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IOT OPERATIONAL EXPERIENCE ON ALICE AND EMMA AT DARESBURY LABORATORY

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ESLS XVIII Workshop, ELLETRA

25th – 26th November 2010

Alice Accelerators and Lasers in Combined Experiments

BASROC CONFORM

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    - Accelerators and Lasers In Combined Experiments
  - EMMA
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- IOT Operational Experience
  - ALICE
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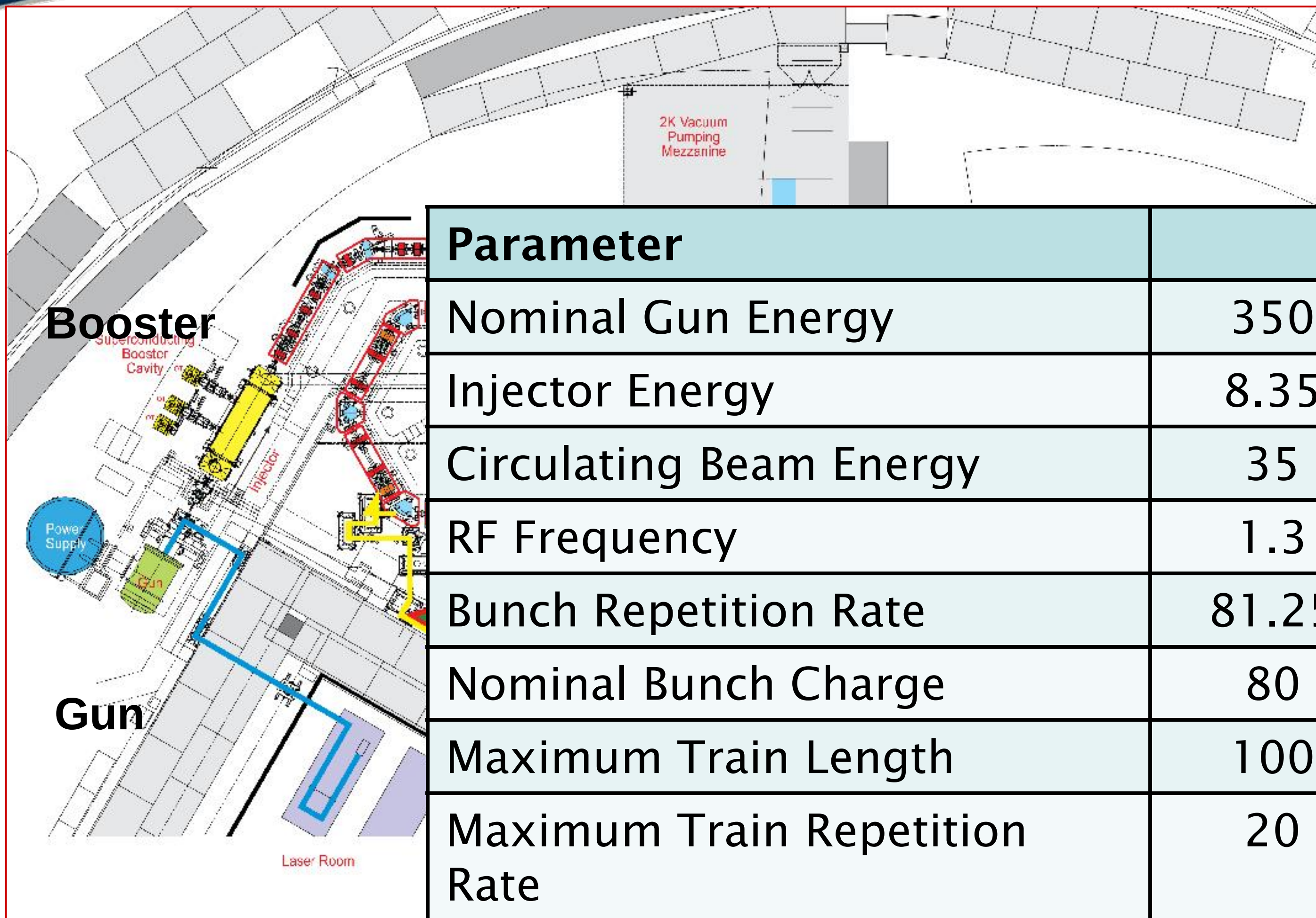
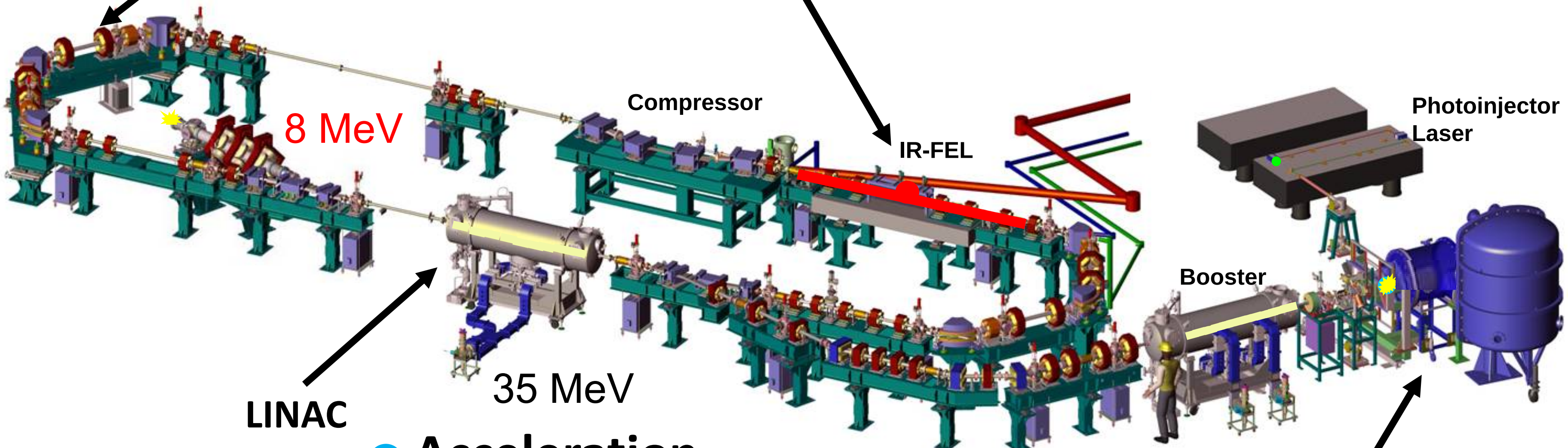
- Summary

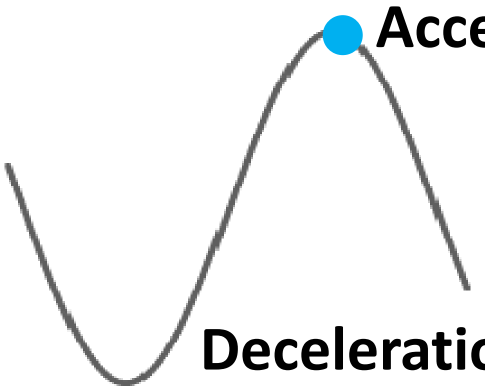
The ALICE Complex



Parameter		Units
Nominal Gun Energy	350	keV
Injector Energy	8.35	MeV
Circulating Beam Energy	35	MeV
RF Frequency	1.3	GHz
Bunch Repetition Rate	81.25	MHz
Nominal Bunch Charge	80	pC
Maximum Train Length	100	µS
Maximum Train Repetition Rate	20	Hz
Maximum Average Current	13	µA

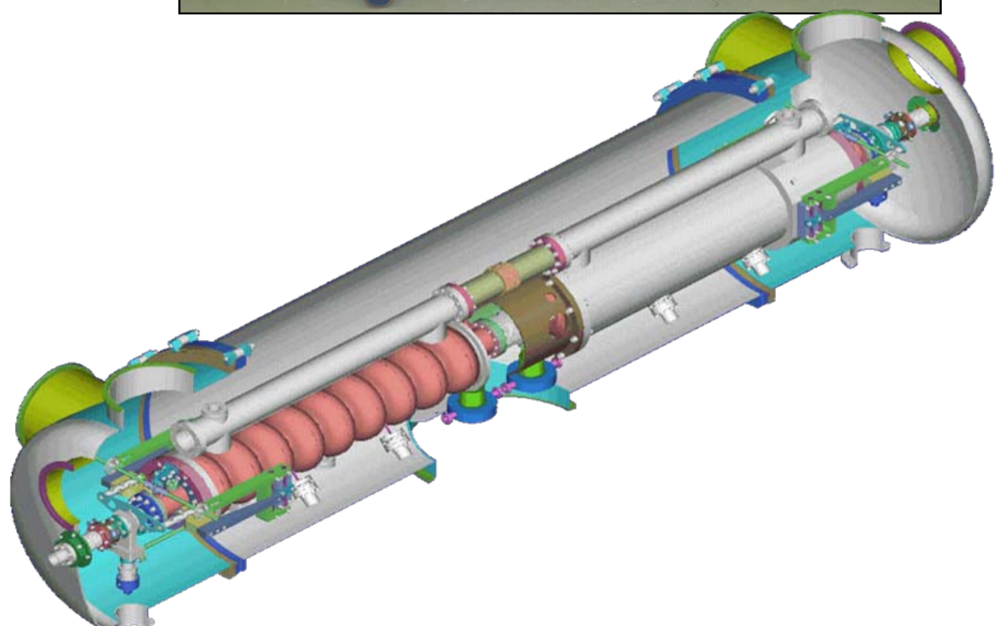
Energy Recovery Linac



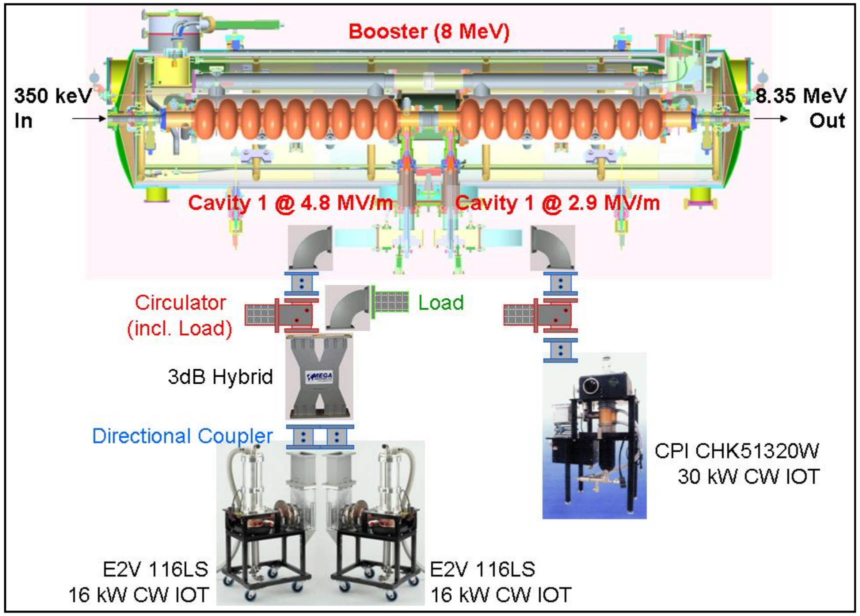


SRF Modules

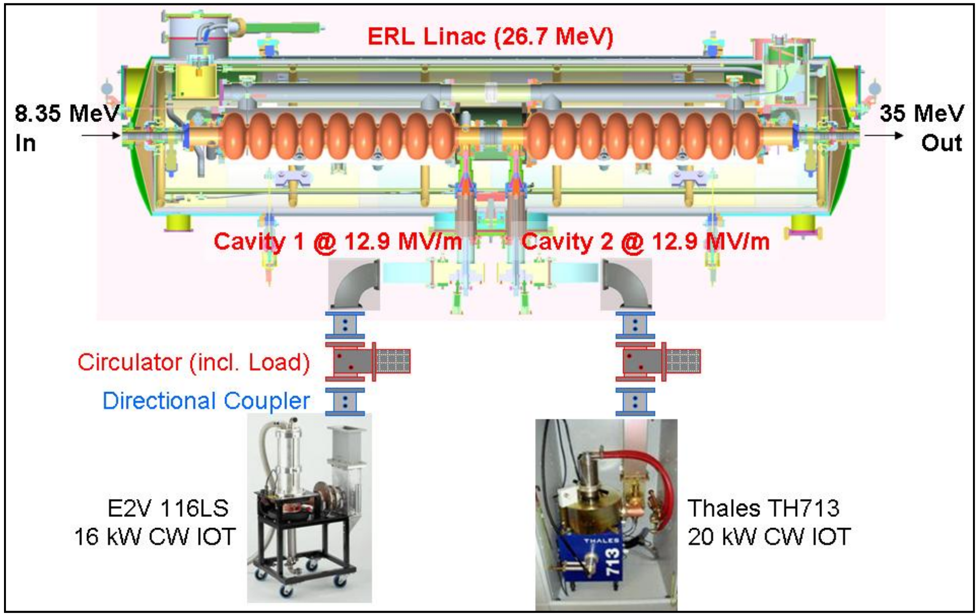
- 2 x Stanford/Rossendorf cryo-modules
  - 1 Booster and 1 Main LINAC.
- Fabricated by ACCEL.
- Booster module:
  - 8 MeV gradient.
  - 52 kW RF power.
- Main LINAC module:
  - 27 MeV gradient.
  - 13 kW RF power.



SRF Modules



Booster (8 MeV)
350 keV In
8.35 MeV Out
Cavity 1 @ 4.8 MV/m
Cavity 1 @ 2.9 MV/m
Circulator (incl. Load)
Load
3dB Hybrid
Directional Coupler
CPI CHK51320W 30 kW CW IOT
E2V 116LS 16 kW CW IOT
E2V 116LS 16 kW CW IOT



ERL Linac (26.7 MeV)
8.35 MeV In
35 MeV Out
Cavity 1 @ 12.9 MV/m
Cavity 2 @ 12.9 MV/m
Circulator (incl. Load)
Directional Coupler
E2V 116LS 16 kW CW IOT
Thales TH713 20 kW CW IOT

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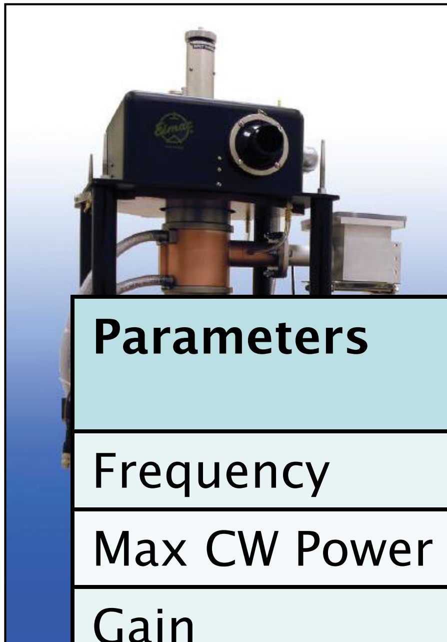
IOT RF Power Sources

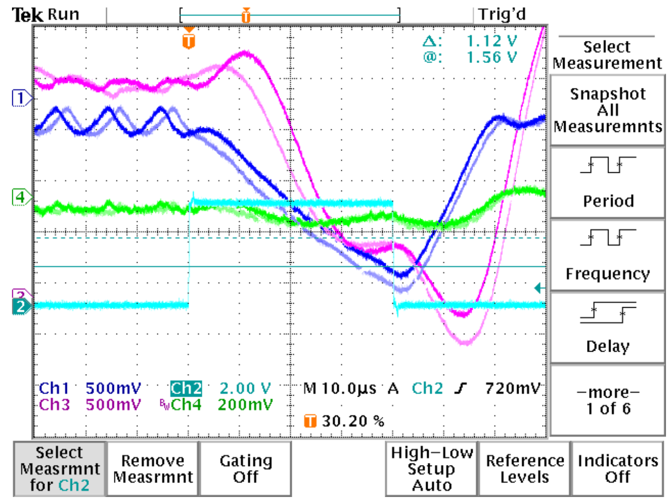
CPI K51320W | **e2v IOT116LS** | **Thales TH713**

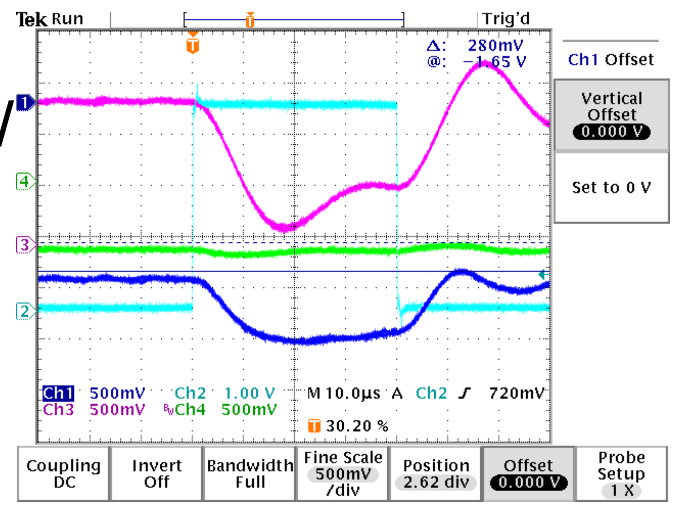


Parameters	CPI K51320W	e2v IOT116LS	Thales TH713	Units
Frequency	1.3	1.3	1.3	GHz
Max CW Power	30	16	16	kW
Gain	21	>20	20.9	dB
Beam Voltage	34	25	25	kV
Bandwidth	4.5	>4	>5	MHz
Efficiency	63.8	>60	60.4	%

IOT Operation

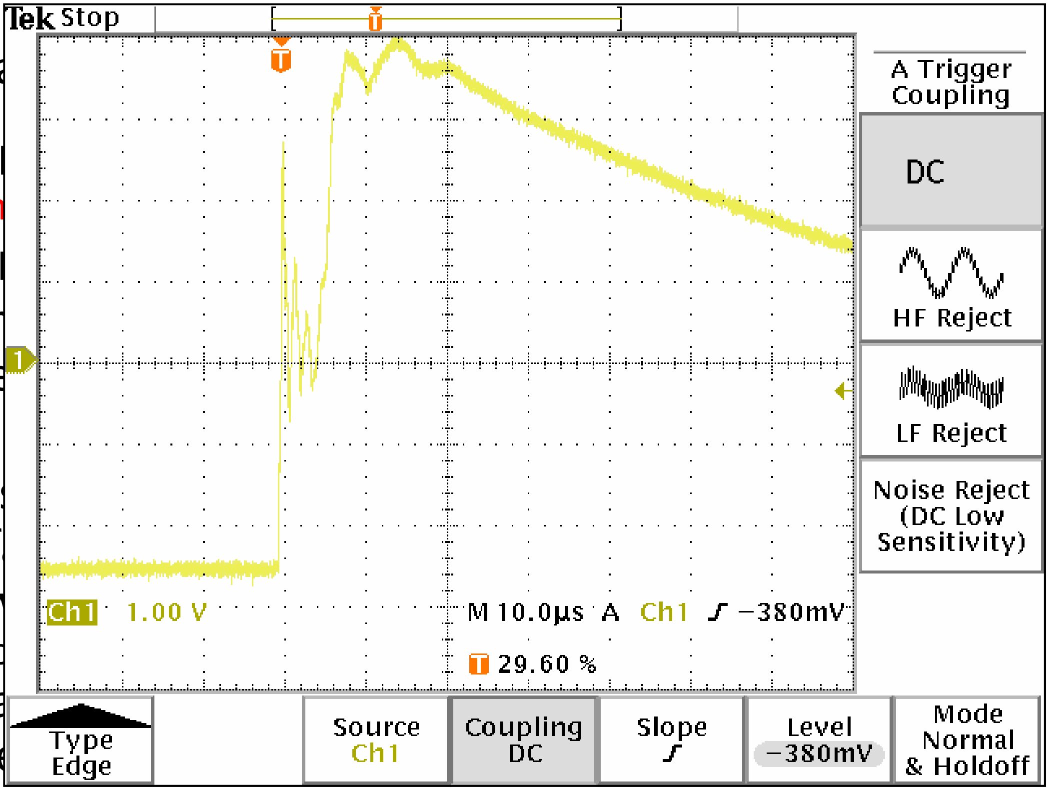
- Operational for 3 years
  - Typically 16 hours/day
  - Approximately 6 months/year
- All IOTs powered from a single 50kV power supply
  - HV limited to ~28kV
  - CPI IOT limited to ~ 21kW
- RF Requirement
  - Initially a 18mS pulse @ 10Hz
  - Now a 5ms pulse @10Hz





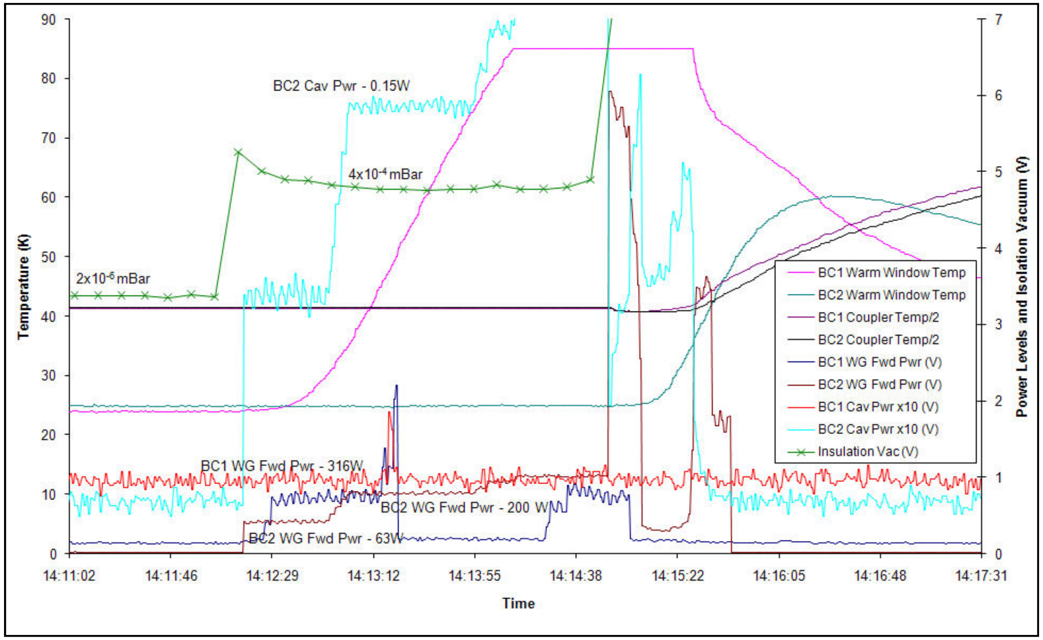
Operational Reliability Issues

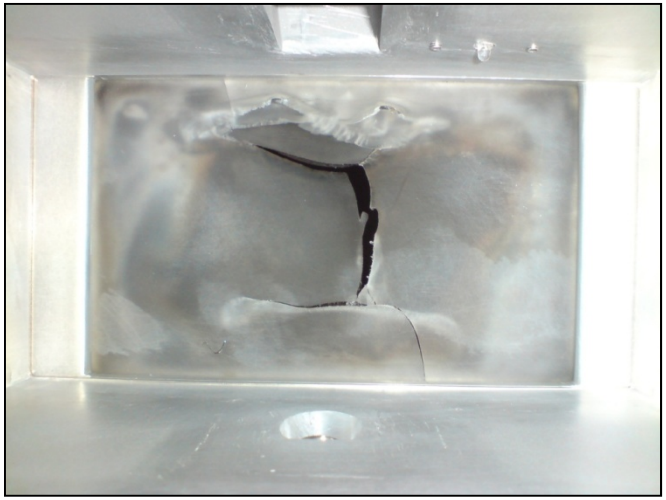
- Numerous ancillary power supplier failures
  - Grid, filament and ion pump supplies
- Single 50kV HVPS
  - Stored energy issues under fault conditions due to long HV cable runs (~60m)
  - Various types of IOTs ha
    - Filament settings
    - Ion pump reference (cat
    - Wiring could not be stan
- Extensive crowbar testi
  - Individual IOTs and com
  - Earthing issue discovere
- Reliable operation with
  - Grid and heater supplie
  - Spare HV cable + ultra f
  - In house grid supplies w
    - Improved output isolati
  - Grid protection diodes a
  - Spark gaps added betw



Isolation Window Failure

- Failure occurred with 300W of forward power!
- Booster fully inspected and cleaned
- No obvious failure mechanism discovered
- Failure similar to one at Rossendorf under CW conditions
- Improvements made to isolation vacuum interlocks
- Broadband RF detectors added to the reflected power monitoring





Booster Cavity 1

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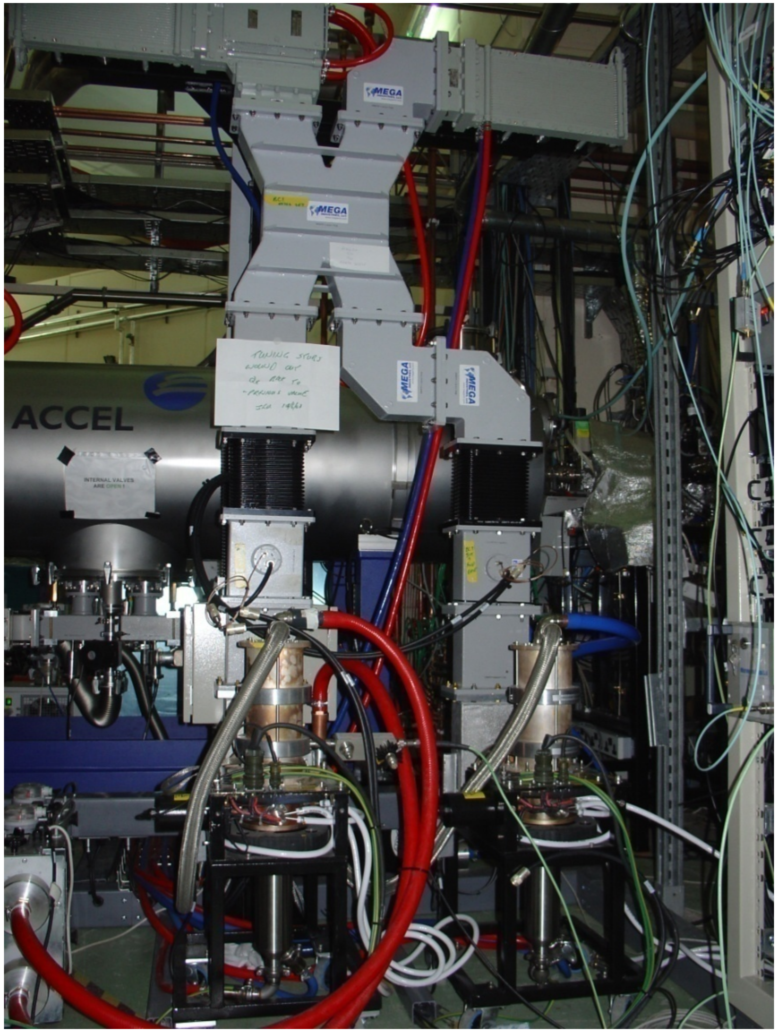
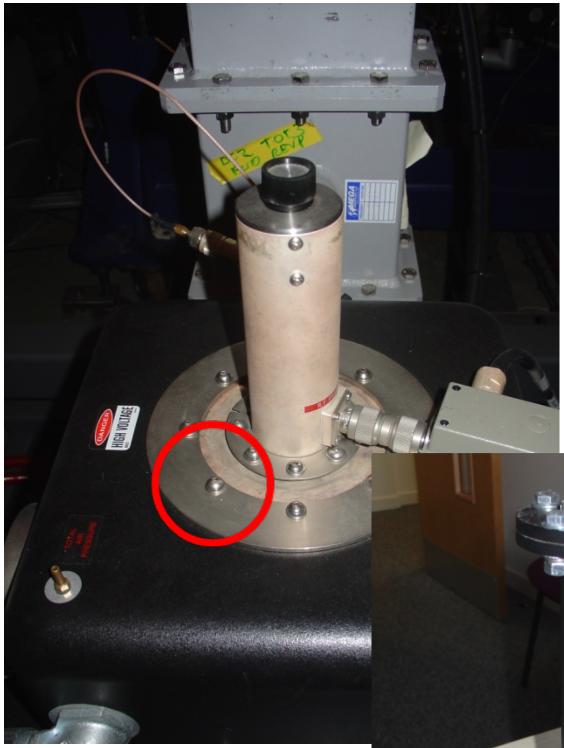
IOT Issues – e2v IOT116LS

- Tube failure
  - After ~18 months
- Tube gassed up on application of filaments
  - Tube unable to sustain HV
- Failure believe to be due to the tube being operated with too high a quiescent current
  - ⇨ Leading to a melted collector or body
  - ⇨ Poisoned cathode due Cu deposition
- Additional protection added to HV PLC
  - DC current trip level included HV PLC program
  - Individual IOT current monitoring



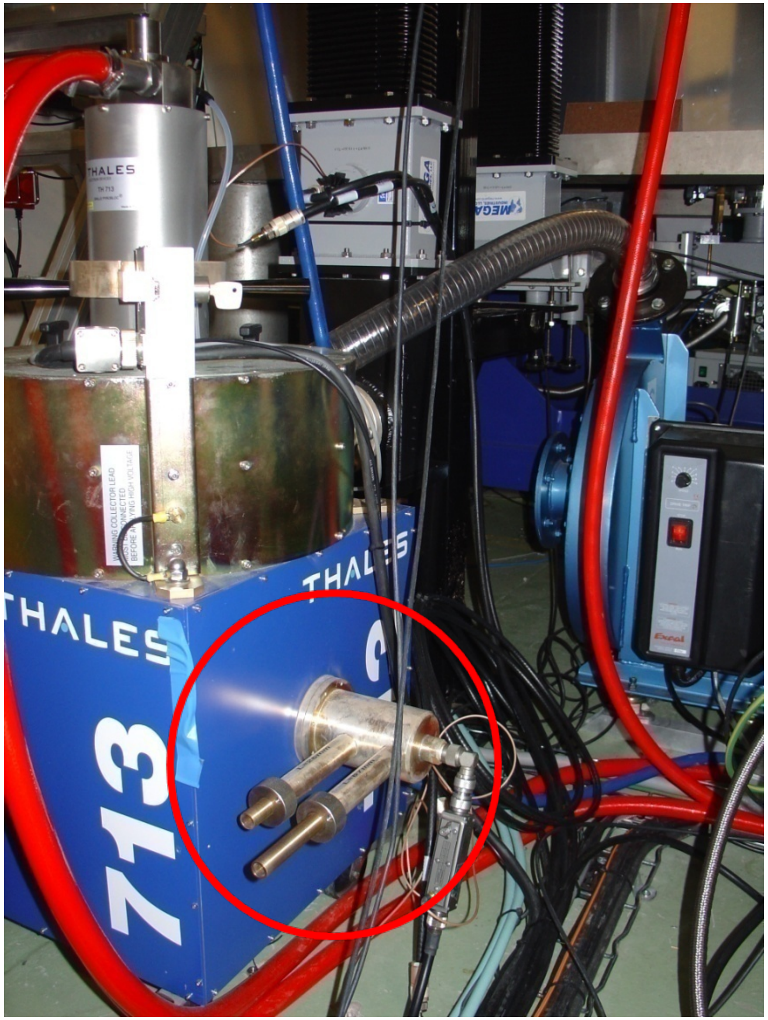
IOT Issues – CPI K51320W

- Issues encountered with loss of output power
- Discovered the input cavity had moved off frequency
  - Difficult to tune and maintain a good input return loss
- Similar issue encountered on spare IOT system
- Resolved by tuning the input whilst tightening the screws on the input base plate
- An improved input cavity has been supplied
  - To be installed and evaluated

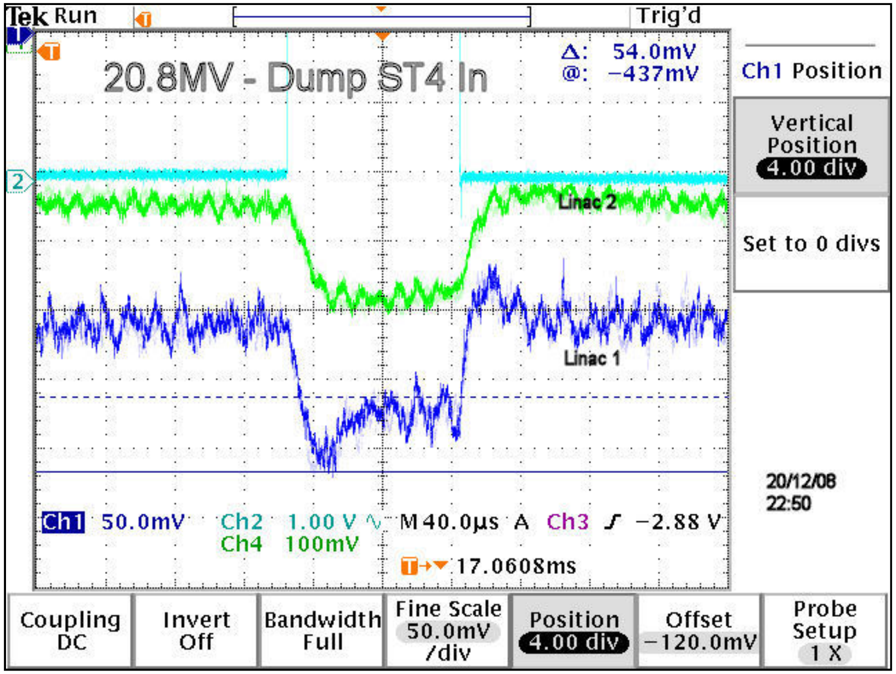


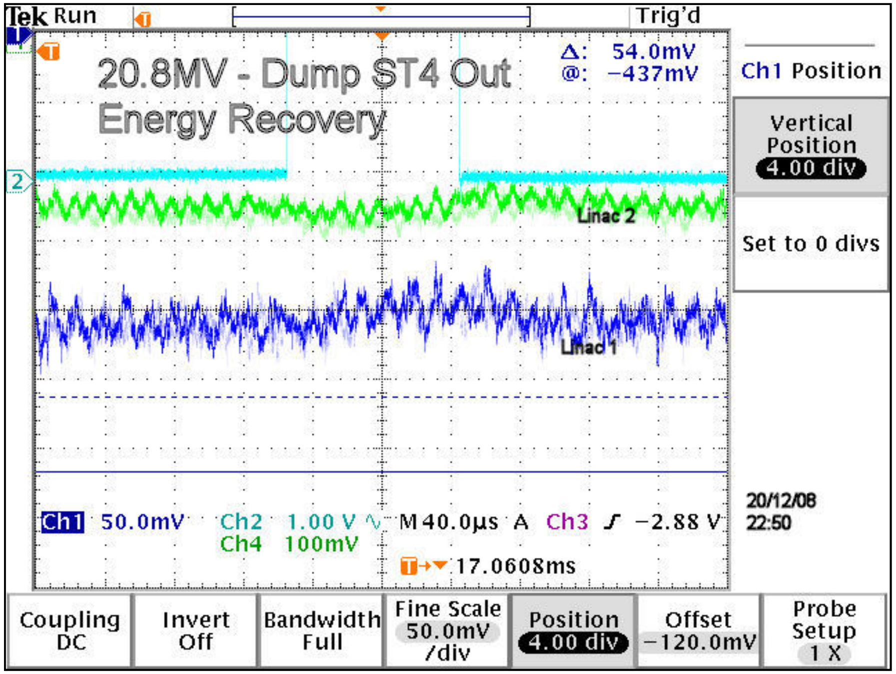
IOT Issues – Thales TH713

- Issues encountered with loss of output power
- Input stub very sensitive to movement
  - Poor input match



Energy Recovery – 20.8MeV





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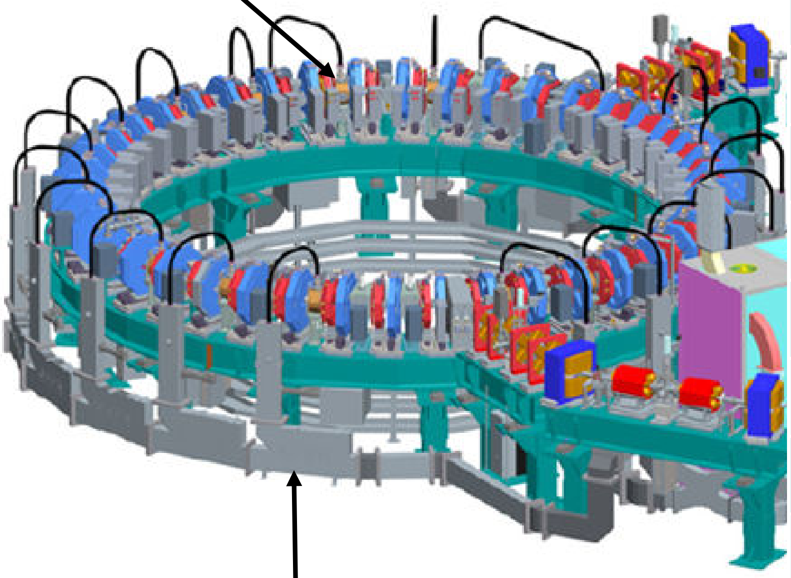
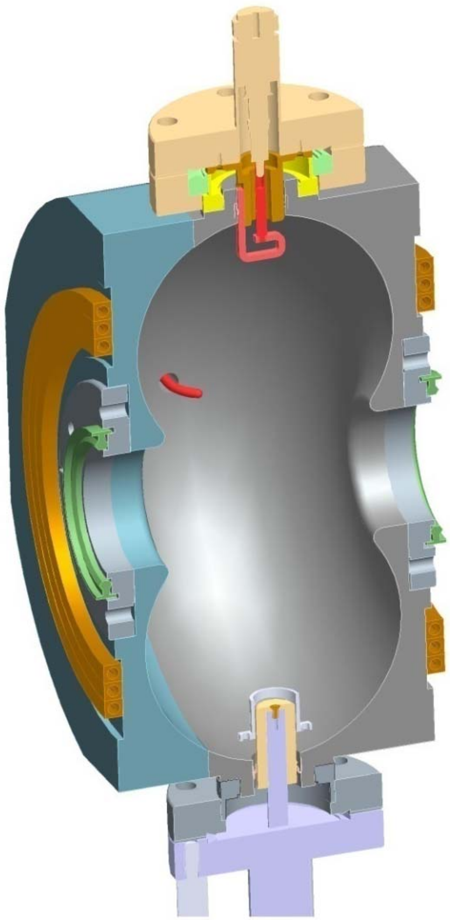
Electron Machine of Many Applications

- Proof of principal Non-Scaling Fixed Field Alternating Gradient Accelerator



Machine Parameters	Value	Units
Frequency	1.3	GHz
Number of Straights	21	
Number of Cavities	19	
Total Acc per Turn	2.3	MV
Upgrade Acc per Turn	3.4	MV
Beam Aperture	40	mm
Pulse Length	1.6	mS
RF Repetition Rate	5-20	Hz
Phase Control	0.3	°
Amplitude Control	0.3	%

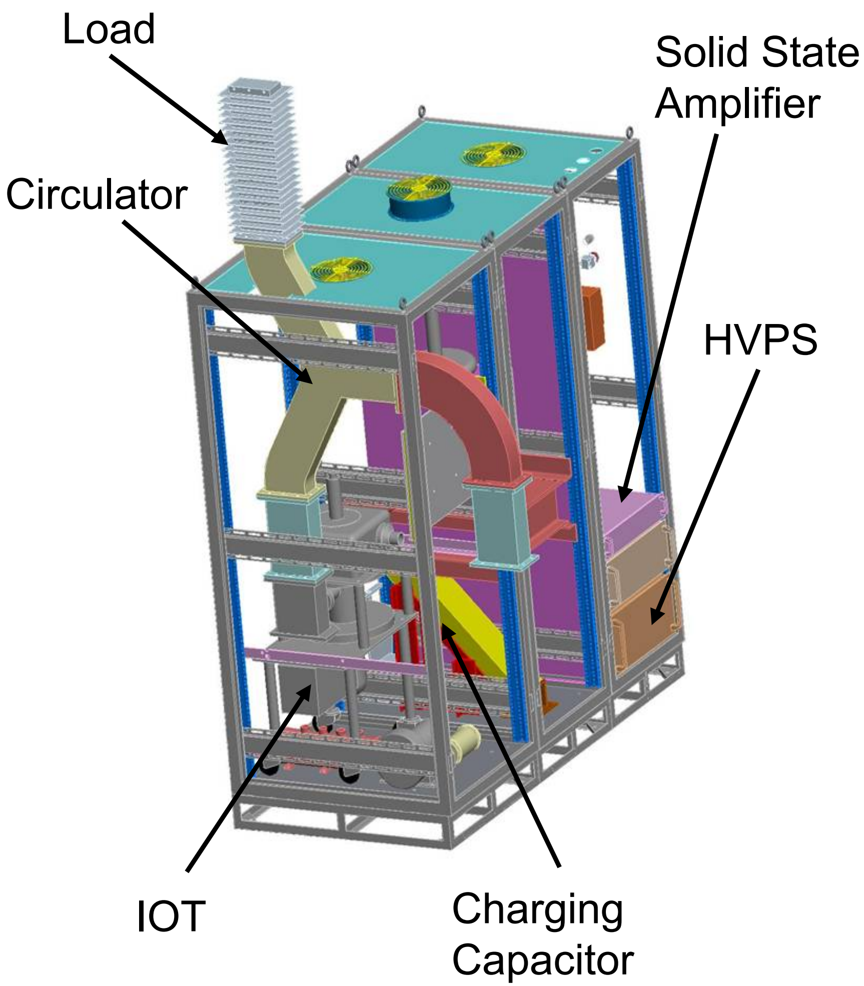
Cavity Design & Specification



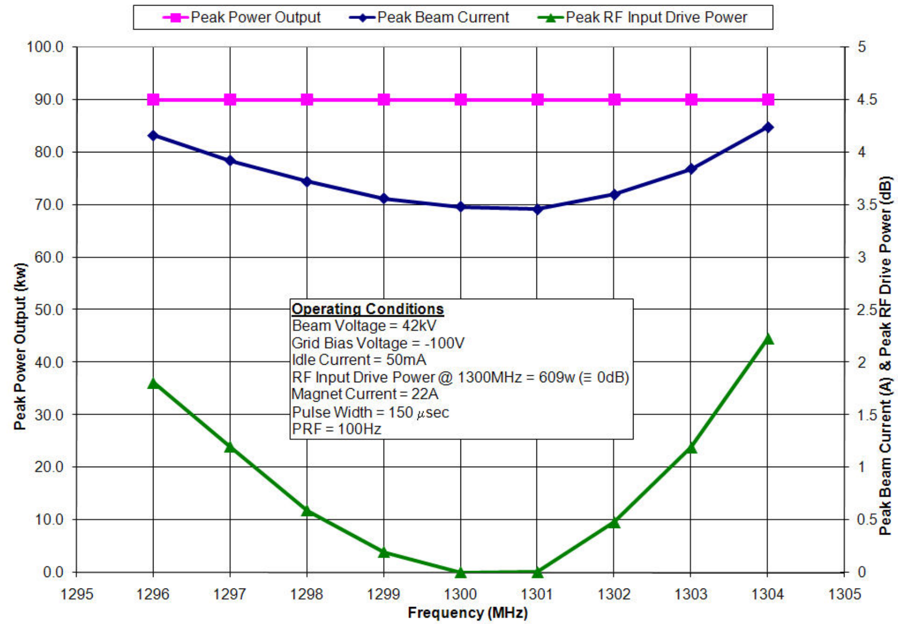
Parameter	Value	
Frequency (GHz)	1.3	
Shunt Impedance (MΩ)	2.5	
Realistic (80%)	2.0	
Qo	20,000	
R/Q (Ω)	100	
Tuning Range (MHz)	-4.0MHz to +1.5MHz	
V_{acc} (kV)	120	180
P_{diss} (kW)	3.6	8.5
Ptot incl 30% Overhead* (kW)	4.7	11.1

* LLRF + Distribution

High Power RF Amplifier



- CPI's VIL409 Heatwave™ IOT-based RF high power amplifier
- 50kV capacitor charging power supply
- 90 kW CPI IOT (VKL9130B)
- 1.5 kW solid state amplifier produced by Bruker, (BLA1500 RF SSPA)
- Embedded processor providing:
  - System control
  - Interfacing with the EMMA EPICS control system

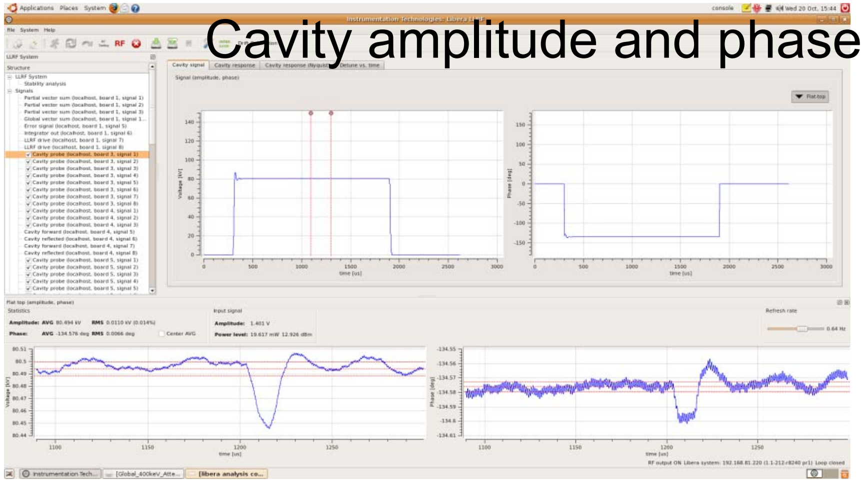


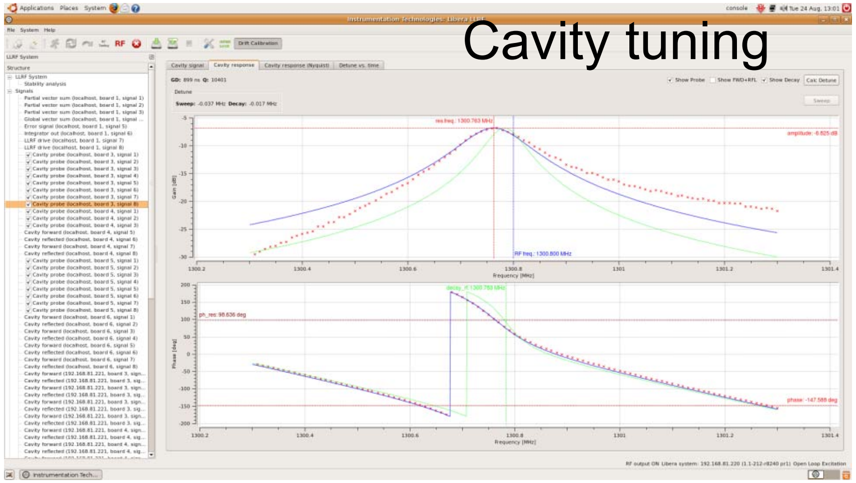
IOT Operational Experience

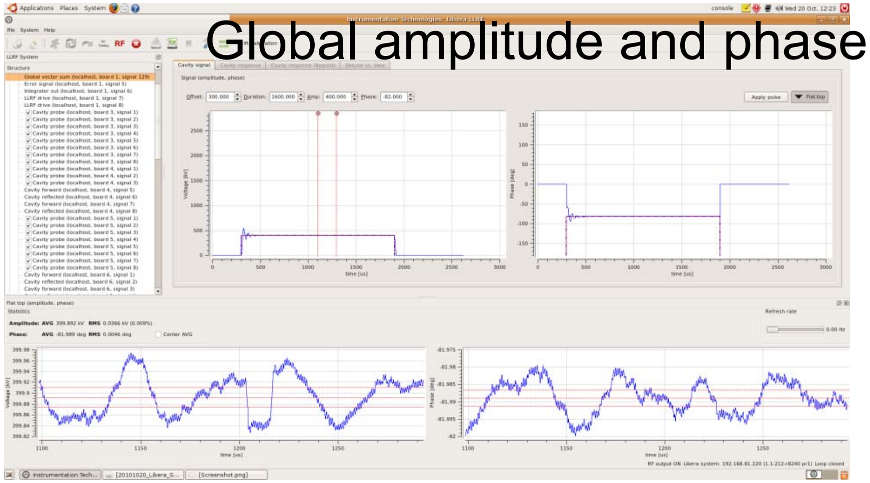
- VKL9130B IOT was developed specifically for EMMA broadband application
  - 90kW peak power
  - 1.6ms pulse, 1 – 20Hz
  - 1.2960 – 1.3015GHz
- Installation and site acceptance completed 2nd October 2009
- Presently commissioning EMMA
- IOT typically run at <30kW at 1.3 and 1.301GHz.
- Operating at 3Hz due kicker power supply limitation
- To date no operational issues with the IOT
- During system testing at CPI, the input cavity was replaced for a new one
  - An improved design spare was also supplied, but not yet installed

EMMA Operation

- RF system commissioned in 3-days
- Cavity phasing
  - Co-phasing initially set roughly using the known phase offset due to the ToF.
  - Individual cavity phase set by beam loading analysis using Libera LLRF system
  - Global phase analysed
- 1000s of turns with no RF
- 10s -100s of turns with RF







Summary & Future Plans

ALICE

- Experience gained in the operation of 3 types of IOTs
  - Reliability issues experienced
- Reliability of HVPS and ancillary systems improved
- RF protection systems improved
- Energy Recovery achieved
- Future work:
  - Linac replacement: DICC 7-cell cryomodule to be installed 2011
  - Replacement of CPI input
  - Development and testing of a digital LLRF system

EMMA

- Commissioning on-going
- Future work:
  - Optimisation of the RF system for operation
  - Develop the RF set-up
  - Increase RF power