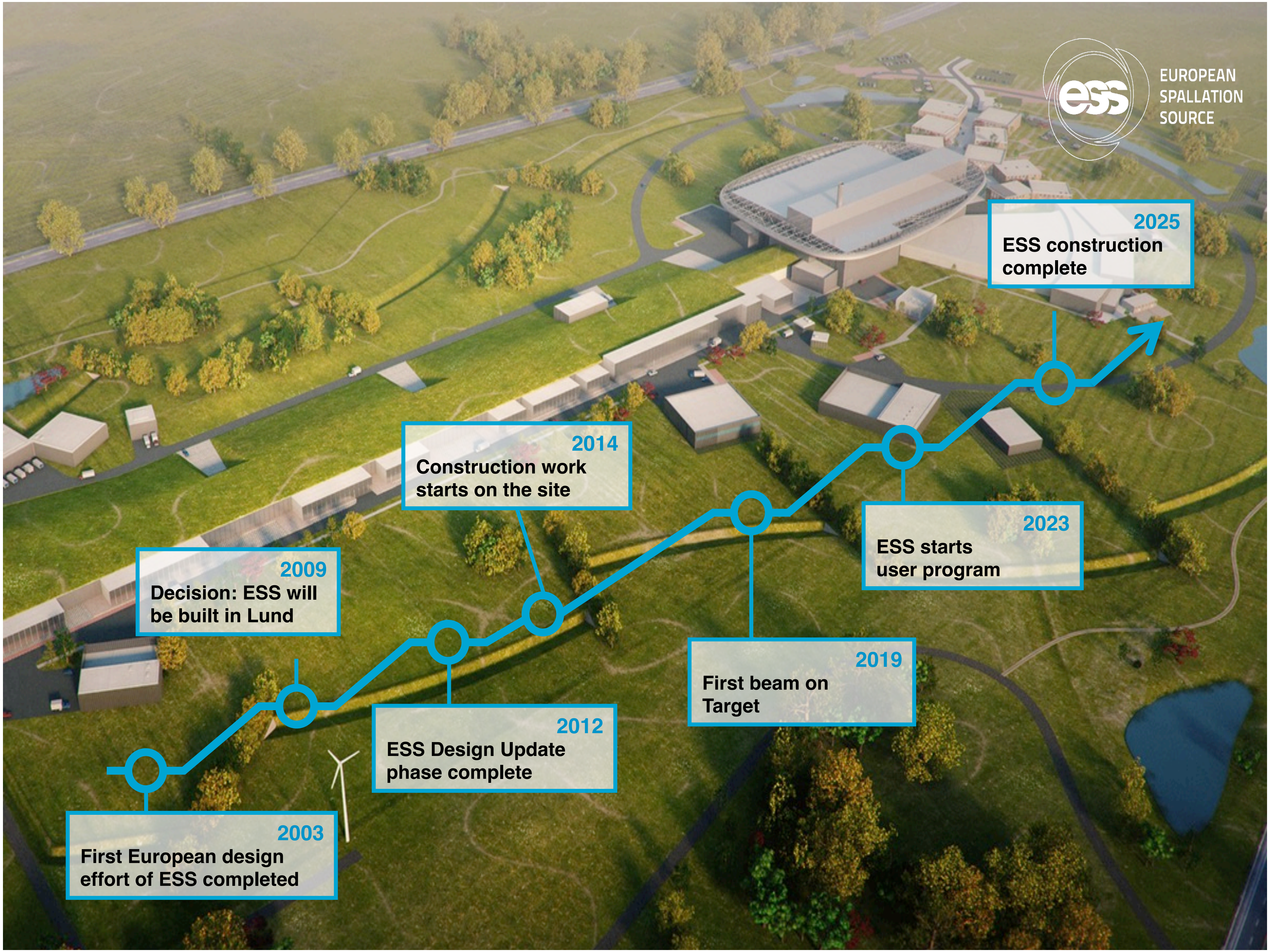
Il coinvolgimento della aziende nei contributi in-kind al progetto ESS

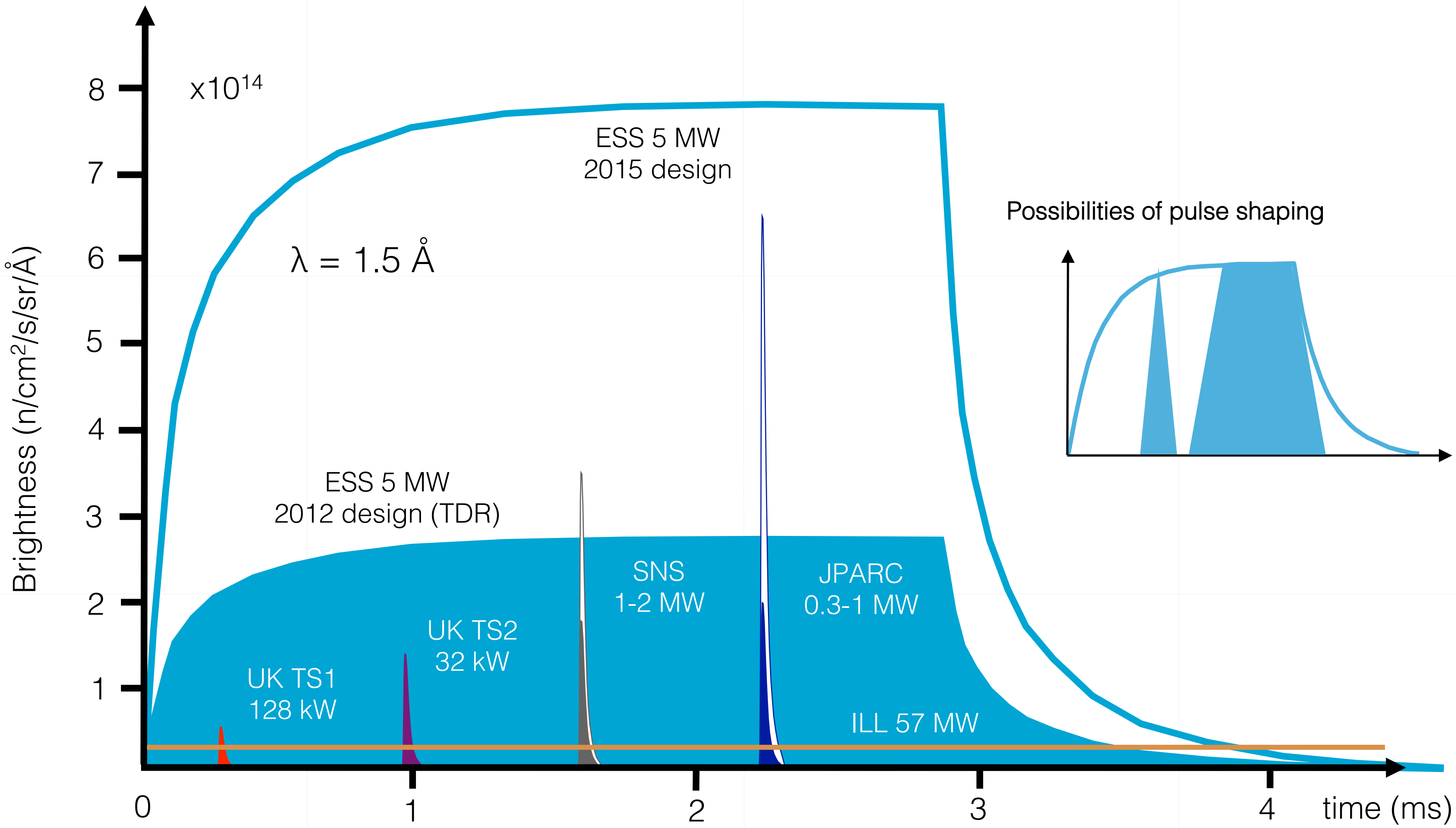
S. Gammino (INFN)


EUROPEAN
SPALLATION
SOURCE
2003
First European design effort of ESS completed
2009
Decision: ESS will be built in Lund
2012
ESS Design Update phase complete
2014
Construction work starts on the site
2019
First beam on Target
2023
ESS starts user program
2025
ESS construction complete

ESS design


High Power
Linear Accelerator:
• Energy: 2 GeV
• Rep. Rate: 14 Hz
• Current: 62.5 mA
Target Station:
• He-gas cooled rotating W-target (5MW average power)
• 42 beam ports
Ion Source
16 Instruments in Construction budget
Committed to deliver 22 instruments by 2028
Peak flux ~30-100 brighter than the ILL
Total cost: 1843 MEuros 2013

Long-pulse performance



Some visions for neutron and light source science

- Higher (Room?) Temperature Super Conductors
- Hydrogen storage substrate
- Efficient membrane for fuel cells
- Flexible and highly efficient solar cells
- Understanding liquid membranes
- Nano scaled structures for controlled drug release
- Self healing materials – smart materials
- Spintronics - Spin-state as a storage of data (10^{23} gain in capacity)
- CO_2 sequestration
- Neutron electric dipole moment
- Neutron oscillations
- And much more…

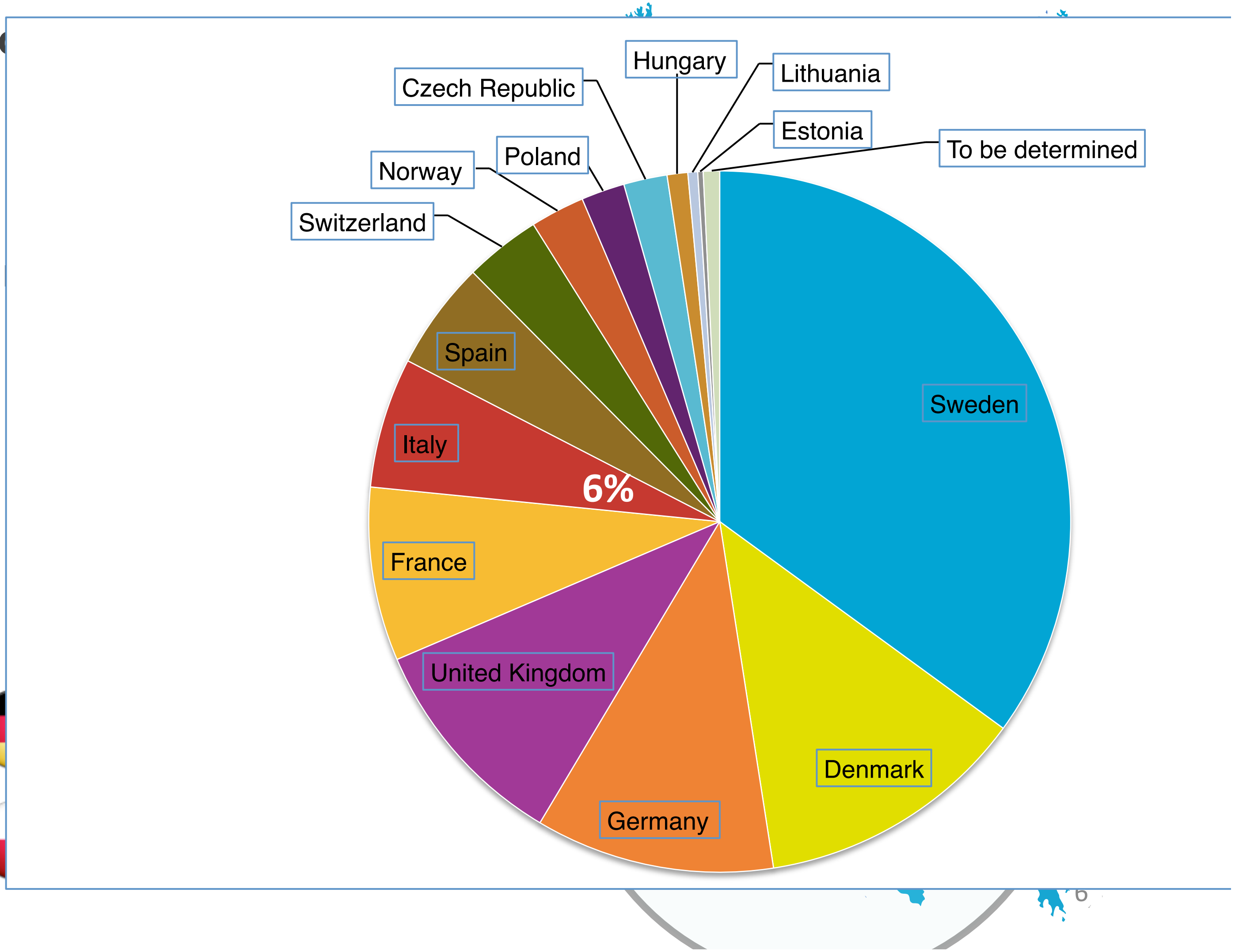
Financing includes cash and deliverables

Host Countries of Swe

Construction 47.5%
Operations 15%

Non Host Member Cou

Construction 52.5%
Operations 85%



Italian committment to ESS

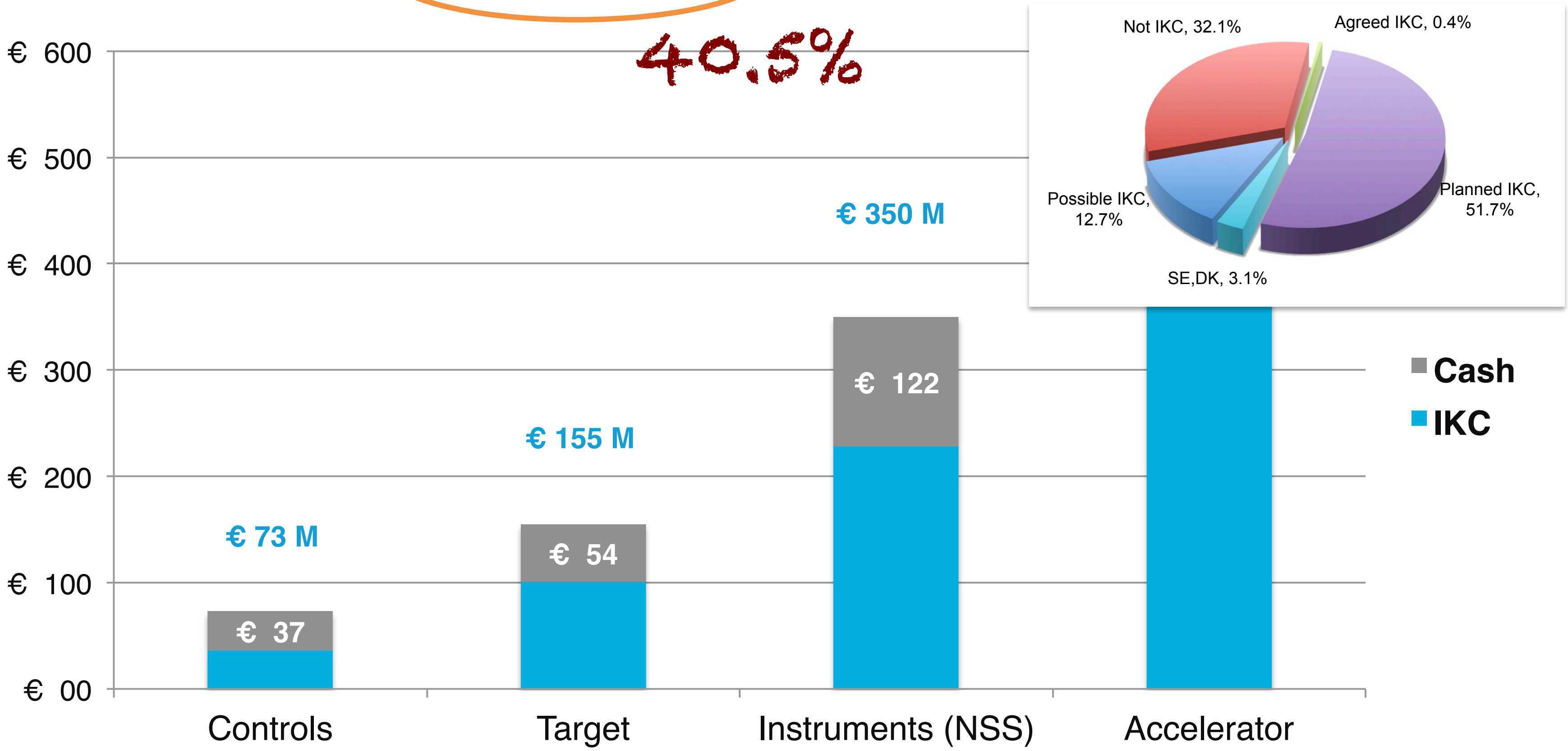
Total Planned Commitment (2013 prices): 110,186 M€ (6,0%)
CASH: 20,8 M€ (19,0%)
IN KIND: 89,39 M€ (81%)

Three Institutions involved: CNR-ELETTRA-INFN
(INFN acts as representing entity)

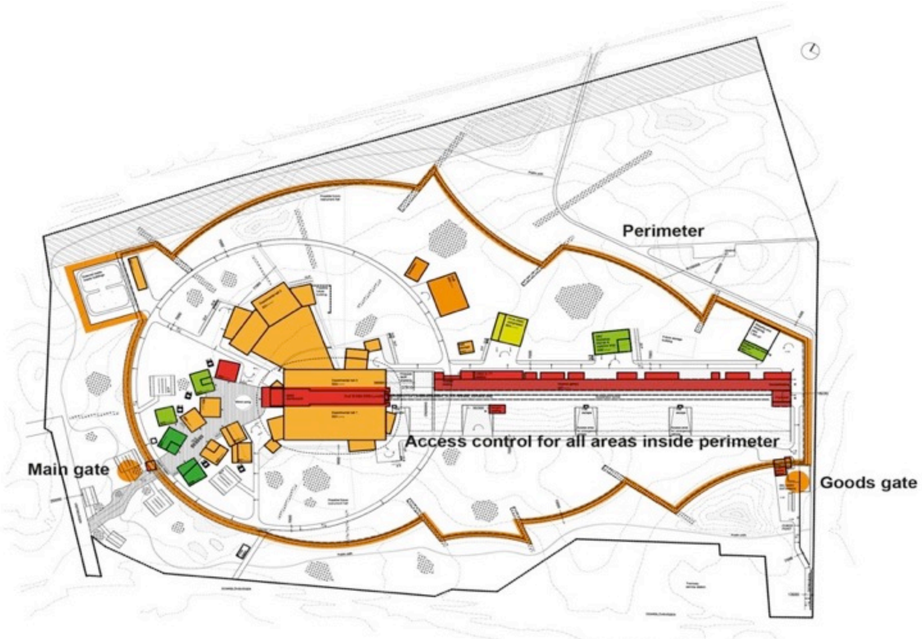
Total IKC to the accelerator (ELETTRA+INFN): 62.51 M€

ESS In-kind goals

Construction cost: € 1.84 Billion
In-kind: € 747.5 Million



Construction



July 2014

Dec 2014

July 2015

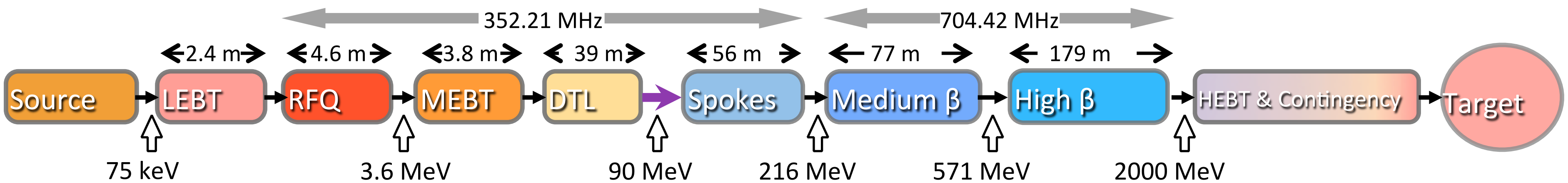
ESS construction

Accelerator Technical performances

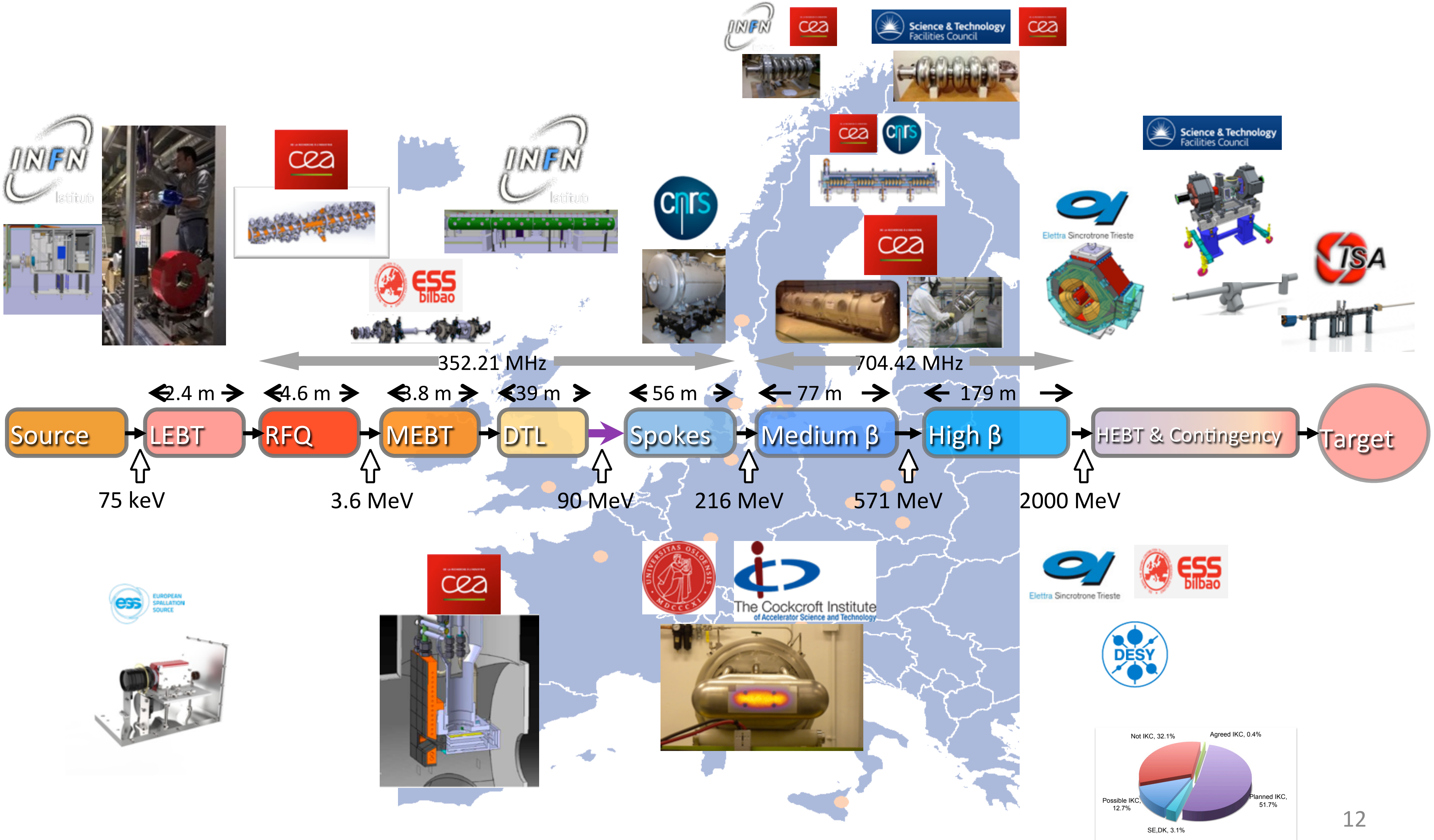
Design Drivers:

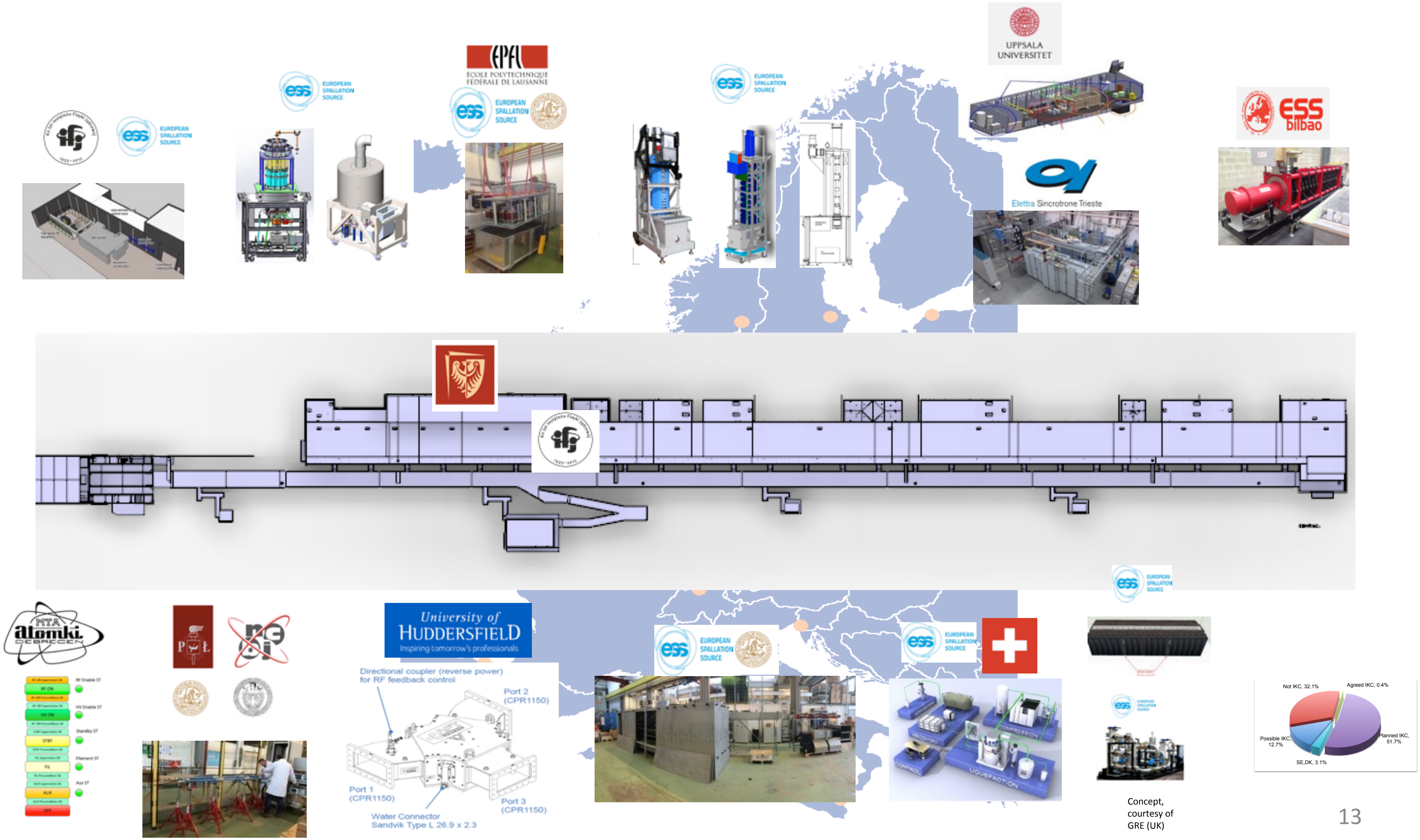
High Average Beam Power
5 MW
High Peak Beam Power
125 MW
High Availability

Key parameters:
-2.86 ms pulses
-2 GeV
-62.5 mA peak
-14 Hz
-Protons (H+)
-Low losses
-Minimize energy use
-Flexible design for mitigation and future upgrades



- First beam at the end of Mediumβ in June 2019
- 5 MW capacity for 2023

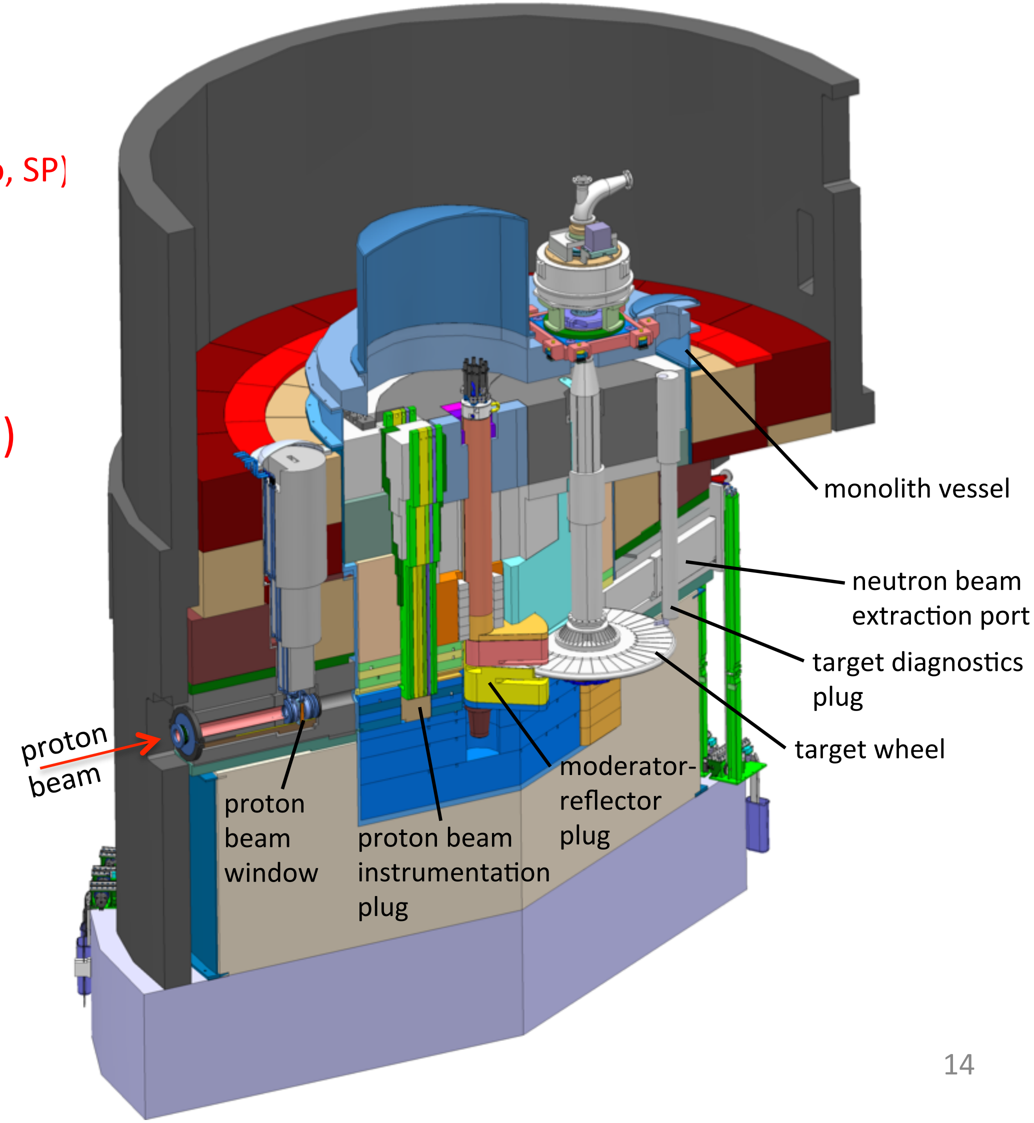

352.21 MHz
704.42 MHz
2.4 m
4.6 m
3.8 m
39 m
56 m
77 m
179 m
Source
LEBT
RFQ
MEBT
DTL
Spokes
Medium β
High β
HEBT & Contingency
Target
75 keV
3.6 MeV
90 MeV
216 MeV
571 MeV
2000 MeV
INFN
cea
Science & Technology Facilities Council
cnrs
ESS bilbao
Elettra Sincrotrone Trieste
ISA
The Cockcroft Institute of Accelerator Science and Technology
DESY
Not IKC, 32.1%
Agreed IKC, 0.4%
Possible IKC, 12.7%
Planned IKC, 51.7%
SE,DK, 3.1%


EUROPEAN SPALLATION SOURCE
EPFL
ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
UPPSALA UNIVERSITET
Elettra Sincrotrone Trieste
ESS bilbao
atomki DEBRECEN
University of HUDDERSFIELD
Inspiring tomorrow's professionals
Directional coupler (reverse power) for RF feedback control
Port 2 (CPR1150)
Port 1 (CPR1150)
Port 3 (CPR1150)
Water Connector Sandvik Type L 26.9 x 2.3
Not IKC, 32.1%
Agreed IKC, 0.4%
Possible IKC, 12.7%
Planned IKC, 51.7%
SE,DK, 3.1%
Concept, courtesy of GRE (UK)

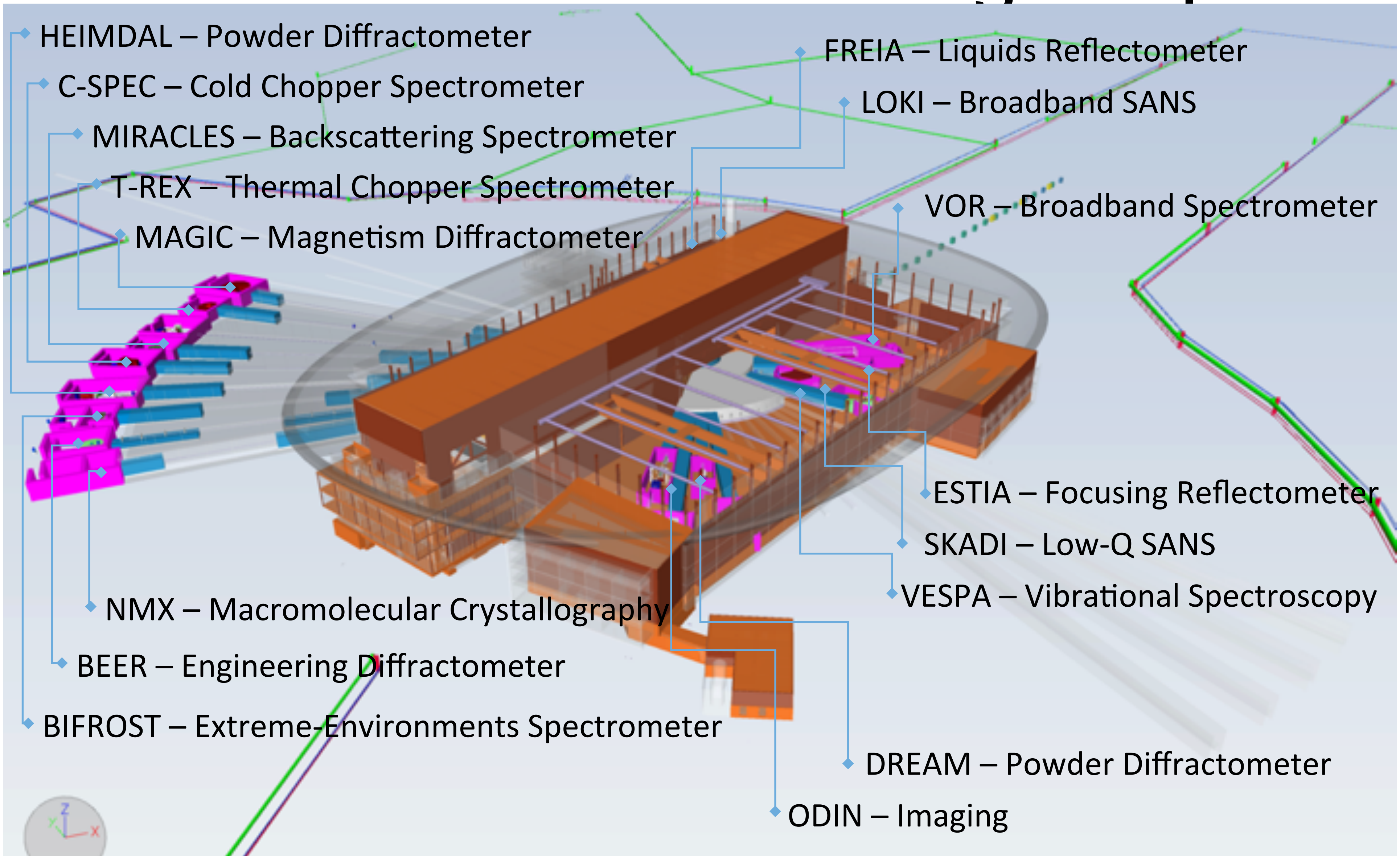
Target, monolith, moderators etc.

<u>Main components</u>:

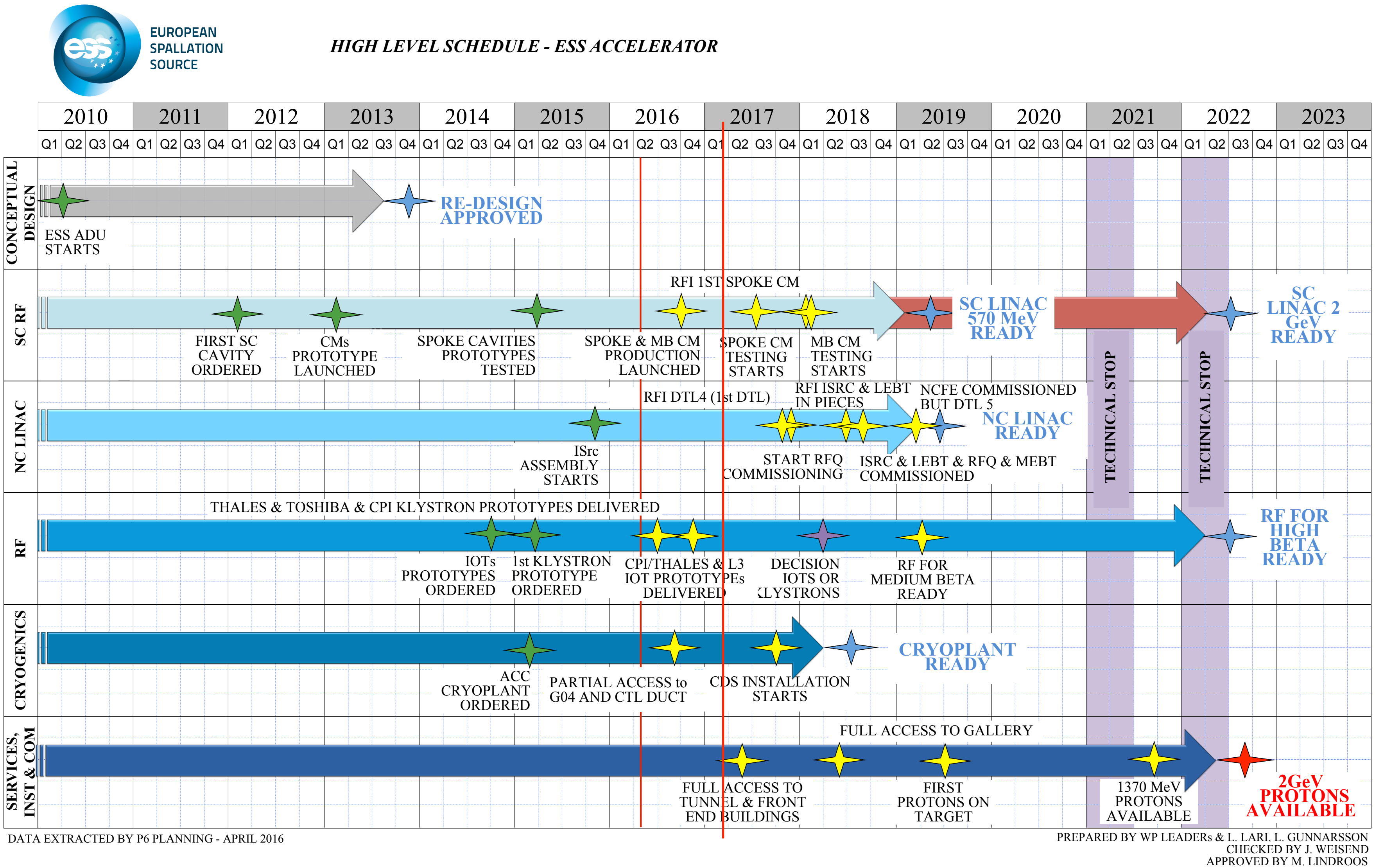
- Monolith:
    - Vessel (6 m diameter x 8 m height) (ESS-Bilbao, SP)
    - Steel shielding (6000 tons)
    - Instrumentation plugs (ESS-Bilbao, SP)
    - Proton beam window (ESS-Bilbao, SP)
    - Neutron shutters (ESS-Bilbao, SP)
    - Neutron beam extraction system
- Rotating Tungsten target (ESS-Bilbao, SP)
    - 2.5 m diameter x 10 cm height
    - 7500 Tungsten bricks (3.5 tons)
    - 0.39 rev./s
- Target He gas-cooling (UJF, CZ)
    - 3 MW capacity
    - 3 kg/s flow rate
    - Dt = 200 degrees C
- High brightness moderators (FZJ, DE)
    - 2 liquid H_2 moderators
    - Water premoderators and moderators
    - He cryoplant (35 kW – 16 K)

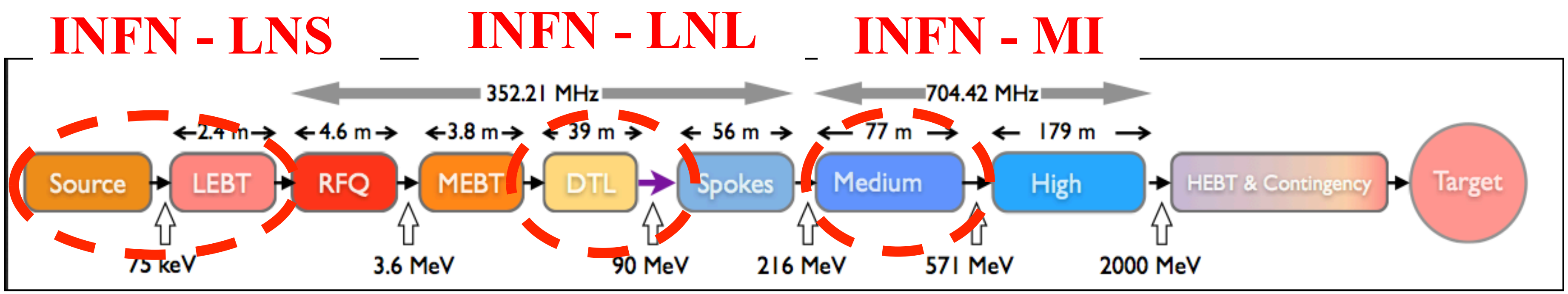


Instrument Suite is taking shape



High Level Master Schedule (Level 1)



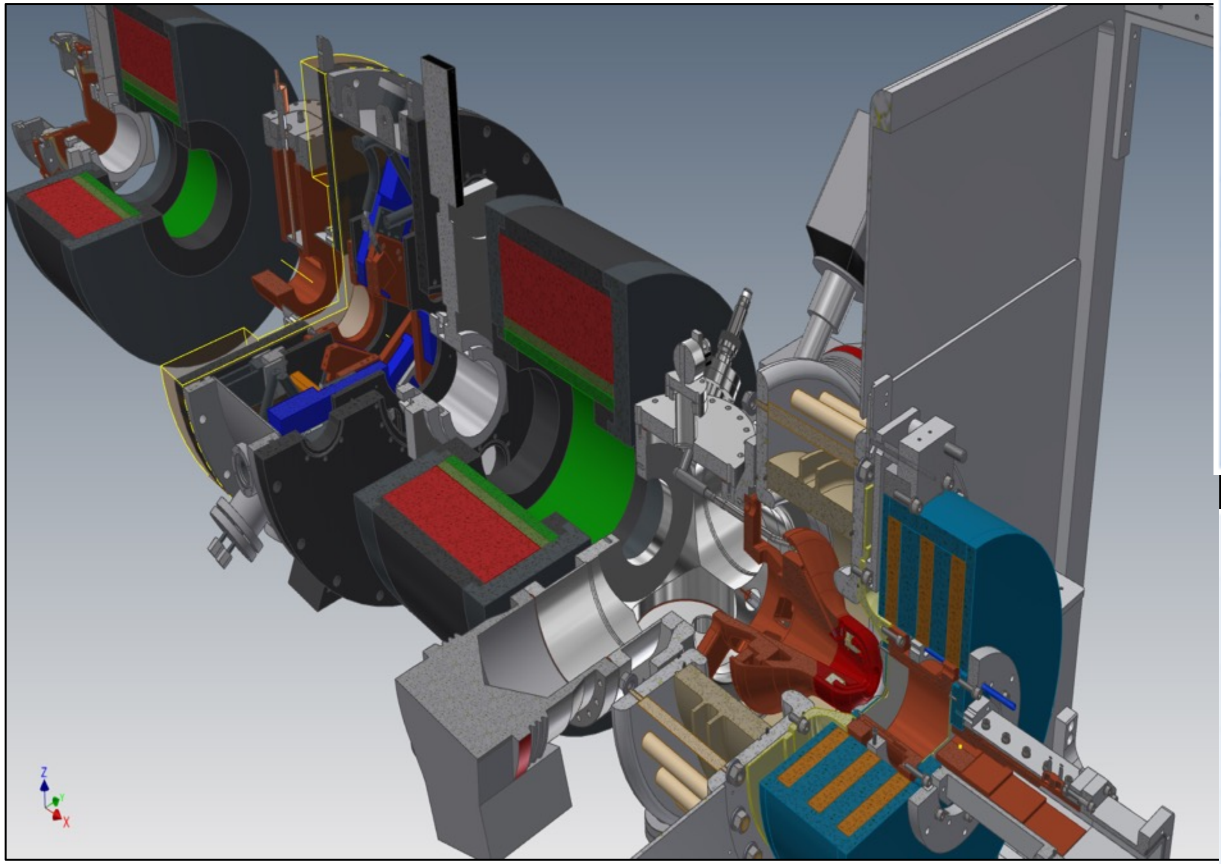


INFN is in charge of:

1. **Ion Source & LEBT (Laboratori Nazionali del Sud)**
2. **Drift Tube Linac (Laboratori Nazionali di Legnaro)**
3. **Medium Beta Superconducting elliptical cavities (LASA-Milano)**

The 3 TAs have been approved by INFN Board and signed in 2016 (DTL in April, Ion Source&LEBT in June, Medium beta cavities in November)

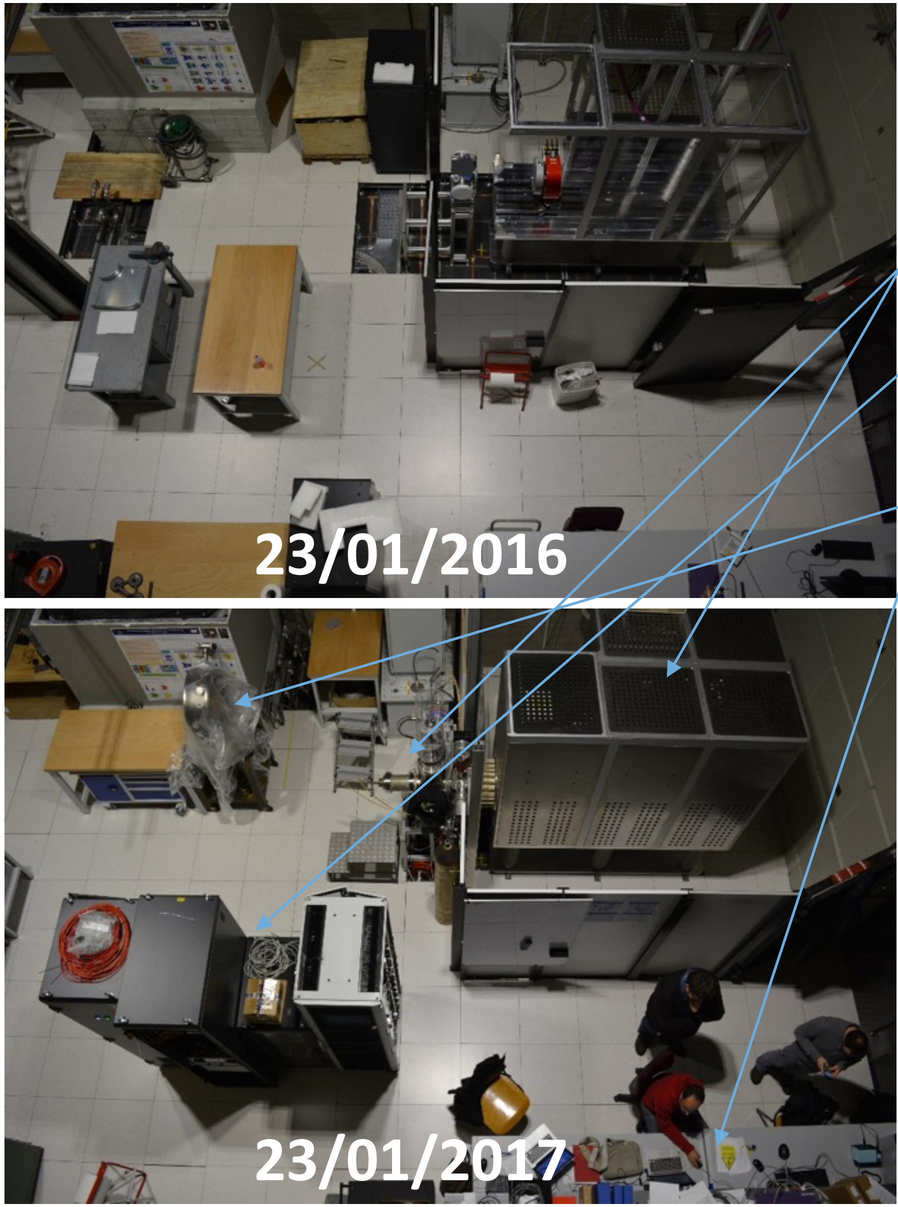
Ion Source & LEBT



Parameters	Value
Nominal proton peak current	74 mA
Proton fraction	> 80 %
Stable operation current range	60-74 mA
Current stability(over 50us period)	± 2 %
Pulse to pulse variation	± 3.5 %
Beam Energy	75 keV (±0.01)
Distance between pulses	1 Hz< f <14 Hz
Restart after vacuum break Restart after cold start	<32 h <16 h

Parameters	Value
Beam current change (2 mA step, ±1 mA res.)	2-74 mA
Nominal pulse length	2.86 ms
Pulse length range (±0.001 ms)	0.005-2.88 ms
99 % rms norm. emit. at RFQ input	< 2.25 pi.mm.mrad
Twiss parameter: α	α= 1.02 ±20%
Twiss parameter: β	β= 0.11 ±10%
Rise and fall time	<20 us
Maximum LEBT pressure	6e-5 mbar

Proton source and LEBT



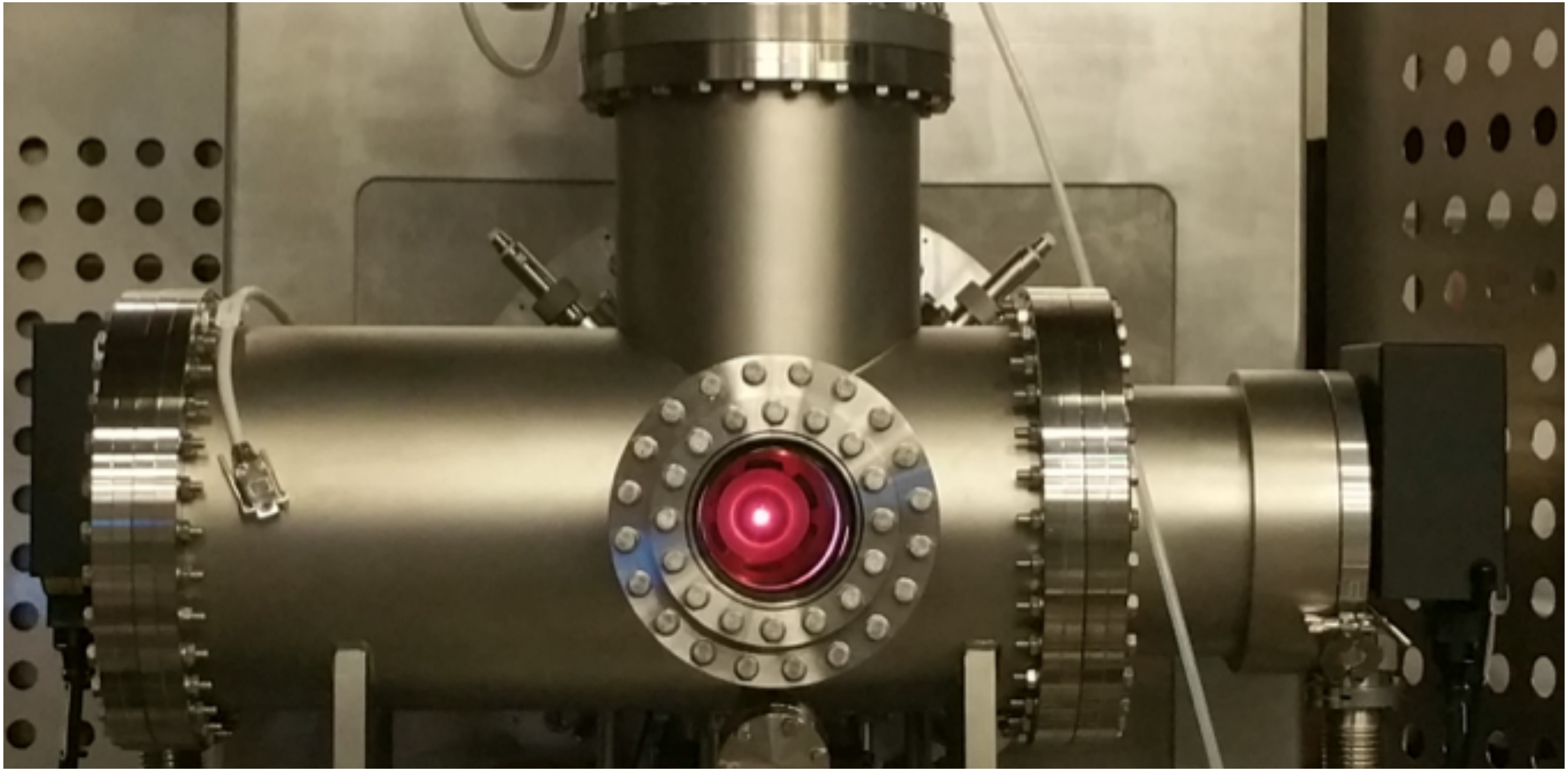
Done in 2016:

- Source and HV platform fully assembled
- LEBT and beam instrumentations for phases 1 and 2 fully assembled
- All four racks fully assembled
- Computers for the source control system fully assembled
- Iris fully assembled
- Solenoids arrived
- Two diagnostic tanks arrived
- Chopper ordered
- LEBT collimator ordered

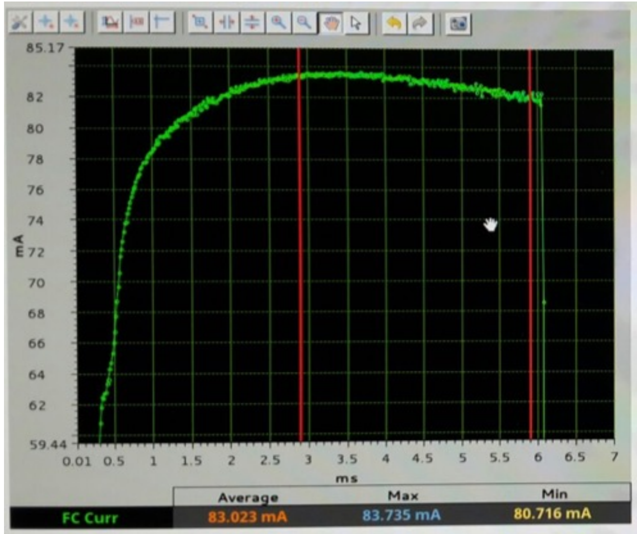
Currently under way:

- Characterization of the source
- Assembly of the full LEBT

First plasma in the ion source in Catar



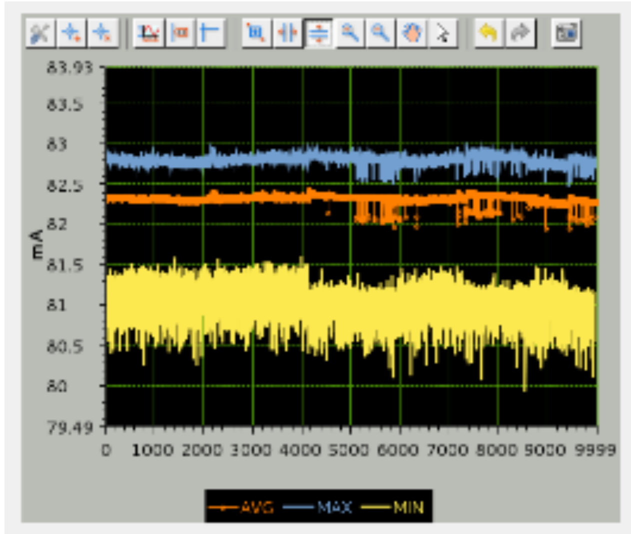
Preliminary beam characterization



Extracted beam: 82 mA (close to goal:90 mA,to be obtained with larger extractor& Alumina wall)

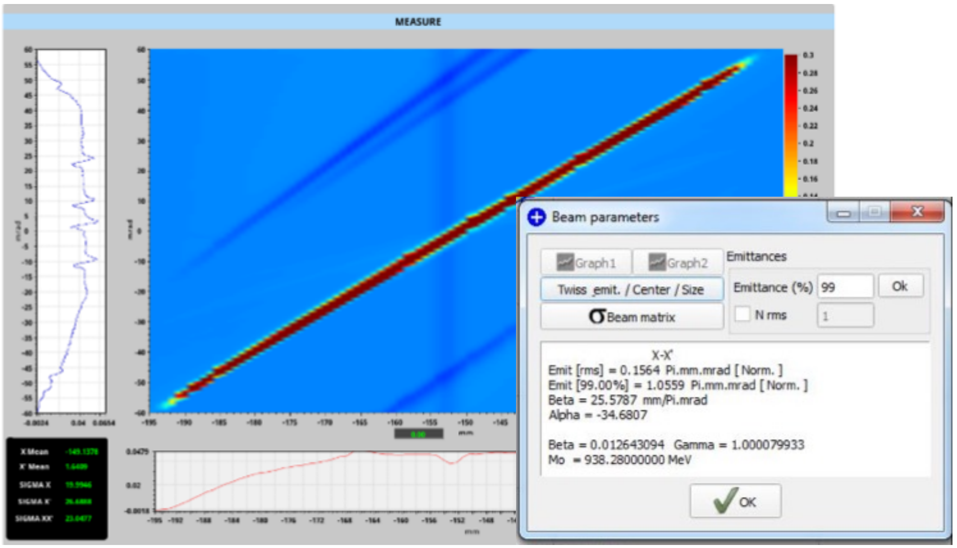
Pulse stability: ±1% **(better than ±2%)**

Pulse repeatability: ±1.8% **(< ±3.5%)**

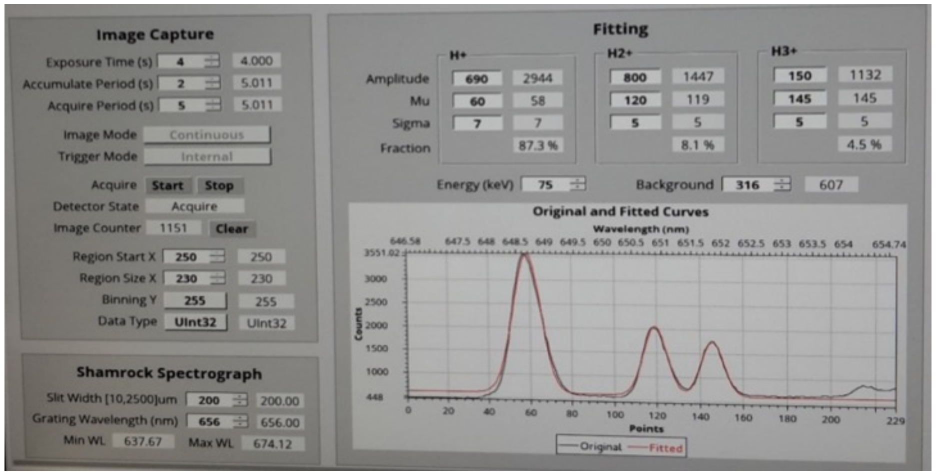


Emittance: 1.06 π.mm.mrad **(< 1.8)**

Max divergence: 55 mrad **(< 80)**



Proton Fraction: 83% **(> 75%)**



Status of the installation

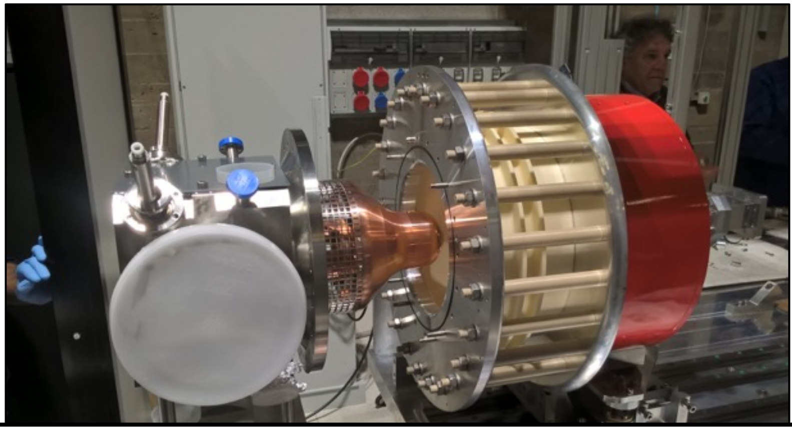
Source is fully assembled and cabled

LEBT is assembled and cabled for the beam commissioning phases 1 and 2

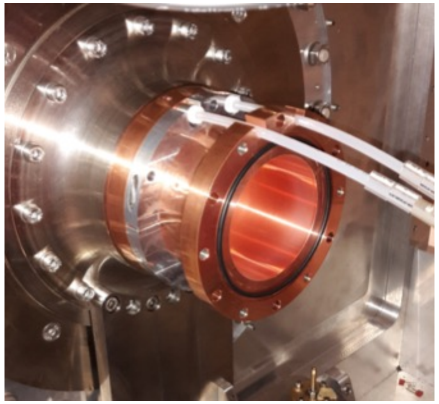
Activity		Start	End	Delay
Phase 1: IS with FC and DSM		03/10/2016	31/10/2016	YES-2mo.
Phase 2: phase 1 + EMU1		02/11/2016	17/03/2017	YES-1.5mo.
Phase 3 and 4: Full LEBT		20/03/2017	29/09/2017	Partially postponed after RFI@Lund
Packaging and shipping		02/10/2017	31/10/2017	//

PS-ESS 2 procurement (>700k€)

High Voltage platform	About 40 k€
LEBT support	few k€
Insulators ceramic	About 60 k€
Extraction System	About 50 k€
High Voltage Power Supply 150 mA 100 kV	About 120 k€
80 kV DC Insulation Transformer	< 60 k€
RF waveguide branching	< 50 k€
LEBT Power supply	About 30 k€
Mechanics	About 30 k€
Magnetic Trap	< 60 k€
Plasma Chamber and Matching transformer	About 50 k€
Insulation Column	40 k€
HV rack + subrack EMC + cable, engineering and controls	About 30 k€
Pink Tube + support	20k€
Magnetic System Power supply	30k€
Magnetron, ATU, Fast shut down	About 40 k€
RF power probes	10k€
workstation analisi dati commissioning	7k€
HVT80RCR Voltage Divider	8k€



insulating column and the extraction electrodes

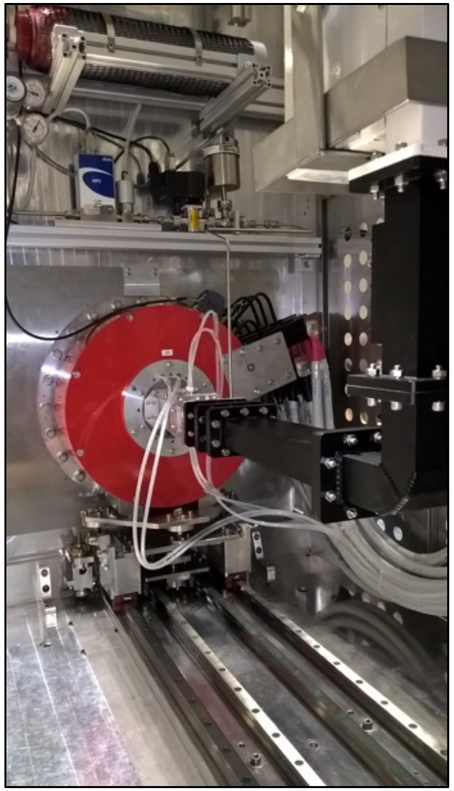


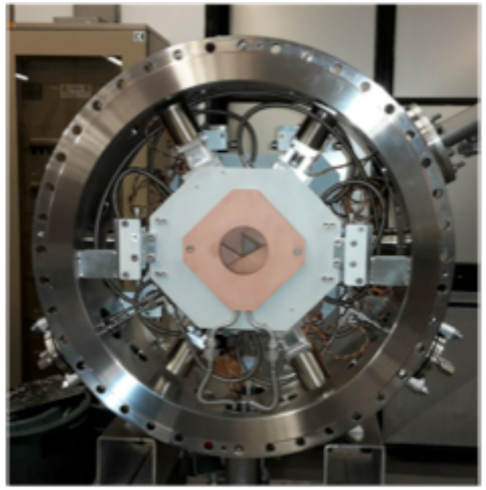
Plasma chamber

Matching Transformer

Source fully assembled with

- ***magnetic system***
- ***plasma chamber***
- ***matching transform***



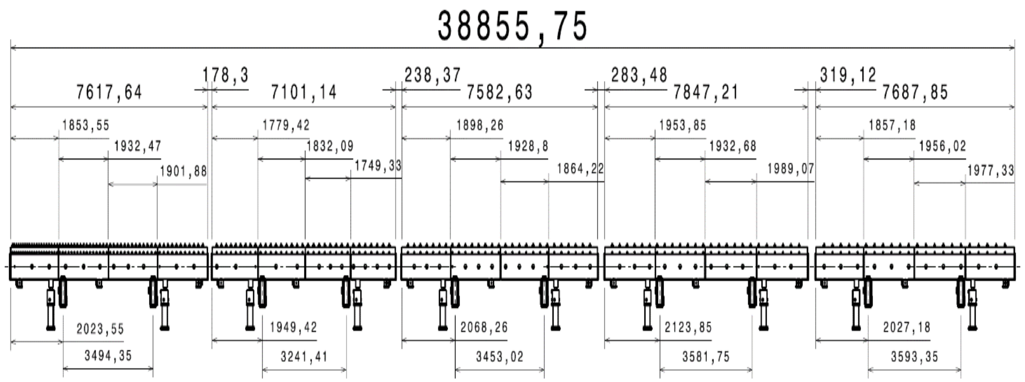


Iris

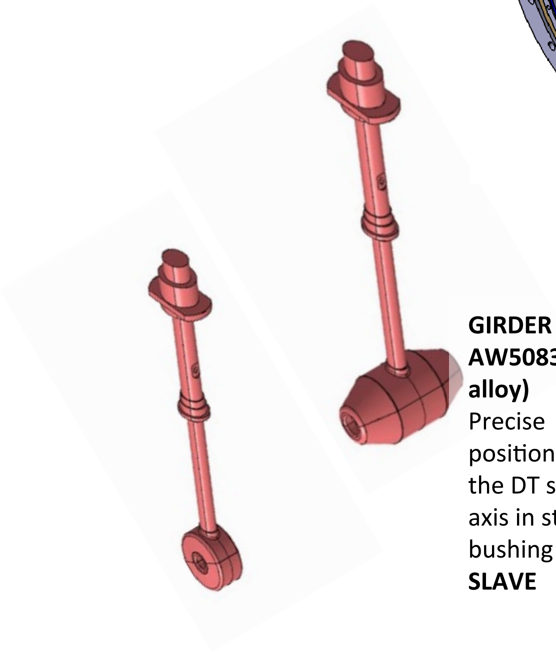
DTL Input (after the design update in 2013)

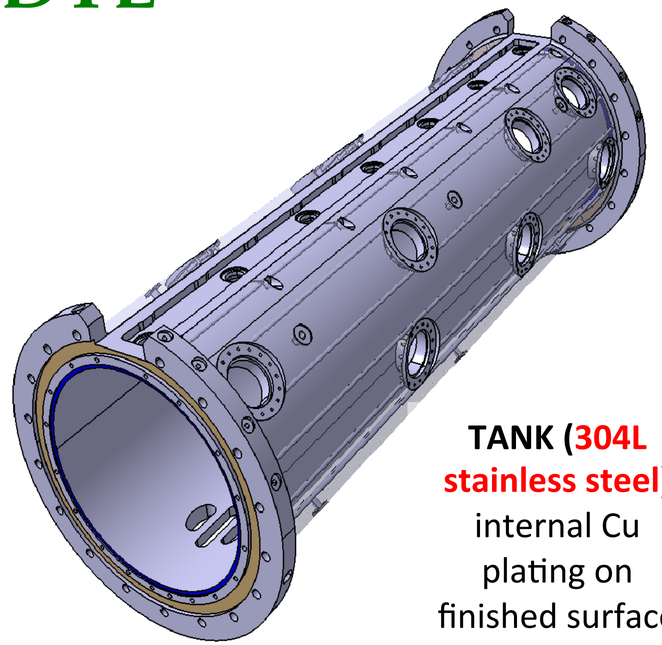
Requirement	Target value	Comment
Particle type	H+	H- are possible
Input energy	3.62 MeV	+- 50 keV
Output energy	90 MeV	
Input current	62.5 mA	Peak, (2.86 ms long with a repetition rate of 14 Hz)
Input emittance	0.28 mm mrad	Transverse RMS normalized
	0.15 deg MeV	Longitudinal RMS
Emittance increase in the DTL	<10%	Design
Beam losses	<1 W/m	Above 30 MeV
RF frequency	352.21 MHz	
Duty cycle	<6%	
Peak surface field	<29 MV/m	1.6 Ekp
RF power per tank	<2.2 MW	Peak, dissipated+beam load, including
Module length	<2 m	Design constraint
Focusing structure	FODO	Empty tubes for Electro Magnetic Dipoles (EMDs) and Beam Position Monitors (BPMs) to implement beam corrective schemes
PMQ field	<62 T/m	

LNL contribution - DTL

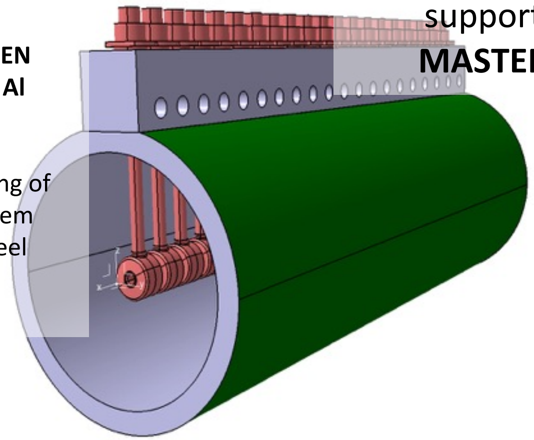


- The DTL mechanical structure
  - 5 Tanks, 4 modules each
  - Drift tubes 61+34+29+26+23=173
- (PMQ n=89, steerers n=30, BPM n=15, empty n=39)
  - RF Components
  - Beam Components
  - Vacuum components (15 manifolds)
  - End plates and 4 intertanks
  - Support and alignment





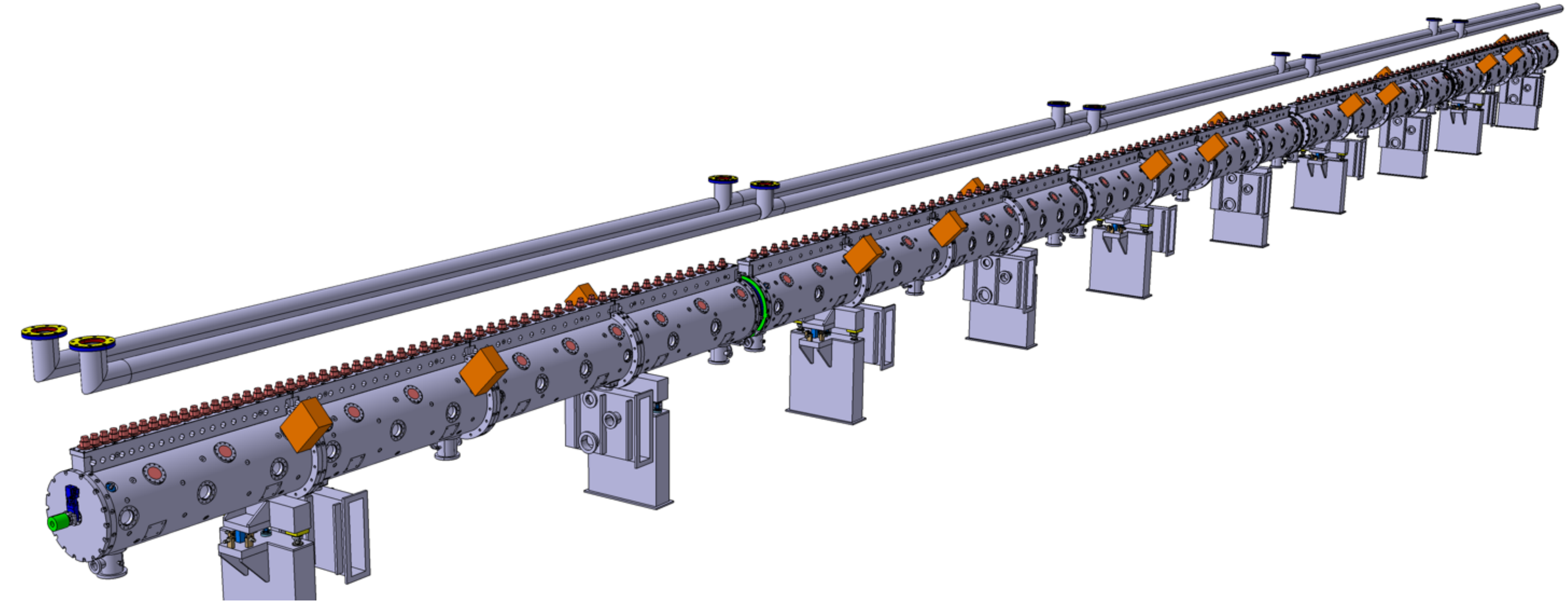
TANK (304L stainless steel)
internal Cu plating on finished surface (Ra 0,8)
high stiffness support
MASTER

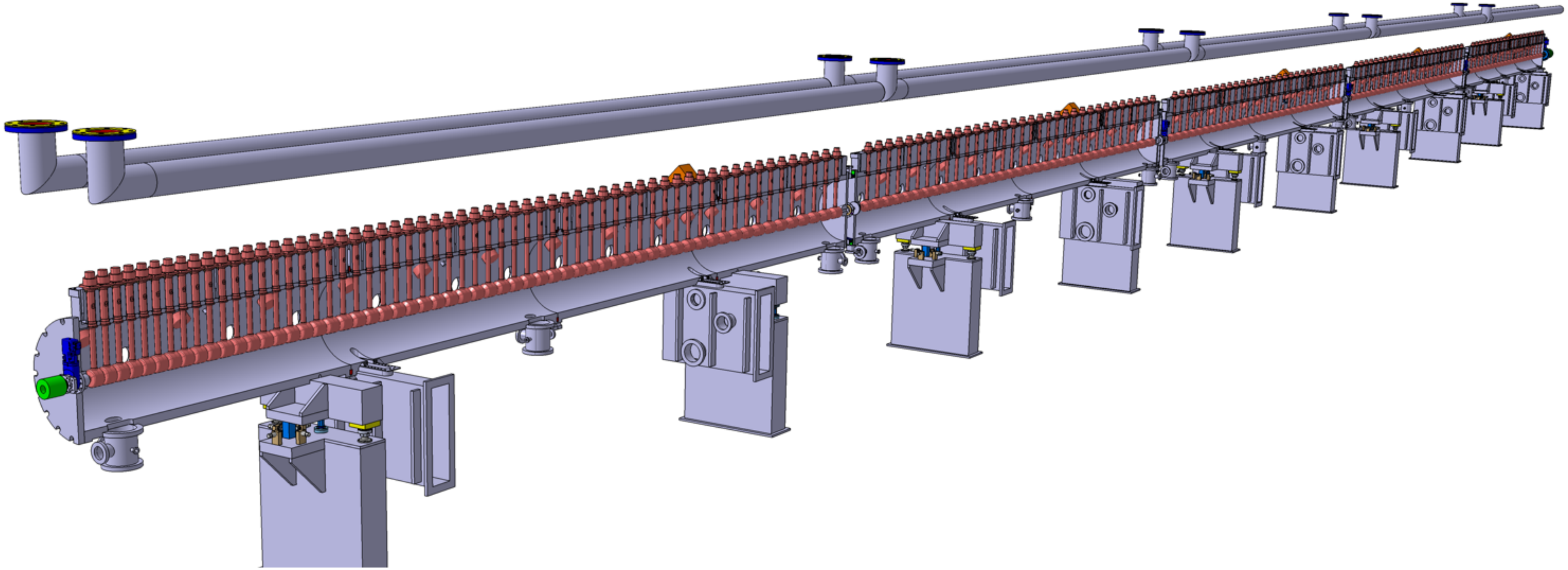


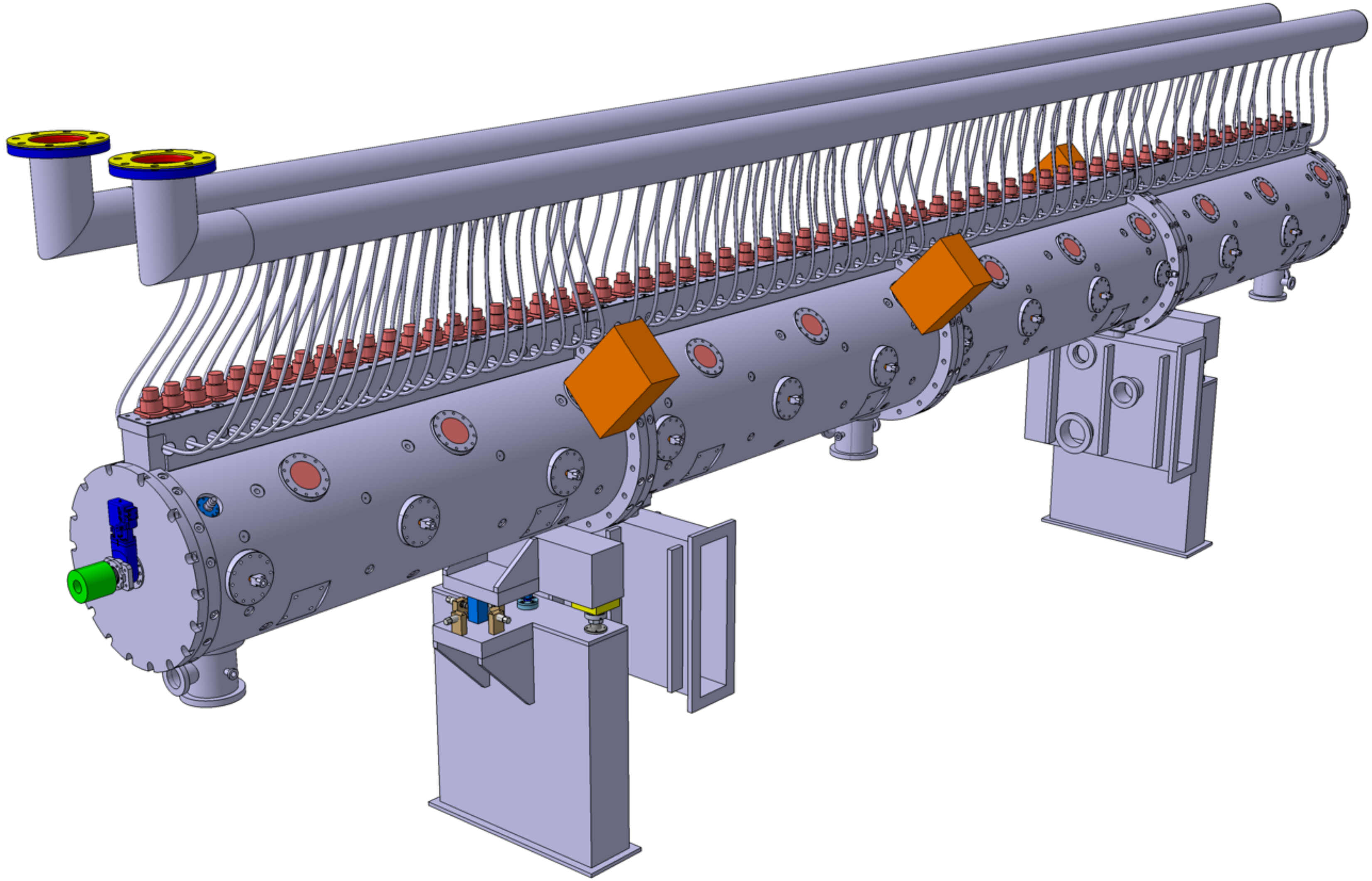
GIRDER (EN AW5083 Al alloy)
Precise positioning of the DT stem axis in steel bushing
SLAVE

DTL organization at partner lab

- Andrea Pisent (WU coordinator, LNL)
- Francesco Grespan (deputy coordinator, LNL)
- Paolo Mereu (Responsible of the Mechanics' design, Torino)
- Michele Comunian (Beam dynamics, LNL)
- Carlo Roncolato (Vacuum system and br LNL)
- Enrico Fagotti (Accelerator Physics and cooling system, LNL)
- Marco Poggi (Beam instrumentation, LNL)
- Mauro Giacchini (Local Control System, LNL)

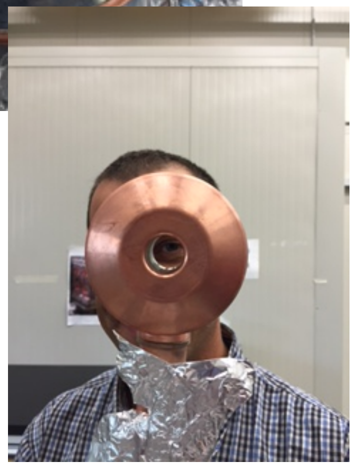


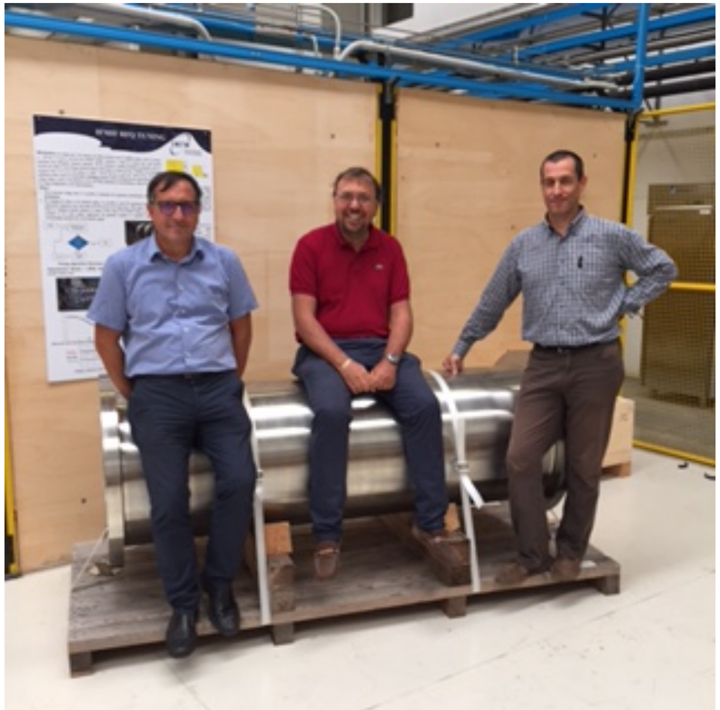




Progress on DTL

DTL drift tube prototypes





Santo Gammino, Andrea Pisent and Paolo Mereu sitting on the first ESS DTL tank

Drift Tube LINAC - calls for tender update

- Forged flanged semifinished cylinders: material delivery
- Procurement for the machining of the complete tanks (module+girder) for tank 3 and tank 4: contract awarded to Cinel;
- Procurement for the machining of the complete tanks (module+girder) for tank 1, tank 2 and tank 5: approval phase by INFN Executive Board;

Further procurements:

- Water skid for DTL cooling water and ancillaries (flow regulators, hydraulic fittings, hoses, …)
- RF windows;
- DTL alignment supports;
- Assembly tools and jiigs;
- Trolley for DTL tank transportation from assembly workshop to accelerator tunnel;
- Slug and movable tuners, Postcouplers, pick-ups;

DTL present schedule

Tank #	Present RFI	Present plan for RFI (for tanks only)	Possible RFI (6 w before installation)	Present plan assy start (RATS)	Present plan drift tubes @ RATS
4	2017-10-23	2018-01-18	*2018-02-16*	2017-07-27	2017-12-01
3	2018-02-22	2018-02-22	*2018-06-01*	2017-09-25	2018-01-30
1	2018-06-01	2018-06-18	*2018-08-31*	2018-01-17	2018-06-25
2	2018-10-01	2018-10-01	*2018-11-02*	2018-04-12	2018-09-03
5	2019-02-01	2019-02-01	*2019-02-08*	2018-09-07	2018-11-19

INFN in-kind contribution: medium beta SC cavities

- **INFN In-Kind contribution:**
  - Niobium procurement for the fabrication of 36 medium beta cavities.
  - Cavity fabrication of 36 medium beta cavities in the industry, including treatments, tuning, Helium tank integration. **Full treatment at the vendor.**
  - Ancillaries, certification activities, documentation.
  - Cold test in a qualified infrastructure (DESY).
  - Transportation in special boxes and delivery at CEA cryomodule assembling facility.
- **INFN R&D on prototypes (already done):**
  - Built 2 prototypes of medium beta cavities.
  - INFN design, using Large and Fine Grain Nb, plug compatible with ESS cryomodule.
  - Full treatment industry.
  - Final handling and test done in the qualified infrastructure at LASA.

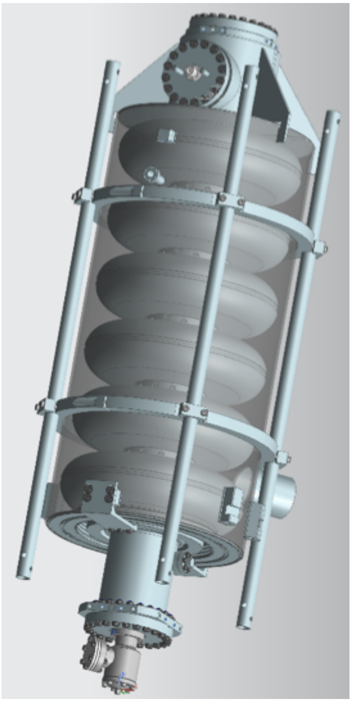
MB cavity technical requirements	
Frequency (MHz)	704.42
Number of cells	6
Geometric beta	0.67
Nominal Acc. Gradient (MV/m)	16.7
E_{peak} (MV/m)	< 45
RF peak power (kW)	1100
Q external	5.9-8 10^5
Q_0 at nominal gradient	> 5 10^9

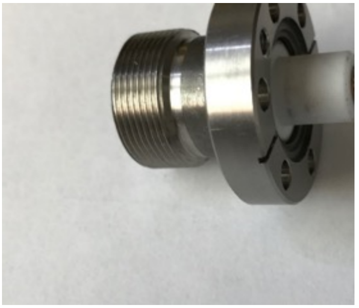
Medium beta SC cavities

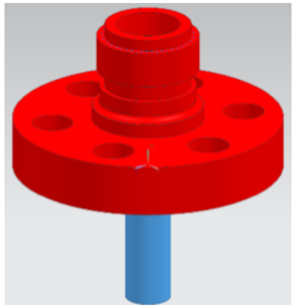
Nb sheets (RRR 300 and RRR 40) for the cavities, CFT in two lots.
CFT already launched, bids under analysis.
CFT budget: 3.3 MEuro

Construction and treatment of the full set of medium beta SC cavities:
CFT under finalization, publication in the next weeks.
Procurement budget: 4.6 Meuro

Cryogenic feedthroughs with HiQ antenna and pick-up: **100 k€**

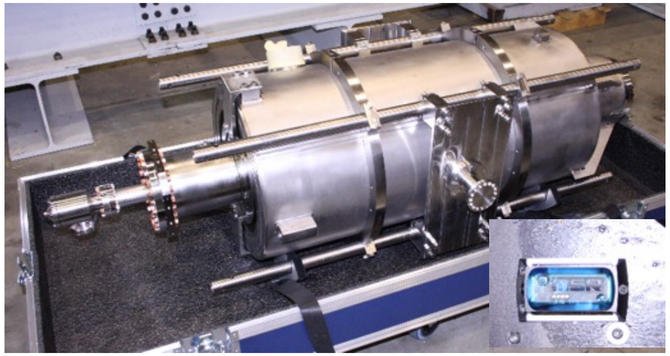






Medium beta SC cavities

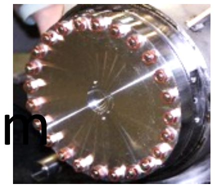
Special boxes with dumpers and shock loggers for cavities transportation from company to DESY and then to CEA: 50 k€



Transportations: 40 k€

All metal UHV valves for SC cavities: 30 k€

Indirect buying: materials that will be bought by the Cavity Contractor:
Ti, NbTi, BCP mixture, special stainless steel low μ_r flanges and bolts (1:4435, 1:4429) , CuNiSil nuts, vacuum components, Al and Cu gaskets, Clean room equipment, etc



Elettra Sincrotrone Trieste

Who we are

No profit shareholder company recognized of national interest pursuant to Law 370/99 of the Italian Republic.

Shareholders: Area Science Park, Friuli Venezia Giulia Region, CNR, Invitalia.

OVERVIEW

Elettra in-kind contributions :

AIK2.1	**Magnets for ESS linac**
AIK7.4	**Beam Diagnostics- Wire Acquisition System for the ESS linac**
AIK8.5	**Spoke RF Power Station**
AIK17.2	**Power Converters for Magnets to the ESS linac**
tbd	**Installations**

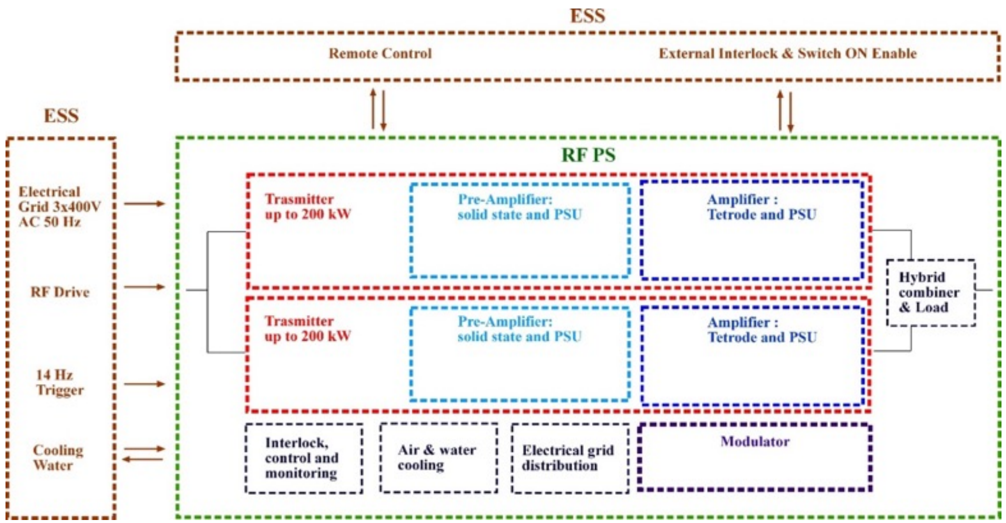
AIK2.1, AIK7.4, AIK8.5, AIK17.2 endorsed at IKRC 10 in October 2016.

SPOKE CAVITIES RF POWER STATIONS (AIK 8.5)

Elettra Sincrotrone Trieste

Scope: build twenty-six pulsed 400 kW@352 MHz RF power stations

Central Frequency - monotone	352.21 MHz
P_N Nominal Power, peak	400 kW
Nominal Power, average	20 kW
Bandwidth -1dB	> ± 1 MHz
Gain at P_N	86 dB
RF Drive Maximum	0 dBm
Operation	Periodic Pulsed
Nominal Repetition Frequency	14 Hz
Nominal Pulse Width	3.5 ms



Each RFPS unit consists of:

- Two equivalent transmitters with amplification chain composed by solid state preamplifier and a 200 kW tetrode amplifier.
- One Modulator to supply both tetrodes.

Construction will be outsourced to industry under Elettra supervision.

STATUS

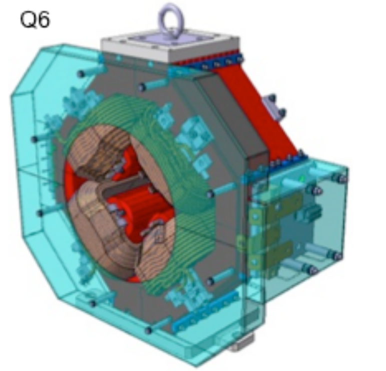
- Working with ESS RF group to optimise and freeze technical specifications to be concluded by April 2017.

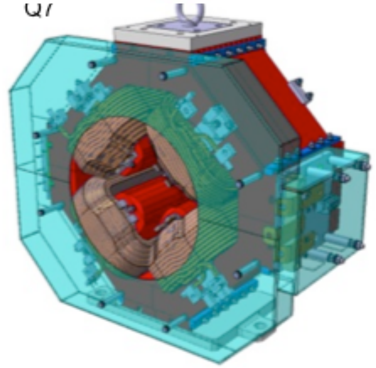
Elettra
Sincrotrone
Trieste

MAGNETS (AIK 2.1)

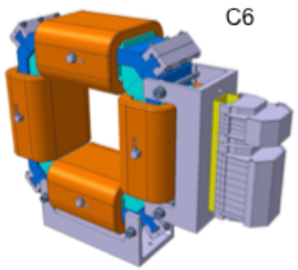
Scope: design and build magnets installed in different parts of the ESS linac

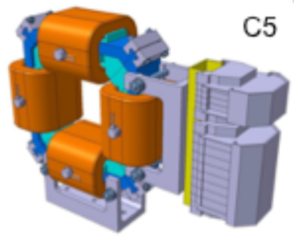
Type	Description	Operating mode	Quantity
Q5	Quadrupole magnet for A2T	DC, water cooled	26
C5	Dual-plane corrector magnet for SPK	DC, air-cooled	13
Q6	Quadrupole magnet for MBL, HBL, HEBT and DmpL	DC, water cooled	95
C6	Dual-plane corrector magnet for MBL, HBL, HEBT, A2Tramp and DmpL	DC, air-cooled	55
Q7	Quadrupole magnet for A2T ramp	DC, water cooled	12
D1	Vertical dipole magnet for HEBT and A2T	DC, water cooled	2
Q8	Quadrupole magnet for A2T	DC, water cooled	6
C8	Dual-plane corrector magnet for A2T	DC, air-cooled	4

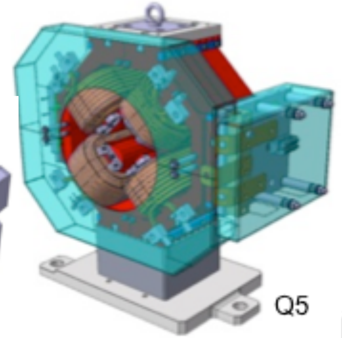




- Activities concentrated on LWU magnets (Q5, Q6, Q7 and C5, C6).
- Trilateral agreement Elettra-ESS-INFN to allow starting of the construction







STATUS

- LWU magnets tender in preparation.
- Remaining magnets: launch of tenders in fall 2017

POWER CONVERTERS FOR MAGNETS (AIK 17.2)

Elettra Sincrotrone Trieste

Scope: design and build power converters for the magnets of the ESS linac

Type	Description	Operating mode	Q.ty
PCC5	Power converters for the “C5” dual-plane correctors	4Q, air cooled	26
PCC6	Power converters for the “C6” dual-plane correctors	4Q, air cooled	110
PCC8	Power converter for the “C8” dual-plane correctors	4Q, air cooled	8
PCQ5	Power converters for the “Q5” quadrupoles	DC, water cooled	26
PCQ6	Power converters for the “Q6” quadrupoles	DC, water cooled	95
PCQ7	Power converters for the “Q7” quadrupoles	DC, water cooled	12
PCD1	Power converters for the “D1” dipoles	DC, water cooled	1
PCQ8	Power converters for the “Q8” quadrupoles	DC, water cooled	6
PCC8	Power converter for the “C8” dual-plane correctors	4Q, air cooled	8

- ✓ Four units in a 19” crate (interface to ESS Control System via Ethernet).

- ✓ Two12 VDC Aux per Crate (1+1 for redundancy)

- ✓ One 24 VDC Bulk AC/DC power supply per Unit.

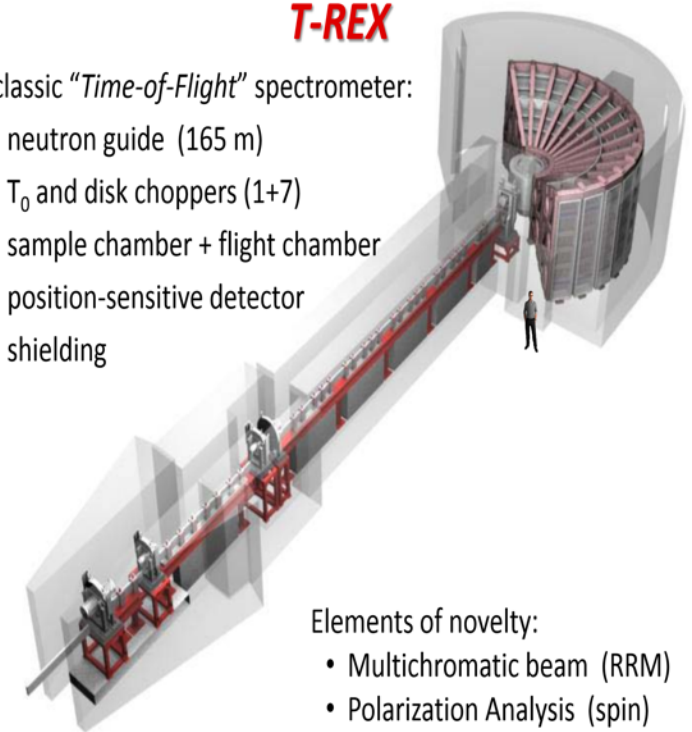
STATUS

- Correctors power converters based on compact Elettra design approved in CDR.
- Finalization of design for industrial production (Built-to-Print Call for Tender) in progress.
- PCQ5, PCQ6 and PCQ7 approved in PDR
- Technical documentation for Call for Tender almost ready.

CNR contribution

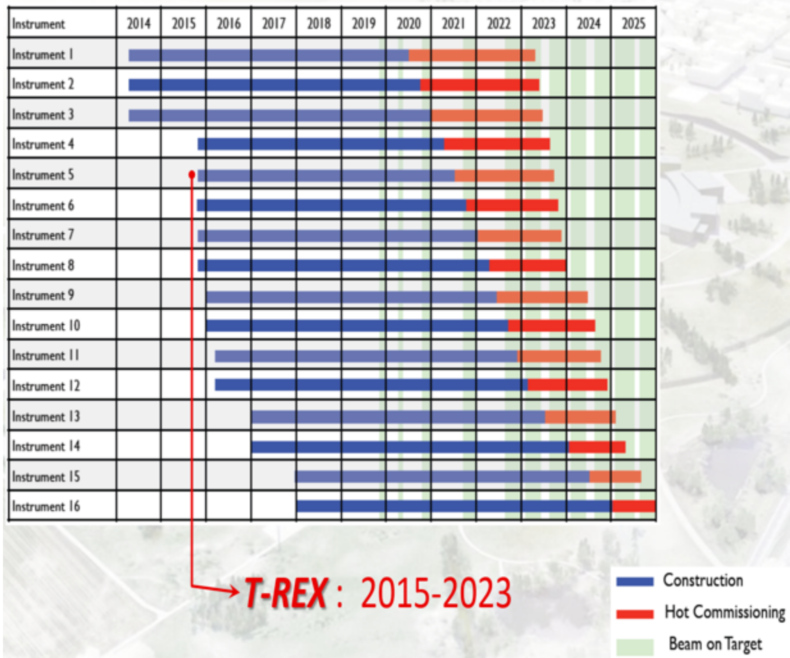
T-REX

A classic "*Time-of-Flight*" spectrometer:
- neutron guide (165 m)
- T_0 and disk choppers (1+7)
- sample chamber + flight chamber
- position-sensitive detector
- shielding



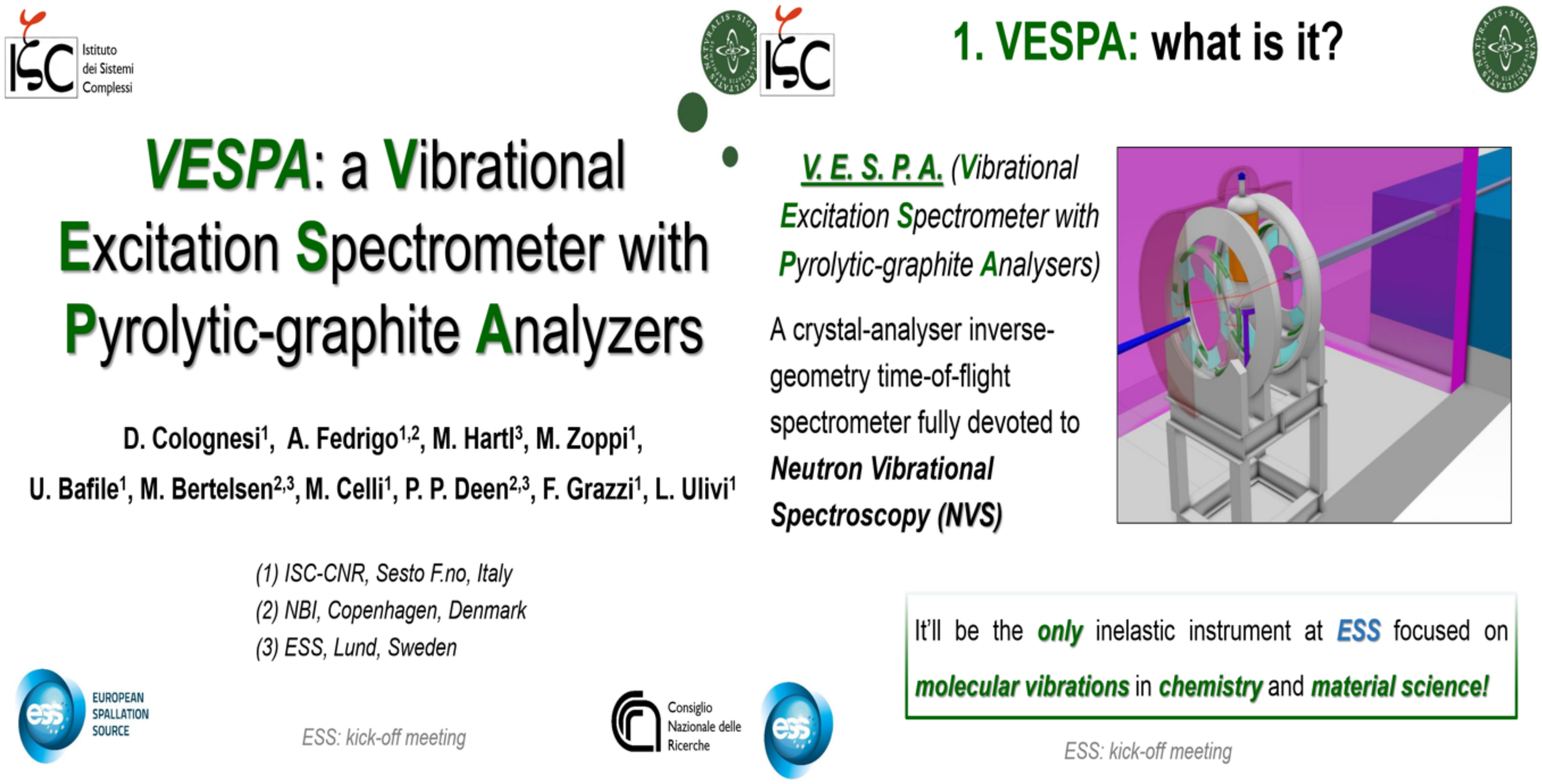
Elements of novelty:
- Multichromatic beam (RRM)
- Polarization Analysis (spin)

Tempistica
(planning ESS)



Courtesy: Andrea Orecchini- Dipartimento diFisica e Geologia
Università di Perugia

CNR contribution



Courtesy: Daniele Colognesi – Istituto dei Sistemi Complessi, Sesto F.no

Useful links

https://europeanspallationsource.se/ilo-partner-countries

https://europeanspallationsource.se/procurement

Possible opportunities

- High beta superconducting cavities;
- Low level RF;
- Controls;
- Mechanics;
- Vacuum systems;
- Cryomodules' parts;
- Technical support, tests, etc…

Summary

- A lot of work has been done by INFN for ESS
- Criticality: the large amount of call for tender to be managed on 2017
- Some delays w.r.t. schedule will not endanger the RFI for the IS&LEBT (some tests postponed after RFI); some others will be absorbed for DTL and for Mβ by means of a faster construction phase.
- The procurement process is strongly based on previous R&D carried out by Italian Research Institutions and companies who already worked in the field or who participated to similar calls in the past will have a slight advantage.
- Because of the know-how required for many procurements, the selection will guarantee a larger advantage to those who have invested in R&D during the past years.

Thank you for your kind attention