Acceleratori & applicazioni

Andrea Ghigo

Laboratori Nazionali di Frascati
Istituto Nazionale di Fisica Nucleare

- La realizzazione dei moderni acceleratori impiegati nella ricerca in fisica nucleare e delle particelle elementari prevede la stretta collaborazione fra gli enti preposti alla loro progettazione e utilizzo e le industrie specializzate nella produzione dei componenti di alta tecnologia che li compongono.
- Il trasferimento tecnologico fra INFN e industria avviene attraverso un processo di scambio collaborativo nel quale si progettano e realizzano apparati che sono spesso pezzi unici e sempre al limite della tecnologia esistente.
- L'industria può poi proporre, nello stesso campo o in altri, la tecnologia così sviluppata.

The INFN Legnaro Laboratory

3 Elettrostatic Accelerators
- **Tandem XTU (16 MV)**
- **Van der Graff (7 MV)**
- **An 2000 (2 MV)**

1 Linac
- **Alpi SC**

1 RFQ injector
- **Piave SC**

Experimental Halls
- **About 10 Detection systems**

An ISOL RIB Facility is planned for construction: SPES

Collaborazioni Scientifiche

RICERCA FORMAZIONE INNOVAZIONE TECNOLOGICA

INFN Laboratori Nazionali di Legnaro

exotic beams for science

Progetto SPES :

fasci esotici e applicazioni

European Organization for Nuclear Research

GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
Spiral2

JINR FLNR Dubna

GSI Helmholtzzentrum für Schwerionenforschung GmbH

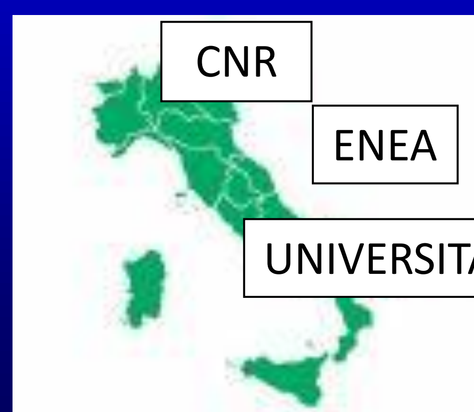
Partecipazioni:

fondazione CNAO

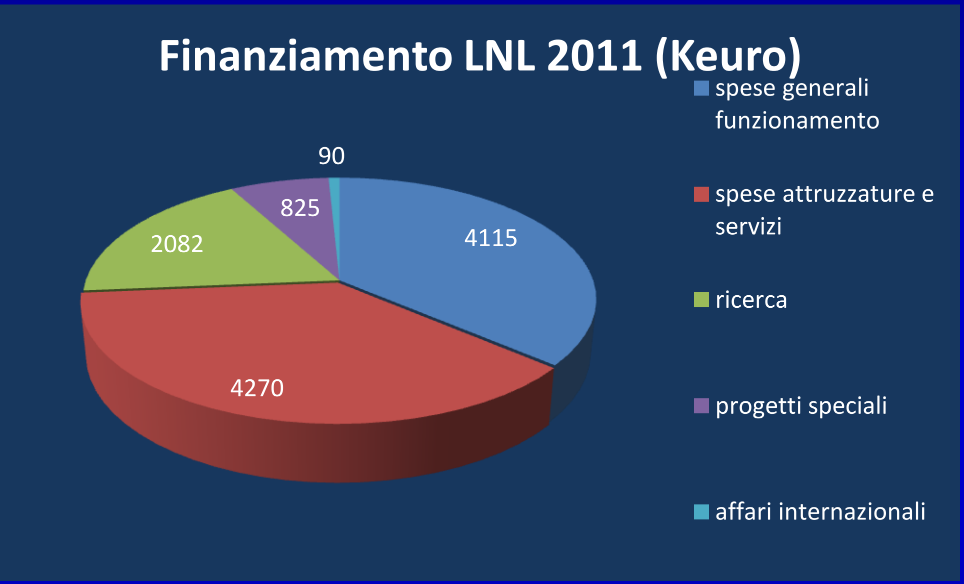
IFMIF

CONSORZIO RFX

Radiofarmaci
Neutroni
Astrofisica
Generation4

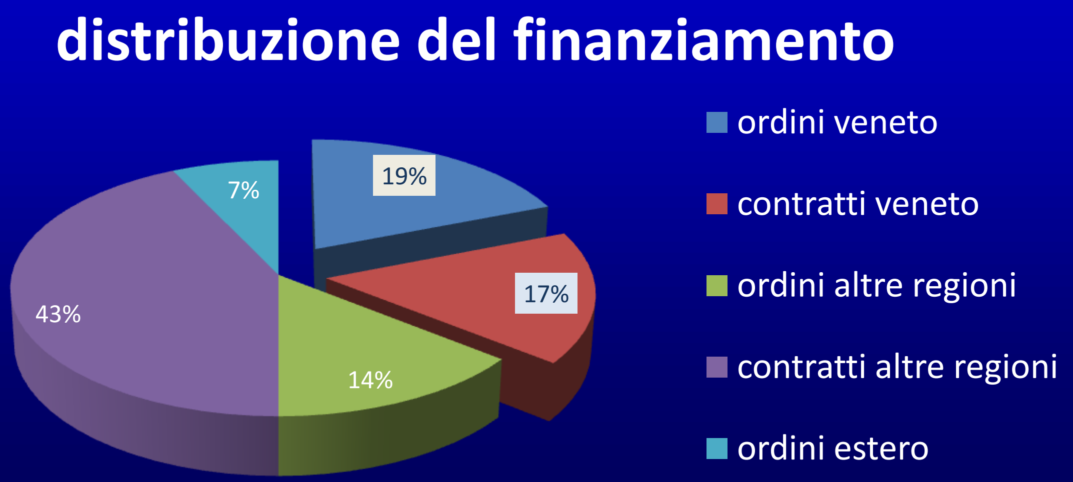


Finanziamento
Laboratori Nazionali di Legnaro



Finanziamento annuo ~ 12 Meuro
Contributo europeo ~10-20%

Piu' del 35% del finanziamento investito per servizi e acquisti nel Veneto



Collaborazioni con attivita' produttive sul territorio

Sviluppo di prodotti ad alto contenuto tecnologico e di innovazione

INFN Laboratori Nazionali di Legnaro

EUROGRAFITE (Mussolente, Vi)
Graphite machining

ALCA (Schio ,Vi)
High precision machining

CINEL (Padova)
Strumenti Scientifici

ZANON (Padova)
Electron Beam Welding

CSC (Padova)
Electron Beam Welding

PICCOLI (Noale)
Lavorazioni in lastra

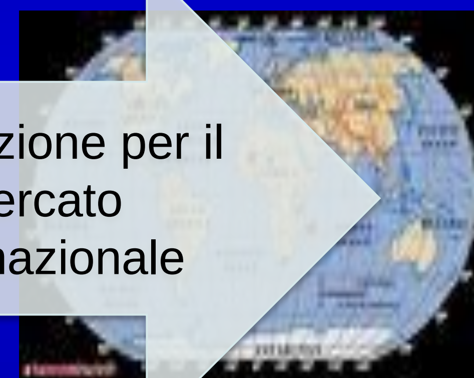
Metalpebo (Saletto,Pd)
Lavorazioni in lastra

SPES exotic beams for science

IRST (Trento)
Silicon detectors

CAEN (Viareggio)
Elettronica

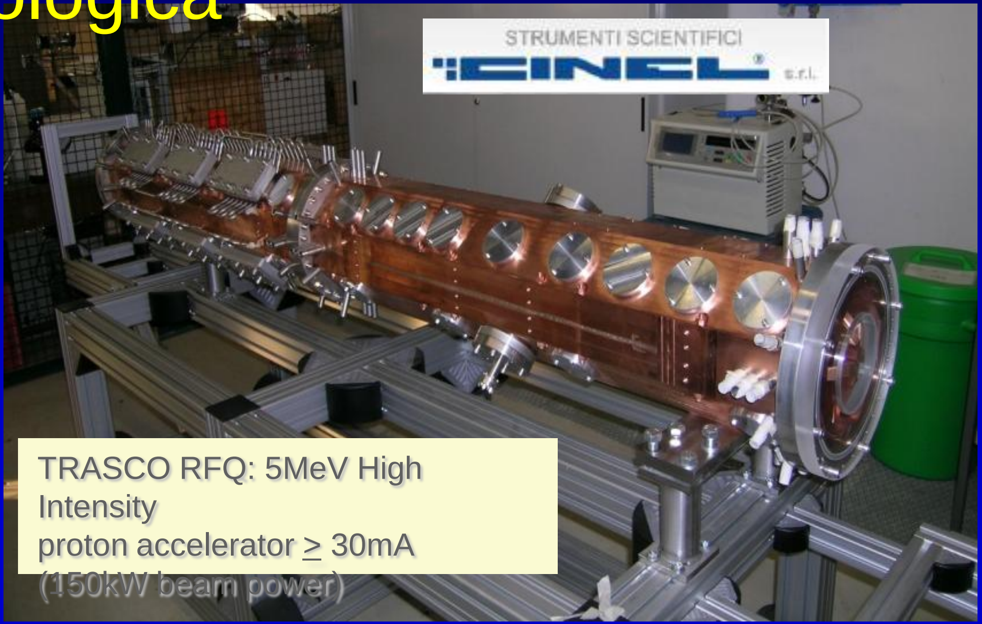
SINTERSUD (Caserta)
Cemented Carbides



Innovazione per il mercato internazionale

Alcune collaborazioni con industrie venete
per l'innovazione tecnologica

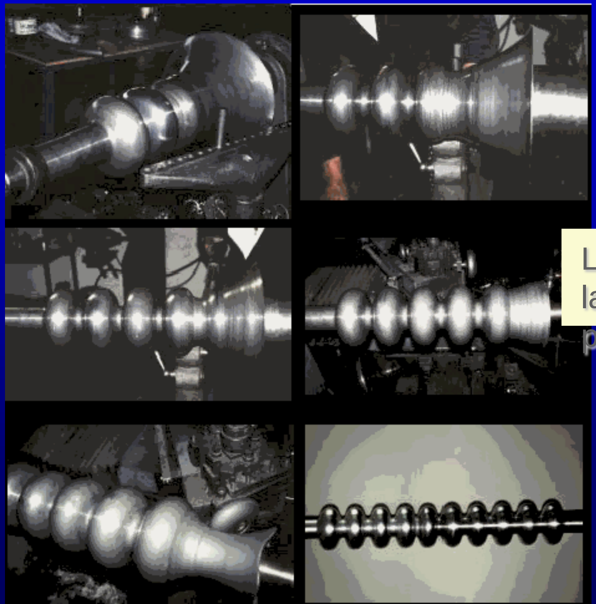
Camera Bersaglio per SPES e ISOLDE-CERN. Temperatura di lavoro del bersaglio 2000ºC , progettazione radiation-hard



TRASCO RFQ: 5MeV High Intensity
proton accelerator ≥ 30mA (150kW beam power)

E. ZANON
SINCE 1919

Saldatura di cavita' Risonanti per acceleratori



Lavorazioni in lastra ad alta precisione

INFN
Istituto Nazionale di Fisica Nucleare

SPES ISOL facility @ LNL

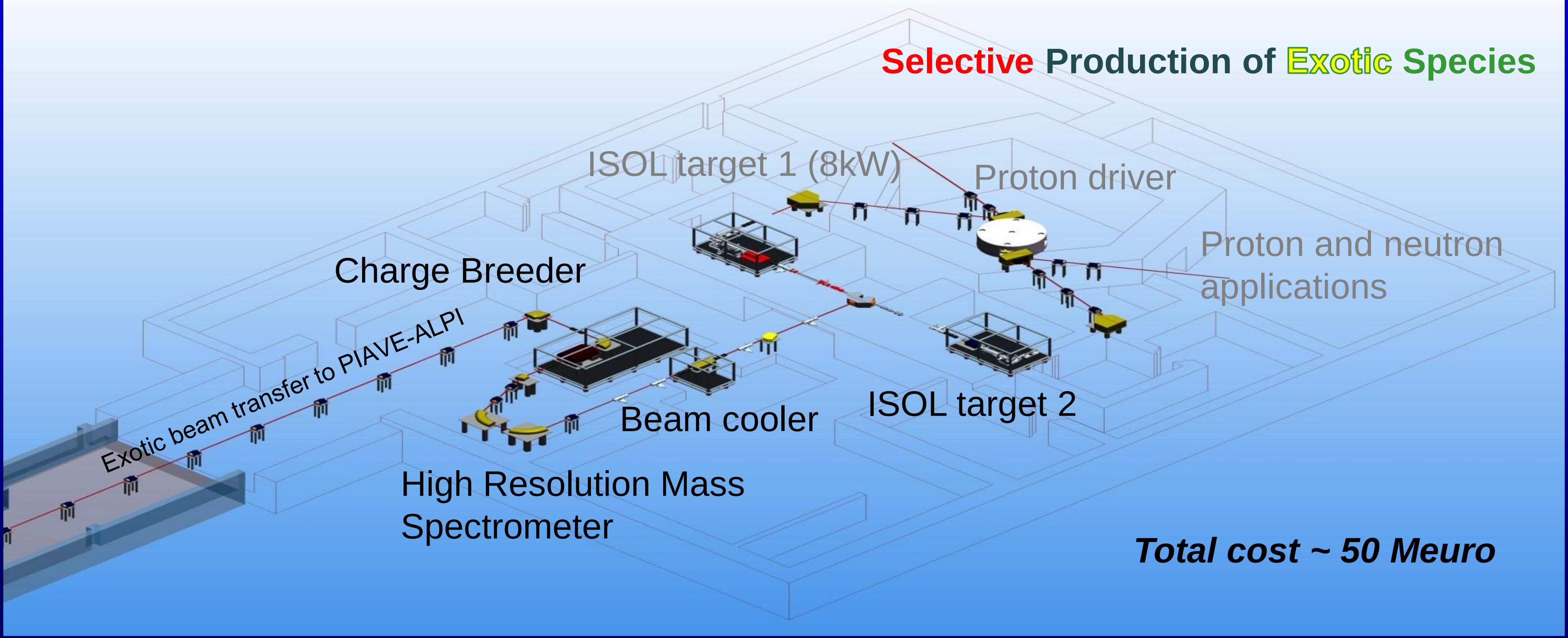
A second generation ISOL facility for neutron-rich ion beams and an interdisciplinary multi-user research center

ISOL BEAM FACILITY

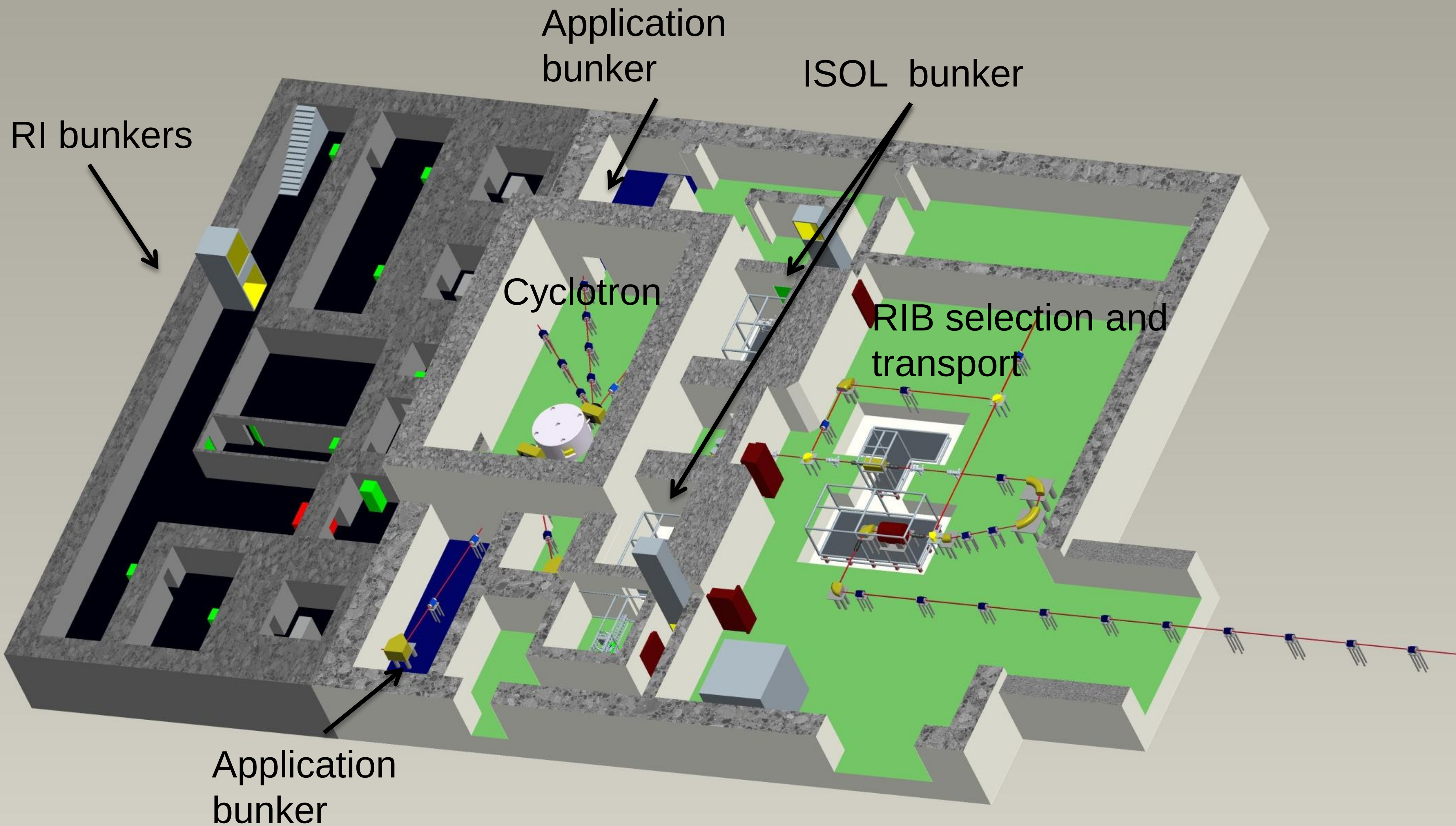
***Primary Beam*: 750 μA, 70 MeV protons from a 2 exit ports New Cyclotron**

***8kW Direct Target*: UCx 10^{13} fission s^{-1}**

***Re-accelerator*: Existing ALPI Superconductive Linac E>10 AMeV for A=130**



SPES Layout, Level -1



Artistic View of the facility

Il Progetto SPES Project

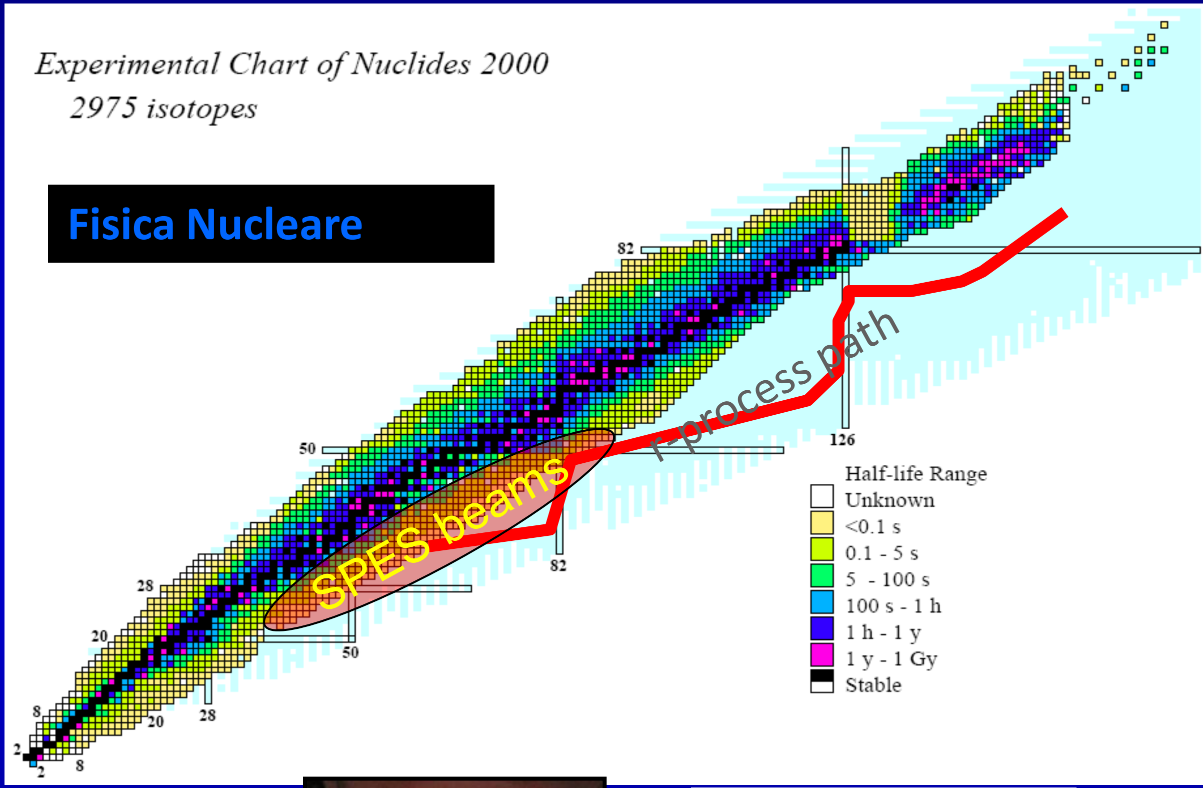
Un progetto multidisciplinare

SPES exotic beams for science

INFN Istituto Nazionale di Fisica Nucleare

CICLOTRONE

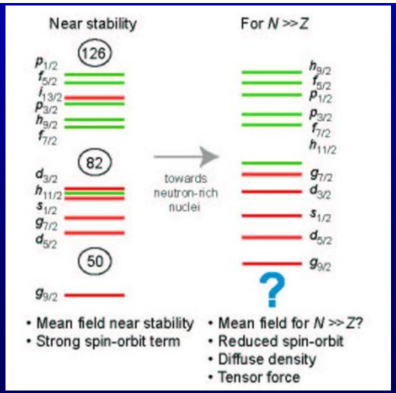
Protoni 70 MeV 750 μA



Fisica Nucleare

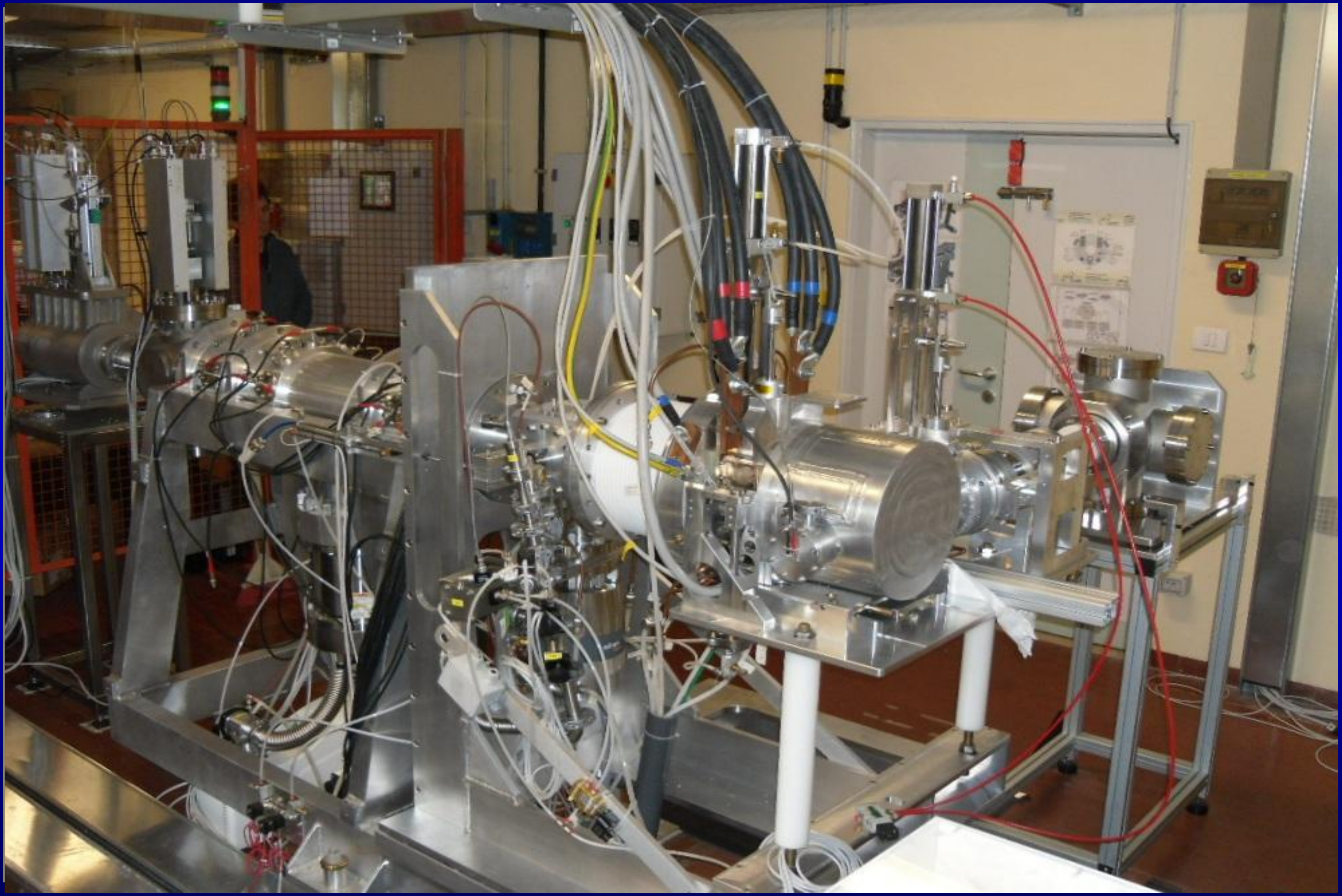
Studio di radioisotopi per la medicina
Studio dei materiali con protoni e neutroni
Studio dei Carburi
ad alta temperatura

PYROMETER

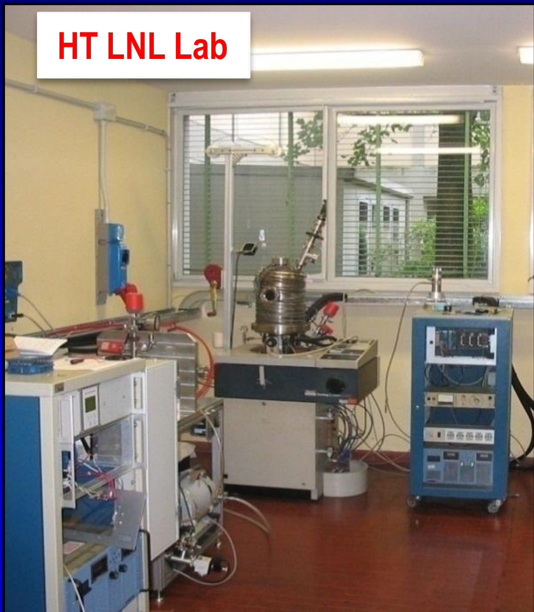


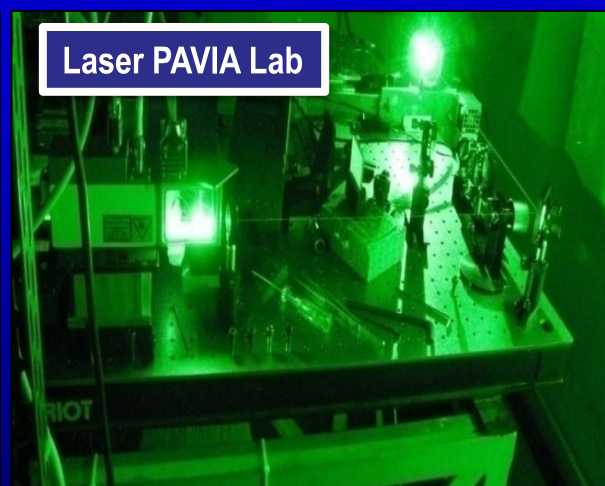
The SPES Front end

ISOL target



The TIS SPES Laboratories





The SPES Cyclotron: main data

- Accelerated particles: H$^-$

- Variable Energy: 35 MeV - 70 MeV
- Maximum beam current accelerated >700 µA
- Maximum beam current at the exit port 500 µA

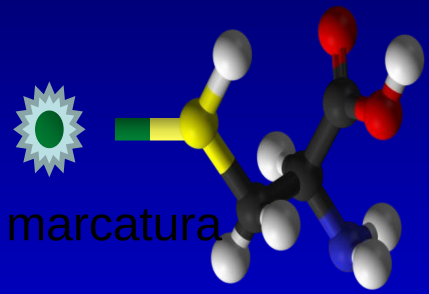
- Extraction system:
  - Stripper → H$^-$
  - Beam shared on two exit ports

- Performances:
  - exit1: 300µA H$^-$ 40MeV
  - exit2: 400µA H$^-$ 70MeV
  - **Dual beam operation**
  - **Running time > 5000 h/year**
  - **Minimum Beam Loss (< 5%)**

CONTRACT started 28 October 2010
DELIVERY 3-4 years (shedule to be fixed according to building)
COST: 10,5Meuro (con IVA)

Actual status: Project evaluated
Construction started

Nuovi Radioisotopi per la medicina



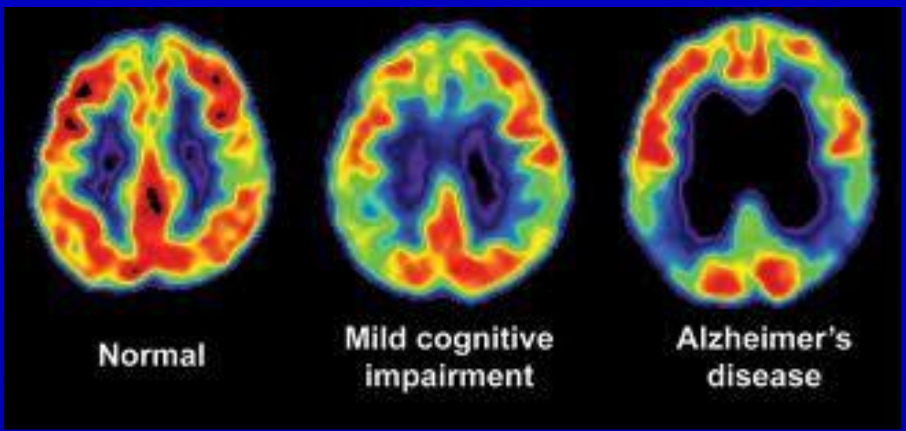
Progetto LARAMED

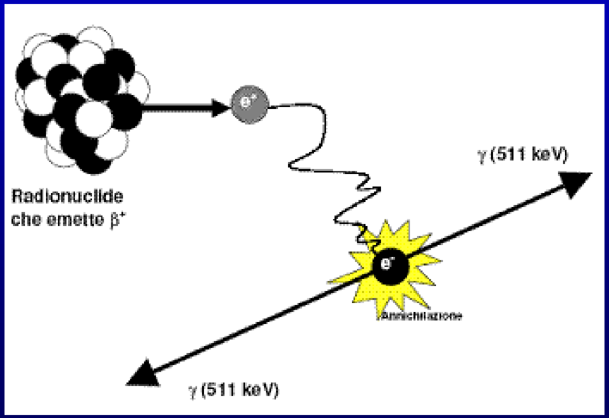
OBIETTIVI:

Produzione di radioisotopi innovativi per la ricerca in medicina nucleare.

Campo di applicazione in diagnostica e terapia oncologica.

PET: positron emission tomography

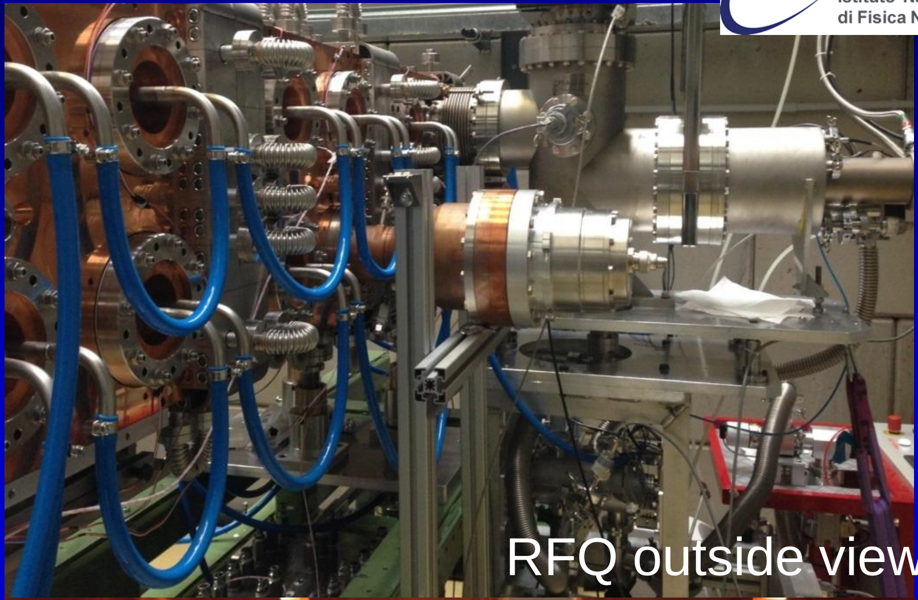


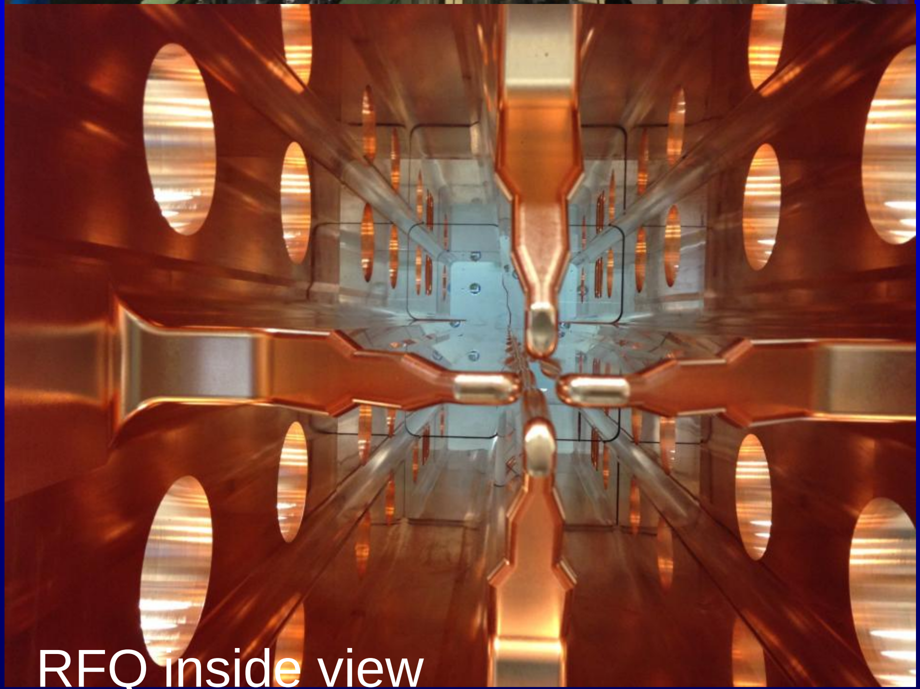


Radionuclide	Target nucleus	Nuclear Reaction	Cross section (mbarns)	Needed energy (MeV)
^{64}Cu	Ni	$^{64}Ni(p,n)$	≈ 675	15
^{68}Ge	Ga	$^{69}Ga(p,2n)$	≈ 550	30
^{82}Sr	RbCl	$^{nat}Rb(p,4n)$	≈ 98	70
^{67}Cu	ZnO	$^{68}Zn(p,2p)$	≈ 10	70
^{44}Sc	Ca	$^{44}Ca(p,n)$	≈ 700	12
^{47}Sc	Ti	$^{48}Ti(p,2p)$	≈ 20	70

Industrie coinvolte in IFMIF EVEDA

- Il progetto IFMIF EVEDA comporta la costruzione **in Giappone** di un linac di 9 MeV per deutoni di intensità mai raggiunta (130 mA). Sorgente di neutroni per il test dei materiali dei futuri reattori di fusione
- L'INFN ha in carico la realizzazione e test dell'RFQ (Radio Frequency Quadrupole), corrispondentemente ad un contributo italiano in-kind di circa **25 M€.**
- La sorgente ha dato il suo primo fascio nei giorni scorsi, l'RFQ sarà in funzione nei primi mesi 2016.
- Molte ditte italiane sono state coinvolte per molte forniture grandi è piccole.
- Fra tutte citiamo le due principali
  - **Cinel SRL per la costruzione e brasatura di moduli dell'RFQ**
  - **La DB elettronica per la fornitura del sistema RF di potenza (220kW, 175 MHz)**

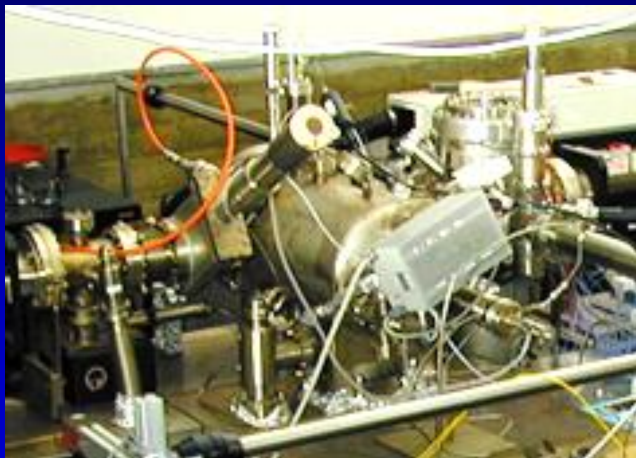

RFQ outside view

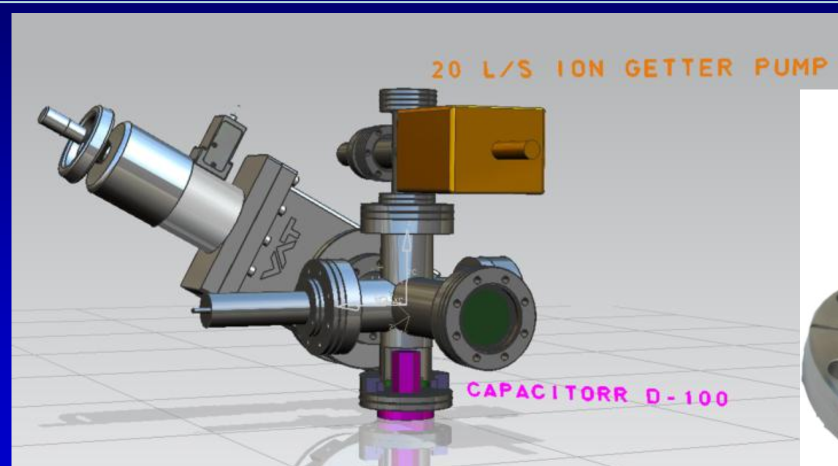

RFQ inside view

INFN – LASA and SAES GETTERS

- Well established collaboration, active since more than 30 years.
- Started in the 80’ with application and criticalities studies of Non Evaporable Getter (NEG) pump for the K800 Cyclotron CS, now at LNS.
- Collaboration is now active on long lifetime high quantum efficiency semiconductor photocathodes, on non evaporable getter (NEG) pumps optimization (particle loss), on ion pump studies and optimization (geometry, electrode material choice, regeneration and regurgitation effects) and the study of methods for “non conventional” vacuum systems design
- Future activities on ion pump optimization and on the coupling of ion pumps with NEG are foreseen.

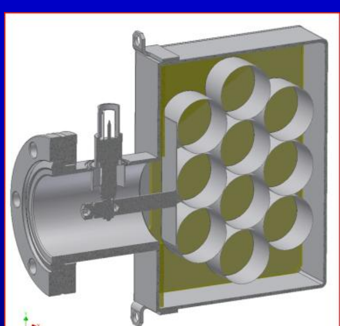
INFN – LASA and SAES GETTERS

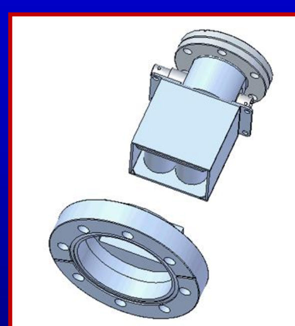


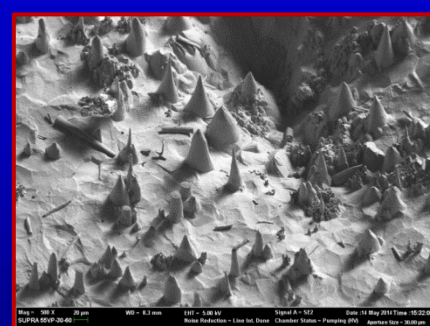


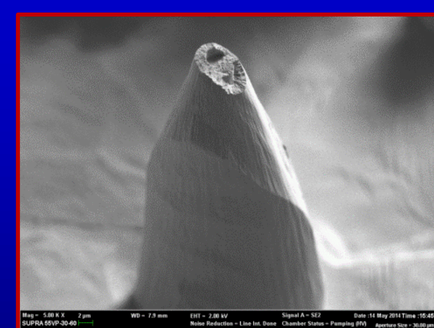
XUHV (10^{-12} mbar) Photocathode preparation chamber

UHV transportation system designed to be compatible with airplane with the NEG pump









Dismountable ion pump designed for the optimization of its geometry, for testing different cathode materials, for studies of instabilities. (Courtesy of T. Porcelli)

INFN – LASA and Ettore Zanon (EZ)

Long time collaboration, started in the 80' with cryostat and RF cavities construction for the CS, the Superconducting Cyclotron, the LEP cavities prototypes, the TESLA 9 cell cavities, going through the Trasco/ADS SC cavities (700 MHz), the development and production of ancillaries for SC cavities (blade tuners), the cryomodules and SC cavities for FLASH (DESY), etc.

Currently INFN - LASA has the responsibility for the in-kind contribution to the XFEL project of 400 SC cavities, cryomodules, and other ancillaries (**33 M€**). Large part of them had been built in collaboration with Ettore Zanon firm.

- 400 XFEL 1.3 GHz SC Nb bulk cavities
- 50 cryomodules (cold mass + vacuum chamber) for XFEL
- 10 third harmonic Nb cavities (3.9 GHz) with blades tuners
- One cryomodule for 3.9 GHz cavities

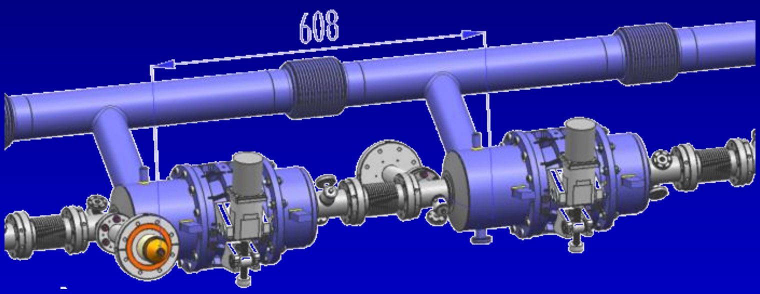
For the XFEL activity EZ built a dedicated infrastructure with 450 m^2 clean room, Electron Beam Welding machine, HV furnace, Ultra pure water and chemical plants. The design, qualification and rump-up had been done within the INFN/DESY collaboration with EZ.

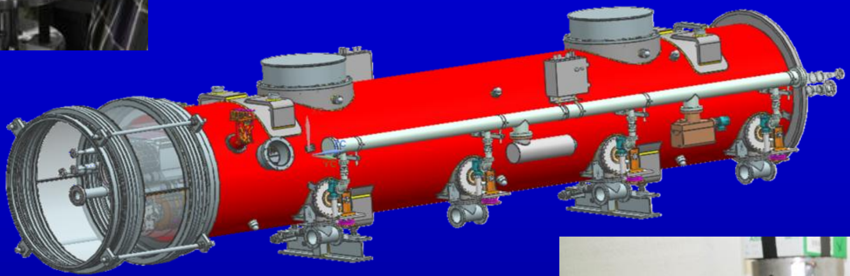
Future development could be on the ESS project, LCLS2.

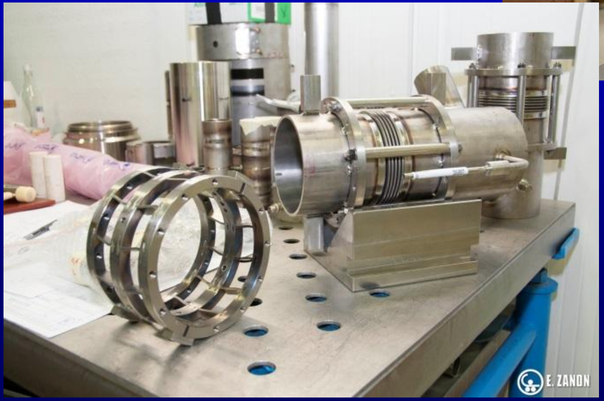
E. ZANON

INFN Istituto Nazionale di Fisica Nucleare

INFN – LASA and Ettore Zanon (EZ)







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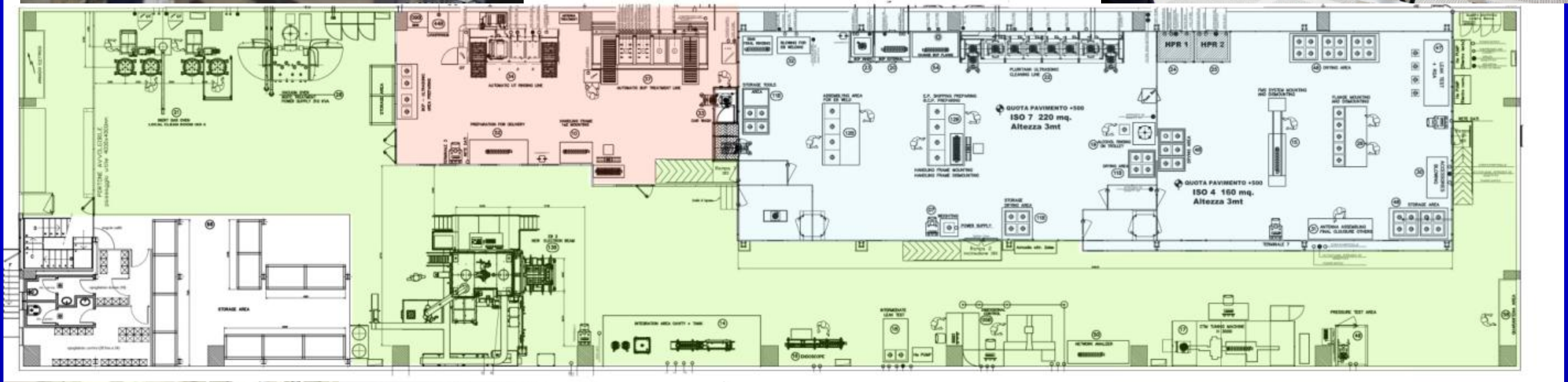
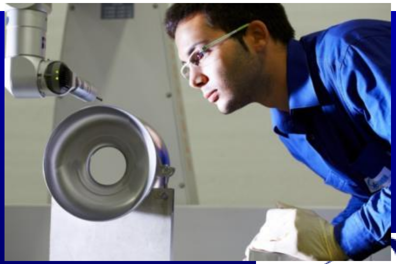
Istituto Nazionale
di Fisica Nucleare

INFN – LASA and Ettore Zanon (EZ)





E. ZANON

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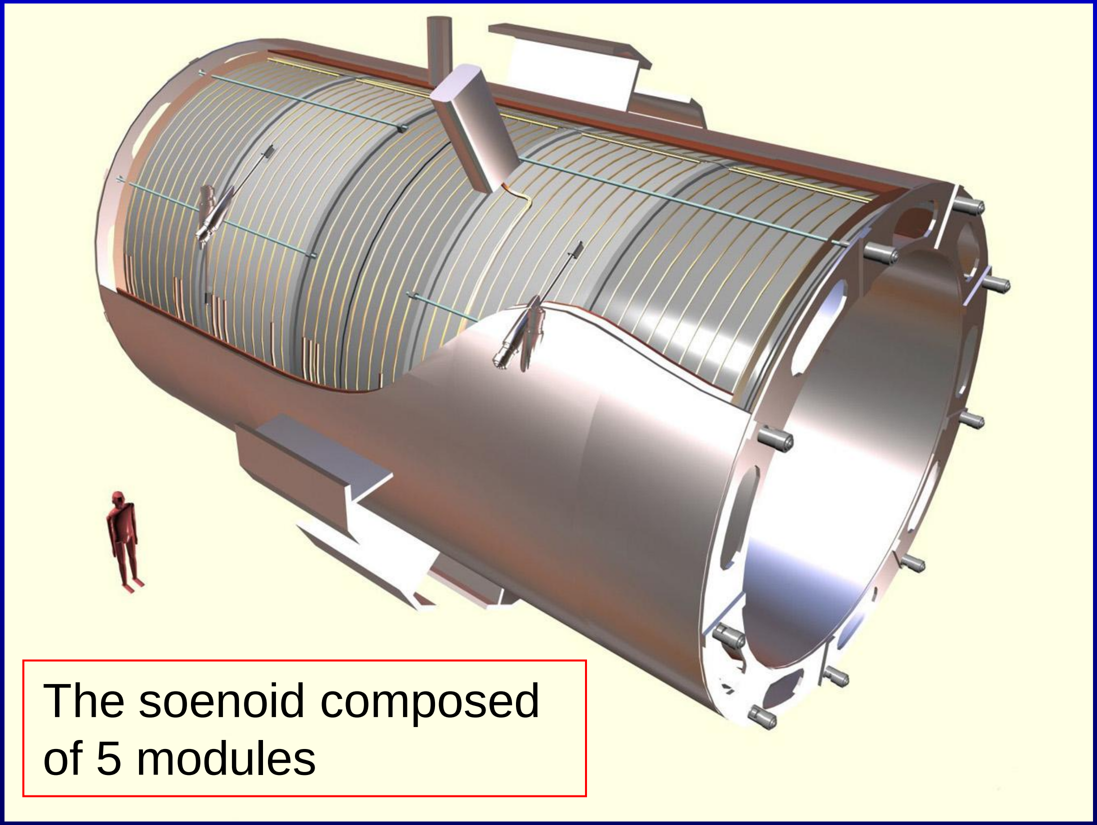
Istituto Nazionale di Fisica Nucleare

The superconducting solenoid for CMS experiment at LHC: INFN-Genova

The superconducting solenoid for CMS experiment at LHC is the largest solenoid ever done: Inner useful diameter 6 m, Length 12.5 m, Weight 250 ton (only coil, excluded the cryostat)



The soenoid composed of 5 modules

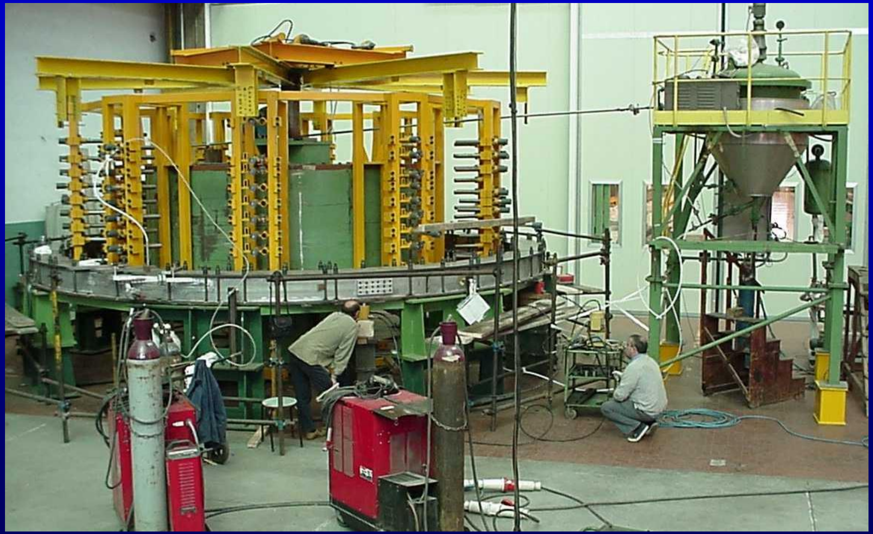
This magnet has the record of stored energy (2.6 GJoule).

The solenoid generate a magnetic field of 4 T.

A curent of 20 kA flows in its windings.

Industrial R&D activities

The winding of the solenoid required a long R&D activity performed by INFN in cooperation with industry (Ansaldo Magneti now ASG Superconductors). The winding methods were developed and a prototype coil was built (1997-1999)



Module construction (2000-2005)

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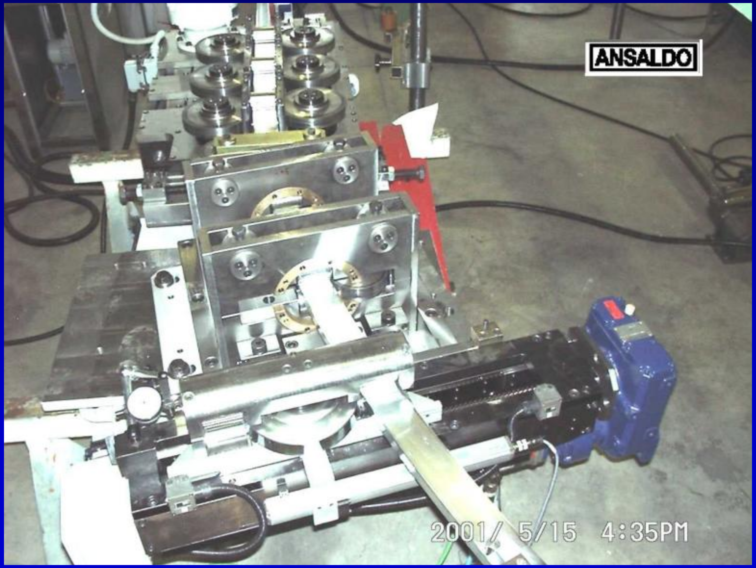


Assembly of modules at CERN (2005-2006)

The magnet was successfully tested in 2006 and performed excellently during the LHC run concluded with the discover of the Higgs boson.

The Laboratori Nazionali del Sud Superconducting Cyclotron

Bending limit	K=800
Focusing limit	Kfoc=200
Pole radius	90 cm
Yoke outer radius	190.3 cm
Yoke full height	286 cm
Min-Max field	2.2-4.8 T
Sectors	3
RF range	15-48 MHz

Versatility (light and heavy ions in a wide energy range)

Reliability (protontherapy)

High intensity (radioactive beams)

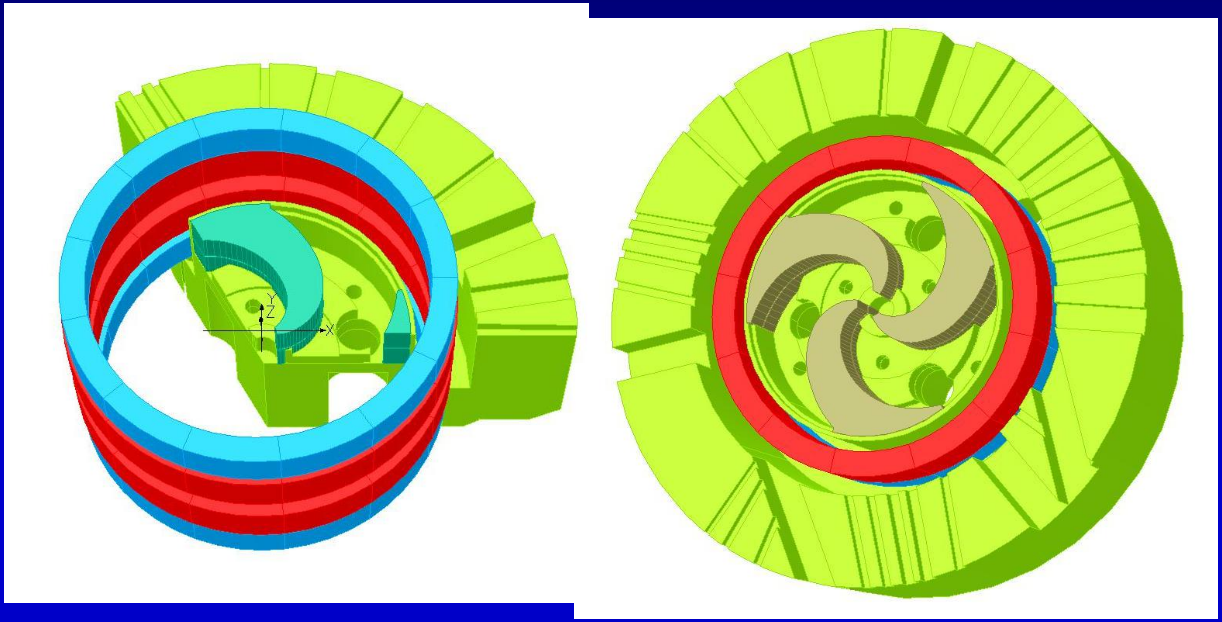
Superconducting Cyclotron upgrade: a new s.c. magnet

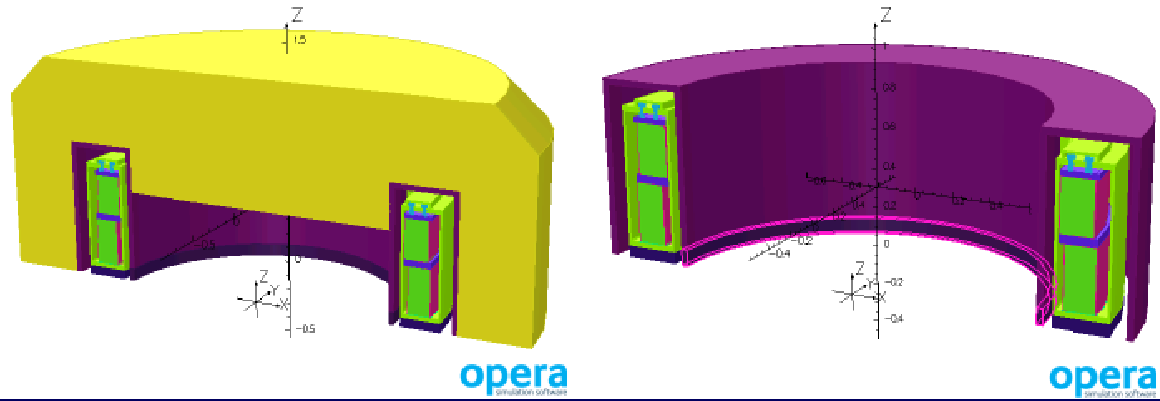
The upgrade is intended to increase the intensity of light ion beams.

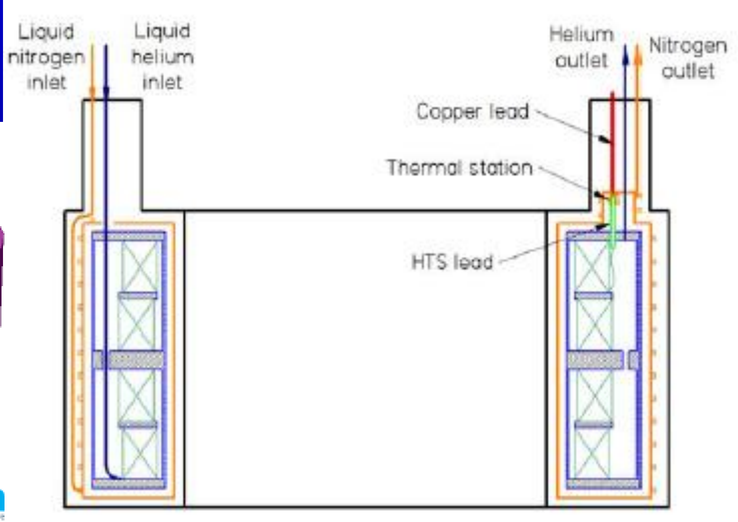
This can be provided by Extraction by stripping.

A new cryostat including s.c. coils is needed to accomodate the new extraction trajectories.

A conceptual design study has been accomplished in collaboration with MIT – USA.

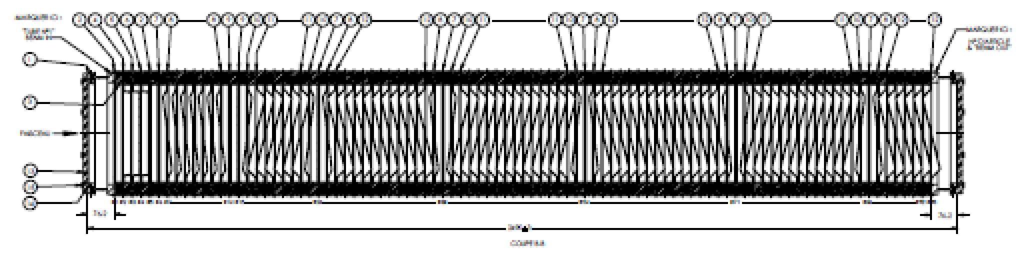






LNS Tandem upgrade : a new Accelerator Tube

Tube n. 1 damaged : high residual pressure in the Low Energy section due to vacuum losses
Order to VIVIRAD, France, dated December 20th 2013: 237.000,00 € for 2 accelerator tubes - Delivered in May 2014



Replacement from the L.E. side

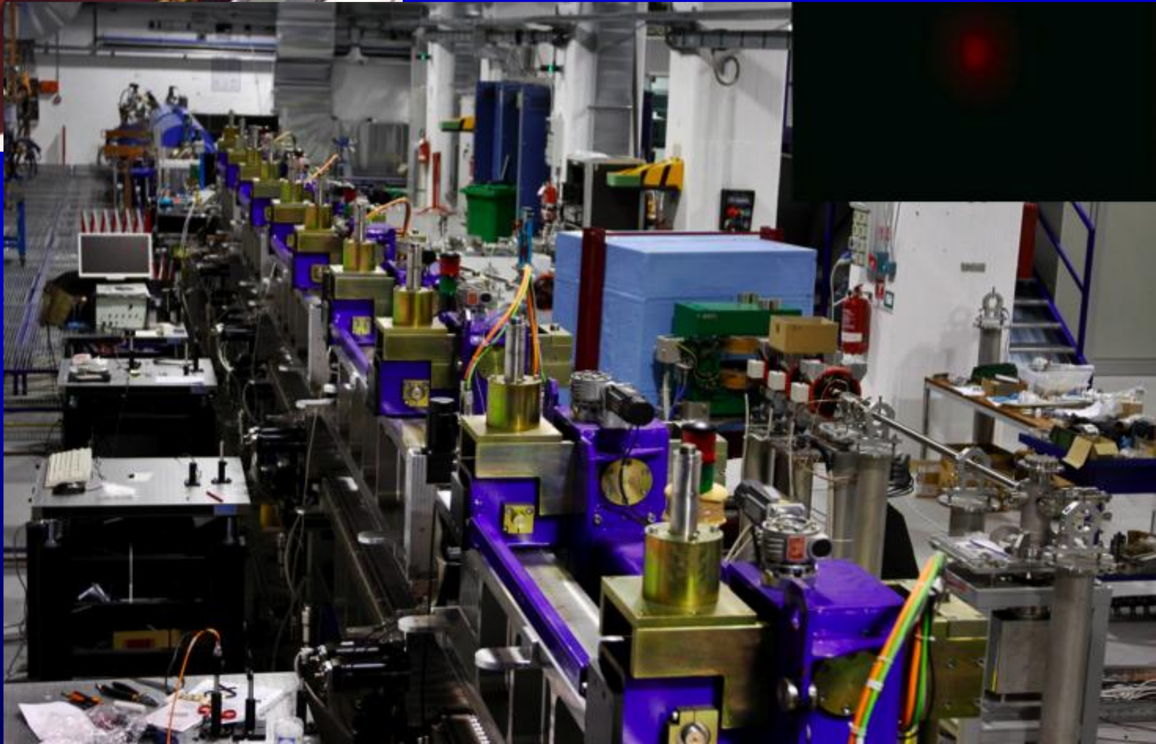
Dedicated system manufactured to remove the old tube and assemble the new one

July 9 2014 – The new tube positioned inside the Tandem

LNF FRASCATI

DAΦNE

e+e- high luminosity
Collider @ 1 GeV



SPARC-LAB

Free Electron Laser
Plasma acceleration
Thomson scattering
THz Facility

ELI-NP

Magurele - Romania

20 MeV Gamma photons source based on Thomson scattering

EuroGammas consortium participants:

INFN: LNF,Fe,Mi,CT,Fi

CNRS: LAL Orsay

Università “la Sapienza”

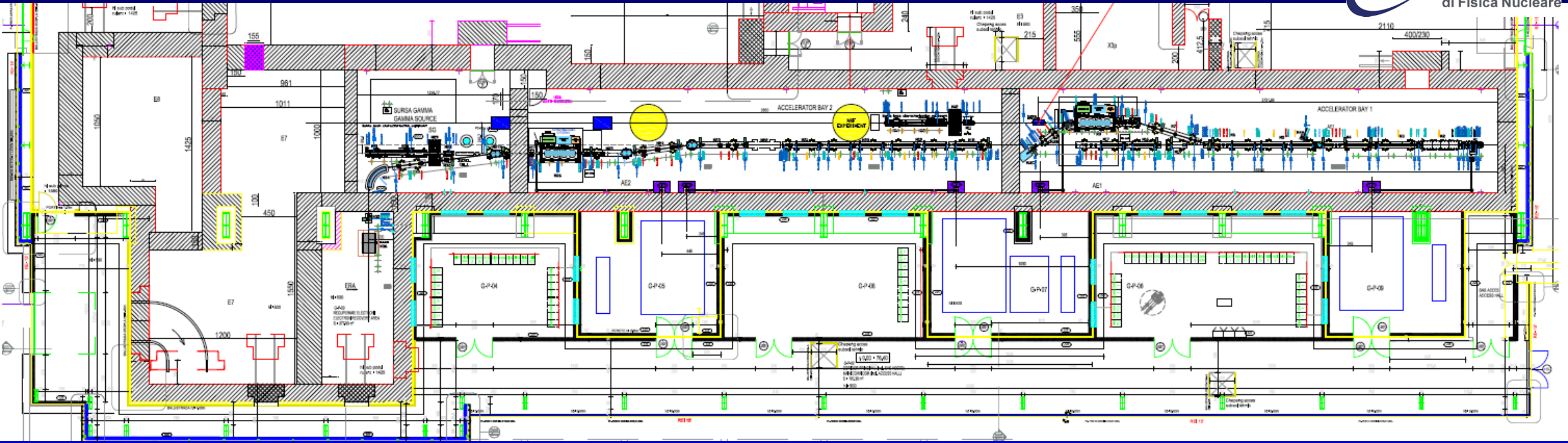
Alsyom

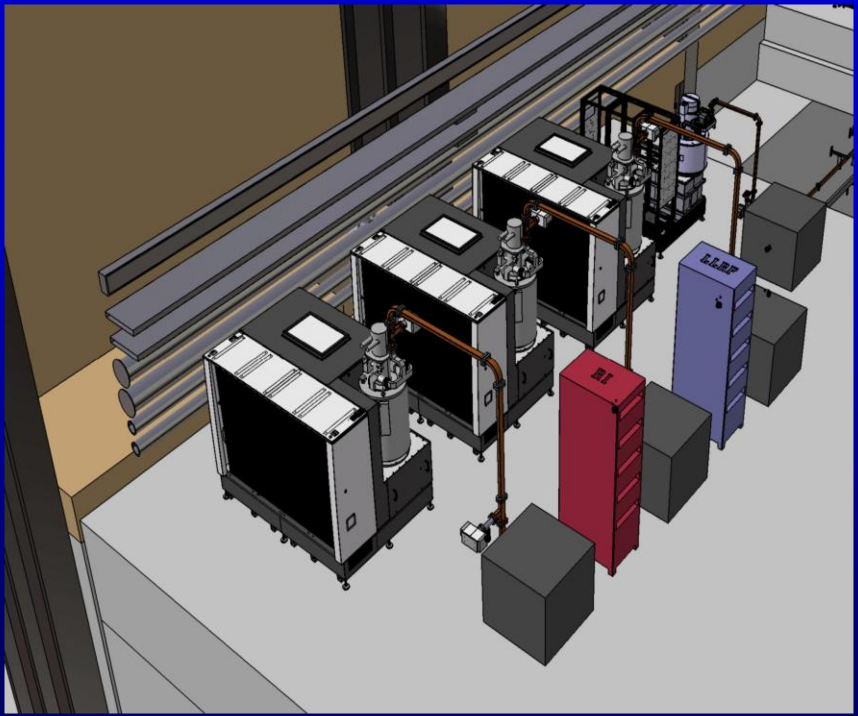
ACP-Amplitude

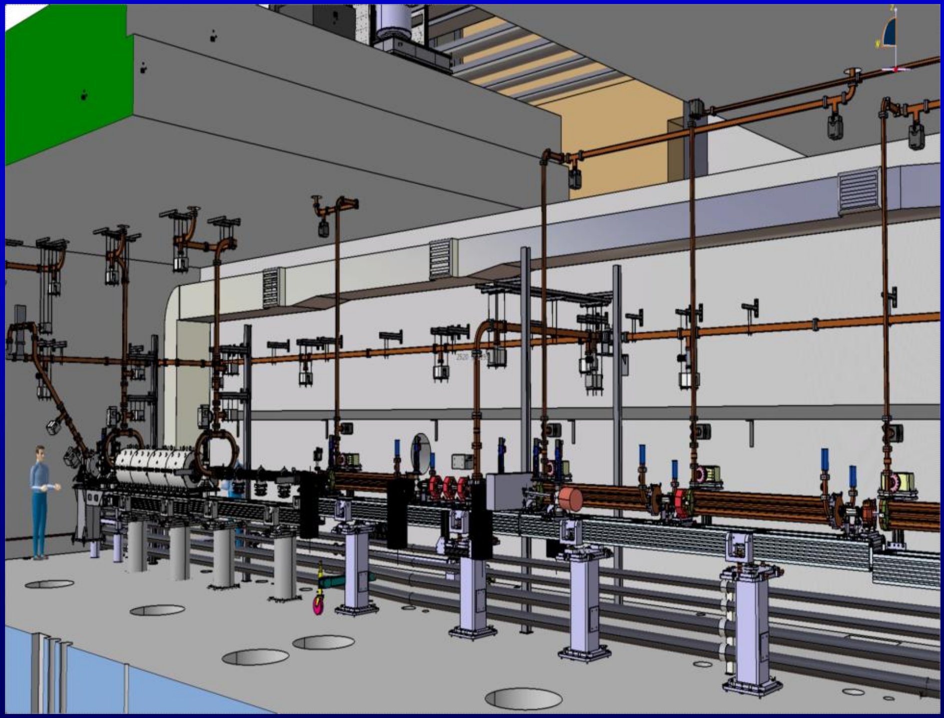
COMEB

Scandinova

Gamma source layout: 720 MeV Linac

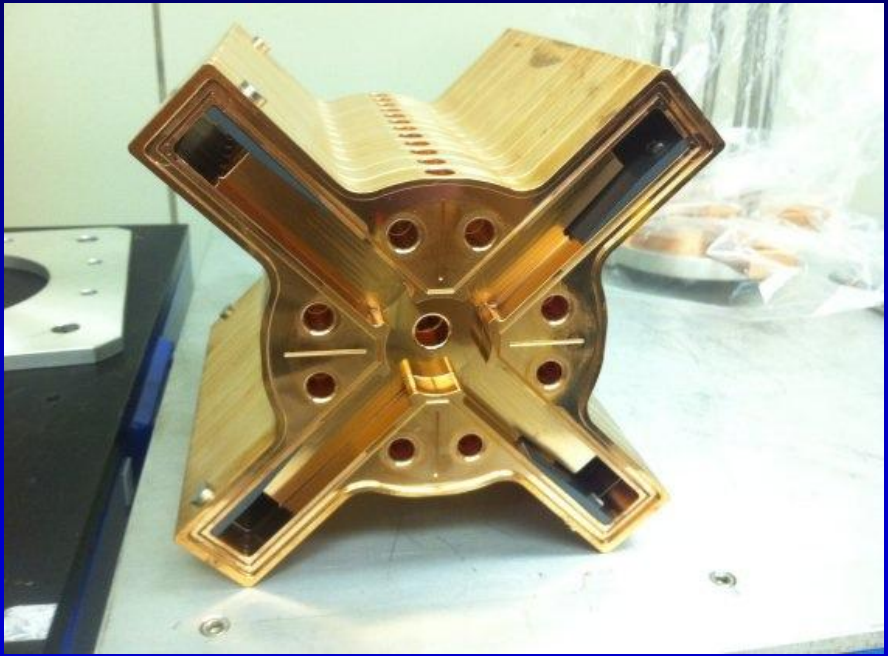


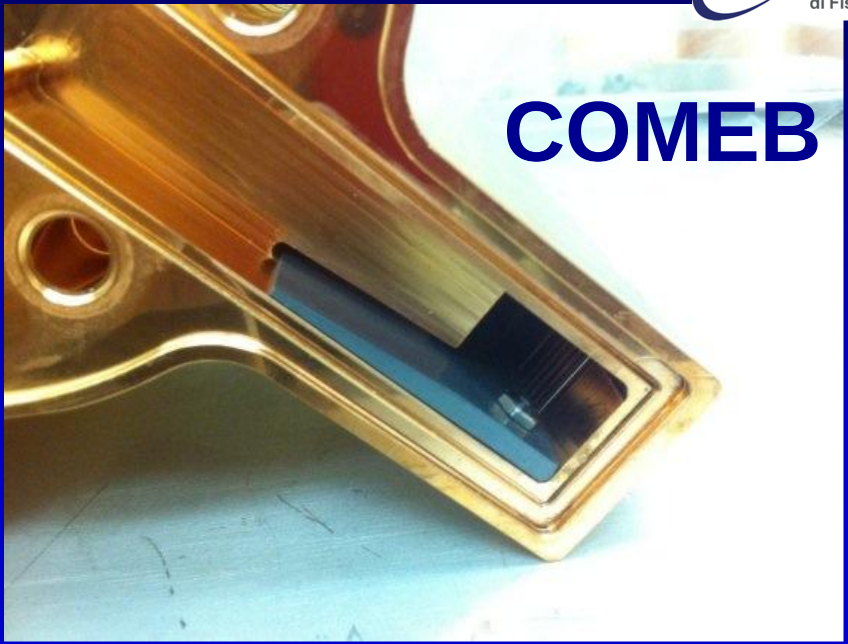




TW accelerating structures fabrication

INFN Istituto Nazionale di Fisica Nucleare



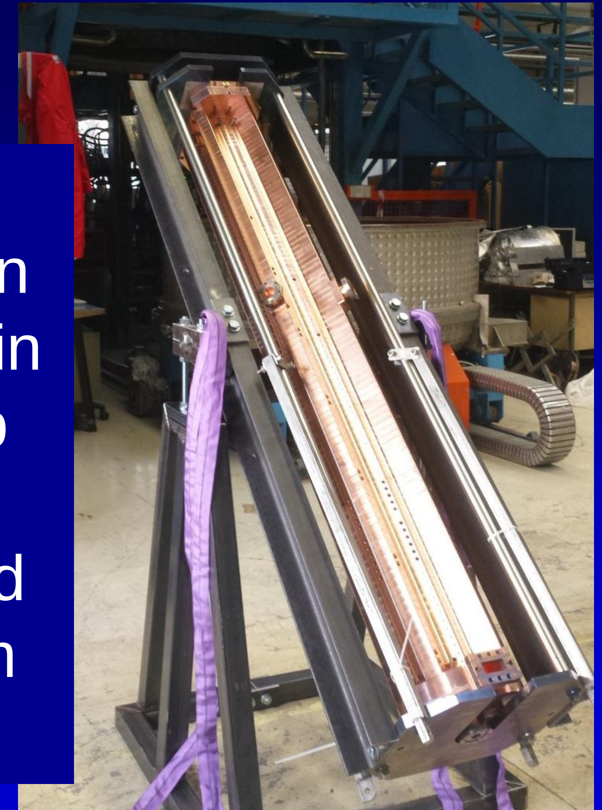


C-Band Accelerating structures with HOM dampers

INFN
Istituto Nazionale
di Fisica Nucleare

Full C-Band accelerating section Brazing procedure in INFN Legnaro lab

First section brazed now under vacuum test



The STAR Project:
Southern european **T**homson source for **A**pplied **R**esearch

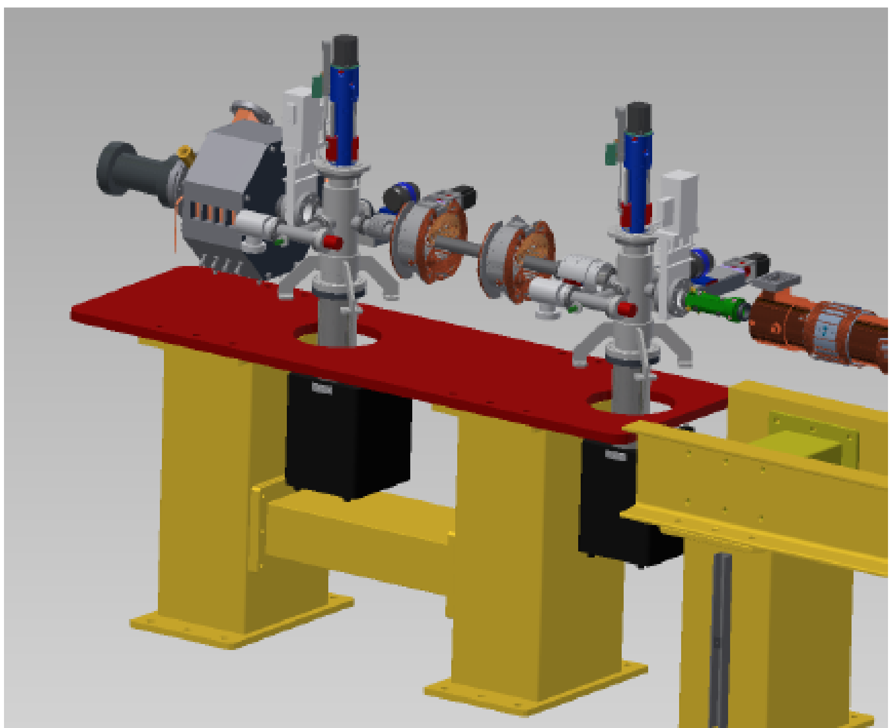


Table 1: Specifications of the RF Photoinjector System

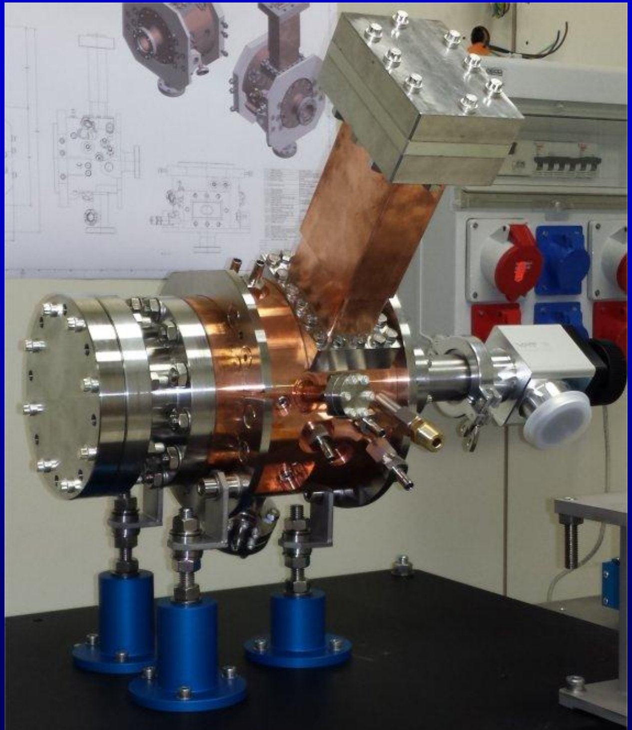
Parameter	Value
Input power	9.5 MW
Output Energy	5 MeV
Operating Frequency	2.856 GHz
Normalized emittance*	≤ 1.0 micron at 500 pC
Repetition rate	Up to 100 Hz
Quality factor Q_0	13,800
Shunt impedance R'_{shunt}	60 MΩ/m
Peak surface field	102 MV/m
Peak cathode field	120 MV/m
External coupling factor (β)	2.0
Operating temperature	40° C
Materials	OFHC grade 1 copper, cross-forged 316L SST flanges, Aluminum stands
Magnetic permeability of flange material	< 1.05
RF flange type	LIL
Braze materials/steps	3-steps: 25/75, 35/65, 50/50 Au/Cu
Material certs	To be delivered to customer
Fasteners	All metric
Warranty	1 year from delivery

Photoinjector

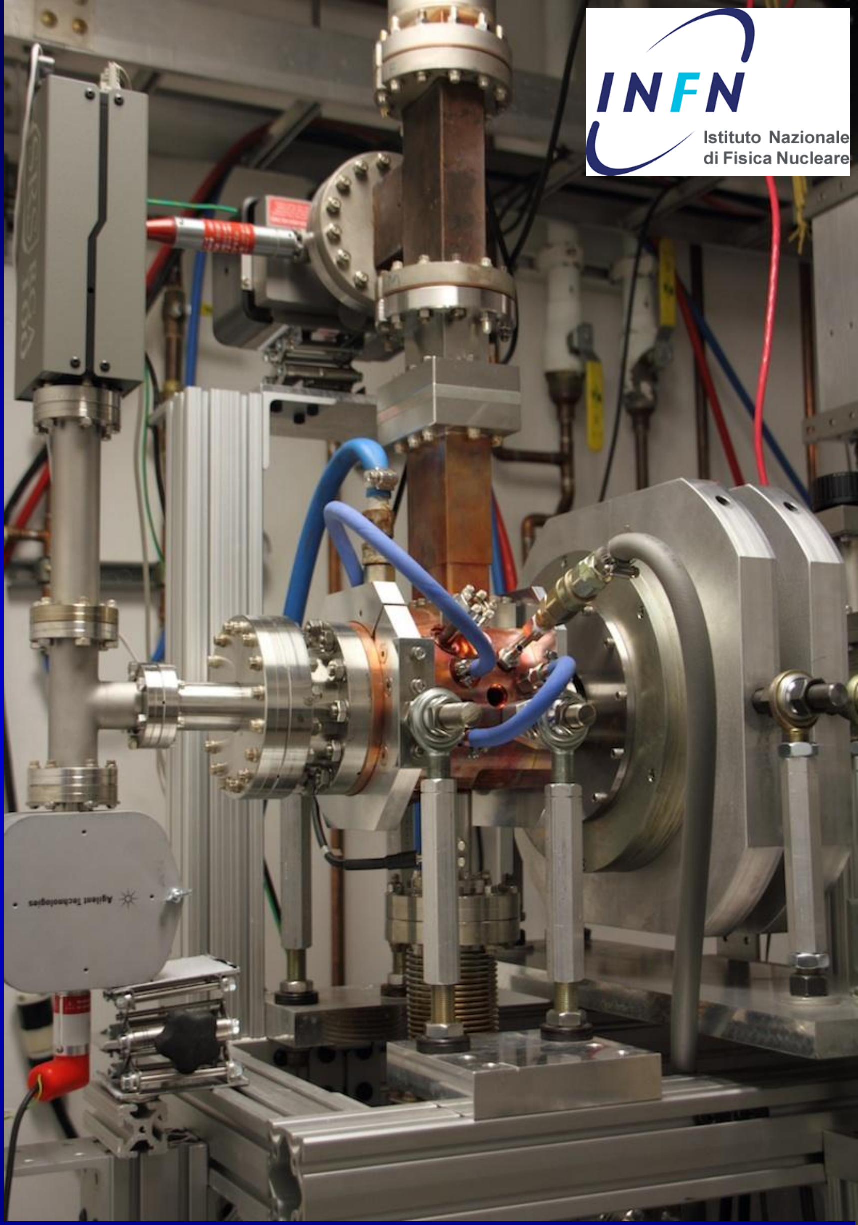
ELI & STAR: S Band GUN

The RF GUN of the ELI NP GBS will be a 1.6 cell gun of the BNL/SLAC/UCLA type implement several new features recently integrated in the new gun developed for the SPARC photo-injector

the structure has been realized without brazing but using special gaskets.



COMEB



Test of the new gun successfully done at UCLA reaching 92 MV/m peak cathode electric field

ESRF ARC VACUUM CHAMBER DESIGN @ LNF-INFN

Our proposal is to verify the feasibility of the arc vacuum chambers realization in aluminum instead of stainless steel.

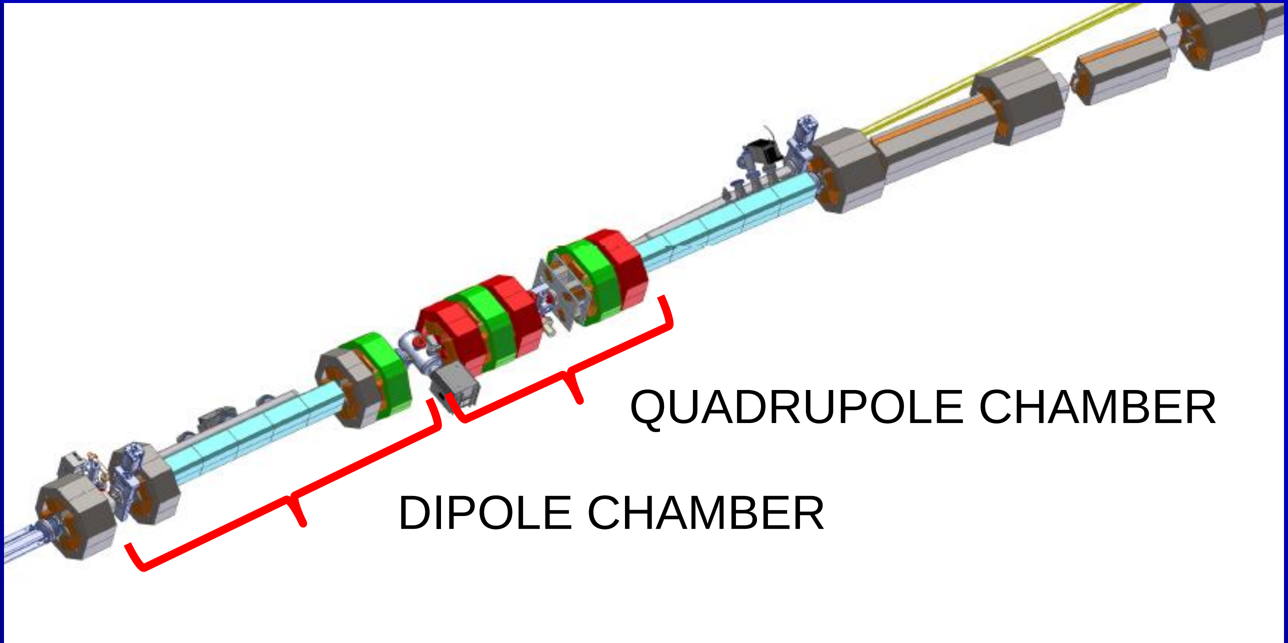
The aluminum would have many advantages summarized below:

1-Reduction of costs

2-Reduction design time

3-Reduction of realization time

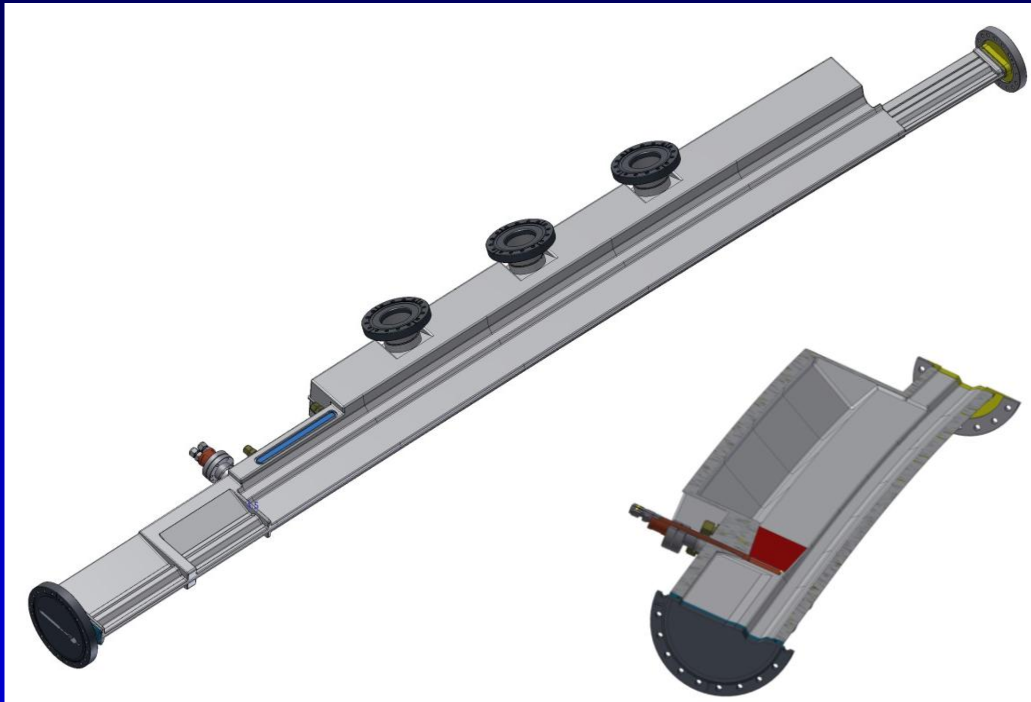
4-Reduction of the time to acquire the material



5-Better performances for the "resistive wall“ impedance

6-Completely a-magnetic material

7-Better Performance from the vacuum point of view



Dipole & quadrupole Vacuum chamber

-The chamber follow the beam trajectory w/o discontinuities

-The flanges can be conflat of alluminum flanges

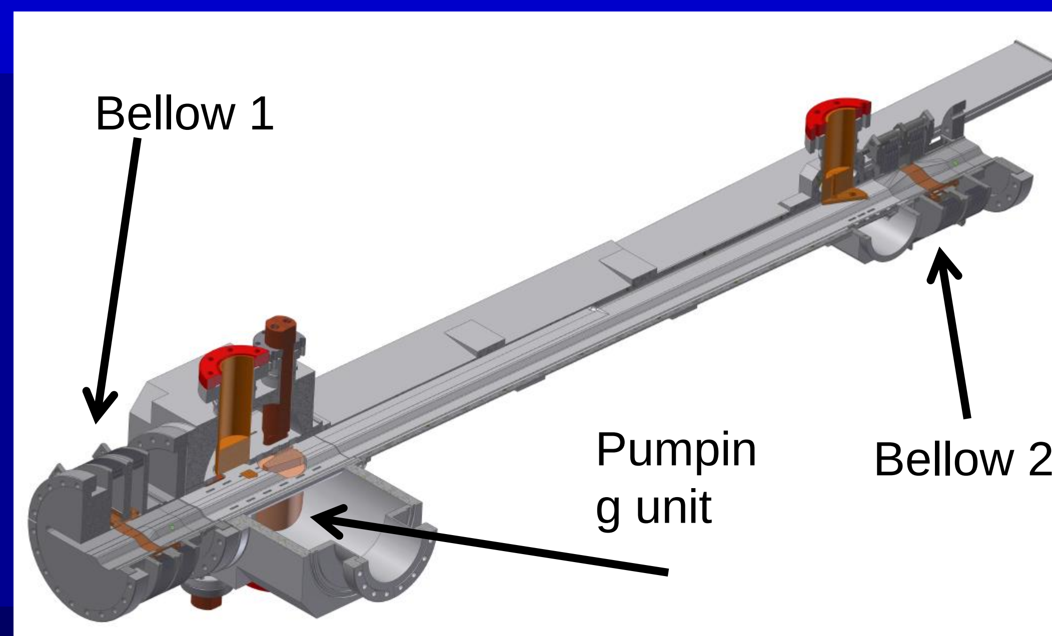
-The chamber is made in two half soldered togeter

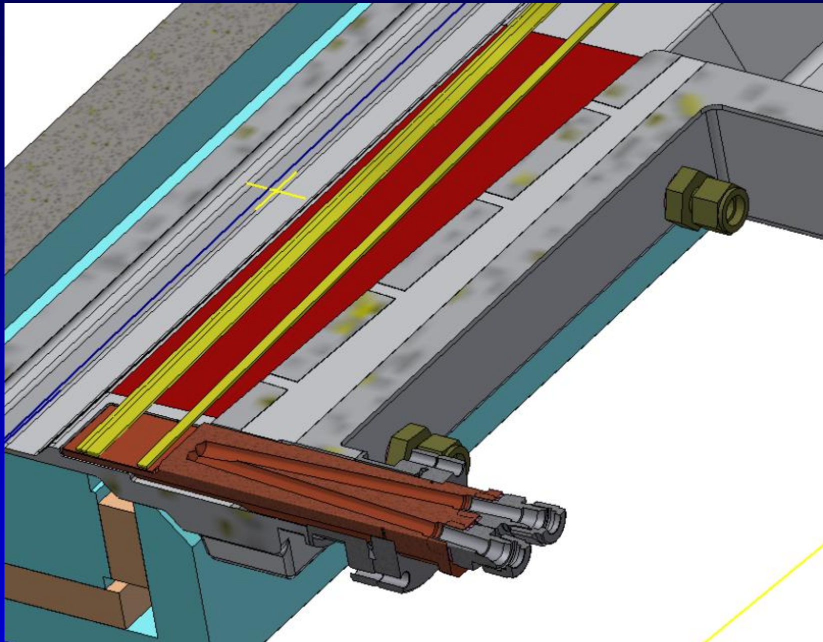
-Maximum bake-out temperature 150 °C

-roughness 0.3-0.4 μm (standard) 0.2 μm easily achievable

-70 kg weight

-pumping port diameter in the drawing 70 mm that can be easily modified to 90 mm

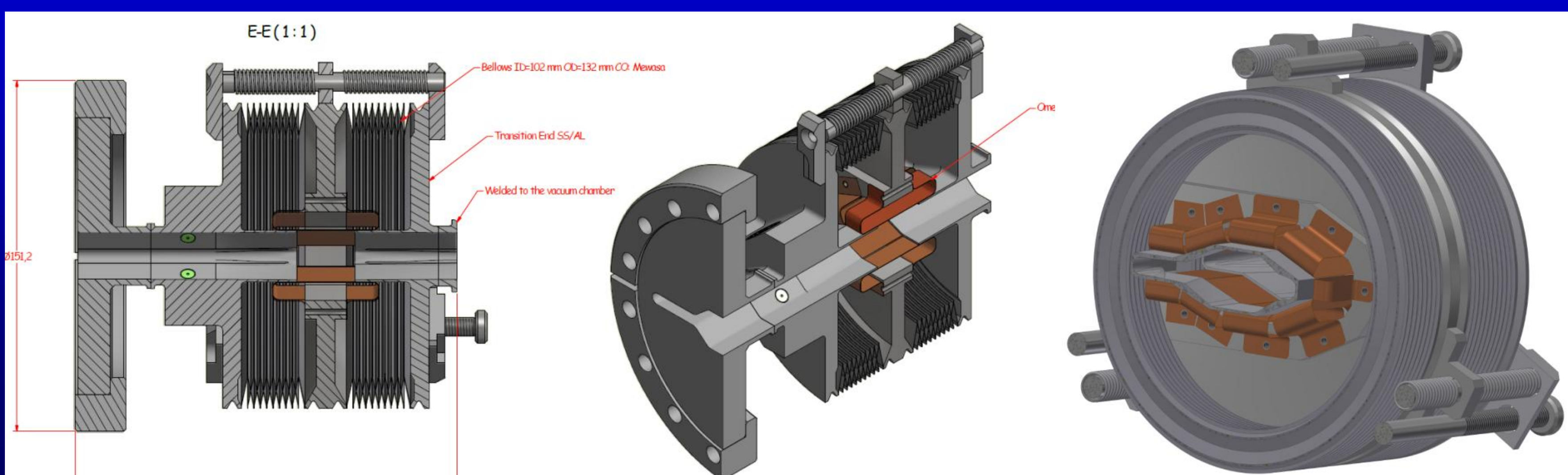




ESRF DIPOLE CHAMBER: ABSORBERS & BELLOWS

Two parallel cooling channels directly integrated on the chamber: total estimated power from the light beam 35 W

Excursion -20 mm in compression (to compensate the bake-out dilatation of the dipole chamber) and +5 mm in expansion



- Esempi di successo dell’industria italiana nel campo degli acceleratori sono innumerevoli:
- la produzione dei magneti superconduttori che l’ANSALDO ha prodotto per LHC, il collisore di protoni lungo 26km installato al CERN;
- le cavità superconduttrici prodotte dalla ZANON per il progetto X-FEL di DESY;
- le camere da vuoto e sezioni acceleranti prodotte dalla CECOM e COMEB per gli acceleratori dell’INFN di Frascati;
- COMEB partner nella costruzione di ELI-NP
- CINEL per l’RFQ di IFMIF

Thanks for your attention!

INFN
Istituto Nazionale
di Fisica Nucleare