University of
BRISTOL

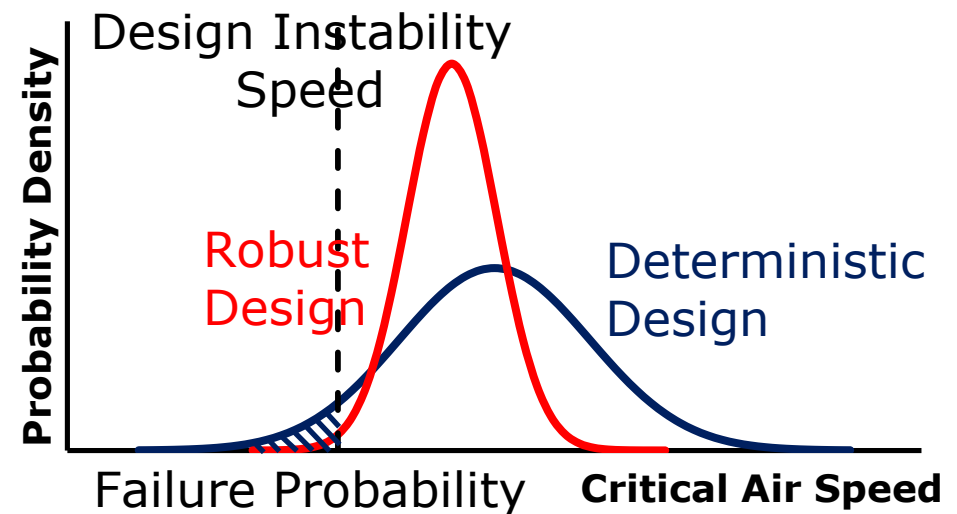# Robust Aeroelastic Design

A Parametric Study

Carl Scarth, Jonathan Cooper,
Paul Weaver

accis

ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE
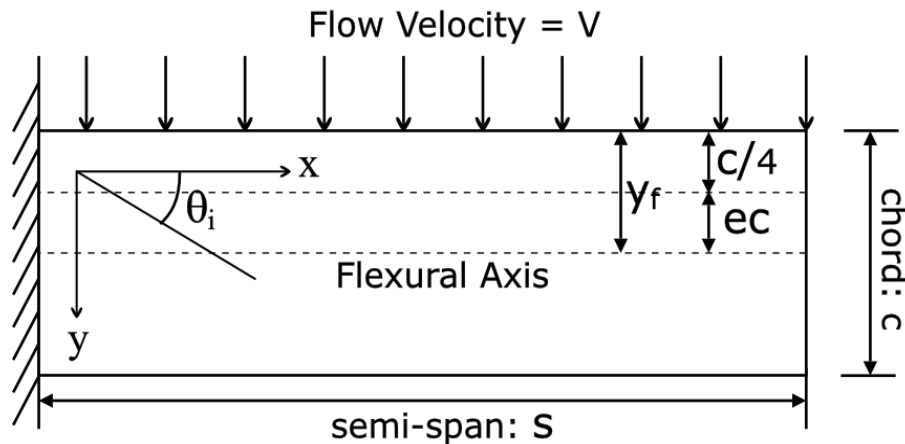
Robust Aeroelastic Design

- **Aeroelasticity:** Static and dynamic interaction of structures with aerodynamic loads

  e.g Divergence, Flutter

- **Aeroelastic Tailoring:** Use of composite anisotropy to offset aeroelastic phenomena

- **Uncertainty:** Lack of knowledge or variability resulting from randomness or approximation

- **Robust Design:** Optimal design with minimal sensitivity to uncertainty
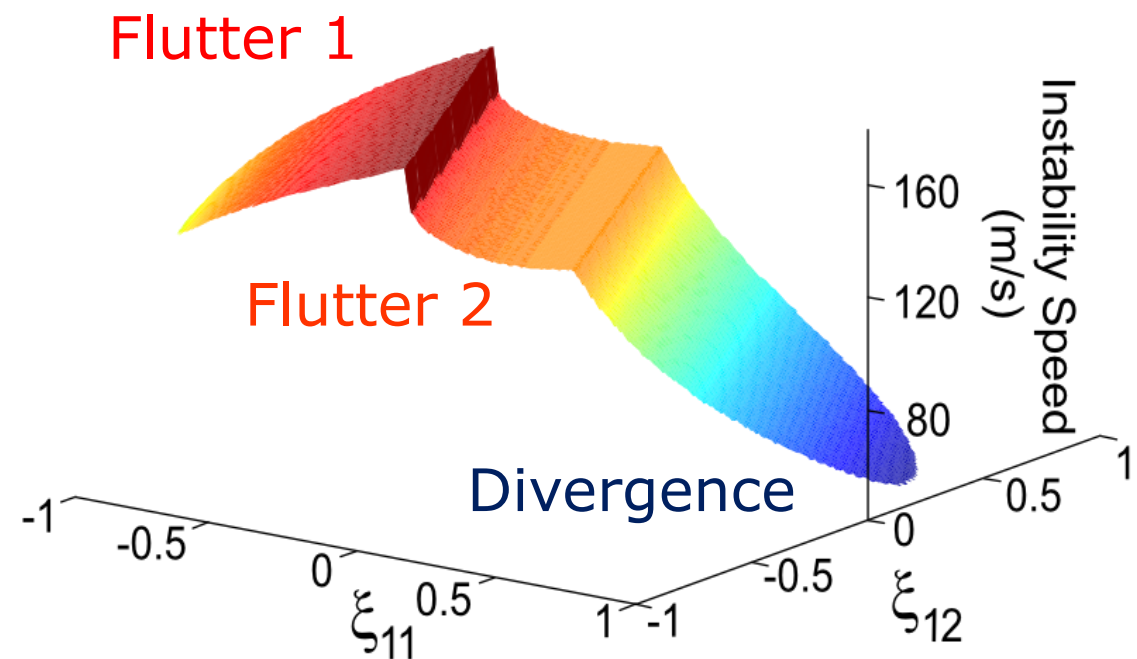
  Very computationally expensive!

University of BRISTOL

ACCIS — ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

Example: Plate Model

$$[A]\ddot{q} + \rho V[B]\dot{q} + \left(\rho V^2[C] + [E]\right)q = 0$$

Flow Velocity = V

θ_i

Flexural Axis

semi-span: S

chord: c

- Wing idealised as plate

- Ply orientations uncertain

- Solved using Rayleigh Ritz

- Uncertainty modelled using Polynomial Chaos Expansion

Response is Discontinuous

Flutter 1

Flutter 2

Divergence

Instability Speed (m/s)

Example Plot of Instability Speed with Bend-Twist Coupling Parameters

University of BRISTOL

ACCIS
ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

Example: $[45_2 \ -45_2 \ 0_2 \ 90_2]_S$

- Multiple modes gives rise to multiple PDF peaks
- Efficient approach superimposes separate distributions

100 samples sufficient
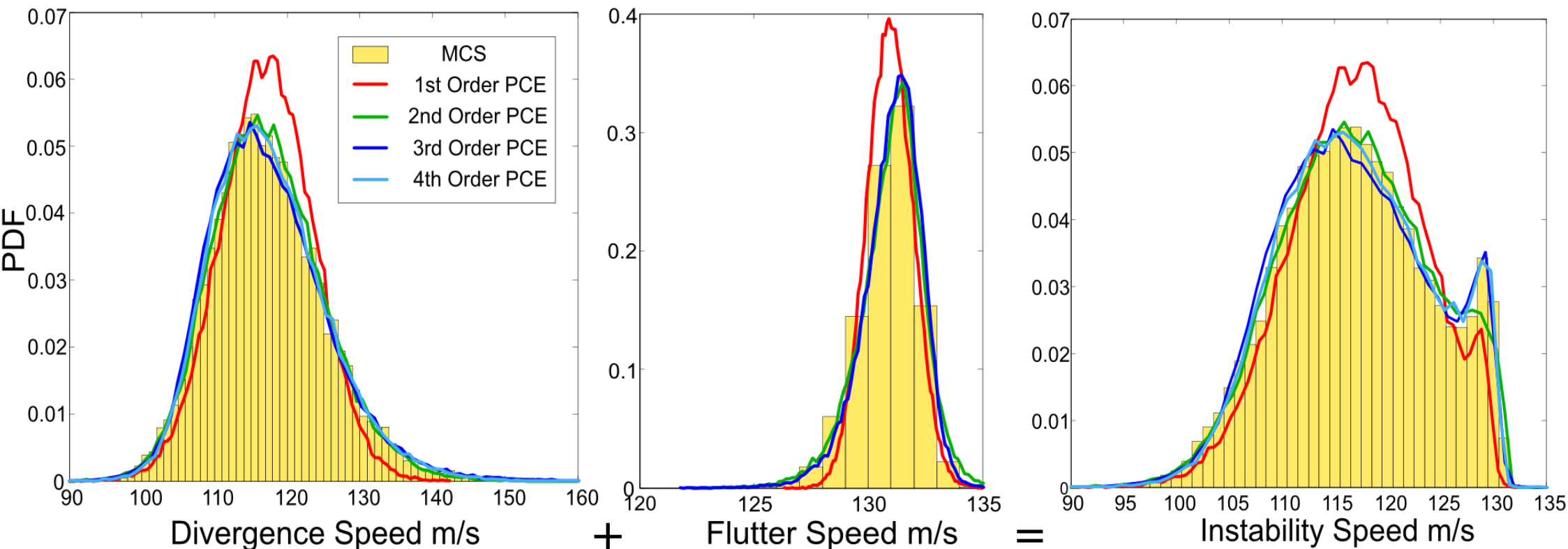
- Order of magnitude reduction in runs compared to Monte Carlo

University of BRISTOL

ACCIS
ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

Parametric Study Results

- Laminates with layup $[x_1 \ x_2 \ x_3 \ x_4 \ 0_2 \ 90_2]_s$, $x_1 - x_4 = \pm 45°$

- Different bend-twist coupling parameter ξ_{11}, same un-coupled properties
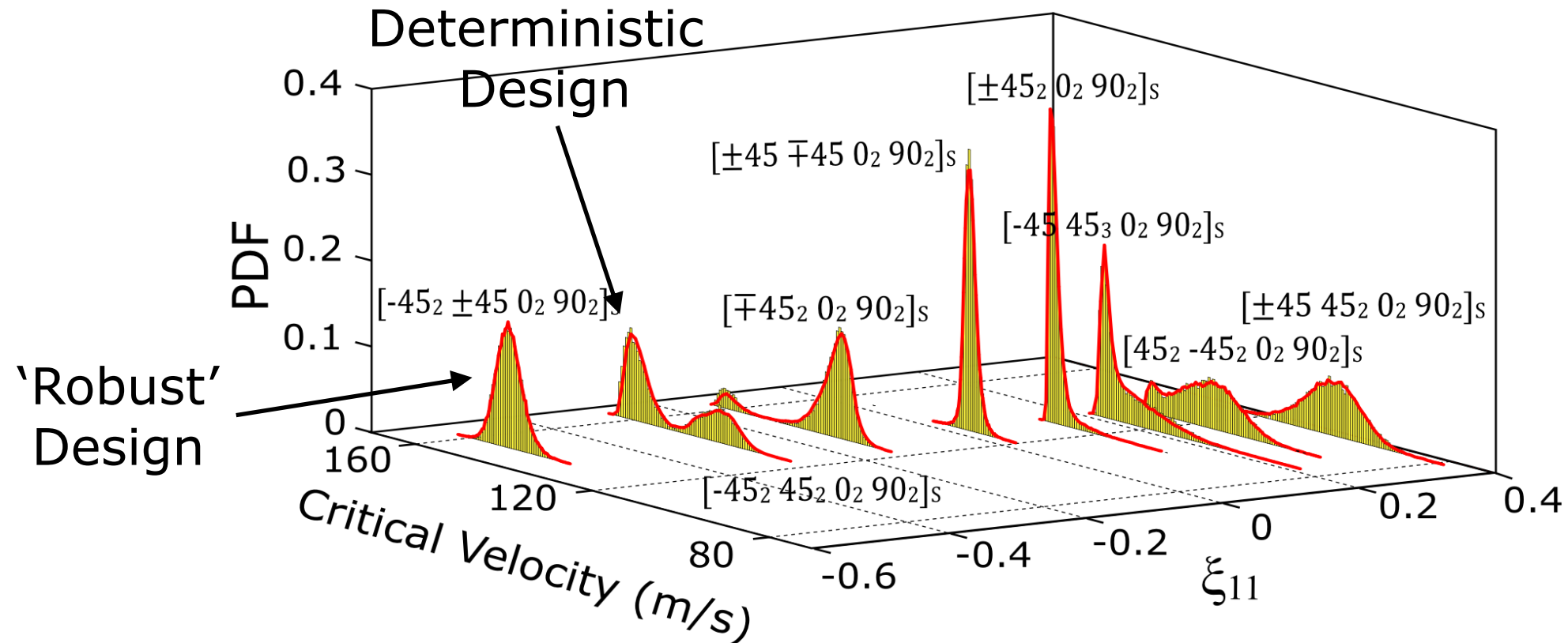
- Mode switch causes significant sensitivity to uncertainty

- Robust design important for aeroelastic tailoring

Thanks for listening