LEHIPA: A Control System Perspective

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Plan of Talk

- **Introduction to LEHIPA**
- **LEHIPA Control System**
- **EPICS in LEHIPA Control System**
- **Future Plans**

LEHIPA

- Low Energy High Intensity Proton Accelerator (LEHIPA)
- 20 MeV 10 mA Proton beam
- Front end of Accelerator Driven System(ADS)
- Successfuly commissioned on August 2023
- EPICS is used in the Control System.

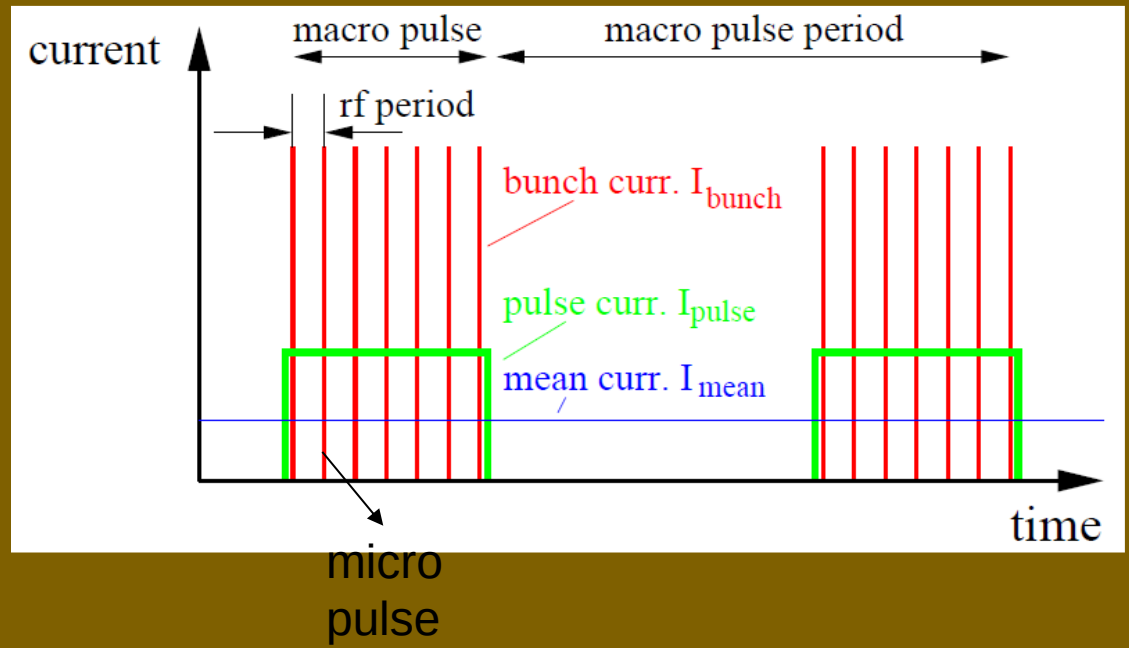
LEHIPA – Important Parameters

Maximum Proton Beam Energy :	21 MeV.
Maximum Beam Power(Average) :	52.5 W.
Maximum RF Pulse Width:	250 us.
Ion Source Maximum Pulse Width:	1 ms.
RFQ RHVPS Pulse Width & Max Rep Rate	400 us / 2 Hz
DTL RHVPS-2 and RHVPS-3 Maximum Pulse Width & Max Rep Rate	200 ms / 4 Hz.
Maximum Peak RF Power for RFQ klystron	700 kW.
Maximum RF Power for DTL 1&2 klystron:	900 kW.
Maximum RF Power for DTL 3&4 klystron:	900 kW (Peak Power)
Maximum Forward Power Per Coupler(Peak Power):	350 kW
Maximum Peak Proton Current in RFQ and DTL	5 mA (Acelerated).
RHVPS Voltage:	Min: 60 kV , Max 95 kV
Vacuum:	RFQ and DTL 1X10-7 Torr or better. Elsewhere 1X 10-6 Torr or better.

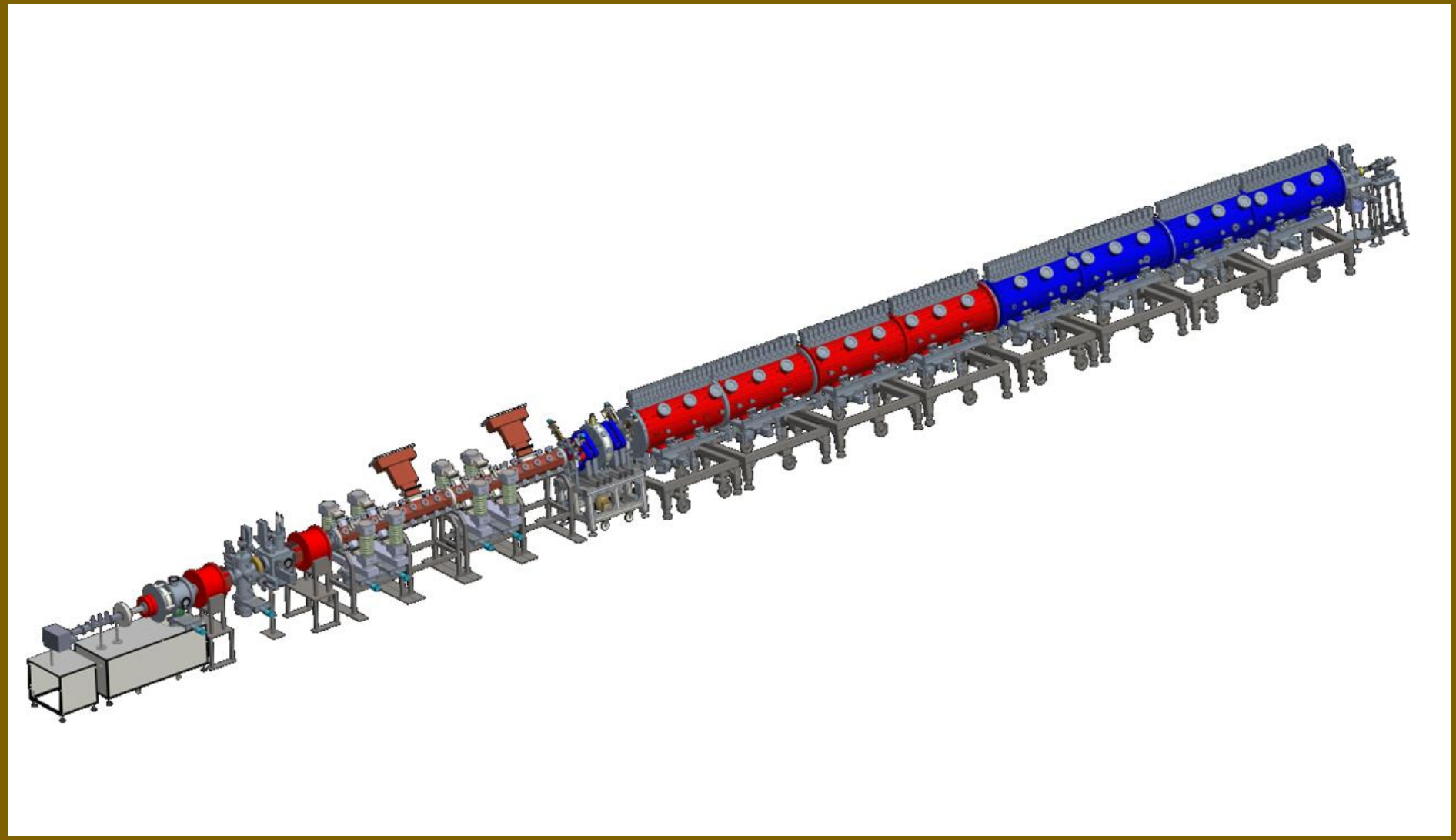
LEHIPA

- **Low Energy High Intensity Proton Accelerator (LEHIPA)**
- **20 MeV 10 mA Proton beam**
- **Successfuly commissioned on August 2023**

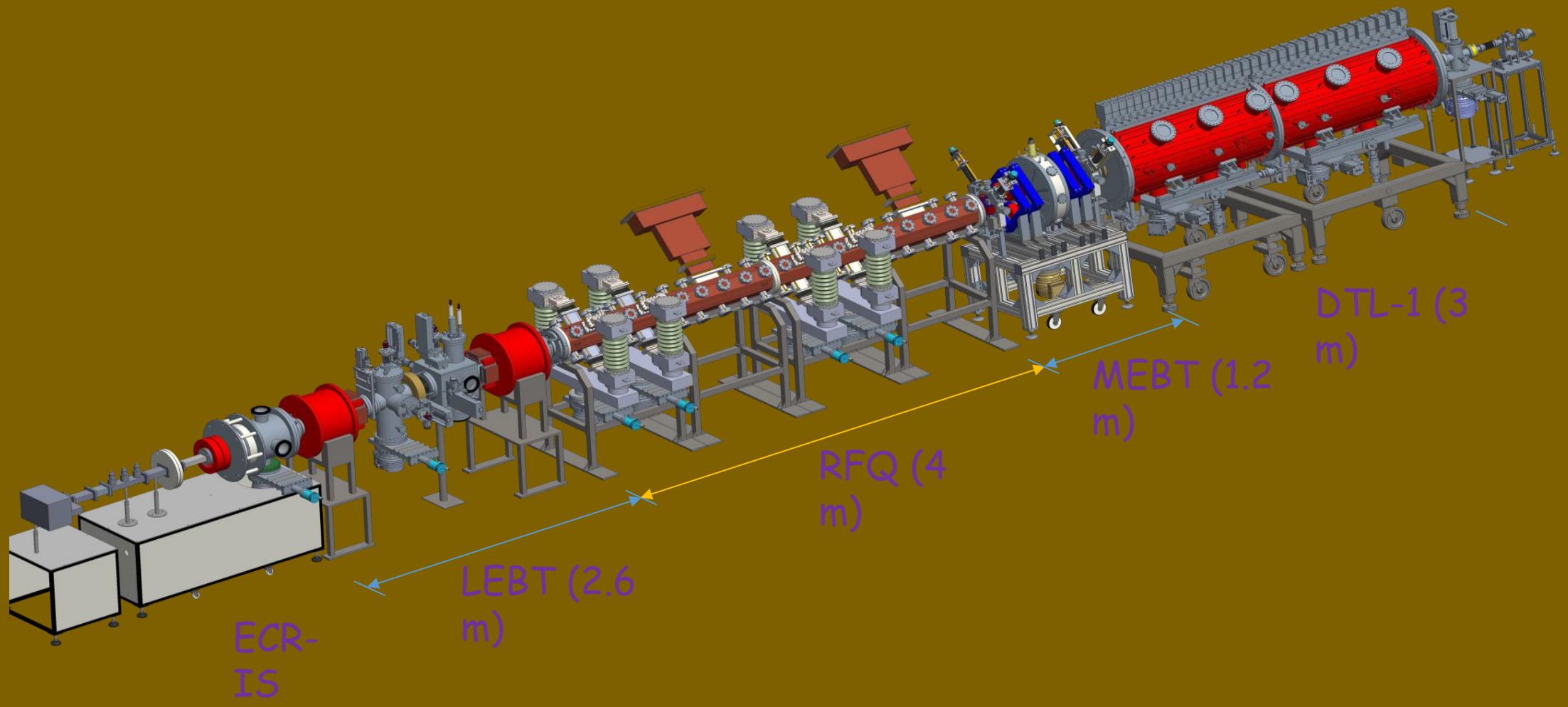
Parameter	Value
T_{RF} (352 MHz)	2.8 ns
Macro pulse width	100 µs
Synchronous Phase, Φ_s	-30^0
Micro pulse (Bunch) width	≤ 710 ps
RMS bunch width	~ 150 ps



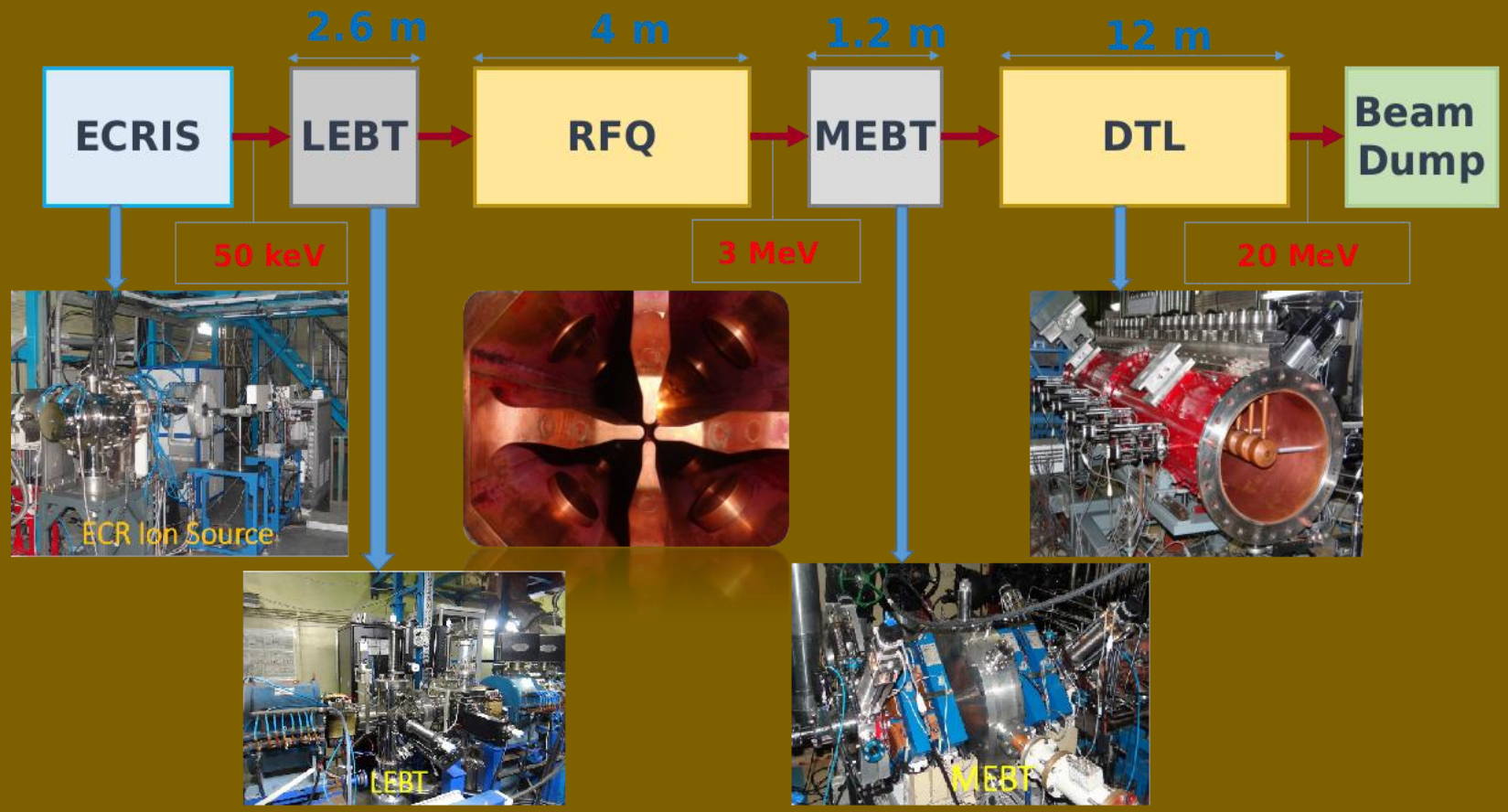
Layout of 20 MeV LEHIPA Facility



Layout of 20 MeV LEHIPA Facility



LEHIPA Subsystems



1. Ion Source
2. LEBT
3. RFQ
4. MEBT
5. DTL
6. BDS
7. Timing System
8. HPRF
9. SSRF
10. LLRF
11. LCW
12. VCIS
13. RHVPS
14. FPIS
15. OPIS

LEHIPA Auxiliary Subsystems

1. **Vacuum System**
   - **1E-7 Torr throughout the length without beam**
   - **1E-6 Torr with beam**
   - **TMP with roots pump as backing pump and SIP is used for pumping**
   - **Vacuum Control and Interlock information system is dealing with vacuum interlocks.**
2. **Cooling Water System**
   - **Low conductivity cooling water system is used to cool the components.**
3. **RF Power Generation System**
   - **352 MHz,1 Mw klystron generates RF power**
   - **Waveguide system transport the power to fed it in cavities.**
4. **DC Supply for RF Power Generation**
   - **Pulse modulator**
   - **Regulated High Voltage Power System**
5. **Beam Diagonistic System**
   - **Faraday Cup**
   - **Wire Scanner**

Subsystems of LEHIPA facility

RHVPS for DTL Klystron

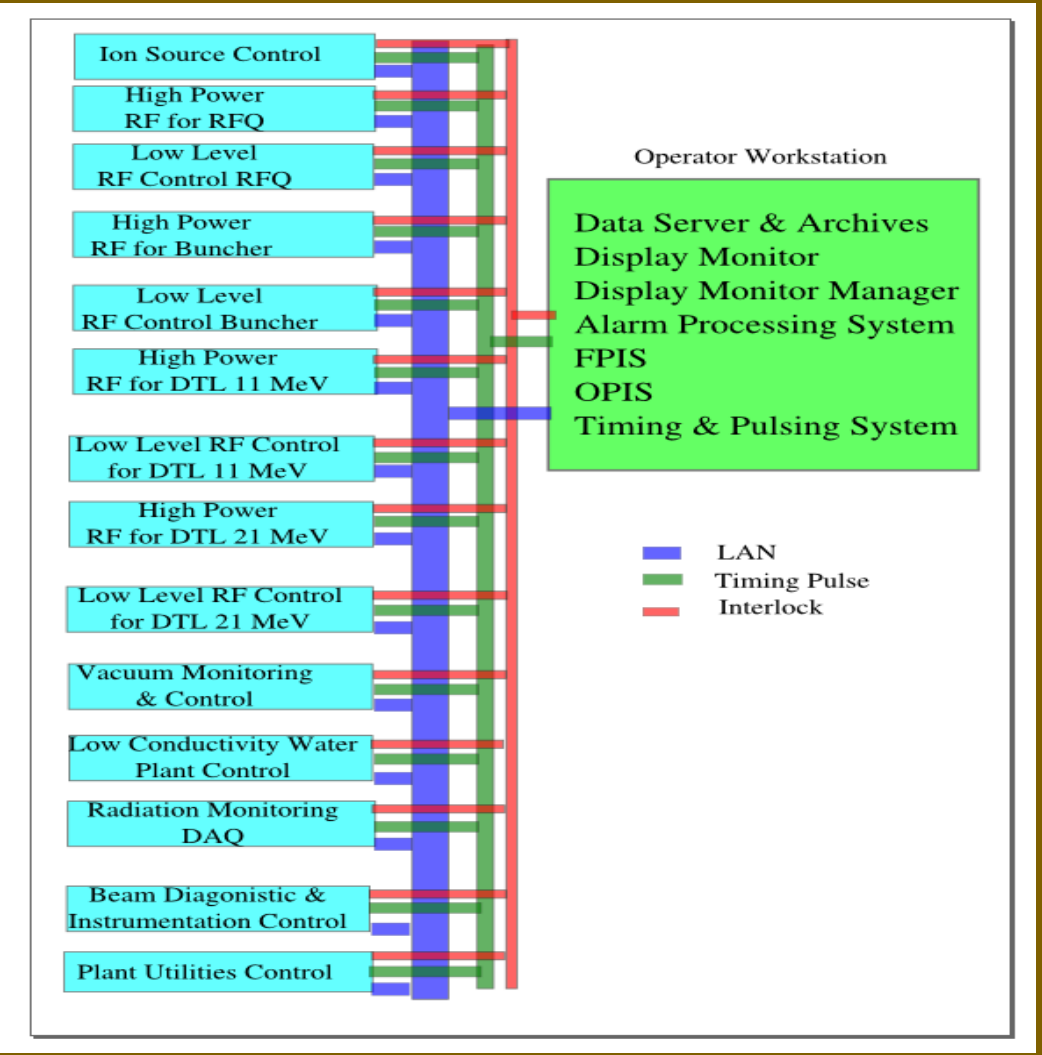
Klystron

LEHIPA Control System

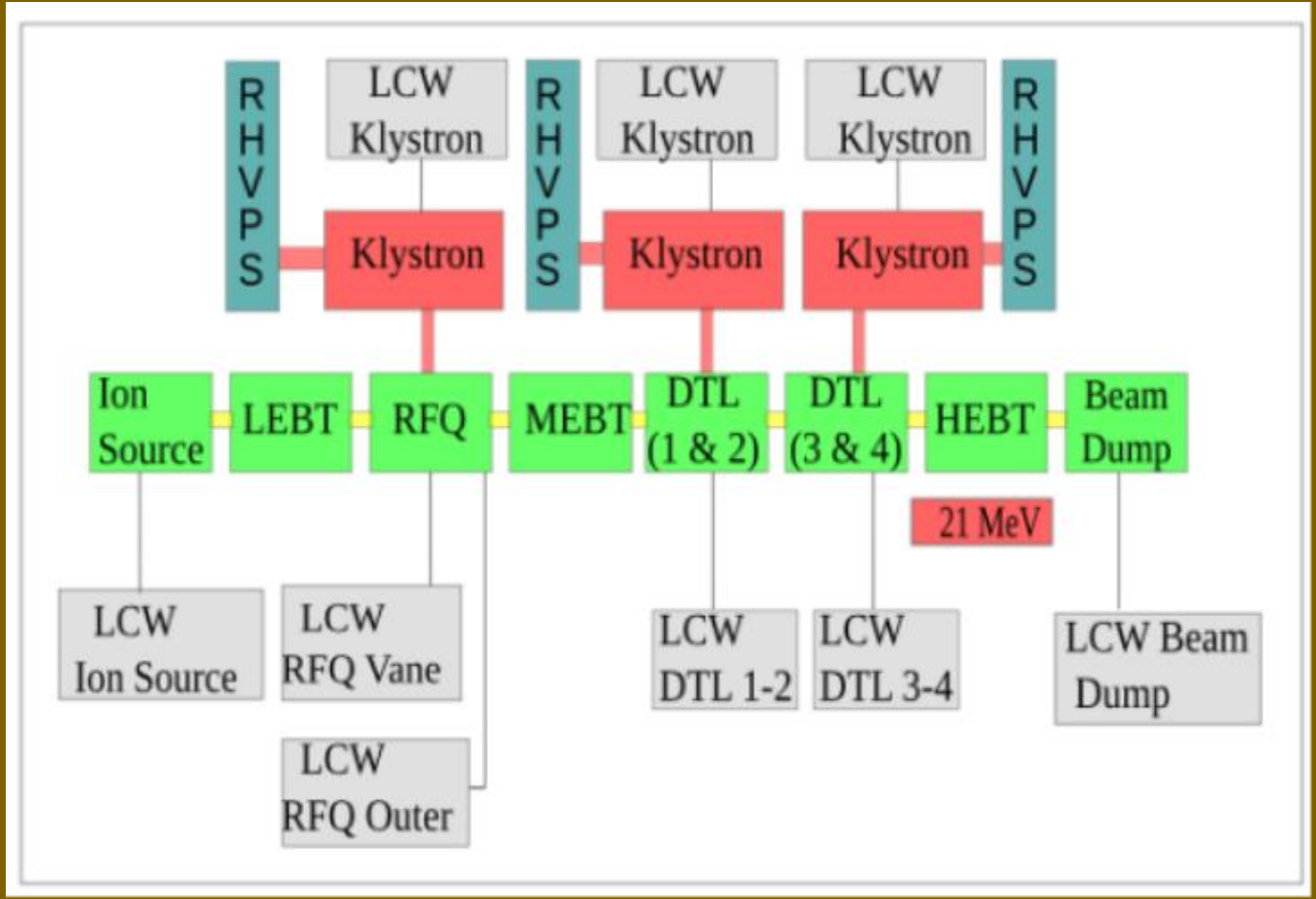
LEHIPA Control System is responsible for

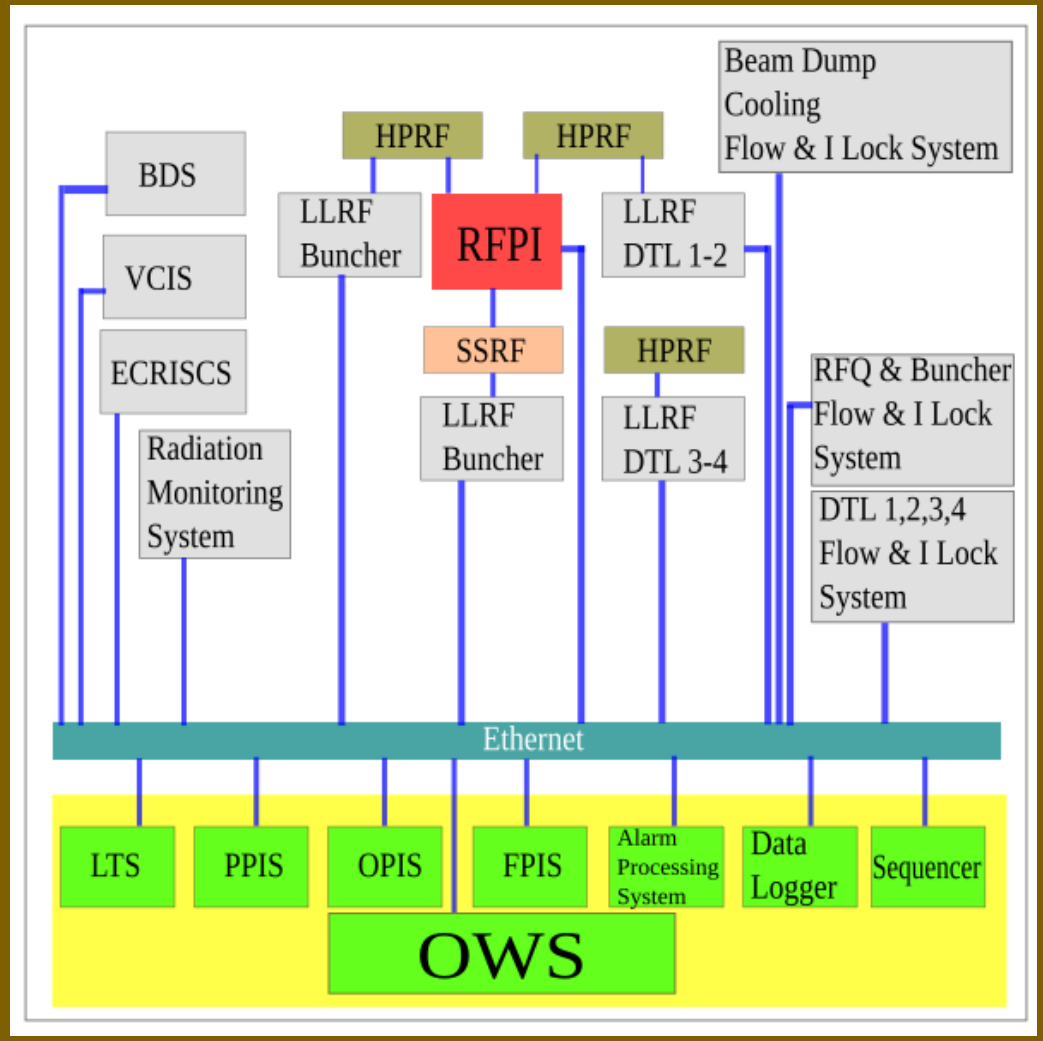
1. Maintaining stable electric filed in the cavity.
2. Timing system to synchronize activities for beam acceleration
3. Data acquisition and presentation of data to operator and user
4. Implementation of operator actions on field devices.
5. Generation of alarm for operator.
6. Acquiring and presenting beam diagnostic data to operator.
7. Machine protection system
   - Fast Protection
   - Slow Protection
8. Personnel Protection System
   - Search and Secure System
9. CCTV monitoring system of LEHIPA
10. Archieving of machine data during operation
11. E Logbook

Architecture of the LEHIPA Control System



Functional Schematic of the LEHIPA Control System





General Specification of the LEHIPA Control System

Sr No	Parameter	Value
1	Classification	Distributed Control System(DCS)
2	Software Platform	Linux,muc OS
3	Programming Language	C/C++,Qt,EPICS Qt,Python
4	Digital Hardware	cPCI,VME,TPLC,RioPLC
5	SCADA	EPICS
6	Communication Protocol	EPICS CAS,MODBUS over TCP/IP,SCPI
7	Response Time	**5 microseconds** for fast protection system to switch of RF Power**200 microseconds** for Beam swtich off

EPICS & LEHIPA

Experimental Physics and Industrial Control System(EPICS) is an open source system which is widely used in acclerators across the world.

LEHIPA Control System uses EPICS to

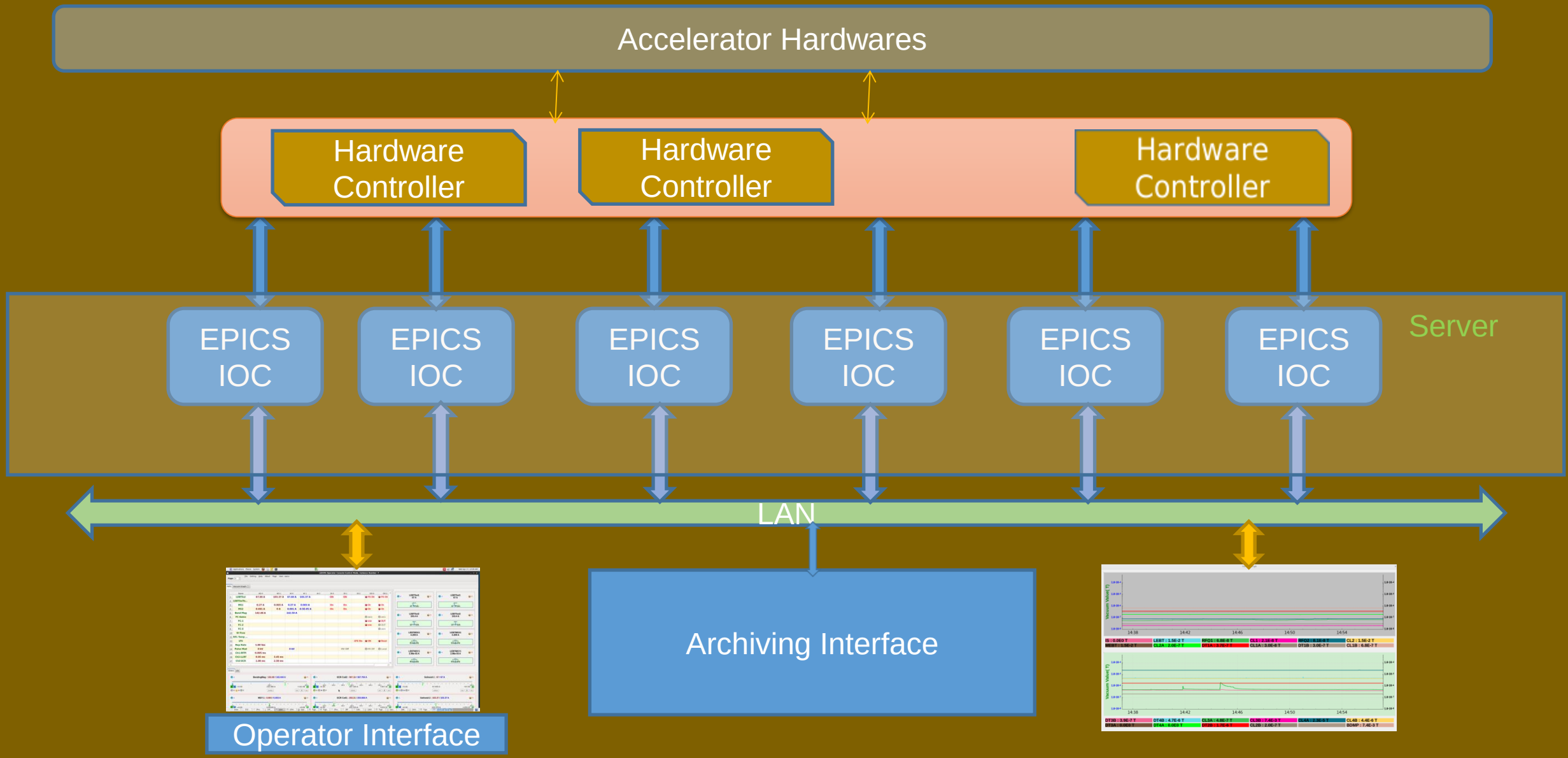
- Switch on and off all the power supplies remotely.
- Set current and voltage in the high voltage and high current power supplies.
- Read back RF power, temperature, humidity,Vaccum value,Valve status
- Set and readback of timing pulses.
- Ensure interlock of Klystron by reading back parameters of the klystron.
- Acquiring and presenting beam diagonistic data
- Sequencing complex repeatative actions

EPICS & LEHIPA

LEHIPA Control System uses EPICS to achieve distributed control

- Each subsystem has its own IOC, which is running in the Raspberry Pi / cPCI crate or linux PC.
- LEHIPA operator interface is custom SCADA for LEHIPA. It is a customized EPICS tool which interacts with field IOCs to set the field values applied by the operator and present the readback to the operator in a meaningful way.
- Development is in an advanced stage to deploy EPICS Sequencer to automate RF conditioning in RFQ.

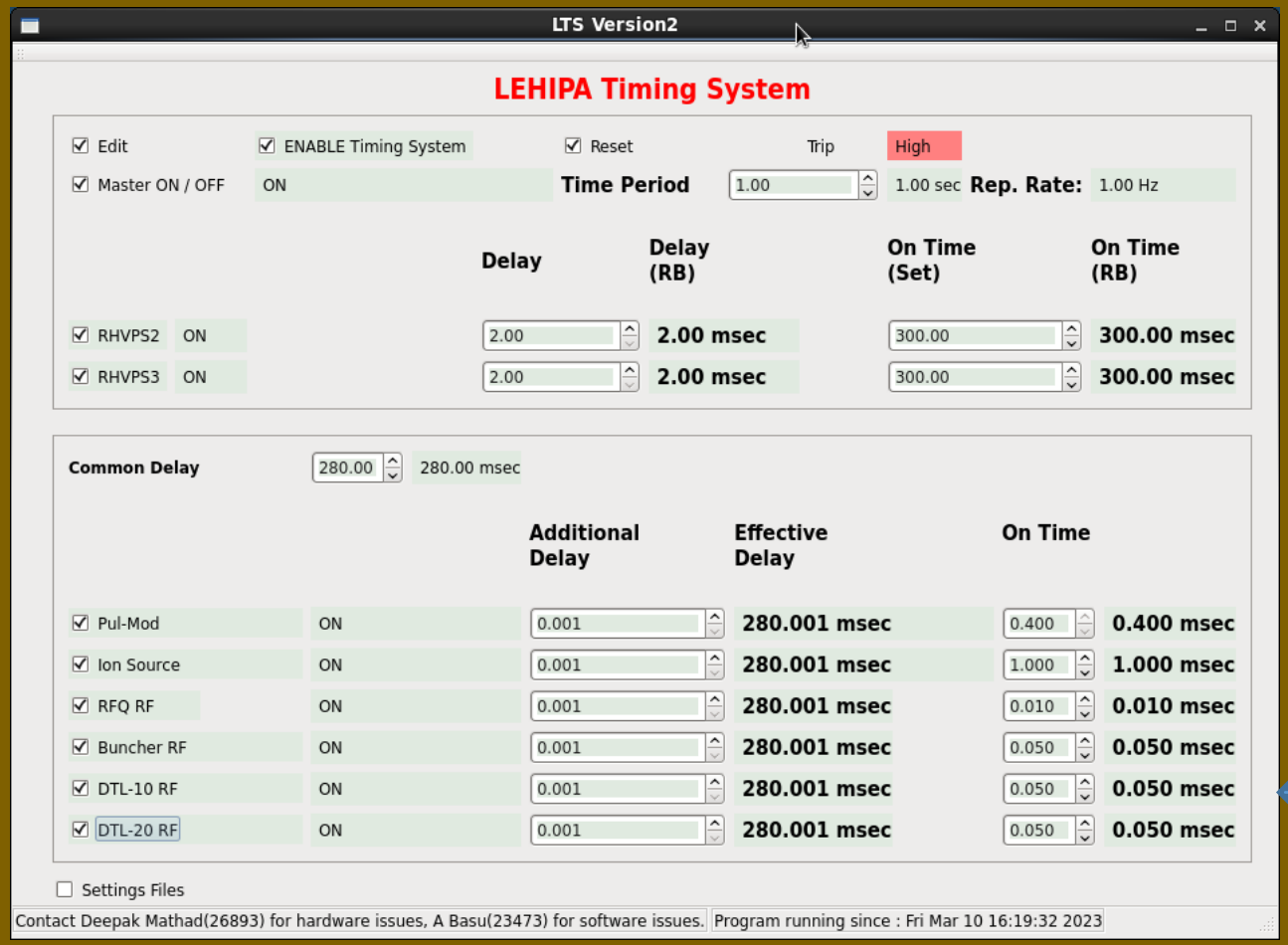
LEHIPA Architecture

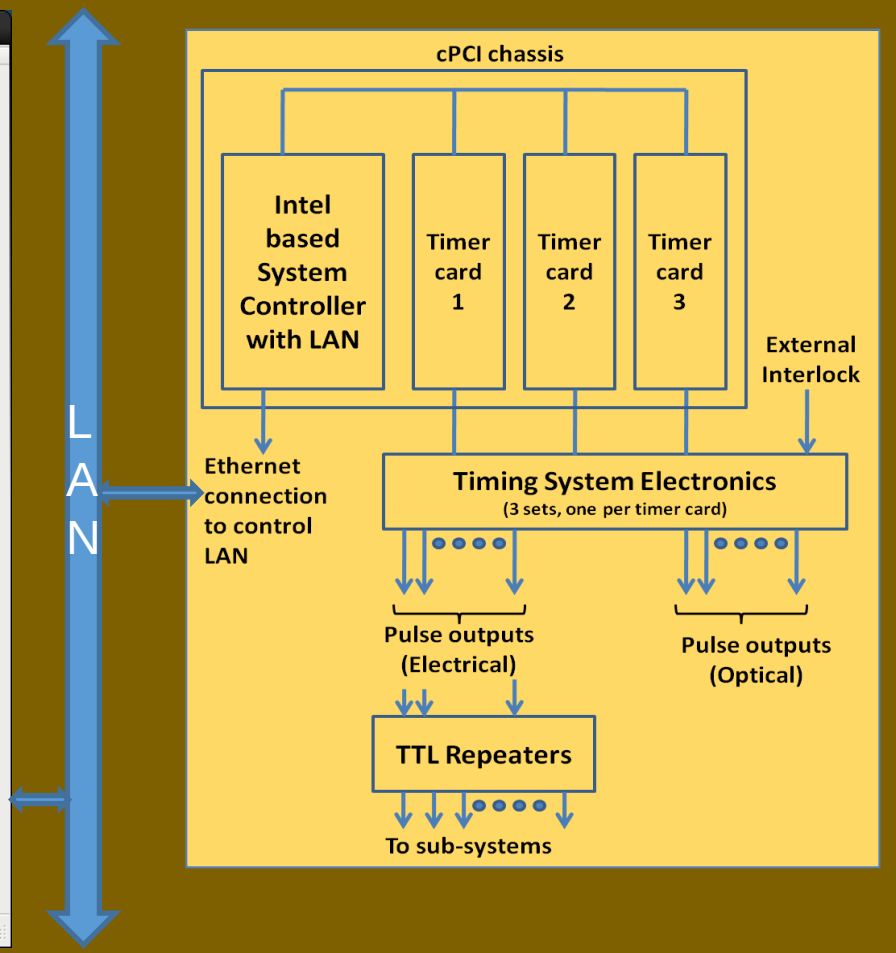


EPICS Statistics

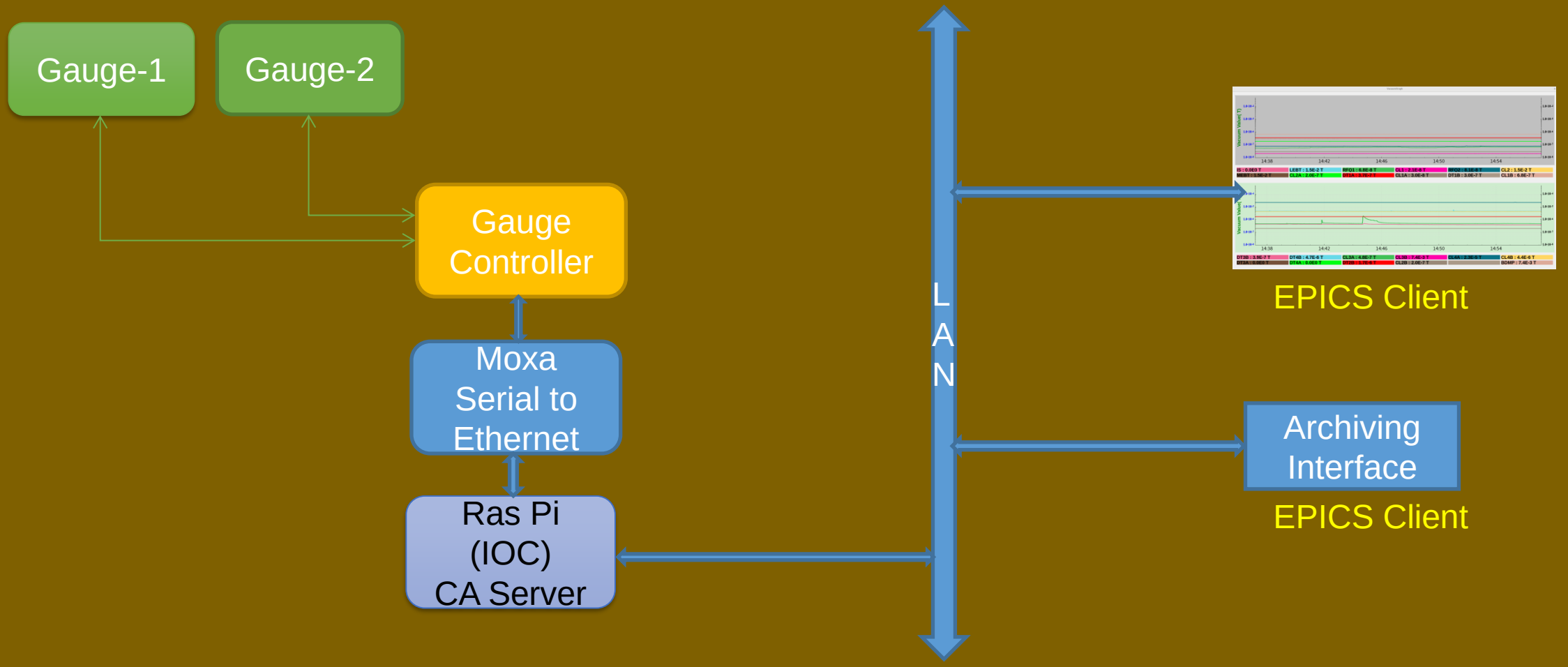
Sr No	Parameter	Count
1	EPICS Version	3.14
2	Number of IOCs	12
3	Number of Pvs	>150
4	Protocols	Modbus over TCP/IP,SCPI
5	Data acquisition mode	Periodic Scanning and IO Interrupt

EPICS in use :LEHIPA Timing System

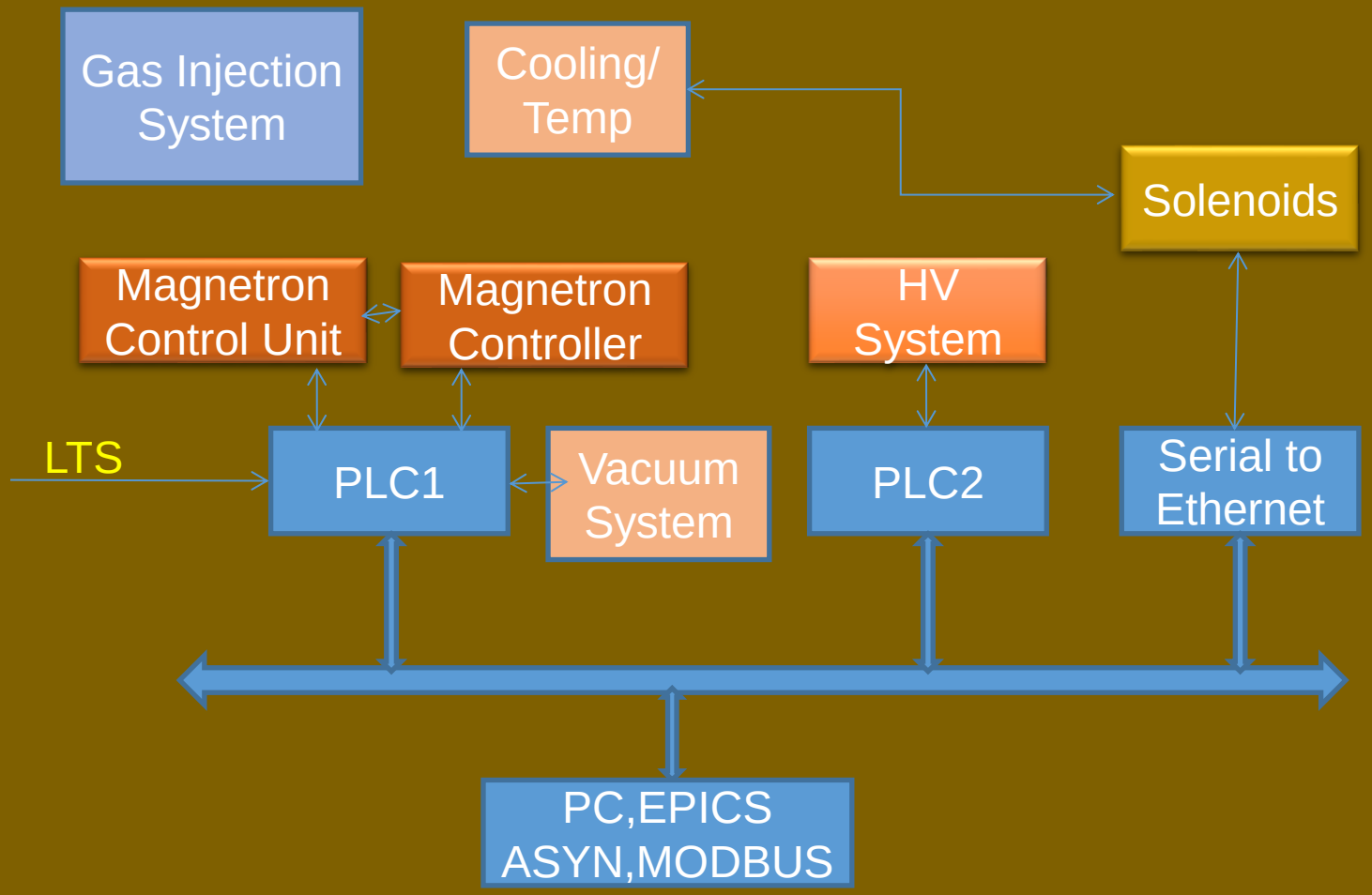




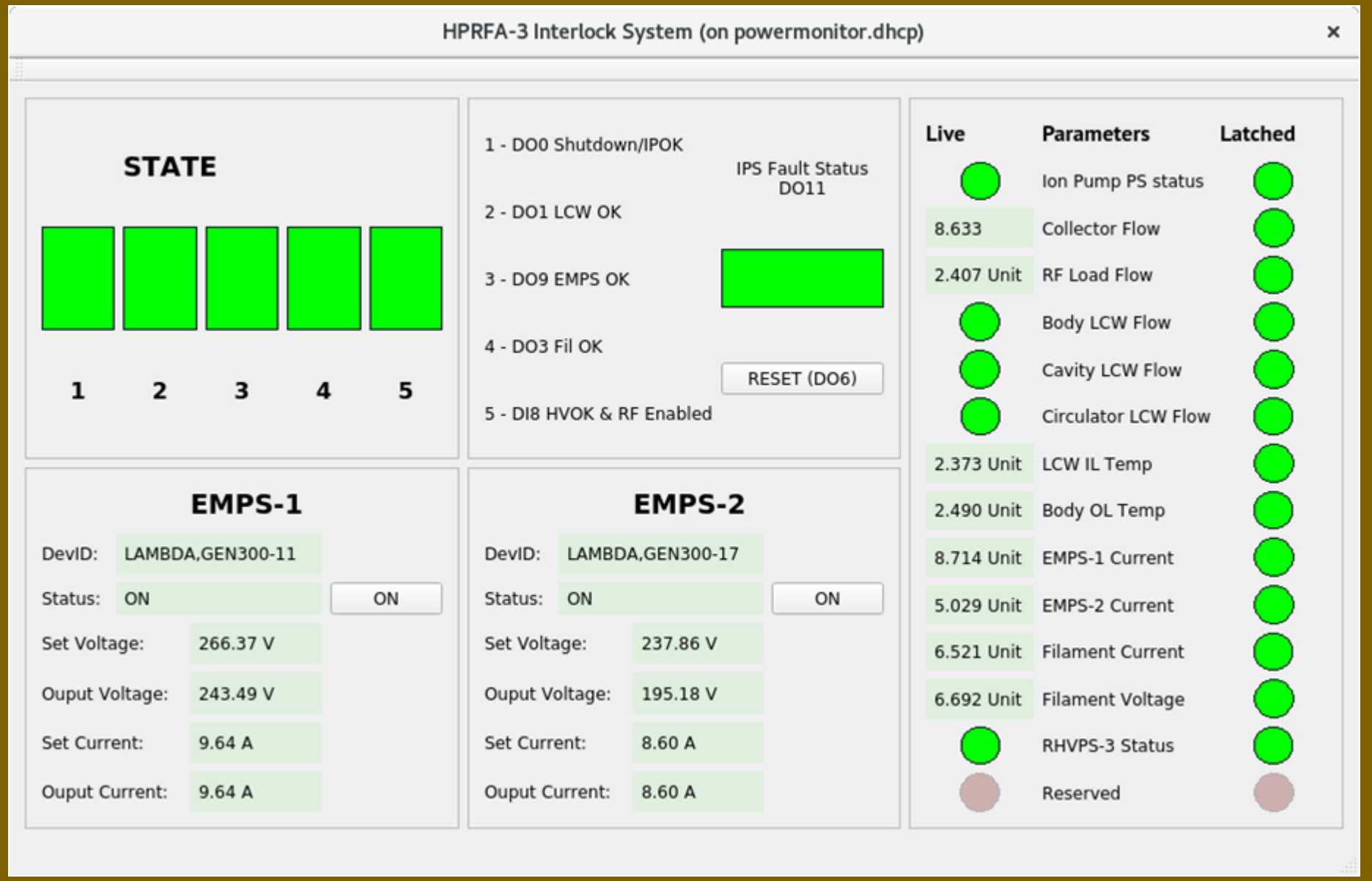
EPICS in use : Vacuum Gauge Reading



EPICS in use : Ion Source Control



EPIC in use: Klystron Protection System – interface with PLC



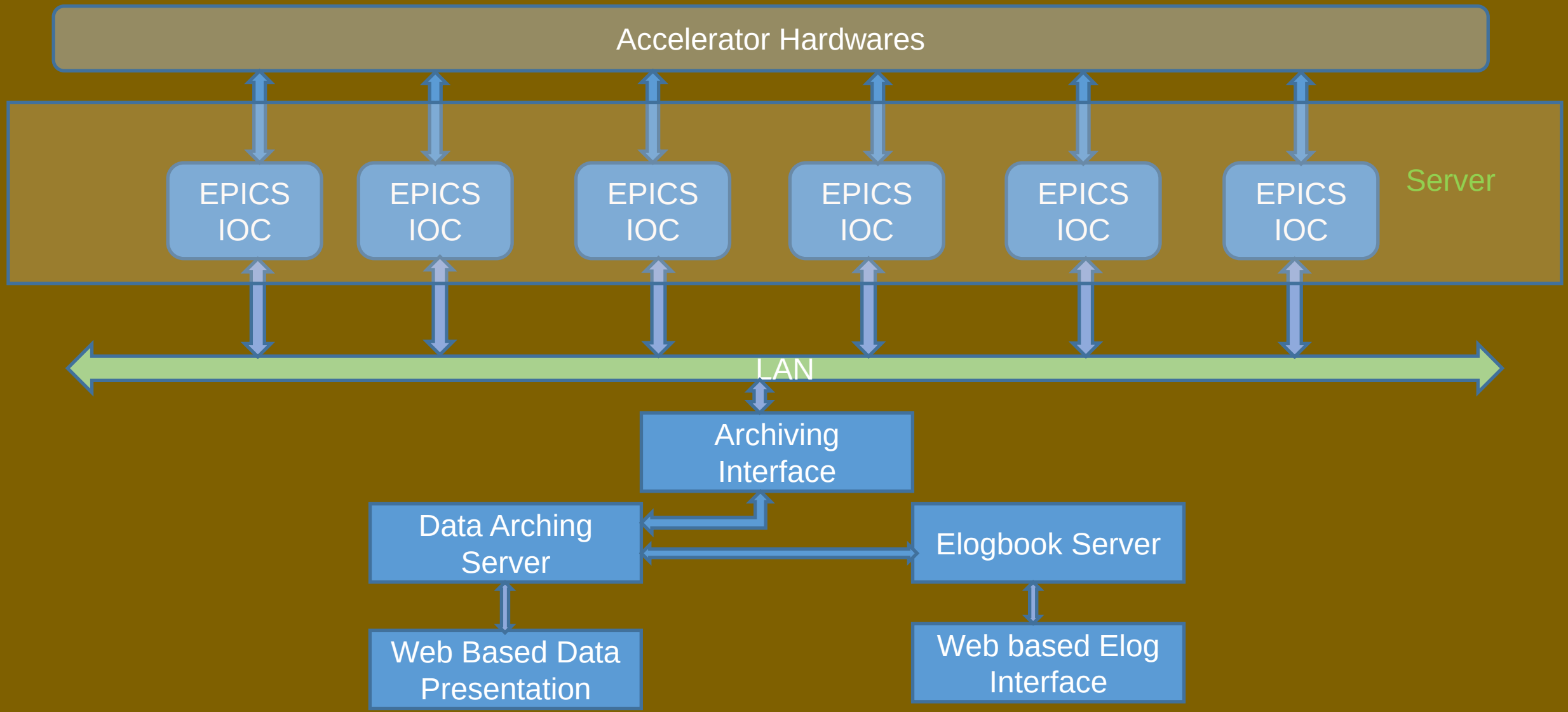
EPICS in Use: LEHIPA Data Archiver

EPICS provide a data archiver as a part of its application toolkit.

However a custom data archiver is developed in LEHIPA

- It is written in Python using pyEPICS.
- Mongodb is used as the database
- Currently time series data is being archived.
- An event base archiving scheme is under design.

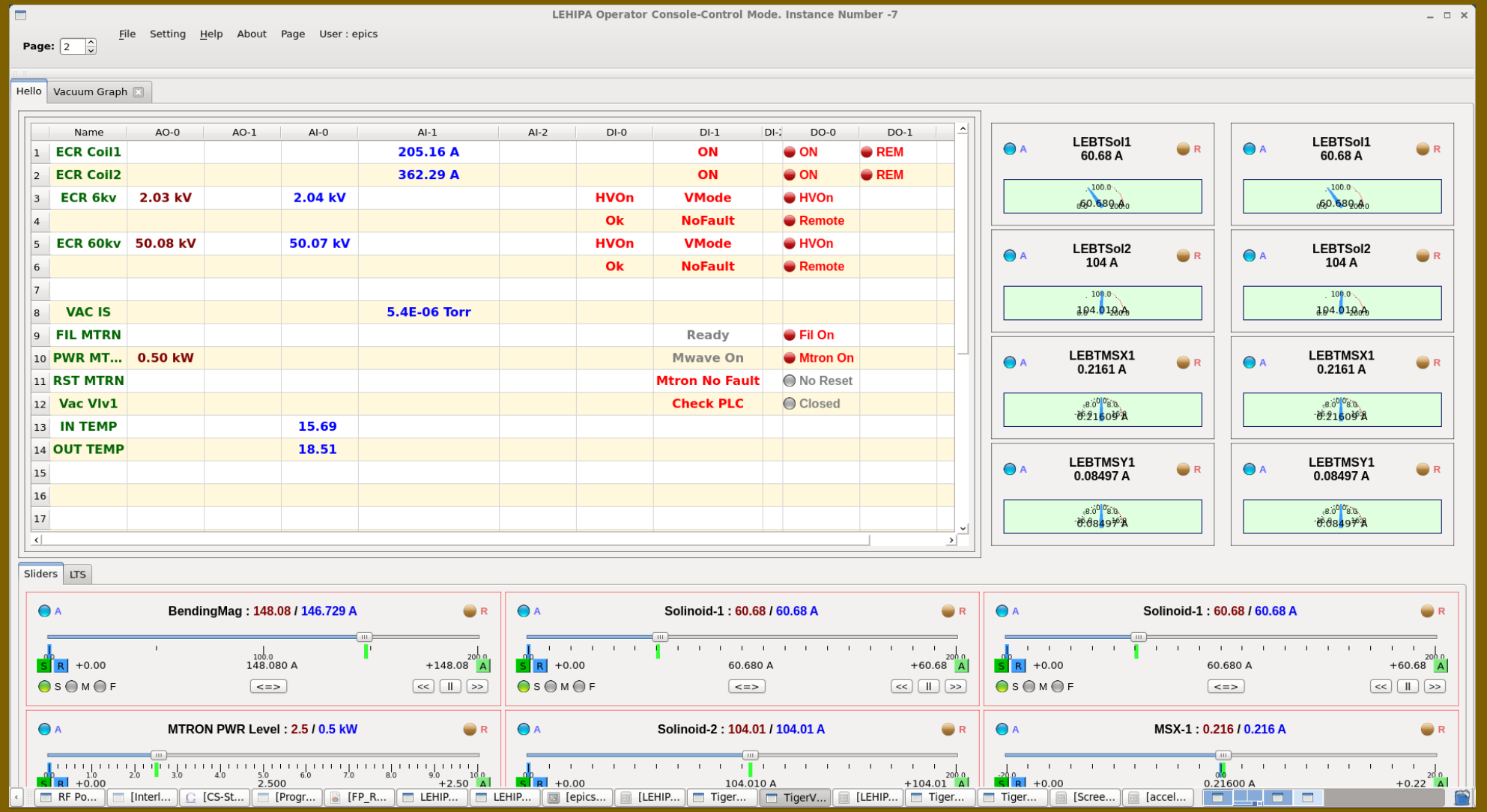
LEHIPA Data Archiver Architecture



LEHIPA Data Archiver-Salient Points

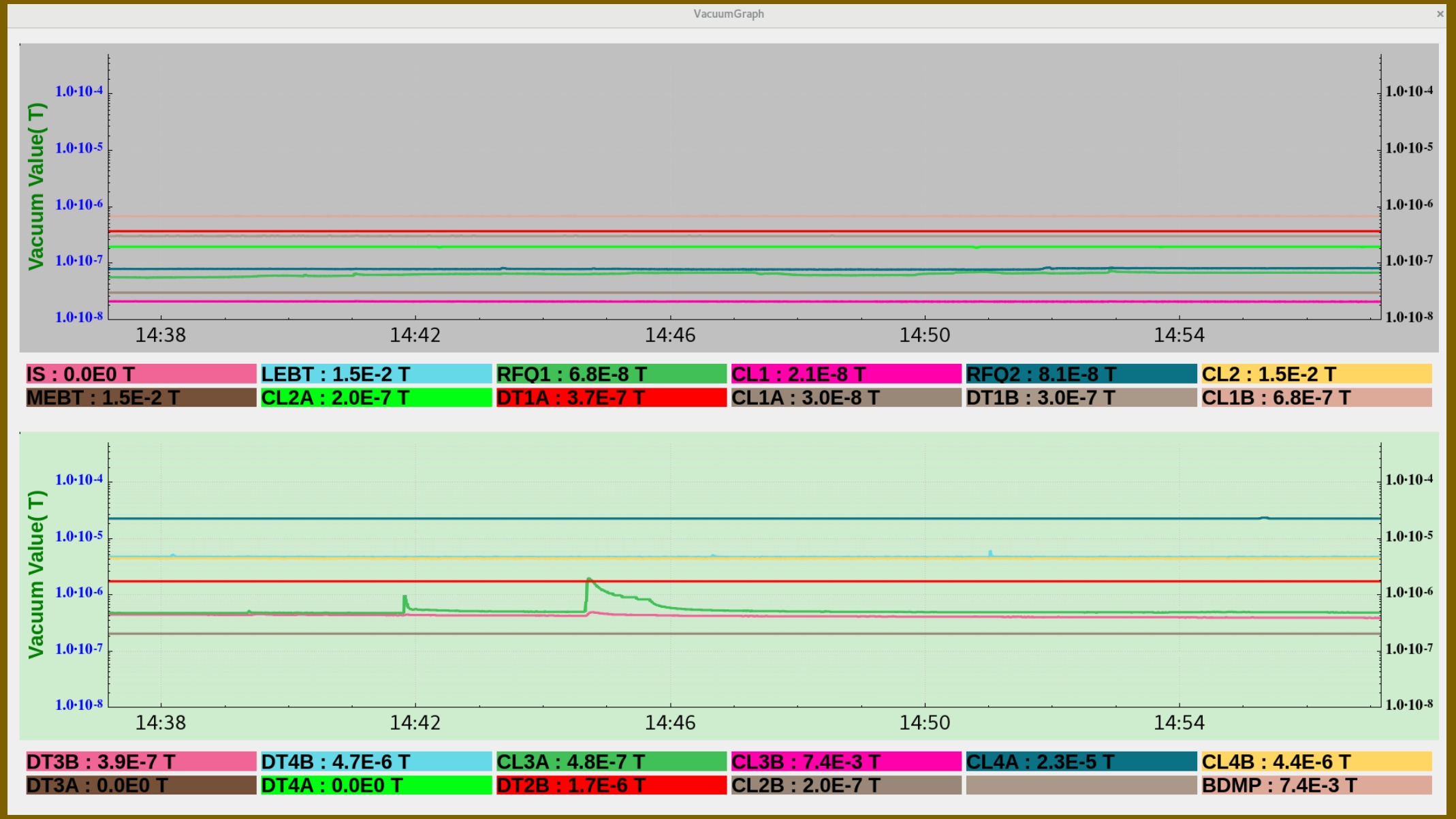
- Data is archived in a RAID server. Server is a 2 X 8 TB Network Attached Storage(NAS) with RAID level 1 (data mirroring).
- The storage disk is hot swappable.
- Server runs on Cent OS-8.
- MongoDB is used as the NoSQL database.
- Database system is configurable by the system admin to add new parameters as and when required.
- Data is saved as BSON format in database.
- Currently it takes approximately 35 millisecond to access 120 PV and push them in the mongoDB database.
- A web-based data retrieval system is designed in node.js . This system is multiuser and is used to access vital data via browser.

EPICS Client-LEHIPA Operator Interface



1. Built Using EPICS-Qt
2. Tables,sliders and buttons are fully configurable in every aspect

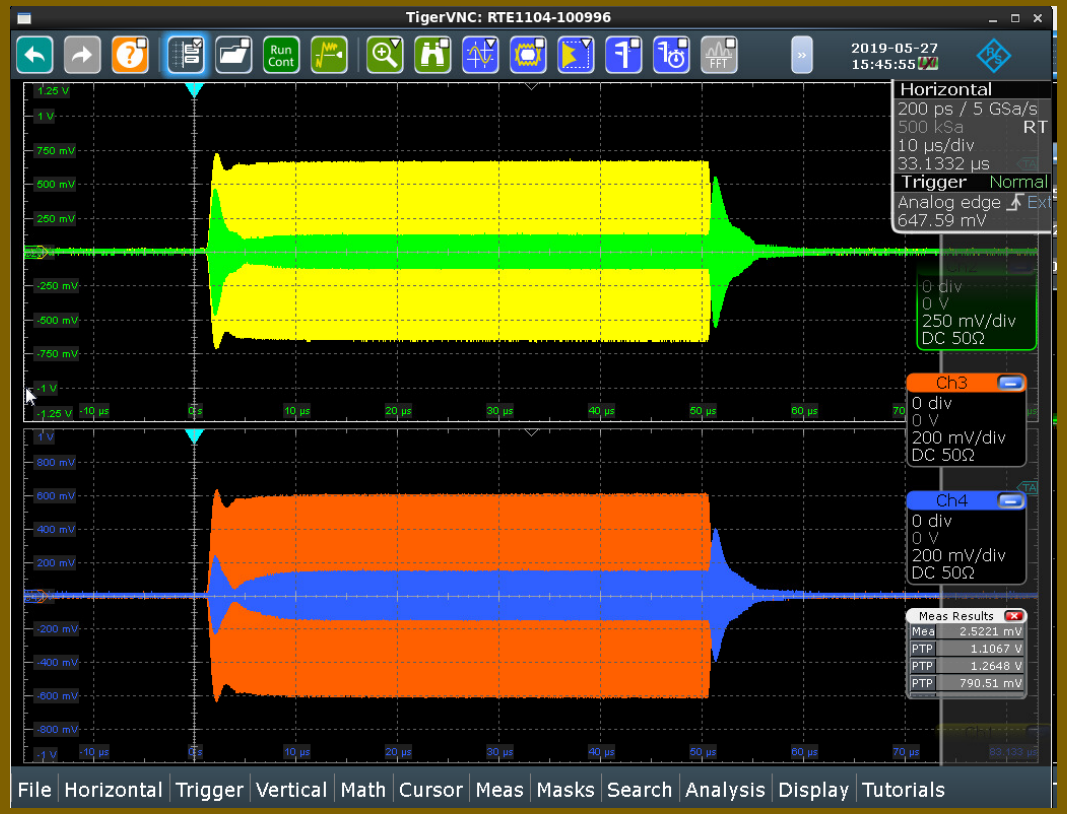
EPICS Client Vacuum Data Chart

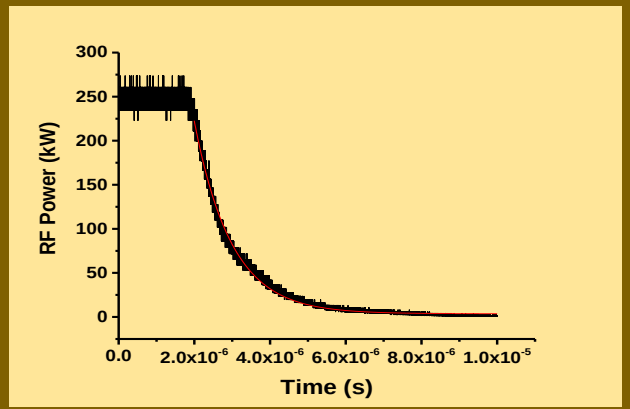


EPICS Sequencer in LEHIPA

- Sequencer is a very powerful feature of EPICS
- Many of the regular acclerator operations can be automated using EPICS sequencer.
- Automated operation enhances the safety of operation.
- LEHIPA is currently testing a EPICS sequencer to automatically RF condition the RFQ
- Upon successful deployment of the RF conditioning sequencer, more such sequencers will be developed and deployed.

High power RF Conditioning of RFQ (Operator Driven)

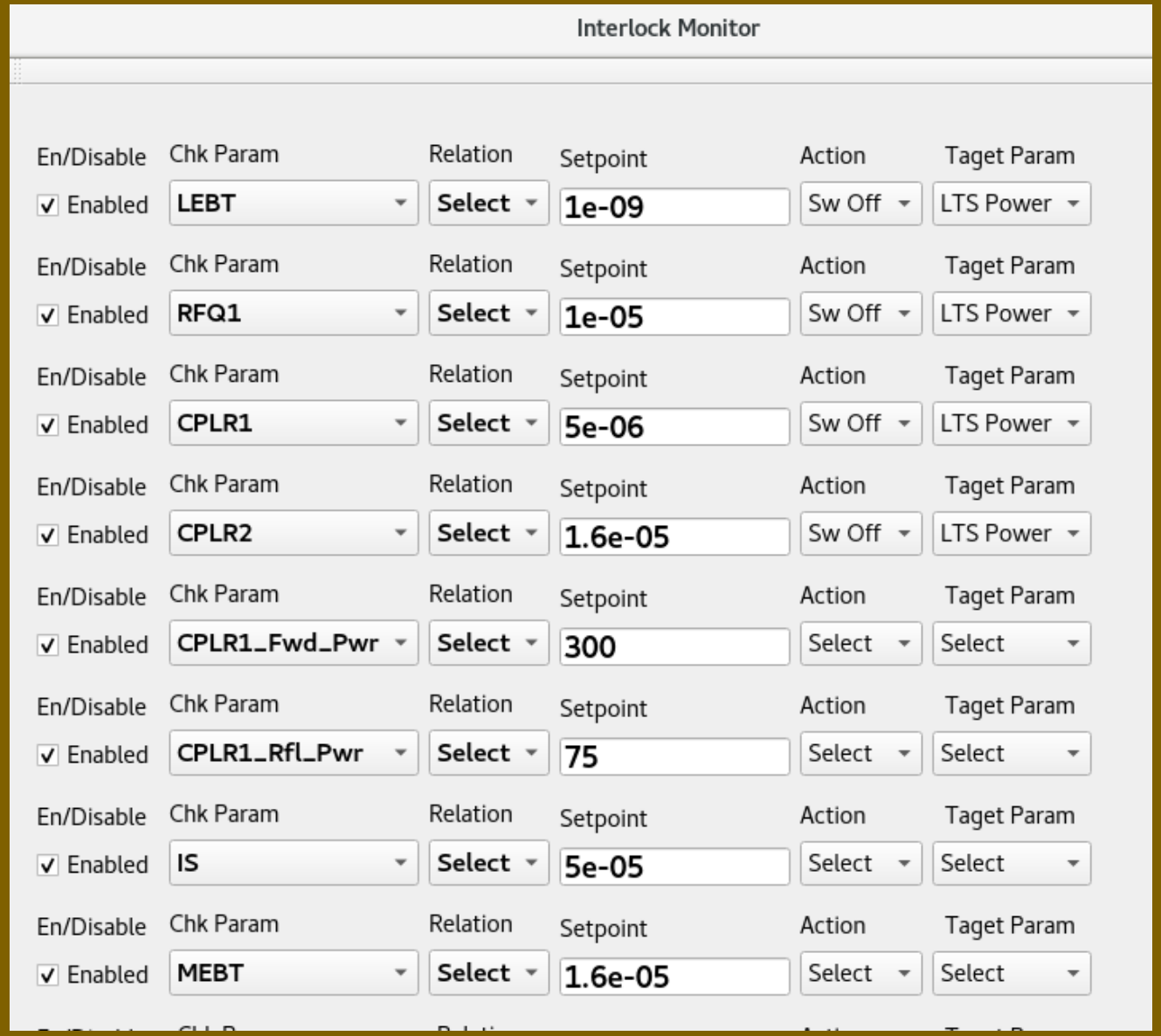




- **Required power level to be 520 kW to have nominal design voltage of 68 kV.**
- **Forward & Reflected powers are continuously monitored.**

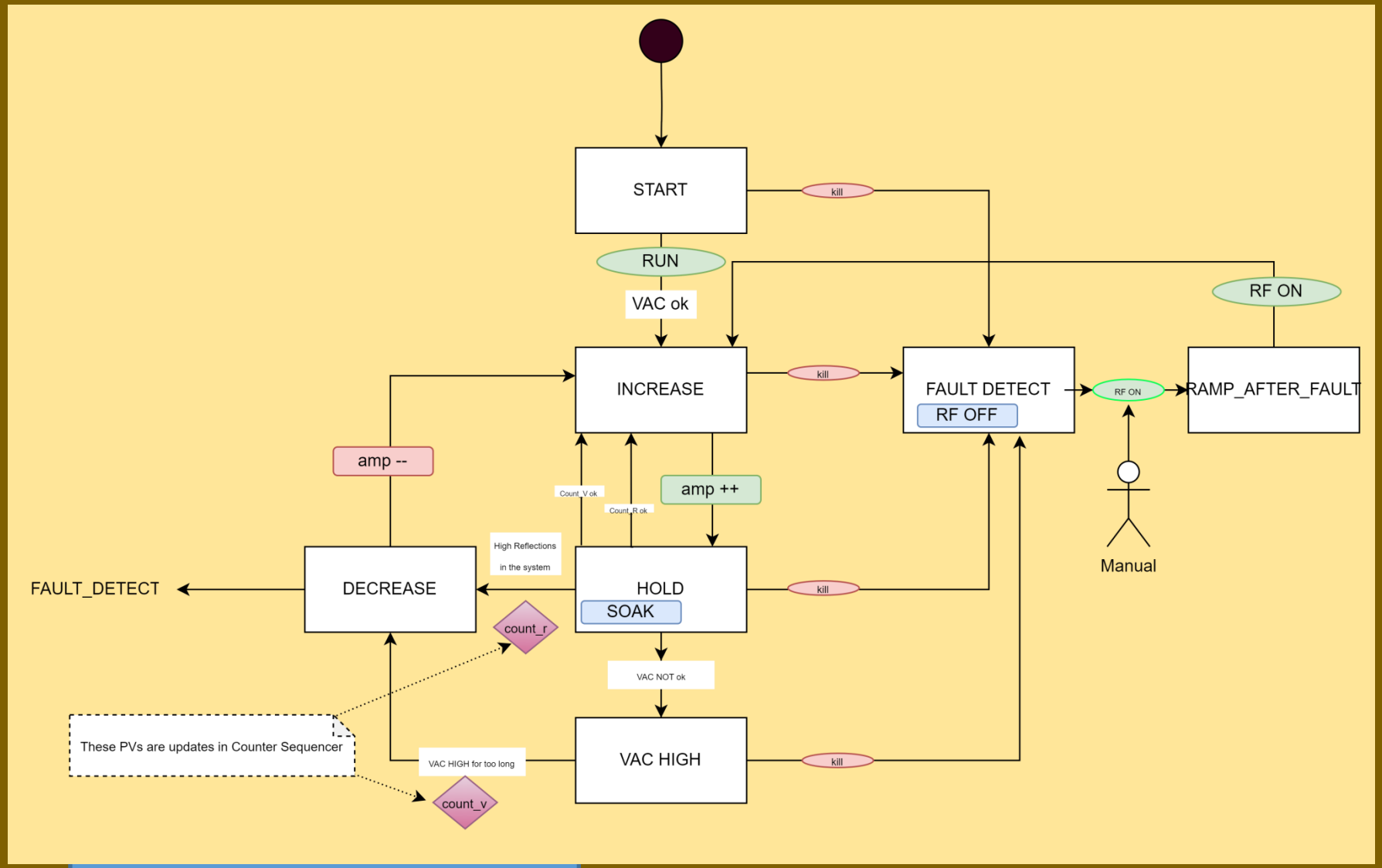
Parameter	Value
RF Pulse	352 MHz, 50 µs, 1 Hz
RFQ RF Power	600 kW (FP)-80 kW (RP)
Q_L	2200

LEHIPA Interlock Monitor



- **1) Acts as the soft interlock.**
- **2) It acts as the vacuum interlock.**
- 3) Essential during operator driven RF conditioning.

LEHIPA RFQ Conditioning Sequencer

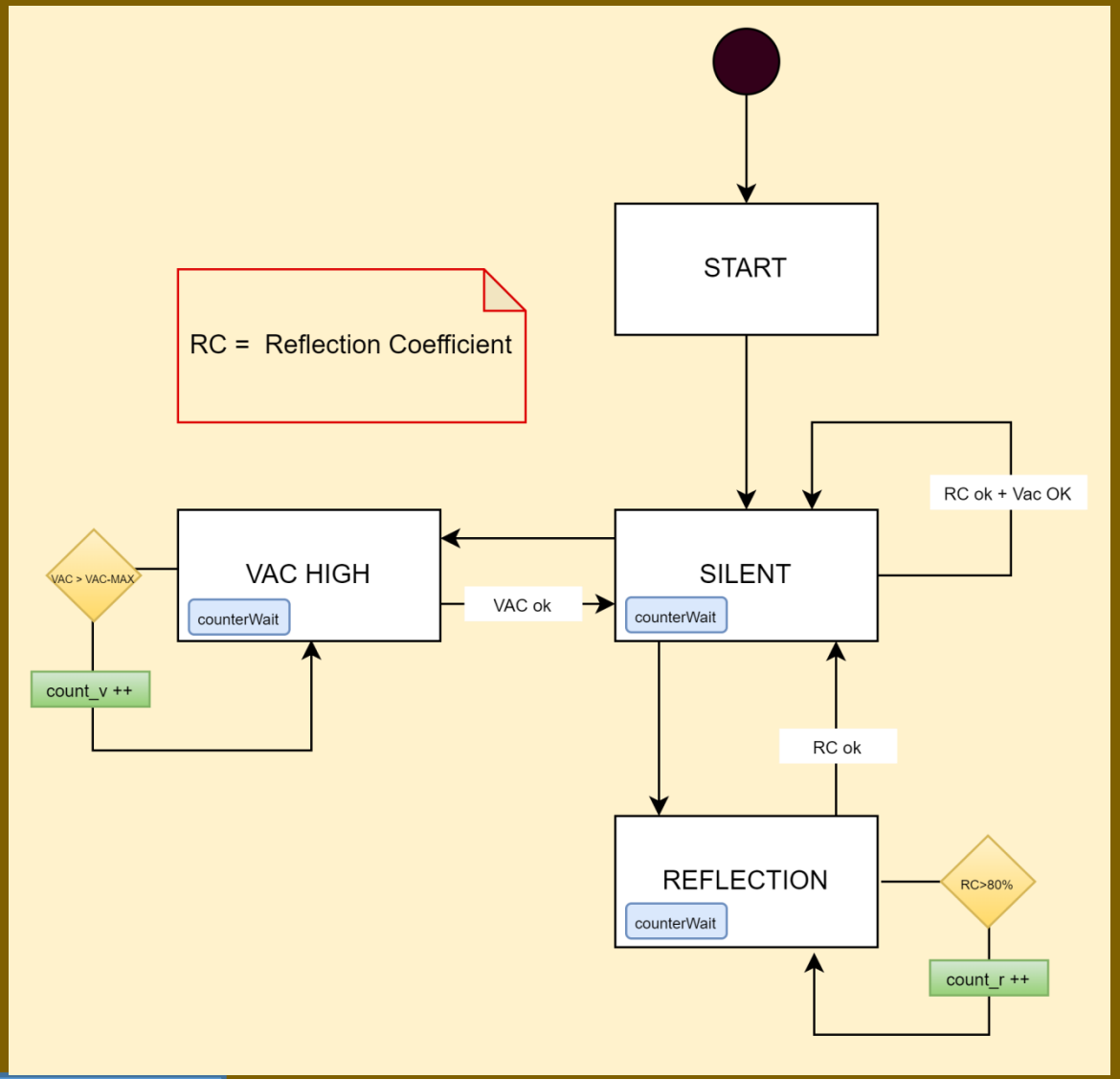


MONITORING PV

Run, Kill
Count_v
Count_r
SoakTime
Amplitude –
SignalGenerator
RF enable
stepIncrement

Refresh Rate = SoakTime

LEHIPA RFQ Counter Sequencer



MONITORING PV

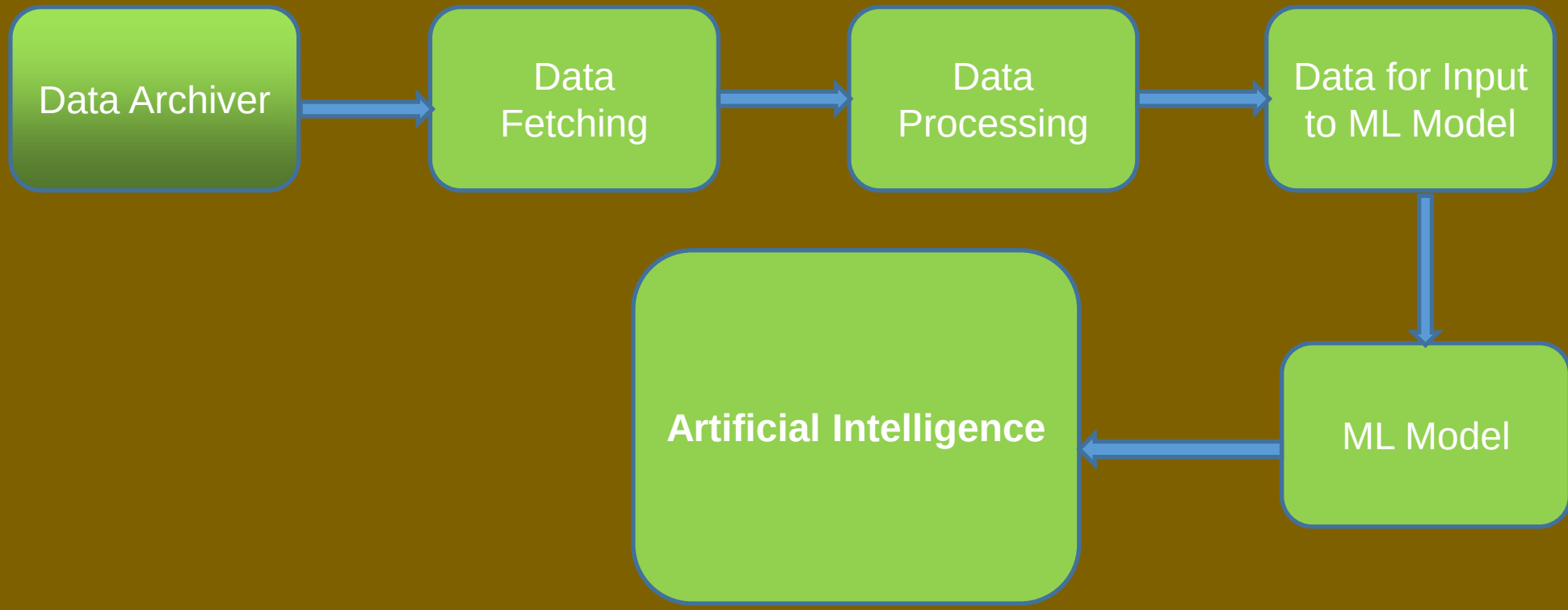
Count_v
Count_r
CounterWait
Field Vacuum
Field Reflected/Forward power

Refresh Rate = counterWait

Future Plans

- IOC in docker container
- Hot standby redundant IOC
- Accessing radiation data in EPICS
- Accessing Camera data in EPICS
- AI/ML analysis of archived data
- AI/ML based beam tuning

AI ML Design in LEHIPA



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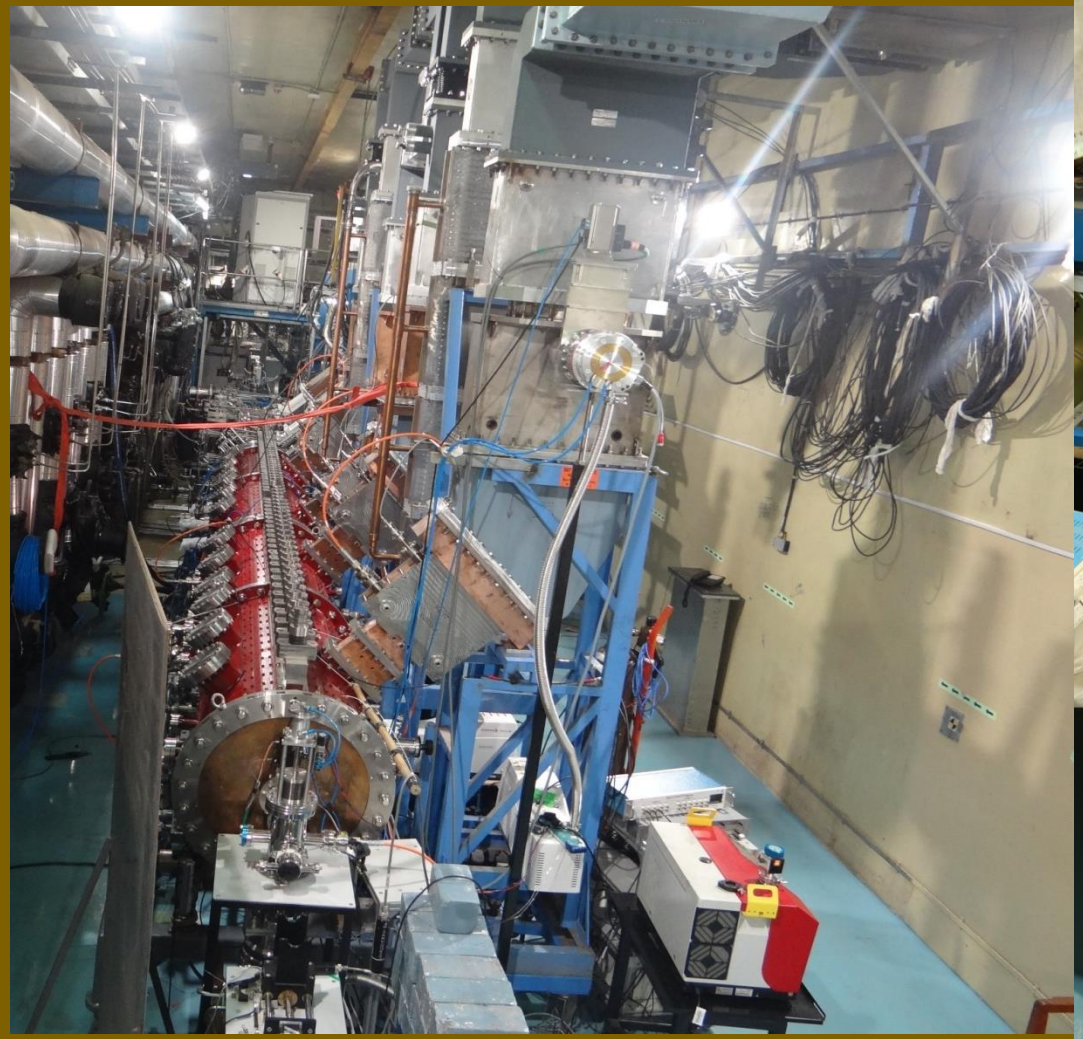
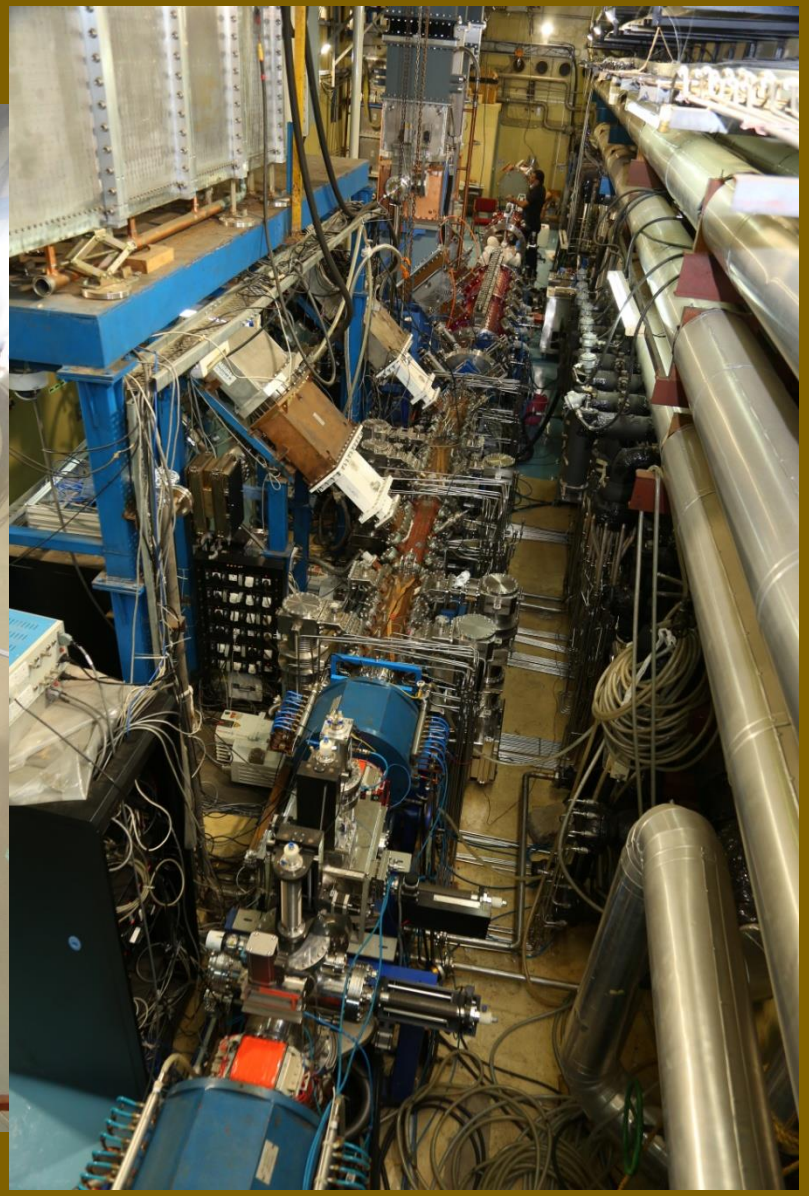
3)Deepak ,Bhumesh,Santhosh,Namrata, Laxman,Pravin

3) Colleagues of IADD

4) All the colleagues of the various other divisions of BARC

LEHIPA





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