Full plume characterization for better understanding of cold spray process quality

Cold Spray Club, Gallipoli 2025-06-26

Jussi Larjo, Oseir Ltd.

HiWatch line

Oseir

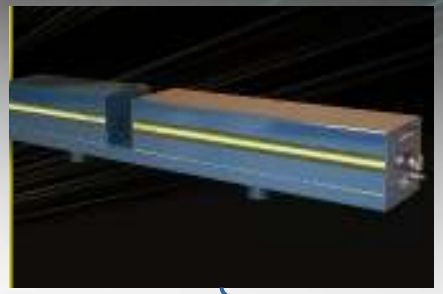
HW Compact

HW

2002

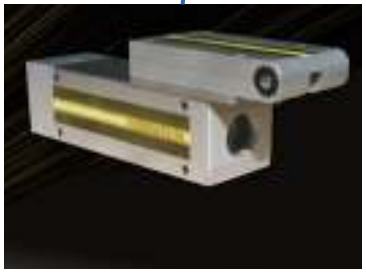
2005

HiWatch HR



2011

HiWatch CS



HiWatch CS2

2015

ShotWatch

2017

2018

HiWatch CS-Q

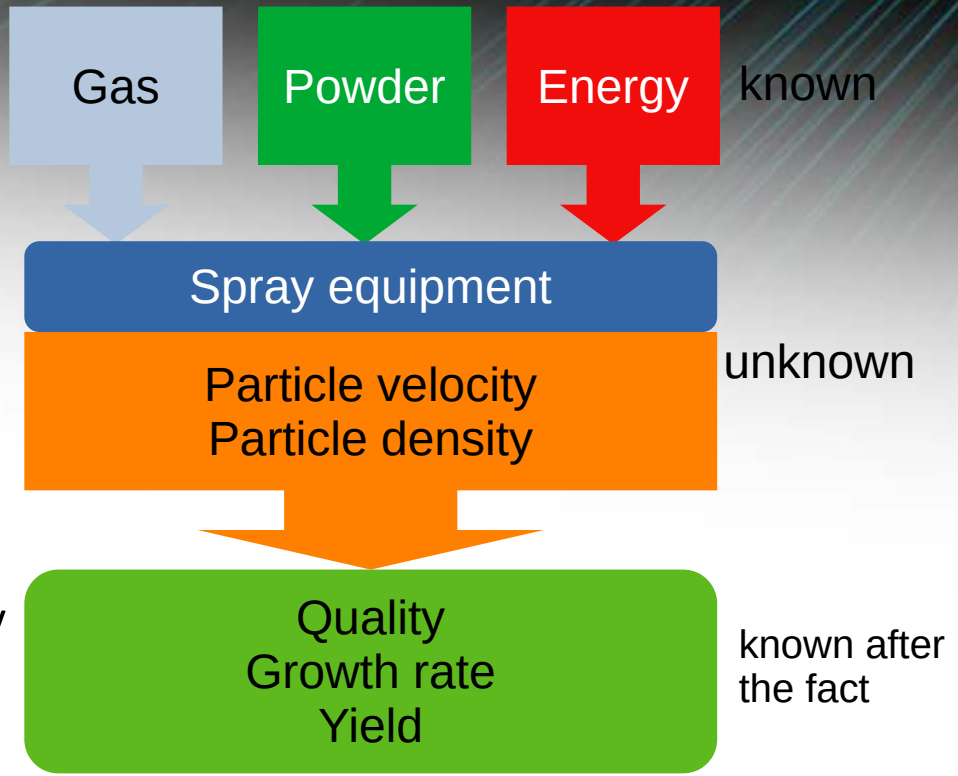
2019

HiWatch HR2

2024

Online monitoring: spray failures

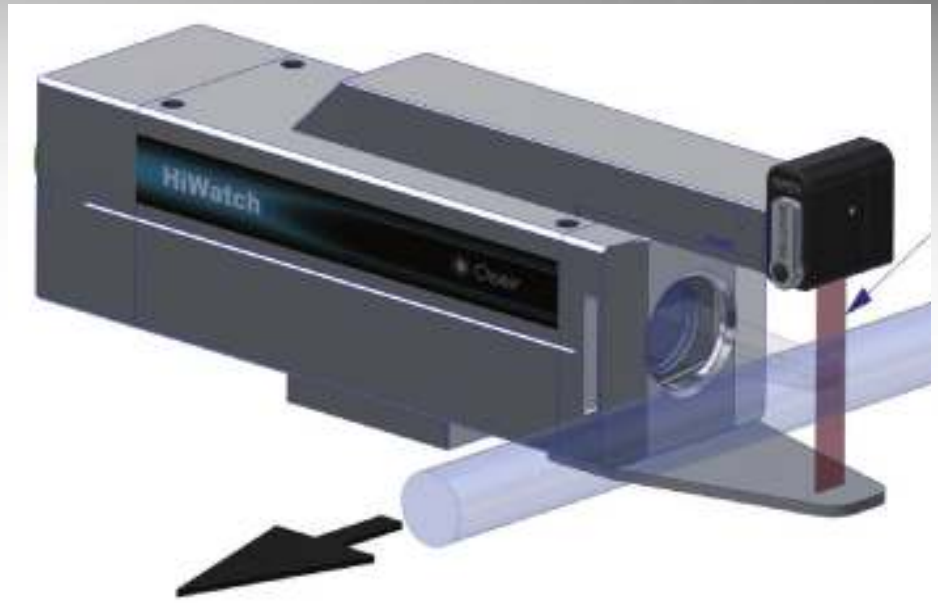
- Feedstock
  - agglomeration
- Equipment wear
  - Nozzle, injector port, feed line
- Gun degradation
  - clogging
- System malfunction
  - Powder feeder
- Operator issues
  - Setup failures
- Affect particle propeties instantly



Agenda

- Why full plume characterization?
  - Full spatial coverage:
    - 3D system (models often still 1D)
    - Particle condition at impact
      - 2D: Nonuniform yield and deposit quality
  - Full time coverage:
    - Condition of spray equipment
      - Nozzle
      - Feed line
      - Powder properties
    - Transient effects
    - Rapid deterioration

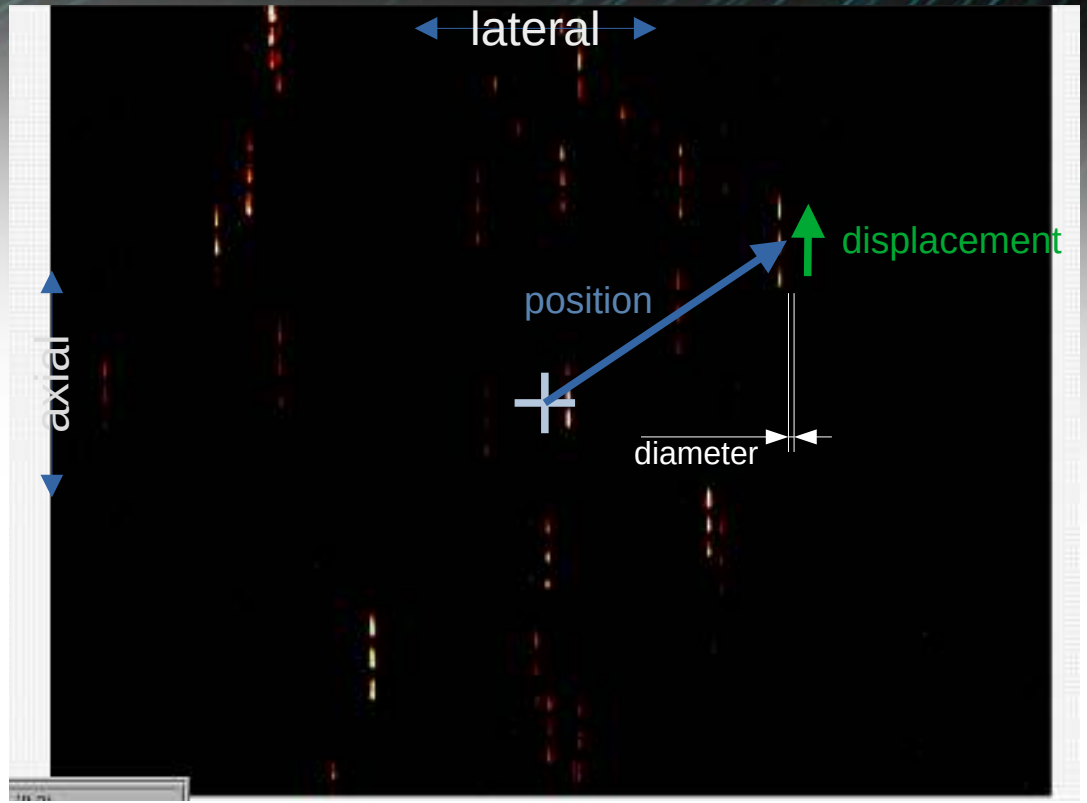
HiWatch CS2



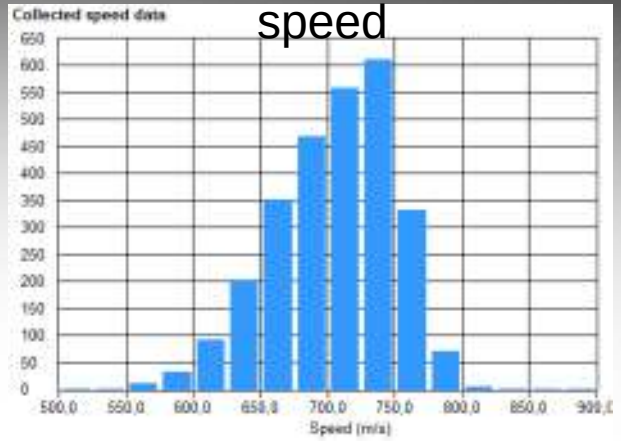
- Simple and lightweight
- Particles detected by scattering
- Results:
  - velocity
  - position
  - size estimate
- Measurement area 8x5mm^2
  - Depth ~0.5mm
- ~5 µm spatial resolution in image plane

2D particle properties from single image: Particle Tracking Velocimetry (PTV)

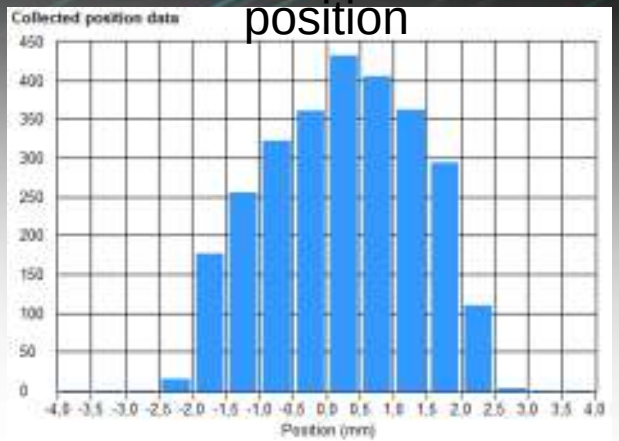
- 3-pulse illumination with time interval t_i
- Particle triplet trace identified by software
  - Position and displacement vectors (**p**, **D**)
  - Velocity: $\mathbf{v} = \mathbf{D}/t_i$
  - Diameter: coarse estimate
    - Pixel resolution insuffcient
    - One-sided illumination
- Lateral and axial components relative to spray orientation
  - Single particle accuracy for **p**,**v** better than 2%



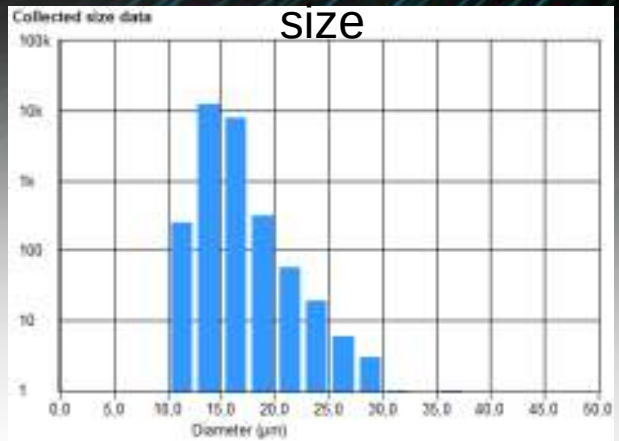
Data gallery:



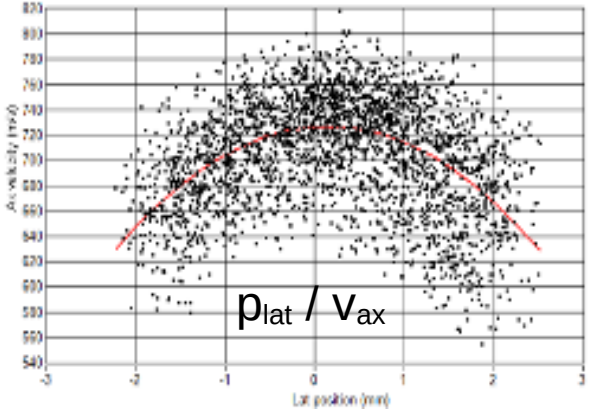
speed



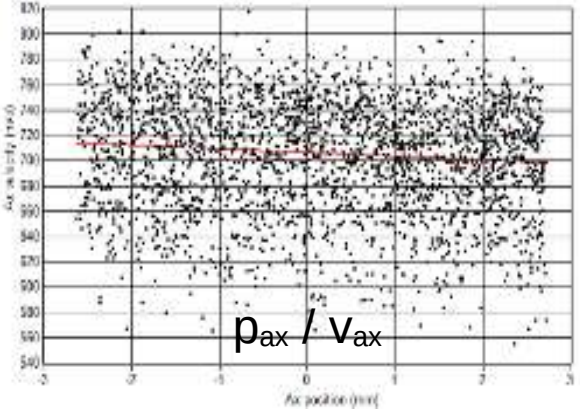
position



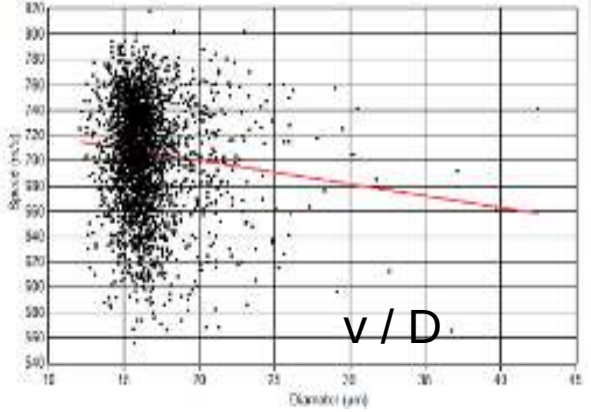
size



p_{lat} / v_{ax}

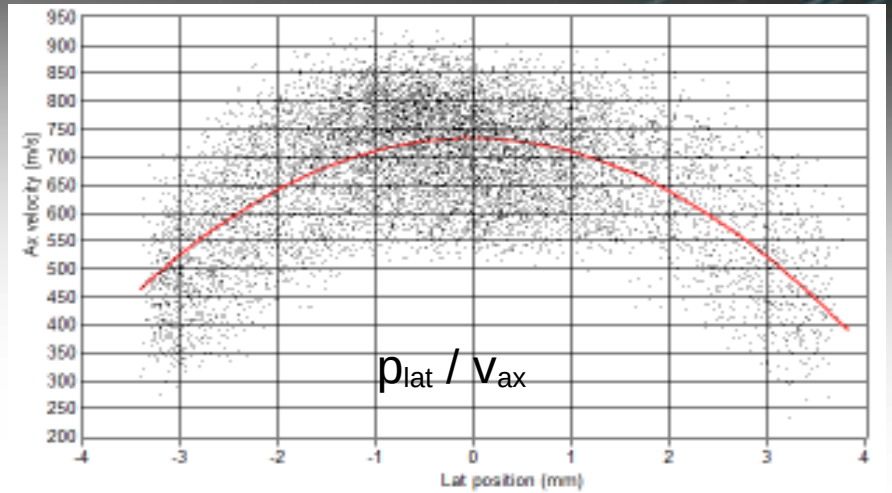


p_{ax} / v_{ax}

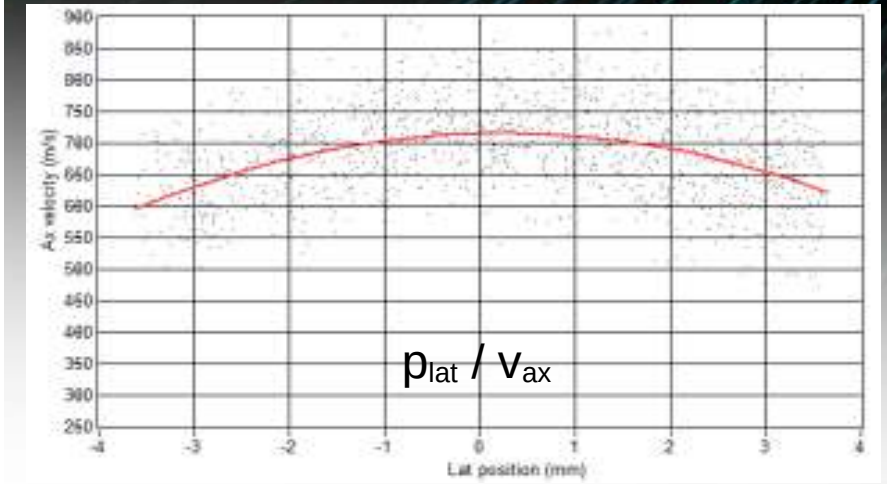


v / D

Full plume analysis: uniformity



- LPCS
  - Cu powder, N2
- Ax velocity variation ~40%
- Expected deposit:
  - Higher growth rate
  - Lower yield & uniformity

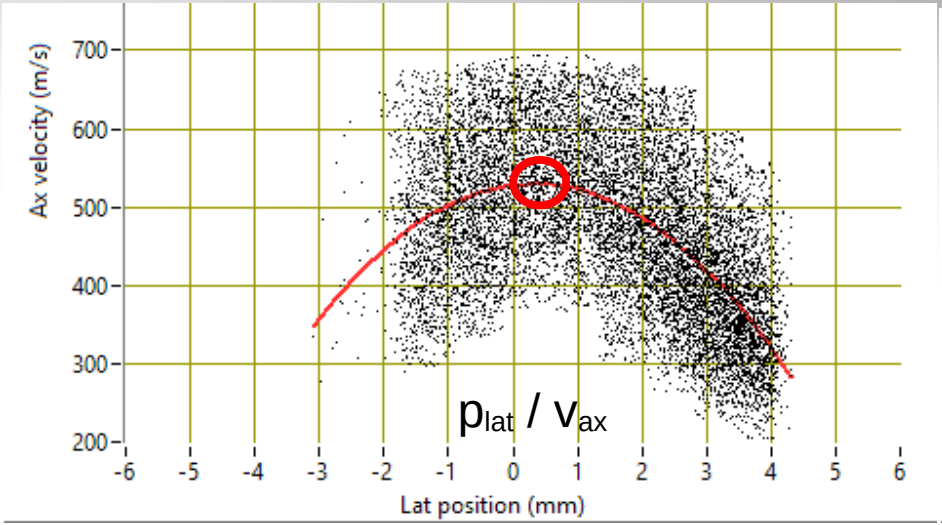


- HPCS
  - Cu powder, N2
- Ax velocity variation ~ 20%
- Expected deposit:
  - Lower growth rate
  - Higher yield & uniformity

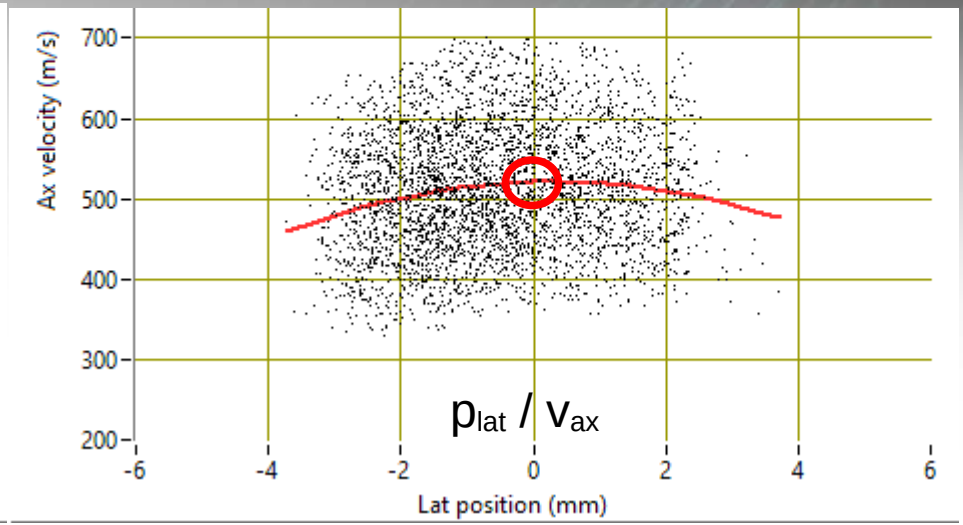
Case: Plume asymmetry

Feed rate and carrier gas flow adjustment

Original feed



Adjusted feed

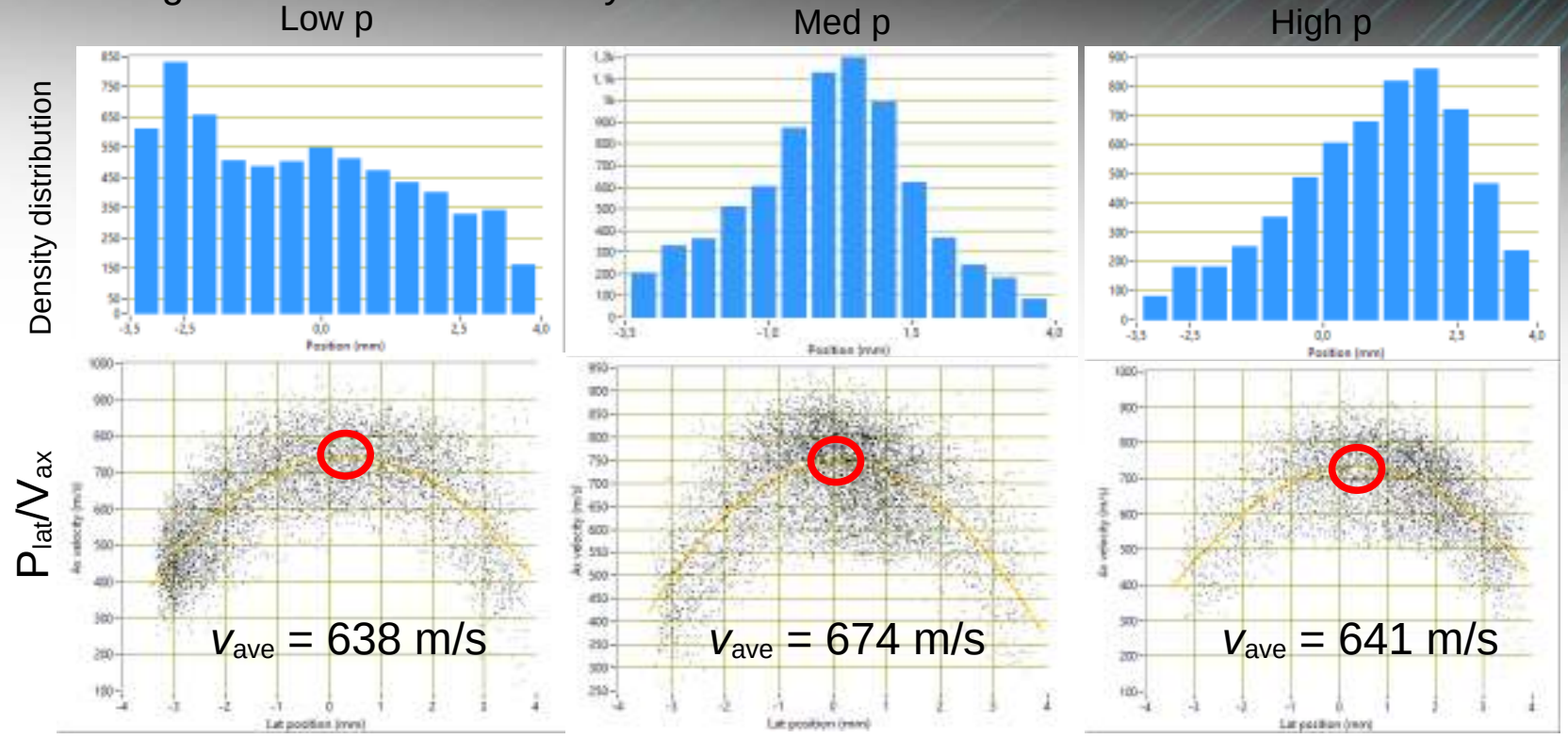


Identical results for point measurement at center axis!

Case: Plume asymmetry effect (b)

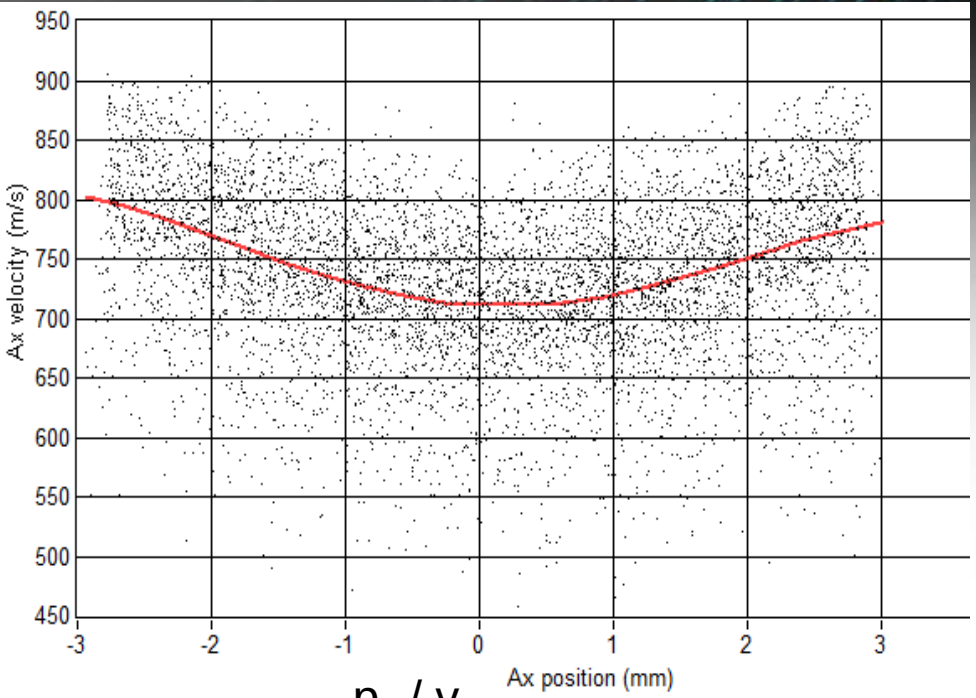
Centerline spray gun: Venturi based feed

- All settings have ~750 m/s velocity at center!



Axial velocity development: Shock front?

- Cu/N2 spray, VRC Gen3
  - Standoff 11mm
- Lat velocity: typical spread
- Ax velocity
  - rapid drop 800 → 700 m/s over 3mm travel
  - Re-acceleration at longer standoff
- Shock front?
  - Similar effect at substrate boundary layer?



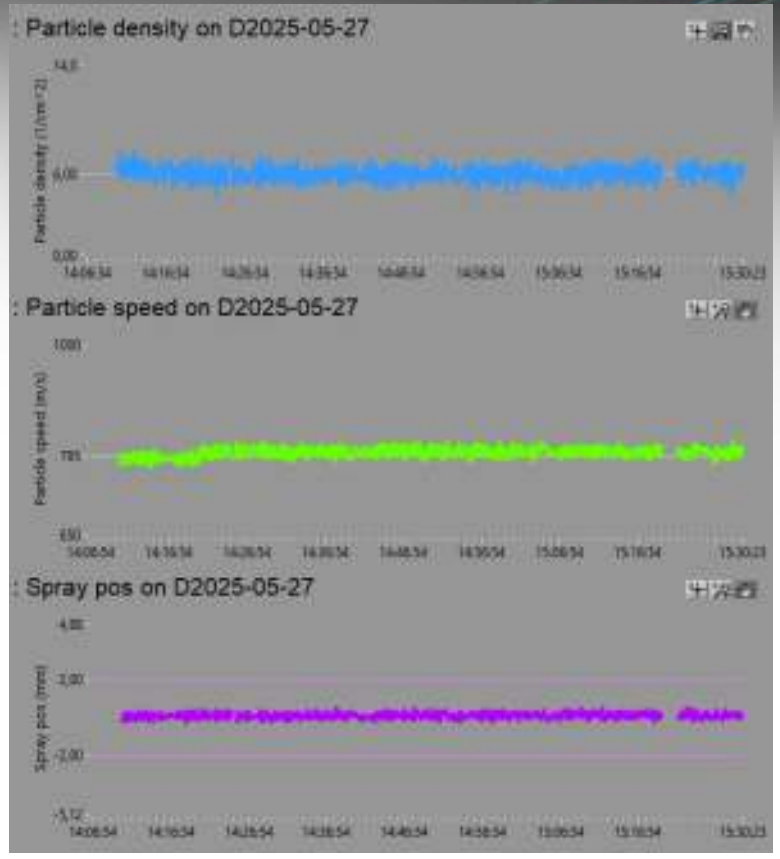
p_{ax}/ v_{ax}

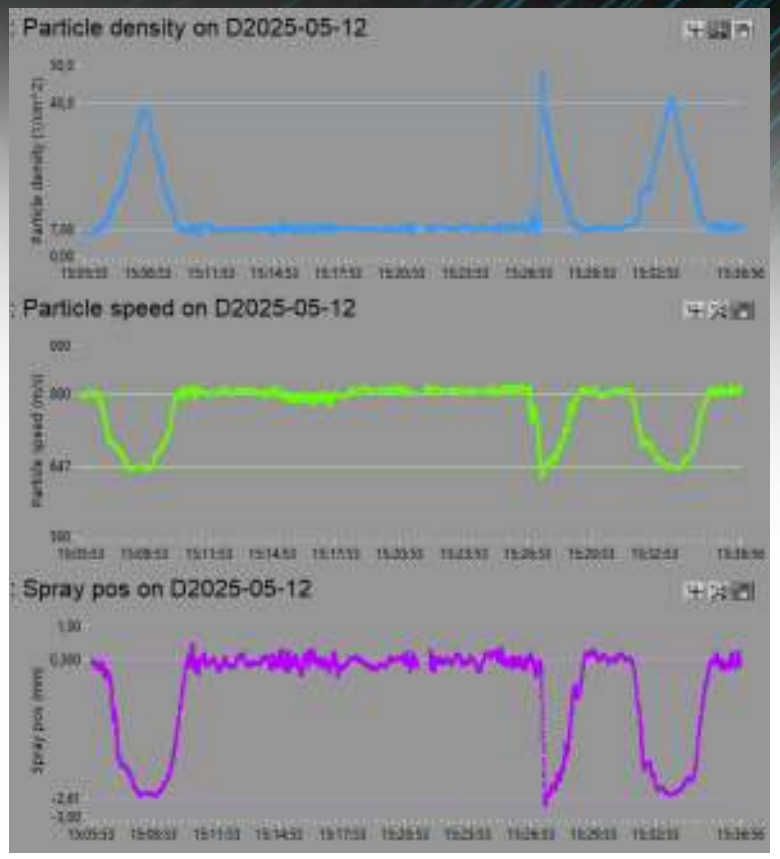
HiWatch CS-Q

- Functionally near equivalent to CS2
- Results:
  - velocity
  - position
  - size estimate
- Gun mountable
- Offers full time coverage of particle properties
  - Tested for up to 4h
  - To be validated for 24/7 operation

HiWatch CS-Q monitoring: Stable and unstable operation during process

Stable: 90min with no anomalies

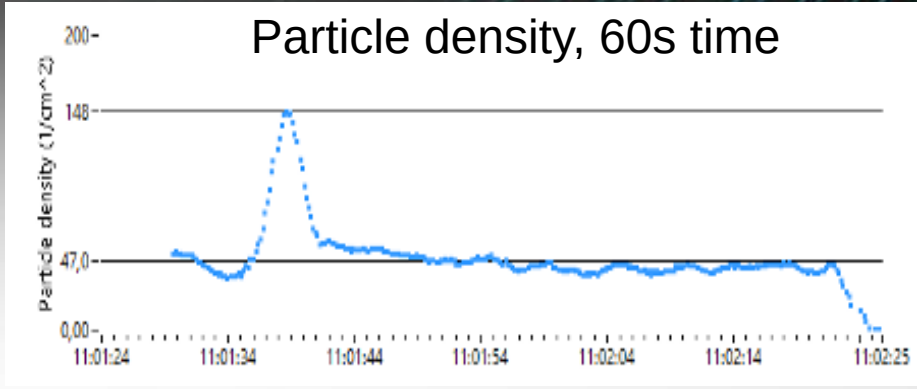


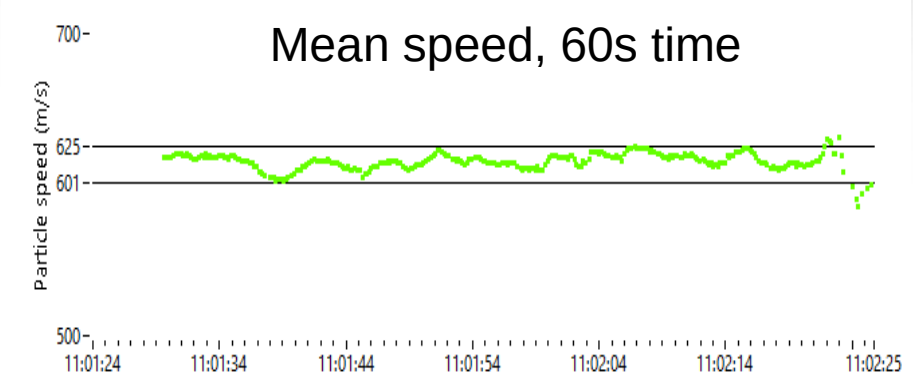


Unstable: 30min with 3 anomalies

Feed stability

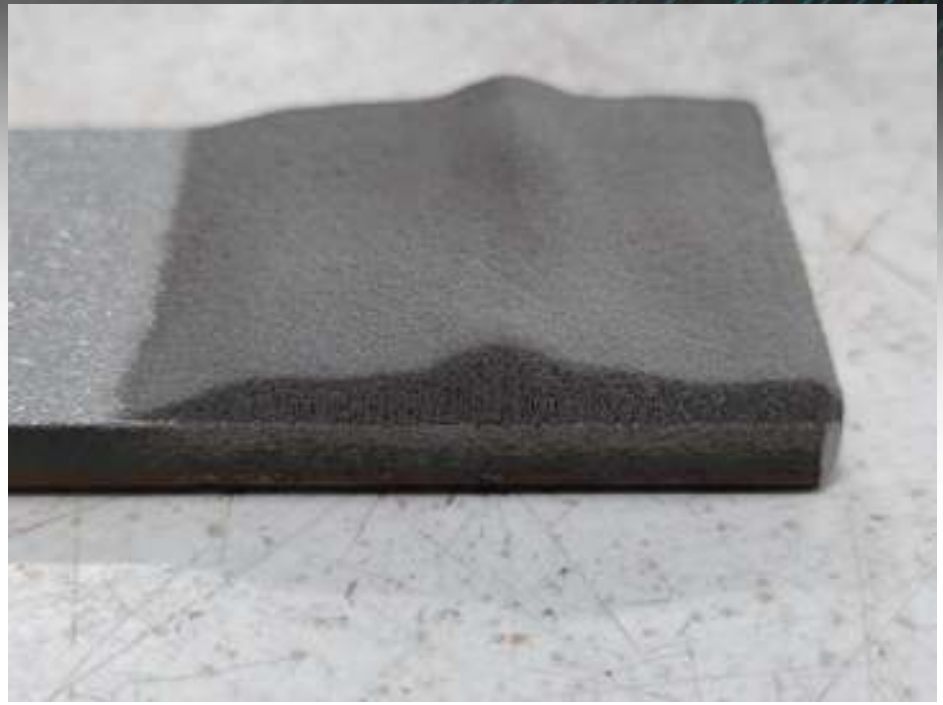
- CS-Q Sensor data
  - Density: large peak seen in middle of first layer
  - Matches the position of the ridge
  - Speed almost unchanged
  - Likely feeder/feed line issue



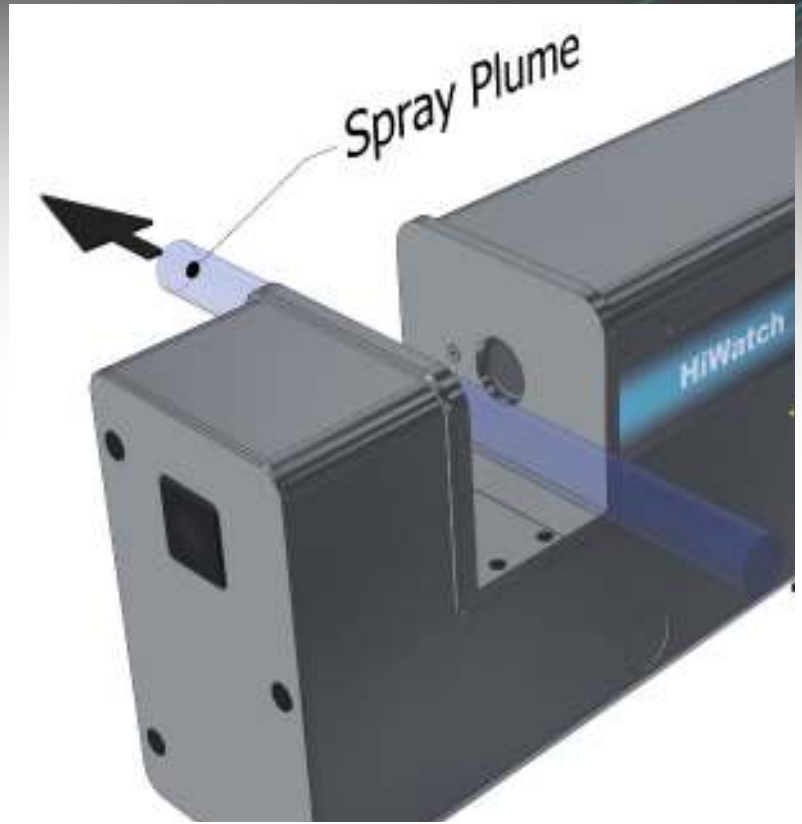


Feed stability

- Test coupon
  - 4 passes
  - Total duration 50 s
- Anomaly in coating thickness
  - Normal: 3mm
  - Ridge : ~4.5mm



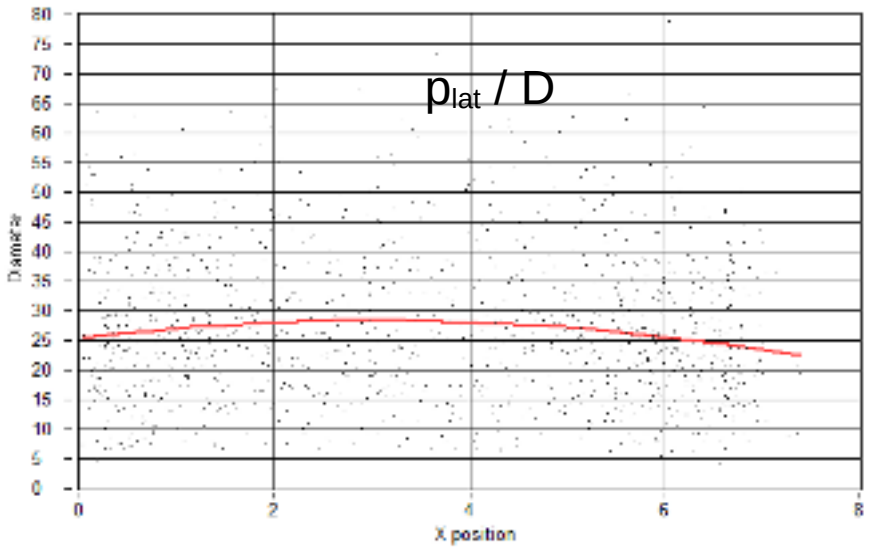
HW HR2: backlight measurement



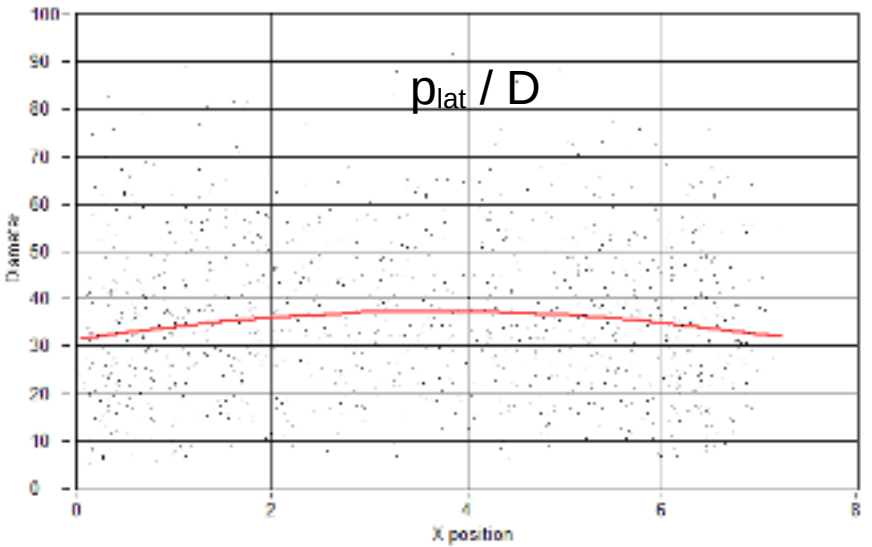
- Particles detected by light extinction (shadow imaging)
- Results:
  - velocity
  - position
  - diameter
- Measurement area 8x5mm^2
- 12MP, 15fps (USB3.1)

Lat position vs Diameter (HR2) PG-100

Al 6061: nom. 10-40µm



Al 6061: nom. 20-50µm



- Result suggests small diameter particles drifting out from center
- Standoff 40mm
- Not seen with other materials

Agenda

- Why full plume characterization?
  - Full spatial coverage:
    - Understand spray uniformity & stability
    - Detect unforeseen features
    - Get particle data over full plume volume
      - Input for sticking/forming models
      - Training sets for AI/neural models
  - Full time coverage:
    - Condition of spray equipment
      - Long term operation
      - Mass production without interruptions
      - Large scale AM
  - Still missing: particle temperature

Agenda

Full plume characterization: manager benefits

- Better yield
- Less downtime
- Easier requirements for process
  - Cheaper equipment
  - No He / high temperature requirement
- More applications
  - With economic sense

Thank you!

Trust is good.
Control enhances trust.

Enjoy gap free trust
with gap free spray control.

HiWatch CS-Q

Available now