The XXIV European Synchrotron Light Source Workshop

MAXIV vacuum system, from design to operation

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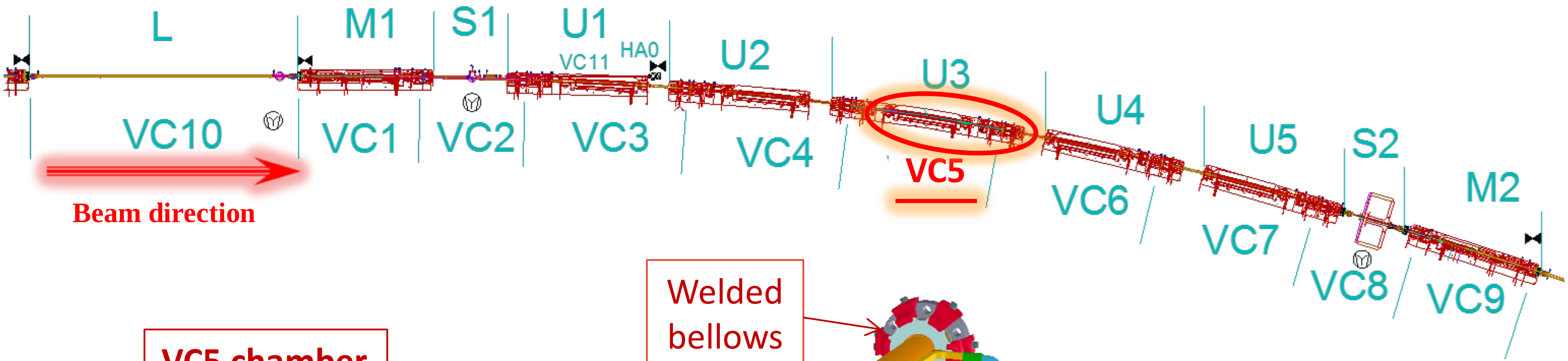
On behalf of the vacuum team

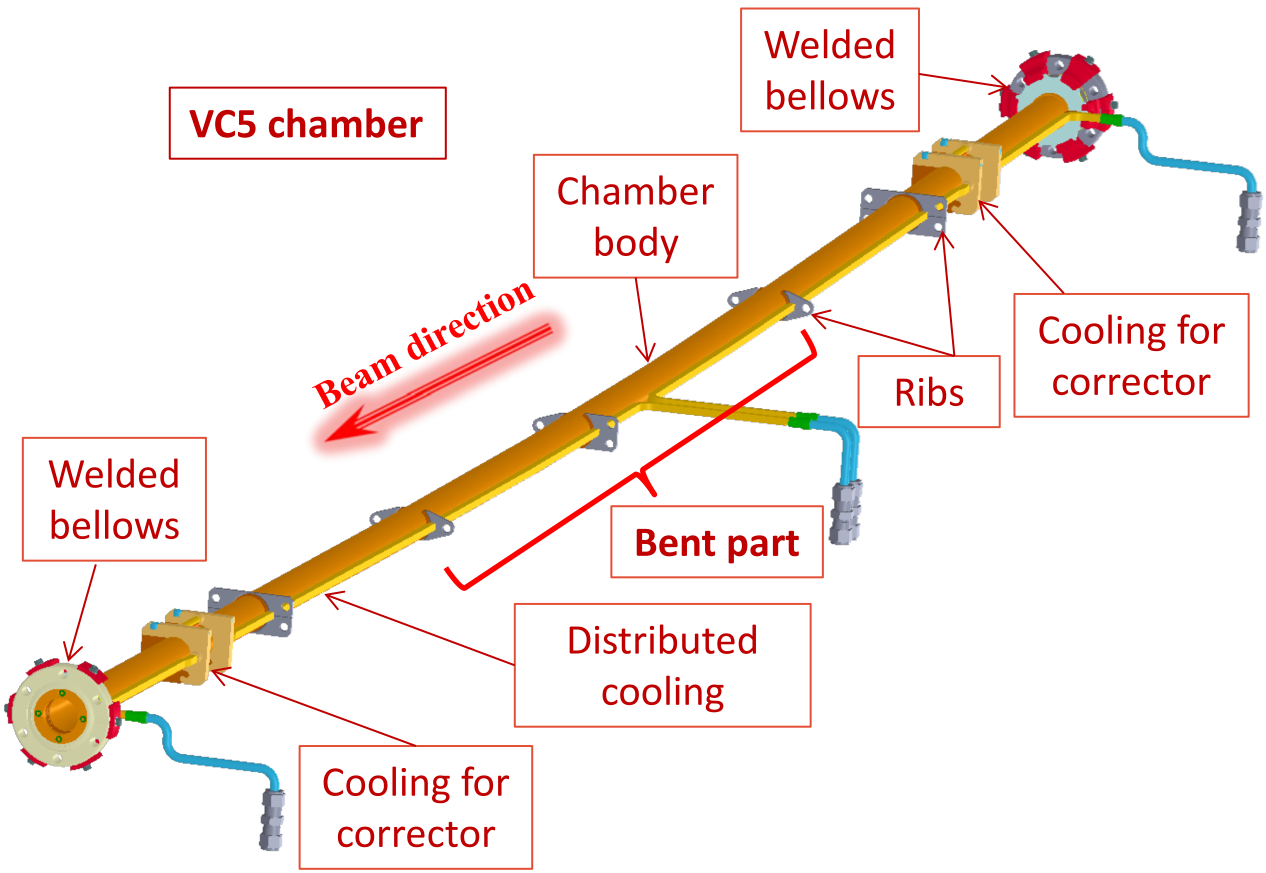
30th Nov. 2016

Contents

- Vacuum system layout.
- NEG-coating R&D at CERN,
- Installation procedure,
- Vacuum commisioning status.

Standard vacuum chamber geometry





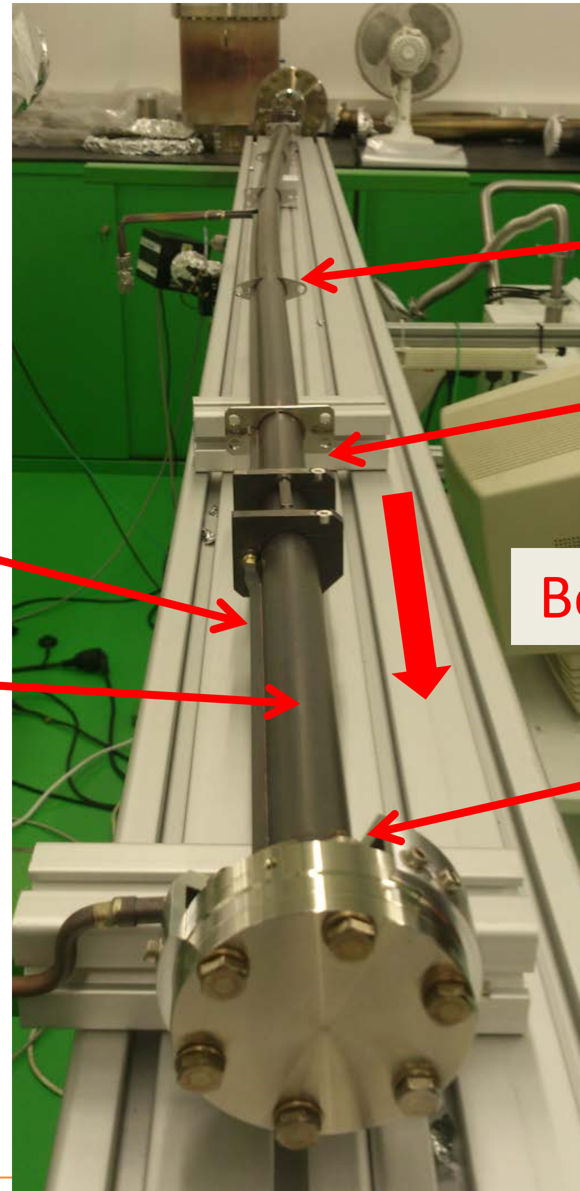
Material: OFS copper

Inside diameter: 22 mm,
Total length: 2.5 m,

Bent part
Arc length: 1 m,
Bending angle: 3^0,
Bending radius: 19 m.

NEG-coated.

General vacuum chamber geometry



Ribs

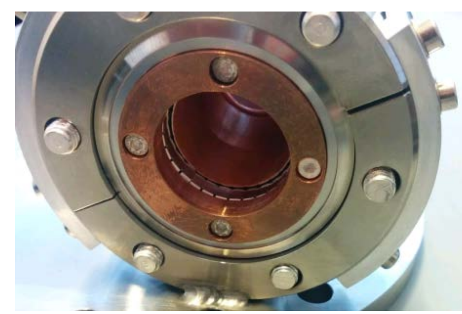
Cooling for corrector area

Distributed cooling

Chamber body

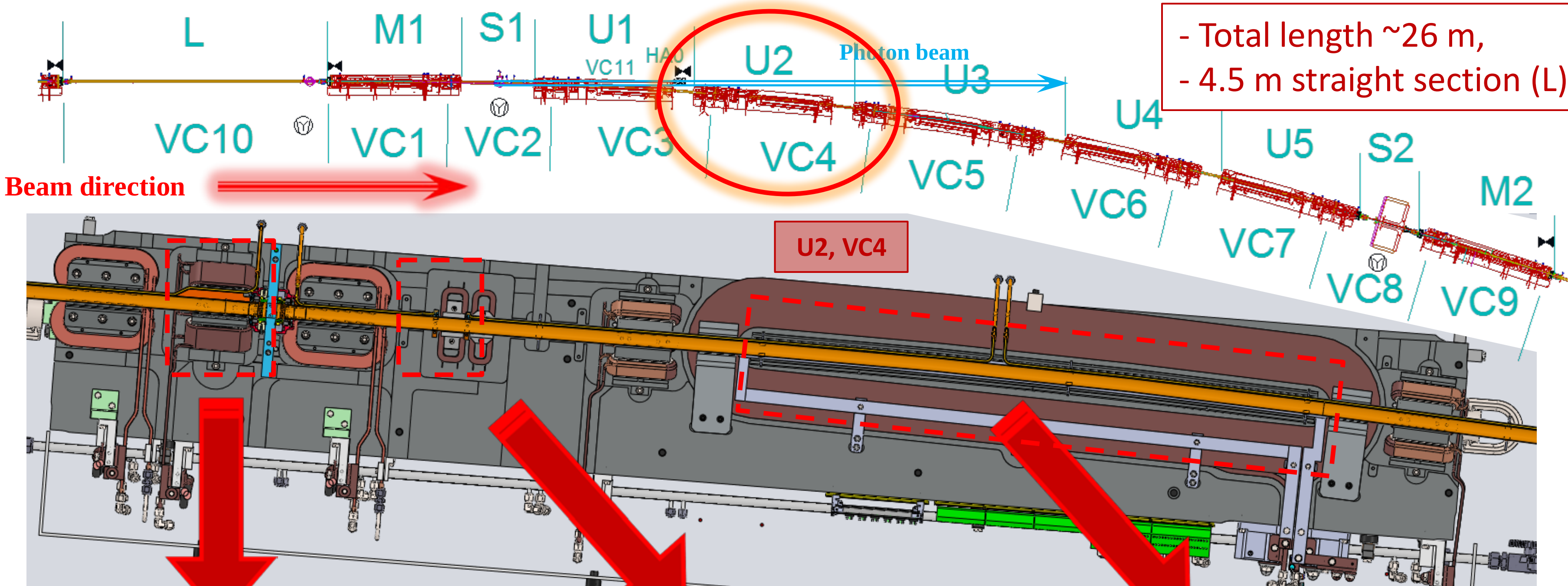
Beam direction

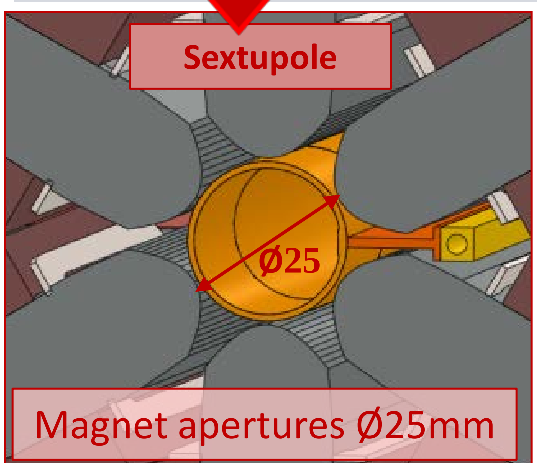
Welded bellows

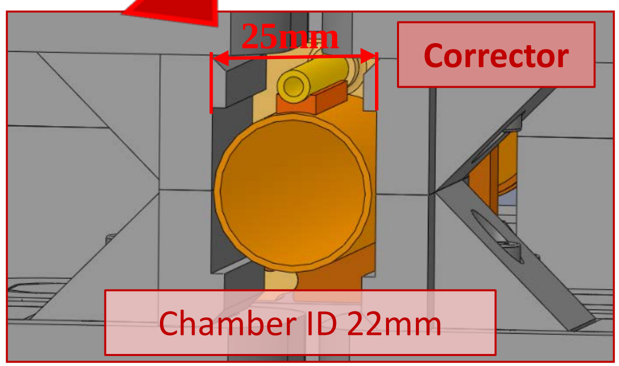


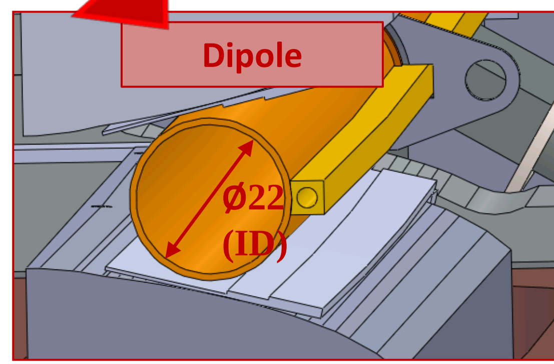
3 GeV magnet layout

- Total length ~26 m,
- 4.5 m straight section (L)



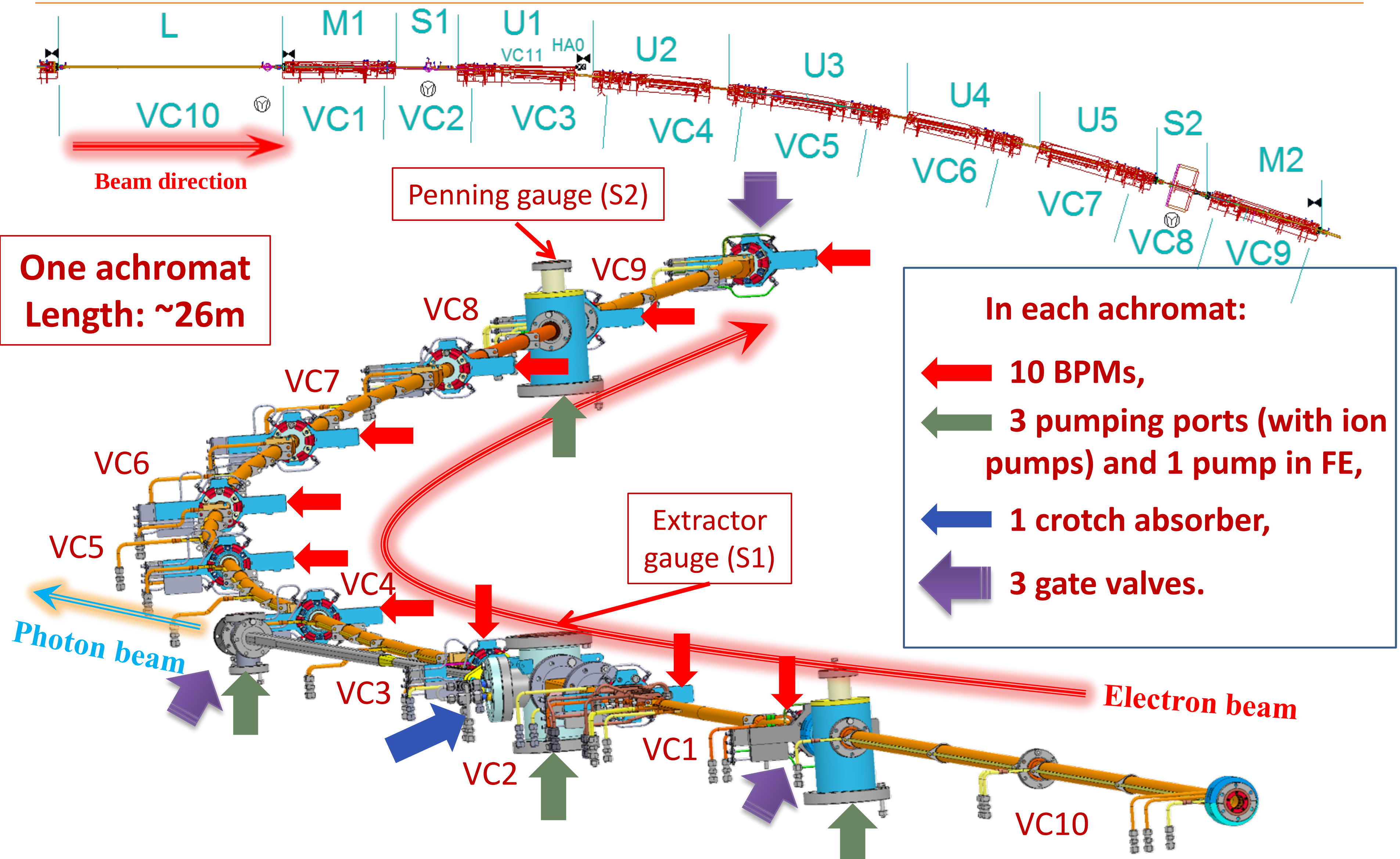






Min. clearance with the iron 0.5 mm, min. clearance with the coils 2 mm.

Vacuum achromat layout



In each achromat:

- **10 BPMs,**
- **3 pumping ports (with ion pumps) and 1 pump in FE,**
- **1 crotch absorber,**
- **3 gate valves.**

NEG-coating R&D at CERN

To validate the coating feasibility 3 main stages of NEG (Ti, Zr, V) coating validation by magnetron sputtering in collaboration with CERN were undertaken. (R&D duration ~2 years).

1. Define and perform initial **surface treatment** of OFS copper substrate.
2. Validate compatibility of NEG-coating (adhesion, thickness, activation behavior):

    a). on etched **OFS copper**.

    b). on **wire-eroded** surfaces and used **brazing alloys**.

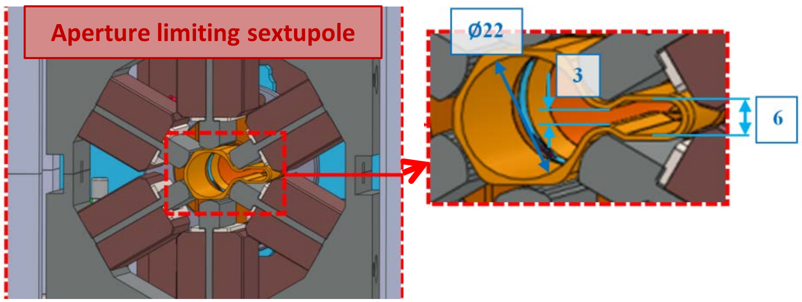
3. NEG-coating validation of compact vacuum chamber **geometries**:

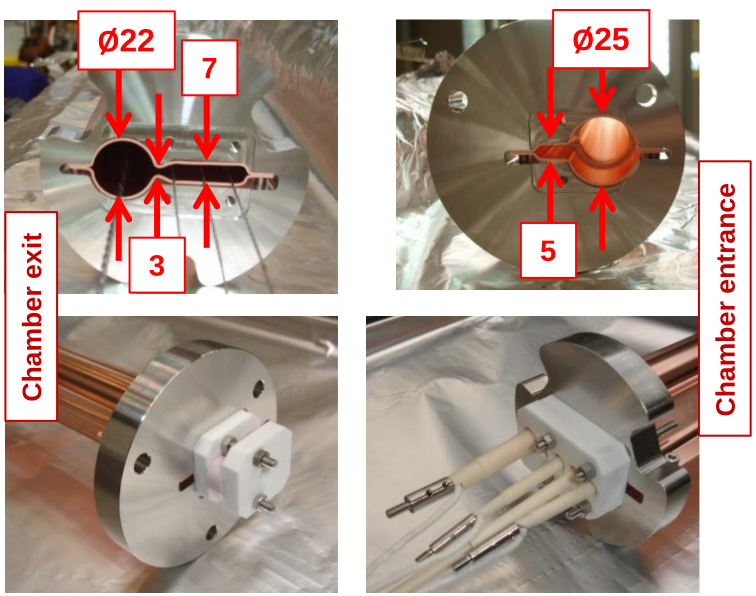
    a). Coating and testing of **small diameter**, **bent** tubes.

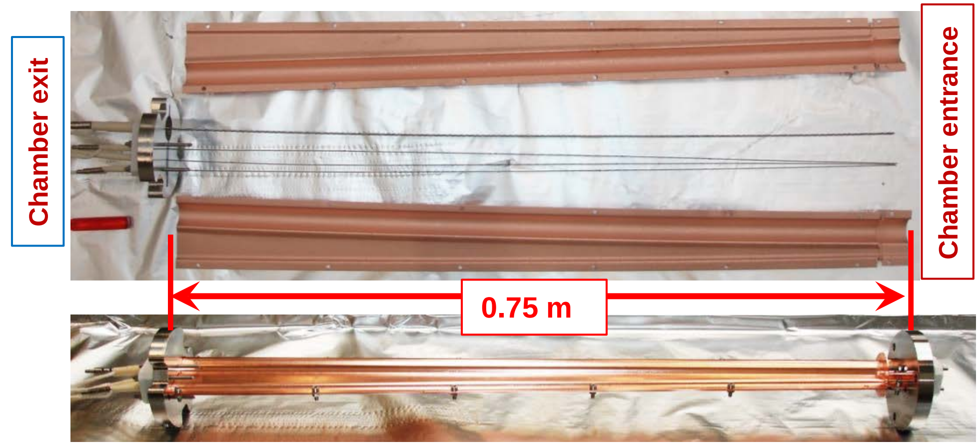
    b). Establish coating procedure/technology and coat chambers of **complex geometry**.

NEG coating: R&D at CERN

- **Example: Develop coating procedure for chambers with small antechamber** –(vertical aperture from 5 to 7 mm).



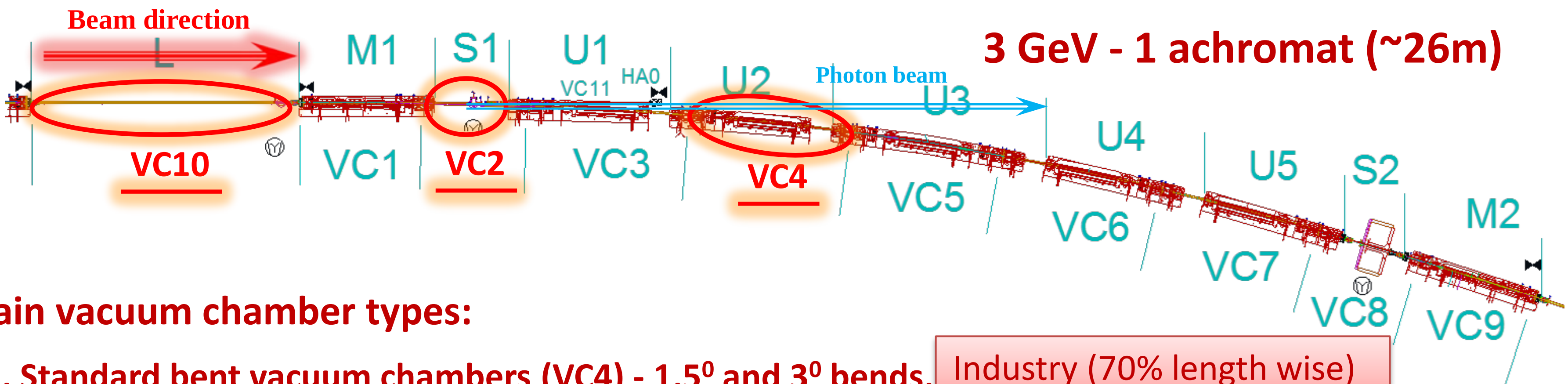




Prototype made at CERN in two halves to be able to inspect the coating quality.

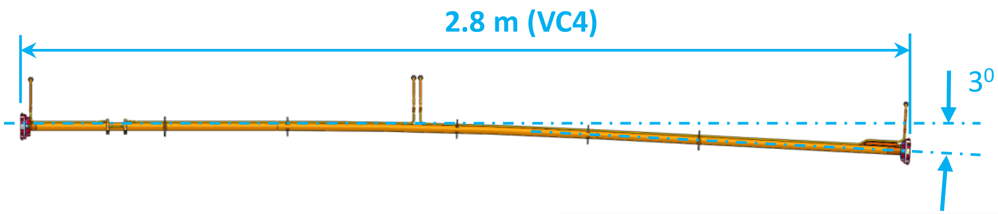
NEG-coating series production

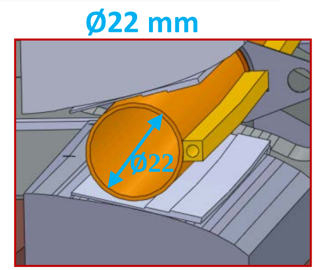
3 GeV - 1 achromat (~26m)



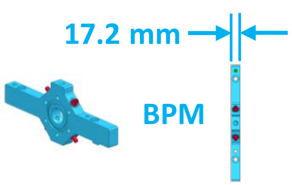
Main vacuum chamber types:

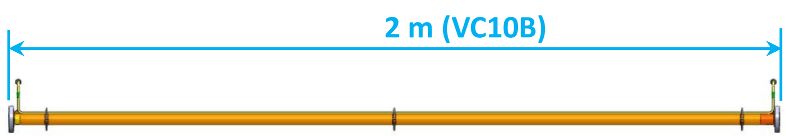
1. Standard bent vacuum chambers (VC4) - 1.5^0 and 3^0 bends, Industry (70% length wise)





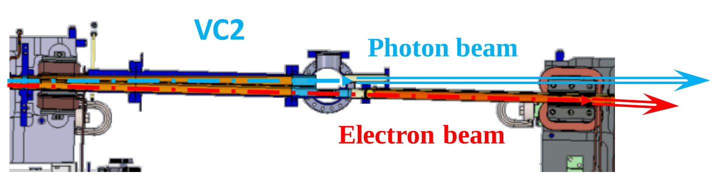
2. Straight vacuum (VC10) chambers, Collaboration with ESRF (15%)

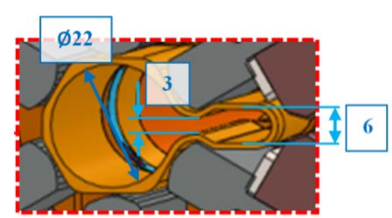




3. Special vacuum chambers.

Collaboration with CERN (15%)



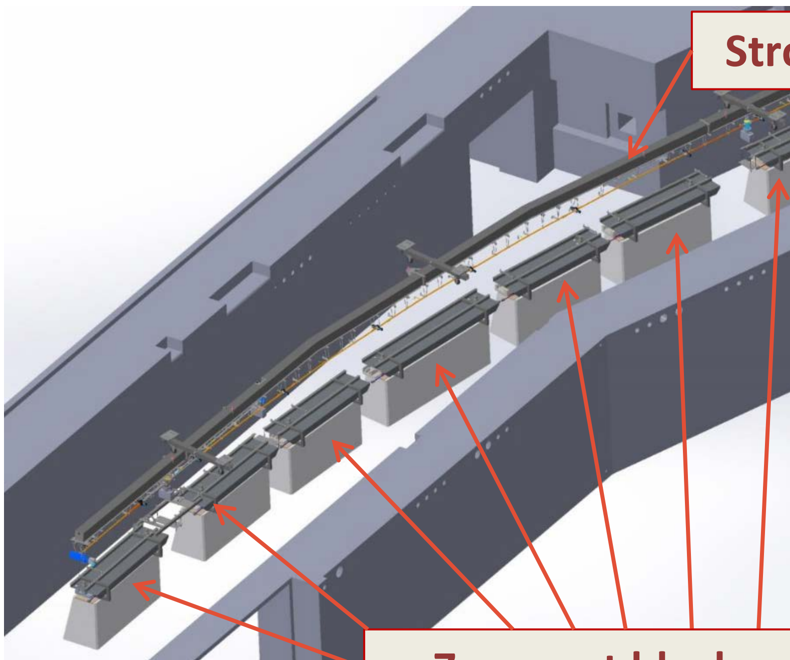


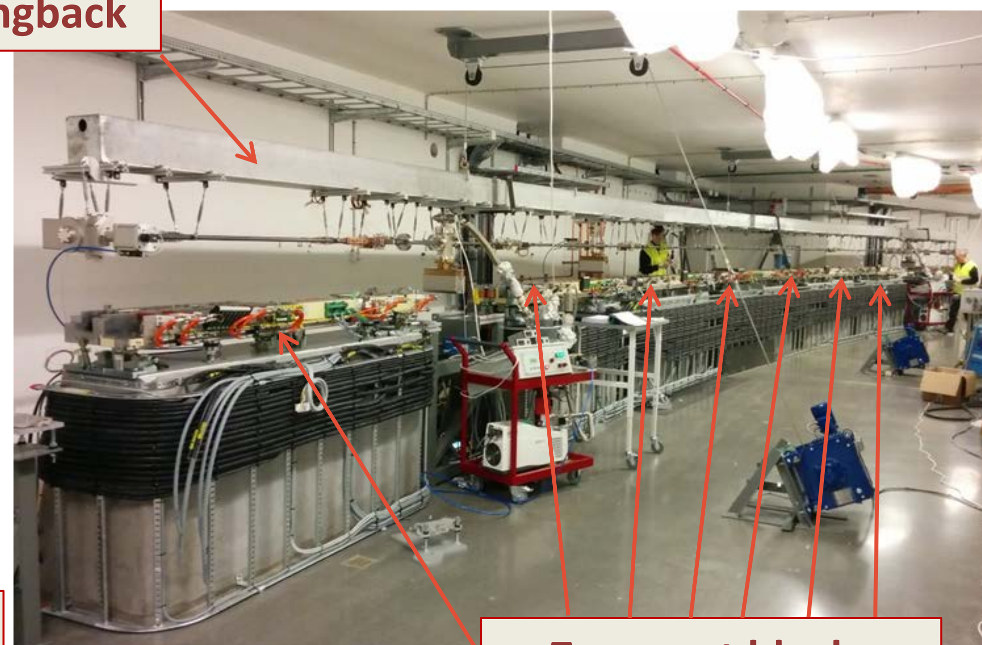
Installation procedure

Ring installation was tested and rehearsed by installing and activating 1 mockup achromat in summer 2014.

Actual installation started in November 2014, ended June 2015

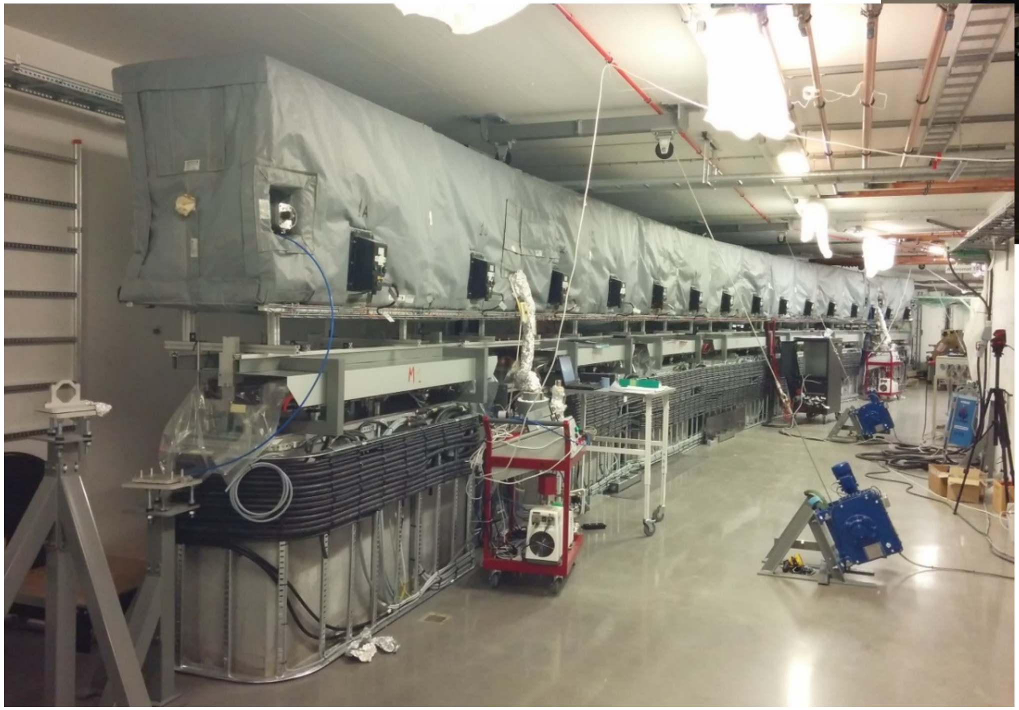
Installation done with help from Budker Institute

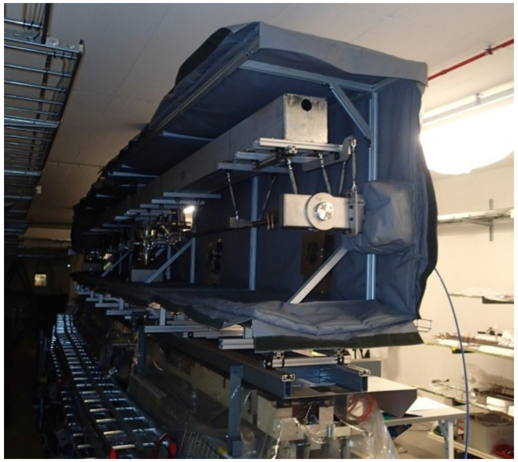




Installation procedure

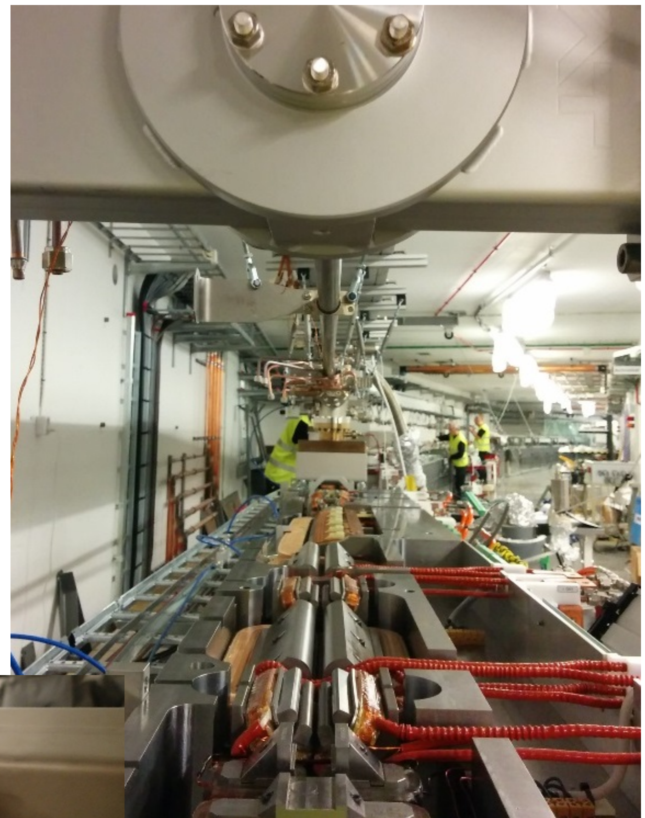
- Assembly in-situ (above magnets),
- Pump down and testing,
- Lifting,
- Bake out (1 day), activation (1 day),

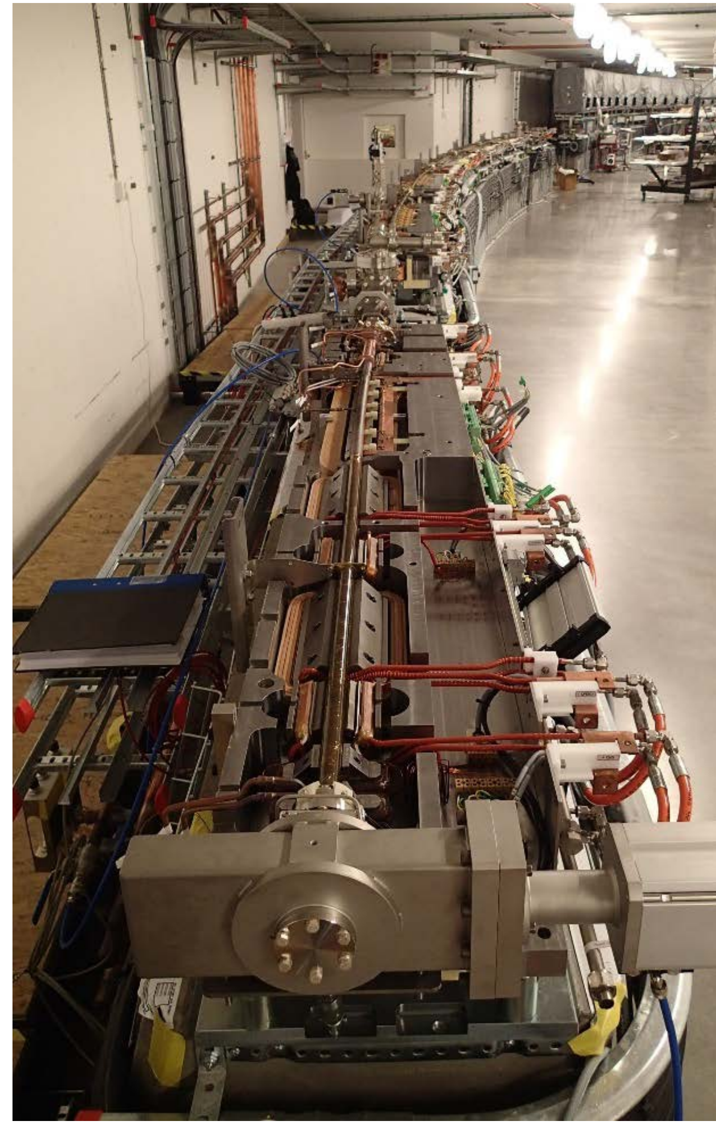




Installation procedure

- Lowering to the bottom magnet half,
- Installation of final equipment (supports, BPM cables),
- Lowering to magnet block.





Coating non-conformities

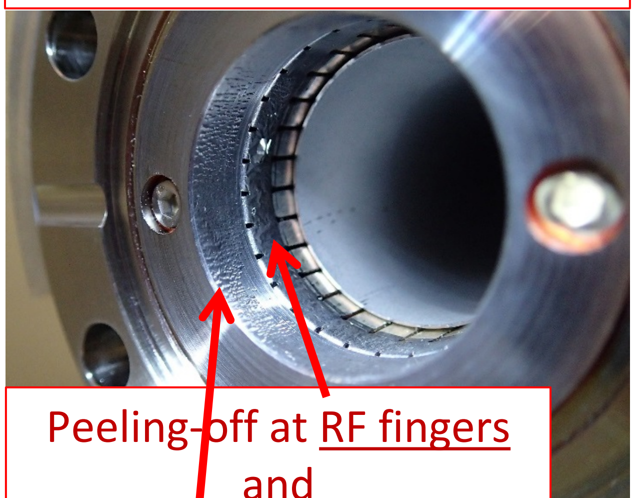
All the chambers were inspected at site before installation.

Observed peeling-off:
At RF fingers Cu-Be insert and Cu end piece. RF fingers and Cu end were not shielded properly during coating.
Solution: new pieces ordered and replaced (without coating).

Peeling-off at the edge of stainless VC. Chamber not aproved for installation.

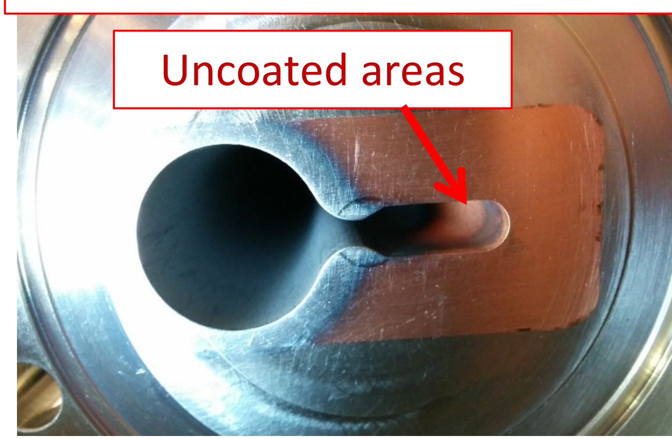
Peeling-off

Severe peeling-off



Peeling-off at <u>RF fingers</u> and <u>Copper end piece</u>

Uncoated areas:
Few cm^2 uncoated, in complex chambers.



Uncoated areas

Commissioning progress

3 GeV storage ring commissioning started in August 2015

Average base pressure:

- **Gauges 2e-10 mbar,**
- **Ion pumps in 8e-11 mbar range.**

Accumulated beam dose:

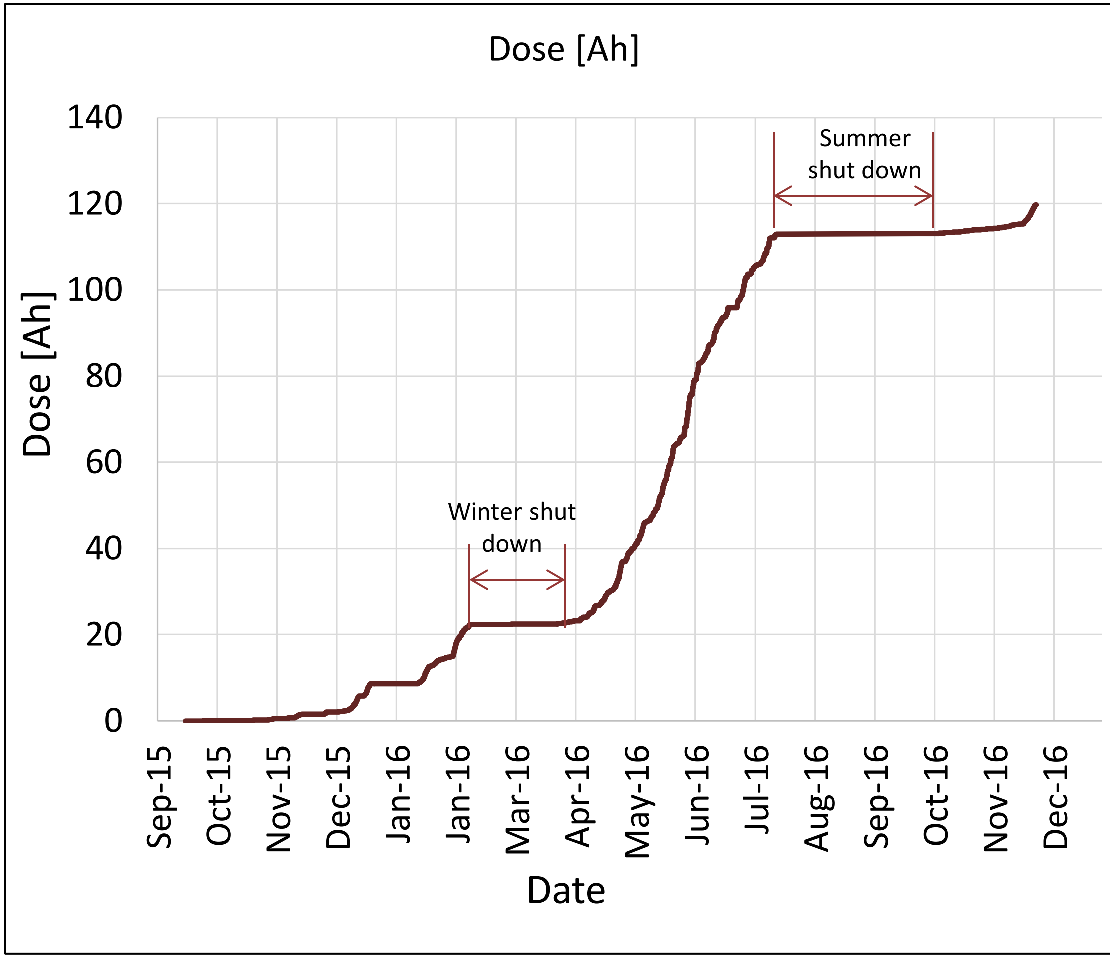
- 120 Ah.

1st shutdown March 2016:

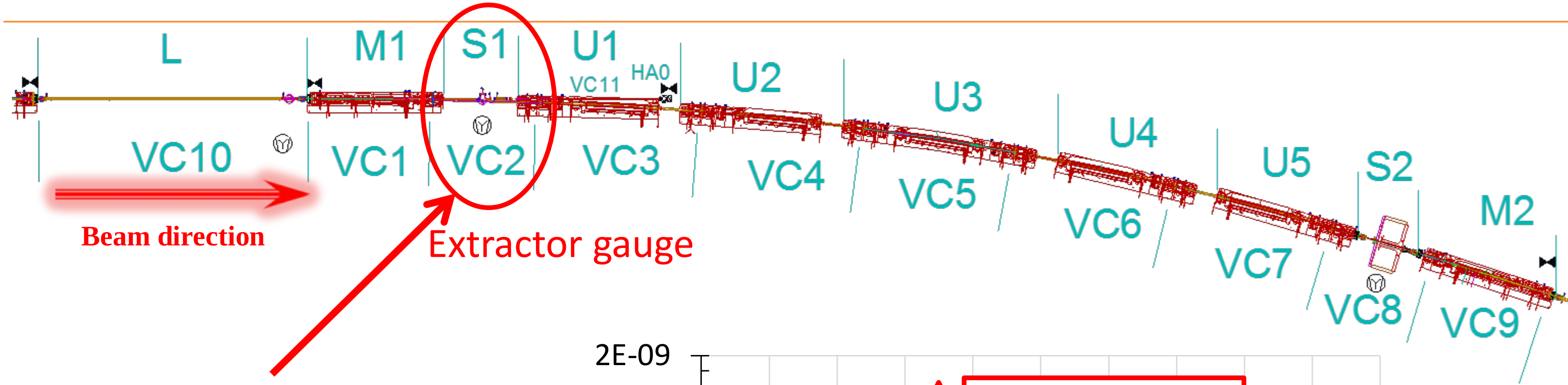
- 2 in-vacuum undulators,

2nd shutdown August 2016:

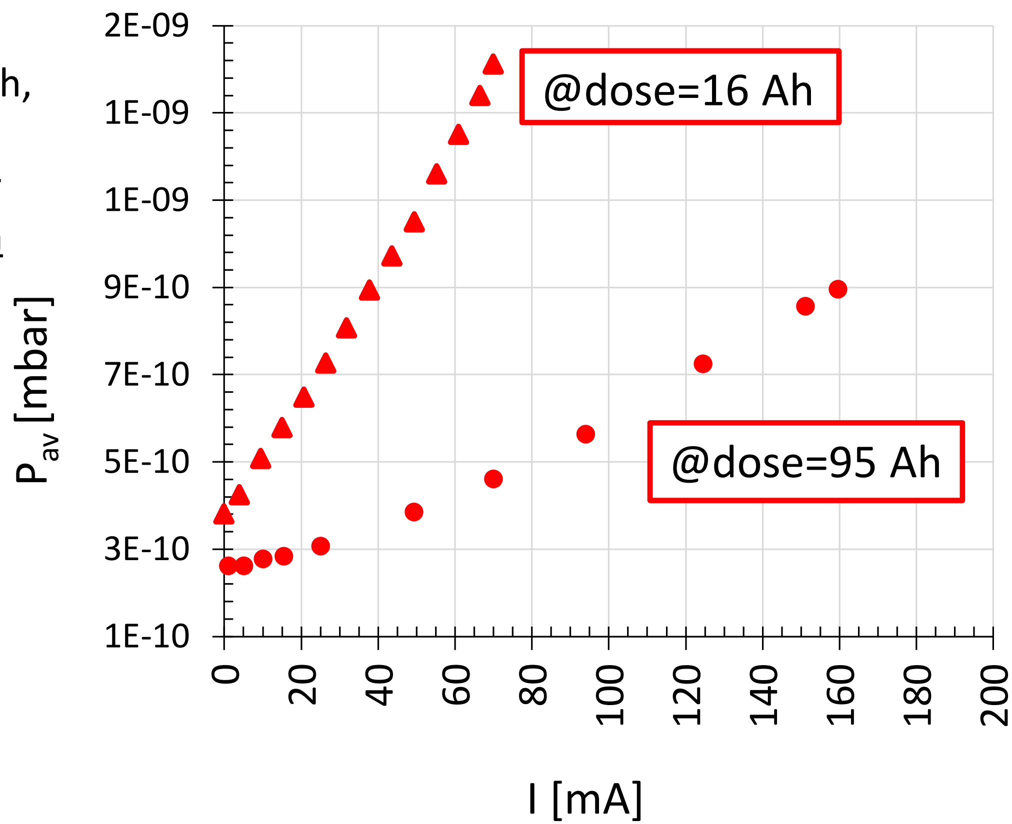
- 2 EPU chambers (8x36mm),
- In-vacum wiggler.



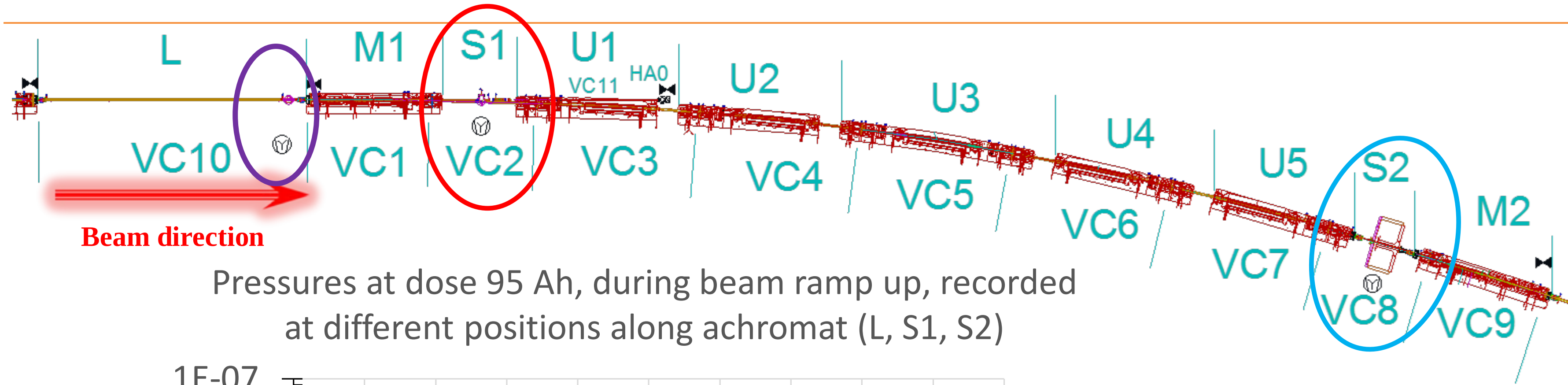
Pressure vs beam current vs dose



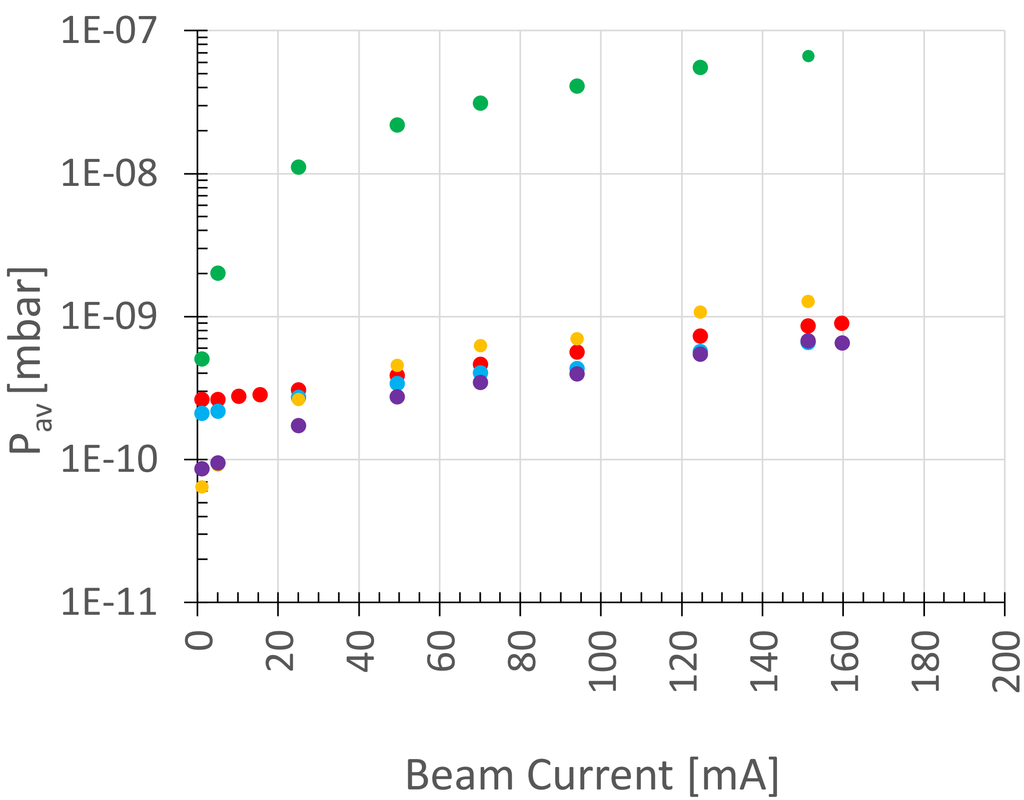
Pressures at dose 16 Ah and 95 Ah, during beam ramp up. (pressure recorded by extractor gauge at **not** NEG coated **crotch absorber** in S1)



Pressure in one achromat vs beam current



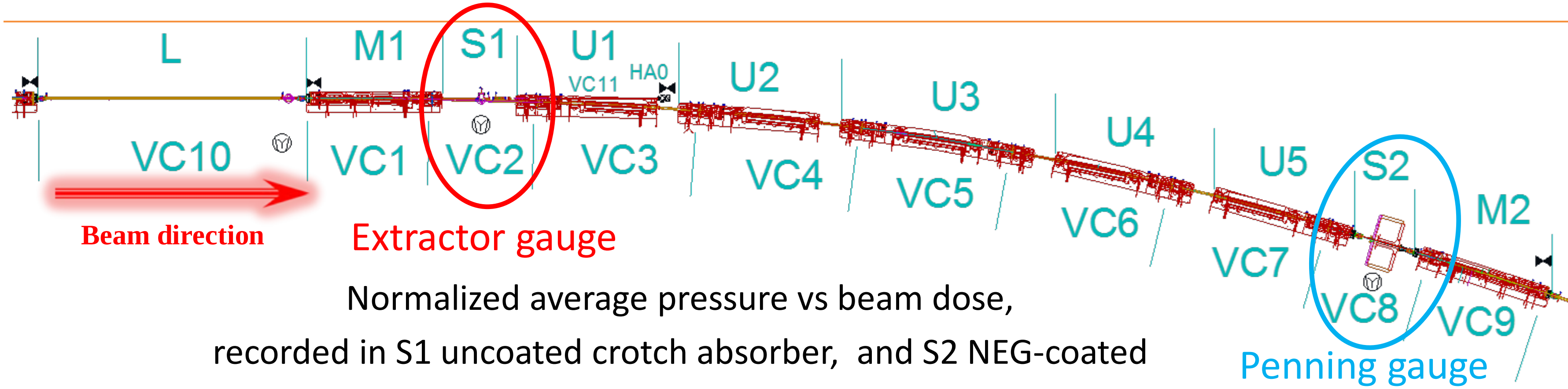
Pressures at dose 95 Ah, during beam ramp up, recorded at different positions along achromat (L, S1, S2)



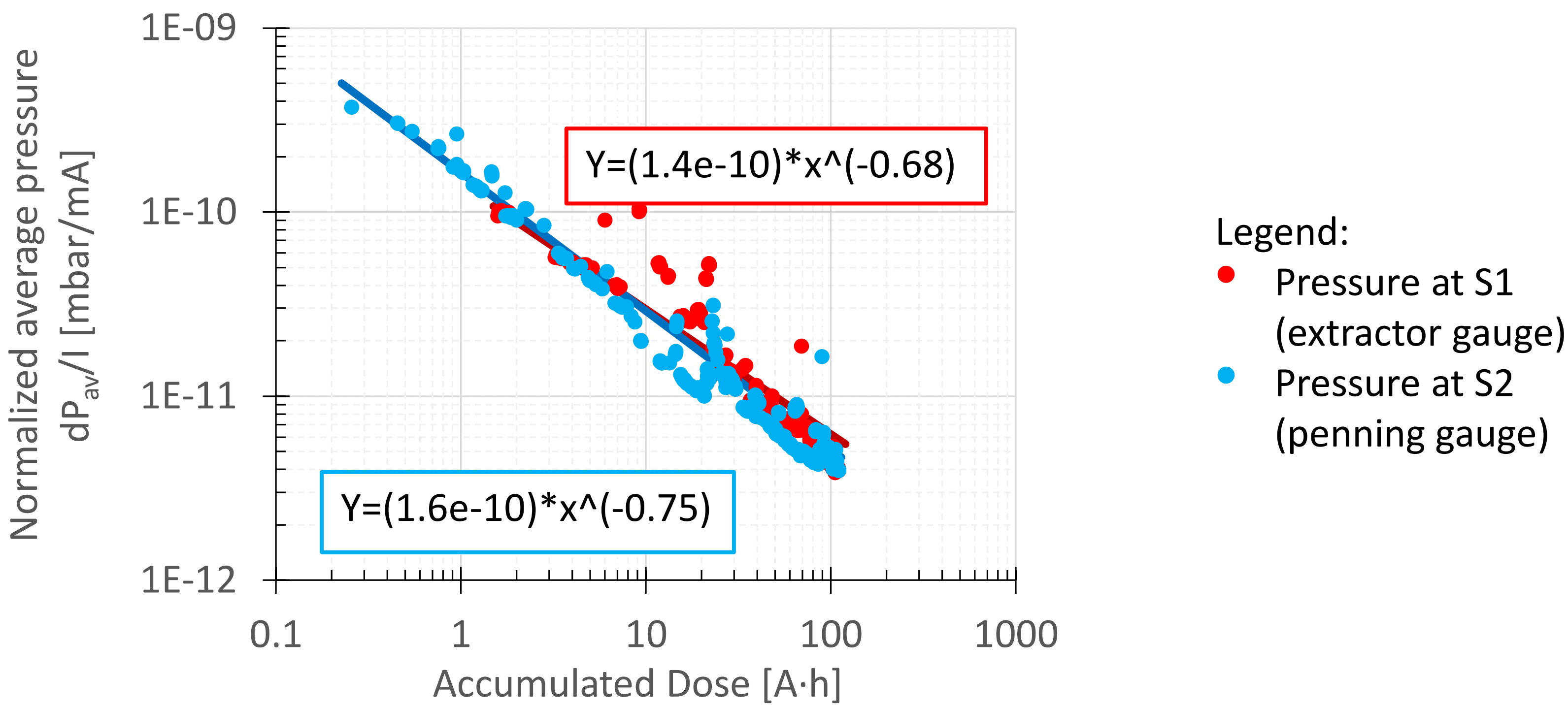
Legend:
- Pressure at S1 (ion pump)*
- Pressure at S1 (extractor gauge)
- Pressure at S2 (penning gauge)
- Pressure at S2 (ion pump)
- Pressure at L (ion pump)

* Pressure at S1 (Ion pump) probably due to electrical effect

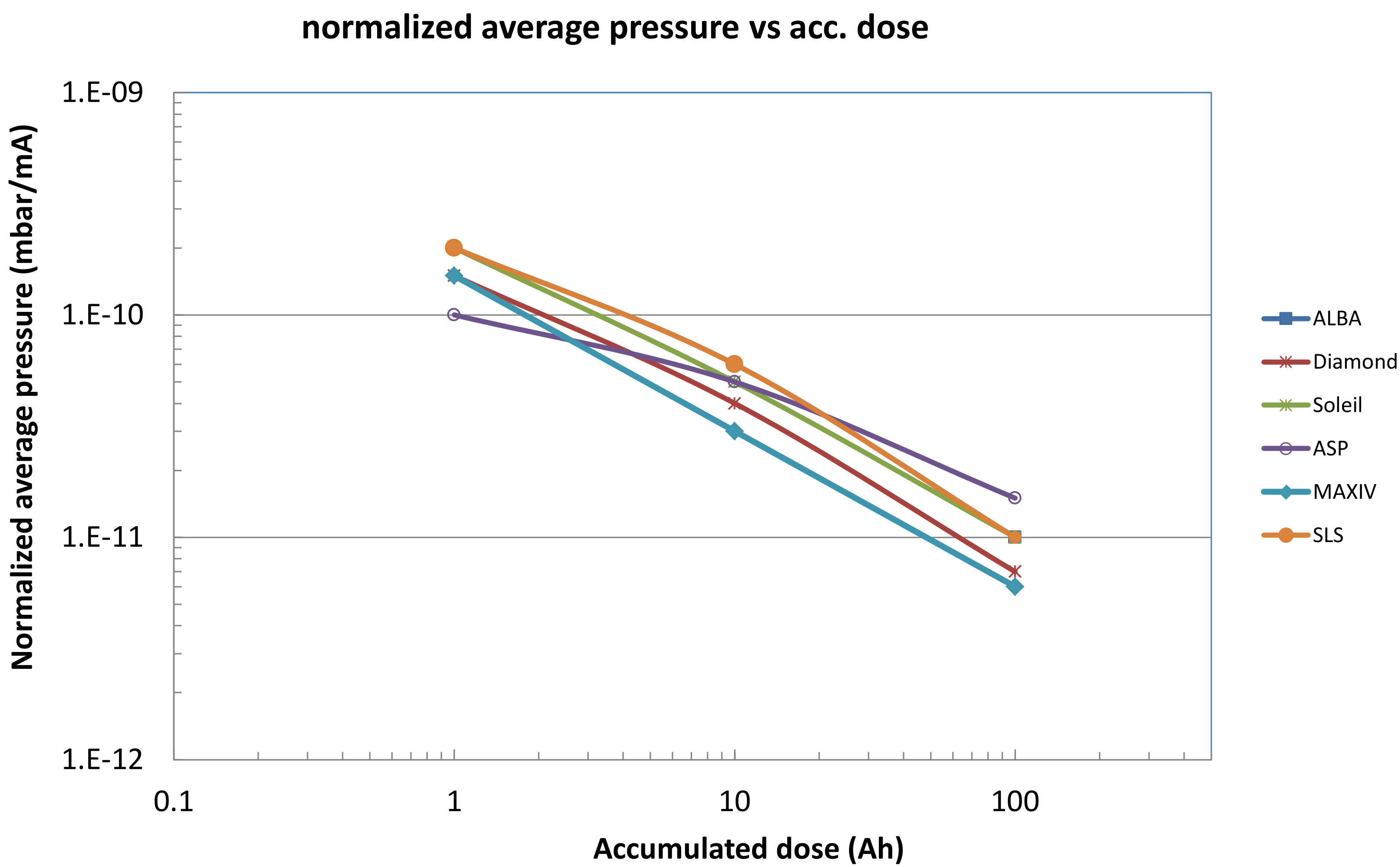
Vacuum conditioning curve



Normalized average pressure vs beam dose,
recorded in S1 uncoated crotch absorber, and S2 NEG-coated

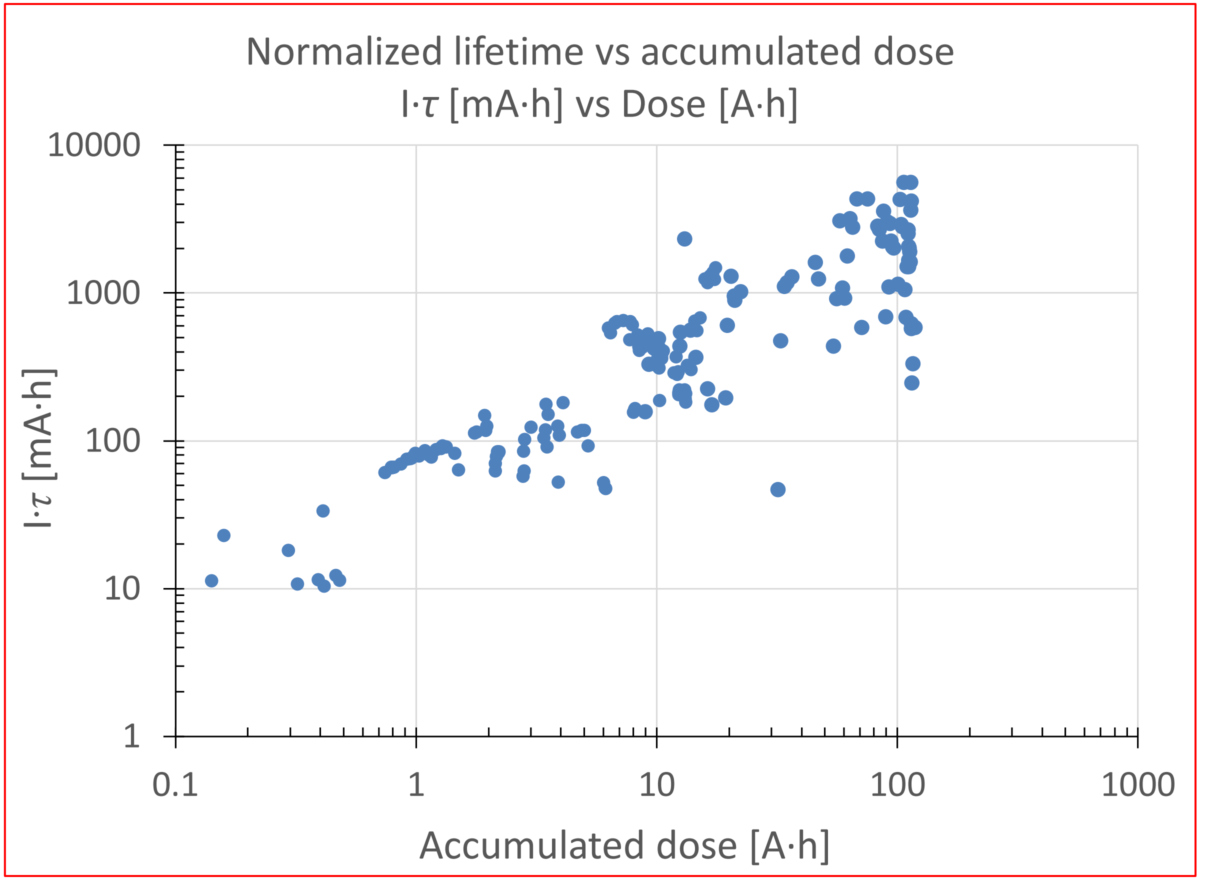


Vacuum conditioning curve



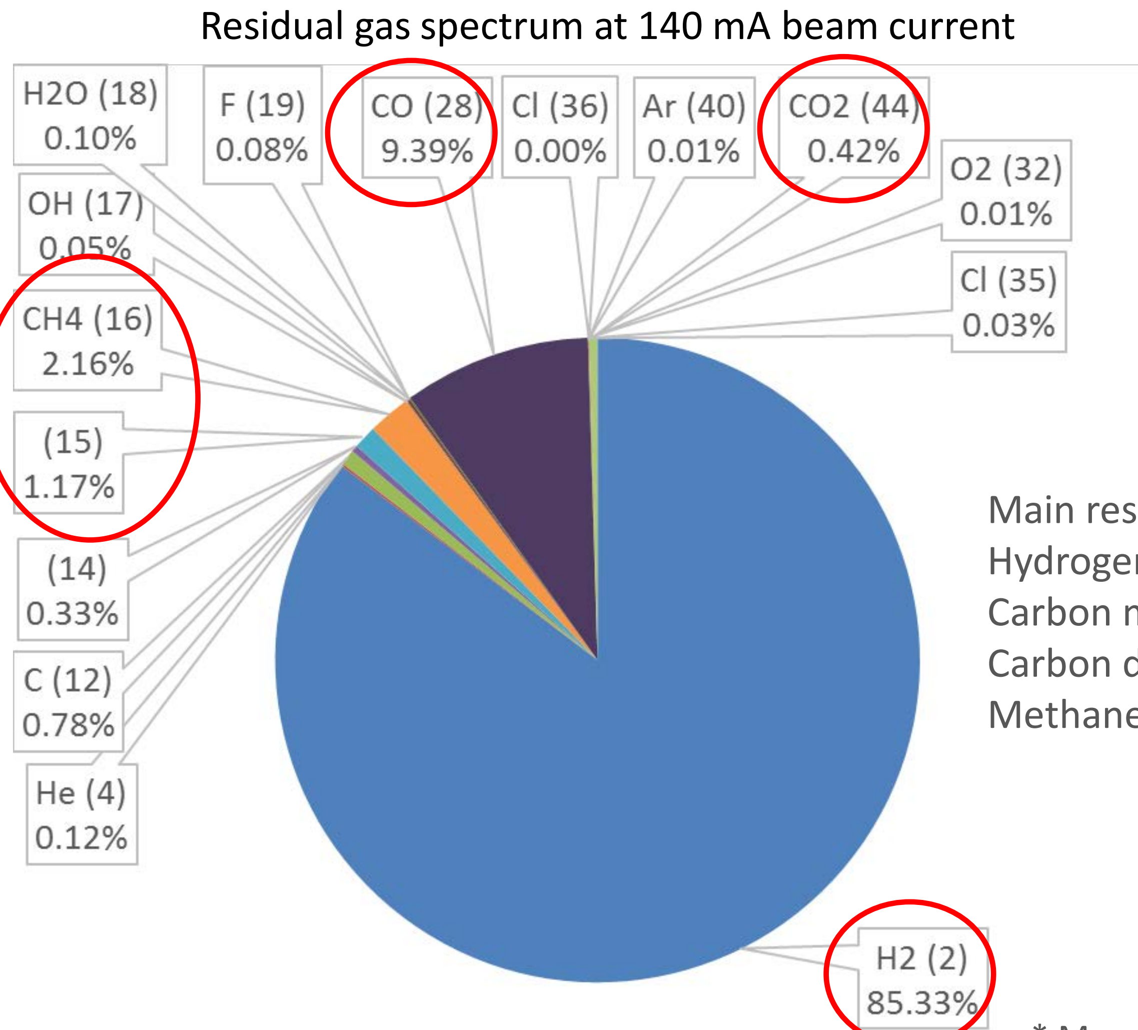
- ALBA: Raquel Monge, privet communication.
- Diamond: M P Cox et al, Commissioning of the diamond light source storage ring vacuum system, Journal of Physics: Conference Series 100 (2008) 092011
- Soleil: J.C. Besson, et al COMMISSIONING & OPERATION OF SOLEIL, WAO 2007. PSI - Scientific and Technical Report 2003 / Volume VI
- SLS: L. Schulz et al, STATUS REPORT OF THE SLS STORAGE RING VACUUM SYSTEM: EXPERIENCE AFTER TWO YEARS OF OPERATION
- ASP: E. Al-Dmour, VACUUM PERFORMANCE IN THE MOST RECENT THIRD GENERATION SYNCHROTRON LIGHT SOURCES, EPAC08.

Lifetime evolution



Maximum stored beam current 198 mA

Residual gas spectrum

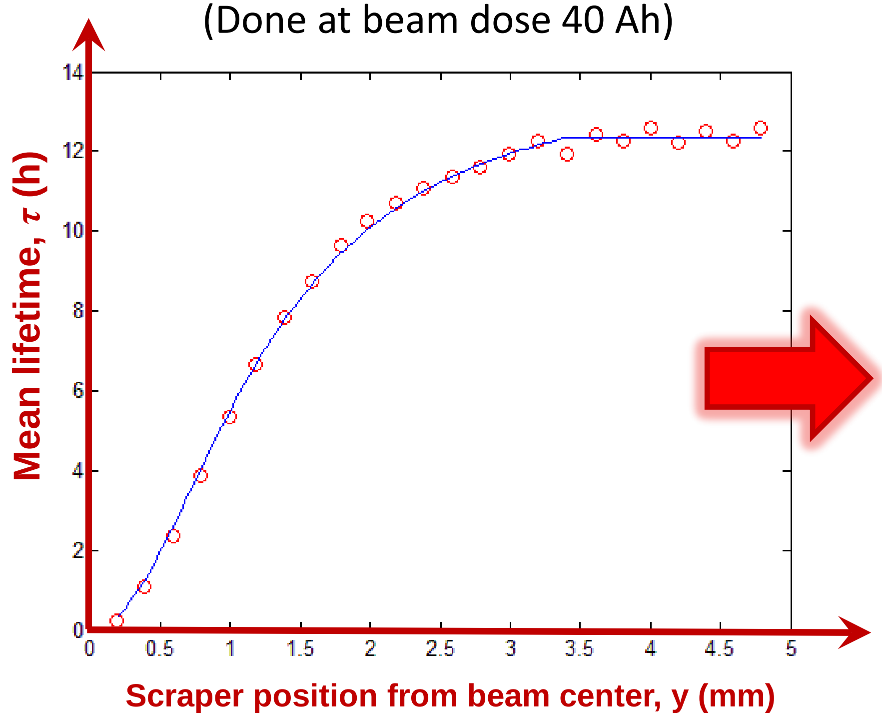


Main residual gasses:
Hydrogen 85.33 %,
Carbon monoxide 9.39 %
Carbon dioxide 0.42 %
Methane 2.16-1.17 %

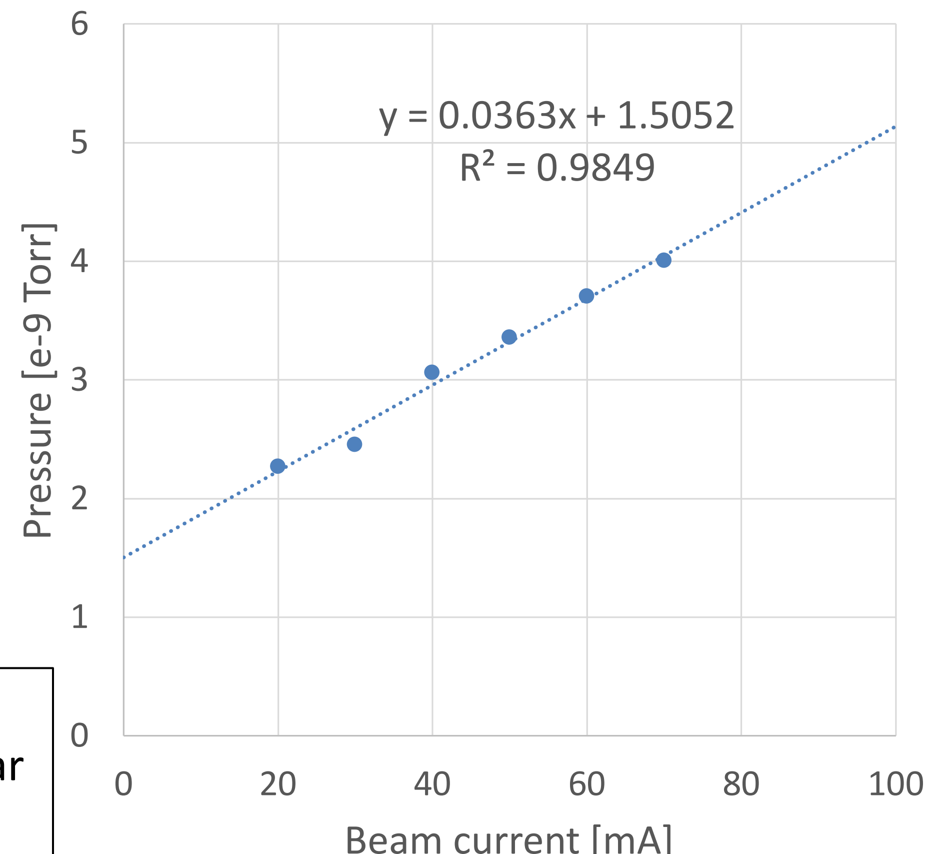
* Mass 16 and 19 is most likely due to intrinsic degassing of the gas spectrometer.

Scraper measurements

Mean lifetime vs vertical scraper distance from the beam center (Done at beam dose 40 Ah)



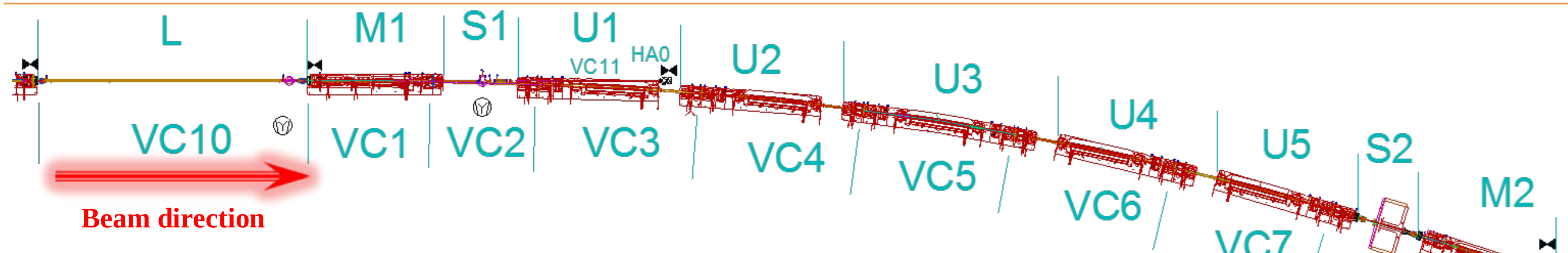
Total average pressure along the beam path (contribution from all gasses based on the RGA spectra)



At 50 mA (dose 40 Ah):	
Average pressure	P = 4.4e-09 mbar
Elastic beam lifetime	$\tau_{elastic}$ = 104.7 h
Inelastic beam lifetime	$\tau_{inelastic}$ = 88.5 h
Touschek lifetime	$\tau_{Touschek}$ = 16.6 h

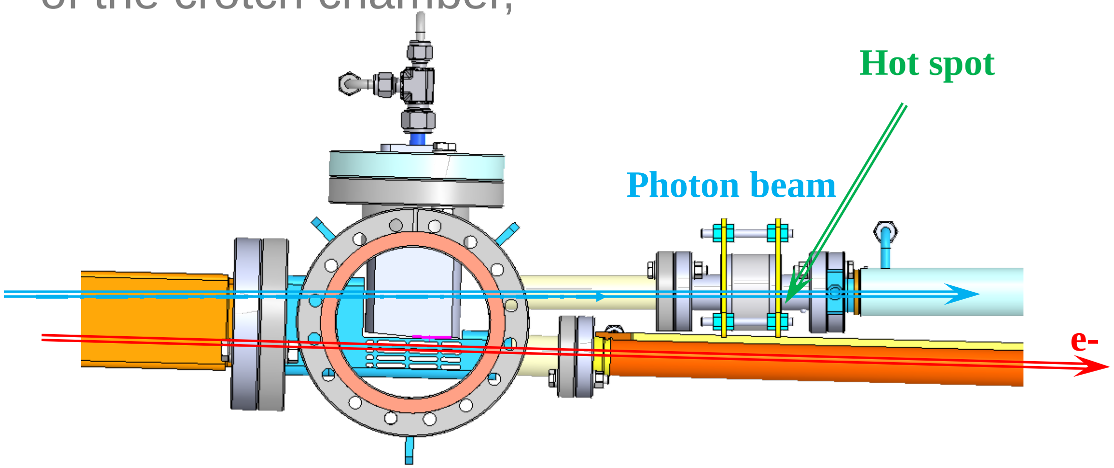
*Scraper measurements and calculations done by Jens Sundberg, Thanks!

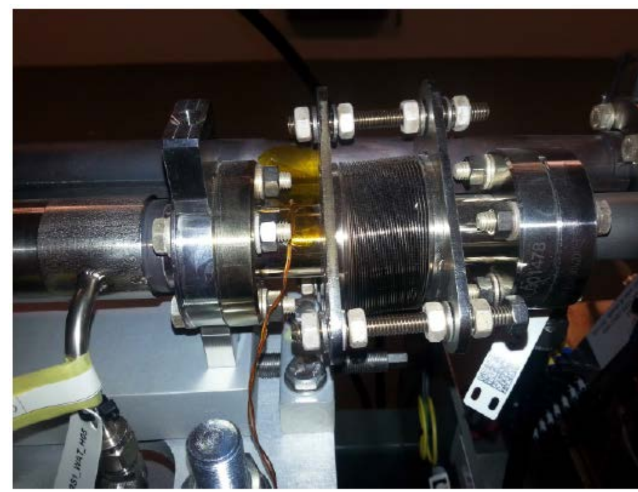
Problems



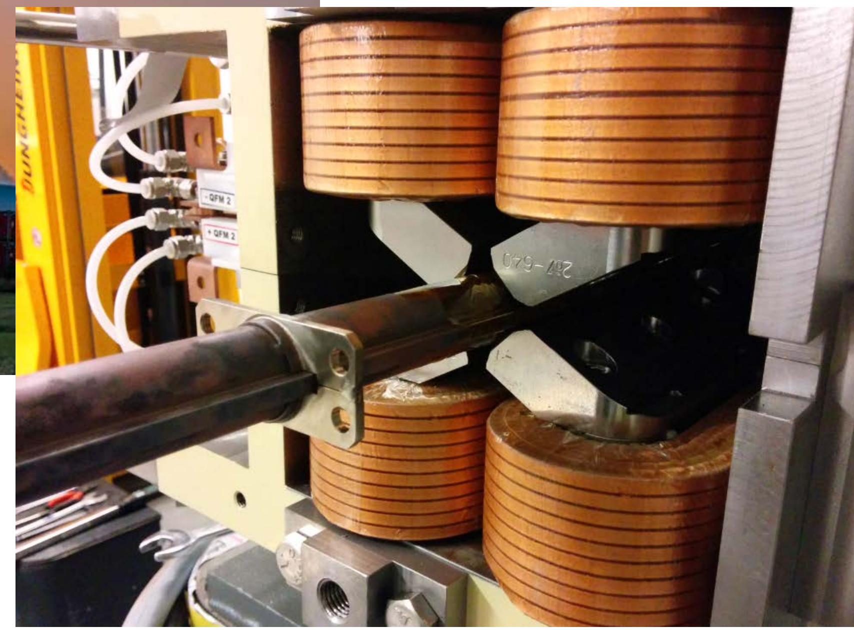
- RF cavity (S2) venting due to broken high power feedthrough during conditioining (with closed valves). Now cavity is removed from the ring and dummy chamber placed as could not be run with high power anymore. Now awaits conditioning outside the ring. Also pick up loops ceramic parts had leaks.

- Hot spots in proximity of crotch absorber (S1), miss-positioning of the crotch chamber,





Thanks for your attention



Acknowledgments:

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