Argonne NATIONAL LABORATORY

Introductory Course: Using LS-OPT® on the TRACC Cluster

2.3 – Multiobjective Optimization; Concrete Slab Bending

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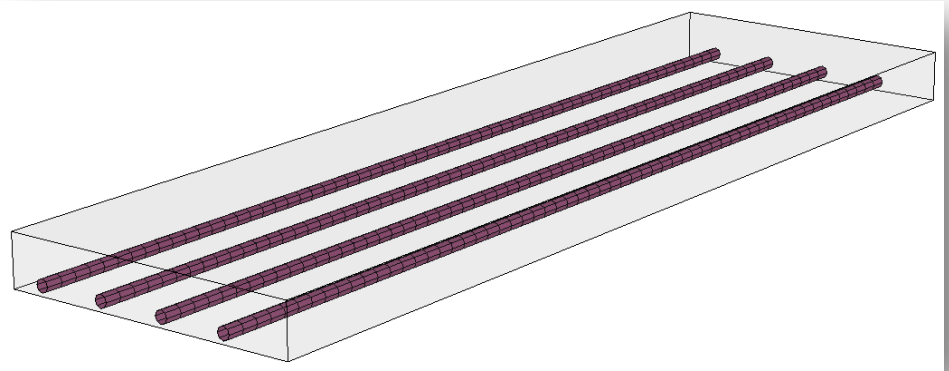
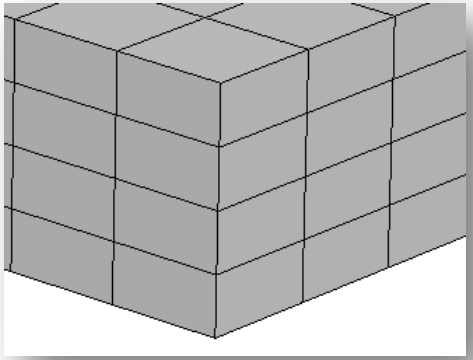
U.S. DEPARTMENT OF ENERGY

Problem Description

- Simply supported concrete slab with rebars
- Loaded with distributed load (*LOAD_SEGMENT_SET) on the whole top surface
- Three design variables:
  - Uniaxial compressive strength (UCS) in *MAT_WINFRITH_CONCRETE
  - size of the bar (discrete variable)
  - z coordinate of top nodes

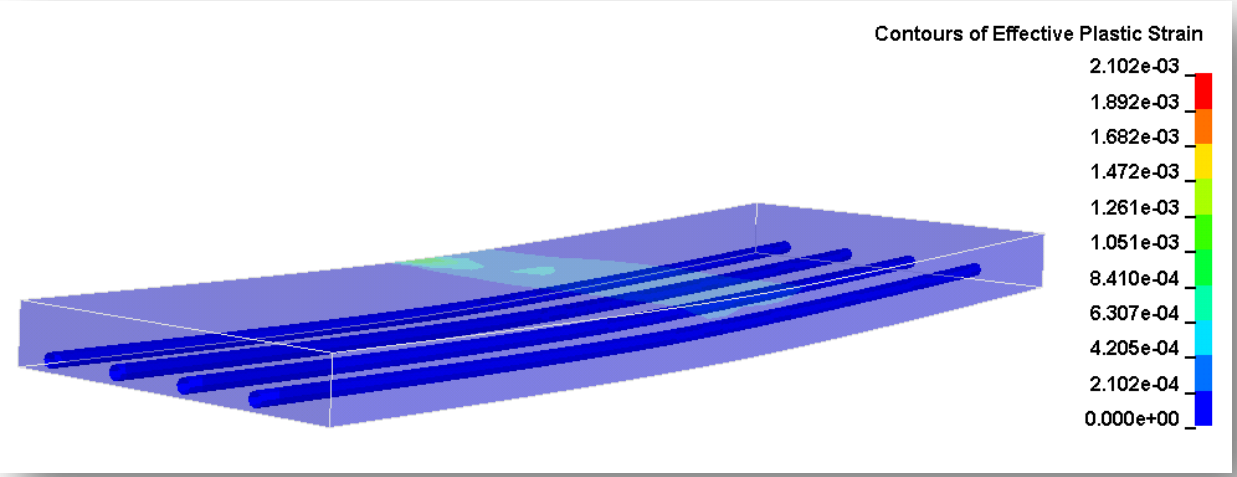




Problem Description

Three objectives:

- min Z- displacement of the slab (central node)
- minimize mass of the structure
- minimize cost of the materials (function of bar size and concrete strength)

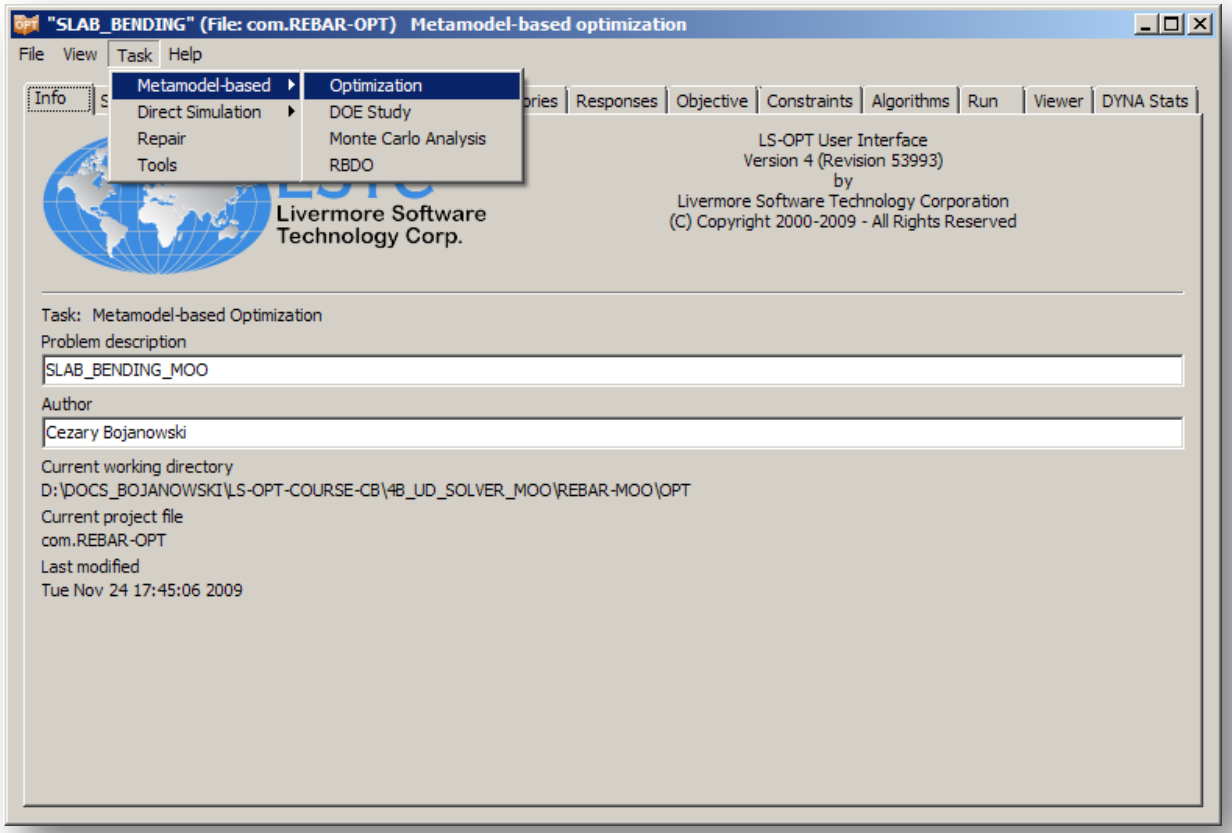


K-file

```
*MAT_WINFRITH_CONCRETE
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$#     mid        ro        tm        pr       ucs       uts        fe     asize
1,0.0868000,<<57000*sqrt(ucs)>>,0.180000,<<ucs>>,<<7*sqrt(ucs)>>,2.0E-4,0.125000
$#       e        ys        eh    uelong      rate      conm      conl      cont
     0.000     0.000     0.000     0.000  0.000000 -1.000000  0.025400  1.000000

*NODE
$#   nid               x               y               z      tc      rc
 10000      13.2346811      41.8973503      <<1.5+dz>>       0       0

*SECTION_BEAM
$#   secid    elform      shrf   qr/irid       cst     scoor       nsm
         2         1     0.000         0         1     0.000     0.000
$#     ts1       ts2       tt1       tt2     nsloc     ntloc
<<bar>>,<<bar>>,,,,

$#US units: in, lbf, sec
```

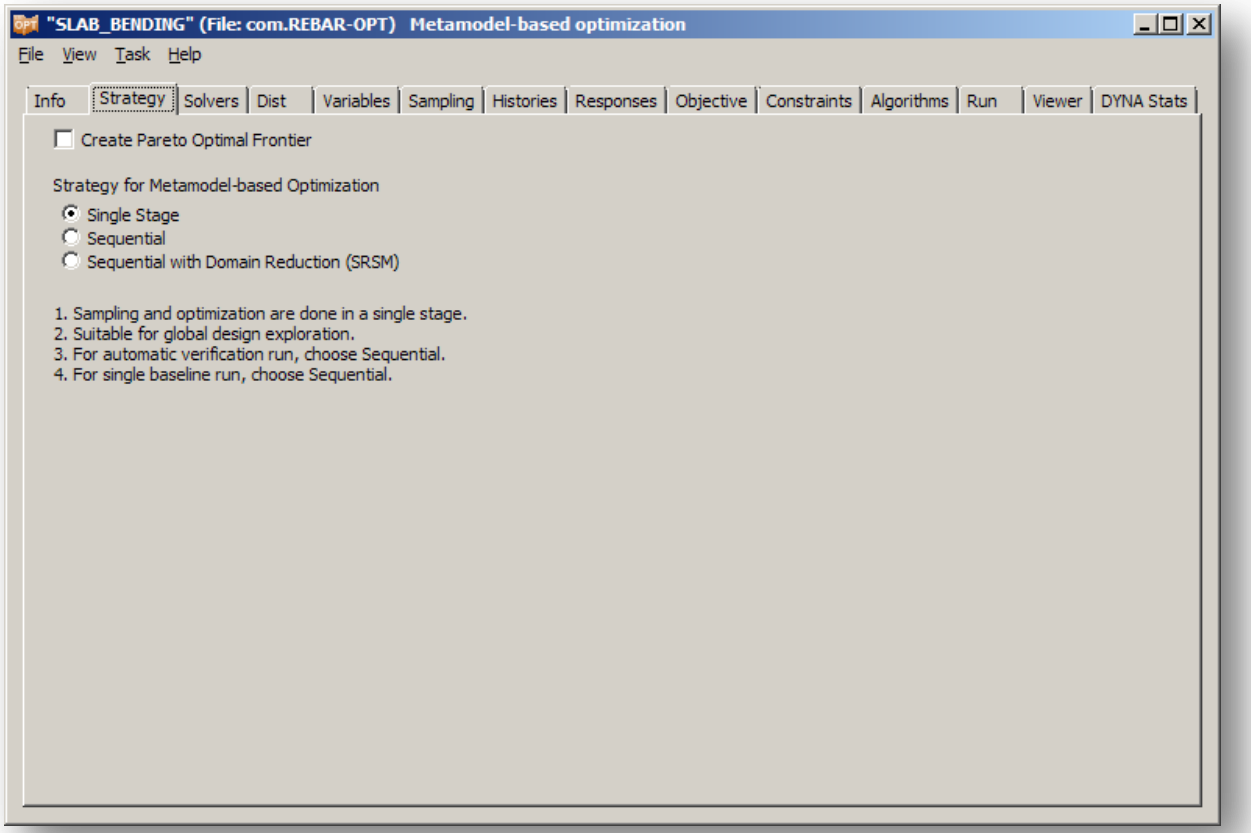
Task

- Go to Task and select Metamodel-based Optimization



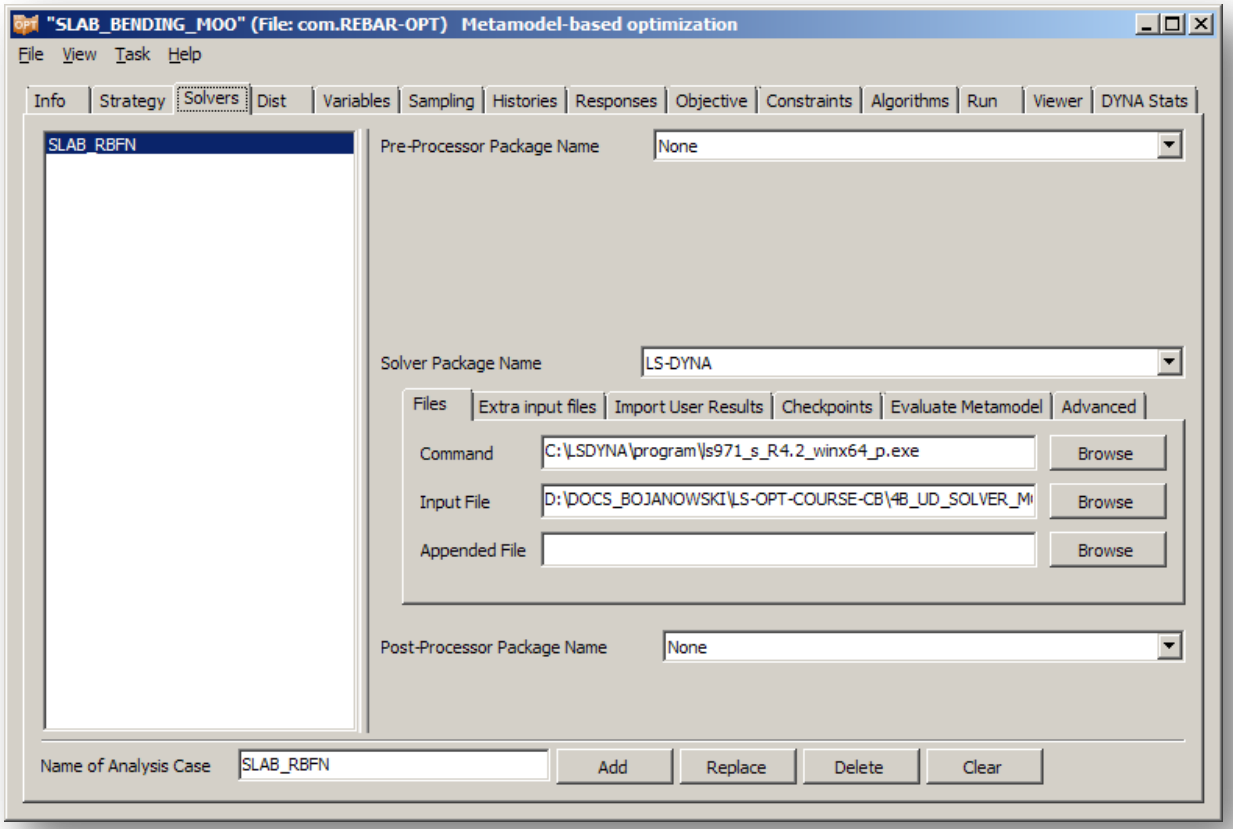
Strategy Tab

- Go to Strategy Task
- Select Single stage strategy



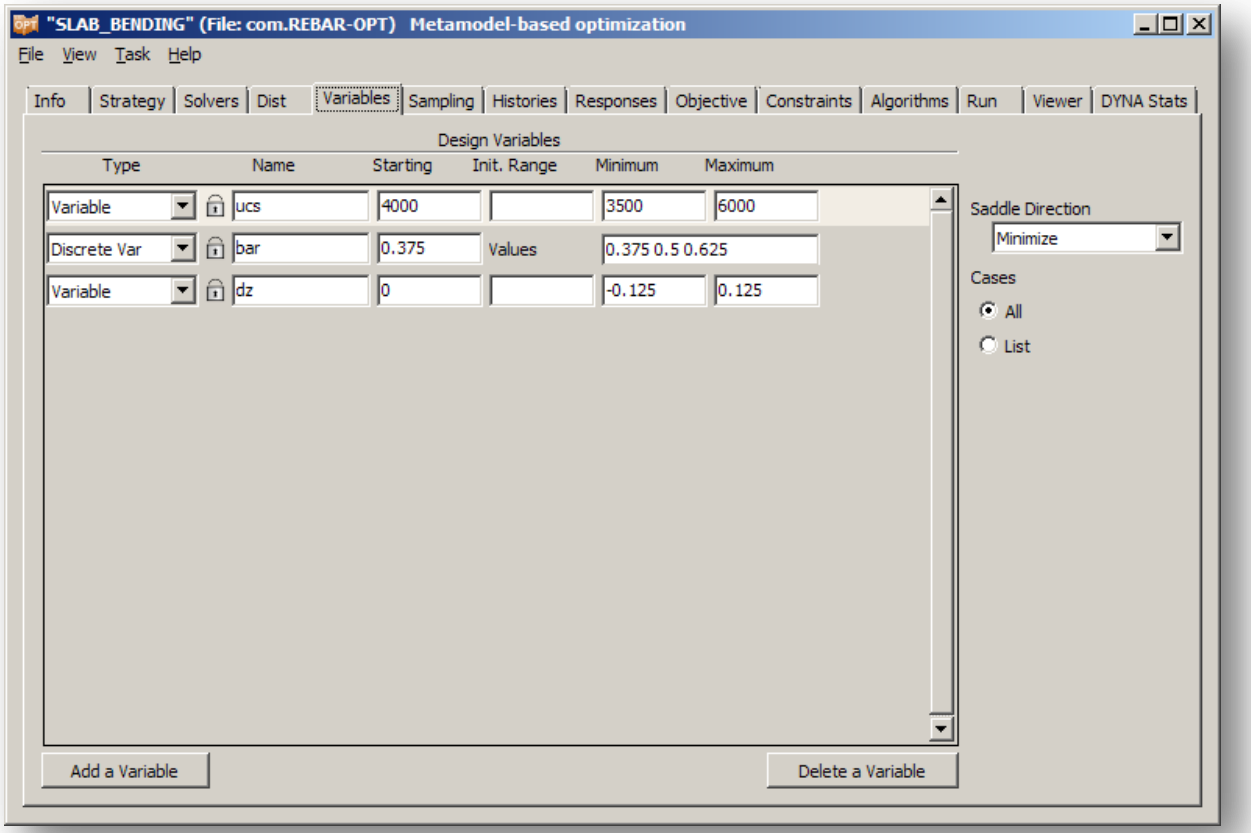
Solvers Tab

- In Solver tab navigate to `lsoptscript`
- Navigate to `REBAR-OPT.k` file in Input file
- Type `SLAB_RBFN` for Name of Analysis Case
- Press Add



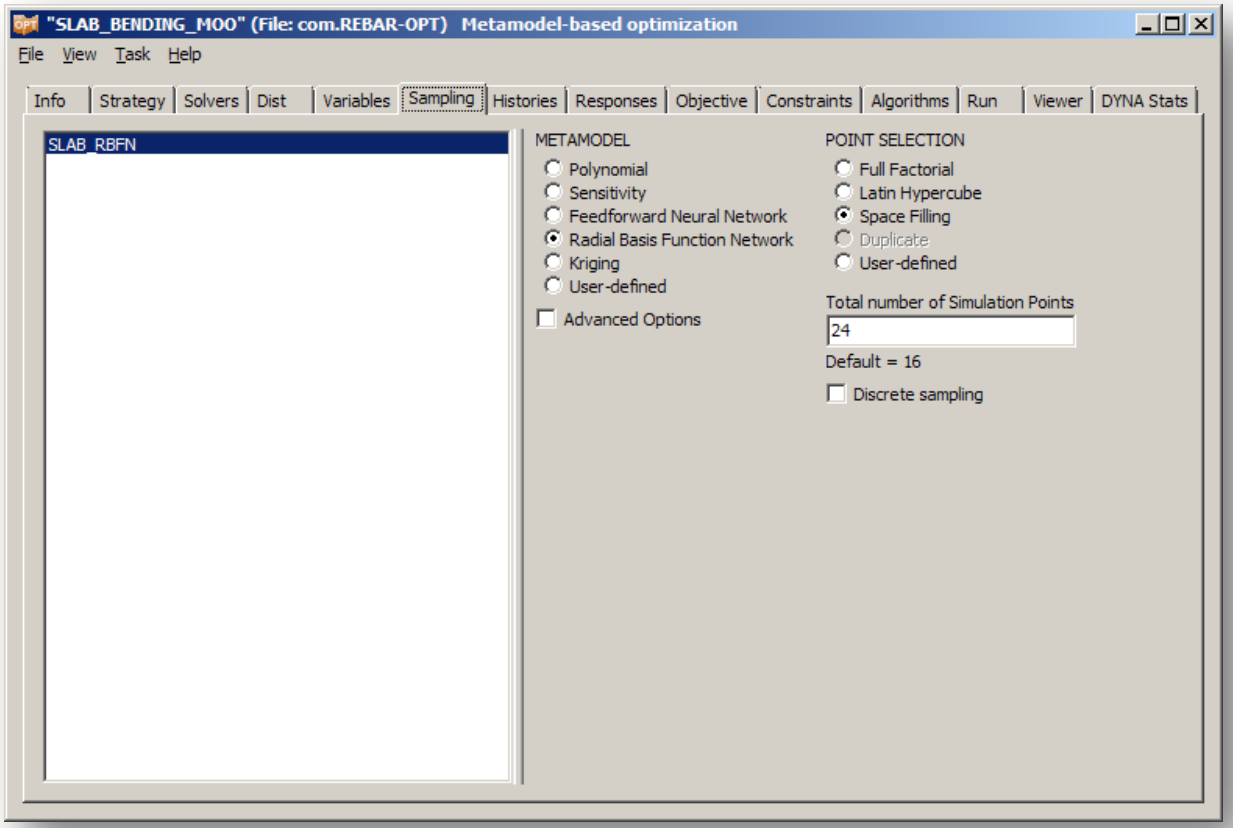
Variables Tab

- In Variables Tab define variable `ucs` with starting value `4000` and bounds `3500` and `6000`
- Define discrete variable bar with three values `3/8`, `4/8` and `5/8` (in of diameter)
- Define variable `dz` with starting value `0` and bounds `+/- 0.125` in



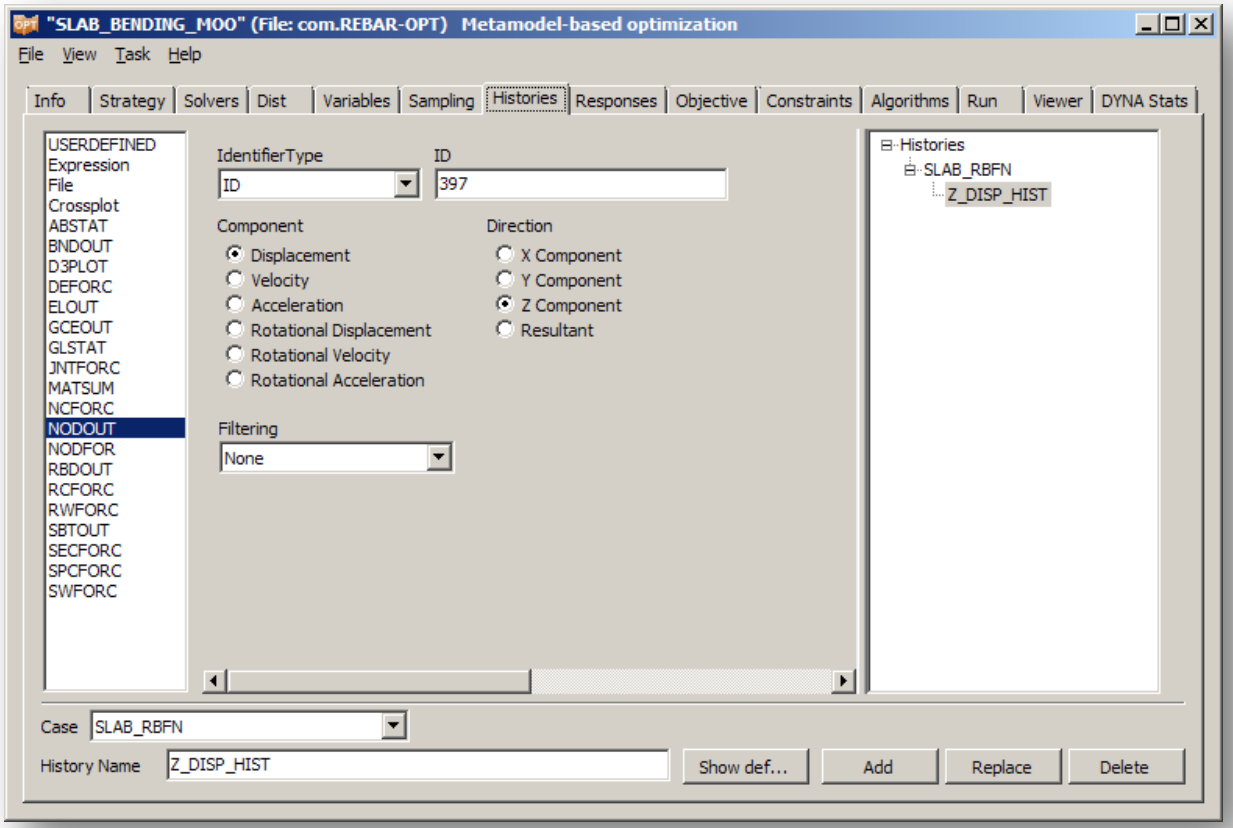
Sampling Tab

- In Sampling Tab select Radial Basis Function Network for Metamodel
- Pick Space Filing Point Selection and
- type 24 for number of simulation points



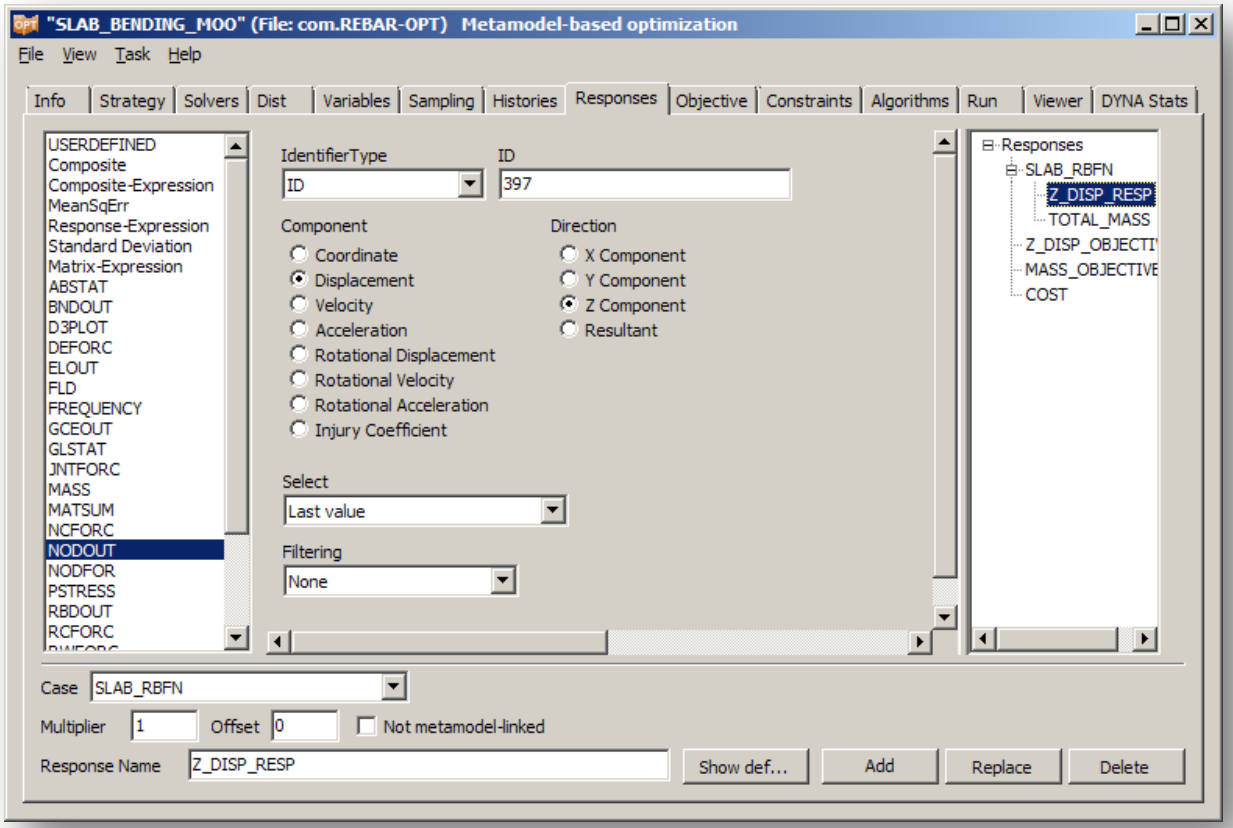
Histories Tab

- In Histories Tab select `NODOUT` and type `397` for ID identifier
- Select Z-component of displacement
- Type `Z_DISP_HIST` for History Name and press Add



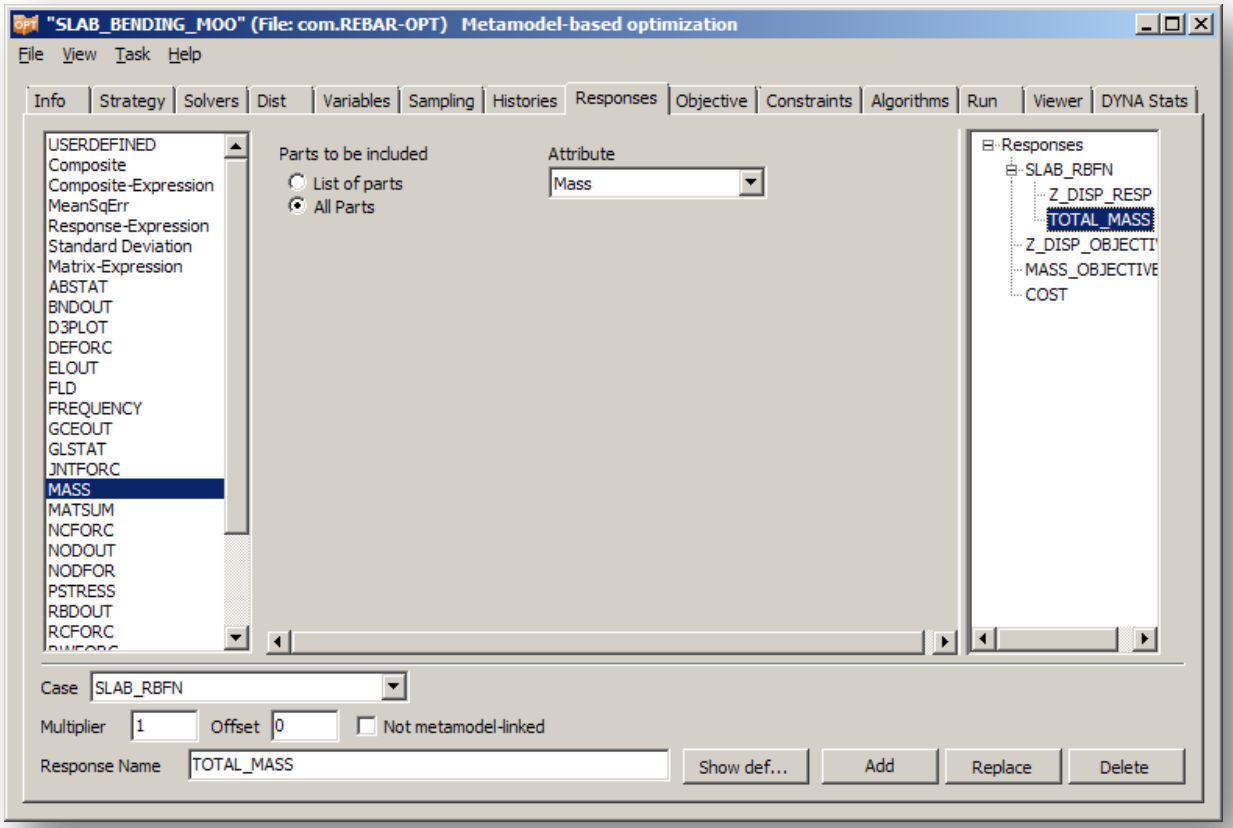
Responses Tab

- In Responses Tab select NODOUT and type 397 for ID identifier
- Select Z-component of displacement
- Type Z_DISP_RESP for Response Name and press Add



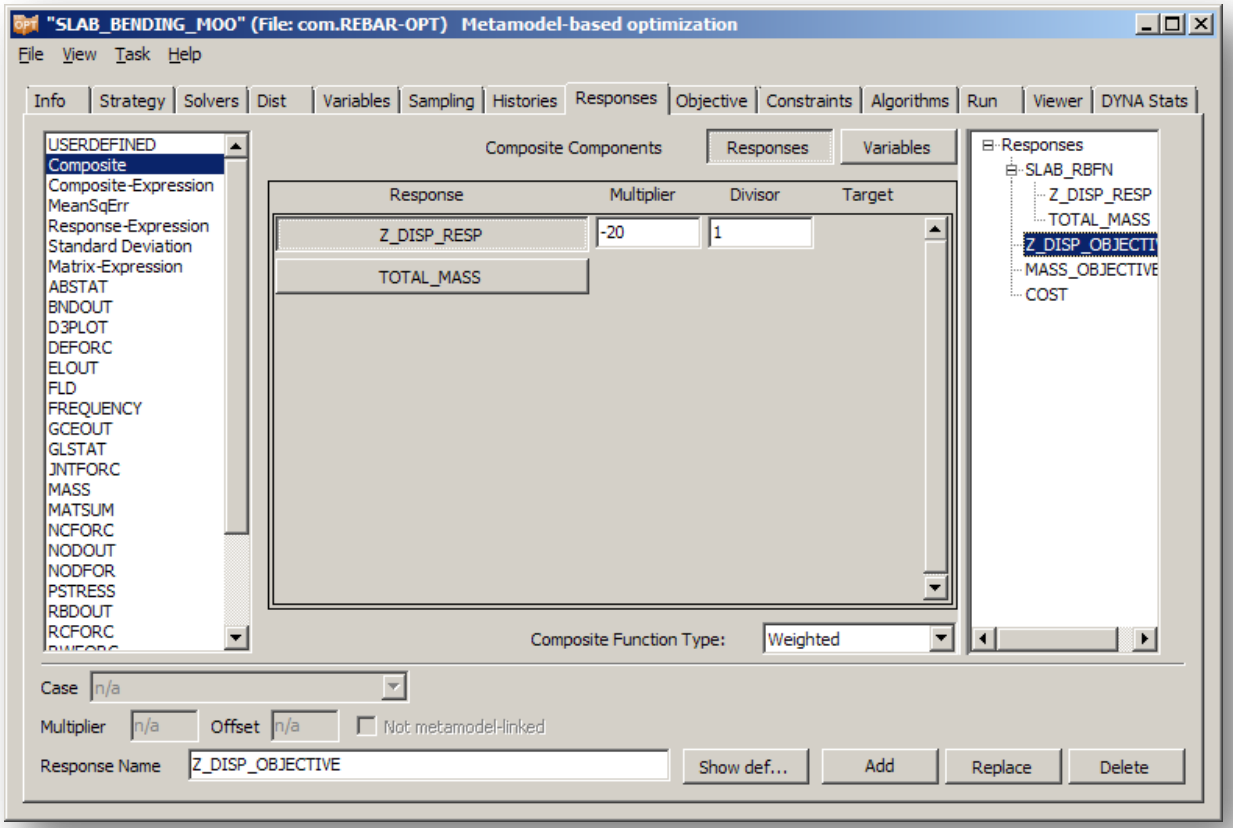
Responses Tab

- In Responses Tab select MASS
- Pick All Parts to be included
- Type TOTAL_MASS for Response Name and press Add



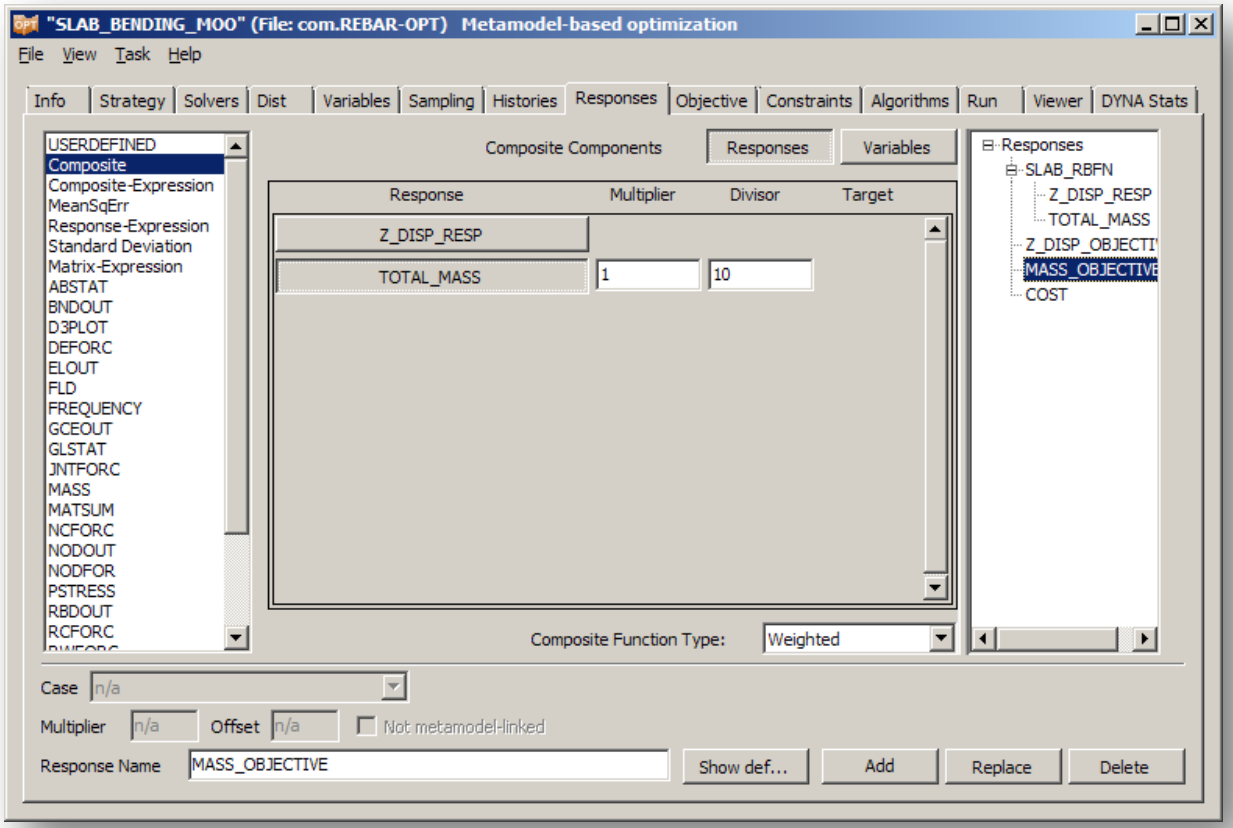
Responses Tab

- To have all objectives with the same order of magnitude they need to be scaled
- Select Composite
- Press `Z_DISP_RESP` and type `-20` for multiplier
- Type `Z_DISP_OBJECTIVE` for Response Name and press Add



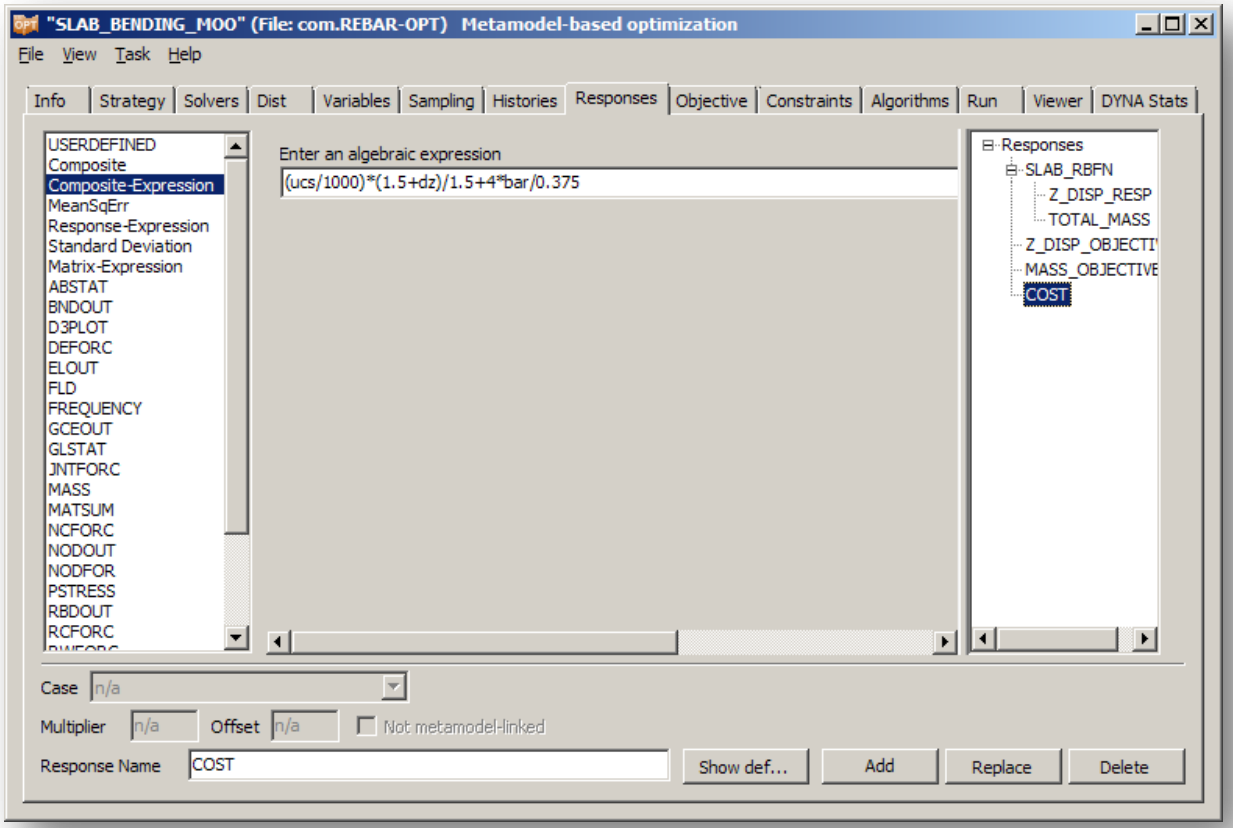
Responses Tab

- Also In Responses Tab select Composite
- Press `TOTAL_MASS` and type `10` for divisor
- Type `MASS_OBJECTIVE` for Response Name and press Add



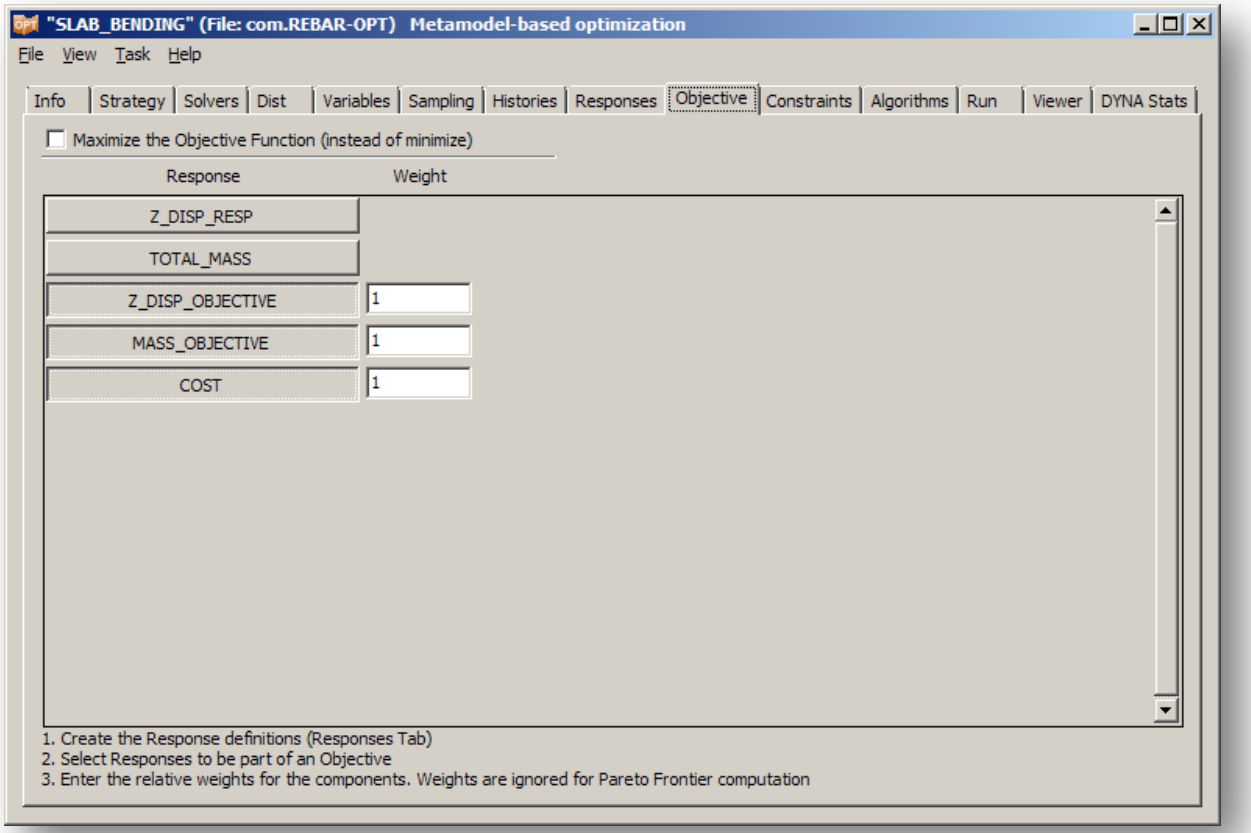
Responses Tab

- Let's define another objective – `COST` as a function of concrete strength and amount of steel and concrete
- For `Composite-Expression` type `(ucs/1000)*(1.5+dz)/1.5+4*bar/0.375)`
- For Response Name type `COST` and press Add



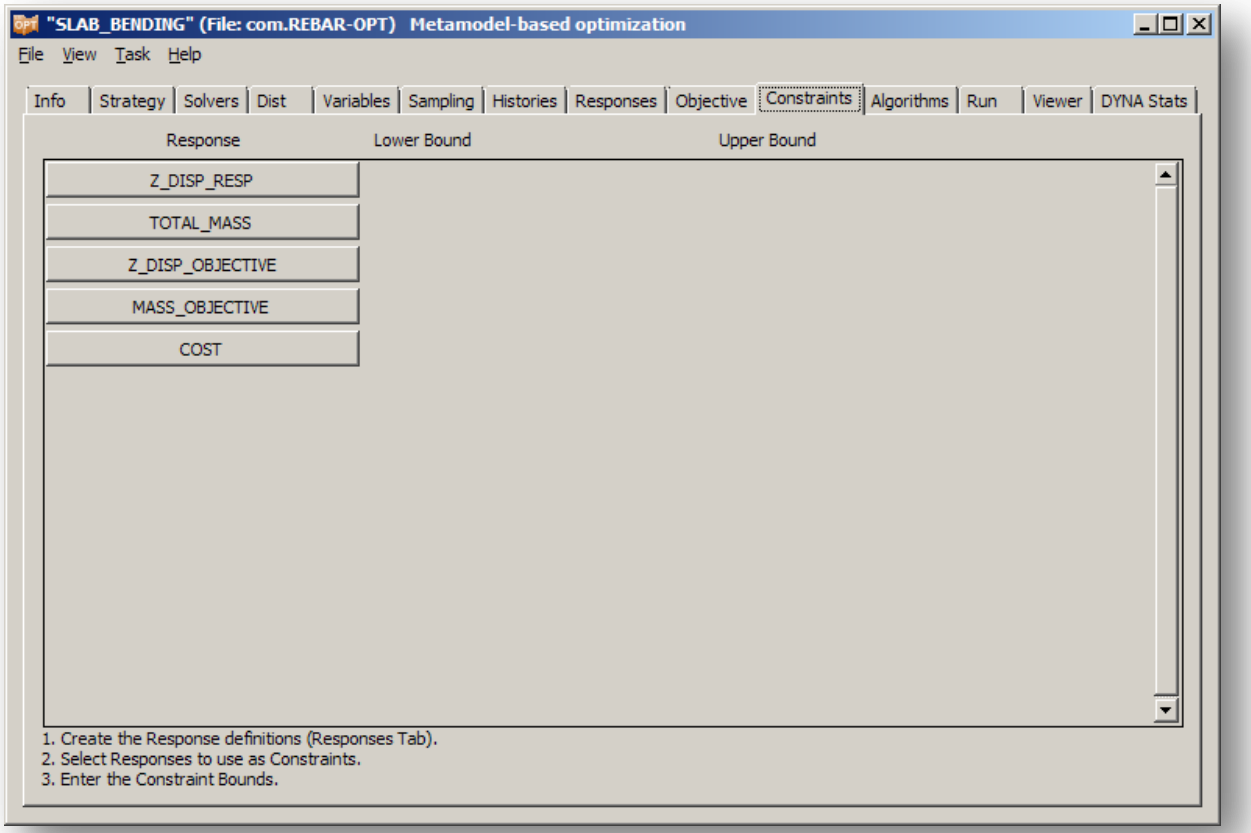
Objectives Tab

- In the Objective panel select: `Z_DISP_OBJECTIVE`, `MASS_OBJECTIVE` and `COST`



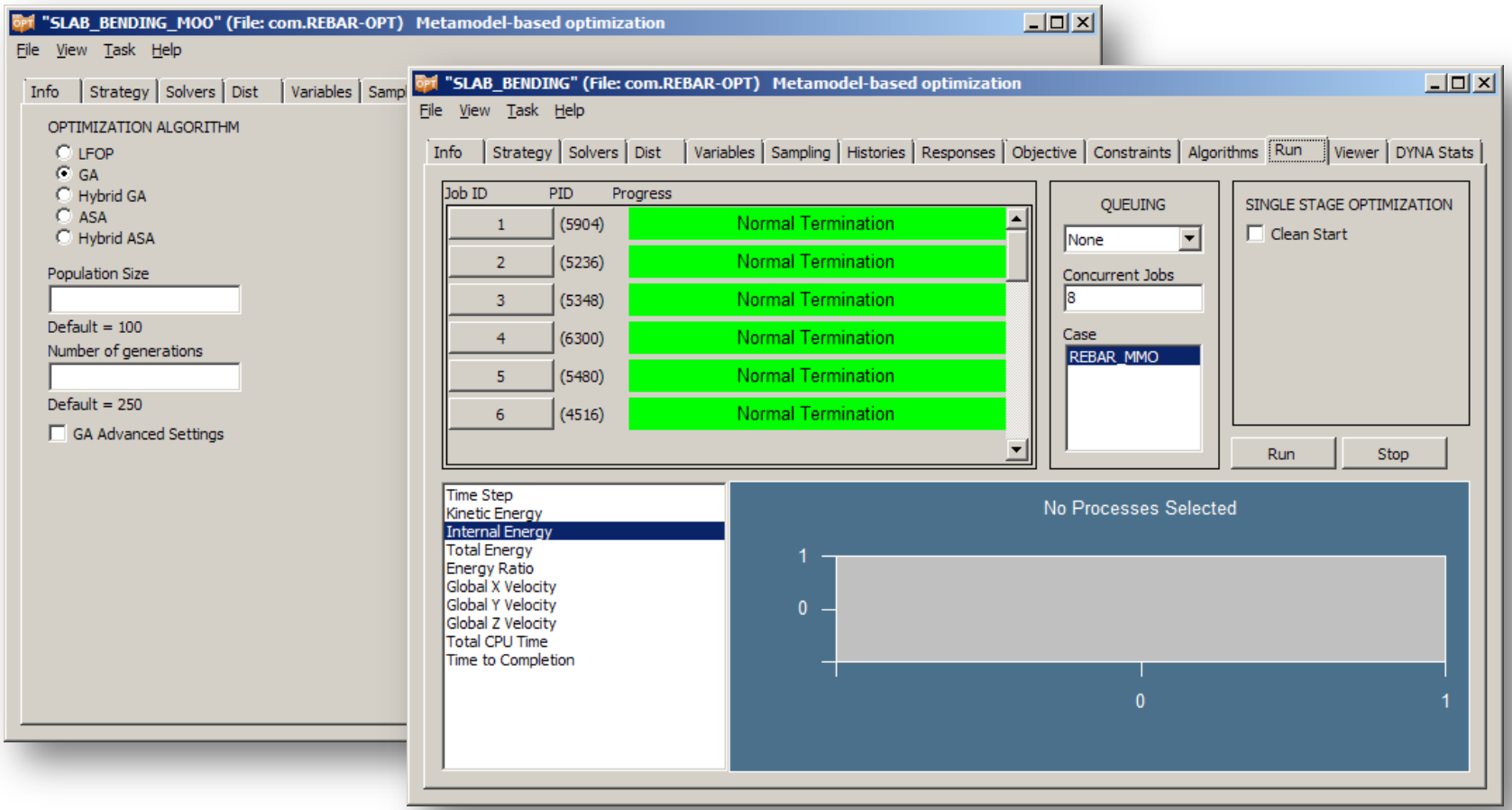
Constraints Tab

- No constraints are defined



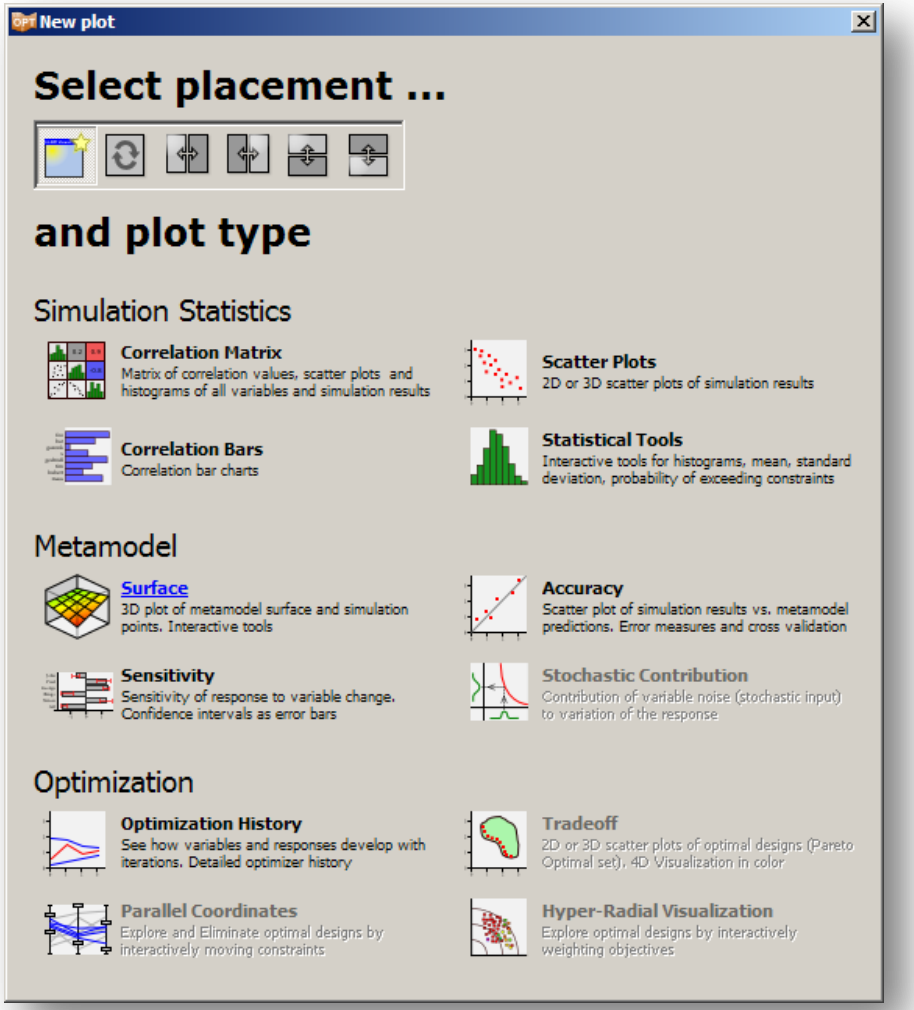
Run Tab

- In Run Tab depending on machine select PBS for Queuing system if TRACC cluster is used or leave none for windows
- Type appropriate number of Concurrent Jobs
- Press Run



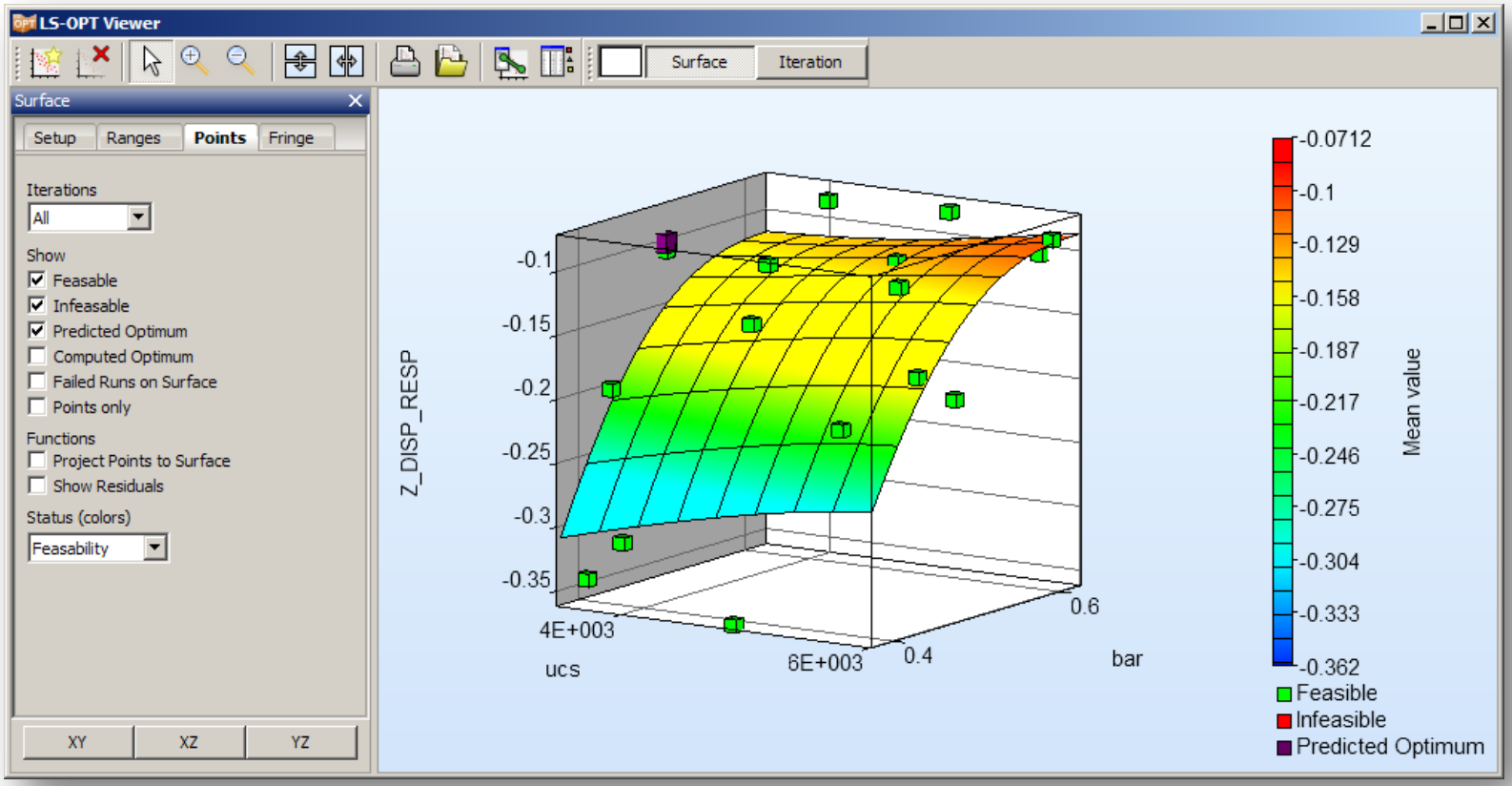
Viewer - Surface

- Go to Viewer Tab
- Select Surface from Metamodel Tools



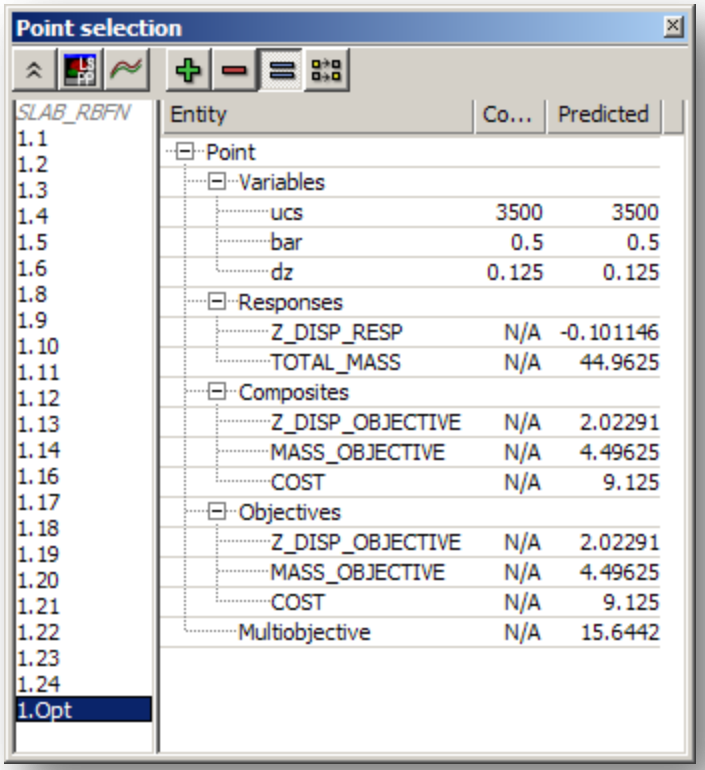
Viewer - Surface

- On Points Tab pick Predicted Optimum



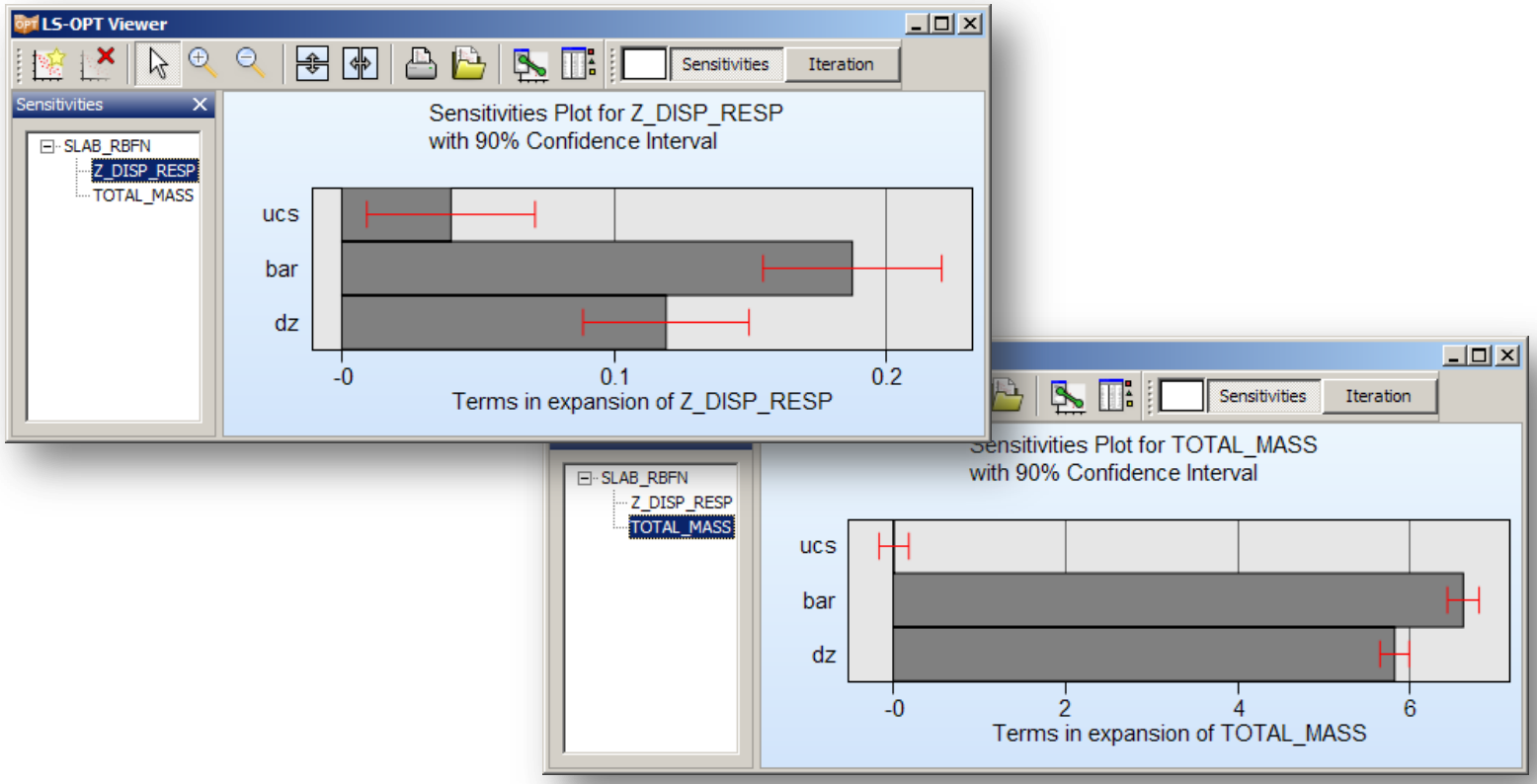
Predicted Optimal Point

- To see the value for predicted optimum click on purple square
- One discrete value was found for multiple objective problem



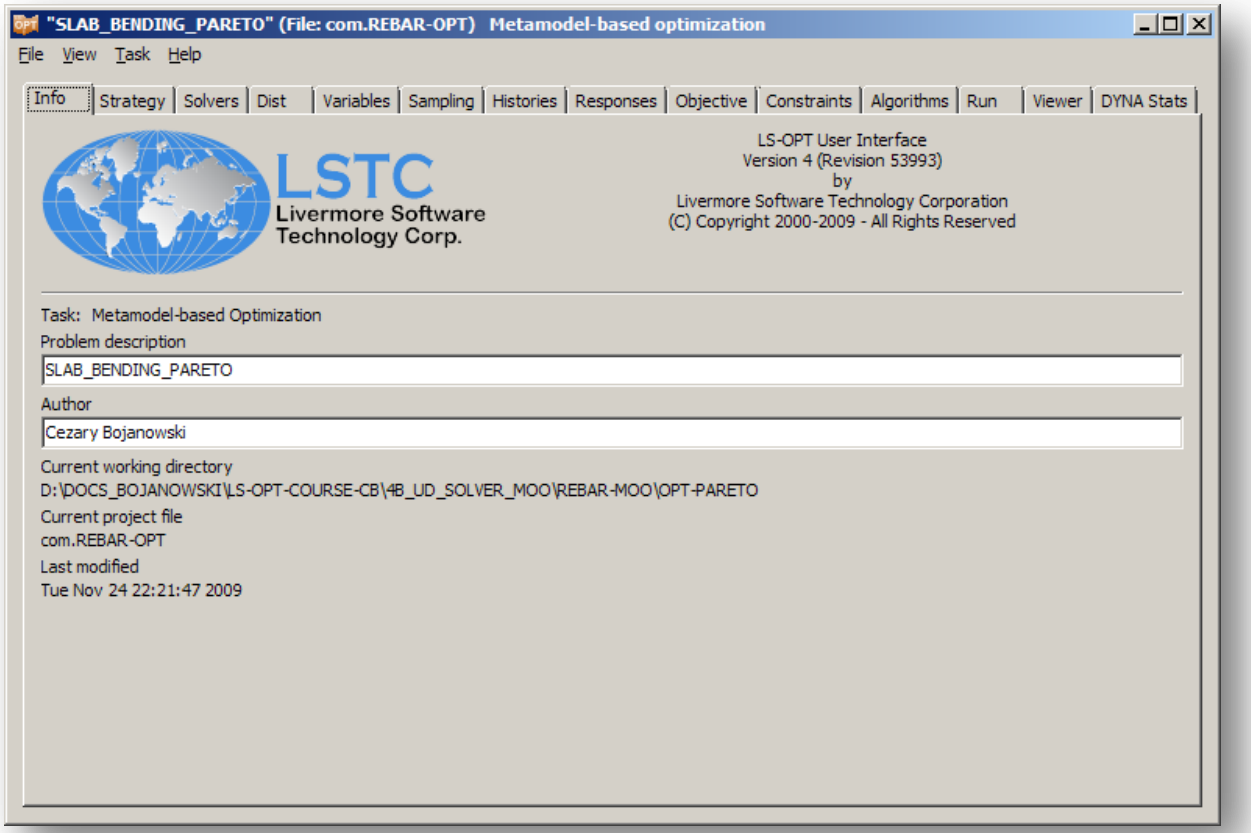
Sensitivities

- Go to Viewer Tab
- Select Sensitivities from Metamodel Tools
- Check which design variables influence the deflection and mass the most
- Note: LS-OPT uses linear Response Surface for sensitivities for other metamodels than polynomial based



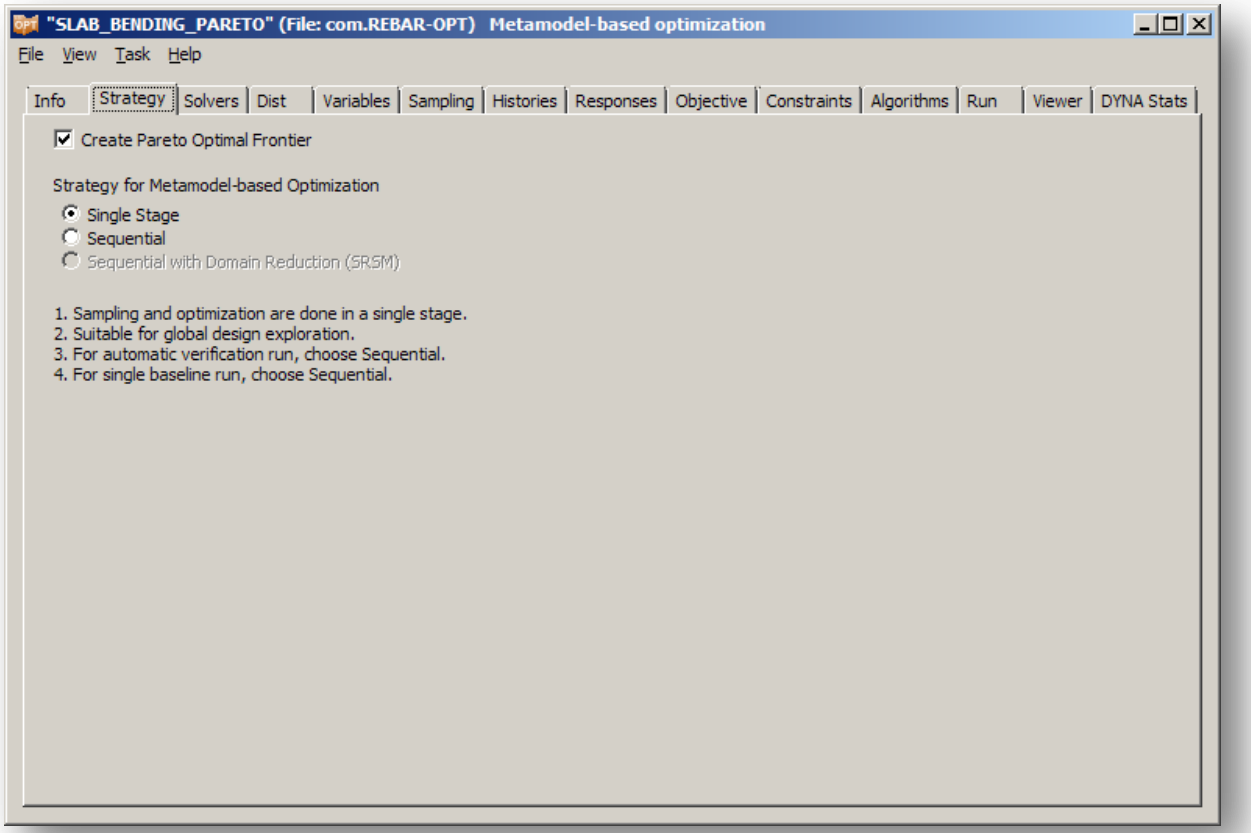
Info Tab

- Save the same file under different name in different folder
- For Problem description type `SLAB_BENDING_PARETO`



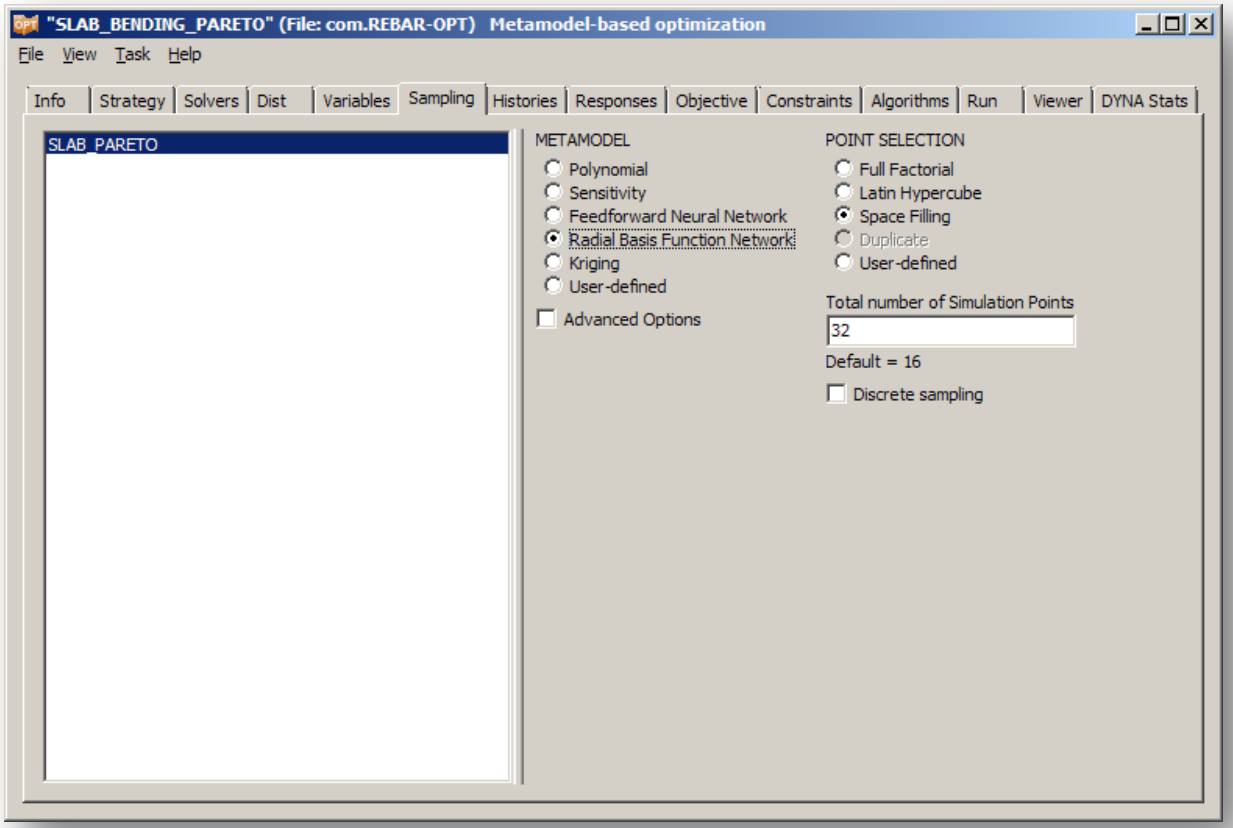
Strategy Tab

- In Strategy Tab check Create Pareto Optimal Frontier
- Make sure Singe Stage strategy is selected



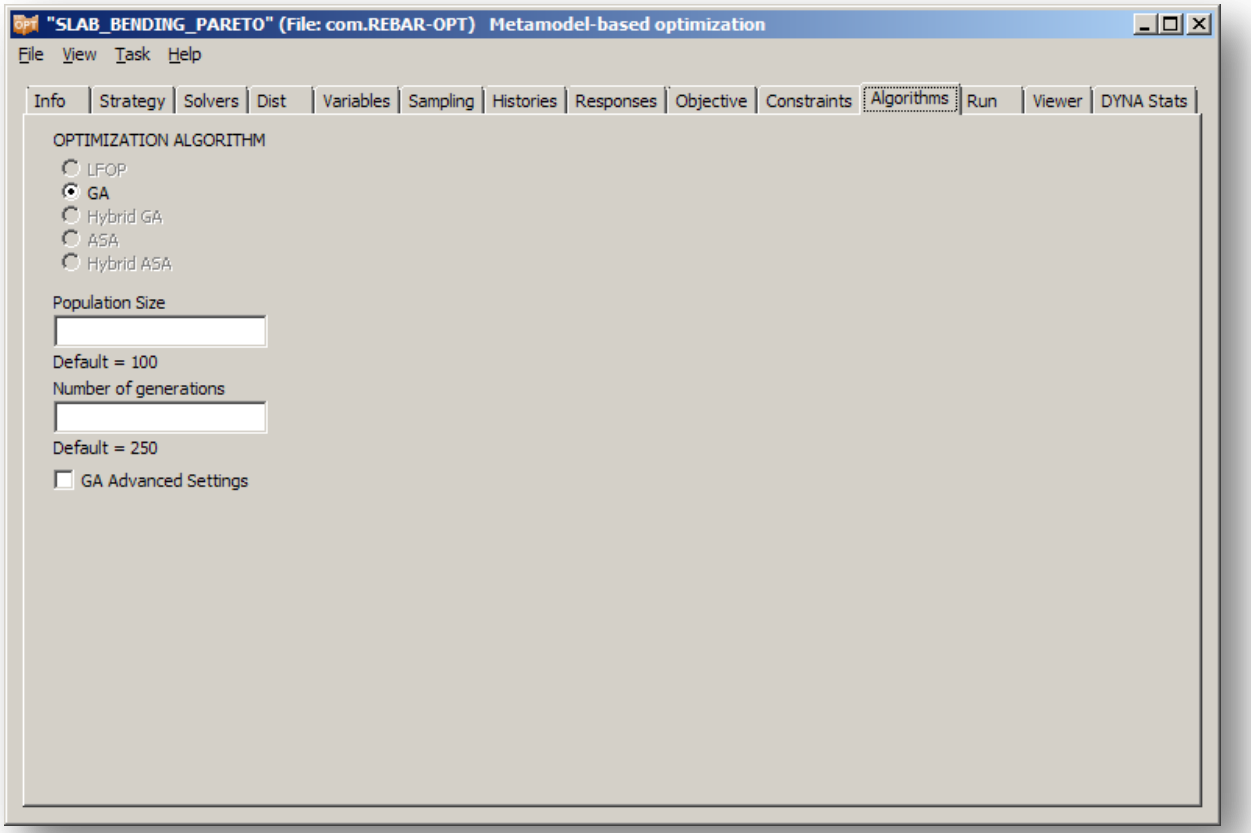
Sampling Tab

- Make sure BRFN with Space Filing point selection is still selected
- Type 32 for total number of Simulation Points



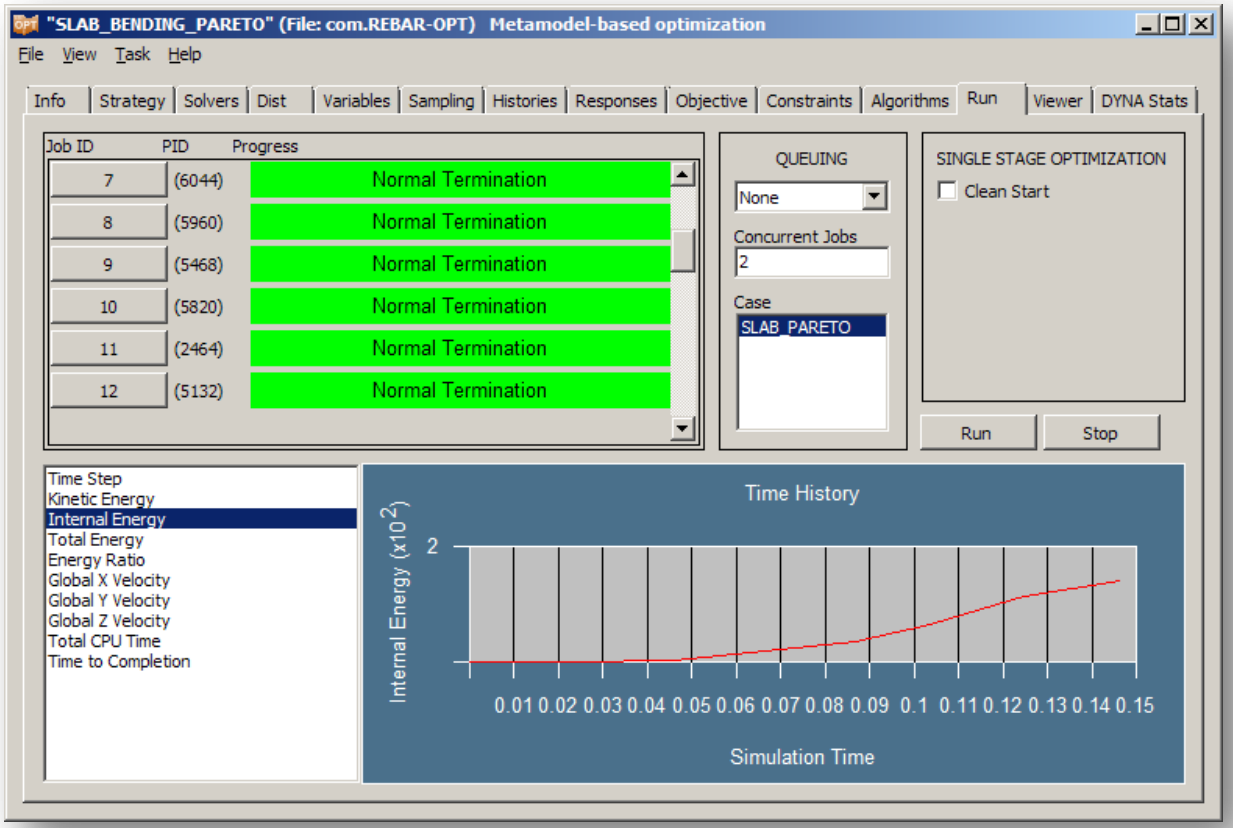
Algorithm Tab

- For Pareto Frontier GA is used



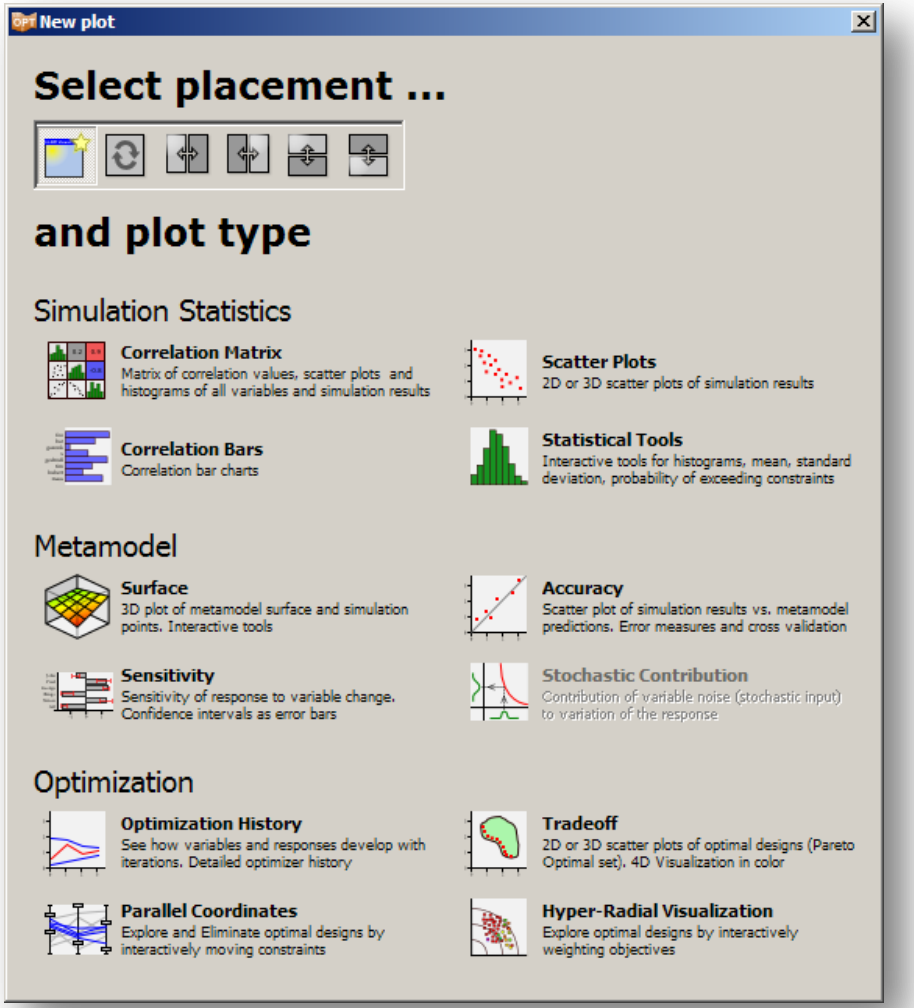
Run Tab

- Press Run leaving previous setting
- Do not check Clear Start – the simulations are already performed



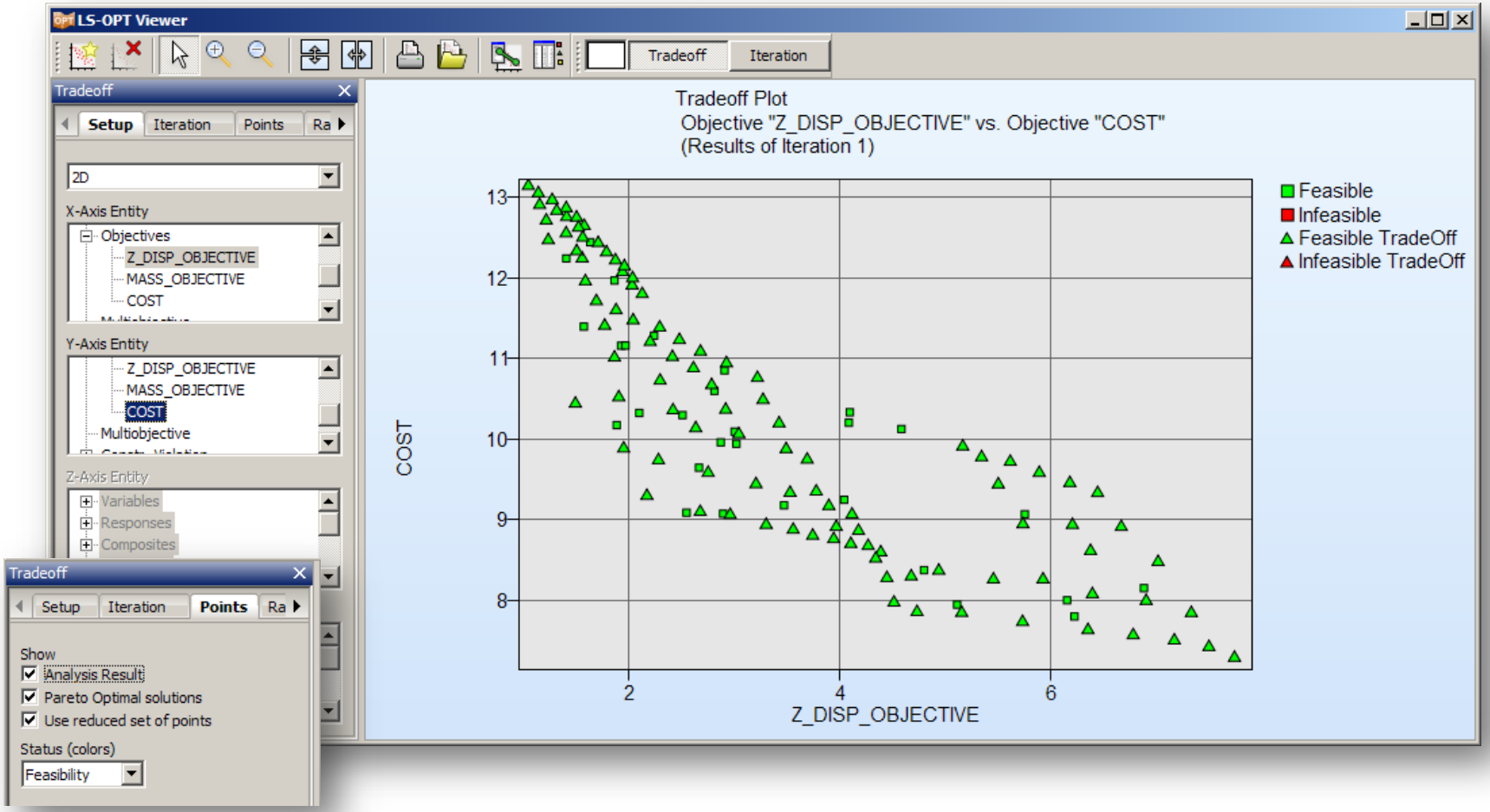
Viewer Tradeoff

- Go to Viewer Tab
- Select Tradeoff from Optimization Tools



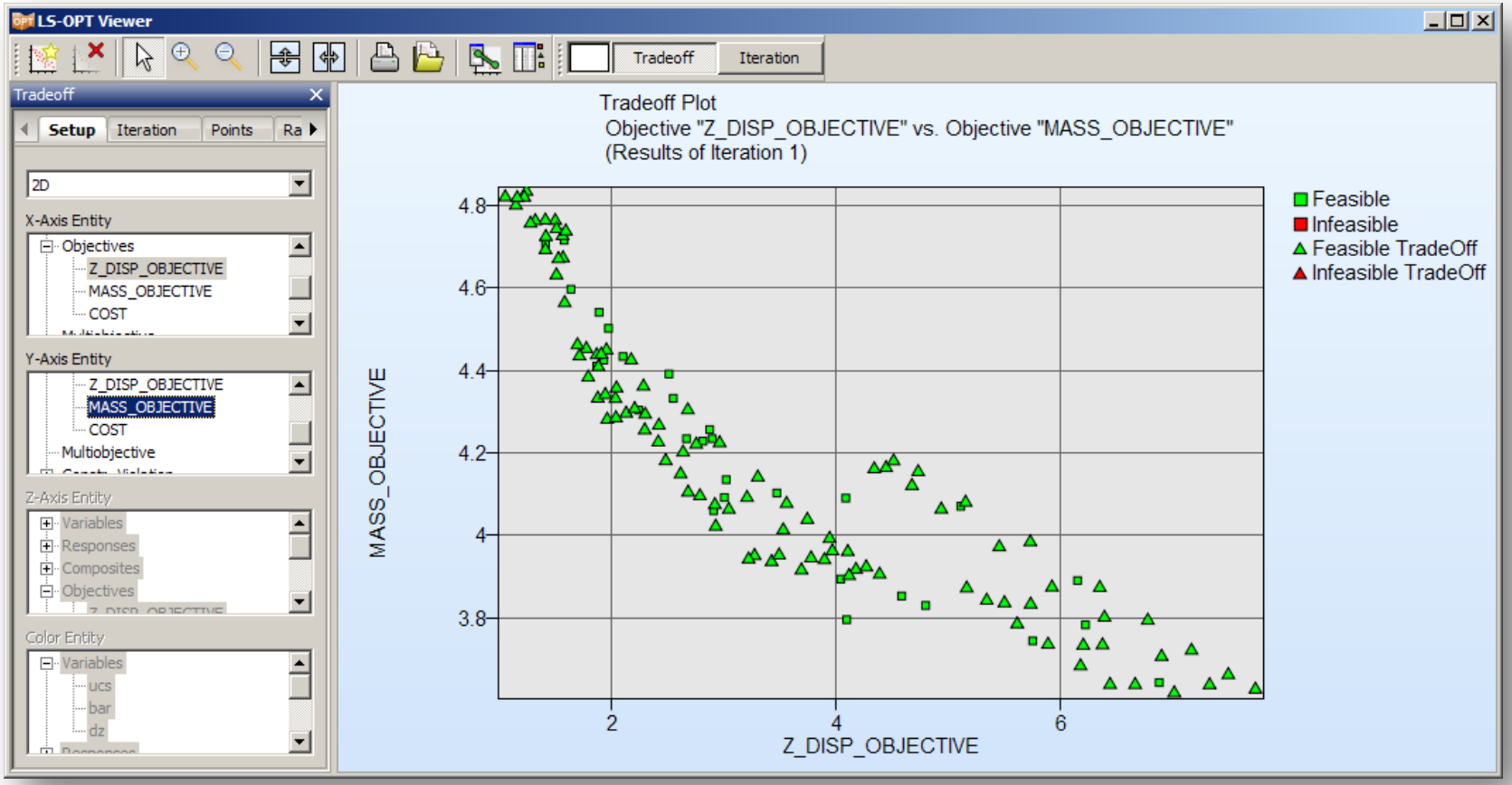
Viewer Tradeoff

- In 2D scheme only two objectives can be seen at a time
- Select `Z_DISP_OBJECTIVE` and `COST`



Viewer Tradeoff

- You can change between objectives
- For three objectives the Tradeoff can be seen in 3D – what next?



Hyper Radial Visualization (HRV)

- HRV maps any number of objectives into 2 dimensional space
- Objectives are selected by users into X and Y groups
- Objectives can be weighed by using sliders in the GUI

$$\min\ f_l(x);\quad l=1,2,\ldots,n$$ Objective functions

$$g_j(x)\le 0;\quad j=1,2,\ldots,m$$ Inequality constraints

$$h_k(x)=0;\quad k=1,2,\ldots,l$$ Equality constraints

$$x_{i,L}\le x_i\le x_{i,U};\quad i=1,2,\ldots,p$$ Bounds on variables (side constraints)

$$\left(\sqrt{\sum_{i=1}^{N_x} W_i \tilde{F}_i^2},\sqrt{\sum_{i=N_x+1}^{n} W_i \tilde{F}_i^2}\right)$$

Hyper Radial Visualization (HRV)

- Conversion of the multi-objective optimization to two-objective problem:

$$\left(\sqrt{\sum_{i=1}^{N_x} W_i \tilde{F}_i^2}, \sqrt{\sum_{i=N_x+1}^{n} W_i \tilde{F}_i^2} \right)$$

- Subject to:

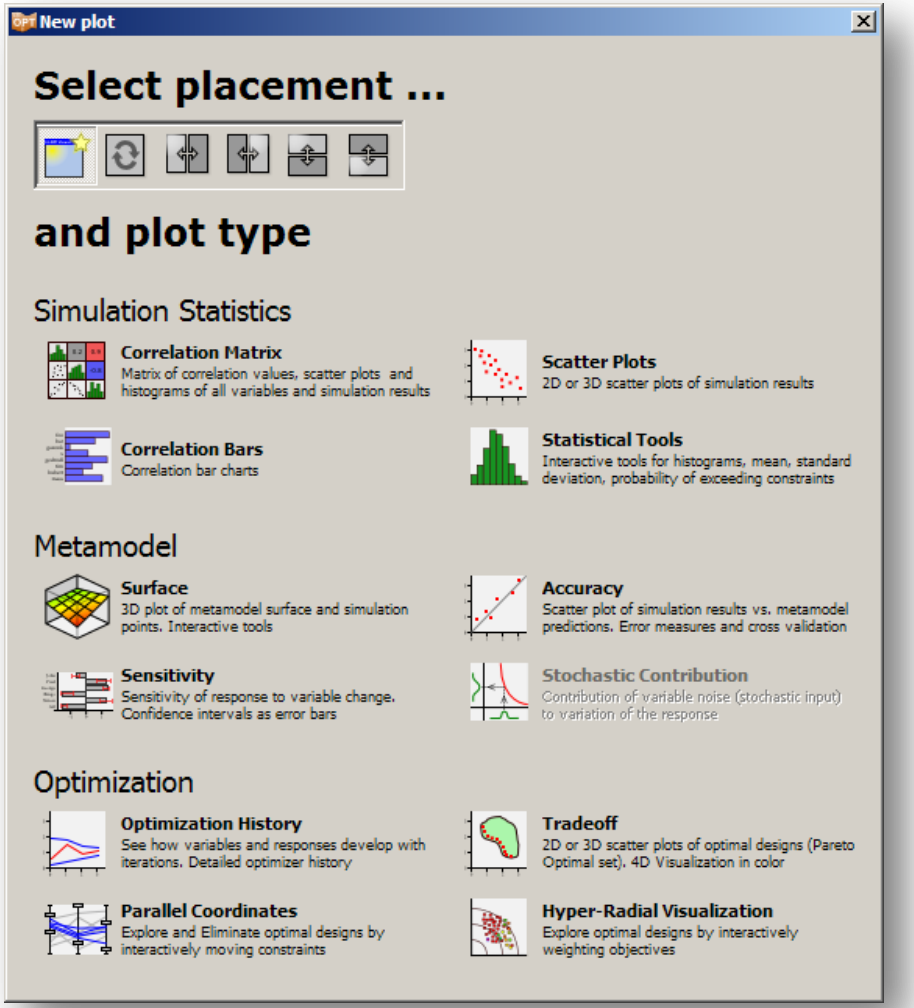
$$\sum_{i=1}^{n} W_i = 1 \quad and \quad W_i > 0$$

- and:

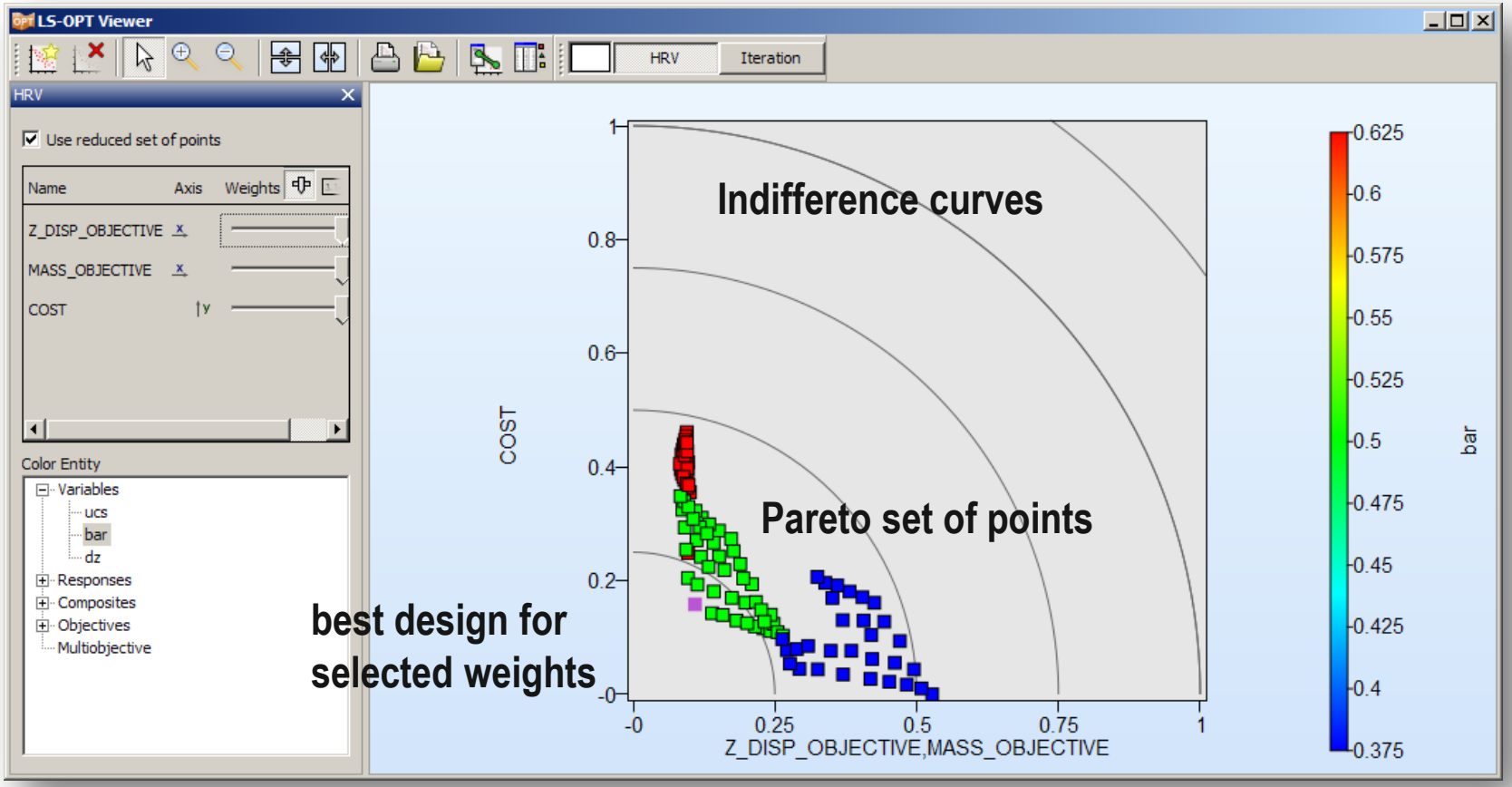
$$\tilde{F}_i = \frac{F_i - F_{i\_min}}{F_{i\_max} - F_{i\_min}} \qquad i = 1,2,...,n \qquad \tilde{F}_i \in [0,1]$$

Viewer – HRV Plot

- Go to Viewer Tab
- Select Hyper-Radial Visualization from Optimization Tools

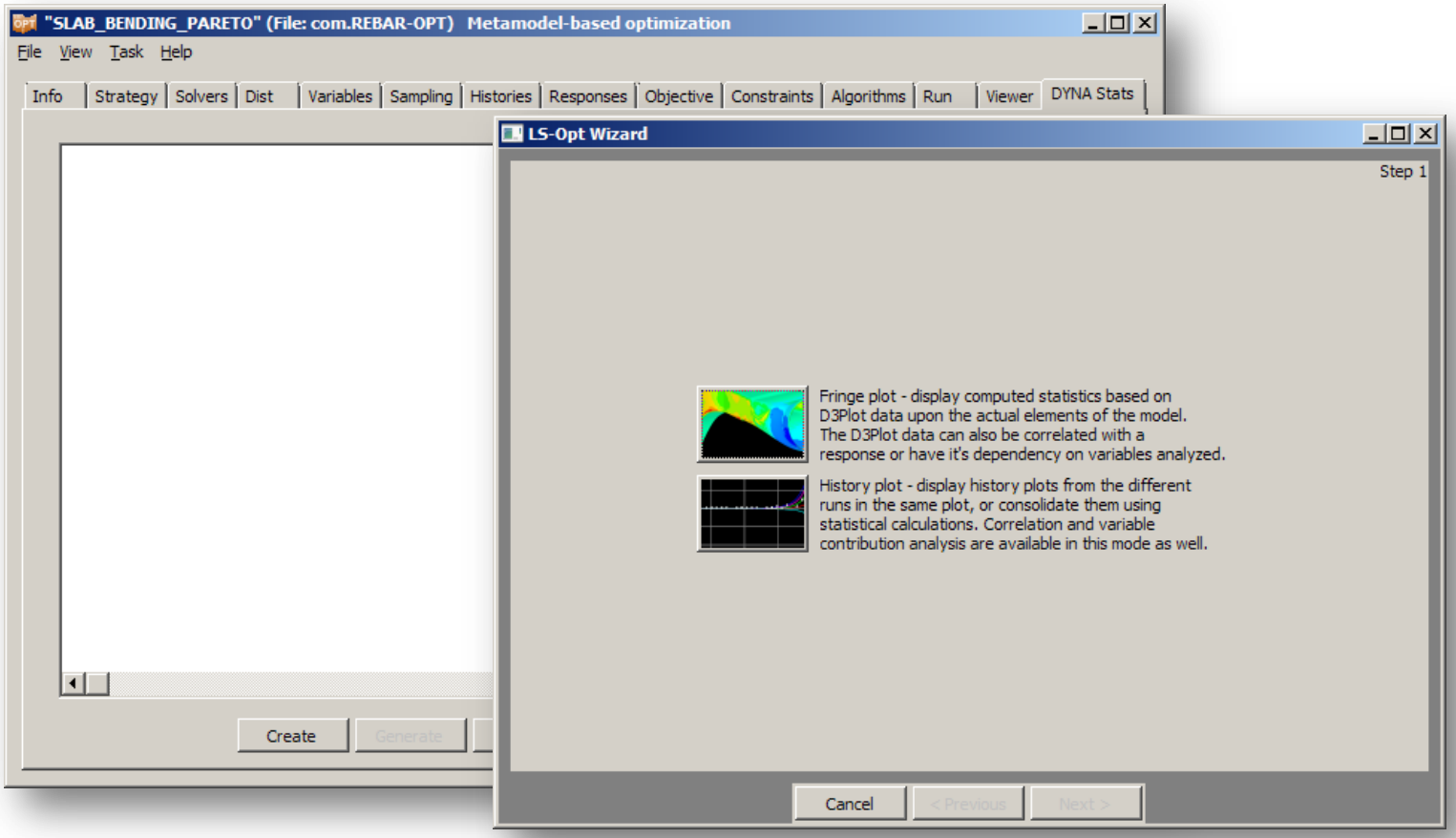


Hyper Radial Visualization (HRV)



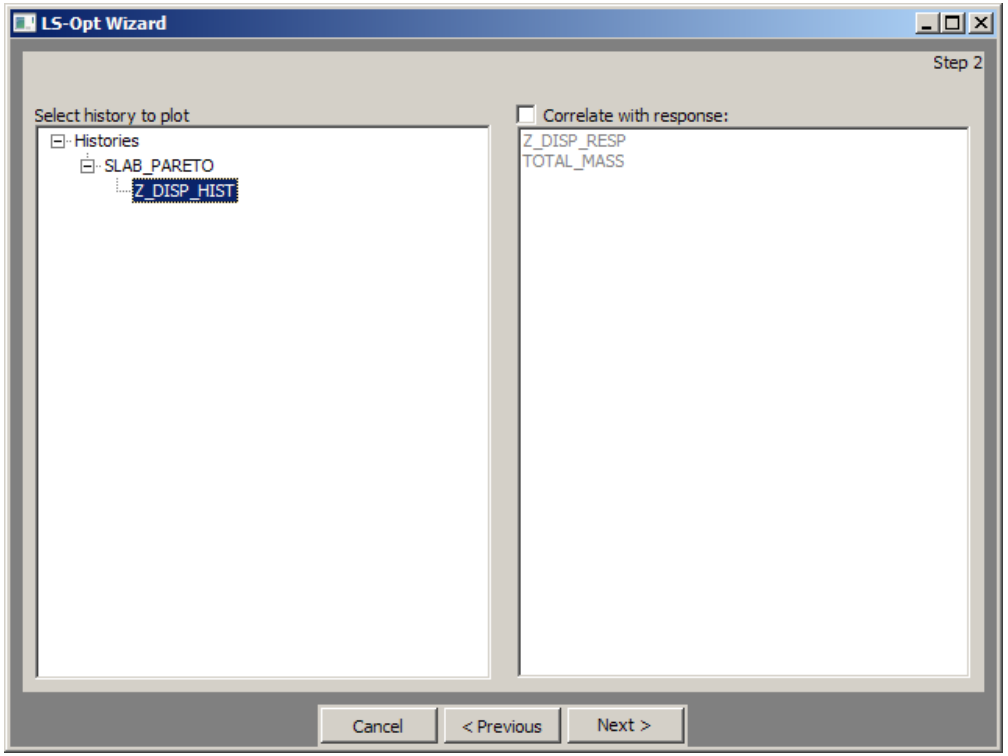
Histories from all Simulations

- Go to DYNA Stats Tab
- From new window select History plot



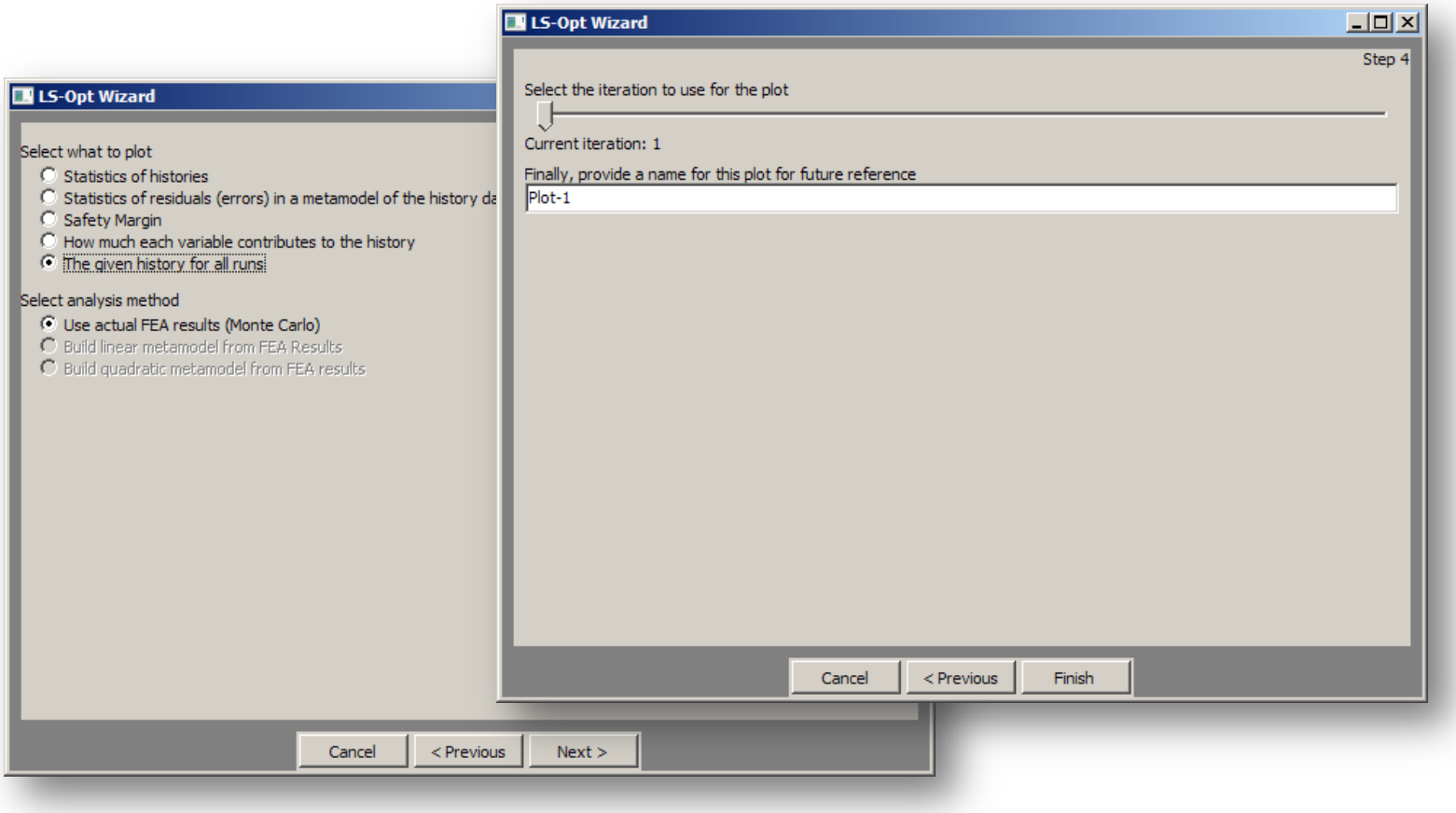
Histories from all Simulations

- Only one History was defined
- Select `Z_DISP_HIST`
- Press Next



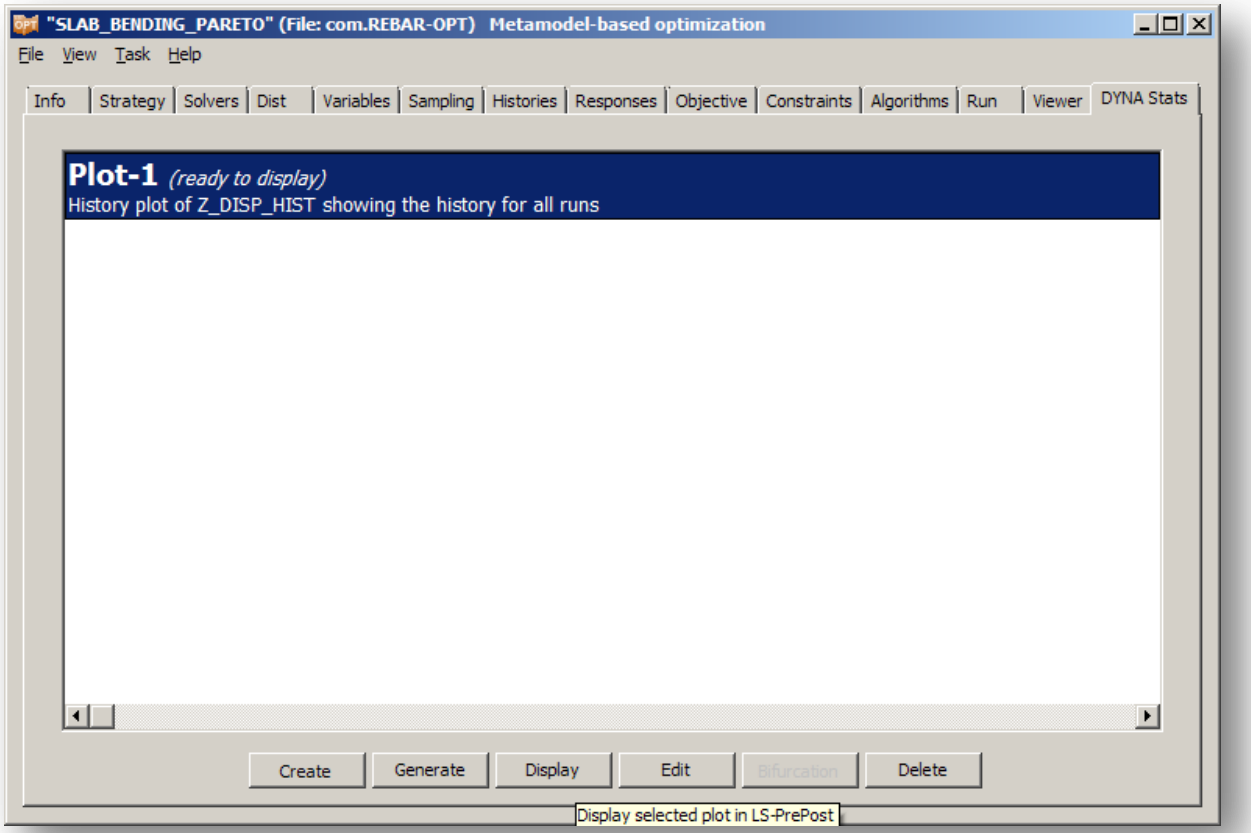
Histories from all Simulations

- Pick The given history for all runs to plot
- Press Next
- On next Window press Finish



Histories from all Simulations

- New plot should be ready to display
- Press Display



Histories from all Simulations

- LS-PREPOST should open wilt d3plots from first simulation
- The graph window should also pop up automatically with all the specified histories from all the runs