Cloud Scattering Probes (FSSP / CDP)

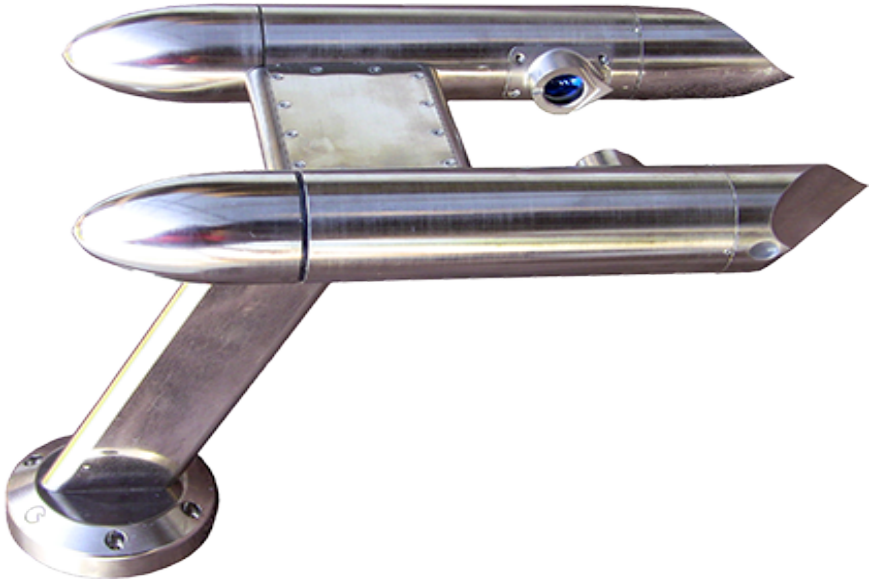
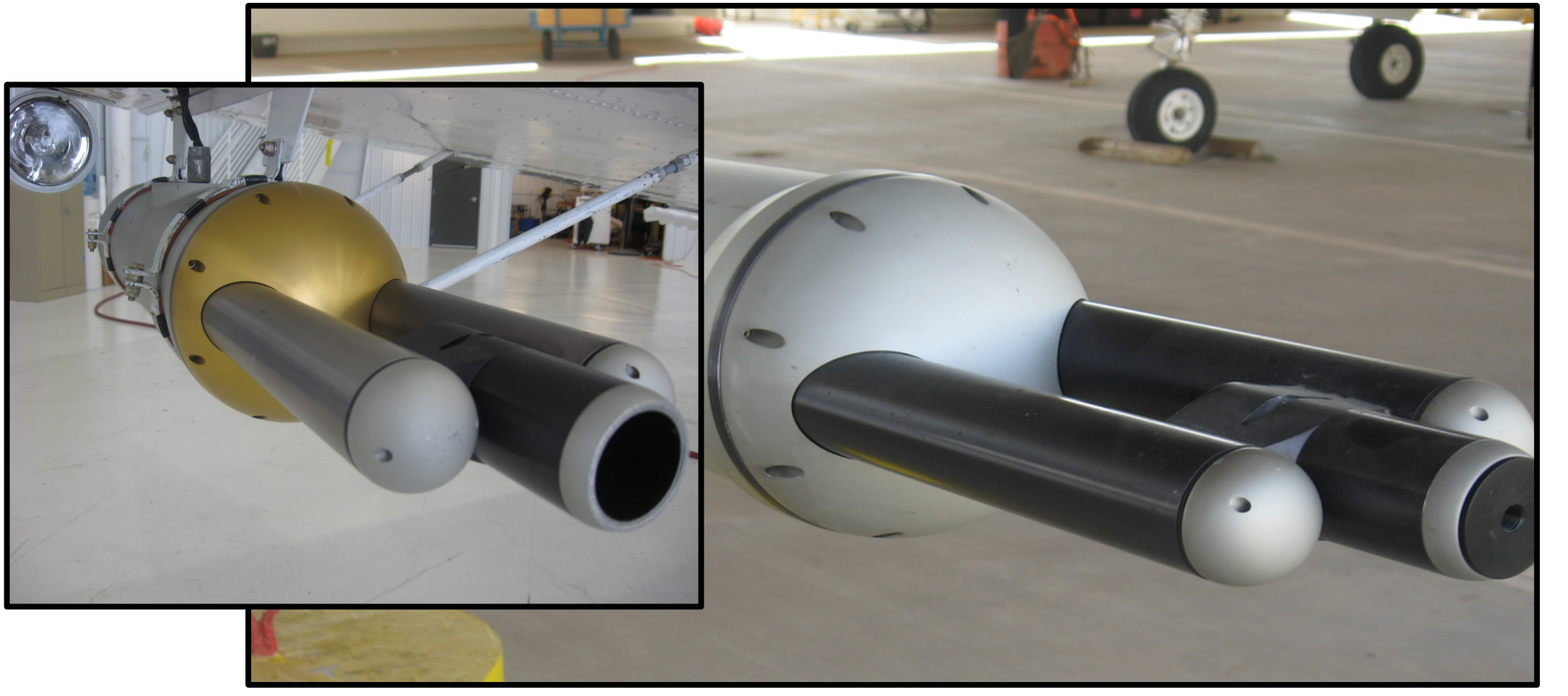
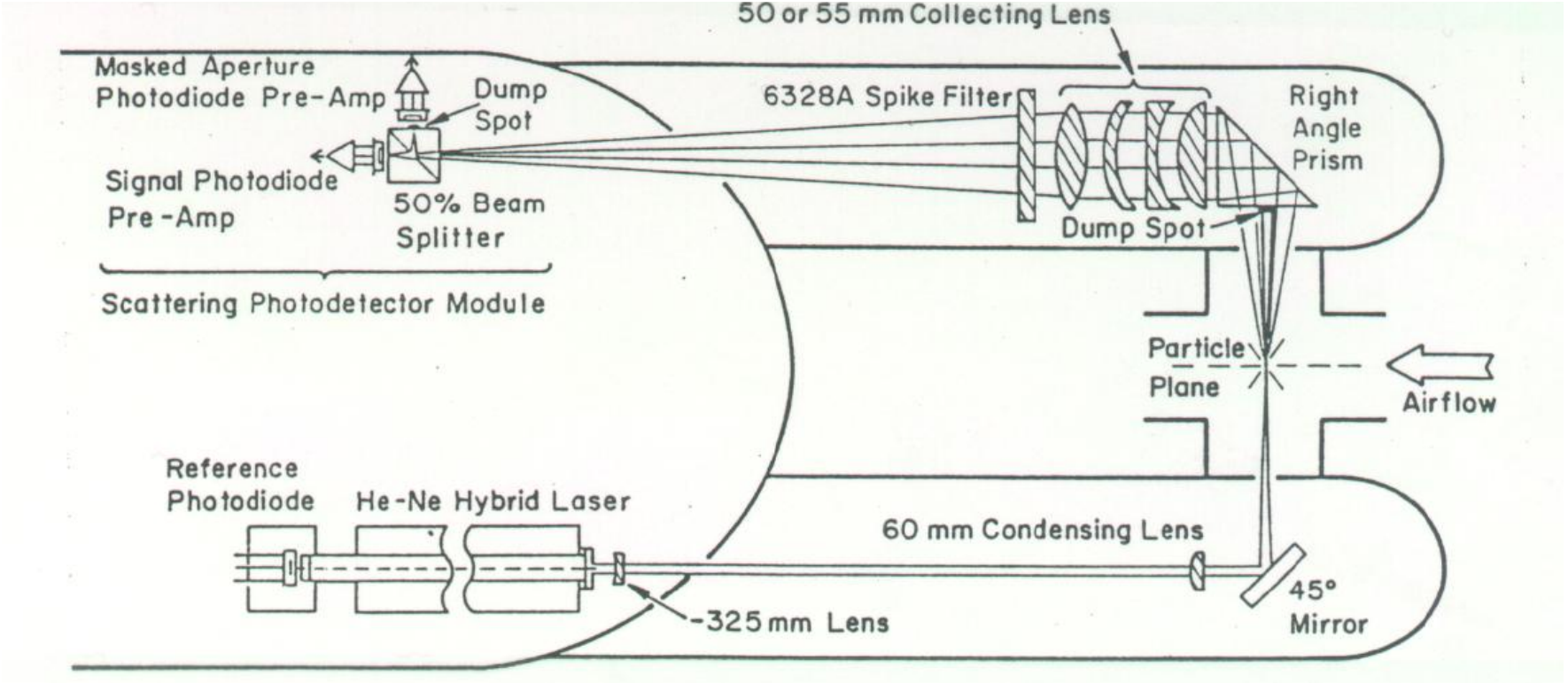


Image from: http://www.dropletmeasurement.com/cloud-droplet-probe-cdp-2

Forward Scattering Spectrometer Probe (FSSP)





- The beam splitter divides the scattered light onto two photodetectors.
- One photodector is optically masked to not receive scattered light from near the laser beam's center of focus.
- Droplets are rejected as being out of the depth of field when the signal from the masked detector exceeds that from the unmasked detector.

FSSP schematic is taken from Dye and Baumgarnder, [1984]

FSSP Effective Sample Volume

Sample Volume = TAS*DOF*BD*(Tc/Ts)

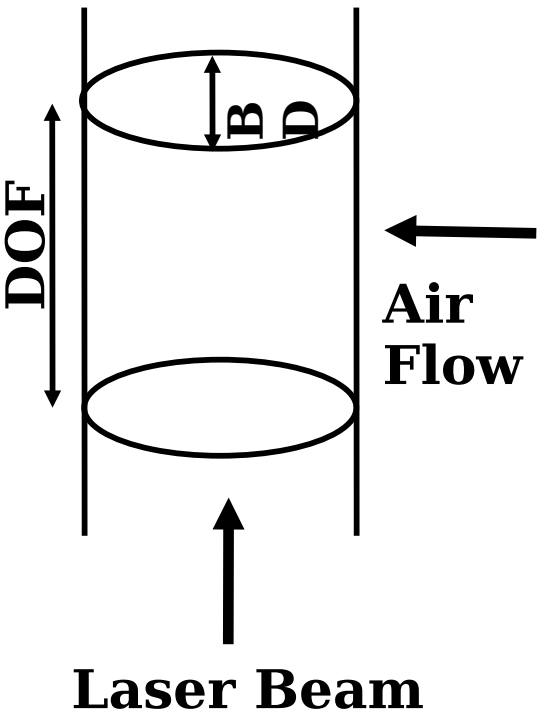
TAS – Aircraft True Air Speed (~100 m/s)

DOF – FSSP Depth of Field (~2.9 mm)

BD – Laser Beam Diameter (~0.2 mm)

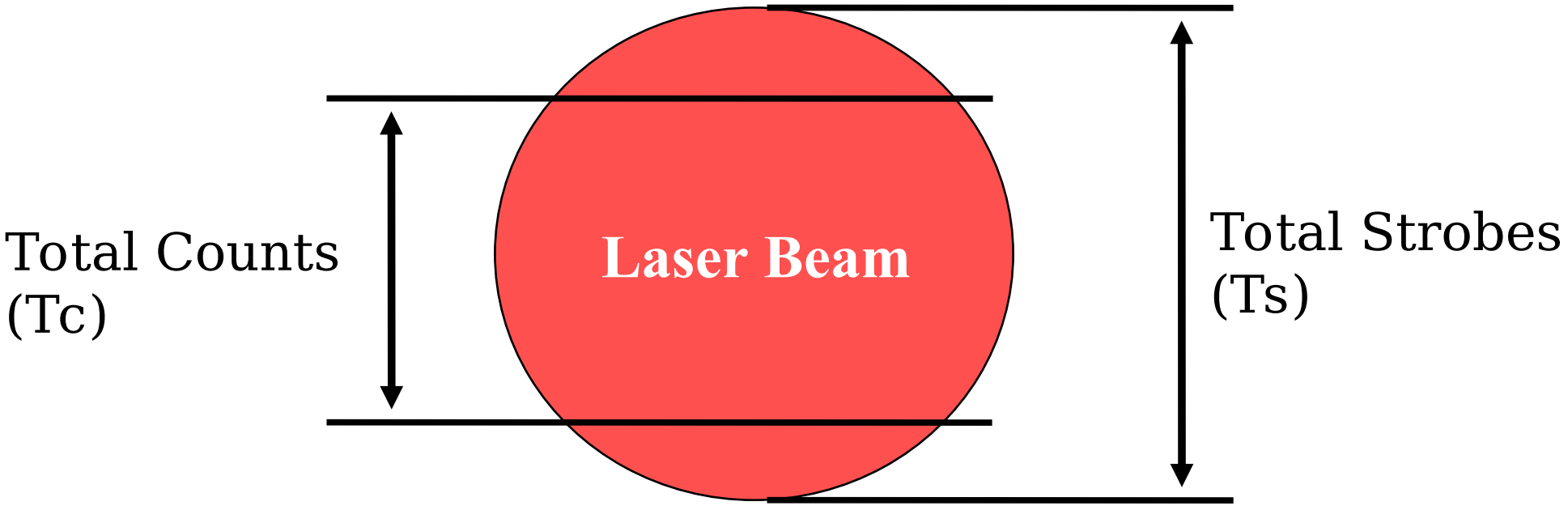
Tc – Number of Droplets Sized (Total Counts)

Ts – Number of Droplets within the DOF (Total Strobes)

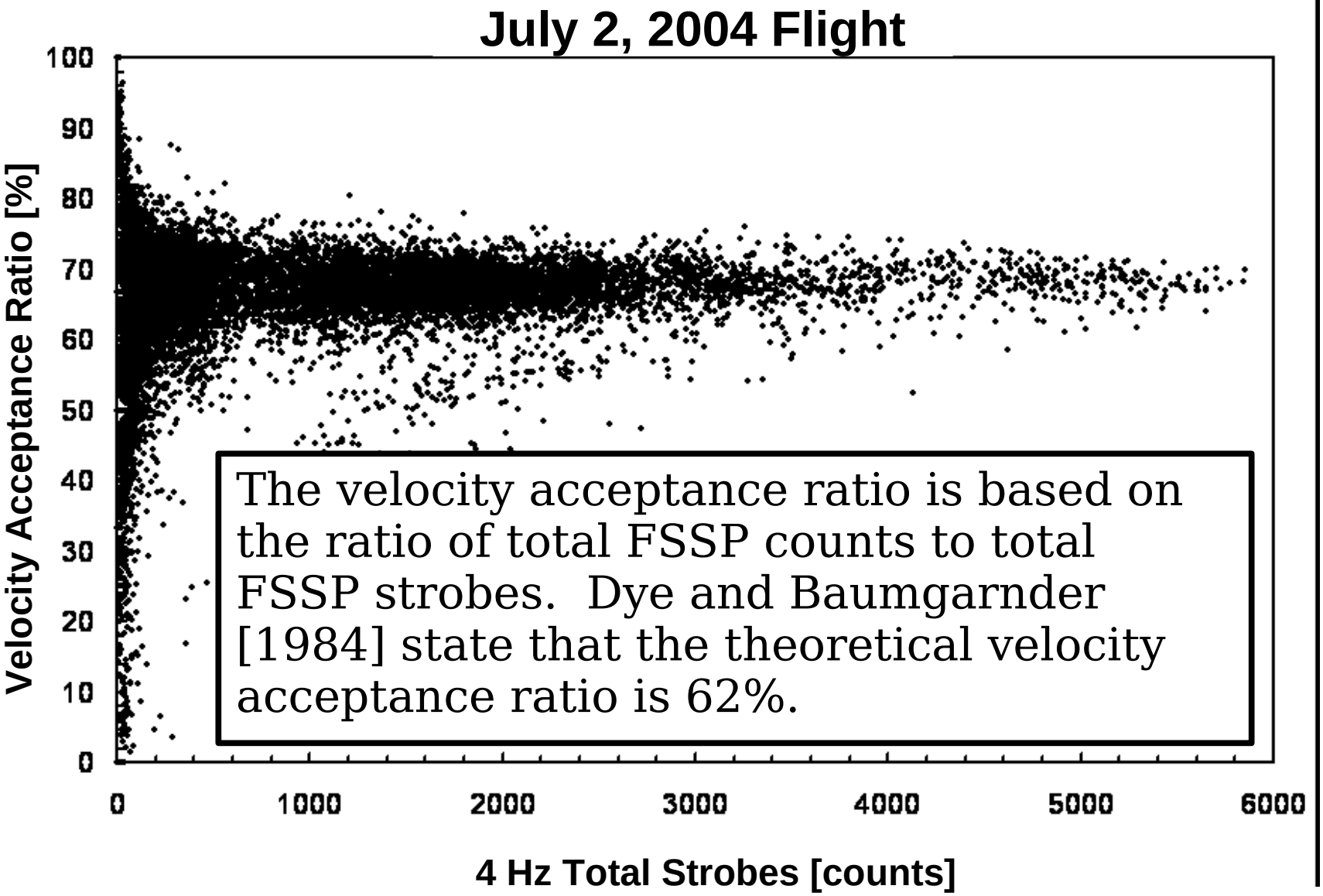


Laser Beam Fraction Correction

Effective Laser Beam Diameter (Tc/Ts)



- The effective laser beam diameter is the fraction of the total diameter where droplets are within the laser beam long enough so they can be sized.
- A running average of droplet transit time through the beam is maintained. If the droplet time within the laser beam is less than the average, it is rejected from sizing but included in the running average.

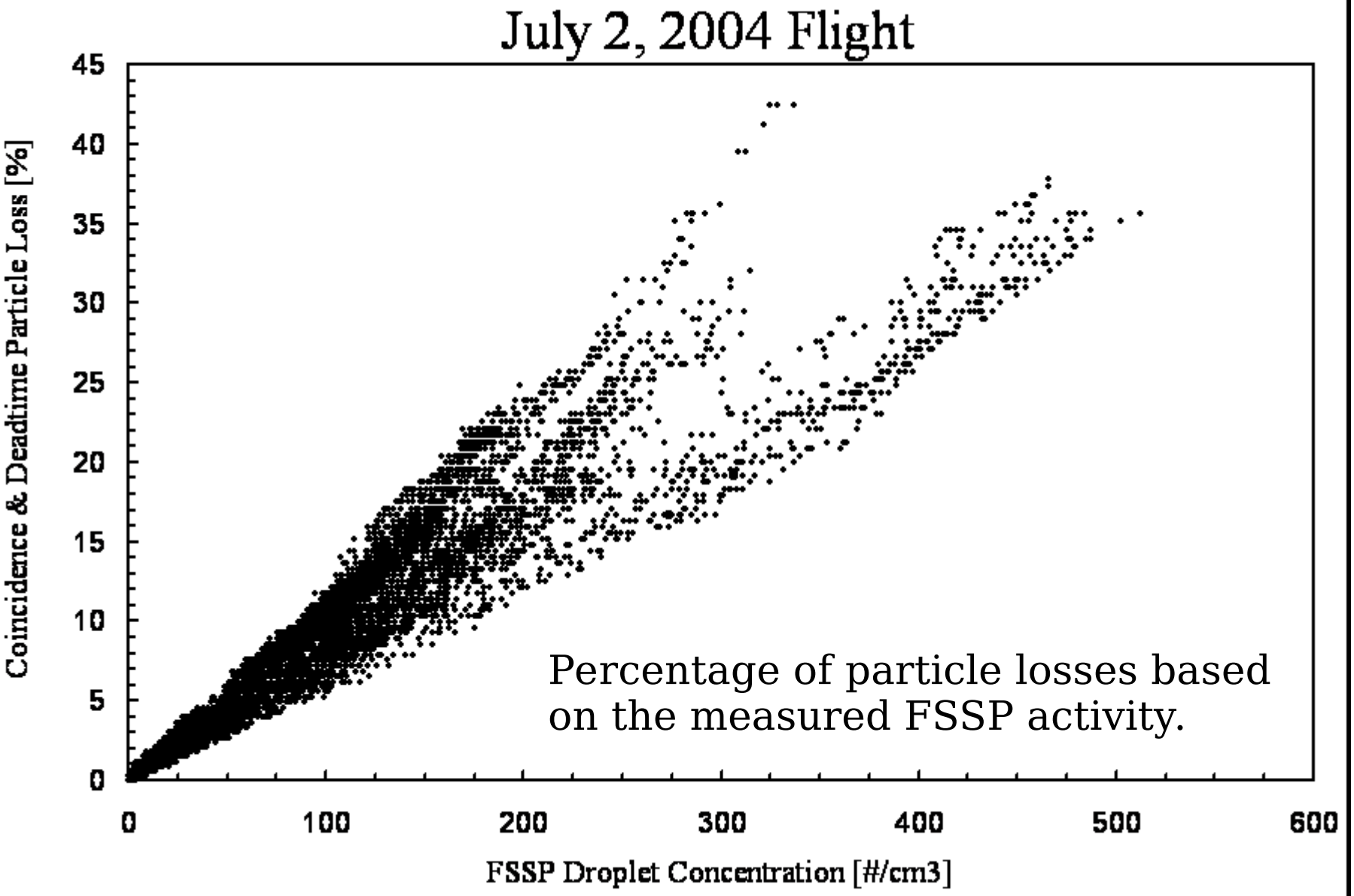

July 2, 2004 Flight
Velocity Acceptance Ratio [%]
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
4 Hz Total Strobes [counts]
The velocity acceptance ratio is based on the ratio of total FSSP counts to total FSSP strobes. Dye and Baumgarnder [1984] state that the theoretical velocity acceptance ratio is 62%.

Coincidence and Dead-time Corrections

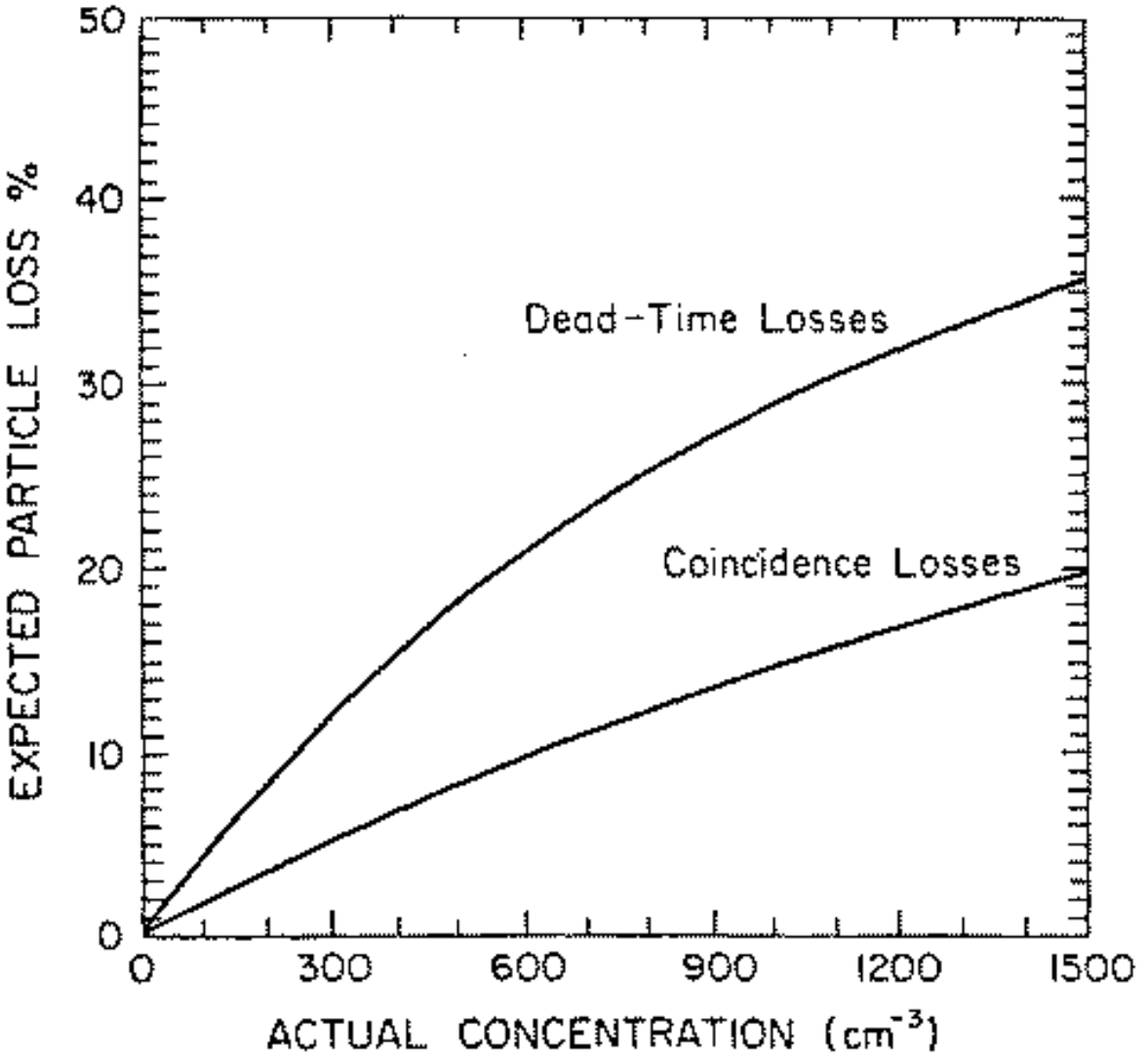
$$cf = \frac{1}{1 - 0.73 * F_a}$$

cf – Correction factor F_a – Activity Fraction

The 0.73 constant is an empirical factor found from computer simulations which takes into account particles which are still in the beam at the end of a reset delay period. This factor is described by Baumgardner [1983] and Baumgardner et al [1985].


July 2, 2004 Flight
Coincidence & Deadtime Particle Loss [%]
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400
500
600
FSSP Droplet Concentration [#/cm3]
Percentage of particle losses based
on the measured FSSP activity.

Theoretical Loss Correction



Cloud Droplet Probe (CDP)

CDP Overview

Technique: Light-scattering

Channels: 10, 20, 30, or 40 size bins

Size Range: 2 – 50 microns

Sample Area: 0.24 mm^2

Air Speed Range: 10 – 200 m/s

Sampling Frequency: Selectable, 0.1 to 10 Hz

Refractive index: Non-absorbing, 1.33

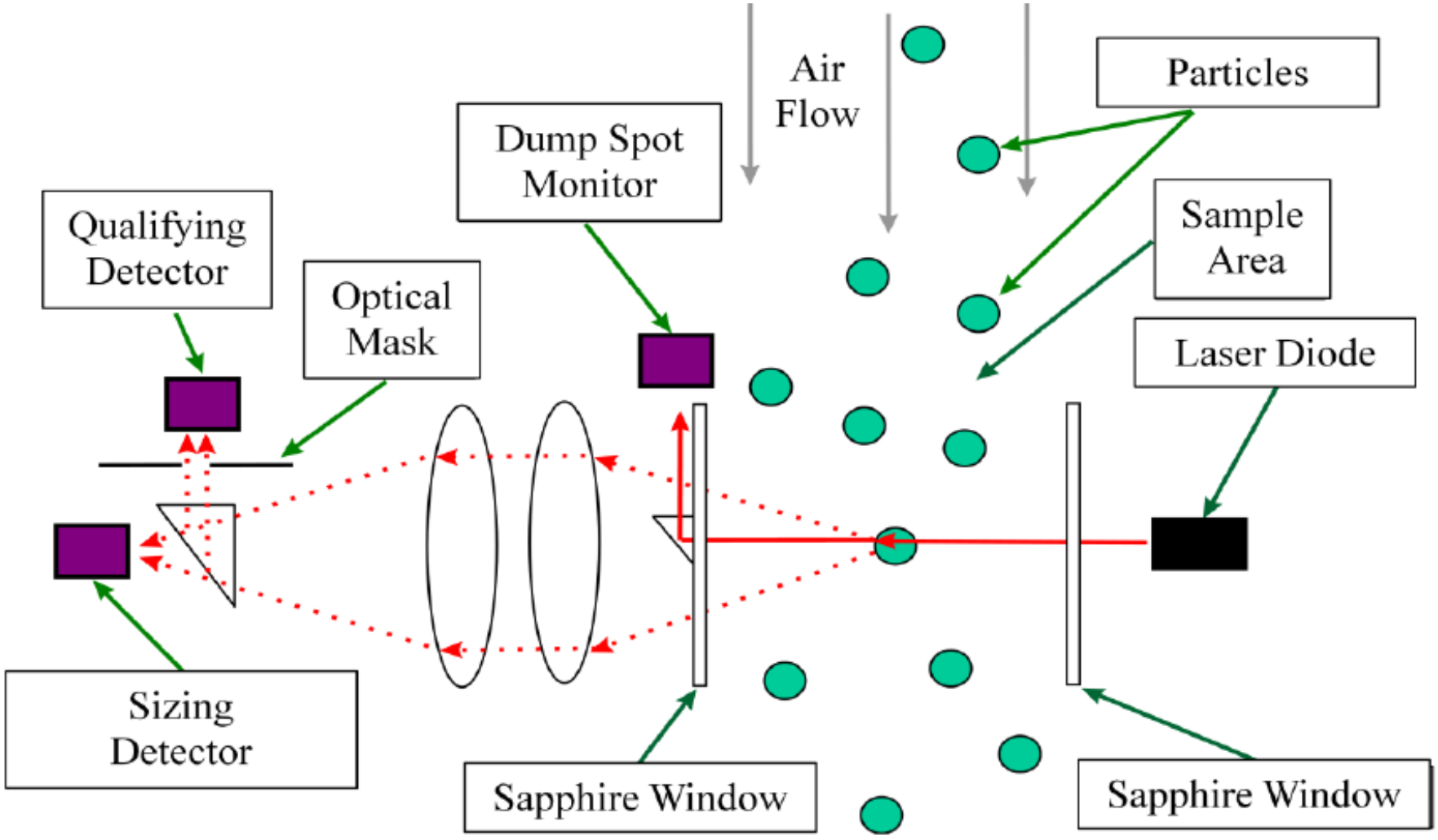
Light Collection Angles: 4 – 12 degrees

Laser: 658 nm, up to 50 mW

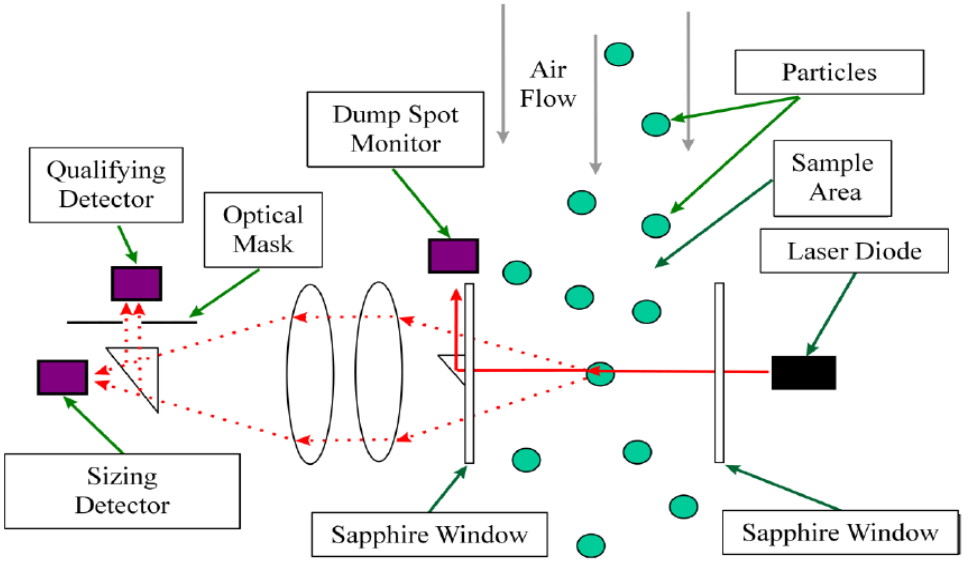
Data System Interface: RS-232 or RS-422

Calibration: Precision Glass Beads

Cloud Droplet Probe: Optical Path

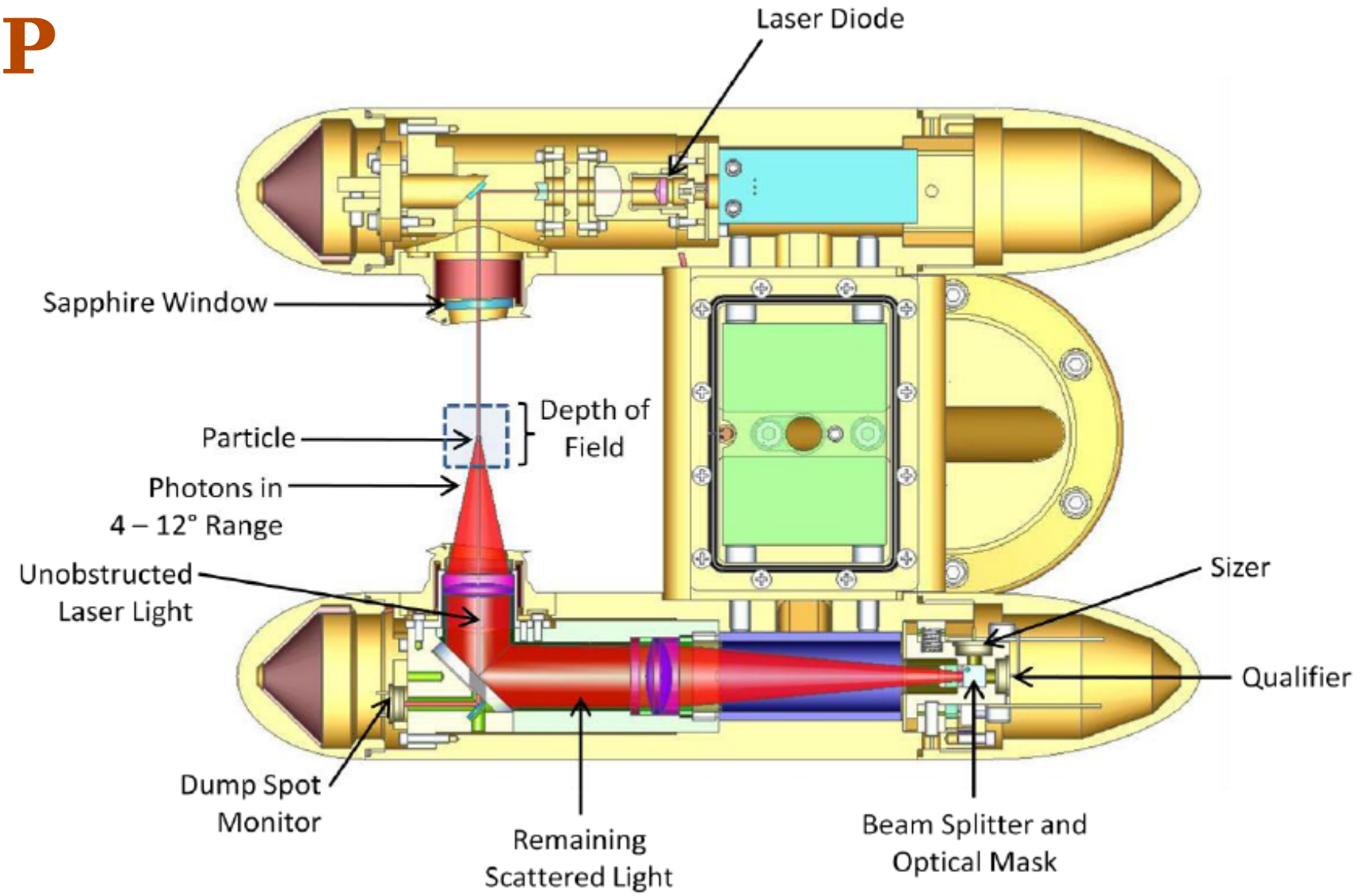


Depth of Field

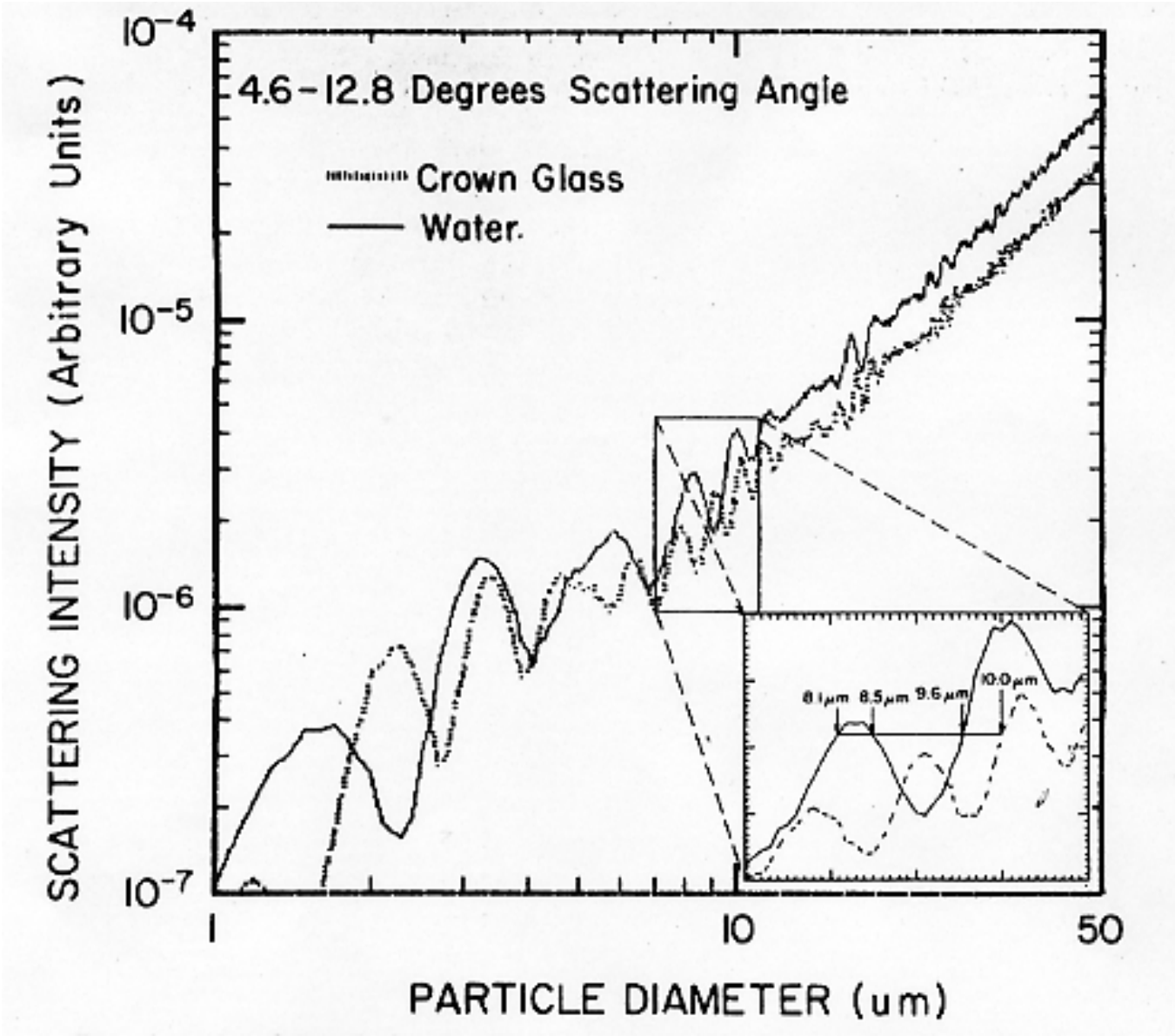


- Forward-scattered photons within a 4 to 12 degree cone from the laser beam are collect. A 50/50 optical beam splitter divides the light into a pair of photodetectors.
- An optical mask filters the optical signal going to the qualifier. Only signals from particles that fall within the laser's depth of field reach the qualifier in significant quantity.
- Both photodetectors convert the photon pulses into electrical pulses. The pulse from the qualifier is multiplied by two. If the resulting signal exceeds the pulse from the sizer, the particle is considered within the depth of field.

CDP


Laser Diode
Sapphire Window
Depth of Field
Particle
Photons in 4 – 12° Range
Unobstructed Laser Light
Sizer
Qualifier
Dump Spot Monitor
Remaining Scattered Light
Beam Splitter and Optical Mask

Sizing Calibration Mie Function



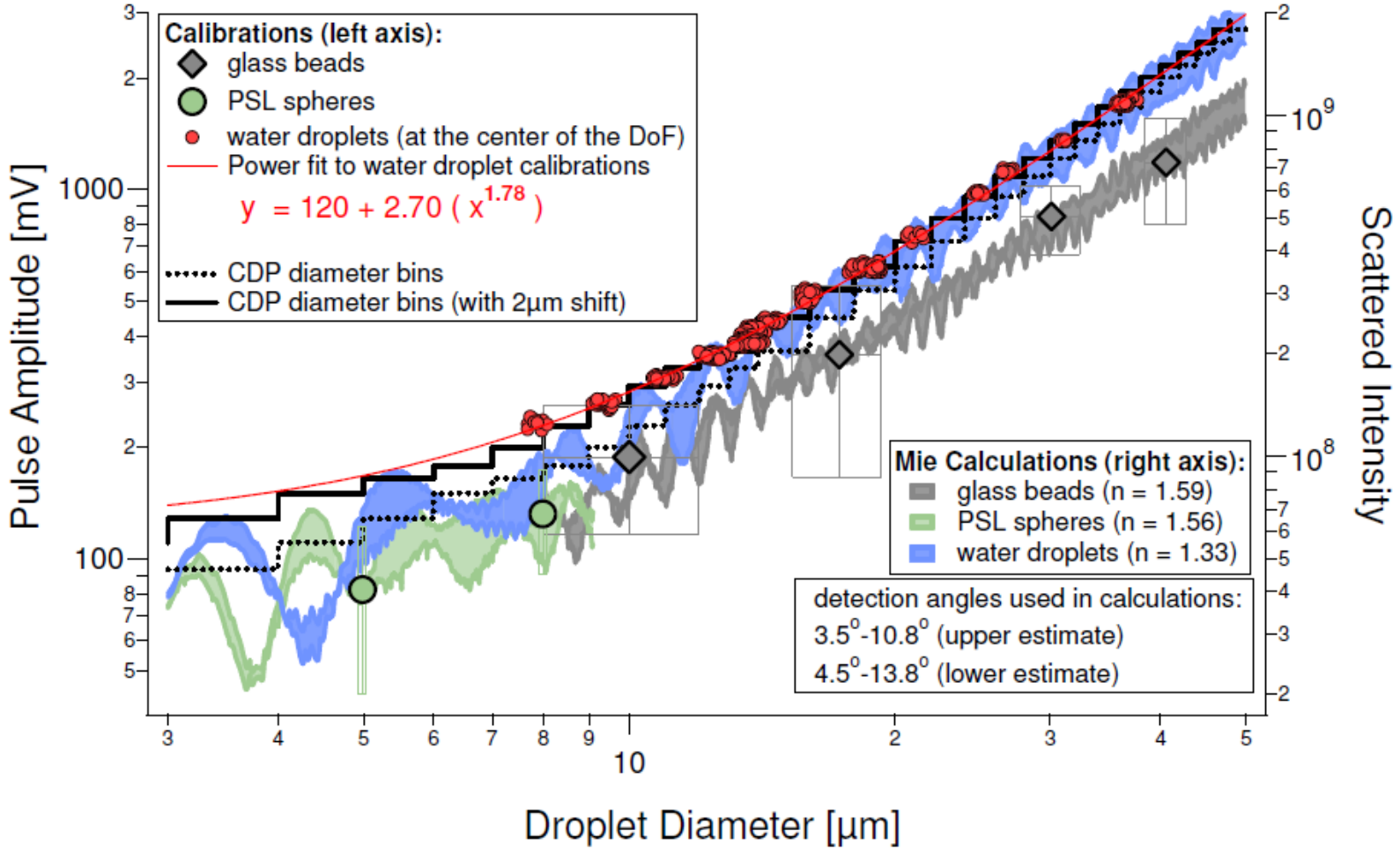
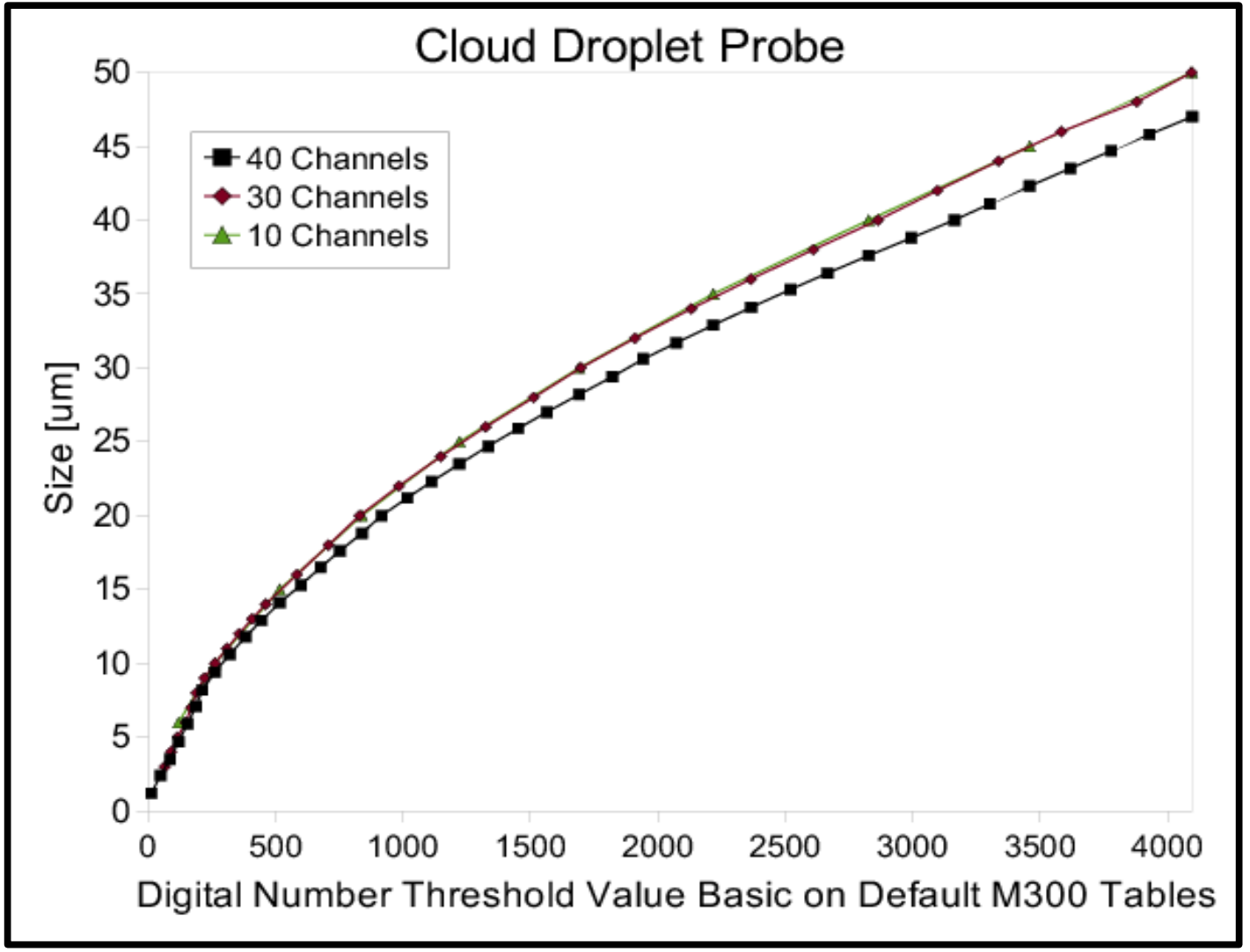


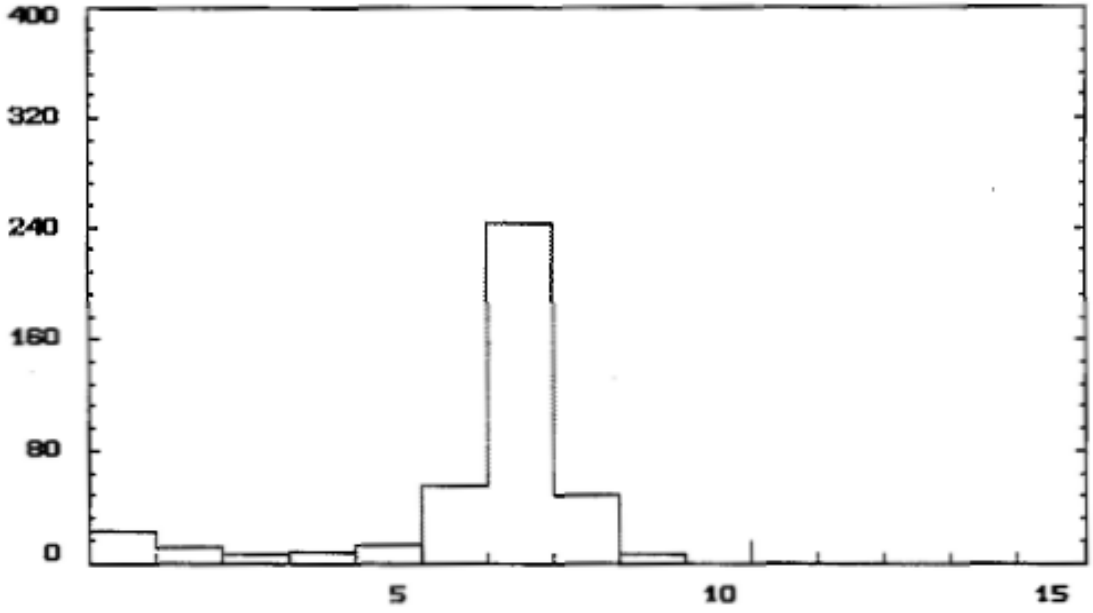
Figure is from Lance et al. [2010]: Atmos. Meas. Tech. Discuss., 3, 3133–3177, 2010, www.atmos-meas-tech-discuss.net/3/3133/2010/ doi:10.5194/amtd-3-3133-2010

Sizing Calibration Particle Size



Size Calibration

Sizing calibrated is done to determine the instrument's channel size boundaries by using the channel counts obtained from measurements on beads of known size.



Chnl	Cts	Size
1	22	2.60
2	11	7.30
3	5	11.20
4	8	14.40
5	12	17.60
6	55	21.00
7	243	24.50
8	49	28.60
9	6	32.80
10	0	38.10
11	0	43.30
12	0	49.10
13	0	53.70
14	0	59.90
15	0	65.20
16		70.70

Range: 0 BeadSize: 30.200 WtrEquiv: 24.600 AvgChnl: 6.98

Probe Type: fssp

Probe S/N:
2091-0581-63
Probe Owner:
UND

Data Taken:
11:13:12.00 to
11:13:33.00
10/23/03

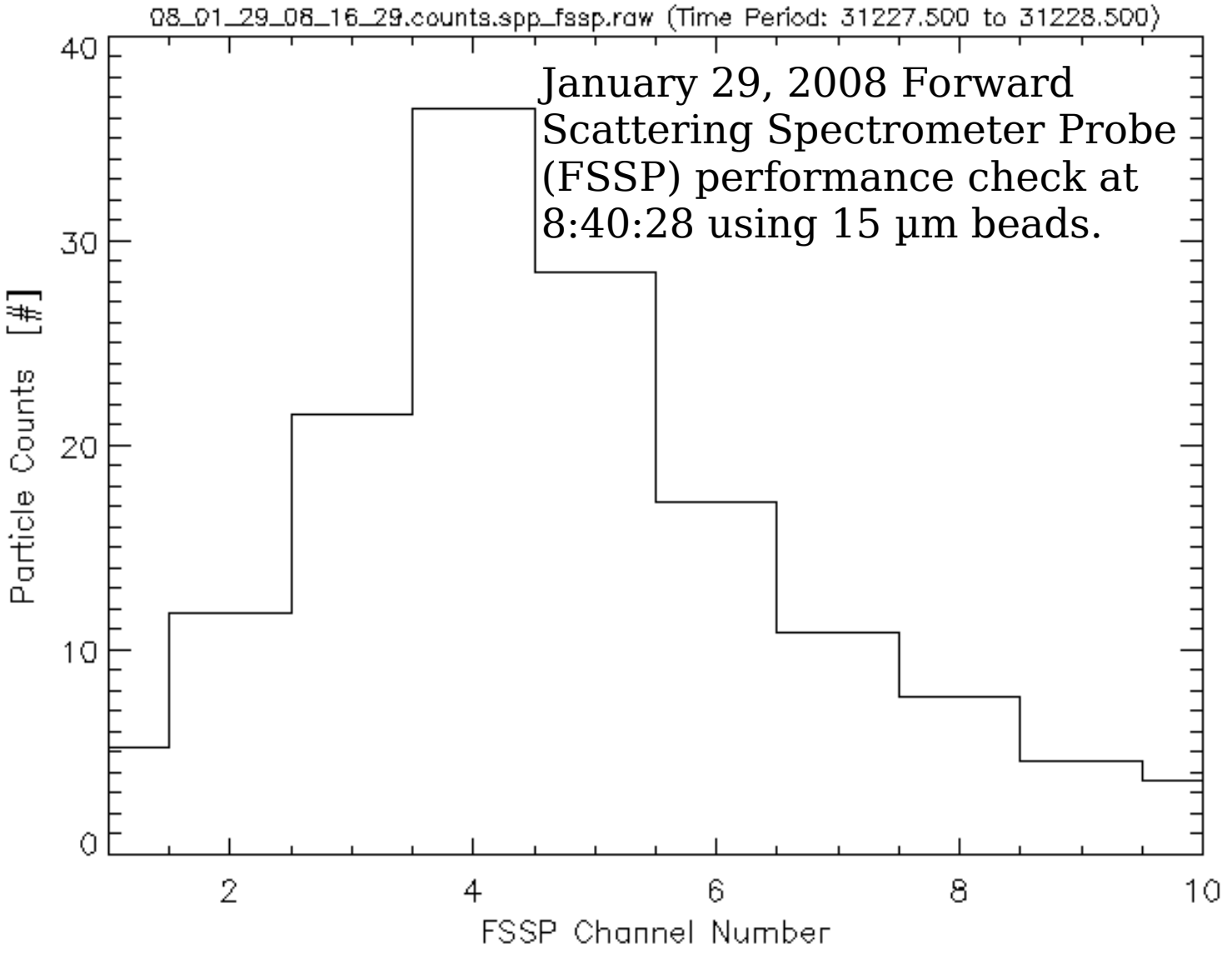
Processed:
10/23/03 11:13:43
Data File:
r0-30pre.cal

MIE Data - File,S/N,Info:
miecurve.dat
default
4.0-12.0;08/30/99

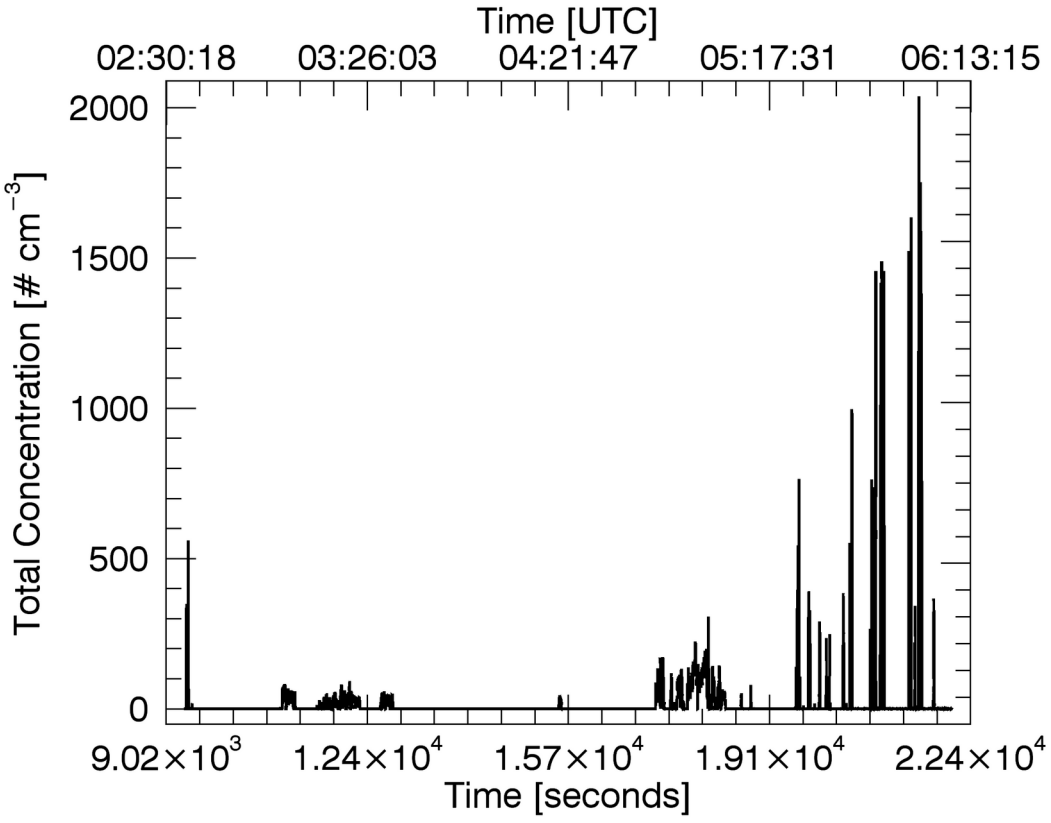
Pha Data - File,S/N,Info:
phadata.dat
default
12/92

Offset Data - File,S/N,Info:
offsets.dat
default
12/92

FSSP Check


08_01_29_08_16_29.counts.spp_fssp.raw (Time Period: 31227.500 to 31228.500)
January 29, 2008 Forward Scattering Spectrometer Probe (FSSP) performance check at 8:40:28 using 15 µm beads.
Particle Counts [#]
0
10
20
30
40
2
4
6
8
10
FSSP Channel Number

Level 3 Data Processing

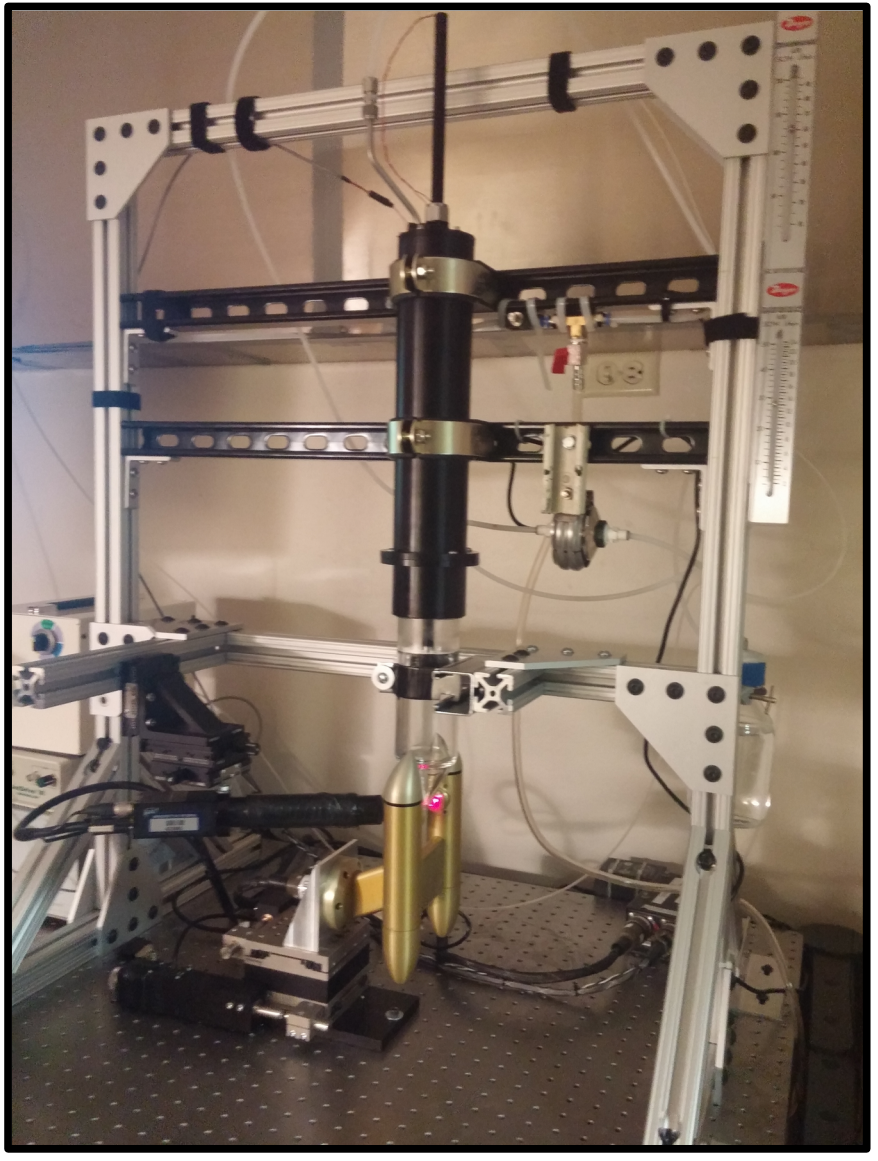


- No level 2 processing for CDP data.
- Level 3 processing (cdp_counts2conc.pro) uses true air speed from *.physical.raw file to convert channel counts into concentrations [# cm-3].
- Auxiliary data are converted from engineering units into physical units.

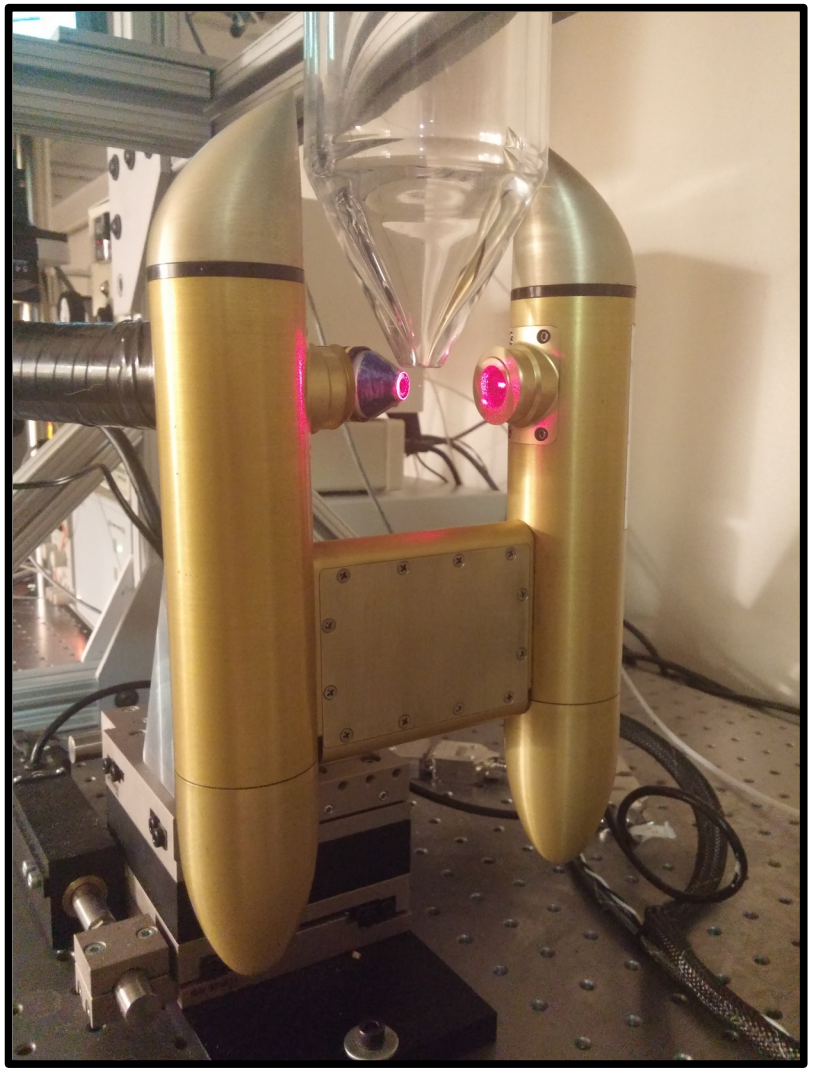
Sample Area for two Cloud Droplet Probes (CDPs)

David Delene

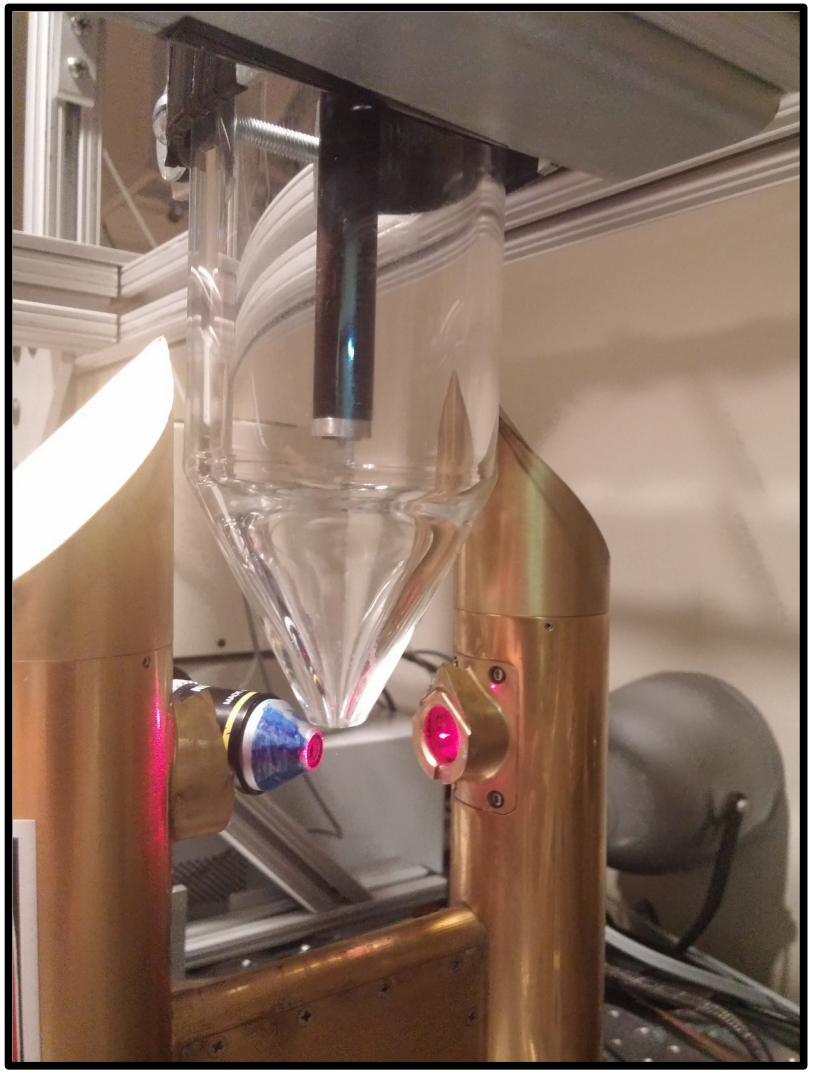
University of North Dakota



UND-CDP (SN 0901-48)

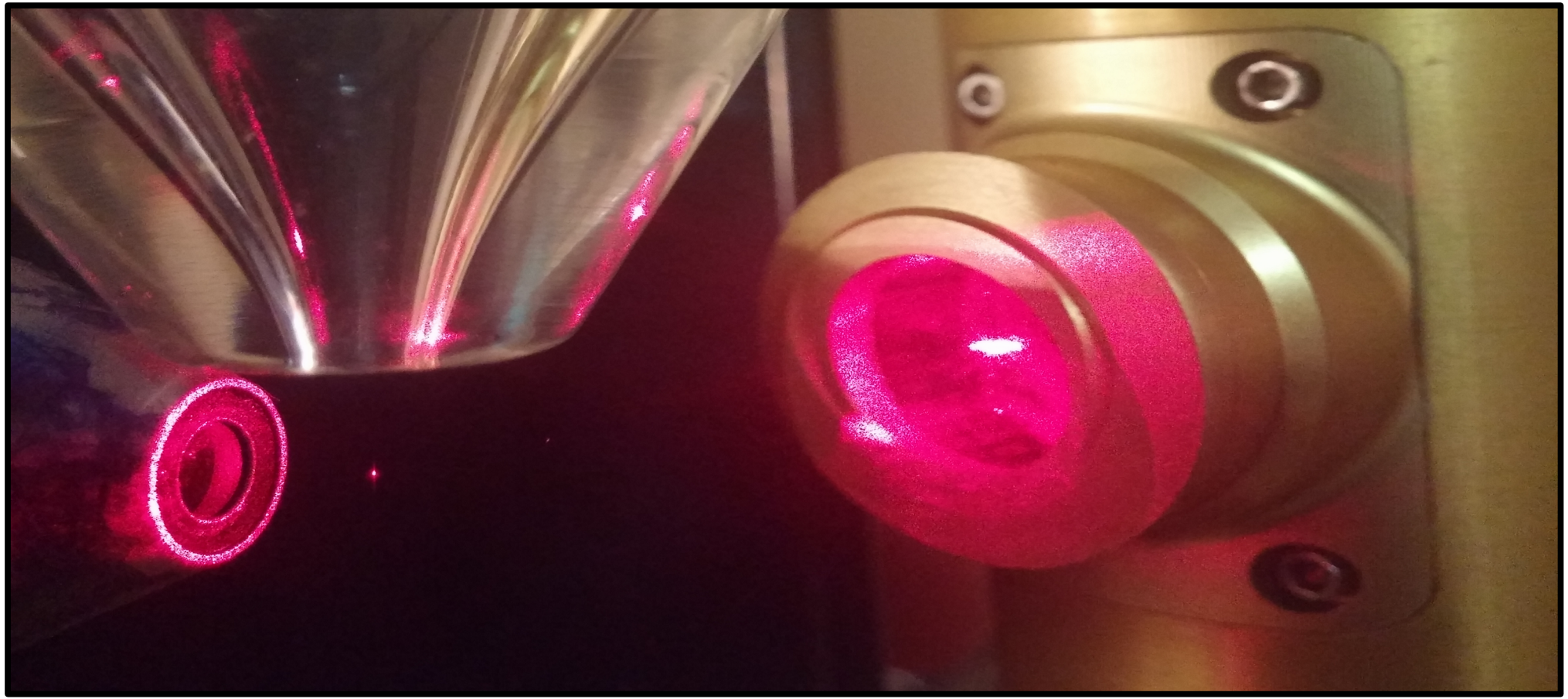


WMI CDP (SN 1406-085)



Typical Sample Area

Cloud droplet probe manual (DOC-0029, Revision M, page 8) states the sample area is **0.24 mm²**.



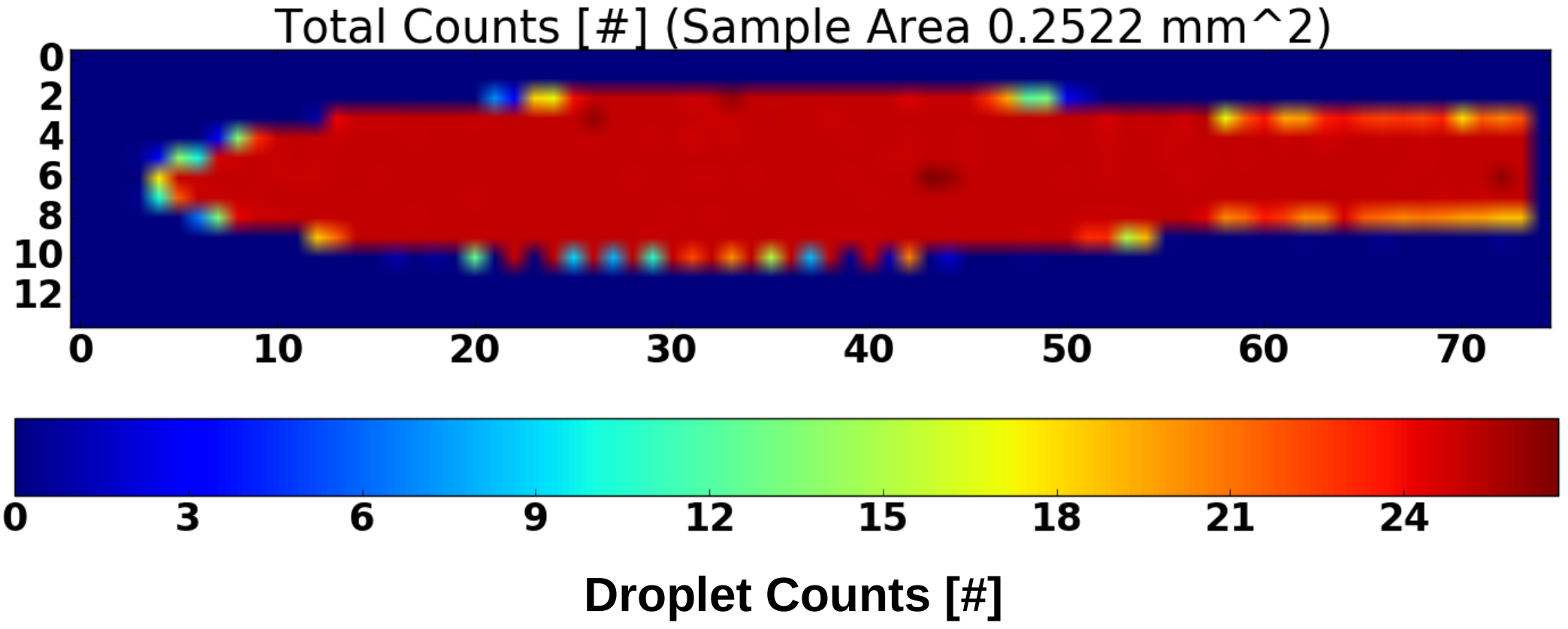
Instrument Comparison Table

	UND Probe			WMI Probe		
Size [um]	**X Dimension**	**Y Dimension**	**Offset**	**X Dimension**	**Y Dimension**	**Offset**
15	74	13	2	74	13	3
28/30	68	13	3	80	15	2
40	74	13	3	74	13	3

convert_cdp2nasa.py
process_MotionControl
convert_MotionControl2nasa.py
cdp_samplevolume.py

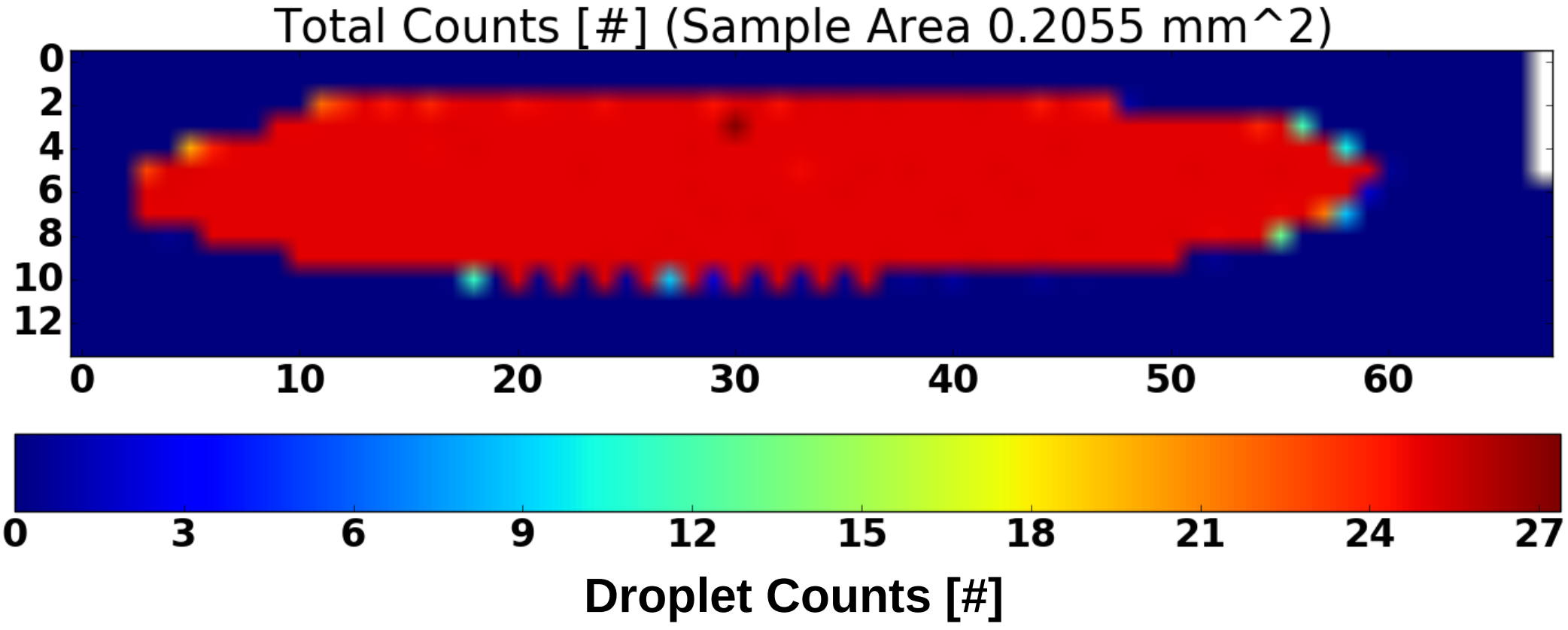
UND-CDP ~15 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



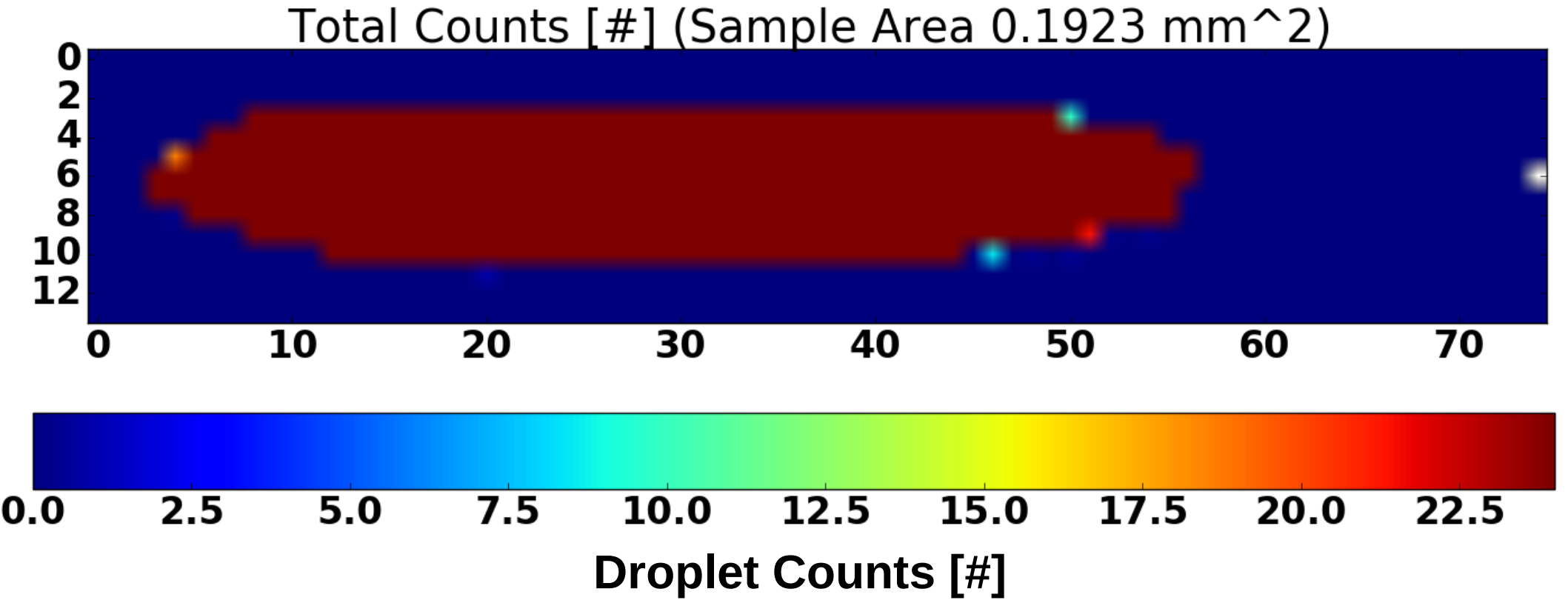
UND-CDP ~28 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



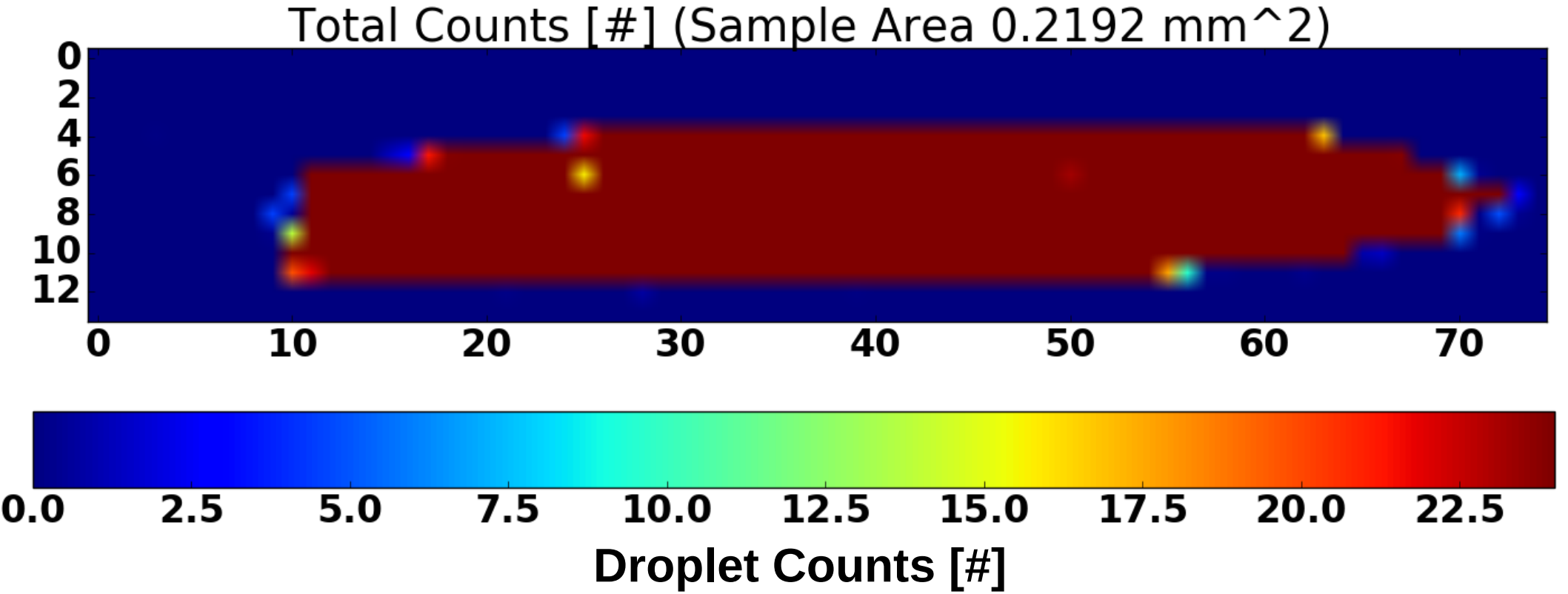
UND-CDP ~40 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



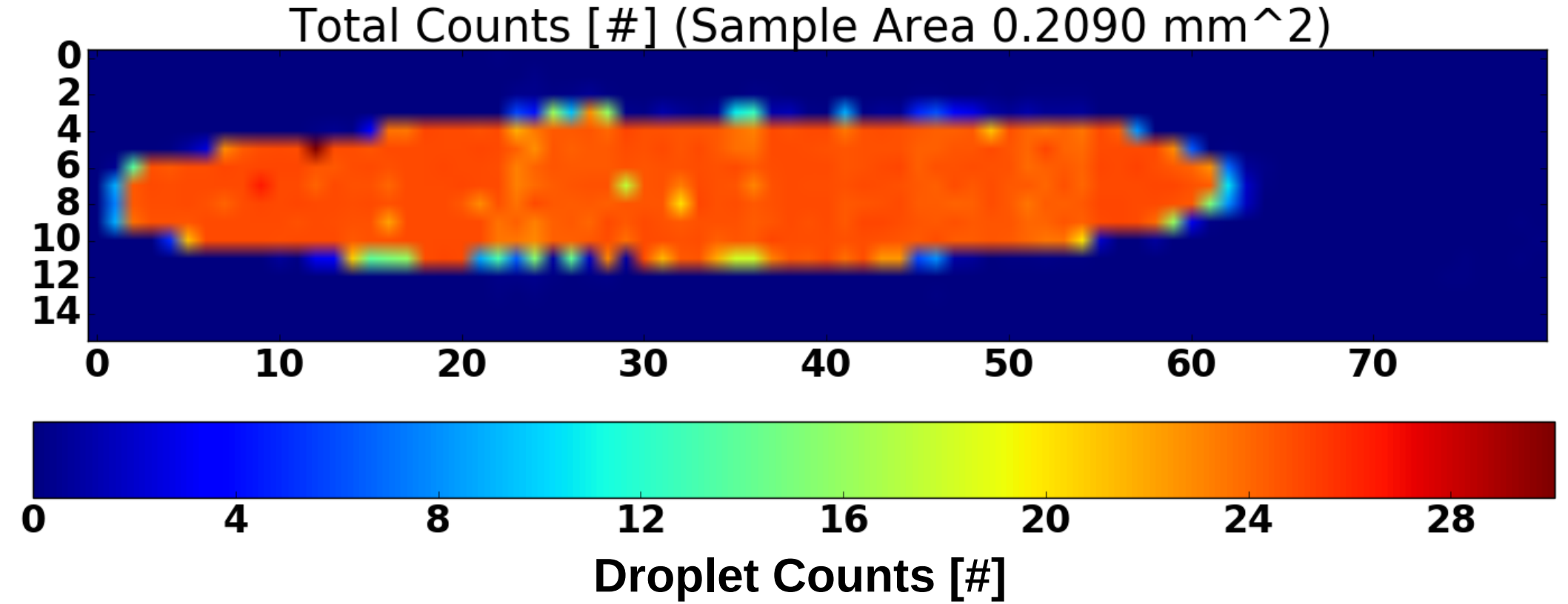
WMI-CDP ~15 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



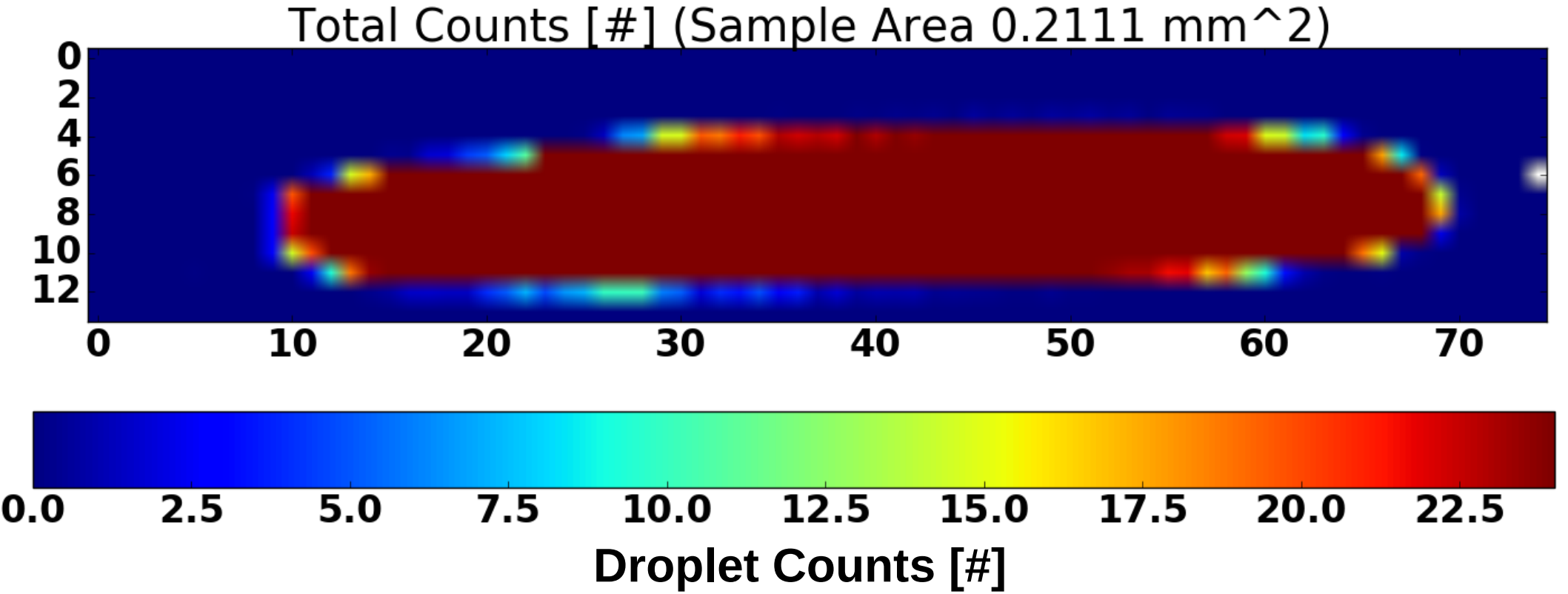
WMI-CDP ~30 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



WMI-CDP ~40 um Droplets

Sample area defined as greater than 50 % of maximum total counts.
The pixel area is 507.38 um^2.



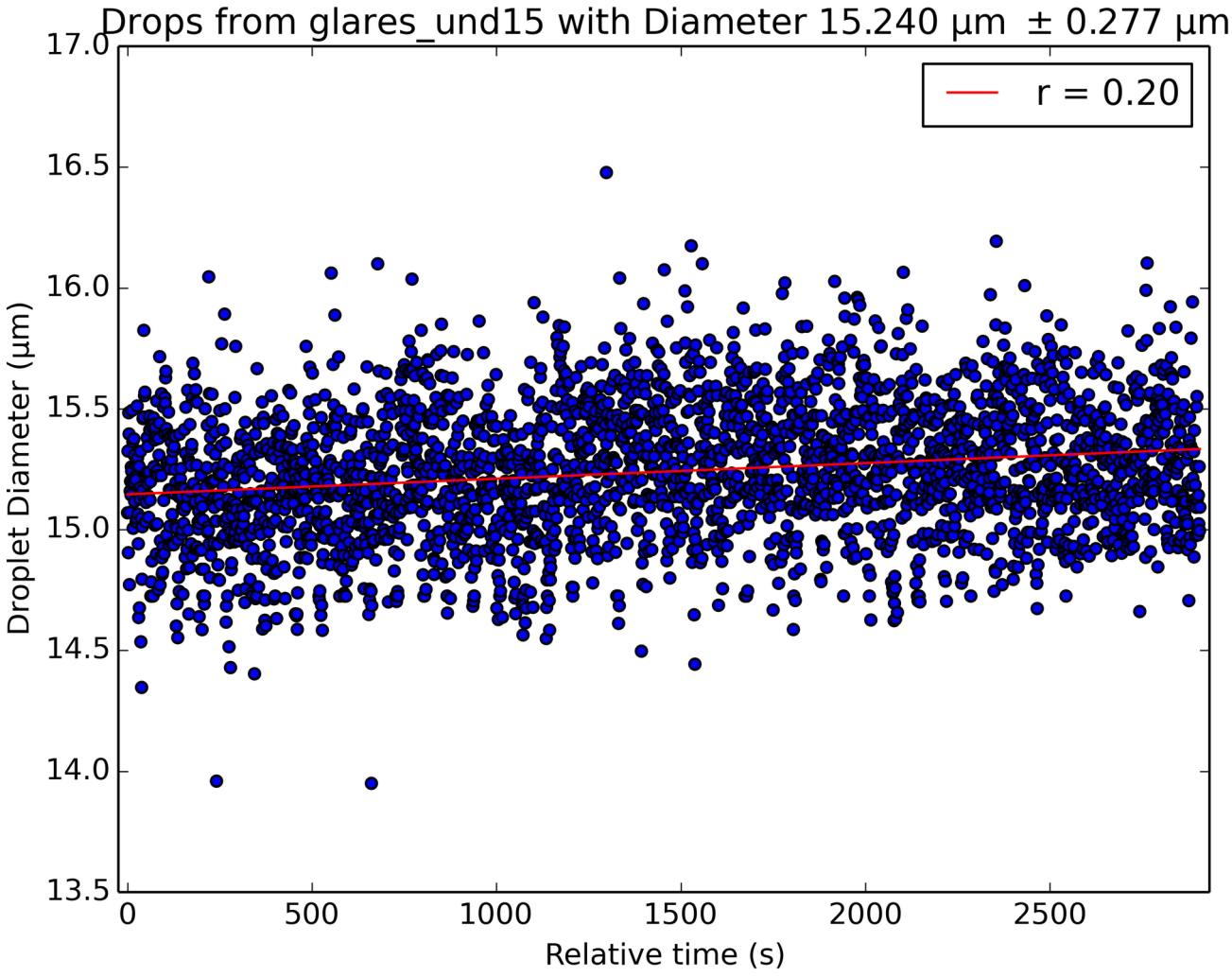
Instrument Measured Sample Area

	UND Probe		WMI Probe	
Size [um]	**Sample Area**	**Relative Error**	**Sample Area**	**Relative Error**
15	0.2522 mm^2	4.8 %	0.2192 mm^2	9.5 %
28/30	0.2055 mm^2	16.8 %	0.2090 mm^2	14.8 %
40 um	0.1923 mm^2	24.8 %	0.2111 mm^2	13.7 %

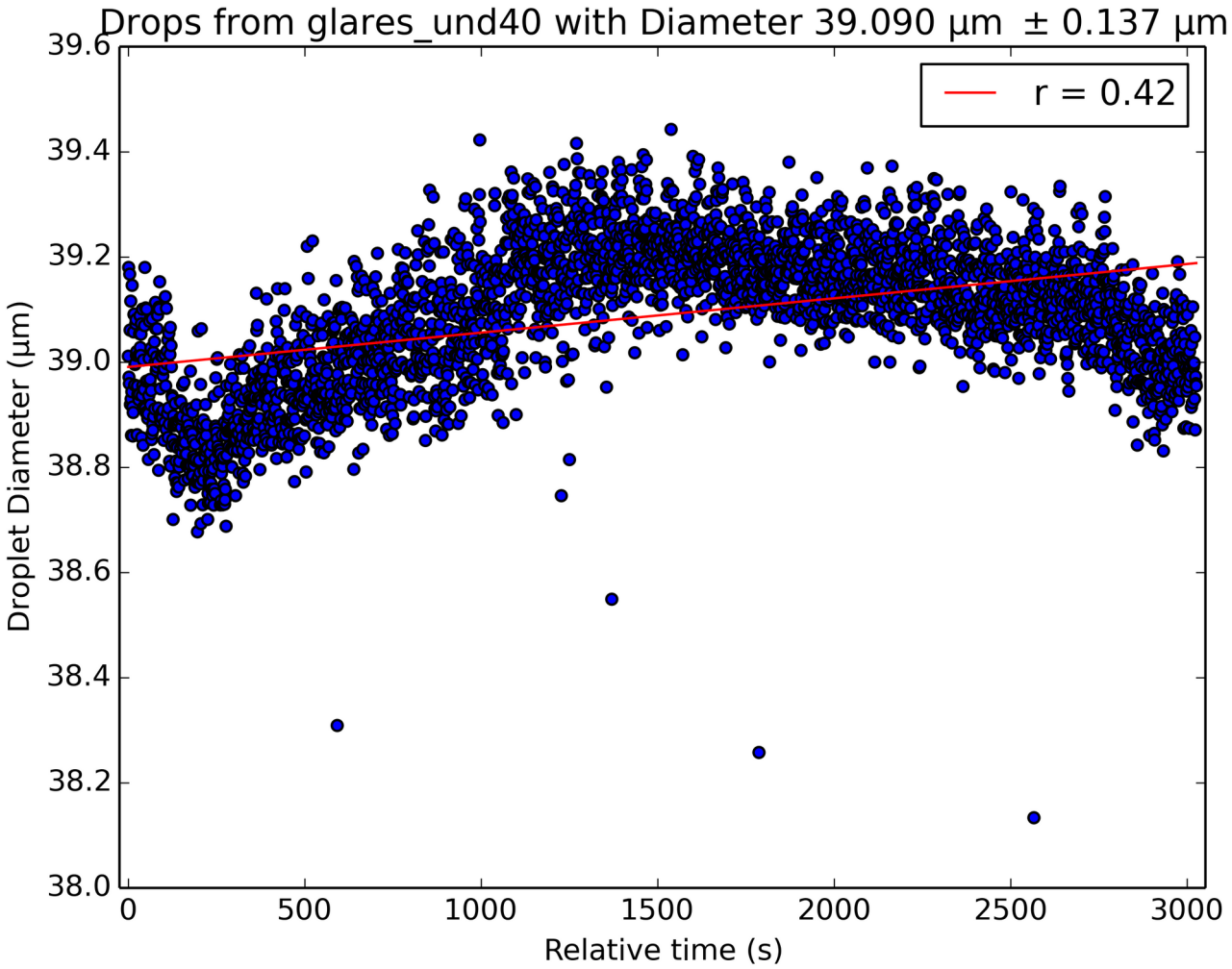
Drop Size Estimated from Glares Photographs

- Program: PixelWidth_Multi.py
- Takes a date and time and calculates the width of each drop based on the whiteness bands in the image.
- The mean and standard deviation are then calculated, and a plot of the overall data is produced, along with a linear regression line.

Glares Photographs Drop Size



Glares Photographs Drop Size



Processing Method and Software

https://adpaa.sourceforge.io/wiki/index.php/.:cdp:Lab

Scripts

convert_cdp2nasa.py
process_MotionControl
convert_MotionControl2nasa.py
cdp_samplevolume.py

Image Processing

PixelWidth_Multi.py