

eeFACT – 2022

Sept-5th 2022

Status report of vacuum system of ESRF

Cristian Maccarrone



| The European Synchrotron

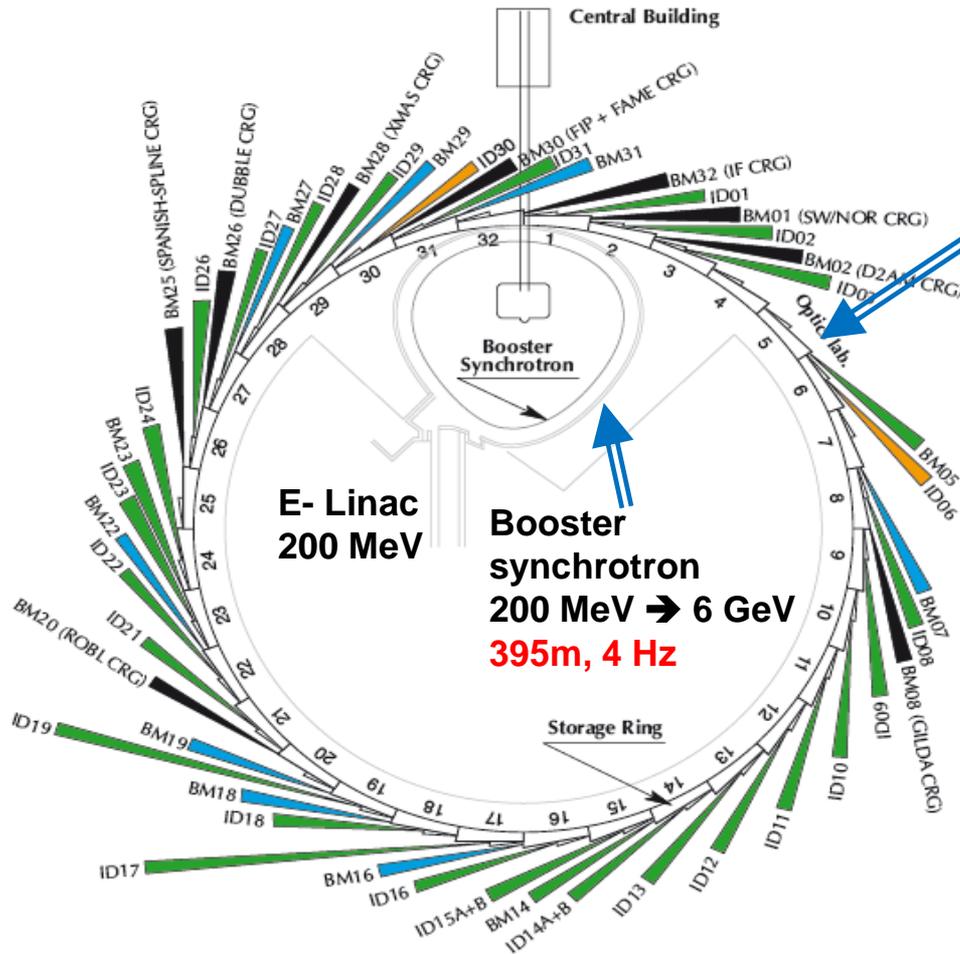
Design

Assembly, Installation

Conditioning

Operation - Reliability / Improvements

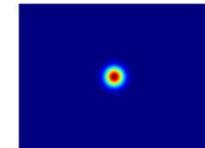
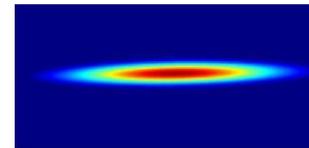
DESIGN - NEW ESRF - EBS



Storage ring
6GeV, 843.39 m

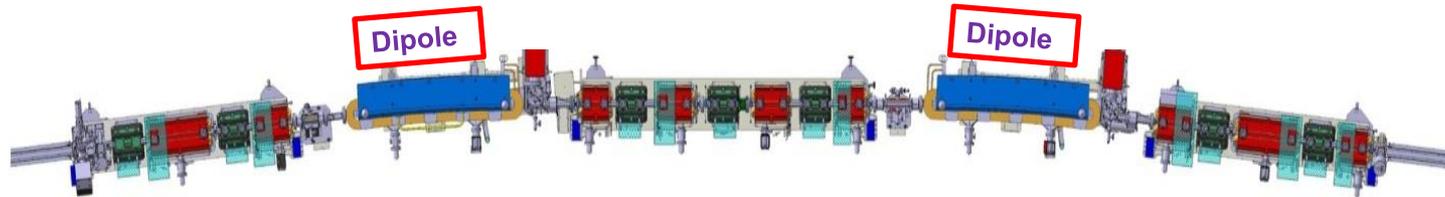
| | | |
|-----------------------------|-----------|--------------|
| Energy | GeV | 6.00 |
| Multibunch Current | mA | 200 |
| Horizontal emittance | nm | 0.133 |
| Vertical emittance | pm | 5 |

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



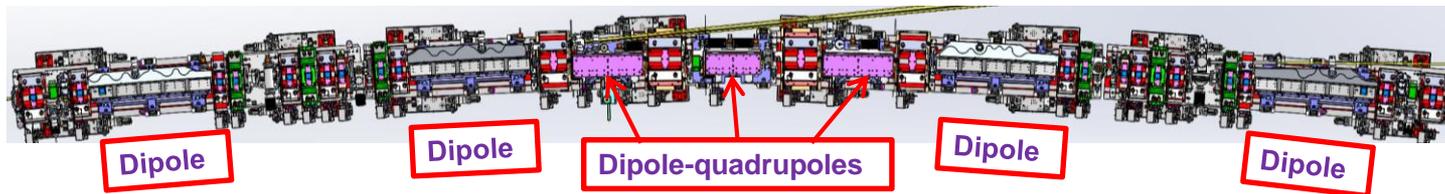
- **Old ESRF lattice**

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



- **New EBS lattice**

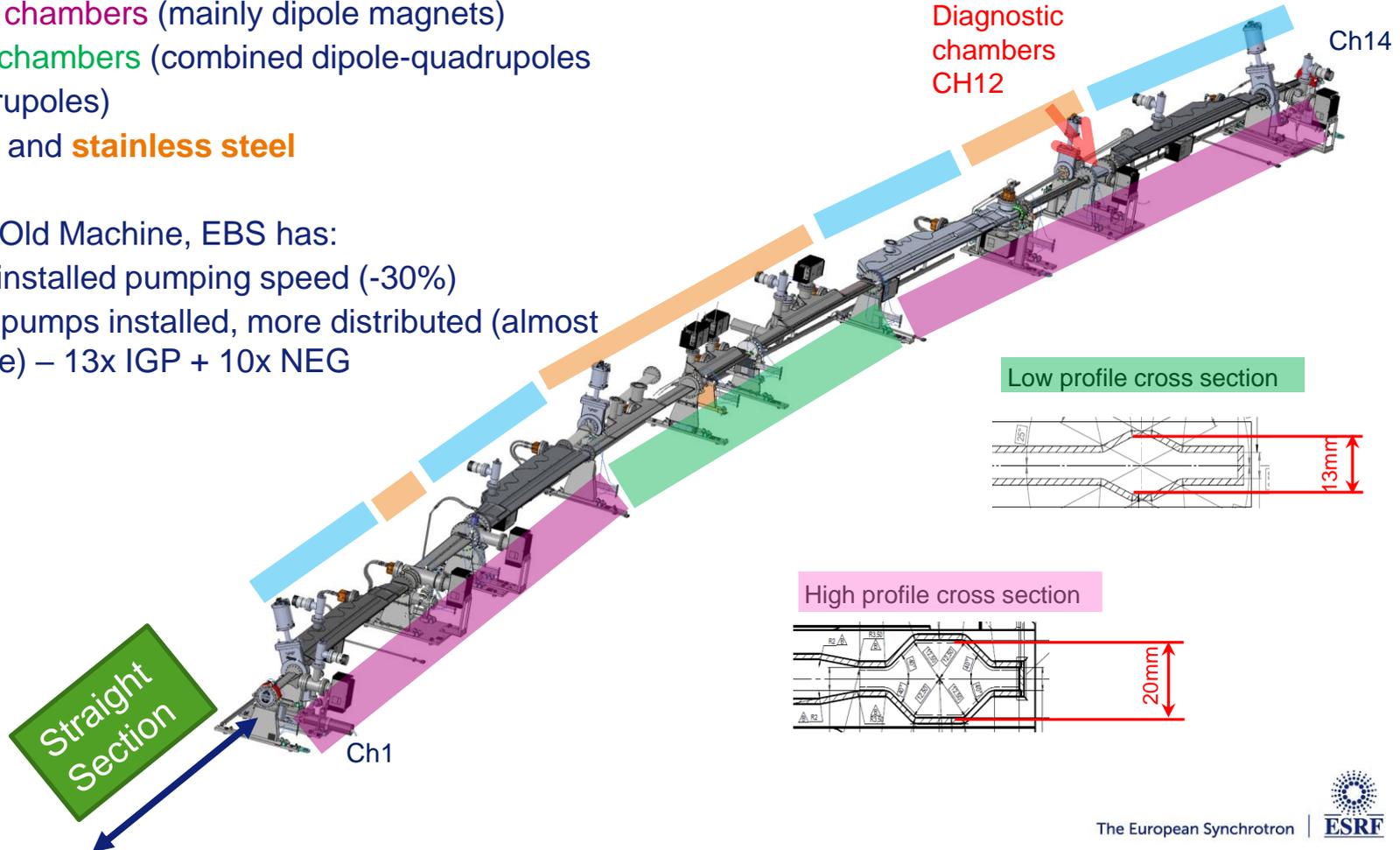
Hybrid 7 Bend Achromat = (4 dipoles + 3 dipole-quad + 24 quad., sext., oct.) per cell - ID length = 5 m



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

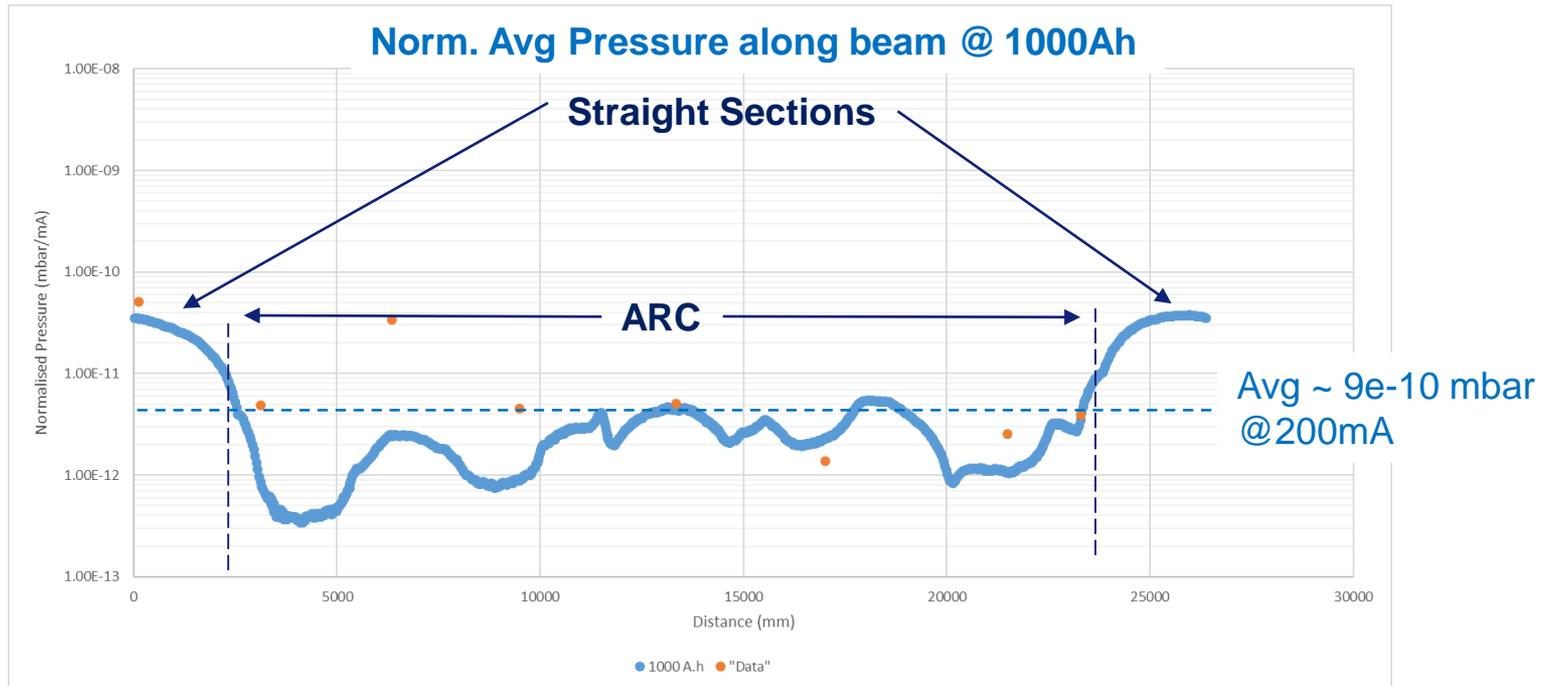
32x STRAIGHT SECTIONS (7m long)

- **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% H₂ 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

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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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Conditioning

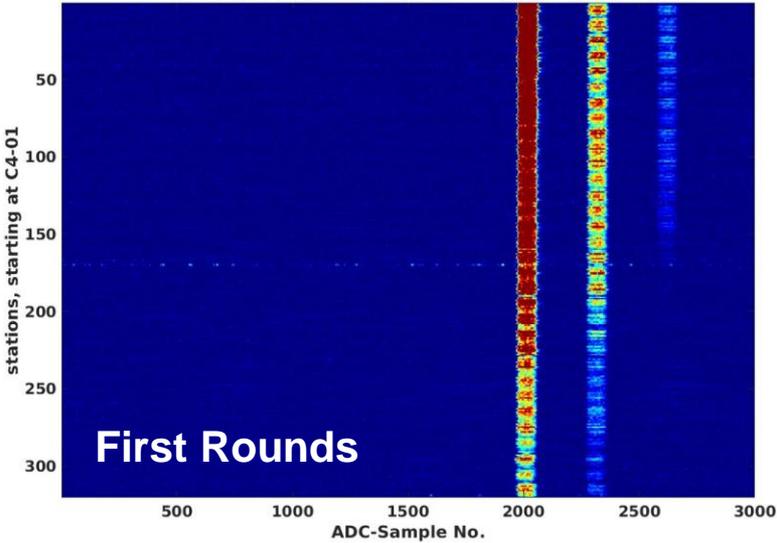
Operation - Reliability / Improvements

CURRENT RUMP-UP

**Tue-Nov-26th 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 6 Dec 2019



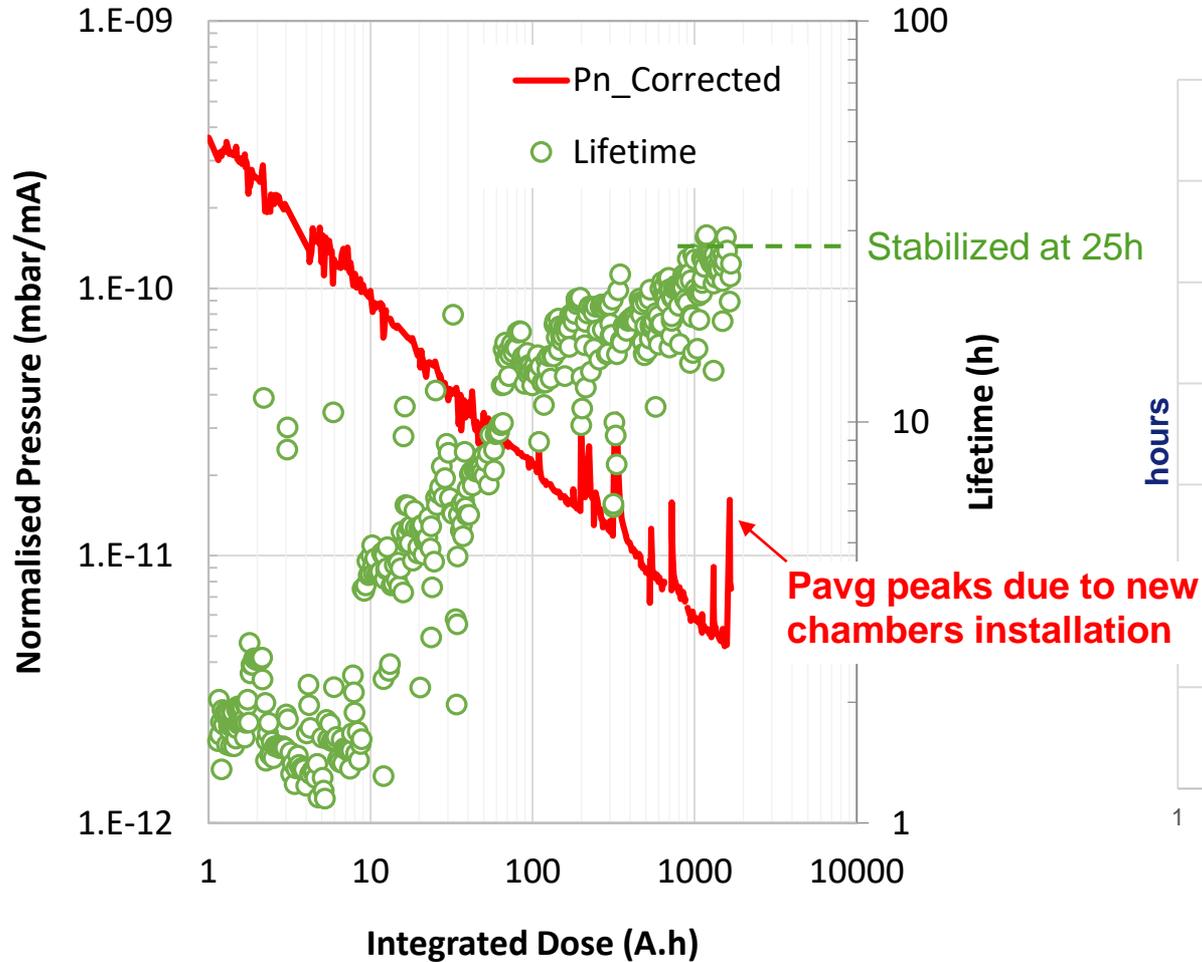
On 28 Feb 2019

200mA Reached!

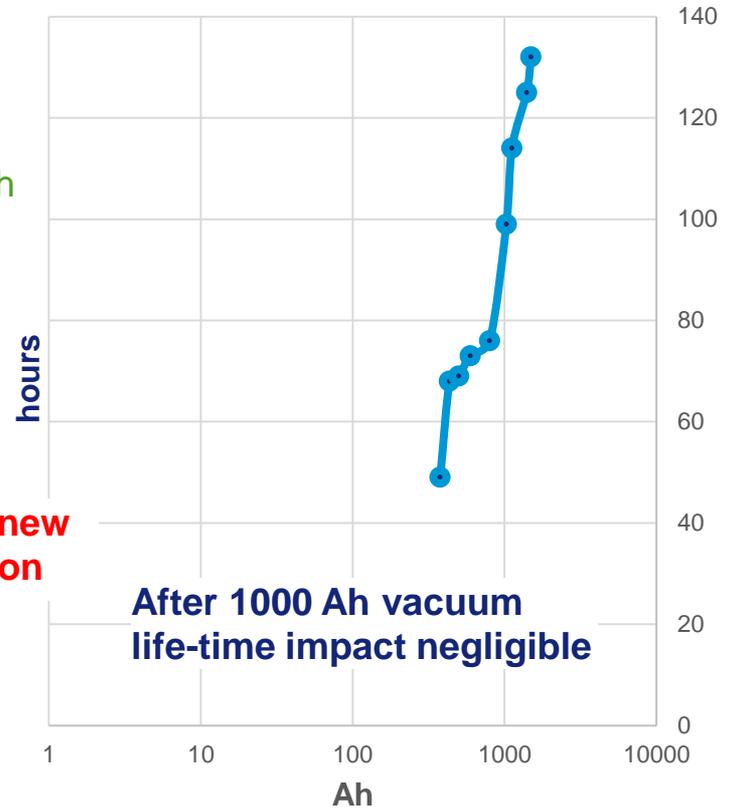


Dynamic: Pavg 6e-9 mbar

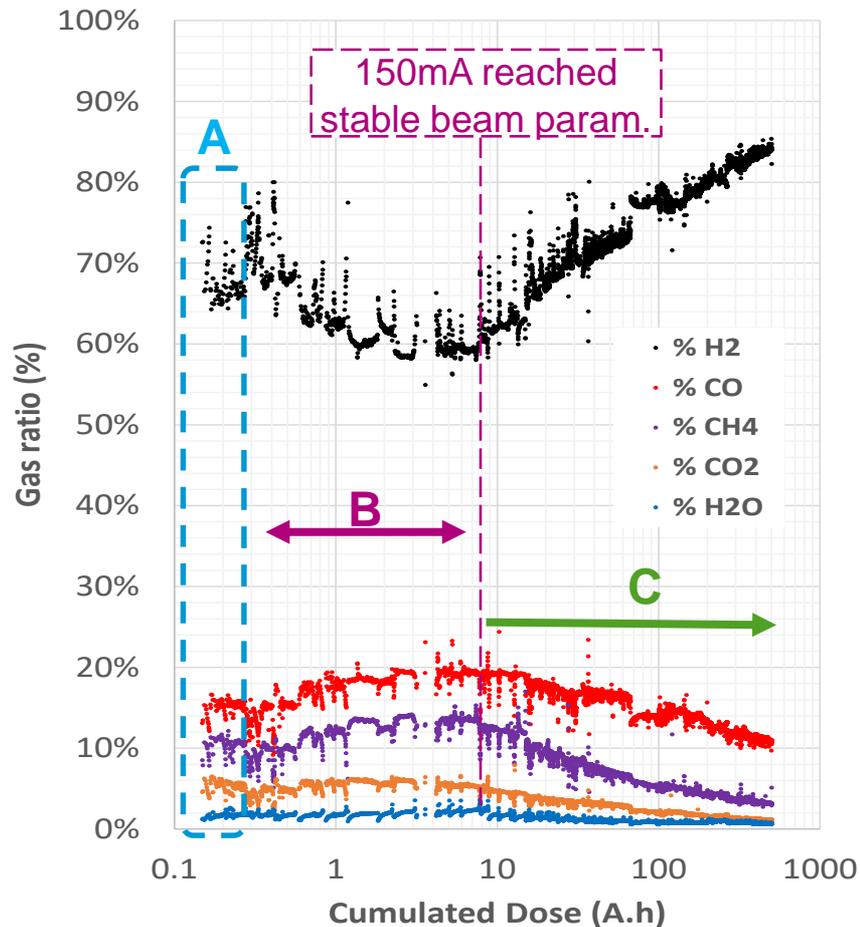
CONDITIONING - LIFETIME



Vacuum Life Time vs Dose



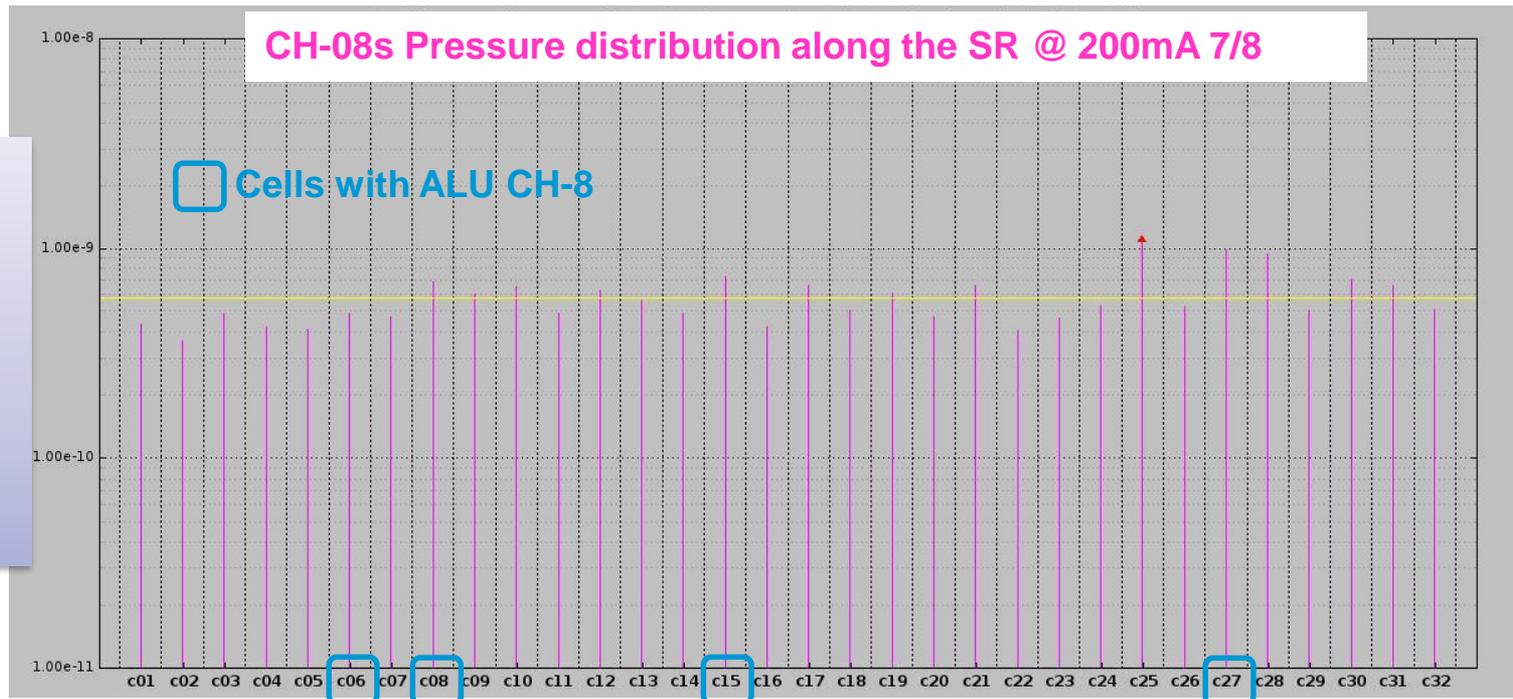
CONDITIONING – VACUUM QUALITY - RGA



- Many RGAs permanently installed: 3x cell
- Static: 90% is H₂
- **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 H₂ becomes increasingly dominant

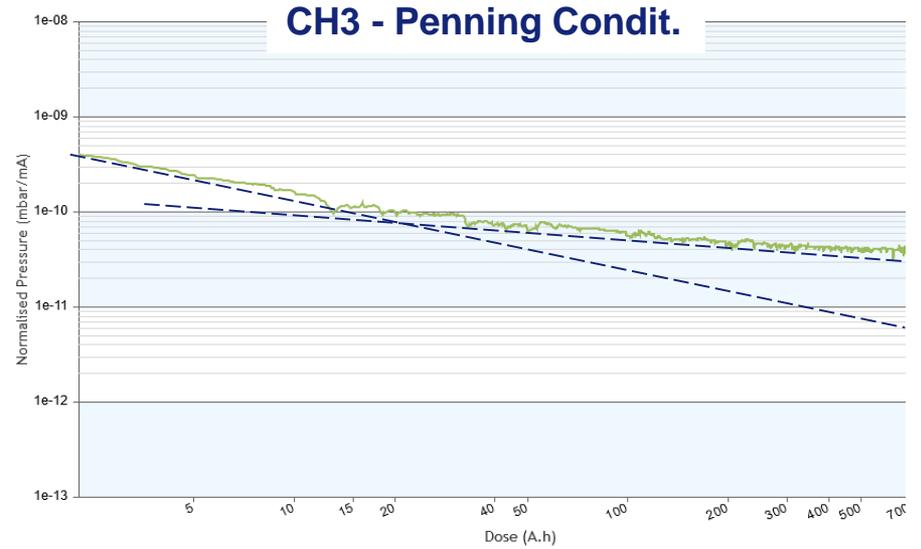
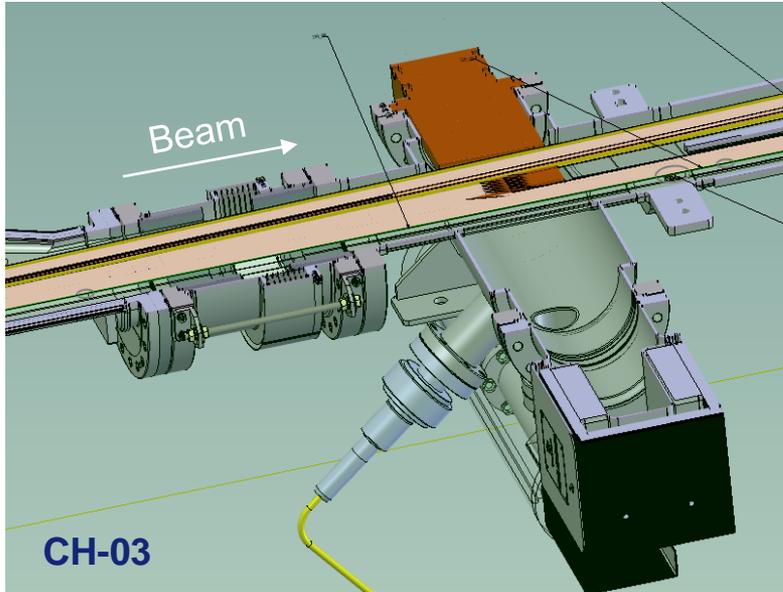
“Skepticism about usage of aluminum chambers due to high PSD”

CH8 example: 32 chambers, 4 of them made in ALU, the rest in SST
Same absorbers, pumps, RF fingers and positions



No significant deviation is visible !!!
Adsorbers' design matters !

Chamb-3 gauge “slowing-down” conditioning Gauge reading affected



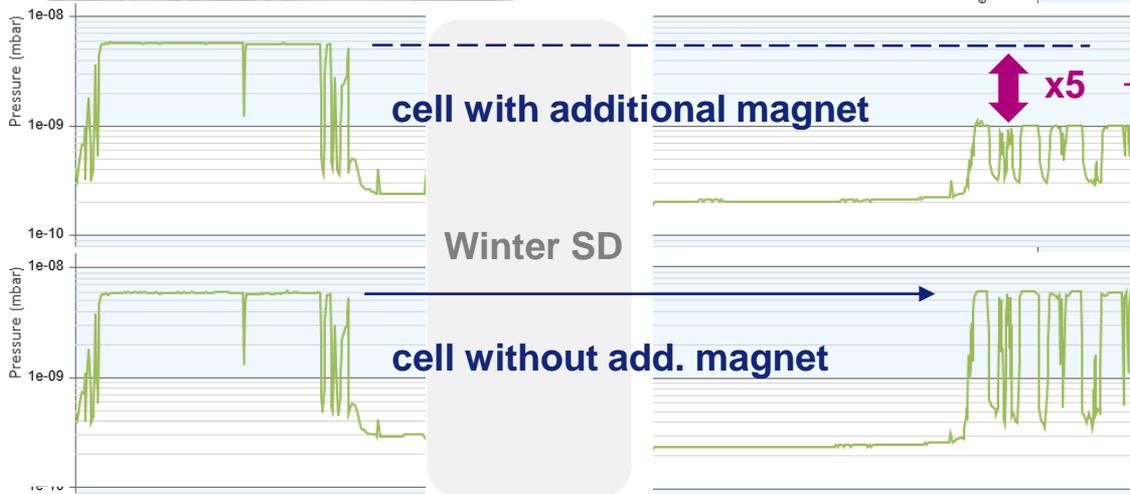
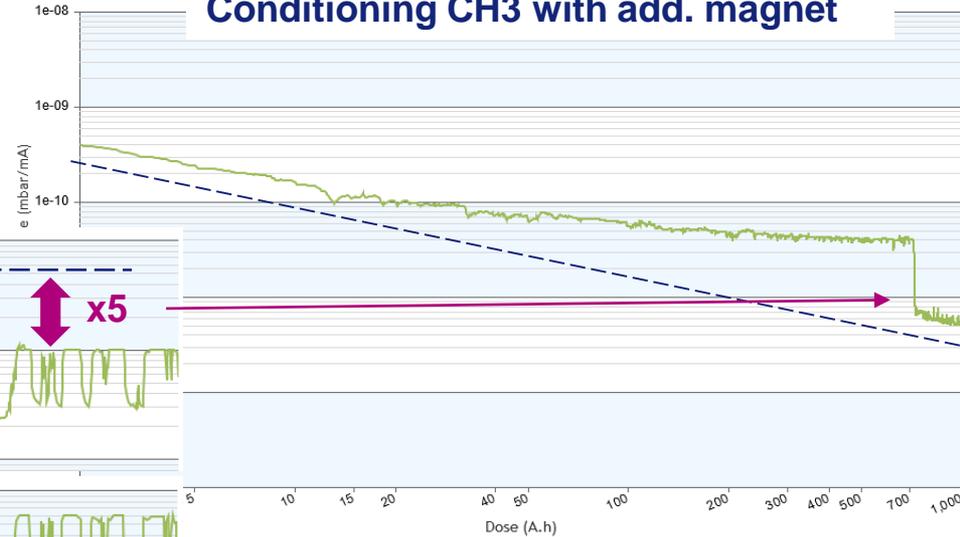
CONDITIONING – GAUGES READING

- **Secondary Electrons:**

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

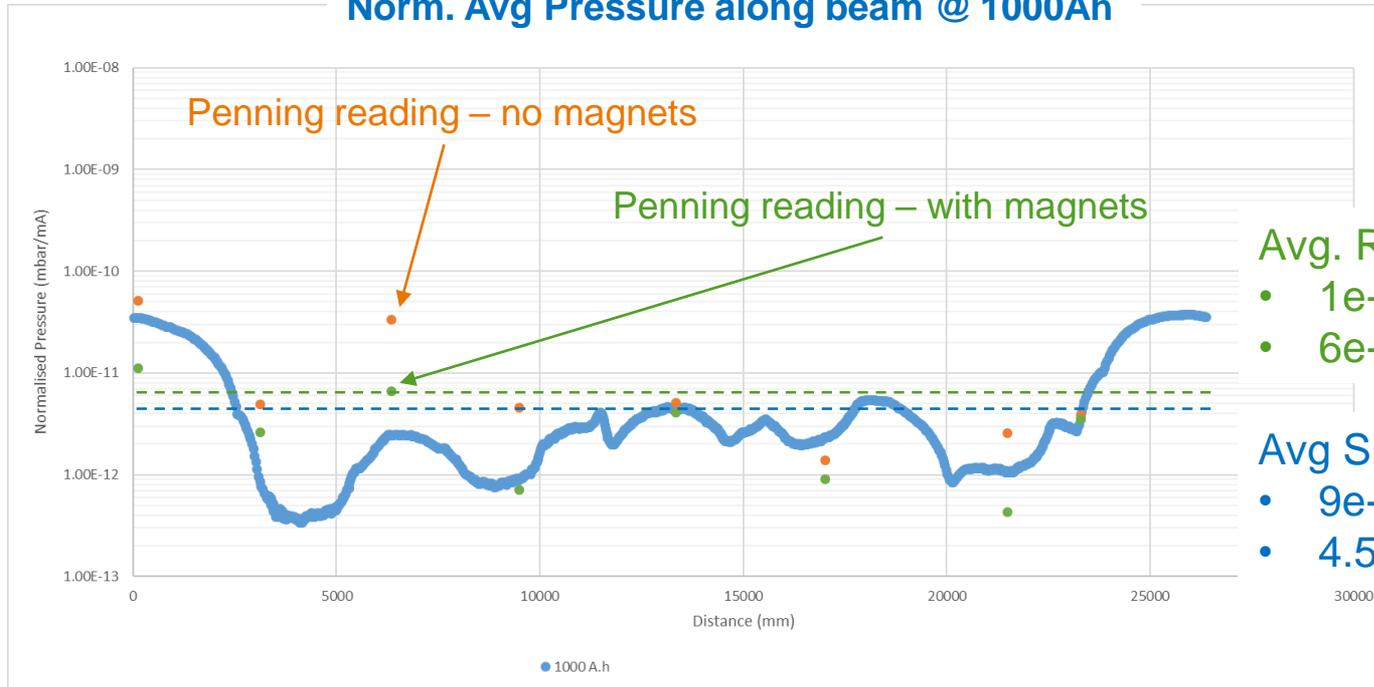


Conditioning CH3 with add. magnet



CONDITIONING – READINGS VS SIMULATION @1000 Ah

Norm. Avg Pressure along beam @ 1000Ah



Avg. Real

- $1e-9$ mbar @ 200mA
- $6e-12$ mbar/mA

Avg Simulation

- $9e-10$ mbar @ 200mA
- $4.5e-12$ mbar/mA

Design

Assembly, Installation

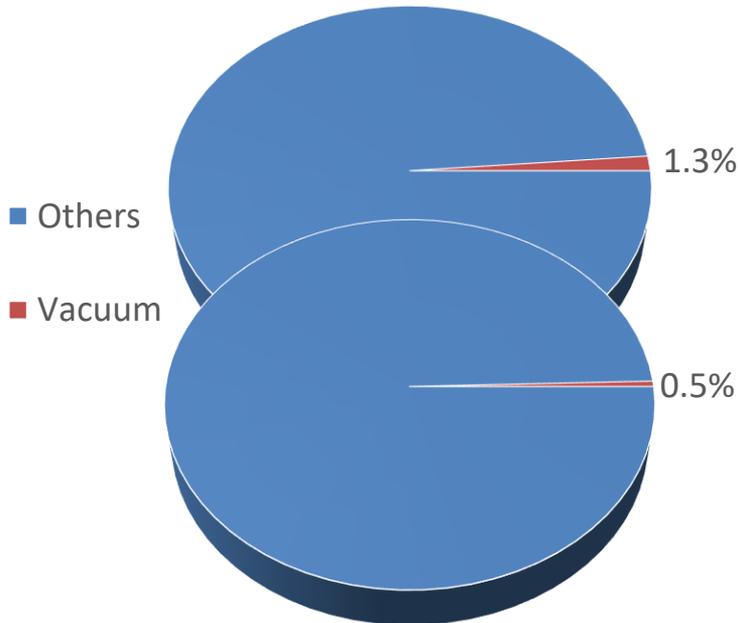
Conditioning

Operation - Reliability / Improvements

2021 - OPERATION - RELIABILITY

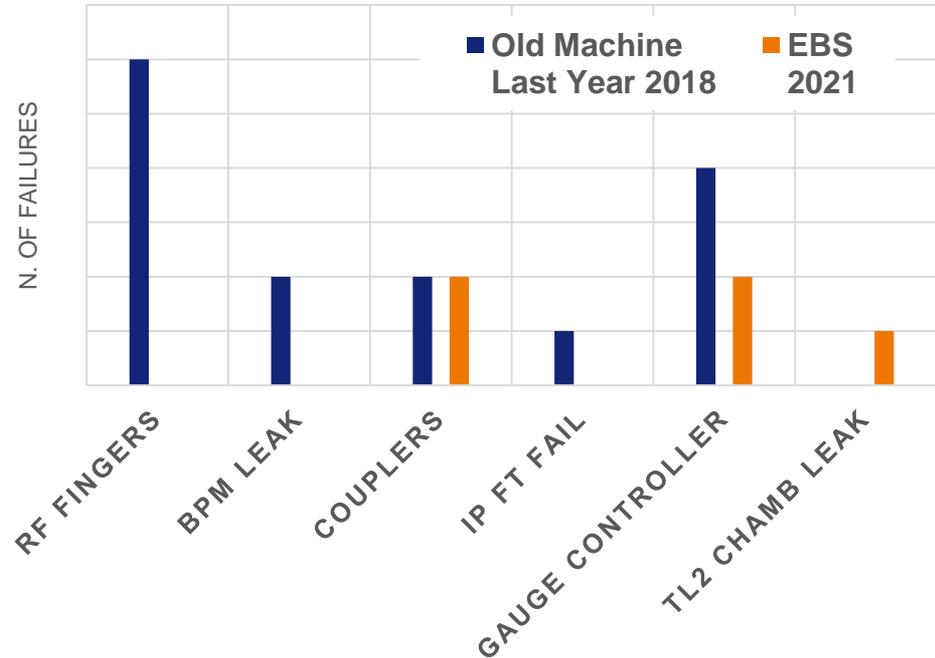
- 2021
 - stable parameters
 - machine conditioned
 - Machine availability > 96%

Beam Failures Events 2021



Beam Down-Time 2021

OLD VS NEW MACHINE FAILURES



So all perfect !?!? 😊

Almost... 😞

OPERATION – KICKERS' LIMITATION

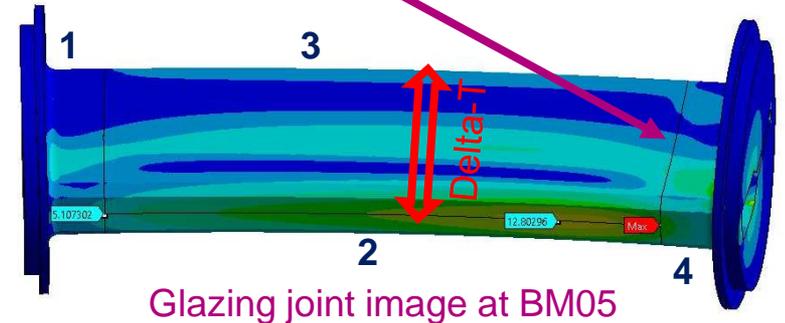
4x Kickers

- Complex internal shape: not symmetric, antechamber + tapered
- -> internal machining -> made of 4 ceramic parts glazed together

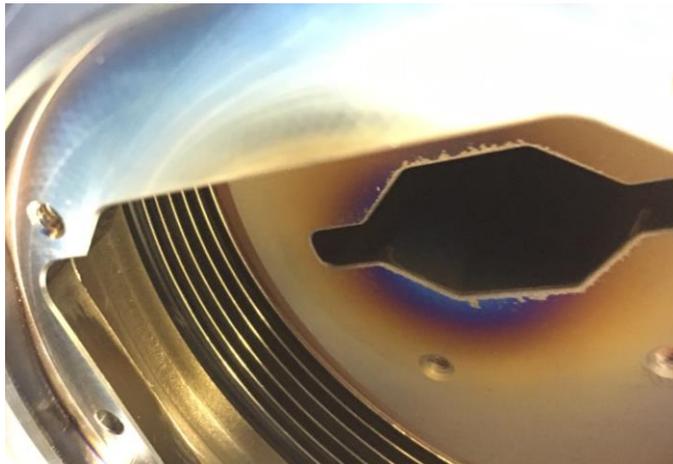
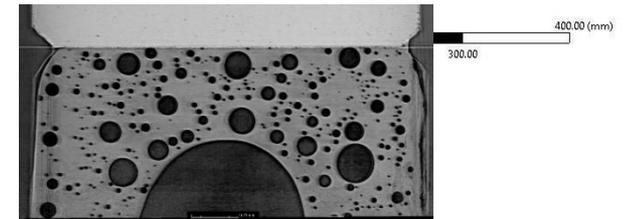
Mechanical

- Up to March-22 - limit at 32 mA in 16 bunch (nom. 96mA)
 - Mechanical stress due to thermal gradient
 - Cause cracks – leaks

Glazing joints - Weak point
Cracks/leaks due to mech/thermal stress



Glazing joint image at BM05



Titanium **coating erosion** on corners

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

OPERATION - KICKERS

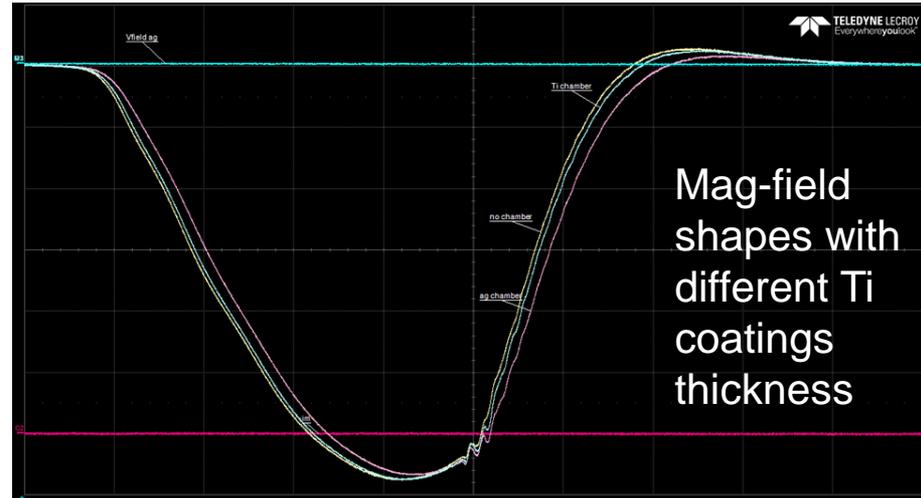
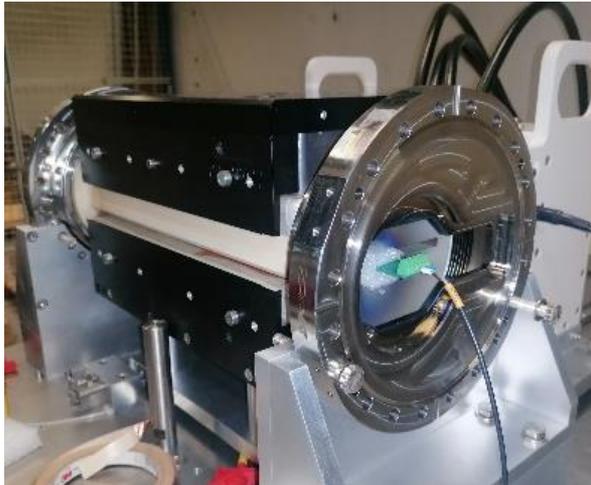
Two main activities/solutions

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



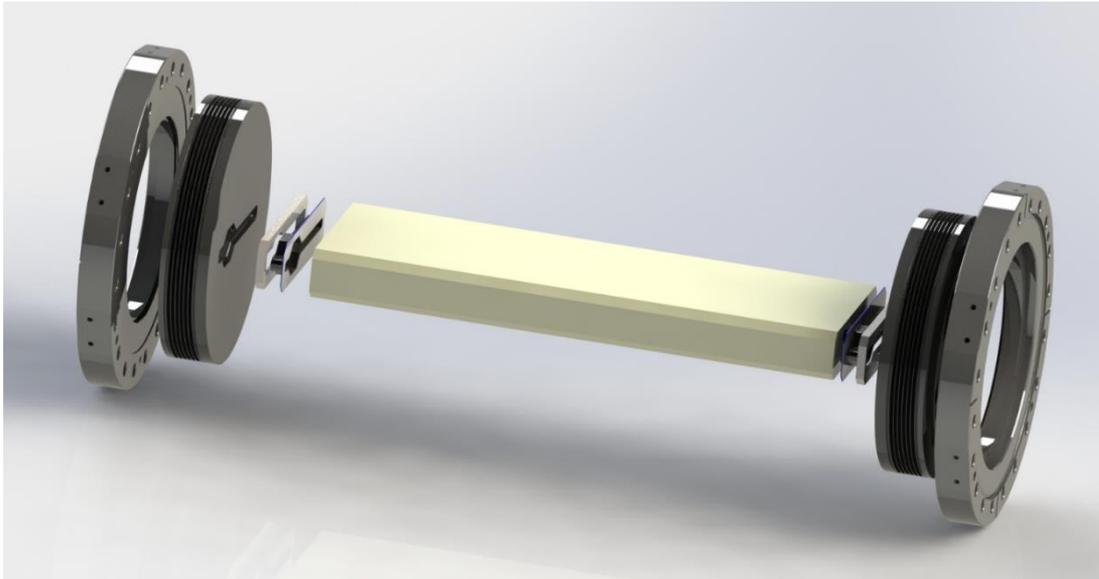
Installed in Winter and March ShutDown

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**



- **Assembly and installation of new EBS done on schedule**
- **Vacuum did not slow 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**