



Status of industrial production for LS2 collimator devices

S. Gilardoni (EN/STI) – for WP5



8th HL-LHC Collaboration Meeting, CERN, 15-18 October 2018

LS2 production inventory

- LS2 collimation upgrades
 - 4+1 dispersion suppressor collimators (TCLD), around IR2/7
 - TCLD → Target Collimator Long Dispersion Suppressor
 - To be installed together with 11 T magnets in IR7
 - Inermet®
 - 8+2 low-impedance collimators (TCSPM), IR7
 - TCSPM → Secondary Collimator with Pick-Up Metallic
 - Jaw of MoGr coated with Mo to improve electrical conductivity – better impact on impedance for HL-LHC intensities

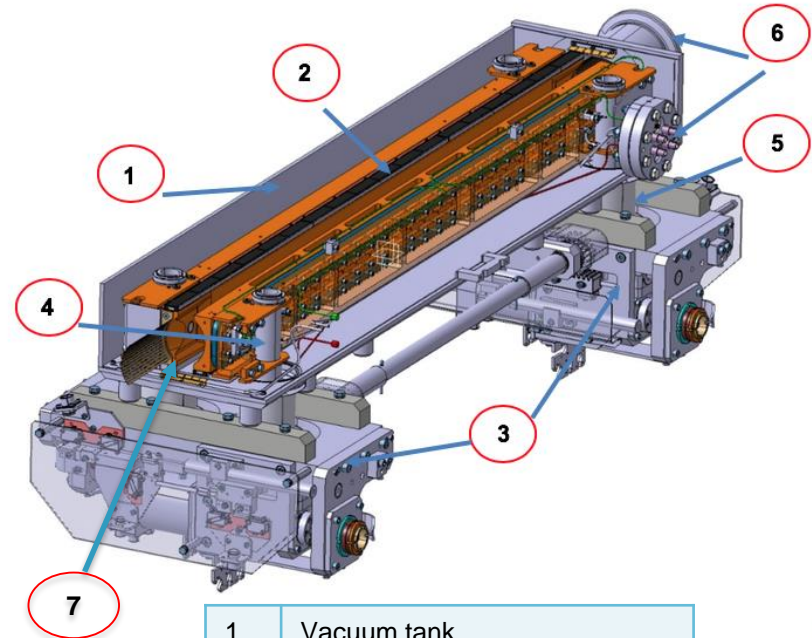
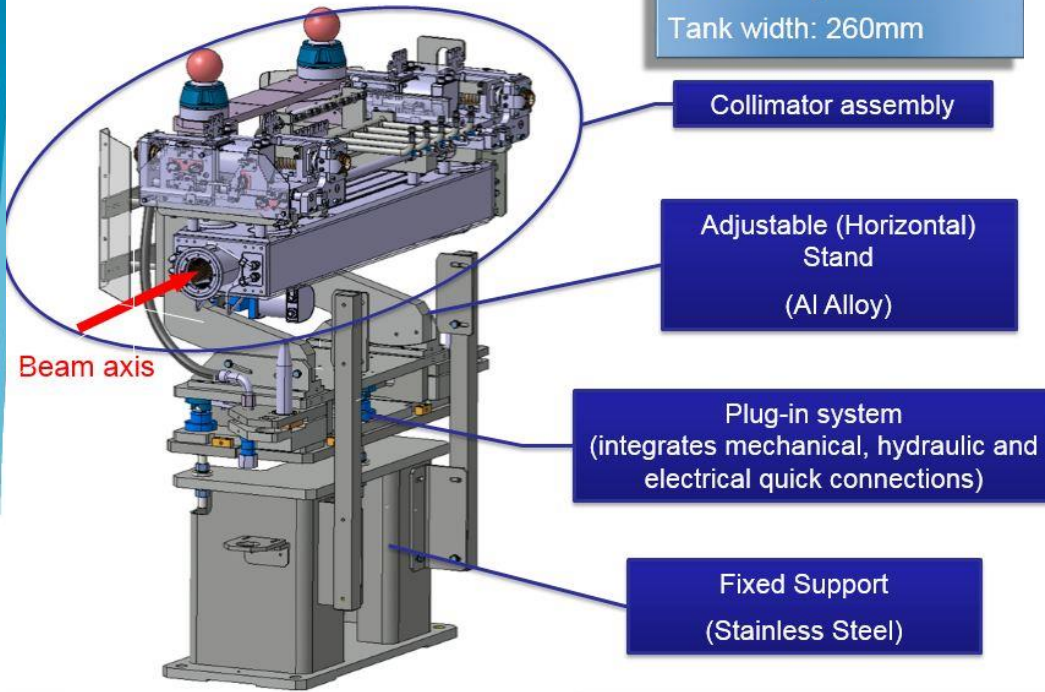
- Primaries consolidation
 - 4+1 TCPMP
 - TCPMP → Primary Collimator with Pick-Up Metallic
 - Jaw of MoGr to improve electrical conductivity – better impact on impedance for HL-LHC intensities
 - No coating because potentially exposed to direct beam impact plus continuous losses

Production strategy

- Collimator assembly (production) from external companies
 - Full collimator (already compliant with UHV requirements) delivered to CERN
 - First qualification done at company premises – include HUV tests
 - Acceptance tests at CERN
 - Alignment of end-switches, anti-collision systems, etc..
 - Installation in tunnel

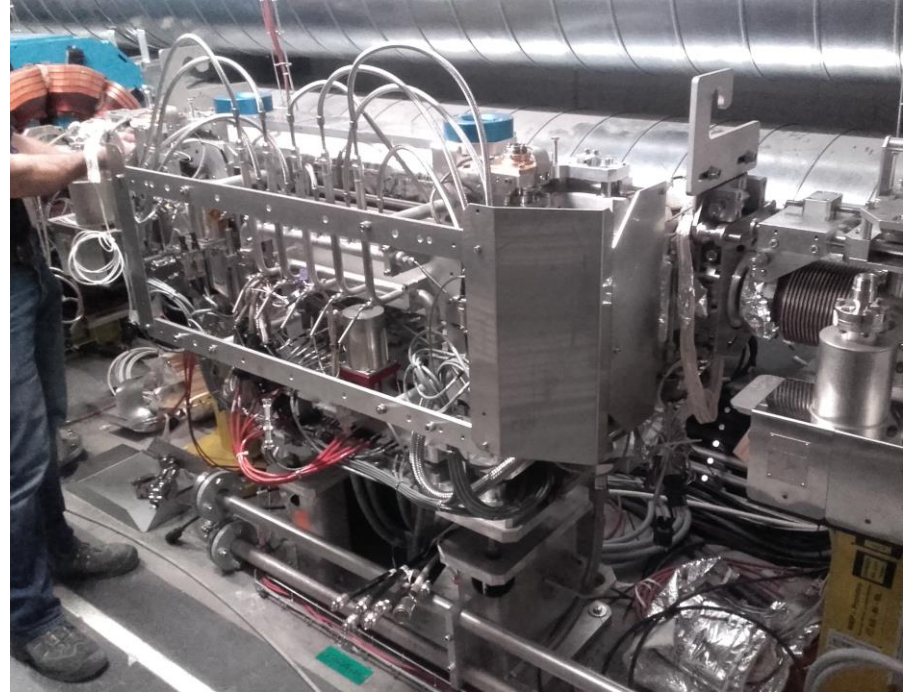
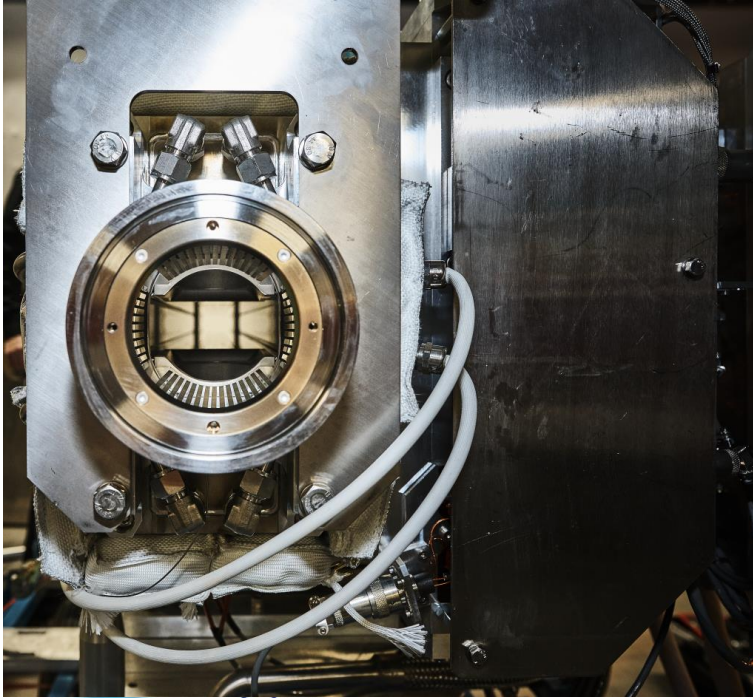
- Raw materials acquired by CERN and delivered for final assembly (only main parts)
 - Raw materials includes Jaw/Absorbing blocks like MoGr (Carbon based material, Copper based material and Inermet®) at final dimensions
 - Stainless steel plates for ultra-high vacuum applications
 - Motors, switches and LVDTs to be fitted onto tables
 - Springs
 - Vacuum flanges
 - Stainless steel bellows
 - Beam instrumentation related parts (button pickups, etc..)

What we are building



1	Vacuum tank
2	Collimator jaws
3	Mechanical tables
4	Shafts
5	Bellows
6	Vacuum flanges
7	Button Pick-ups (BPMs)

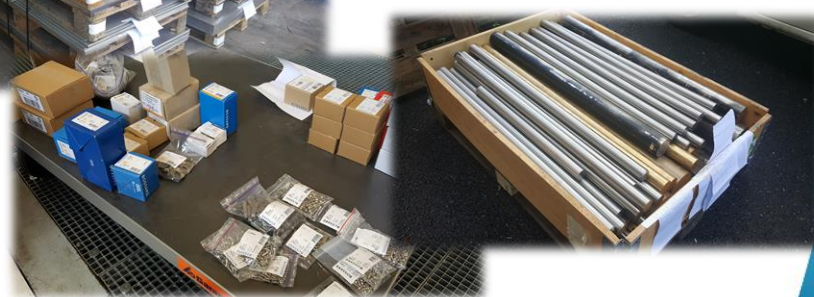
Final assembly – pre-LS2 production



Last year (2017) status summary

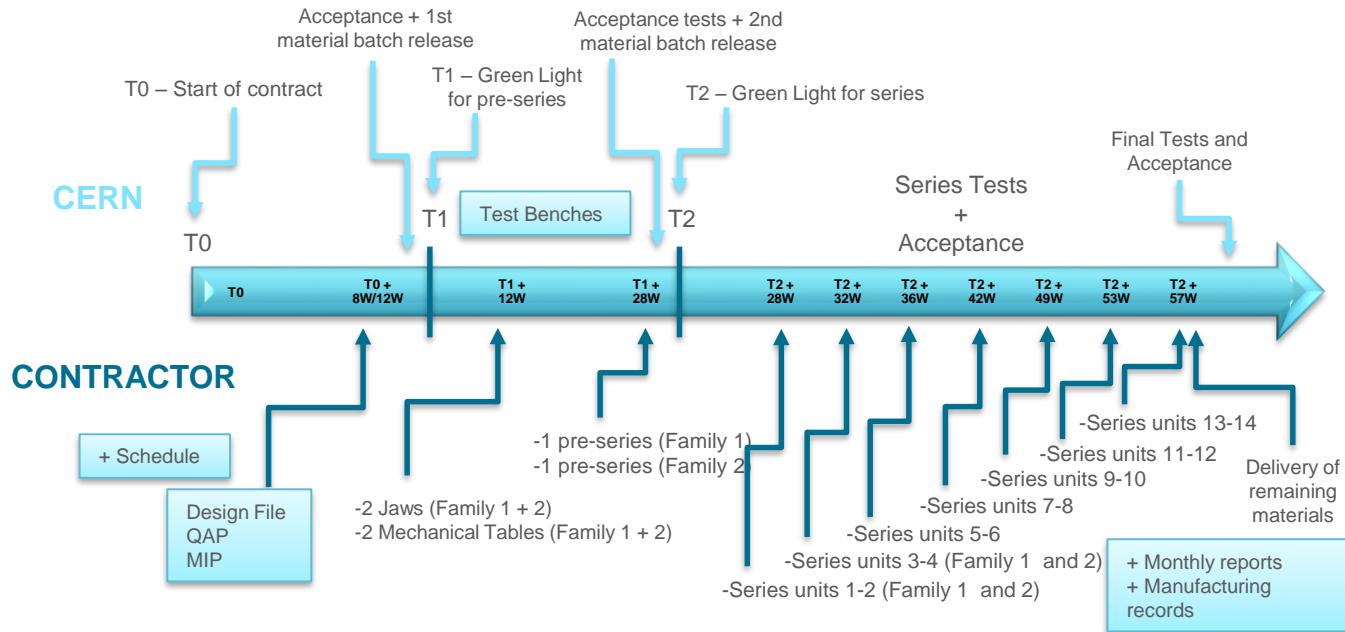
- TCSPM Prototype Manufacturing
 - Installed, 2 years of operation
- TCLD Prototype Manufacturing
- LS2 Collimators Production
 - Market Survey (MS-4272)
 - Invitation to Tender (IT-4272)
 - Finance Committee (12/2017)
 - Contract award (01/2018)
 - Material Procurement
 - Raw material
 - Commercial components

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Last year (2017) status summary

First proposed Production Schedule



Collimator's supports/cradles manufacturing

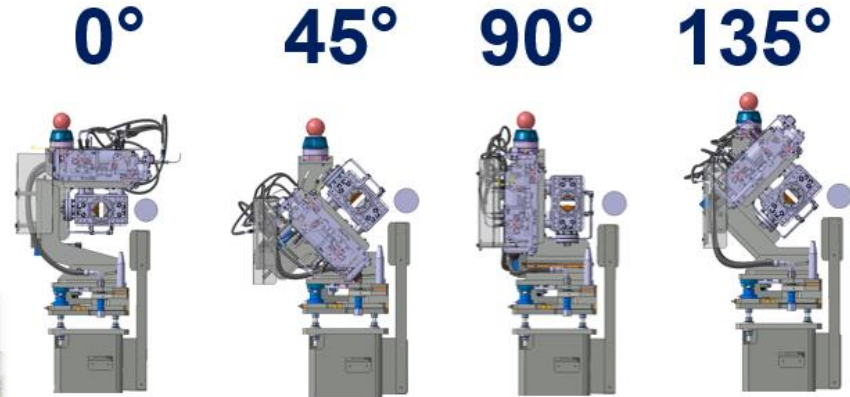
Production for LS2:

- 8 units – 0° layout
- 2 units – 45° layout
- 6 units – 90° layout
- 6 units – 135° layout
- 4 units – TCLD support

Contract awarder to Ges Muhendislik (Turkey)

Production Status

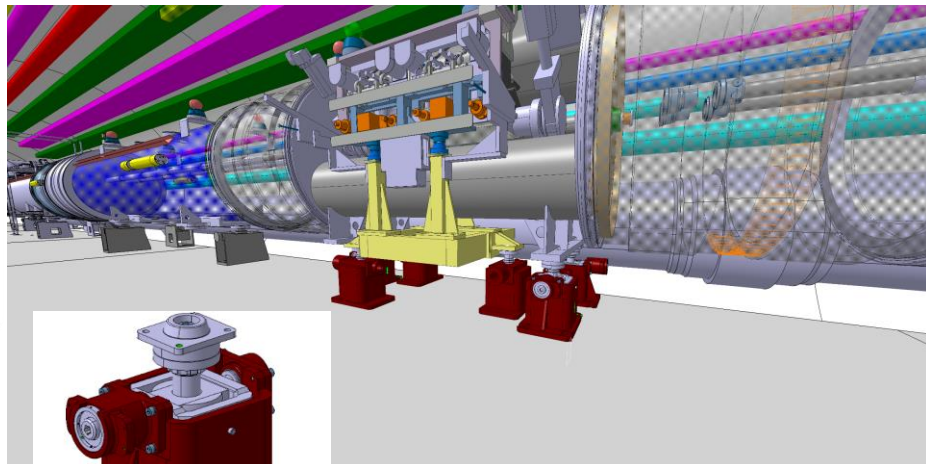
- Visited on [05/10/2018](#)
- Raw material procurement stage
- TCLD supports in progress



	JULY 18	AUG.18	SEP.18	OCT.18	NOV.18	DEC.18	JAN.19	FEB.19	MARCH19	APR.19
COLLIMATOR 0	BOM LIST PREPARING AND CONTROLLING	PRODUCTION & PROCESSPLANNING AND PROCUREMENT ACTIVITIES	PRODUCTION QUALITY CONTROL						DELIVERY	
COLLIMATOR 45			PRODUCTION QUALITY CONTROL						DELIVERY	
COLLIMATOR 90			PRODUCTION QUALITY CONTROL							DELIVERY
COLLIMATOR 135			PRODUCTION QUALITY CONTROL							DELIVERY
TCLD SUPPORT			PRODUCTION QUALITY CONTROL				DELIVERY			

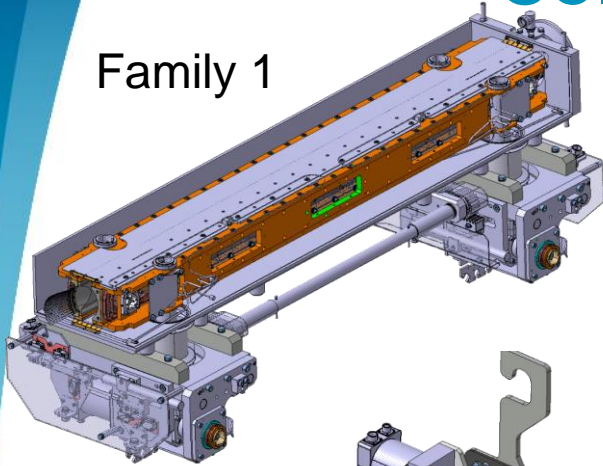
Collimator's Jacks manufacturing

- Jacks - production for LS2
 - 15 for TCLD collimators
 - 15 for Cryostat
 - Pre-series 3 units for acceptance
- Contract awarder to AMF (UK)
- Production Status
 - Visited on 10/07/2018
 - Pre-series batch (3 jacks) received & approved 26/09/2018
 - Series production in progress
 - Series Reception on 01/2019

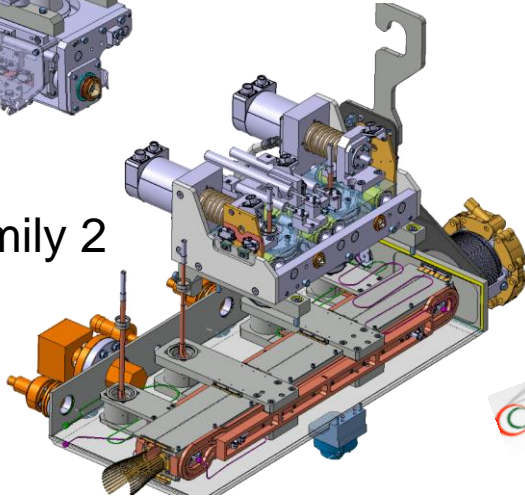


Collimation Production for LS2

Family 1



Family 2



Family	Collimator Types	Units
Family 1	TCSPM*	10
	TCPMP*	5
Family 2	TCLD	5
Options		
Family	Collimator Types	Units
Family 1	TCTPM	4
Family 2	TCLD	2

- Contract awardee to CINEL (ITALY) specialized in:

- Precision Machining
- Welding and cleaning
- Vacuum brazing
- 3D measurements
- Precise assembly

- Produced LS1 collimators

Contract award 01/2018

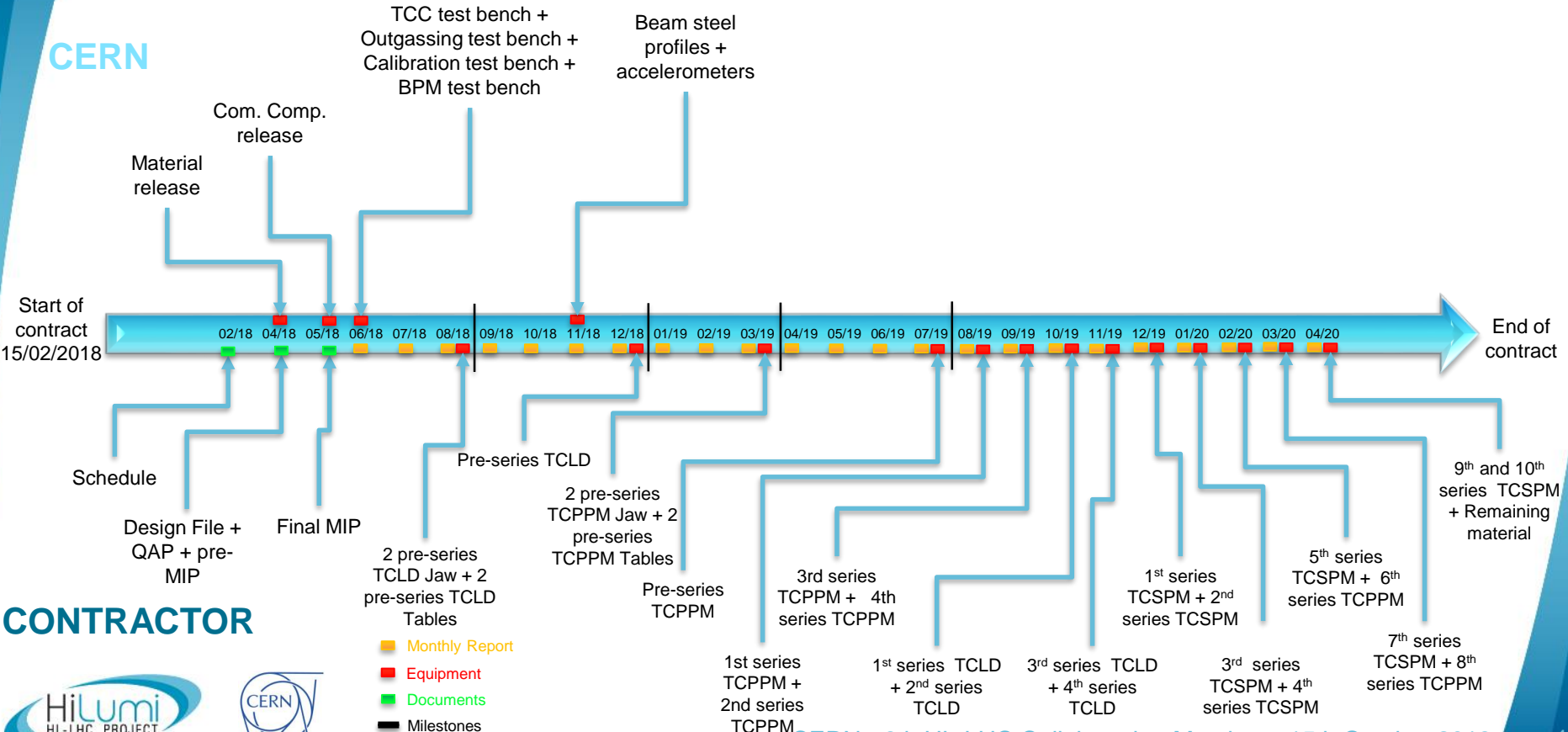
Kick of meeting 02/2018

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*TCSPM and TCPMP differs only in coating for the jaw absorbing blocks

Collimators production - Deliverables time-line

CERN



CONTRACTOR



Collimators production follow up

Follow up - EDMS/MTF Documentation traceability

- Tests and reports
- Design modifications/proposals
- Procedures
- Quality Assurance Plan (QAP)
- Manufacturing Inspection Plan (MIP)

The screenshot displays a hierarchical tree structure of documents and folders. The main folder is 'Collimation (VP5)', which contains sub-folders for 'Minutes', 'Presentations', 'Administration', 'Engineering drafts & notes', 'Fabrication, Assembly and Verification drafts & notes', and 'Industrial Production'. The 'Industrial Production' folder is expanded, showing 'LS2 Collimators Production' and 'Documents shared by CERN'. The 'Documents shared by CERN' folder is further expanded, showing a list of documents including '2000110 (v.1) Agenda for meeting 02-07-2018', '2000111 (v.1) Kick off meeting Agenda 15-02-2018', '2000113 (v.1) Minutes from Kick-off meeting 15-02-2018', '2004640 (v.1) Minute from meeting 02-07-2018', '2025634 (v.1) Minutes meeting 25-07-2018', and '2025635 (v.1) Agenda visit AMF 10-07-2018 for TCCLD Jacks'. The 'Presentations' folder is also expanded, showing '1811903 (v.1) TCCLD SHORT COLLIMATOR ASSEMBLY drawing folder LHCTCLDA0002', '1921547 (v.1) TCCLD drawing folder for serie production (Cooled BPM)', '1836366 (v.1) Assembly TCSPM drawing folder LHCTCSPM0160 (serie production - cooled BPM)', '2000528 (v.1) TCCLD tank modifications', and '2026716 (v.1) TCCLD mechanical table modifications, after assembly 25-07-2018'. The '3D Models' folder is also expanded, showing '1811903 (v.1) TCCLD SHORT COLLIMATOR ASSEMBLY drawing folder LHCTCLDA0002', '1921547 (v.1) TCCLD drawing folder for serie production (Cooled BPM)', '1836366 (v.1) Assembly TCSPM drawing folder LHCTCSPM0160 (serie production - cooled BPM)', '2000528 (v.1) TCCLD tank modifications', and '2026716 (v.1) TCCLD mechanical table modifications, after assembly 25-07-2018'. The 'Procedures' folder is also expanded, showing '2026747 (v.1) Traceability of Mo-Gr blocks for TCCLD', '2028330 (v.1) TCC procedures for set up and testing', 'Templates', 'Shipments', 'Tests performed at CERN', 'Manufacturing records CERN equipment', 'Documents provided by CERN', 'Contract Management', 'Deliveries CERN', 'Detailed Design File', 'TCCLD', 'TCPPM', 'TCSPM', 'Quality Assurance Plan', and 'MIP and Procedures'.

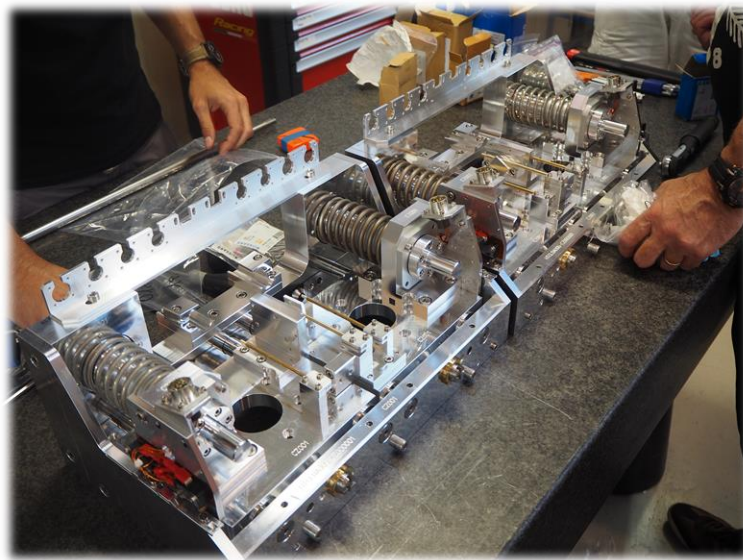
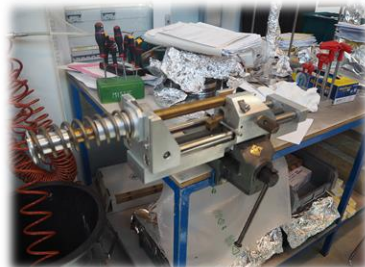
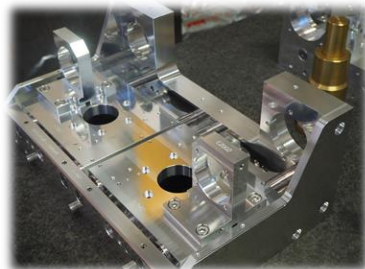
Many thanks to
ATS-DO

Collimators production milestones

TCLD pre-series Mechanical tables

- Assembled at Cinel on 07/2018
- Received, tested and approved at CERN on 08/18

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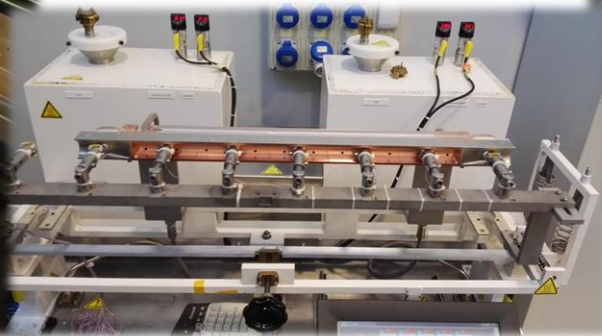
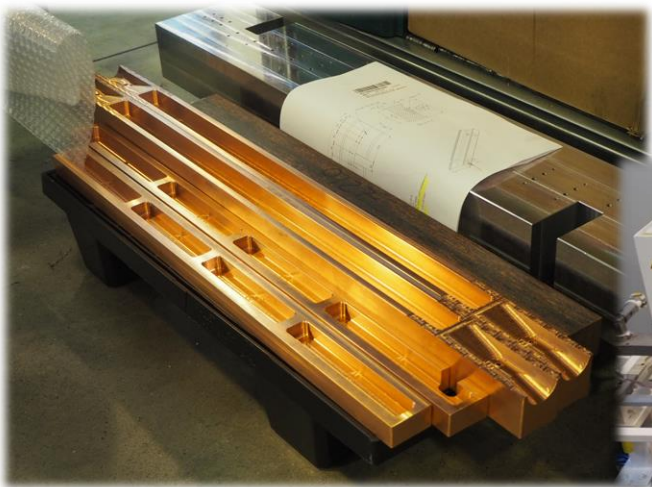
Collimators production milestones

TCLD pre-series Jaws and RF contacts

- Brazed at Cinel on 09/2018
- Received at CERN on 10/18



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Collimators production milestones

CERN deliveries to Cinel

- Raw material (03/2018)
- Commercial components for TCLD pre-series (06/2018)
- Thermal Contact Conductance (TCC) test bench (08/2018)
- BPM and torque-meter Test benches (08/2018)
- Outgassing test bench (02/2019)



Many thanks to
EN-SMM, BE-BI & TE-VSC

Collimators status summary

Production Status

- TCLD pre-series on going
 - TCLD Mechanical Tables finished (07/2018)
 - TCLD Mechanical Tables received and tested at CERN (08/2018)
 - TCLD jaws brazed and metrology tested (09/2018)
 - TCLD tank manufacturing on going

Next steps until end 2018

- TCLD pre-series collimator
 - TCLD brazed jaws to be tested at CERN (10/2018)
 - TCLD jaws to be final assembled at Cinel (11/2018)
 - TCLD pre-series collimator assembly (11/2018)
 - TCLD 3D metrology + tests + fine tuning (12/2018)
 - TCLD collimator reception milestone 18/12/2018
- TCSPM/TCPPM pre-series tank manufacturing will start in 11/2018

Next year (2019) foreseen production/activities

TCSPM/TCPPM

- Foreseen reception at CERN
 - Pre-series Mechanical Tables (03/2019)
 - Pre-series jaws (03/2019)
 - Pre-series collimator (07/2019)
 - 2 TCPPM series collimators (08/2019)
 - 2 TCPPM series collimators (09/2019)
 - Collimators supports/Cradles (04/2019)

TCLD

- Foreseen reception at CERN
 - 2 TCLD series collimators (10/2019)
 - 2 TCLD series collimators (11/2019)
 - Collimators jacks (01/2019)
 - Collimators supports (01/2019)

Collimators Surface Activities

- Control Reception
- Ready for installation activities
 - Tuning/adjusting activities
 - 272 layout preparation and cradles assembly
 - Mechanical tests
 - Electronic measurements and tests
 - Alignment activities
 - Vacuum activities + bake out

LS2 collimators “ready for installation” schedule

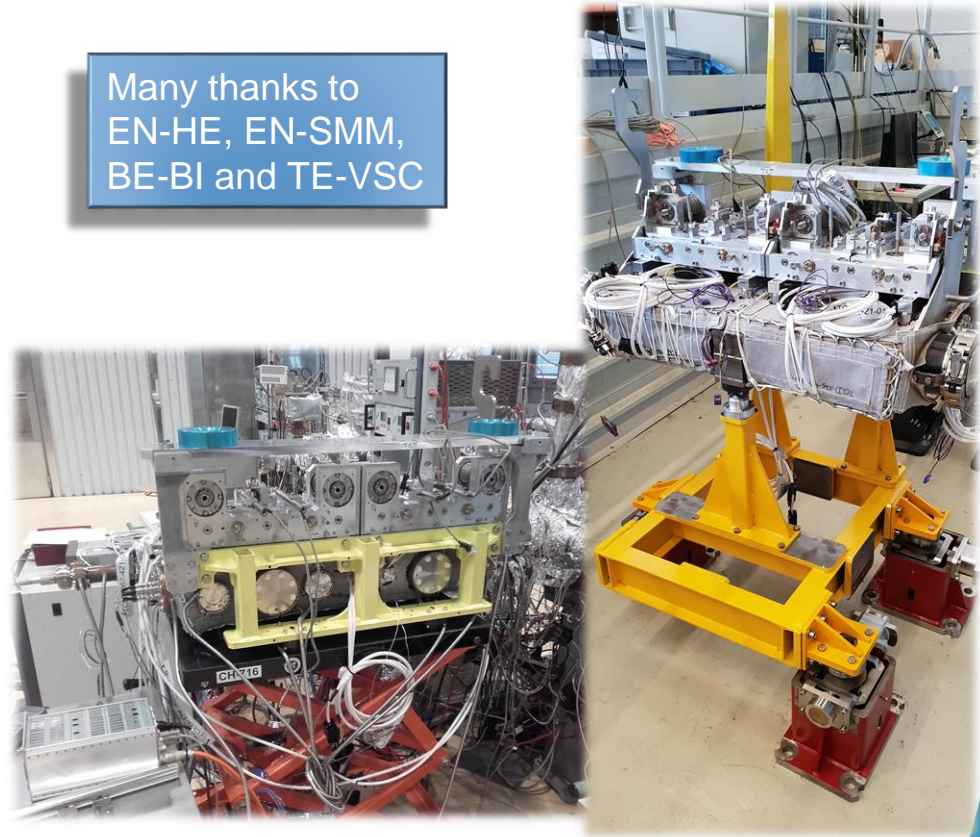
Equipment	Location	Ready to install
TCSPM.6L7.B2	LSS7L	01-Jul-20
TCSPM.E5L7.B2	LSS7L	01-Jul-20
TCSPM.D4L7.B2	LSS7L	02-Jun-20
TCSPM.B4L7.B1	LSS7L	02-Jun-20
TCSPM.B4R7.B2	LSS7R	28-Feb-20
TCSPM.D4R7.B2	LSS7R	28-Feb-20
TCSPM.E5R7.B1	LSS7R	04-May-20
TCSPM.6R7.B2	LSS7R	04-May-20
Equipment	Location	Ready to install
TCLD.10L2.B1	C11L2	05-Feb-20
TCLD.10R2.B1	C11R2	05-Feb-20
TCLD.8L7.B1	C8L7	05-Mar-20
TCLD.8R7.B1	C8R7	05-Mar-20
Equipment	Location	Ready to install
TCPP.D6L7.B1	LSS7L	03-Feb-20
TCPP.C6L7.B1	LSS7L	03-Feb-20
TCPP.D6R7.B2	LSS7R	20-Dec-19
TCPP.C6R7.B2	LSS7R	20-Dec-19

Many thanks to
EN-ACE

TCLD prototype validation activities

- Activities along the year
 - Mechanical tables torque tests
 - BPM flanges and cables installation and validation
 - Heating jackets installation and design validation
 - Outgassing test performed and compliant
 - Patch panel + electrical connections
 - Survey/Alignment validation

Many thanks to
EN-HE, EN-SMM,
BE-BI and TE-VSC



TCLD prototype validation activities

TCLD + Cryostat installation test (week 08/10/18)



Foreseen Installation test

- Real tunnel mock up b.927
- Scheduled for week 22/10/18



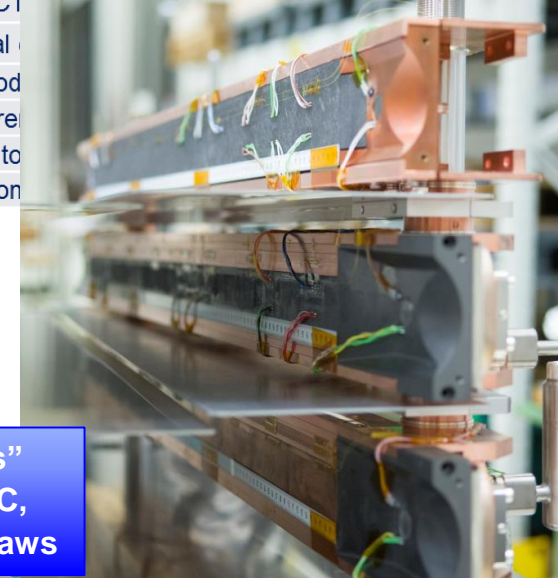
Many thanks to EN-
HE, EN-MME, EN-
SMM, TE-MS, EN-
VSC and ATS-DO

MoGr overview

- Produced by spark-plasma sintering
- Graphite matrix with carbide reinforcement
- Very high **thermal properties and robustness to beam impact**
- Electrical conductivity: factor of 4-5 higher than Phase I CFC and factor ~15 wrt isostatic graphite**
- Successfully tested in two HiRadMat experiments:** survived to peak power density 2x HL-LHC asy. Dump
- Contract awarded to Nanokare (Spain)

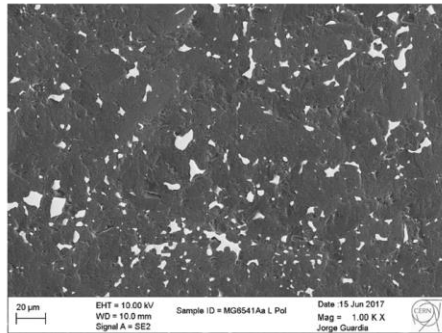
MoGr Technical specification

Property	Orientation		Unit
	*	⊥	
Density at 20°C	2.40 – 2.60		[g/cm ³]
Specific heat at 20°C	>0.6		[J/(g·K)]
Electrical conductivity at 20°C	>0.90		[MS/m]
Thermal Diffusivity 20°C /at 300°C	>390/120	>25/8	[mm ² /s]
Thermal conductivity at 20°C /at 300°C	>500/300	>35/25	[W/(m·K)]
Volumetric CTE 20-1000°C	7		[10 ⁻⁶ K ⁻¹]
Coefficient of thermal expansion 20-1000°C	7		[10 ⁻⁶ K ⁻¹]
Young's Modulus	140		[GPa]
Flexural strength	140		[MPa]
Flexural strain to failure	0.2		[mm/m]
Dimensional stability	0.2		[%]



HRMT-23 “Jaws” experiment: CFC, MoGr and CuCD jaws

Microstructure



In-plane polished surface



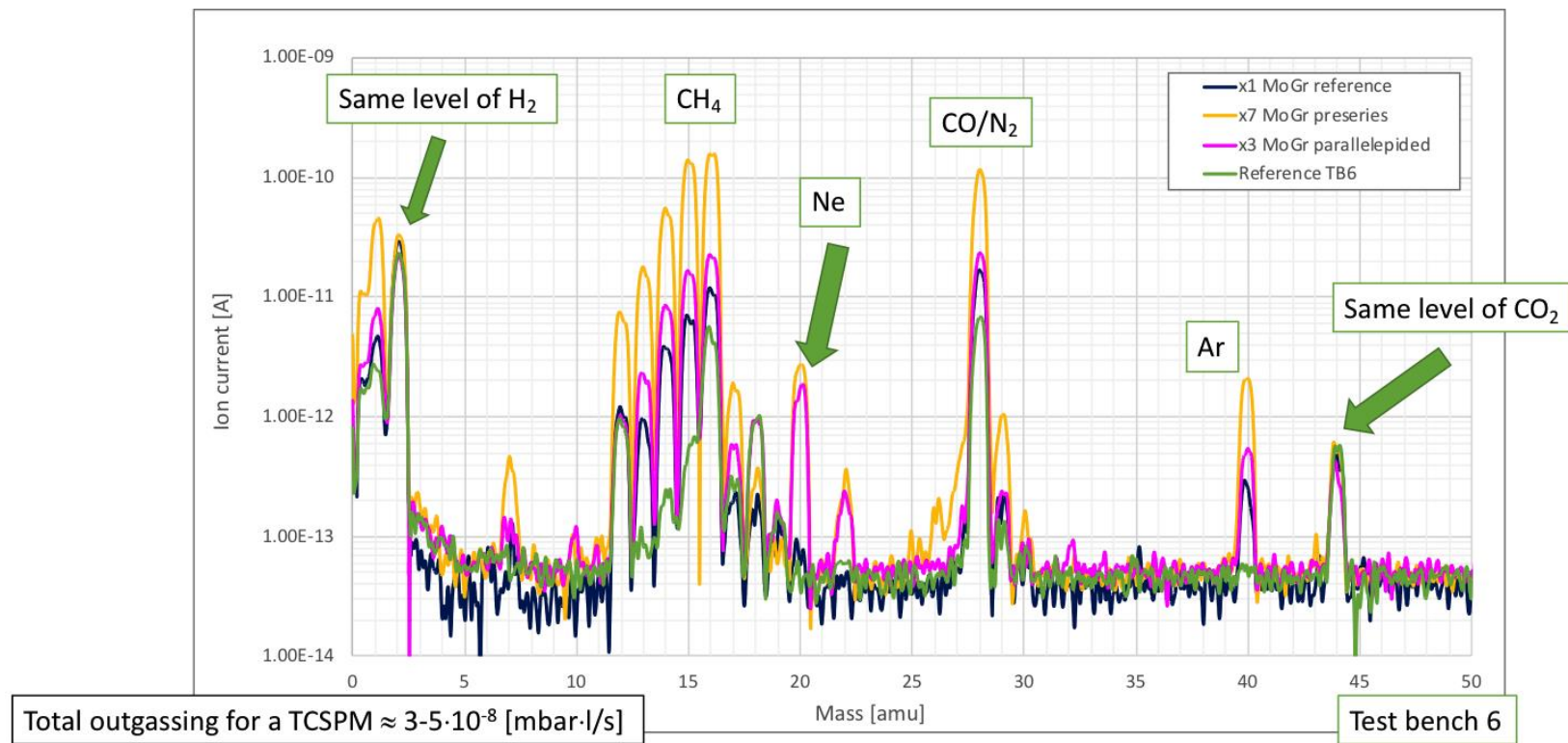
Perpendicular fracture surface

MoGr production status

- **1st pre-series:** shipped to CERN in May.
 - Very good thermomechanical and electrical properties
 - *Total outgassing out of spec → rejected*
 - *Reason identified: sintering temperature 100 °C higher than the grade validated during the company qualification*
- **2nd pre-series:** correct sintering temperature, material received end of August
 - Acceptance tests completed on early September
 - *Total outgassing lower than 1st preseries by a factor of 50 and within spec, no high-mass species*
 - *Content of air and methane out of spec for single material, but foreseen to be acceptable when installed in a collimator with two NEG cartridges*
 - Material available for shipping to the collimator manufacturer
- **3rd batch:** under delivery (40% already at CERN, TODAY should receive the rest)
- **Next batches:** production rate 1 batch/month



Overview of RGA scans of MoGr samples

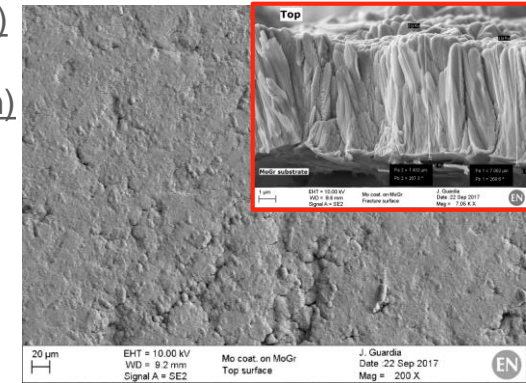


Mo coating on MoGr

- Prototype coated at CERN:
 - Magnetron sputtering in Kr on actual MoGr material, thickness $6\ \mu\text{m} \pm 0.5\ \mu\text{m}$
 - RF impedance measured with eddy currents meets specifications ($< 100\ \text{n}\Omega\cdot\text{m}$)
 - No adhesion issues (adhesion $> 6\text{MPa}$)
 - Outgassing rate is x2 the value before coating (mechanism under investigation)
- Running firm selection for coating all the blocks:
 - Coating test in 2 firms: 3 identical blocks, one in each firm and one coated at CERN
 - To be verified for impedance and outgassing, results by end of October
- Alternative: graphite R7550
 - One block coated, outgassing and impedance measurements in progress



Prototype: Cu and Mo coating



	Substrate roughness	Mo grain size (average)	Amount of coating discontinuities	Coating conductivity (MS/m)		Coating resistivity (nΩ.m)
Glass	~0	+	no	+ ☺	4.3 [DC] 5.0 [RF]	232 [DC] 200 [RF]
Alumina	+++	++	++	+ ☺	4.6 [DC] 4.1 [RF]	218 [DC] 244 [RF]
MoGr	+	++	+	+++ ☺	- 14.3-16.7 [RF]	- 60-70 [RF]
CFC	++++	++	(big voids)	- ☹	n.d. (≈substrate)	n.d. (≈substrate)

Expected UHV performances of TCPPM/TCSPM

- Uncoated MoGr production not optimal wrt UHV performances
 - Porosity of the material seems to be the source of the observed outgassing
 - Total outgassing rate within specification
 - Specific gas outgassing (RGA) non-conformity
 - Air and CH₄
- Final collimators TCPPM expected to be compatible with LHC UHV requirements
 - Simulation of pressure and gas distribution used to analyse the impact of:
 - Total CH₄ outgassing rate
 - Internal leak rate → Possible remedies by installation of NEG cartridges
 - Extra passive getters already foreseen with no design modifications to improve vacuum in IP7
- Still some concerns for TCSPM with MoGr coated with Mo
 - Plan “C” already proposed, alternative jaw bulk material with Mo or Cu coating
 - Impact on production being evaluated
 - New coating results should arrive this week

Mechatronics* (I/II) : LVDTs, Motors, Switches

- 500 rad-hard motors ordered
 - 300 Delivered and tested in 2018
 - 50 to be delivered in December 2018
 - 150 To Be delivered for the first half of 2019

- 700 rad-hard LVDTs ordered
 - 600 Received and tested in 2018
 - 100 to be received in December 2018

LHC Collimators Motor



LHC Collimators LVDT



*Production for all collimators: CONS, LIU, HL-LHC(LS2+LS3)

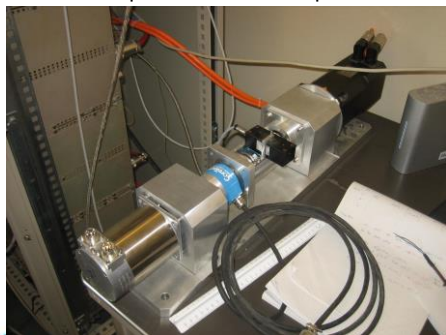
Mechatronics (II/II) : LVDTs, Motors, Switches

- Rad-hard Switches market survey for 1200 pieces to be started in November 2018. Delivery foreseen in 2019
 - New infrastructure cable requests done
 - The ordered components will cover also the new LS3 collimators
 - Order anticipated for cost reduction
- Control components for the new LS2 collimator to be launched in 2019
- Collimator production acceptance tests-bench updated with new torque sensors (both at CERN and at in industry)
- Control full renovation taking place during LS3

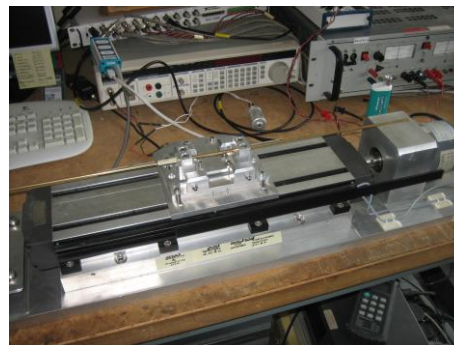
Control rack for the collimators acceptance tests in industry



Motor Torque test-bench setup



LVDTs acceptance test-bench



Conclusions

- LS2 collimator production started as planned
- Main components being in production
- Some concerns for
 - Procurement of Beam instrumentation items: analysis impact on final production ongoing. No major showstoppers but close follow up.
 - Coated MoGr – plan C being evaluated right now

Spare slides

Vacuum simulation: scaled gas distribution

