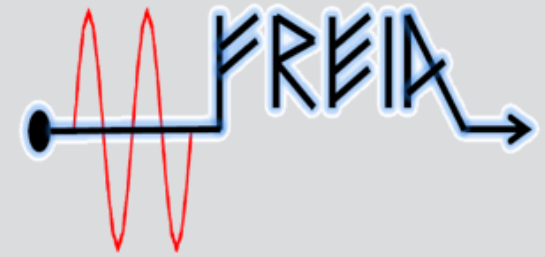




UPPSALA
UNIVERSITET



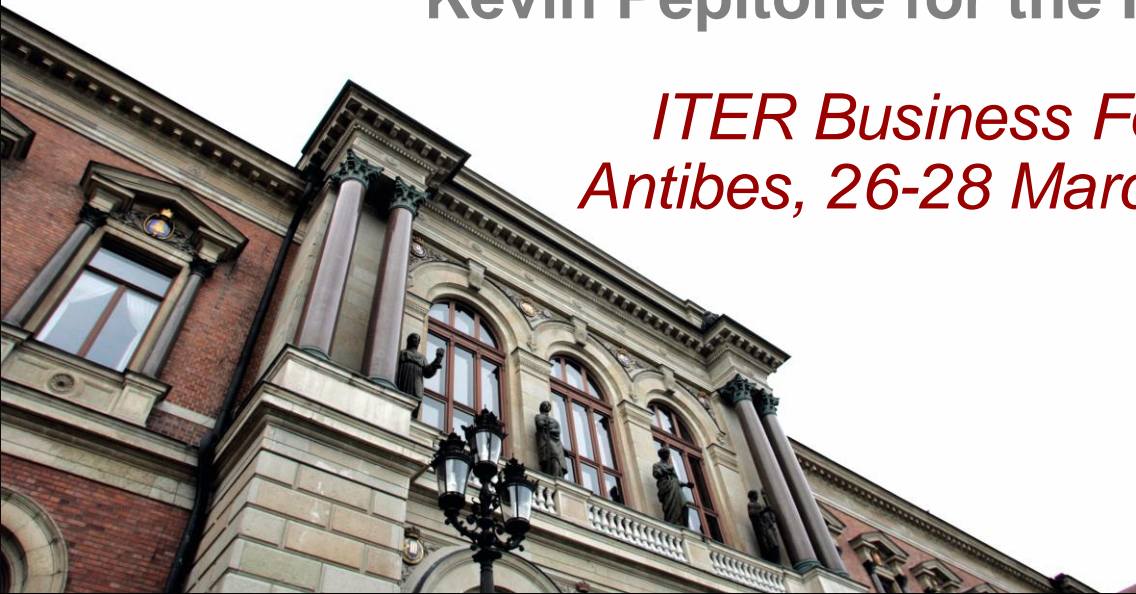
FREIA Laboratory

Facility for Research Instrumentation and Accelerator Development

at Uppsala University

Kévin Pepitone for the FREIA Team

*ITER Business Forum
Antibes, 26-28 March 2019*



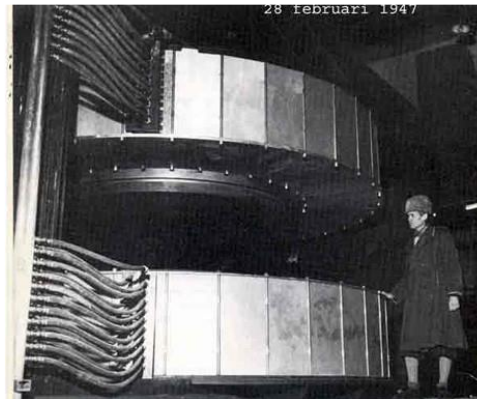
1477: Uppsala University, oldest in Scandinavia

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



1940's: The (odorous) 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)





Instrumentation and Accelerator Physics and Development



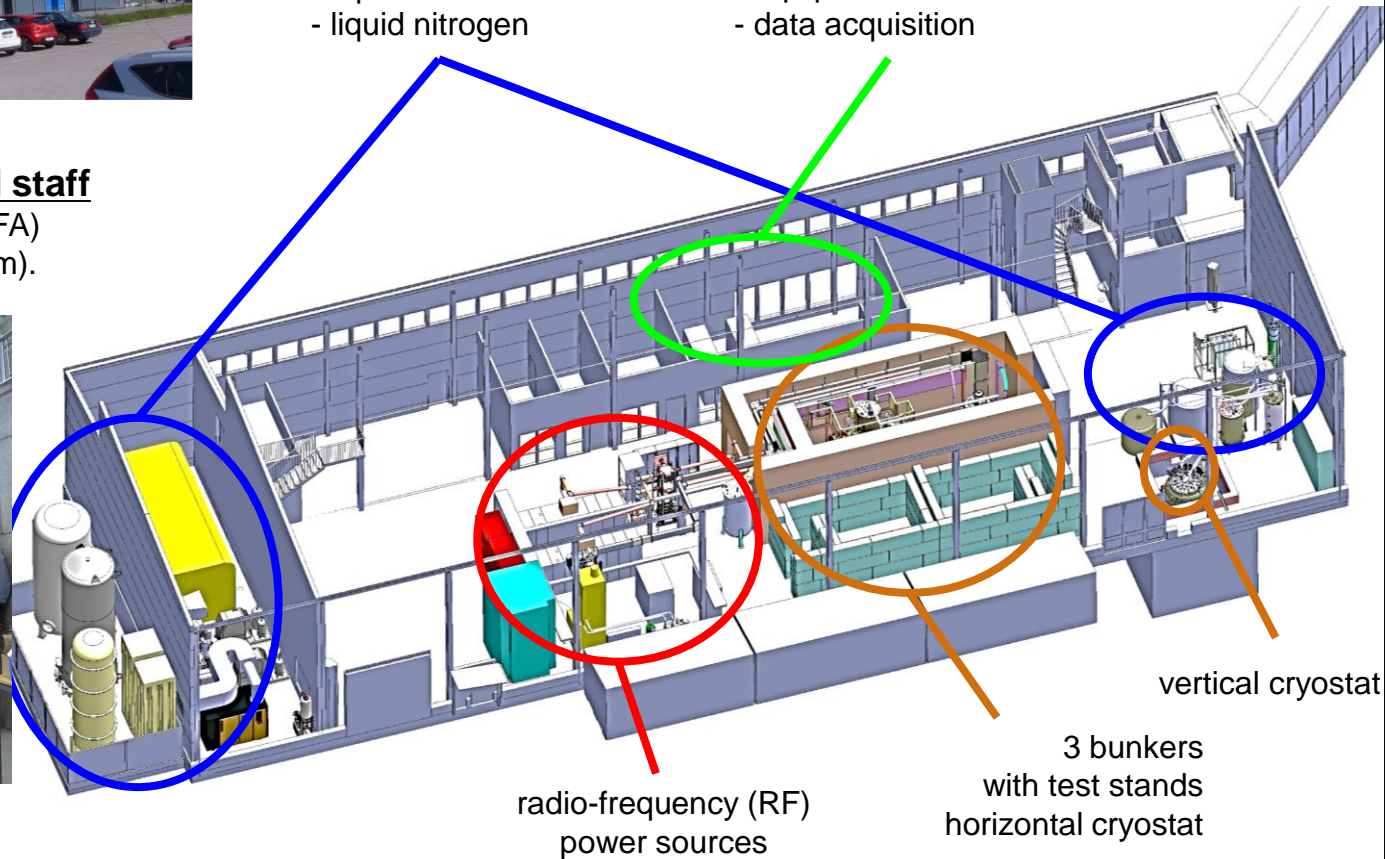
State-of-the-art Equipment

- cryogenics
 - liquid helium
 - liquid nitrogen

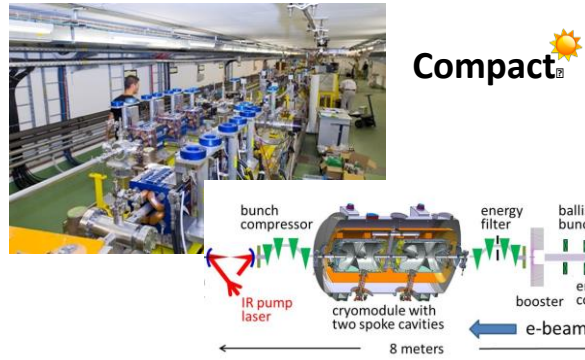
- control room
 - equipment controls
 - data acquisition

Competent and motivated staff

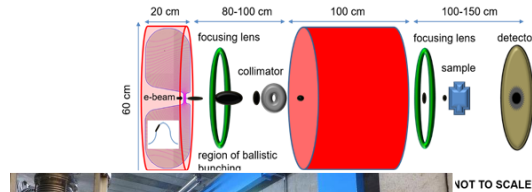
collaboration of physics (IFA)
and engineering (Teknikum).



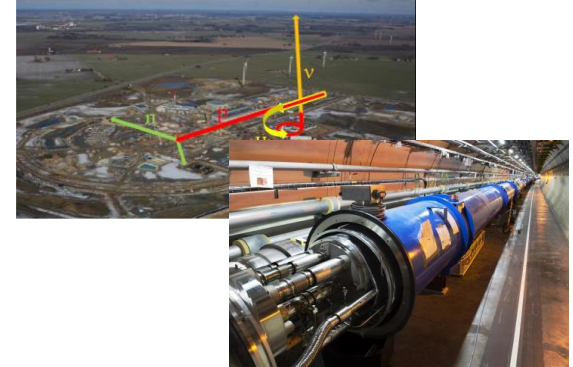
Ultra Bright Electron Beams



Advanced Instrumentation



High Intensity Proton Beams



SC Cavities & Magnets



Cryogenics



RF Generation & Control





- **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 m³ gasbag
- 3x 25 m³/h compressor
- 10 m³ 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 m³ LN2 tank



Helium gas recovery system

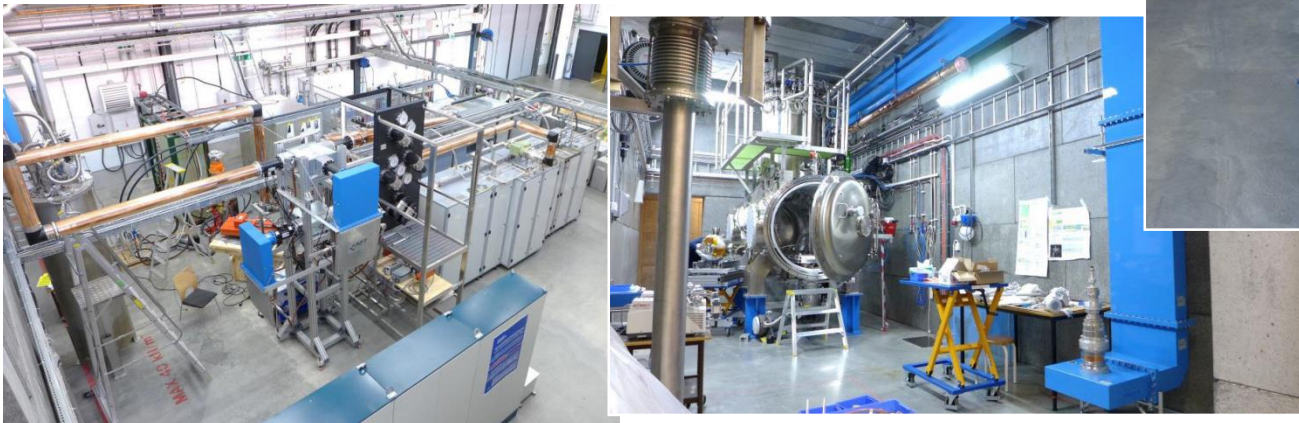
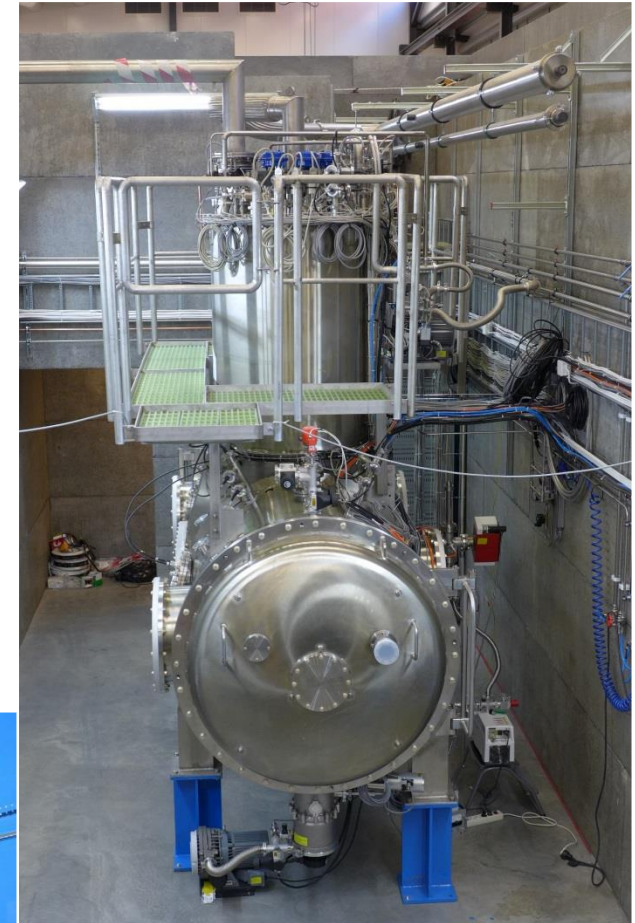


Sub-atmospheric
pumping station

“HNOSS” Horizontal Cryostat

HNOSS = Horizontal Nugget for Operation of Superconducting Systems

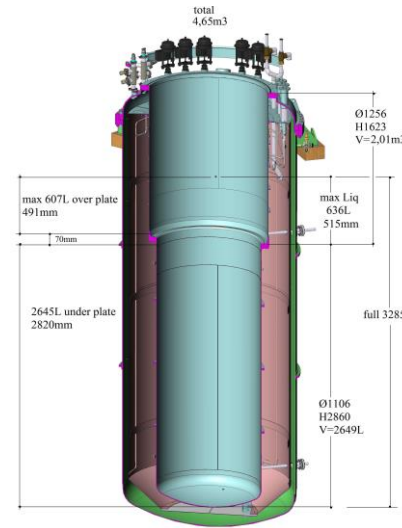
- Test of superconducting cavities/devices
 - 3240 x \varnothing 1200mm inner volume
 - up to two cavities simultaneously,
 - each equipped with helium tank,
- Low or High power RF testing
 - fundamental power coupler (top, bottom, side)
 - (cold) tuning system
- Operation in the range 1.8 to 4.5K.



- **Under commissioning**

- **Test of SC cavities & magnets**

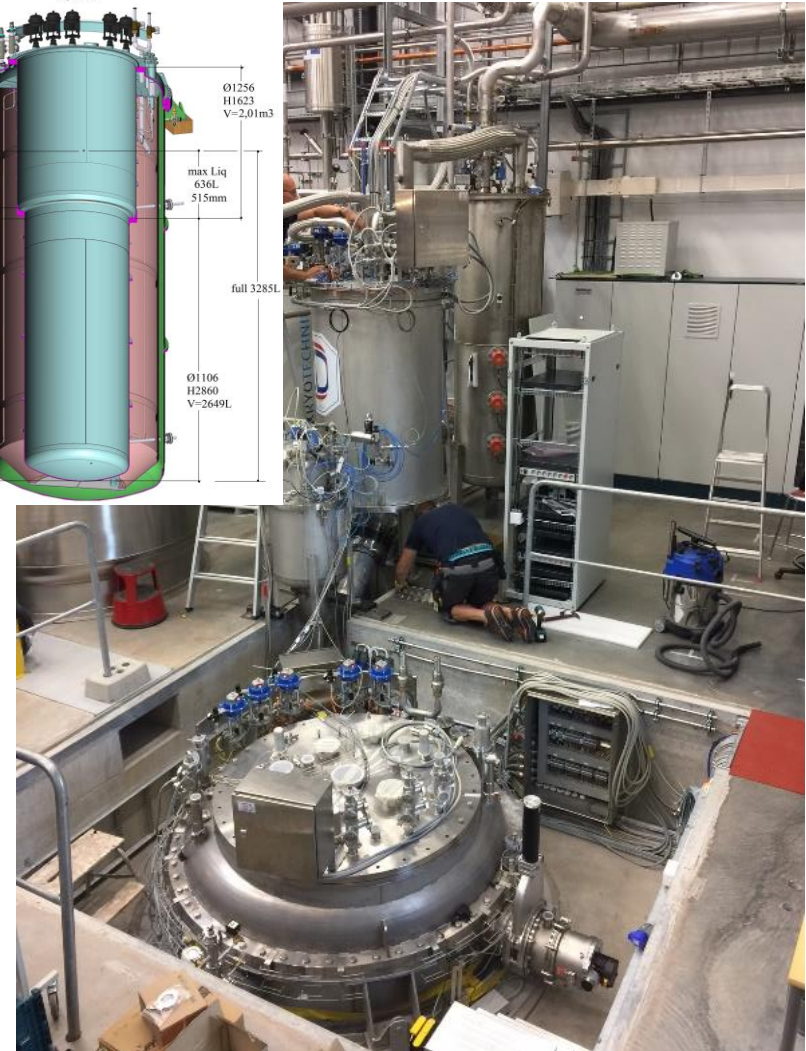
- 3.2m x \varnothing 1.1m total volume
- 2.65m x \varnothing 1.1m below lambda plate
 - design includes joint for lambda plate



- **Operation in the range 1.8 to 4.5K**

- **Three operation modes**

- vacuum
- liquid bath
- pressurized bath with 2K heat exchanger



- **Hélène single spoke cavity (IPNO)**

- antenna, low power
- self-excited loop (SEL)
- RF calibration procedures



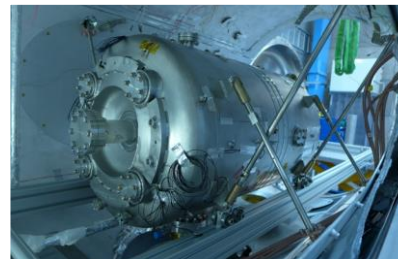
- **Germaine double spoke (IPNO)**

- antenna and cold tuner, low power
- cryogenics: cooling, heat load
- LLRF, SEL
- Q_0 , gradient, microphonics



- **Romea cavity package (IPNO)**

- power coupler and tuner, nominal gradient
- Q_0 and gradient, microphonics, fill time, Lorentz force detuning
- tuner operation



- **RF Station 352 MHz (2x)**

- acceptance and functional test
 - including RF distribution components
- soak test
- pulsed and CW operation on cavity

- **RF Station 704 MHz**

- acceptance & operation of modulator

- **High- β elliptical cavity package (CEA)**

- FPC conditioning ok
- under test



- **ESS Cryomodules**

- prototype, arrived August 2018
- 13 series during 2019 - 2020



High Power RF Amplifiers



704 MHz Klystron

- **1.1 MW, 3 ms, 14 Hz**
 - on loan from ESS
 - Ampegon/PPT modulator
 - Toshiba klystron



CERN 50 kW CW

352 MHz Tetrodes

- **2x 400 kW, 3.5 ms, 14-28 Hz**
 - combined output 2 tetrodes TH595
- **50 kW CW**
 - on loan from CERN
 - tetrode TH571b
 - 352 or 400 MHz output cavity



- **SSA development**

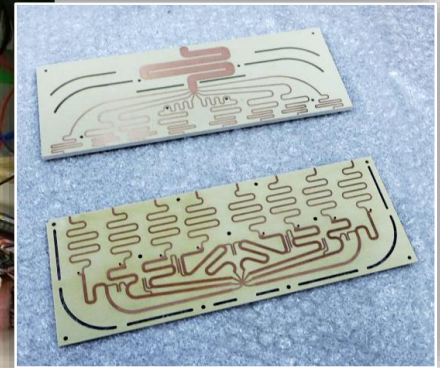
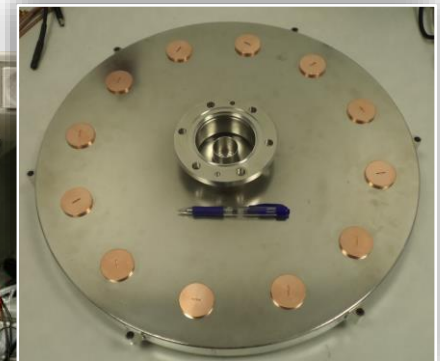
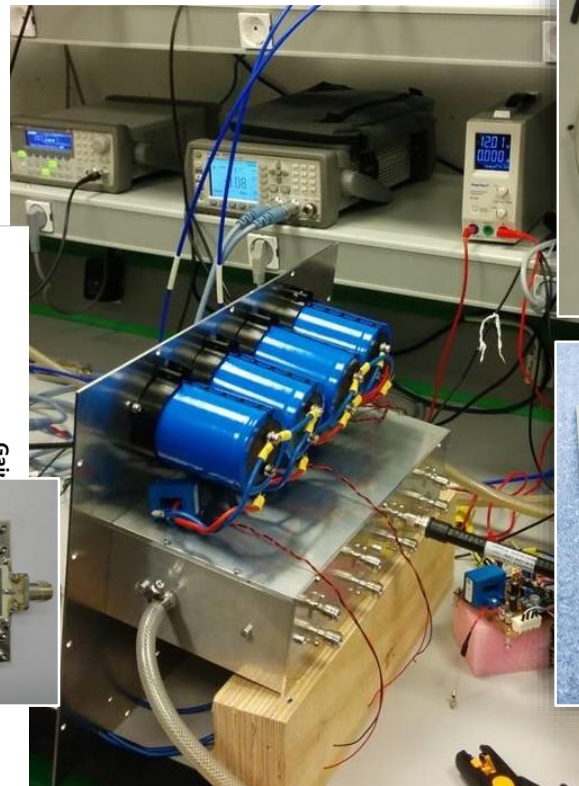
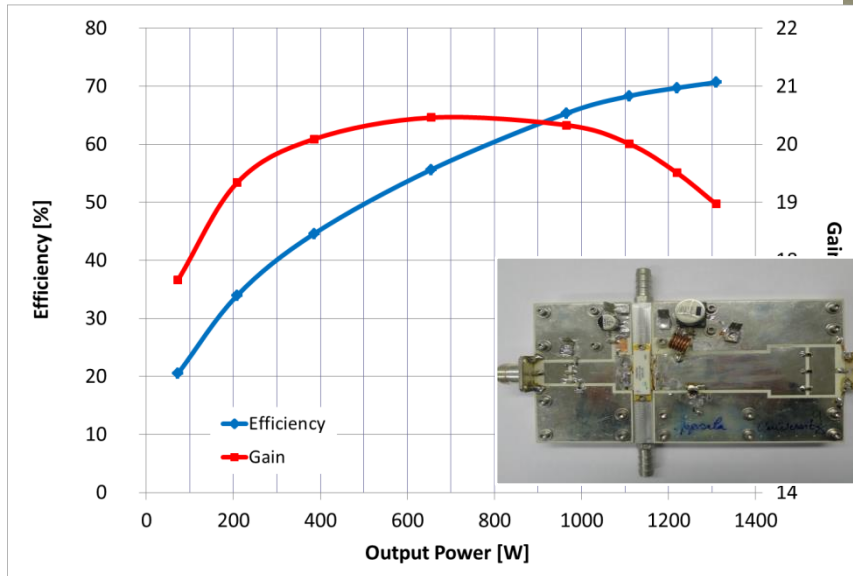
- single ended RF power amplifier
- based on BLF188XR
- 1250 W and 70% efficiency

- **SSA demonstrator**

- 10 kW, 8 modules

- **Compact Combiners**

- compact cavity combiner 100 kW
- planar Gysel combiner 10 kW



- **Slow Controls & Safety Interlock**

- connecting different sub-systems: cryogenics, cryostats, powering, ...
- Siemens PLC, Nat.Instr. cRIO
- EPICS interface with data archiver

- **LLRF**

- Self excited loop 352/704 MHz
 - pulsed or CW operation
- Nat. Instr. PXI and LabVIEW
 - digital phase control for SEL
 - extended RF measurements
- Lund Univ/ESS μ TCA system
 - timing, external signal generators

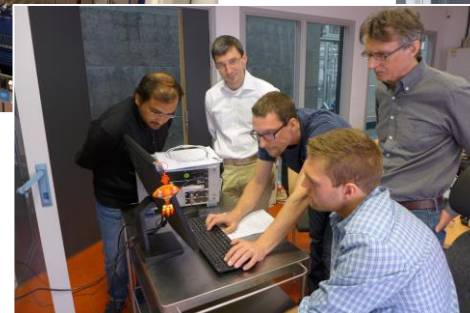
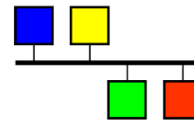
- **Fast Magnet Quench Monitoring**

- Nat.Instr. PXI and LabVIEW
 - based on CERN developments

- **Software**

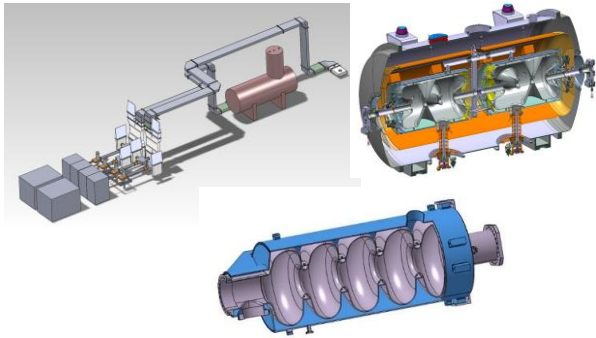
- EPICS and archiver
- LabVIEW code
 - klystron auto conditioning
 - power coupler auto conditioning
 - pulse length, power level, repetition rates
- SEL control and data acquisition
- cavity frequency shift tracing
- dynamic Lorentz force detuning

EPICS



High Brilliance Proton Beams

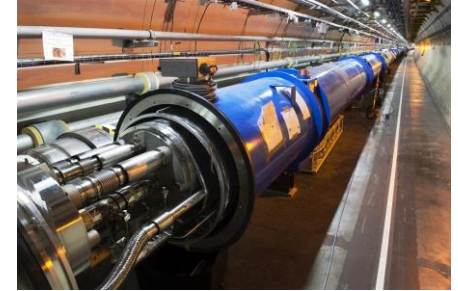
ESS Superconducting Linac



ESS Neutrino Super Beam

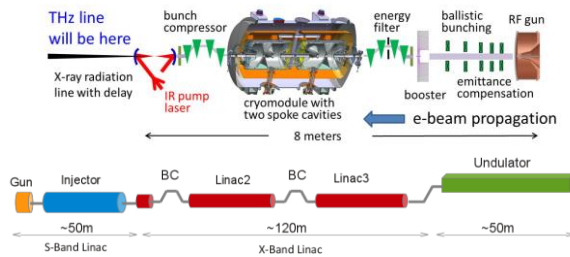


HiLumi LHC



High Brilliance Electron Beams

FELs

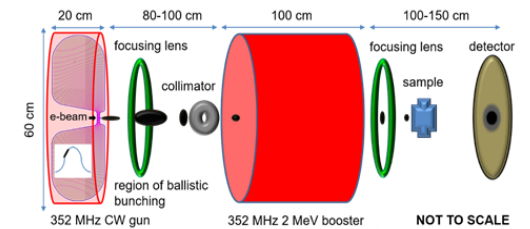


FEL = Free Electron Laser

CLIC



Ultrafast Electron Diffraction



Uppsala University & FREIA Laboratory actively developing accelerator and instrumentation technology

Development, verification, and testing

- cavity (package)
- high power RF
- RF solid-state and power combiners
- LLRF
- Controls

Research

- high brilliance beams
- superconducting RF
- vacuum/RF breakdown

Academic Teaching

