Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Accelerator Division

Accelerator activities in Laboratori Nazionali di Frascati

Antonio De Santis
Laboratori Nazionali di Frascati – INFN

2024 European Edition of the International Workshop on the Circular Electron-Positron Collider, Marseille, FRANCE

Outline: LNF Accelerator activities

CERN
Geneva

FCC_ee MDI
FCC_ee Injector

IFIN-HH
Magurele

SSRIP

Scalable Source
Radio Isotope
Production

Numerous and diversified activity

Excellent technical support

Multi-disciplinary

Maintaining expertise in colliders

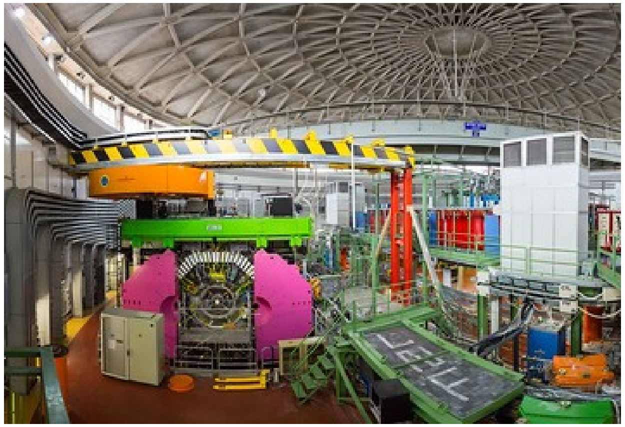
Large collaborations

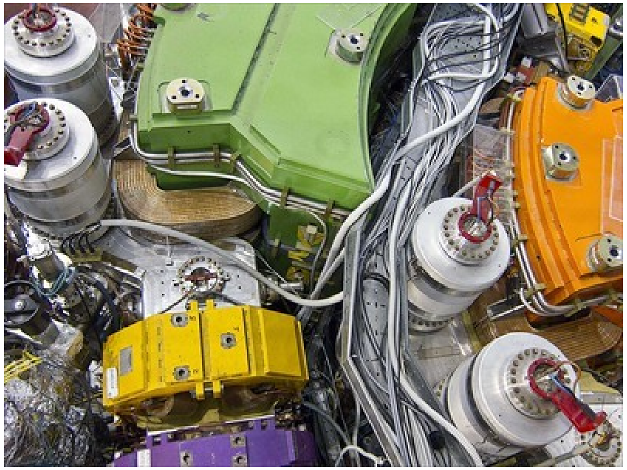
Growing expertise in plasma acceleration and light source

STAR2_TT

UniCal
Rende

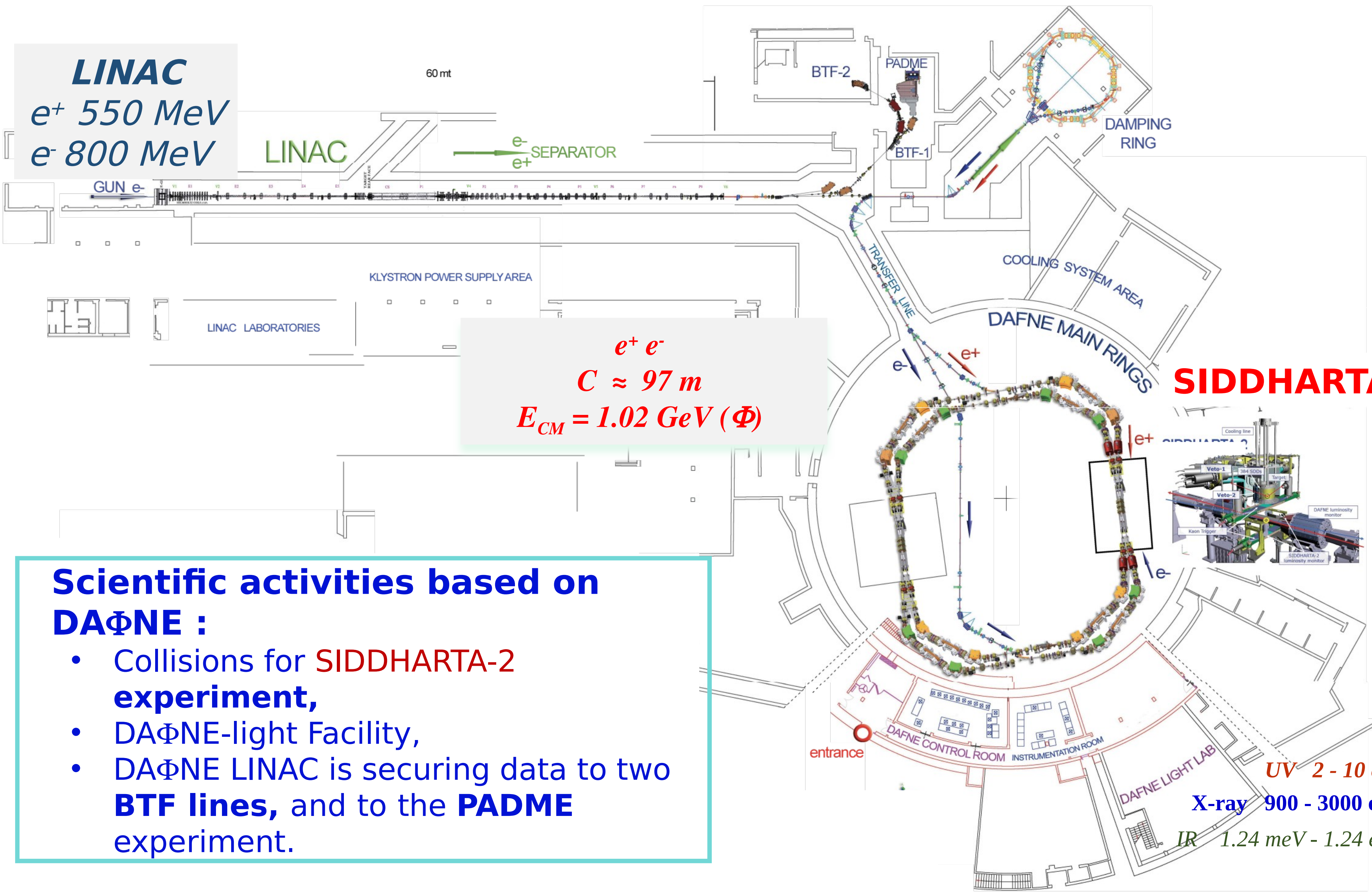

DAFNE





DAFNE accelerator complex layout

LINAC
e^+ 550 MeV
e^- 800 MeV



$e^+ e^-$
$C \approx 97\ m$
$E_{CM} = 1.02\ GeV\ (\Phi)$

Scientific activities based on DAΦNE :

- Collisions for SIDDHARTA-2 **experiment,**
- DAΦNE-light Facility,
- DAΦNE LINAC is securing data to two **BTF lines,** and to the **PADME** experiment.

The enduring interest in DAΦNE

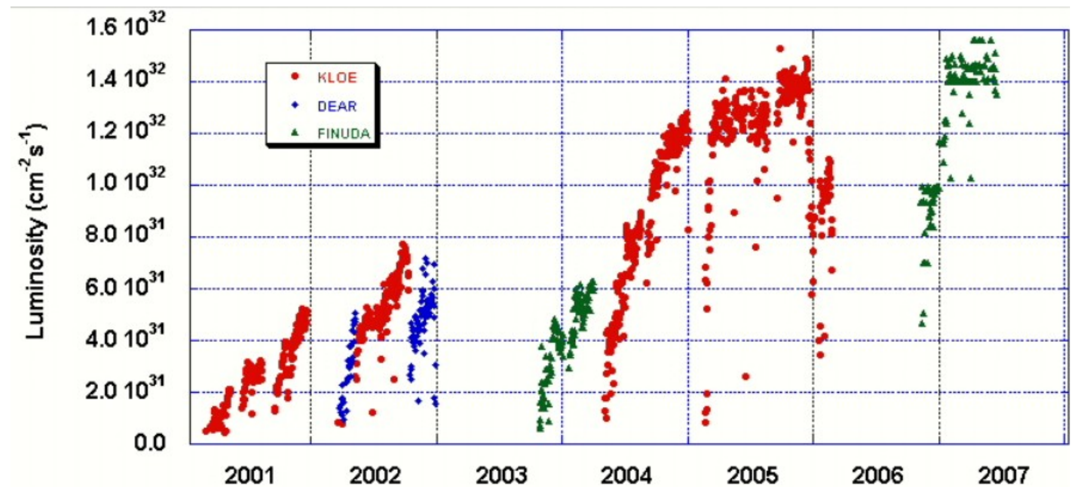
The DAΦNE lepton collider has been powering physics research at the LNF since almost 20 years. This has been possible because DAFNE implemented and successfully tested, with detectors of different complexity, a new collision scheme: the ***Crab-Waist Collision Scheme***.

The *Crab-Waist* concept was conceived, implemented, and tested in about two years, and allowed to increase the DAFNE luminosity by about a factor three, reducing at the same time the background on the detector.

The family tree of the **Crab-Waist** Is still growing

Colliders	Location	Status
DAΦNE	Φ-Factory Frascati, Italy	In operation (SIDDHARTA, KLOE-2, **SIDDHARTA-2**)
SuperKEKB	B-Factory Tsukuba, Japan	Adopted CW collision in 2020
SuperC-Tau	C-Tau-Factory Novosibirsk, Russia	Russian mega-science project
SuperCharmTau	Tau-Charm Factory Sarov, Russia	Design study
SuperTauCharm	Tau-Charm Factory Hefei, China	Proposed, significant R&D funding
FCC-ee	Z,W,H,tt-Factory CERN,Switzerland	91 km, CDR
CEPC	Z,W,H,tt-Factory China	100 km, CDR released in September 2018

DAFNE History



1998-2002: KLOE

2002: DEAR

2003: FINUDA

2004-06: KLOE

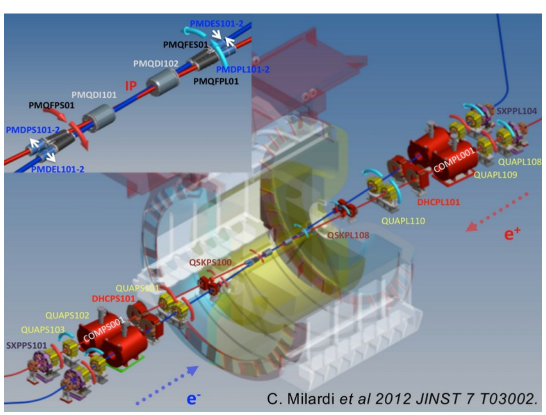
2007: FINUDA

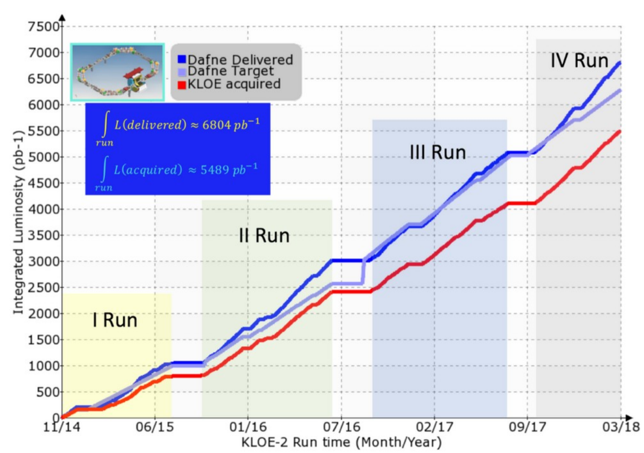
Native Collision scheme

Crab-Waist Collision scheme

2009: SIDDHARTA

2010-13: KLOE-2 (Test Run)

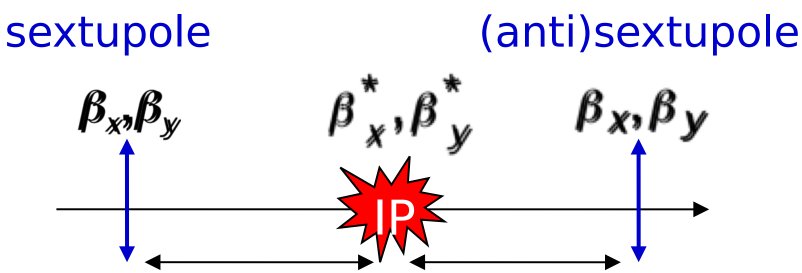




2014-18: KLOE-2

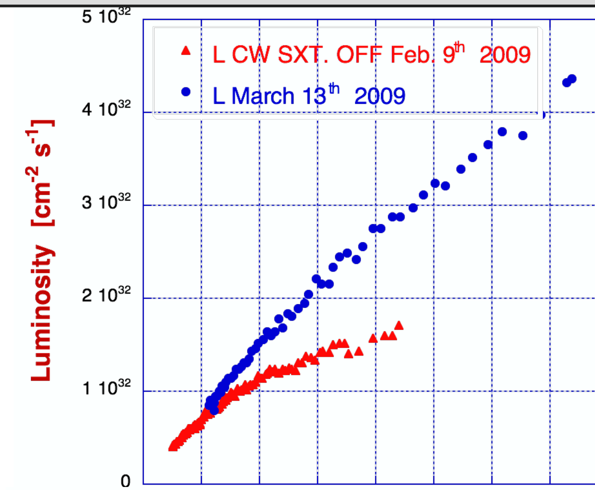
Crab-Waist collision scheme

Large horizontal crossing angle.
Large Piwinsky angle.
Overlap area, no longer bunch length, is the limit to avoid hourglass effect, this allows to have a *lower* β^*_y *at IP.*
Beam-beam non-linear resonances suppressed by a *pair of Crab-Waist Sextupole*

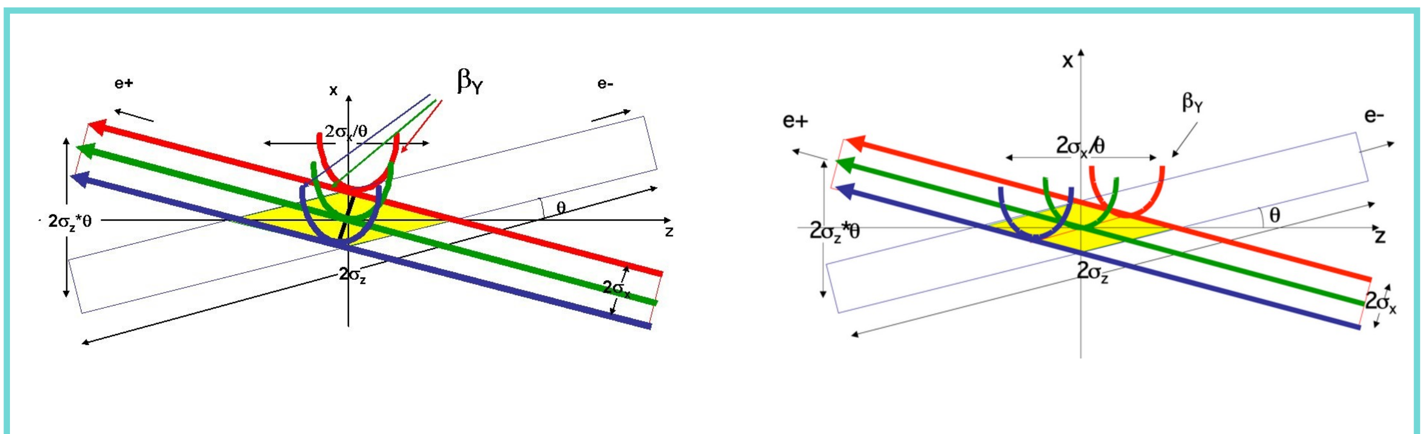


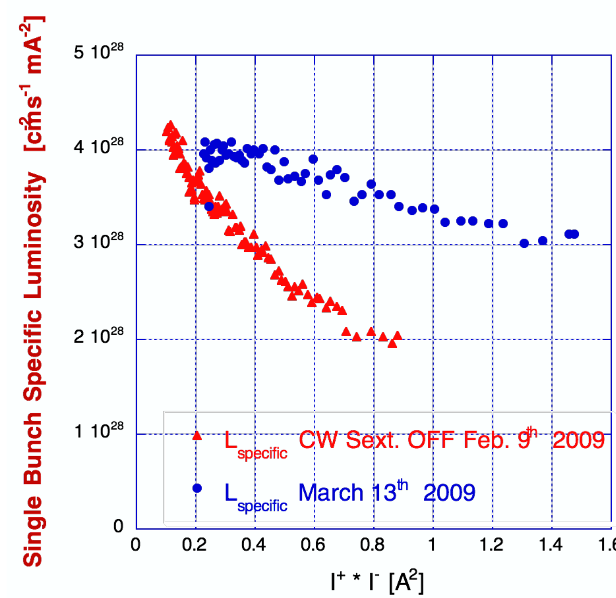
$$\Delta\nu_x = \pi$$

$$\Delta\nu_y = \frac{\pi}{2}$$



Crab-Waist transformation





P. Raimondi , *2° SuperB Workshop, March 2006,*
M.Zobov et al., Phys.Rev.Lett. 104 (2010) 174801,
C. Milardi et al., Int.J.Mod.Phys.A24, 2009.

SIDDHARTA-2 Timeline

SIDDHARTINO test setup

Sep - Dec 2019 collider new IR commissioning for SIDDHARTA-2

Mid Jan – March 2020 (pandemic)

February – Jul 2021

Apr – Jul 2022 SIDDHARTINO run completed, *and preliminary run with Deuterium target*

Jul 2022 – Apr 2023 SIDDHARTA-2 final setup assembly

SIDDHARTA-2 Setup

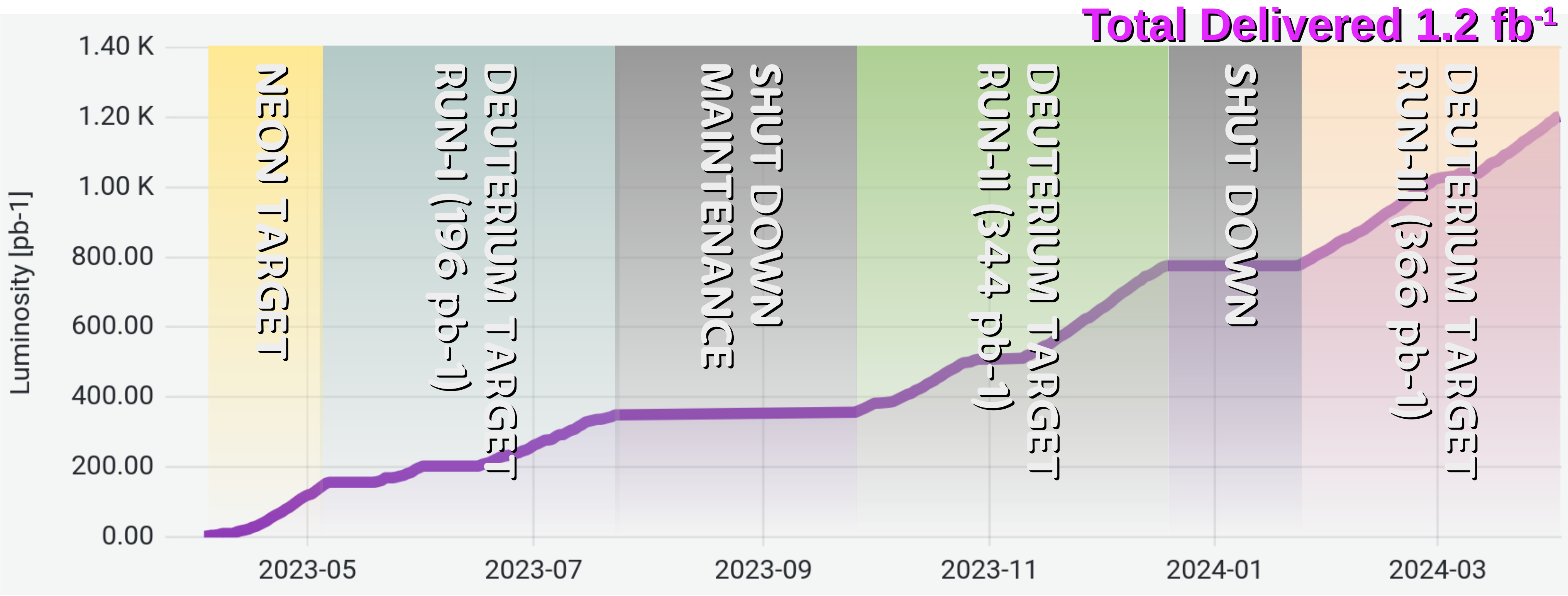
Apr – May 2023 *Neon run*

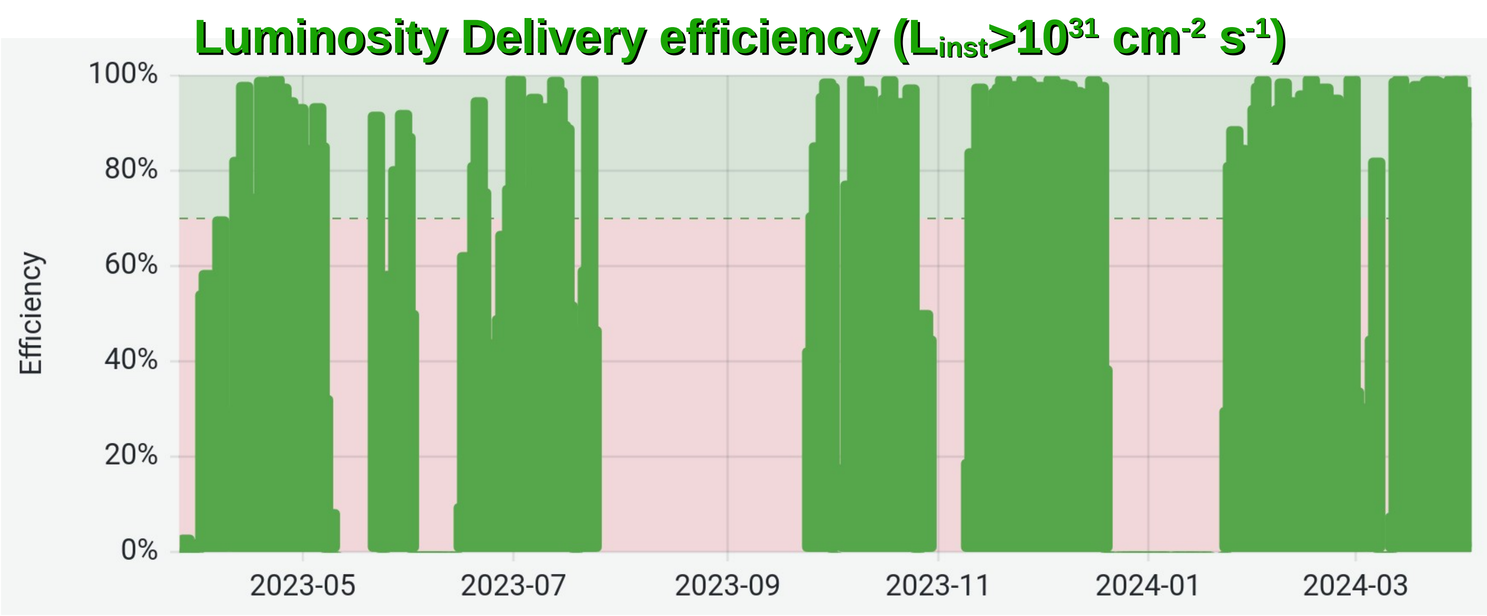
May – Jul 2023 Deuterium Run I

Oct – Dec 2023 Deuterium Run II

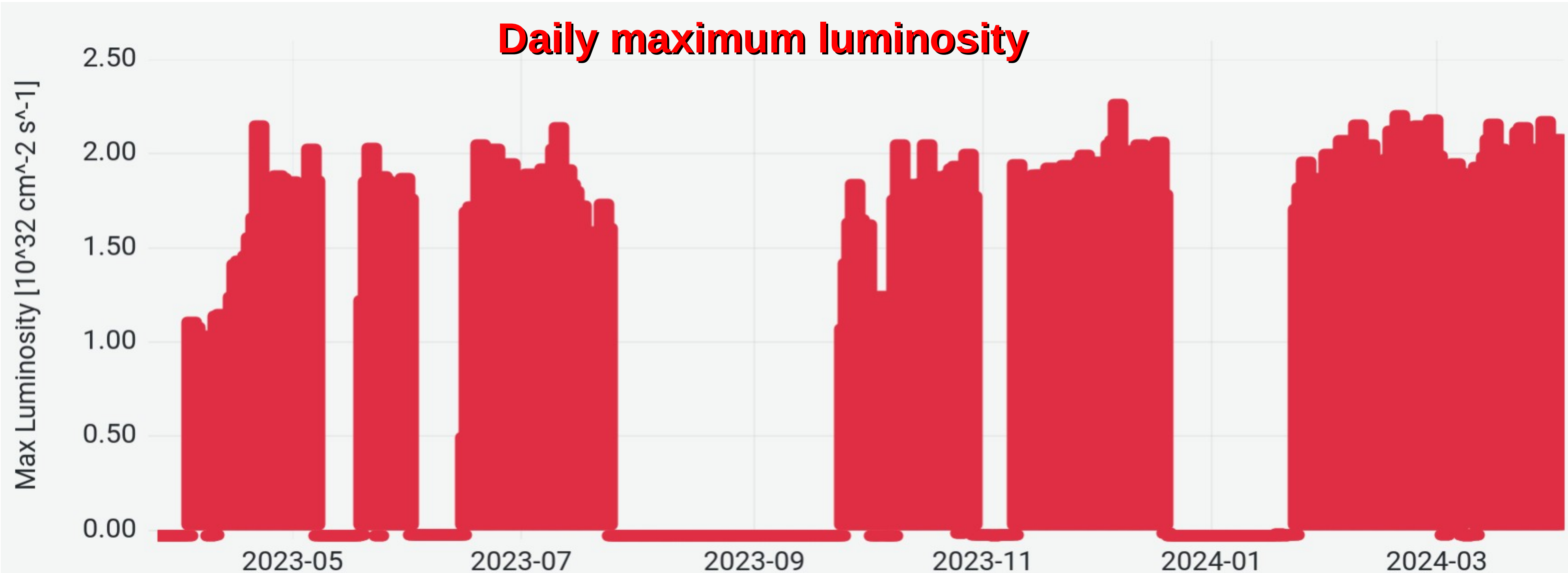
Feb 2024 – Now Deuterium Run III

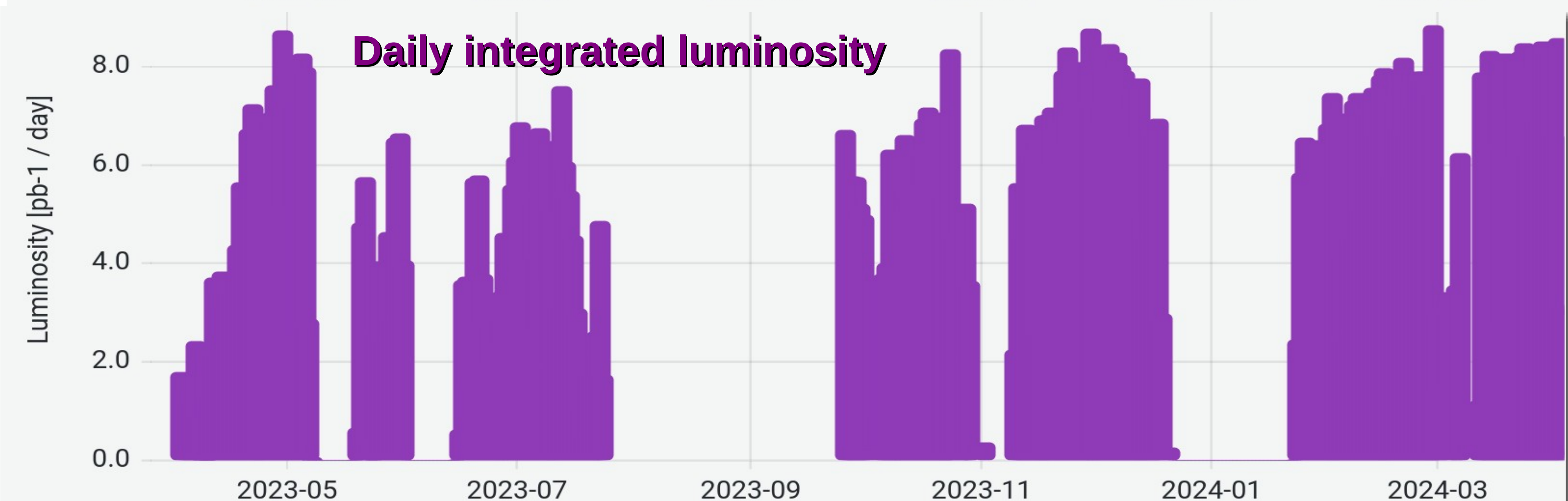
SIDDHARTA-2 Physics Run





SIDDHARTA-2 Physics Run



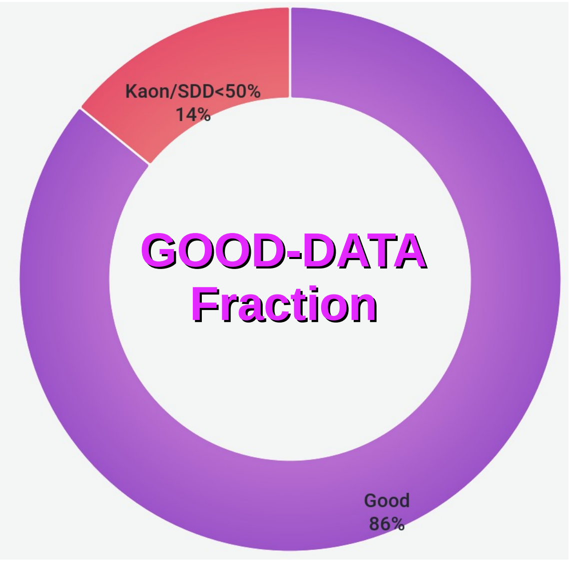


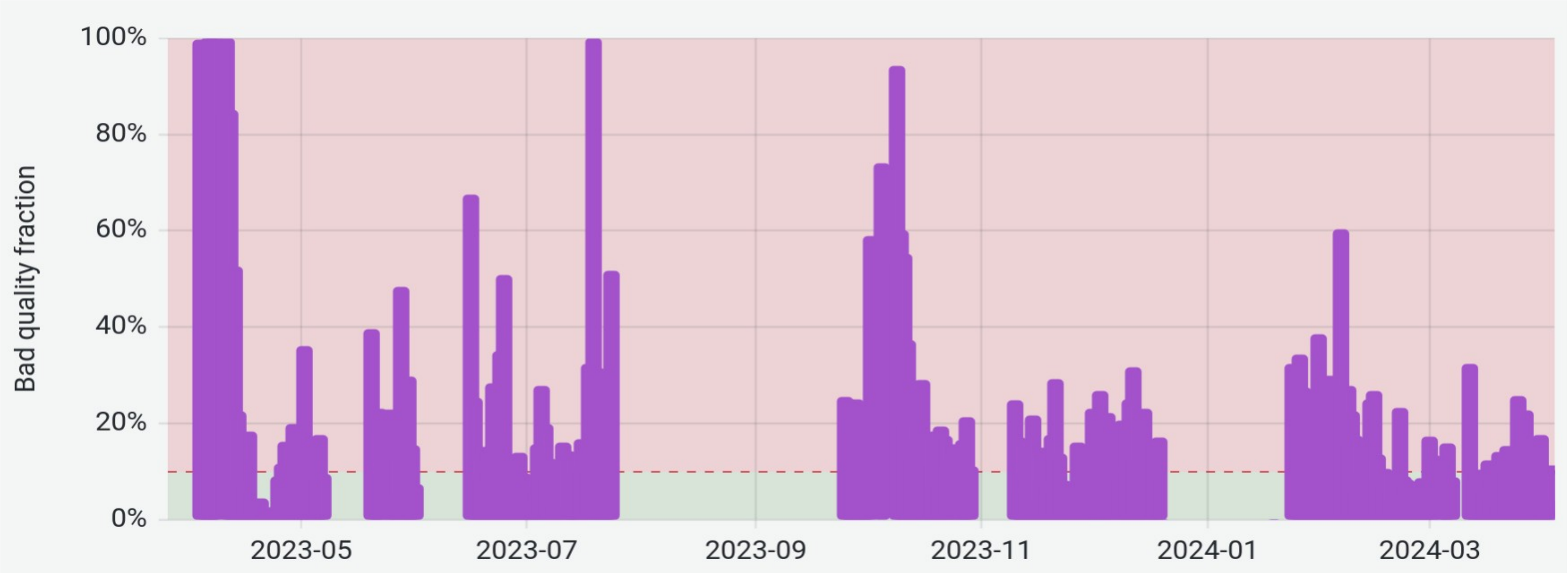
SIDDHARTA-2 Physics Run

Performance tune-up includes machine induced background minimization

During the SIDDHARTA-2 phase 86% of the delivered luminosity has physics grade (according to experiment definition)

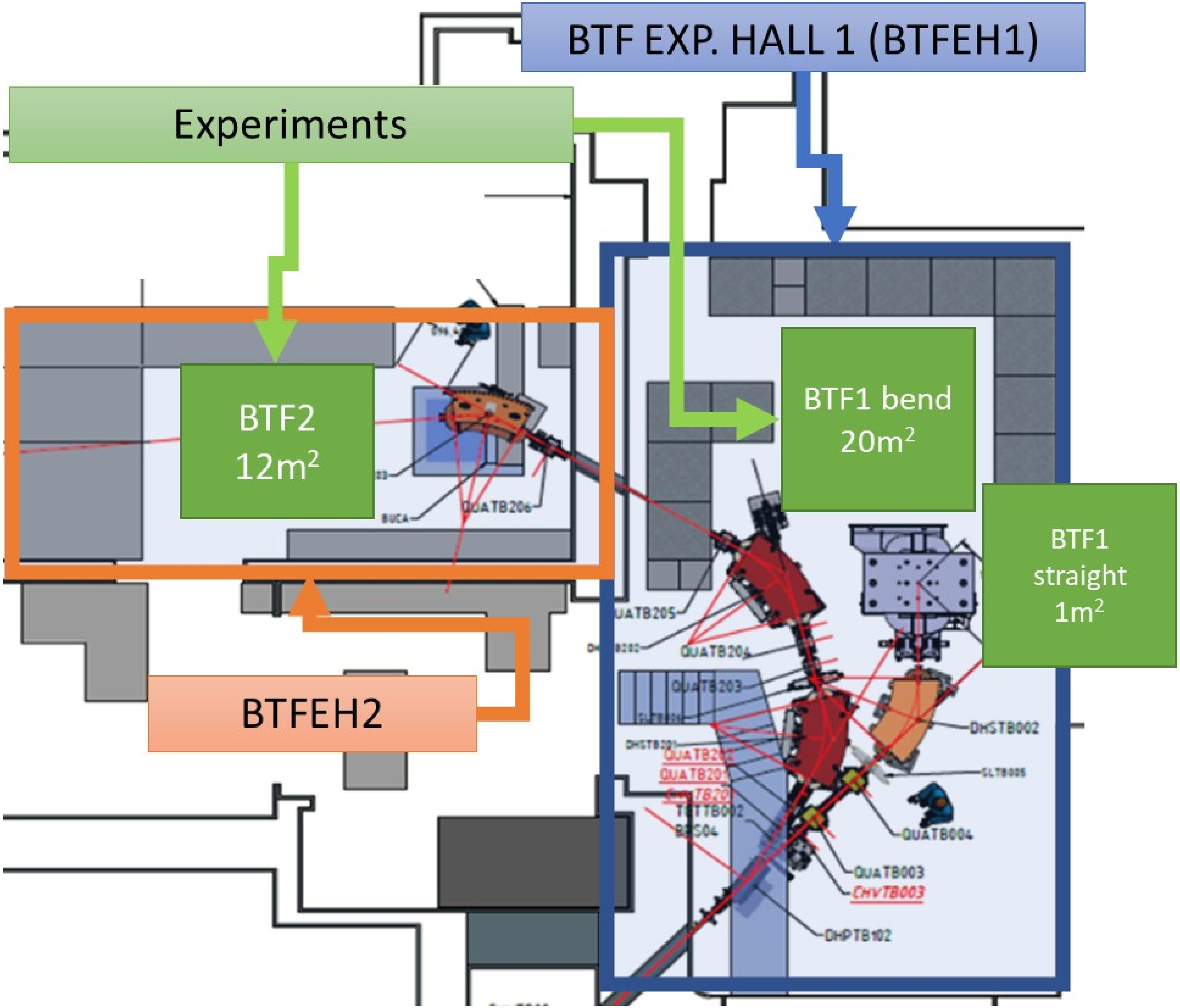
Continuous improvements have been obtained adjusting collider setup and keeping the optimal

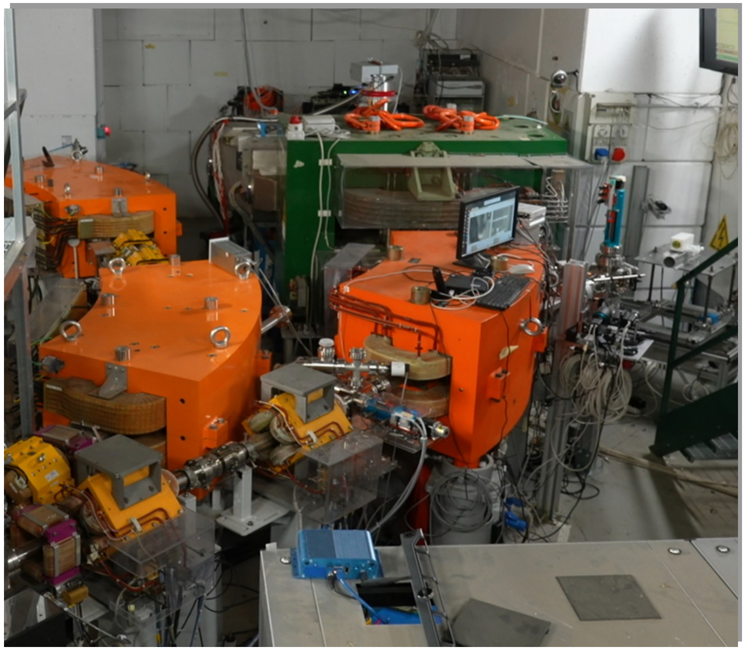




Beam Test Facility

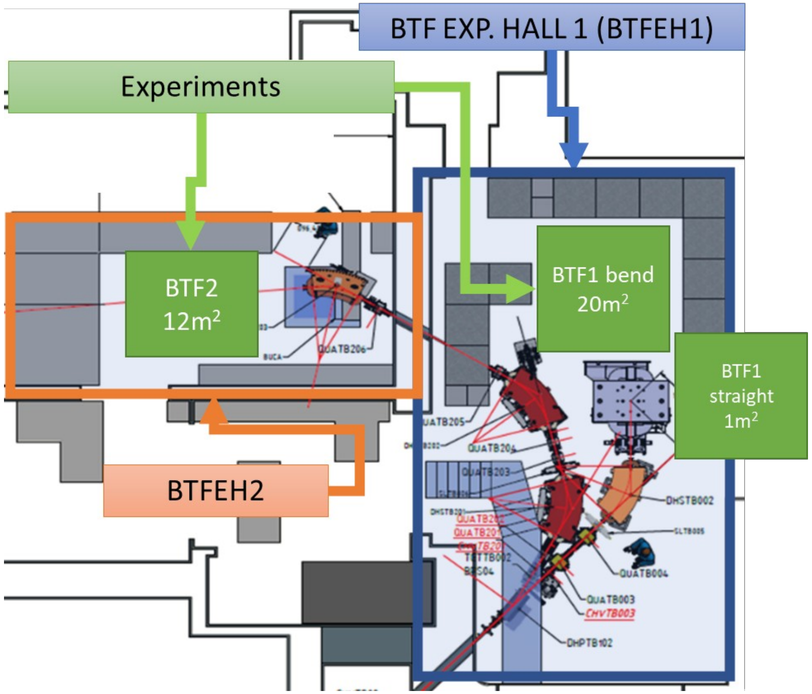
BTF Layout

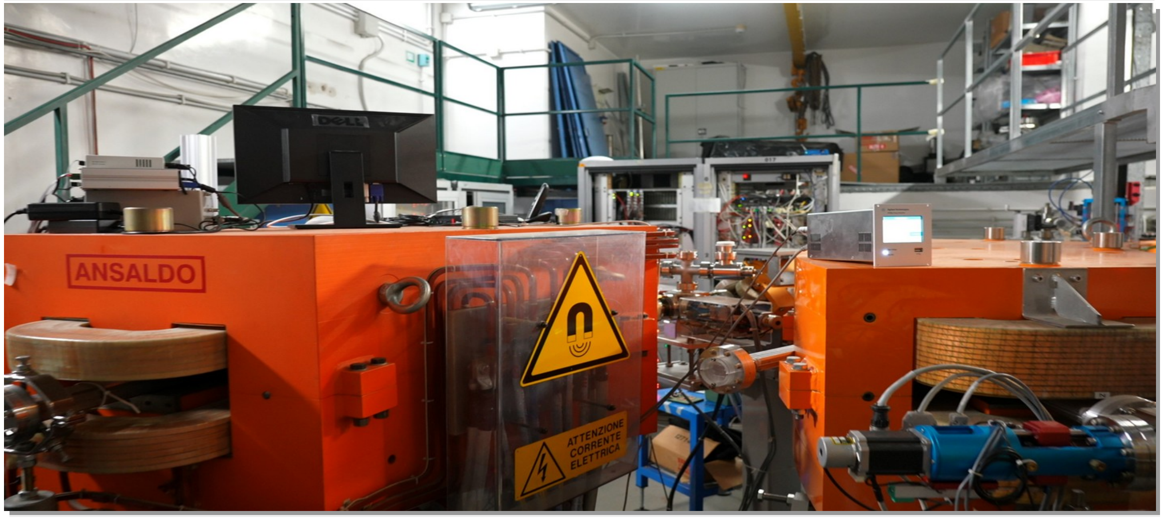

BTF EXP. HALL 1 (BTFEH1)
Experiments
BTF2
12m^2
BTF1 bend
20m^2
BTF1
straight
1m^2
BTFEH2
QUATB206
BUCA
UATB205
QUATB204
QUATB203
QUATB202
QUATB201
TGTTB002
DHSTB002
SLTB005
QUATB004
QUATB003
CHVTB003
DHPTB102



BTFEH1 – BTF1 (2 lines)

- Hall Operative devoted to PADME/X17 experiment (dark matter searches)
- Foreseen activity in 2024 Q4
- Straight Line used for irradiation with electron/positron using the full DAFNE LINAC power (10^{10} particle/pulse)
- Hall authorized for high dose experiments

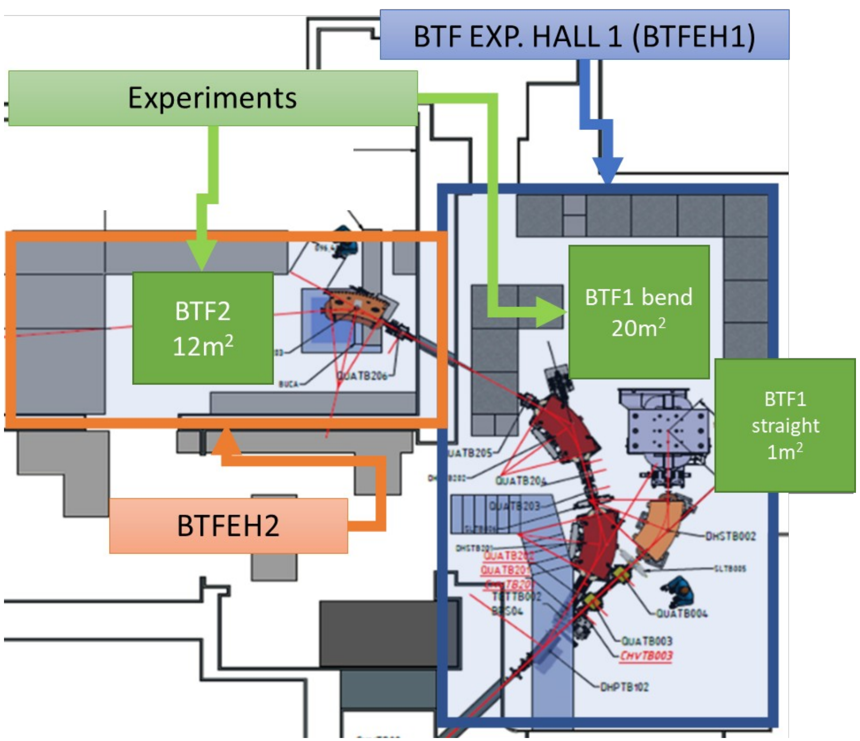




BTF Hall2

BTFEH2 – BTF2 (1 line)

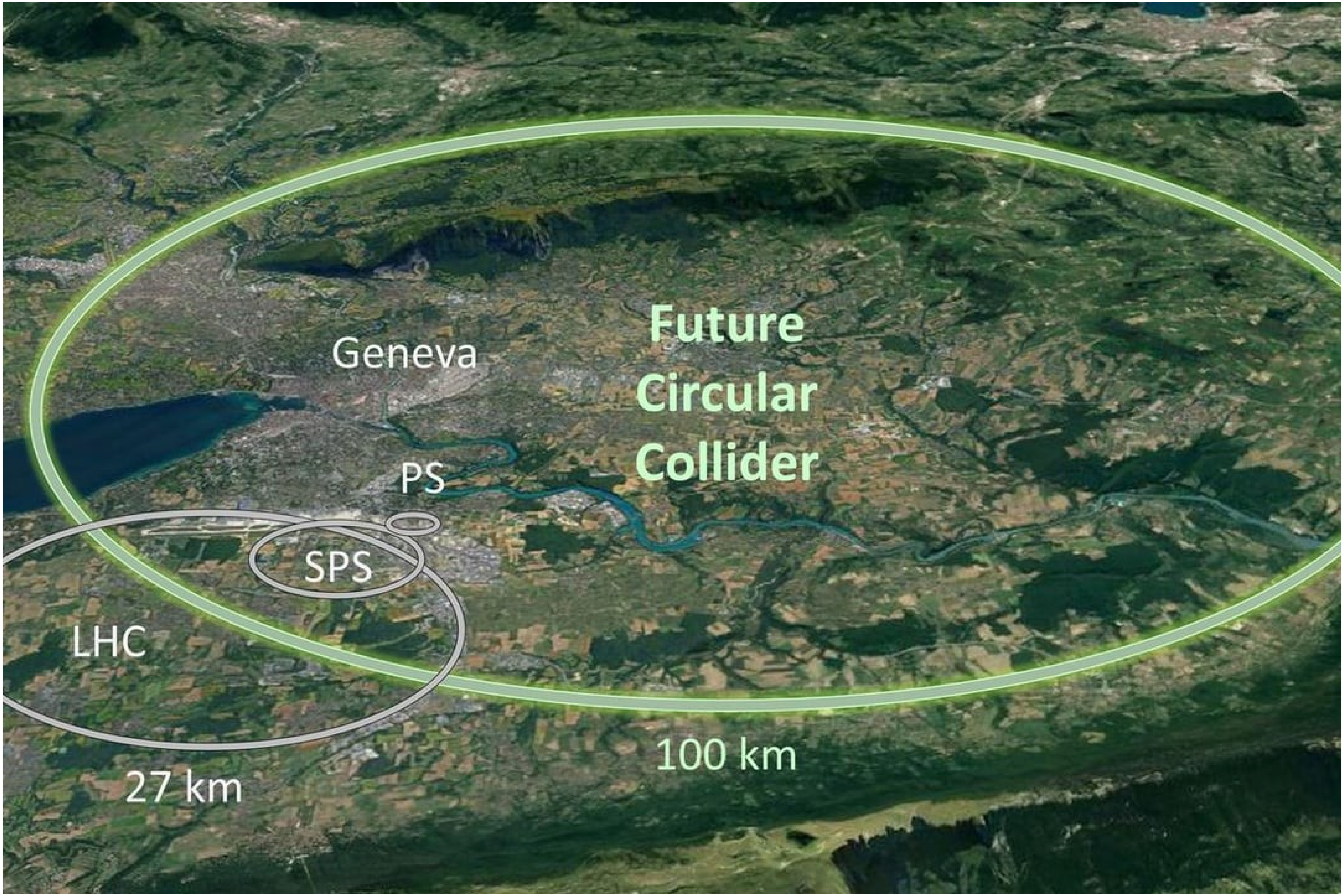
- Hall operative since 2022
- **BTF2 line to external users**
  - Weekly based user shifts
  - **Only secondary beam**
  - 0.4x0.4mm² at BTF2 Exit window
- Beamtime in 2024 till June



Beam Test Facility characteristics

Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle Type (Dependance)	e^+ / e^- (User)	e^+ / e^- (DAΦNE status)	e^+ / e^- (User)		e^+ / e^- (User)	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	167–700 (e-) 250–550 (e+)	25–500	25–700
Best Energy Resolution at the experiment	0.5% at 500 MeV	0.5%/1%	0.5%	Energy dependent	1% at 500 MeV	
Repetition rate (Hz)	Variable from 1 to 49 (DAΦNE status)		1–49 (User)		Variable from 1 to 49 (DAΦNE status)	1–49 (User)
Pulse length (ns)	10		1.5–320 (User)		10	Expected 10-100
Intensity (particle/bunch)	1–10^5 (Energy dependent)	1 to 10^7 / $1x10^{10}$	1–10^5 (Energy dependent)	1 to 10^{10}	1–10^4 (Energy dependent)	
Max int flux	$1x10^{10}$ part./s				$1x10^6$ part./s	
Beam waist size(mm)	0.5–55 X / 0.35–25 Y (vacuum window dependent)				0.4x0.4	
Divergence (mrad)	Down to 0.5				Down to 0.5	

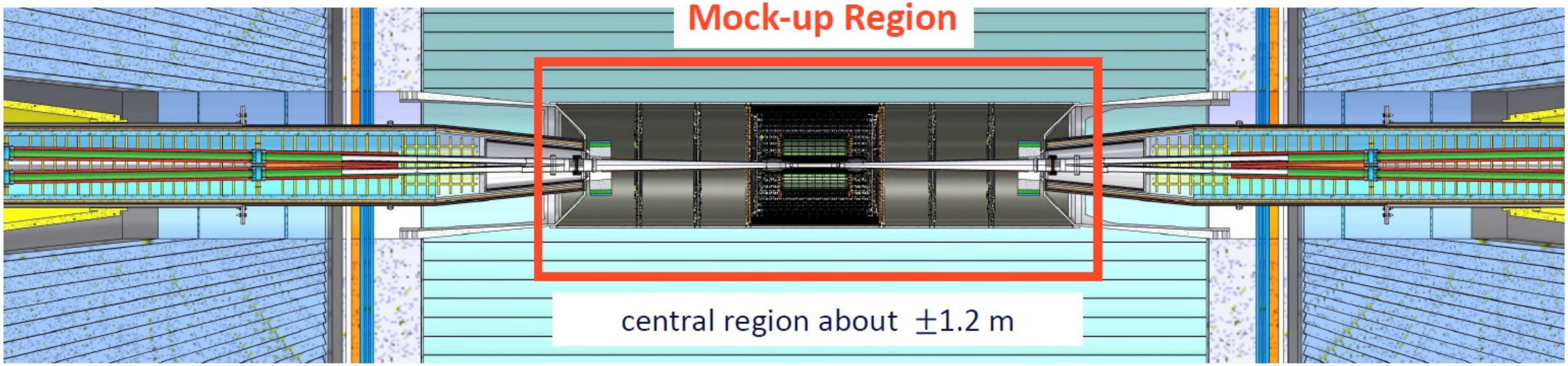
- Pulsed **electron** and **positron** beams (up to 49 pulses/second)
- Wide range: from 10^10 down to single particle per bunch, continuous energy selection
- Different ranges of parameters in respect of
  - selected hall,
  - primary o secondary beam
  - **running modes: time sharing and dedicated beam time**


Geneva
Future
Circular
Collider
PS
SPS
LHC
27 km
100 km

Italian participation to the FCC_ee study and LNF contribution

- Interaction region and Machine-Detector Interface **LNF**, Pisa, Perugia (FCCIS, AidaInnova)
- Collimation studies, CERN doctoral student & Sapienza /**LNF**
- Superconducting RF cavities, LNL (iFAST)
- Collective effects, INFN-Roma1, **LNF** (FCCIS)
- Hybrid crystal Positron source, INFN-Ferrara (PRIN)
- Beam dynamics e+ beamline from source to damping ring, INFN-Milano
- Bunch-by-bunch current control via Compton scattering, INFN-Milano
- Positron Damping Ring e+ and TL, **LNF** (CHART)
- High-field magnets for FCC-hh, [separate project and funding] INFN-Genova, INFN-Mi

FCC-ee Interaction Region



IR based on the crab-waist scheme, compact and crowded with tight constraints and many technical challenges → mockup needed for R&D and prove state-of-the-art technological solutions and test its feasibility

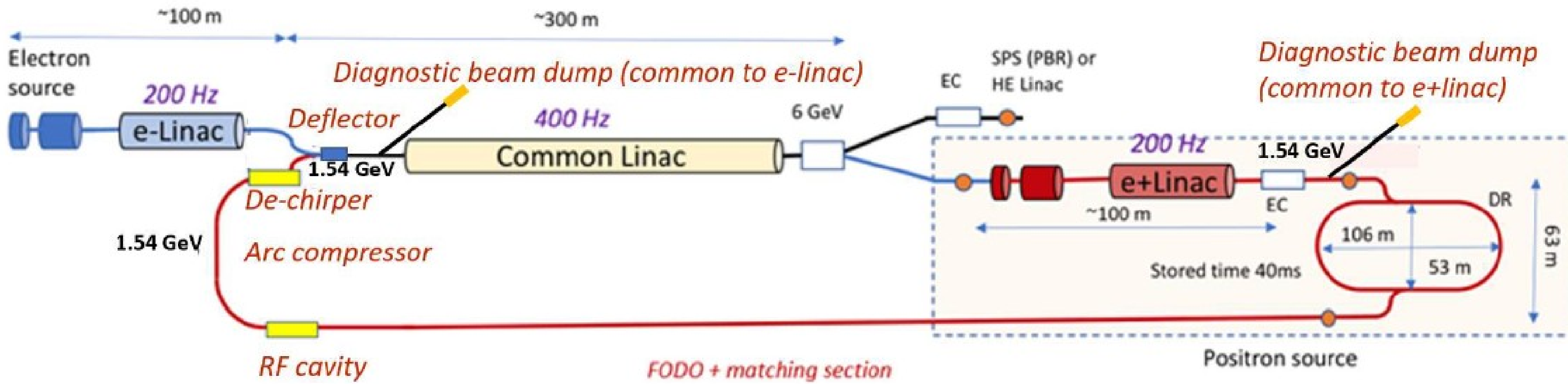
Approved project, will be built in Frascati in joint venture CERN-INFN. Addendum CERN-INFN signed by CD 26.01.2024

Relevant dates:

Starting date	1.11.2023
Delivery to INFN-LNF of the central AlBeMet chamber	30.11.2024
End date	31.12.2025

Dedicated talk:
A. Ciarma **- Overview of MDI challenging issues of circular colliders**
Thursday@9:30

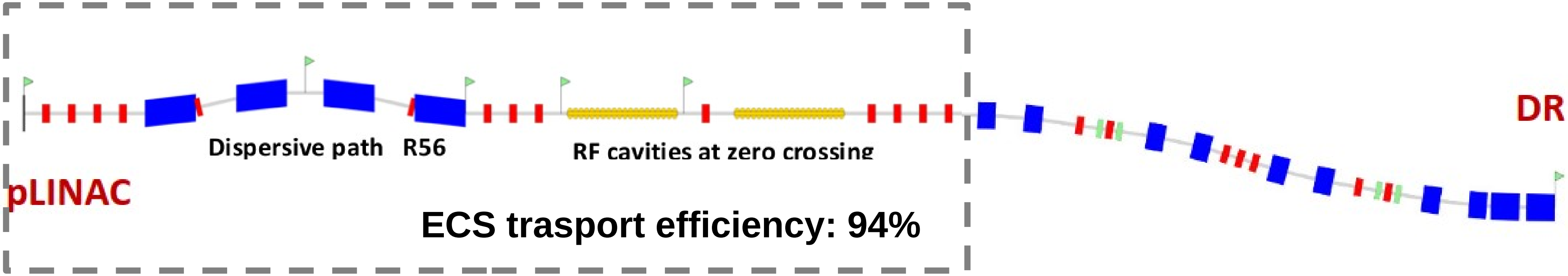
FCC_ee Injector complex: general layout



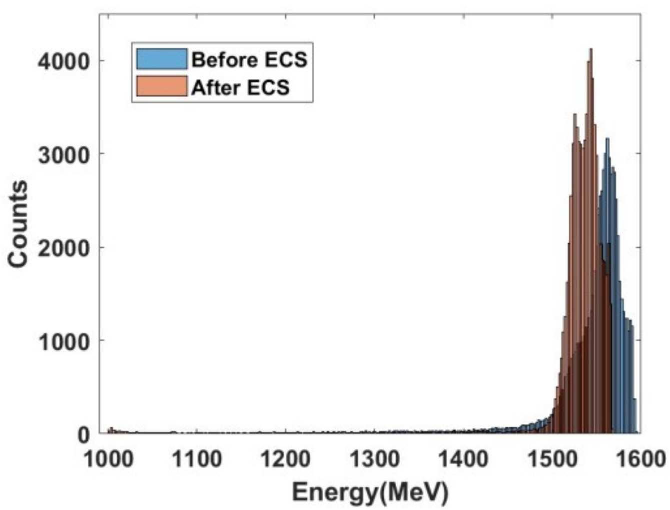
Project structure:

- **WP1/2**: Electron Source, Electron and Positron Linacs
- **WP3:** Positron Source: Target and Capture System
- **WP4: Damping Ring and Transfer Lines (LNF)**
- **WP6:** PSI Positron Production (P3) Project

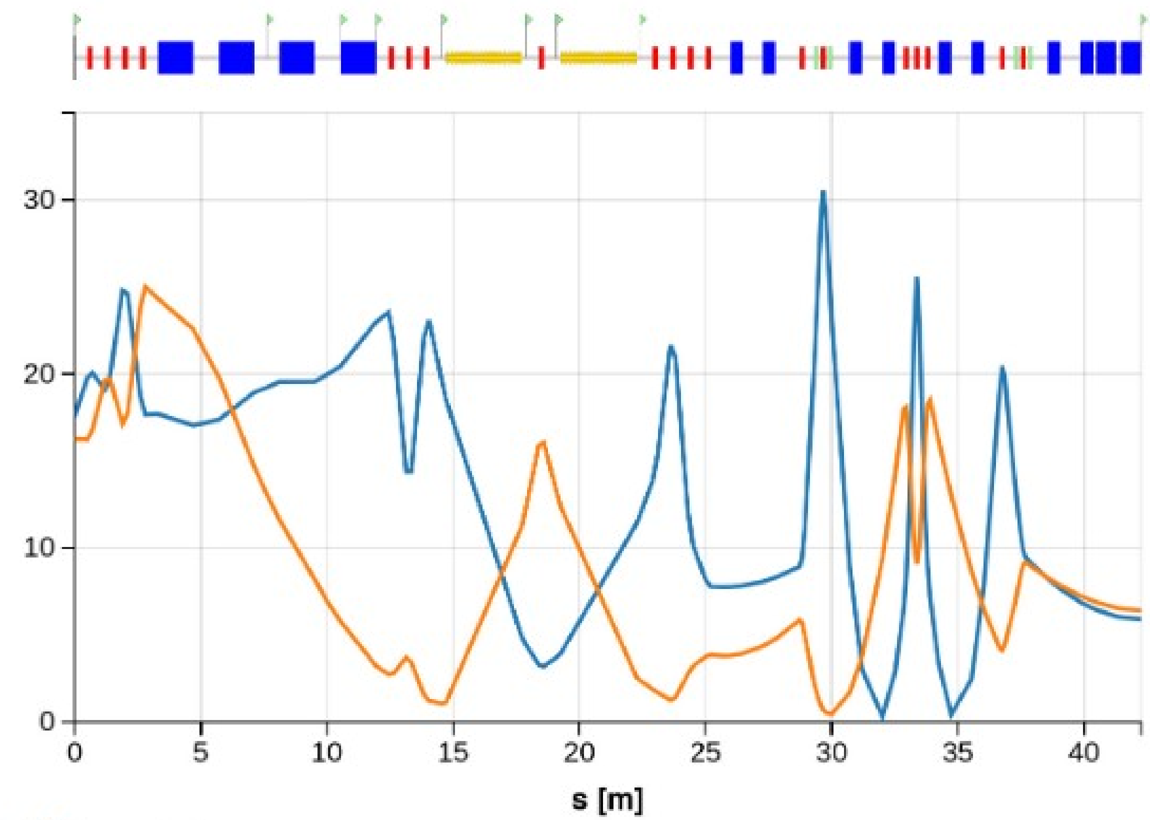
FCC_ee Injector: transfer line from LINAC to DR



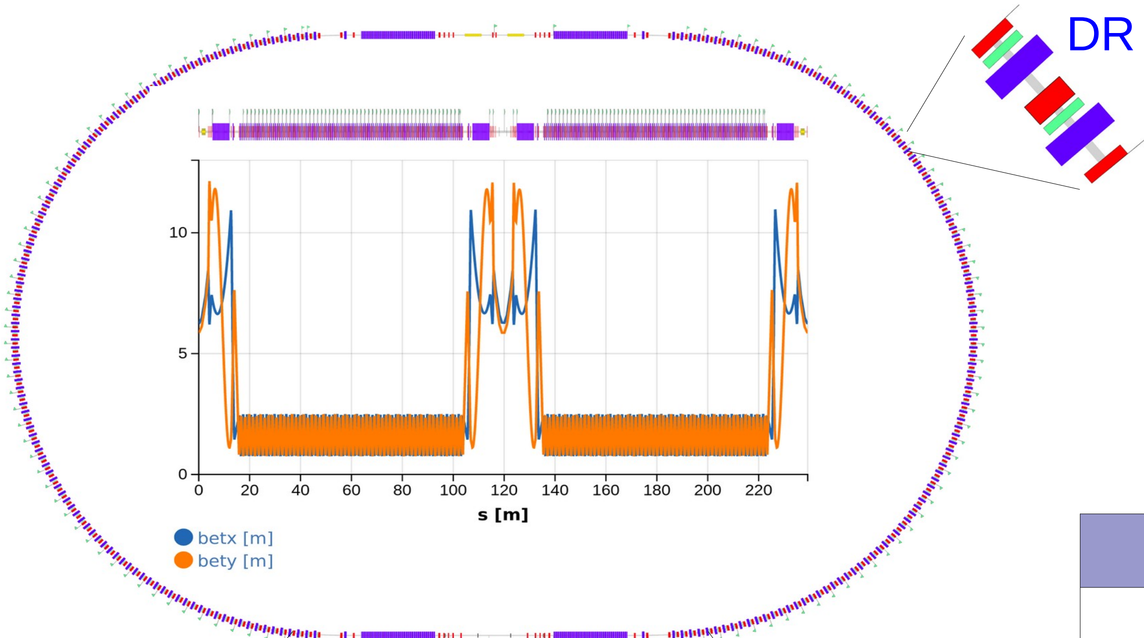
Parameters	Value	Unit
Dipole Bending angle	0.2256 (12.9)	rad (deg)
Dipole Magnetic length	1.395	m
Distance between dipoles	1	m
R56	0.205	m
Max dispersion	0.56	m
Number of Cavities	2	
RF frequency	2	GHz
Accelerating Gradient	20	MV/m
Accelerating Voltage	99	MV



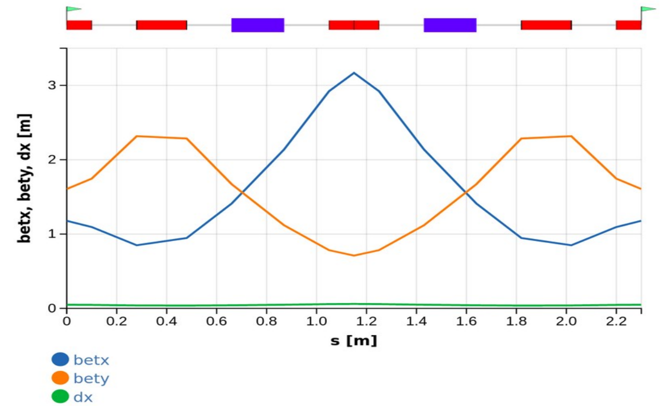
Tlp from LINAC to Damping Ring



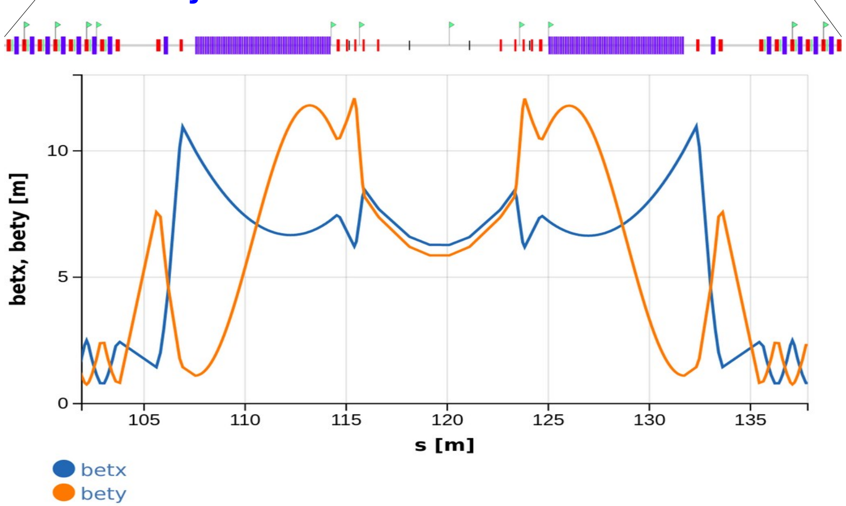
FCC_ee@LNF: Damping ring



DR DBA Cell



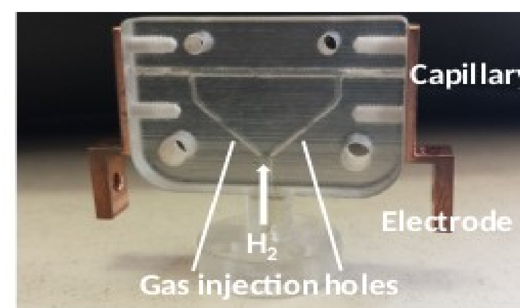
Injection section



Parameter	FCC_ee DR
Circumference	**239.2 m**
Harmonic number	**319**
Eq. Emittance (x/y/z)	**1.01 nm/ - / 1.46 μm**
Dipole length, Field	**0.21 m, 0.66 T**
Wiggler #,Lenght, Field	**4, 6.64 m, 1.8 T**
Cavity #, Lenght, Voltage	**2, 1.5 m, 4 MV**
Bunch stored #, charge	**18 , 4.0 nC**
Damping Time (x/y/z)	**10.8 / 10.8 / 5.4 ms**
Store Time	**42.5 ms**
Energy loss per turn	**0.227 MV**
SR Power Loss (WGL)	**15.7 kW**

EuPRAXIA

Credit: INFN and Mythos – consorzio stabile s.c.a.r.l.



EuPRAXIA network

European Plasma Research Accelerator With Excellence In Applications

“the first European project that develops a dedicated particle accelerator research infrastructure based on novel plasma acceleration concepts and laser technology”

- *Building a facility with very high field plasma accelerators, driven by lasers or beams*
- *1 – 100 GV/m accelerating field*
- *Shrink down the facility size*

- *Provide a practical path to more research facilities and ultimately to higher energies for the same investment in terms of size and costs*
- *Enable frontier science in new regions and parameter regimes*


FEATURE EuPRAXIA

Surf's up *Simulation of electron-driven plasma wakefield acceleration, showing the drive electron beam (orange/purple), the plasma electron wake (grey) and wakefield-ionised electrons forming a witness beam (orange).*

EUROPE TARGETS A USER FACILITY FOR PLASMA ACCELERATION

Ralph Assmann, Massimo Ferrario and Carsten Welsch describe the status of the ESFRI project EuPRAXIA, which aims to develop the first dedicated research infrastructure based on novel plasma-acceleration concepts.

Energetic beams of particles are used to explore the fundamental forces of nature, produce known and unknown particles such as the Higgs boson at the LHC, and generate new forms of matter, for example at the future FAIR facility. Photon science also relies on particle beams: electron beams that emit pulses of intense synchrotron light, including soft and hard X-rays, in either circular or linear machines. Such light sources enable time-resolved measurements of biological, chemical and physical structures on the molecular down to the atomic scale, allowing a diverse global community of users to investigate systems ranging from viruses and bacteria to materials science, planetary science, environmental science, nanotechnology and archaeology. Last but not least, particle beams for industry and health support many societal applications ranging from the X-ray inspection of cargo containers to food sterilisation, and from chip manufacturing to cancer therapy.

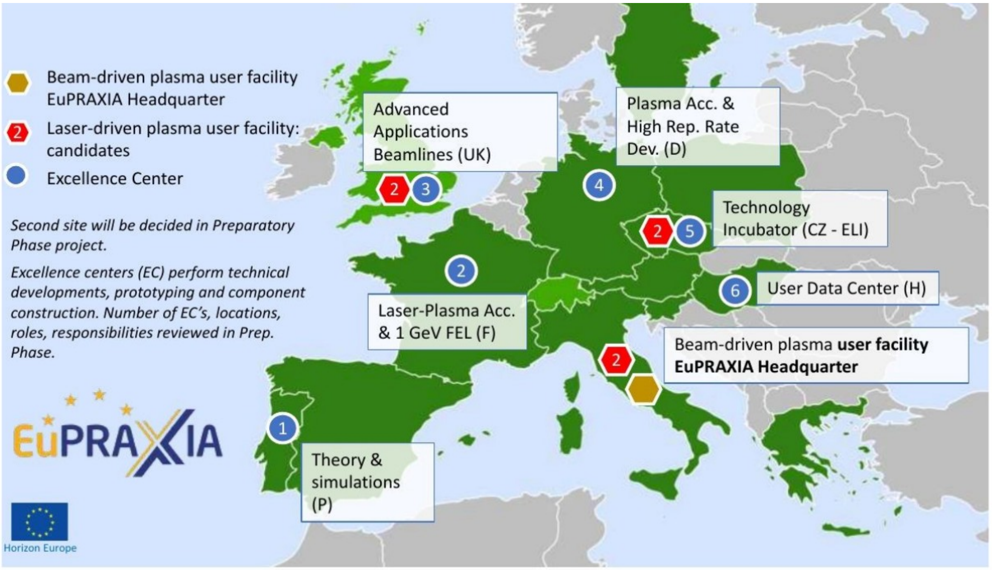
This scientific success story has been made possible through a continuous cycle of innovation in the physics and technology of particle accelerators, driven for many decades by exploratory research in nuclear and particle physics. The invention of radio-frequency (RF) technology in the 1920s opened the path to an energy gain of several tens of MeV per metre. Very-high-energy accelerators were constructed with RF technology, entering the GeV and finally the TeV energy scales at the Tevatron and the LHC. New collision schemes were developed, for example the mini “beta squeeze” in the 1970s, advancing luminosity and collision rates by orders of magnitudes. The invention of stochastic cooling at CERN enabled the discovery of the W and Z bosons 40 years ago.

However, intrinsic technological and conceptual limits mean that the size and cost of RF-based particle accelerators are increasing as researchers seek higher beam energies. Colliders for particle physics have reached a

THE AUTHORS
Ralph Assmann *DESY and INFN,* **Massimo Ferrario** *INFN,* **Carsten Welsch** *University of Liverpool/INFN.*

CERN COURIER MAY/JUNE 2023 25

https://cerncourier.com/a/europe-targets-a-user-facility-for-plasma-acceleration/

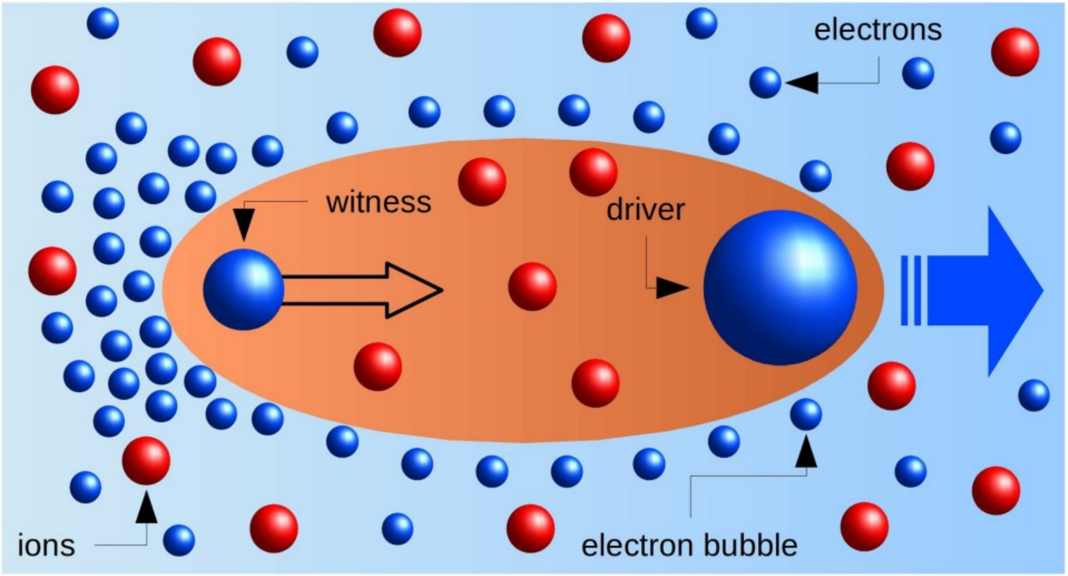


Two **EuPRAXIA** pillars at **LNF**:

1) **EuPRAXIA@SPARC_LAB**
   Plasma acceleration stage
   X-Band LINAC
   Two FEL (4-10 nm e 50-180 nm)

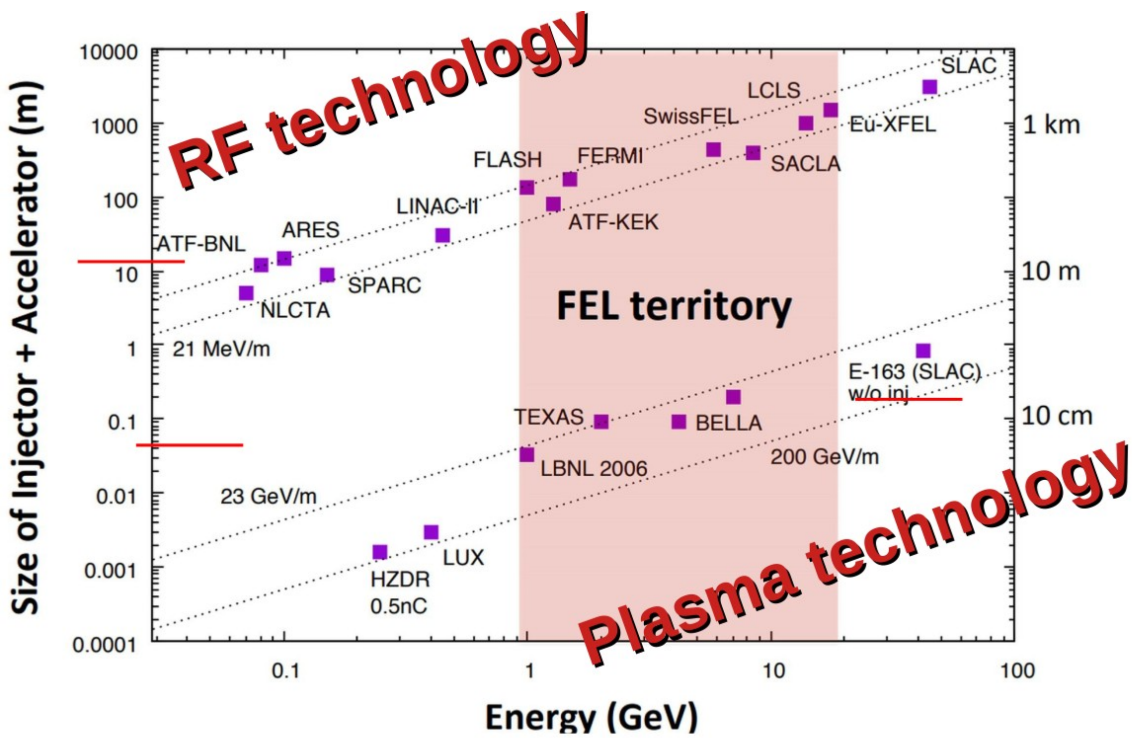
2) EuAPS (Advanced Photon Sources)
   a fast, cheap and compact X-ray source

Plasma acceleration



$$E_0 = \frac{m_e c \omega_p}{e} \simeq 96\sqrt{n_0(cm^{-3})}$$

$$\rightarrow E_0 \approx 10 \frac{GV}{m} @ n_0 = 10^{16}\, cm^{-3}$$



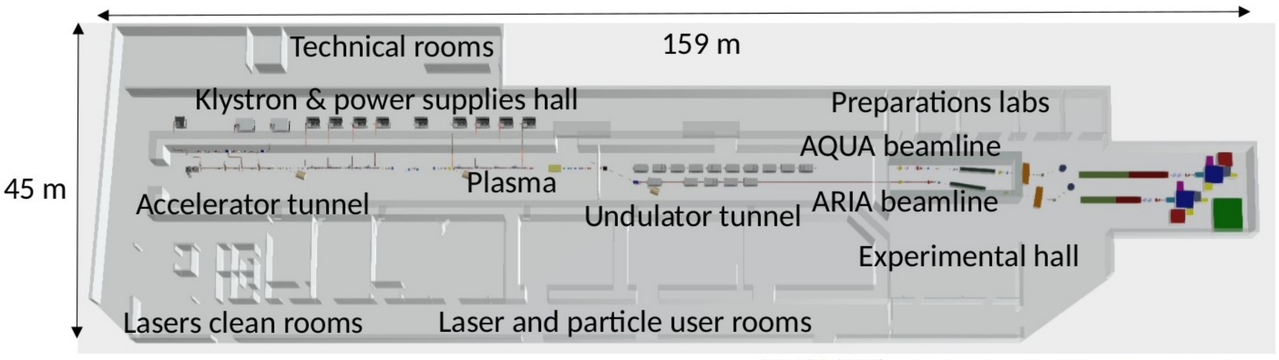
The **driver** creates the positive sphere (or ***bubble***). It can be a

- *particle bunch (PWFA)*
- *laser pulse (LWFA)*

The **witness** can be

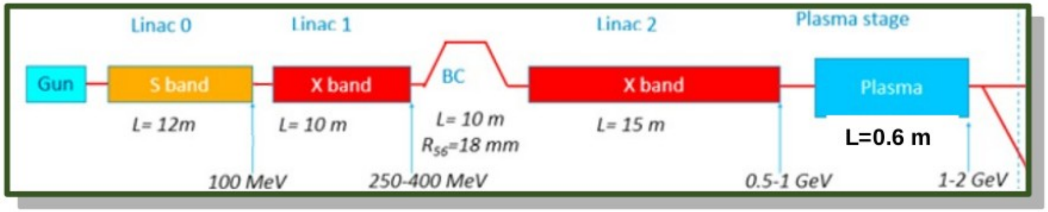
- *Self-injected*
- *Externally injected*

EuPRAXIA@SPARC_LAB layout



Credit: INFN and Mythos – consorzio stabile s.c.a.r.l.

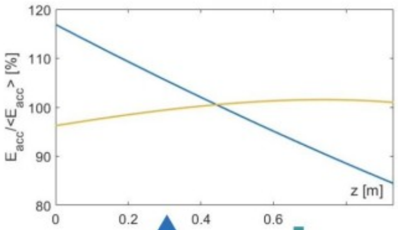
Parameter	Unit	PWFA	X-band
Electron Energy	GeV	1-1.2	1
Bunch Charge	pC	**30-50**	**200-500**
Peak Current	kA	1-2	1-2
RMS Energy Spread	%	0.1	0.1
RMS Bunch Length	μm	**6-3**	**24-20**
RMS norm Emittance	μm	1	1
Slice Energy Spread	%	≤0.05	≤0.05
Slice norm Emittance	um	0.5	0.5

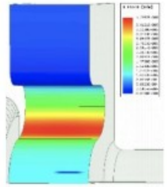


Two different configurations:

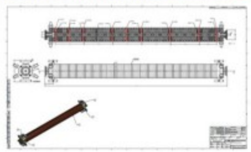
- 500 MeV beam from the X-band linac + 500 MeV from the compact plasma module
  - *Smaller accelerated charge*
  - *Shorter pulses*
  - *Final energy easily upgradable (up to 5 GeV) with similar building occupancy*
- 1 GeV beam from the X-band linac alone (requires additional RF power)
  - *Larger charge per bunch*
  - *Longer pulses*
  - *It exploits the largest RF field achievable with X-band technology*

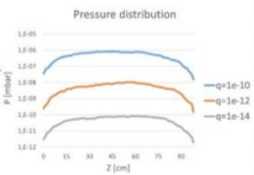
X-band LINAC, tests @ TEX

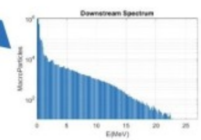




1. **E.m. design**: *done*
2. **Thermo-mechanical analysis**: *done*
3. **Mechanical design**: *done*
4. **Vacuum calculations**: *done*
5. **Dark current simulations**: *done*
6. **Waveguide distribution simulation with attenuation calculations**: *done*





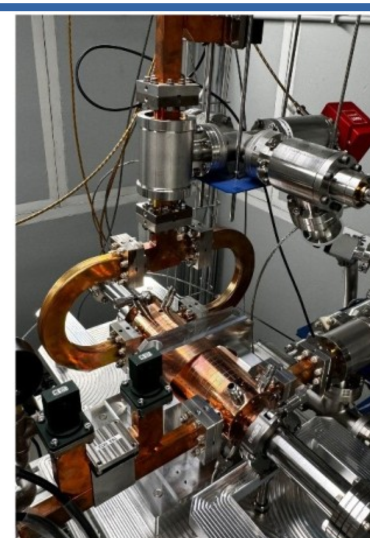


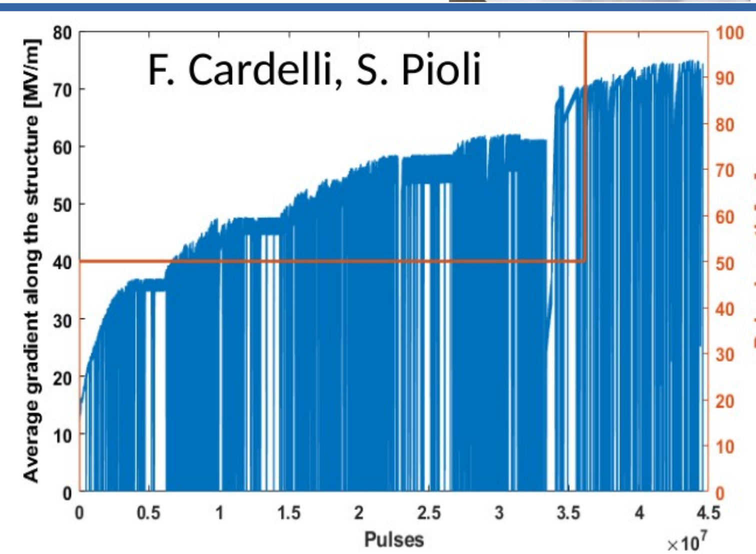
PARAMETER	Value: with linear tapering	Value: w/o tapering
Frequency [GHz]	11.9942	
Average acc. gradient [MV/m]	**60**	
Structures per module	2	
Iris radius a [mm]	**3.85-3.15**	**3.5**
Tapering angle [deg]	0.04	0
Struct. length L_s act. Length (flange-to-flange) [m]	**0.94 (1.05)**	
No. of cells	112	
Shunt impedance R [MΩ/m]	93-107	100
Effective shunt Imp. $R_{sh\ eff}$ [MΩ/m]	350	347
Peak input power per structure [MW]	70	
Input power averaged over the pulse [MW]	51	
Average dissipated power [kW]	1	
P_{out}/P_{in} [%]	25	
Filling time [ns]	130	
Peak Modified Poynting Vector [W/μm²]	3.6	4.3
Peak surface electric field [MV/m]	160	190
Unloaded SLED/BOC Q-factor Q_0	150000	
External SLED/BOC Q-factor Q_E	21300	20700
Required Kly power per module [MW]	**20**	
RF pulse [μs]	**1.5**	
Rep. Rate [Hz]	**100**	

D. Alesini, F. Cardelli

First EuPRAXIA@SPARC_LAB X-band structure prototype at TEX Facility

- RF prototype 20 cells, constant impedance
- Input pulse of 35 MW, 100 ns, 50 Hz repetition rate
- **Average gradient 74 MV/m and**
- **Peak gradient 80 MV/m**



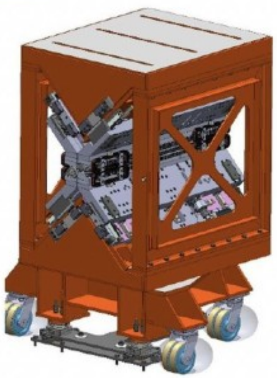


FEL beamlines

Two FEL lines:

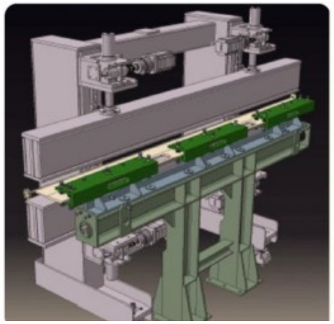
L. Giannessi

1) *AQUA*: Soft-X ray SASE FEL – Water window optimized for 4 nm (baseline)

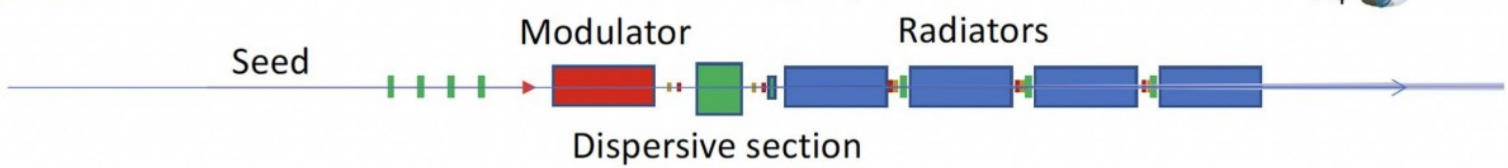


SASE FEL: 10 UM Modules, 2 m each – 60 cm intraundulator sections.
Two technologies under study: Apple-X PMU (baseline) and planar SCU.
Prototyping in progress

FERMI FEL-1 Radiator

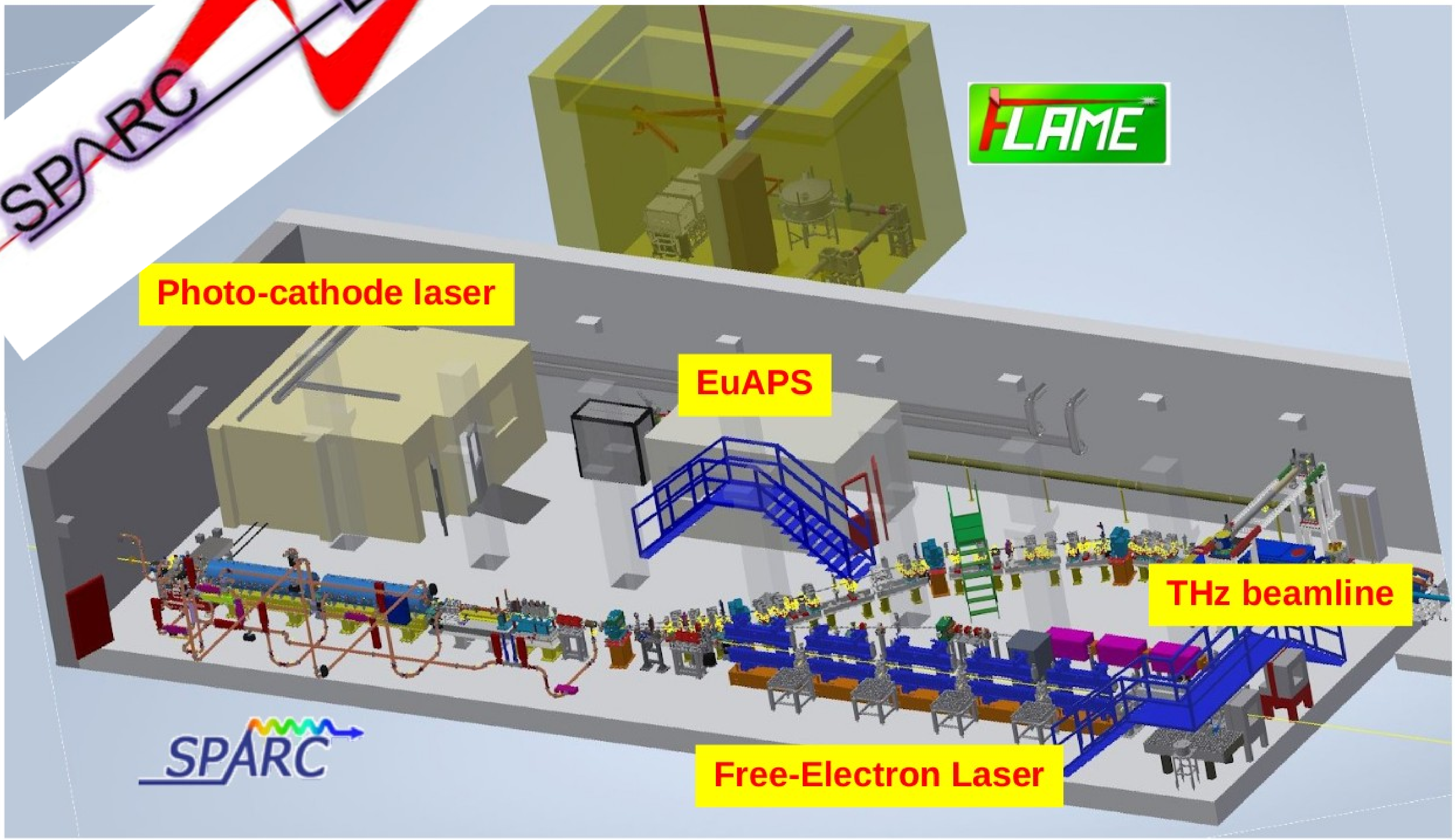


2) *ARIA*: VUV seeded HGHG FEL beamline for gas phase



SEEDED FEL – Modulator 3 m + 4 Radiators APPLE II – variable pol. 2.2 m each – SEEDED in the range 290 – 430 nm (see former presentation to the committee and *Villa et al. ARIA—A VUV Beamline for EuPRAXIA@SPARC_LAB. Condens. Matter 2022, 7, 11.*) – Undulator based on consolidated technology.

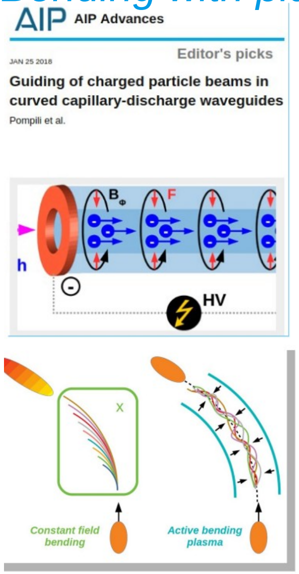
Parameter	Unit	AQUA PWFA	AQUA X-band	ARIA PWFA	ARIA X-band
Radiation Wavelength	*nm*	3-10	4-10	50-180	50-180
Photons per Pulse	$\times 10^{12}$	0.25-1	0.25-1	10-60	12-150
Photon Bandwith	*%*	0.3	0.3	3	0.05
Configuration		SASE		HGHG seeding	

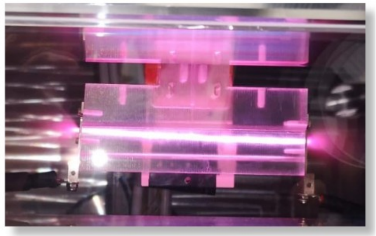


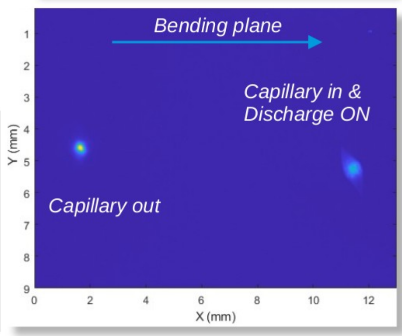
Ferrario, M., et al. "SPARC_LAB present and future." NIMB 309 (2013): 183-188.

SPARCLab Milestones

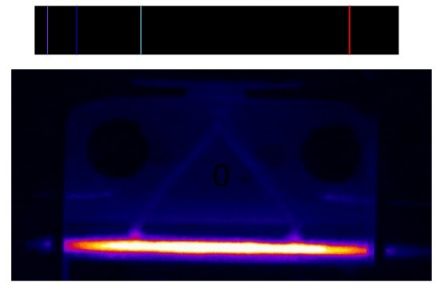
Bending with plasma





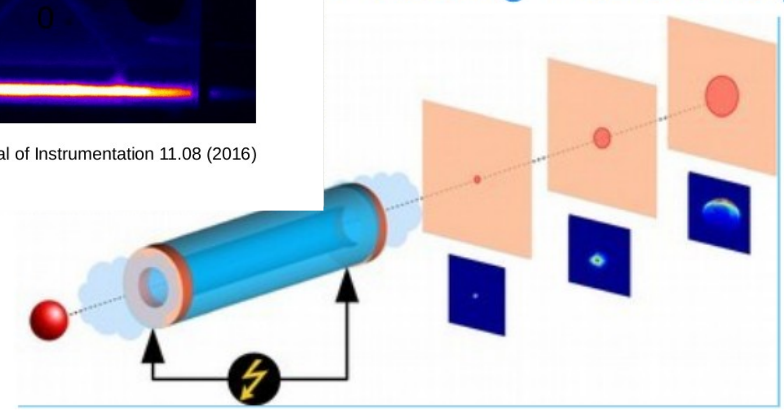


Plasma characterization



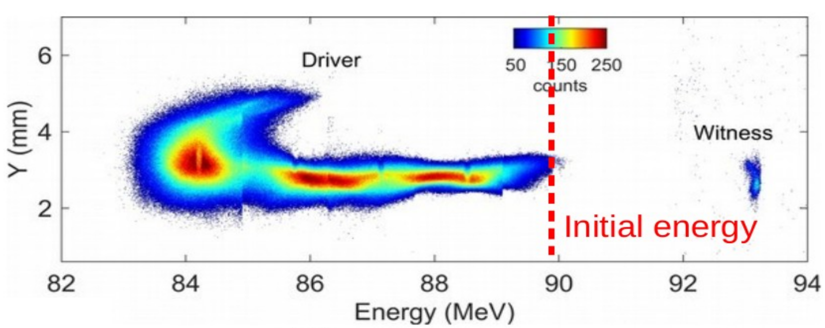
Biagioni, A., et al., Journal of Instrumentation 11.08 (2016)

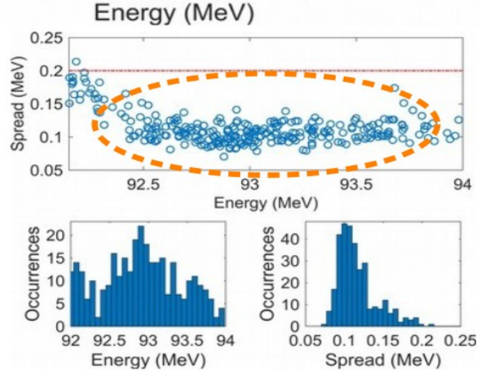
Focusing with active-plasma lenses



Pompili, R., et al., Physical review letters 121.17 (2018): 174801.

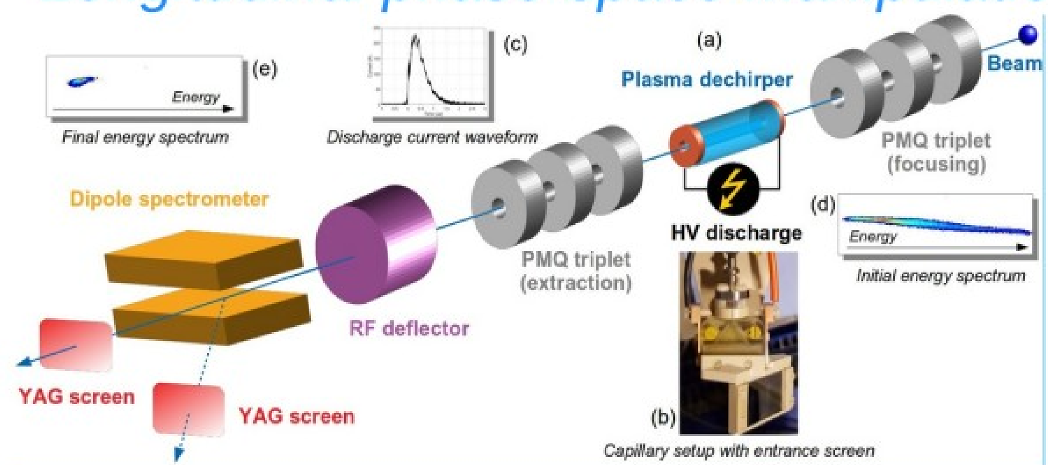
Energy spread control





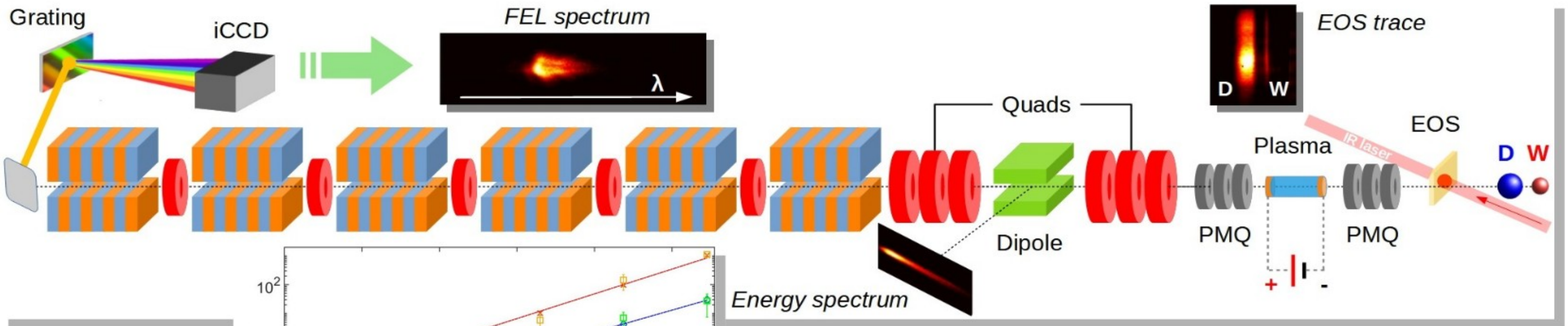
Pompili,R., et al, Nature Physics 17,499 (2021)

Longitudinal phase-space manipulation

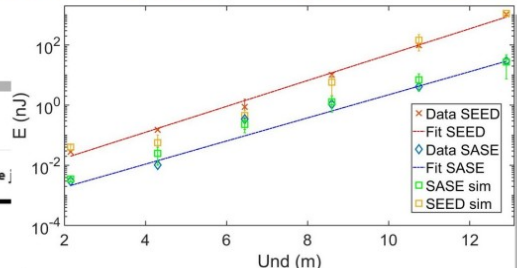


V. Shpakov et al. Phys. Rev. Lett. 122, 114801 (2019)

SPARCLab Milestones



First FEL with PWFA

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Article | Published: 25 May 2022

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R. Pompili, D. Alesini, ... M. Ferrario + Show authors

Nature **605**, 659–662 (2022) | Cite this article


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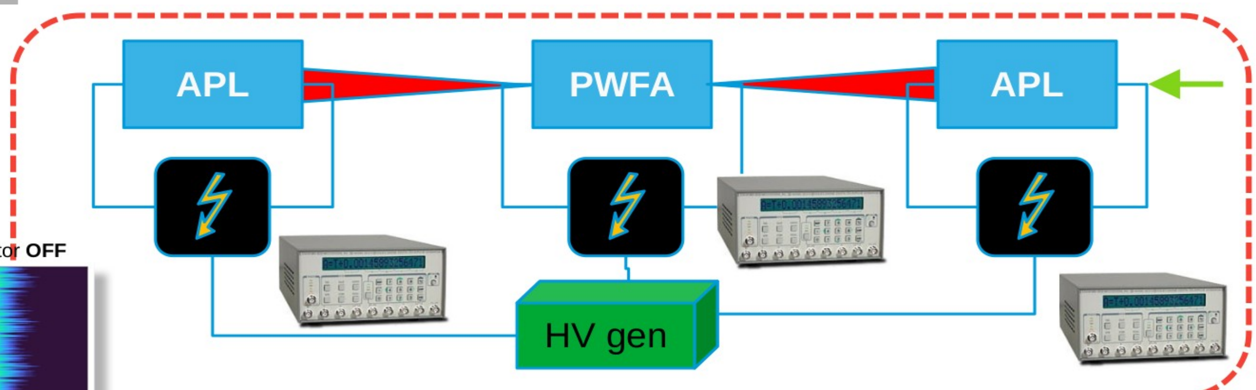
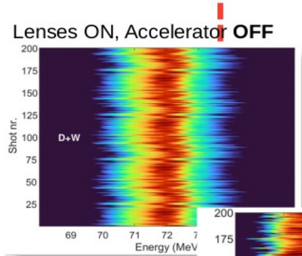
Stable Operation of a Free-Electron Laser Driven by a Plasma Accelerator

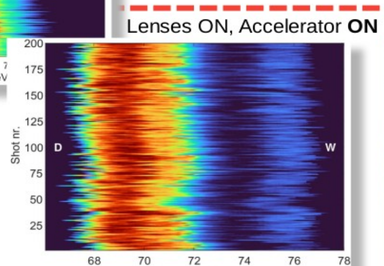
M. Galletti *et al.*

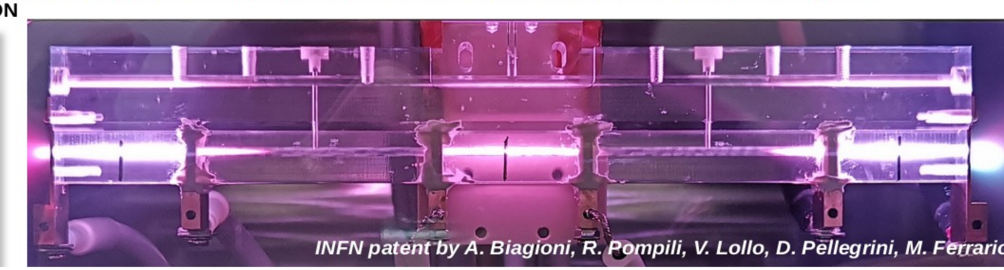
Phys. Rev. Lett. **129**, 234801 – Published 29 November 2022



"All-in-one" capillary







SPARCLab upgrade under SABINA project

SOURCE OF ADVANCED BEAM IMAGING FOR NOVEL APPLICATIONS

BANDO: INFRASTRUTTURE DI RICERCA PNIR
POR-FESR 2014-2020

- Goals:
  - ✓ SPARC technical plants consolidation aimed at doubling the uptime (from ≈1200 to ≈2400 h/y)
  - ✓ New instrumentation (photoinjector, beam transport, diagnostics,…)
  - ✓ Set up of 2 new user facilities:
    1. THz: spectroscopic analysis (single point or imaging), also at cryogenic temperatures
    2. FLAME: surface coating tests (at green and IR wavelengths), vacuum tests

LNF Accelerator activities: Conclusions

CERN
Geneva

FCC_ee MDI
FCC_ee Injector

Numerous and diversified activity

Excellent technical support

Multi-disciplinary

Maintaining expertise in colliders

Large collaborations

Growing expertise in <u>plasma acceleration</u> and light source

IFIN-HH
Magurele

SSRIP

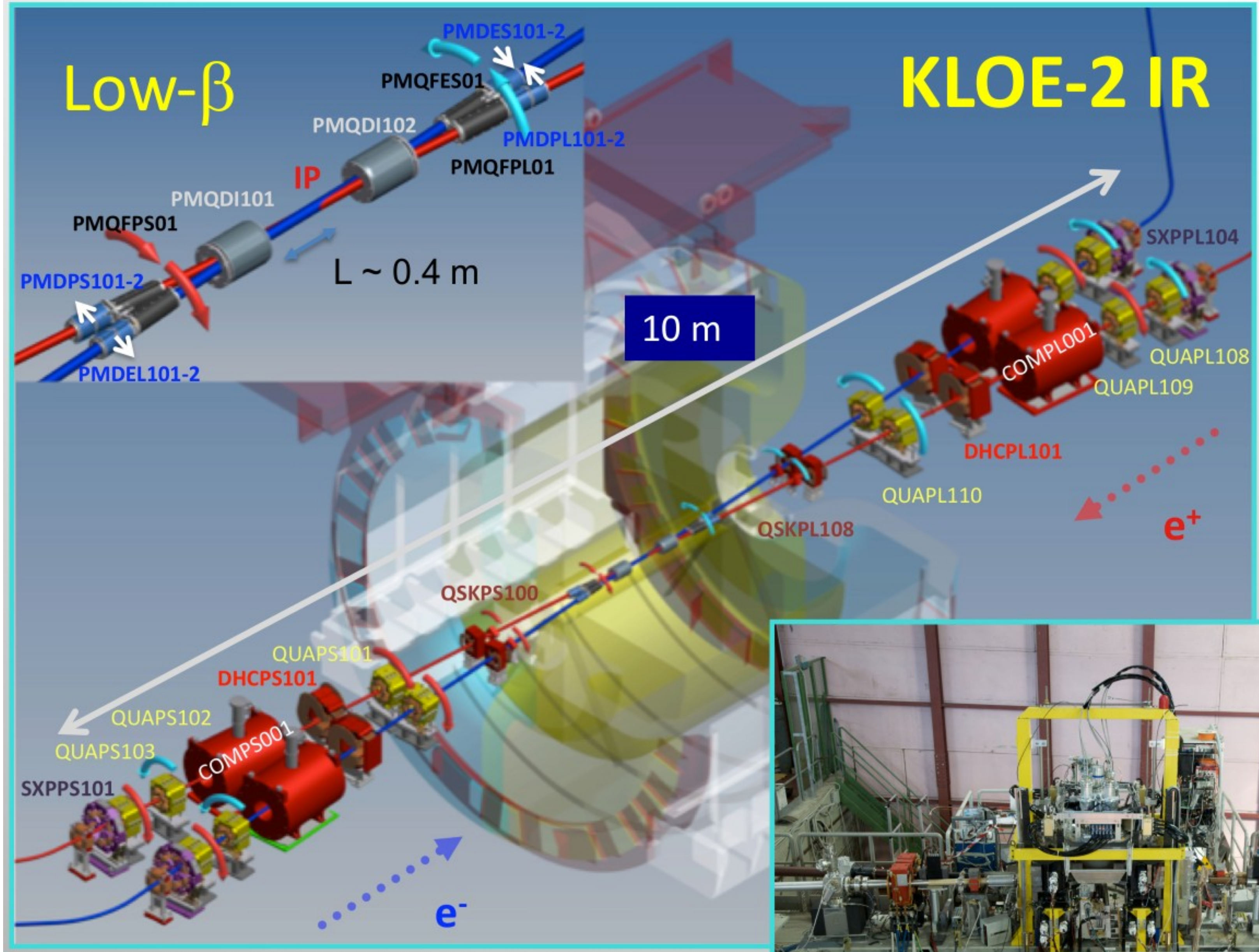
Scalable Source
Radio Isotope
Production

STAR2_TT

UniCal
Rende

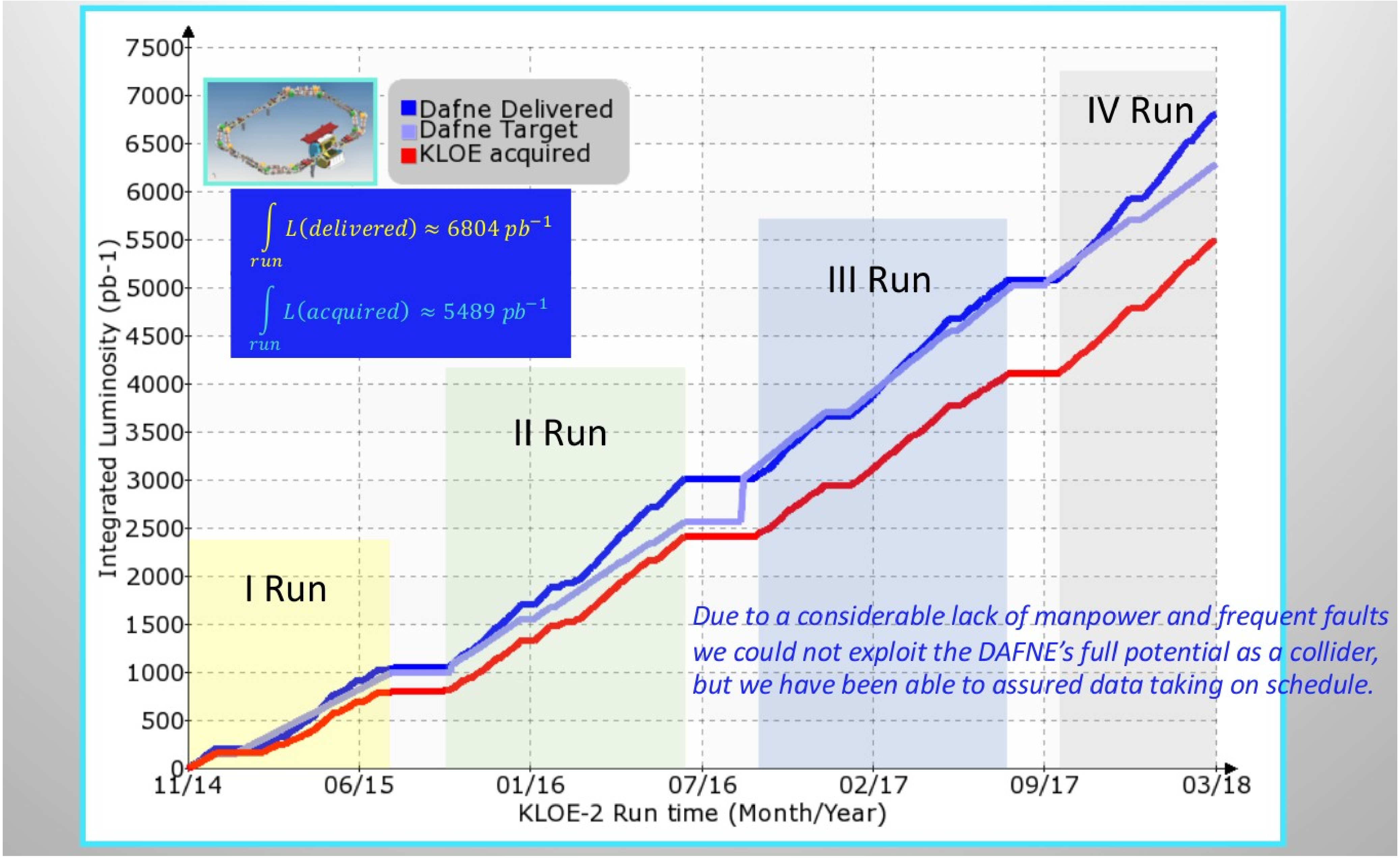
SPARE SLIDES

KLOE-2 Interaction region



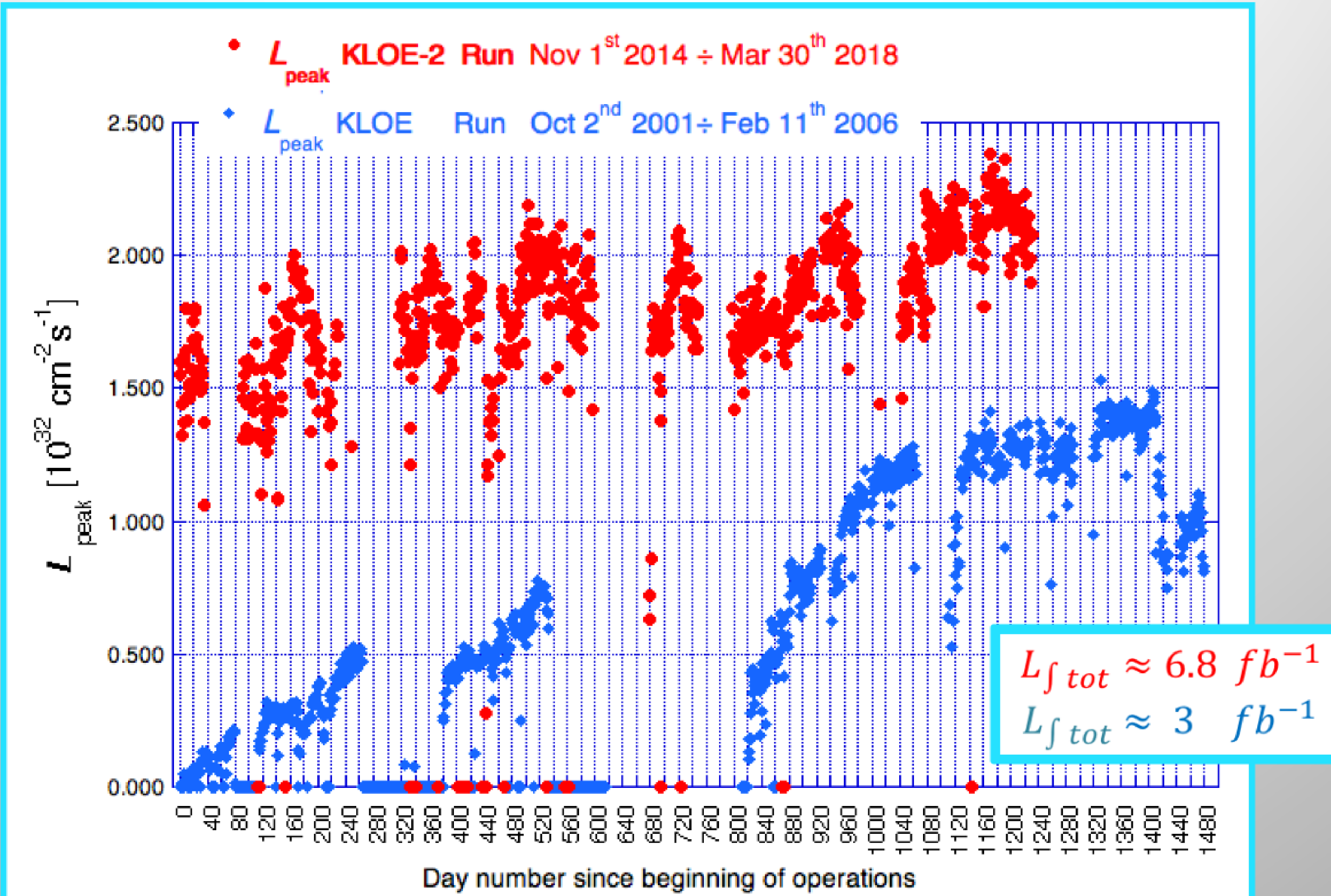
C. Milardi *et al 2012 JINST 7 T03002.*

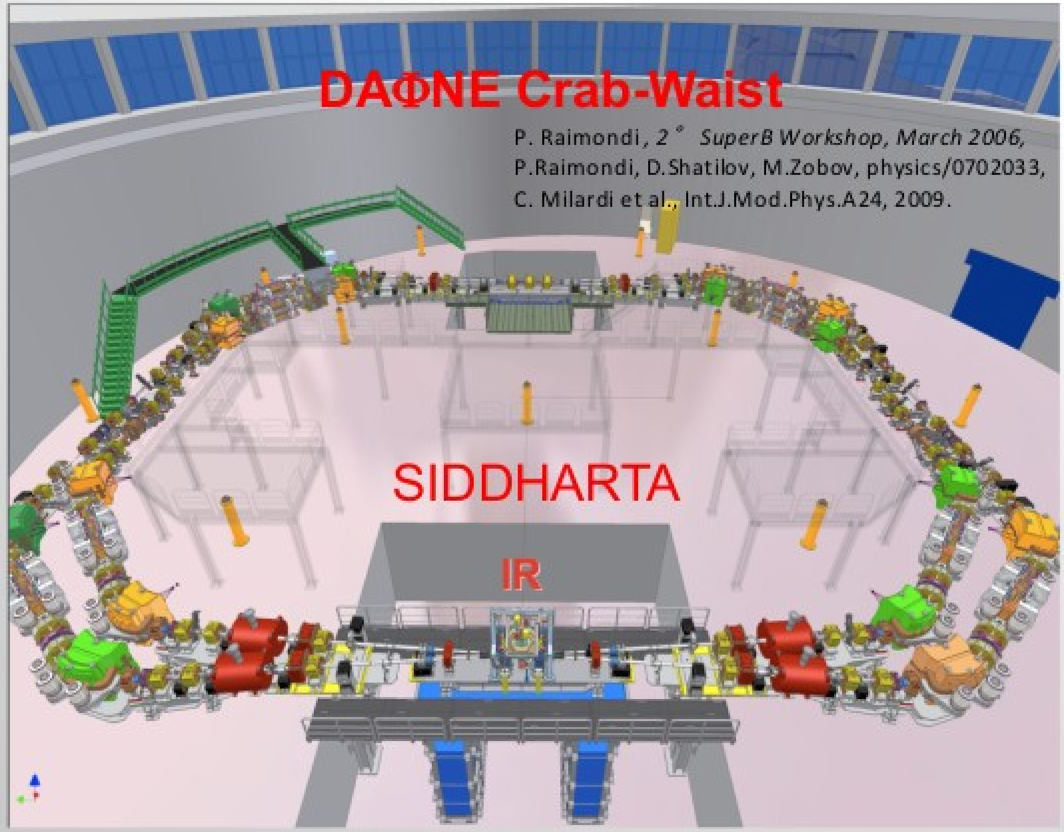
KLOE-2 Run (2014-2018)



Crab-Waist luminosity gain

Crab-Waist provides a 59% increase in terms of peak luminosity as evidenced by data taken by the same detector with the same accuracy





	DAΦNE native	DAΦNE *Crab-Waist*
Energy (MeV)	510	510
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm•mrad)	0.34	0.28
β_x^* (cm)	160	23
σ_x^* (mm)	0.70	0.25
$\Phi_{Piwinski}$	0.6	1.5
β_y^* (cm)	1.80	0.85
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
Bunch spacing (ns)	2.7	2.7
I_{bunch} (mA)	13	13
σ_z (mm)	25	15
N_b	120	120

- Large Piwinski angle and Crab-Waist scheme provided:
  - optimal control of the beam-beam interaction
  - a factor 3 higher L_{peak}
  - complete elimination of the LRBB

$L_{peak} = 4.5 \cdot 10^{32}\ cm^{-2} s^{-1}$

$L_{\int 1\,day} = 15.0\ pb^{-1}$

$L_{\int 1\,hour} = 1.033\ pb^{-1}$ *(test run)*

$L_{\int run} \sim 2.8\ fb^{-1}$ *(logged by the experiment)*

M. Zobov et al., Phys.Rev.Lett.104:174801, 2010.

DAFNE most noticeable features	*Original contributions to the circular collider physics*
1. Highest luminosity @ Φ energy **$4{,}5 \cdot 10^{32}$ $cm^{-2}s^{-1}$** 2. High intensity of colliding beams (maximum currents 2.5A e-, 1.4A e+) 3. Long damping time (110.000 turns) 4. Shortest bunch separation (2.7 ns) 5. Complicated aluminium vacuum chamber (impedance, eCloud) 6. Very nonlinear optics (short magnets with large apertures, wiggler nonlinearities, crosstalk between the two rings) 7. …	1. Low impedance vacuum chamber components (in use) 2. Sofisticated feedback systems (in use, in constant evolution) 3. Wigglers with «wiggling» poles (in use) 4. Parasitic crossings compensation with wires (used for FINUDA, KLOE) 5. Collisions with negative momentum compaction factor (tested experimentally) 6. e-Cloud clearing electrodes (were using) 7. Collisions with a very high crossing angle (proposal) 8. Strong RF focusing (proposal) **9. Crab Waist collision scheme** (in operation) 10. …

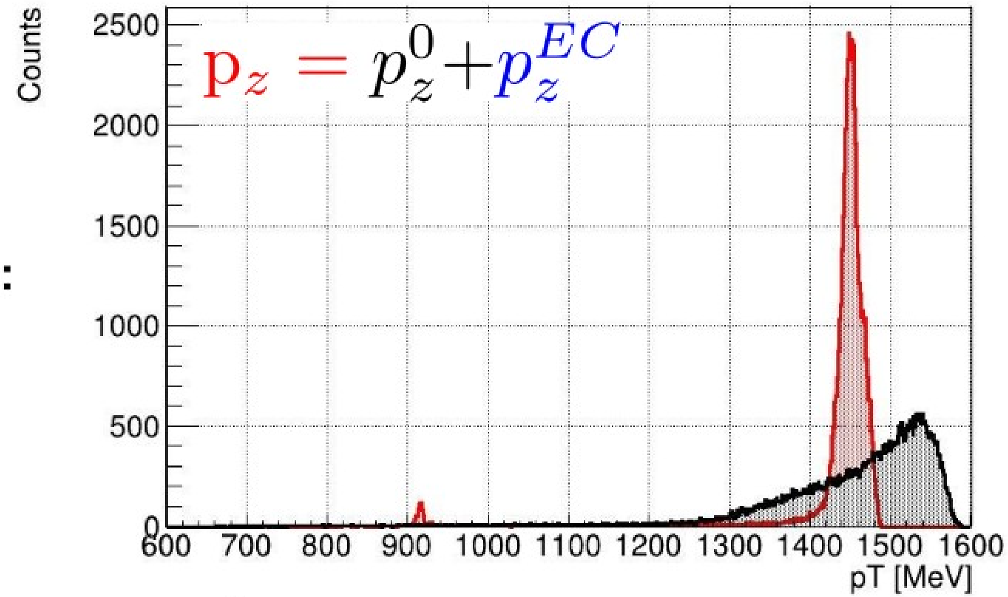
Energy compressor optimization

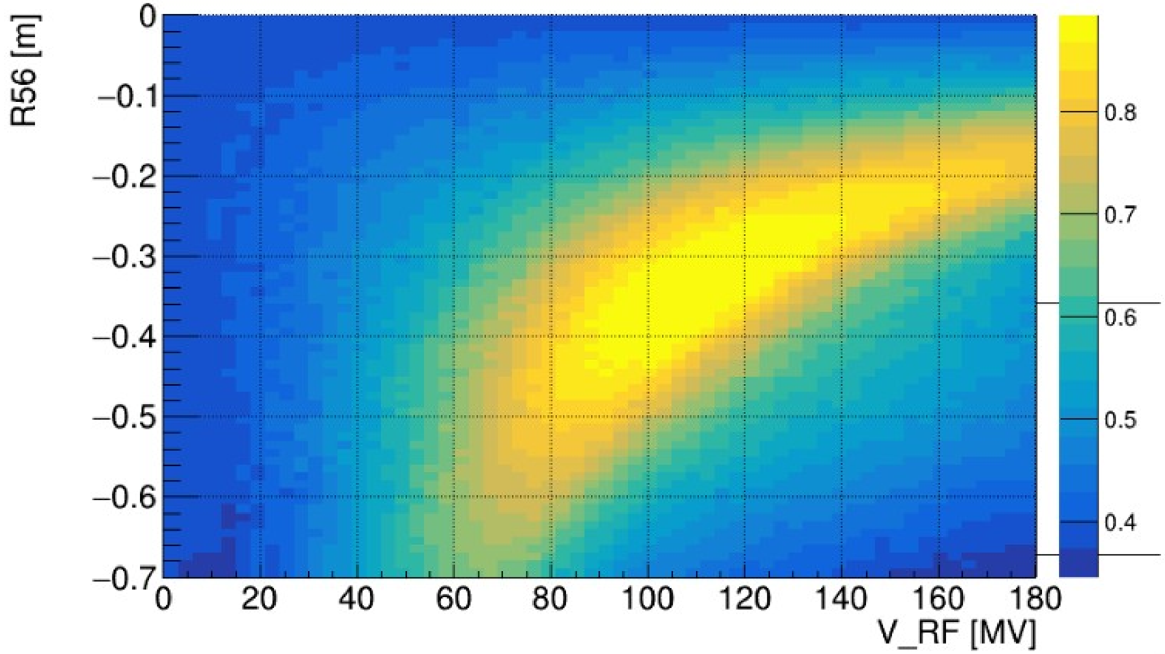
$$\delta t = t_0 - t_{ref}$$
$$\delta p_z = p_z^0 - p_z^{ref}$$

R_{56} + zero-crossing cavity transform:

$$t_{56} = \delta t + R_{56}\frac{\delta p_z}{p_T}$$

$$p_z^{EC} = V_{RF}\sin(2\pi f_{RF} t_{56})$$





V_{RF} and R_{56} parameter scan to *maximize the fraction of particle within 2% of the central energy*.

Result (only analytical):

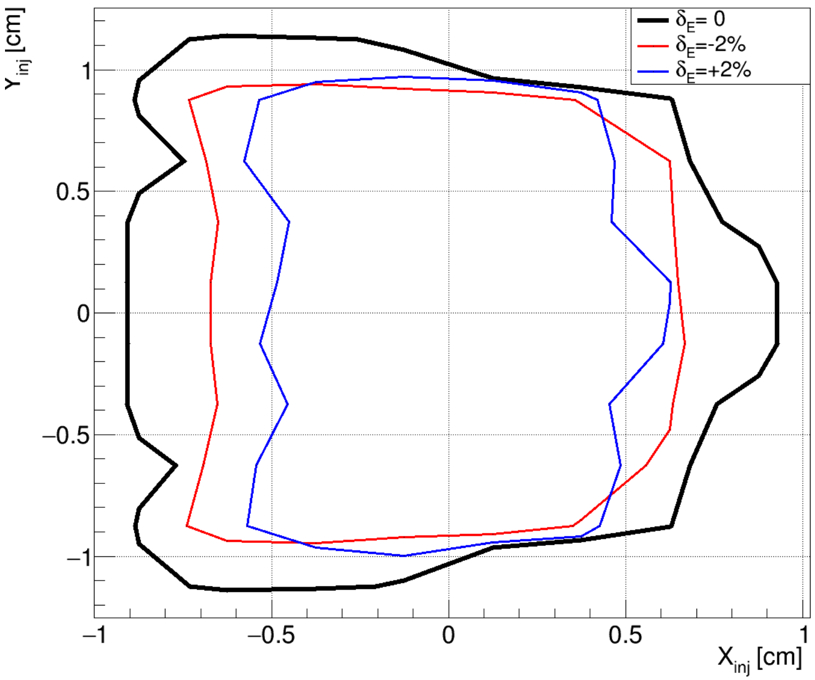
V_{RF} = 100 MV
R_{56} = - 0.35 m

Results with Elegant simulation slightly different.

C. Milardi, DR and TLs for FCC-ee pre-injector, FCC Week, Jun 5-9 2023, London, Great Britain.

FCC_ee@LNF: Damping Ring

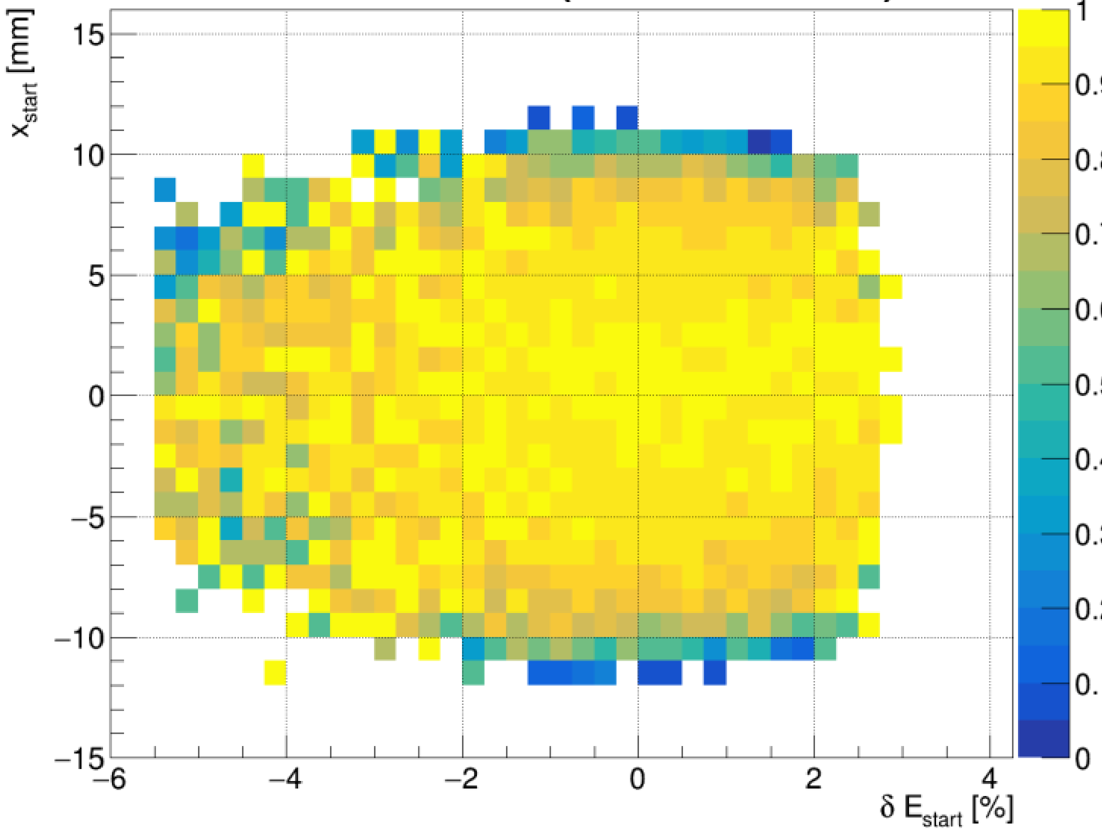
Transverse acceptance

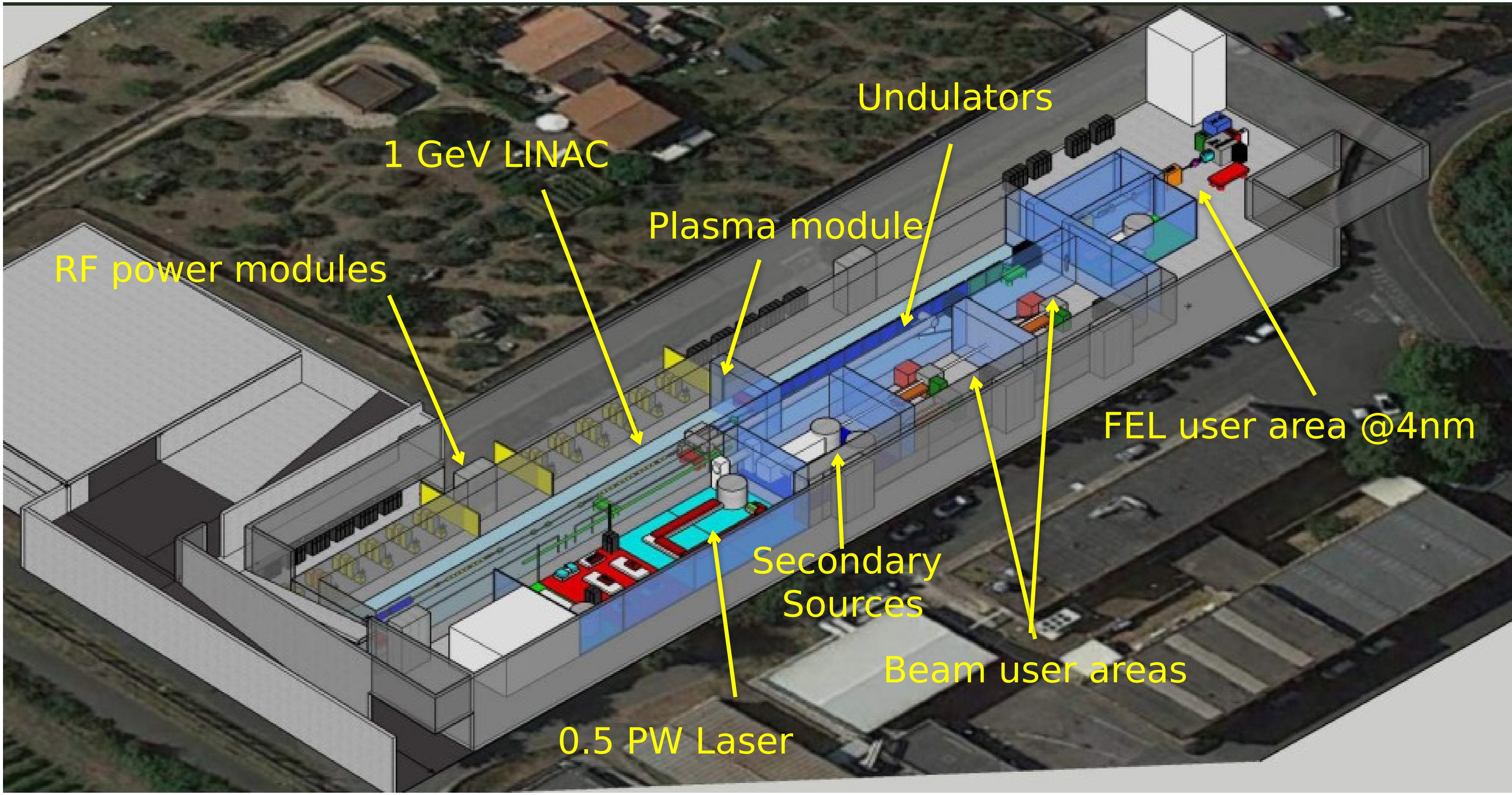


At large energy deviation most of the losses are concentrated in the tail of the distribution as expected. Global DR acceptance:

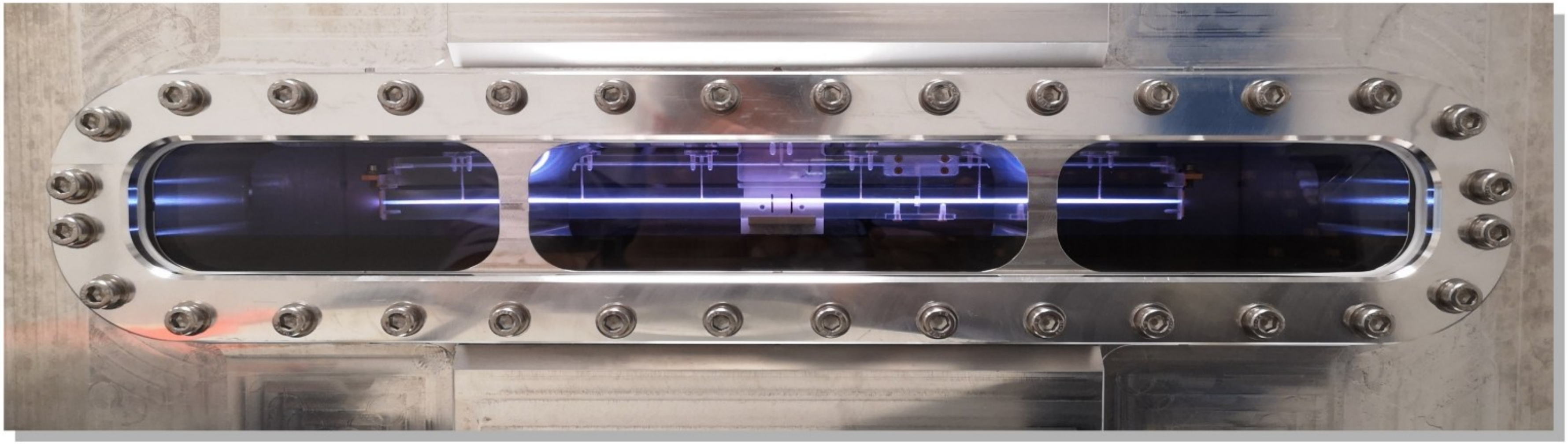
$$f_{ACC} = 0.939 \times 0.917 = 86.1\%$$

Particle losses (ratio out/in)



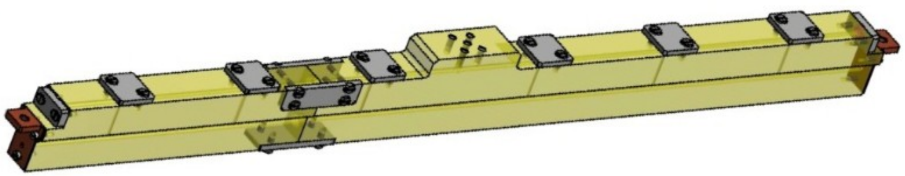

Undulators
1 GeV LINAC
Plasma module
RF power modules
FEL user area @4nm
Secondary
Sources
Beam user areas
0.5 PW Laser

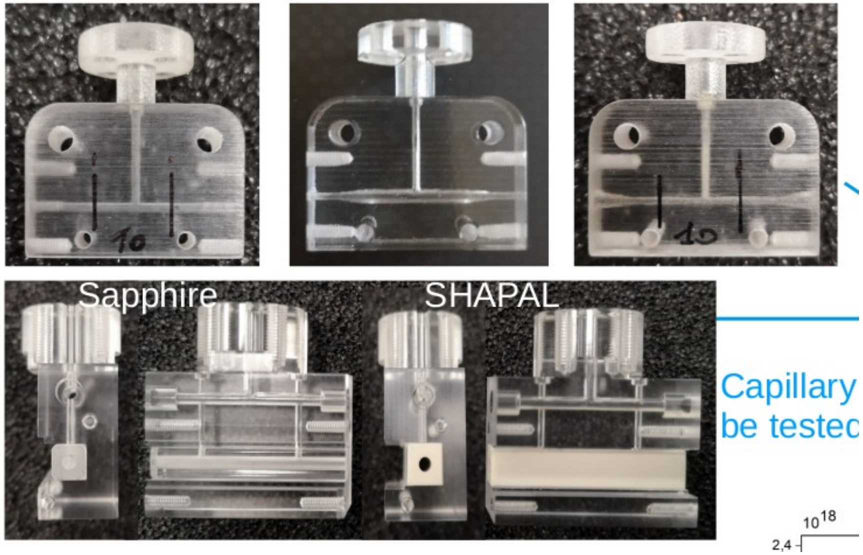
Plasma module



- 40 cm long capillary → 1[st] prototype for the EuPRAXIA facility
  - *Made with special junction to allow negligible gas leaks (<10^{-10} mbar)*
  - *Next step is to extend its length to 60 cm as required by last studies*
- Operating conditions
  - *1 Hz repetition rate (to be increased up to 100 Hz)*
  - *10 kV – 380 A minimum values for ionization*
  - *6 inlets for gas injection. Electro-valve aperture time 8-12 ms*

A. Biagioni, V. Lollo

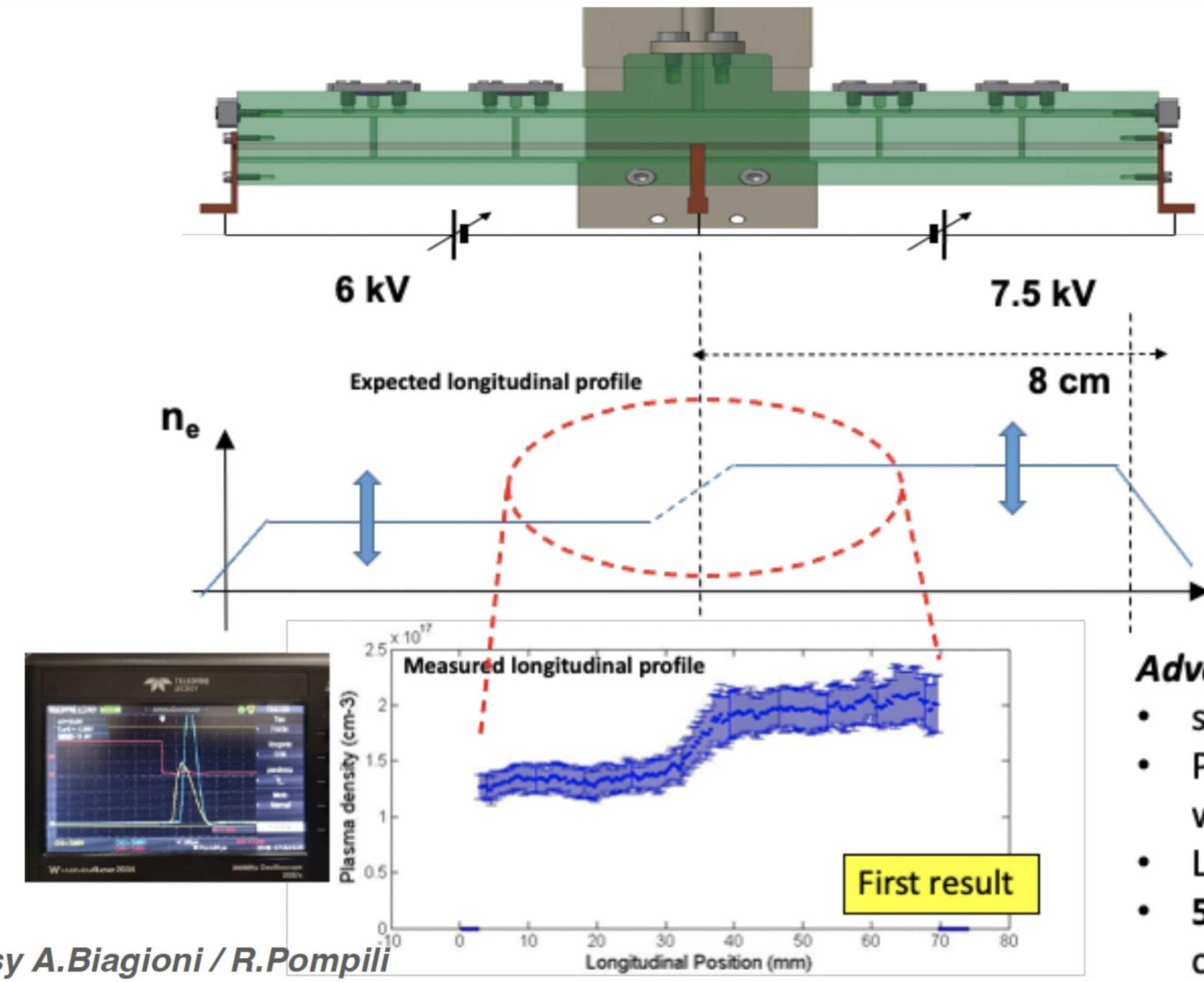


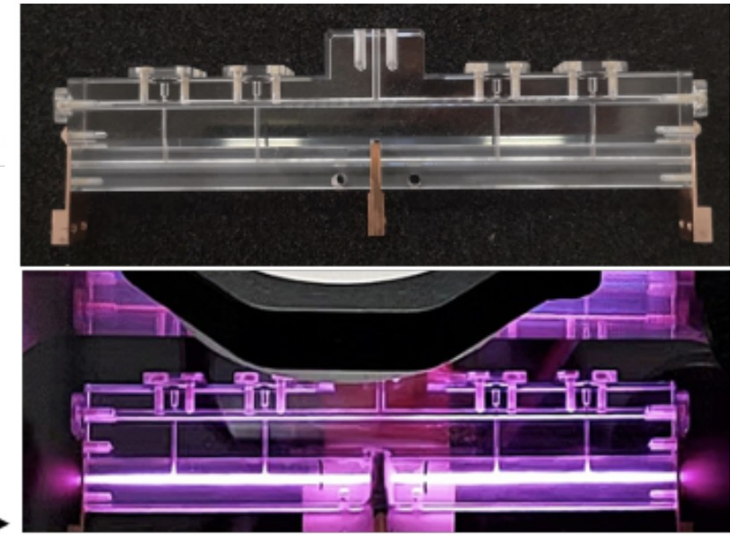


Capillary be testec

Large R&D program for the capillary
Material and shape on a smaller scale
3D printing for fast prototyping

Plasma module

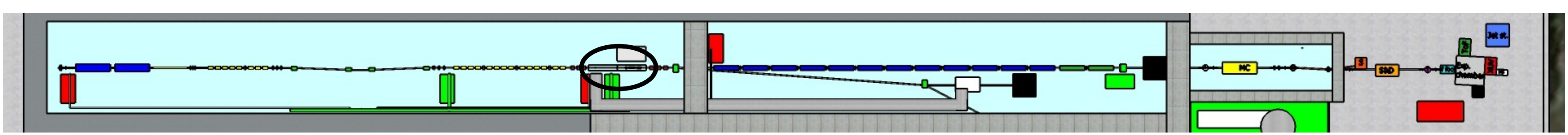




Advantages:

- several independently controllable sections
- Plasma sources larger than 40 cm (m-scale) with HV pulses less than 10 kV
- Longitudinal density modulation
- **5 GeV** case for EuPRAXIA (1.5 GV/m m-scale capillary - density 10^{16} cm-3)

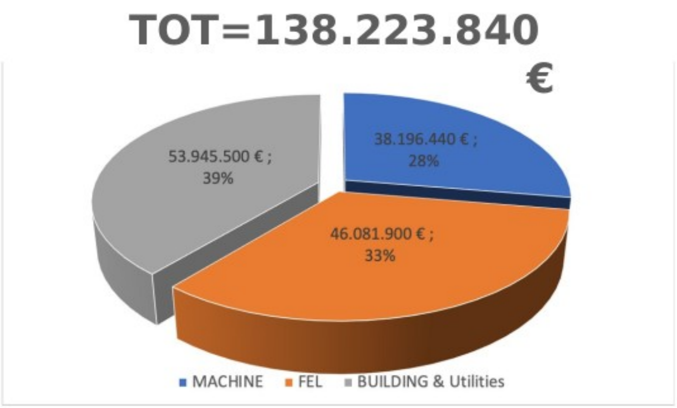
ourtesy A.Biagioni / R.Pompili

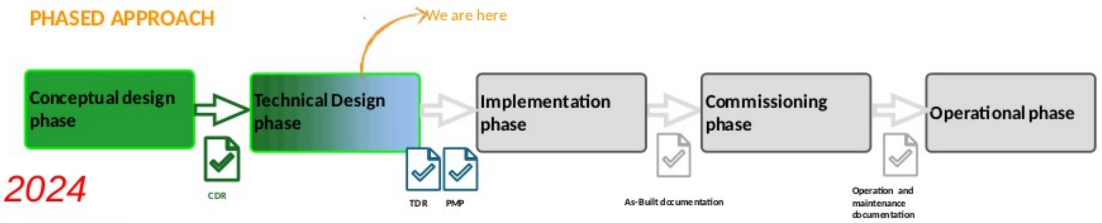


EUPRAXIA Baseline

EuPRAXIA timeline

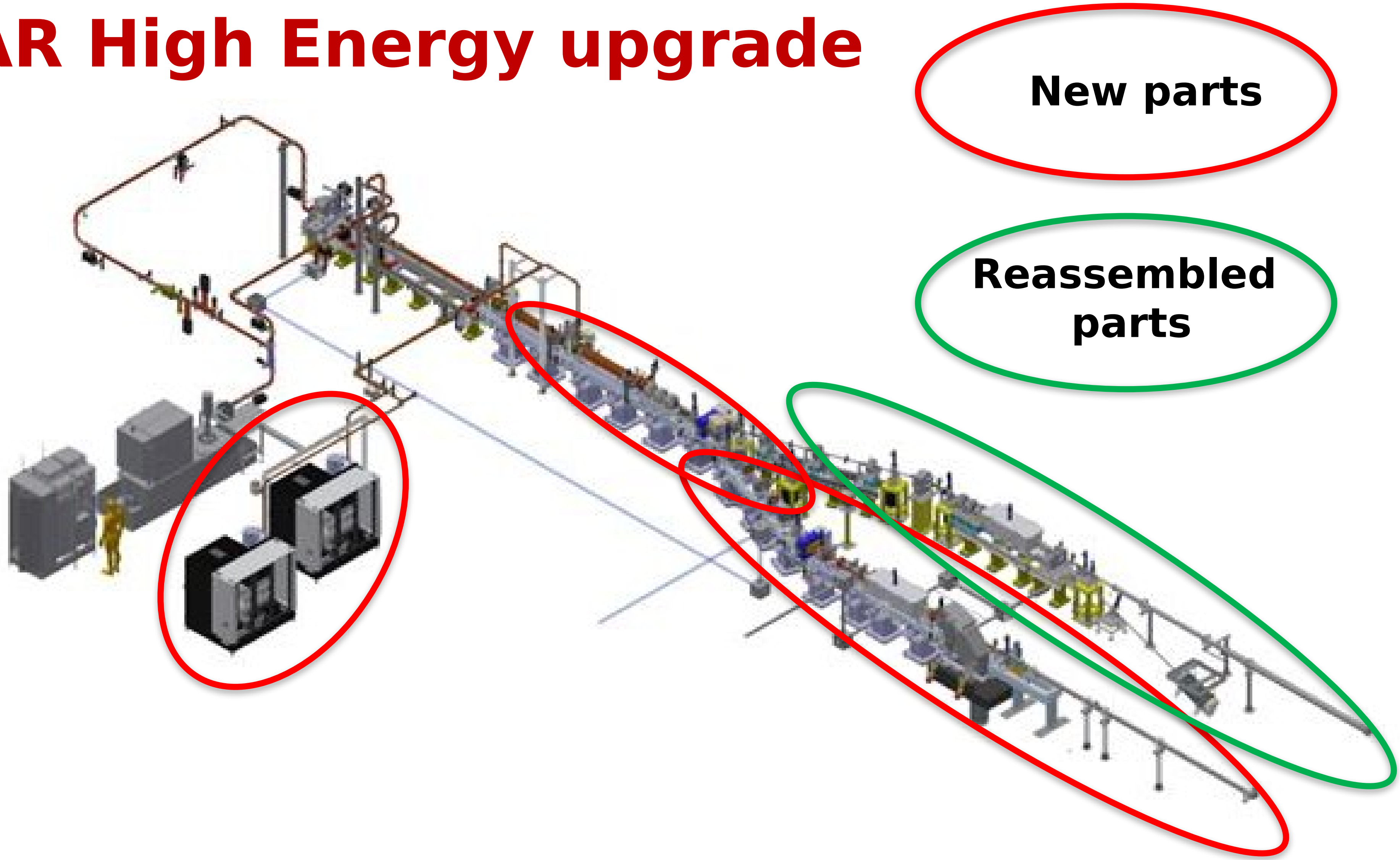
- EuPRAXIA has been included in the ESFRI 2021 Roadmap
  - *ESFRI Roadmap lasts 10 years, i.e. in order to become a ESFRI Landmark project we have to enter the full operational phase (user activities) by 2031.*
- The implementation of the Phase I of the EuPRAXIA@SPARC_LAB Beam Driven Pillar has been funded by Italian Government in 2019 with 108 M€ (commitment for the ESFRI Application).
  - *Italian Government funding is until 2030.*
- 4 M€ are being used for the TDR phase
- Latest news
  - *First draft of the **TDR** to be completed within June 2024*
  - *Executive layout is ongoing (to be completed within 2024)*
  - *3. Autorizzazione dalla sovrintendenza - OK*
  - *4. Autorizzazione dai VVFF - OK.*
  - *5. Gara per la verifica del progetto - terminata e in fase di aggiudicazione.*
  - *Tender for the building should be assigned within 2025*





A. Falone

STAR High Energy upgrade



Accelerator Division structure

Divisione Acceleratori

(STRUTTURA ORGANIZZATIVA AL 4/3/2024)

Responsabile di Divisione:
Alessandro Gallo

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Etisken O.

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Gatti G. ⁎
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\# Art. 6
• Art. 15
° Art. 36
◊ Operatore
Δ Congedo
⁎ Aspettativa
Responsabile