CERN STI/LP operational experience

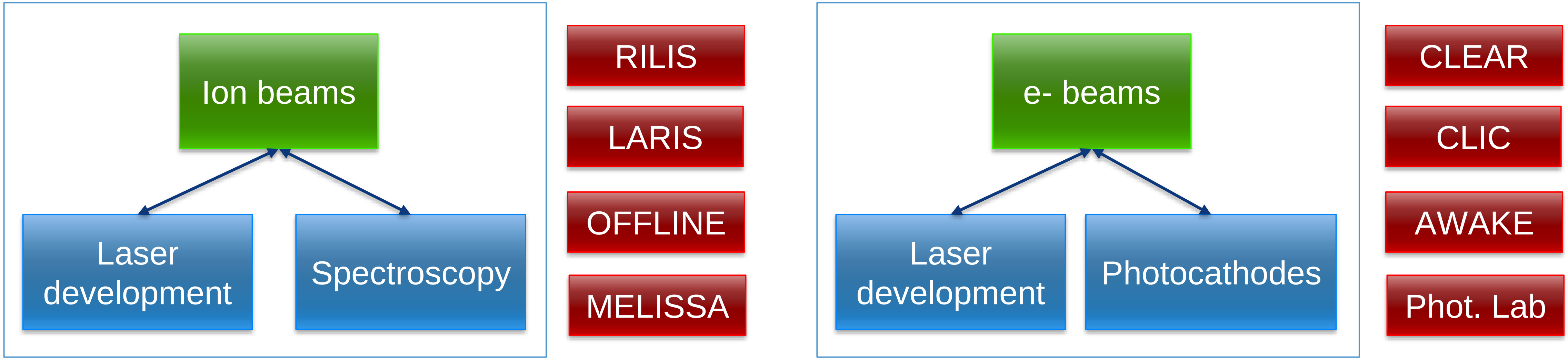
Eduardo Granados

On behalf of the SY-STI-LP section

FCC EPOL Workshop 21st September 2022

Mandate

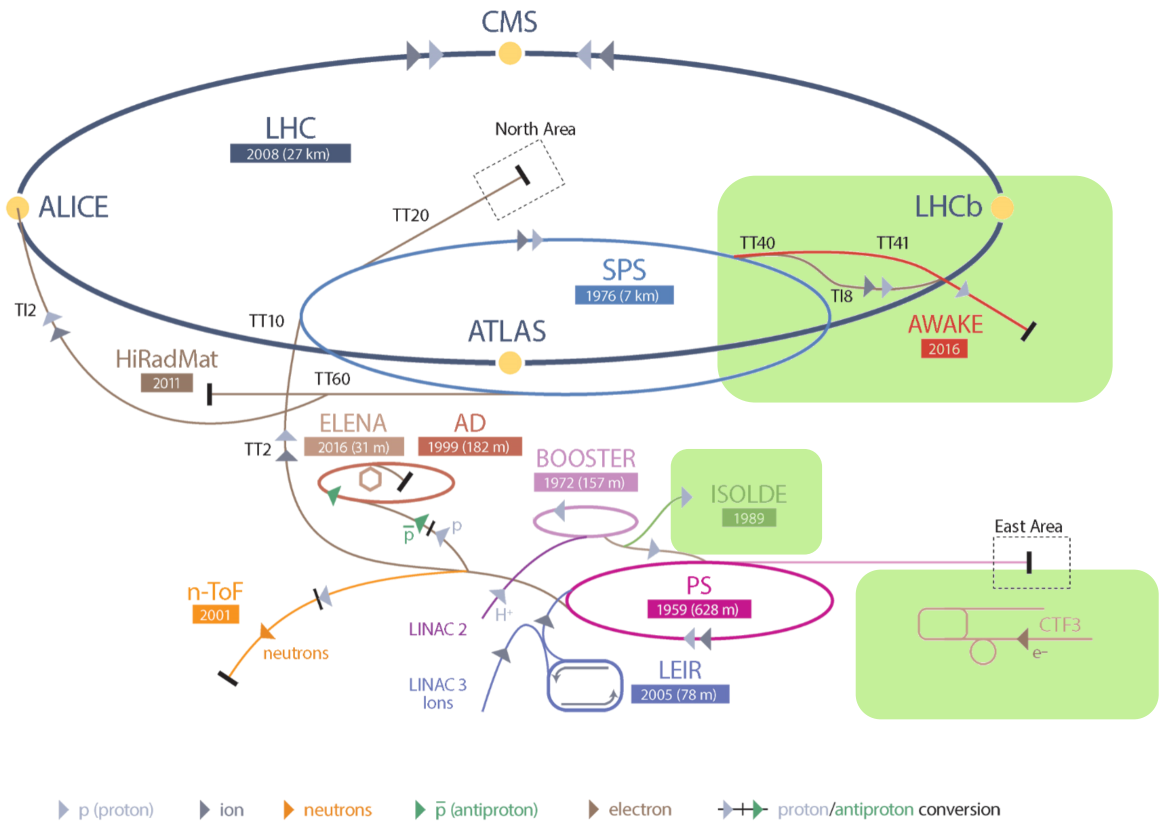
"The LP section is responsible for ***laser installations and optical beamlines used to produce charged particle beams*** in the CERN accelerators complex and research facilities"



+ Support for laser applications in the AT sector, including safety aspects.
+ Training networks (LISA)
+ Knowledge Transfer (@RILIS, @CLEAR)

Lepton and ion beams at CERN

- Next generation of colliders ("Higgs factories") will likely use leptons instead of hadrons exclusively:
  - CLIC (multi-TeV electron-positron collisions)
  - FCC-ee/eh
  - LHeC (PERLE)
- Accelerator R&D + synergies with other facilities worldwide:
  - AWAKE: Plasma wakefield accelerators and components (High gradient, LWFA)
  - CLEAR: Particle sources for medical applications (CHUV)
  - Radiation testing [for space missions, medicine] (ESA)
  - Gamma Factory at CERN
  - CompactLight Collaboration, Inverse Compton Scattering source at CLEAR.
  - Photocathode R&D: For high repetition rate sources (GHz) and plasmonically assisted photoemission.
- Ion Beam production at ISOLDE employing lasers



Outline

- Part I: Photocathode preparation facility at CERN
  - Development of co-deposition of Cs_2Te and Cs_3Sb photocathodes
  - Lifetime studies in RF and DC guns, XPS surface analysis
  - Plasmonic photocathodes
- Part II: Overview on CERN photoinjector activities
  - CTF3 / CLEAR Facilities
  - AWAKE experiment
  - Laser upgrades for photoinjectors
- Part III: Laser ion source RILIS at ISOLDE
  - The ISOLDE laboratory
  - RILIS laser laboratory
  - Diamond Raman laser development
  - MELISSA radioisotopes for medical applications
- Conclusions and outlook

Part I: Photocathode R&D at CERN

“Common” photocathode technologies

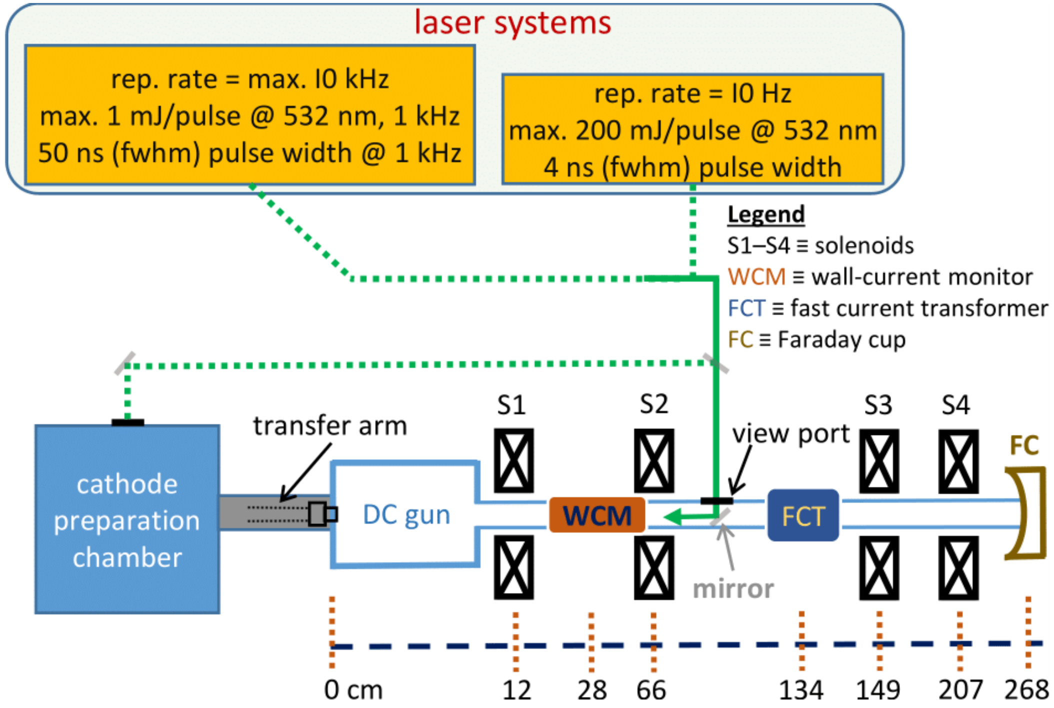
Class	Material	QE	Wavelength	Gun	Application
Normally conducting metals	Cu, Mg	10^{-5} - 10^{-4}	UV	NC-RF	Low Rep rate FELs (LCLS, SwissFEL…)
Super-conducting metals	Nb, Pb	10^{-5} - 10^{-4}	UV	SC-RF	High Rep rate FELs
Positive electron affinity semiconductor	Cs_2Te, Cs_3Sb , K_2CsSb …and others…	0.1 – 0.2	Visible – UV	NC-RF, DC	FELs, ERLs
Negative electron affinity semiconductor	GaAs, etc	0.1-0.35	IR – Visible	DC (XHV)	Polarized sources, ERLs (ALICE)

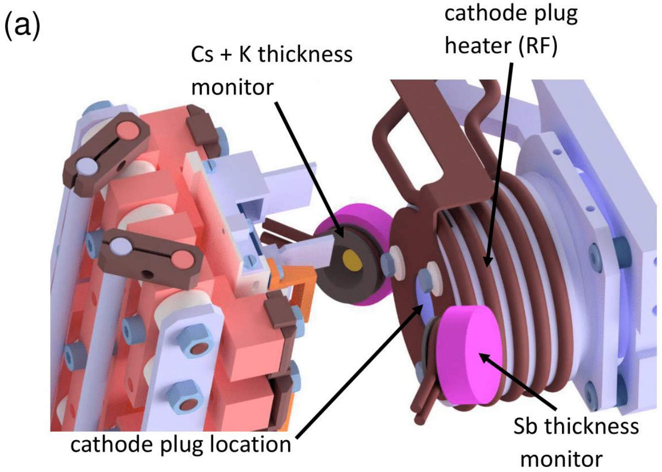
- **Metals**
  - Low quantum efficiency -> requires high power lasers -> plasma is formed
  - Robust and simple
- **Semiconductors**
  - High quantum efficiency at extended wavelength range.
  - More difficult to maintain – x-rays and ions can cause decomposition and surface damage, vacuum…
  - Cs_2Te is quite standard, but requires UV

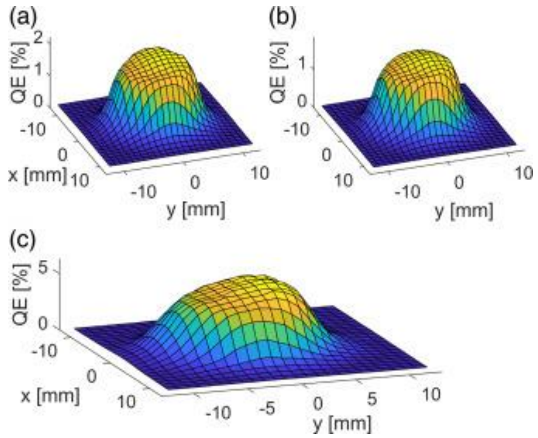
- **CERN Photoemission lab**
  - Cs_2Te photocathodes (UV, high QE) → current workhorse for AWAKE and CLEAR guns.
  - Bi-alkali photocathodes (green, high charge) → proposed for CLIC.
  - Cu cathodes for single bunch RF guns
  - NEW: Plasmonically enhanced metal photocathodes.

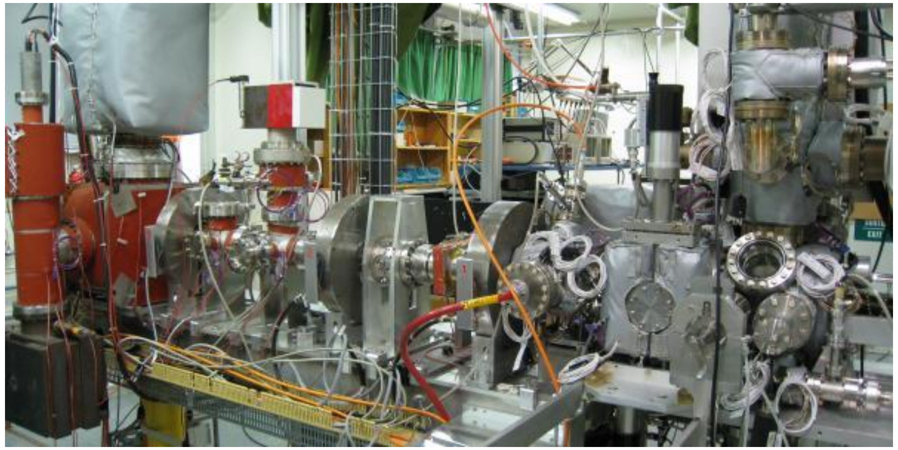
Photoemission lab @ CERN

- >25 years producing cathodes
- Fabrication, lifetime studies, characterization





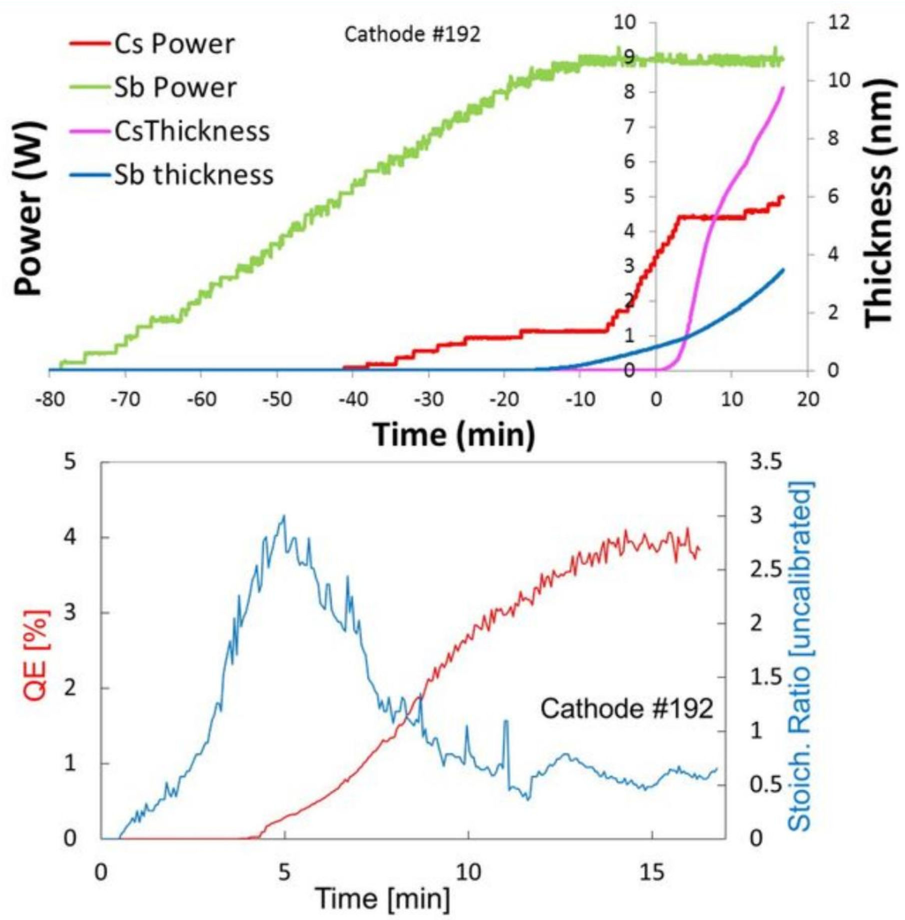




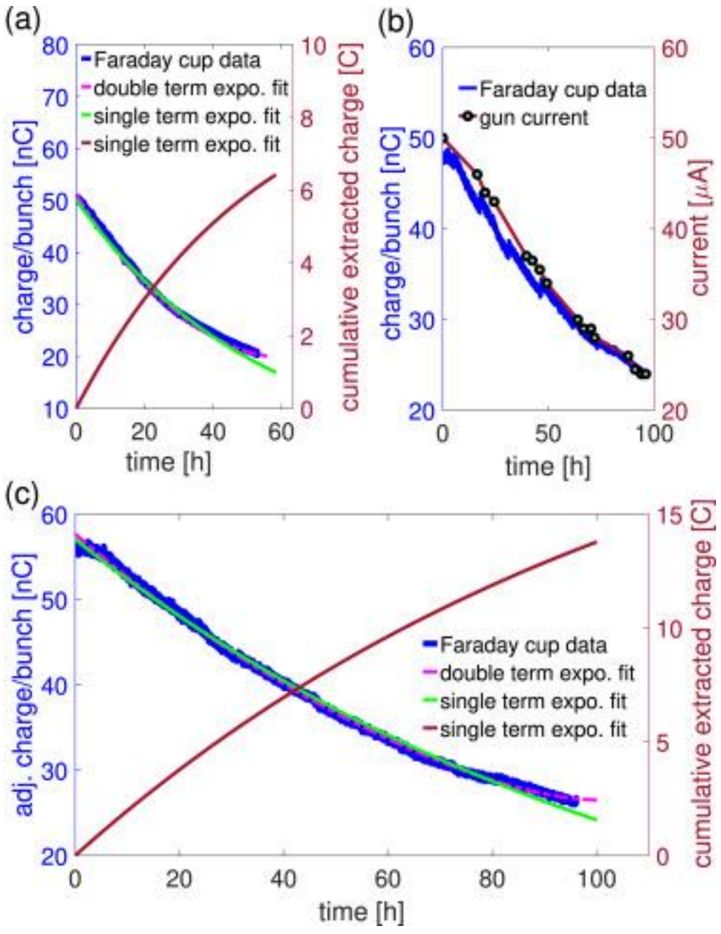
Co-deposition process

- Co-deposition: Cs and Sb (or Te) evaporated at the same time. The metallic elements can mix together in the vapour phase.
- The evaporators power is adjusted in order to reach a maximum value of QE.
- Average pressure during the process is 1e-8 mbar.
- Once the cathodes are fabricated, they undergo QE testing spatially, lifetime studies and XPS characterization.

Production process



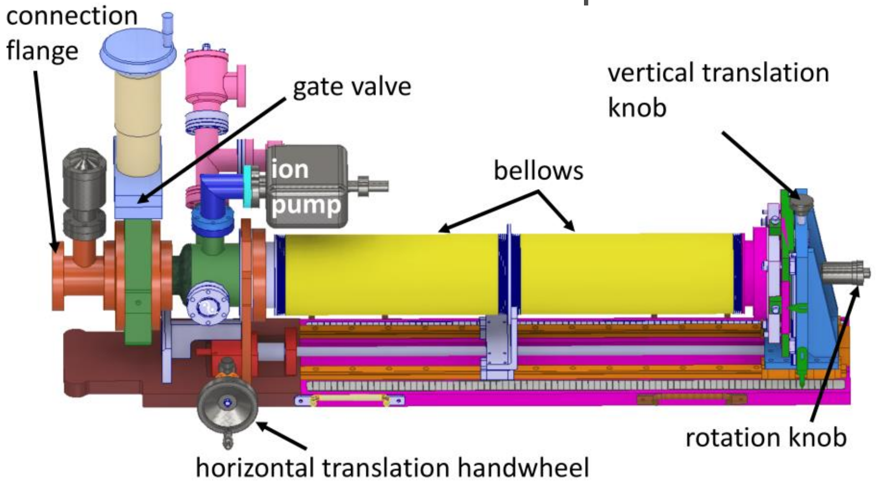
Lifetime studies

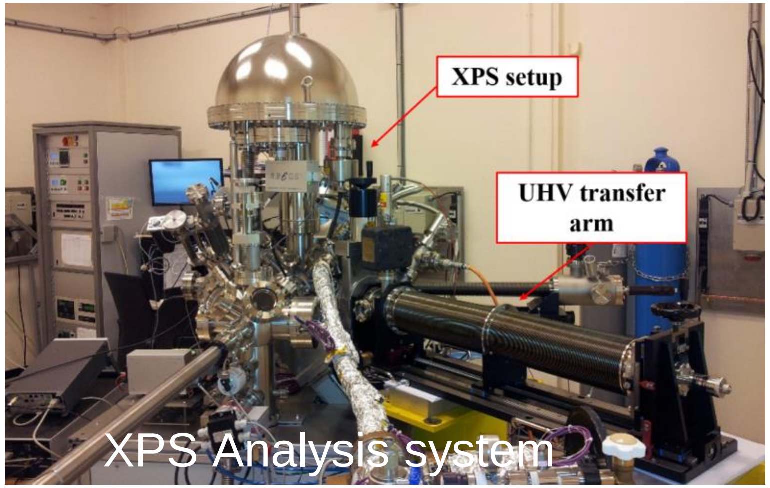


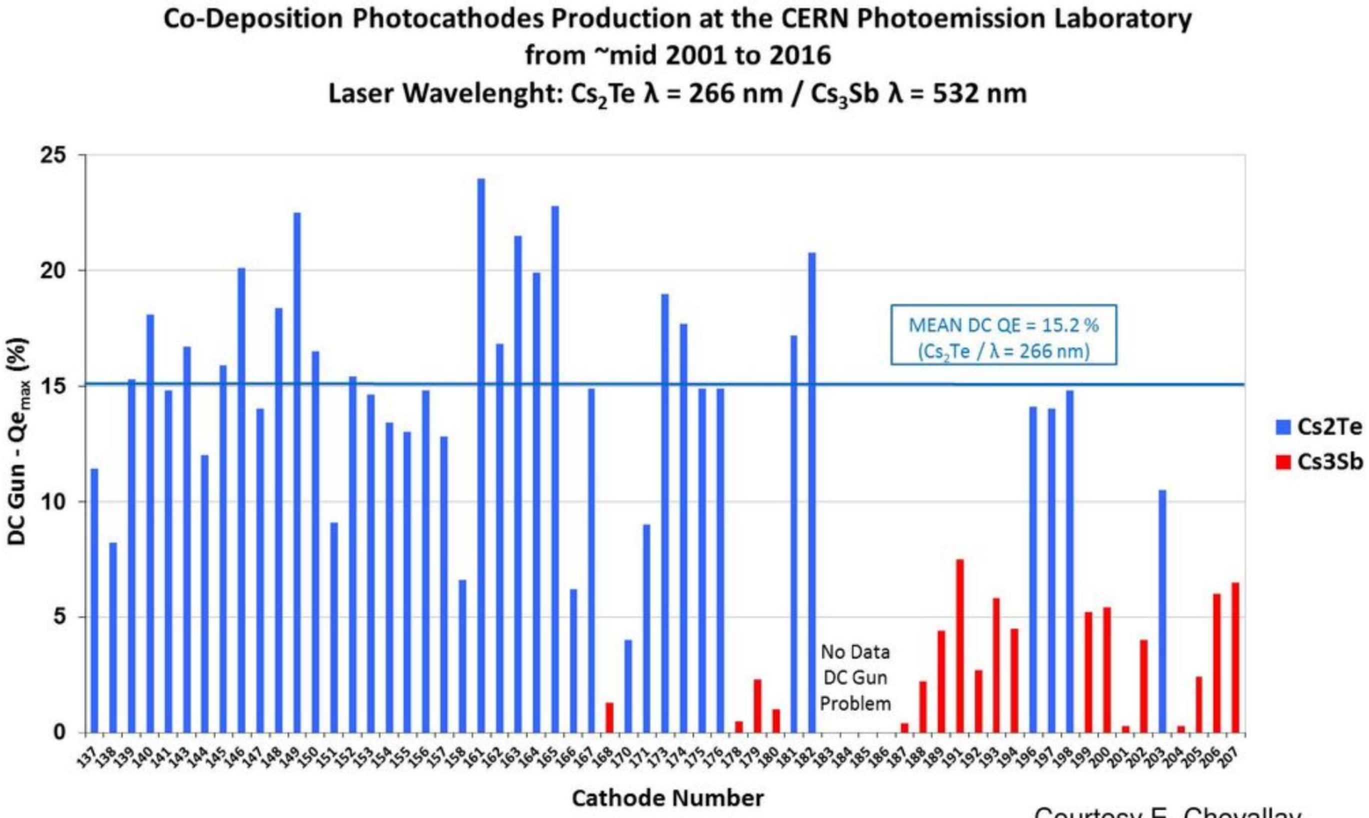
H. Panuganti, E. Chevallay, V. Fedosseev, M. Himmerlich, Synthesis, surface chemical analysis, lifetime studies and degradation mechanisms of Cs-K-Sb photocathodes, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 986, 2021

Photocathode production, transport and characterization

Photocathode transport device





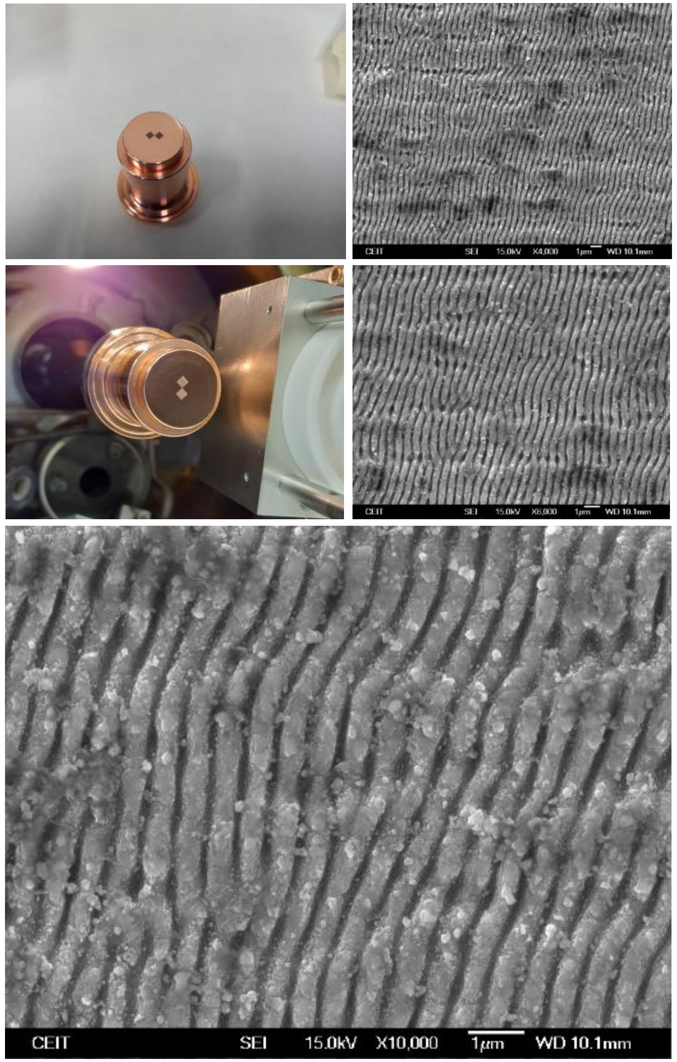


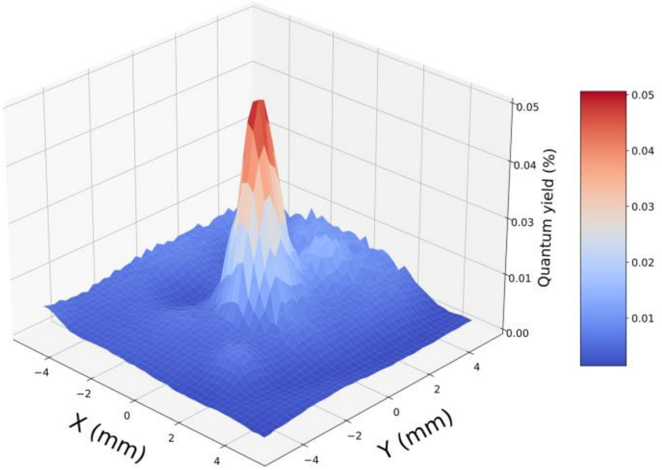
Courtesy E. Chevallay

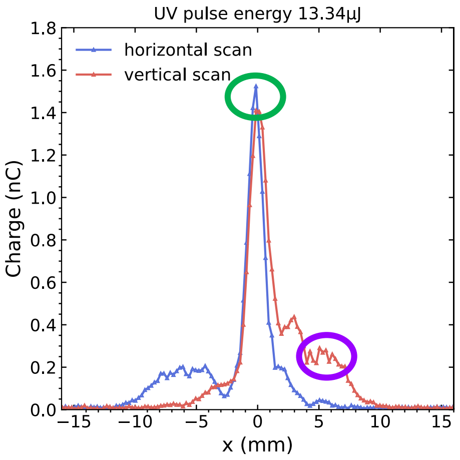
Cs_3Sb and CS_2Te photocathode experience at CERN

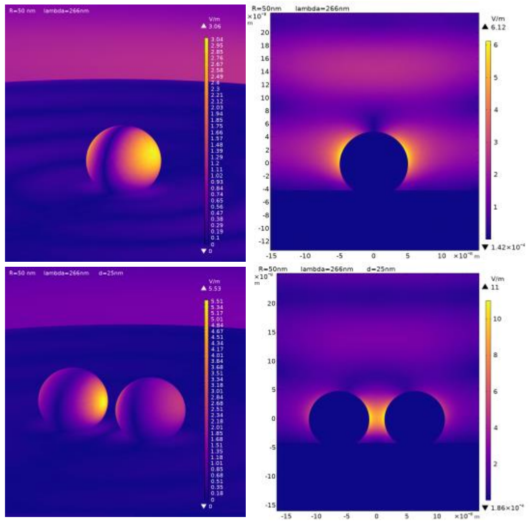
- Cs_3Sb seems to be less robust than Cs_2Te and more sensitive to non-optimal operation conditions.
- For obtaining good lifetimes with Cs_3Sb cathodes it is important to have the following conditions:
  - Excellent vacuum
  - Very stable phase between RF and laser
  - Linear charge extraction regime of the gun. Otherwise non-extracted e- can cause desorption in the gun -> bad lifetime.
  - Good laser beam shape characteristics
- More studies are needed, but mature technology with great potential for high charge production in ERLs for example.
- Capability of adapting photocathode design to specific projects, including future accelerators such as LHeC and FCC-eh.

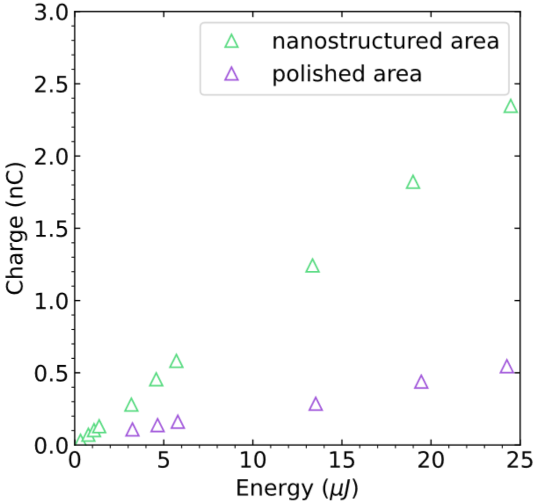
Plasmonically enhanced metallic photocathodes

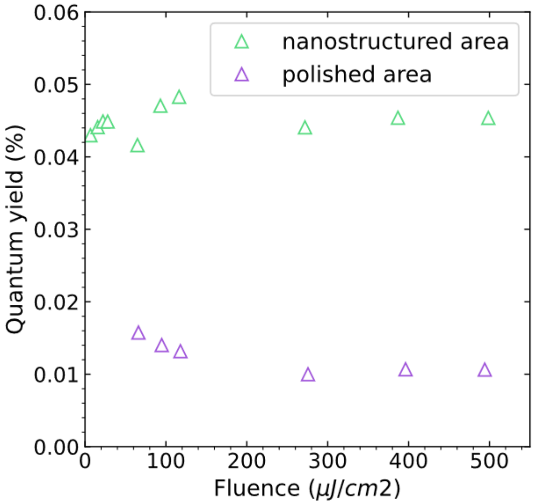


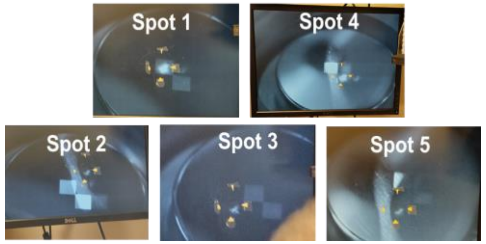








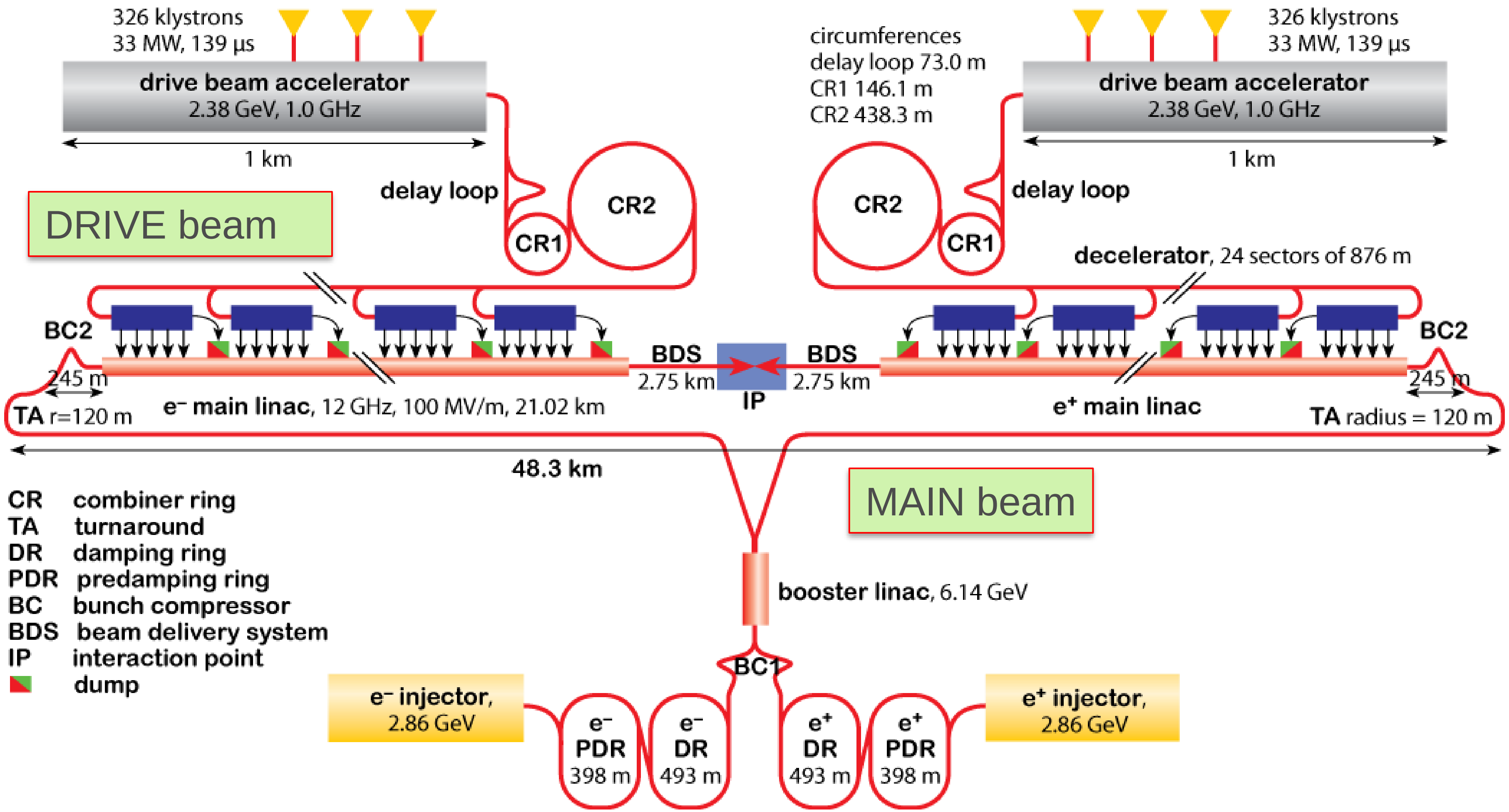




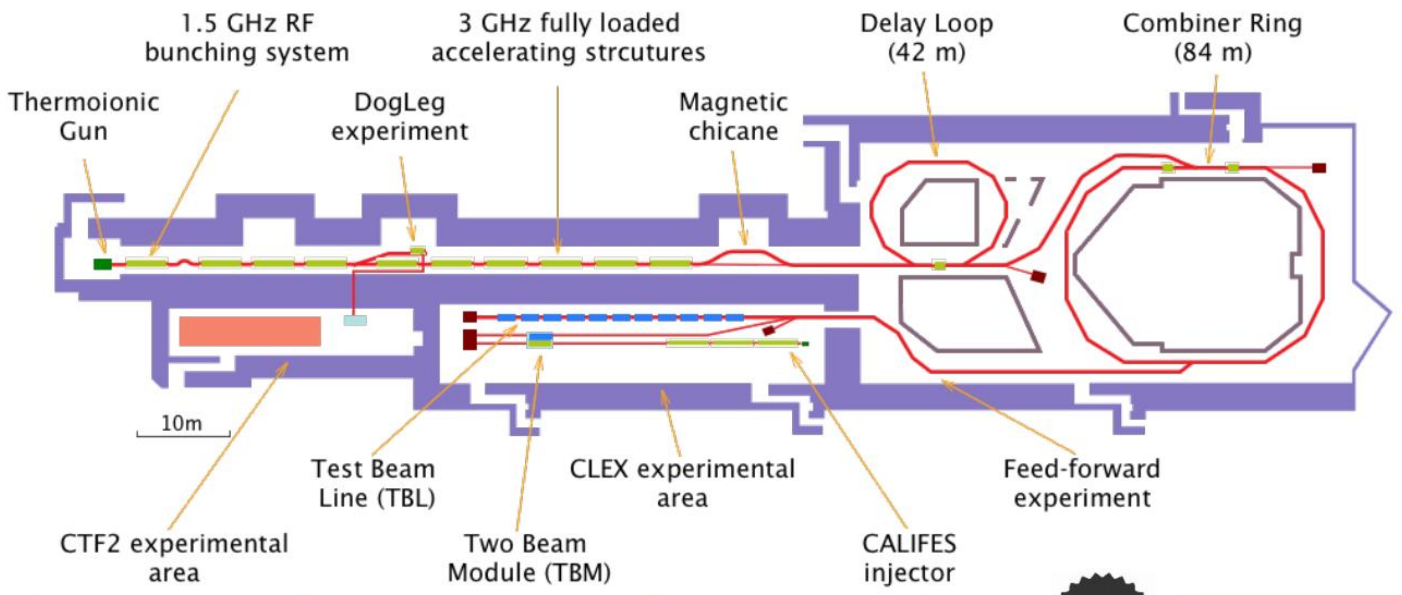
Name	Cu2p	O1s	C1s	K2p	Te3d	Cs3d
XPS_spot_01	42.8	16.1	20.1	0.2	20.1	0.6
XPS_spot_02	44.1	5.6	21.0	0.1	28.0	1.0
XPS_spot_03	44.3	4.0	22.7	0.1	27.8	1.0
XPS_spot_04	42.9	14.8	20.3	0.3	21.1	0.6
XPS_spot_05	43.9	4.7	22.1	0.1	28.3	1.0

Part II: CERN Photoinjector activities

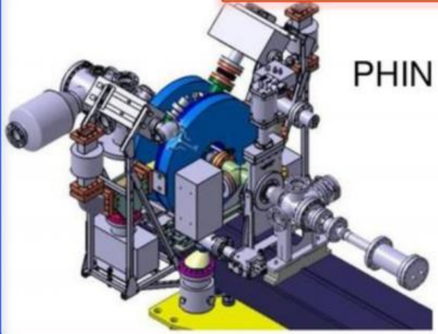
CLIC accelerator concept



CLIC Test Facility (CTF3)



DRIVE beam



PHIN

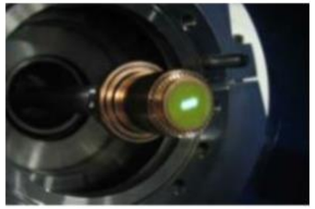
Cs_2Te / Cs_3Sb
Co-deposition

Now at:

AWAKE

MAIN beam

Cs_2Te @ CALIFES
In-situ, dual layer



NEW

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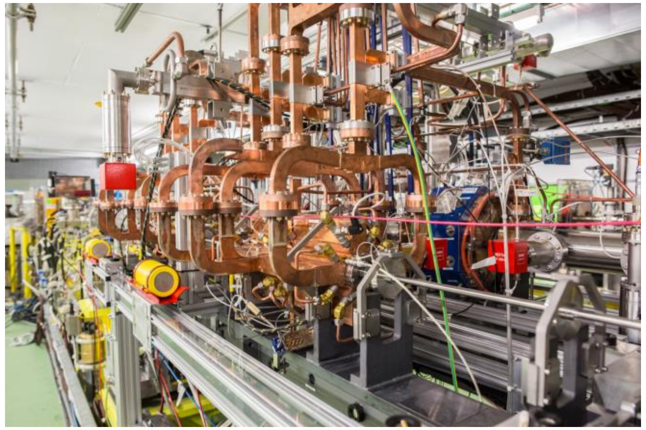
Test facility for:

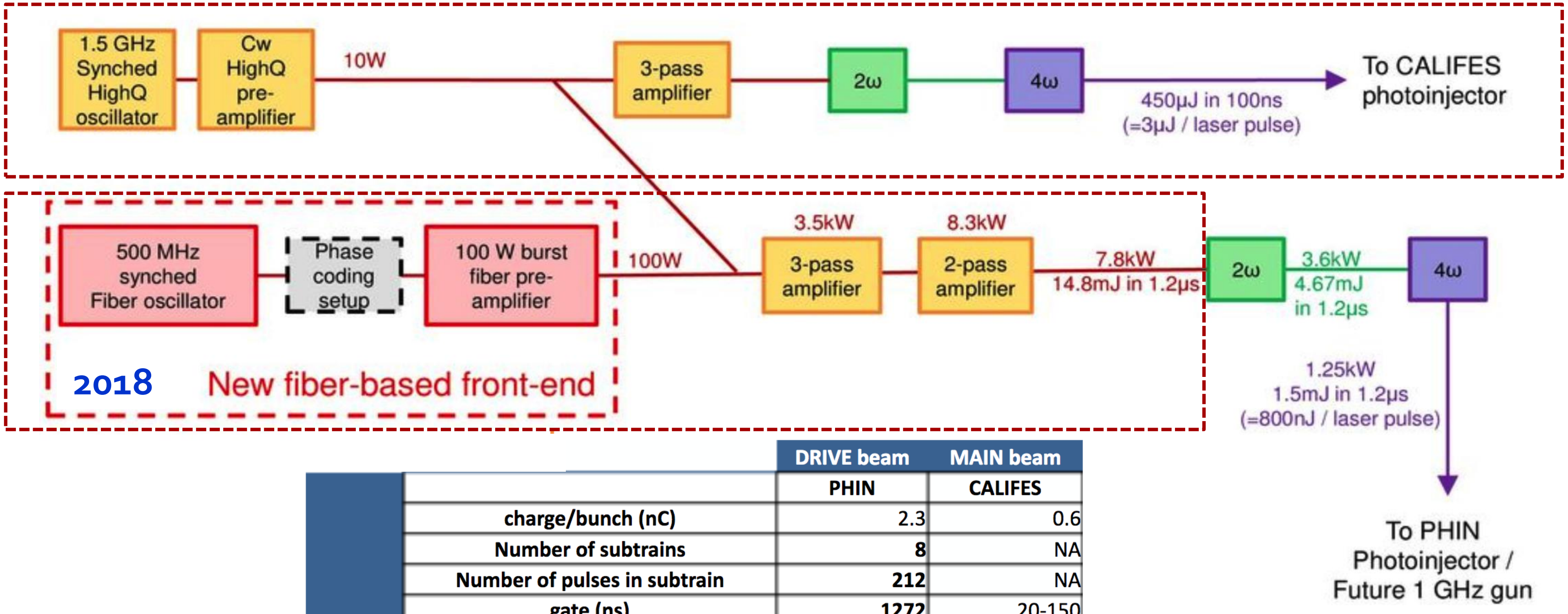
- X-band technology
- Bunch compression
- Advanced beam dynamics
- Plasma lens, AWAKE…
- Wakefield physics
- Radiation studies



Laser development for CLIC

CLIC
Main Beam

CLIC
Drive Beam



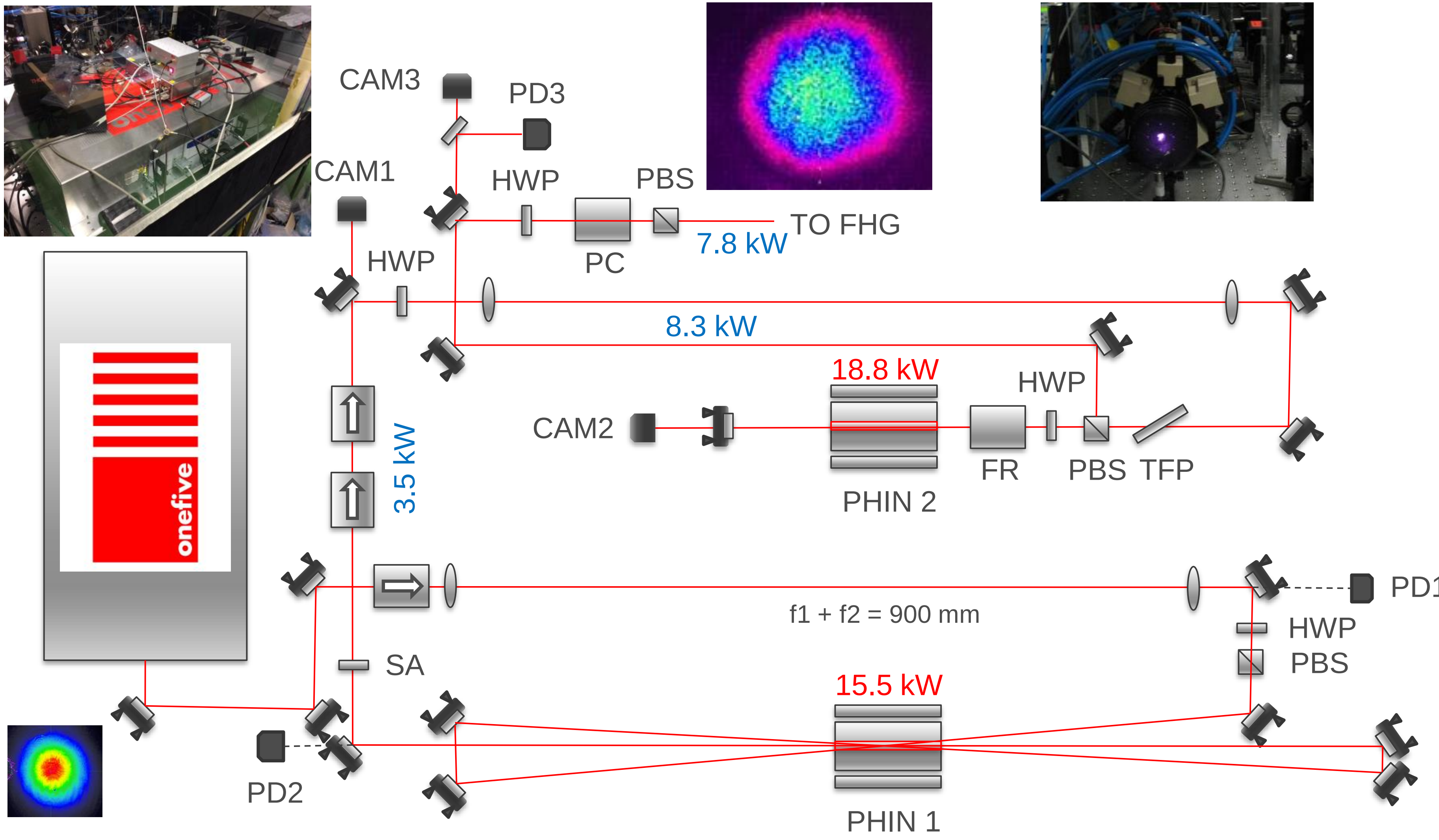
Now CLEAR photoinjector

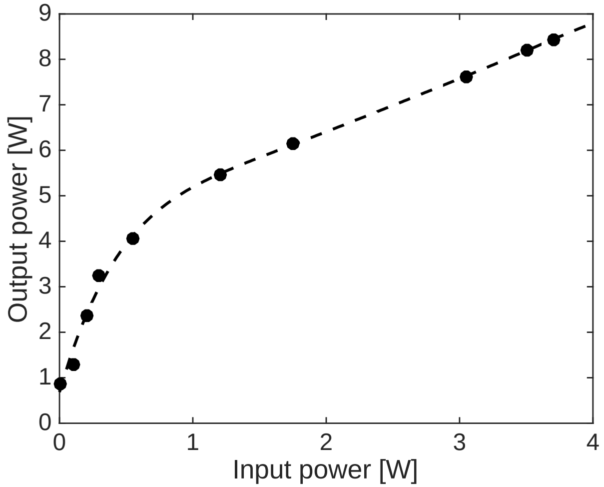
Now ICS source @ CLEAR

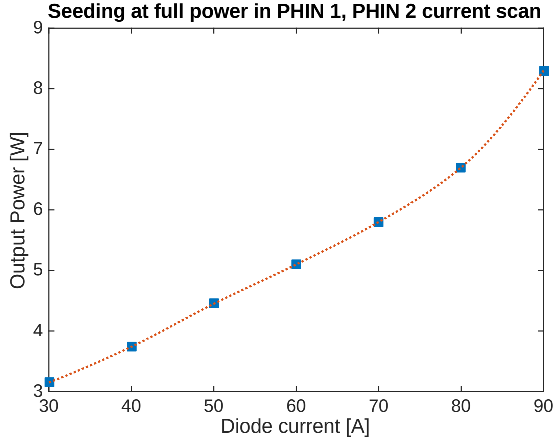
Electrons	DRIVE beam	MAIN beam
	PHIN	CALIFES
charge/bunch (nC)	2.3	0.6
Number of subtrains	**8**	NA
Number of pulses in subtrain	**212**	NA
gate (ns)	**1272**	20-150
bunch spacing(ns)	0.666	0.666
bunch length (ps)	10	10
Rf reprate (GHz)	1.5	1.5
number of bunches	1802	32
machine reprate (Hz)	**5**	5
margine for the laser	**1.5**	1.5
charge stability	**<0.25%**	<3%
QE(%) of Cs2Te cathode	**3**	0.3

E. Granados, E. Chevallay, V. Fedosseev, H. Panuganti “Capabilities and performance of the CLEAR facility photo-injector laser”, CERN OPEN 2020-002 (2019)

CLIC drive beam laser in 2022 (now for Inverse Compton Scattering experiments at CLEAR in 2023)



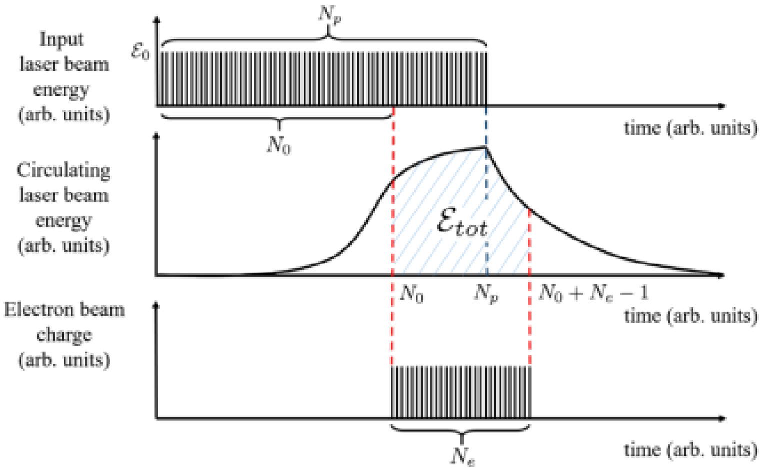




CLIC drive beam laser in 2022 (now for Inverse Compton Scattering experiments at CLEAR in 2023)

- 2 laser set-ups at CLEAR suitable for ICS:
  - PHIN 1 has a lower burst repetition rate of 5 Hz. The beam quality is low, more than 50% power may not be coupled with the best mode matching.
  - The One-five laser is useful for higher Q cavities. It has a near-perfect beam quality, compact and fully independent of the CLEAR control system → would like to consider this laser for FP cavity
- Fabry-Perot enhancement cavity in burst mode could be feasible

Parameter	PHIN 1	One-five	Photo-injector	Unit
P_{avg}	7	2	10	W/s
Burst rep rate	5	10	10	Hz
Micropulse rep rate	0.5	0.5	1.5	GHz
Burst duration	< 300 µs	< 1 ms	< 120 ns	
Wavelength	1047	1047	1047	nm
Pulse duration	4	4	4.7	ps
Micropule energy	9.3	0.4	10–15	µJ
Burst energy	1400	200	2.3	mJ
# pulses in each burst, N_p	150,000	500,000	180	



Pierre Favier et al, Phys. Rev. Accel. Beams **21**, 121601 (2018)

Table 2: Projected parameters of the photons generated by the HPCI-based ICS source.

Parameter	Value	Unit
Energy	360	keV
Source *rms* spot size, σ_γ	10	μm
Total flux, $\mathcal{F}$	9×10^{13}	ph/s
Flux in a 1.5 mrad cone	2×10^{13}	ph/s
Average brilliance, $\mathcal{B}$	4×10^{14}	[1]
Peak brilliance, $\hat{\mathcal{B}}$	3×10^{22}	[1]

[1] ph/(s mm^2 mrad^2 0.1%BW).

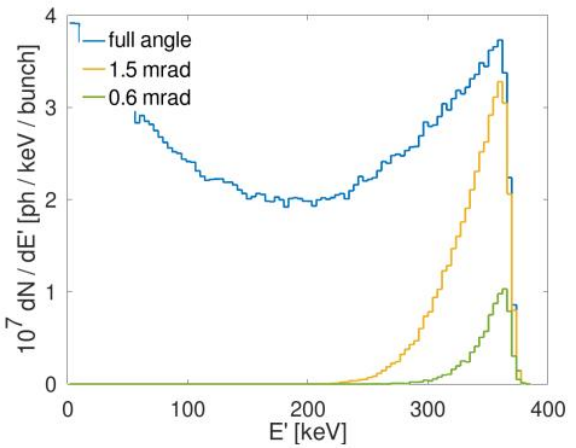
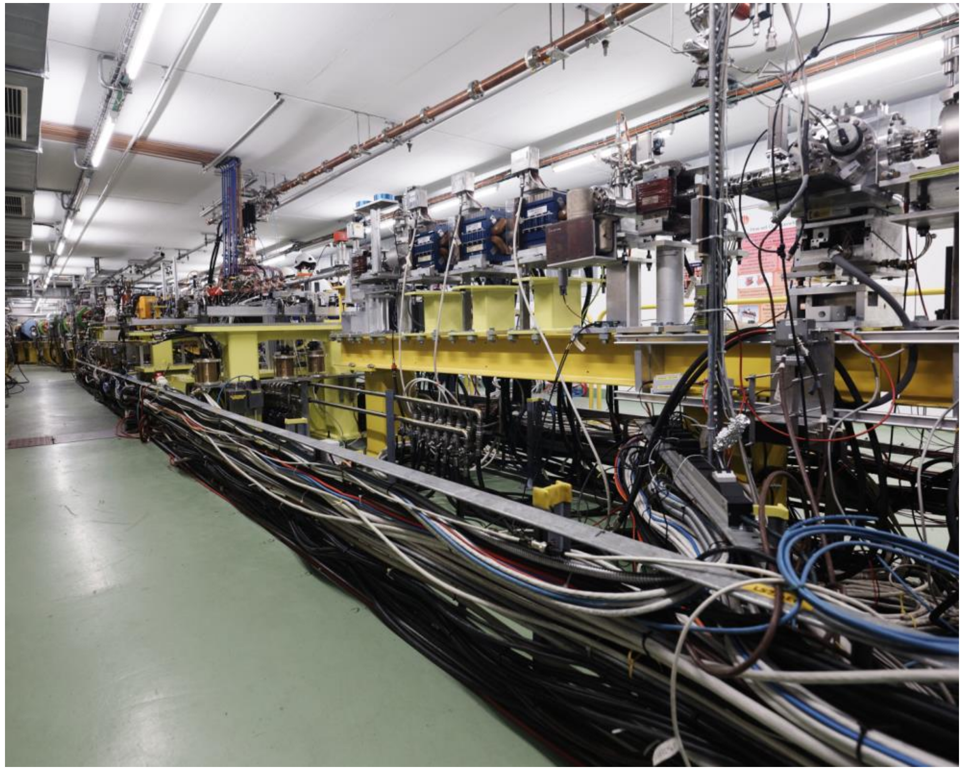


Figure 2: Scattered photon spectra from RF-Track generated by the HPCI-based ICS source. The 0.6 mrad spectrum corresponds to an energy bandwidth of 5%.

Musat, V.; Latina, A.; D'Auria, G. A High-Energy and High-Intensity Inverse Compton Scattering Source Based on CompactLight Technology. Photonics 2022, 9, 308. https://doi.org/10.3390/photonics9050308

CLIC main beam -> CLEAR facility

- Multipurpose e- accelerator operating since 2017 and until 2025.
  - CLEAR is a versatile 200 MeV electron linac + a 20 m experimental beamline, operated at CERN as a multi-purpose user facility.
  - Currently **>98% uptime** for photoinjector.
  - Providing a test facility at CERN with **high availability, easy access and high quality e- beams**.
  - Performing R&D on accelerator components, including beam instrumentation prototyping and **high gradient RF technology**
  - Providing an irradiation facility with high-energy electrons, e.g. for testing electronic components in collaboration with ESA or for medical purposes (**VHEE/FLASH**)
  - Performing R&D on novel accelerating techniques – electron driven plasma and THz acceleration.
  - Maintaining CERN and European expertise for electron linacs linked to future collider studies



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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

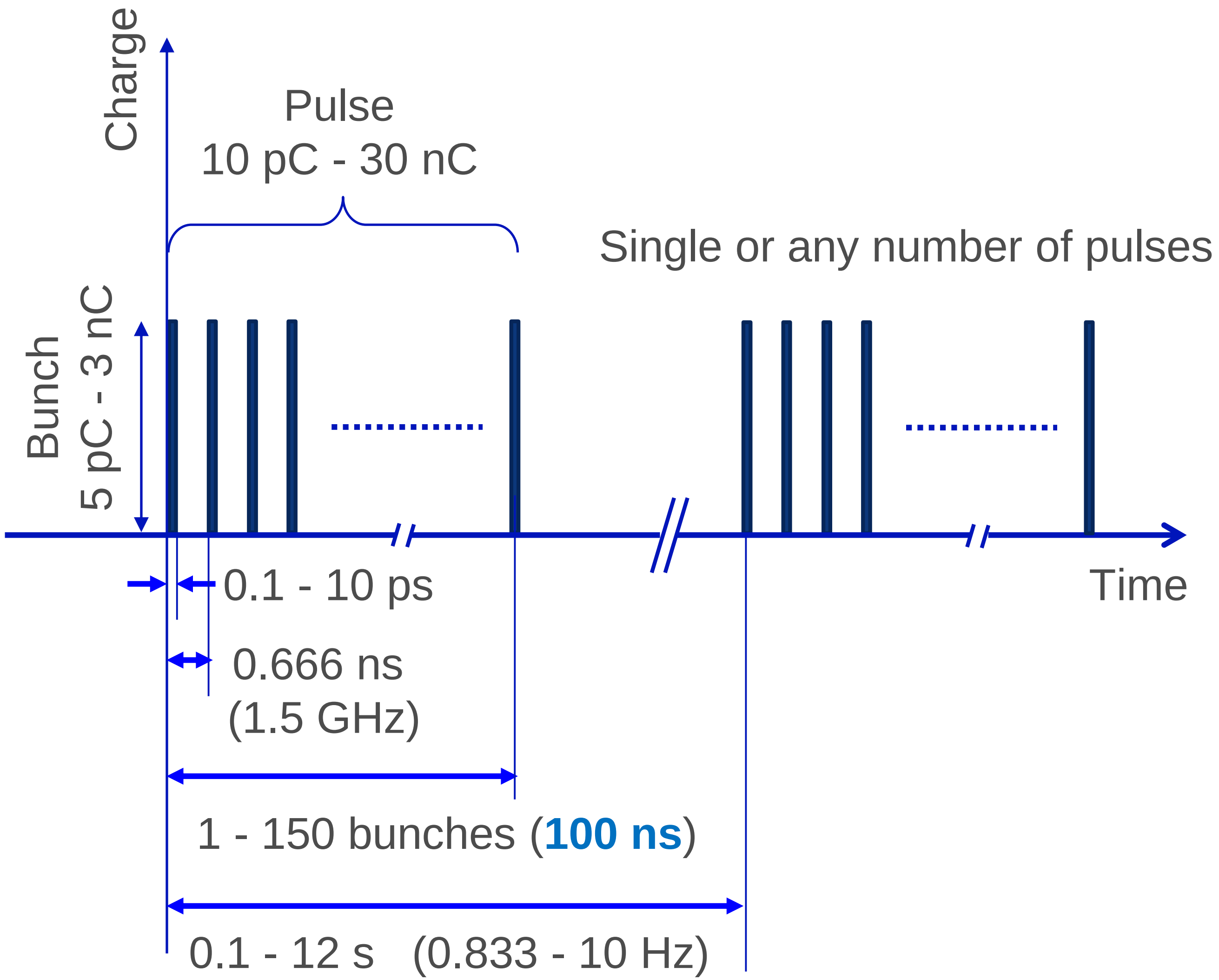
CHUV Centre hospitalier universitaire vaudois

esa European Space Agency

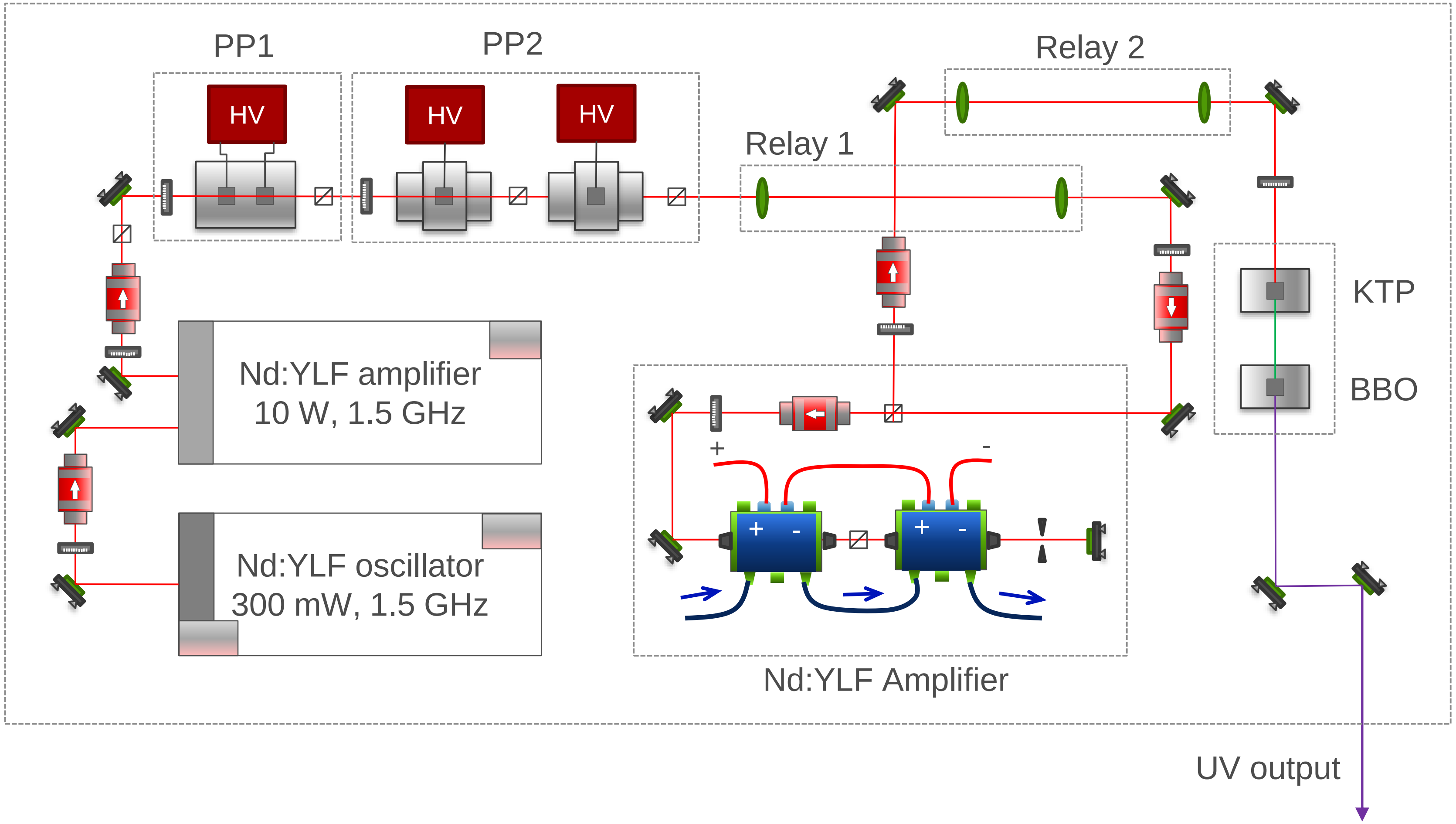
CERN IRRAD Proton Facility

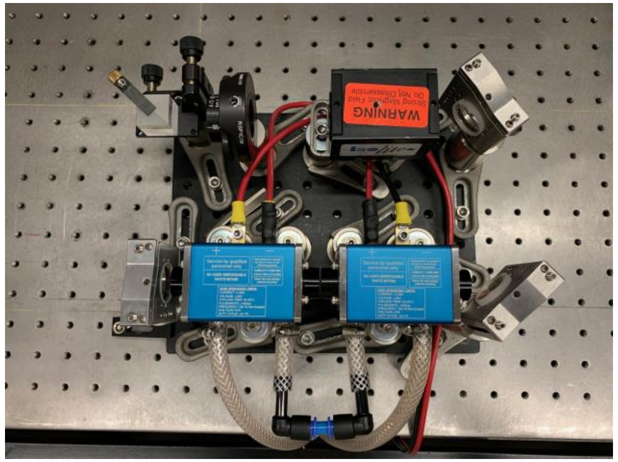
CLEAR Facility photoinjector

Beam parameter	Range
Energy	**60 – 220 MeV**
Energy Spread	< 0.2 % rms (< 1 MeV FWHM)
Bunch Length	0.1 ps – 10 ps rms
Bunch Charge	5 pC – 2 nC
Number of bunches per train	1 to ~150
Maximum total train charge	**80 nC**
Normalized emittances	3 mm to 30 mm (bunch charge dependent)
Repetition rate	0.8 to 10 Hz
Bunch spacing	1.5 GHz (from Laser) or 3GHz (double-pulse setup in the UV)



CLEAR laser development





E. Granados "Upgrade of the CLEAR diode-pumped Nd:YLF power amplifier", CERN OPEN 2020-001 (2020)

CLEAR laser development

Oscillator output

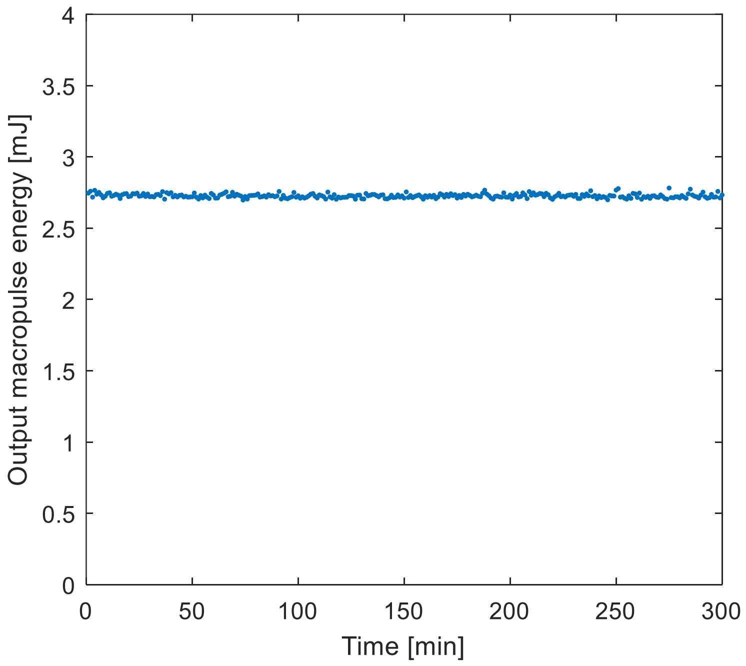
Parameter	Value
P_avg	321.1 mW
P_max	322.6 mW
P_min	320.2 mW
P_std	0.47%
Pk-Pk	0.75%

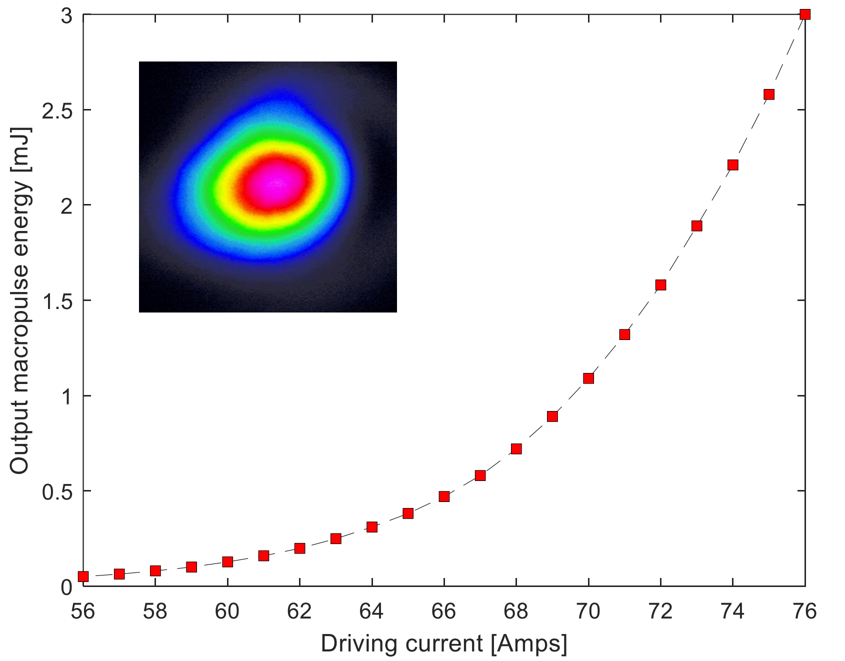
Pre-amp output

Parameter	Current value
P_avg	**9.68 W**
P_max	9.75 W
P_min	9.60 W
P_std	**0.37%**
Pk-Pk	**1.53%**

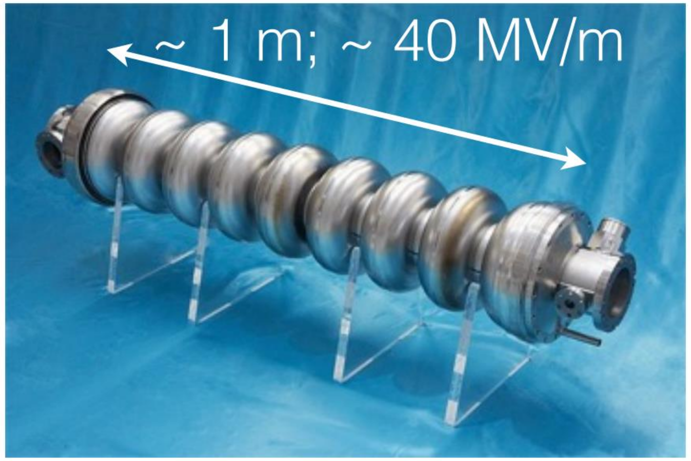
Main amplifier output

Parameter	Value
E_avg	2.726 mJ
E_max	2.781 mJ
E_min	2.697 mJ
E_std	**0.52%**
Pk-Pk	3.08%

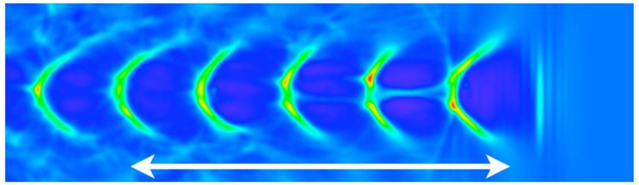




PHIN electron gun -> AWAKE Collaboration

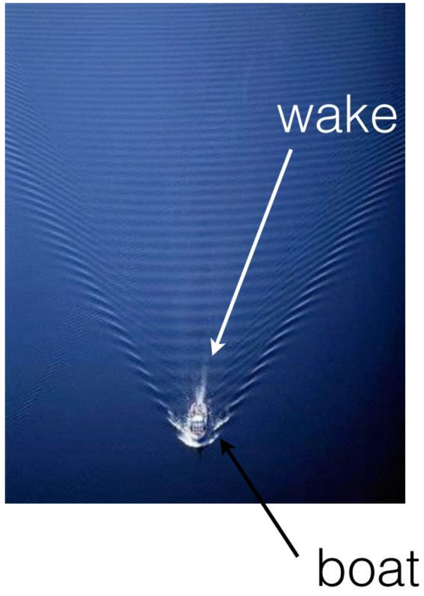


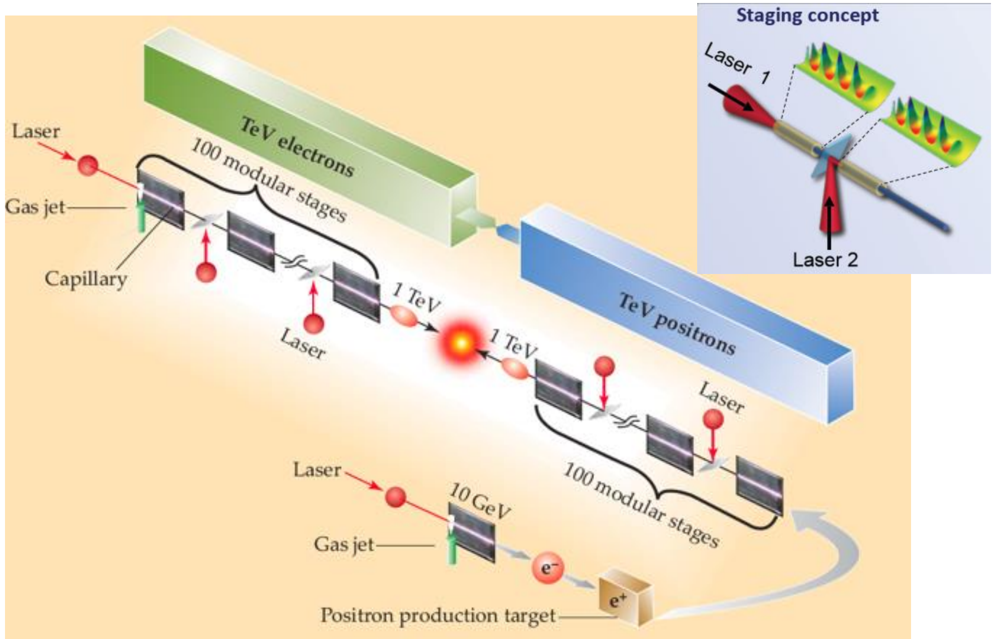
a section of RF cavity



~ 50 μm; ~ 100 GV/m

a plasma wave





e+/e- collider @ 1 TeV in a few 100s meters

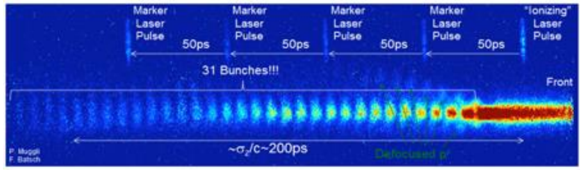
- Conventional Accelerators are large (100 m) and expensive (10-100 M$)
- Conventional accelerators cannot achieve better than a few 10 MV/m or you get breakdown
- Plasma waves are a possible alternative – providing a route to small scale accelerators and radiation sources

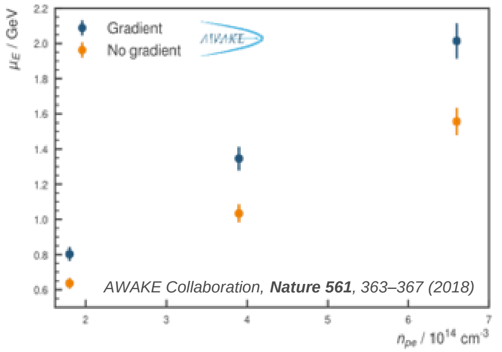
Laser technology to develop
High repetition rate (10's kHz)
High average power (100's kW)
High efficiency (10's de %)

Leemans & Esarey, Physics Today 2009

Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE)

- Accelerator R&D project based at CERN, taking advantage of high energy proton beams
- "It is a proof-of-principle experiment investigating the use of plasma wakefields driven by a proton bunch to accelerate charged particles"
- Collaboration of 22 institutes world-wide
- AWAKE Run 1:
  - 1st milestone: Demonstrate seeded self-modulation of the proton bunch in plasma (2016/2017)
  - 2nd milestone: Demonstrate electron acceleration in plasma wakefield driven by a self-modulated proton bunch (2018)
- AWAKE Run 2 (2021-2028):
  - Accelerate an electron beam to higher energies of 0.5-1 GV/m while preserving the electron beam quality and demonstrate scalable plasma sources technology.
- AWAKE after 2028: Application to physics experiments (dark photon search etc).



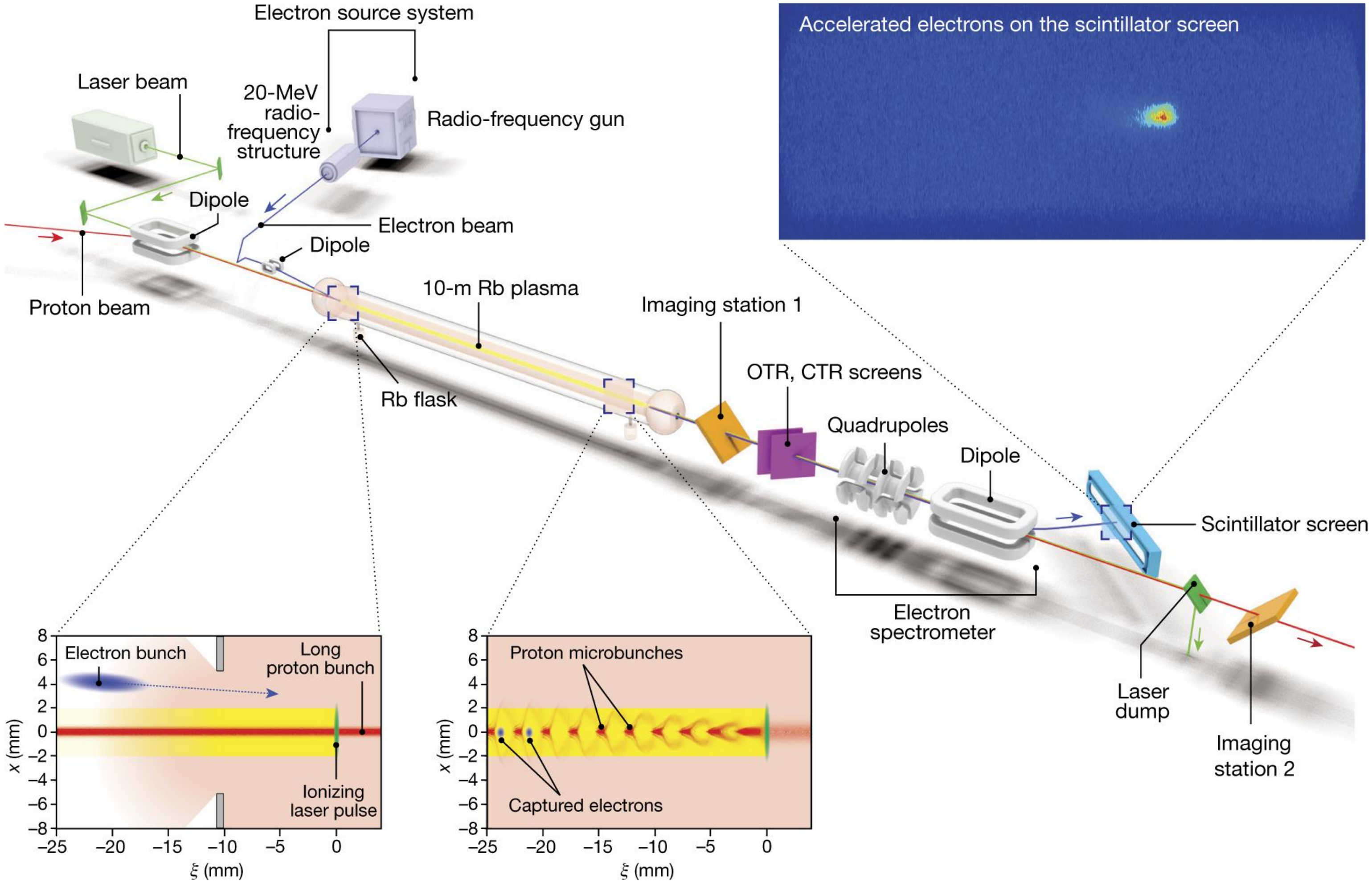


*AWAKE Collaboration, **Nature 561**, 363–367 (2018)*

AWAKE Collaboration, Phys. Rev. Lett. 122, 054802 (2019).
M. Turner et al. (AWAKE Collaboration), 'Phys. Rev. Lett. 122, 054801 (2019).
M. Turner, P. Muggli et al. (AWAKE Collaboration), Phys. Rev. Accel. Beams 23, 081302 (2020)
F. Braunmueller, T. Nechaeva et al. (AWAKE Collaboration), Phys. Rev. Lett. July 30 (2020).
A.A. Gorn, M. Turner et al. (AWAKE Collaboration), Plasma Phys. Control Fusion, Vol. 62, Nr 12 (2020).
F. Batsch, P. Muggli et al. (AWAKE Collaboration), PRL (2021).

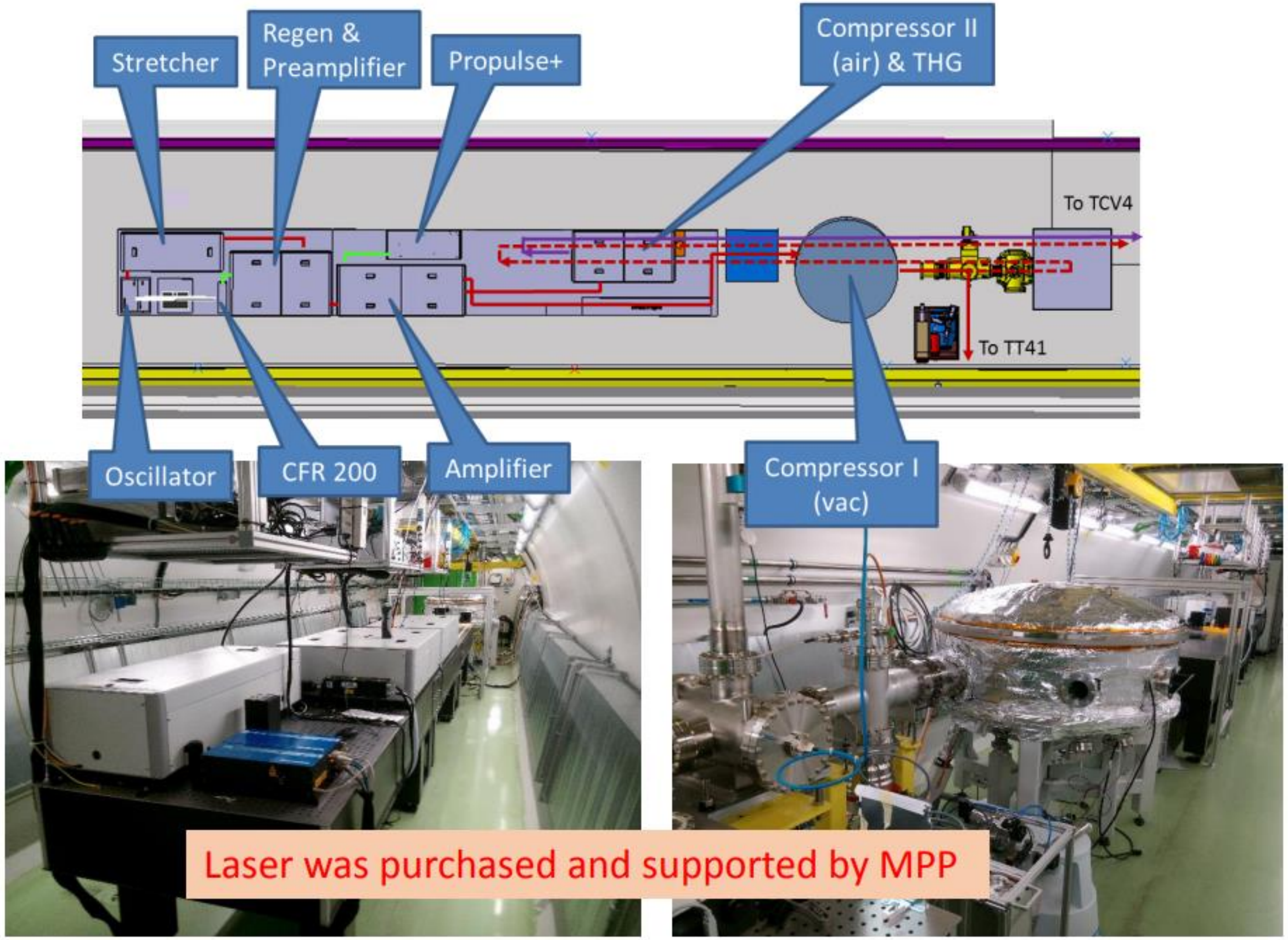
AWAKE Run 1

- Proof-of-principle experiment: wakefield plasma acceleration using a proton bunch as a driver, a world-wide first.
- It demonstrated acceleration of a low-energy witness bunch of electrons from 15-20 MeV to several GeV over a short distance (~10 m) by creating a high acceleration gradient of several GV/m
- Our contribution:
  - UV beam generation, delivery, and photocathode, diagnostics.
  - IR beam delivery for plasma generation, diagnostics.
  - Experimental and laser support



Nature volume 561, pages363–367(2018)

AWAKE Run 1 laser beamlines



Laser beam to plasma cell

- λ = 780 nm
- t pulse = 120 fs
- E = 450 mJ

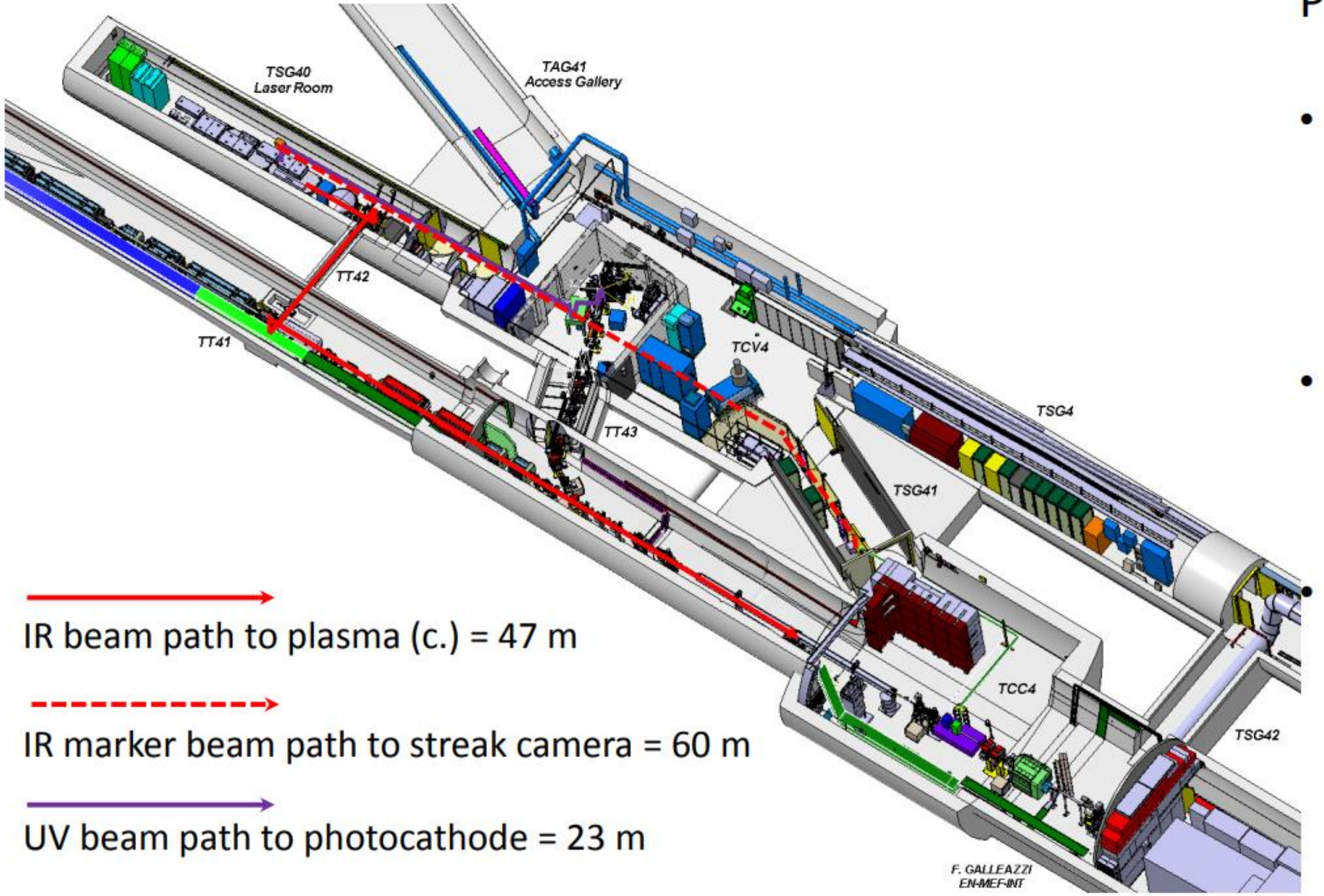
Laser beam to streak camera (“time marker”)

- λ = 780 nm
- t pulse = 120 fs,
- E ≈ 0.01 mJ

Laser beam to electron gun

- λ = 260 nm
- t pulse = 0.3-10 ps
- E = 0.1 - 2 μJ

AWAKE Run 1 laser beamlines



IR beam path to plasma (c.) = 47 m

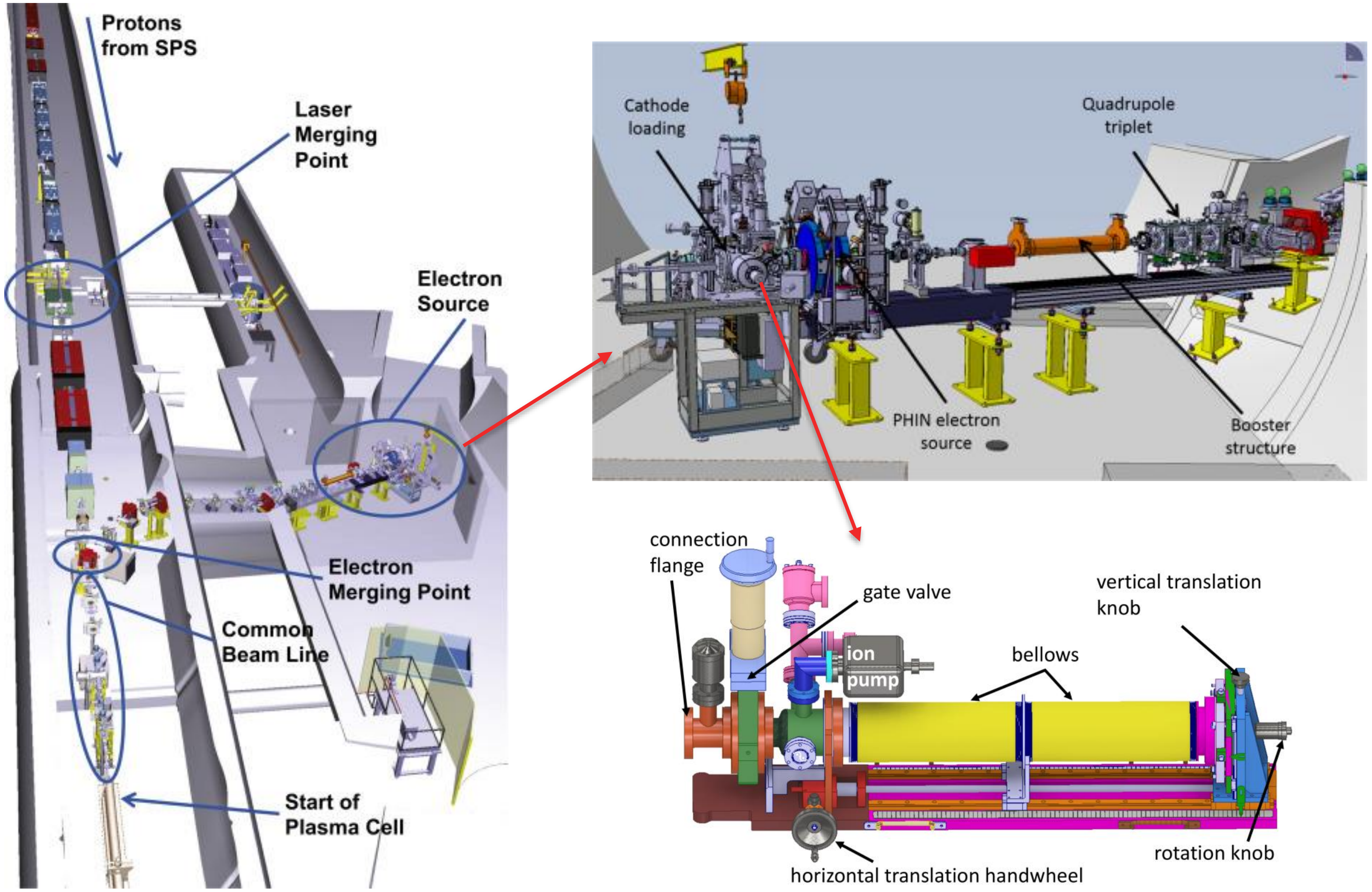
IR marker beam path to streak camera = 60 m

UV beam path to photocathode = 23 m

Problems and their mitigation

- Pointing instability
  - Use of rigid support for optics
  - Applying beam imaging
  - Transport in vacuum
- Beam drifts
  - Temperature stabilization
  - Alignment algorithm
- Optics damage
  - Beam size increasing
  - Decreasing the pulse energy within the possible margin: E (IR) < 200 mJ

AWAKE Run 1 e- injector

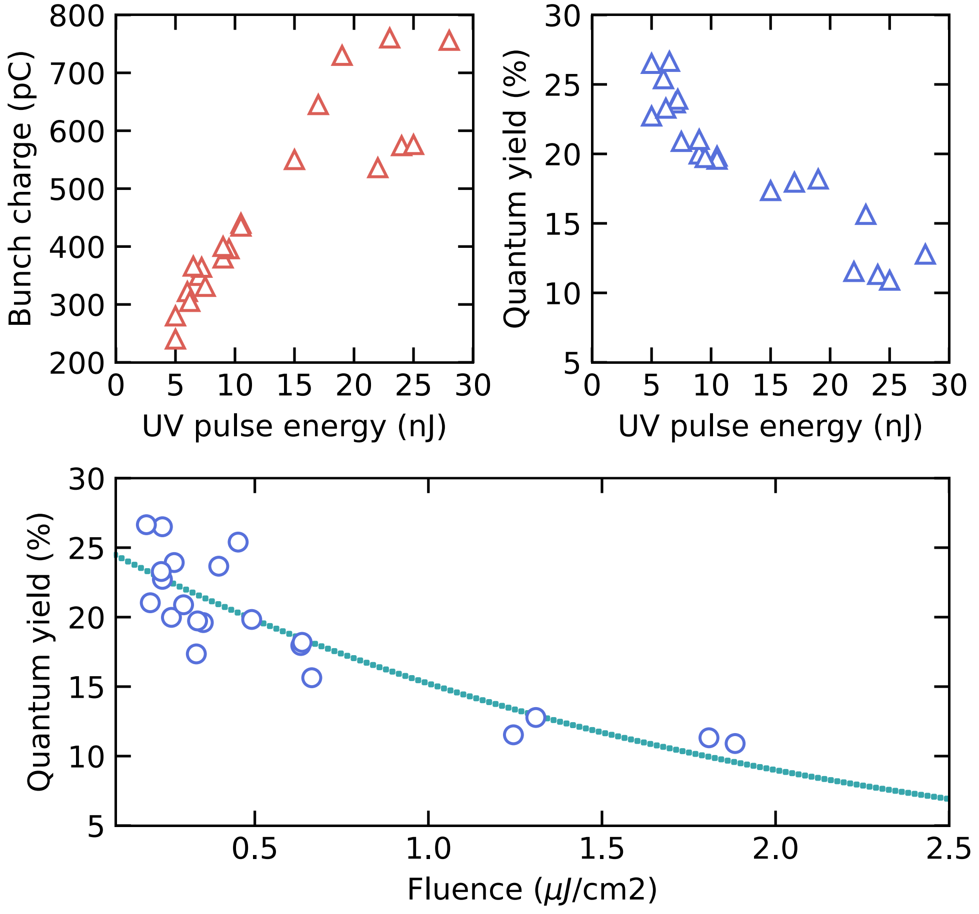


Cs_2Te cathodes produced in the Photoemission lab

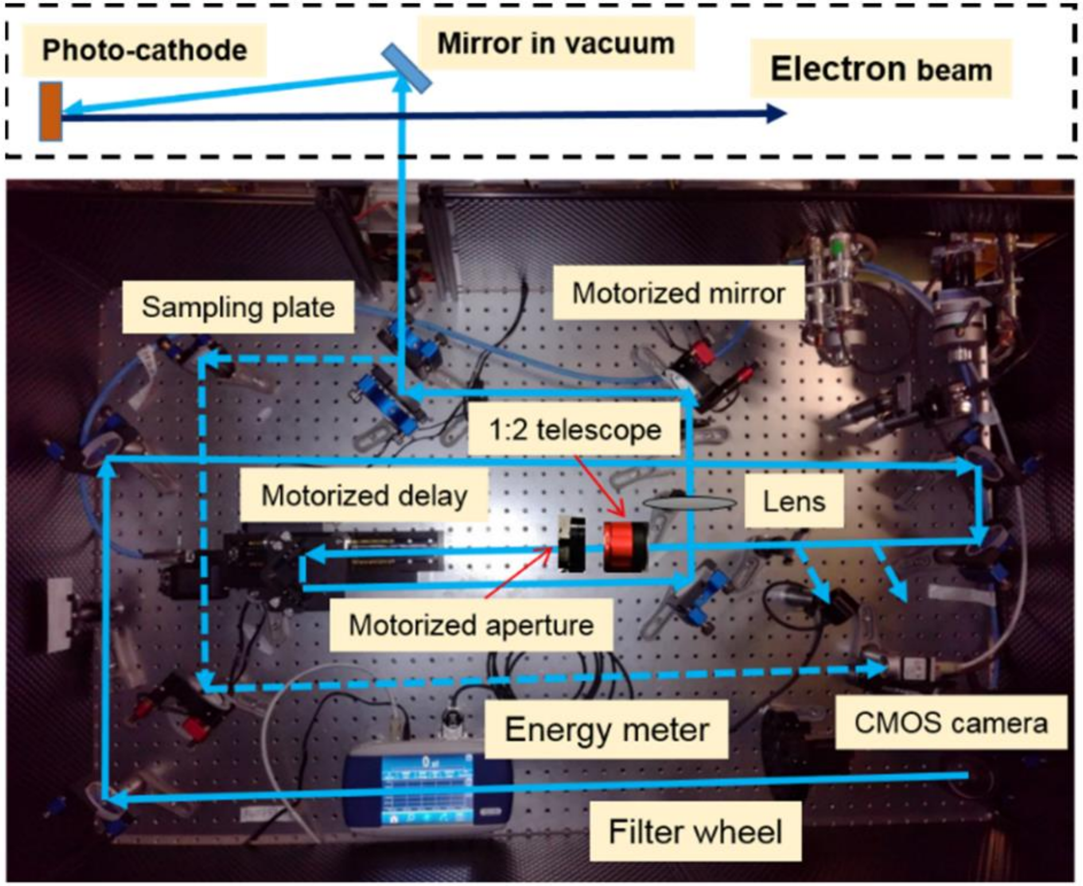
Parameter	Value
Beam energy	18.5 MeV
Energy spread	0.5 %
Stability	10^-2
RMS bunch length	2-3 ps
Bunch charge	100-600 pC
Emmitance	2-5 um
Beam size plasma focus	~190 um

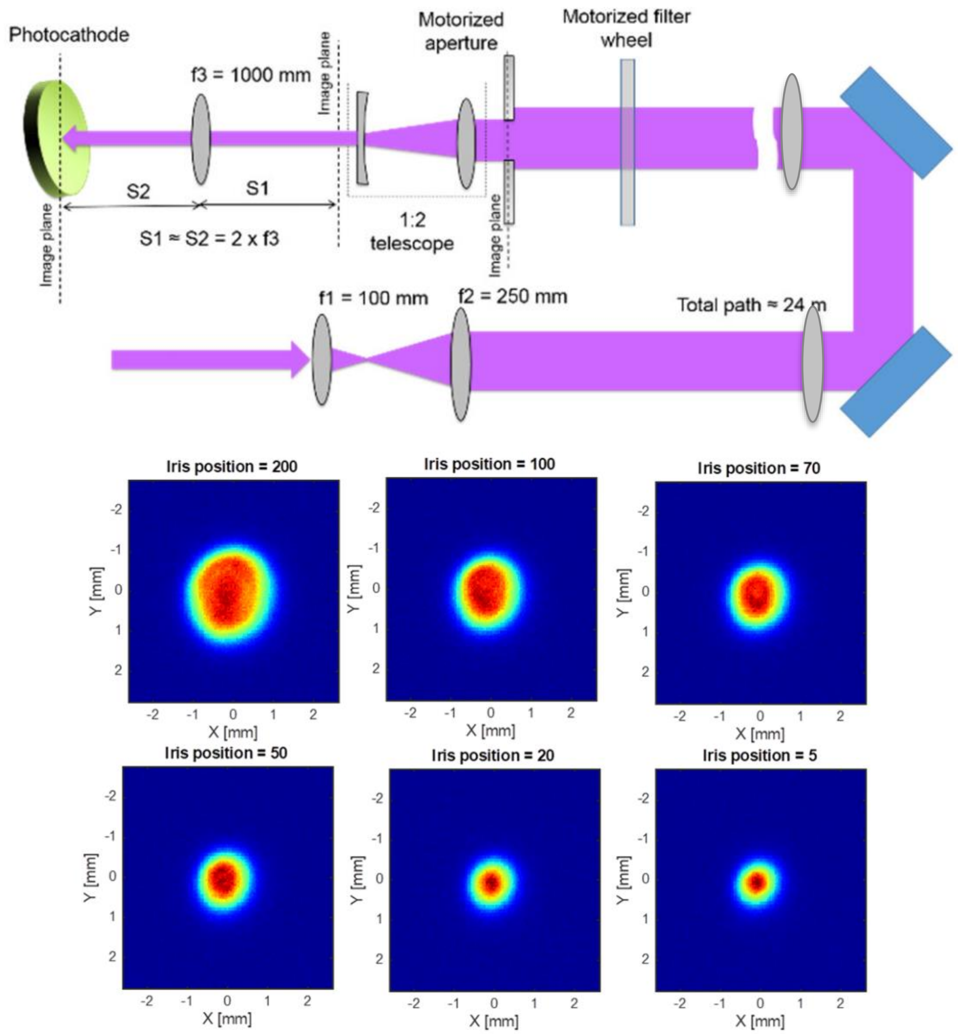
AWAKE Photocathode

- **Photocathode performance at AWAKE RF-photoinjector**
  - **Maximum measured QE ~ 26%,** good agreement with DC-GUN measurements
  - Saturation Fluence ~ 1.5 µJ/cm²
  - Issues to measure pulse energy bellow 5 nJ and charge higher than 800pC during the commissioning tests
  - Photocathode performing very well during last months of intense operation at AWAKE run 2b



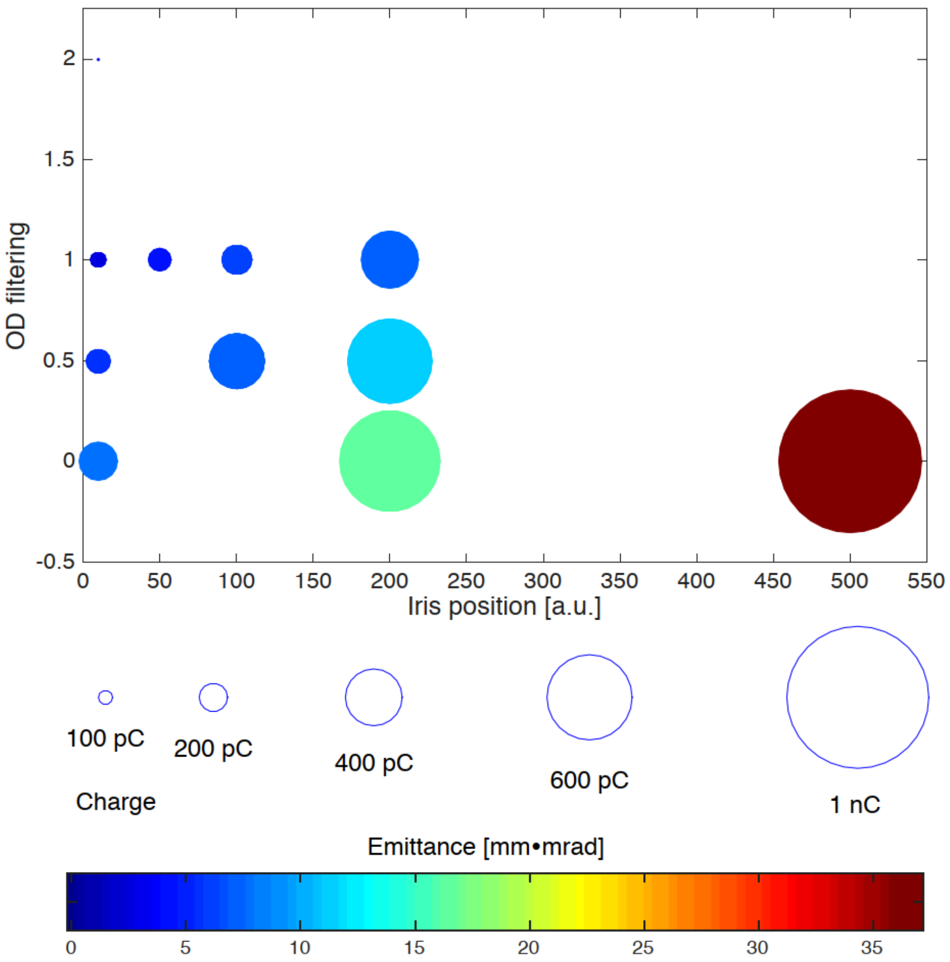
AWAKE photoinjector illumination

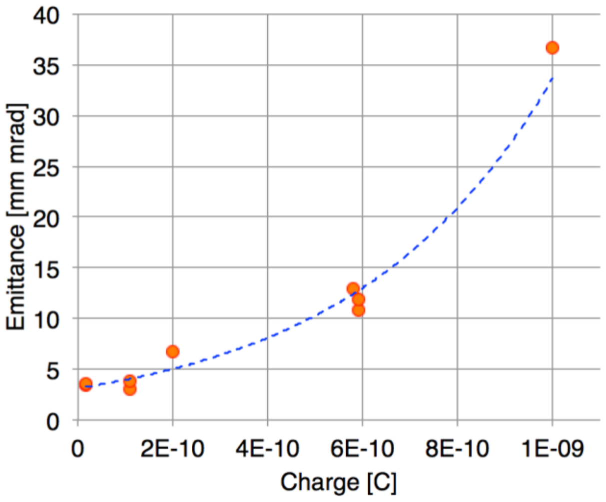


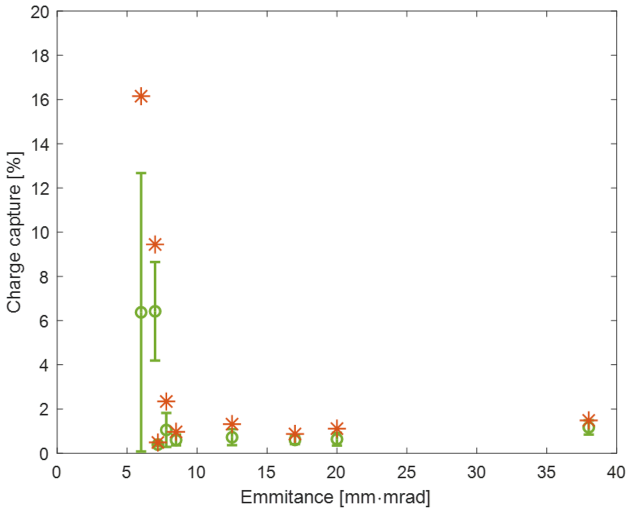


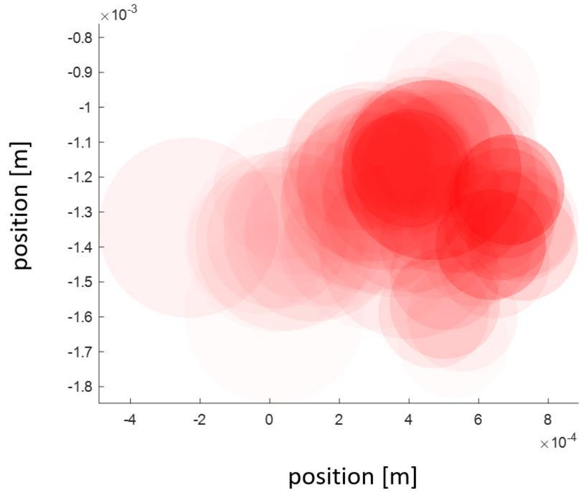
V. Fedosseev et al "Generation and delivery of an ultraviolet laser beam for the RF-photoinjector of the AWAKE electron beam", 10th International Particle Accelerator Conference (2019)

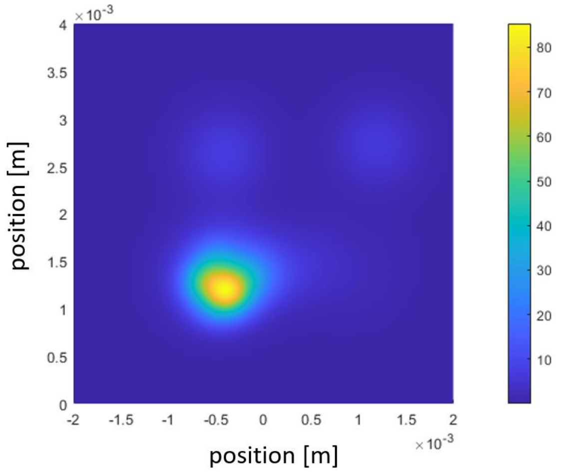
Mapping charge capture at AWAKE





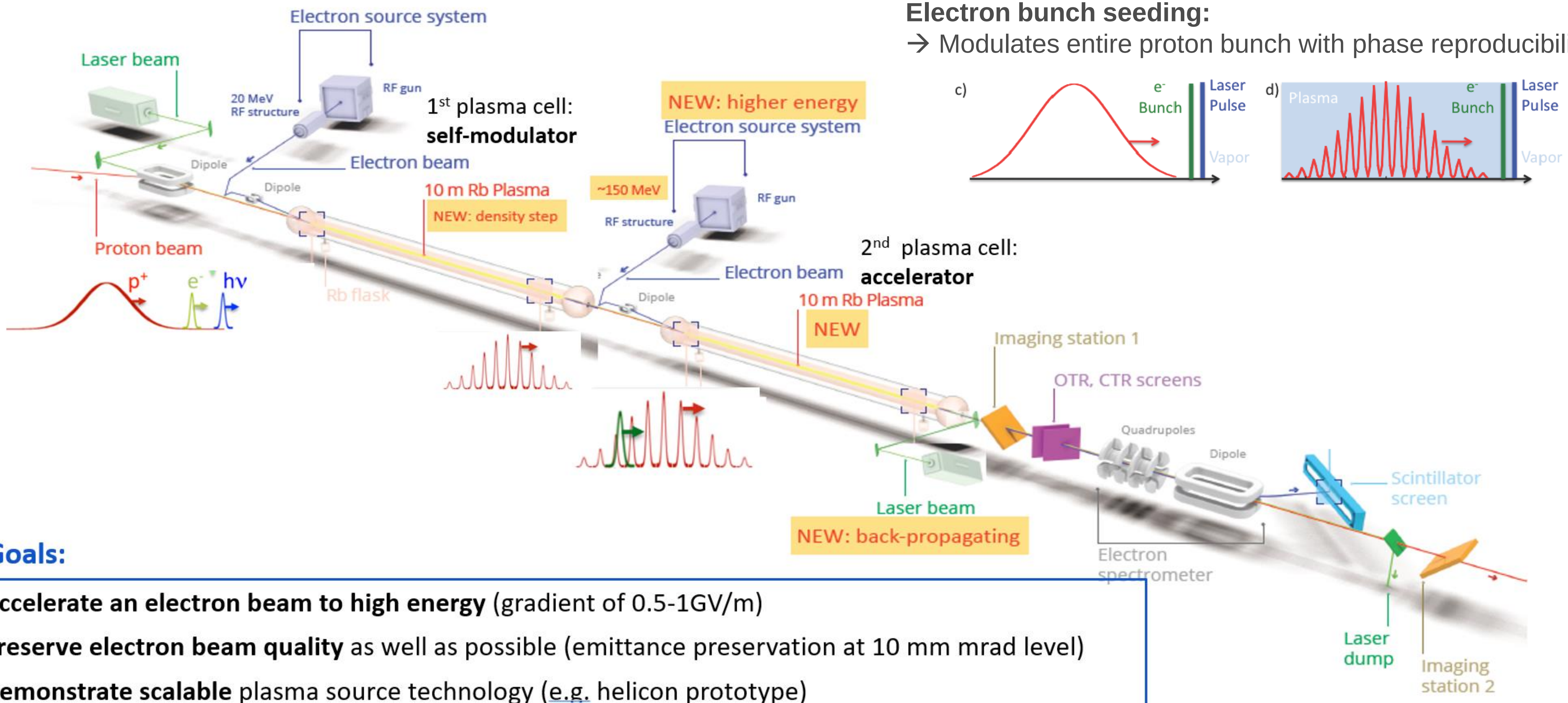






E. Granados et al "Mapping charge capture and acceleration in a plasma wakefield of a proton bunch using variable emittance electron beam injection", arXiv:2206.14075 (2022)

AWAKE run 2 (2021-2028)



Electron bunch seeding:

→ Modulates entire proton bunch with phase reproducibility

Goals:

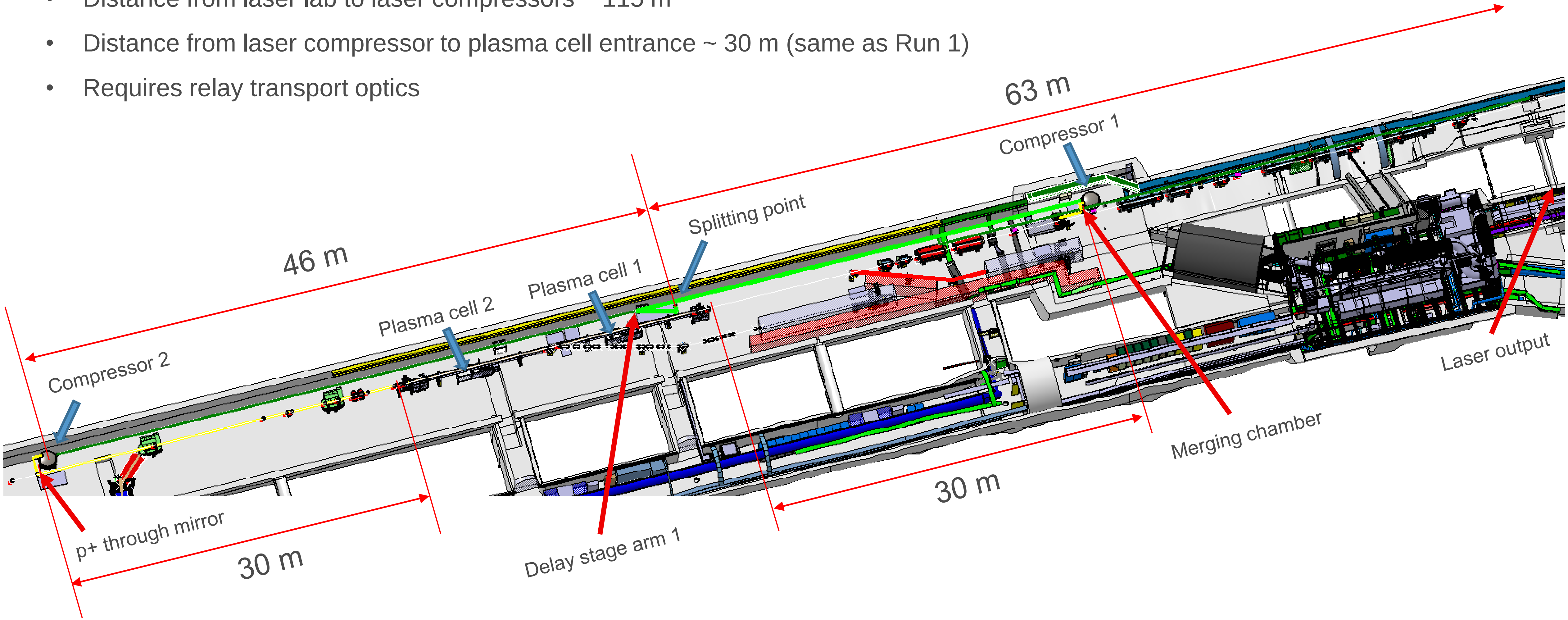
Accelerate an electron beam to high energy (gradient of 0.5-1GV/m)

Preserve electron beam quality as well as possible (emittance preservation at 10 mm mrad level)

Demonstrate scalable plasma source technology (e.g. helicon prototype)

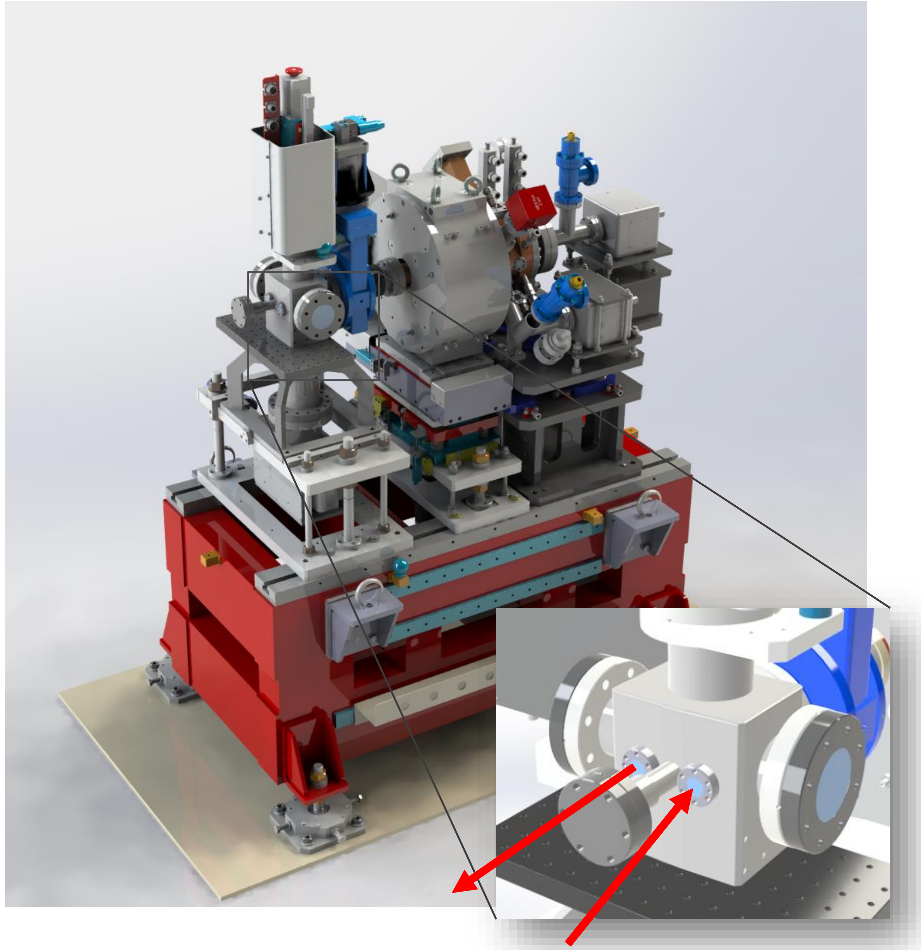
AWAKE 2 (ionizing lasers beam delivery)

- Distance from laser lab to laser compressors ~ 115 m
- Distance from laser compressor to plasma cell entrance ~ 30 m (same as Run 1)
- Requires relay transport optics



AWAKE Run 2 e- gun

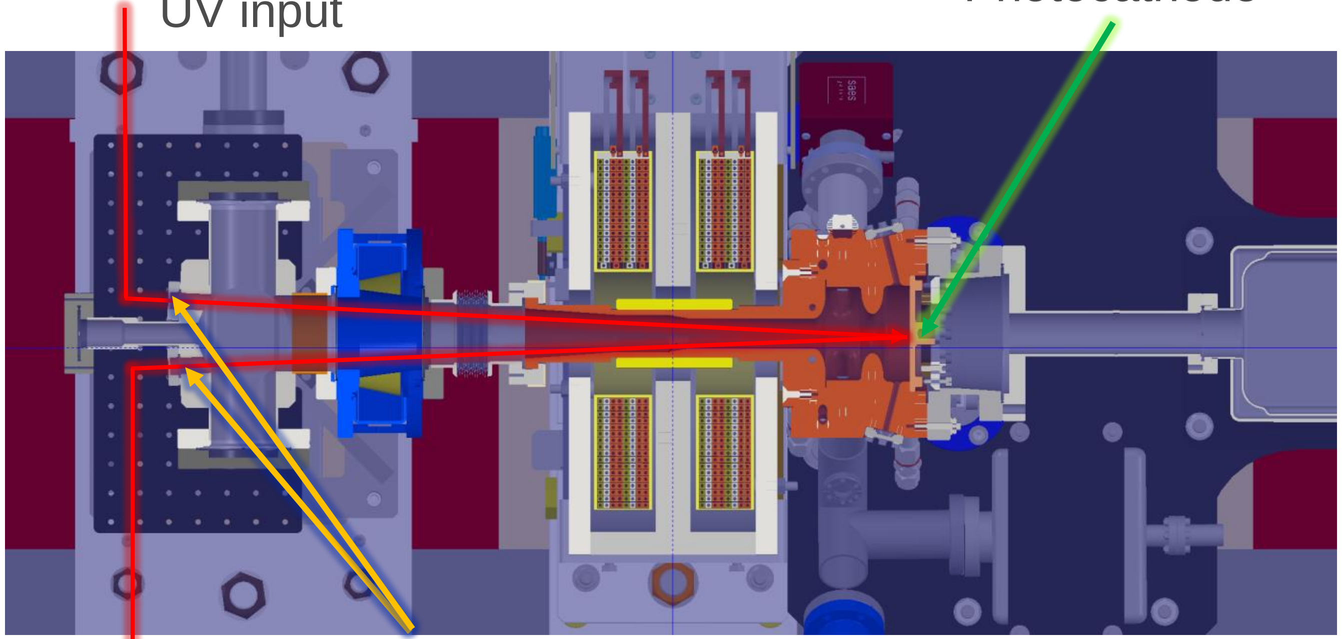
Femtosecond gun from INFN



- Will be installed at CLEAR during 2021-2022
- Possibility of *virtual* and *real* diagnostics
- Initially with Cu cathode, eventually Cs_2Te
- Compatible load-lock system

UV input

Photocathode

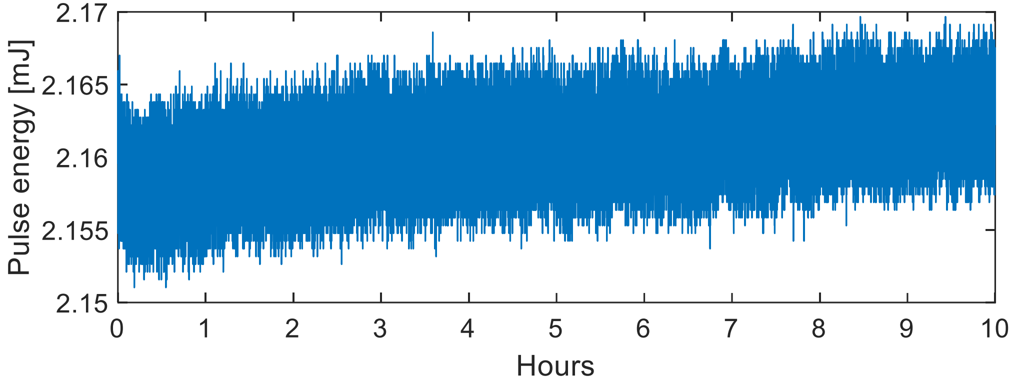


Vacuum windows

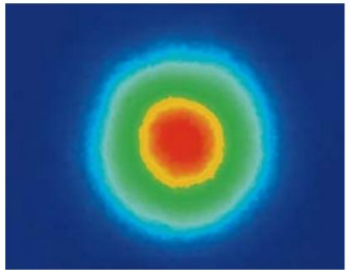
UV reflected beam (diagnostics)

AWAKE Run 2 photoinjector laser

- Light Conversion Pharos system already purchased (delivery Dec 2020, integration & commissioning mid-2022)
  - Yb-doped fiber technology
- Designed to operate with both Cu or Cs2Te
- Variable pulse duration from < 300 fs up to > 5 ps
  - Requires multiple harmonic stages or UV stretcher.
- Synchronizable to RF (1.5 GHz) reference
- Expected maximum charge production:
  - Cu cathode : **~ 400 pC**
  - Cs_2Te : > **1 nC**



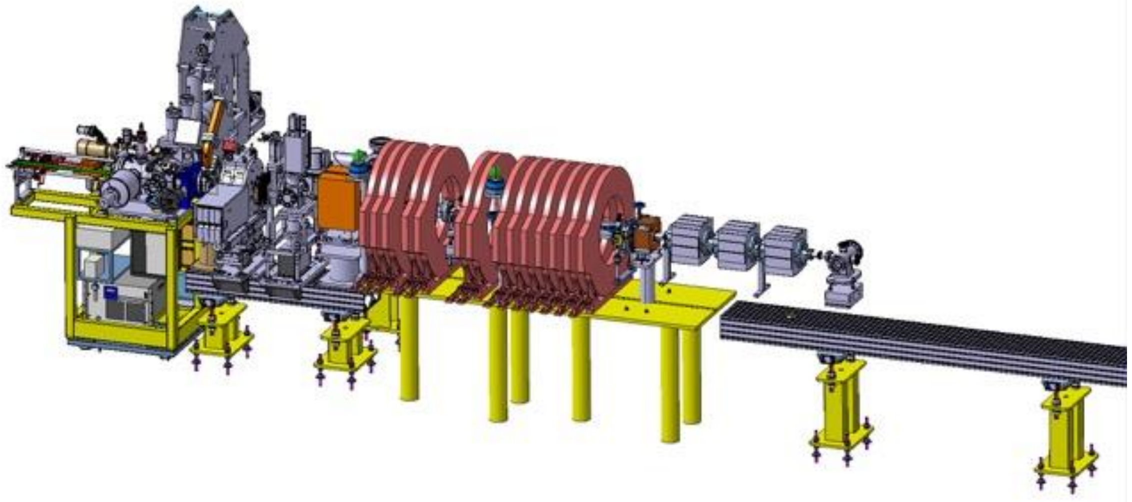
Pulse energy @ 1030 nm	2 mJ
Pulse energy @ 257 nm	~ 400 uJ (RMS <0.06%)
Repetition rate	0 – 200 kHz
Average Power	20 W
M^2	<1.3
Pulse duration	190 fs – 10 ps

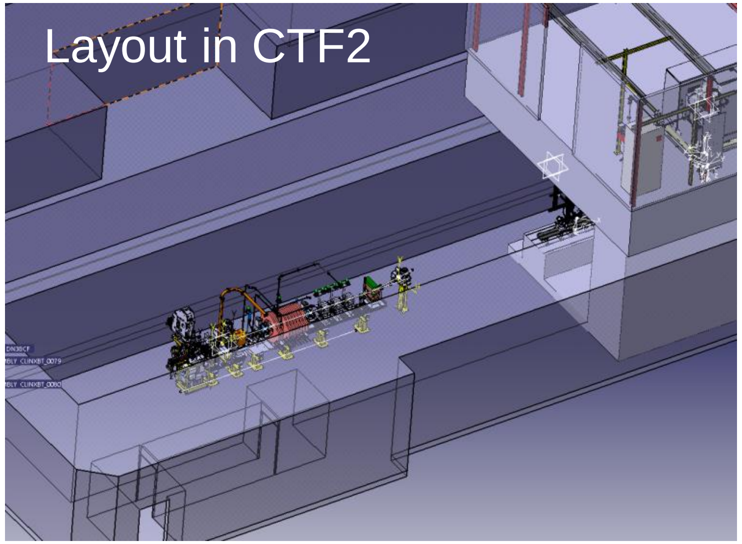


Typical PHAROS near field beam profile at 200 kHz

AWAKE Run 2 femtosecond e- gun

- **Demonstrate velocity bunching** with x-band and **emittance preservation/control**
- Show **reliable high gradient** x-band operation
- **Study mechanical/integration** aspects
- Test **diagnostics**
- **Optimise final design** for AWAKE
- Get team together, **gain momentum** for challenging AWAKE Run2 injector

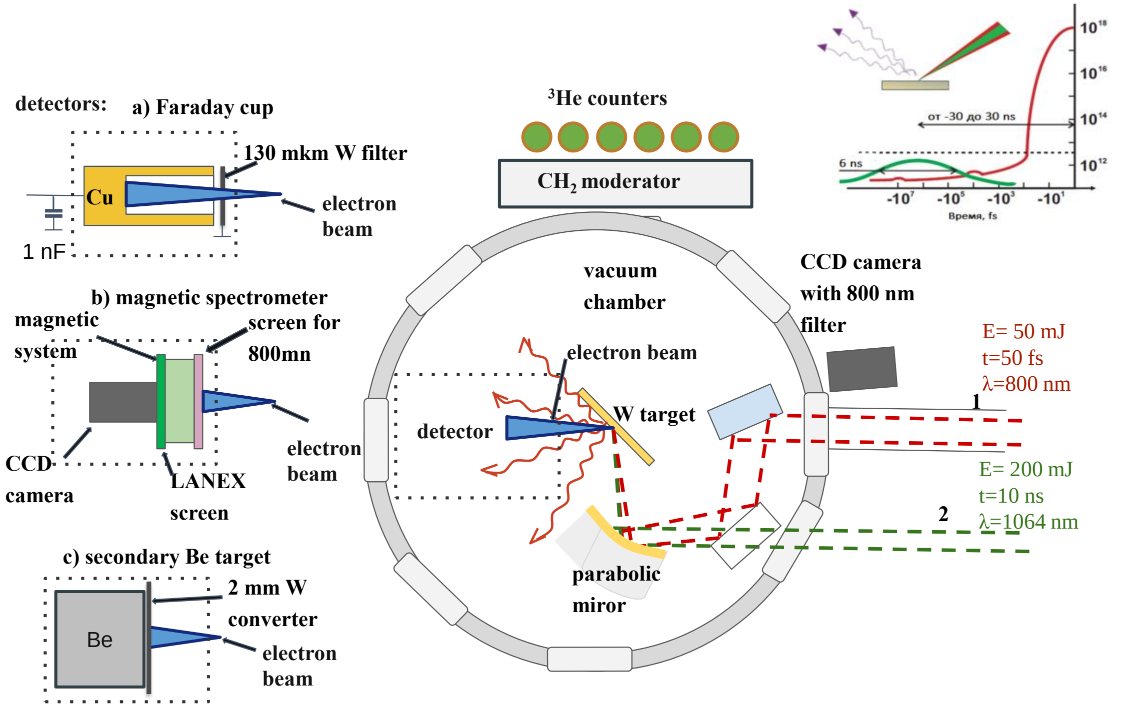




Prototype injector in CTF2:
60-70 MeV and typically 100 pC single bunch, bunch length 200-300 fs (goal), emittance ~ 1 um, Laser osc. frequency 75 MHz, rep. rate up to 3 kHz, Length: 5 m

AWAKE Run 2 LWFA injector (e4AWAKE)

- The project aims to realize "laser-assisted electron injection" in AWAKE, as proposed in Ref. [1], taking advantage of the AWAKE Run 2 experimental setup without interfering with it.
- Current proposal includes input from:
  - CERN: (BE-ABP-LAF, SY-STI-LP, SY-BI-PM, TE-VSC-BVO, HSE-RP-AS, EN-MME-EDS, TE-MSC-NCM, TE-VSC-SCC, EN-ACE-OSS, SY-RF-MKS, BE-CEM-MRO, BE-CEM-MTA)
  - Max Plank Institute for Physics, Munich, Germany: use of the AWAKE laser, laser expertise, Rb expertise and used of Rb glovebox, Rb
  - Dusseldorf University, Germany: simulation of wakefield acceleration in Run 2c setup
  - Wigner Institute, Budapest, Hungary: simulation of laser ionization in both demonstrator chamber and Run 2c setup
  - Moscow State University, Russia: expertise and design of demonstrator chamber
  - LOA, Ecole Polytechnique, ENSTA Paris, France and LIDYL, CEA, CNRS, Universite Paris-Saclay, France: expertise and design of demonstrator chamber

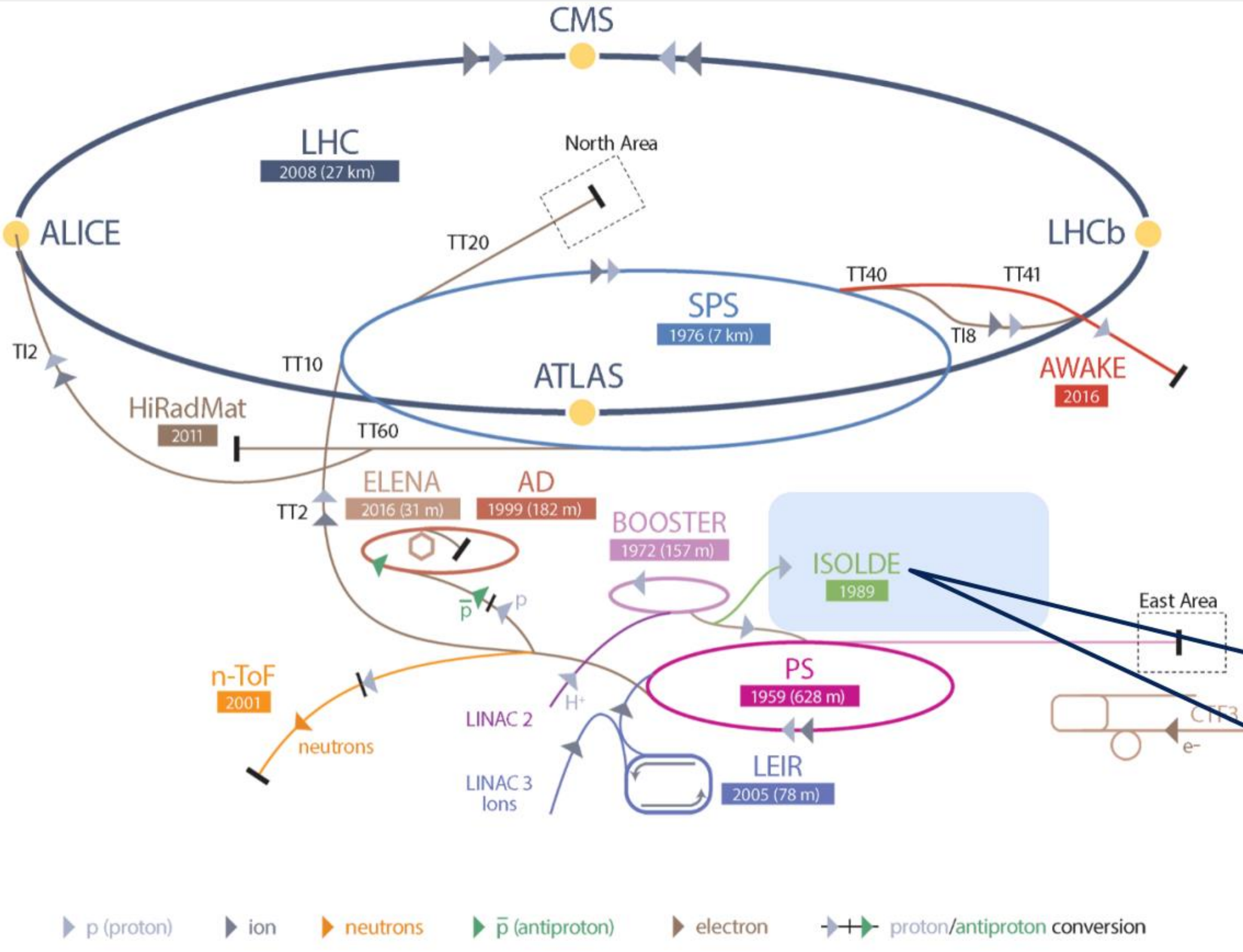


Sketches and picture for Demonstrator, based on [2] and [3]
The CERN demonstrator would likely be smaller, with diagnostics outside the vacuum.

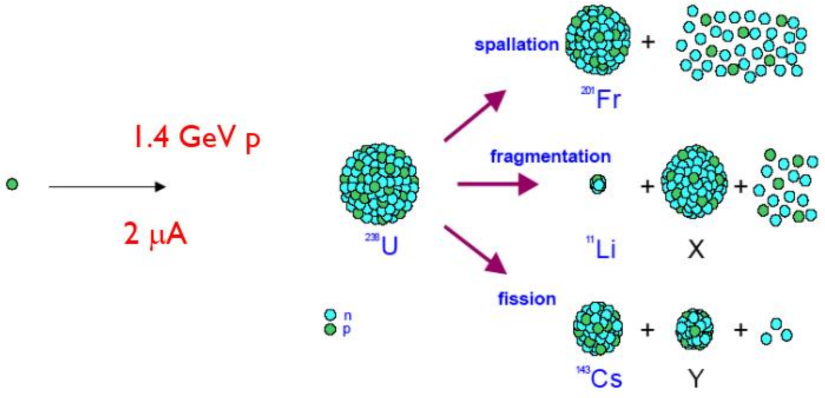
[1] V. Khudiakov, A. Pukhov, Optimized laser-assisted electron injection into a quasi-linear plasma wakefield, https://arxiv.org/abs/2109.03053
[2] M. Thevenet et al, Vacuum laser acceleration of relativistic electrons using plasma mirror injectors, *Nature Physics* **12**, pages 355–360 (2016), https://arxiv.org/abs/1511.05936
[3] I. Tsymbalov et al, Well collimated MeV electron beam generation in the plasma channel from relativistic laser-solid interaction, *Plasma Phys. Control. Fusion* **61** 075016 (2019) https://iopscience.iop.org/article/10.1088/1361-6587/ab1e1d

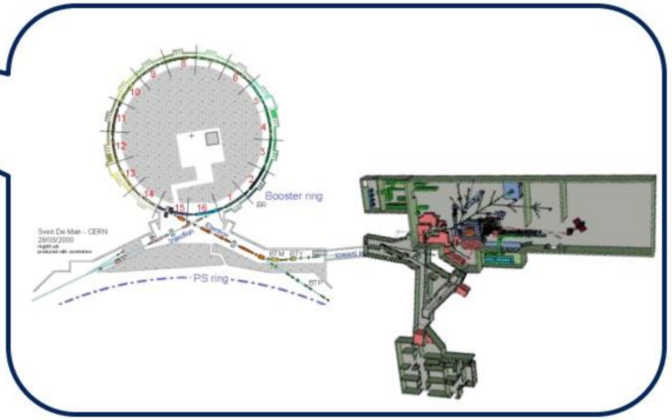
Part III: Laser ion sources at ISOLDE (RILIS)

Ion beams, ISOLDE in the CERN accelerator complex



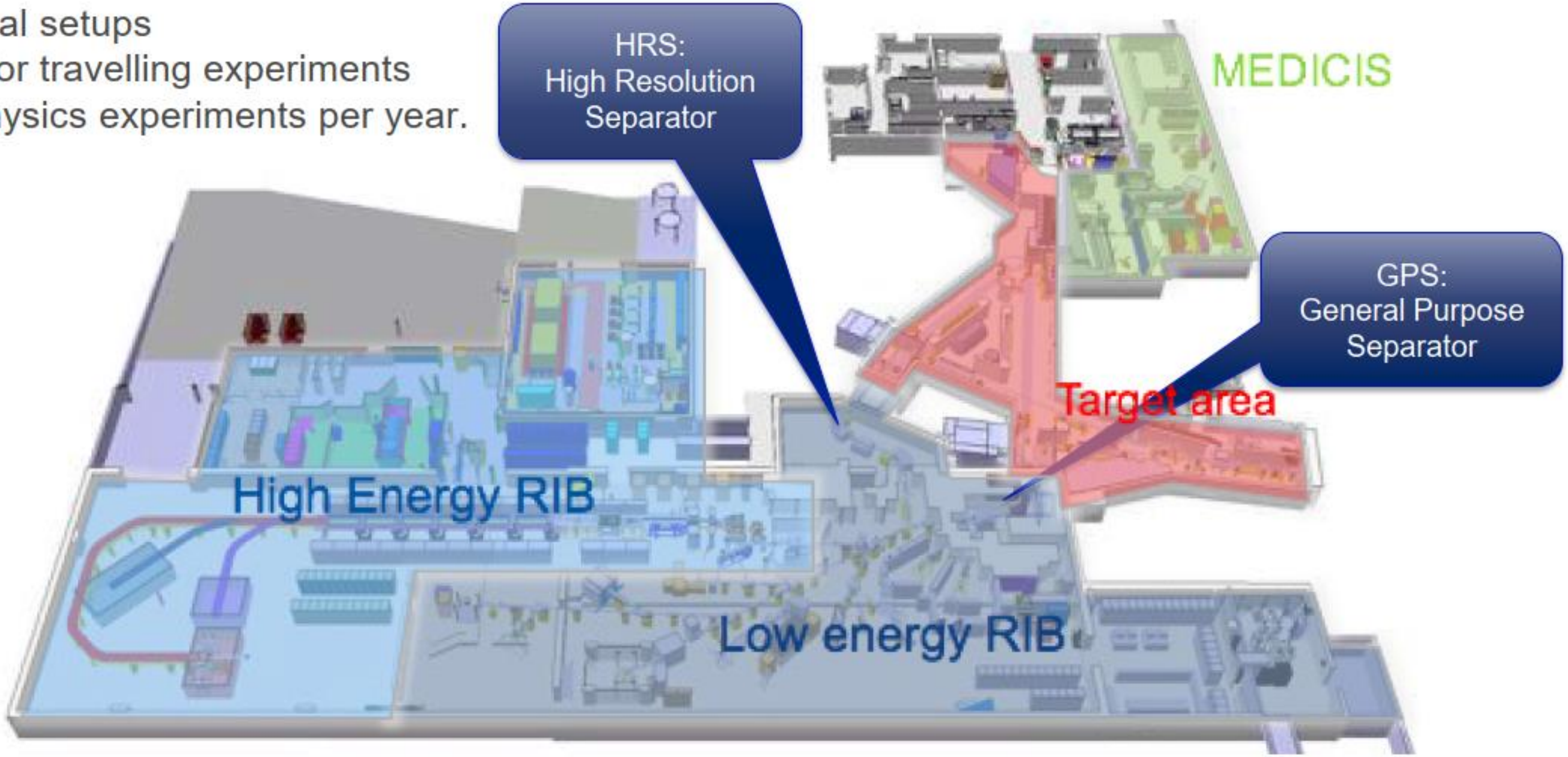
Delivers yearly >3000 h of radioactive ion beams by means of two target stations



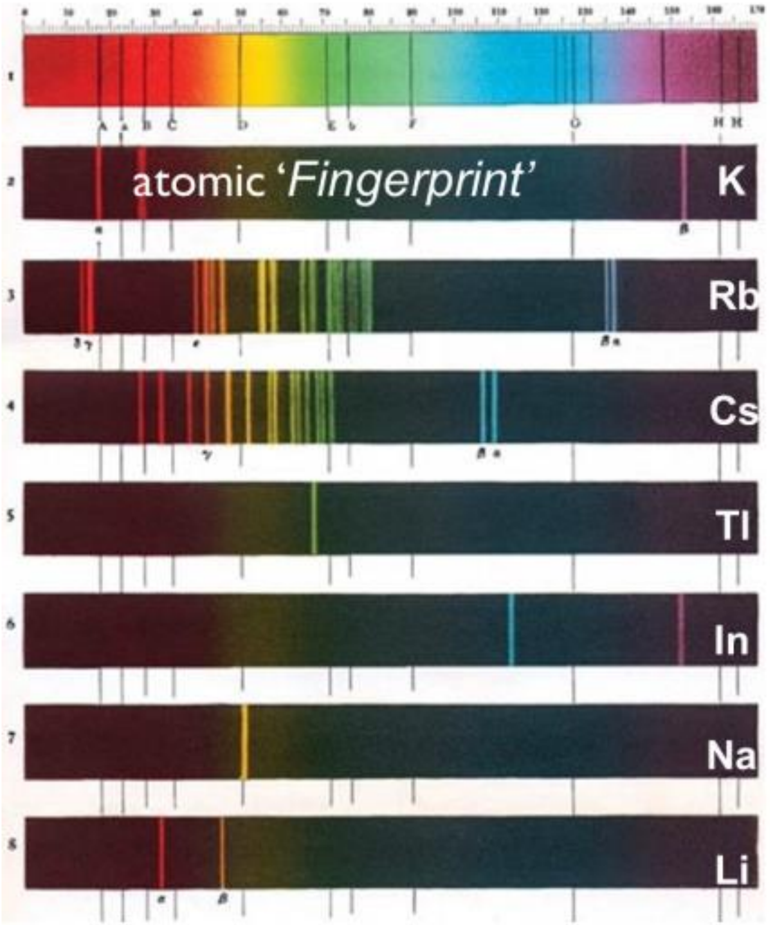


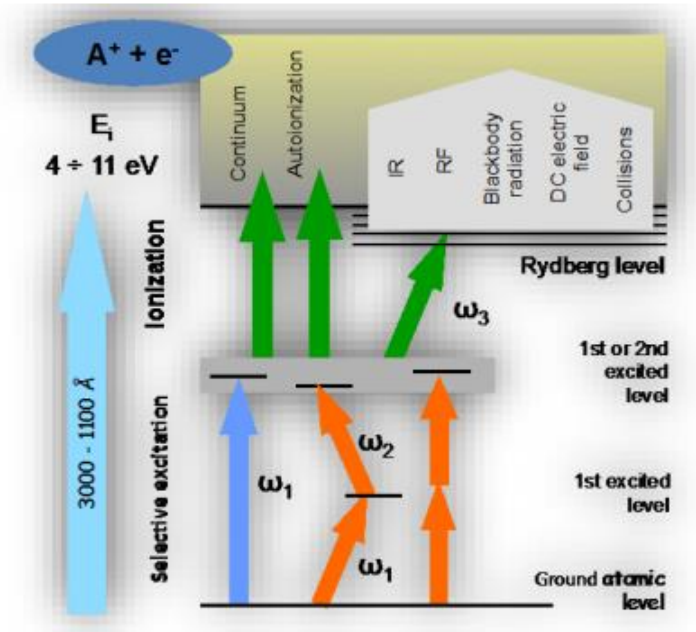
The ISOLDE Laboratory: target and experimental areas

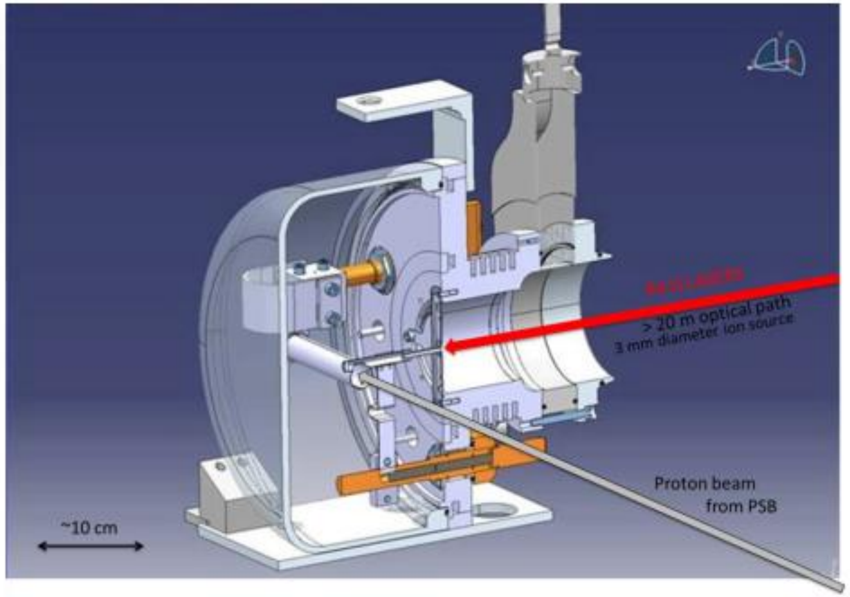
- 12 beam lines
- 10 fixed experimental setups
- Temporary setups for travelling experiments
- Over 50 different physics experiments per year.



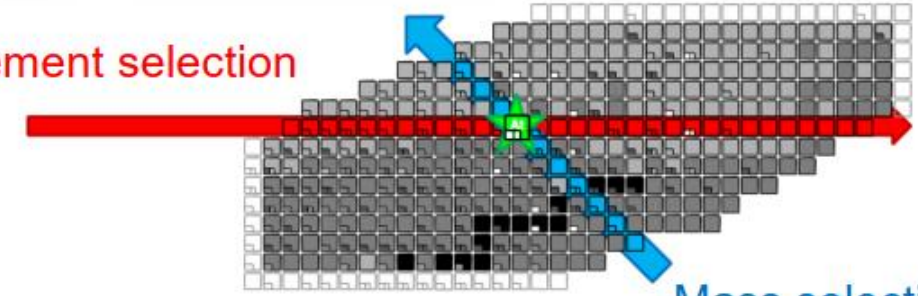
Resonance Ionization Laser Ion Source (RILIS)







Element selection

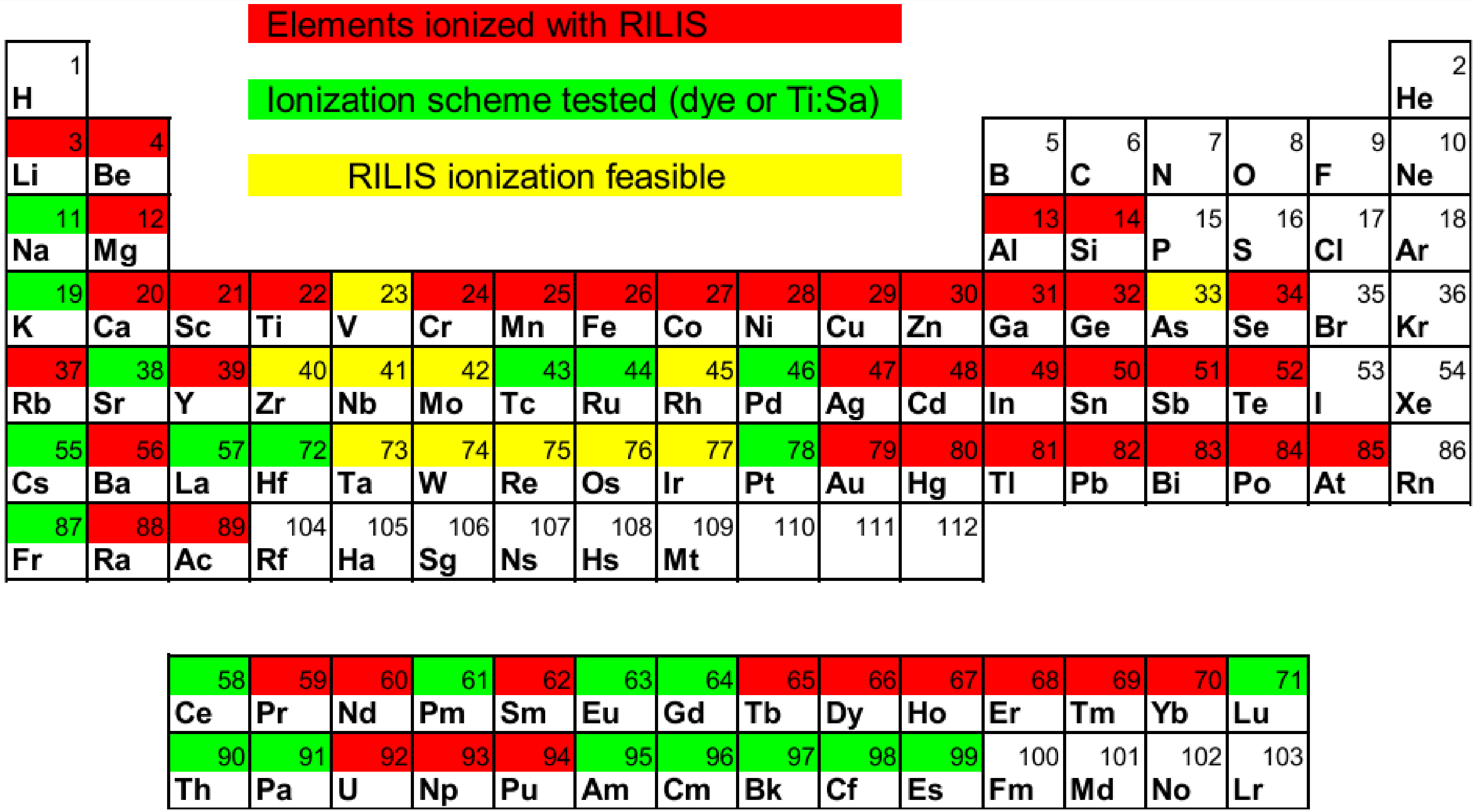


Mass selection

Hot-cavity RILIS:
T ≈ 2100 °C

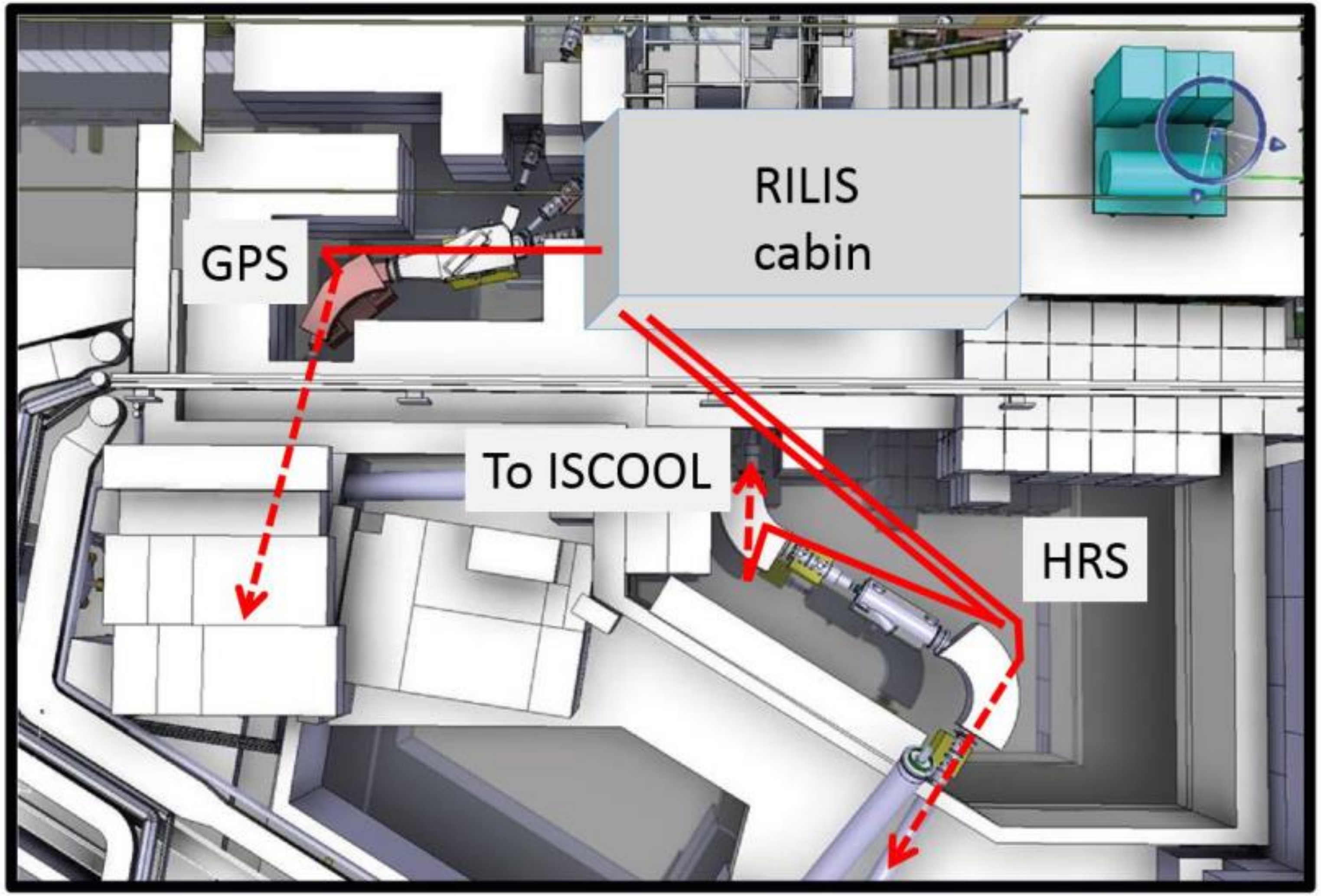
Ionization efficiency
10-30%

RILIS Ion beams



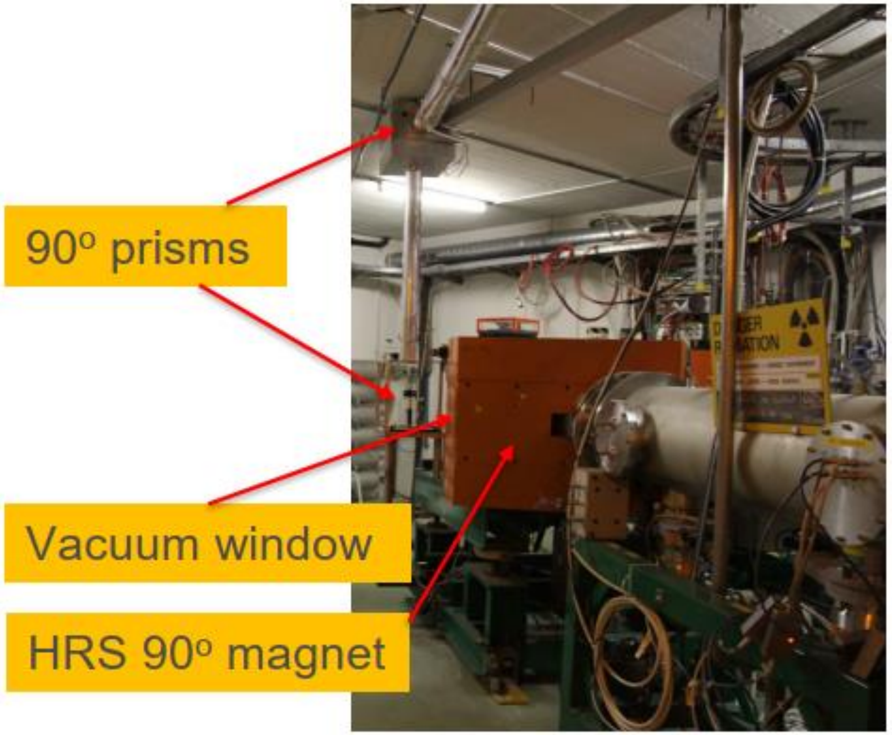
Ion beams of 48 elements have been produced at ISOLDE with RILIS

RILIS at ISOLDE Facility

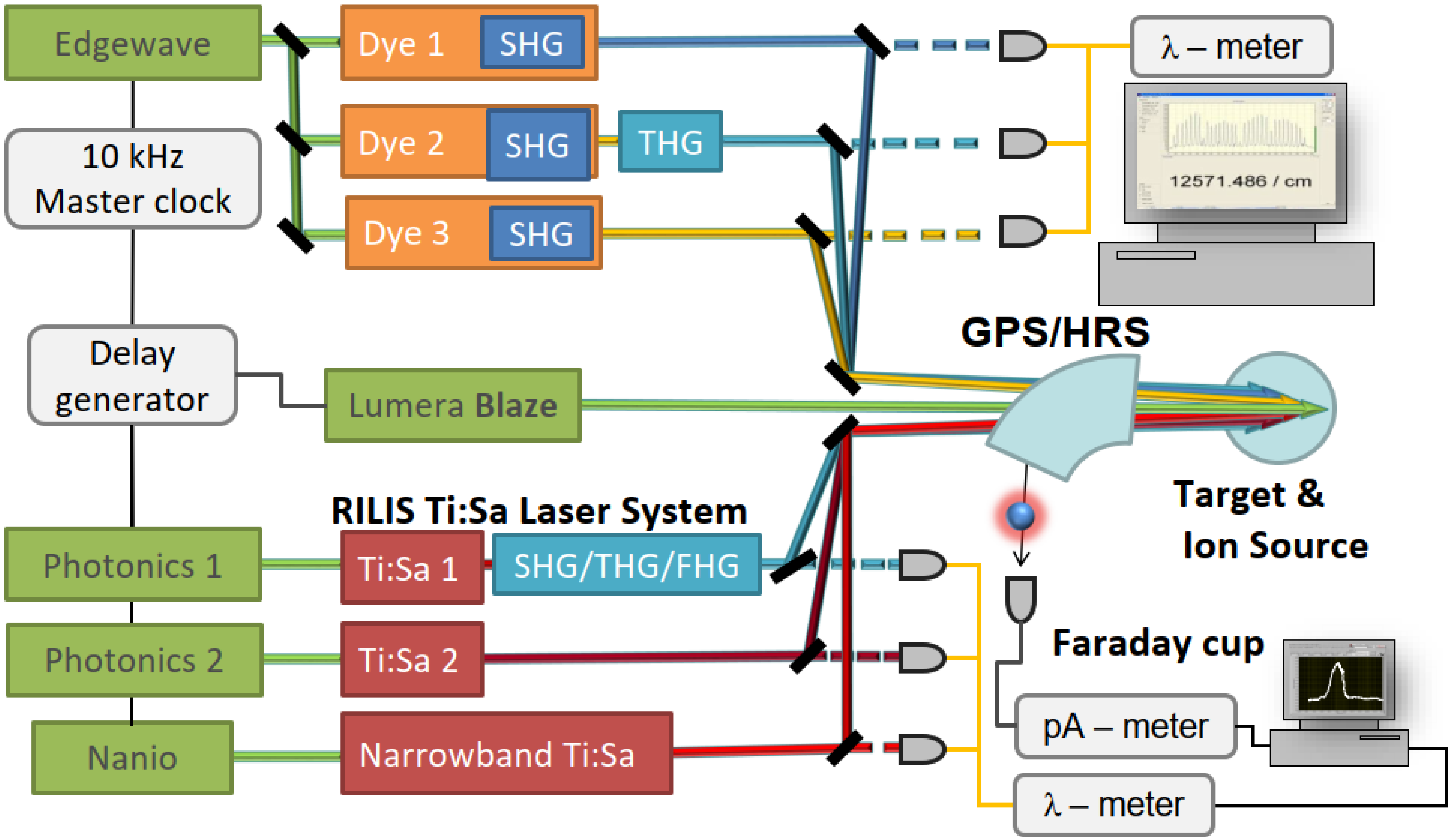


Laser beams transported to:

- GPS Frontend, ~18 m
- HRS Frontend, ~23 m
- Gas-filled Paul trap ISCOOL ~20 m



RILIS laser setup (simplified)



RILIS laser setup

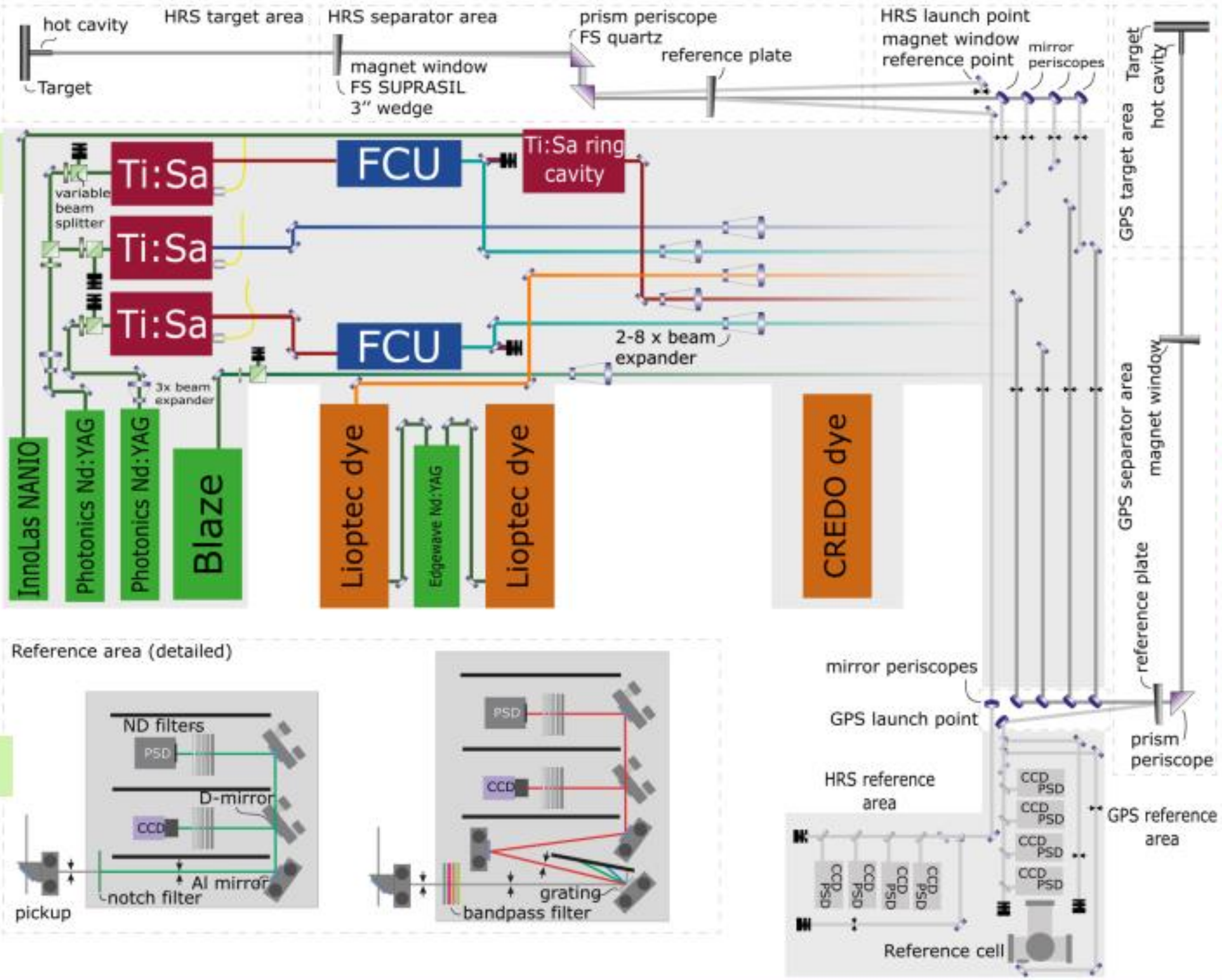
Industrial grade
10 kHz Nd:YAG/YVO lasers

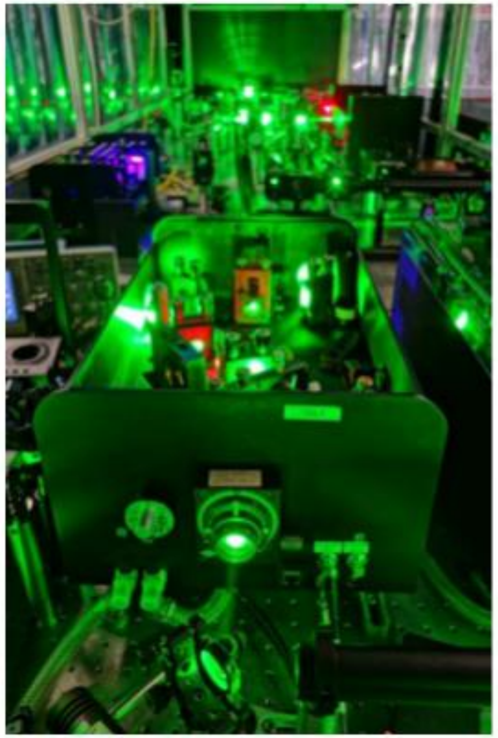
Photonics
60 W

InnoLas
18 W

Lumera
40 W

EdgeWave
100 W

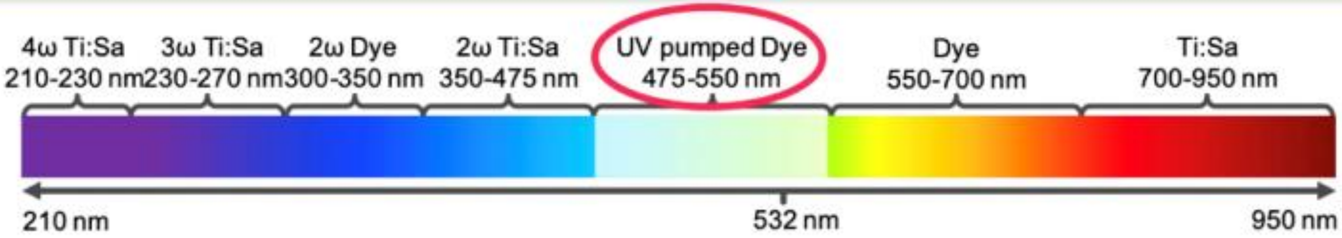


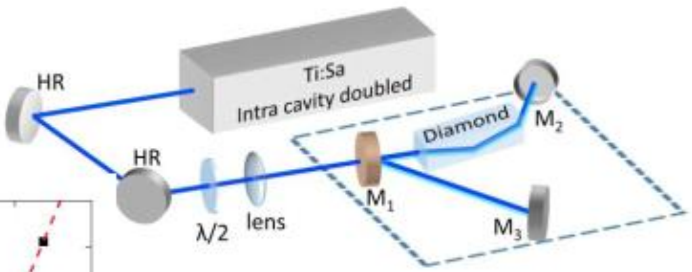


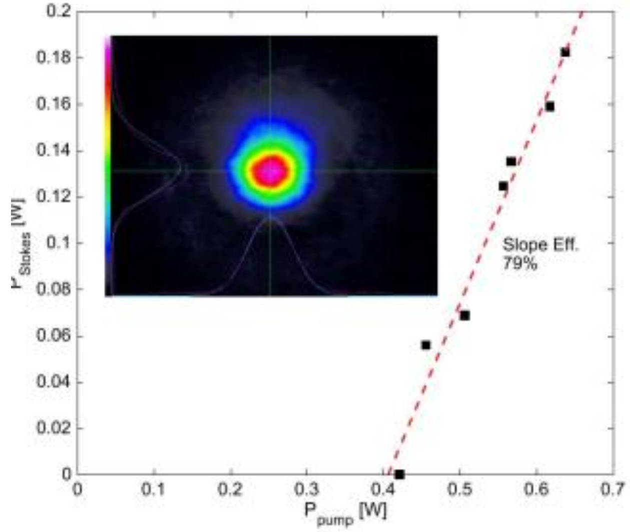
Tuning range
210 – 950 nm

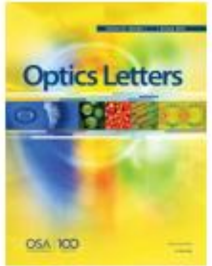
Diamond Raman lasers at RILIS

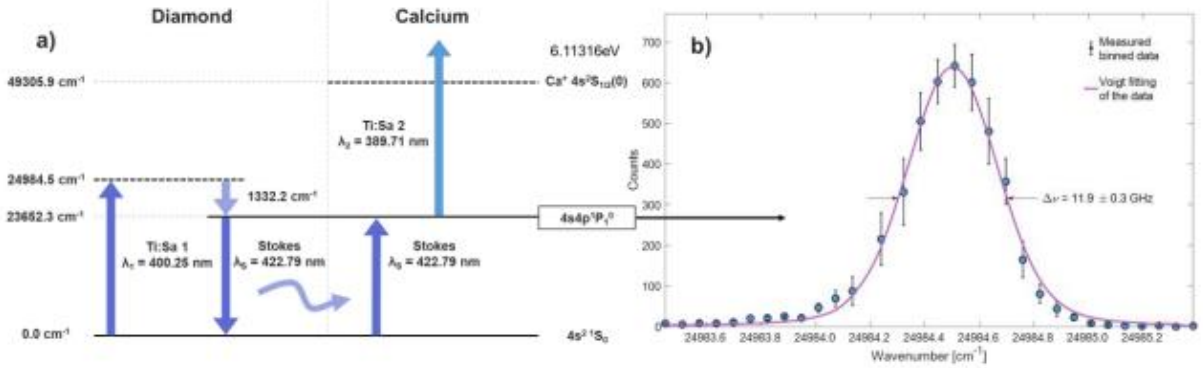
Broadband:
To extend the Ti:Sa tuning range towards the UV pumped dye range

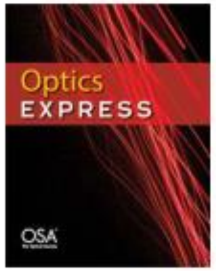


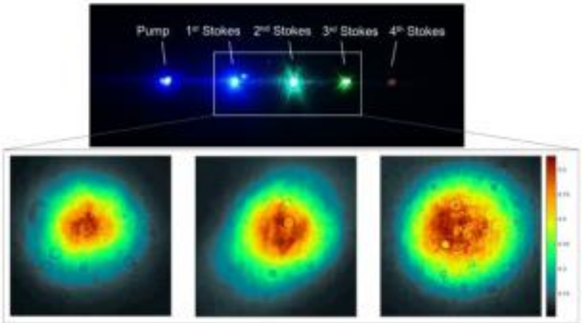










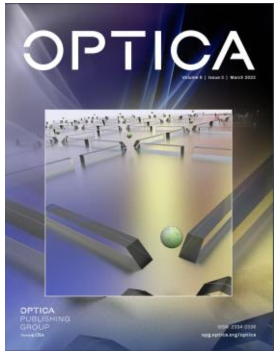


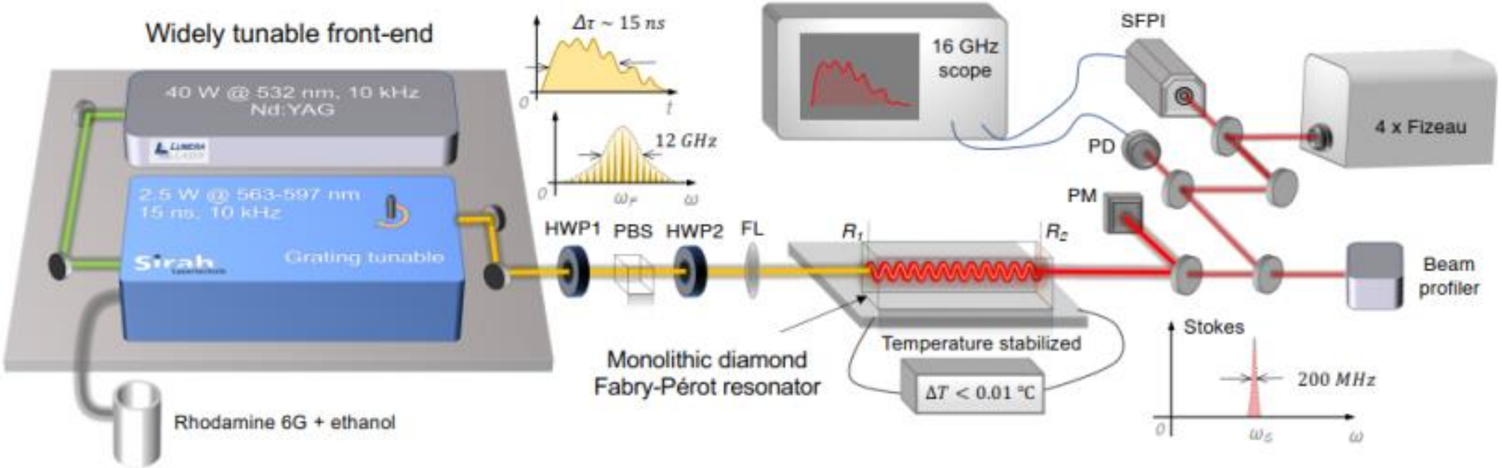
K. Chrysalidis et al, Opt. Lett. 44(16), 3924–3927 (2019)

D. Talan Echarri et al., Optics Express 28(6), 8589 (2020)

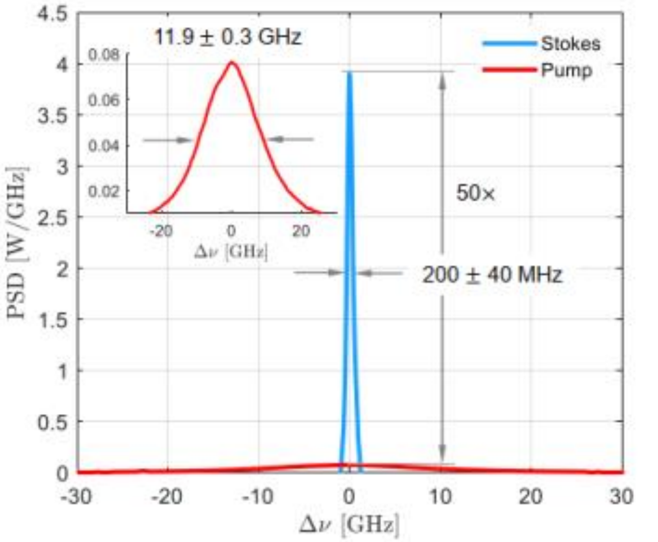
Diamond Raman lasers at RILIS

Narrowband:
To enable laser spectroscopy with a laser line width ~ 10x narrower than is currently possible with RILIS lasers





KT project “Singular light”



Stokes spectral squeezing via phonon resonant interaction in diamond

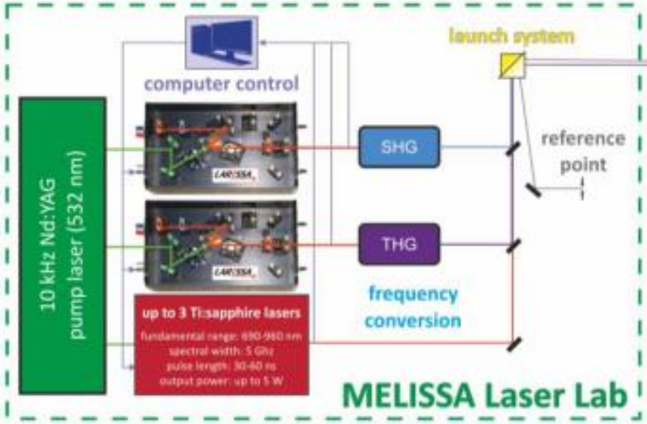
E. Granados, et al, "Spectral synthesis of multimode lasers to the Fourier limit in integrated Fabry–Perot diamond resonators," Optica 9, 317-324 (2022)

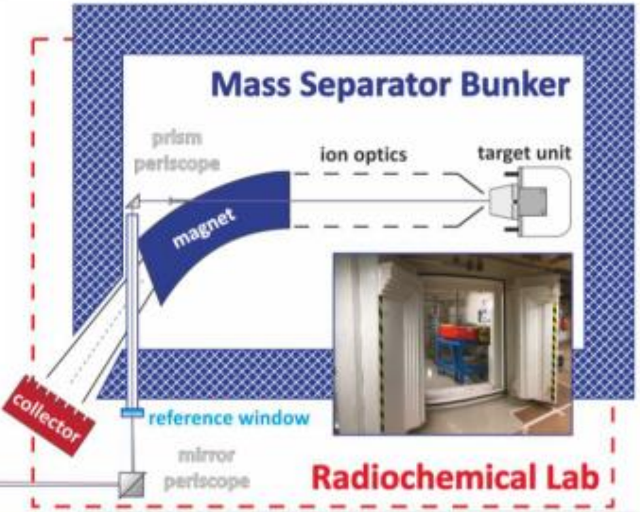
MEDICIS Laser Ion Setup at CERN (MELISSA)

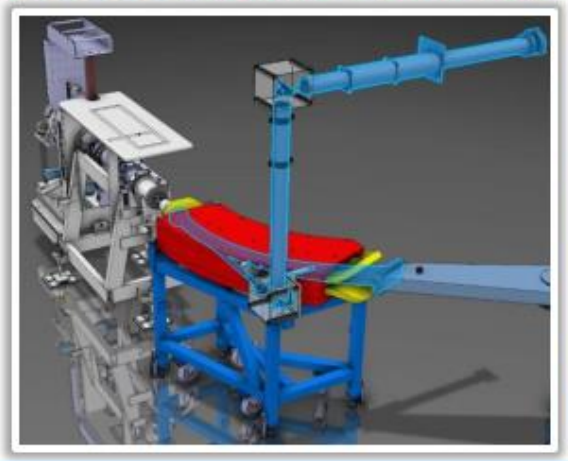
MEDical Isotopes Collected from ISOLDE – facility for production of medical isotopes for research in radiopharmaceutical science

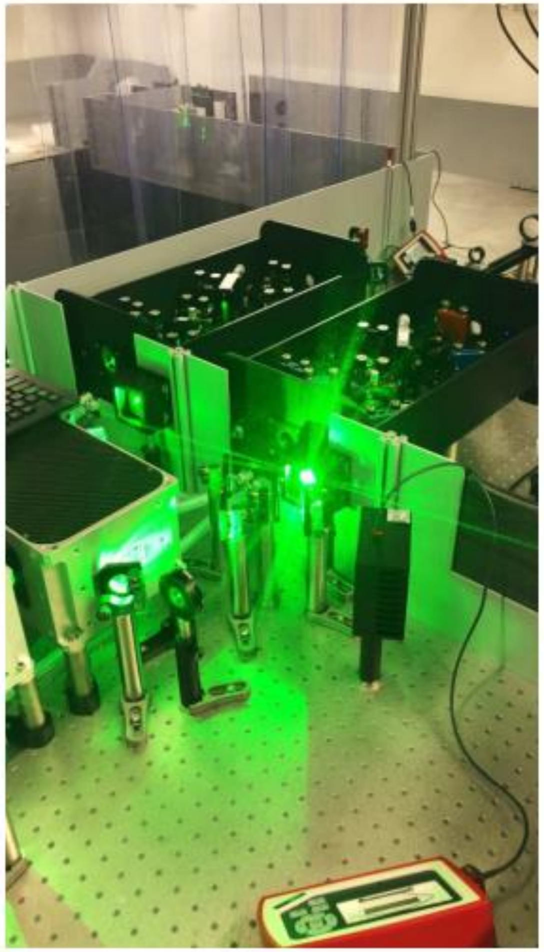
Long-lived radio-isotopes
- Produced in a cold target (at ISOLDE or elsewhere)
- Transported to the MEDICIS front-end
- Extracted by heating the target material
- Ionized and mass-separated
- Collected on a substrate
- Shipped to medical research laboratories

Sm-153
Tb-155, Tb-149
Er-169
Tm-167
Yb-175
Ac-225









Setup similar to RILIS, based on Ti:Sapphire lasers

Summary

- Multiple users facility at CERN profit from charged particle beams produced using laser technology
  - Electron sources of existing and future lepton accelerator requite robust photocathodes and high-quality laser beams
  - Plasma created by high-intensity laser beams enables conditions for self-modulation of high energy proton bunches and wake-field acceleration
  - RILIS systems at ISOLDE and MEDICIS are essential for isobaric purity of delivered radioactive ion beams
- Laser development directions are defined by expanding requirements for new and higher quality particle beams

Acknowledgements

Sources, Targets and Interactions (STI) – Simone Gilardoni

Lasers and Photocathodes section (LP) – Bruce Marsh

<u>Current members:</u>

Katerina Chrysalidis – STAFF
Eduardo Granados – STAFF
Ralf Rossel – STAFF

Isabelle Fontaine – FELL
Reinhard Heinke – FELL
A. Jaradat – FELL
Miguel Martinez – FELL
Cyril Bernerd – PJAS

Ralitsa Mancheva – DOCT
Baptiste Groussin – TECH
Isabelle Hendriks – TECH
Georgios Stoikos – TECH

<u>Former members:</u>

Valentin Fedosseev
Eric Chevallay
Shane Wilkins
Camilo Granados
Matthieu Veinhard
Christoph Seifert
Tom Day Goodcare
Sebastian Rothe
Daniel Fink
Harsha Panuganti
Anna-Maria Bachmann
Florence Friebel
Daniel Talan Echarri

Christoph Hessler
Mikhail Martyanov
Piotr Gach
Irene Martini
Marta Csatari
Massimo Petrarca
Nathalie Lebas
Vaila Leask
Vadim Gadelshin

Thank you for
your attention!