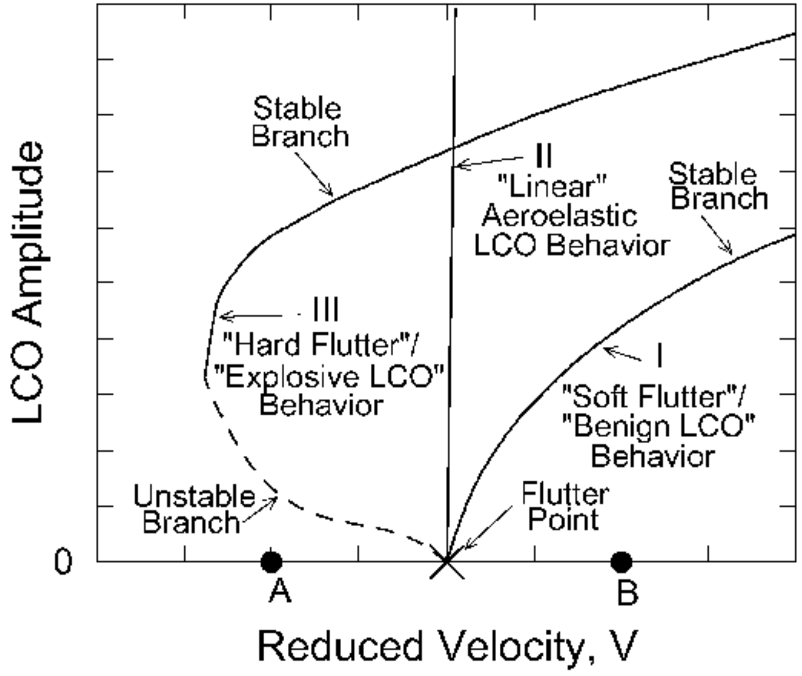
BSCW Stability at M=0.8, AoA=5.0

- **The flow is nonlinear**
  - Stability characteristics are then potentially dependent on perturbation amplitude
- **Participants are using different forms and amplitudes of perturbation**
  - Release from undeformed jig shape
  - Generalized velocity perturbations
- **If this case is not a linear flutter (independent of perturbation size), how do we compare results across groups?**
  - What variable do we put on the y-axis?



LCO behaviors [1]

[1] Thomas et al. “Modeling Viscous Transonic Limit Cycle Oscillation Behavior Using a Harmonic Balance Approach, ” Journal of Aircraft, 2002

Approach

- **Pawel has asked some participants for their simulation history data as an initial test**
  - Modal displacements and velocities versus time, dynamic pressure, freestream velocity, mode shapes.
- **We've put together python scripts to process this data from each group into the same data structures**
  - Computes several variables that could potentially be the y-axis
  - Computes a damping value using the Matrix Pencil method
  - Assign an "eyeball" observation: look at time history and assign "damping" as unstable, lightly damped, unknown, etc.
- **Generate a plot: {y-var} versus dynamic pressure, color symbols by damping**

```
def get_technion_signals(self):
    directory = 'technion_ezair'
    signals = [
        EZAirSignal(f'{directory}/EZAir_Flutter_Data_10_Jul_2022_Qinf_50psf_Uinf_132m2s_gvel0.csv', 0.0, 'lightly unstable'),
        EZAirSignal(f'{directory}/EZAir_Flutter_Data_01_Sep_2022_Qinf_75psf_Uinf_132m2s_gvel0.csv', 0.0, 'unstable'),
```

```
def get_nasa_gvel_perturbation_signals(self):
    directory = 'nasa_gvel'
    signals = [
        AehistSignal(f'{directory}/Q25/Gvel0p5', 38.0, 'lightly damped'),
        AehistSignal(f'{directory}/Q25/Gvel5', 38.0, 'lightly damped'),
        AehistSignal(f'{directory}/Q50/Gvel5', 22.8, 'lightly damped'),
```

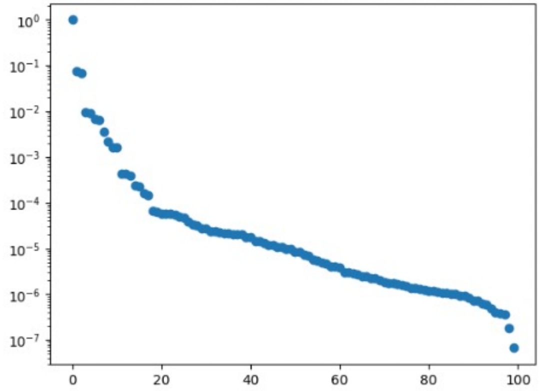
Start time for Matrix pencil

Matrix Pencil Method [2]

1. **Choose start time and end time from original signal***
2. **Assumes a Prony series solution + noise term**

$$y_n = \sum_{k=1}^{M} c_k e^{s_k n} + w_n, \qquad n = 1, \ldots, N$$

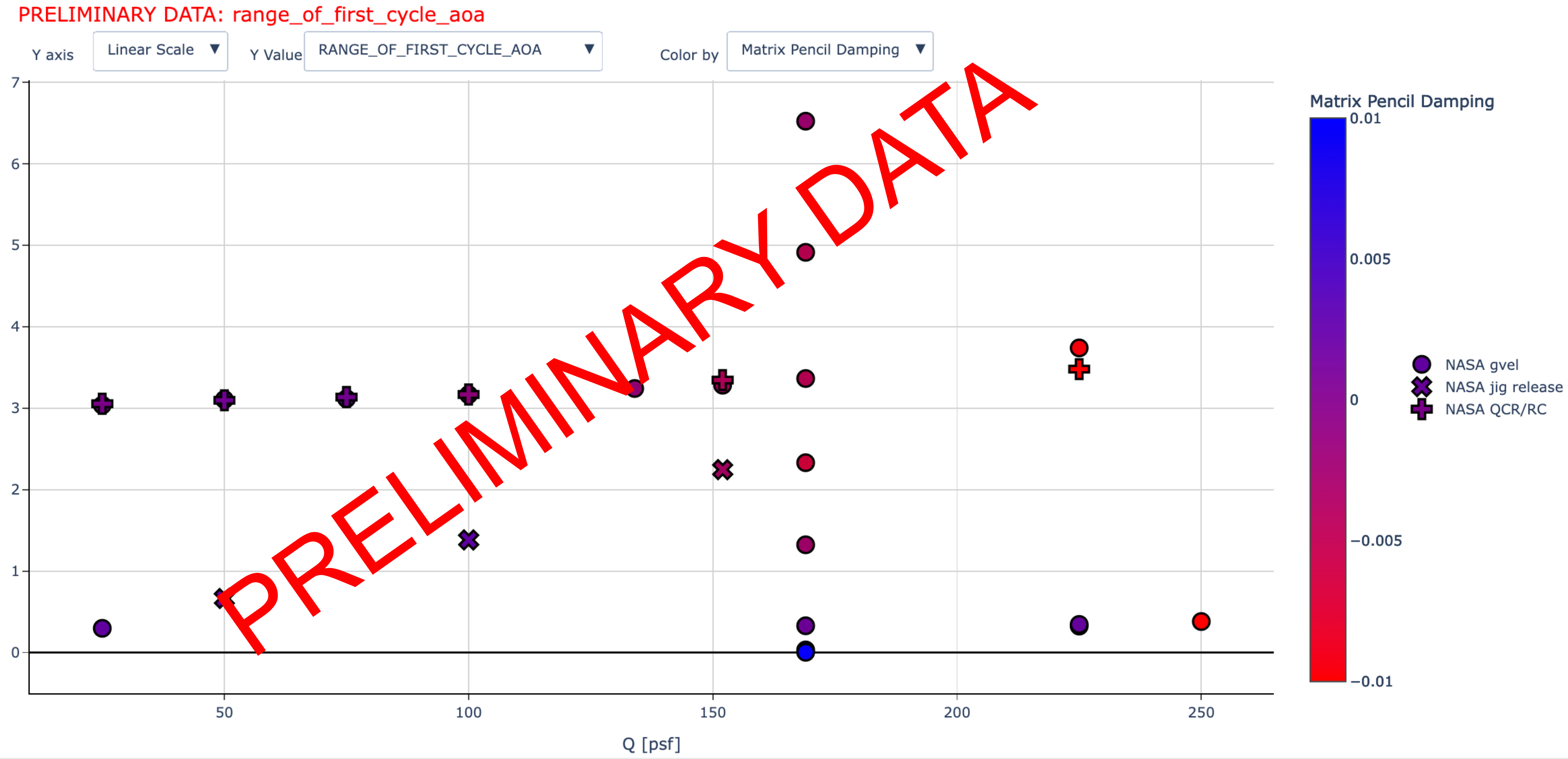
3. **Filter the noise based on singular values of Hankel matrix of the time series**



4. **After filtering, the eigenvalues of the system represent the components of the Prony series,** *damping* = Re(s_k)

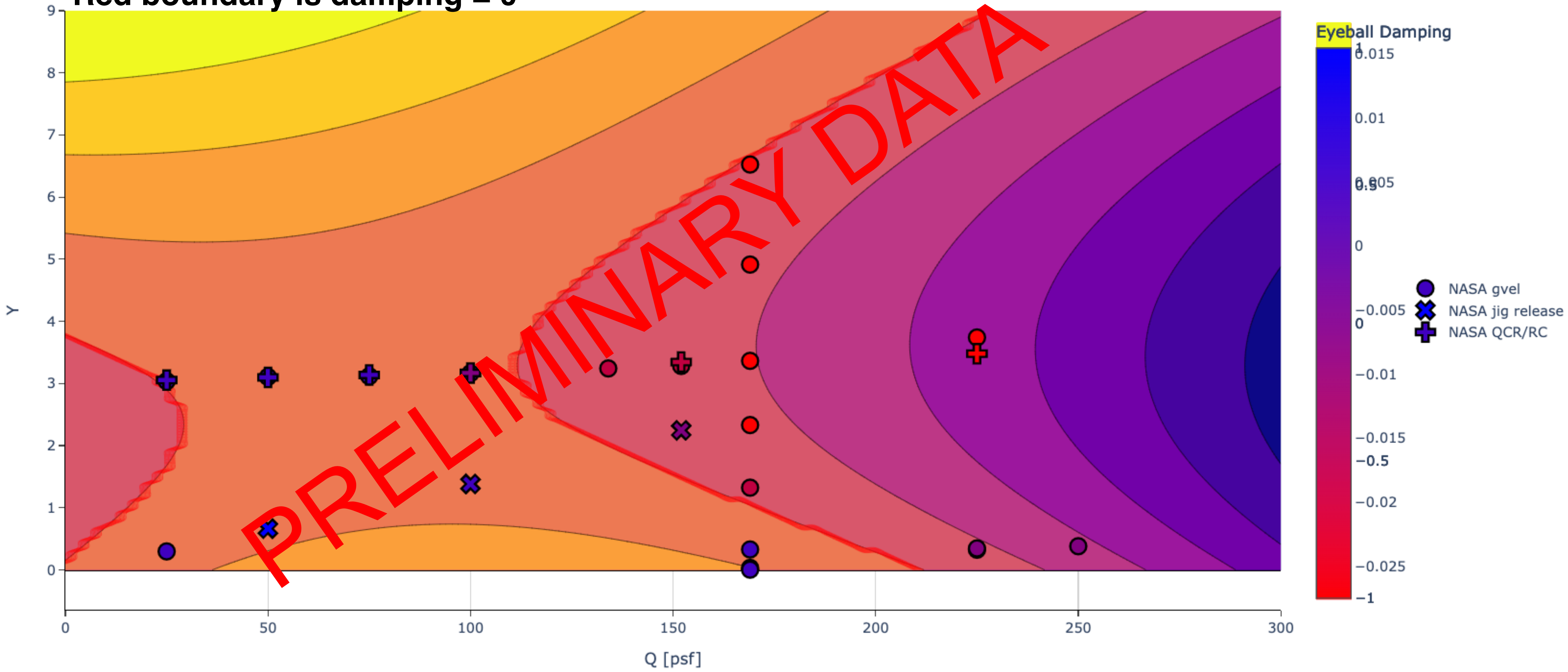
[2] Kiviaho et al. "Flutter Boundary Identification from Time-Domain Simulations Using the Matrix Pencil Method" AIAA Journal, 2019

Resulting plot: FUN3D data



FUN3D Stability Boundary

- Fit a Kriging model to FUN3D data
- Red boundary is damping = 0



Resulting plot: all provided data

Questions to explore

- **How long of a window should the matrix pencil be applied over?**
  - Linear assumption for Prony series could be poor if the damping is varying over a long signal history?
- **Other ideas for what the y axis variable should be?**
- **Are there any trends across participants that can be established?**
- **For data sets that disagree, how do we determine why the predictions are different? More detailed information about flow characteristics?**