HELMHOLTZ

RESEARCH FOR
GRAND CHALLENGES

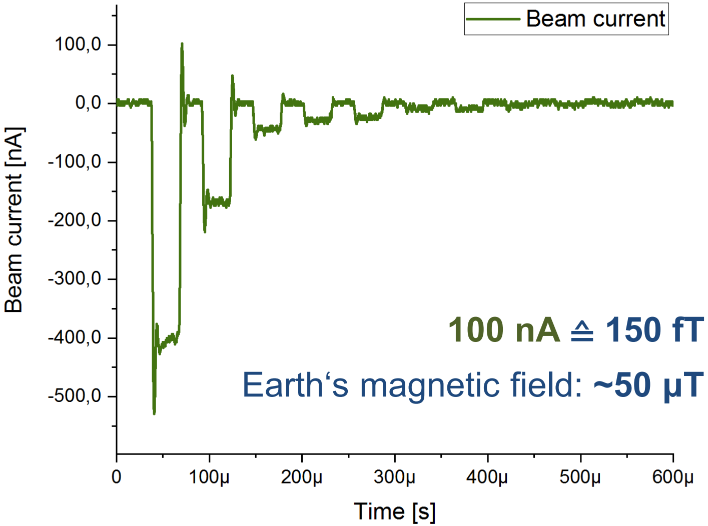
11:00 – 12:00
Flash talk session 1

Chairman: Sebastian Maier (KIT/LAS)

David Haider

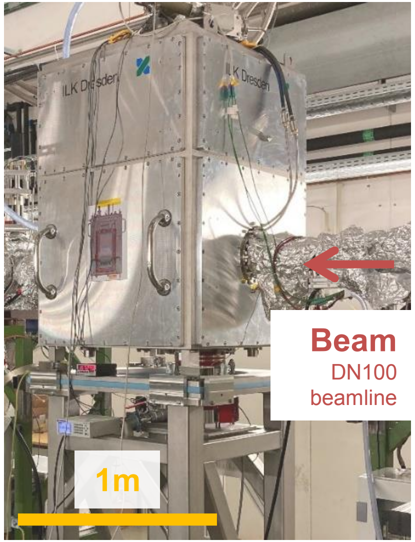
Cryogenic beam current monitor based on sensitive SQUID magnetometry

Matter and Technologies - student retreat



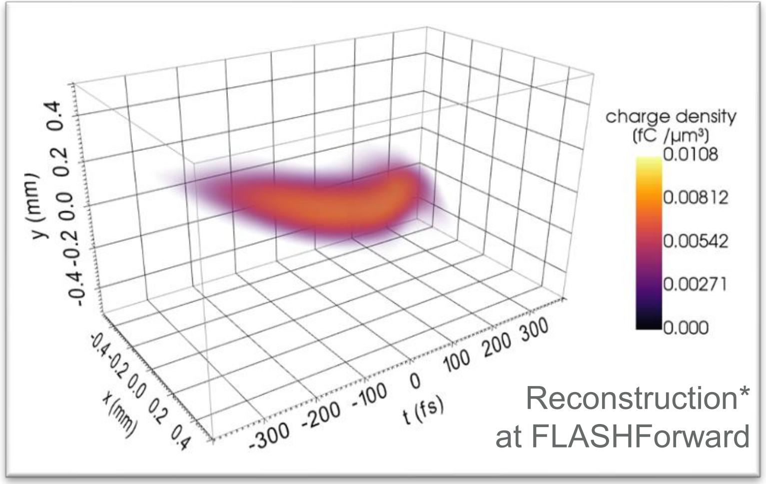
100 nA ≙ 150 fT

Earth‘s magnetic field: **~50 µT**



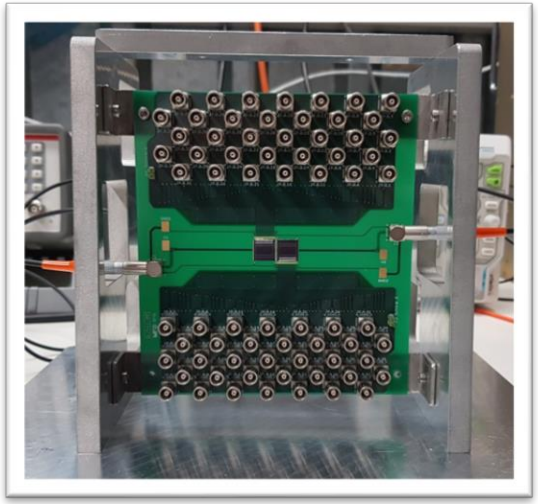
Novel beam instrumentation for short and low charge electron bunches

Transversal and longitudinal phase space characterization



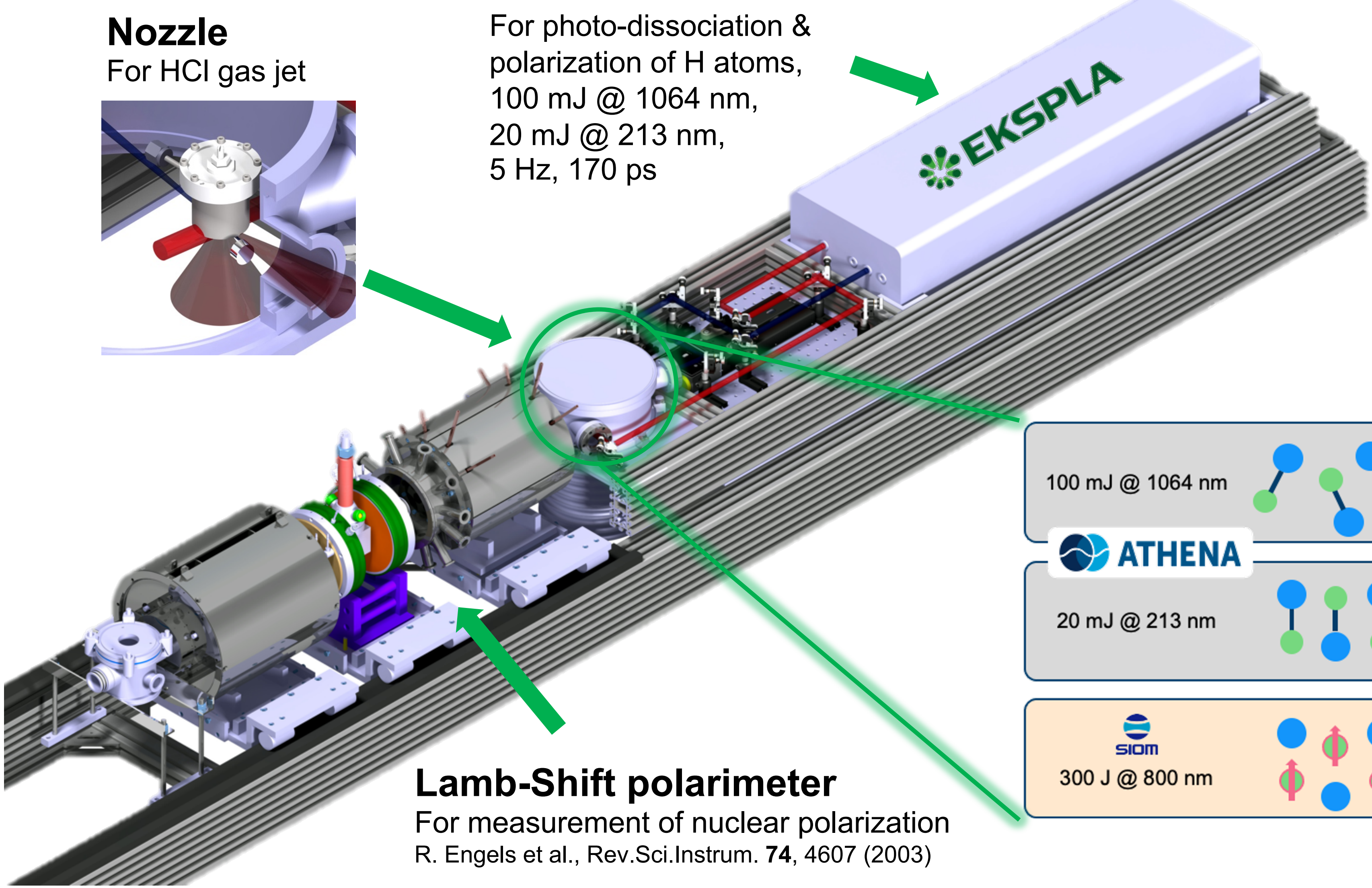
Reconstruction*
at FLASHForward

- **ARES:** linear electron accelerator at the SINBAD facility (DESY).
- Dedicated to accelerator R&D studies with sub-fs short electron bunches.
- **PolariX TDS:** Tomographic reconstruction techniques to obtain **full phase space** of the beam.
- **STRIDENAS:** Silicon based **beam profile monitor** for the detection of sub-pC charge electron beams. (S Jaster-Merz *et al* 2020 *J. Phys.: Conf. Ser.* **1596** 012047)



* D. Marx et al. J. Phys.: Conf. Ser. 874 012077, 2017

POLARIZED PROTON ACCELERATION @ FZJ

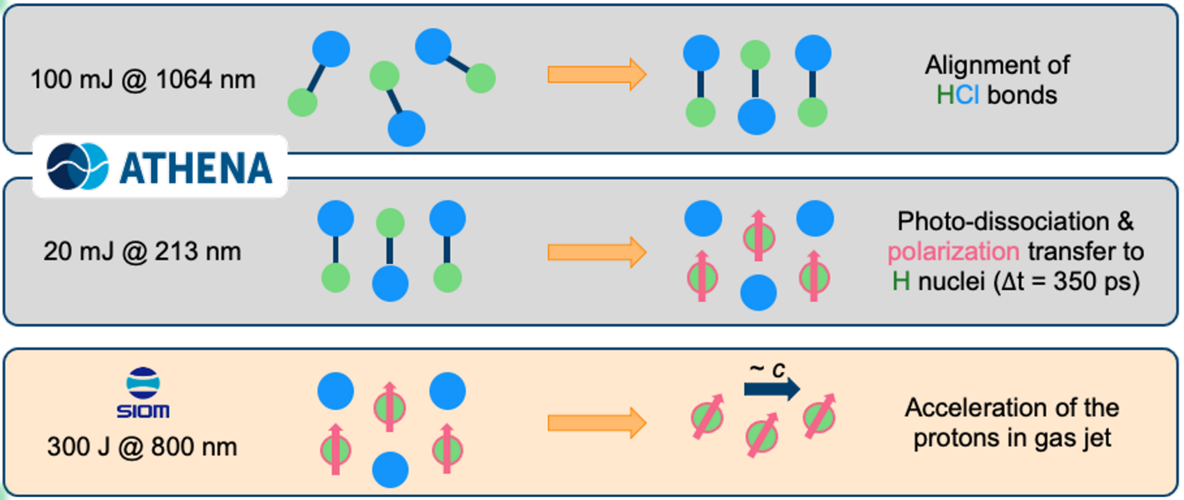


Nozzle
For HCl gas jet

IR/UV Laser
For photo-dissociation &
polarization of H atoms,
100 mJ @ 1064 nm,
20 mJ @ 213 nm,
5 Hz, 170 ps

Lamb-Shift polarimeter
For measurement of nuclear polarization
R. Engels et al., Rev.Sci.Instrum. **74**, 4607 (2003)

Setup described in:
Markus, Büscher, Anna Hützen et al.,
High Power Laser Sci. Eng. **8**, E36 (2020)



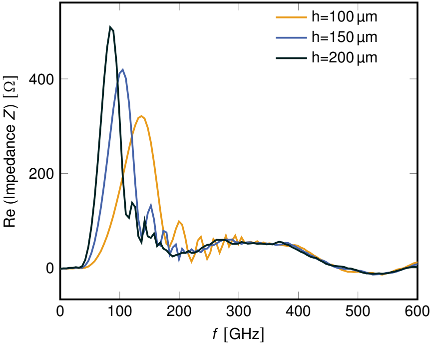
100 mJ @ 1064 nm — Alignment of HCl bonds

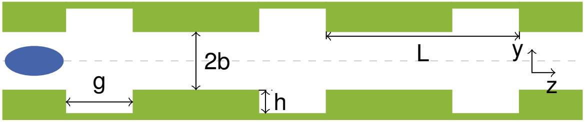
20 mJ @ 213 nm — Photo-dissociation & polarization transfer to H nuclei (Δt = 350 ps)

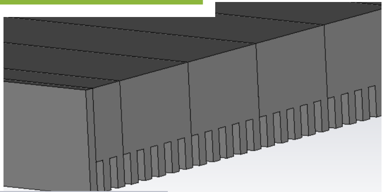
300 J @ 800 nm — Acceleration of the protons in gas jet

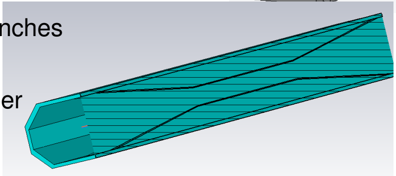
Impedance studies of a corrugated pipe

UltraSync project
French-German collaboration









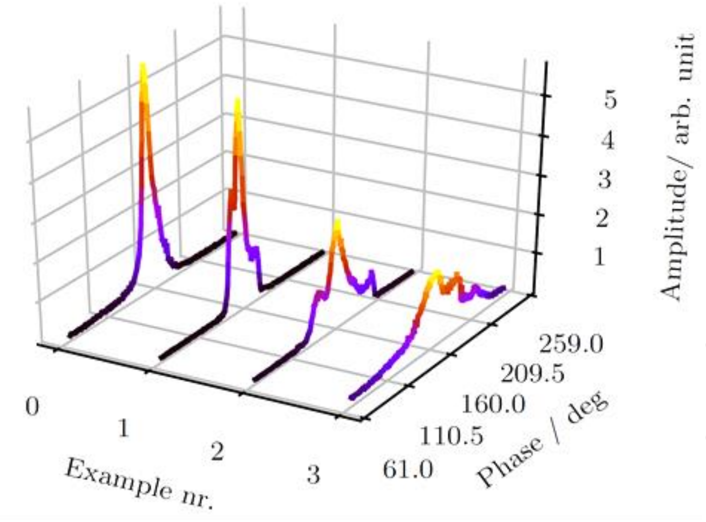
Controlling of microbunching instabiliy for short bunches and intense THz radiation

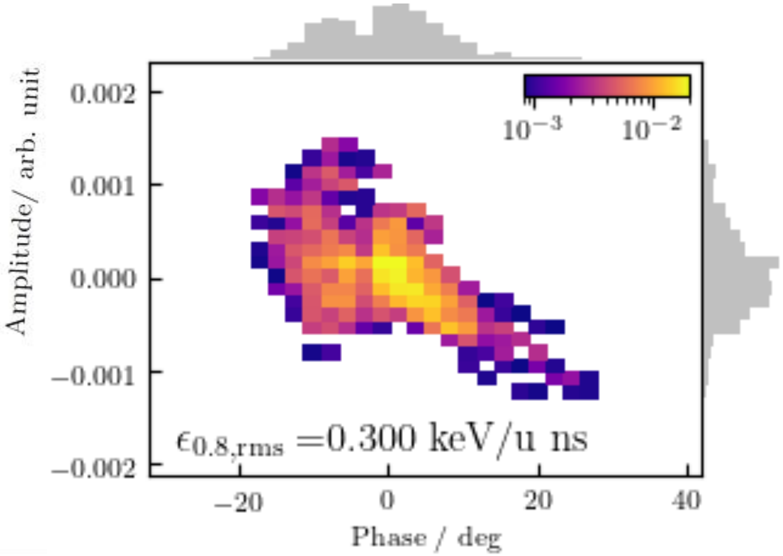
- Design of an impedance manipulation chamber
- Simulation of corrugated pipe impedance

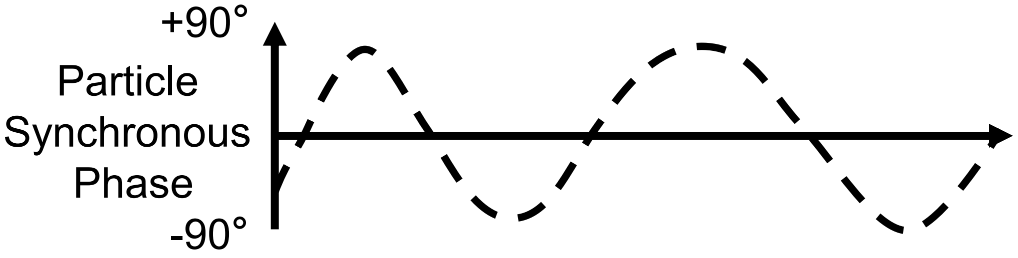
Heavy ion beam dynamics for the Helmholtz Linear Accelerator (HELIAC)

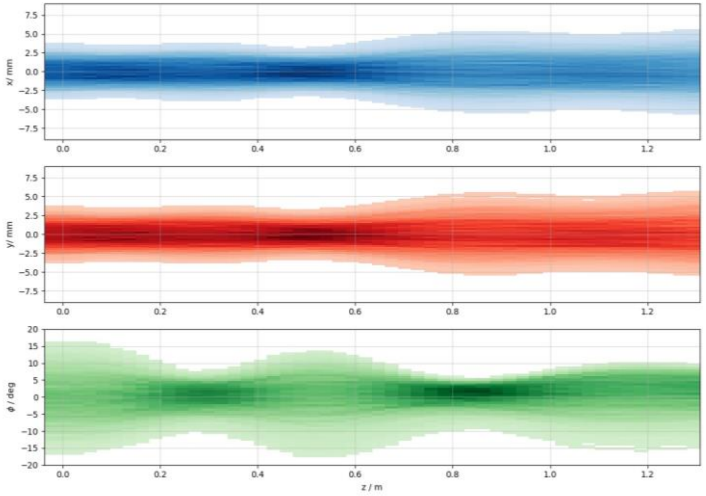
- ✓ Longitudinal
  energy reconstruction from
  a set of phase measurements

- ✓ Planning & comissioning
  of a collimation system









⌛ Design of an
Alternating Phase Focussing injector

JOHANNES GUTENBERG UNIVERSITÄT MAINZ JG|U GSI

HIM HELMHOLTZ Helmholtz Institute Mainz

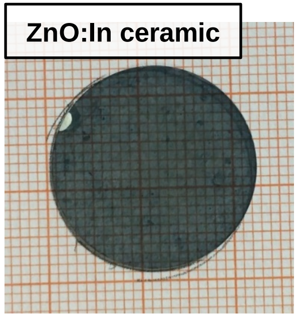
Novel Radiation Hard and Fast Scintillator for Beam Diagnostics

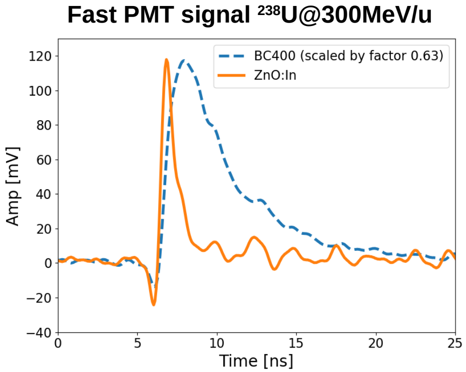
Maxim Saifulin (GSI, TU Darmstadt)

The work is done in collaboration with Research Institutes from Russia and Latvia

Goal (Scintillation Detector for Beam Diagnostics):

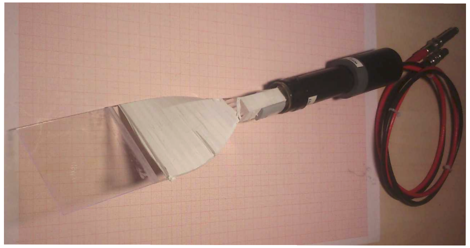
- Beam intensity measurements at HEBT in GSI
- Heavy ion beams (SIS18): from Carbon to Uranium
- Energies: from 250 MeV/u to 1 GeV/u


ZnO:In ceramic


Fast PMT signal ^{238}U@300MeV/u

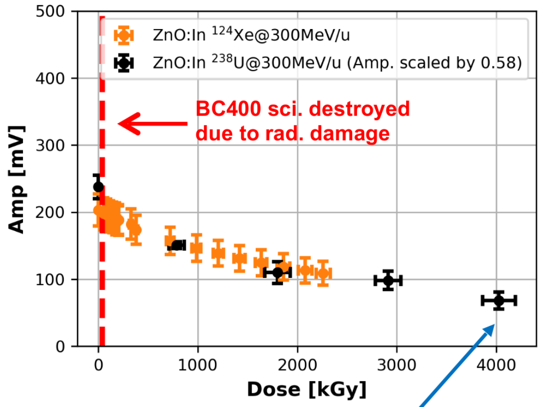
Advantages of In or Ga doped ZnO ceramics:

- **~100 times longer operation** time compared to plastic scintillator
- **Radiation damage can be removed** by annealing
- **Fast scintillation** decay time ~0.7 ns
- Scintillation light can be easily red by conventional photomultipliers



Currently used detectors based on plastic scintillator (BC400) require frequent maintenance due to radiation damage

IBIC-2019, P. Boutachkov et. al.
https://doi.org/10.18429/JACoW-IBIC2019-MOPP005



1E+12 ^{238}U/cm^2, or 3E+12 ^{124}Xe/cm^2

EDM Measurements in Storage Rings

February 1, 2021 | Maximilian Vitz

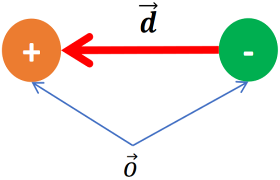
Member of the Helmholtz Association

Physics case

- Asymmetry between matter and antimatter ⇒ Sakharov: Source of CP-Violation ⇒ EDM

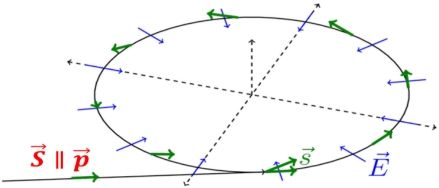
EDM:

- permanent separation of charges
- closely connected to the spin
- predicted by the SM but unmeasurable small



Measuring method:

- use a storage ring as a charged particle trap
- inject particles with spin and momentum aligned
- apply radial electric field and measure build-up of vertical polarization



Spin Coherence Time

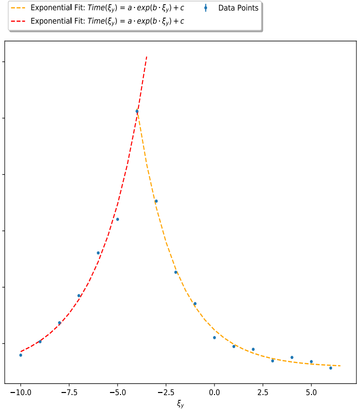
- to reach statistical sensitivity ⇒ keep spins aligned as long as possible (1000 s)
- Coherent particle bunch is needed ⇒ SCT ⇒ time until the total polarization falls below 1/e

Spin Decoherence:

- Particles are off-momentum
- Particles do not see identical fields
- Particles are not on same orbit
- Spin resonances

Solution:

- Bunching and cooling of the beam
- Change system parameters
  $\Rightarrow$ Chromaticity: $\xi = \Delta Q / \Delta p$



Laser cooling of heavy ions at SIS100

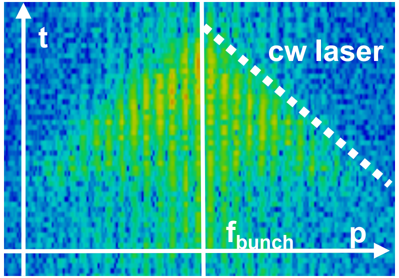
S. Klammes, P. Spiller, Th. Walther, and D. Winters

Motivation

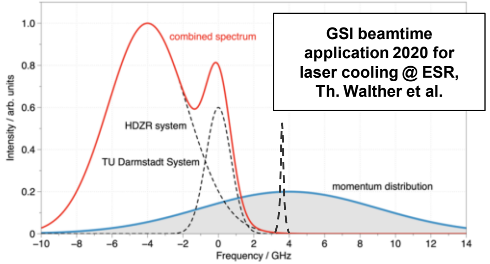
- worldwide unique
- possibility to deliver **very cold** (small relative longitudinal momentum spread $\Delta p/p$, small emittance ε) and **very short ion bunches** to FAIR experiments (e.g. plasma physics)
- **key for precision experiments** (e.g. laser spectroscopy of electronic structure of heavy ions)
- highly relativistic ion energies of SIS100 allow **cooling of many ion species** by exploiting the huge Doppler shift (γ up to 13): Z = 10 - 60
    - higher cooling efficiency with increasing ion beam energy
- only foreseen beam cooling method at SIS100

Goal

- **first application of laser cooling at a large synchrotron** using novel cw & pulsed laser systems



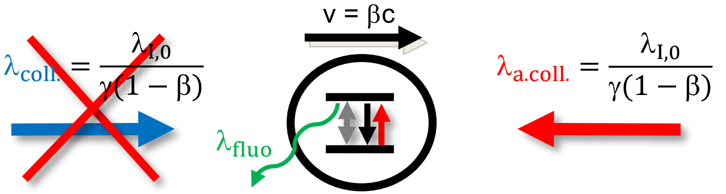
Reduction of $\Delta p/p$ of a C^{3+} ion beam by detuning the laser wavelength with respect to the bunching frequency performed at the ESR @ GSI



GSI beamtime application 2020 for laser cooling @ ESR, Th. Walther et al.

White light laser cooling:
The combination of cw and pulsed laser systems allows simultaneous and fast laser cooling of a broad ion momentum distribution.

Principle of laser cooling of relativistic ion beams

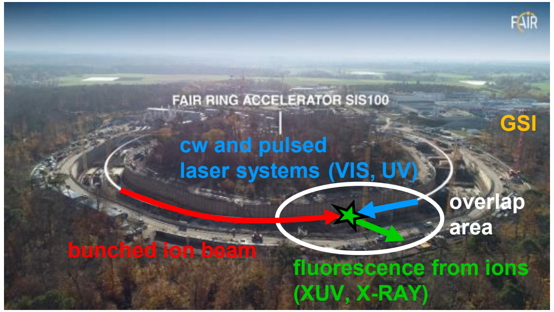


$$\lambda_{coll.} = \frac{\lambda_{I,0}}{\gamma(1-\beta)}$$

$$\lambda_{a.coll.} = \frac{\lambda_{I,0}}{\gamma(1-\beta)}$$

The ion absorbs many directional momenta from the photons and decays each time with a random recoil, which averages out to zero after many scattering events, leaving a net deceleration of the ion. Together with the counteracting force of the rf-buncket, laser cooling can be achieved.

SIS100 laser cooling facility



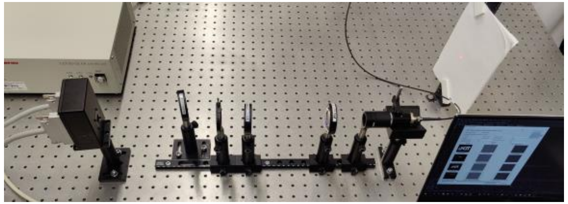
© GSI/FAIR/L. Möller

By meeting the energetic and spatial overlap conditions of the ion and laser beam, XUV fluorescence photons will be emitted from the ions and detected by a novel in vacuo XUV detection system.

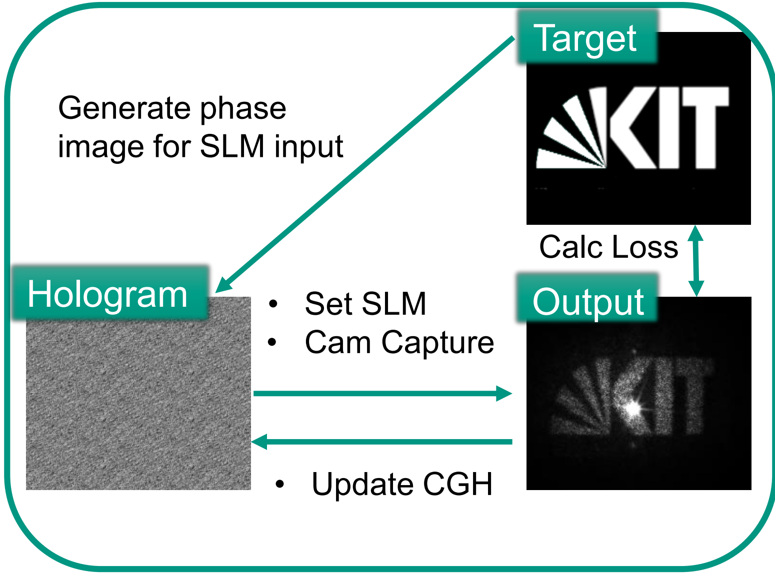
Modulation of Photoinjector Laser with SLM

- Electron bunch characteristics in low-energy section strongly depend on the driving Laser property
- Use Spatial Light Modulator to manipulate the Laser and the generated electron bunch
- Problem: Existing non-linear transformations distort the modulation; Hologram generation not trivial
- Idea: Use ML algorithms
  - Iterative optimization: with camera & SGD
  - NN as surrogate model

Test setup:



Courtesy: Carl Sax



Active Learning for Material Recovery

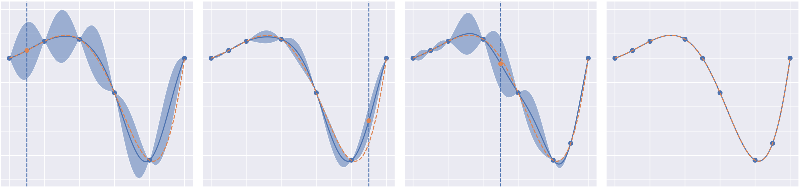
Mario Teixeira Parente (`m.parente@fz-juelich.de`)

MT-DMA Student Retreat

February 01, 2021

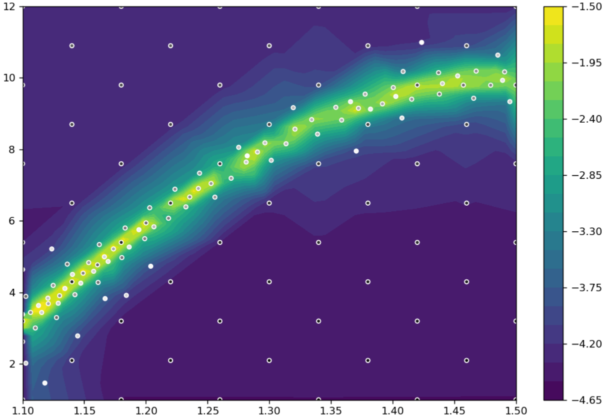
Active Learning with GPR

- With **Gaussian Process Regression** (GPR), you can
  - *approximate functions* while at the same time you
  - *quantify uncertainty* about the approximation itself.



Material discovery

- **Example:** Neutron intensity over 1D reciprocal space and energy.



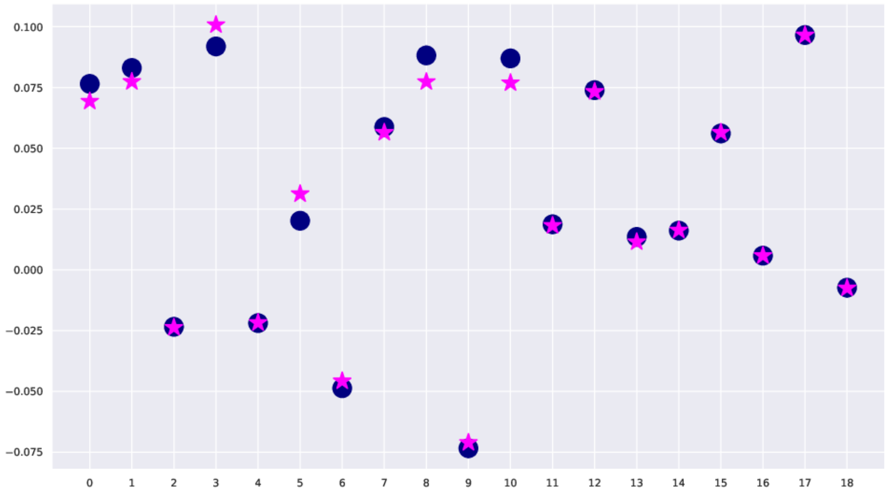
Thank you for your attention!

More **details** on GPR can be found in

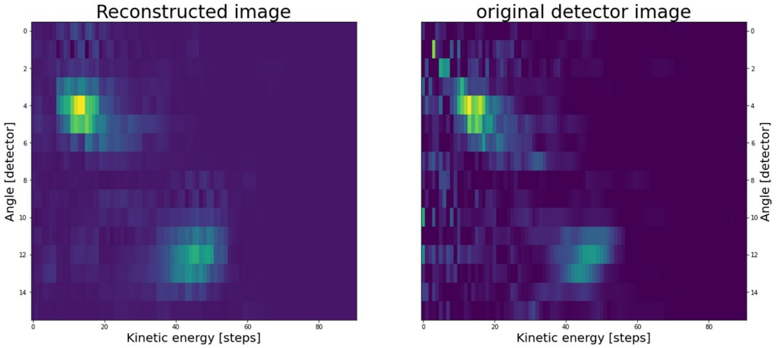
C. Williams and C. Rasmussen. *Gaussian Processes for Machine Learning*. MIT Press. 2006. (`http://www.gaussianprocess.org/gpml/chapters/RW.pdf`).

SIMULATION-AIDED MACHINE LEARNING FOR NANOMETER OPTICS

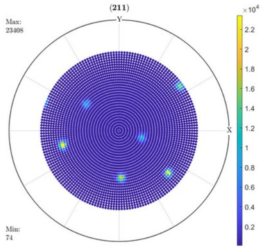
1. Electron Gun Offset finding & Optimization



2. Noise reduction in Angular Streaking

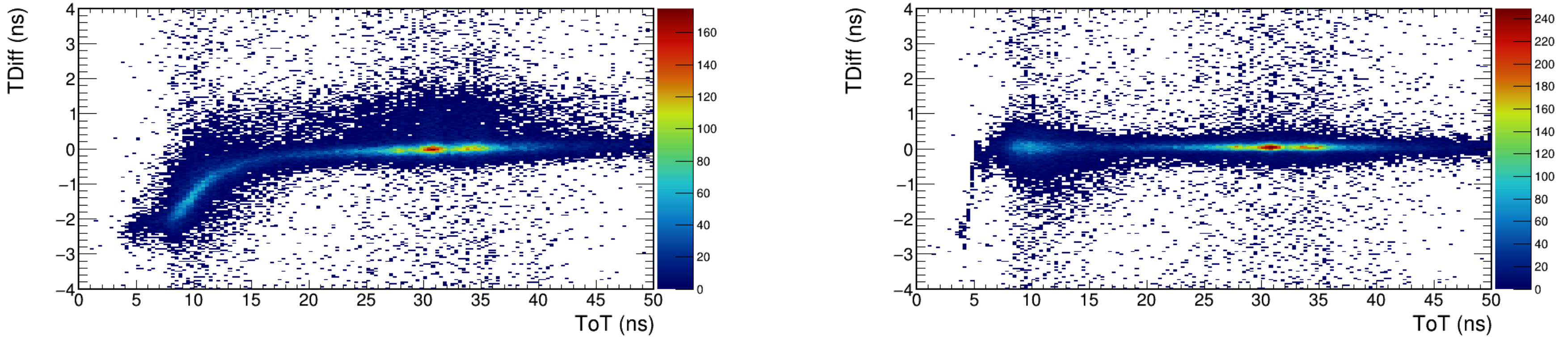


3. Grain Orientation Approximation



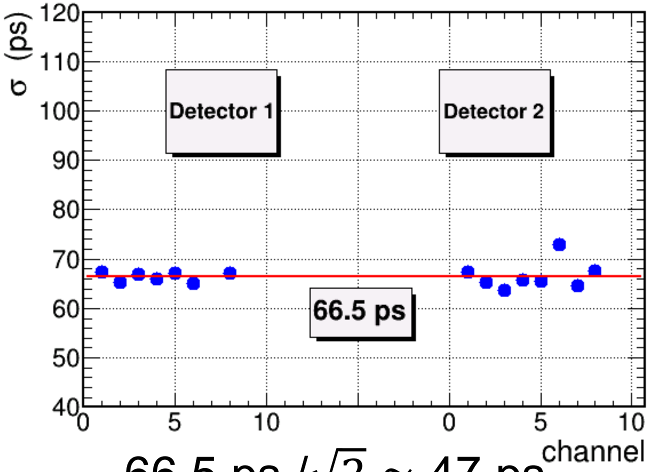
x = 12°
y = 28° ?
z = 168°

LGADs for Timing Applications in HADES



- Prototype T0 detector based on Low Gain Avalanche Diode (LGAD) technology, tested with a 1.92 GeV proton beam at COSY
- Operated in air without cooling
- Two detectors for simultaneous x- and y-position measurements
- Signals with low Time over Threshold (ToT) arise from capacitive coupling between channels

https://arxiv.org/abs/2005.12965



$66.5 \text{ ps} / \sqrt{2} \approx 47 \text{ ps}$

Karlsruhe Institute of Technology

HELMHOLTZ
ASSOCIATION

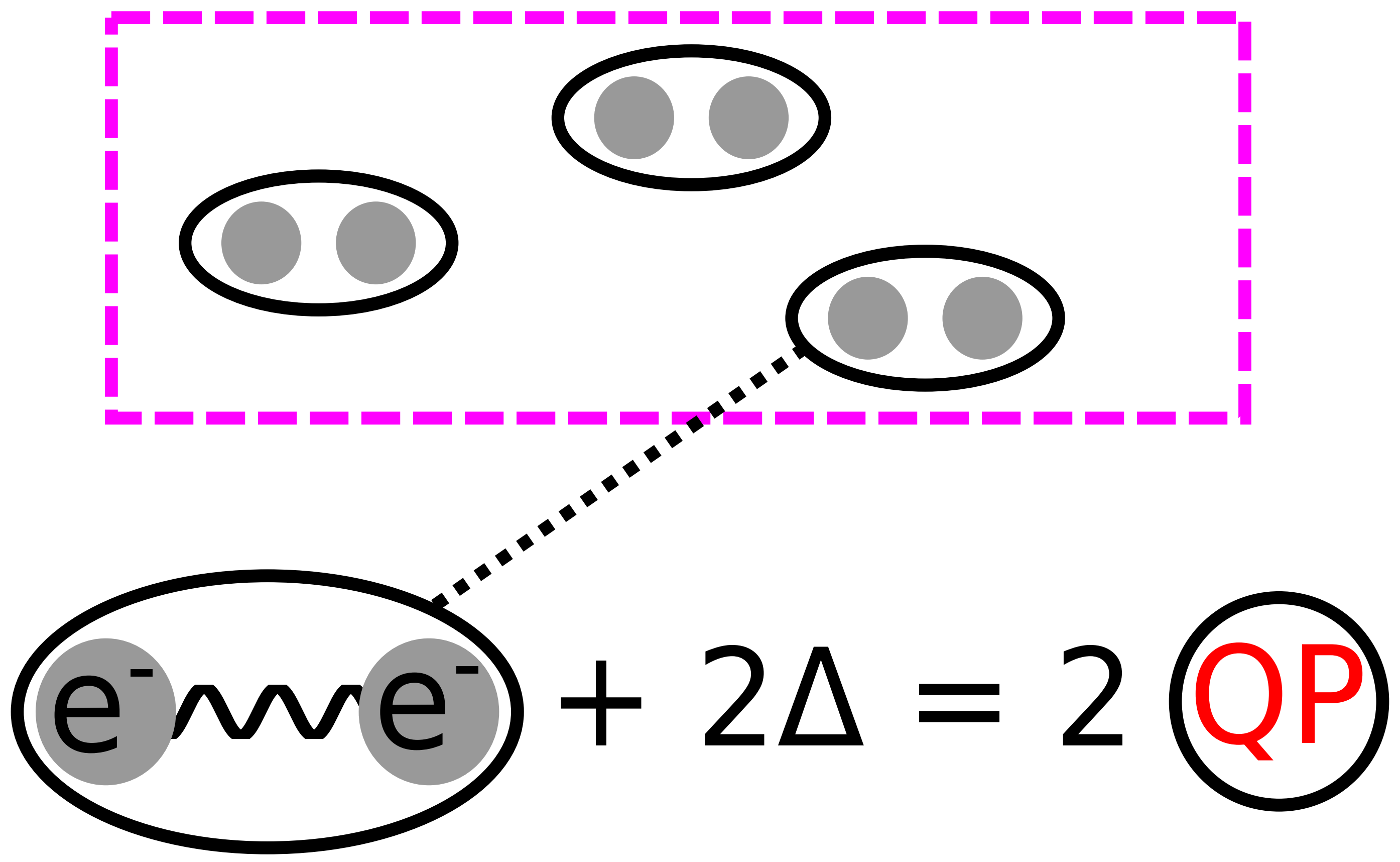
Alexander von Humboldt
Stiftung/Foundation

Physikalisches
Institut

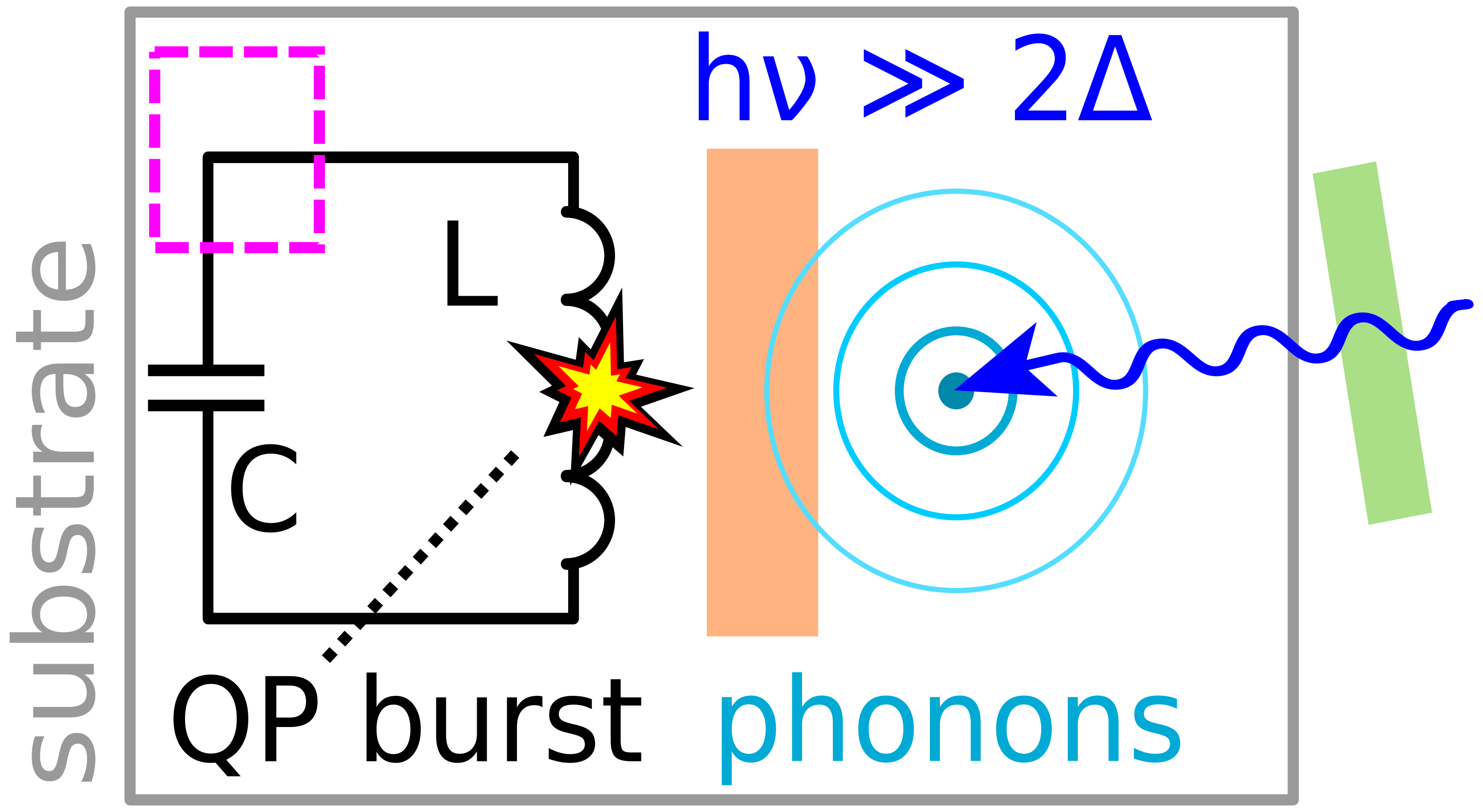
Diagnostics and abatement of quasiparticle poisoning in superconducting circuits

Francesco Valenti, KIT - francesco.valenti@kit.edu

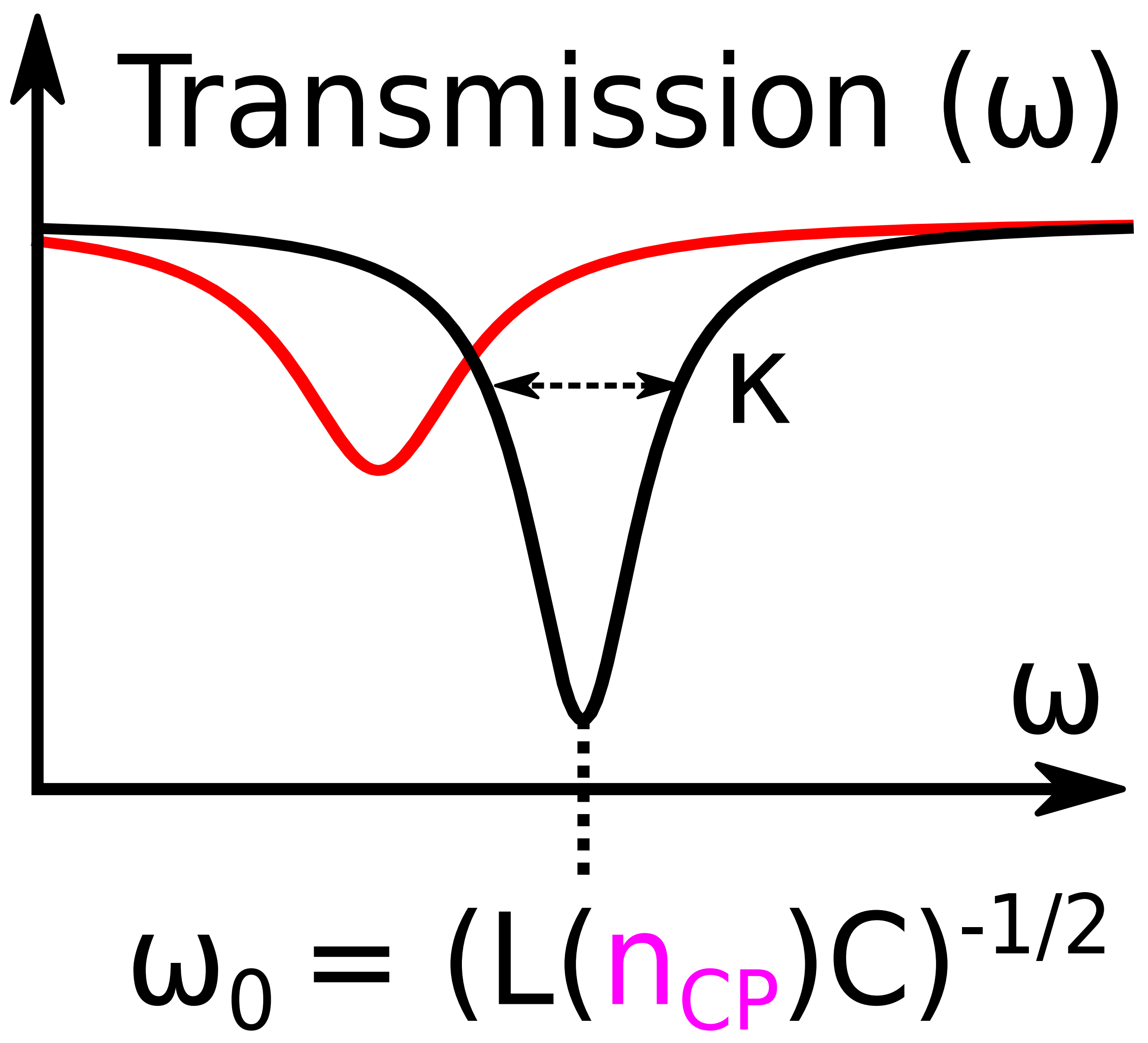
Cooper pairs (CP):
e$^-$ bound by phonons

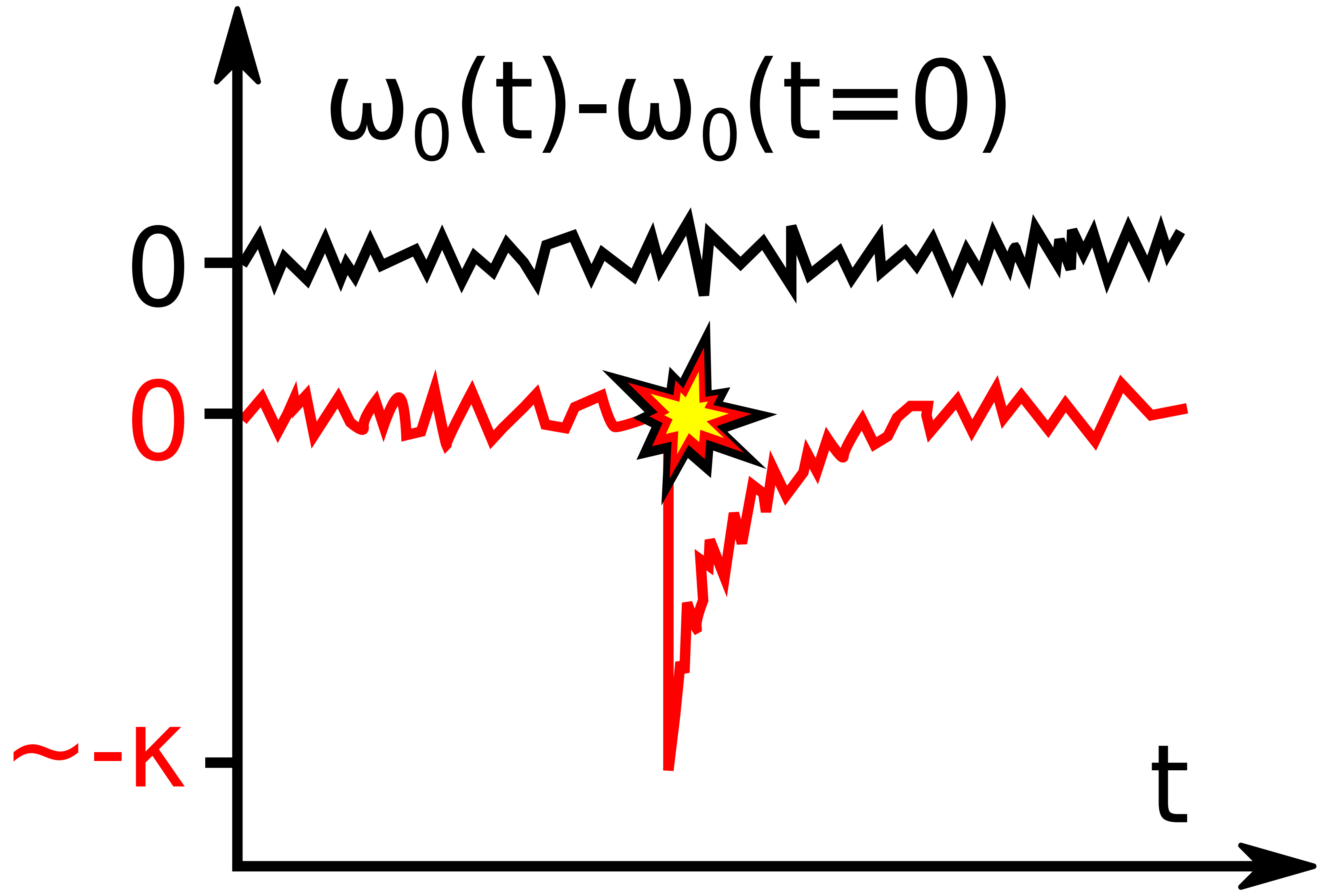


SC resonator



Quasiparticles (QPs) = degradation





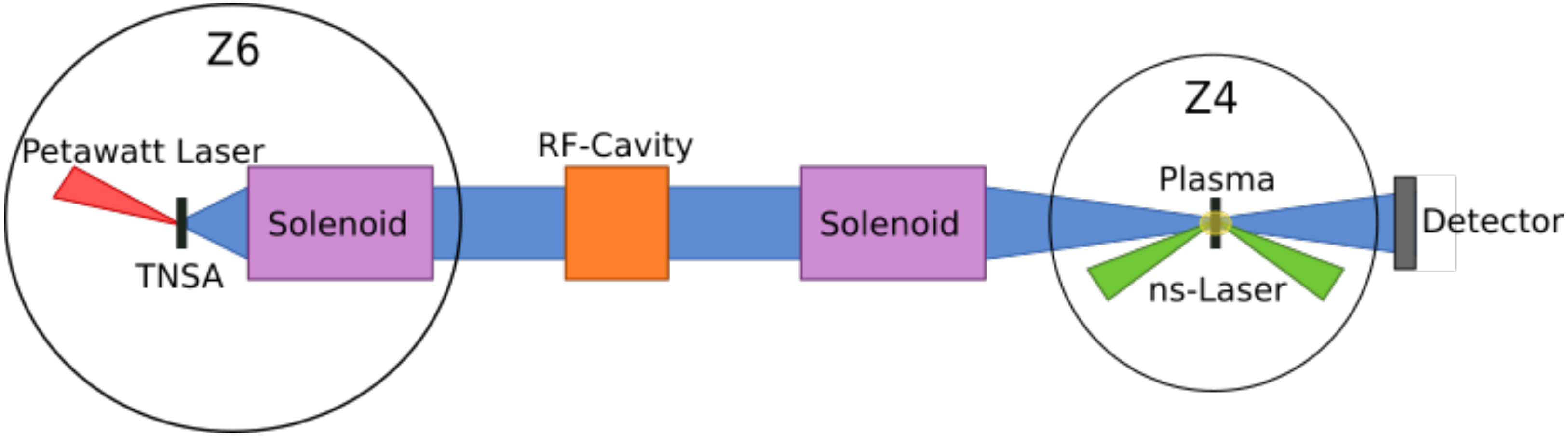
Projects

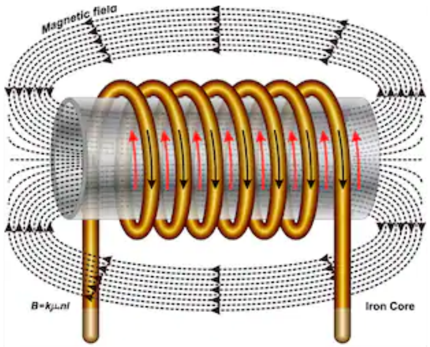
Reducing radiation:
-Valenti, Cardani et al., arXiv:2005.02286 (subm. to Nat. Comm.)

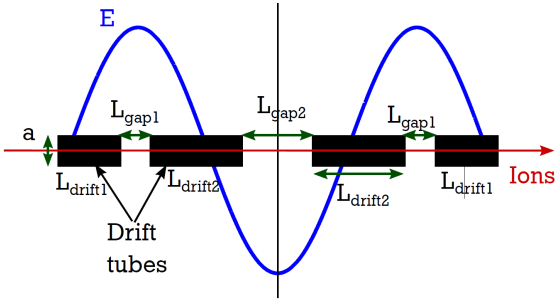
Reducing phonons:
-Valenti et al., PRApp 11,054087 (2019).
-Valenti, Henriques et al., APL 115,212601 (2019).

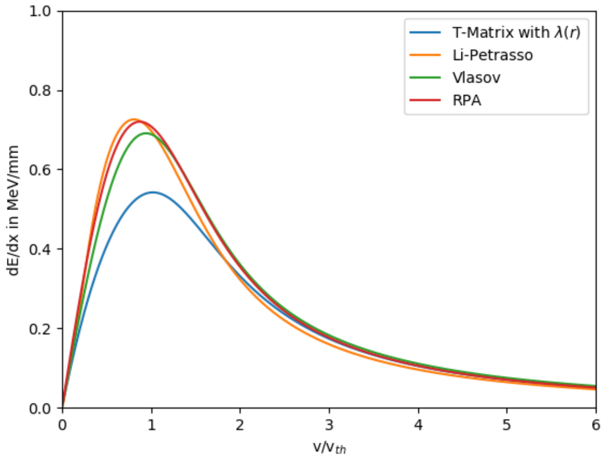
See my talk at the MT retreat for more information!

Energy Loss Measurement with LIGHT



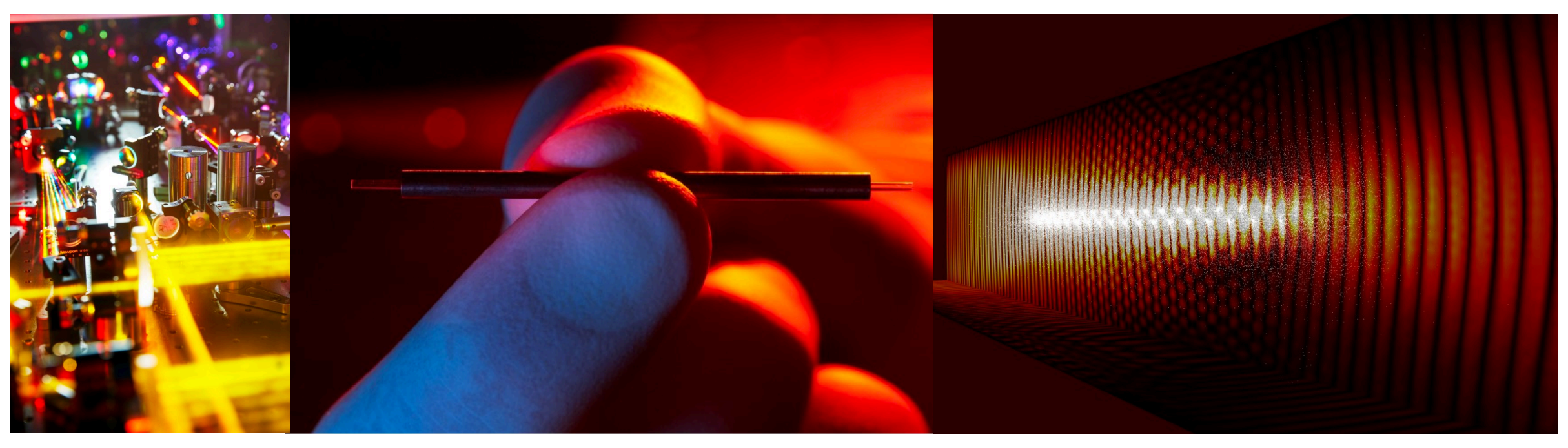






sub-ns carbon ion bunch for stopping power experiments

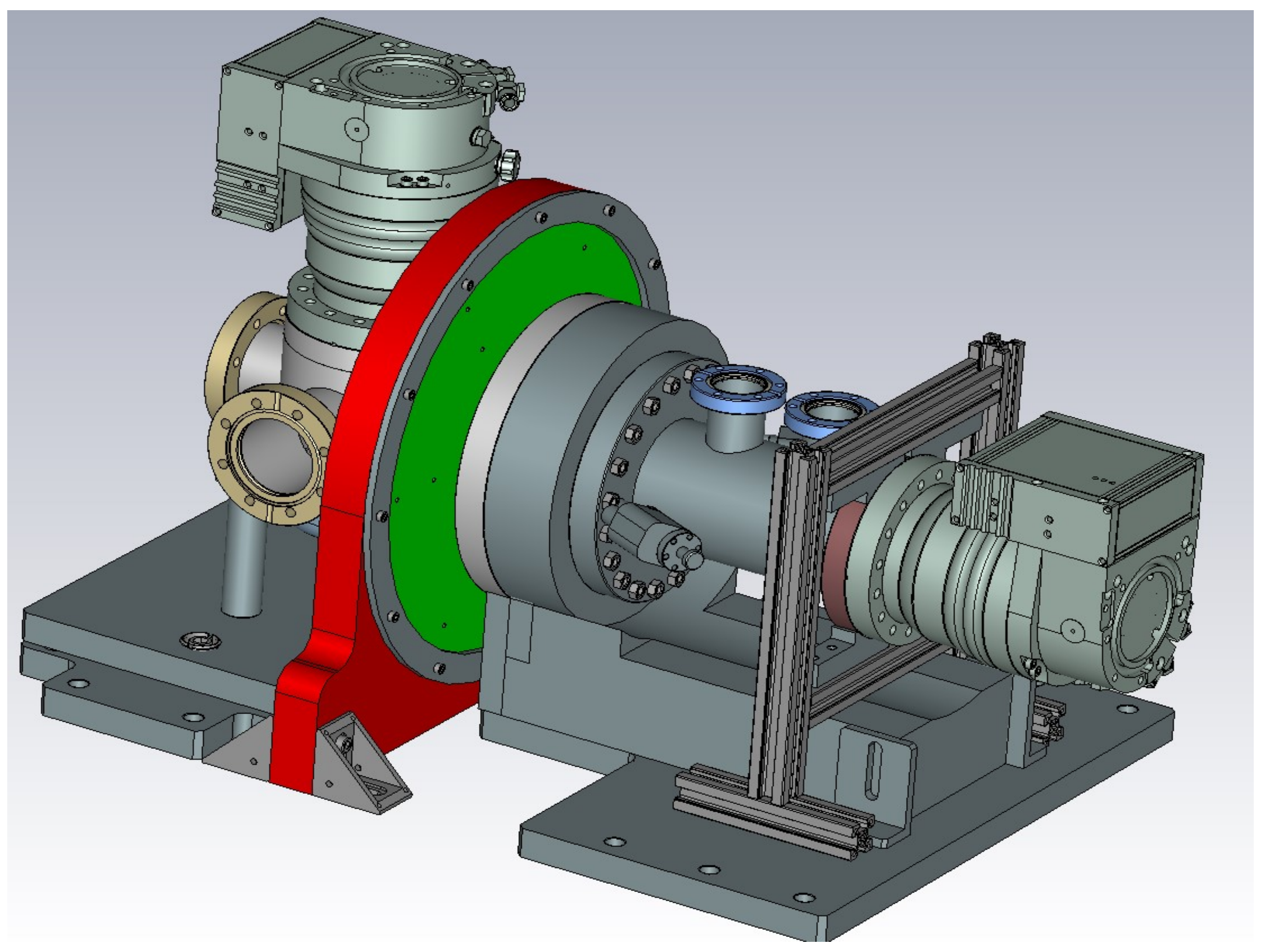
AXSIS compact RF gun



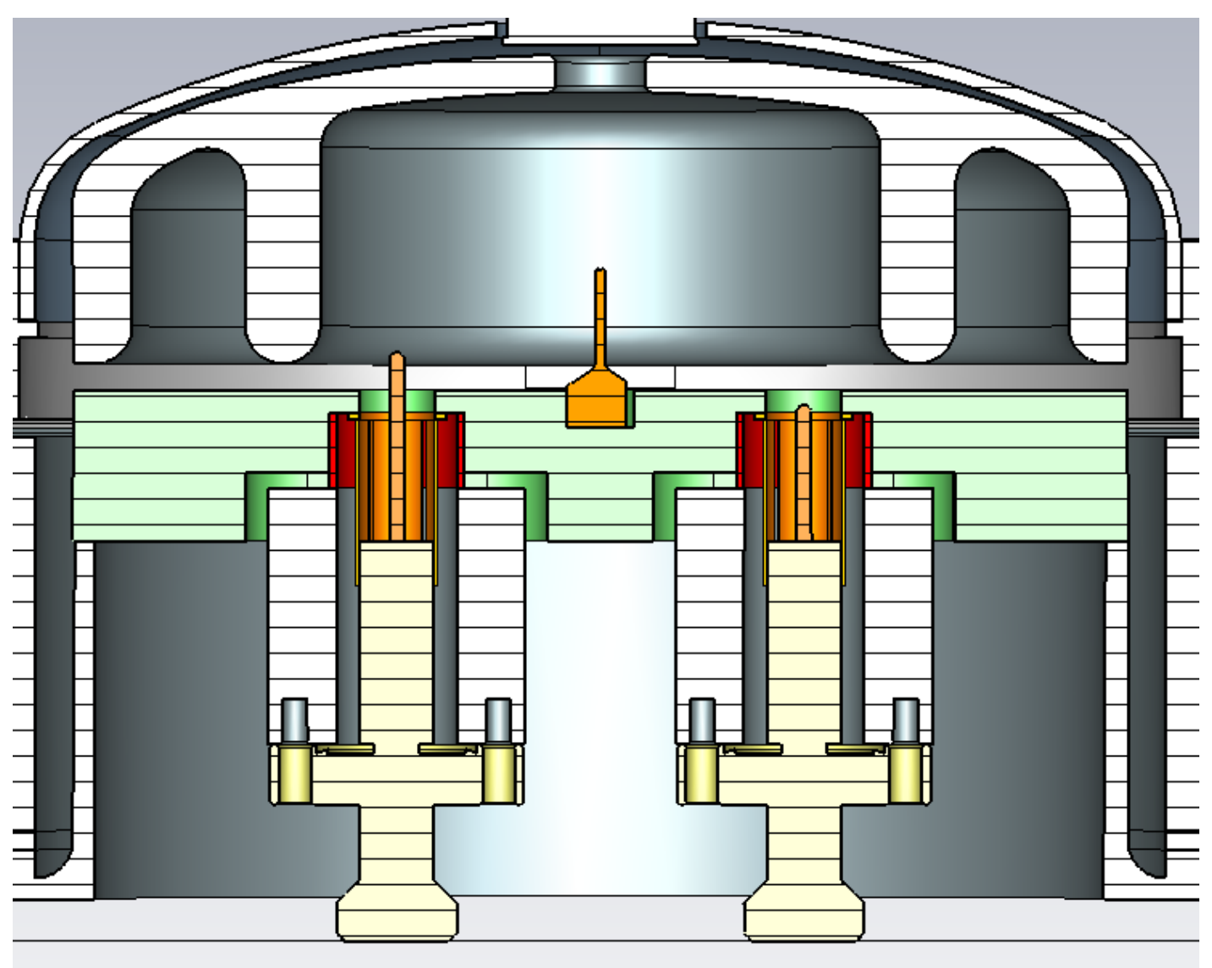
Reza Bazrafshan, Moein Fakhari, Timm Rohwer, Klaus Flöttman, Franz Kärtner

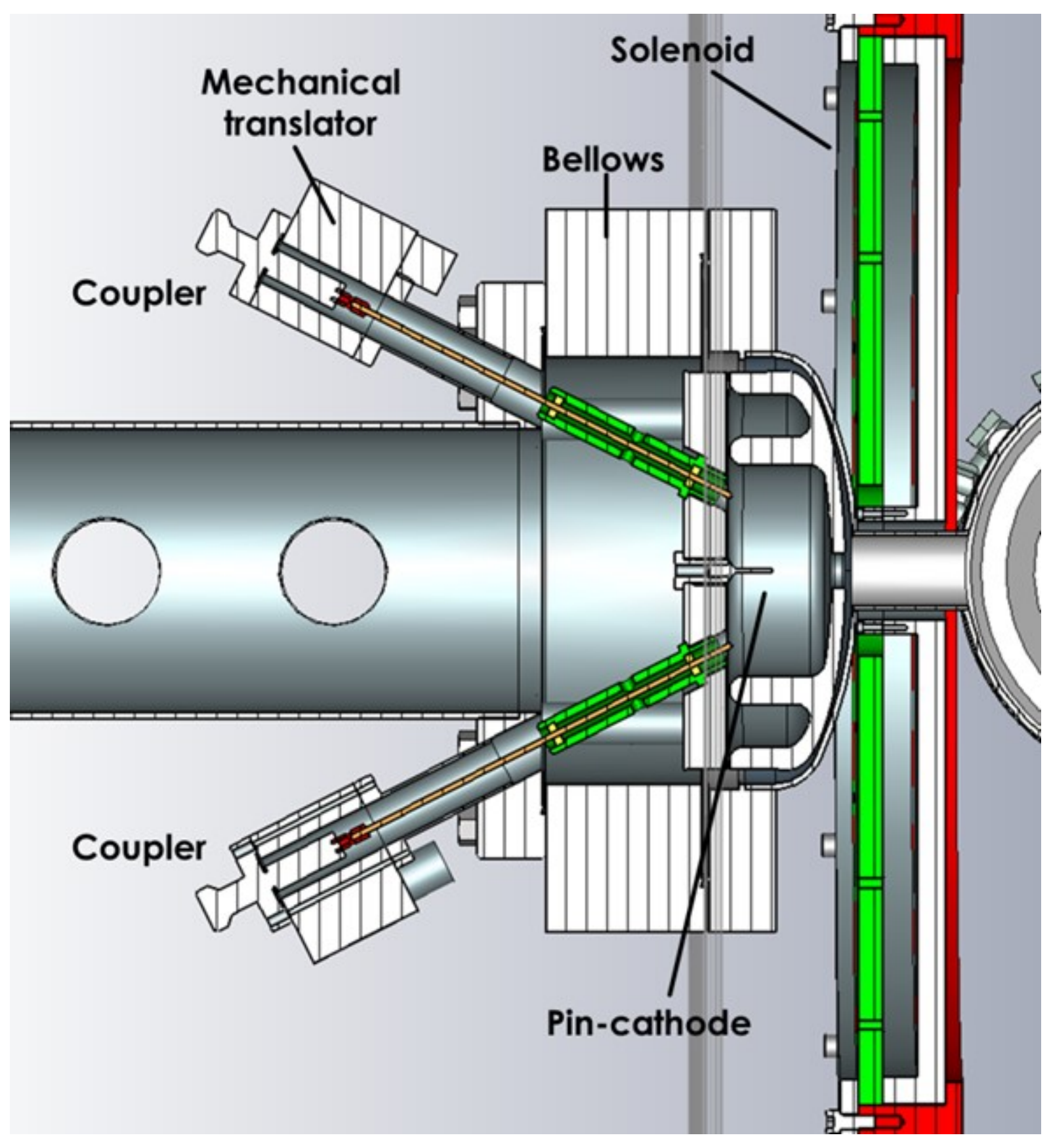
Introduction

AXSIS RF gun is an S-band compact RF gun with a frequency of 2.998 GHz, which can accelerate pC charge electron bunches up to 150 keV at 100 fs pulse length. A pin-cathode has been used in the cavity in order to increase the electric field on the cathode while using a compact amplifier of 10 kW max. Power. A solenoid just after the gun focusses the electron beam in transverse direction.



Two coaxial couplers have been connected to the cavity: one coupling antenna, and one probe for reading the electric field. The anode part is fixed, while the cathode part can be moved by a translator. For optimal coupling between the coupler and the cavity, a translator is installed at the end of the coupler.

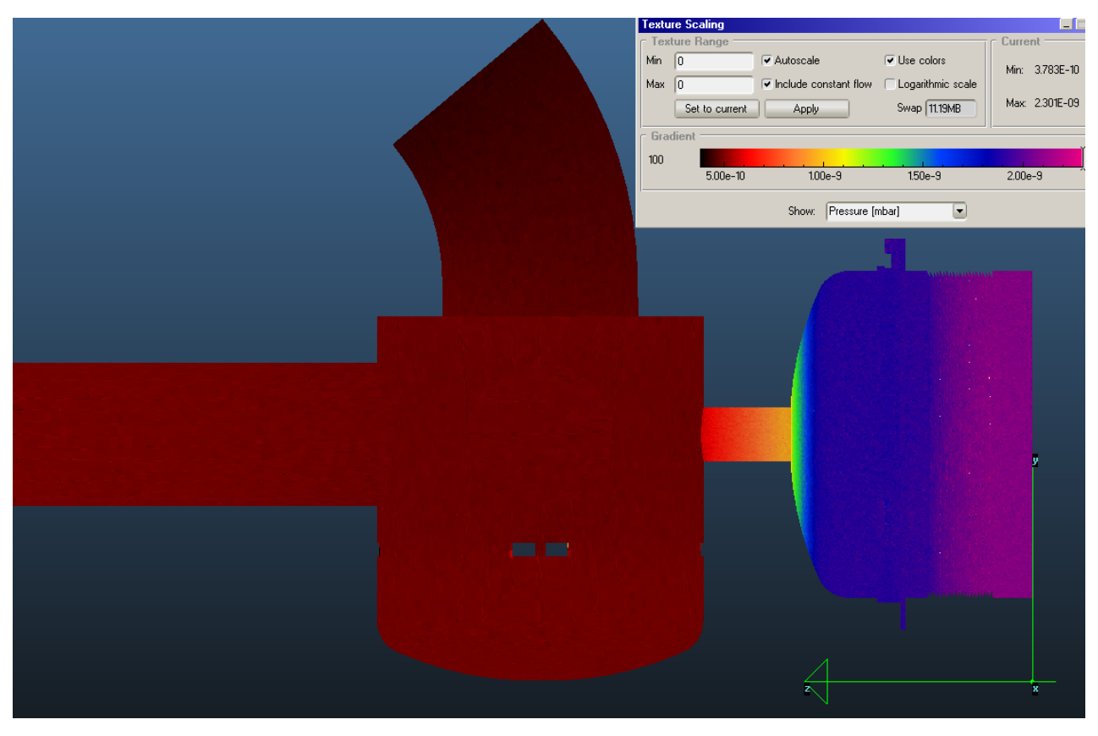


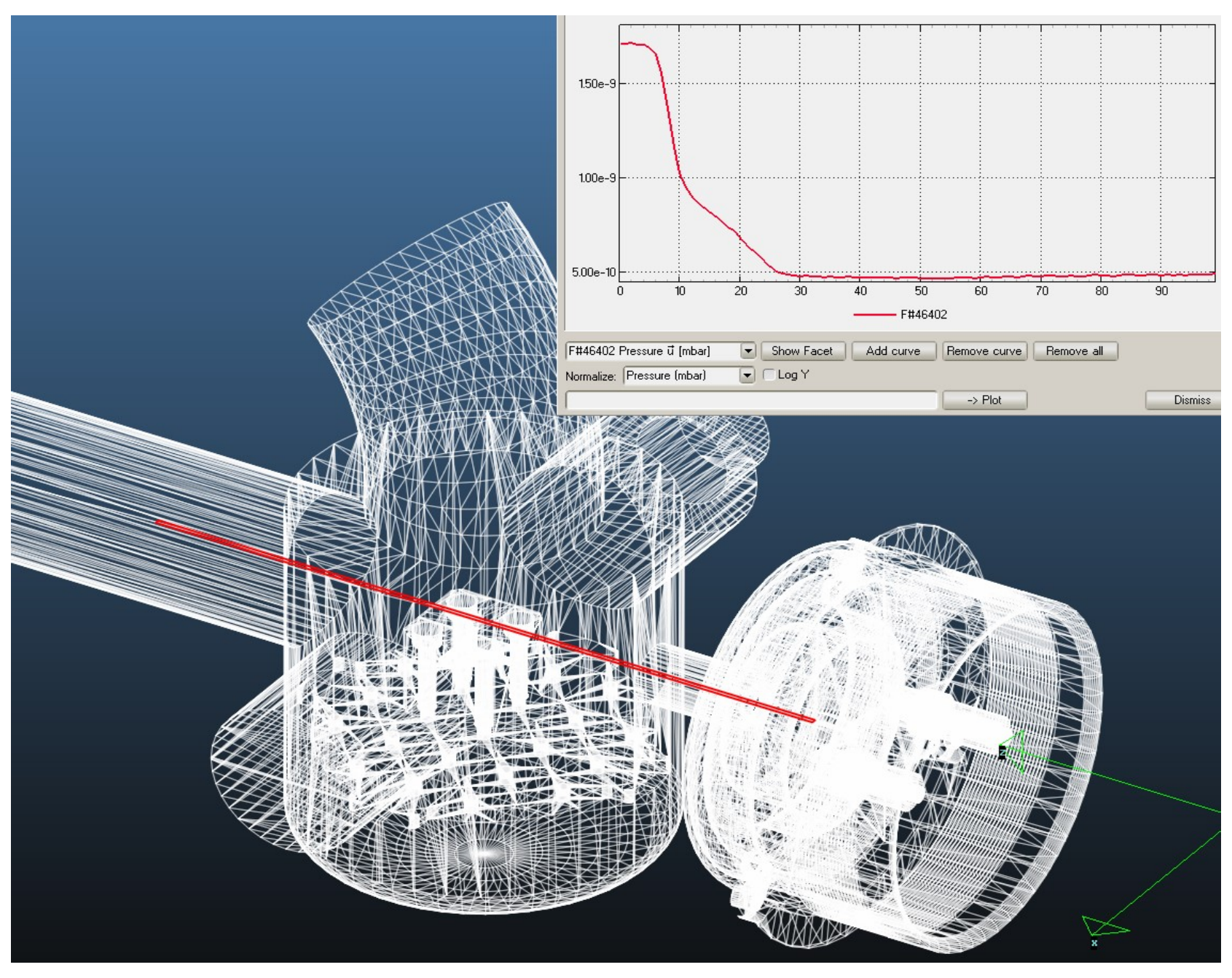


Vacuum simulation

outgassing rate: $1 \times 10^{-11}\ \mathrm{torr}\ \frac{\mathrm{l}}{\mathrm{s}} \frac{1}{\mathrm{cm}^2}$

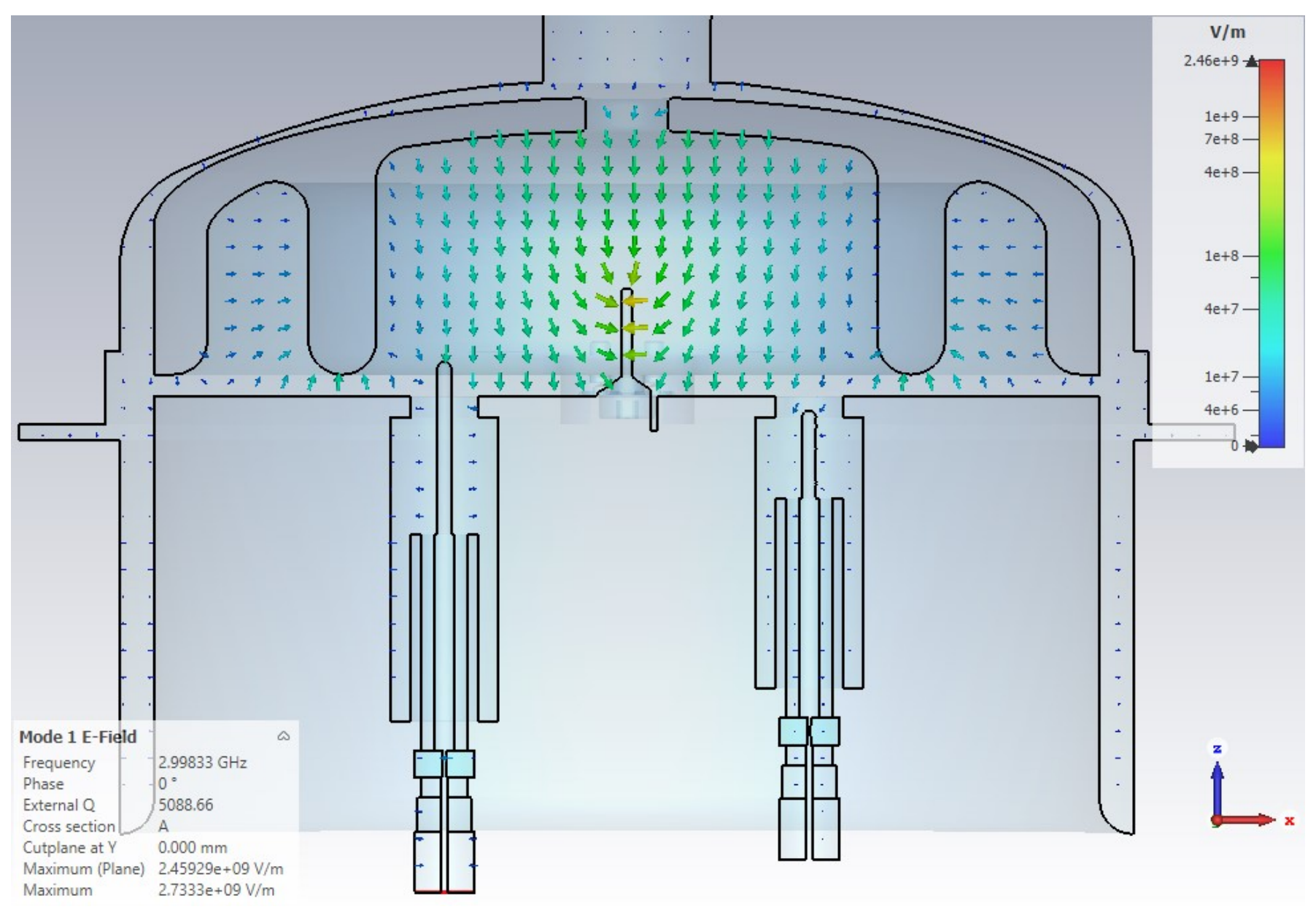
pumping speed = 250 $^{\mathrm{l}}/_{\mathrm{s}}$



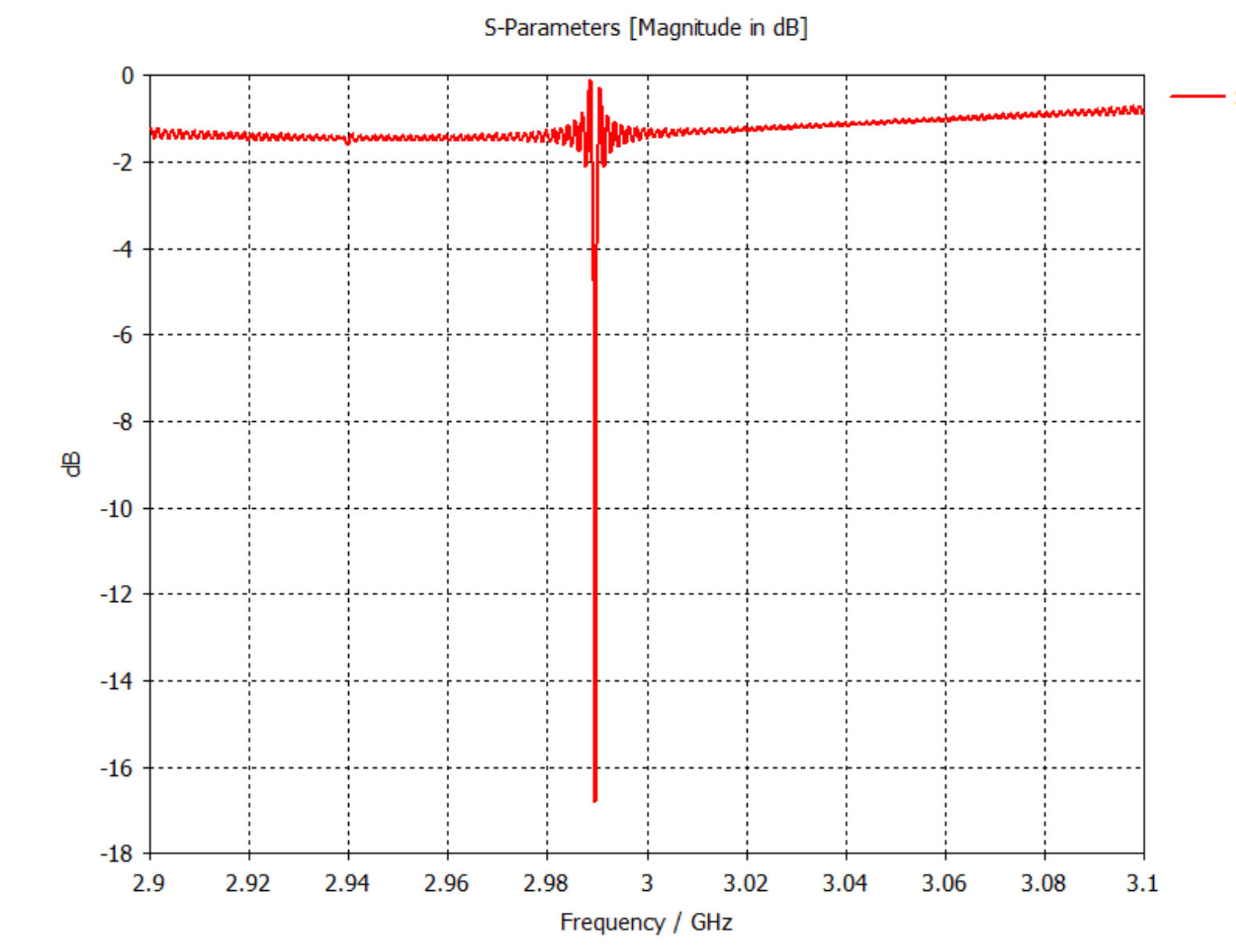


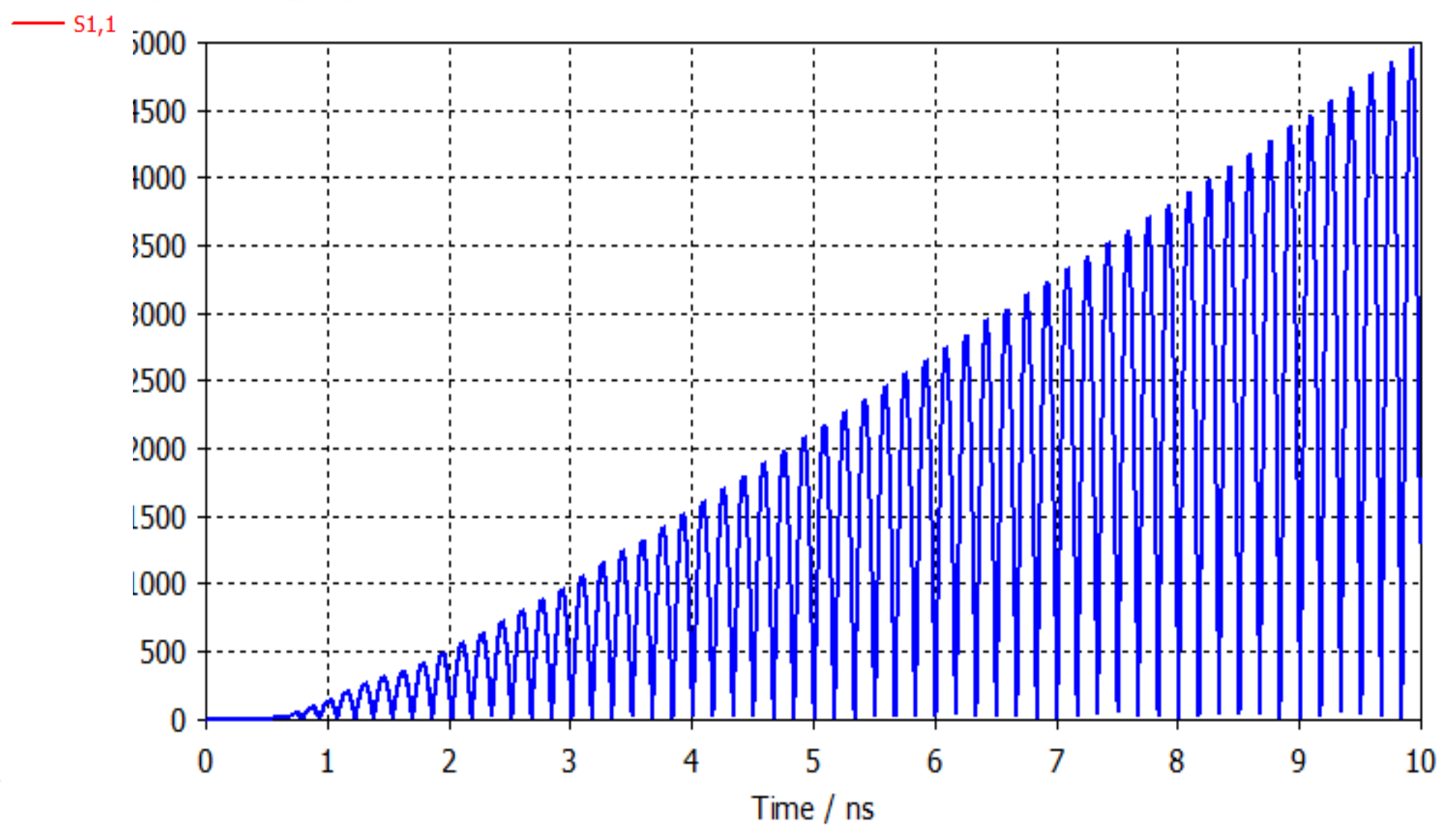
RF Simulation

Resonance frequency of TM_{010} $\boldsymbol{\pi}$-mode to 2.998 GHz. The unloaded quality factor for this geometry and mode is about 12,000.

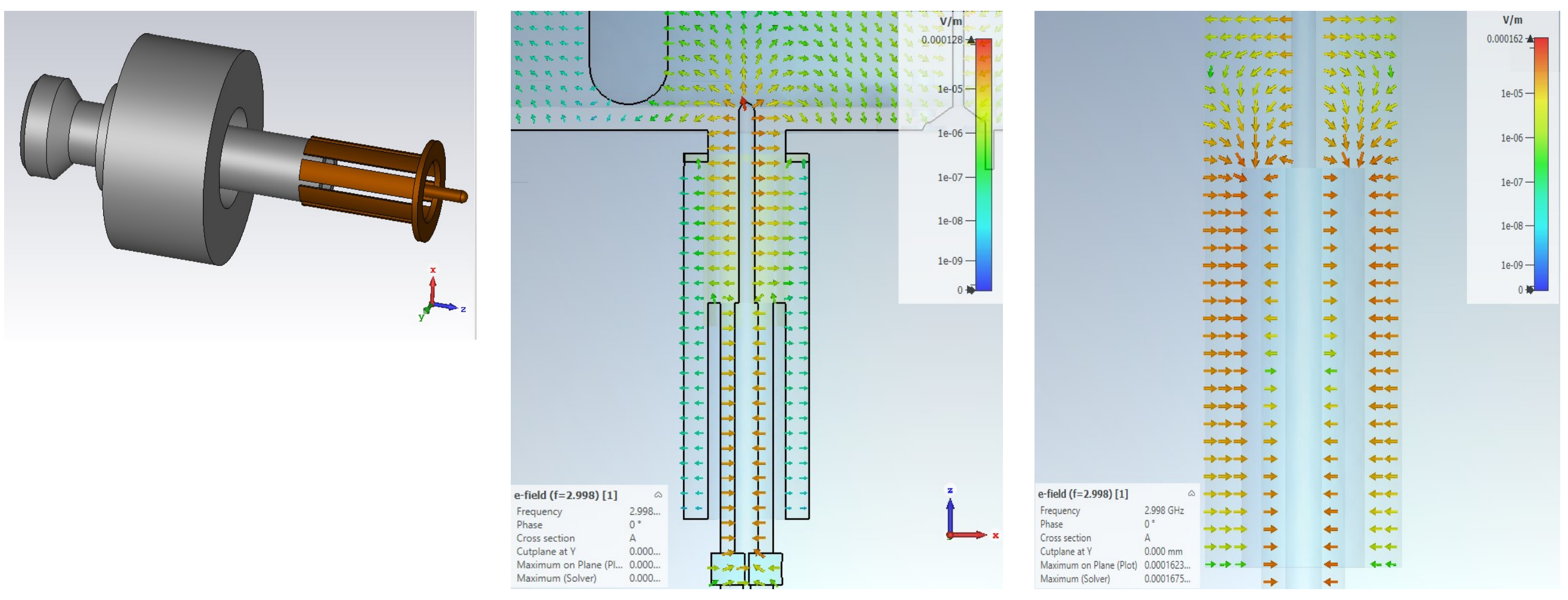


S parameter (left) and Feeding the cavity (right):

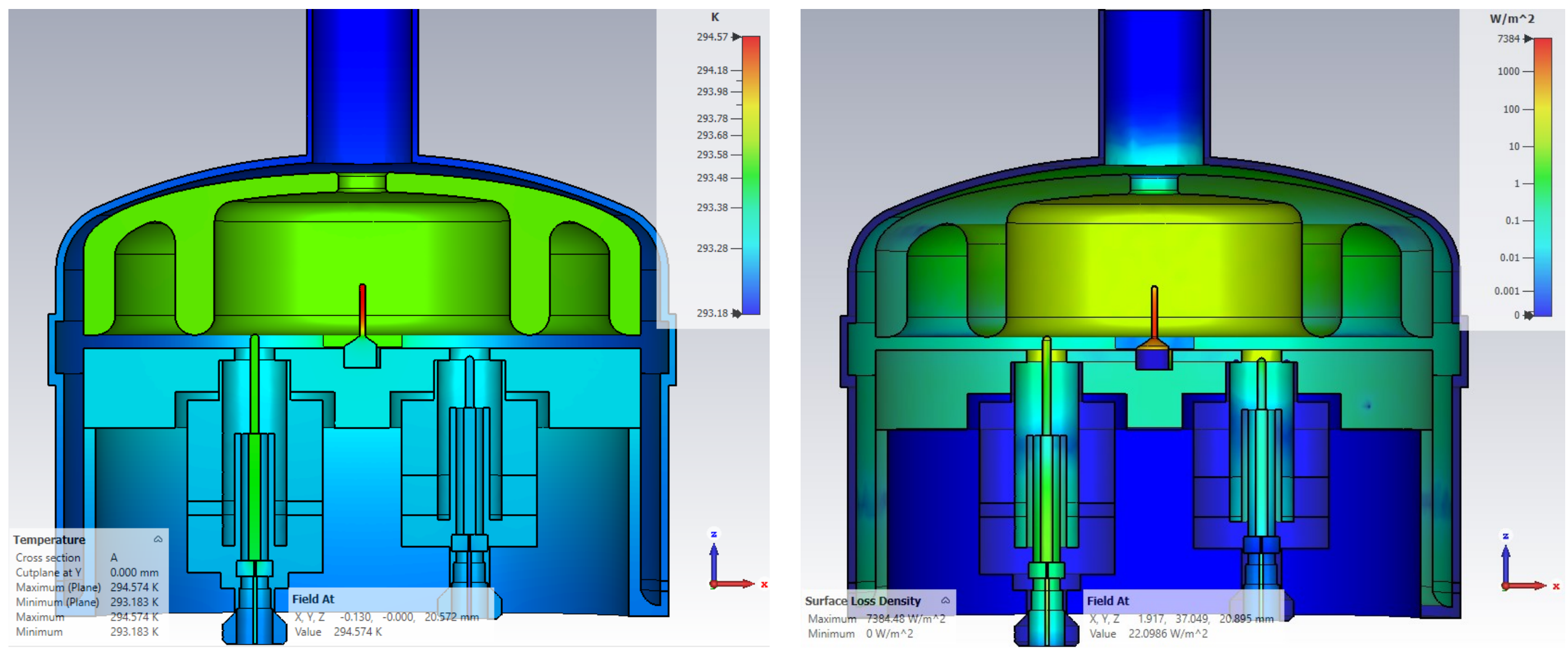




Using the RF finger to reduce the electric field around the feedthrough

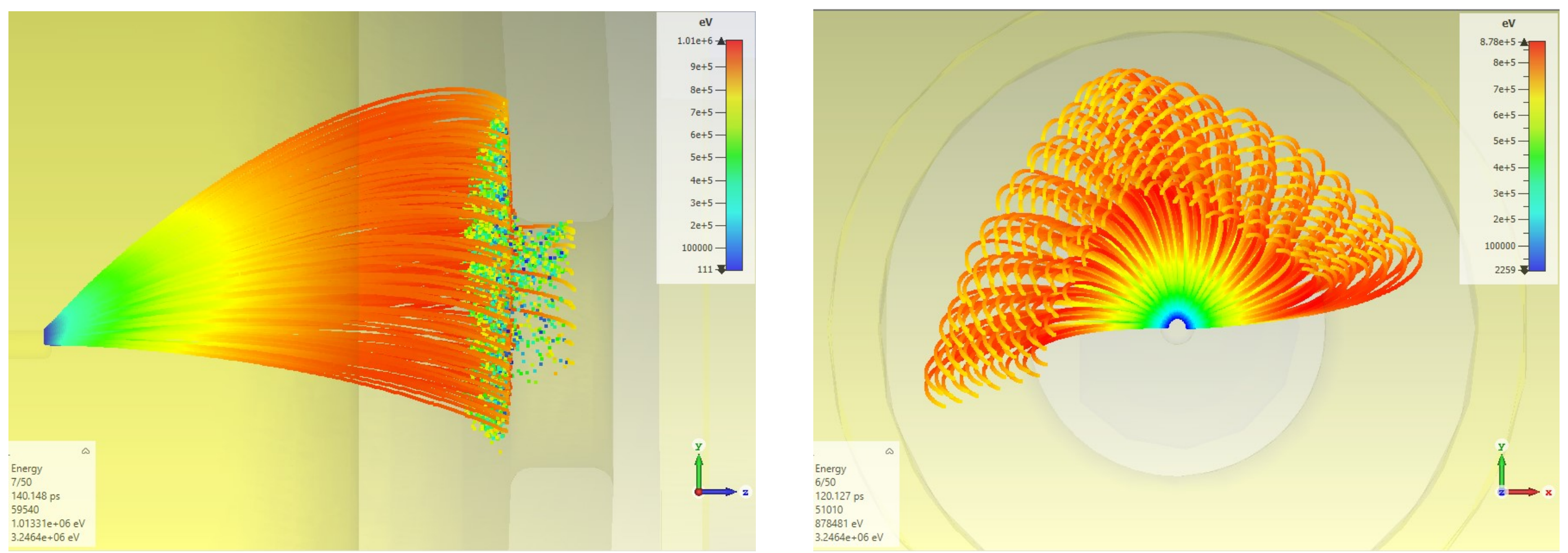


Thermal Surface loss due to ohmic losses (left), Tempreture distribution (right)

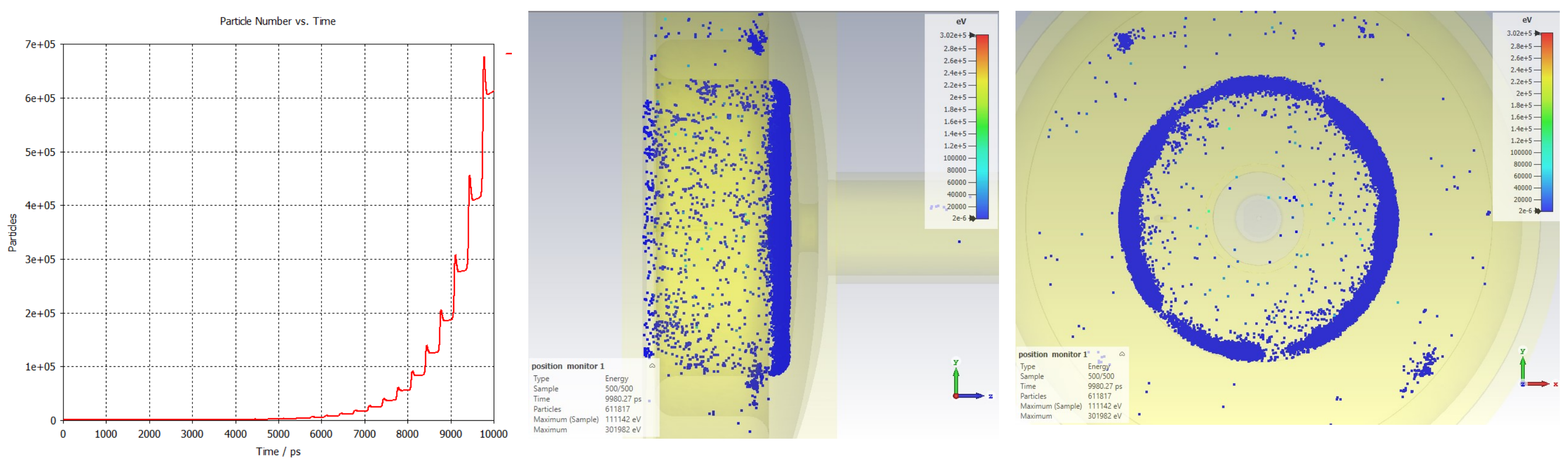


Multipacting simulation

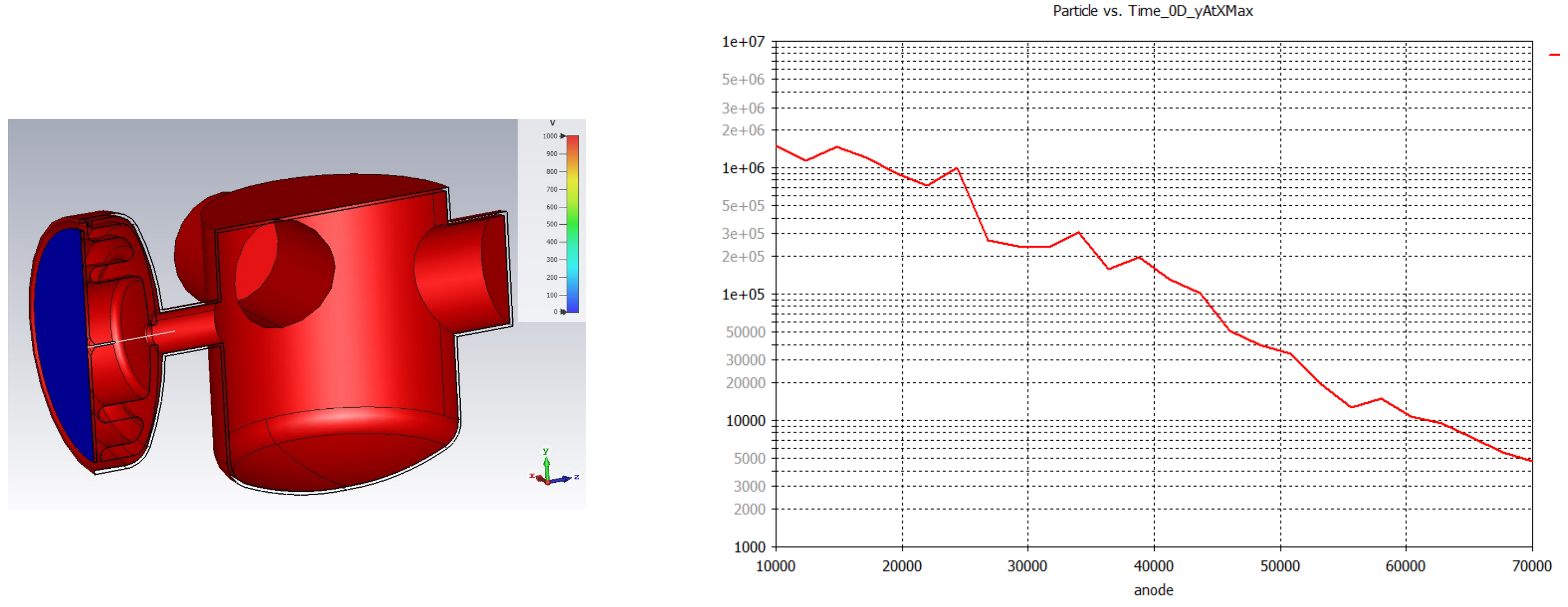
Trajectory of the electrons in Electric and magnetic field



Electron accumulation due to the electric field and multipacting phenomenon after 10 ns

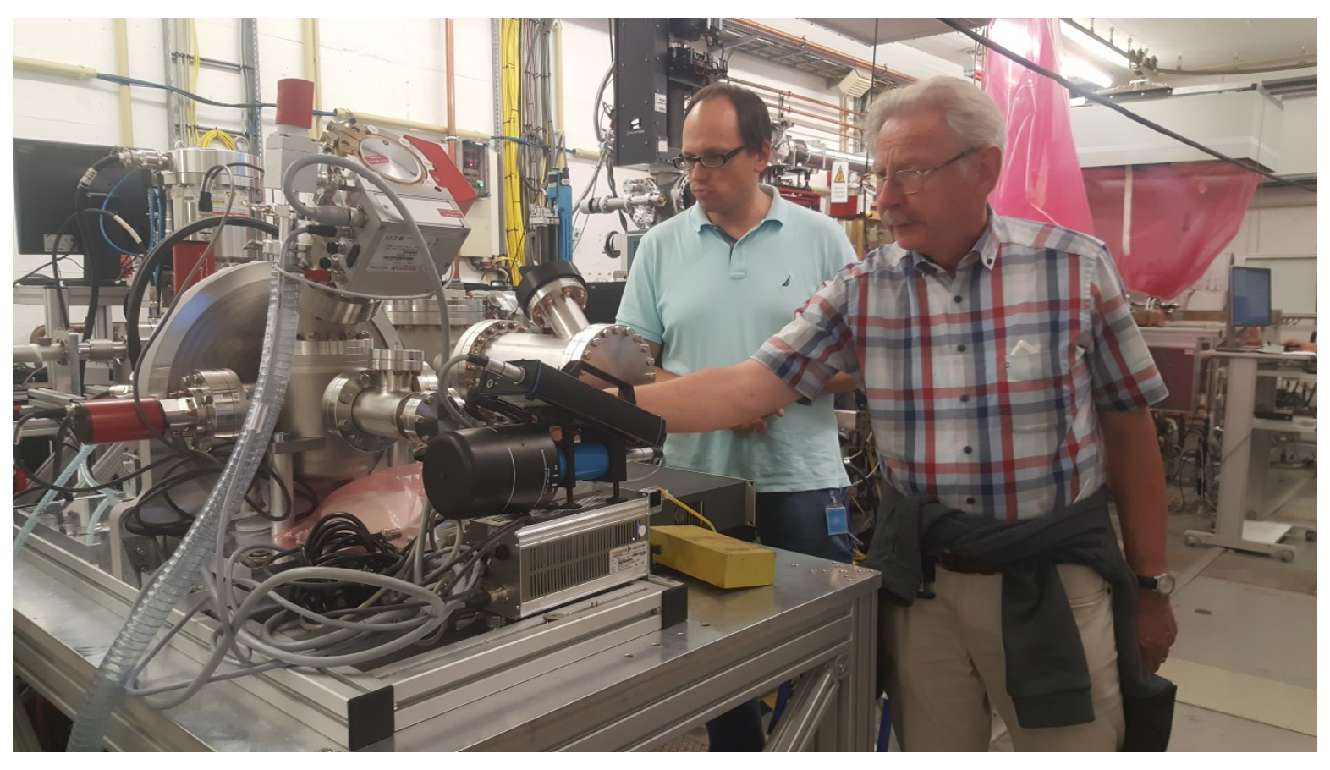


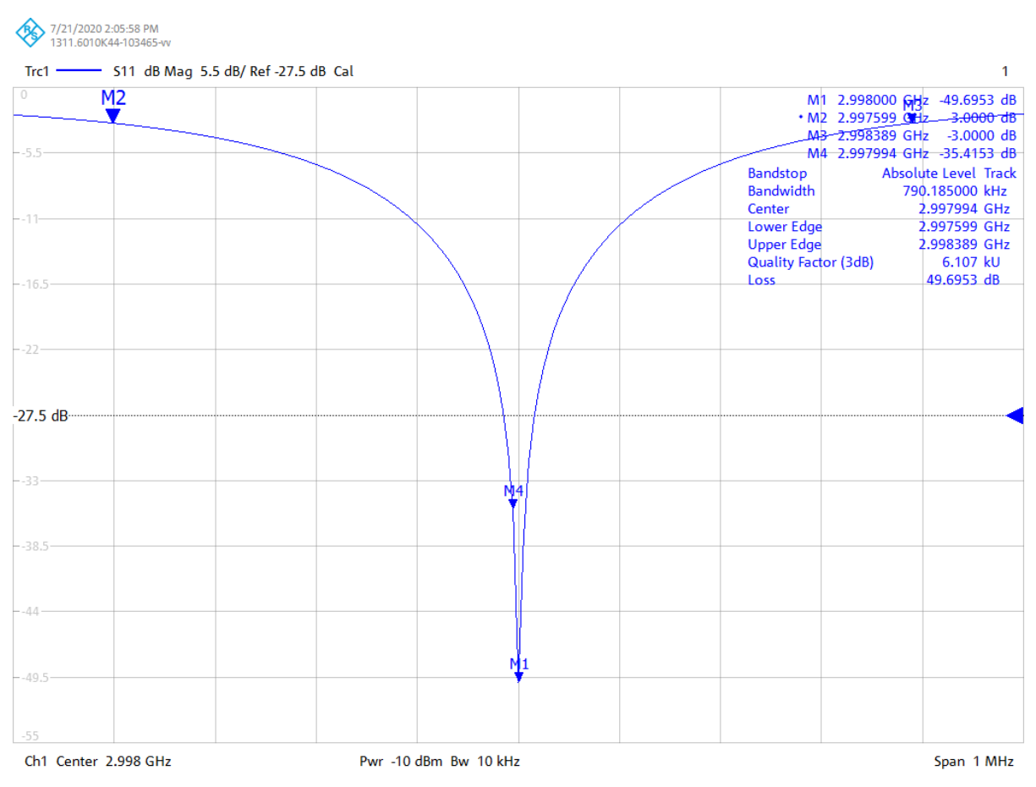
Suppression the multipacting with DC Voltage

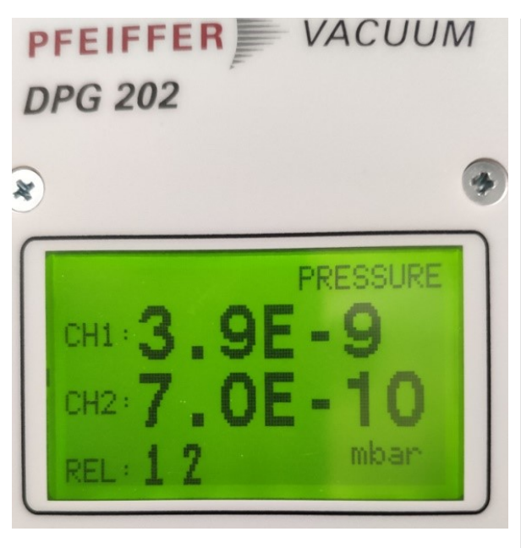


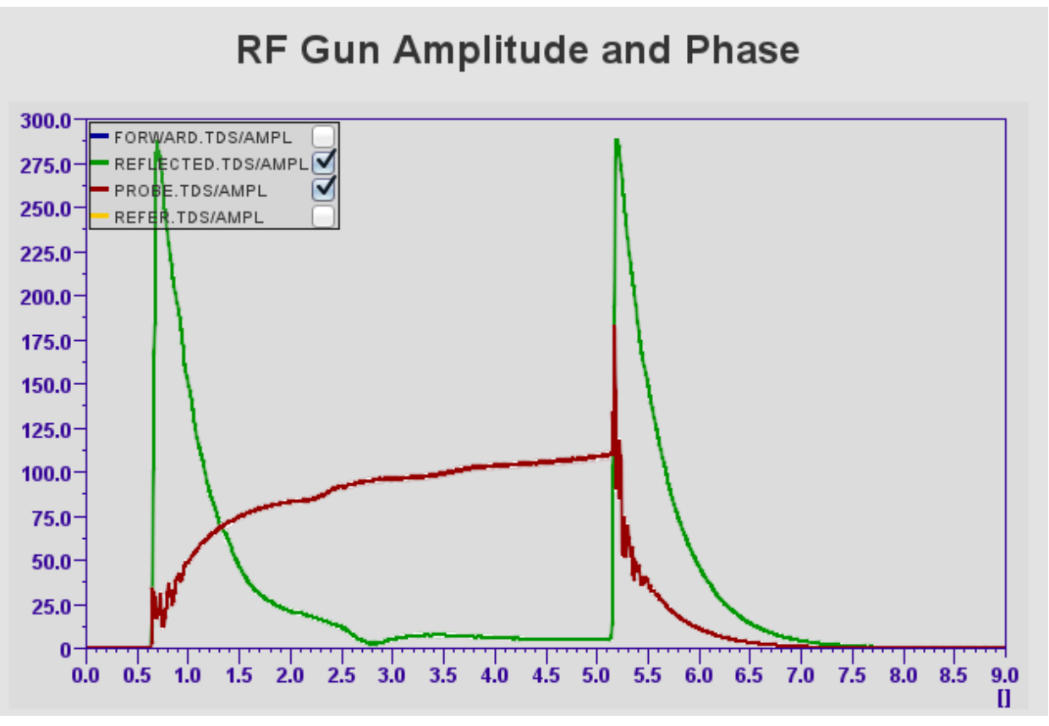
Operation at REGAE

No radiation outside of the GUN at full power (10kW) has been confirmed by D3 while operating in the REGAE tunnel. Beam charge up to 450 pC and Q-factor > 6,000 have been confirmed.







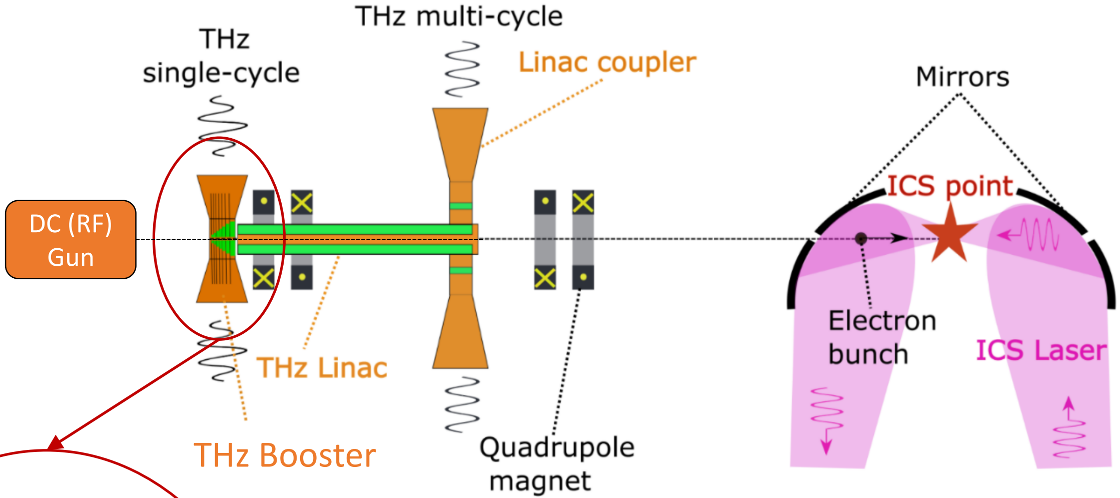


HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

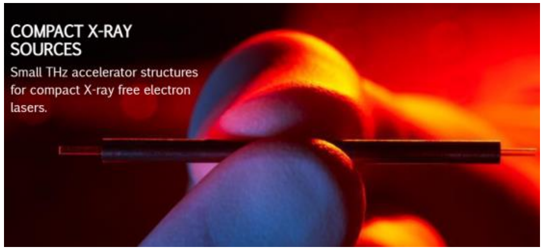
DESY

Design of a booster for THz based accelerators

- Fabrication of compact X-ray sources and lasers is a challenging and promising field of research.
- THz based accelerators are good candidates to achieve such a compact x-ray source in comparison with traditional particle accelerators whose length is measured in kilometers.
- We use a booster after DC or RF gun to accelerate electrons up to 430KeV and a Linac to Higher energies (20MeV).
- We are designing a multi-layer segmented booster to accelerate electrons up to 430 MeV

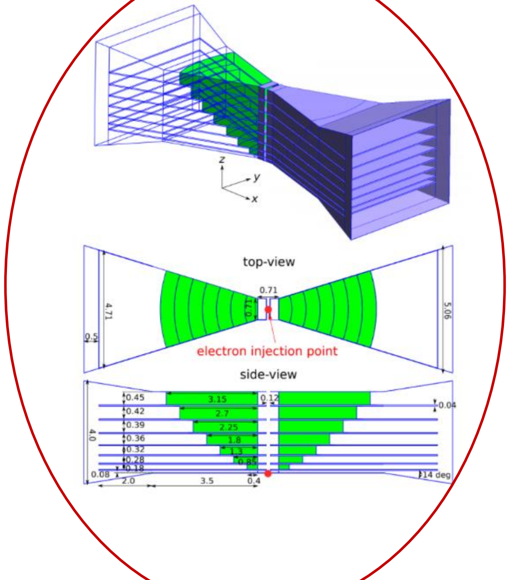


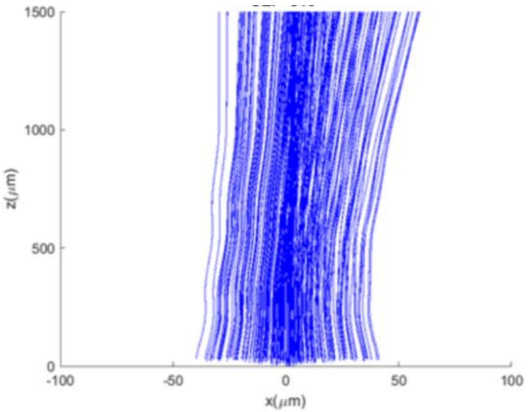
Schematic layout of the THz-driven compact x-ray source



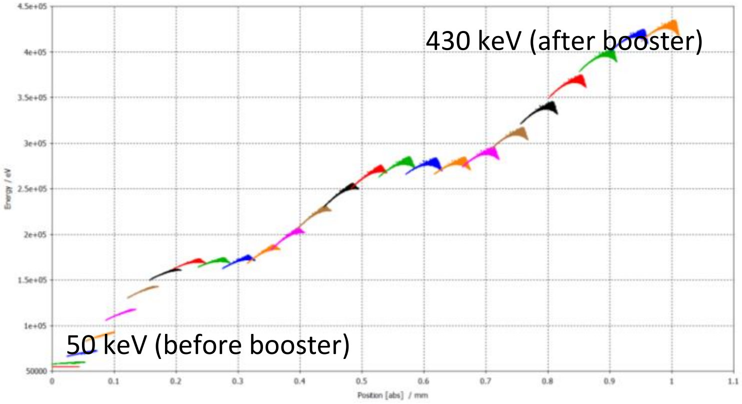
COMPACT X-RAY SOURCES

Small THz accelerator structures for compact X-ray free electron lasers.





Up to 1 degree deflection has been estimated due to imperfections in fabrication



Energy of electron bunches inside the booster in different time frames