PASSIVE SCALAR DISSIPATION IN A TURBULENT ROUND JET.

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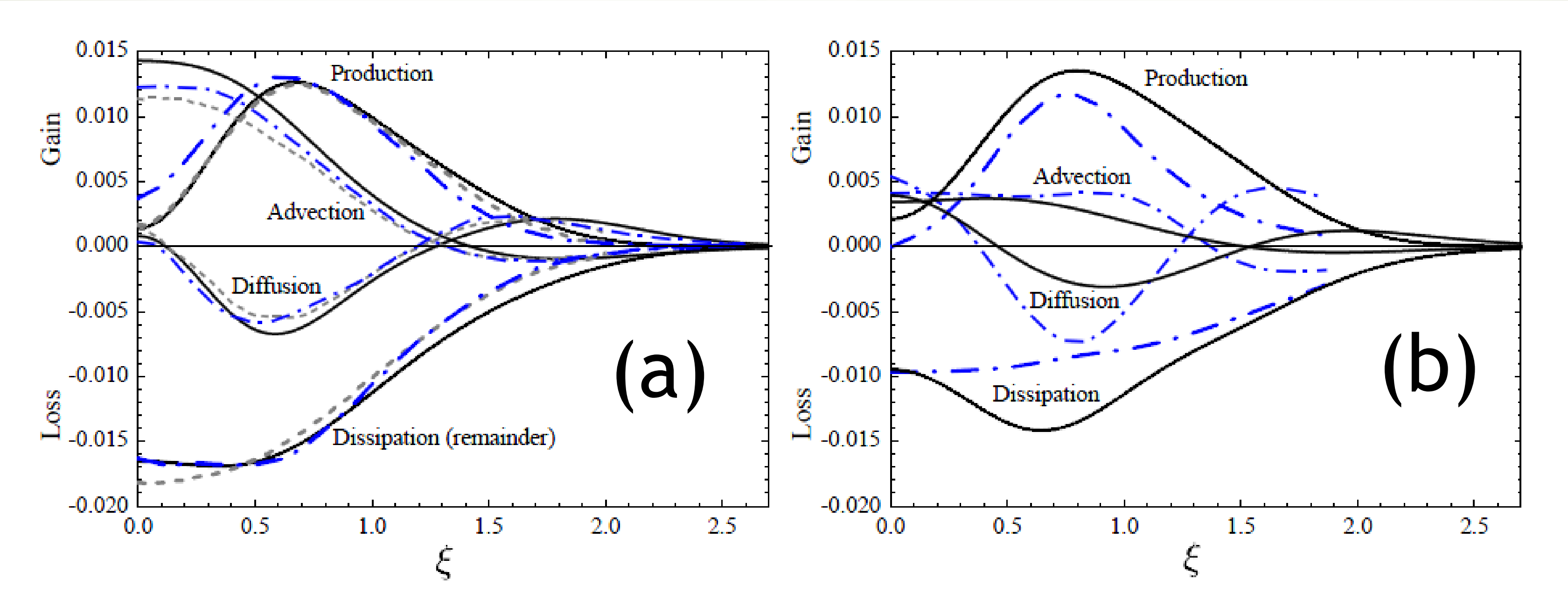
Outline:

- **Introduction**
- **Experimental details**
- **Flow characteristics**
- **Prediction of scalar dissipation and small scale lengths on the jet centerline.**
- **Consequences of self-preservation out of the jet centerline.**
- **Conclusions**

Introduction



—·— Panchapakesan and Lumley, 1993 —·— Antonia and Mi, 1993
- - - - Bogey and C. Bailly , 2009

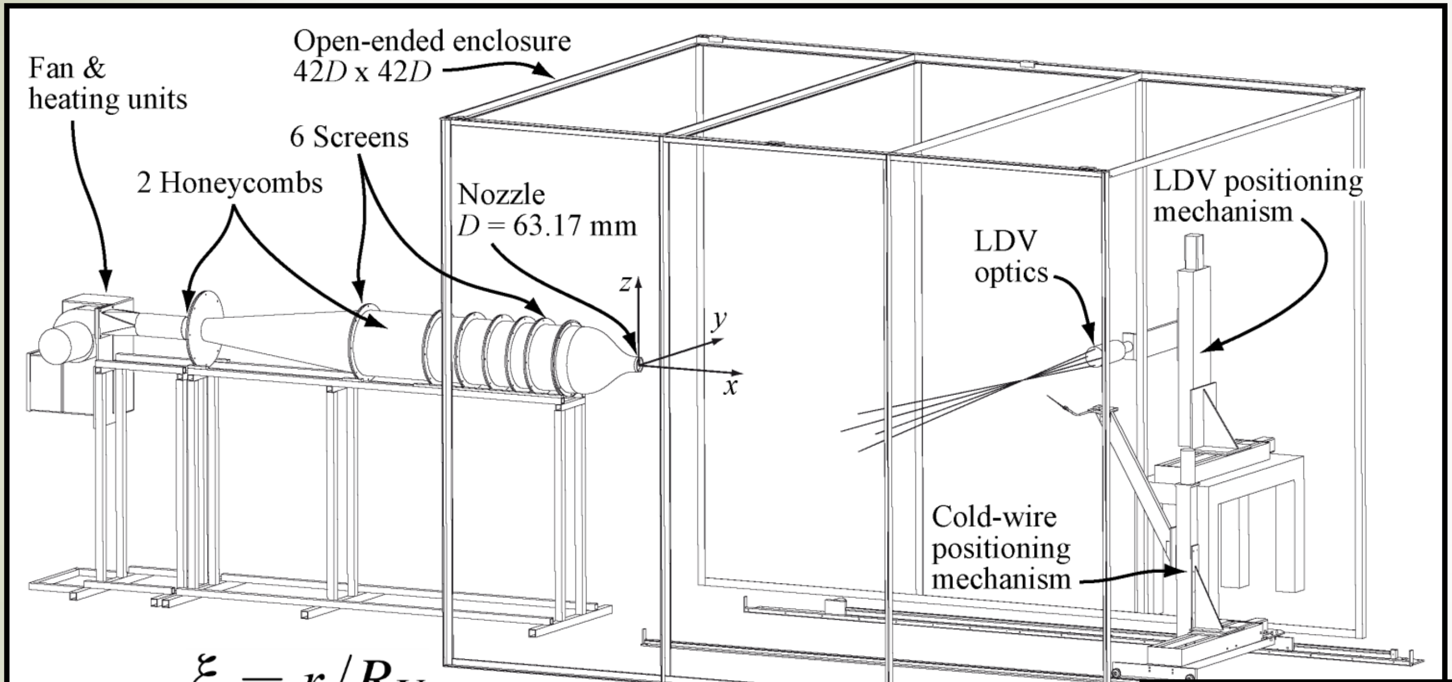
Budgets of turbulent kinetic energy, Reynolds stresses, variance of temperature fluctuations and turbulent heat fluxes in a round jet.
Alexis Darisse, Jean Lemay and Azemi Benaissa
J. Fluid Mech. (2015), vol. 774, pp 95-142.

Introduction

Bibliography

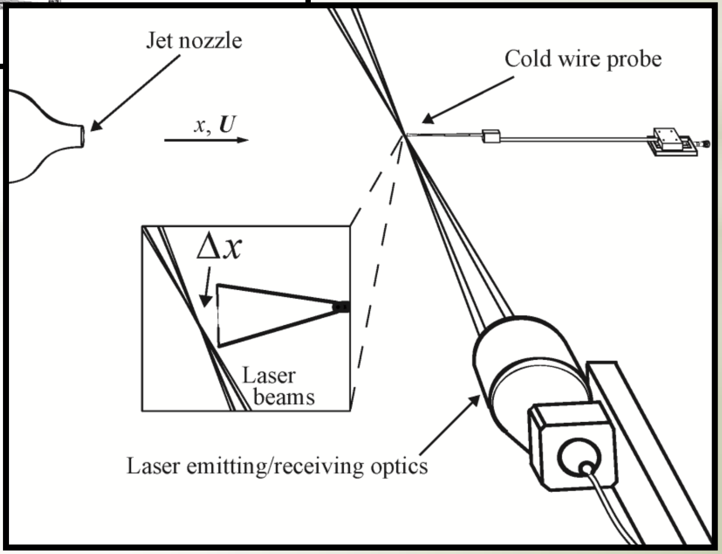
- Landau and Lifshitz (1959)
- Friehe, Van Atta and Gibson (1971)
- Antonia, Satyaprakash, Hussain (1980)
- Ruffin, Schiestel, Anselmet, Amielh and Fulachier (1994)
- Dimotakis (2000)
- Duffet and Benaissa (2012)
- Benaissa and Gisselbrecht (2013)
- Mi, Xu and Zhou (2013)
- Thiesset, Antonia and Djenidi (2014)
- Lemay, Djenidi, Antonia and Benaissa (2019)

Experimental details (Exp 1)



$$\xi = r/R_U$$

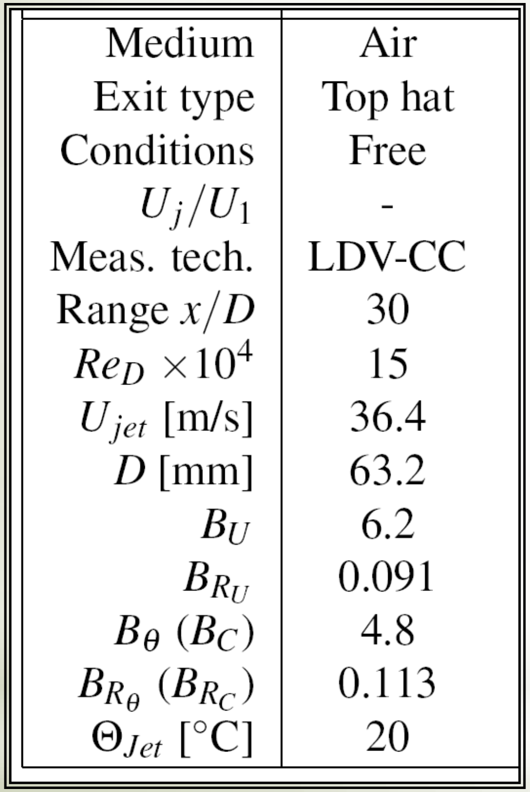
Jet facility



Measurement point

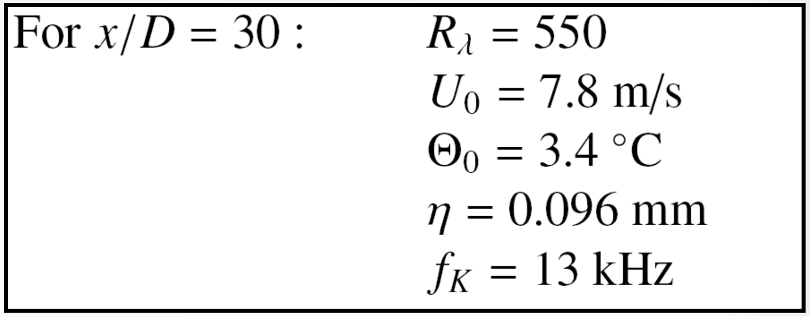
Experimental details (Exp 1)

Jet flow Conditions:



Medium	Air
Exit type	Top hat
Conditions	Free
U_j/U_1	-
Meas. tech.	LDV-CC
Range x/D	30
$Re_D \times 10^4$	15
U_{jet} [m/s]	36.4
D [mm]	63.2
B_U	6.2
B_{R_U}	0.091
B_θ (B_C)	4.8
B_{R_θ} (B_{R_C})	0.113
Θ_{Jet} [°C]	20

Measurement position:



For $x/D = 30$:

$R_\lambda = 550$

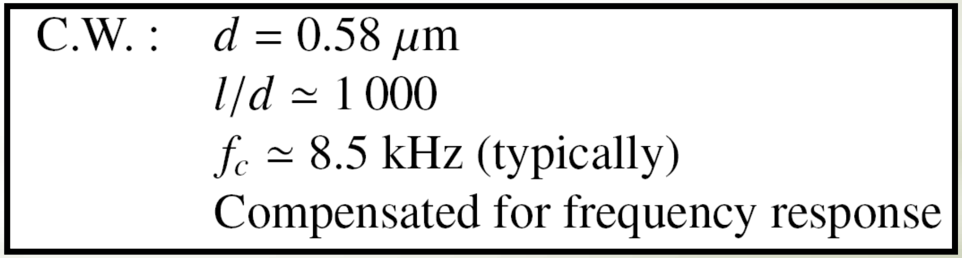
$U_0 = 7.8$ m/s

$\Theta_0 = 3.4$ °C

$\eta = 0.096$ mm

$f_K = 13$ kHz

Cold wire characteristics:



C.W. :

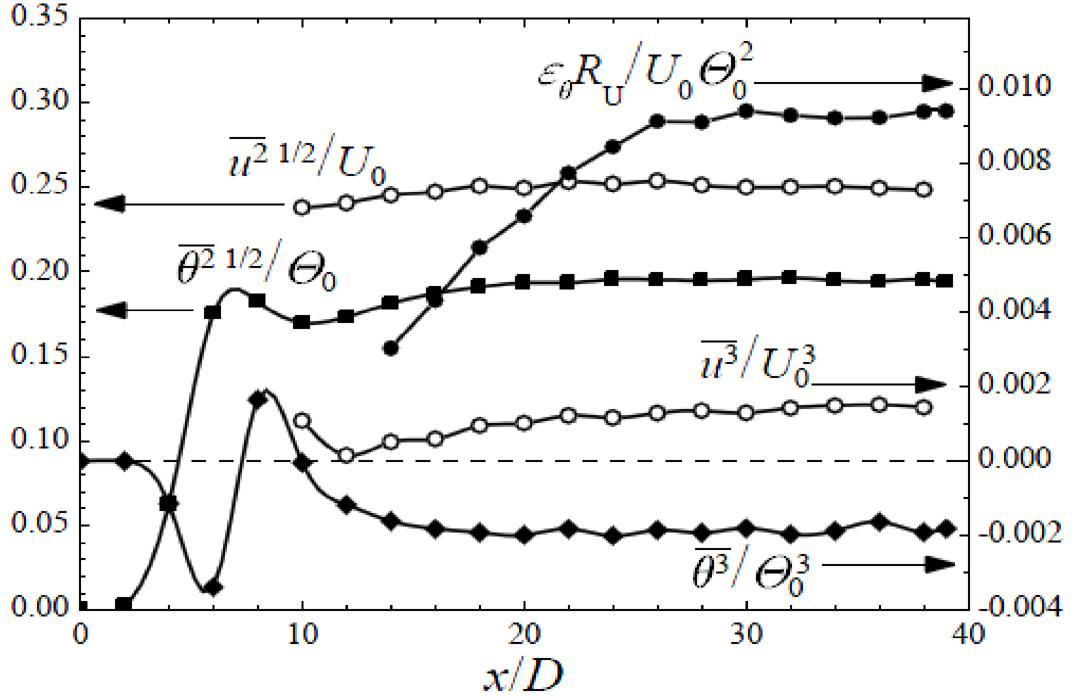
$d = 0.58\ \mu$m

$l/d \simeq 1\,000$

$f_c \simeq 8.5$ kHz (typically)

Compensated for frequency response

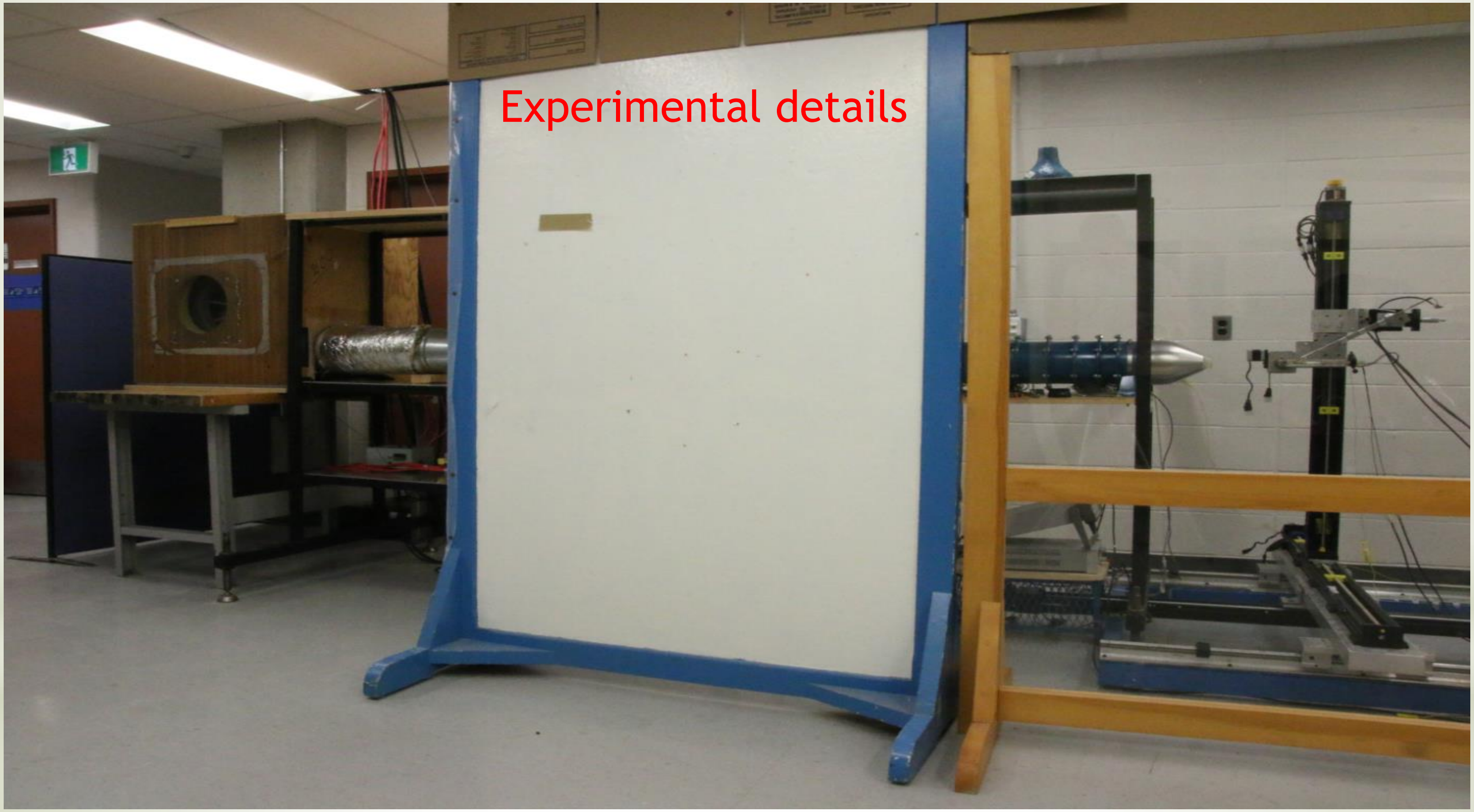
Flow characteristics (Exp 1)



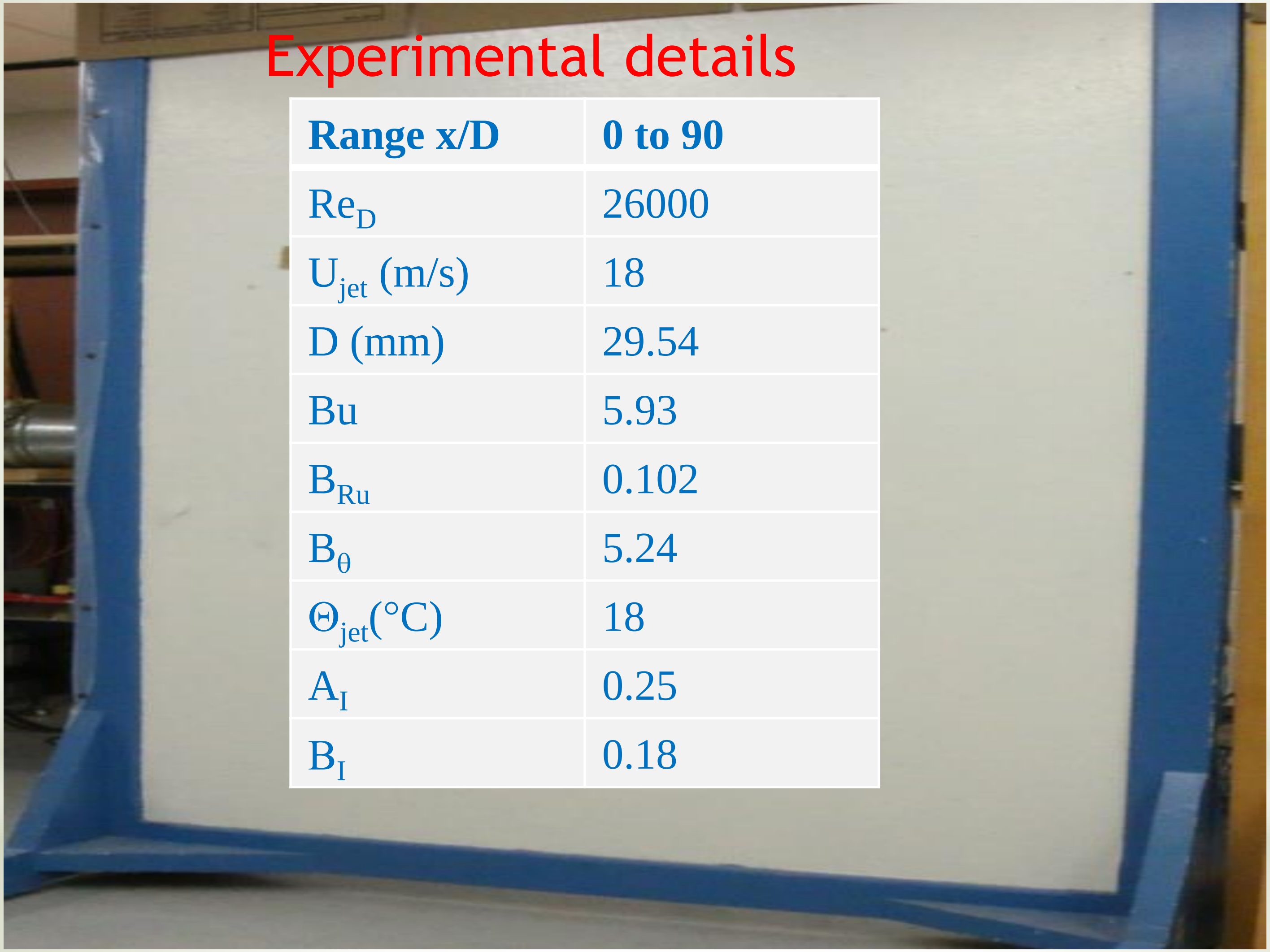
$$\varepsilon_K R_u/U_0^3 = 0.01652$$

Self similar behavior on the jet centerline is reached at *x/D* =30

Experimental details (Exp 2)

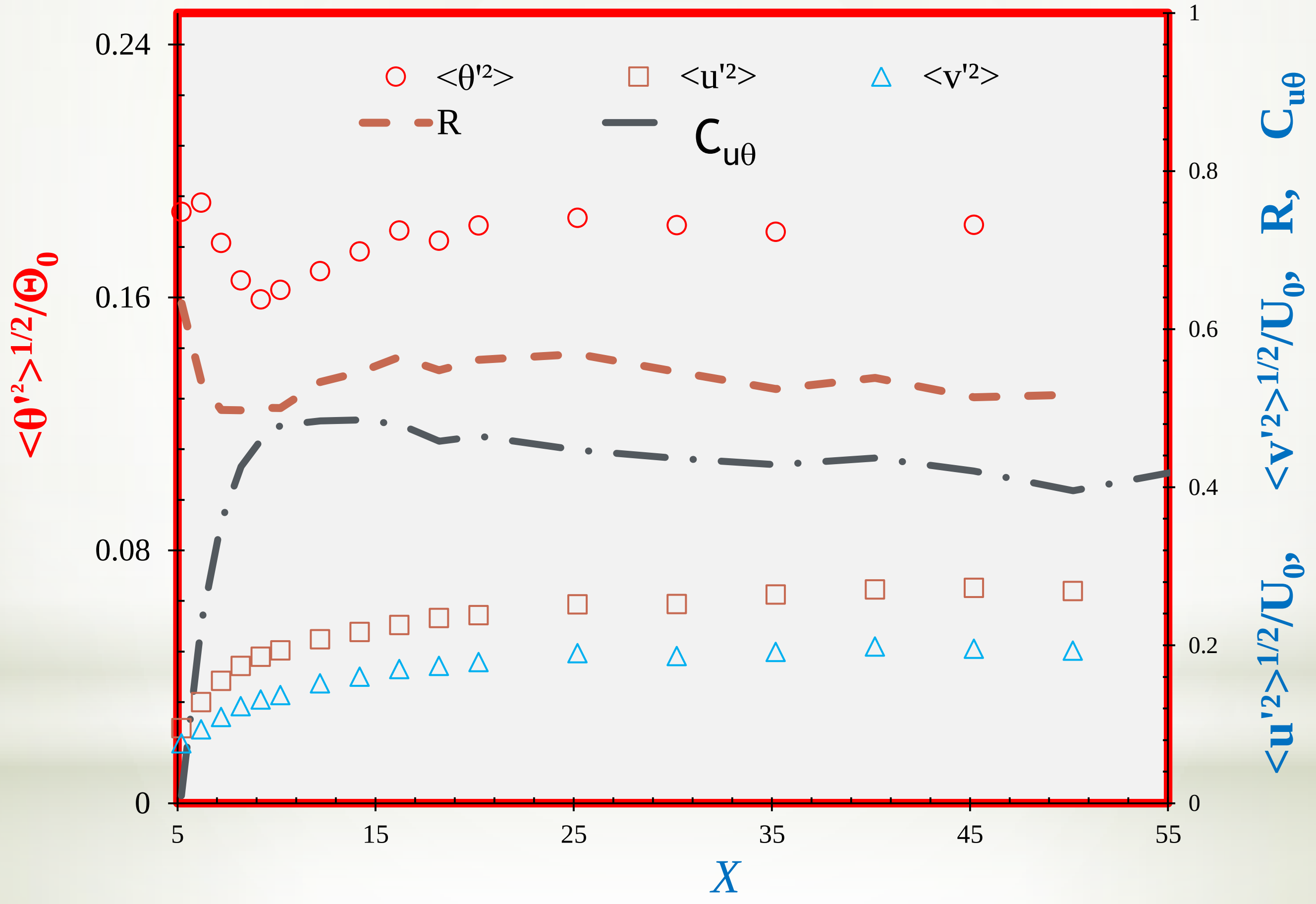


Experimental details



Range x/D	**0 to 90**
Re_D	26000
U_{jet} (m/s)	18
D (mm)	29.54
Bu	5.93
B_{Ru}	0.102
B_θ	5.24
Θ_{jet}(°C)	18
A_I	0.25
B_I	0.18

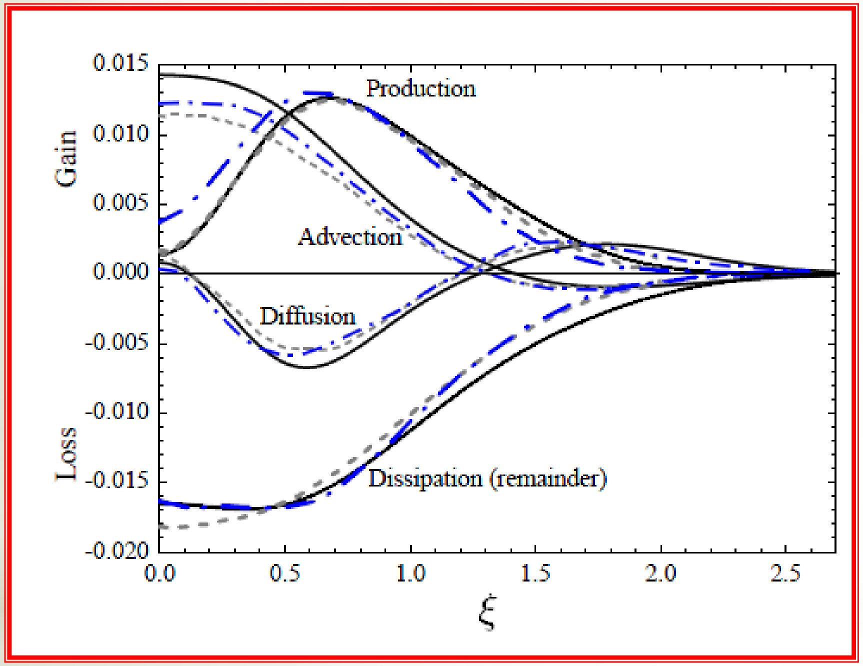
Experimental details (Exp 2)



Prediction of scalar dissipation and small scale lengths on the jet centerline.

Kinetic energy budget

— · — Panchapakesan and Lumley, 1993
- - - - Bogey and C. Bailly , 2009



$$\frac{\varepsilon_k D}{U_j^3} = A_{\varepsilon k}.\left(\frac{x - x_0}{D}\right)^{-4}$$

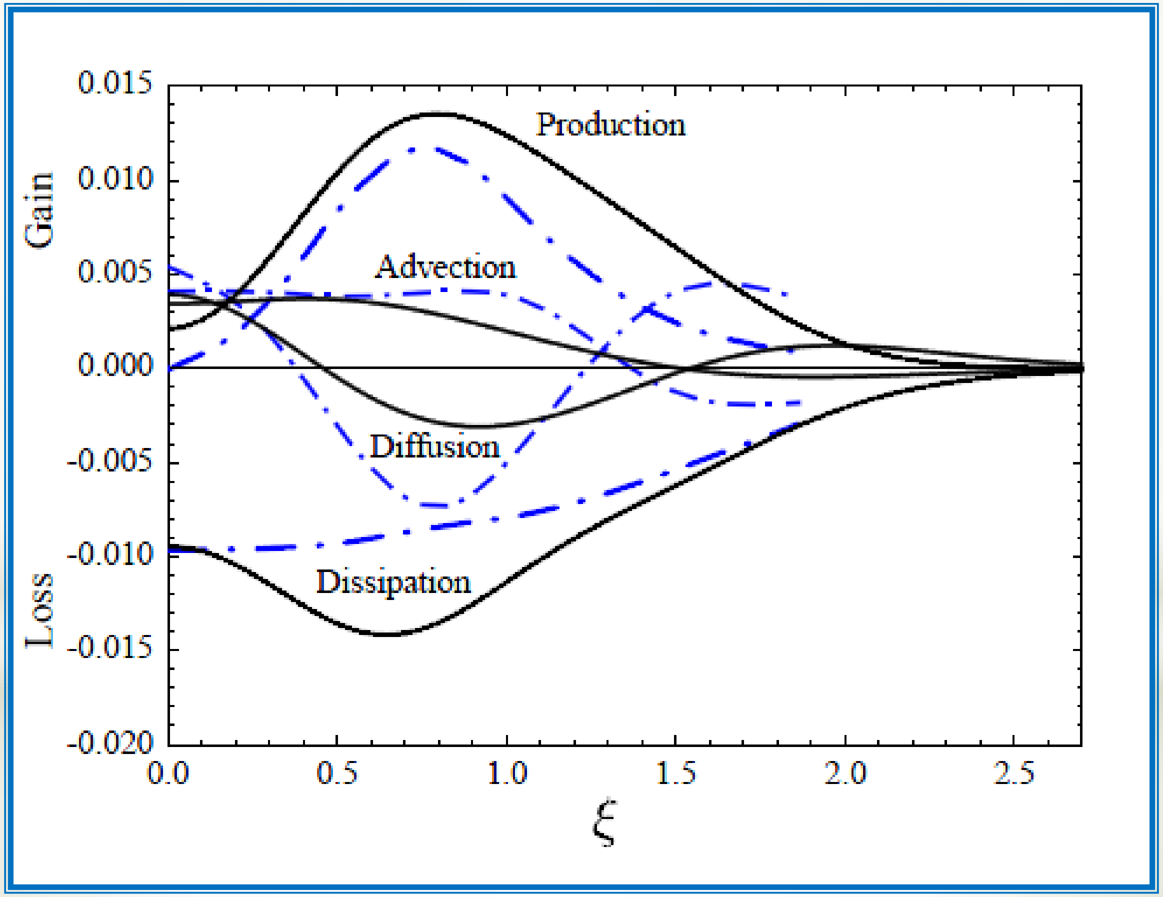
$$\frac{\varepsilon_k R_u}{U_0^3} = \varepsilon_k^* = B_{RU} A_I^2 (2 + R)$$

$$A_I = \frac{u}{U_0} \text{ and R} = \left(\frac{v}{u}\right)^2$$

$$A_{\varepsilon k} = B_U^3 A_I^2 (2 + R)$$

Prediction of scalar dissipation and small scale lengths on the jet centerline.

temperature variance budget — · — Antonia and Mi, 1993



Budget of $\theta^2/2$ on the jet centerline

$$\boxed{\epsilon^*_{\theta_{Axis}} = -C^*_{\theta_{Axis}} + P^*_{\theta_{Axis}} + D^*_{\theta_{Axis}} + M^*_{\theta_{Axis}}}$$

$$\boxed{\Rightarrow \epsilon^*_{\theta_{Axis}} = B_{R_U}\,\gamma\left[\frac{\overline{\theta^2}}{\Theta_0^2} + \frac{\overline{u\theta}}{U_0\Theta_0} + \frac{\overline{u\theta^2}}{U_0\Theta_0^2}\left(\frac{1}{2\gamma}+1\right)\right] - \frac{\mathrm{d}}{\mathrm{d}\xi}\left(\frac{\overline{v\theta^2}}{U_0\Theta_0^2}\right)\Bigg|_{\xi=0} + M^*_{\theta_{Axis}}}$$

$\boxed{0.00948}$ $\boxed{0.00343}$ $\boxed{0.00212}$ $\boxed{-1.24\times10^{-5}}$ $\boxed{0.00395}$ $\boxed{-2.37\times10^{-6}}$

$$\boxed{\epsilon^*_\theta \simeq B_{R_U}\left[B_I^2 + c_{u\theta}A_IB_I + c_\theta\left(\frac{\mathcal{R}+1/2}{\mathcal{R}+2}\right)\right].}$$

Darisse et al. (2014)

$$\boxed{A_{\epsilon_\theta} \simeq B_U B_\theta^2\left[B_I^2 + c_{u\theta}A_IB_I + c_\theta\left(\frac{\mathcal{R}+1/2}{\mathcal{R}+2}\right)\right],}$$

Lemay et al. (2019)

From the budget ratios

$$A_{\epsilon\theta} = 2.76 B_I^2 B_U B_\theta^2$$

From the time scale ratio

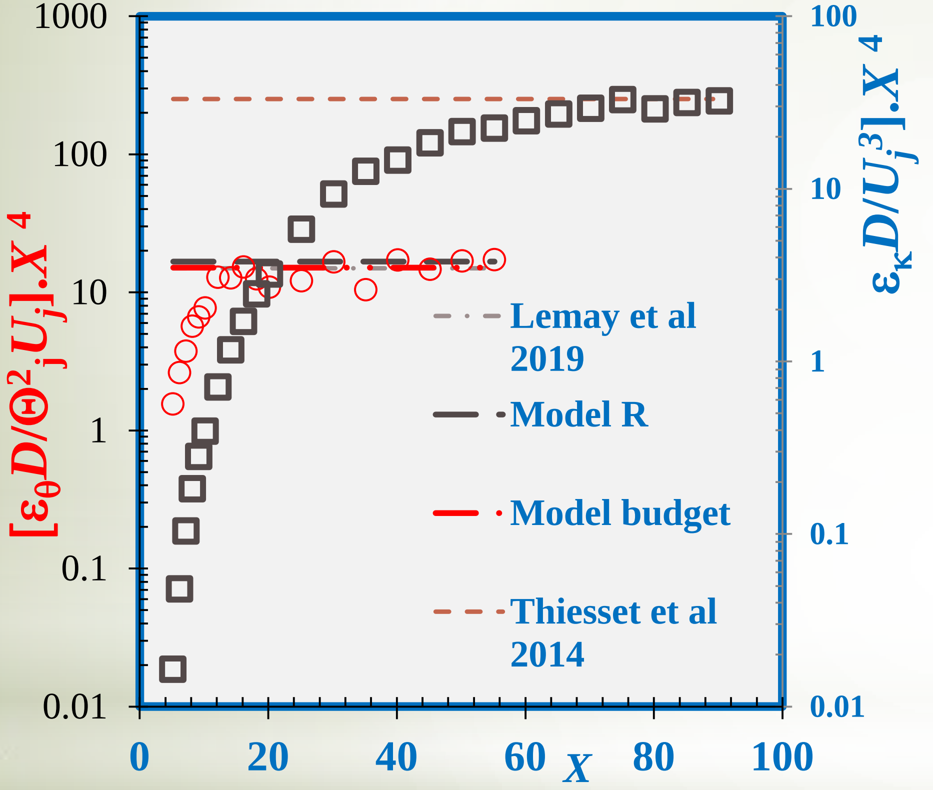
$$\Re = \frac{\theta^2/2\epsilon_\theta}{k/\epsilon_k}$$

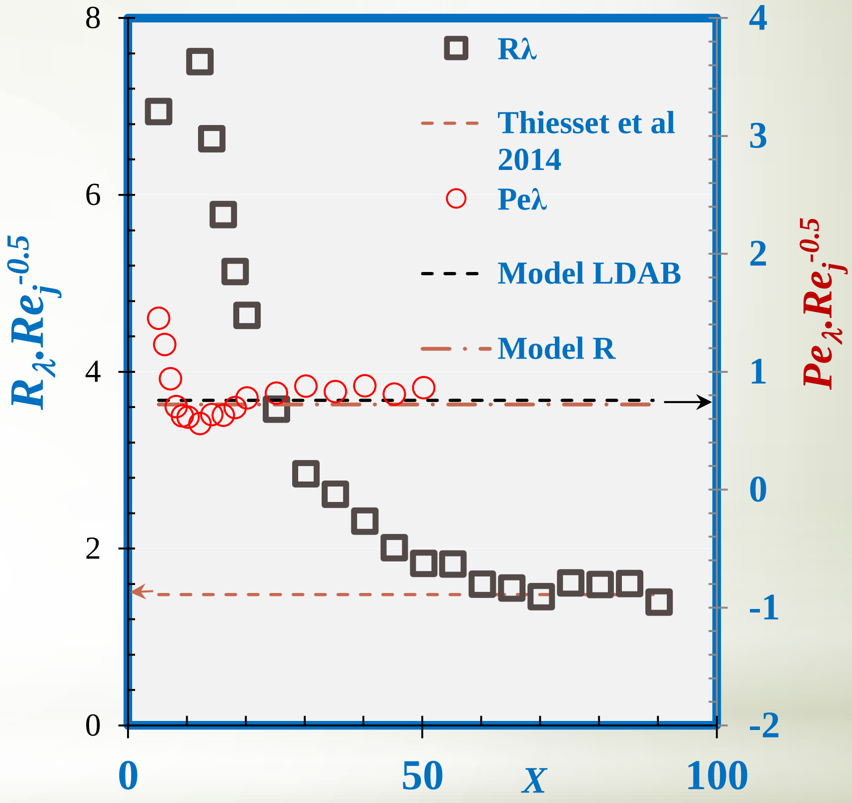
$$A_{\epsilon\theta} = \frac{1}{2\Re} B_I^2 B_U B_\theta^2 [\frac{2+R}{0.5+R}]$$

$$\frac{\lambda_\theta}{D} = \left[\frac{3B_I^2 B_\theta^2}{Pr Re_j A_{\epsilon_\theta}}\right]^{1/2} \frac{(x-x_0)}{D}$$

$$\frac{Pe_\lambda}{Re^{1/2}} = B_U A_I B_I B_\theta \sqrt{\frac{3Pr}{A_{\epsilon\theta}}}$$

* Dissipation, R_λ and Pe_λ





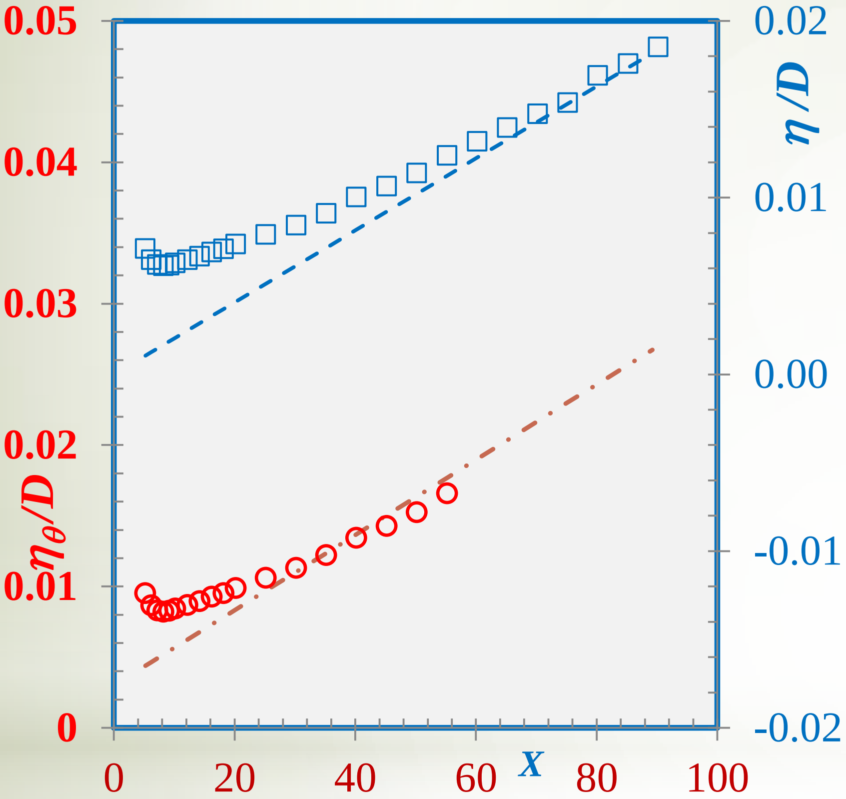
Thiesset et al 6.4 %

Lemay et al 2 %, Model R 9 %, Budget 3 %

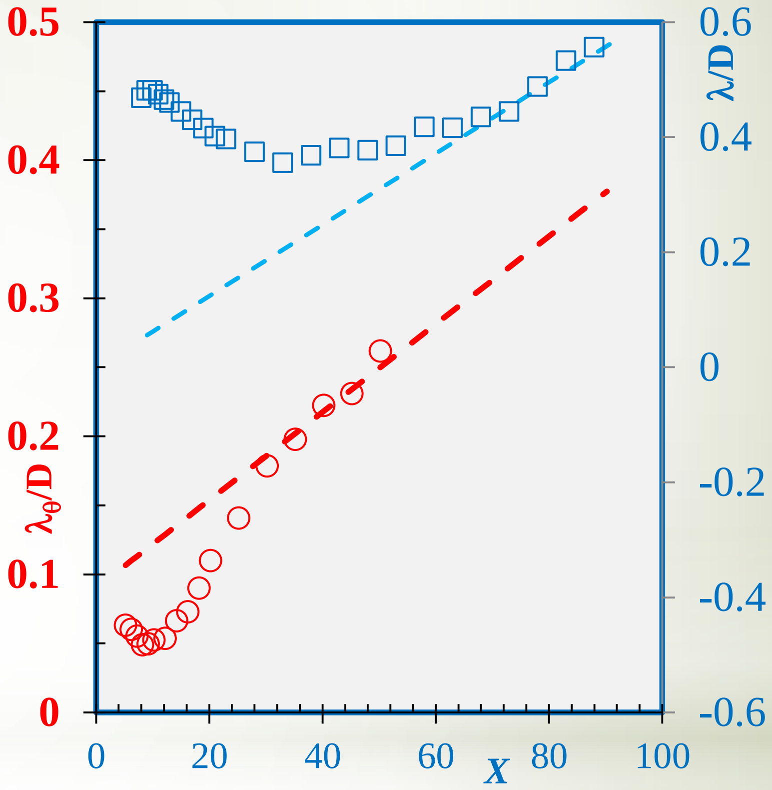
Thiesset et al 5 %

Lemay et al 6 %, Model R 11 %,

Small scale length evolution on the centerline

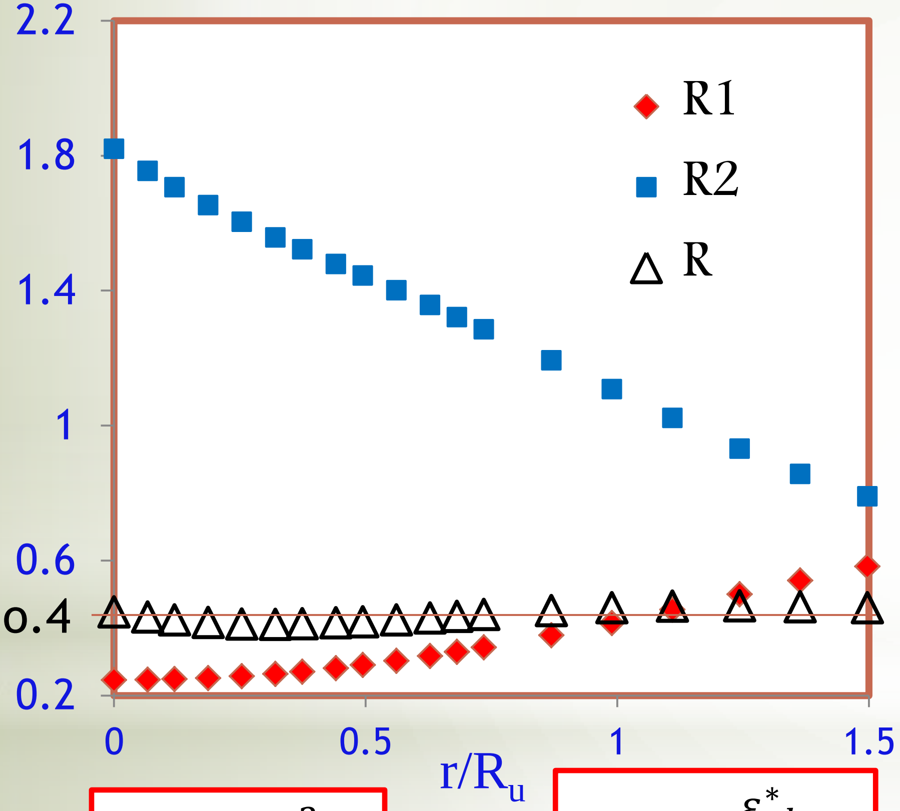


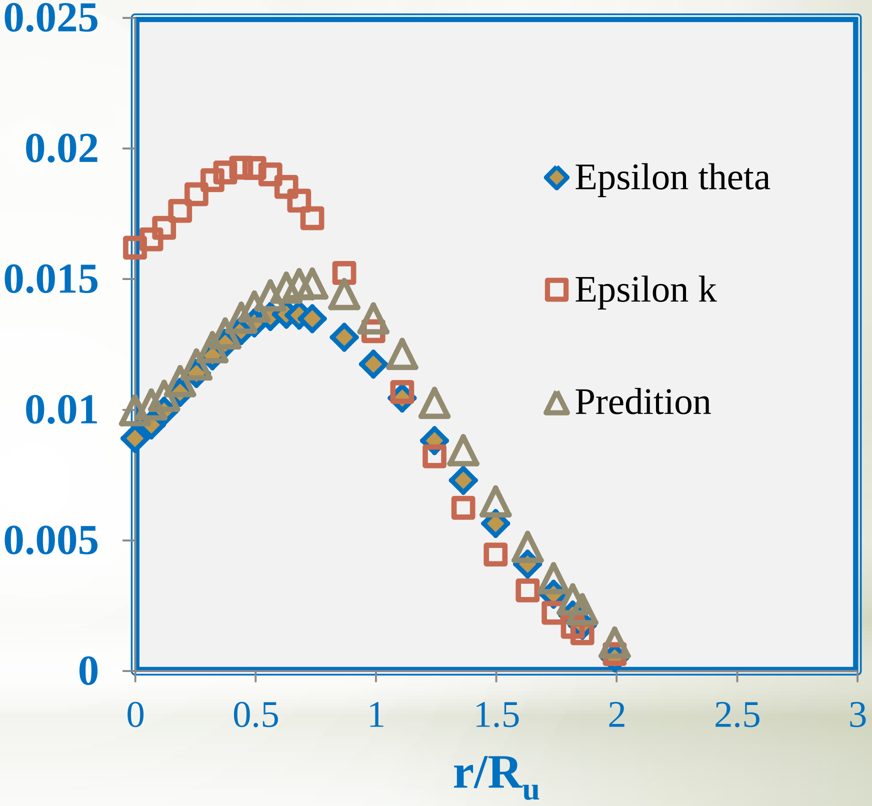
η Thiesset et al 8 %



λ_θ Lemay et al 6 %

Prediction of scalar dissipation and small scale lengths out of the jet centerline.



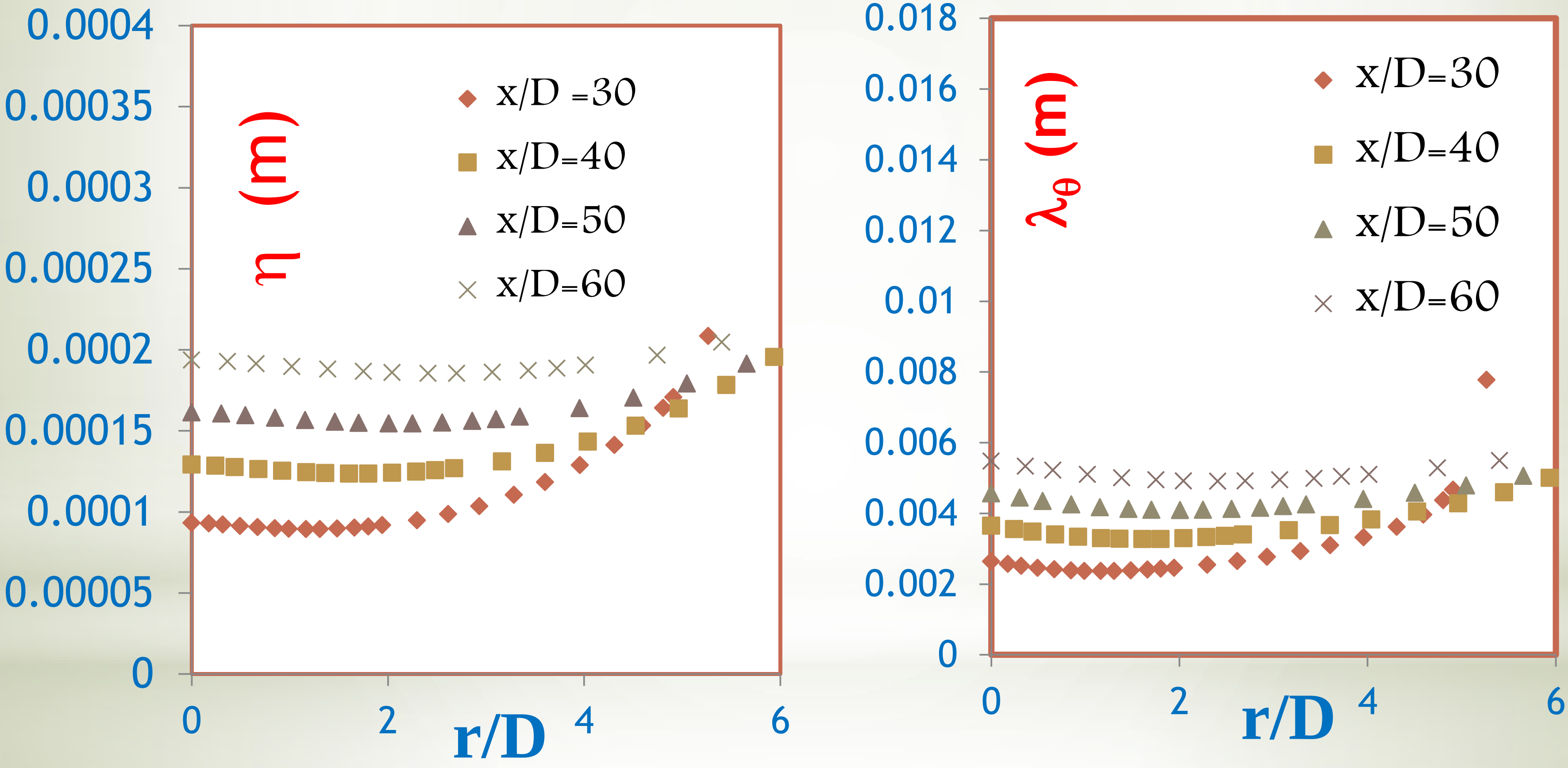


$$R_1 = \frac{\frac{\theta^2}{\Theta_0}}{2 * \frac{k}{U_0}}$$

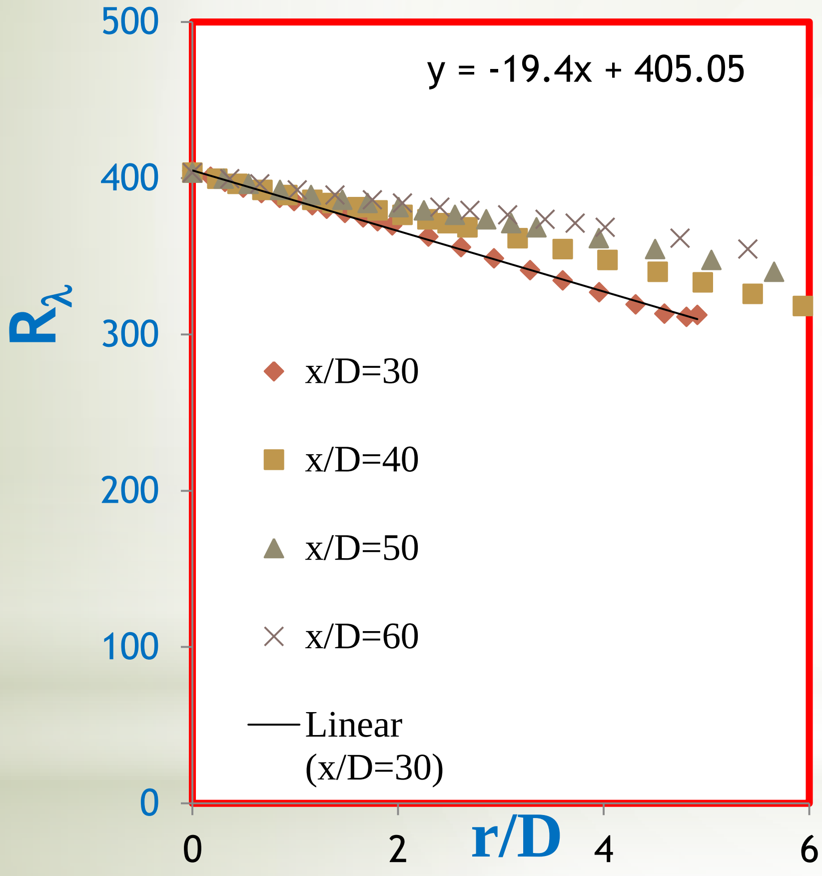
$$R_2 = \frac{\varepsilon^*{}_k}{\varepsilon^*{}_\theta}$$

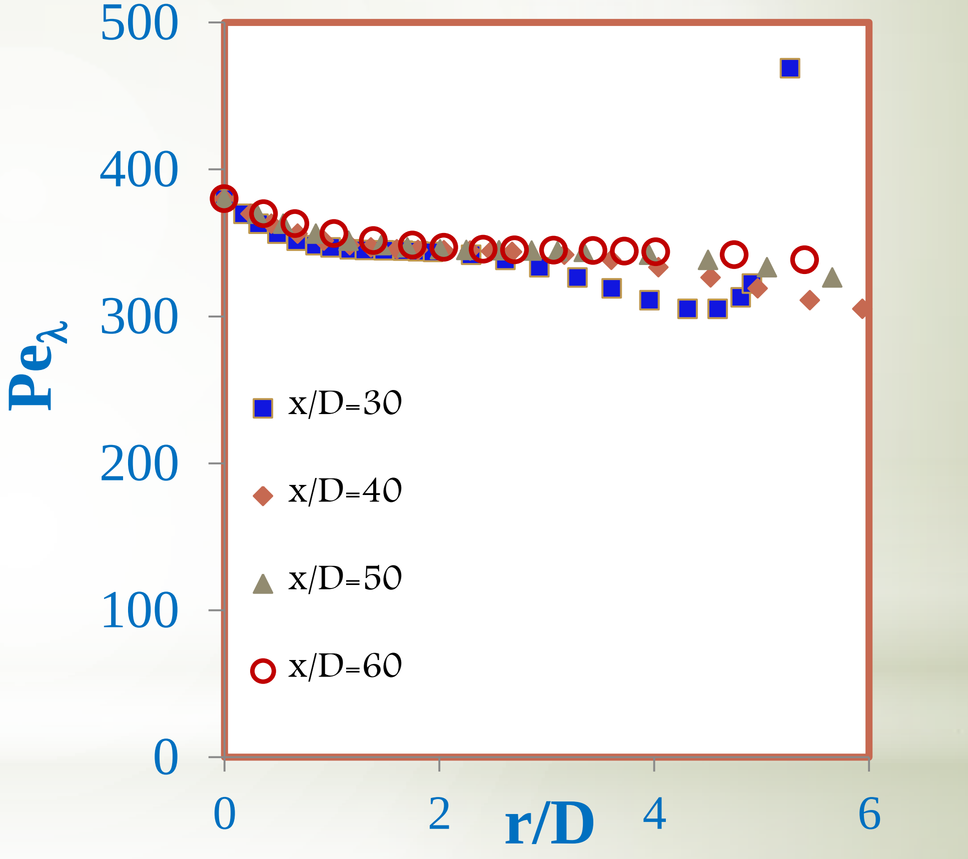
R= $R_1 \times R_2$ (time scale ratio)

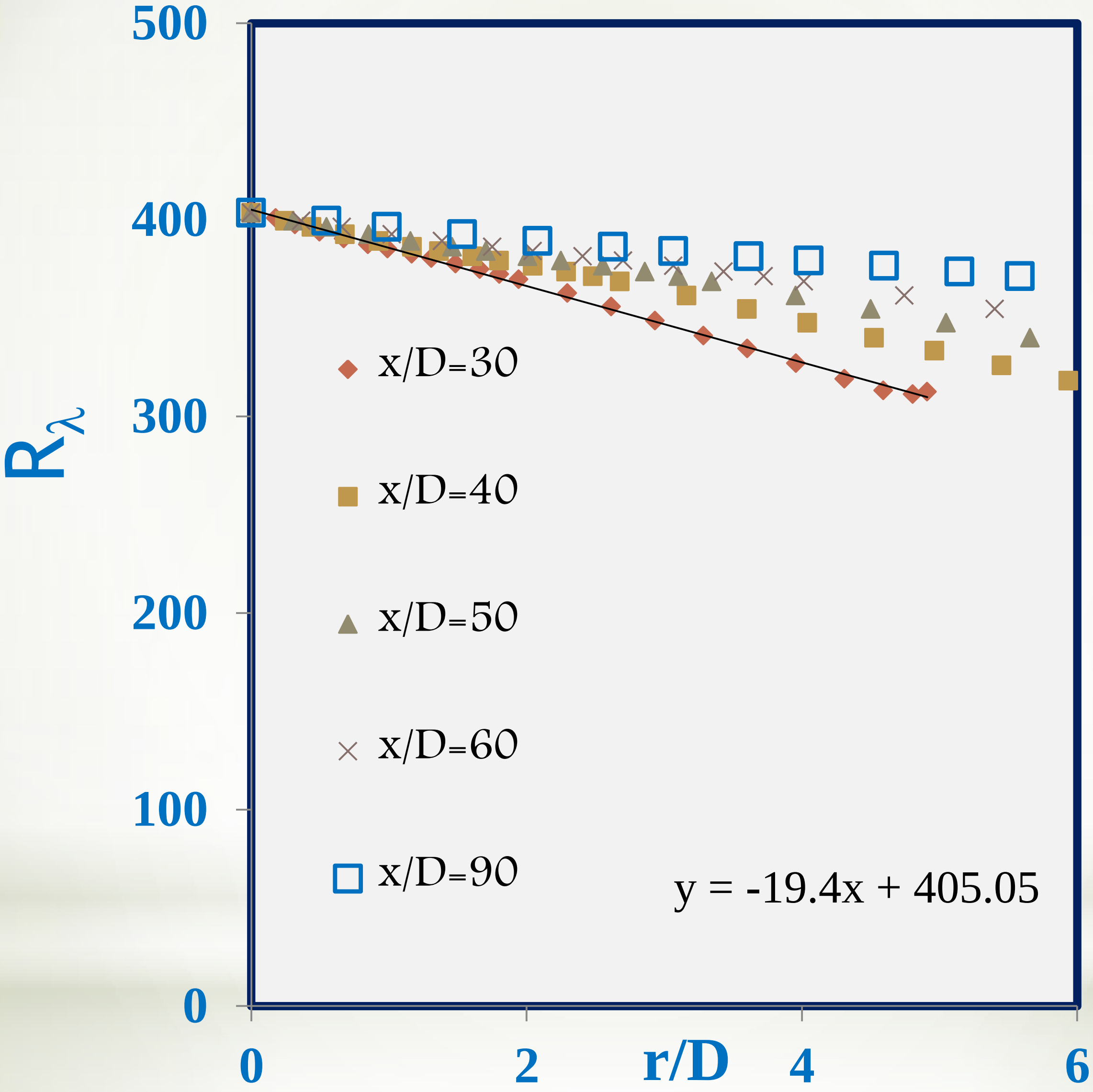
* Consequences of self-preservation out of the axis (Kolmogorov and Corrsin length scales)



* Consequence of self-preservation out of the jet centerline axis (R_λ and Pe_λ)






500
400
300
200
100
0
R_λ
0
2
r/D
4
6
x/D=30
x/D=40
x/D=50
x/D=60
x/D=90
y = -19.4x + 405.05

Conclusions

- **Prediction relationship for kinetic energy dissipation - Thiesset et al (2014) (6.4%).**
- **Test of the prediction relationship of temperature dissipation -Lemay et al (2019) (2 %).**
- **Introduction of new relationships for temperature dissipation (R 9 % and Budget 3 %).**
- **Observation of the behaviour outside the centerline of turbulent length scales and R_λ and Pe_λ (Validity of the linear laws for small scale lengths ~ 2D).**
- **Future work, consequence of the complete self-similarity on spectral distributions of k and θ.**