LABORATOIRE
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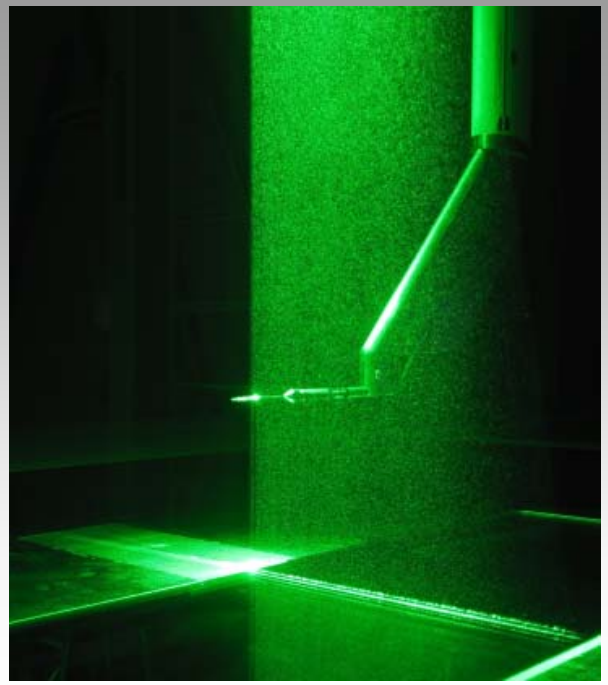
Pressure-velocity correlations in a high Reynolds number turbulent boundary layer



Y. Naka, M. Stanislas, J.M. Foucaut, S. Coudert

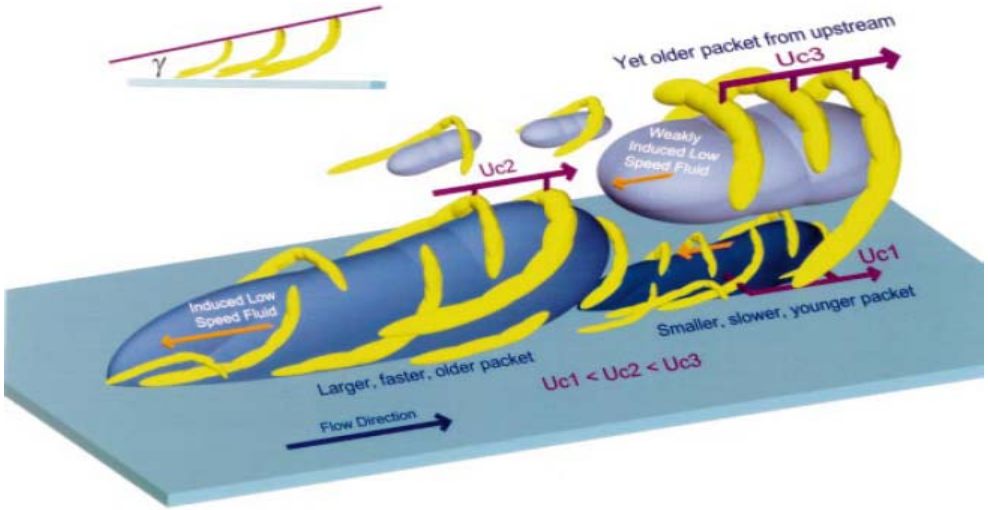
cnrs dépasser les frontières

Université Lille1 Sciences et Technologies

CENTRALE LILLE

ARTS ET MÉTIERS ParisTech

Large scale Coherent Structures

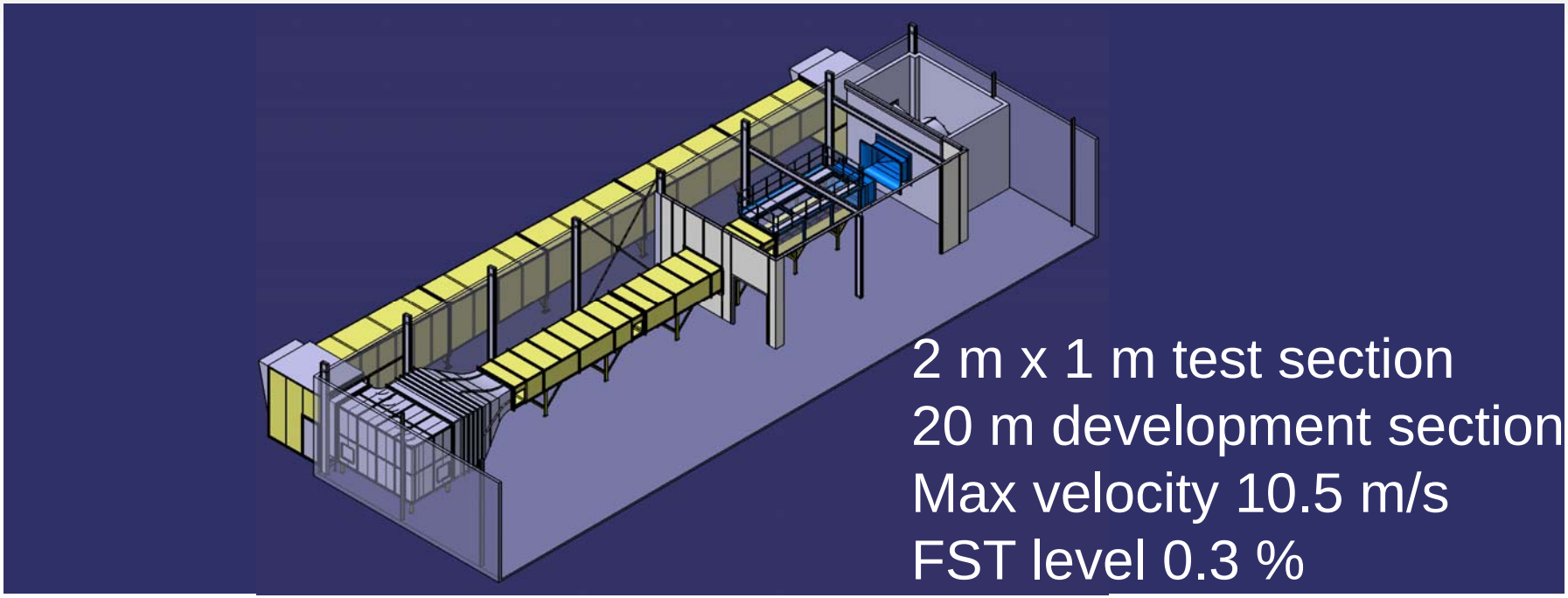


Conceptual model of hairpin packets

Adrian et al. (2000, JFM)

How does the wall and field pressure correlate with velocity ?
How does it relate to coherent structures ?

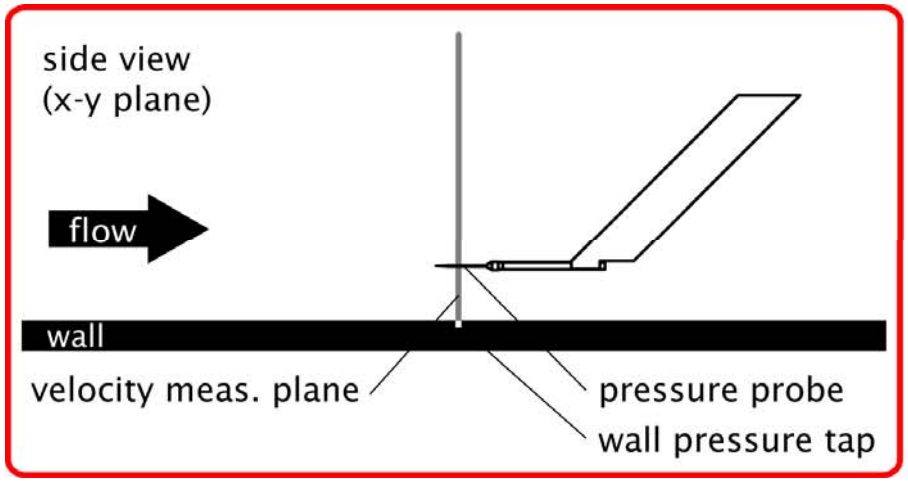
LML wind-tunnel

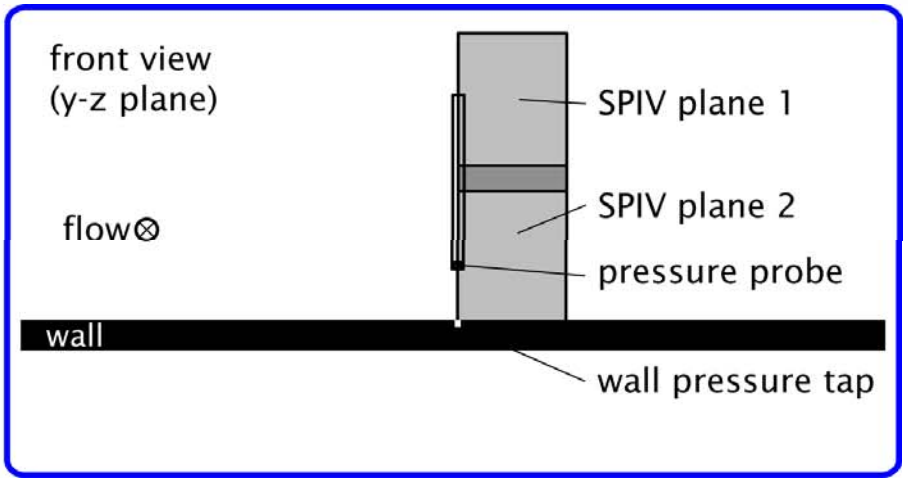


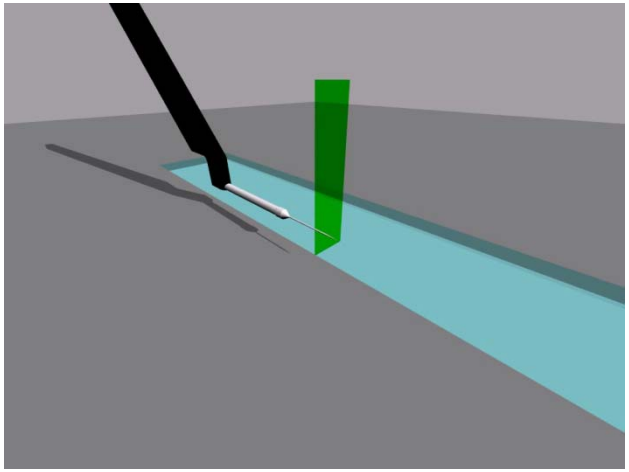
2 m x 1 m test section
20 m development section
Max velocity 10.5 m/s
FST level 0.3 %

U_e $(\mathrm{m\,s^{-1}})$	u_τ $(\mathrm{m\,s^{-1}})$	ν/u_τ $(\mu\mathrm{m})$	δ (m)	δ^+ $-$	θ (m)	R_θ $-$
3	0.111	134	0.33	2 500	0.036	7300
5	**0.186**	**80**	**0.28**	**3 500**	**0.029**	**10 000**
10	0.350	45	0.285	6 400	0.028	18 000

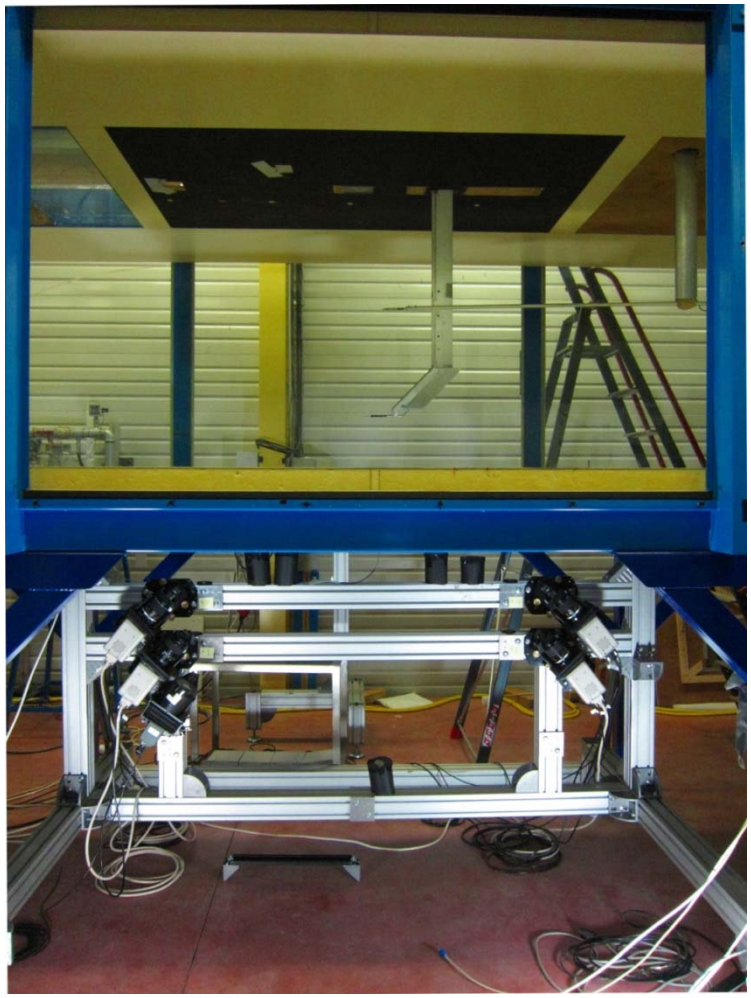
Experimental set-up

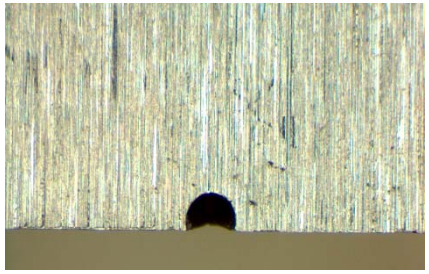






Experimental set-up



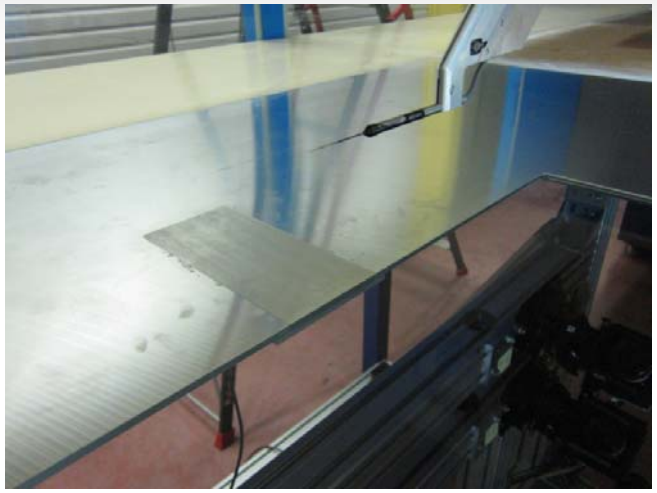


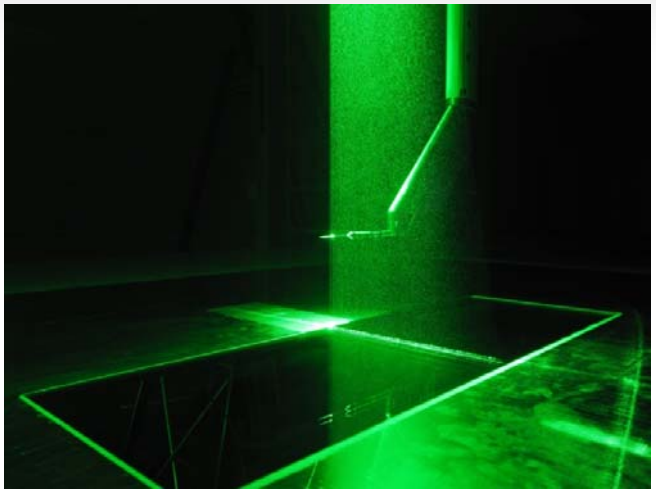
Wall tap $\Phi = 0.5$ mm

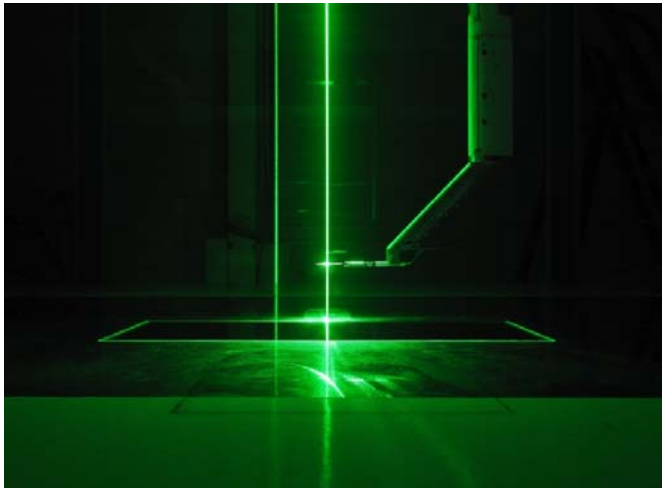
$\Phi = 1.0$ mm

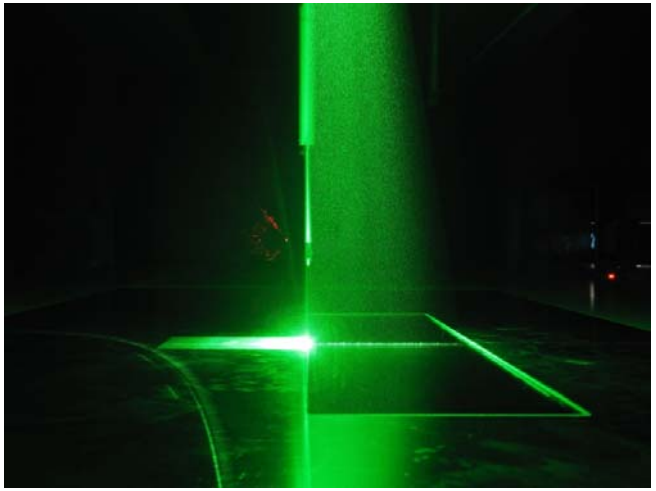
$\Phi = 0.4$ mm, 2 holes

View of the experiment



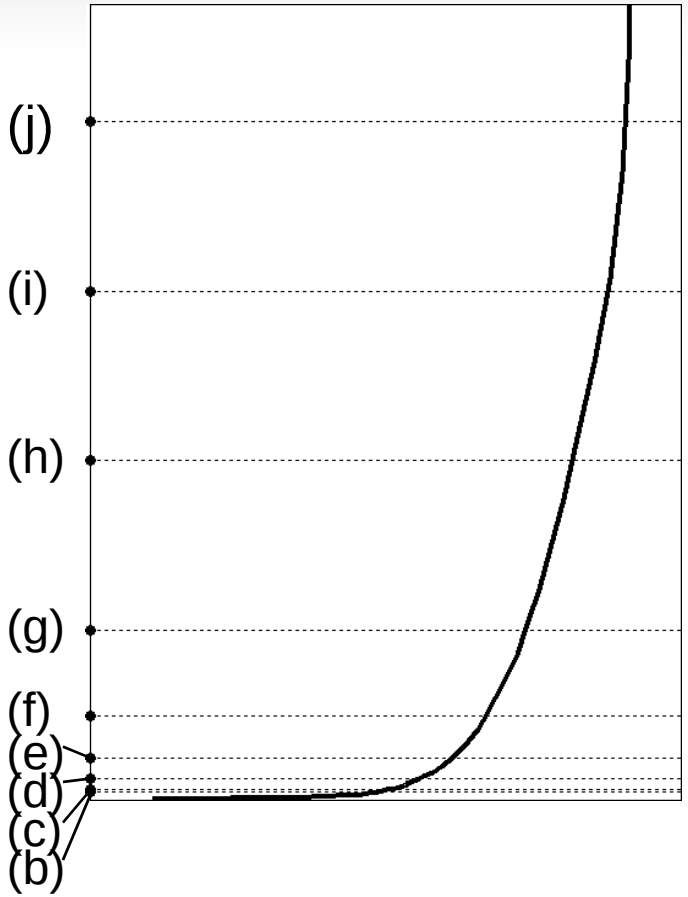






Measurement conditions

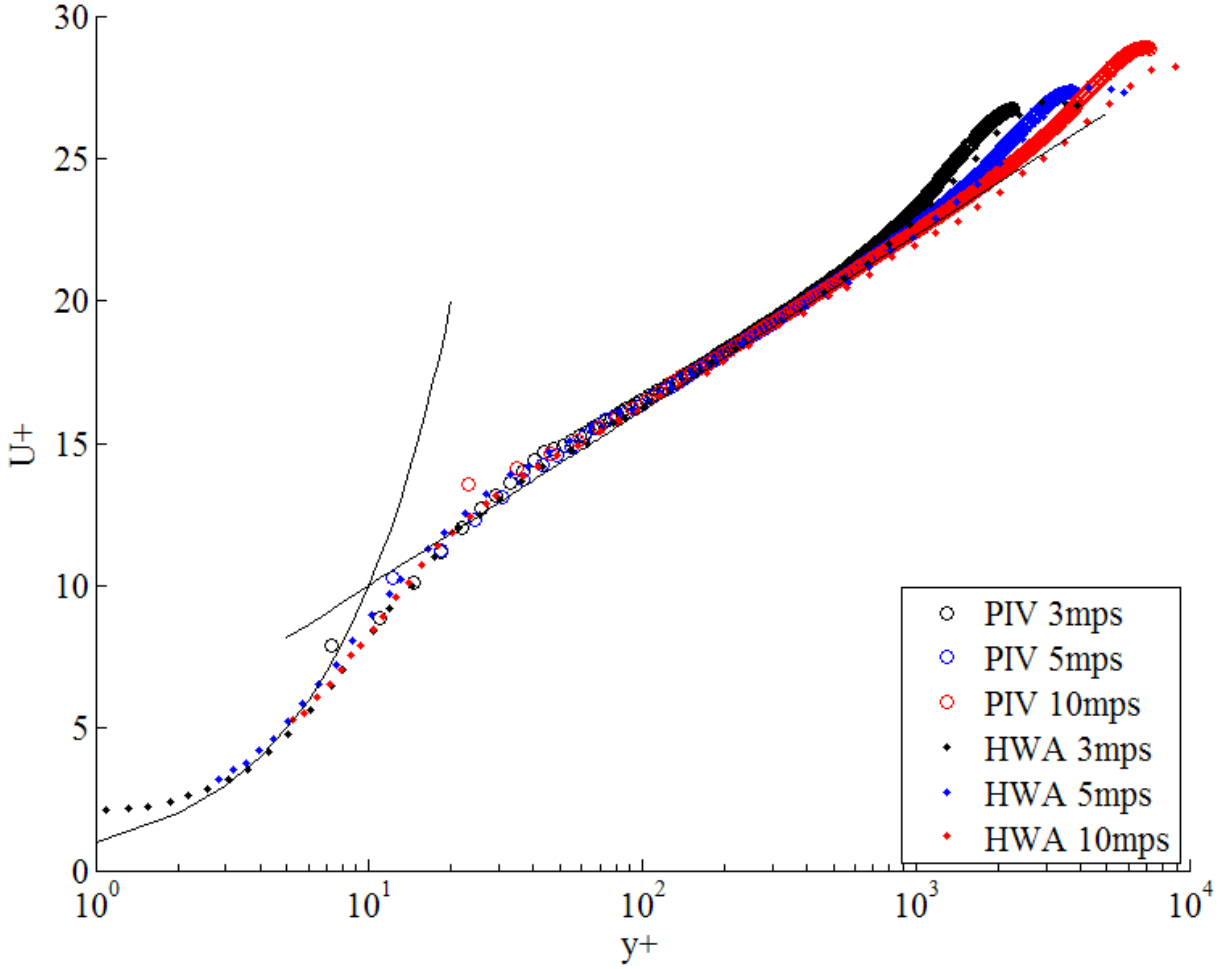
- U_s = 3, 5, 10 m/s
- δ ~ 0.3 m
- Re_θ = 7 300, 10 000, 18 000
- 4 Hz SPIV, 40 kHz pressure
- 10 000 velocity fields
- 9 wall normal pressure probe positions



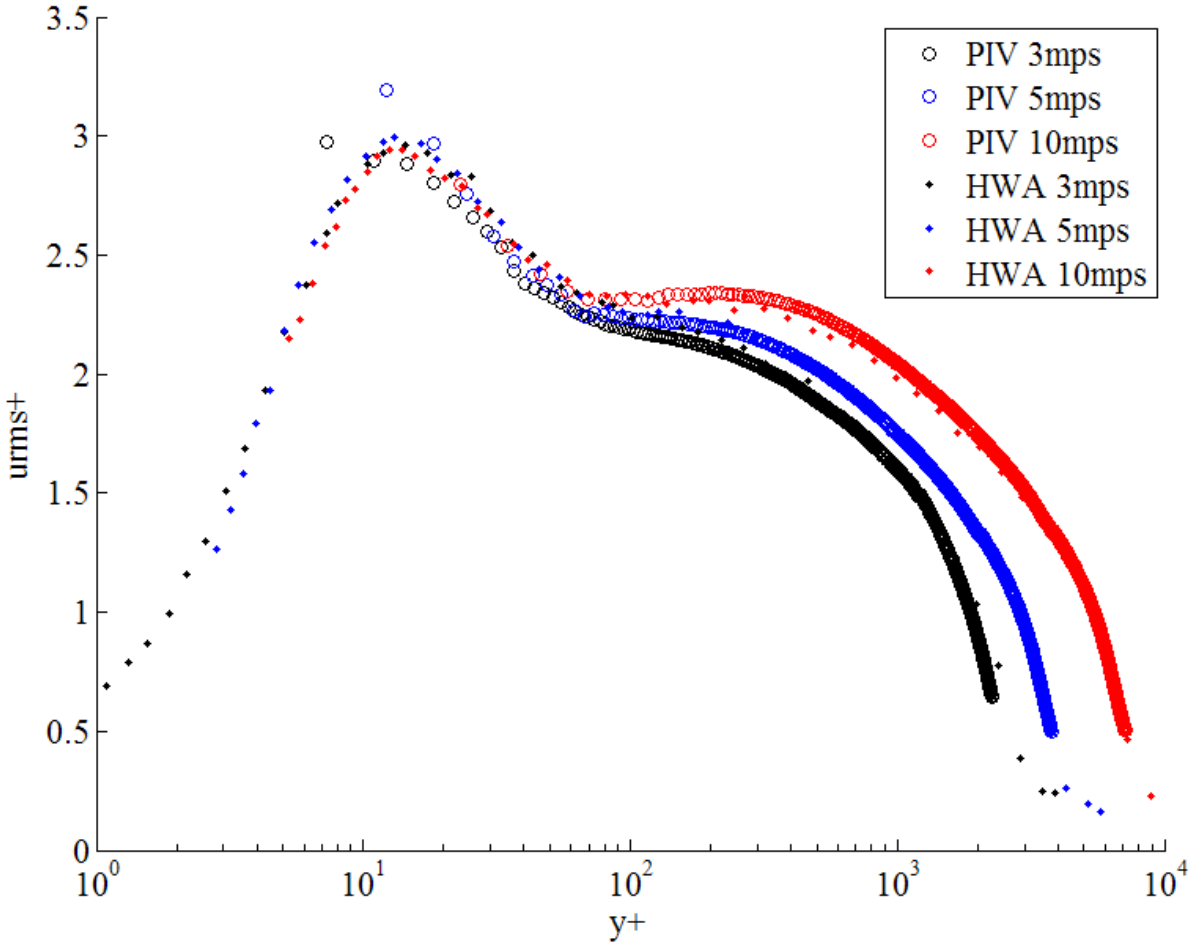
@Re_θ=10 000

#pos	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
y+	0	46	56	117	237	477	959	1921	2883	3846
y/δ	0	0.014	0.016	0.033	0.068	0.14	0.27	0.55	0.82	1.1

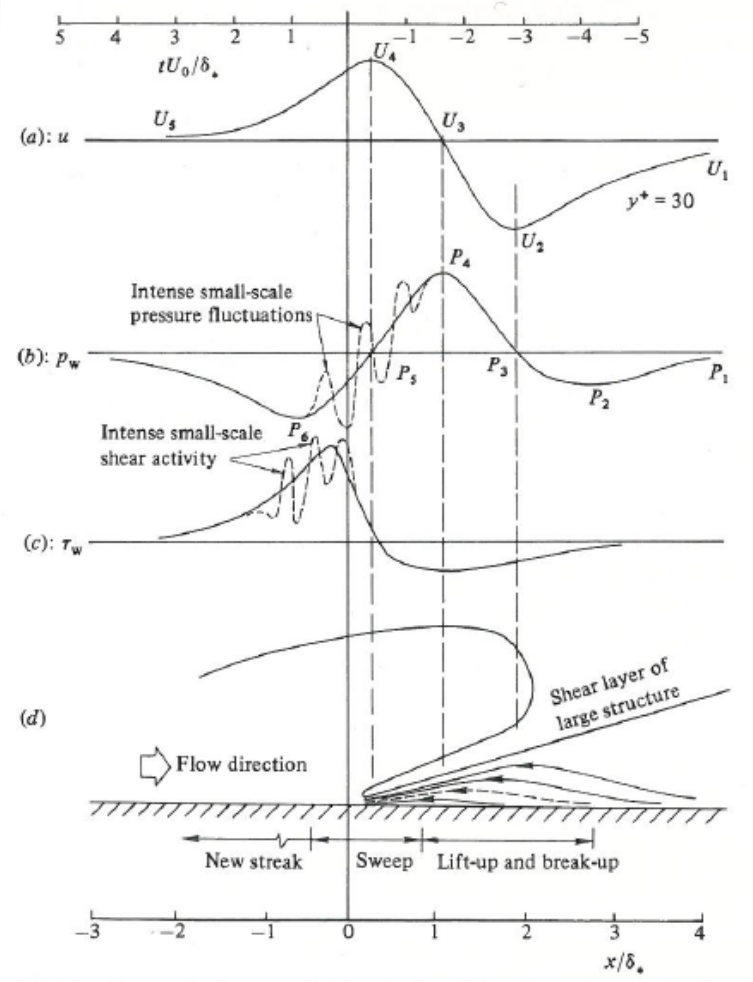
Mean velocity profile

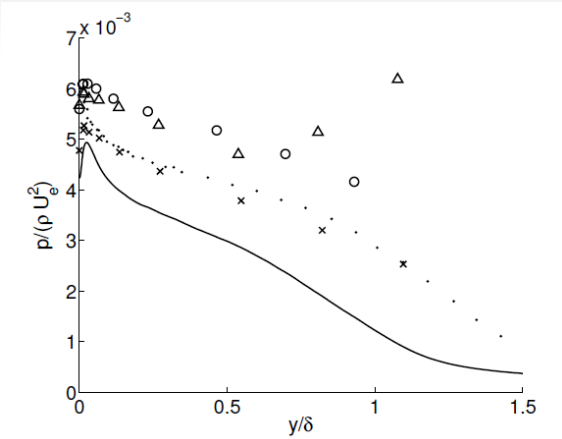


Streamwise velocity fluctuation

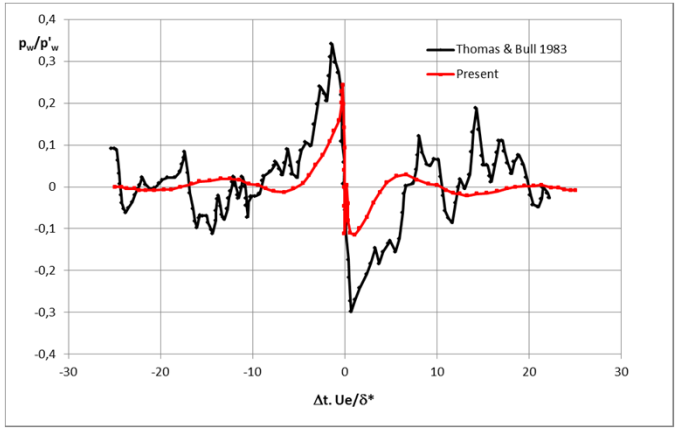


Wall pressure fluctuations





….Tsuji et al. 2007, ---- Schlatter & Orlu 2010



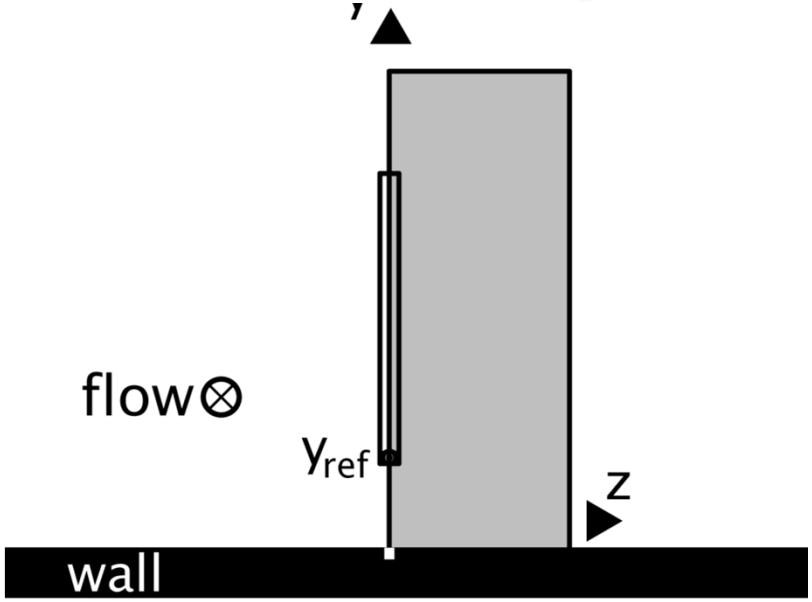
Thomas & Bull 1983

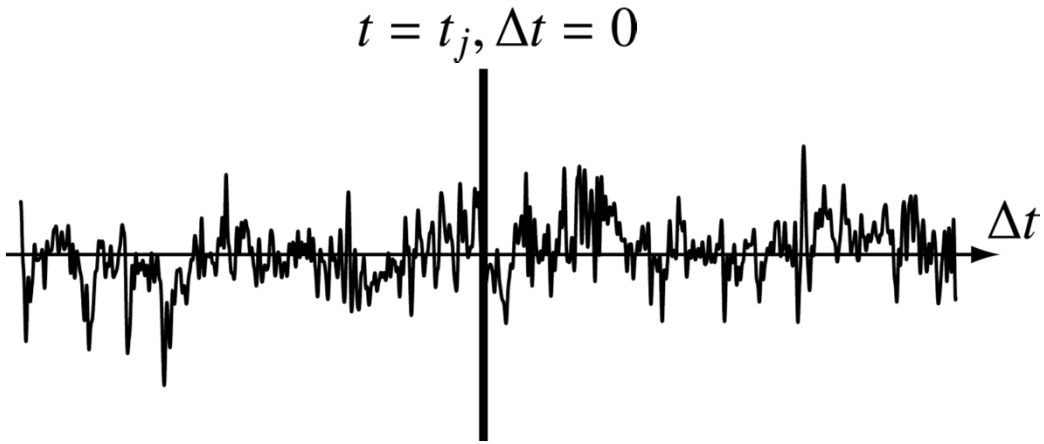
Space-time pressure-velocity correlation

$$R_{pu_i}(\Delta t, y_p, \Delta y, \Delta z) = \overline{p(t+\Delta t, y_p, 0)u_i(t, y_p+\Delta y, \Delta z)}$$

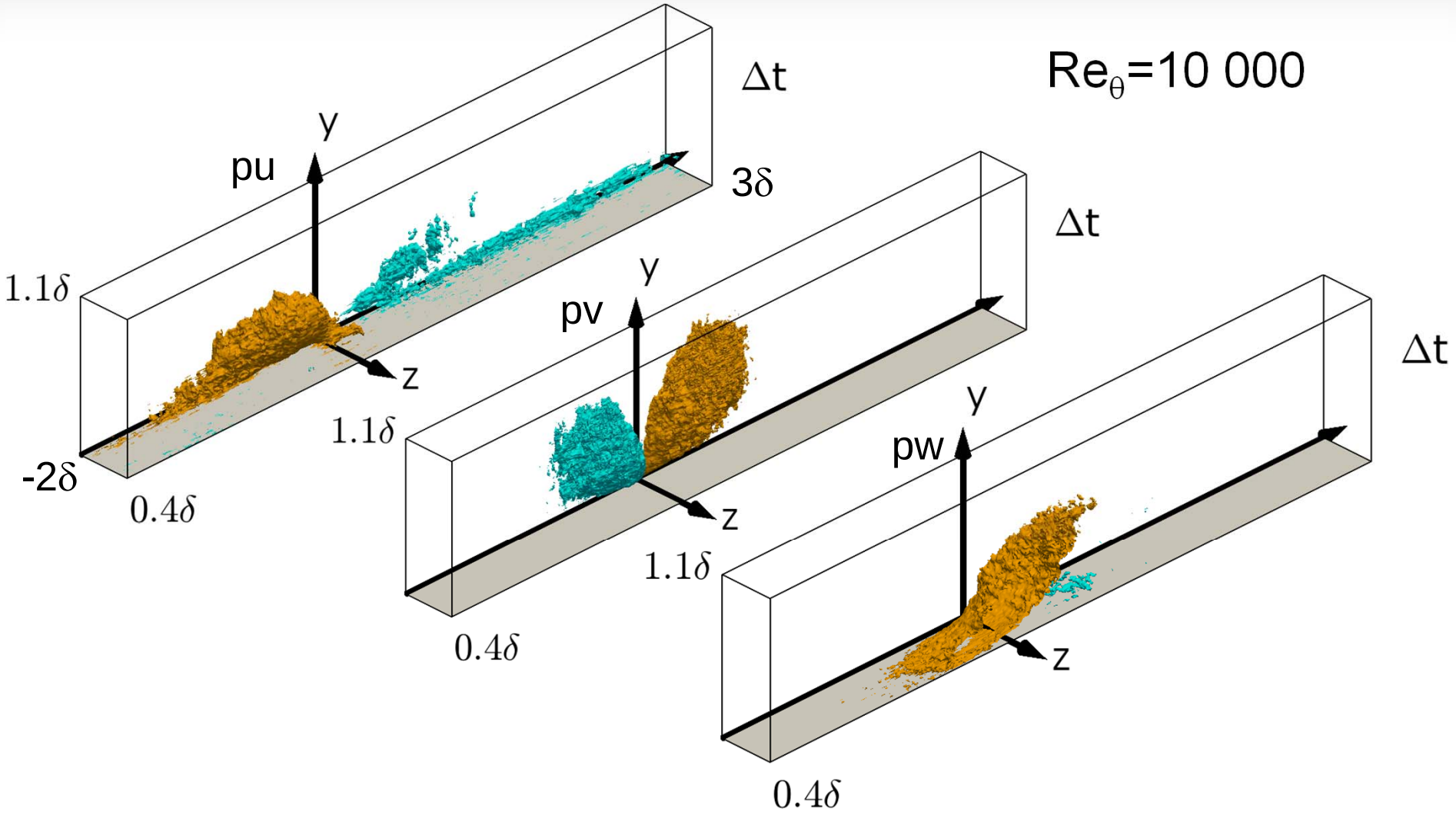
$$= \sum_{j=1}^{N} \{p(t_j+\Delta t, y_p, 0)u_i(t_j, y_p+\Delta y, \Delta z)\}/N$$

t_j : time of SPIV recording

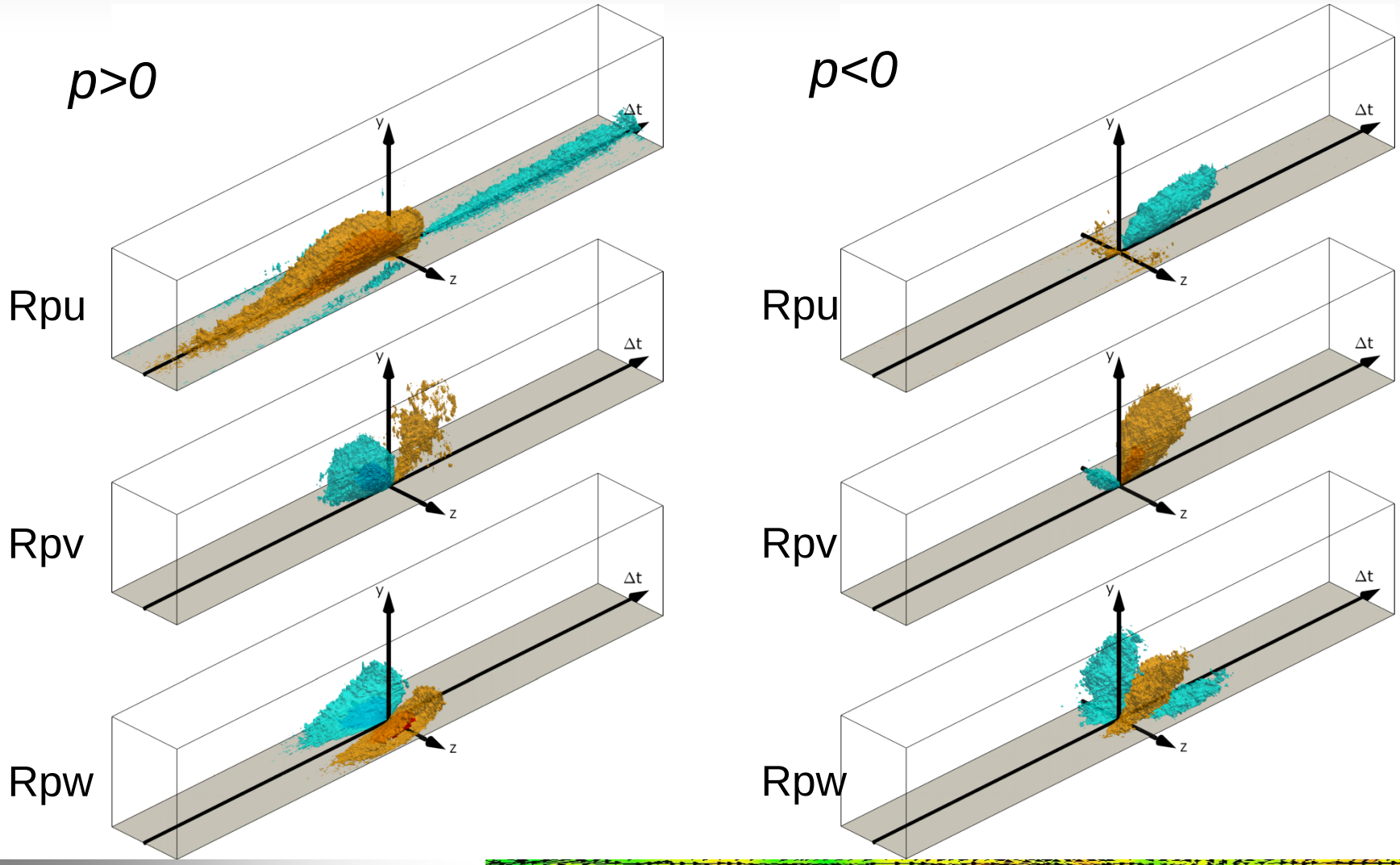




Wall pressure-velocity correlations

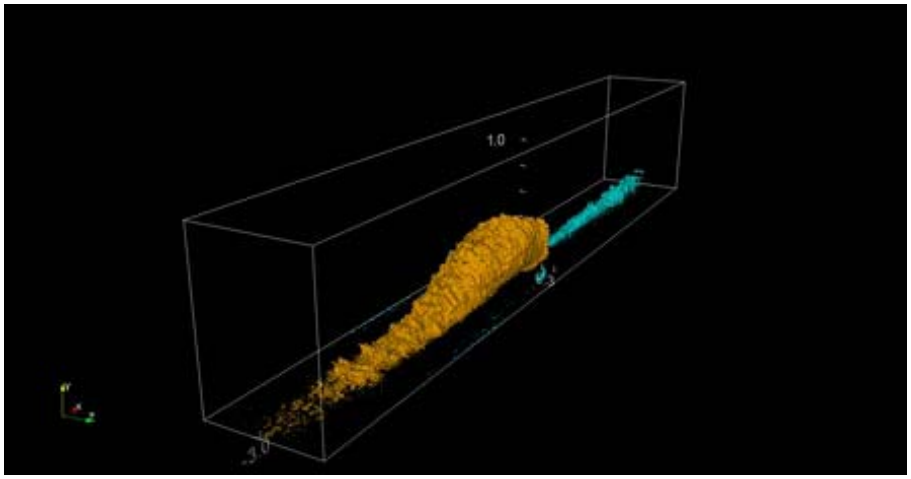


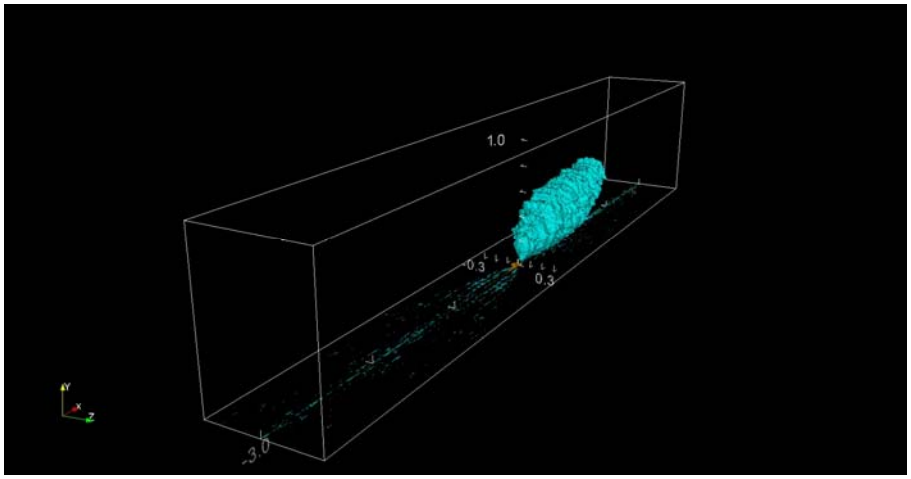
Wall pressure velocity correlations conditioned by the sign of the wall pressure



Wall pressure-velocity correlations

Re_θ=10 000

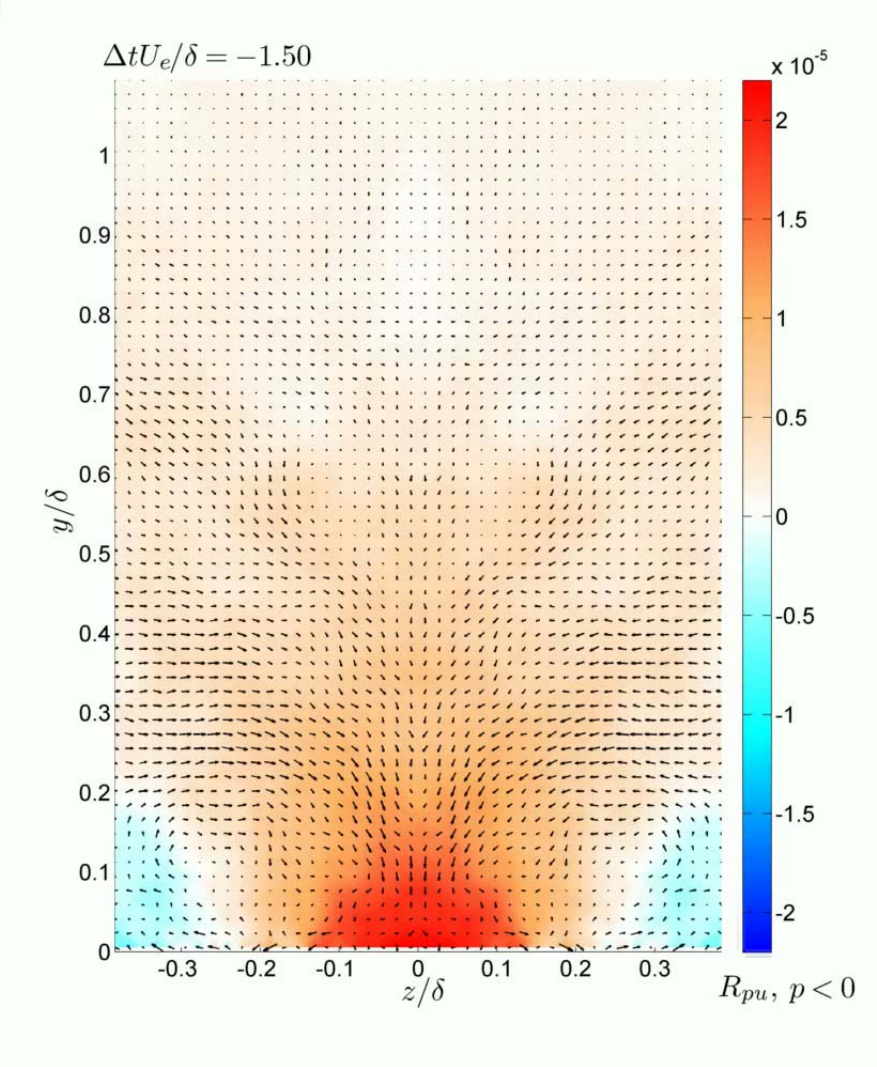




<pu> for p>0

<pu> for p<0

Wall pressure-velocity correlations

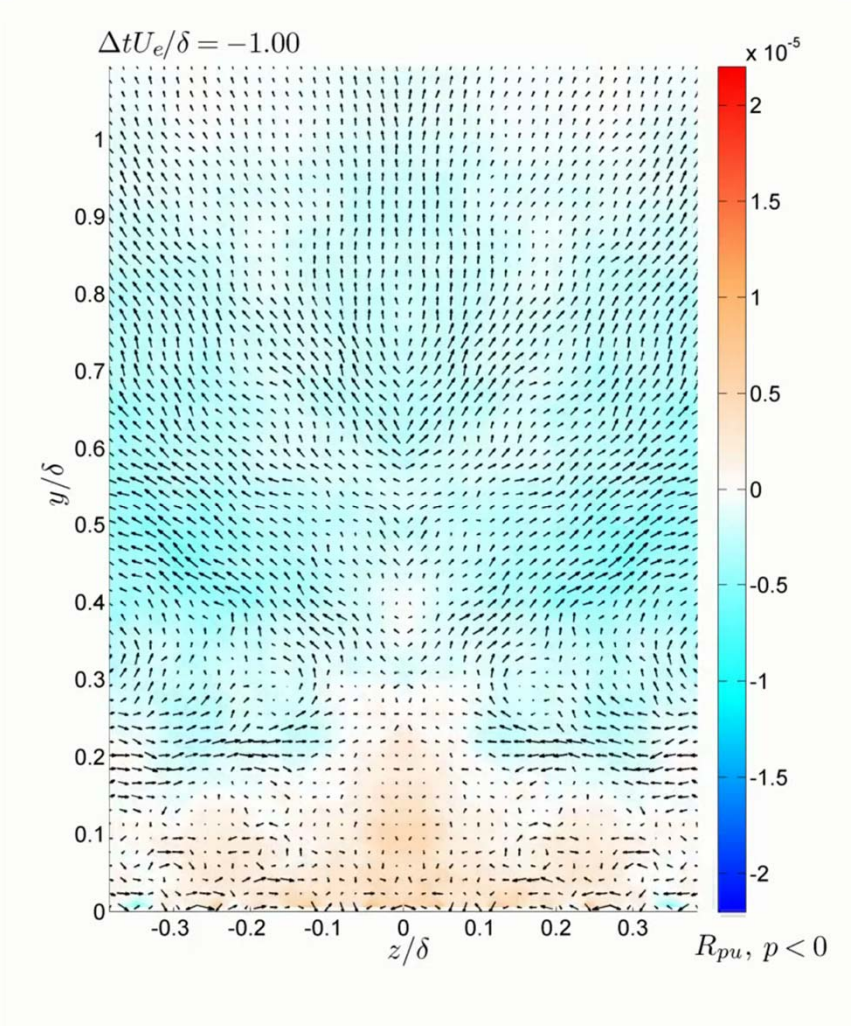


Re_θ=10 000

<pu>, <pv>, <pw>

for p>0

Wall pressure-velocity correlations



Re_θ=10 000

<pu>, <pv>, <pw>

for p<0

Field pressure-velocity correlations

y_p/δ=1.1

y_p/δ=0.82

y_p/δ=0.55

y_p/δ=0.27

y_p/δ=0.14

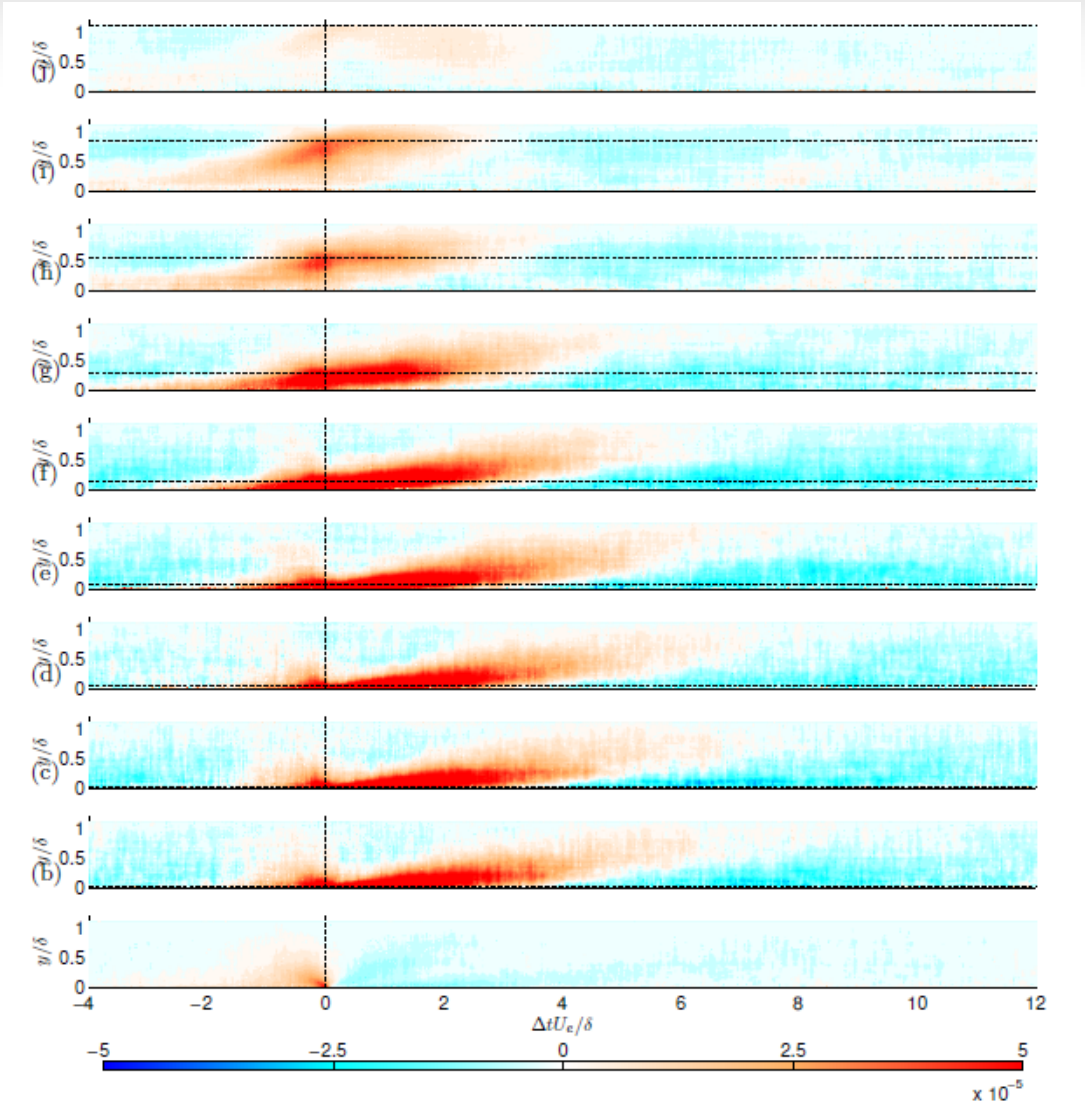
y_p/δ=0.068

y_p/δ=0.033

y_p/δ=0.016

y_p/δ=0.014

y_p/δ=0.0



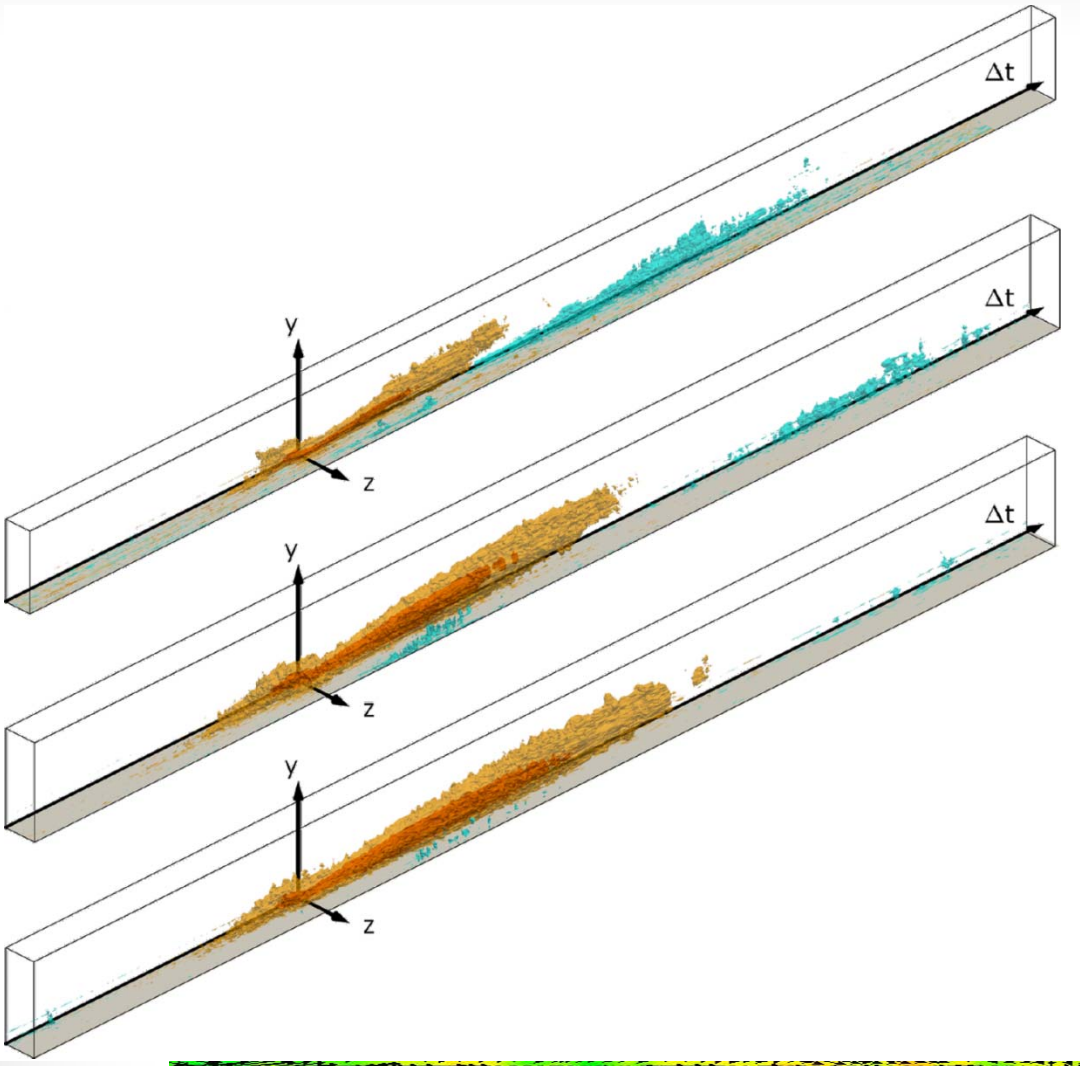
@Re_θ=10 000

Field pressure-velocity correlations

Re_θ= 7 300

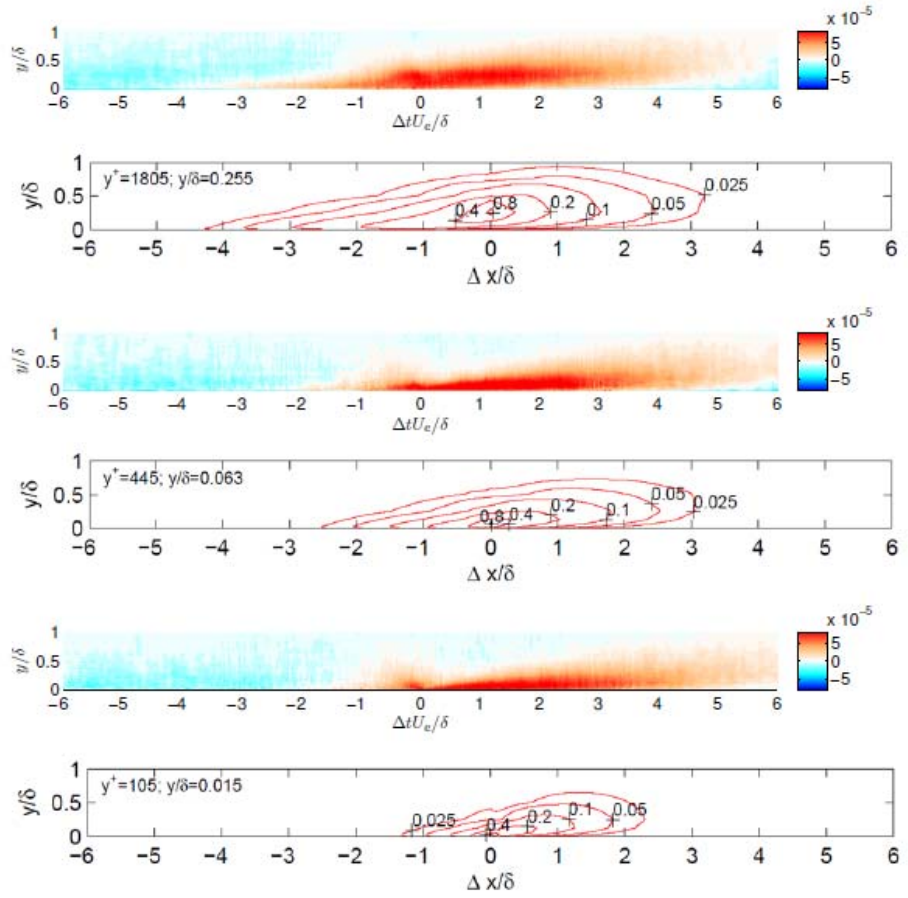
Re_θ=10 000

Re_θ=18 000



y_0/δ=0.014 @ Re_θ=10 000

Field pressure-velocity correlations



Conclusion

- Pressure velocity correlations were successfully measured in a high Reynolds number boundary layer,
- Large scale structures clearly influence the fluctuating pressure field,
- But differently at the wall and in the field,
- Reynolds number has a significant influence mostly on the <pu> correlation