



---

# LHC Collimator Jaw Vibration Measurement using a Laser Doppler Vibrometer

---

H. Richter, R. Wilfinger, J. Lettry, I. Efthymiopoulos, R. Assmann, S. Redaelli and the ATB-EA and collimation teams



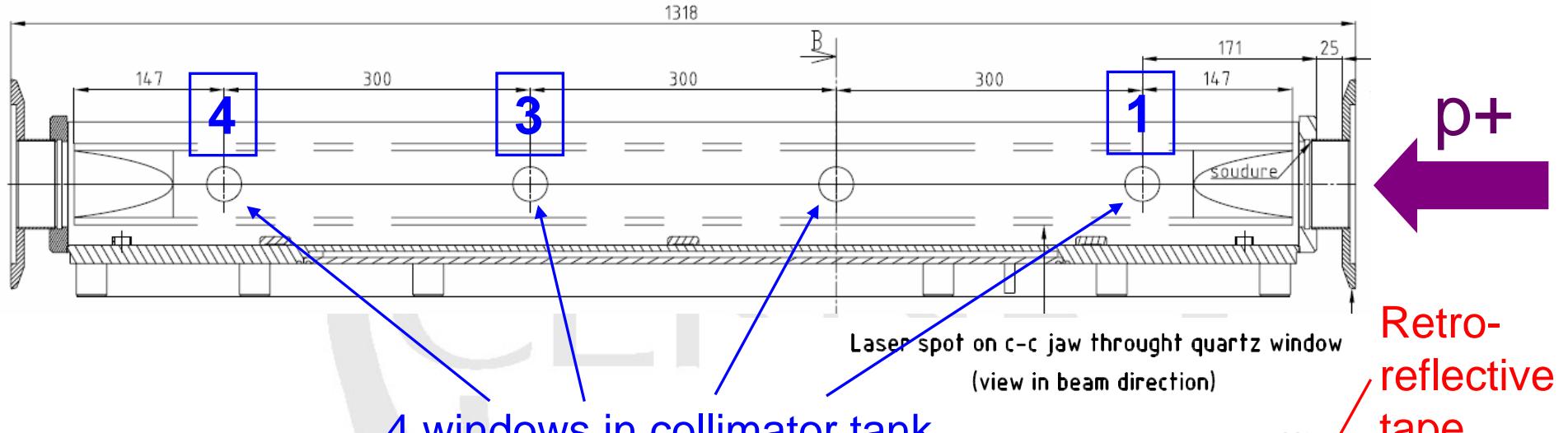
# Outline



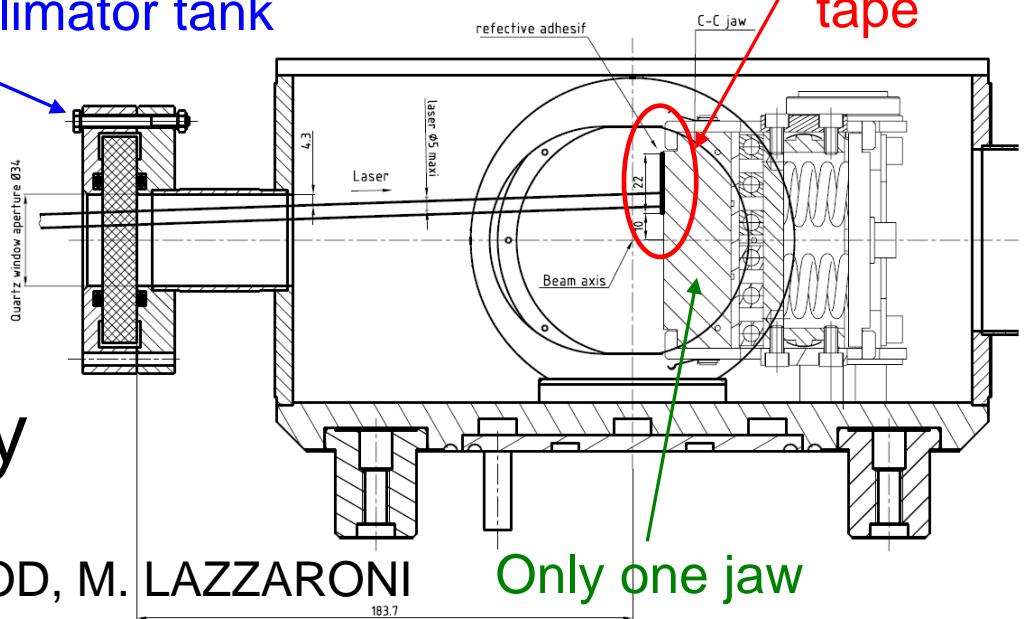
- Measurement setup
- Cleaning up of raw data
- Repetitivity test
- Comparison of jaw movement along different locations
- Comparison if jaw movement for different beam intensities
- Outlook



# Collimator Modifications



Laser Doppler Vibrometer (LDV)  
measures out-of-plane surface velocity



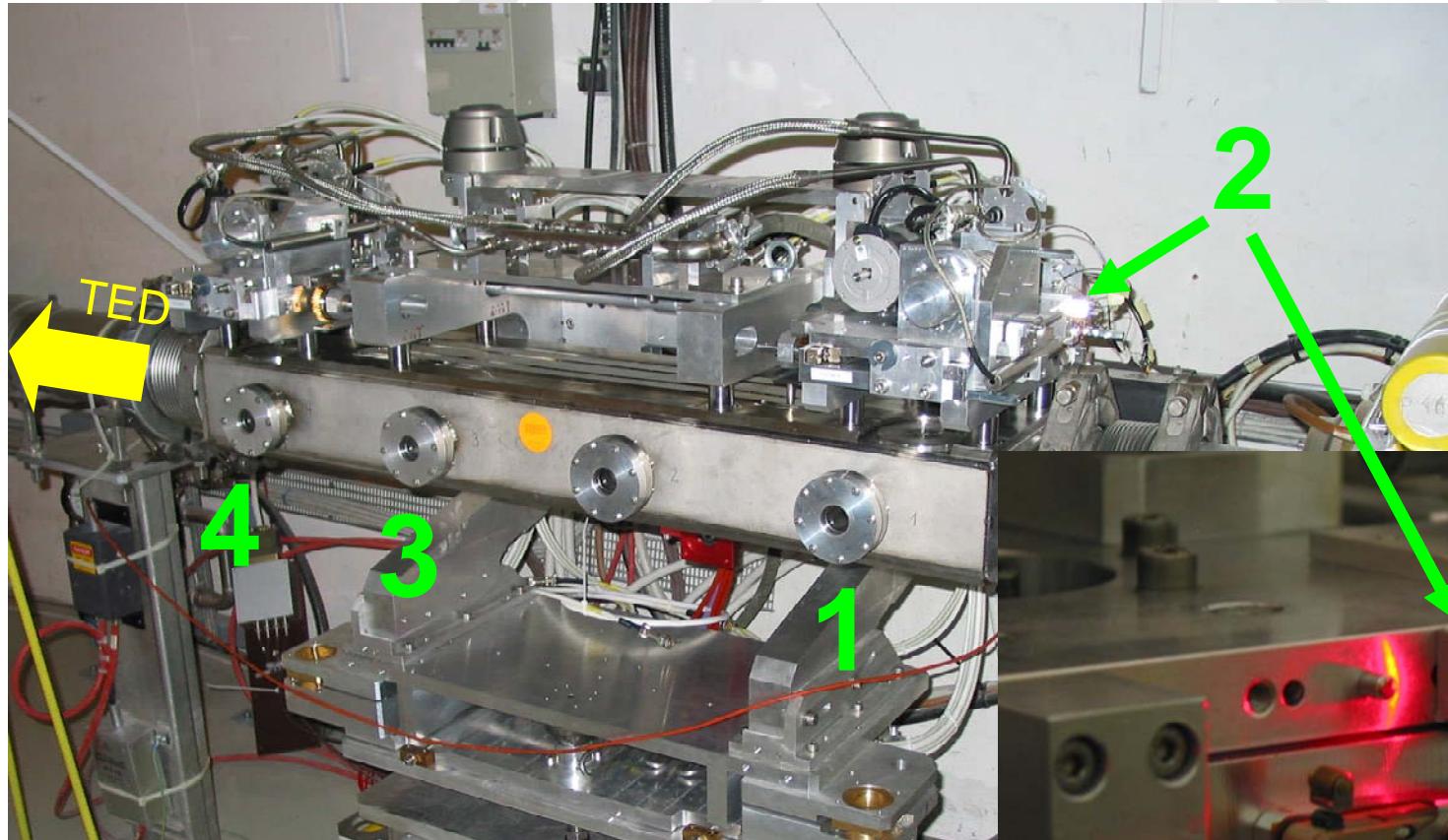
Sketches: courtesy S. GIROD, M. LAZZARONI



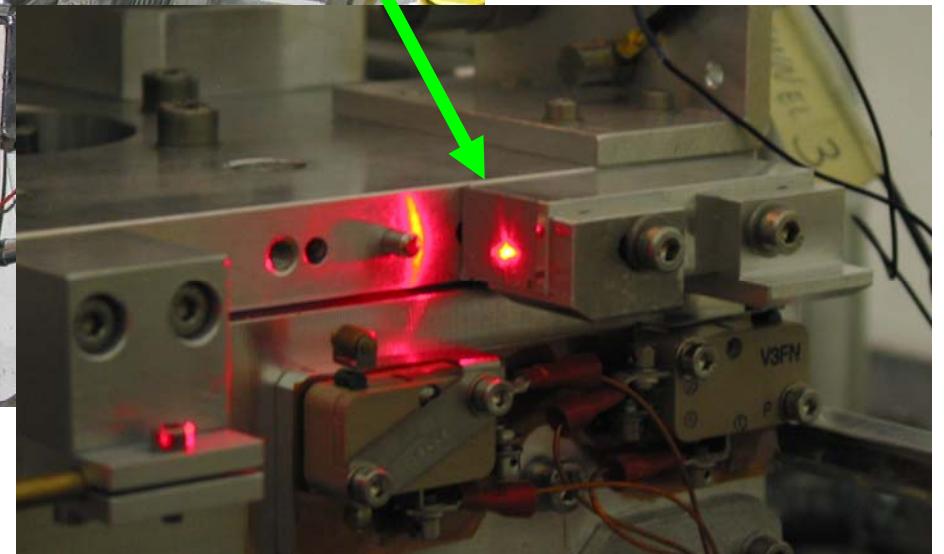
# Test Setup – Jaw and Measurement Spots



Measurement points #1, #3 and #4 directly on collimator jaw surface

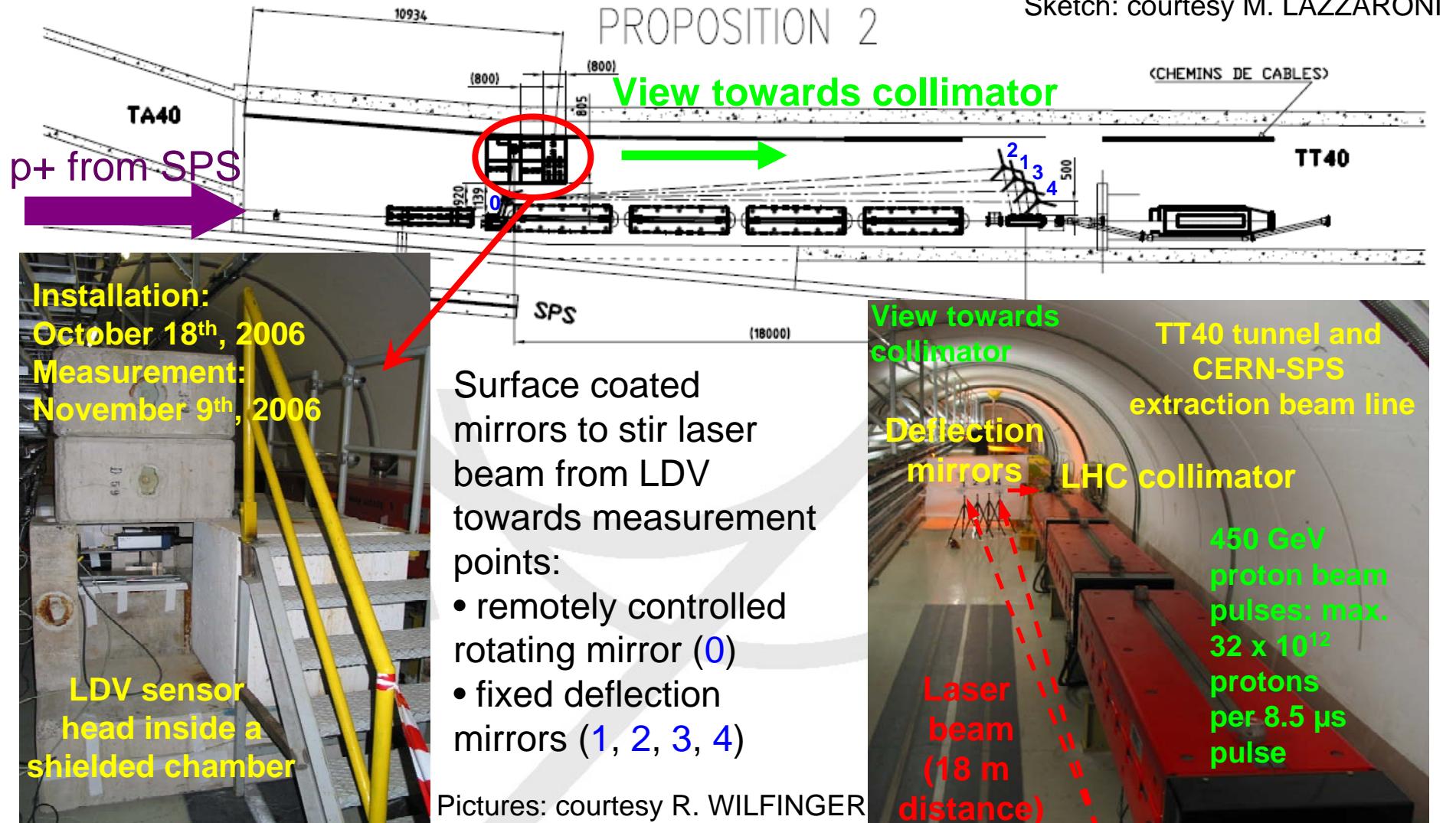


Measurement point #2 on the jaw support table. An accelerometer is fixed on the table for comparison (S. REDAELLI et. al.)





# Setup - Laser Doppler Vibrometer





# SPS Beam Parameters



- Proton beam with kinetic Energy of 450 GeV from SPS
- Beam time profile:
  - 1 bunch:
    - Bunch length: 1 ns
    - Bunch spacing: 25 ns
    - 10E10 protons
  - 1 batch:
    - 48 bunches
    - Batch spacing: 200 (8 x 25) ns
- Different proton beam intensities:
  - 480E10 p (1 batch)
  - 960E10 p (2 batches)
  - 1920E10 p (4 batches)
  - 2880E10 p (6 batches)
- Different beam impact parameters:
  - +5 mm (inside jaw)
  - +4 mm
  - +3 mm
  - +2 mm
  - +1 mm
  - 0 mm (surface)
  - -1 mm
  - -2 mm (outside jaw)
- Beam size: 1 mm (FWHM)



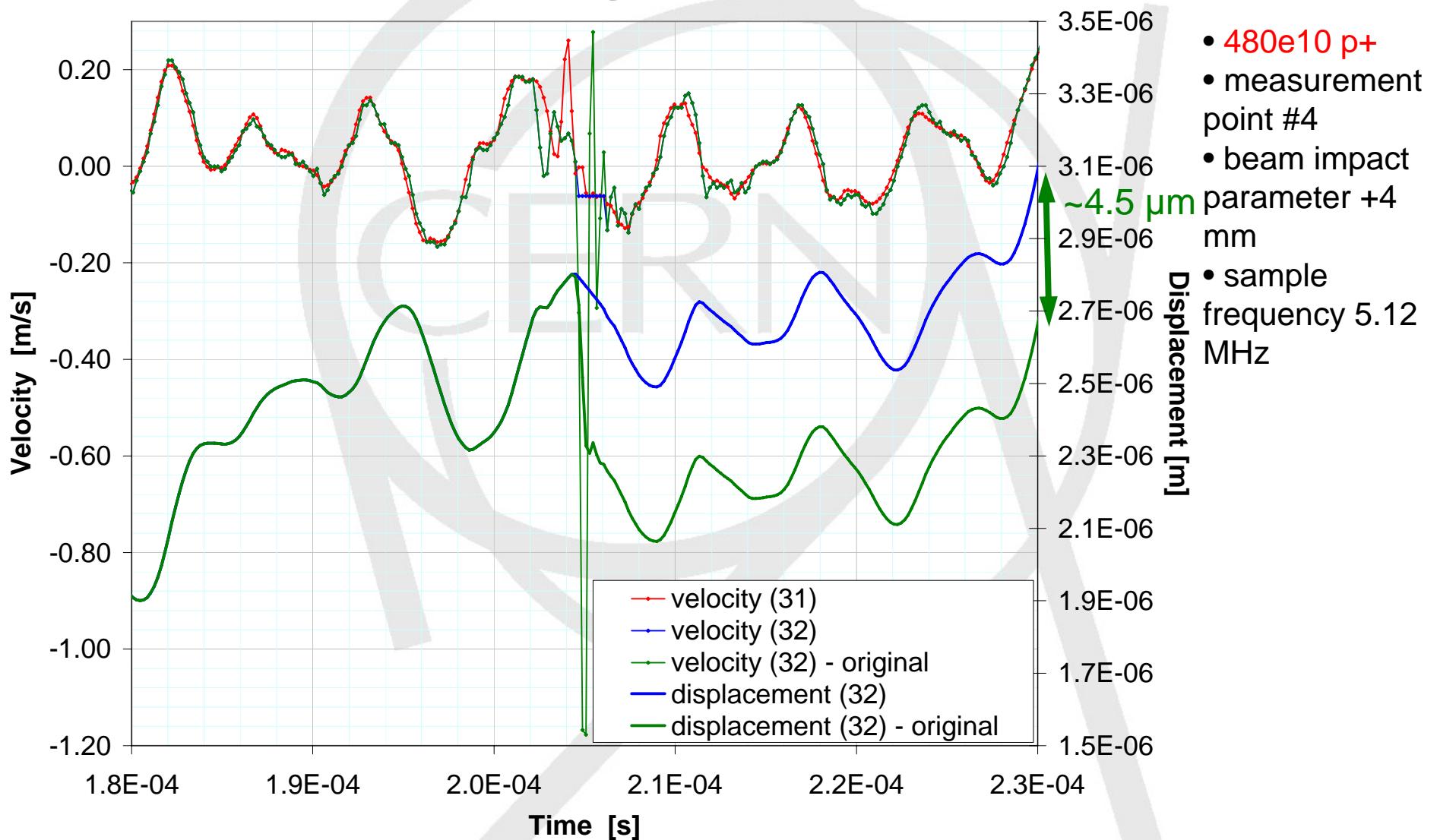
# Cleaning Up Raw Data



- Missing calibration factors
  - Glitches: likely due to vertical jaw movement (t.b.c) => difficult to distinguish
- 
- Partially recuperated by comparison with measurement with known calibration factor
  - Obvious „glitches“ were removed from data. Missing data was replaced by average values of left and right neighbours of glitch

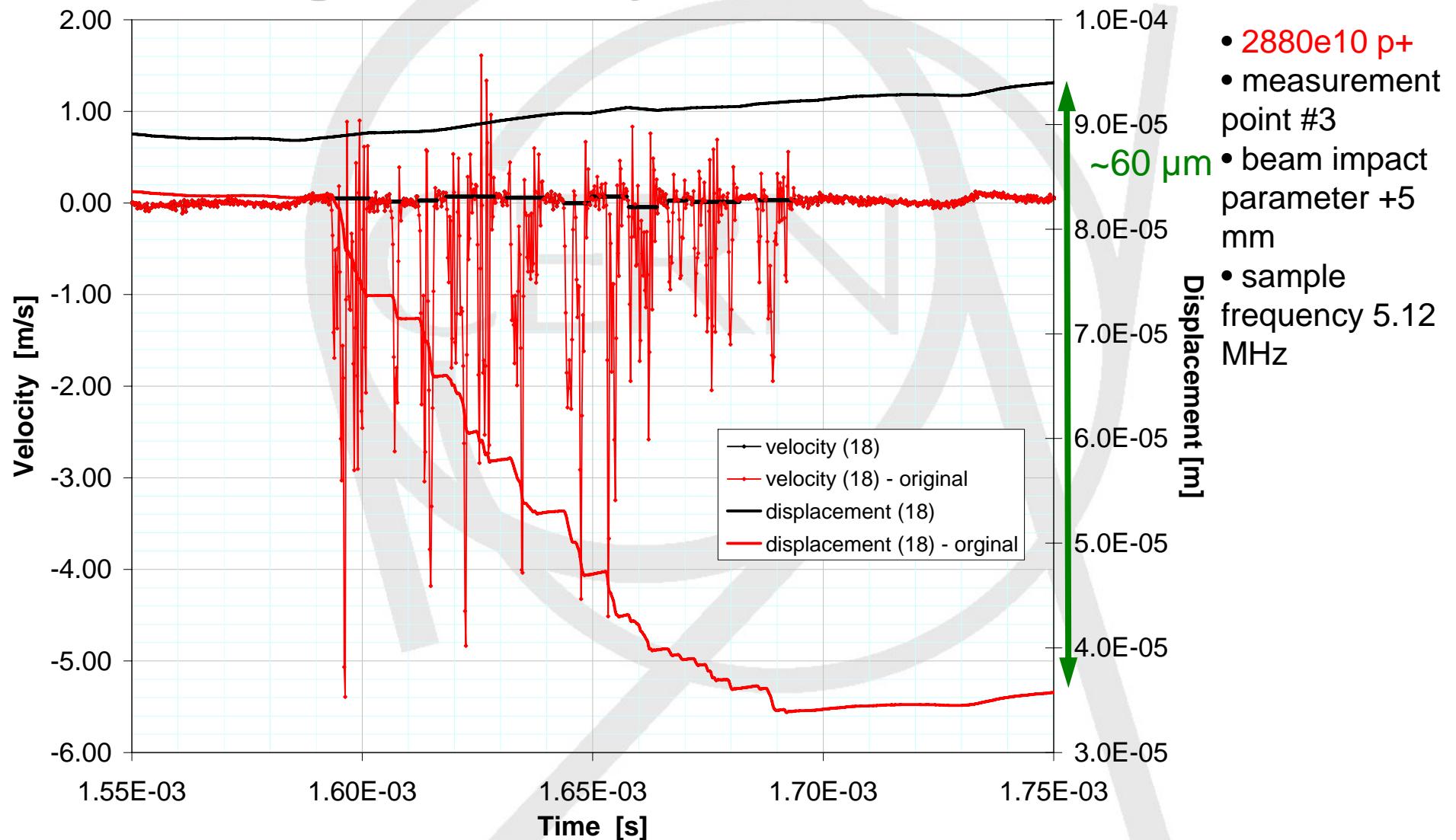


# Removal of Glitches – Low Intensity





# Removal of Glitches – High Intensity





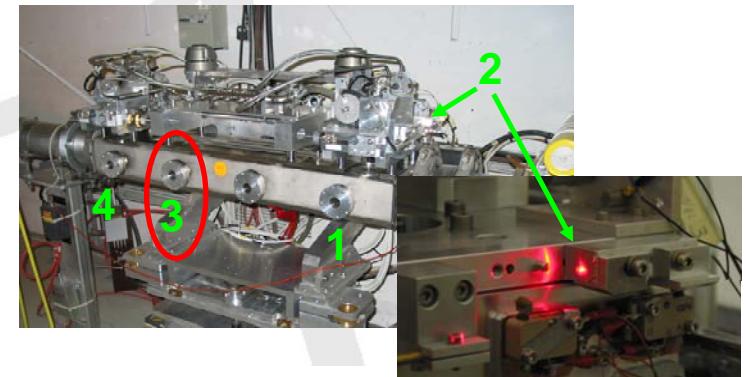
# Repetitivity Test



## Parameters:

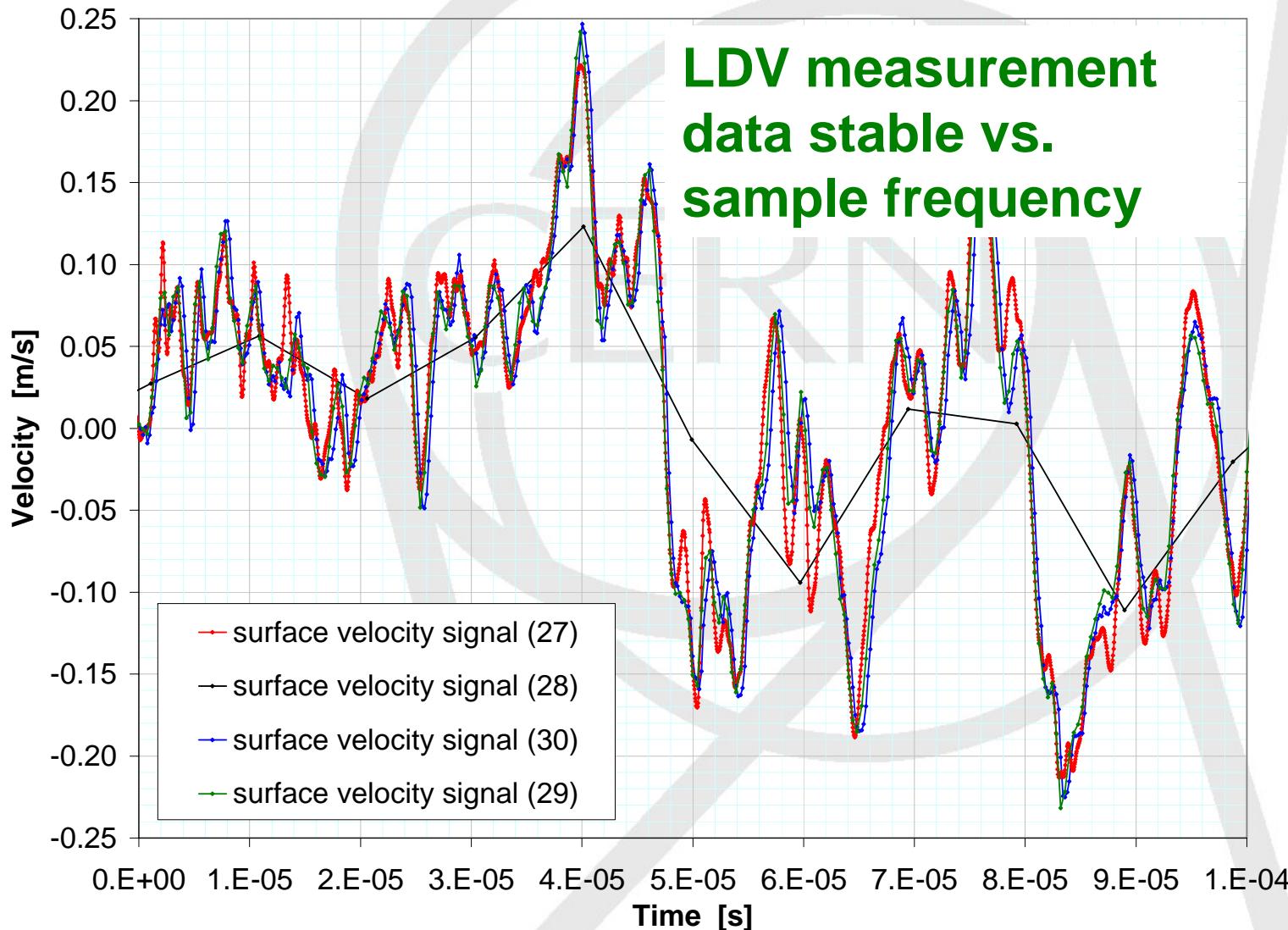
- Low intensity range: 480E10 protons (1 batch)
- beam impact parameter: +4 mm
- For each measurement point 4 recorded velocity-time-signals => comparison possible

→ Example follows for measurement point #3 (no glitches, all calibration factors known)





# Measurement Point #3 – Velocity (first 100 $\mu$ s)

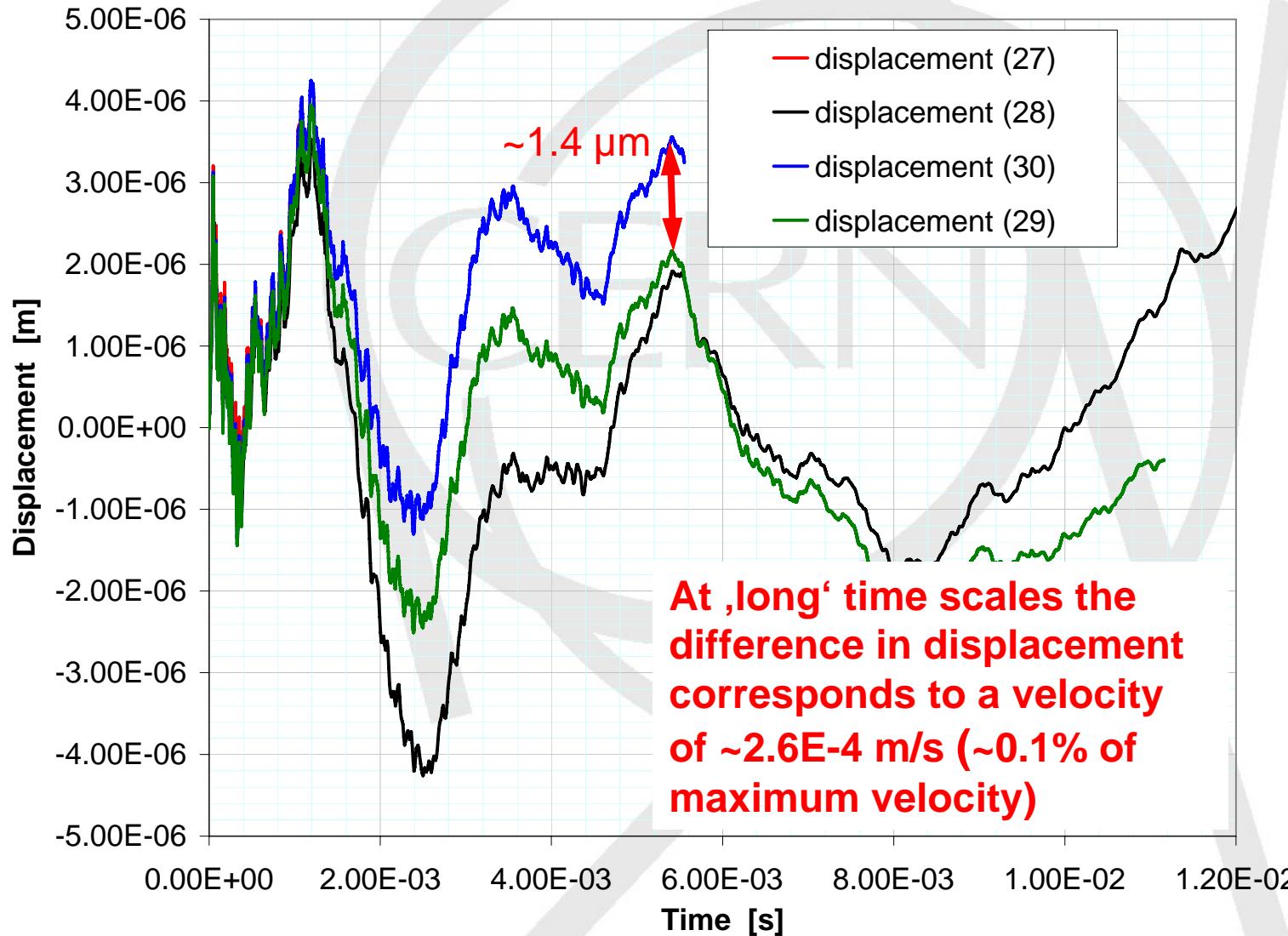


- 480e10 p+
- measurement point #3
- beam impact parameter +4 mm
- no glitches removed
- all calibration factors known

signal	sample frequency [MHz]	recording time [ms]
27	25.6	1.28
28	0.1024	320
29	2.56	12.8
30	5.12	6.4



# Measurement Point #3 – Displacement (first 12 ms)



- 480e10 p+
- measurement point #3
- beam impact parameter +4 mm
- no glitches removed
- all calibration factors known

signal	sample frequency [MHz]	recording time [ms]
27	25.6	1.28
28	0.1024	320
29	2.56	12.8
30	5.12	6.4



# Dependency on Measurement Location

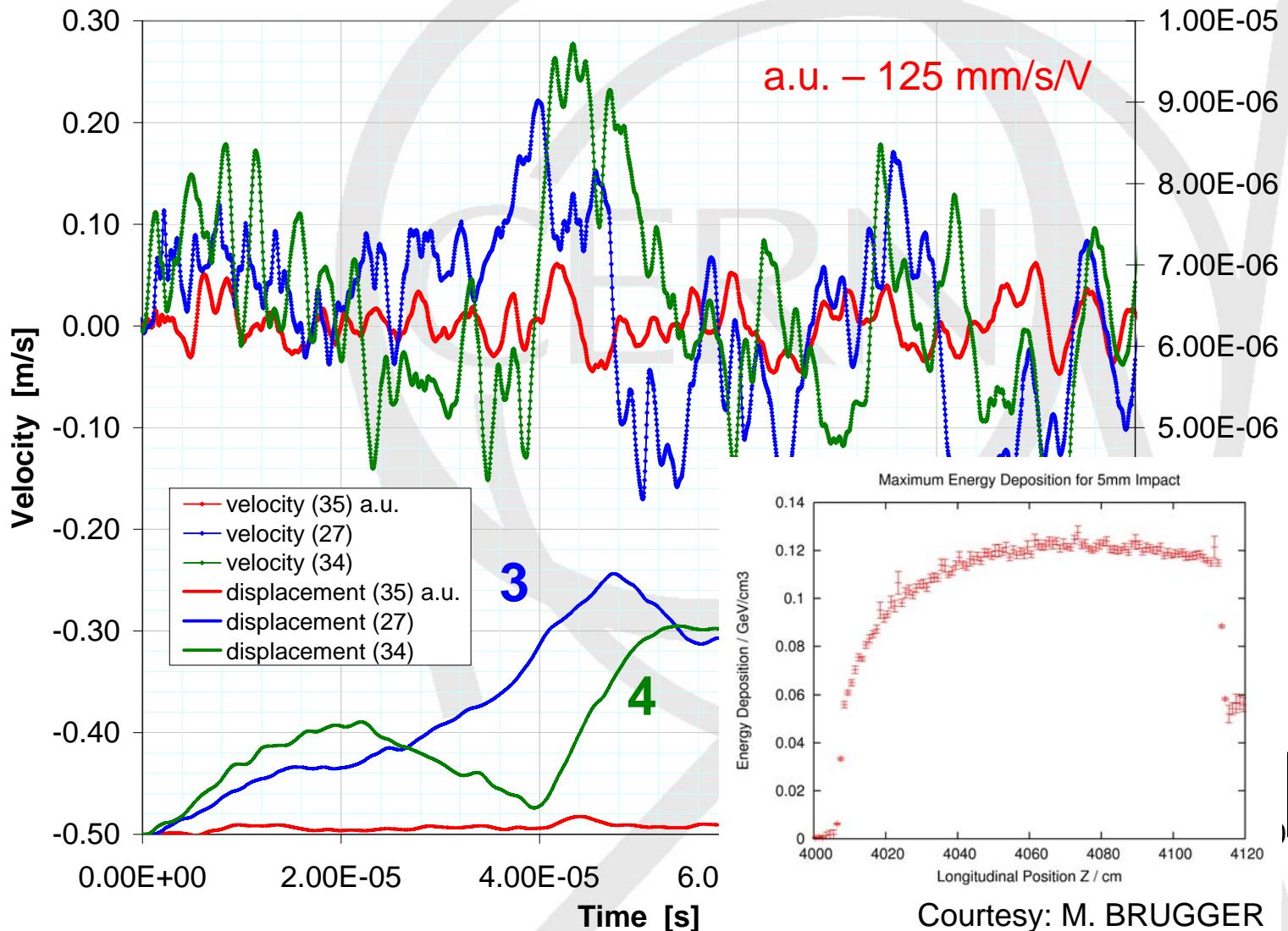


## Parameters:

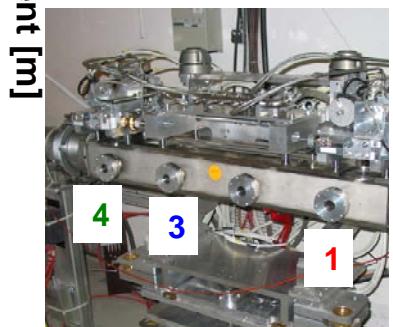
- 480E10 protons (1 batch)
- beam impact parameter: +4 mm
- Measurement points on collimator jaw (#1, #3, #4)
- calibration factor only unknown for measurement point #1
- No glitches



# Dependency Measurement Point – Velocity & Displacement (100 $\mu$ s)



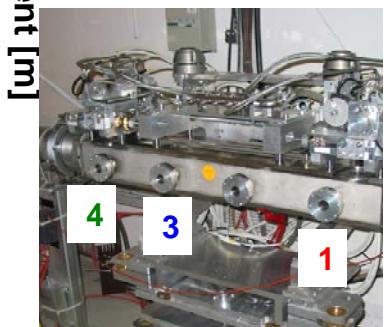
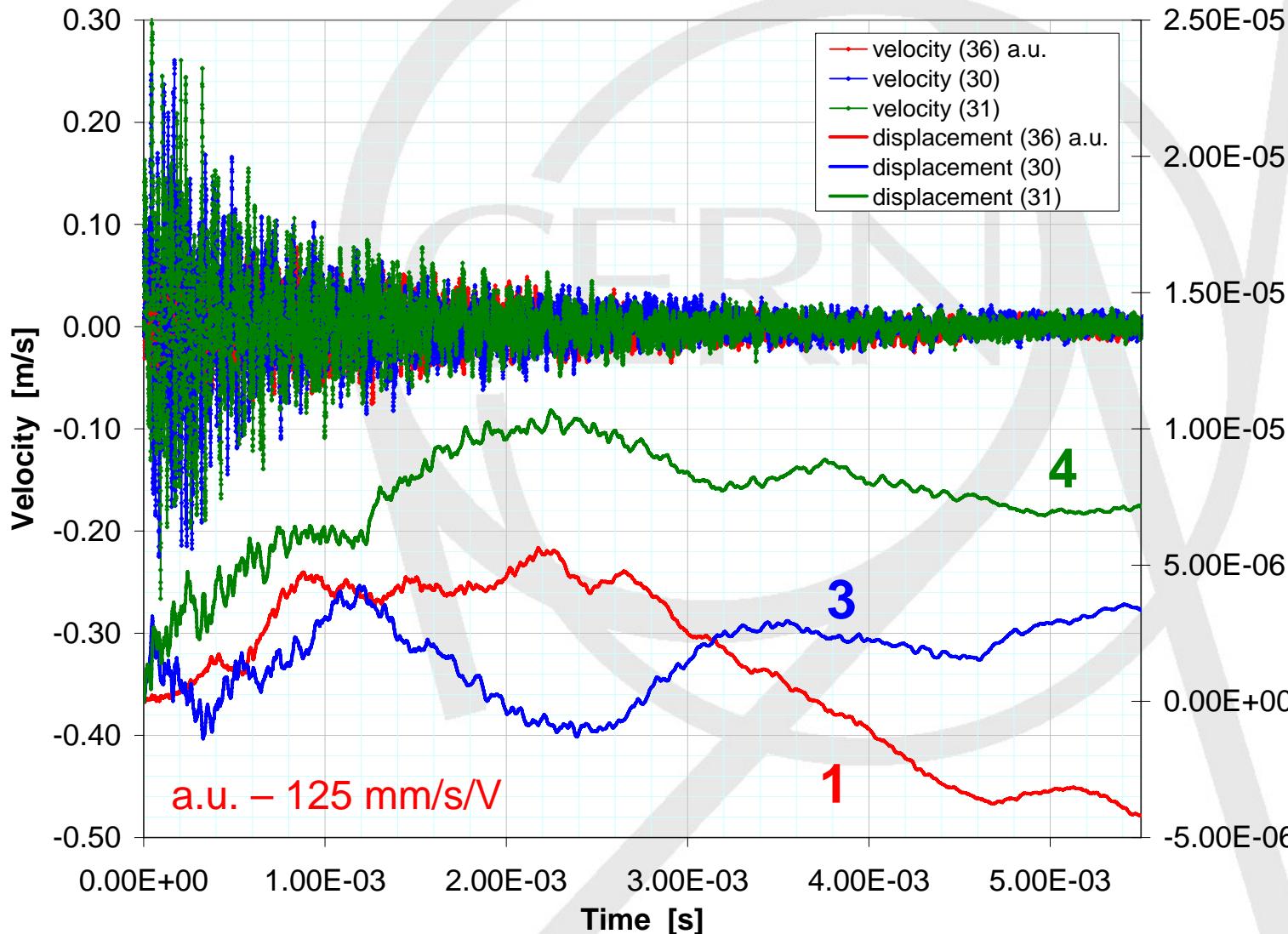
- 480e10 p+
- beam impact parameter +4 mm
- no glitches removed
- calibration factor unknown for MP #1



signal	Measurement point
27	3
34	4
35	1



# Dependency Measurement Point – Velocity & Displacement (5.5 ms)



signal	Measurement point
27	3
34	4
35	1

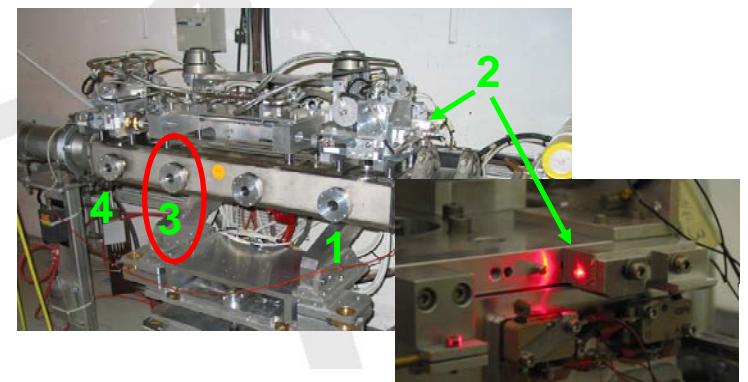


# Dependency on Beam Intensity



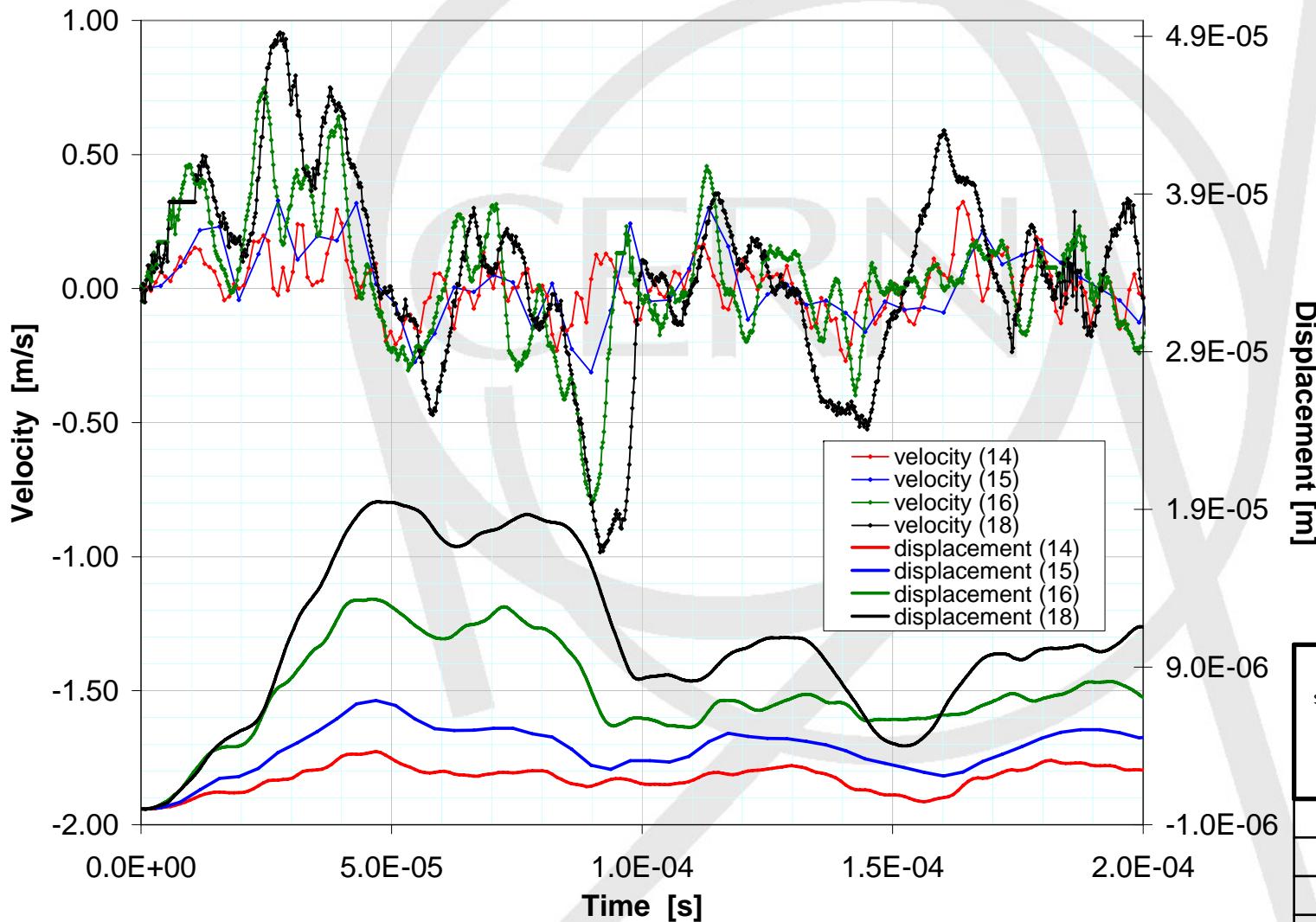
## Parameters:

- beam impact parameter: +5 mm
- Measurement point #3
- Glitches removed extensively for signal 16 and 18
- calibration known





# Dependency Beam Intensity – Velocity & Displacement (200 $\mu$ s)



- beam impact parameter +5 mm
- measurement point #3
- glitches removed for 16 and 18
- calibration factors known

signal	number of protons (number of batches) [*E+10] (-)	sample frequency [MHz]
14	480 (1)	1.024
15	960 (2)	0.256
16	1920 (4)	5.12
18	2880 (6)	5.12



# Conclusions & Outlook



## Conclusions:

- LDV measurements are reproducible
- Displacement („first response“) scales according to beam intensity

## Outlook:

- A technical note on these results in preparation (including comparison for different beam impact parameters – work in progress)
- Frequency spectra have been obtained by LDV in parallel, but not yet analysed



# Acknowledgments



Special thanks to:  
Alessandro BERTARELLI  
Chiara BRACCO  
Markus BRUGGER  
Alessandro DALLOCCHIO  
Verena KAIN  
Michael LAZZARONI  
Jacques LETTRY  
Matteo MAGISTRIS  
Helmut VINCKE  
Roman WILFINGER