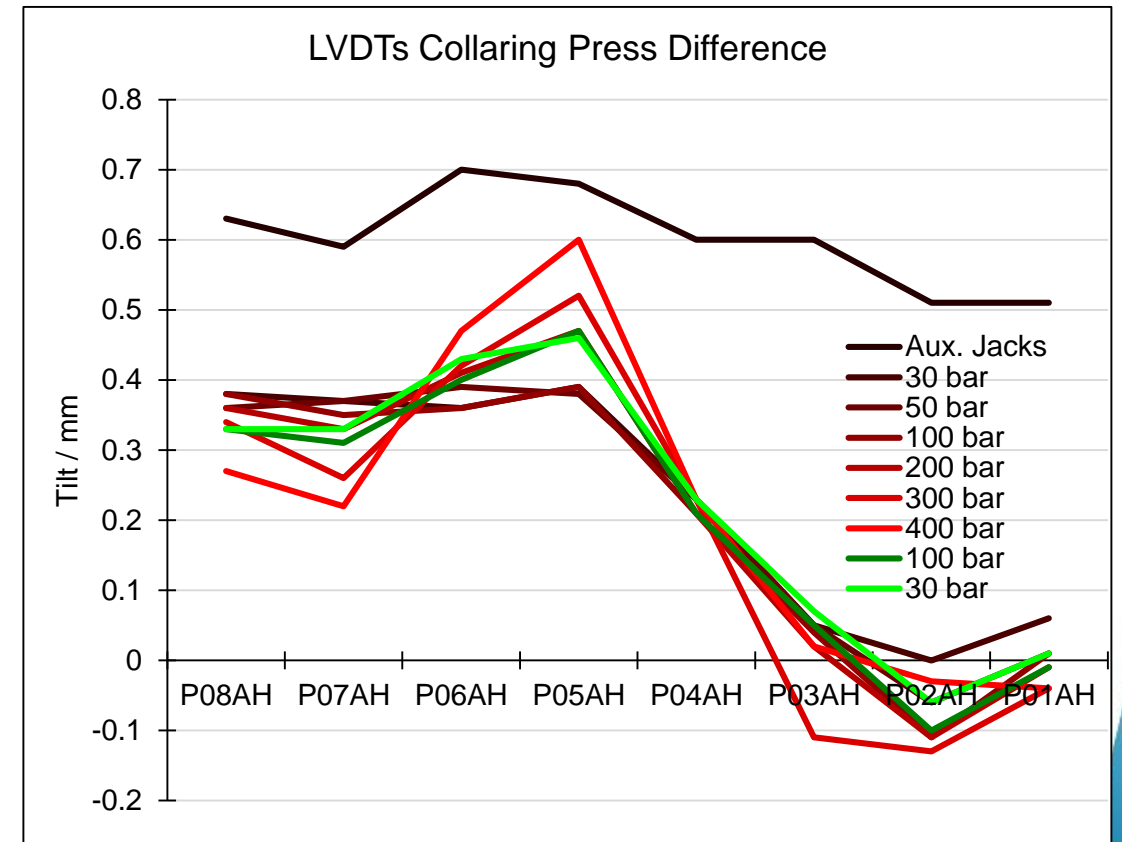
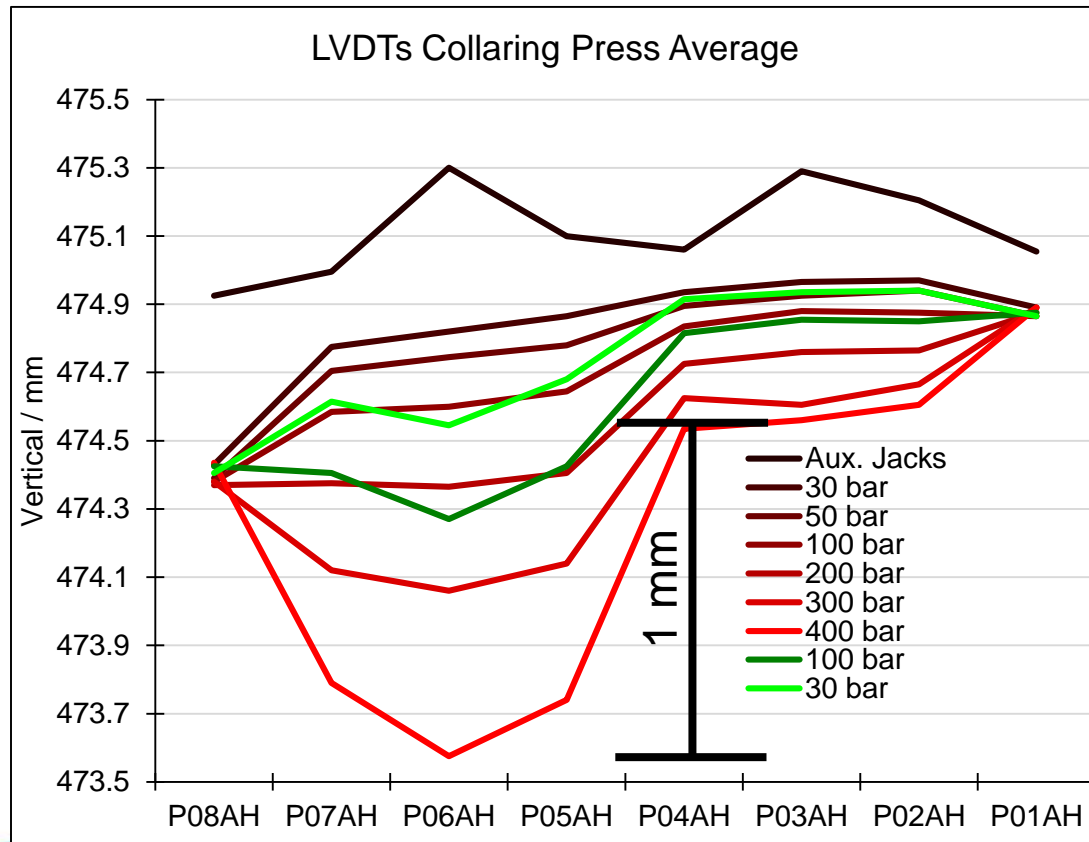
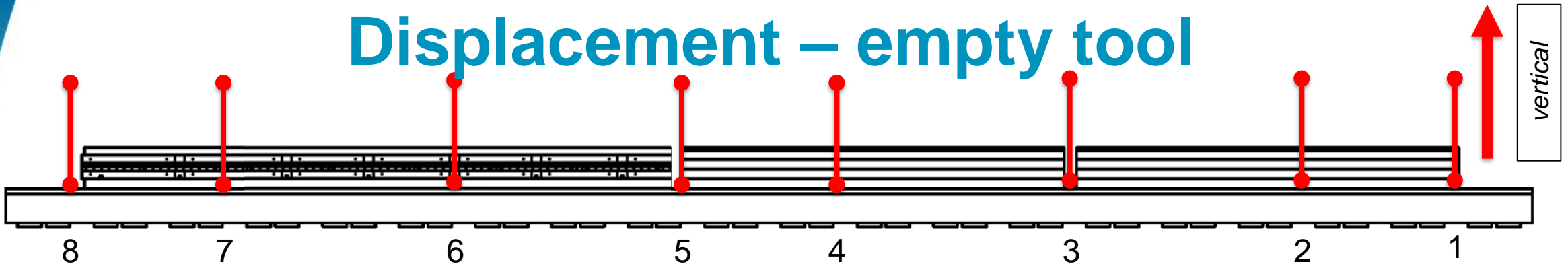


# Collaring 11 T CR1&2 – trial collaring

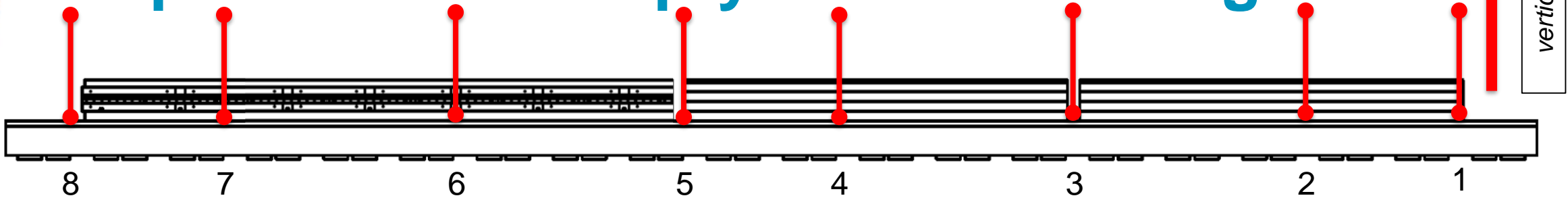
2018-07-25

Christian Löffler, Jose Luis, Michael Daly,  
Thibault Genestier

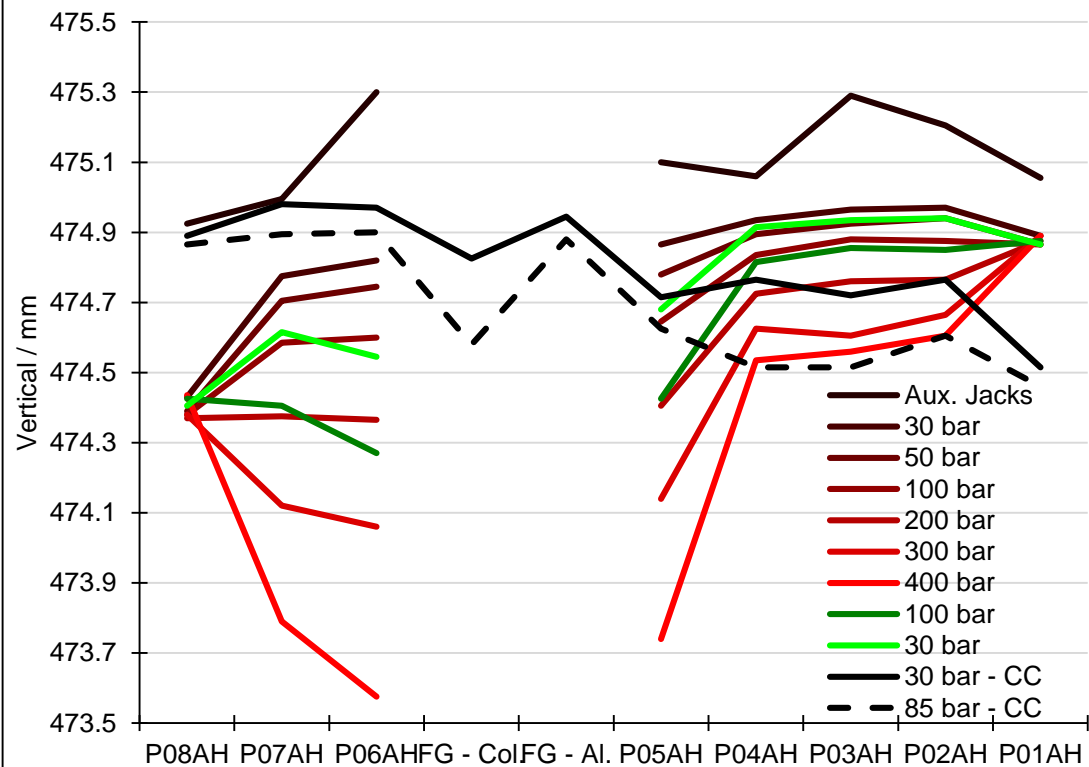
# Displacement – empty tool



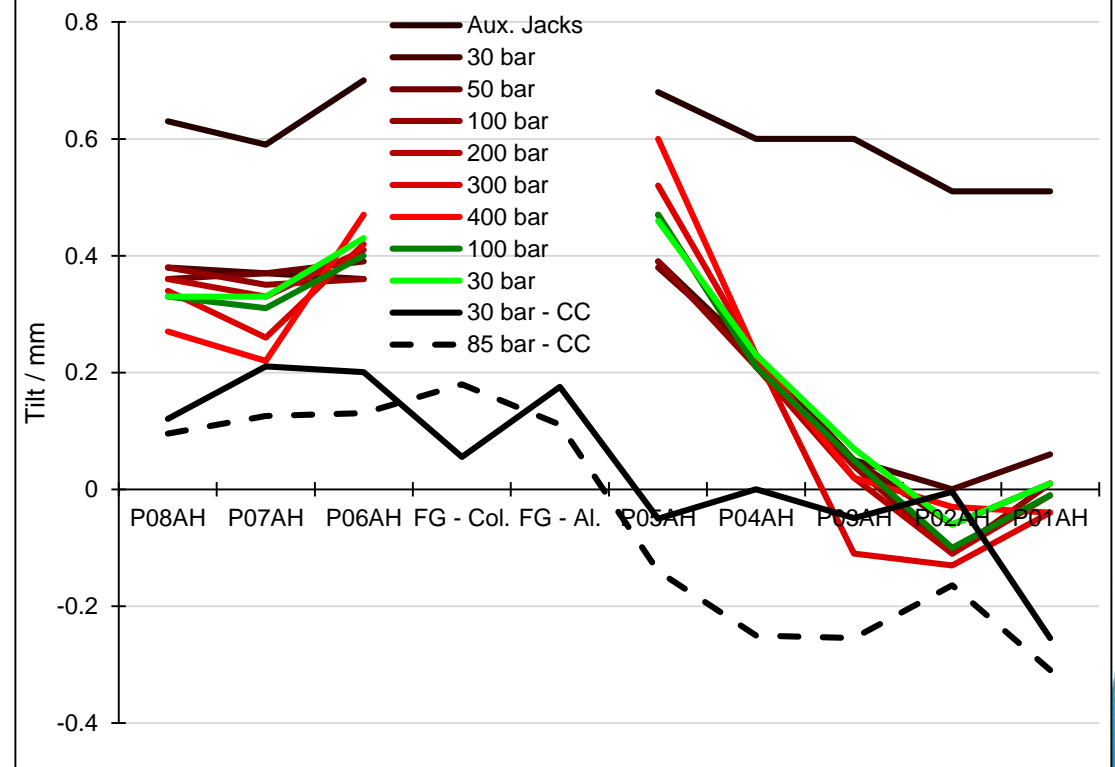
# Displacement – empty tool & collaring CR1&2



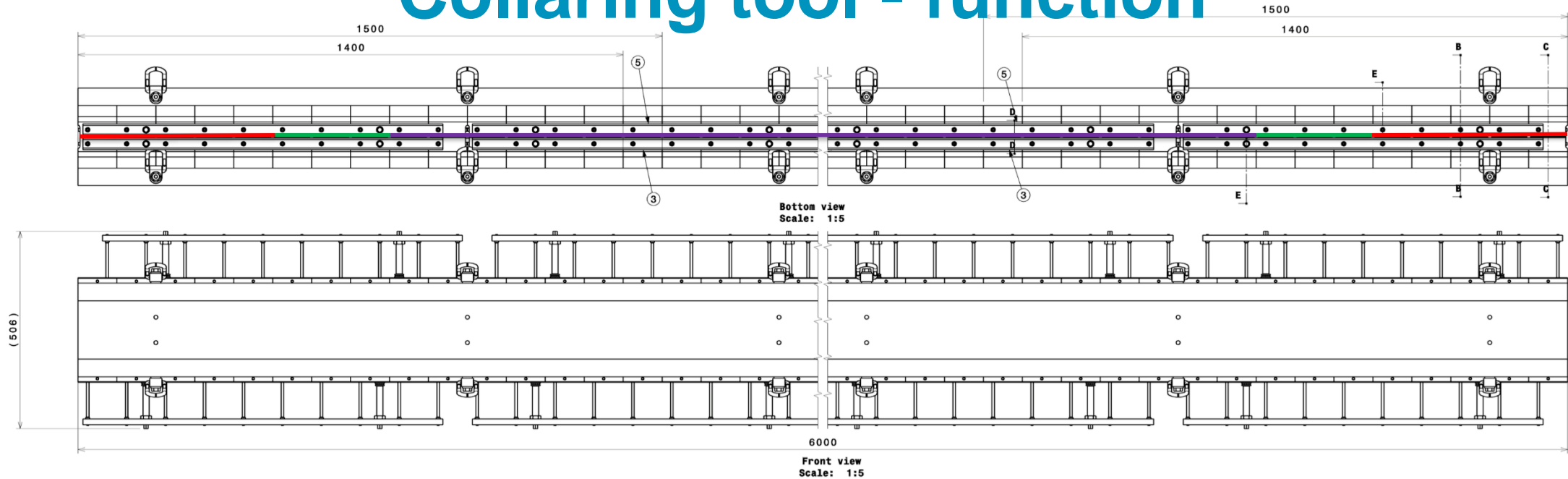
LVDTs Collaring Press Average



LVDTs Collaring Press Difference

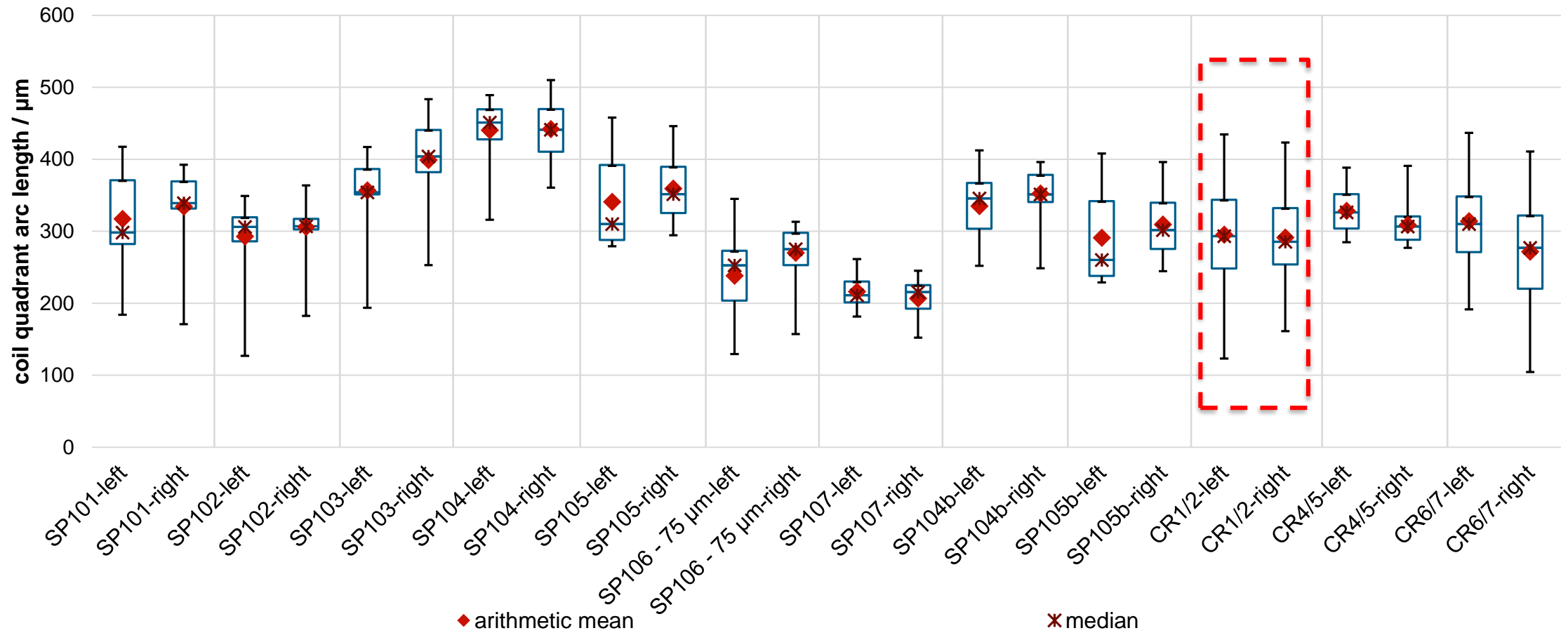


# Collaring tool - function



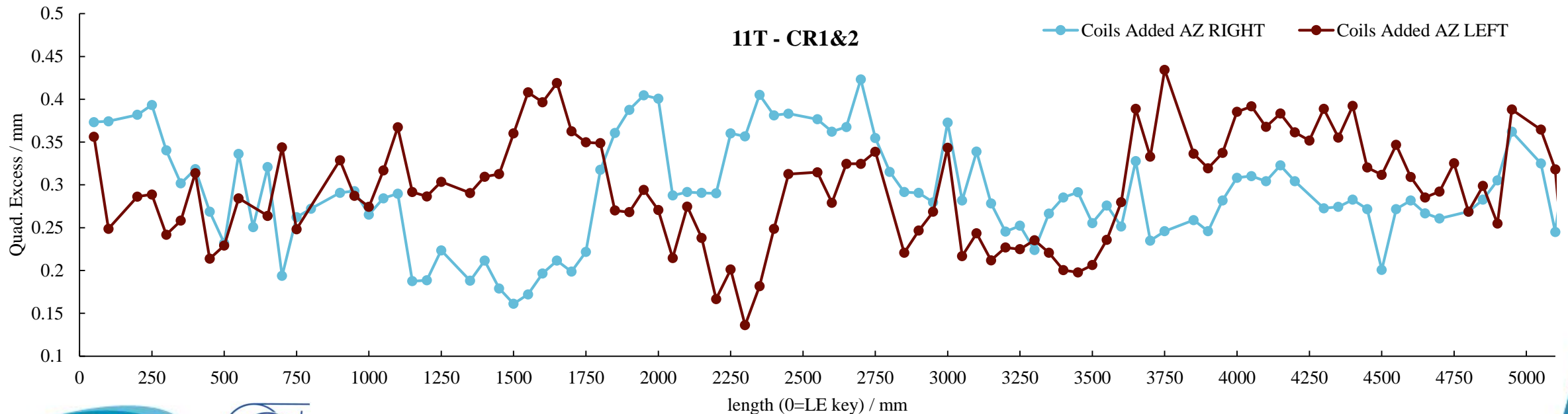
- Stopper height
  - 70.00 mm
  - 69.90 mm
  - 69.85 mm
- Protecting the heads with larger stoppers
  - Proven with FUJI test
- With the next collaring test the position will be optimized

# Collared Coil excess overview - boxplot



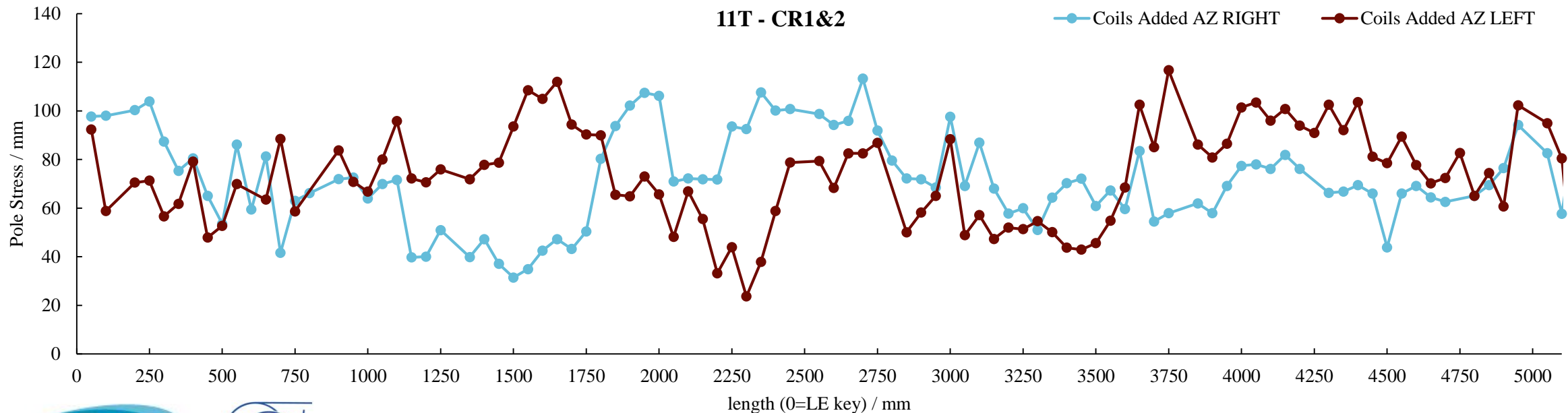
# TF – Excess to Pole Stress

- 11T Dipole Task Force Meeting #18
  - Collared coils of MBHSP107 - Relationship between coil stresses and deformed collared coils – slide 16
- **Excess[ $\mu\text{m}$ ] \* 0.312 - 18.8 = Pole Stress [MPa]**

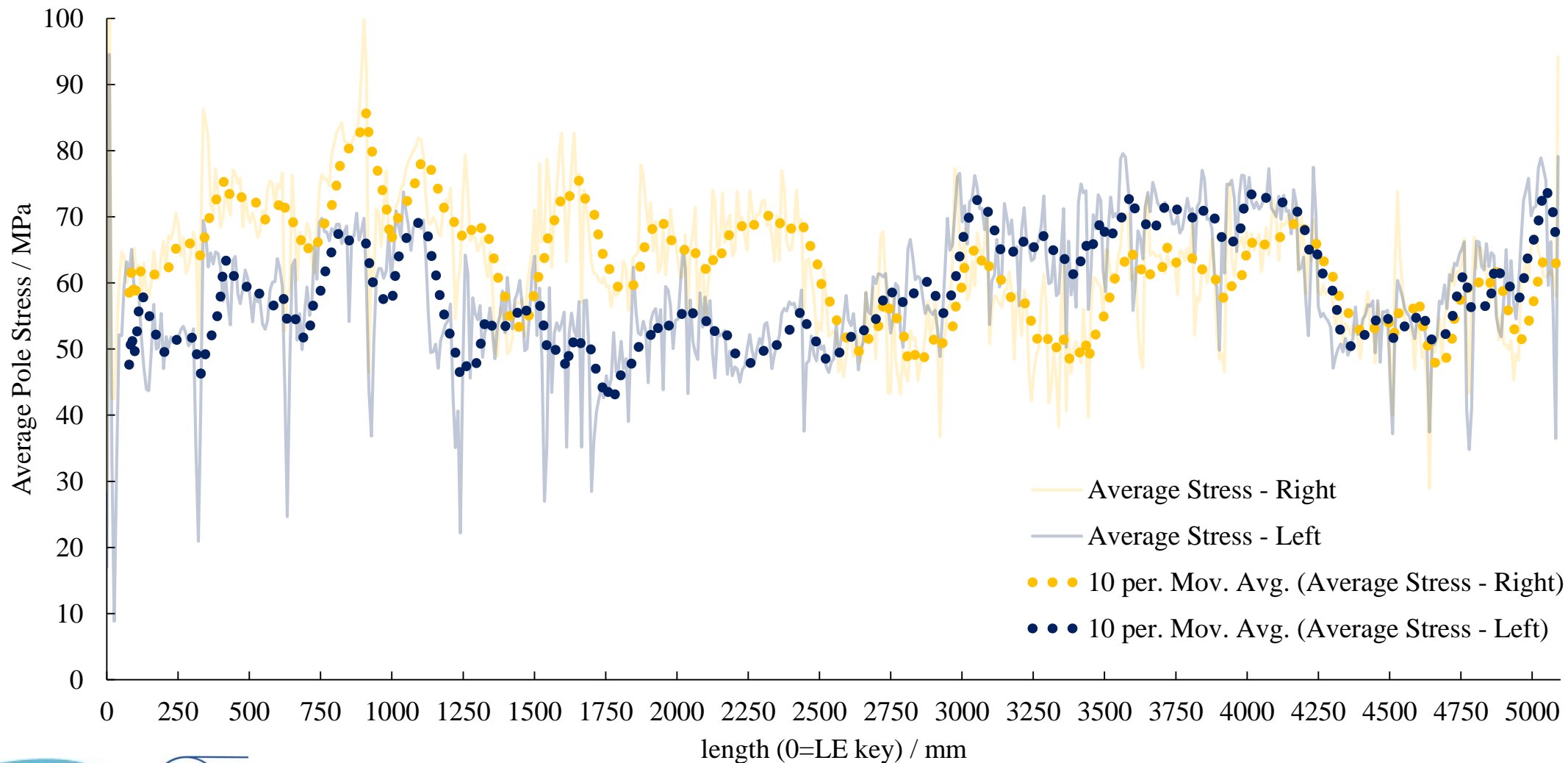


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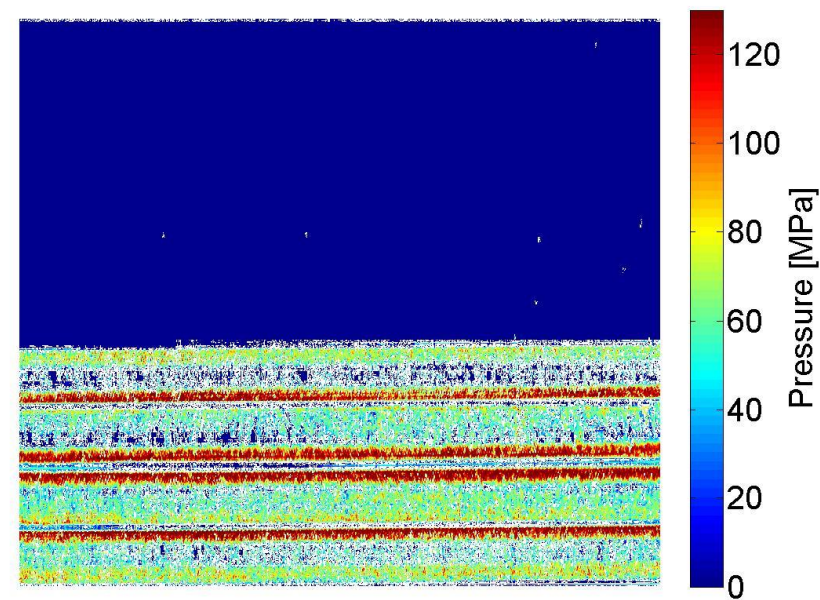
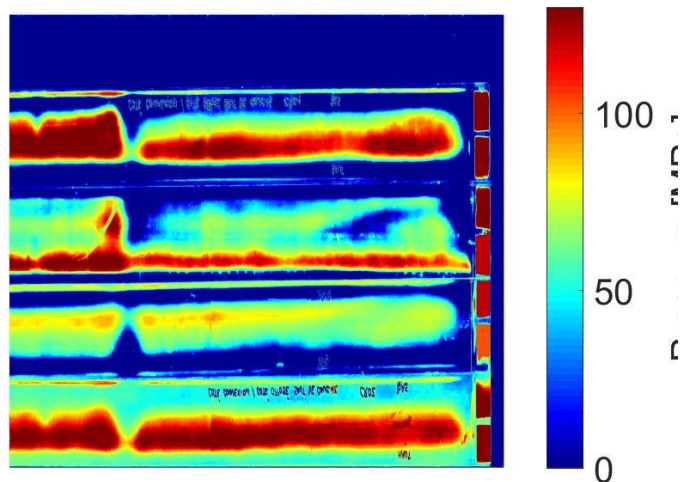
# HS FUJI – CR1&2 - 2017





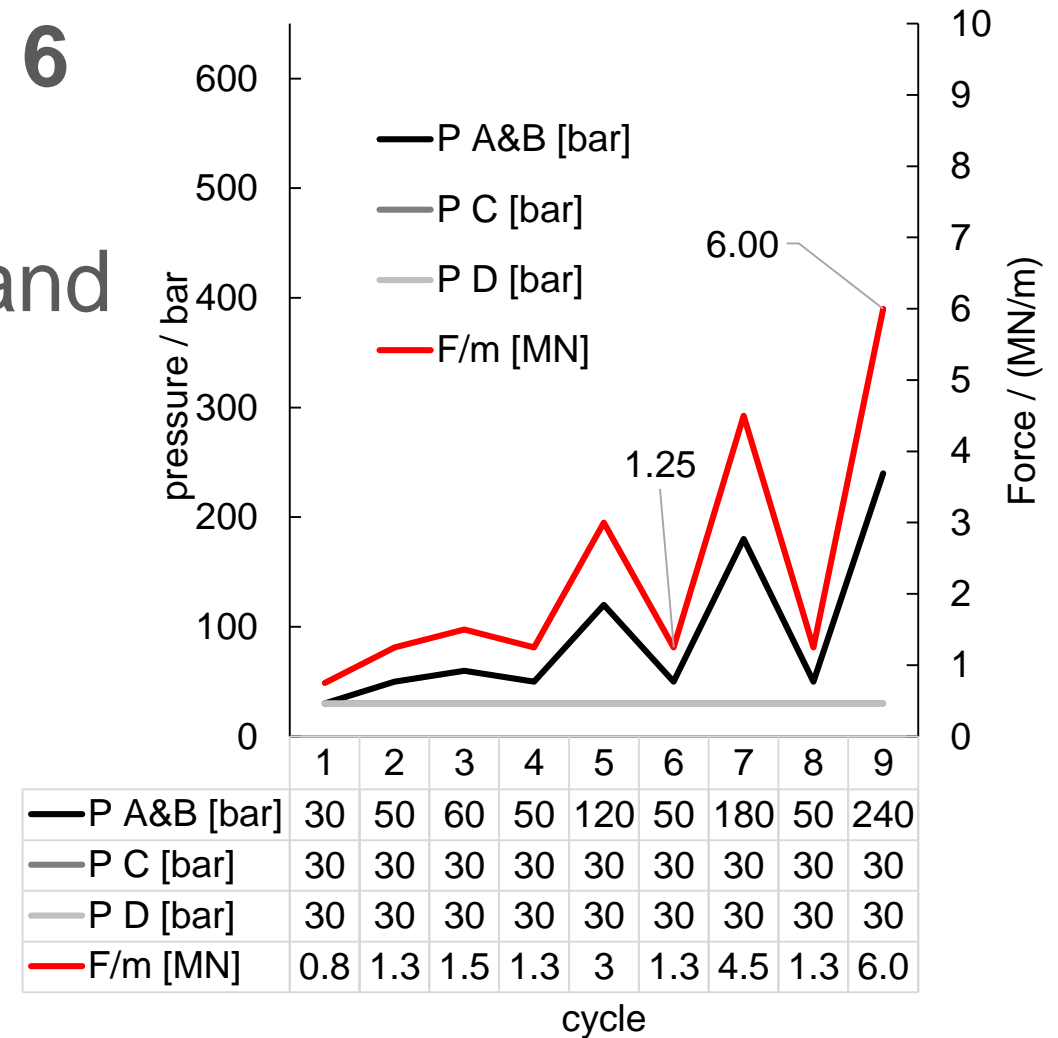
# HS FUJI – CR1&2 - 2017

- No clear correlation between stress on pole and excess
- Only one grade of FUJI was used -> needs to be changed
- Many spots of saturation



# Series collaring – stopper 69.85 mm

- Smaller stopper should give us **6 MN/m**
- Collared models with 5 MN/m and same stopper
  - SP106 – max. 345; AV 254  $\mu\text{m}$
  - SP107 – max. 261; AV 211  $\mu\text{m}$



By changing the stopper from 70.0 to 69.85 mm, the collaring force should be reduced by 40%.

# CR1&2 – trial collaring

- 2 instrumented collars (quad. Excess 235  $\mu\text{m}$ )
  - Tool in press (no hydraulic) 48 & 35 MPa traction stress
  - 30 bar 115 & 95 MPa
  - 60 bar 192 & 148 MPa
  - 85 bar 226 & 180 Mpa
- The keys seemed to be in at 85 bar, therefore we stopped the collaring
  - Keys are not in, 0.4 mm missing at some locations (30  $\mu\text{m}$  more vertical displacement)

# CR1&2 – trial collaring

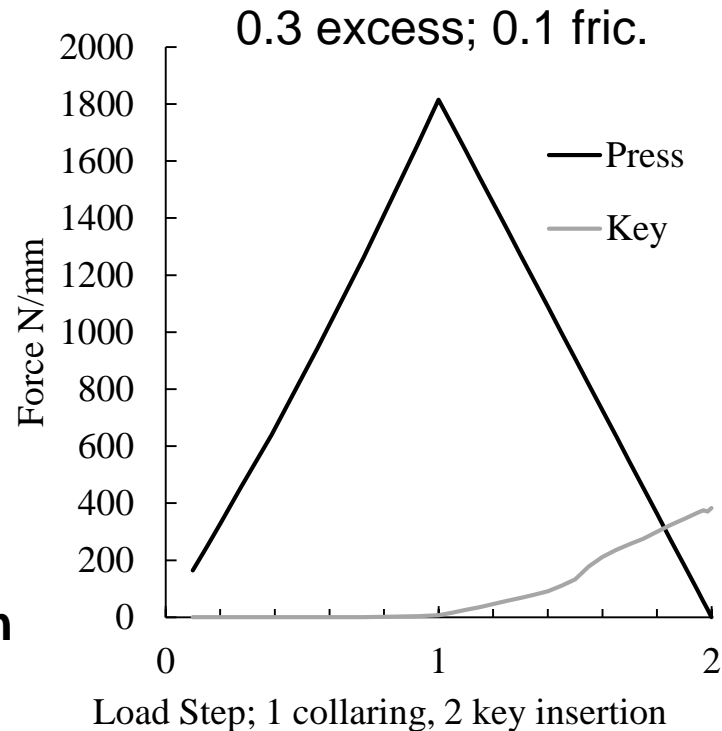
- 3 instrumentations show that the stoppers are in contact at 30 bars
- **Next step:**
  - FUJI paper on the stoppers during de collaring
  - Re-collaring at higher force

# CR1&2 – trial collaring

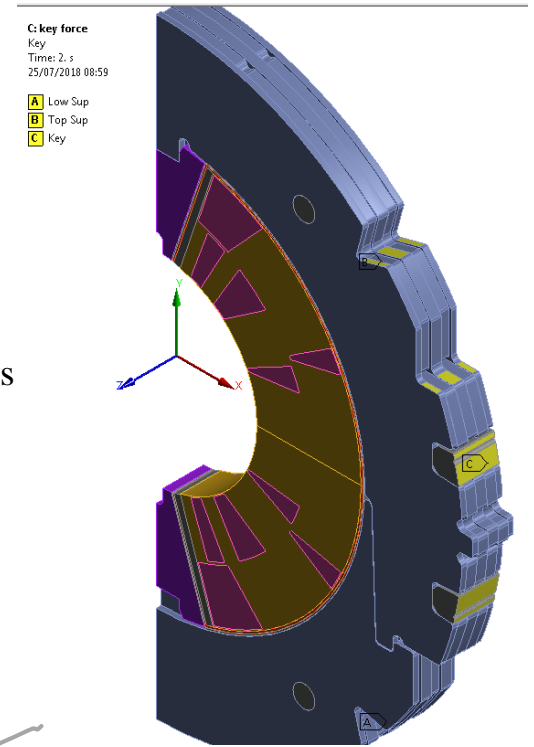
- 2<sup>nd</sup> collaring
  - Same force 85 bar -> 2.125 MN/m
  - Collaring Key fixture screw enforced tightened
  - Result
    - Keys are mainly in, around 0.1 mm missing
    - We went from 0.4 to 0.1 mm, just with the screws
  - Conclusion
    - Increase the force slightly and use the screws
    - Remove the spring loaded key insertion system

# Collared Coil – Key Insertion

- Is it possible to insert the key with the screws?
  - Assuming the key gap is not fully open
- FE and arithmetical analysis



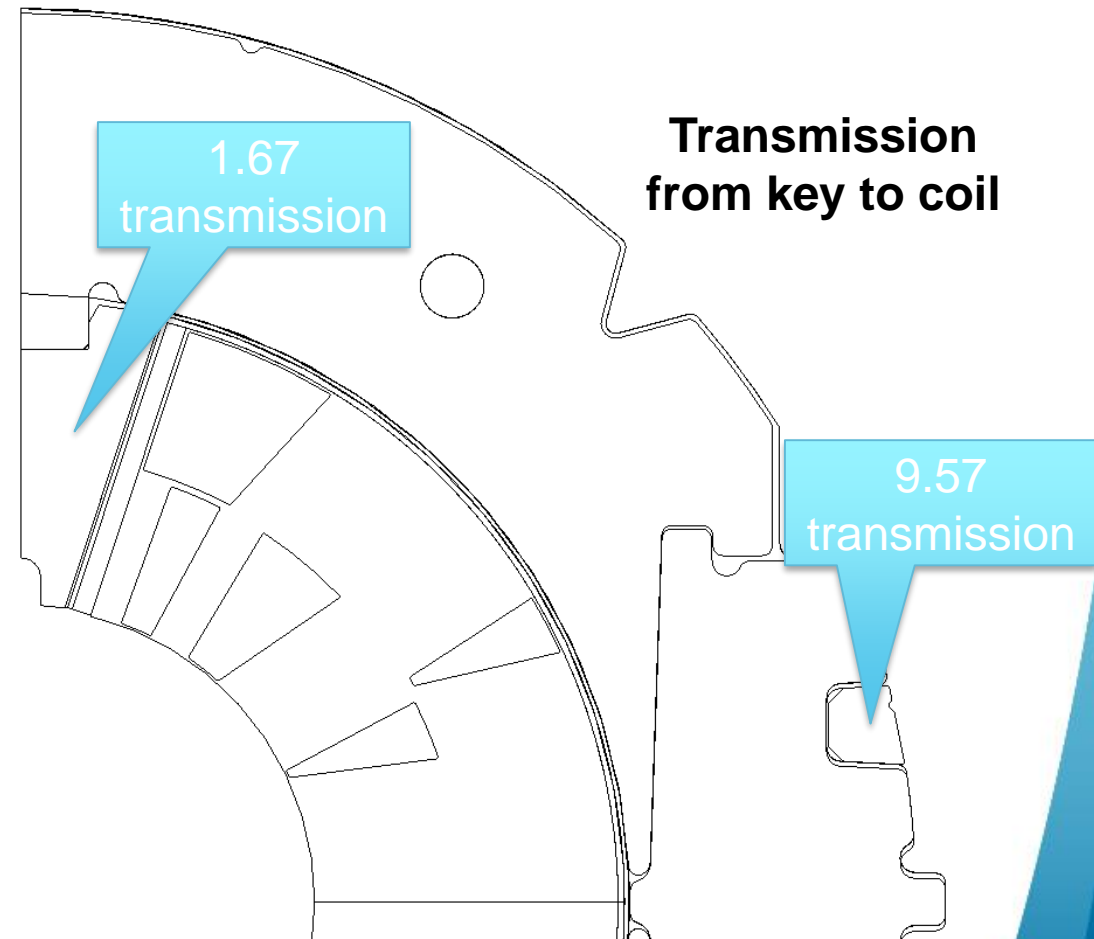
**LS 1: Press**  
**LS 2: Keys Forced in**



# Collared Coil – Key Insertion

- Meaning 1 N on the key is  $(9.57 \times 1.67) = 15.98$  N
- Or  $1/15.98$  for displacement
- For an excess of 0.3 mm and 0.1 friction:

in N	Force Pole	Force Key	Ratio
Ana. $\mu$ 0.1	3133	696	4.50
Ana. $\mu$ 0.0	3133	196	16.00
FEA $\mu$ 0.1	2861	383	7.48



# Collared Coil – Key Insertion

- Max. Force with our screws is 10 kN
  - One screw per 100 mm
- Preliminary conclusion
  - It is possible with a  $\mu=0.2$  to compress 50  $\mu\text{m}$  of coil quadrant, just with the screws (9.9 kN /  $\mu=0$ , 1.6 kN)
  - The problem will be that the key will stick out between the screws by 410  $\mu\text{m}$  (elastic curve equation)
  - More screws! -> 30  $\mu\text{m}$  stick out





**fin**

# Excel Calculation

Name Input	Symbol
Modulus Coil / GPa	Mc
Arc Length Coil / mm	Lc
Modulus Collar / GPa	Mco
Arc Length Collar / mm	Lco
Modulus Key / GPa	Mk
Height Key / mm	h
Width Key / mm	w
Quad. Excess / mm	Lq
Width Pole / mm	Lp
Width Collar / mm	Lwc
Width Segment / mm	Lsegment
Friction Coefficient	$\mu$

Name	Value
Screw Force / N	33
Screw Force Friction / N	60
Pole Top Force (Half) / N	190
Normal Key Force / N	120
Normal Pole Force / N	190
Vertical Force of the Key / N	14
Elongation Collar / mm	7.3
Ration Elongation Coil/Collar	0.3
Key Excess / mm	30
Max. Bending Key	34
ly Key / mm <sup>4</sup>	12
Area Load	0.1

## Force reation pole to key

Symbol	Value	Unit
Fk	1175.00	
Fkf	4178.90	Ratio
Fp	11256.34	Stress / MPa
Fkn	11240.91	Stress / MPa
Fpn	18798.089	Stress / MPa
Fkv	11256.34	Stress / MPa
Lco	0.03	
Rcc	2.72	
Lek	4.79	
Bk	0.00	
ly	1669.27	
Qz	348.24	
Relation Pole	1.67	
Relation Key	9.57	

# Sensors

- #1 16 LVDTs for the full table
- #2 8 Laser Sensors on the tool
- #3 12 Dial Gages for the horizontal tool movement
- #4 8 Dial Gages to measure the angle of the laser sensors

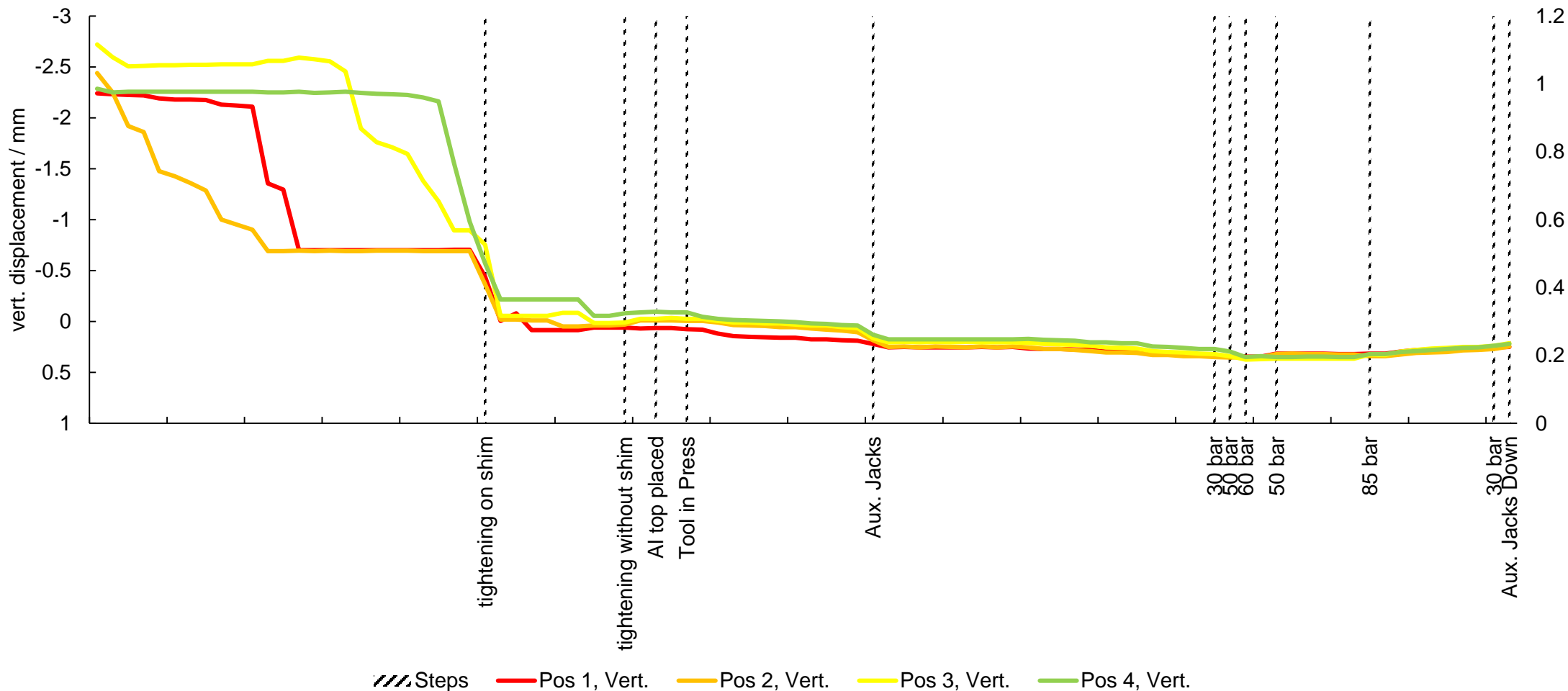
# Laser Sensor



- the sensors zero is with a stopper height of 70.00 mm under the press at minimum force (100 kN/m, aux. cylinders)
- Every 1 m one pair of sensors installed on the tool, 8 in total
- Linearity 8-10  $\mu\text{m}$
- Repeatability 0.5  $\mu\text{m}$

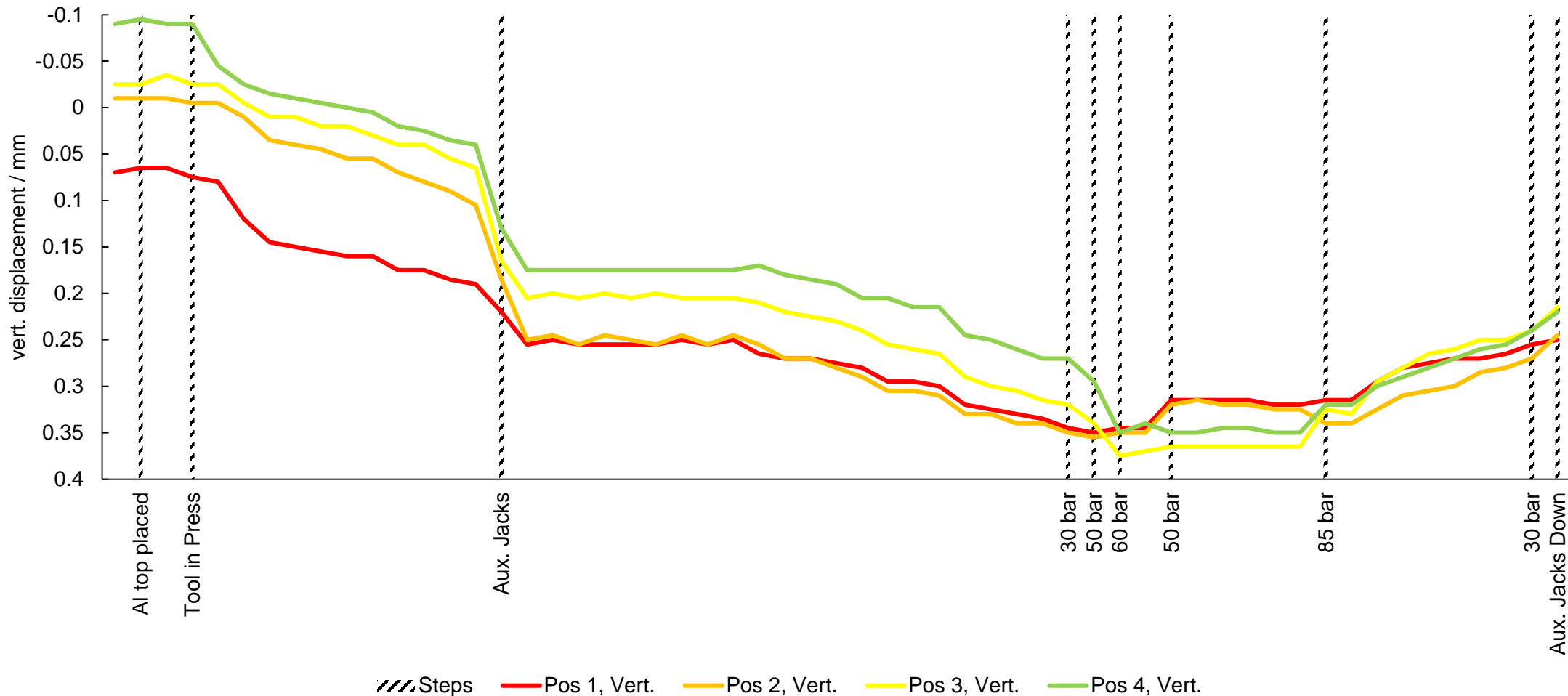
# Laser Sensor

Vertical displacement, tool laser sensors, average left & right



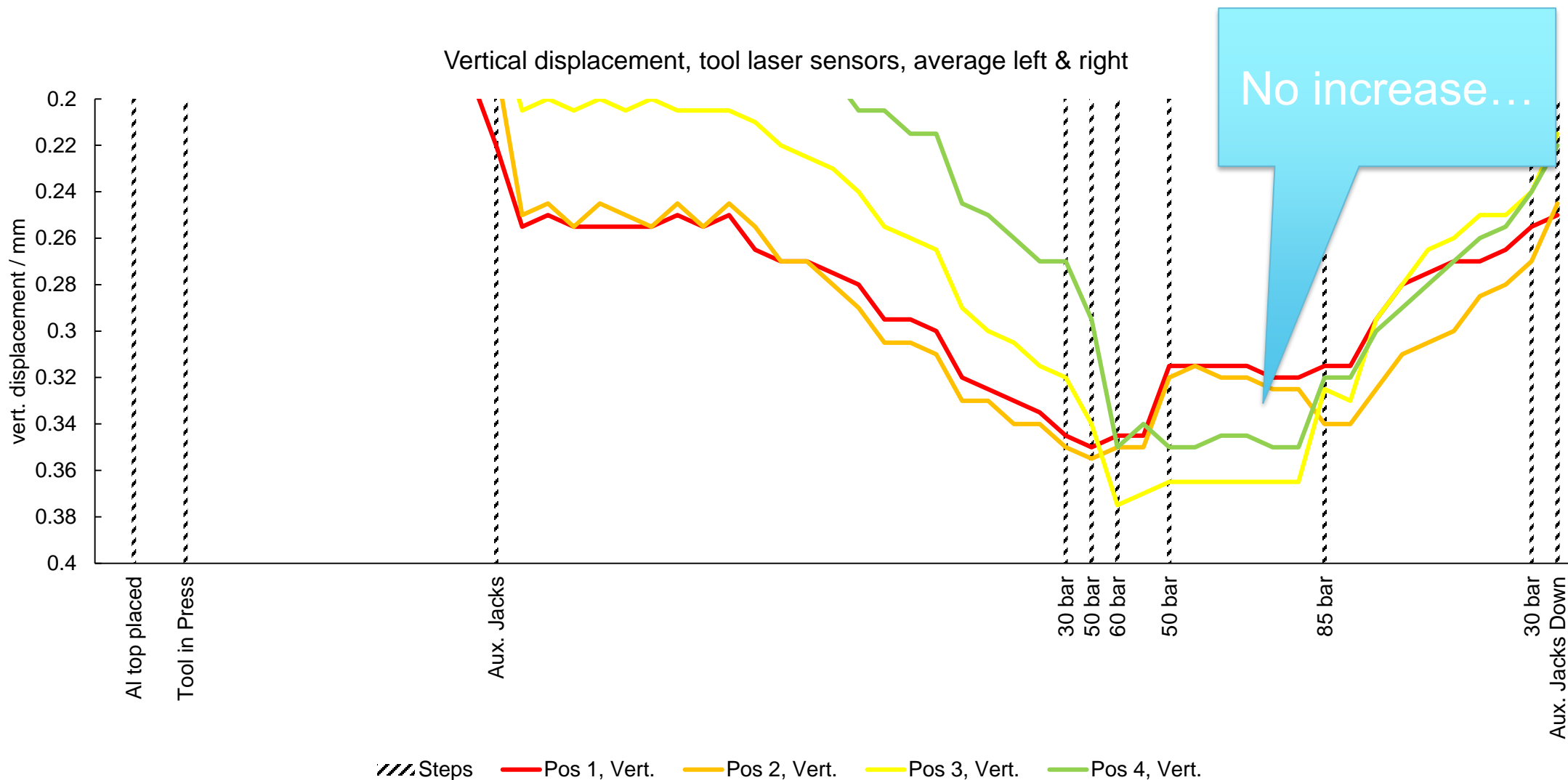
# Laser Sensor

Vertical displacement, tool laser sensors, average left & right



Steps
 — Pos 1, Vert.
 — Pos 2, Vert.
 — Pos 3, Vert.
 — Pos 4, Vert.

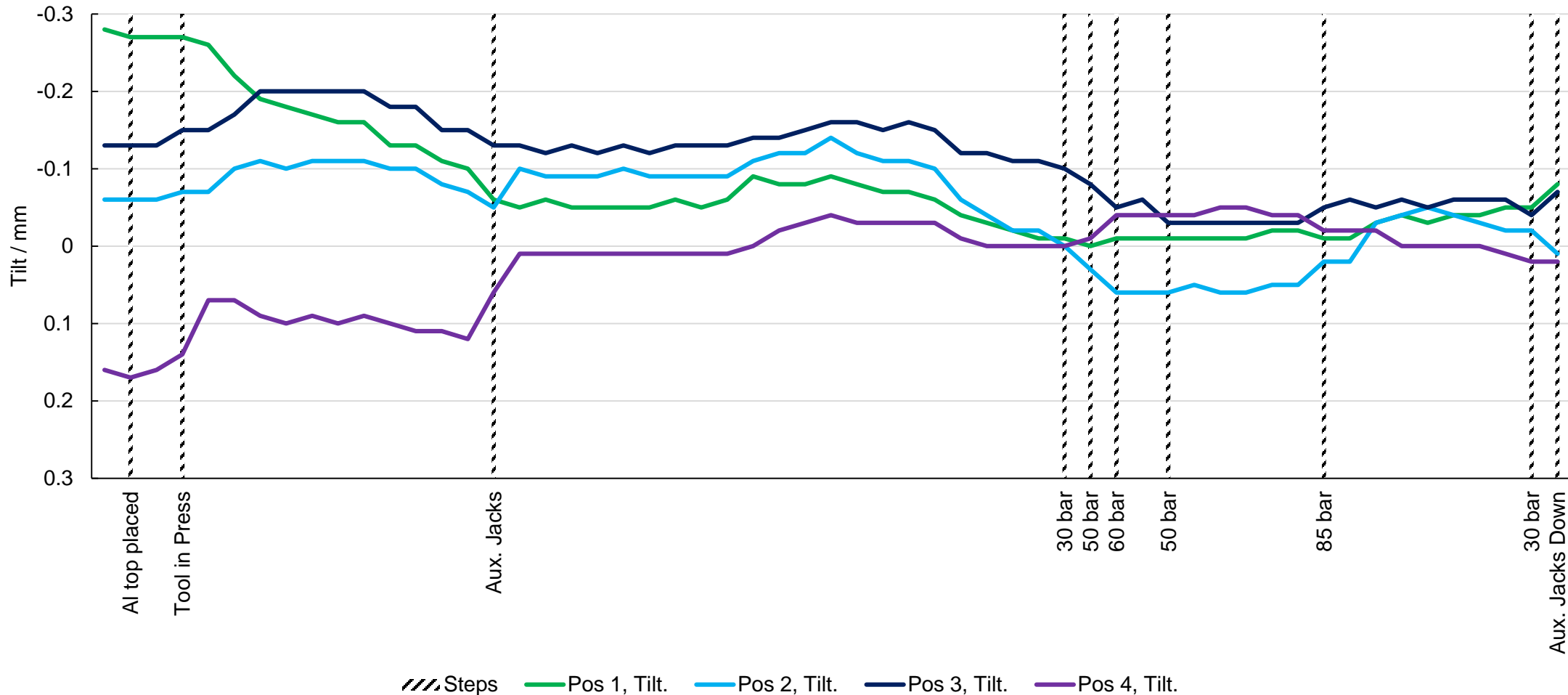
# Laser Sensor



No increase...

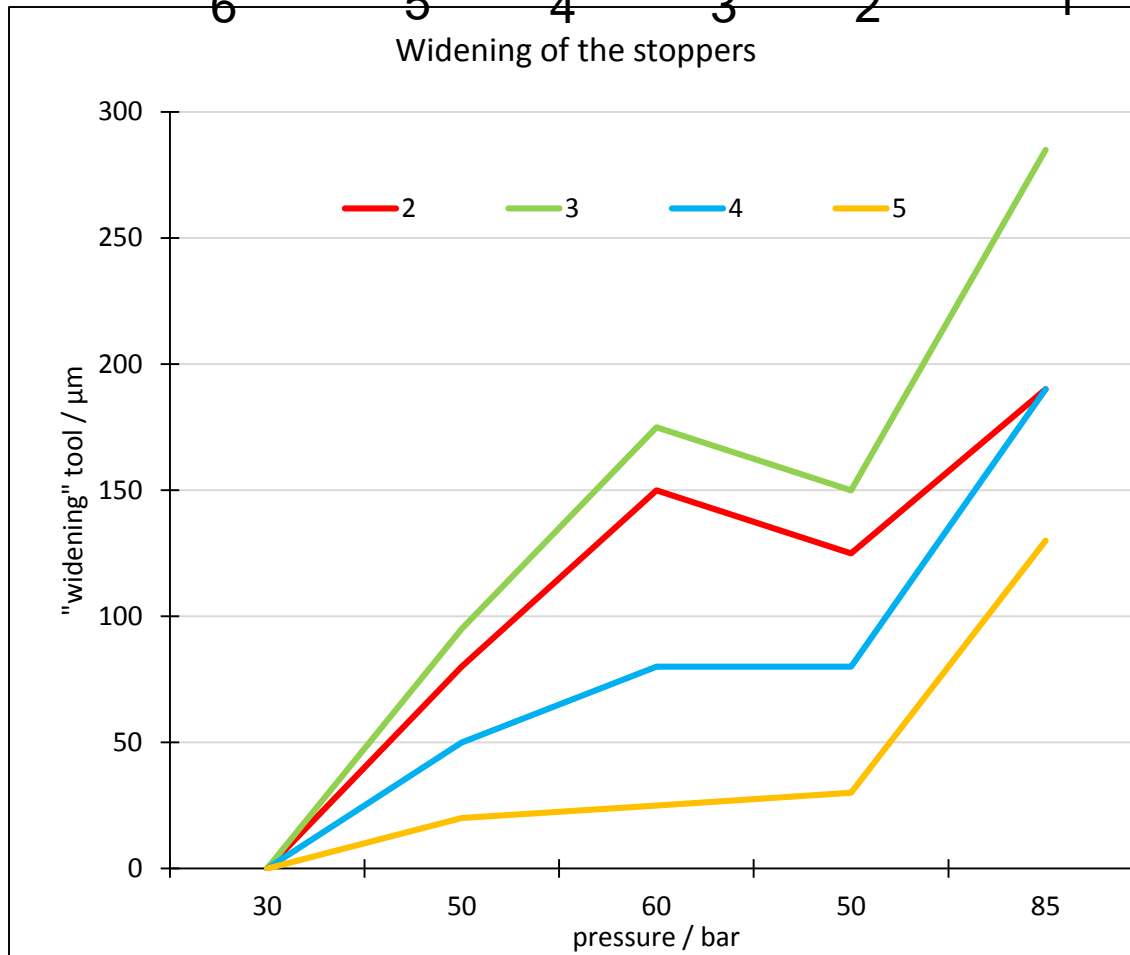
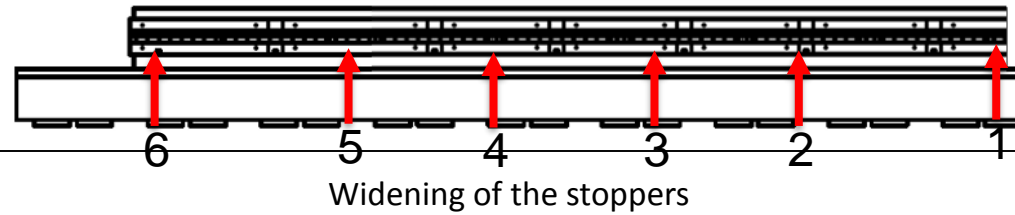
# Laser Sensor

Tilt, tool laser sensors, difference left & right





# Dial gages - horizontal

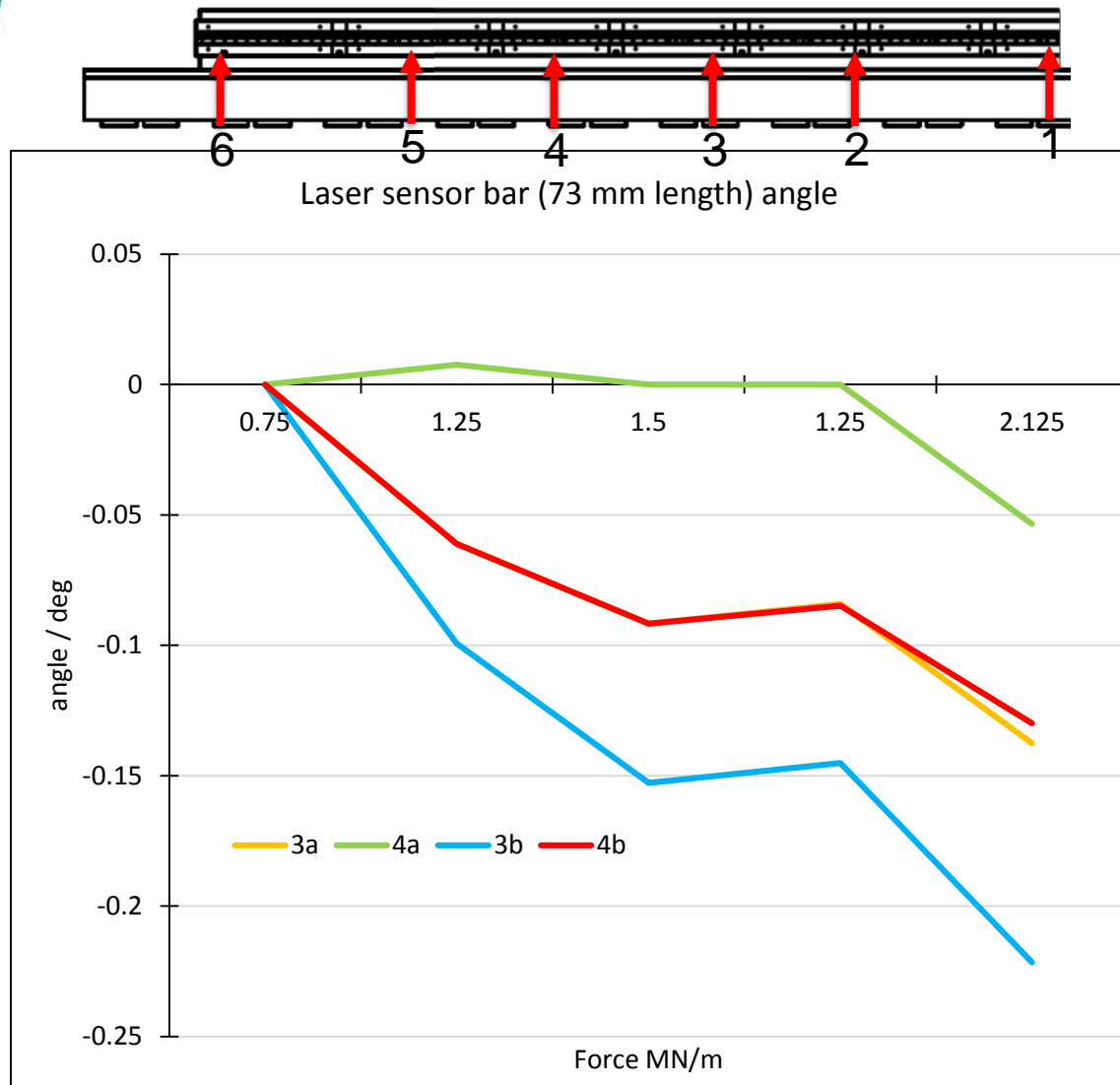


Meas. location



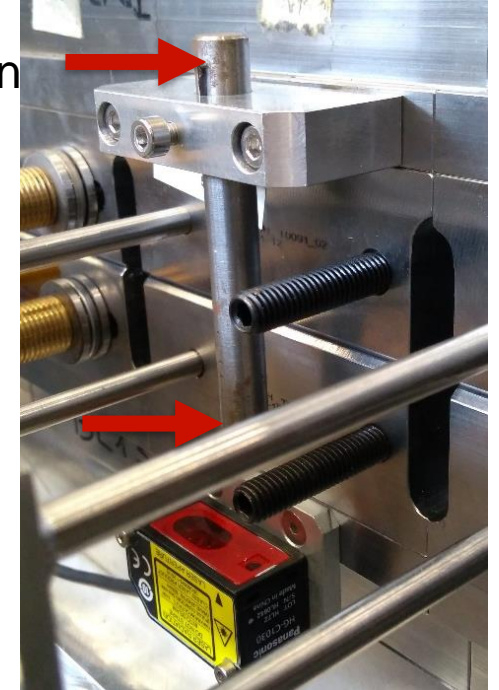
- Sensor 1 & 6 failed during the test
- Horizontal movement is observable at 30 bar
- Indication that even at low pressure the stoppers are partially in contact

# Dial gages – angle laser sensor



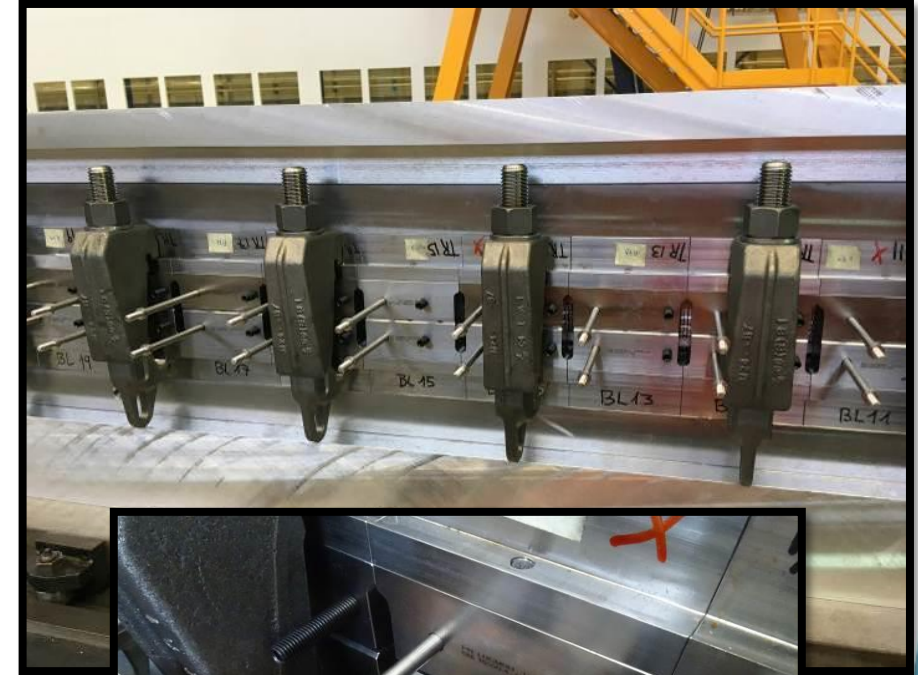
Meas. location

- Angle is constantly increasing after 30 bar (750 kN/m)



# #1 – tighten the clamping screws

- Place every second block
- Max. load per clamp is 230 kN
  - Max. torque 900 NM
- Starting from the LE, tighten the screws in  $0.1$  mm steps to:
  - **70.2** mm
  - **70.0** mm
- Stopper “height” 69.85 mm



## #2 – insert the collaring keys

- Insertion through sliding
- Release the insertion springs
- Place the top AL-Block



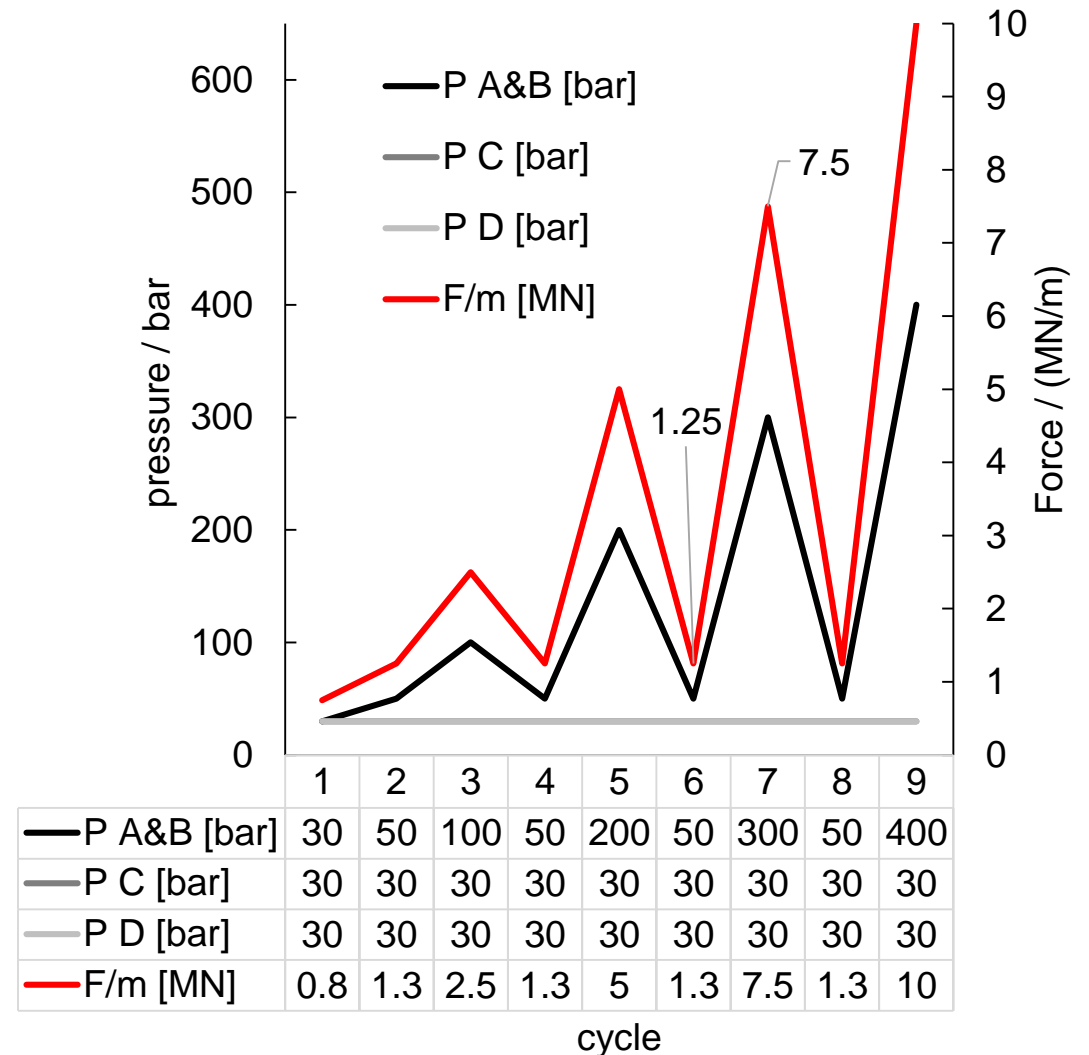
# #3 – collaring

- Insert the tool in the press, pay attention to the leads
- Follow the standard “collaring protocol”
  - *Next slides*



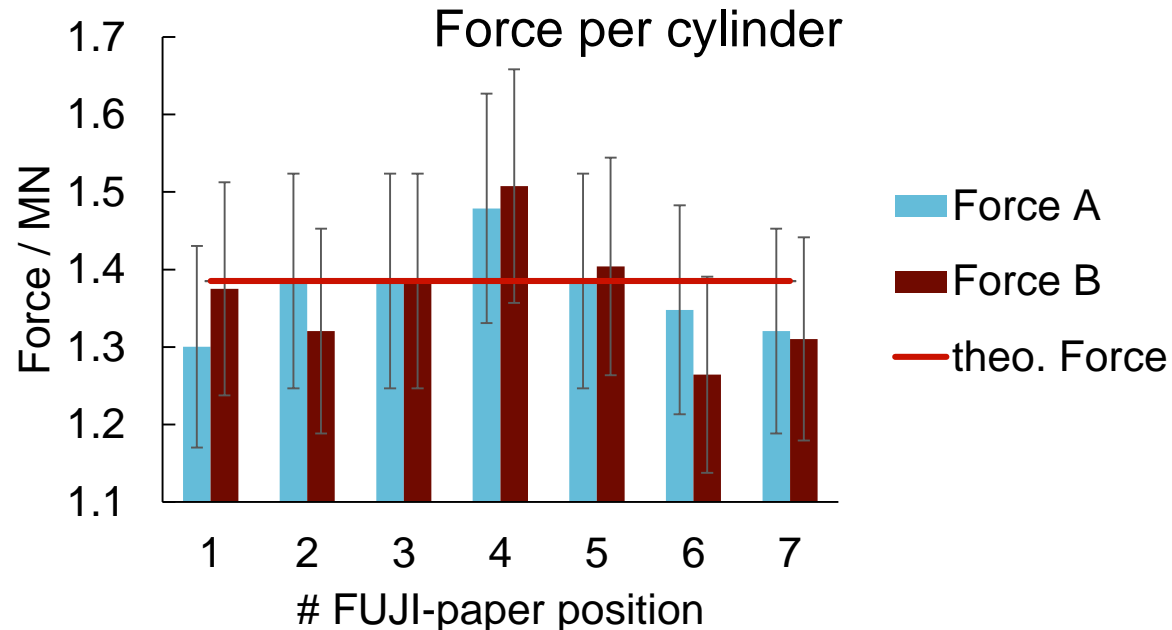
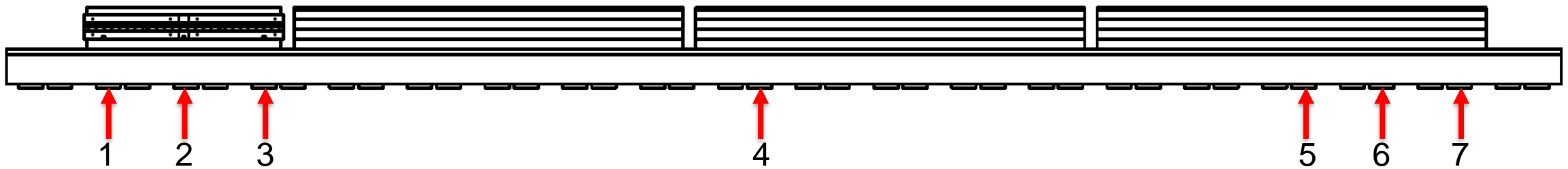
# Previous collarings – stopper 70 mm

- CR000001-3 have been collared at **10 MN/m**
  - Quad. Excess:
    - CC1 – max. 434; AV 292  $\mu\text{m}$
    - CC2 – max. 391; AV 319  $\mu\text{m}$
    - CC3 – max. 437; AV 293  $\mu\text{m}$



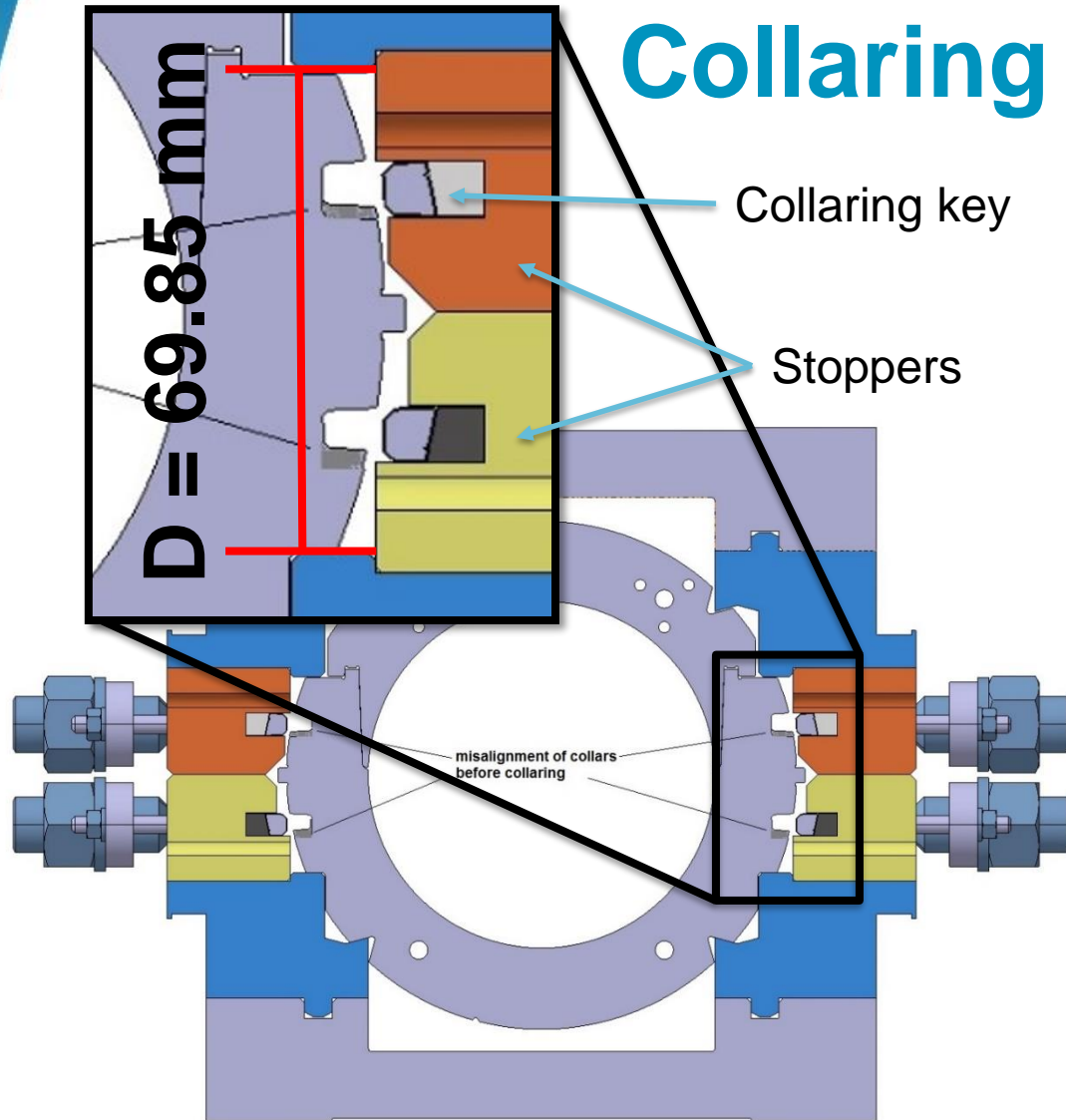
By changing the stopper from 70.0 to 69.8 mm, the collaring force should be reduced by 40%.

# Force measurements – early 2016



- Measured values at 200 bar:
  - Theoretical force per cylinder: 1.385 MN
  - Side A average force: 1.372 MN
  - Side B average force: 1.367 MN
- All of the results are in the range of error given by FUJIFILM

# Collaring tool - function



- D is **69.85** mm when the coils are collared, this distance is a result of the keys being fully inserted
  - Stoppers **69.85** mm – 180 collaring tool
  - Final collaring at **69.8** mm – compression of the stoppers by **50**  $\mu\text{m}$
  - Transfer function between collaring key and vertical displacement;  $\tan(4^\circ)$  – factor **14**



# 11T - CR1&2

