FREIA

Facility for Research Instrumentation and Accelerator Development

Infrastructure and Control Architecture

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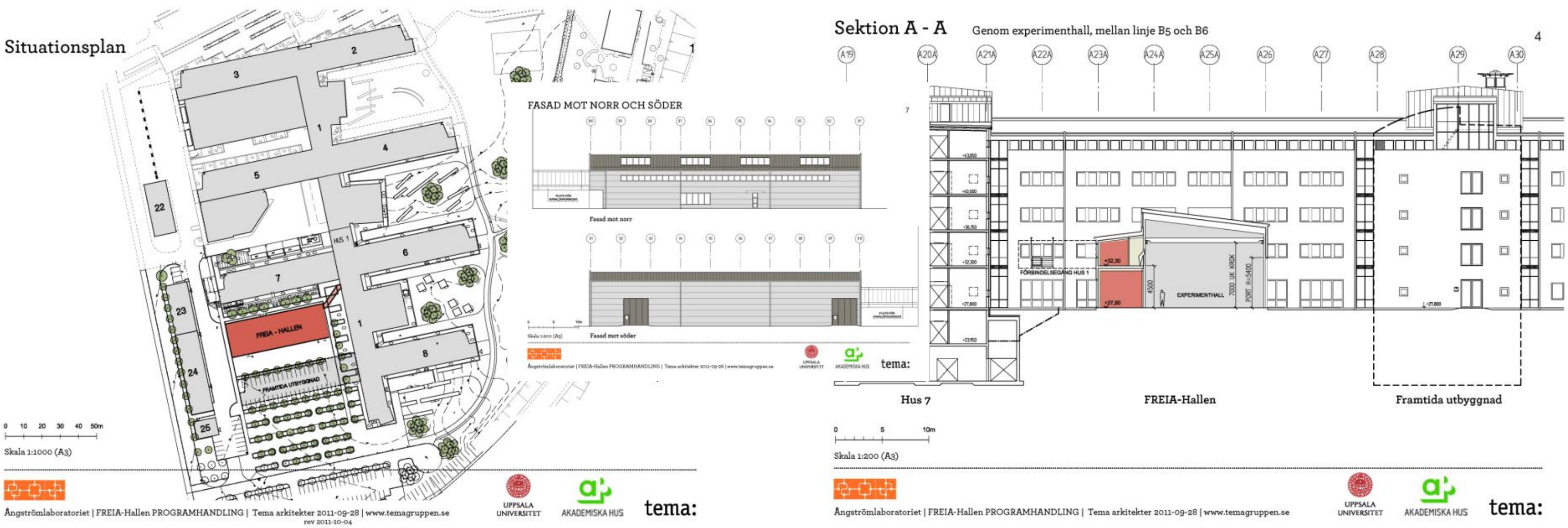
Why FREIA?

Several circumstances

- test stand for ESS needs large experiment space and bunker
- university’s helium liquefier in need of replacement

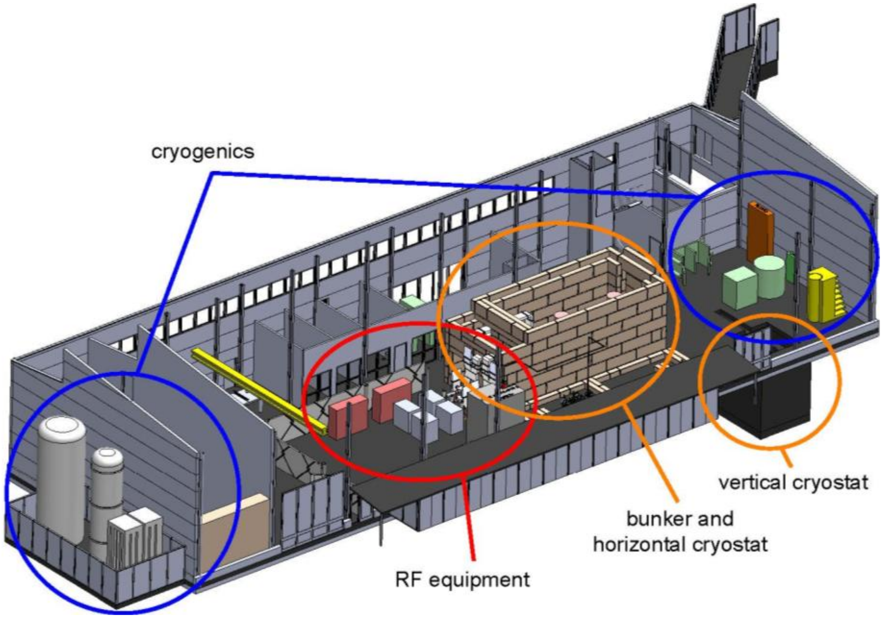
University decides on new construction at the Ångström laboratory (2010)



What FREIA?

Facility for Research Instrumentation and Accelerator Development

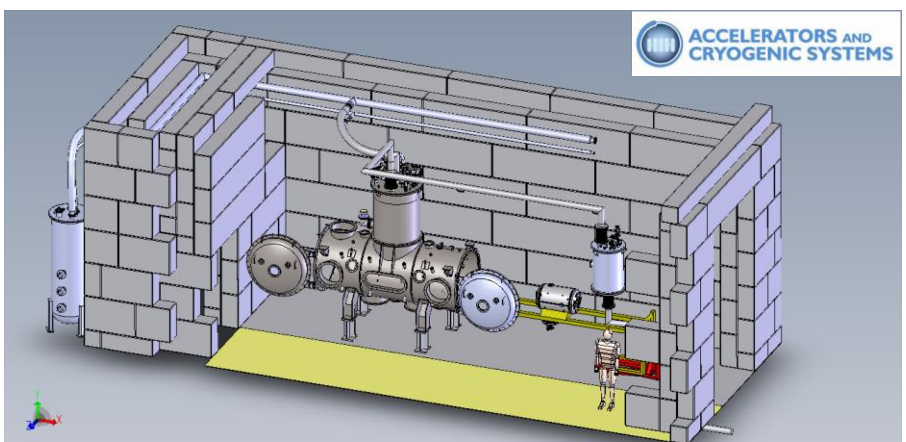
- General Infrastructure
  - LHe and LN2 production and distribution
  - small workshop, control room
  - concrete bunkers
- RF/SRF test stands
  - RF sources: 352 MHz (12 GHz in future)
  - horizontal test cryostat (vertical in future)
- Neutron generator
  - neutron tomography, detector tests
  - student exercises and projects

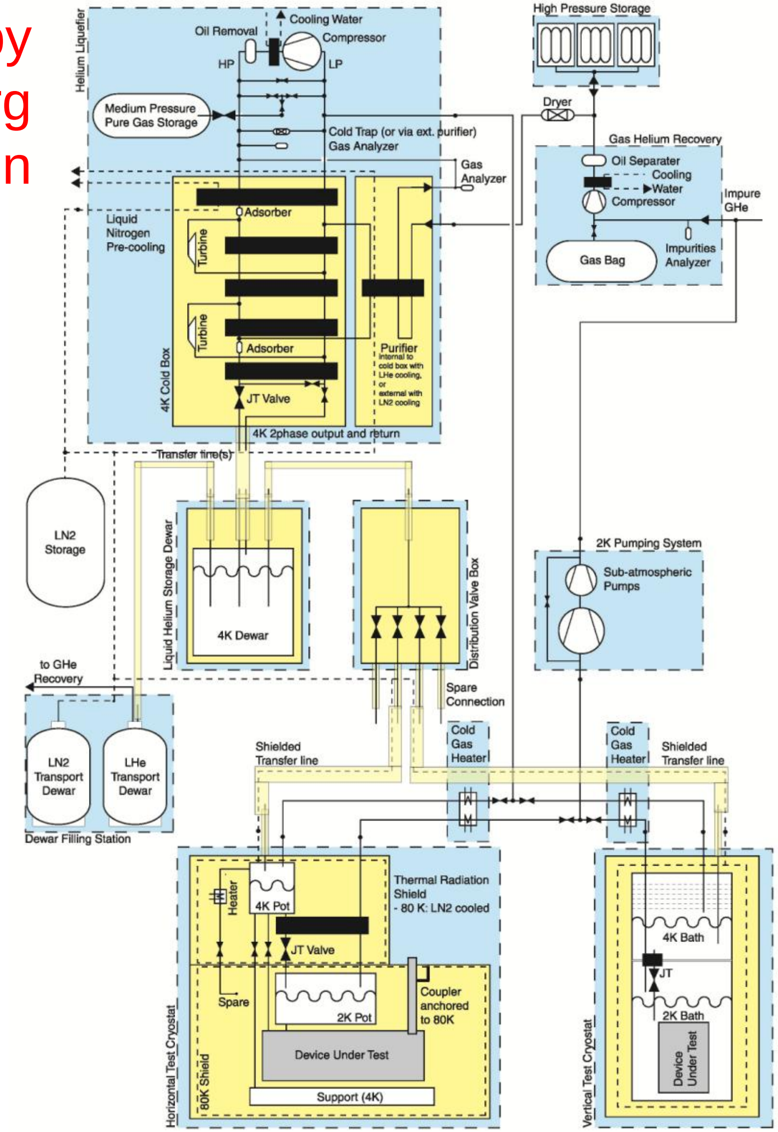


FREIA Cryogenic Centre

supported by Wallenberg foundation

- Multiple users
  - external users (dewars)
  - horizontal test cryostat
  - vertical test cryostat (future extension)
- Liquid nitrogen
  - 20 m3 tank
- Helium liquefier & recovery system
  - 140 l/h peak load at 4 K, 2000 l storage dewar
  - 80 m3/h recovery, 100 m3 gas balloon
  - ~8 g/s, 80 W peak load at 2 K





UU Responsibility for ESS Accelerator

UPPSALA UNIVERSITET

1) Contribution to the technical design & construction effort

- design concept 352 MHz spoke source
- design concept RF distribution
- survey test stand infrastructure and requirements
- study of upgrade scenarios RF systems for ESS power upgrade

2) Development 352 MHz RF power station for spokes

- soak test with water load and SRF spoke resonator, incl. LLRF
- collaboration with industry to develop tetrode and solid-state based prototypes

3) System test, RF power station with spoke cavity and cryomodule

- fully dressed prototype cavity (in test cryostat)
- complete prototype cryomodule (2 cavities)

4) Acceptance test spoke cryomodules (EoI submitted)

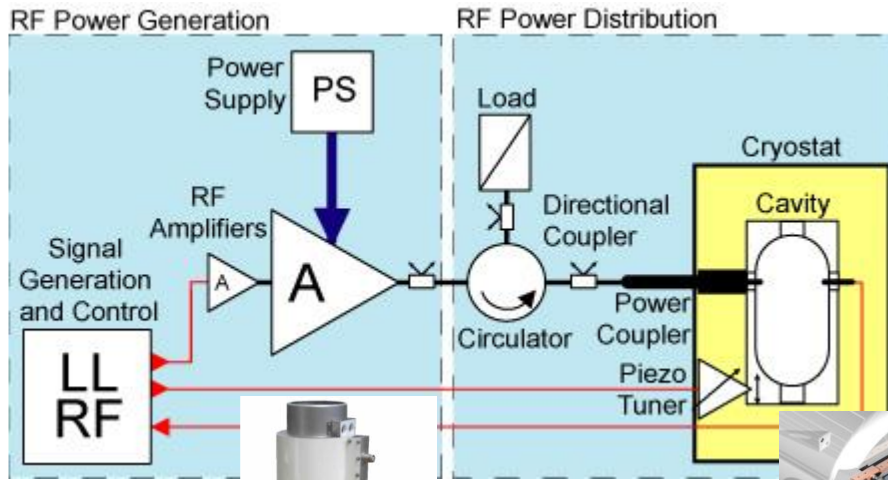
- for all final cryomodules before installation

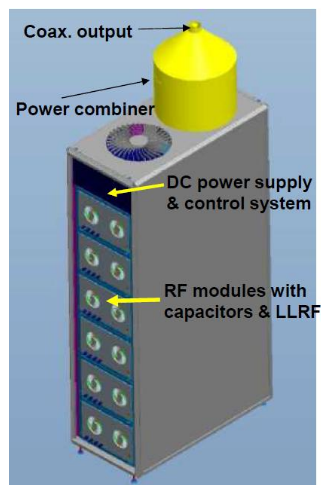
Test Stand Matrix		f	P	prototype				series			
				low power		high power		low power		high power	
		[MHz]	[kW]	where	when	where	when	where	when	where	when
P0	Cavities										
	ion source	--	--	LNS		LNS				on site	
	LEBT buncher	352	10	LNS ?		LNS ?				on site	
	RFQ	352	1000	CEA		CEA				on site	
	MEBT	--	--	ESS-B ?		ESS-B ?				on site	
	DTL	352	2100	LNL		CERN (Linac4)				on site	
	double spoke	352	240	IPNO		**UU**	2014/5	??		--	
	medium beta	704	500	CEA		CEA		DESY ?		--	
	high beta	704	900	CEA		CEA		DESY ?		--	
P1	Couplers										
	double spoke	352	800	IPNO		CEA		??		??	
	medium beta	704	650	CEA ?		CEA		??		??	
	high beta	704	1200	CEA		CEA		??		??	
P2	RF System										
	modulator	--	5600	--	--	ESS		--		ESS	
	NC linac	352	2800	--	--	ESS		--		ESS	
	double spoke	352	300	--	--	**UU**	2014	--		ESS	
	medium beta	704	600	--	--	ESS		--		ESS	
	high beta		1200	--	--	ESS		--		ESS	
P3	Cryomodule										
	double spoke	352	2x 300	IPNO		**UU**	2015/6	IPNO		**UU**	2017/8
	medium beta	704	4x650	CEA	--	CEA	--	CEA/ESS		ESS	
	high beta	704	4x1200	--	--	--	--	CEA/ESS		ESS	

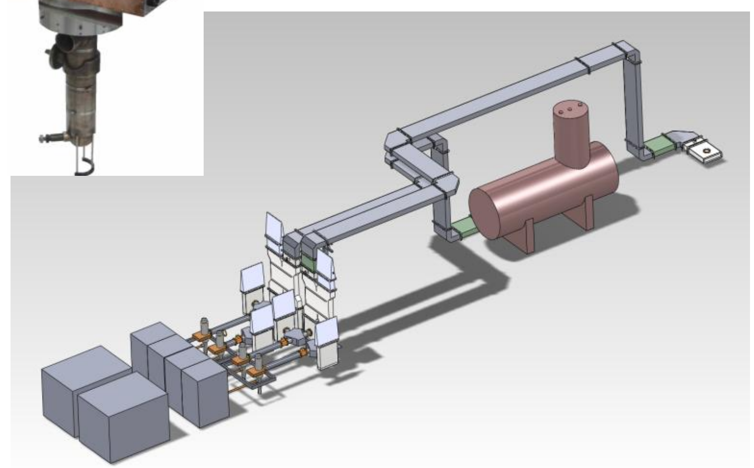
FREIA 352 MHz RF Source

RF source development

- 350 kW power amplifier
  - for FREIA testing (2pc)
  - for ESS linac (26pc)
- tetrode based: 2xTH595
  - commercial available solution
  - confirmed >200 kW per tetrode
  - soak test at FREIA
- solid-state based:
  - commercial development
  - promises high MTBF, low MTTR
  - soak test at FREIA





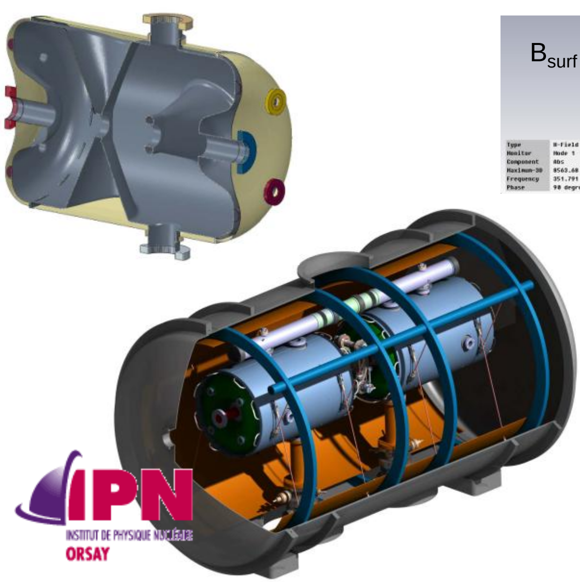


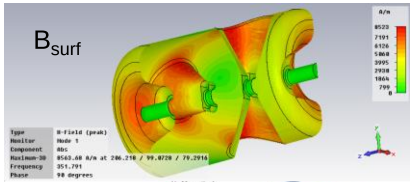
Approved Projects

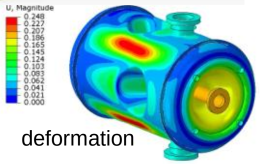
ESS Spoke Linac

High power test RF system, spoke cavity and cryomodule

- high power testing of RF power source, LLRF controls, amplitude and phase stability with cavity
- test cavity tuning system, dynamic load, electron emission and multipactoring







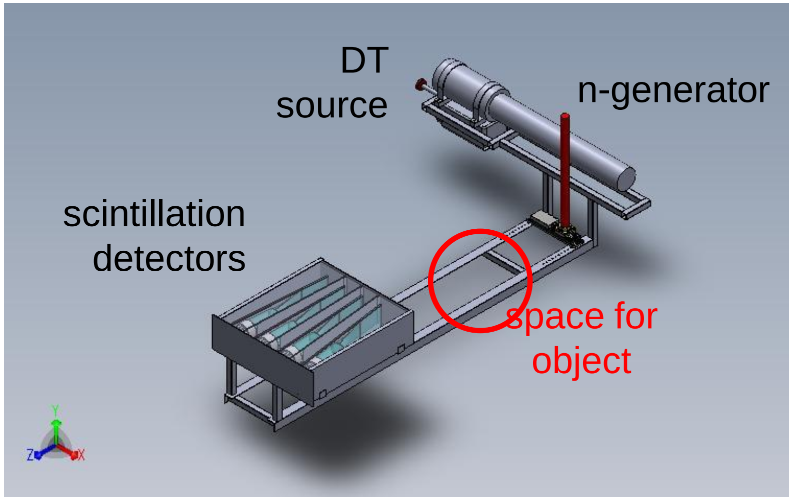
Peak fields @ 8 MV/m
- E_{surf} = 35 MV/m
- B_{surf} = 56 mT

Deformation 0.25 mm
Cryo loss = 15 W

Neutron Generator

Access to neutrons

- neutron tomography and detector tests
- student exercises and projects
- physics experiments in combination with Ge gamma-detector
  - – nuclear fission
  - – activation analysis



Control System Overview

EPICS

- EPICS
- Subsystems
  - Cryogenics (Linde)
  - Test cryostat (CryoDiffusion)
  - Vacuum
  - RF Power Supplies & Amplifiers (Electrosys)
  - LLRF (LU)
  - Timing
  - Safety systems (MPS, PPS)
- Instrumentation
- Control System Studio

Subsystems

- **Cryoplant (Linde)**
  - Local controls based on Siemens Simatic S7-315 PLC
  - Has local controls and interface to EPICS
- **Cooling water**
  - Pumps
  - Valves
  - PLC controller

- **RF Power Supplies & Amplifiers (Electrosys)**
  - Anode PS
  - Control Screen PS, Grid Screen PS
  - Filament PS
  - Solid State Amplifier

Controlled locally by microcontroller and interfaced to Epics via Ethernet. Digital input/outputs for overall status and interlocks

LLRF

- **LLRF**
  - **Initial solution for tests on a dummy load**
    - Function generator
    - Digital oscilloscope
    - Vector network analyzer
    - LabView
  - **Final solution for the cavity tests**
    - LLRF system supplied by ESS based on system developed at DESY

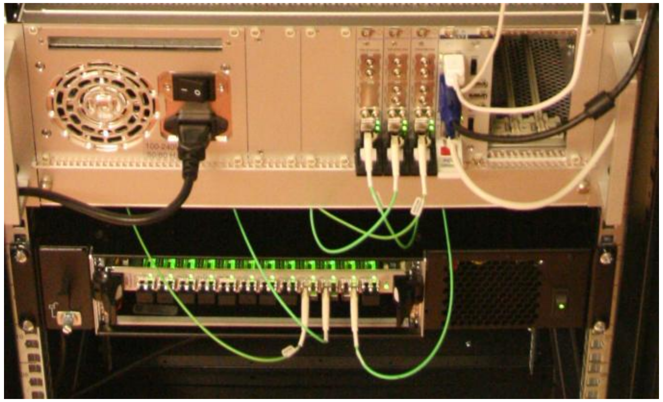
Timing system

- **Timing**

Event generator

Micro-Research cPCI-EVG-230

- Front panel RF input and programmable divider /1, /2, /3, ..., /12, /14, ..., /20 to generate event clock
- Event clock rate 50 MHz to 125 MHz
- Front panel mains synchronization input
- 4 hardware inputs
- Optional side-by-side module for additional 6 inputs
- Up to 255 events
- Heart-beat
- Can be used for distribution of interlock signals



Event receiver

Micro-Research cPCI-EVR-230

- 2 front panel trigger inputs
- 2 universal I/O slots for four hardware outputs
- Optional side-by-side module for three additional universal I/O slots
- Jitter typically < 25 ps rms
- RF Clock 88.052500 MHz
- Event granularity ~110 ns

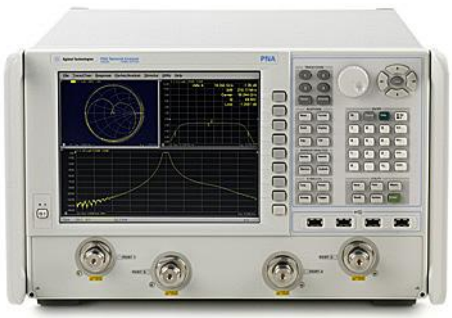
Safety Systems

- **M**achine **P**rotection **S**ystem
  - PLC for the ”slow” interlocks – tenths of ms
  - Fast interlocks implemented in hardware
  - Interlock distribution possible on the timing system bus
  - Post mortem data

- **P**ersonnel **P**rotection **S**ystem
  - Radiation protection system
  - Access control
  - RF leakage interlock

Instrumentation

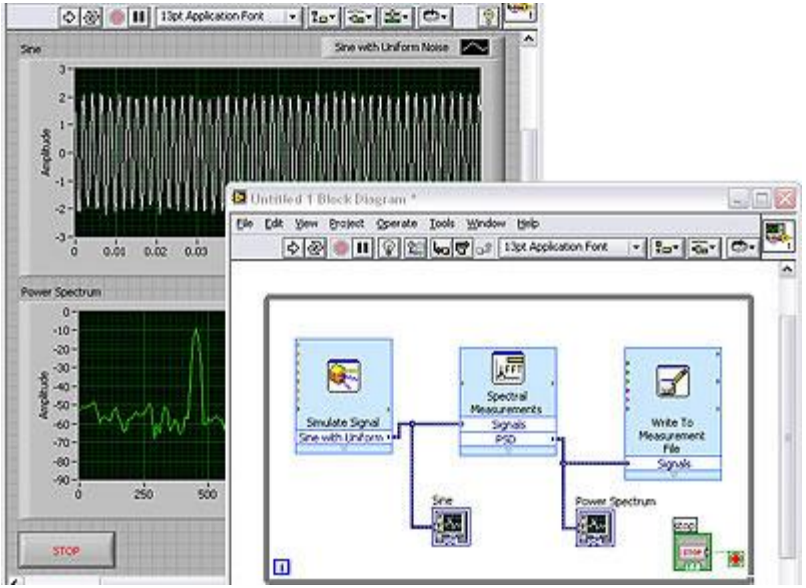
- Laboratory instruments
  - Digital oscilloscopes
  - Vector Network Analyzer with power measurement probes (Agilent N5221A)
  - Signal generators



Agilent Technologies

- Programmed with LabVIEW

NATIONAL INSTRUMENTS LabVIEW

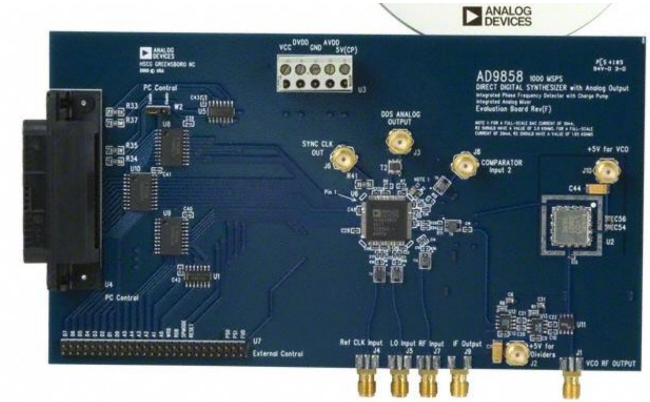


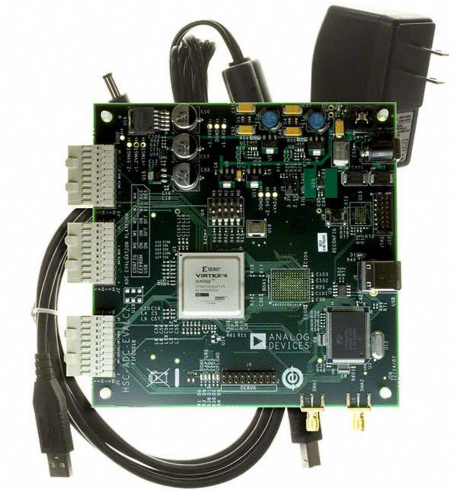
- Integrated with EPICS

Instrumentation

- Fast ADC for directly sampling the signals from the directional couplers and cavity antenna
  - sampling at 150 MSa/s, 14 bits,
  - input bandwidth > 400 MHz
  - no need for mixers
  - inexpensive system

- Direct digital synthesizer (DDS) for generating RF signal to the cavity





Instrumentation

- NI PXIe based system
  - Fast ADC
  - FPGA

Chassis Controller Instrument Modules

Specification	NI PXIe-5160			NI PXIe-5162		
Variant	Good	Better	Best	Good	Better	Best
Form Factor	PXIe (x4)			PXIe (x4)		
ADC Resolution	10-bit			10-bit		
Onboard Memory	64 MB	2 GB	2GB	64 MB	1 GB	1 GB
Number of Channels	2	2	4	2	2	4
Sample Rate (4 Channel)	N/A	N/A	1.25 GS/s	N/A	N/A	1.25 GS/s
Sample Rate (2 Channel)	2.5 GS/s			2.5 GS/s		
Sample Rate (1 Channel)	**2.5 GS/s**			5 GS/s		
Input Impedance	50 Ohm / 1 MOhm			50 Ohm / 1 MOhm		
Real-time Bandwidth (50 Ohm)	500MHz			1.5 GHz		
Real-time Bandwidth (1 MOhm)	300 MHz			300 MHz		
Input Ranges (50 Ohm)	50, 100, 200, 500 mV 1, 2, 5 V			50, 100, 200, 500 mV 1, 2, 5 V		
Input Ranges (1 MOhm)	50, 100, 200, 500 mV 1, 2, 5, 10, 20, 50 V			50, 100, 200, 500 mV 1, 2, 5, 10, 20, 50 V		
Coupling	AC/DC			AC/DC		
Selectable Filters	20 MHz, 175 MHz			20 MHz, 175 MHz		

Summary

Infrastructure

- Experimental area approx. 700 m^2
- Cryogenic plant (LHe)
  - peak140 l/min at 4 K
  - 2000 l storage dewar
  - 80 W peak load at 2 K
- Available electrical power 900 kVA
- Cooling capacity (deionized water) 600 kW
- 3 concrete bunkers
- 352 MHz, 350 kW RF power station
- 352 MHz RF distribution
- Horizontal test cryostat
- Place for vertical cryostat

Control System

- Based on Epics
- Subsystems with autonomous local controllers integrated with Epics
- Use of PLC systems wherever possible
- Use of ESS' Control Box for faster controls and timing
- Laboratory instruments programmed with LabVIEW
- Fast measurements (RF signals) using NI PXIe system and LLRF