Future IR ai LNS: il caso di Km3NeT, EliMed e Upgrade del Ciclotrone Superconduttore

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Catania Jul. 6° 2015

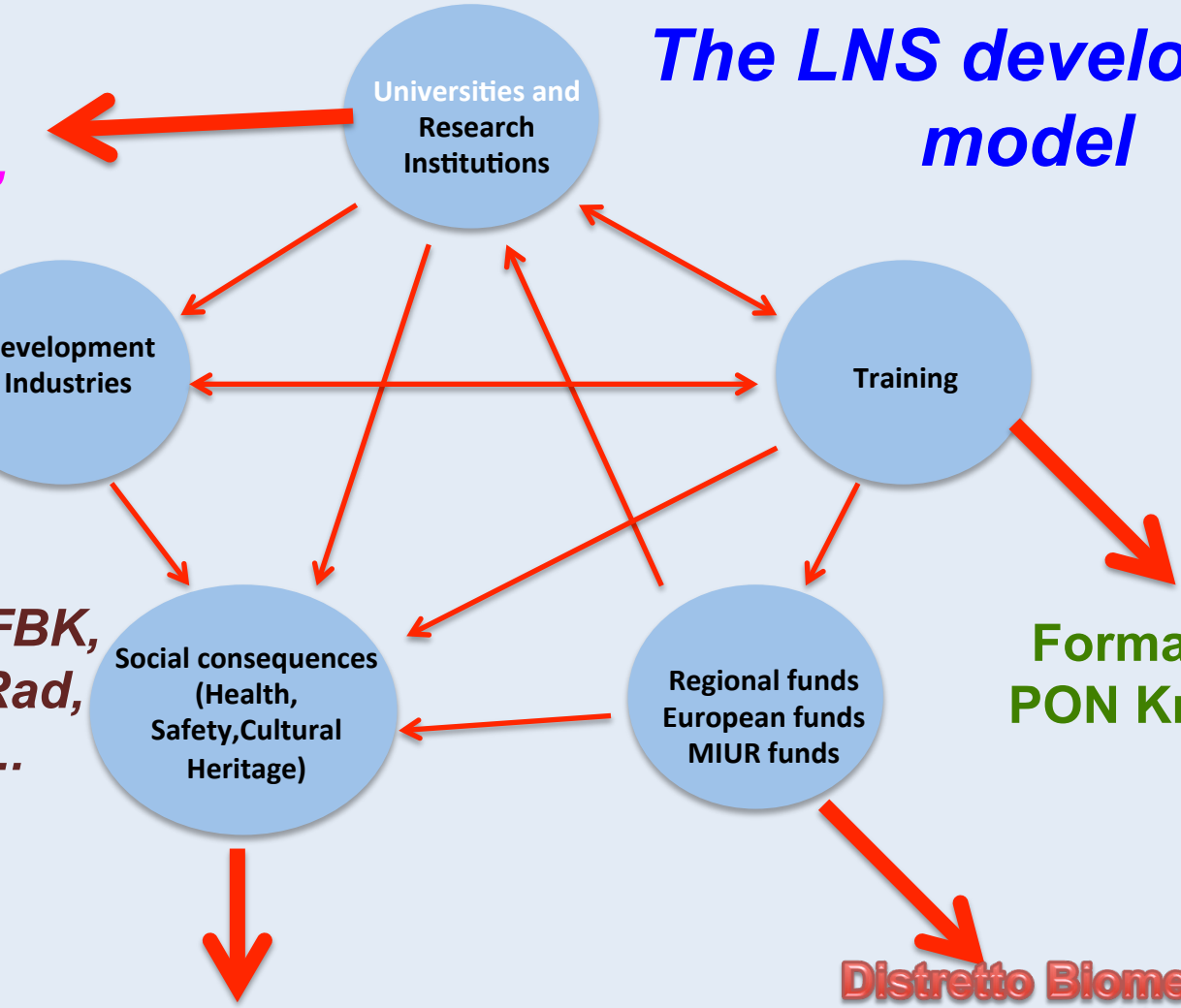
I Laboratori Nazionali del Sud dell'INFN

Laboratori Nazionali del Sud (LNS) is the most southern laboratory of INFN and with the wider spectra of research acitivies. Founded in 1976, nowdays are constituted by 250 people (120 permanent staff) including researches, technicians, doc and post-doc, undergraduate, etc. LNS are an advanced technological and research pole in Italy. Budget 11 M€ per year (exc. Salaries)

The research and development activities find applications in medicine, biophysics, photonics and cultural heritage. About 400 external users per year.

The LNS development model

Uni CT, CNR, INGV, INAF, ISPRA, CSFNSM, Catania Ricerca



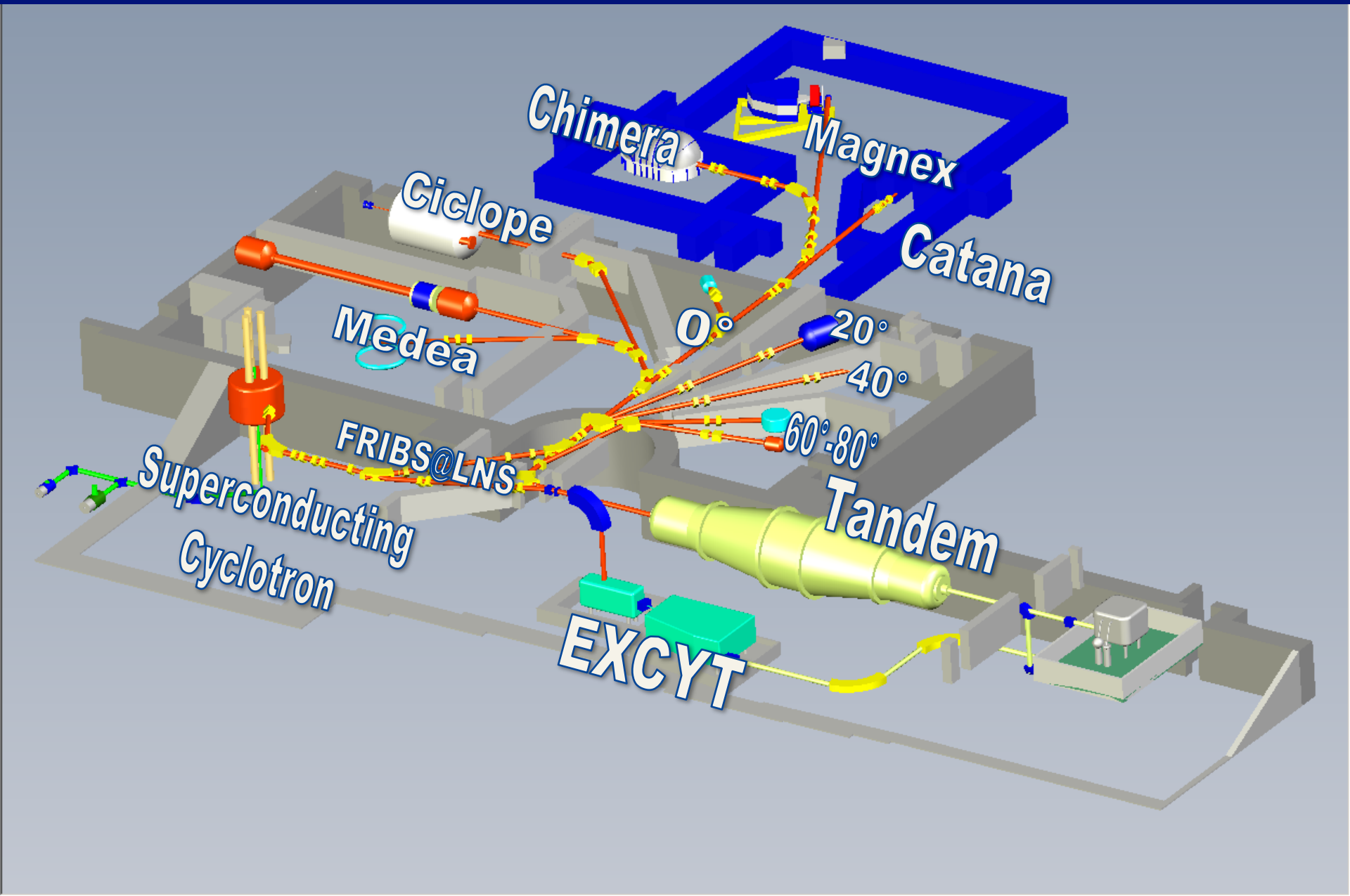
STM, IBA, Best, FBK, Caen, IMT, MapRad, Confindustria..

Formazione
PON Km3NeT

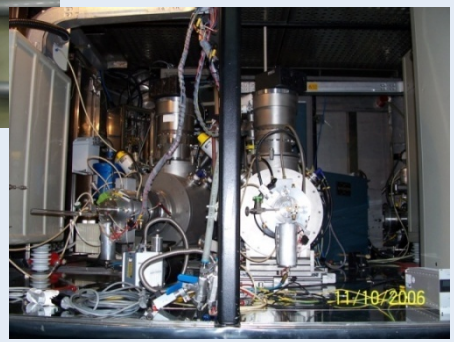
- CATANA: 300 patients, 95% success
- LANDIS: Coll. with CNR-IBAM (Misurata Coins, Dead Sea Scrolls…)
- Radioactive Waste Management: Sogin
- Enviromental Radioactivity Lab
- Radiobiology Lab

Distretto Biomedico
Dstretto del Mare
Distretto Beni Culturali
PON-POR Projects
FIRB/SIR-Prin
H2020

LNS lay-out: accelerators and experimental halls



Accelerator equipment for ion beam production



450 KV injector
2 sputtering sources

Normal conducting ECR source CAESAR

Superconducting ECR source SERSE

The ββ decay

1) 2ν double β-decay

1) Does not distinguish between Dirac and Majorana

2) Experimentally observed in several nuclei since 1986

ν and anti-ν can be distinguished

ν and anti-ν are the same

2) 0ν double β-decay

Neutrino has mass

Neutrino is Majorana particle

Violates the leptonic number conservation

Experimentally not observed

Beyond the standard model

Il caso fisico che richiede intensità: il doppio β decay

- Grande accettanza angolare
- Possibilità di misurare a 0°
- Possibilità di rivelare ^{16}O, ^{18}F, ^{18}Ne, ^{20}Ne
- Spettri ad alta risoluzione
- Distribuzioni angolari fino a 10 nb/sr

Reazioni di doppio scambio carica (^{18}O,^{18}Ne) e (^{20}Ne,^{20}O) determinazione dell'elemento di matrice nucleare nel doppio β decay

Reazione DCX già studiata $^{40}Ca(^{18}O,^{18}Ne)^{40}Ar$ – exp. DOCET nov.2012

2 test run ottobre 2014 e febbraio 2015 con ^{18}O a 15 e 25 MeV/amu

Intensità 6 enA (limite max del rivelatore) - statistica scarsa fattore 10

Per una reazione di maggior interesse come $^{116}Sn(^{18}O,^{18}Ne)^{116}Cd$

sez. d'urto 10, risoluzione 10, energia 10 → intensità 60 eμA – P ≈ kwatt

Fasci radioattivi sviluppati a oggi con FRIBS@LNS

primary beam	beam	intensity (kHz/ 100W)
18O 55 AMeV	16C	120
setting 11Be	17C	12
	13B	80
	11Be	20
	10Be	60
	8Li	20
18O 55 AMeV	14B	3
setting 12Be	12Be	5
	9Li	6
	6He	12
13C 55 AMeV	11Be	50
setting 11Be	12B	100
36Ar 42 AMeV	37K	100
setting 34Ar	35Ar	70
	36Ar	100
	37Ar	25
	33Cl	10
	34Cl	50
	35Cl	50
20Ne 35 AMeV	18Ne	50
setting ne18	17F	20
	21Na	100
70Zn 40 AMeV		
setting 68Ni	68Ni	20

^{38}S (CHIMERA – GMR)

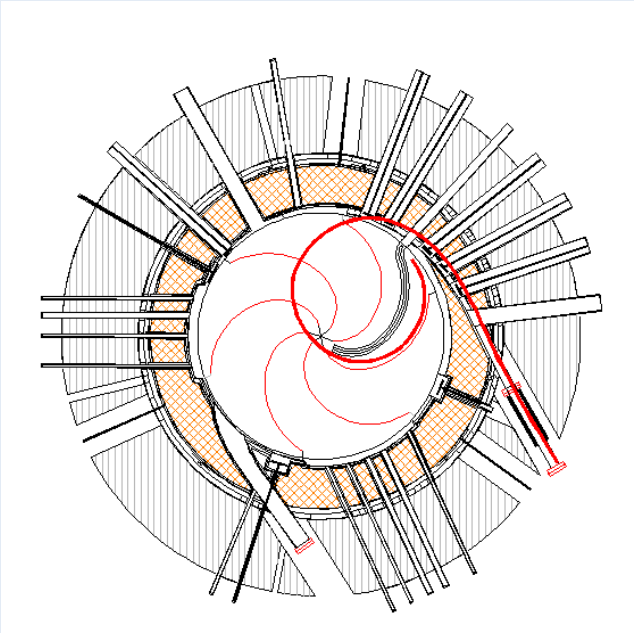
^{68}Ni (CHIMERA – Pigmy R.)

^{8}He (CHIMERA – Reson.^{9}He)

^{14}Be (test experiment)

^{38}S (MAGNEX – GMR)

Estrazione per stripping: alta efficienza >99%



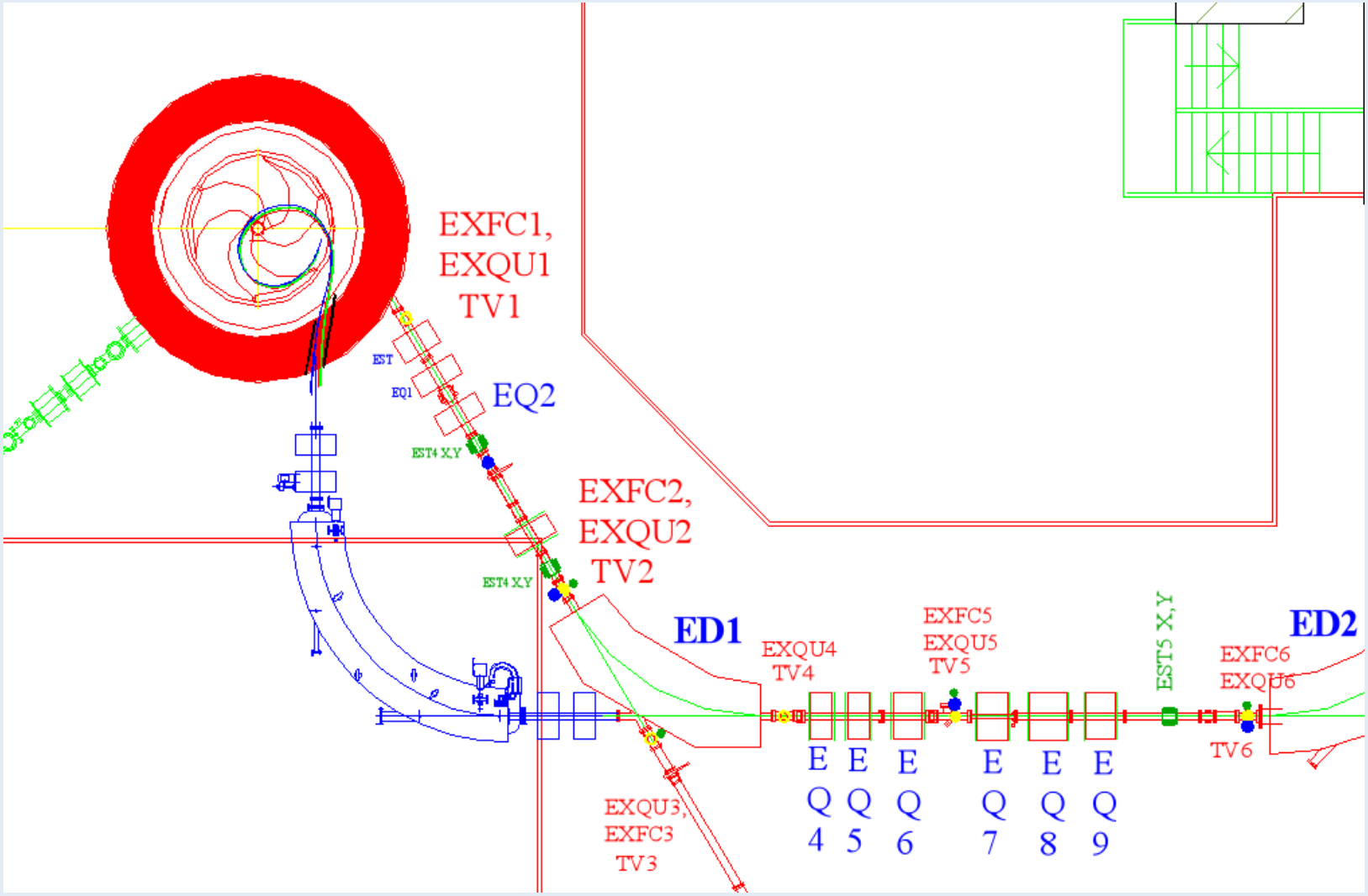
L'estrazione per stripping è basata sulla diminuzione di rigidità magnetica dello ione accelerato, causata da un aumento dello stato di carica o un decremento della massa, a seguito dell'attraversamento di un sottile foglio di carbonio (stripper).

12C 15 MeV/u	**F(5)=8.35e-4**	**F(6)=0.99917**
12C 20 MeV/u	**F(5)=3.20e-4**	**F(6)=0.99968**
18O 15 MeV/u	**F(7)=3.14e-3**	**F(8)=0.99690**
18O 20 MeV/u	**F(7)=1.29e-3**	**F(8)=0.99870**
18O 30 MeV/u	**F(7)=3.74e-4**	**F(8)=0.99963**
20Ne 15 MeV/u	**F(9)=8.90e-3**	**F(10)=0.99110**
20Ne 20 MeV/u	**F(9)=3.26e-3**	**F(10)=0.99670**
20Ne 30 MeV/u	**F(9)=9.51e-4**	**F(10)=0.99910**

Atomic Data and Nuclear Data Tables, Vol. 51, No. 2, July 1992, Table 2 pag.187

Per ioni leggeri ad energie elevate, la frazione di popolazione dello stato di carica q=Z dopo uno stripper di spessore pari allo spessore di equilibrio è >99%

Sezione aggiuntiva della linea di estrazione



Costo del criostato stimato dal MIT

					($k)	
Final design				$	1,500	Final analyses and detailed design drawigns for shop fabrication.
Composite strand (1:1 / Cu:NbTi)	2,351	(kg)	200	$	470	High quality NbTi strand at $200/kg
Copper Channel	5,433	(kg)	10.45	$	57	$5/lb ($3/lb commodity price + $20/lb channel forming)
Conductor Cabling	28,000	(m)	2	$	56	$2/m
Integrated Conductor	28,000	(m)	5	$	140	$5/m
Tooling				$	75	Spools, rollers, bending tools, taping heads.
Coil Insulating and Winding	7,784	(kg)	70	$	545	
Current leads	2,000	A		$	50	Recent price paid for 2 kA HTS leads/ 2 sets required
Coil case	5,800	(kg)	40	$	232	$40/kg for SS
Coil Instrumentation				$	15	
Vacuum Pressure Impregantion in mold and assemble coil into case.				$	150	Labor, mold, resin, heater, and miscellaneous fittings.
LN2 shield (Al)	372	(kg)	5.00	$	2	
Cryostat Steel	7,300	(kg)	40	$	292	
Assemble coil into cryostat with LN2 shield & MLI				$	200	Labor, welding, leak checking
Cold testing coil in factory (no iron				$	150	Includes cost of Lhe
Iron yoke				$	-	Reuse same iron yoke
Iron assembly (at LNS site)				$	-	Assembly by INFN-LNS labor
Coil alignment in iron and acceptance testing (on site)				$	-	
Refrigerator cost				$	-	
Helium piping and misc. cold mass components				$	100	Reuse INFN-LNS refrigerator but requires some new cryogenic piping, valves, and fittings.
Power supply				$	-	Reuse INFN-LNS power supply
Shipping (coil in cryostat)				$	20	
Management				$	150	
	21,256	(kg)				
				$	4,204	
Contingency (30%)			30%	$	1,261	
		Total Magnet Cost		$	5,465	

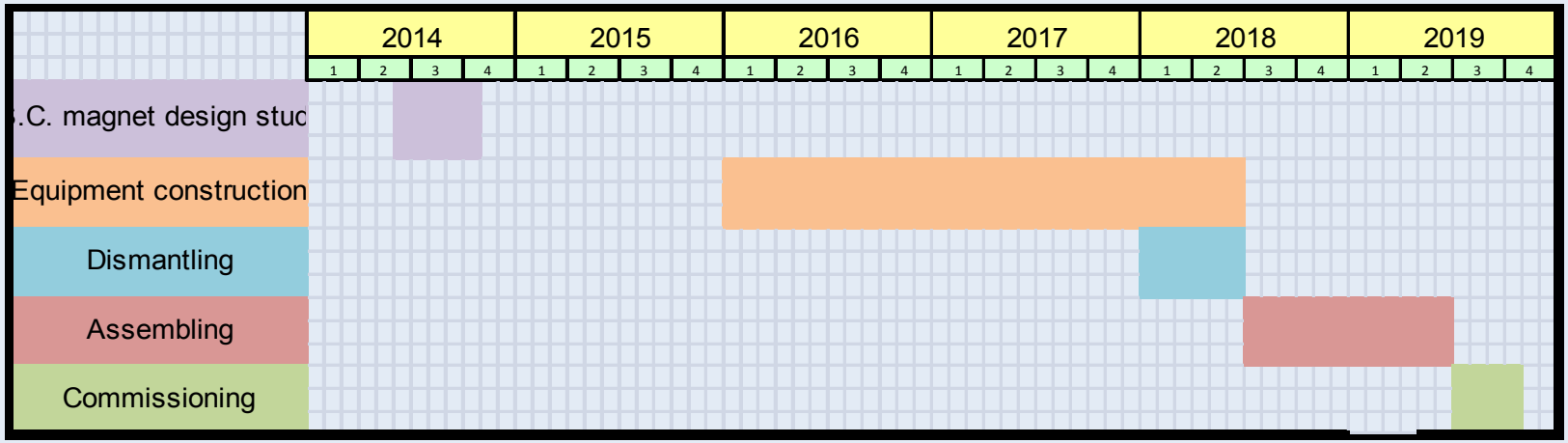
Magnete s.c.: criostato e bobine 5.1

- Sistema meccanico per lo Stripper
- Canali magnetici
- Nuovo liner
- Matching
- Linea di fascio Ciclotrone-sale misura 0.5

- Nuovi trim coils 0.5
- Nuovi alimentatori t.c. 1.5
- Nuovi alim. linee 0.5
- Liquefattore di elio 0.4

Equipment “Intensità”	2.2 M€
Equipment “Affidabilità”	2.9 M€
Total	10.2 M€

Stima dei tempi



	Start	End
Studio nuovo magnete s.c.	06/2014	10/2014
Realizzazione magnete e altri apparati	01/2016	06/2018
Smantellamento	01/2018	06/2018
Montaggio	06/2018	06/2019
Commissioning	06/2019	10/2019

I punti di forza del progetto

Intensità significativamente più elevata per ioni leggeri con A<20:

NUMEN
FRIBS@LNS
sperimentazione con fasci stabili intensi oggi disponibili in altri laboratori
produzione di radioisotopi

Diagramma operativo immutato - tutti i fasci accelerabili restano disponibili con estrazione elettrostatica:

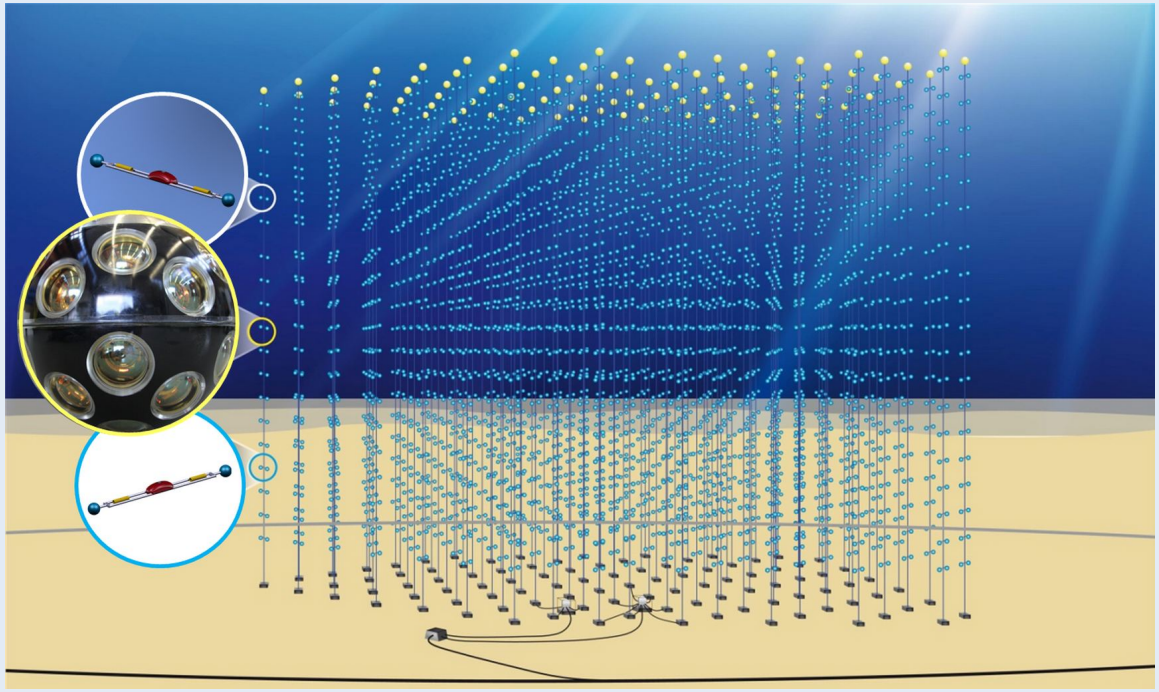
protoni per CATANA
fasci medio-pesanti con A>20

Grado di affidabilità più elevato:

Criostato
Liquefattore
Trim coils

The giant-scale detector KM3NeT

Faintness of neutrino fluxes and small interaction probabilities oblige to use large natural target such as sea-water: a volume of 5 km^3 of seawater will be instrumented with optical detectors.



5 building blocks
120 Detection Units (DU)
750 m DU height
180m DU distance
5 km^3 volume
Budget 210 M€

KM3NeT-It is funded by INFN since 1999 (NEMO)
In 2012 the project was awarded with a
PON grant of 21 M€

KM3NeT is a EU funded ESFRI Infrastructure since 2006.
INFN leaded the Prparatory Phase

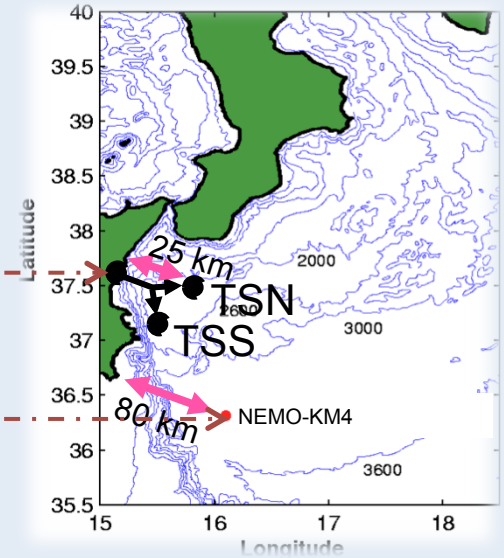
KM3 - cosa è

- Un telescopio sottomarino per la rivelazione di neutrini astrofisici di alta energia da installare a profondità abissali al largo delle coste della Sicilia (Portopalo di Capo Passero)

- La sua struttura e la sua tecnologia lo rendono una piattaforma unica per attività di ricerca multidisciplinari in ambiente marino profondo

I Siti Cablati della Sicilia

- L'INFN, negli ultimi 10 anni, utilizzando fondi ordinari dell'Istituto e finanziamenti a valere su PON (2000-2006, 2007-2013), POR (2000-2006) ha sviluppato due siti cablati in ambiente marino profondo
  - **Catania**
    - Infrastruttura cablata a 25 km dalla costa
    - 2100 metri di profondità
    - Primo nodo operativo di EMSO
    - Presenza di stazioni per il monitoraggio acustico (SMO) e multiparametrico (EMSO MEDIT, SN1)
  - **Portopalo**
    - Infrastruttura cablata a 100 km dalla costa
    - 3500 metri di profondità
    - Sito di costruzione del telescopio sottomarino per la rivelazione di neutrini KM3NET
    - Sito di installazione del Nodo EMSO e delle infrastrutture EMSO MEDIT

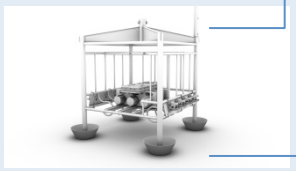


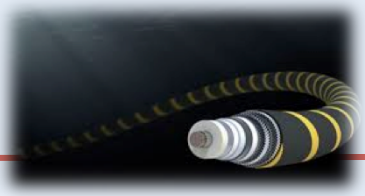
Sito Cablato di Catania

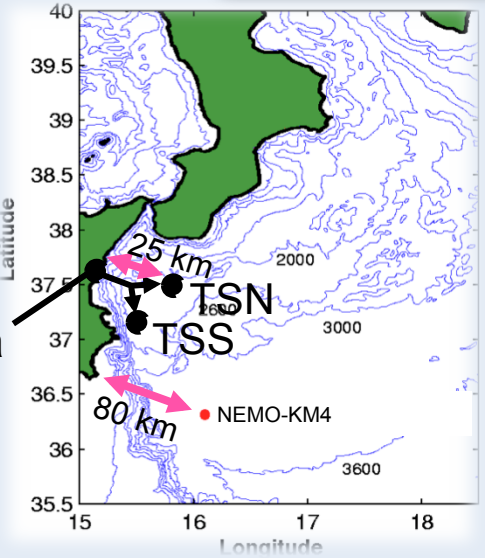
Stazione di terra

Infrastruttura cablata per attività multidisciplinari

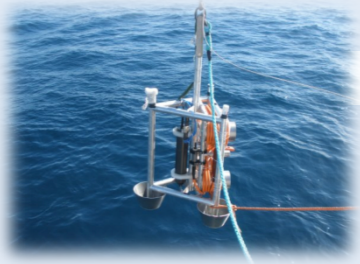
Test bench per nuove tecnologie



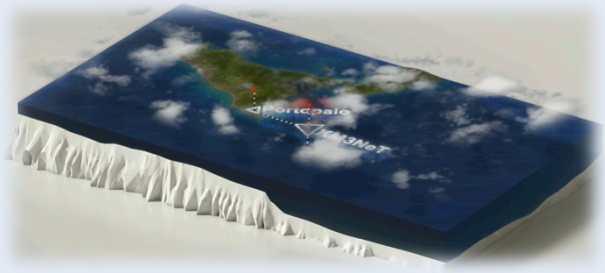




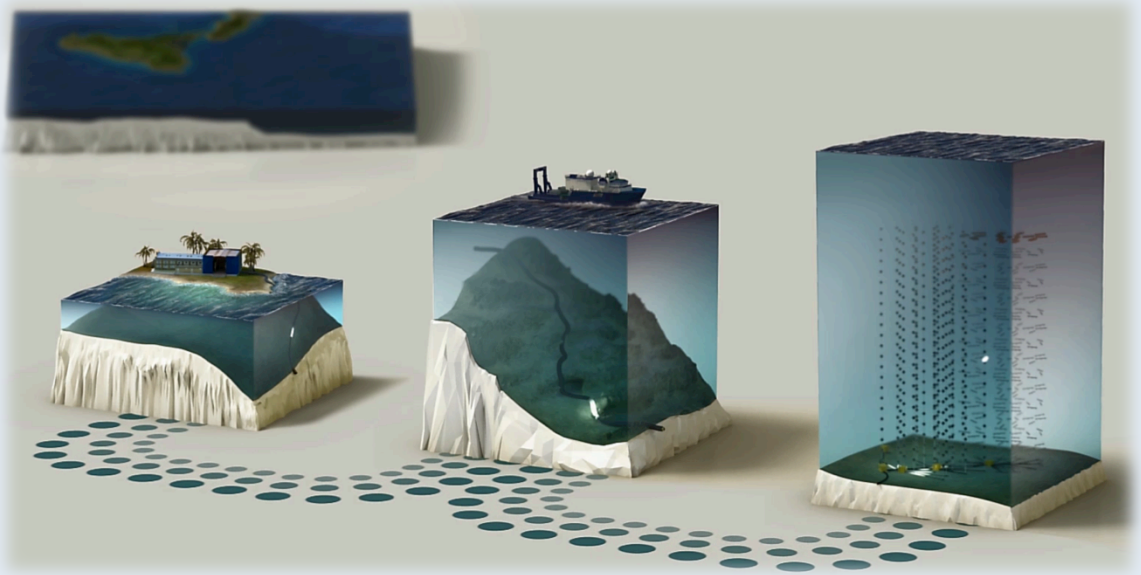
Catania



Sito cablato di Portopalo

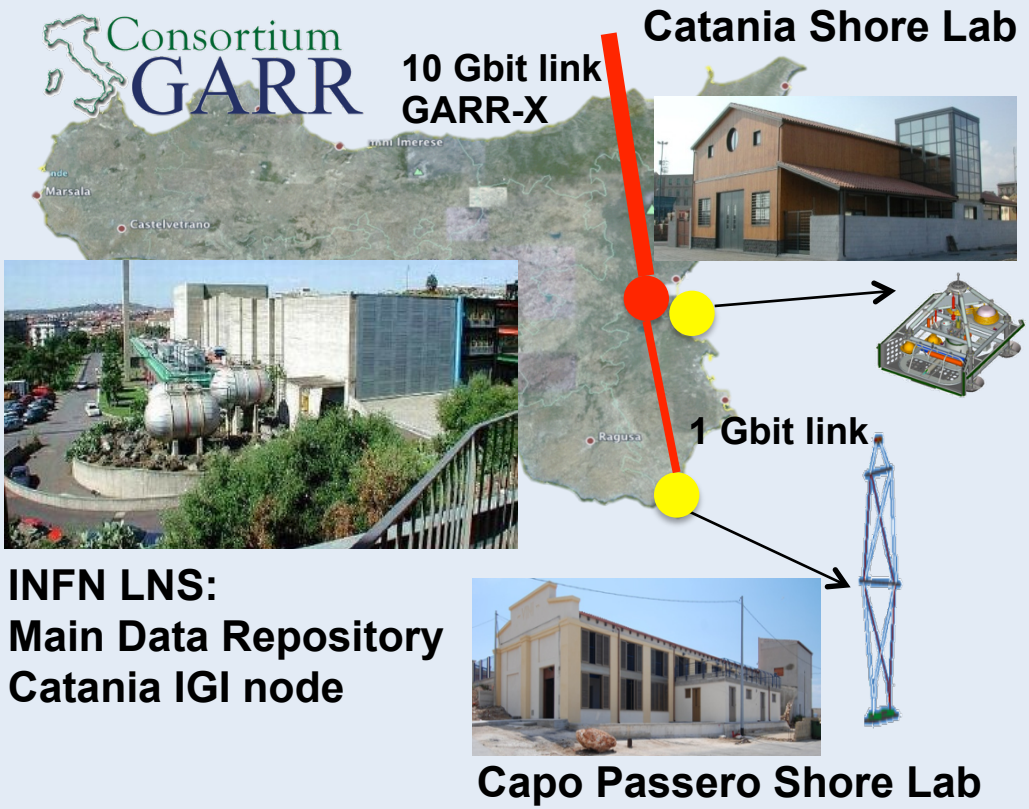


Sito di installazione del telescopio sottomarino KM3



Infrastruttura per attività multidisciplinari di ricerca in ambiente marino profondo utilizzata dai principali EPR Italiani ed Università

Capo Passero: optical fibre link from deep-sea to LNS



INFN is a main partner of GARR and of the Italian GRID-computing Infrastructure

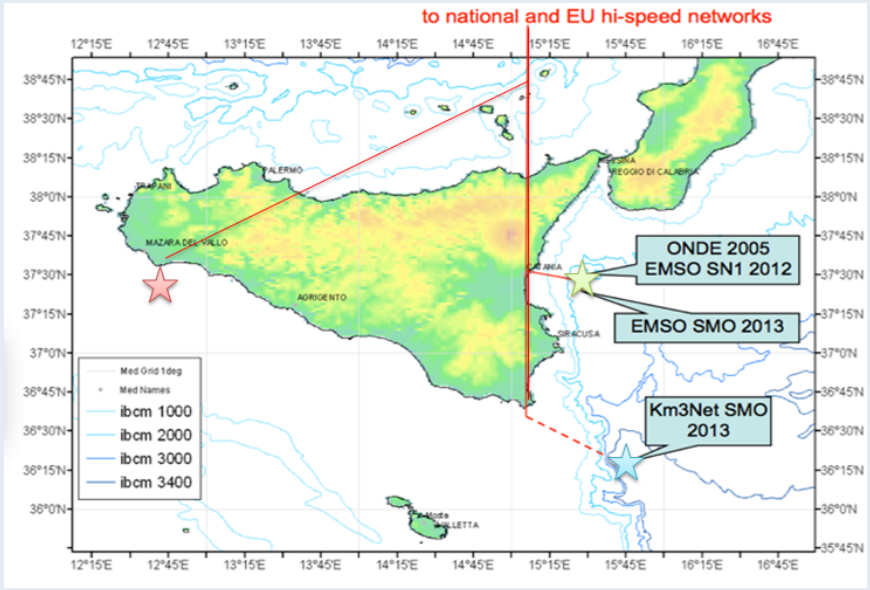
Capo Passero is the first KM3NeT site with direct optical fiber high speed connection from deep-sea to a node of the European GRID-computing Infrastructure

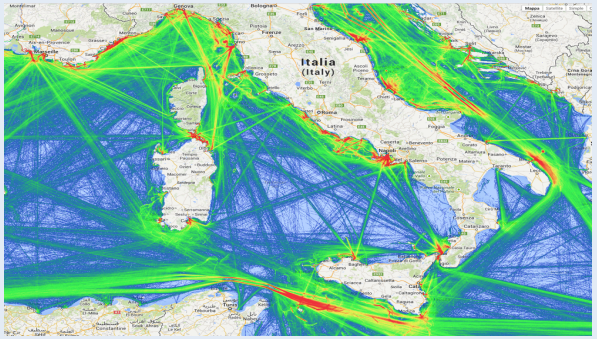
INFN Catania is a major site of the Italian GRID

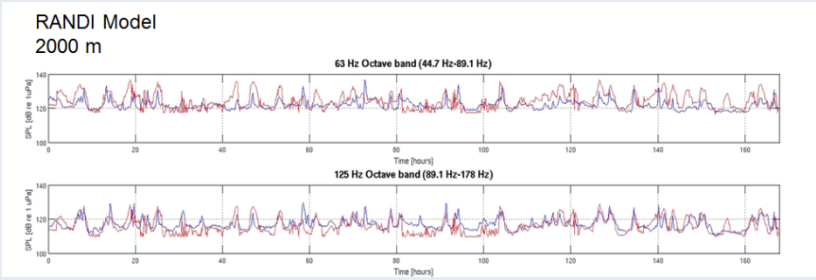
I siti cablati e la Marine Strategy

- Le infrastrutture cablate possono essere utilizzate come piattaforma
  - per l'acquisizione di dati acustici
  - per l'installazione di strumentazione / sensori utili per aumentare la capacità di acquisire dati ed informazioni

  con l'obiettivo di poter ottemperare, su molti descrittori, alle richieste della UE sulla Marine Strategy relativamente all'area del Canale di Sicilia



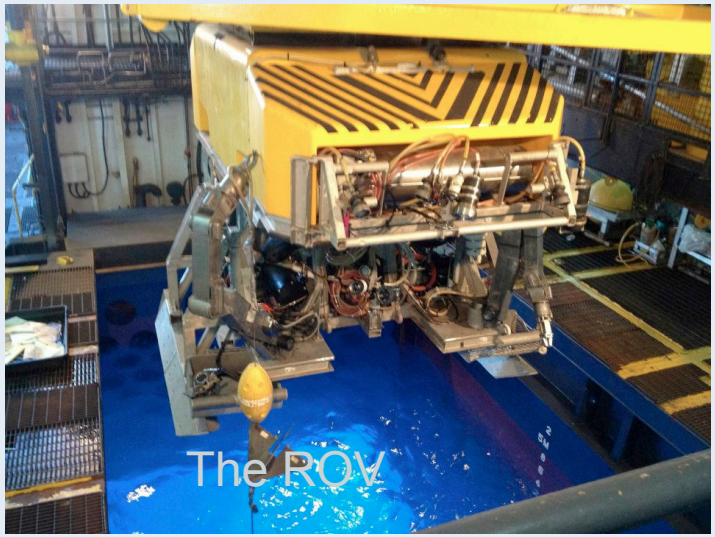




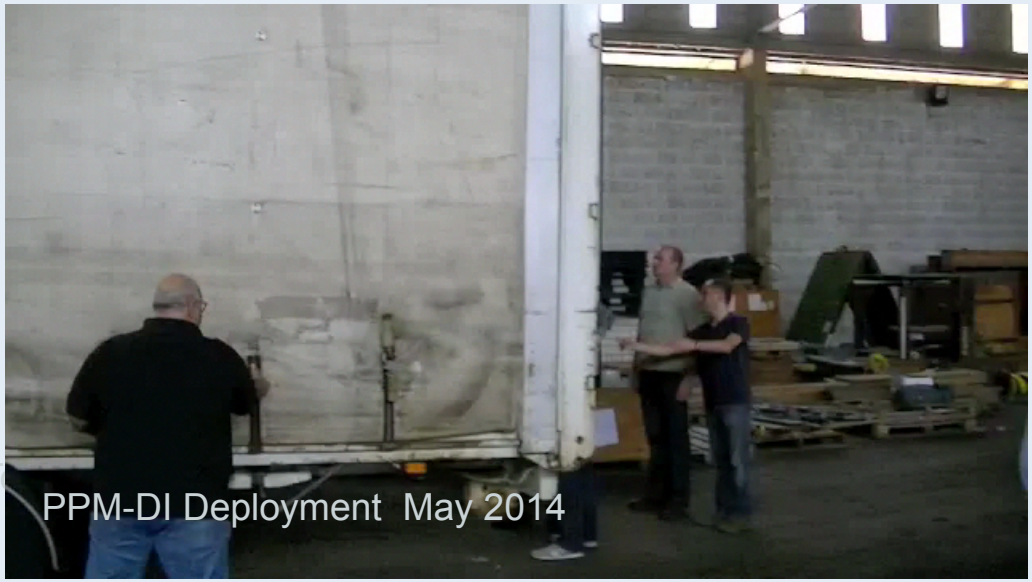
Esempio di analisi dati acquisiti dalle stazioni cablate per fornire informazioni sul D11

Sea Operation: deployment and connection

The DSV Nautical Tide


The ROV

Tower Deployment April 2013


PPM-DI Deployment May 2014

KM3NeT and EMSO

Common efforts with the Earth and Sea Science Community

KM3NeT

european multidisciplinary seafloor observatory emso

Real Time Environmental Monitoring

Toulon, Sicily and Hellenic: sites of common interest for KM3NeT and EMSO

Oceanography (water circulation, climate change):
Current intensity and direction, Water temperature, Water salinity ,...

Geophysics (geohazard):
Seismic phenomena, low frequency passive acoustics, magnetic field variations,...

Biology (micro-biology, cetaceans,...):
Passive acoustics, Biofouling, Bioluminescence, Water samples analysis,...

I siti cablati e le ricadute sul territorio

- Realizzazione di un polo di ricerca internazionale multidisciplinare sul Mare.
- Posizione di leadership dell'Italia e della Sicilia nel settore della ricerca marina.
- Ricadute economiche e tecnologiche sulle aziende locali.
- Ricadute sul settore dei servizi.
- Investimenti sul territorio (Ricerca e Produzione).
- Formazione di nuove figure professionali.
- Creazione di nuove imprese (startup – spin off).
- Miglioramento qualità della vita (monitoraggio qualità acque, pesca, protezione coste, monitoraggio early warning, ..).

ELIMED

- ELI-Beamlines MEDical and multidisciplinary applications

ELI (Extreme Light Infrastructure)

new type of European large scale laser infrastructure specifically designed to produce the highest peak power (10 PW) and focused intensity;

ELI-Beamlines
Czech Rep.

ELI-ALPS
Ungary

ELI-NP
Romania

ELIMAIA

X-ray sources

Exotic physics

...

ELIMAIA

WP1: laser transport and characterisation

WP2: laser matter interaction and diagnostic

WP3: transport beam-lines (in vacuum and in-air)

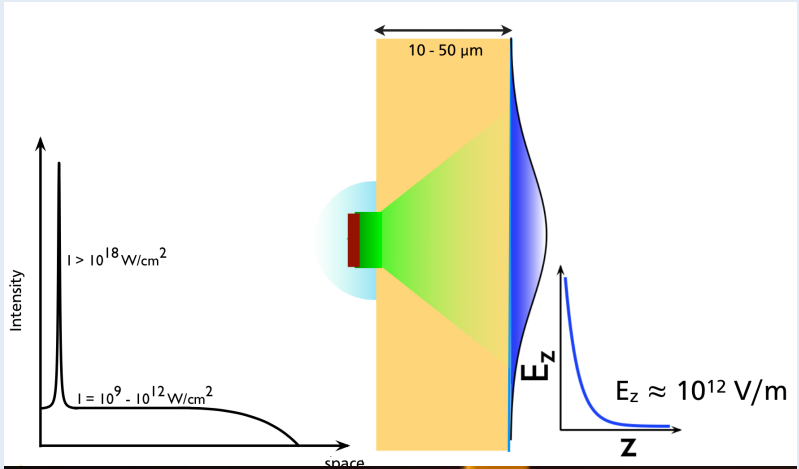
WP4: Monte Carlo

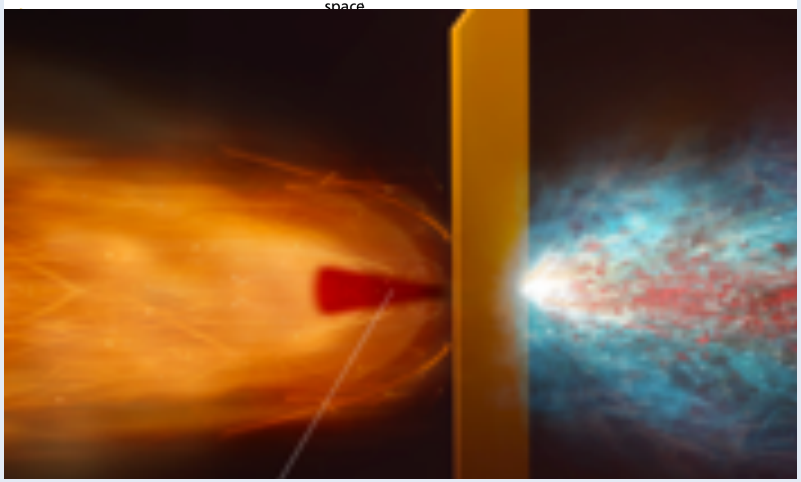
WP5: ion diagnostic, dosimetry and samples irradiation

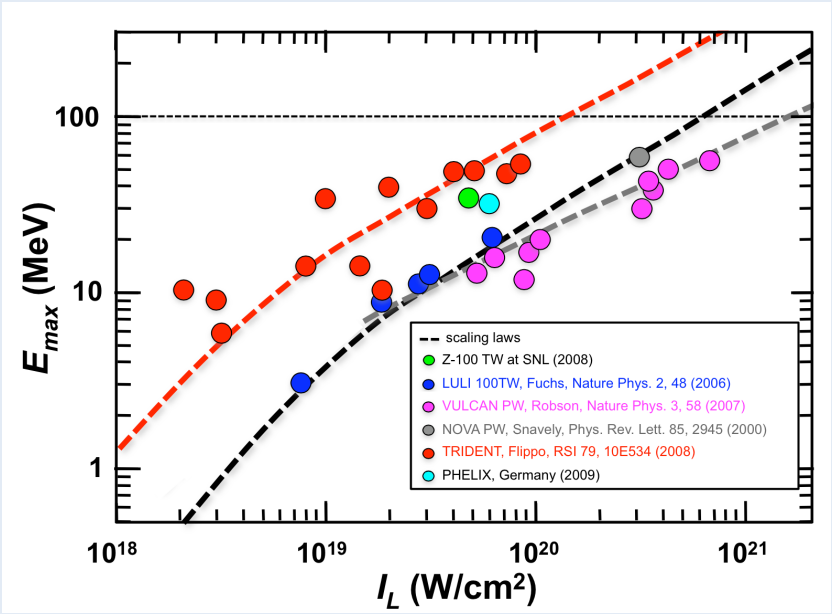
ELIMED

Ion acceleration mechanisms from ultra-thin foils and high-power laser

Huge developments in the last ten years

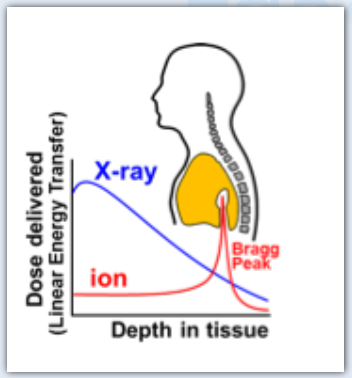






Potential applications for the medica and multidisciplinary field?

Laser-based hadrontherapy??



Cell irradiation experiments with laser-driven protons

S. D. Kraft, et al. NJP 12, 085003 (2010)

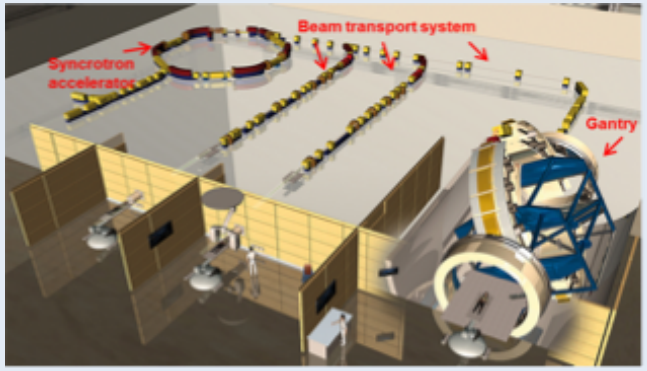
A. Yogo et al, Appl. Phys. Lett., 98, 053701 (2011)

D. Doria et al., AIP Advances, 2, 011209 (2012)

Conventional hadrontherapy facilities:

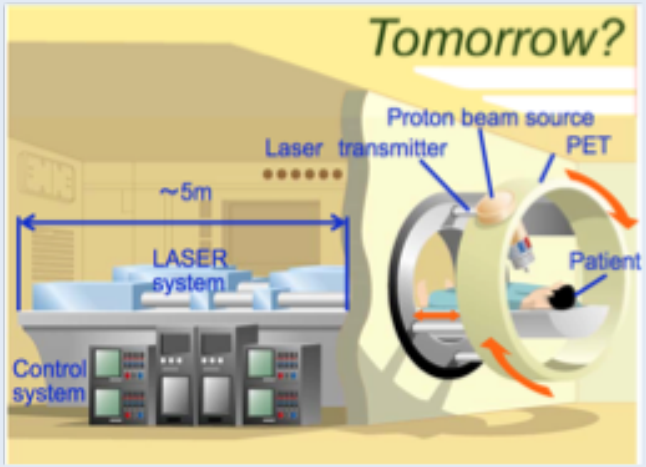
- ***High complexity for the beam production, acceleration and transport***
- ***High cost***

http://newscenter.lbl.gov/2010/10/18/ion-beam-therapy/



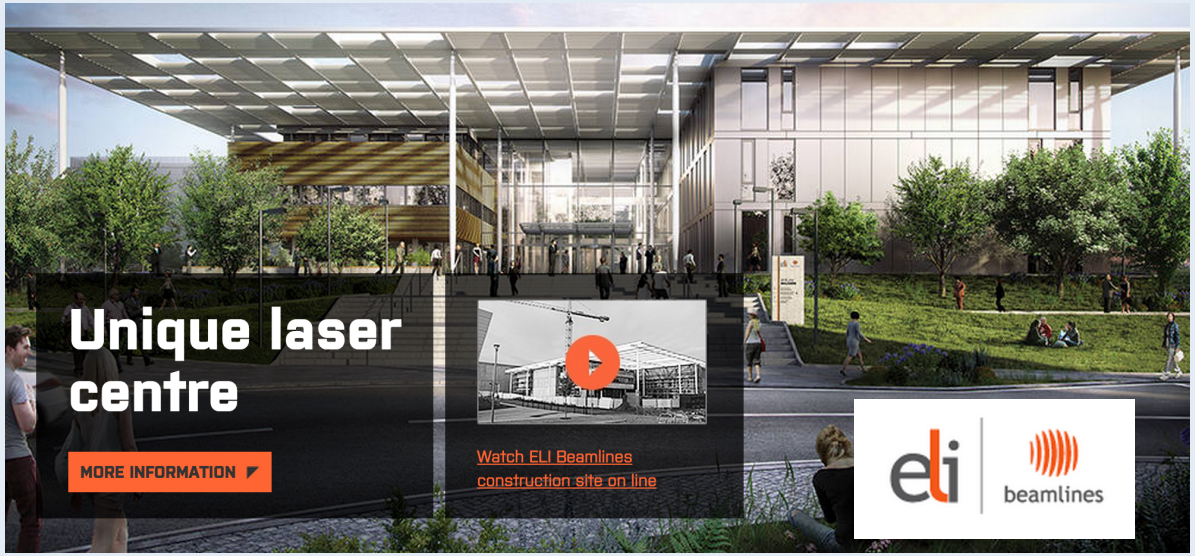
Laser-based hadrontherapy facilities:

- ***Compactness***
- ***Cost-reduction***
- ***Innovative treatment modalities:***
  - Variable energies in the accelerator (no degraders needed)
  - Hybrid treatment (protons, ions, electrons, gamma-rays, neutrons)
  - In-situ diagnostics (PET, X-rays)

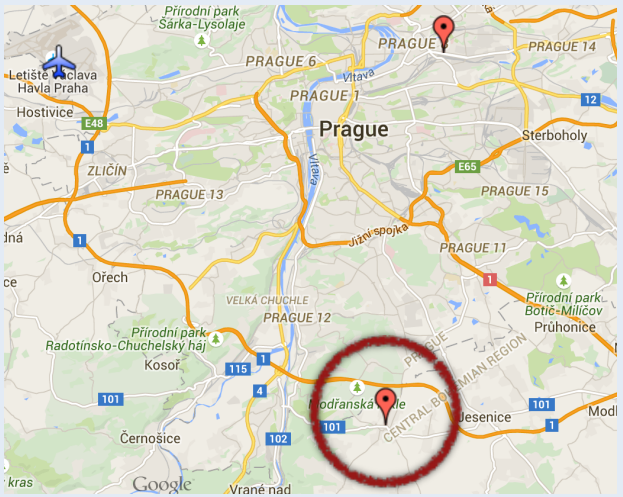


What is ELIMED?

Design and realise the first open to Users laser-driven transport beamline and associated dosimetric tools to evaluate/demonstrate the applicability of laser-driven beams in multidisciplinary and medical fields

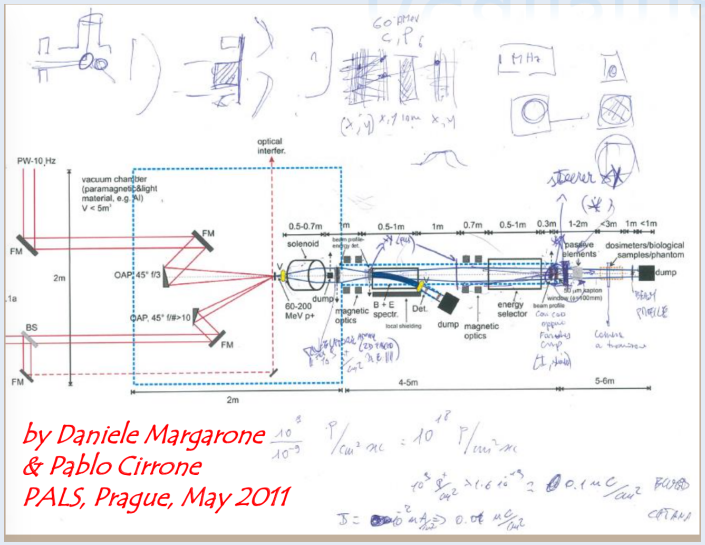


Dolní Břežany
Central Bohemian
40 km from Prague



Realising the ELIMED idea

2011



Fyzikální ústav
Akademie věd ČR, v. v. i.

INFN

Memorandum of Understanding for a scientific and technologic collaboration towards medical applications at ELI Beamlines

Between the

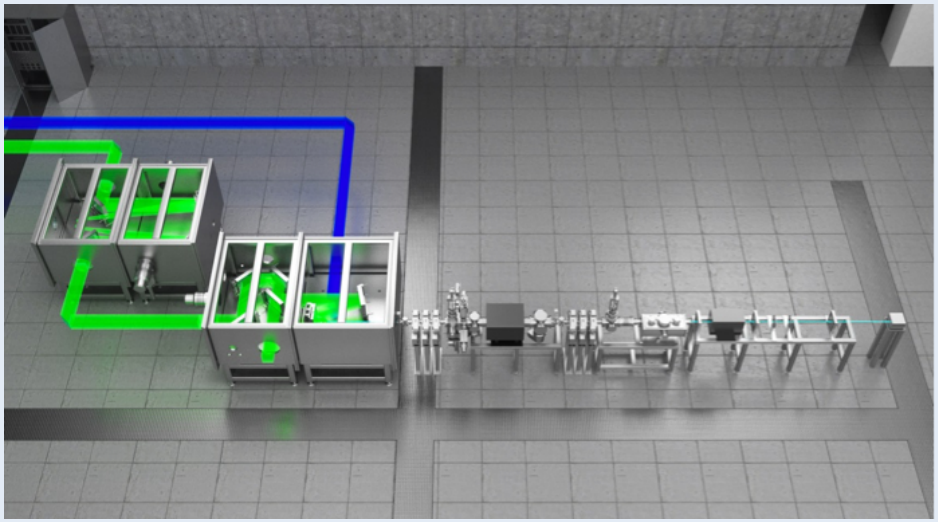
ELI-Beamlines, Institute of Physics of AS CR, public research institution (FZU),
Prague, Czech Republic

And

Laboratori Nazionali del Sud (LNS), of INFN, public research institution,
Catania, Italy

2012

2013



4. WORK SUBJECT-MATTER; WORK SCOPE

4.1. The Contract concerns the design, assembling, performance optimization, and delivering to the Client at the Client's Place of Business of a complete transport beamline and a number of dosimetric endpoints that will enable the users to apply laser-driven ion beams in multidisciplinary fields in accordance with this Contract (hereinafter the "***System***"). Furthermore, the scope of this Contract mainly encompasses (i) various training services to be provided to the Client's personnel in compliance with Article 13 of this Contract (ii) a royalty free licence, if any according to Article 14, to use the System for the purposes of the use of the ELI-Beamlines Project after completion and (iii) the possible realization of the Additional System, subject to the exercise of the Call Option right by the Client under par. 4.6 (the System and the other parts of the works/services are hereinafter referred to as the "***Works***").

– 5 DIC. 2014

Signed in Prague on 8/12/2014

Signed in Rome on _____

On behalf of: **Fyzikální ústav AV ČR, v. v. i.**

Signature:

Name: Prof. Jan Řídký, DrSc.

Title: the Director

On behalf of: **INFN, Instituto Nazionale di Fisica Nucleare**

Signature:

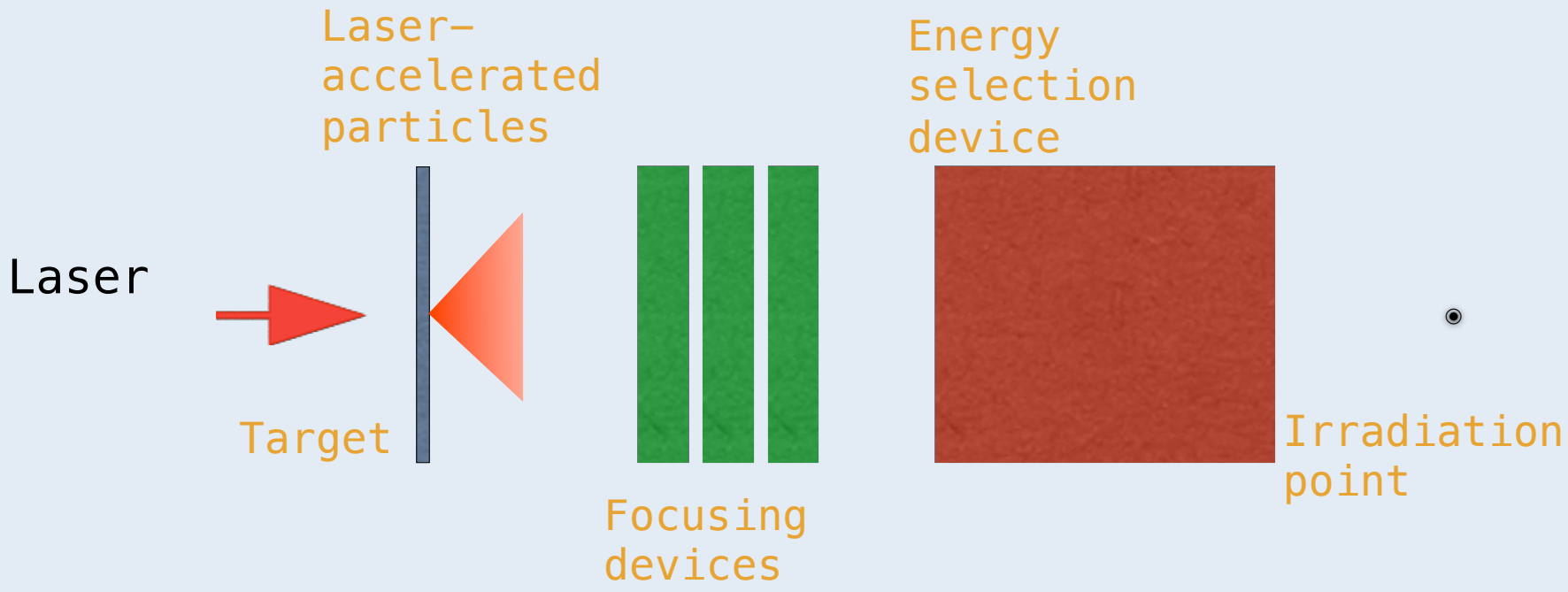
Name: Prof. Fernando Ferroni

Title: the President

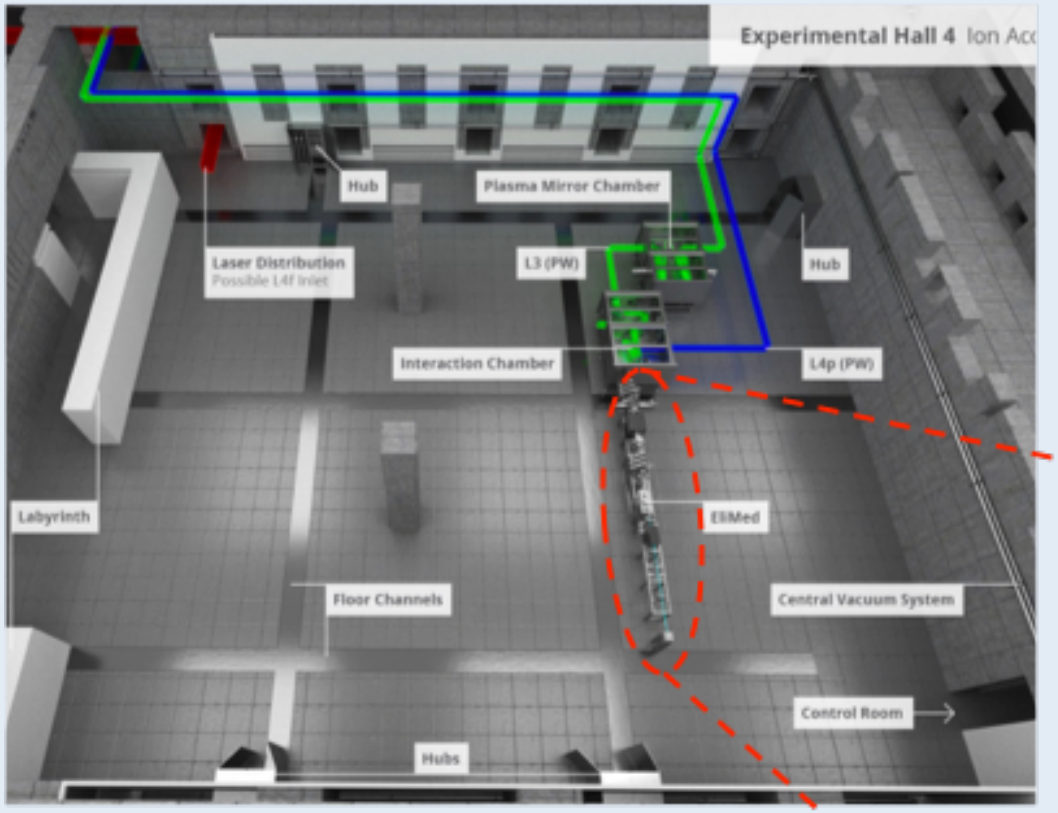
ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
(Prof. Fernando Ferroni)

2014

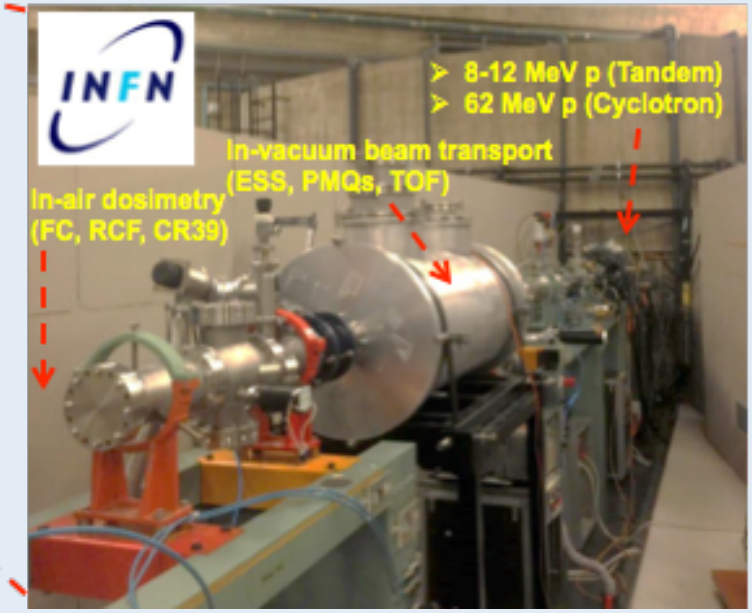
ELIMED transport beamline concepts



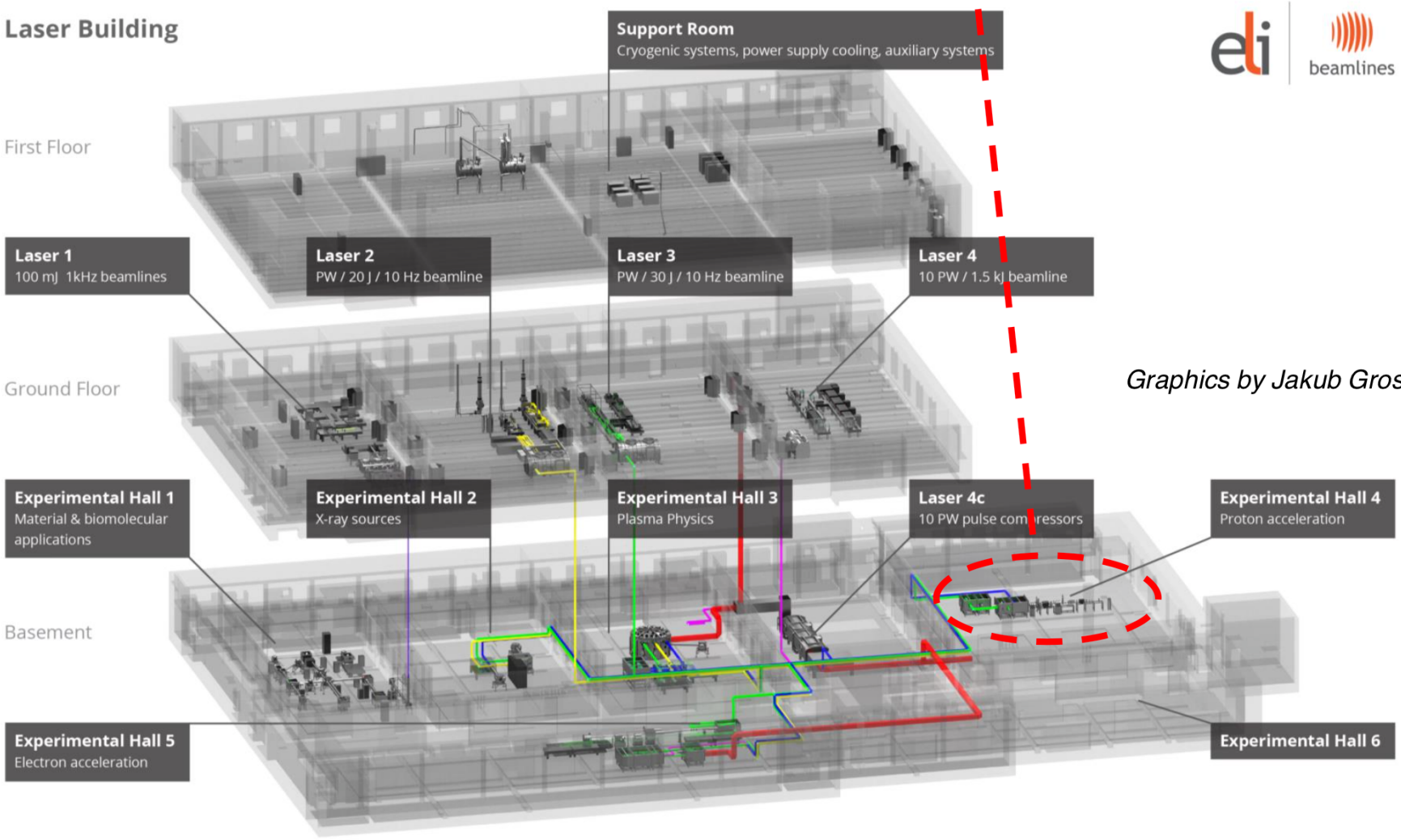
Eccellenza dei LNS nel campo del beam transport e delle applicazione mediche della fisica nucleare (CATANA prima facility clinica italiana per la protonterapia)



ELIMED prototype @ INFN-LNS



ELIMAIA in E4



Graphics by Jakub Grosz

LNS and Regional Strategy

We are part of 3 new "Distretti Tecnologici" (Technological District) togheter with the sicilian universities (Palermo, Catania and Messina), CNR, INGV, ENEA, SME and large companies (STM, Fidia, Alenia, Farmitalia, …)

Distretto Biomedico: Prototype of Ion Gantry for Hadrontherapy (LNS, CNR-IBAM, Catania Univ, Cometa. Hitec2000, C3SL, Unico)

Distretto del Mare: application of submarine acoustic detectors for marine hazard (LNS, INGV, ENEA, Wass Alenia, SME consortium)

Distretto Beni Culturali: application of nuclear technology (Coirich, CNR)

INFN-LNS is component of the Catania Ricerche consortium together with CNR, Catania Univ. Farmitalia and Camera di Commercio of Catania.

Energy Saving at LNS: Rebuilding the lab

Thank you