FREIA Laboratory

Facility for Research Instrumentation and Accelerator Development

Overview ESS Test & Development Program

Roger Ruber for the FREIA Team

ESS TAC 14-16 October 2015

Why ?

- Validation technical design and performance
- Optimization technical design
- Acceptance testing of series components
- Training of staff

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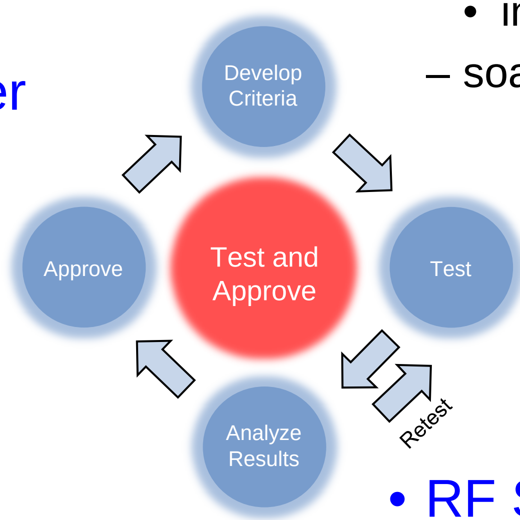
Reminder – Some History

- **2006**: Closure CELSIUS ring at Uppsala
  - join CTF3 collaboration on RF development
- **2009**: ESS-S and Uppsala start discussion on collaboration
- **2010**: Uppsala decides to construct the FREIA Laboratory
  - support from KAWS and Swedish Government
- **2011**: Collaboration agreement ESS – Uppsala
  - development of 704 MHz RF
- **2013**: Amendment and change of direction
  - development of 352 MHz RF & test of spoke cavity/cryomodule
  - study solid-state amplifier technology
- **2015**: Extended collaboration for ESS construction
  - development and test of 352 MHz spoke cryomodules and controls
  - test of 704 MHz RF

Test Program

- Bare spoke cavity
  - with antenna (and helium tank)
  - low power
  - self-excited loop
- Spoke cavity with tuner
  - with antenna and tuner
  - low power
  - LLRF
- Dressed spoke cavity
  - with power coupler, tuner
  - full power
  - LLRF
- Cryomodule & Valve Box
  - full power on two cavities
  - LLRF



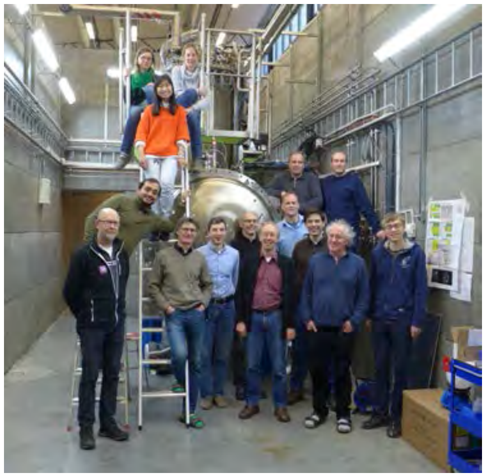
- RF Station 352 MHz
  - acceptance test
  - functional test
    - including RF distribution components
  - soak test
- RF Station 704 MHz
  - acceptance test
    - first modulator, then klystron
  - functional test
    - including RF distribution components
  - soak test

What have we been doing since then…

A lot of information in the following slides,
which you can read offline for future reference.

What & Whom?

Facility for Research Instrumentation and Accelerator Development



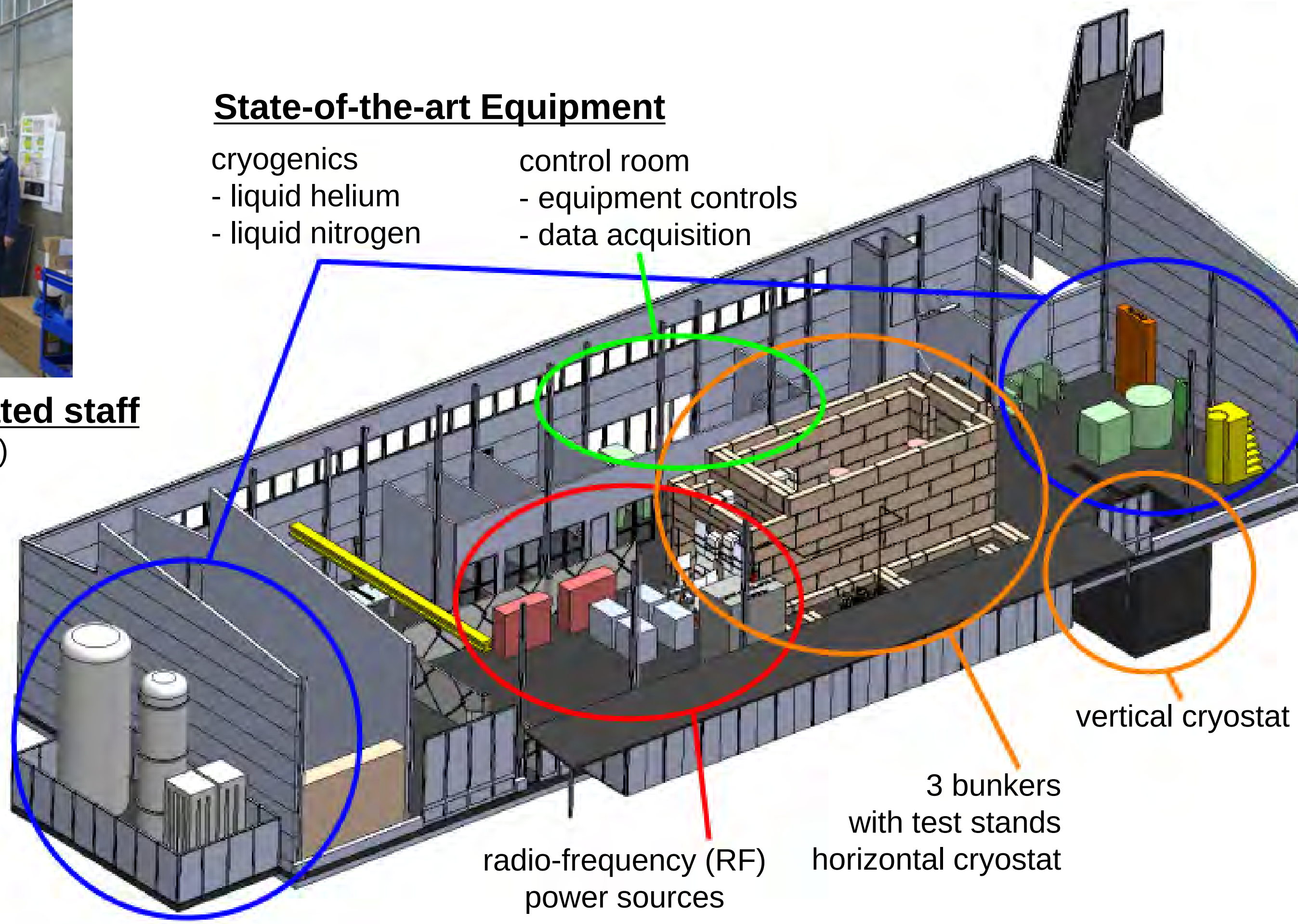
Competent and motivated staff
collaboration of physics (IFA)
and engineering (Teknikum).

Funded by KAWS, Government, Uppsala Univ.

State-of-the-art Equipment

cryogenics
- liquid helium
- liquid nitrogen

control room
- equipment controls
- data acquisition



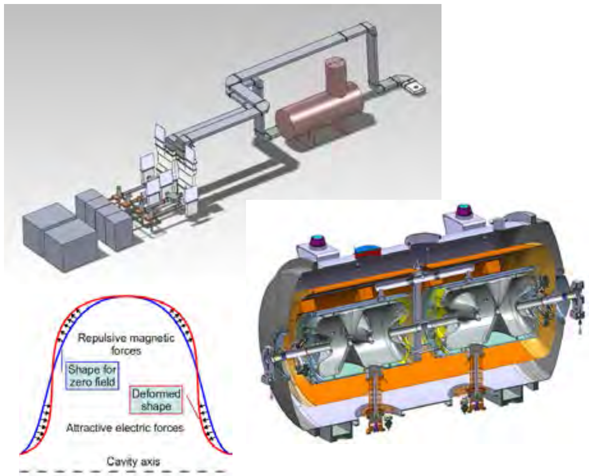
vertical cryostat

3 bunkers
with test stands
horizontal cryostat

radio-frequency (RF)
power sources

Overview of Activities

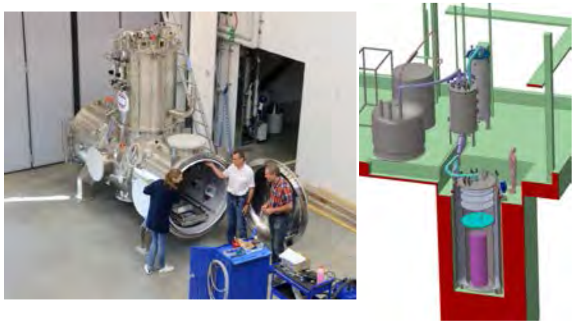
ESS Spoke Linac



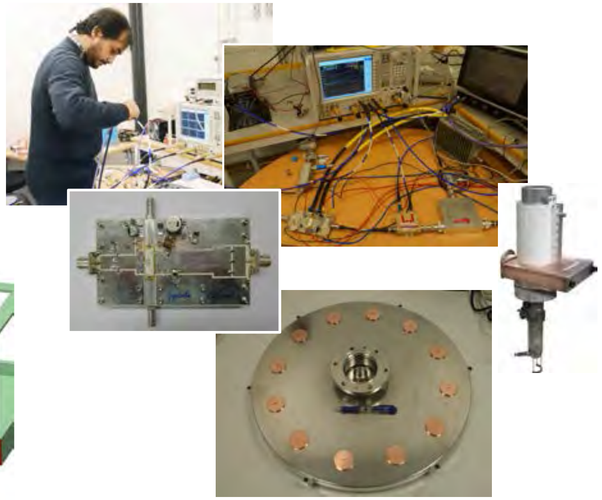
linearcollider.org/M.Grecki

Cryogenics

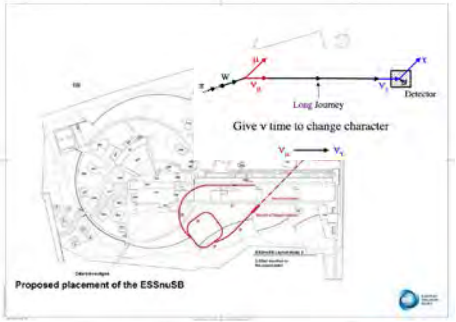
Cryo Test Stands



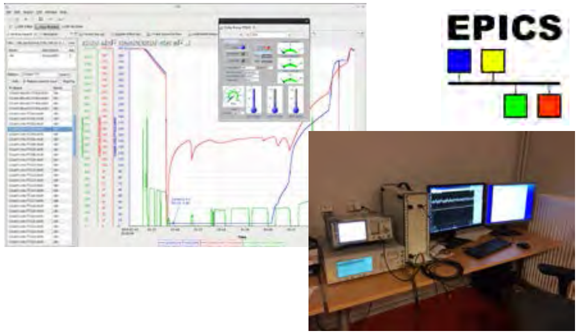
High Power RF Amplifiers Solid-state & Vacuum Tube



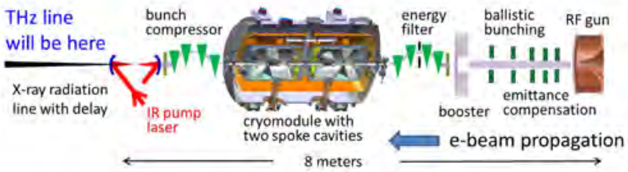
ESS neutrino Super-beam



Controls & Data Acquisition



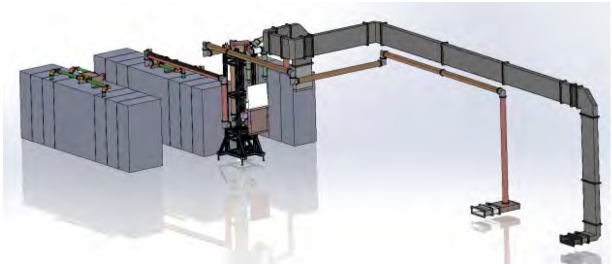
THz-FEL



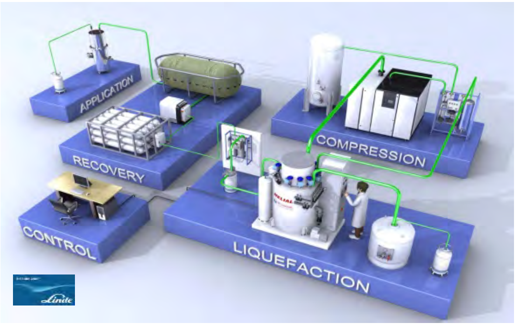
RF = Radio Frequency
SRF = Superconducting RF
FEL = Free Electron Laser

Horizontal SRF Test Stand

Three main subsystems:



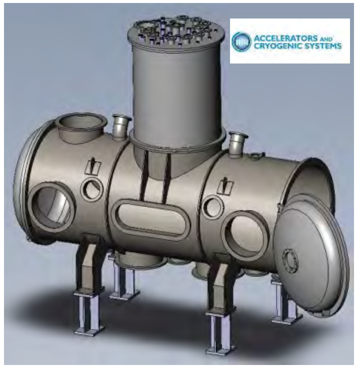
RF Power Source



Cryogenics

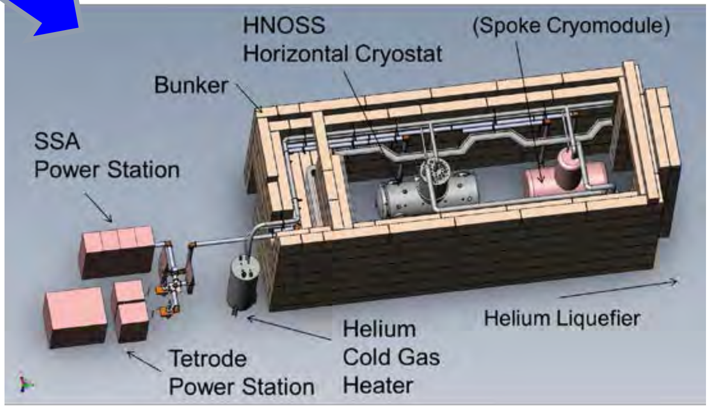
Courtesy of P. Duthil

SRF Cavity
(superconducting)



Horizontal Cryostat

Implementation



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Cryogenics

FREIA

Helium gas recovery system

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

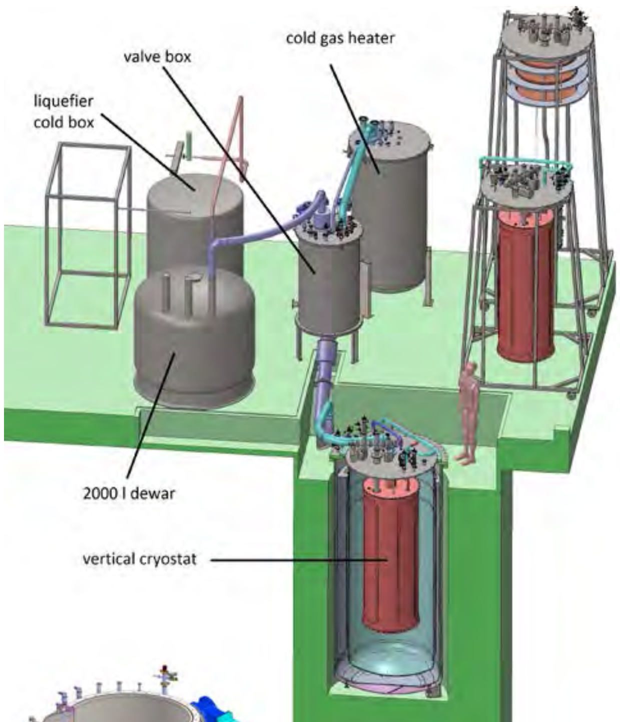
Sub-atmospheric pumping station

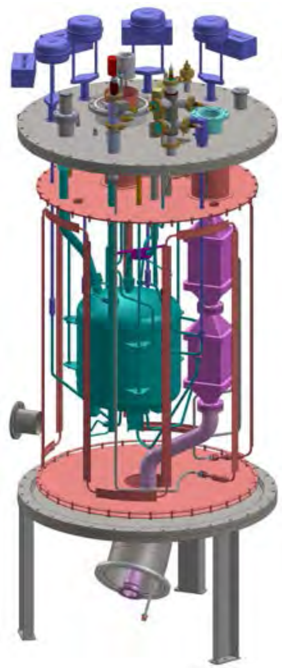
HNOSS - Horizontal Cryostat System

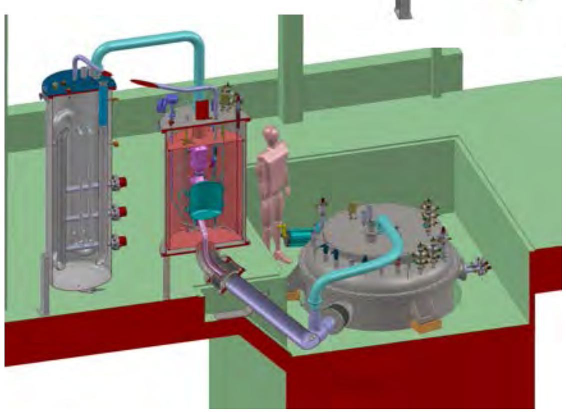
HNOSS: Horizontal Nugget for Operation of Superconducting Systems

- Main Vacuum Vessel
  - 3240 x ø1200mm inner volume
  - “beam” axis at 1600mm
- Valve box (on top of main vessel)
  - Distribute cryogens
  - 4K and 2K pots, JT-valve, heat exchanger
  - 5K supercritical helium
- Interconnection box (ICB)
  - Distributes cryogens to HNOSS and CM
- Cryogenic transfer lines
  - LN2 and LHe
- Cold gas heater for return flow
  - re-heating from 2K to 300K
- Control system

Planned - Vertical Cryostat System







Gersemi

- Operation modes
  - vacuum
  - sub-atmospheric liquid bath
  - pressurized liquid bath
- Main Vacuum Vessel
  - 4436 x ø1100mm inner volume
  - 2869 mm below lambda plate
- Valve box
  - Distribute cryogens
  - 4K pot, JT-valve, heat exchanger
  - 5K supercritical helium
- Cold gas heater for return flow
  - re-heating from 2K to 300K
- Cryogenic transfer lines
  - LN2 and LHe
- Control system

High Power RF Amplifiers




RF Distribution

- Components
  - phase shifter/reflectometer: MEGA (US)
  - circulator/load: AFT (GE)
- Lines
  - coax: Exir (SE)
  - waveguide: Exir (SE)

352 MHz, 400 kW, 3.5 ms, 14-28 Hz

- Uppsala design
  - investigation and tube choice 2012
    - combine two water cooled TH595
  - design review December 2012
  - call for tender Spring 2013 & Fall 2014
- Itelco-Electrosys (Orvieto, IT)
  - ordered June 2013
  - financial problems during 2014
  - factory test May 2015
  - acceptance test August 2015
- DB Elettronica/DB Science (Padua, IT)
  - ordered December 2014
  - factory test foreseen October 2015

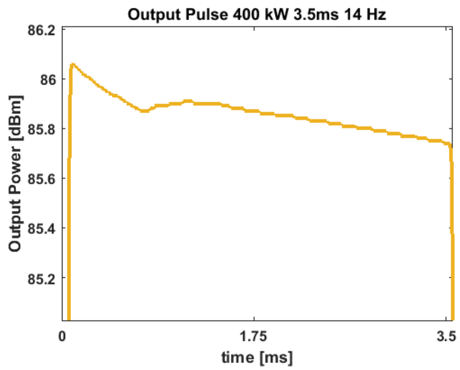
352 MHz, 50 kW, CW

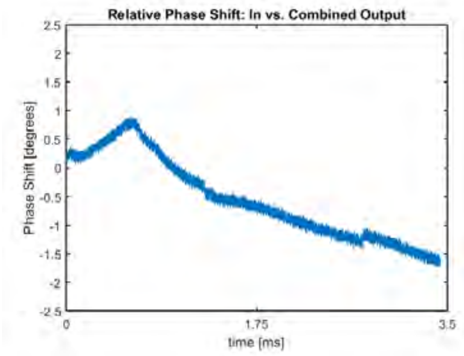
- CERN (loan since Feb.2015)
  - tube TH571b

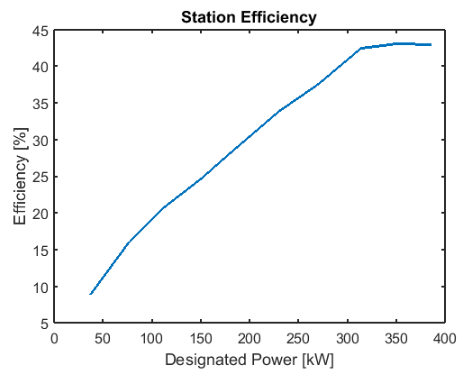
RF Station #1 (Itelco-Electrosys)

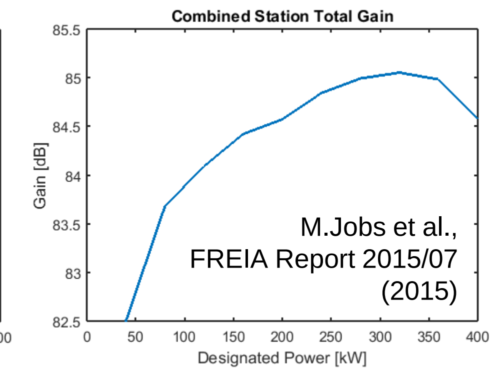
FREIA Report 2015/07

- Station performs well
- Fulfils major specifications
- Some remarks
  - series switches
    - parallel RC to improve performance
  - screen grid response time a bit long
    - testing & investigating alternatives
  - linearity slightly out of specification (<100kW due to gain variation)
  - anode efficiency HPA2 slightly below requirements (<65%) at full power
- Now testing circulators & loads









M.Jobs et al., FREIA Report 2015/07 (2015)

Station #2 (DB Elettronica)

- 24h test at 400 kW
  - starting today
- Factory testing halted (01-Oct)
  - sparking at one cavity due to damaged HV cable
  - Thales arranged repair cavity
  - working ok at 200 kW (12-Oct)
- Previous tests
  - 24h test stopped due to water leak in dummy load (04-Aug-2015)
  - up to 400 kW output pulse
  - crowbar test ok (30-Jul-2015)

RF Development

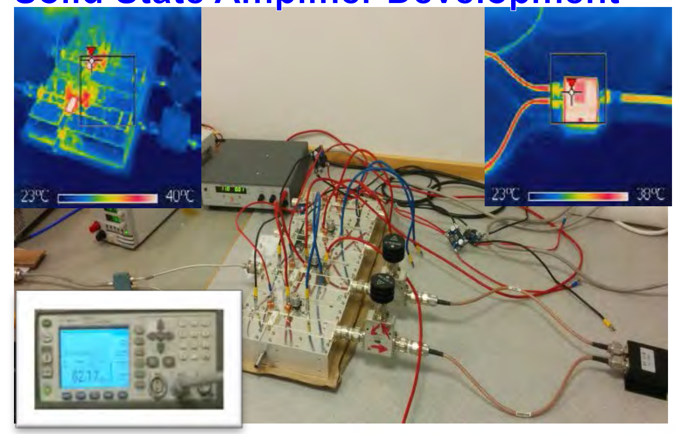
Solid State Amplifier

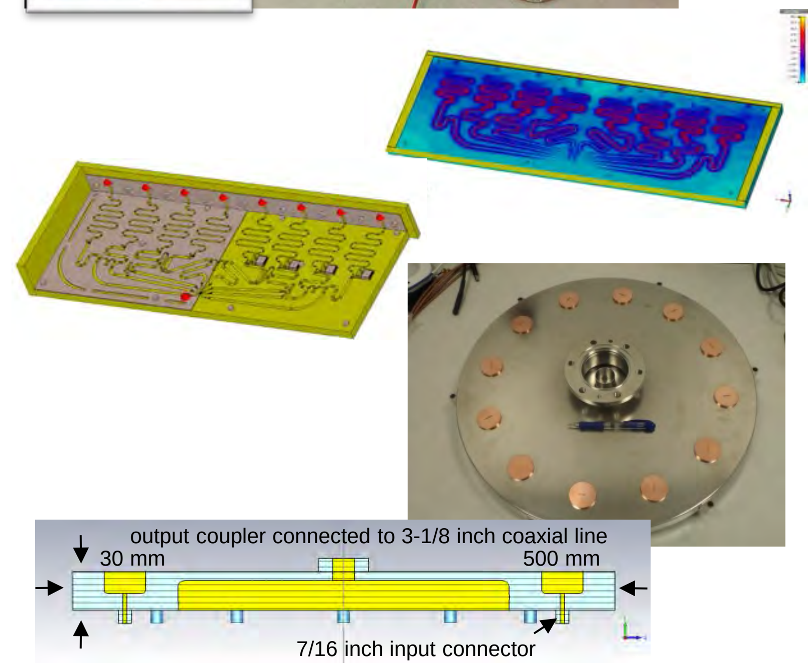
- transistor module optimization (efficiency)
- 100 kW compact combiner
- 10 kW planar gysel combiner

Self-excited Loop

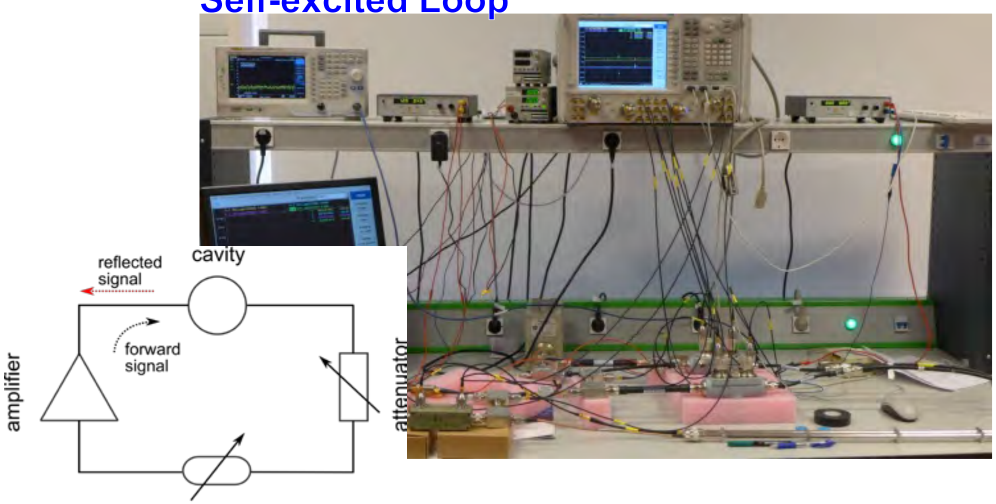
- for cavity w/o fundamental power coupler

Solid State Amplifier Development

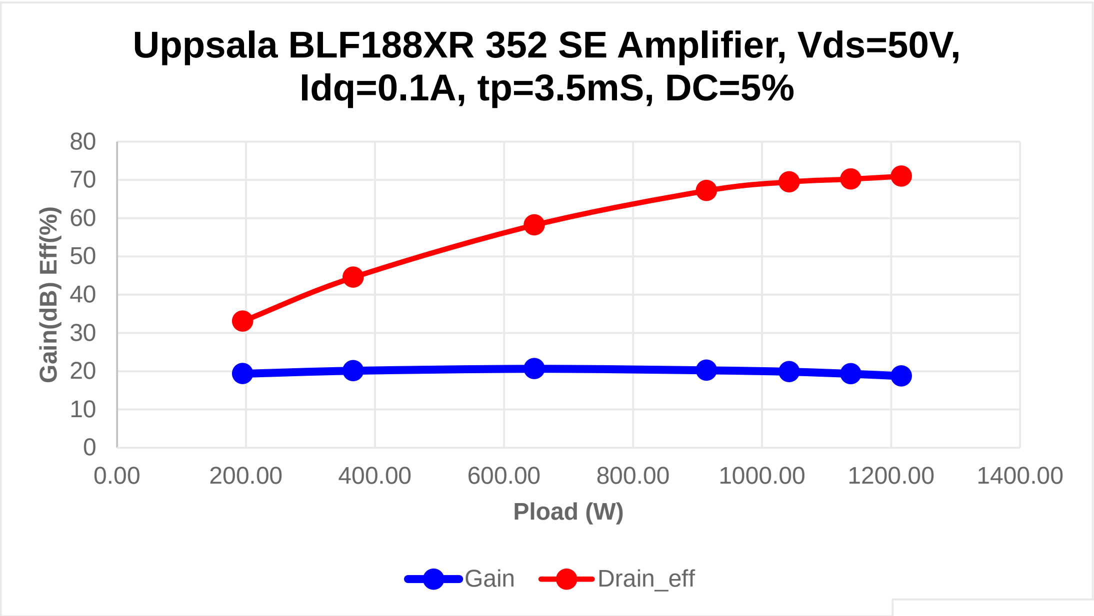


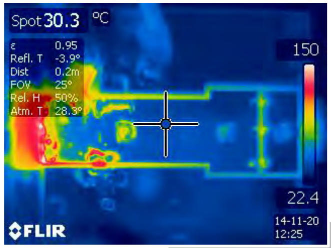


Self-excited Loop

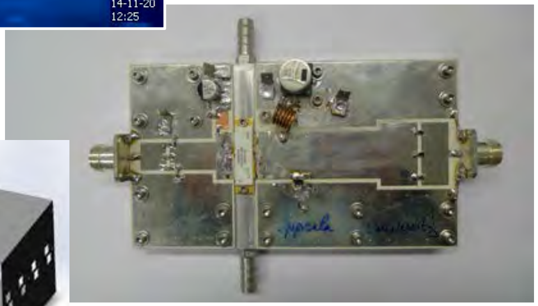


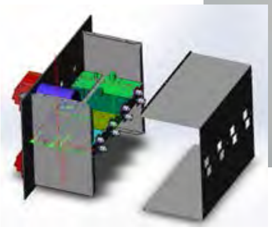
Solid State Single Ended Amplifier

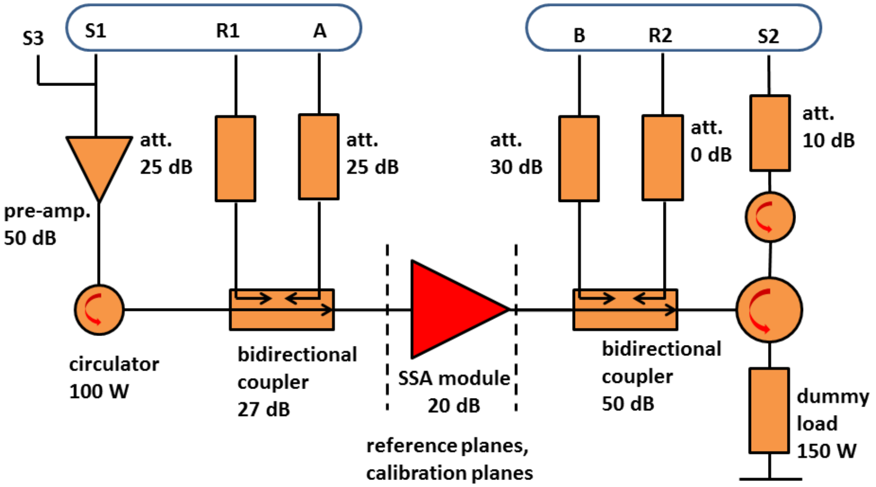


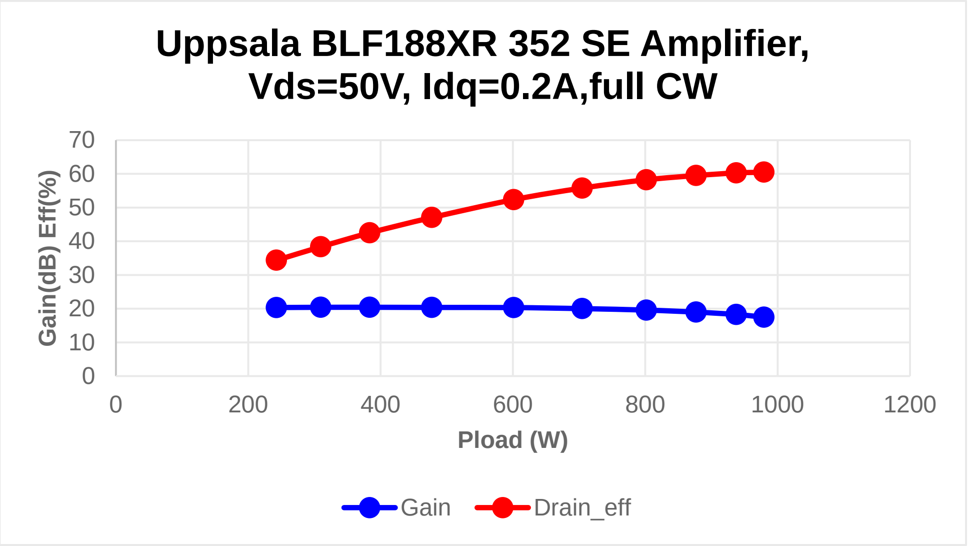


Pload =1.3 kW
Duty Cycle=5%.









Low Level RF and Controls

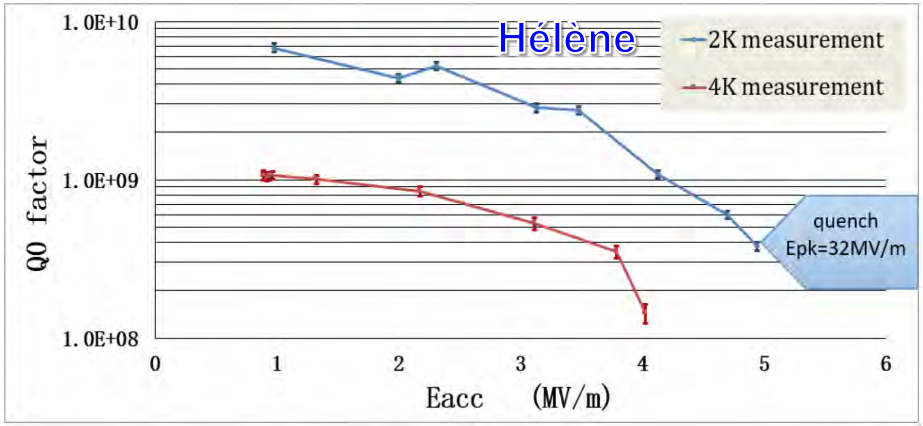
- **Lund Univ. LLRF**
  - arrived 21-Apr-2015
  - µTCA base (DESY development)
  - tested on "Hélène"
- **In-house development LLRF**
  - Nat. Instr. PXI and LabVIEW based
  - digital phase control for self-excited loop
  - extended RF measurements on top of LU-LLRF
  - testing on copper cavity
- **Controls and interlock systems**
  - EPICS interface with data archiver
    - connecting different sub-systems: Linde, Cryo Diffusion, Leybold ...
  - Siemens PLC and Nat.Instr. cRIO hardware
- **Radiation monitoring system**
  - Rotem MediSmarts
  - 2 points inside bunker, 3 points outside bunker

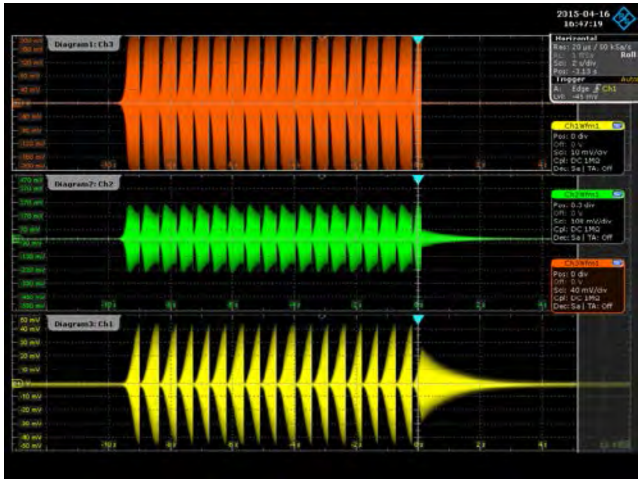
EPICS

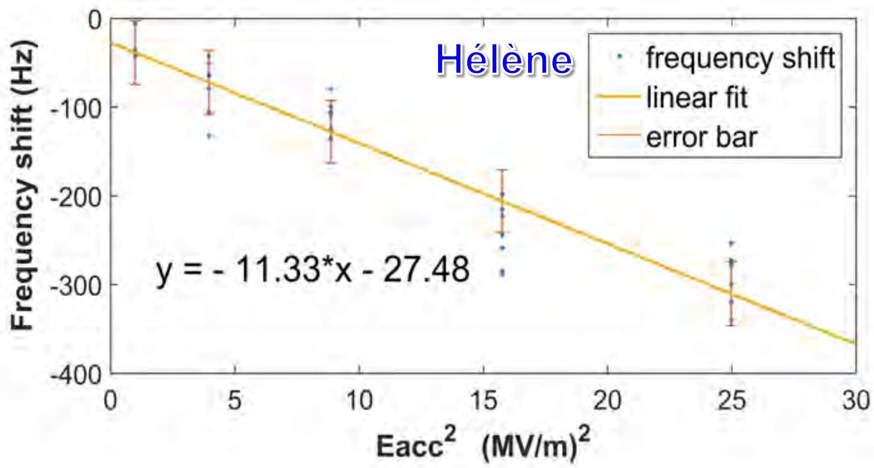
And what we are up to now…

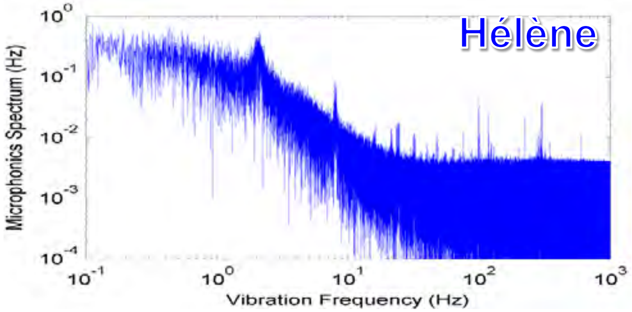
Single Spoke Cavity (Hélène)

H. Li et al., SRF'15 (2015) TUPB083





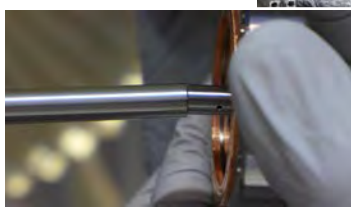


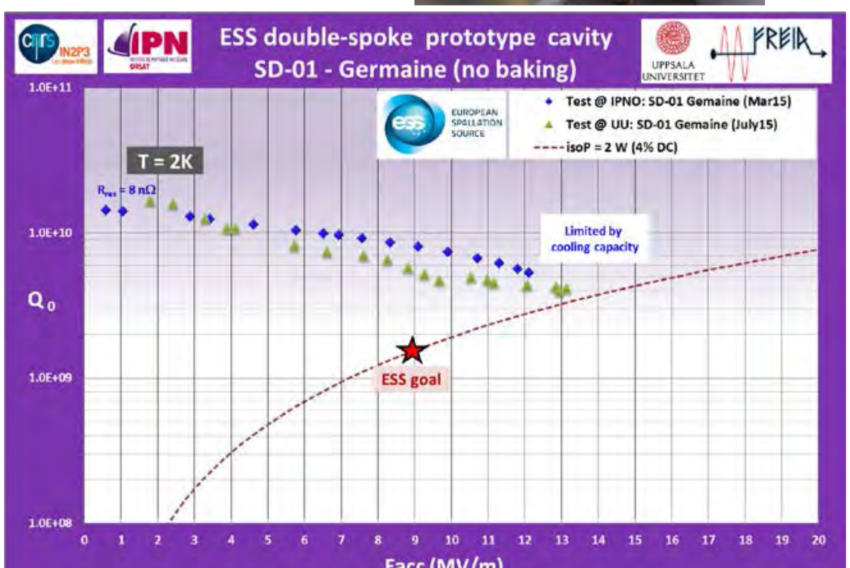


Double Spoke Cavity (Germaine)

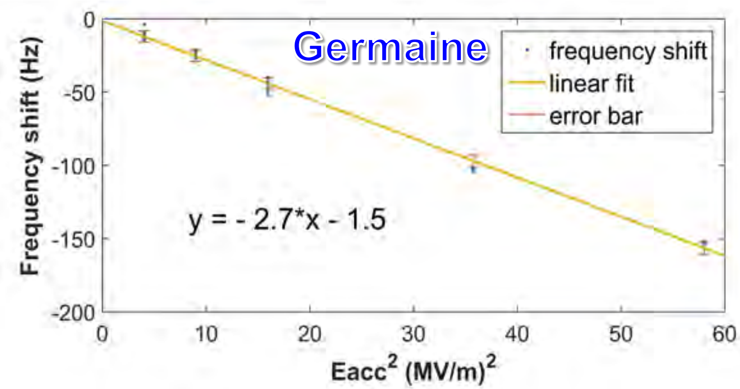
H. Li et al., SRF’15 (2015) TUPB083

- Q measurement
  - deviation slope compared to Orsay measurement
  - DC short at antenna
    - fixed

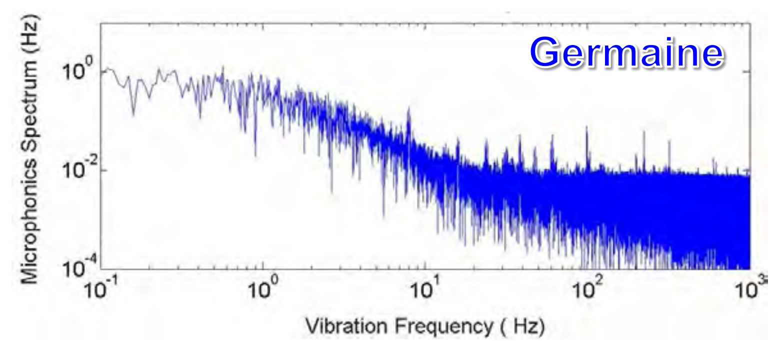




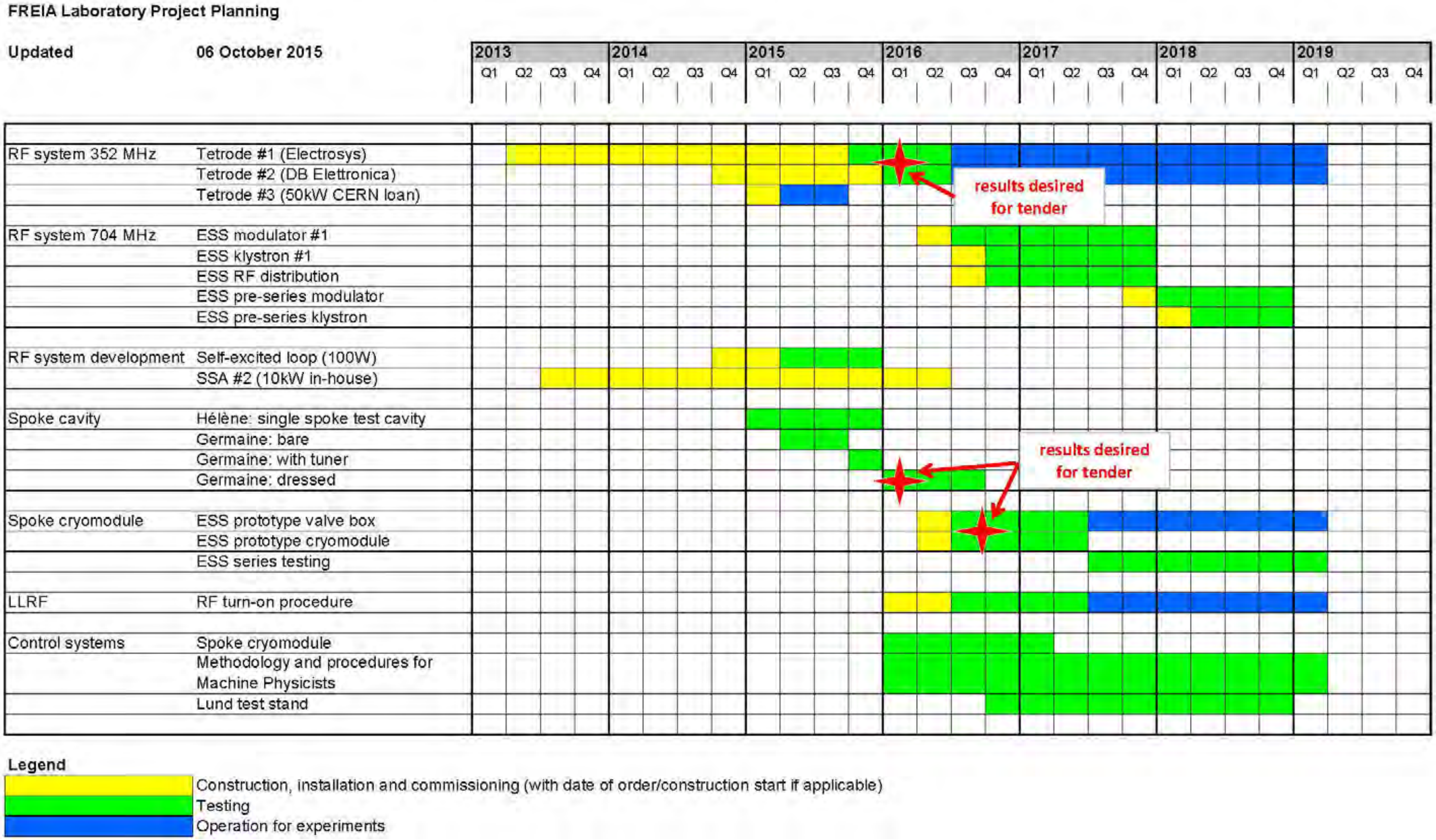
- Lorentz force detuning
  - different from Orsay measurement, but without tuner
    - tuner installed this week



- Microphonics



Time Schedule



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Some Numbers…

- **Personnel**
  - Staff:
    - 9 engineers + 4 researchers + 2 post-doc
    - of which 3 part time 30 – 50%
  - Other divisions:
    - 2 Physics (HEP) + 2 Engineering (SSE)
    - all part time 5 – 50%
  - PhD students:
    - 3 Physics (HEP) + 1 Engineering (SSE)

- **Publications** (since 2012)
  - Articles in refereed journals: 11
  - Conference proceedings: 28
  - Internal reports: 28
  - Student thesis: 4


YT4P400K