CERN's Beam Intercepting Devices for Projects and Operation

Antonio Perillo-Marcone

on behalf of EN-STI

CERN | EN ENGINEERING DEPARTMENT

STI Group (Engneering Department)

EN ENGINEERING DEPARTMENT

STI - Sources, Targets & Interaction

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- O. Aberle
- S. De Man
- D. Grenier
- E. Grenier-Boley
- K. Kershaw
- I. Lamas Garcia
- F. Nuiry
- A. Perillo Marcone
- R. Seidenbinder

EN-STI-TCD Mandate

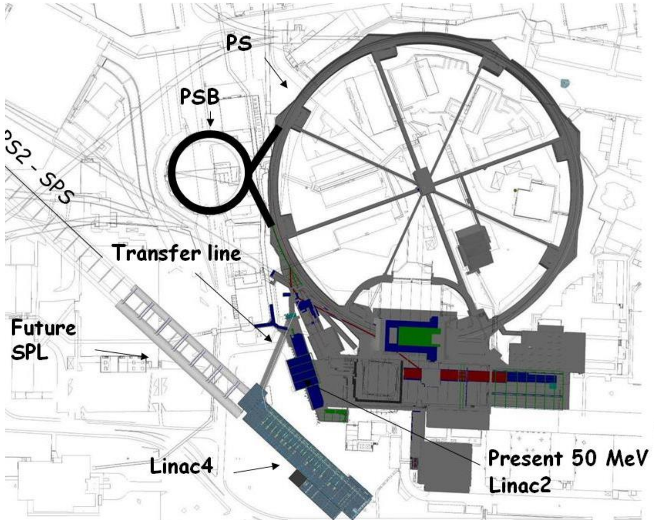
- Responsible for all beam-intercepting devices (BIDs)
- Conceptual studies, manufacturing, installation and maintenance of mechanical systems of BIDs
  - Thermo-mechanical studies of all BIDs
  - R&D activities
  - Continuous development of expertise in materials under extreme operation and mixed field irradiation
- Technical coordination and supervision of n_TOF and AD target areas
- Design, testing and operation of focusing magnetic horns
- Remote handling compliant design of BIDs

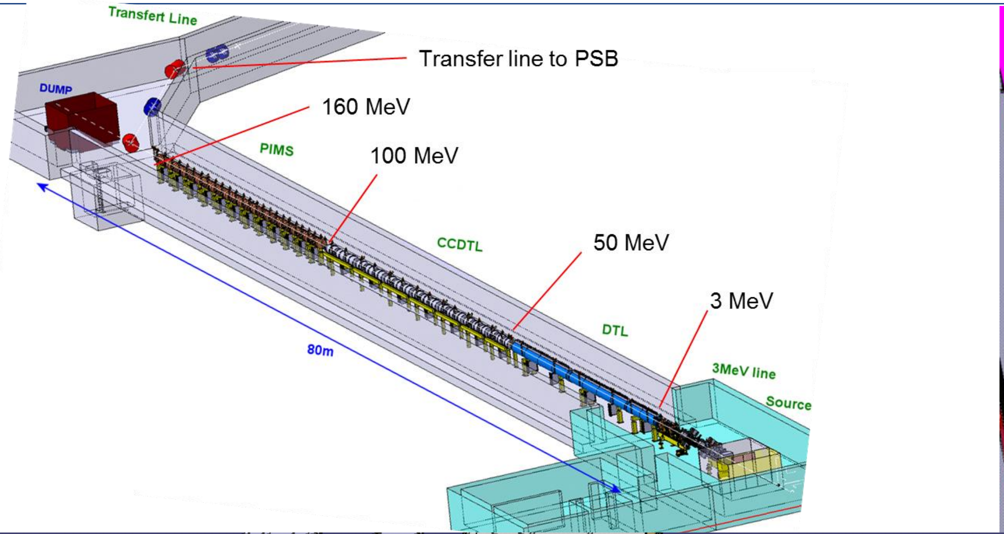
Beam Intercepting Devices

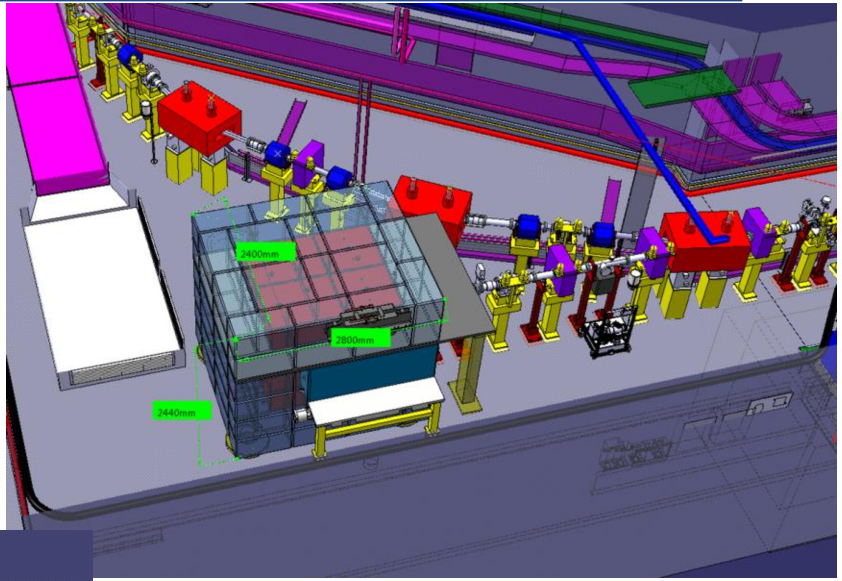
Safety function	Beam cleaning & control	Physics
Beam stoppers	Collimators	**Particle producing targets**
Beam dumps	Scrapers	
	Strippers	
	Slits	

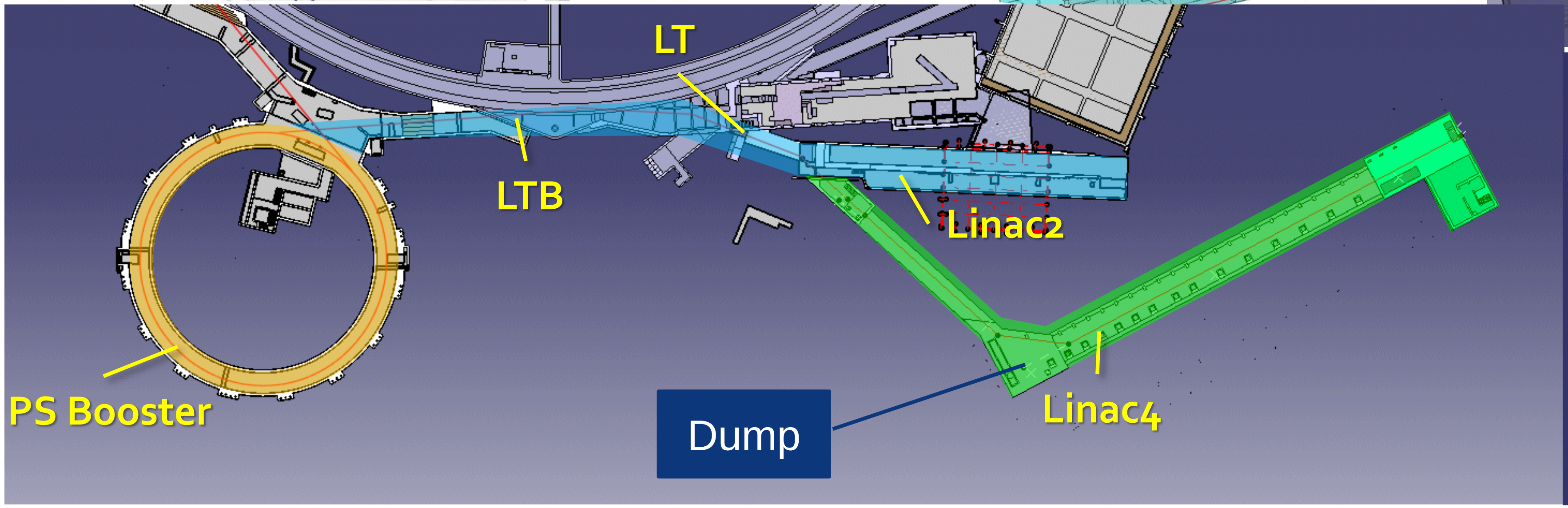
Linac 4 Dump

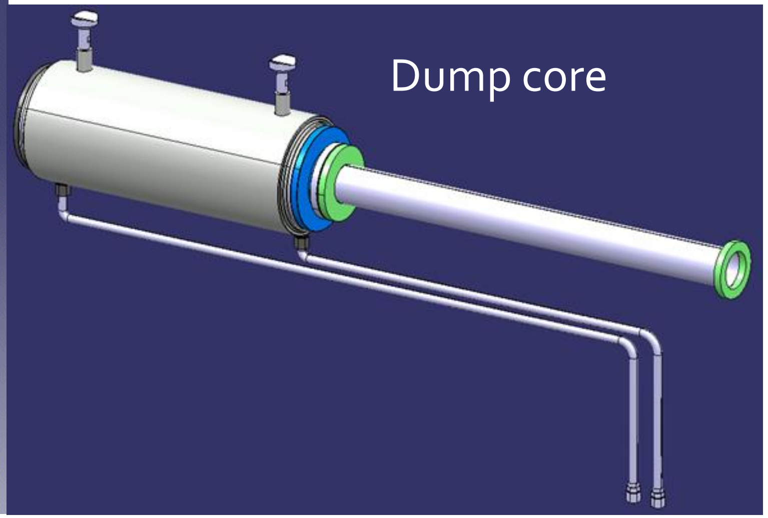
C. Maglioni
D. Grenier



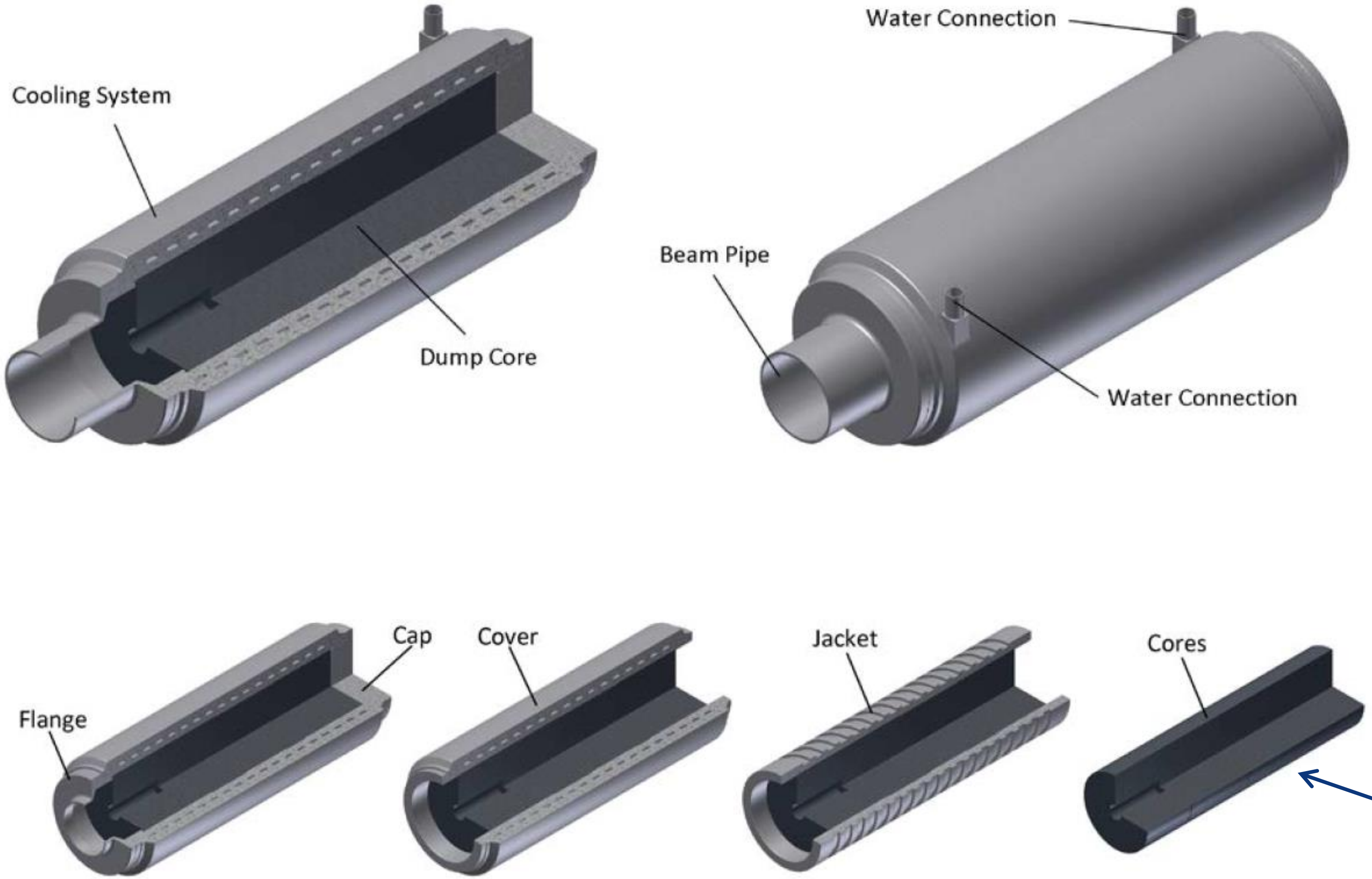


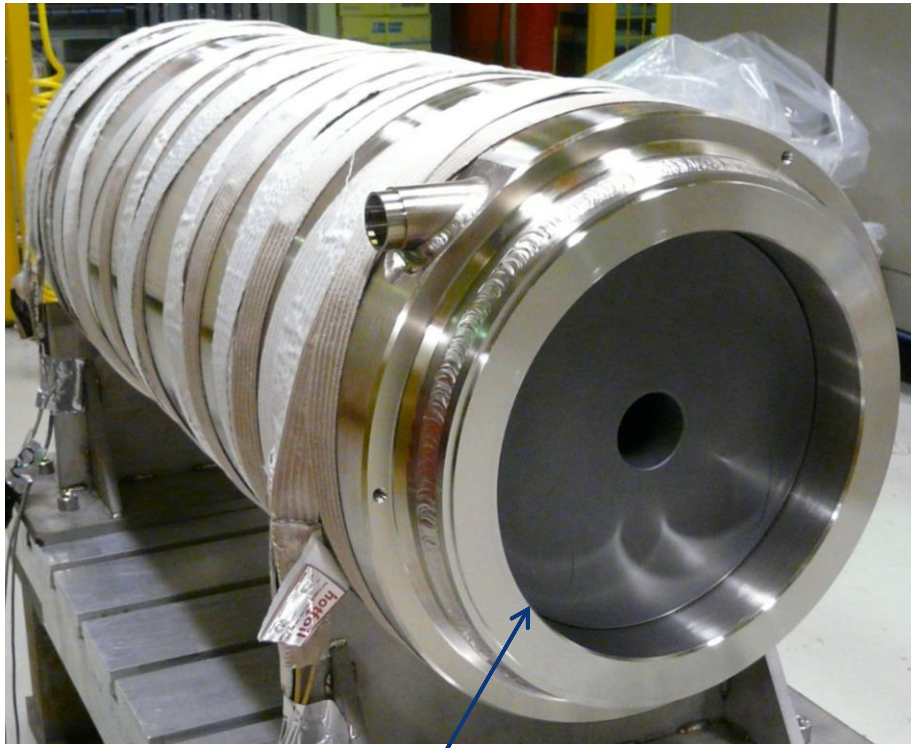






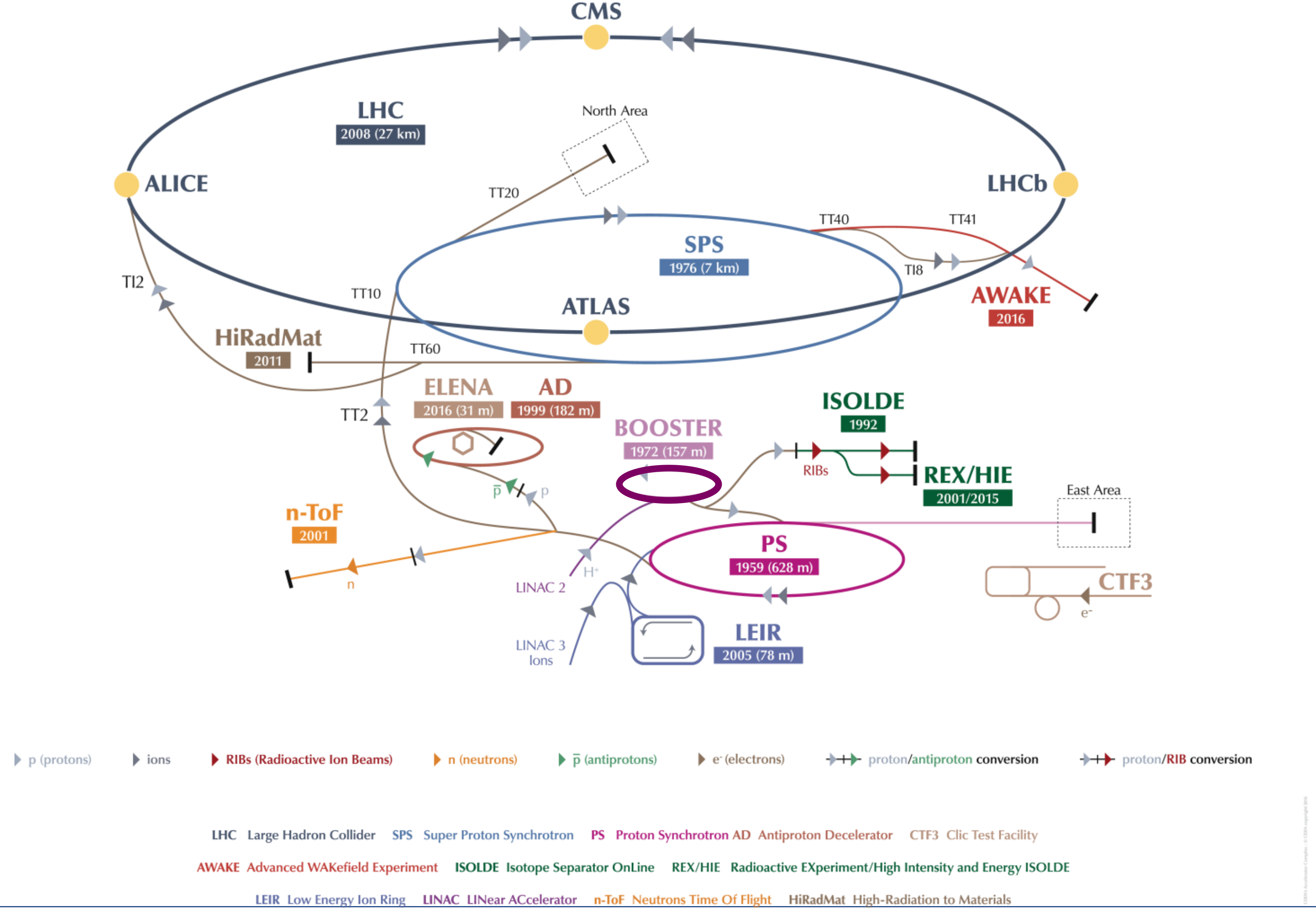
Linac 4 Dump Core





ϕ 217 mm

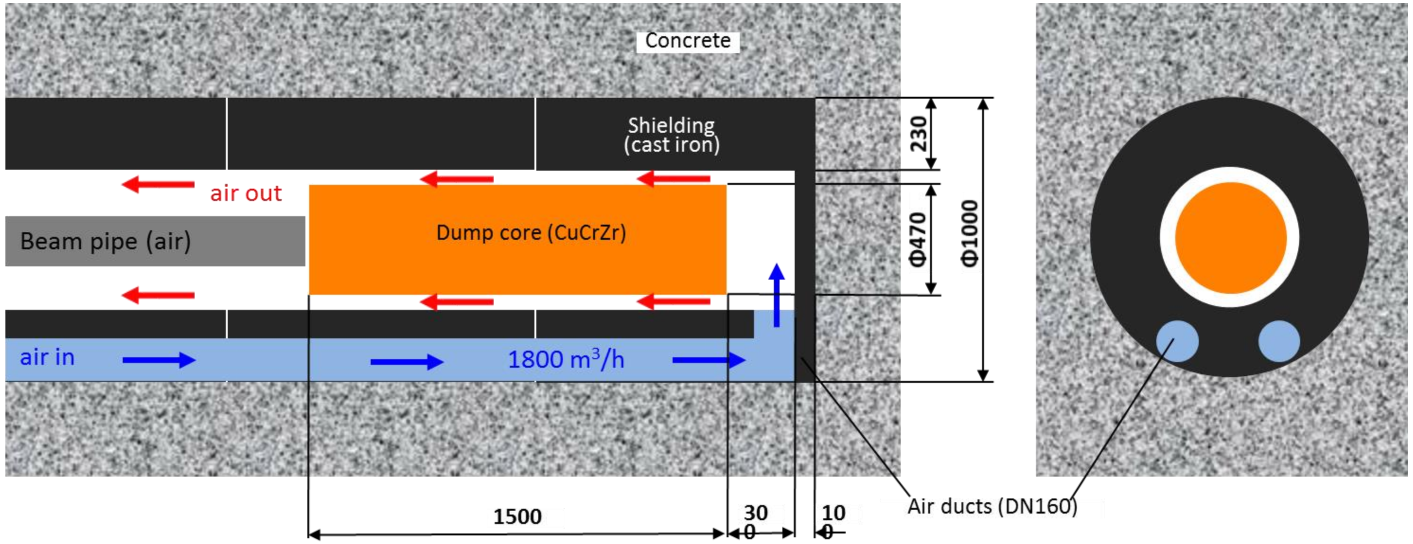
PS Booster Devices

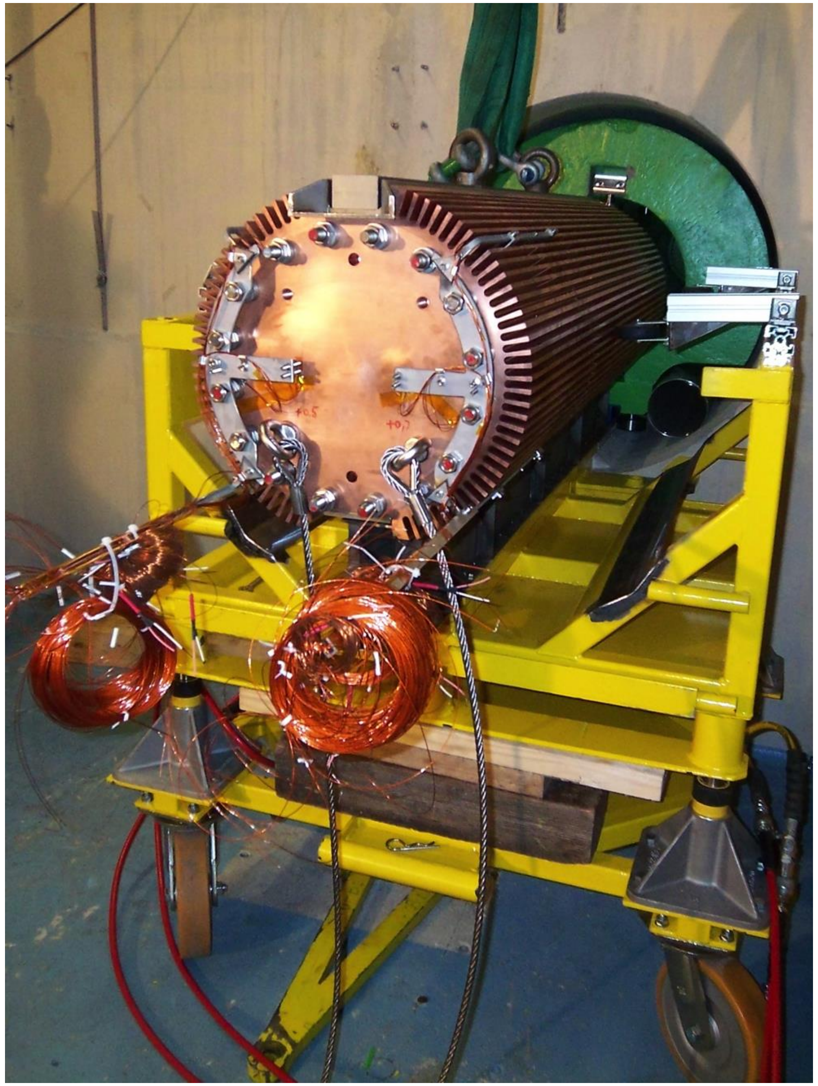


PSB Dump

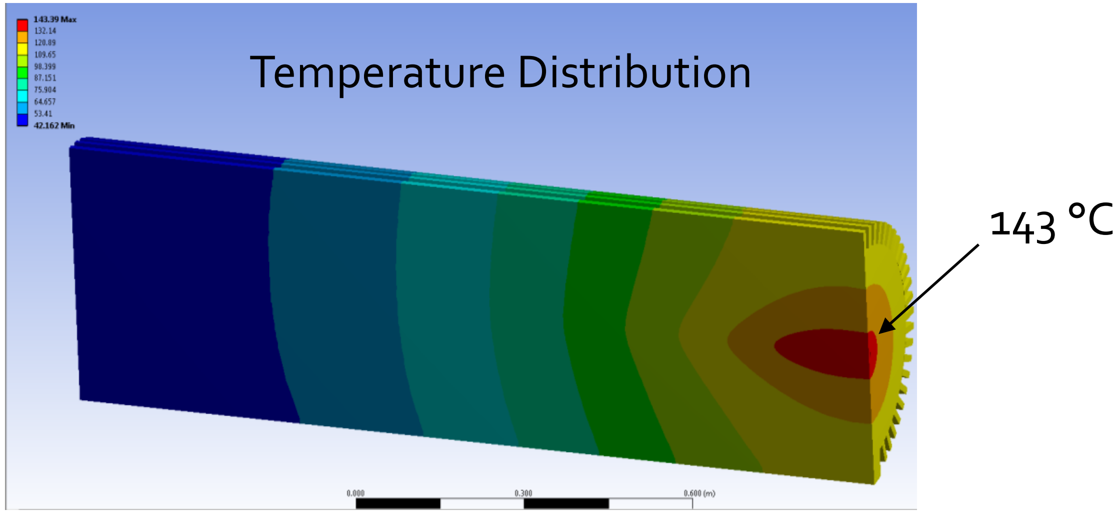
Managed by
A. Perillo-Marcone

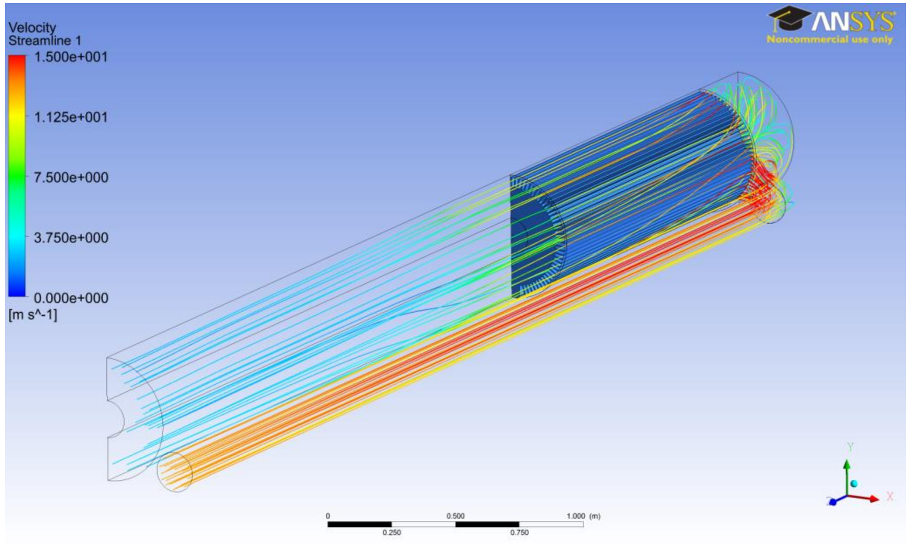
- **Design parameters:**
  - Max beam intensity: 1E14 p+/pulse
  - Beam energy: 2 GeV
  - Pulse period: 1.2 s
  - Max. Average power to dump : 9.44 kW

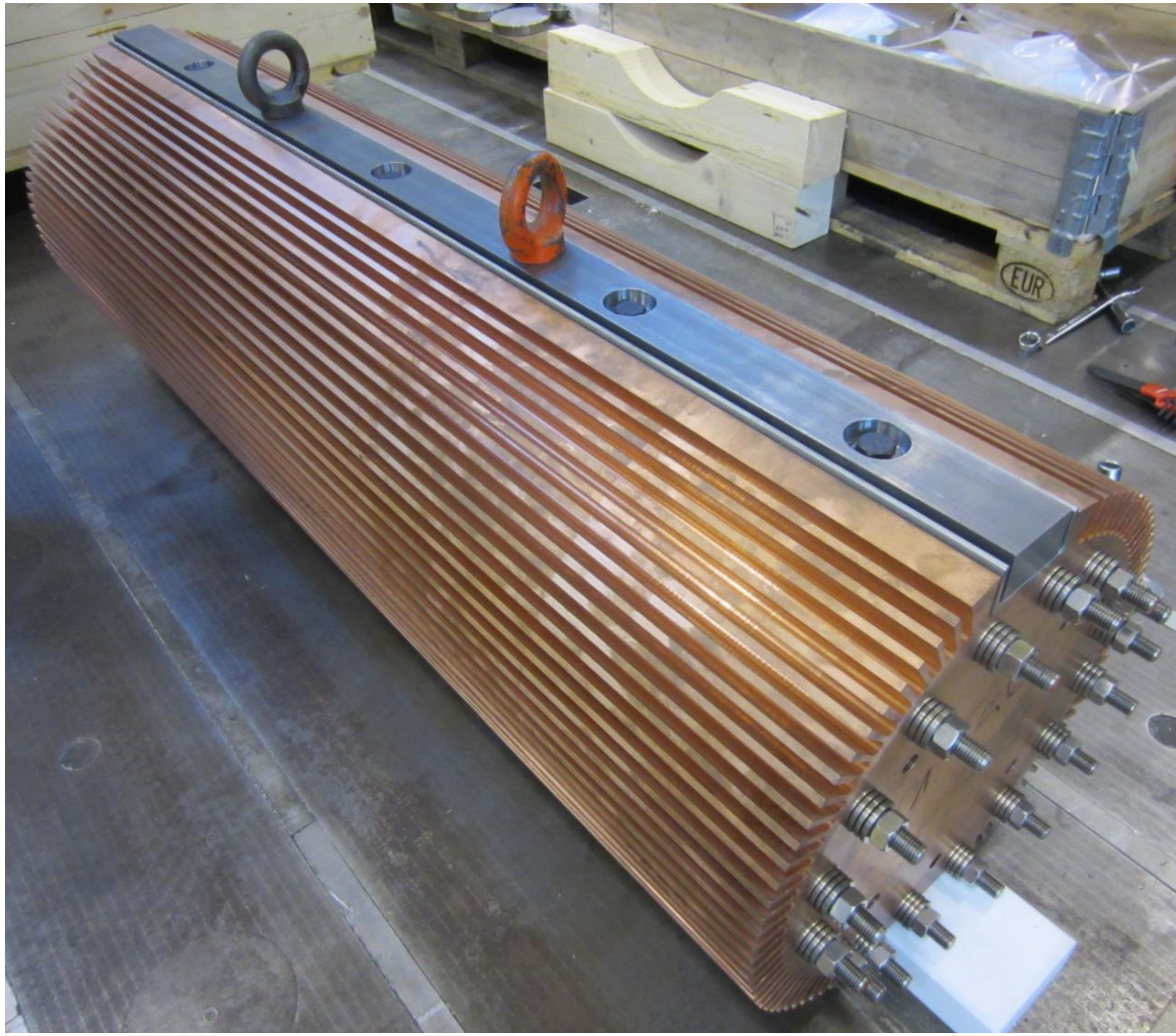




PSB Dump Core

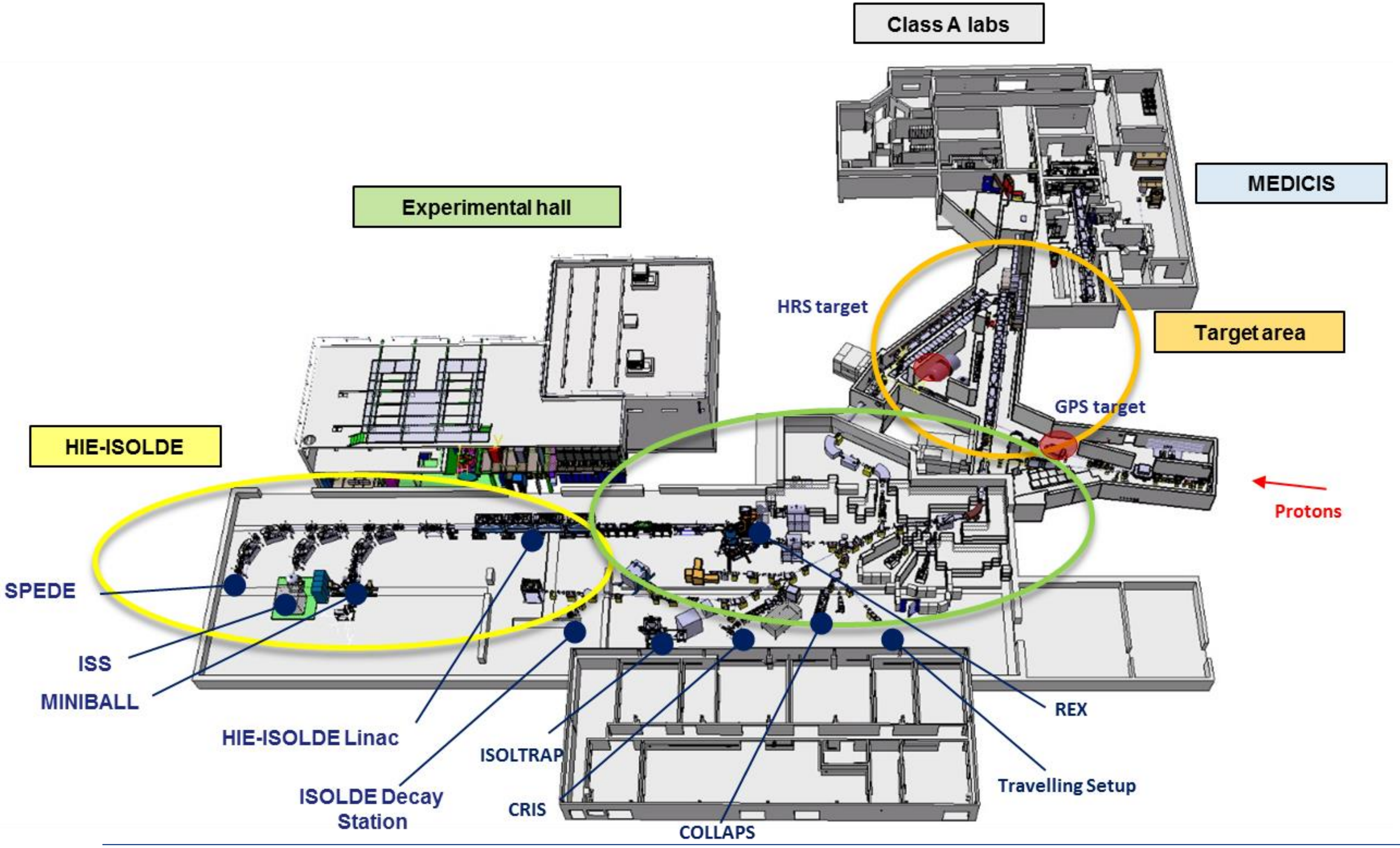






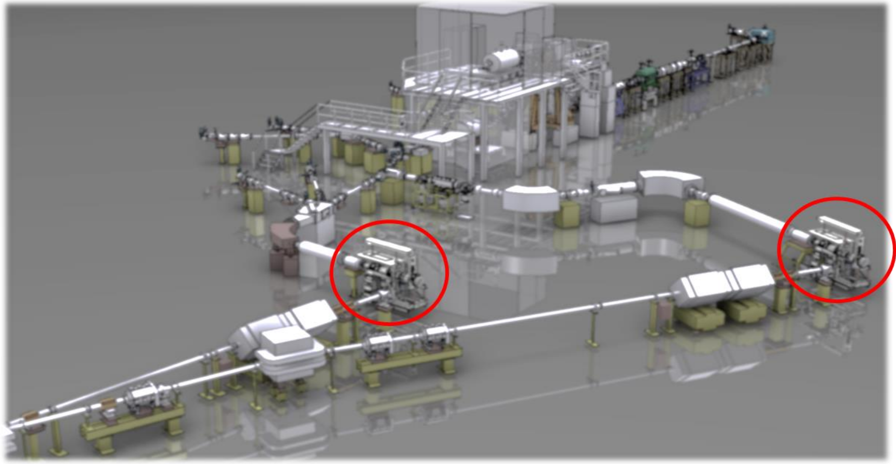
ISOLDE: a radioisotope factory

Managed by
R. Catherall



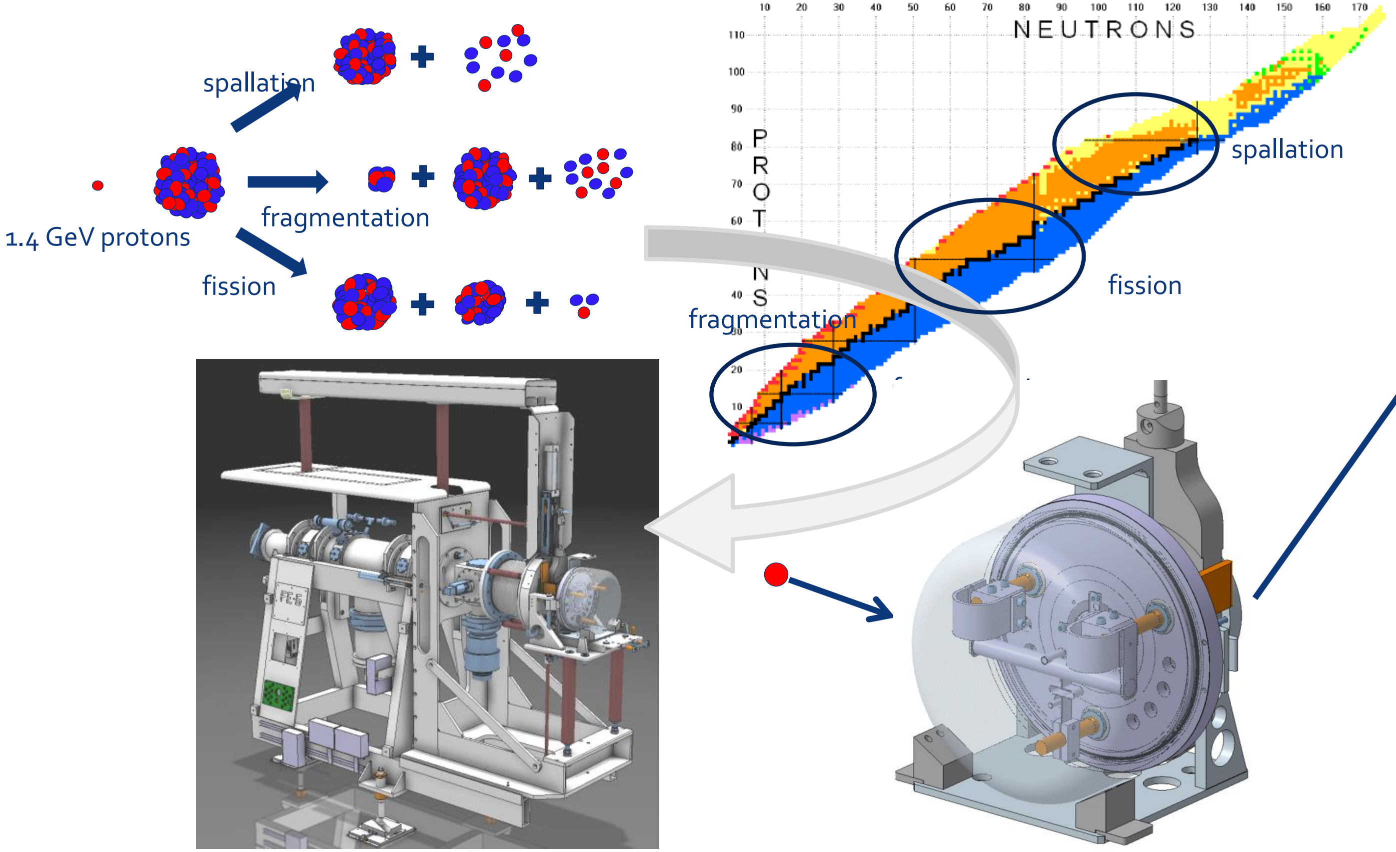
Two target stations operating alternatively

- General Purpose Separator (GPS) and High Resolution Separator (HRS)
- Nearly 1300 isotopes/isomers available from 73 chemical elements at 60 keV ➔ **largest choice for any ISOL facility in the world**
- **Over 1300 users**



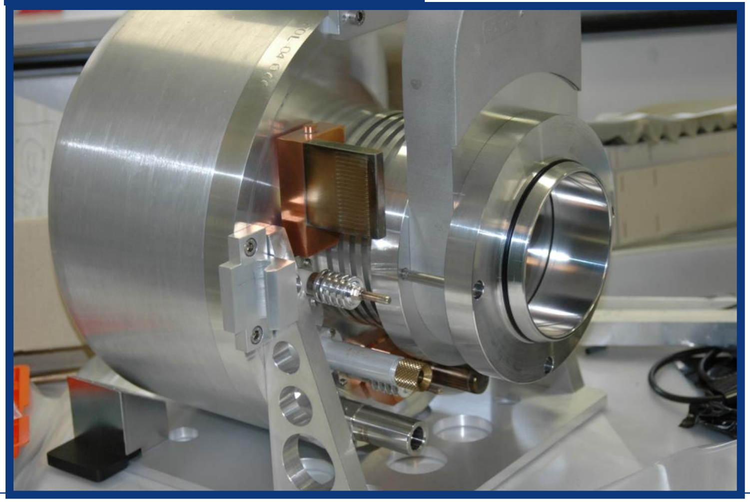
The ISOL* production method

* Isotope separation on-line



Front End (target station)

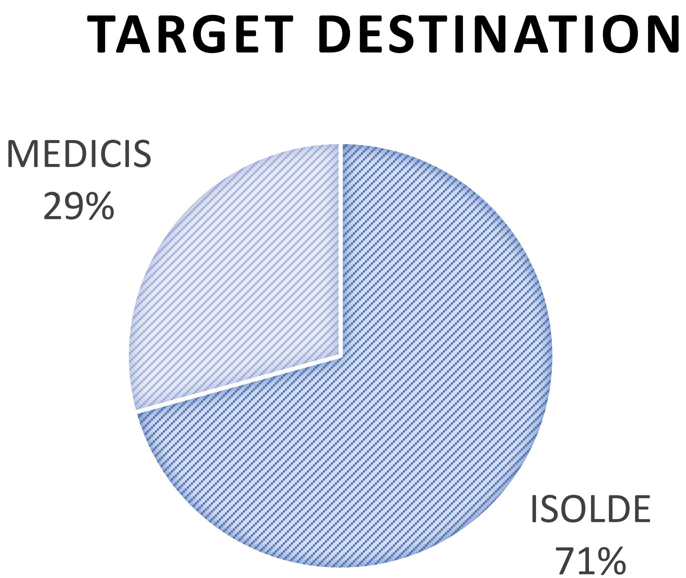
Target Unit

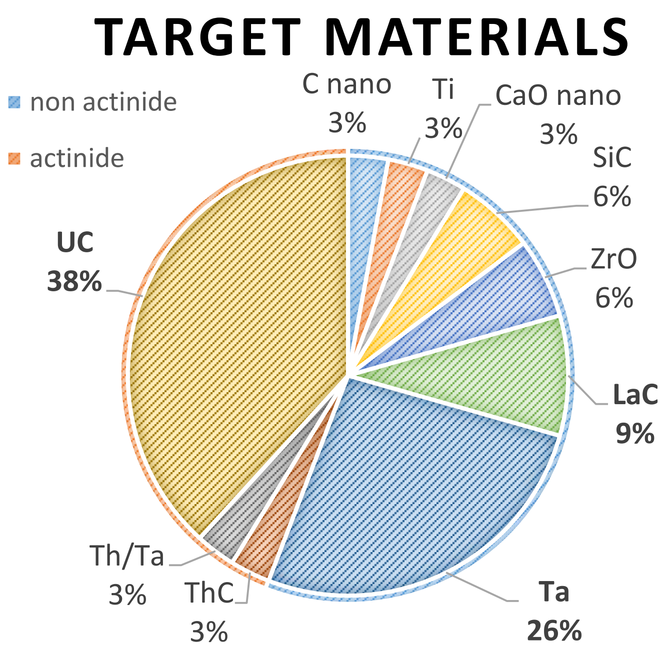


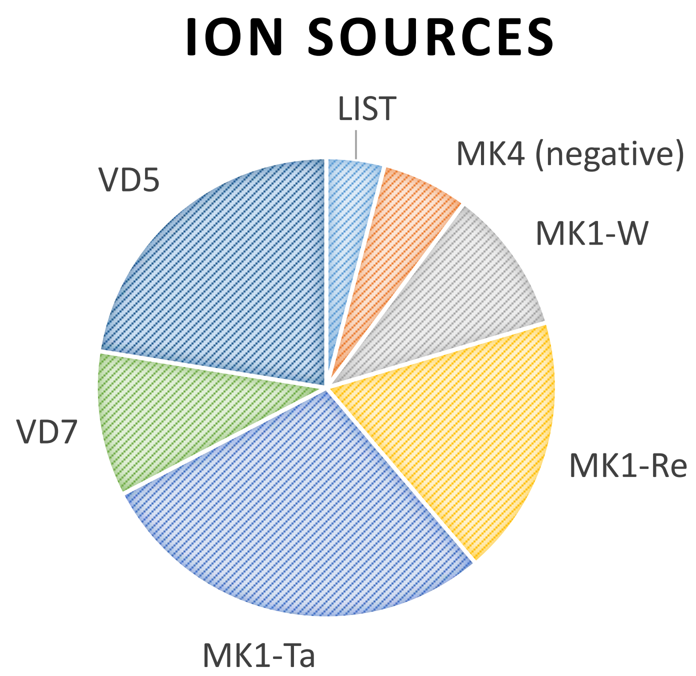
Target unit pumped to ~**10^{-6}mbar** and

Target material heated up to **2000˚C** for the release of radio-isotopes

ISOLDE Target Production 2018







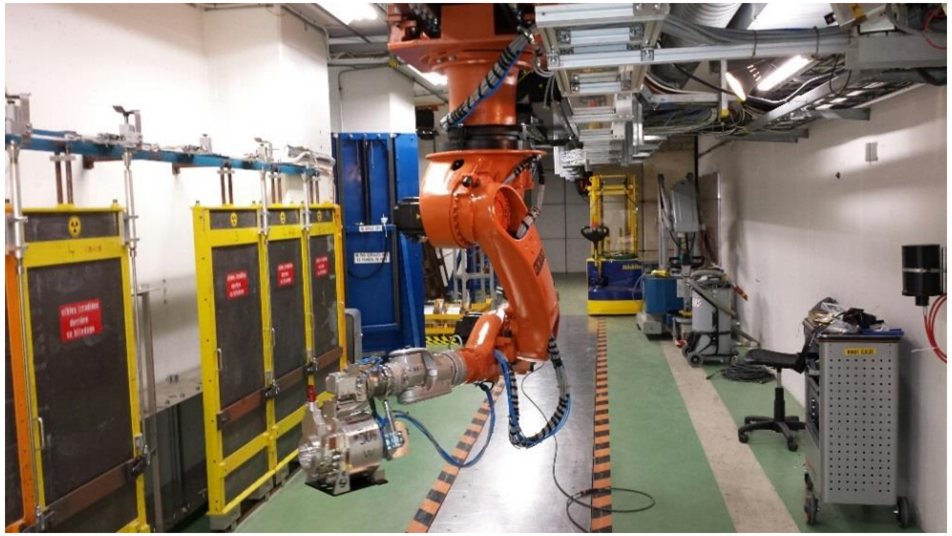
Total targets assembled end of 2018 : **49**

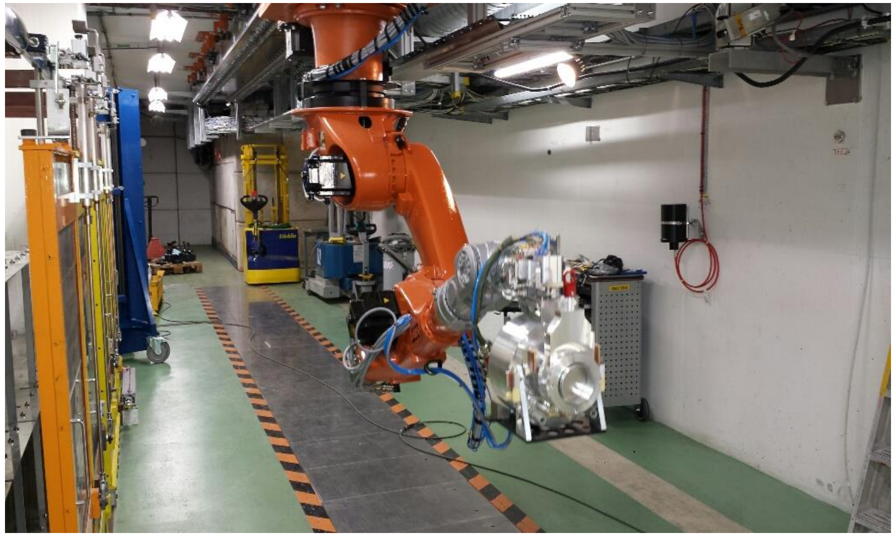
- Delivered to ISOLDE: **29**
- Delivered to MEDICIS: **10** + 2 in December
- Used for development: **8** (16%)

- **10 different materials**
- Mostly carbides and metal foils
- Most popular: **uranium carbide**

- ***7 different ion sources***
- LIST and negative ion source back in action

Target Handling with Robots

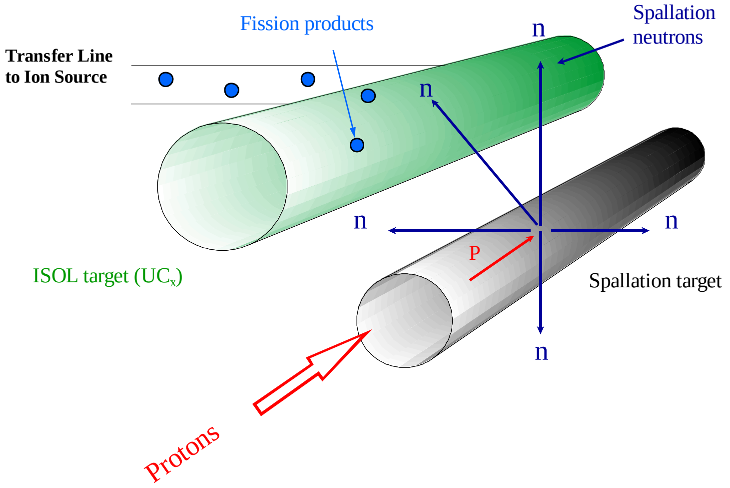


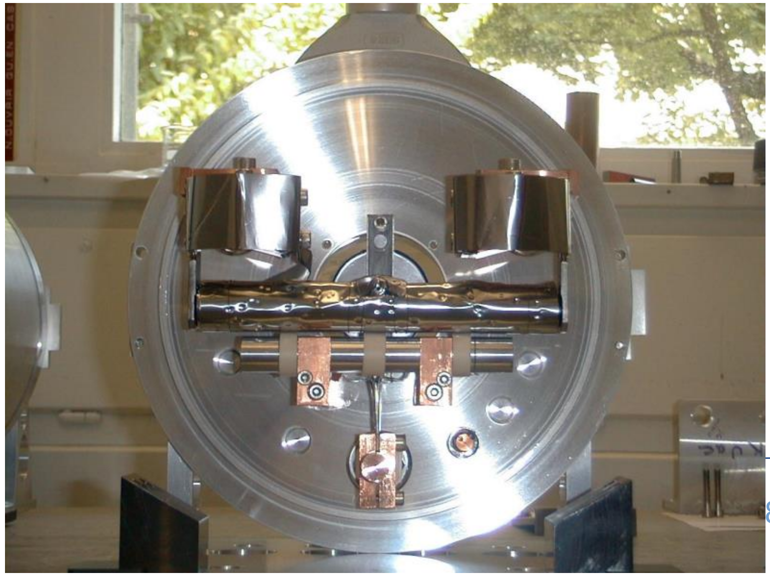


Several Different Targets

Neutron induced fission from actinide targets

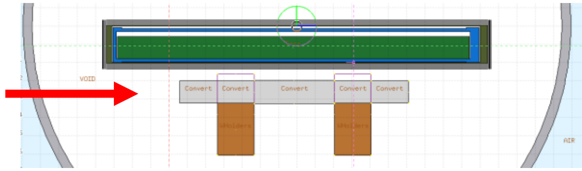
Actual Target Converter Assembly at ISOLDE



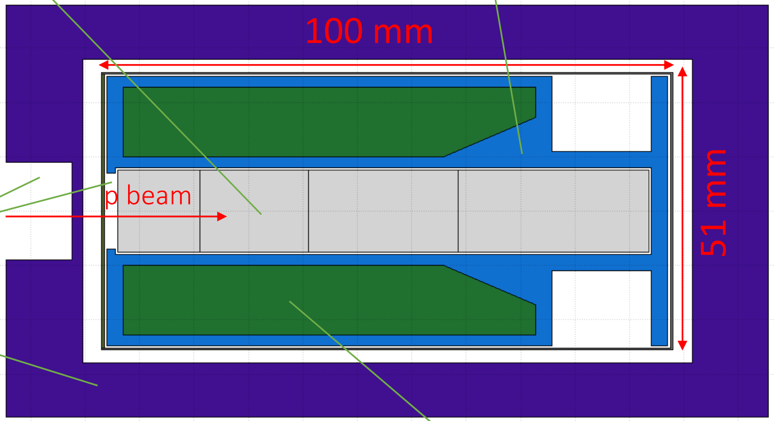


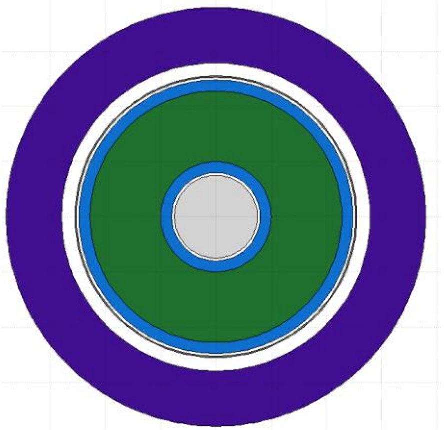
P2n Converter

Converter very close to uranium carbide – high neutron flux!



Graphite container



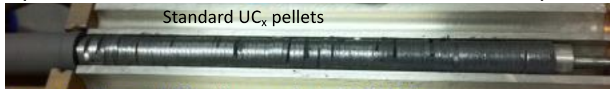


Avoid proton scattering

Thermal Shielding

- Sigratherm® - “graphite foam”
- 0.2 g/cm^3
- Low thermal conductivity

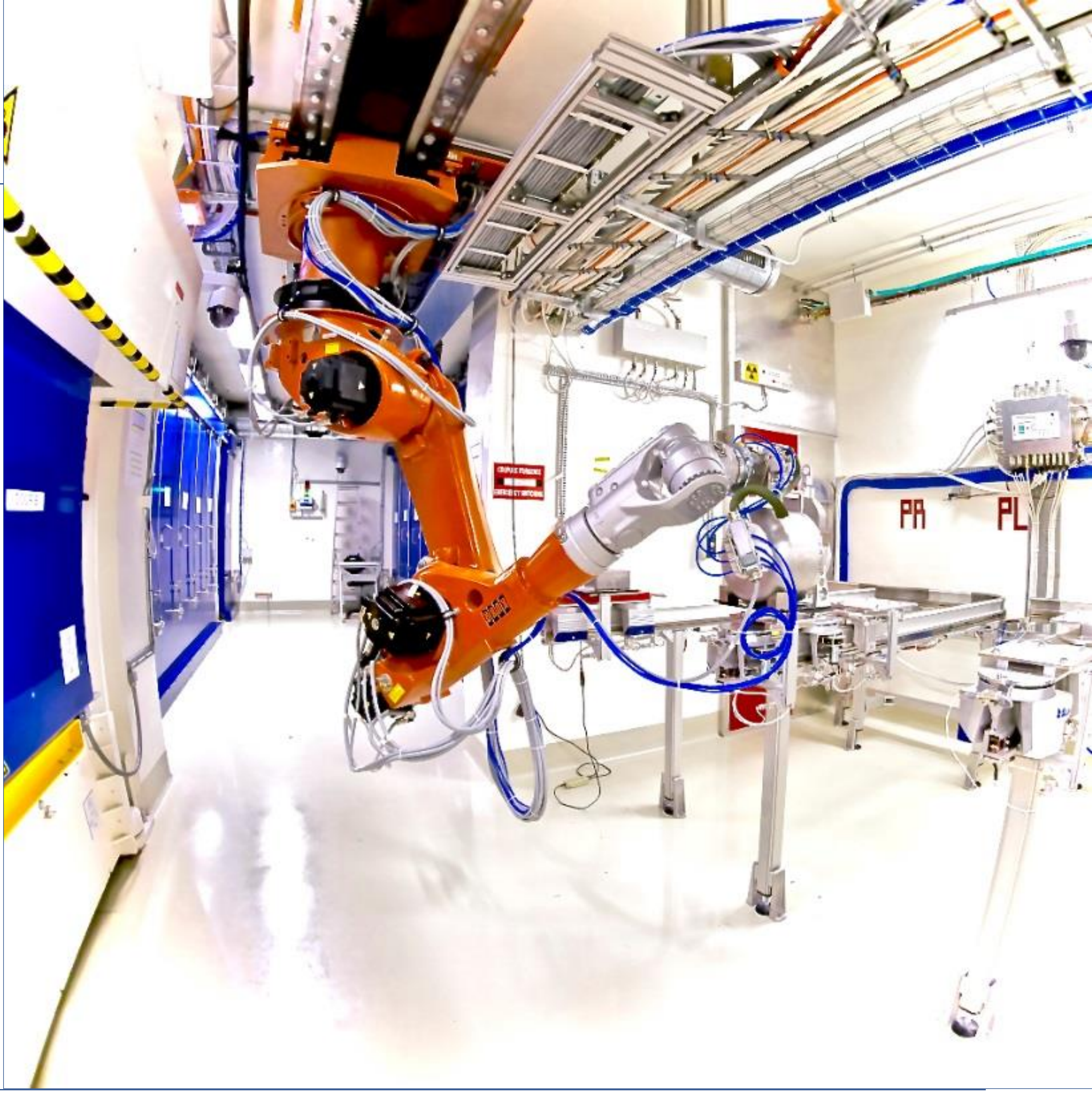
UC_x: new procedure has to be made for annular shape



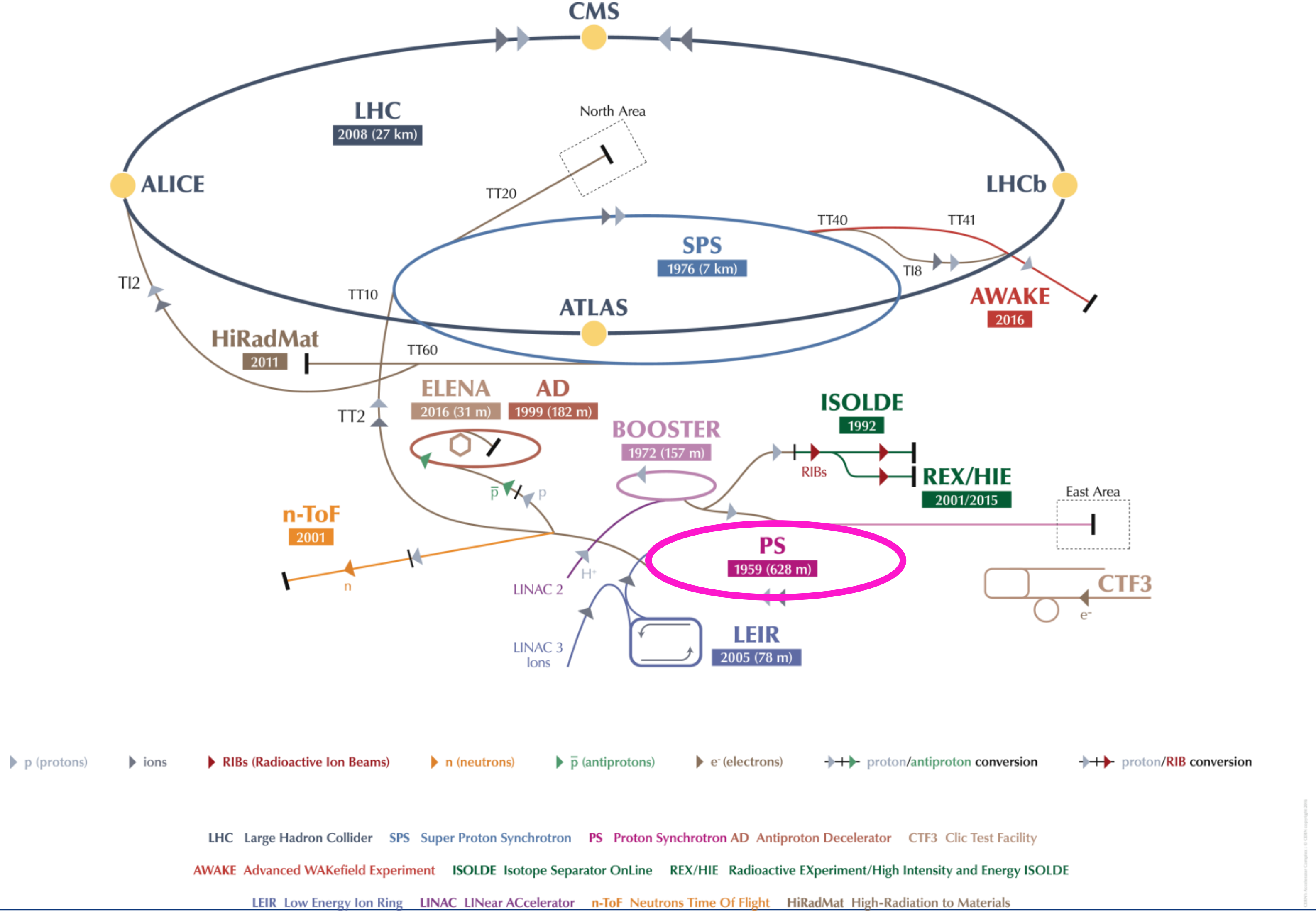
CERN – MEDICIS

Non-conventional radioisotopes
for medical research*

*La plateforme de recherche
biomédicale CERN-MEDICIS



PS Devices

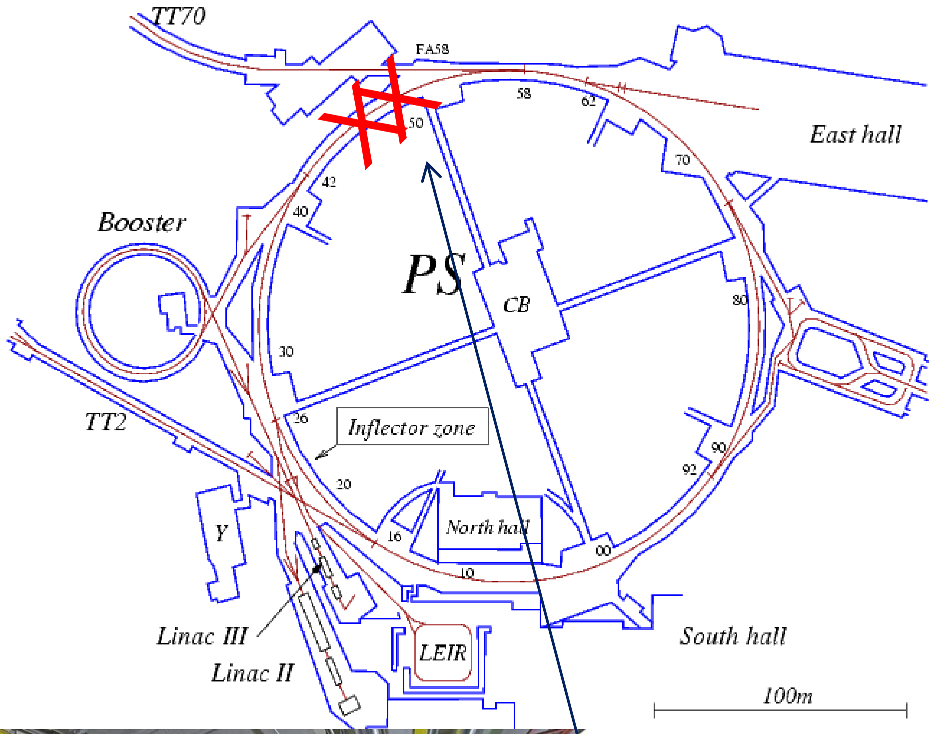


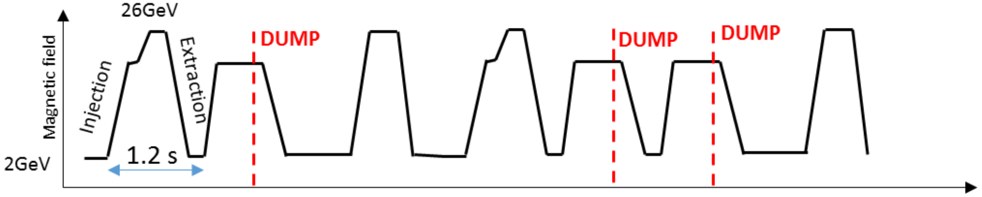
CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT20
TT40
TT41
SPS
1976 (7 km)
TI8
TI2
TT10
ATLAS
AWAKE
2016
HiRadMat
2011
TT60
ELENA
2016 (31 m)
AD
1999 (182 m)
TT2
ISOLDE
1992
BOOSTER
1972 (157 m)
RIBs
REX/HIE
2001/2015
East Area
p̄
p
n-ToF
2001
PS
1959 (628 m)
n
H⁺
LINAC 2
CTF3
e⁻
LINAC 3
Ions
LEIR
2005 (78 m)
p (protons)
ions
RIBs (Radioactive Ion Beams)
n (neutrons)
p̄ (antiprotons)
e⁻ (electrons)
proton/antiproton conversion
proton/RIB conversion
LHC Large Hadron Collider
SPS Super Proton Synchrotron
PS Proton Synchrotron
AD Antiproton Decelerator
CTF3 Clic Test Facility
AWAKE Advanced WAKefield Experiment
ISOLDE Isotope Separator OnLine
REX/HIE Radioactive EXperiment/High Intensity and Energy ISOLDE
LEIR Low Energy Ion Ring
LINAC LINear ACcelerator
n-ToF Neutrons Time Of Flight
HiRadMat High-Radiation to Materials

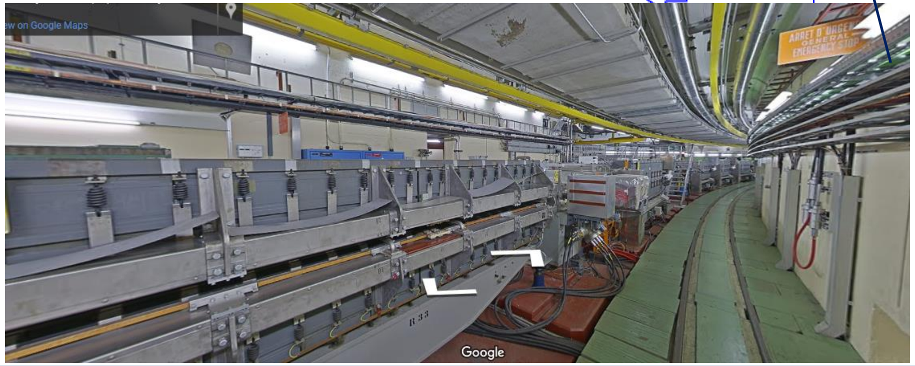
PS Internal Dump

Managed by F.X. Nuiry

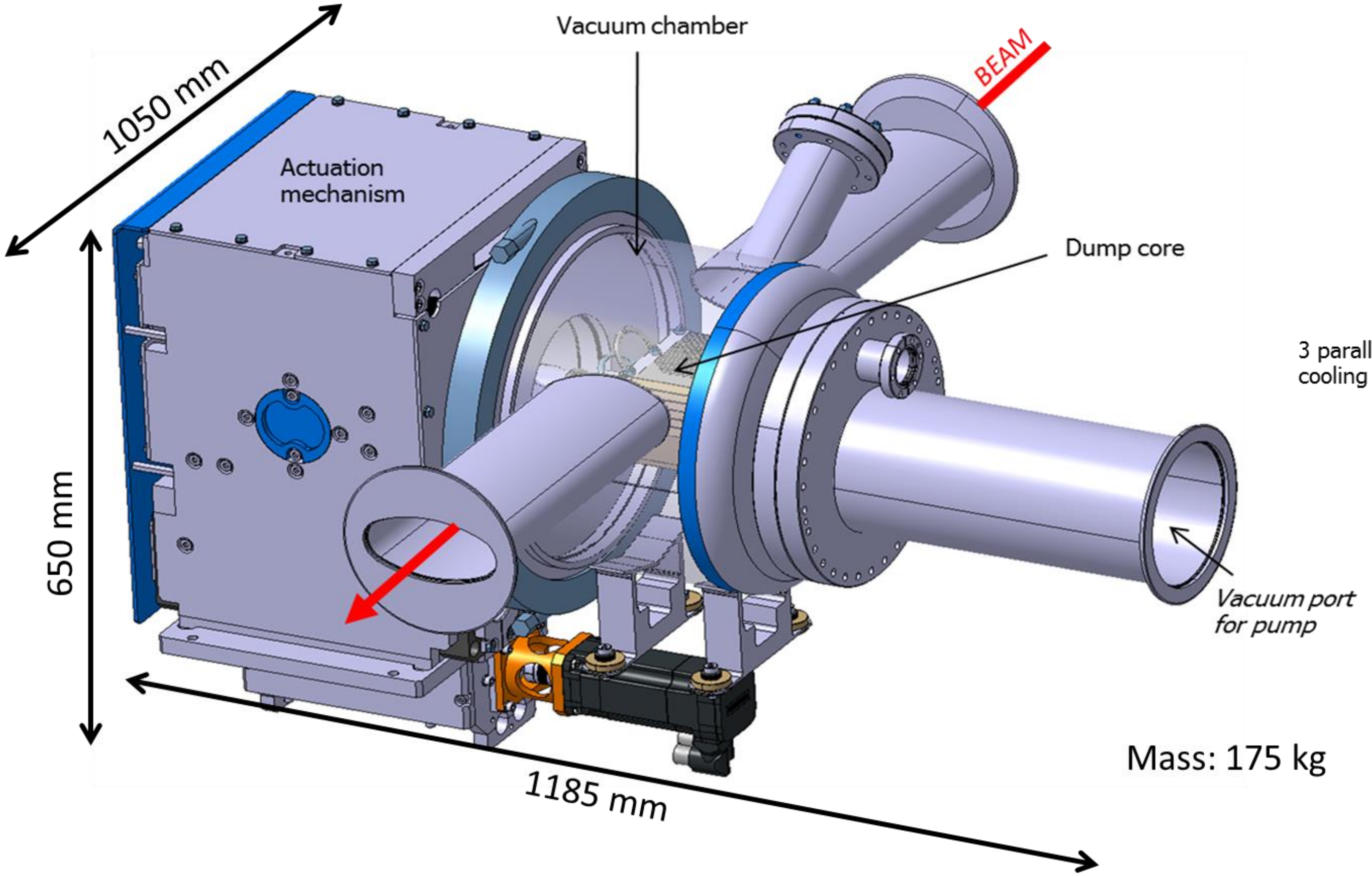
BEAM	LHC 25 ns 2015	LHC25ns HL
Particles	Protons, for LHC	
Pulse Intensity:	8.7×10^{12}	2.4×10^{13}
Continuous pulses to study	Minimum 4 pulses	Minimum 4 pulses
Beam revolution time:	2.1 µs	2.1 µs
Pulse Period (Basic Period):	3.6 s	3.6 s
Rms size (σ_h x σ_v) [mm × mm]	1.85 x 0.98	1.74 x 0.87
Max momentum	26 GeV/c	26 GeV/c
Intensity density*	76	252
Total shaving time	approx. 4 ms	approx. 4 ms
Total beam energy	**35 kJ**	**96.3 kJ**
Total energy on the dump	**3.2 kJ**	**8.3 kJ**
T_{max} on dump	**415°C**	**1154°C**



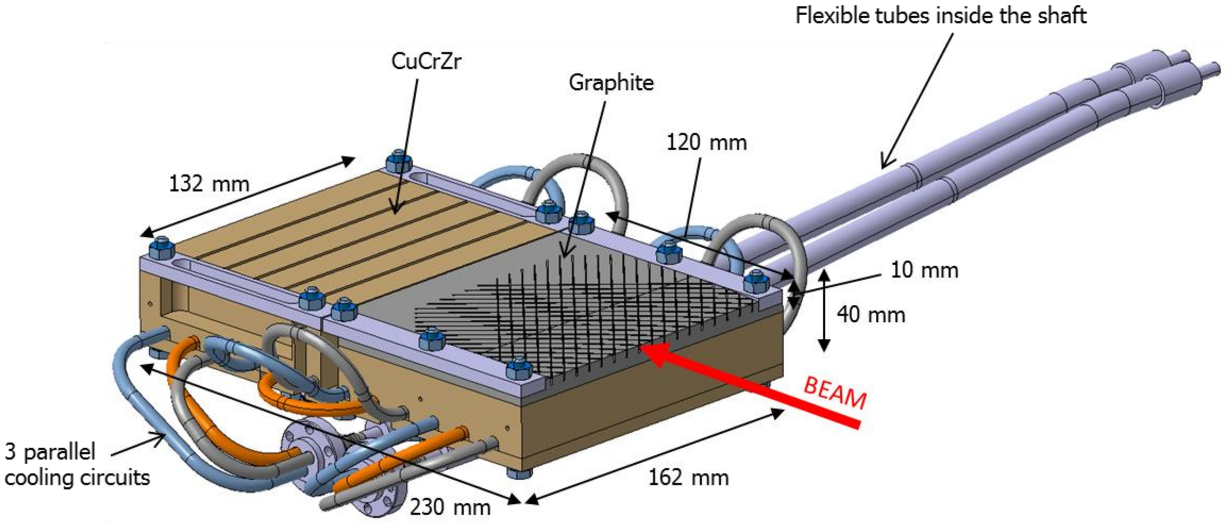




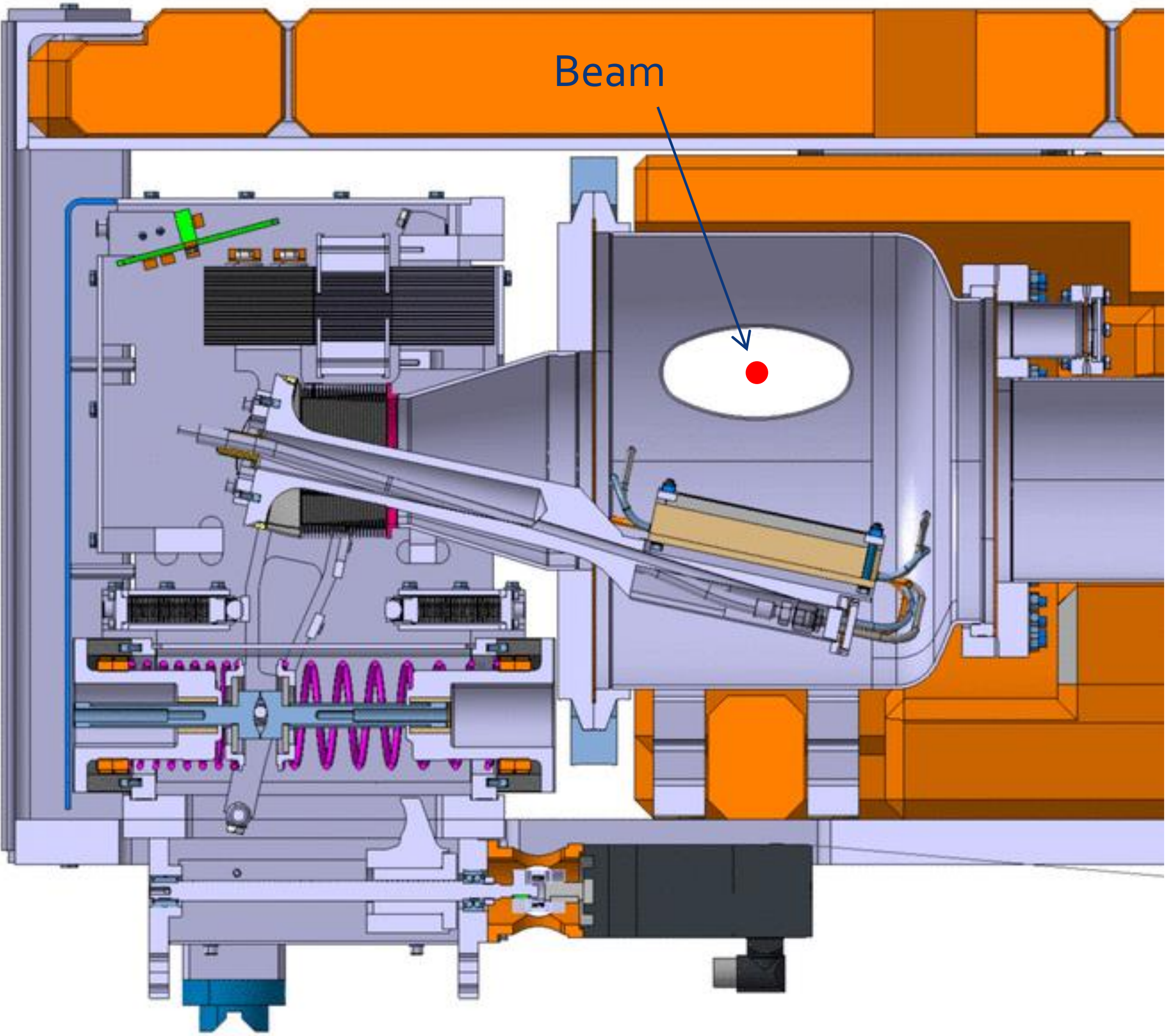
PS Dump – Proposed Design



Mass: 175 kg

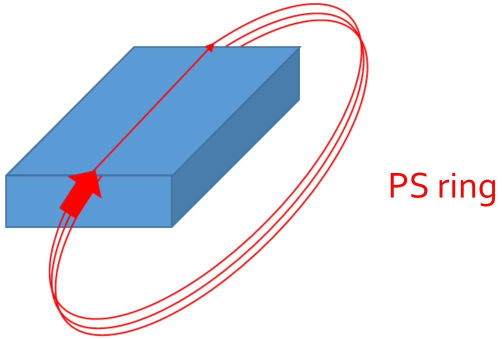


PS Dump Kinematics

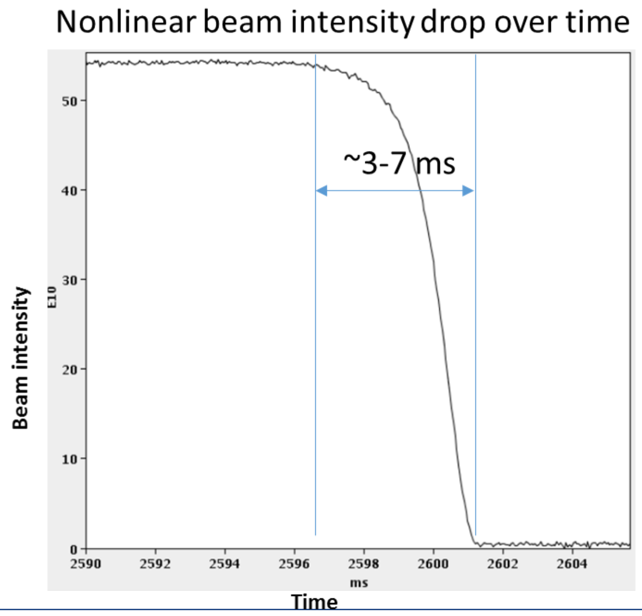


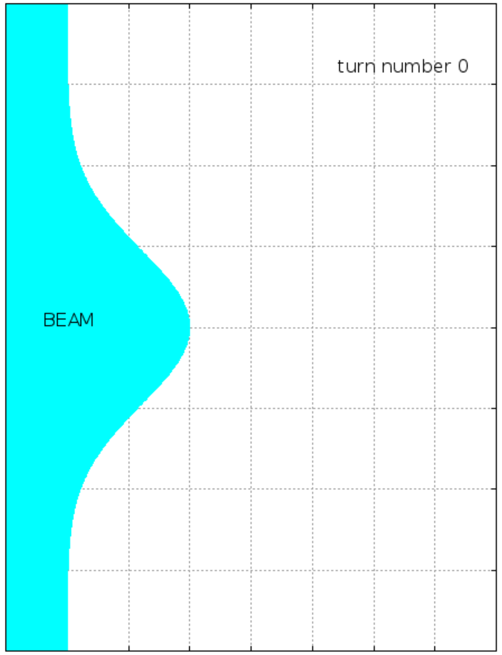
- Cycle time: <300 ms
- Angular movement: +/-6°

→dump tangential velocity ~0.8 m/s



Beam turn after beam turn, the dump intercepts a small fraction of the beam protons





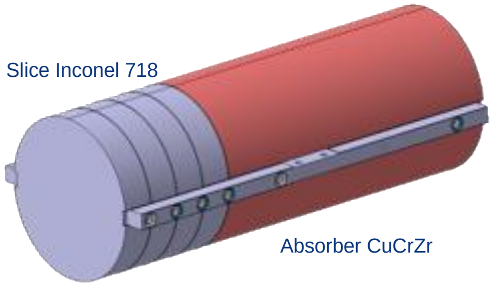
PS Beam Stoppers

Managed by
E. Grenier-Boley

Safety devices, usually designed to withstand one or few pulses

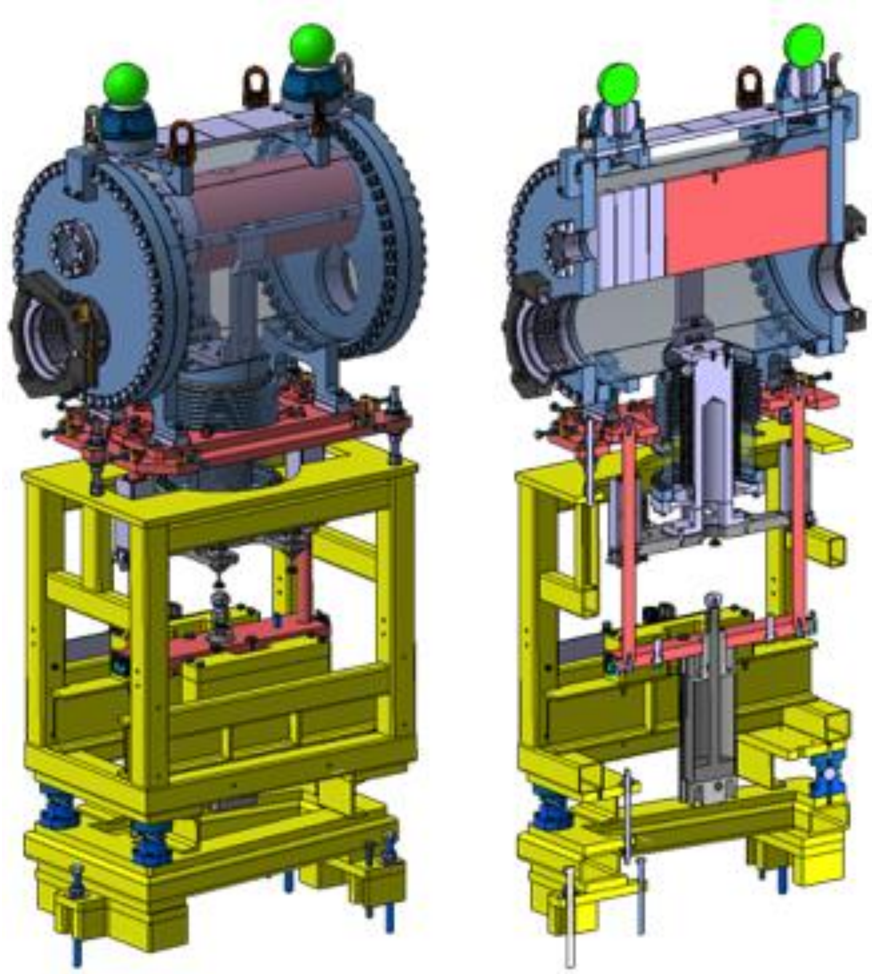
Present Situation

- 9 different designs in all the PS complex
- Lack of spare devices
- Poor documentation
- Difficult management of spare parts



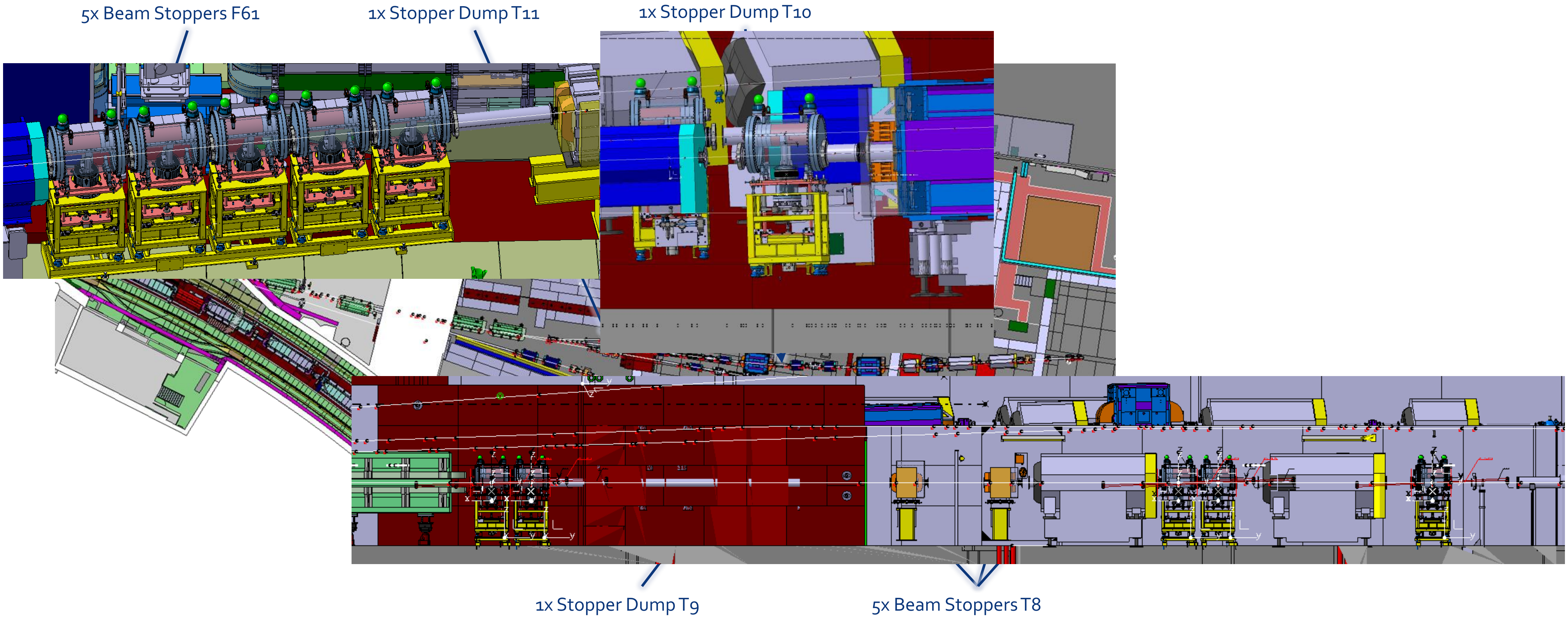
Proposed Design

- Adaptable in all areas (fully standard)
- Pneumatic standard actuator with Rad-Hard gaskets
- Shocker in case of fall
- Less efforts on the pneumatic actuator with the vacuum

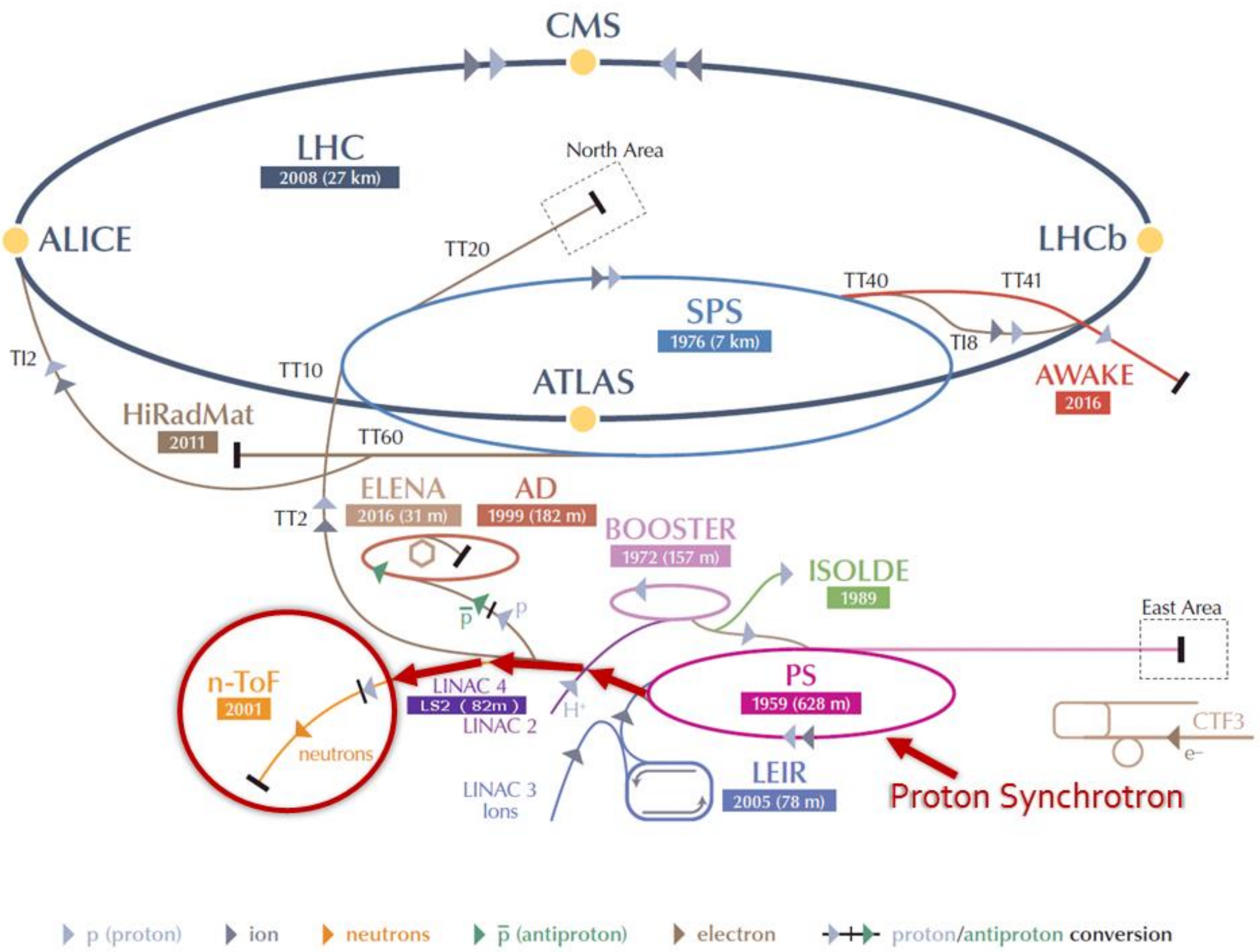


BEAM PARAMETERS	
Beam energy	26 GeV/c
Number of bunches	6
Total pulse length	1.1 μs
Intensity per pulse	2.3×10^{13} particles
Beam size ($\sigma_{horizontal}$ / $\sigma_{vertical}$)	1.50 mm / 1.39 mm

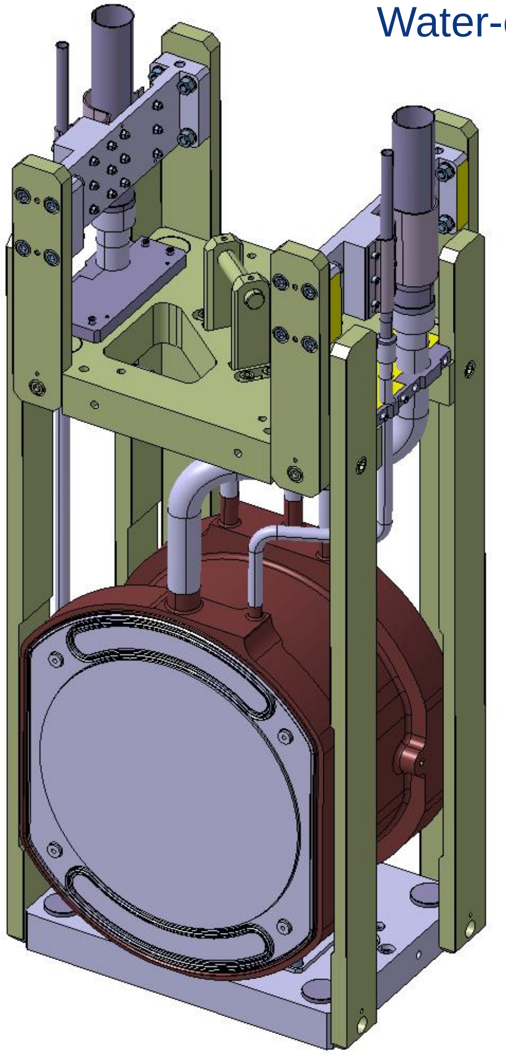
East Area – Beam Stoppers



The n_TOF Facility

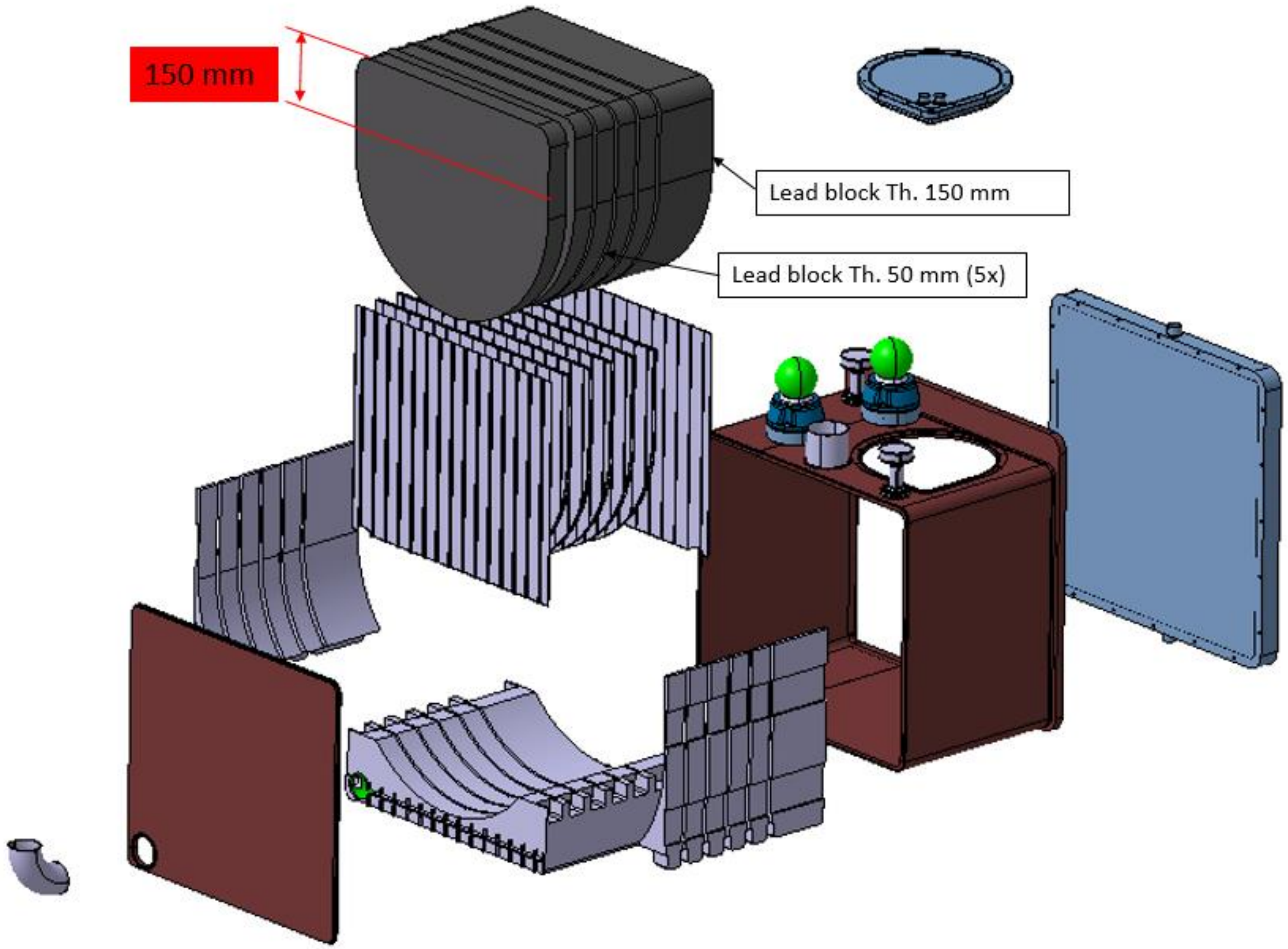


Water-cooled, pure lead target



Future n_TOF Target

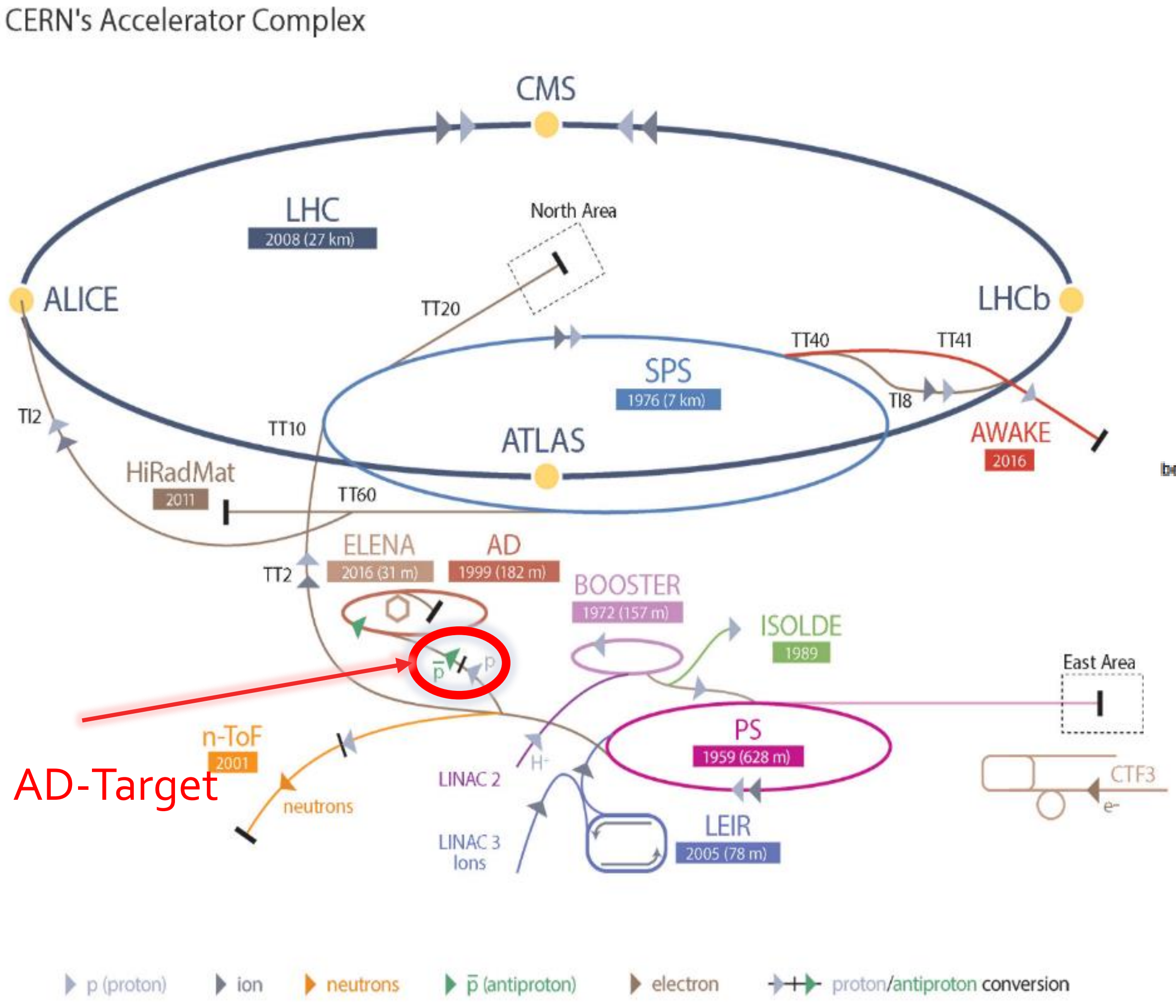
Managed by
M. Calviani
R. Esposito

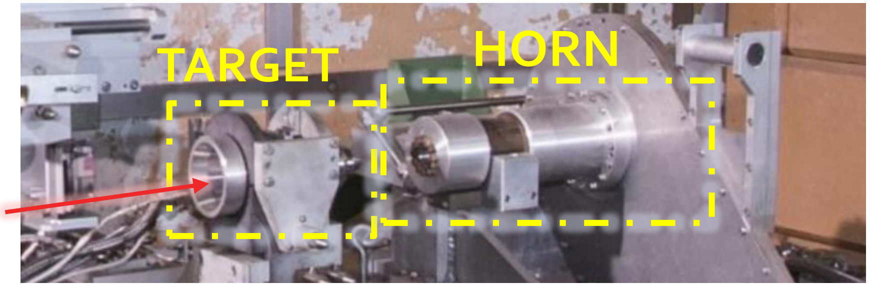


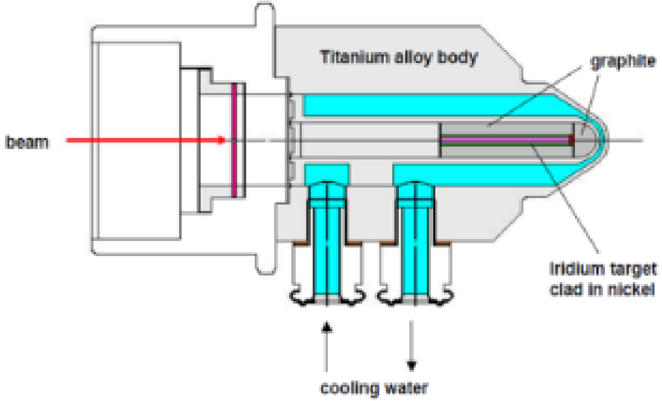
N_2-cooled Pb sliced target

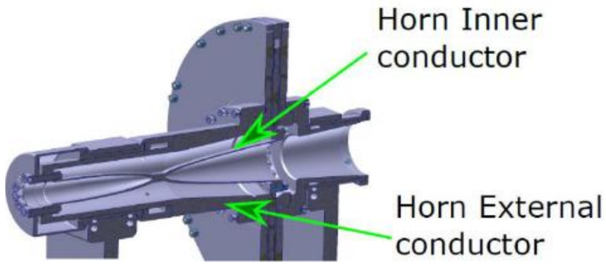
- Technologically innovative, but appears the most appealing from a physics as well as technological perspective
- Operational simplification: no high-Z contaminated H_2O, no ion-exchangers, etc.

Antiproton Decelerator Target







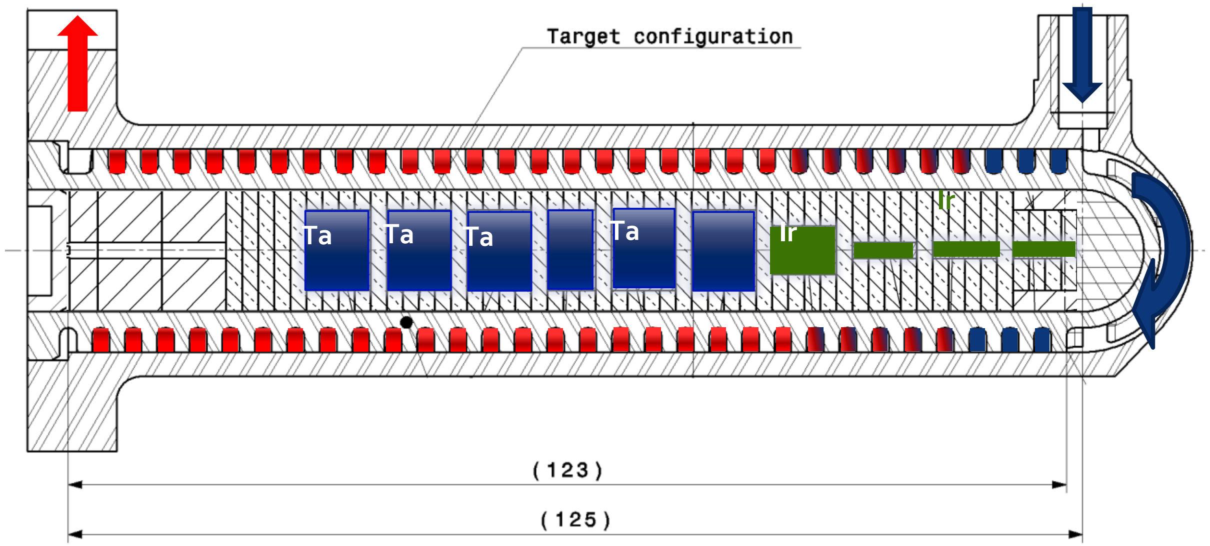


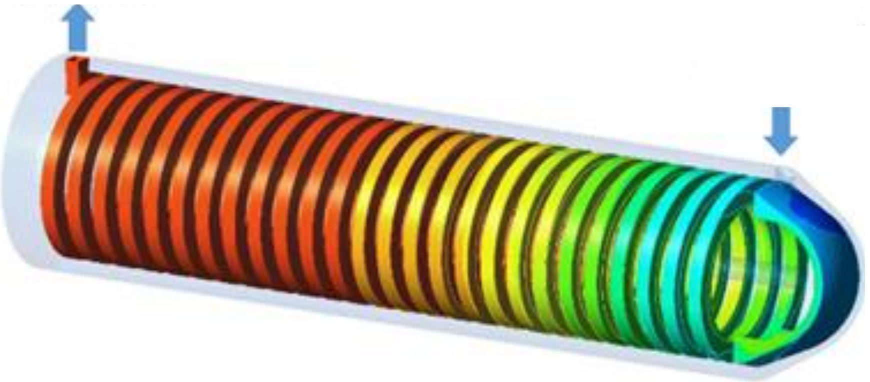
- Antiprotons are produced by colliding a 26 GeV/c proton beam with a fixed **target**
- Collected at 3.5 GeV/c by a magnetic horn, focused and injected to the AD-ring

Future AD Target

See C. Torregrosa's presentation on thursday

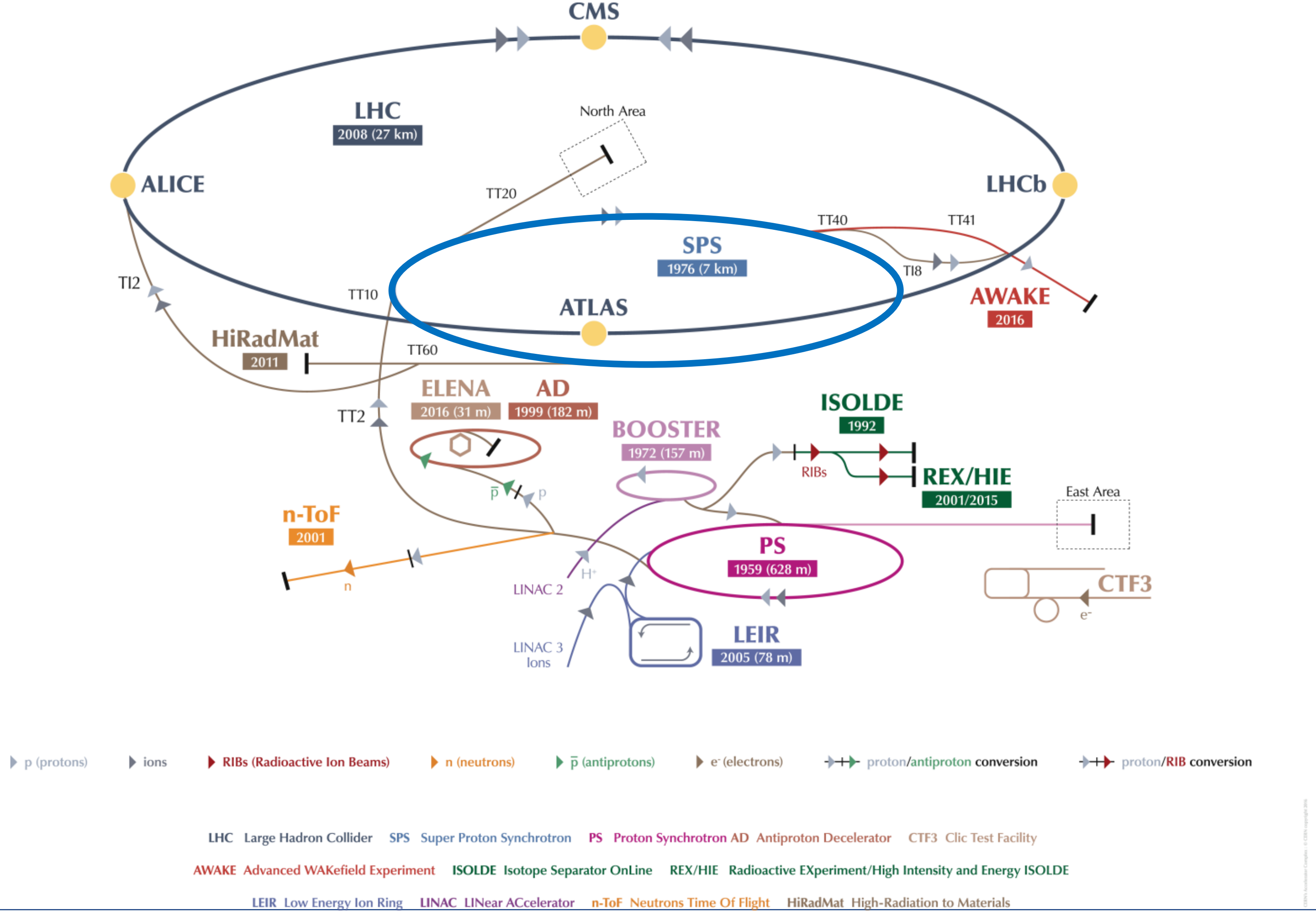
C. Torregrosa





- Substantially more compact (Ø30 mm external diam vs old. Ø 100 mm)
- **Pressurized-Air-cooled** (**5-6 bars**) double wall Ti-6Al-4V assembly, with an internal serpentine.
- New core & matrix configuration
  1) Larger core diameter (up to 10 mm)
  2) Multi-material core configuration (Ta, Ir)
  3) Expanded graphite **(EG)** as matrix material

SPS Devices

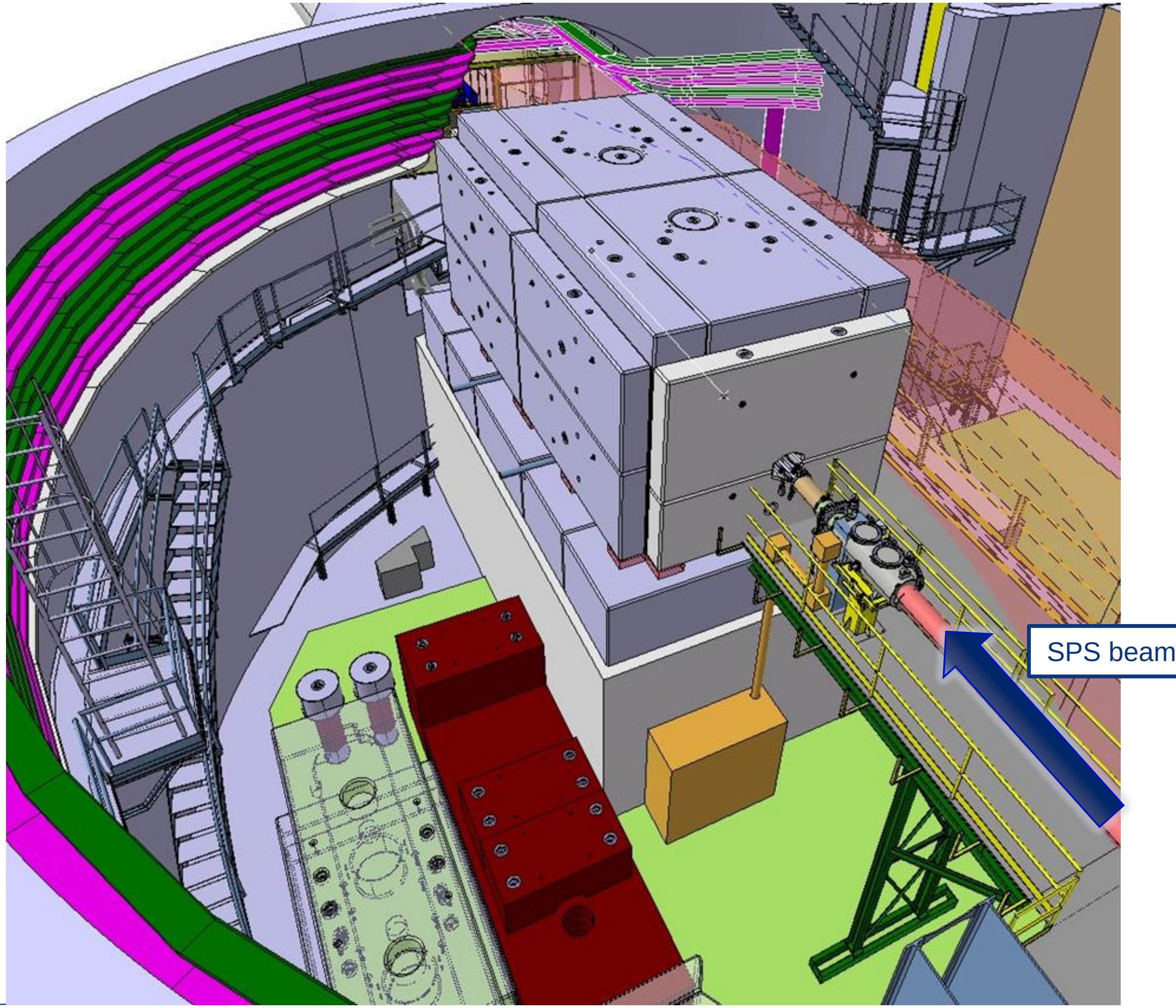


CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT20
TT40
TT41
SPS
1976 (7 km)
TI8
TI2
TT10
ATLAS
AWAKE
2016
HiRadMat
2011
TT60
ELENA
2016 (31 m)
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1992
RIBs
REX/HIE
2001/2015
East Area
n-ToF
2001
p̄
p
n
LINAC 2
H⁺
PS
1959 (628 m)
CTF3
e⁻
LINAC 3
Ions
LEIR
2005 (78 m)
p (protons)
ions
RIBs (Radioactive Ion Beams)
n (neutrons)
p̄ (antiprotons)
e⁻ (electrons)
proton/antiproton conversion
proton/RIB conversion
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron AD Antiproton Decelerator CTF3 Clic Test Facility
AWAKE Advanced WAKefield Experiment ISOLDE Isotope Separator OnLine REX/HIE Radioactive EXperiment/High Intensity and Energy ISOLDE
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

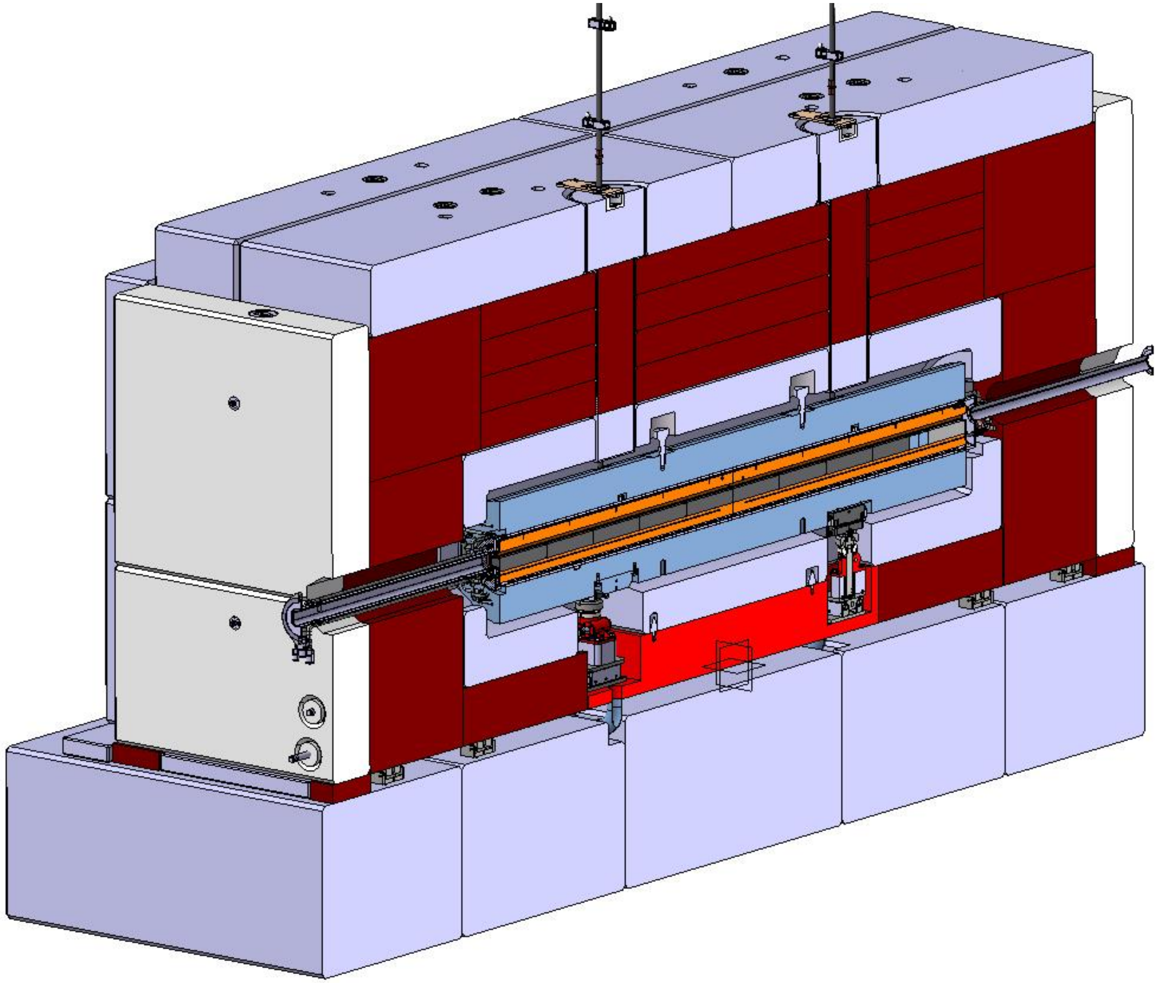
SPS Dump

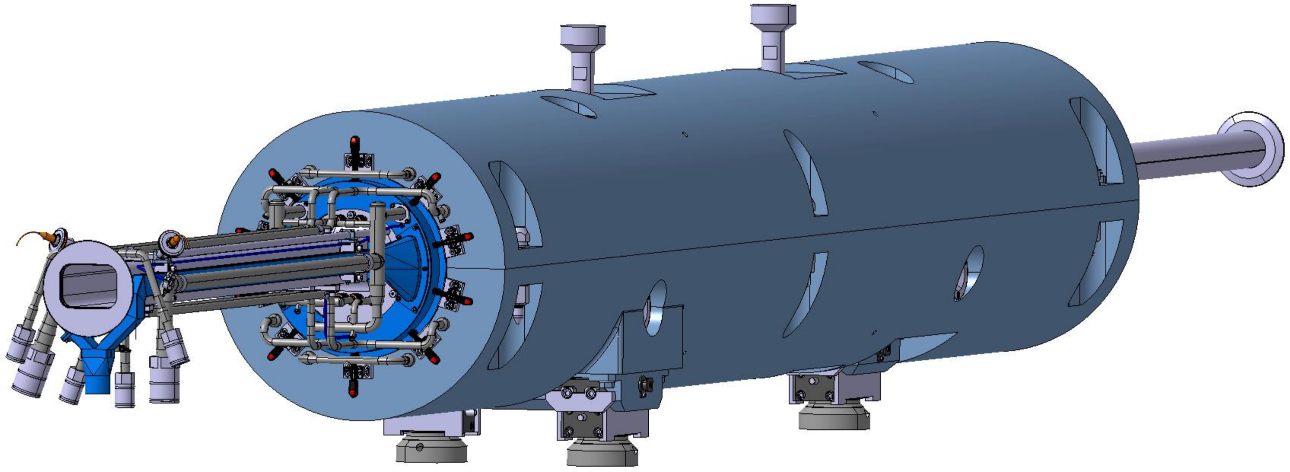
Managed by
A. Perillo-Marcone

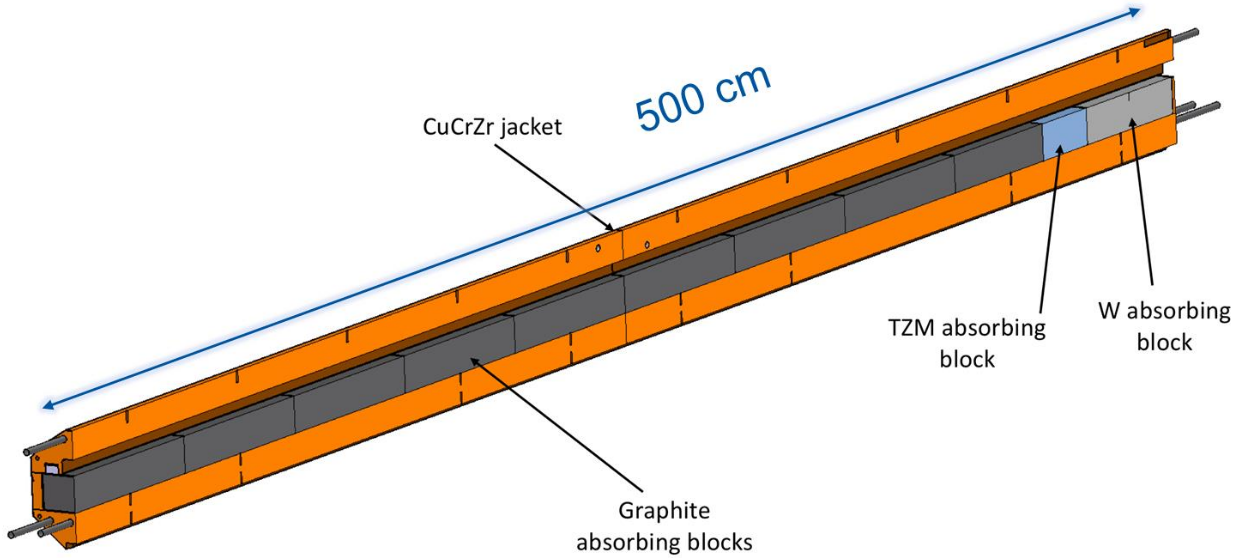
- Internal Dump
  - Direct effect on SPS operation
- UHV environment
- High average beam power ~260 kW
- Little/no-maintenance possible
- High thermomechanical loads
- Long-term operation (~20 years)
  - Fatigue
  - Irradiation damage



SPS Dump



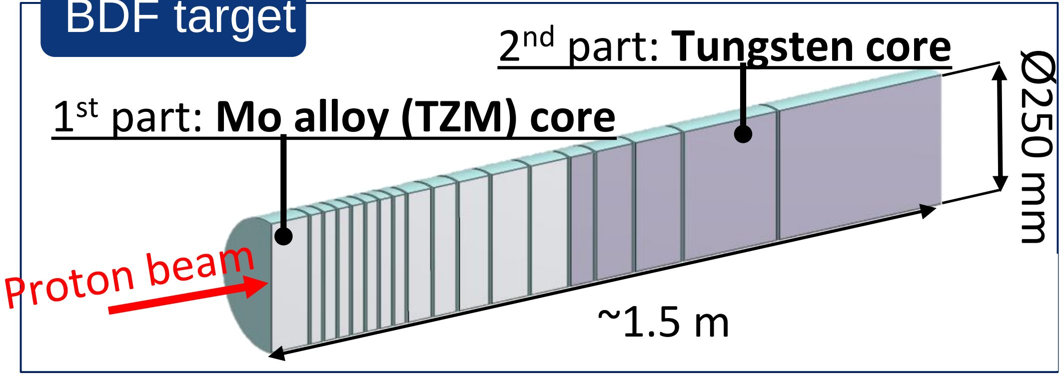


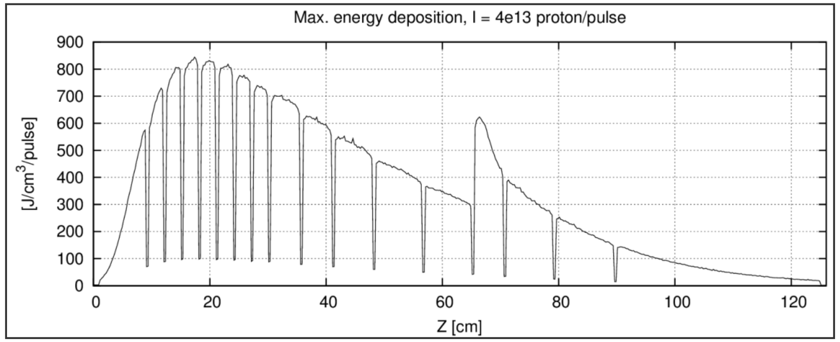

500 cm
CuCrZr jacket
TZM absorbing block
W absorbing block
Graphite absorbing blocks

Future BDF Target

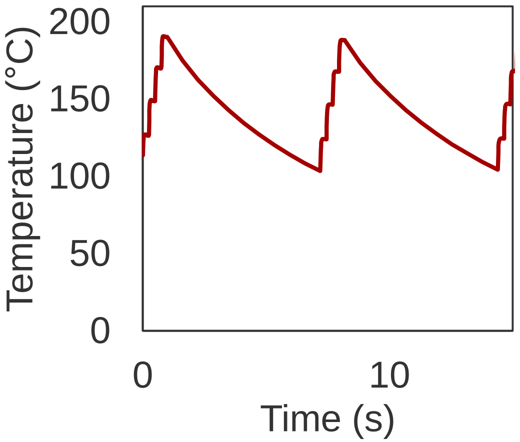
See M. Lamont's (Monday) and E. Lopez/A. Perillo-Marcone's (Thursday) presentations

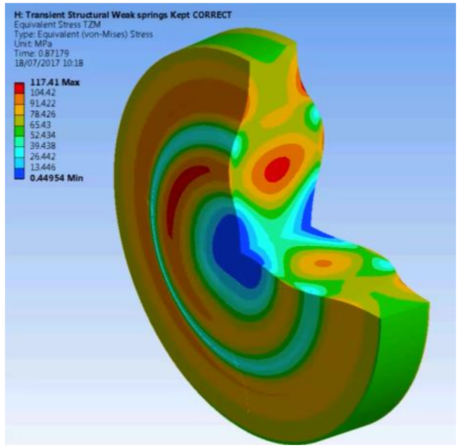
BDF target





FEM Most solicited block: #9 (TZM)

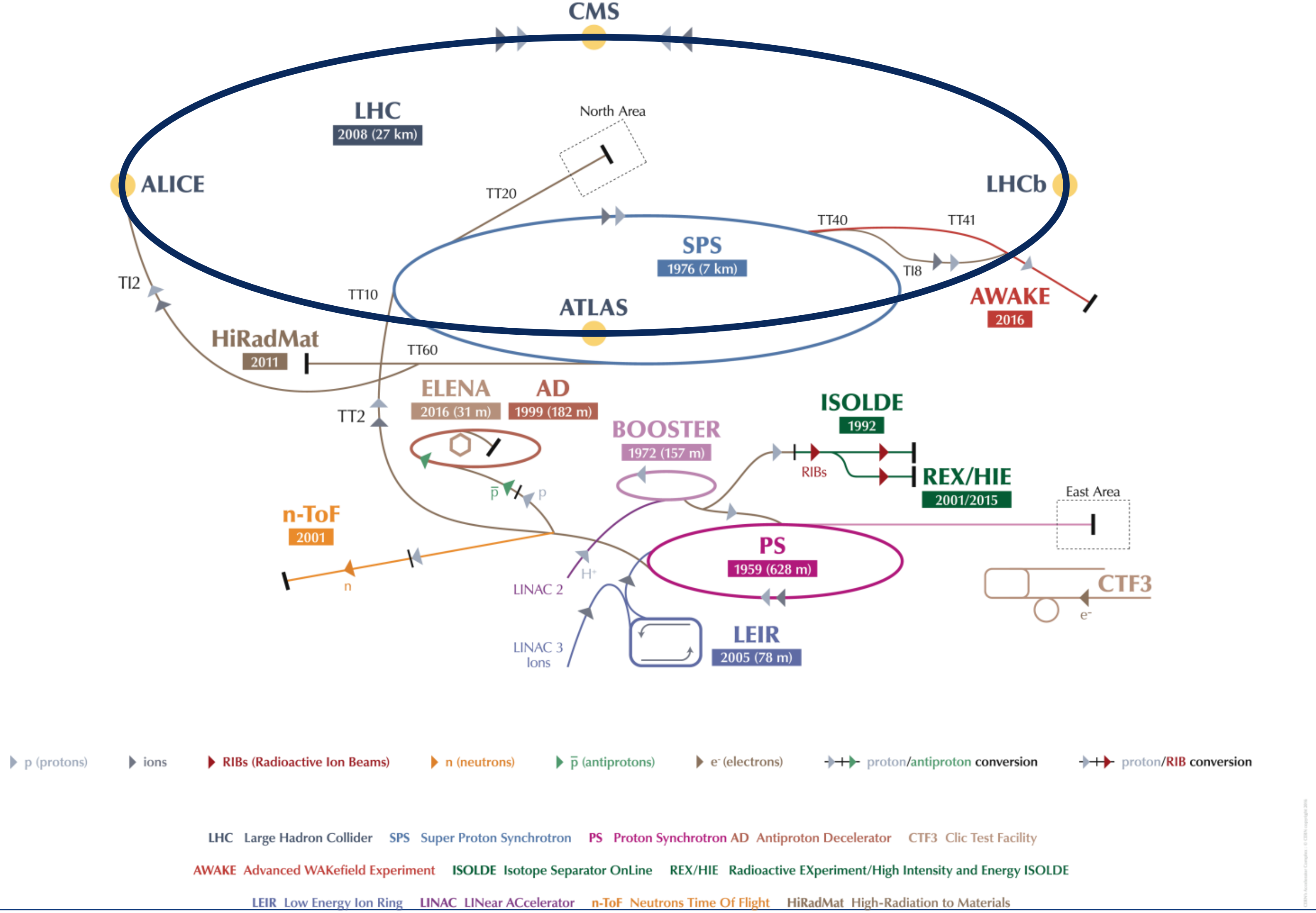




Temperature /stress field

Material	Max. temperature (°C)	Max. stress (MPa)
TZM	180	130 (VM)
W	150	80 (MPS)

LHC Devices


CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT20
TT40
TT41
SPS
1976 (7 km)
TI8
TI2
TT10
ATLAS
AWAKE
2016
HiRadMat
2011
TT60
ELENA
2016 (31 m)
AD
1999 (182 m)
TT2
ISOLDE
1992
BOOSTER
1972 (157 m)
RIBs
REX/HIE
2001/2015
East Area
n-ToF
2001
PS
1959 (628 m)
CTF3
LINAC 2
LINAC 3
Ions
LEIR
2005 (78 m)
p (protons)
ions
RIBs (Radioactive Ion Beams)
n (neutrons)
p̄ (antiprotons)
e⁻ (electrons)
proton/antiproton conversion
proton/RIB conversion
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron AD Antiproton Decelerator CTF3 Clic Test Facility
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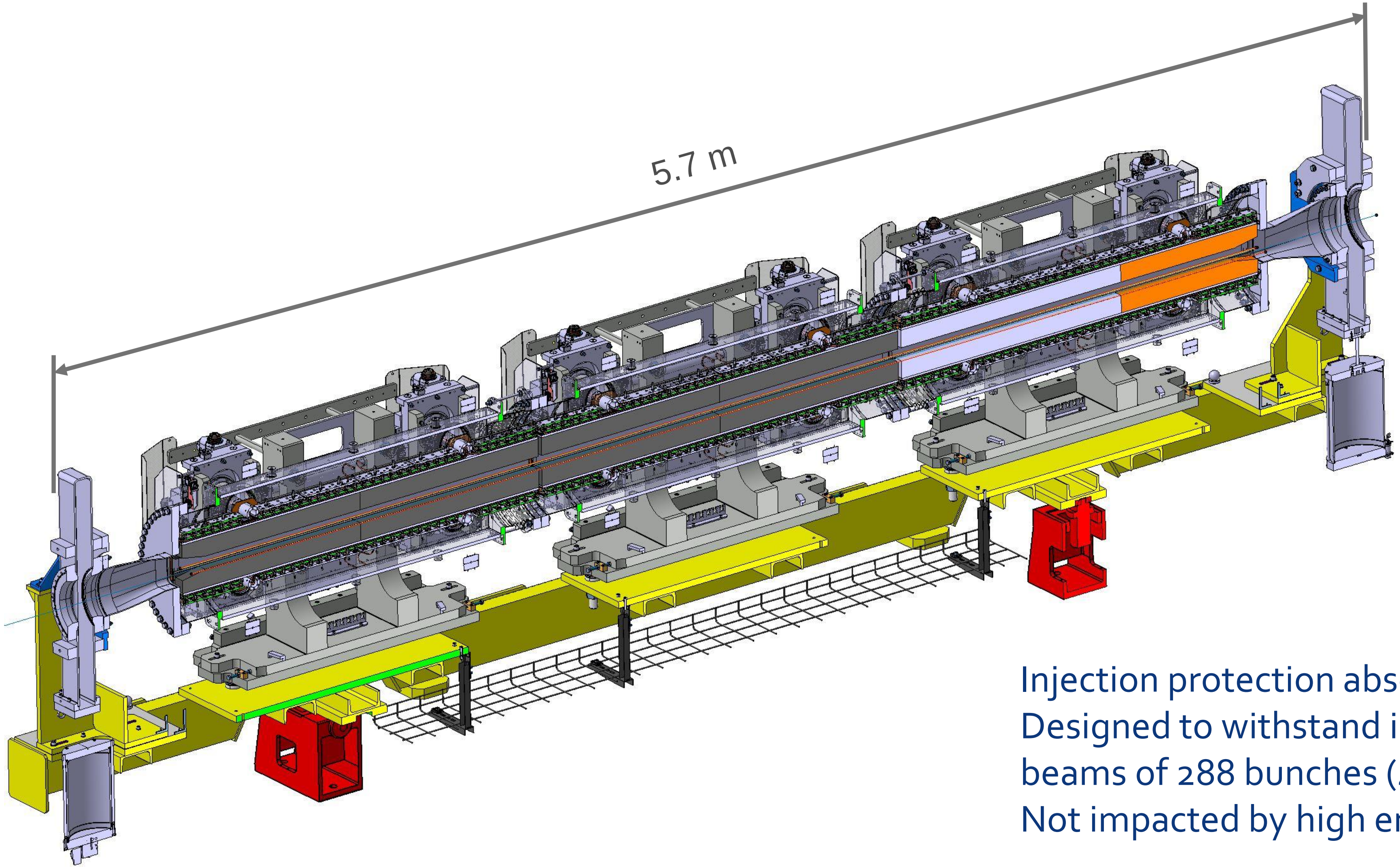
Injection Protection Absorbers

Managed by
A. Perillo-Marcone



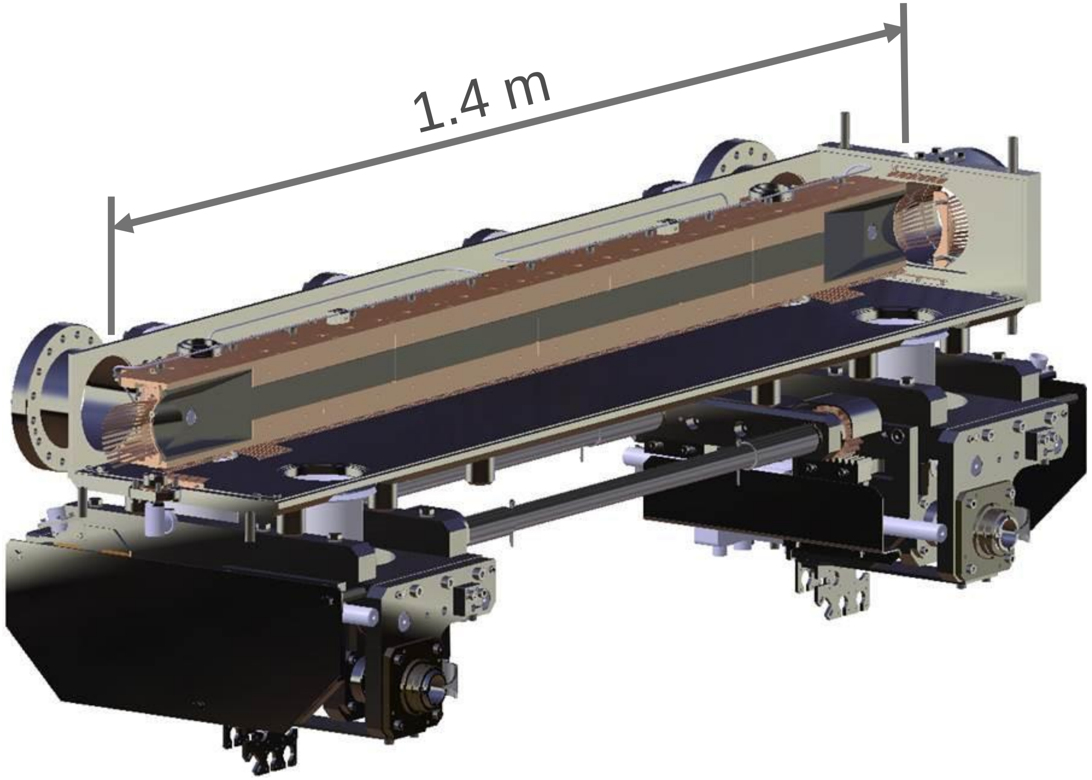
Injection protection absorber.
Designed to withstand impacts of Standard and BCMS beams of 288 bunches (450 GeV).
Not impacted by high energy beams (only 450 GeV).

Collimators

Managed by
I. Lamas (EN-STI)
In collaboration with EN-MME

- Different types of collimators
  - Primary (low-Z, MoGr and CFC)
  - Secondary (low-Z, MoGr and CFC)
  - Tertiary (high-Z, W or CuCD)

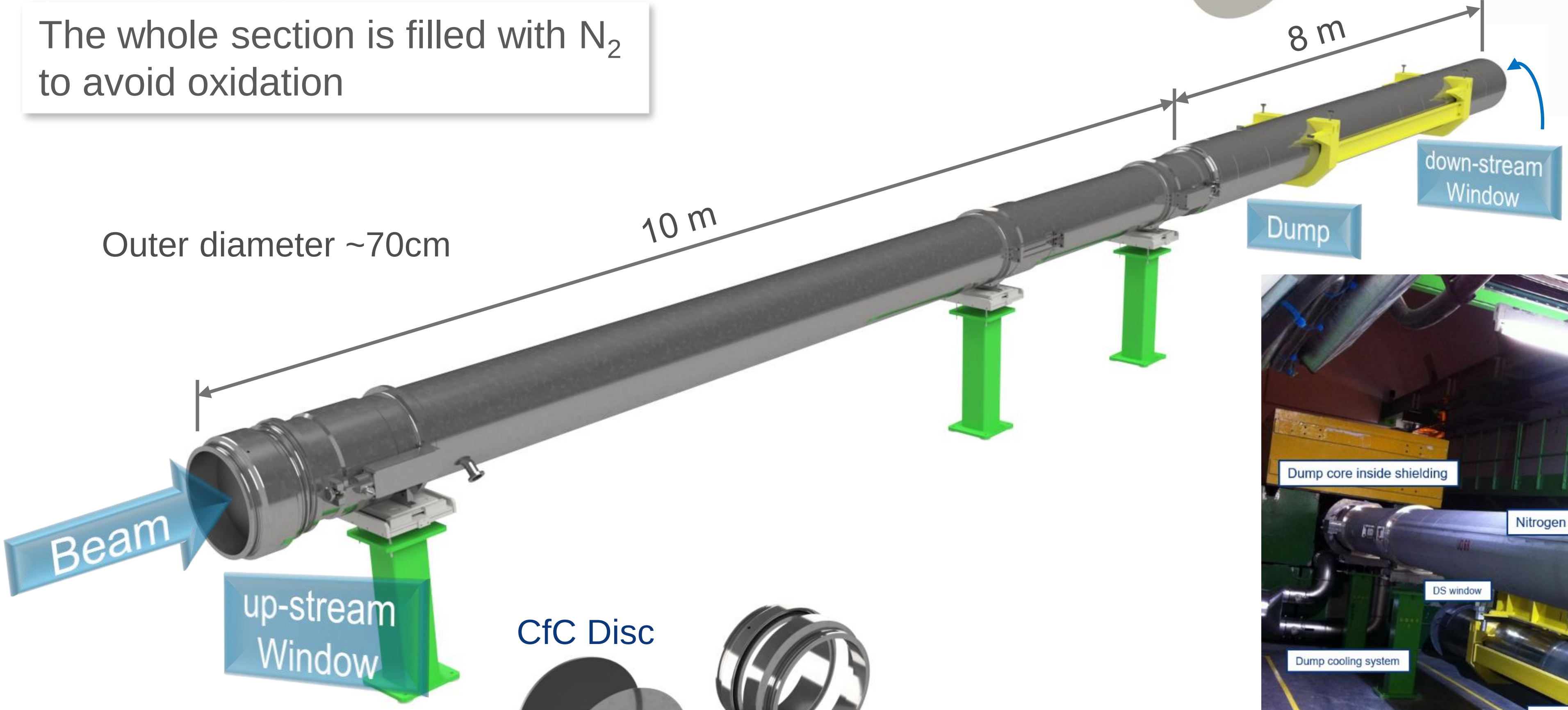
- Thermo-mechanical loading scenarios
  - Slow losses
    - Nominal operation: 1h BLT (Beam LifeTime)
    - Accidental case: 0.2h BLT (10 s)
  - Direct beam impact (accidental scenarios)
    - Asynchronous beam dump: 8 full LHC bunches
    - Beam injection error: 288 SPS bunches



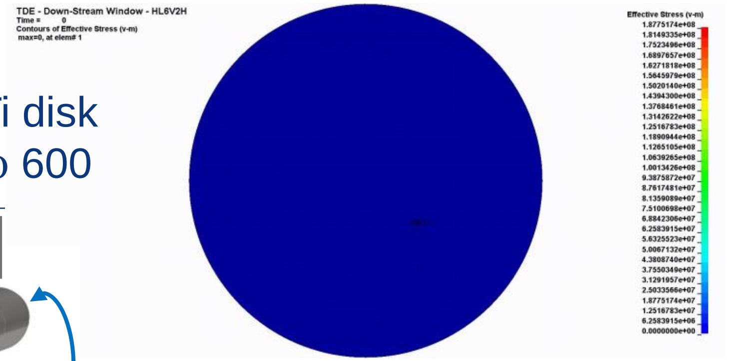
LHC Dump

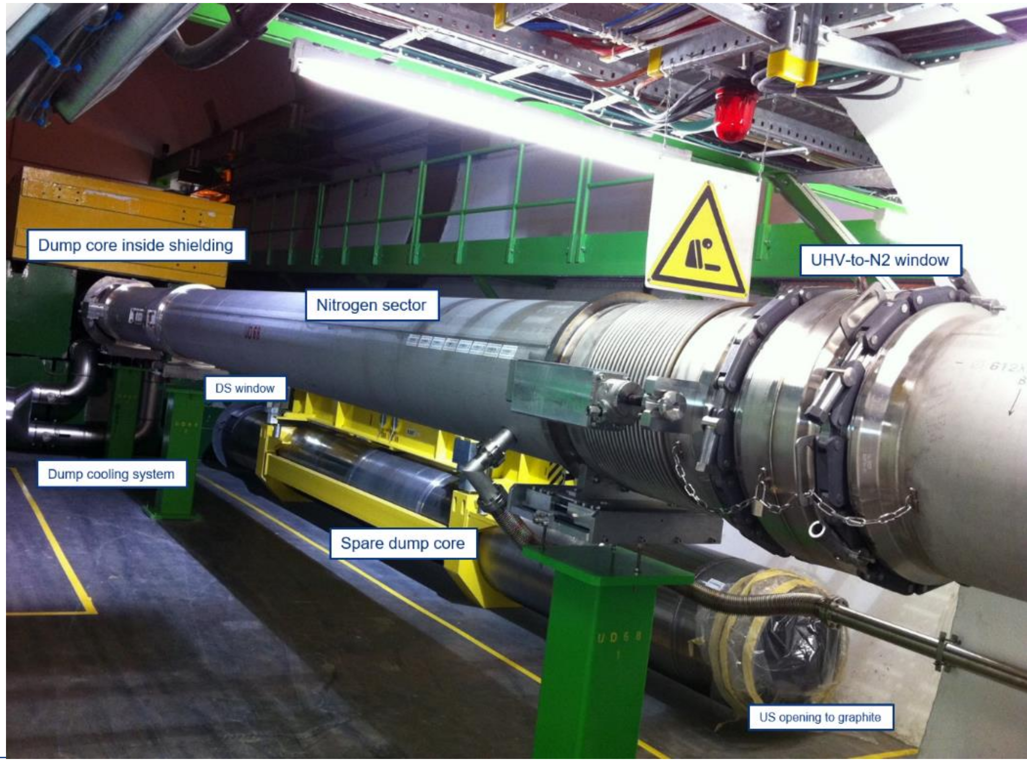
The whole section is filled with N_2 to avoid oxidation

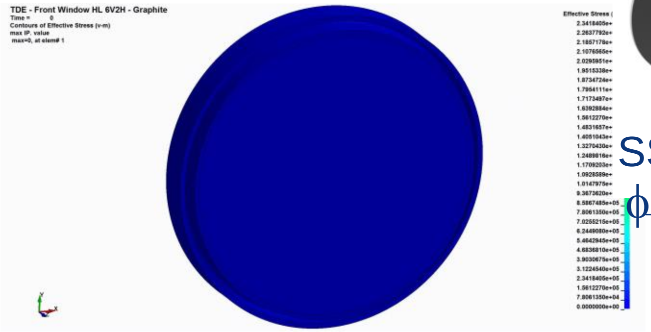
Outer diameter ~70cm



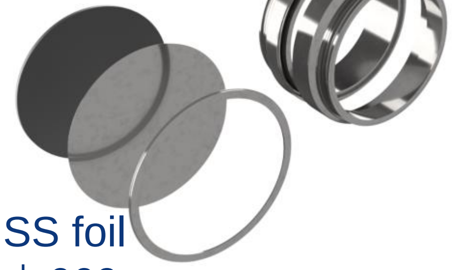
Ti disk
ϕ 600





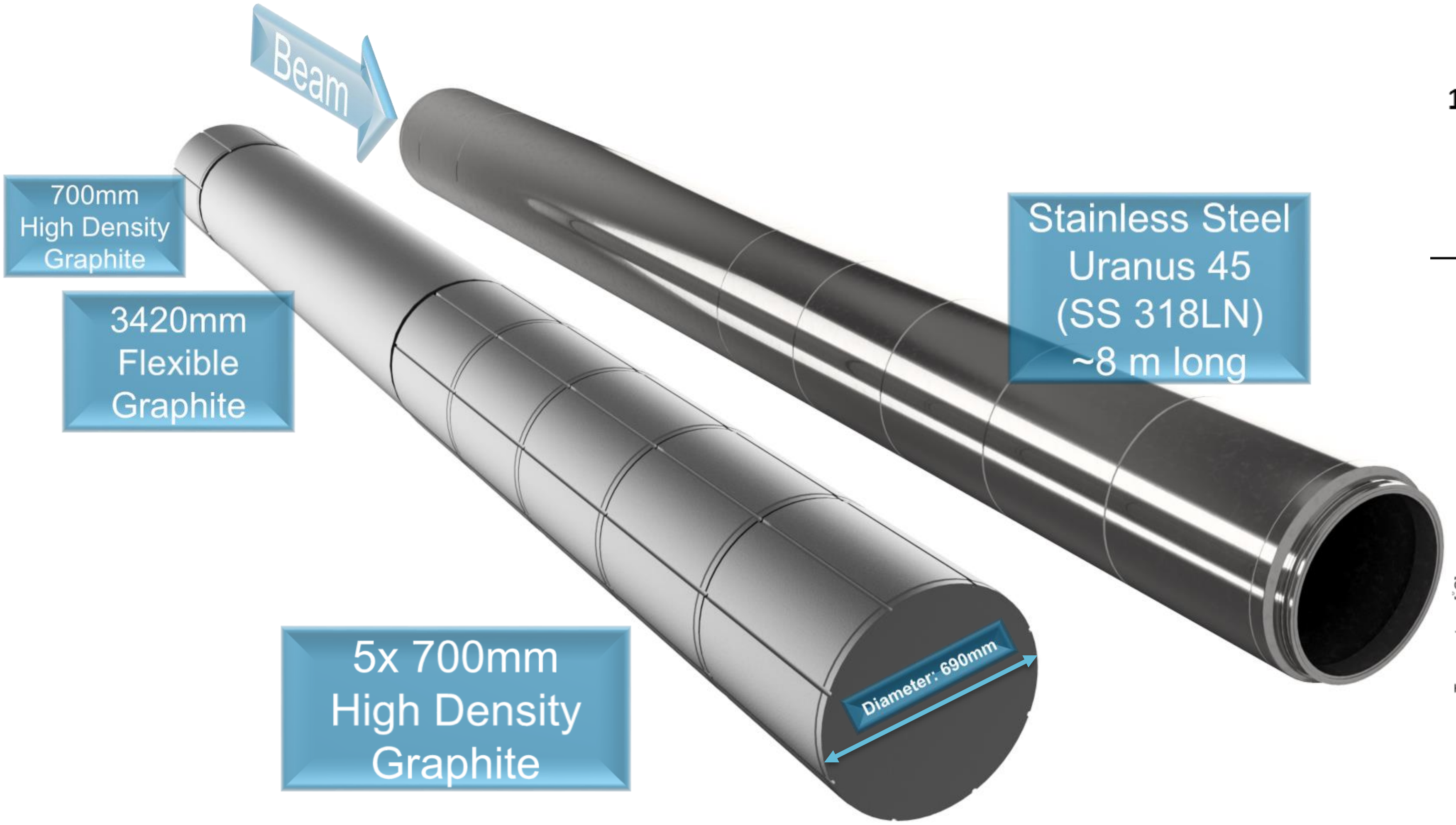


CfC Disc

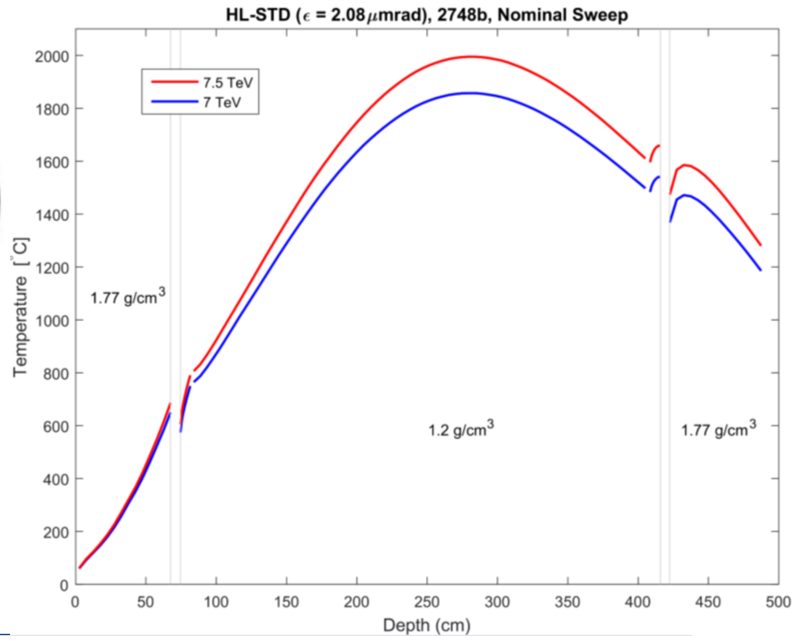


SS foil
ϕ 660

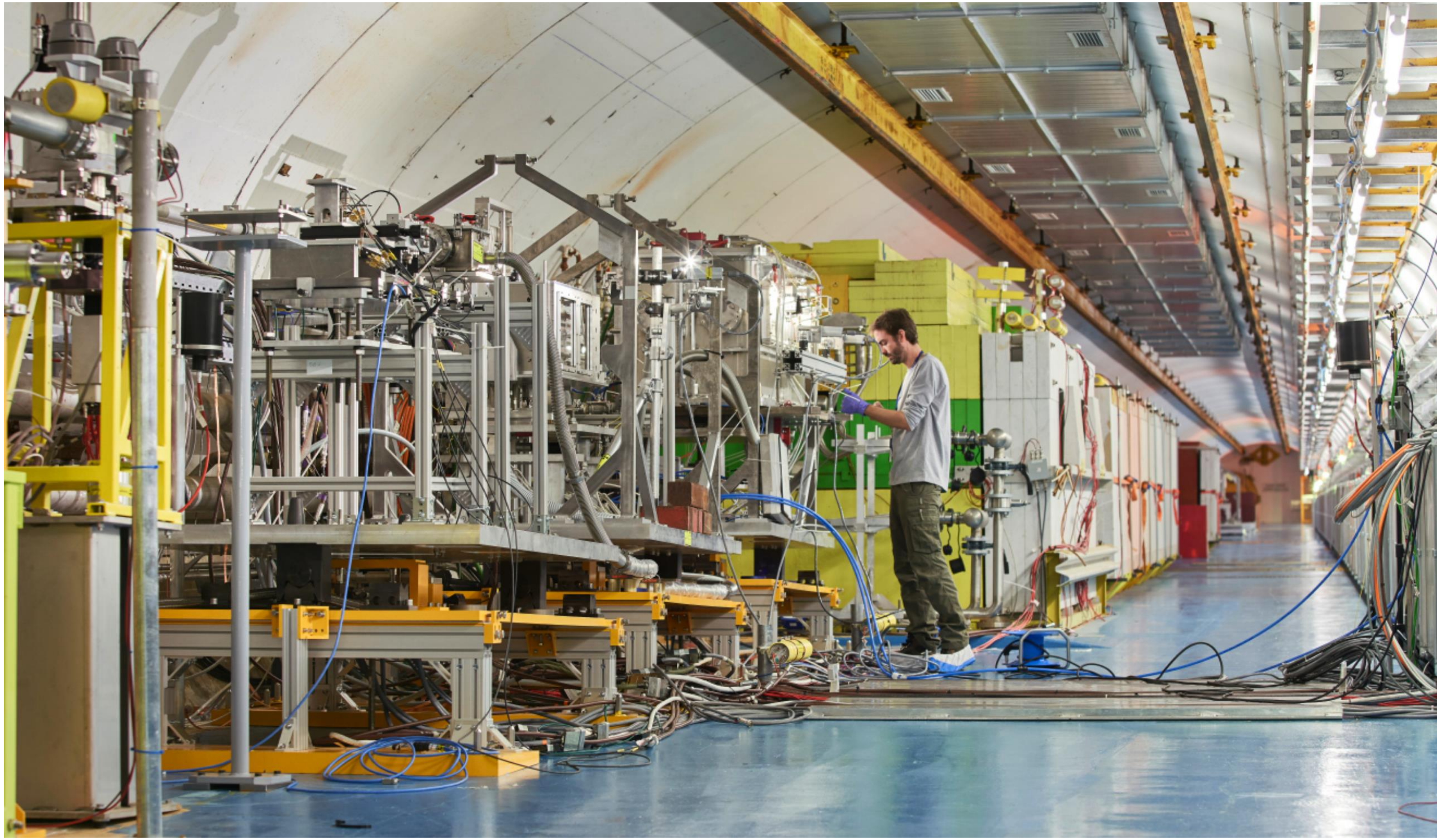
LHC Dump Core



HL Beam Parameters		
LHC BCMS	**LHC Standard 25ns**	**LHC BCMS Retrigger Scenario**
7 TeV	7 TeV	7 TeV
2.0E11	**2.3E11**	**2.3E11**
1.37 µm rad	**2.08 µm rad**	**1.7 µm rad**
HL	HL	HL
2604	2748	2604



Several HiRadMat Experiments



See F. X. Nuiry's presentation on thursday

Thank you for your attention.