Status of the ELI Beamlines facility

R. Versaci on behalf of
the ELI Beamliens RP group

SATIF-16, 28-31 May 2024, LNF

ELI ERIC

The **Extreme Light Infrastructure (ELI)**

- Research Infrastructure, part of
  the European ESFRI Roadmap

- 1.1.2011 start of
  parallel implementation of 3 sites
- 30.4.2021 ELI ERIC founded
- Founding members: CZ, HU, IT, LT
- Founding observers: DE, BG, RO

- Countries interested in joining:
  CH, ES, PL, PT

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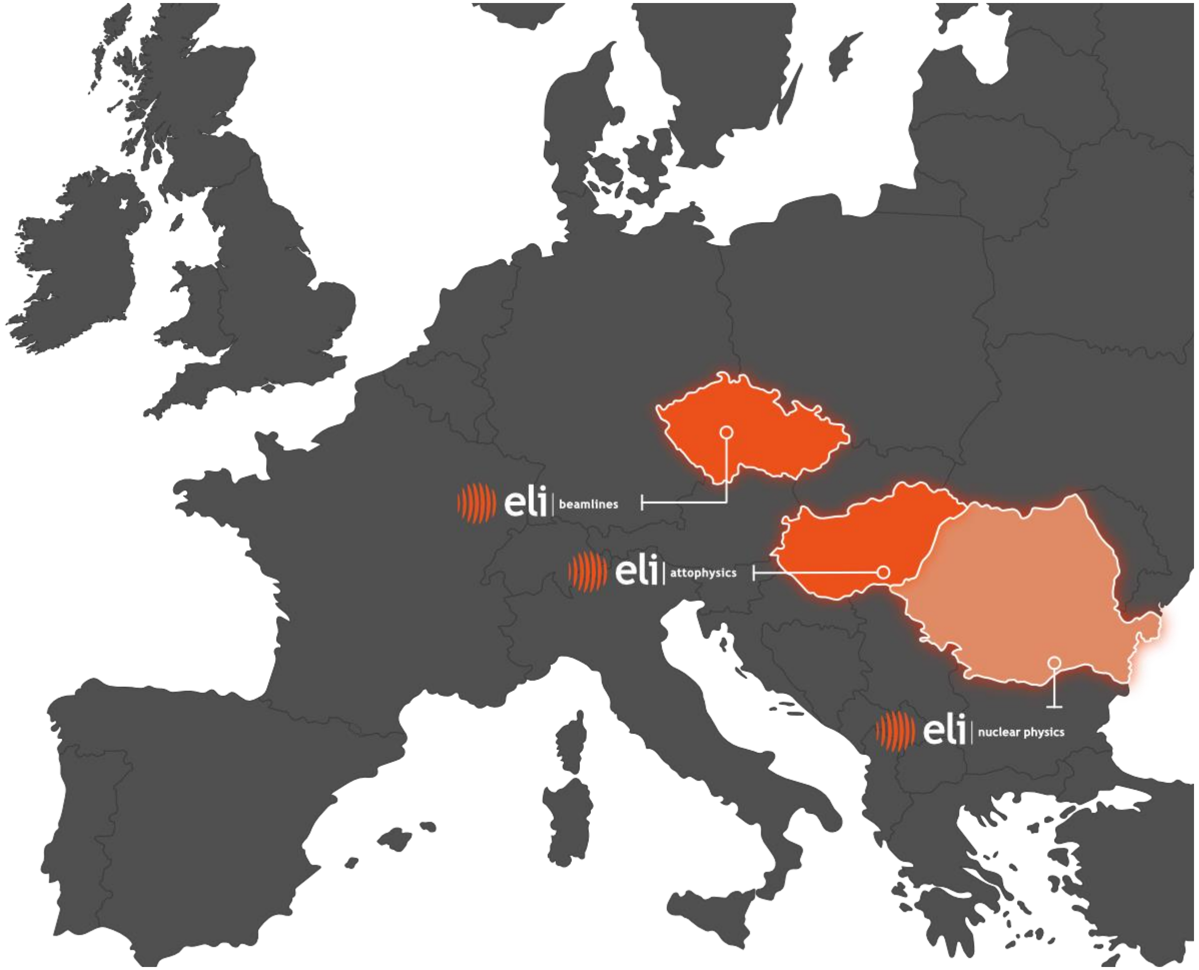
ELI Sites

- **ELI ALPS - Hungary**
  - Ultrafast physical processes
  - Attosecond measurement techniques
- **ELI Beamlines – Czech Republic**
  - Secondary sources
  - Medical imaging and diagnostics, radiotherapy
- **ELI NP – Romania**
  - Photonuclear Physics
  - Exotic nuclei



ELI ALPS

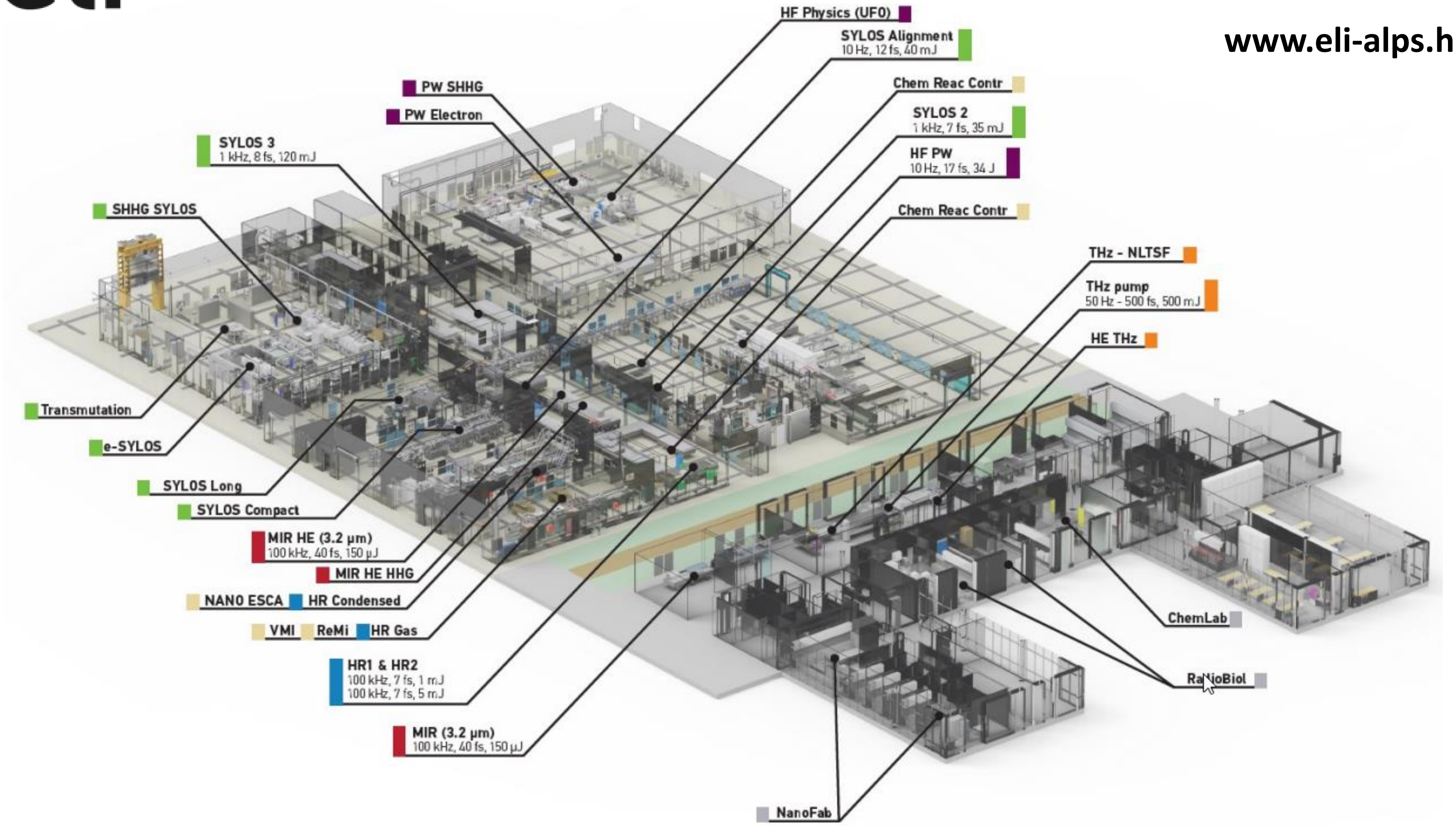
www.eli-alps.hu

- "Attosecond Light Pulse Source"
- Szeged, Hungary
- Light sources between THz (10^{12} Hz) and X-ray (10^{18} - 10^{19} Hz) frequency range
- 5 laser systems
- 8 experimental stations

Applications:
- Attosecond studies in atomic and molecular dynamics
- Nanophysics, materials science
- Plasma physics
- Radiobiology
- THz spectroscopy

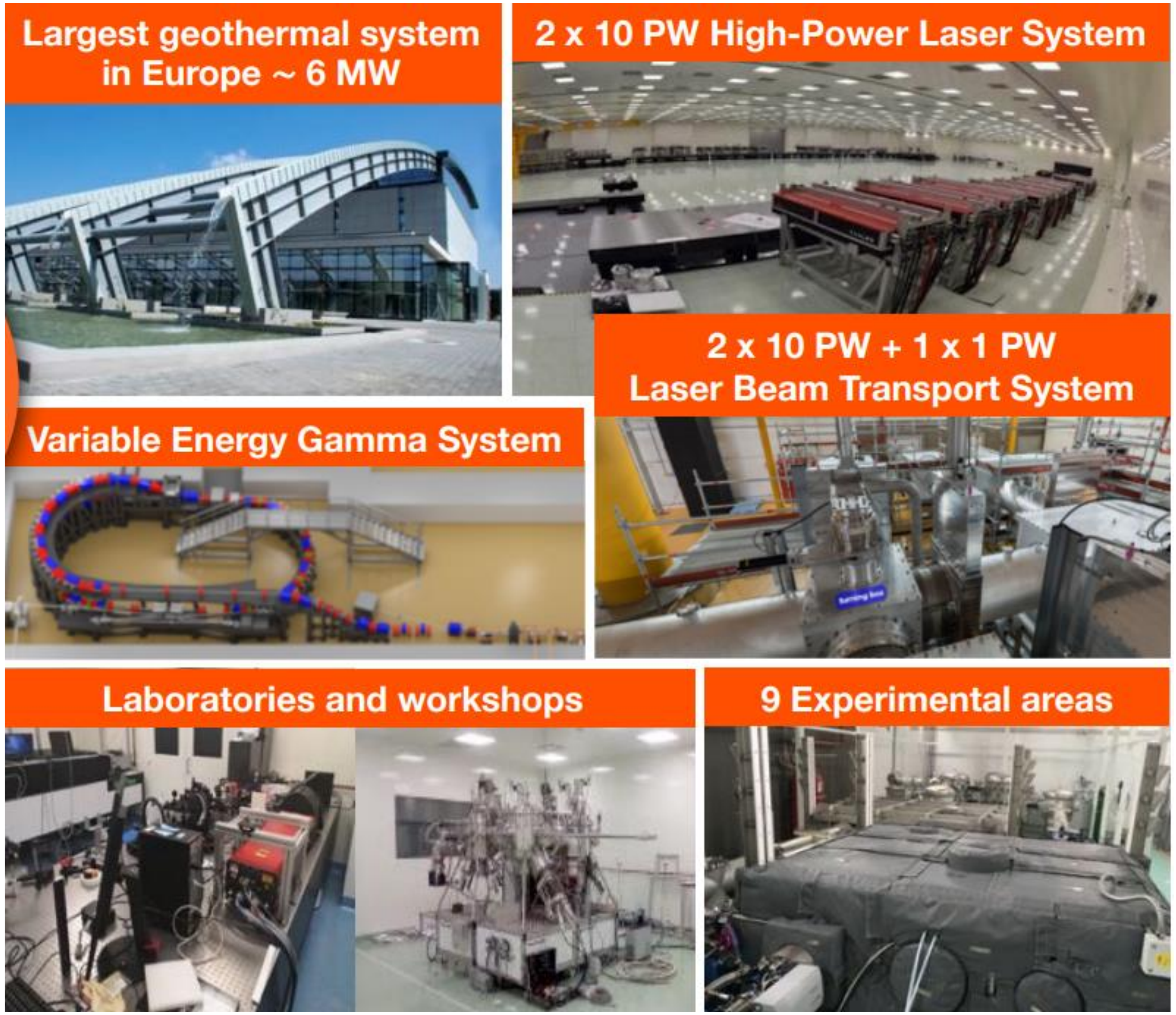
ELI ALPS

www.eli-alps.hu



ELI NP

www.eli-np.ro



Magurele, Romania

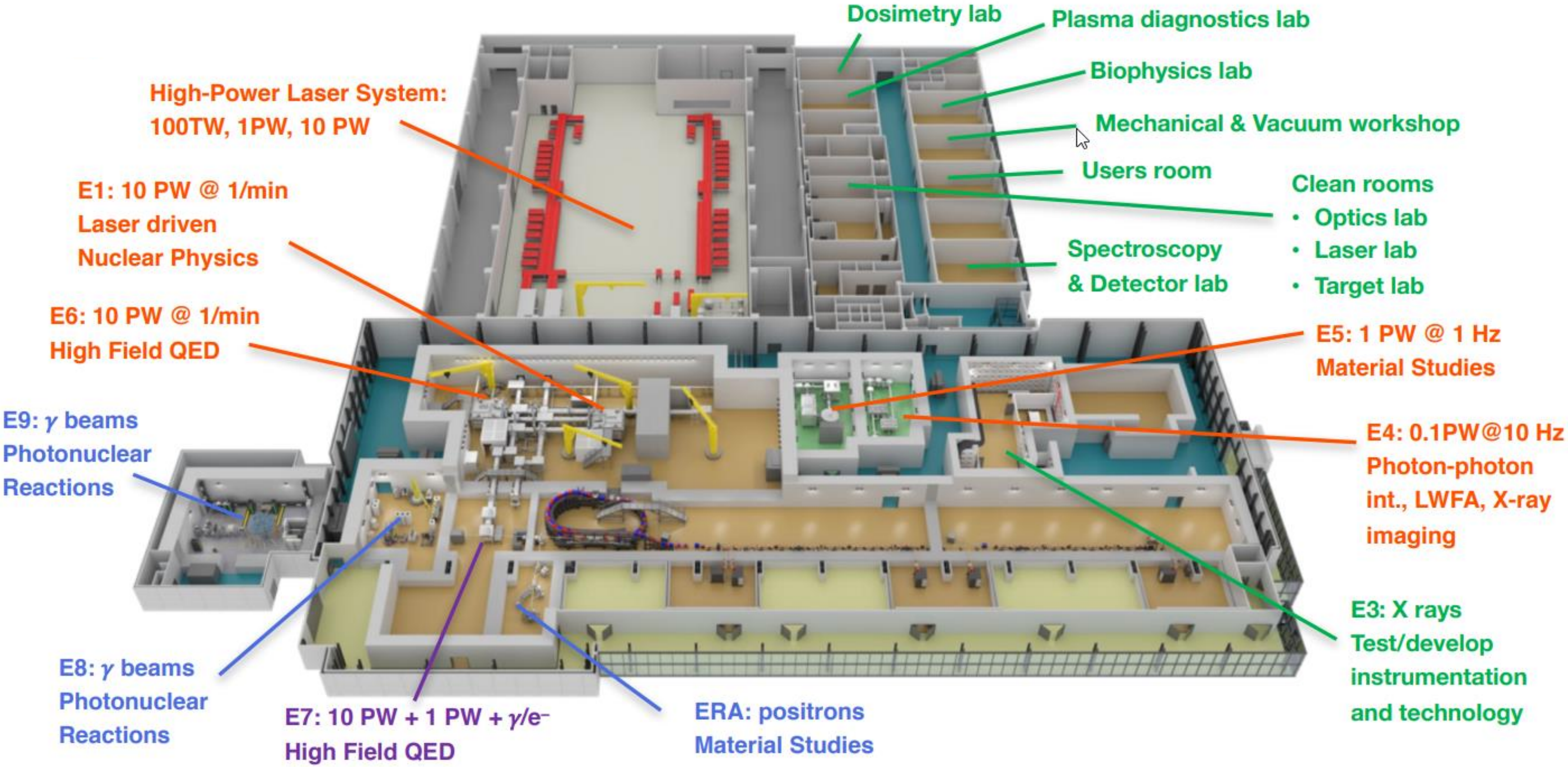
- 2 laser systems
- Intensities 10^{23}-10^{24} W/cm^2

Applications:

- Photonuclear reactions
- Exotic nuclear physics
- Astrophysics
- Characterization of laser – target interaction

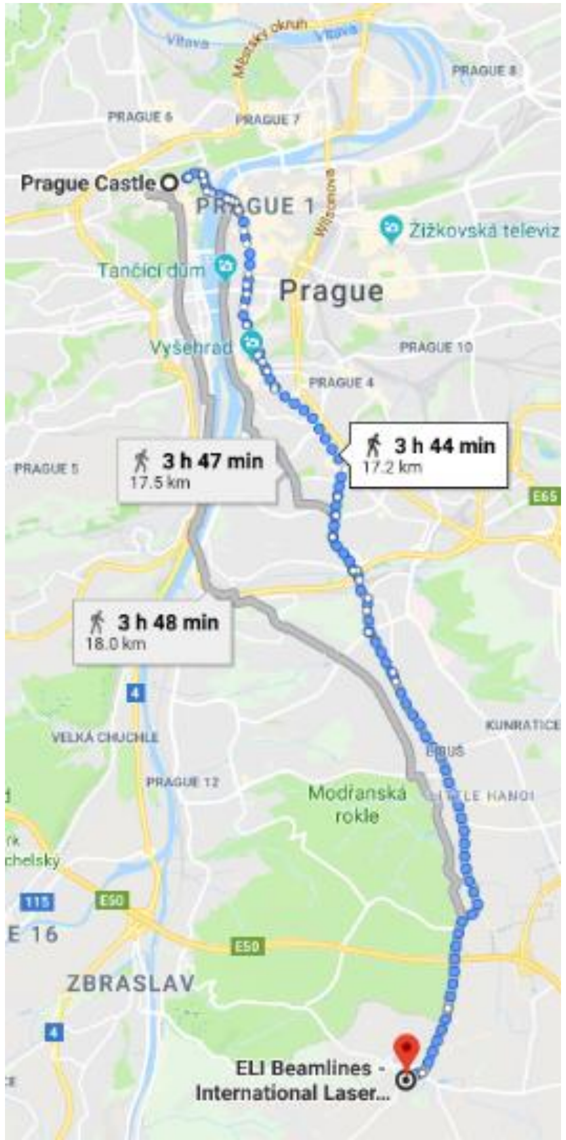
ELI NP

www.eli-np.ro



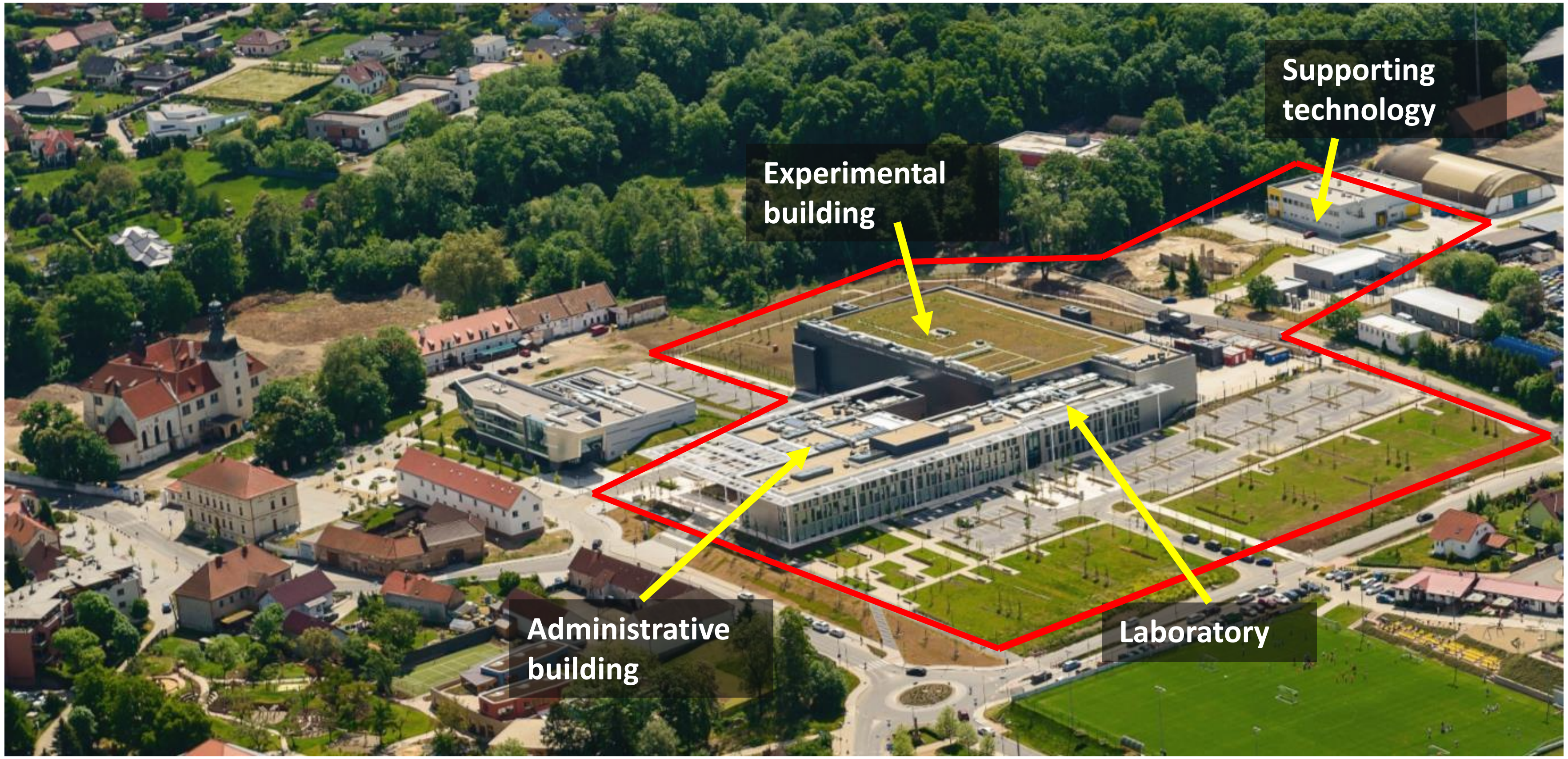
ELI Beamlines

www.eli-beams.eu



Integrated in the ERIC from 1.1.2023

Located on the outskirts of Prague



ELI Beamlines

www.eli-beams.eu

4 PW class laser

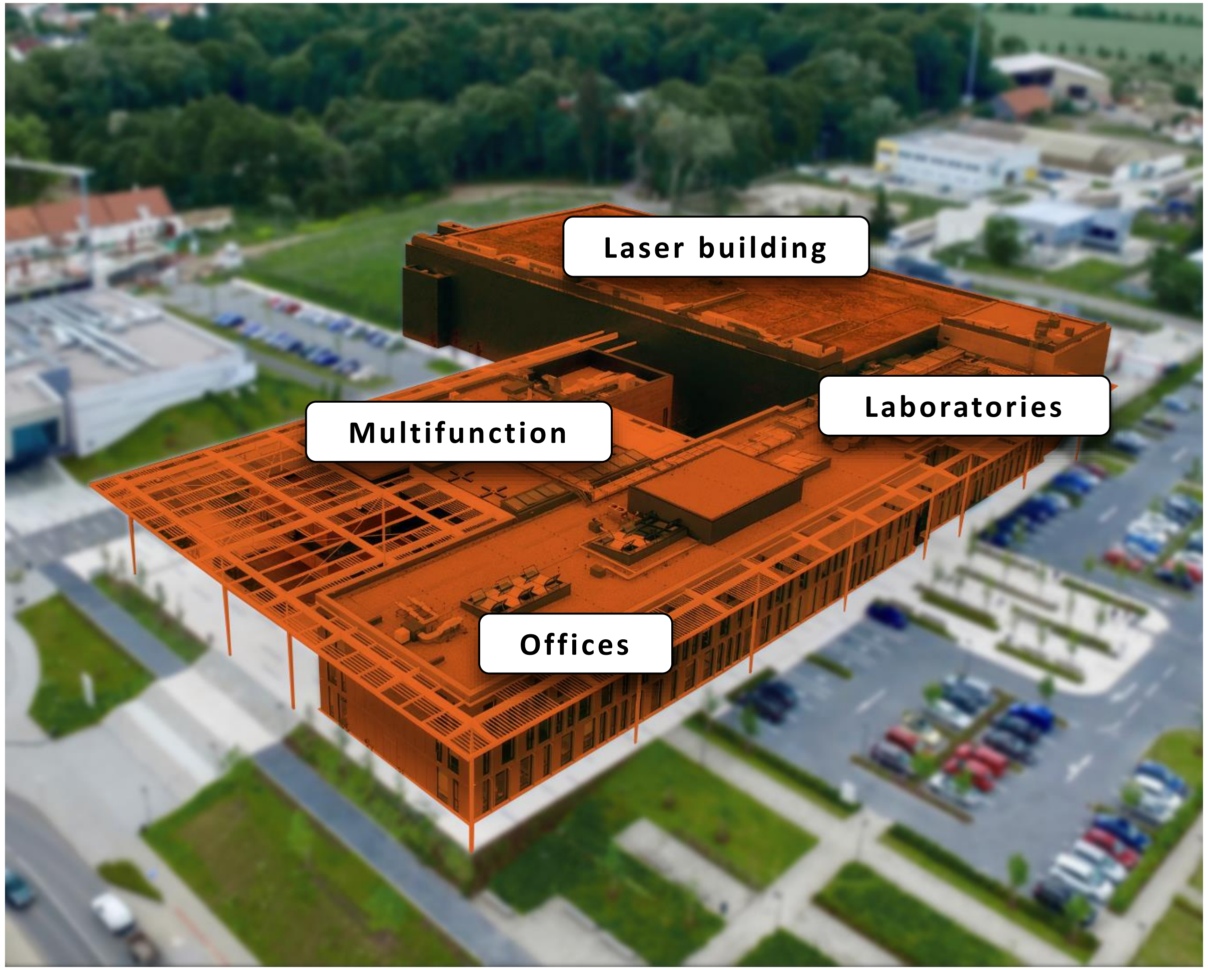
Multiple commercial lasers

7 secondary sources, like
X-rays, e-, and Ion Accelerators

10 user stations

350 international staff

31’000 m^2 area



ELI Beamlines

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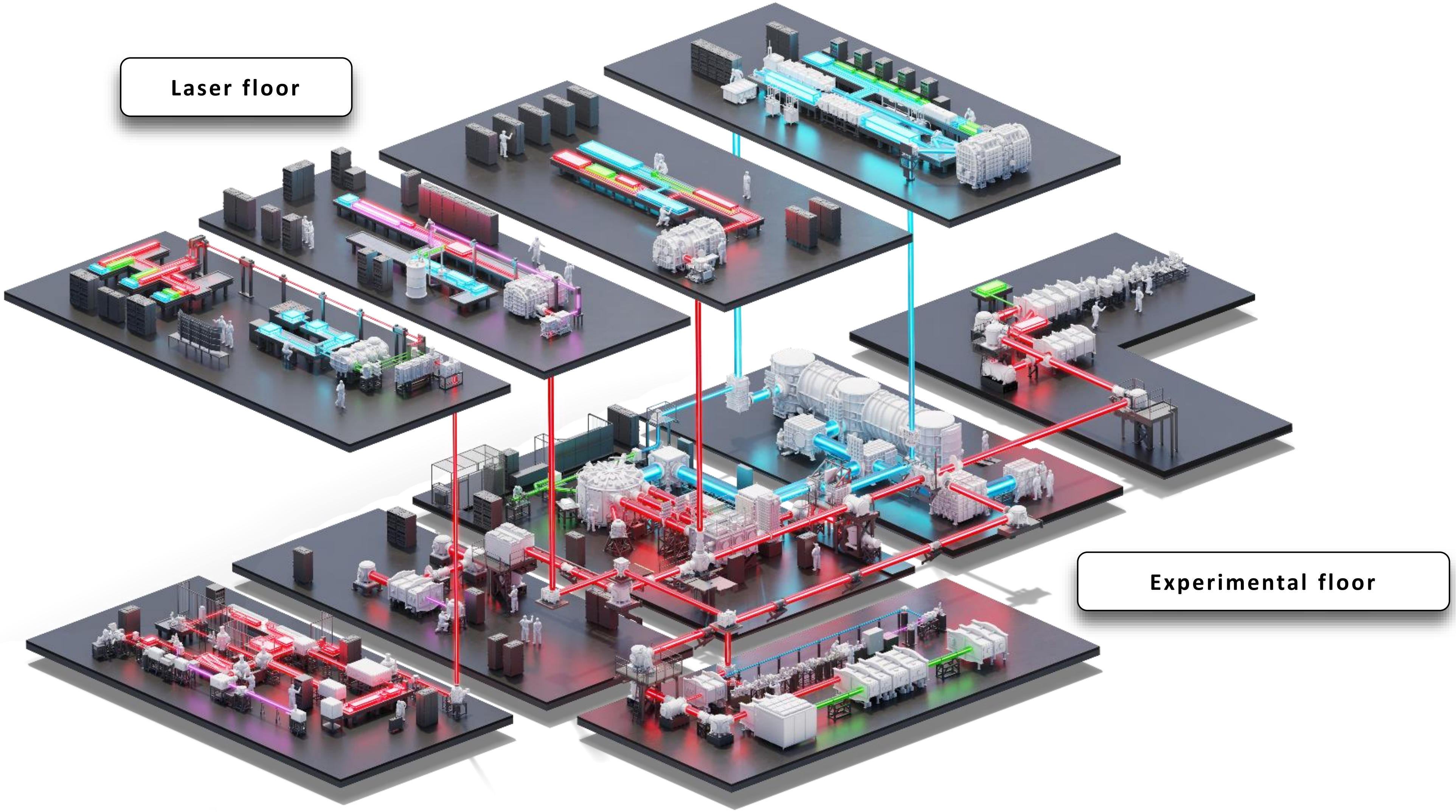


ELI Beamlines lasers

L1-Allegra: 10 TW, 100 mJ, 1 kHz

L2-Duha: 100 TW, 2 J, 50 Hz

L3-HAPLS: 1 PW, 30 J, 10 Hz

L4-Aton: 10 PW, 1,5 kJ, 0.016 Hz

ELI Beamlines experimental stations

ELI Beamlines experimental stations

Ion acceleration
- Available for users
- 1st phase: protons up to 60 MeV
- Later 200-300 MeV

Plasma physics
- Available for users
- Mixed source with large angle emission

ELI Beamlines experimental stations

From spontaneous to coherent electron radiation

- Commissioning ongoing
- Up to 600 MeV electron, 1% spread
- λph ~ 2-5nm (water-window)

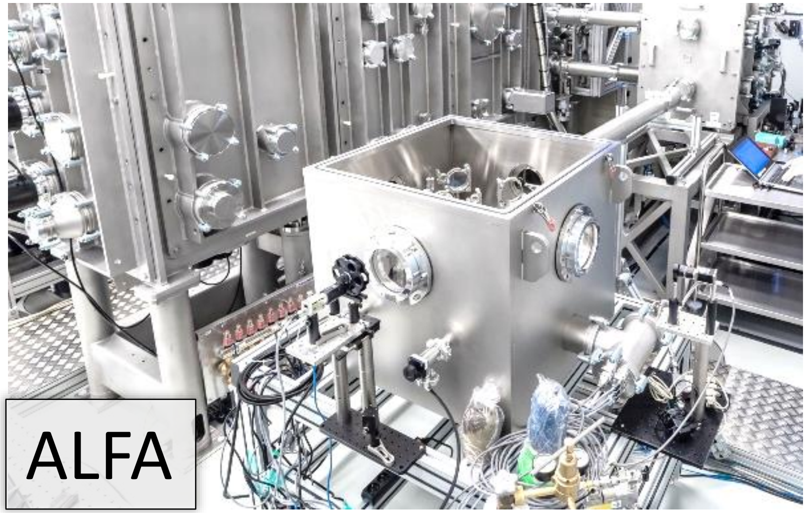
Electron acceleration

- Available for users
- 1st phase: multi-GeV
  - 1.5 GeV in the last campaign

ELI Beamlines experimental stations

E2

- First beam last month
- Electrons up to 2 GeV
- X rays used for experiments



ALFA

- Available for user
- 1kHz repetition rate
- ~150 MeV in spring 2022

Source terms overview

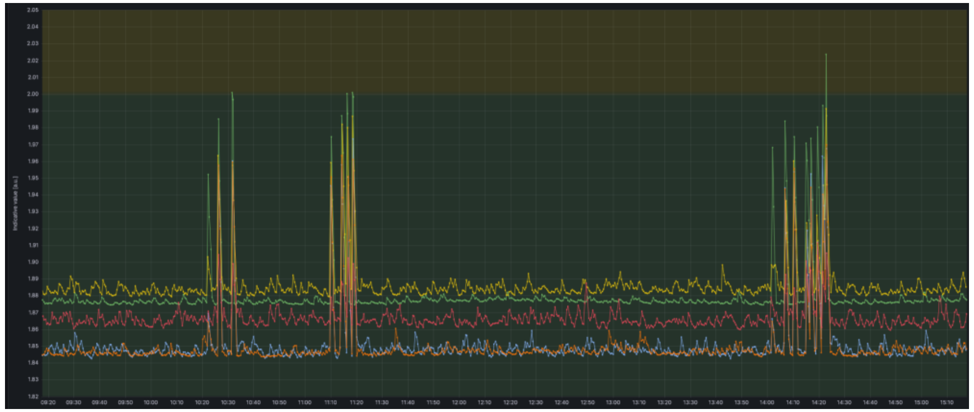
- Pulsed – length of primary pulse ~10^{-14}s
- Low repetition rate: 0.1 Hz – 1 kHz
- Mixed field: e-, e+, γ, p, n, μ
- Wide spread of energies (10^0 eV to 10^9 eV)
- Extremely high dose rate in a single pulse
- Strong magnetic field (10^2 kV/m)

Source term not well known!

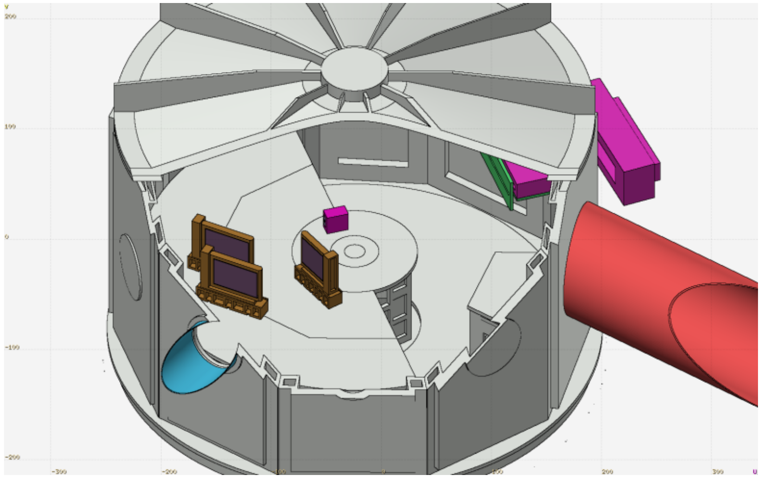
- Subject of research
- Strongly dependent on the experiment

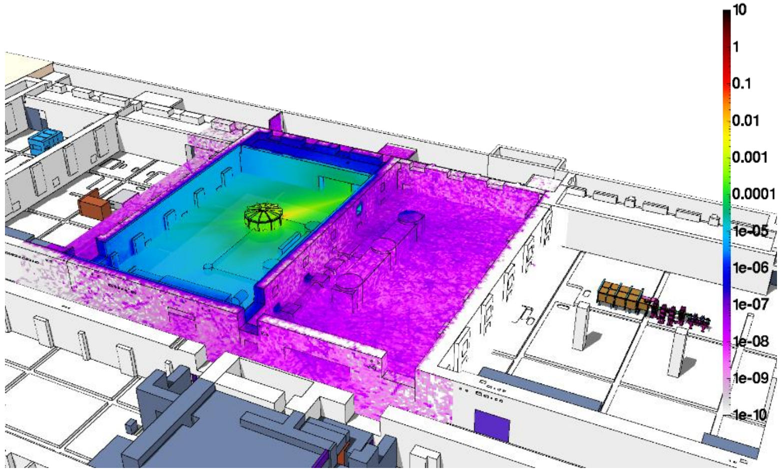
RP Standard Measures

- Monte Carlo assessment
- People not allowed in the experimental area
  Personal Safety Interlock in place
- Monitoring system of ionizing radiation



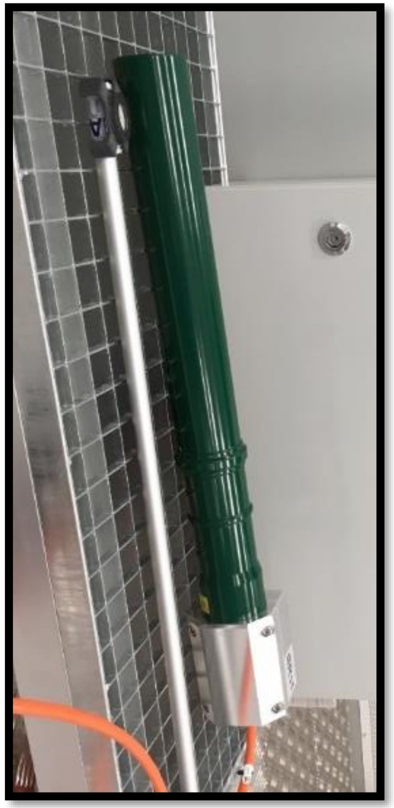
FLUKA https://fluka.cern/





Monitoring system

- Monitoring system of ionizing radiation (γ , n)
  - In the experimental area to “control the experiments” and benchmark simulations
  - In the control room and service areas for RP purposes



Personal Safety System

Laser halls	Beam transport	Experimental halls
• LSS • Laser hazard only • Inhouse • Running since 2018	• PSI • Laser & vacuum hazard • 3 BT running • 1 BT installed	• PSI • Laser, radiation, HV, gas • Rockwell automation • Fully installed and working since February 2024

Personal Safety System

PSI information panel

Radiation & gas monitoring

PSI semaphore

Access system

PSI control panel

PSI keys

PSI Beam OFF button

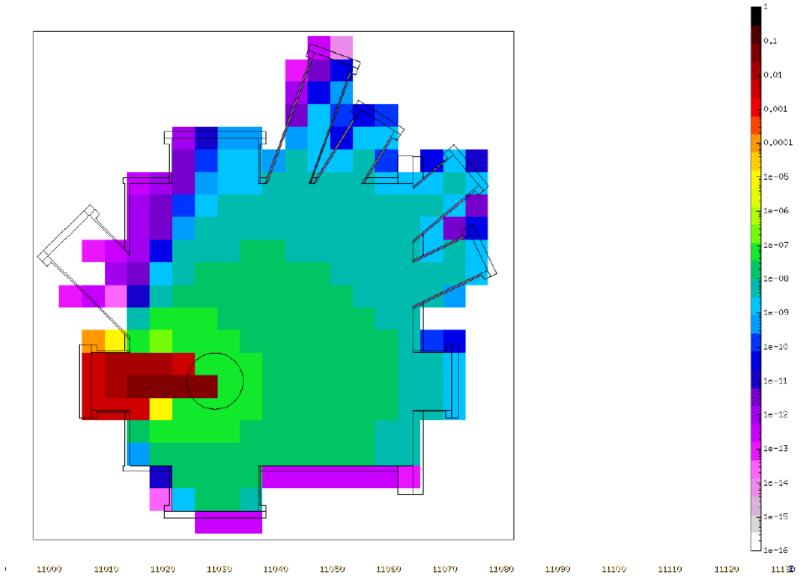
Lesson learned #1

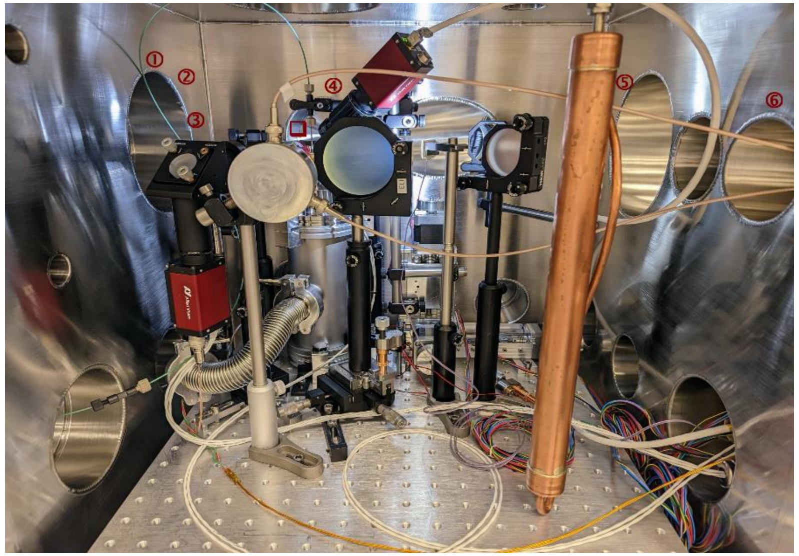
Small setup, commercial Class 4 laser “Astrella“

- Rep. rate 1 kHz, water jet target
- Expected source term: protons, 1 MeV
- Experimental chamber wall: 1 cm thick steel

No measurable radiation expected outside

Experimental data:
12 µSv/h rate detected by EPD in close chamber vicinity
Cumulative dose collected by OSLs up to 200 µSv/over 12 hour operation



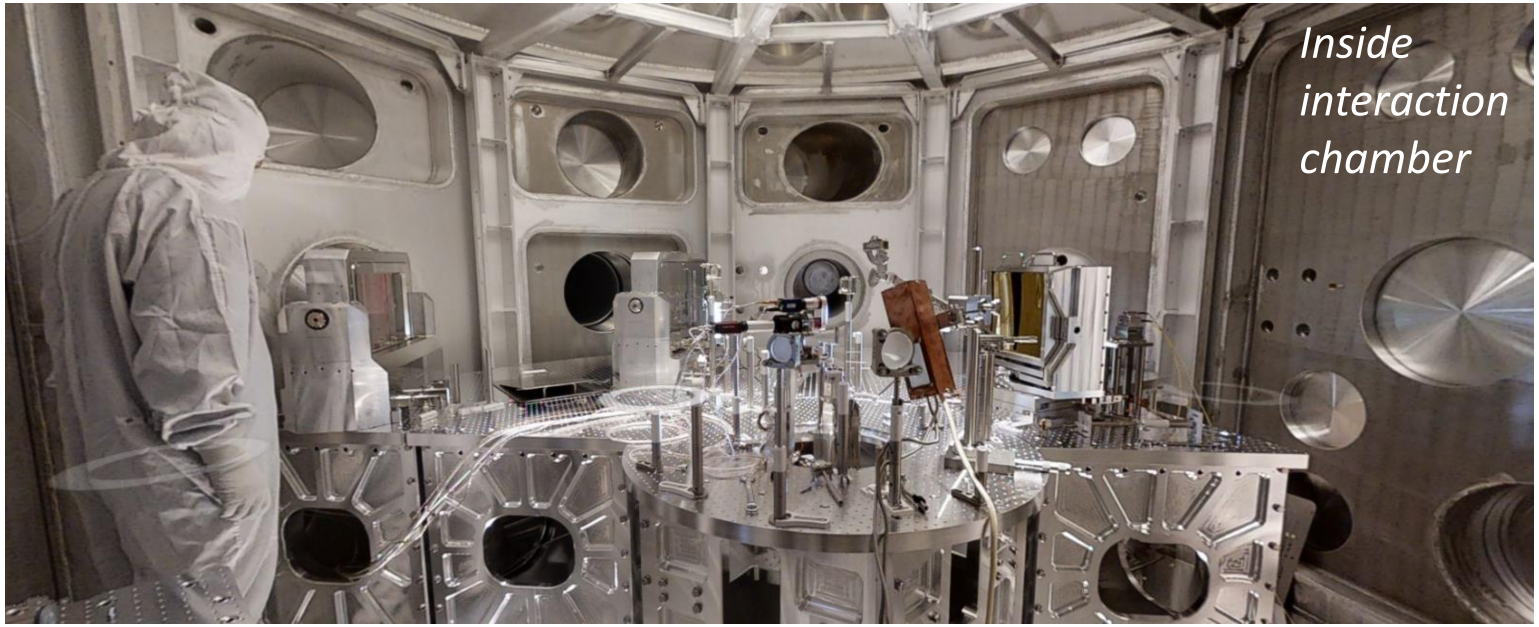


Lesson learned #2

"Short Focal Length" experiment

- Test of target systems
- L3 laser HAPLS, gradual ramp up to 12J, 3.10^{-14} s laser pulse length
- Single shots to sequences at 3.3 Hz for 20 s
- Production of X-rays and of low energy electrons
- Expected source term: 10^{-7}C of electrons/shot, Maxwell-Boltzmann T=1.4 MeV

No radiation expected above background level ~0.1 µSv/h



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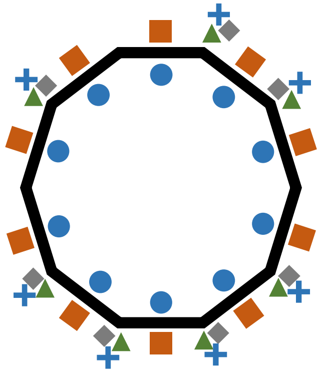
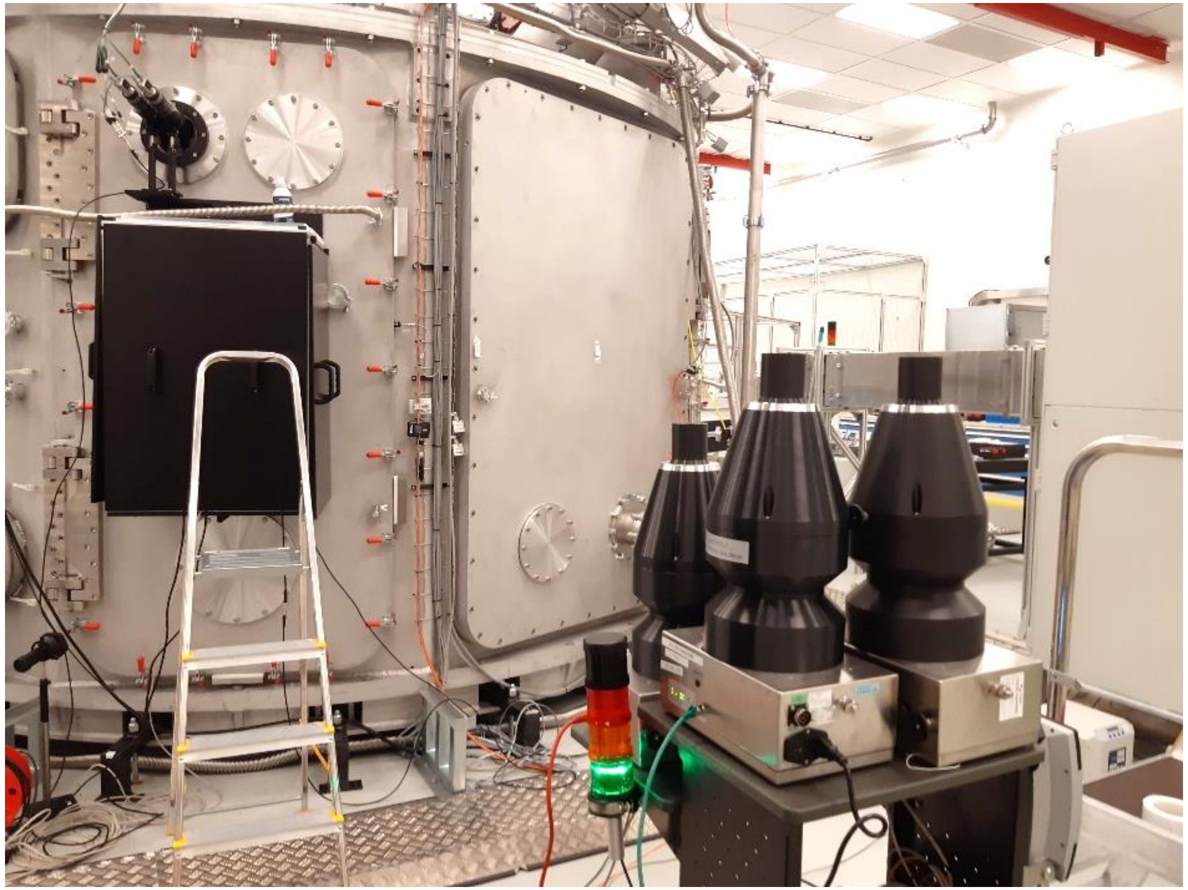
Lesson learned #2

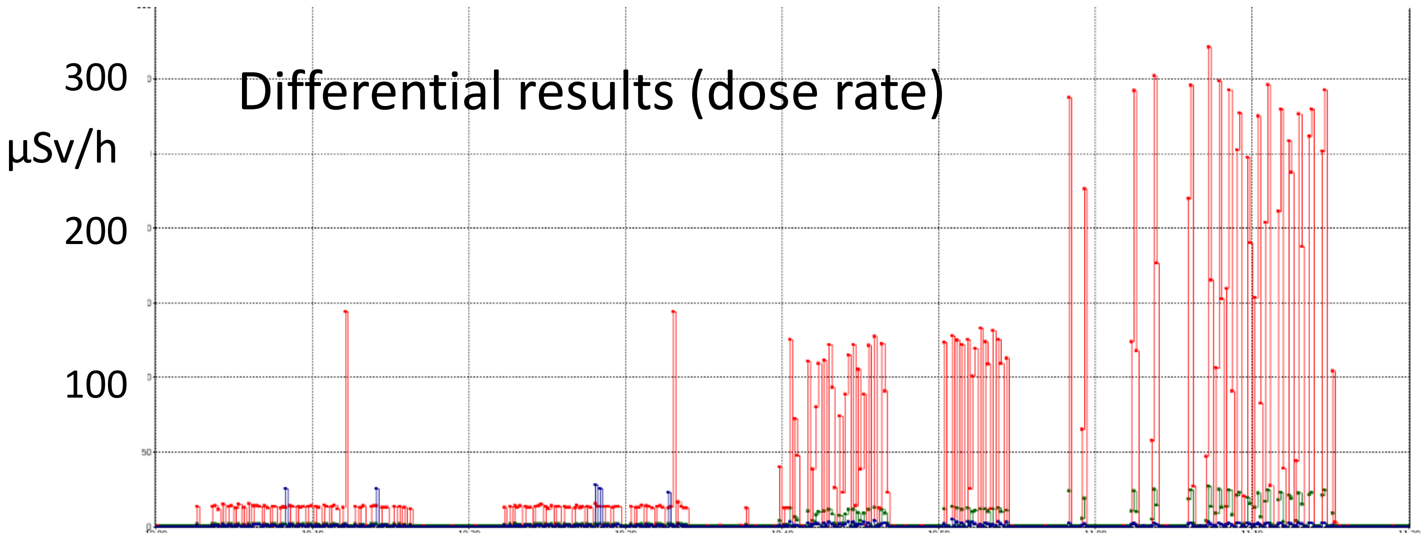
- Active systems:
  - LB6419-PANDORA
  - EPDn
  - Sensitive to γ only: EPDg, CryRad
- Passive systems
  - Bubble detectors
  - CR39
  - Sensitive to γ only: OSL, DIS
- At beam height over 2π

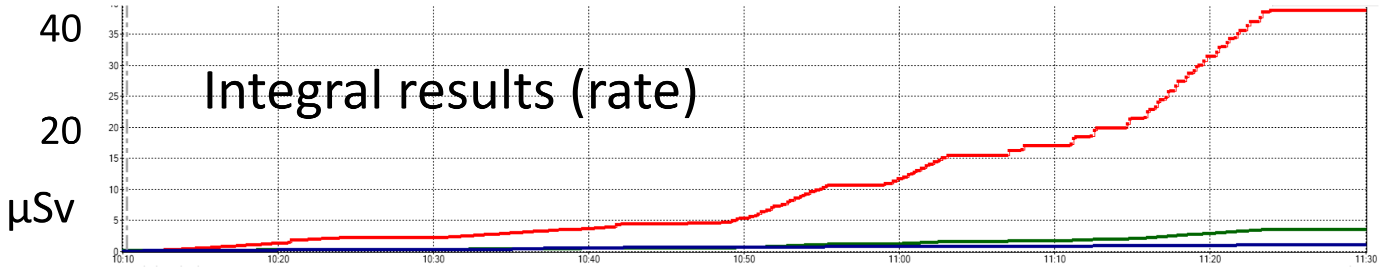




Lesson learned #2

While no radiation expected above background level ~0.1 µSv/h,
on day 1, active detector measured ~3 µSv/h of neutrons about 20 MeV





- HE neutron
- LE neutron
- Gamma

LB6419 - Pandora

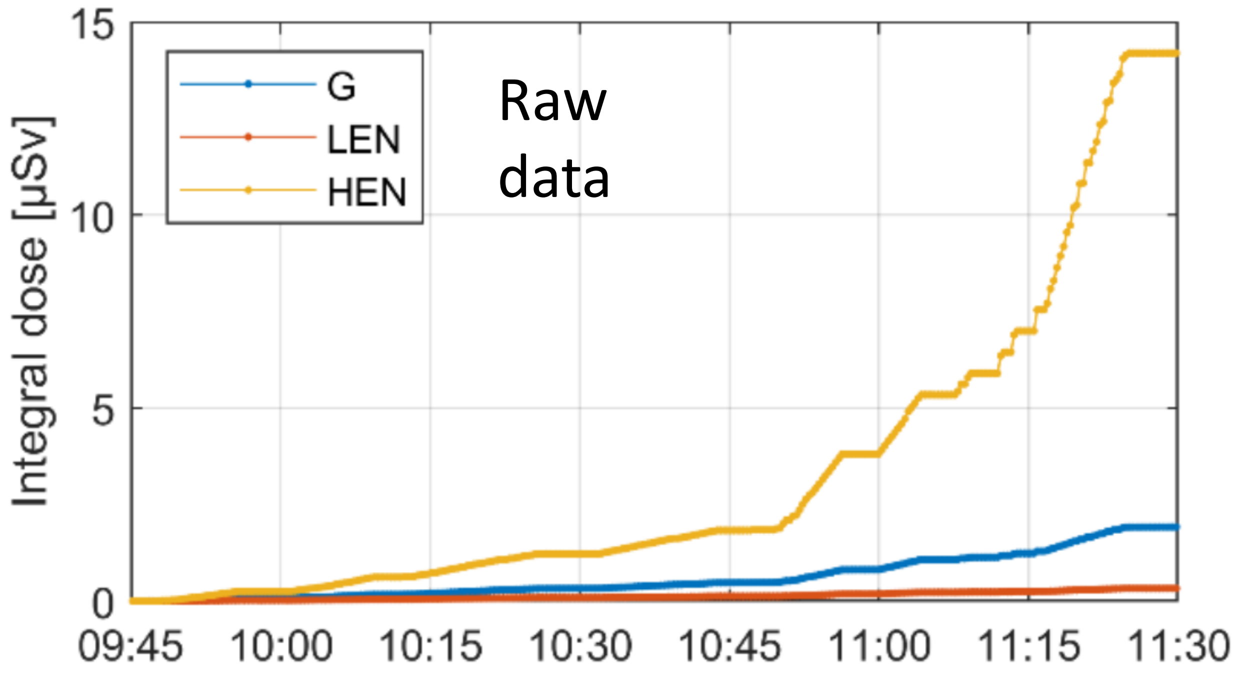
Lesson learned #2

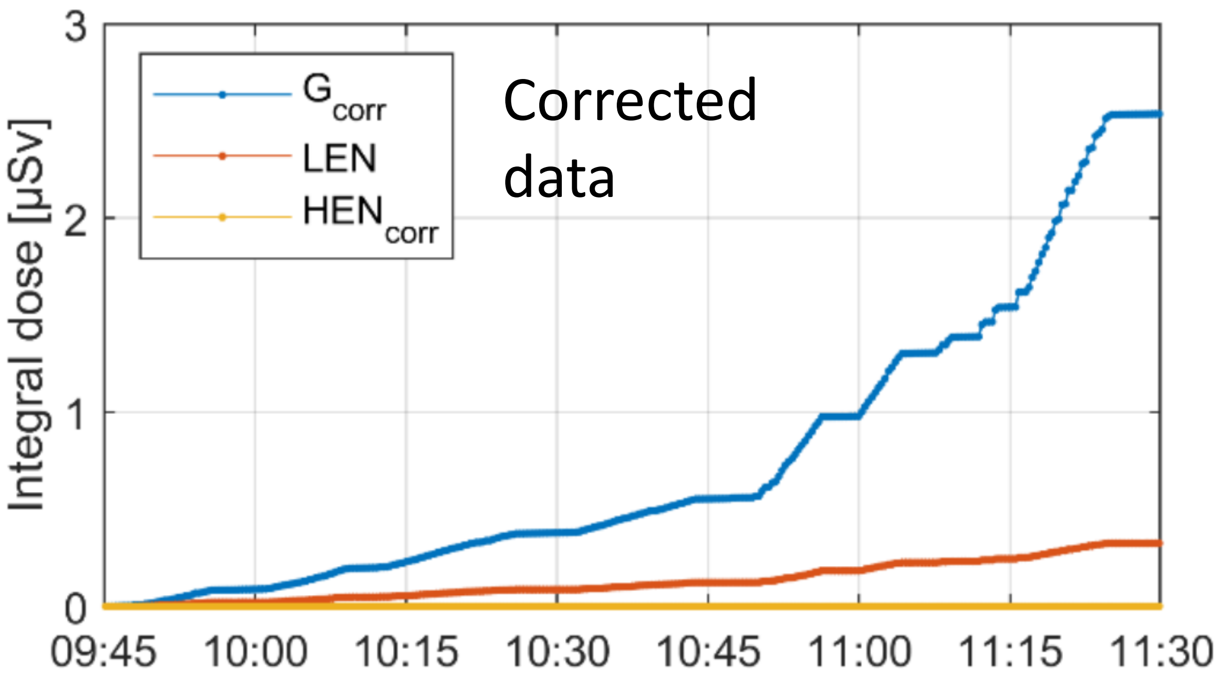
Data re-analyzed together with A. Leuschner

Re-analysis based on

- energy deposition spectrum
- timing of the signal

LE neutron
HE neutrons
gamma





Conclusions

Until now:

- The interlock and monitoring systems worked perfectly
- Ambient dose levels in populated areas compatible with background
- Designed shielding and protection measures proved adequate

MC simulations:

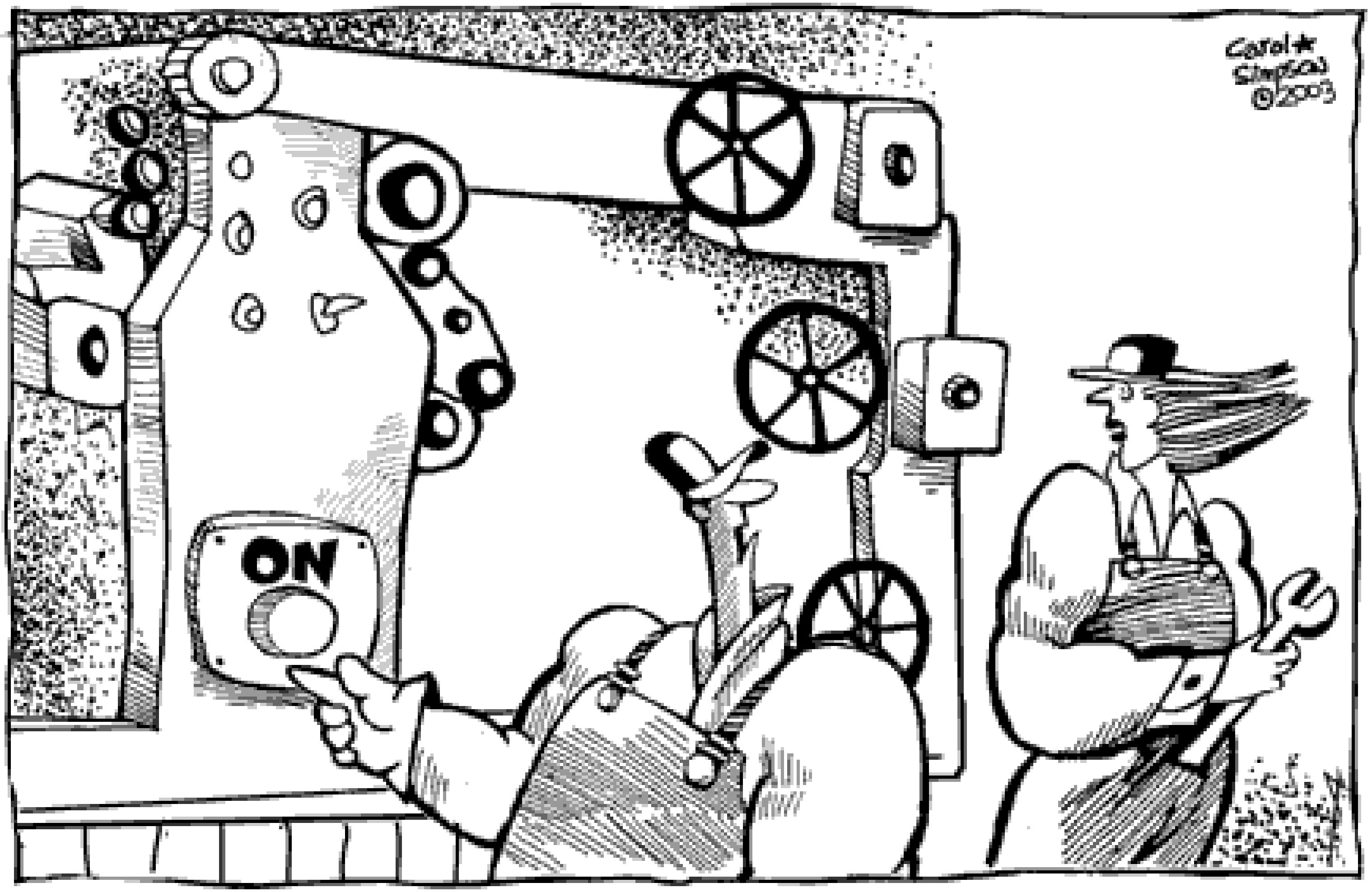
- As solid as the input, often the generated radiation is more energetic than expected
- Cannot reproduce campaigns:

  too many unknown parameters, shot-to-shot differences

Important:

- Higher safety factor than in conventional facilities is needed
- Interpretation of detector readings requires critical thinking

Conclusions



"This machine is perfectly safe...
As long as you never press this button."