National Science Foundation

University of California at San Diego
NHERI
Natural Hazards Engineering Research Infrastructure

UC San Diego
JACOBS SCHOOL OF ENGINEERING
Structural Engineering

Example Use of Research Tools

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Joint Researcher Workshop
UC San Diego, Lehigh & SimCenter

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University of California, San Diego

LEHIGH NHERI
Real-Time Multi-Directional Testing Facility

University of California at San Diego
NHERI
Natural Hazards Engineering Research Infrastructure

SIMCENTER
COMPUTATIONAL MODELING AND SIMULATION CENTER

Objectives

- Demonstrate use-cases of our research tools
- Get feedback on existing features
- Collect requests for new features

Research Tools

- **quoFEM** **Uncertainty Quantification and Optimization**

- **EE-UQ** **Structural Response Estimation under Earthquakes**
- WE-UQ Structural Response Estimation under Wind
- CWE CFD Analysis for a Building

- **PBE** **Damage and Loss Assessment for a Building**
- rWHALE Damage and Loss Assessment for an Urban Region

Case study

example application: Buckling Restrained Braced Frames

1. Design an experiment	quoFEM
2. Calibrate a numerical component model	quoFEM
3. Simulate structural response	EE-UQ
4. Estimate damage and losses	PBE

Case study

example application: Buckling Restrained Braced Frames

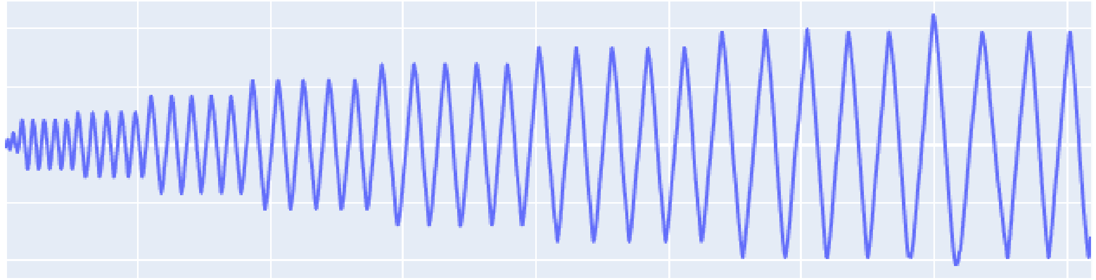
1. Design an experiment	**quoFEM**
2. Calibrate a numerical component model	quoFEM
3. Simulate structural response	EE-UQ
4. Estimate damage and losses	PBE

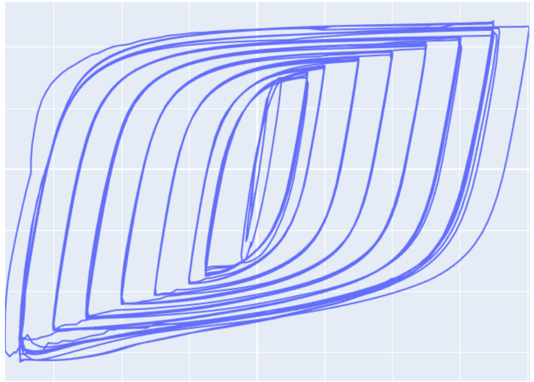
Design an experiment

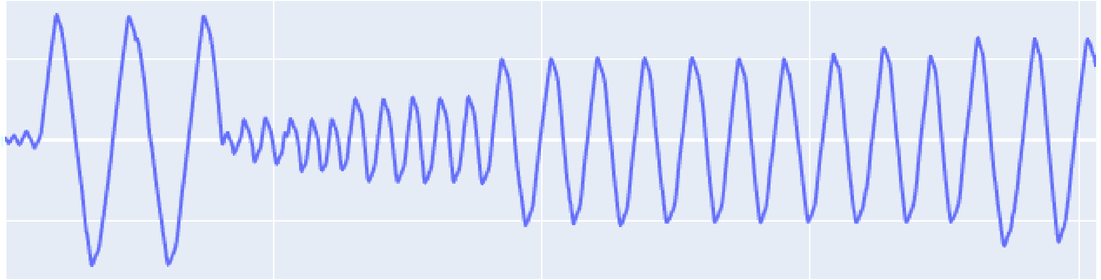
setting: uniaxial cyclic load test of a Buckling Restrained Brace

objective: estimate maximum tension/compression during test

problem: some attributes of the specimen are not known
new load protocol



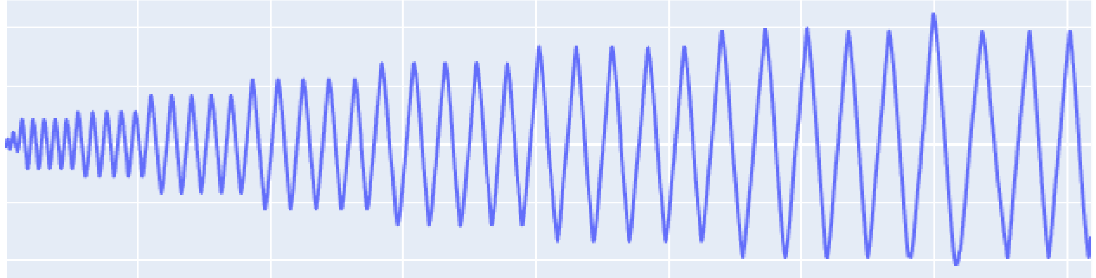


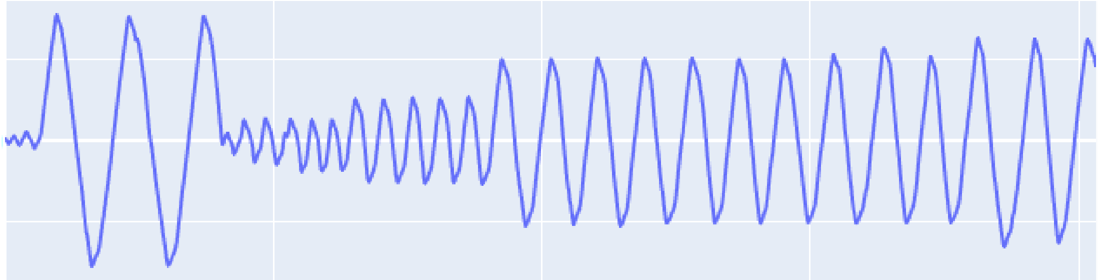


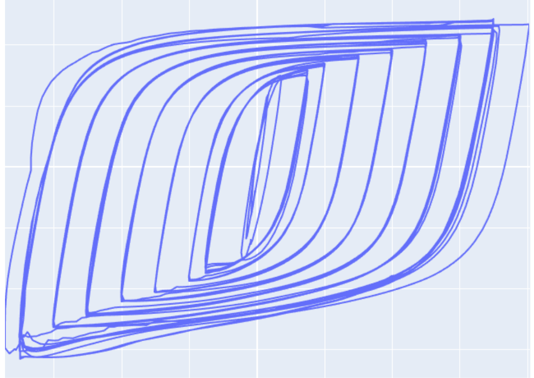
?

Design an experiment

**quoFEM: sample the joint distribution of uncertain attributes
simulate the experiment; estimate max loads**







?

Design an experiment

First, through literature review get:

- conservative bounds for attributes
- simplified BRB model in OpenSees

Then, prepare:

- new load protocol
- script to simulate experiment
- script to extract max forces

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Design an experiment

First, through literature review get:

- **conservative bounds for attributes**
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Then, prepare:

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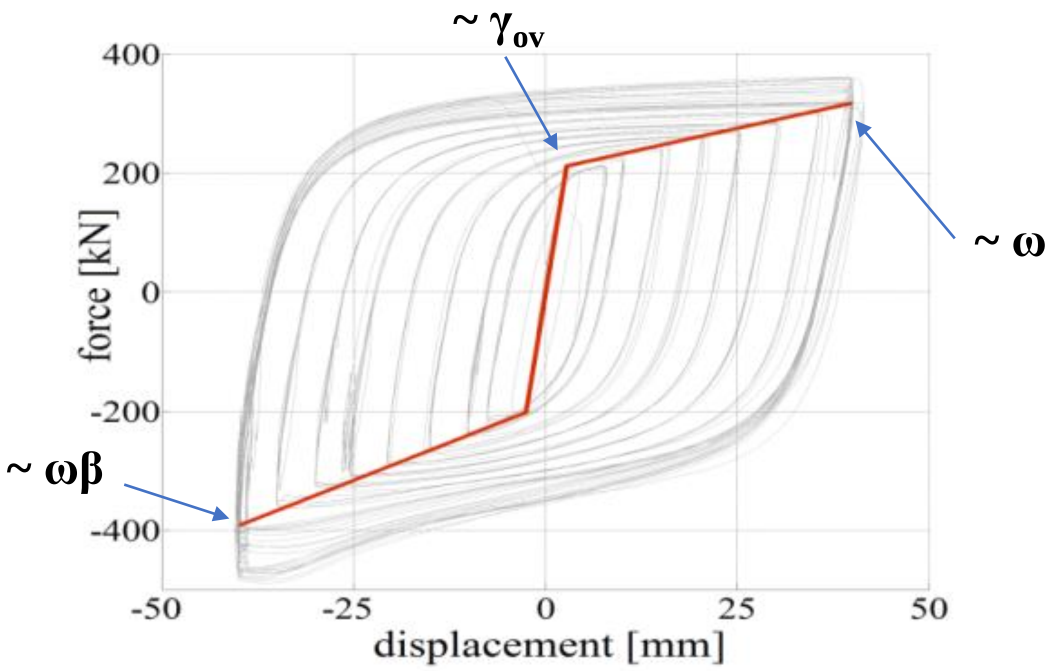

γ_{ov}	1.10 – 1.20
ω	1.35 – 1.75
β	1.01 – 1.30
ω_{iso}	0.05 – 0.30

Design an experiment

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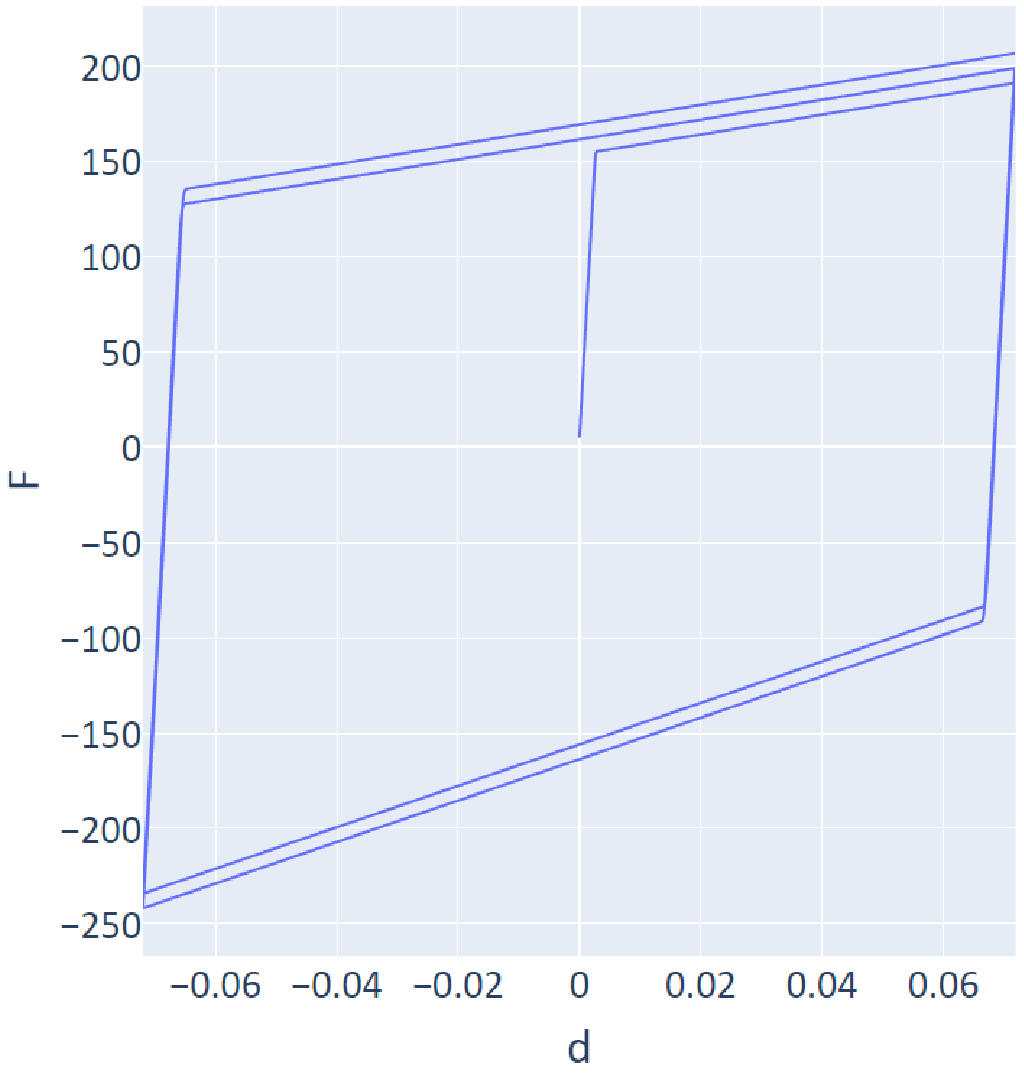

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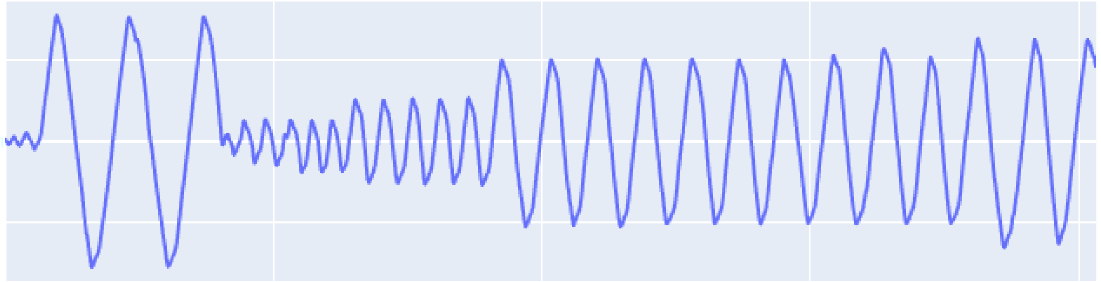

Then, prepare:

- **new load protocol**
- script to simulate experiment
- script to extract max forces

```
set disp_protocol { 0.125 -0.125 0.25 -0.25
    3.0 -3.0 3.0 -3.0 3.0 -0.125 0.25 -0.25
    0.5 -0.5 0.5 -0.5 0.5 -0.5 0.5 -0.5 0.5
    -0.5 1.0 -1.0 1.0 -1.0 1.0 -1.0 1.0 -1.0
     1.0 -1.0 2.0 -2.0 2.0 -2.0 2.0 -2.0 2.0
     -2.0 2.0 -2.0 2.0 -2.0 2.0 -2.0 2.0 -
    2.0 2.0 -2.0 2.0 -2.0 }
```

disp_protocol.tcl

Design an experiment

First, through literature review get:

- conservative bounds for attributes
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Then, prepare:

- new load protocol
- **script to simulate experiment**
- script to extract max forces

```
model BasicBuilder -ndm 1 -ndf 1

set l 2.500
set A_y 600
set f_DM 1.39
set f_SM 1.13

# hyperparameters
pset gammaOv 1.1
pset omega 1.55
pset omegaIso 0.4;
pset beta 1.15

set l [expr $l*$m]
set A_y [expr $A_y*$mm2]

set f_yk [expr 235.0 * $MPa]
set E_s [expr 210.0 * $GPa]

# calculate material props
set E_0  [expr $f_SM*$E_s];
set f_y  [expr $gammaOv*$f_yk];
set eps_y [expr $f_y/$E_0]
```

BRB_response.tcl

Design an experiment

First, through literature review get:

- conservative bounds for attributes
- simplified BRB model in OpenSees

Then, prepare:

- new load protocol
- **script to simulate experiment**
- script to extract max forces

```
set matBRB 51
uniaxialMaterial Steel4 $matBRB $f_y $E_0 \
                -asym \
                -kin $b_k $R_0 $r_1 $r_2 $b_kc $R_
                -iso $b_i $rho_i $b_l $R_i $l_yp $
                -ult $f_u $R_u $f_u $R_u

element corotTruss 0 0 100 $A_y $matBRB

recorder Node -file "force_disp.out" -time -node 1

pattern Plain 1 Linear {
  load 100 [expr 1.0*$kN]
}

set IDctrlNode 100
set IDctrlDOF 1

constraints Plain
numberer RCM
system BandGeneral
test NormDispIncr 1.e-10 100
algorithm NewtonLineSearch -maxIter 100
```

BRB_response.tcl

Design an experiment

First, through literature review get:

- conservative bounds for attributes
- simplified BRB model in OpenSees

Then, prepare:

- new load protocol
- script to simulate experiment
- **script to extract max forces**

```python
#!/usr/bin/python
# written: adamzs 09/19

import numpy as np
import pandas as pd

def process_results(response):

    res = pd.read_csv('force_disp.out',
        sep=' ', header=None, names=['F', 'd'])

    F_c = np.abs(res['F'].min())
    F_t = res['F'].max()

    with open('results.out', 'w') as f:
        f.write('{} {}'.format(F_c, F_t))
```

postprocess.py

```
-262.325 227.717
```

results.out

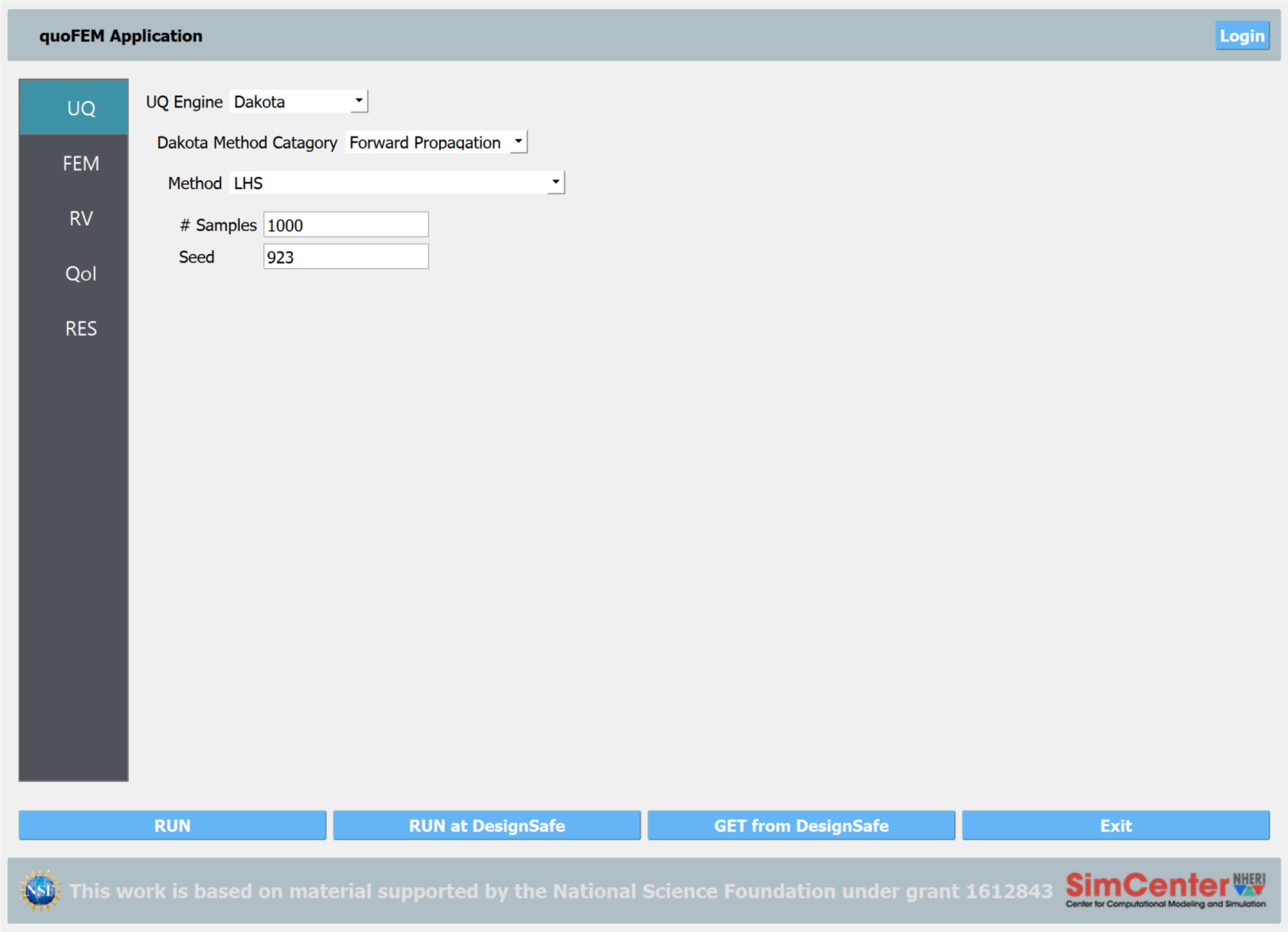
Design an experiment

select the type of problem

-> **forward propagation**

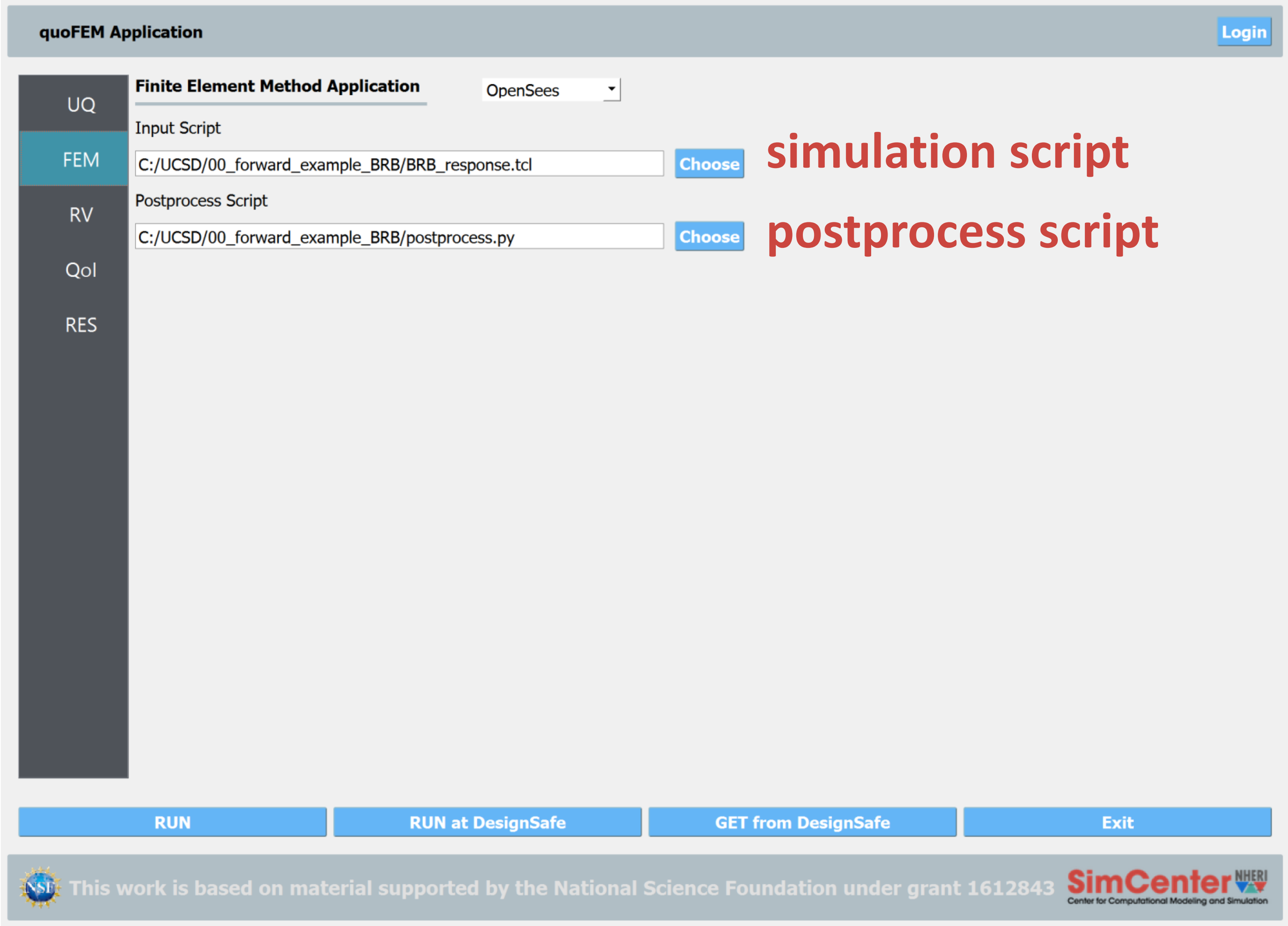
available methods:

- **Latin Hypercube Sampling**
- Monte Carlo Sampling
- Importance Sampling
- Gaussian Process Regression
- Polynomial Chaos Expansion



Design an experiment

load the pre-defined scripts



simulation script

postprocess script

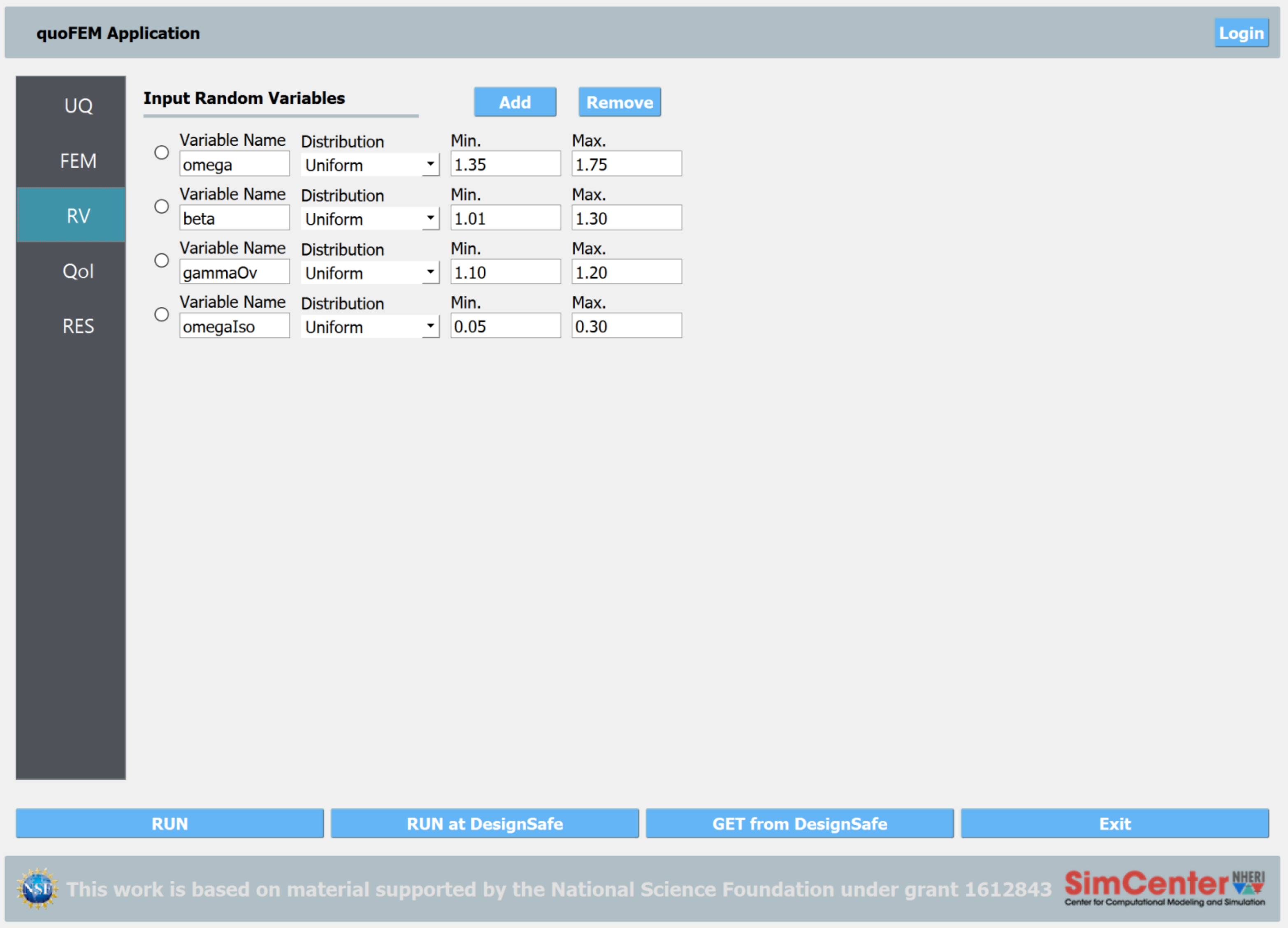
Design an experiment

BRB_response.tcl

```
# hyperparameters
pset gammaOv 1.1
pset omega 1.55
pset omegaIso 0.4;
pset beta 1.15
```

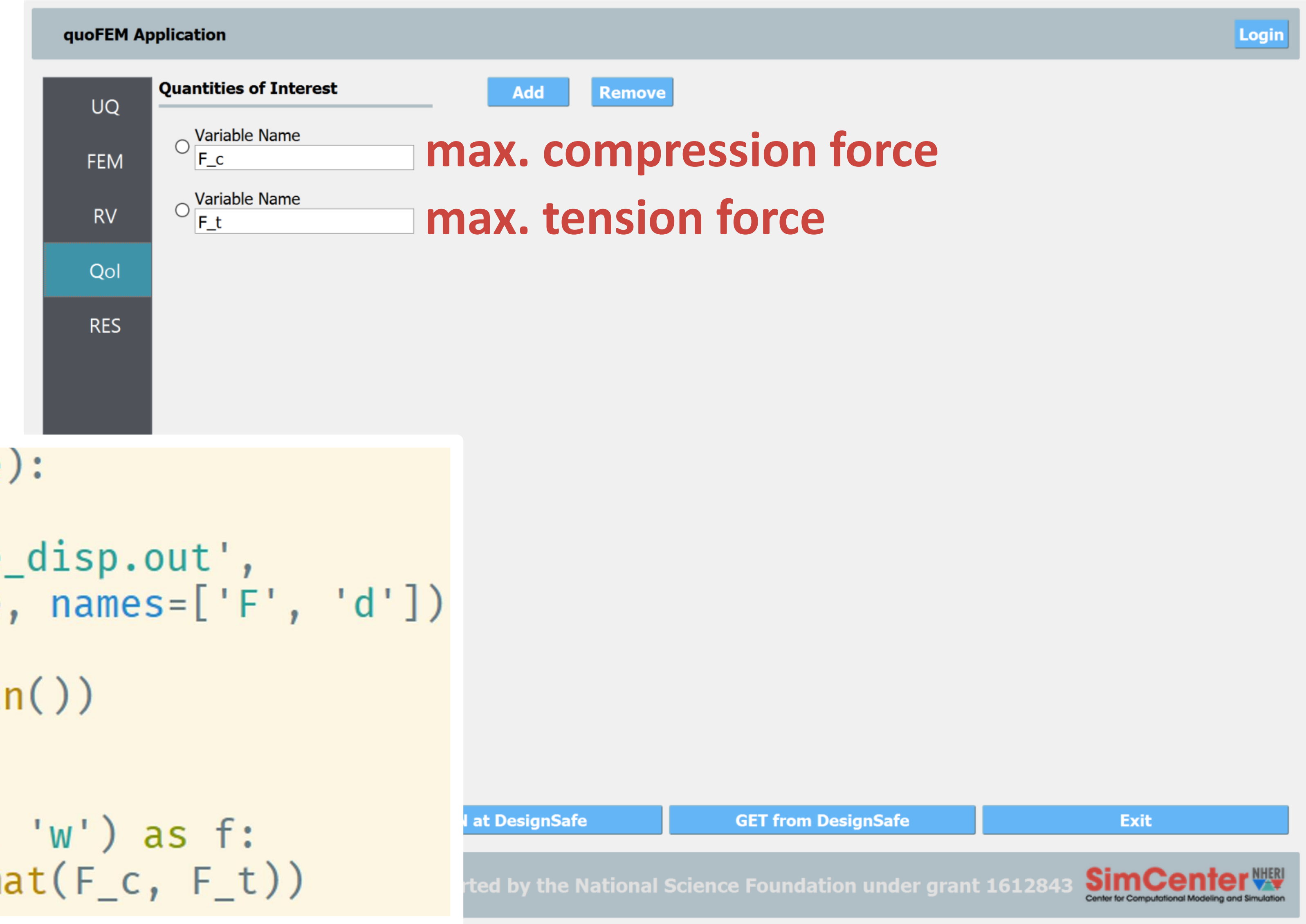
supported distributions:

- Normal, Lognormal
- Uniform
- Beta
- Weibull
- Gumbel



Design an experiment

specify the
Quantities of Interest



postprocess.py:

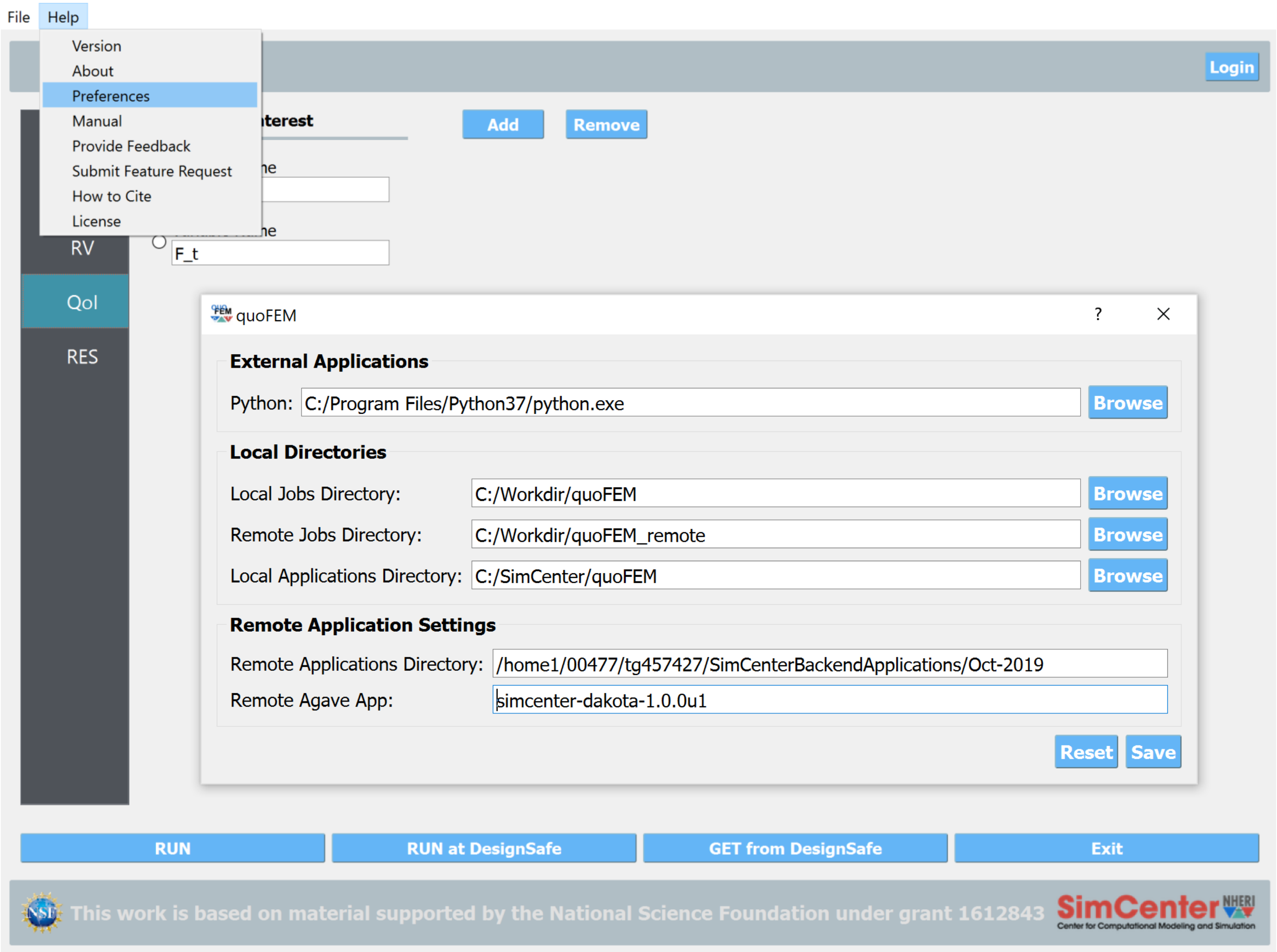
```python
def process_results(response):

    res = pd.read_csv('force_disp.out',
        sep=' ', header=None, names=['F', 'd'])

    F_c = np.abs(res['F'].min())
    F_t = res['F'].max()

    with open('results.out', 'w') as f:
        f.write('{} {}'.format(F_c, F_t))
```

Design an experiment

quoFEM

advanced users can

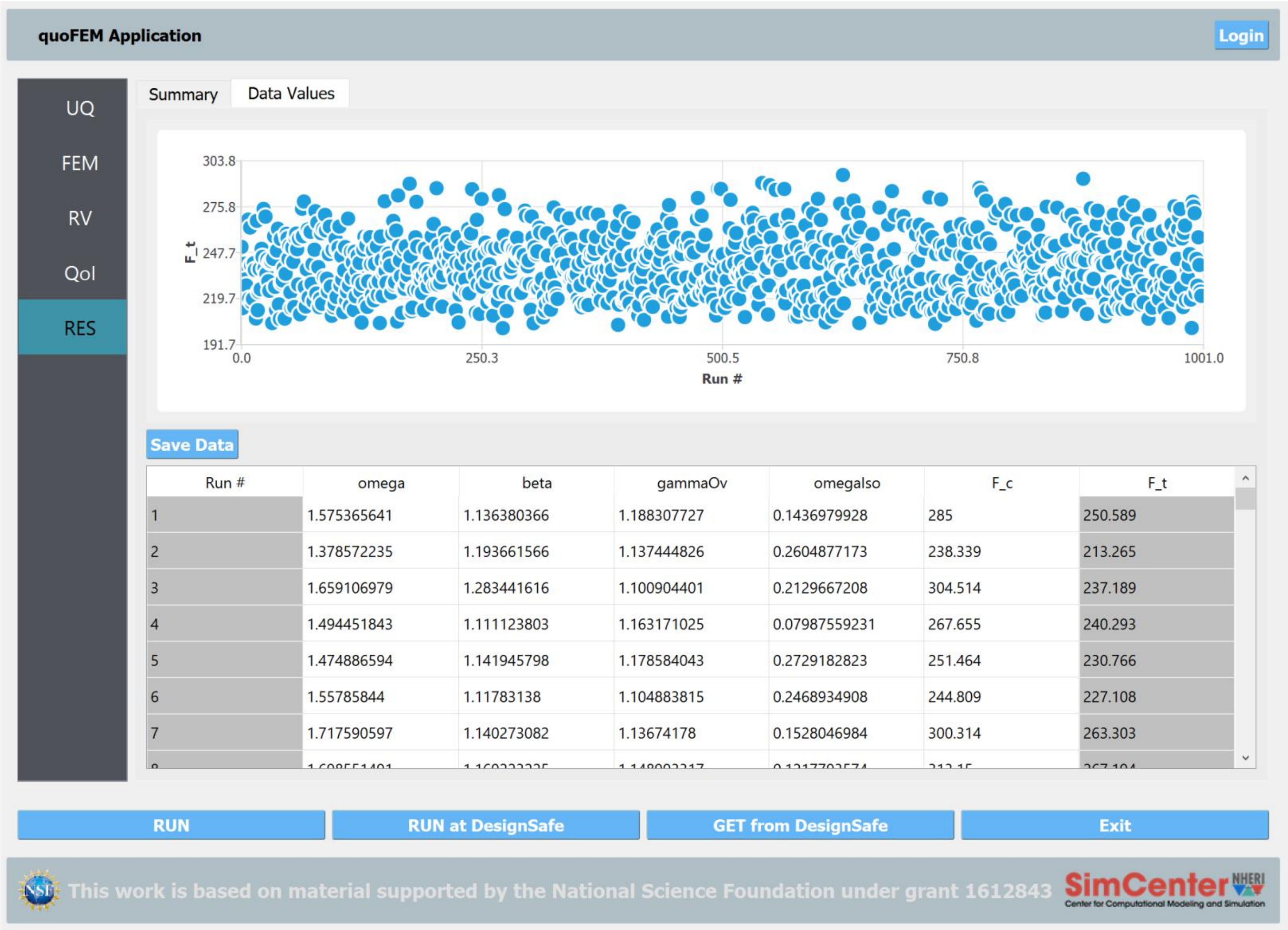
- specify their python interpreter
- edit working directories



Design an experiment

result visualization

scatterplots show sampled inputs and corresponding outputs

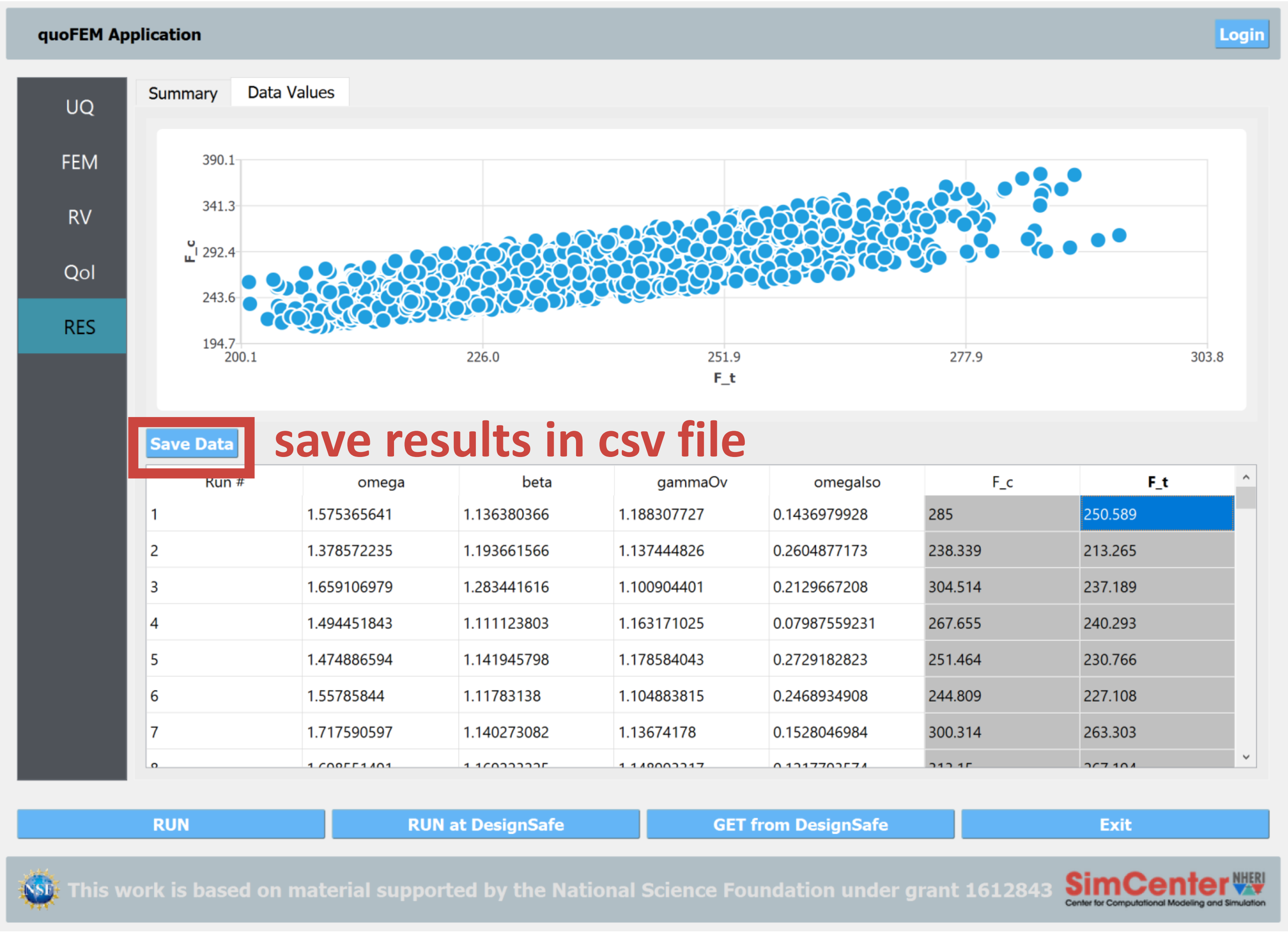


Design an experiment

result visualization

scatterplots show sampled inputs and corresponding outputs

and **joint distributions**



Run #	omega	beta	gammaOv	omegaIso	F_c	F_t
1	1.575365641	1.136380366	1.188307727	0.1436979928	285	250.589
2	1.378572235	1.193661566	1.137444826	0.2604877173	238.339	213.265
3	1.659106979	1.283441616	1.100904401	0.2129667208	304.514	237.189
4	1.494451843	1.111123803	1.163171025	0.07987559231	267.655	240.293
5	1.474886594	1.141945798	1.178584043	0.2729182823	251.464	230.766
6	1.55785844	1.11783138	1.104883815	0.2468934908	244.809	227.108
7	1.717590597	1.140273082	1.13674178	0.1528046984	300.314	263.303

Design an experiment

advanced visualization and data processing

easy to load csv in Python, MatLAB, or Excel

```
import pandas as pd
import plotly.express as px
res = pd.read_csv("C:/UCSD/00_forward_example_BRB/output_UCSD.csv",
                  sep=',\t', dtype=float)
res.head(10)
```

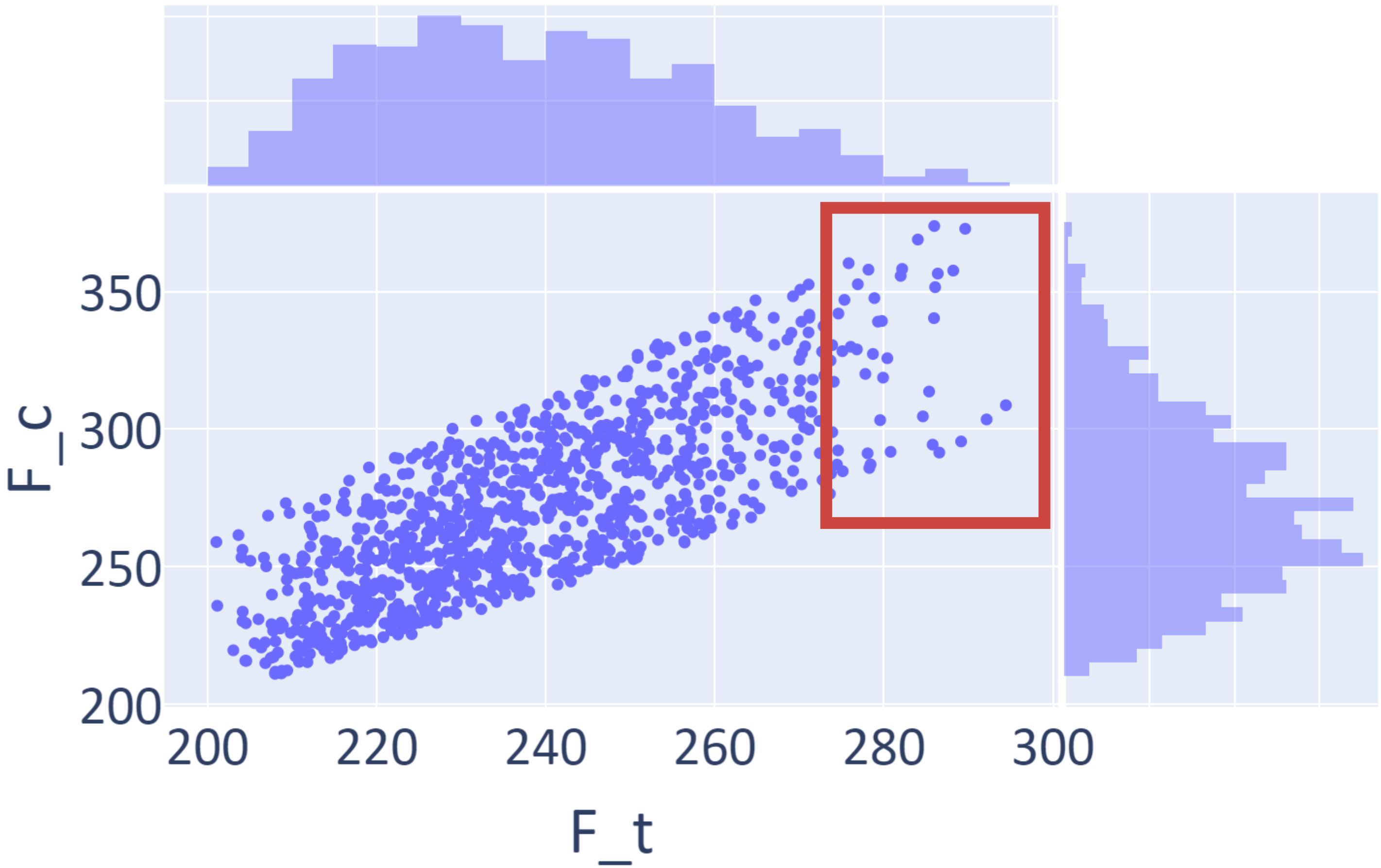
	Run #	omega	beta	gammaOv	omegaIso	F_c	F_t
0	1.0	1.57537	1.13638	1.18831	0.143698	285.000	250.589
1	2.0	1.37857	1.19366	1.13744	0.260488	238.339	213.265
2	3.0	1.65911	1.28344	1.10090	0.212967	304.514	237.189
3	4.0	1.49445	1.11112	1.16317	0.079876	267.655	240.293
4	5.0	1.47489	1.14195	1.17858	0.272918	251.464	230.766
5	6.0	1.55786	1.11783	1.10488	0.246893	244.809	227.108
6	7.0	1.71759	1.14027	1.13674	0.152805	300.314	263.303
7	8.0	1.69855	1.16922	1.14899	0.121779	313.150	267.194
8	9.0	1.40822	1.20869	1.17317	0.176460	257.507	218.961
9	10.0	1.73973	1.10822	1.18051	0.253128	289.577	262.384

Design an experiment

advanced visualization and data processing

```
fig = px.scatter(res, x='F_t', y='F_c',
                 marginal_x='histogram', marginal_y='histogram',
                 height=500, width=800)
fig['layout'].update(font=dict(family="Calibri", size=28))
fig.show()
```

joint distribution with marginals

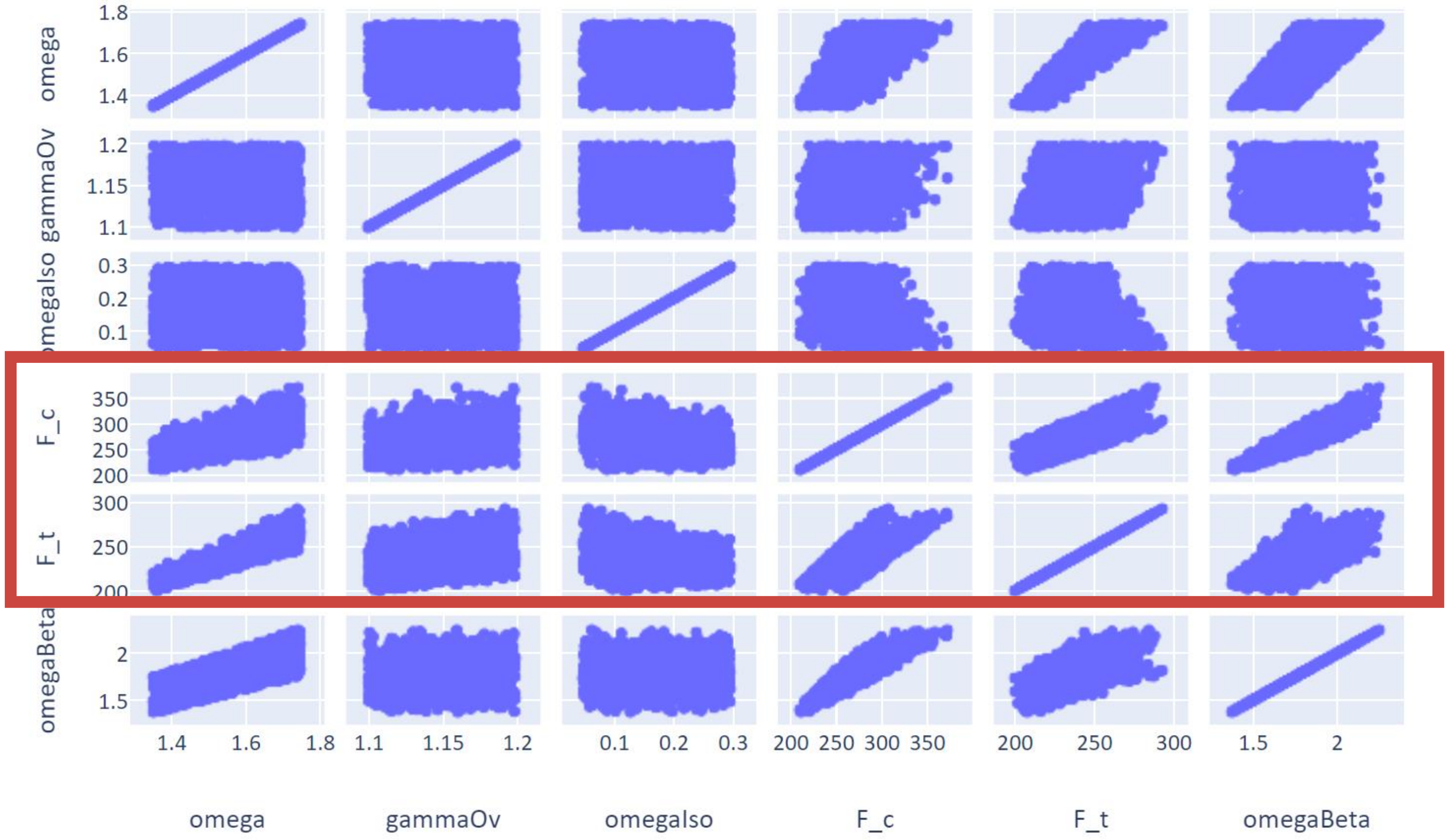


Design an experiment

advanced visualization and data processing

use scatter matrix to identify dependencies

```
fig = px.scatter_matrix(res,
                        dimensions=['omega','omegaBeta','omegaIso',
                                    'gammaOv','F_c','F_t'],
                        height=500, width=800)
fig['layout'].update(font=dict(family="Calibri", size=15))
fig.show()
```

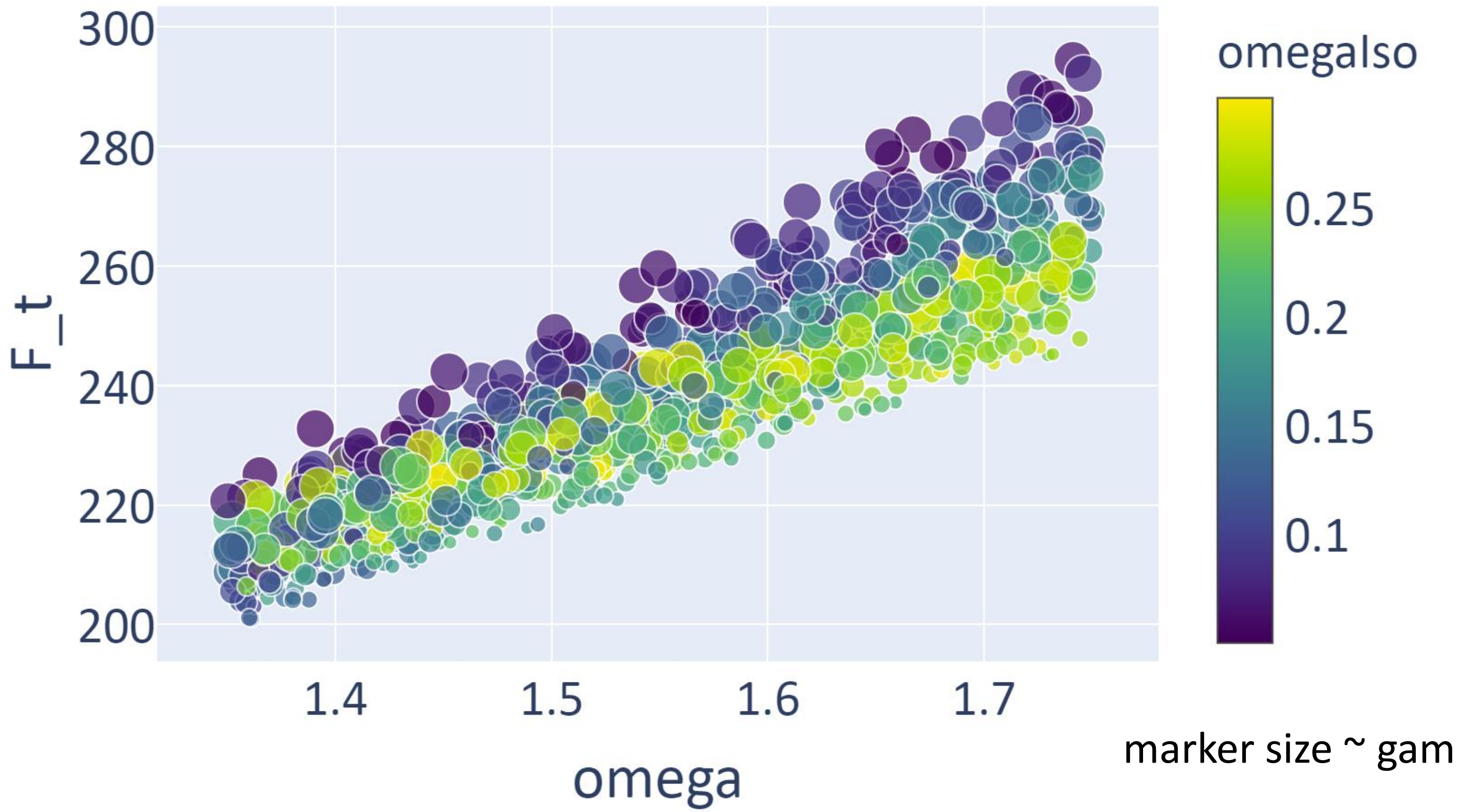


Design an experiment

advanced visualization and data processing

```
res['gammaOv_viz'] = np.log(res['gammaOv']*10.0-9.9)
fig2 = px.scatter(res, x='omega', y='F_t', color='omegaIso',
                  color_continuous_scale=px.colors.sequential.Viridis,
                  size='gammaOv_viz', size_max=20, height=500, width=800)
fig2['layout'].update(font=dict(family="Calibri", size=28))
fig2.show()
```

use color and marker size to visualize dependency on 3 parameters



marker size ~ gammaOv

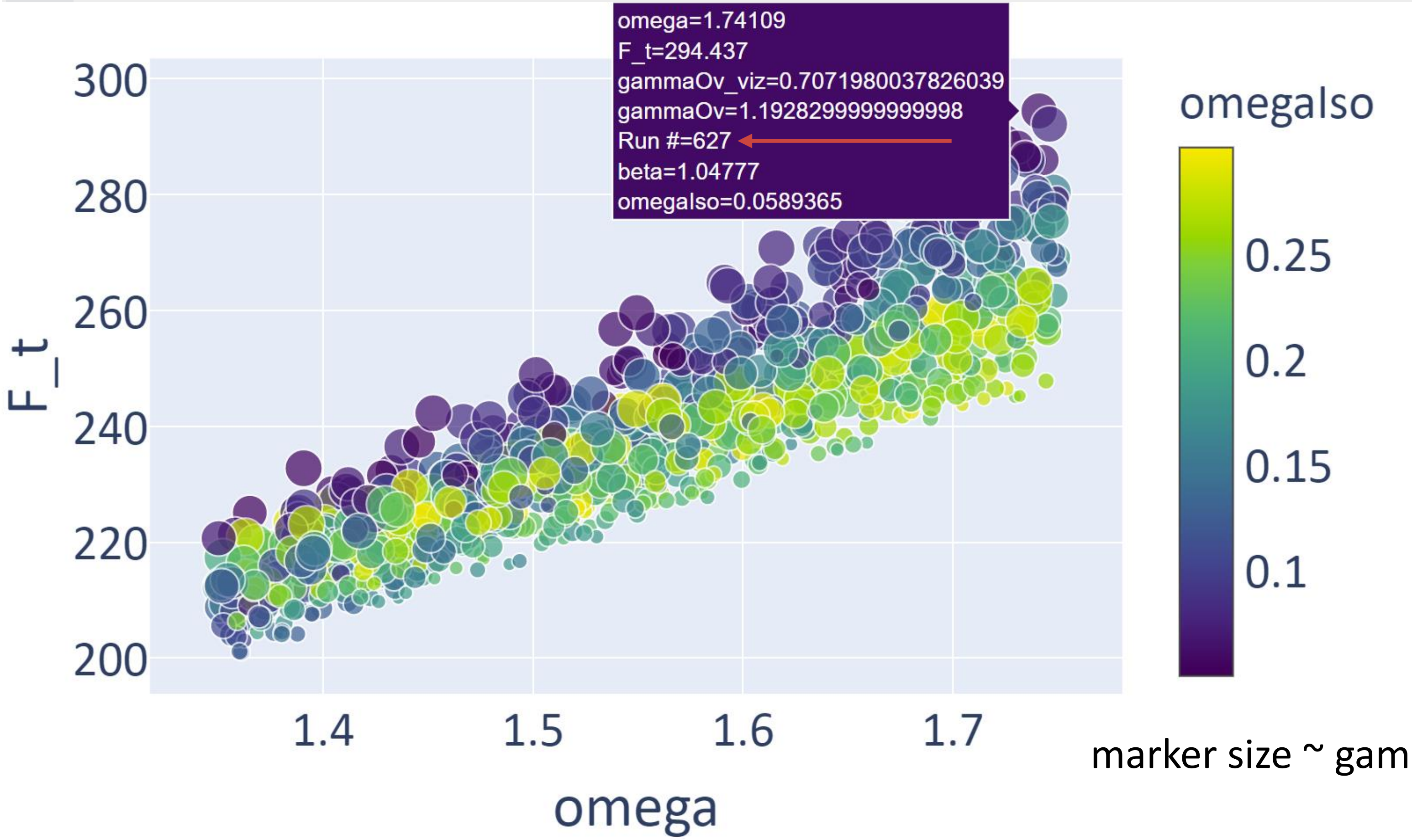
Design an experiment

quoFEM

advanced visualization and data processing

raw data is available for every simulation

```
res['gammaOv_viz'] = np.log(res['gammaOv']*10.0-9.9)
fig2 = px.scatter(res, x='omega', y='F_t', color='omegaIso',
                  color_continuous_scale=px.colors.sequential.Viridis,
                  size='gammaOv_viz', size_max=20, height=500, width=800)
fig2['layout'].update(font=dict(family="Calibri", size=28))
fig2.show()
```



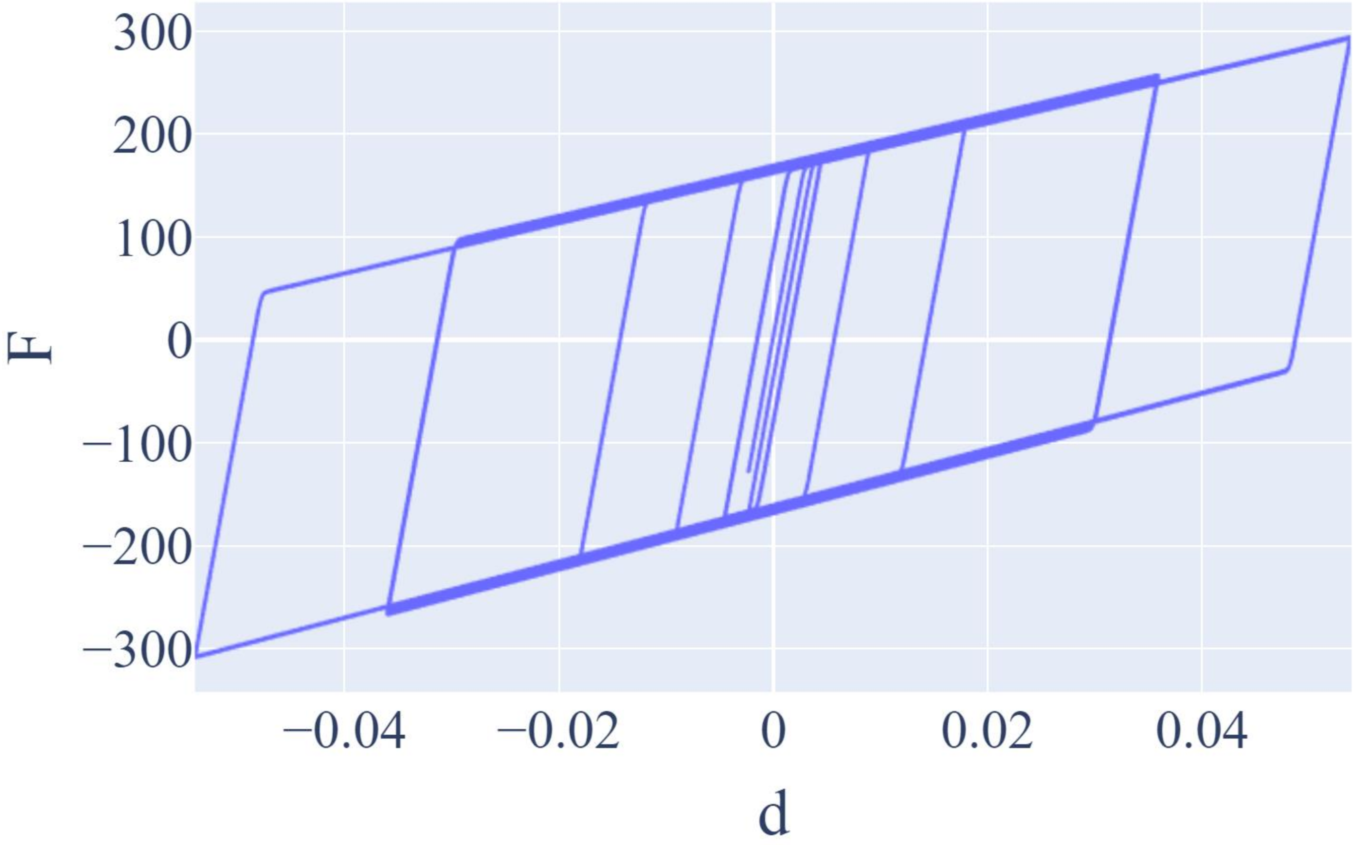
marker size ~ gammaOv

Design an experiment

advanced visualization and data processing

```
output_file = "C:/Workdir/quoFEM/tmp.SimCenter/workdir.627/force_disp.out"
res = pd.read_csv(output_file, sep=' ', header=None, names=['F', 'd'])
fig = px.line(res, x='d', y='F', height=500, width=800)
fig['layout'].update(font=dict(family="Calibri", size=28))
fig.show()
```

raw data is available for every simulation



Case study

example application: Buckling Restrained Braced Frames

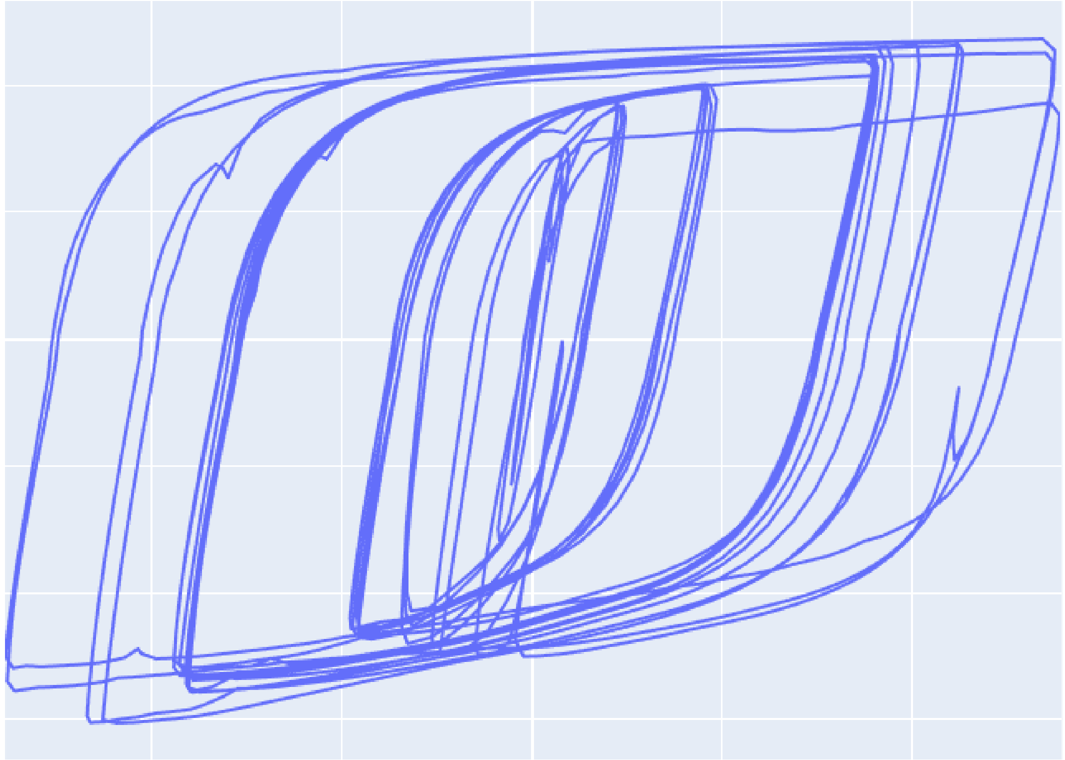
1. Design an experiment — quoFEM
2. **Calibrate a numerical component model — quoFEM**
3. Simulate structural response — EE-UQ
4. Estimate damage and losses — PBE

Calibrate component model

objective: calibrate Buckling Restrained Brace model parameters

problem: complex behavior, large number of material parameters

quoFEM: minimize error between simulation and reference result



Calibrate component model

Prepare:

- reference data from test results
- complex BRB model in OpenSees
- updated simulation script
- script with the objective function

Calibrate component model

Prepare:

- **reference data from test results**
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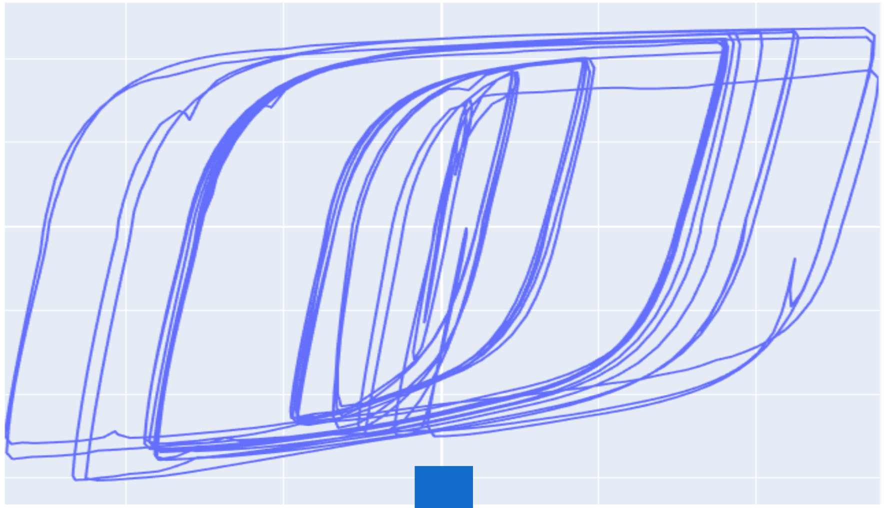


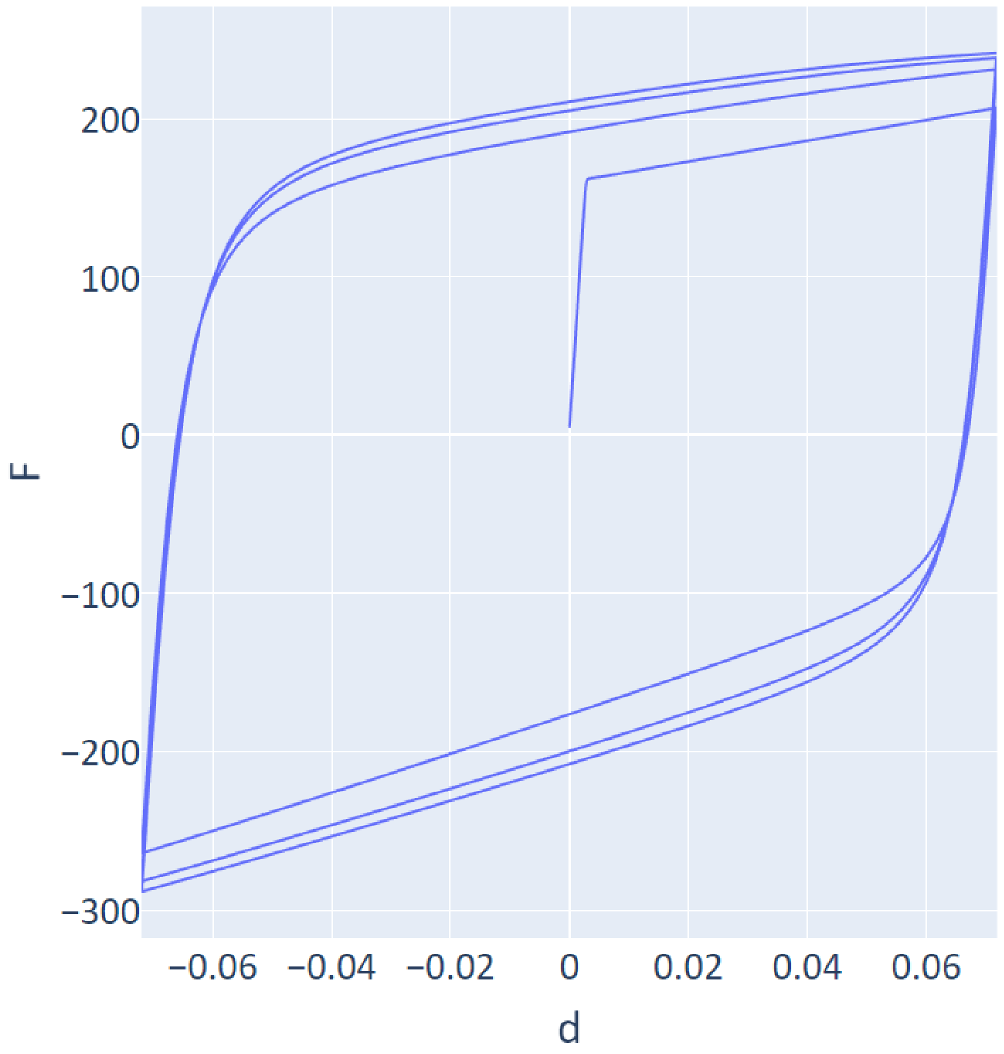
```
78.96559395918378,1[illegible]215204081632668
52.411307755102094,0.9329030612244907
26.90855167346942,0.5383724489795925
4.500137142857147,0.1784795918367349
-18.123096000000018,-0.21307142857142883
-38.138502857142896,-0.5226428571428579
-59.64269926530619,-0.8938724489795928
-74.79477551020416,-1.2276428571428586
-73.4783206530613,-1.2275918367346954
-43.2296948571429,-0.7959540816326539
-23.08952375510207,-0.4911122448979598
```

reference.txt

Calibrate component model

Prepare:

- reference data from test results
- **complex BRB model in OpenSees**
- updated simulation script
- script with the objective function



Calibrate component model

Prepare:

- reference data from test results
- complex BRB model in OpenSees
- **updated simulation script**
- script with the objective function

```
model BasicBuilder -ndm 1 -ndf 1

set l 2.500
set A_y 600
set f_DM 1.39
set f_SM 1.13

# hyperparameters
pset gammaOv 1.15
pset omega 1.4
pset omegaIso 0.25;
pset beta 1.15
pset rhoxi 0.3
pset rx1 0.925
pset fxult 1.55
pset fxultc 2.5

set l [expr $l*$m]
set A_y [expr $A_y*$mm2]

set f_yk [expr 235.0 * $MPa]
set E_s [expr 210.0 * $GPa]

# calculate material props
set E_0  [expr $f_SM*$E_s];
set f_y  [expr $gammaOv*$f_yk];
set eps_y [expr $f_y/$E_0]
```

BRB_response.tcl

Calibrate component model

Prepare:

- reference data from test results
- complex BRB model in OpenSees
- updated simulation script
- **script with the objective function**

```python
#!/usr/bin/python
# written: adamzs

import numpy as np
import pandas as pd

def process_results(response):

    data = pd.read_csv('reference.txt',
        header=None, names=['F_ref','d'])
    # convert displacements to [m]
    data['d'] = data['d']/1000.

    sim = pd.read_csv('force_disp.out',
        sep=' ', header=None, names=['F','d'])
    data['F_sim'] = sim['F']

    eps_s = (data['F_sim'] - data['F_ref'])**2.
    eps_srss = np.sqrt(np.sum(eps_s)/len(data.index))

    with open('results.out', 'w') as f:
        f.write("{:.6f}".format(eps_srss))
```

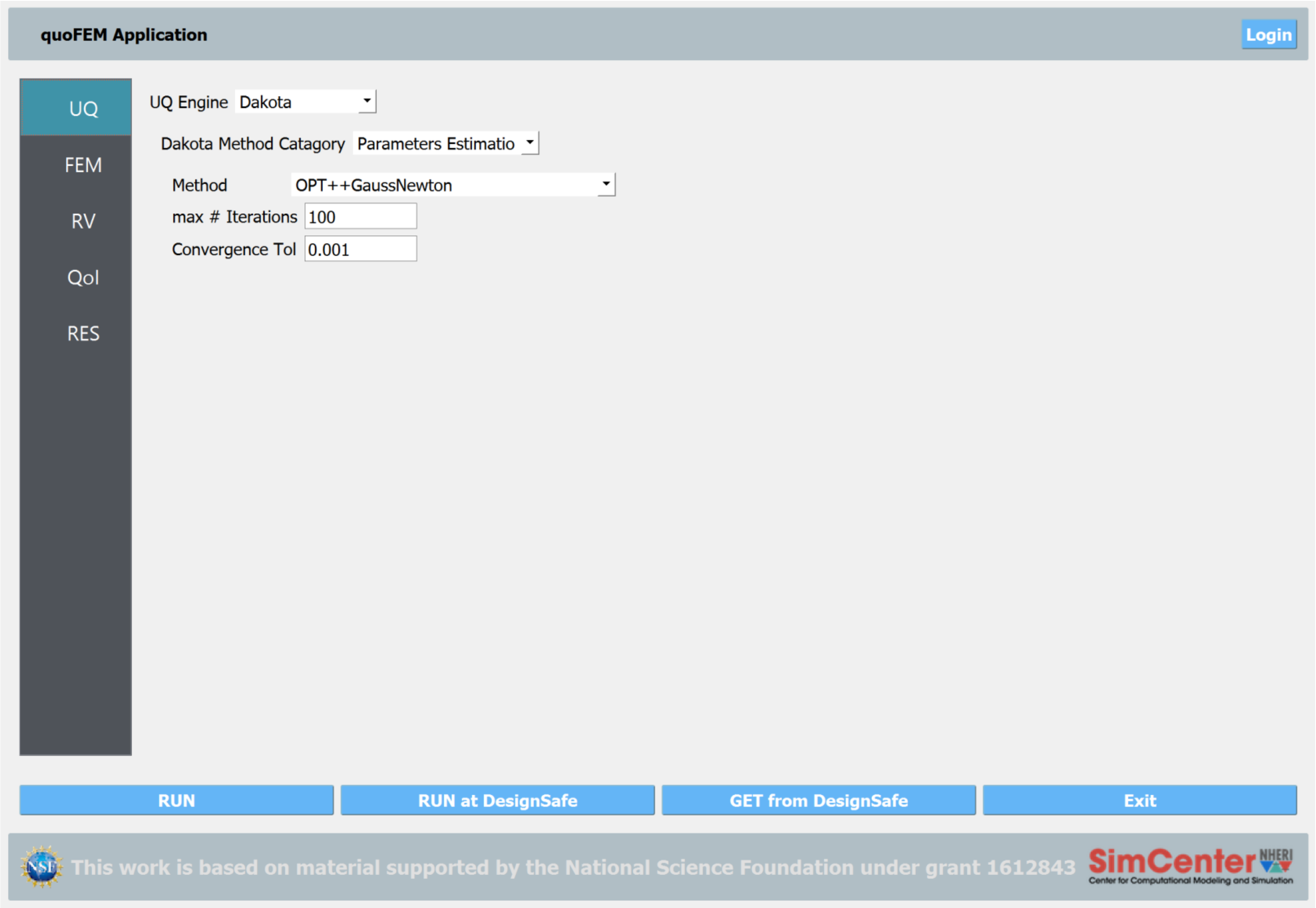
postprocess.py

Calibrate component model

select the type of problem
-> **parameter estimation**

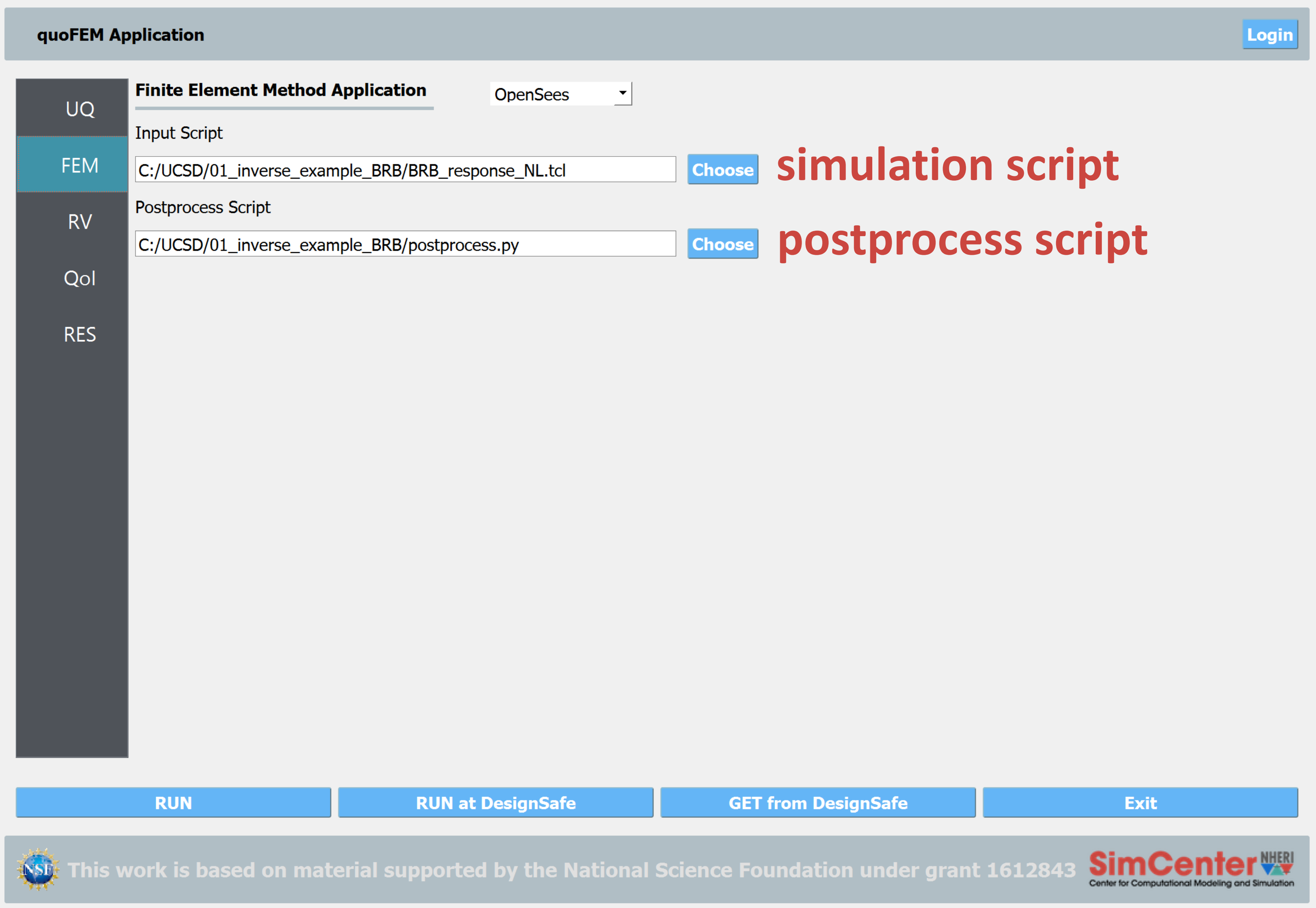
Gauss-Newton is a gradient-based optimization method

we also have Bayesian methods for solving the inverse problem



Calibrate component model

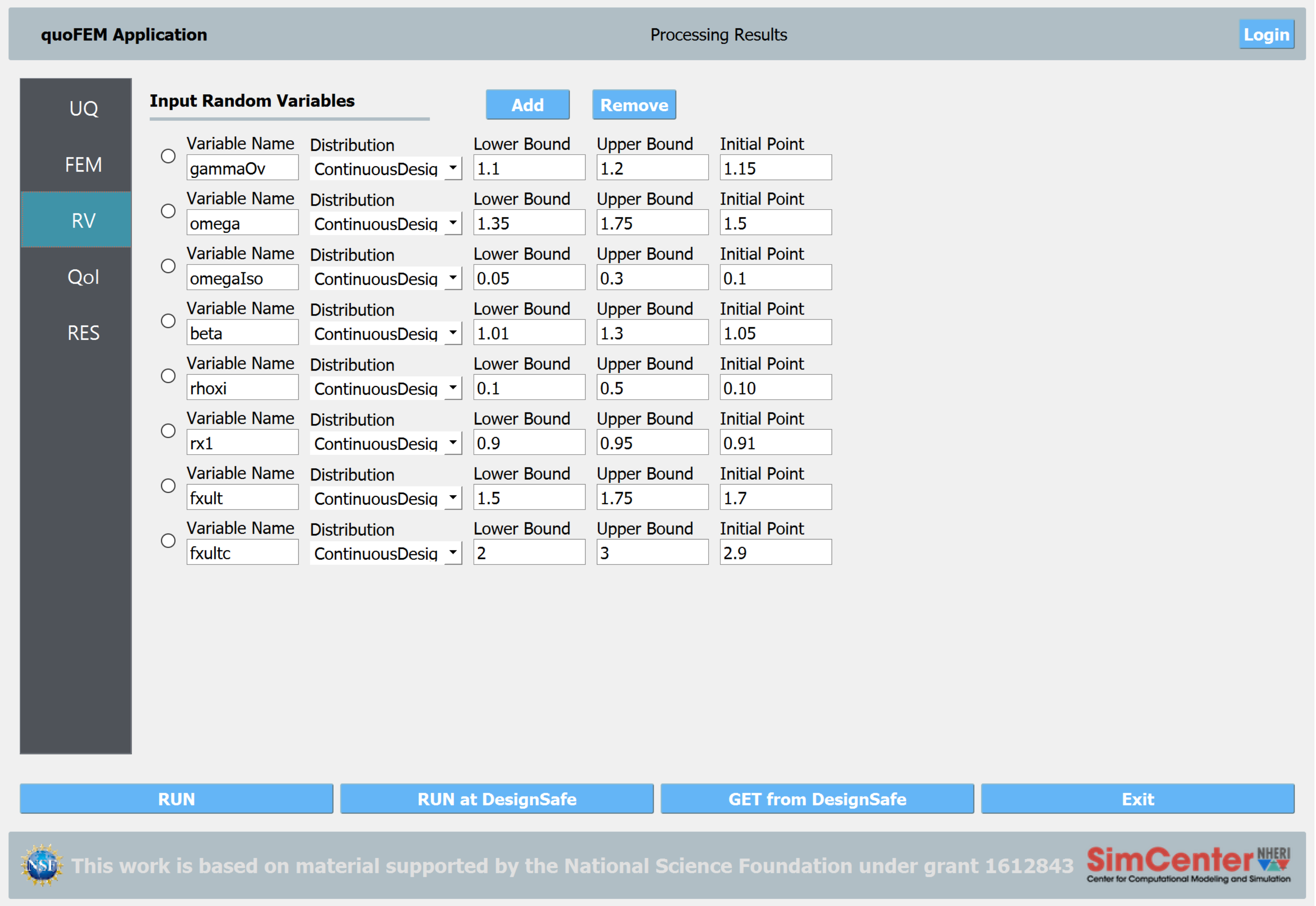
load the pre-defined scripts



Calibrate component model

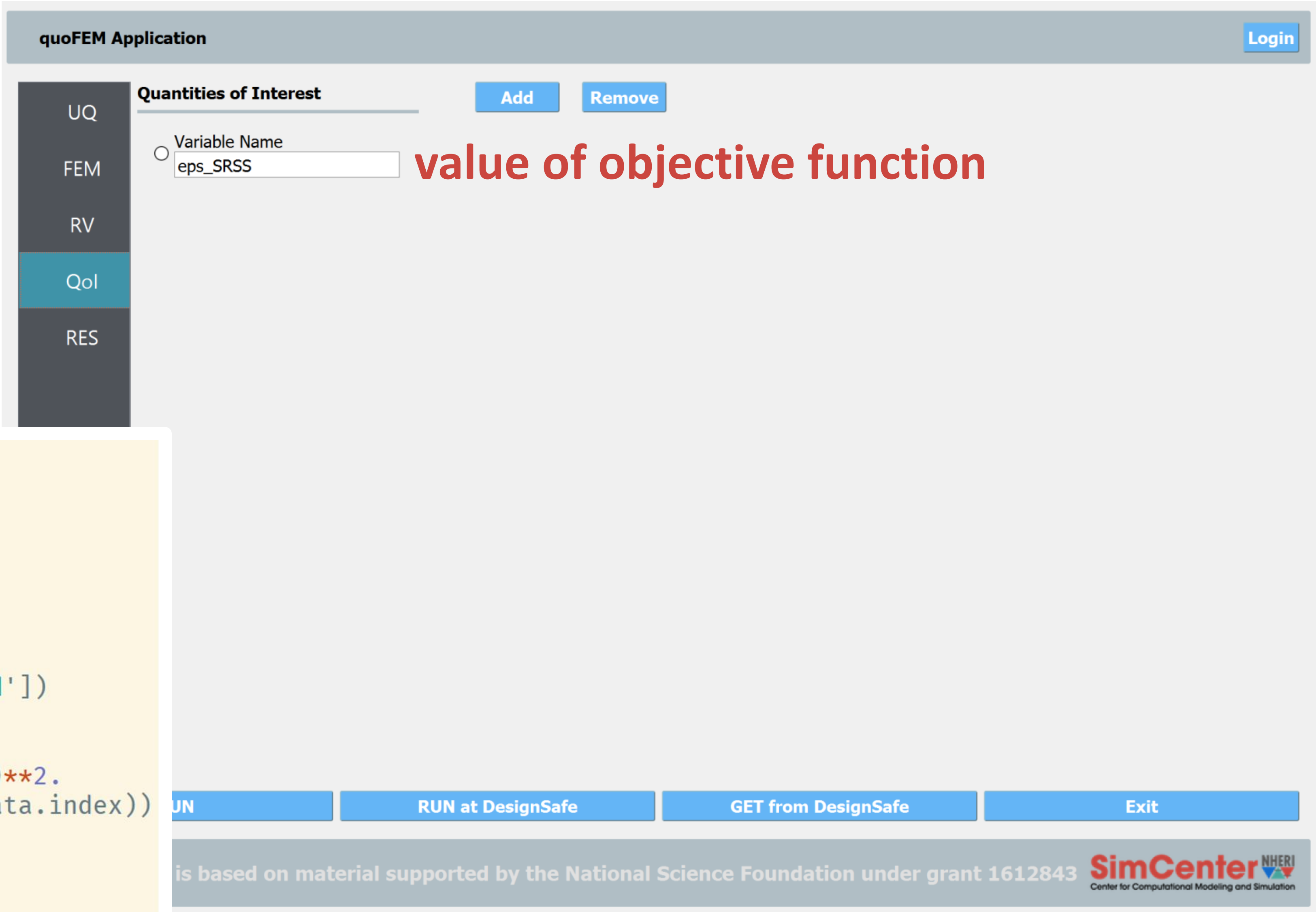
quoFEM

```
# hyperparameters
pset gammaOv 1.15
pset omega 1.4
pset omegaIso 0.25;
pset beta 1.15
pset rhoxi 0.3
pset rx1 0.925
pset fxult 1.55
pset fxultc 2.5
```



Calibrate component model

specify the
Quantities of Interest

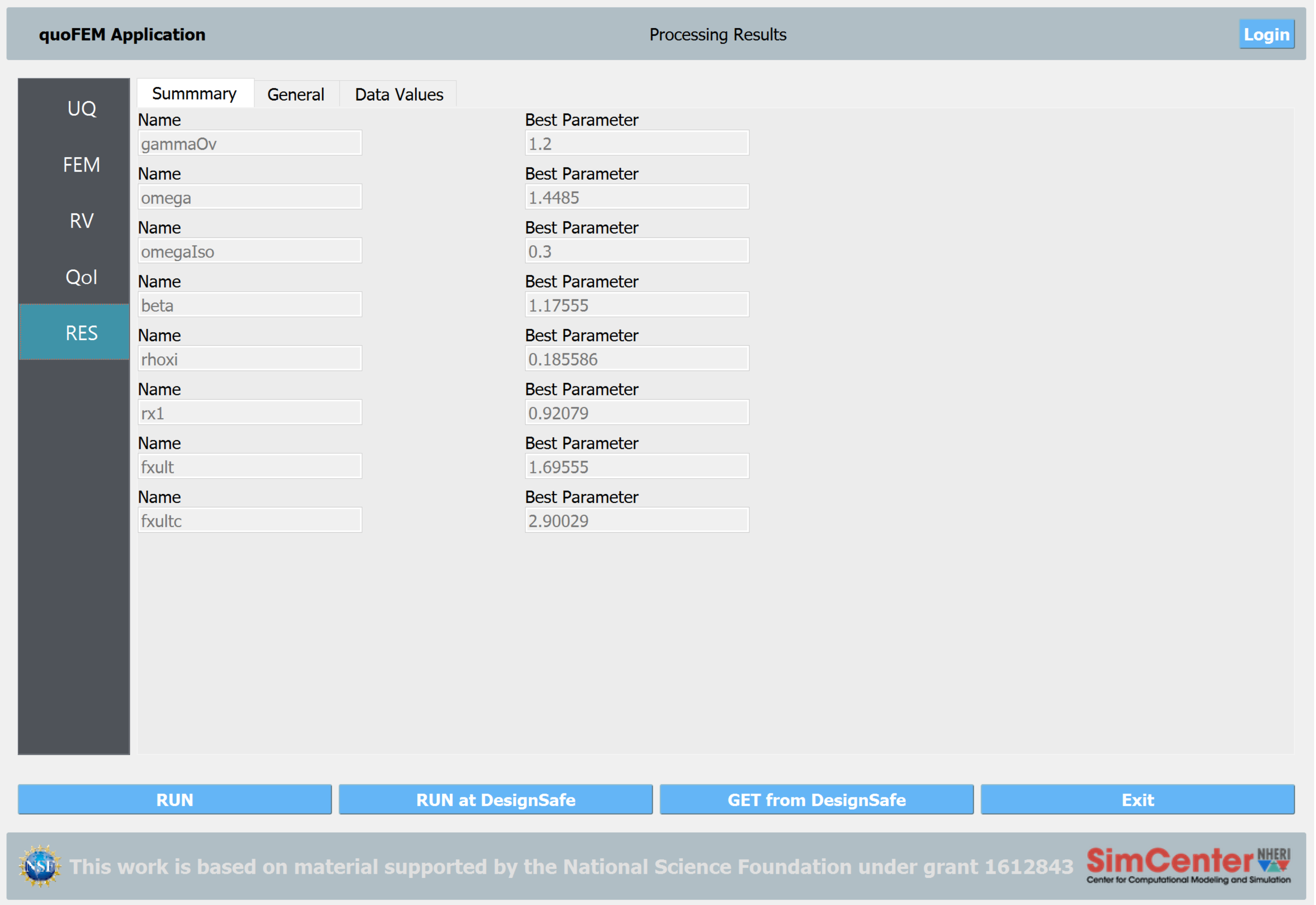


value of objective function

postprocess.py:

```python
def process_results(response):

    data = pd.read_csv('reference.txt',
        header=None, names=['F_ref','d'])
    # convert displacements to [m]
    data['d'] = data['d']/1000.

    sim = pd.read_csv('force_disp.out',
        sep=' ', header=None, names=['F','d'])
    data['F_sim'] = sim['F']

    eps_s = (data['F_sim'] - data['F_ref'])**2.
    eps_srss = np.sqrt(np.sum(eps_s)/len(data.index))

    with open('results.out', 'w') as f:
        f.write("{:.6f}".format(eps_srss))
```

Calibrate component model

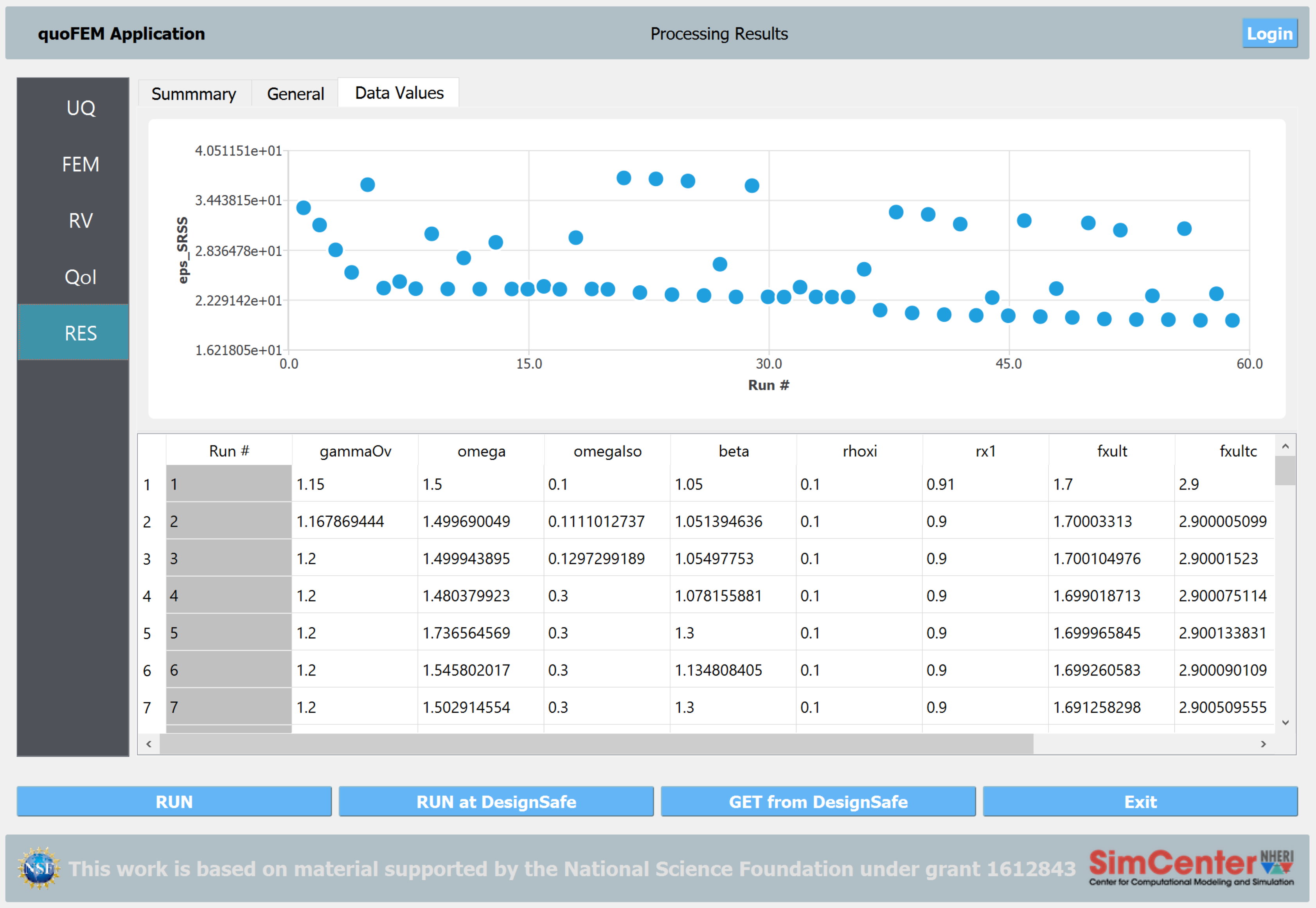


Calibrate component model

quoFEM

result visualization

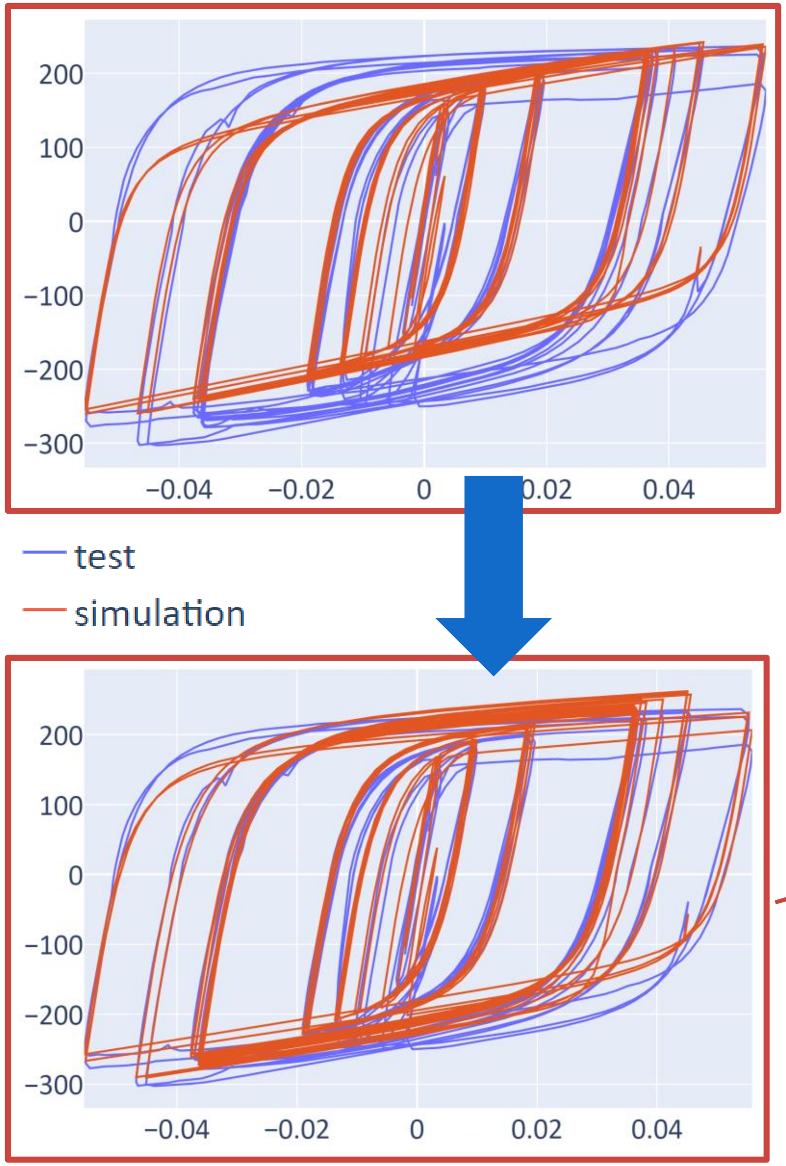
scatterplot shows convergence



	Run #	gammaOv	omega	omegaIso	beta	rhoxi	rx1	fxult	fxultc
1	1	1.15	1.5	0.1	1.05	0.1	0.91	1.7	2.9
2	2	1.167869444	1.499690049	0.1111012737	1.051394636	0.1	0.9	1.70003313	2.900005099
3	3	1.2	1.499943895	0.1297299189	1.05497753	0.1	0.9	1.700104976	2.90001523
4	4	1.2	1.480379923	0.3	1.078155881	0.1	0.9	1.699018713	2.900075114
5	5	1.2	1.736564569	0.3	1.3	0.1	0.9	1.699965845	2.900133831
6	6	1.2	1.545802017	0.3	1.134808405	0.1	0.9	1.699260583	2.900090109
7	7	1.2	1.502914554	0.3	1.3	0.1	0.9	1.691258298	2.900509555

Calibrate component model

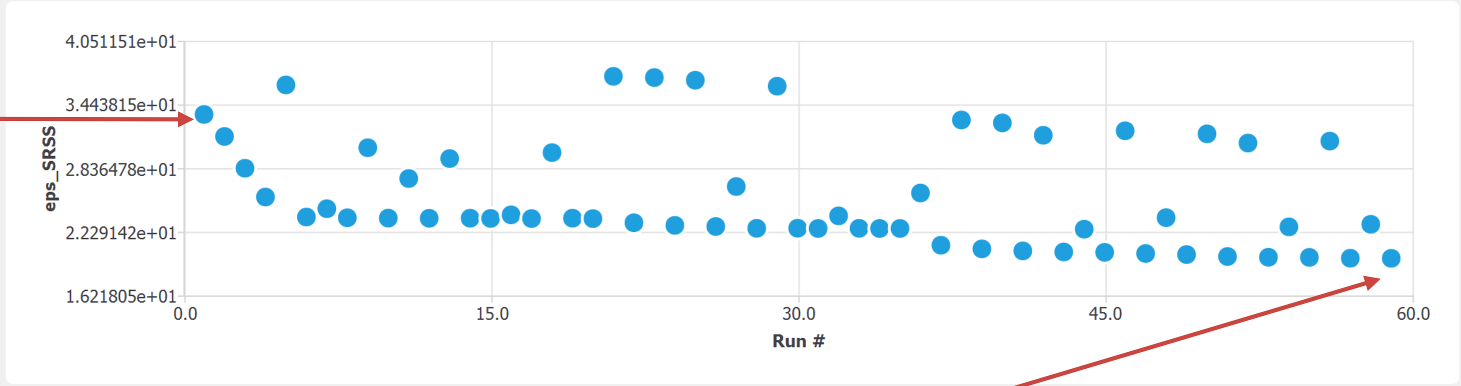
quoFEM



quoFEM Application | Processing Results | Login

UQ
FEM
RV
QoI
RES

Summmary | General | Data Values



	Run #	gammaOv	omega	omegaIso	beta	rhoxi	rx1	fxult	fxultc
1	1	1.15	1.5	0.1	1.05	0.1	0.91	1.7	2.9
2	2	1.167869444	1.499690049	0.1111012737	1.051394636	0.1	0.9	1.70003313	2.900005099
3	3	1.2	1.499943895	0.1297299189	1.05497753	0.1	0.9	1.700104976	2.90001523
4	4	1.2	1.480379923	0.3	1.078155881	0.1	0.9	1.699018713	2.900075114
5	5	1.2	1.736564569	0.3	1.3	0.1	0.9	1.699965845	2.900133831
6	6	1.2	1.545802017	0.3	1.134808405	0.1	0.9	1.699260583	2.900090109
7	7	1.2	1.502914554	0.3	1.3	0.1	0.9	1.691258298	2.900509555

RUN | RUN at DesignSafe | GET from DesignSafe | Exit

This work is based on material supported by the National Science Foundation under grant 1612843

SimCenter NHERI Center for Computational Modeling and Simulation

Case study

example application: Buckling Restrained Braced Frames

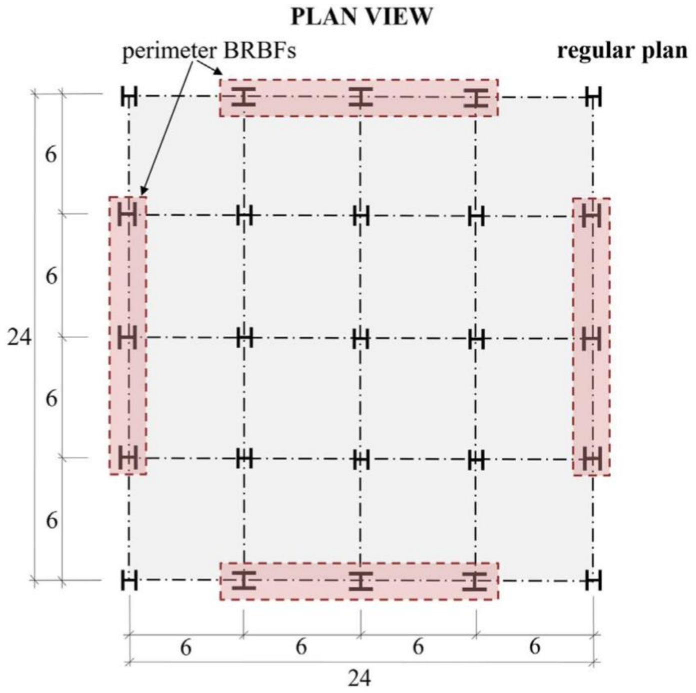
1. Design an experiment — quoFEM
2. Calibrate a numerical component model — quoFEM
3. **Simulate structural response — EE-UQ**
4. Estimate damage and losses — PBE

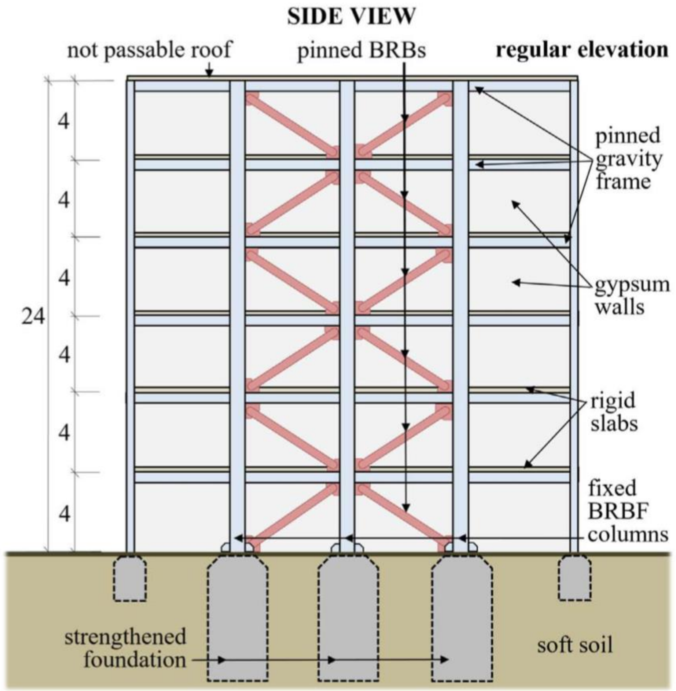
Simulate structural response

objective: estimate interstory drifts and floor accelerations in an earthquake scenario

problem: complex, computationally expensive calculations

EE-UQ: conveniently run simulations through DesignSafe





Simulate structural response

Prepare:

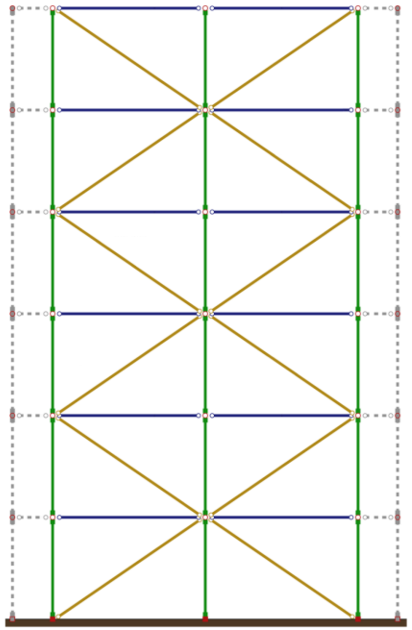
- BRBF model in OpenSees
- ground motion records from PEER NGA2

Adam Zsarnóczay adamzs@stanford.edu

Simulate structural response

Prepare:

- **BRBF model in OpenSees**
- ground motion records from PEER NGA2



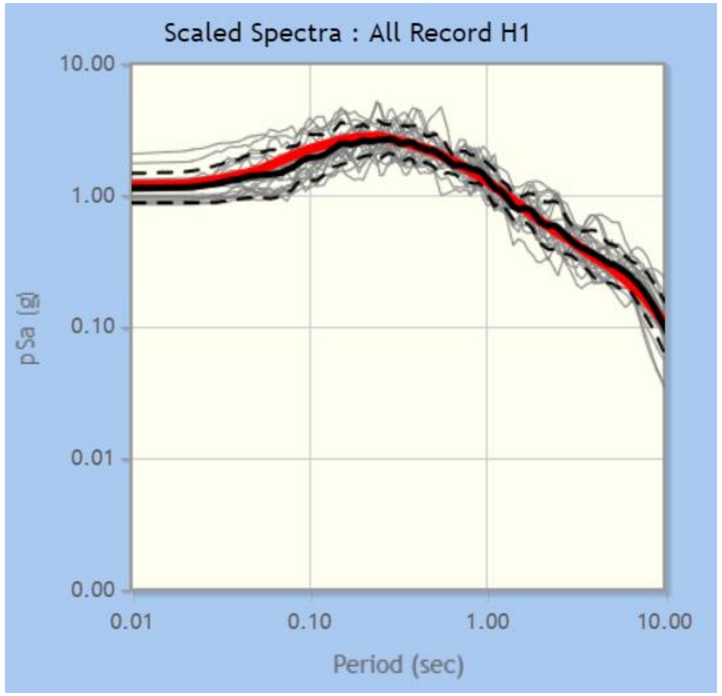
```
# load the core methods
source core/setAnalysis.tcl
source core/setRecorders.tcl
source core/Basics.tcl

# load the model info
source BRBF/Zsarnoczay_Vigh_2017/6AHHD.tcl

# specify the story height and the nodes
# for drift monitoring
set h {4.0 4.0 4.0 4.0 4.0 4.0}
set driftNodes {0 100 200 300 400 500 600}

# build the model
set pushover 0
source core/ModelBuilder.tcl
```

BRBF.tcl

Simulate structural response

Prepare:

- BRBF model in OpenSees
- **ground motion records from PEER NGA2**

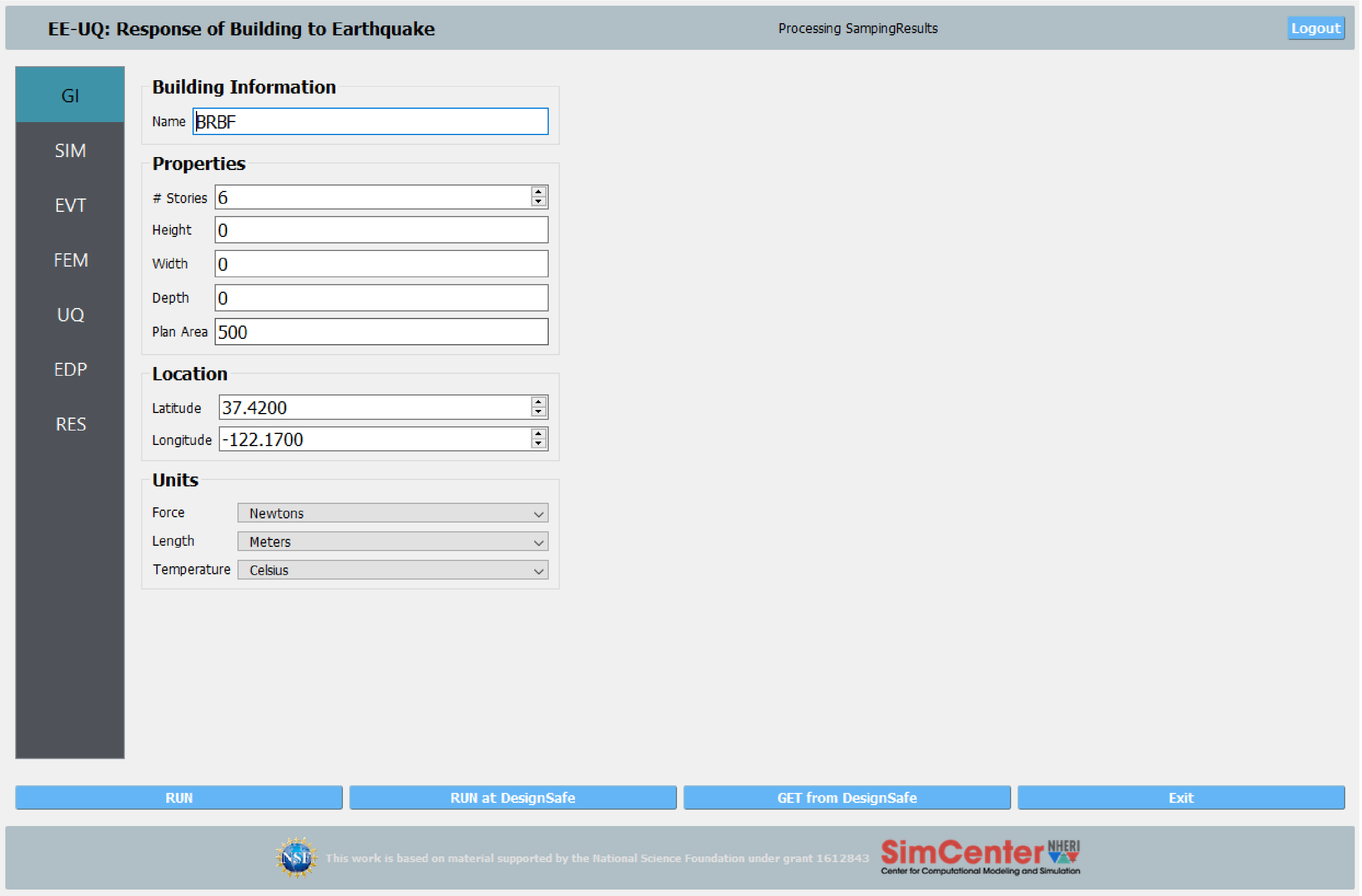



```
RSN143_TABAS_TAB-L1.AT2,1.4637
RSN1193_CHICHI_CHY024-E.AT2,3.1806
RSN1489_CHICHI_TCU049-E.AT2,3.9083
RSN1511_CHICHI_TCU076-E.AT2,3.1206
RSN1521_CHICHI_TCU089-E.AT2,3.5561
RSN1524_CHICHI_TCU095-E.AT2,3.2244
RSN1546_CHICHI_TCU122-E.AT2,3.9546
RSN1549_CHICHI_TCU129-E.AT2,2.0144
RSN1605_DUZCE_DZC180.AT2,2.3368
RSN3750_CAPEMEND_LFS270.AT2,3.718
RSN5827_SIERRA.MEX_MDO000.AT2,2.4069
RSN5829_SIERRA.MEX_RII000.AT2,2.7287
RSN5975_SIERRA.MEX_CXO360.AT2,3.6221
RSN5991_SIERRA.MEX_E10320.AT2,3.1185
RSN6890_DARFIELD_CMHSN10E.AT2,3.7356
RSN6893_DARFIELD_DFHSS17E.AT2,3.6641
RSN6906_DARFIELD_GDLCN55W.AT2,1.5617
RSN6911_DARFIELD_HORCN18E.AT2,1.9323
RSN6923_DARFIELD_KPOCN15E.AT2,3.4101
RSN8161_SIERRA.MEX_E12360.AT2,2.8477
```

Records.txt

Simulate structural response

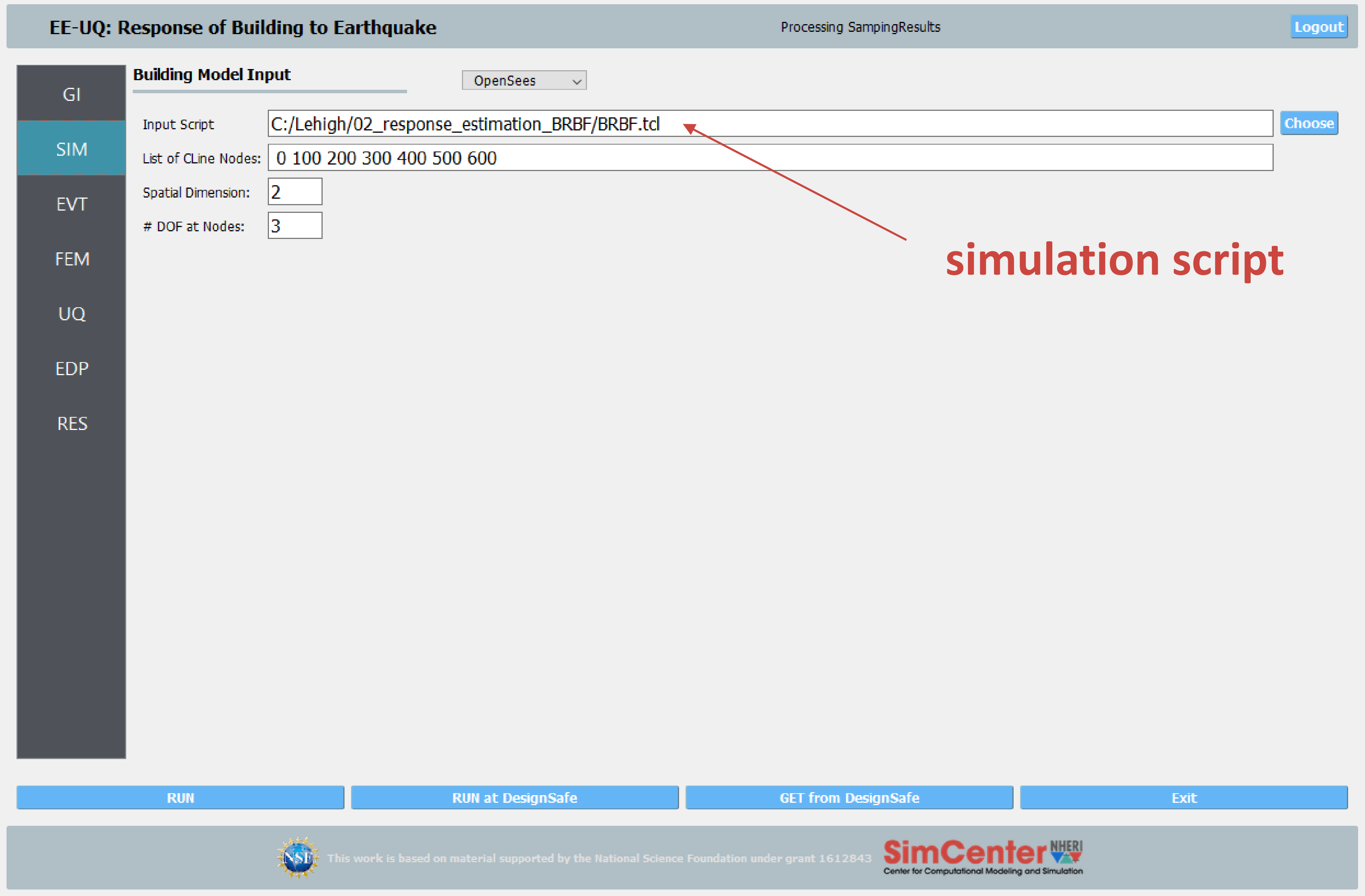
general information



Simulate structural response

EE-UQ

load the pre-defined simulation script



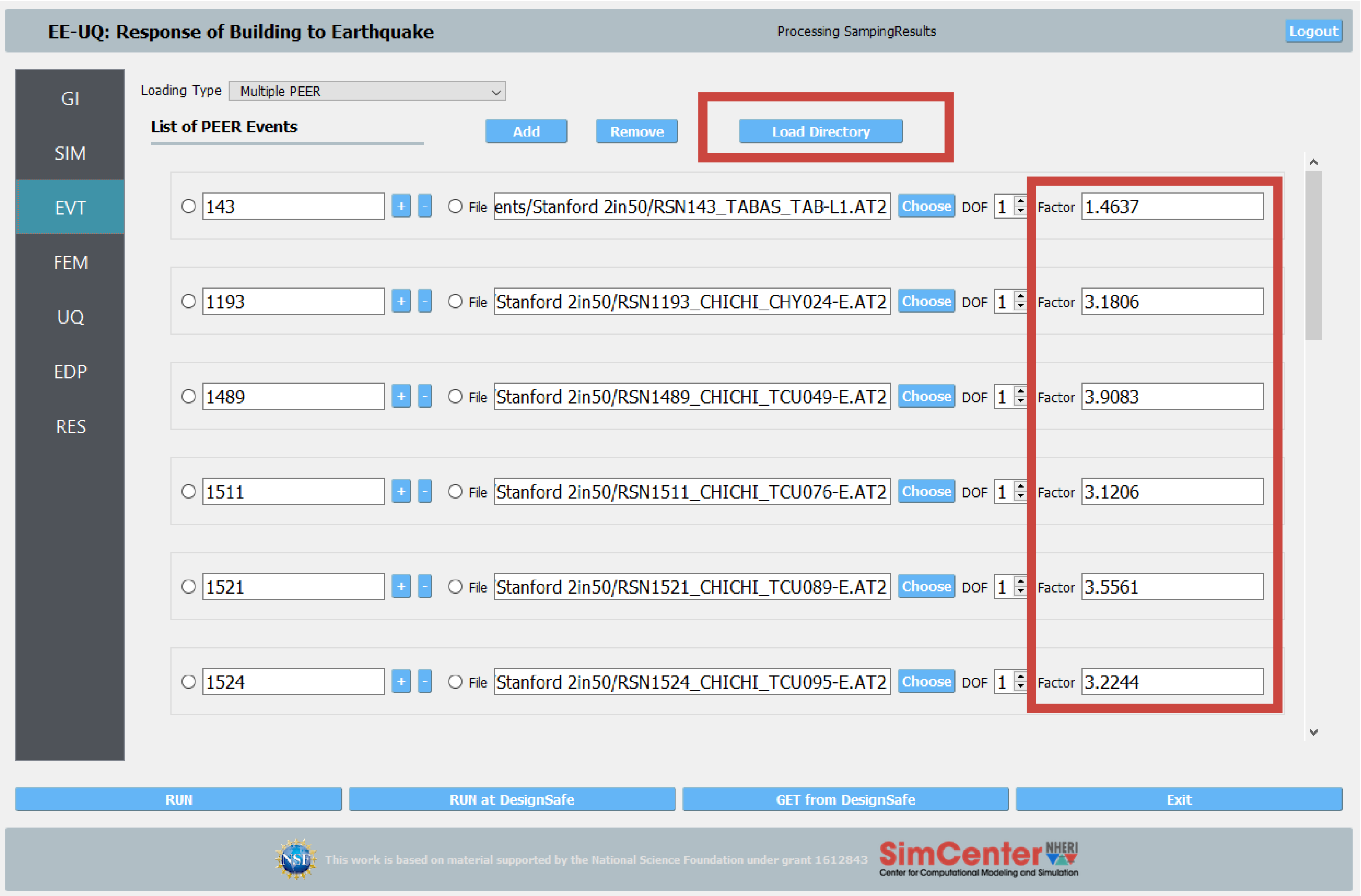
Simulate structural response

EE-UQ

load the selected ground motions

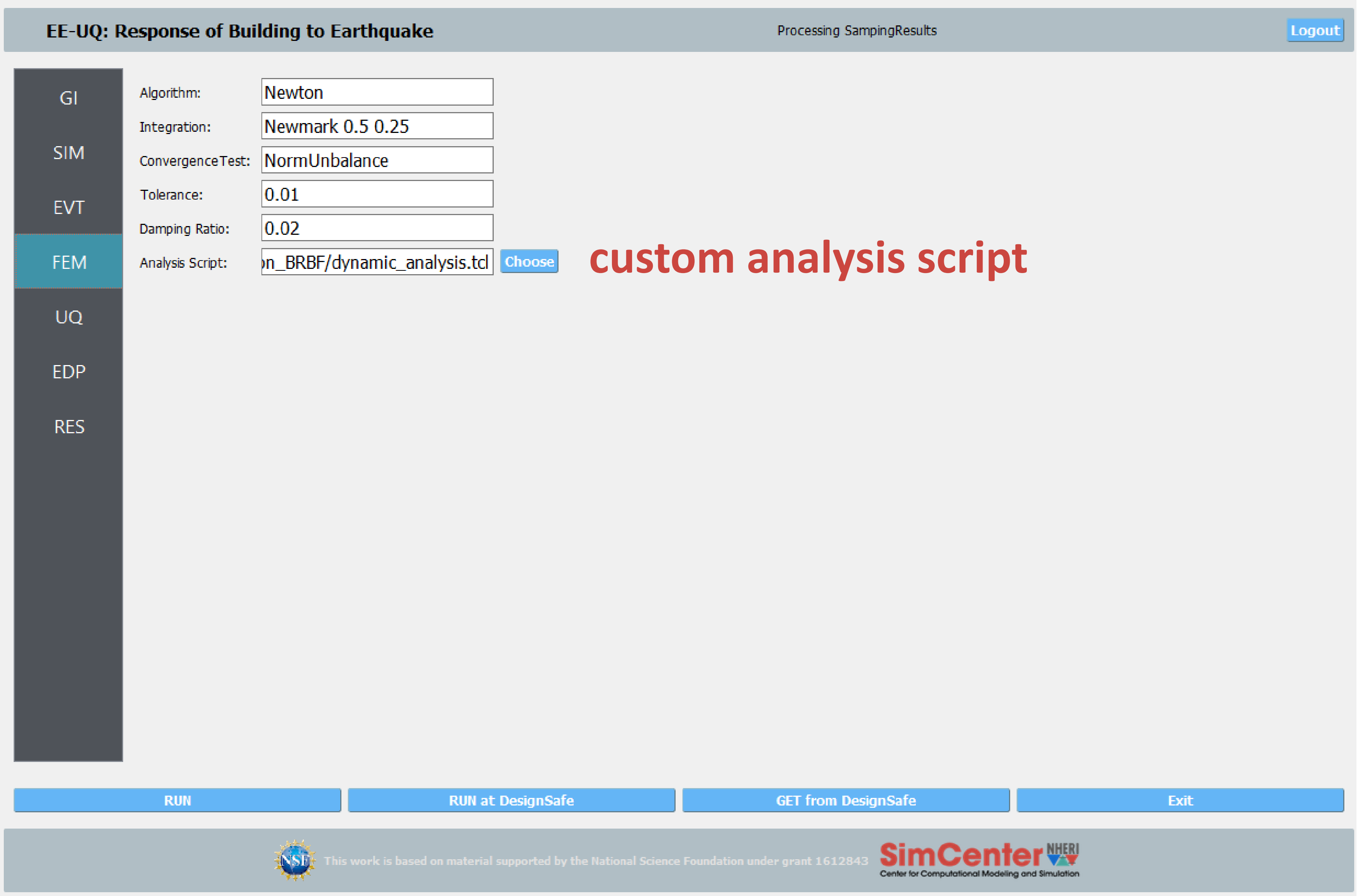
```
RSN143_TABAS_TAB-L1.AT2,1.4637
RSN1193_CHICHI_CHY024-E.AT2,3.1806
RSN1489_CHICHI_TCU049-E.AT2,3.9083
RSN1511_CHICHI_TCU076-E.AT2,3.1206
RSN1521_CHICHI_TCU089-E.AT2,3.5561
RSN1524_CHICHI_TCU095-E.AT2,3.2244
RSN1546_CHICHI_TCU122-E.AT2,3.9546
RSN1549_CHICHI_TCU129-E.AT2,2.0144
RSN1605_DUZCE_DZC180.AT2,2.3368
RSN3750_CAPEMEND_LFS270.AT2,3.718
RSN5827_SIERRA.MEX_MDO000.AT2,2.4069
RSN5829_SIERRA.MEX_RII000.AT2,2.7287
RSN5975_SIERRA.MEX_CXO360.AT2,3.6221
RSN5991_SIERRA.MEX_E10320.AT2,3.1185
RSN6890_DARFIELD_CMHSN10E.AT2,3.7356
RSN6893_DARFIELD_DFHSS17E.AT2,3.6641
RSN6906_DARFIELD_GDLCN55W.AT2,1.5617
RSN6911_DARFIELD_HORCN18E.AT2,1.9323
RSN6923_DARFIELD_KPOCN15E.AT2,3.4101
RSN8161_SIERRA.MEX_E12360.AT2,2.8477
```

Records.txt



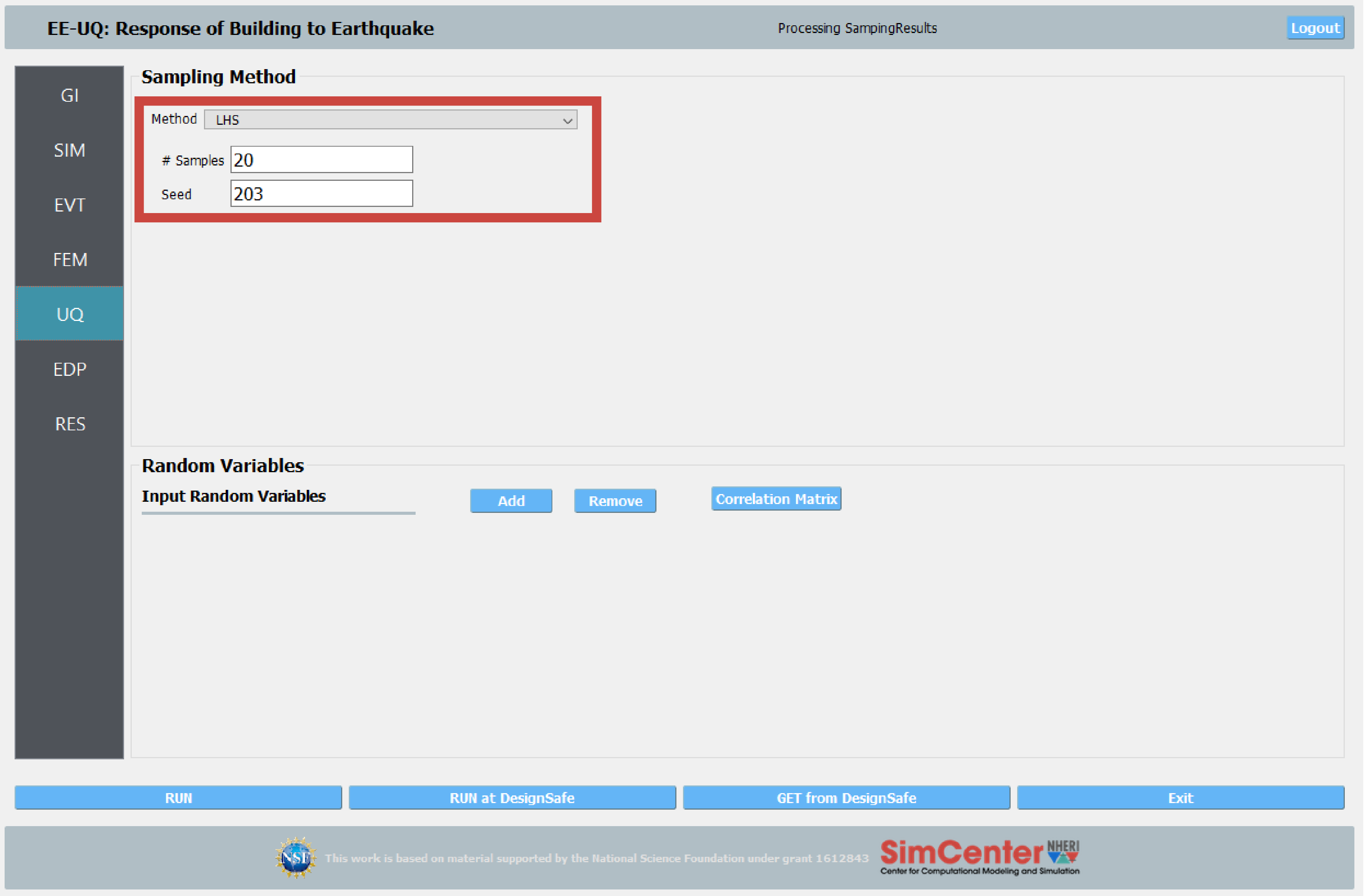
Simulate structural response

set up the analysis



Simulate structural response

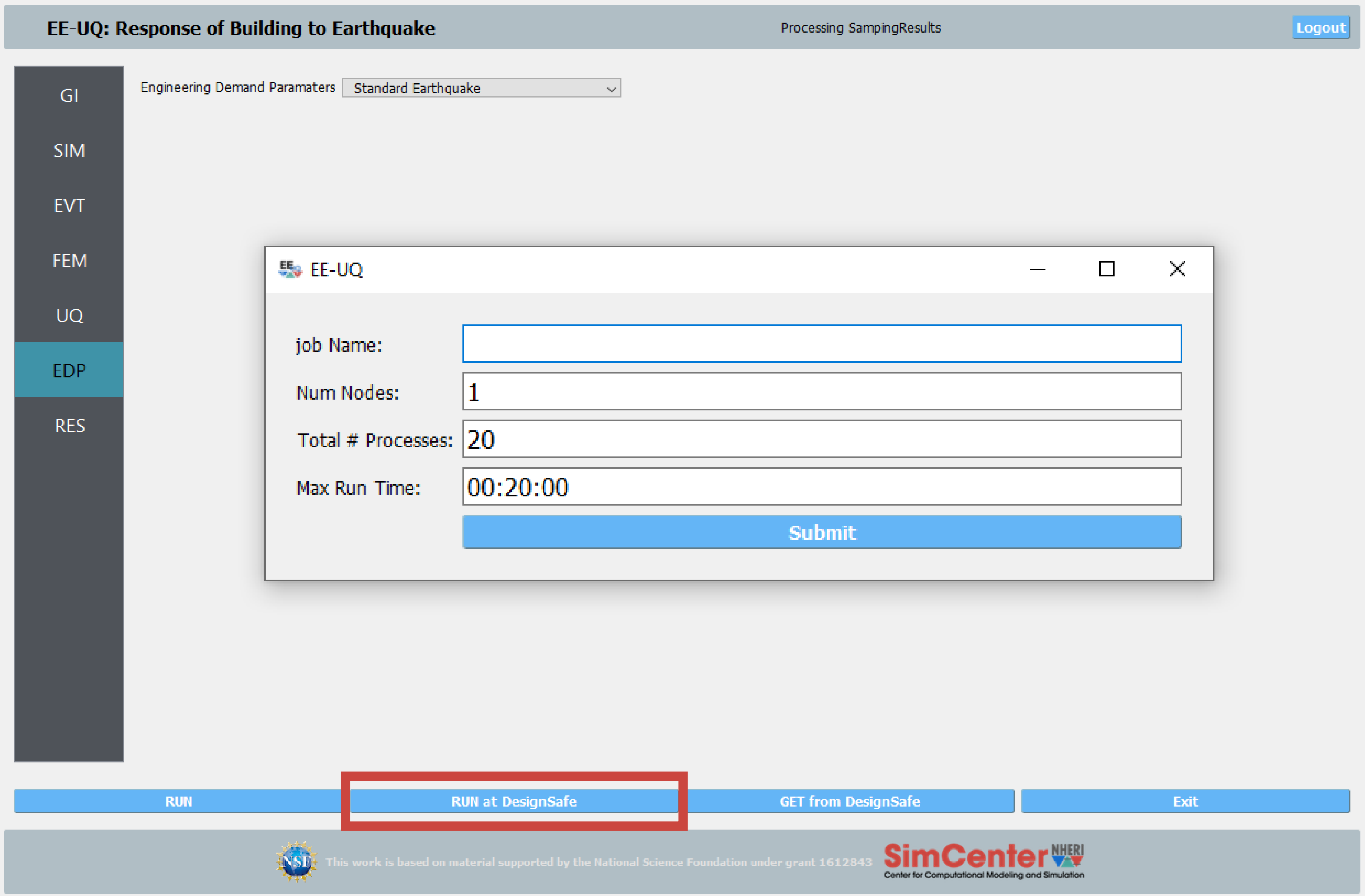
define random variables



Simulate structural response

choose EDPs

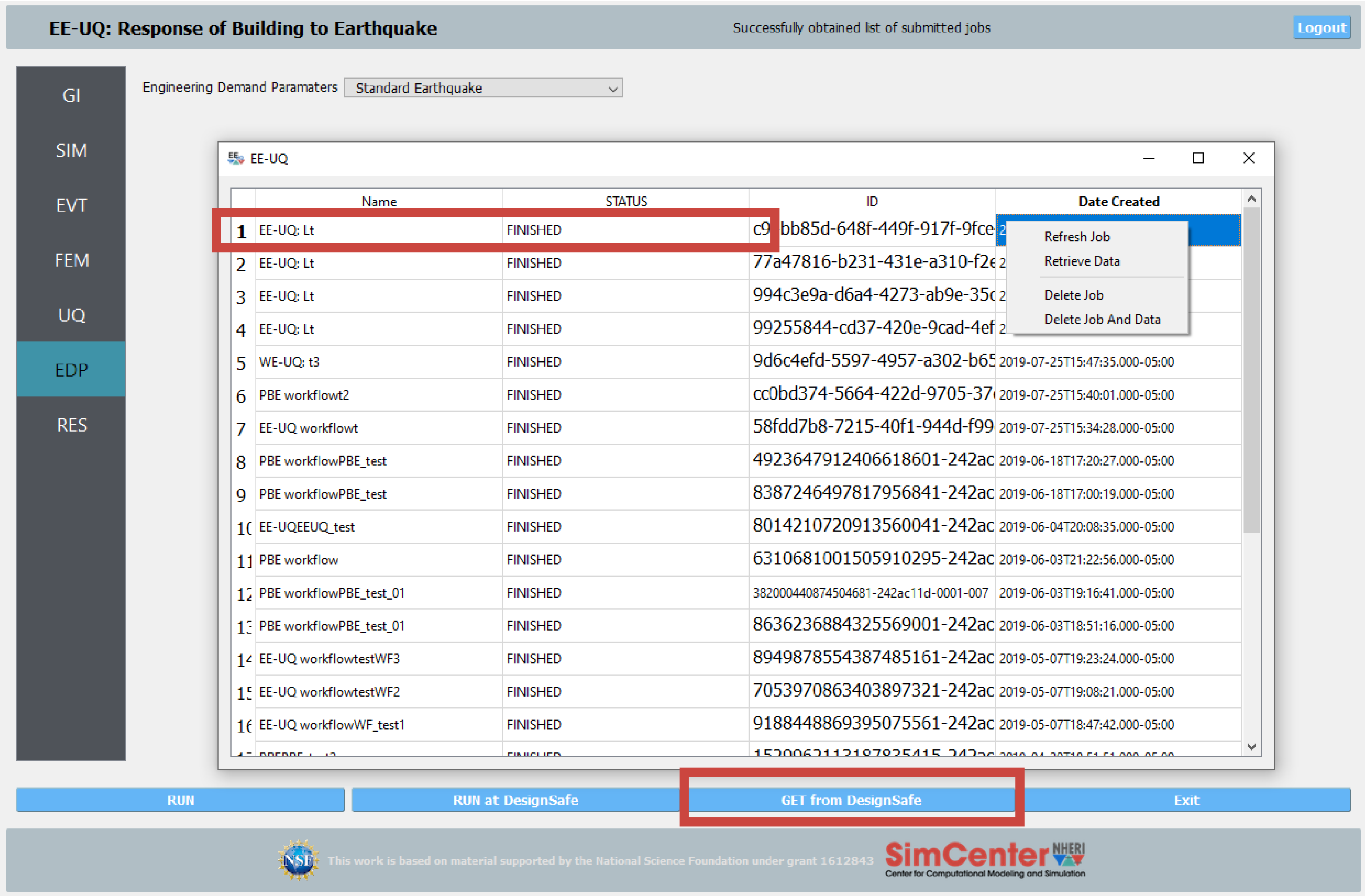
run remotely!



Simulate structural response

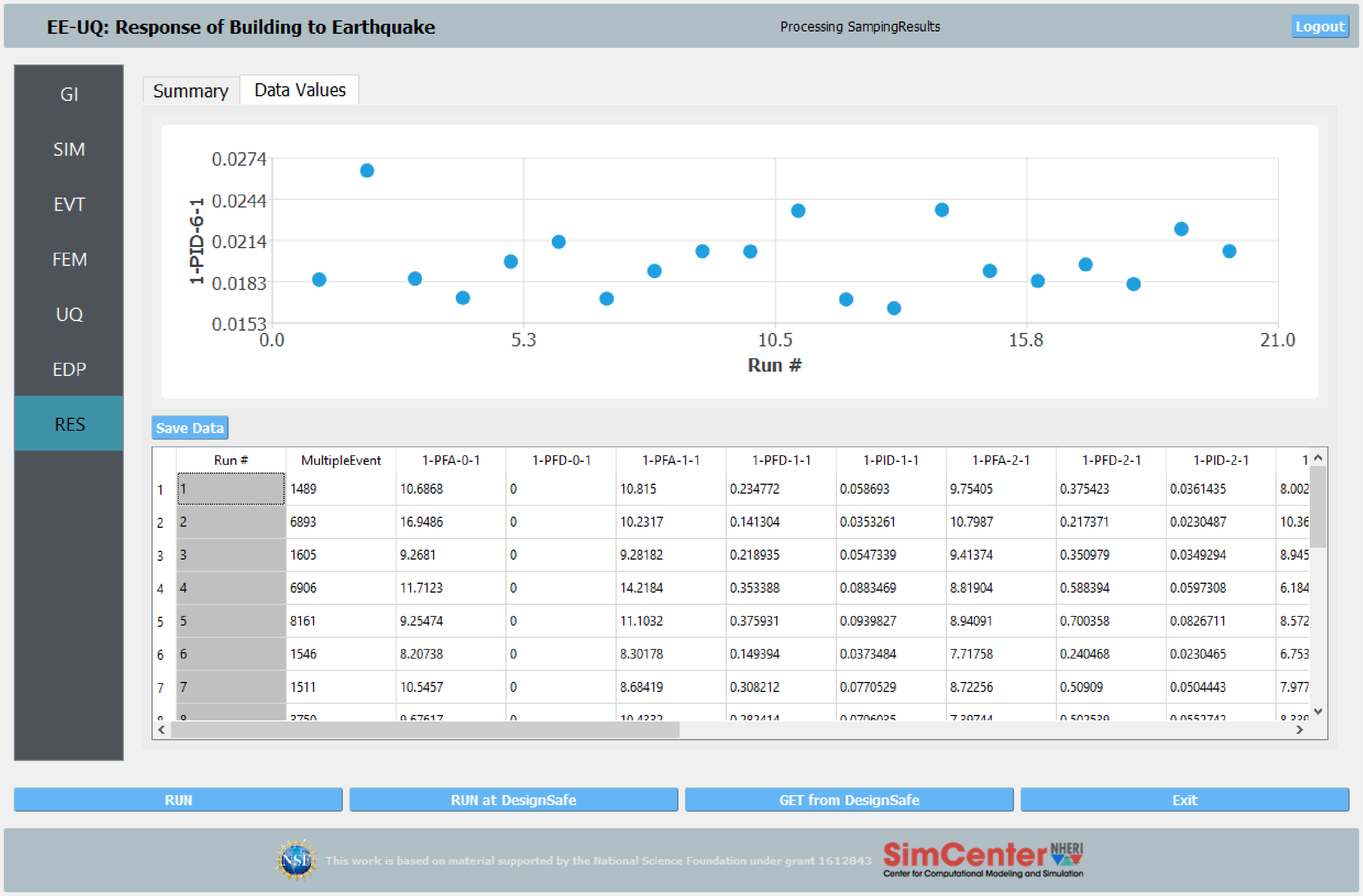
EE-UQ

collect results from DesignSafe



Simulate structural response

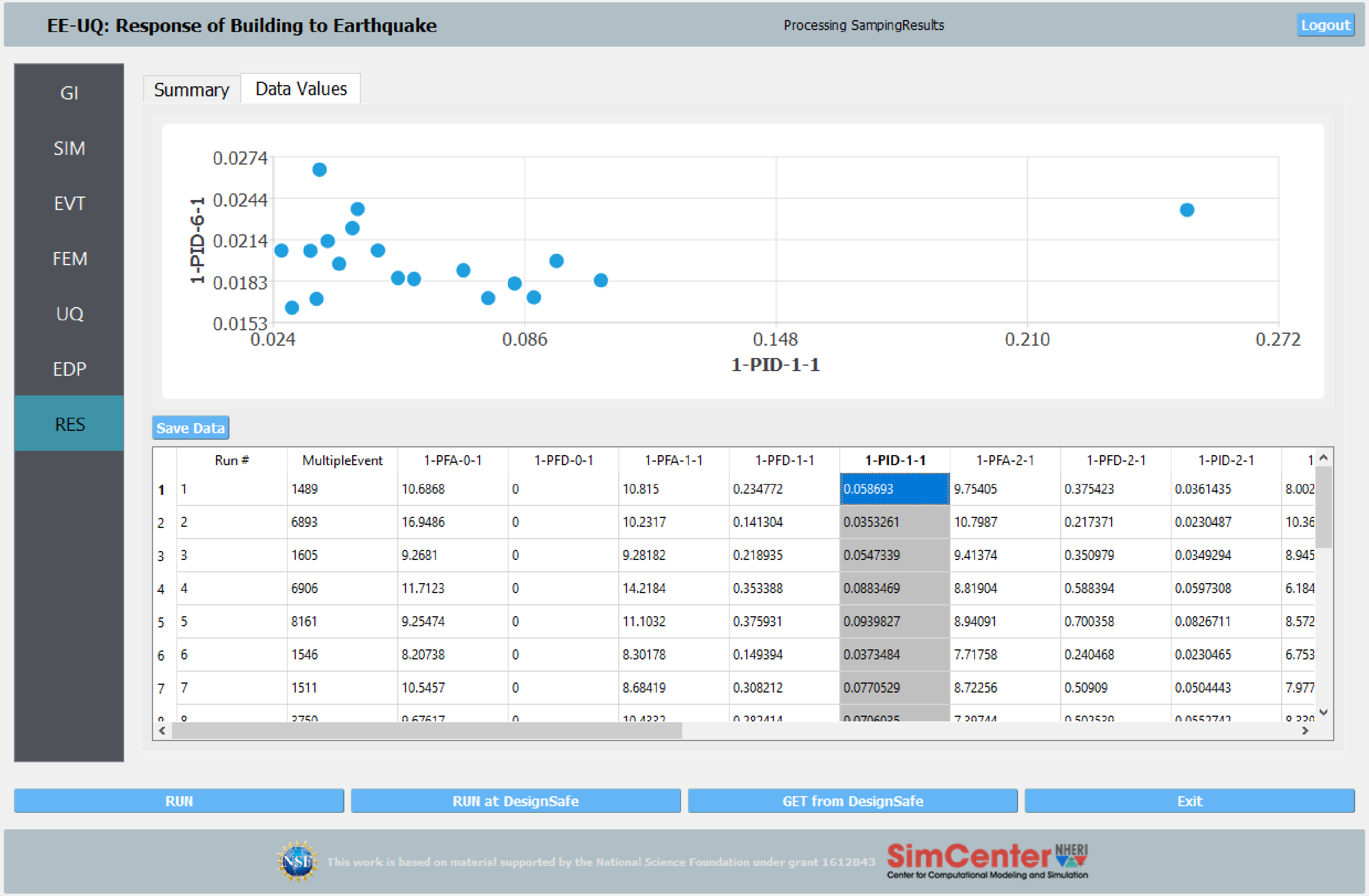
show EDPs for each analysis



Simulate structural response

EE-UQ

show joint
EDP distribution



	Run #	MultipleEvent	1-PFA-0-1	1-PFD-0-1	1-PFA-1-1	1-PFD-1-1	1-PID-1-1	1-PFA-2-1	1-PFD-2-1	1-PID-2-1	1
1	1	1489	10.6868	0	10.815	0.234772	0.058693	9.75405	0.375423	0.0361435	8.002
2	2	6893	16.9486	0	10.2317	0.141304	0.0353261	10.7987	0.217371	0.0230487	10.36
3	3	1605	9.2681	0	9.28182	0.218935	0.0547339	9.41374	0.350979	0.0349294	8.945
4	4	6906	11.7123	0	14.2184	0.353388	0.0883469	8.81904	0.588394	0.0597308	6.184
5	5	8161	9.25474	0	11.1032	0.375931	0.0939827	8.94091	0.700358	0.0826711	8.572
6	6	1546	8.20738	0	8.30178	0.149394	0.0373484	7.71758	0.240468	0.0230465	6.753
7	7	1511	10.5457	0	8.68419	0.308212	0.0770529	8.72256	0.50909	0.0504443	7.977
[illegible]	8	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Case study

example application: Buckling Restrained Braced Frames

1.	Design an experiment	quoFEM
2.	Calibrate a numerical component model	quoFEM
3.	Simulate structural response	EE-UQ
4.	**Estimate damage and losses**	**PBE**

Estimate damage and loss

setting: damage and loss assessment of a BRBF

objective: estimate damage and losses in an earthquake scenario

problem: connect response estimation with loss assessment
develop and use a custom damage and loss model for BRBF

PBE: conveniently run the whole workflow using pelicun

Estimate damage and loss

Prepare:

- custom components for BRBF loss model
- building information

Estimate damage and loss

PBE

Prepare:

- **custom components for BRBF loss model**
- building information


```
{
  "Name": "Steel Buckling Restrained Brace (BRB), Single
    Diagonal brace, Weight of brace > 41 plf and < 99 plf.",
  "QuantityUnit": [
    1,
    "EA"
  ],
  "Directional": true,
  "Correlated": false,
  "EDP": {
    "Type": "Story Drift Ratio",
    "Unit": [
      1,
      "ea"
    ],
    "Offset": 0
  },
  "GeneralInformation": {
    "ID": "B1033.111b",
    "Description": "None",
    "Author": "John Wallace",
    "Official": true,
    "DateCreated": "2012-10-12T16:47:42.0245683-07:00",
    "Approved": true,
    "Incomplete": false,
    "Notes": "None"
  },
```


B1033.111b.json

Estimate damage and loss

Prepare:

- **custom components for BRBF loss model**
- building information


```
"DSGroups": [
  {
    "MedianEDP": 0.02,
    "Beta": 0.4,
    "CurveType": "LogNormal",
    "DSGroupType": "Single",
    "DamageStates": [
      {
        "Weight": 1.0,
        "LongLeadTime": false,
        "Consequences": {
          "ReconstructionCost": {
            "Amount": [
              58395.7011,
              39709.0768
            ],
            "Quantity": [
              3.0,
              7.0
            ],
            "CurveType": "Normal",
            "Beta": 0.2986,
            "Bounds": [
              0,
              "None"
            ]
```


B1033.111b.json

Estimate damage and loss

Prepare:

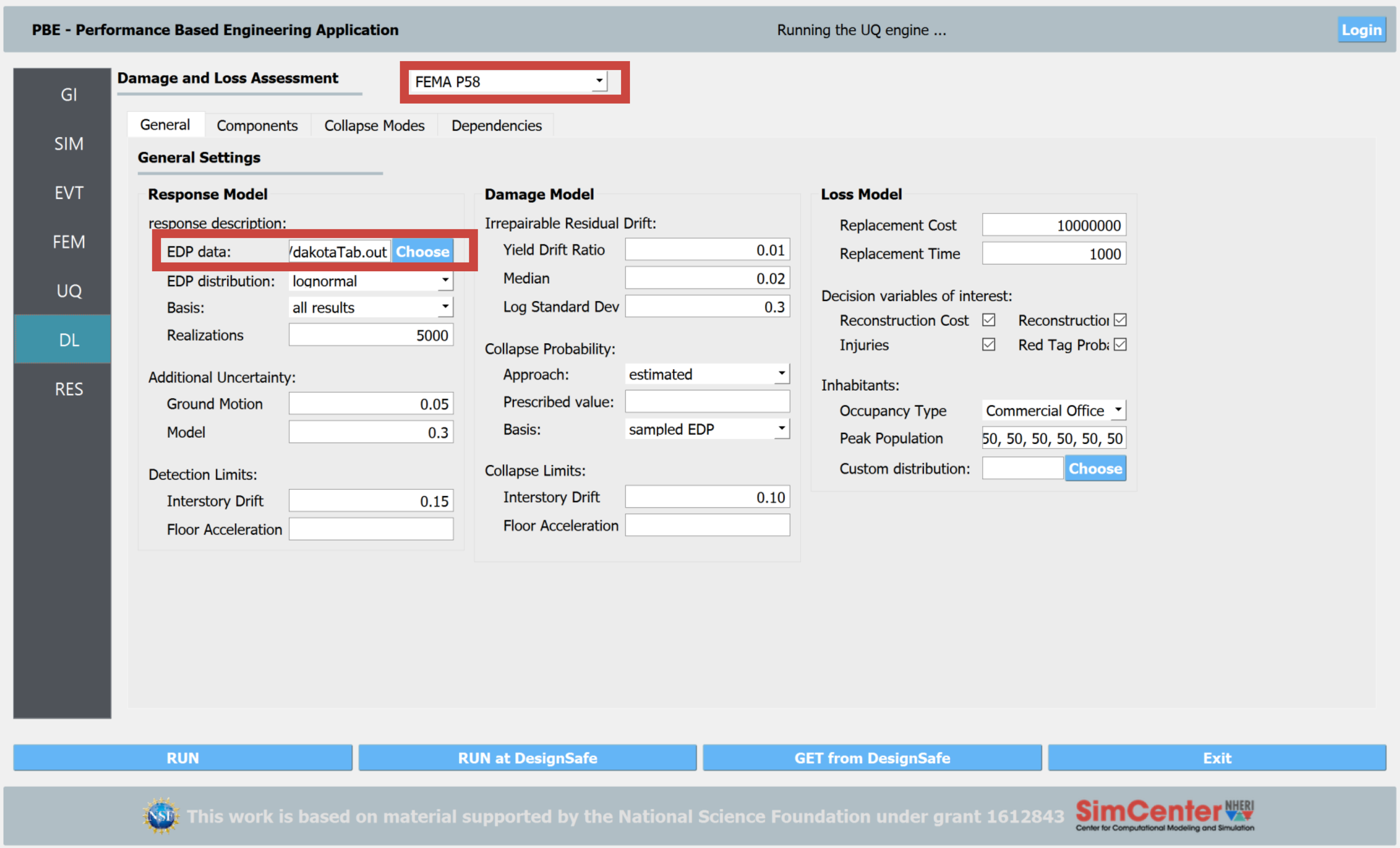
- custom components for BRBF loss model
- **building information**

replacement cost: $10,000,000
replacement time: 1000 days
population: 300
occupancy type: Commercial Office

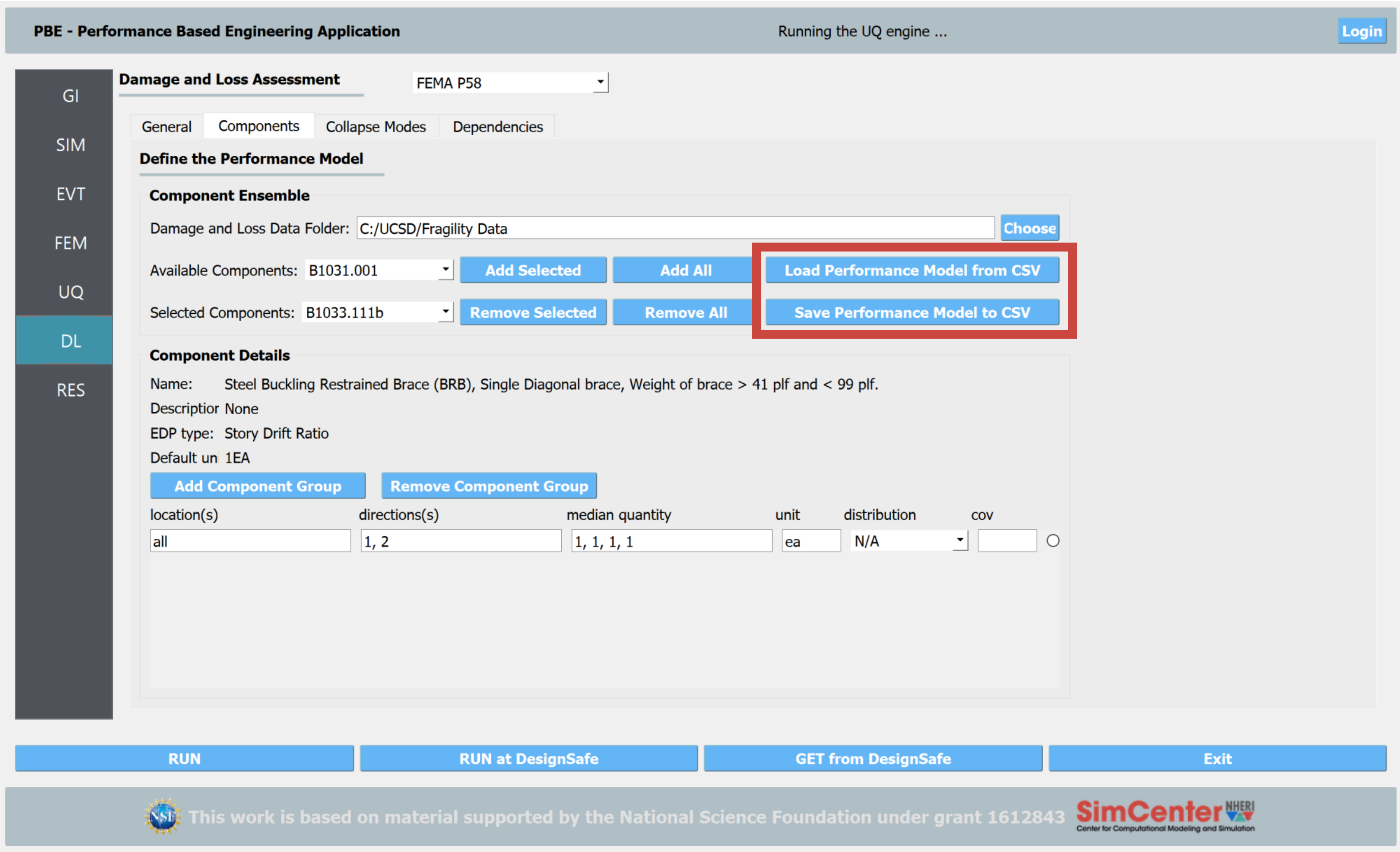
types, quantities, locations of structural components and non-structural components

collapse modes and consequences

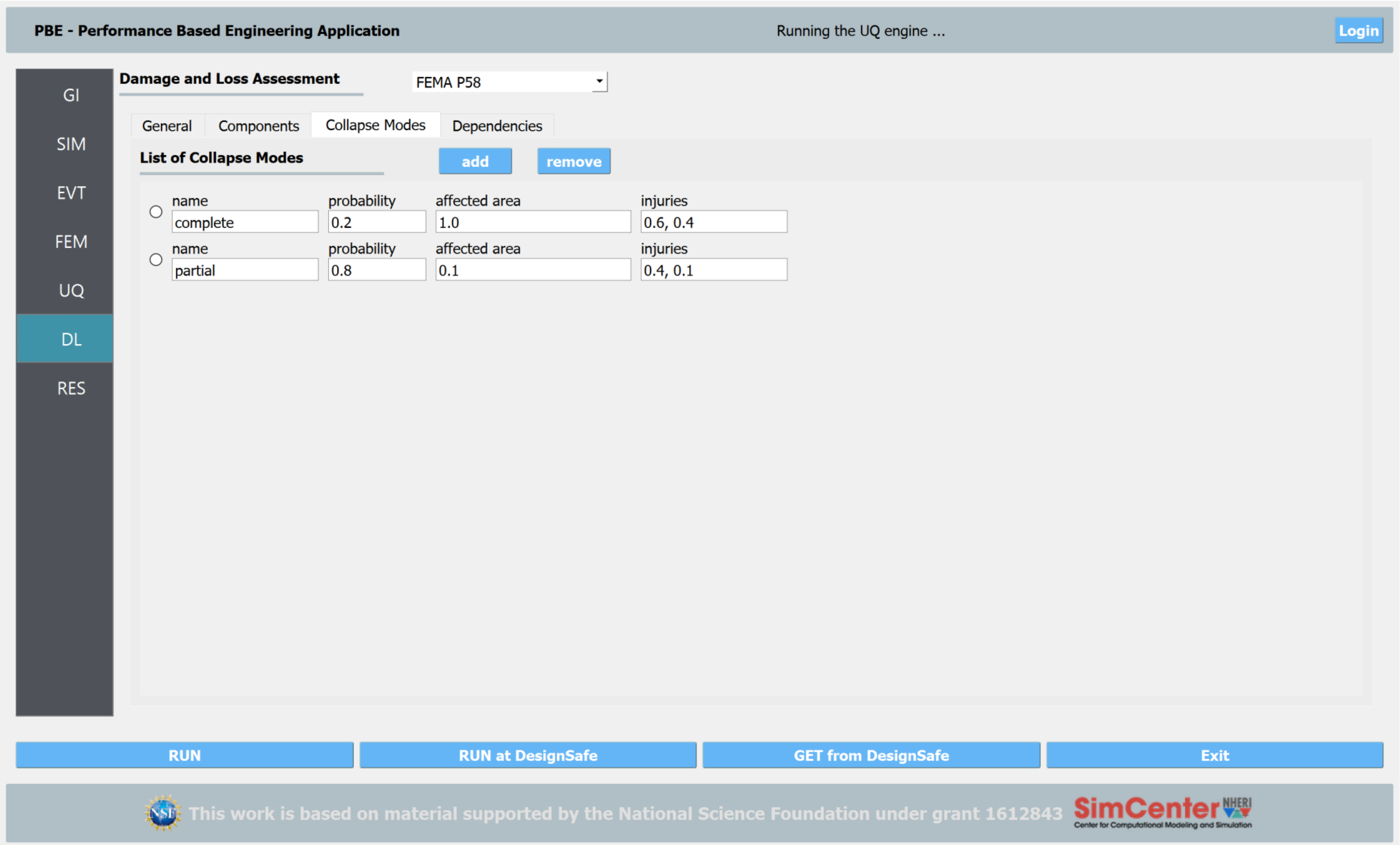
Estimate damage and loss



Estimate damage and loss



Estimate damage and loss



Estimate damage and loss

PBE - Performance Based Engineering Application   Running the UQ engine ...   Login

GI | SIM | EVT | FEM | UQ | DL | RES

Summary | Data Values

Decision Variable	Mean	Standard Dev.	Minimum	10^{th} Percentile	Median	90^{th} Percentile
event time: month	6.4364	3.48758	1	2	6	11
event time: weekday?	0.7084	0.454545	0	0	1	1
event time: hour	11.6982	6.86802	0	2	12	21
inhabitants:	88.8344	104.111	0	0	0	285
collapses: collapsed?	0.0998	0.299763	0	0	0	0
collapses: mode	0.785571	0.410837	0	0	1	1
red tagged?:	0.995557	0.0665184	0	1	1	1
reconstruction: irrepairable?	0.528549	0.49924	0	0	1	1
reconstruction: cost impractical?	0.11263	0.316214	0	0	0	1
reconstruction: cost	7.62358e+06	3.28379e+06	986410	2.39672e+06	1e+07	1e+07

RUN | RUN at DesignSafe | GET from DesignSafe | Exit

This work is based on material supported by the National Science Foundation under grant 1612843

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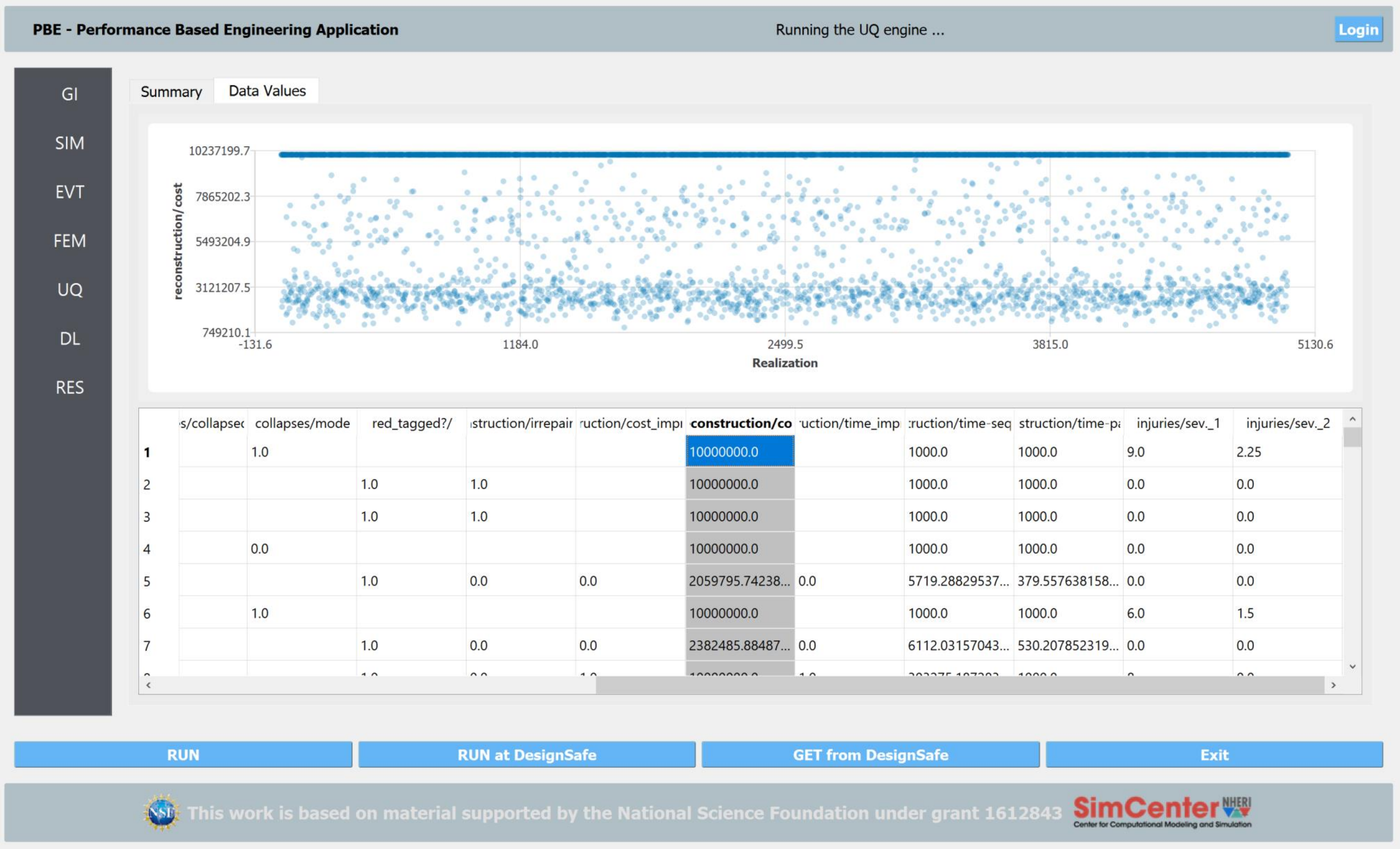
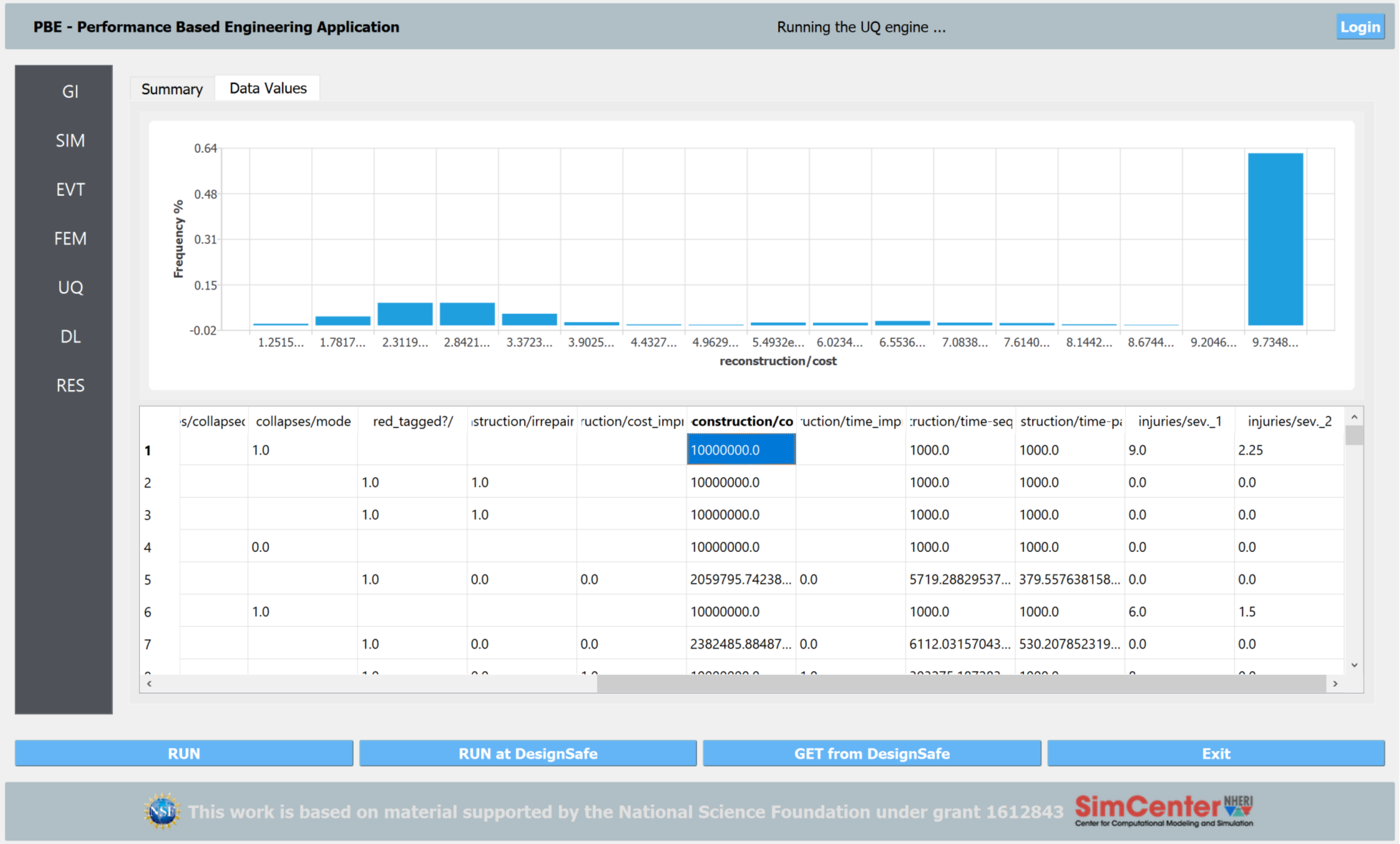
Estimate damage and loss

PBE



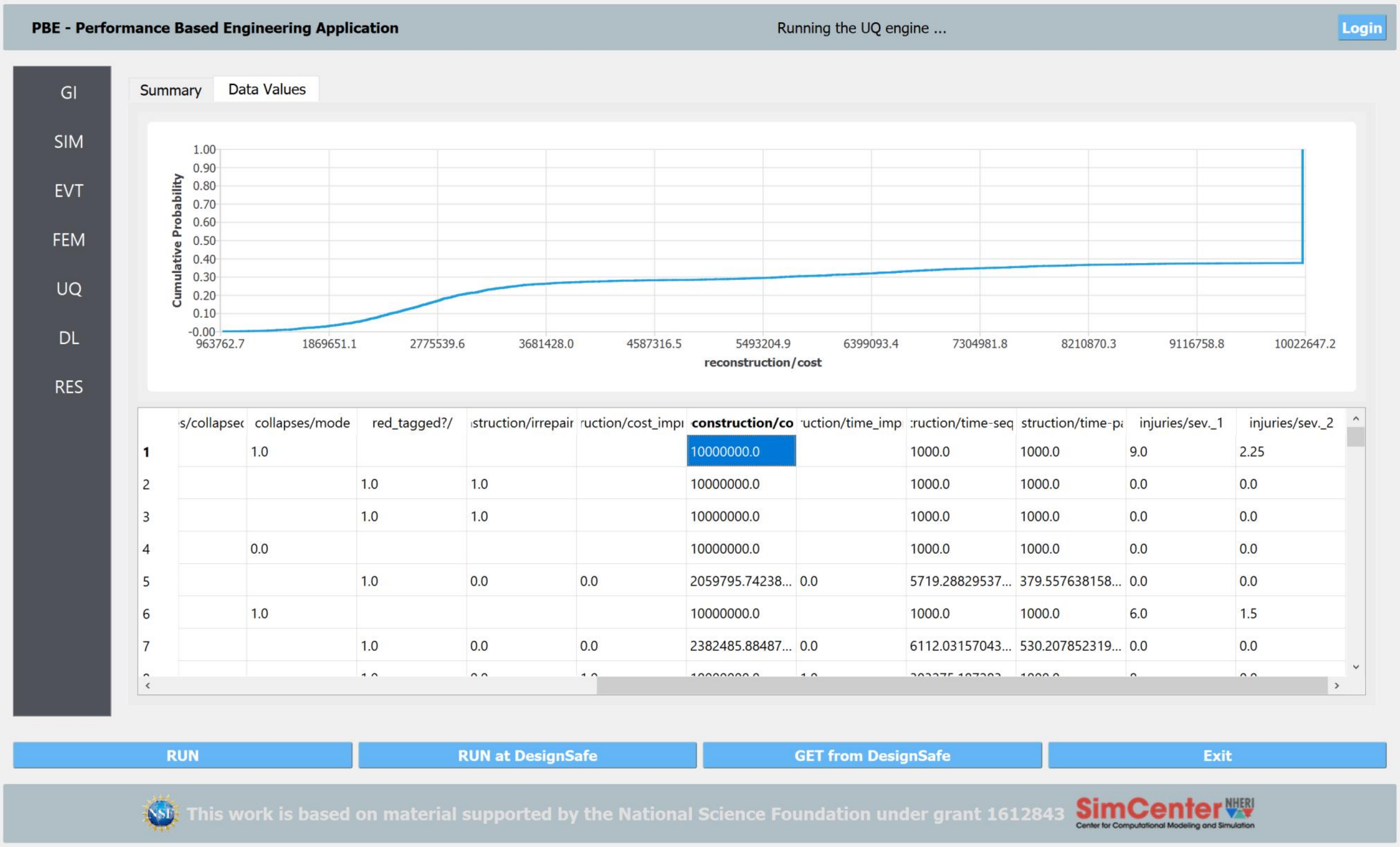
Estimate damage and loss

PBE



Estimate damage and loss

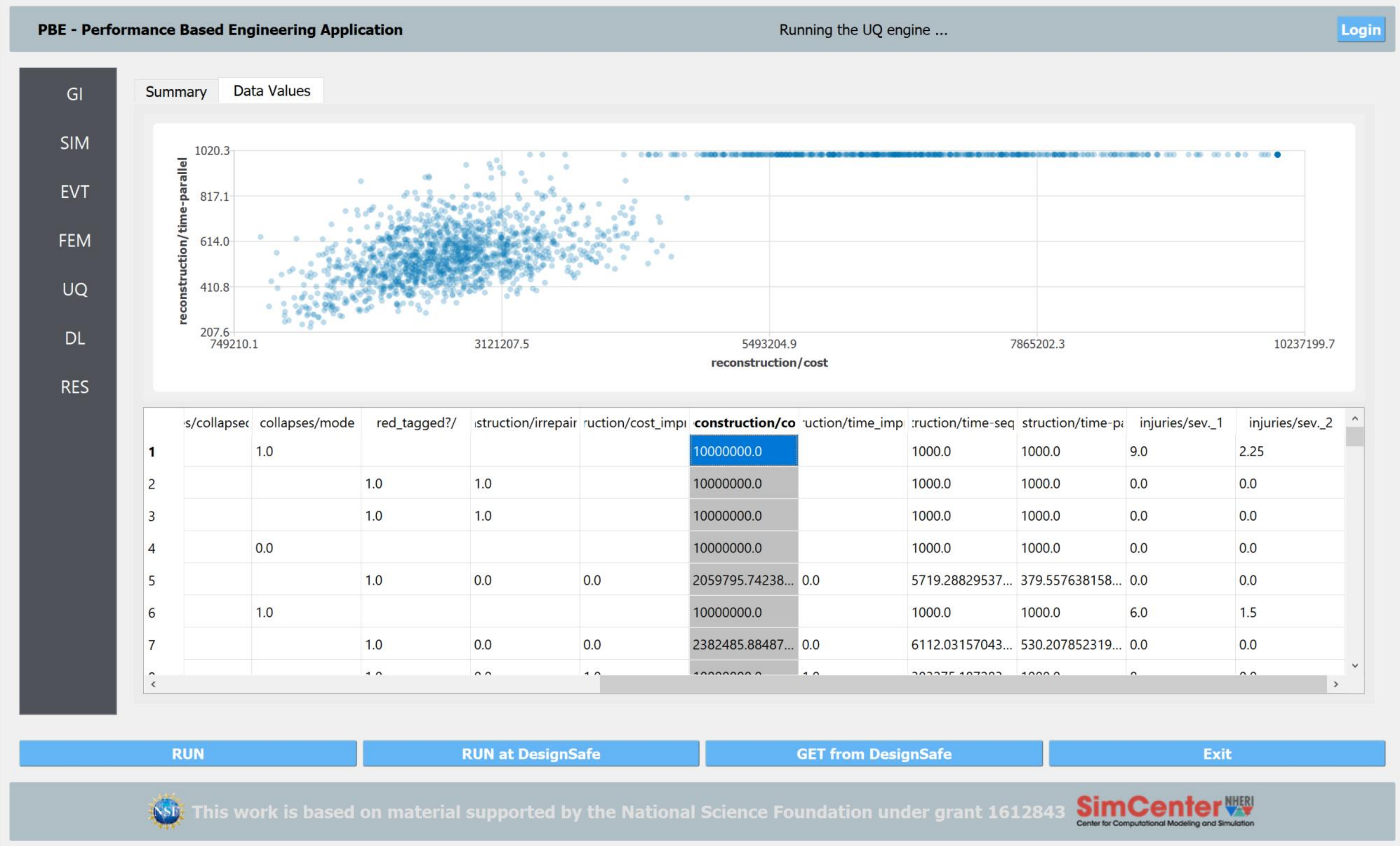
PBE



	s/collapsec	collapses/mode	red_tagged?/	istruction/irrepair	ruction/cost_impı	construction/co	uction/time_imp	ruction/time-seq	struction/time-pa	injuries/sev._1	injuries/sev._2
1		1.0				10000000.0		1000.0	1000.0	9.0	2.25
2			1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
3			1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
4		0.0				10000000.0		1000.0	1000.0	0.0	0.0
5			1.0	0.0	0.0	2059795.74238...	0.0	5719.28829537...	379.557638158...	0.0	0.0
6		1.0				10000000.0		1000.0	1000.0	6.0	1.5
7			1.0	0.0	0.0	2382485.88487...	0.0	6112.03157043...	530.207852319...	0.0	0.0

Estimate damage and loss

PBE



Research Tools

- **quoFEM** **Uncertainty Quantification and Optimization**

- **EE-UQ** **Structural Response Estimation under Earthquakes**
- WE-UQ Structural Response Estimation under Wind
- CWE CFD Analysis for a Building

- **PBE** **Damage and Loss Assessment for a Building**
- rWHALE Damage and Loss Assessment for an Urban Region

Objectives

- Demonstrate use-cases of our research tools
- **Get feedback on existing features**
- **Collect requests for new features**

National Science Foundation

University of California at San Diego NHERI Natural Hazards Engineering Research Infrastructure

UC San Diego JACOBS SCHOOL OF ENGINEERING Structural Engineering

Example Use of Research Tools

https://simcenter.designsafe-ci.org/research-tools

Adam Zsarnóczay, Postdoctoral Researcher

Stanford University, SimCenter

adamzs@stanford.edu

Joint Researcher Workshop

UC San Diego, Lehigh & SimCenter

December 16-17, 2019

University of California, San Diego

LEHIGH NHERI Real-Time Multi-Directional Testing Facility

University of California at San Diego NHERI Natural Hazards Engineering Research Infrastructure

SIMCENTER COMPUTATIONAL MODELING AND SIMULATION CENTER