SimCenter NHERI

Center for Computational Modeling and Simulation

Example use of Research Tools

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

Adam Zsarnóczay
adamzs@Stanford.edu

NSF award: CMMI 1612843

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

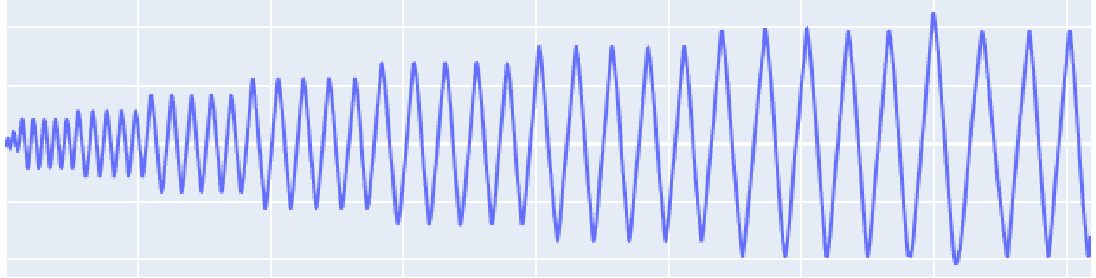
1.	**Design an experiment**	**quoFEM**
2.	Calibrate a numerical component model	quoFEM
3.	Simulate structural response	EE-UQ
4.	Estimate damage and losses	PBE

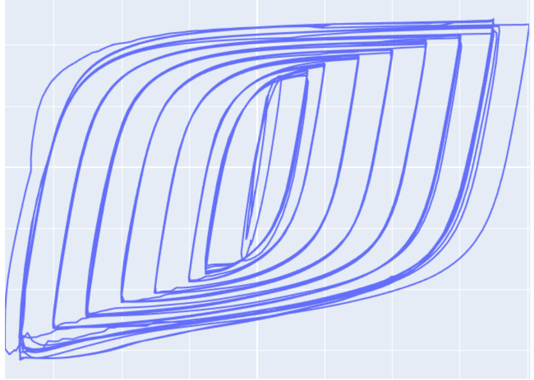
Design an experiment

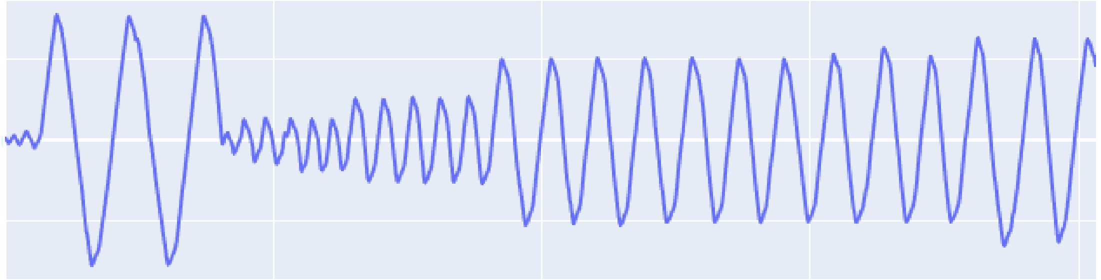
setting: uniaxial cyclic load test of a Buckling Restrained Brace

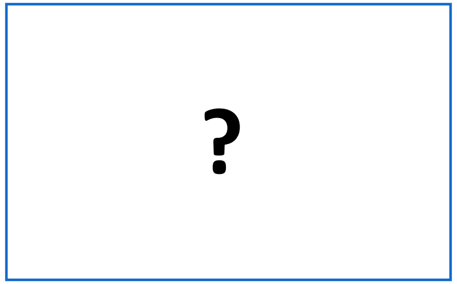
objective: estimate maximum tension/compression during test

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





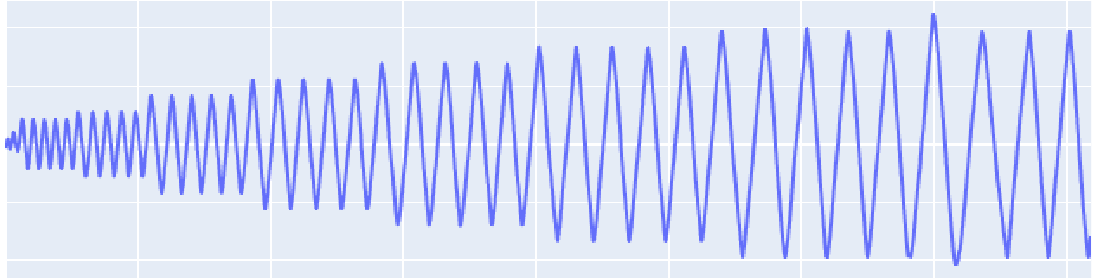


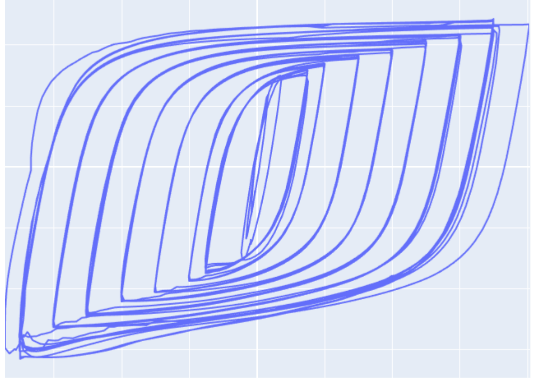


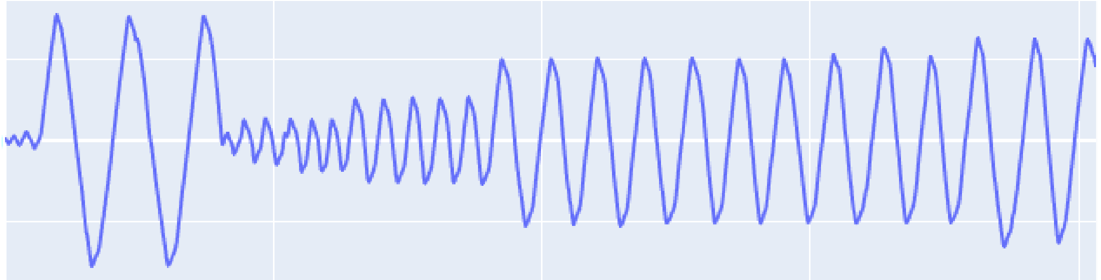
?

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

Adam Zsarnóczay adamzs@stanford.edu

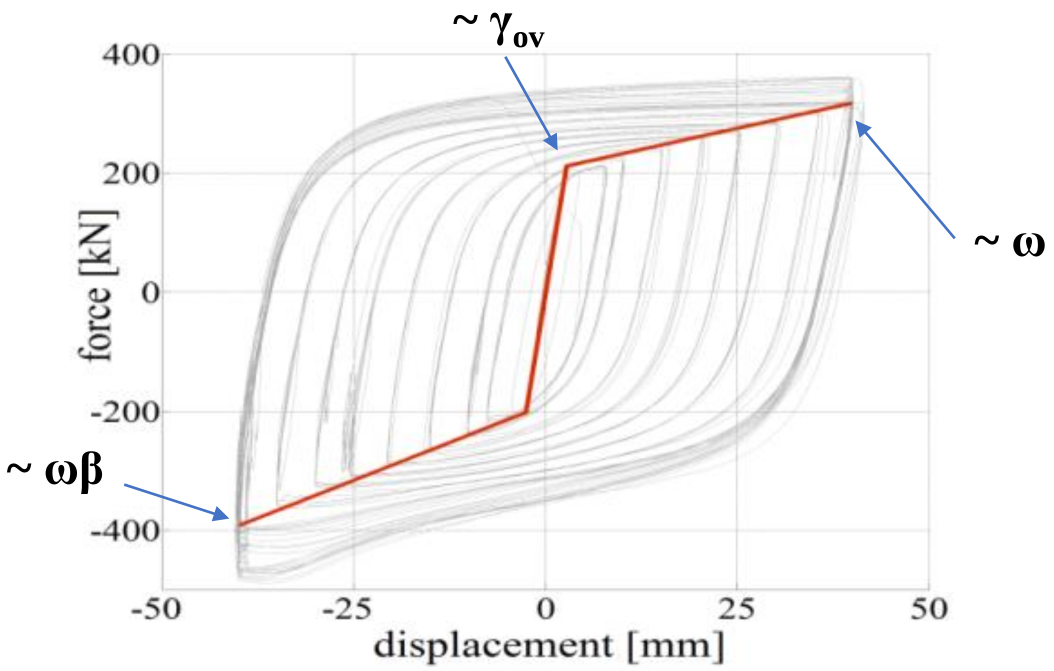
Design an experiment

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



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

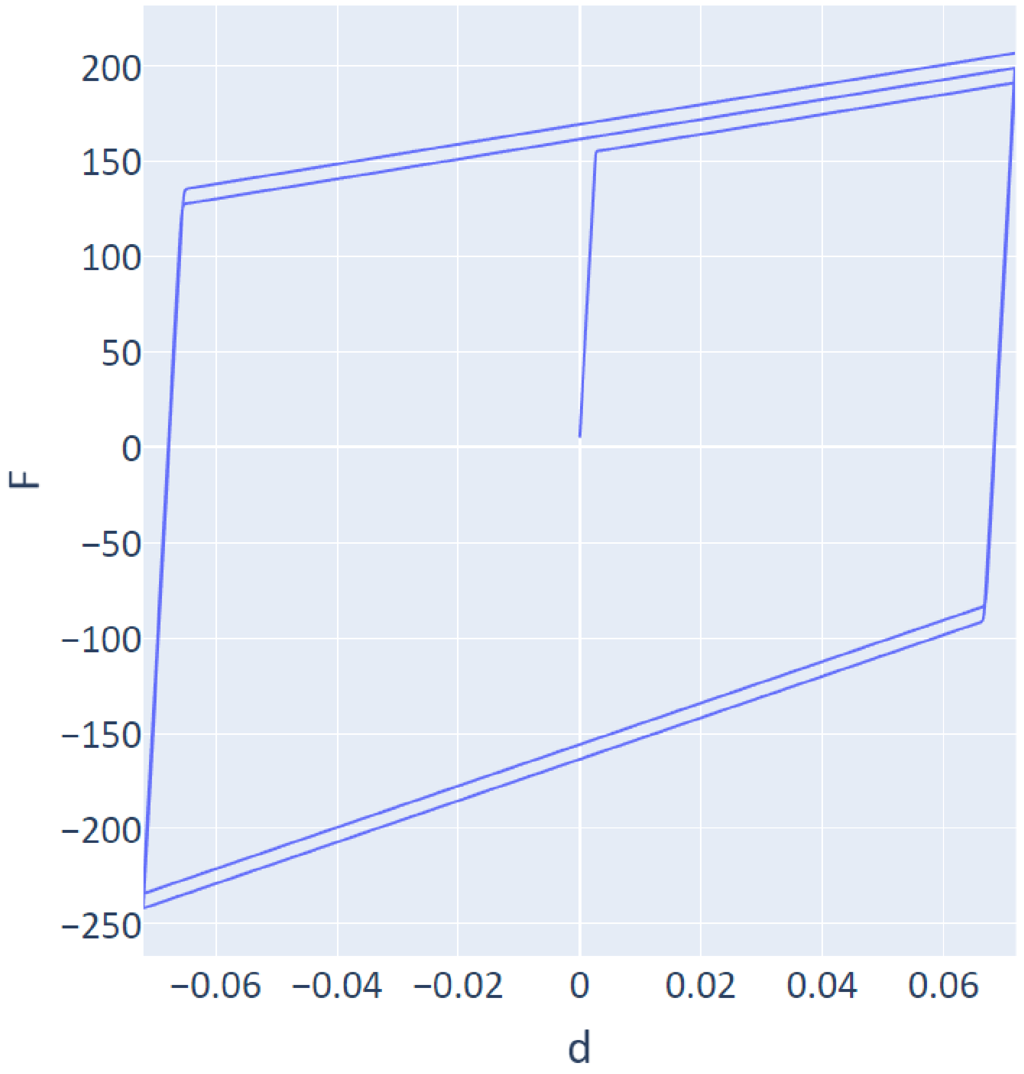
Design an experiment

First, through literature review get:

- conservative bounds for attributes
- **simplified BRB model in OpenSees**

Then, prepare:

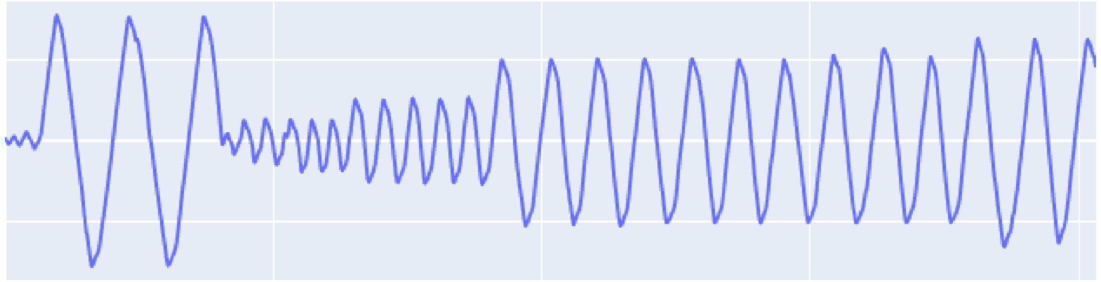
- new load protocol
- script to simulate experiment
- script to extract max forces



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 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
- simplified BRB model in OpenSees

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))
```

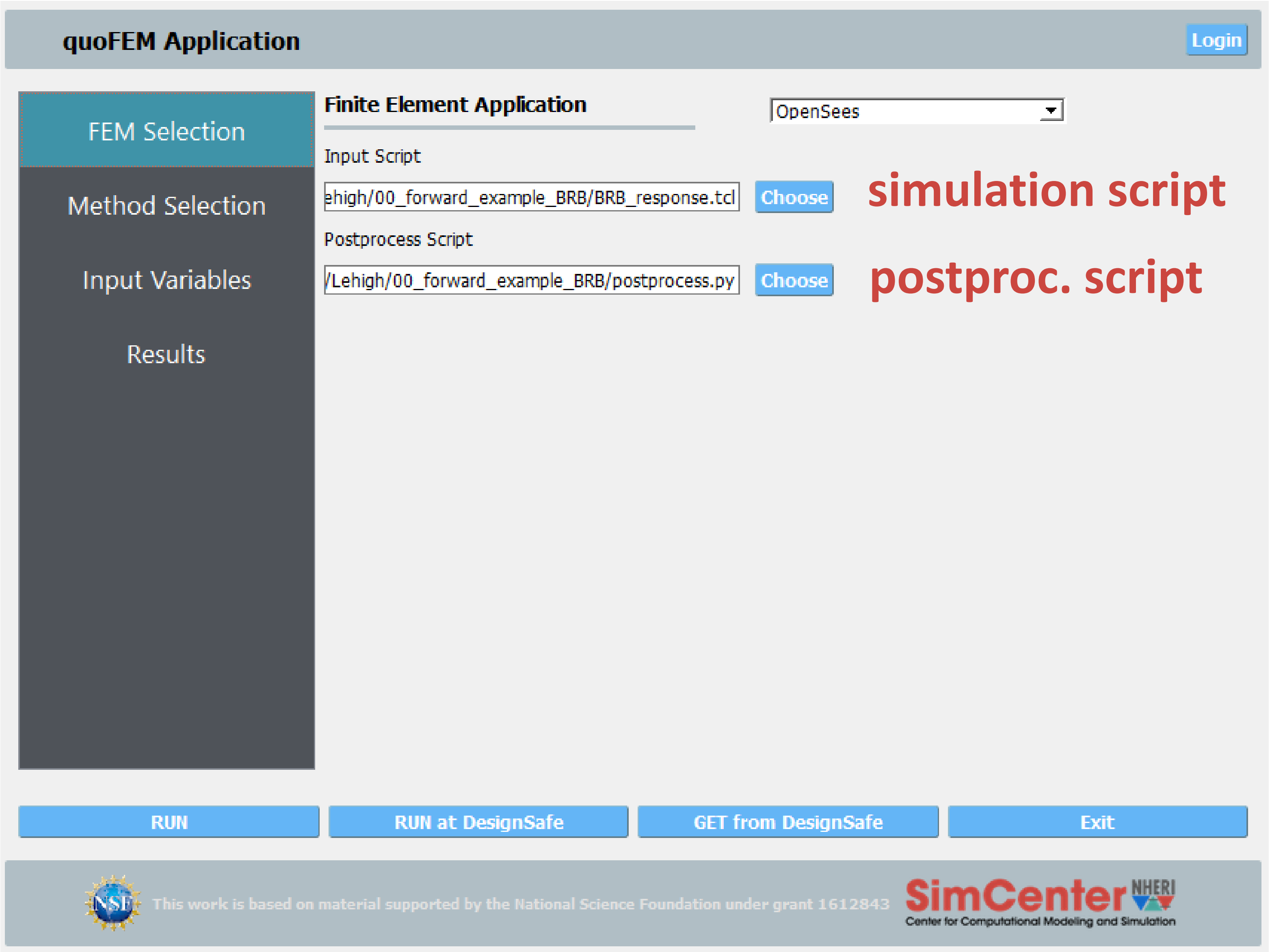
postprocess.py

```
-262.325 227.717
```

results.out

Design an experiment

load the pre-defined scripts



Design an experiment

select the task

available methods for forward propagation

- Latin Hypercube Sampling
- Monte Carlo Sampling
- Importance Sampling
- Gaussian Process Regression

Design an experiment

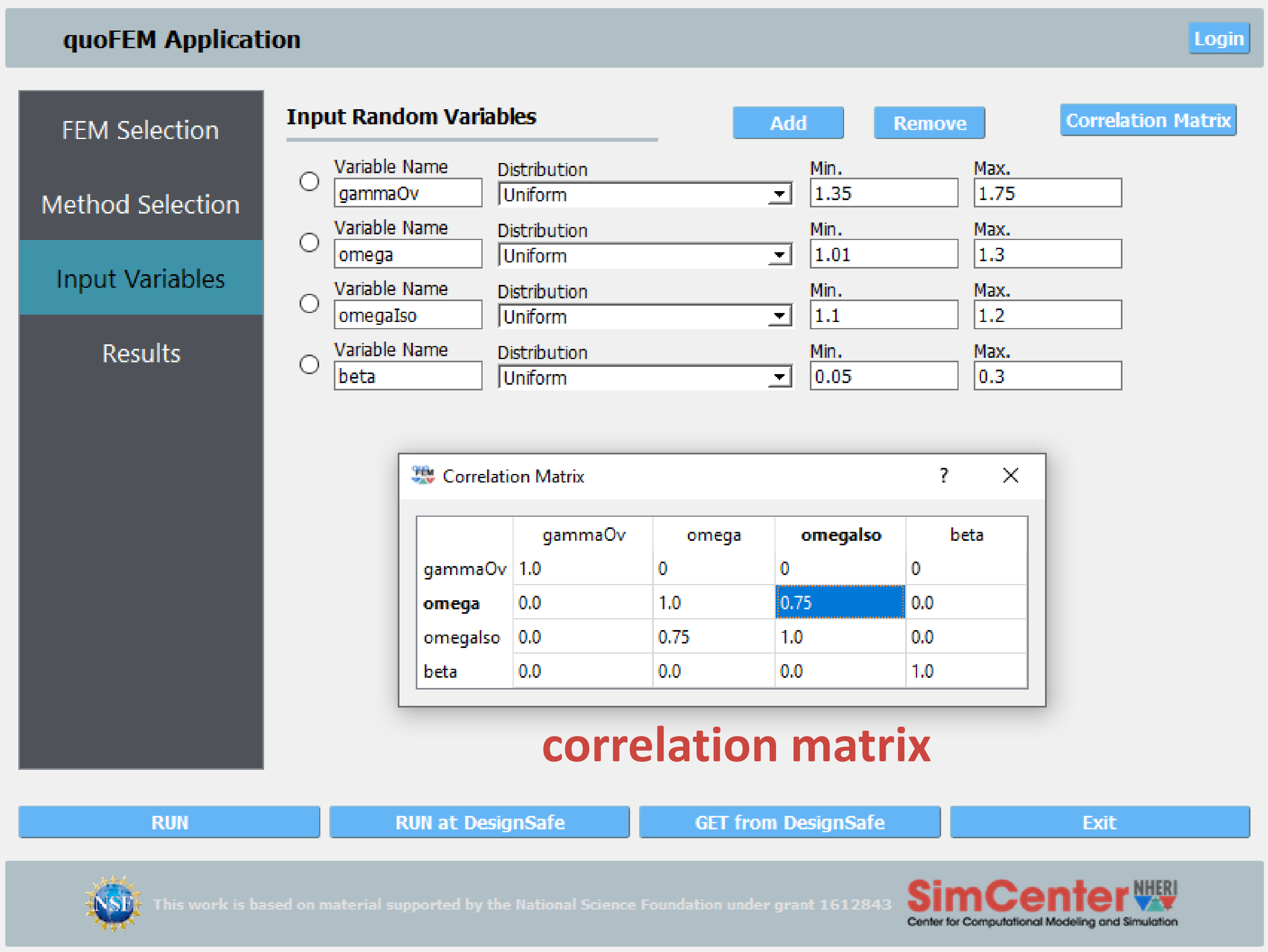
quoFEM

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

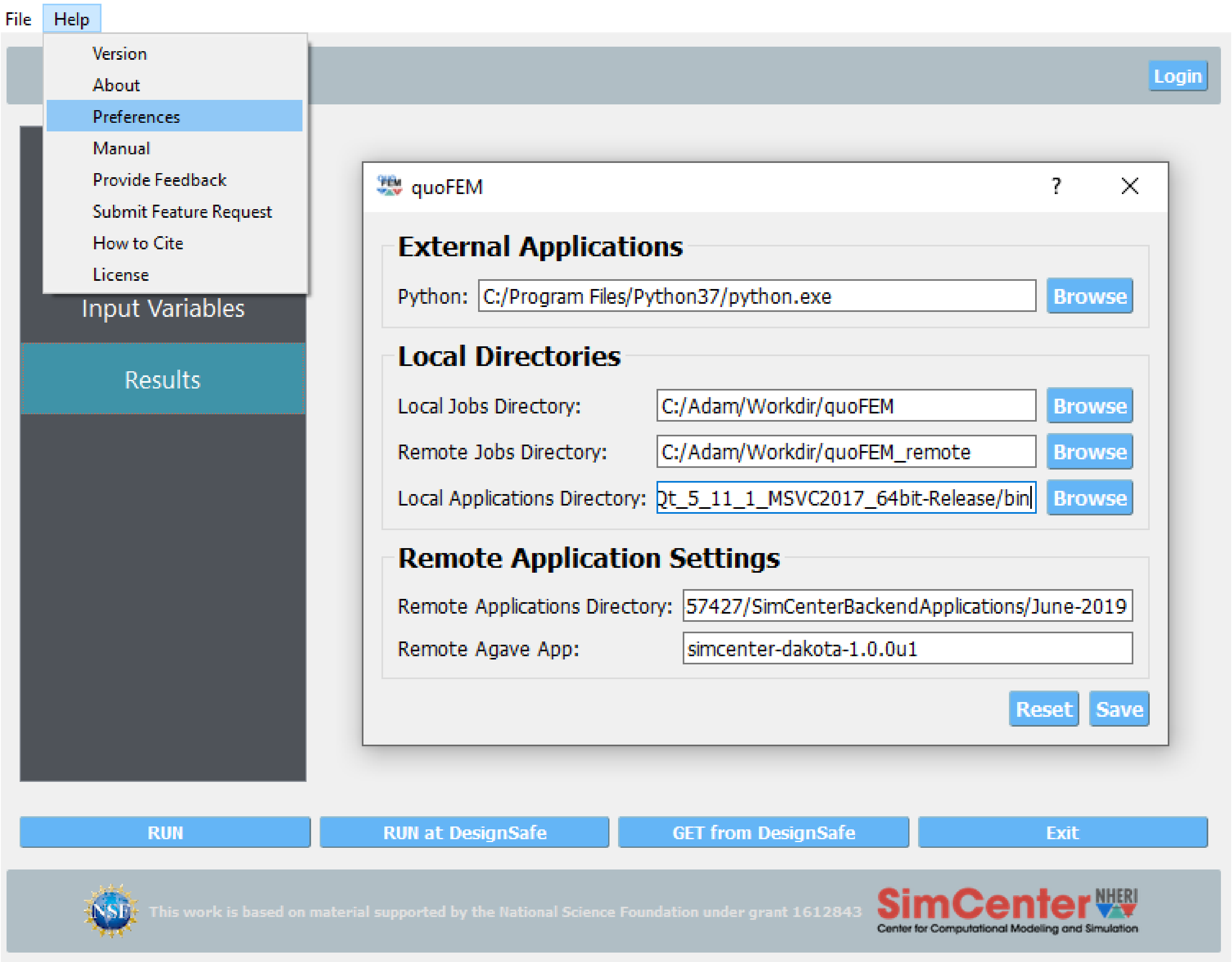


correlation matrix

Design an experiment

advanced users can

- specify their python interpreter
- edit working directories

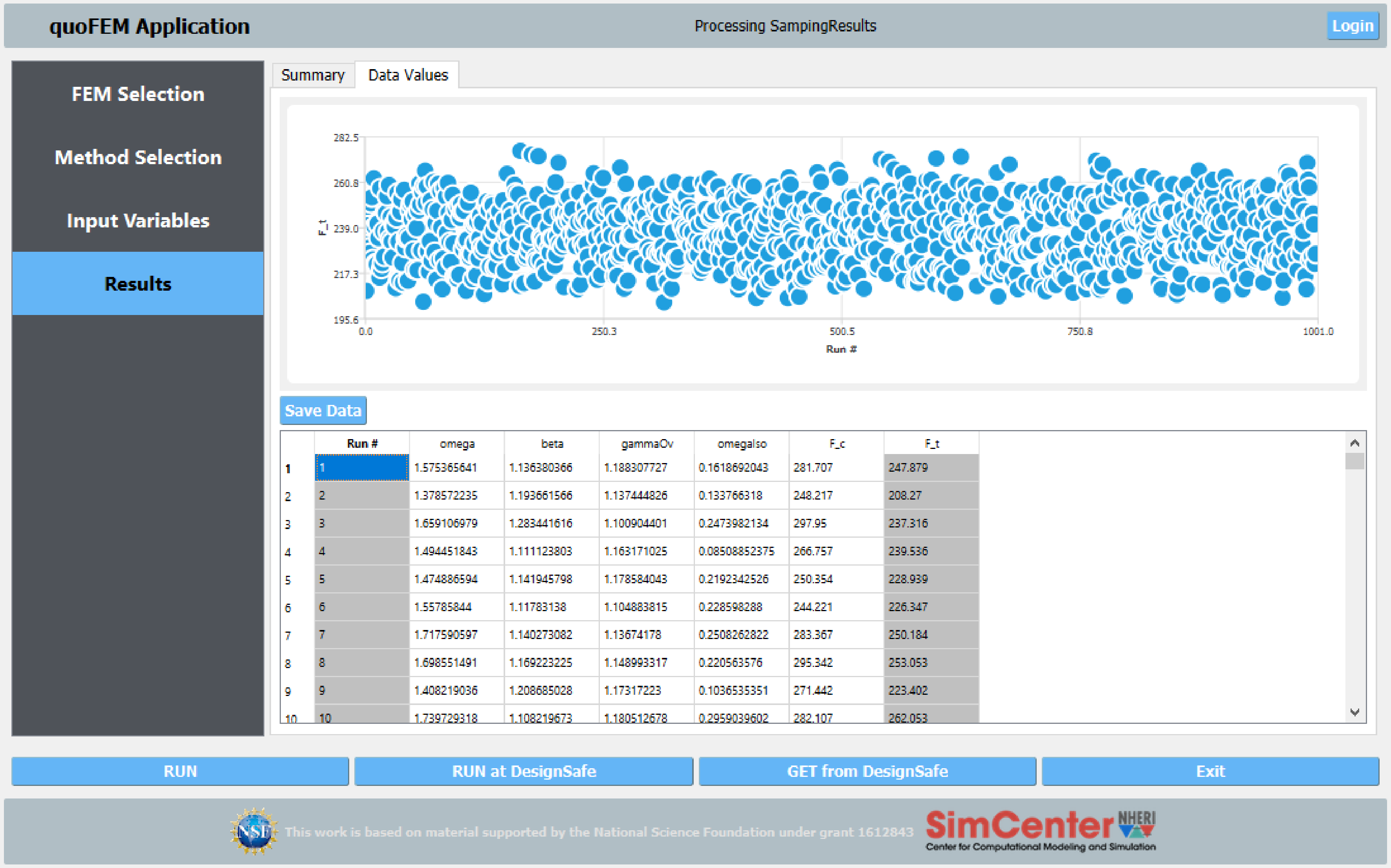


Design an experiment

quoFEM

result visualization

scatterplots show sampled inputs and corresponding outputs



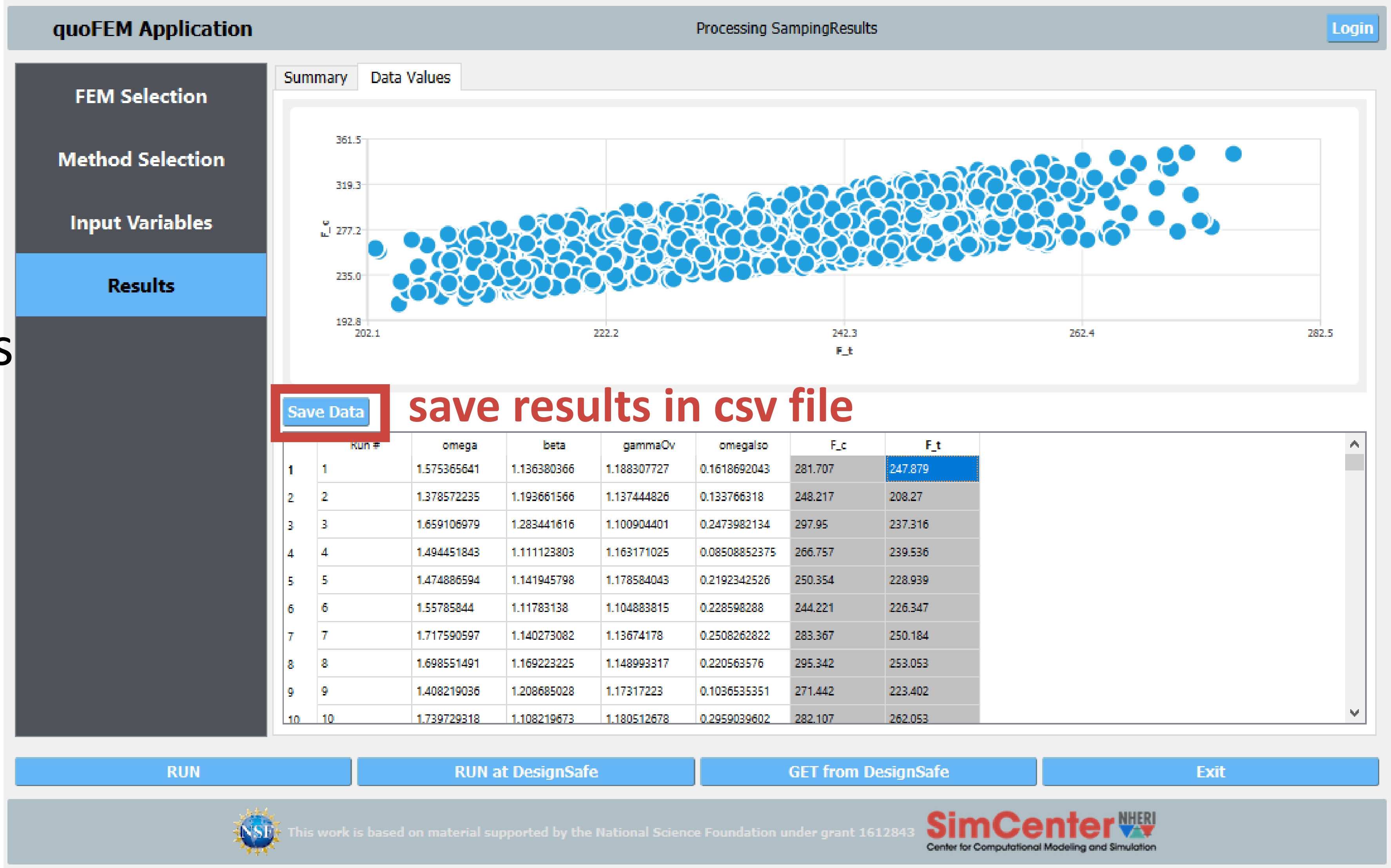
Design an experiment

quoFEM

result visualization

scatterplots show sampled inputs and corresponding outputs

and joint distributions



Design an experiment

advanced visualization and data processing

```
import pandas as pd
import plotly.express as px
res = pd.read_csv("C:/Lehigh/00_forward_example_BRB/output.csv", sep=', ')
res.head(10)
```

easy to load csv in Python, MatLAB, or Excel

	Run #	omega	beta	gammaOv	omegaIso	F_c	F_t
0	1	1.57537	1.13638	1.18831	0.161869	281.707	247.879
1	2	1.37857	1.19366	1.13744	0.133766	248.217	208.270
2	3	1.65911	1.28344	1.10090	0.247398	297.950	237.316
3	4	1.49445	1.11112	1.16317	0.085088	266.757	239.536
4	5	1.47489	1.14195	1.17858	0.219234	250.354	228.939
5	6	1.55786	1.11783	1.10488	0.228598	244.221	226.347
6	7	1.71759	1.14027	1.13674	0.250826	283.367	250.184
7	8	1.69855	1.16922	1.14899	0.220564	295.342	253.053
8	9	1.40822	1.20869	1.17317	0.103654	271.442	223.402
9	10	1.73973	1.10822	1.18051	0.295904	282.107	262.053

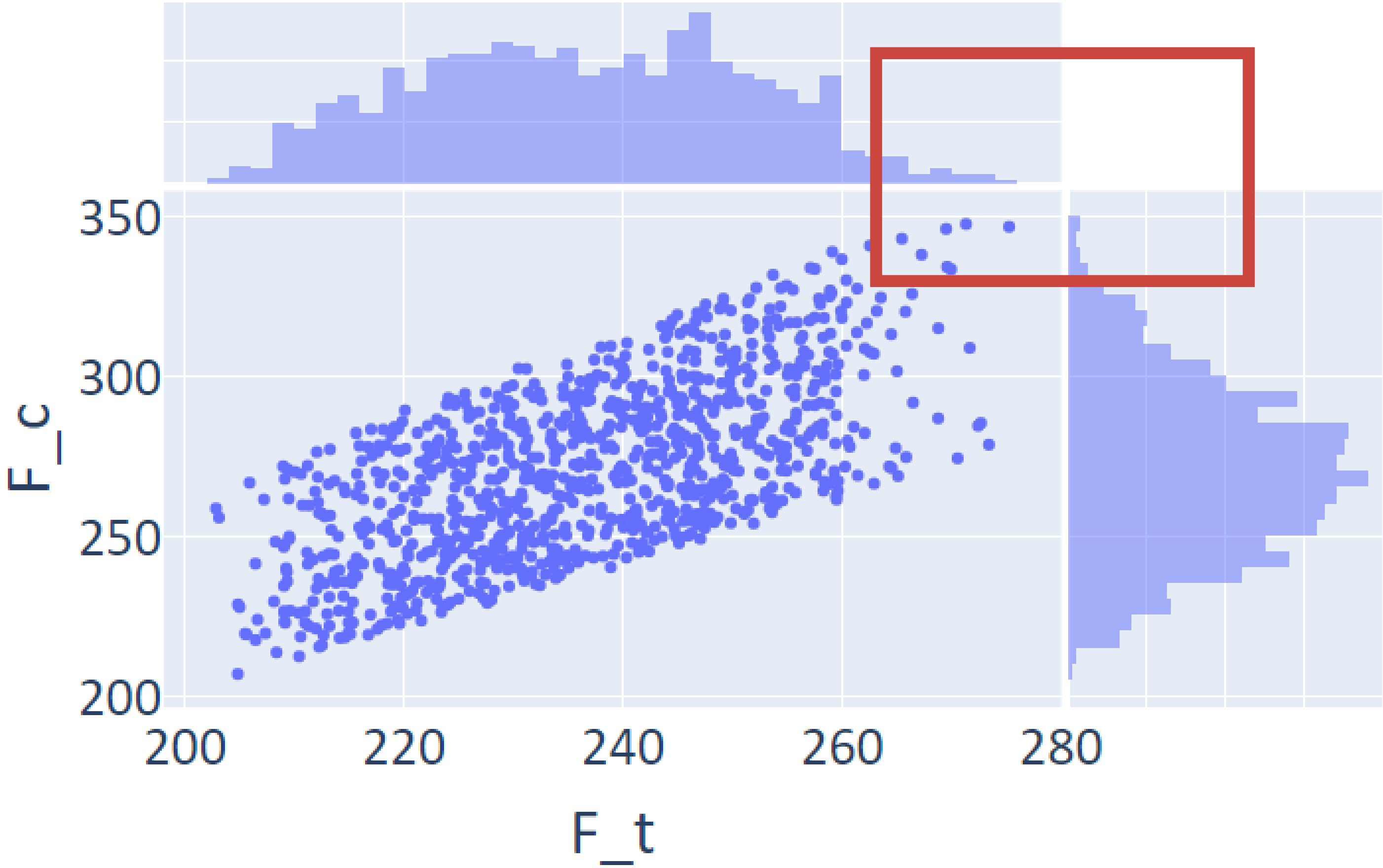
Design an experiment

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

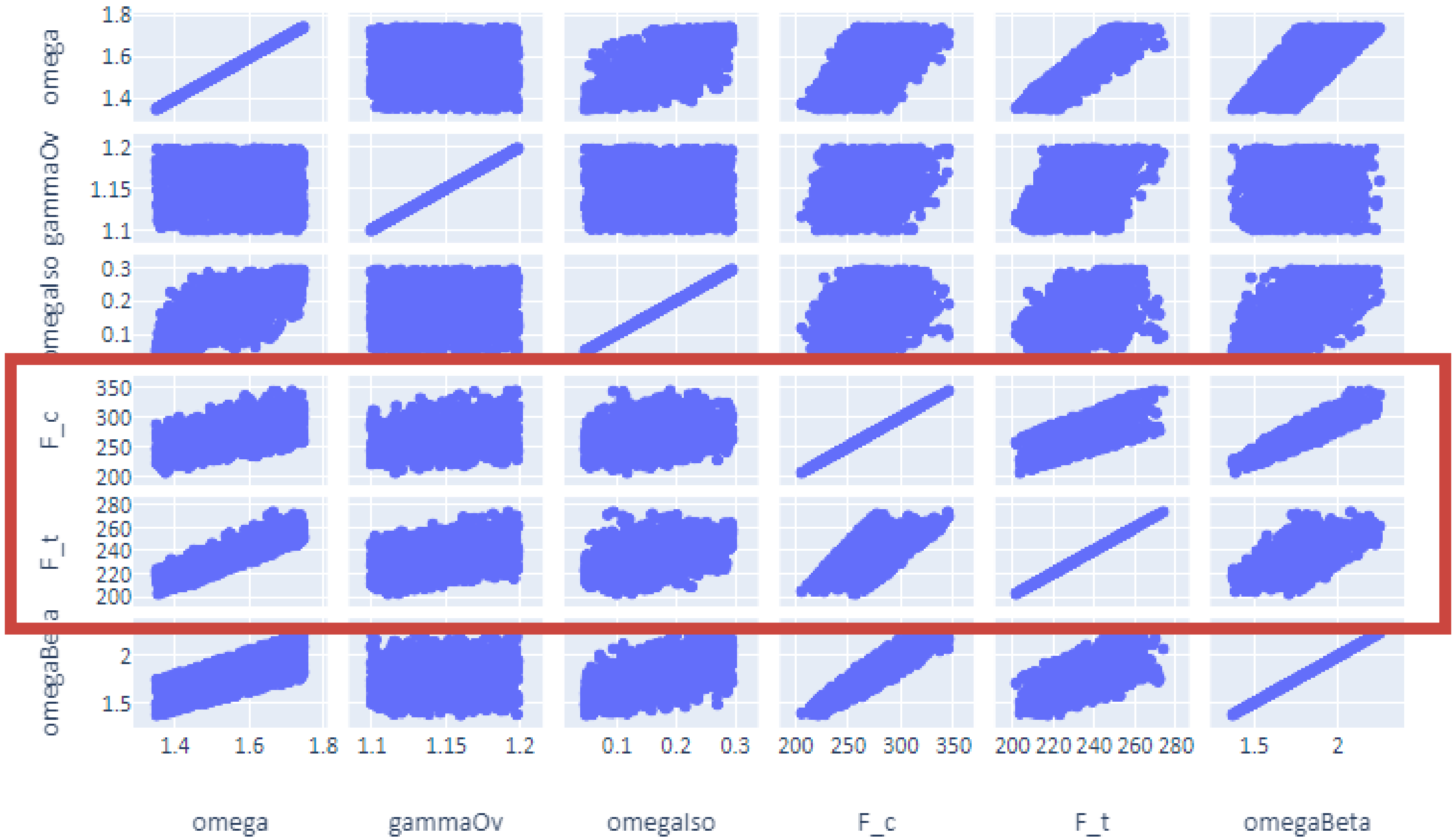


Design an experiment

advanced visualization and data processing

use scatter matrix to identify dependencies

```python
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()
```

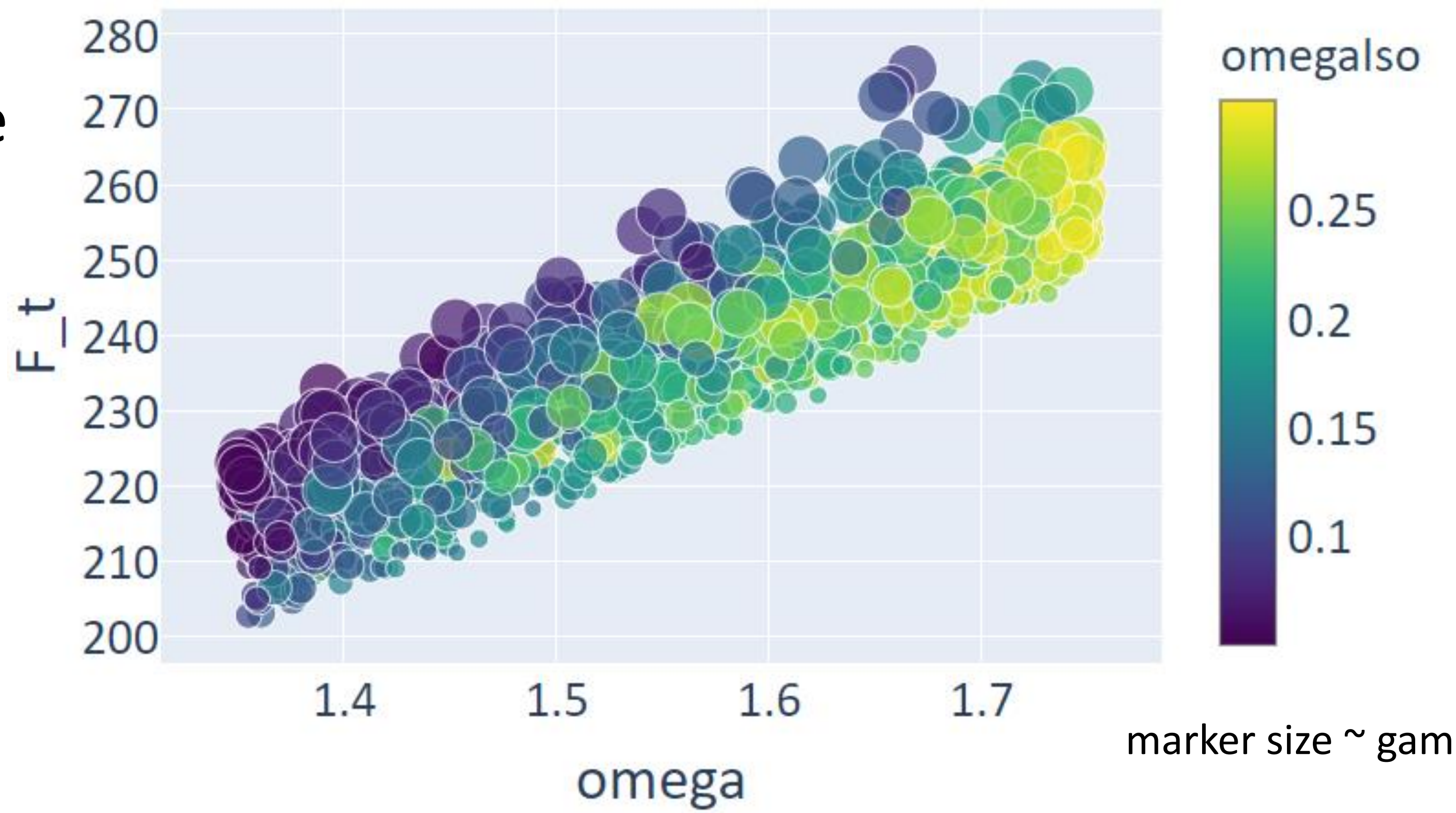


Design an experiment

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



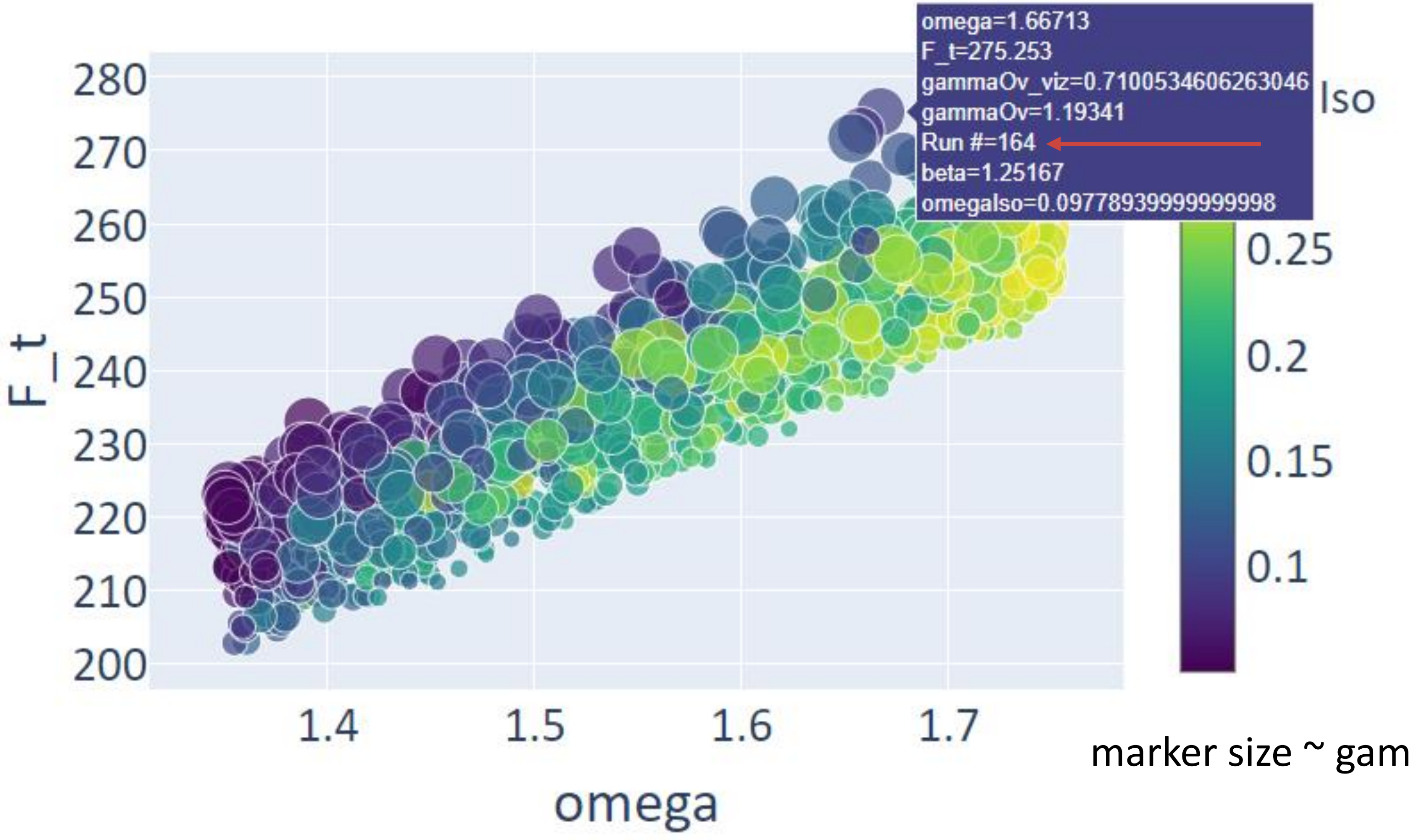
marker size ~ gammaOv

Design an experiment

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()
```



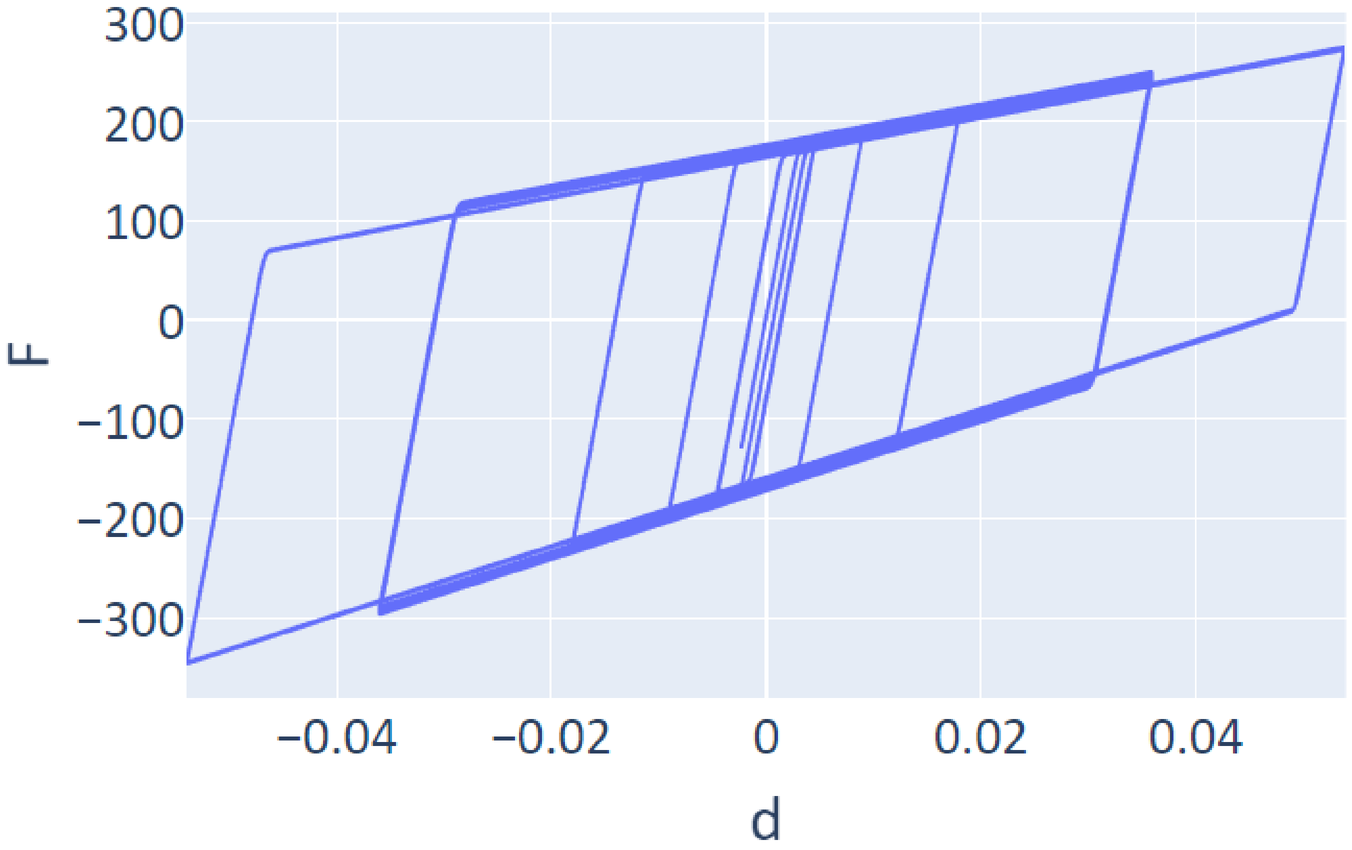
marker size ~ gammaOv

Design an experiment

advanced visualization and data processing

raw data is available for every simulation

```
output_file = "C:/Users/zsarn/Documents/quoFEM/tmp.SimCenter/workdir.164/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()
```



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

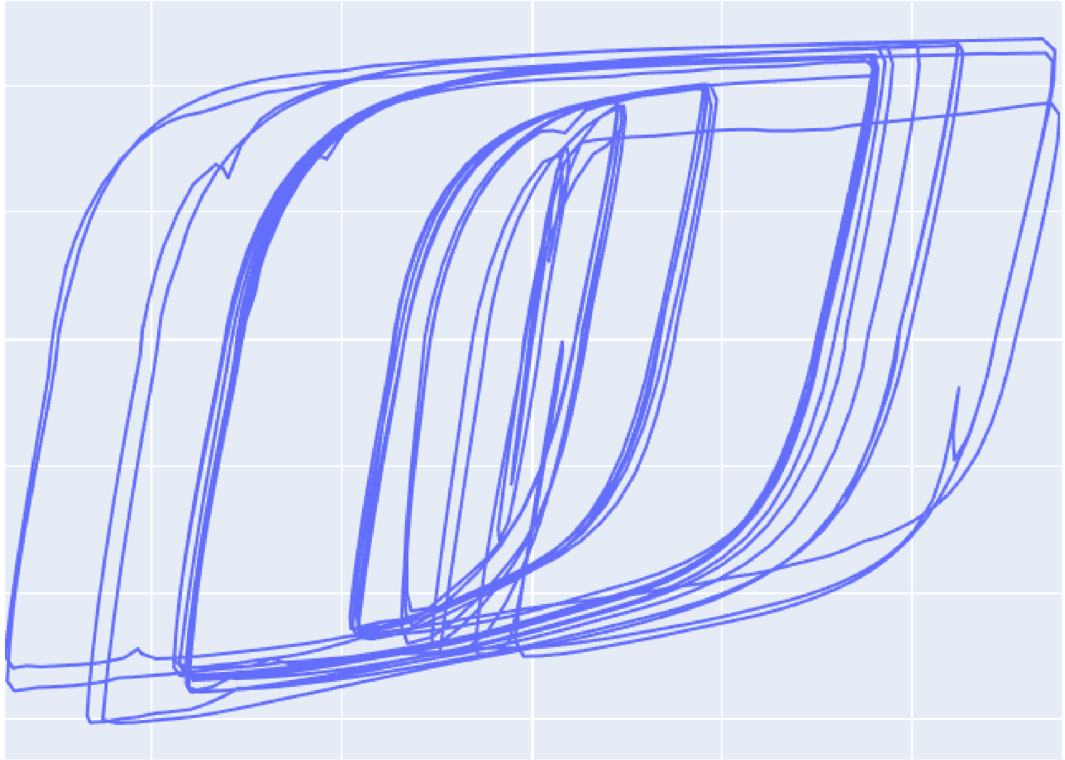
Adam Zsarnóczay adamzs@stanford.edu

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:

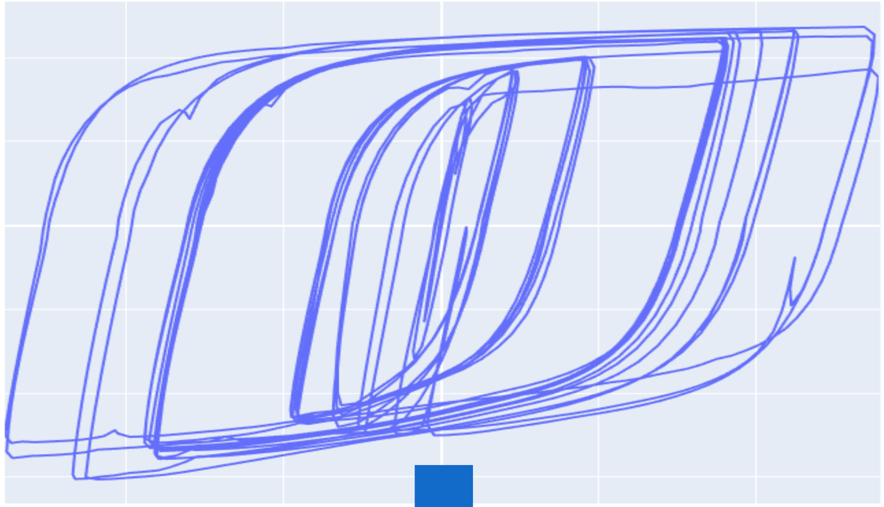
- reference data from test results
- complex BRB model in OpenSees
- updated simulation script
- script with the objective function

Calibrate component model

quoFEM

Prepare:

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



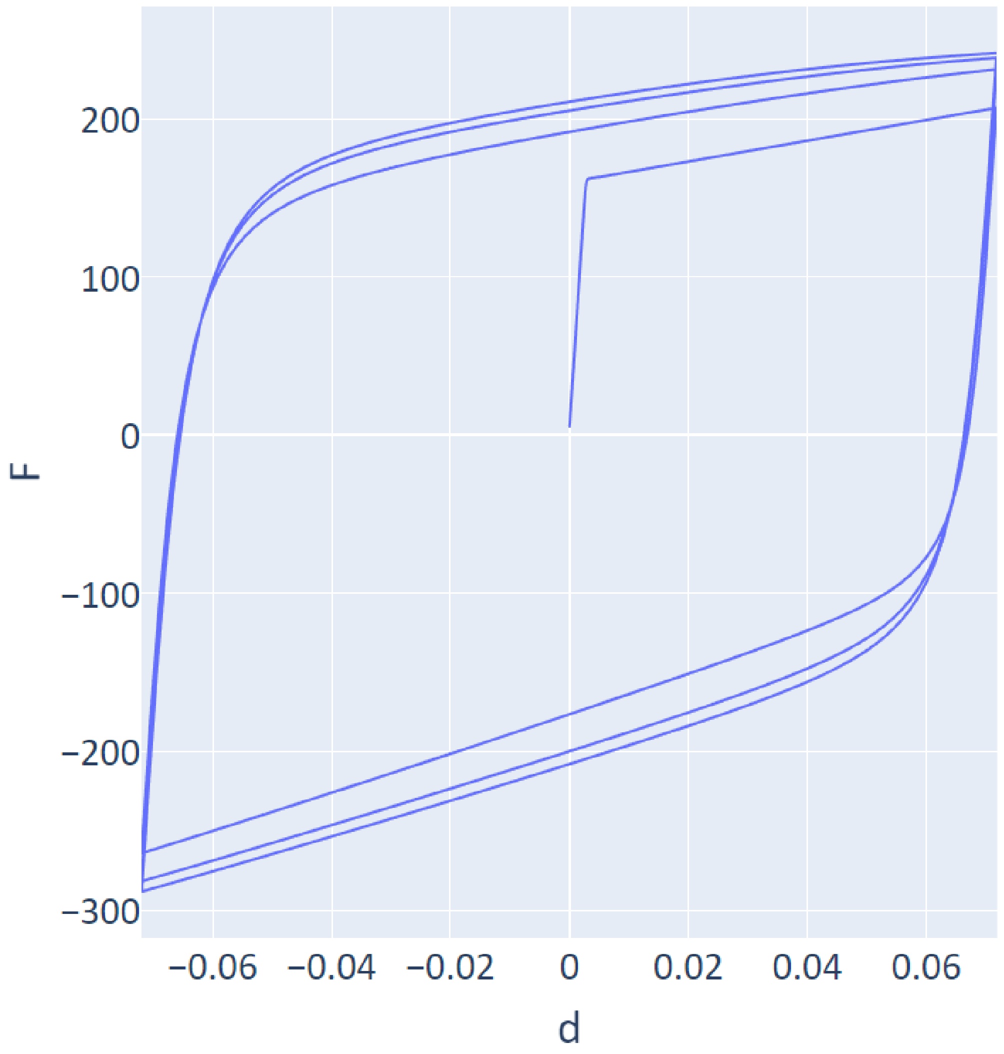
```
78.96559395918378,1[illegible]215204081632668
52.411307755102094,0.9329030612244907
26.90855167346942,0.5383724489795925
4.500137142857147,0.1784795918367349
-18.123096000000018,-0.21307142857142883
-38.138502857142896,-0.5226428571428579
-59.64269926530619,-0.8938724489795928
-74.79477551020416,-1.2276428571428586
-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:

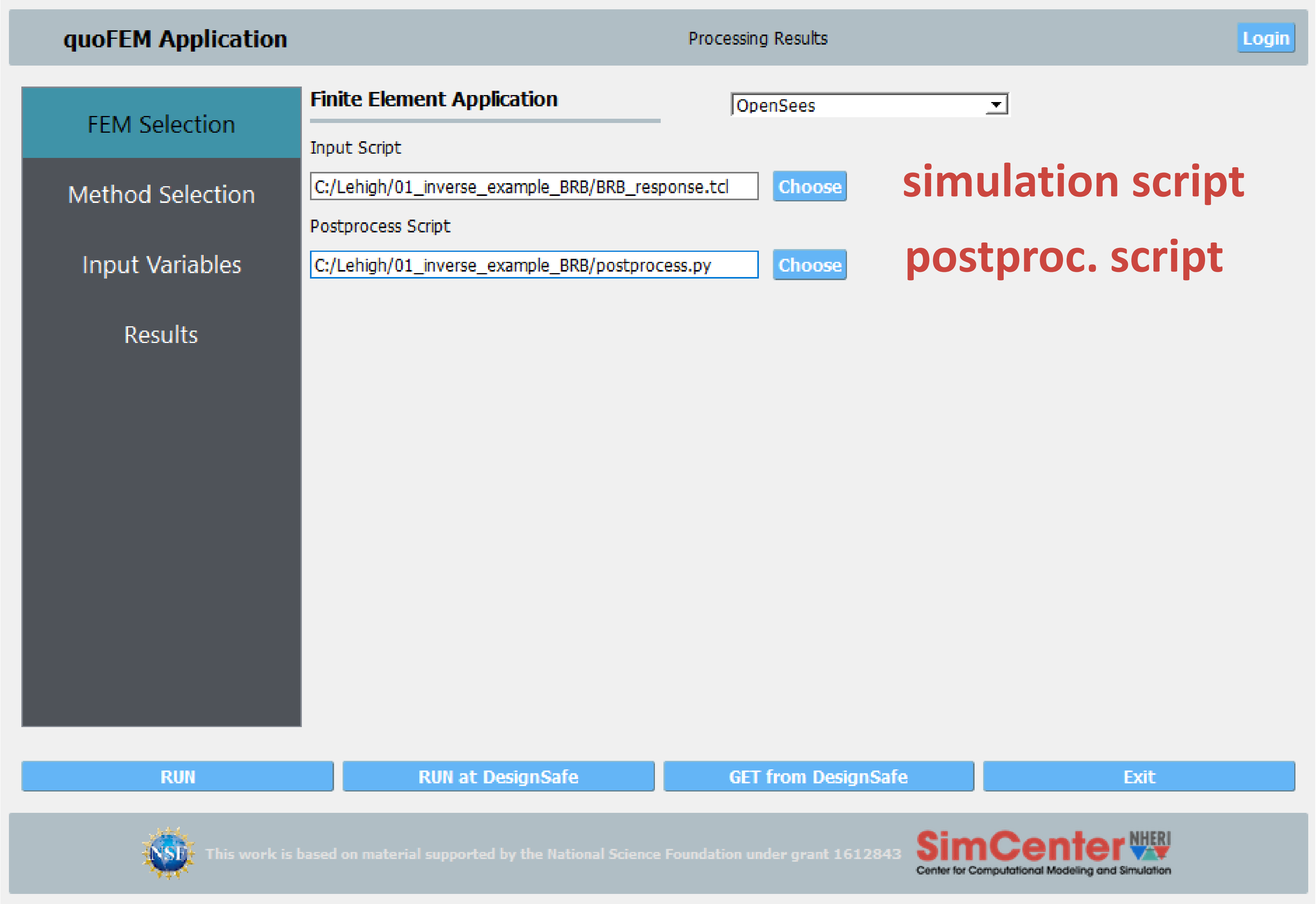
- reference data from test results
- complex BRB model in OpenSees
- updated simulation script
- **script with the objective function**

```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

load the pre-defined scripts



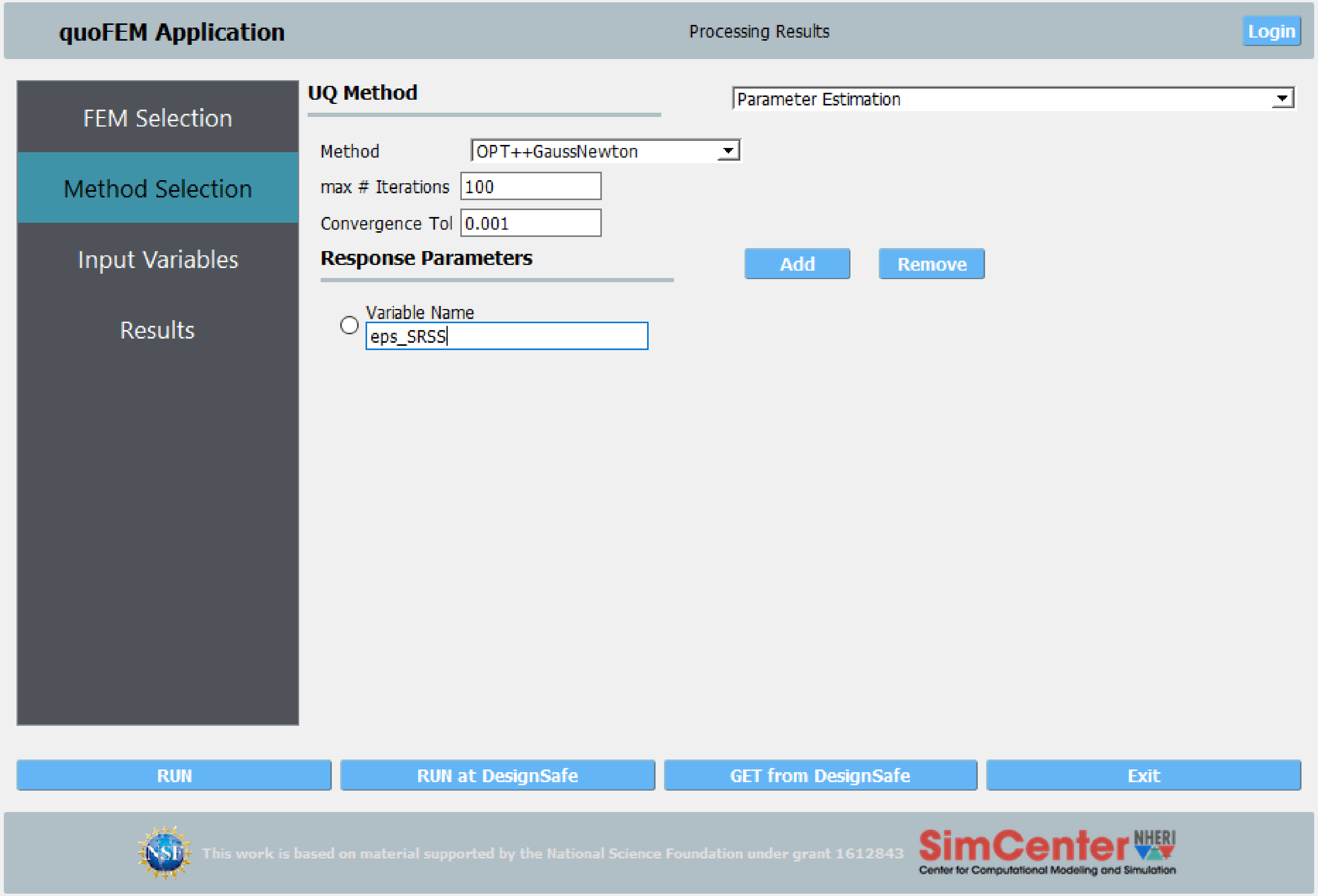
Calibrate component model

quoFEM

select the task

Gauss-Newton is a gradient-based optimization method

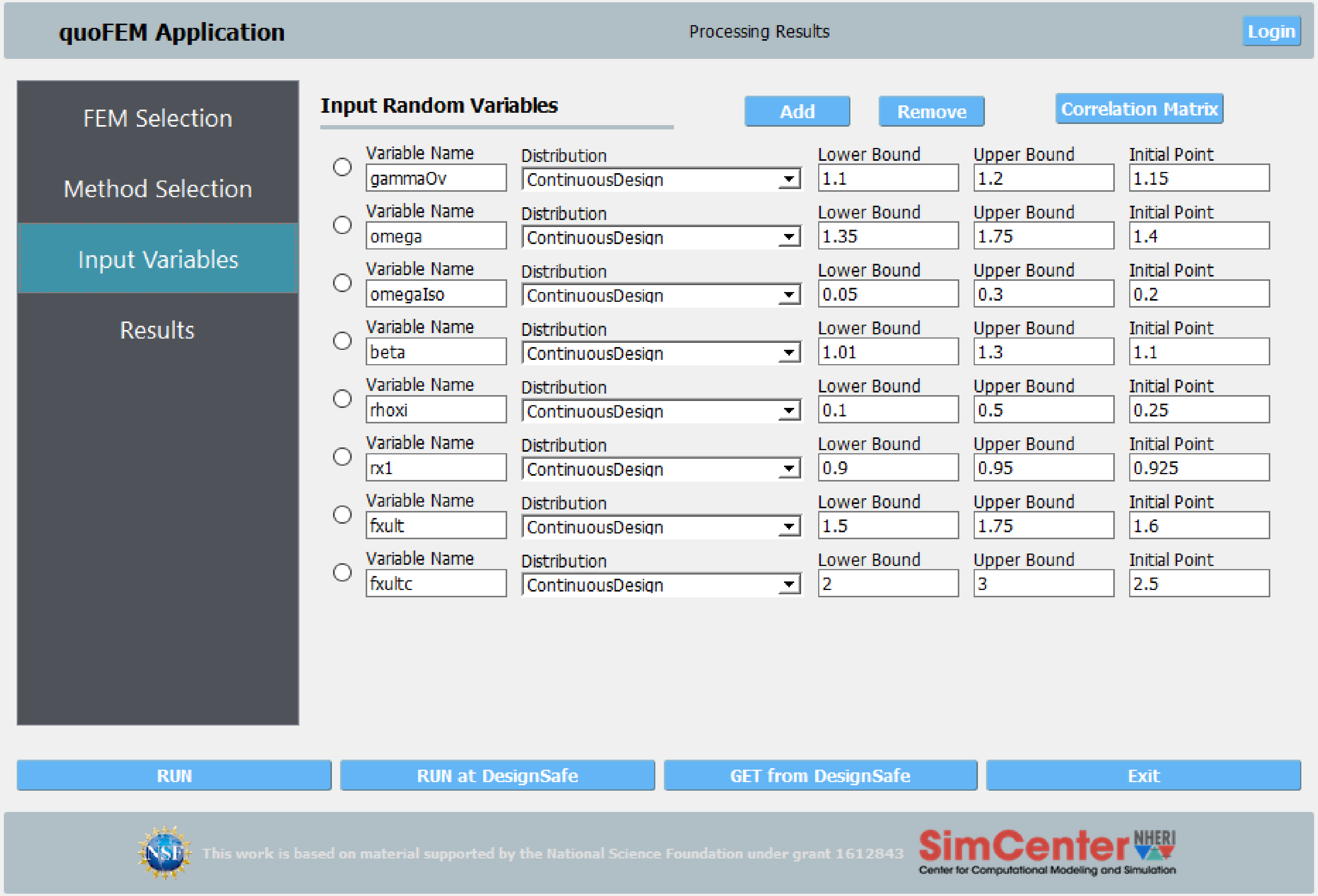
we are also adding Bayesian methods for solving the inverse problem



Calibrate component model

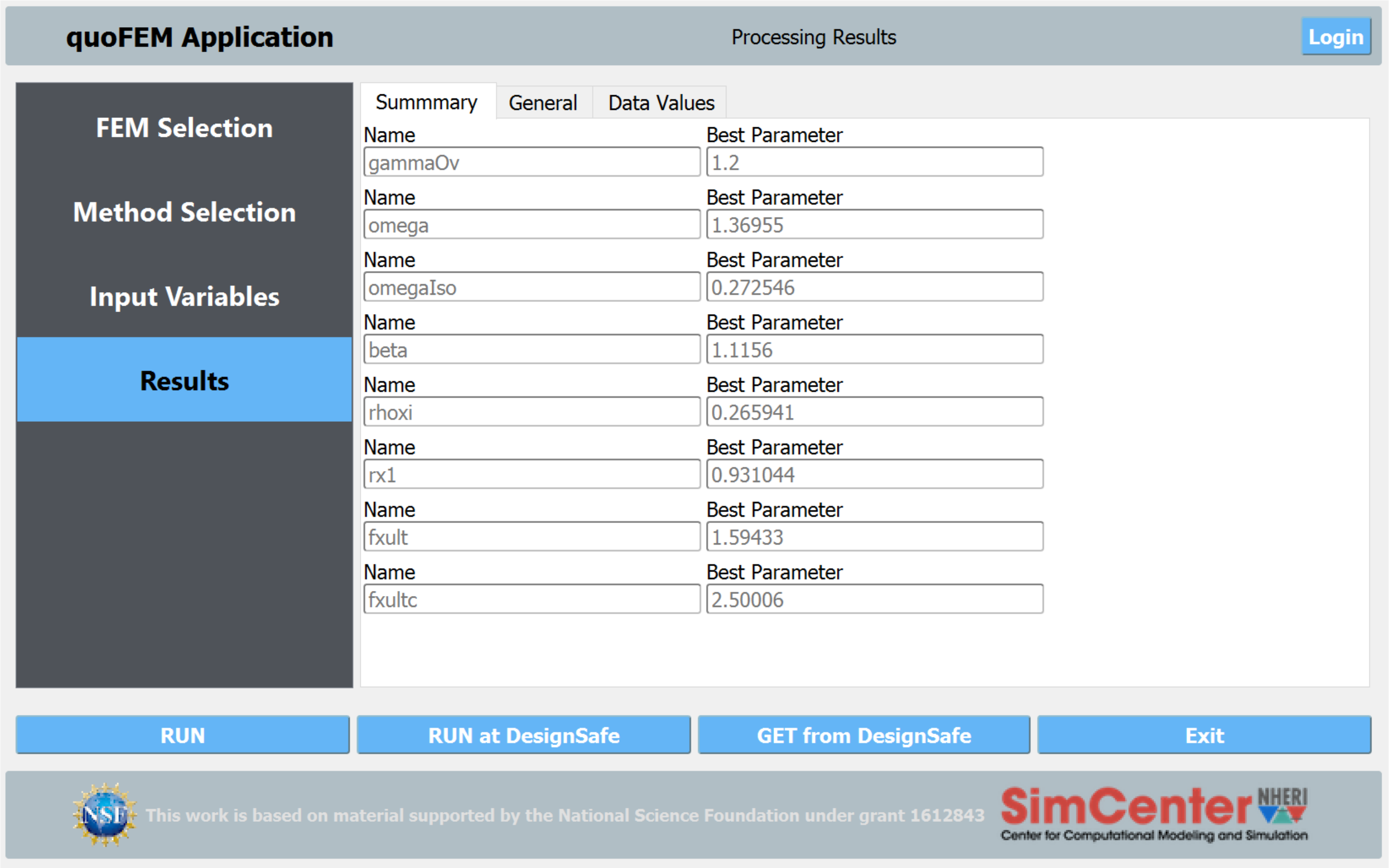
quoFEM

```
# 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

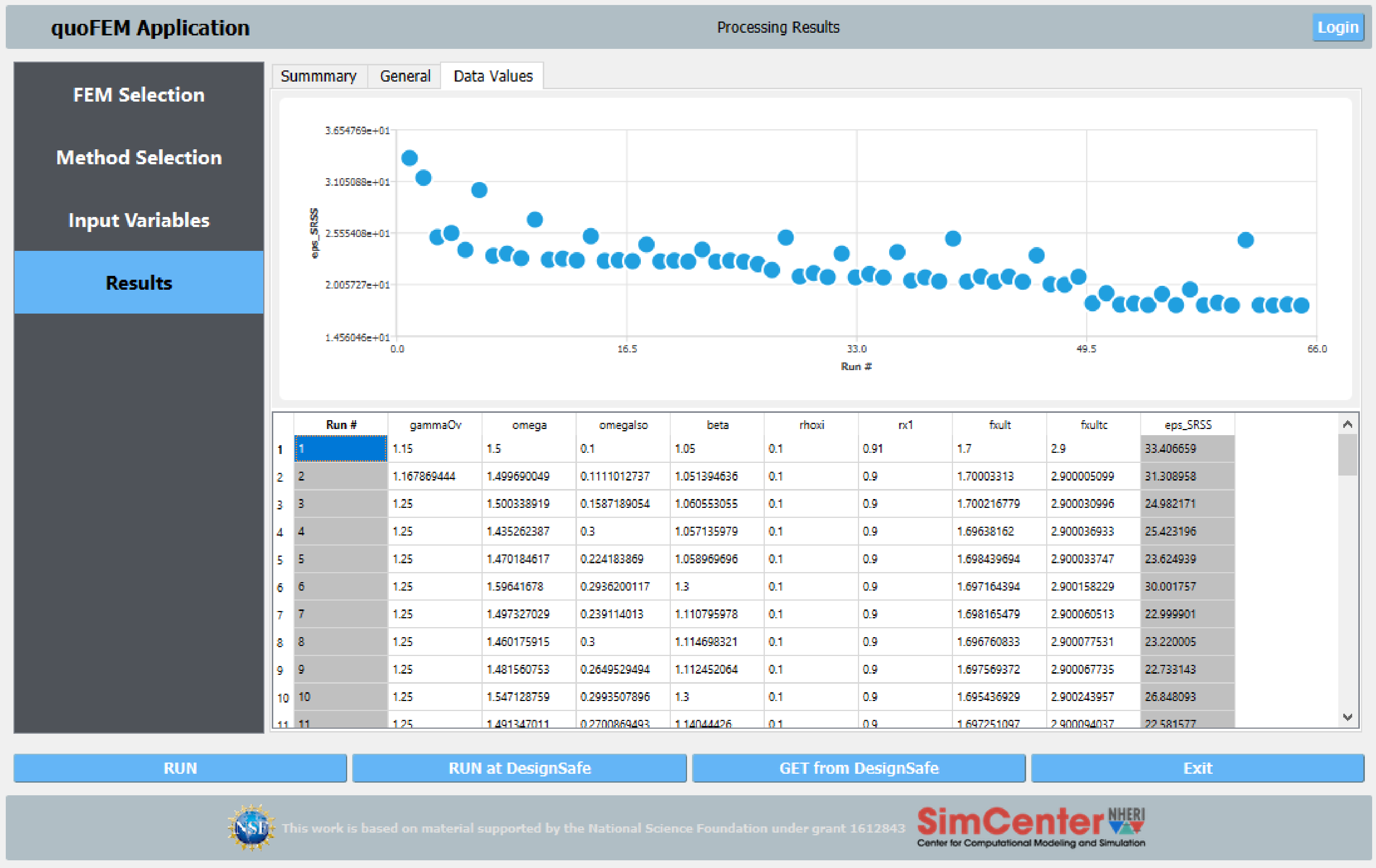
quoFEM



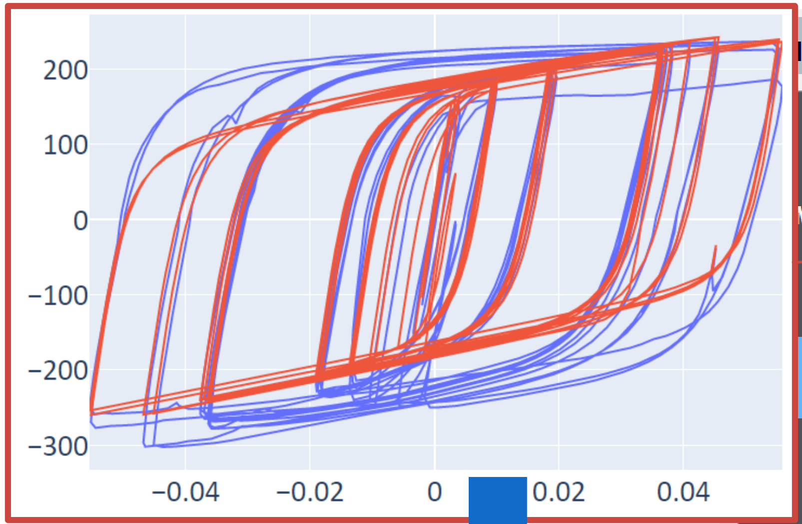
Calibrate component model

result visualization

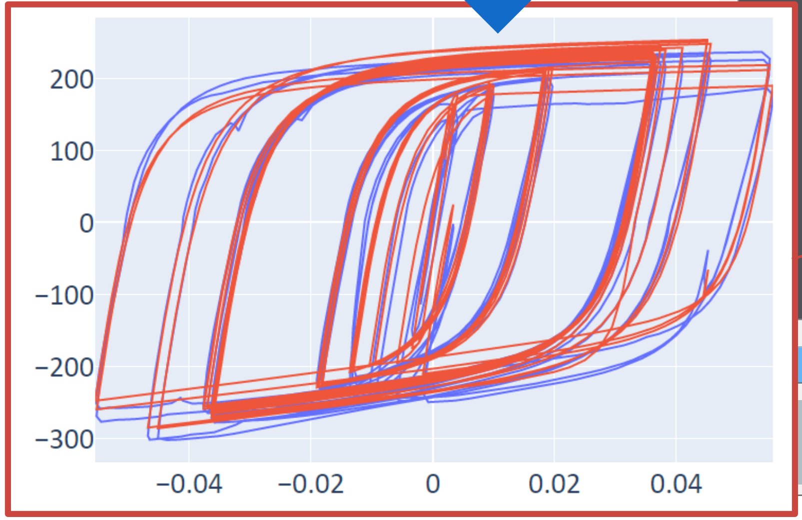
scatterplot shows convergence

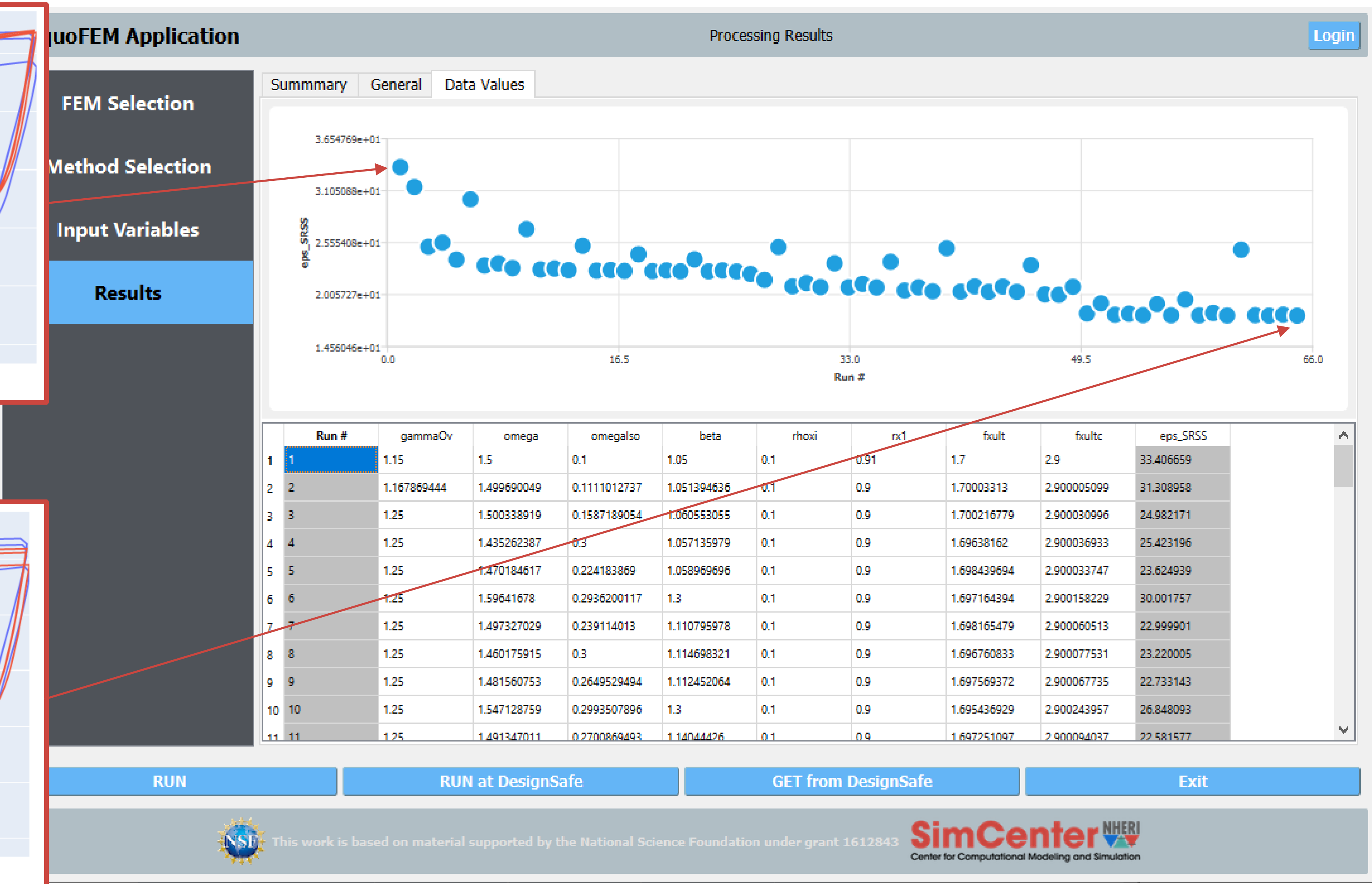


Calibrate component model



test
simulation





	Run #	gammaOv	omega	omegalso	beta	rhoxi	rx1	fxult	fxultc	eps_SRSS
1	1	1.15	1.5	0.1	1.05	0.1	0.91	1.7	2.9	33.406659
2	2	1.167869444	1.499690049	0.1111012737	1.051394636	0.1	0.9	1.70003313	2.900005099	31.308958
3	3	1.25	1.500338919	0.1587189054	1.060553055	0.1	0.9	1.700216779	2.900030996	24.982171
4	4	1.25	1.435262387	0.3	1.057135979	0.1	0.9	1.69638162	2.900036933	25.423196
5	5	1.25	1.470184617	0.224183869	1.058969696	0.1	0.9	1.698439694	2.900033747	23.624939
6	6	1.25	1.59641678	0.2936200117	1.3	0.1	0.9	1.697164394	2.900158229	30.001757
7	7	1.25	1.497327029	0.239114013	1.110795978	0.1	0.9	1.698165479	2.900060513	22.999901
8	8	1.25	1.460175915	0.3	1.114698321	0.1	0.9	1.696760833	2.900077531	23.220005
9	9	1.25	1.481560753	0.2649529494	1.112452064	0.1	0.9	1.697569372	2.900067735	22.733143
10	10	1.25	1.547128759	0.2993507896	1.3	0.1	0.9	1.695436929	2.900243957	26.848093
11	11	1.25	1.491347011	0.2700869493	1.14044426	0.1	0.9	1.697251097	2.900094037	22.581577

Case study

example application: Buckling Restrained Braced Frames

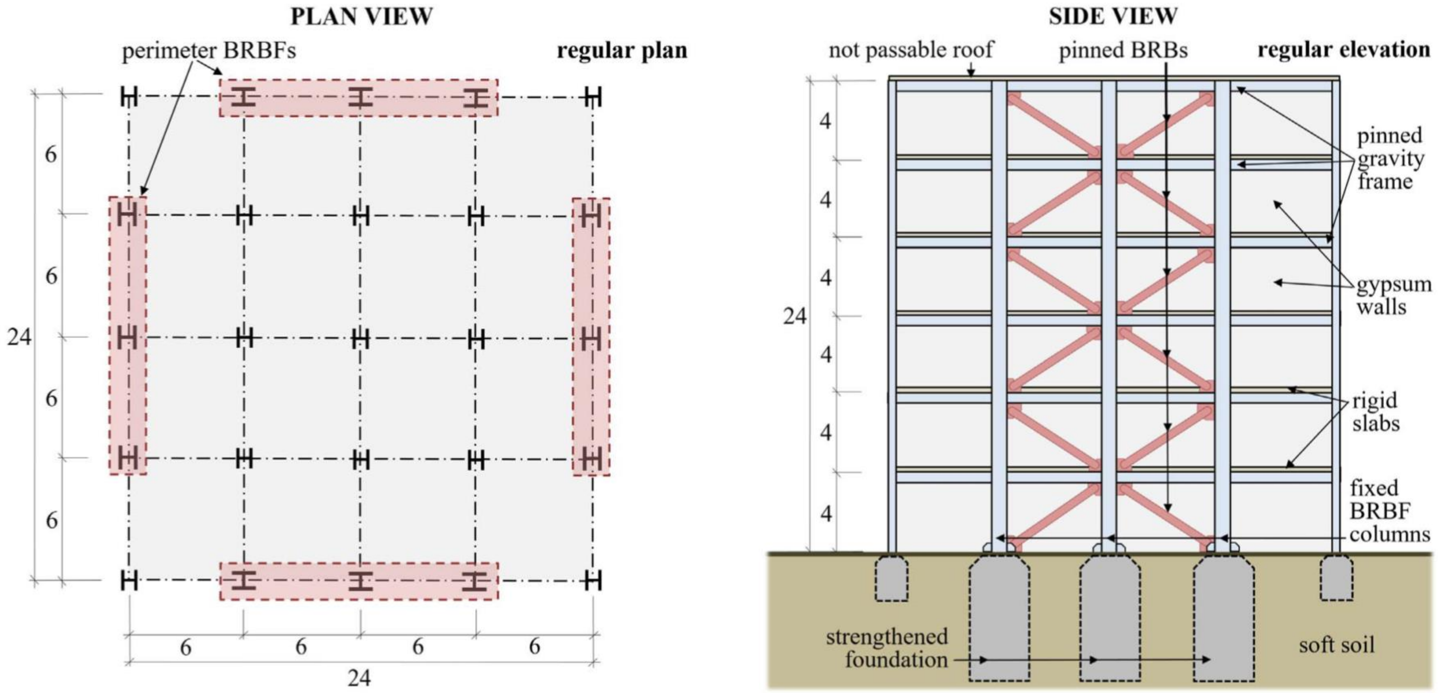
1. Design an experiment — quoFEM
2. Calibrate a numerical component model — quoFEM
3. **Simulate structural response — EE-UQ**
4. Estimate damage and losses — PBE

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

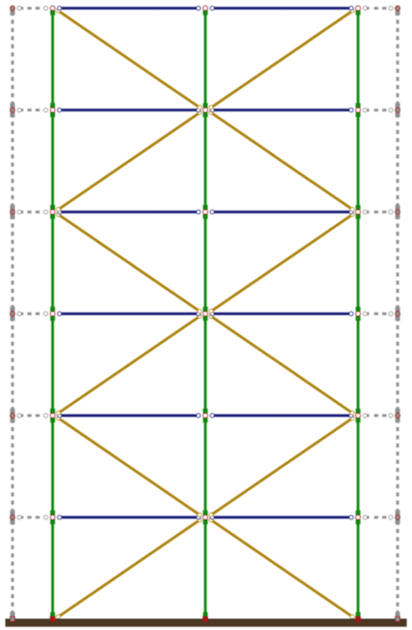
Prepare:

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

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
```

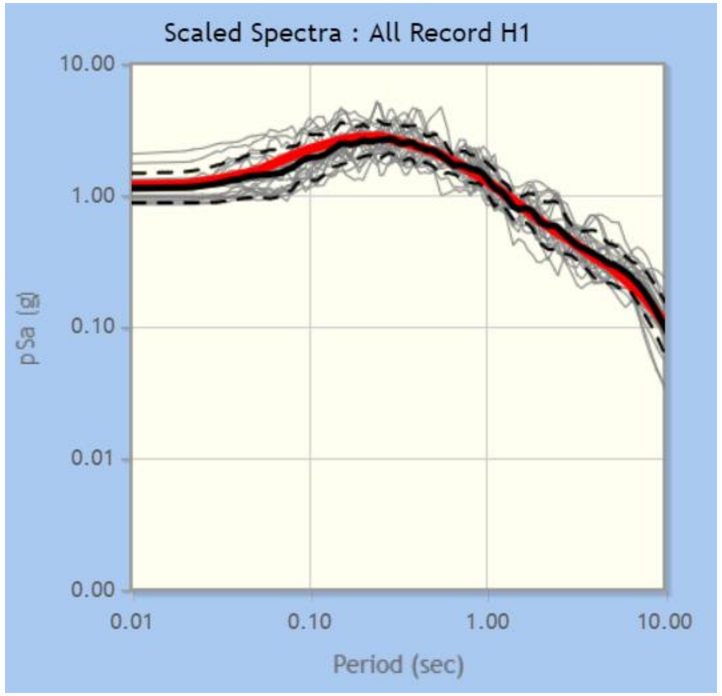
BRBF.tcl

Adam Zsarnóczay adamzs@stanford.edu

Simulate structural response

Prepare:

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

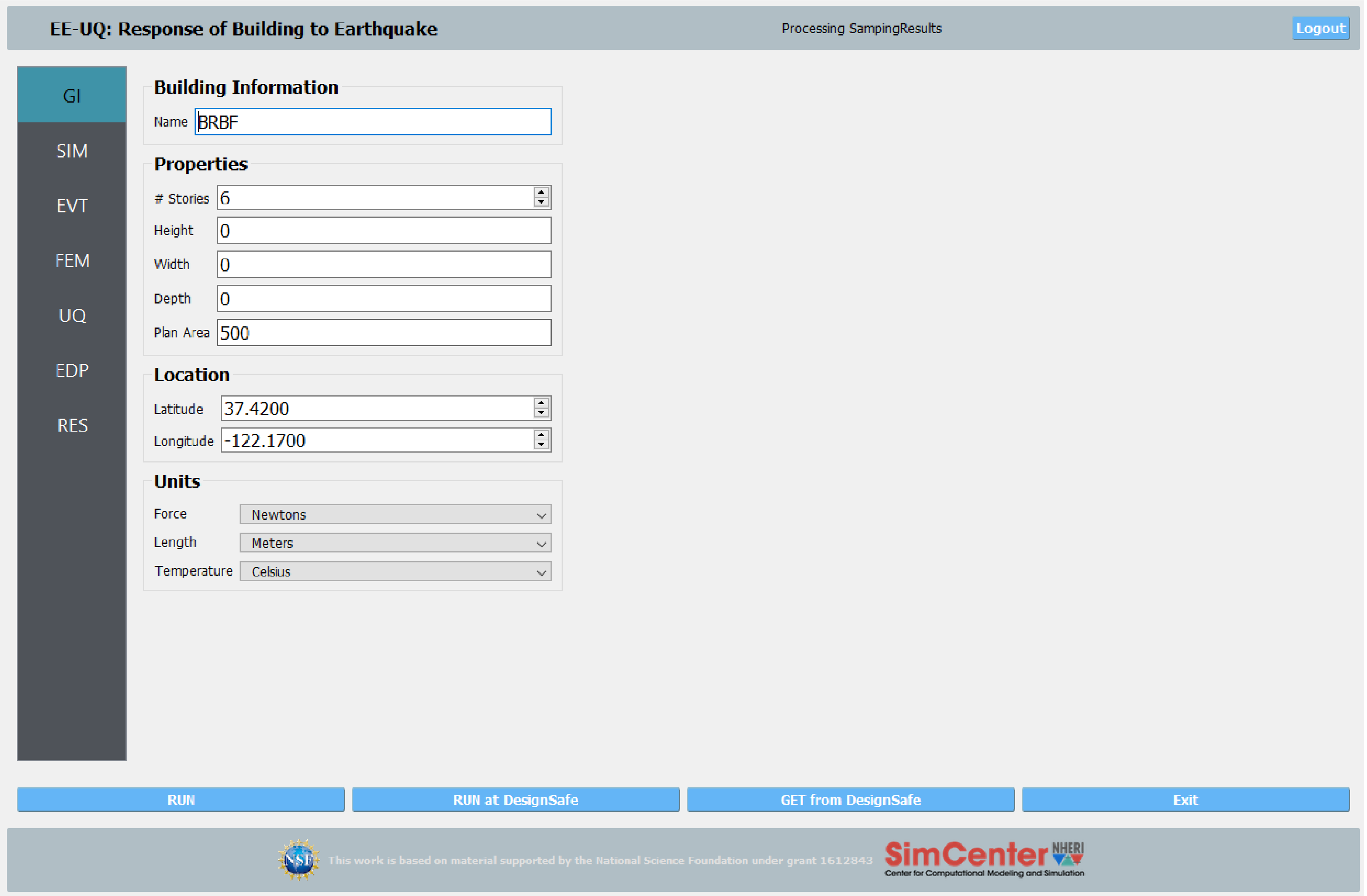



```
RSN143_TABAS_TAB-L1.AT2,1.4637
RSN1193_CHICHI_CHY024-E.AT2,3.1806
RSN1489_CHICHI_TCU049-E.AT2,3.9083
RSN1511_CHICHI_TCU076-E.AT2,3.1206
RSN1521_CHICHI_TCU089-E.AT2,3.5561
RSN1524_CHICHI_TCU095-E.AT2,3.2244
RSN1546_CHICHI_TCU122-E.AT2,3.9546
RSN1549_CHICHI_TCU129-E.AT2,2.0144
RSN1605_DUZCE_DZC180.AT2,2.3368
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

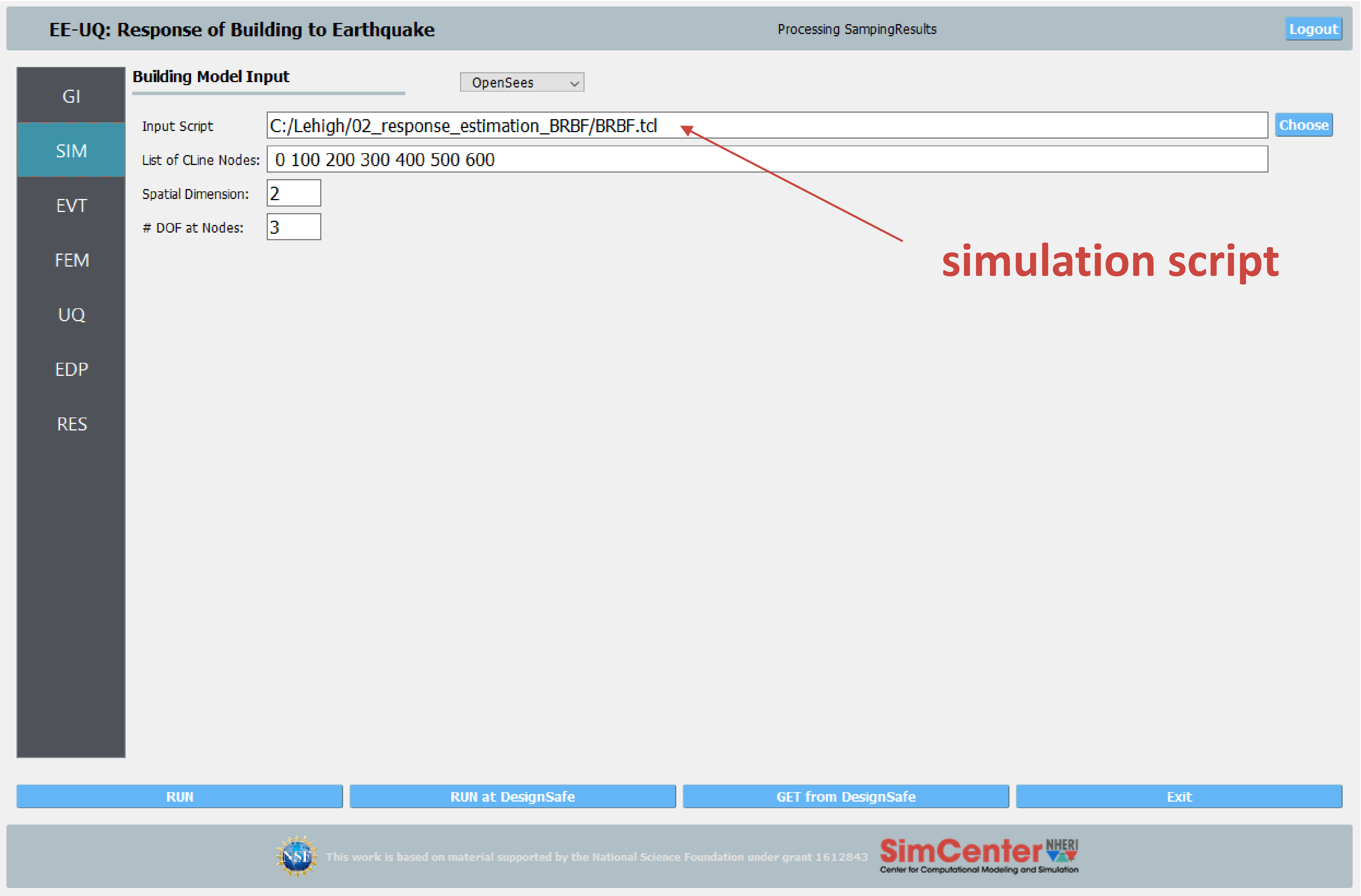
Simulate structural response

general information



Simulate structural response

load the pre-defined simulation script



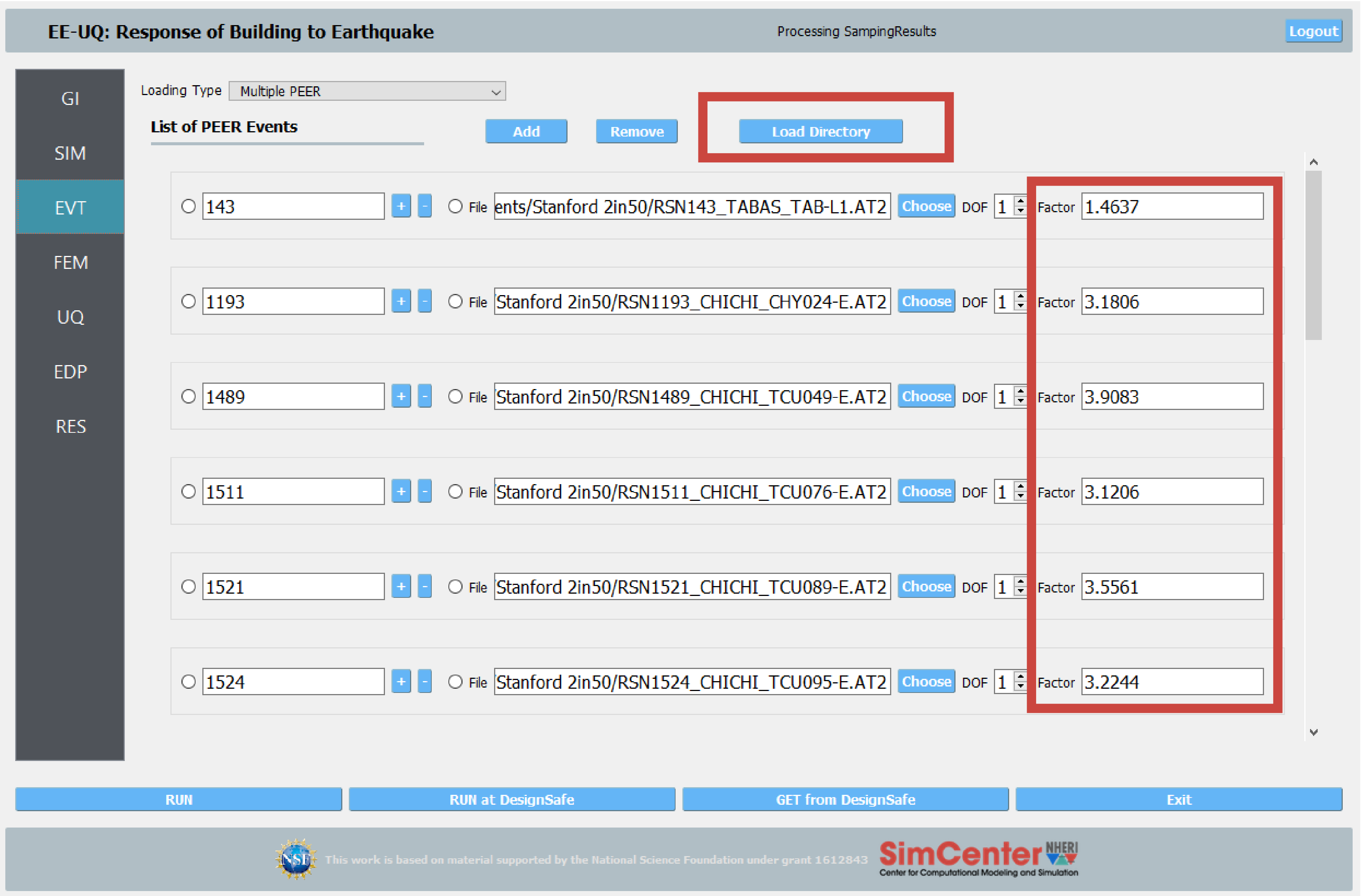
Simulate structural response

EE-UQ

load the selected ground motions

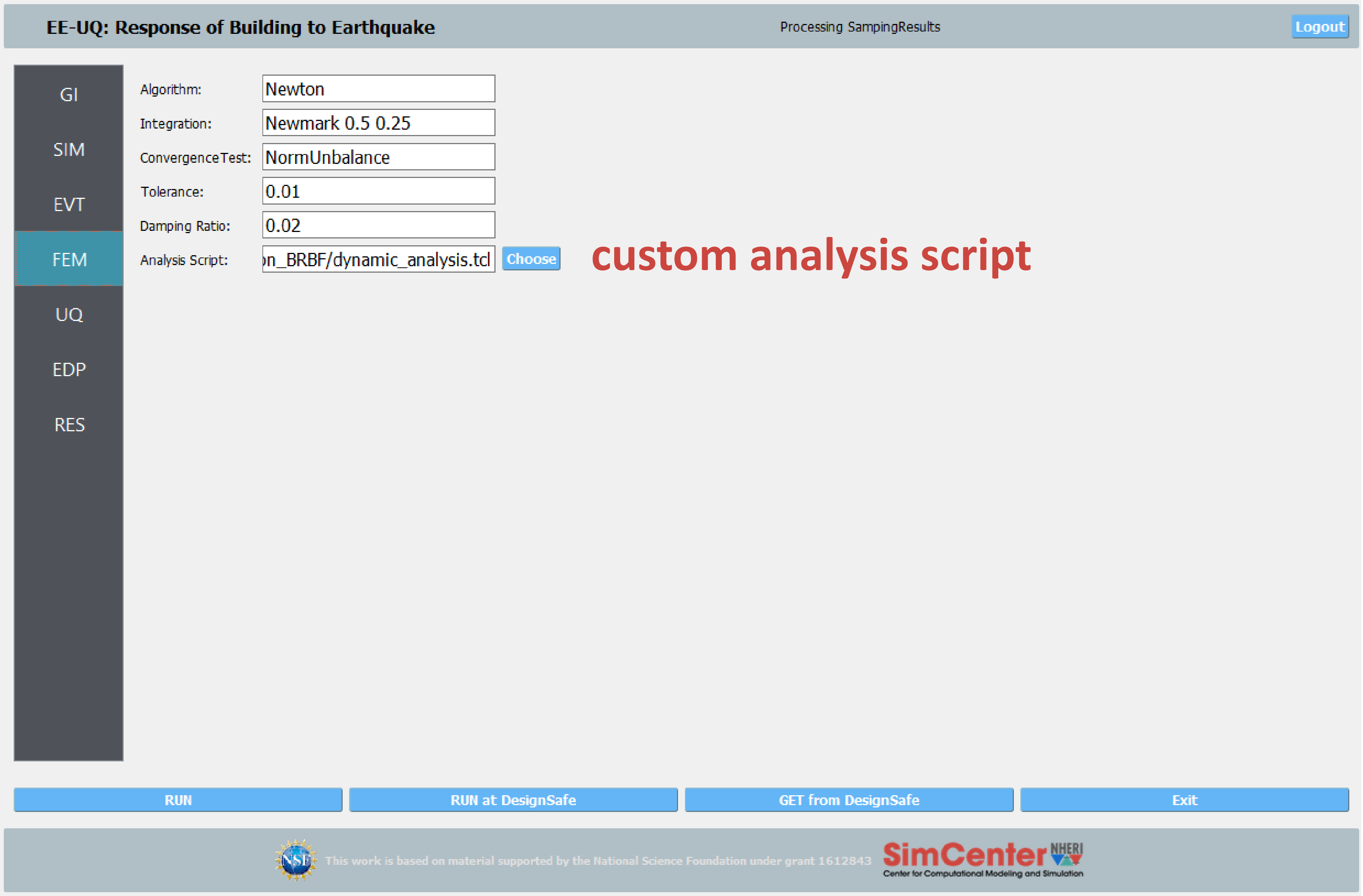
```
RSN143_TABAS_TAB-L1.AT2,1.4637
RSN1193_CHICHI_CHY024-E.AT2,3.1806
RSN1489_CHICHI_TCU049-E.AT2,3.9083
RSN1511_CHICHI_TCU076-E.AT2,3.1206
RSN1521_CHICHI_TCU089-E.AT2,3.5561
RSN1524_CHICHI_TCU095-E.AT2,3.2244
RSN1546_CHICHI_TCU122-E.AT2,3.9546
RSN1549_CHICHI_TCU129-E.AT2,2.0144
RSN1605_DUZCE_DZC180.AT2,2.3368
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

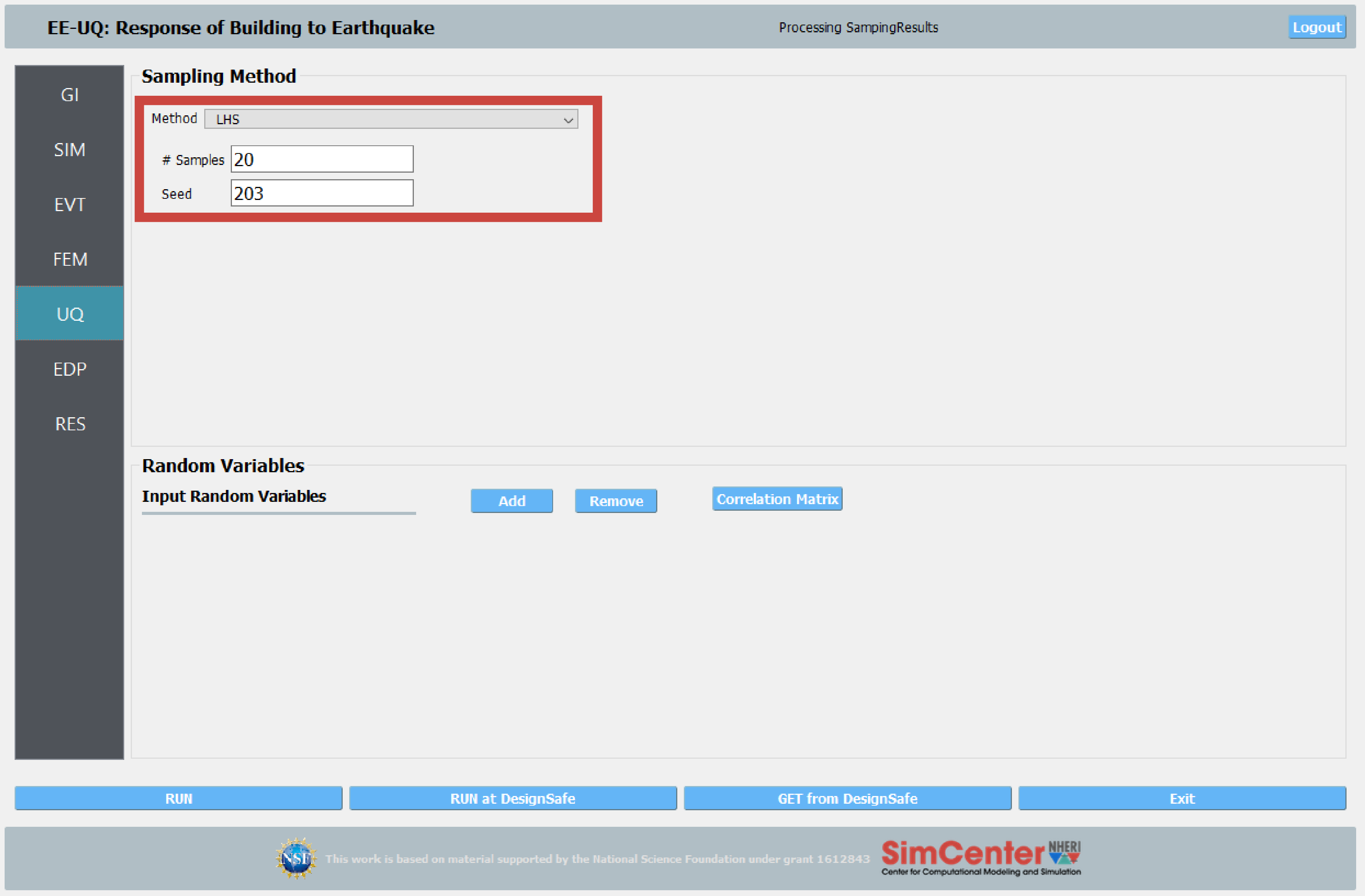
set up the analysis



custom analysis script

Simulate structural response

define random variables

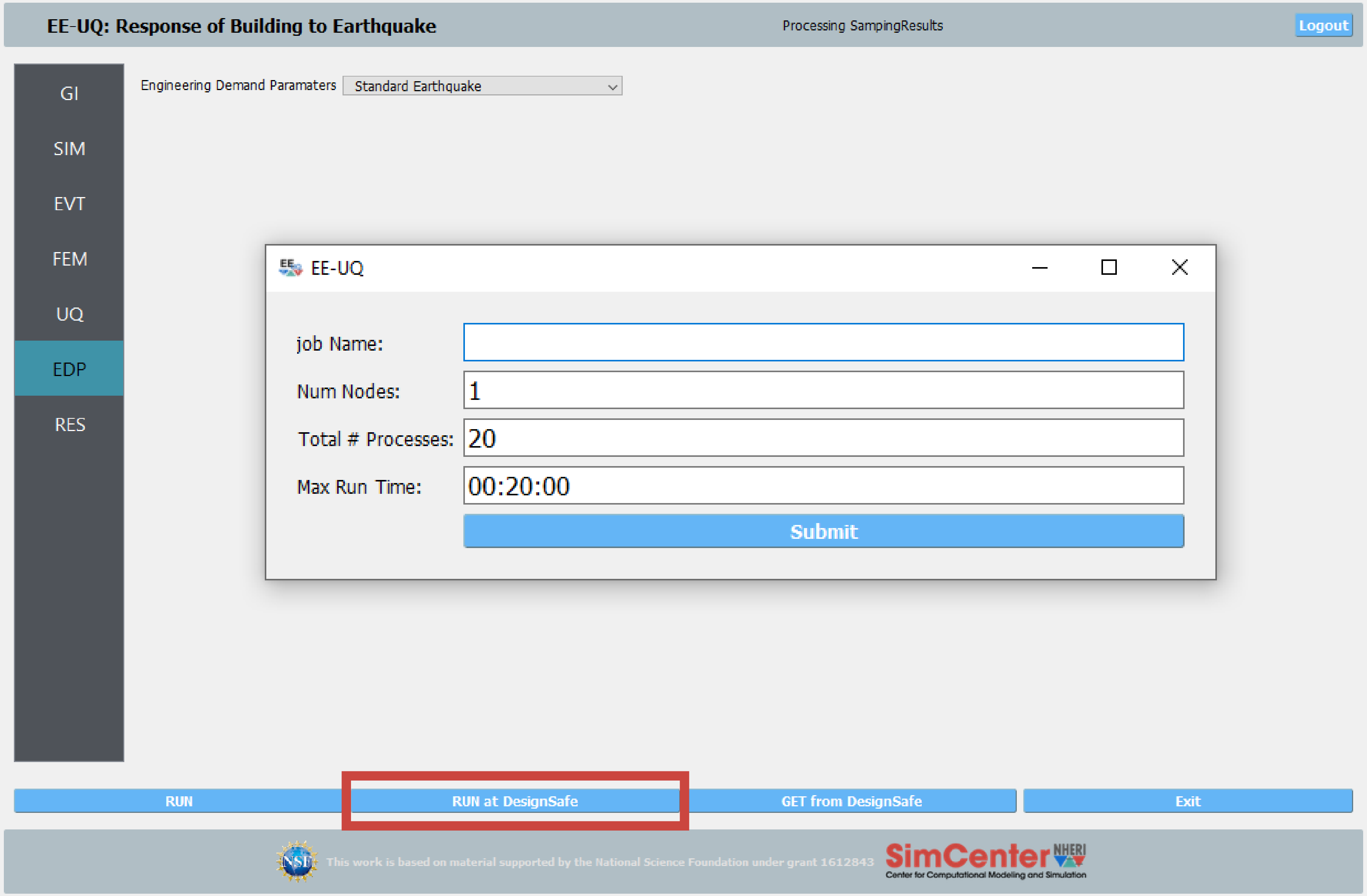


Simulate structural response

EE-UQ

choose EDPs

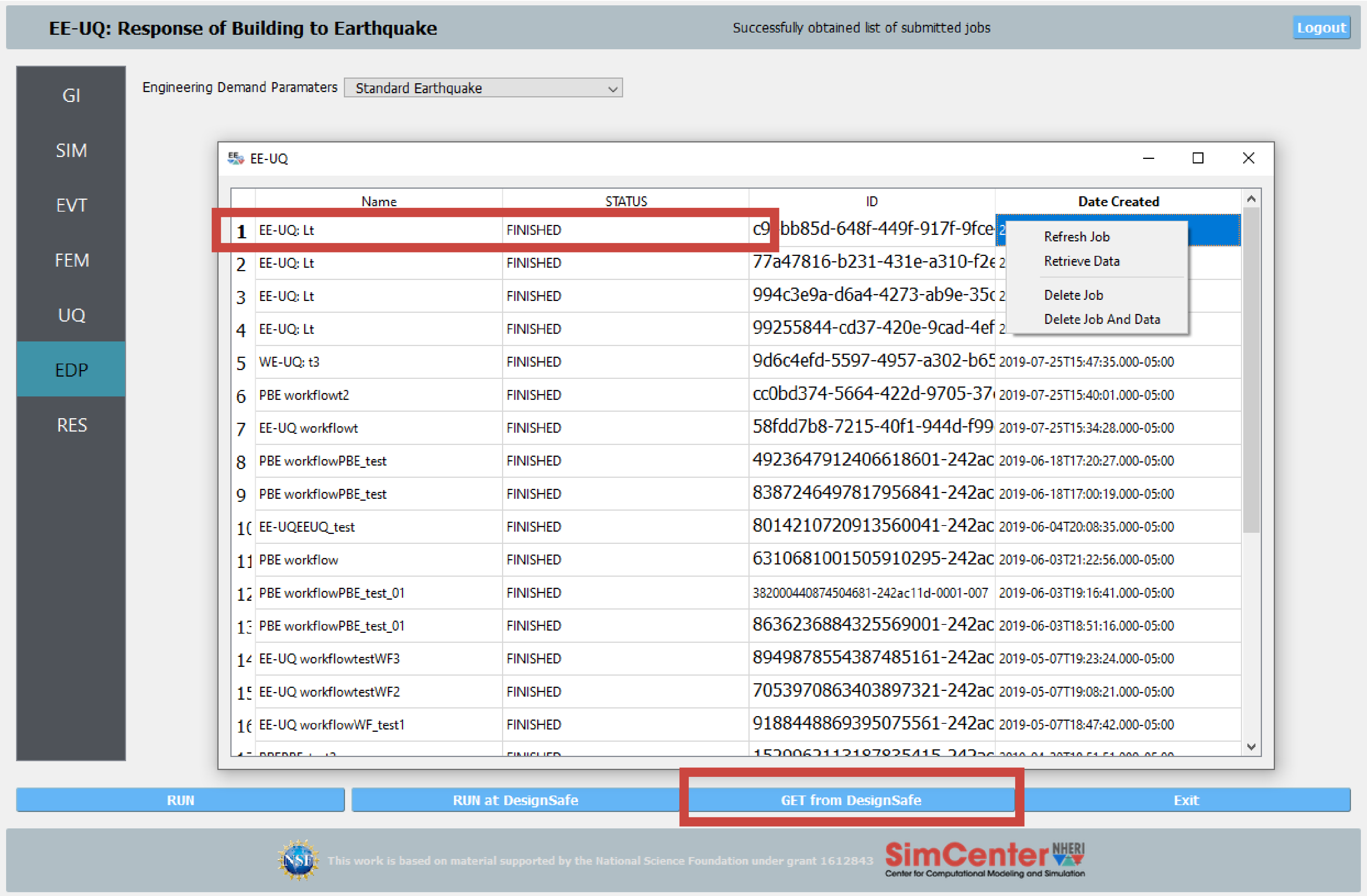
run remotely!



Simulate structural response

EE-UQ

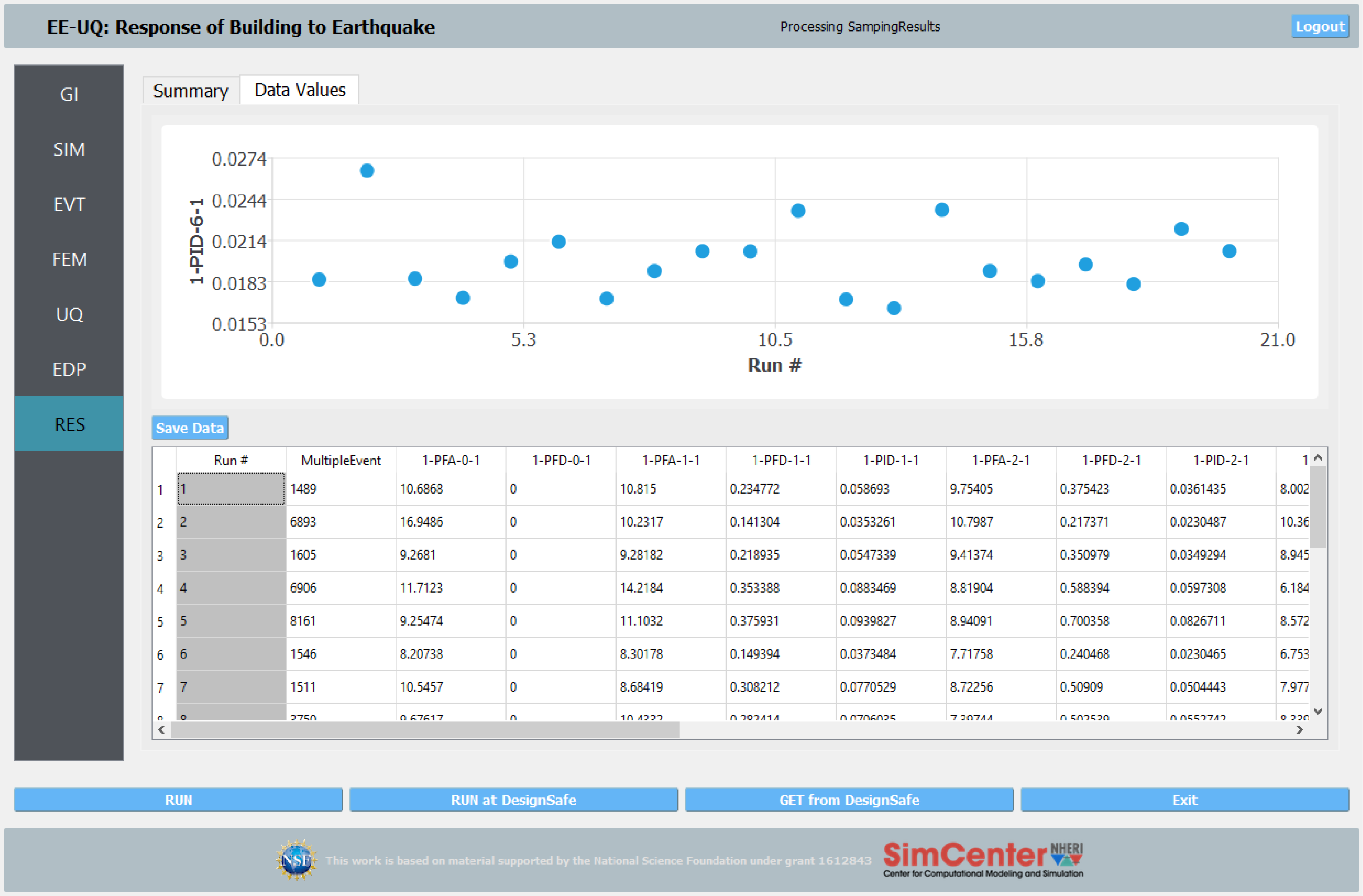
collect results from DesignSafe



Simulate structural response

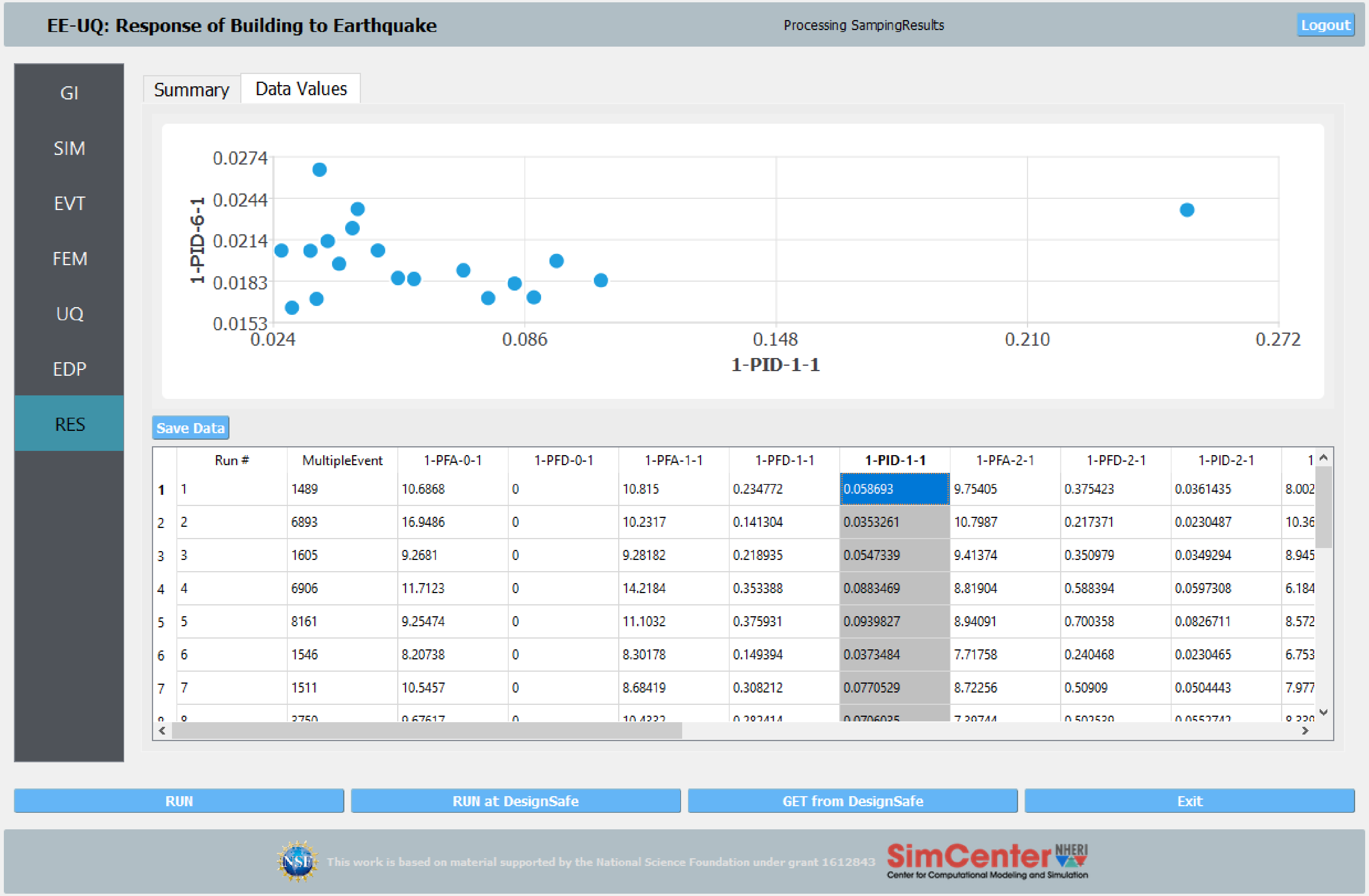
EE-UQ

show EDPs for each analysis



Simulate structural response

show joint
EDP distribution



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

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**

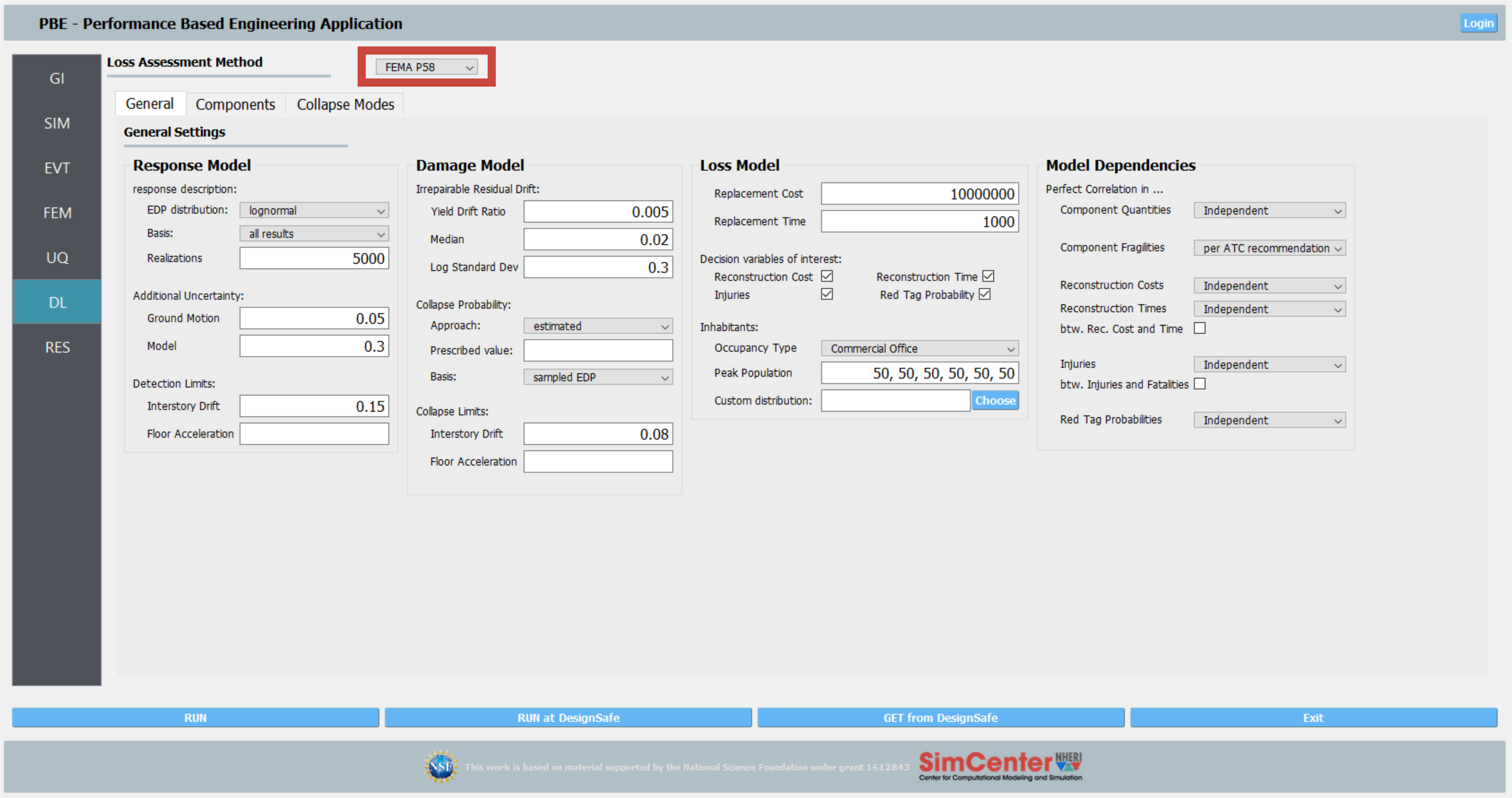
replacement cost: $10,000,000
replacement time: 1000 days
population: 300
occupancy type: Commercial Office

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

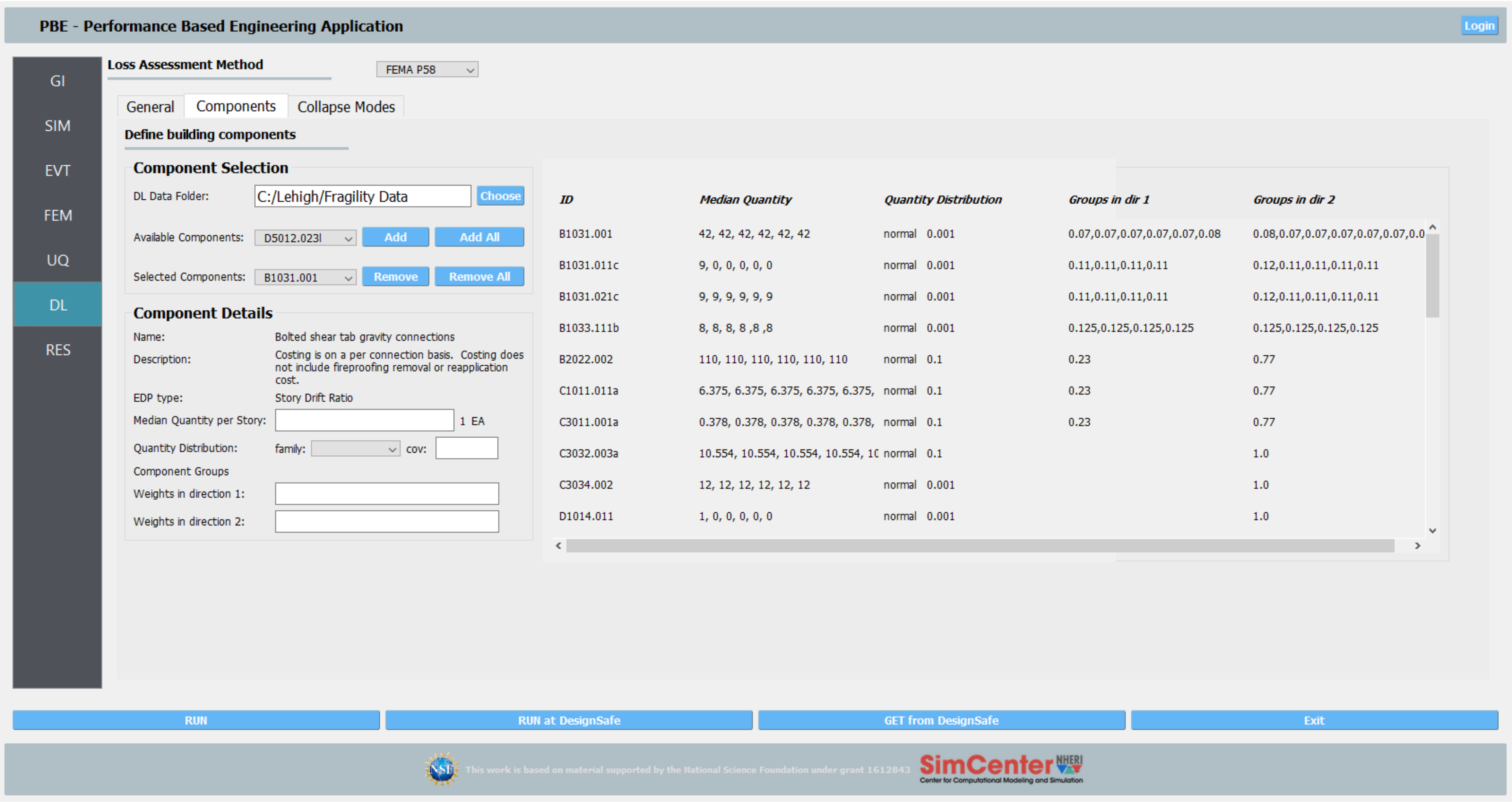
collapse modes and consequences

Estimate damage and loss

PBE

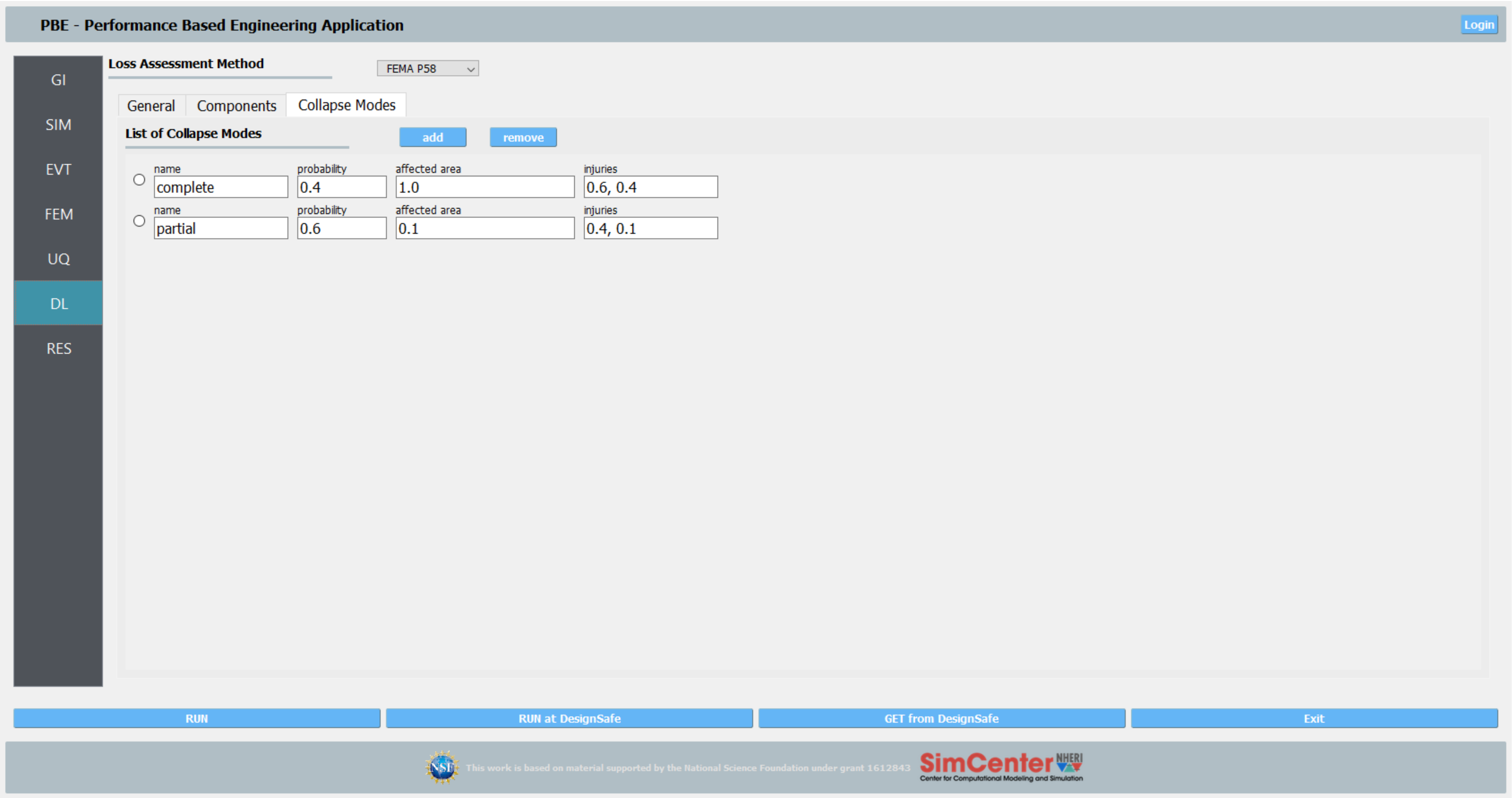


Estimate damage and loss



Estimate damage and loss

PBE



Estimate damage and loss

PBE

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	10th Percentile	Median	90th Percentile	Maximum
event time: month	6.4552	3.44476	1	2	6	11	12
event time: weekday?	0.7294	0.444314	0	0	1	1	1
event time: hour	11.5724	6.94118	0	2	12	21	23
inhabitants:	87.7108	104.189	0	0	0	285	300
collapses: collapsed?	0.0038	0.0615331	0	0	0	0	1
collapses: mode	0.736842	0.452414	0	0	1	1	1
red tagged?:	0.972094	0.16472	0	1	1	1	1
reconstruction: irrepairable?	0.250954	0.433605	0	0	0	1	1
reconstruction: cost impractical?	0	0	0	0	0	0	0
reconstruction: cost	3.90927e+6	3.5626e+6	1.06473e+6	1.51521e+6	1.941e+6	1e+7	1e+7
reconstruction: time impractical?	0	0	0	0	0	0	0
reconstruction: time-sequential	3975.23	1872.72	1000	1000	4590.66	5865.82	10477.9
reconstruction: time-parallel	609.231	242.364	249.093	383.179	500.825	1000	1000

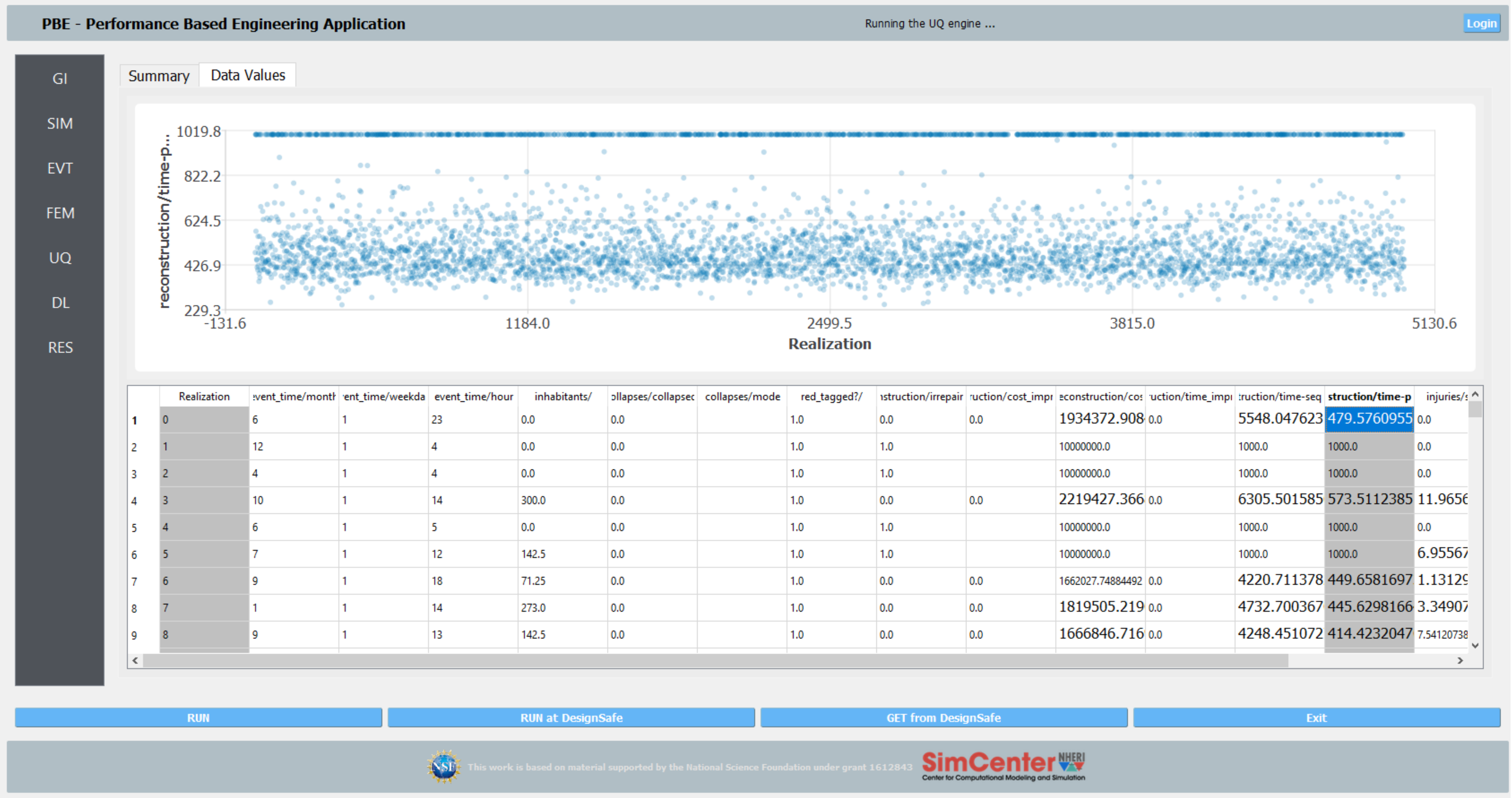
RUN | RUN at DesignSafe | GET from DesignSafe | Exit

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

SimCenter NHERI Center for Computational Modeling and Simulation

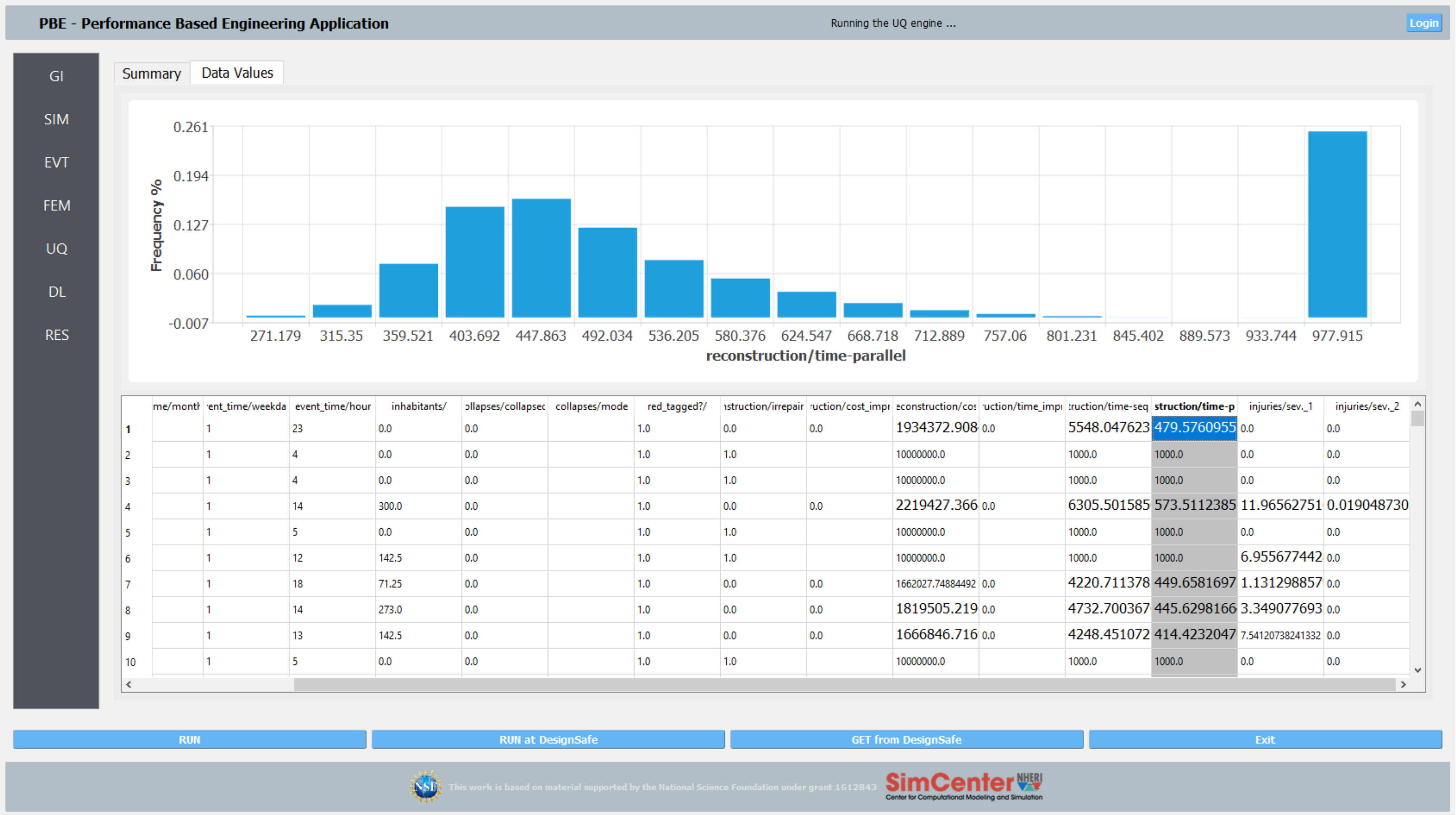
Estimate damage and loss

PBE



	Realization	vent_time/month	ent_time/weekda	event_time/hour	inhabitants/	ollapses/collapsec	collapses/mode	red_tagged?/	struction/irrepair	uction/cost_impr	econstruction/cos	uction/time_impr	ruction/time-seq	struction/time-p	injuries/s
1	0	6	1	23	0.0	0.0		1.0	0.0	0.0	1934372.908	0.0	5548.047623	479.5760955	0.0
2	1	12	1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0
3	2	4	1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0
4	3	10	1	14	300.0	0.0		1.0	0.0	0.0	2219427.366	0.0	6305.501585	573.5112385	11.9656
5	4	6	1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0
6	5	7	1	12	142.5	0.0		1.0	1.0		10000000.0		1000.0	1000.0	6.95567
7	6	9	1	18	71.25	0.0		1.0	0.0	0.0	1662027.74884492	0.0	4220.711378	449.6581697	1.13129
8	7	1	1	14	273.0	0.0		1.0	0.0	0.0	1819505.219	0.0	4732.700367	445.6298166	3.34907
9	8	9	1	13	142.5	0.0		1.0	0.0	0.0	1666846.716	0.0	4248.451072	414.4232047	7.54120738

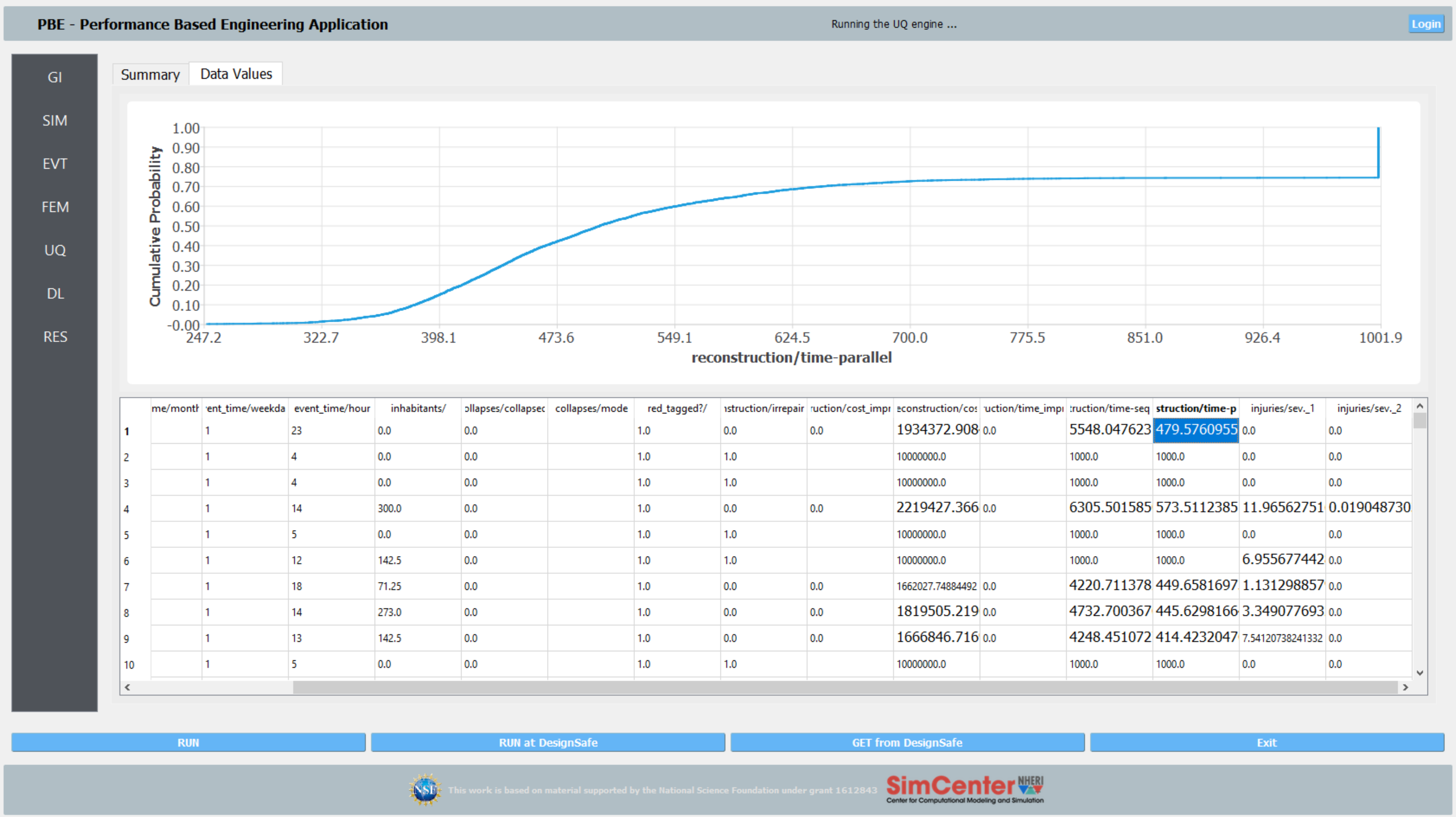
Estimate damage and loss



	me/month	ent_time/weekda	event_time/hour	inhabitants/	ollapses/collapsec	collapses/mode	red_tagged?/	ıstruction/irrepair	ruction/cost_impr	econstruction/cos	uction/time_impr	truction/time-seq	struction/time-p	injuries/sev._1	injuries/sev._2
1		1	23	0.0	0.0		1.0	0.0	0.0	1934372.908	0.0	5548.047623	479.5760955	0.0	0.0
2		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
3		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
4		1	14	300.0	0.0		1.0	0.0	0.0	2219427.366	0.0	6305.501585	573.5112385	11.96562751	0.019048730
5		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
6		1	12	142.5	0.0		1.0	1.0		10000000.0		1000.0	1000.0	6.955677442	0.0
7		1	18	71.25	0.0		1.0	0.0	0.0	1662027.74884492	0.0	4220.711378	449.6581697	1.131298857	0.0
8		1	14	273.0	0.0		1.0	0.0	0.0	1819505.219	0.0	4732.700367	445.6298166	3.349077693	0.0
9		1	13	142.5	0.0		1.0	0.0	0.0	1666846.716	0.0	4248.451072	414.4232047	7.54120738241332	0.0
10		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0

Estimate damage and loss

PBE



	me/month	ent_time/weekda	event_time/hour	inhabitants/	ollapses/collapsec	collapses/mode	red_tagged?/	istruction/irrepair	uction/cost_impi	econstruction/cos	uction/time_impi	truction/time-seq	struction/time-p	injuries/sev._1	injuries/sev._2
1		1	23	0.0	0.0		1.0	0.0	0.0	1934372.908	0.0	5548.047623	479.5760955	0.0	0.0
2		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
3		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
4		1	14	300.0	0.0		1.0	0.0	0.0	2219427.366	0.0	6305.501585	573.5112385	11.96562751	0.019048730
5		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
6		1	12	142.5	0.0		1.0	1.0		10000000.0		1000.0	1000.0	6.955677442	0.0
7		1	18	71.25	0.0		1.0	0.0	0.0	1662027.74884492	0.0	4220.711378	449.6581697	1.131298857	0.0
8		1	14	273.0	0.0		1.0	0.0	0.0	1819505.219	0.0	4732.700367	445.6298166	3.349077693	0.0
9		1	13	142.5	0.0		1.0	0.0	0.0	1666846.716	0.0	4248.451072	414.4232047	7.54120738241332	0.0
10		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0

Estimate damage and loss

PBE

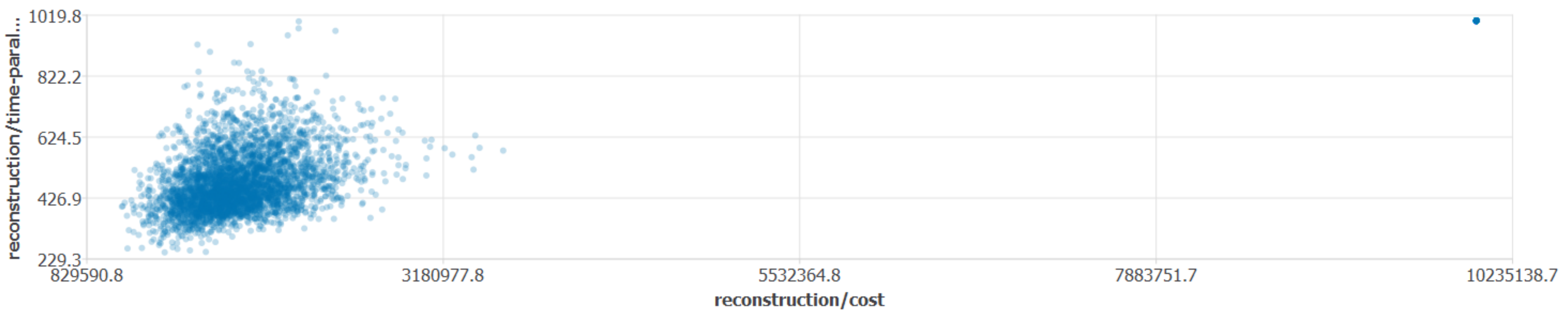
PBE - Performance Based Engineering Application

Running the UQ engine ...

Login

GI
SIM
EVT
FEM
UQ
DL
RES

Summary | Data Values



	me/month	ent_time/weekda	event_time/hour	inhabitants/	ollapses/collapsec	collapses/mode	red_tagged?/	nstruction/irrepair	ruction/cost_impr	econstruction/co	uction/time_impr	truction/time-seq	struction/time-pa	injuries/sev._1	injuries/sev._2
1		1	23	0.0	0.0		1.0	0.0	0.0	1934372.908	0.0	5548.047623	479.5760955	0.0	0.0
2		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
3		1	4	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
4		1	14	300.0	0.0		1.0	0.0	0.0	2219427.366	0.0	6305.501585	573.5112385	11.96562751	0.019048730
5		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0
6		1	12	142.5	0.0		1.0	1.0		10000000.0		1000.0	1000.0	6.955677442	0.0
7		1	18	71.25	0.0		1.0	0.0	0.0	1662027.74884492	0.0	4220.711378	449.6581697	1.131298857	0.0
8		1	14	273.0	0.0		1.0	0.0	0.0	1819505.219	0.0	4732.700367	445.6298166	3.349077693	0.0
9		1	13	142.5	0.0		1.0	0.0	0.0	1666846.716	0.0	4248.451072	414.4232047	7.54120738241332	0.0
10		1	5	0.0	0.0		1.0	1.0		10000000.0		1000.0	1000.0	0.0	0.0

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

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**

SimCenter NHERI

Center for Computational Modeling and Simulation

Example use of Research Tools

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

Adam Zsarnóczay
adamzs@Stanford.edu

NSF award: CMMI 1612843