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ELBEX WP3
Beam dumps (INFN contribution)

M. Benettoni and M. Morandin
INFN- PD

INFN PADOVA

People involved

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- Massimo Benettoni
  - Mechanical Engineer, head local mechanical design group in INFN - Padova
- Marco Romanato
  - Mechanical designer
- Sergii Vasiukov
  - LUXE Post-doc
- M.M.

INFN Responsibility

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- WP3 includes the following deliverables:
  - INFN main responsibility:
    - D3.1 – Engineering design of the electron dump
    - D3.2 – Engineering design of the photon dump
    - D3.3 – Electron beam dump
    - D3.4 – Photon beam dump
  - DESY responsibility
    - D3.5 – Target chamber
    - D3.6 – TDC dipole magnet
- Coordination of the WP could be carried out by two co-coordinators or one coordinator and a deputy coordinator from INFN and DESY

INFN Padova Mechanical Design Service: overview

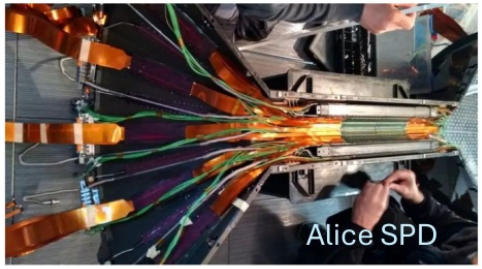
ean Union

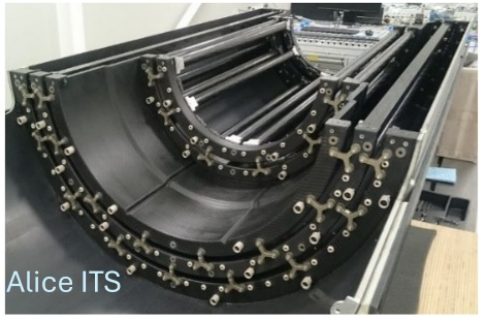
Composed by 8 staff: 3 bachelor engineers, 5 graduate mechanical designers

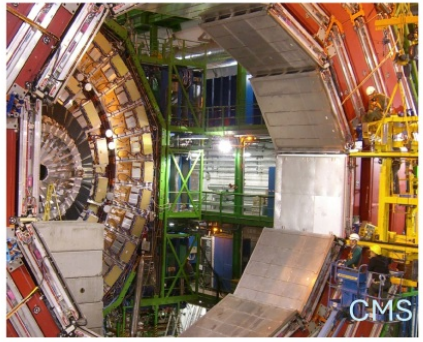
Involved in R&D, design, prototyping, qualification, production … up to delivery, installation and commissioning of detectors and accelerators components ..

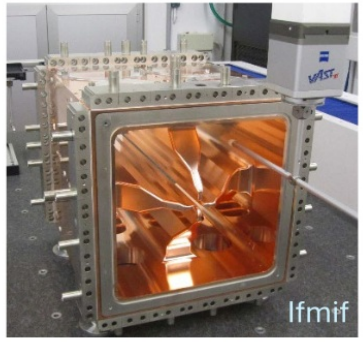
In the far and recent past we have contributed to many projects, e.g.:

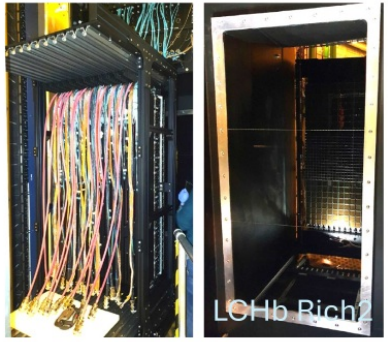
- **Alice tracker (Cern)**
- **Belle II Dirc (KEK, Japan)**
- **CMS muon chambers (Cern)**
- **CTA mirrors (Canary islands)**
- **Icarus (LNGS and Fermilab)**
- **Ifmif RFQ (Rokkasho, Japan)**
- **LHCb RICH (Cern)**
- **Galileo (LNL, Italy)**
- **Zeus muon chambers (DESY)**







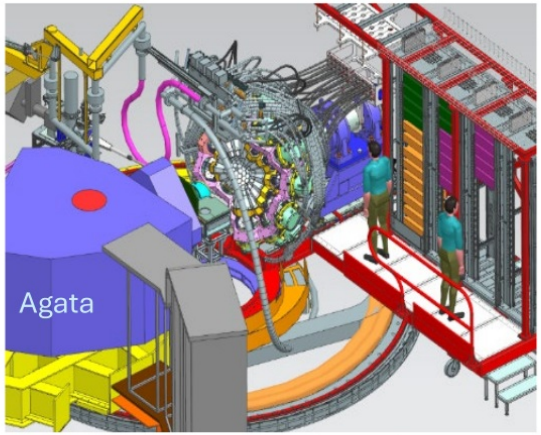


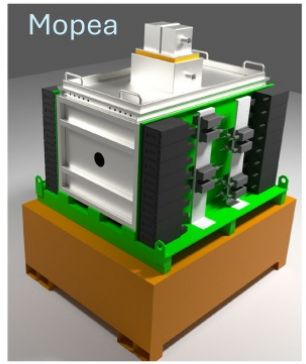


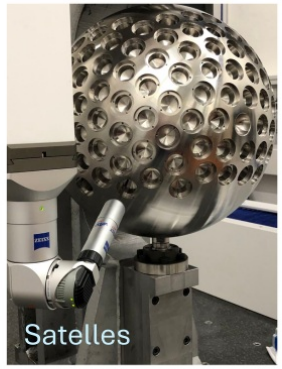
INFN Padova Mechanical Design Service: current activities

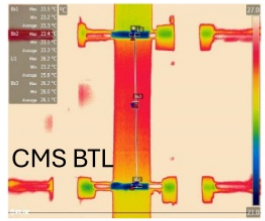
Currently involved in > 15 project of detectors, experiments, accelerators:

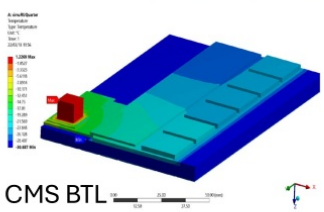
- **ALADDIN (CERN)**
- **AGATA (LNL, Italy)**
- **CMS BTL (CERN)**
- **CTA (Canary Islands, Spain)**
- **DTT-NBI (Italy)**
- **ENUBET (CERN)**
- **GERDA Legend (GSSI, Italy)**
- **HEAT (LNL, Italy)**
- **I.FAST (EU project)**
- **MOPEA (LNL, Italy)**
- **MUON-E (CERN)**
- **MUTOMCA (KKK Germany)**
- **NUCL-EX (LNL, Italy)**
- **QUAX (LNL, Italy)**
- **SATELLES (...space)**
- **SPES (LNL, Italy)**
- **VIRGO (Pisa, Italy)**
- and others ..

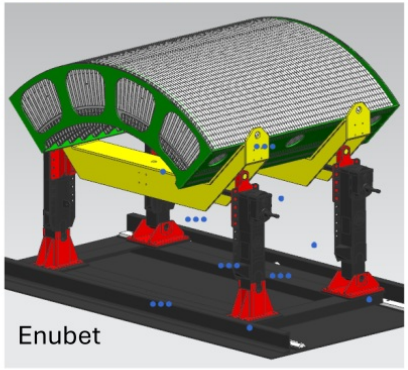


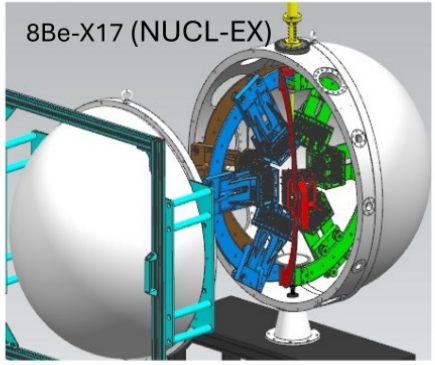












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INFN Padova Mechanical Design Service tools & know-how

- Mechanical design: Siemens NX CAD
- Finite Element Analysis: Ansys Workbench, Ansys Fluent
- Thermography : Flir IR camera
- Metrology: Zeiss Accura CMM measuring machine
- Metrology: Hexagon measuring arm

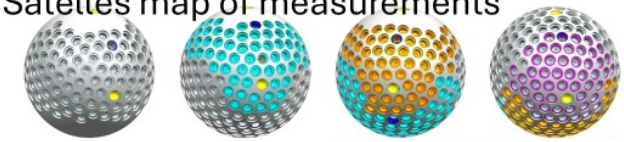
Personnel past and periodic training:

- NX and Ansys periodic training on different subjects
- Geometrical dimensioning and tolerancing GD&T courses
- Zeiss Aukom level II metrology training and certification
- Phase array ultrasound scanning of structural discontinuities (weldings, gluing, composites)
- Experiences in metallic and composite structures and detectors, glueing, brazing and welding applications, cooling circuitries, vacuum applications ...

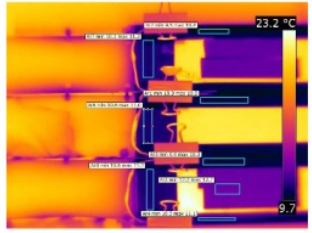
Measuring machine

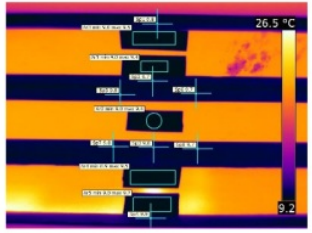
Measuring arm

Satelles map of measurements



CCR Nr.	Ø37.3 [37.3-37.4]	Error [mm]	Ø26.9 [26.9-27]	Error [mm]	205.278	5.9 [5.9-5.95]	Error [mm]	True Position	Error [mm]
Nominal	37.300	0.100	26.900	0.100		5.900	0.050	0.1	
5	37.361		26.948		205.231	5.947		0.097	
6	37.372		26.947		205.203	5.975	0.025	0.158	0.058
10	37.343		26.927		205.203	5.975	0.025	0.153	0.053
11	37.328		26.954		205.150	6.028	0.078	0.161	0.061





CMS timing layer prototype IR imaging

Beam dumps

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- The task related to the beam dumps consists of the design, manufacturing, ~~integration, installation and commissioning~~ of the two beam dumps in the ELBEX experimental area following the extraction and transfer lines.
- The design phase involves radiation flux simulations, where a close collaboration with the DESY radiation protection group is foreseen. The mechanical design related to the dump and its cooling system, as well as the manufacturing and delivery lies within the responsibility of INFN.
- The mounting and shielding of the dumps will be provided by DESY.
- ~~The installation, integration and commissioning of the dumps in the experimental area will be a joint effort betweenDESY and INFN~~

Status

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- Electron beam dump:
  - main elments of the baseline conceptual design exist since 2019
  - design assumptions to be verified
  - work to finalize the conceptual design and to then develop the final design can start soon
- Photon beam dump
  - most requirements and contraints come from the NPOD detector
  - development of the conceptual design will require still a significant amount of work using MC simulation to find the best cost/performance compromise
  - final mechanical desing can start when electron dump final desing is finished

Electron dump

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- Max. Energy 17.5 GeV
- Max bunch charge: 1 nC
- Max repetition rate: 10 Hz
- Max power released : 175 W
- Most stringent requirements:
  - containmant of 99% of beam energy
  - limits on radiation released and activation
  - vacuum tightness

Radio protection issues

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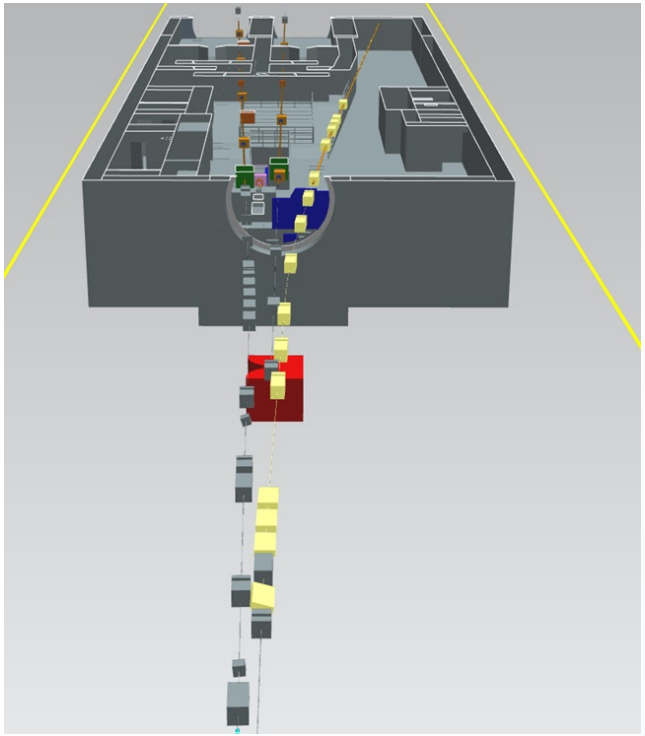
- Requirements given by:
  - people can working in the XTD2 tunnel while LUXE is running
  - limits for activation of air, water and soil
  - EU-XFEL electronics racks in XS1 annex
- Components affected:
  - beam dump (INFN-PD)
  - shielding, (alarm system ?)
    - who is going to be responsible for these ones ?



Beam dump structure

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- Al core, due to lower neutron production and higher tolerance to fatigue effects
- outer shell and backstop in copper to benefit of the higher density
- Al core is part of the transfer line vacuum system
- size of Al determined by
  - energy containment
  - strength endurance (avoid any risk of vacuum leaks)
    - MARS simulation indicates 20 cm length is suffcient to limit specific heat to 15 Jg
    - in addition size of incoming elecron beam should be limited to
      $\sigma_x \sigma_y \geq$ 100 um^2 for a safe long term dump operation
- size of copper part defined by the 99% energey absorption requirement

e-dump baseline design

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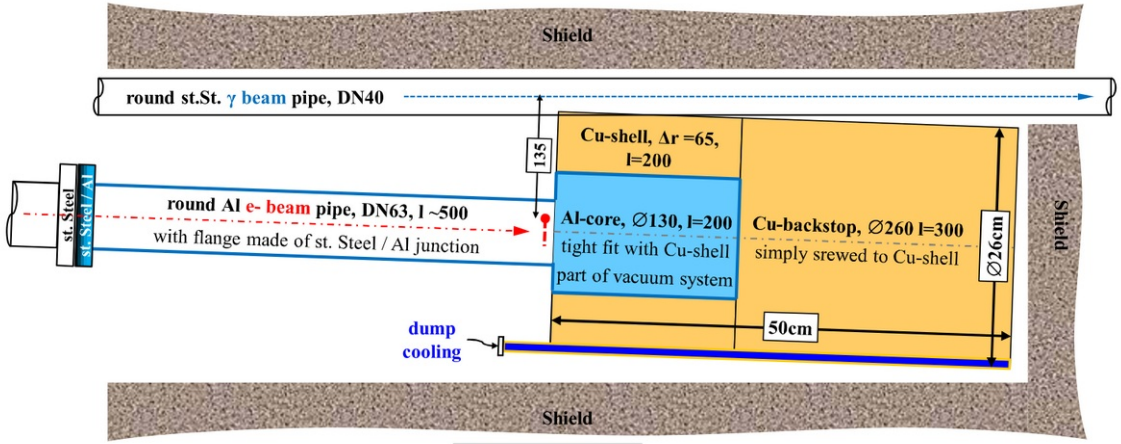
- 99% energy containment
  - Al inner cylinder: 130 mm dia. x 200 mm
  - Cu outer shell: OD: 260 mm x 200 mm
  - Cu backstop: 260 mm x 300 mm length

Property		Al	Cu
ρ	$[\frac{g}{cm^3}]$	2.7	8.96
X_0	[cm]	8.9	1.44
E_c	[MeV]	40	19
R_M	[cm]	4.67	1.61
$R_{99\%}$ (20GeV)	[cm]	23.4	8.1
$L_{99\%}$ (20GeV)	[cm]	156	30



Longitudinal Cut

lenghts without units are in mm

Electron dump work program

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Electron beam dump draft schedule

1. Conceptual design **< spring 2025**

Radiation Modeling and Simulations: to optimize thickness and arrangement of Aluminum core and Copper layer and esteem dose distribution within dump and surrounding area.
Structural Integrity and Safety: vs thermal, vacuum and mechanical loads
Cooling Systems conceptual design, expected dissipated power 175W

2. Final Design **till end 2025**

- **Mechanical Design**: beam dump, support structure, thermal continuity, cooling, vacuum line termination.
- Request of certification by DESY: Material and/or structure and welding certifications …?
- **Integration and Alignment**: way to measure dump wrt to beam position, cooling connections and controls, space for installation and accessability.
- **Cooling Systems**. Final design of cooling loop and components
- **Monitoring system?**: e.g temperature monitor, radiation levels….

3. Production and commissioning **from early 2026**

- **Tendering and production**: find capable and pro-active suppliers for production of beam dump and vacuum line termination: material procurement, machining, welding, assembly, checks and qualification

Photon dump
Options evaluated in 2023

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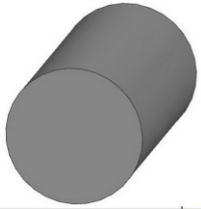
Photon beam dump options: dimensions and masses (work in progress ...)



photon beam dump Full Tungsten D300 x L600	
I.D. diameter	0
O.D. diameter	300
length	600
volume (dm3)	42.4
density	19.2
mass	814.3
OVERALL MASS	814.3

"composite" photon beam dump: Tungsten D200 x L600 + Lead donut to D500	
I.D. diameter	0
O.D. diameter	200
length	600
volume (dm3)	18.8
density	19.2
mass (W)	361.9
I.D. diameter	200
O.D. diameter	500
length	600
volume (dm3)	42.4
density	11.3
mass (W)	479.2
OVERALL MASS	841.1

Full Lead photon beam dump: D500 x L1000	
I.D. diameter	0
O.D. diameter	500
length	1000
volume (dm3)	196.3
density	11.3
mass	2218.7
OVERALL MASS	2218.7

Cost estimates

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Photon beam dump, cost esteem (to update, raw materials quotations @ 2023)

photon beam dump Full tungsten D300 x L600	cost kE vat included		photon beam dump mixed tungsten/lead	cost kE vat included		photon beam dump lead L1000	cost kE vat included
Tungsten cylinder 850 kg	125		Tungsten cylinder D200 x L600, 400 kg	60			
			Lead donut D500 x L600, 1.1 ton	10		Lead cylinder D500 x L1000, 2.2 ton	17

Additional costs:
machining, support carpentry, assembly, checks and test, certificates, packing, shipping … esteem ~30k €

Photon dump work program

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1. Conceptual design — **till Fall 2025**

- **Choice of Materials**: Tungsten and lead due to high atomic numbers and density vs secondary radiation
- Combination of both materials for different layers of the dump to optimize performance wrt cost and dimensions.
- **Dimensions and Geometry**: Size and geometry vs energy and intensity of the photon beam and integration with downstream detectors (***baseline is 600 mm long, Φ200 mm W, Φ500 mm Pb***)
  Quishpe Raquel Estefania @KIT already working on it
- **Thermal Load:** Negligible <1W?

2. Design — **spring 2026**

- **Mechanical Design**: beam dump, support structure. Request of certification by DESY: Material and/or structure and welding certifications …?
- **Structural Integrity and Safety**: vs mechanical loads, seismic loads, etc…
- **Integration and Alignment**: way to measure dump wrt to beam position, space for installation and accessability.

3. Production and commissioning — **2nd half 2026**

- **Tendering and production**: find capable and pro-active suppliers for procurement and machining of tungsten and lead components: material procurement, machining, lead foundry, welding, assembly, checks and qualification

Deliverables

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- program in line with schedule of deliverables included in the proposal

D3.1	Engineering design of the electron dump	WP3	3 - INFN	R — Document, report	PU - Public	24
D3.2	Engineering design of the photon dump	WP3	3 - INFN	R — Document, report	PU - Public	24
D3.3	Electron beam dump	WP3	3 - INFN	DEM — Demonstrator, pilot, prototype	PU - Public	39
D3.4	Photon beam dump	WP3	3 - INFN	DEM — Demonstrator, pilot, prototype	PU - Public	39