I-LUCE
INFN Laser indUced particles acCEleration

Status and perspectives with the upcoming facility at INFN-LNS

GAP Cirrone, G Cuttone, S Tudisco G Petringa, R Catalano

Layout

1. Laser-driven acceleration

2. I-LUCE facility: perspectives at INFN-LNS

3. Funds

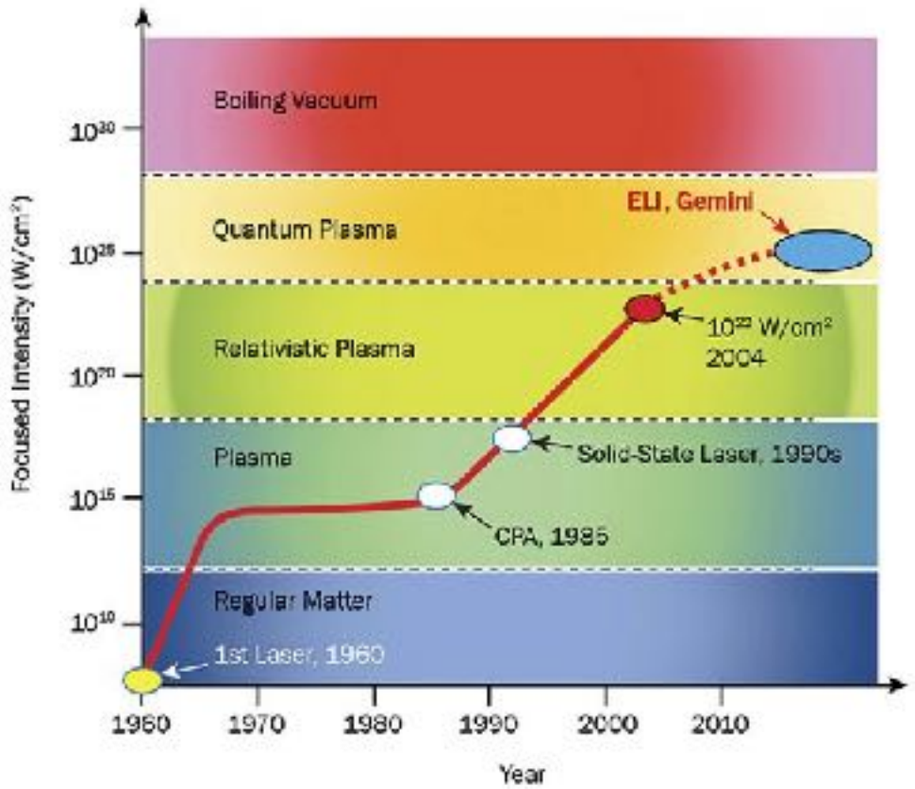
Laser-driven particle acceleration

Laser-driven particles acceleration

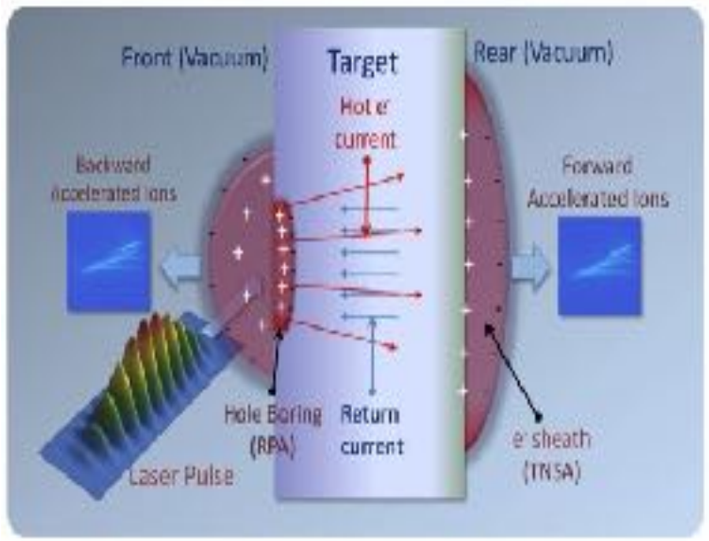
Nowadays approaches for electrons and ions acceleration are different but both based on some high-power laser interacting with some material (gas for electrons and solid for ions)

Laser-driven particles acceleration

LASER SYSTEMS	High energy CPA systems	Ultrashort CPA systems
Technology	Nd: Glass	Ti:Sa
Energy	100's J	10's J
Pulse duration	>100's fs	10s fs
Intensity [W/cm2]	10^{21} Wcm2	10^{21} Wcm2
Rep rate	1 shot/hours	1-10 Hz



Laser-solid target interaction for protons, ions acceleration

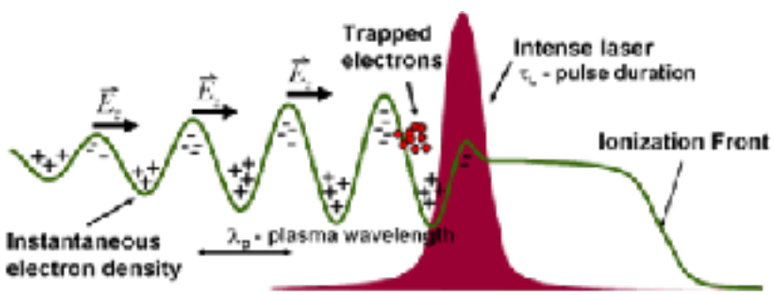


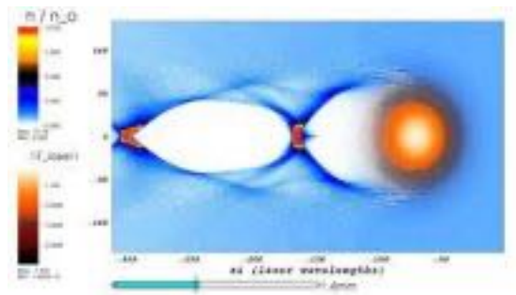
- Multi species production: g, e-, p, ions
- Emax ~ 10 TV/m
- Short distance (~μm)

Proton characteristics

High energy: up to ~ 98 MeV
Pulse duration ≈ 10s fs - 100s ps
ppb ≈ 108-1011
Broad energy spectra (100%)
Wide angular divergence (≈ 10°-20°)

Laser Wake Field Acceleration (LWFA) for electrons

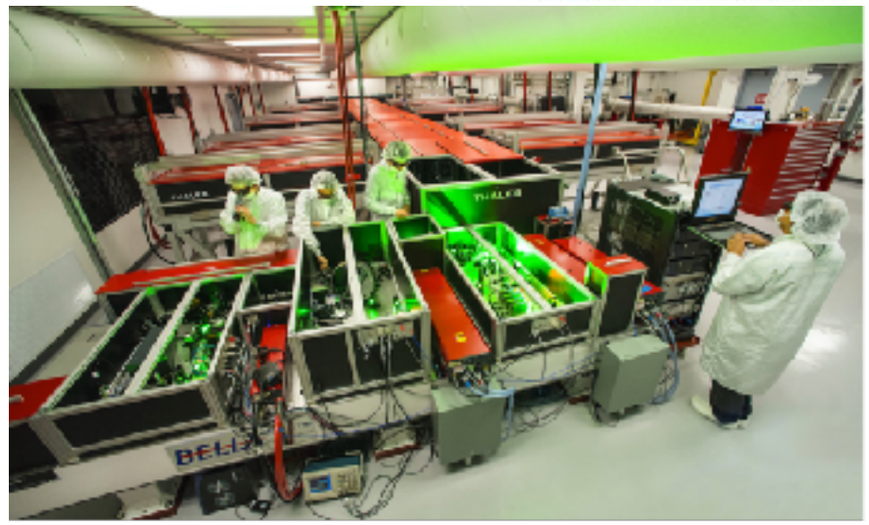




7.8 GeV have been reached at the BELLA (Berkeley Lab) in 2019 using two lasers

How a laser system appears

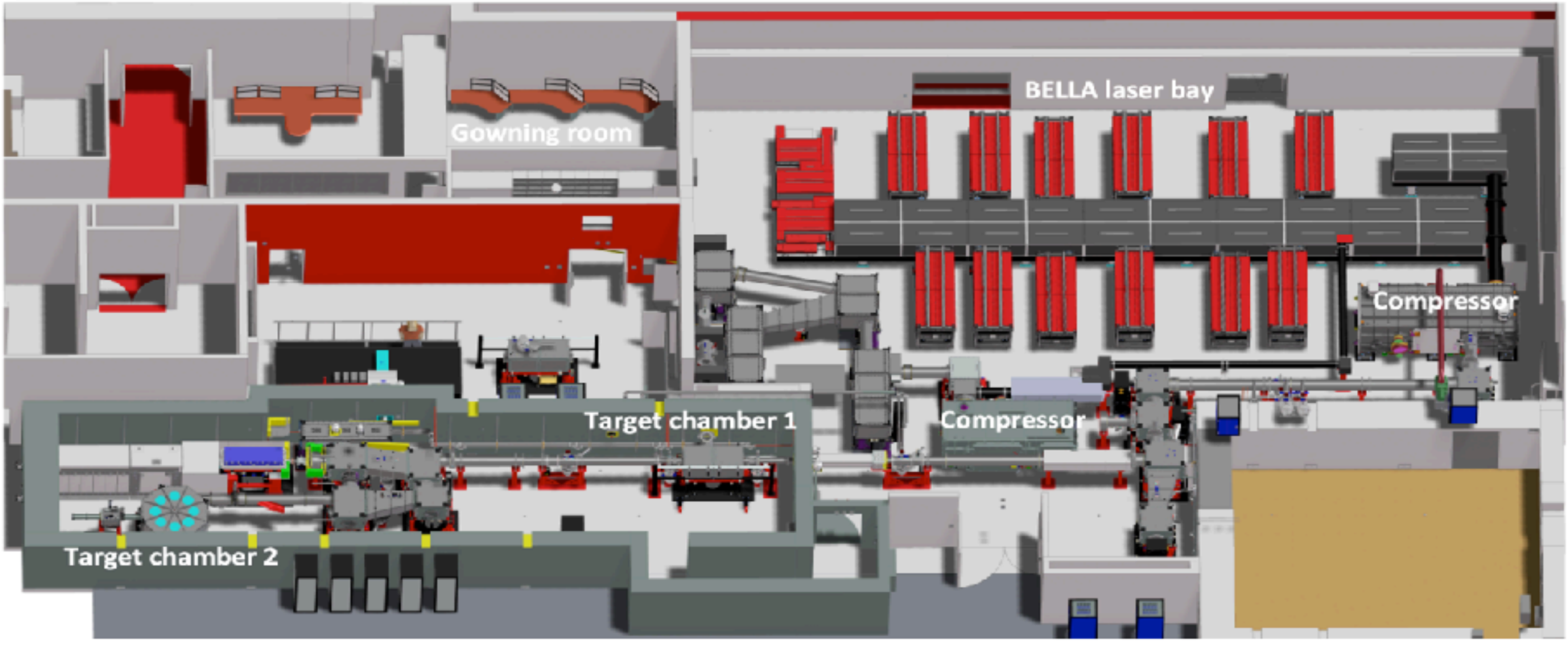
Istituto Nazionale di Fisica Nucleare



The BeLLA facility at Berkeley lab (US)

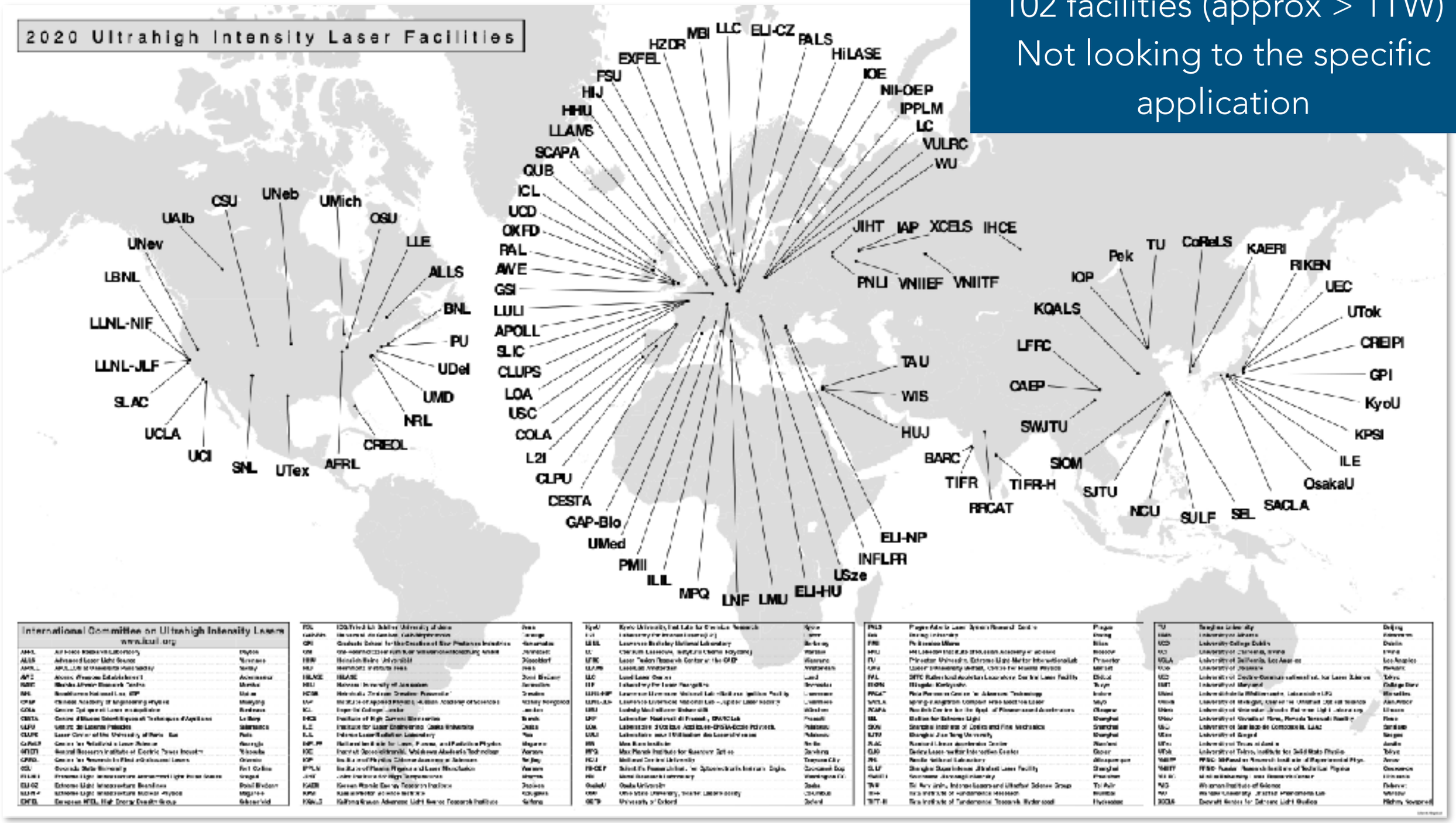
- Mostly acceleration studies
- 10 TW, 50 TW and 1 PW outputs available
- Electron beams 0.01 – 8 GeV
- Ion beams: protons up to 60/80 MeV

Acceleration of high charge ion beams with achromatic divergence by petawatt laser pulses
Steinke et al. Phys. Rev. Accel. Beams 23, 021302 (2020)



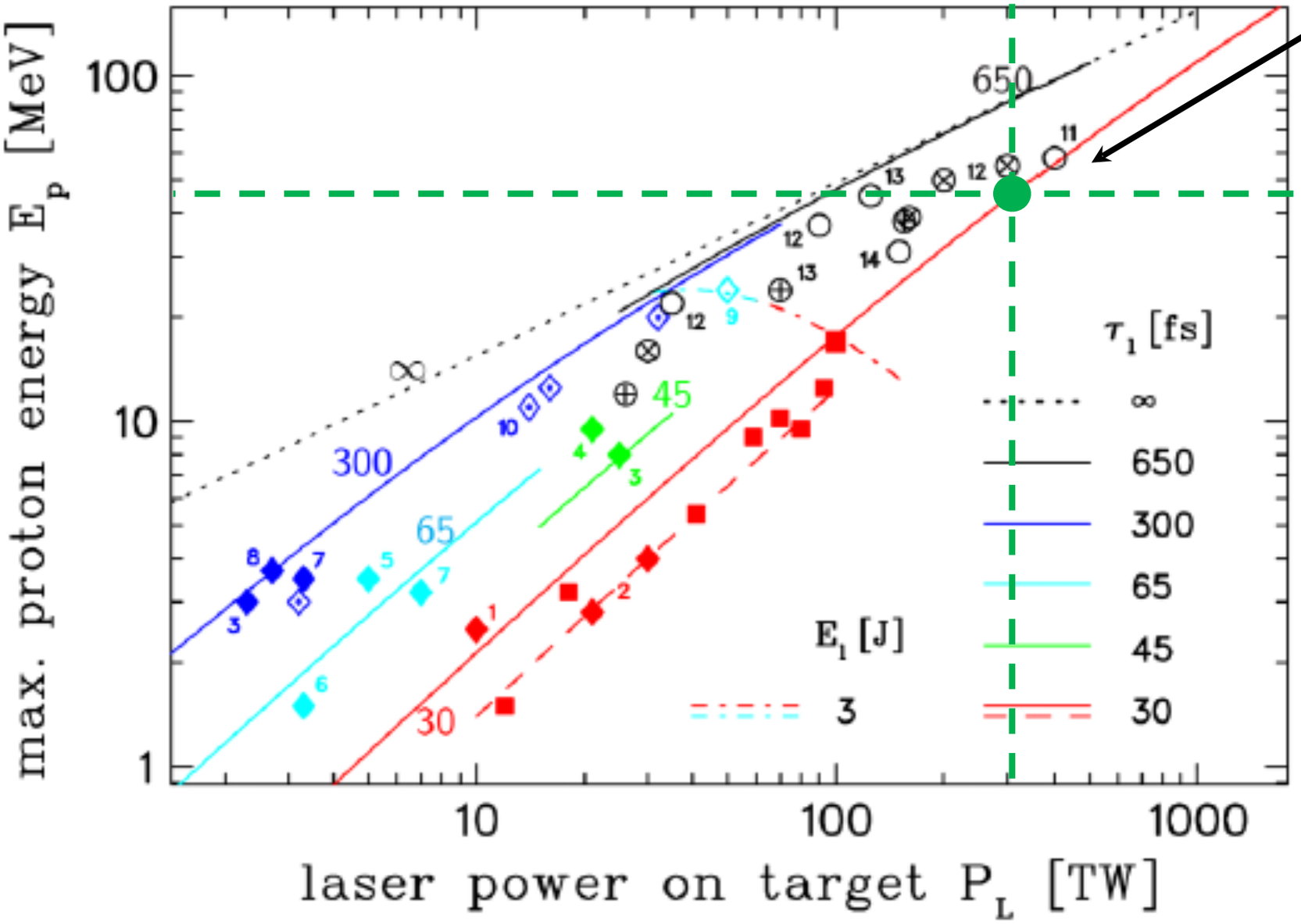
2020 world lasers facilities

102 facilities (approx > 1TW)
Not looking to the specific application



From ICUIL (International Committee on Ultra-High Intensity Lasers)
https://www.icuil.org/

Scaling law for proton acceleration



I-LUCE @ LNS

The two data set are related to two different ‘family’ of laser system

The scaling of proton energies in ultrashort pulse laser plasma acceleration
K Zeil et al 2010 New J. Phys. 12 045015

INFN contribution in high power lasers-plasma interaction

1997-1998 -- ECLISSE proposal for an hybrid source and first MoU with PALS laboratory (CZ)

2010 – the LILIA project (INFN Committee V)

Ion acceleration at FLAME

MoU with ELI-Beamlines Institute (Z)

2013 – ELIMED project (INFN Committee V)

Development of transport devices and dosimetric systems for laser driven beams up to 30 MeV

2014 – ELIMED tender (Competitive project after a tender published by ELI-beamlines)

Development of transport devices and dosimetric systems for laser driven proton/ion up to 200 MeV

Beamline installed at running at the ELI-Beamline facility

2016 to 2022 L3IA and LP2A projects (INFN Committee V)

Laser-driven transport, dosimetry and radiobiology

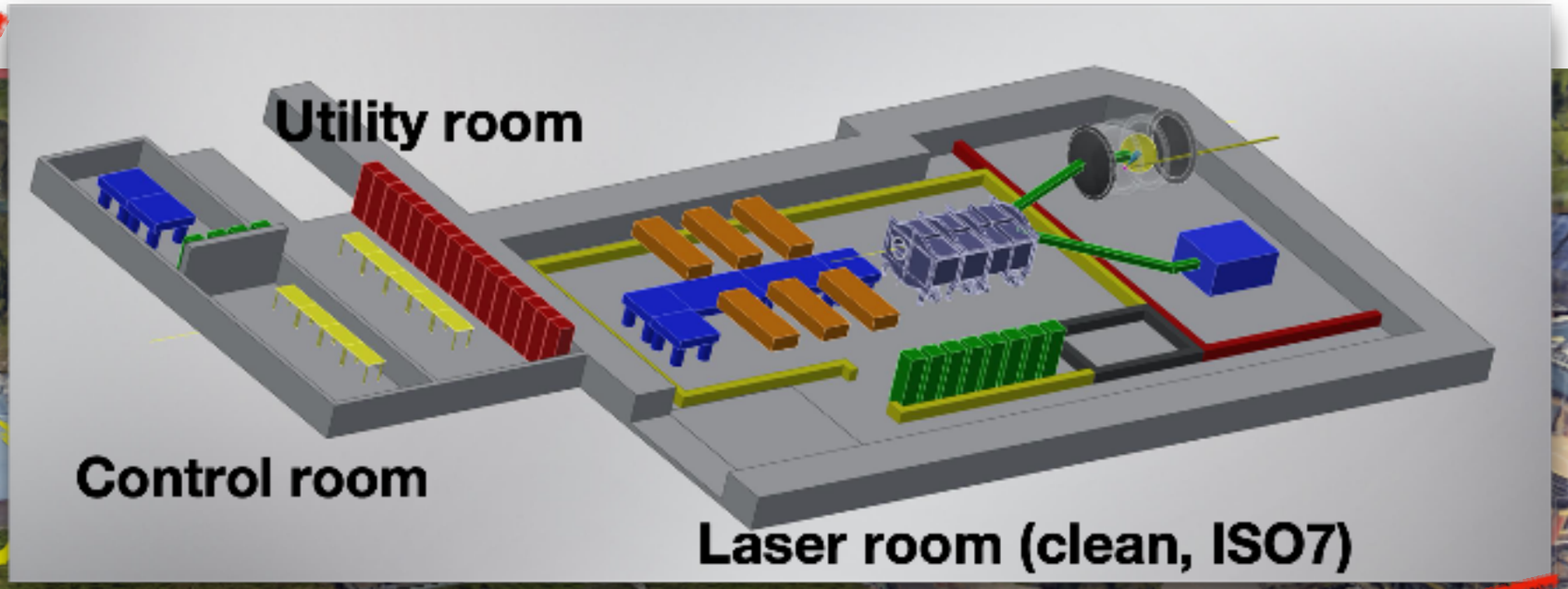
2020 – IMPULSE project (H2020)

Innovative detectors for laser-driven and FLASH beams in collaboration with many European laser facilities

2022 – I-LUCE

I-LUCE
@ INFN-LNS

Beamlines



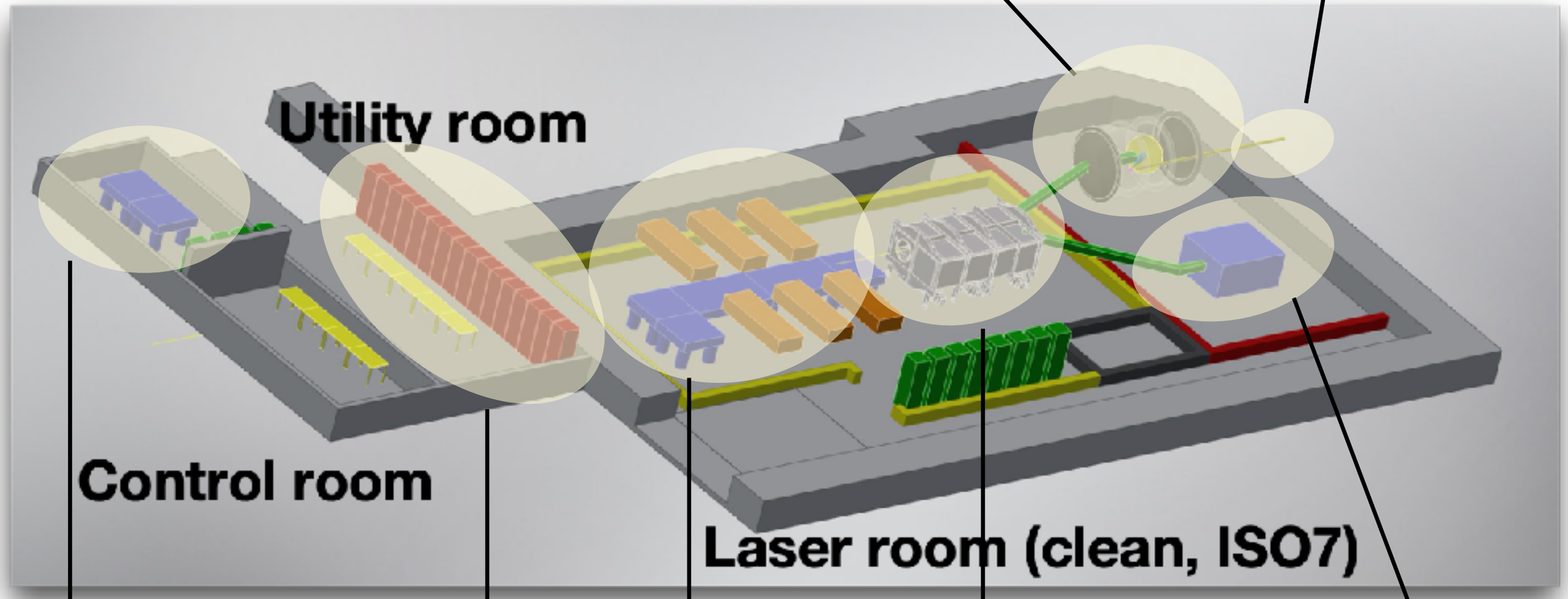
Laser-area

Cyclotron

Tandem accelerator

Plasma–ion interaction chamber; Plasma and nuclear physics studies

Ion beams from Cyclotron and Tandem



Optical laboratory

Pumps laser bias supplies

Laser system

Laser compressor chamber

Proton-, ion– and electron acceleration

I-LUCE facility

I-LUCE: INFN Laser IndUced particle acCeleration

BCT will fund a 45TW laser system;

EUAps and SAMOTHRACE will fund the upgrade to 500TW laser system

aim: e- and proton acceleration to obtain “FLASH” regime and biological irradiation

INFN will take care of the whole infrastructure and beams facility

First phase
1TW, 25fs, 30mJ, 10Hz
and
45TW, <25fs, >1J, 5Hz
Upgradable to 300TW

Second phase
500TW, <25fs, >1J, 5Hz
to
1PW, <25fs, 10J, 1Hz

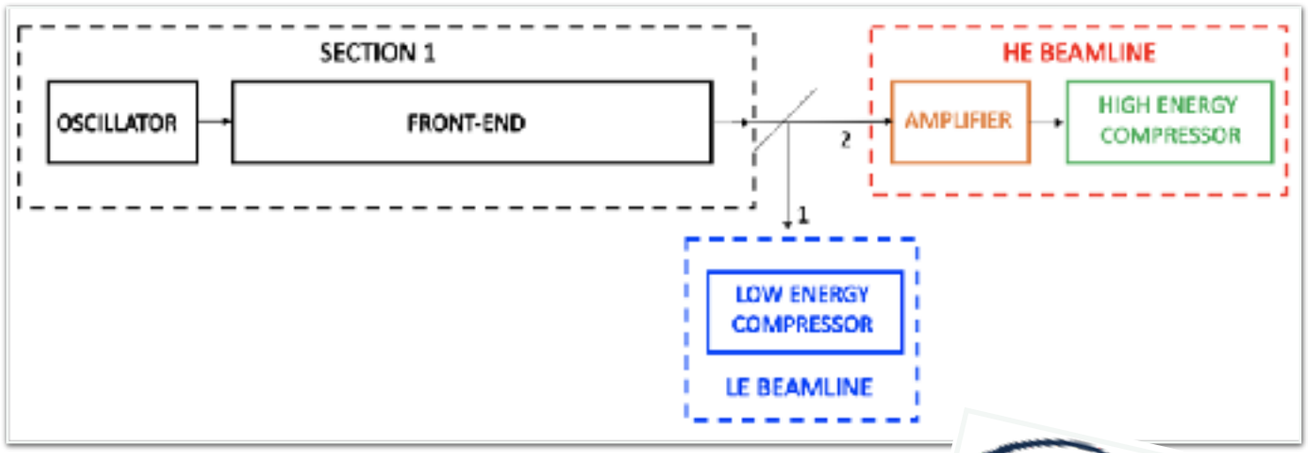
I-LUCE facility

Laser tender is starting

Middle 2024 the first experimental station

Two laser lines and three experimental stations:

- **Fusion studies**
- **Acceleration**
- **Plasma-ion interaction**



Laser Power	~ 1 TW
Energy per pulse	25-30 mJ
Pulse duration	**25-30 fs***
Contrast ratio ns	< 1*10-8
Contrast ratio @5 ps	> 10^5
Contrast ratio @100 ps (ASE)	> 10^{10}
Repetition rate	**10 Hz**

Laser Power	500 TW
Energy per pulse	≥ 10 J
Pulse duration	<= 25 fs
Contrast ratio ns	< 1*10-8
Contrast ratio @5 ps	> 10^5
Contrast ratio @100 ps (ASE)	> 10^{10}
Repetition rate	**1 Hz**
Path to upgrade up to 1PW	Compressor optics ready for the upgrade up to 1PW
Pointing stability	<50 μrad
Beam diameter (FWHM)	50-60 mm
Strehl ratio	>=0.65 (without deformable mirror) >=0.8 (with deformable mirror)

GAP Cirrone, PhD - pablo.cirrone@lnfn.it

* we are discussing the possibility to increase the pulse duration

Breast Cancer Therapy

&

&

Samothrace

BCT & EUAPS & SAMOTHRACE

Istituto Nazionale di Fisica Nucleare

BCT - Fondo per lo sviluppo e la coesione 2014-2020

Repubblica Italiana

REGIONE SICILIANA

GIUNTA REGIONALE

Deliberazione n. 389 dell'1 novembre 2019.

"FSC 2014/2020. Patto per lo sviluppo della Regione Siciliana. Riprogrammazione delle risorse della deliberazione della Giunta regionale n.3 del 3 gennaio 2019 – Allegato B – Area Tematica 3.a 'Sviluppo economico e produttivo'"

ORIGINALE

ATTI DELLA GIUNTA REGIONALE

REPUBBLICA ITALIANA

REGIONE SICILIANA

GIUNTA REGIONALE

Deliberazione n. 94 del 13 marzo 2019.

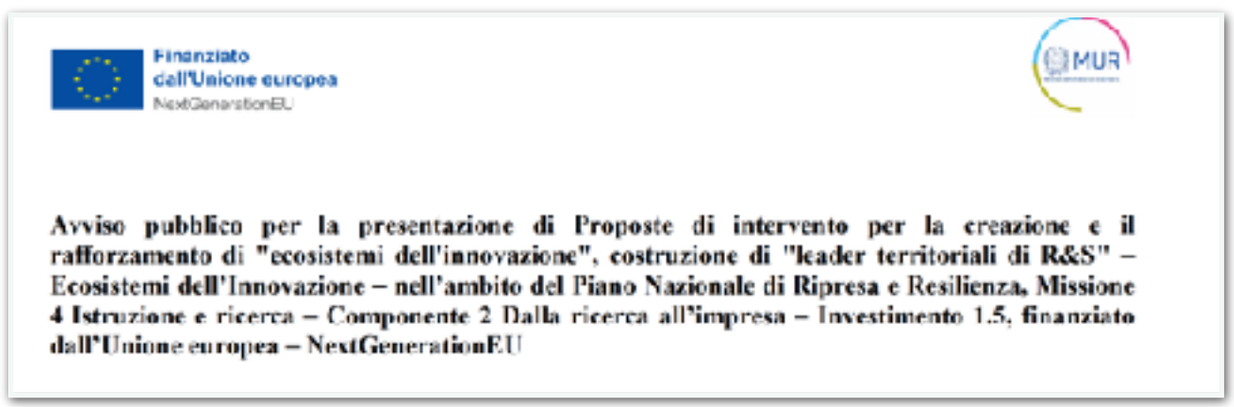
"Progetto di ricerca "BCT" - Trattamento del *Breast Cancer* con radiosensibilizzanti in radioterapia convenzionale e protonterapia - Apprezzamento".

La Giunta Regionale

EUAPS

"Rafforzamento e creazione di Infrastrutture di Ricerca" da finanziare nell'ambito del PNRR
Missione 4, "Istruzione e Ricerca" - Componente 2, "Dalla ricerca all'impresa" - Linea di investimento 3.1, "Fondo per la realizzazione di un sistema integrato di infrastrutture di ricerca e innovazione",
finanziato dall'Unione europea - NextGenerationEU

Samothrace



Finanziato dall'Unione europea NextGenerationEU

MUR

Avviso pubblico per la presentazione di Proposte di intervento per la creazione e il rafforzamento di "ecosistemi dell'innovazione", costruzione di "leader territoriali di R&S" – Ecosistemi dell'Innovazione – nell'ambito del Piano Nazionale di Ripresa e Resilienza, Missione 4 Istruzione e ricerca – Componente 2 Dalla ricerca all'impresa – Investimento 1.5, finanziato dall'Unione europea – NextGenerationEU

The BCT project

Main aim

identification and study of new therapeutical approaches for the breast cancer treatment

to improve the efficacy of the actual protocols and reduce the number of death per year

How?

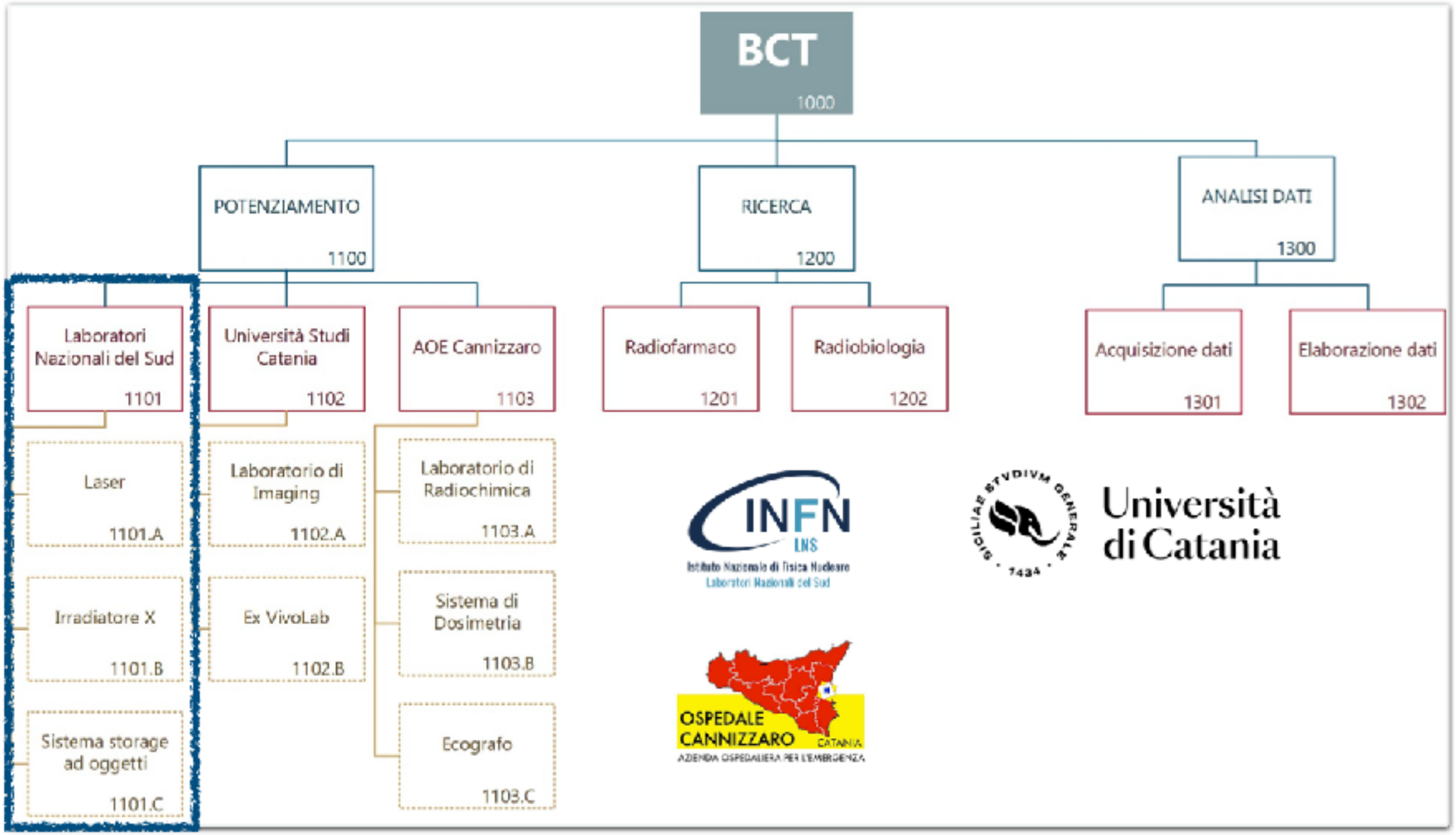
New and specific radiotherapeutic approaches: protontherapy and FLASH therapy

Use of drugs to improve the radiosensitivity

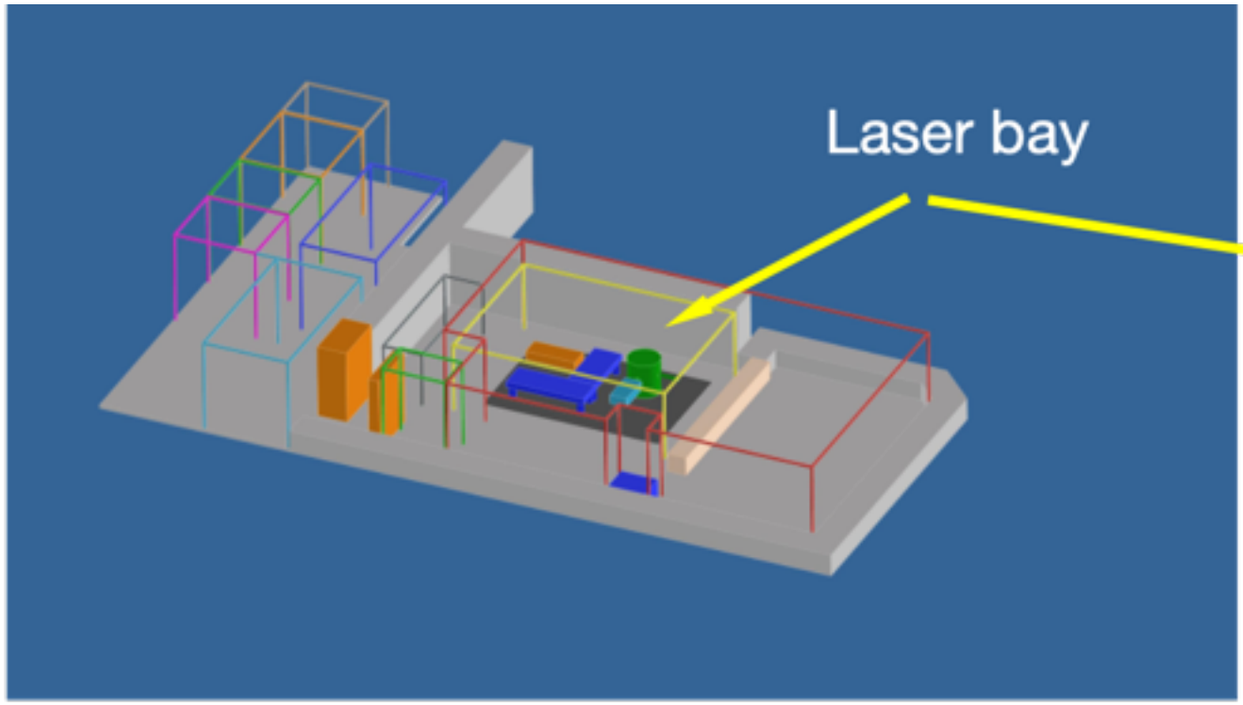
Four working packages:

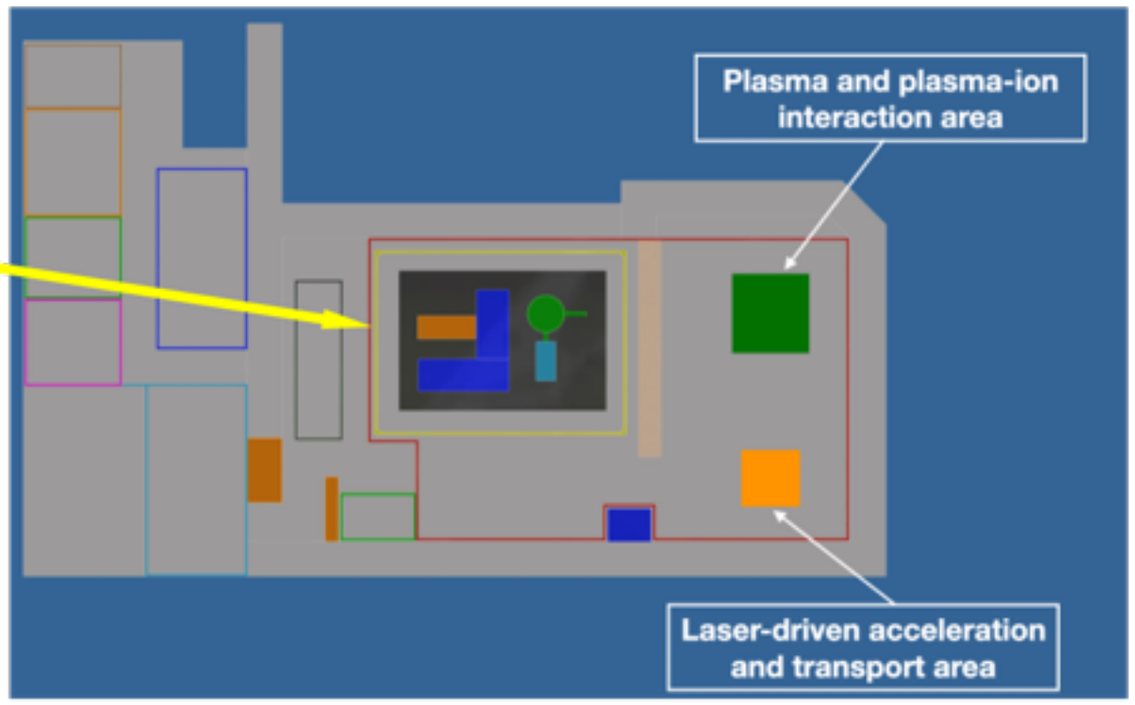
biology, radiochemistry, clinical and apparatus development

The BCT project



Towards the second phase

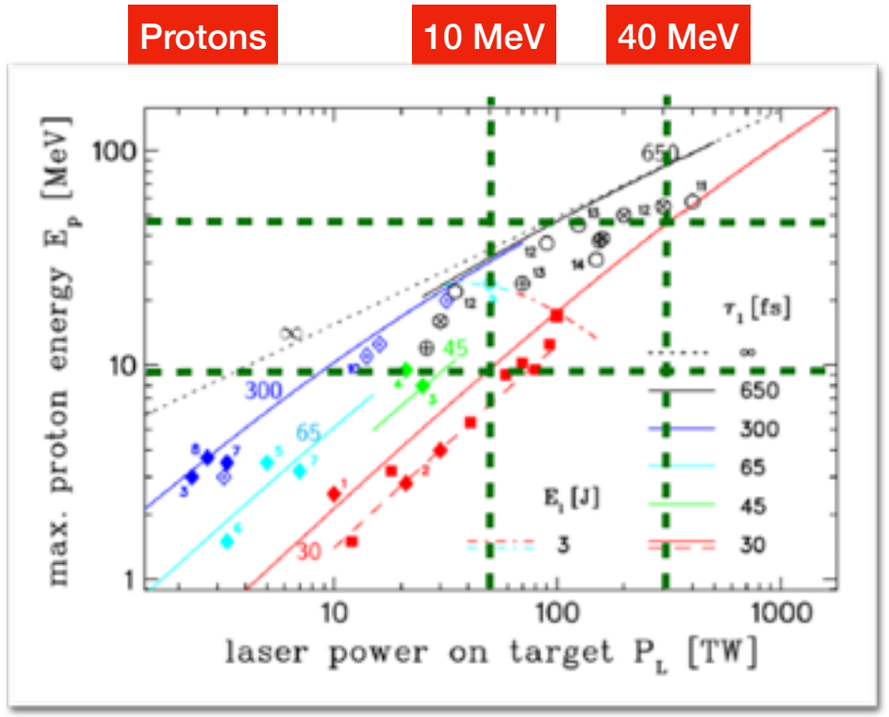




Energy on target: 45 TW - 500 TW
Pulse duration: < 25 fs
Repetition rate: 1 Hz - 5 Hz
Upgradable to 1 PW

Protons
- 15 MeV (first phase)
- 50-100 MeV (second phase)

Electrons
- 170 MeV (first phase)
- 800 MeV (second phase)



The scaling of proton energies in ultrashort pulse laser plasma acceleration To cite this article: K Zeil et al 2010 New J. Phys. 12 045015

EUPRAXIA Advanced Photon Sources proposal (EUAPS)

Bando PNRR

Published on December 28th, 2021

Finanziato dall'Unione europea NextGenerationEU

REFORMS AND INVESTMENTS UNDER THE RECOVERY AND RESILIENCE PLAN
NextGenerationEU

Call for proposals

Intervention field 6: Investment in digital capacities and deployment of advanced technologies
DESI dimension 4: Integration of digital technologies + ad hoc data collections
055 - Other types of ICT infrastructure (including large-scale computer resources/equipment, data centres, sensors and other wireless equipment)

Mission 4 – "Education and Research"
Component 2: from research to business
Investment 3.1: "Fund for the realisation of an integrated system of research and innovation infrastructures
Action 3.1.1 "Creation of new research infrastructures strengthening of existing ones and their networking for Scientific Excellence under Horizon Europe

- Total available funds 400 M€
- Minimal request 15 M€ of which 40% to the Southern Regions
- Personell funding allowed provided that 40% is reserved to women
- **To be completed no later than December 31rst 2025**

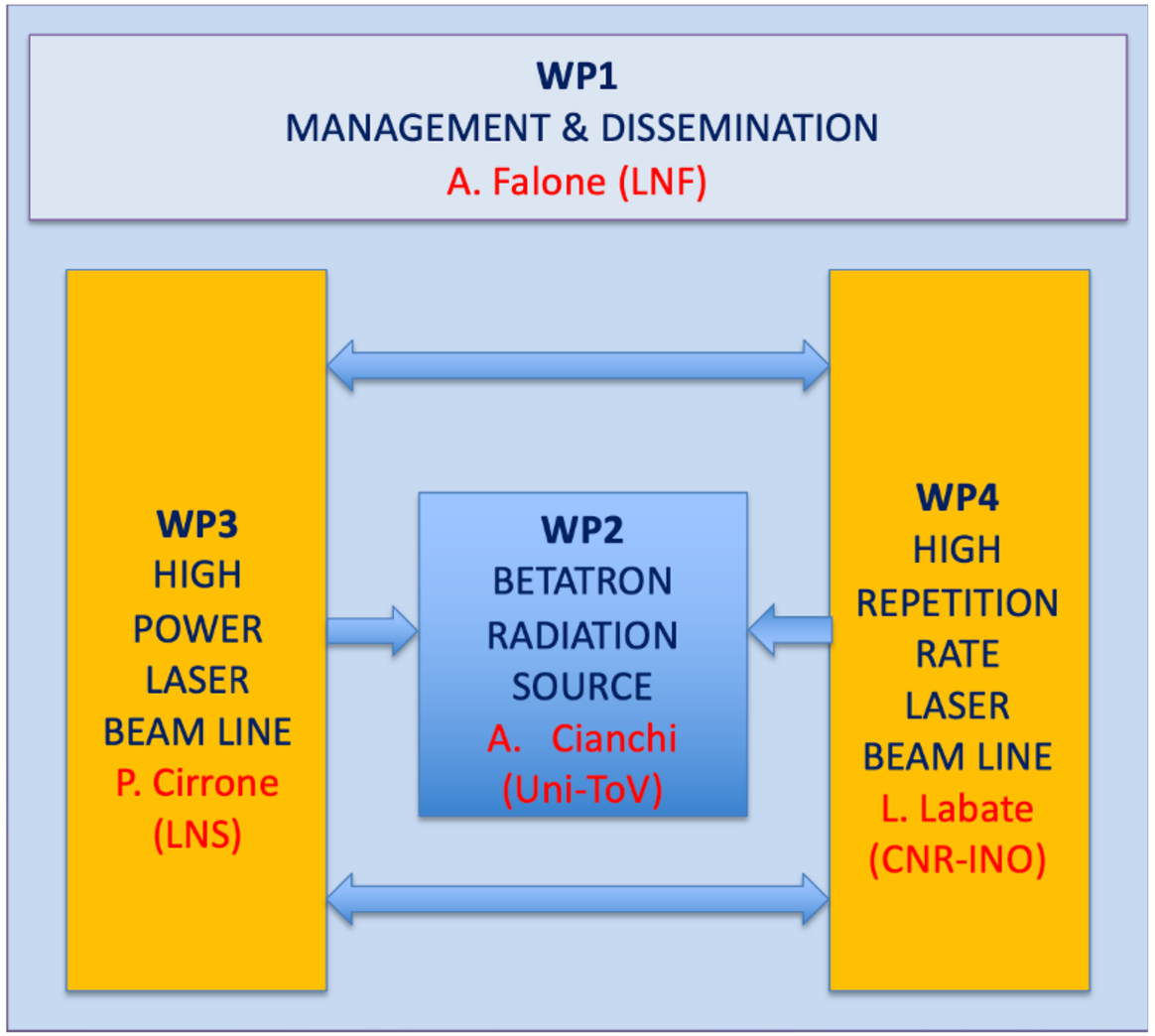
Nome IR	Capofila	Ambito	e Tipo
ACTRIS	CNR	ENV	Distributed
ANAEE	CNR	H&F	Distributed
Auger	INFN	PSE	Single site
BBMRI	CNR	H&F	Distributed
BRIEF	SS S. Anna	DIGIT	Distributed
CERIC-ERIC	Area Sci. Park	PSE	Distributed
CESSDA	CNR	SCI	Distributed
CLARIN-IT	CNR	SCI	Distributed
CTA	INAF	PSE	Distributed
DANUBIUS-RI	CNR	ENV	Distributed
DARIAH ERIC	CNR	SCI	Distributed
DiSSCo	CNR	ENV	e-IR
DTT	ENEA	ENE	Single site
EATRIS	CNR	H&F	Distributed
EBRAINS	CNR	H&F	Distributed
ECCSEL	OGS	ENE	Distributed
ECORD	CNR	ENV	Distributed
ECRIN	CNR	H&F	Distributed
E-ELT	INAF	PSE	Single site
EGO	INFN	PSE	Single site
EIRENE RI	CNR	ENV	Distributed
ELETTRA	Area Sci. Park	PSE	Single site
ELI	CNR	PSE	Distributed
ELIXIR - IT	CNR	H&F	Distributed
eLTER	CNR	ENV	Distributed
EMBRC	SZN	H&F	Distributed
EMSO	INGV	ENV	Distributed
EPOS	INGV	ENV	Distributed
E-RIHS	CNR	SCI	Distributed
ESRF Grenoble	CNR	PSE	Single site
ESS ERIC	INAPP	SCI	Distributed
ESS ERIC (Spallation)	INFN	PSE	Single site
ET	INFN	PSE	Single site
EUFAR	CNR	ENV	Distributed
EuPRAXIA	INFN	PSE	Distributed
Euro-Argo	OGS	ENV	Distributed
EURO-BIOIMAGING	CNR	H&F	Distributed
EUROFEL	Area Sci. Park	PSE	Distributed
EuroNanoLab (ENL)	CNR	PSE	Distributed
EVN - JIVE	INAF	PSE	Distributed
FERMI	Area Sci. Park	PSE	Single site
Fondazione CMCC	INGV	ENV	Distributed
GARR-X	GARR	DIGIT	e-IR
IBISBA-IT	CNR	H&F	Distributed
ICOS	CNR	ENV	Distributed
ILL	CNR	PSE	Single site
INFRAFRONTIER	CNR	H&F	Distributed
INSTRUCT-ERIC	CNR	H&F	Distributed
ISBE	CNR	H&F	Distributed
ISIS	CNR	PSE	Distributed
KM3-NET	INFN	PSE	Distributed
LBT	INAF	PSE	Single site
LENS	CNR	PSE	Single site
LIFEWATCH	CNR	ENV	Distributed
LNF	INFN	PSE	Single site
LNGS	INFN	PSE	Single site
LNL	INFN	PSE	Single site
LNS	INFN	PSE	Single site
LOFAR	INAF	PSE	Distributed
METROFOOD-RI	ENEA	H&F	Distributed
MIRRI	Torino	H&F	Distributed
NFFA	CNR	PSE	Distributed
OPENAIRE	CNR	DIGIT	Distributed
OPERAS	CNR	SCI	Distributed
Phen-Italy - nodo IT di EMPHASIS	CNR	H&F	Distributed
PRACE-Italy	OGS	DIGIT	e-IR
RESILIENCE	CNR	SCI	Distributed
RFX	CNR	ENE	Single site
SESAME	INFN	PSE	Single site
SHARE-ERIC	CNR	SCI	Distributed
SIOS	CNR	ENV	Distributed
SKA	INAF	PSE	Distributed
SoBigData	CNR	DIGIT	Distributed
TNG	INAF	PSE	Single site

Tabella 10: IR ad alta priorità

Curtesy of M Ferrario, INFN-LNF

EUPRAXIA Advanced Photon Sources proposal (EUAPS)

EuAPS Scientific Coordinator:
M. Ferrario (INFN-LNF)
EuPRAXIA/EuAPS Integration:
R. Assmann (DESY & INFN)



Scientific Advisory Committee

Operating Units Board

Scientific and Technical Board

Curtesy of M Ferrario, INFN-LNF

WP3 organization

Istituto Nazionale di Fisica Nucleare

WP3: High Power Laser beamline

WP 3	High Power Laser beam line (INFN-LNS)						
	Task	Deliverables			Milestones		
3.1	Clear room realisation	D3.1.1	Infrastructure realisation	M24	M3.1.1	Clean room design	M4
					M3.1.2	Procurement and first payment	M10
					M3.1.3	Second payment	M14
					M3.1.4	Third payment	M20
					M3.1.5	Assembling, commissioning and fourth payment	M24
3.2	Laser design and realisation (PW scale/10 Hz)	D3.2.1	Laser design procurement and installation	M30	M3.2.1	Laser Design	M6
					M3.2.2	Procurement and first payment	M10
					M3.2.3	Second payment	M16
					M3.2.4	Third payment	M24
					M3.2.5	Assembling, commissioning and fourth payment	M30
3.3	Target system for high repetition rate (up to 10 Hz)	D3.3.1	Design and realisation of the target system	M30	M3.3.1	Design and procurement	M24
					M3.3.2	Realization and test	M30
3.4	Plasma diagnostic	D3.4.1	Plasma diagnostic: acquisition and installation	M10	M3.4.1	Design and procurement	M10
3.5	Secondary beam diagnostic	D3.5.1	Secondary beam diagnostic: acquisition and installation	M30	M3.5.1	Design, procurement and mechanical realisations of diagnostic	M18
					M3.5.2	Calibration under conventional beams	M30

Thanks for listening

Left to right:
Roberto Catalano, Davide Passarello, Pablo Cirrone, Emilio Zappalà, Nino Amato, Luciano Pandola, Giuliana Milluzzo, Michele Costa, Mariacristina Guarrera, Serena Fattori, Antonio Russo, Beatrice Cagni, Alma Kurmanova, Carmen Altana,Andrea Matamoros, Giuliana Navarra, Salvo Tudisco, Giacomo Cuttone, Giada Petringa, Gustavo Messina
INFN-LNS Medical Physics Group - Catania, April 30, 2021