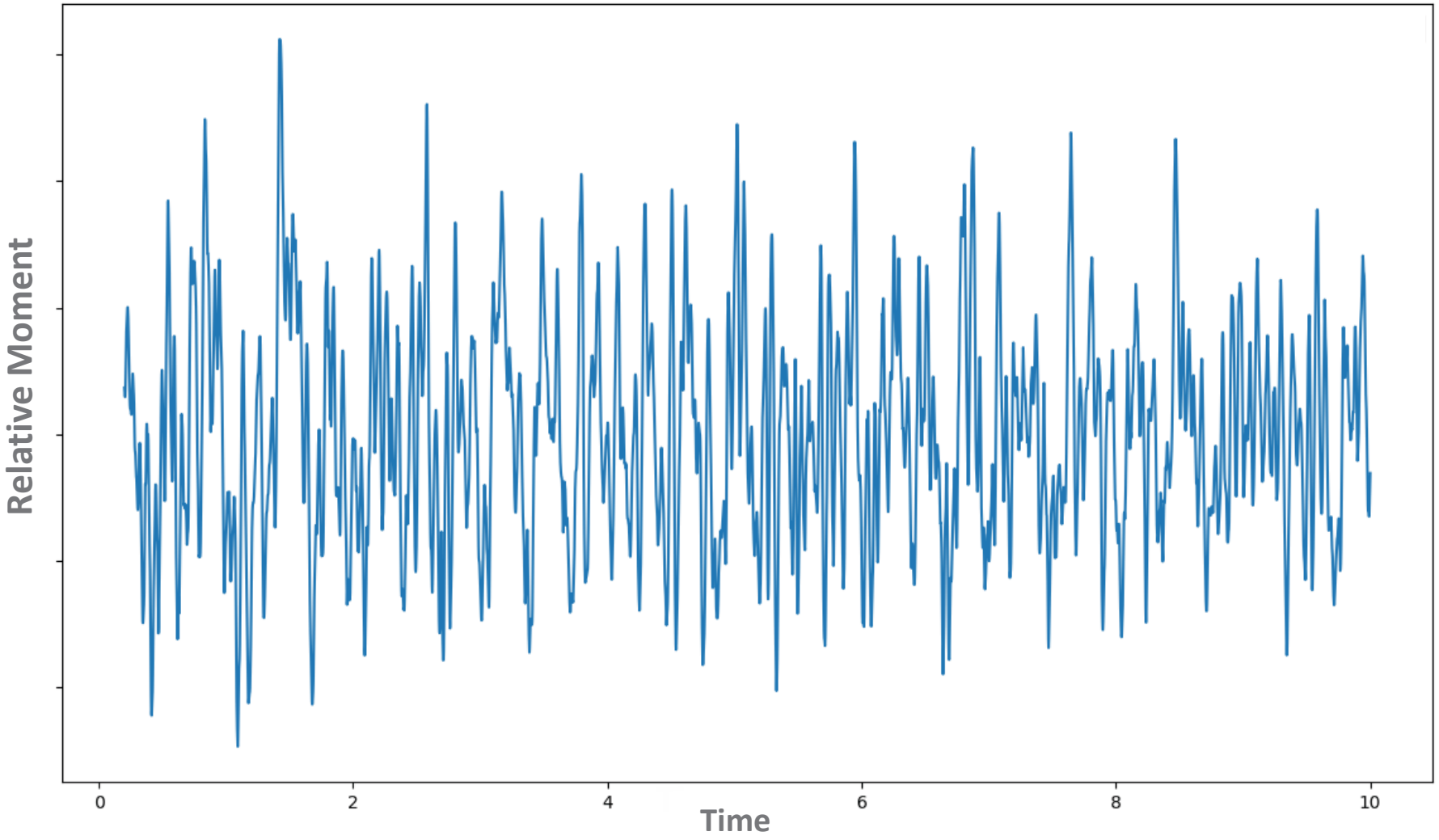
Moment Rear

$$M_{rel} = M_{front} - M_{rear}$$

Relative Moment

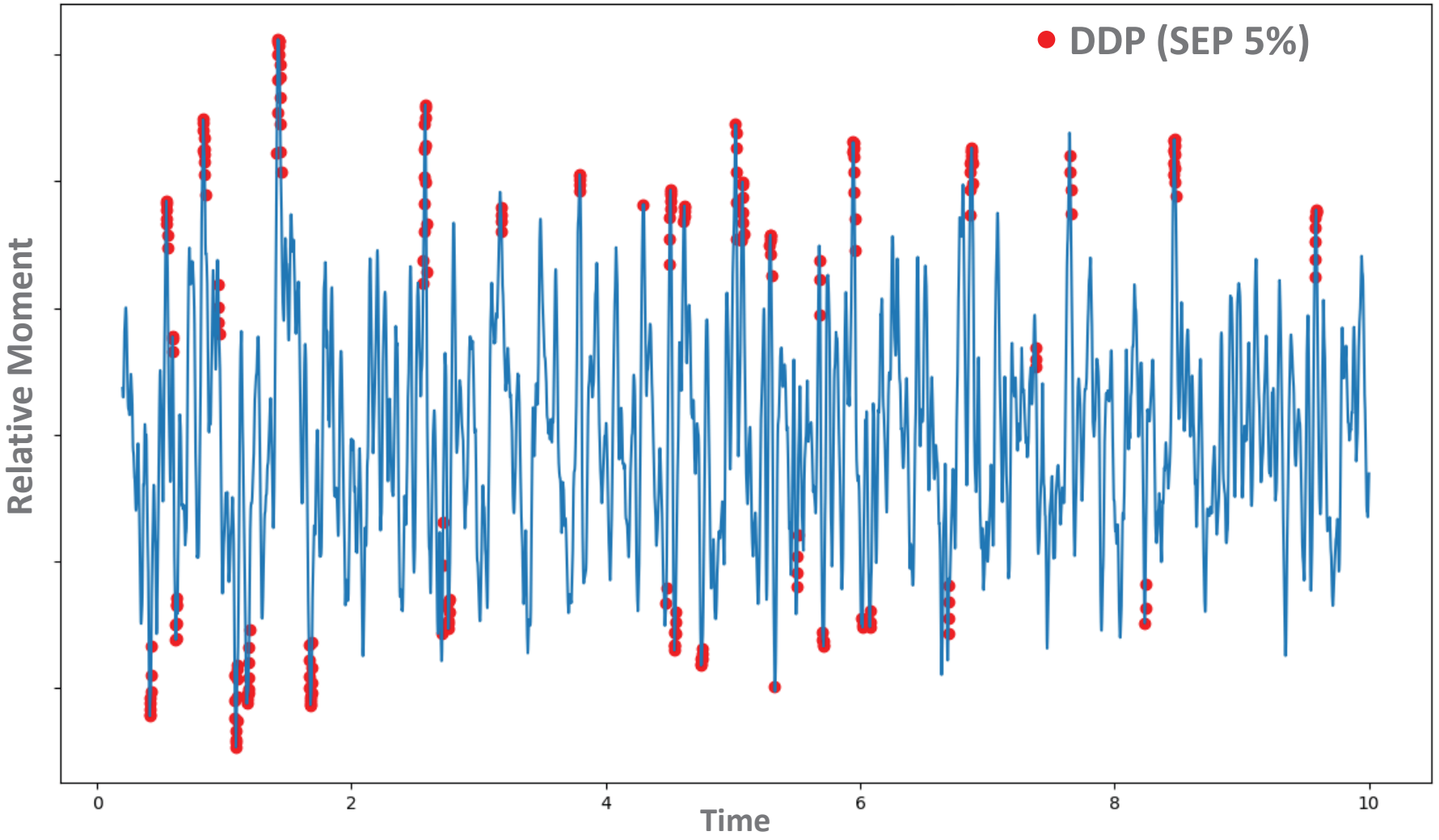
CEVT

Relative Moment



CEVT

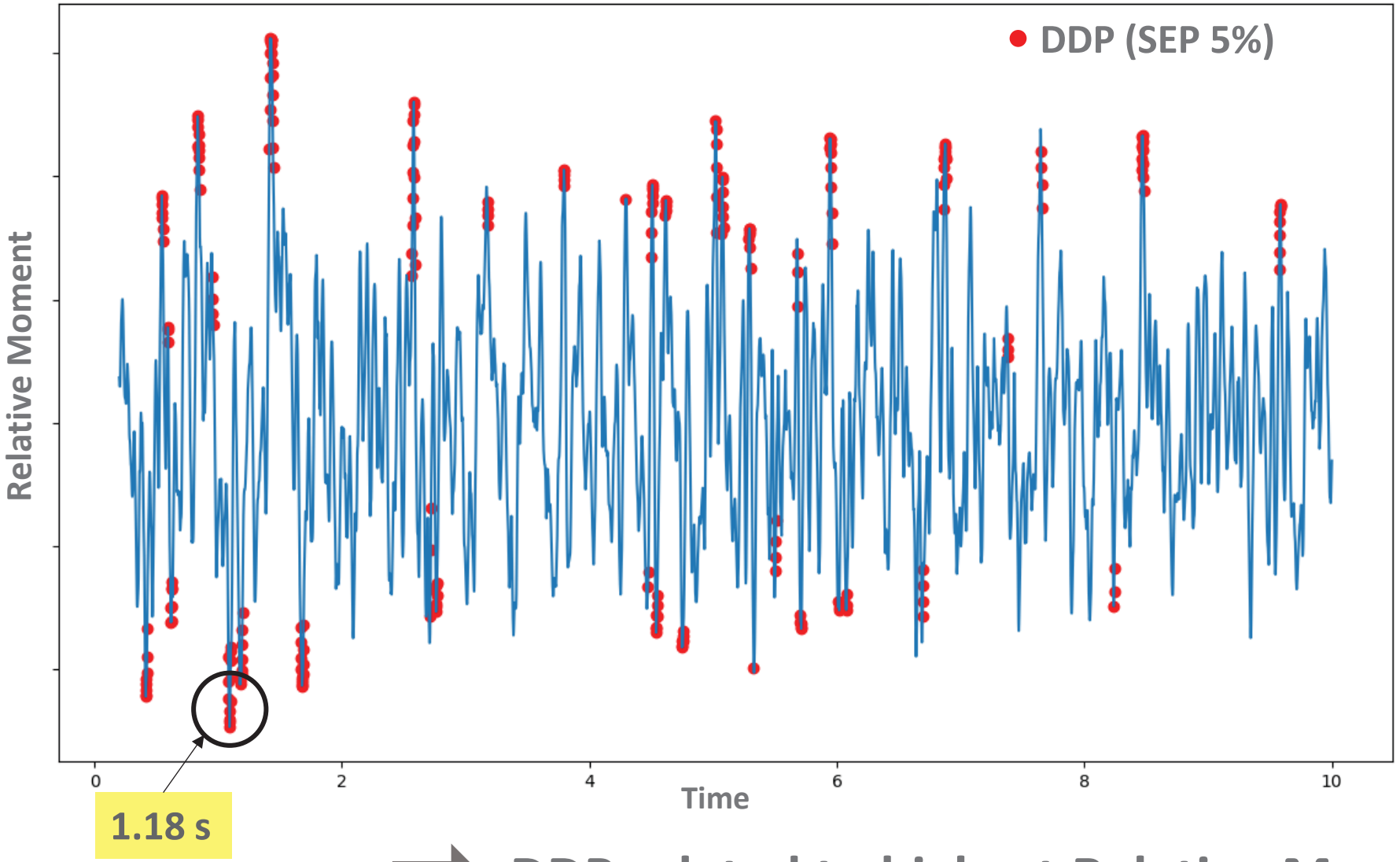
Relative Moment



DDP related to highest Relative Moment

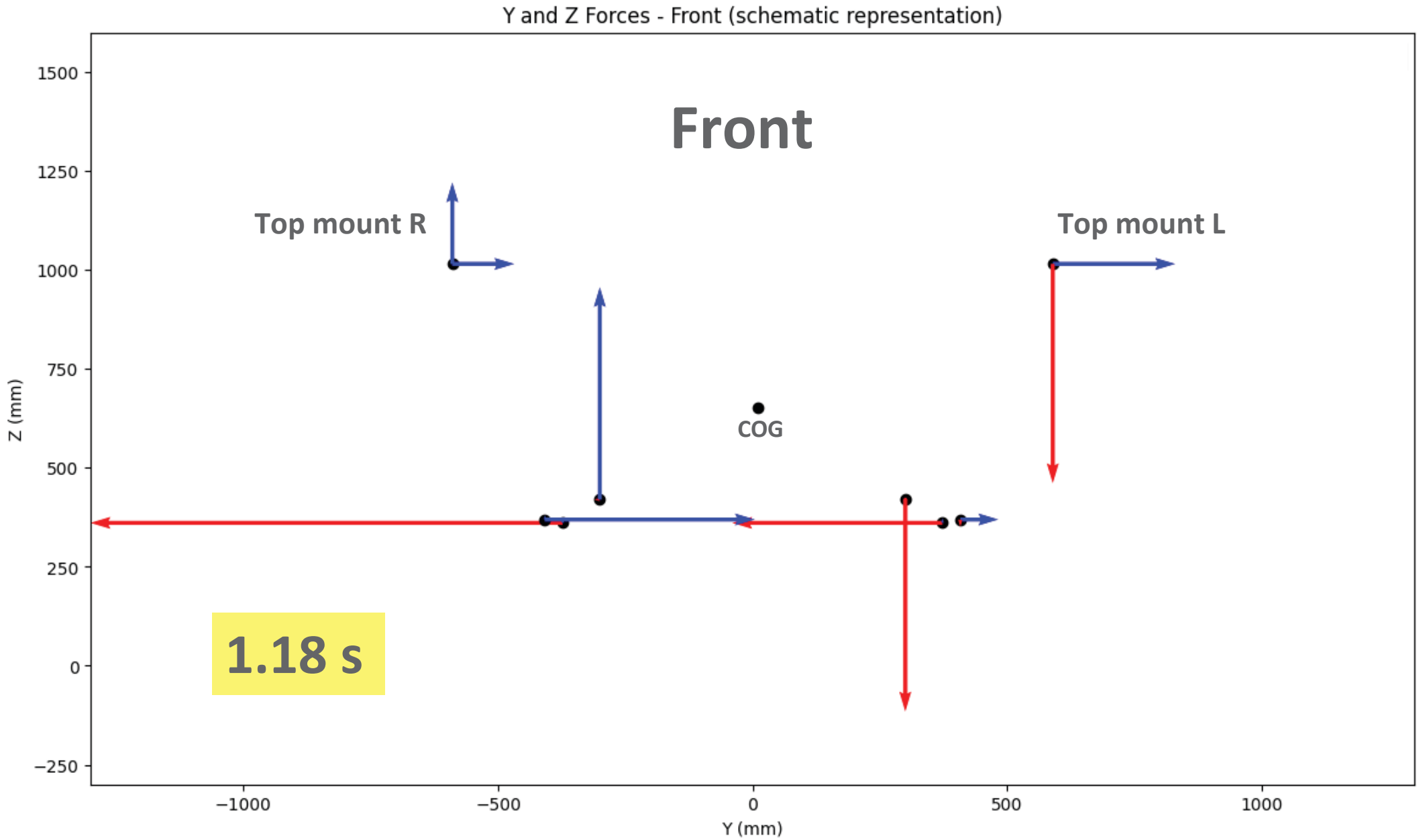
CEVT

Relative Moment



DDP related to highest Relative Moment

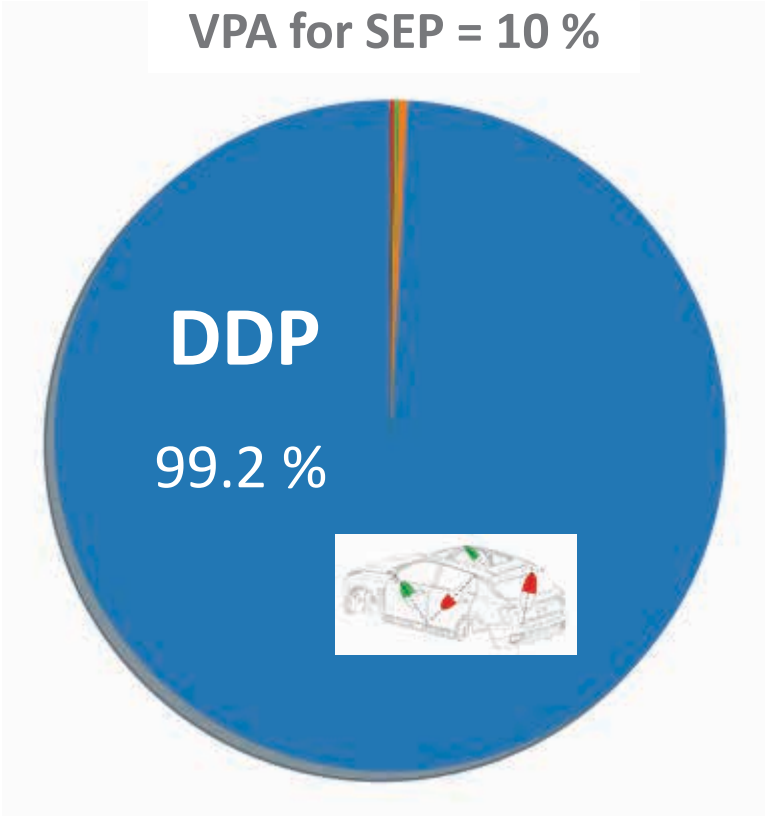
CEVT


Y and Z Forces - Front (schematic representation)
Front
Top mount R
Top mount L
COG
1.18 s
Z (mm)
Y (mm)
1500
1250
1000
750
500
250
0
−250
−1000
−500
0
500
1000

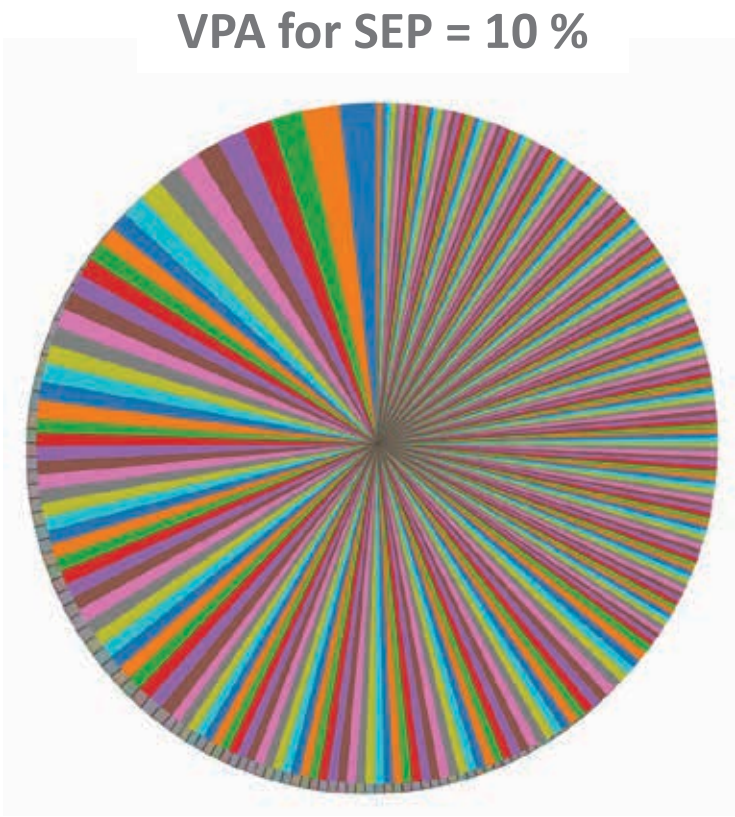
CEVT

Dominant Distortion Pattern

Force Pattern

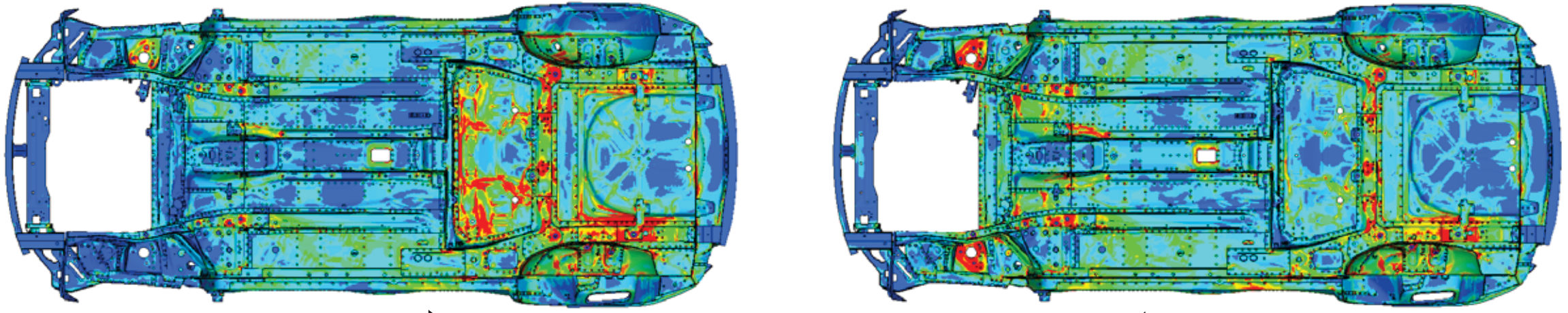


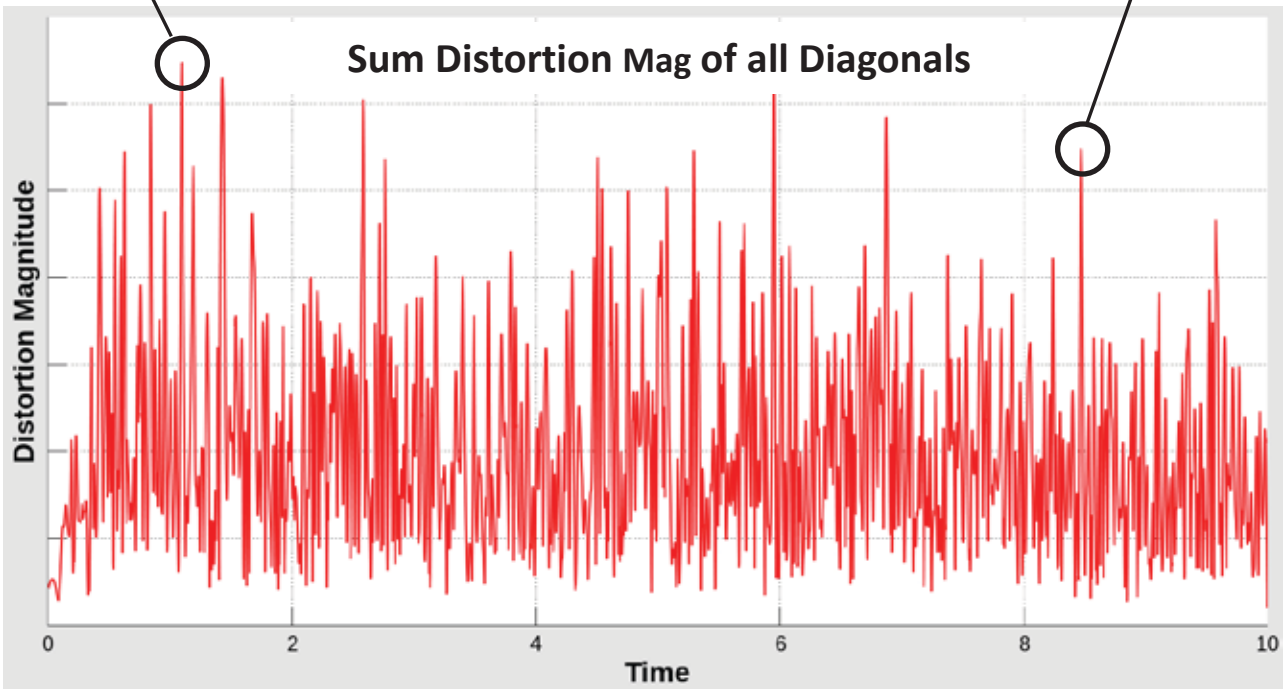
!



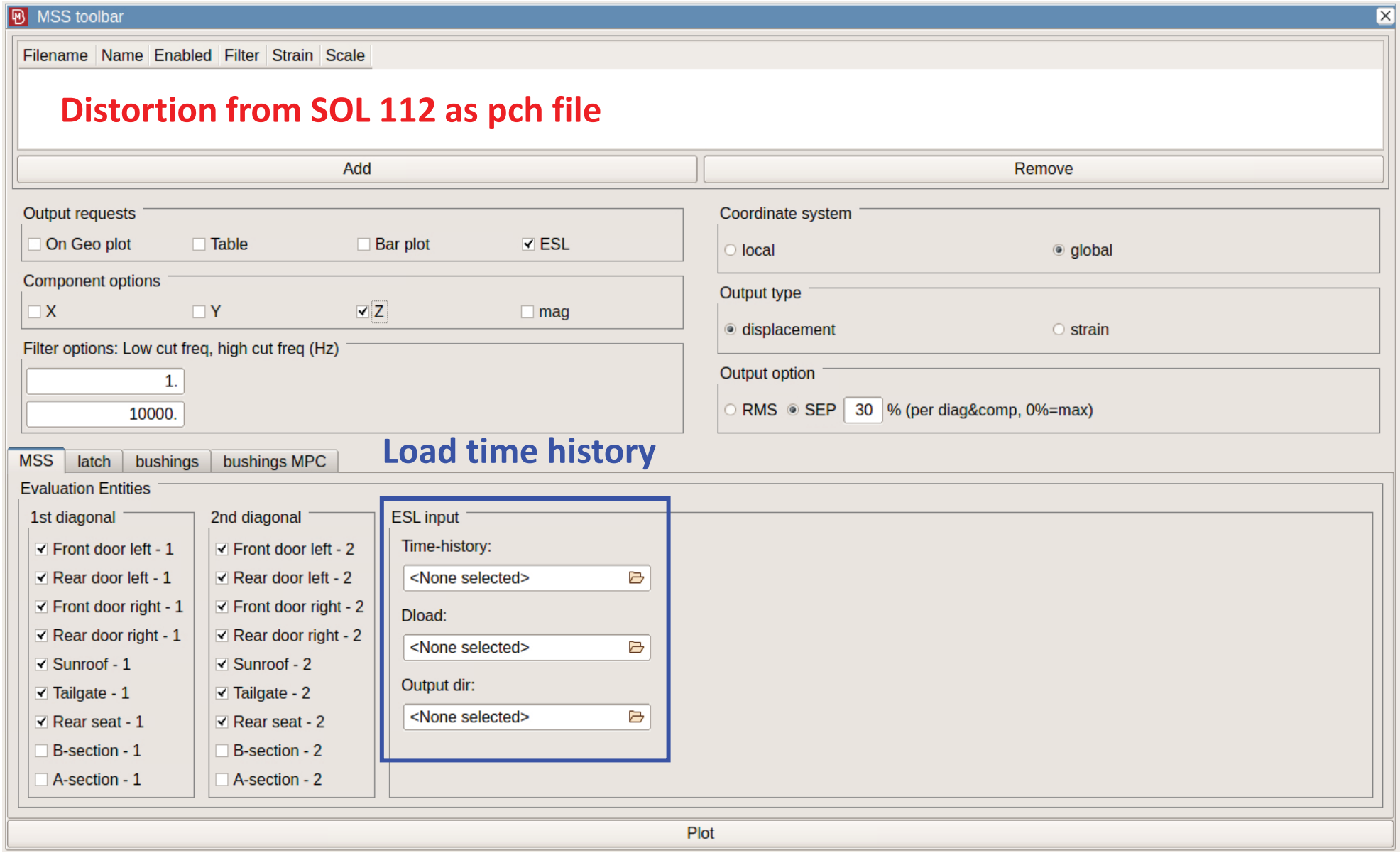
CEVT

Stress contour plot

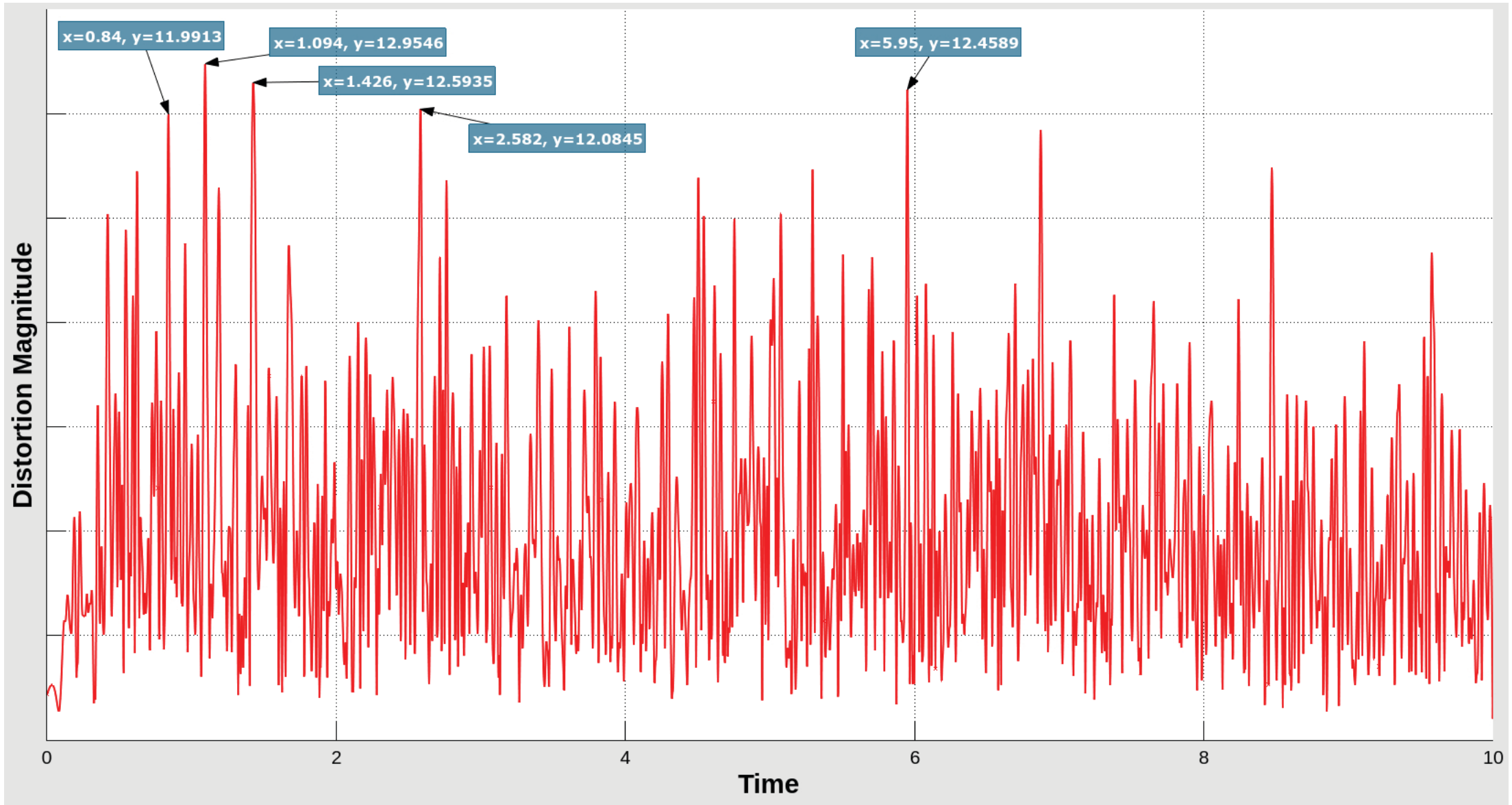




CEVT


MSS toolbar
Filename
Name
Enabled
Filter
Strain
Scale
Distortion from SOL 112 as pch file
Add
Remove
Output requests
On Geo plot
Table
Bar plot
ESL
Component options
X
Y
Z
mag
Filter options: Low cut freq, high cut freq (Hz)
1.
10000.
Coordinate system
local
global
Output type
displacement
strain
Output option
RMS
SEP
30
% (per diag&comp, 0%=max)
Load time history
MSS
latch
bushings
bushings MPC
Evaluation Entities
1st diagonal
Front door left - 1
Rear door left - 1
Front door right - 1
Rear door right - 1
Sunroof - 1
Tailgate - 1
Rear seat - 1
B-section - 1
A-section - 1
2nd diagonal
Front door left - 2
Rear door left - 2
Front door right - 2
Rear door right - 2
Sunroof - 2
Tailgate - 2
Rear seat - 2
B-section - 2
A-section - 2
ESL input
Time-history:
<None selected>
Dload:
<None selected>
Output dir:
<None selected>
Plot

CEVT


x=0.84, y=11.9913
x=1.094, y=12.9546
x=1.426, y=12.5935
x=2.582, y=12.0845
x=5.95, y=12.4589
Distortion Magnitude
0
2
4
6
8
10
Time

CEVT

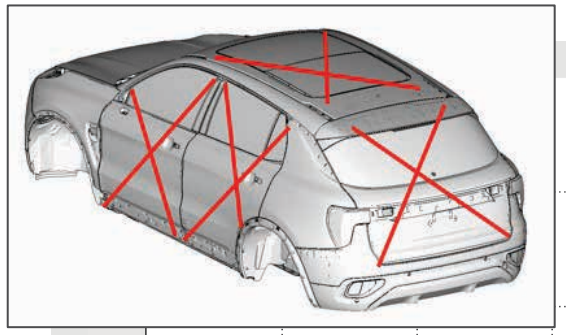
5 ESL files

- pattern_esl_nr_1_input_pnt_547.nas
- pattern_esl_nr_2_input_pnt_713.nas
- pattern_esl_nr_3_input_pnt_2975.nas
- pattern_esl_nr_4_input_pnt_1291.nas
- pattern_esl_nr_5_input_pnt_420.nas

SOL 101 inertia relief

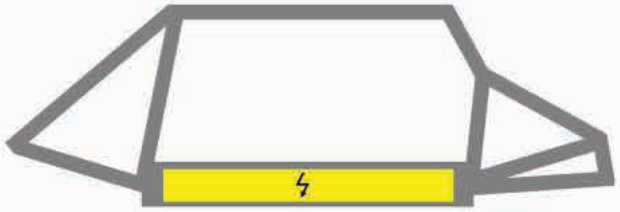
```
$$ META point id: 1291
$$ pch x-value: 2.582
$$ pch y-value: 12.084505468417802
$$ DLOAD x-value: 2.582
$$ DLOAD index  : 1291
$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORCE           155000131       -100.732 1.0     0.0     0.0
FORCE           155000131       -616.837 0.0     1.0     0.0
FORCE           155000131       -106.204 0.0     0.0     1.0
FORCE           155000231       -92.1506 1.0     0.0     0.0
FORCE           155000231       -1084.06 0.0     1.0     0.0
FORCE           155000231       -42.6575 0.0     0.0     1.0
FORCE           155000132       -20.3440 1.0     0.0     0.0
FORCE           155000132       -50.7934 0.0     1.0     0.0
FORCE           155000132       -15.1549 0.0     0.0     1.0
FORCE           155000232       -216.167 1.0     0.0     0.0
FORCE           155000232       434.3574 0.0     1.0     0.0
FORCE           155000232       -70.4572 0.0     0.0     1.0
FORCE           156700141       -122.388 1.0     0.0     0.0
FORCE           156700141       -169.124 0.0     1.0     0.0
FORCE           156700141       -577.598 0.0     0.0     1.0
FORCE           156700241       -153.113 1.0     0.0     0.0
FORCE           156700241       -425.065 0.0     1.0     0.0
FORCE           156700241       517.7055 0.0     0.0     1.0
FORCE           155000163       31.40463 1.0     0.0     0.0
FORCE           155000163       -5.15434 0.0     1.0     0.0
FORCE           155000163       909.4758 0.0     0.0     1.0
FORCE           155000263       -42.8932 1.0     0.0     0.0
FORCE           155000263       -10.8633 0.0     1.0     0.0
FORCE           155000263       -926.060 0.0     0.0     1.0
FORCE           171000204       -202.895 1.0     0.0     0.0
FORCE           171000204       -0.47983 0.0     1.0     0.0
FORCE           171000204       -4.92513 0.0     0.0     1.0
FORCE           171000104       -188.038 1.0     0.0     0.0
FORCE           171000104       -0.45356 0.0     1.0     0.0
FORCE           171000104       -3.42368 0.0     0.0     1.0
FORCE           166600321       -265.331 1.0     0.0     0.0
FORCE           166600321       33.43146 0.0     1.0     0.0
FORCE           166600321       101.1342 0.0     0.0     1.0
FORCE           166600421       -660.688 1.0     0.0     0.0
FORCE           166600421       55.51377 0.0     1.0     0.0
FORCE           166600421       -265.052 0.0     0.0     1.0
FORCE           166200351       -102.649 1.0     0.0     0.0
FORCE           166200351       119.3053 0.0     1.0     0.0
FORCE           166200351       1022.253 0.0     0.0     1.0
```

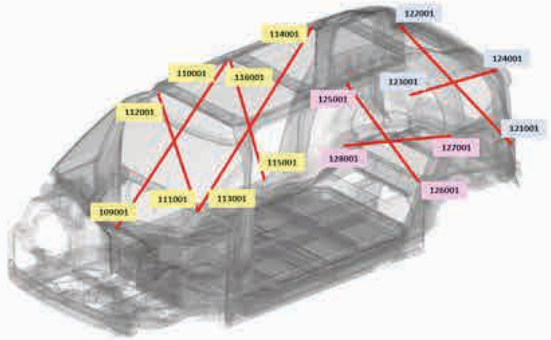
CEVT

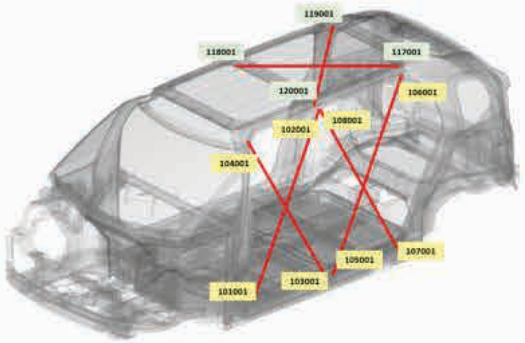


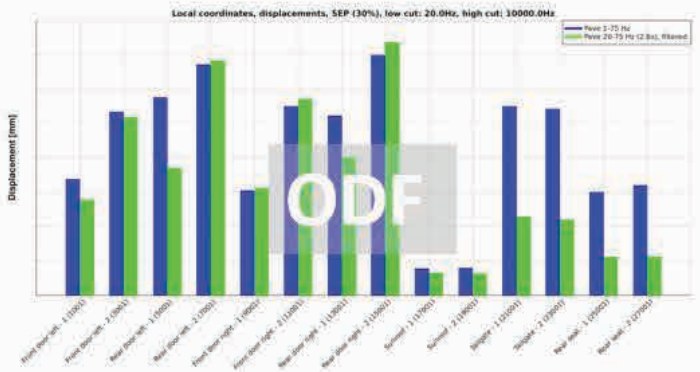
Equivalent Static Load ESL
based on DDP

CEVT




114001
122001
110001
116001
124001
123001
112001
125001
121001
127001
115001
128001
111001
113001
126001
109001

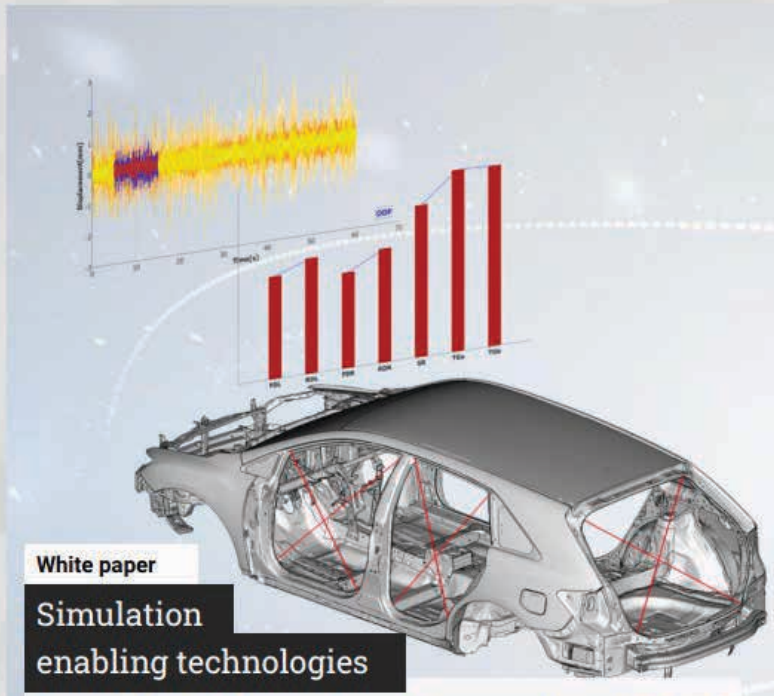

119001
118001
117001
120001
106001
108001
102001
104001
105001
107001
101001
103001


Local coordinates, displacements, SEP (30%), low cut: 20.0Hz, high cut: 10000.0Hz
Displacement [mm]
ODF

CEVT

BETA
SIMULATION SOLUTIONS

physics on screen

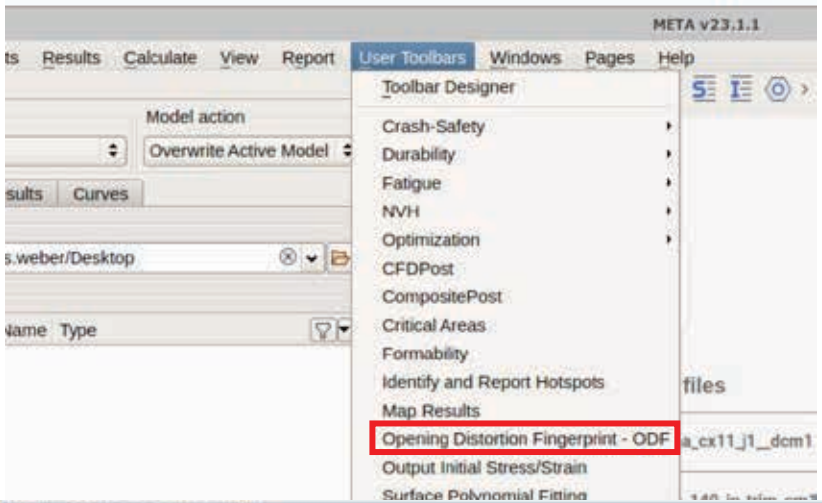


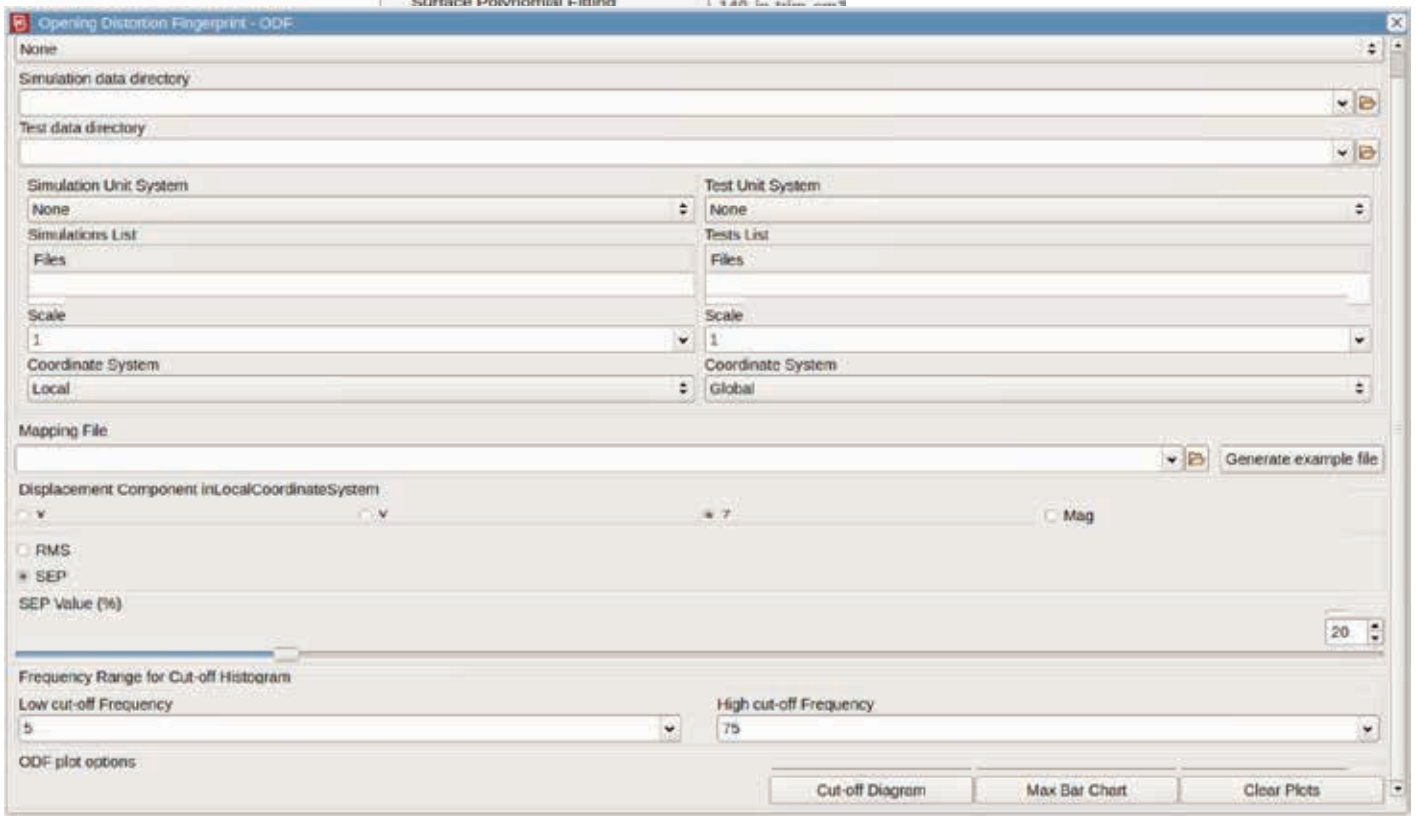
White paper

Simulation enabling technologies

Opening Distortion Fingerprint (ODF)

The Opening Distortion Fingerprint (ODF) is a method to evaluate the opening stiffness on vehicle body using dynamic results instead of static loads. It can be used to limit the distortion in the closure openings, and enable a deeper analysis of the dynamic forces acting on the body.





CEVT

SAE 2022-01-0950

2022-01-0950 Published 15 Jun 2022

Opening Distortion Fingerprint (ODF) - A New Body Evaluation Method for Perceived Quality and Vehicle Dynamics

Jens Weber CEVT AB
Viktor Jönsson Altan Sverige AB
Lars Hansson Wolkesson & Hansson Teknisk Akustik AB
Roberta Varela Altair Engineering GmbH
Britta Käck Altair Engineering Inc.

Citation: Weber, J., Jönsson, V., Hansson, L., Varela, R. et al., "Opening Distortion Fingerprint (ODF) - A New Body Evaluation Method for Perceived Quality and Vehicle Dynamics," SAE Technical Paper 2022-01-0950, 2022, doi:10.4271/2022-01-0950.

Received: 07 Dec 2021 Revised: 21 Mar 2022 Accepted: 24 Mar 2022

Abstract

The body performance of an electrical vehicle is significantly affected by the structural integration of the stiff battery package. In addition, the body topology of future electrical vehicles/mobility solutions will differ clearly from conventional ones, e.g. no B-pillar. This makes the current body requirement such as static torsional stiffness less relevant.

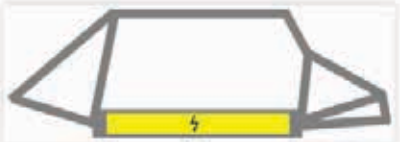
In order to meet the new challenges during the virtual development phase a new body evaluation method has been developed. The method uses the dynamic distortion in all openings in a complete vehicle setup to calculate the so-called Opening Distortion Fingerprint (ODF). The ODF evaluation is performed in time and frequency domain. The application of this new method is shown in both test and simulation.

There are two main areas of application. One of them is Perceived Quality where the ODF can be used as a new body assessment criterion. This also includes the calculation of an equivalent static load (ESL) based on the ODF, which can be used for optimization purposes. The second area is Vehicle Dynamics. The ODF, together with the operating deflection shape (ODS) enables a deeper analysis of the interaction between the wheel suspension/drive line and the body. A test example is presented where a dominant pitch mode of the drive line could be predicted based on the ODF and then confirmed by the ODS.

Introduction

The stiffness of the vehicle body is an important parameter for both Perceived Quality and Vehicle Dynamics. On the one side the stiffness is very strongly related to the relative displacement between different subassemblies (e.g. instrument panel and door panel) and within a subassembly, which are mounted to the body [1,2]. And on the other side it has a clear impact on the interaction between the wheel suspension/drive line and the body. Since many years the static torsional stiffness is used as a requirement on the body structure. Currently the automotive industry is in a transition phase

FIGURE 1 New body structure with integrated battery.



VDI Berichte Nr. 2407, 2022

Vehicle Stiffness Evaluation in MBD Simulation Using the ODF Method (Opening Distortion Fingerprint)

J. Weber, **P. Ugale**, **S. Olsson**, CEVT AB, Gothenburg, Sweden;
R. Varela, Altair Engineering GmbH, Böblingen

Abstract

Within Durability the combination of Multi Body Dynamics (MBD) and Finite Element (FE) simulation has been applied for many years. First, the MBD simulation is calculating the forces between a detailed chassis model and a simplified trimmed body model. In a second step, the time history of the forces is applied on the detailed FE model of the trimmed body in order to perform the durability analysis. The increased application of this simulation procedure also within Perceived Quality shifts the focus from strain/stress to deformation evaluation of the body. To make this hybrid-simulation more efficient, the evaluation of the body deformation is performed directly in the MBD simulation. To enable this process the detailed FE model of the trimmed body is converted to a flexible MBD model including all the necessary output points for the body evaluation. An example of this enhanced process is shown where the new body evaluation method ODF (Opening Distortion Fingerprint) is applied. By automizing this process the benefit of the ODF outcome becomes even more clear. Beside using ODF as efficient health check for the complex MBD simulation of a complete vehicle, it can be also used as assessment criteria for Perceived Quality and for a deeper understanding of the interaction between the chassis and the body (Vehicle Dynamics).

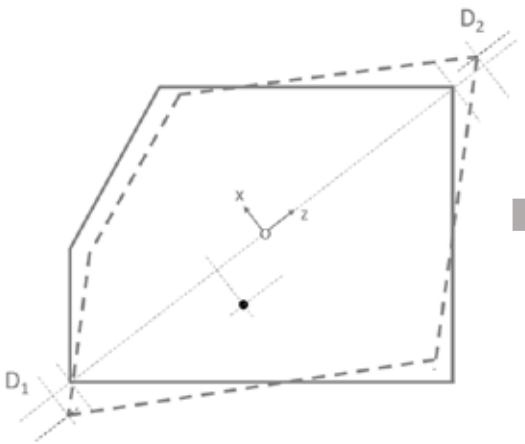
Introduction

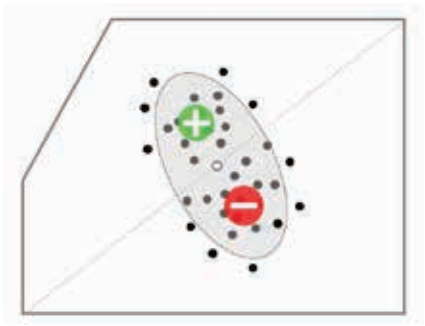
The static torsional stiffness has been used as assessment criteria for vehicle bodies since

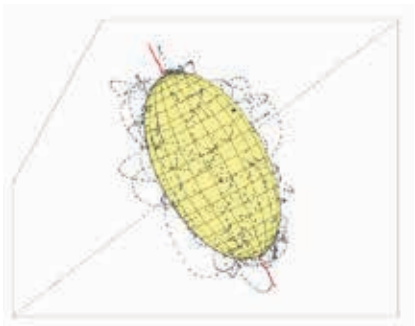
CEVT

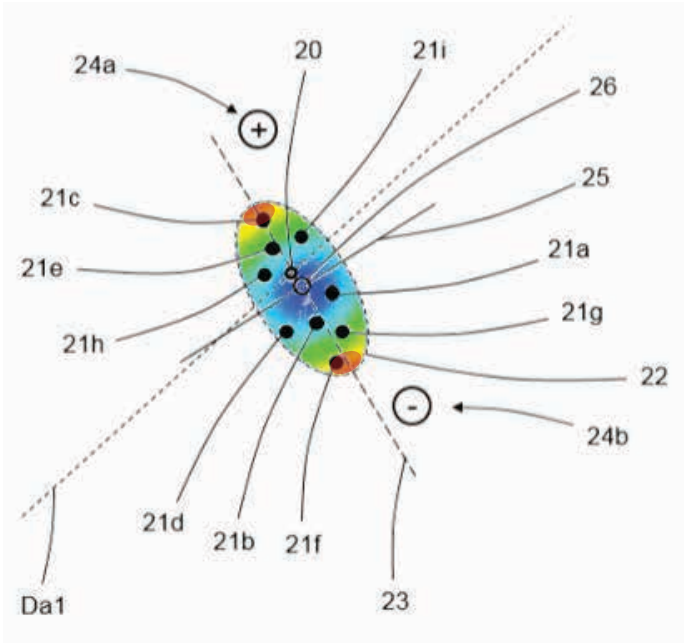
Tack så mycket!

jens.weber@cevt.se









Ref: ”Die kleine Raupe Nimmersatt” von Eric Carle

CEVT