

Status and execution of the Elettra 2.0 upgrade project

Emanuel Karantzoulis
on behalf of the Elettra team

www.elettra.eu



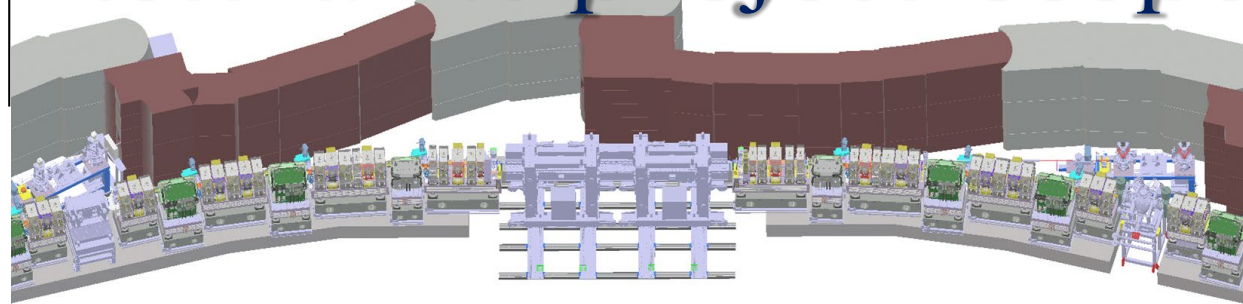
End user mode on 2/7/2025 at 12:30 with a ceremony. The dark period started immediately after as programmed, first task the removal of the old machine





Elettra
Sincrotrone
Trieste

Elettra 2.0 project scope



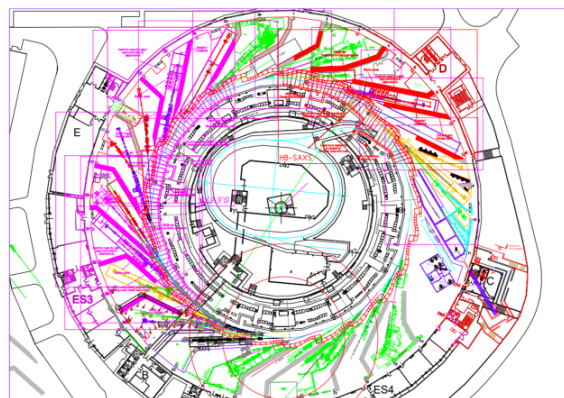
- Replace of Elettra storage ring with a low emittance, diffraction limited storage ring, operating at 2.4GeV (main operating energy) and 2 GeV for a limited period of time (to allow partners to upgrade)
- Increase of the number of slots available for insertion devices
- Build new beamlines and upgrade most of existing beamlines.
- Let open the possibility for installing bunch deflectors for short pulses (1ps at FWHM)
- Update the injectors (pre-injector linac, booster synchrotron and transfer lines).
- Modify and/or upgrade infrastructures, i.e. buildings and conventional facilities as needed for the implementation of the facility.
- Provide the new buildings necessary for the implementation of the project.

Parameter	Value	unit
Energy	2.4	GeV
Circumference	259.2	m
Emittance	212	pm rad
coupling	3	%
Harmonic number	432	
Average current	400	mA
Energy loss per turn	450 (620*)	keV
RF peak voltage	2	MV
Parameter	Value	unit
Main radiofrequency	499.654	MHz
Bunch length rms	6 (15**)	ps
Energy spread rms	0.09	%

* Including all IDs and SBs

** Including 3HC at 2.5x

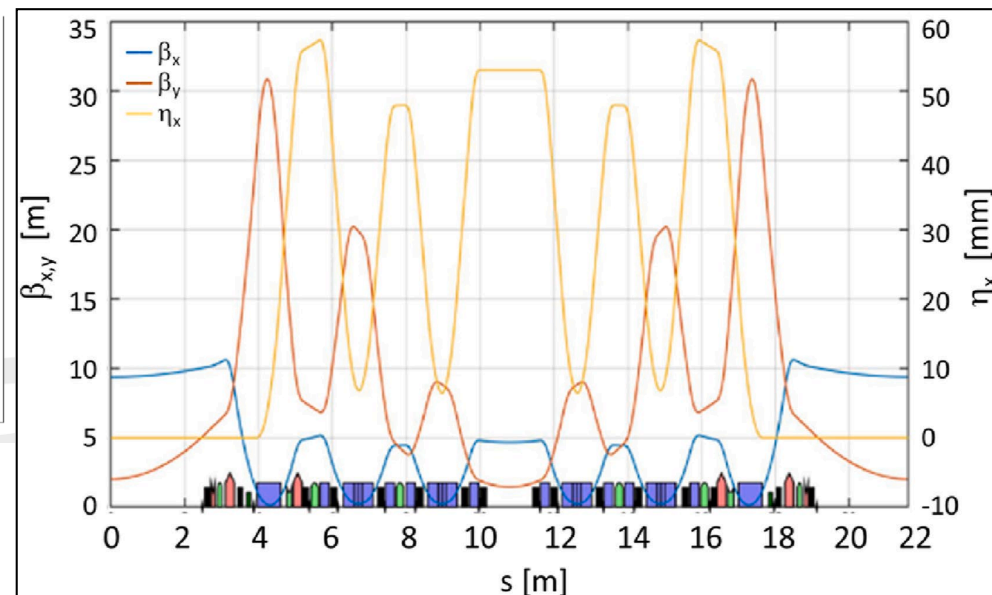
	Long Straights	Short Straights
σ_x (um) / σ_x' (urad)	36 / 5.7	63 / 6
σ_y (um) / σ_y' (urad)	3.2 / 1.9	3.5 / 1.8



10th Low Emittance Rings Workshop 2025 - DESY Hamburg 8/10/2025

Emanuel Karantzoulis

Lattice: Enhanced, symmetric six-bend achromat (S6BA-E) (phase 1)





The Elettra 2.0 performance

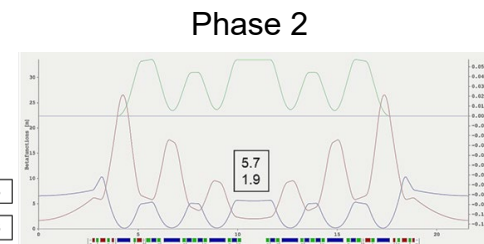
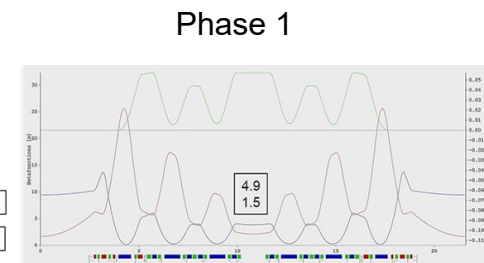
Elettra 2.0 will operate mostly at 2.4 GeV with a bare **emittance** of 212 pm-rad.
The **brilliance** will increase by more than 2 orders of magnitude at 10 keV, 36 times at 1 keV.
The **coherence** level will increase by a factor of 60 at 1 keV.

Emittance reduction	48 times
Useful length at long straights	4.94 m
Useful length at short straights	1.26 m
Useful length as % of total length	28.5%

Circumference (m)	259.2	259.2
Energy (GeV)	2	2.4
Number of cells	12	12
Geometric emittance (nm-rad) 1% coupling	0.148	0.212
Horizontal tune	33.27	33.27
Vertical tune	8.14 (9.14)	8.14 (9.14)
Betatron function in the middle of straights (x, y) m	(9.5,1.9) (6.3,1.6)	(9.5,1.9) (6.3,1.6)
Horizontal natural chromaticity	-73	-73
Vertical natural chromaticity	-67	-67
Horizontal corrected chromaticity	+1	+1
Vertical corrected chromaticity	+2	+2
Momentum compaction	1.3e-004	1.3e-004
Energy loss per turn (no IDs) (keV)	217	450
Energy spread	7.7e-004	9.3e-004
Jx	1.625	1.625
Jy	1.00	1.00
JE	1.376	1.376
Horizontal damping time (ms)	9.8	5.7
Vertical damping time (ms)	15.9	9.2
Longitudinal damping time (ms)	11.6	6.7
Dipole field (T)	<0.8 +1.16T central	<1+1.46T central
Quadrupole gradient in dipole (T/m)	<19	<22
Quadrupole gradient (T/m)	<50	<60
Sextupole gradient (T/m ²)	<3500	<4000
RF frequency (MHz)	499.654	499.654
Beam revolution frequency (MHz)	1.1566	1.1566
Harmonic number	432	432
Orbital period (ns)	864.6	864.6
Bucket length (ns)	2	2
Natural bunch length (mm, ps)	1.3, 4.3	1.7, 5.7
Synchrotron frequency (kHz)	3.13 (@2MV)	2.86 (@2MV)

Key performance indicator

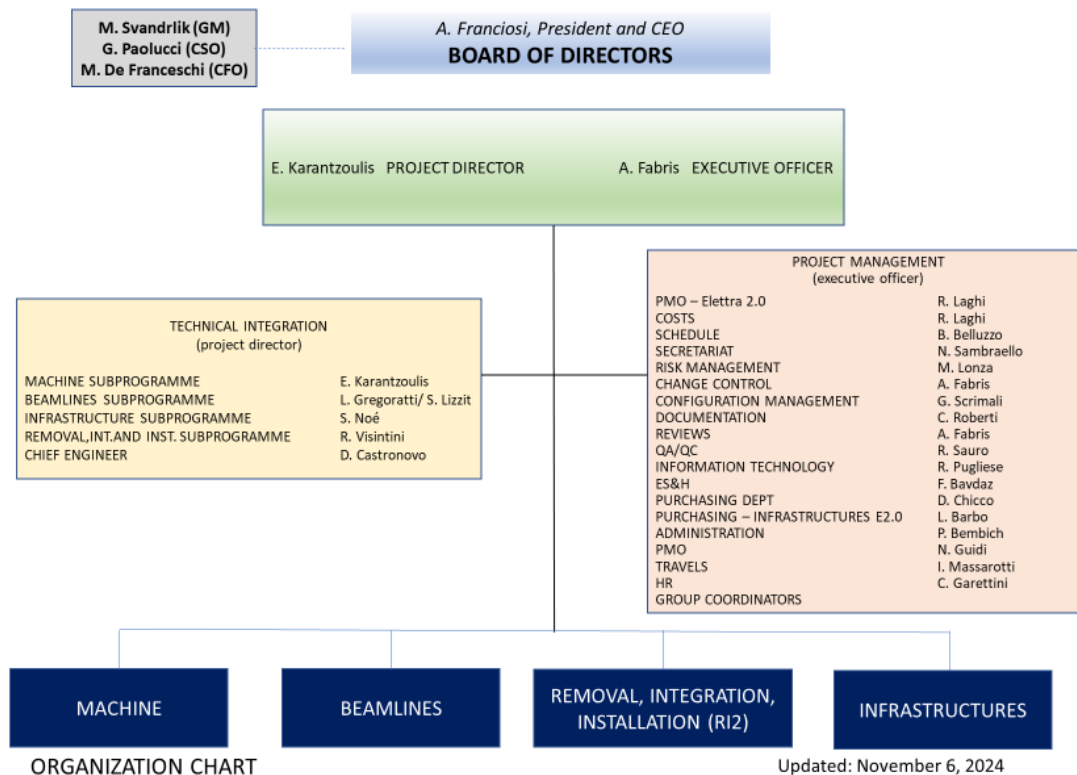
	End machine commissioning	End friendly users	Project completed
Optics	Phase 1	Phase 1	Phase 2
Current (mA)	150	250	400
Lifetime (h)	>3	>5	>10
Inj efficiency (%)	>50	>70	>90
Hor emittance (pmrad)	<300	<250	<220
Ver emittance (pmrad)	<50	<20	<8
Stability (in σ)	0.2	0.1	0.05
Fill patterns	Multibunch, sb	+ hybrid + every other bunch	all available
Up-time (%)		>93	>96
MTBF (h)		>24	>70



		Elettra	Elettra 2.0
Operating for users		1994-2025	2027-
Beam energy	GeV	2.4 (25%) --- 2.0 (75%)	2.4 GeV (2.0 for some time)
Photon energies	keV	0.003-25	0.015 - 60
e - emittance - coupling	nm-rad	10 --- 7 - 1%	0.212 --- 0.150 - 3%
ID slots		11 Long + 1 short	11 Long + 5 short
Beam lines (IDs, Dipoles)	#	28 (19, 9)	32 (25 3 IVU, 7 3-4 from 3 SB)
e-beam size at LS (σ_x, σ_y)	μm	286,16	36,6
Brilliance (ph/s/mm ² /mrad ² /0.1%bw)		2x10 ¹⁹	10 ²²
Coherence ratio at 1 keV	%	0.5	30
e - intensity	mA	160 --- 310	400
Lattice - symmetry		2BA - 12 fold	S6BA-E(nhanced)-12 fold
Fill patterns		multi-bunch, single or few bunch, hybrid	whatever

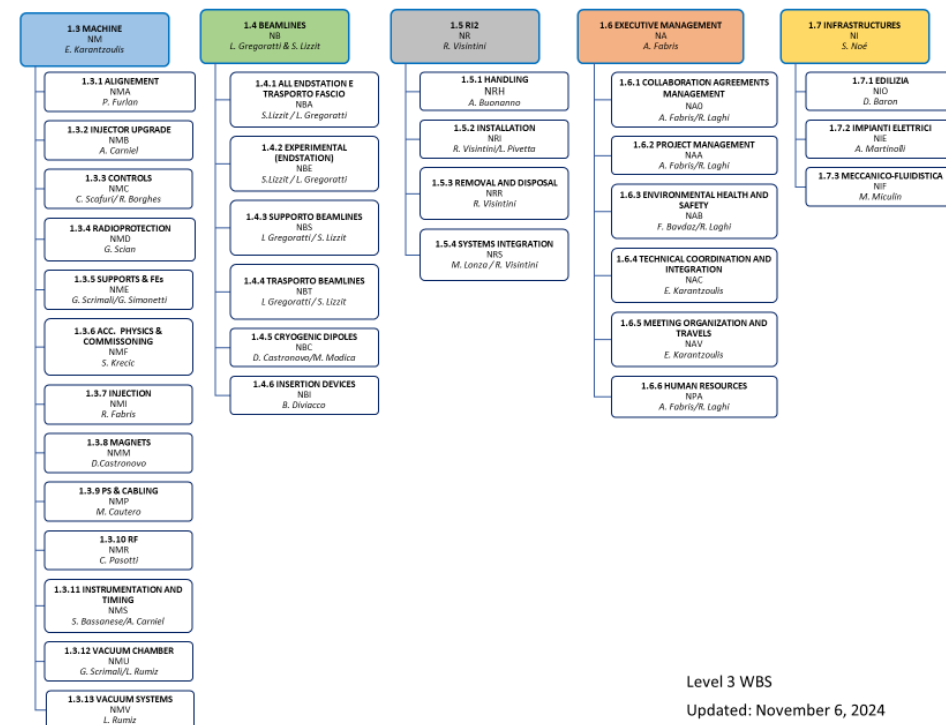


Elettra
Sincrotrone
Trieste



ORGANIZATION CHART

Updated: November 6, 2024

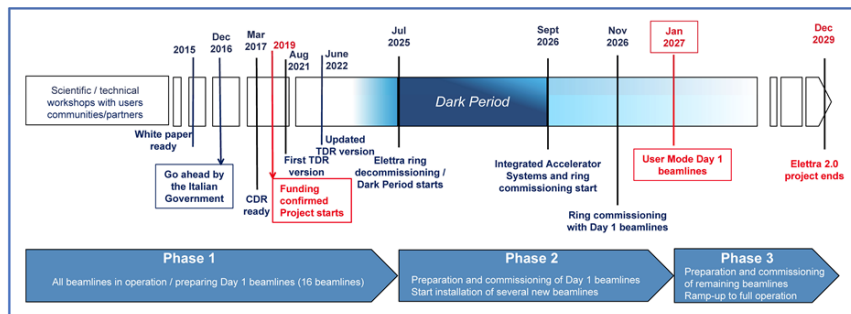
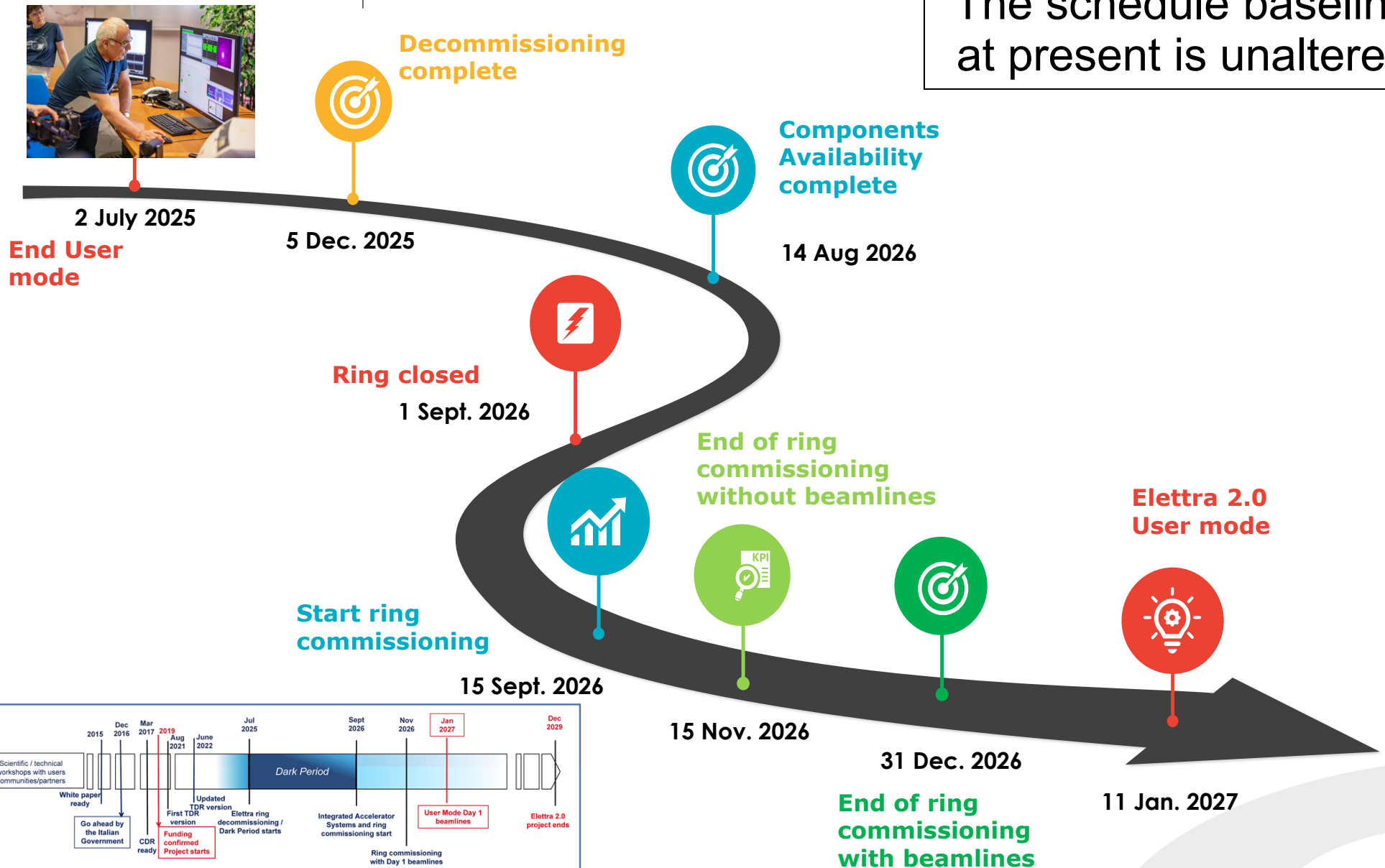


Level 3 WBS

Updated: November 6, 2024

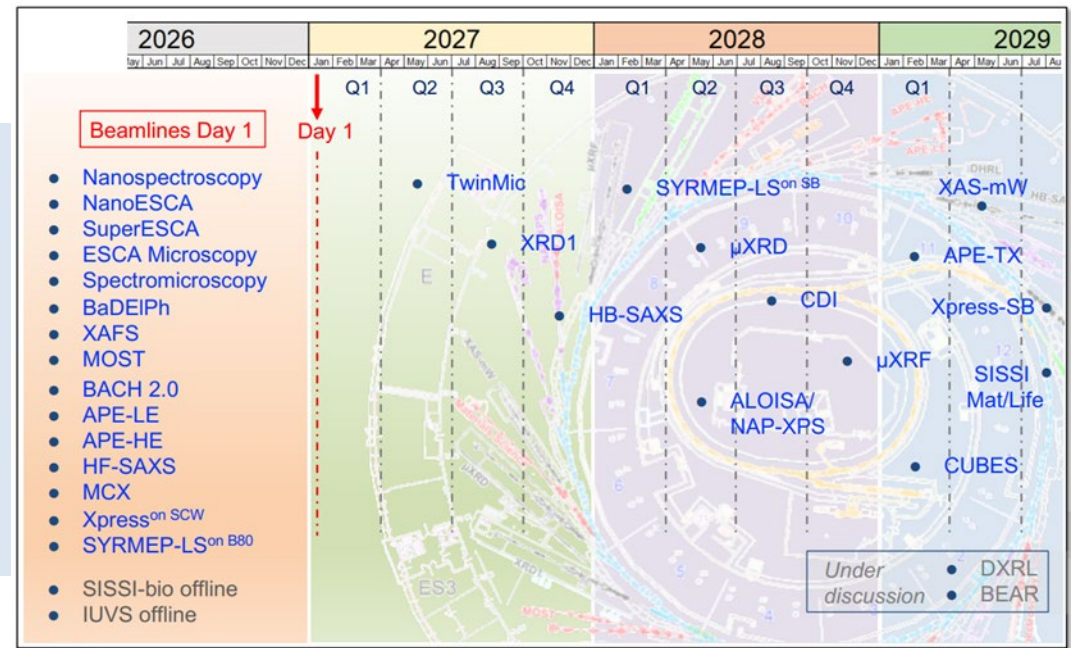
Major milestones

The schedule baseline at present is unaltered



Beam lines

- Increased # of beam lines. Also 5 in the short straights.
 - Shift towards tender and hard x-rays (65% proposals for hard x rays).
- One at very hard up to 140 KeV for lung diagnostic and cure, 3 micro spot based on IVU and 1 coherent diffraction image.
- Not all available at day 1



8 beam lines are removed

9 Beam lines keep the same position

7 Beam lines keep the same sector

4 Beam lines moved to a different sector

2 End stations moved to a new sector

10 new beam lines

Up to 32 beamlines

9 → 12 Bls hard X-rays

- 2 on ScBM **2 NEW**
- 3 on IVU for micro-spot **3 NEW**
- 4 on sW in SS **1 NEW**
- 2 on SCW
- 1 on BM

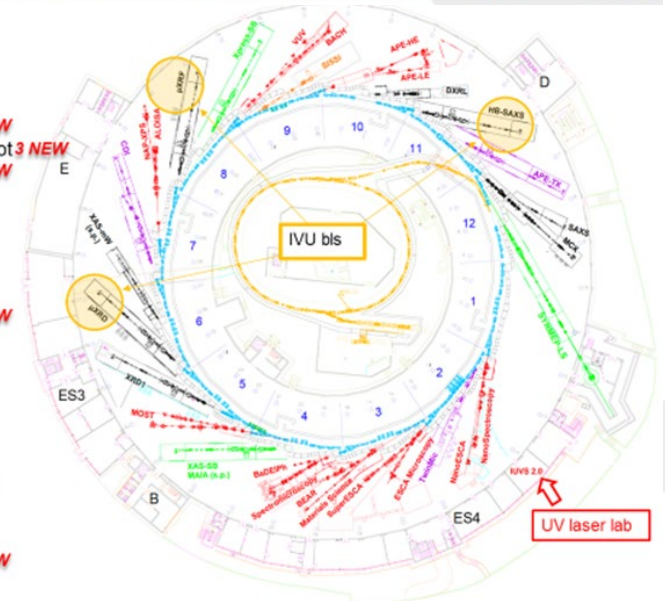
0 → 3 Bls Soft-tender X

- 1 APU in SS
- 1 EPU in SS **1 NEW**
- 1 EPU in LS

17 → 15 Bls VUV-SoftX

- 7 on EPU in LS
- 2 on LPU in LS
- 2 on F8 in LS
- 2 on APU (LP) in SS
- 2 on BM

2 → 2 IR/THz beamline **1 NEW**



Storage space

2 new prefabricated buildings of 700 m² each, the experimental hall and space rent in the industrial region of Trieste.

BUT space it is never enough!



Storage space , vacuum lab, and magnet measurements lab

Mainly old machine





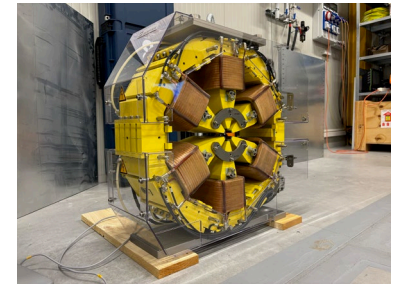
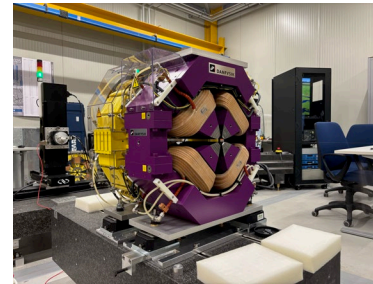
Elettra
Sincrotrone
Trieste

Magnets and power supplies

MAGNETS

Ref. D. Castronovo

- **First girder assembled**
- All quadrupoles magnets delivered
- Sextupoles and octupoles magnets:
 - 4 out of 6 deliveries completed
 - Last delivery: scheduled early Jan. '26
- Bending magnets:
 - First of Series measured
 - In production
 - Last delivery scheduled mid Jan. '26



POWER SUPPLIES

- All dipoles PS delivered
- All multipolar magnets PS delivered
- Corrector PS:
 - 450 out of 700 built
 - Completion foreseen mid Nov. '25
- Contract for racks' assembly effective



Multipolar magnets P.S. in storage

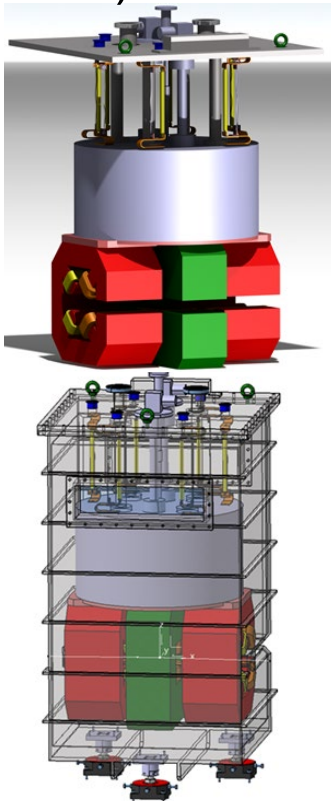
Ref. M Caupro



SC magnets and IDs

Ref. B. Diviacco

Two super-
conducting
6 T dipoles
(60 – 140
keV)

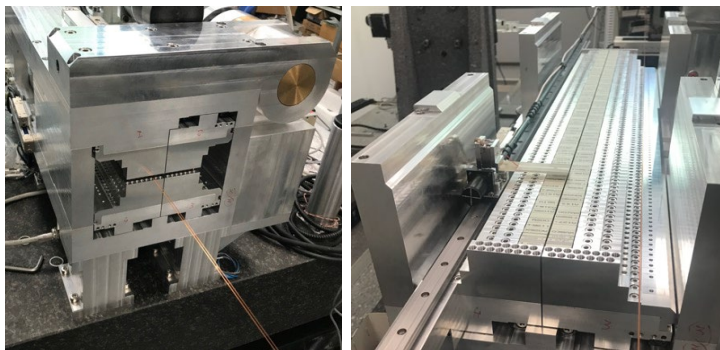


Ref. D. Castronovo, M.
Modica, EK



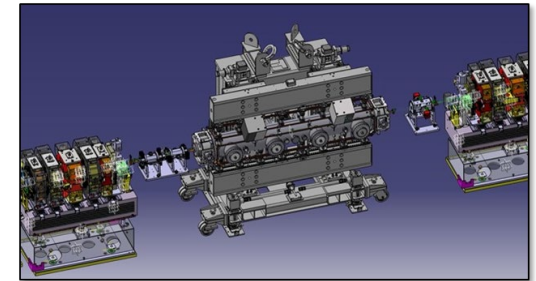
Four APPLE-II Undulator
– outsourced to **KYMA**)

One of the requirements for the new lattice is to extend the number of beamlines. In fact five out of the twelve short straight sections are dedicated to the beam lines and due to space limitations compact undulators and wigglers are developed with a useful length of only 80 cm. Already 4 short IDs are build in house.

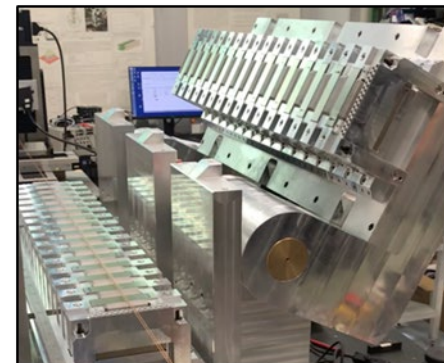


EU32: compact EPU for the APE-TX beamline

ID	Beamline	Position	Period (mm)	Nper	Length (m)	Bo (T)	Kmax
EU100	Nanospectr/NanoESCA	S01_Long	100.4	2 x 20	2 x 2.0	1.02 0.78	Ky=9.6 Kx=7.3
APU	TwinMic	S02_Short	39.6	19	0.8	0.82	Ky=3.0
U46	SuperESCA/ESCAmicroscopy	S02_Long	46.0	2 x 49	4.6	0.92	Ky=4.0
Figure-8	Spectroμ/BaDElPh	S03_Long	140	2 x 16	2 x 2.2	0.75 0.14	Ky=9.8 Kx=3.6
EU50	MOST-HE	S04_Long	50.4	28	1.5	0.85 0.62	Ky=4.0 Kx=2.9
EU132	MOST-LE	S04_Long	132.0	18	2.6	0.40 0.65	Ky=4.9 Kx=8.0
W96	XRD1	S05_Short	96.4	15 poles	0.8	1.83	Ky=16.5
IVU17	μXRD	S05_Long	17.0	117	2	0.94	Ky=1.5
W96	XAS-mW	S06_Long	96.4	15 poles	0.8	1.83	Ky=16.5
EU44	CDI	S06_Long	44	2 x 45	2 x 2.1	0.58 0.58	Ky=2.4 Kx=2.4
Twin-APU	ALOISA	S07_Short	75.6	10	0.8	0.43	Ky=3.0
	NAP-XPS	S07_Long	39.6	19	0.8	0.46	Ky=1.7
IVU22	μXRF	S07_Long	22.0	90	2	1.27	Ky=2.6
EU77	BACH-LE	S08_Long	77	28	2.1	0.92 0.64	Ky=6.6 Kx=4.6
EU47	BACH-HE	S08_Long	47	44	2.0	0.62 0.62	Ky=2.7 Kx=2.7
EU125	APE-LE	S09_Long	125.36	17	2.1	0.77 0.60	Ky=9.0 Kx=6.9
EU44	APE-HE	S09_Long	44	45	2.1	0.58 0.58	Ky=2.4 Kx=2.4
IVU17	HB-SAXS	S10_Long	17.0	117	2	0.94	Ky=1.5
EU32	APE-TX	S11_Short	32.4	22	0.8	0.83 0.61	Ky=2.5 Kx=1.9
SCW	HF-SAXS/MCX/Xpress	S11_Long	64	49 poles	1.5	2.5	Ky=19.6



Short-period in-vacuum LPUs will be used to extend the photon energy range into the hard X-ray regime, reaching up to 18 keV (period 17.2-22 mm).



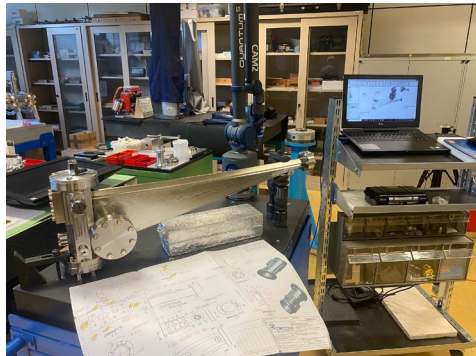
$\lambda_0 = 96.4$ mm
 $N_{\text{POLES}} = 15$
gap = 12 mm
 $B_0 = 1.8$ T
 $K = 16$

Chambers and vacuum systems

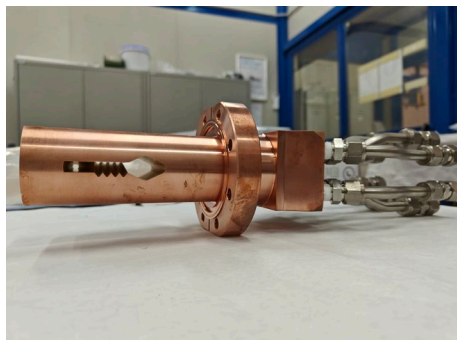
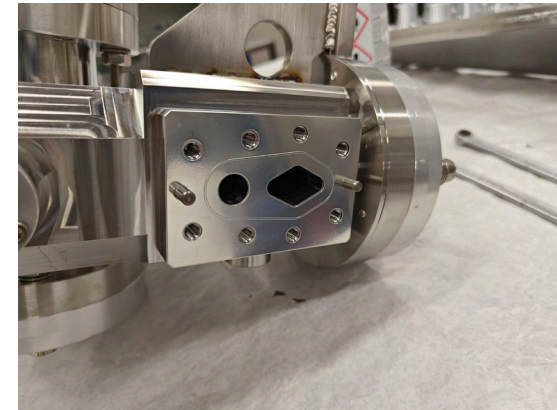
- Ion pumps and NEG pumps: delivered
- Vacuum gauges: delivered
- Vacuum valves: in production, First batch received, last scheduled in March '26
- Vacuum chambers:
 - Under construction
 - Dipole chamber prototype under SAT.
 - Deliveries in batches. Last item scheduled in Aug. '26
- Other vacuum components (bellows, absorbers, tapers, etc): under construction, to be completed in Spring 26

Ref. L. Rumiz

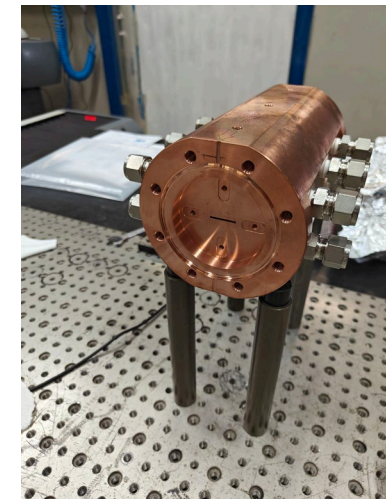
Ref. G. Scrimali



Dipole vacuum chamber tests



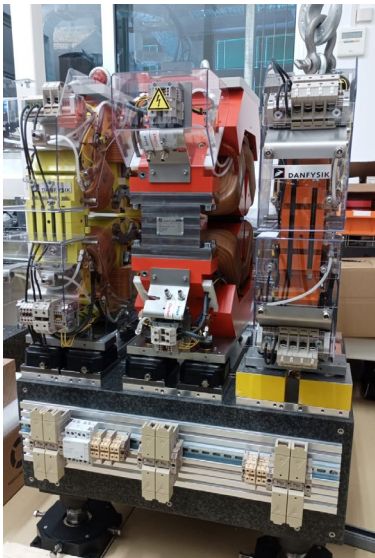
Photon absorbers



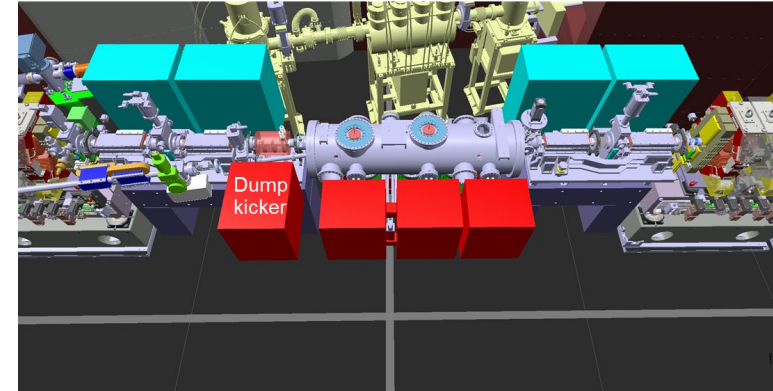
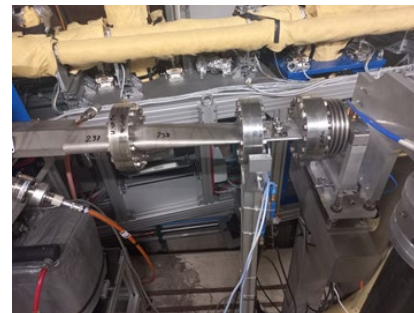
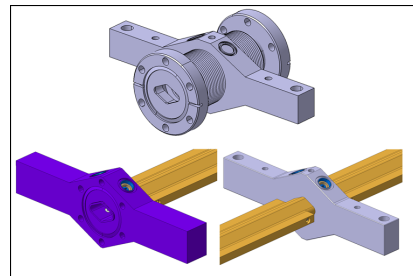
Mask
L. Rumiz

Supports, BPMs and Injection

8 granite slabs per achromat for the multipoles (1.5x0.6x0.3 m) + 6 for the dipoles in total 168 girders.



item	status
BPM electronics	All delivered – 8 already installed in Elettra
BPM feedthroughs	Delivery expected to be completed in Feb. 2026



Kickers: Design phase from the contractor (Danfysik) completed. Delivery expected within June 2026.

Septum: Design phase from the contractor (Research Instruments) close to completion

Ceramic Chambers: Contract signed on January 2025 (Kyocera) . Delivery expected in Jan – Feb 2026

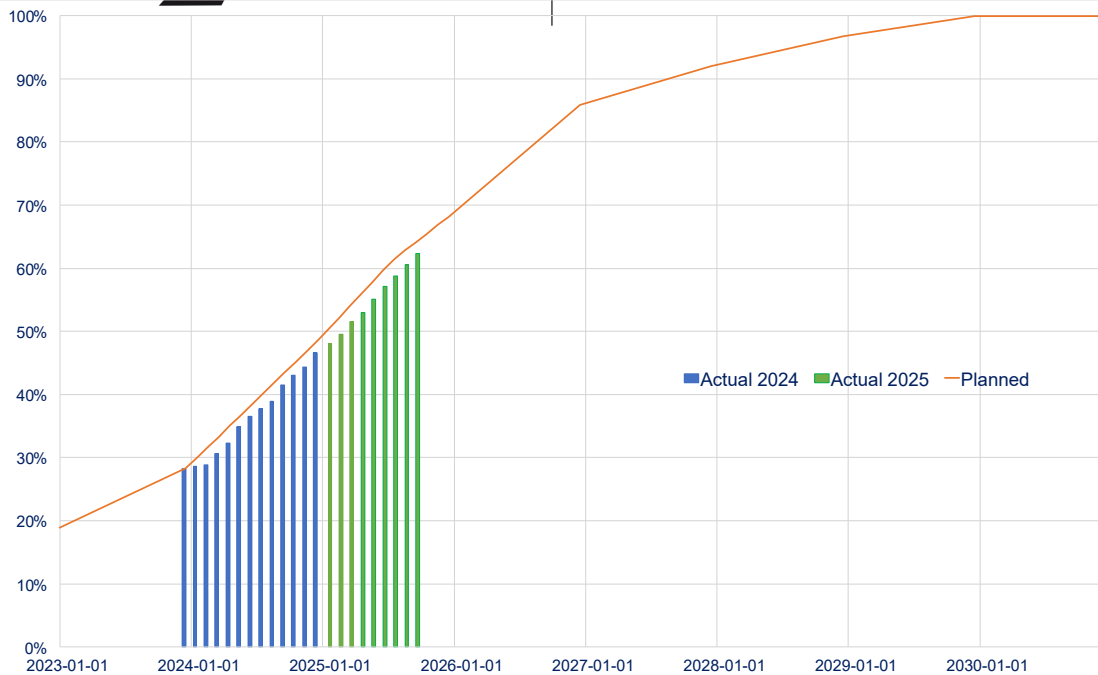
Dump kicker: The Contractor (Research Instruments) received the invitation letter

Girders and mechanical supports for injection, all received

Component	State	Shipping to Elettra
Wedges	(MC SYSTEMS (AIRLOCK))	received
Magnets plates	(COSTAM)	received
Granite slabs	(ZALI)	received
Alignment feet	(PIGNAT/MEC+)	received
Basements	Ordered and arriving (JJ-XRAY)	12/2025
Grouting plates	Ordered and arriving (OCSAM/MICRA)	11/2025

Project progression

Ref: A. Fabris



	MONTH	ACTUAL	PLANNED	DELTA
2024	0	25.28%	25.28%	0.00%
	1	28.60%	29.97%	-1.37%
	2	28.91%	31.65%	-2.75%
	3	30.60%	33.34%	-2.74%
	4	32.29%	35.02%	-2.73%
	5	34.88%	36.71%	-1.83%
	6	36.57%	38.39%	-1.82%
	7	37.77%	40.08%	-2.31%
	8	38.96%	41.76%	-2.80%
	9	41.57%	43.44%	-1.87%
	10	43.04%	45.13%	-2.09%
	11	44.53%	46.81%	-2.49%
	12	46.57%	48.50%	-1.93%
2025	0	46.57%	48.50%	-1.93%
	1	48.00%	50.35%	-2.35%
	2	49.59%	52.21%	-2.61%
	3	51.55%	54.06%	-2.51%
	4	53.55%	55.77%	-2.22%
	5	55.17%	57.63%	-2.46%
	6	58.76%	61.48%	-2.72%
	7	60.57%	62.82%	-2.24%
	8		64.16%	
	9		65.50%	
	10		66.84%	
	11		68.18%	

**Percent Complete at the end of September 2025: 62,30 %
(64.16% planned)**

Percent complete= (value of work performed)/(budget approved at completion)*100

Project management tools are in place and actively used to monitor the project. They include: Work Breakdown Structure, Project Management Plan, Configuration Management Plan, Change Control Process, **Risk Management Plan**, Risk Registry, **Schedule and budget control**.

Spending overview

Total Value (Planned)

172,25 M€

All values VAT included
All values updated to September 30, 2025

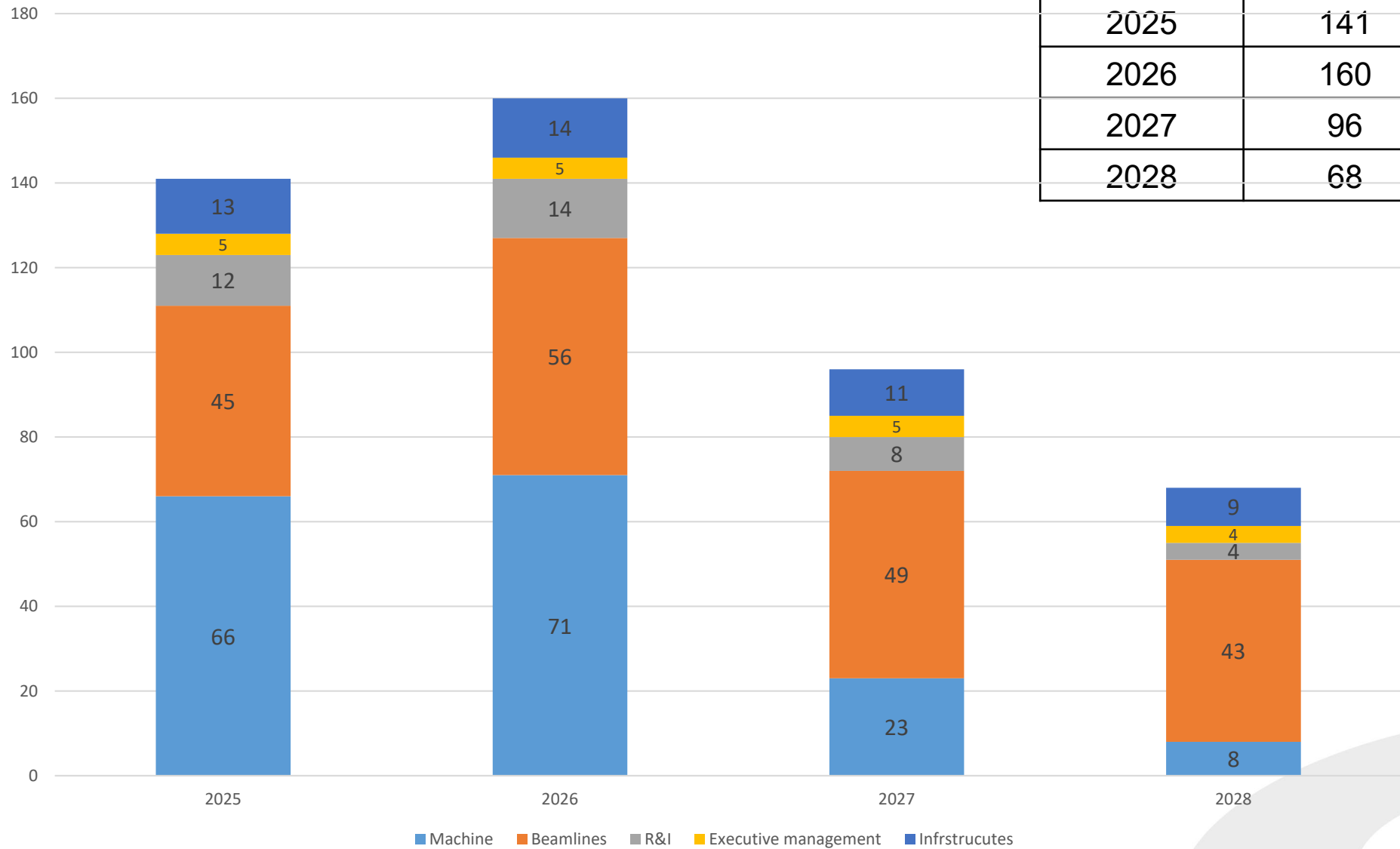
Total Value (Committed)

**149,93 M€
(87,0 %)**

Total Value (To be committed)

**22,32 M€
(13,0 %)**

FTEs distribution



Year	total FTEs
2025	141
2026	160
2027	96
2028	68

CURRENT TOP PROJECT RISKS

Ref. M. Lonza

- Risks are tracked and actively managed
- Mitigation plans implemented and monitored
- 234 Active risks
- Since 6 months ago 84 risks solved
- Still no catastrophic risks are present

#	Risk Title	Risk level	Mitigation plan
1	Delay of radioprotection license necessary to start commissioning with beam	Medium	– Strictly monitor authorization process – Work in close collaboration with Authorities to anticipate any request of additions
2	Dipole vacuum chambers: NEG coating could take longer than expected, producing delay in the chambers delivery	Medium	– Work in close collaboration with the Supplier to optimize time of chambers NEG coating – Investigate the possibility to temporarily install a few chambers without coating
3	BPM Pickups development delay and performance	Medium	– Work in close collaboration with the Supplier – Impact reduced via pursuing of an alternative design involving a different manufacturer
4	Interference of R&I activities with infrastructure yards in storage ring building	Medium	– Impact reduced by careful organization of occupation of yard areas and regular coordination briefings
5	Delay of injection septum magnet and chamber	Medium	– Close control of intermediate milestones during contract execution – Organize an efficient and on-time septum installation and integration

Other potential delay threats

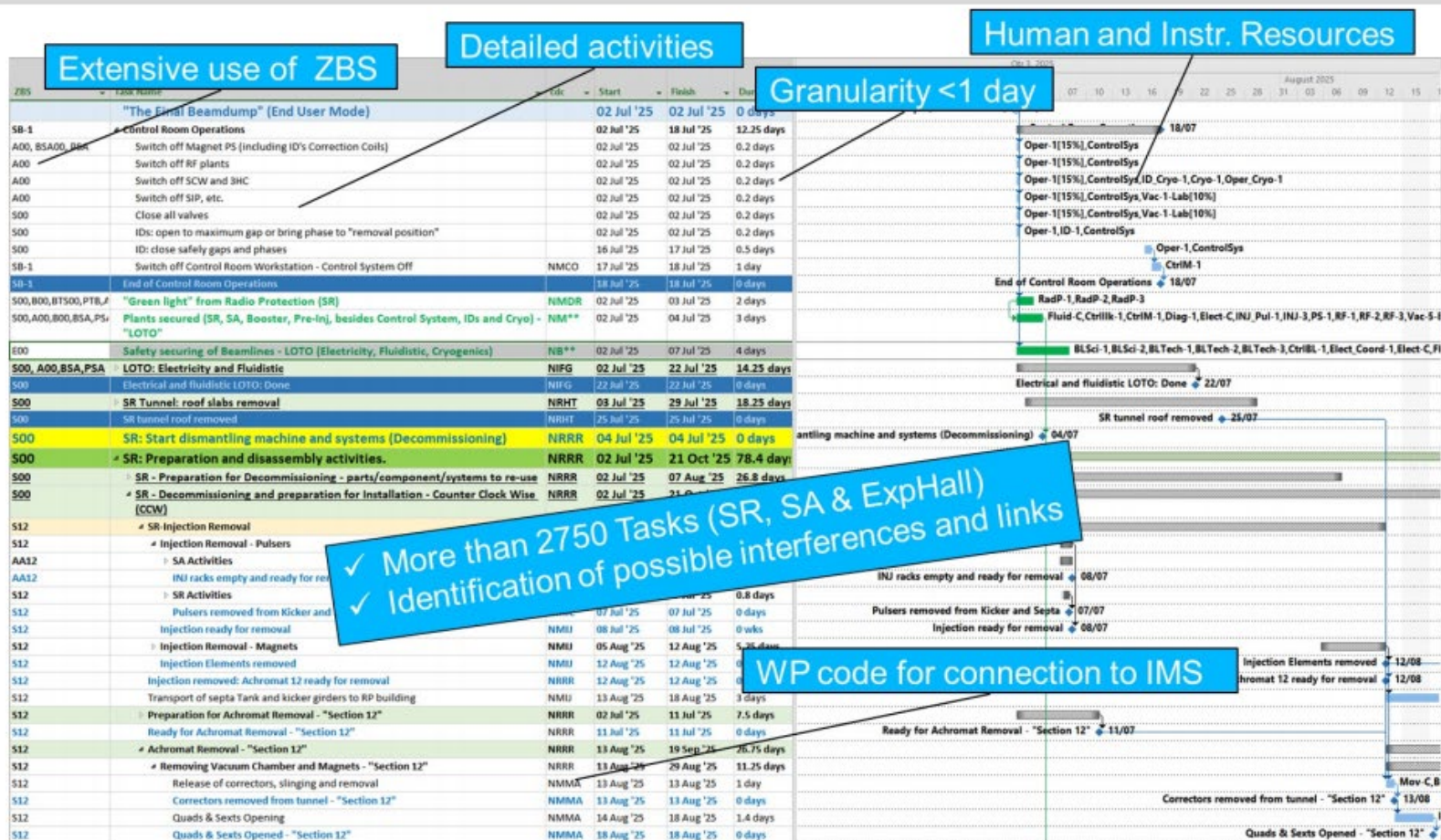
- ✓ *Bureaucracy and legal time stand still during tender*
- ✓ *Personnel loss for career opportunities*
- ✓ *Pensioning*
- ✓ *Lack following companies very closely*
- ✓ *Lack checking and/or storing in a traceable way arriving material*
- ✓ *Ignoring or letting for later small and/or trivial issues, they might become a serious threat towards the end*



Dark Period schedule

Ref: R. Visintini

- 2750+ tasks identified and reported (Current version 15.2.5)
- Interconnects activities in SR, SA, and ExpHall, with resources and levelling of overallocation.
- It is synchronized with the Integrated Master Schedule of the Project
- Based on Zone Breakdown Structure (ZBS),
- WP codes are associated to the tasks to correlate with the IMS.

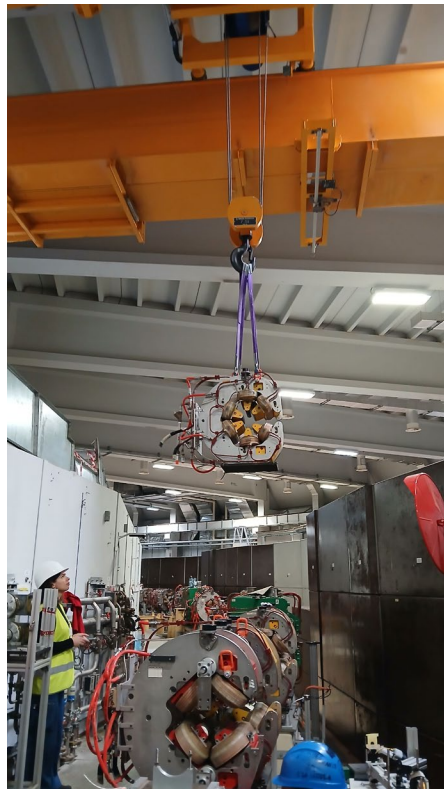
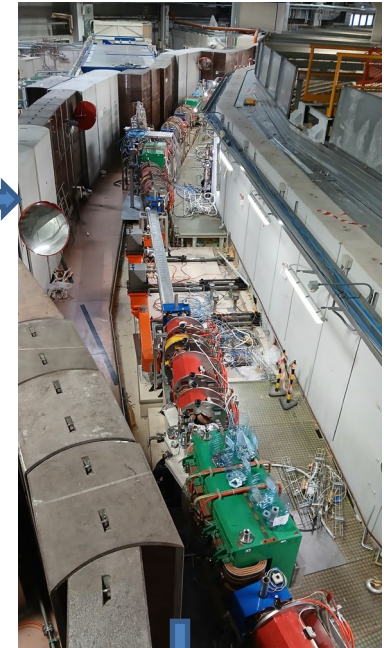
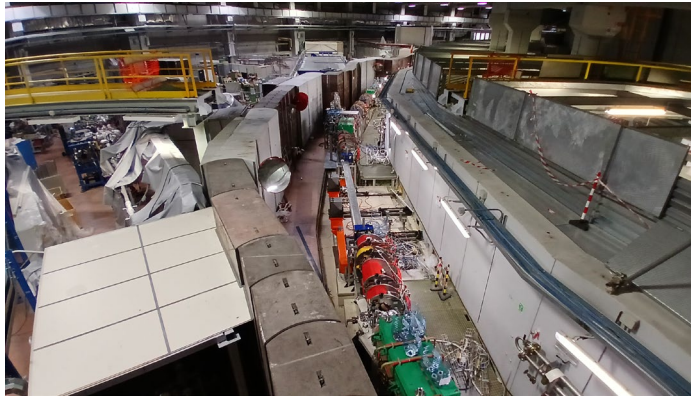


WP: work
package

IMS: integrated
management
system

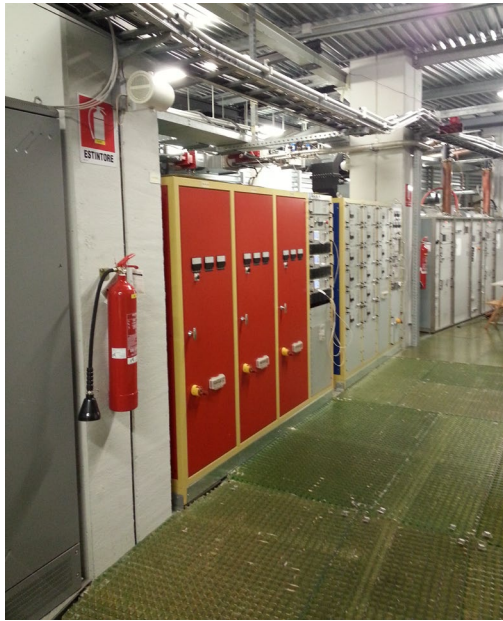
Dark period activities highlights

Storage ring removal



Dark period activities highlights

Service area removal





Conclusions

- ❖ We are now concentrated on the completion of procurement of the remaining components and services, needed to ensure the start of the facility commissioning according to plan.
- ❖ The start of Dark Period marked a new phase of the Project with new challenges in terms of work organization, planning and execution.
- ❖ Project management tools are in place and actively used to monitor the Project.
- ❖ The schedule is continuously monitored, mitigation strategies are in place for possible delays, however at present we do not consider schedule baseline changes.
- ❖ According to the schedule the new ring will be completed for commissioning in September 2026

Thank you for your attention





Elettra
Sincrotrone
Trieste

Elettra has been a very successful and stable storage ring

