NORCC Workshop 2023

Status report
Activity 3, accelerators

Erik Adli (Activity leader)
Kyrre N. Sjøbæk, Elisabeth R. Lindberg (NORCC)
Department of Physics, University of Oslo, Norway

Vilde F. Rieker, Steinar Stapnes, CERN and *University of* Oslo (CERN-funded)

Victoria. M. Bjelland, NTNU and CERN (CERN-NTNU program)

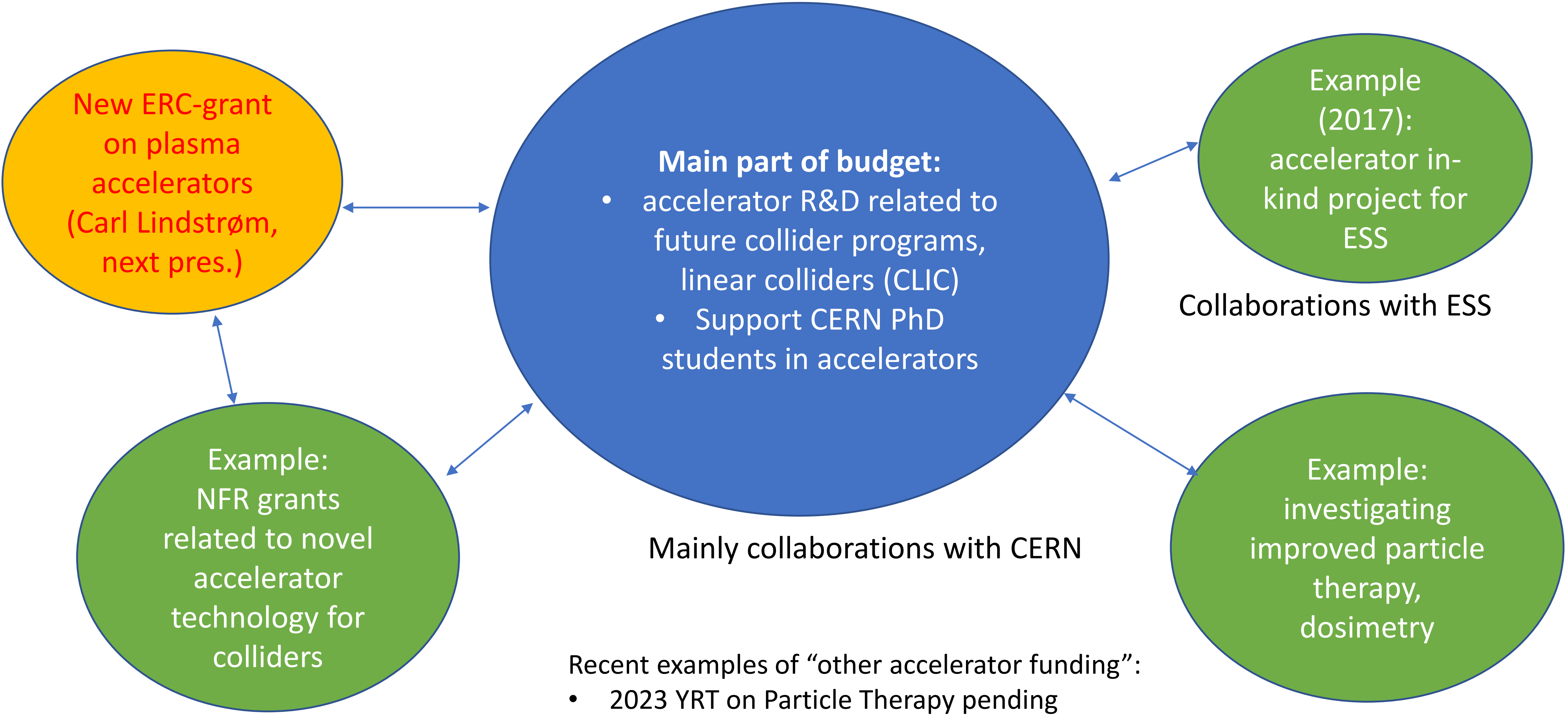
Carl A. Lindstrøm, Gevy Cao, Ole G. Finnerud, Ben Chen, Daniel Kalvik, Eric F. Fackelman
University of Oslo, Oslo (funded by related accelerator activities)

Erik.Adli@fys.uio.no

September 27, 2023

Activities 2020-2026

- Main part of the (small) budget: core CERN collider activites
- Some parts of budget, related accelerated activites, used to “seeding” other activities, “feeding” back to main activity



New ERC-grant on plasma accelerators (Carl Lindstrøm, next pres.)

Main part of budget:
- accelerator R&D related to future collider programs, linear colliders (CLIC)
- Support CERN PhD students in accelerators

Mainly collaborations with CERN

Example (2017): accelerator in-kind project for ESS

Collaborations with ESS

Example: NFR grants related to novel accelerator technology for colliders

Collaborations with SLAC, DESY and CERN

Example: investigating improved particle therapy, dosimetry

Collaboration with CERN
Potential collaborations with OUS

Recent examples of “other accelerator funding”:
- 2023 YRT on Particle Therapy pending
- 2023 ERC StG –funded

Highlights from NORCC core funding

Development of novel active plasmas lenses for strong beam focusing and future colliders. Two paper published, **first post-covid experimental run Aug. 2023.**

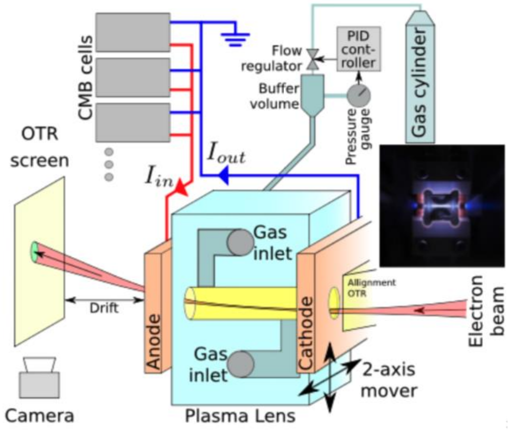
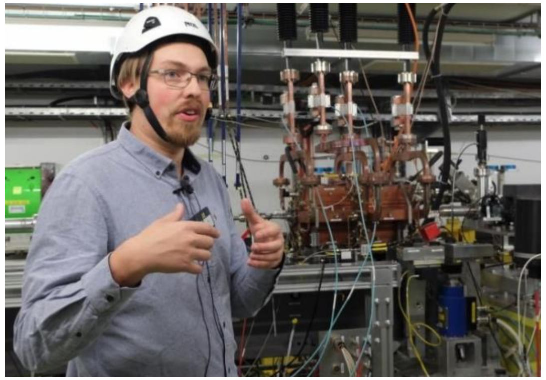


FIG. 1. Overview of the most relevant components of the CLEAR Plasma Lens Experiment and the path of the beam. Insert: Plasma lens capillary during a discharge.



Collaboration with CERN, Oxford and DESY

New master student, Elisabeth R. Lindstad.

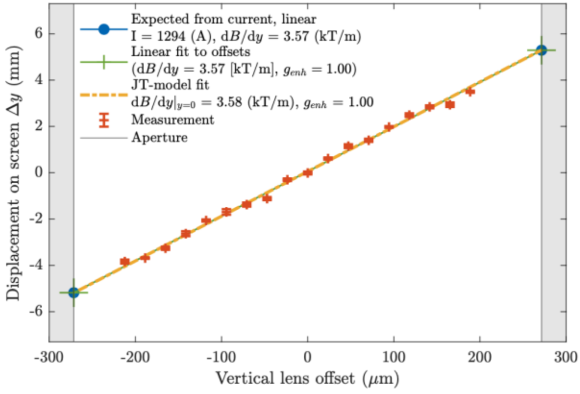


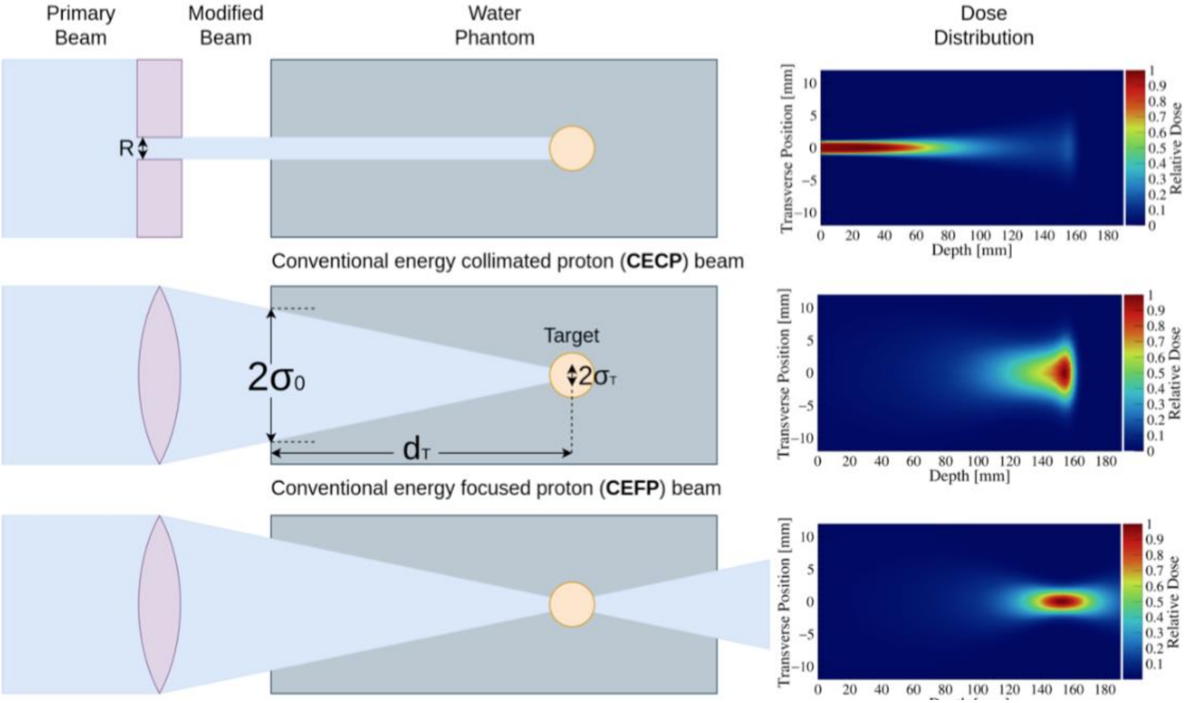
FIG. 3. Beam displacement as a function of lens offset in argon on peak current, for measuring the field gradient.

K. N. Sjobak, NFR YRT Application, "Hyperfocus": Particle accelerator final focus systems for improving precision of dose delivery for medical applications and irradiation test stands

[1] K. Sjøbæk, E. Adli et al., "SStrong focusing gradient in a linear active plasma lens"
Phys. Rev. Accel. Beams 24, 121306 (2021)
[2] S-Y. Kim, K. Moon, M. Chung, K. Sjøbæk, E. Adli et al., "Witness electron beam injection using an active plasma lens for beam-driven plasma wakefield accelerators"
Phys. Rev. Accel. Beams 24, 121304 (2021)

Development of advanced beam focusing for proton therapy (application of CERN-technology)

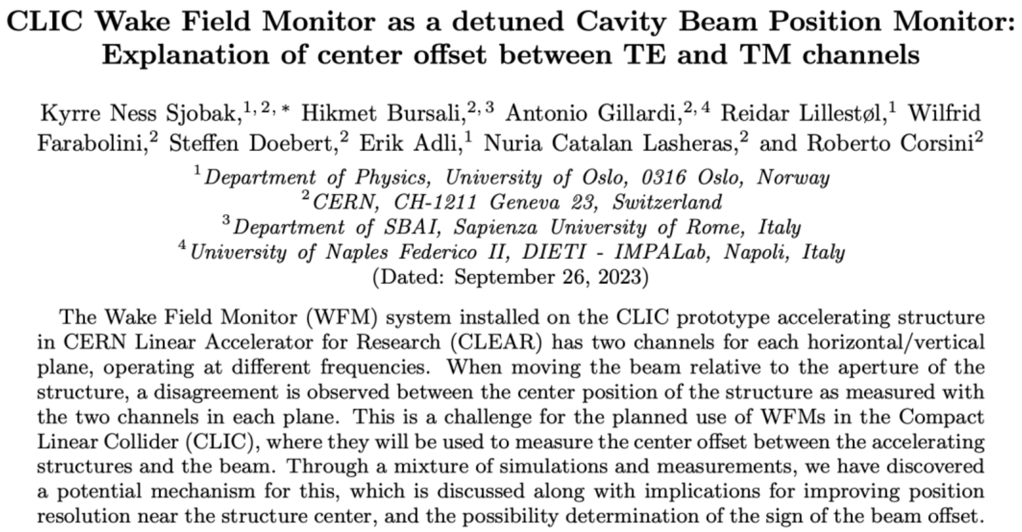
We study how our expertise in advanced beam optics, for example needed for future particle colliders, can be applied to improve proton therapy.



Principle of advanced beam shaping techniques for proton therapy. From [4].

*[3] **F. Reaz**, "Advanced beam shaping for spatially fractionated proton beam therapy", Master thesis, UiO, 2021*
*[4] **F. Reaz, K. N. Sjobak**, E. Malinen, N. Edin, **E. Adli**, "Sharp dose profiles for high precision proton therapy using focused proton beams", Nature **Sci Rep 12**, 18919 (2022)]*
*[5] K. Kokurewicz et al., "An experimental study of focused very high energy electron beams for radiotherapy", Nature **Commun Phys 4, 33 (2021)***
https://www.nature.com/articles/s42005-021-00536-0

Highlights from NORCC core funding

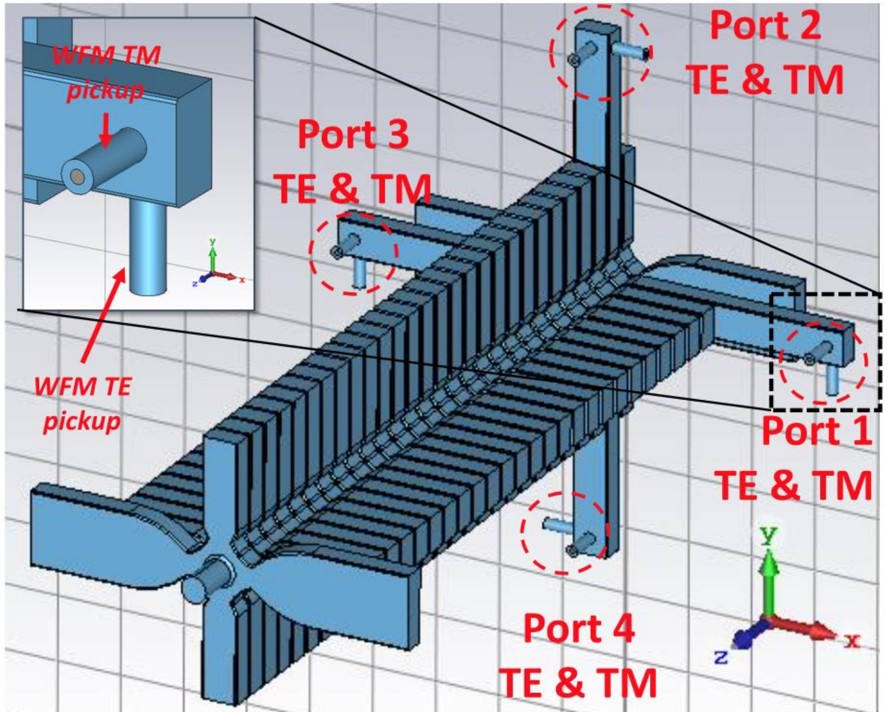


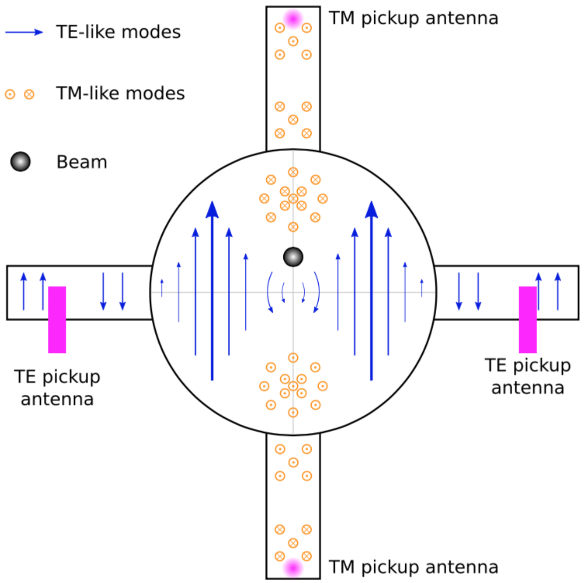
CLIC Wake Field Monitor as a detuned Cavity Beam Position Monitor: Explanation of center offset between TE and TM channels

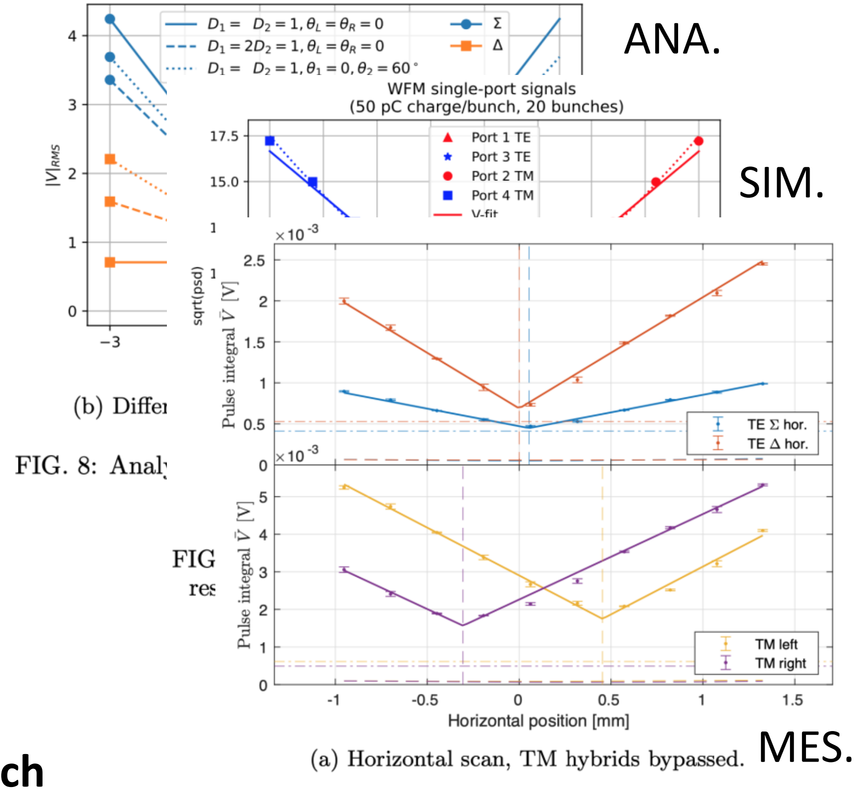
Kyrre Ness Sjobak,[1,2,*] Hikmet Bursali,[2,3] Antonio Gillardi,[2,4] Reidar Lillestøl,[1] Wilfrid Farabolini,[2] Steffen Doebert,[2] Erik Adli,[1] Nuria Catalan Lasheras,[2] and Roberto Corsini[2]
[1] *Department of Physics, University of Oslo, 0316 Oslo, Norway*
[2] *CERN, CH-1211 Geneva 23, Switzerland*
[3] *Department of SBAI, Sapienza University of Rome, Italy*
[4] *University of Naples Federico II, DIETI - IMPALab, Napoli, Italy*
(Dated: September 26, 2023)

The Wake Field Monitor (WFM) system installed on the CLIC prototype accelerating structure in CERN Linear Accelerator for Research (CLEAR) has two channels for each horizontal/vertical plane, operating at different frequencies. When moving the beam relative to the aperture of the structure, a disagreement is observed between the center position of the structure as measured with the two channels in each plane. This is a challenge for the planned use of WFMs in the Compact Linear Collider (CLIC), where they will be used to measure the center offset between the accelerating structures and the beam. Through a mixture of simulations and measurements, we have discovered a potential mechanism for this, which is discussed along with implications for improving position resolution near the structure center, and the possibility determination of the sign of the beam offset.

Kyrre N. Sjobak et al, arXiv:2307.06681 (2023)







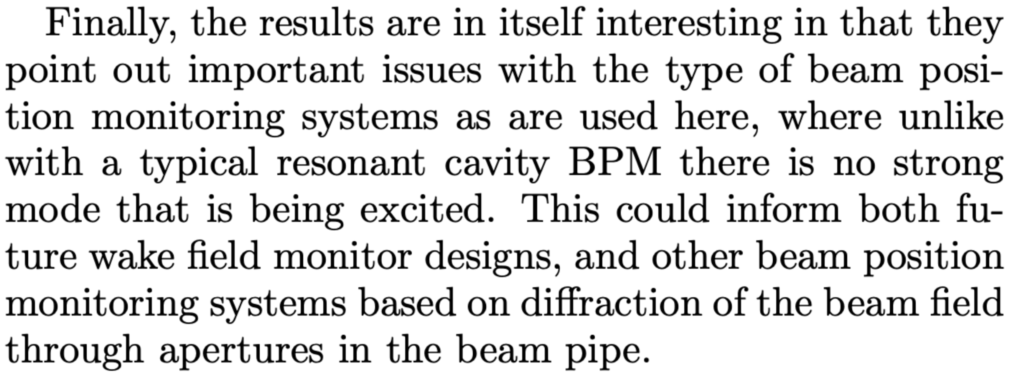
(b) Differ

FIG. 8: Anal

FIG res

(a) Horizontal scan, TM hybrids bypassed.

Related to our core
X-band High-Gradient research

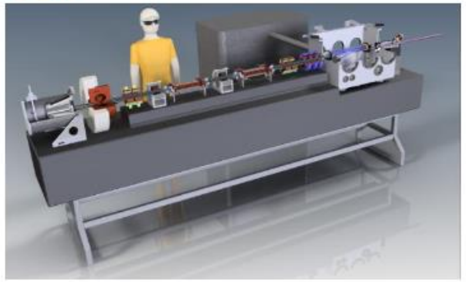


Finally, the results are in itself interesting in that they point out important issues with the type of beam position monitoring systems as are used here, where unlike with a typical resonant cavity BPM there is no strong mode that is being excited. This could inform both future wake field monitor designs, and other beam position monitoring systems based on diffraction of the beam field through apertures in the beam pipe.

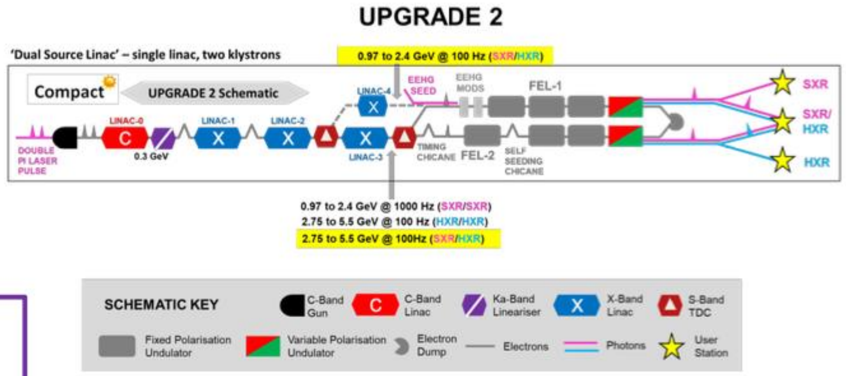
Conclusion of a long story started by postdoc Reidar Lillestøl, in 2014 !

Applications of X-band technology: Topic for tomorrow,"Future Accelerator activities"

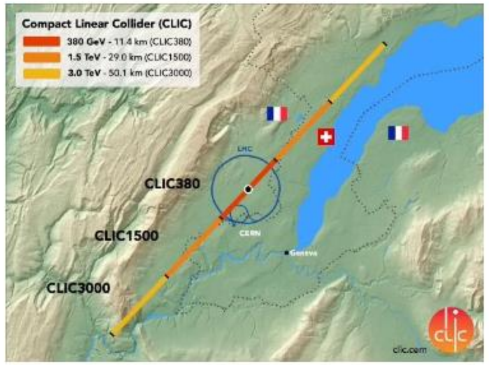
X-band and high-gradient applications overview



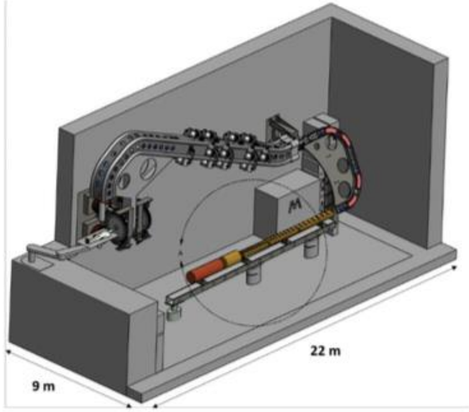
Light source - Inverse Compton Scattering Source



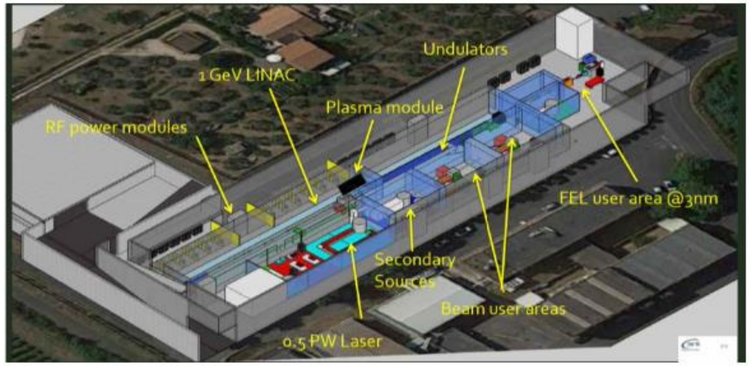
Light source - XFEL



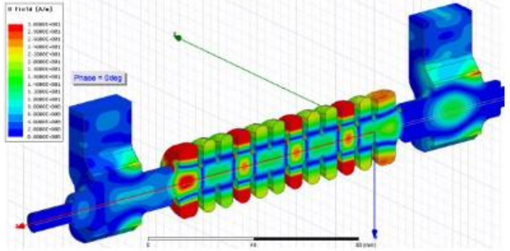
Linear collider

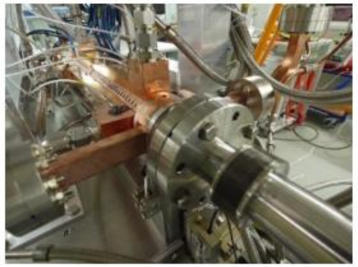


Medical applications



GeV-range research linacs





Beam manipulation

Steffen Doebert, Walter Wuensch on behalf of the CLIC /X-band collaboration

Vilde F. Rieker, CERN-UiO PhD

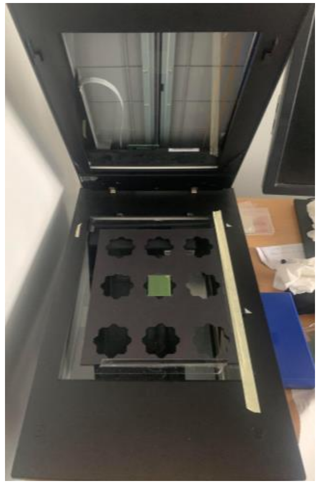
VHEE/FLASH Real Time Dosimetry Monitoring

Benchmarking against well established and dose-rate independent dosimetry methods

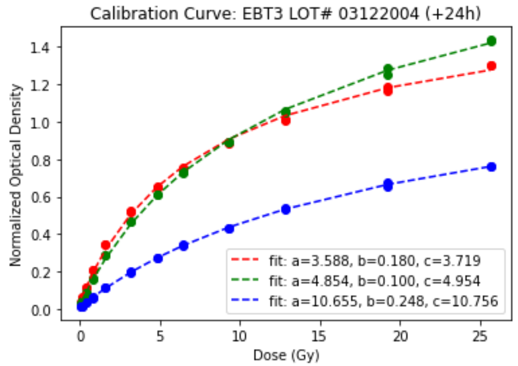
Cut and engrave radiochromic films

Calibrate

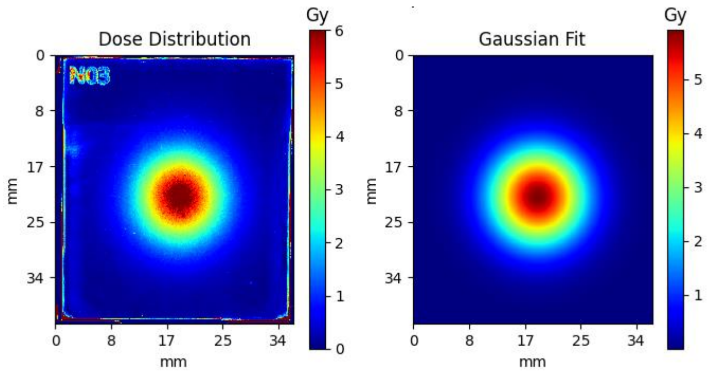
Irradiate



Scan (one by one)



Process to find relationship between dose and darkening for given batch

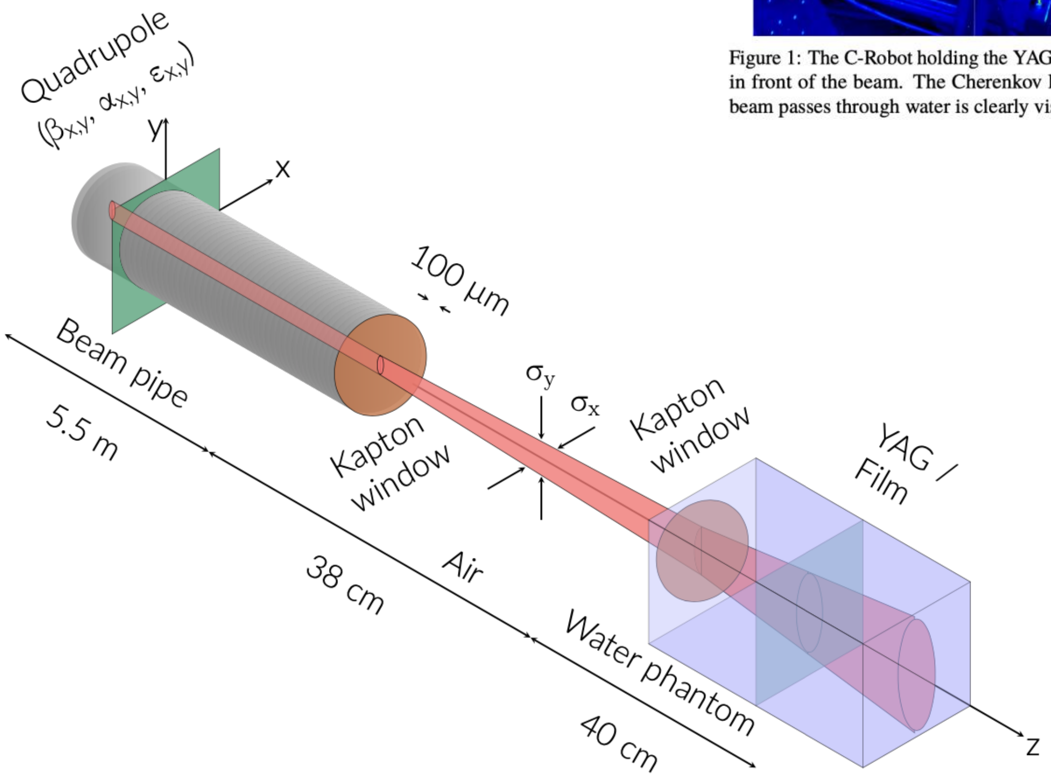


Process to determine dose distribution and correlate with beam parameters

… which are "passive", i.e. manual, time consuming and repetitive.

Vilde F. Rieker, CERN-UiO PhD

Experimental Setup



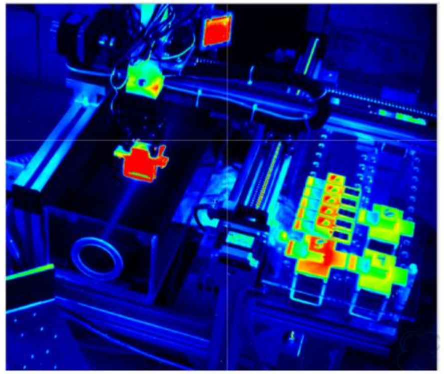
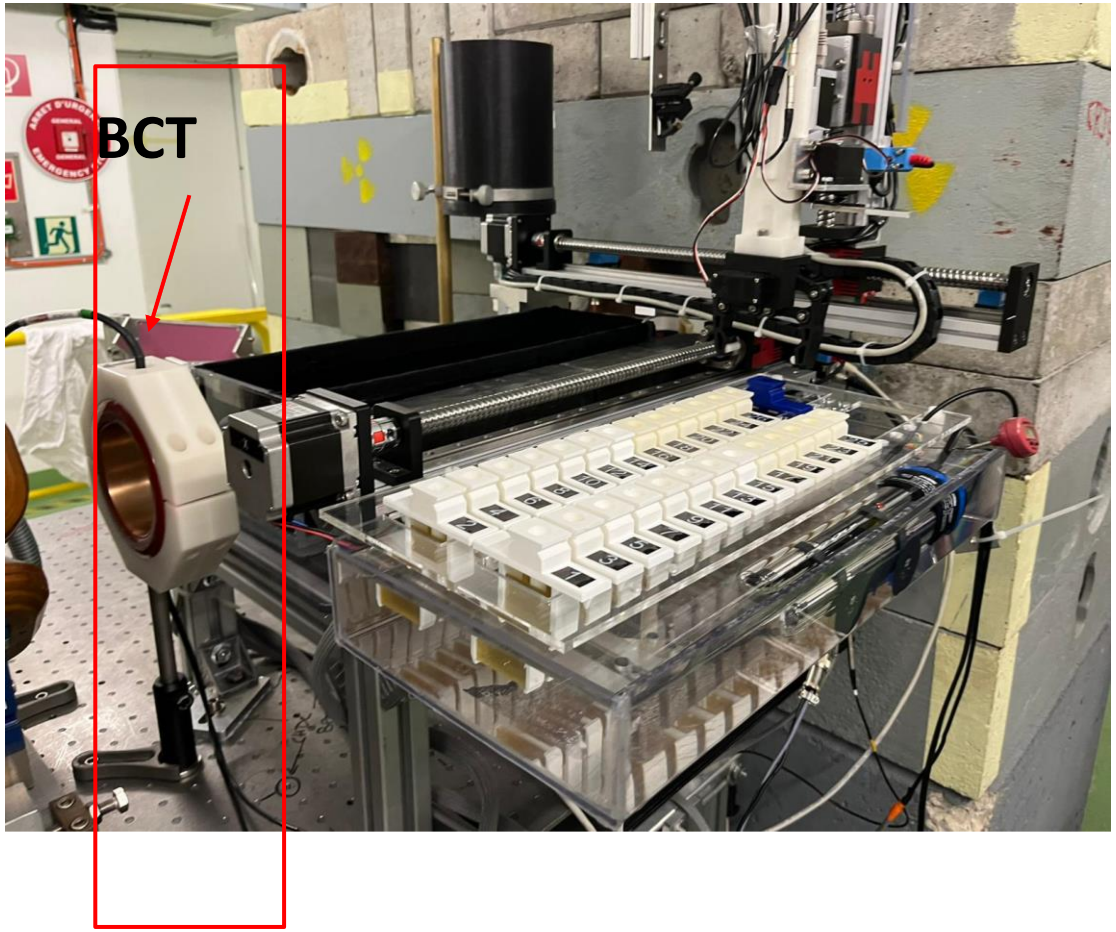
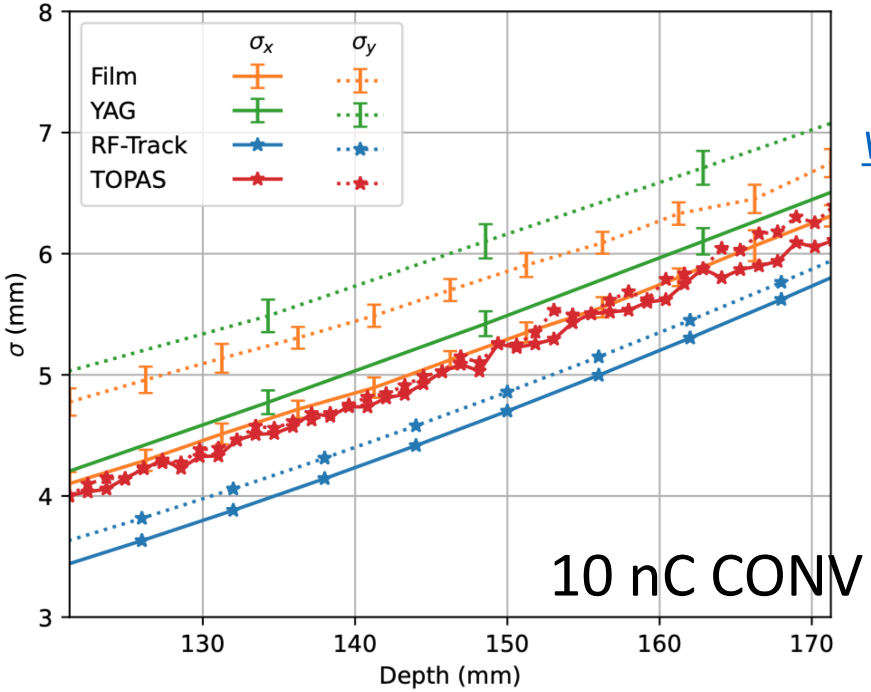


Figure 1: The C-Robot holding the YAG screen inside water in front of the beam. The Cherenkov light emitted as the beam passes through water is clearly visible.



UNIVERSITY OF OSLO

Beam Size Evaluation in CLEAR



10 nC CONV

Figure 4: The evolution of the 1σ beam size as a function of depth, as measured by the films and YAG screens irradiated under CONV conditions.

[V.F. Rieker et al., IPAC'23]

14th International Particle Accelerator Conference,Venezia JACoW Publishing
ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: doi/jacow-ipac2023-thpm060/index.html

BEAM INSTRUMENTATION FOR REAL TIME FLASH DOSIMETRY: EXPERIMENTAL STUDIES IN THE CLEAR FACILITY*

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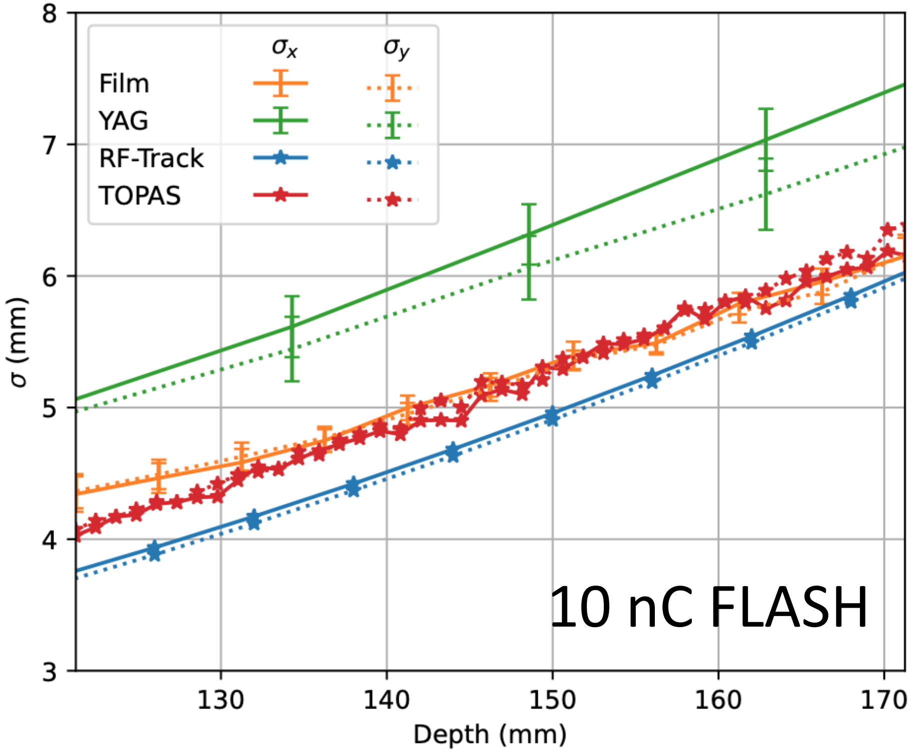
CERN, Geneva, Switzerland
E. Adli, K.N. Sjobak, University of Oslo, Norway
J. J. Bateman[3], P. Korysko[3], C. S. Robertson [3], University of Oxford, United Kingdom
[1]also at University of Oslo, Norway, [2]also at University of Ankara, Ankara, Turkey
[3]also at CERN, Geneva, Switzerland



10 nC FLASH

Figure 5: The evolution of the 1σ beam size as a function of depth, as measured by the films and YAG screens irradiated under FLASH conditions.

Electron Field Emission and Plasmonics role in Vacuum breakdown

Victoria M. Bjelland (M. Kildemo), NTNU/CERN PhD, RF break down

Introduction

The Compact Linear Accelerator (CLIC) is a proposed accelerator intended to collide electrons and positrons up towards 3TeV energy.

This required high electric fields. However, when materials are exposed to this high field, they can experience breakdowns.

During a breakdown, the beam is lost and surface damage can be found, see Figure 1b.

The reason behind this mechanism is unknown!

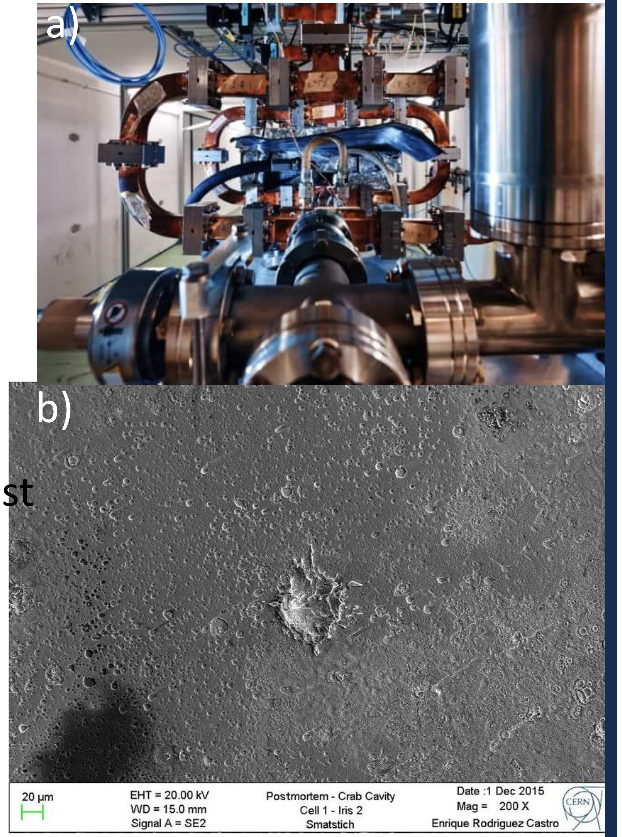


Figure 1: a) CLIC prototype. b) SEM image of breakdown damage.

Experimental Setup

Breakdown studies in accelerator structures using RF waves, is severly difficult!
To easier test this, a DC setup was built, see Figure 2a.

A Marx generator applies short pulses of high voltage to the system.
An oscillosocpe can monitor the signal given to the system and its response.

The Large Electrode System (LES) is the heart of the system Figures 2a and 2b. Inside, are two electrdoes (anode and cathode), having a very small gap between them (20-100um) using spacers.

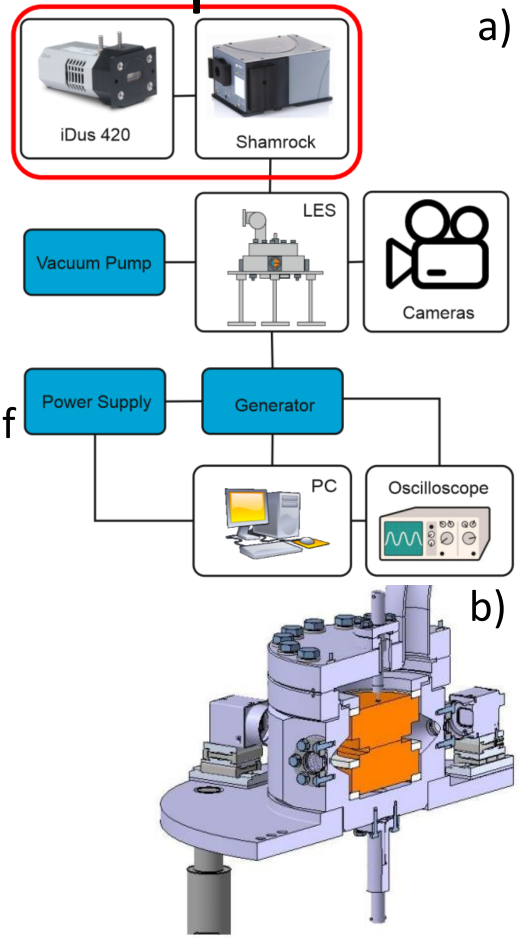


Figure 2: a) Experimental setup with the differnt components attached to it. b)Inside view of the LES. Two electrodes have a small gap, enabling a high electric field.

(M. Kildemo)

Victoria M. Bjelland

Results and Project Aspects

Current Result

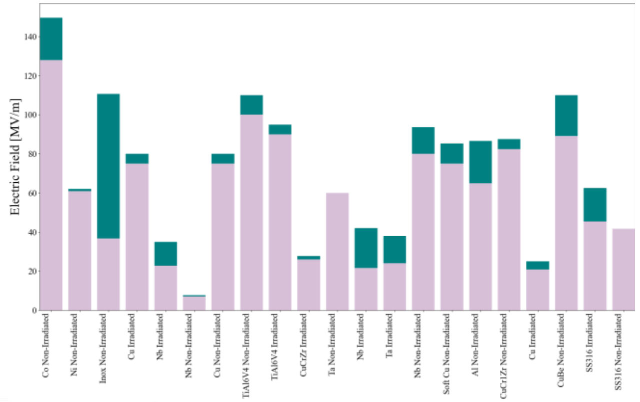
Conditioning is a method where a material is exposed to an increasingly stronger electric field while maintaining a low enough breakdown rate, see Figure 1 a).

Many metals and alloys have undergone testing to establish their electric field limit, see Figure 1 b).

Other tests can be undergone while applying the high electric field like:

- Electric field emission
- Light emission (due to current)
- Light emission due to breakdowns
- Localization of field emitters (under development)

We also test more «exotic type» of materials, such as additively manufactured electrodes and frustum shaped electrodes, for different applications.



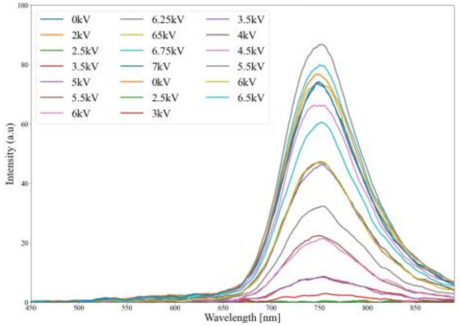


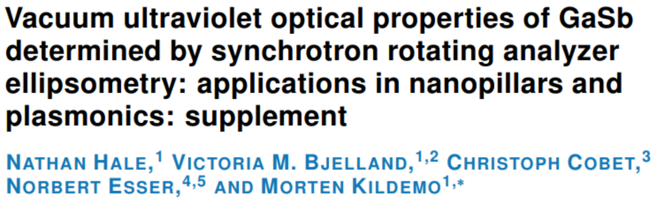
Figure 1: a) Conditioning example. b) Maximum (green) and final (pink) electric field of materials tested at CERN. c) Light emission spectrum from CuBe when applying different voltages.

Future Aspects

- How to link plasmonics into the LES system.
- Looking for field emitters
- In co-operation with the photoemissiong group

Current Publications

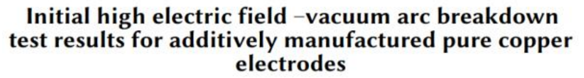
Non-approximative Kinetics of Triplet-Triplet Annihilation at Room Temperature: Solvent Effects on Delayed Fluorescence



Vacuum ultraviolet optical properties of GaSb determined by synchrotron rotating analyzer ellipsometry: applications in nanopillars and plasmonics: supplement

NATHAN HALE,[1] VICTORIA M. BJELLAND,[1,2] CHRISTOPH COBET,[3] NORBERT ESSER,[4,5] AND MORTEN KILDEMO[1,*]

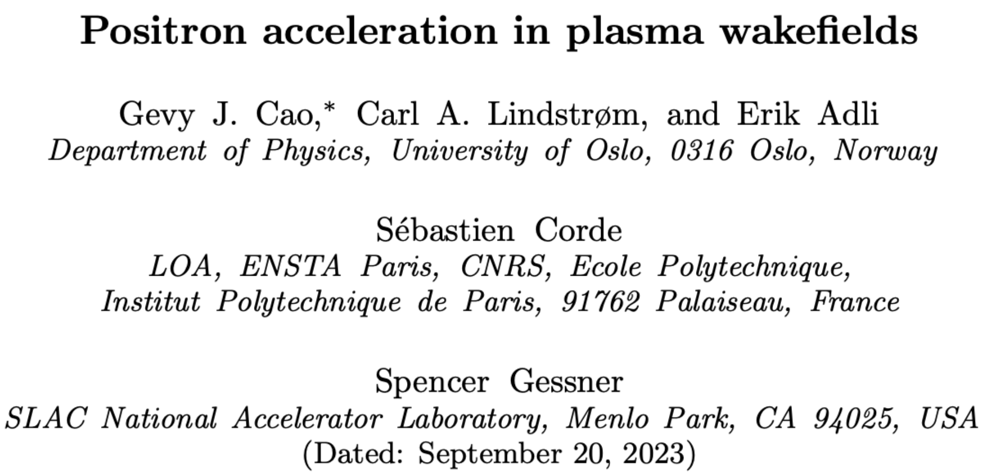
Link



Initial high electric field –vacuum arc breakdown test results for additively manufactured pure copper electrodes

Presented at IPAC 2023 by Andris Ratkus

Plasma acceleration (FRIPRO project)



Positron acceleration in plasma wakefields

Gevy J. Cao,* Carl A. Lindstrøm, and Erik Adli
Department of Physics, University of Oslo, 0316 Oslo, Norway

Sébastien Corde
LOA, ENSTA Paris, CNRS, Ecole Polytechnique,
Institut Polytechnique de Paris, 91762 Palaiseau, France

Spencer Gessner
SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA
(Dated: September 20, 2023)

A hybrid, asymmetric, linear Higgs factory based on plasma-wakefield and radio-frequency acceleration

B Foster[1,2,*], **R D'Arcy**[1,2] **and C A Lindstrøm**[3]

[1] John Adams Institute for Accelerator Science at University of Oxford, Oxford, United Kingdom
[2] Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
[3] Department of Physics, University of Oslo, Oslo, Norway
[*] Author to whom any correspondence should be addressed.

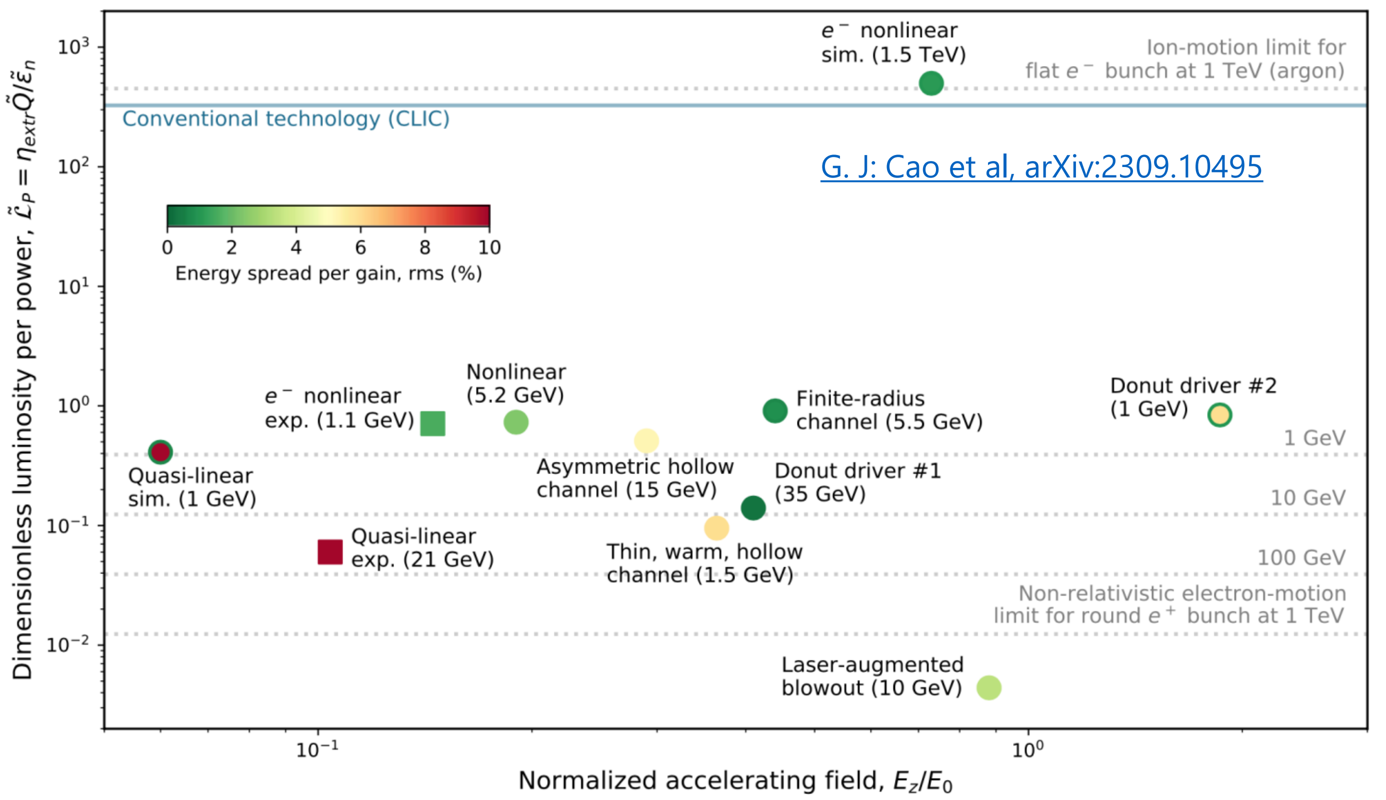
E-mail: brian.foster@physics.ox.ac.uk

Keywords: plasma-wakefield, Higgs, factory, hybrid

New 2023:

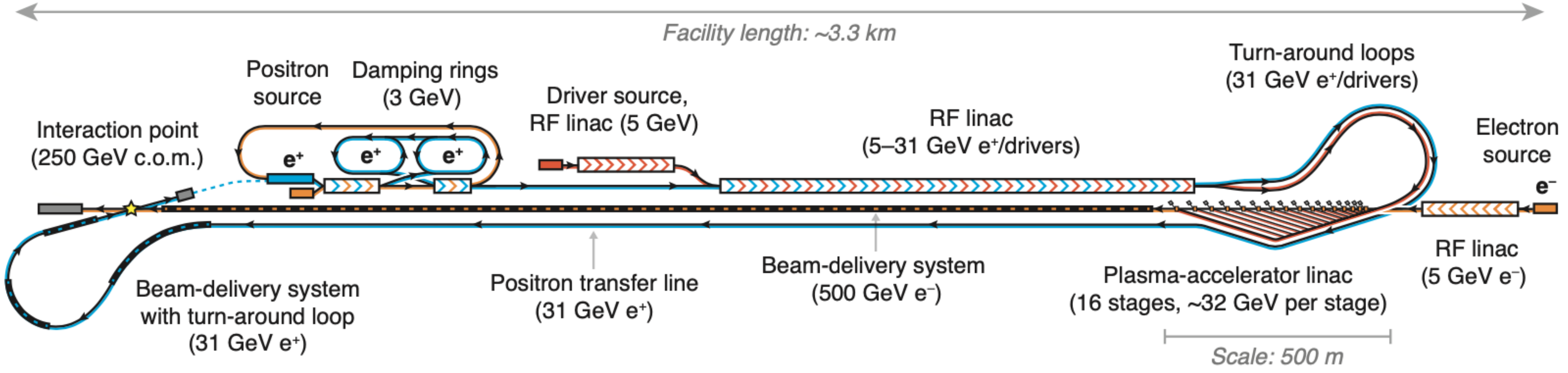
- **Postdoc, Ben Chen**
- **PhD Ole Gunnar Finnerud**
- **Master Daniel Kalvik**

Comparison of proposed positron schemes (+electron schemes and RF)



G. J: Cao et al, arXiv:2309.10495

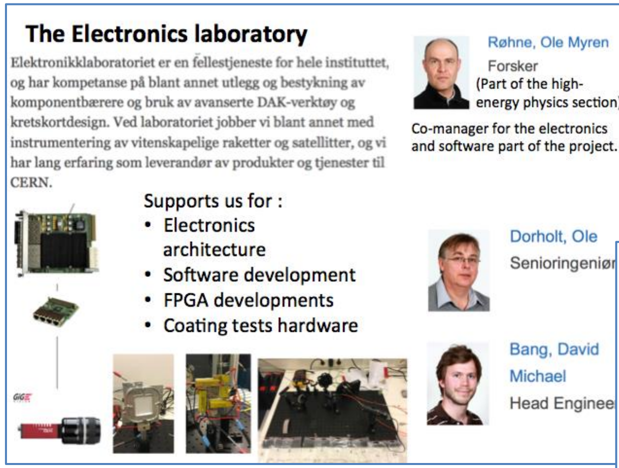
B. Foster, R. D'Arcy and C. A. Lindstrøm, *New J. Phys.* **25,** 093037 (2023)



Finalization of the ESS Oslo in-kind contribution:

- **At start 2024: contract terminates**, and funding ends
- all deliveries will be formally completed, all hardware sent to ESS, documented, final in-kind report
- systems will not be installed in final location, beam comissioning will happen under ESS responsibility
- Oslo will likely get small assistance contract for commissioning

The ESS project:
Has utilized a **broad spectrum of Oslo resources**. Increasinged our competence for future participation in accelerator projects.



The Electronics laboratory

Elektronikklaboratoriet er en fellestjeneste for hele instituttet, og har kompetanse på blant annet utlegg og bestykning av komponentbærere og bruk av avanserte DAK-verktøy og kretskortdesign. Ved laboratoriet jobber vi blant annet med instrumentering av vitenskapelige raketter og satellitter, og vi har lang erfaring som leverandør av produkter og tjenester til CERN.

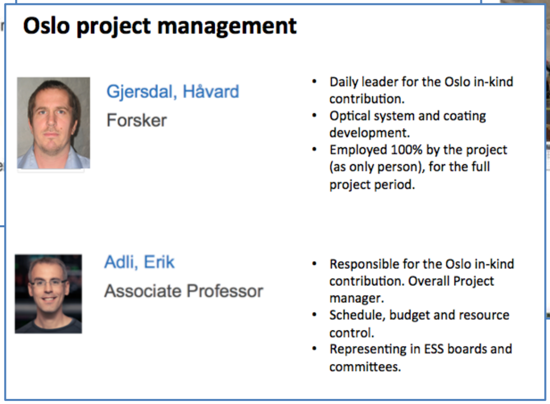
Supports us for :
- Electronics architecture
- Software development
- FPGA developments
- Coating tests hardware

Røhne, Ole Myren
Forsker
(Part of the high-energy physics section)

Co-manager for the electronics and software part of the project.

Dorholt, Ole
Senioringeniør

Bang, David Michael
Head Enginee



Oslo project management

Gjersdal, Håvard
Forsker

- Daily leader for the Oslo in-kind contribution.
- Optical system and coating development.
- Employed 100% by the project (as only person), for the full project period.

Adli, Erik
Associate Professor

- Responsible for the Oslo in-kind contribution. Overall Project manager.
- Schedule, budget and resource control.
- Representing in ESS boards and committees.

The Instrument Workshop

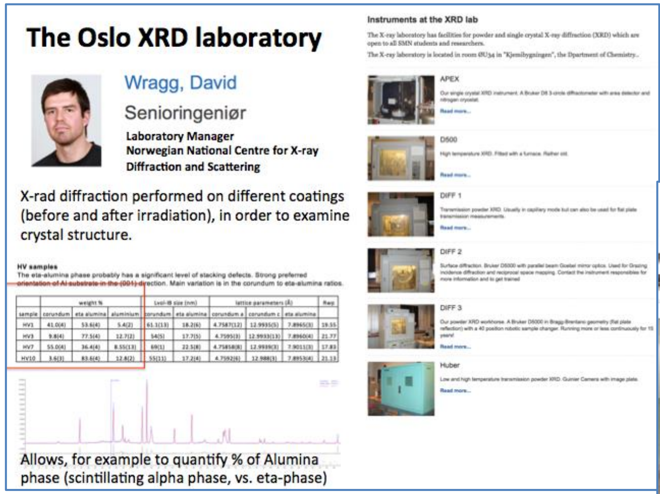
Verkstedet samarbeider med alle de vitenskapelige gruppene ved instituttet. Instrumentmakerne lager blant annet utstyr som benyttes i raketter og satellitter, og er underleverandør til flere eksperimenter ved det europeiske forskningssenteret CERN.

Supports us for :
- Tooling and machining
- Optical prototype
- Opto-mechanical components
- CAD

Borg, Hans
Avdelingsleder

Ringnes, Jonas
Avdelingsingeniør

Lithun, Maren Charlotte
Overingeniør



The Oslo XRD laboratory

Wragg, David
Senioringeniør
Laboratory Manager
Norwegian National Centre for X-ray Diffraction and Scattering

X-rad diffraction performed on different coatings (before and after irradiation), in order to examine crystal structure.

HV samples
The eta-alumina phase probably has a significant level of stacking defects. Strong preferred orientation of Al substrate in the (001) direction. Main variation is in the corundum to eta-alumina ratios.

	weight %			Lvol-IB size (nm)		lattice parameters (Å)			Rwp
sample	corundum	eta alumina	aluminium	corundum	eta alumina	corundum a	corundum c	eta alumina	
HV1	41.0(4)	53.6(4)	5.4(2)	61.1(13)	18.2(6)	4.7587(12)	12.9935(5)	7.8965(3)	19.55
HV3	9.8(4)	77.5(4)	12.7(2)	54(5)	17.7(5)	4.7595(3)	12.9933(13)	7.8960(4)	21.77
HV7	55.0(4)	36.4(4)	8.55(13)	69(1)	22.5(8)	4.75858(8)	12.9939(3)	7.9011(3)	17.83
HV10	3.6(3)	83.6(4)	12.8(2)	55(11)	17.2(4)	4.7592(6)	12.988(3)	7.8953(4)	21.13

Allows, for example to quantify % of Alumina phase (scintillating alpha phase, vs. eta-phase)

Instruments at the XRD lab

The X-ray laboratory has facilities for powder and single crystal X-ray diffraction (XRD) which are open to all SMN students and researchers.

The X-ray laboratory is located in room ØU34 in "Kjemibygningen", the Dpartment of Chemistry..

APEX
Our single crystal XRD instrument. A Bruker D8 3-circle diffractometer with area detector and nitrogen cryostat.
Read more...

D500
High temperature XRD. Fitted with a furnace. Rather old.
Read more...

DIFF 1
Transmission powder XRD. Usually in capillary mode but can also be used for flat plate transmission measurements.
Read more...

DIFF 2
Surface diffraction. Bruker D5000 with parallel beam Goebel mirror optics. Used for Grazing incidence diffraction and reciprocal space mapping. Contact the instrument responsibles for more information and to get trained

DIFF 3
Our powder XRD workhorse. A Bruker D5000 in Bragg-Brentano geometry (flat plate reflection) with a 40 position robotic sample changer. Running more or less continuously for 15 years!
Read more...

Huber
Low and high temperature transmission powder XRD. Guinier Camera with image plate.
Read more...

New accelerator development lab. infrastructure

Will be used for Optical system prototype, laser tests and, in future, other accelerator development.

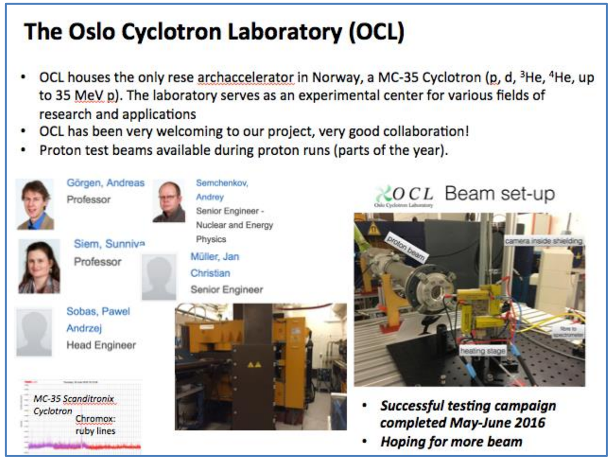
Danielsen, Kjell Martin
Senior Engineer

Purchasing.

Loose, Dag Magnus
Principal Engineer

Room manager.

- **Room and refurbishment contribution to the project from the Department of Physics**
- **Thanks to everyone who worked hard to get the new lab in good shape for the ESS visit!**



The Oslo Cyclotron Laboratory (OCL)

- OCL houses the only rese archaccelerator in Norway, a MC-35 Cyclotron (p, d, ^{3}He, ^{4}He, up to 35 MeV p). The laboratory serves as an experimental center for various fields of research and applications
- OCL has been very welcoming to our project, very good collaboration!
- Proton test beams available during proton runs (parts of the year).

Görgen, Andreas
Professor

Semchenkov, Andrey
Senior Engineer - Nuclear and Energy Physics

Siem, Sunniva
Professor

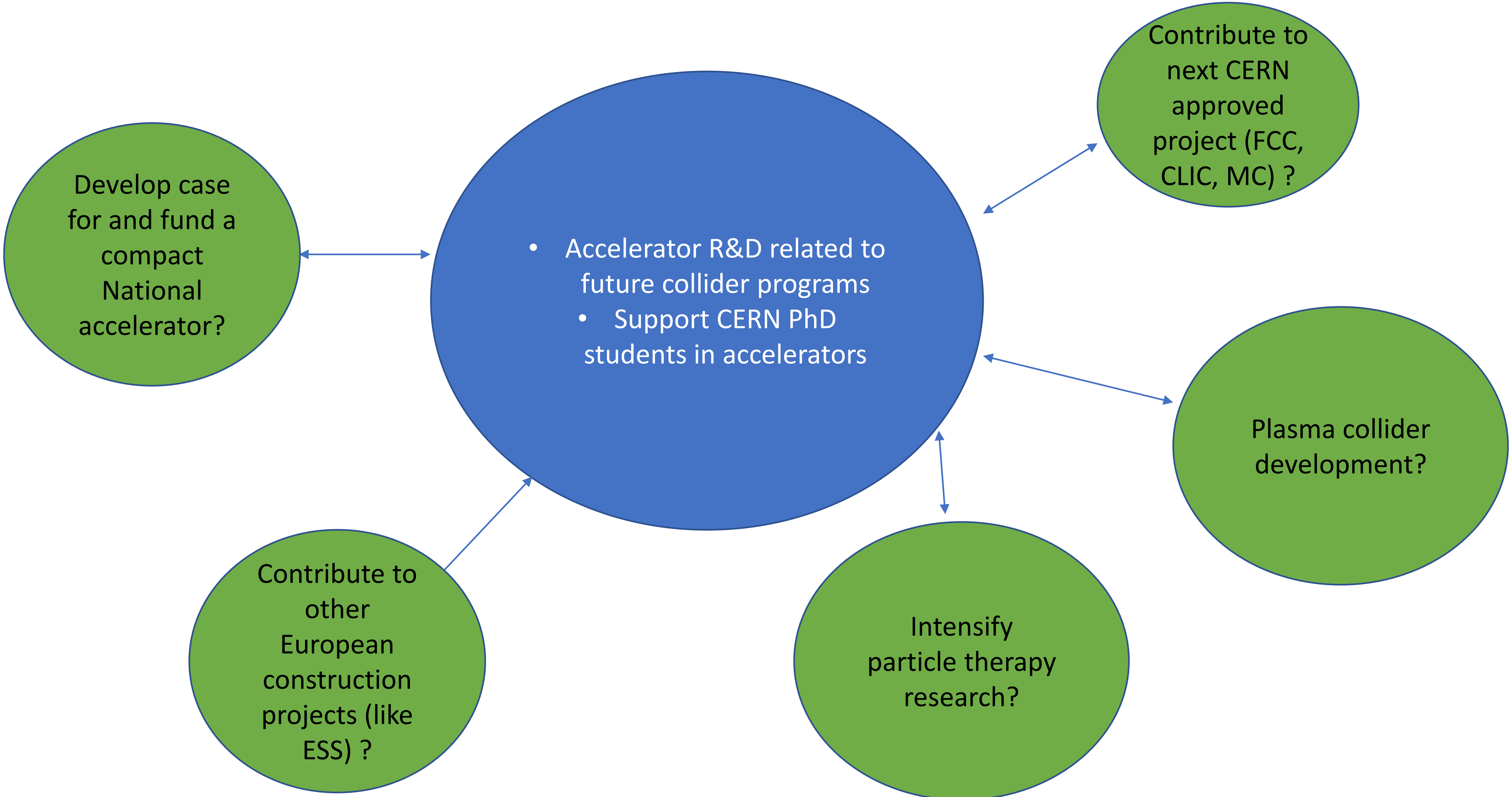
Müller, Jan Christian
Senior Engineer

Sobas, Pawel Andrzej
Head Engineer

OCL Beam set-up

- ***Successful testing campaign completed May-June 2016***
- ***Hoping for more beam***

Activities 2027- discussion tomorrow



- Accelerator R&D related to future collider programs
- Support CERN PhD students in accelerators

Develop case for and fund a compact National accelerator?

Contribute to next CERN approved project (FCC, CLIC, MC) ?

Plasma collider development?

Intensify particle therapy research?

Contribute to other European construction projects (like ESS) ?

NORC Activity 3 Budget

Payroll and direct expenses: covers < 75% of a researcher at UiO.

Other operating expenses: should cover necessary CERN experiments, computers, conferences/workshops. Currently < 100 kNOK/year, insufficient

Model only possible as long as we have signifiant other external funding.

Next NORCC period:

Due to success of attracting funding, would be resonable to increase core activity to minimum one 100% researcher + sufficient operation

- or more, depending on the strategic plans for the centre

END

Project Highlights: AM Electrodes and Frustum Electrodes

Additively Manufactured Electrodes

Additive manufacturing opens many possible doors regarding more complex cavity designs.

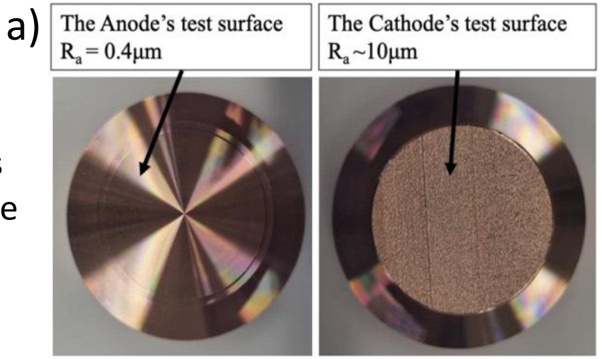
However, it is unknown how well these structures will perform under the presence of a high electric field.

Therefore, an AM cathode and anode was prepared to be tested at CERNs DC lab, see Figure 1 a).

Initial testing shows promising results regardings its ability to withstand breakdowns, reaching limits close to those experienced by mirror polished surfaces.

Test 1 is with a gap of 275μm and test 2 is with a gap of 115μm, as shown in Figure 1 b).

These results have been presented on IPAC 2023 by Andris Ratkus.



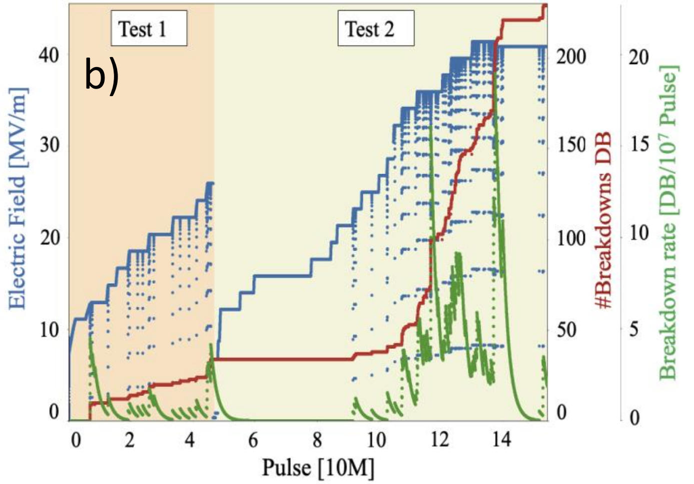


Figure 1: a) AM electrodes, where the anode's surface has been polished, but the cathode surface is as manufactured. b) Conditioning test having 275μm (test 1) and 115μm (test 2) gaps.

Frustum Electrodes

It is not well enough understood the connection between applying high electric fields and conditioning.

Therefore, an electrode having a higher electric field in the middle with linearly decreasing field torwards the edge of the electrode was designed, see Figure 2 a).

The electrode can be divided into 5 areas, as shown in Figure 2b). An average electric field on each area and the corresponding breakdowns/cm^2 can be extracted, see Figure 2b).

In area 1, the final electric field is 80MV/m. In area 2, the final electric field is 78.3MV/m. However, the breakdowns/cm^2 is much lower at the end of conditioning. This trend follows in area 3, 4 and 5.

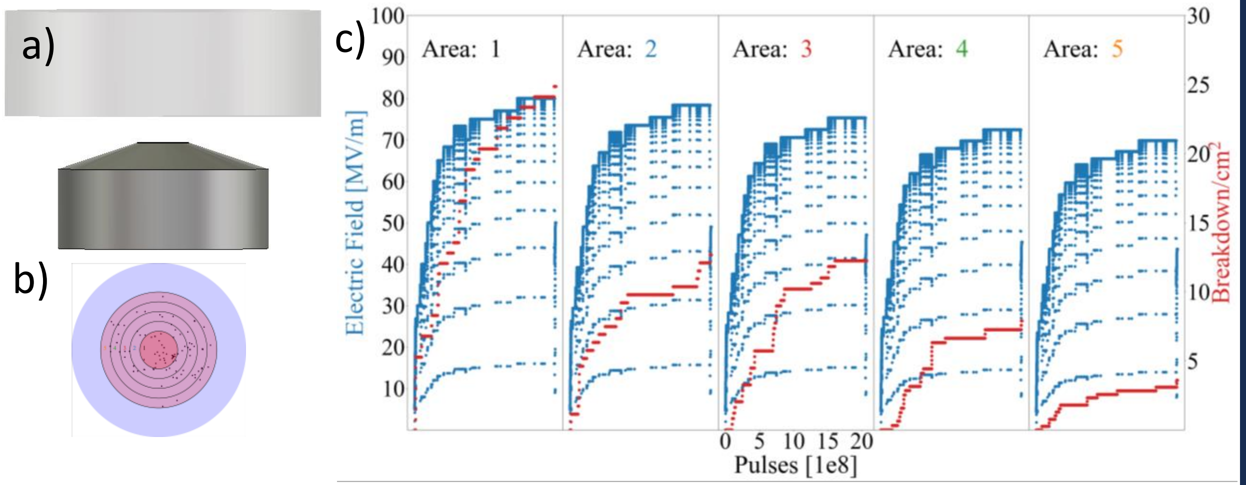


Figure 2: a) Regular cathode and frustrum cathode. b) Breakdown distribution on the electrode and how it is divided into 5 regions. c) Average electrcif field and calculated breakdowns /cm^2 in each region.