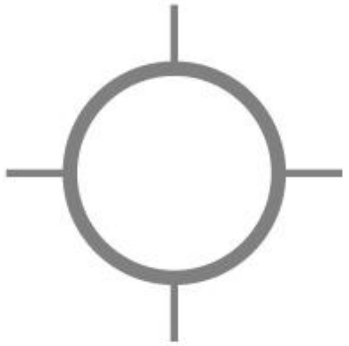
SY/STI group presentation

S. Gilardoni - SY/STI

SY/STI: Sources, Targets and Interactions Group

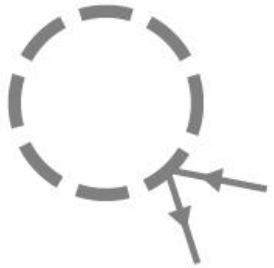
Sources

Build and operate **all CERN laser**-based particle **sources** and lasers for beam ionization/spectroscopy of short-lived nuclides
→ **~10 laser facilities to operate**
→ **Electron sources for CLIC/AWAKE**



Targets

Design **produce**, operate **all CERN secondary particle** production targets
→ **operation of the ISOLDE/n_TOF facilities and AD-target**
→ **responsible of the use of 75% of CERN protons**

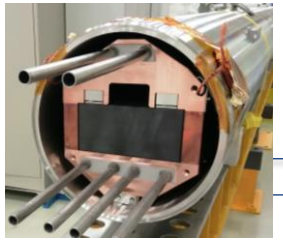


Interactions

Design, produce, operate beam intercepting devices in circular accelerators and transfer lines
→ **More than 250 devices**
→ **LHC collimation systems, dumps, etc…**
→ **Devices for accelerator and personnel safety**

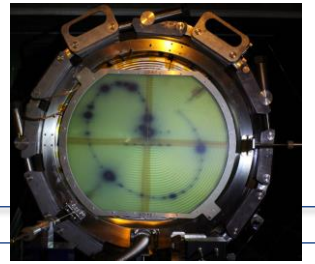
Monte-Carlo Simulations beam-matter interactions
→ **Fluka development and Geant4**

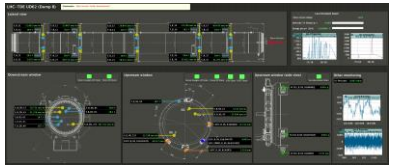
Targets, Collimators and Dumps

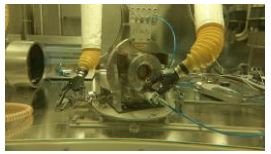




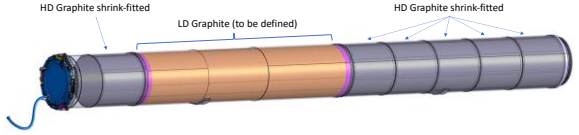






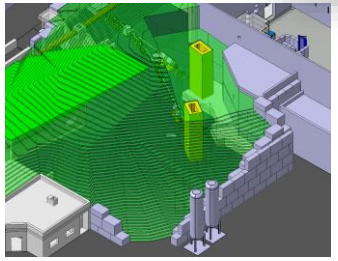
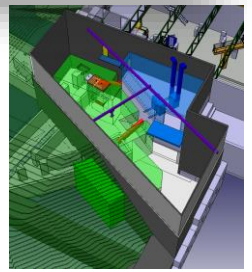


HD Graphite shrink-fitted
LD Graphite (to be defined)
HD Graphite shrink-fitted



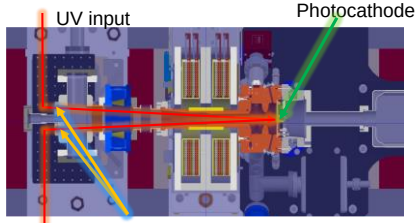
Radioactive Beam Sources & ISOLDE Facility

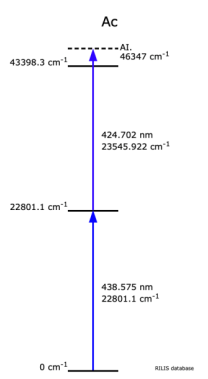


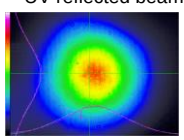




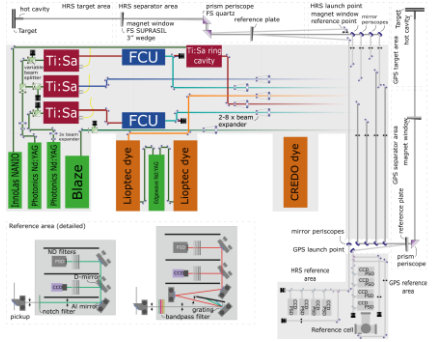

STI

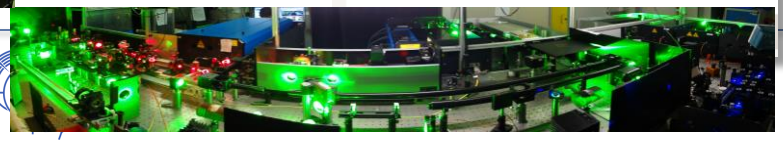
Laser and Photocathodes



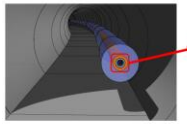
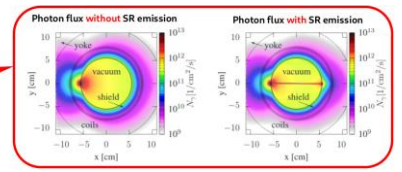


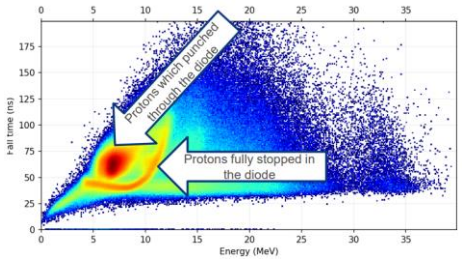


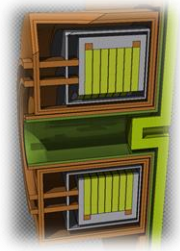



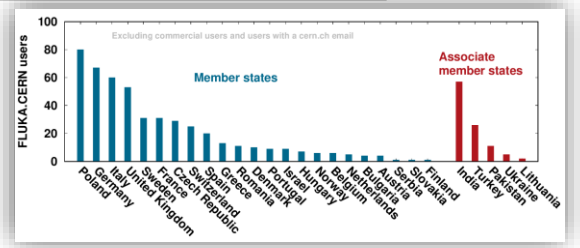


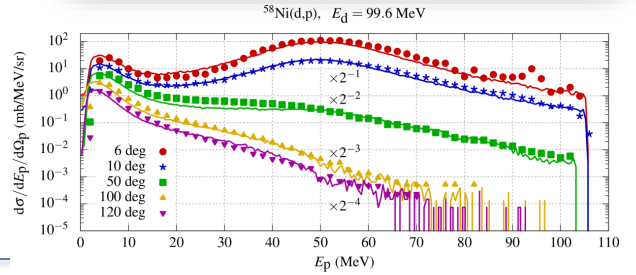
Beam-Machine Interactions - FLUKA









SY/STI: Sources, Targets and Interactions Group

~ 120-110 members
~ 1/3 staff, ~ 1/3 fellows

A multicultural group

STI

Many transversal activities in very different domains

Mechanics

Material Science

Nuclear physics

Simulation codes

Facility operation

R2E

HiLumi HL-LHC PROJECT

FCC hh ee he

...

Direct responsibilities in major projects and in accelerator operation.
Many LS2 devices, more coming for LS3

Preparing the CERN future
PBC, FCC, Muon Collider, CLIC

esa

KEK-JAPAN

MICHIGAN STATE

20+ international collaborations
Few active EU funded projects
Strong collaboration with other Groups

CNUV

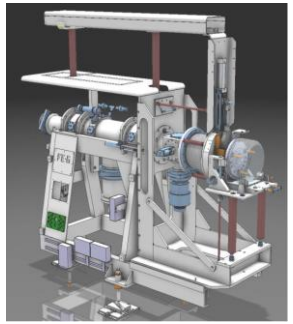
INFN

...

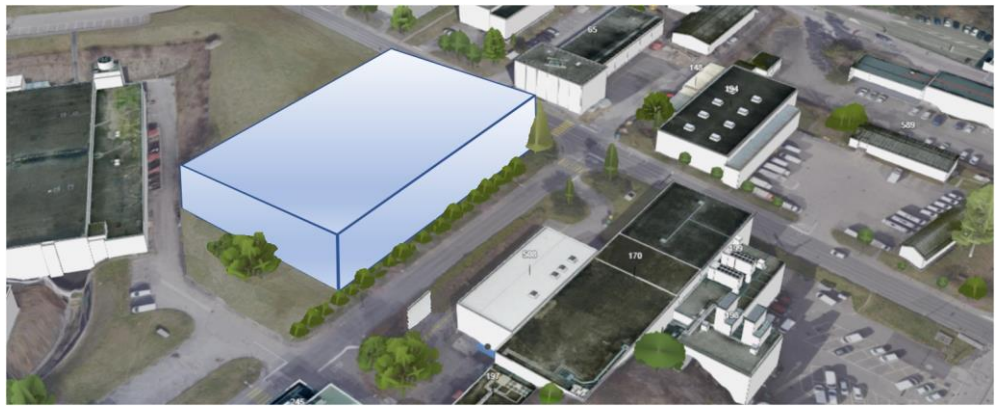
n_TOF and ISOLDE facilities: ~1000 users

ISOLDE: a unique worldwide rare isotope production facility

- **45 experiments** for more than **500 users / year**
- Pulsed proton beam (**50% of CERN protons**)
- Three class A laboratories (ISOLDE, MEDICIS, Nanolab)

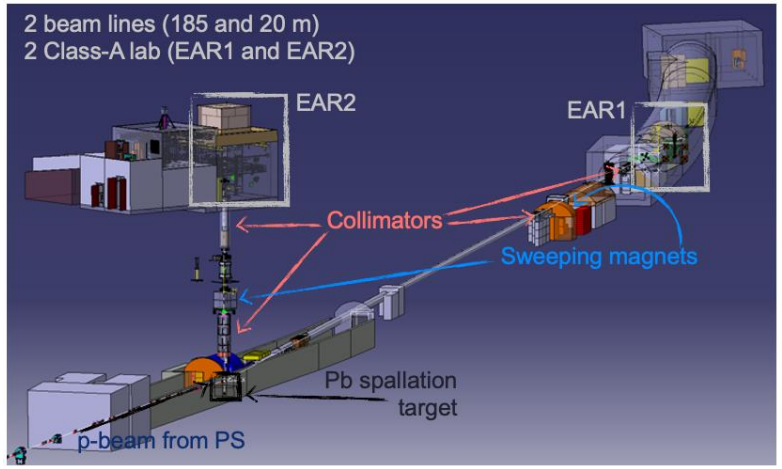


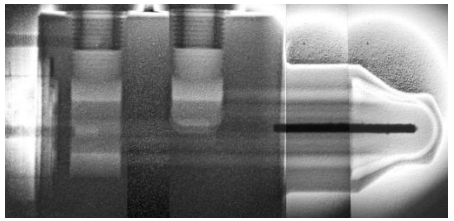
EPIC: ISOLDE exp. Building (LS4)
Exploiting the **P**otential of **I**SOLDE at **C**ERN

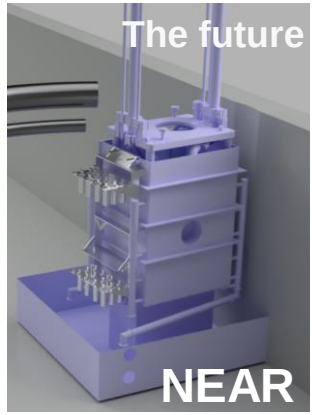


n_TOF: a unique worldwide spallation neutron source

- **46 institutes** for two class A laboratories - experiment areas
- Pulsed neutron beam (**from 25% of CERN protons**) on Pb target







Comments on industrial partners

- **Looking for industrial partners ready to share know-how and ideas on R&D**
  - We develop with industry
- **From very small to somehow medium (on CERN scale)**
- **Small production requiring ingenuity from companies in developing “one-of-a-kind” or to find innovative solutions in different fields in very different fields**
  - Materail science : innovative material for nuclear application
  - New material processing
  - Beam-matter interaction → simulation and simulation tools
  - Laser technologies
  - Nuclear related technologies and processes

SPS internal beam dump crisis: from paper to reality in 1 year

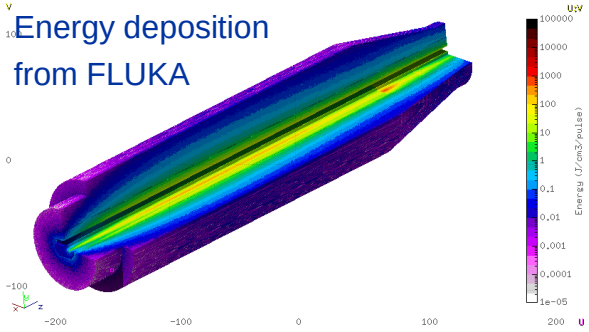
SPS internal beam dump:
- **4.3 m long, 30 cm diameter, ~ 30 tons including the shielding**
- 60 kW beam power to absorb (now 250 kW → house is 10 kW)
- **Internal to SPS primary vacuum**

→ **Developed vacuum leak in April 2016 → no spare available**
→ **Possible consequences: no physics for 1 year in LHC and SPS**

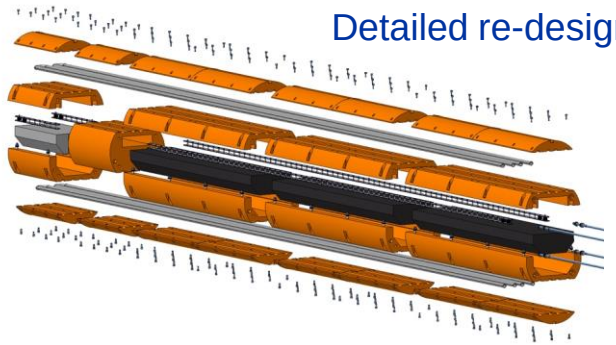
Actions leading to success with impressive support from the sector:
- Worked with management to optimize physics program
- Organized crash program to produce a new one in record time
- Revise spare policy for similar devices

LHC beam dumps in similar situation
Elaborating these days the strategy for spares.

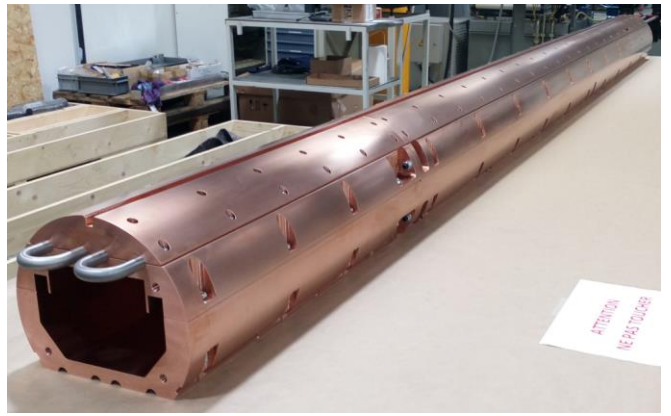
Energy deposition from FLUKA

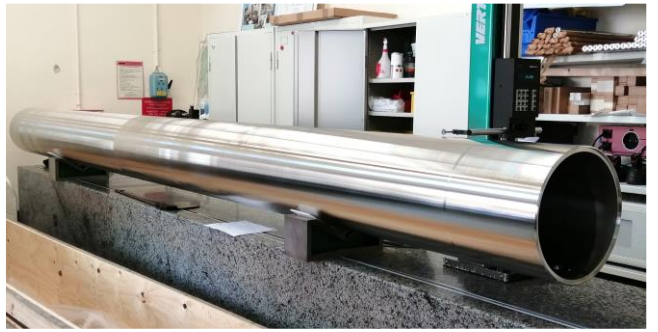


Detailed re-design



Follow-up of production in industry



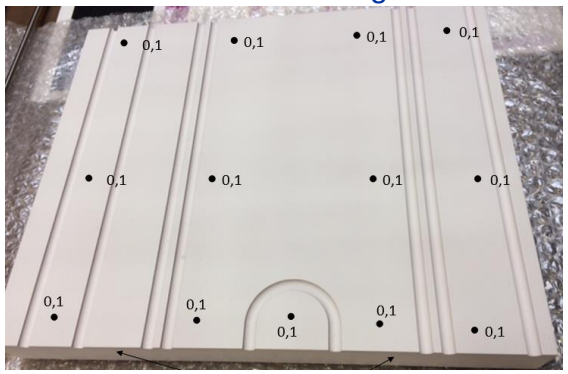


Assembly, installation, operation

PS Dump 2019: cooling pipe hipping in CuCrZn

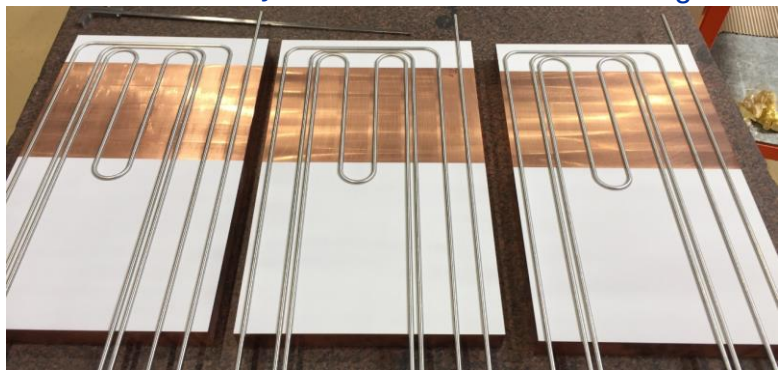
CuCr1Zr machining

Alumina coating

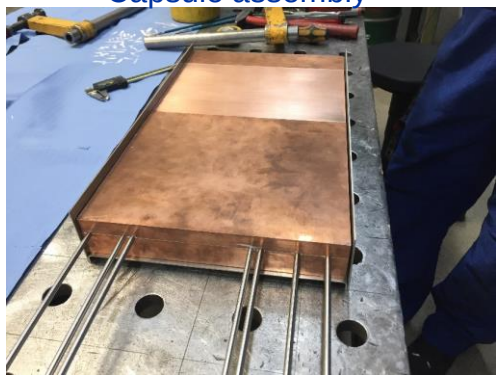


Tube assembly tests

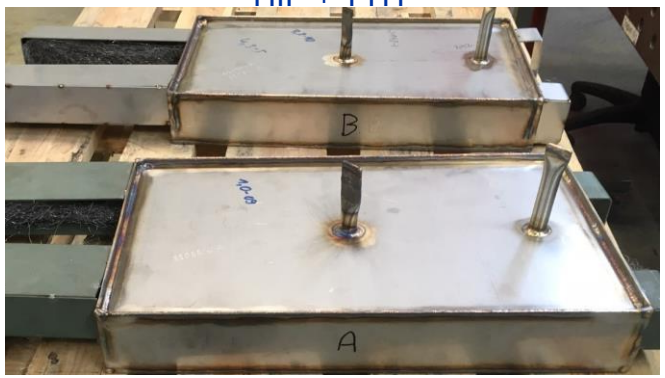
Alumina finishing



Capsule assembly

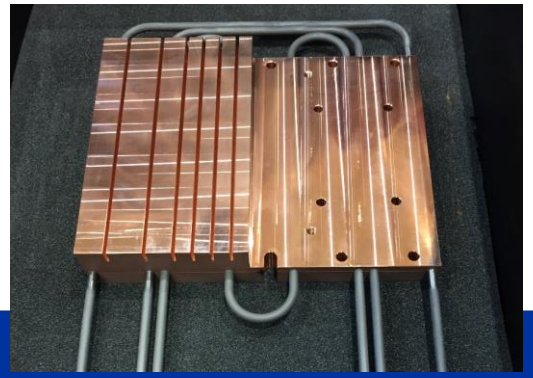


HIP + TTH



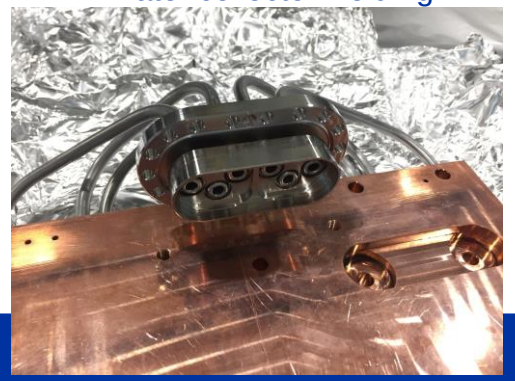
Capsule opening

Machining



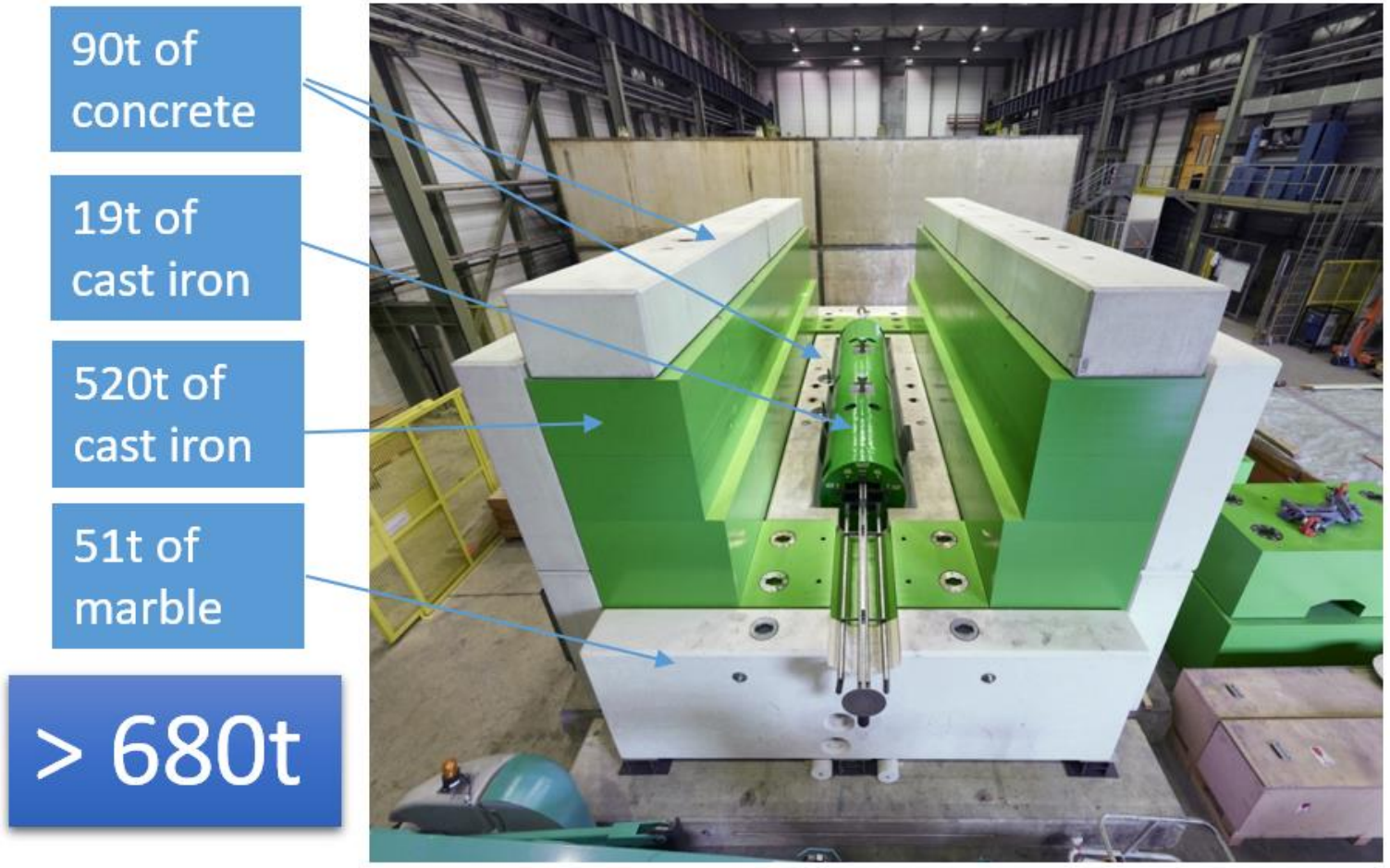
Tubes bending

Water collector welding

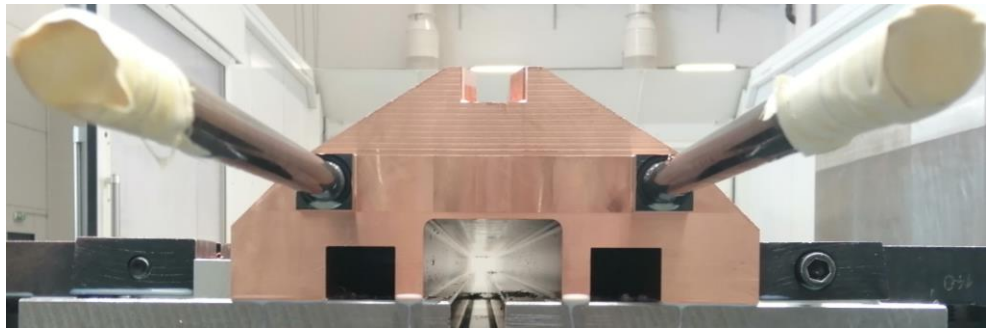


Upscaling the technology: internal SPS beam dump

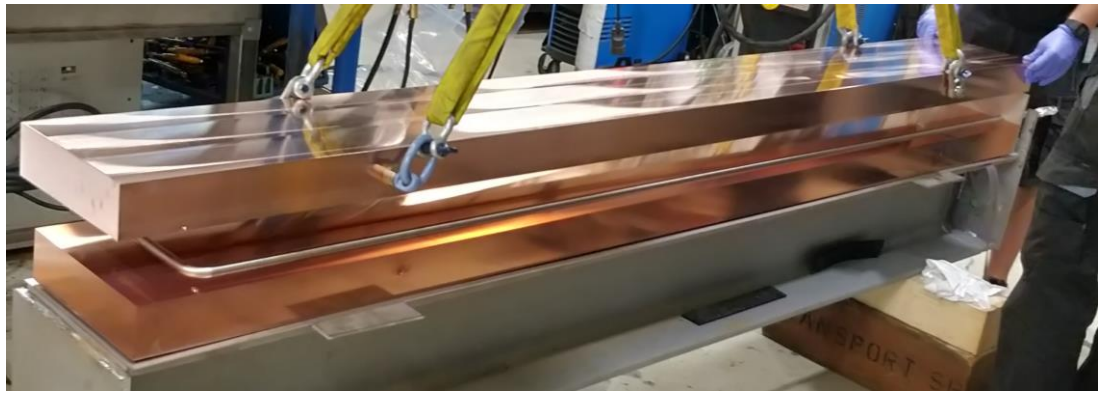
- **Beam dump shielding mock-up built and validated in BB5**



LIU TIDVG5 dump core: a technical marvel



CuCrZr block with embedded stainless-steel pipes by HIPing

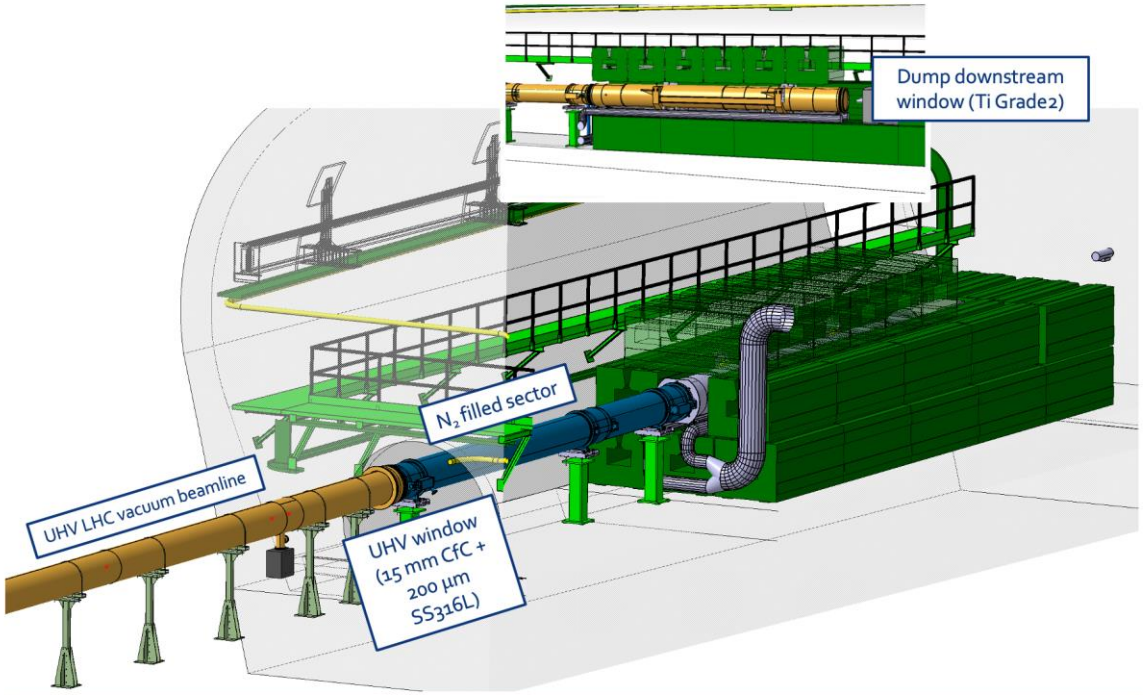


Machining by EN/MME

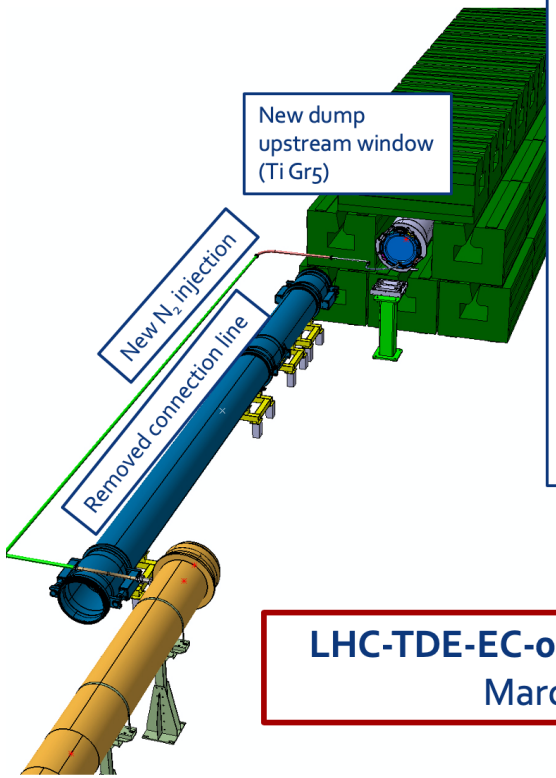
Small-size production of large-size objects

Reminder : LHC-beam dumps

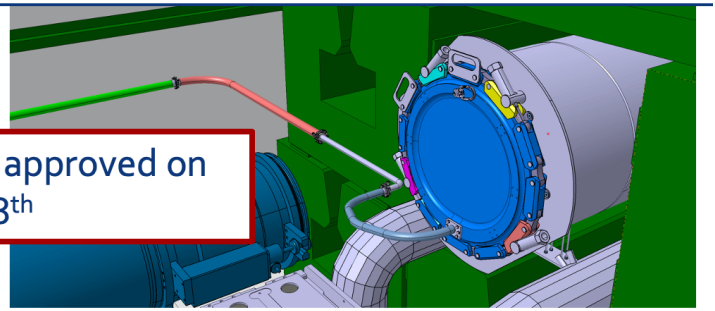
Pre-LS2 configuration of LHC dump block



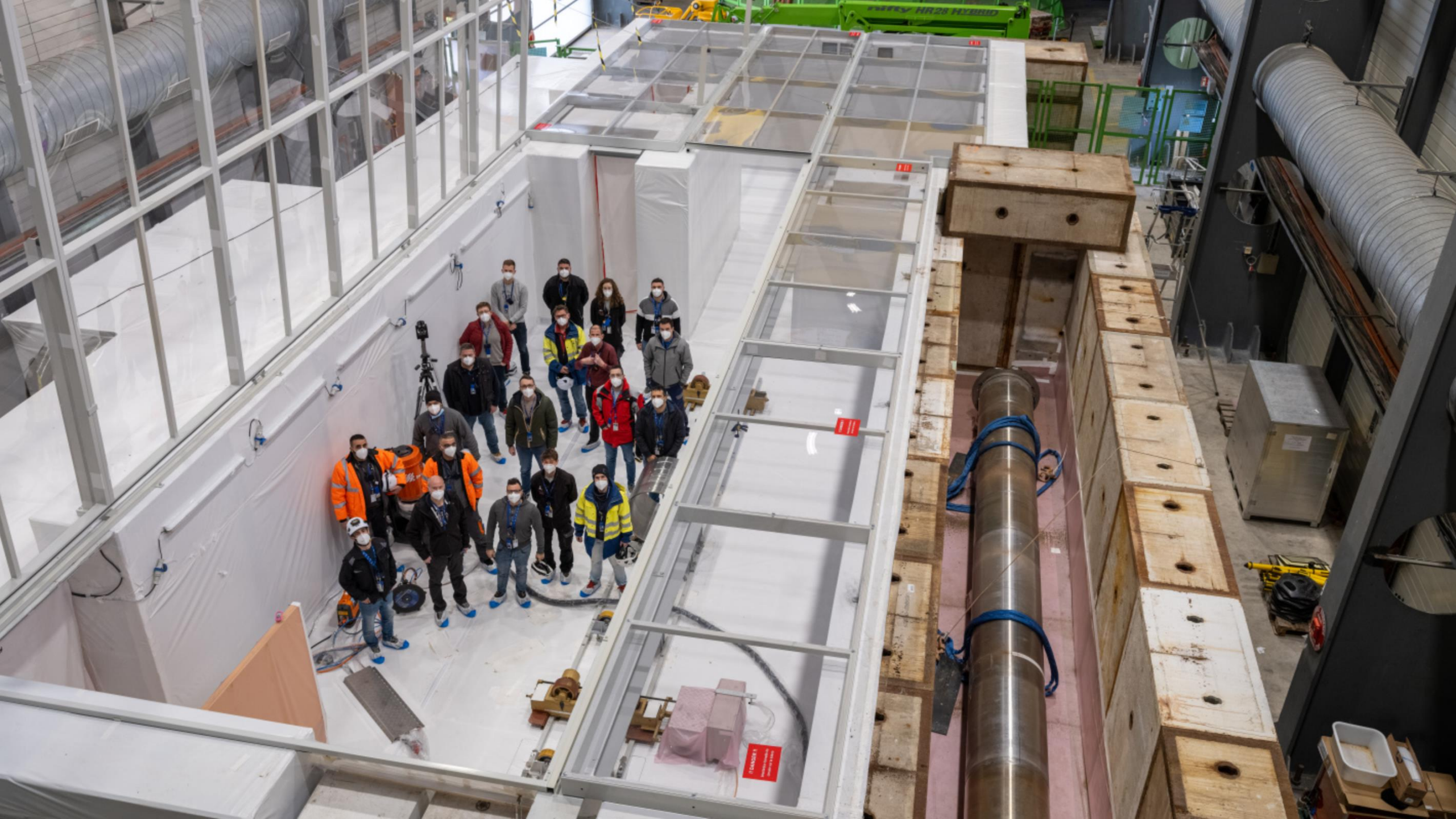
approved Run3 ~~proposed~~ configuration



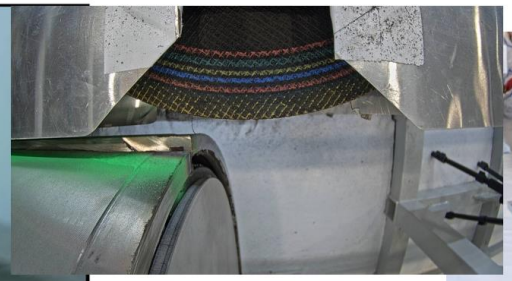
- Dump disconnected from UHV line
- New dump upstream window
  - Ti Grade5 10 mm, clamped EPDM gasket
- New dump downstream window
  - Ti Grade5, 10 mm, Conflat
- Upgrade cradle support with dump suspended on steel cables
- Instrumented dumps

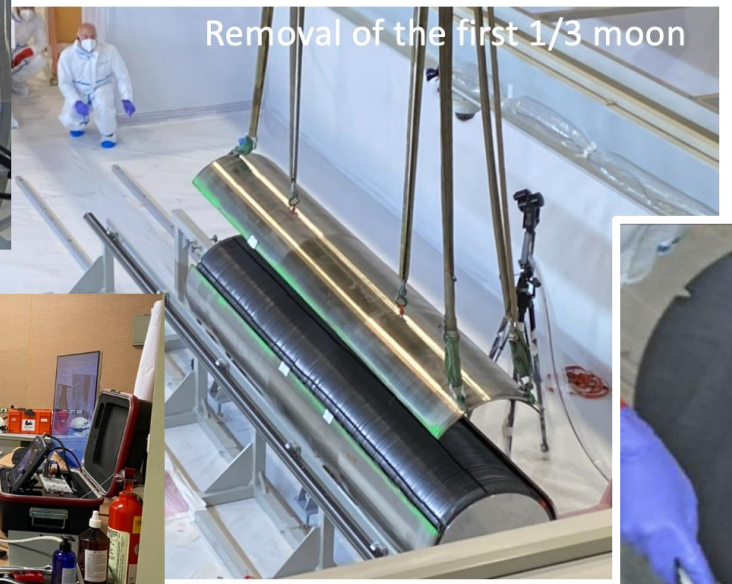


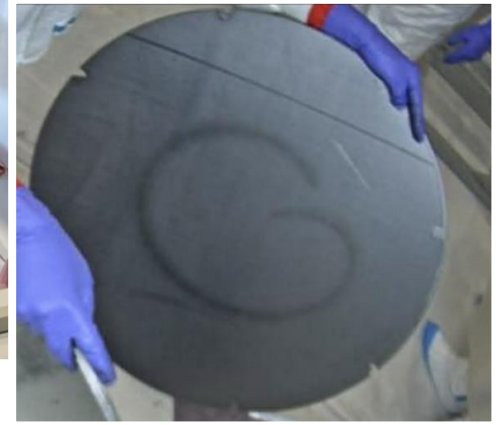
LHC-TDE-EC-0004 approved on March 18th

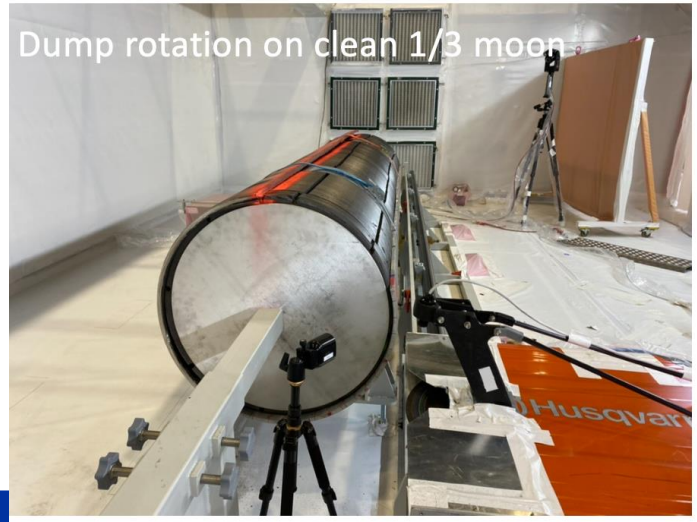


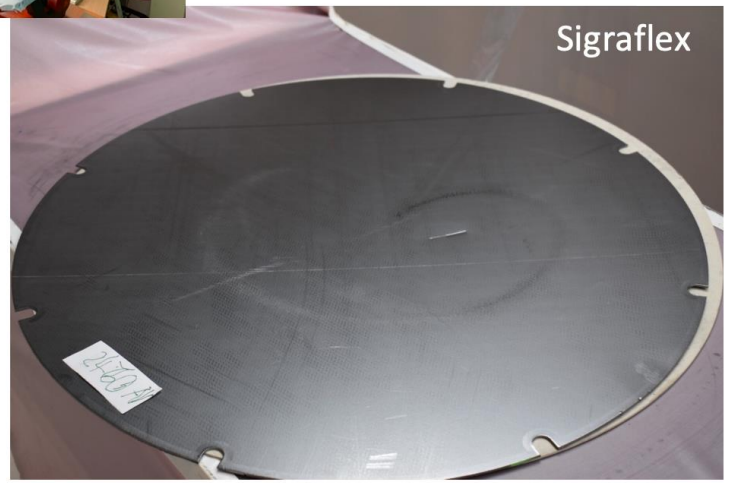
LHC beam dump autopsy



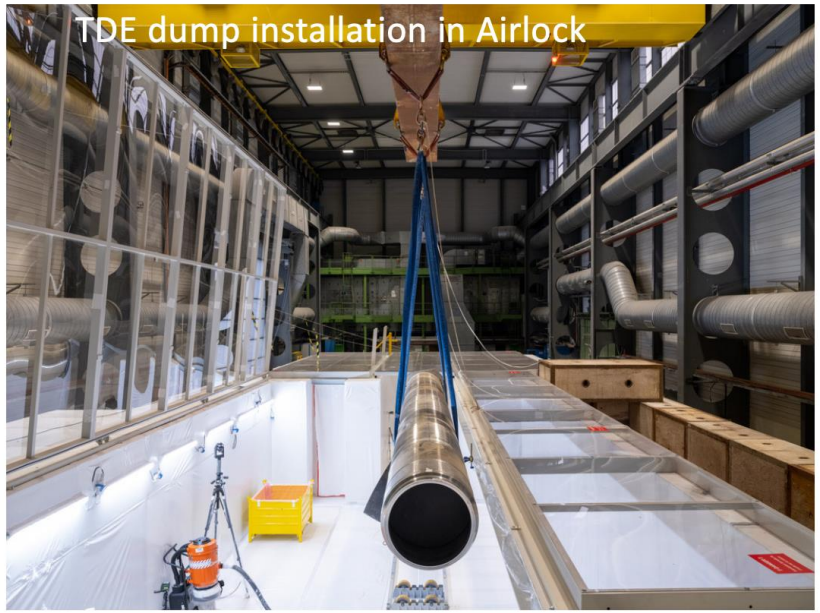


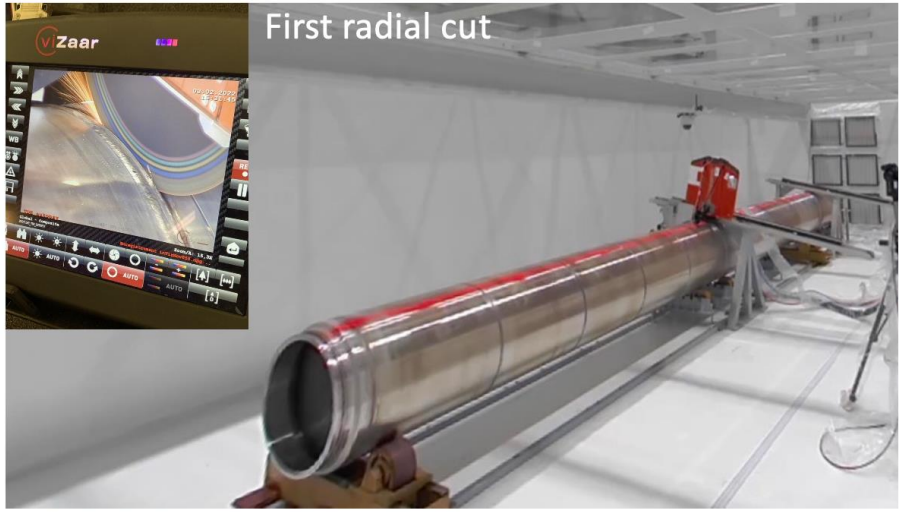


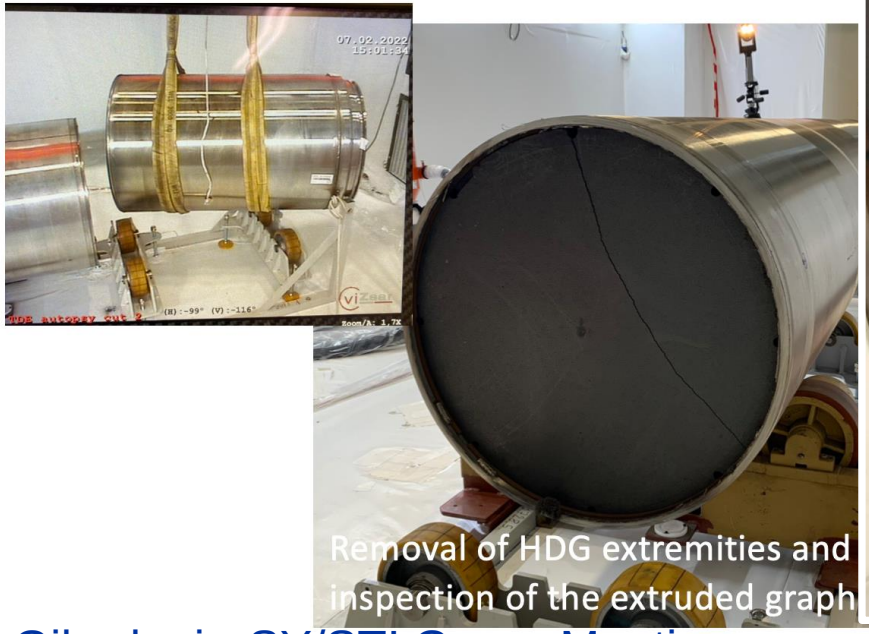




LHC beam dump autopsy

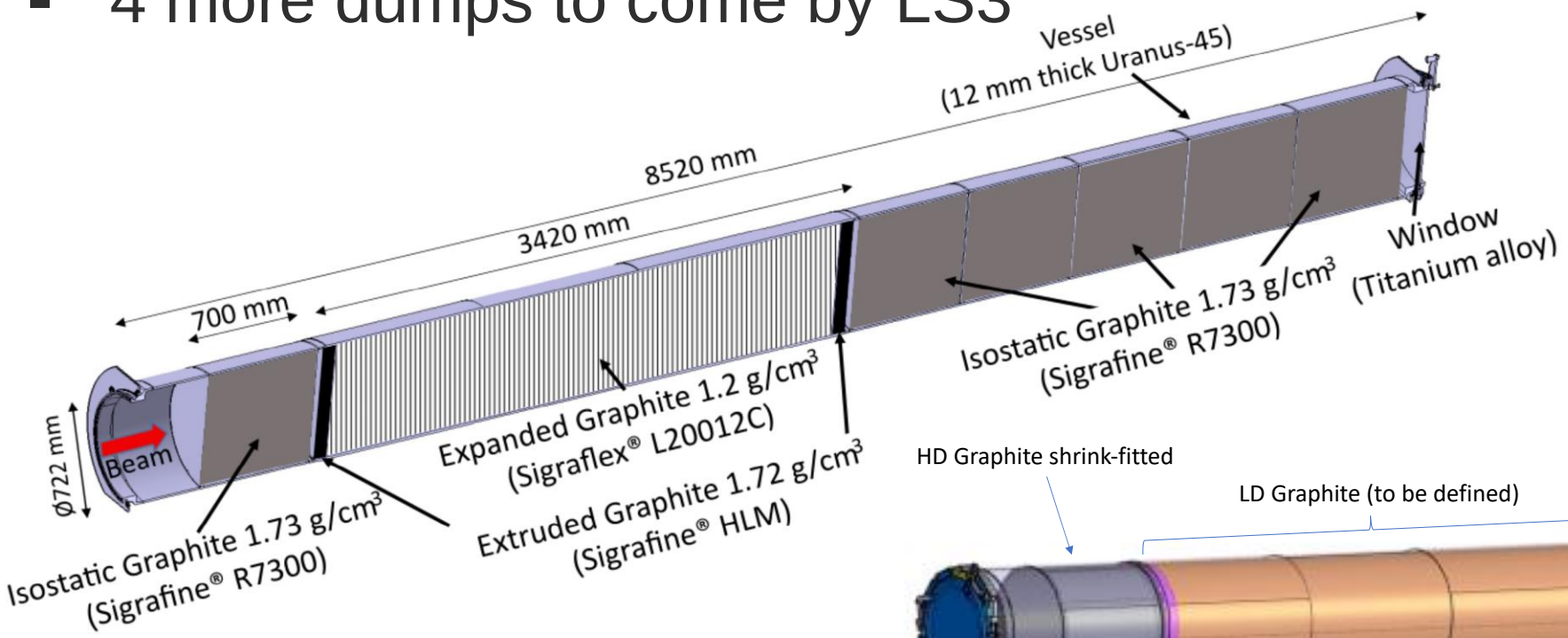


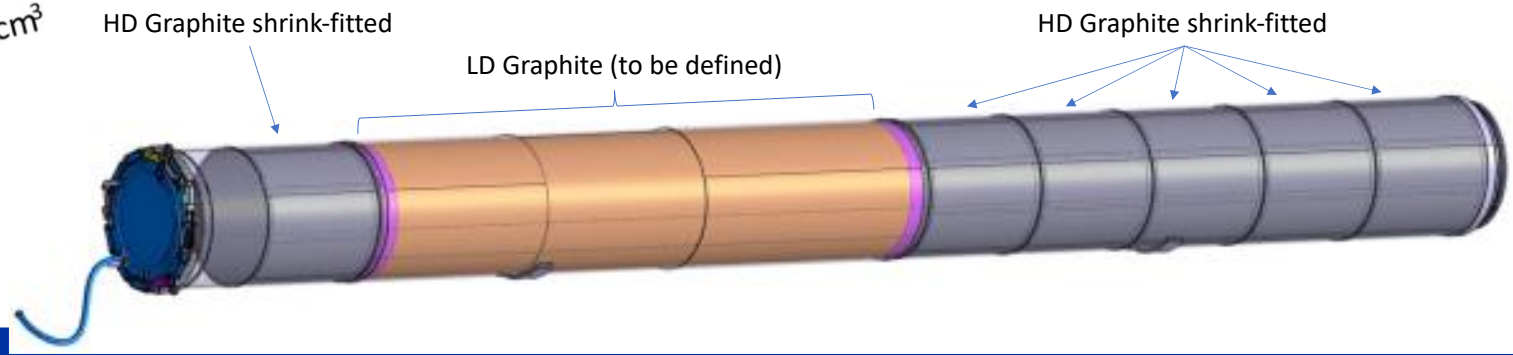




TDE spare works at beam on dump

- Project started aimed at building 2 LHC spare dumps by mid 2023 – challenging deadline due to challenging raw material situation
- 4 more dumps to come by LS3





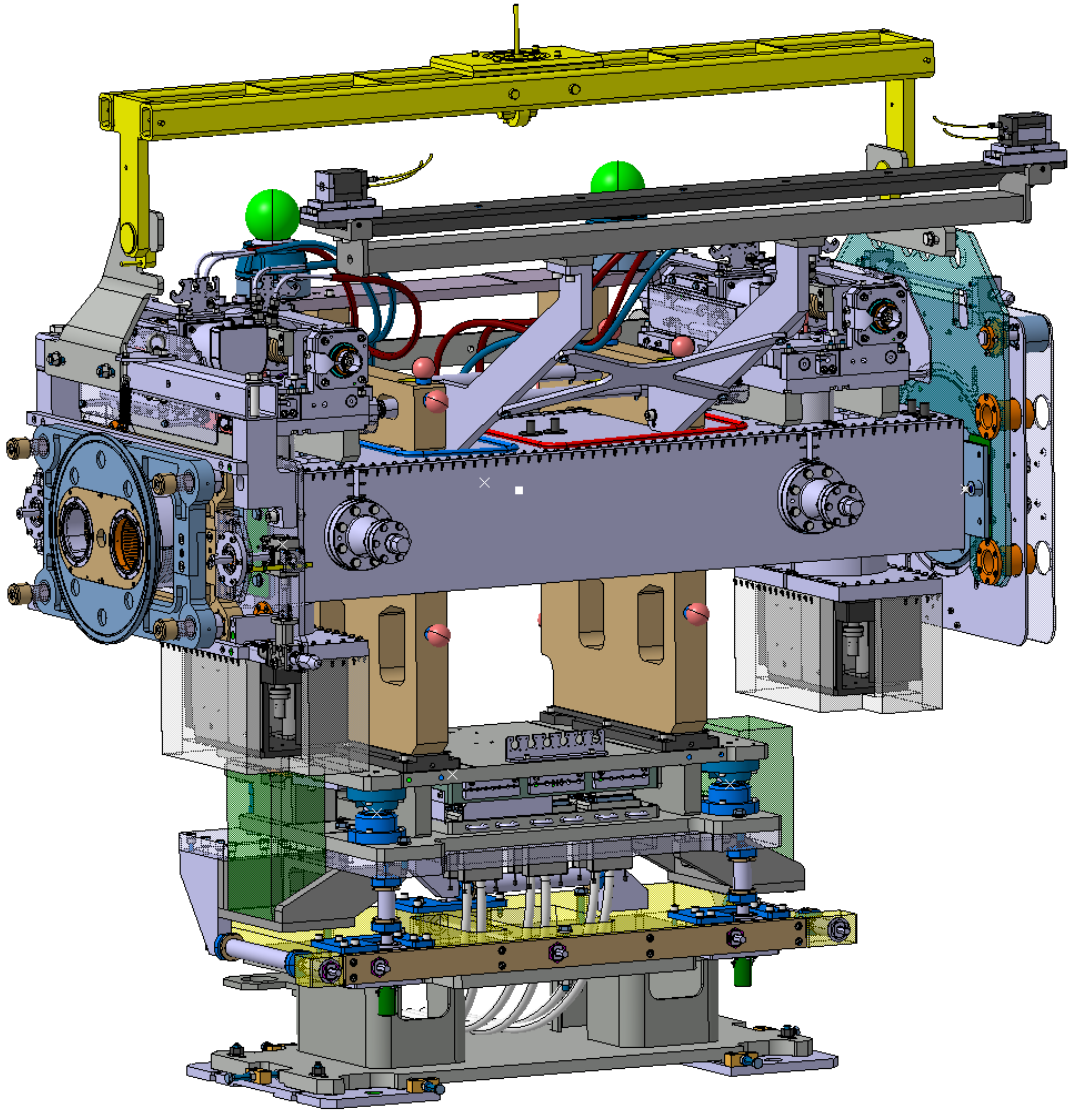
Medium-size production of medium size objects

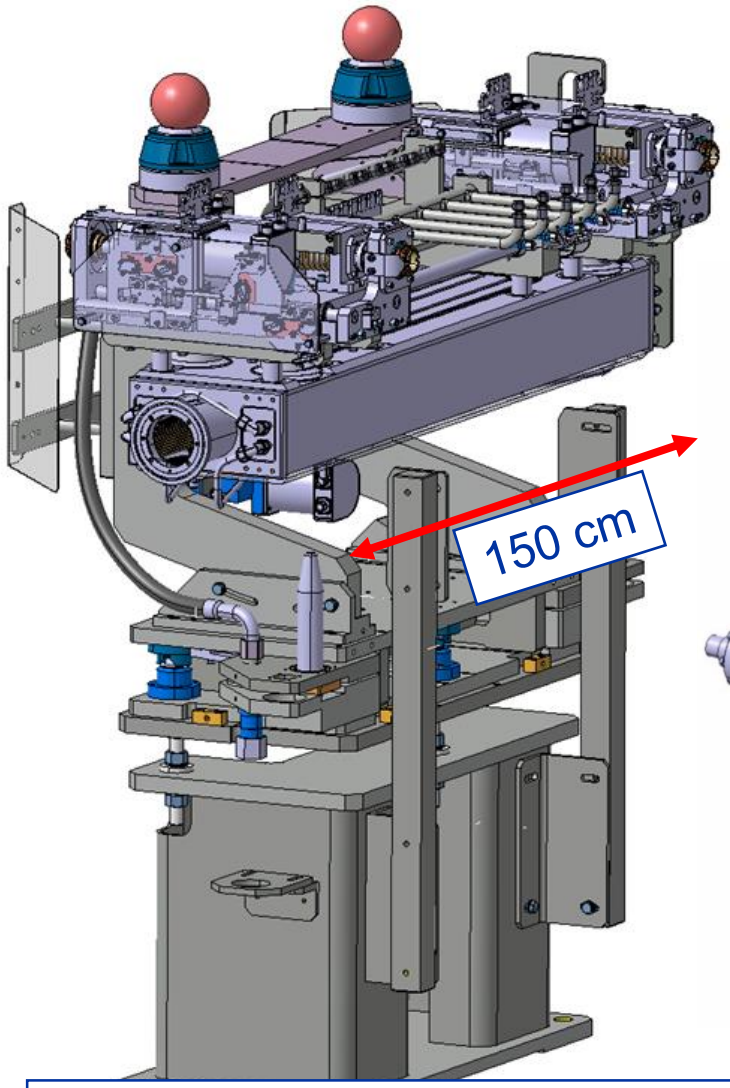
HL-LHC collimators

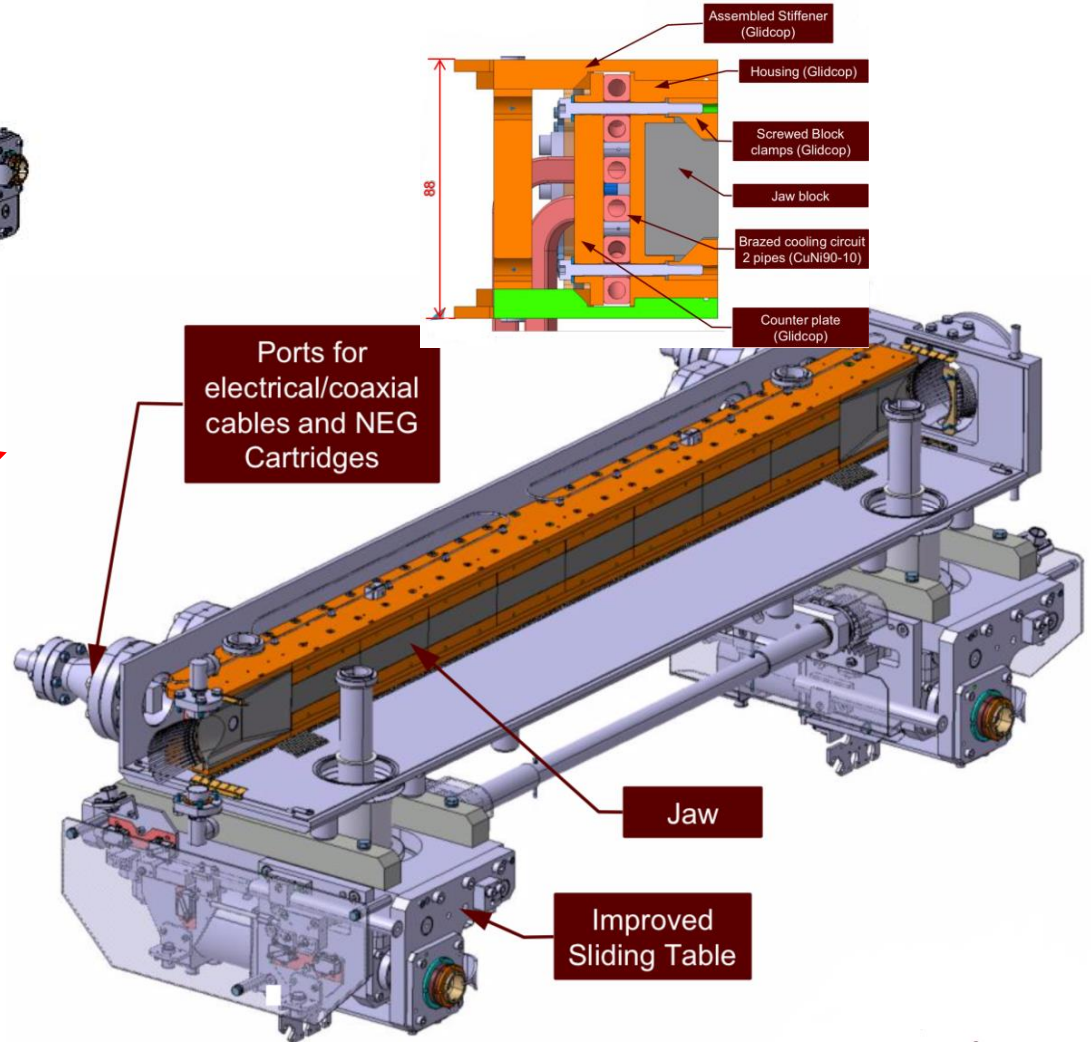
- LS3 upcoming industrial production
- **Decision to re-insource the production of ~50 units** in view of LS3 (larger than LS2 production) from the in-kind

Collimator Description	Names	LS3 installation				Design	Jaw material		Functional specification status April 2021
		Operational	Total series Production	Spares	CERN Protos				
Tertiary collimators	TCTPXH	4	4	1	1	LHCTCTPXH_0001	Two possibilities: Inermet 180 (tapering in CuCr1Zr), CuCD (tapering in MoGr) (selected for the proto)		EDMS 2519805
	TCTPXV	4	5	1	-	LHCTCTPXV_0001	Inermet 180 (tapering CuCr1Zr)		
	TCTPM	4	5	1	-	TCSPM Design	Two possibilities: Inermet 180 (tapering in CuCr1Zr), CuCD (tapering in MoGr)		
	(TCTP)	4 (re-used)	-	-	-	LHCTCTP_0001	Inermet 180		EDMS 1304880
Physics debris collimators	TCLP	4	5	1	-	TCSPM design	Inermet 180 (tapering CuCr1Zr)		EDMS 2276600
	TCLPX	4	5	2	1	LHCTCLPX__0001	Inermet 180 (tapering CuCr1Zr)		
	(TCTP)	4 (re-used)	-	-	-	LHCTCTP_0001	Inermet 180		EDMS 1304880
Physics debris collimator Masks	TCLM	4 TCLM4 8 TCLM5/6	15	3	-	LHCTCLM_0001 and LHCTCLM_0002	Inermet 180 for TCLM4	TCLM5 & 6: Copper OFE	EDMS 2276600
DS collimators	TCLD	2 (point 7)?	-	-	-	LHCTCLDA0001	Inermet 180		-
Low-Impedance secondary collimators	TCSPM	10 (point7)	12	2	-	LHCTCSPM0160	MoGr with Mo coating		Copy/paste of LS2 production

HL-LHC collimators



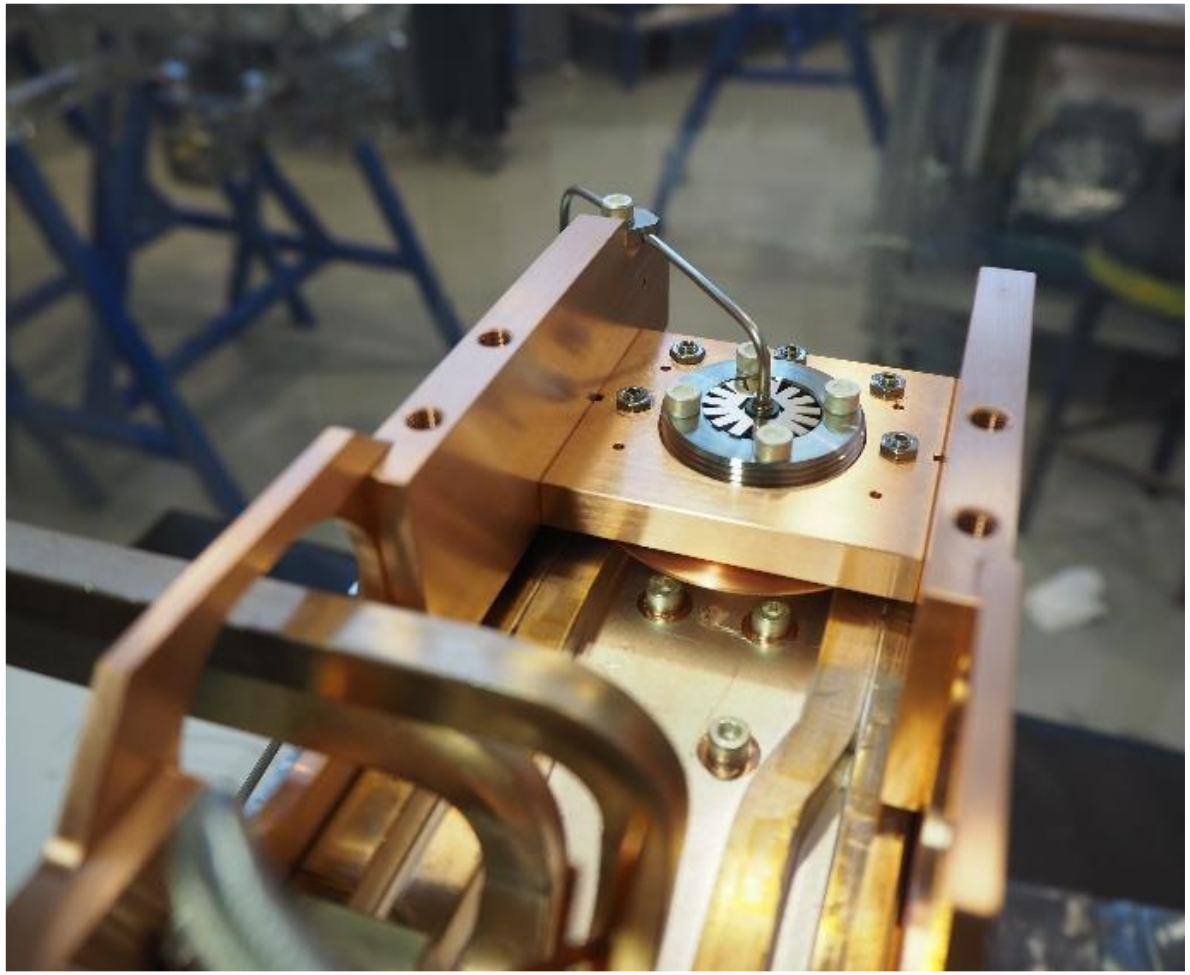


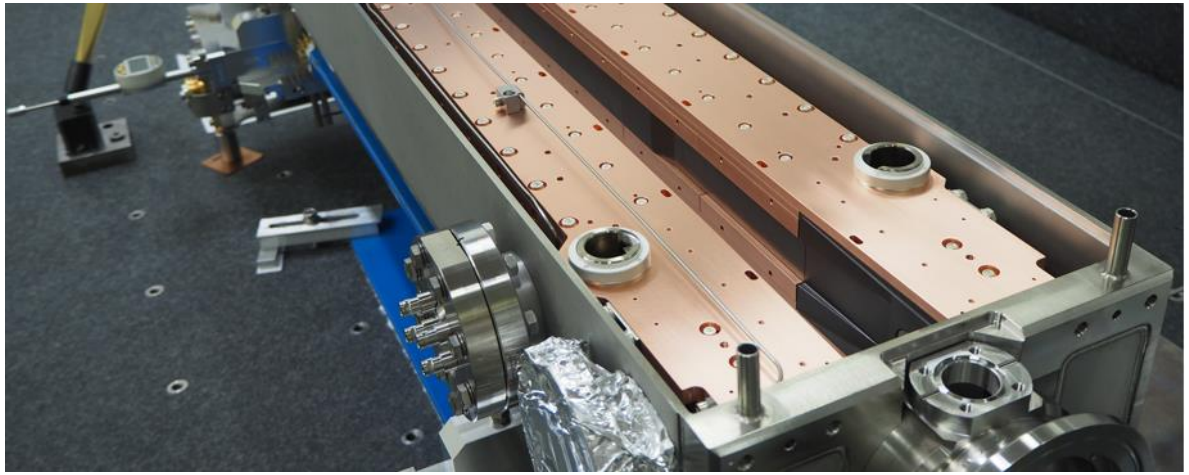


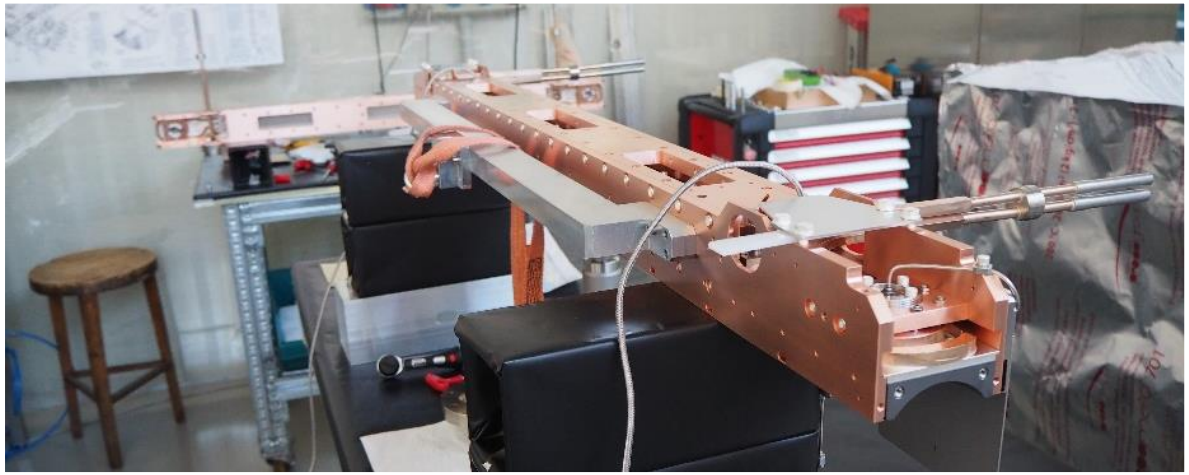
Each collimator jaw designed (and tested) to cope with:

- **10 kW steady losses of 1 hour**
- **Direct beam impact at injection and during asynchronous beam dumps at 7 TeV**

HL-LHC collimators: upcoming industrial production





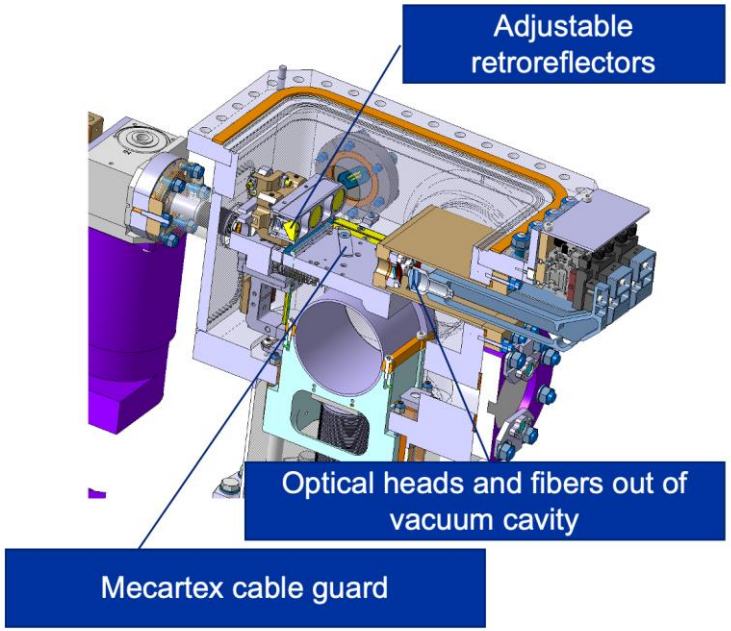


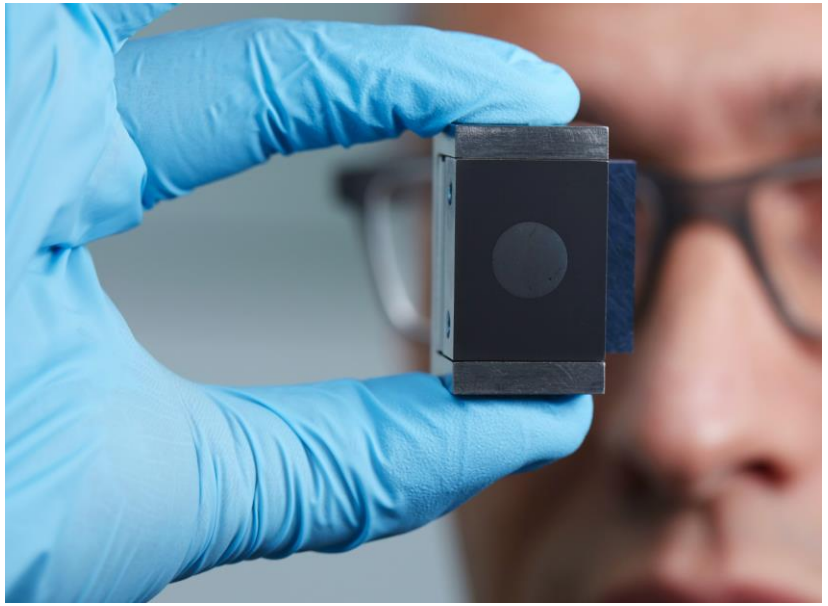
Medium-size production of small-size objects

HL-LHC crystal collimators TCPC

- LHC crystal collimators designed, built and installed during 2021, in order to compensate for lack of 11 T magnets

- Now re-insourcing crystal for collimators: Si technology

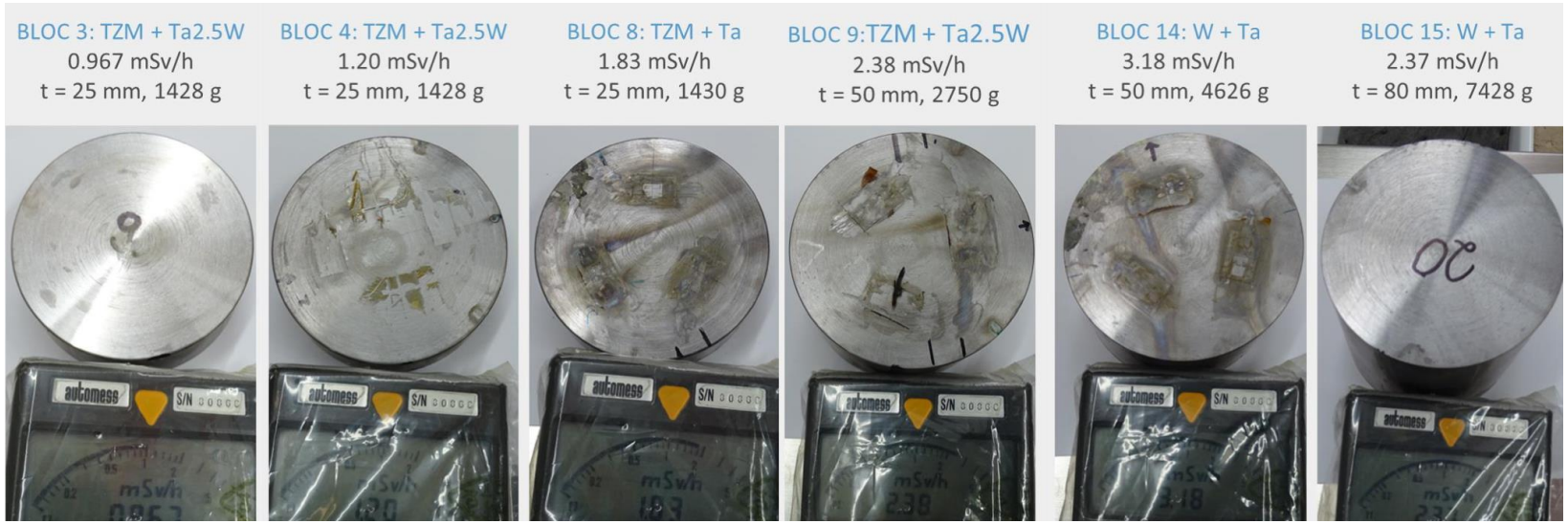


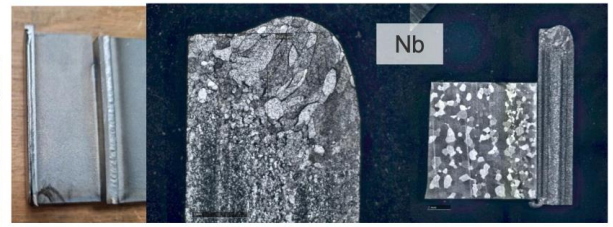


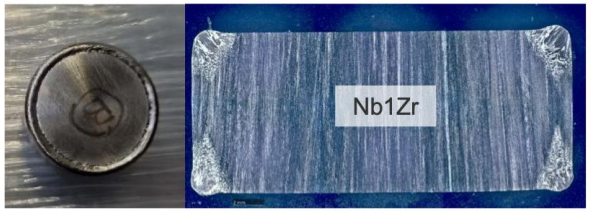
Example of PIE of target materials in industry

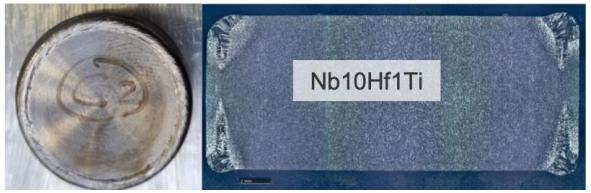
Graphiic material for beam-intercepting devices

Beam Dump Facility studies
Target systems design (R&D)

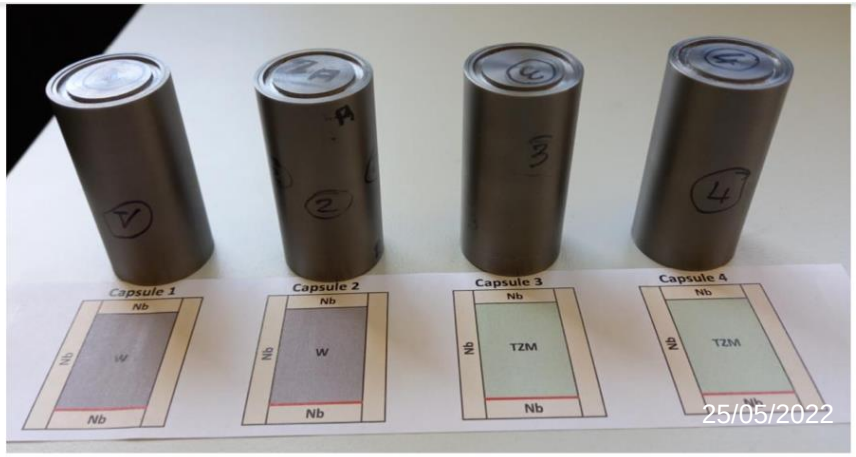






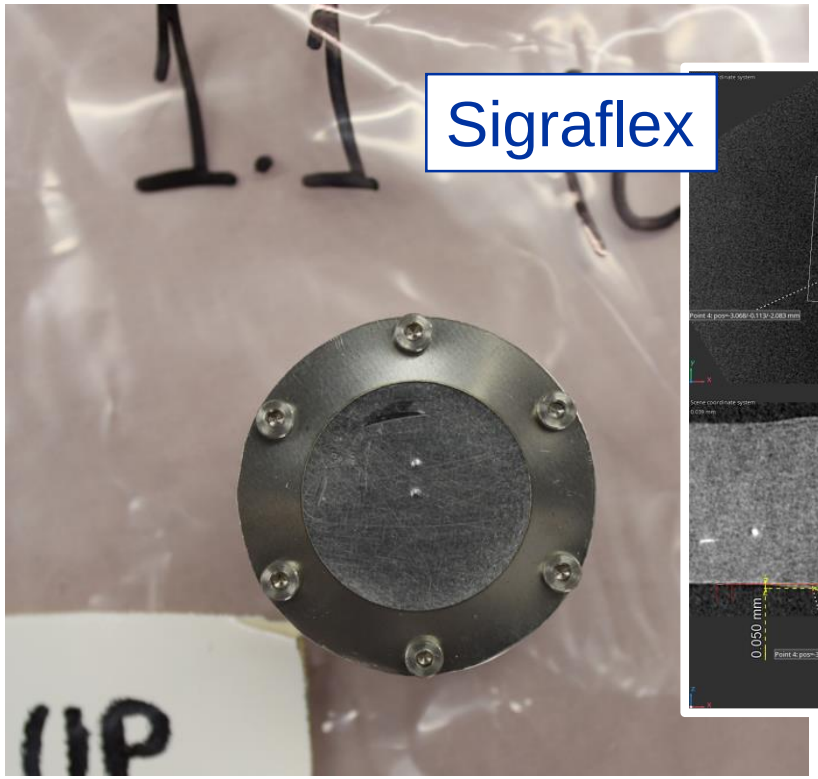


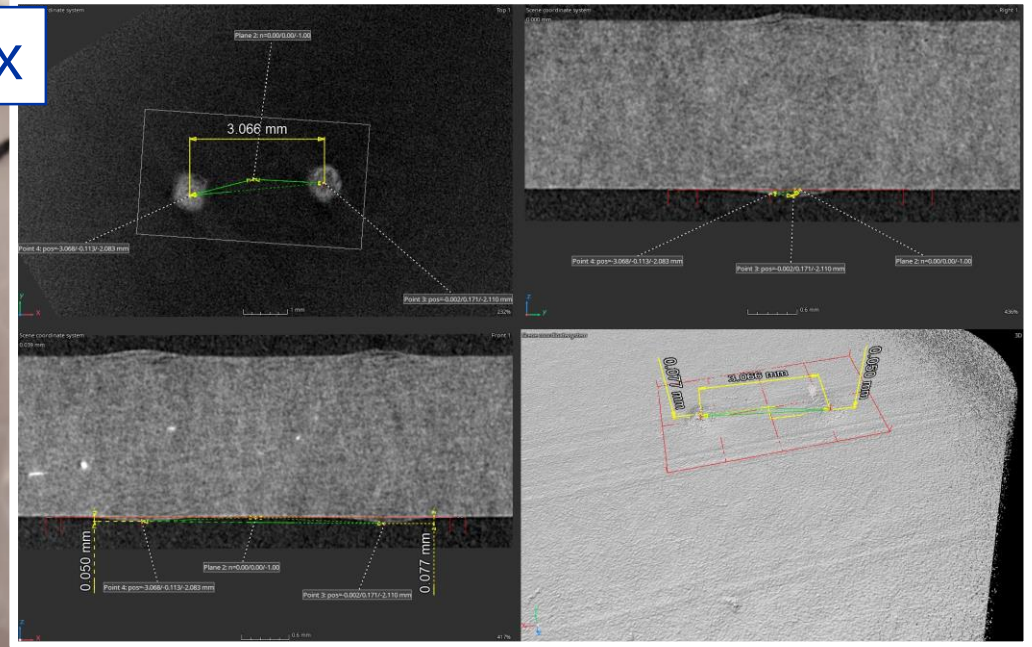
ID	Material	Gas atmosphere	Temp. T_f (°C)	Ramp: (°C/min)	Results
1	Ta2.5W	50% Argon: 50% Air	400	10	- Mass gain: +0.05 % - Slight surface oxidation (non-visible)
2			500		- Mass gain: +0.26 % - Oxide layer: thin greyish brittle - Oxide location: on flat surfaces
3			600		**- Mass gain: +9.31 %.** - Oxide layer: thick and brittle - Oxide location: on flat surfaces - Shape: platelets expanding outwards - Large volume expansion
4			700		- Mass gain: +4.29 %. - Pulverized white oxide powder
5			800	2	- Mass gain: +0.75 % - Slight surface oxidation
6		Argon 6.0			- Mass gain: +0.31 % - Slight surface oxidation
7				40	**- Mass gain: +1.47%** - Oxide layer: white and brittle surface
8		50% Argon: 50% Air	400	10	- Mass gain: +0.09 % - Slight surface oxidation
9	TZM				- Mass gain: +0.11 % - Slight surface oxidation
10			800	2	**- Mass gain: +3.93 %** - Strong oxidation - Volatilization of MoO_3 - Condensation on the lid and the outside ring of the oven
11	W		400	10	- Mass gain: +0.04 % - Slight surface oxidation
12			800	2	**- Mass gain: +1.46 %** - Strong oxidation - Yellow powder type oxide on surface

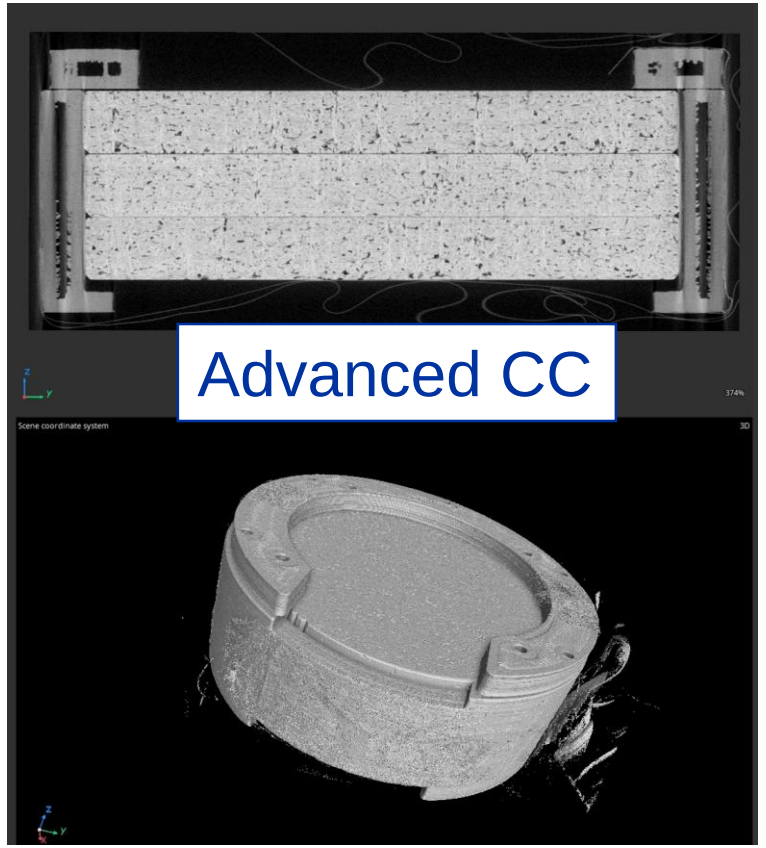


HRMT56 – R&D on low density graphitic materials
post irradiation examination

- Analysis and discussions still ongoing, but preliminary data are available
- Wealth of data available on different grades of advanced carbon-based materials





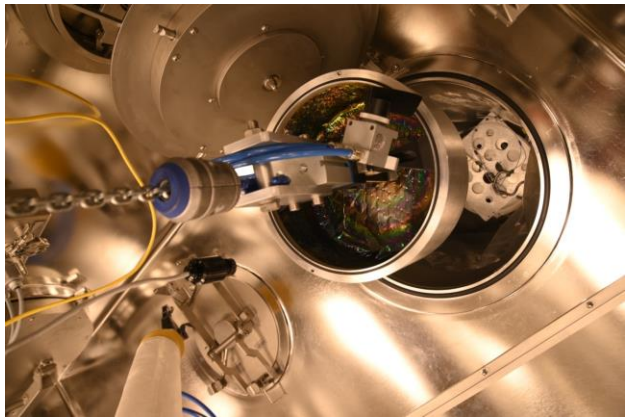


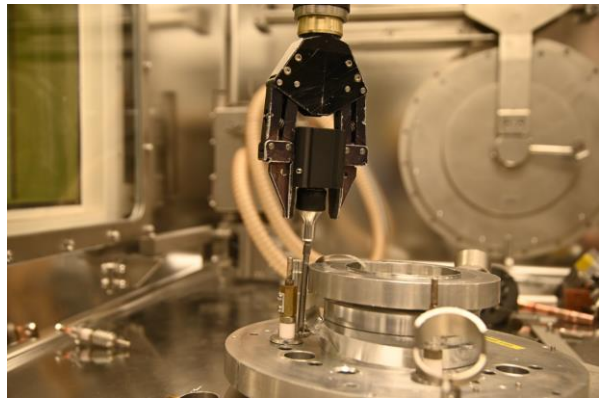
Nuclear waste

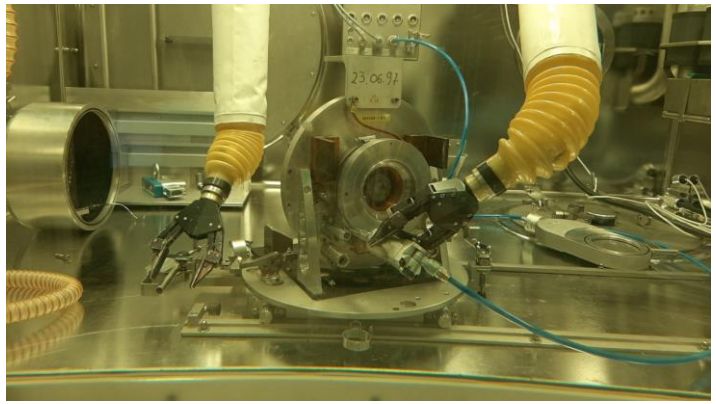
ISOLDE Target Elimination: ISOLDE Hot-Cell

- Use of the ISOLDE Alpha-Gamma hotcell (two compartment, one operated under inert atmosphere)
- **Currently hot-cell commissioning and process development.**

- **Strong interest in industry support for optimizing the dismantling processes**







Targets for pilot campaign in 2022 ready

High performace computing for simulations

FLUKA

https://fluka.cern

FLUKA-4.2.1 released Dec 14, 2021:

- Novel model for deuteron interactions below 150 MeV/n
- Advanced magnetic field definition (analytical up to decapole + 2D/3D field maps for interpolation)
- Fluence-to-dose coefficients from recent ICRP116 and ICRU95

FLUKA community: over 1700 registered users

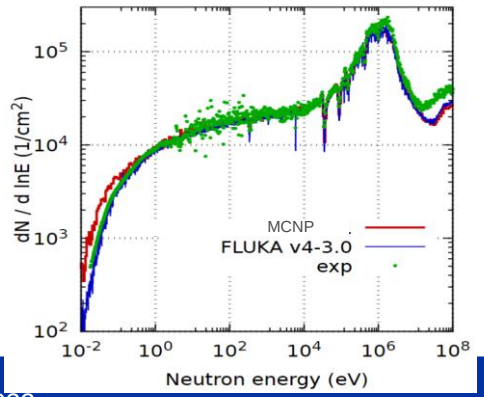
June, 2021: FLUKA Online Training.

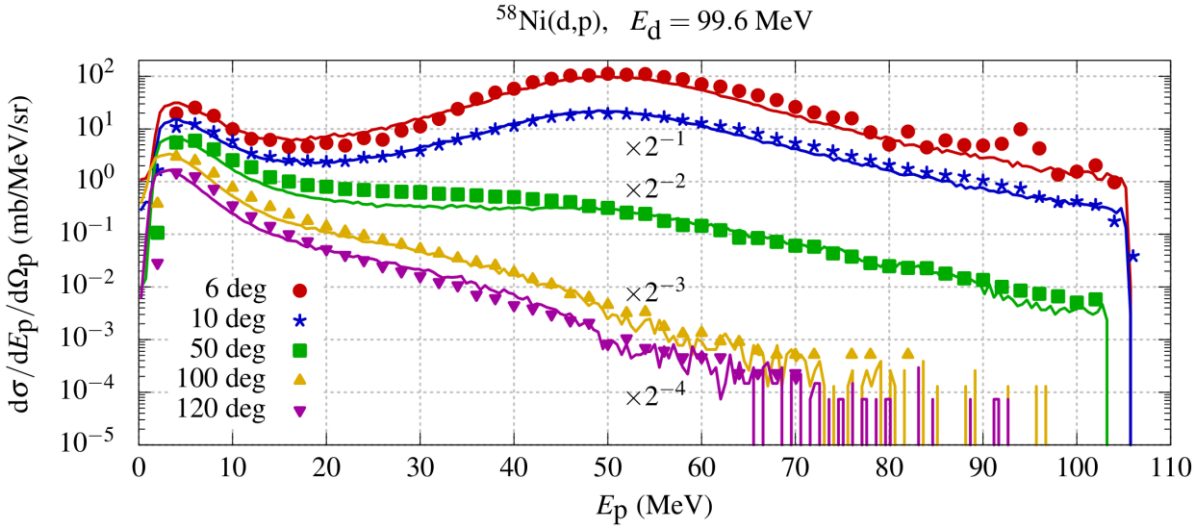
FLUKA user forum, lively activity, over 1200 discussion posts

https://fluka-forum.web.cern.ch/

Work ongoing:

Point-wise low-energy neutron interactions





New Capabilities of the FLUKA Multi-Purpose Code

C. Ahdida, D. Bozzato, D. Calzolari, F. Cerutti*, N. Charitonidis, A. Cimmino, A. Coronetti, G. L. D'Alessandro, A. Donadon Servelle, L. S. Esposito, R. Froeschl, R. García Alía, A. Gerbershagen, S. Gilardoni, D. Horváth, G. Hugo, A. Infantino, V. Kouskoura, A. Lechner, B. Lefebvre, G. Lerner, M. Magistris, A. Manousos, G. Moryc, F. Ogallar Ruiz, F. Pozzi, D. Prelipcean, S. Roesler, R. Rossi, M. Sabaté Gilarte, F. Salvat Pujol, P. Schoofs, V. Stránský, C. Theis, A. Tsinganis, R. Versaci, V. Vlachoudis, A. Waets and M. Widorski

ORIGINAL RESEARCH article

Front. Phys., 27 January 2022 | https://doi.org/10.3389/fphy.2021.788253

frontiers in Physics

FLUKA course for beginners in Brussels (16-20 May 2022), in collaboration with

ULB UNIVERSITÉ LIBRE DE BRUXELLES

The mid-term future

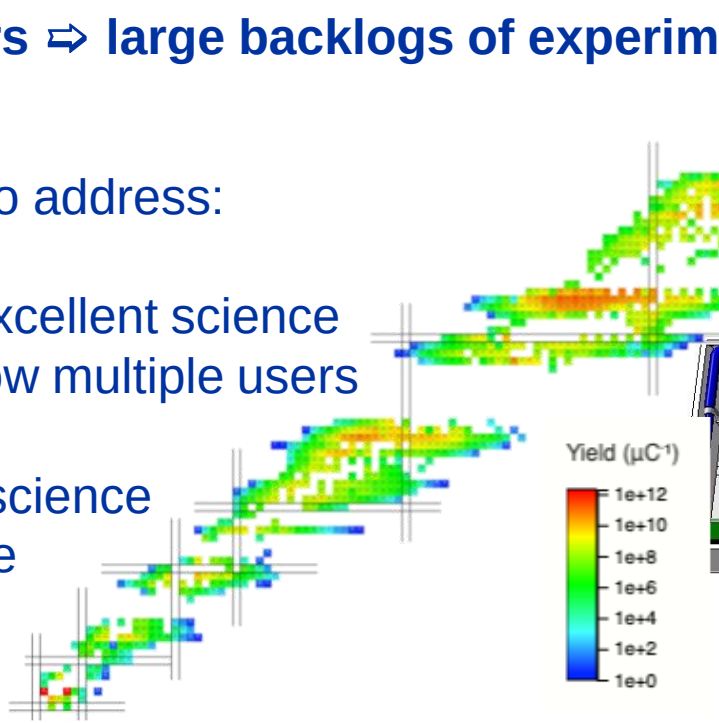
Produced > 1300 isotopes of 75 chemical elements – more than any other RIB facility worldwide.
Isotopes: Predicted ~6000 → Discovered ~3000

Variety of beams ⇔ breadth of science.
Very popular with users ⇨ large backlogs of experiments (Karl's talk).

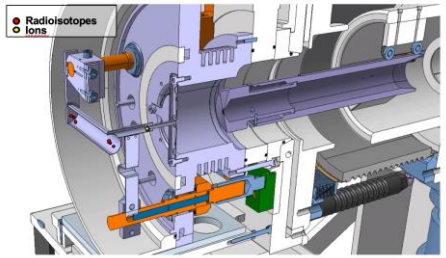
Improvements planned to address:

CAPACITY – do more excellent science
e.g., increase yields, allow multiple users

CAPABILITY – do new science
e.g., deliver more isotope species

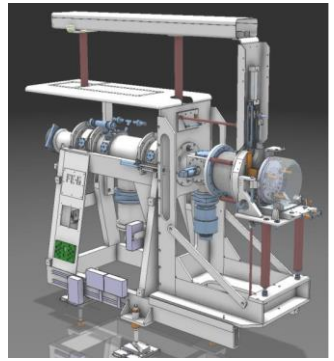


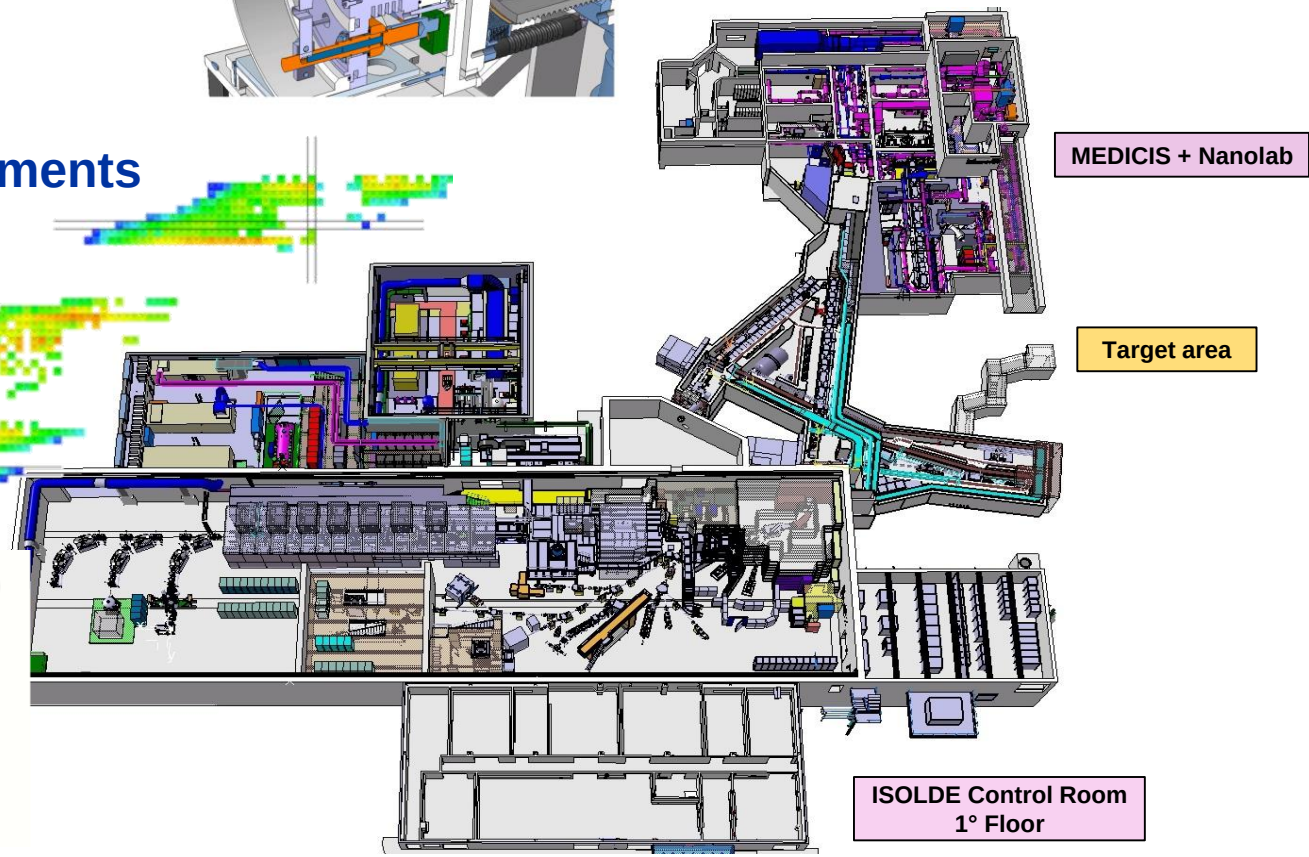
Targets



Front-ends

Class A labs





MEDICIS + Nanolab

Target area

ISOLDE Control Room
1° Floor

Ideas for ISOLDE Consolidation, Upgrades and Expansion

Mid-term goals (2022-LS3)

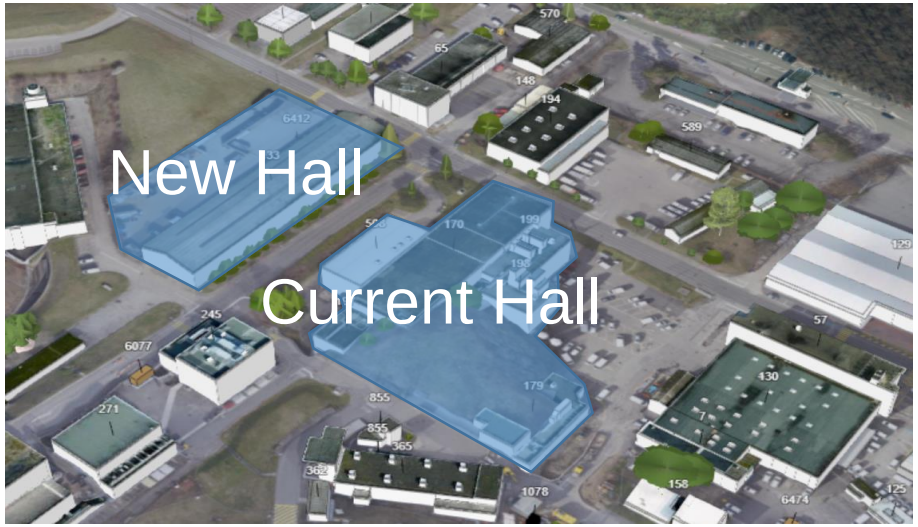
- Nano-material based targets.
- New beam dumps for existing target stations and update to modern radiological standards and to receive higher energy protons at higher intensity.
- Upgrade of BTY transfer line from Booster to ISOLDE to deliver 2-GeV
- Parallel RIB operation.

➔ **Increase RIB beam intensity by factor 1 to 40, with exotic proton-rich nuclides and light fragments benefitting most.**

- **Safety: FIRIA[1] → Upgrade of ventilation and improve fire safety**

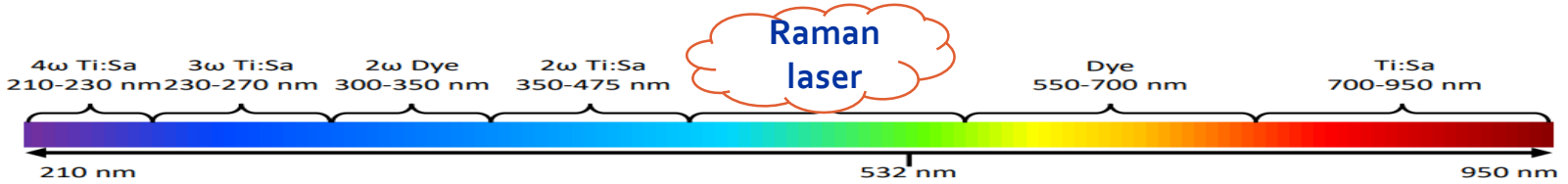
Long-term goals (> LS3): EPIC proposal → More Space (not only…)

- A new ISOLDE building + target stations
- Dedicated space and facilities for new (and existing) low-energy experiments
- Improved beam purity (mass resolution) and quality (time structure)
- Parallel operation with exisiting (HIE-ISOLDE) facility
- Extra-Space for new re-accelerated RIB experiments, including a new compact storage ring

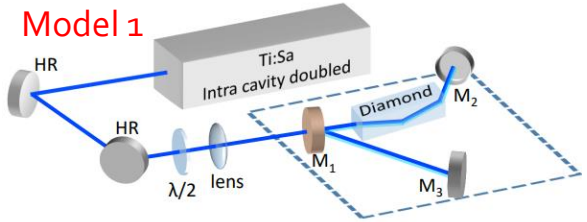


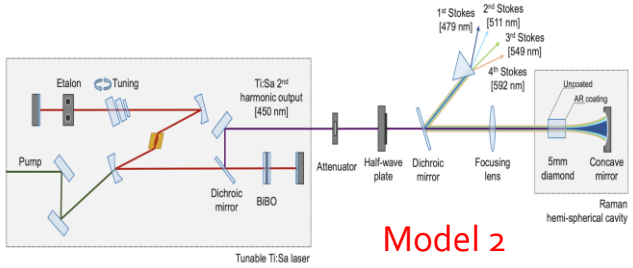
Solid-state Raman lasers for RILIS

Closing the gap between Ti:Sapphire 2nd harmonic and dye laser tuning ban

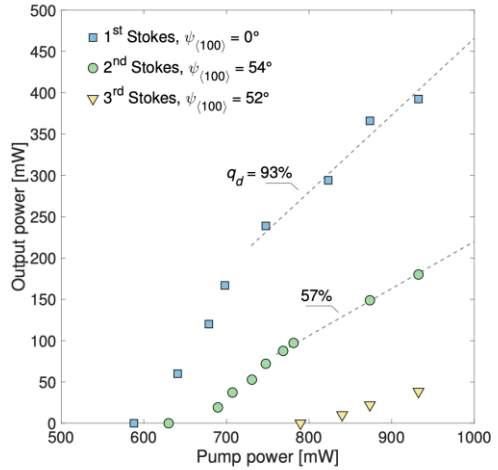


Efficient cascaded broadband diamond Raman laser demonstrated (450-600 nm)

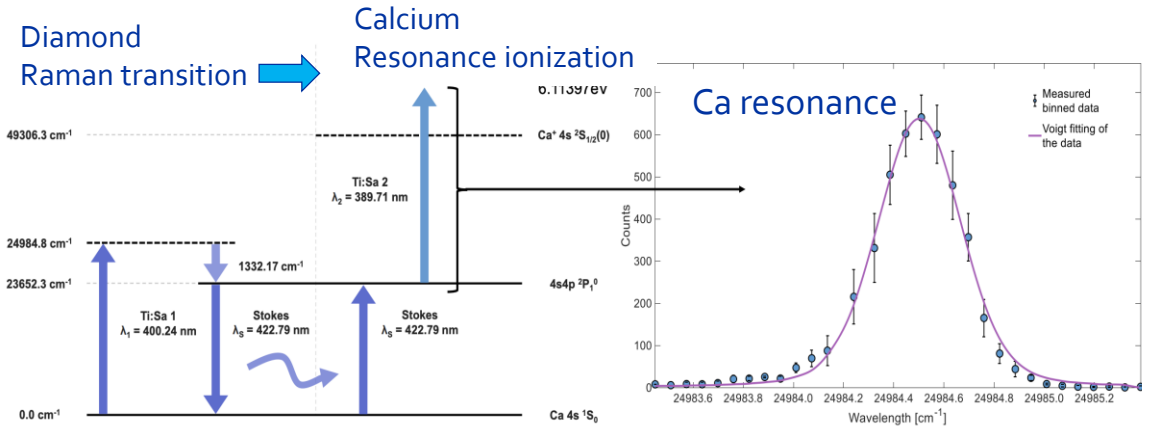


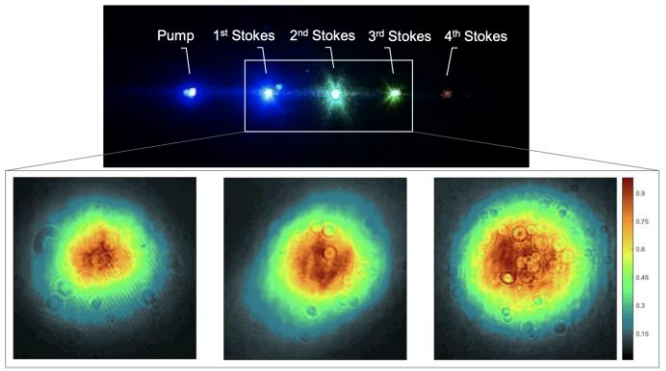


Model 2



- First time spectroscopy using Raman lasers

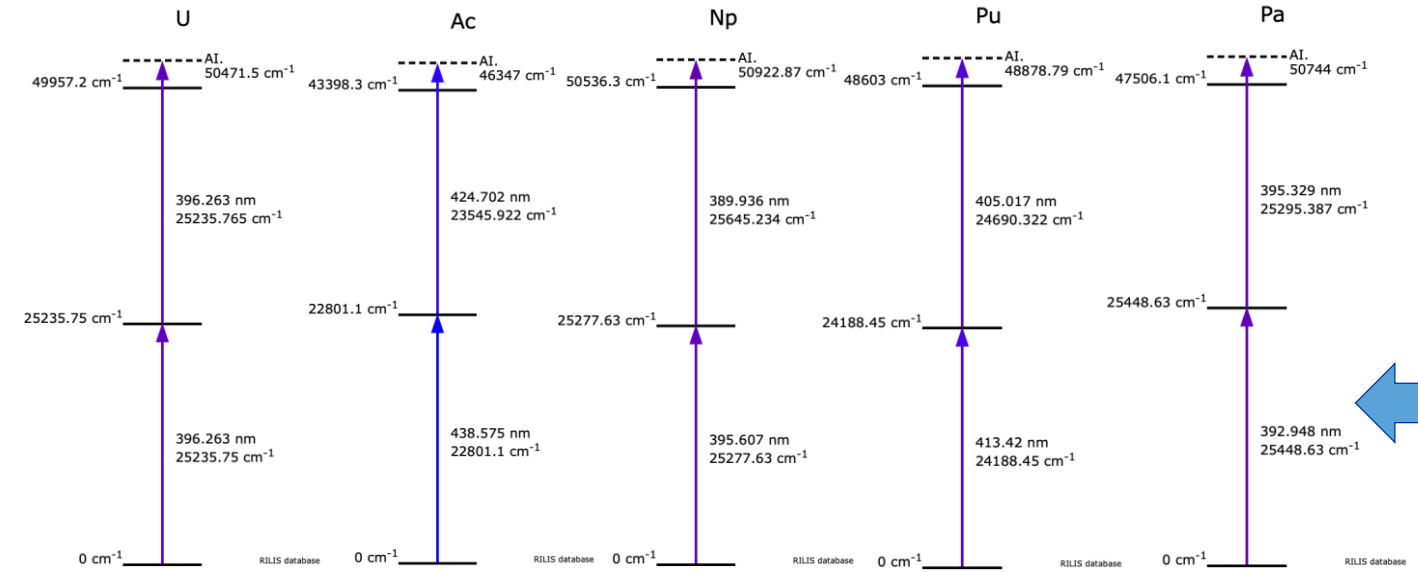




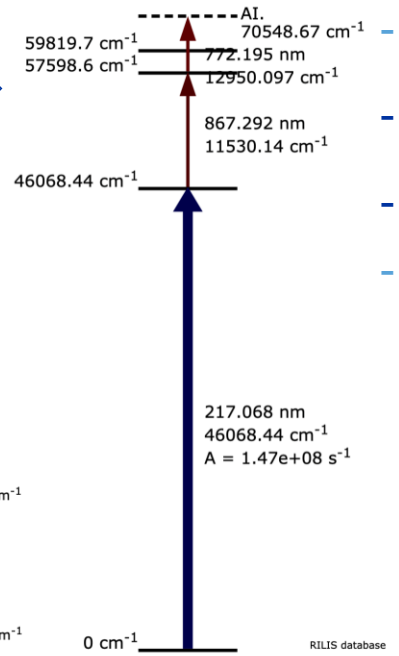
RILIS operation in 2021

→ **21 weeks out of 23 weeks of ISOLDE operations**

- Elements: Ag, Mg, Cu, Ca, In, Au, Ac, Zn, Pb*, Sb, Dy, Sc, Be
- physics runs: 17
- TISD runs*: 4



*Pb



- New Pb laser ionization scheme
- Developed Jan 2021 (Master thesis)
- First used on-line Sep 2021
- **Efficiency enhancement by factor 10**

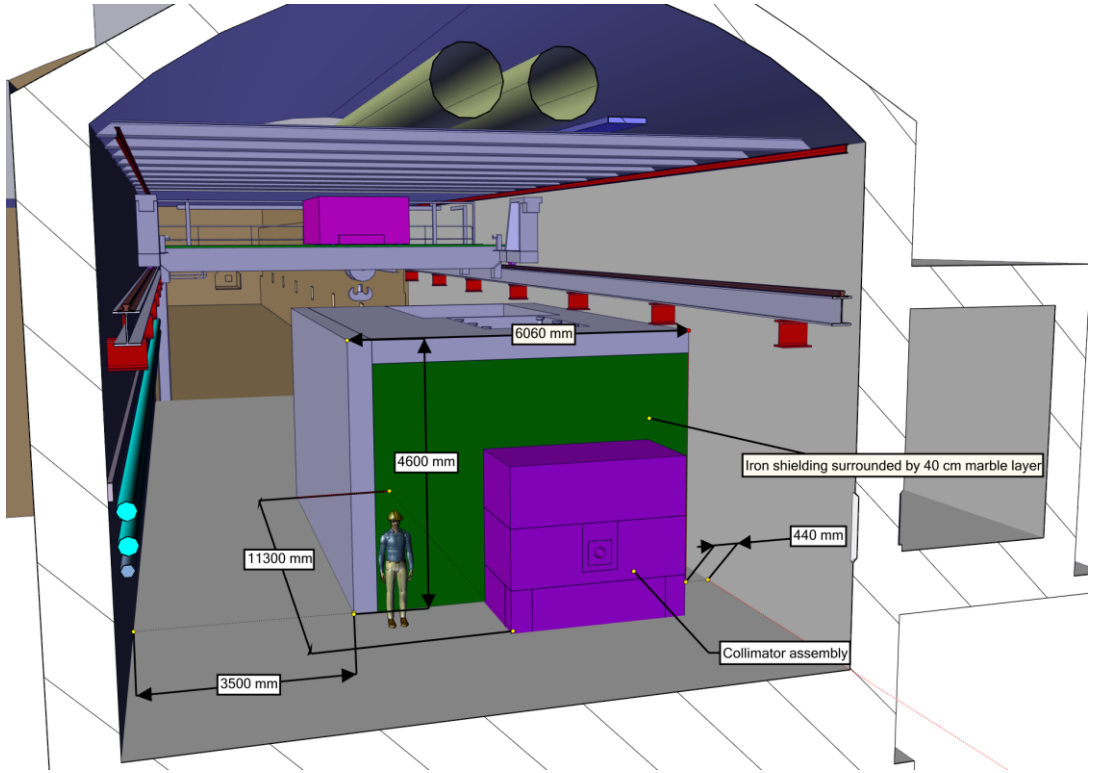
LISA
LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

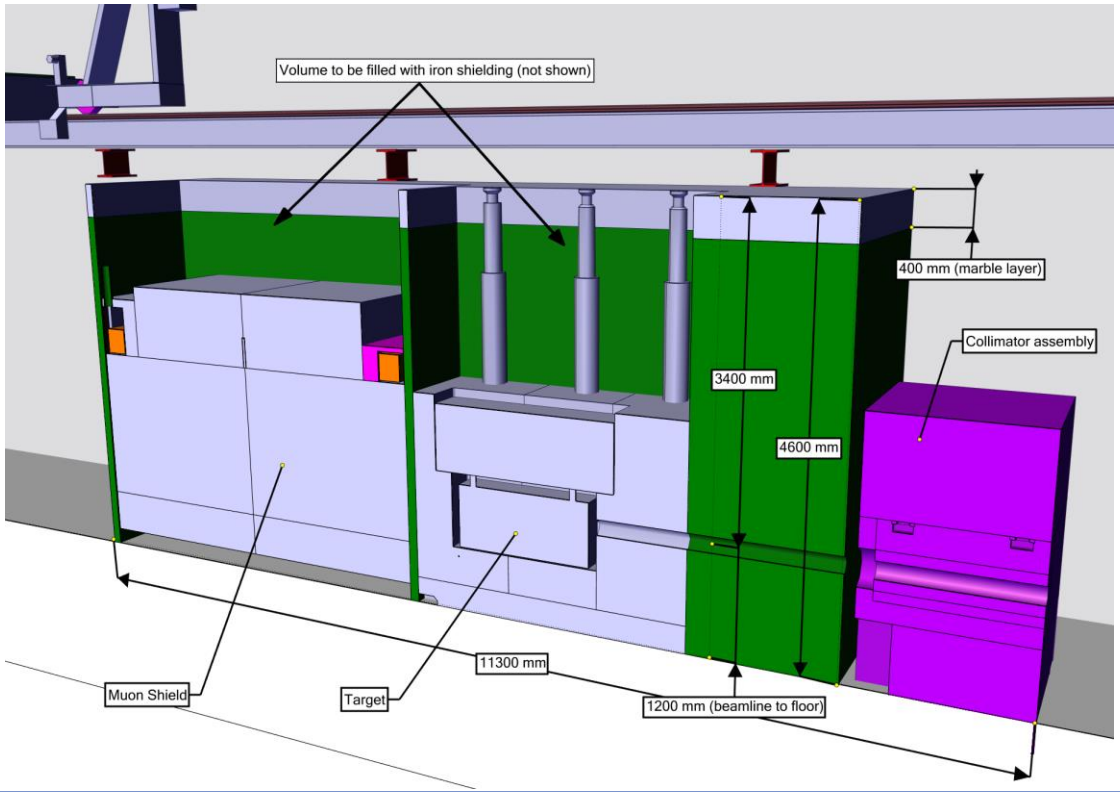
- TISD on Actindes extraction for LISA student projects
- Many actinide schemes tested on-line
- Np, Pu, Ac were seen!
- Additionally molecular extraction tested

Long term future

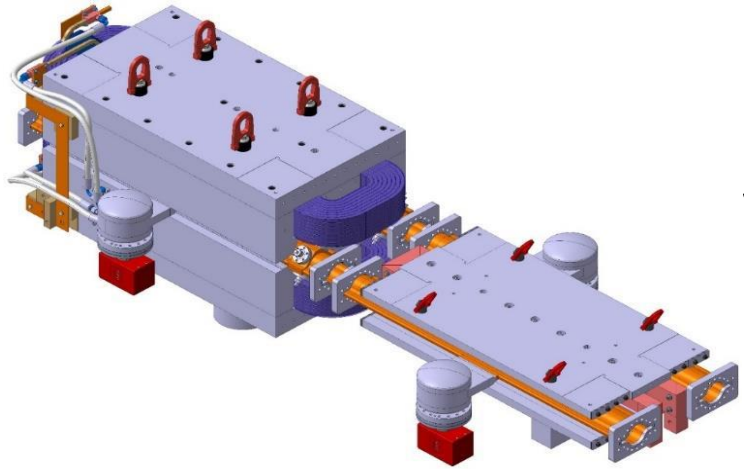
Beam Dump Facility studies
Target complex design

- Material science, target area, telemanipulation, etc..





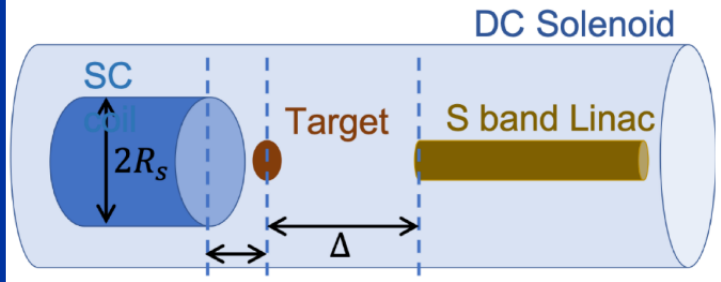
FCC key deliverables: prototypes by 2025



FCC-ee arc half-cell mock up
including girder, vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs, cooling + alignment systems, technical infrastructure interfaces.

400 MHz SRF cryomodule,
with prototypes of multi-cell cavities
High-efficiency RF power sources

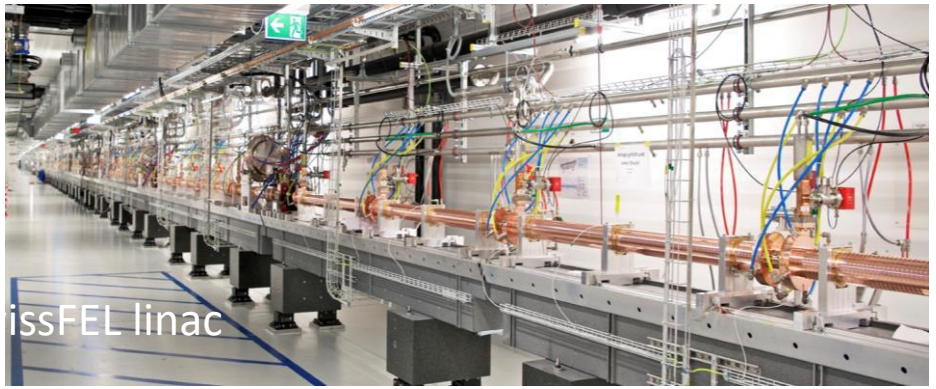
high-yield positron source
target with DC SC solenoid or flux concentrator



positron capture linac
large aperture S-band linac

- Freq : 2.856 GHz
- 90 cells per structure
- Length: 3.254 m
- Distance between two TWs: 45 cm
- Gradient: 20 MV/m
- Aperture: 30 mm

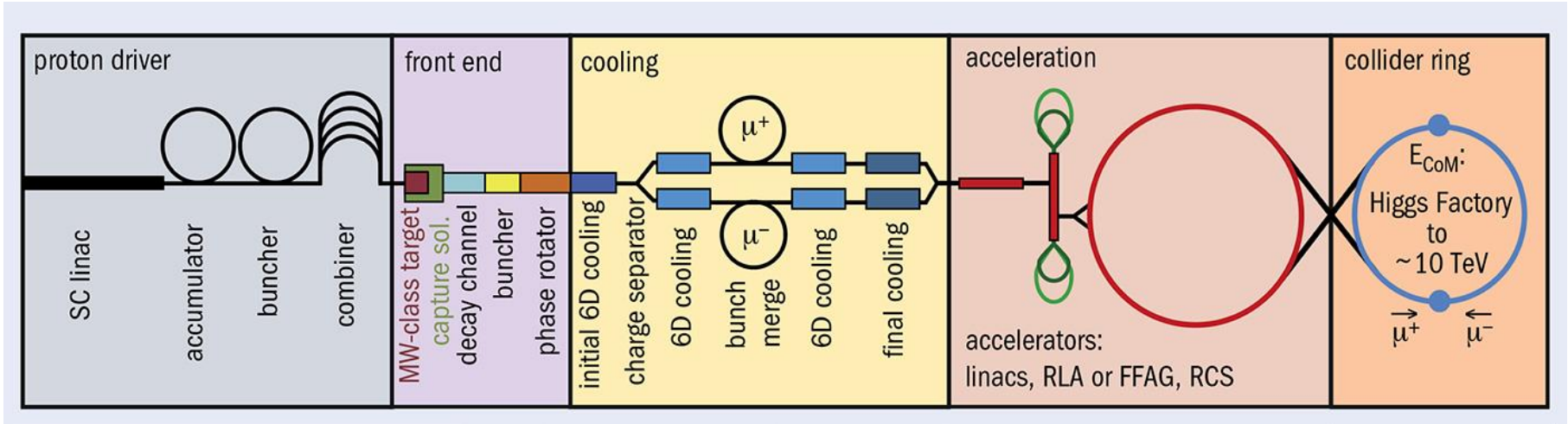
beam test of e^+ source & capture linac at SwissFEL – yield measurement



Muon collider: What could be tested or developed

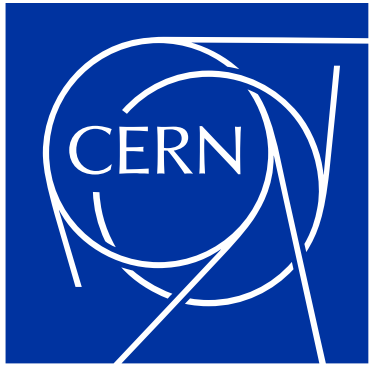
Proton driver
- Single beam impact
- Material damage
- Obs: Linac4 is running

Cooling
- Material testing
- *6D cooling*



Target station – including dump
- Material choices for p production
- Pion production
- Single beam impact
- Material damage

Acceleration
- Material testing (damage)
- Acceleration techniques
- Recombination



home.cern