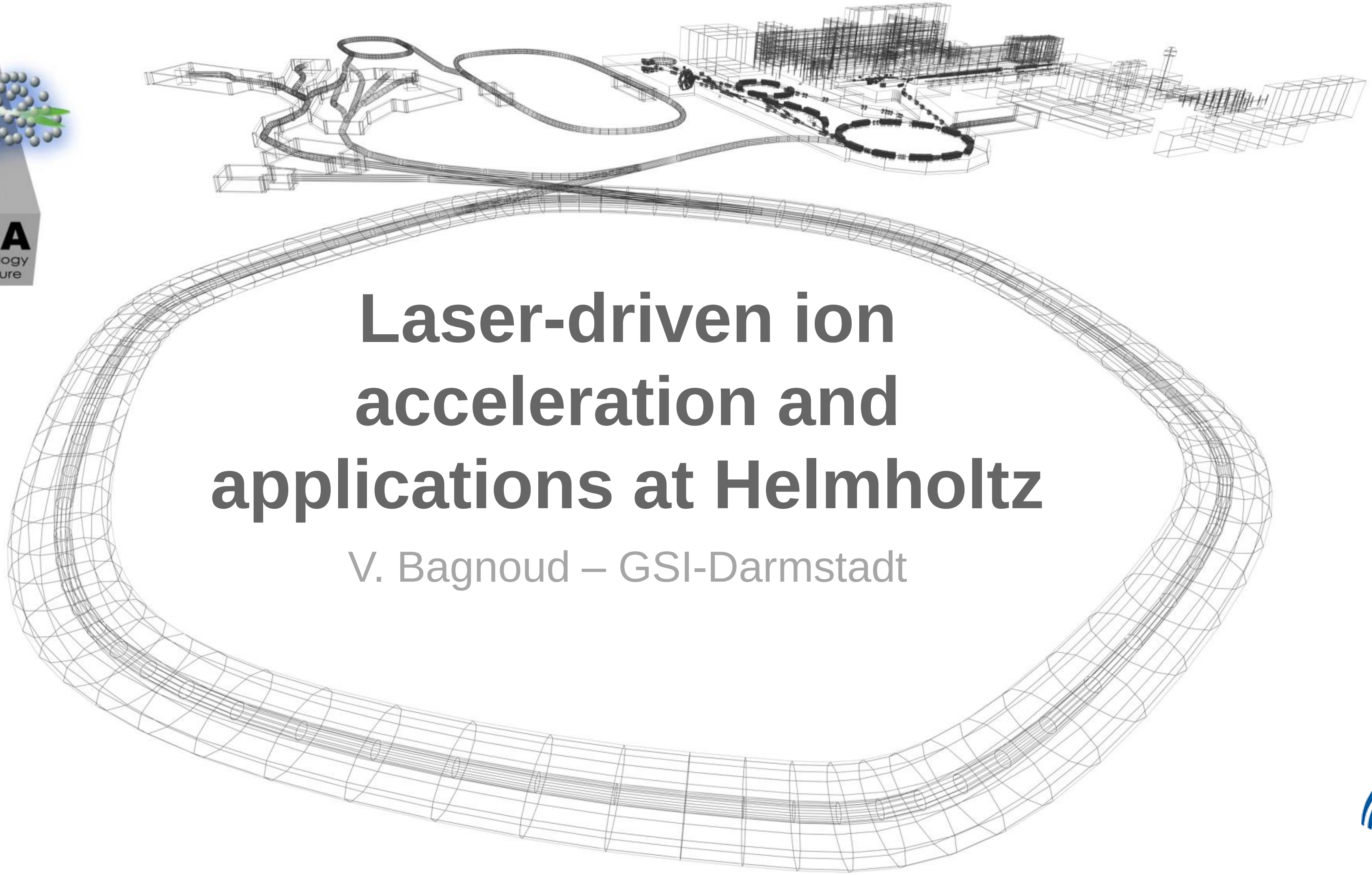
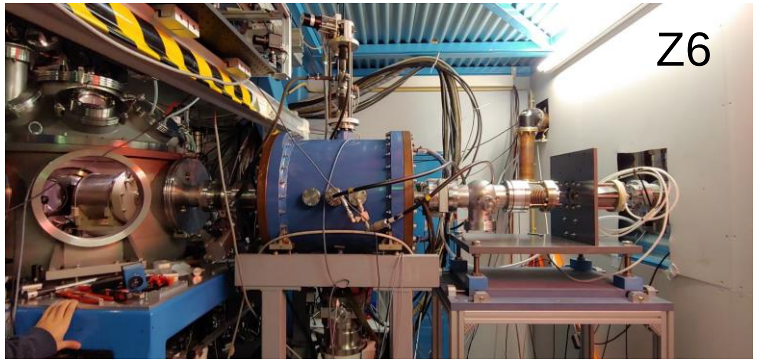


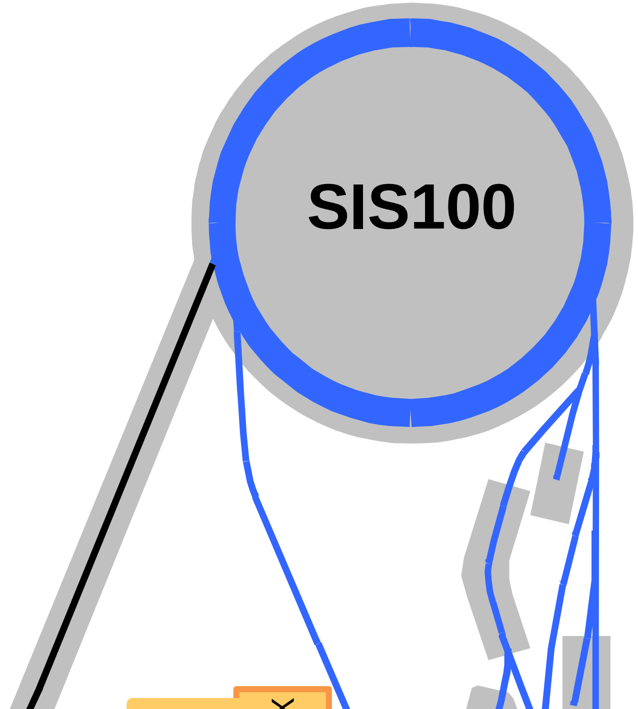
# Laser-driven ion acceleration and applications at Helmholtz

V. Bagnoud – GSI-Darmstadt

# Motivation for laser-driven ion acceleration at Helmholtz

- Applications in oncology at HZDR
- Injection of GSI's SIS-100 synchrotron as demonstrator (LIGHT project)
- Backlighting of high-energy-density matter at FAIR/GSI
- Neutron and spin-polarized particles (Jülich, GSI)





GSI's accelerator

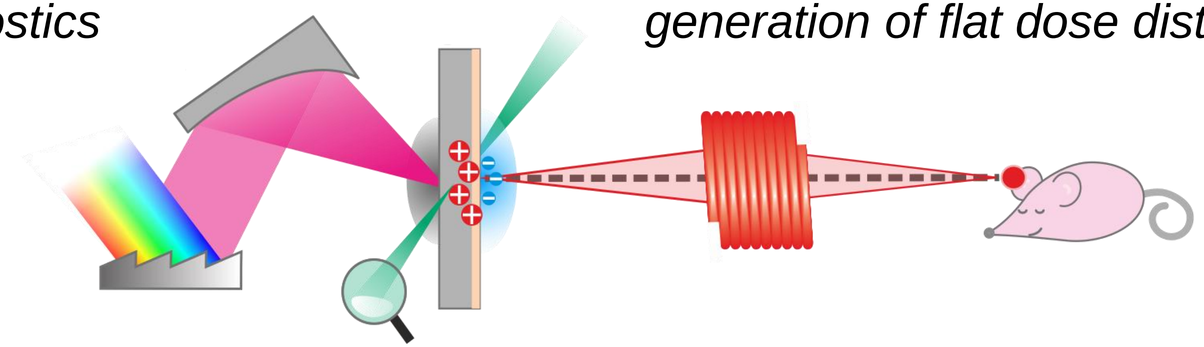
# First in-vivo proton irradiation at a compact laser plasma accelerator

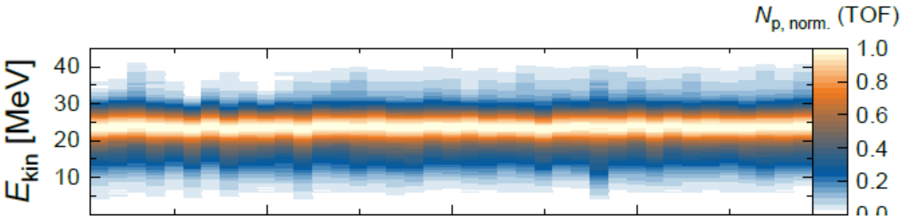
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

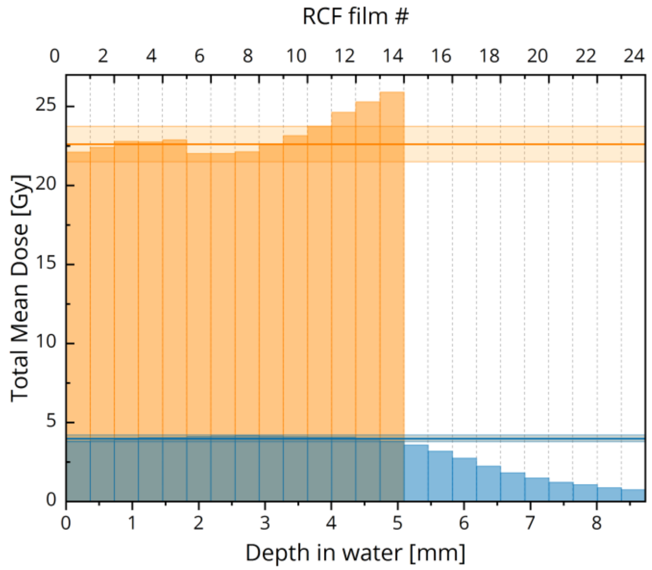
- Goal: investigate high dose rate effects (in medicine and materials research)
- proton pulses have been routinely generated in TNSA mode over many month on demand - filtered spectra for application – depth dose distribution (> 20 Gy / shot)

***PW laser*** *(15J in 30fs PM-cleaned)*
*full on-target diagnostics*

*compact* ***pulsed magnet beam transport*** *(cf LIGHT)*
*generation of flat dose distribution in single pulse*



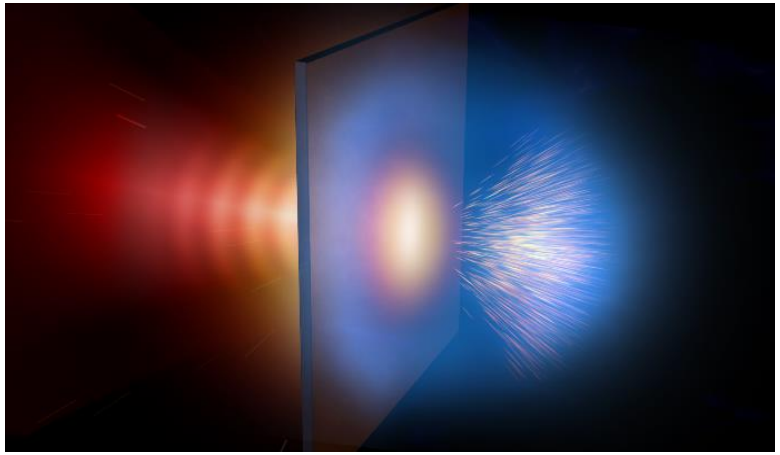


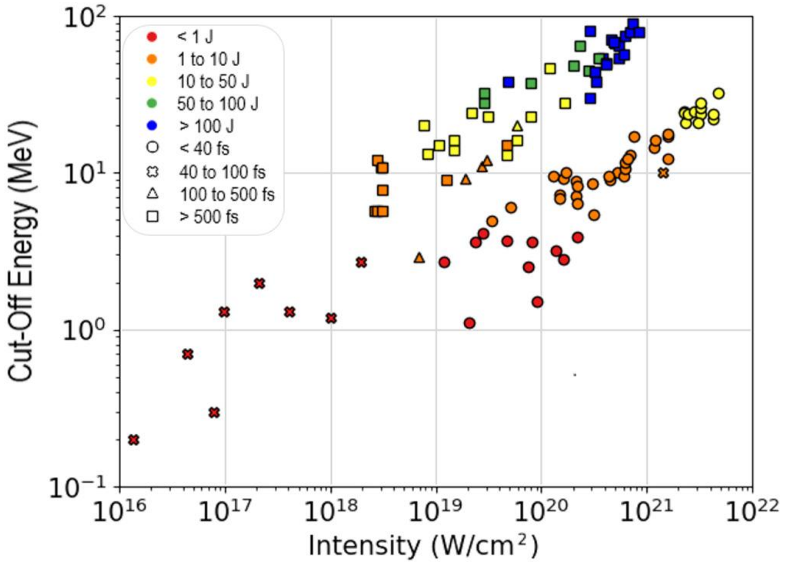




*F. Kroll, E. Beyreuther, et al., in review; T. Ziegler, et al., Sci. Rep. 11, 7338 (2021); F. Brack, et al., Sci. Rep. 10, 9118 (2020)*

# Laser-ion driven acceleration

- Pioneered in 2020 at LLNL (USA)[1]
- Relies on the generation of strong transient (picosecond) gradients and charge separation
  - local fields ~TV/m
- Currently an active field of R&D
  - particle generation (efficiency, particle energy, divergence)
  - beam manipulation and conditioning (HZDR, ELI Med, LIGHT)
- Helmholtz currently leading in this field



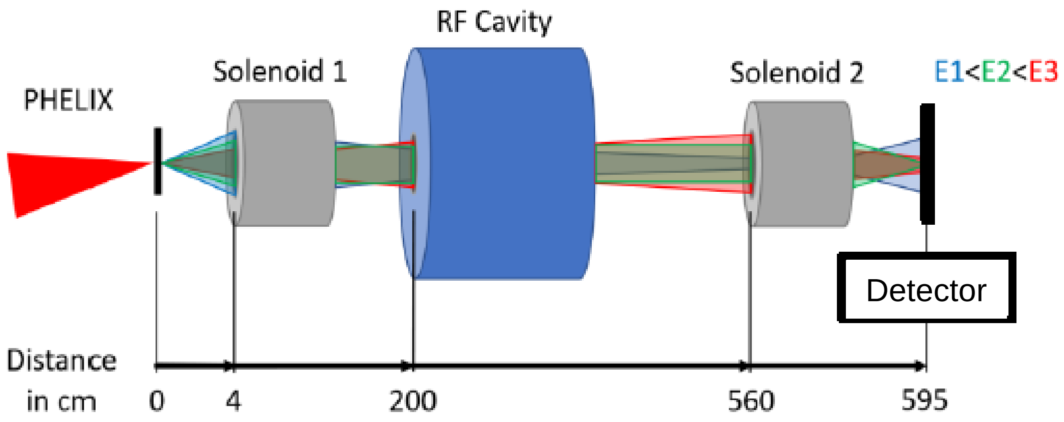



1 – R.A. Snavely et al. PRL (2000)

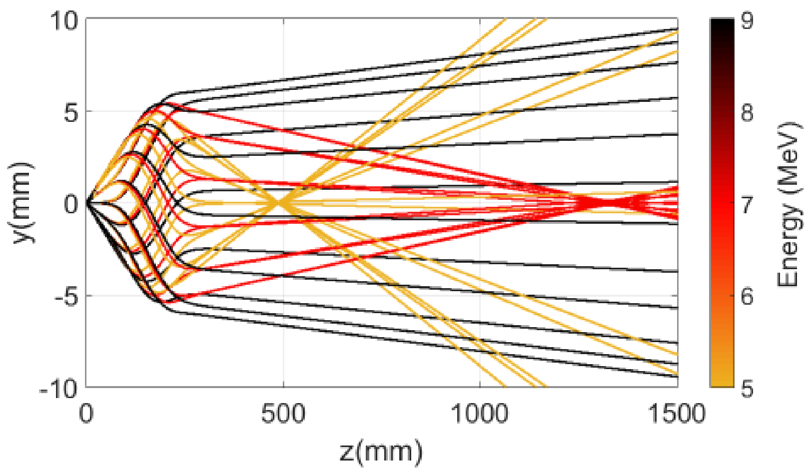
[M. Zimmer et al., Phys. Rev. E **104**, 045210 (2021)]

# Challenges in laser-driven acceleration at GSI: beam conditioning and injection

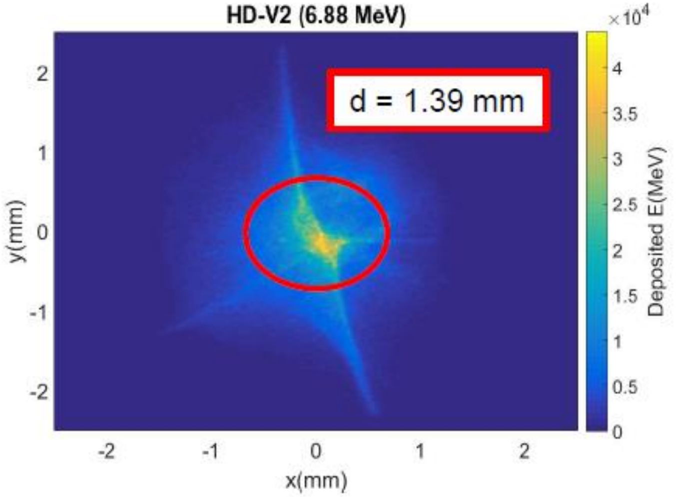
- Laser-ion acceleration uses TNSA for its efficiency and robustness
- The source emittance is very low but it is rapidly destroyed because of its **angular divergence** and **chromaticity**




simulations of trajectories in the first solenoid

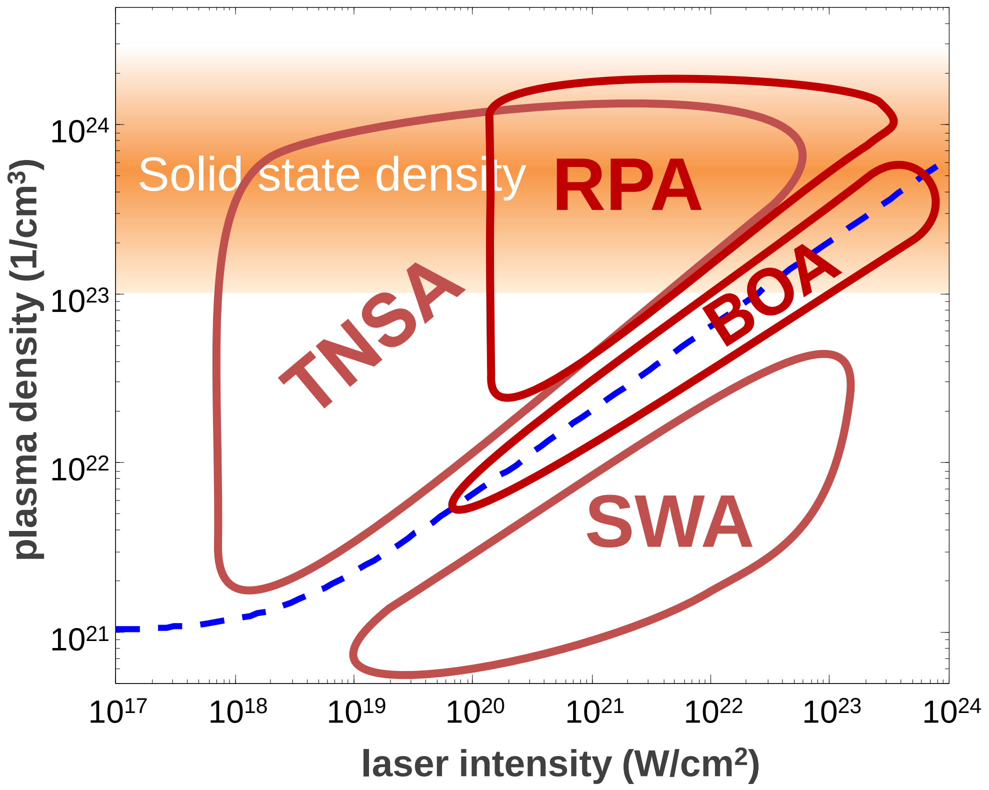



beam profile at the end of the LIGHT beamline



# Challenges in laser-driven acceleration at GSI: source development – particle acceleration

- **T**arget **N**ormal **S**heath **A**cceleration (TNSA) is the most robust and extensively experimentally studied scheme – with drawbacks (spectrum, divergence)
- **R**adiation **P**ressure **A**cceleration relies on opaque plasma during the interaction
- **R**elativistically-**I**nduced **T**ransparency **A**cceleration (RITA or BOA) works at the transition between opaque and transparency and yields the best results so far
- **S**hock-**W**ave **A**cceleration requires under-critical plasma and advanced gas jet targets, but are adapted to highrepetition rates -> IN2P3



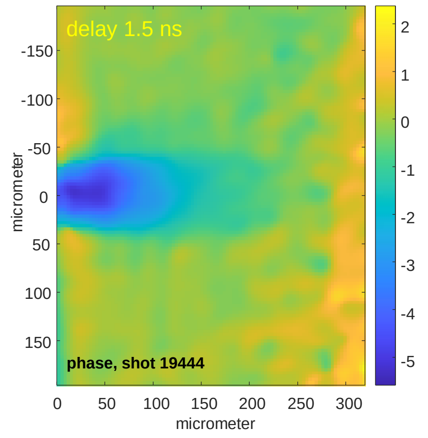

**A perfect understanding of the plasma conditions during the interaction is essential**

# Common topics of research between CENBG and GSI

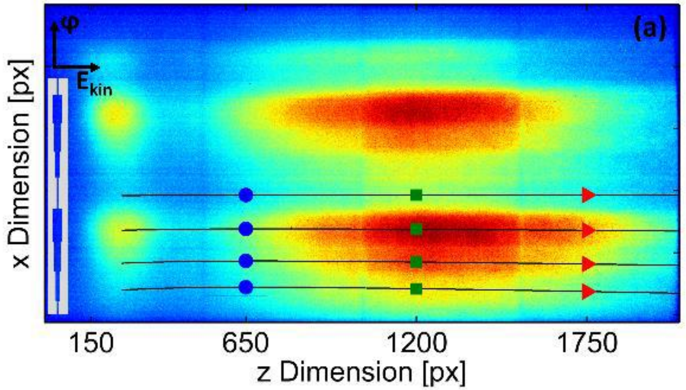
- For shock-wave acceleration, a precise knowledge and control of the gas jet density distribution is mandatory
  - GSI has developed a suite of optical measurement tools integrated within the WOMBAT package (open source https://git.gsi.de/phelix/lv/wombat_ce )

- The laser-driven ion beams, non-standard online beam characterization tools must be developed

Plasma characterization by interferometry (GSI)




Radeye detector trace in a Thomson parabola [F. Linder et al., RSI (2018)]



# Specific questions in the framework of DM Lab

- are there CNRS members interested in spending a sabbatical year at KIT, DESY or GSI?
  - not immediately but discussion going with CELIA/LULI (INP)
- would short term trips (longer than a "meeting day trip" but well shorter than a year-long sabbatical) further your project
  - project in 2022: target characterization and metrology (Master), looking for candidates on post doc level that could apply for external sources (DAAD)
- discussions of all DMLab topics (like the kickoff)
  - must be looked at. One likely topic is on detection and signal analysis.