

**eeFACT – 2022**

Sept-5th 2022

**Status report of vacuum system of ESRF**

**Cristian Maccarrone**



**The European Synchrotron**

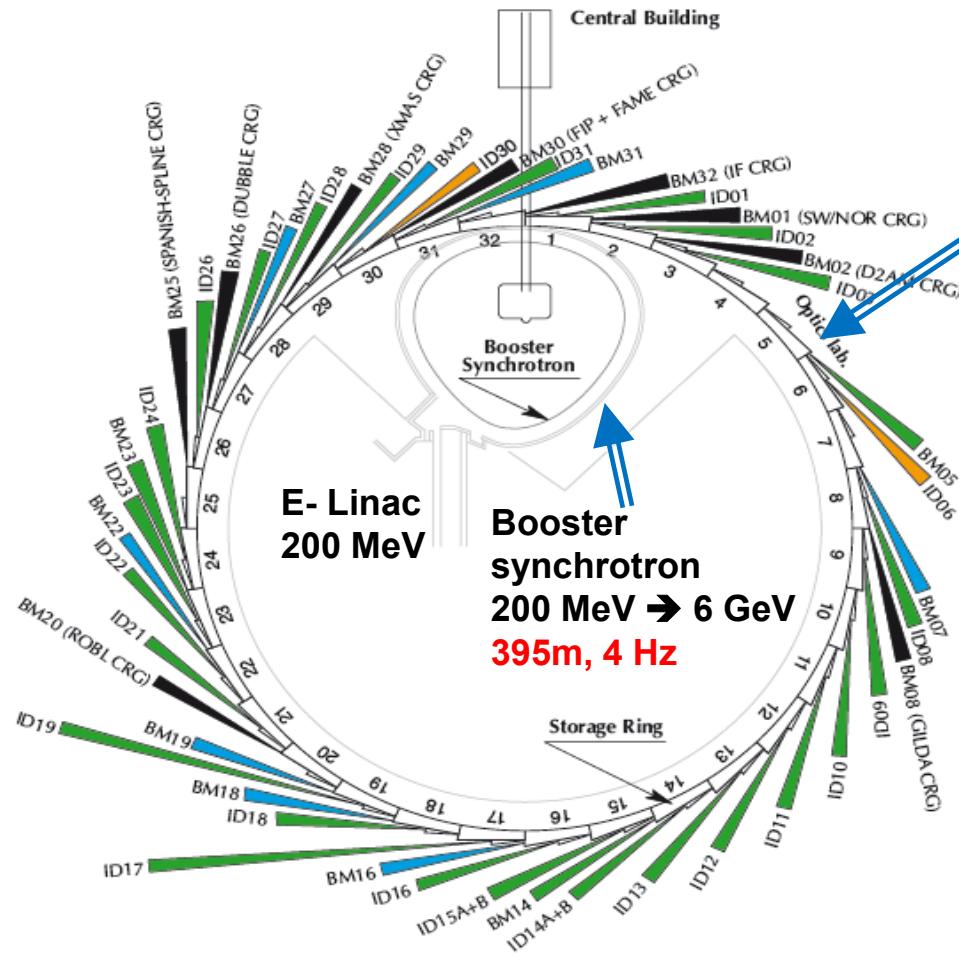
Design

Assembly, Installation

Conditioning

Operation - Reliability / Improvements

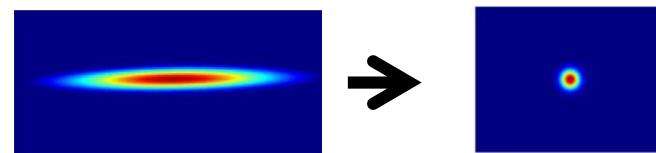
# DESIGN - NEW ESRF - EBS



**Storage ring  
6GeV, 843.39 m**

Energy	GeV	6.00
Multibunch Current	mA	200
<b>Horizontal emittance</b>	<b>nm</b>	<b>0.133</b>
Vertical emittance	pm	5

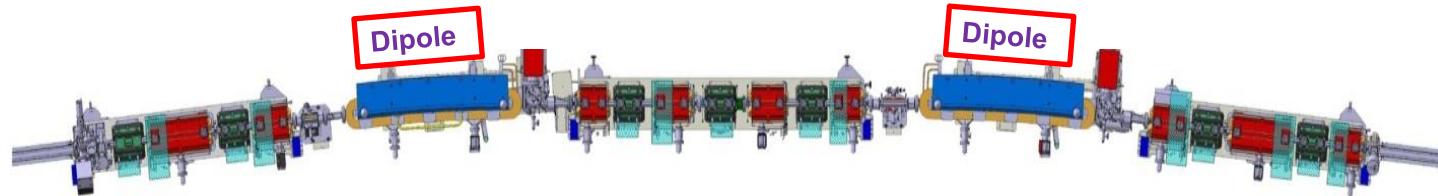
- Fit in the same tunnel, same FE and BeamLines positions, same injection...
- 32 cells with Straight Section + Arc



# DESIGN - LATTICE

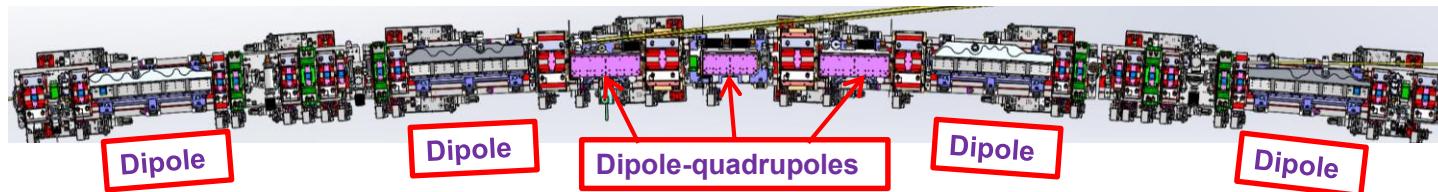
- **Old ESRF lattice**

Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell - ID length = 5 m (standard) / 6m / 7m



- **New EBS lattice**

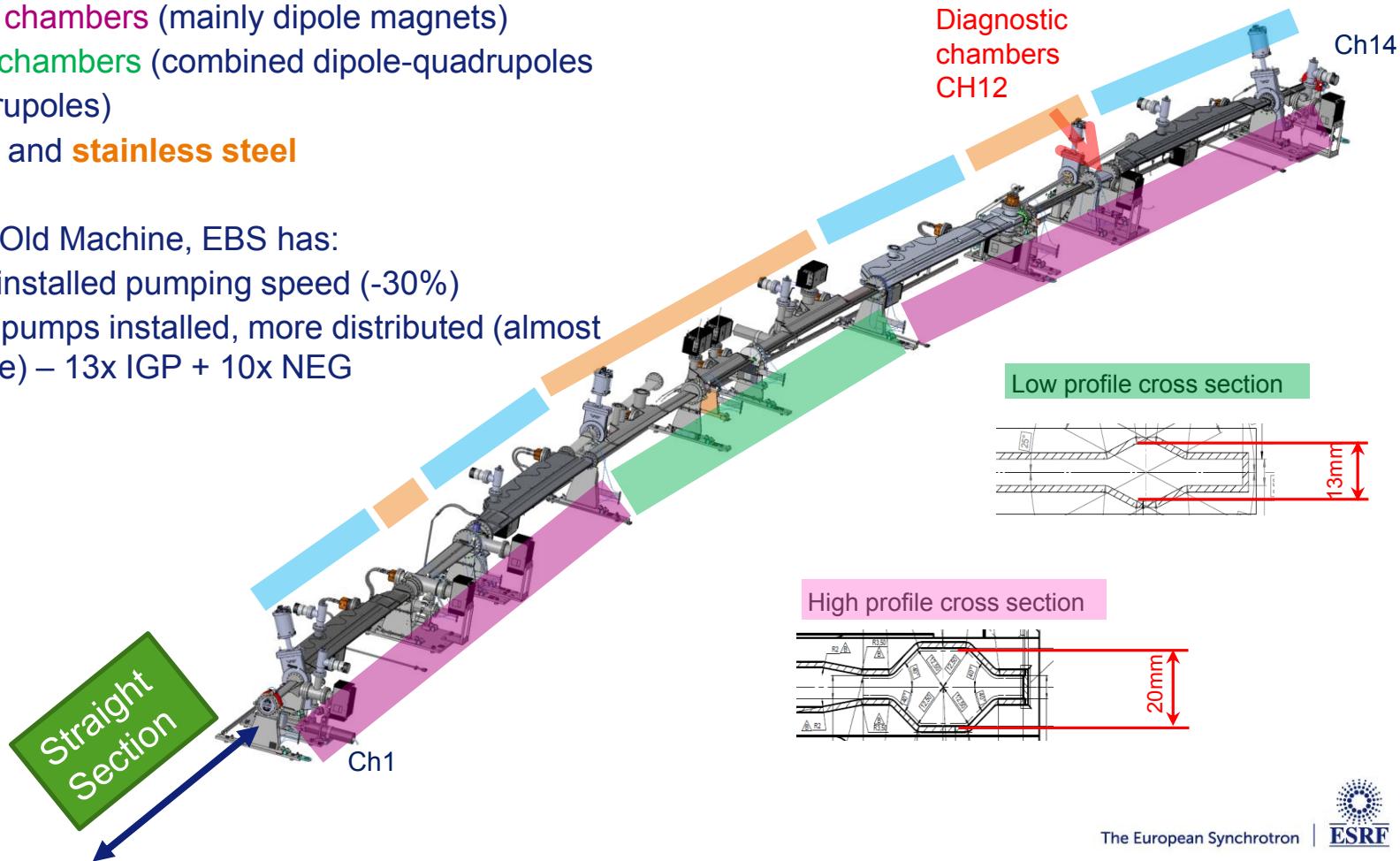
Hybrid 7 Bend Achromat = (4 dipoles + 3 dipole-quad + 24 quad., sext., oct.) per cell - ID length = 5 m



**31 magnets per cell instead of 17!**

# DESIGN - VACUUM CHAMBERS - ARC

- 12 Chambers per arc
  - High profile chambers (mainly dipole magnets)
  - Low profile chambers (combined dipole-quadrupoles & HG quadrupoles)
  - Aluminium and stainless steel
- 
- Respect to Old Machine, EBS has:
    - Less installed pumping speed (-30%)
    - More pumps installed, more distributed (almost double) – 13x IGP + 10x NEG



# DESIGN - VACUUM CHAMBERS – STRAIGHT SECTIONS

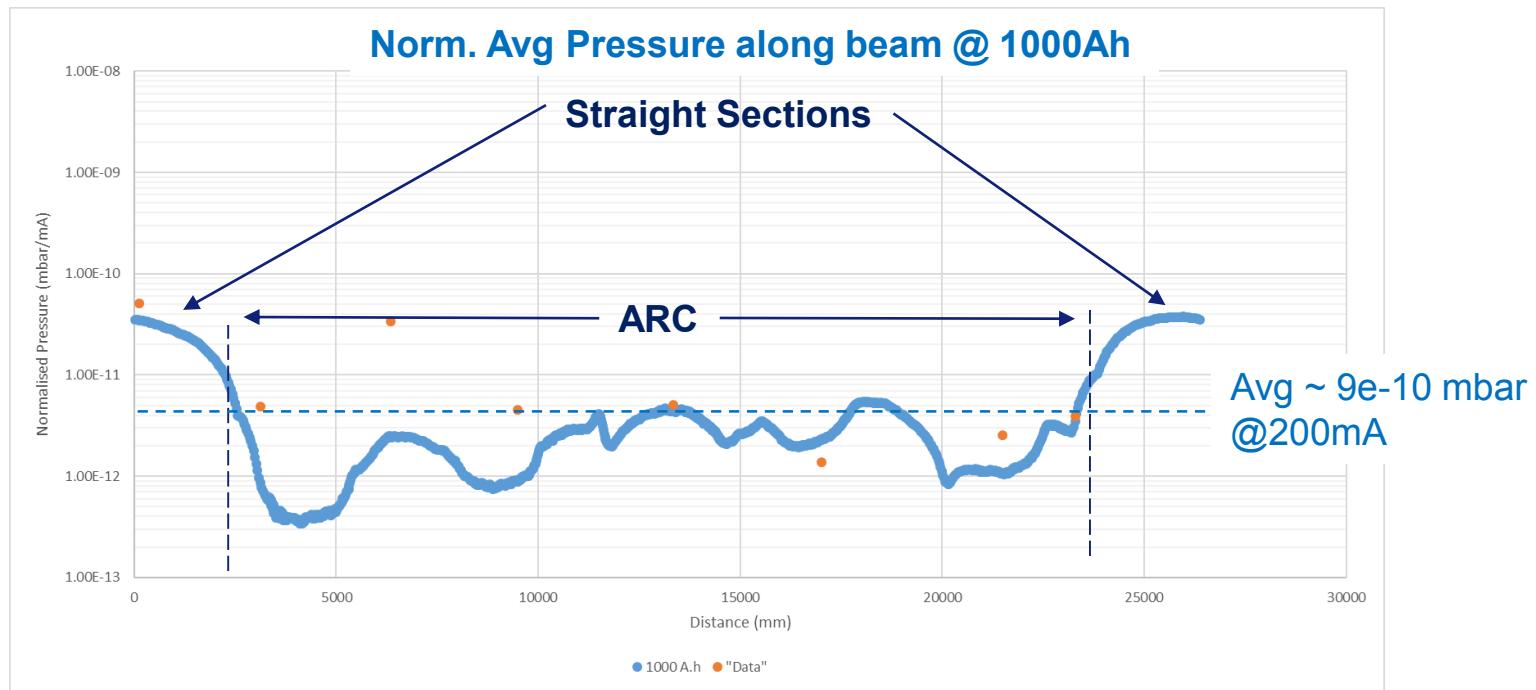
32x STRAIGHT SECTIONS (7m long)

- **2x chamber at extremities for quadrupoles**
- Internal “real” straight section 5m long
- 1x Injection
- 3x RF Cavities
- 13x with IN-VACuum Undulator
- 15x with IN-AIR Undulator
  - **Aluminum chambers (ID-5000)**
  - elliptical section 8 x 56 mm 5m long
  - NEG coated
  - Highest pressures in the SR
  - Cell-14 used to pre-condition NEG coated chambers



## DESIGN – SIMULATED PRESSURE PROFILE @1000 A\*H

- Gas: 90% H<sub>2</sub> and 10% CO
- Pumping speeds: all nominal
- PSD yields:
  - as measured at ESRF desorption beamline for copper (different from real one used CuZrVd)
  - as measured at ESRF desorption beamline for NEG coated IDs



Design

**Assembly, Installation**

Conditioning

Operation - Reliability / Improvements

# ASSEMBLY – COATING CH1 & CH14 (AND ID CHAMBERS)



## CH-1 and CH-14

- All chambers (34+34) NEG coated at ESRF
- 2x chambers per run
- One week each run roughly



ID

- All IDs chambers (22) - All 5m long

# ASSEMBLY AND INSTALLATION

## Assembly

- By girder in dedicated area
- Bake-out, alignment
- Stored under N2



## Installation

- 32 ARCS + 32 Straight Section installed and baked in 8 months



- **No big issue unless burst-disks (over-pressure protection) opening during bake-out...!!!!**

Design

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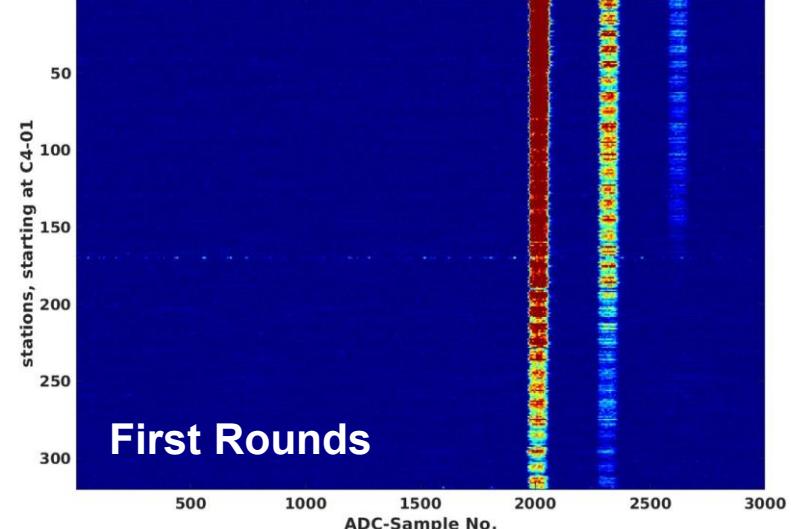
Operation - Reliability / Improvements

# CURRENT RUMP-UP

Tue-Nov-26<sup>th</sup> Tunnel closed  
One week ahead of plan

2 Dec 2019

SUM of the 4 (absolute of) ADCs      Turn1    Turn2    Turn3



Static: Pavg 8e-10 mbar

On 28 Feb 2019

200mA Reached!

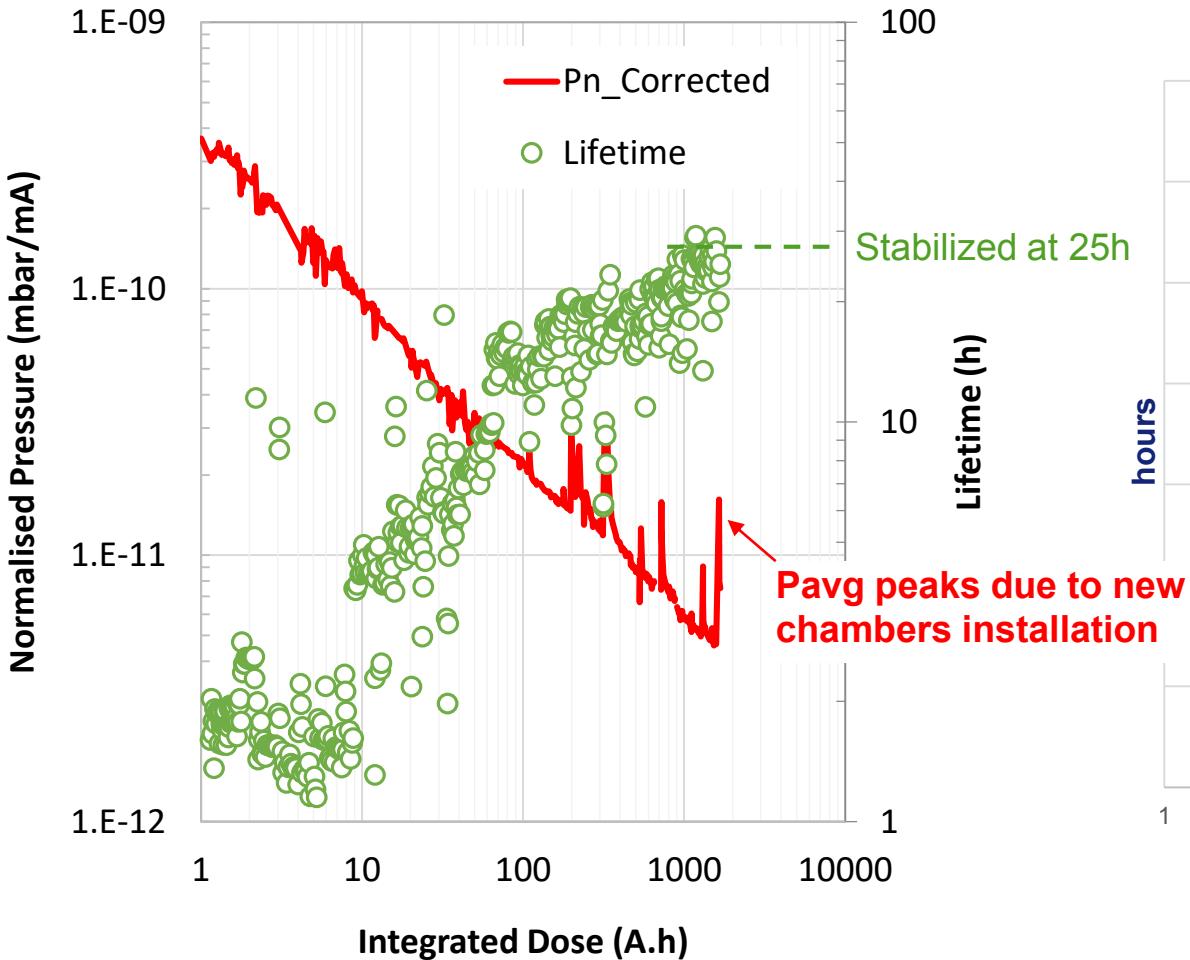


On 6 Dec 2019

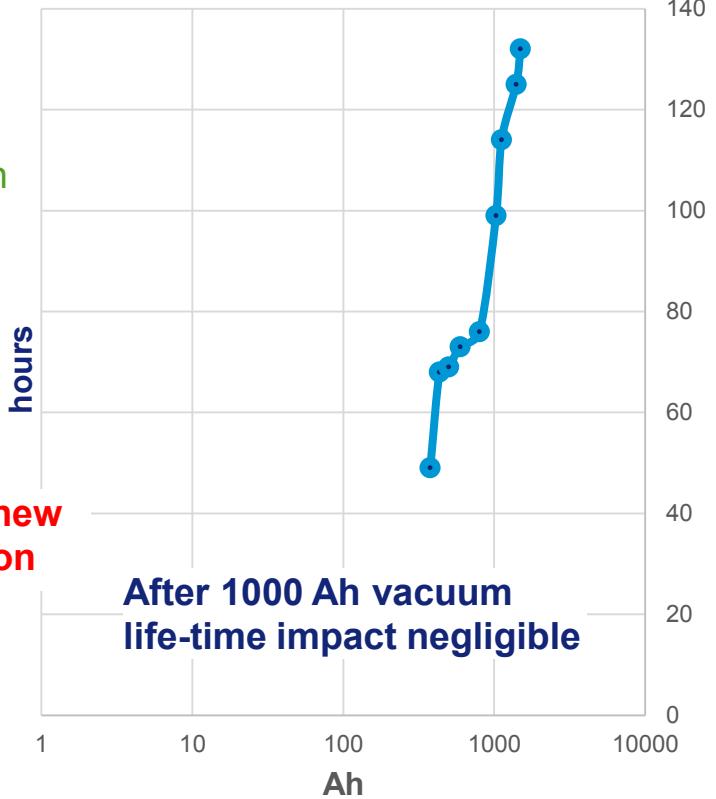


Dynamic: Pavg 6e-9 mbar

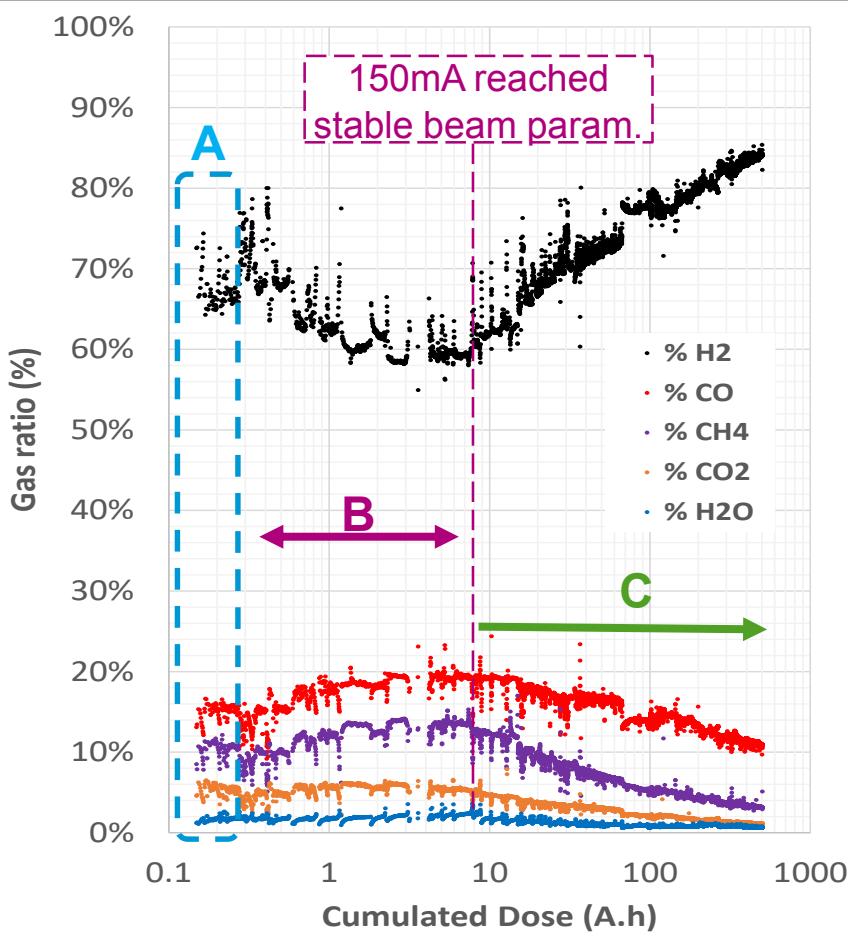
# CONDITIONING - LIFETIME



Vacuum Life Time vs Dose



## CONDITIONING – VACUUM QUALITY - RGA



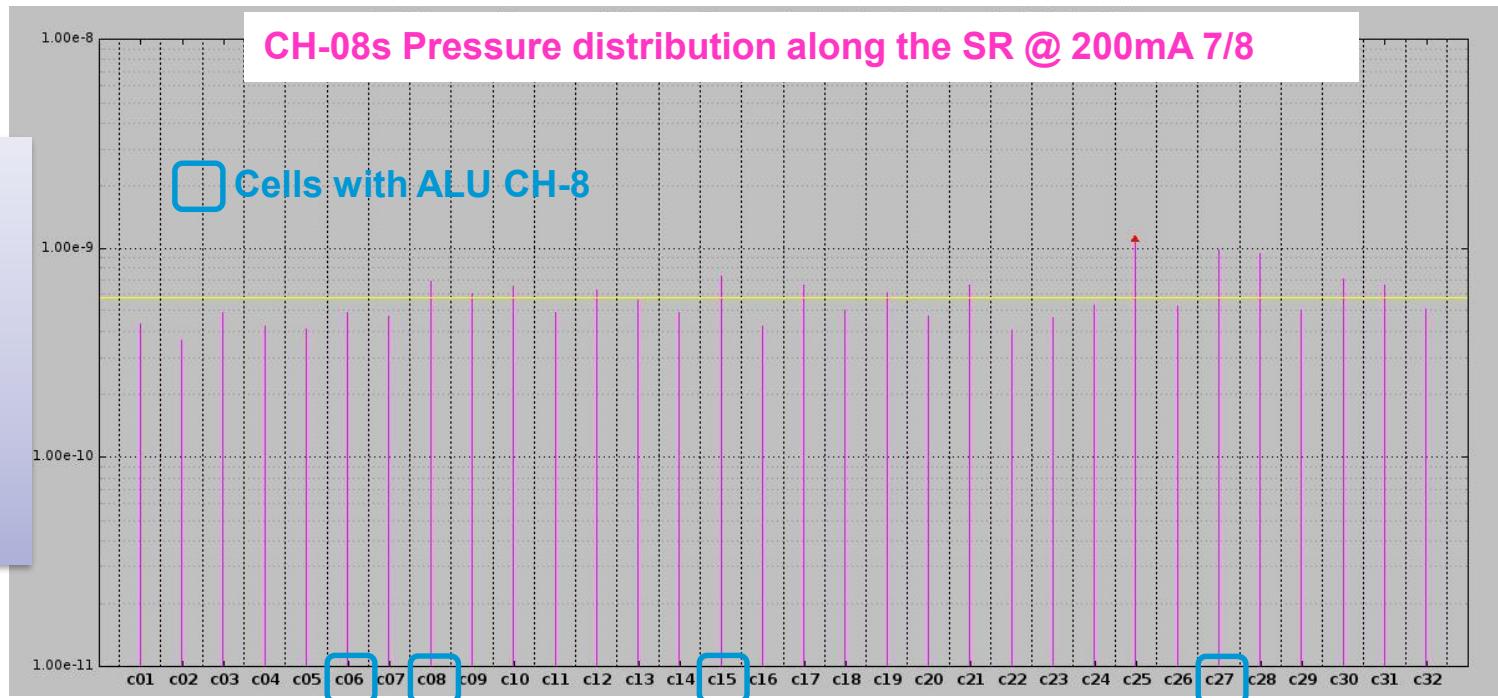
- Many RGAs permanently installed: 3x cell
- Static: 90% is H<sub>2</sub>
- **A - With beam, at the beginning, contribution of “other gases” increases, due to PSD**
- **B - The increasing trend for “other gases” before 10Ah, is due to the gradual current ramp-up and beam “waving”**
- **C - After stabilisation of operation parameters, the conditioning effect clearly becomes visible and H<sub>2</sub> becomes increasingly dominant**

# CONDITIONING – ALUMINUM CHAMBER

“Skepticism about usage of aluminum chambers due to high PSD”

CH8 example: 32 chambers, 4 of them made in ALU, the rest in SST

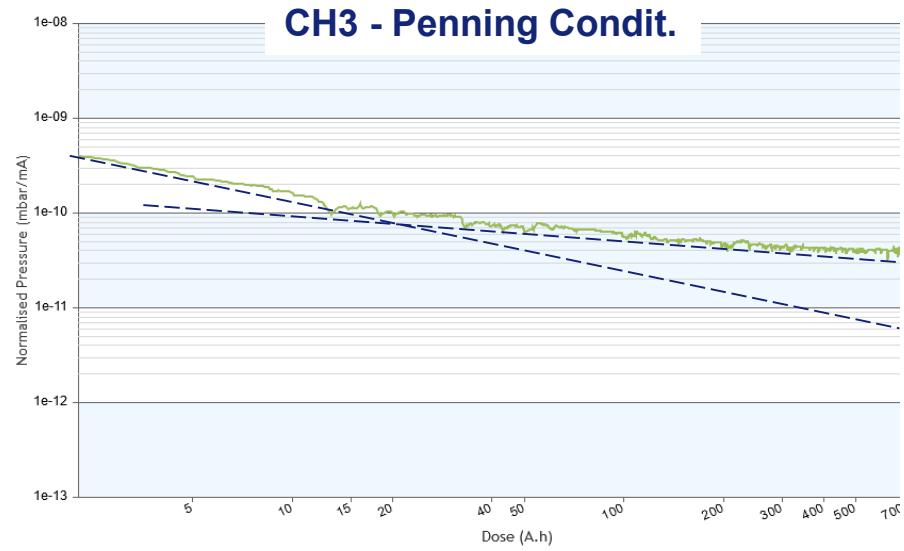
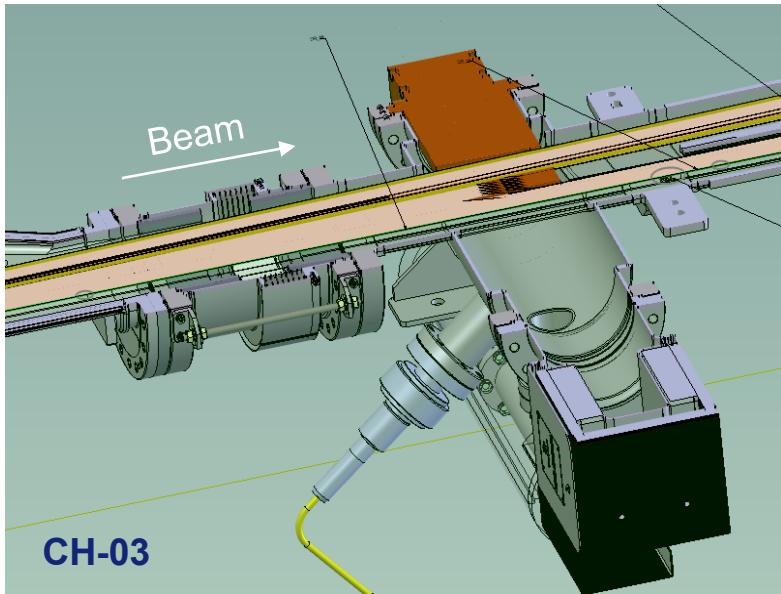
Same absorbers, pumps, RF fingers and positions



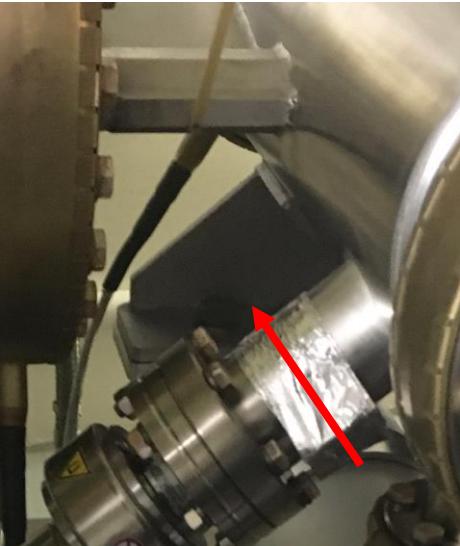
# CONDITIONING – GAUGES READING

Chamb-3 gauge “slowing-down” conditioning

Gauge reading affected

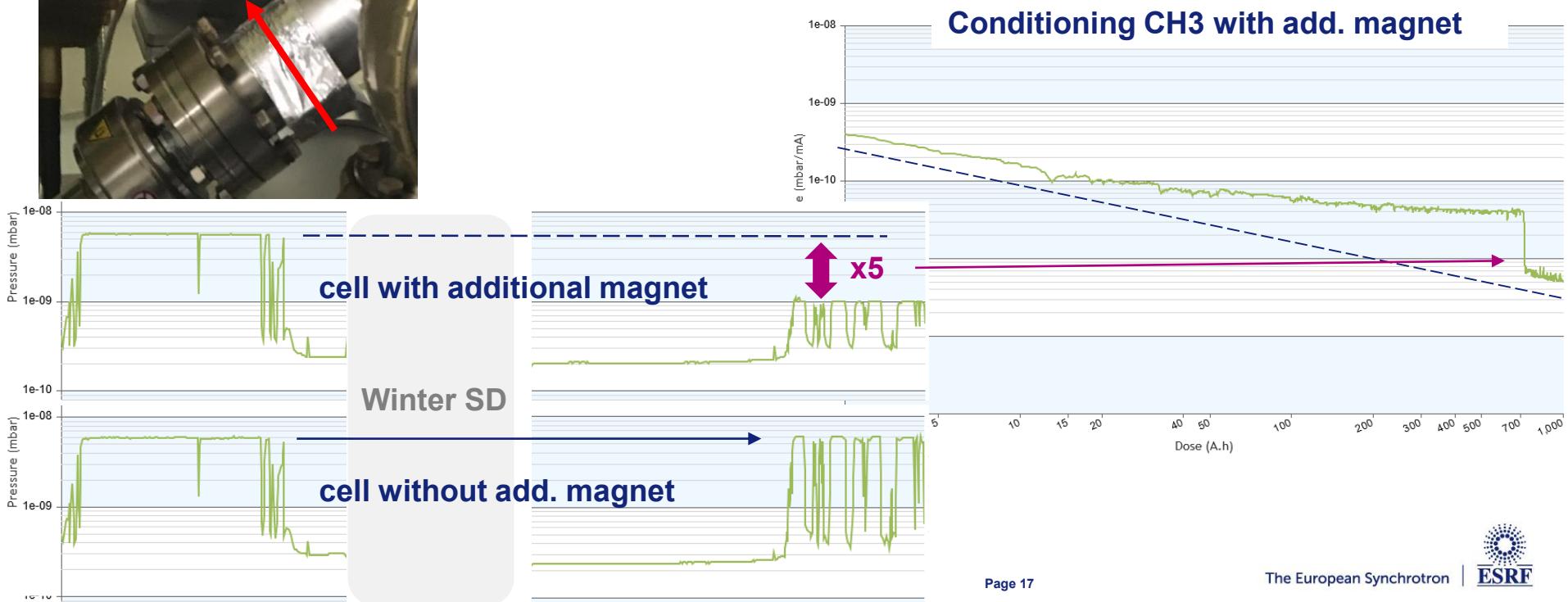


# CONDITIONING – GAUGES READING

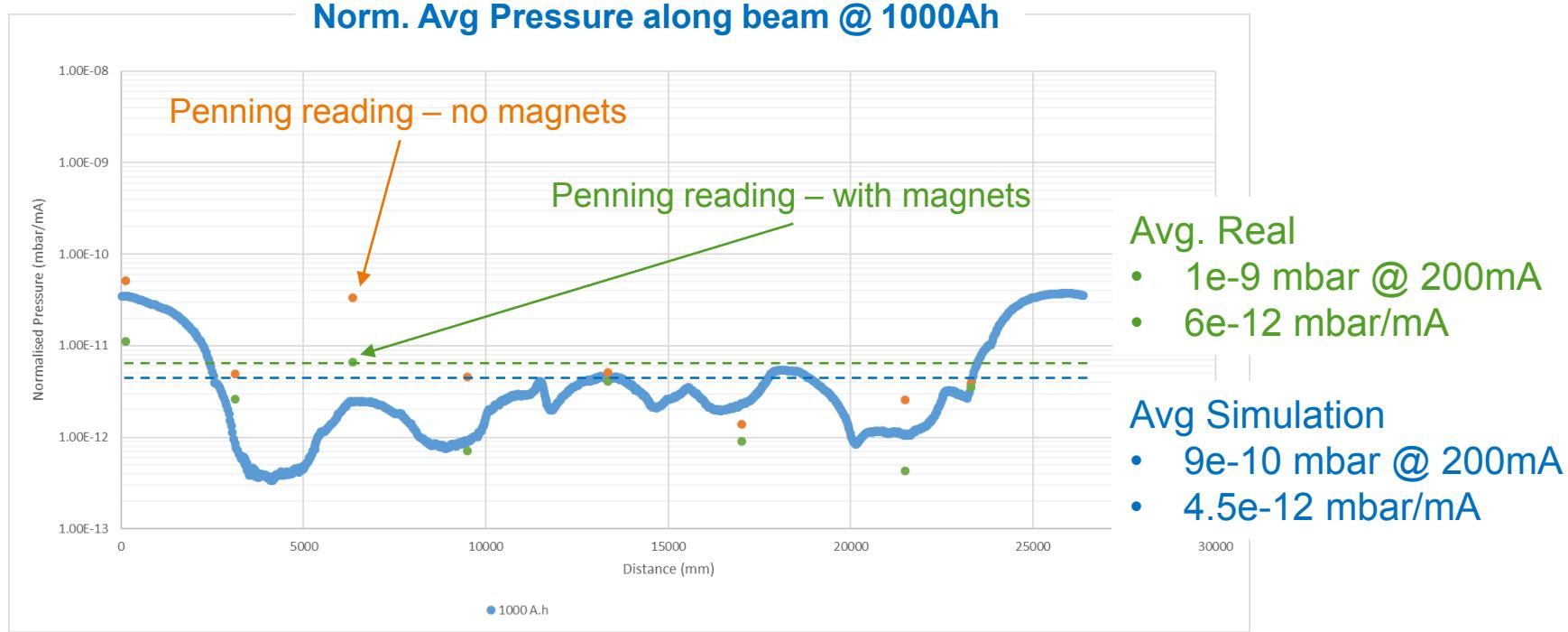


- **Secondary Electrons:**

- Installed magnets with mag field perpendicular to the gauge axis
- Pressure is about factor 5 lower and in line with IP



# CONDITIONING – READINGS VS SIMULATION @1000 Ah



Design

Assembly, Installation

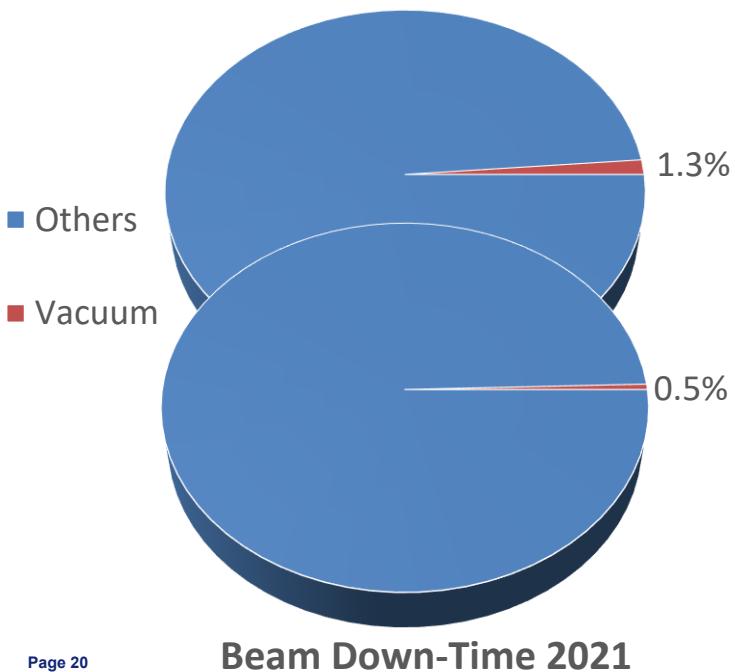
Conditioning

**Operation - Reliability / Improvements**

# 2021 - OPERATION - RELIABILITY

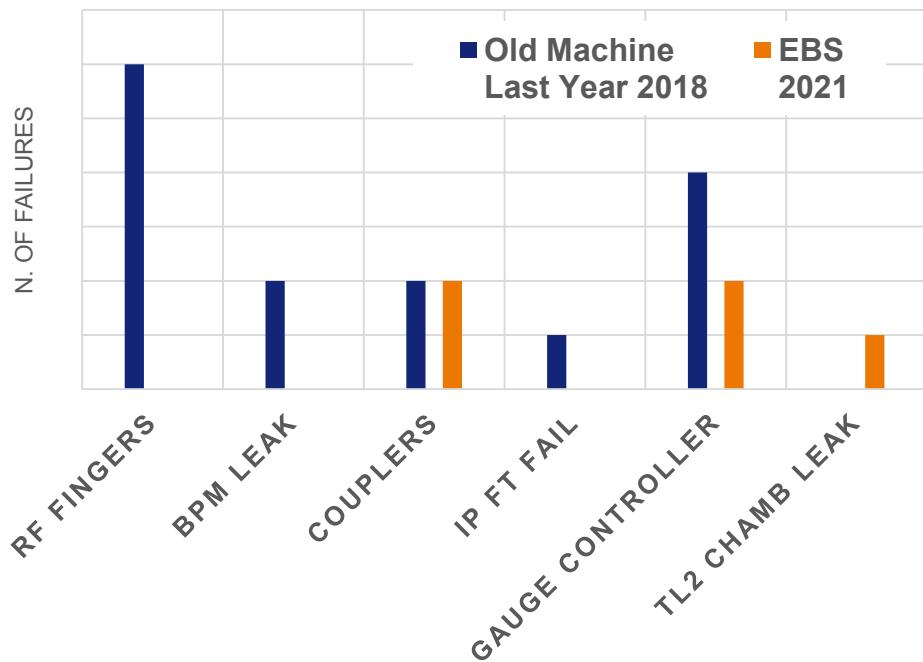
- 2021
  - stable parameters
  - machine conditioned
  - Machine availability > 96%

Beam Failures Events 2021



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OLD vs NEW MACHINE FAILURES



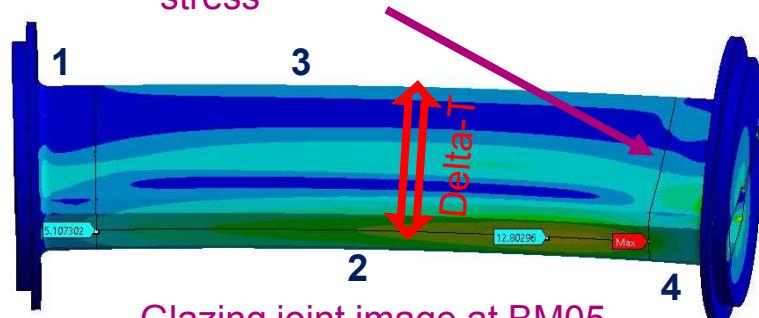
So all perfect ?!? 😊  
Almost... 😞

# OPERATION – KICKERS’ LIMITATION

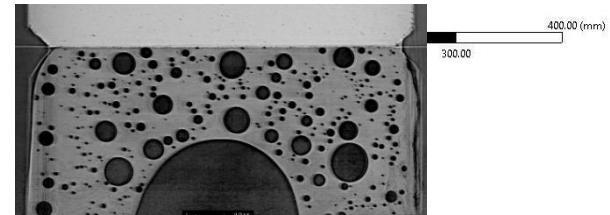
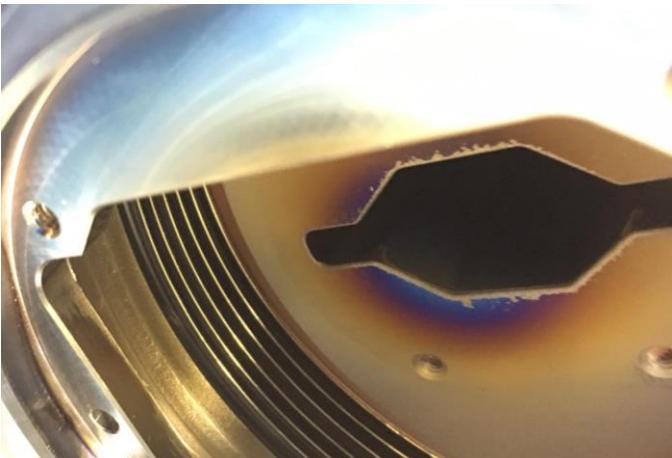
4x Kickers

- Complex internal shape: not symmetric, antechamber + tapered
- -> internal machining -> made of 4 ceramic parts glazed together
- Up to March-22 - limit at 32 mA in 16 bunch (nom. 96mA)
  - Mechanical stress due to thermal gradient
  - Cause cracks – leaks

Mechanical



Glazing joint image at BM05



Titanium **coating erosion** on corners

- not good contact between RF finger and ceramic
- Cause injection perturbation

## OPERATION - KICKERS

Two main activities/solutions

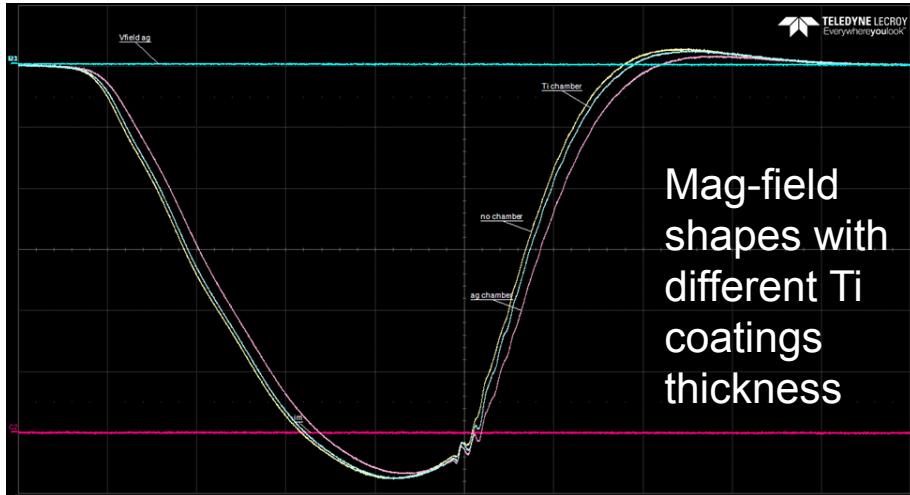
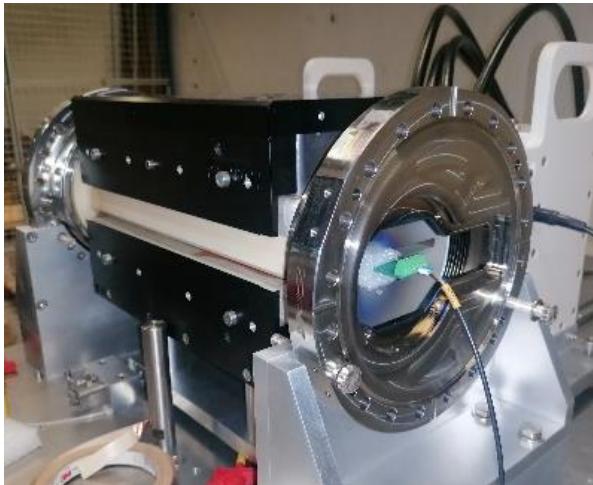
Existing kickers

Additional coating -> Reduce total resistance by factor 10 (20 -> 2 ohm)

Same power (hence stress) with x3 current (x9 power) -> 32 to 96 mA

New Kickers Design

Many tests, with different coatings (resistance) to be sure to not affect the mag field

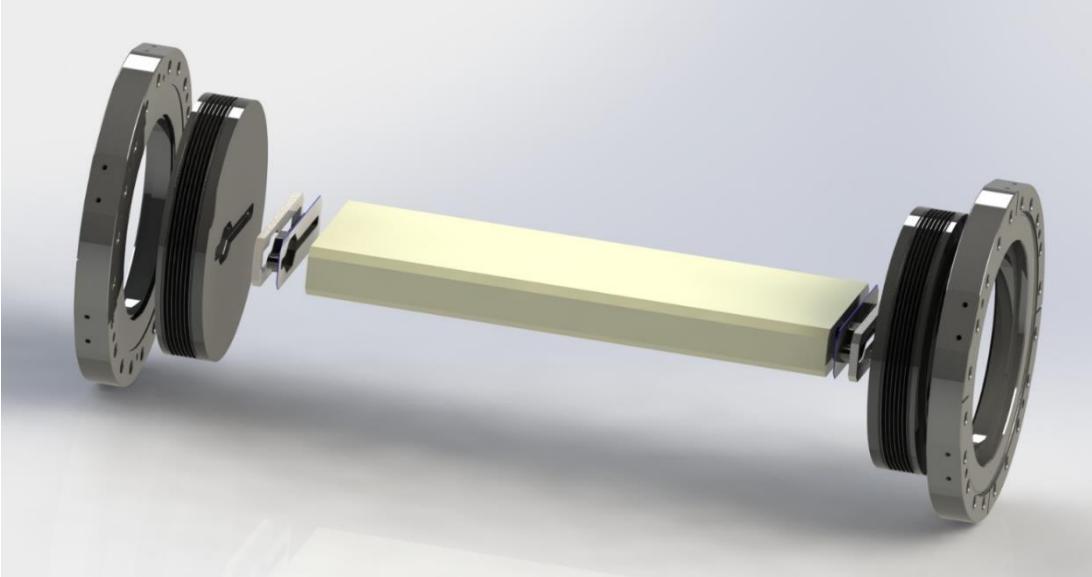


Installed in Winter and March ShutDown  
75mA in 16-bunch validated

Final test at full current to be scheduled (waiting for additional spares)

## OPERATION – KICKERS' NEW-DESIGN

- No glazing joints (single body)
- Common design for all 4x kickers (today we have one design for K1K4 and one K2K3)
- Production challenging due to internal shape
- **Installation foreseen by summer 2023**



## CONCLUSIONS

- **Assembly and installation of new EBS done on schedule**
- **Vacuum did not slowed down commissioning and full current has been achieved in 3 months**
- **The machine is well conditioned after 1000 Ah and impact of vacuum on lifetime is negligible**
- **Reliability of the machine, and in particular of vacuum, are very good**
- **Future developments are focused on kickers in order to achieve full current in timing modes**