The European EIC TWAC Project on Terahertz Dielectric Acceleration

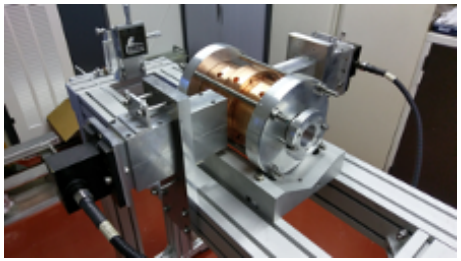
Christelle Bruni

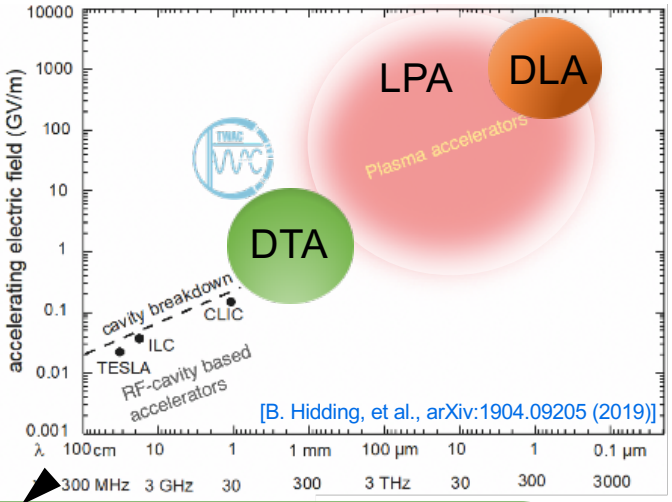
On behalf of TWAC consortium

Funded by the European Union and the Swiss State Secretariat for Education, Research and Innovation (SERI).

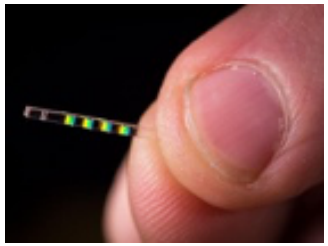
Towards compact accelerators ?

RF





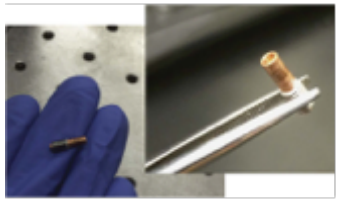
DLA

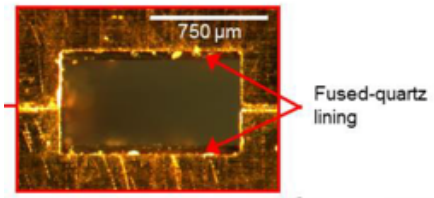


ACHIP

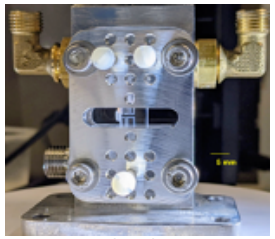
DTA

[E. Nanni, et al. Nat Commun **6**, 8486 (2015)], [F. Kartner et al., NIMA 829, 24(2016)], [M.T. Hibberd et al., Nat. Phot. 14, 755 (2020)], [H. Tqng et ql., PhysRevLett.127.074801 (2021)]]



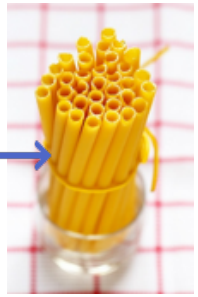


LPA



TWAC is funded by :

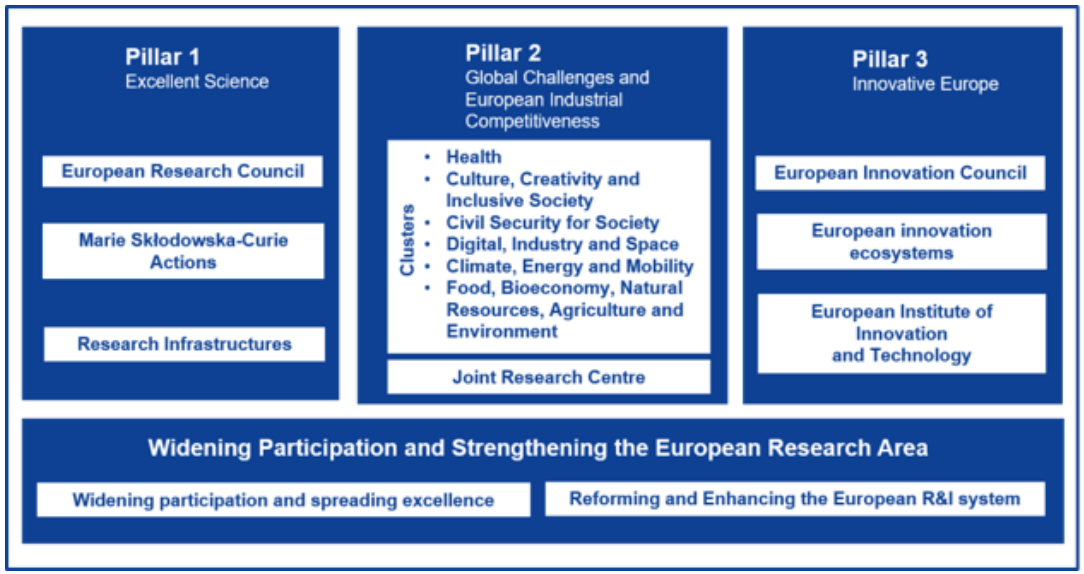
Compact, 'cleaner' and lighter accelerators



- TWAC offers a new approach to **simultaneously overcome multiple limitations while reducing the size of accelerators**. It aims to serve both research and industrial purposes with the goal of moving towards 'cleaner' and lighter accelerators, catering to **applications ranging from research accelerators to cancer treatments**
- TWAC proposes to simplify infrastructures by replacing RF sources with **optical sources**
- ZITA (cannelonni pasta) : the accelerator structure will be able to withstand high accelerator field strengths within **millimeter-scale** dimensions

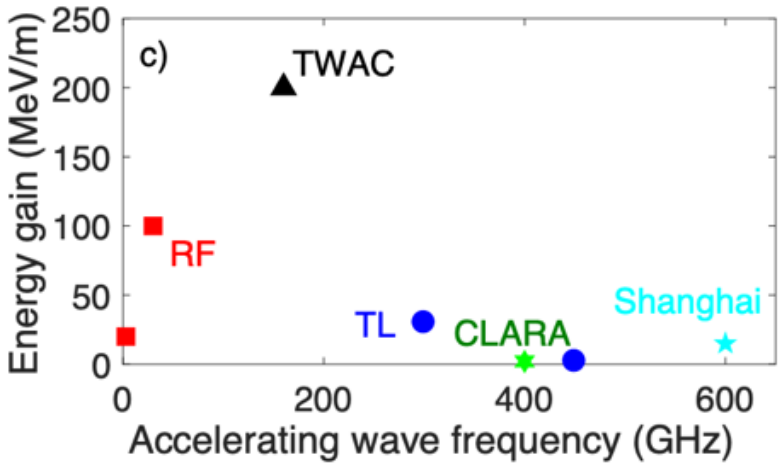
EIC Pathfinder Open – call 2021

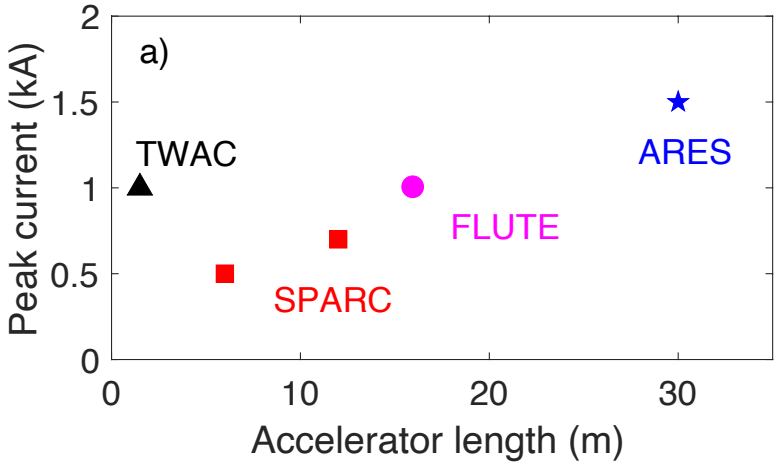
- Project funded by Europeen Innovation Concil, Pillar 3 of Horizon Europe, twin of ERC for Innovation
- The EIC supports research teams in the research and development of **innovative technologies** that are high-risk and high-potential, **fostering advanced interdisciplinary scientific collaborations**
- **Granted in 2022** with 3.1 Meuros + 0.5 Meuros from sefri



European Innovation Council

Objective: compact high gradient accelerator





- To demonstrate a high energy gain per meter accelerating structure in the gap between the RF technologies and laser plasma accelerators
- To demonstrate electron bunch compression

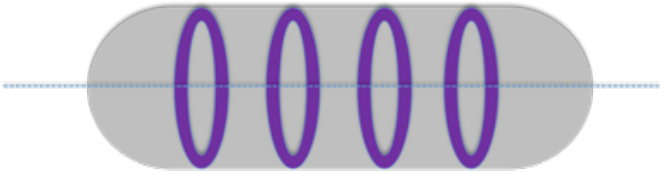
- TWAC will offer a high current electron source on a metre scale compared to RF accelerators
- Only a unique combination of ZITA with a state-of-the-art conventional and stable femtosecond electron source (RF-gun) can achieve this unique performance

TWAC is funded by :

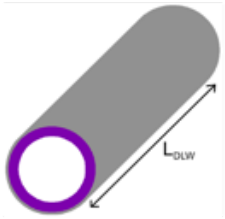
What is ZITA ? ZITA is the accelerator

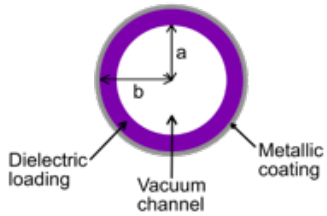
- Circular wave guides are the basis of accelerating cavity to propagate an accelerating mode
- But the phase velocity in such a perfectly conducting guide is always larger than the speed of light
- To keep synchronism condition between electrons and accelerating field, we need to slow down the wave

Iris to slow down
—>In classical RF structures
—> Complex structures at cm scale

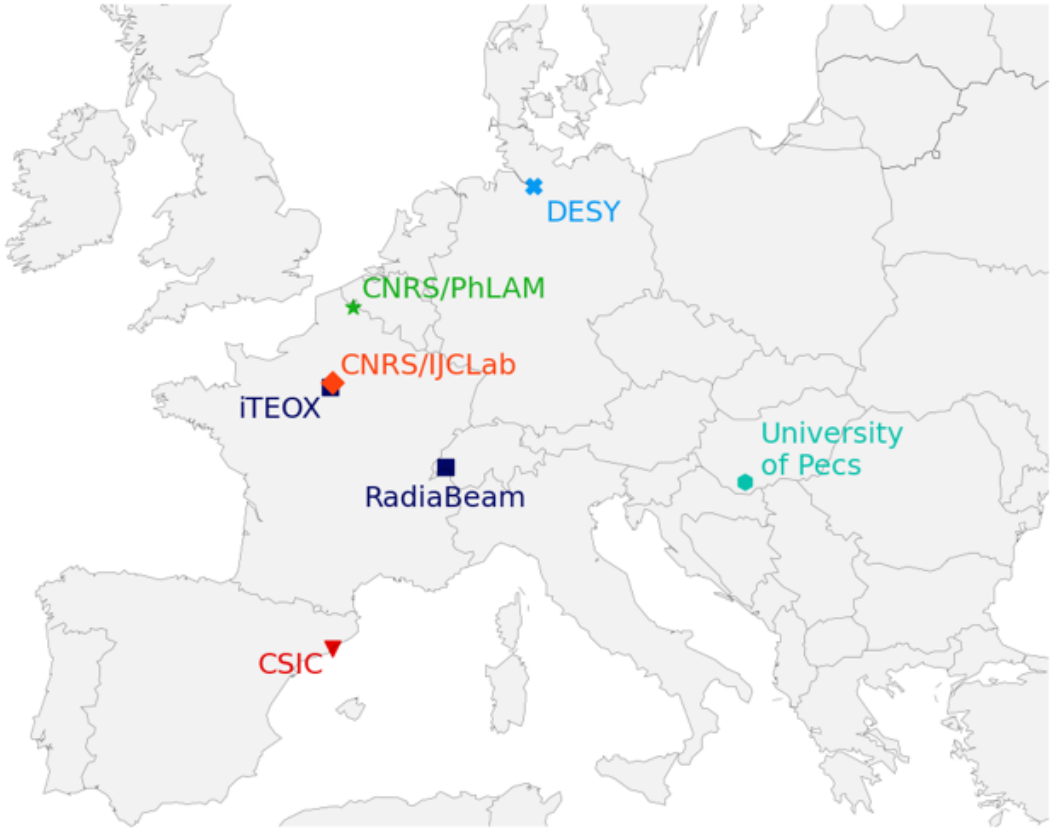


Dielectric to modify the wave vector
—> 'Simple' structure shape, but at mm scale for THz
—> Metalic coating for field confinement





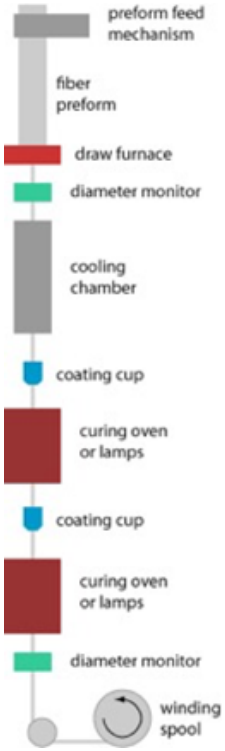
TWAC Partners

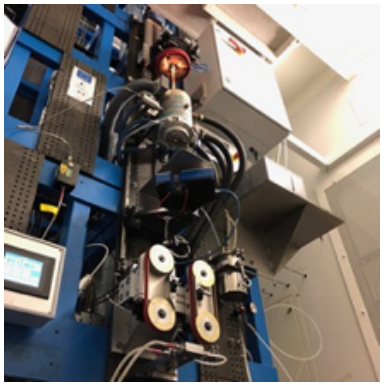


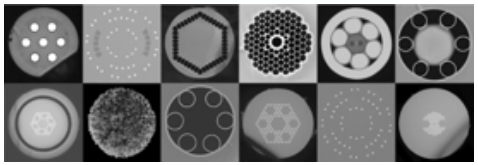
Partners & expertise:

- **CNRS/IJCLab:** Accelerator physics
  + High energy laser + TWAC prototype
- **CNRS/PhLAM:** Beam dynamics
  modelling
  + ultrafast THz/electron diagnostics
- **CSIC:** Dosimetry
  FLASH radiotherapy
- **DESY:** Electron diagnostics
  + test facility for benchmarks
- **iTEOX**: Valorisation
- **University of Pécs:**
  High power THz source
- **RadiaBeam:**
  Valorisation

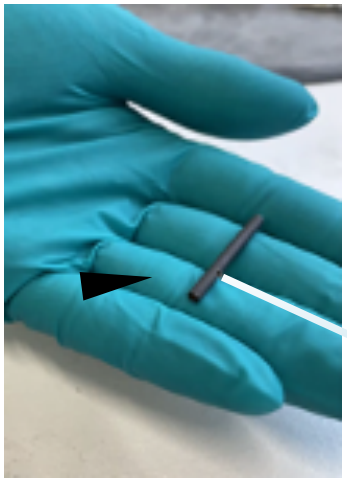
ZITA Is The Accelerator

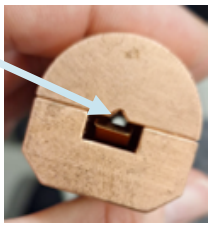






ZITA
Prototypes ready





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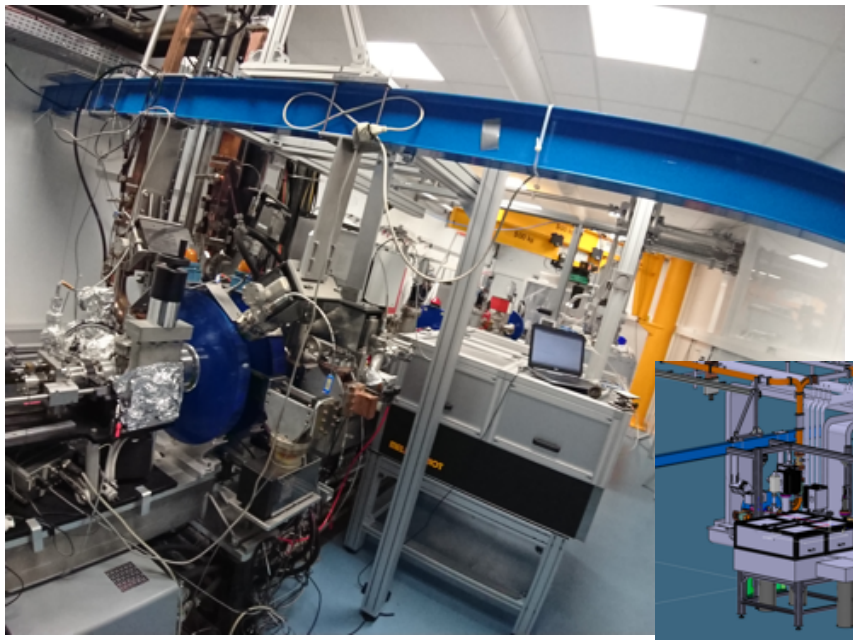
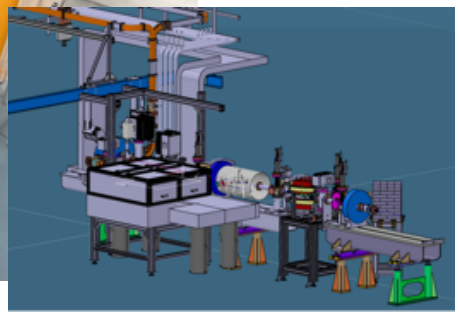
nded by :

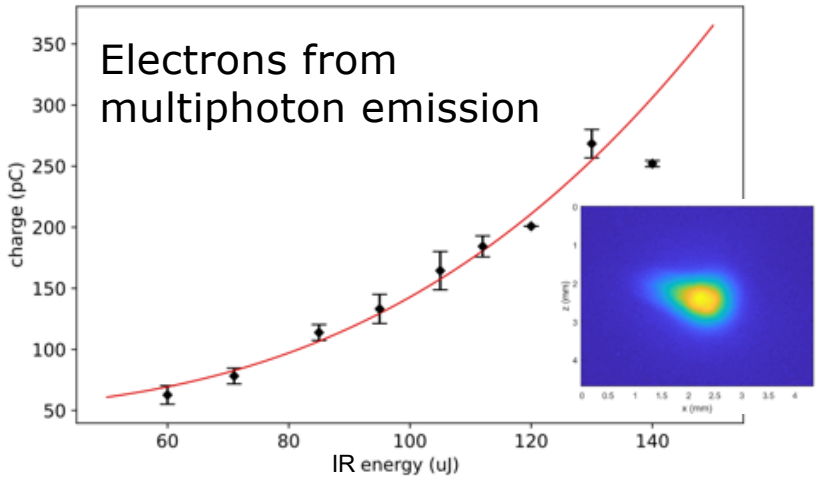
New infrastructure for photonics/accelerator interface

- 8 MeV electron source (PHIL)
- Joule-class laser (LASERIX)
- Laser plasma acceleration (PALLAS)





Photocathode fs-IR laser



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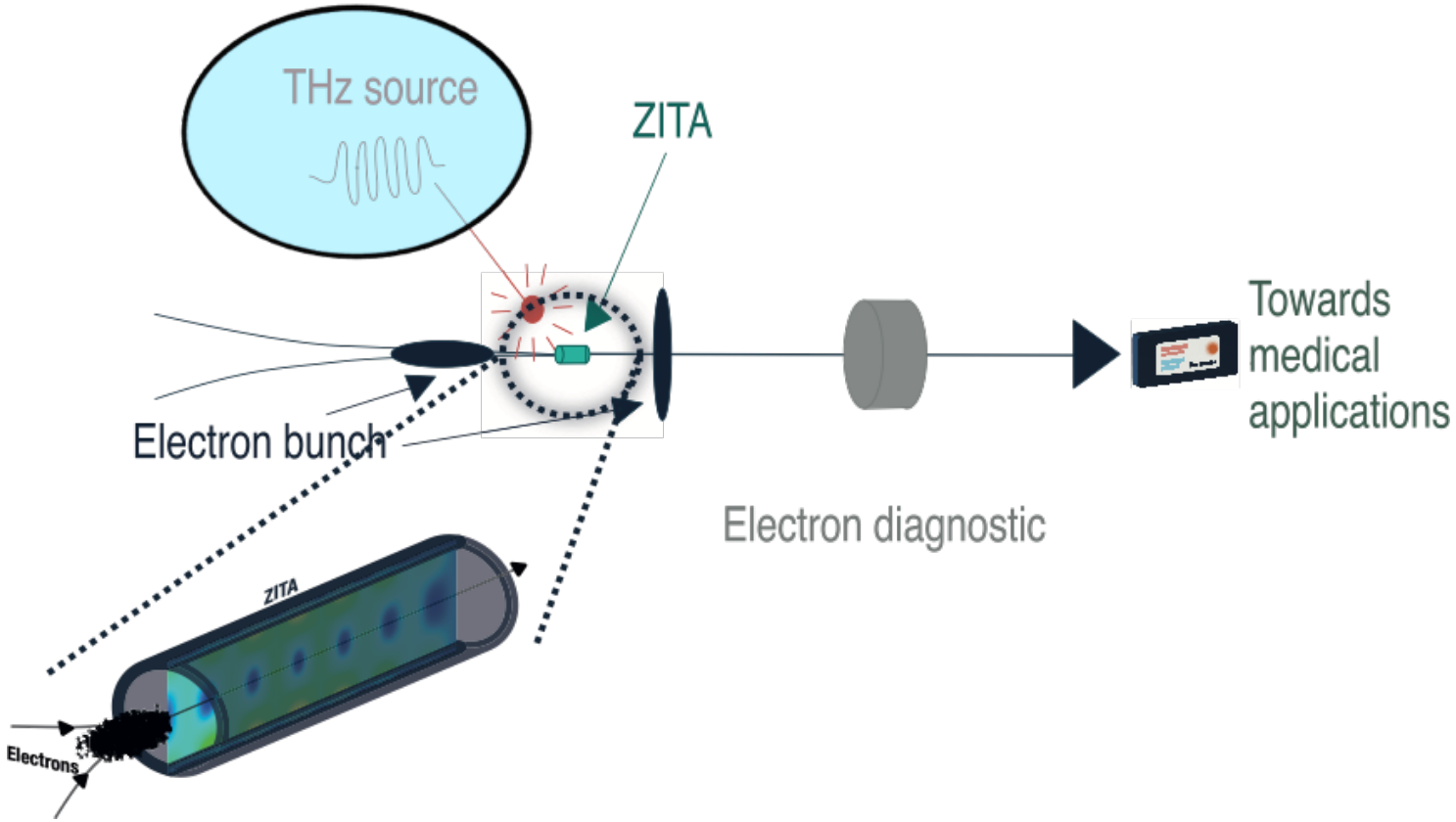
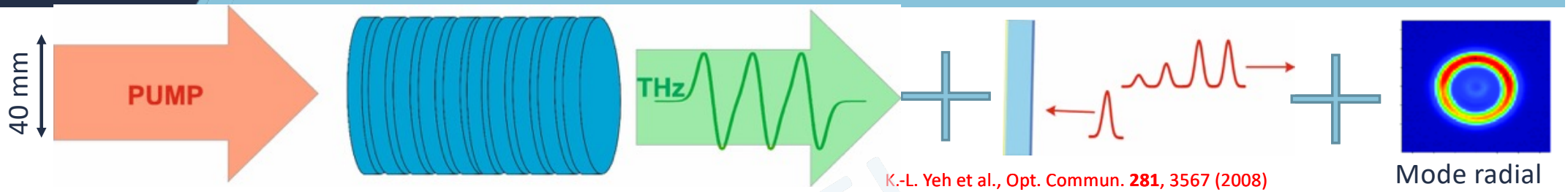

THz source
ZITA
Towards
medical
applications
Electron bunch
Electron diagnostic
ZITA
Electrons

THz source



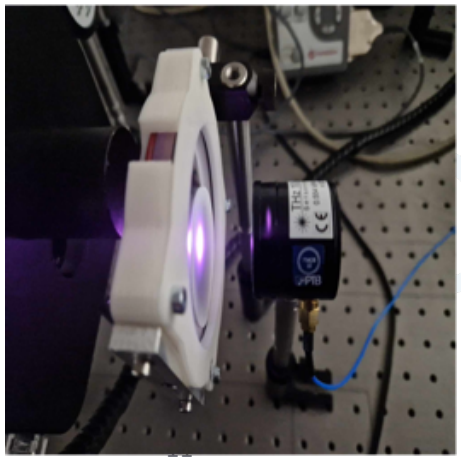
K.-L. Yeh et al., Opt. Commun. **281**, 3567 (2008)

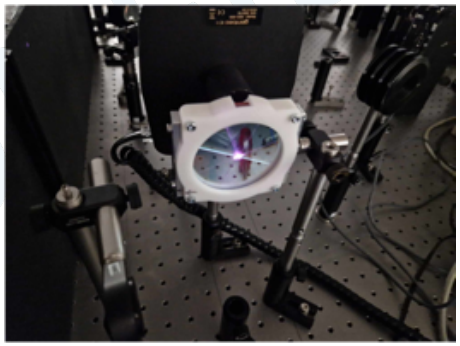
- LN wafer-stack

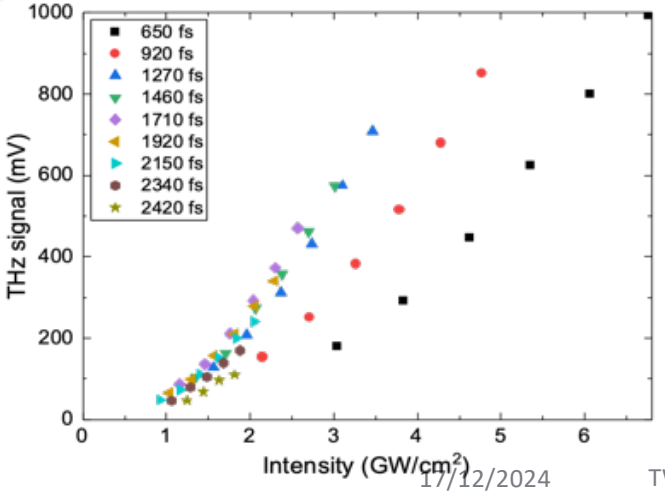
F. Lemery et al., Commun. Phys. **3**, 150 (2020)

C. Mosley et al., Opt. Express **31**, 4041 (2023)

Challenge : obtenir des gradients comparable à la RF, et des largeurs spectrales les plus petites possible
Validation **theorique** → OK 100MV/m





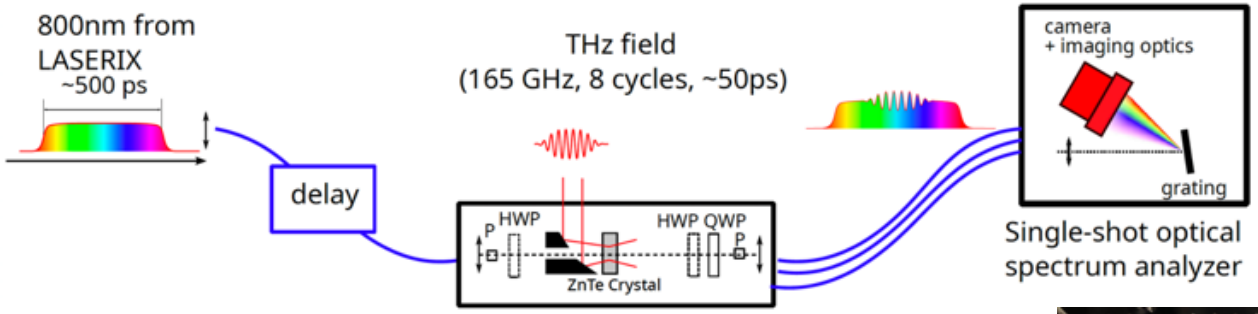


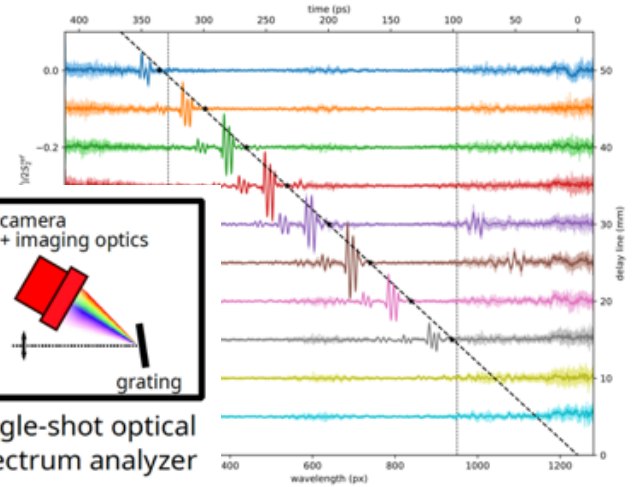
<u>On-going exp.</u>
with the high energy laser LASERIX @IJCLab
(Ti:Sa laser, ≳1 J)

TWAC is funded by :

THz diagnostics: Electro-Optic detection

Task 2.4 THz detection:
EO setup for monitoring THz accelerating field

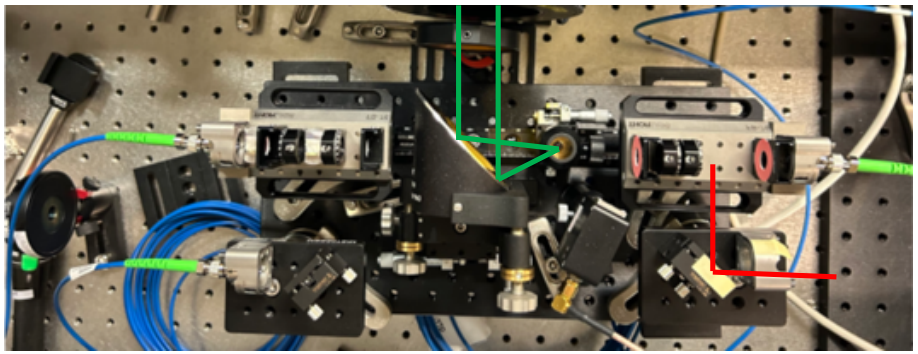




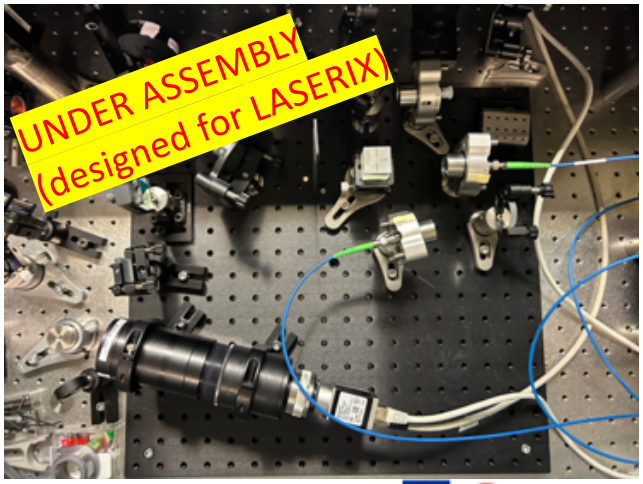
EO "head"

- EO head and OSA are on separated boards (flexibility)
- Challenge: long THz pulse (> 50 ps) to be recorded/monitored

→ New design for the spectrometer and EO head

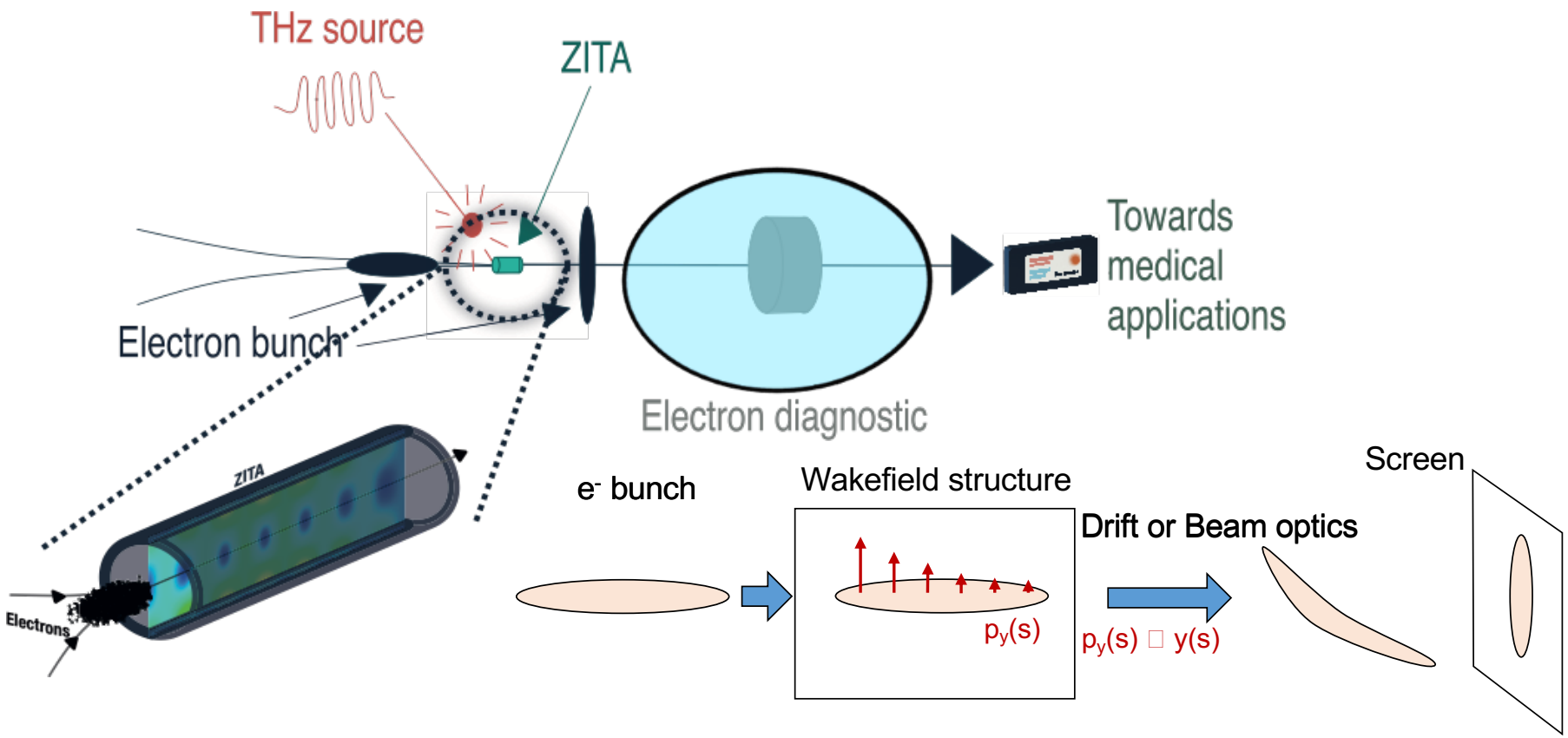


EO head on a 15 cm x 30 cm breadboard

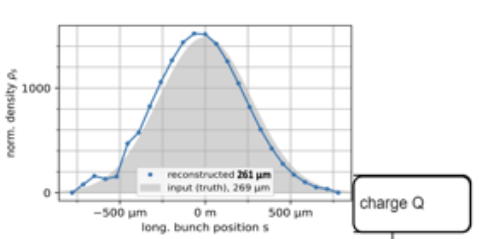


Spectrometer 42 cm x 45 cm board

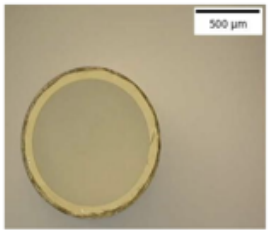
TWAC is funded by :


THz source
ZITA
Electron bunch
Towards
medical
applications
Electron diagnostic
ZITA
Electrons
e- bunch
Wakefield structure
Drift or Beam optics
Screen
py(s)
py(s) □ y(s)

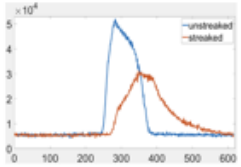
Passive streaking studies at ARES → ijclab

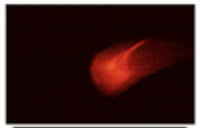


Successful reconstruction on simulated dataset (Gaussian and parabolic)

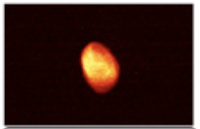


Streaker: coated fused silica tube

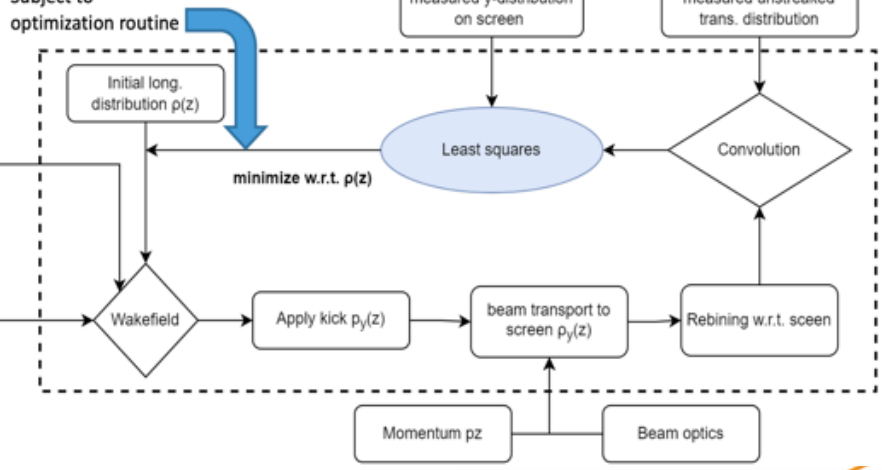




measured y-distribution on screen



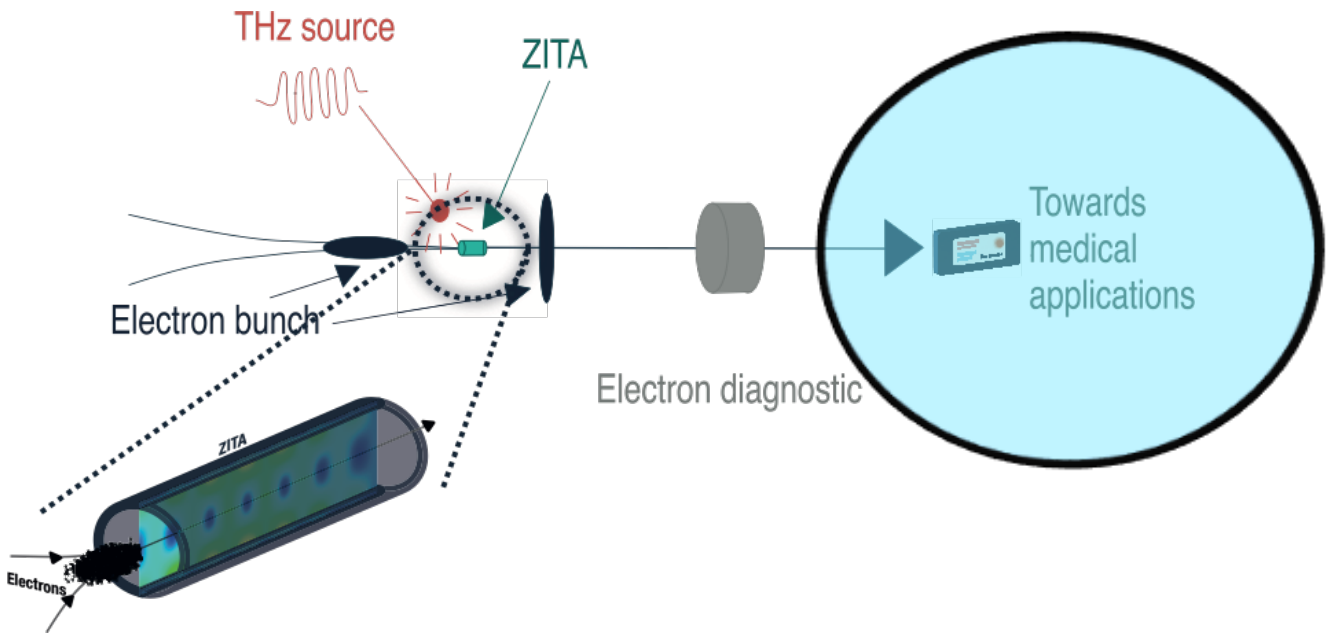
measured unstreaked trans. distribution



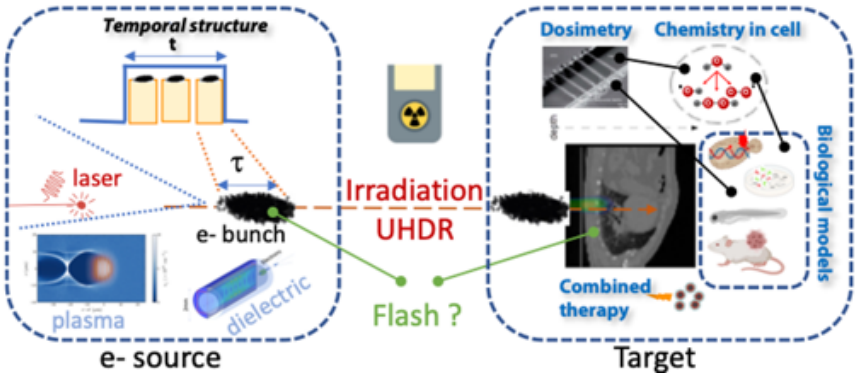
Data analysis ongoing: time profile reconstruction to be made through a forward propagation algorithm.

Chamber under design for IjClab

WP5 Towards societal applications ?

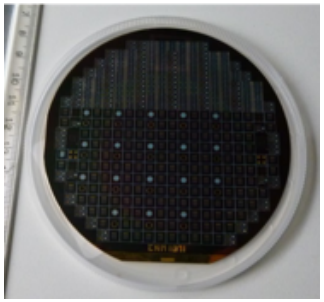


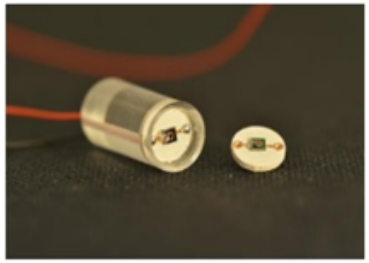
Dosimetry detector

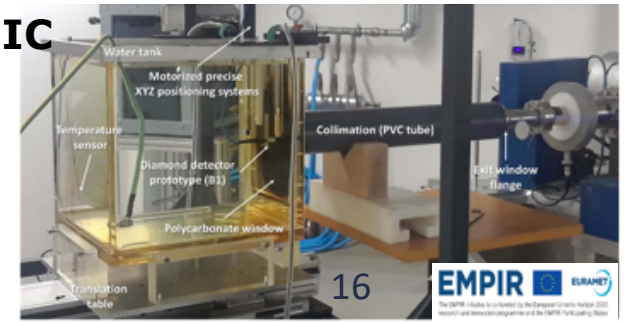


- 52% of cancers are treated by Radiotherapy.
- New paradigm: **irradiation time triggers the Flash effect sparing healthy tissues** compared to standard RT.
- New groundbreaking accelerator technology is needed.

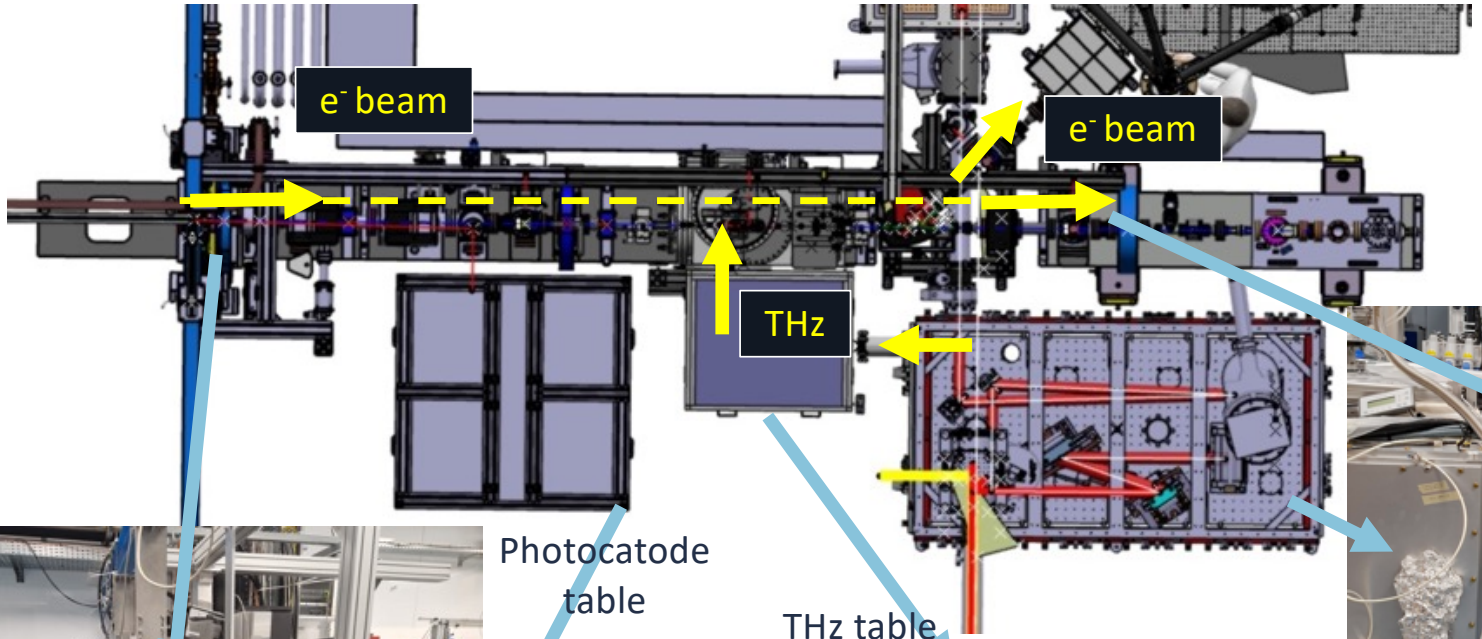
SiC Detectors@CSIC

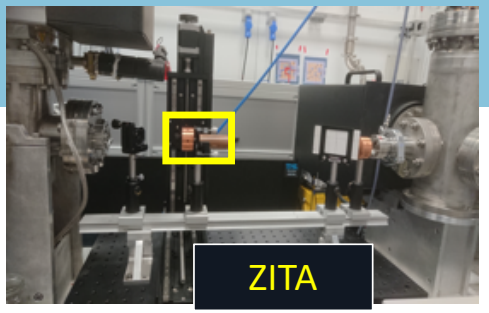




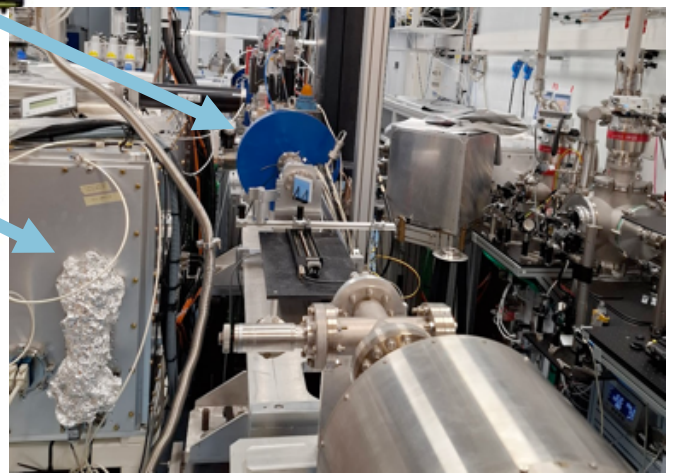


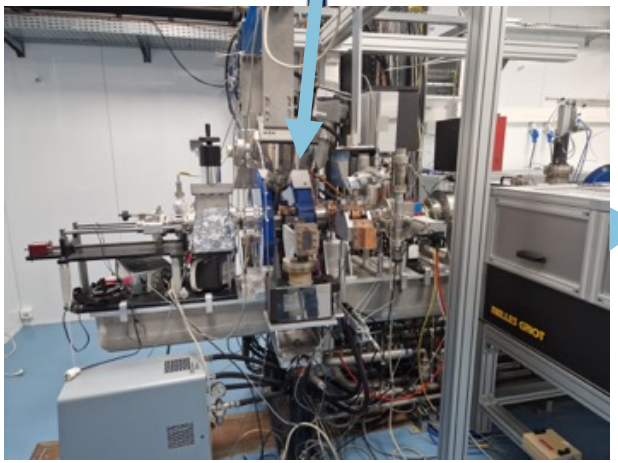
Prototype at CNRS/IJCLab





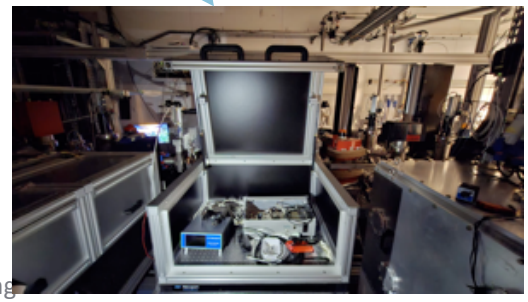
Dosimetry area





Photocatode table

THz table



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