Overview of LS2 production

Inigo Lamas Garcia
SY-STI-TCD
1. Chronological overview including:
   1. Main milestones
   2. Main Non-conformities
   3. Conclusions and lessons learnt
Collimation Production for LS2

<table>
<thead>
<tr>
<th>Family</th>
<th>Collimator Types</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>Family 1</td>
<td>TCSPM</td>
<td>10</td>
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<tr>
<td>Family 2</td>
<td>TCPPM</td>
<td>5</td>
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<tr>
<td>Family 2</td>
<td>TCLD</td>
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<td>4</td>
</tr>
<tr>
<td>Family 2</td>
<td>TCLD</td>
<td>2</td>
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2nd HiLumi Industry Day – October 31st 2016 – IST Lisbon
Competences and Technologies involved in the manufacturing of a LHC collimator

- Manufacturing Engineering
- High Precision Dry Machining
- Surface Treatments
- UHV Cleaning
- Vacuum Brazing
- EBW and TIG welding
- UHV leak testing and outgassing
- Assembly of UHV components in precise mechanisms
- 3D metrology and assembly adjustments
7\textsuperscript{th} HL-LHC Collaboration Meeting – 16\textsuperscript{th} November 2017 – Ciemat Madrid
TCSPM Prototype Manufacturing

Many thanks to EN-MME and the Main Workshop
TCSPM Prototype Jaws Assembly

Many thanks to EN-MME and the Main Workshop
TCSPM Prototype Assembly

Many thanks to EN-MME and the Main Workshop
TCSPM Prototype Tests

Many thanks to EN-ACE and TE-VSC
TCSPM Prototype Installation

Installed during YETS16/17

Indirect Impedance Measurements during MD

Many thanks to EN-HE and BE-ABP
Many thanks to EN-MME, EN-HE, EN-ACE and the Main Workshop.
Market Survey (MS-4272)

Pre-qualification phase:

- MS-4272 documents sent to 34 companies on the 20\textsuperscript{th} of February;
- 1726492 v.1.0
- LHC-TC-CS-0002 v.1.0 [https://edms.cern.ch/document/1726492/1.0](https://edms.cern.ch/document/1726492/1.0)
- Seven firms submitted answers to the MS-4272 Qualification Questionnaire;
- After a detailed analysis of the answers, three companies were not Pre-Qualified;
- Four companies were Pre-Qualified after an official visit to their facilities.

Many thanks to the Technical Audit Team.
Market Survey (MS-4272)

Final Qualification phase:

- Extensive Qualification campaign through advanced technology samples in order to validate the four companies know-how and processes, such as:
  - High precision dry machining;
  - UHV Cleaning;
  - Surface Treatments and Vacuum Brazing;
  - TIG and EB welding.
Market Survey (MS-4272)
Final Qualification phase, samples characterization:

- High precision dry machining
  - Full metrological control
  - UHV Cleaning on Cu OFE and St. Steel 316LN
    - Fourier Transform Infrared Spectroscopy (FT-IR)
    - X-ray Photoelectron Spectrometry (XPS)
- Surface Treatments and Vacuum Brazing
  - Full metrological control
  - UHV conformity by outgassing test
  - Ultrasound test
  - Metallography inspections
- TIG and EB welding
  - Leak test
  - Penetrant liquids tests
  - X-rays
  - Metallography inspections

https://edms.cern.ch/document/1832539/1
https://edms.cern.ch/document/1823289/2
https://edms.cern.ch/document/1825303/1
https://edms.cern.ch/document/1836446/1
https://edms.cern.ch/document/1856217/1
Many thanks to G. Arnau
EN-MME-MM

US images of brazed qualification samples
Metallographic images of brazed qualification samples

Many thanks to M. Crouvizier ENMME-MM
Two out of the four companies successfully passed the samples characterization campaign;

IT-4272 documents sent to both companies on the 26th of September;

1821032 v.0.6

LHC-TC-CI-0002 v.0.6

Bidders Conference held on the 11th of October;

Bids were opened on the 1st of November;

One company selected: Bids difference > 20%, no splitting strategy possible;

Peers review for the FC0017 document on 17th of November;

On time for December Finance Committee;
Production Plan

T0 – Start of contract

T1 – Green Light for pre-series

T2 – Green Light for series

Series Tests + Acceptance

Acceptance + 1st material batch release

Acceptance tests + 2nd material batch release

CERN

CONTRACTOR

T0

T0 + 8W/12W

T1 + 12W

T1 + 28W

T2 + 28W

T2 + 32W

T2 + 36W

T2 + 42W

T2 + 49W

T2 + 53W

T2 + 57W

- Series units 1-2 (Family 1 and 2)

- Series units 3-4 (Family 1 and 2)

- Series units 5-6

- Series units 7-8

- Series units 9-10

- Series units 11-12

- Series units 13-14

Delivery of remaining materials

- 2 Jaws (Family 1 + 2)

- 2 Mechanical Tables (Family 1 + 2)

- 1 pre-series (Family 1)

- 1 pre-series (Family 2)

- Schedule

+ Monthly reports

+ Manufacturing records

Design File
QAP
MIP

Final Tests and Acceptance

+ Schedule
Materials Logistic

Raw Material

- 85% already received
  - St. Steel 304/316/316LN
  - Aluminum
  - Copper/Brass
  - Kapton
  - Glidcop (in progress)

- Control list
  - Quantity
  - Type
  - Dimensions
  - Reference numbers
  - Drawings concerned

Many thanks to R. Illan EN-STI
Materials Logistic

Commercial Components

- 90% already ordered
- Control list
  - Roller Screw
  - Guiding shaft
  - Bellows
  - Cu-Ni Pipes
  - PT100 cables
  - Electrical equipment
    - BPM cables
    - Switches
    - Step Motors
  - TCLD absorbing blocks

- Is crucial to match the absorbing material production with the collimators industrial production plan

Many thanks to R. Illan EN-STI
Production Follow-up

Start of the contract (tentative date: 1\textsuperscript{st} of February 2018)

- Kick-off meeting.
- Monthly report:
  - Current progress;
  - Issues encountered and solutions proposed;
  - Information about risks in failing.
- Stakeholders:
  - Technical Officer (CERN);
  - Procurement officer (CERN);
  - Technical Responsible for production follow-up (Contractor);
  - Technical Responsible for the commercial follow-up (Contractor).
Production Follow-up

Documentation to be provided by the contractor:

3.7 Information and Documentation

The supply shall include the documents listed below, as a minimum. These documents shall be provided for approval by CERN throughout the execution of the contract:

- Detail Design File (see §3.7.2);
- Quality Assurance Plan (see §3.7.3);
- Manufacturing and Inspection Plan including all the related manufacturing and testing procedures (see §3.7.4);
- Manufacturing Records (see §3.7.5);
- Vacuum brazing documentation (see §3.3.2);
- Periodical calibration reports of the testing equipment provided by CERN.

The documentation shall be provided according to the schedule stated in §4.1 of the Technical Specification.
Production Follow-up

Quality and Acceptance

- Schedule (processes and methods)

- Detailed design file:
  - Production drawings which shall be provided to CERN for approval;
  - List of modifications wrt. the drawings provided by CERN for information.

- Quality Assurance Plan of the firm.

- Manufacturing and Inspection Plan (MIP): Sequence of manufacturing and control steps to produce the collimators:
  - Cleaning procedures;
  - Detailed production procedure for the back stiffeners;
  - Assembly procedure of the jaws;
  - Assembly procedure of mechanical tables and jaws to the vacuum vessel;
  - Procedure of preparation of jaw surface;
  - Vacuum brazing procedure;
  - Procedure for the collimator adjustment;
  - UHV Leak Test procedure;
  - Handling procedures;
  - Labelling procedure.
Production Follow-up

Quality and Acceptance

- Manufacturing Records:
  - All metrology and adjustments reports;
  - The vacuum test reports and leak test reports;
  - The torque test reports;
  - All the BPM test reports;
  - All the Thermal Contact Conductance test reports;
  - All non-conformity reports as soon as they occur.

- Vacuum brazing documentation:
  - Brazing procedure;
  - Log of the parameters for the control of the brazing cycle.

- Periodical calibration reports of CERN equipment.

- Tests at contractor premises:
  - Vacuum leak tightness;
  - Outgassing test;
  - Testing of cooling water circuit of the jaws;
  - Testing of the cooling water circuit of the finished collimator;
  - Metrology and adjustments;
  - Torque tests;
  - BPM tests;
  - Thermal contact conductance tests.
QA HL-LHC Project – Handling of documentation

Many thanks to H. Garcia Gavela
ATS-DO

Project Documentation - > EDMS

Manufacturing Records - > MTF
The contractor shall use CERN tools for storing and handling the documentation:

- **EDMS (Engineering & Equipment Data Management Service)** to upload the design file, schedule, QAP & MIP (and the requested procedures);

- **MTF (Manufacturing & Testing Folder)**: All the manufacturing data (records of QC activities and non-conformities) will be handled via MTF.

CERN will pre-create all the E-documents (both in EDMS and MTF) and the contractor shall just have to upload the files in the corresponding place;

CERN will provide support to handle the documentation in the tools (and training if necessary);

To use EDMS, CERN lightweight account is required ([Link to create one](#)) whereas to use MTF a CERN nice account has to be created (instructions will follow);

E-Groups will be created for communication purposes.

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Many thanks to H. Garcia Gavela
ATS-DO
Year 2017 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)
  - CERN Quality Plan and acceptance defined
  - EDMS and MTF structure defined
- Material Procurement
  - Raw material
  - Commercial components

MILESTONE ACHIEVED
8th HL-LHC Collaboration Meeting – 15th October 2018 - CERN
**External company**

**Collimators production**

**Company: CINEL**

- Based in Padua
- Specialized in:
  - Precision Machining
  - Welding and cleaning
  - Vacuum brazing
  - 3D measurements
  - Precise assembly
- Contract award 01/2018
- Kick of meeting 02/2018
Collimators production - Deliverables time-line

Start of contract 15/02/2018

End of contract

Com. Comp. release
Material release
Schedule
Design File + QAP + pre-MIP
Final MIP
Pre-series TCLD
2 pre-series TCLD Jaw + 2 pre-series TCLD Tables
TCC test bench + Outgassing test bench + Calibration test bench + BPM test bench
Beam steel profiles + accelerometers

CERN

CONTRACTOR

Monthly Report
Equipment
Documents
Milestones

Material release

Pre-series TCPPM
3rd series TCPPM + 4th series TCPPM
1st series TCSPM + 2nd series TCSPM
5th series TCSPM + 6th series TCPPM
9th and 10th series TCSPM + Remaining material

Beam steel profiles + accelerometers

2 pre-series TLD Jaw + 2 pre-series TCPPM Tables

3rd series TCPPM + 4th series TCPPM

1st series TCPPM + 2nd series TCPPM

2nd series TCPPM + 3rd series TCPPM

3rd series TCPPM + 4th series TCPPM

5th series TCSPM + 6th series TCPPM

7th series TCSPM + 8th series TCPPM

1st series TCPPM + 2nd series TCPPM

1st series TCPPM + 2nd series TCPPM

3rd series TCPPM + 4th series TCPPM

7th series TCSPM + 8th series TCPPM

End of contract

Beam steel profiles + accelerometers
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
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 awardee to Ges Muhendislik (Turkey)

- Production Status
  - Visited on 05/10/2018
  - Raw material procurement stage
  - TCLD supports in progress

<table>
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<tr>
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<th>JULY 18</th>
<th>AUG.18</th>
<th>SEP.18</th>
<th>OCT.18</th>
<th>NOV.18</th>
<th>DEC.18</th>
<th>JAN.19</th>
<th>FEB.19</th>
<th>MARCH19</th>
<th>APR.19</th>
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<td>PRODUCTION &amp; PROCESS PLANNING AND PROCUREMENT ACTIVITIES</td>
<td>PRODUCTION QUALITY CONTROL</td>
<td>DELIVERY</td>
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<td>DELIVERY</td>
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Collimator’s Jacks manufacturing

- **Jacks - production for LS2**
  - 15 for TCLD collimators
  - 15 for Cryostat
    - Pre-series 3 units for acceptance

- **Contract awarer 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

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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

<table>
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<tr>
<th>Property</th>
<th>Orientation</th>
<th>Unit</th>
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<tr>
<td>Density at 20°C</td>
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<td>[g/cm³]</td>
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<tr>
<td>Specific heat at 20°C</td>
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<td>[J/(g K)]</td>
</tr>
<tr>
<td>Electrical conductivity at 20°C</td>
<td>&gt;0.90</td>
<td>[MS/m]</td>
</tr>
<tr>
<td>Thermal Diffusivity 20°C /at 300°C</td>
<td>&gt;390/120</td>
<td>[mm²/s]</td>
</tr>
<tr>
<td>Thermal conductivity at 20°C /at 300°C</td>
<td>&gt;500/300</td>
<td>[W/(m K)]</td>
</tr>
<tr>
<td>Volumetric CTE 20-1000°C</td>
<td>&lt;7</td>
<td>[10⁻⁶K⁻¹]</td>
</tr>
<tr>
<td>Coefficient of thermal expansion 20-1000°C</td>
<td>&lt;2.9</td>
<td>&lt;15 [10⁻⁶K⁻¹]</td>
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<tr>
<td>Young’s Modulus at 20°C</td>
<td>35&lt;E&lt;70</td>
<td>[GPa]</td>
</tr>
<tr>
<td>Flexural strength at 20°C</td>
<td>&gt;60</td>
<td>[MPa]</td>
</tr>
<tr>
<td>Flexural strain to rupture at 20°C</td>
<td>&gt;2500</td>
<td>&gt;4000 [μm/m]</td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>&lt;0.05</td>
<td>&lt;0.25 %</td>
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</table>
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
Mo coating on MoGr

- Prototype coated at CERN:
  - Magnetron sputtering in Kr on actual MoGr material, thickness 6 μm +/- 0.5 μm
  - RF impedance measured with eddy currents meets specifications (< 100 nΩ.m)
  - No adhesion issues (adhesion > 6MPa)
  - 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

<table>
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<tr>
<th>Substrate roughness</th>
<th>Mo grain size (average)</th>
<th>Amount of coating discontinuities</th>
<th>Coating conductivity (MS/m)</th>
<th>Coating resistivity (nΩ.m)</th>
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<tbody>
<tr>
<td>Glass</td>
<td>~0</td>
<td>+</td>
<td>-</td>
<td>4.3 [DC] 5.0 [RF] 232 [DC] 200 [RF]</td>
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<tr>
<td>Alumina</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>4.6 [DC] 4.1 [RF] 218 [DC] 244 [RF]</td>
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<tr>
<td>MoGr</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>14.3-16.7 [RF] 60-70 [RF]</td>
</tr>
<tr>
<td>CFC</td>
<td>++++</td>
<td>++</td>
<td>- n.d. (=substrate)</td>
<td>n.d. (=substrate)</td>
</tr>
</tbody>
</table>

Prototype: Cu and Mo coating
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
Overview of RGA scans of MoGr samples

Total outgassing for a TCSPM $\approx 3\cdot10^{-8}$ [mbar l/s]
JIT (MoGr / Collimators)

- TCSPM/TCPPM Mo-Gr reception and deliveries timeline
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

*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
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

HL-LHC INTEGRATION REPORT FOR INSTALLATION APPROVAL - WP5: TCLD Integration Study
- TCLD (WP5) Installation Procedure
- TCLD (WP5) Safety Assessment Form
- TCLD (WP5) Specific Risk Assessment

Many thanks to EN-HE, EN-SMM, TE-MSC, EN-VSC and 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
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)
- Non-conformities

Many thanks to ATS-DO
Collimators production milestones

CERN and 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
TCLD collimator reception milestone

TCLD pre-series collimator reception milestone

18/12/2018

Surface activities in 272 to START…

Collimation Review 2019
LS2 Collimators surface activities planning

2113986 v.4 "TCD LS2 MasterPlan" by INIGO LAMAS GARCIA in status: In Work
Link: https://edms.cern.ch/document/2113986/1/approvalAndComments

2268247 v.1 “Collimation Activities Coordination”
Link: https://edms.cern.ch/document/2268247/1
LS2 collimators “ready for installation” schedule

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Location</th>
<th>Ready to install</th>
</tr>
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<tbody>
<tr>
<td>TCSPM.6L7.B2</td>
<td>LSS7L</td>
<td>01-Jul-20</td>
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<tr>
<td>TCSPM.E5L7.B2</td>
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<td>01-Jul-20</td>
</tr>
<tr>
<td>TCSPM.D4L7.B2</td>
<td>LSS7L</td>
<td>02-Jun-20</td>
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<tr>
<td>TCSPM.B4L7.B1</td>
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<td>02-Jun-20</td>
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<tr>
<td>TCSPM.D4R7.B2</td>
<td>LSS7R</td>
<td>28-Feb-20</td>
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<tr>
<td>TCSPM.E5R7.B1</td>
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<td>04-May-20</td>
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<thead>
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<th>Equipment</th>
<th>Location</th>
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<td>TCLD.10L2.B1</td>
<td>C11L2</td>
<td>05-Feb-20</td>
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<table>
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<tr>
<th>Equipment</th>
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<tbody>
<tr>
<td>TCPP.D6L7.B1</td>
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<td>03-Feb-20</td>
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<tr>
<td>TCPP.C6L7.B1</td>
<td>LSS7L</td>
<td>03-Feb-20</td>
</tr>
</tbody>
</table>
Year 2018 summary

- Contract signature
- Kick-off meeting
- Start of production - T0
- Test benches set up
- Pre-series started and several modifications along the way
- Many PE launched and from many groups
- Reception and validation of several components
- Studies on TCLD prototype (integration, safety, electronics, etc.)
- TCLD pre-series
  - 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
  - TCLD brazed jaws tested at CERN (10/2018)
  - TCLD jaws 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 start in 11/2018
- Planification of surface activities (b.272) and installation activities

https://edms.cern.ch/document/1887258/1.0
https://edms.cern.ch/document/2061573/1
9th HL-LHC Collaboration Meeting – 16th October 2019 – FERMILAB Chicago
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
  - Impedance measurements
  - Vacuum activities + bake out

**Collimators Tunnel Activities**
- 2 TCAPM of new production
- TCTW relocation
- TCSPM proto endoscopie
LS2 production/procurement inventory status

**LS2 Collimators Production**
(5 TCPPM, 10 TCSPM & 5 TCLD)
DR-6490686 - IT-4272

**Manifolds**
DR-7427660 – DO-31931

**Plug-in system (Connectors)**
DR-6854219 – Single Tender

**Fixed Supports**
DR-6854220 – DO-31249

Hoses and rigid pipes
DO-31933

Tendering finished

Tendering on-going

Tendering not started

Many thanks to ATS-DO
LS2 production/procurement inventory status

**Jaw Absorber Blocks**
- MoGr (TCPM, TCSPM)  
  DR-6272020 - IT-4201  
- CFC (TCSPM) back-up for TCSPM  
  DR-7039188 – Single Tender  
- Tungsten Heavy alloy (c<50k, No DR)

**Stainless Steel 304L, 316L & 316LN**  
  c<50k (Central Stores)

**LVDT**  
  DR-6734749 – IT-3425

**Hard-Rad Mech. Switches**  
  DR-7478086  
  DO-31829

**Gildcop for back stiffener and housing blocks**  
  DR-6850041 - Single Tender

**Bake-out jackets**  
  DR-6891552 – DO-30880

**316LN Connector Flanges**  
  DR-6849315 - DO-31067

**Vacuum Si$_2$O Cables**  
  DR-6843955 – Single Tender

**Roller Screws**  
  DR-6854217 – Single Tender

**Guiding Shaft & Bearings**  
  DR-6854216 – Single Tender

**Welded Bellows**  
  DR-6854215 – DO-30814

**Pick-up buttons**  
  DR-6956113 - DO-31068  
  DO-31045

**External Cable assemblies**  
  DR-6849313 +  
  DR-6956223  
  Delivery ongoing  
  (MS-4441)

**Stepped Motors**  
  DR-6723429 – IT-3385

**Control Systems**  
  Framework contract

Many thanks to ATS-DO
TCLD pre-series acceptance at CERN

- TCLD pre-series reception at CERN

- Torque Test

Collimator Torque Measurements Test Report

<table>
<thead>
<tr>
<th>Test Bench Number</th>
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<tbody>
<tr>
<td>Collimator</td>
<td>HICTCLDA001-C20001</td>
</tr>
<tr>
<td>Test Operator</td>
<td>JLENDARO</td>
</tr>
<tr>
<td>Date</td>
<td>13 February 2019 15:52</td>
</tr>
<tr>
<td>Plates ID</td>
<td>Plates ID</td>
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<tr>
<td>Software Build</td>
<td>07/01/2019 15:01:08</td>
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<tr>
<td>Environment</td>
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<tr>
<td>Orientation</td>
<td>PN Support</td>
</tr>
<tr>
<td>Jaw Convention</td>
<td>CERN Standard (Machine)</td>
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<tr>
<td>Top Jaw</td>
<td>NA</td>
</tr>
<tr>
<td>Comments</td>
<td>TCLD collimator (preproduction)</td>
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Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
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<tbody>
<tr>
<td>Switch Test</td>
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<tr>
<td>Repeat Test Jaw AC</td>
<td>Performed</td>
</tr>
<tr>
<td>Repeat Test Jaw BD</td>
<td>Performed</td>
</tr>
<tr>
<td>Static Test Jaw AC</td>
<td>Performed</td>
</tr>
<tr>
<td>Static Test Jaw BD</td>
<td>Performed</td>
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</table>

Static Torque

Dynamique Torque Out to In number 10

Table:

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<thead>
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<td>0.001104</td>
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<tr>
<td>B</td>
<td>0.393220</td>
<td>0.393018</td>
<td>0.000202</td>
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<tr>
<td>C</td>
<td>0.394430</td>
<td>0.394320</td>
<td>0.000110</td>
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<tr>
<td>D</td>
<td>0.392910</td>
<td>0.392810</td>
<td>0.000100</td>
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## TCLD pre-series acceptance at CERN

- **Targets Alignment**
  
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<th>ID</th>
<th>R</th>
<th>S</th>
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<tr>
<td>Fiducial A</td>
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<td>-151.086</td>
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<td>Fiducial B</td>
<td>-43.986</td>
<td>536.898</td>
<td>544.706</td>
</tr>
</tbody>
</table>

- **BPM Test**

EDMS 2112684

EDMS 2116026
TCLD pre-series acceptance at CERN

- UHV Test
  - 1 RGA SPECTRA AFTER 48H AT ROOM TEMPERATURE
  - 2 NORMALIZED RGA SPECTRA TO H2-DRIVEN LIMITS

- LVDT Calibration
  - EDMS 2158285
  - GREEN LIGHT FOR TCLD SERIES PRODUCTION

- Impedance sims and tests
Year 2019 external production
Year 2019 external production
Year 2019 external production

- First 2 TCPPM jaws:
  - Assembled and validated at Cinel on 06/2019
  - Received at CERN on 07/2019
  - Jaw #1 brazing validated through outgassing tests
  - Jaw #2 used as testbench to make MoGr batches flatness conform
Year 2019 external production

- Extensive metrology campaign due to non-conformities on MoGr blocks
Year 2019 external production

Components ready for assembly:

- 5 TCPPM vacuum tanks with mechanical tables
Year 2019 external production

Components ready for assembly:

- 5 TCPPM vacuum tanks with mechanical tables
- 14 TCPPM/TCSPM jaws qualified after TCC test
Year 2019 external production

Components ready for assembly:

- 5 TCPPM vacuum tanks with mechanical tables
- 14 TCPPM/TCSPM jaws qualified after TCC test
- 10+20 TCPPM/TCSPM mechanical tables validated after torque test
Year 2019 external production

Components ready for assembly:

- 5 TCPPM vacuum tanks with mechanical tables
- 14 TCPPM/TCSPM jaws qualified after TCC test
- 10+20 TCPPM/TCSPM mechanical tables validated after torque test
- 4 TCLD tanks
- 8 TCLD mechanical tables
Year 2019 external production

- Final assembly of first 2 TCPPM units:
  - Jaws #1, #2, #3 and #4 inserted
  - Mechanical stops adjusted
  - BPM and torque tested
  - Ready for cover EBW
Year 2019 external production summary

- Final assembly of first 2 TCPPM units:
  - Bake-out foreseen for the 3rd of October…**BUT**
Year 2019 external production summary

Ti BPM buttons issue (Non-Conformity)

- Issues found at CINEL on 3 Ti buttons for TCPPM#1 + 2 Ti buttons for TCPPM#2; pin detached from contact, no traces of brazing

  - Titanium BPM buttons:
    - Ti buttons are not 100% reliable. We have doubts on the CuBe connector, which is EBW with the Titanium.
    - The rise of $T^\circ$ during welding could have affect to the elasticity of the CuBe pin, and so for the contact.
    - From Christian Boccard feedback, 1st Ti buttons pre-series was rejected because of bad contact.
    - 2nd Ti buttons pre-series passed the tests and was accepted. These buttons has been used on TCPPM#1 and #2.
    - A series production of 120 Ti buttons passed the contact tests. Nevertheless, further controls (metrology, elasticity) on the CuBe pins will follow, to ensure that they are acceptable for the collimators production (2-3 next weeks).

  - St.Steel BPM buttons:
    - TCLD pre-series, currently present at CERN, has been assembled with St. Steel buttons, with no further issues.
    - For TCPPM#1 and #2, we are going to proceed for St. Steel buttons. This point is to be agreed asap between Manfred Wendt, Christian Boccard and Stefano Redaelli, so that Cinel could start by tomorrow mounting them on the jaws.
    - If needed, there are in stock enough St. Steel buttons to complete the LS2 collimators production.
    - 24 x St. Steel BPM buttons has been shipped to Cinel, so that they will be ready by tomorrow afternoon to re-start the final assembly sequence of TCPPM#1 and #2.
Year 2019 external production summary

- **TCPPM #1 and #2** delivered and accepted 29/11/2019 (3 months delay)
- New schedule needed
- **TCPPM#3 and TCPPM#4** to be delivered 17/12/2019
- **BUT…**
**Issue on TCPPM#3**

**TCPPM #3 not leak tight**

- The leak is in the high $10^{-3}$ mbar*l/s range. Note that the individual bellows test is done after the EBW of the bellows to the chamber with the positioning tool still in place taking the bellows correctly. The maximum of the leak is when we put the Helium with a capillary tube between the membranes pointing to the inner weld. Putting Helium along the external welds we get a lower leak rate meaning that most likely this is a failure of an inner weld. There are no visible defects from the outside. The bellows are protected by inner screens during the welding of the shaft to the bellows and during the welding of the bellows to the chamber. After welding to the chamber all the bellows are individually leak checked before allowing the assembly of the in-vacuum components and this is the first and only test of the bellows membranes (the weld to the shaft is also leak tested but this first test does not involve the bellows membranes).
Issue on TCPPM#3

- Non-conformity doc -> https://edms.cern.ch/document/2355344/0.9

Description of the NC
NC Evaluation and corrective actions
Preventive actions put in place (New MIP version)
Tests at CERN
COMVAT Failure Analysis
Issue on TCPPM#3

- TCPPM #3 was repaired at CINEL
- Non-conformity doc -> https://edms.cern.ch/document/2355344/0.9

Description of the NC

NC Evaluation and corrective actions

Preventive actions put in place (new MIP version)

Tests at CERN

COMVAT Failure Assessment report
Issue on TCPPM#3

- Non-conformity doc -> https://edms.cern.ch/document/2355344/0.9

Description of the NC

NC Evaluation and corrective actions

Preventive actions put in place (new MIP version)

Tests at CERN

COMVAT Failure Assessment report

Figure 3: Particle breakage at leak point under light microscope

Figure 1: Leak point_outer_seam_30_0

Figure 2: Affected membrane pair separated out

Figure 4: Particle breakage at leak point under light microscope
Issue on TCPPM#3

- Non-conformity doc -> https://edms.cern.ch/document/2355344/0.9

  Description of the NC

  NC Evaluation and corrective actions

  Preventive actions put in place (new MIP version)

  Tests at CERN

  COMVAT Failure Assessment report

  LESSON LERNT in view of new production:
Year 2019 production summary

- All material and commercial components delivered but:
  - MoGr absorber blocks* (Just-In-Time deliveries)
  - BPM cables** (issues with USA supplier, currently only 9 units can be equipped)
- TCLD pre-series delivered and accepted
- TCLD series production ahead
- TCPPM and TCSPM series production ahead
- TCPPM #1 and #2 delivered and accepted 29/11/2019
- TCPPM #4 delivered and accepted 17/12/2019
- TCPPM #3 not leak tight – repair strategy and negotiations and to be considered spare
- Schedule redefined and TCLDs are to be prioritized
- Resume production for TCLD series
Year 2019 tunel status summary

- **LS2-WP5 -> TCLD slot equipment**
  - Jacks installed and pre-aligned
  - Support installed and pre-aligned
  - Water connections in place

~5mm clearance on Drawing. Collimator lifting plate re-machined to avoid interference
10th HL-LHC Collaboration Meeting – October 2020 – CERN
# 2020 Collimators Surface Planning

- **2113986 v.4** "TCD LS2 MasterPlan" by INIGO LAMAS GARCIA in status: In Work
  
  Link: [https://edms.cern.ch/document/2113986/1/approvalAndComments](https://edms.cern.ch/document/2113986/1/approvalAndComments)

- **2424912 v.1** "Week 41_Coordination activités collimation en surface et dans le tunnel"
  
  Link: [https://edms.cern.ch/document/2424912/1/approvalAndComments](https://edms.cern.ch/document/2424912/1/approvalAndComments)
2020 TCLD external production
2020 TCLD delivery

- All TCLD series at CERN!
  - TCLD#2 and #3 received on January 2020
  - TCLD#4 and #5 received on June 2020* (no needed for LS2)
2020 (COVID*) TCSPM/TCPPPM production and delivery

- TCSPM#1 and #2 delivered on June 2020*
- TCSPM#3 and TCPPM#3 (repaired) delivered on June 2020*
- TCSPM#4 and TCPPM#5 delivered on July 2020*
- TCSPM#5 and TCSPM#6 delivered on September 2020*
- TCSPM#7 and TCSPM#8 delivered on October 2020*
- TCSPM#9 and TCSPM#10 delivered on November 2020*
Year 2020 milestones

CERN reception milestones

TCLD#1,2 & 3
- TCLD#4 & 5
- TCSPM#3 & TCPPM#3
- TCSPM#1 & 2

LHC Installation milestones

TCPPM#1 & 2
- TCLD#1
- TCSPM#1 & 2
- TCPPM#1 & 2
- TCLD#2

TCSPM#4 & TCPPM#5
- TCSPM#5

TCSPM#6
- TCSPM#5

Feb | June | July | Aug | Sep
Year 2020 Surface activities
Vacuum acceptance test at @ TE-VSC-BVO

- LS2 surface vacuum validation before LHC machine installation:
  - 5 x TCPPM → LHC point 7 [MoGr blocks jaws];
  - 10 x TCSPM → LHC point 7 [MoGr blocks + Mo coating jaws];
  - TCLDs (test on going) → LHC DS area – not presented here.

- Procedure milestones and criteria:
  - Pump down & leak detection;
  - Bake out cycle: 48h00* / 250°C under vacuum;
  - 48h after bake-out at R.T. → Outgassing rate + Residual gas analysis (RGA);
  - Leak test;
  - Vacuum acceptance test validated if:
    - Outgassing rate < 2.10^{-7} [mbar·l/s];
    - Leak tightness confirmed.

(*was increased to 72 hours for TCSPM with 2nd generation MoGr blocks to try decrease outgassing rate)
TCPPM and TCSPM RGA analysis

TCPPM no NEG installed:
- Atomic mass units (mass 15 and 16) indicating a clear presence of methane
- Air internal leakage from MoGr block visible (mass 28 & 40): N\textsubscript{2} and Ar

TCSPM with NEG pump installed:
- NEG $\rightarrow$ H\textsubscript{2} (mass 2) clear pumping increase
- Atomic mass units (mass 15 and 16) indicating a clear presence of methane
- Stronger Air internal leakage from MoGr block visible (mass 28 & 40): N\textsubscript{2} and Ar
TCPPM and TCSPM outgassing rate results

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<tr>
<th>Designation</th>
<th>Outgassing rate [mbar.l/s]</th>
<th>Comment</th>
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<tbody>
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<td>TCPPM-CZ01</td>
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</tr>
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<td>TCPPM-CZ02</td>
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<td>TCPPM-CZ03</td>
<td>5.7E-07</td>
<td>Leak bellow repair</td>
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<tr>
<td>TCPPM-CZ04</td>
<td>2.3E-07</td>
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<td>TCPPM-CZ05</td>
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<td>TCSPM-CZ01</td>
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<td>TCSPM-CZ03</td>
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<td>TCSPM-CZ05</td>
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<td>TCSPM-CZ08 - 2nd bo + NEG D400</td>
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</table>

Test of TCPPM #3 (spare) to be repeated after TCSPM to verify results.

TCSPM #6 results show that:
- Gain of about 50% after 3x successive bo cycles (as expected considering ≈15% gain after each cycle)
- Gain of about factor 10 with NEG installed as foreseen (ECR NEG INSTALLATION: EDMS 2245028)
- Gain of factor ≈14 with optimisation of bake out cycle

Clear indication that even with high effort on controlling and optimizing the MoGr blocks without the integration of additional pumping we would have been on a border line from vacuum outgassing level point of view.
Collimators External-Internal production

<table>
<thead>
<tr>
<th>Asset number</th>
<th>Collimator</th>
<th>Location</th>
<th>Delivery date at CERN (On 05/10/2020)</th>
<th>Ready to install (On 05/10/2020)</th>
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<td>TCSPM.D4R7.B1 (TCSPM)</td>
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<td>HCTCSPM001-CZ000006</td>
<td>TCSPM #6</td>
<td>TCSPM.E8L7.B2</td>
<td>Delivered</td>
<td>15/10/2020</td>
<td>19/10/2020</td>
</tr>
<tr>
<td>HCTCAPM002-CR000001</td>
<td>TCAPM #1</td>
<td>TCAPM.A5L7.B1</td>
<td>Delivered</td>
<td>02/03/2020</td>
<td>03/06/2020</td>
</tr>
<tr>
<td>HCTCAPM001-CR000001</td>
<td>TCAPM #2</td>
<td>TCAPM.A5R7.B2</td>
<td>Delivered</td>
<td>27/04/2020</td>
<td>18/06/2020</td>
</tr>
<tr>
<td>HCTCPPM001-CZ000003</td>
<td>TCP #3</td>
<td>TCP.C6L7.B1</td>
<td>Delivered</td>
<td>13/08/2020</td>
<td>-</td>
</tr>
</tbody>
</table>

- All activities have been scheduled in coordination with EN-ACE -> Collimators no longer on the critical path;

- All documentation written accordingly -> MTF has never been more updated 😊;

- Several discussion, but finally all activities in the tunnel include all preparation work, coordination and sequence follow up and hands on work for slot equipment and commissioning;
Collimators External production

- All material and commercial components delivered conform:
  - MoGr absorber blocks (Just-In-Time deliveries)
  
  End-of-manufacturing report:
  https://edms.cern.ch/document/2155433/2.1

  NANOKER wrap-up meeting:
  https://edms.cern.ch/document/2424349/1/approvalAndComments

N. Biancacci et al., "Resistivily Characterization of Molybdenum-Coated Graphite-Based Substrates for High-Luminosity LHC Collimators", Coatings 2020, 10(4), 201
Collimators External production

- All material and commercial components delivered conform:
  - BPM cables (issues with USA supplier, but all delivered and accepted)
    - Successfully resumed the production of higher temperature cables for LS3;
    - Leak tight after they finally procured good-quality components;
    - BPM pick-up: whole LS2 production with stainless steel buttons, after NC with Ti ones;
    - All blind mate connecters for TCPPM/TCSPM received in June;
    - Quick-disconnect feature for new HL-LHC collimators;
    - Tunnel installations proceed well;
Collimators Aux External production

- All cradles have been delivered, retouched and assembled at 272
- All manifolds have been delivered
- All transition for collimator NEG cartridge have been delivered
- All flexibles and rigid pipes have been delivered
2020 LHC activities

- LS2-WP5 -> Installation 2 TCAPMs new production
- MME production but STI to follow up from design to installation as technical support
2020 LHC activities

- LS2-WP5 -> Exchange 4 TCPs for 4 TCPPMs new production
- The 4 TCP have been replaced by 4 new TCPPM
  
  Endoscopy performed on the removed HCTCP_001-CQ000110 and HCTCP_001-CQ000111

Two TCPPMs for Beam 1

Key for Run 3 and HL-LHC era: better impedance from MoGr (uncoated), improved operation through BPMs, lifetime of warm quads ok for HL-LHC lifetime!
2020 LHC activities

- LS2-WP5 -> TCLD slot equipment and installation
- Jacks installed and pre-aligned
  Support installed and pre-aligned
  Water connections in place
  Issue with cabling and CC

**DS collimation in IP2-L**

For the ALICE upgrade: TCLD at the connection cryostat will catch secondary beams from ion collisions. 1 TCLD per side.
2020 LHC activities

- LS2-WP5 -> Exchange 2 TCSPGs for 2 TCSPMs new production and installation of 6 TCSPMs new production
- All support installed and pre-aligned
  All ancillaries equipped (water connections in place, BPM plug-ins, controls, etc.)

5 new TCSPMs in the LHC IR7!
Year 2020 production summary

- All material and commercial components delivered JIT
- Full TCLD series production delivered and accepted
- Full TCPPM series production delivered and accepted
  - TCPPM #3 leak repair successfully
- Full TCSPM series production delivery and accepted
- TCPPM#1 and #2 installed
- Both TCAPM units installed
- TCLD#1 and #2 units installed
- TCSPM #1, #2, #3 and #4 installed
- TCPPM #4 and #5 installed
- TCSPM #7 and #8 installed
Thank you for your attention!