UPPSALA UNIVERSITET

FREIA

FREIA Laboratory

Facility for Research Instrumentation and Accelerator Development
Department of Physics and Astronomy

Overview of

Infrastructure and Resources

Roger Ruber

for the FREIA Team

Uppsala, 10 November 2020

SAC meeting on Ångström FEL

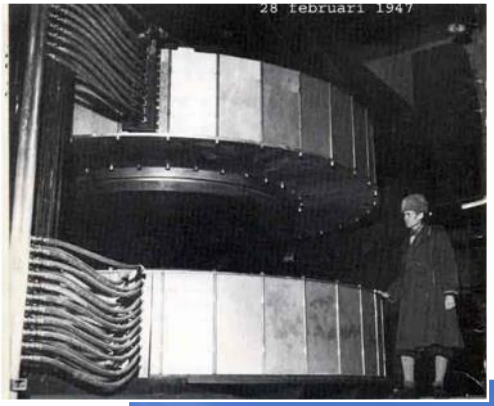
Uppsala Accelerator History

1477: Uppsala University, oldest in Scandinavia

- 25'000 students, 7'000 staff
- historical profiles: Linné, Rudbeck, Celsius, Ångström, Svedberg

1940's: The(odore) Svedberg builds a cyclotron

- Gustaf Werner synchro-cyclotron (1947 - 2016)
  - nuclear physics & oncology
- CELSIUS ring (1984 - 2005)
  - nuclear & particle physics



2000's: External projects

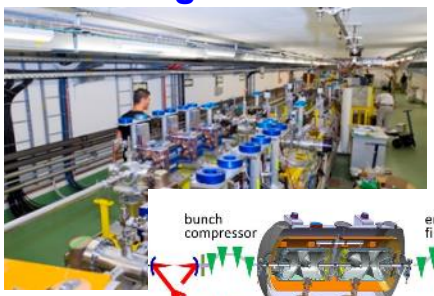
- CTF3/CLIC (since 2005)
- FLASH/XFEL (since 2006)
- ESS (since 2009)

2010's: New ventures

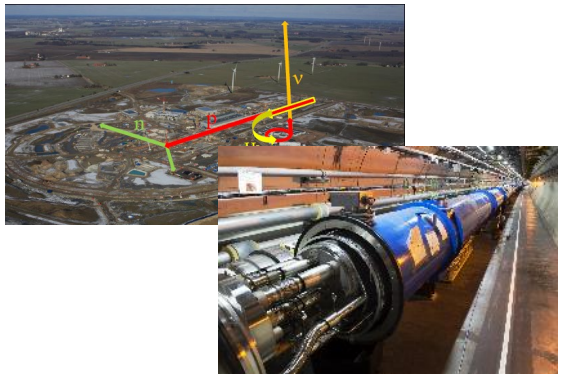
- FREIA laboratory (est. 2011)
- Skandion clinic (est. 2015)

Accelerator Research & Development

Ultra Bright Electron Beams



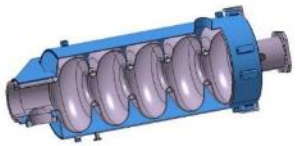
High Intensity Proton Beams



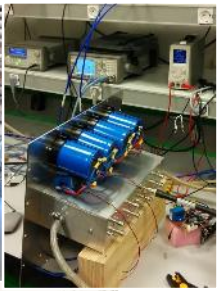
Accelerator Physics

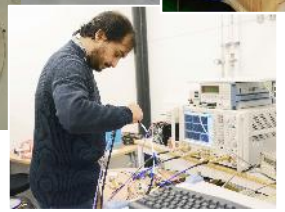
Cryogenics & Test Stands

SC Cavities & Magnets



RF Generation & Control





Accelerator Technology

FREIA Laboratory

Facility for Research Instrumentation and Accelerator Development

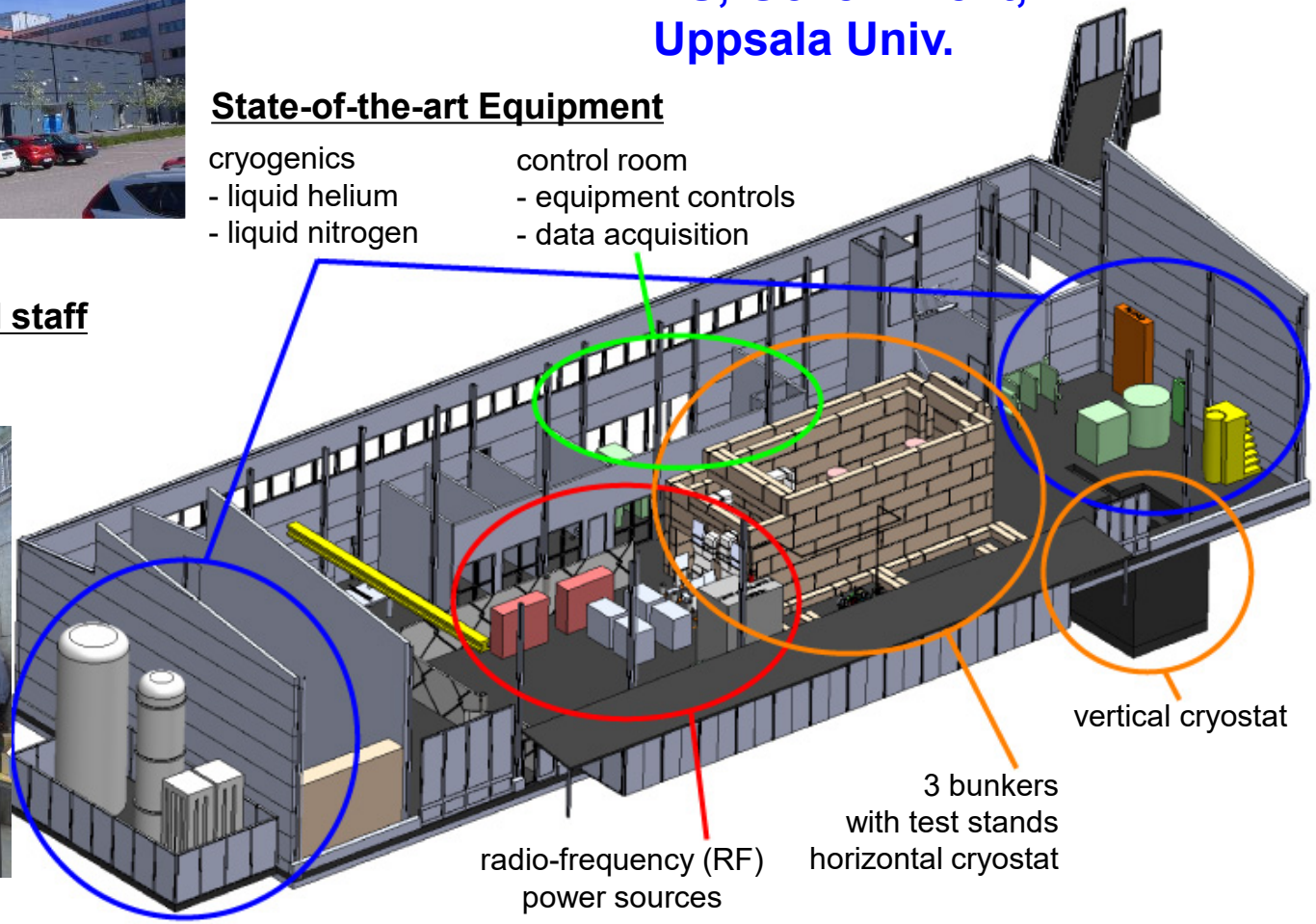
Funded by
KAWS, Government,
Uppsala Univ.

State-of-the-art Equipment

cryogenics
- liquid helium
- liquid nitrogen

control room
- equipment controls
- data acquisition

Competent and motivated staff
collaboration of physics (IFA)
and engineering (Teknikum).



Cryogenics

- **Helium liquefaction**
  - 150 l/h at 4.5K (LN2 pre-cooling)
  - 2000 l LHe dewar/buffer, 3+1 outlets
  - cryostats connected in closed loop
- **Gas recovery**
  - 100 m^3 gasbag
  - 3x 25 m^3/h compressor
  - 10 m^3 200 bar storage
- **2K Pumping**
  - ~3.2 g/s at 10 mbar
  - ~4.3 g/s at 15 mbar
  - 110(90)W at 2.0(1.8)K
- **Liquid nitrogen**
  - 20 m^3 LN2 tank

“Hnoss” Horizontal Cryostat

Nordic mythology: Hnoss is one of Freia’s daughters

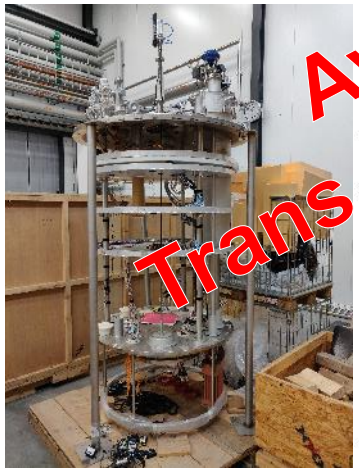
- Test of superconducting cavities/devices
  - 3240 x ø1200mm inner volume
  - up to two cavities simultaneously,
  - each equipped with helium tank,
- Low or High power RF testing
  - fundamental power coupler (top, bottom, side)
  - (cold) tuning system
- Operation in the range 1.8 to 4.5K

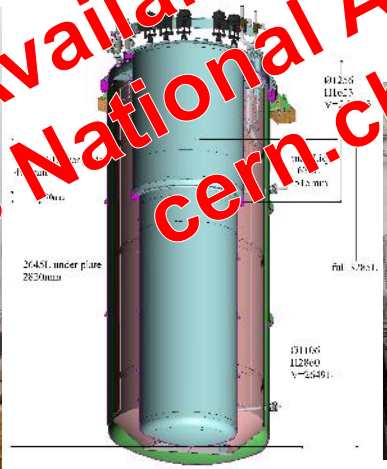
Available as ARIES Trans National Access Facility cern.ch/aries

“Gersemi” Vertical Cryostat

Nordic mythology: Gersemi is one of Freia’s daughters

- Test of SC cavities & magnets (<350kJ)
  - 3.2m x ø1.1m total volume
  - 2.65m x ø1.1m below lambda plate
    - design includes joint for lambda plate
- Three operation modes
  - vacuum; liquid bath; pressurized (bath with 2K heat exchanger)
- Operation in the range 1.8 to 4.5K





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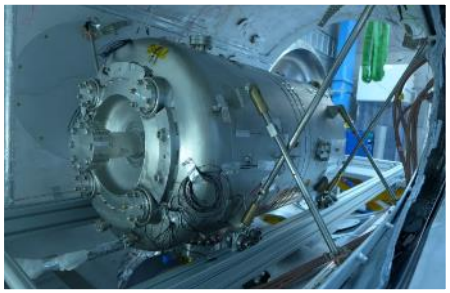
SRF Cavities Testing

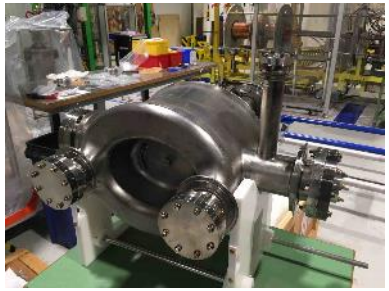
ESS Double-spoke, 352 MHz

- Prototype cavity
  - test **without** and **with** power coupler
  - RF conditioning
  - Q_0, gradient, fill time,
  - Lorentz force detuning, microphonics
  - test LLRF, SEL,
  - tuner operation
  - nominal gradient

H. Li et al, NIM A927 (2019) 63



- **HL-LHC Crab, 400 MHz**
  - prototype cavity, w/o He jacket
  - double quarter wave (DQW)
  - first cavity test in vertical cryostat
    - successfully completed 8-Oct!



ESS Elliptical, 704 MHz

- RF stations
  - acceptance test of HV modulator for ESS local test stand
  - test RF distribution (circulator, load)
- Prototype high beta elliptical
  - with power coupler and tuner
  - RF conditioning
  - Q_0, gradient, fill time, heat load
  - Lorentz force detuning, microphonics
  - test LLRF, SEL, tuner operation

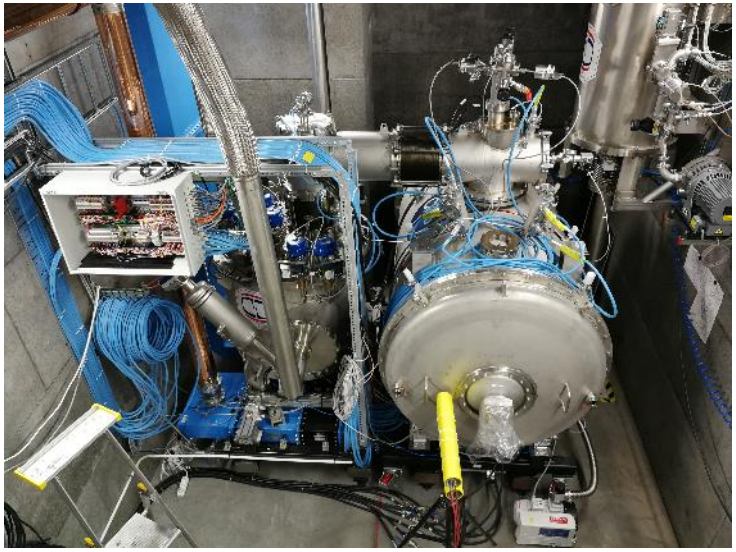
H. Li et al, LINAC 2018, THOP066

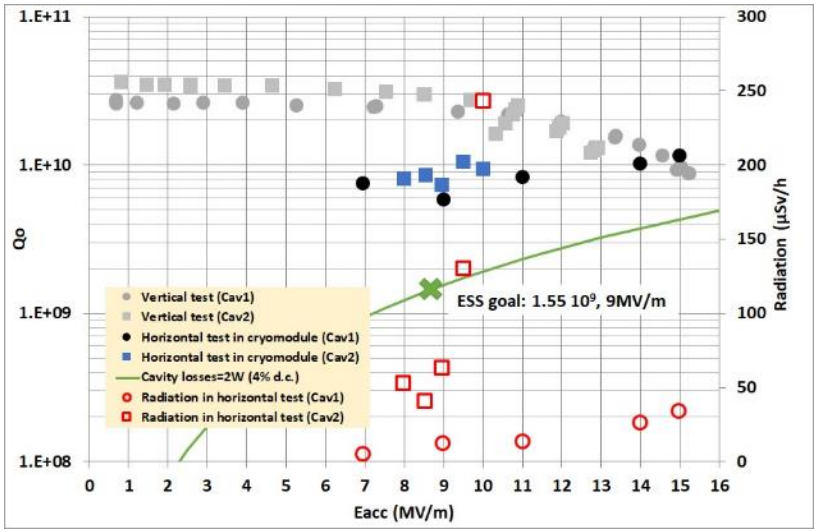
SC Magnet Testing

- Preparing to commission Gersemi with a superconducting magnet
- Operation with “magnet insert”
  - lambda plate to separate 2K pressurized helium from 4K helium
  - heat exchanger with sub-atmospheric 2K helium to cool the pressurized 2K helium

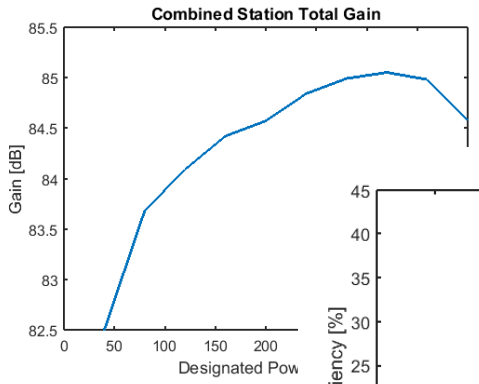
- **ESS Prototype cryomodule (2019)**
  - RF conditioning
    - ~3 days/cavity at warm
    - MP bands were consistent with HNOSS test
      - strength depends on pulse length,
      - 1st/2nd conditioning…
    - no activity at cold
  - Cavity performance
    - multipacting regions similar as test in Hnoss:
      - 2-3; 4-5; 7-8 MV/m
    - Q0 higher than ESS goal
    - frequency sensitivity 28 Hz/mbar
- **ESS Series cryomodules (2020-2022)**
  - 13 cryomodules, 1st arrived 19-Oct
  - 6-8 weeks turn-over time

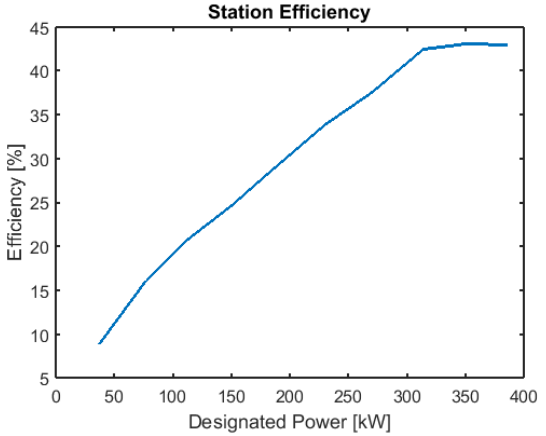
H. Li et al,
FREIA Report 2019/08
urn:nbn:se:uu:diva-409815

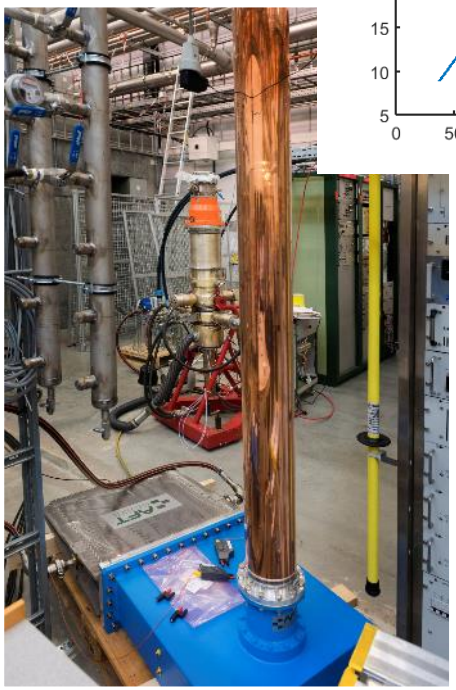




High Power RF Amplifiers





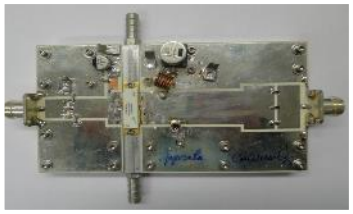


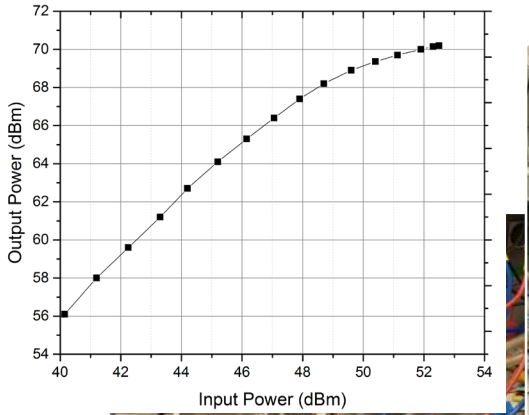
- **400 kW pulsed (352 MHz)**
  - 2 stations, each 2 tetrodes TH595(A)
  - 3.5 ms, 14-28 Hz
  - developed for ESS project

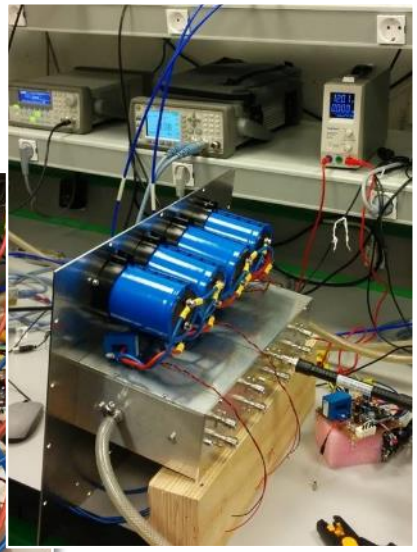
RF Amplifier R&D

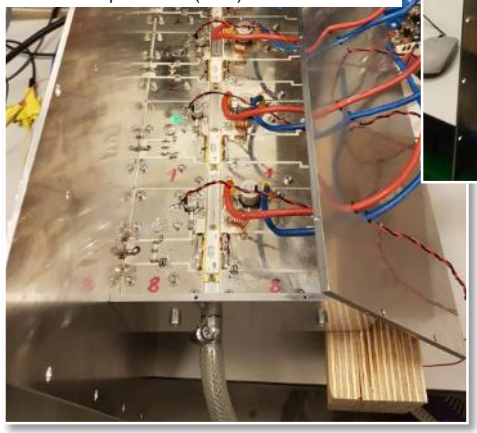
Transistor Amplifiers 352 MHz

- 8 modules, 10.5 kW
- 69% efficiency
  - pulsed 14 Hz, 3.5 ms





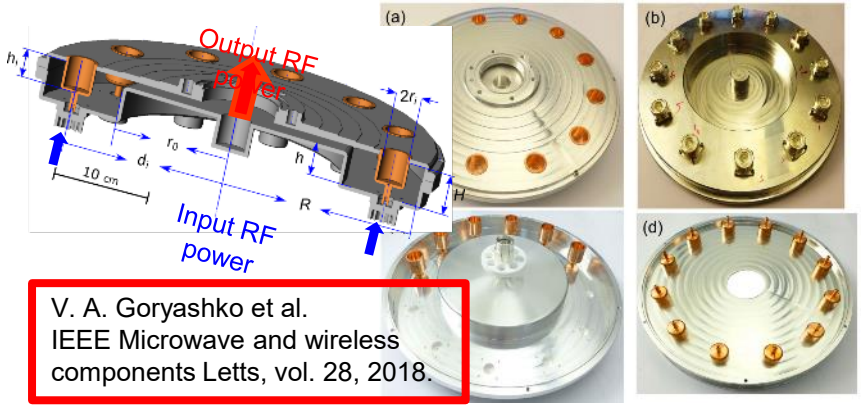




L. Hoang Duc et al. Rev. Sci. Instr. Vol. 90, 2019 (104707).

Compact Combiners 352 MHz

- Cavity combiner
  - 200 kW, 12 input ports
  - 0.2% insertion loss



V. A. Goryashko et al. IEEE Microwave and wireless components Letts, vol. 28, 2018.

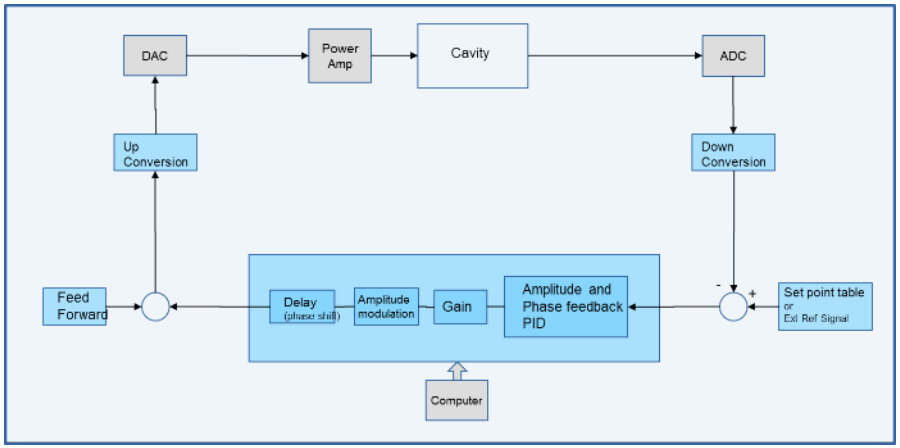
- Planar Gysel combiner
  - 10 kW, 8 inputs
  - line coupling compensates parasitic coupling

M. Jobs et al. IEEE Trans. Components, Packaging Manufacturing Tech., vol. 8, 2018.

Digital LLRF Development

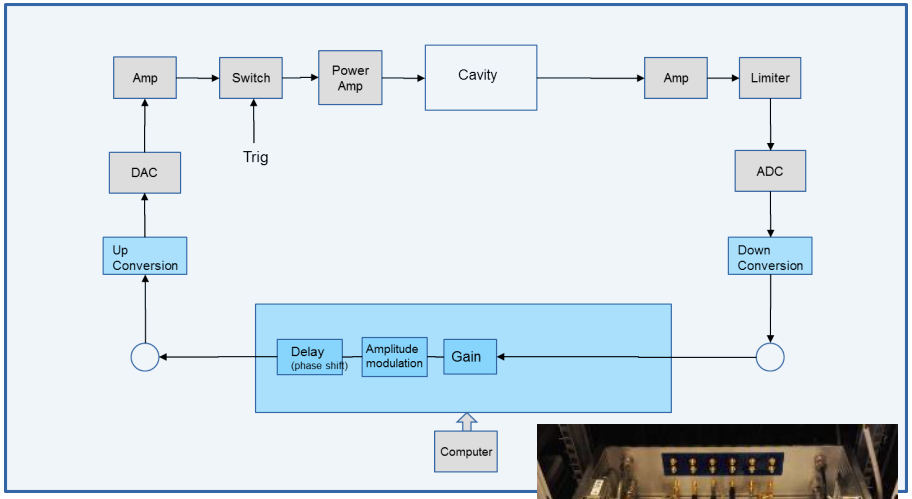
Signal Driven

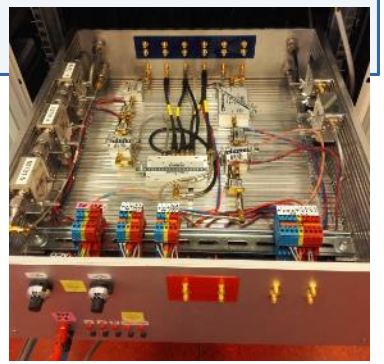
- 2 ADC inputs at 250 Msps
  - (*) analogue bandwidth of 750 MHz
- 2 DAC outputs at 500 Msps
- Digital downconversion to baseband 0 Hz, no analog mixers
  - downconverted signal at 10 Msps or 1 Msps, selectable
- undersampling to operate at any frequency from 10 to 750 MHz*



Self-excited Loop

- CW or
- pulsed mode
  - switch closes the loop for a duration of 2.86 ms, repetition rate of 14 Hz.



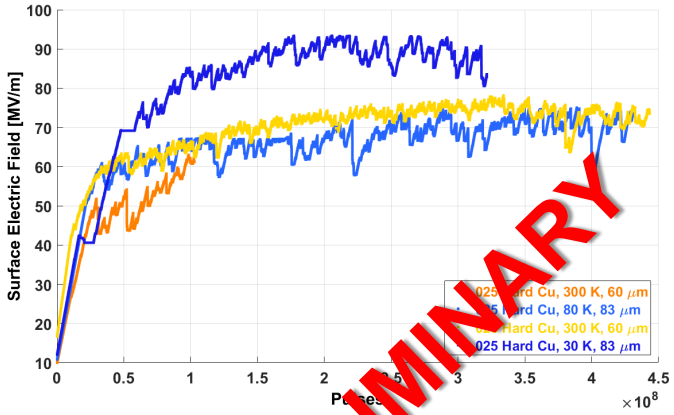


Code in the FPGA

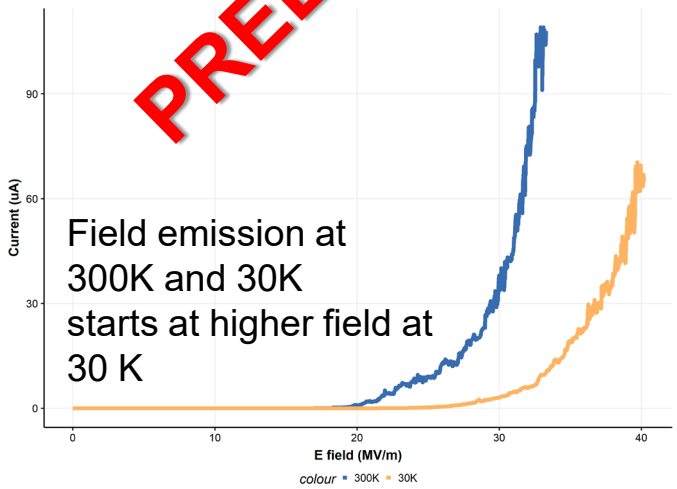
Cryogenic DC Spark System

- Field emission and BDR as a function of temperature
- Complement to RF tests
  - very high repetition rate, pulsed DC
  - simple geometry (large planar electrodes)
  - similar high-field behavior in RF and pulsed DC
  - allows in depth studies of the fundamental physics of high-fields (e.g. material and surface science)
  - possibility to find new and potentially important connections between the high-gradient NC and SC fields.

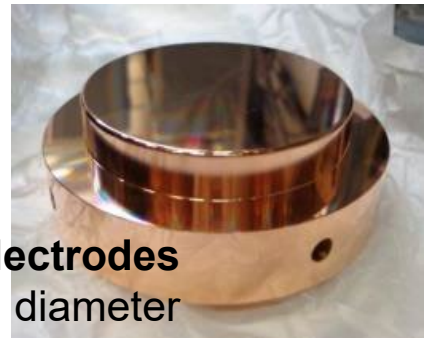
Electrodes at 30K reached almost 20% higher field gradient than at 300 K.



PRELIMINARY



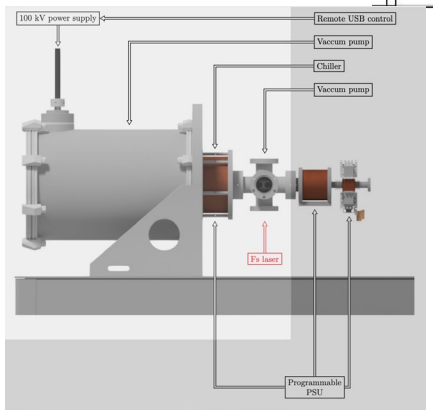
Field emission at 300K and 30K starts at higher field at 30 K



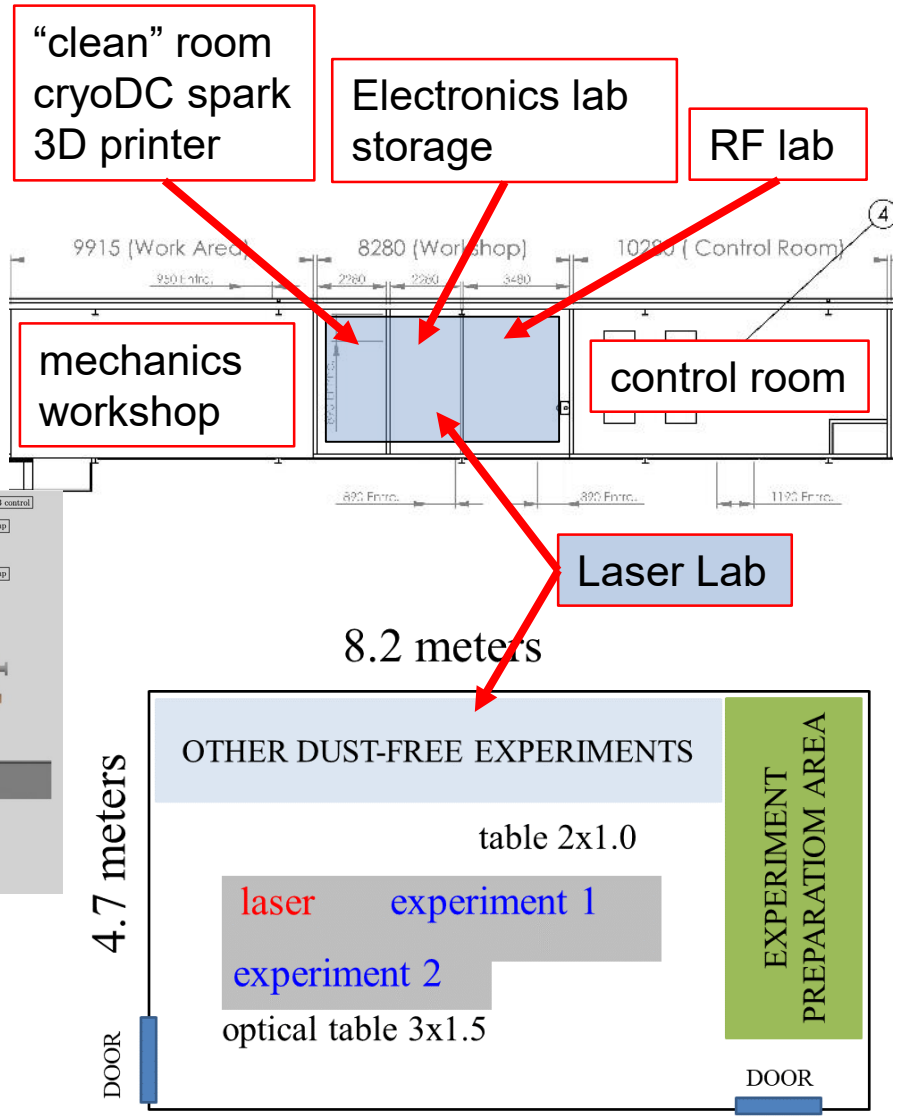
OFE-Cu electrodes
50 mm diameter
60 µm gap

Establishing a New Laser Lab

- **Existing**
  - 800 nm laser from Eng. Dept. used for THz experiments (higher harmonic at 270 nm)
- **Acquire**
  - 100 kV DC photo-gun (Cu-cath.)
  - 280 nm laser / amplifier (tbd)
  - pulse picker for laser
- **Hire**
  - laser expert



- **Total area: 39 m²**
  - 8.28 m x 4.73 m
  - RF lab: 3.48 x 4.73 = 16.5 m²
  - El. lab: 2.28 x 4.73 = 10.8 m² (x2)



Personnel Resources

- **About 30 staff and 4 PhD student**
  - 3 professor/lecturer (instrumentation, accelerators, electronics/RF)
    - ongoing recruitment: Associate Professor in Physics with specialisation in Photon and Charged Particle Beams
  - 13 researcher/post-doctoral
  - 15 engineer/technician
- **Core competence areas**
  - accelerators
  - beam lines and end stations
  - instruments and methods
  - engineering for accelerators and instruments
  - coordination and project management
- **Moderate or lack of competence**
  - lasers and photo cathodes
  - decided last week to open a recruitment process

Summary

Uppsala University & FREIA Laboratory actively developing accelerator and instrumentation technology

Technology Development

- SRF cavities
- SC magnets
- RF power generation
- LLRF and controls

Physics Research

- high brilliance beams
- superconducting RF
- RF breakdown

Academic Teaching

- accelerators and photonics