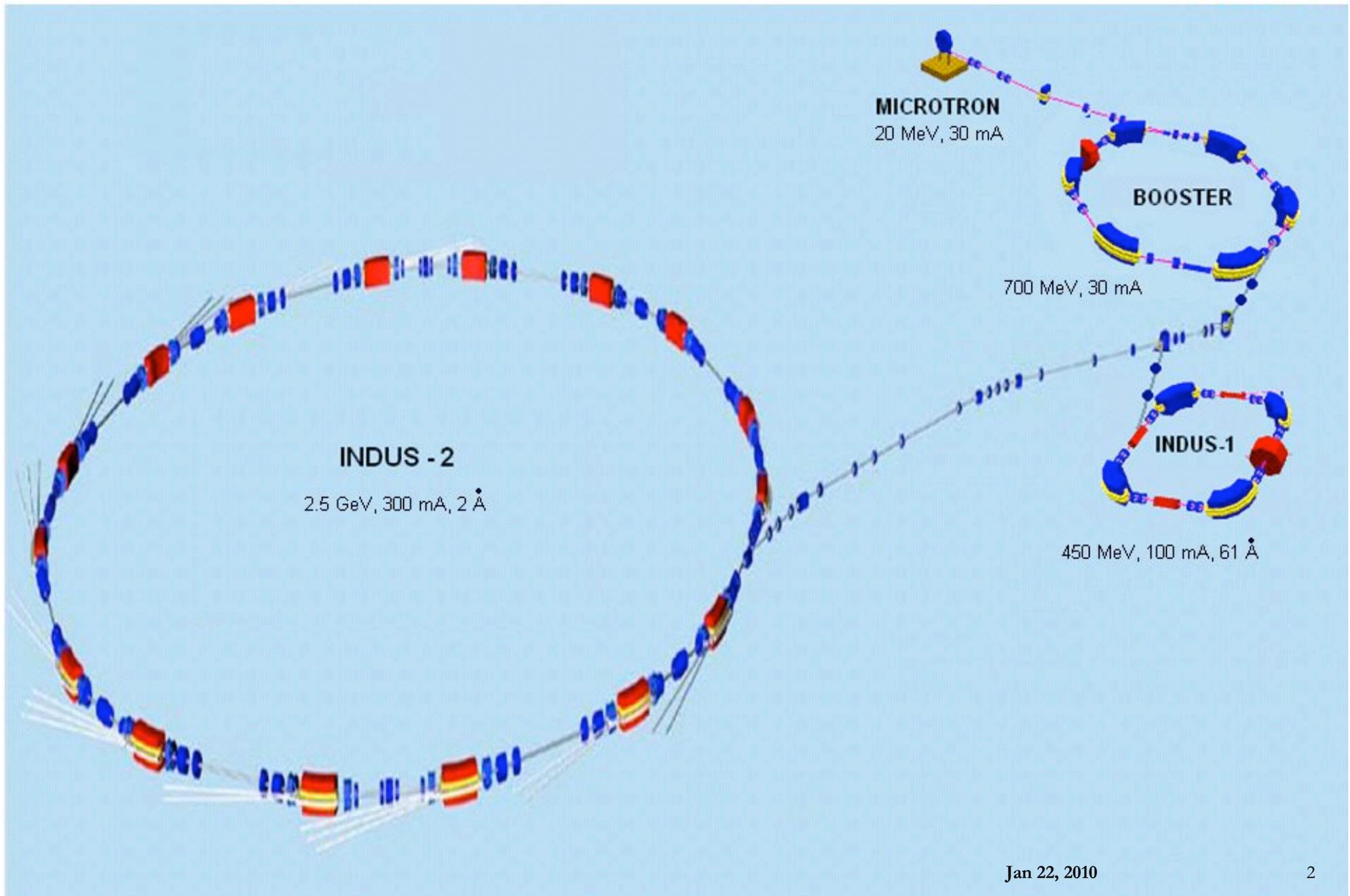




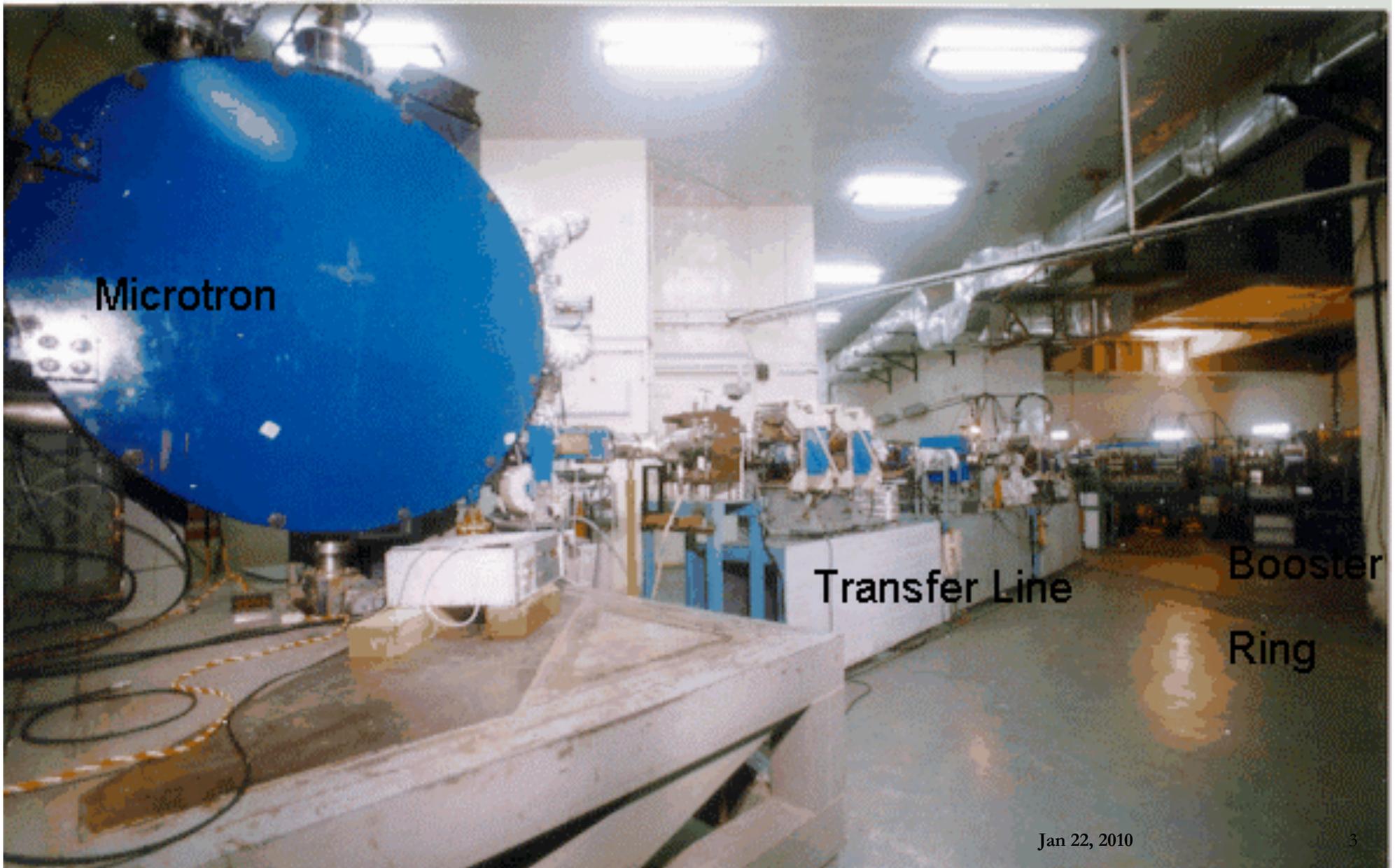
EPICS Based Control System for Microtron at RRCAT, Indore

Prachi Chitnis
Raja Ramanna Centre for Advanced Technology
Indore, INDIA

Indus-1 & Indus-2 Synchrotron Radiation Sources at RRCAT



Injector System of Indus Rings



Microtron Control Room



Main Control Room



Jan 22, 2010

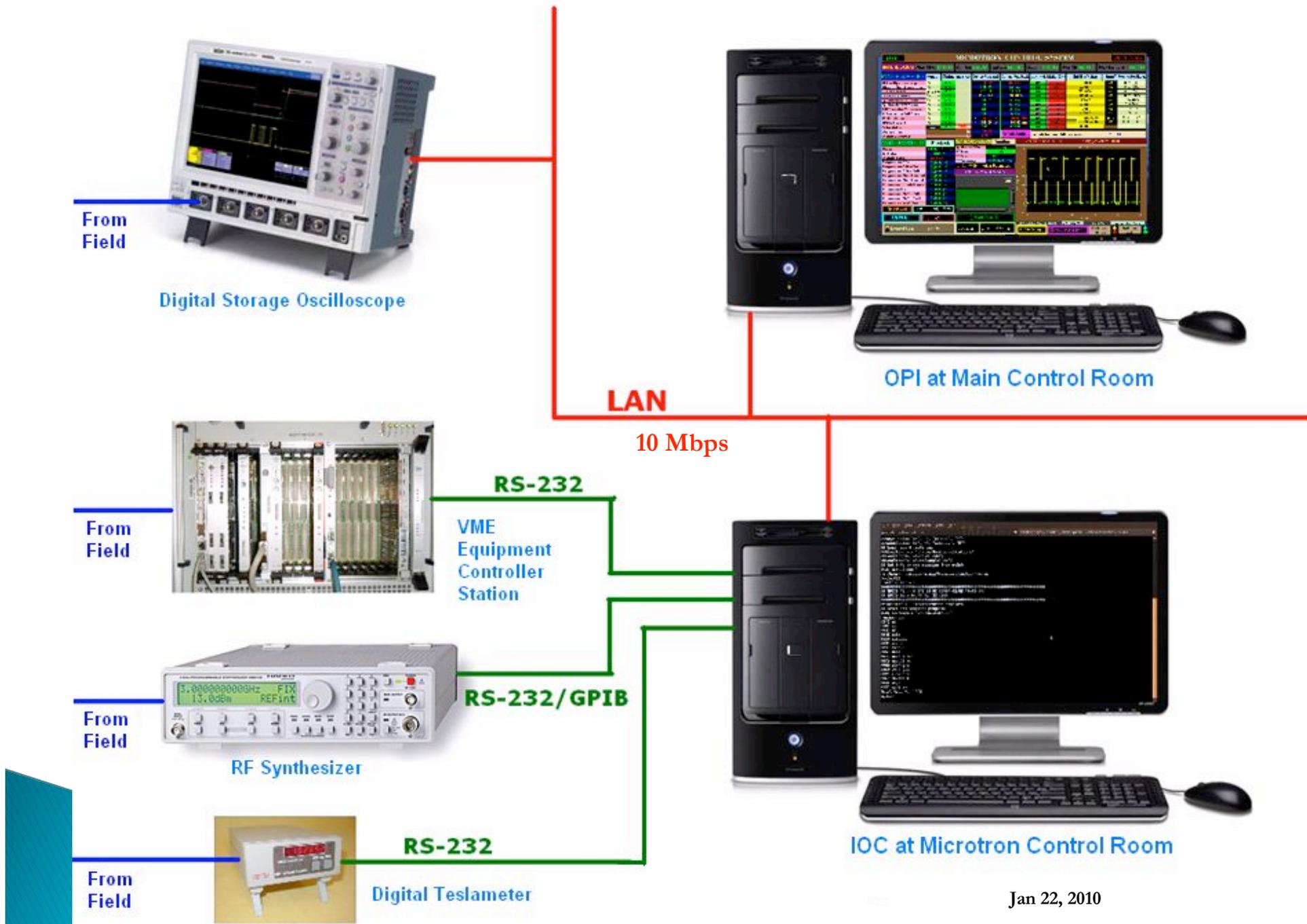
Existing Microtron Control

- LabVIEW 6.1 based, Windows 2000
- Old system
- Expandability issues
 - Control hardware upgradation of Indus-1
 - System enhancements
- One-to-one control
- Heterogeneous SCADA
- Version upgrade cost

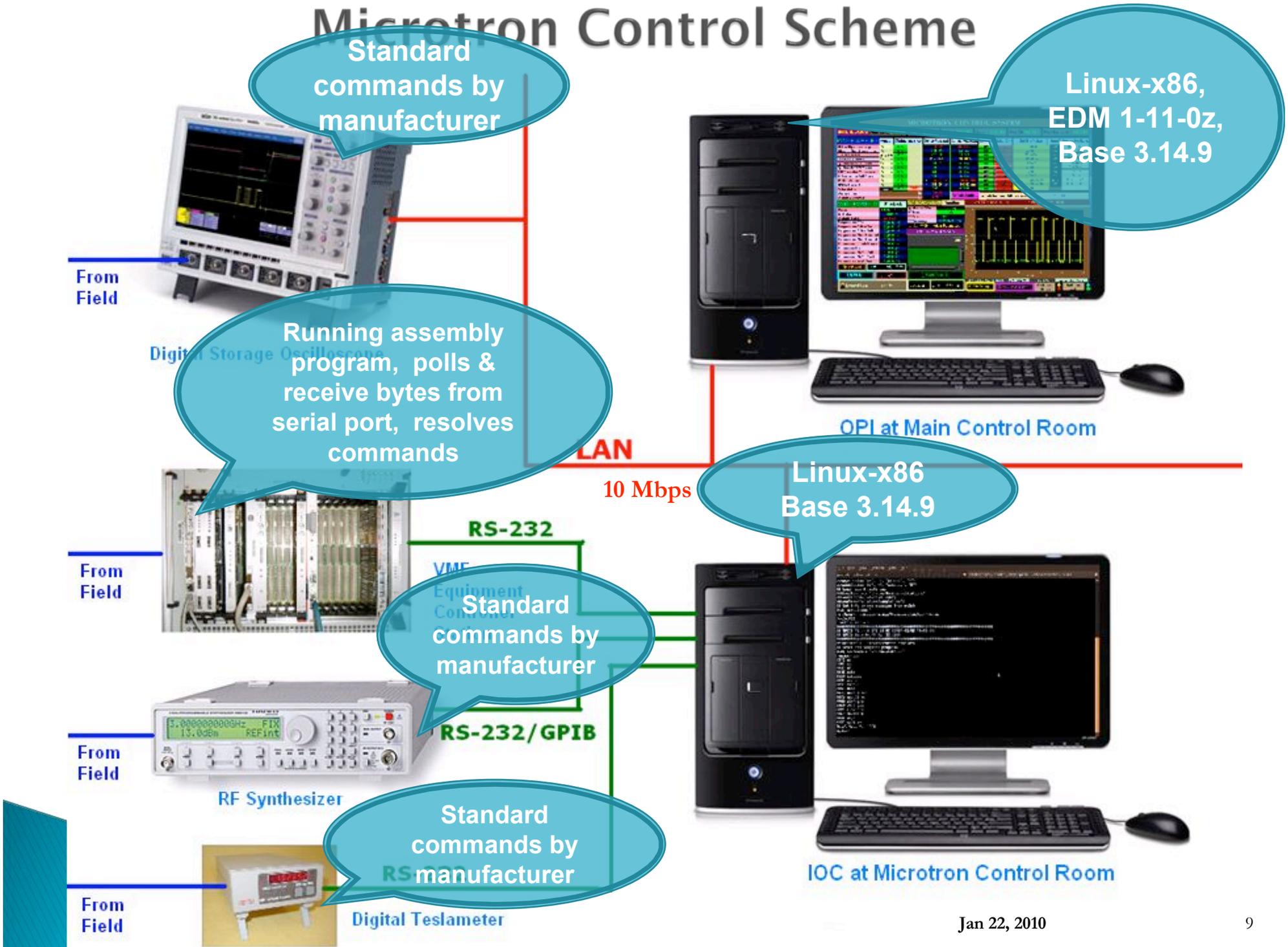
First experience with EPICS [3] at RRCAT

Microtron Control System Design

Microtron Control Scheme



Microtron Control Scheme



Standard commands by manufacturer

Linux-x86, EDM 1-11-0z, Base 3.14.9

From Field

Running assembly program, polls & receive bytes from serial port, resolves commands

LAN
10 Mbps

OPI at Main Control Room

Linux-x86
Base 3.14.9

From Field

Standard commands by manufacturer

From Field

RF Synthesizer

Standard commands by manufacturer

From Field

Digital Teslameter

IOC at Microtron Control Room

Microtron field variables

~150 process variables to be administered by EPICS

Interfaced to	Devices	Link Type	No of I/O points
VME station	<ol style="list-style-type: none"> 1. 11 Power Supplies – Klystrons, Dipole, Quadrupoles, Correction coils, Cathode & Steering coils <ol style="list-style-type: none"> 1. Remote/Local status signals 2. ON/OFF status signals 3. Analog status signals(current/voltage/power) 4. ON and OFF control signals 5. Analog control signals (current/voltage) 6. Polarity 2. 6 Safety Interlocks signals 3. 10 Temperature signals 4. AC Mains Voltage 5. Vacuum level 6. Cycling control 	RS-232	103

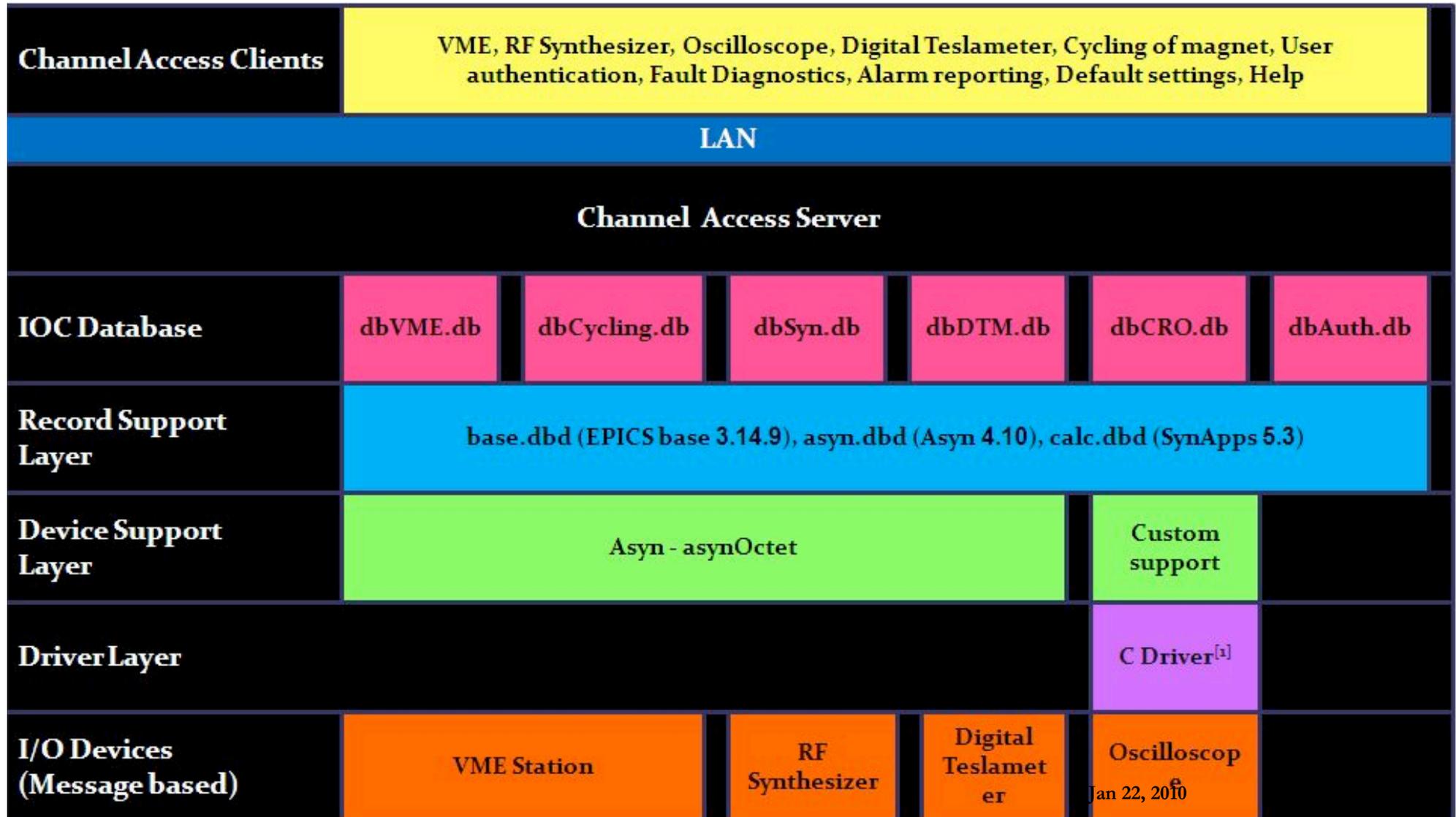
Field variables

Interfaced to	Devices	Link Type	No of I/O points
RF Synthesizer	<ol style="list-style-type: none"> 1. RF synthesizer make 2. RF Status (ON/OFF) 3. RF Level 4. RF Carrier Frequency 	RS-232 / GPIB	4
Digital Storage Oscilloscope	<ol style="list-style-type: none"> 1. RF Forward Power 2. RF Reflected Power 3. Cathode emission signal 4. FCT Signal – bunch current 	Ethernet	4
Digital Teslameter	<ol style="list-style-type: none"> 1. Dipole magnet field 	RS-232	1
Derived	<ol style="list-style-type: none"> 1. Trip alarms of all power supplies 2. Cathode runtime 	-	11
Miscellaneous	<ol style="list-style-type: none"> 1. VME program status 2. VME CPU reset 3. User data 4. DSO settings 5. RF synthesizer settings 6. Fault information 		~35

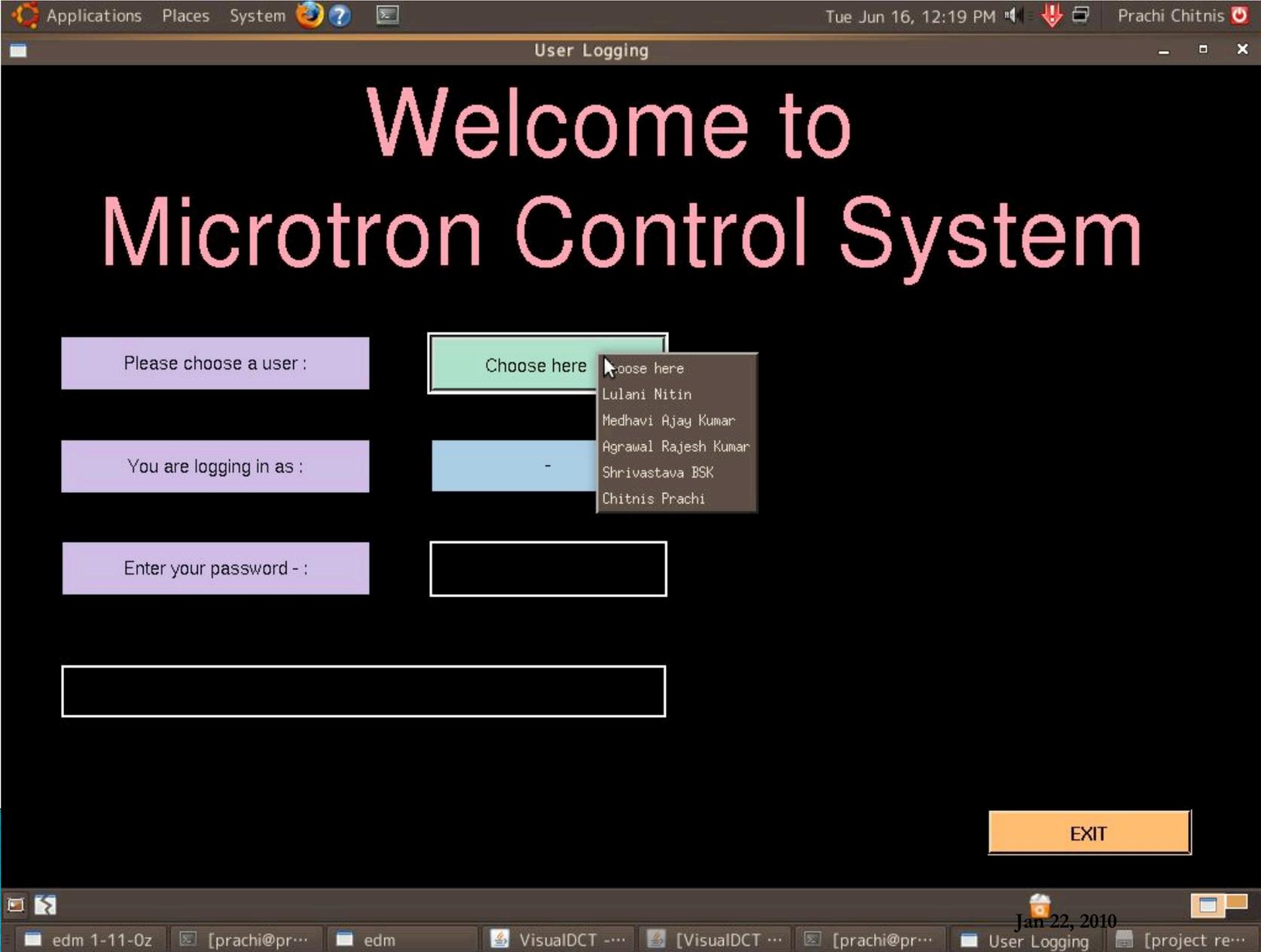
IOC Features

- ▶ Hierarchical design of IOC database
- ▶ Error checking modules
- ▶ Event based processing given precedence over periodic processing (scanning (event/passive)/output on change)
- ▶ While the CPU being reset, readback polling is disabled
- ▶ Setting records disabled during Local status of Power supplies

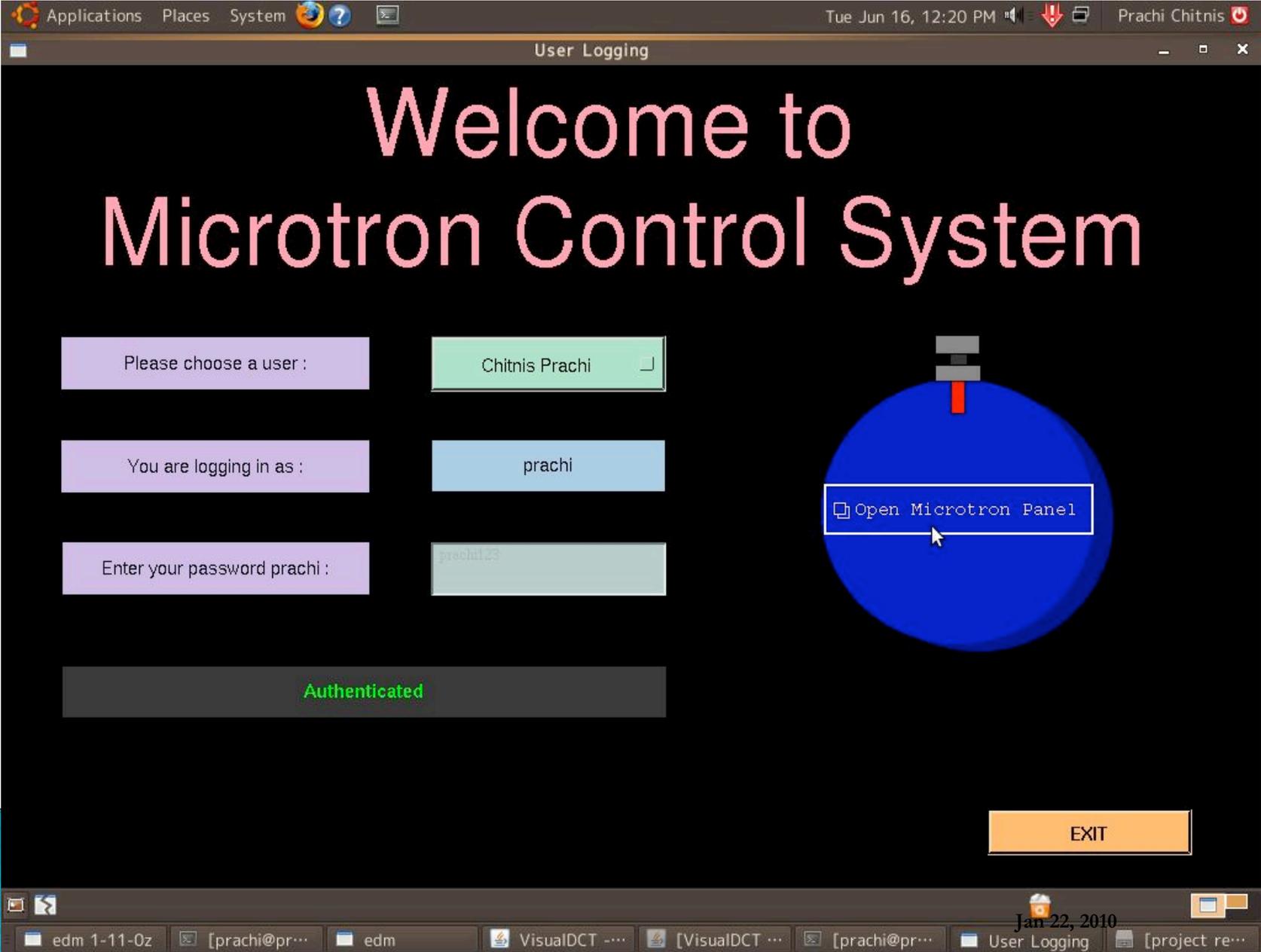
IOC design



User Authentication



User Authentication



The OPI

EDM 1-11-0z

START
MICROTRON CONTROL SYSTEM
EXIT PROGRAM

INTERLOCKS
Water Flow **GOOD**
Air Flow **GOOD**
Rad Low **GOOD**
Vacuum **GOOD**
Door Cls **GOOD**
Search & Scram **GOOD**

POWER SUPPLIES	Access	Status	Trip Status	Device Readback	Setting Readback	Make ON	Make OFF	Set the Value	Done?	Permissible Range
Driver Klystron Voltage	Remote	ON		10.00 kV	10.00 kV	ON	OFF	10.0000	OK	0 to 10 kV
Klystron Modulator Voltage	Remote	ON		5.00 kV	5.00 kV	ON	OFF	5.0000	OK	0 to 13 kV
Cathode Current	Remote	ON		74.96 A	74.95 A	ON	OFF	75.0000	OK	0 to 109 A
Magnet P/S Current	Remote	ON		235.04 A	235.00 A	ON	OFF	235.0000	OK	0 to 250 A
Quadrupole 1 P/S Current	Remote	ON		5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
Quadrupole 2 P/S Current	Remote	ON		5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
RH Correction Coil Current	Remote	ON		4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
LH Correction Coil Current	Remote	ON		4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
VS Coil Current	Remote	ON		+ 295.02 mA	+ 295.00 mA	ON	OFF	295.0000	Error!	0 to 300 mA
HS Coil Current	Remote	ON		+ 280.00 mA	+ 280.00 mA	ON	OFF	280.0000	OK	0 to 300 mA
Azimuthal Setting	Local	ON	TRIP!	0.00 V	0.00 V	ON	OFF	0.0000		
Cathode Power				0.00 W						
Magnet P/S Voltage				0.00 V						

Default Settings
Cathode Runtime (DD:hh:mm:ss) 0 : 0 : 8 : 14

VAC, TEMPS ETC.

Readback	
Vacuum	1.000e-07 mBar
AC Mains	230.01 V
Magnetic Field	NO PROBE
Temperature - Inlet	50.0 deg C
Temperature - Driver Body	50.0 deg C
Temperature - Driver Coil	50.0 deg C
Temperature - Modulator Body	50.0 deg C
Temperature - Modulator Coil	50.0 deg C
Temperature - Dipole Magnet	50.0 deg C
Temperature (7)	50.0 deg C
Temperature - Magnet P/S	50.0 deg C
Temperature - Magnet Coil	50.0 deg C
Temperature - Cavity Out	50.0 deg C

SYN PARAMETERS

Readback	
Synthesizer Make	Hameg
RF Status	ON
RF Level	12.0 dBm
RF Frequency	2.856800000 GHz

Set RF Synthesizer Parameters

FAULT DIAGNOSTICS

Clear

CRO PARAMETERS

LeCroy_Waveform1.DESC

CRO Signals

CPU Reset

VME CPU Prog Status

Help

Cycling

Fault Tree *|*

Enter sample no./diff in integer

Croy_SmplNo.VA

Time in sec

LeCroy_TimeDiv.VAL

Logged User : prachi

Logout only

Logout & Re-login

CRO Settings

Auto Correct Emission

Power Refl Power

Emission FCT

The OPI

EDM 1-11-0z – MEDM – client commands in terminal

START

MICROTRON CONTROL SYSTEM

EXIT PROGRAM

INTERLOCKS Water Flow **GOOD** Air Flow **GOOD** Rad Low **GOOD** Vacuum **GOOD** Door Cls **GOOD** Search & Scram **GOOD**

POWER SUPPLIES	Access	Status	Trip Status	Device Readback	Setting Readback	Make ON	Make OFF	Set the Value	Done?	Permissible Range
Driver Klystron Voltage	Remote	ON		10.00 kV	10.00 kV	ON	OFF	10.0000	OK	0 to 10 kV
Klystron Modulator Voltage	Remote	ON		5.00 kV	5.00 kV	ON	OFF	5.0000	OK	0 to 13 kV
Cathode Current	Remote	ON		74.36 A	74.95 A	ON	OFF	75.0000	OK	0 to 109 A
Magnet P/S Current	Remote	ON		235.04 A	235.00 A	ON	OFF	235.0000	OK	0 to 250 A
Quadrupole 1 P/S Current	Remote	ON		5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
Quadrupole 2 P/S Current	Remote	ON		5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
RH Correction Coil Current	Remote	ON		4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
LH Correction Coil Current	Remote	ON		4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
VS Coil Current	Remote	ON		+ 295.02 mA	+ 295.00 mA	ON	OFF	295.0000	Error!	0 to 300 mA
HS Coil Current	Remote	ON		+ 280.00 mA	+ 280.00 mA	ON	OFF	280.0000	OK	0 to 300 mA
Azimuthal Setting	Local	ON	TRIP!	0.00 V	0.00 V	ON	OFF	0.0000		
Cathode Power				0.00 W						
Magnet P/S Voltage				0.00 V						

VAC, TEMPS ETC.

Readback	
Vacuum	1.000e-07 mBar
AC Mains	230.01 V
Magnetic Field	NO PROBE
Temperature - Inlet	50.0 deg C
Temperature - Driver Body	50.0 deg C
Temperature - Driver Coil	50.0 deg C
Temperature - Modulator Body	50.0 deg C
Temperature - Modulator Coil	50.0 deg C
Temperature - Dipole Magnet	50.0 deg C
Temperature (7)	50.0 deg C
Temperature - Magnet P/S	50.0 deg C
Temperature - Magnet Coil	50.0 deg C
Temperature - Cavity Out	50.0 deg C

SYN PARAMETERS

Readback	
Synthesizer Make	Hameg
RF Status	RF ON
RF Level	Syn 12 dBm
RF Frequency	2.856800000 GHz

FAULT DIAGNOSTICS

CPU Reset VME CPU Prog Status

Help Cycling Fault Tree *|*

Logged User : prachi Logout only Logout & Re-login

CRO PARAMETERS LeCroy_Waveform1.DESC

Enter sample no./diff in integer Croy_SmplNo.VA Time in sec LeCroy_TimeDiv.VAL

CRO Settings Auto Correct Emission

Power Emission Refl Power FCT

OPI Features

Coloring guide – MEDM –no white widget

START
MICROTRON CONTROL SYSTEM
EXIT PROGRAM

INTERLOCKS
Water Flow **GOOD**
Air Flow **GOOD**
Rad Low **GOOD**
Vacuum **GOOD**
Door Cls **GOOD**
Search & Scram **GOOD**

POWER SUPPLIES	Access	Status	Trip Status	Device Readback	Setting	Readback	Make ON	Make OFF	Set the Value	Done?	Permissible Range
Driver Klystron Voltage	Remote	ON		10.00 kV	10.00 kV	10.00 kV	ON	OFF	10.0000	OK	0 to 10 kV
Klystron Modulator Voltage	Remote	ON		5.00 kV	5.00 kV	5.00 kV	ON	OFF	5.0000	OK	0 to 13 kV
Cathode Current	Remote	ON		74.96 A	74.95 A	74.95 A	ON	OFF	75.0000	OK	0 to 109 A
Magnet P/S Current	Remote	ON		235.04 A	235.00 A	235.00 A	ON	OFF	235.0000	OK	0 to 250 A
Quadrupole 1 P/S Current	Remote	ON		5.00 A	5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
Quadrupole 2 P/S Current	Remote	ON		5.00 A	5.00 A	5.00 A	ON	OFF	5.0000	OK	0 to 10 A
RH Correction Coil Current	Remote	ON		4.00 A	4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
LH Correction Coil Current	Remote	ON		4.00 A	4.00 A	4.00 A	ON	OFF	4.0000	OK	0 to 5 A
VS Coil Current	Remote	ON		+ 295.02 mA	+ 295.00 mA	+ 295.00 mA	ON	OFF	295.0000	Error!	0 to 300 mA
HS Coil Current	Remote	ON		+ 280.00 mA	+ 280.00 mA	+ 280.00 mA	ON	OFF	280.0000	OK	0 to 300 mA
Azimuthal Setting	Local	ON	TRIP!	0.00 V	0.00 V	0.00 V	ON	OFF	0.0000		
Cathode Power				0.00 W							
Magnet P/S Voltage				0.00 V							

VAC, TEMPS ETC.

	Readback
Vacuum	1.000e-07 mBar
AC Mains	230.01 V
Magnetic Field	NO PROBE
Temperature - Inlet	50.0 deg C
Temperature - Driver Body	50.0 deg C
Temperature - Driver Coil	50.0 deg C
Temperature - Modulator Body	50.0 deg C
Temperature - Modulator Coils	50.0 deg C
Temperature - Dipole Magnet	50.0 deg C
Temperature (7)	50.0 deg C
Temperature - Magnet P/S	50.0 deg C
Temperature - Magnet Coil	50.0 deg C
Temperature - Cavity Out	50.0 deg C

SYN PARAMETERS

	Readback
Synthesizer Make	Hameg
RF Status	ON
RF Level	12.0 dBm
RF Frequency	2.856800000 GHz

Set RF Synthesizer Parameters

FAULT DIAGNOSTICS

CPU PARAMETERS

Cathode ... 0 : 0 : 8 : 14

LeCroy_Waveform1.DESC

Enter sample no./diff in integer Time in sec

CPU Reset

Logged User : prachi

Clipped settings

Alarm levels

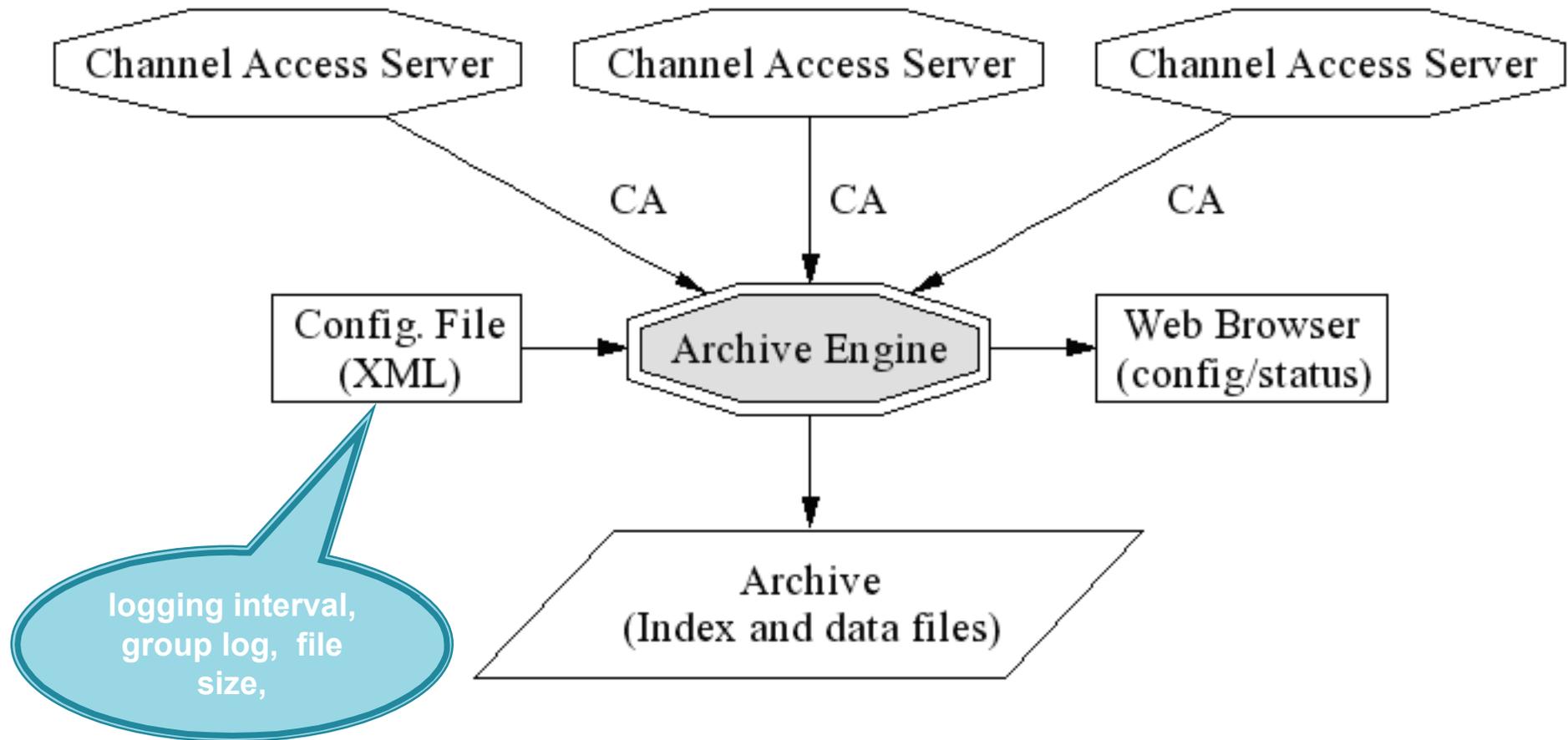
Disabled on reset, interlock fail, cycling, logout, local mode

Contrast for visibility

Help feature

Two user modes

Database logging



File Edit View History Bookmarks Tools Help

http://127.0.0.1:4812/groups

WordWeb Online Loo...

Groups file:///home/p...gineconfig.xml

Groups

Name	Enabled	Channels	Connected
DriverKlystronPS	Yes	8	8
KlystronModulatorPS	Yes	8	8
CathodePS	Yes	9	9
MagnetPS	Yes	9	9
Quadrupole1PS	Yes	8	8
Quadrupole2PS	Yes	8	8
RHCCoilPS	Yes	8	8
LHCCoilPS	Yes	8	8
VerticalSCPS	Yes	9	9
HorizontalSCPS	Yes	9	9
Interlocks	Yes	6	6
Temperature	Yes	10	10
Misc	Yes	8	5
IFRSynthesizer	Yes	8	0
HamegSynthesizer	Yes	8	0
Total		124	105

[-Main-](#) [-Groups-](#) [-Config-](#)

(Status for 09/22/2009 15:03:12. Use *Reload* from the Browser's menu for updates)

Done



Database logging

- ▶ Central database for Indus systems – SQL server based
- ▶ Using JCA
- ▶ Java script and JDBC

Fault Diagnostics [4,5,6]

- ▶ Detection of anomalous system behavior
- ▶ Identification of the cause for the deviant behavior
- ▶ Expert System Diagnosis – knowledge based on experience and expertise encoded in machine storable structure
- ▶ Fault tree n rule based reasoning system
- ▶ Forward chaining algorithm technique
- ▶ Non-expert operators can troubleshoot a fault

Fault Diagnostics [4,5,6]

- 3 categories of fault prone systems in accelerators [2]
 - Hardware components (cavities, magnets etc.)
 - Auxiliary infrastructure (water, air, electrical power etc.)
 - Control system.
- Availability of control faults at a place
 - Online fault logging system – 2 years data
 - Operational logbooks – 1 year data
- Two modules
 - Fault prediction
 - Fault diagnosis

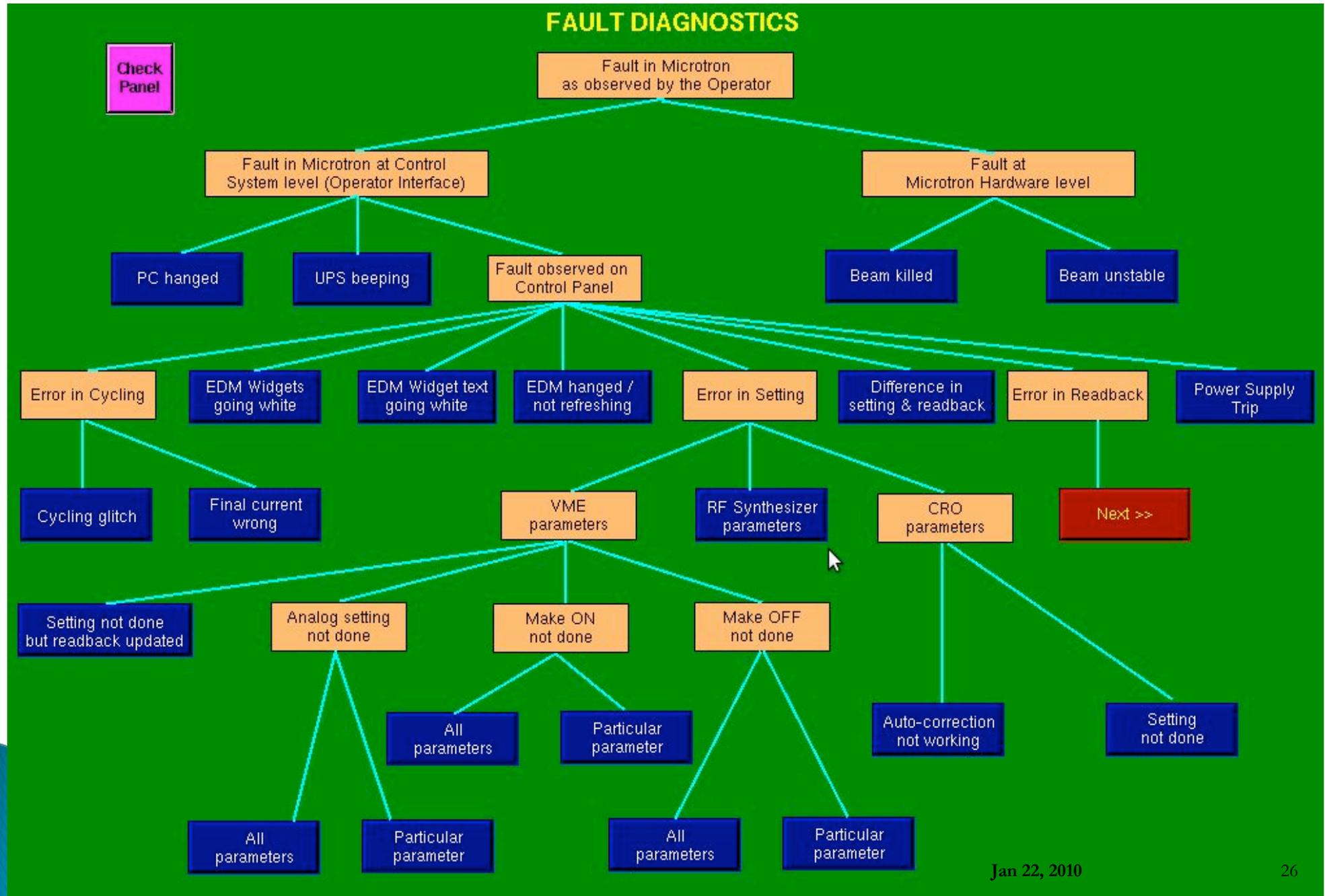
Fault Prediction

- ▶ Active - Monitors the anomalies occurring - Warns user
 - AC mains voltage fluctuations
 - Dipole magnetic field changing
 - Vacuum pressure rising
 - Error checking modules
 - ...
- ▶ ~13 different predictions

Fault Diagnosis

- ▶ Passive – helps operator to troubleshoot a fault observed – reaches a probable cause
- ▶ ~40 different types of faults
- ▶ Two parts
 - System-wise hierarchical fault tree
 - Rule based reasoning system for each leaf fault
 - Check panel on EDM
- ▶ E.g. current setting for a power supply not done

Fault Tree



Rule based reasoning

Fault: VME - Analog Setting not done - Particular Parameter

>> Did you follow proper start-up procedure?	Verify proper start-up procedure being followed or not
>> Were there any recent software modifications?	Ask system engineer
>> Were there any recent hardware modifications?	Ask system engineer
>> Refresh the EDM panel	Middle mouse button click - Menu
>> Power supply in local mode	Check on the panel
>> Power supply tripped	Check on the panel
>> Interlock status bad	Check on the panel, check the respective system for interlock
>> Command queue timeout	Check on IOC server panel if any queue timeout messages are there
>> Temporary error in VME reading	It may correct automatically
>> VME CPU program error	Check the status of the program with 'VME CPU Prog Status' button
>> Reset the VME CPU	Reset the VME CPU and/or click 'CPU Reset' button on panel
>> Link failure	Tighten the connections, check for breakage
>> Serial port not functioning	Check the port / Change it to another
>> VME DAC card problem	Check the hardware
>> Problem at device end	Check the respective device
>> Inform the concerned system expert	

Improvements achieved by using EPICS

- ▶ Interaction between controllers – Access to PVs
- ▶ Integration of Indus-1 controls
- ▶ Homogeneous system
- ▶ Accelerator specific tools
- ▶ Free n open source
- ▶ Modularity – suits to control hardware upgradation of Indus-1
- ▶ Huge EPICS community

Conclusion

- ▶ The testing of the project is done in lab environment, field testing is on
- ▶ Due to its easy adaptability to hardware changes, EPICS is best suited prospective to hardware upgradation.
- ▶ Mostly involves graphical programming, eases enhancements and changes, and debugging.
- ▶ The knowledge gained will be utilized for upgrading the Indus-1 control systems.

References

- [1] http://optics.eee.nottingham.ac.uk/lecroy_tcp/driver_source/tarballs/lecroy_tcp-1.00.tar.gz
- [2] D. Barni et al., “Basis for the reliability analysis of the proton linac for an ADS program”, Proceedings of the PAC ’03
- [3] <http://www.aps.anl.gov/epics/>
- [4] P. Duval et al., “Fault identification in accelerator control”, http://adweb.desy.de/mcs/Mst_content/fault_identification.pdf
- [5] T. Himel et al., “Availability and reliability issues for ILC”, Proceedings of PAC’07
- [6] S. Narasimhan et al., “Automated diagnosis of physical systems”, Proceedings of ICALEPCS07, Knoxville, Tennessee, USA

Thank You!