METEOMET

Metrology for Meteorology

ENV58 MeteoMet2. Metrology for Essential Climate Variables

Rainfall simulators for calibration purposes

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Precipitation micro-physical characteristics

✓ **Drop Size Distribution**
(*Waldvogel, 1974; Yangang , 1992*)

- MP distribution (*Marshall and Palmer, 1948)*

$$N(D) = N_0 \exp(-\lambda D)$$

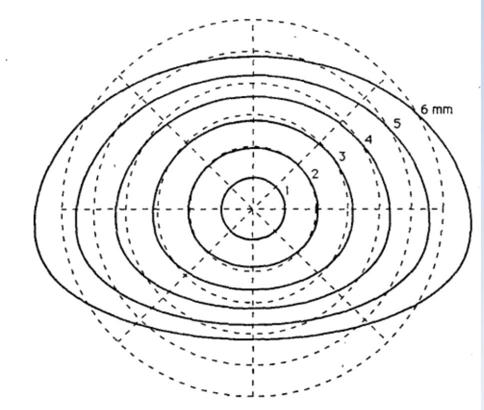
- Gamma distribution (*Ulbrich, 1983)*

$$N(D) = N_0 \, \mathrm{D}^{\mu} \exp(-\lambda D)$$

✓ **Drop shape**
(*Pruppacher and Beard, 1970*; Beard and Chuang, 1986; *Feng and Beard, 2011*)

- spherical, D < 1 mm
- oscillations of the surfaces around an oblate shape, D ≥ 1 mm

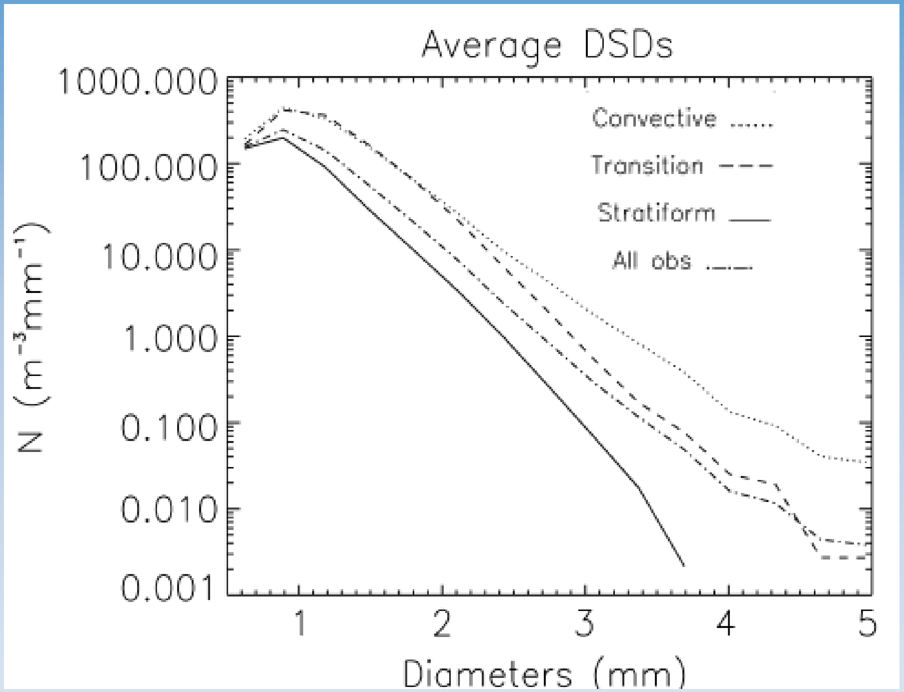
↳ Axis ratio = α = α (a_0) ≤ 1
a_0 = equivalent radius



✓ **Terminal velocity**
(*Spilhaus, 1947; Beard, 1970*)

Precipitation micro-physical characteristics

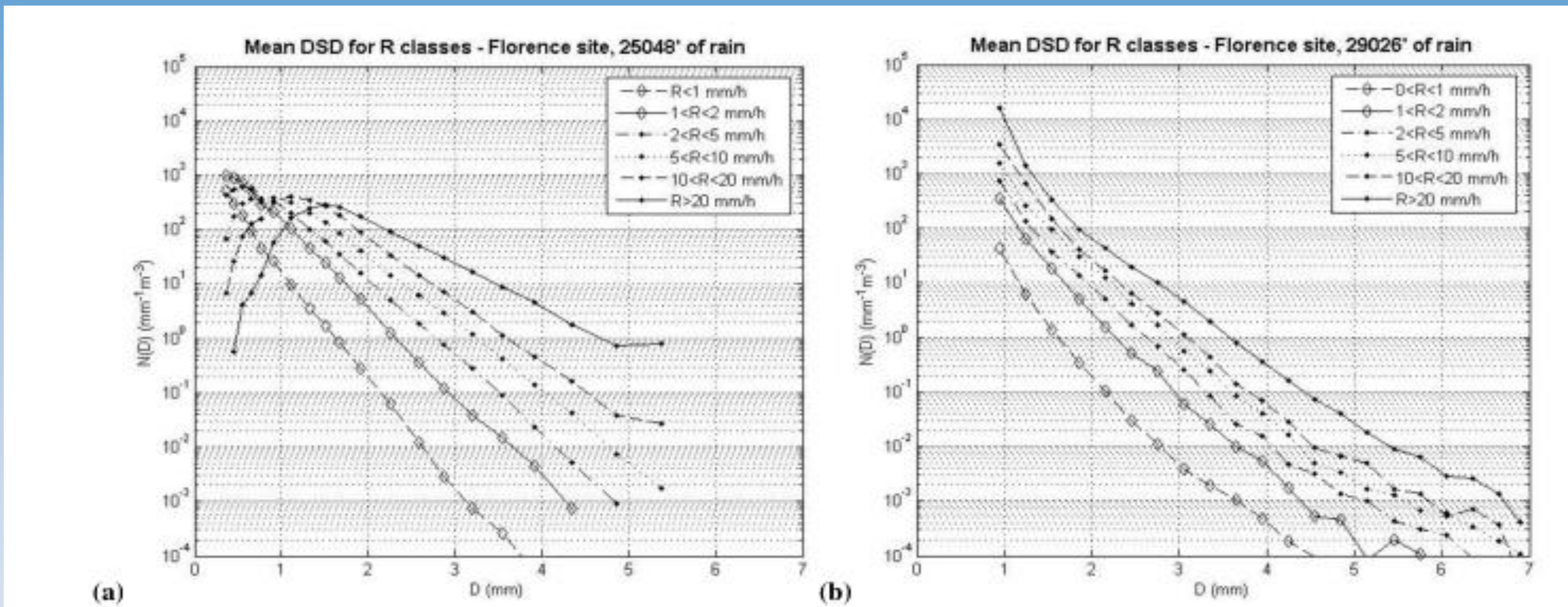
Drop Size Distribution variability with the type of rain



Optical disdrometer observations, Costa Rica (Campos et al., 2005)

Precipitation micro-physical characteristics

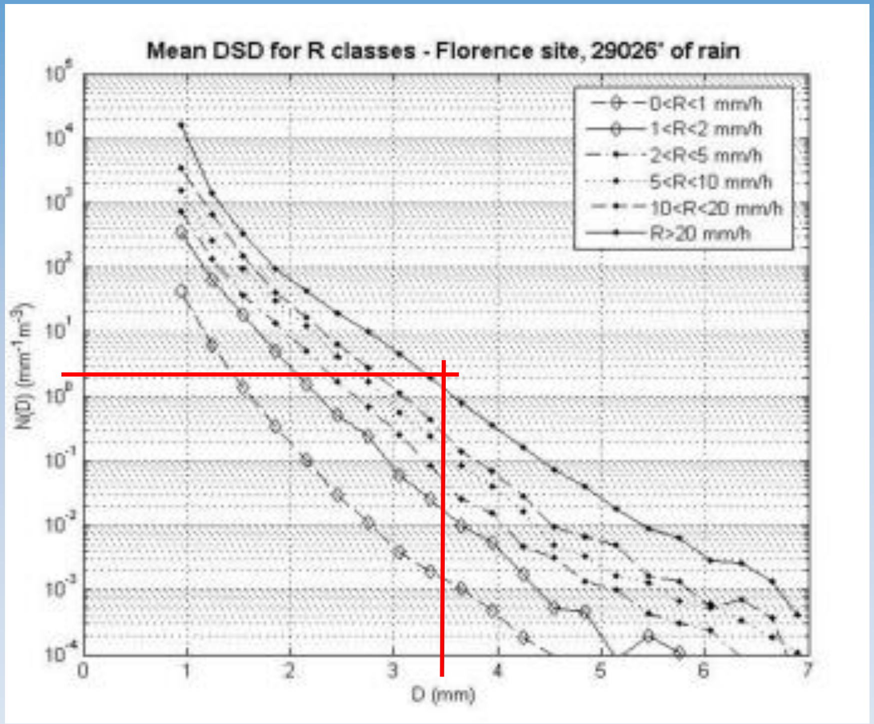
Drop Size Distribution variability with rainfall intensity



Co-located DSD measurements made by an impact Joss-Waldvogel disdrometer (a) and a X-band radar disdrometer (b) in Florence (Caracciolo et al., 2008)

Precipitation micro-physical characteristics

Drop Size Distribution, impact on the design of a rainfall simulator



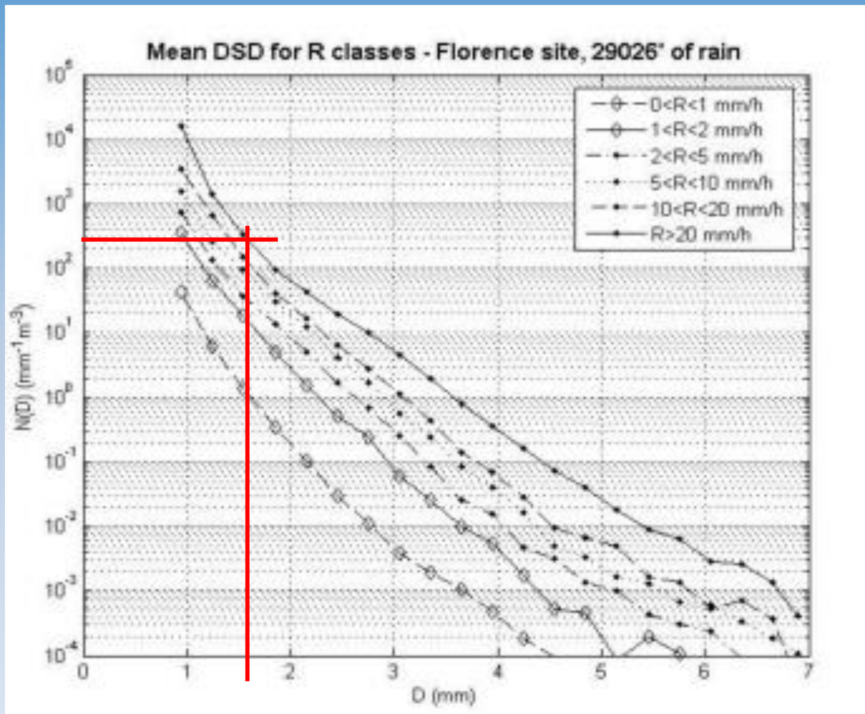
X-band radar disdrometer, Florence (Caracciolo et al., 2008)

For a standard **200 cm²** collector:

D	*mm*	3.50
N(V=1m³)	-	2
N(V=0.02m³)	-	0.04
w	*m/s*	9
F	*Hz*	0.36

Precipitation micro-physical characteristics

Drop Size Distribution, impact on the design of a rainfall simulator



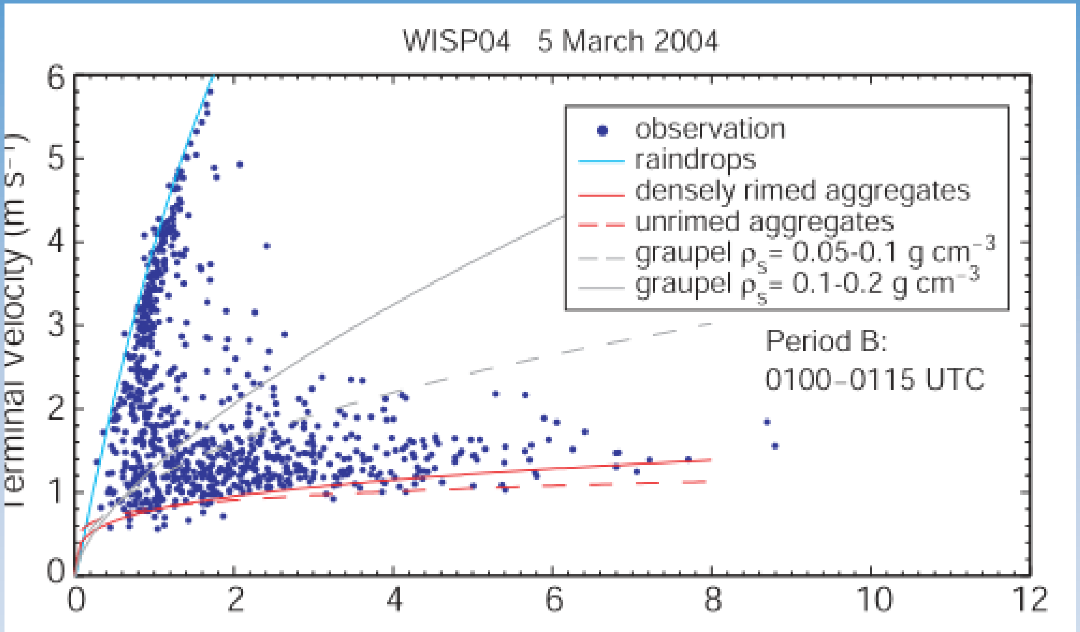
X-band radar disdrometer, Florence (Caracciolo et al., 2008)

For a standard **200 cm²** collector:			
D	*mm*	3.50	1.70
N(V=1m³)	-	2	200
N(V=0.02m³)	-	0.04	4
w	*m/s*	9	6
F	*Hz*	0.36	24

E.g. 5 dispensers which generate droplets at 5 Hz

Precipitation micro-physical characteristics

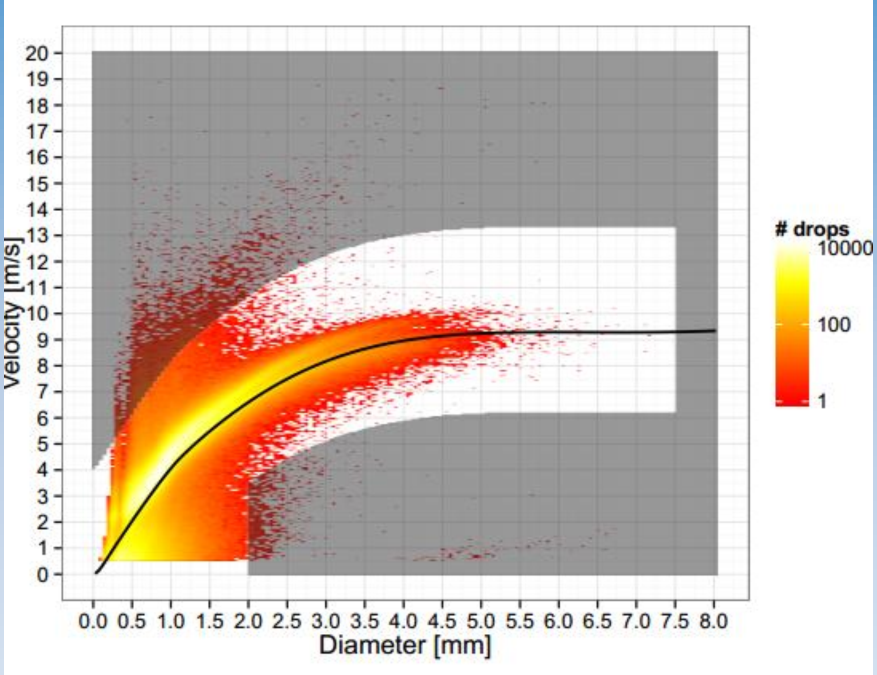
Droplet terminal velocity variability with the type of rain



2DVD observations by Ikeda et al (2008) at the Marhsall field site (CO,USA). The terminal velocity relation for rain is from Brandes et al. (2002). The relations for graupel and snow aggregates are from Locatelli and Hobbs (1974).

Precipitation micro-physical characteristics

Droplet terminal velocity variability



Occurrence of velocity/diameter combinations, with drop counts on a log scale, recorded by a 2DVD disdrometer during the HyMeX campaigns in the autumns of 2012 and 2013 by Rapauch and Berne (2014). The black line indicates the Beard (1976) expected terminal drop velocity.

Precipitation micro-physical characteristics

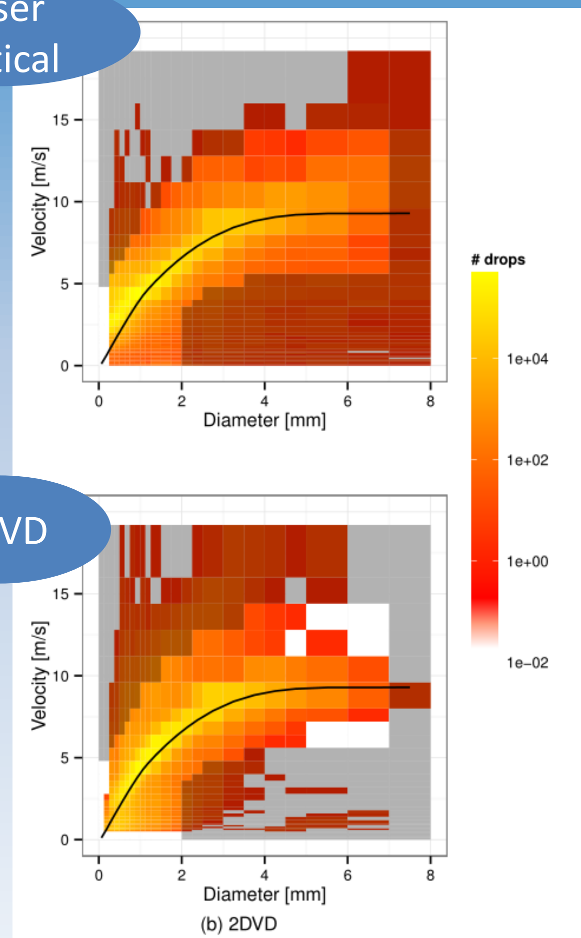
Droplet terminal velocity measured by different instruments

Laser Optical

- Overestimations at the low diameter
- Large scatter over the whole D domain

2DVD

- Large scatter and occurrence of suspicious high velocity values



Occurrence of velocity / diameter combinations, with drop counts on a log scale, recorded by a laser optical disdrometer and the 2DVD disdrometer during the HyMeX campaigns in the autumns of 2012 and 2013 by Rapauch and Berne (2014). The black line indicates the Beard (1976) expected terminal drop velocity.

Dealing with the calibration of non-catching type rain gauges

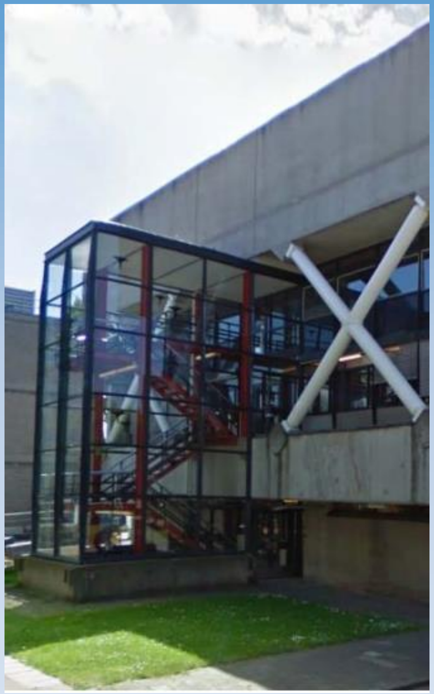
Examples from literature

- Generation towers (*de Jong and Hut, 2011*)
  - ❖ No generation of realistic Drop Size Distributions, diameter-todiameter test
  - ❖ Single droplet generation at a level equal to 12 meter
- Falling of artificial particles (*Kruger and Krajewski, 2001*)
  - ❖ Different medium with not realistic hydro-dynamic behavior
- Field comparison with traditional rain gauges like TBRG (*de Jong and Hut, 2011, Kasparis et al., 2010, Lane et al., 2014*)
  - ❖ The resolution of the standard gauge measurements is coarser than the disdrometers observations
  - ❖ The reference gauges should be dynamically calibrated and the residual errors must be taken into account

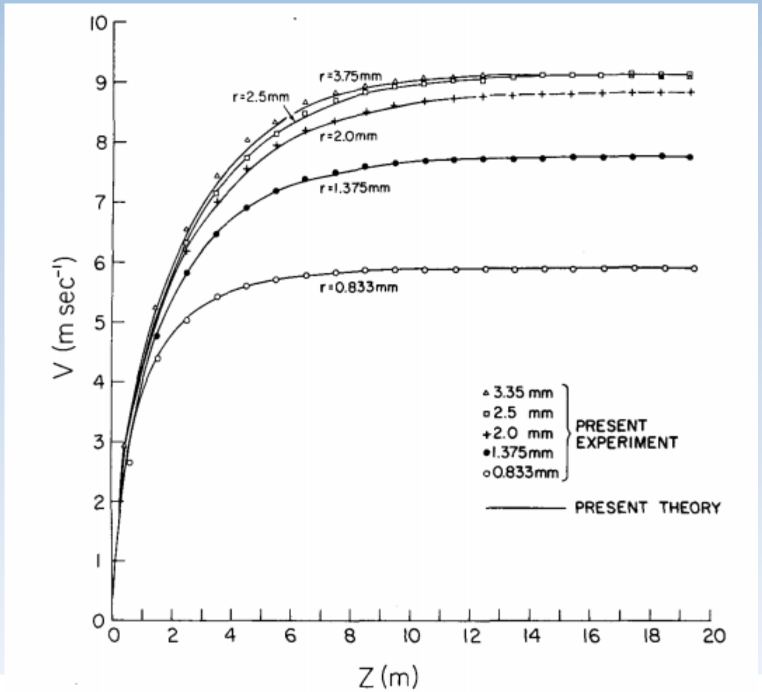
Dealing with the calibration of non-catching type rain gauges

Generation towers (*de Jong and Hut, 2011*)

- Generally adopted to calibrate impact disdrometers
- **No generation of realistic Drop Size Distributions**, diameter-to-diameter test
- **No drops size validation**
- Single droplet generation at a level equal to 12 meter to reach terminal velocity.



Delft University of Technology (*de Jong and Hut, 2011*)

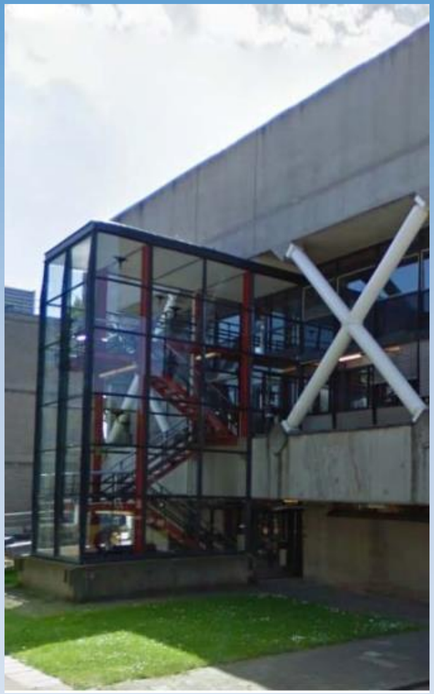


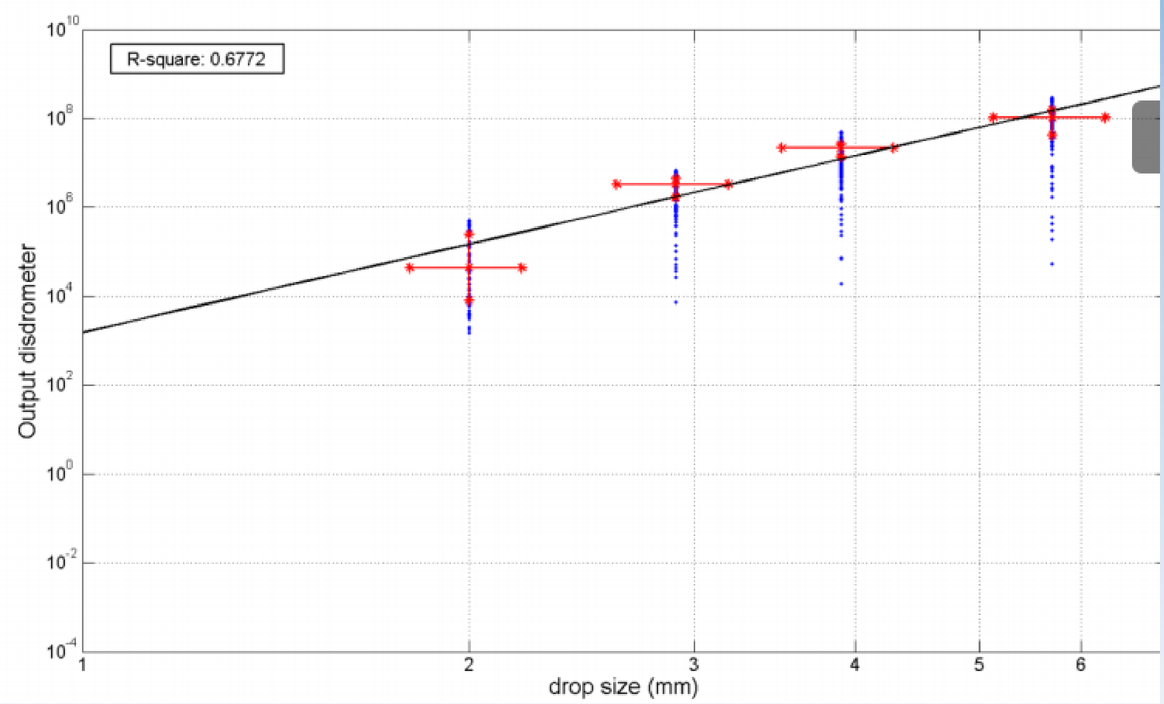
Variation of fall velocity V with distance Z after release from rest of water drops in air (1000 mb and 20°C).
(*Wang and Pruppacher, 1977*)

Dealing with the calibration of non-catching type rain gauges

Generation towers (*de Jong and Hut, 2011*)

- Generally adopted to calibrate impact disdrometers
- No generation of realistic Drop Size Distributions, diameter-to-diameter test
- No drops size validation
- Single droplet generation at a level equal to 12 meter to reach terminal

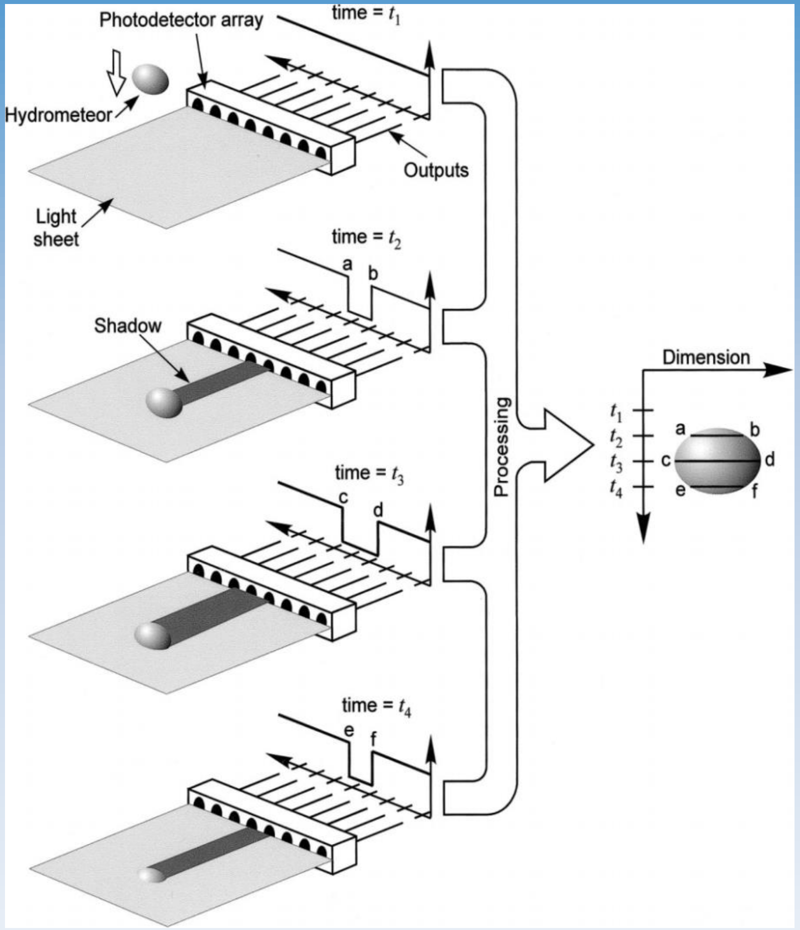




Delft University of Technology (top panel) and an impact disdrometer calibration curve (right panel)
(*de Jong and Hut, 2011*)

Dealing with the calibration of non-catching type rain gauges

Falling of artificial particles (*Kruger and Krajewski, 2001*)



(Kruger and Krajewski, 2001)

- Generally used to calibrate optical and video disdrometers
- **Metal/plastic spheres with not realistic hydro-dynamic behavior**
- **No generation of realistic Drop Size Distributions**, diameter-to-diameter test

Dealing with the calibration of non-catching type rain gauges

Field comparison with traditional rain gauges like TBRG (*Kasparis et al., 2010, Lane et al., 2014*)

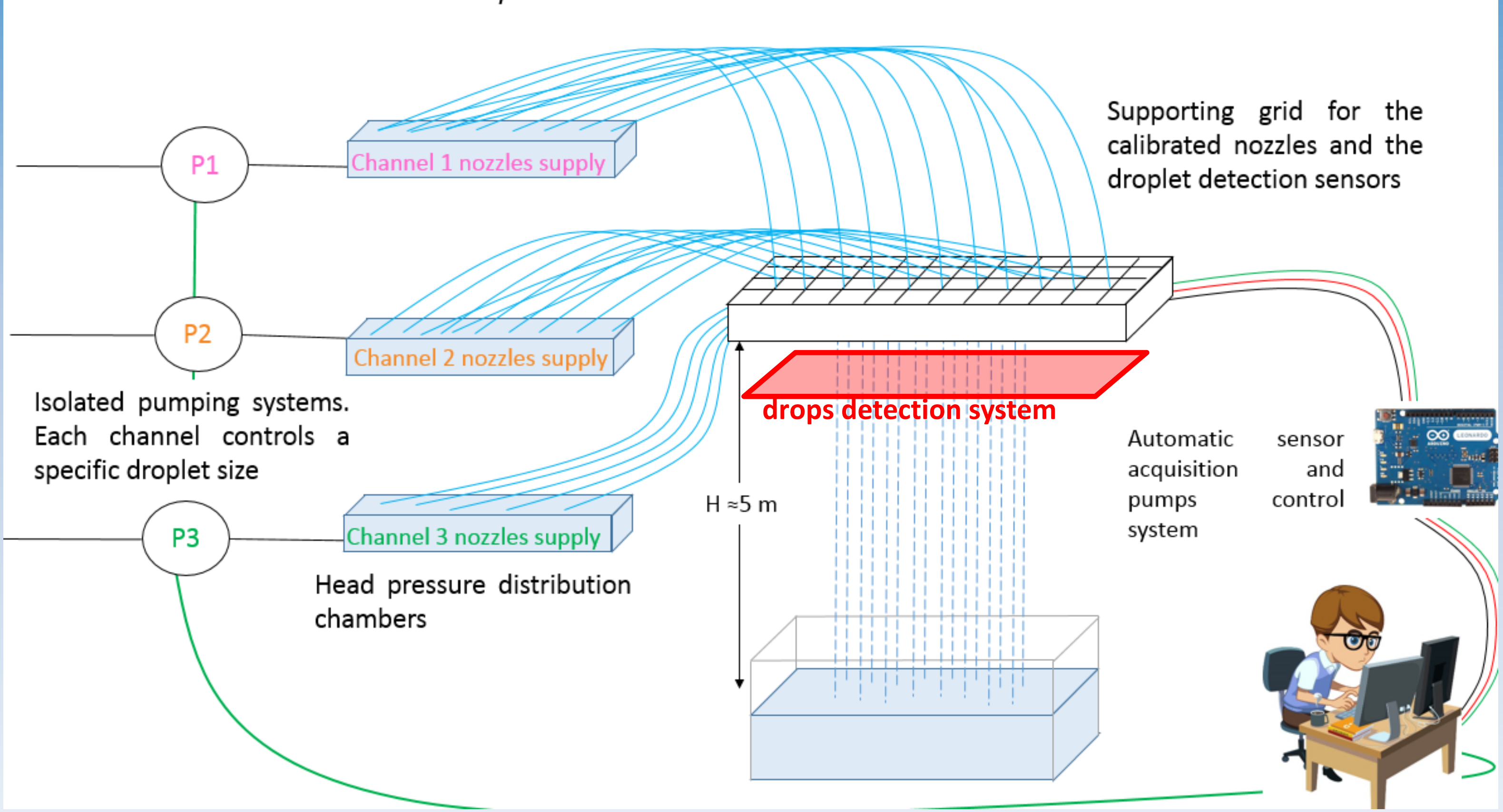
- Technique usually adopted in operational conditional for **adaptive calibration**.
- The resolution of standard gauges used to obtain reference measurements is coarser than the disdrometers observations.
- **The reference gauges should be dynamically calibrated and the residual errors must be taken into account.**
- Standard gauges such as tipping-bucket and weighing type gauges do not provide droplets falling velocity and size distribution observations (usually measured by disdrometers).

(Lane et al., 2014)

The idea of a laboratory rainfall simulator

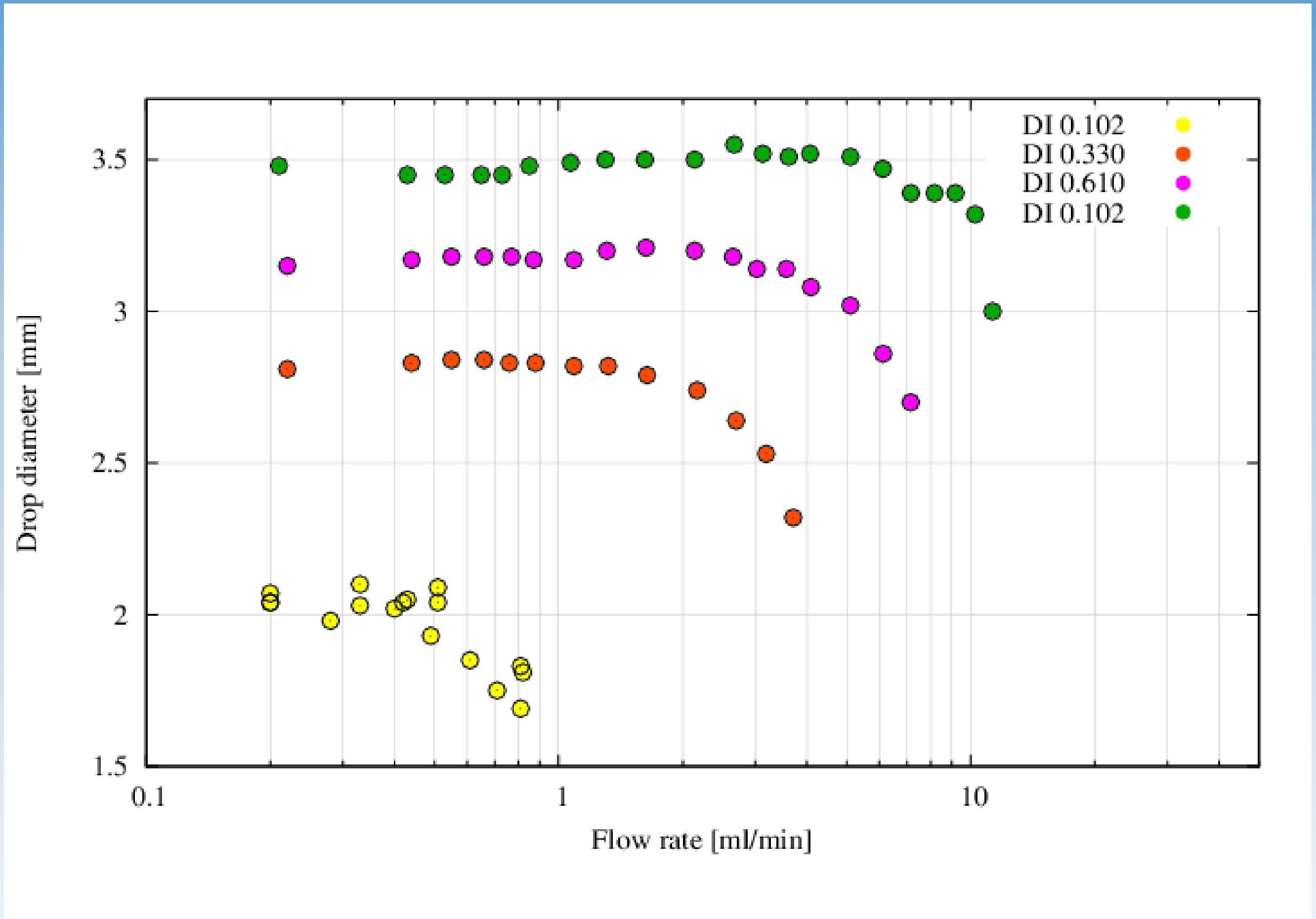
Key feature: generation and real-time validation of different DSDs

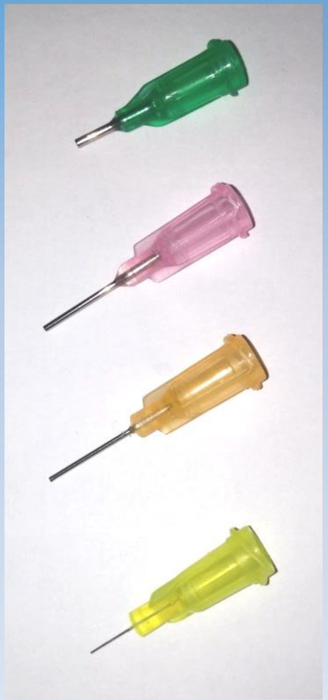
Concept of the **LC-PRIN** *rainfall simulator*



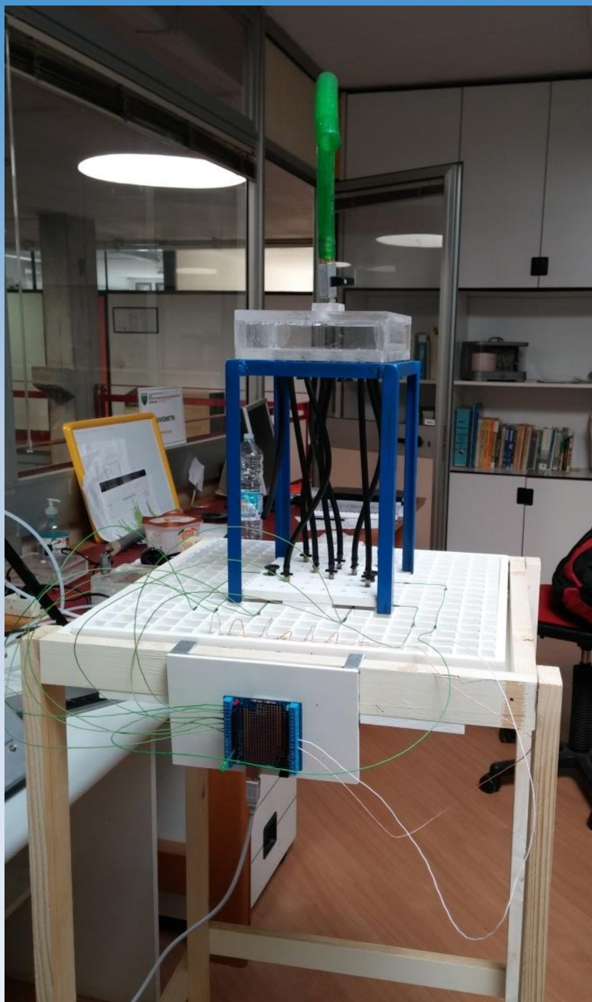
The idea of a laboratory rainfall simulator

The calibrated nozzles driven by a controlled water head and the drops detection system allow a precise DSD monitoring





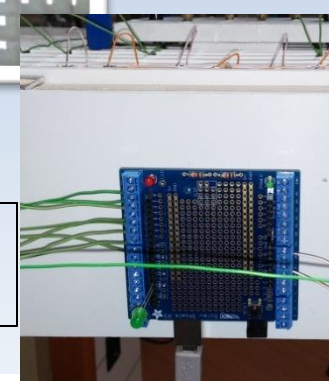
The idea of a laboratory rainfall simulator



Head pressure distribution chamber

Supporting grid for calibrates nozzles

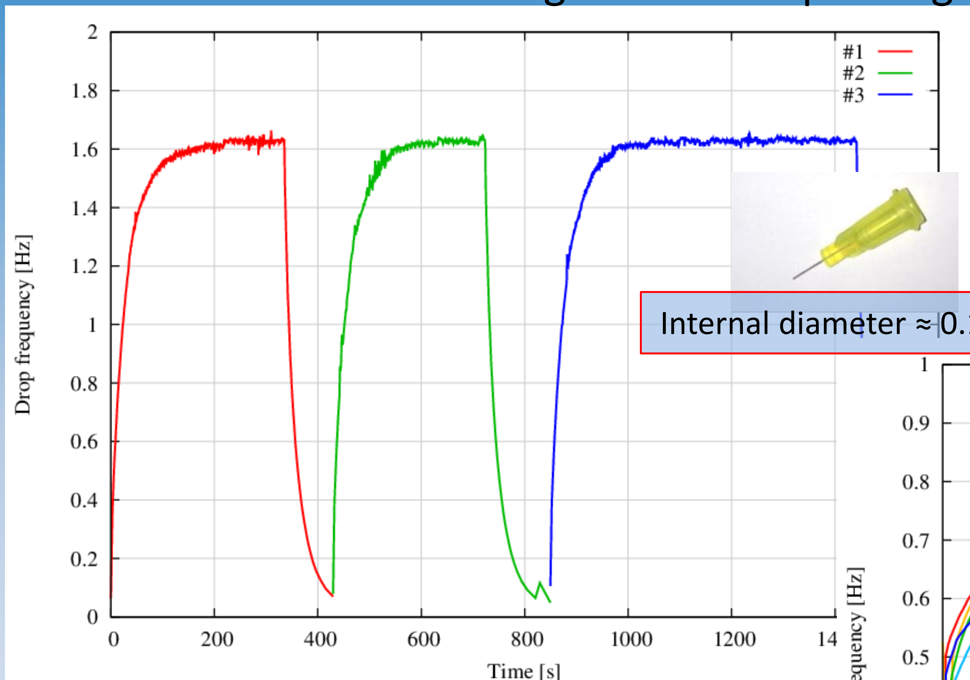
Droplet detection sensor



Automatic sensors acquisition

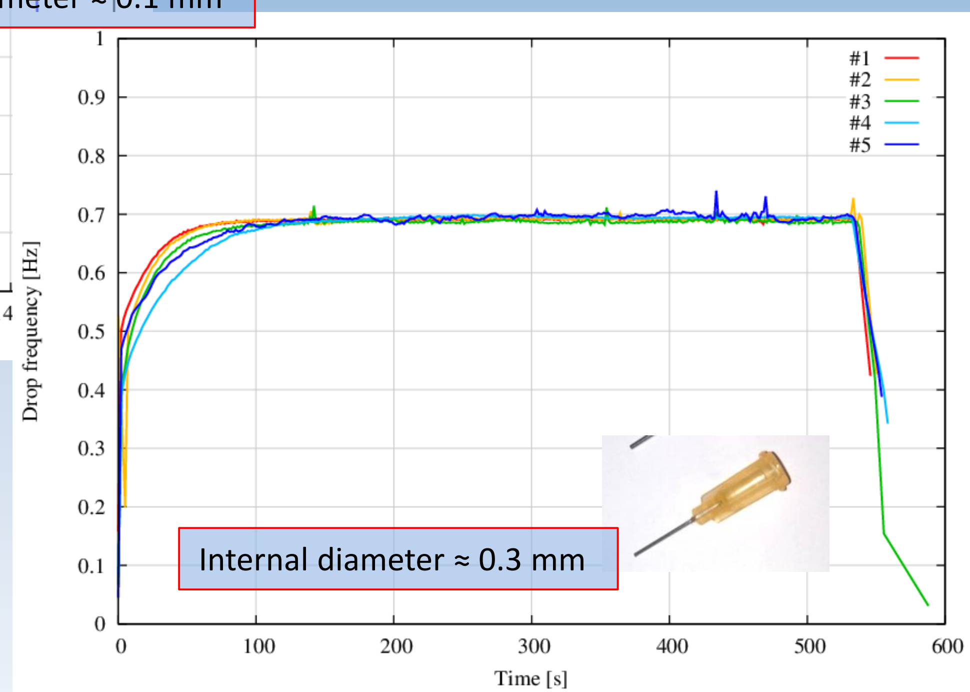
Preliminary testing

Single nozzle dispensing - repeatability tests



Internal diameter ≈ 0.1 mm

Since the nozzle dispensing is realized by imposing constant flow rate values, ***a constant drops time period (or frequency) corresponds to equally sized drops generation***.

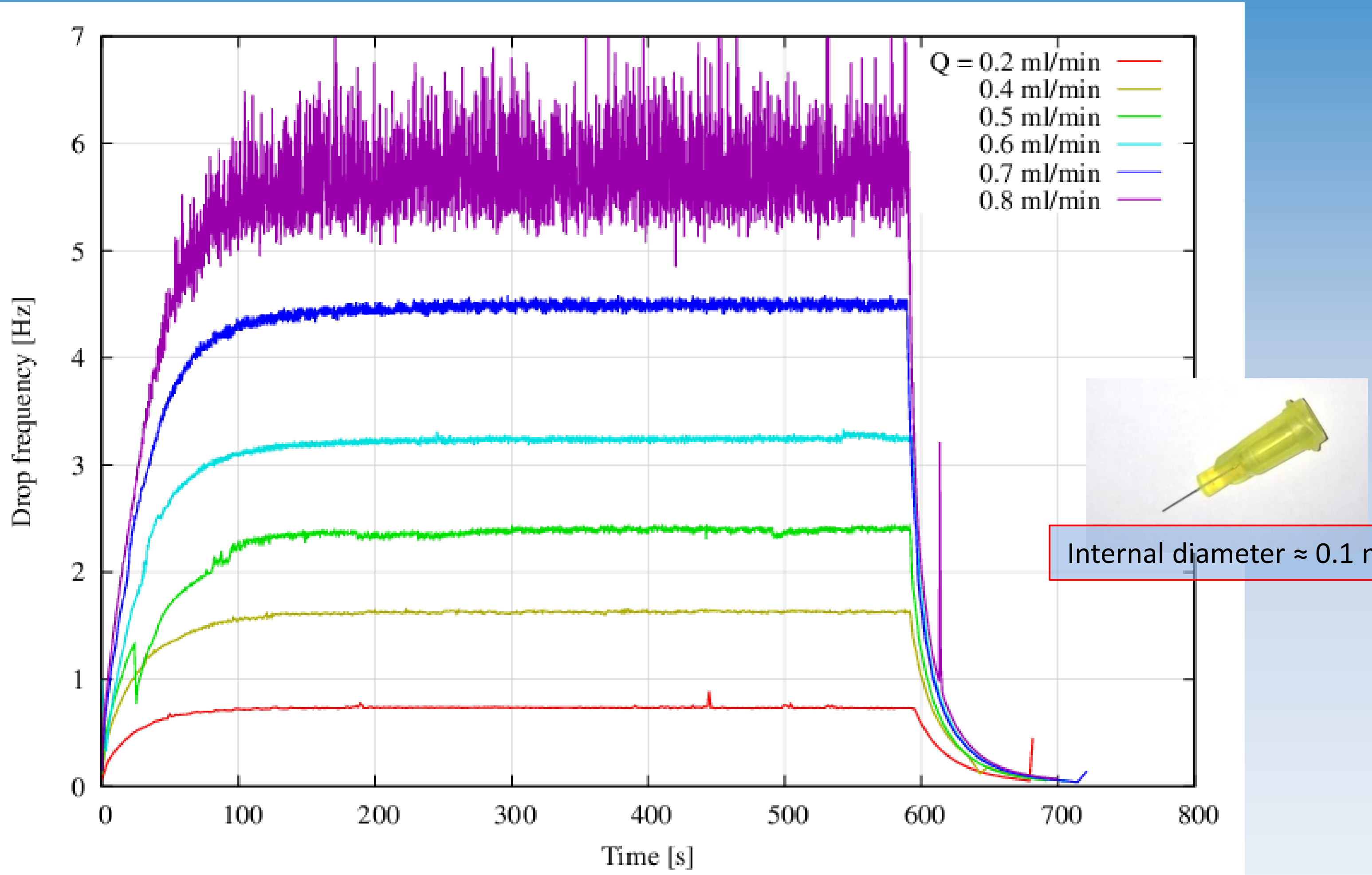


Internal diameter ≈ 0.3 mm

- The repeatability of the steady state drops frequency/size is demonstrated for both the nozzle sizes
- A bigger nozzle diameter is associated with a shorter warming-up time

Preliminary testing

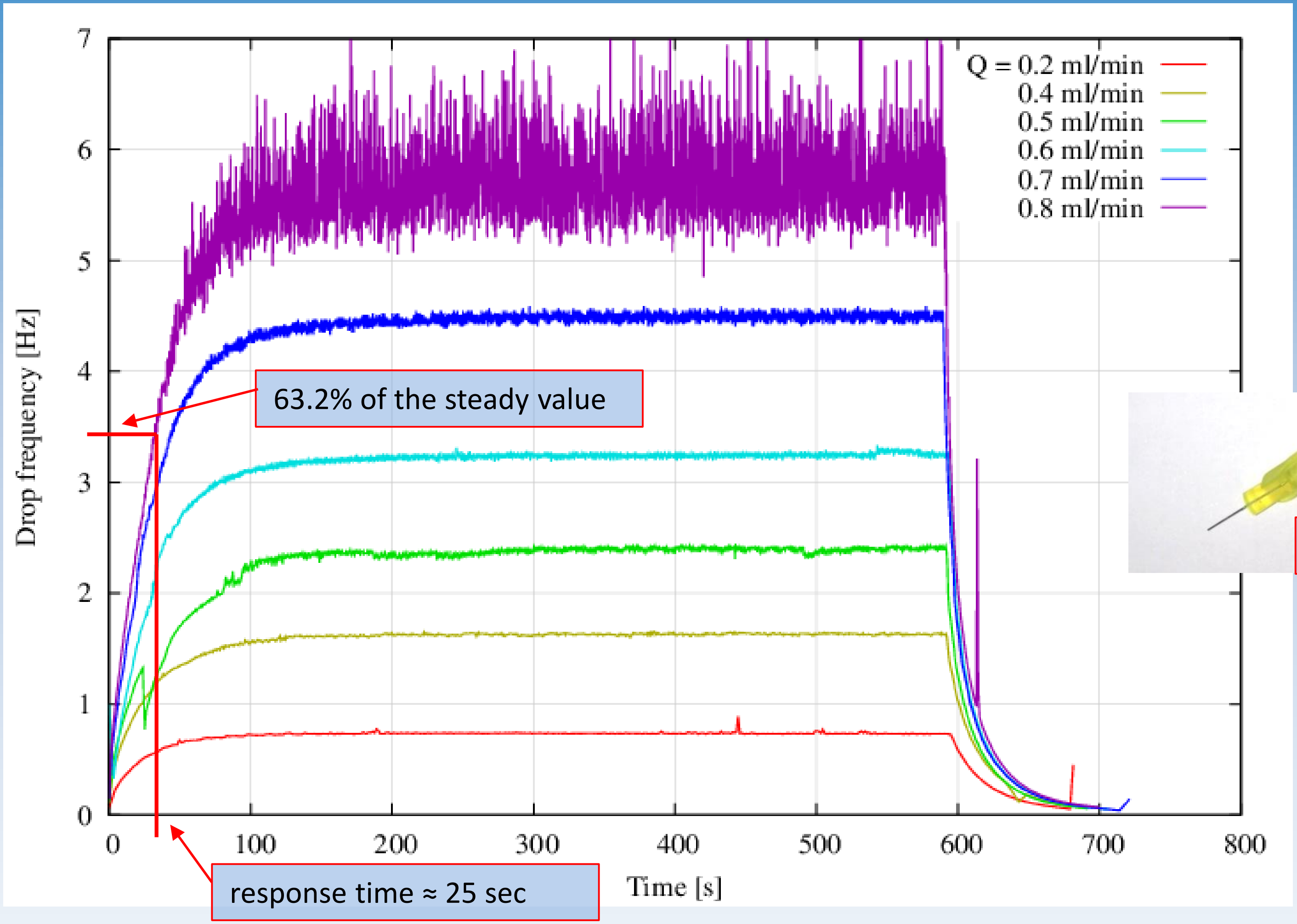
Single nozzle dispensing – response time



Internal diameter ≈ 0.1 mm

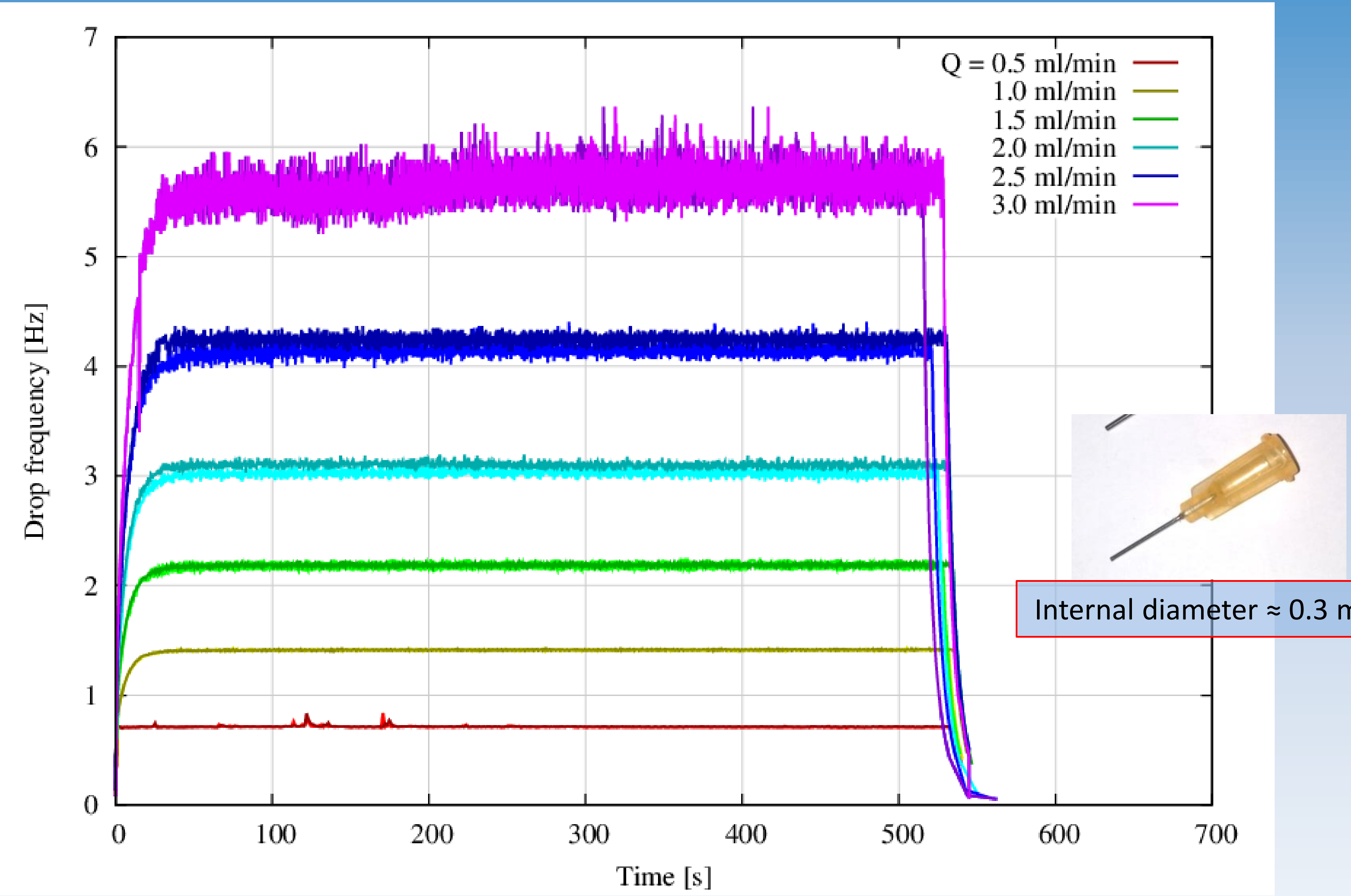
Preliminary testing

Single nozzle dispensing – response time



Preliminary testing

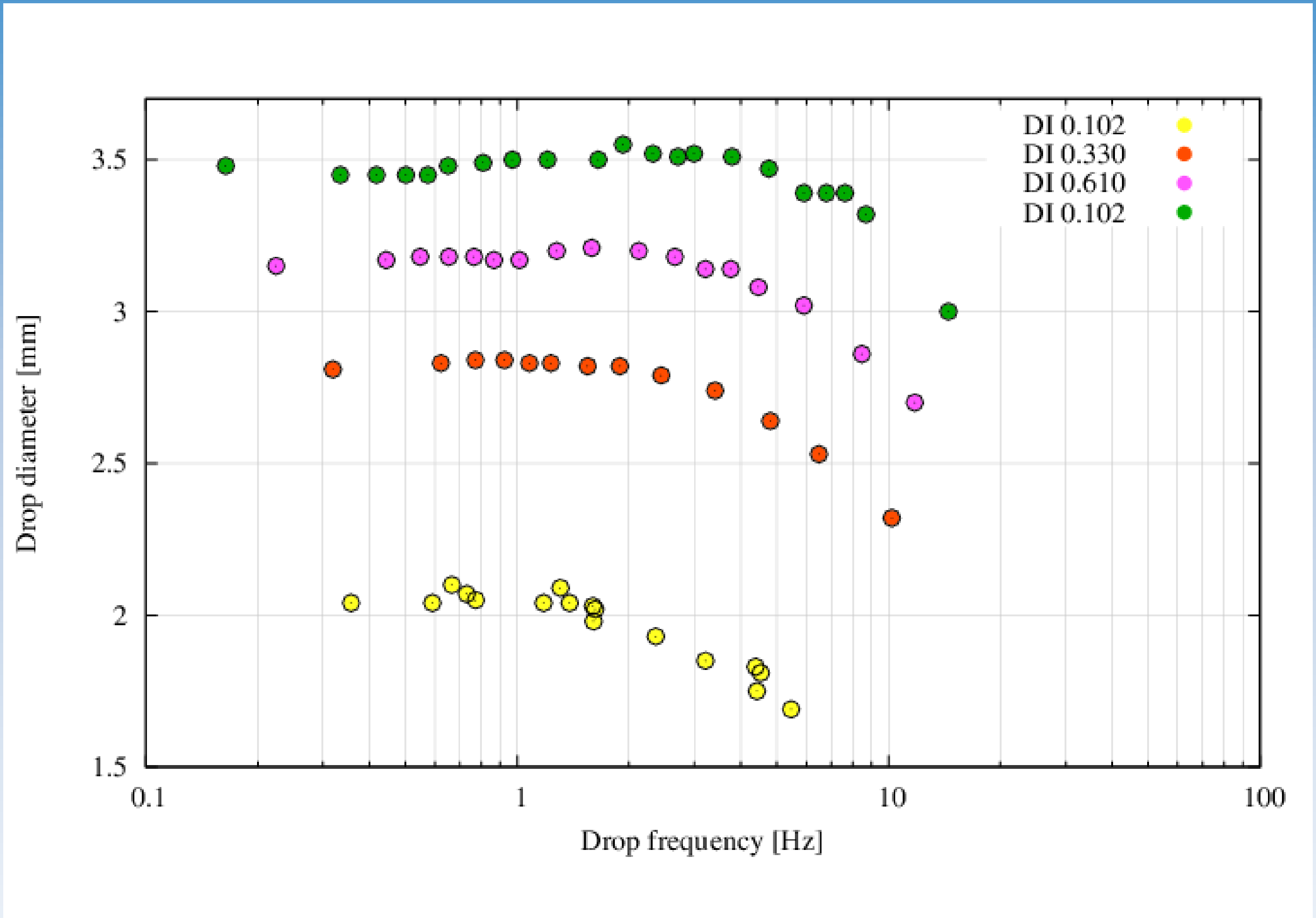
Two nozzles dispensing – repeatability and response time



Internal diameter ≈ 0.3 mm

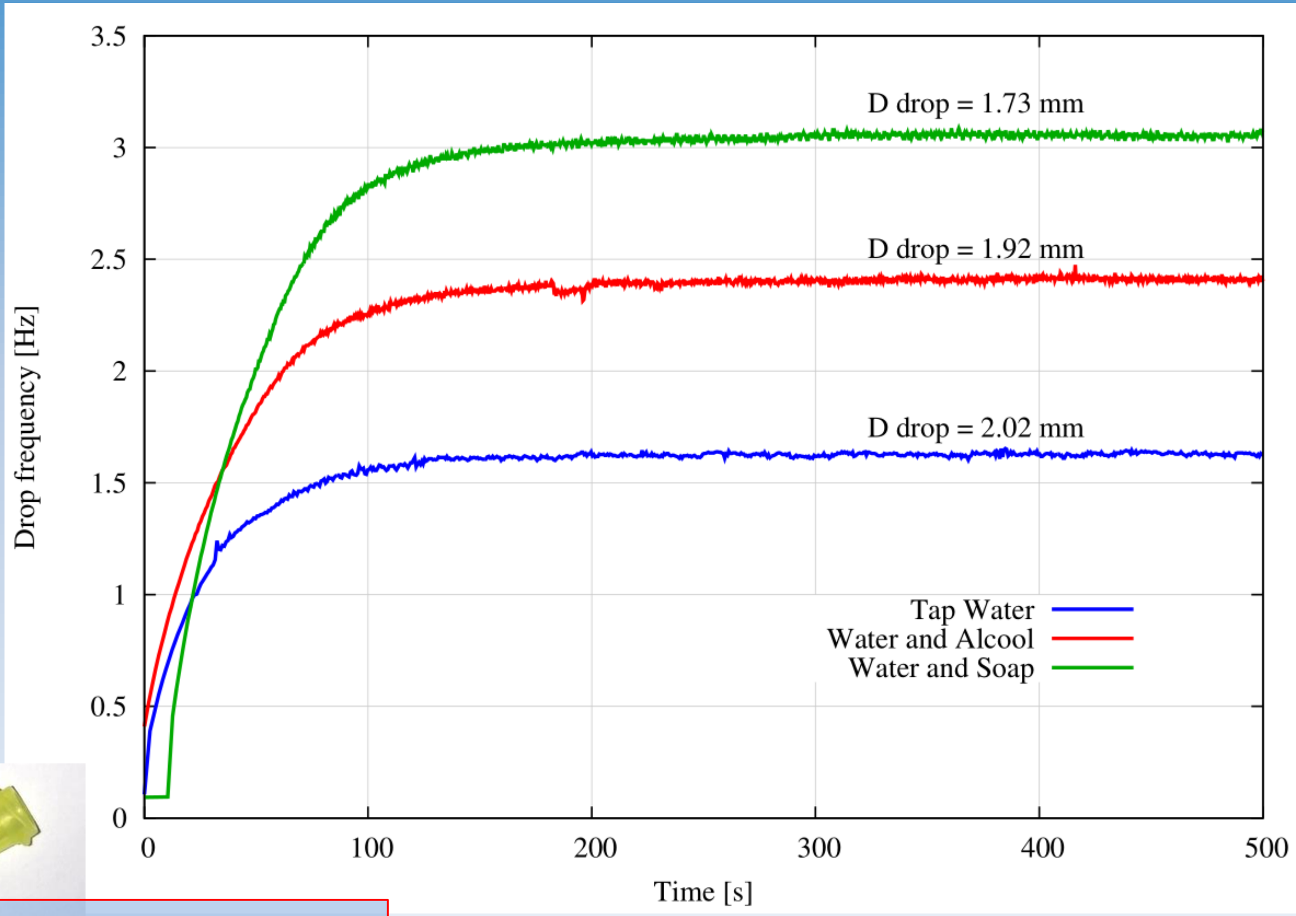
Preliminary testing

Assessment of the drops equivalent diameter



Preliminary testing

Influence of the water mixtures on the drops diameter



Internal diameter ≈ 0.1 mm

Considerations from the pilot design

- The current design is based on the **simulation of realistic DSDs with a real-time validation system**. More work has to be done to generate droplets that fall with their terminal velocity.
- **The repeatability of the droplet size/relationships has been demonstrated**. A warming-up time must be accepted before starting the calibration, this is particularly true in case of small nozzles (D.I.<=0.303 mm).
- **It's necessary to expand the calibrator analysis to the simultaneous dispensing from a larger number of nozzles (>> 2)** in order to check the spatial distribution of the simulated DSD for different gauge sensing areas.
- The random position of rain drops over the disdrometers sensing area is here approximated by adopting a large number of operational nozzles.
- The choice of optimal nozzle diameters that allow the simulation of realistic DSDs has to be done. **In a first instance the DSD could be synthetized in three mean diameter classes**. More nozzle sizes must be tested.