Material and Manufacturing challenges for Beam Intercepting Devices at CERN
few examples

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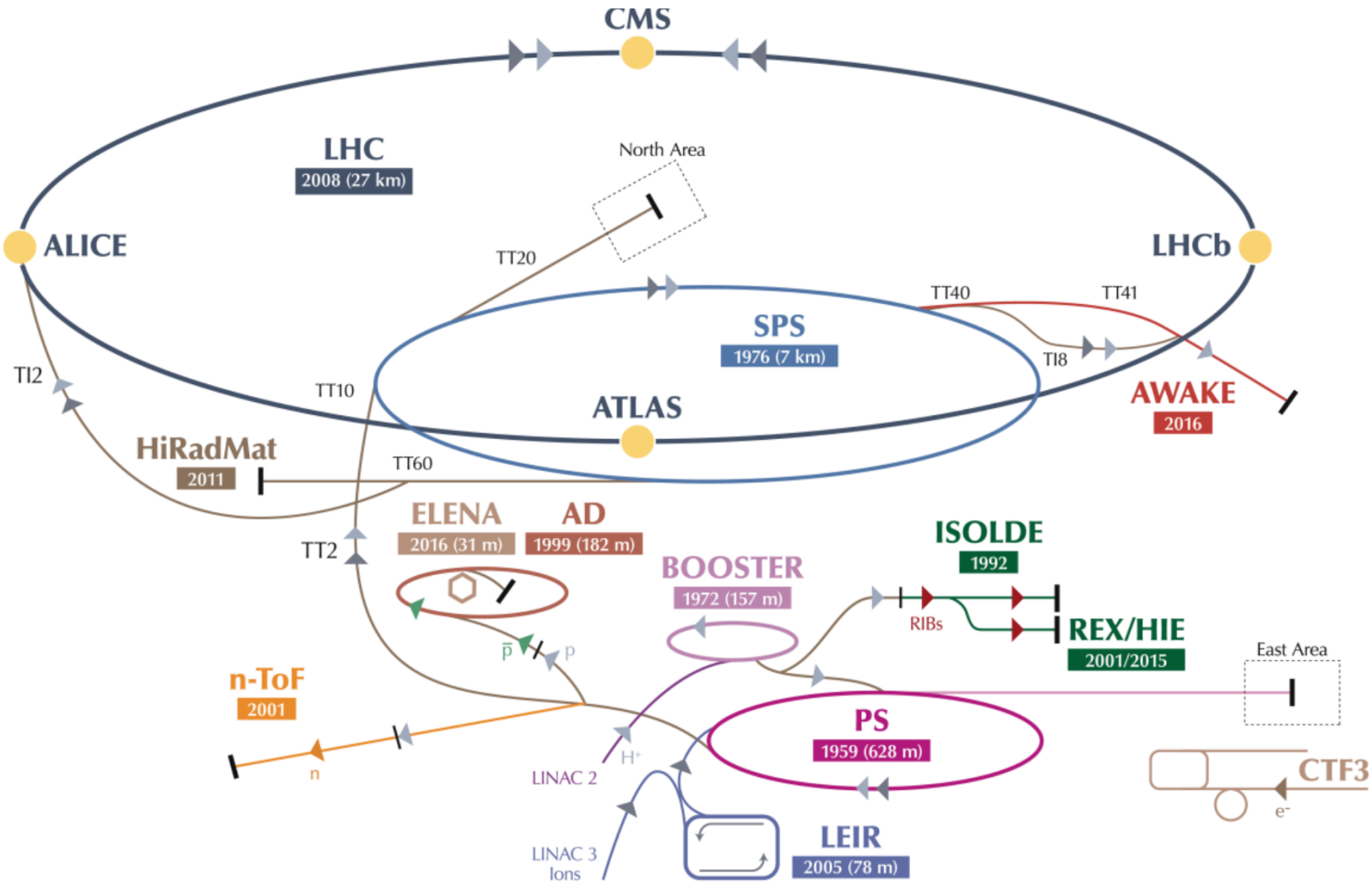
Introduction

- Beam Intercepting Devices are essential part of the functioning of any accelerator complex
  - Protect equipment and personnel
  - Guarantee specific beams sizes
  - Safely dispose unwanted beams
  - Produce secondary particle beams for experiments
- Need to act on harsh environments
- Usually the most radioactive elements in the complex
- Reliability is a key factor

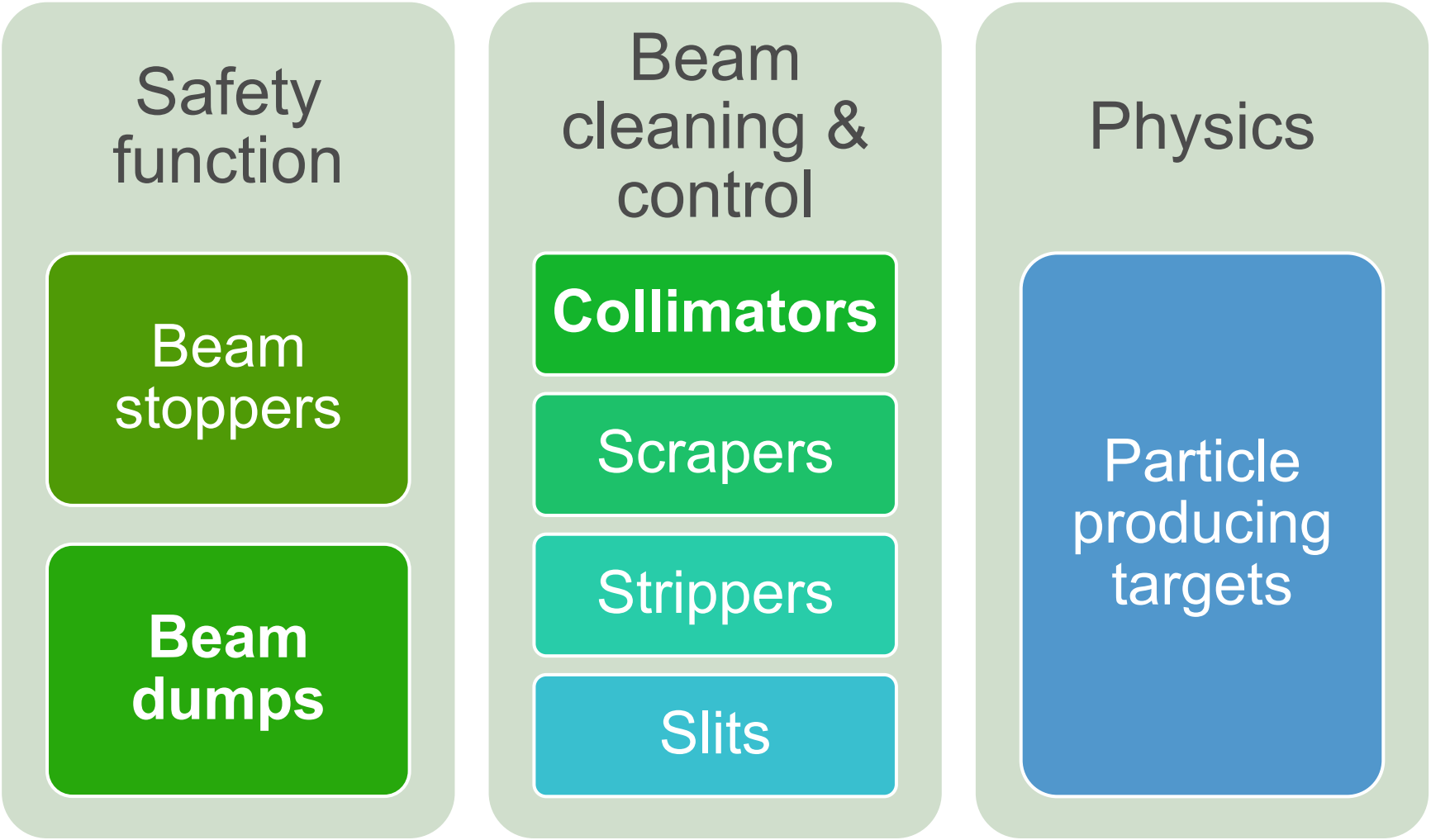


~250 devices scattered from the Linac source stopper (45 keV) to the LHC main dump (7 TeV)

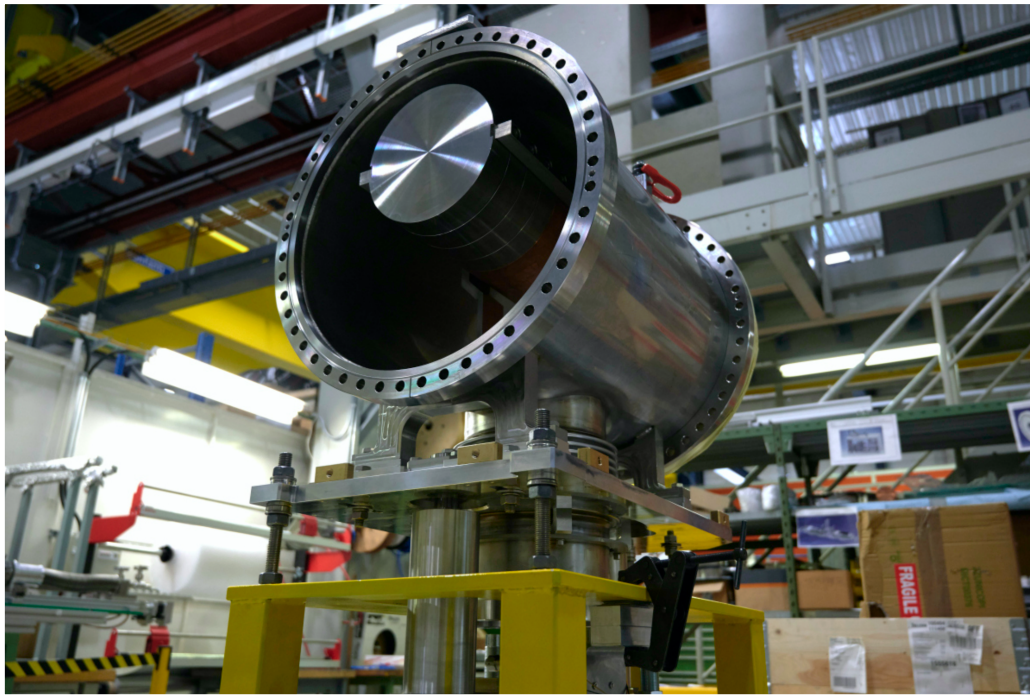
What type of challenges do we have?

- Devices must be able to withstand **operation** and **accident** scenarios, plus protect delicate equipment
  1. **UHV** requirements (10^{-10} mbar) also in *movable* parts
  2. **High energy densities** (~kJ/cm^3/pulse) as well **power densities** (several MW/cm^3)
  3. **High beam intensity/energy** (~750 MJ for LHC dump)
  4. **High average deposited power** (~250 kW for LIU SPS beam dump or ~350 kW for Beam Dump Facility) (see F.-X. Nuiry presentation at BiSS 2019)
  5. **Physics requirements**, often implying the use of non-structural materials (Pb or Ir)
  6. **Impedance**, especially for colliders
  7. **Radiation damage** on absorbing materials

Beam Intercepting Devices at CERN



Beam stoppers in the PS complex



Challenges:

- Energy density
- Personnel protection
- Actuation system
- Compact design

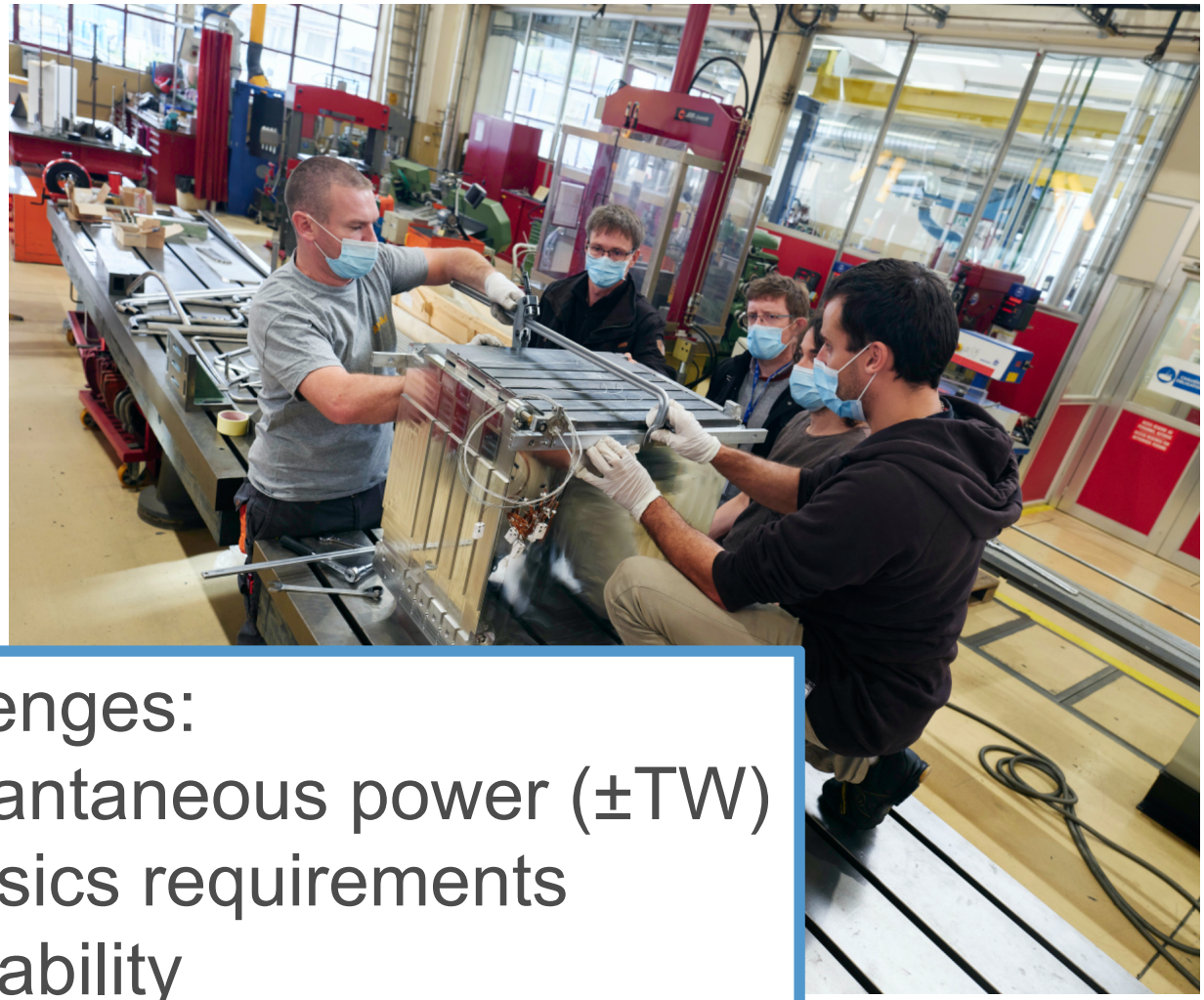
SPS internal beam dump (1/2)

Challenges:

- Average power (300 kW)
- UHV environment
- Reliability

SPS internal beam dump (2/2)

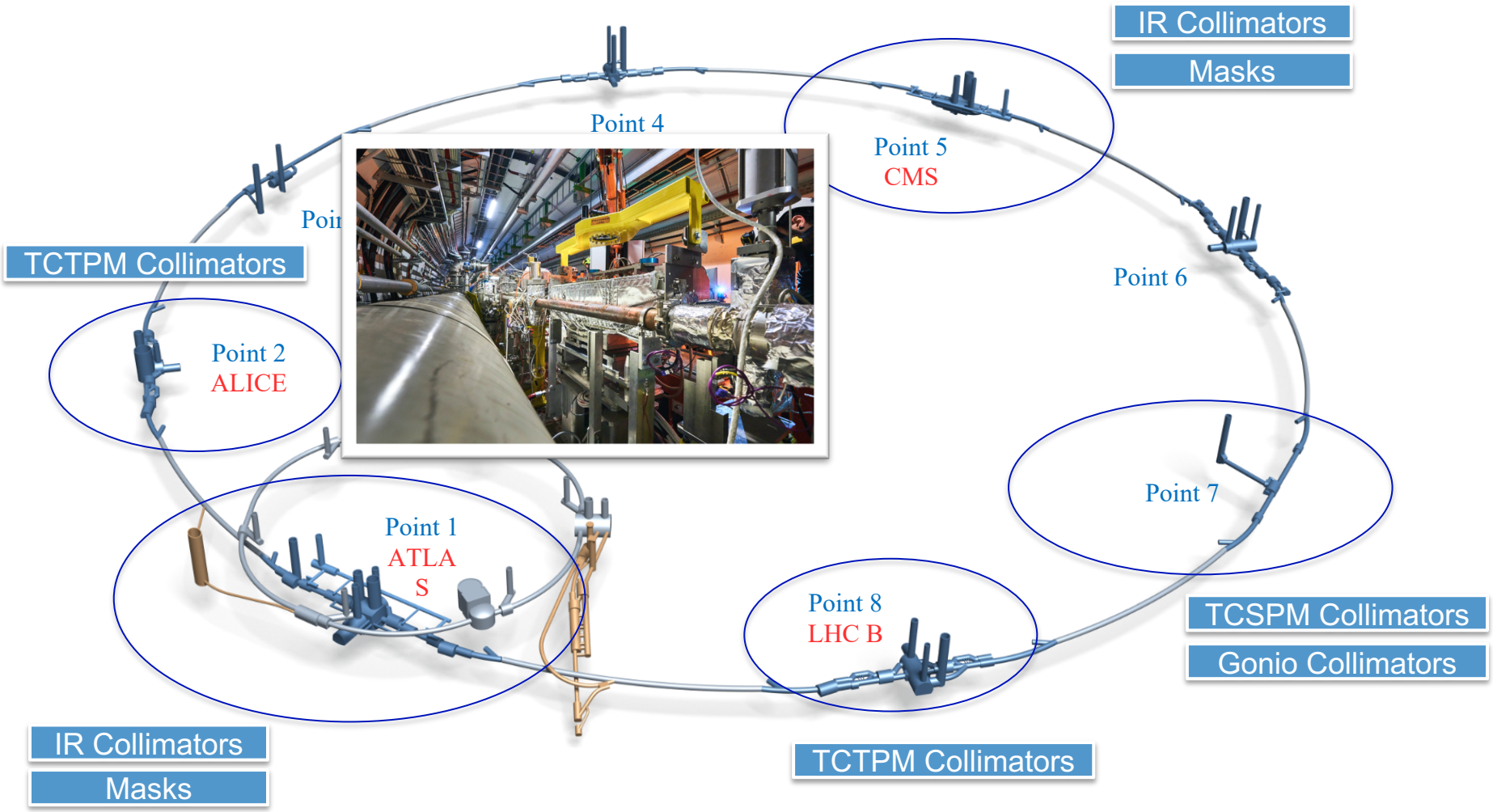
n_TOF neutron spallation target



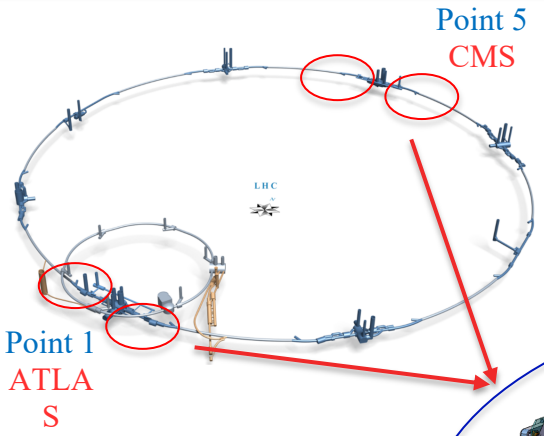
Challenges:
- Instantaneous power (±TW)
- Physics requirements
- Reliability

Just a couple of examples in view of CERN's Long Shutdown 3

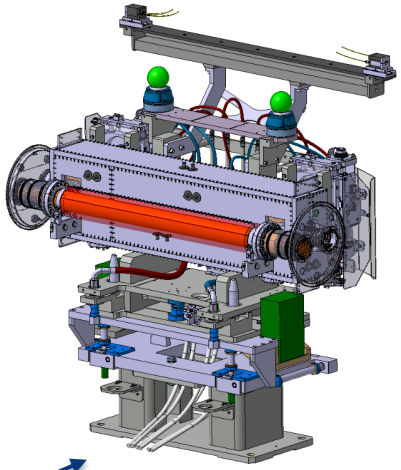
LHC Collimators for LS3

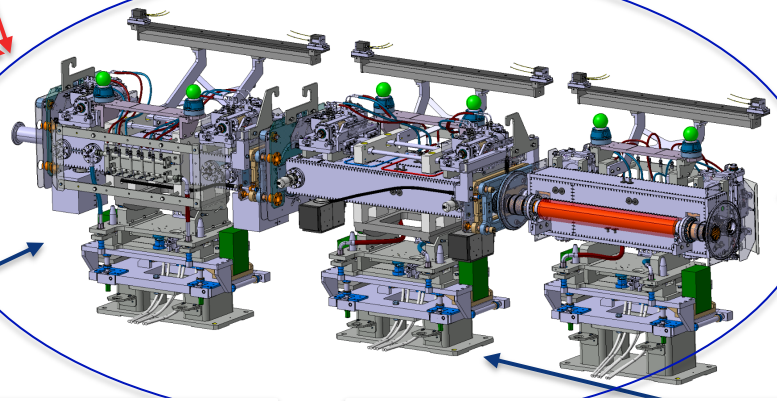


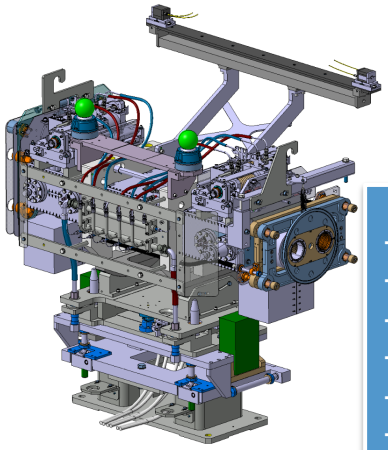
IR Collimators – Points 1 & 5



TCSPXV
- Units to be installed: 4
- Material: Tungsten (Inermet 180)
- Active surface: 1000mm
- FRAS integrated
- External vacuum chamber
- Maximum half-gap 30mm

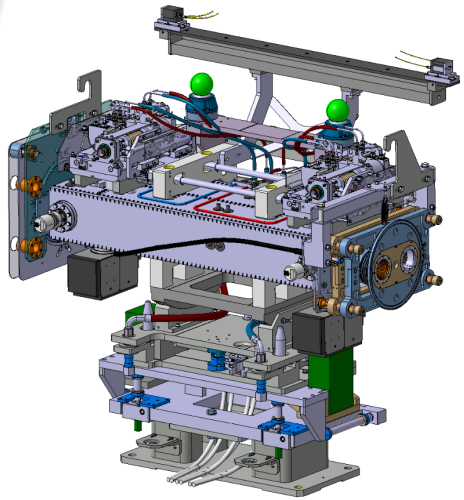




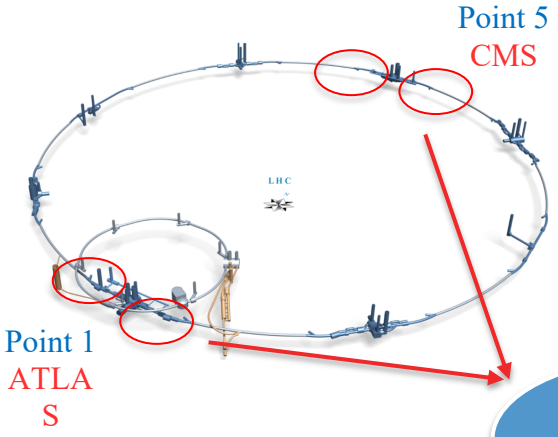


TCLPX
- Units to be installed: 4
- Material: W (Inermet 180)
- Active Surface: 1000mm
- FRAS integrated
- BPM connector integrated
- Vacuum interconnections
- Internal Vacuum chamber
- Maximum half-gap 40mm

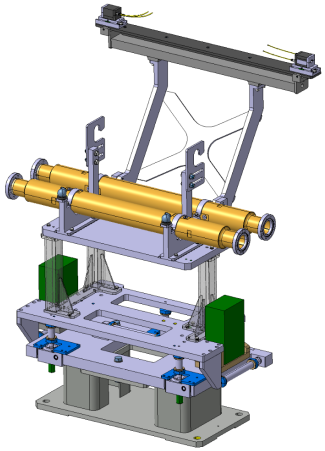
TCSPXH
- Units to be installed: 4
- Material: CuCD
- Active Surface: 1000mm
- FRAS integrated
- BPM connector integrated
- Vacuum interconnections
- Internal vacuum chamber
- Maximum half gap: 40mm



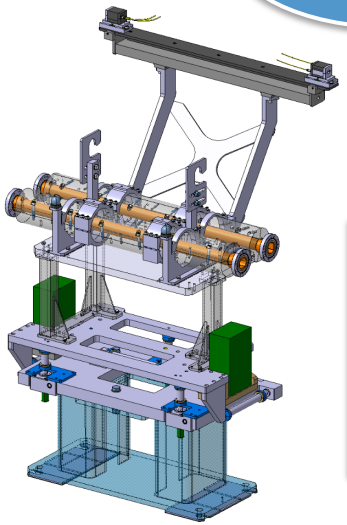
Masks – Points 1 & 5



Masks

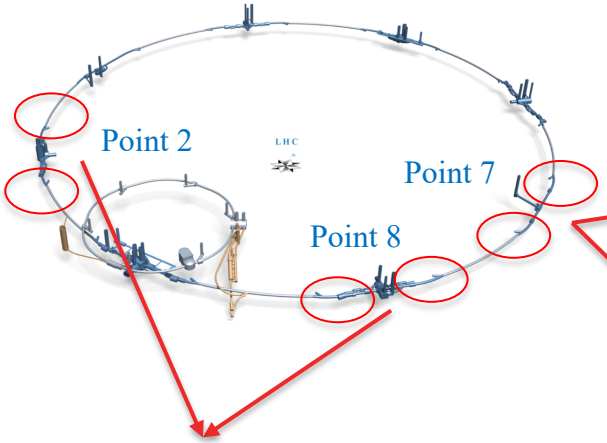


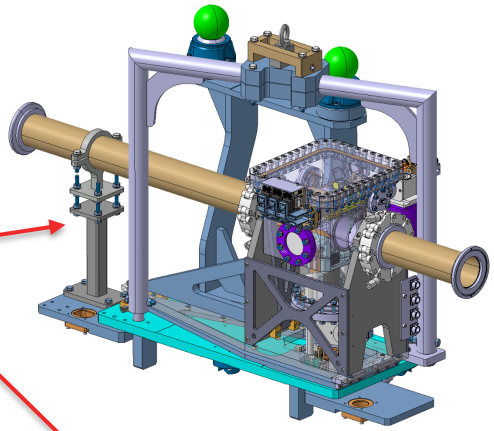
TCLM (Q5 & Q6)
- Units to be installed: 8
- Material: Cu
- Length: 1000mm
- FRAS integrated
- Round outer shape Ø10mm



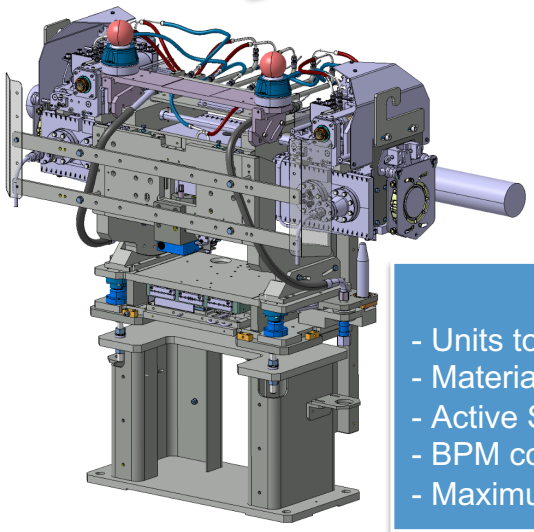
TCLM (Q4)
- Units to be installed: 4
- Material: W (Inermet 180)
- Length: 1000mm
- FRAS integrated
- Round outer shape Ø14mm

Collimators – Points 2, 7 & 8

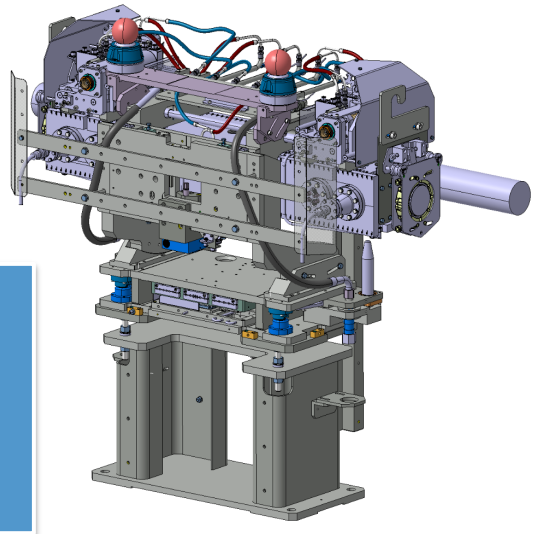




GONIOMETER
- Units to be installed: 8
- Material: Bent Crystal
- Crystal length: 4±1mm
- Linear stroke: >50mm
- Angular range: ±10mm



TCTPM
- Units to be installed: 8
- Material: W (Inermet 180)
- Active Surface: 1000mm
- BPM connector integrated
- Maximum half-gap: 30mm



TCSPM
- Units to be installed: 14
- Material: Mo Coated Graphite
- Active Surface: 1000mm
- BPM connector integrated
- Maximum half-gap: 30mm

HL-LHC external beam dump

- 8.5 m long, Ø720 mm diameter, 6200 kg cylinders, suspended on two cables
- Graphitic absorbing core
- Steel shielding around
- Up to 710 MJ to absorb per dump, air cooled
- High residual dose rates

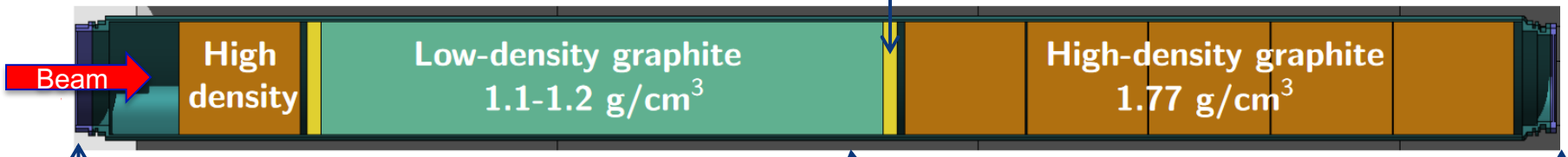
LHC beam dumps: vessel and beam windows

Shrink fitted Sigrafine®
R7300 P500 (700 mm)

Sigraflex®
3260 mm (2 mm thick), L20012-C

2 x Sigrafine® HLM
Extruded, 80 mm thick

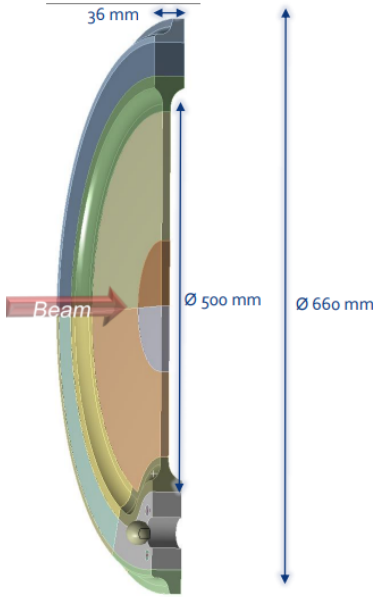
Shrink fitted Sigrafine®
R7300 P500 (5 x 700 mm)



Ti Grade 5, 10mm thick beam window

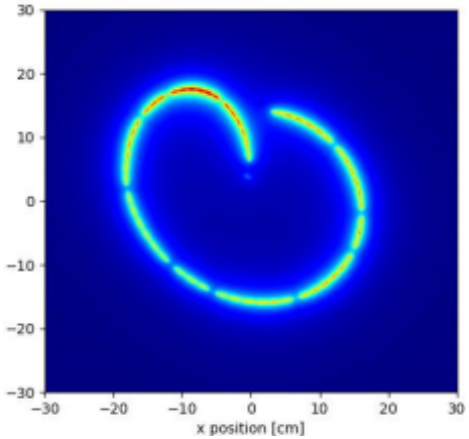
Duplex stainless steel (318L) vessel, 12 mm thick

Ti Grade 5, 10mm thick beam window

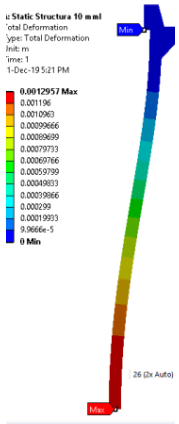


Half view of the window

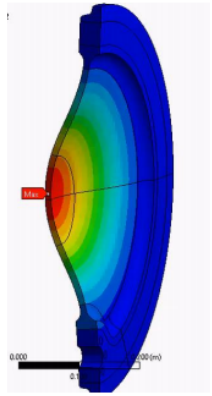
Load directly induced by the beam impact



Static load due to vacuum and N2 over pressure



Dynamic response: vessel vibrations



Looking for low-and high-density carbon-based materials

- Peak temperature of 1900˚C expected 400 time per year (2600˚C for accidents)
- Nitrogen environment
- Product available in plates Ø720 mm diameter minimum

Carbon/Carbon

- Carbon fiber preform
- Carbon matrix
- Density: 1.0 g/cm^3, 1.5 g/cm^3 and 1.8 g/cm^3
- Graphitization temperature at least of 2000˚C

Carbon fiber-reinforced silicon carbide (C/SiC) (max 1400˚C):

- Density around 2.7 g/cm^3

Isostatic polycrystalline graphite

- Density of 1.8 g/ cm^3

Summary of the key components needed

Core material	Expected need dimensions (under study)
High-density carbon-based (graphite) 1.8 g/cc	Ø750 mm x 4500 mm (several blocks)
Low-density carbon-based (Carbon carbon) 1.0 and 1.5 g/cc	Ø750 mm x 3500 mm (several plates)
Metallic vessel Uranus 318L Or **INVAR** Or **TiGr5**	1 Cylinder, leak tight ~Ø750 mm x 9000 mm
Downstream + upstream Flange Stainless steel	For the large beam windows (~Ø750 mm)
Ti beam windows Ti Grade 5 or 23	Ø660 mm x 40 mm (several plates)
Vacuum chains	2 units with handling system

Conclusions

- Quick glimpse of challenges we are and will be facing in the future at CERN
- Currently finalizing Long Shutdown 2 activities in view of complex restart in early 2021
- Next Long Shutdown in 2025-2026, procurement to be launched few years earlier
- More general considerations about challenges of high intensity absorbers available here:
  - M. Calviani – J-PARC Symposium 2019
- *For more questions, please don't hesitate to contact me (Marco.Calviani@cern.ch)*