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Velocity Spectra from Various HeII Flows at Finite Temperature

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Velocity spectra from various He-II flows at finite temperature

3 experimental confirmations
of Maurer & Tabeling 1998 paper

Institut Néel
CNRS & Université J. Fourier

Collaboration TSF
UJF, INP, CNRS, CEA, ENSL

Main contributors

- "Chunk" turbulence experiment — Institut Néel, CNRS/UJF
  F. Gauthier (PhD), B. Chabaud, **P.-E. Roche**

- Grid and Wake experiments : TSF collaboration
  - Institut Néel, CNRS/UJF : **J. Salort** (PhD), **P.-E. R.**, P. Thibault
    + technical support : A. Gerardin, G. Garde, C. Guttin,…
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    + technical support : M. Bon Mardion, A. Forgeas,…
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  - CEA/Saclay : B. Dubrulle, F. Daviaud

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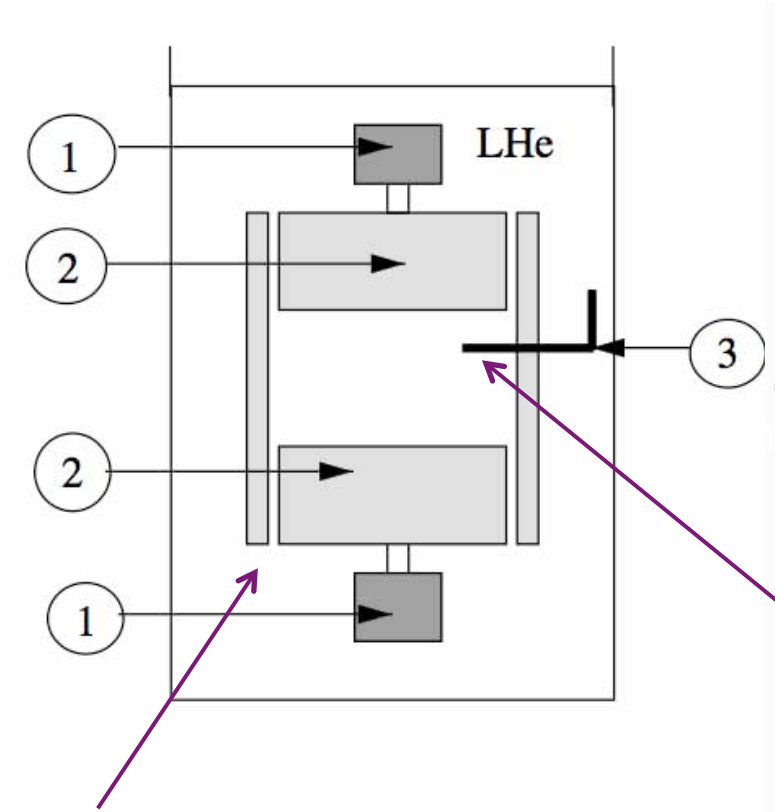
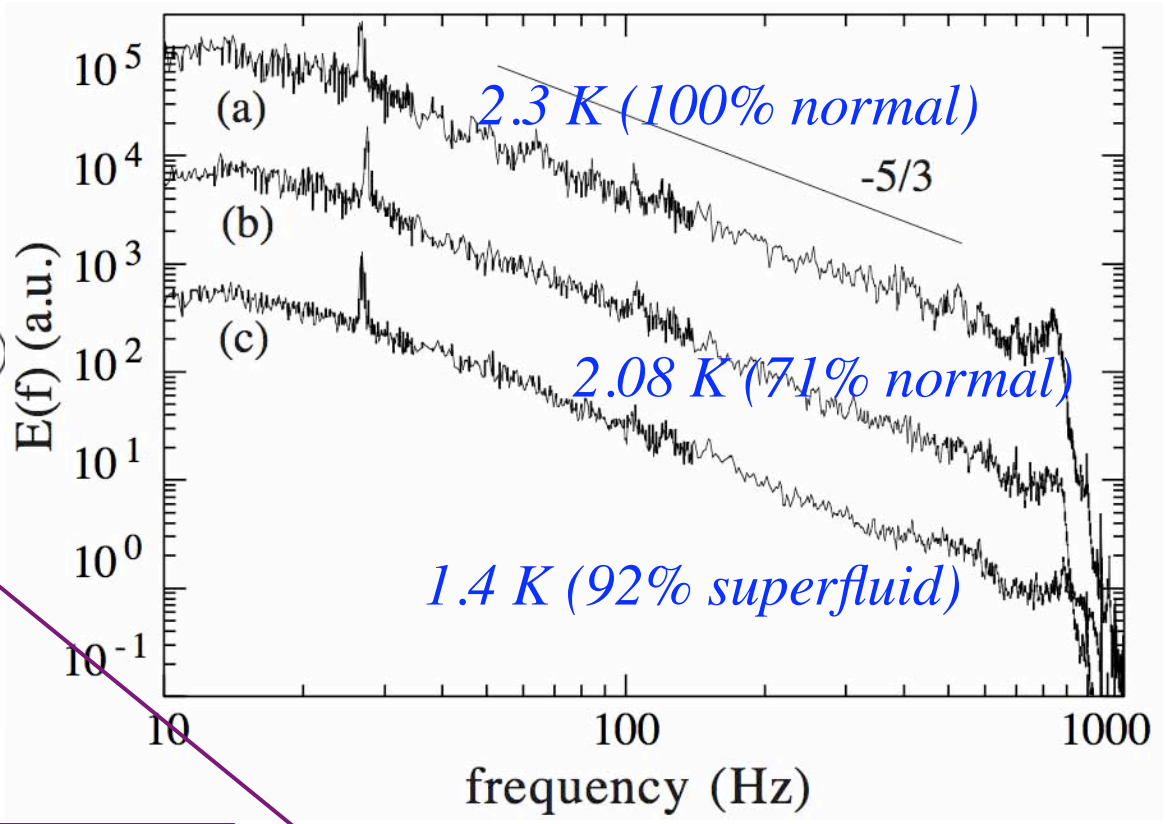
Local investigation of superfluid turbulence,
J. Maurer and P. Tabeling, EPL (1998)



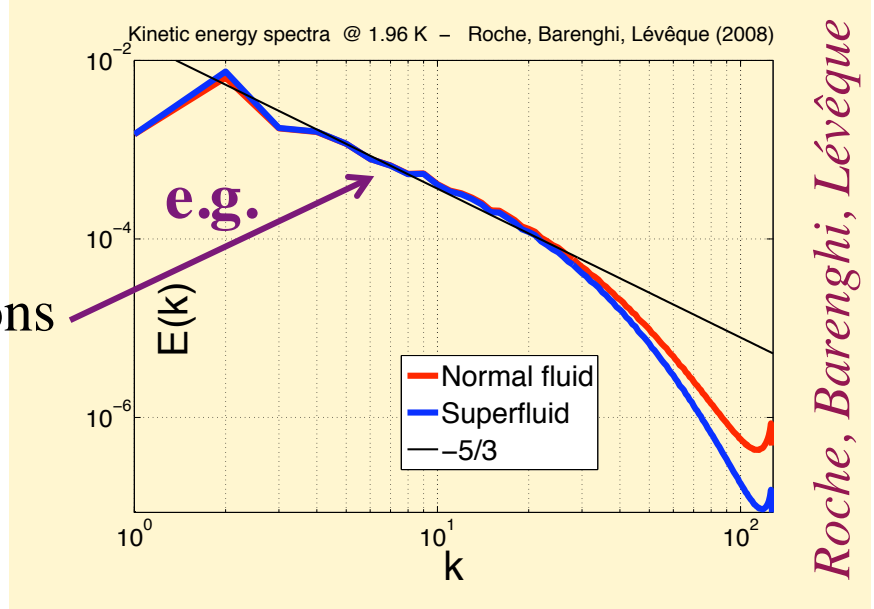


Von Karman flow of liquid ^{4}He :
Diameter : 8 cm, Height : 20 cm
Mean velocity on probe : V = 0.8 m/s
Turbulence intensity v/V = 20-30 %

Probe :
Stagnation pressure probe
Φ_e=1.2 mm, f_{reson} ~ 900 Hz

Motivations

- Complementary results :
  - Several consistent numerical simulations
  - Theoretical understanding



- So why spend time, effort and € trying to confirm it ?
  - Our first pressure probe : developed to check another local probe
  - Maurer & Tabeling paper :
    Unconfirmed decade-old experiment ; unique flow and probe
  - Statistical analysis of velocity fluctuations in He-I vs. He-II

Parameters explored in the present study :

- Types of flow
  - ⇨ “chunk” turbulence + wake turbulence + grid turbulence
- Reynolds number
  - ⇨ estimated R_λ from 150 to 1400 (Maurer et Tabeling $R_\lambda \sim 1400$)
- Turbulence intensity v_{rms} / V_0

  For 30 % turbulence intensity, based on classical turbulence estimation, the signal from a stagnation-pressure probe consists in :
  - *the expected velocity contribution (~75% of total signal)*
  - *a quadratic correction term (~11%)*
  - *a static pressure term (~15%)*
  - *events with flow-probe angle of attack (yaw angle) exceeding 15°*

  ⇨ Turbulence intensity varied from 1.5% to 35%
- Pressurisation of flow
  - ⇨ to prevent bubbles in He-I

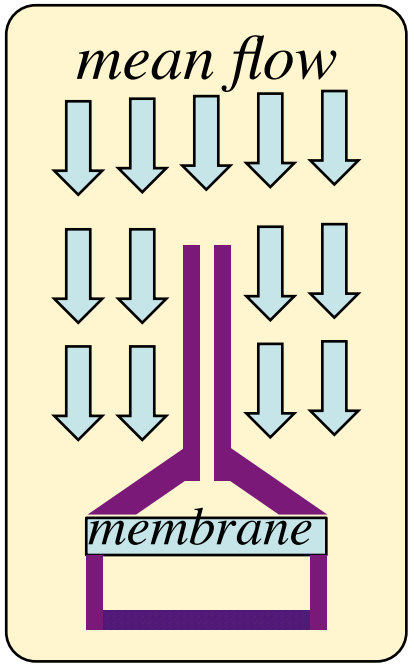
A word on probes

- Commercial piezo-resistive probes
  with nozzle of diameter $\Phi_e \sim 1$ mm

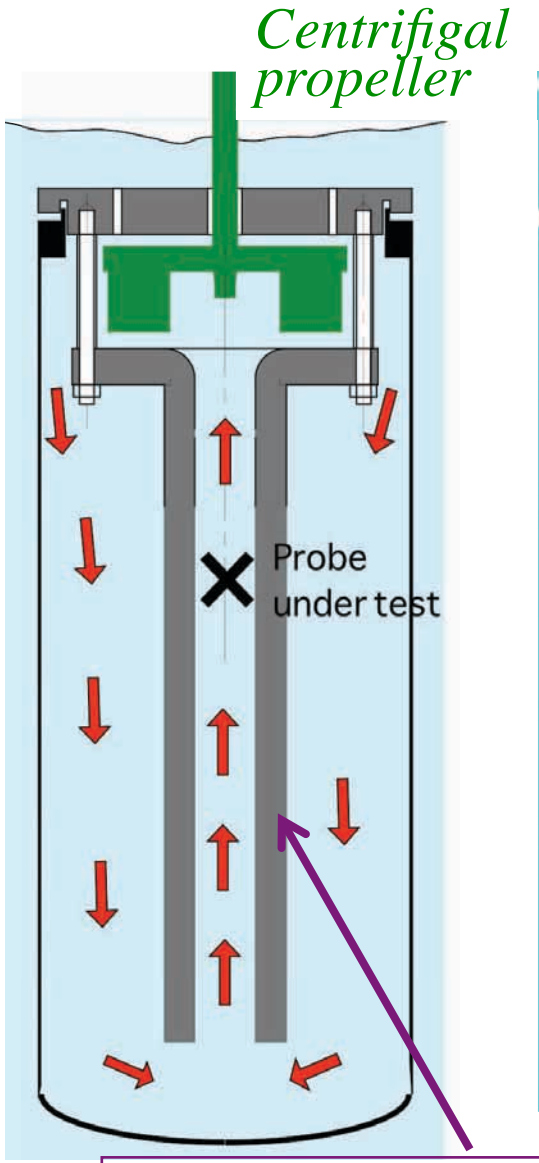
- Space resolution : nozzle diameter Φ_e

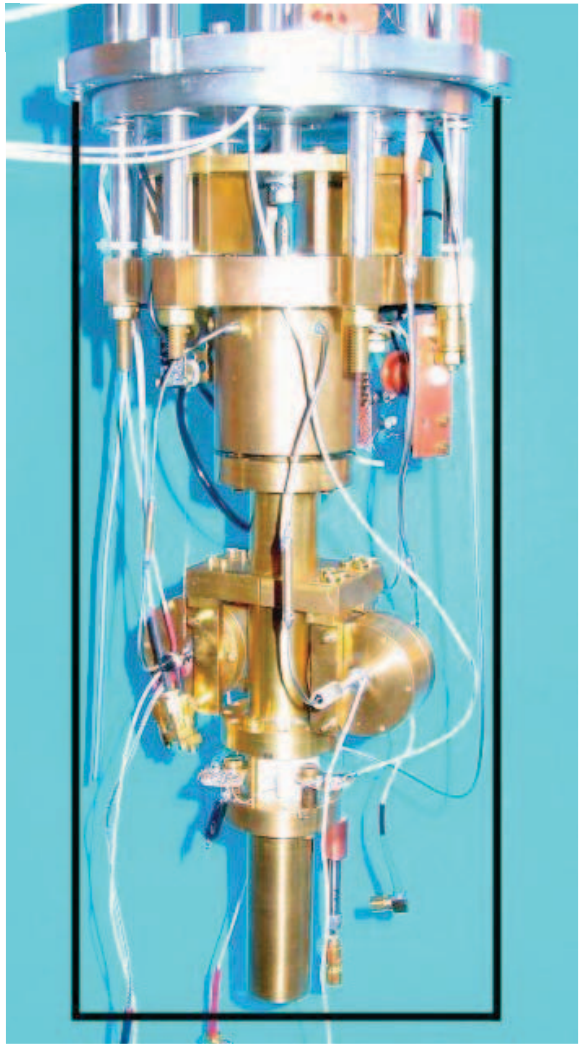
- Useful Time resolution = min (Φ_e/V , f_{nozzle})
  where f_{nozzle} is determined by
  - organ pipe resonance
  - orifice + cavity resonance (Helmoltz)
  - transmitting tube + cavity resonance

- Sensitivity : $\delta P \sim \delta(\rho.V^2/2)$
  - taking V~1 m/s , $\delta V \sim V_{rms} \sim 10\%.V$, ρ~145 kg/m^3
    δP_{rms} ~ 1 Pa ~ 100 dB acoustic
  - typical microphone sensitivity

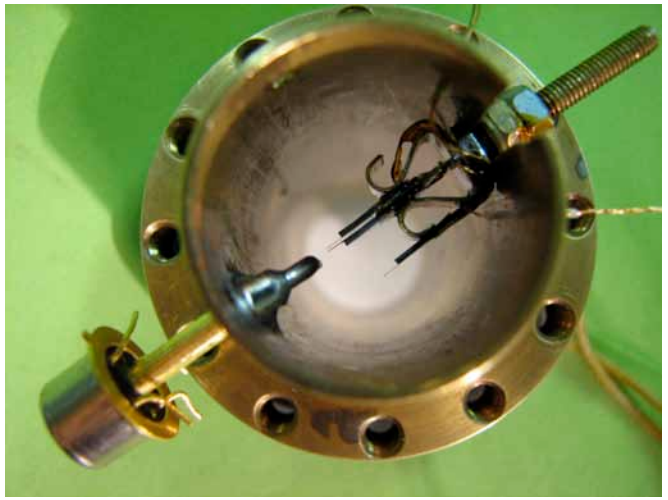


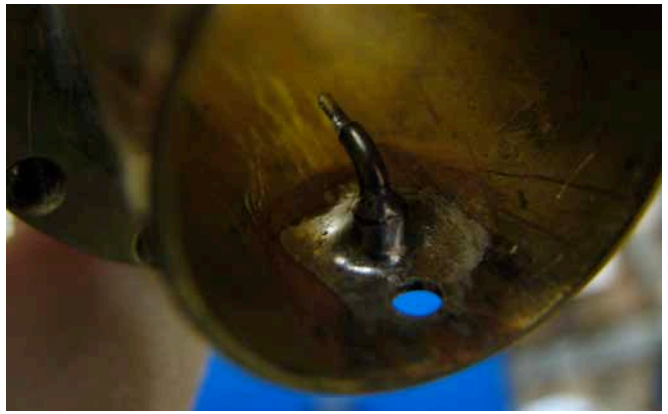
“Chunk” turbulence in a pipe





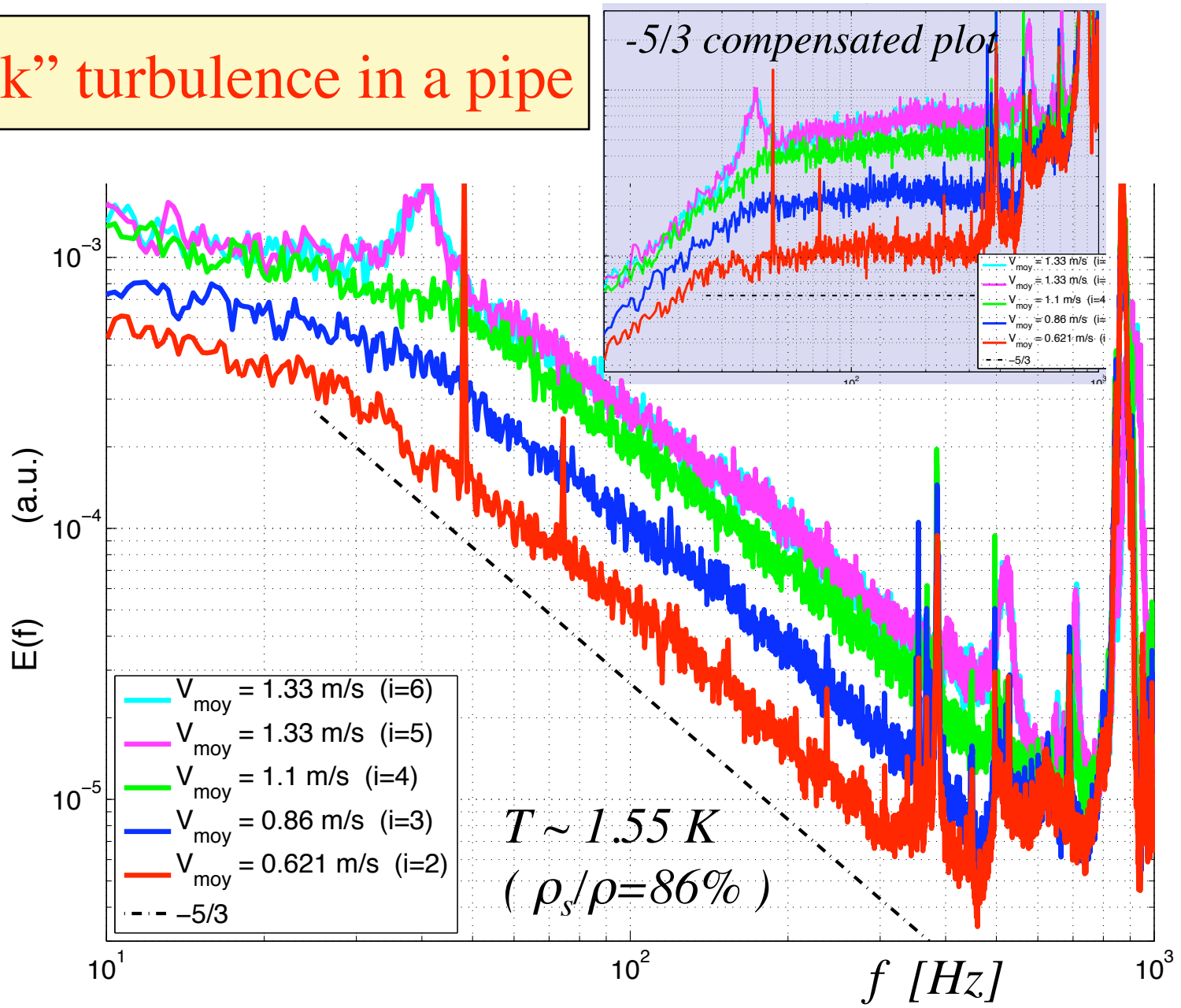
- High Re (Re ~ 10^6 in He-I)
- Fixed mean direction
- Turbulence intensity ~ 30 %





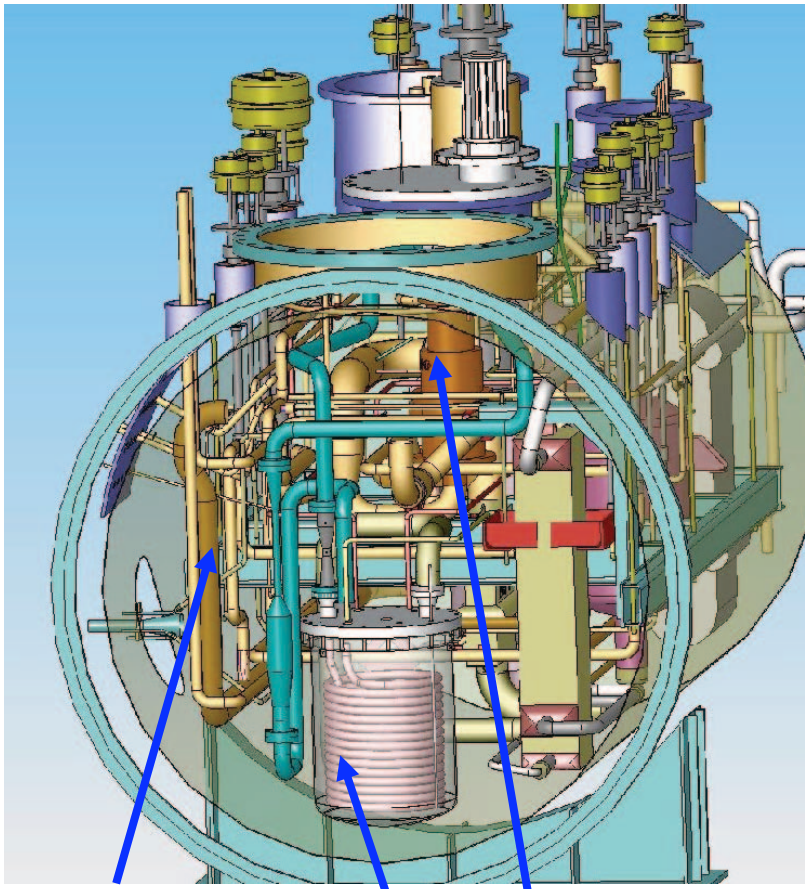
Φ= 23 mm , L ~250 mm , V : up to 1.3 m/s

“Chunk” turbulence in a pipe



Spectra are compatible with -5/3 scaling
over the 1 decade in the upper inertial range frequency

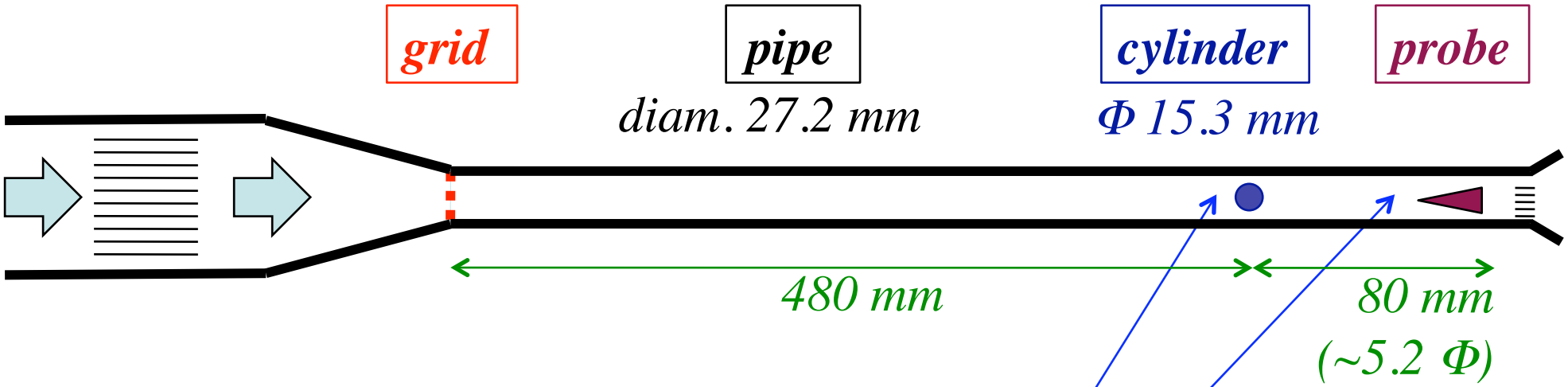
TSF : a pressurised He-I / He-II Loop with mass flow up to 700 g/s



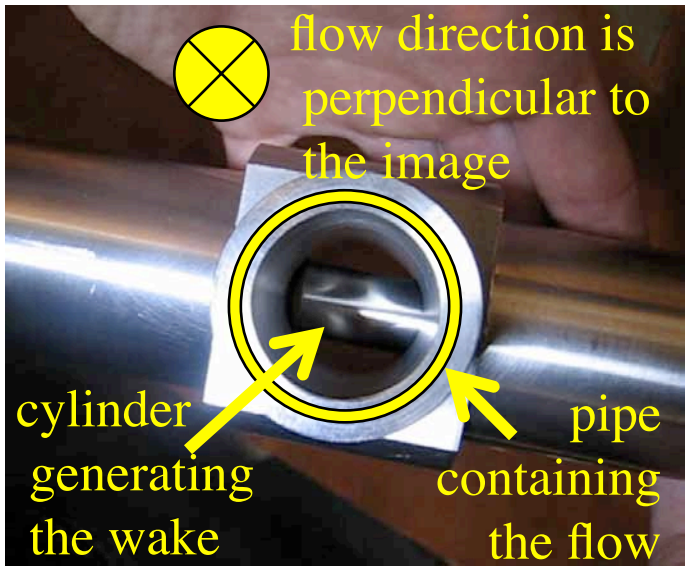
Cooling power :
400W @ 1.8K

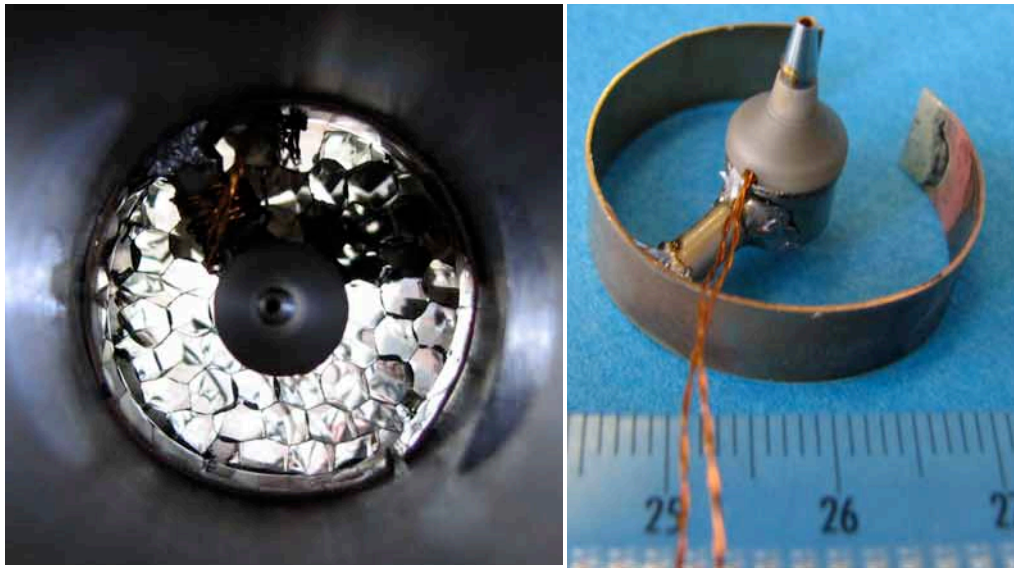
Test section
Heat exchanger : Φ=30 mm , L > 10 m
Barber et Nichols centrifugal pump (ΔP=300 mbar)

Confined wake Turbulence



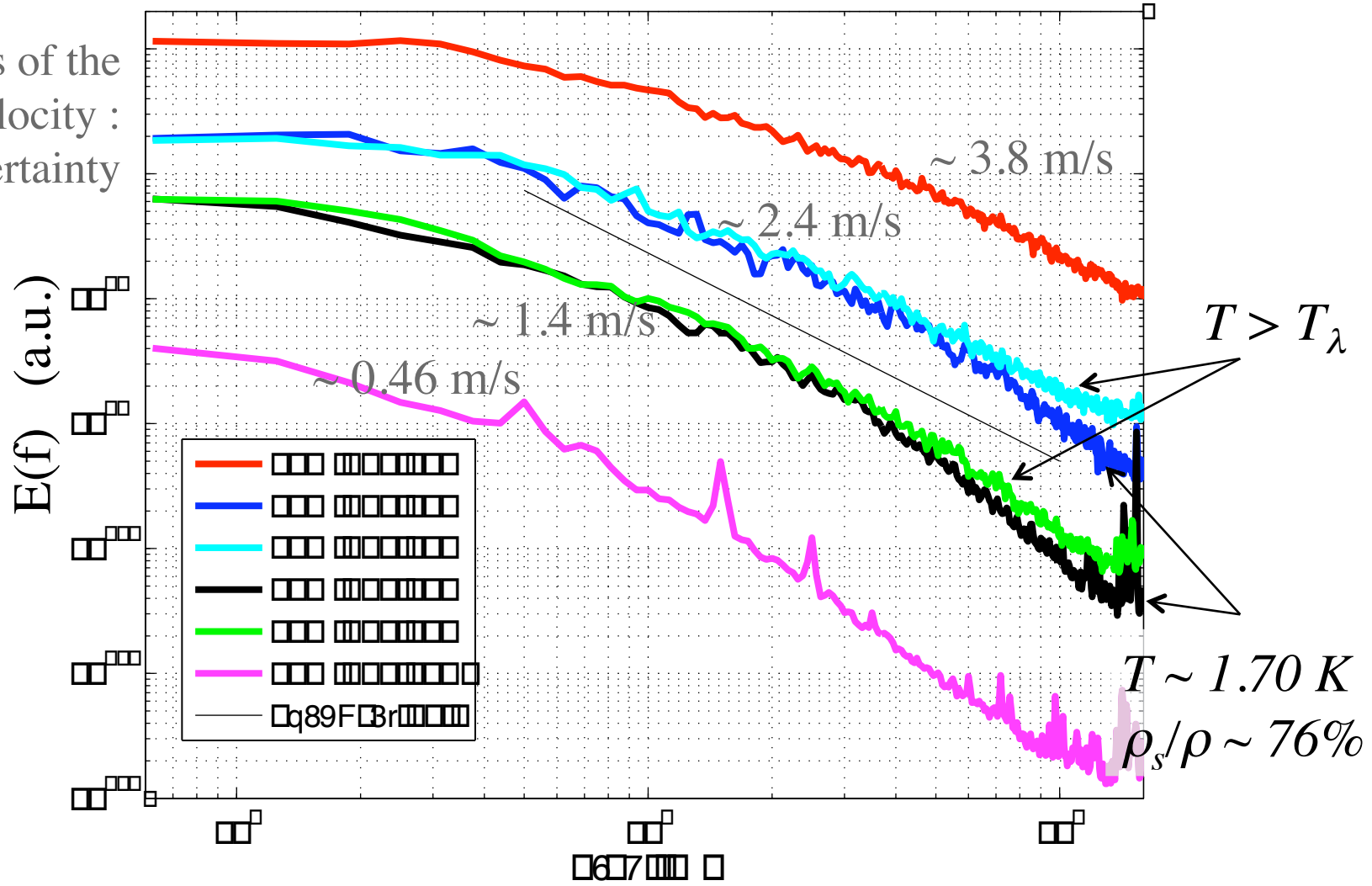
- Estimated turbulence intensity : ~ 1.5 %
  10 %





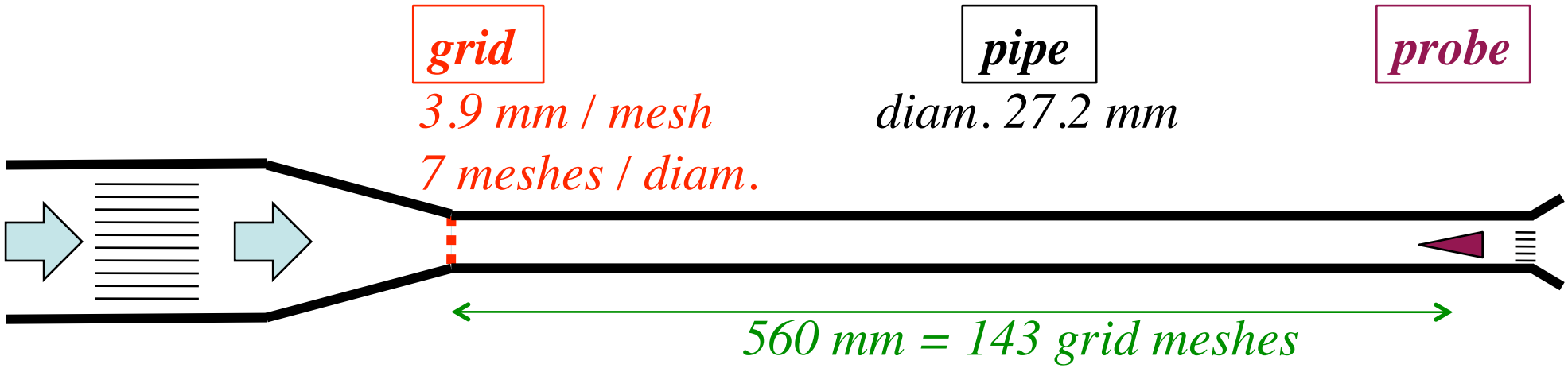
Confined wake Turbulence

estimations of the mean velocity : 15 % uncertainty



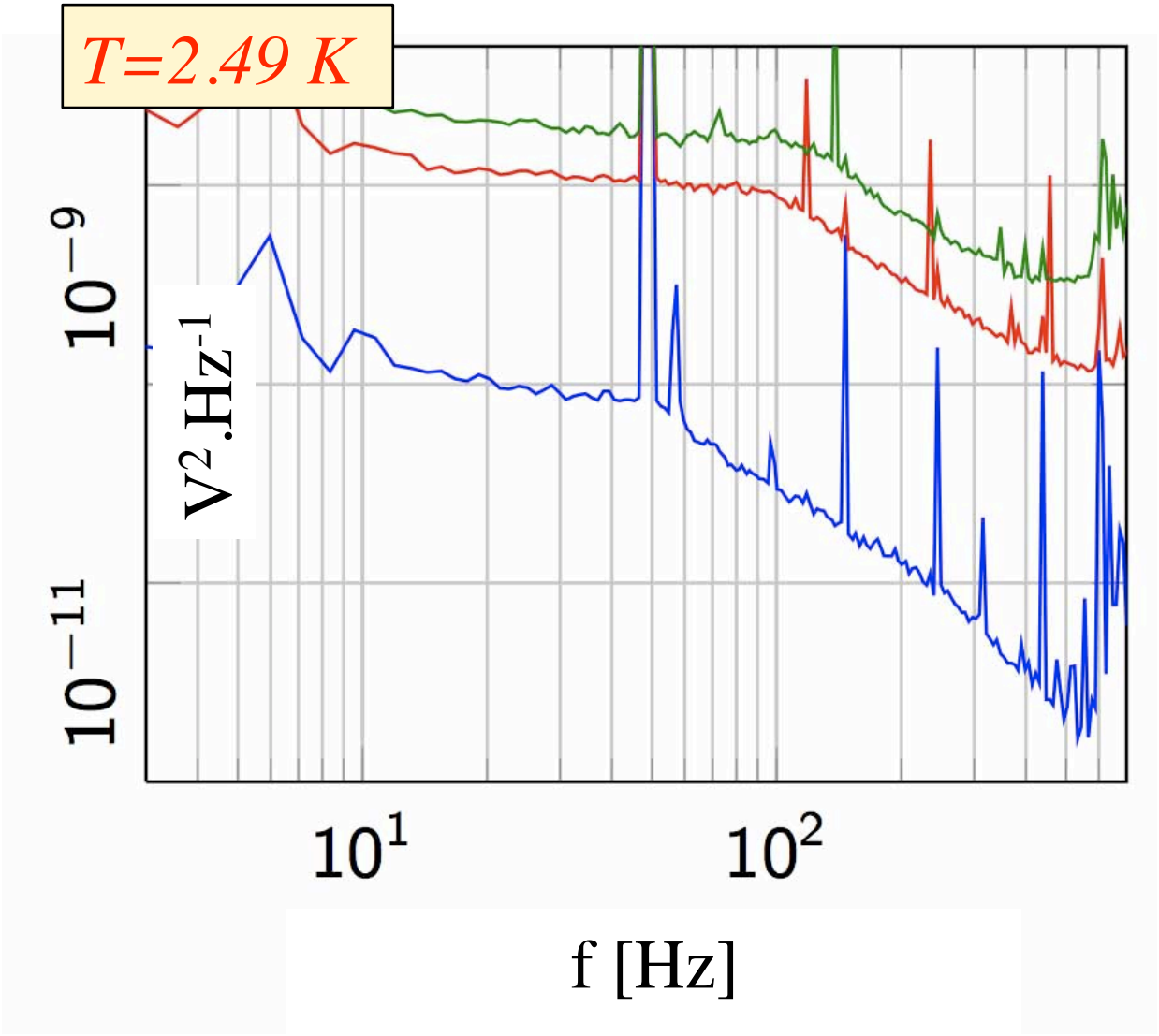
Nearly overlapping spectra in He-I and He-II over ~ 2 decades of frequency

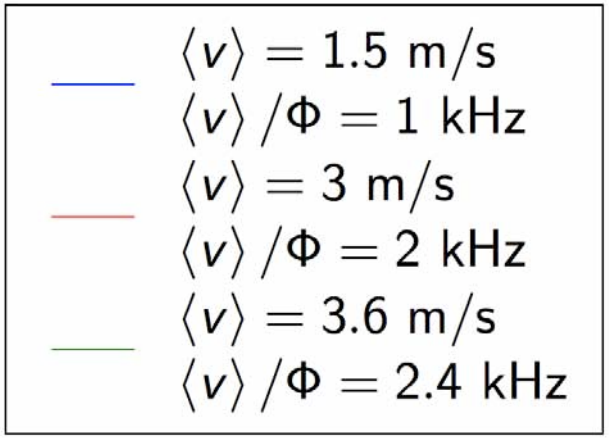
Grid Turbulence

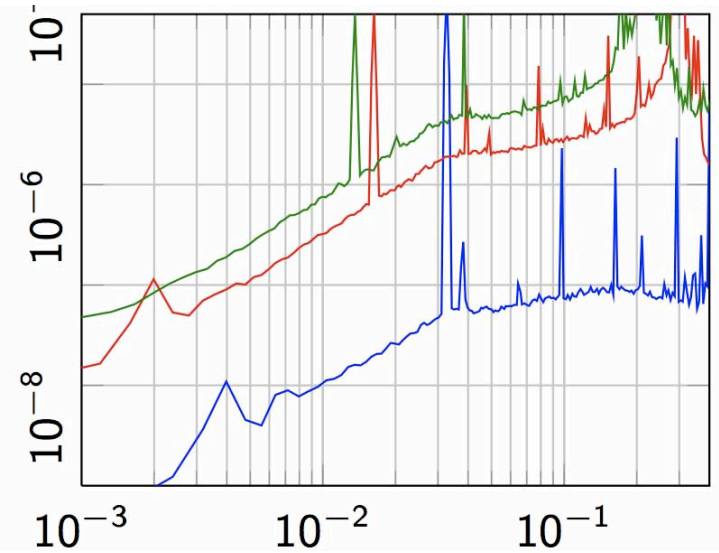


- very well known & very “clean” flow (isotropic,…)
- low turbulence intensity
  -> fluctuation of stagnation pressure ~ fluctuations of velocity

Grid Turbulence (preliminary results)
He-I



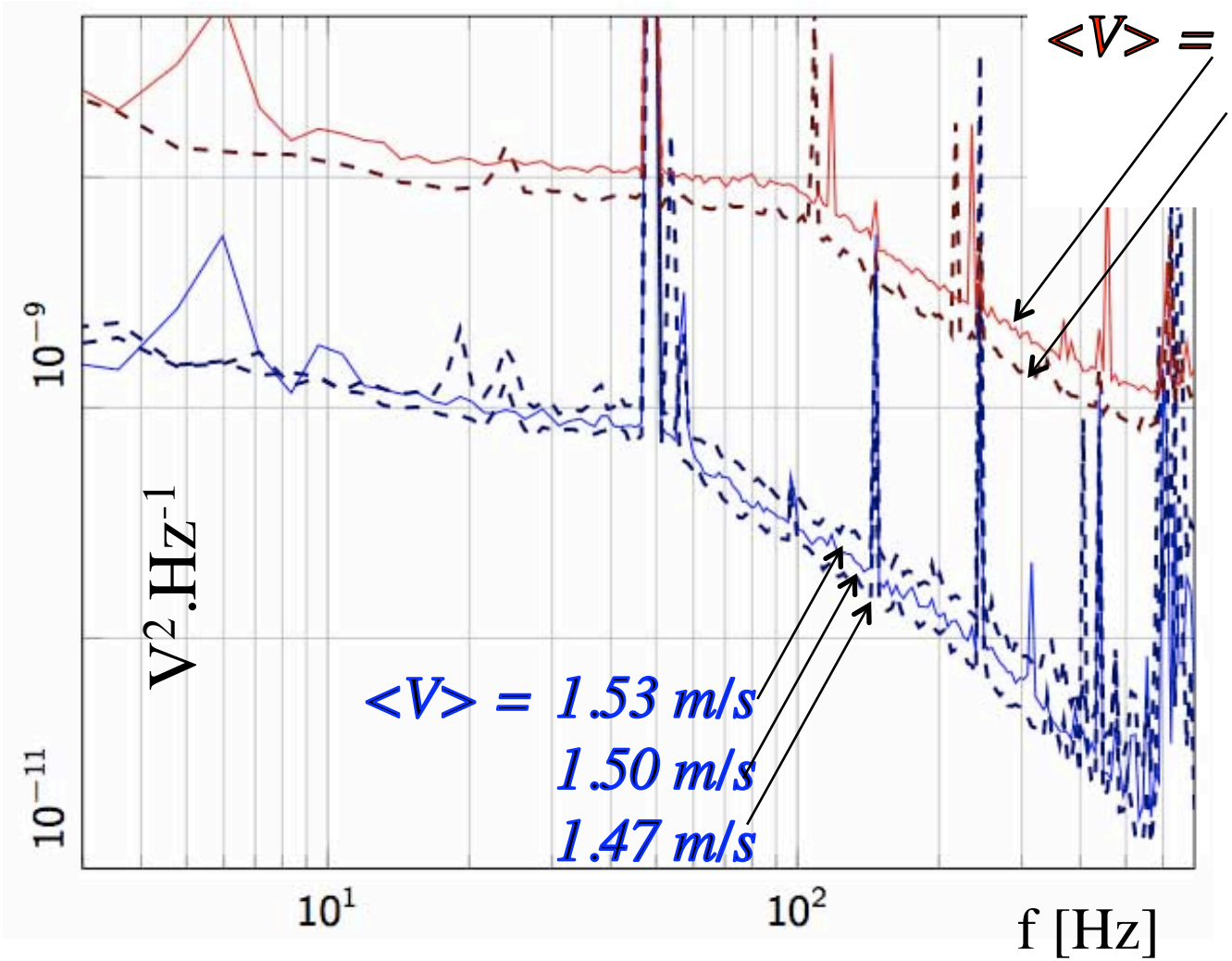




Grid Turbulence (preliminary results)
He-I versus He-II

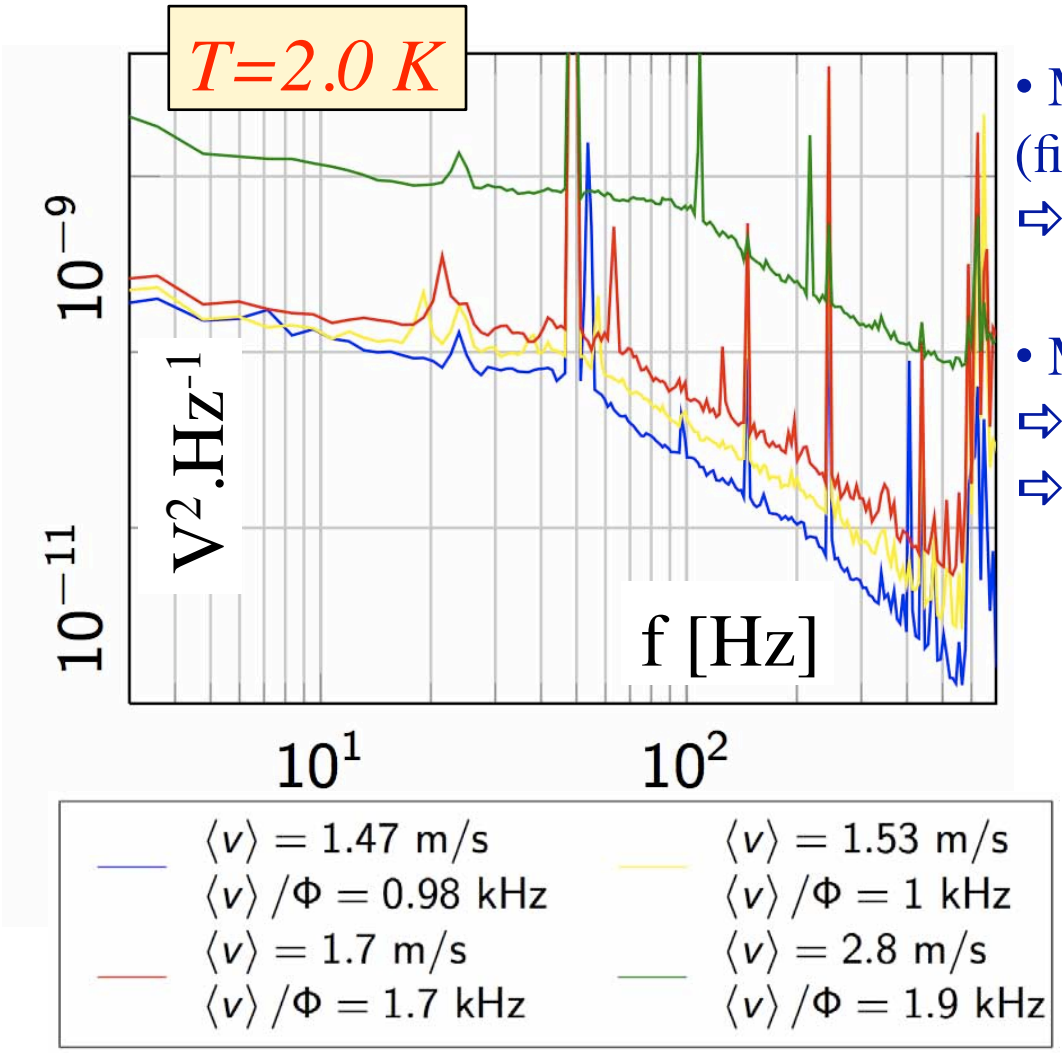
T=2.49 K

T=2.0 K
$\rho_s/\rho \sim 43\%$



⇨ Similarity between the 2 spectra above and below T_λ

Grid Turbulence (preliminary results)
He-II



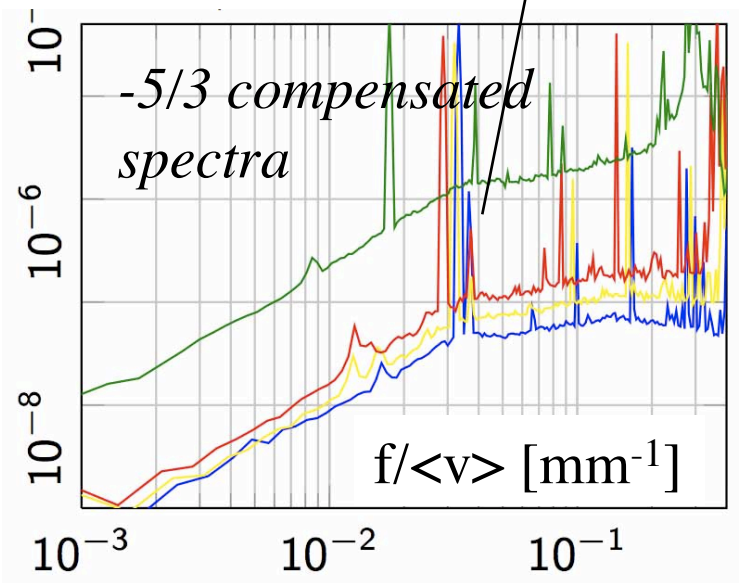
- Measured Turbulence intensity : 1.7 % (first estimation to be confirmed)

⇨ Consistent with classical grid turbu

- Measured Low freq corner @ $(28\ mm)^{-1}$

⇨Lg Integral scale $28/5\pi \sim 1.8$ mm

⇨ Consistent with classical grid turbu



Conclusions & Perspectives

- Maurer & Tabeling observation (= identical spectra above and below T_λ) is confirmed, in particular with :
  - a nearly pure velocity signal, thanks to a turbulence intensity < 2 %
  - various flows
- Short-term perspective (2009)
  - Repeat the Grid turbulence measurements with increased resolution and sensitivity

    -> statistical analysis of intermittency

LABORATOIRE cnrs dépasser les frontières EN LUTTE

« Bad », « inefficient », « archaic », « ideologues », « partisans », « conservatives », « blind », « immobile », « refusing to face reality », « installed in the comfort of self-evaluation » « working in obsolete, archaic and rigid structures »,…

from Nicolas Sarkozy, Jan. 22nd 2009 public speech on French researchers and French research system