Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
EuPRAXIA Advanced Photon Sources

WP2 Betatron Source

Alessandro Cianchi

University of Rome Tor Vergata & INFN

On behalf of SPARC_LAB & Eupraxia collaborations

INFN

TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA

Outline

- What we are going to do?
  - Betatron source
- Where?
  - In the SPARC tunnel @ LNF
- Who?
  - INFN-LNF, INFN-Mi, CNR-Montelibretti, CNR-Potenza, Tor Vergata
- When?
  - Schedule

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Betatron was always a hot topic

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 012801 (2017)

Trace-space reconstruction of low-emittance electron beams through betatron radiation in laser-plasma accelerators

A. Curcio,[1,2,*] M. Anania,[1] F. Bisesto,[1,2] E. Chiadroni,[1] A. Cianchi,[3] M. Ferrario,[1] F. Filippi,[1,2] D. Giulietti,[4] A. Marocchino,[1] M. Petrarca,[5] V. Shpakov,[1] and A. Zigler[1,6]

APPLIED PHYSICS LETTERS **111**, 133105 (2017)

Single-shot non-intercepting profile monitor of plasma-accelerated electron beams with nanometric resolution

A. Curcio,[1,2,a)] M. Anania,[1] F. Bisesto,[1,2] E. Chiadroni,[1] A. Cianchi,[3] M. Ferrario,[1] F. Filippi,[1,2] D. Giulietti,[4] A. Marocchino,[1] F. Mira,[5] M. Petrarca,[5] V. Shpakov,[1] and A. Zigler[1,6]

J. Plasma Phys. (2015), *vol.* 81, 495810513 © Cambridge University Press 2015
doi:10.1017/S0022377815000926

Resonant interaction between laser and electrons undergoing betatron oscillations in the bubble regime

Alessandro Curcio[1,2,†], Danilo Giulietti[3], Giuseppe Dattoli[4] and Massimo Ferrario[2]

Nuclear Instruments and Methods in Physics Research B 402 (2017) 388–392

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

First measurements of betatron radiation at FLAME laser facility

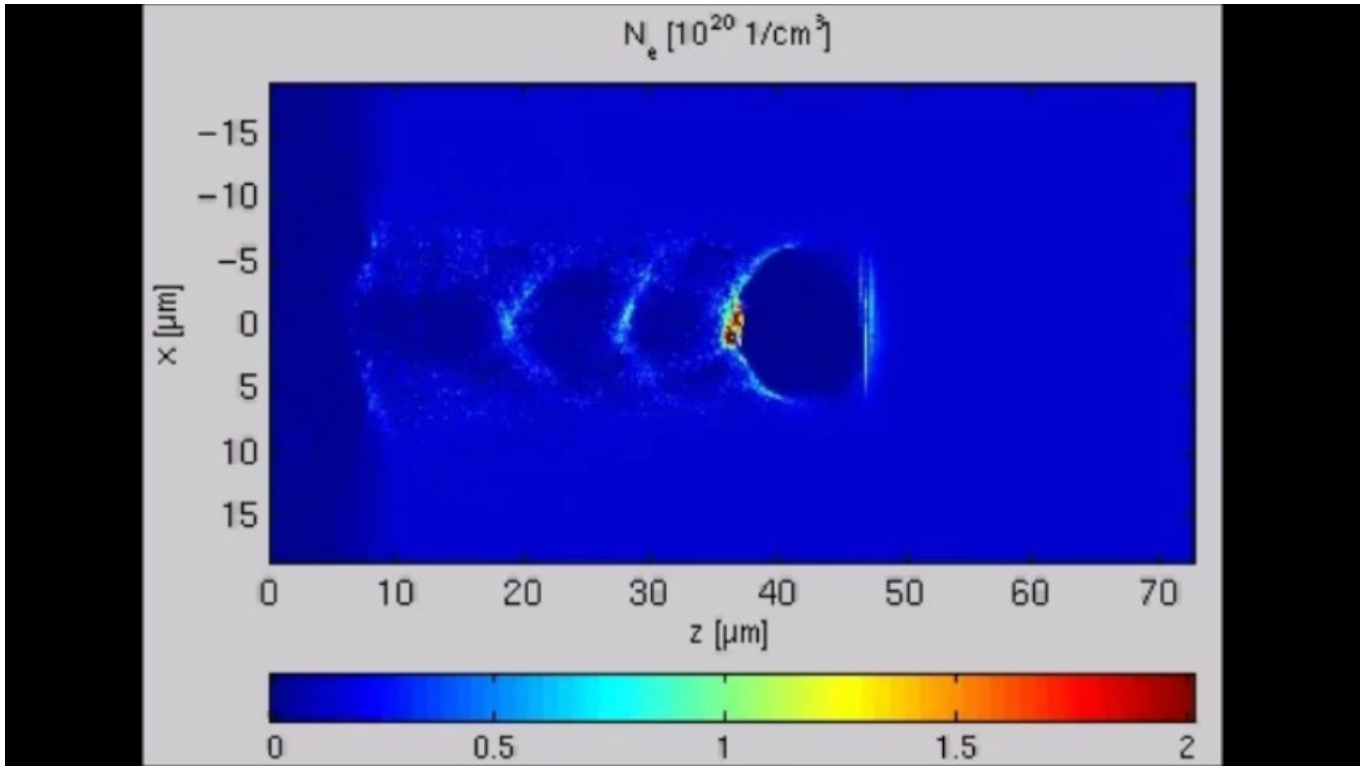
A. Curcio [a,b,*], M. Anania [a], F. Bisesto [a,b], E. Chiadroni [a], A. Cianchi [a], M. Ferrario [a], F. Filippi [a,b], D. Giulietti [c], A. Marocchino [a], F. Mira [b], M. Petrarca [d], V. Shpakov [a], A. Zigler [a,e]

applied sciences

Article

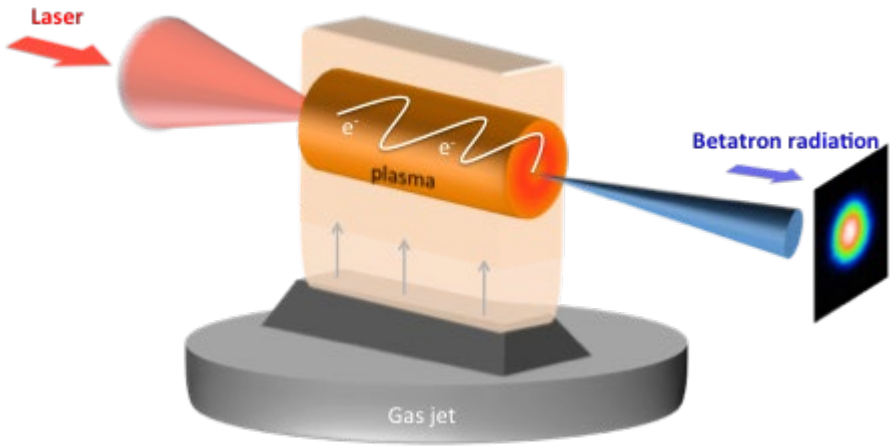
Performance Study on a Soft X-ray Betatron Radiation Source Realized in the Self-Injection Regime of Laser-Plasma Wakefield Acceleration

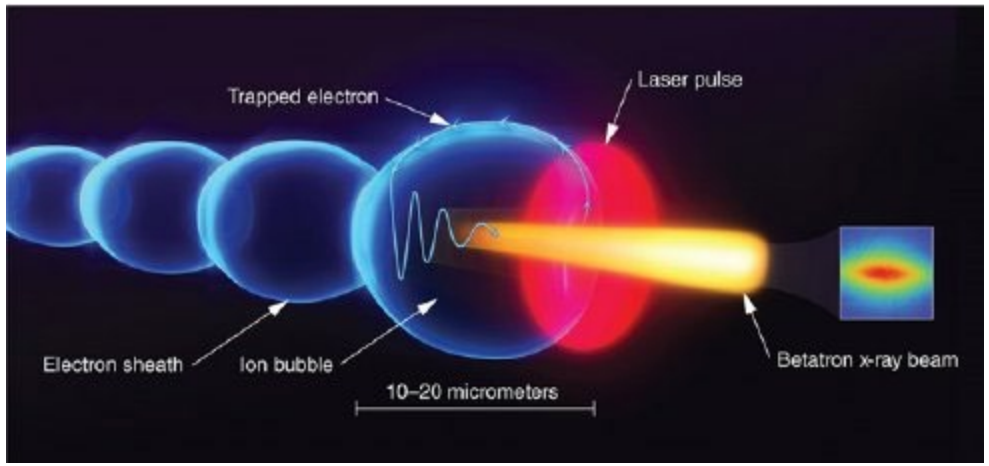
Alessandro Curcio [1,*], Alessandro Cianchi [2,3,4], Gemma Costa [5], Francesco Demurtas [2], Michael Ehret [1], Massimo Ferrario [5], Mario Galletti [2,3,4], Danilo Giulietti [6], José Antonio Pérez-Hernández [1] and Giancarlo Gatti [1]



- High power laser ionize the gas and create a plasma bubble
- Electron are self injected in the back of the bubble
- These charges are accelerated by intense electric field (>GV/m)
- The uncontrolled injection produces betatron oscillation

Betatron radiation emission

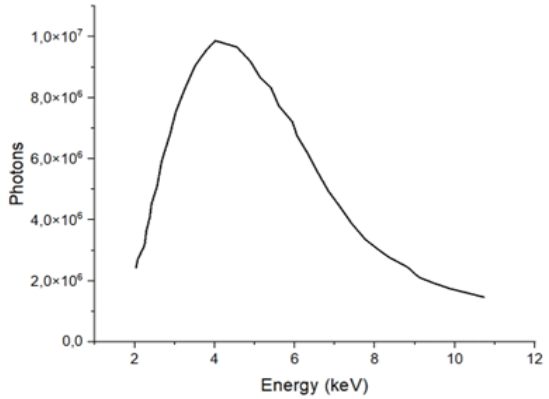




- The radiation has its own characteristics of both FELs and synchrotrons
  - Large bandwidth as Synchrotrons
  - Short pulse duration like a FEL

First measurements of betatron radiation at FLAME laser facility

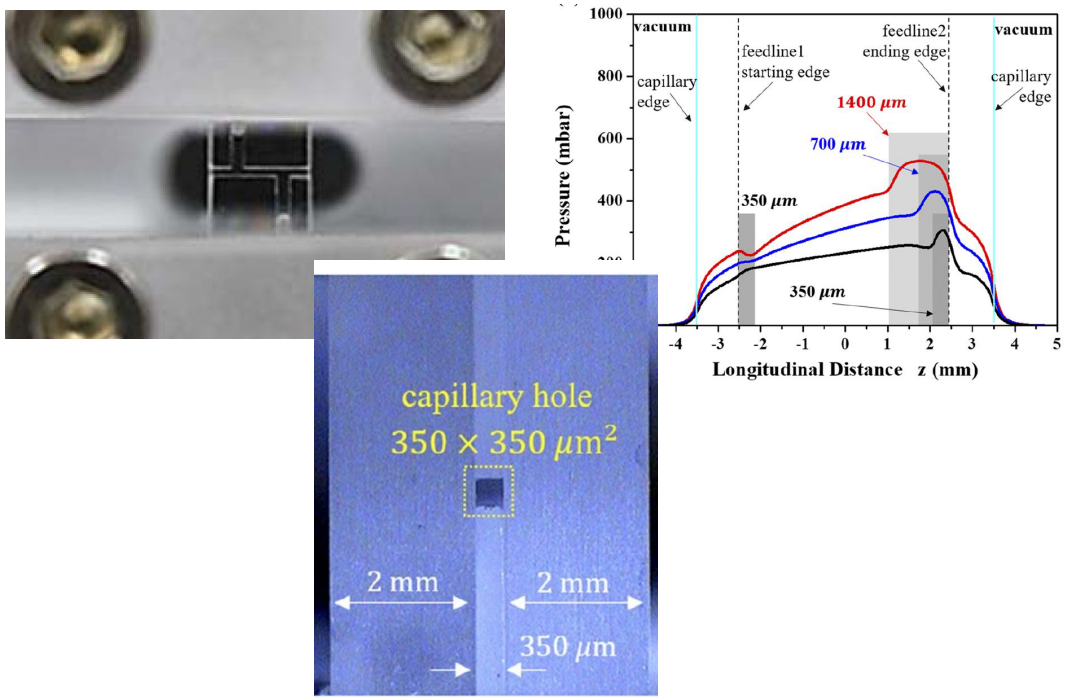
A. Curcio [a,b,*], M. Anania [a], F. Bisesto [a,b], E. Chiadroni [a], A. Cianchi [a], M. Ferrario [a], F. Filippi [a,b], D. Giulietti [c], A. Marocchino [a], F. Mira [b], M. Petrarca [d], V. Shpakov [a], A. Zigler [a,e]



Expected Parameters

Parameter	Value	unit
Electron beam Energy	100-800	MeV
Plasma Density	10^{17}-10^{19}	cm^{-3}
Photon Critical Energy	1 -10	keV
Number of Photons/pulse	10^{6}-10^{9}	
Repetition rate	1-10	Hz
Beam divergence	3-20	mrad

Gas cell (Pallas Collaboration)



J. Kim et Al., RSI 25, 92, 023511 (2021)

- The high brightness beam target developed by PALLAS project in collaboration with LNF could be an interesting *opportunity*.

- No strong modifications to the Interaction chamber
- Vacuum pumping system
- Rep Rate (10 Hz)
- Neutral gas pressure(1 bar)

- Laser ablation/sapphire materials
- Complicate machining

Courtesy A. Biagioni

Possible applications

In order of increasing difficulty

- 1- Static imaging
- 2- Static absorption spectroscopy
- 3- Static emission spectroscopy
- 4- Time-resolved pump-probe absorption spectroscopy
- 5- Time-resolved pump-probe emission spectroscopy
- 6- Time resolved imaging (plasma dynamics).

Courtesy F. Stellato

Where?

- The source will be hosted at LNF-INFN
- Several parts will be realized at CNR (Photon Diagnostics) and at Tor Vergata (User end station)
- INFN-Mi will take care of simulation and data analysis

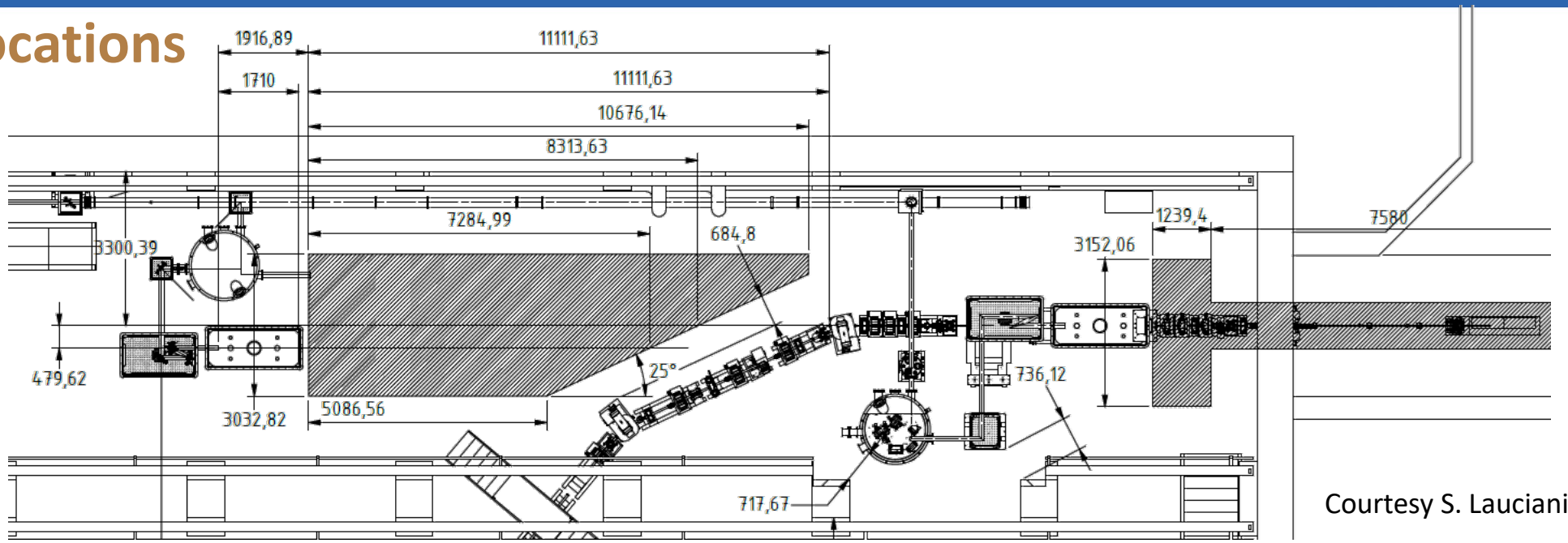
Activity	Where	Target
2.1	INFN-Mi	Simulation & Data Analysis
2.2	LNF-INFN	Plasma source
2.3	LNF-INFN	Synchronization
2.4	CNR-Potenza	Photon Diagnostics
2.5	Tor Vergata	End user station
2.6	CNR- Montelibretti	Photon time diagnostics

Two phases

- The betatron X rays source will be developed at FLAME bunker optimizing:
  - Laser parameters
  - Plasma source devices
  - Electron diagnostics
  - X rays spectrum
  - Photon flux

- At the beginning of 2024 it will be moved in the SPARC bunker, with the installation of a new compressor and a refurbishing of the old one.
- The main goal is to make a replica of the source developed at FLAME
- The advanced photon diagnostics and the user end station will be tested and installed during/after the commissioning of the source

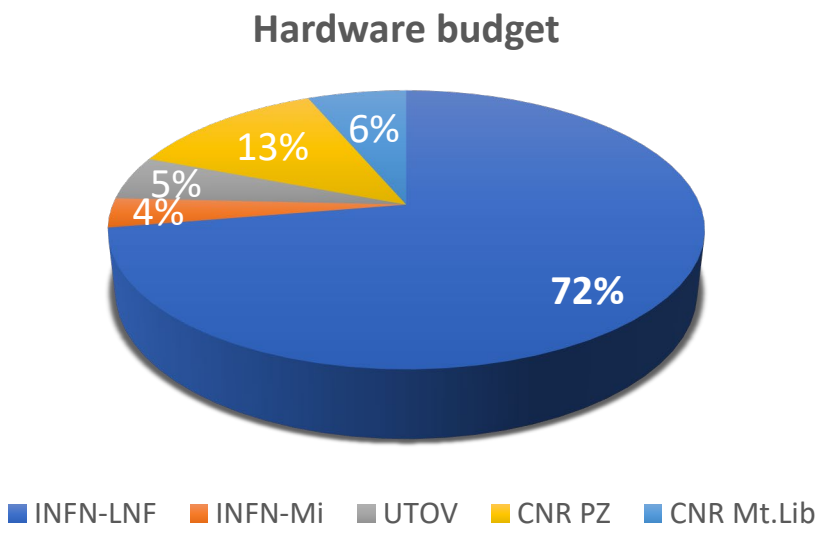
Possible locations



Courtesy S. Lauciani

- EuAPS setup fits in two different positions inside the SPARC bunker
- Both of them have advantages and disadvantages
- The final position will be defined before the summer based on these parameters:
  - Best source performance
  - Possibility to capture the electron in the future in a dedicated beamline
  - Space for users, including future upgrade
  - Different schemes for betatron production

Budget



	Costs included in the request for funding		
	To be located within the eight southern Regions	To be located outside the eight southern Regions	**Total requested grant**
a. Fixed term personnel specifically hired for the project	120.000,00	878.000,00	998.000,00
b. Scientific instrumentation and technological equipment, software licenses and patent	1.000.000,00	6.840.400,00	7.840.400,00
c. Open Access, Trans National Access, FAI principal implementation	0,00	0,00	0,00
d. Civil infrastructures and related systems	0,00	0,00	0,00
e. Indirect costs, including running costs	78.400,00	540.288,00	618.688,00
f. Training activities	0,00	0,00	0,00
Total	1.198.400,00	8.258.688,00	9.457.088,00

Recruitment situation

Activity	Location	Request description	Actual situation	Situation	Possible candidates?
2.1	INFN-Mi	Tecnologo TD x 24 mesi	Tecnologo TD x 24 mesi	Competition ongoing	yes
2.1	INFN-Mi	Tecnologo TD x 24 mesi	Tecnologo TD x 24 mesi	Competition ongoing	yes
2.2	INFN-LNF	Tecnologo TD x 30 mesi	1 Tecnologo TD x 24 mesi	Competition ongoing	yes
2.2	INFN-LNF	Tecnologo TD x 30 mesi	1 Tecnologo TD x 24 mesi	Competition ongoing	yes
2.4	CNR-PZ	Tecnologo TD x 2 anni	Tecnologo TD x 2 anni	Competition ongoing	yes
2.5	UTOV	Tecnologo TD x 30mesi	1 Tecnologo TD x 24 mesi	in cda	yes
2.5	UTOV	Ricercatore TD x 30 mesi	1 Tecnologo TD x 24 mesi	in Department in April	no
2.6	CNR-Montelib	Ricercatore TD x 1 anno	Ricercatore TD x 1 anno	Out in May	yes

- It is easy to foresee that there will be some budget (about 100k) for additional positions or to switch to other activities
- The amount of the money requested was not for 30 but for 36 months, so the saving will be about 200k

2.1 Timeline (INFN-Mi) Simulations & Data Anlaysis

D 2.1.1 Hardware procurement

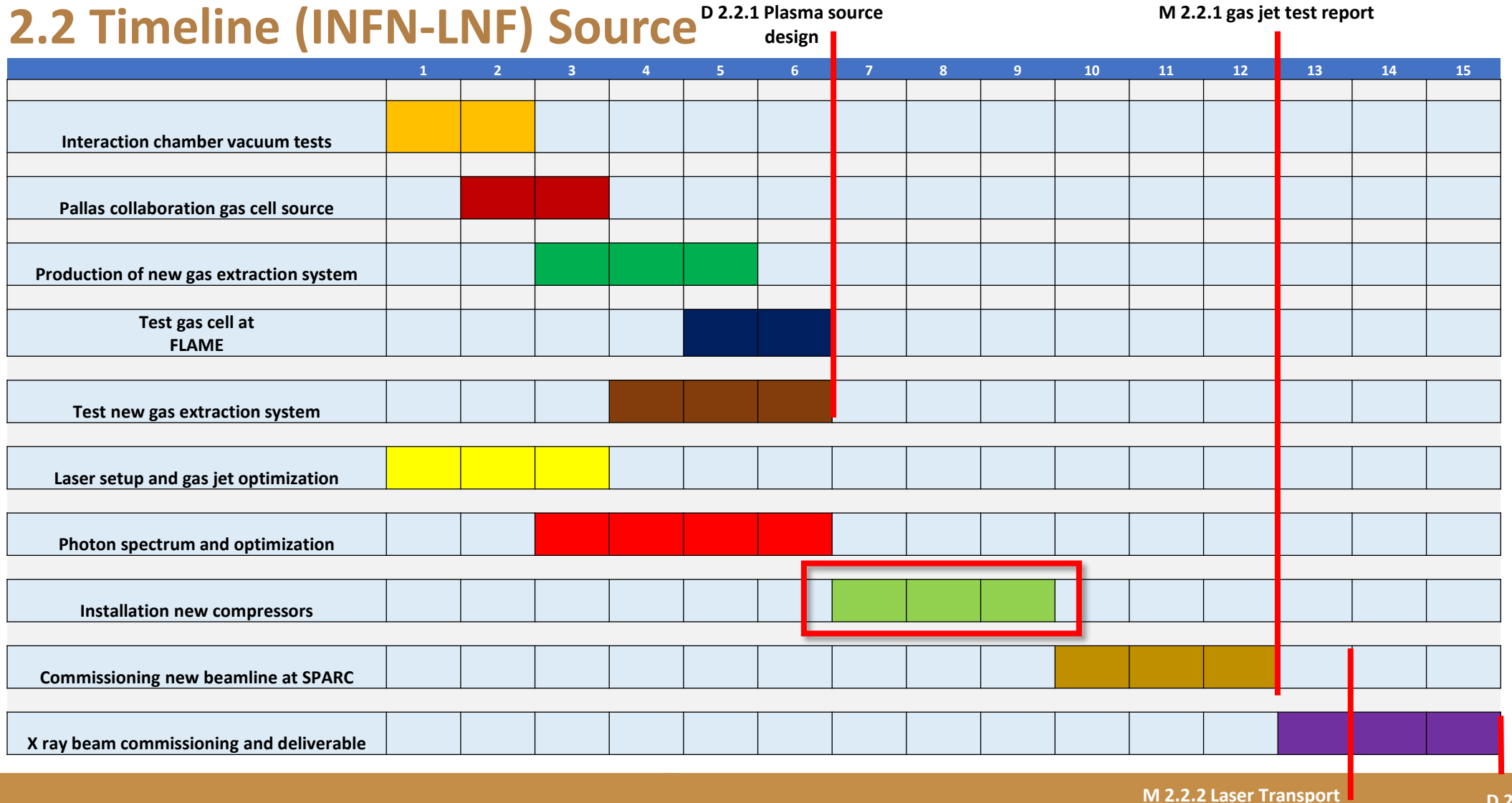
M 2.1.1 Hardware Commissioning

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hardware procurement and commissioning														
SW developing and benchmarking														
Simulation for preliminary setup														
Simulation of different injection scheme														
Optimization of choosen setup														

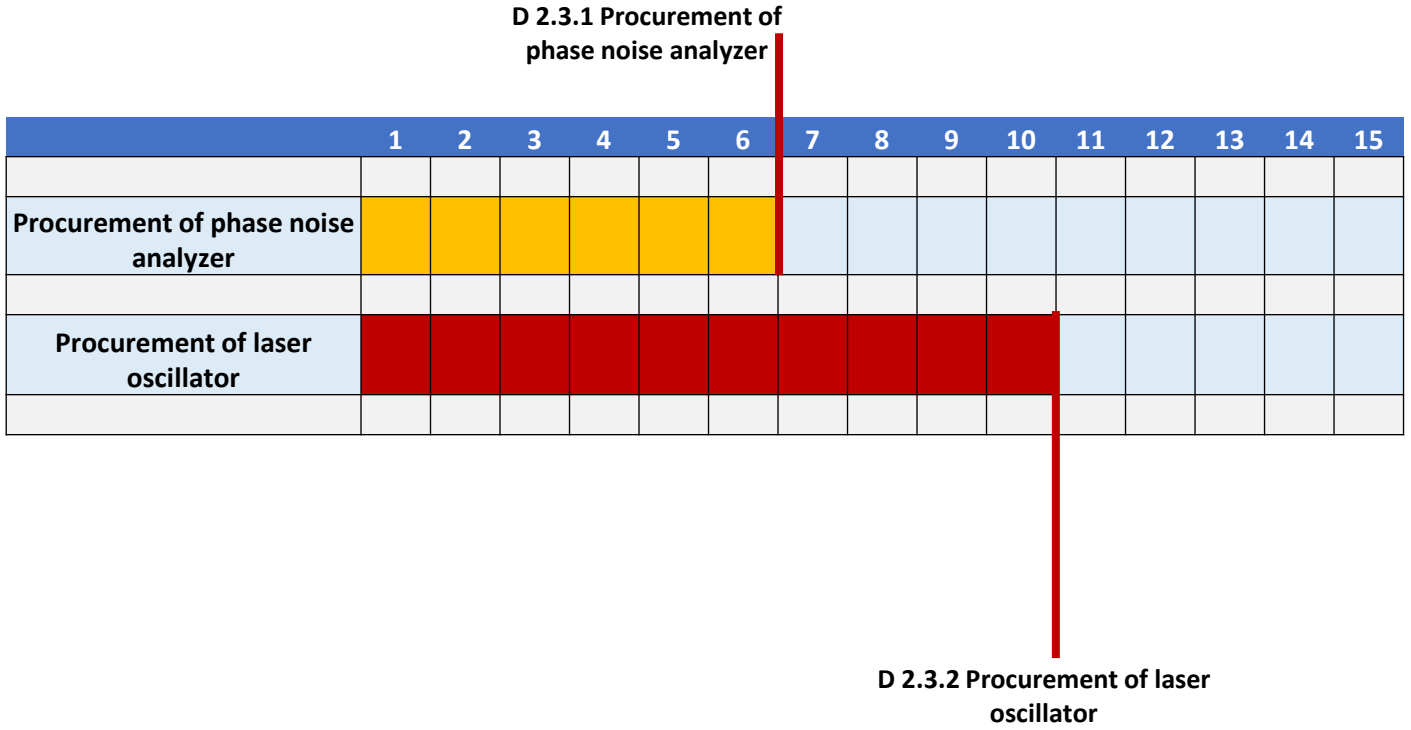
D 2.1.2 Data analysis tools

M 2.1.2 Report on simulations

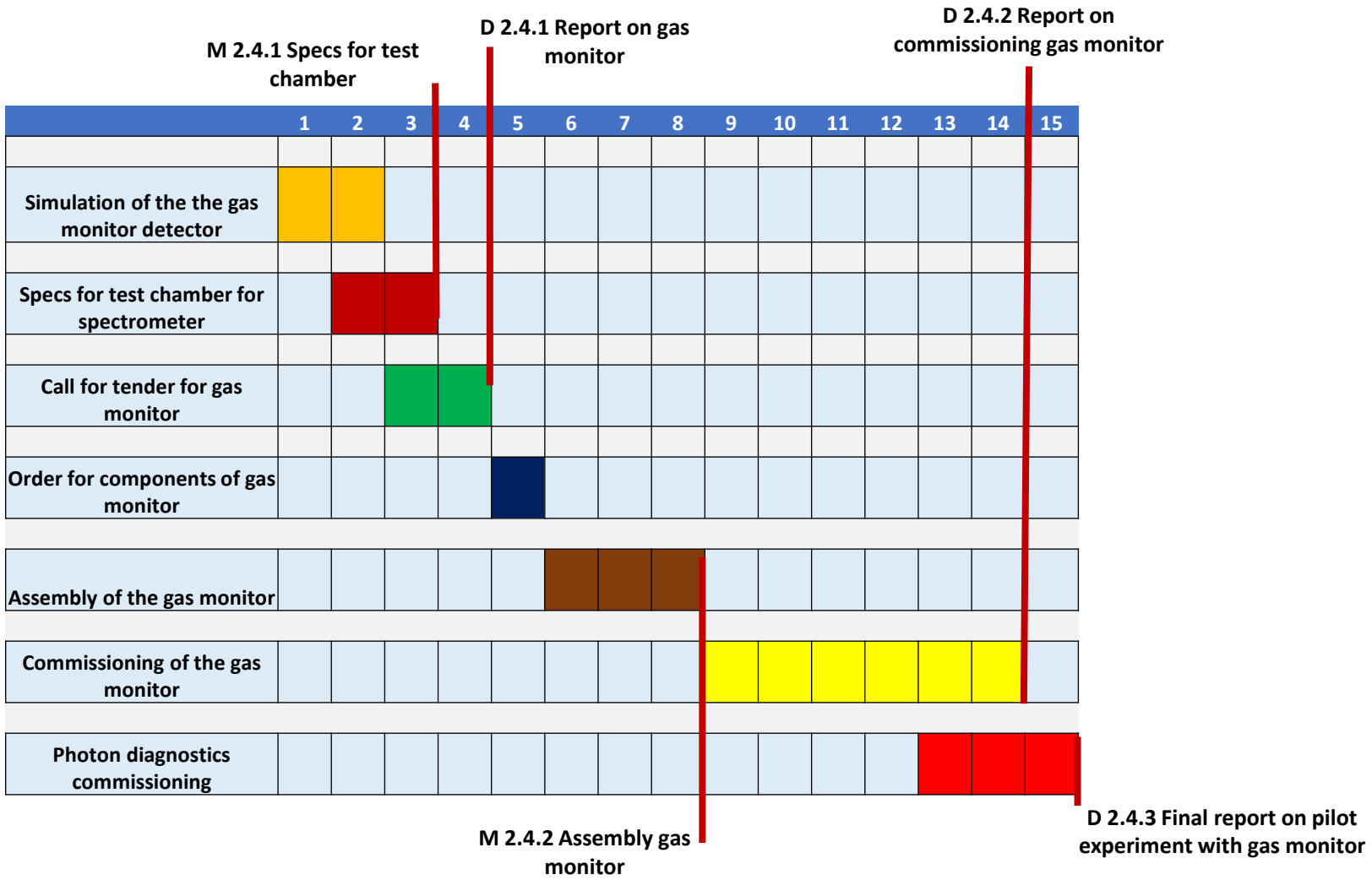
2.2 Timeline (INFN-LNF) Source



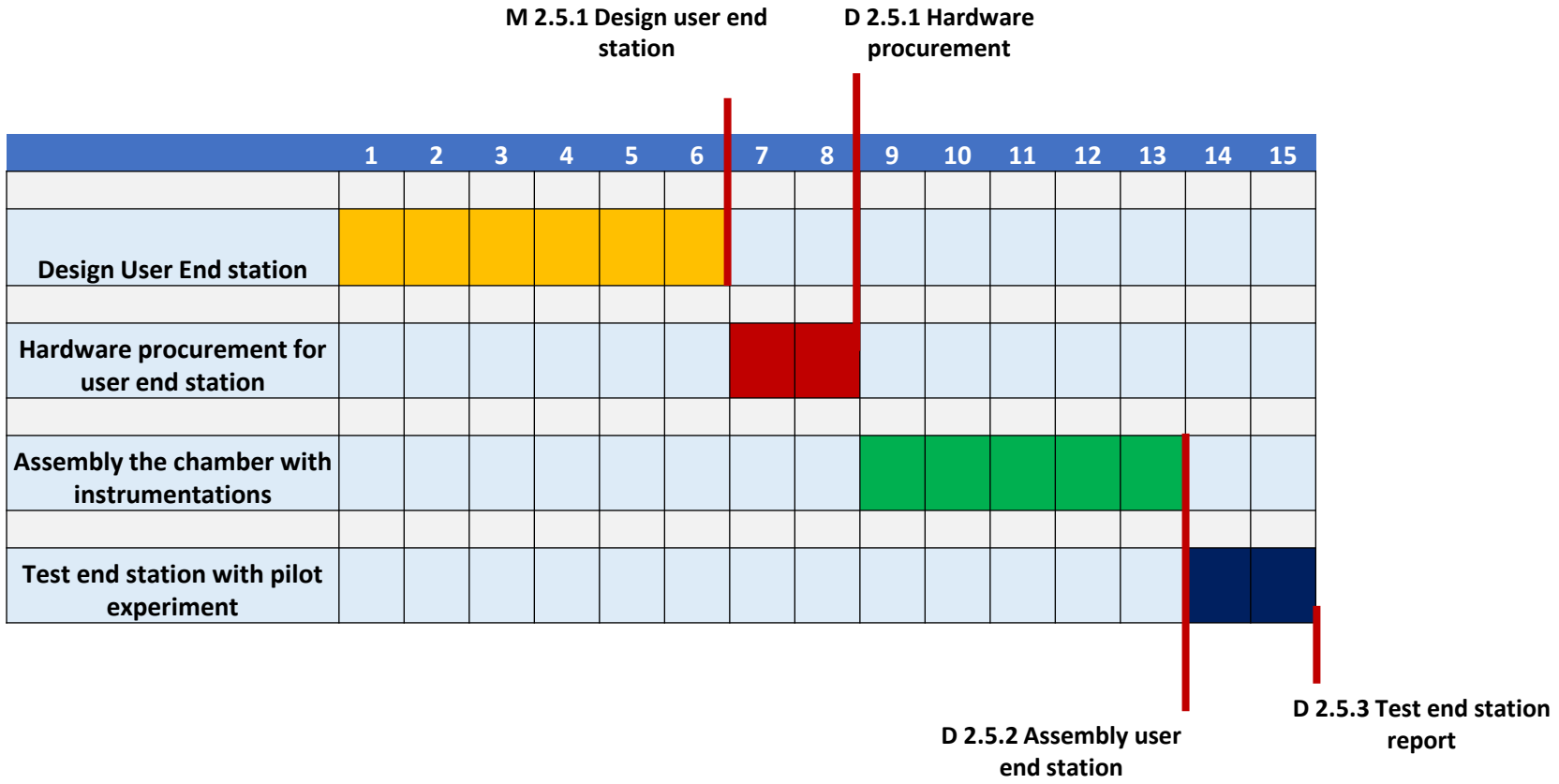
2.3 Timeline (INFN-LNF) Synchronization



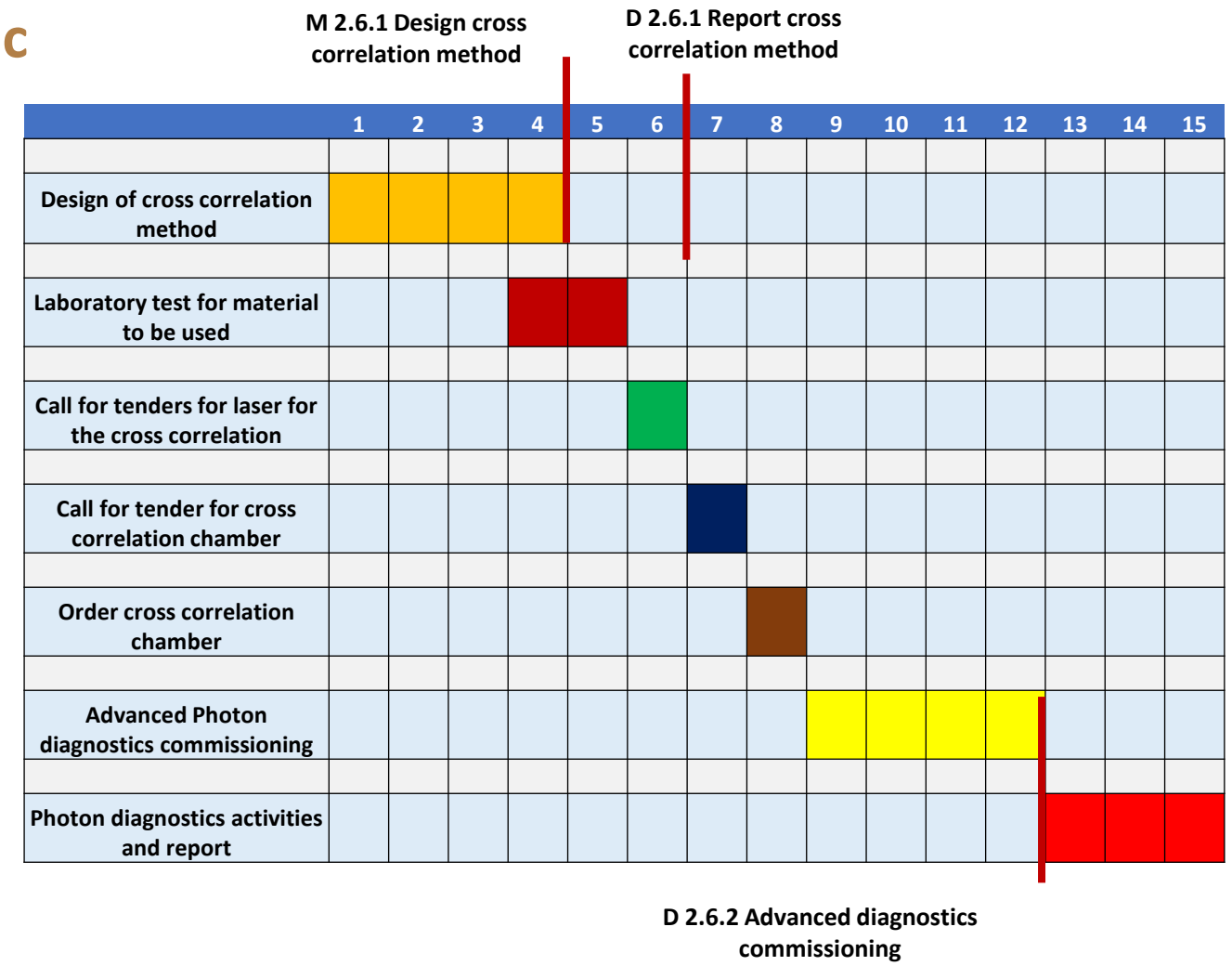
2.4 Timeline CNR Potenza Photon diagnostics



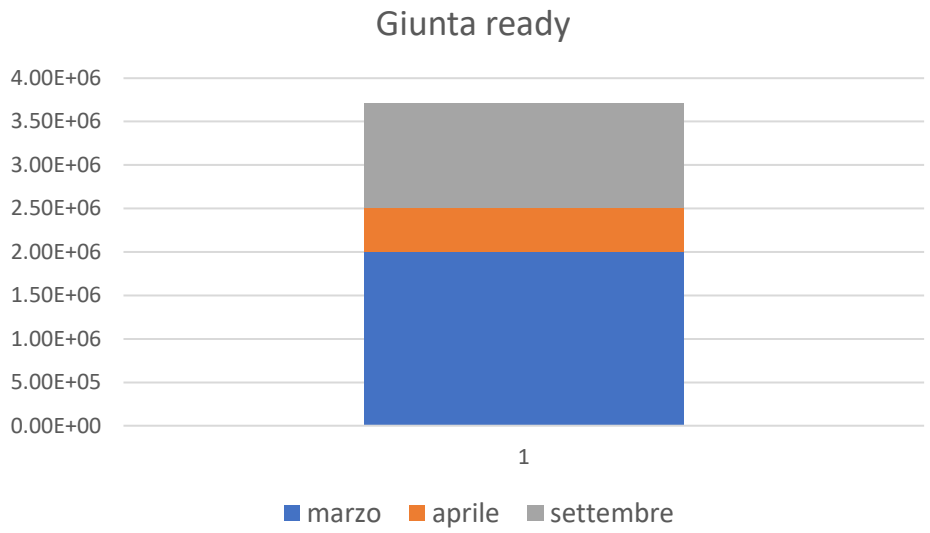
2.5 Timeline (UniTOV) End user station



2.6 Time Photon Diagnostic (CNR Montelibretti)



INFN



Tender needed to be approved in giunta	**3712000**
In progress (no tender)	**328000**
No tender	**322000**
To be defined after definition of the layout (July23)	**1213000**

Hardware acquisition situation (it is just a guess)

	Total Budget	Likely to be spent in 2023	Remain	%
CNR	1.5 M	0.9 M	0.6 M	40%
INFN	5.9 M	5.4 M	0.5 M	8%
UTOV	0.4 M	0.1 M	0.3 M	75%
	7.8 M	6.4 M	1.4 M	18%

Critical points

- Tender duration can severely affect the installation in the tunnel, and it will resolve in an overall delay
- Finalize all the tenders and all the equipment procurements for the end of this year is unfeasible and also wrong (likely 20% of the budget could be out of this window)
- Recruitment is not guarantee and 1-2 positions could be at risk
- The support of the technical services of LNF should be at maximum, while they are busy with several other projects.

Conclusions

- We are used to work fast because we usually run in competition for high level impact factor papers (like Nature, for instance)
- However, the big amount of hardware to buy in short time, the reduced number of people involved, the difficulty of the tasks can be a risk for the time schedule of the project
- We will do everything to speed up the purchases as much as possible, bearing in mind that many parts still need to be designed

Finally it's over

Thank you for your attention