Asymptotic behaviour of the shearless turbulent kinetic energy mixing

ETC - 11

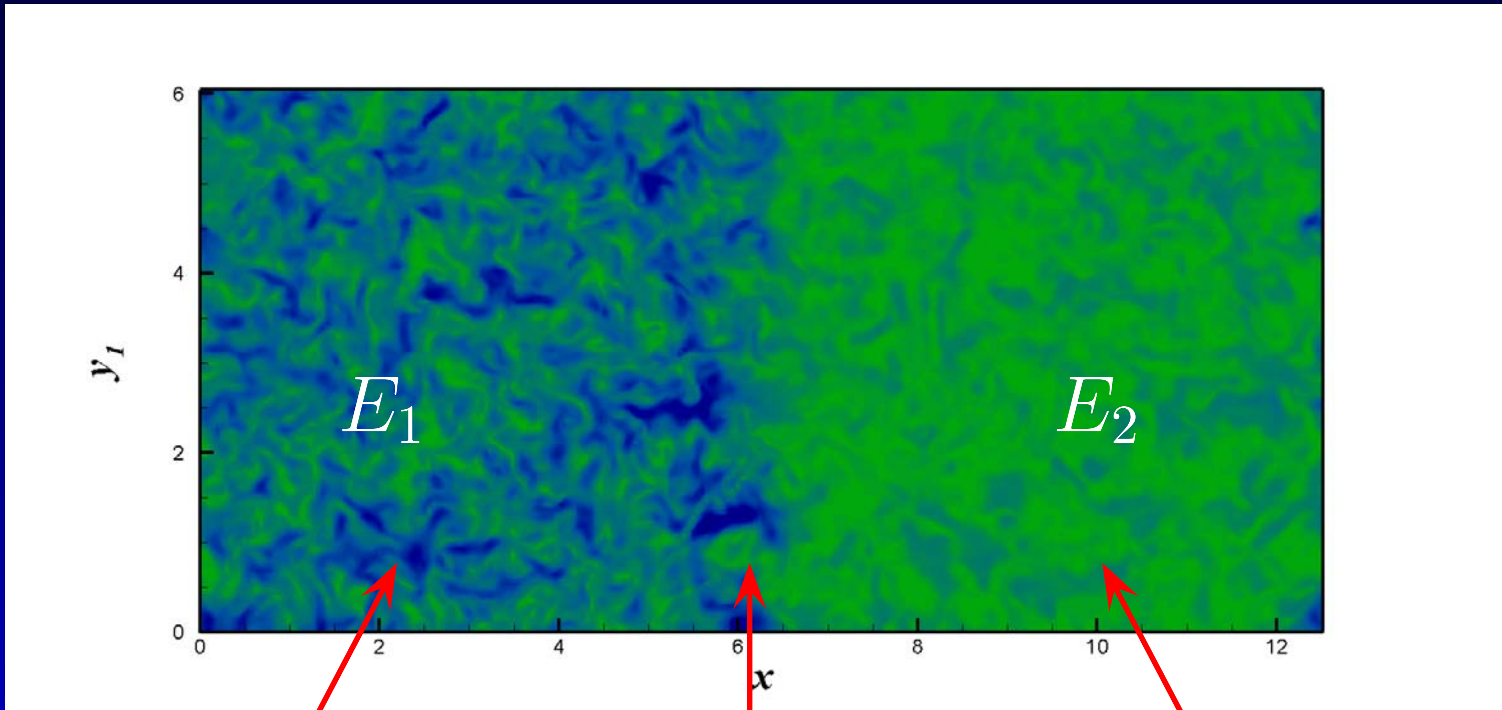
Daniela Tordella, Michele Iovieno, Peter R. Bailey

michele.iovieno@polito.it

Dipartimento di Ingegneria Aeronautica e Spaziale
Politecnico di Torino,
Corso Duca degli Abruzzi 24, 10129 Torino, Italy

Turbulent shearless mixing

Ref: *J. Fluid Mech.* **549**, 441-451, (2006).



Run Movie 1-2

1-High energy turbulence

2-Low energy turbulence

Mixing layer

- no mean shear
- no turbulent kinetic energy production
- a gradient of integral scale may/may not be present
- Gaussian ?

- if the integral scale gradient is removed,
  does the TSM remain intermittent?
  is the intermittency reduced?

- we show that it is still highly intermittent

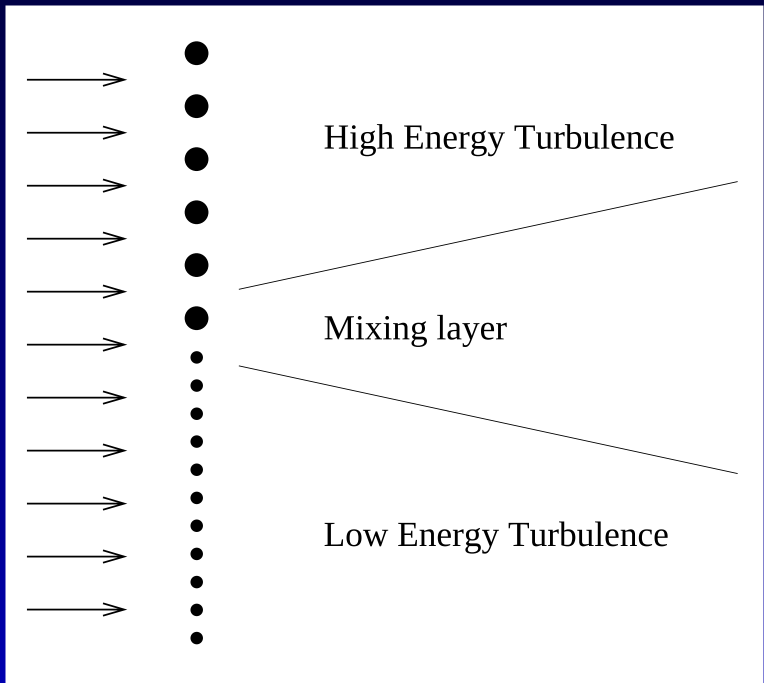
→ is thus the presence of a turbulent kinetic energy gradient a *sufficient condition for Gaussian departure*?

Main features

- Self-similar stage of decay
- $\overline{u_1^2} \approx \overline{u_2^2} \approx \overline{u_3^2}$
- High intermittency, function of:
  - gradient of turbulent kinetic energy $\Rightarrow \mathcal{E} = E_1/E_2$
  - gradient of integral scale $\Rightarrow \mathcal{L} = \ell_1/\ell_2$

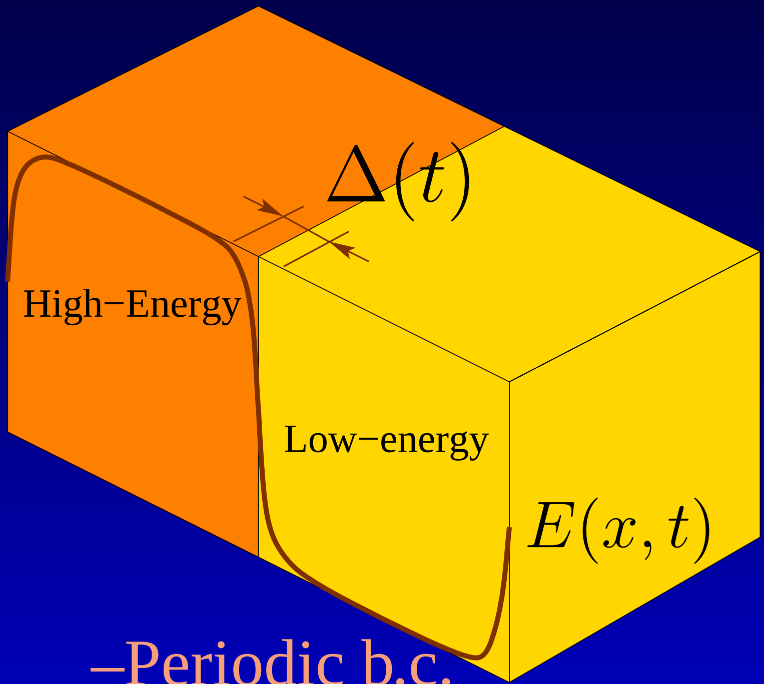
- The mixing process is
  - *ENHANCED* if the energy gradient is concurrent with the integral scale gradient ($\mathcal{L} > 1$)
  - *REDUCED* if the energy gradient is opposite to the integral scale gradient ($\mathcal{L} < 1$)

State of the art



- Grid turbulence experiments:
  - Gilbert *JFM* 1980
  - Veeravalli-Warhaft *JFM* 1989

State of the art



–Periodic b.c.

–Temporal decay

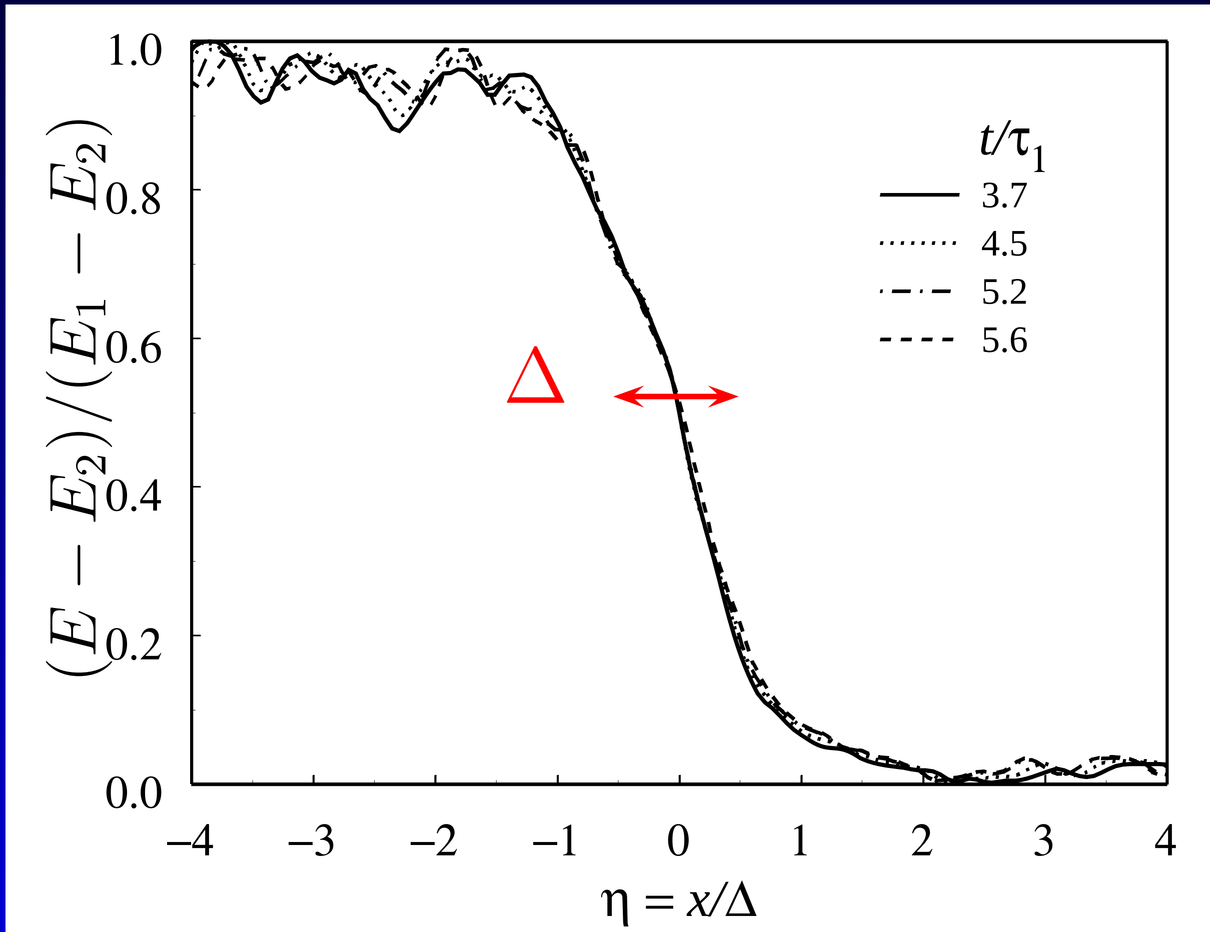
- Grid turbulence experiments:
  ▶ Gilbert *JFM* 1980
  ▶ Veeravalli-Warhaft *JFM* 1989
- Numerical experiments:
  ▶ Briggs *et al. JFM* 1996
  ▶ Knaepen *et al. JFM* 2004
  ▶ Tordella-Iovieno *JFM* 2006

Present work

- We consider shearless mixings with a *uniform scale*: the mixing is generated by the gradient of energy only $\Rightarrow$ $\mathcal{E}$ only parameter ($\mathcal{L} = 1$, $\mathcal{E} \neq 1$)
- The behaviour of the mixing in the limit of very high energy ratio $\mathcal{E}$ is investigated.
- Method: DNS, parallelepiped domain ($2\pi \times 2\pi \times 2n\pi$, $n = 2$ and $n = 4$), $Re_\lambda = 44$, LES, same domain and $Re_\lambda = 44 - 450$

Self similarity

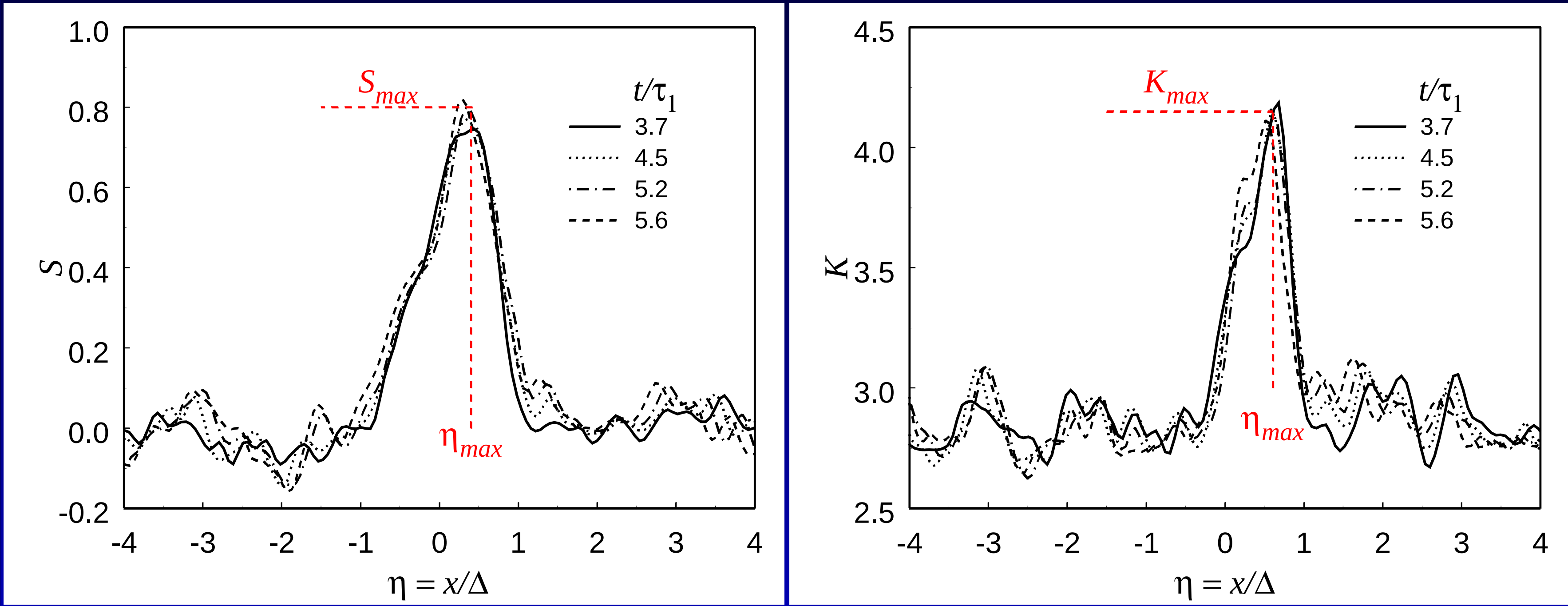
$\mathcal{E} = 6.7$



$\Delta(t)$ is the conventional mixing layer thickness

Intermittency - $\mathcal{E} = 6.7$

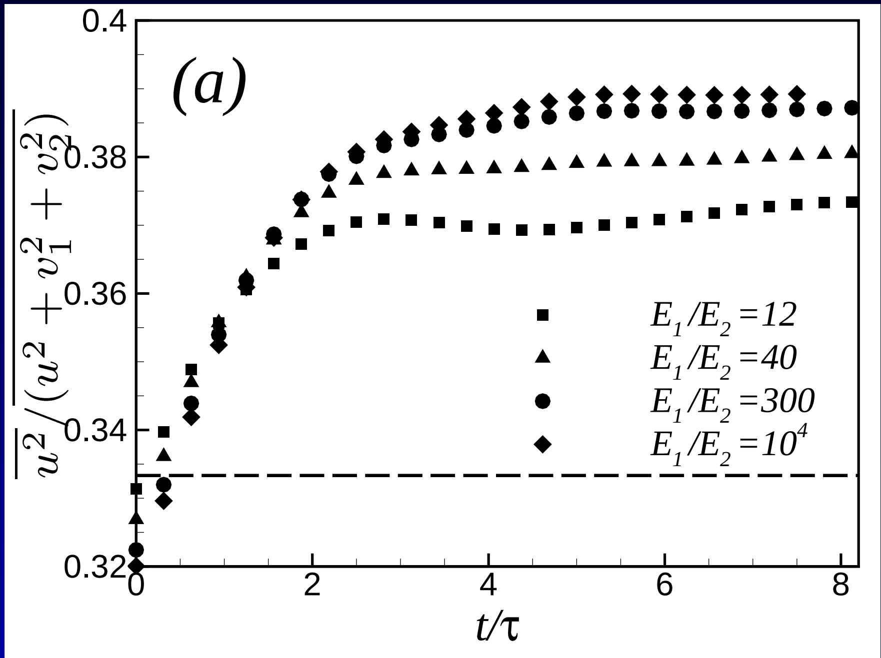
$S = \overline{u^3}/\overline{u^2}^{3/2}$ $K = \overline{u^4}/\overline{u^2}^2$



S_{max}, K_{max} = maximum of Skewness and Kurtosis in the mixing layer

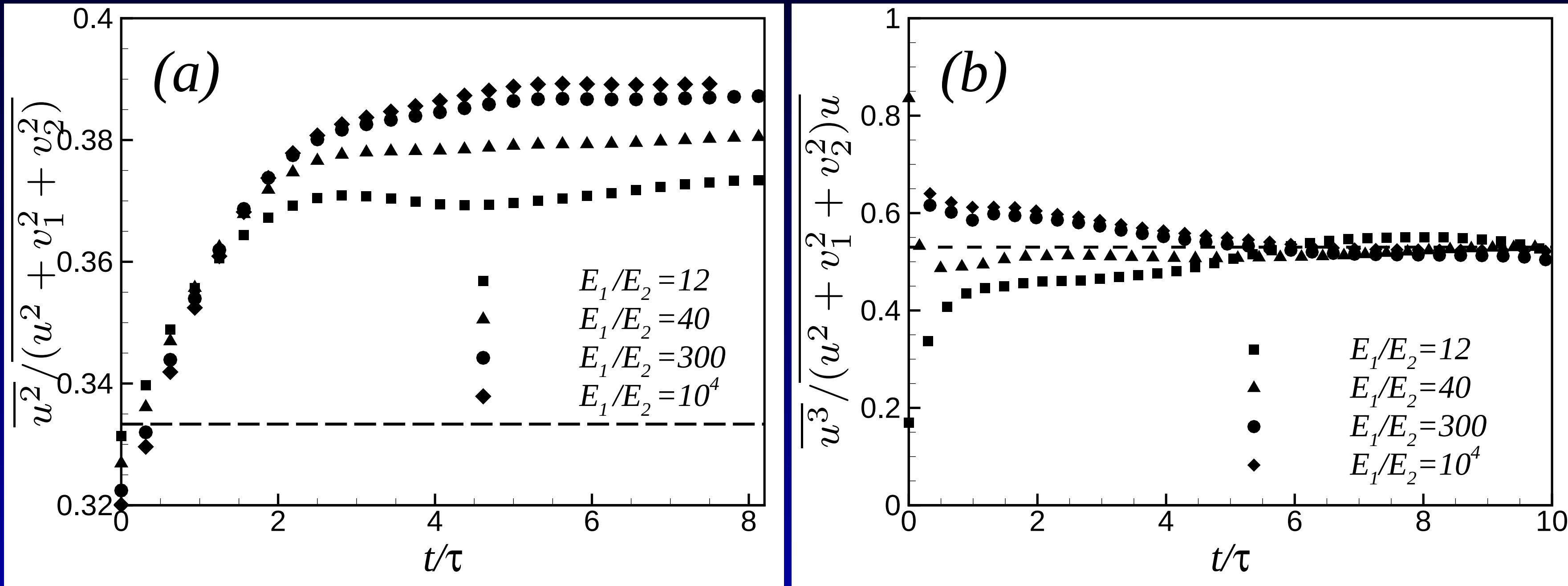
η_{max} = position of the maximum in the mixing layer

Anisotropy



Left: second order moment anisotropy

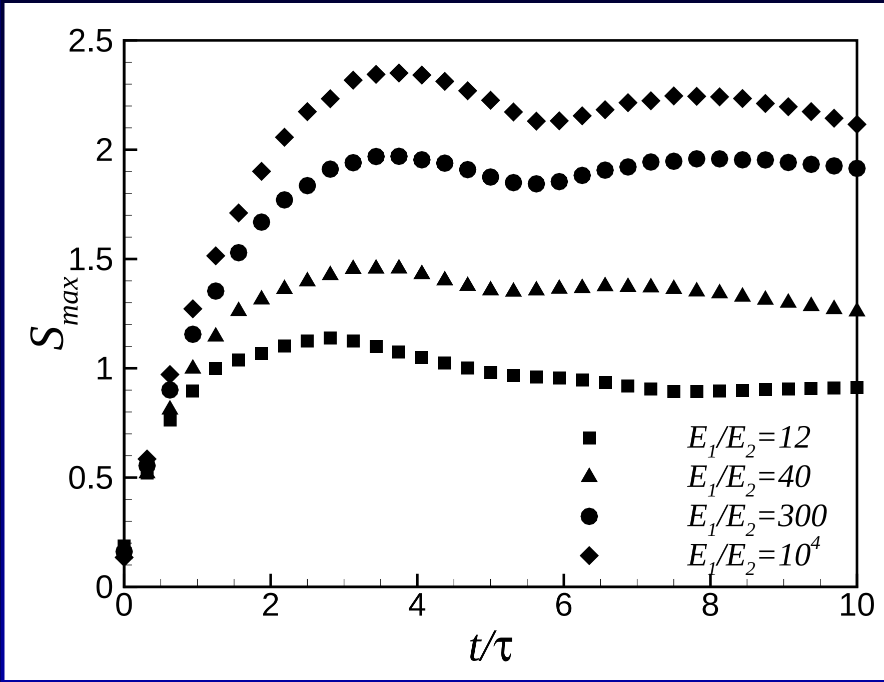
Anisotropy

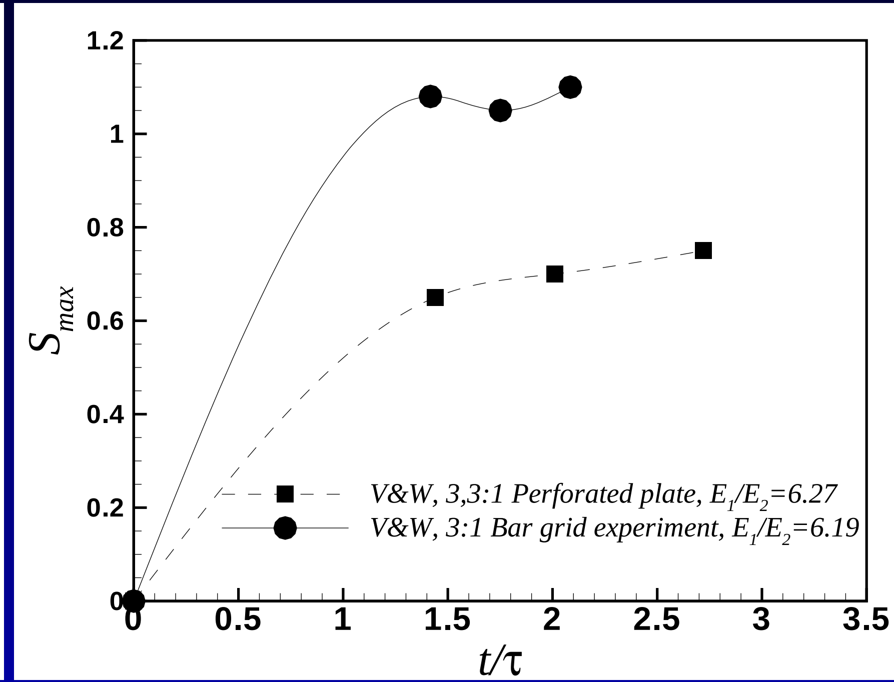


Left: second order moment anisotropy

Right: third order moment anisotropy

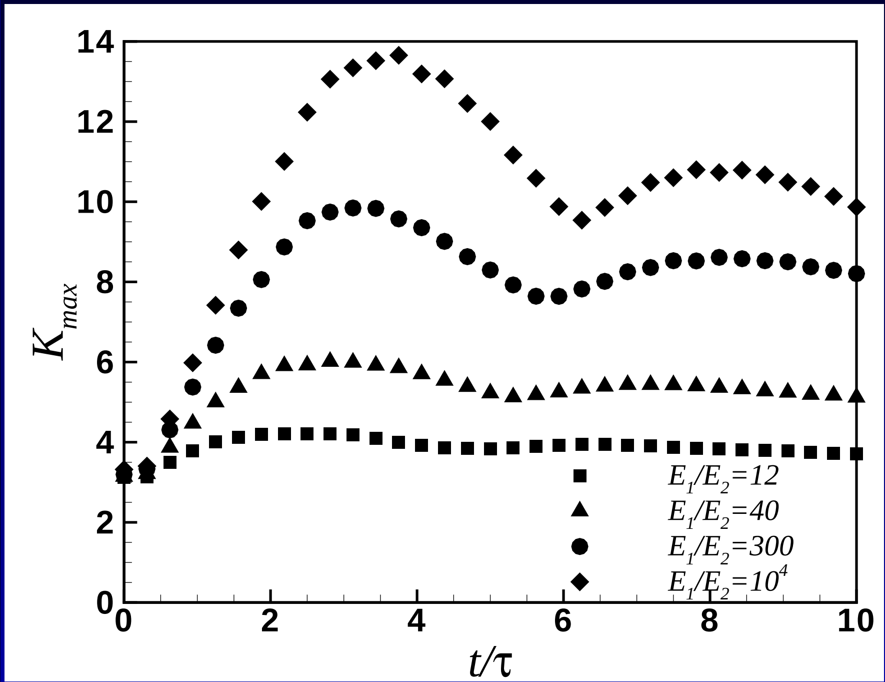
Inhomogeneity: Skewness evolution

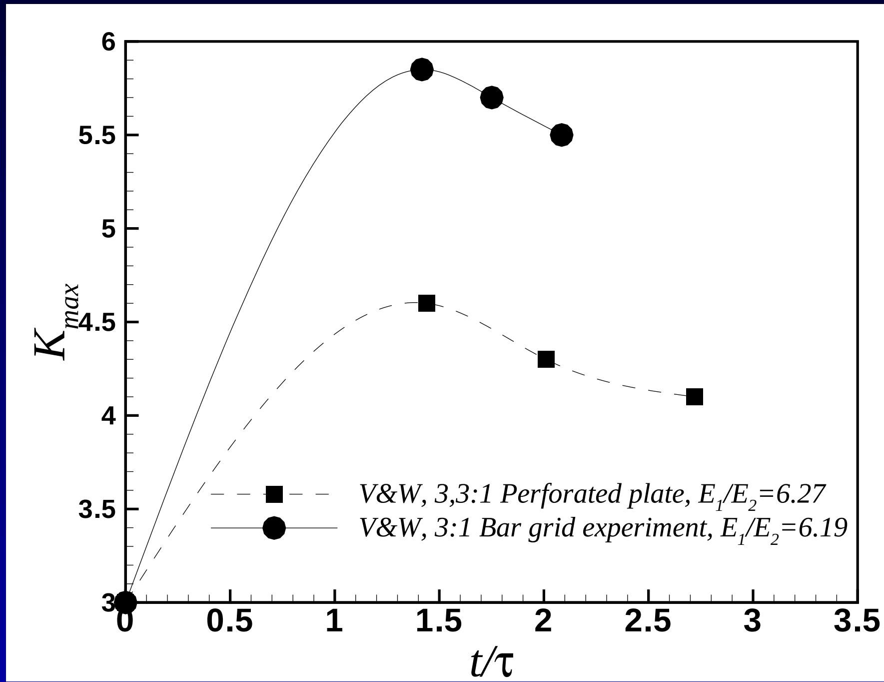




Time evolution of the maximum of skewness within the mixing.

Inhomogeneity: Kurtosis evolution

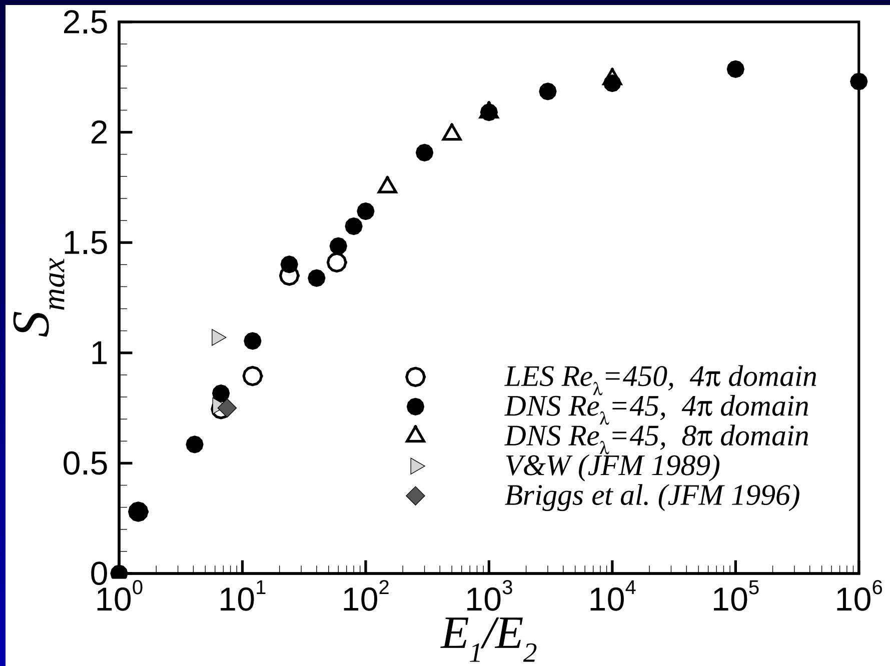


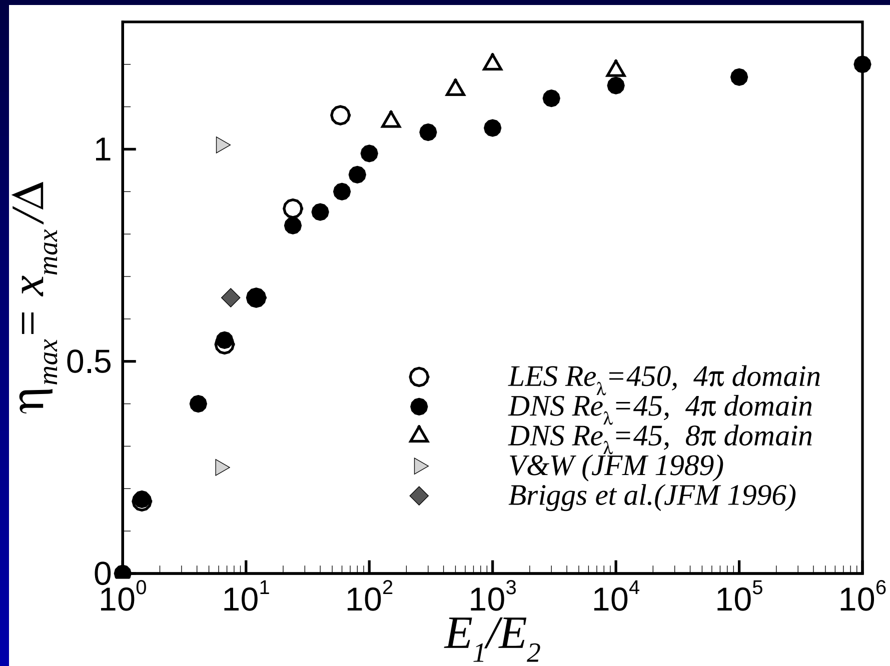


Time evolution of the maximum of kurtosis within the mixing.

Asymptote for $E_1/E_2 \to \infty$

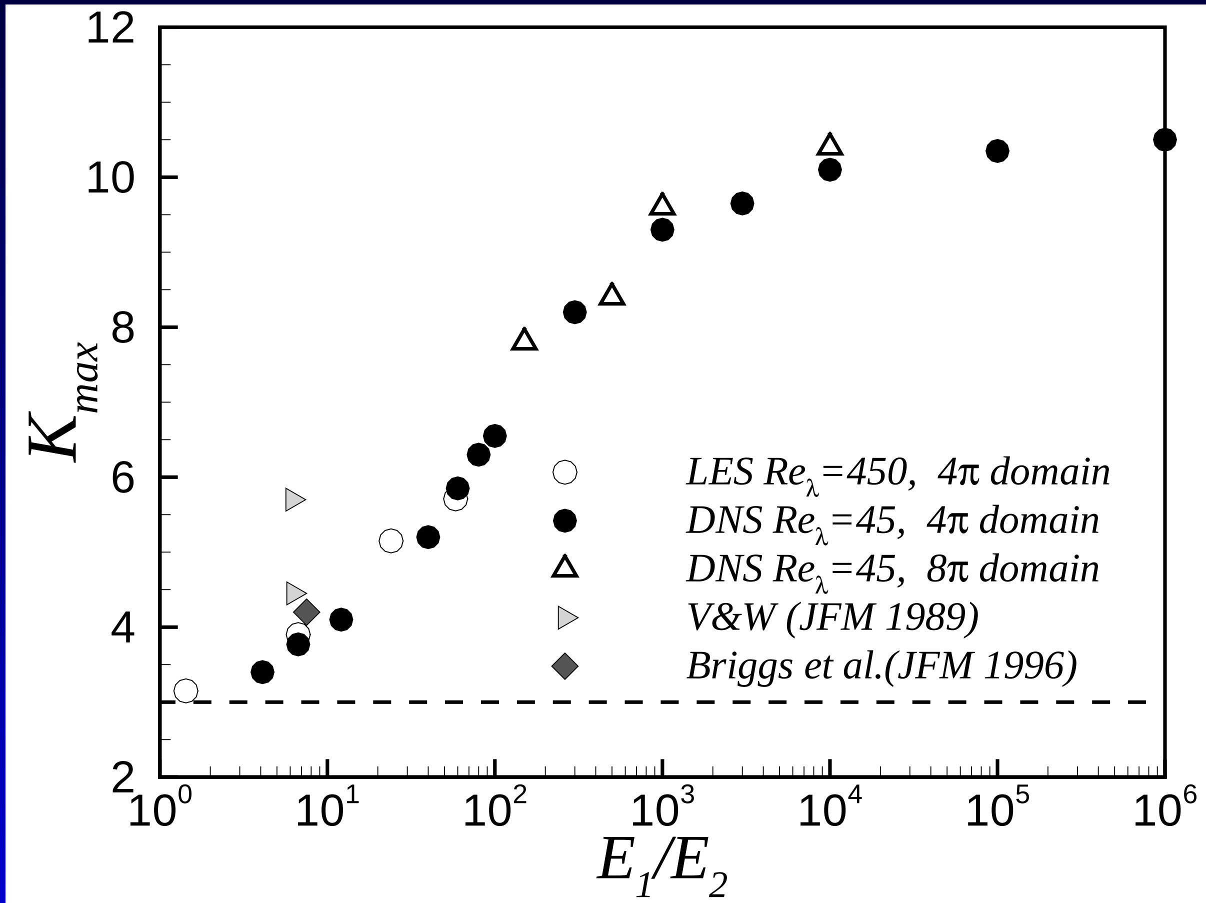
Skewness





Asymptote for $E_1/E_2 \to \infty$

Kurtosis



Conclusions

- Simulations which span a large range of energy ratios, $6 \leq \mathcal{E} \leq 10^6$, show:
  - high anisotropy of third order moments
  - the mixing is always highly intermittent even if integral scale is uniform across the mixing $\Rightarrow$ *a gradient of turbulent kinetic energy is a sufficient condition for gaussian departure*.
  - penetration tends to 1.2Δ for $E_1/E_2 \to \infty$