Experiments on Quantum turbulence in a Cryogenic wind tunnel

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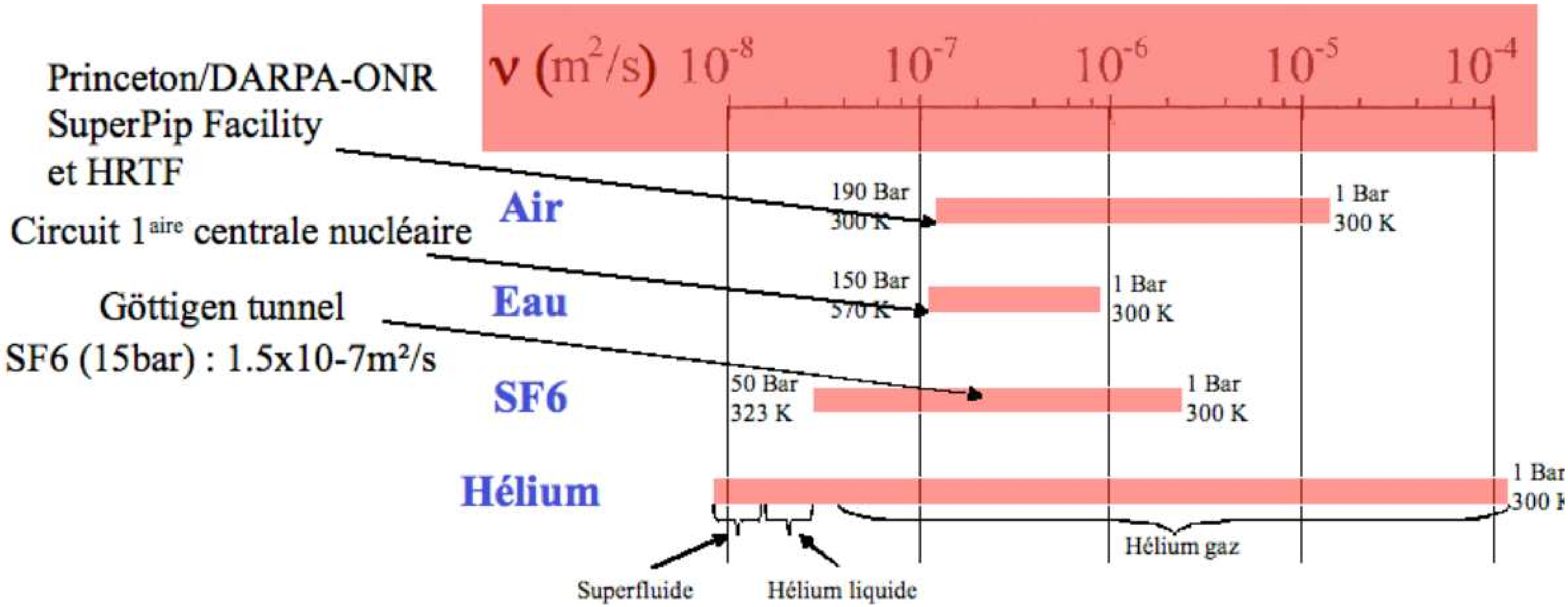
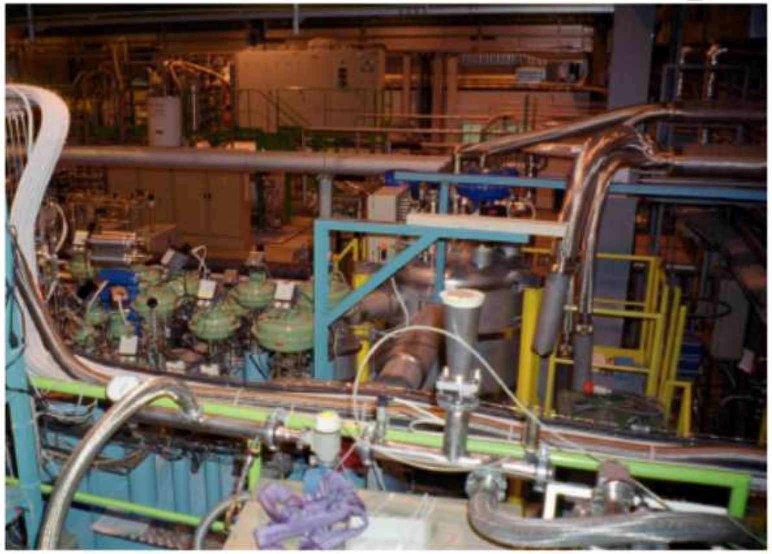
On the use of Helium for experiments



→ Wide range of viscosities

The GReC experiment

5. Experimental Set-Up

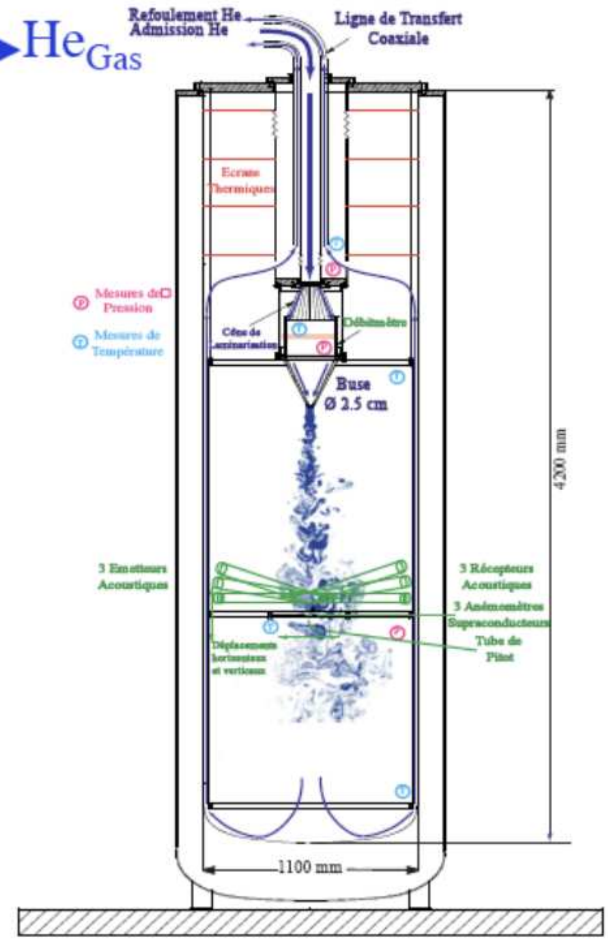


He_{Liq} Coaxial Line → He_{Gas}

\+

Heating

Flow Set-Up



Helium Production

- Linde refrigerator : Refrigeration Power 6 kW
  overall Electrical Power consumption : several MW !
- Gaseous Helium Flow Rate @ 4 K : 20g/s -> 300g/s
  from heating of Liquid Helium @ 2,7 K
- T and Q regulation : heating control in the coaxial transfer line
- Loop back on (P, T, Q) measured in the jet flow

The GReC experiment

13. Flow Reynolds Numbers and Scales

Helium Viscosity @ $T_{op} \sim 4.7$ K : $\nu_{He} = 8.10^{-8}$ ($\sim \nu_{air}/230$!)

Mass Flow Rates : Q = 21 g/s up to 250 g/s

Mean Velocity (@50 D_{Nozzle}) : from 35 cm/s up to 4 m/s

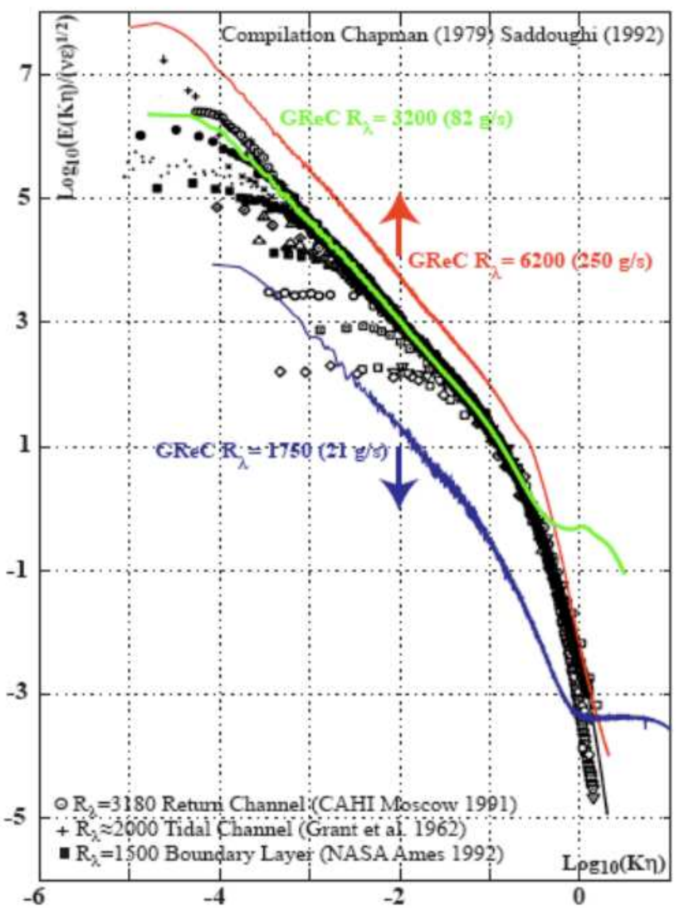
Reynolds numbers : Re = 8.10^5 up to 10^9
Taylor Reynolds numbers : R_λ = 1300 up to 6000

Integral Scale : L ~ 30 cm
Taylor Scales : λ = 1.7 mm down to 0.4 mm
Kolmogorov Scales : η = 20 μm down to 0.4 μm

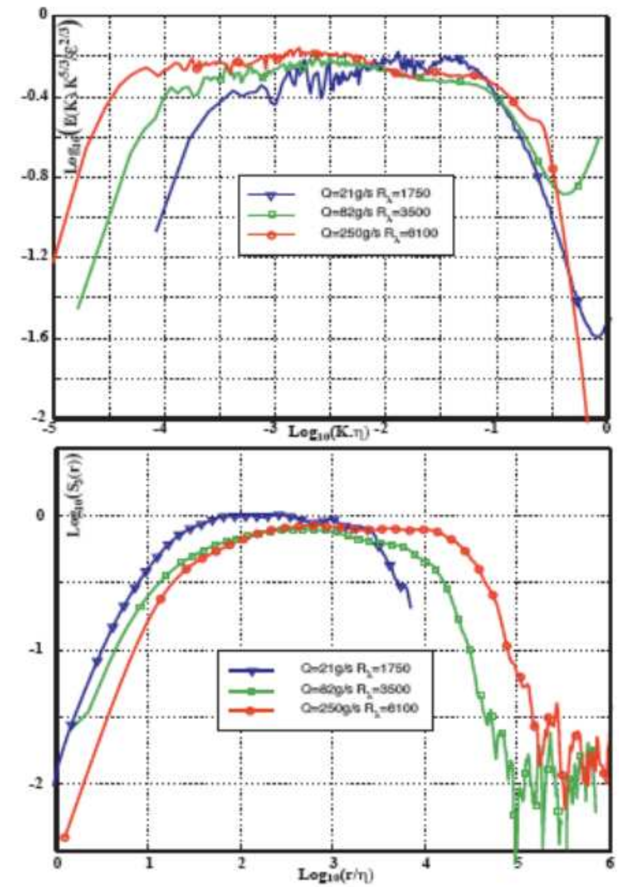
Time series up to 10^9 samples @ $F_{sampling}$ = 1.25 MHz

The GReC experiment
14. Scaling Laws inertial range

The -5/3 law (Kolmogorov 1941)



-5/3 and 4/5 laws (K41)



The TSF experiment
1. Aims

- TSF : "Turbulence Superfluide français"

- Fully developped Grid turbulence

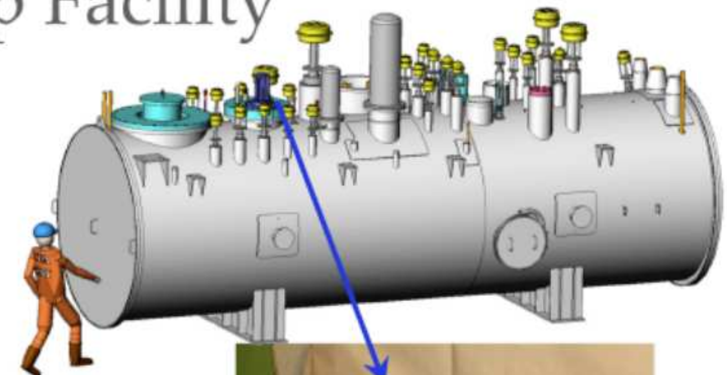
  ✓ Liquid Helium in the normal state ⇨Classical turbulence at $R_\lambda \sim 450$
  - o Grid turbulence ~ best approximation of Homogeneous Isotropic turbulence
  - o Low velocity fluctuations level : $u'/U \approx 3\%$
  - o High R_λ scales separation
  - o Scaling laws (structure functions), intermittency, ...

  ✓Liquid Helium in the superfluid state ⇨Quantum turbulence
  - o shape of the energy spectrum in the dissipative range ?
  - o do the dissipative process influence (modify) intermittency ?
  - o internal vs inertial intermittency ?
  - o mutual interaction of the normal and superfluid turbulent velocities ?
  - o dynamic of superfluid vorticity lines (second sound probe, P. Roche).

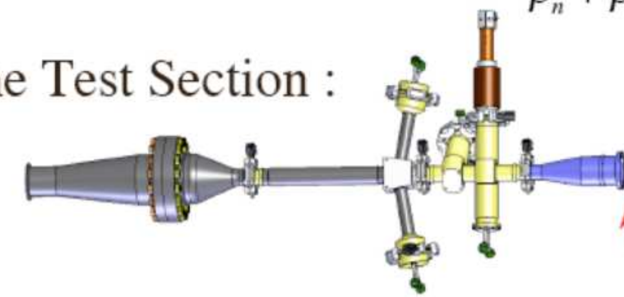
The TSF experiment
3. The CryoLoop Facility

Flow rate 750 g/s achieved at a temperature of 1.9 K

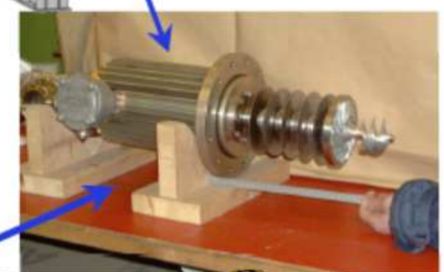
- ✓ 400 W of cooling power around 2 K
- ✓ Square Grid mesh size : 3.9 mm in 27.3 mm Pipe
- ✓ 2.2 K > T > 1.64 K ⇨ $0 \le \frac{\rho_s}{\rho_n + \rho_s} \le 80\%$

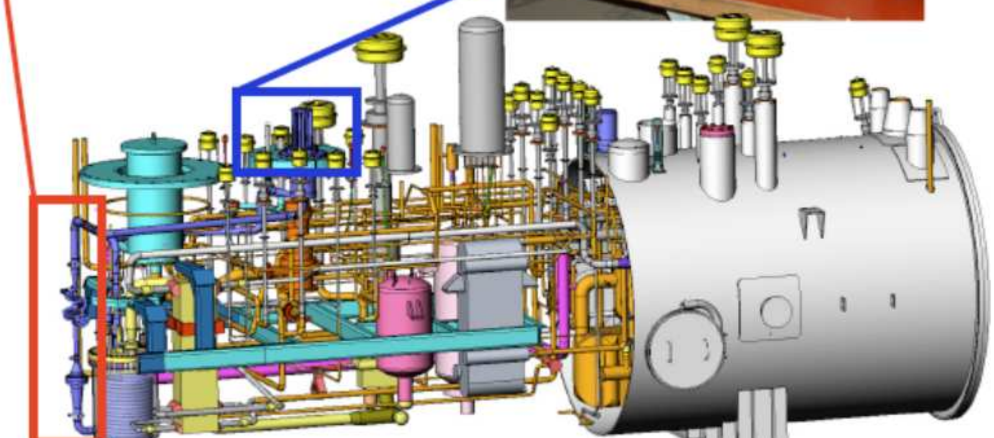


The Test Section :

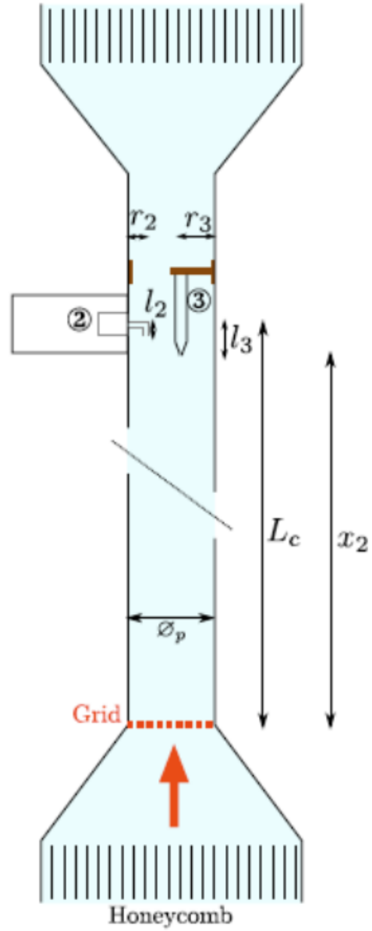


The Atlas pump :





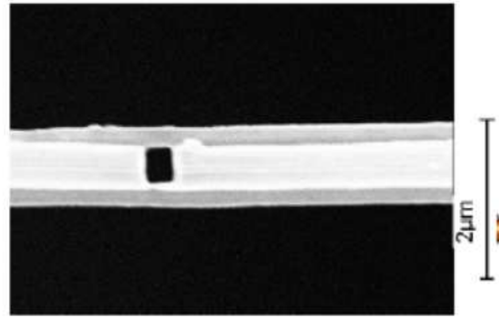
TSF: Dimensions



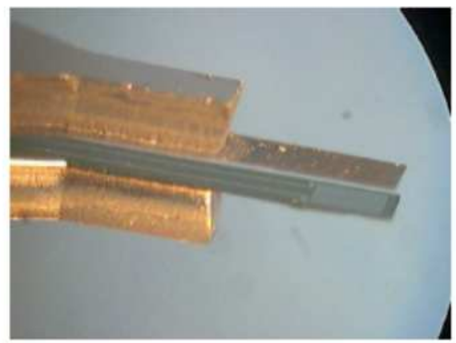
$\varnothing_p$	27.2 mm	L_1	61 mm	l_2	3 mm	l_3	9 mm
$\varnothing_c$	15.3 mm	r_1	8 mm	r_2	7 mm	r_3	11 mm
L	565 mm	$\varnothing_{i1}$	0.4 mm	$\varnothing_{i2}$	0.6 mm	$\varnothing_{i3}$	0.4 mm
L_c	479 mm	$\varnothing_{o1}$	0.6 mm	$\varnothing_{o2}$	0.9 mm	$\varnothing_{o3}$	0.6 mm
M	3.9 mm/mesh	n_M	7 mesh/diam	$\varnothing_{\text{ref}}$	0.5 mm	d_{ref}	15 mm
Ψ	3.5 mm	α	15°				

The TSF experiment
4. Sensors

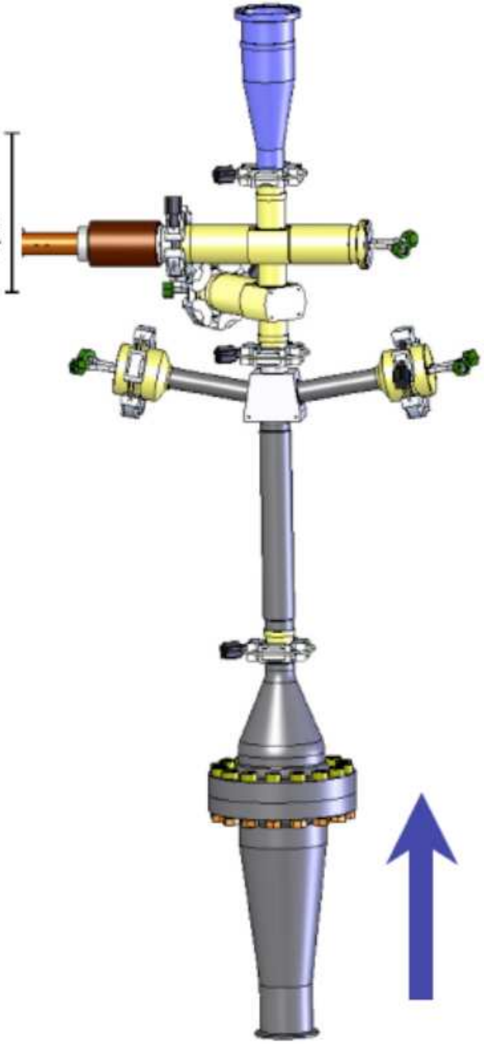
- Eulerian Velocity measurement
  with supra-conductor hot-wire
  only for the normal fluid
  (need a viscous boundary layer !)
  and Pitot tube
  P. Diribarne & P. Thibault



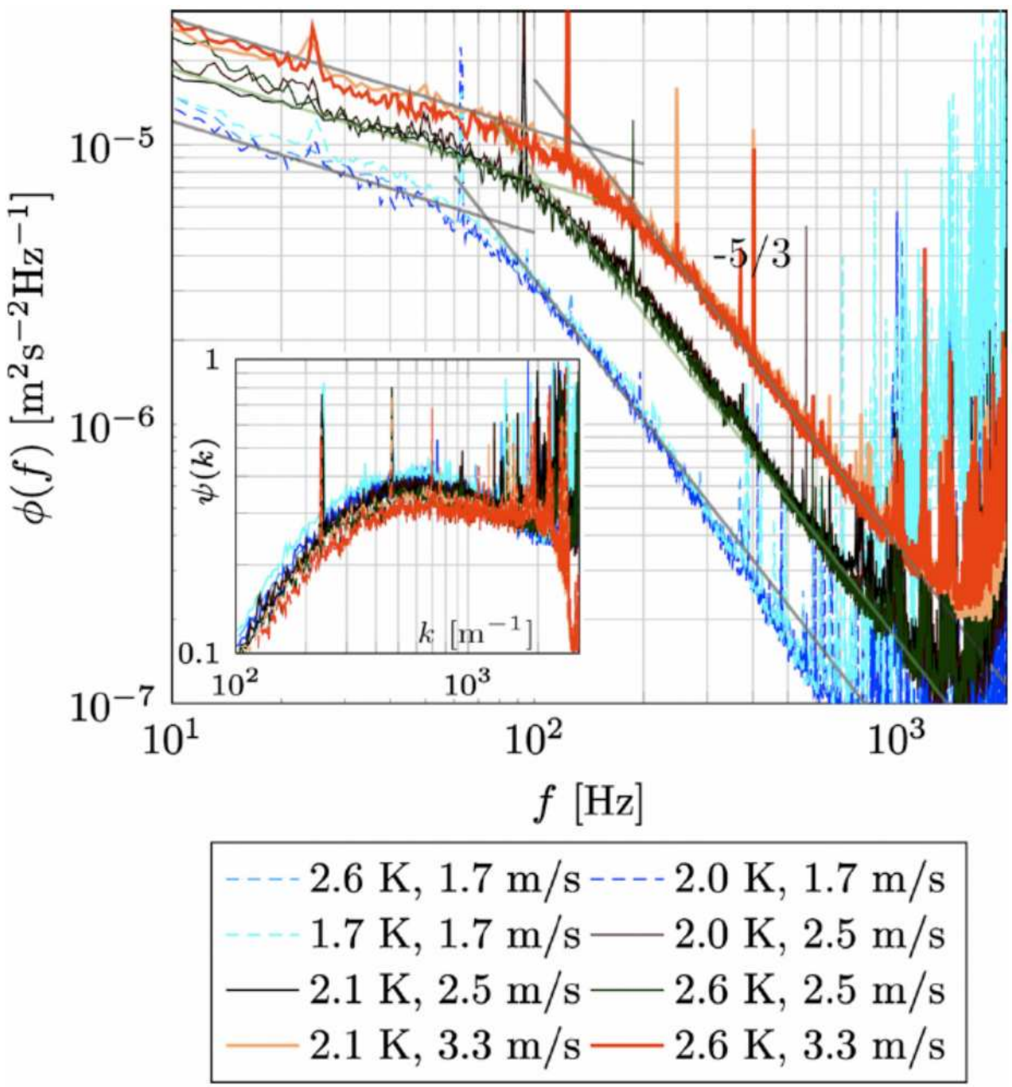
- Second sound Vorticity probe
  Thermal propagative waves
  only for the super-fluid
  P. Roche



- Acoustic scattering probe
  Spectral vorticity measurements
  in both normal and super fluids
  Y. Gagne & C. Baudet

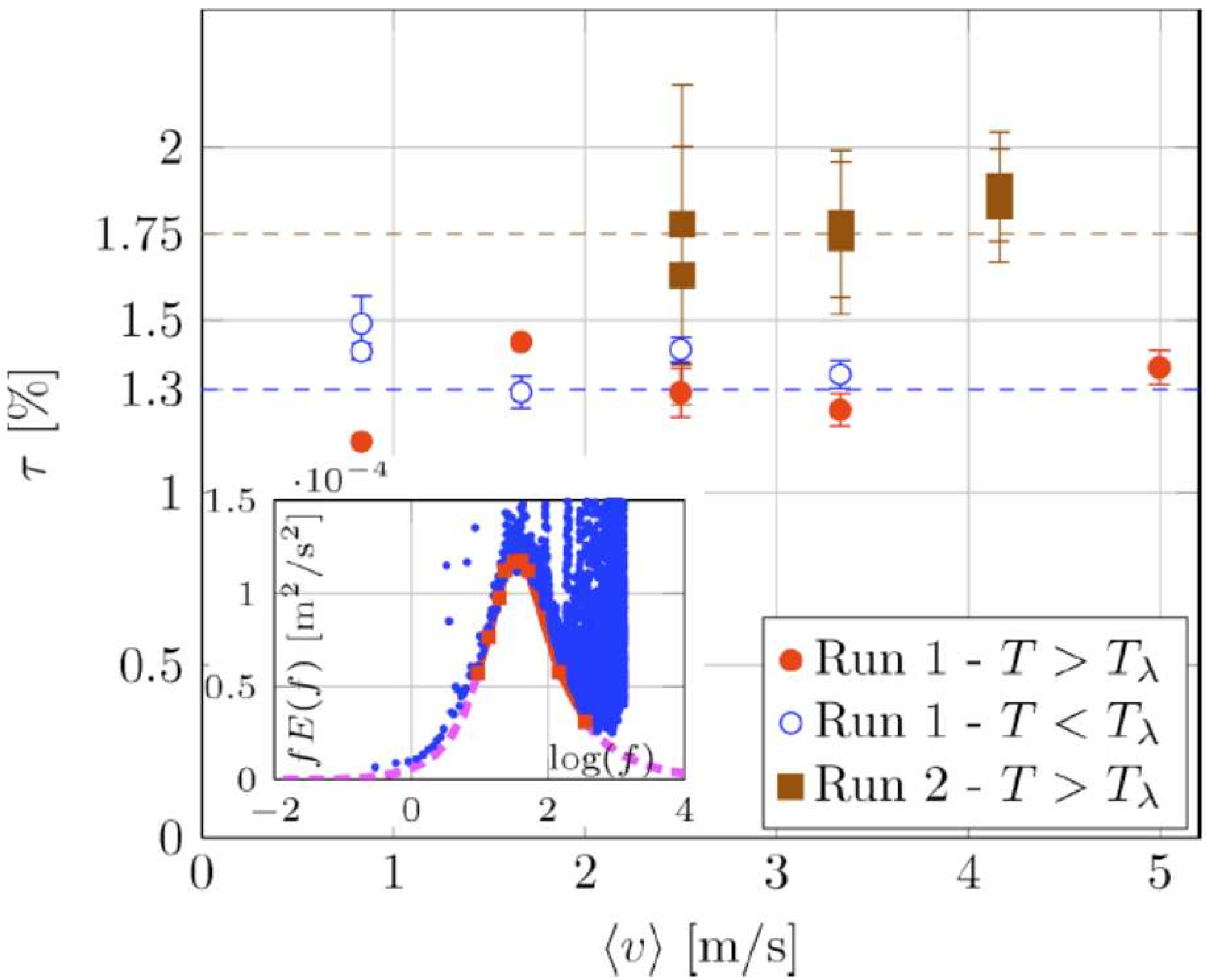


TSF: Spectra from the Pitot Tube

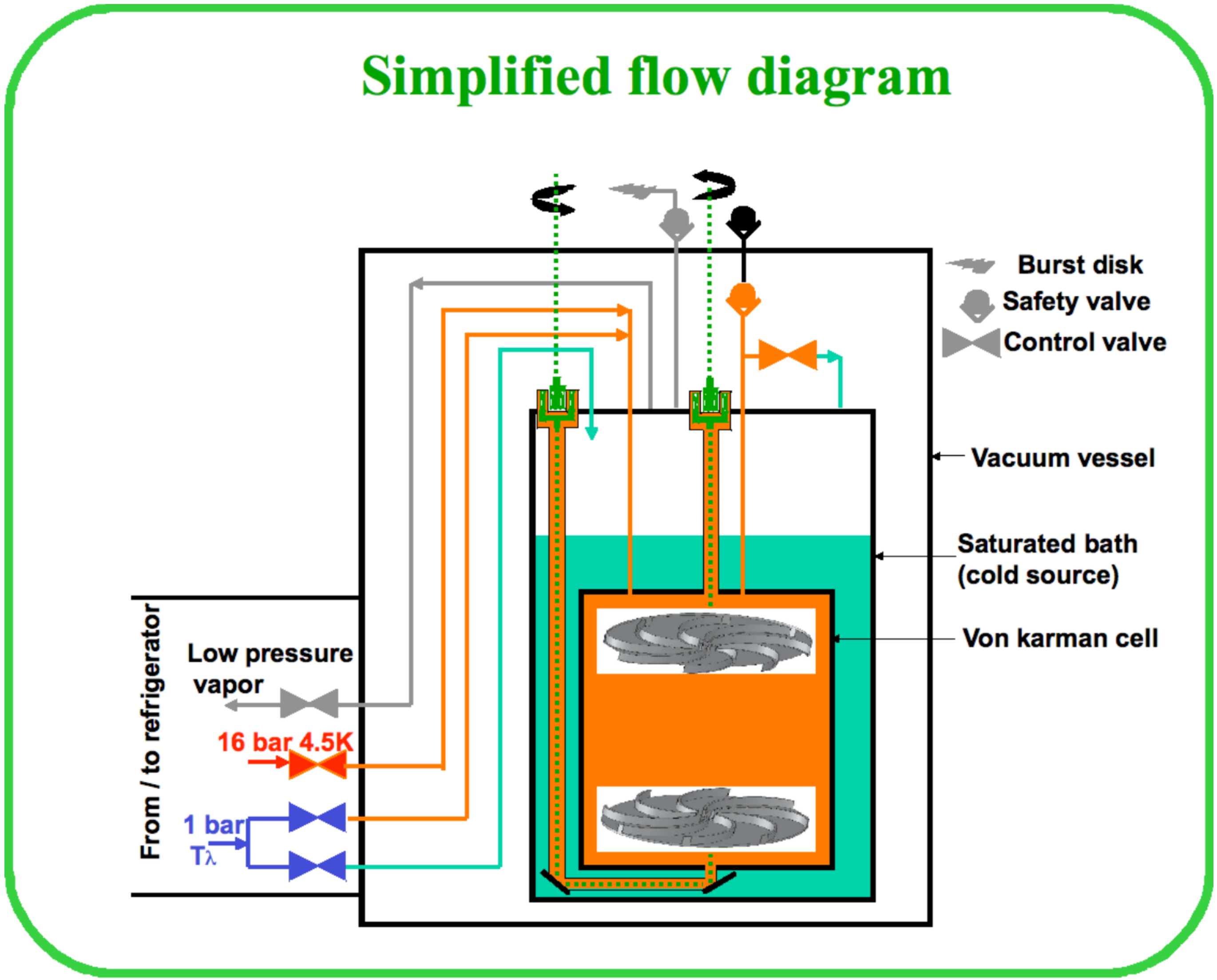


$\rightarrow$ Consistent with Maurer-Tabeling measurements

TSF: Turbulence rate from the Pitot Tube

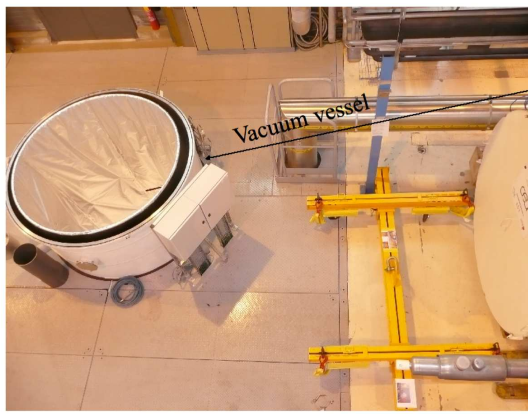


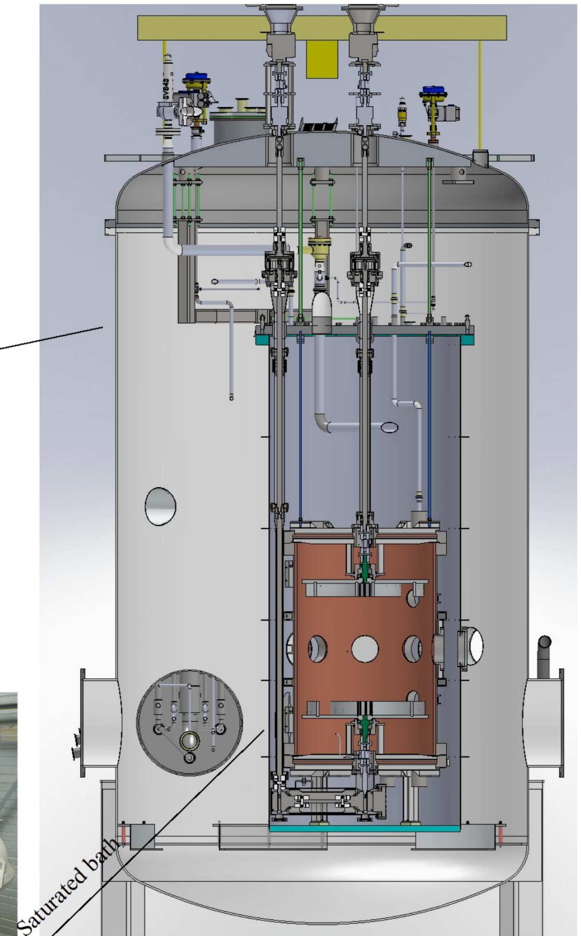
Superfluid High Reynolds number von Karman experiment



→ Going to higher dimensions (2011-2012)

***S**uperfluid **H**igh **Re**ynolds number von **K**arman experiment*





***S**uperfluid **H**igh **Re**ynolds number von **K**arman experiment*

Aluminium turbines (machined from one big alumium sheet)

Conclusions - Perspectives

- TSF (cryogenic windtunnel)
  - hot-wire too fragile
  - not enough room for sound-scattering measurements
  - Pitot tubes
    - Confirmation of the $k^{-5/3}$-power spectrum (Maurer-Tabeling)
    - Turbulence rate independent on the superfluid transition
- SHREK (von Karman flow)
  - Measures starting 2012
  - Integral scale much bigger $\rightarrow$ going down to small scales with Pitot tubes
  - Measuring energy flux with Pitot
  - Quantifying intermittency with sound scattering

Publications

- P.-E. Roche et al., Vortex density spectrum of quantum turbulence, EPL 77, 66002, 2007.
- B. Rousset et al., Tsf experiment for comparison of high Reynolds number turbulence in both He I and He II: First results, AIP Conf. Proc. 53, 633, 2008.
- P. Diribarne, et al., in Advances in Turbulence XII, ETC12, edited by B. Eckhardt, Springer-Verlag, Marburg, 2009, p. 701.
- J. Salort et al., Turbulent velocity spectra in superfluid flows, Phys. Fluids 22, 125102 (2010).