WP12 – Normal-conducting high-gradient rf

WP12 2nd annual meeting, 8 April 2015

Walter Wuensch

Introduction

The overall objective of this task is to advance high-gradient and X-band technology for CLIC and for other applications such as XFELs, Compton sources, short bunch beam manipulation etc.

Over this past year we have made **excellent** progress in a number of areas.

Details are in our 1st deliverable, *Initial Progress Report of Task 12.3* and we will hear about recent highlights in the next three presentations.

I would like now to present to you some developments from the broader normal-conducting community to help give context to the activities in this task.

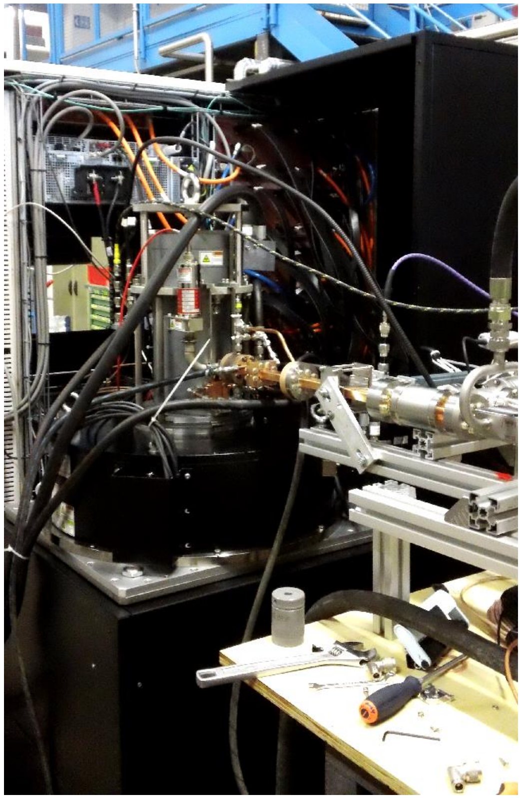
Content

- High-power testing capability news at CERN – key test bed for X-band and high-gradient technology.
- High-efficiency klystron development for CLIC, ESS, FCC, LCWS etc. – Subtask 12.3.2 is fully integrated and played an important role in it's launch.
- Proposal for the long-term exploitation of CALIFES – Possible future facility for our work.

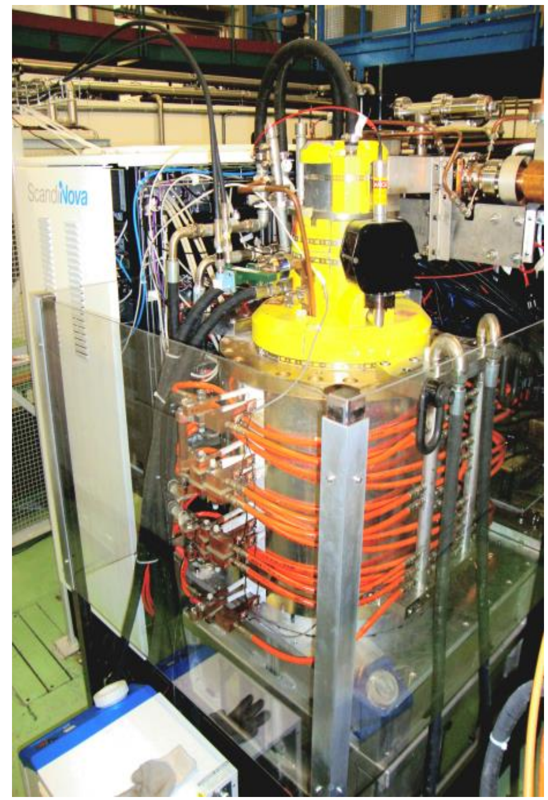
For more information please have a look at the CLIC workshop website:
http://indico.cern.ch/event/336335/

X-band klystrons

We now have two types of *commercial* X-band power sources running at CERN.

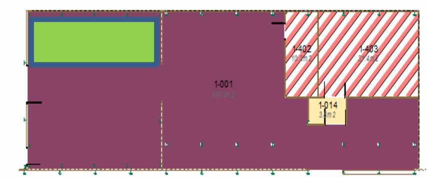


Toshiba 6 MW, 5 μs, 400 Hz
1 at CERN, 3 more by July
2 on option (no solenoids)

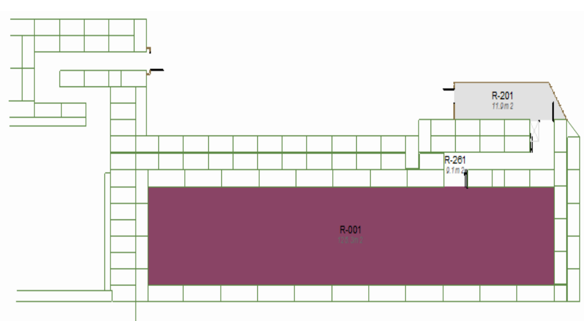


CPI 50 MW, 1.5 μs, 50 Hz
Two at CERN, third later this year
(Plus one SLAC XL-5 which needs repair)

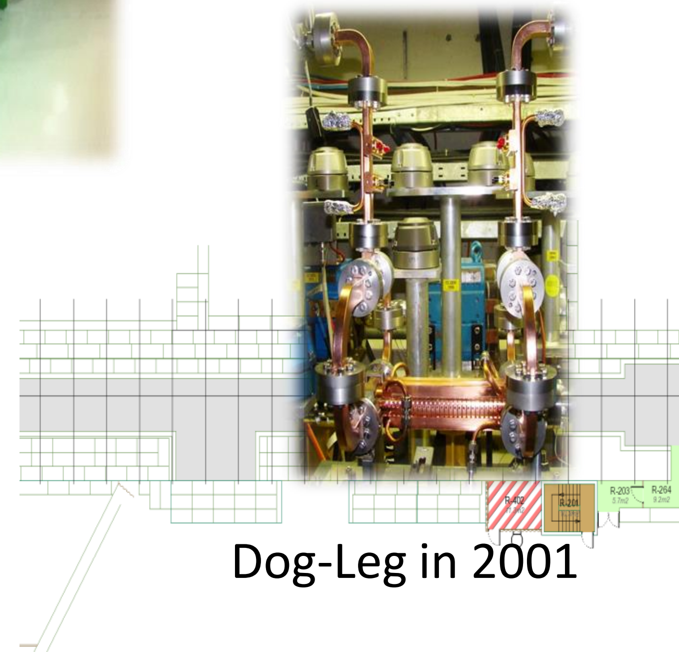
Xbox1 in b. 2013



CTF3 klystron gallery



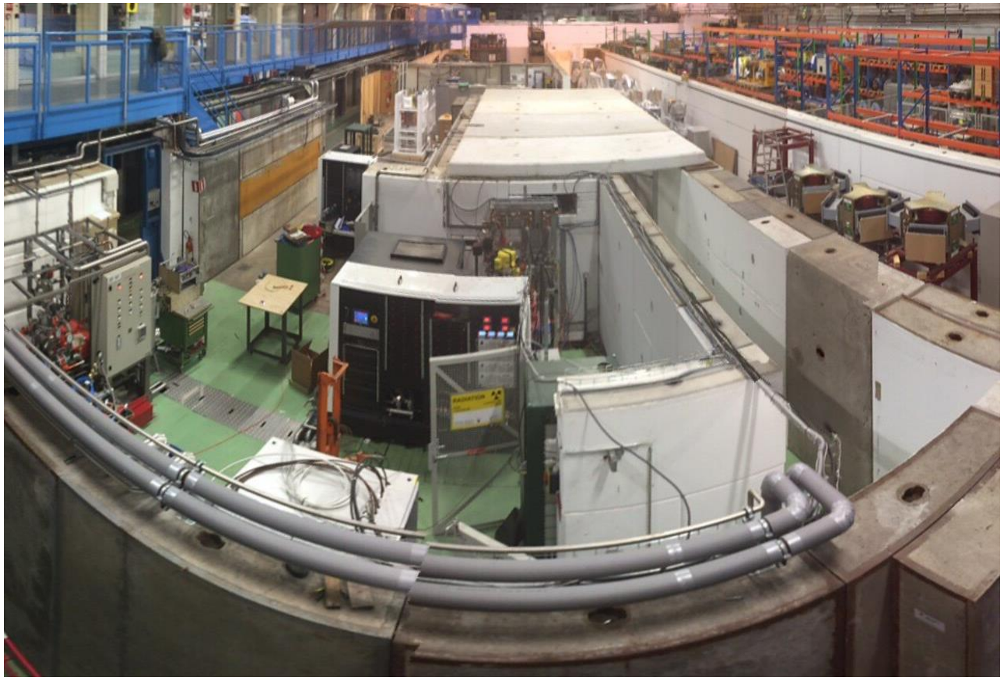
CTF2

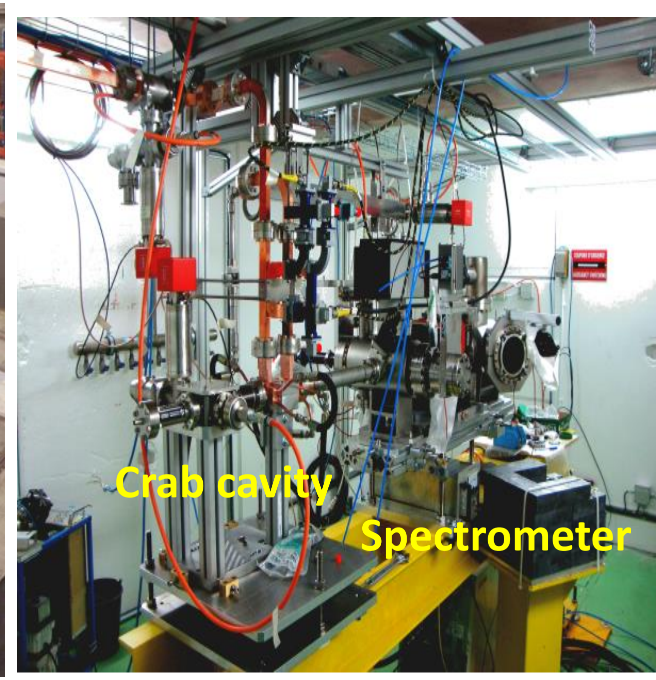


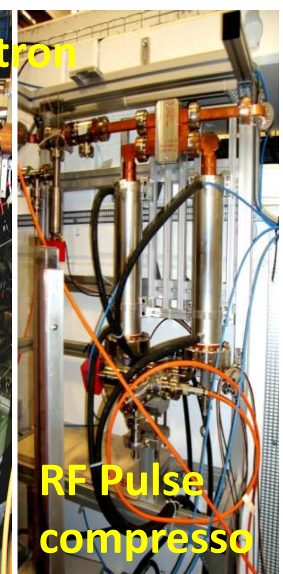
Dog-Leg in 2001

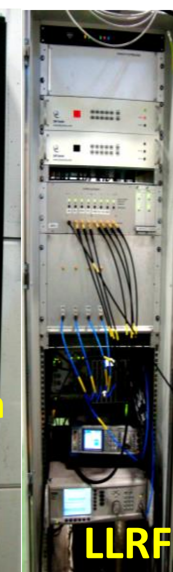
N. Catalan Lasheras

Xbox2 in b. 150

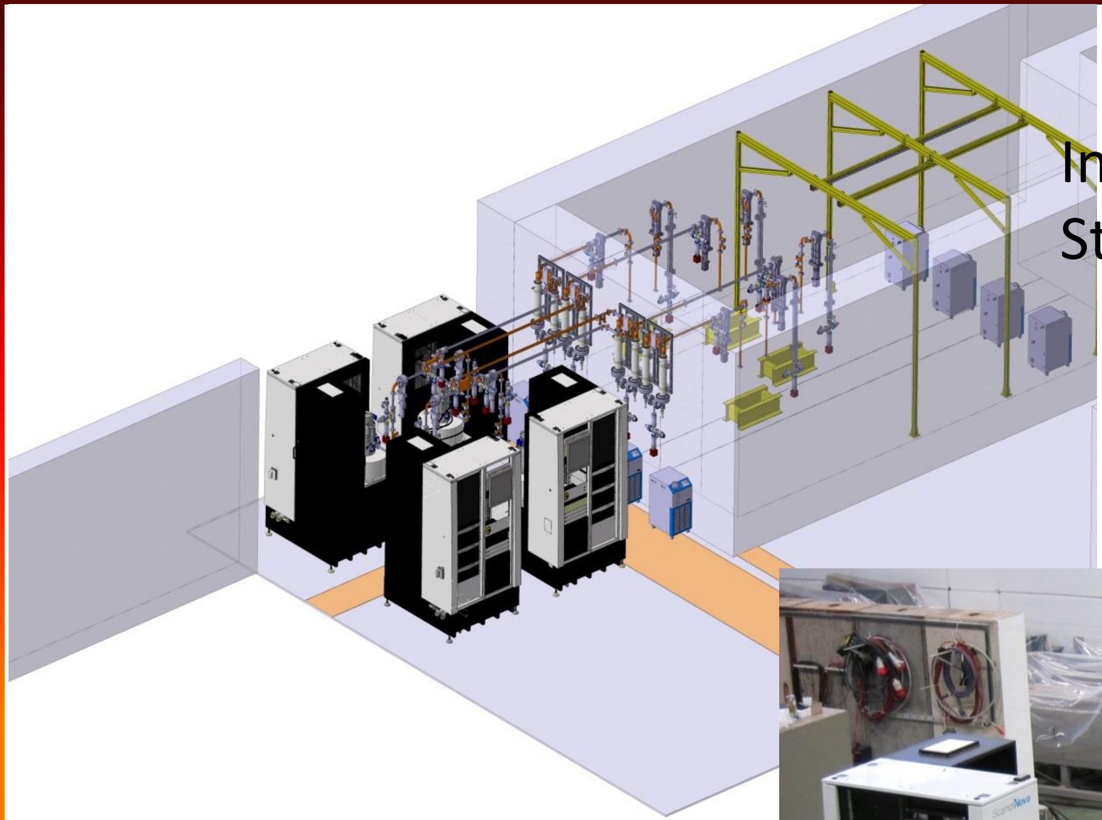




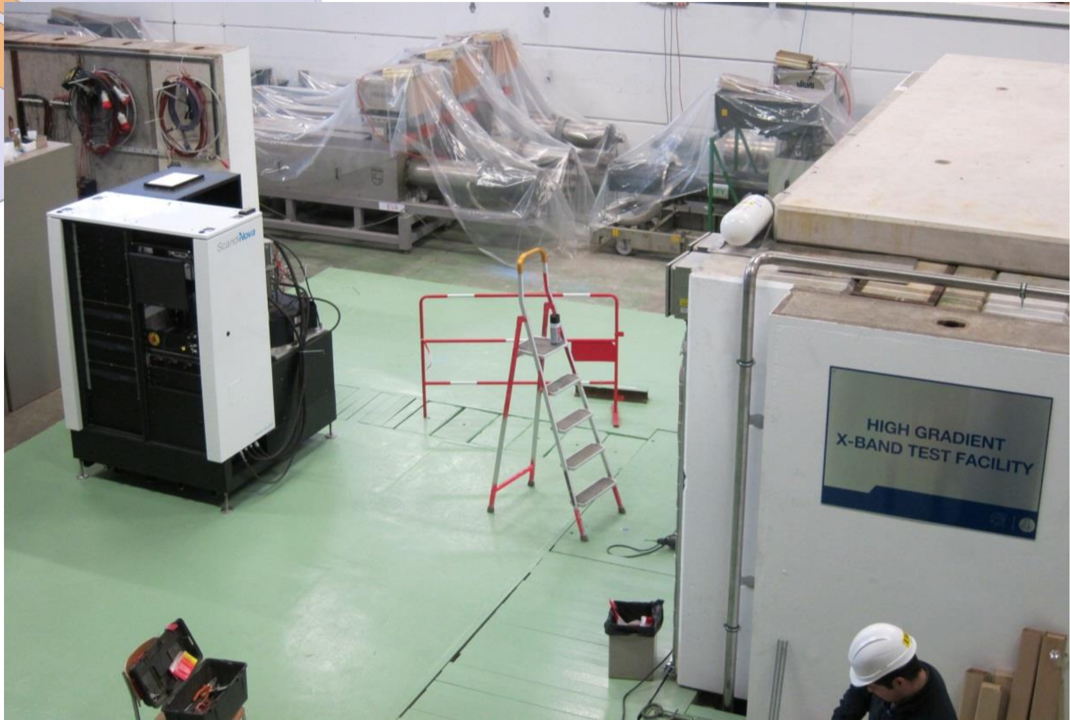




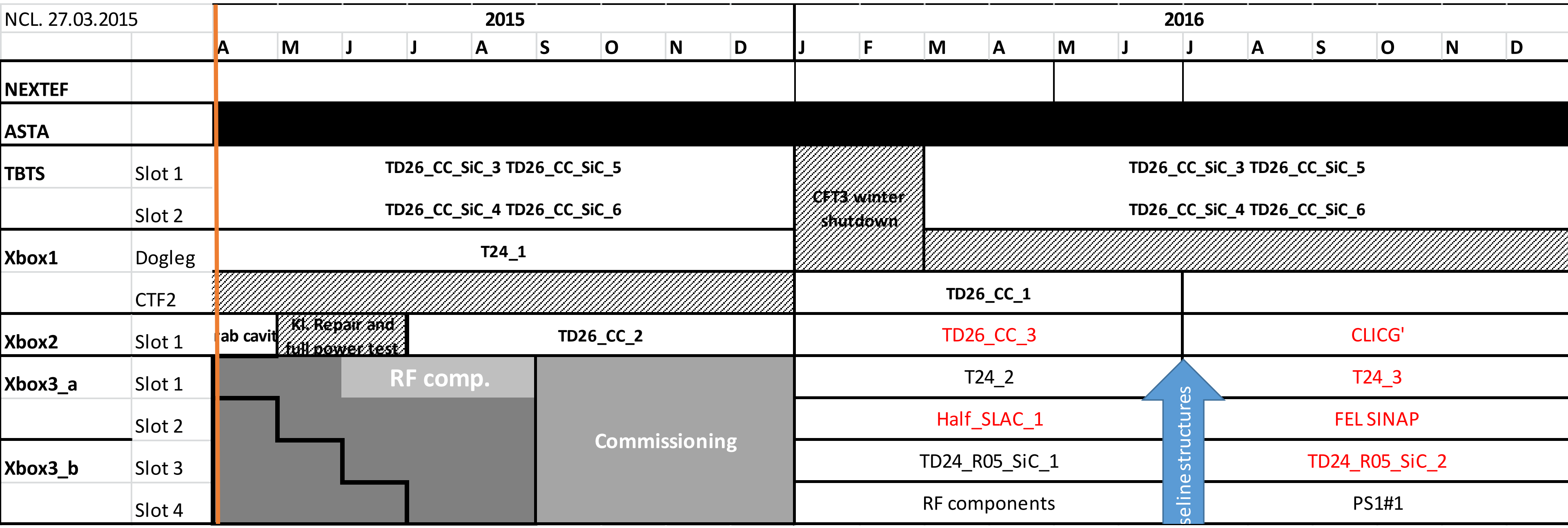
Xbox3 in b. 150



Installation progressing well.
Start-up May/June



The resulting testing program



- XBox-1 and 2 running routinely
- Delivery, installation, commissioning and testing for XBox-3 in progress.
- Steadily increasing testing capacity near end of year.

Motivation

- The increase in efficiency of RF power generation for the future large accelerators such as CLIC, ILC, ESS, FCC and others is considered a high priority issue.
- Only a few klystrons available on the market are capable of operating with 65% efficiency or above. Over decades of high power klystron development, approaching the highest peak/average RF power was more important for the scientific community and thus was targeted by the klystron developers rather than providing high efficiency.
- The deeper understanding of the klystron physics, new ideas and massive application of the modern computation resources are the key ingredients to deign the klystron with RF power production efficiency at a level of 90% and above.

The coordinated efforts of the experts in the Labs and Universities with a strong involvement of industrial partners worldwide is the most efficient way to reach the target … thus HEIKA.

HEIKA up-to-date mailing list (January 2015)

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- PLOUIN Juliette
- DALENA Barbara

Thales
- MARCHESIN Rodolphe
- VUILLEMIN Quentin

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- LINGWOOD Christopher
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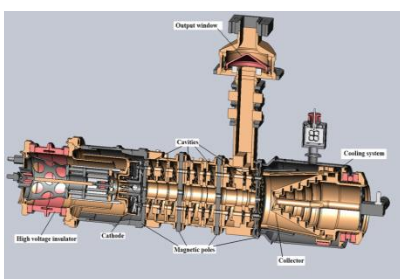
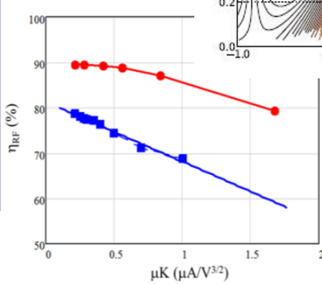
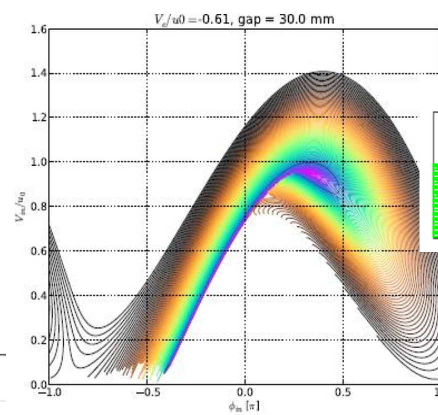
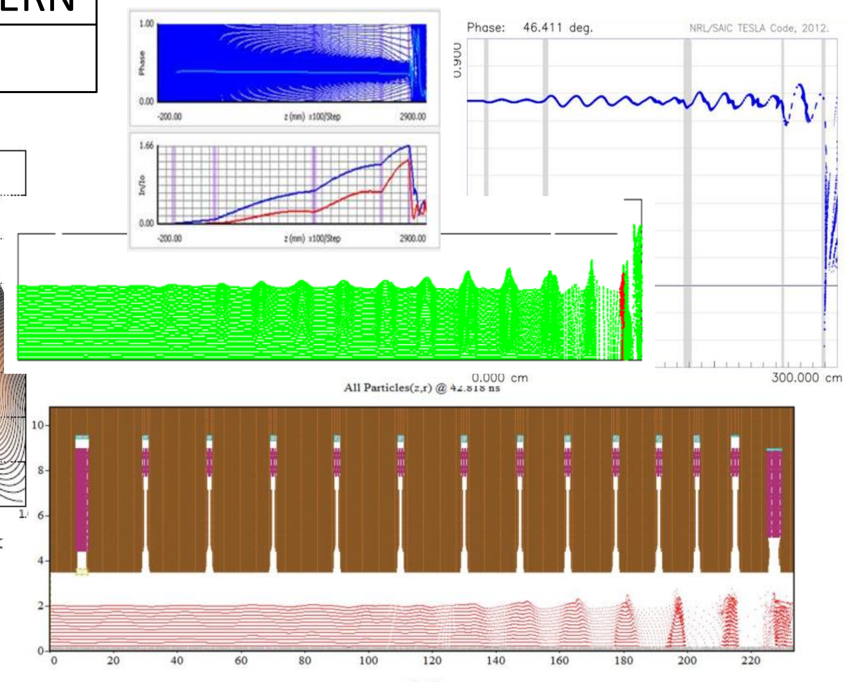
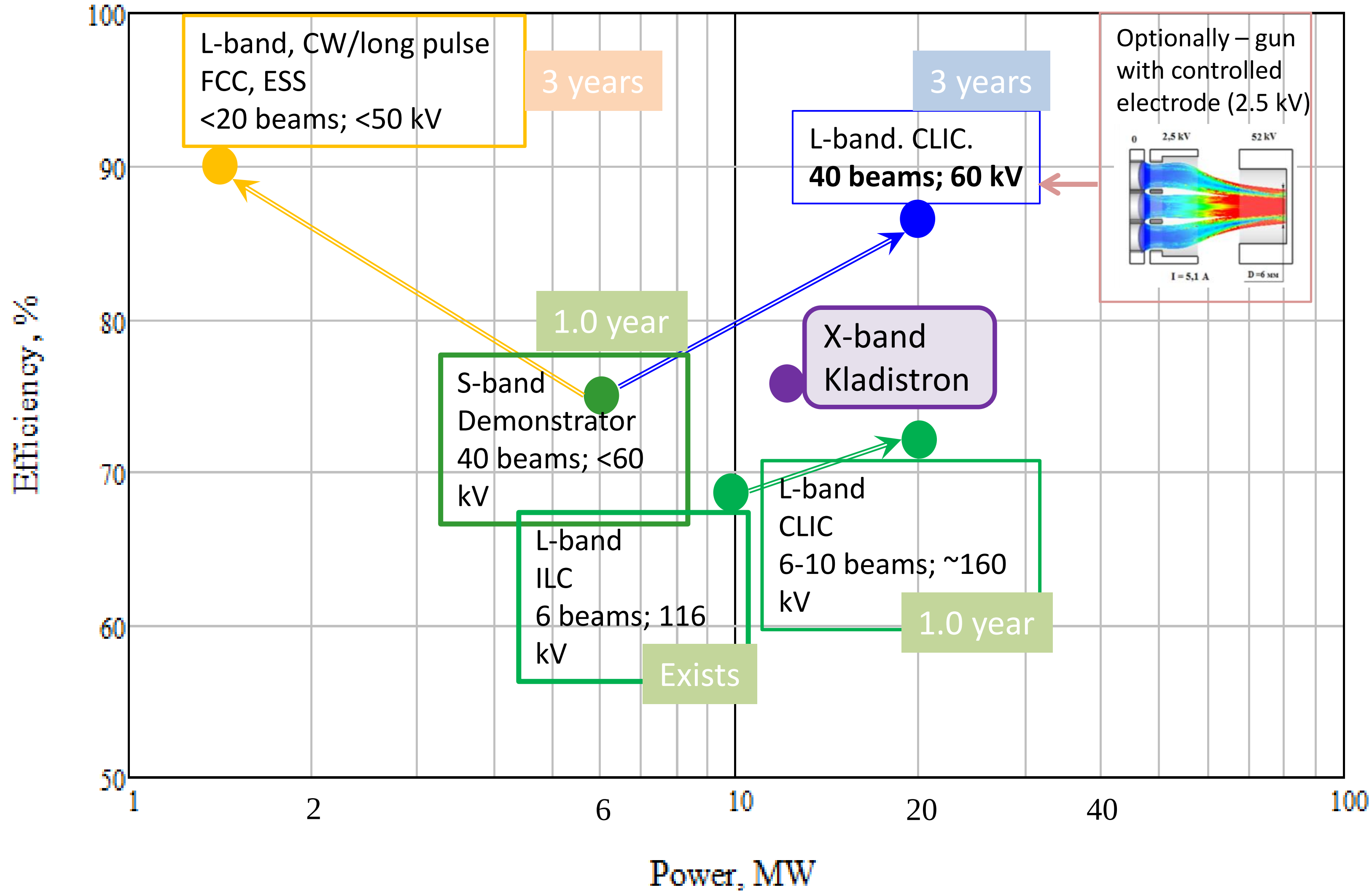




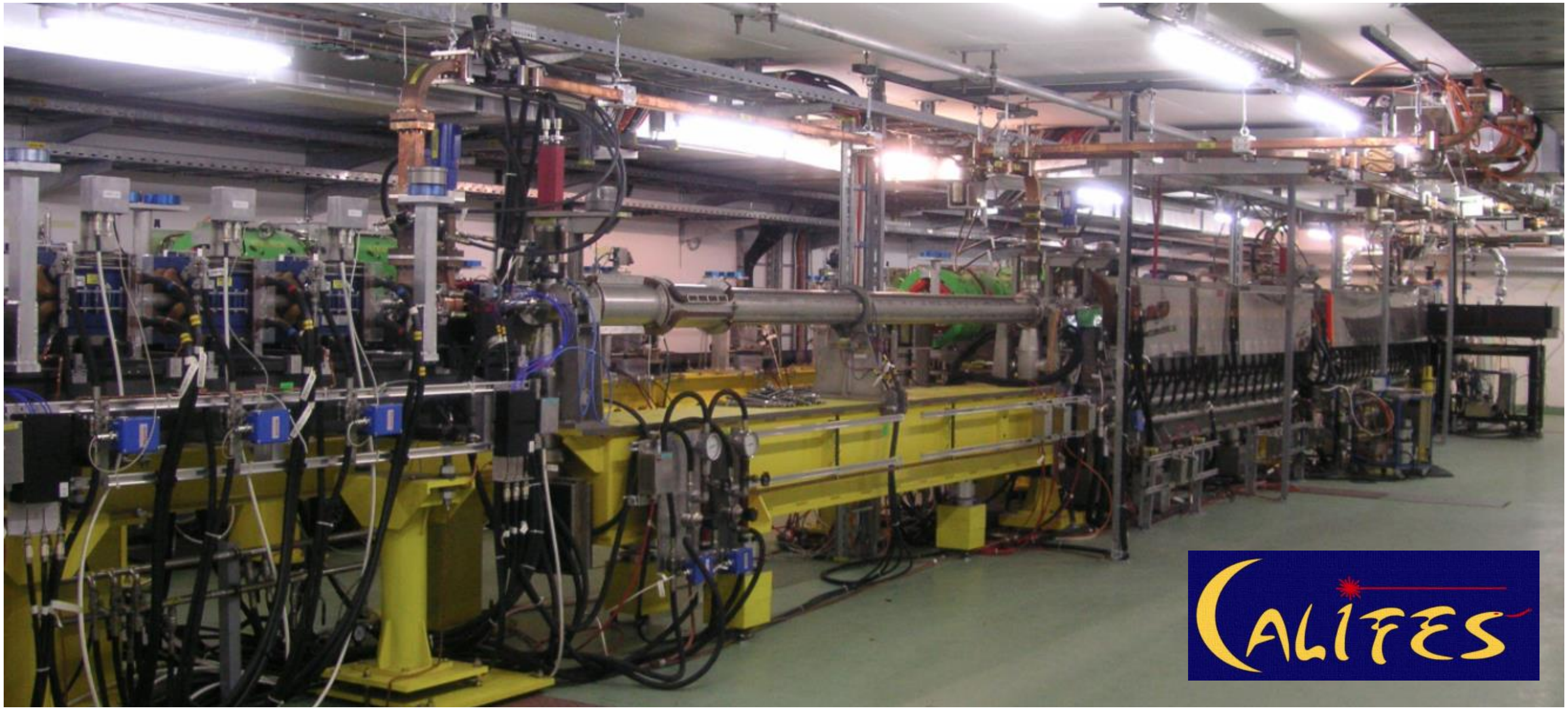


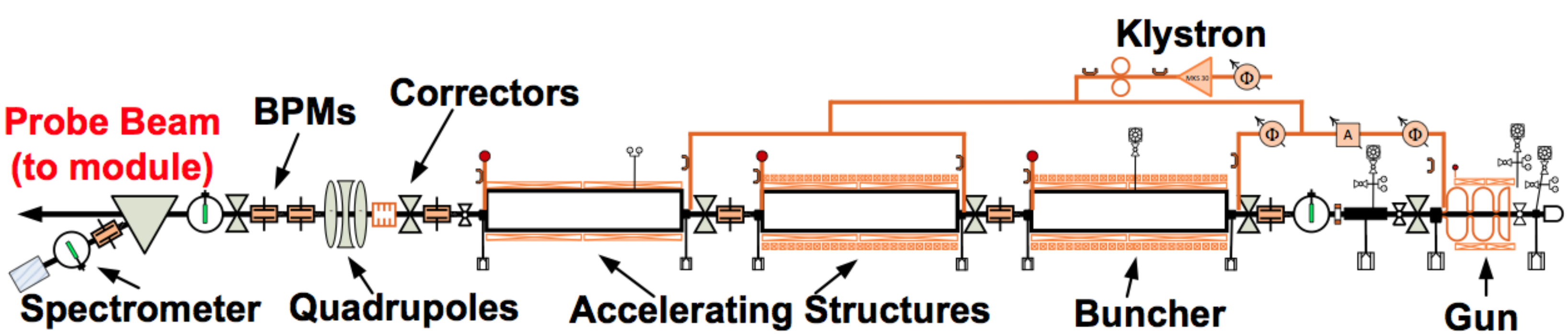


Roadmap for high-efficiency high RF power klystron development



CALIFES


CALIFES


Klystron
Probe Beam
(to module)
BPMs
Correctors
Spectrometer
Quadrupoles
Accelerating Structures
Buncher
Gun

CALIFES Beam parameters

- 0.01-1.5 nC bunches, 1.5 (3) GHz spacing (0.667 ns/0.333 ns)
- From single bunch to 200 ns train
- Rep rate 1-10 Hz
- Energy 150 - 200 MeV
- Normalized emittance 4 μm
- Energy spread ± 0.5 %
- Bunch length 1-2 ps and above
- May provide lower energy (>10 MeV), need to study transport
- Typical beam sizes 0.25 × 0.25 mm, uniform beam sizes obtained up to now 5 mm × 5 mm (up to few cm surely feasible).

"Ultimate" test area layout to cover BI needs

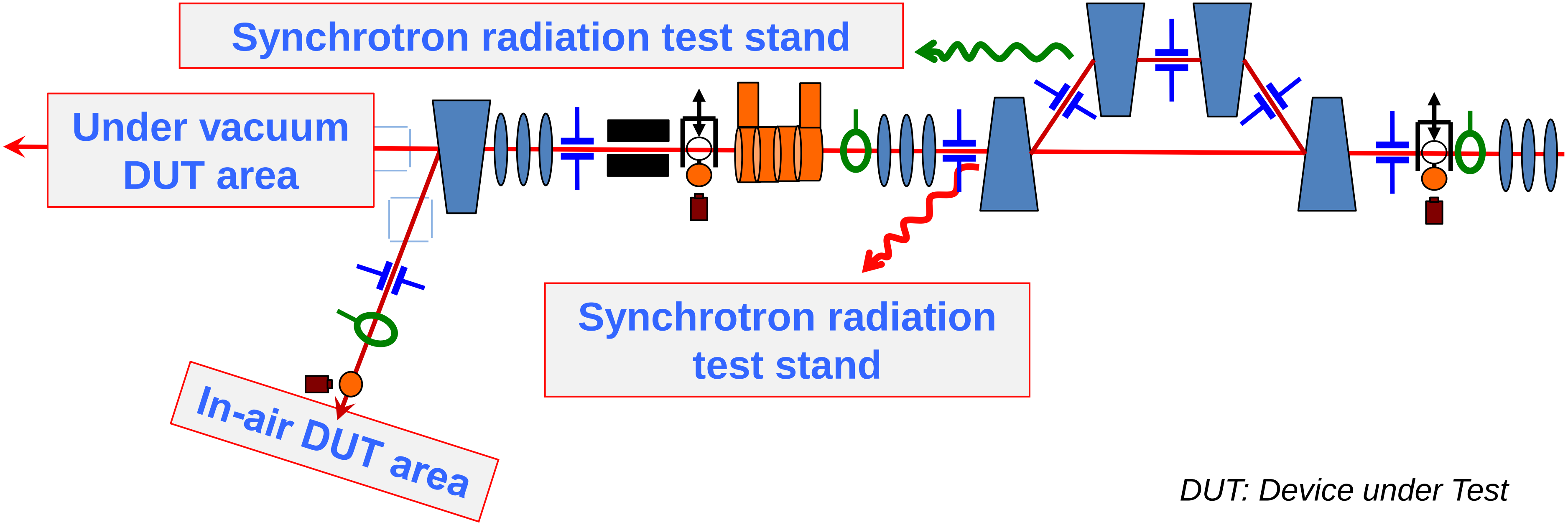
T. Lefevre

Collimator

- Reduce the bunch intensity before the DUT zones
- Reduce bunch length further in combination with RF deflector

RF deflector
for crabbing
Time to position correlation

Magnetic chicane
Shorten or lenghthen
100fs up to 200ps



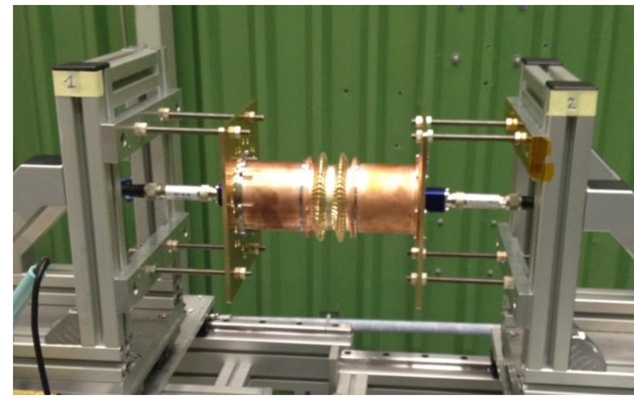
DUT: Device under Test

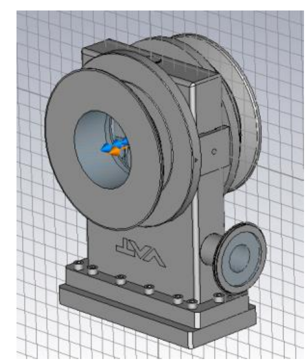
Impedance measurements - Context

B. Salvant - CERN

- Impedance team involved in design and approval of new and modified equipment in all CERN circular machines (in particular PSB, PS, SPS and LHC, but also AD, ELENA and CLIC damping rings).

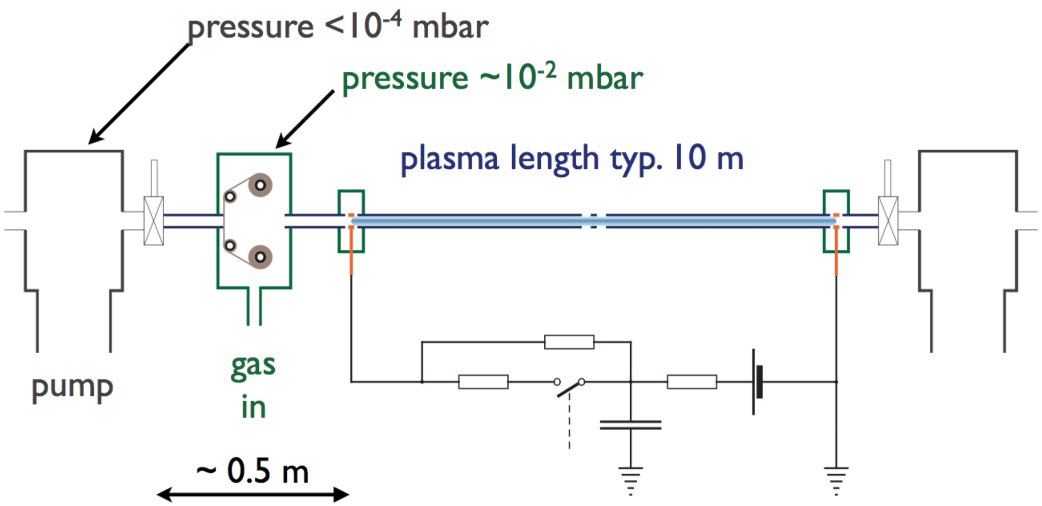
- Tools at our disposal:
  - Bench measurements with wires and probes
    → problem: not direct measurement of impedance or wake, and possibly strong perturbation of the EM fields
  - Numerical simulations
    → problem: difficulty to reproduce reality with a model (e.g. design errors, small features, coatings, matching errors) , simulated exciting bunch is not a delta function.





→ Measurement with electron bunches could be an interesting complement to these existing tools

CALIFES: cheap and simple PWFA



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[1]John Adams Institute for Accelerator Science, Imperial College , London, UK
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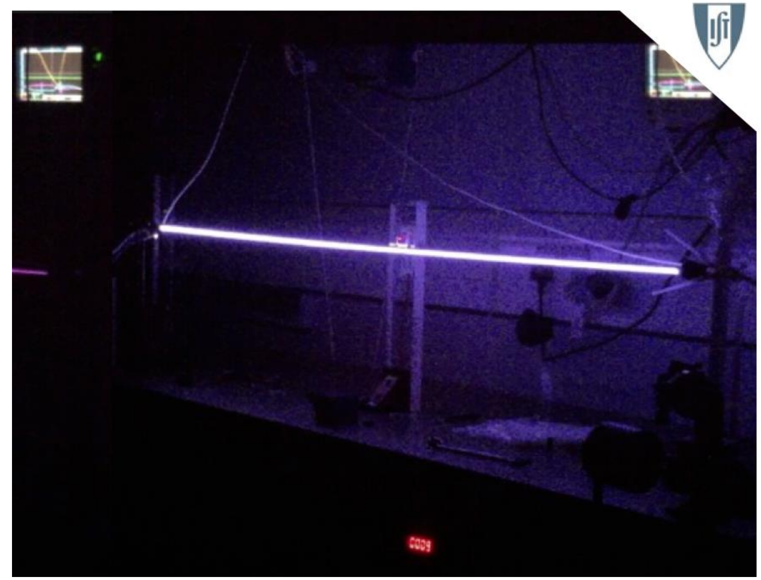


As the CALIFES beam line is already well equipped with beam diagnostics, both before and after the TBM, first PWFA experiments can be performed by the addition of a plasma source at/close to the location of the TBM.

We foresee a **gas discharge plasma source**. This has a relatively simple design, easy to fit into CTF3, and does not require a costly laser system for ionization.

Potential tests for an X-band FEL using the Califes beam

From presentation A. Latina from CLIC workshop.

#	Applications	Tests
1	X-band linearizer	· Check the first CLIAPSI structure CERN-PSI-Elettra (with the 400 μm misalignment)
2	Wake Field monitors	· Activation and calibration · Acquisition systems
3	High frequency bunch spreader/separator	· Bunch separation with RF cavities · Possibility to work out with bunch distances from ns up to μsec · Beam quality degradation (emittance, energy spread)
4	X-band deflectors	· Beam tests · Time resolution (< 10 fs)
5	High frequency Photoinjector	· Beam tests and characterization (i.e. C-band)
6	Bunch compression	· Beam compression studies · Emittance preservation · Longitudinal diagnostics and instrumentation
7	Timing and synchronization	· RF synchronization measurements
8	Low energy test stand for X-band FELs (adding an X-band module downstream the bunch compressor)	· Beam acceleration studies
9	Advanced beam dynamics tests	· Purely-magnetic compression schemes, CSR-free DBA, beam-based measurements

New hardware required (rows 3, 5, 6, 8, 9) — Hardware already available (rows 1, 2, 4, 7)

Upcoming events

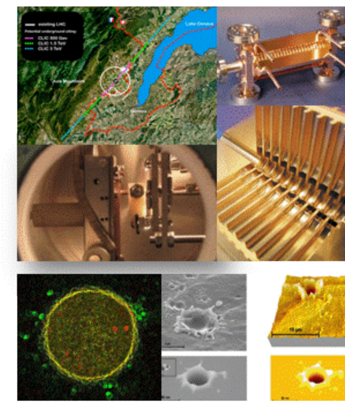
The workshop aims to combine the efforts of researchers in different fields to understand the mechanisms underlying the highly intriguing phenomenon of electrical breakdown. The workshop will cover rf and dc types of electrical breakdowns, including theory, experiment, and simulation. The workshop will be preceded by a half-day mini-school on modeling surface (electrode) evolution processes relevant to electrical breakdown phenomena.

Topics

Experiments: vacuum arcs, dc spark systems, rf accelerating structures, materials, diagnostics, techniques and technologies for high gradients, and arcing in fusion devices.

Theory and simulations: surface modification under electric and electromagnetic fields, PIC and PIC-DSMC plasma simulations, dislocation activity, plasma-wall interactions, and surface damage and evolution.

Applications: particle accelerators, discharge-based devices, electrostatic failure mitigation, fusion devices, satellites and other industrial interests.



Venue

The workshop will be held in Saariselkä, Lapland. Lappish ruska is the time of beautiful autumn colors.

Organizers

Flyura Djurabekova
HIP, University of Helsinki, Finland

Walter Wuensch, Sergio Calatroni
CERN, Switzerland

Matthew Hopkins
Sandia National Laboratories, USA

Yinon Ashkenazy
Hebrew University of Jerusalem, Israel

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