



First results with Laser treated surface in COLDEX

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38th HL-LHC TCC, CERN, 5th October 2017

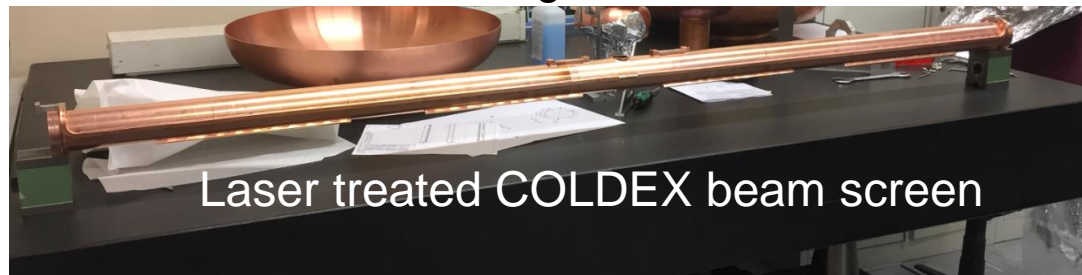
OUTLINE

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1. Description

LESS surfaces for COLDEX

- This beam screen was built in **collaboration** with CERN-STFC-University of Dundee (DR 6558493)
- **Laser treated segments** with ID 67 mm were delivered to CERN, assembled at CERN and installed in the SPS during last EYETS (wk12)
 - a 2.2 m long **COLDEX beam screen** is made of 9 segments



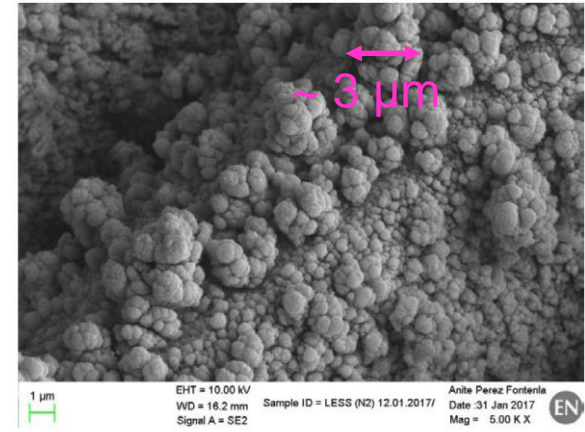
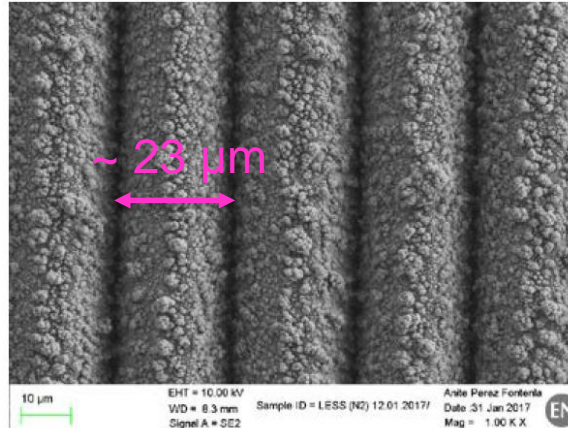
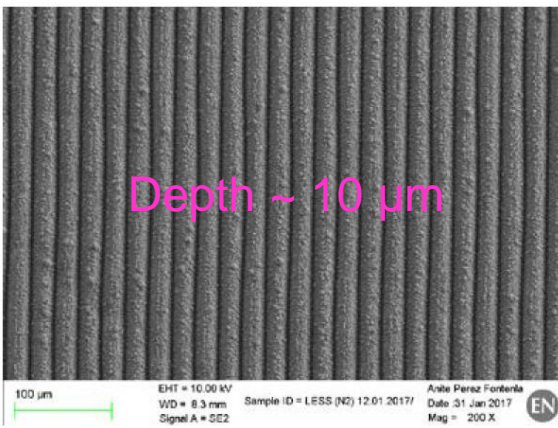
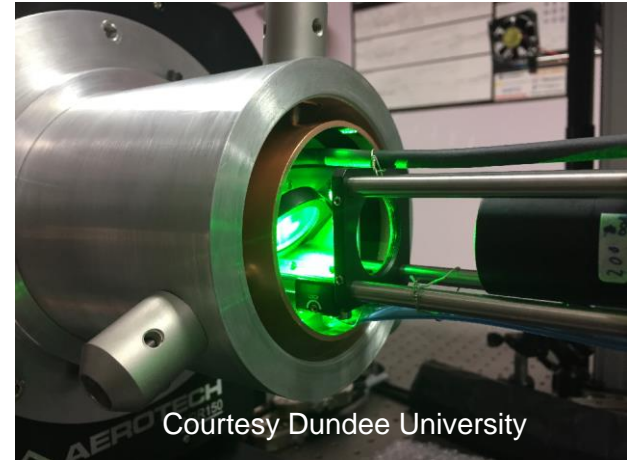
- a 216 mm long **WArm MultiPActing Calorimeter** (WAMPAC 5.3) made of laser treated copper was also built and installed in the COLDEX experiment



- A dummy segment was used to measure SEY in the laboratory
 - $SEY_{max} = 0.9$ at room temperature

LESS surfaces for COLDEX

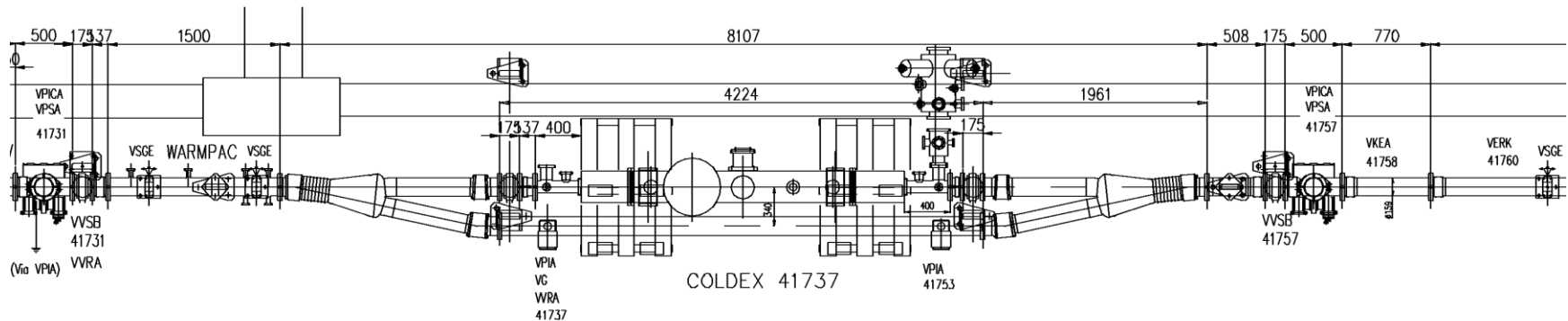
- Laser treatment parameters:
 - Under N_2 ,
 - 532 nm (2.3 eV), repetition rate = 200 kHz
 - Pulse length < 15 ps
 - Focal spot diameter = 12 μm
 - Intensity = 0.4 TW/cm² (10^{30} ph/s/cm²)
 - Rotating speed = 10 mm/s
 - Advancing speed = 1-2 μm /s
- 3 days/segment (244.5 mm length, ID67)
 - Delivery from Wk2-7
- LESS treatment is of type “C2”
 - A **single groove with “cauliflower”** like shape on the top of the ridge
 - Grooves are perpendicular to the beam



COLDEX in SPS BA4

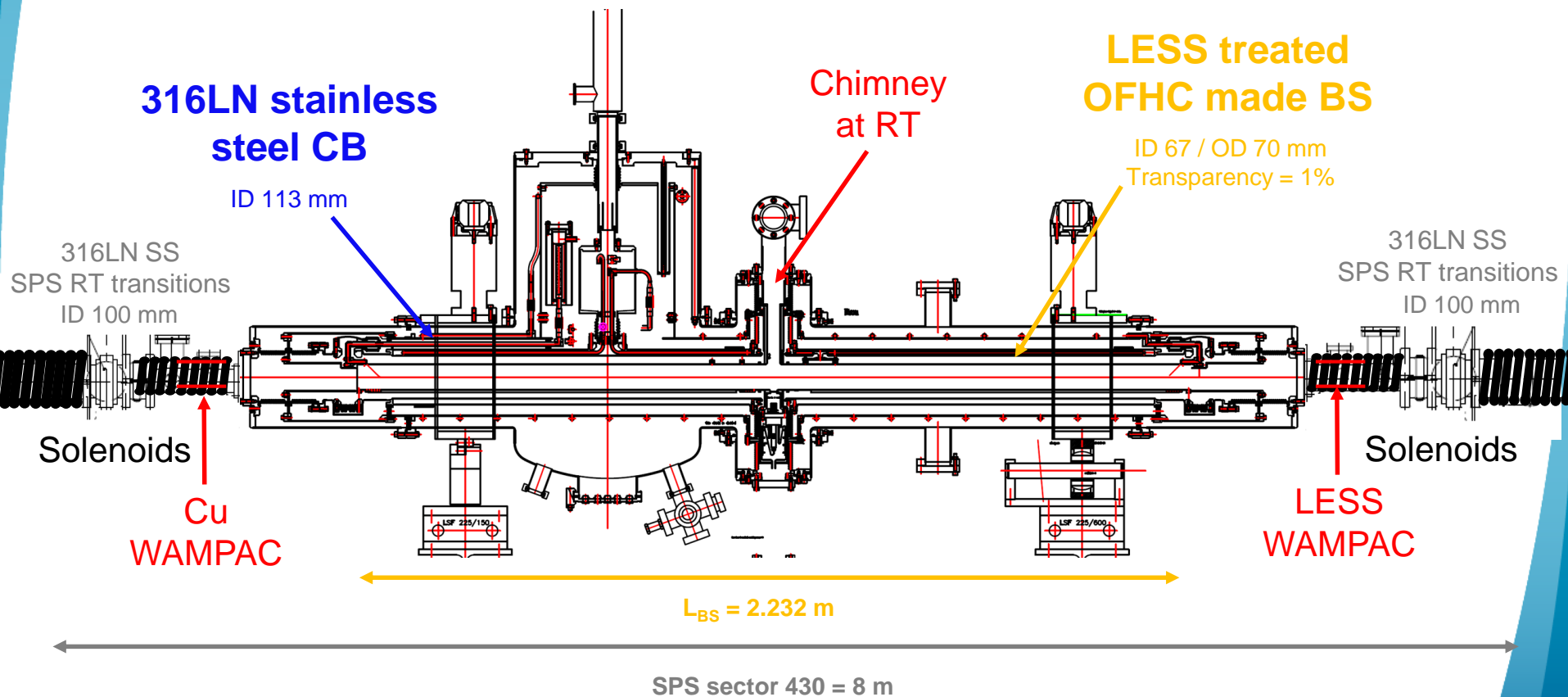
- The COLDEX set up is installed in a **bypass** of SPS BA4 to **study electron cloud effects**
- It mimics a **LHC type cryogenic beam vacuum system** (no magnetic field)

No identified resource (Fellow or PJAS) yet to replace the previous Fellow



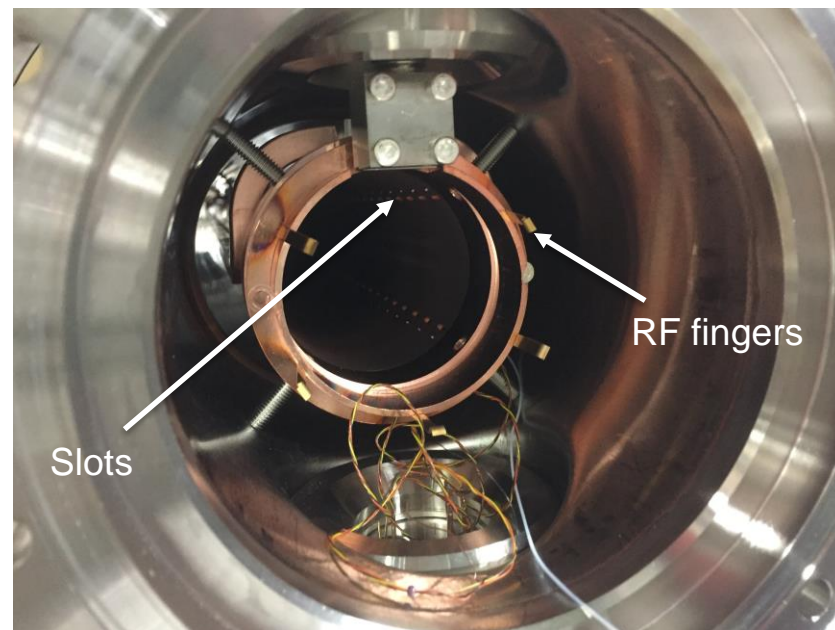
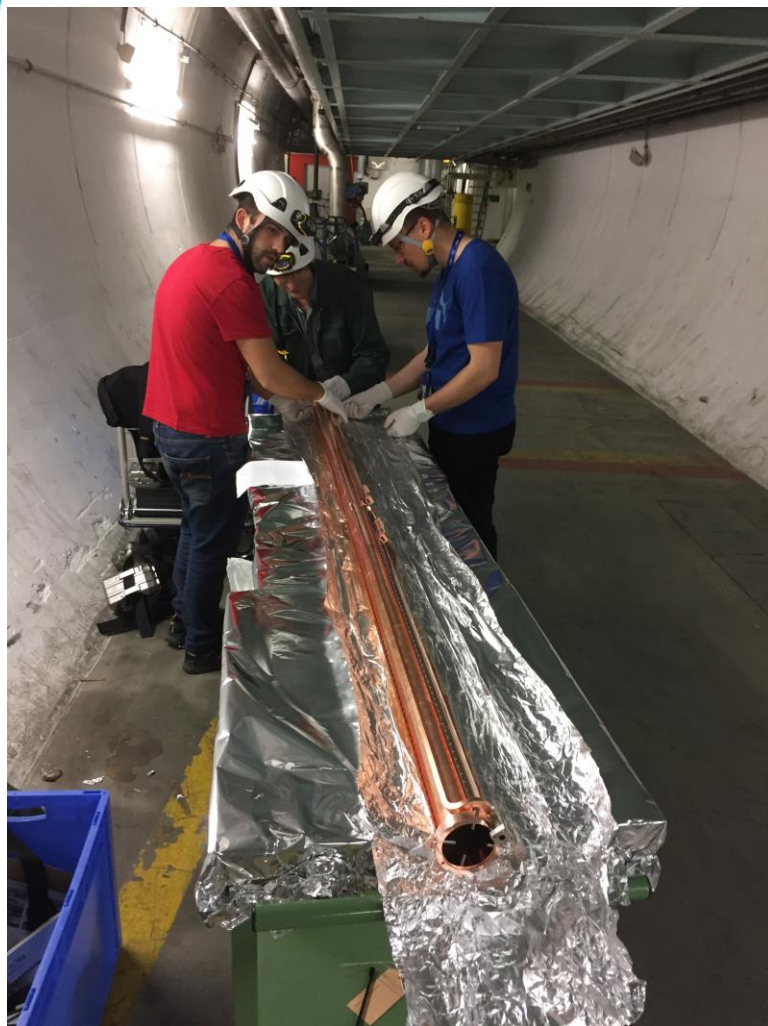
Laser Treatment Studies with COLDEX

- COLDEX Studies with SPS beams:
 - a 2.2 m long LHC type cryogenic beam vacuum system
 - a **beam screen** temperature from 10 to 100 K and a **cold bore** temperature from 3 to 4.5 K
- Measure of pressure, heat load and electron activity without and with gas condensates



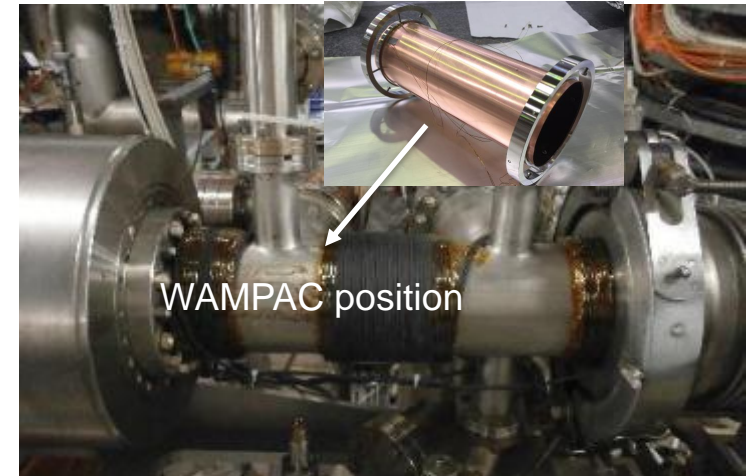
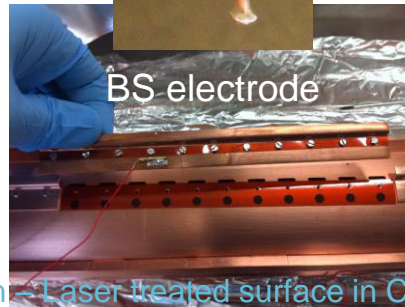
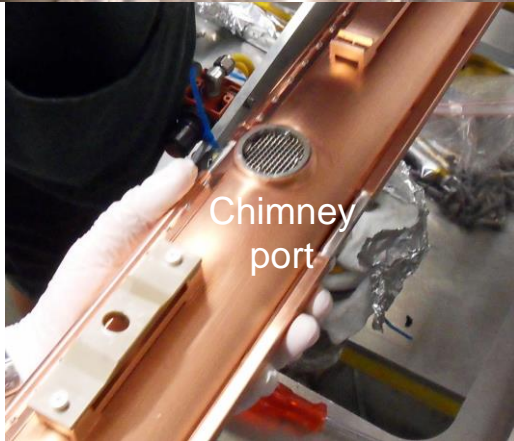
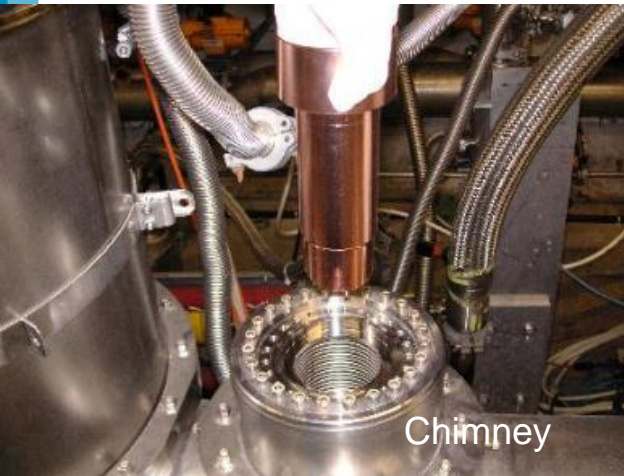
COLDEX LESS Beam screen

- ~2.2 m, ID 67 beam screen
- 1% perforated with slots (7.5x2)
- Laser treated surface



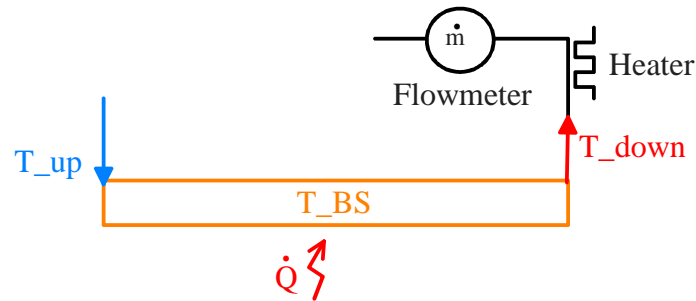
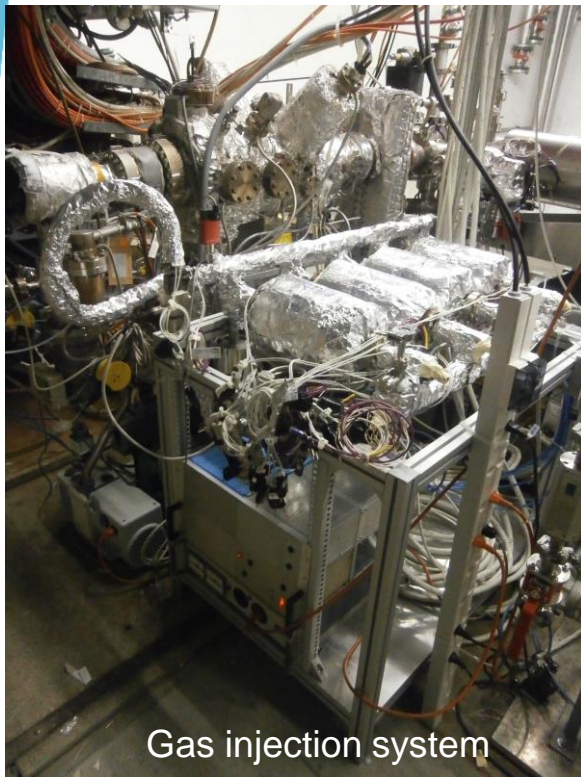
COLDEX instrumentation

- A **chimney**, located in the middle of COLDEX, collected the gas from the BS held at cryogenic temperature
- **Electrodes** are inserted into the chimney and behind the BS slots
- **Solenoids** are wrapped at the COLDEX extremities

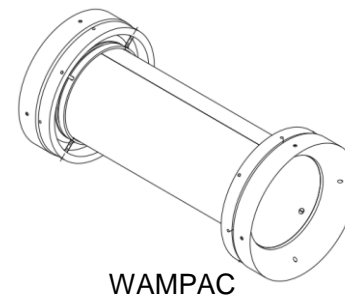
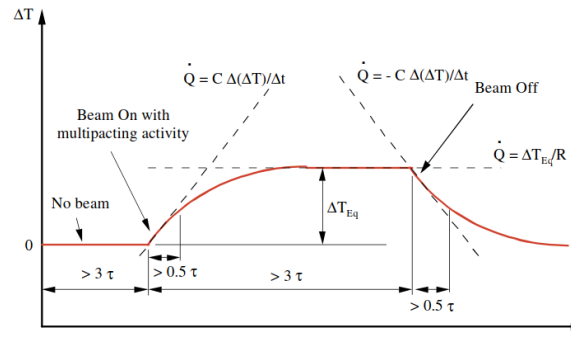
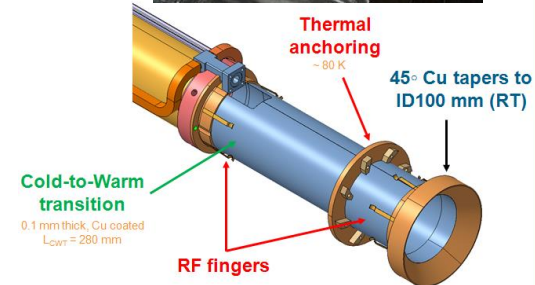
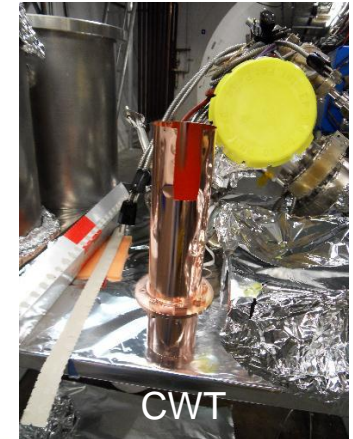


COLDEX instrumentation

- Total and partial **pressures** can be measured in the centre and at the extremities
- **Heat load** onto the BS can be derived from temperature sensors and He flow meters
- Warm calorimeters (**WAMPAC**) are installed at each extremities
- Cold warm transitions (CWT) are installed at each extremities
- **Gas injection system**



$$\dot{Q} = \dot{m} [h_{He}(T_{down}) - h_{He}(T_{up})]$$



$$\dot{Q} = \frac{\Delta T_{eq}}{R}$$

$$\dot{Q} = c \frac{d\Delta T}{dt}$$

2. Results

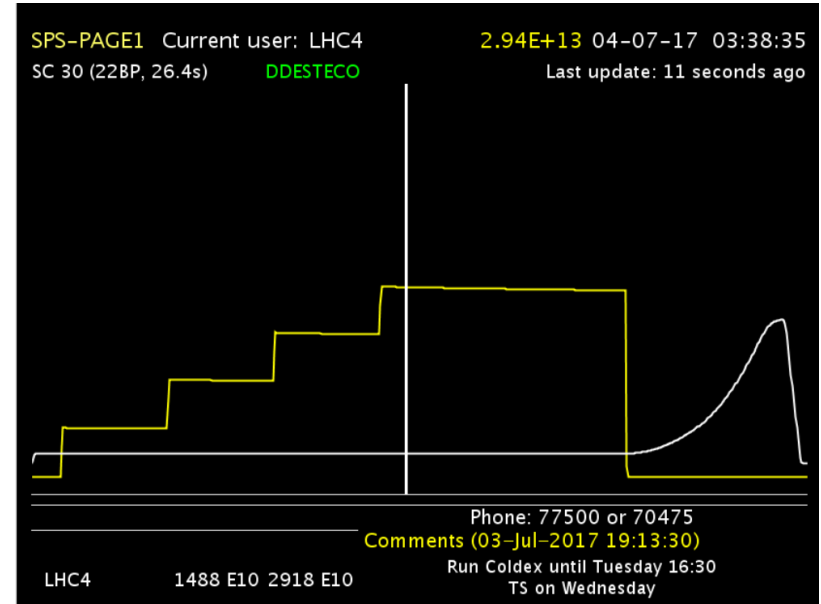
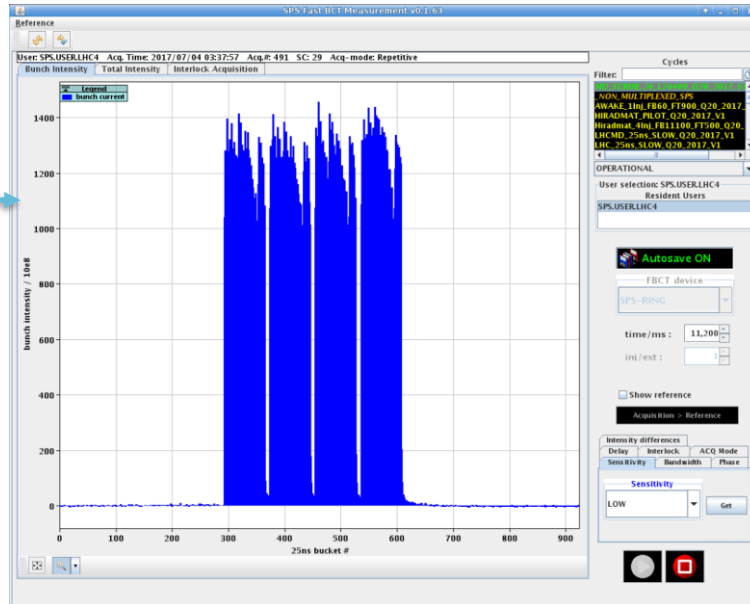
COLDEX: SPS MD requests

- 8 SPS dedicated MD requests submitted to address experimentally the performance of LESS in cryogenic systems
 - additional studies will be requested in case of unexpected multipacting behaviour, resistive wall impedance heating, gas surface effect etc.
- In parallel: vacuum characterization at cryogenic temperature, without beam, with all gases of interest (COLDEX GIS)

CERN Machine Development			MD Requests	New MD Request	Beams	Schedule	rsalemme	
SPS (8)								
Dedicated: 8 (192h requested)								
MD2111: COLDEX LESS treatment - BS 5-20 K (24h requested)			MD1- 3 rd July 2017			Created by Roberto Salemmme		
MD2114: COLDEX LESS treatment - BS 40-80 K (24h requested)			MD2- 20 th Sept. 2017			Created by Roberto Salemmme		
MD2115: COLDEX LESS treatment - Multipacting triggering (24h requested)						Created by Roberto Salemmme		
MD2116: COLDEX LESS treatment - H2 preadsorption (24h requested)						Created by Roberto Salemmme		
MD2117: COLDEX LESS treatment - CO preadsorption (24h requested)			MD3- 11 th Dec. 2017			Created by Roberto Salemmme		
MD2118: COLDEX LESS treatment - CO2 preadsorption (24h requested)						Created by Roberto Salemmme		
MD2119: COLDEX LESS treatment - H2O or high SEY gas preadsorption (24h requested)						Created by Roberto Salemmme		
MD2120: COLDEX LESS treatment - warm run (24h requested)						Created by Roberto Salemmme		

Operational conditions

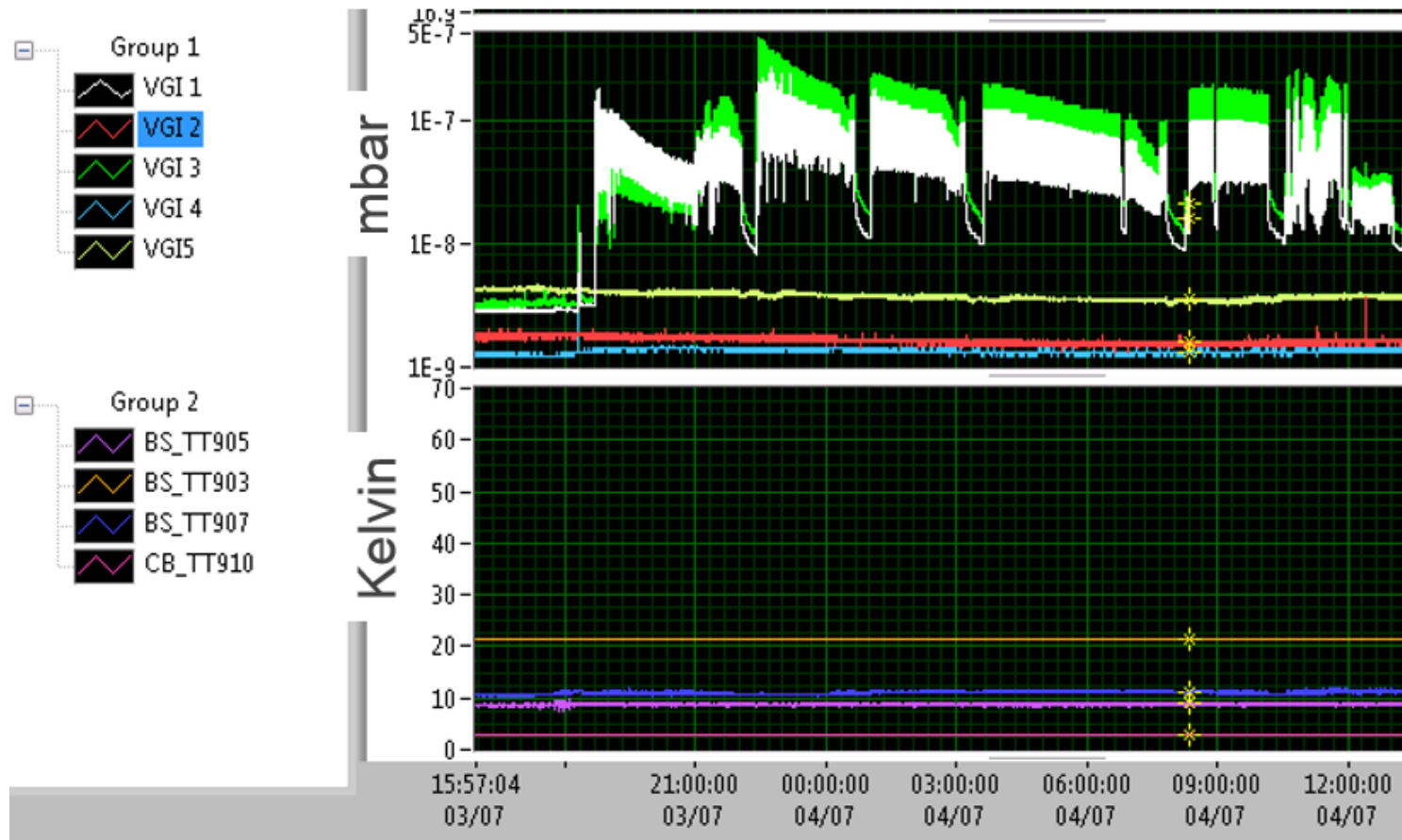
- Proton beam parameters
 - 4 batches of 72 bunches
 - 26 GeV
 - 0.9 to $1.4 \cdot 10^{11}$ protons per bunches



- COLDEX temperatures:
 - Beam screen at 10 K, 50 K and 50+/- 10 K
 - Cold bore at 3 K *i.e.* the vapour pressure from the CB is $\ll 10^{-10}$ mbar

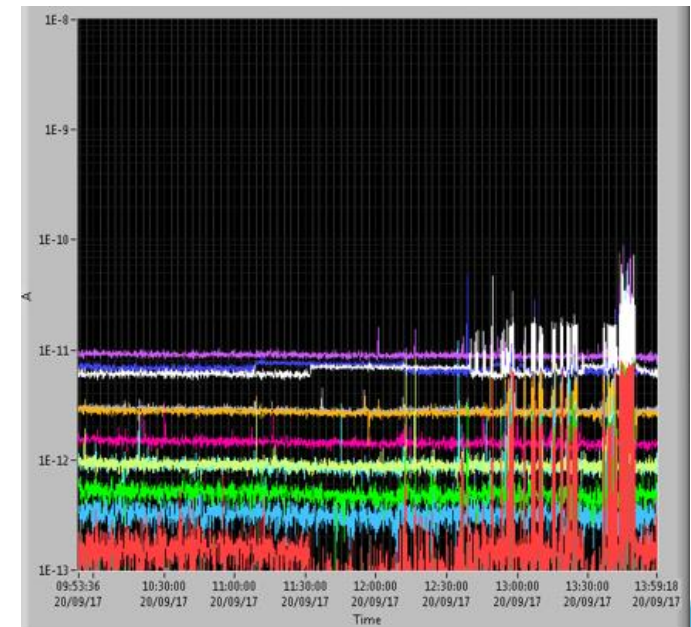
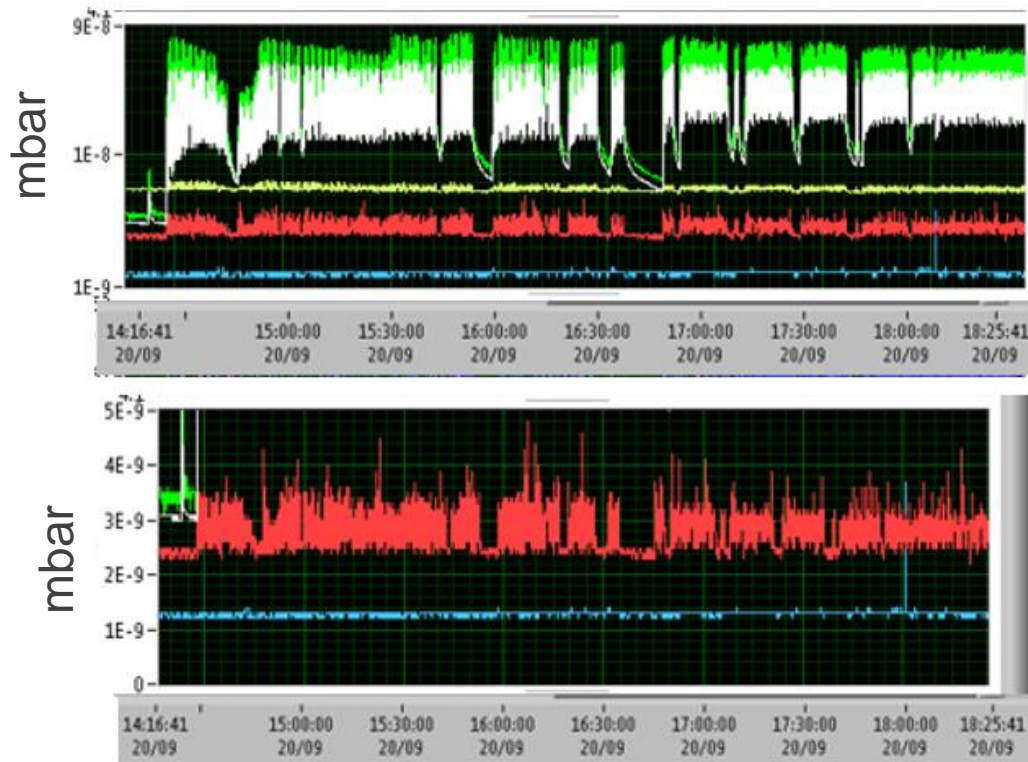
Pressure at 10 K

- Pressure rises in the 10^{-7} mbar range are observed at COLDEX extremities (green and white curve)
- At 10 K (red curve) :
 - $\Delta P < 10^{-10}$ mbar



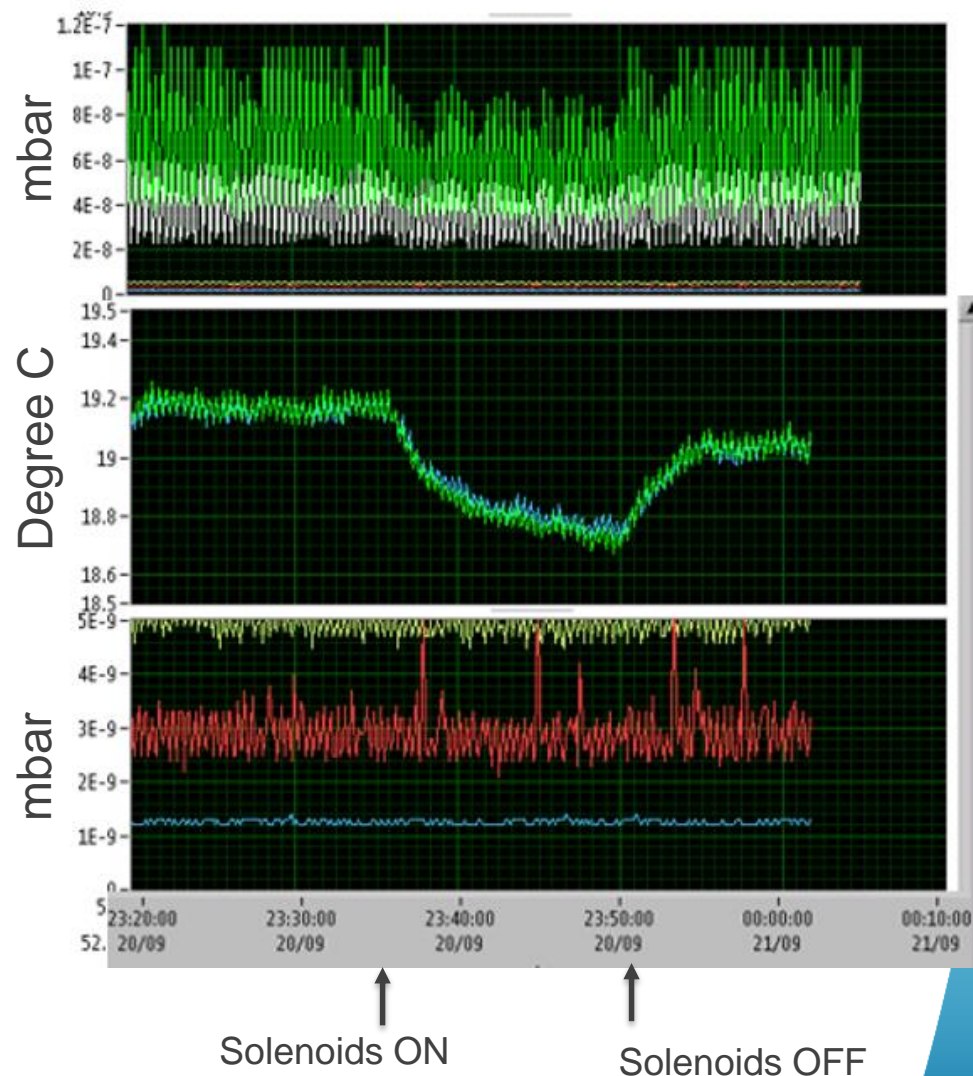
Pressure at 50 K

- Pressure rises in the 10^{-7} mbar range are observed at COLDEX extremities (left, green and white curve)
- At 50 K :
 - $\Delta P \sim$ a few 10^{-9} mbar (left, red curve)
 - H_2 is the main gas (right, white curve)



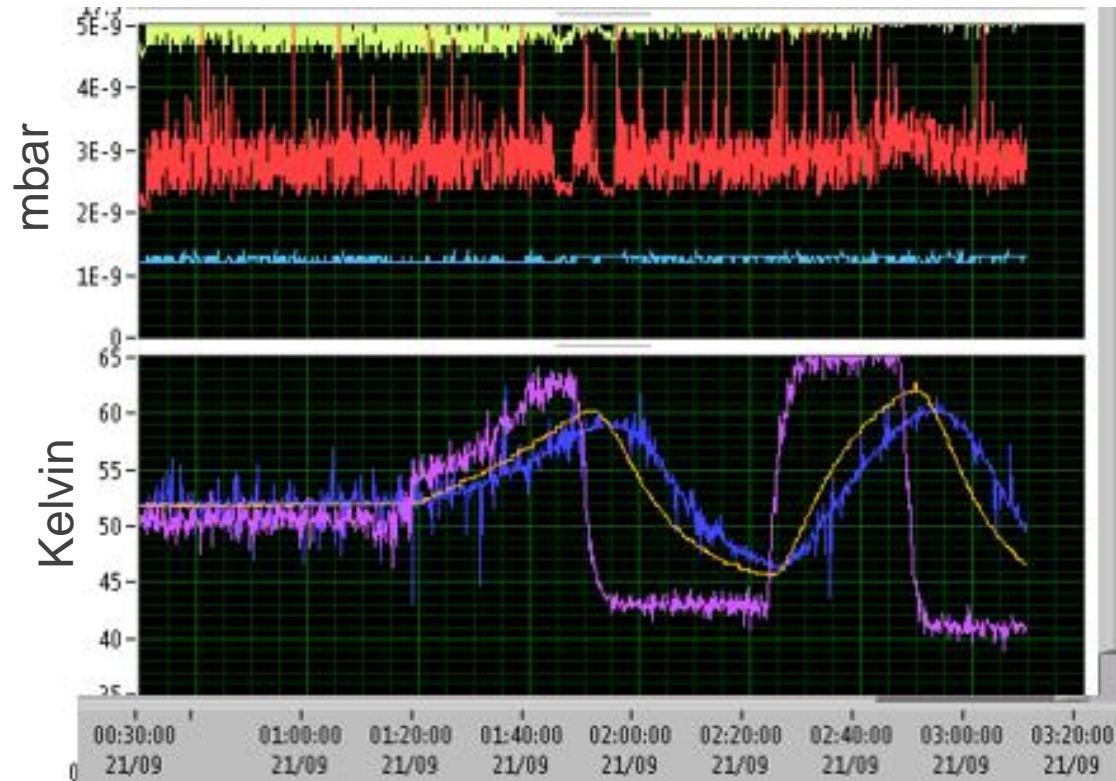
Pressure at 50 K: Impact of solenoids

- With beam ON, at 23:35, solenoids are switched ON, then OFF at 23:50
- Pressure at COLDEX extremities is reduced
- Dissipated power on Cu WAMPAC is reduced by ~ 0.3 W/m (green curve)
- Solenoids do not reduce the observed pressure:
desorption is happening inside COLDEX



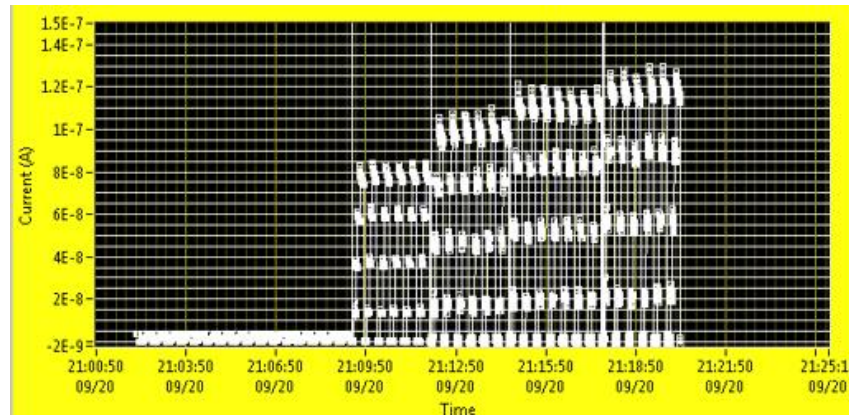
Pressure at 50 K: Oscillation studies

- The beam screen temperature was varied from 50 +/- 10 K:
No significant pressure excursion were observed



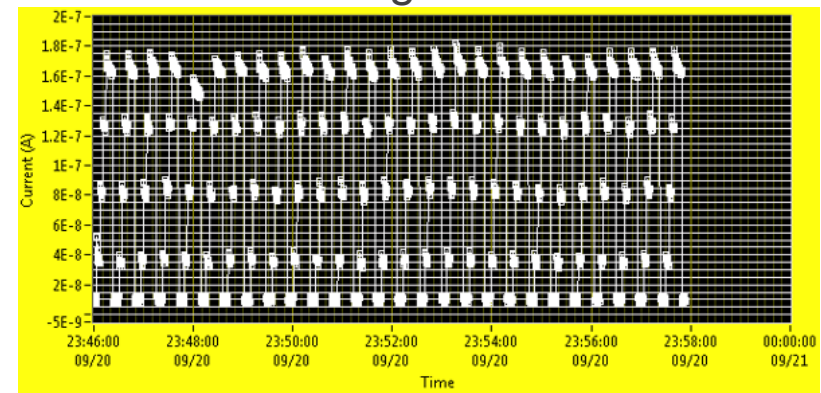
Electron activity

- When scanning the applied voltage from 0 to 80 V in step of 20 V, electron current up to $\sim 0.1 \mu\text{A}$ were measured at the beam screen electrode



- Applying a solenoid field at the COLDEX extremity did not reduced significantly the measured current with the electrode voltage set at 500 V

Collected electrons are produced inside the beam screen

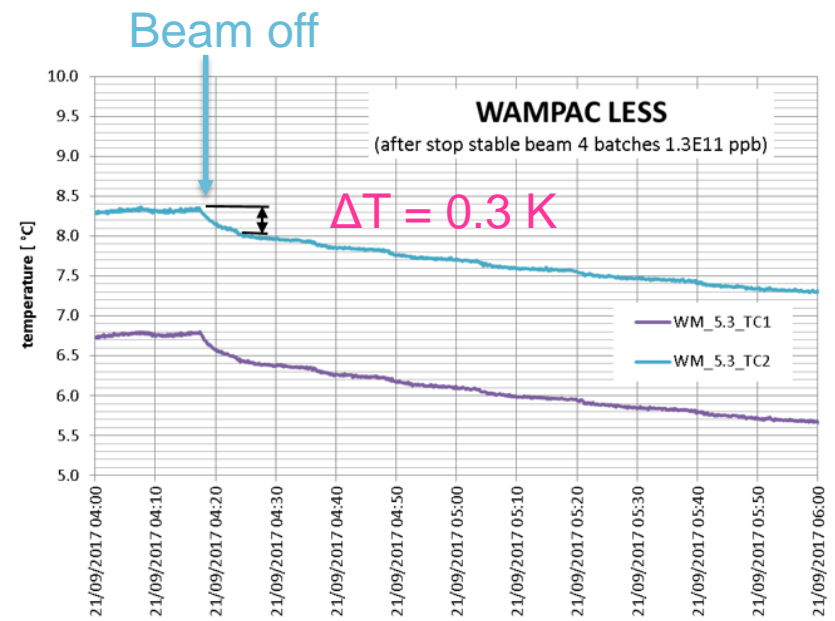
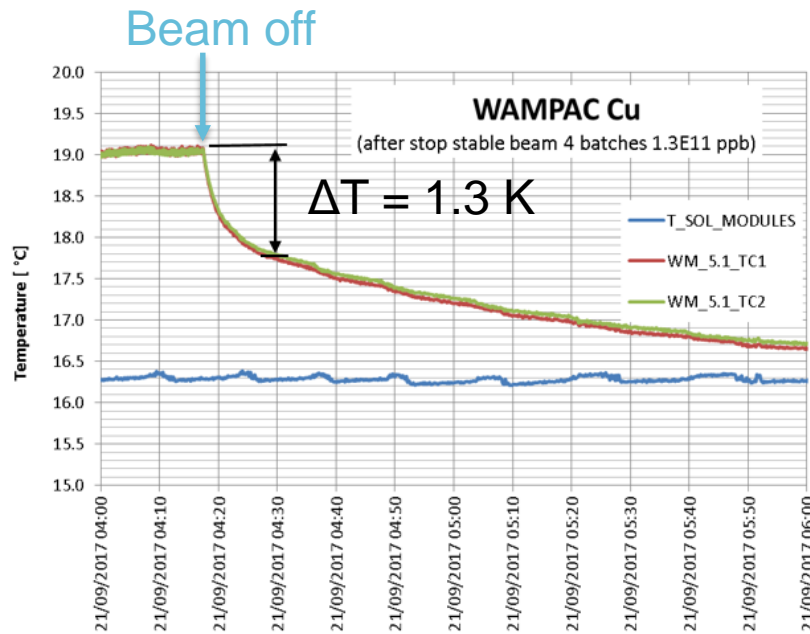


← Solenoids ON Solenoids OFF →

- NB: The chimney electrode did not measured any current above 5 nA

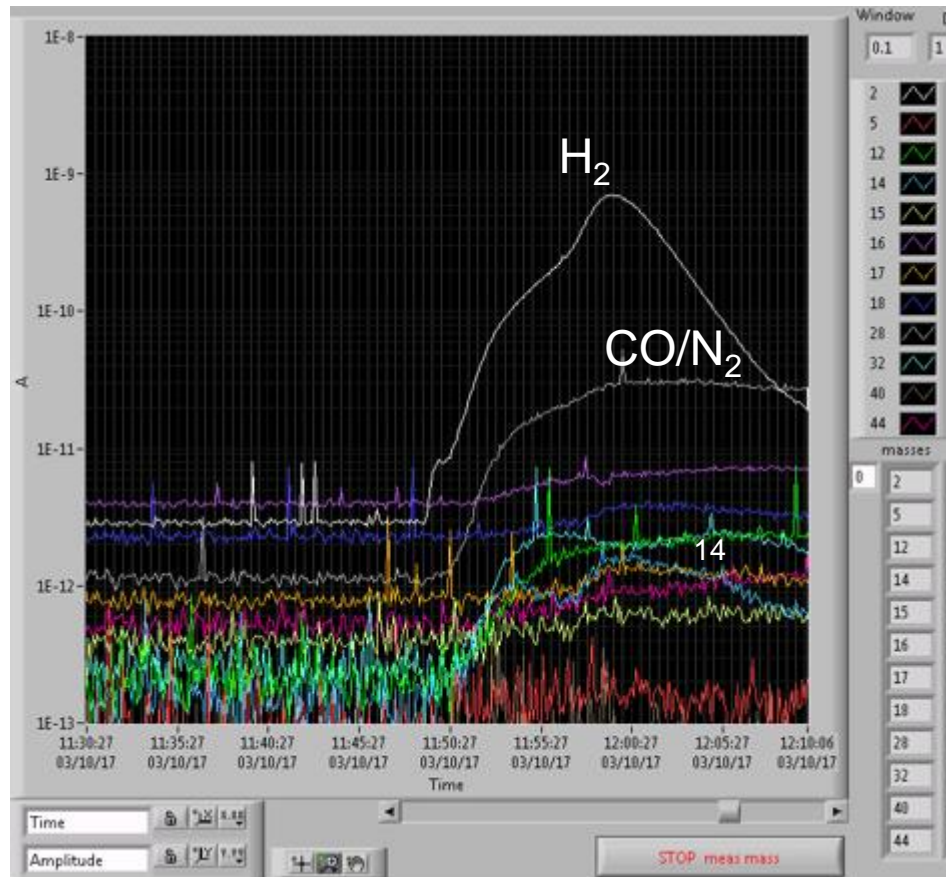
Heat load

- On the beam screen held at cryogenic temperature:
 - Observed heat load ≤ 0.5 W/m
- At room temperature, heat load are observed on the Cu and LESS WAMPACs:
 - WAMPACs are *in-situ* calibrated by Joule effect (sensitivity ~ 70 mW/m)
 - Cu: 0.9 W/m (in agreement with previous observations and $\delta_{\max} \sim 1.3$ -1.4)
 - LESS: 0.2 W/m
 - all sources included (electrons, ions, impedance, losses)



Natural warm-up

- Beam screen desorbed first (CB at 2.8 K)
- H₂ desorption peak is observed between 20-30 K
- N₂ and (or) CO is desorbed between 30-35 K



3. Summary

Summary

- The COLDEX **Laser Engineered Structure Surface** (LESS) beam screen was produced from segments which were laser treated at the University of Dundee and assembled at CERN
- So far, two MD were performed in the SPS
- The results showed that the **LESS mitigates multipacting at cryogenic temperature** in the studied range (10– 50K):
 - Heat load are below 0.5 W/m
 - Pressure rise are in the range of a $\sim 10^{-9}$ mbar
 - Electron activity has been observed on the beam screen electrode but not on the Chimney one (sensitivity?)
- Thermal desorption studies showed that **H₂ is desorbed** from the LESS surface **in the range 20-30K**. N₂, is also observed, probably due to air trapping within the LESS.
- **Some heat load** (~ 0.2 mW/m) was measured on the LESS surface held **at room temperature**
- Future characterisation with and without beam will be conducted in 2018

Acknowledgments

- STFC, University of Dundee, TE-VSC and EN-MME colleagues for the deep commitment towards the beam screen production, & assembly on time for installation in the COLDEX bypass
- TE-CRG and BE-OP for providing a high quality of support with excellent cryogenic and beam performances during the studies
- TE department, the HL-LHC project and the FCC study offices for the support



Thank you for your attention



A Natural Warm Up of a St. Steel Cold Bore

COLDEX #14 19-25/3/99,
Cu BS. Natural warm up of CB at 2.2 K/h (TBS>20 a 50 K)

