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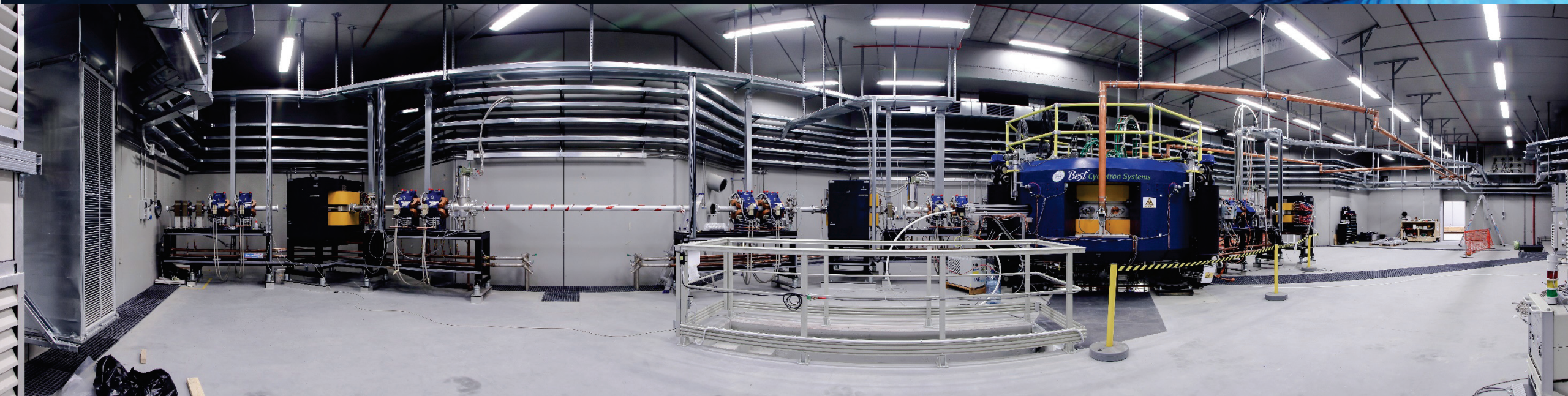
Status of High Intensity Proton Beam Facility at Laboratori Nazionali di Legnaro (INFN)

MARIO MAGGIORE ON BEHALF OF LNL CYCLOTRON TEAM



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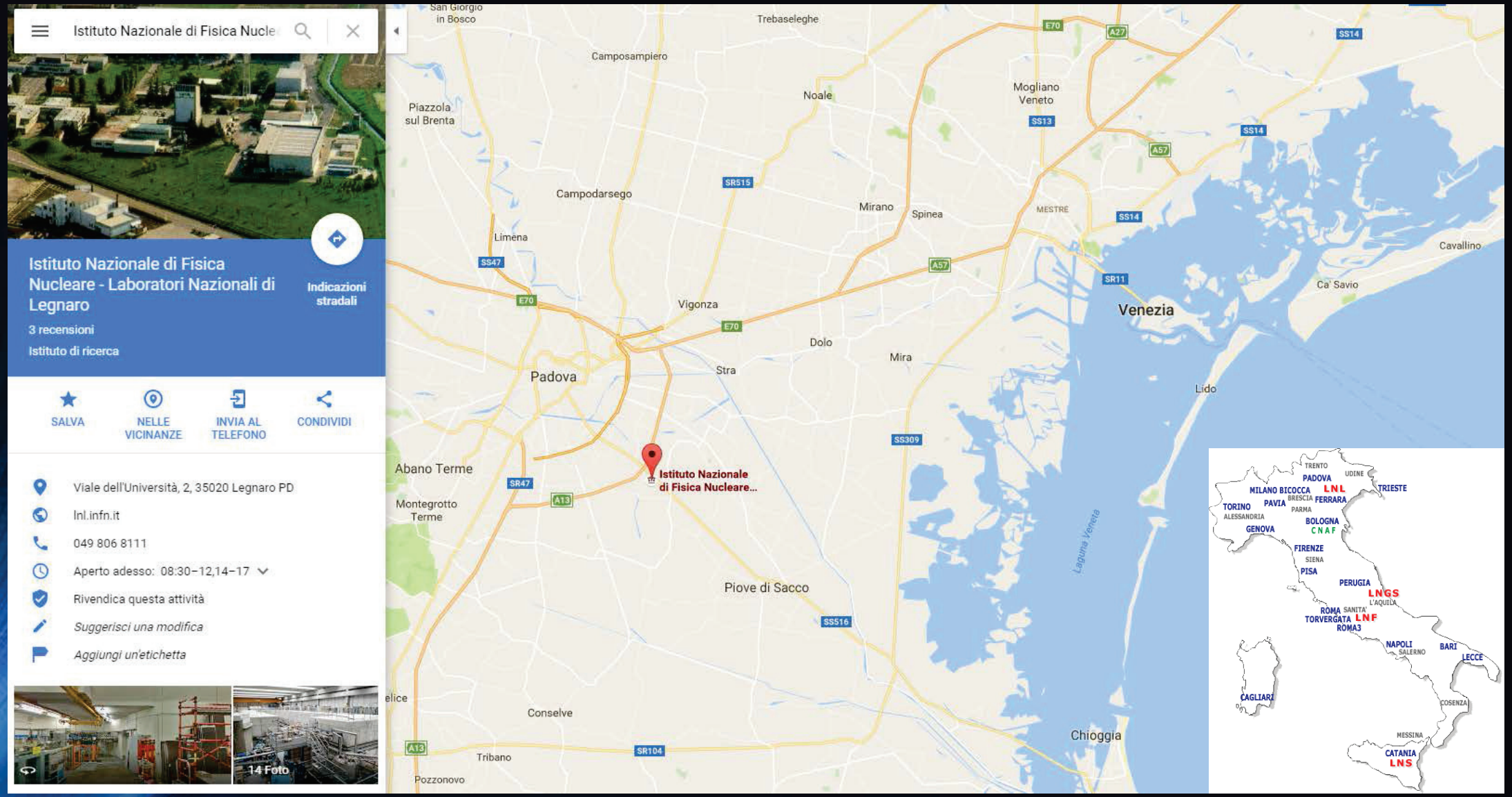
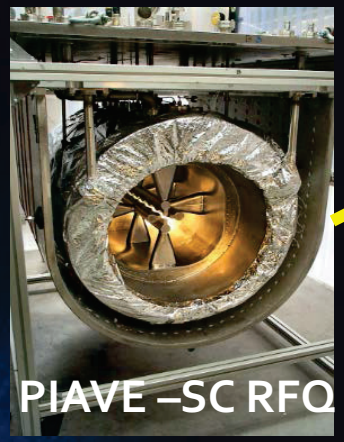
Outline

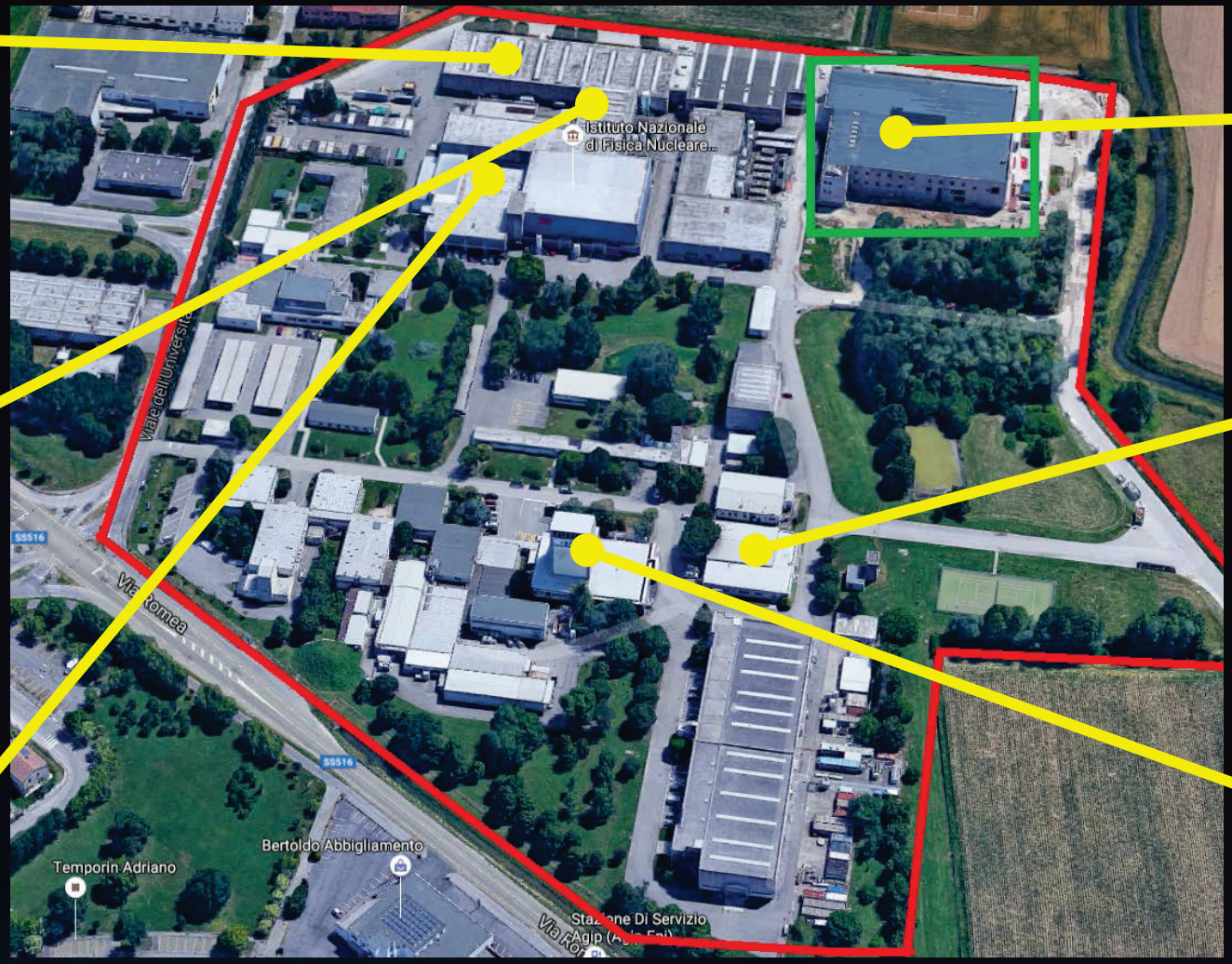
- Brief intro of LNL-INFN
- From SPES project to High Intensity Beam Facility
- High Intensity Beam Applications (NEPIR and LARAMED projects)
- Status of Cyclotron Installation and Commissioning

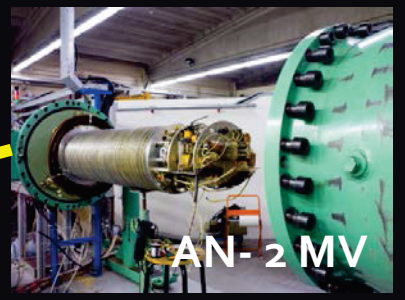
Laboratori Nazionali di Legnaro -INFN



Accelerators at Legnaro Labs…







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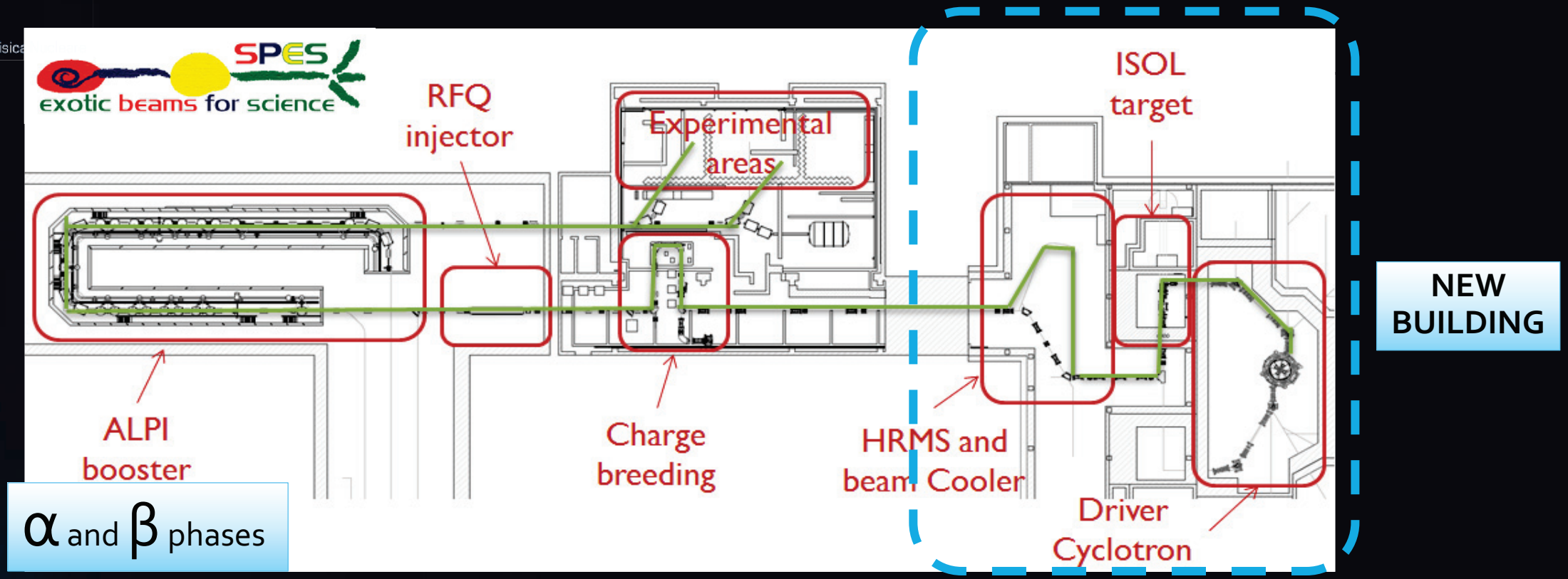
SPES
exotic beams for science

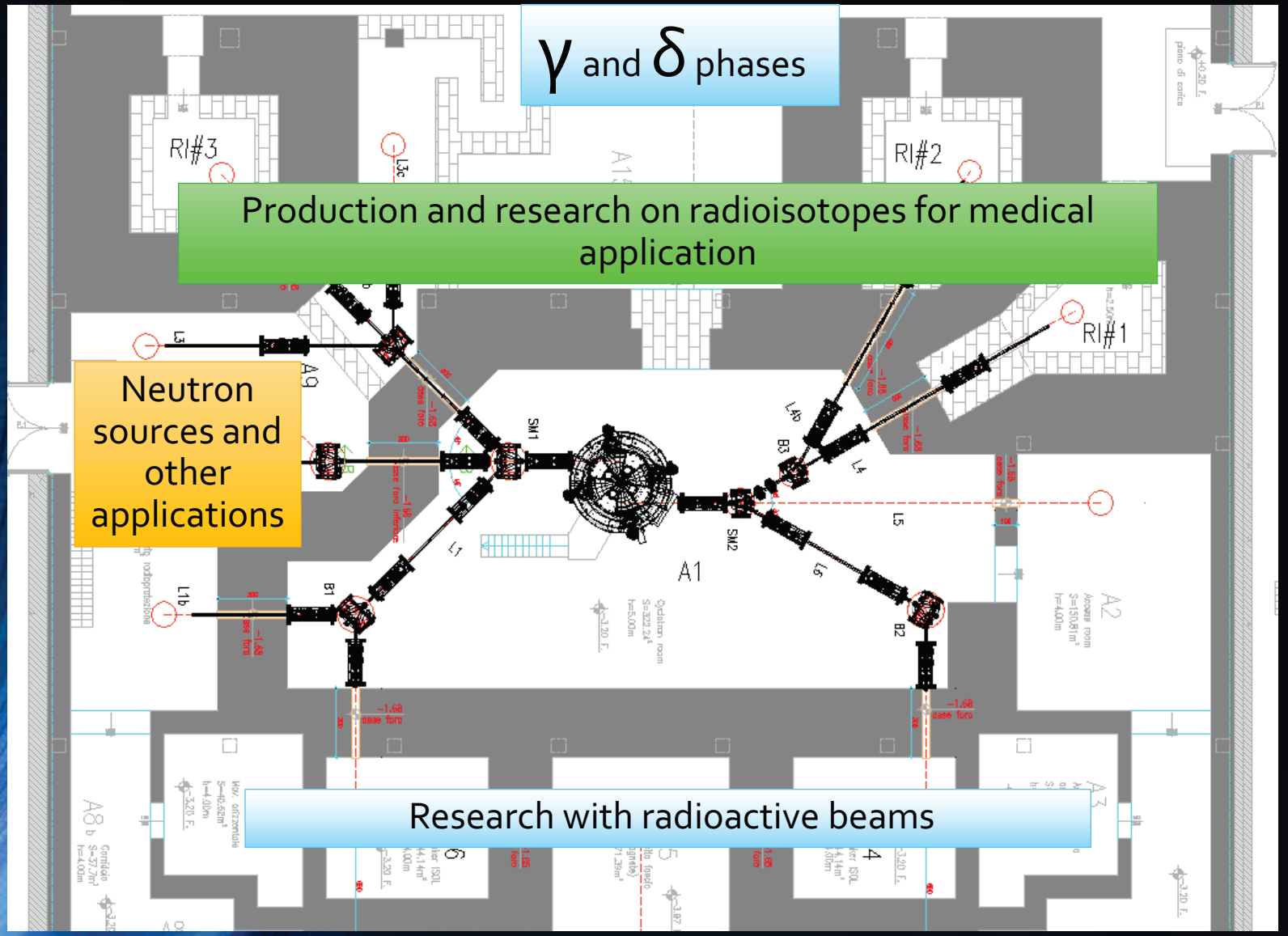
SPES: Selective Production of Exotic Species

- Flagship of INFN on Nuclear Physics and Astrophysics Research
- 50 Meuro budget fully funded (Alpha and Beta phases)
- It consists of 4 phases:
  - **Alpha**: Cyclotron (primary beam driver) and High Intensity Beam Deliver
  - **Beta**: RIBs production and Physics at Low and High Energy (Re-acceleration)
  - **Gamma**: R&D on Radioisotope for Medical Application (LARAMED project, partially funded)
  - **Delta**: Neutrons and Applications (NEPIR, TDR under study)
- Construction started in 2010 with Cyclotron and in 2012 with Building
- Completion of SPES Project is expected in 2019



- Cyclotron and beamline under commissioning
- ISOL target on test stand
- HRMS and beam cooler under study
- Charge Breeder ready to be installed
- RFQ (RT) injector under study, final design is in progress
- ALPI upgrade is ongoing

Final Configuration of Cyclotron and Beamlines



- Up to 9 irradiation target points
- 2 ISOL target stations (A6, A4)
- 3 Shielded bunker (RI #1,#2,#3) for High Intensity irradiation
- 4 medium and low intensity target areas (A8, A9, A15)

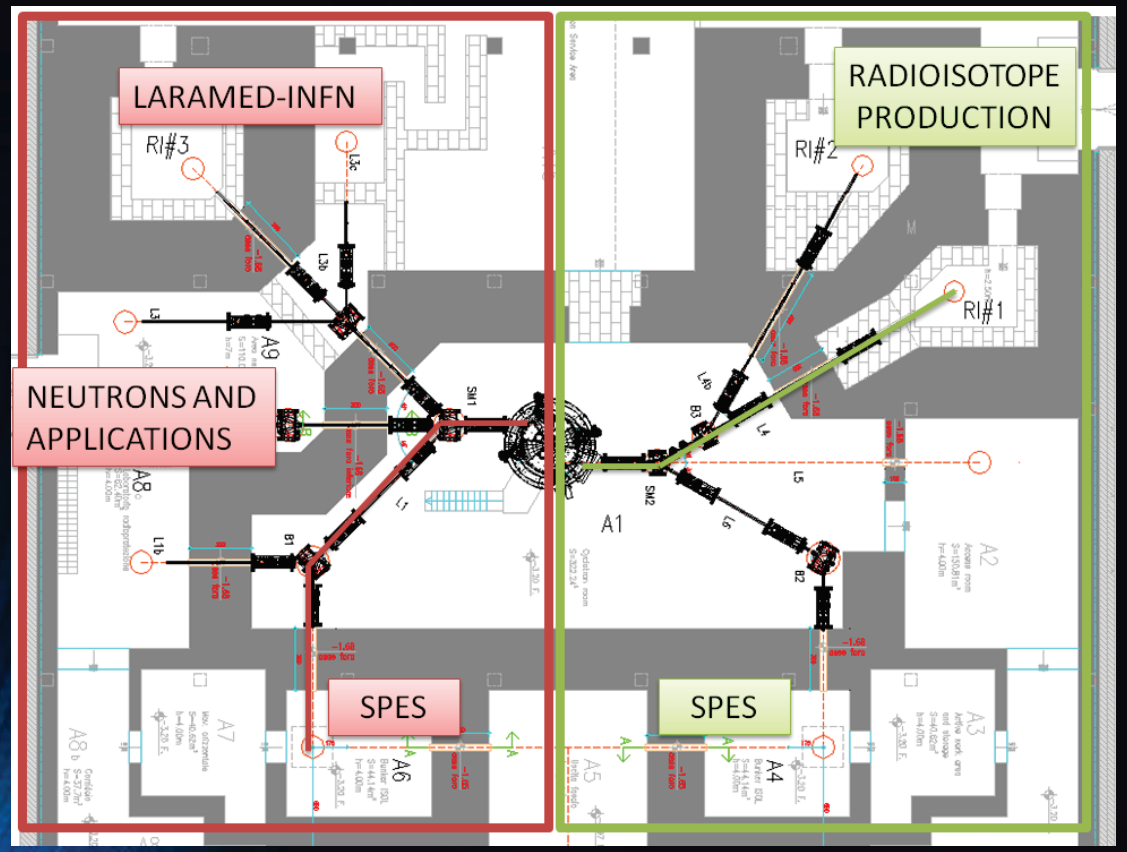
LARAMED (Laboratory of Radionuclides for Medicine) project

- A research laboratory (RILAB) owned jointly by INFN and CNR for:
  - Nuclear cross section measurements through stack-foils activation technique
  - A proving ground for high power target test
  - Low activity production of experimental radioisotopes (^{64}Cu, ^{67}Cu, ^{89}Z, ^{47}Sc…)
- A production facility (RIFAC) operated by INFN and a private partner for production of ^{82}Sr/^{82}Rb and ^{68}Ga/^{68}Ge
- Collaboration with CNR, ARRONAX

NEPIR (NEutron and Proton IRradiation facility) project

- QMN: Quasi Mono-energetic Neutron source with a controllable energy peak in the 20-70Mev energy range
- ANEM: Atmospheric Neutron Emulator to get a fast neutrons (E>1 MeV) with a continuous energy distribution similar to that of neutrons found at flight-altitudes and sea-level for SEE testing
- SLOWNE: a high intensity slow neutron (E<1 MeM) flux for applications

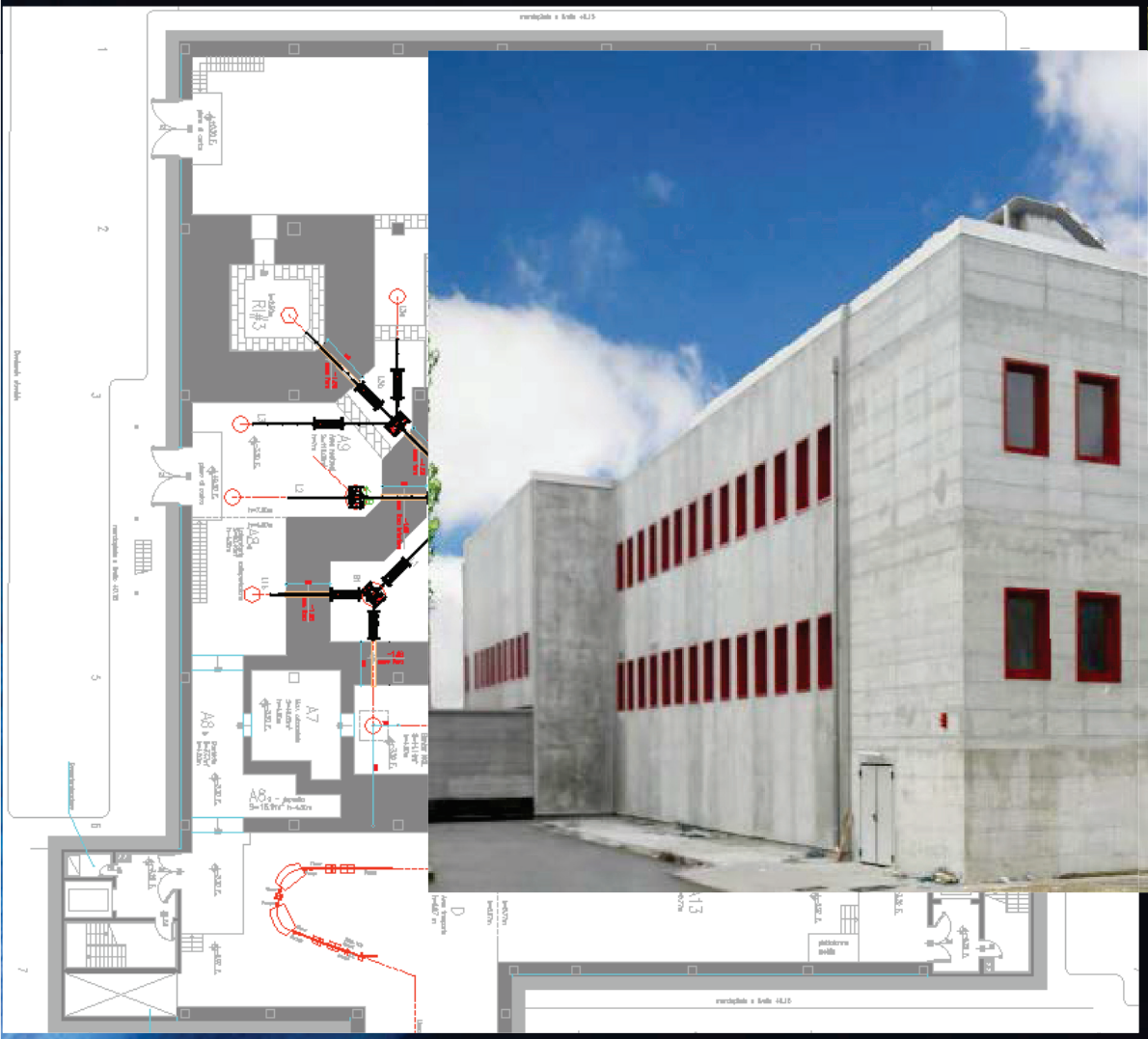
Beam Cyclotron Sharing (example)



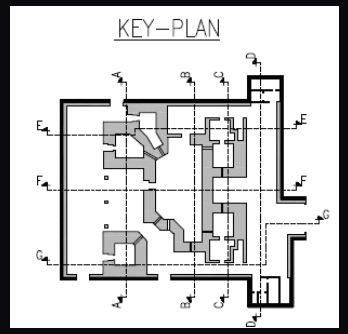
ROOM	BTL name	MAIN USE	MAX ENERGY AND CURRENT BEAM (protons)
A6	L1	SPES ISOL TARGET 1	40 MeV, 250uA
A8	L1B	TBD	
A9	L2	NEUTRONS (NEPIR)	35-70 MeV, 50 uA
A9	L3	NEUTRONS (NEPIR)	TBD (low power)
RI3	L3b	LARAMED-INFN	35-70 MeV, 200uA
A15	L3c	LARAMED-INFN	35-70 MeV, low power
RI1	L4	RADIOISOTOPE PRODUCTION	35-70 MeV, 500-700uA
RI2	L4b	RADIOISOTOPE PRODUCTION	35-70 MeV, 500-700uA
A4	L6	SPES ISOL TARGET 2	40 MeV, 250uA

STATIONS	week 1		week 2		week 3		week 4		week 5		week 6		week 7		week 8		week 9		week 10	
	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current	Energy	Current
ISOL (SPES)	40	250	40	250	ISOL mainten.		40	250	40	250	ISOL mainten.		ISOL mainten.		40	250	40	250	CYCLOTRON MAINTENANCE	
RI Production	40	≤ 450	40	≤ 450	> 40	> 350	40	≤450	40	≤ 450	>40	> 350	> 40	> 350	40	≤450	40	≤ 450		
Other Apps.					> 40	< 350					>40	< 350	> 40	< 350						

The New Building for SPES project

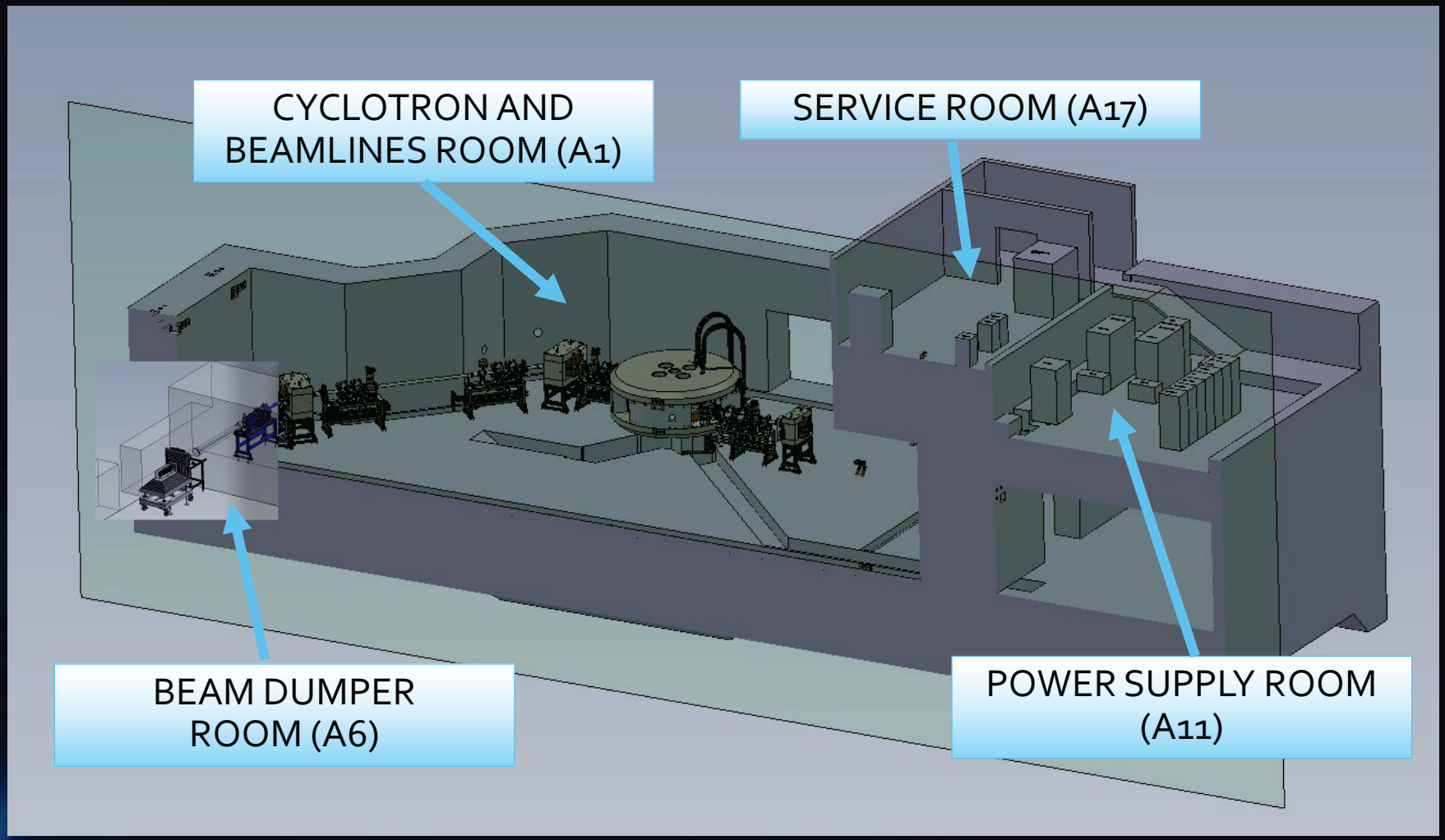


- 4 years to complete the work
- No additional costs respect to the initial budget
- It was a success of public tender management… in Italy

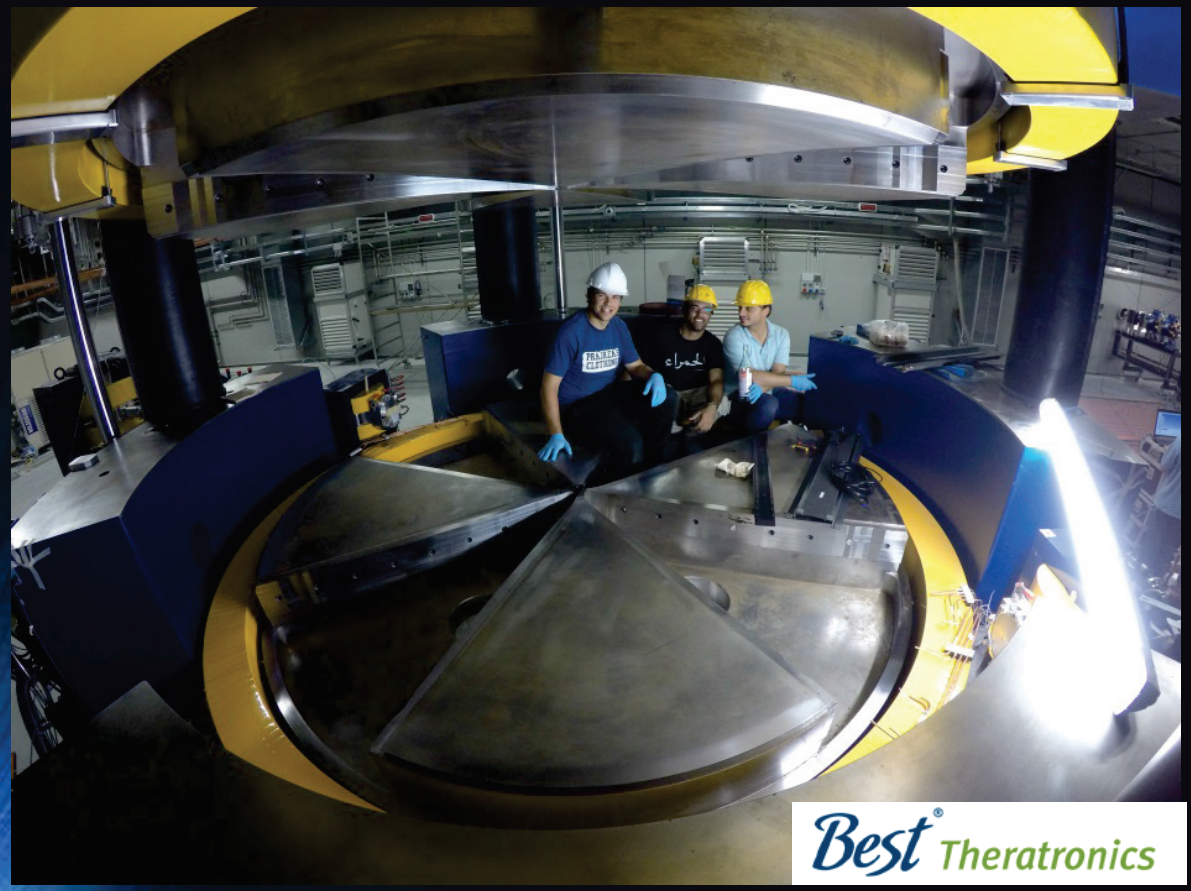


- 3 levels :
  - -1 floor : heavy shielded section to hold cyclotron and high activation areas (bunkers, ISOL target and RIBs transport)
  - 1th floor: services, conventional and special plants, ancillary laboratories and control room
  - 2nd floor: offices

Cyclotron Areas Arrangement



The Cyclotron



Main Parameters	
Accelerator type	Cyclotron AVF with 4 sectors, Resistive Magnet
Particle	Protons (H^- accelerated)
Energy range	35-70 MeV
Max Current Intensity	700 µA (variable within the range 1µA-700µA)
Extraction	Dual stripping extraction
Max Magnetic Field	1.6 T (Bo = 1 T)
RF System	nr. 2 delta cavities; harmonic mode=4; f_{RF} =56 MHz; 70 kV peak voltage; 50 kW RF power (2 RF amplifiers)
Ion Source	Multi-cusp volume H^- source; I_{ext} =8mA; V_{ext}=40 kV; axial injection
Dimensions	Φ=4.5 m, h=2 m, W=190 tons

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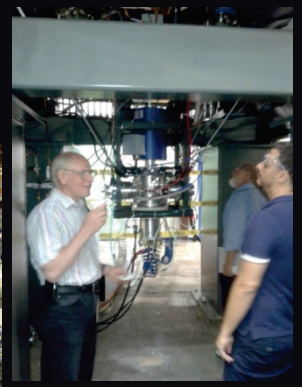
Brief Summary of Cyclotron Roadmap till 2014

- Cyclotron and one beamline supplied by BEST Cyclotron System Inc (CAN) who won the public tender in 2010
- Study and Design started in 2011
- Magnet ready in factory (Ottawa) in 2013 (magnetic field mapping)
- RF cavity system installed on mid 2013
- Ion source and injection line installed in 2014
- First beam injected (1 MeV) in factory in Sept. 2014
- Factory Acceptance Test concluded in Nov. 2014



Cyclotron installation at LNL (2015)

Ottawa, Jan 2015, Cyclotron leaving Factory

Legnaro, May 2015, Cyclotron at LNL

LNL, May 2015, first day of operation

Upper pole installation during 2nd day

BEST and INFN "joint venture"

Completion of installation (cyclotron and infrastructure) in 2015- mid2016


Power Supply room


Services room


Water plant


Beamlines installation

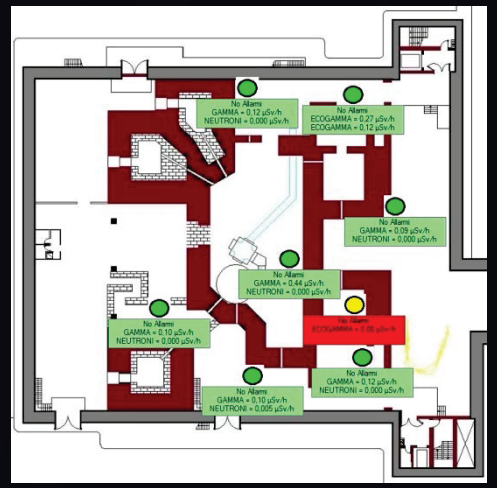

Sliding shielded doors

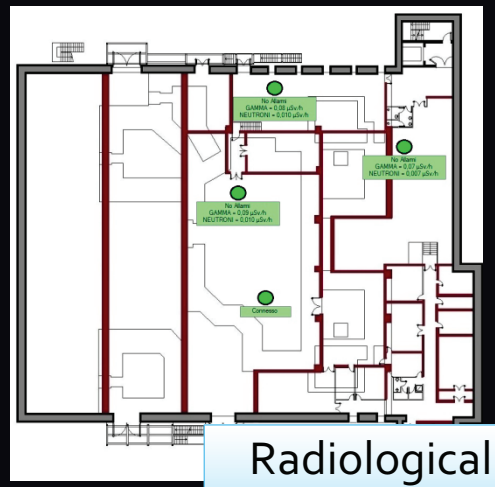

Labyrinth between A1/A2 rooms

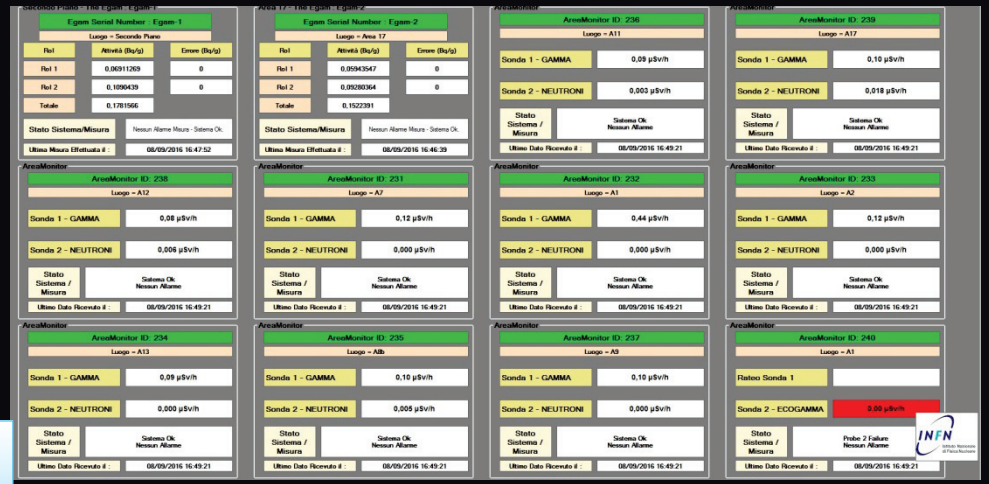
Cyclotron and beamlines today

Beam Commissioning

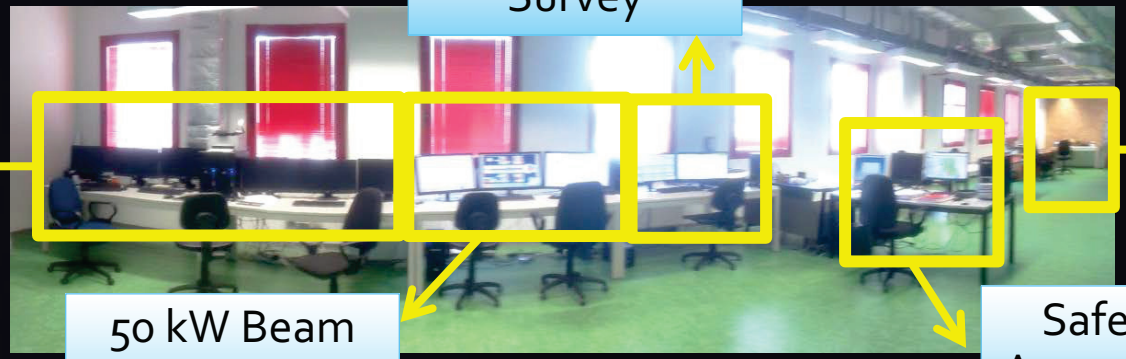
- On Feb 2016 BEST starts the beam commissioning:
  - Low power test (injection, acceleration) (Feb 2016)
  - Low power beam extracted (May 2016)
  - High power beam extracted and delivered to beam dumper (July 2016-today)
- INFN supervises and provides technical support and supplies some component:
  - Low power faraday cups
  - High power beam dumper
  - Last section of beamline (high radiation environment)
  - Beam loss monitors (prototypes)
  - **Safety and Radiological Survey System**







Radiological Survey

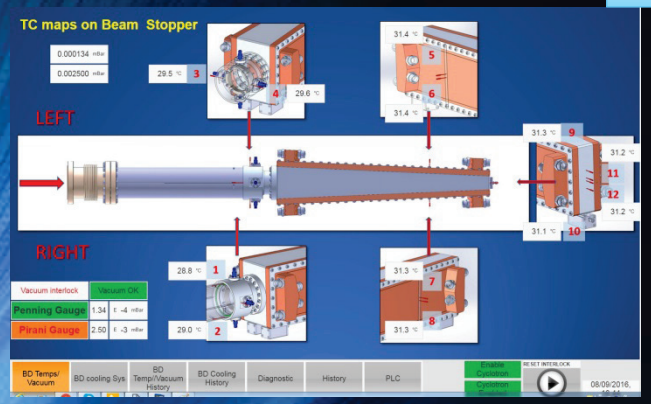


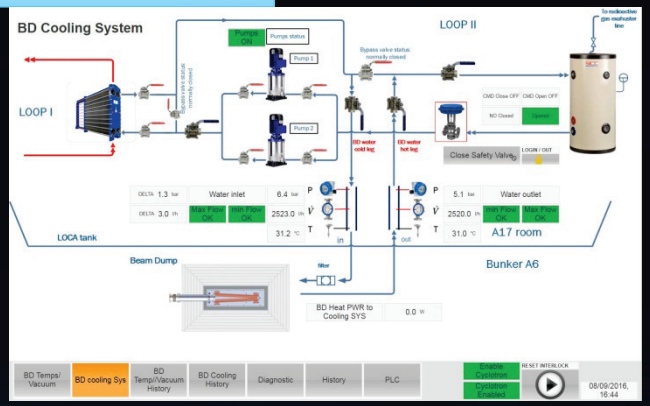
CYCLOTRON & BEAMLINES

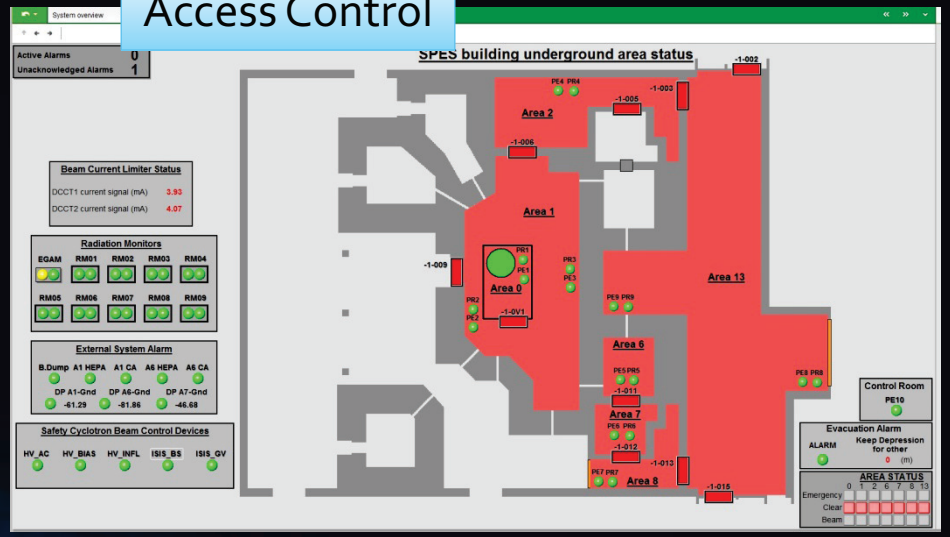
SERVICES AND PLANTS CONTROL

50 kW Beam dumper

Safety and Access Control

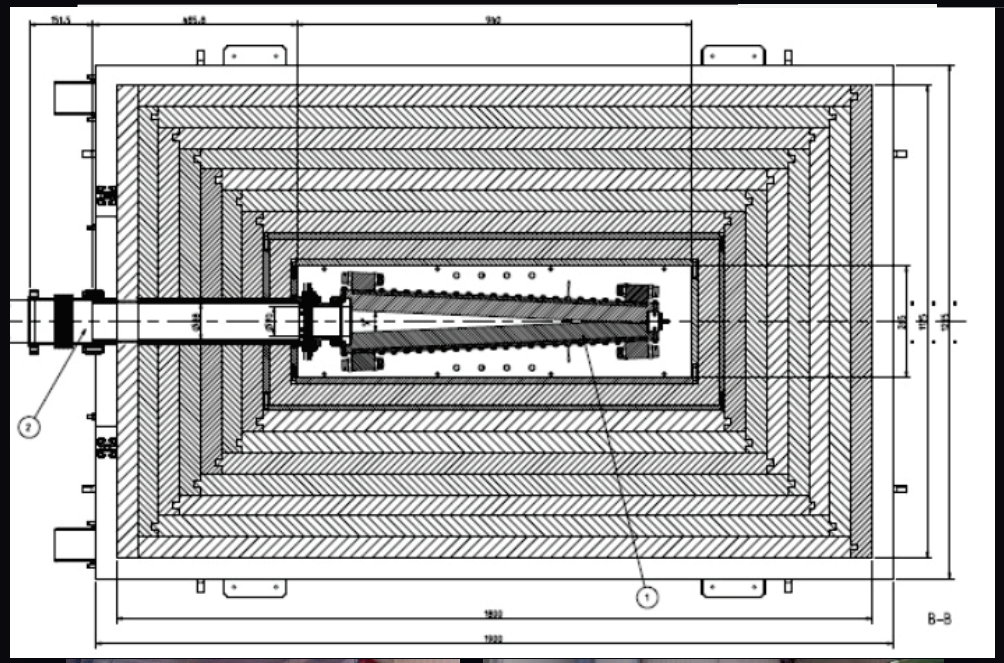


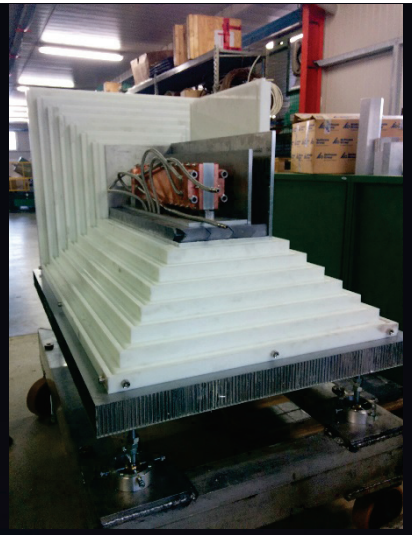




50 kW Beam Dumper

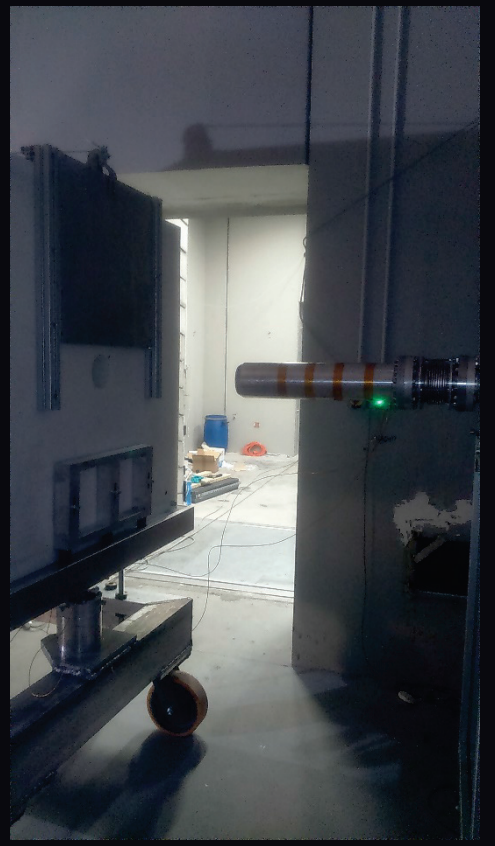
- Two copper plates tilted by 10 deg
- Aluminum frame
- Indium sealing between Cu and Al material
- Water cooled (6 bar)
- Lead shielding and additional external layers of HDPE for neutron flux reduction
- Up to 12 probes for monitoring of temperature of different sections
- All safety devices are redundants





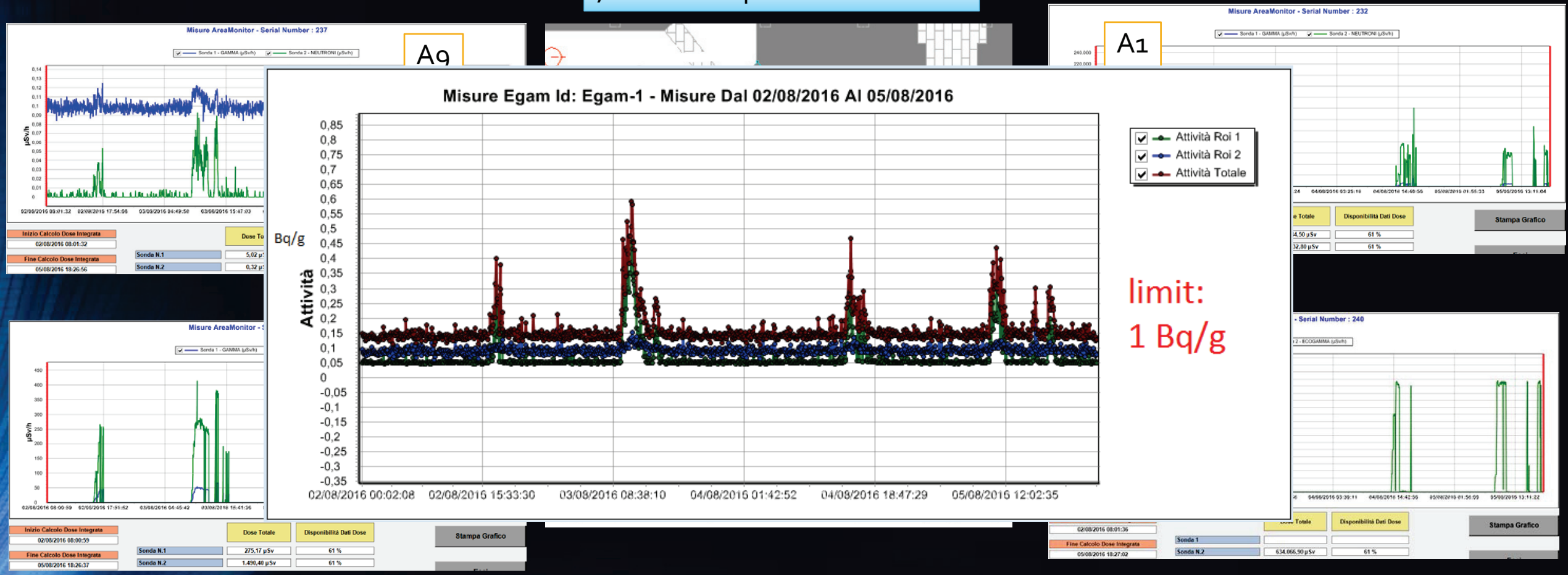
Installation and beam commissioning

- In June the installation in the bunker was accomplished out
- Alignment done by laser tracker system
- In July beam commissioning started at low power and full energy (70MeV)
- Vacuum level (no beam) 1.5 x 10 E -5 mbar
- 500 μA and 70 MeV achieved (35 kW) in Sept
- Stop for a detectable vacuum leak
- Device not fully compromised, but operational in safe condition up to 15-20 kW



Beam loss monitoring by the Radiation Survey System

70 MeV 100 µA thru BL1 to BD



Conclusions

- The SPES project is now entering its construction phase. The project is fully funded and its completion (first RIB produced by ISOL) is expected in 2019-2020.
- The high intensity facility whose core is the cyclotron is developing: two main project for applications of high intensity beam are respectively in advanced phase (LARAMED) and design evaluation (NEPIR)
- The installation of cyclotron supplied by BEST is concluded and the commissioning of the accelerator and beamline is in progress and it should be accomplished out by the end of this year.
- The machine achieved 500 μA (35kW) without particular problems and shows very good performance in terms of acceleration efficiency and transmission as well.
- In 2017 the cyclotron should be fully operational: very exciting perspectives for LNL future in nuclear physics and interdisciplinary research.

Thanks to people involved in this project:

Cyclotron: A. Lombardi, P.Antonini, D.Campo, L. Pranovi

Infrastructure and Service: M. Calderolla, N. Ciatara, A. Calore, P.Favaron
Target and Safety: J. Esposito, D. Benini, L. De Ruvo, E.Boratto
Radioprotection: D. Zafiropulos, L. Sarchiapone
Controls and Diagnostics: M. Bellato, F. Gelain
Cyclotron Consultants: L. Calabretta, C. De Martinis

Team of Best Cyclotrons System Inc.

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