Leading-edge flow separation control using DBD plasma: Effect of the Reynolds number

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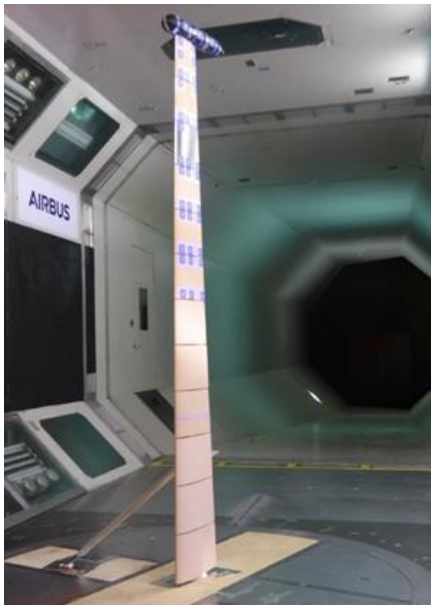
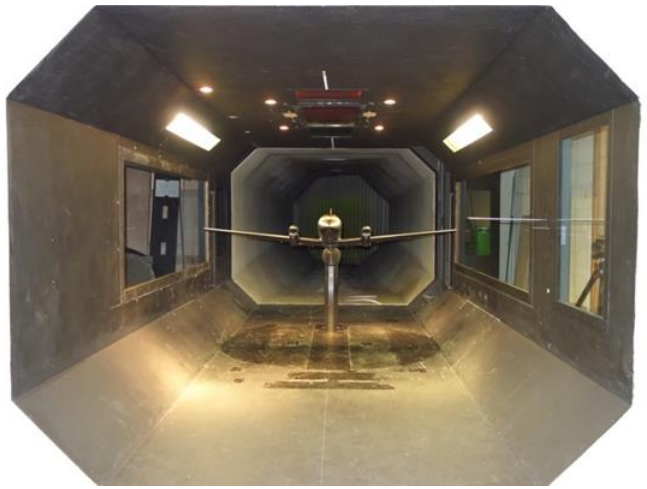
TAILSURF project

Clean Sky 2
JOINT UNDERTAKING

University of Nottingham
UK | CHINA | MALAYSIA



University of Glasgow



University of BRISTOL

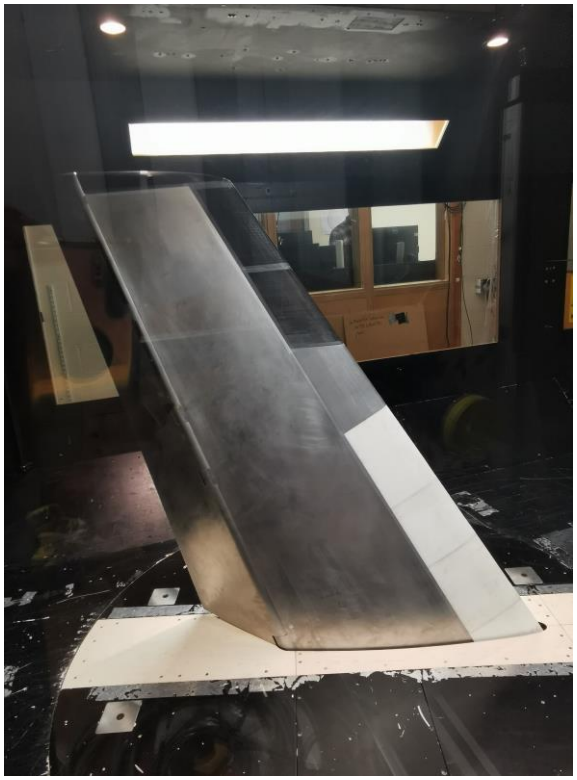
Objective

To study innovative flow control devices for size reduction of the empennage of large passenger aircraft.

Wind tunnels and test models

Mean aerodynamic chord = 0.982 m, Span = 1.6 m
Sweep angle = 27.2°, Taper ratio = 0.46

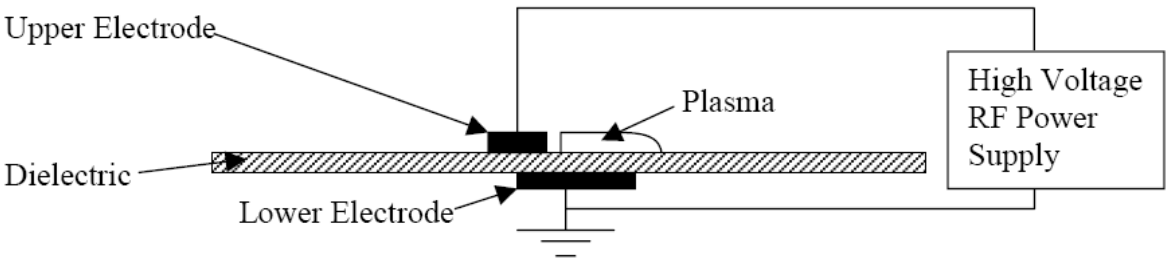
¼ model



Glasgow tunnel: 2.7 x 2.1 x 5.4 m

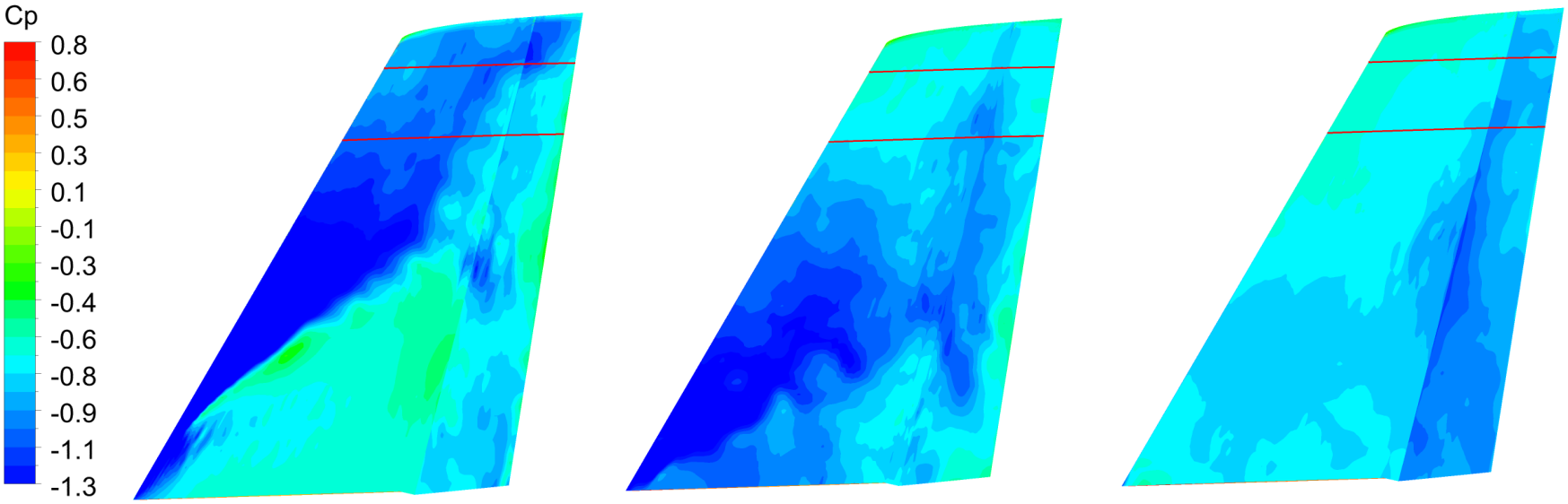
Nottingham tunnel: 0.9 x 0.9 x 1.5 m

Plasma actuators



LES results of the baseline

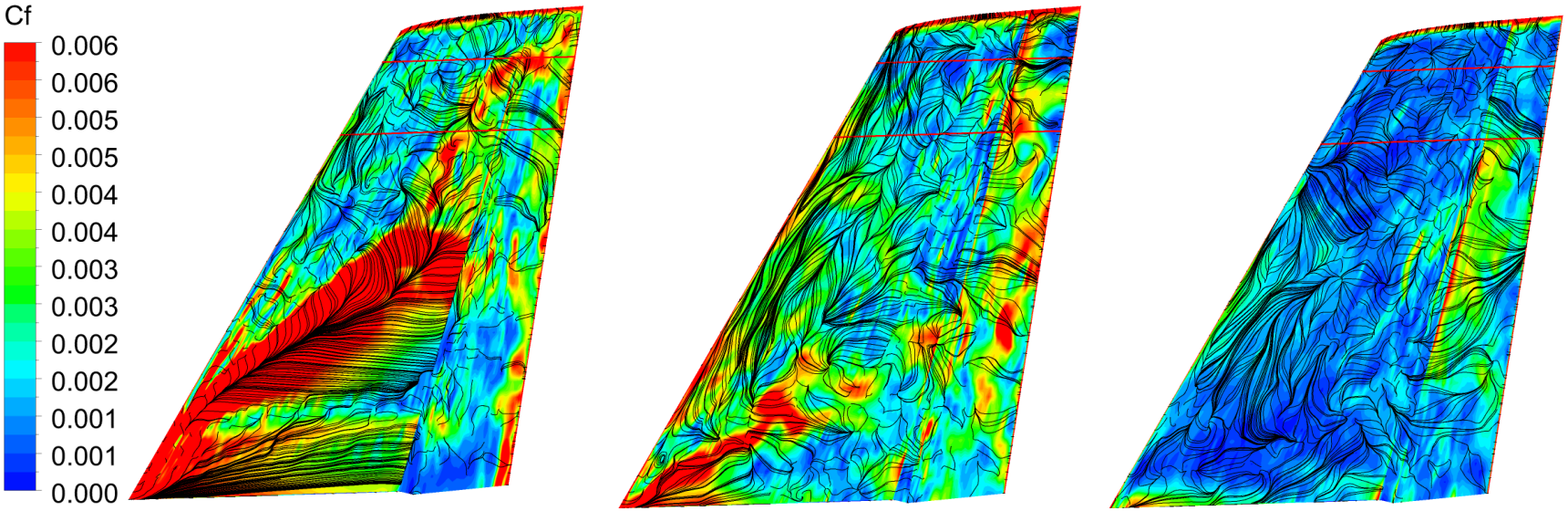
C_p distributions at the rudder angle $\delta = 30°$



$\beta = 8°$ $\beta = 14°$ $\beta = 20°$

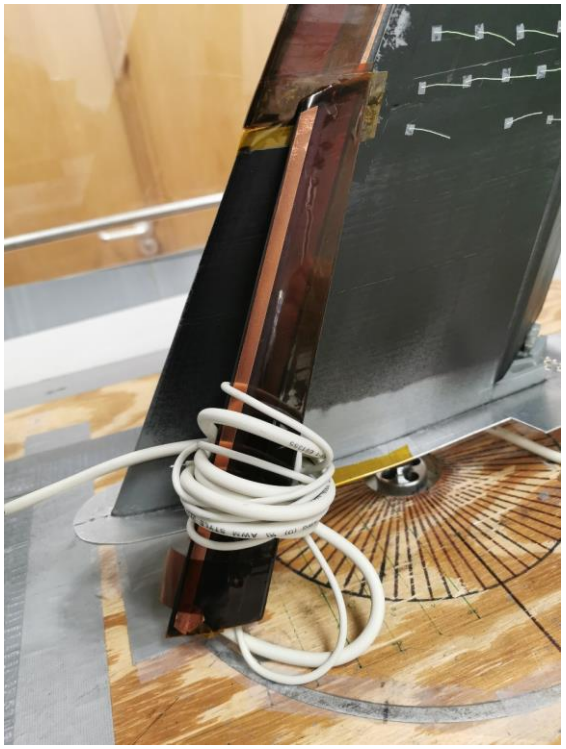
LES results of the baseline

C_f distributions at the rudder angle $\delta = 30°$



$\beta = 8°$ $\beta = 14°$ $\beta = 20°$

Effect of plasma position

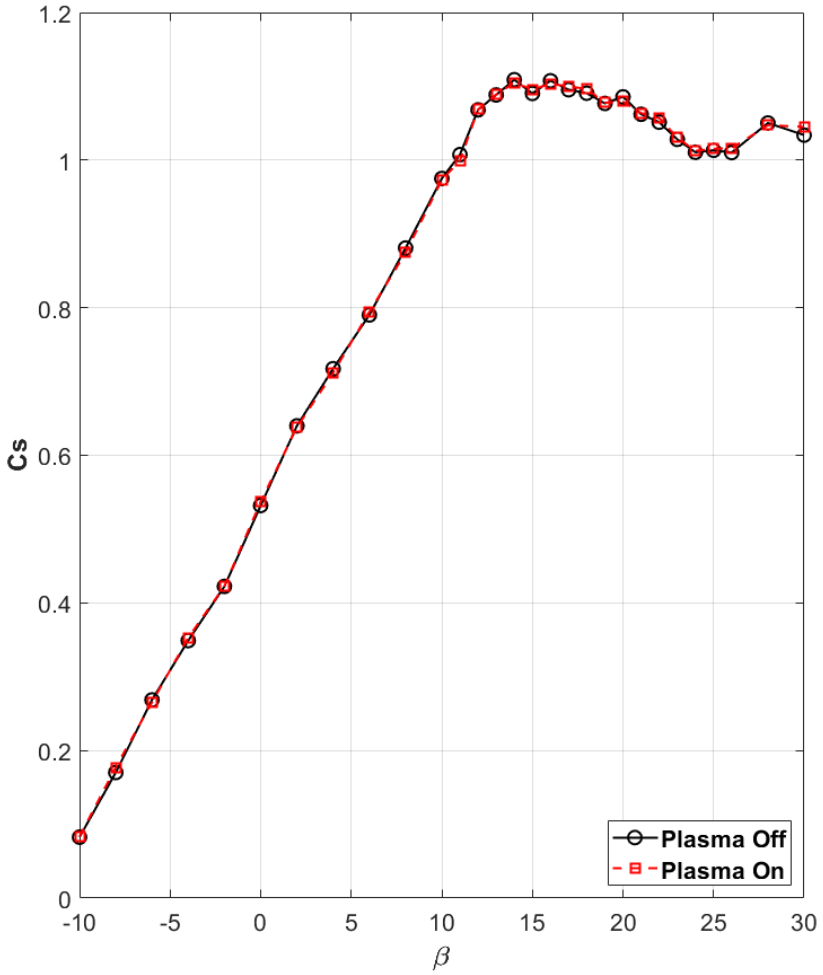


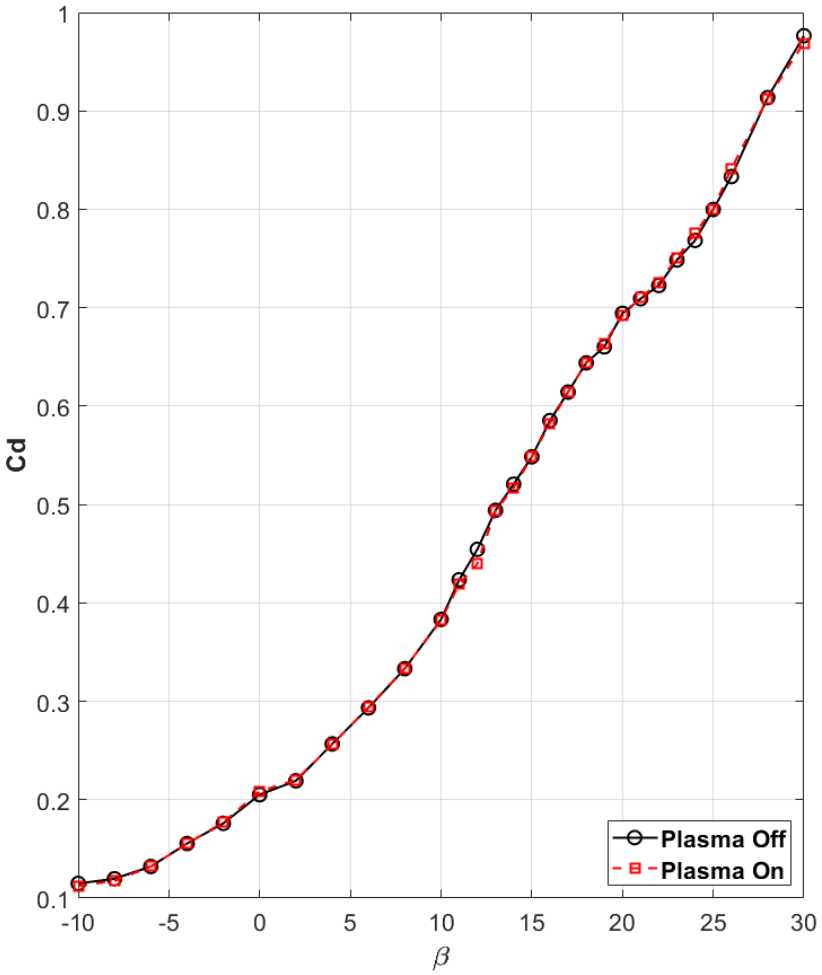
Position of the plasma actuators is critical for flow separation control.

For the leading-edge flow separation control, the plasma actuators must be positioned exactly at the leading edge.

Effect of plasma position

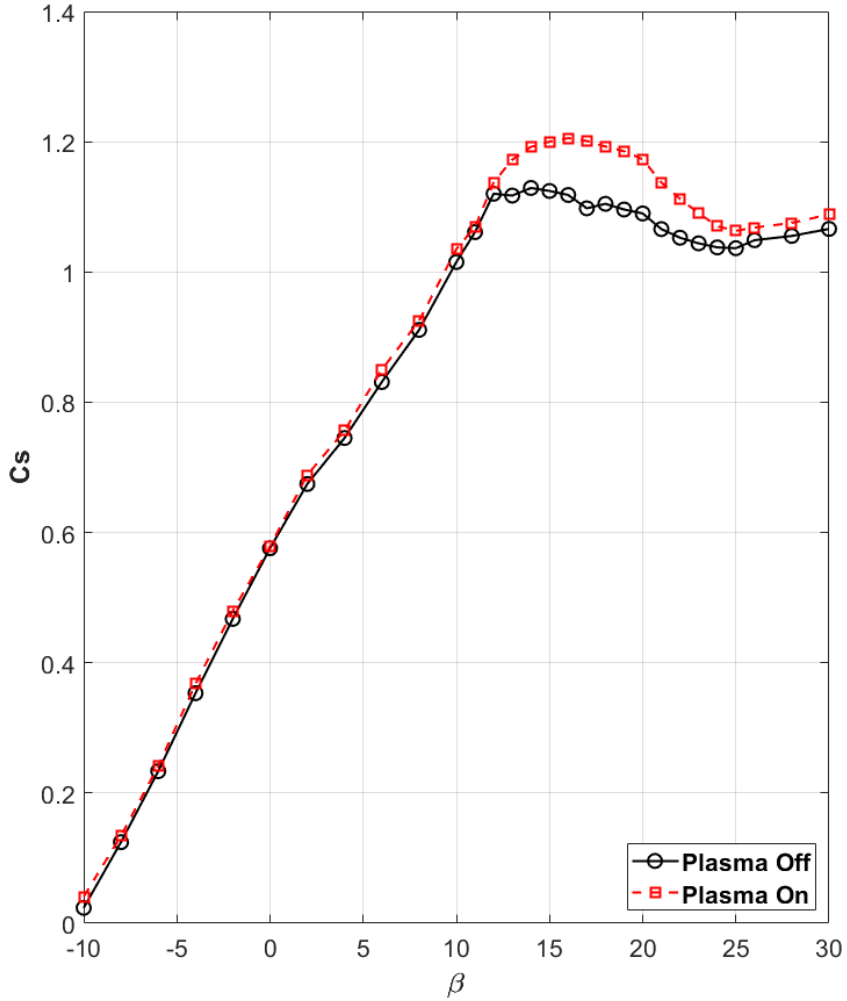
2.5mm off the Leading edge $\delta = 30^{\circ}$

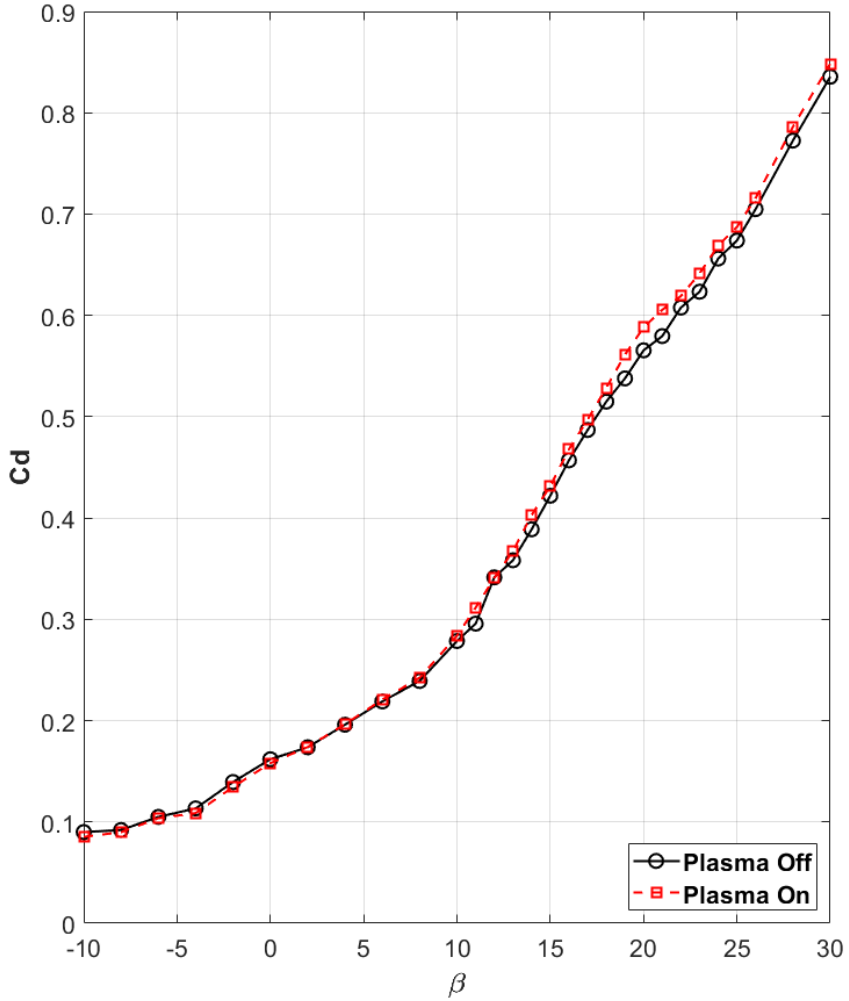




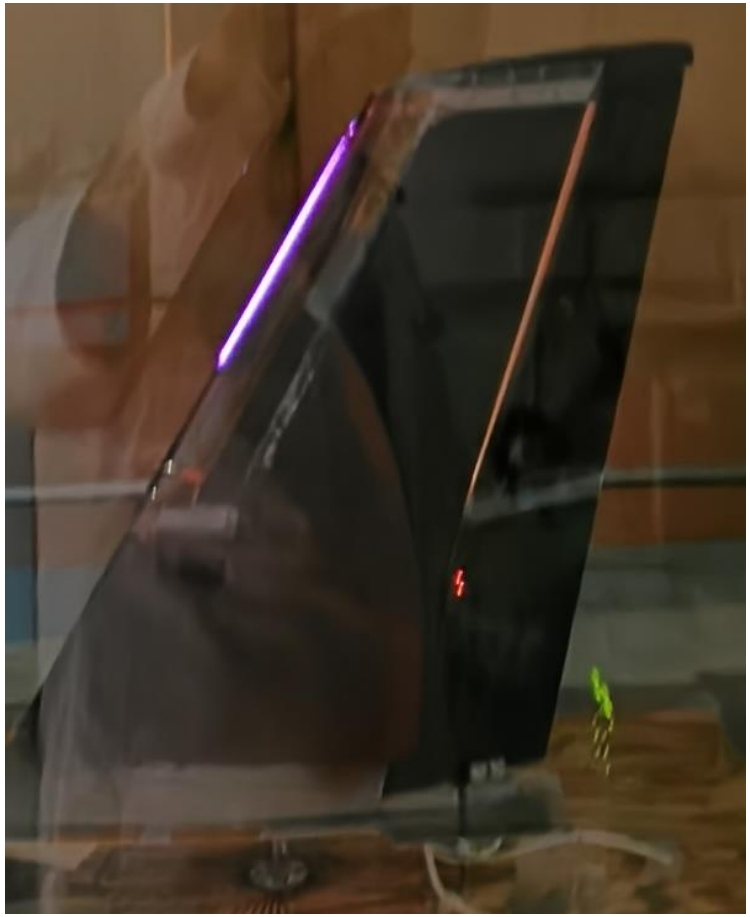
Effect of plasma position

Exactly on the Leading edge $\delta = 30^{\circ}$



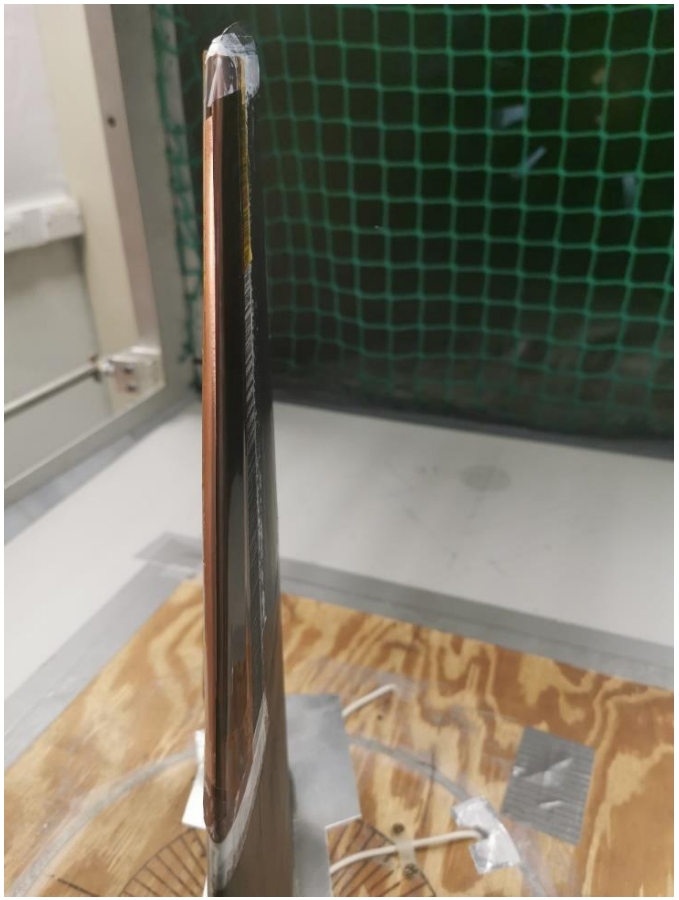


Effect of freestream velocity

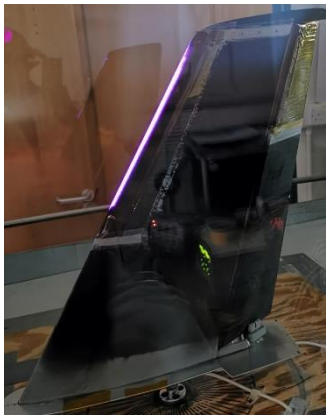


Plasma covers 30% span along the leading edge

Nottingham wind tunnel results



β = 0°



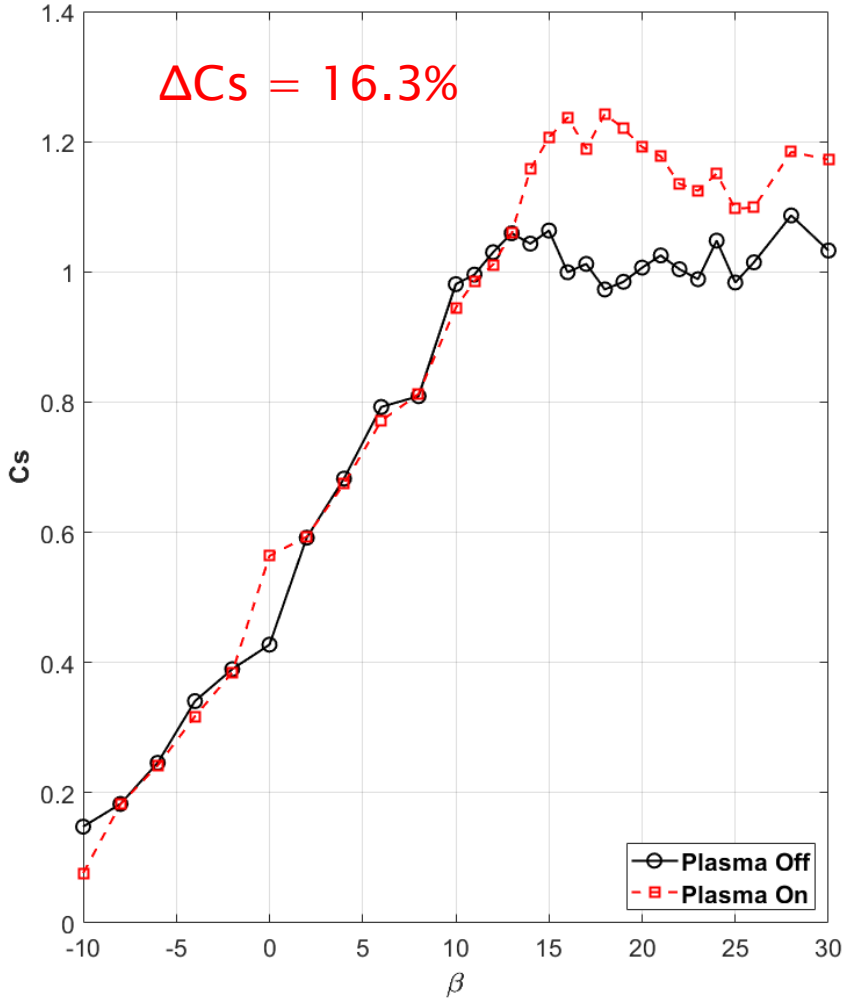
β = 10°

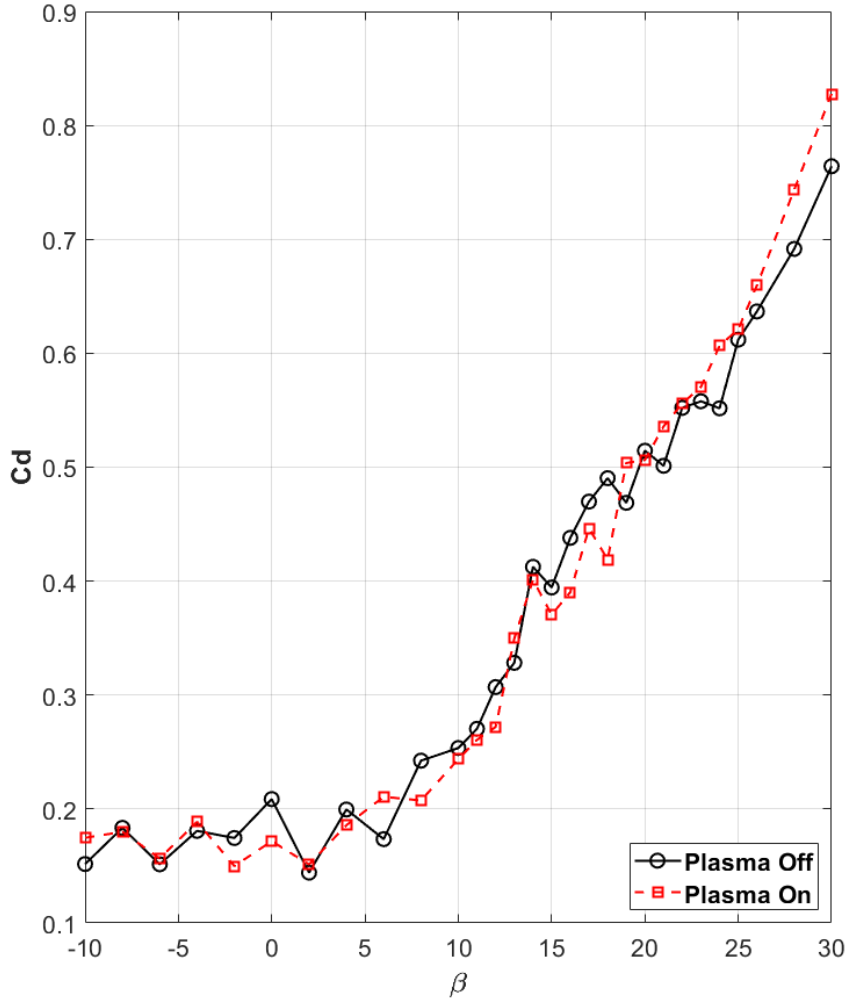
β = 20°

β = 30°

Effect of freestream velocity

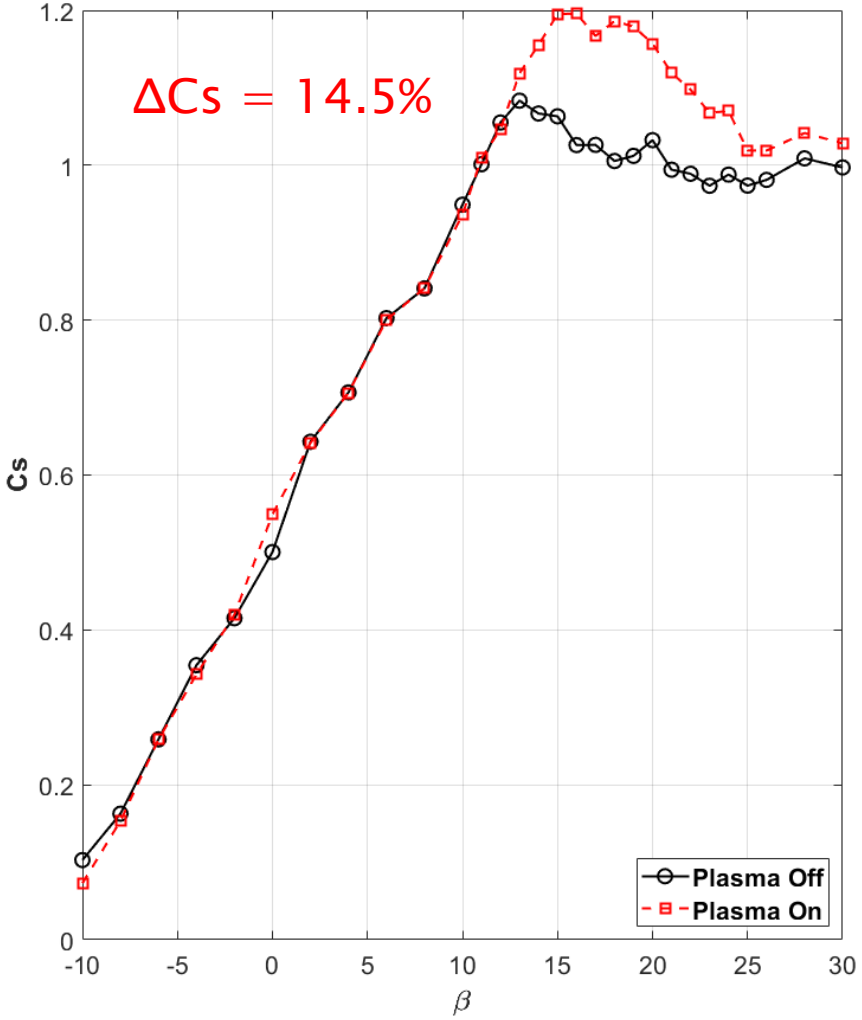
U = 5 m/s $\delta = 30°$

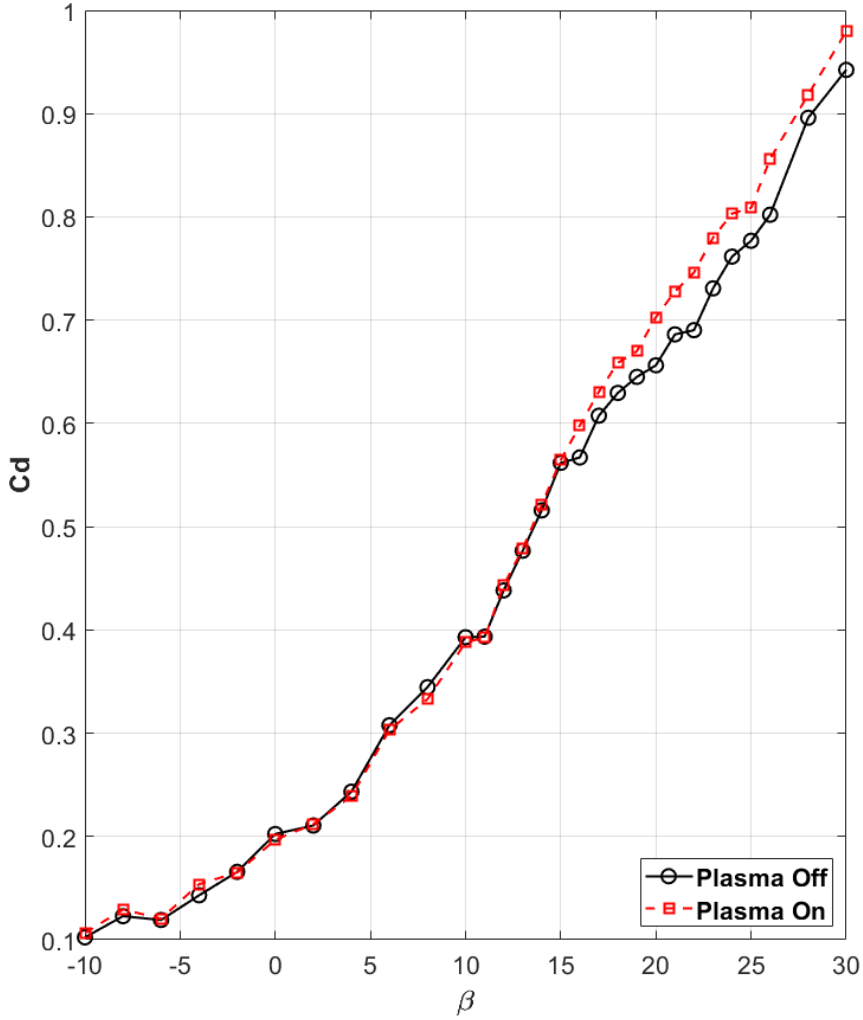




Effect of freestream velocity

U = 7.5 m/s $\delta = 30^{\circ}$

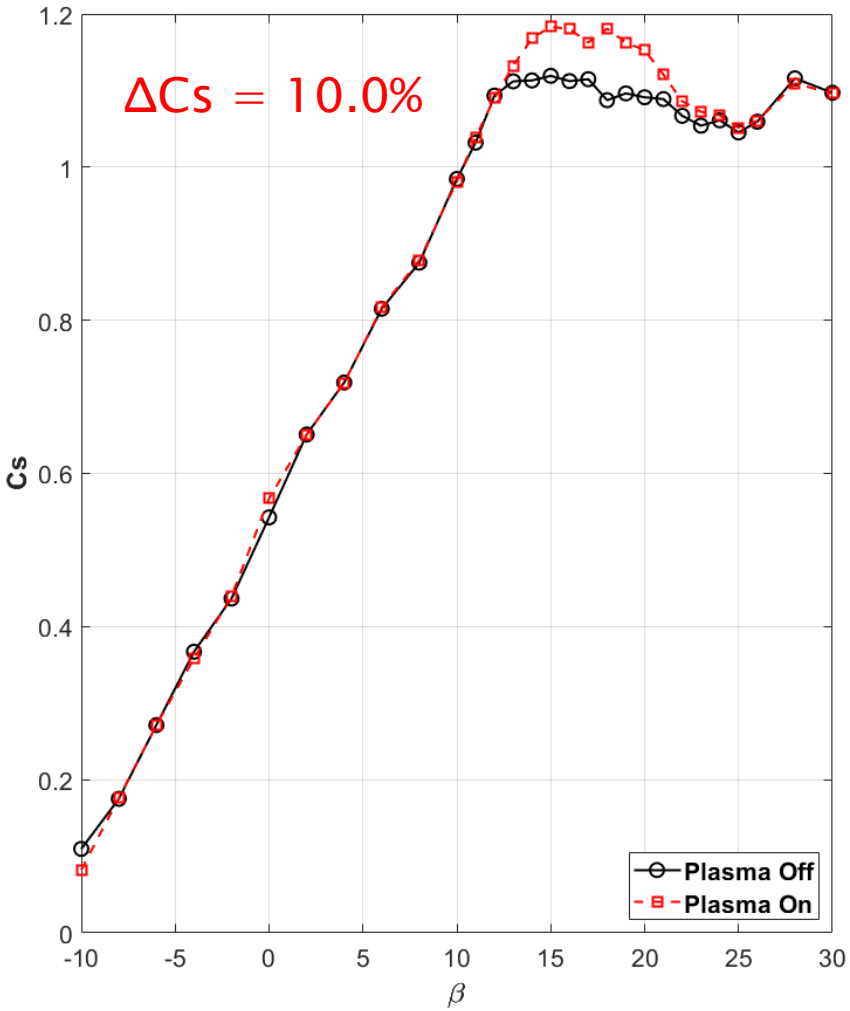


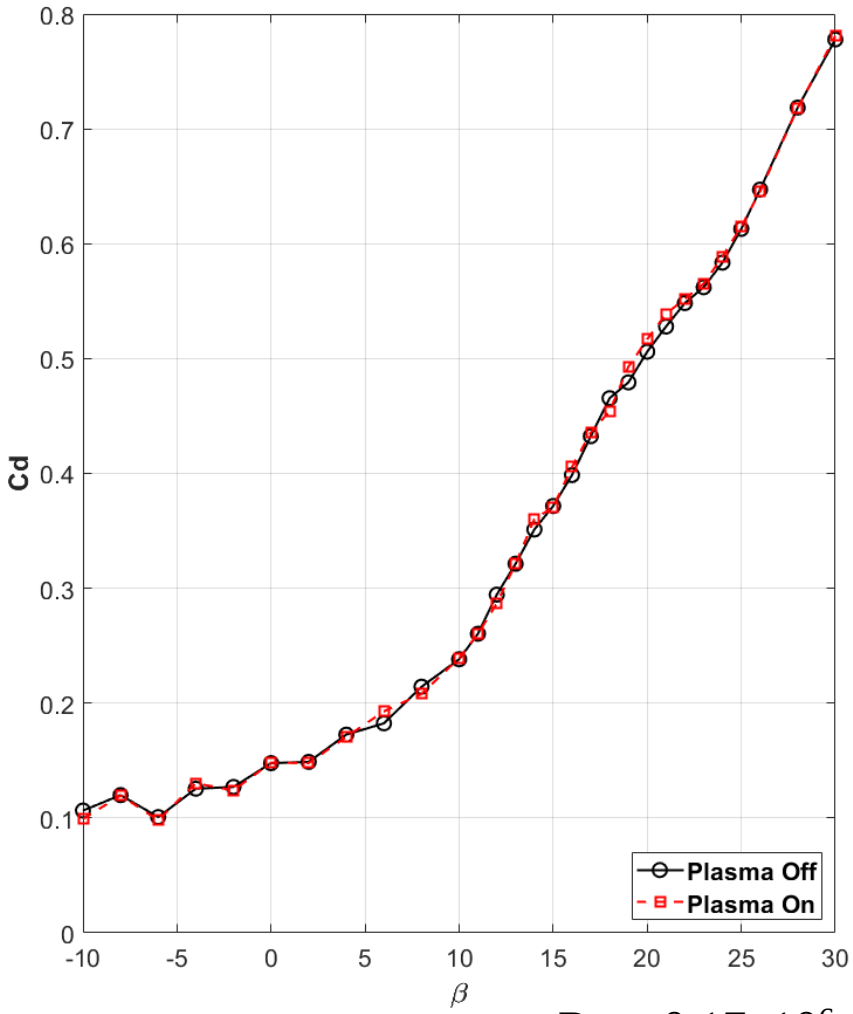


Effect of freestream velocity

U = 10 m/s

$\delta = 30^{\circ}$

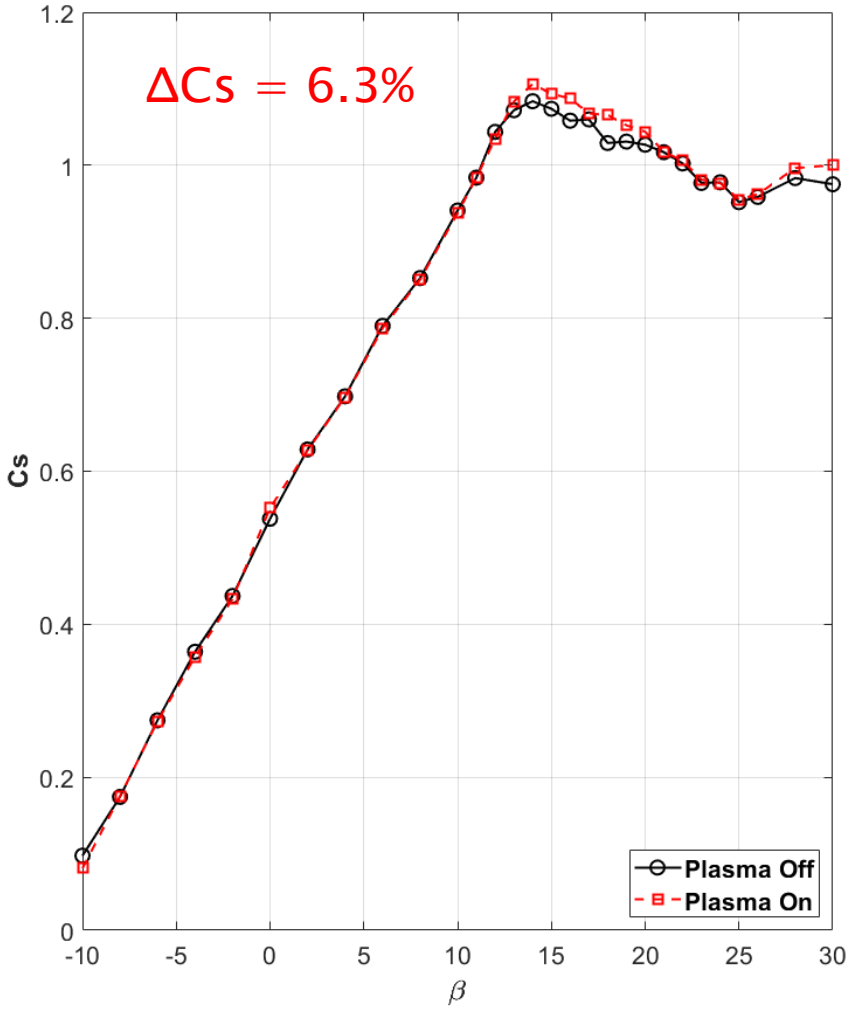


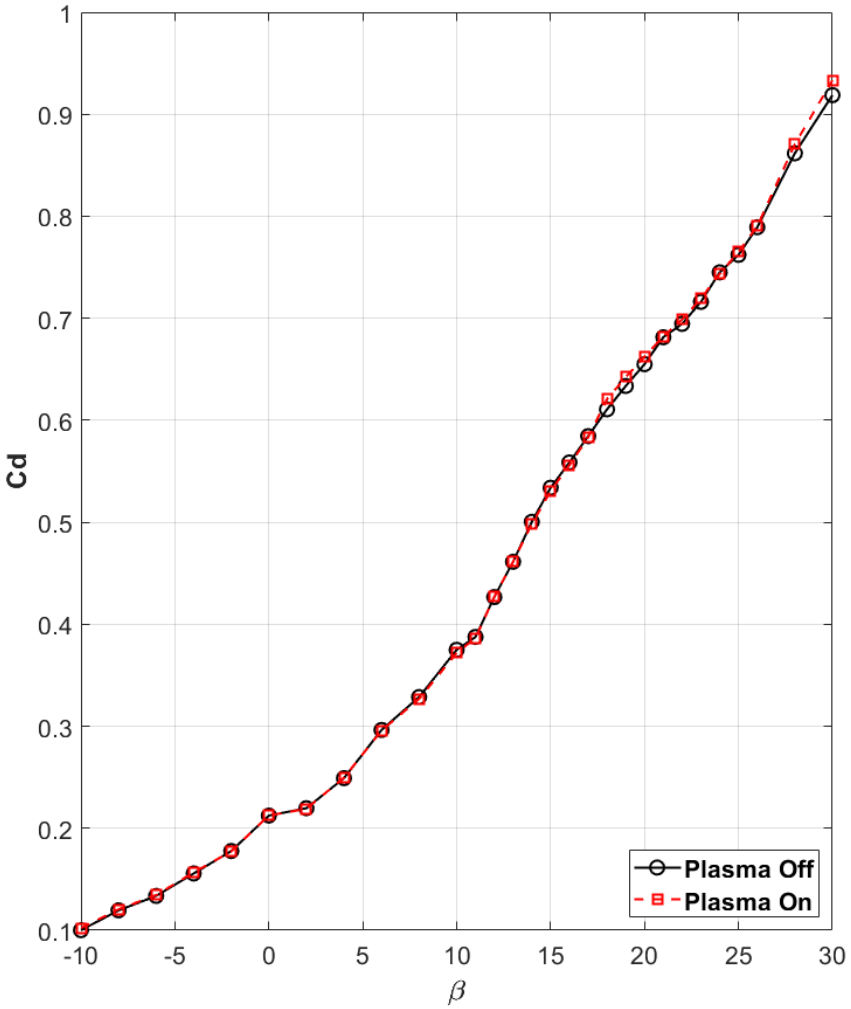


Re = 0.17×10^{6}

Effect of freestream velocity

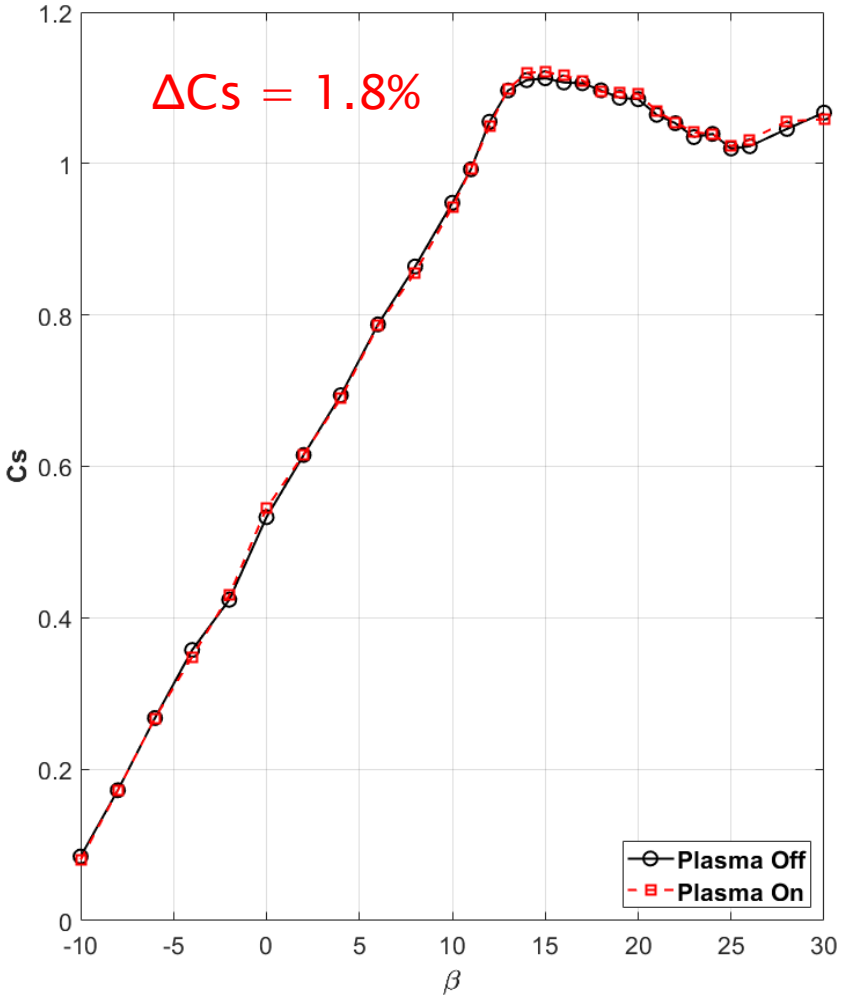
U = 12.5 m/s $\delta = 30^{\circ}$

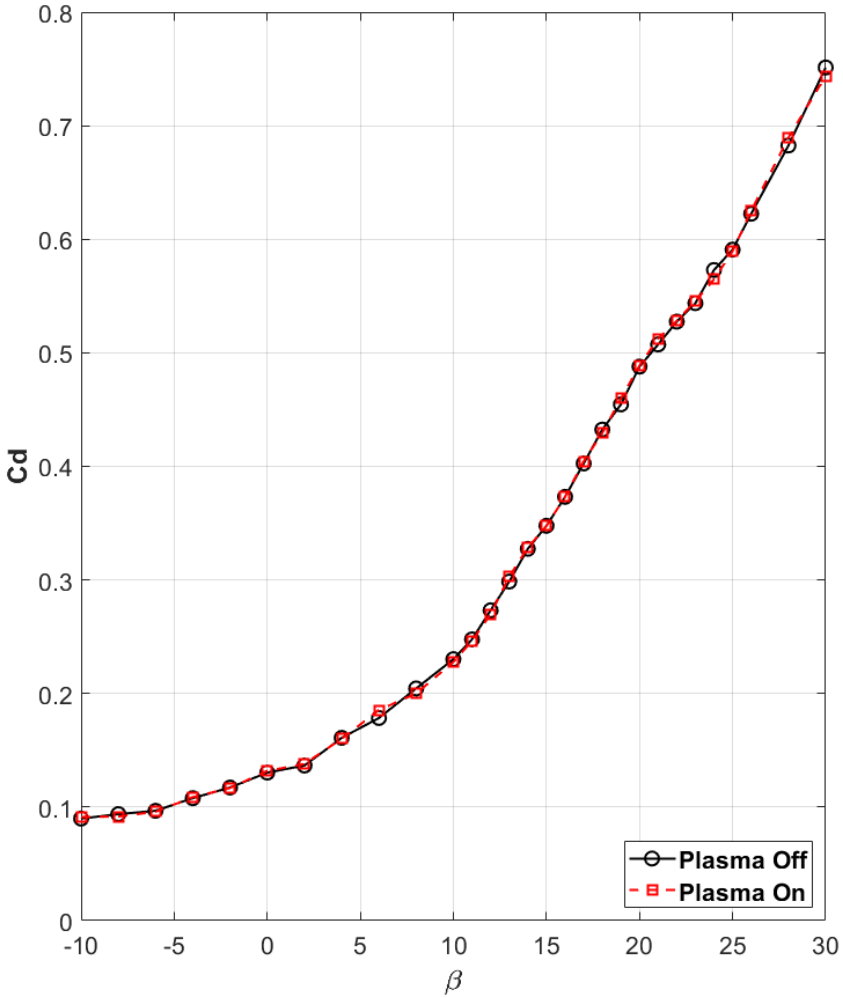




Effect of freestream velocity

U = 15 m/s $\delta = 30^{\circ}$

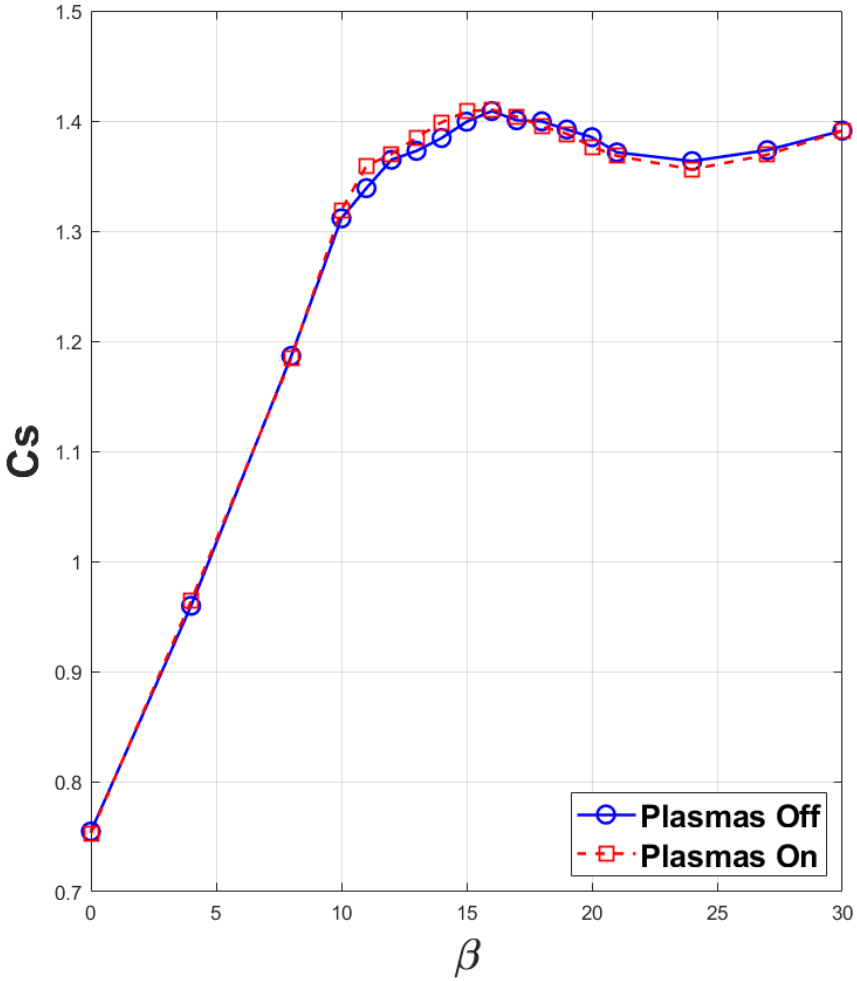


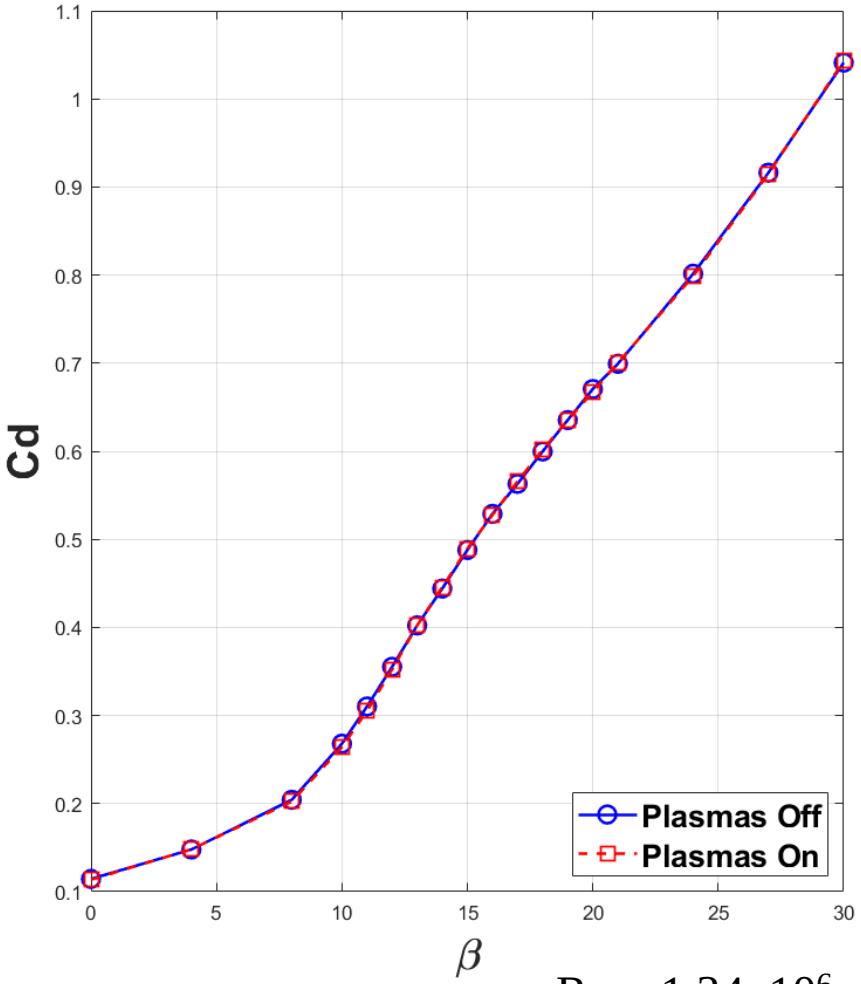


Glasgow wind tunnel results

Glasgow wind tunnel results

U = 20 m/s $\delta = 30^{\circ}$

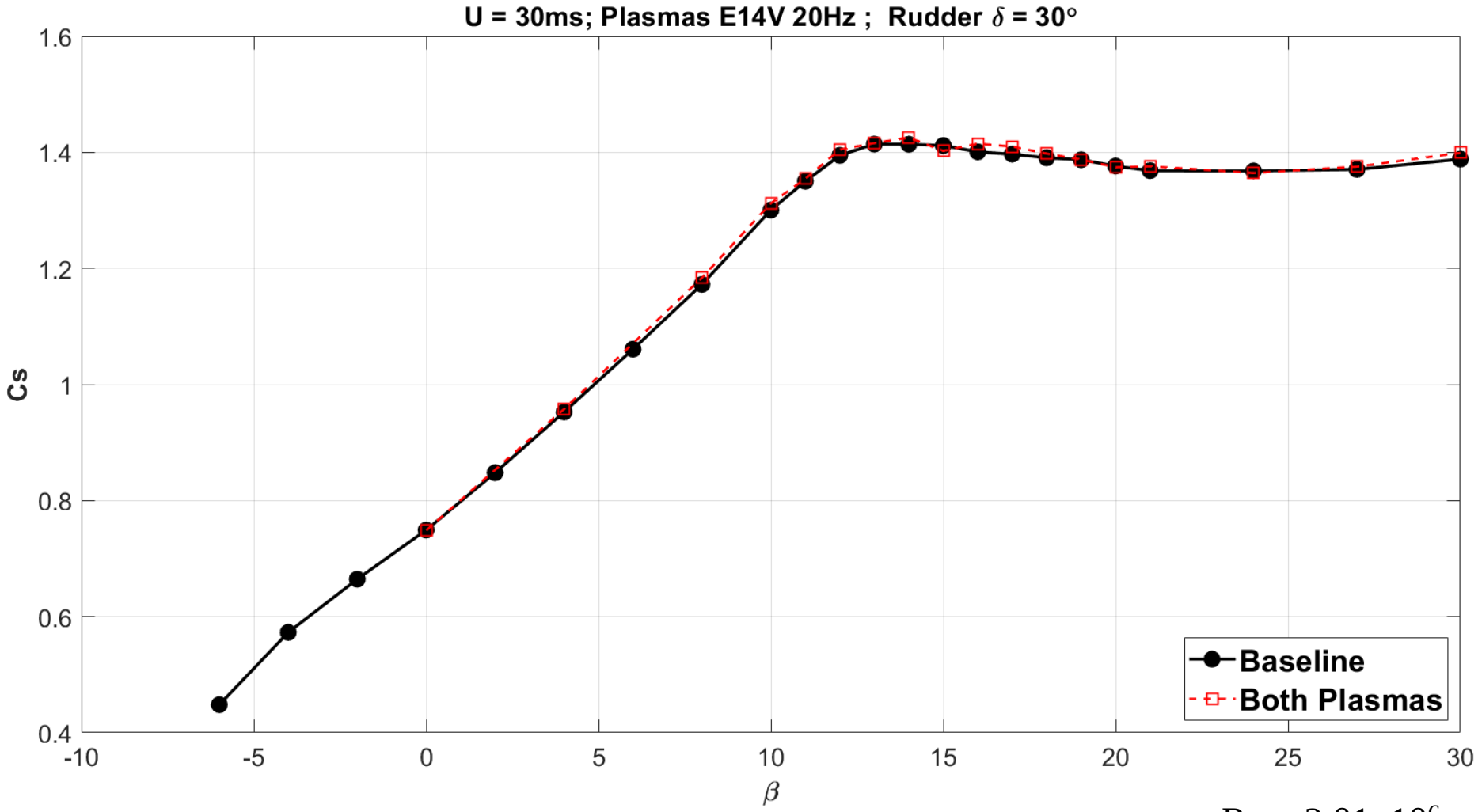




Re = 1.34×10^{6}

Glasgow wind tunnel results

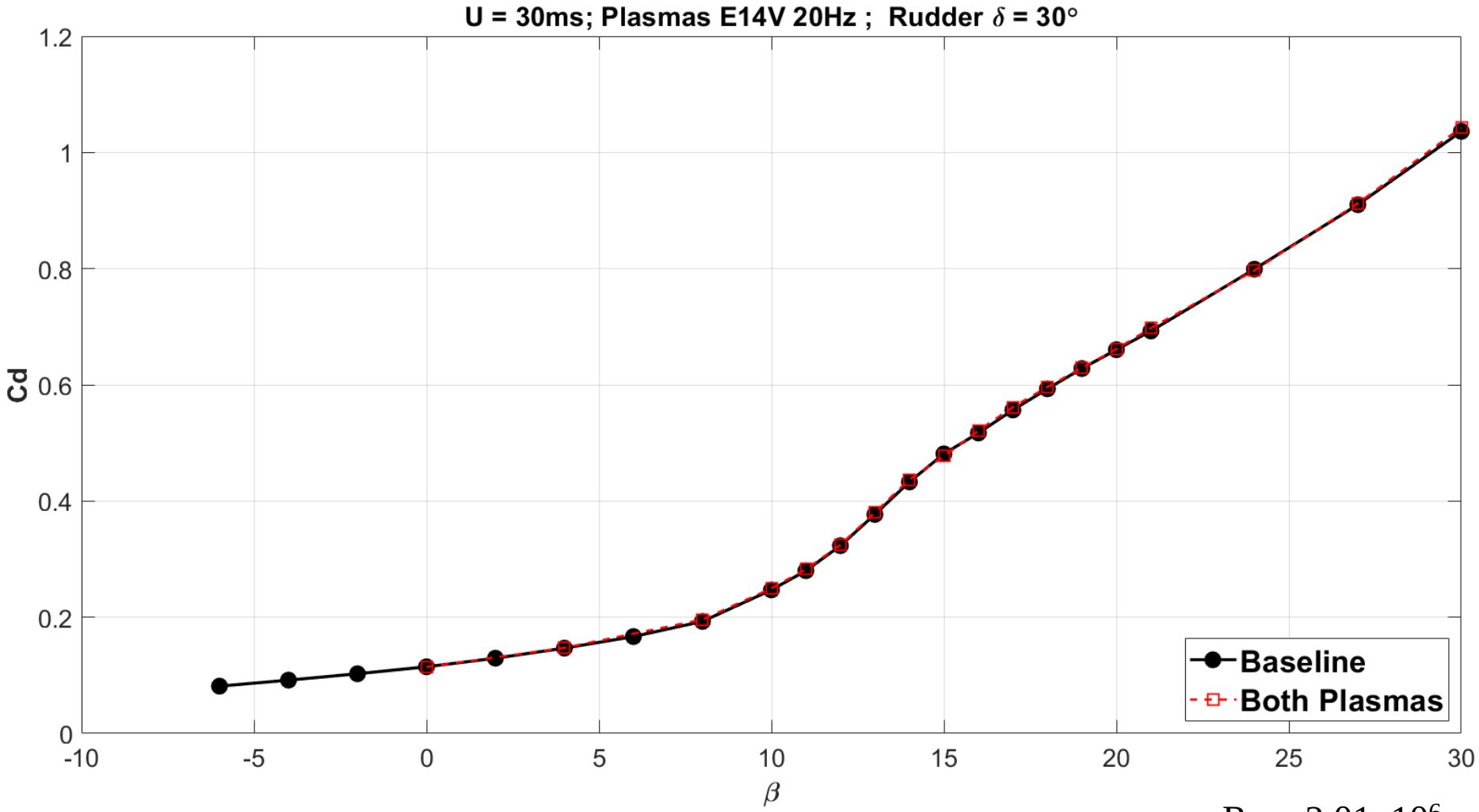
U = 30 m/s **d** = 30°



Re = 2.01×10^6

Glasgow wind tunnel results

U = 30 m/s **d** = 30°



Re = 2.01×10^6

Conclusions

- Important parameter for the flow separation control is the velocity ratio between the plasma induced velocity and the freestream.

- The plasma actuators must be placed at the leading edge to control the LE flow separation.

- There seems to be some effect of leading-edge curvature as well as the plasma discharge length.