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# Comparison of optical probes and X-ray tomography for bubble characterization in fluidized bed methanation reactors

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WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

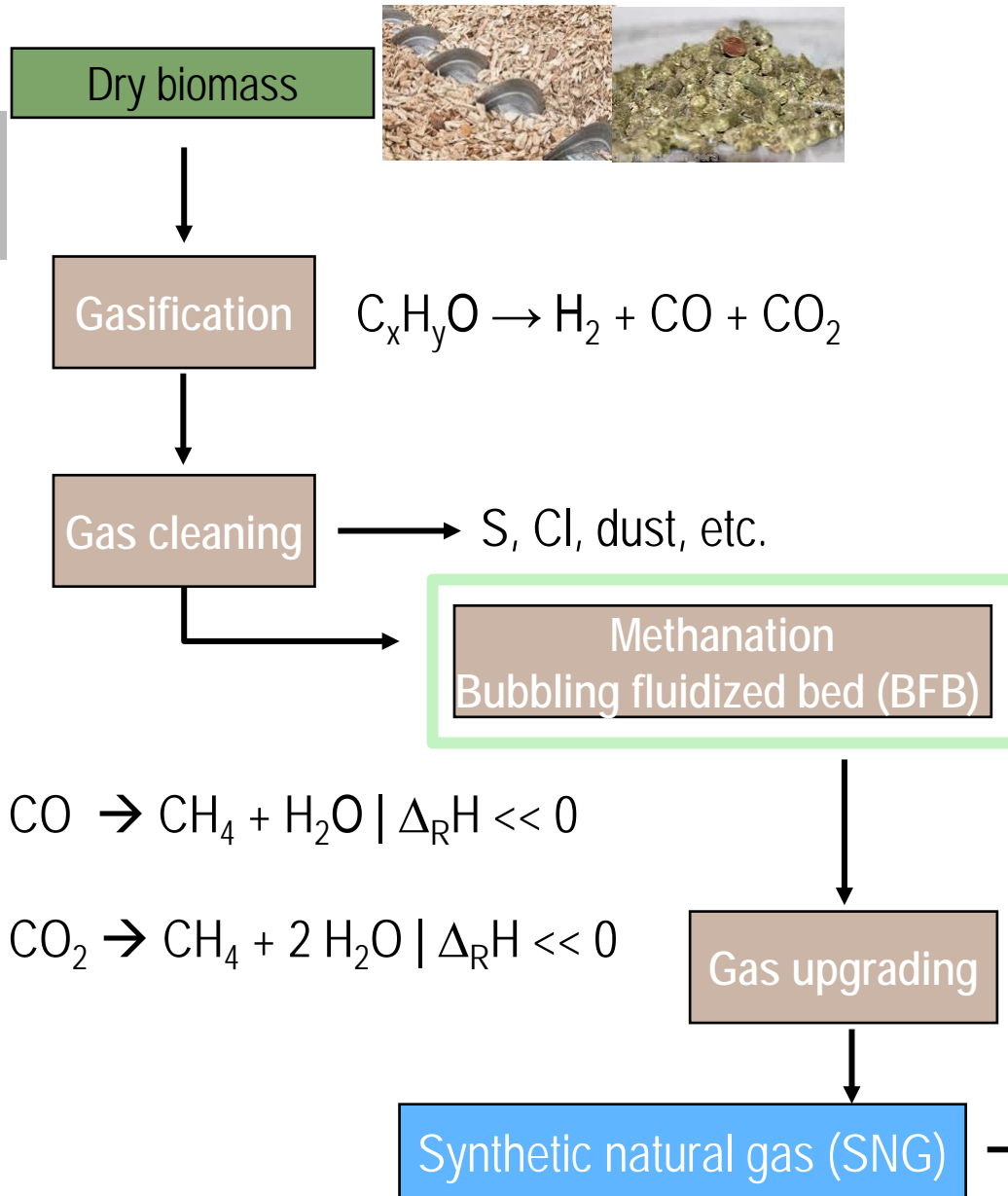


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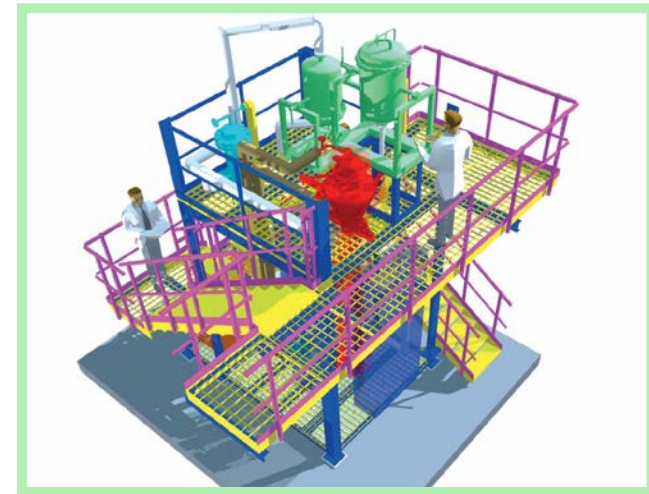
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# Comparison of optical probes and X-ray tomography for bubble characterization in fluidized bed methanation reactors

# Process chain for renewable CH<sub>4</sub> - production



Pilot-scale  
methanation reactor (160 kW SNG)  
under construction at PSI



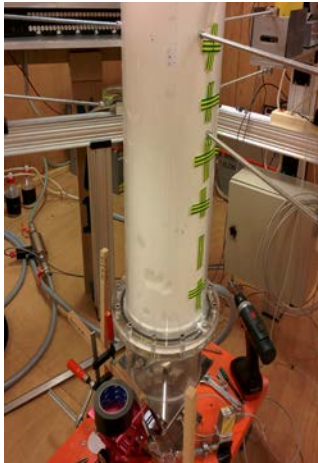
Feed into natural  
gas grid



## Determination of bubble properties important for reactor modelling and proper scale-up

### X-ray tomography:

Investigation of fluidization state  
over the entire cross-section



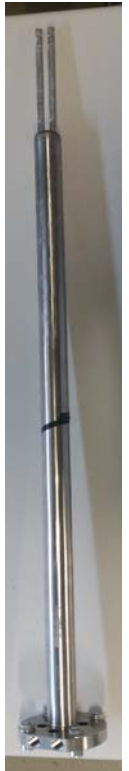
Only for Plexiglas column  
**No reactive conditions !!**

### Optical sensor:

Only pointwise measurements



Applicable at steel reactor (pilot plant)  
**Reactive conditions**

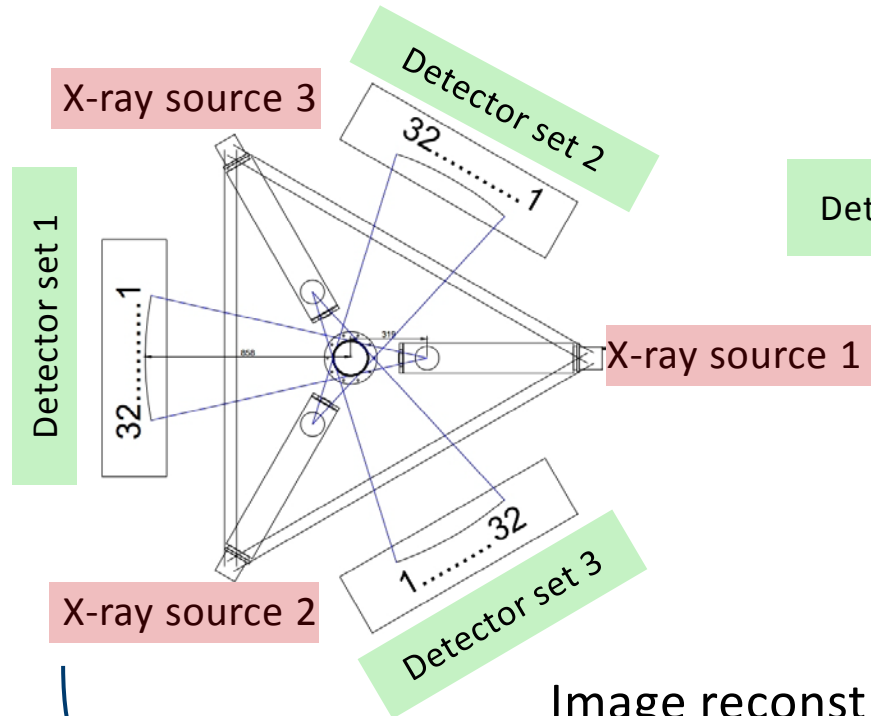


### Principal objective:

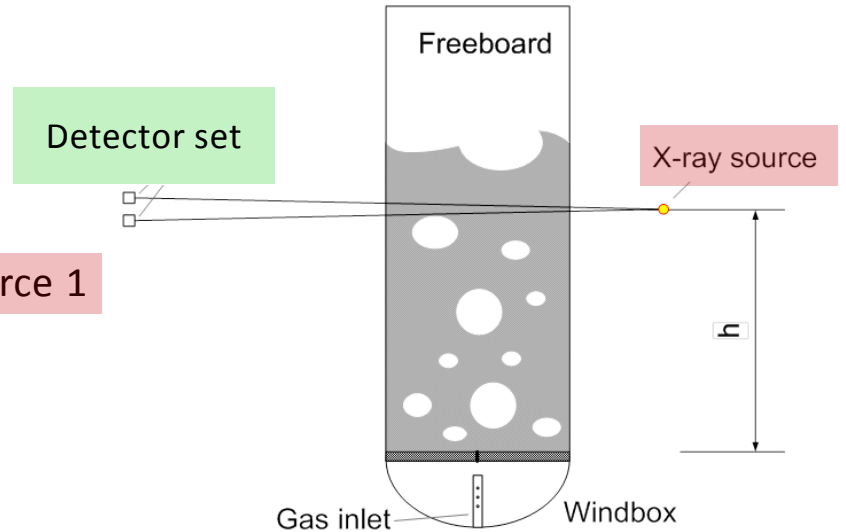
- Work out differences between both methods
- ➔ Assessment of data obtained at pilot-scale reactor with optical sensor

# Measurement setup – X-ray measurement

Top view



Side view



## X-ray setup:

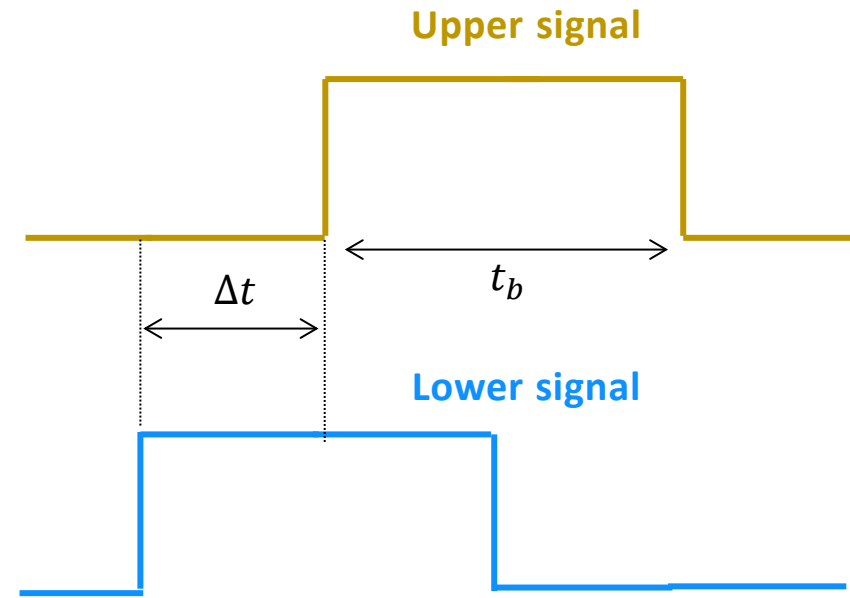
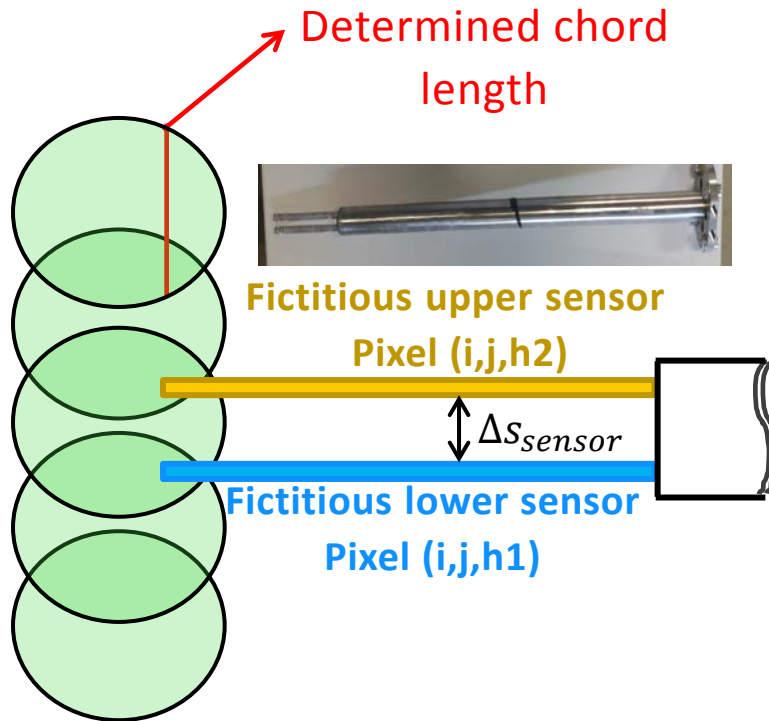
2500 Hz measurement frequency

Resolution of 55x55 pixels

Cold flow model (No reaction !)



# Measurement setup – optical measurement



- Due to pointwise measurements:
  - Only **chord length** of bubble gets accessible for optical evaluation

$$u_b = \frac{\Delta s_{sensor}}{\Delta t}$$

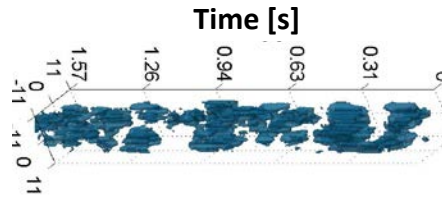
$$d_{chord} = u_b \cdot t_b$$

# Procedure to compare X-ray vs. optical evaluation

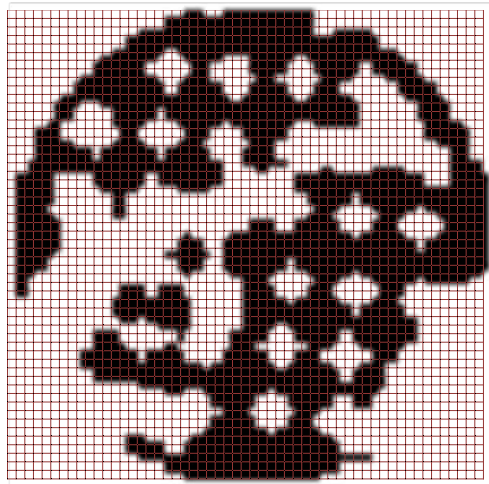
Reconstructed  
XRT - image



Quasi 3-D reconstruction  
of bubbles



Possibility to generate **artificial optical signal** from reconstructed X-ray images



Filtering

Algorithm for  
evaluation of XRT  
data

Comparison BRV /  
chord length (optical)  
vs. Vol. eq. diameter  
(X-ray)

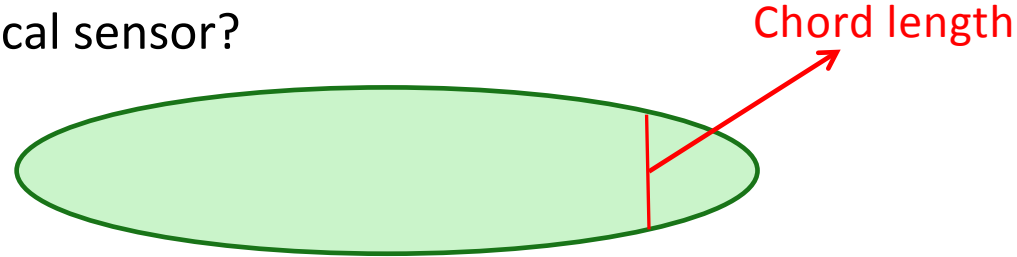
Algorithm for  
evaluation of optical  
signal



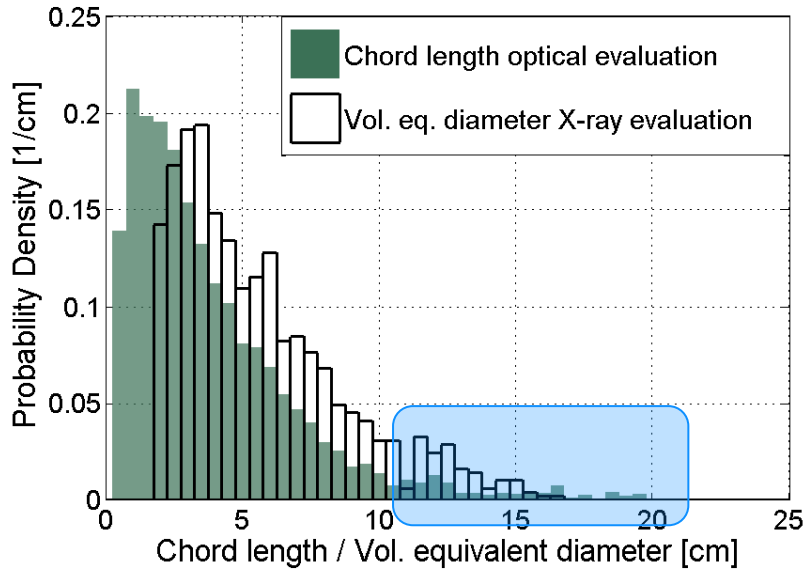
# Detection of slugging with optical probes

- Detection of slugging with optical sensor?

Flat bubble: Large bubble volume  $\neq$  large chord length

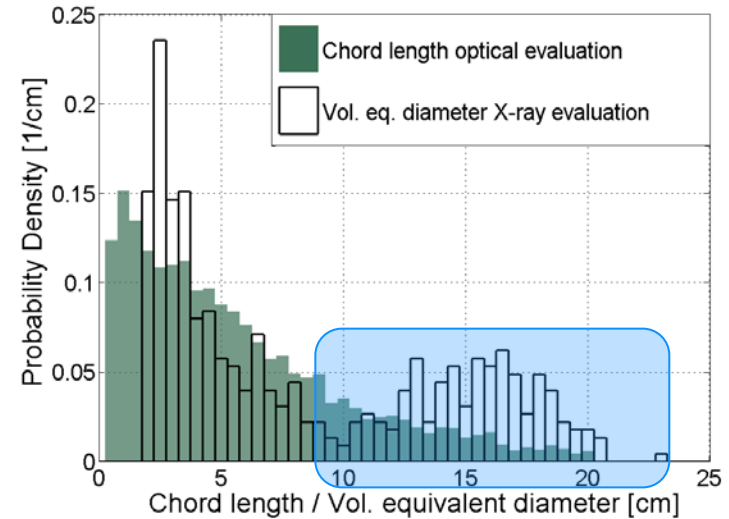


$H = 56 \text{ cm}$   $u / u_{mf} = 3$



No 2<sup>nd</sup> peak for X-ray evaluation  $\rightarrow$  no slugging  
 $\rightarrow$  Optical: Fraction with chord length  $> 10 \text{ cm}$   $\downarrow$

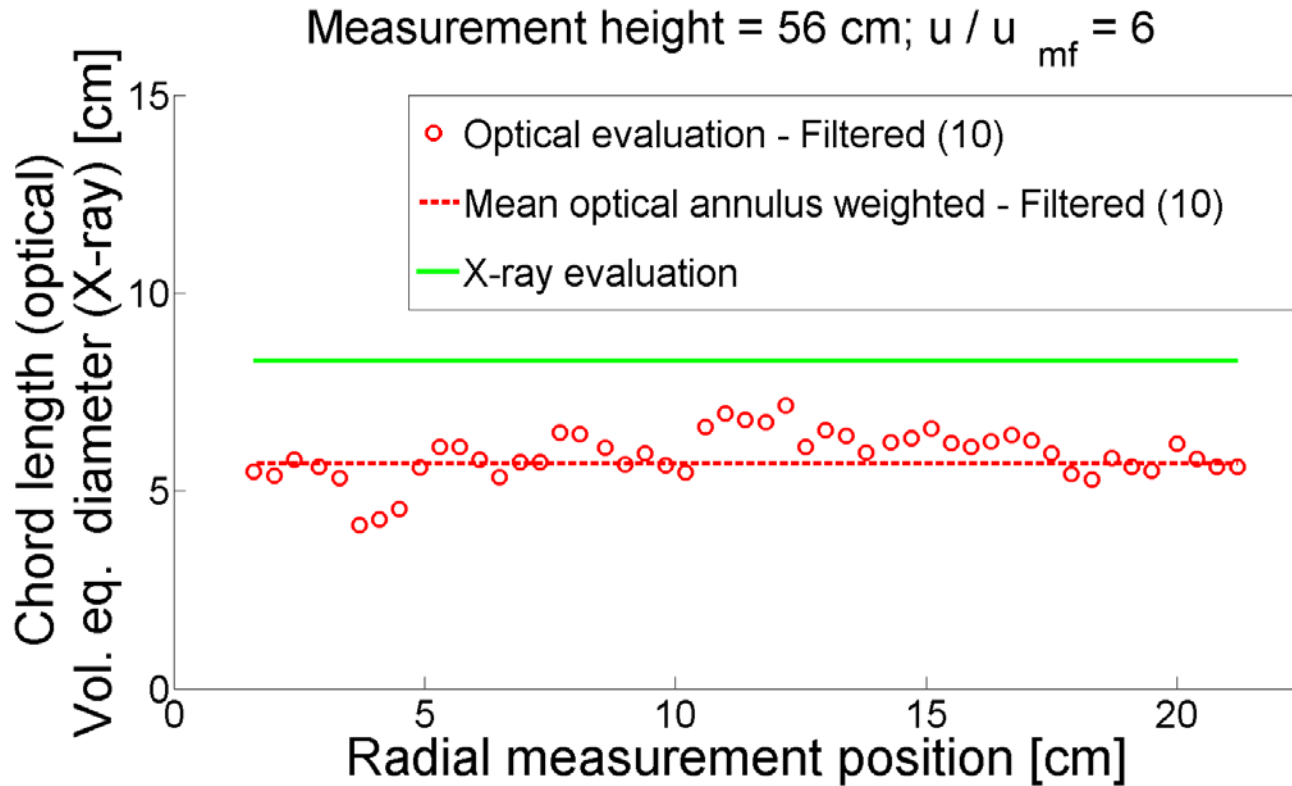
$H = 56 \text{ cm}$   $u / u_{mf} = 6$



2<sup>nd</sup> peak for X-ray evaluation  $\rightarrow$  slugging  
 $\rightarrow$  Optical: Fraction with chord length  $> 10 \text{ cm}$   $\uparrow$

$\rightarrow$  Fraction of bubbles with chord length  $> 10 \text{ cm}$  ( $\approx$  half of column -  $\emptyset$ ) may be indicator for slugging

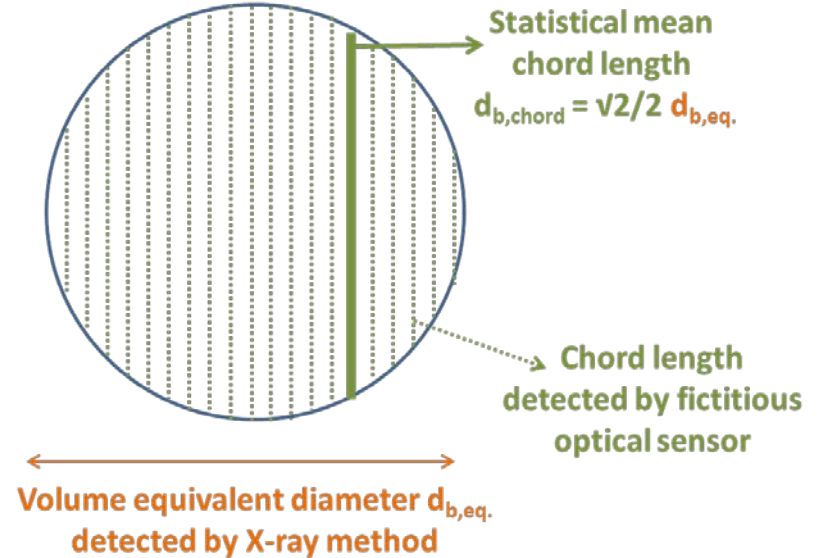
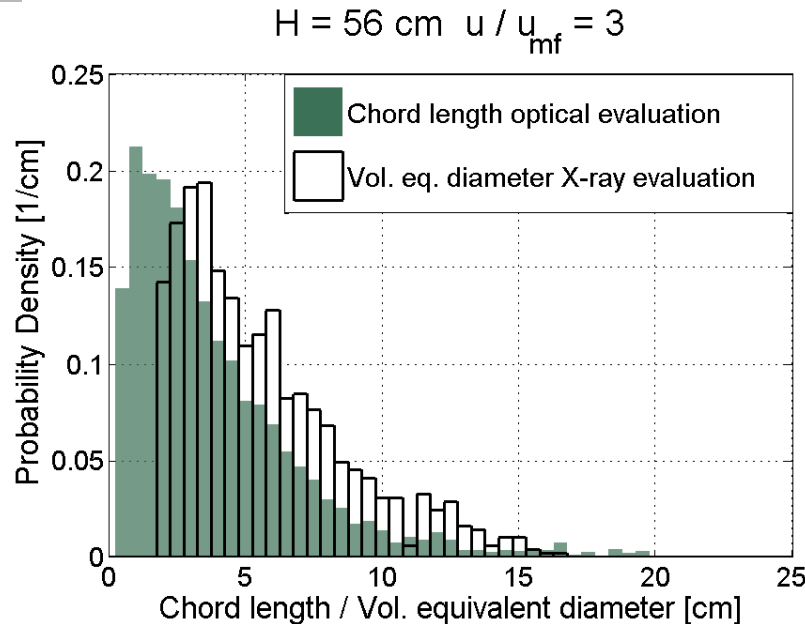
# Comparison bubble size X-ray vs. optical evaluation



- Optical mean chord length annulus weighted
- Mean chord length (optical) roughly 40 % smaller than mean diameter (X-ray)

➔ Explanation for discrepancies ?

# Discussion of discrepancies between X-ray and optical evaluation



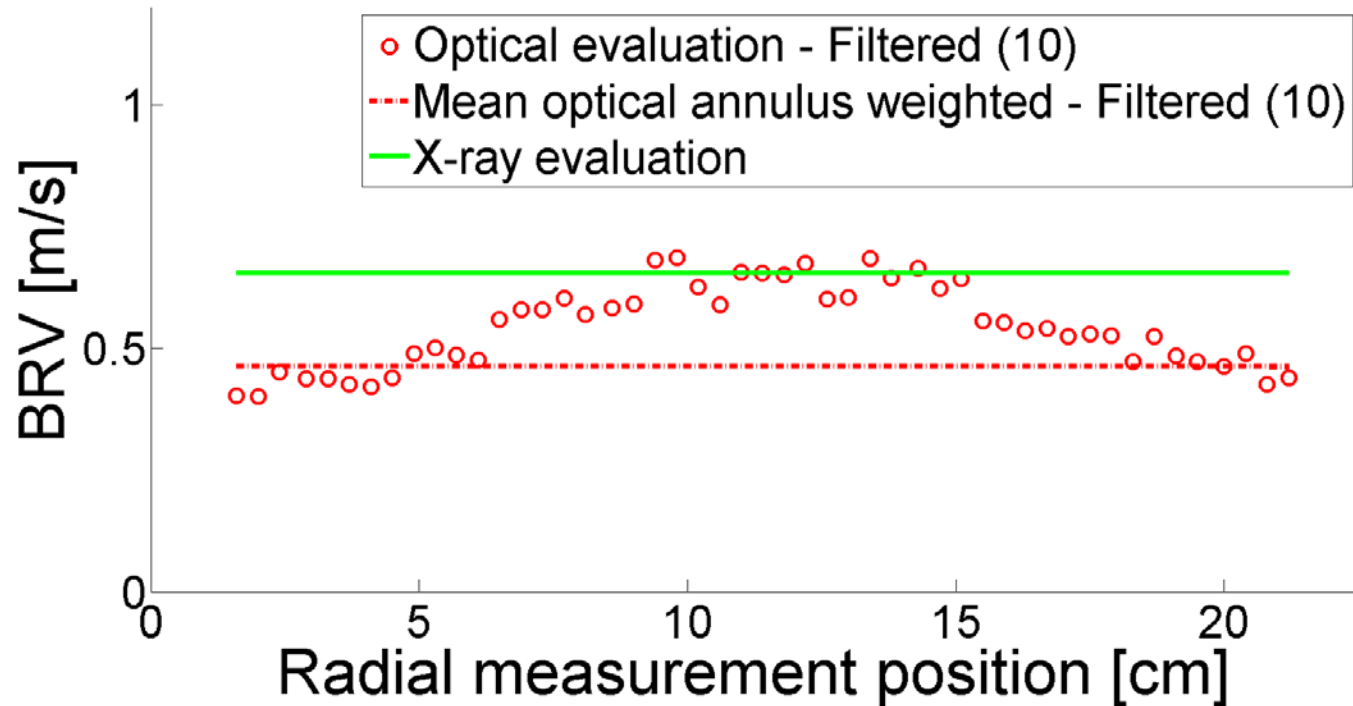
- 2 Main reasons for discrepancies between both evaluation methods:

- Possibility to detect bubbles smaller than 1.8 cm only for optical method
- Same bubble is hit at several positions by fictitious optical sensor

➔ Statistical mean chord length:  $d_{b,chord} = \frac{\sqrt{2}}{2} d_{b,Vol.equivalent} \quad (70.7 \%)$

# Comparison BRV of optical vs. X-ray evaluation

Measurement height = 56 cm;  $u / u_{mf} = 6$

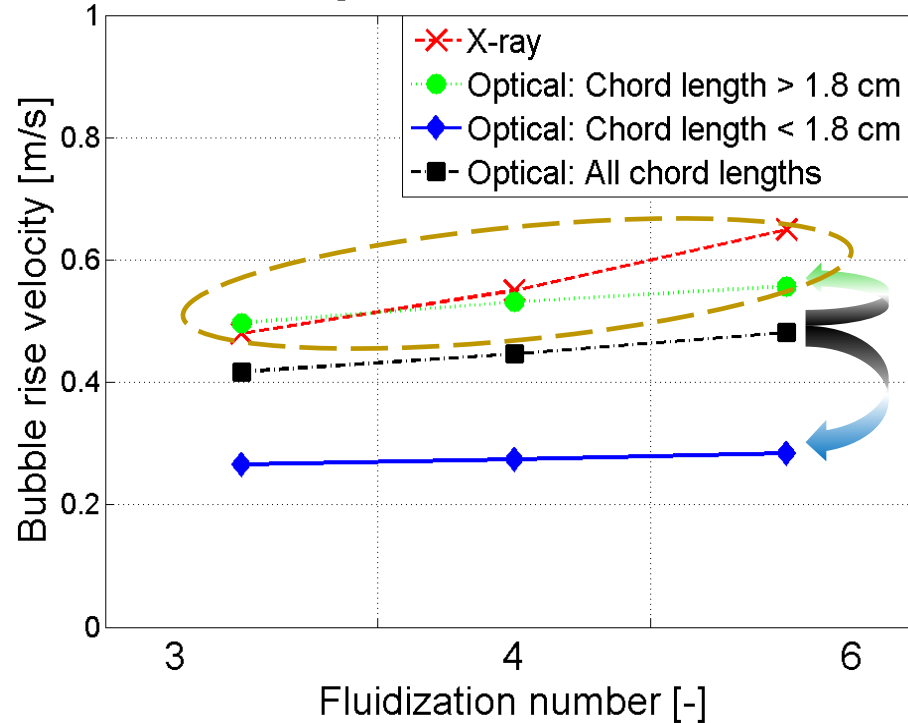


- Optical mean value again annulus weighted
- Similarity to findings concerning bubble size:
  - BRV smaller for optical evaluation

**➔ Explanation for discrepancies ?**

# Explanation of discrepancies for BRV

Better accordance if only bubbles  $> 1.8$  cm are regarded



**IMPORTANT: Determination of proper BRV for especially large bubbles:**

- Possible procedure for future optical measurements:

- ➔ Negligence of bubbles smaller than 1.8 cm (uncritical concerning breakthrough of reactants)

- ➔ More precise determination of mean BRV for larger bubbles

# Key findings and outlook

- Fraction of bubbles with chord length  $> 10$  cm ( $\approx$  half of column diameter) may serve as indicator for slugging
- Differences in bubble properties between X-ray and optical evaluation method determined and explained

## Next step:

- ➔ Evaluation of data set generated with optical sensor at the pilot-scale plant to determine the bubble properties especially for large bubbles precisely

Thank you for  
your attention

