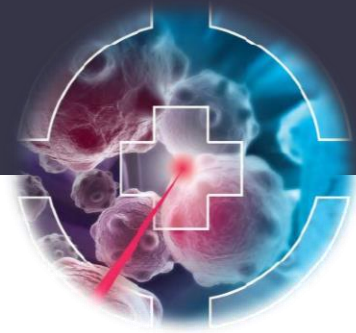


Luigi Casalegno
Fondazione CNAO





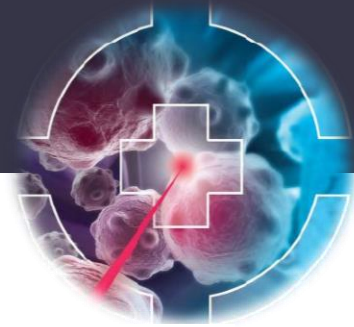
Visual Identity



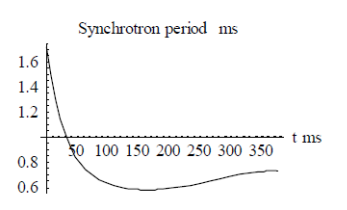
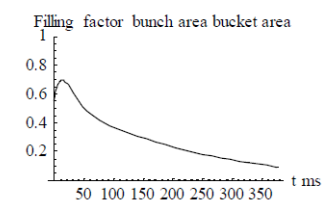
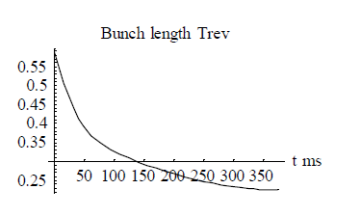
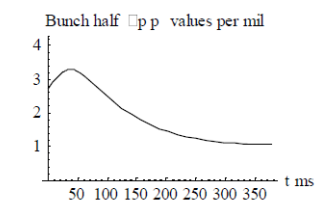
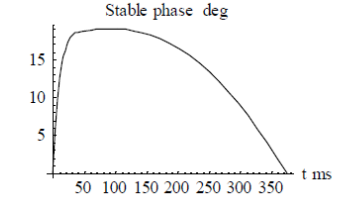
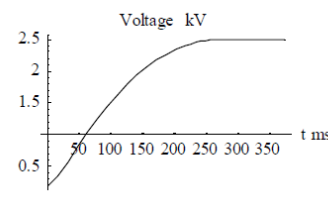
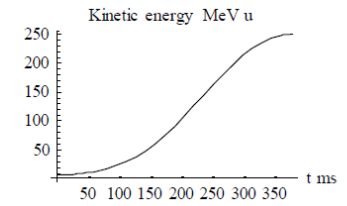
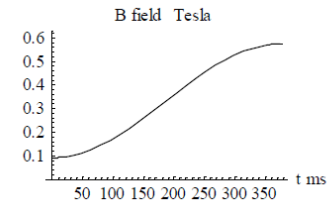
This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement 675265

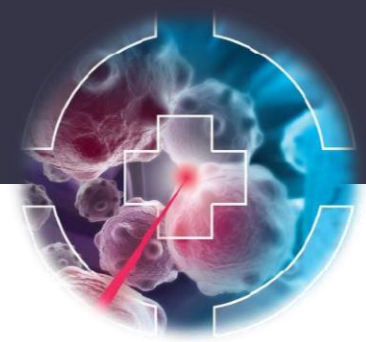


The synchrotron challenge

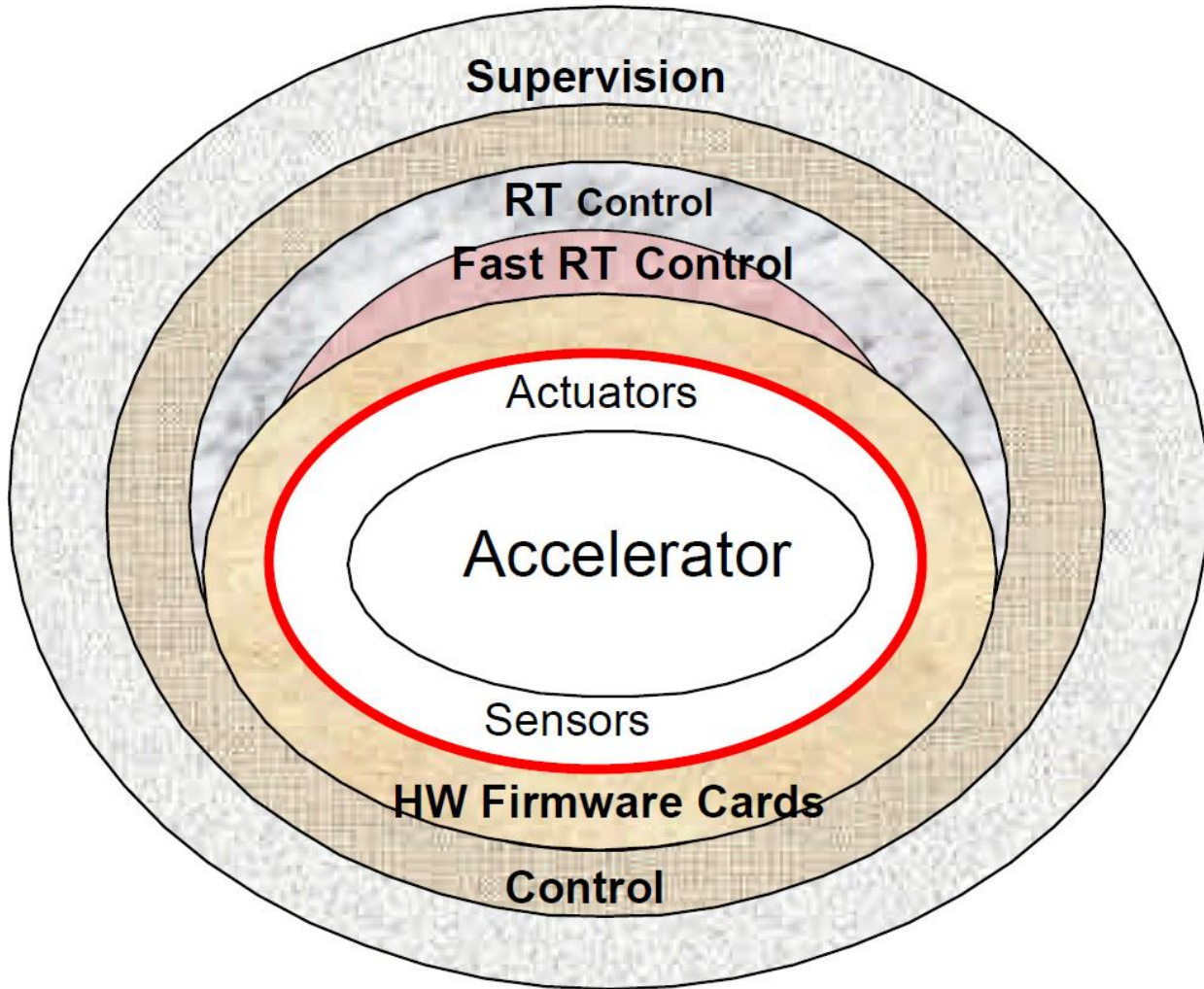
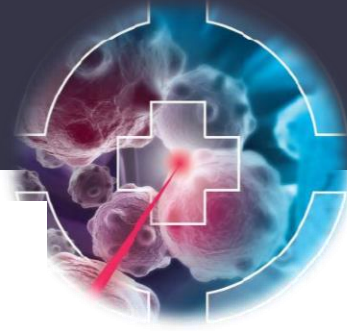


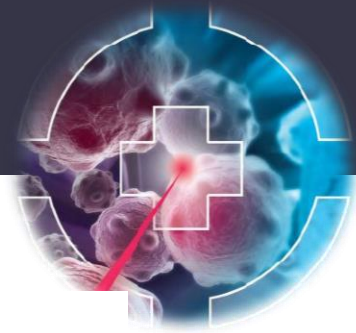
- About 180 power supplies
 - 4 Radio frequencies
 - Pulse to pulse modulation
- ↓
- Time synchronization
 - Execution synchronization
 - Cycle based (from 1 to 5 s)



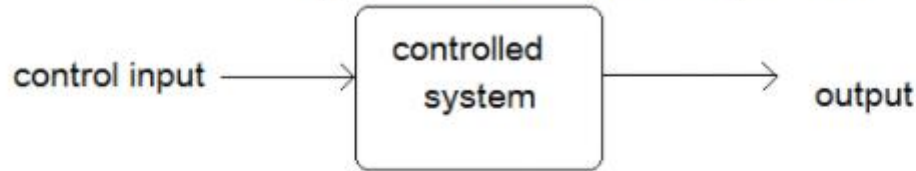


- The tumor volume has to be split into slices orthogonal to the accelerated beam. Each slice corresponds to a specific beam energy.
- A treatment is a sequence of beams by means of which all the slices that make the tumor volume are irradiated. It is a cyclical behavior, where each cycle has a preconfigured events sequence, always with the same structure, that implies a different setup of the devices for different cycles
- This goal is achieved using a sequencer that synchronizes the accelerator activities. This sequencer is built into the timing system.
- No guarantee of the next cycle type is possible up to the end of the present cycle

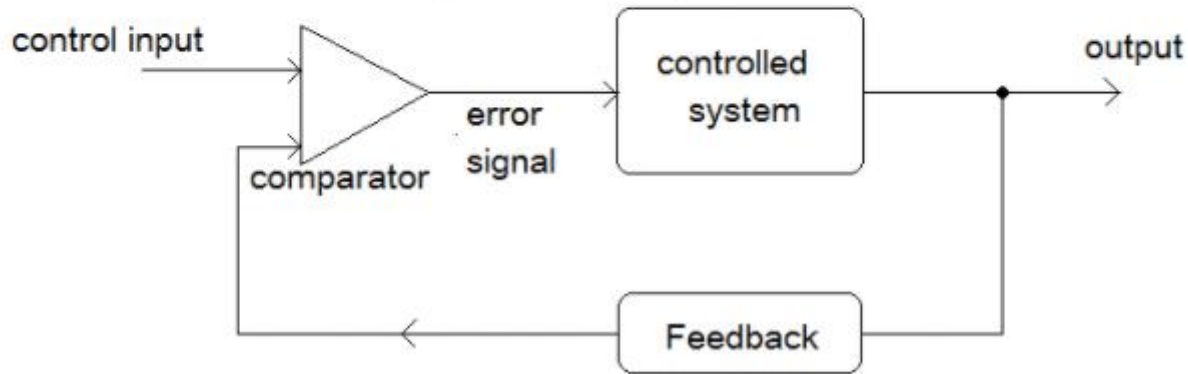




Open loop control system

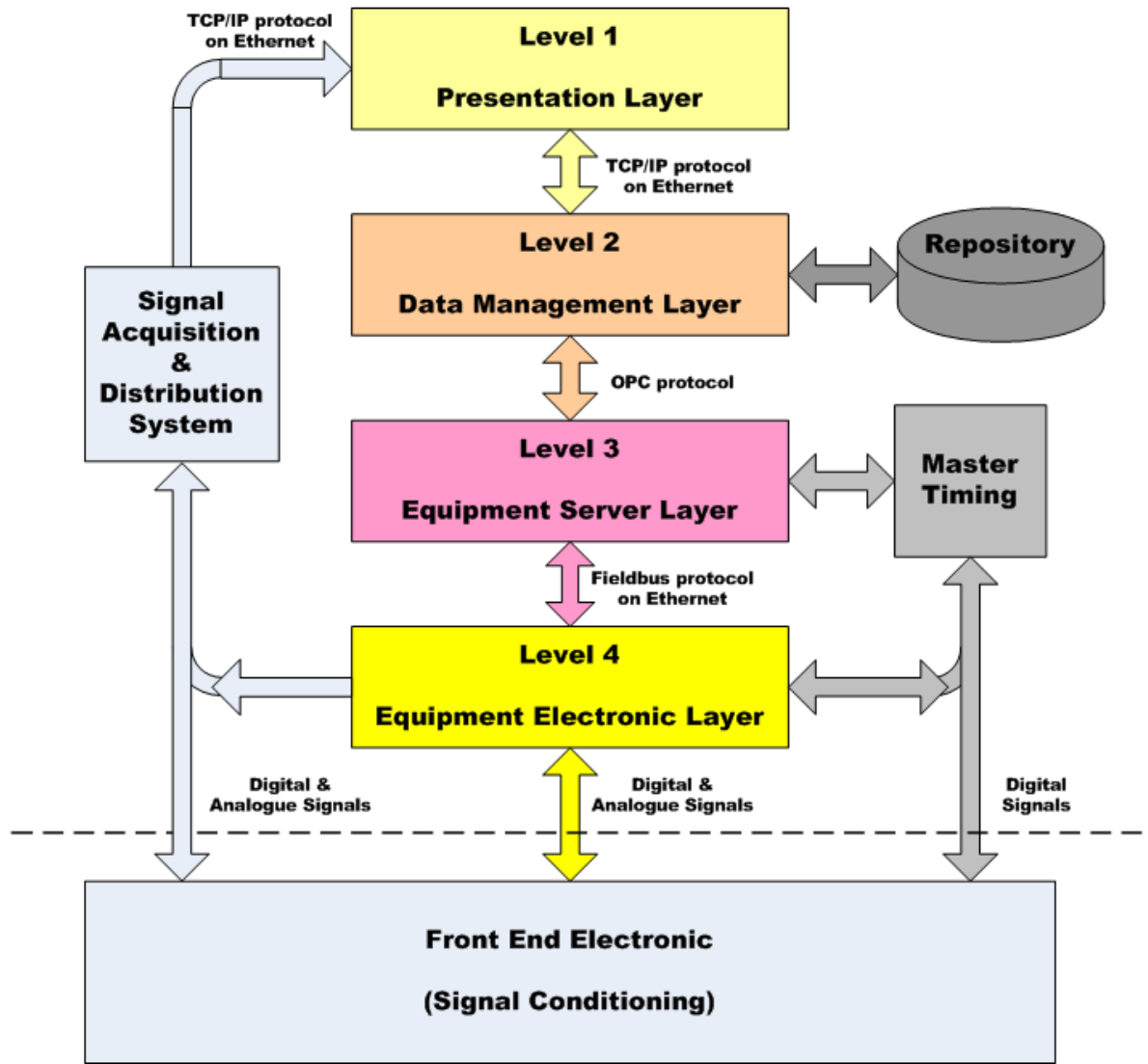


Close loop control system



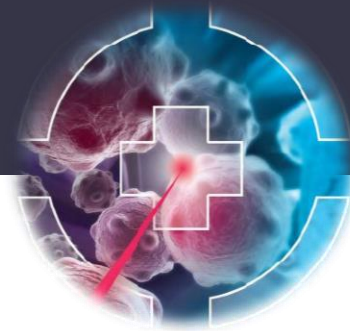


Control System Conceptual Model





The Cycle Code



Cycle Code Builder

Energy (MeV/u) Particle Treatment Line

X Size Y Size Injection Grid

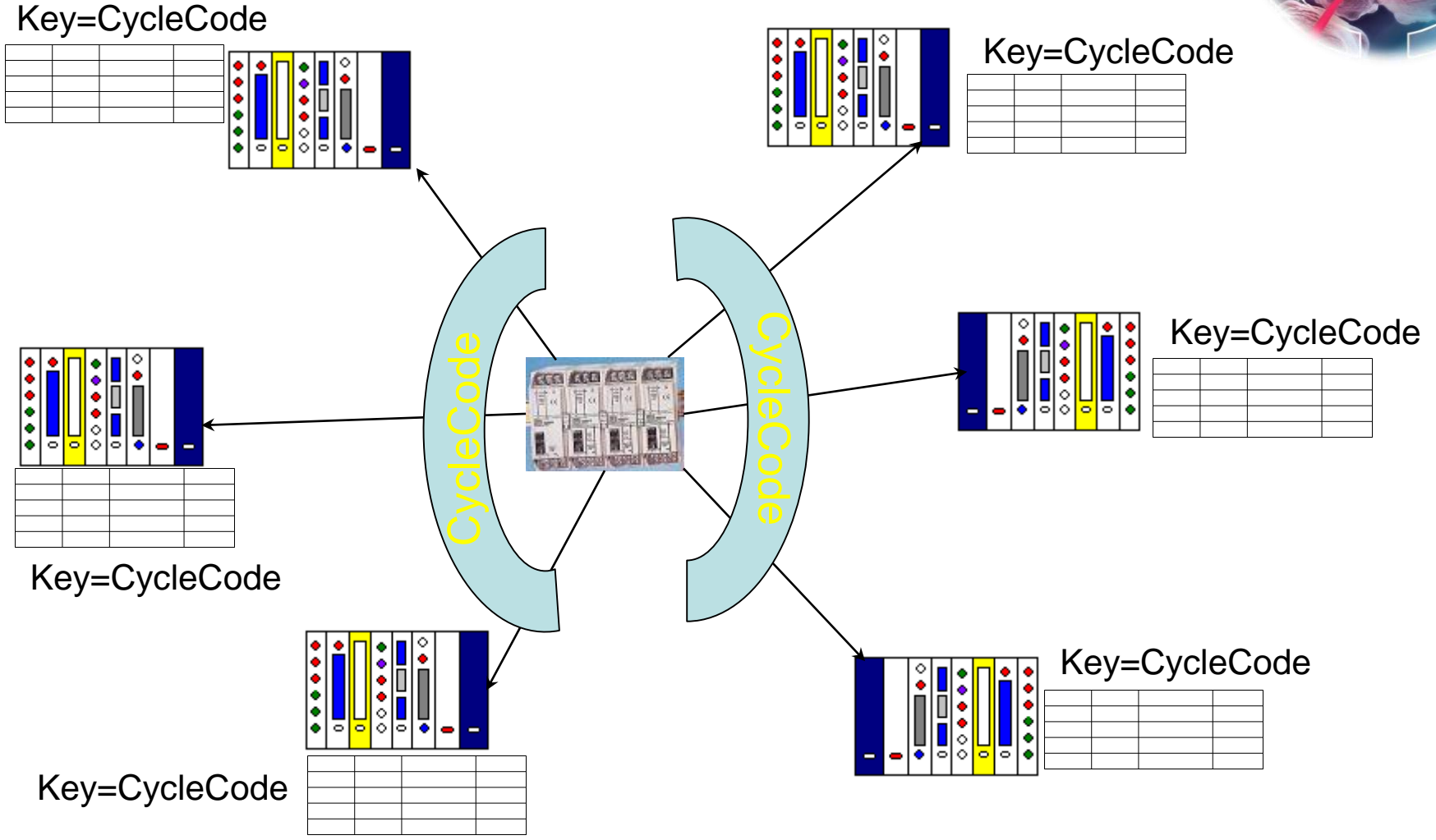
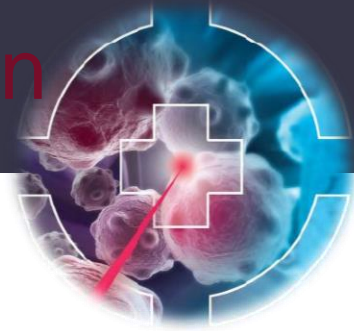
Spill Length Mode Cycle Code Version

Resulting Cycle Code

68 bits								
Energy	Particle Type	Treatment Line	X Size	Y Size	Injection Grid	Spill Length	Machine Model	Cycle Code Version
15 bits	4 bits	3 bits	4 bits	4 bits	3 bits	4 bits	2 bits	8 bits

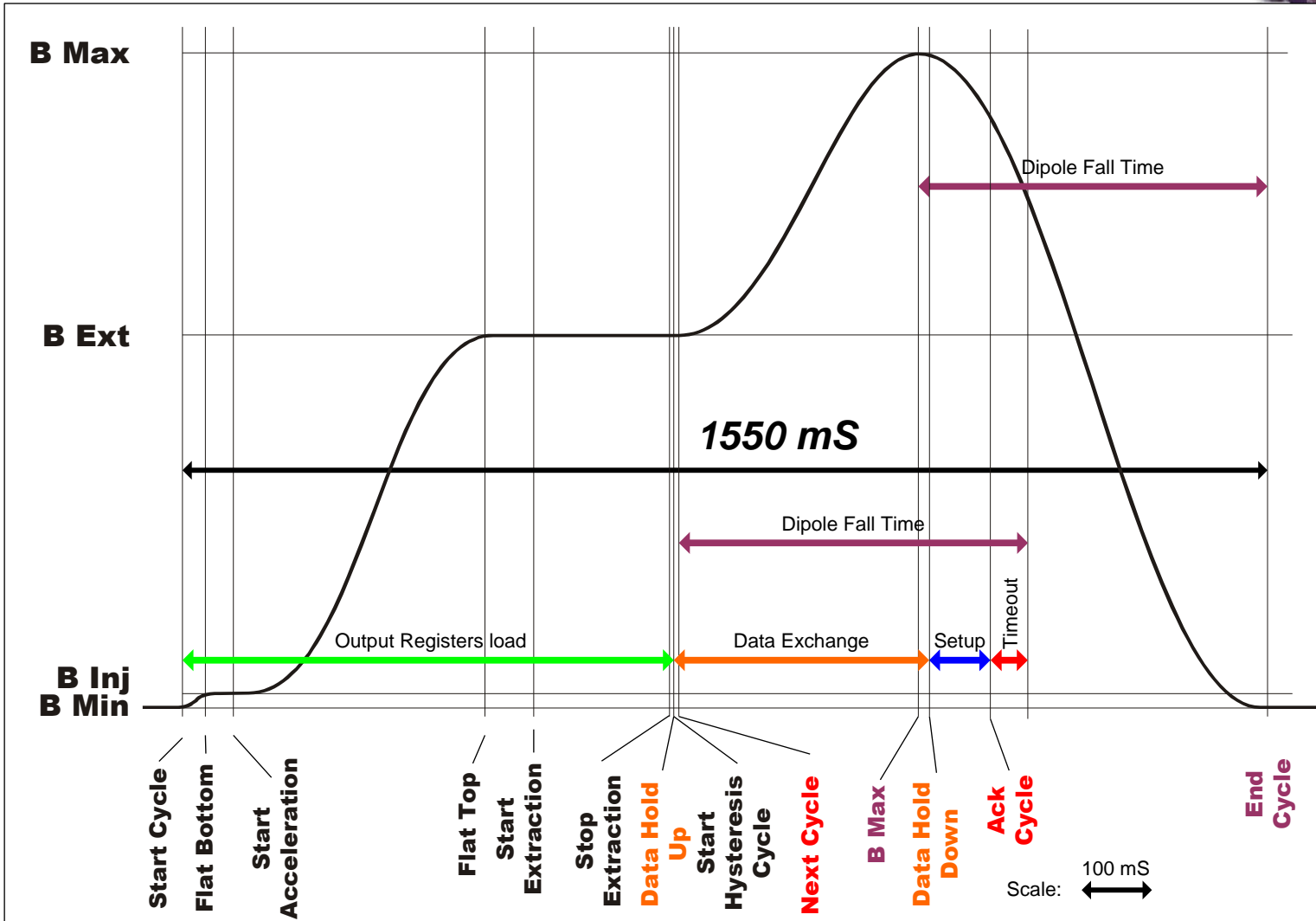
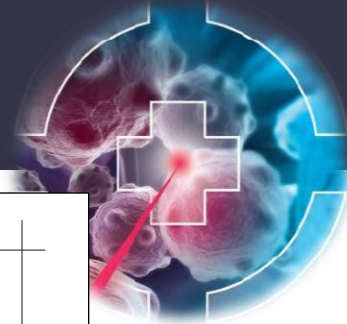


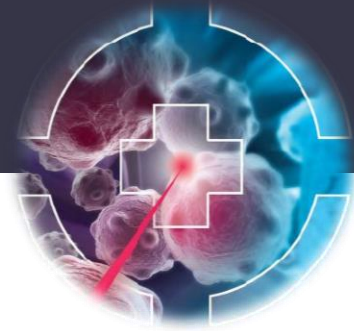
Sequencing and Synchronization



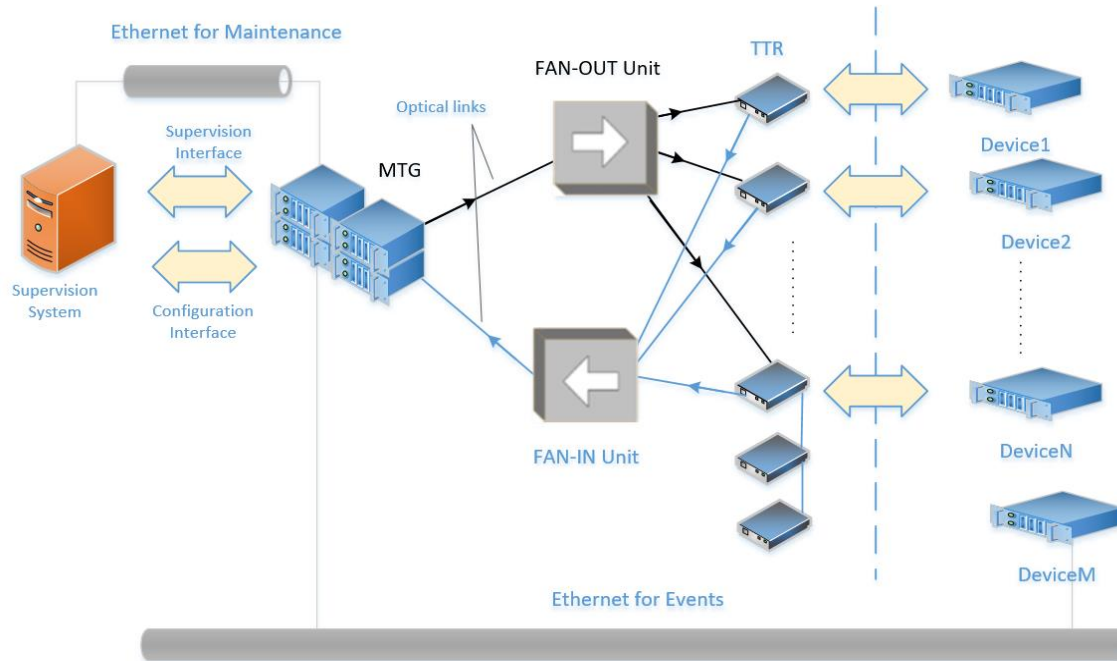


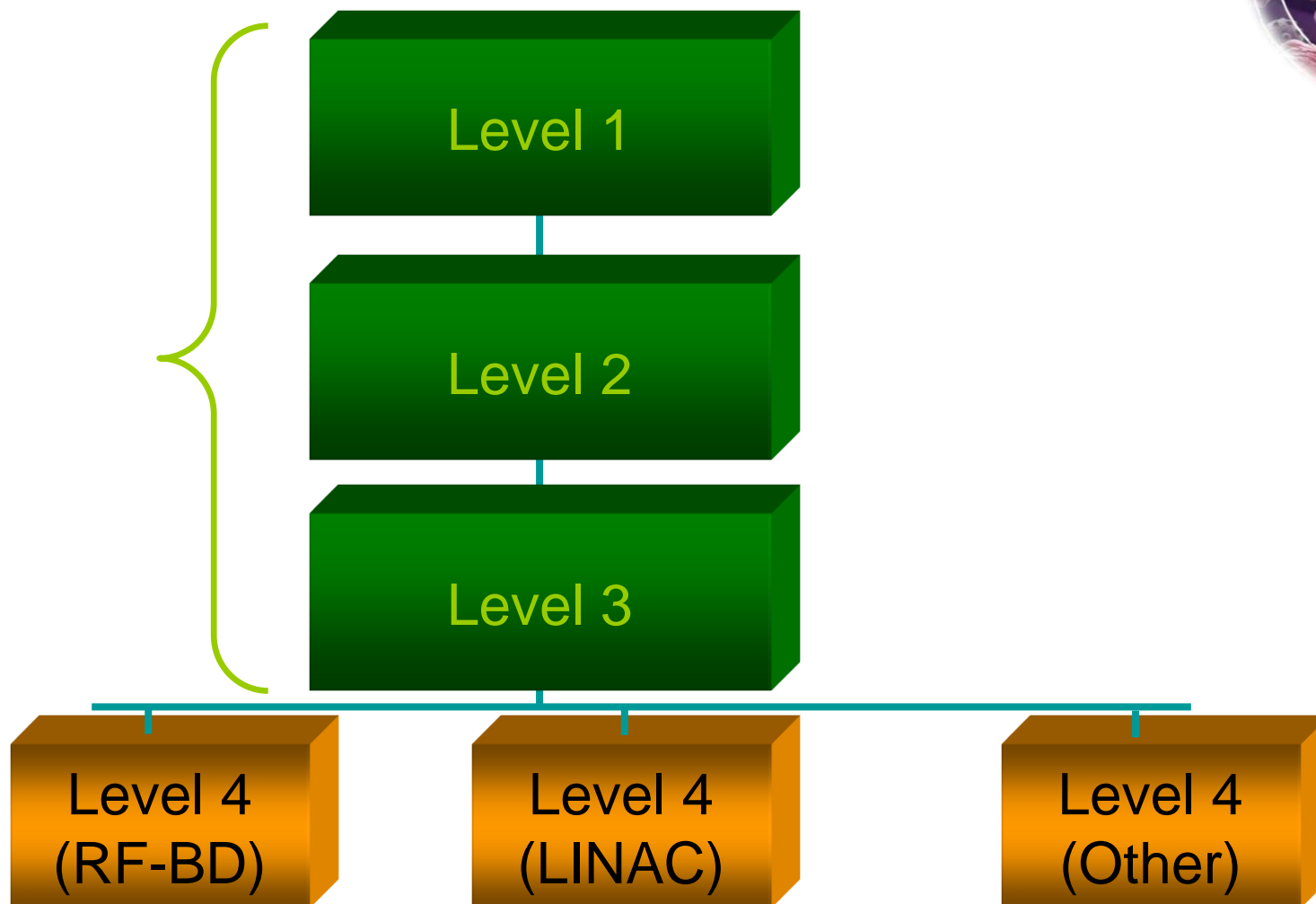
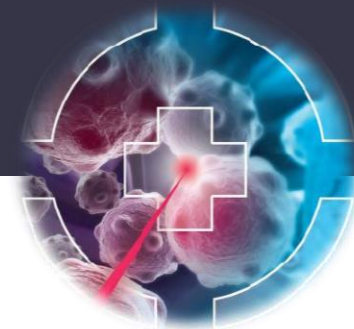
Timing conceptual model

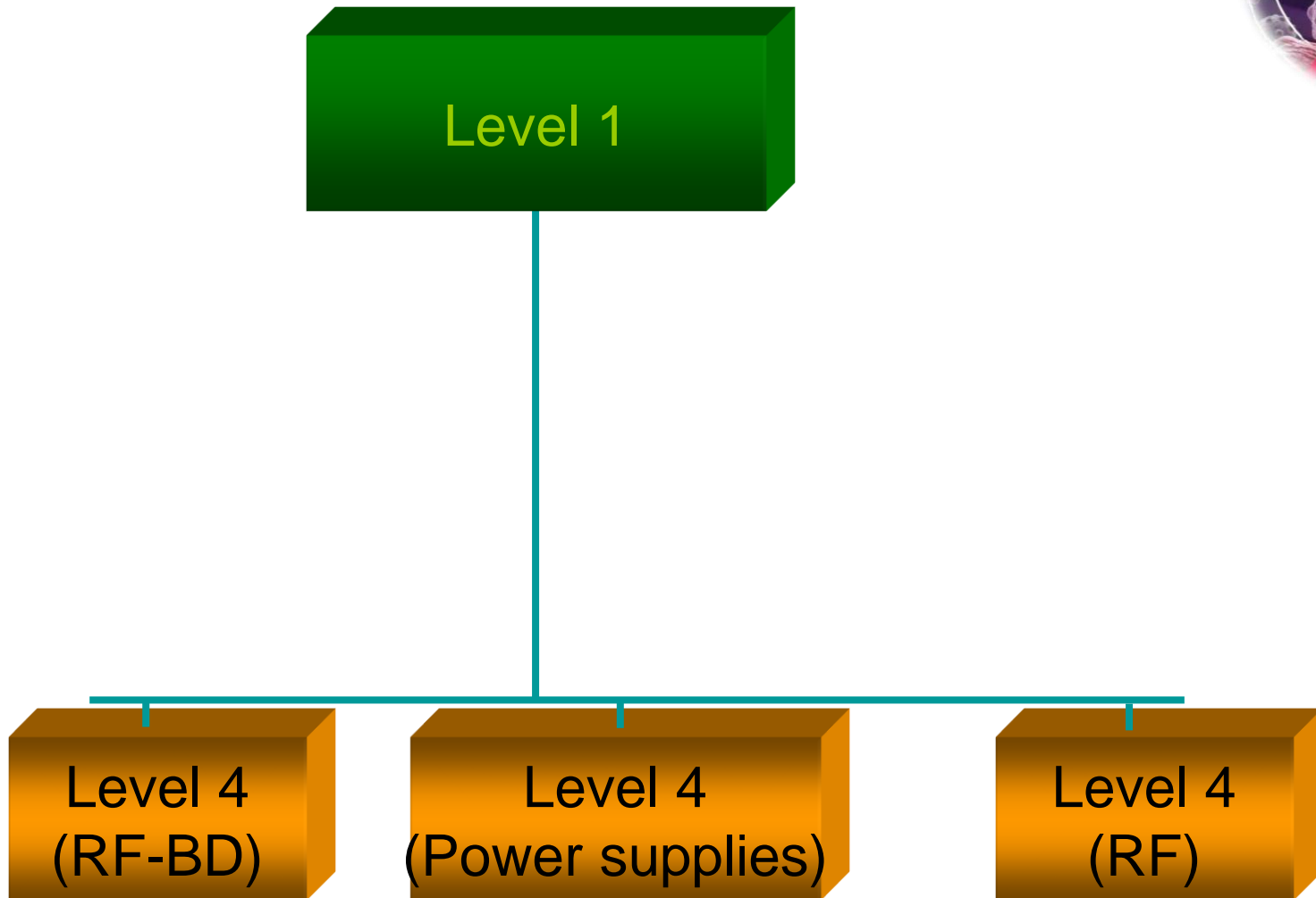
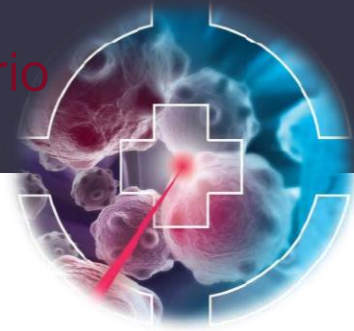




- STAR topology – Daisy chaining
- Bidirectional link
- Up to 100 devices with fiber optics link and custom cPCI receiver (100 ns jitter)
- Up to 250 devices with TCP/IP link (1 ms jitter)

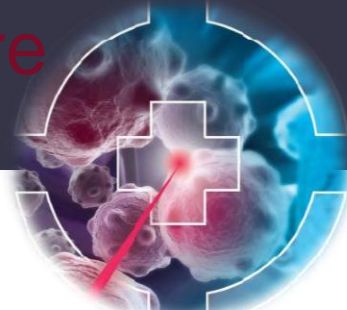








Control System Software Architecture



service
service



Control System

process

service
service



procedure

service
service



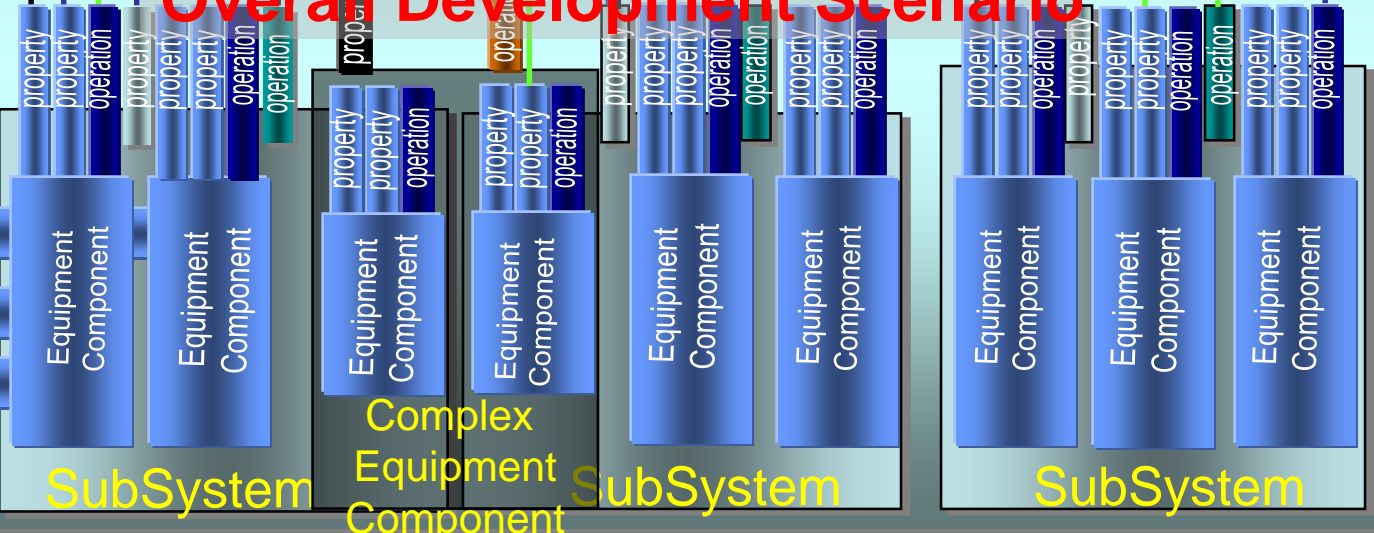
procedure



Overall Development Scenario

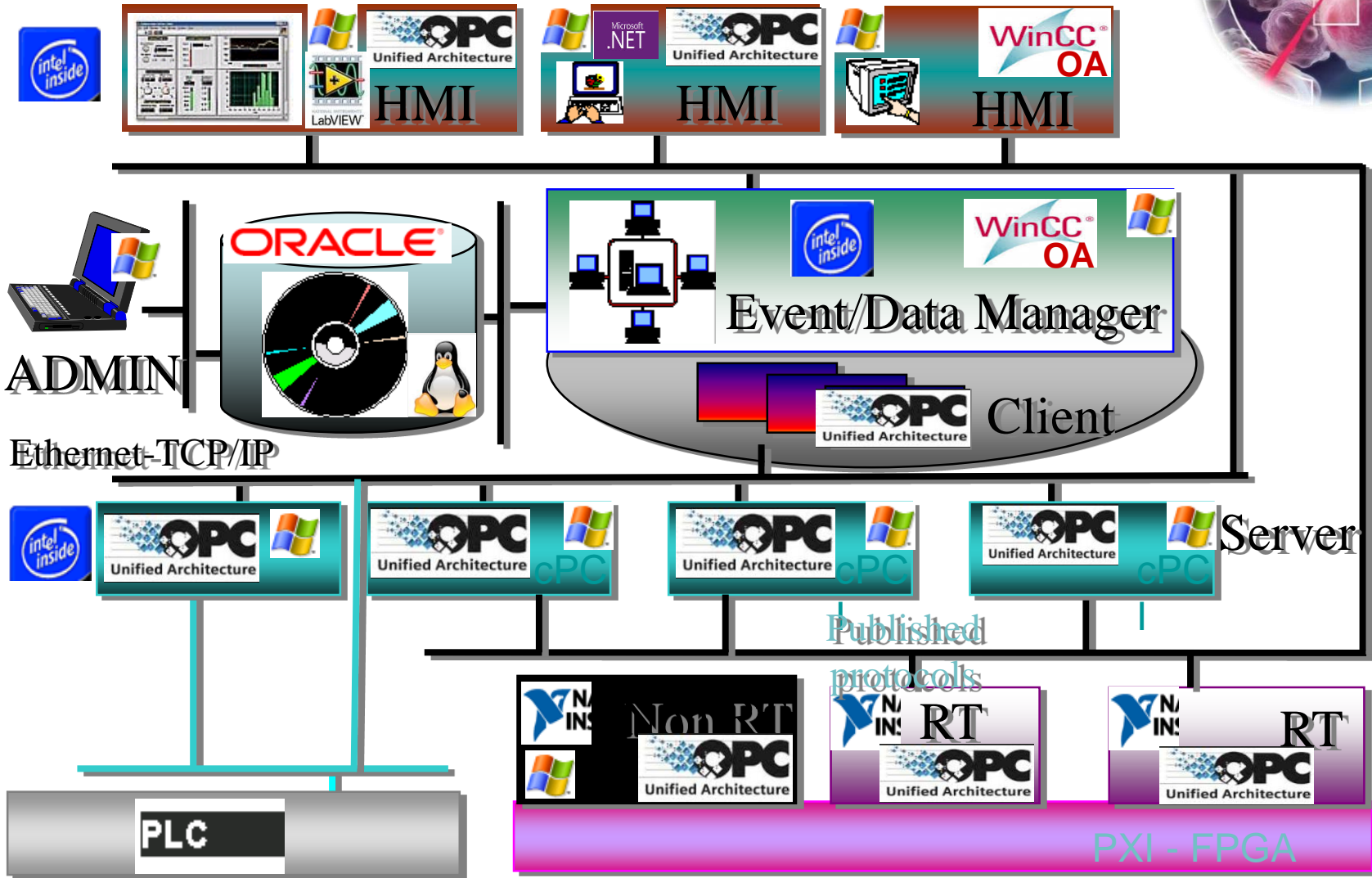
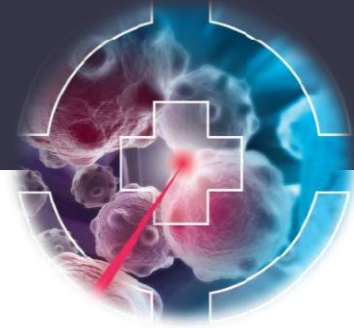


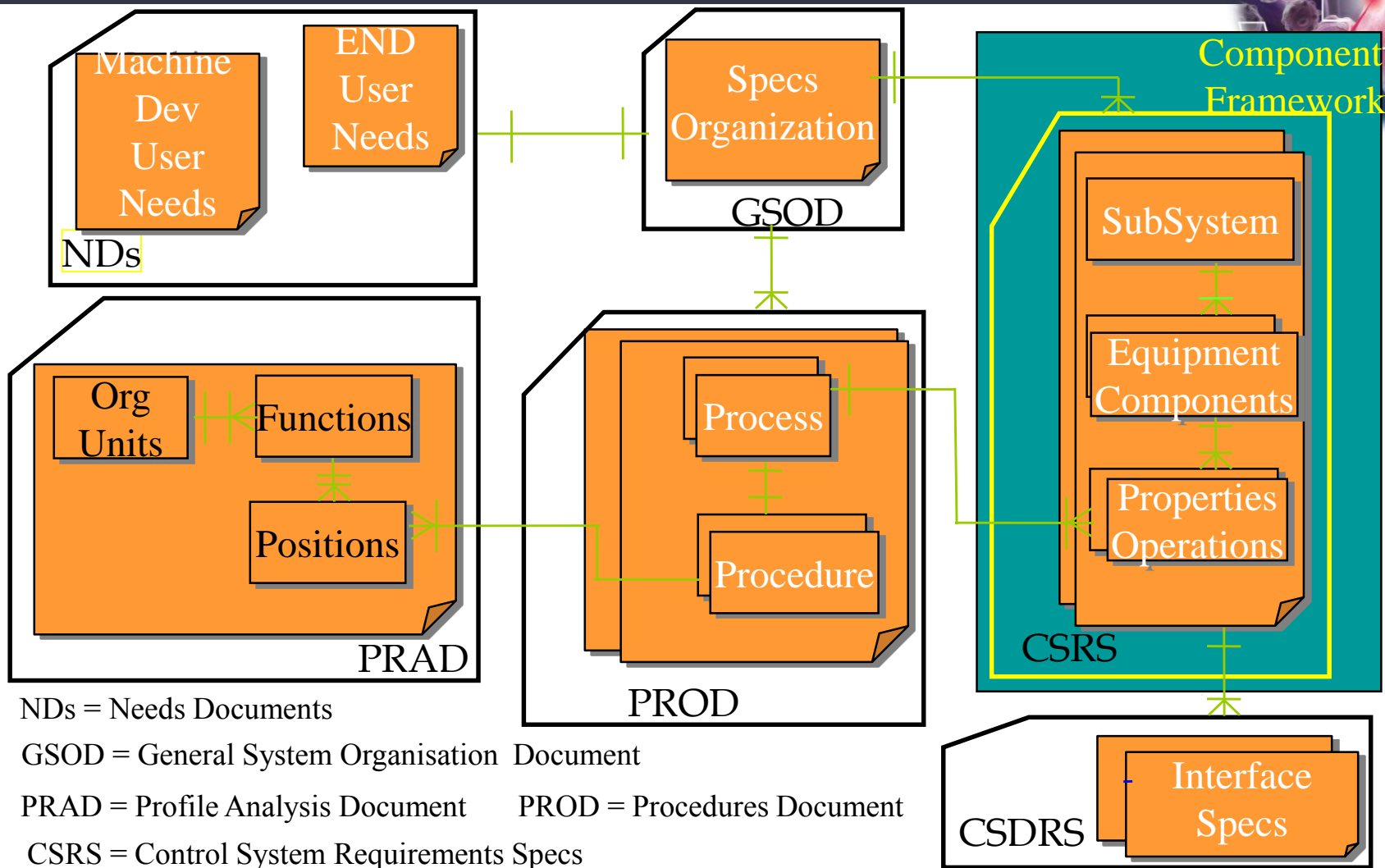
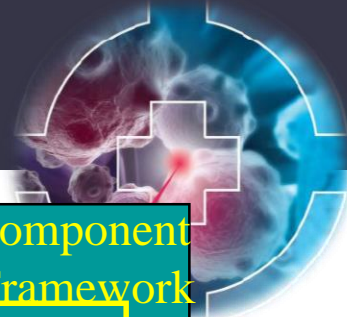
Virtual instrument
Virtual instrument
Virtual instrument





Infrastructure - Overview





NDs = Needs Documents

GSOD = General System Organisation Document

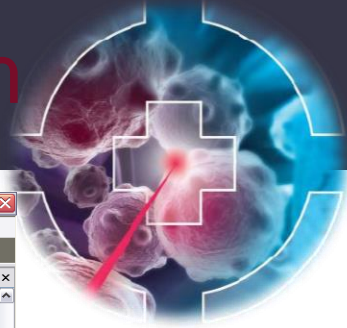
PRAD = Profile Analysis Document PROD = Procedures Document

CSRS = Control System Requirements Specs

CSDRS = Control System Detailed Requirements Specs



Repository Management System



The screenshot displays the CCSRepository application window. The main area shows a detailed layout of the CNAO Control System Repository, featuring a large circular structure and several linear sections. The components are color-coded: blue for drift sections, red for steering magnets, and green for matching sections. A legend box in the center provides details for specific sections:

- L2020A: DRI - Drift, Straight section
- LN002A: ITM - InterTank Matching section
- LN002B: IMC - Intertank section Steering magnet
- LN002C: QD1 - PSLINAC-EqComp
- LN002D: QD2 - PSLINAC-EqComp
- LN003A: PHI - BSLINAC-EqComp
- L2019C: DRI - Drift, Straight section

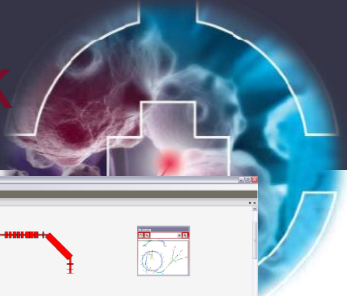
The left sidebar contains a hierarchical tree view of the repository components, including:

- Accelerator layout
 - ACQ - Air Cored Quadrupole S6012A
 - ACT - Alternate Current Tran M3027A
 - BDC - Bumper Dipole for du S9016A
 - BDI - B drawing
 - SD S3
 - BDS - I S3
 - BEC - I S4
 - BOK - I S4
 - H3
 - H4
 - H5
 - T2
 - T2003A
 - T2028A
 - U1021A
 - U2003A
 - U2025A
 - V2003A
 - V2025A
 - V2029A
 - Z2002A
 - Z2009A
 - Z2028A
- BSE - Beam Stopper for Extr
 - T1007B
 - U1005B
 - V1025A
 - Z1007B
- BSL - Bellows for LEBT
 - L1005B
 - L1007B
 - L1021B
 - L1023B
 - L2007B
 - L2013B
 - L2015B
 - O1007B
 - O1016B
 - O1021B
 - O1024B
 - O2007B
 - O2016B
 - O2021B
 - O2024B
- BS1 - Bellow Synchrotron typ
 - H1008A
 - H1017A
 - H1025A
 - SA006A
 - SA021A
 - SB008A

The bottom status bar indicates the current baseline is 1.0.2 and the database is cnao.



Specification Documents Framework



3.2. COMPONENTS

3.2.1. EQUIPMENT NAME: <Equipment><equipmentName>BINST-PUEqComp</equipmentName>

```

<property>
PROPERTY: <propertyName> FFT channel </propertyName>
; → Data-Type: <datatype-size=YY>String</datatype>
; → Direction: <direction>RW</direction>
<ClassAttribute>1</ClassAttribute>
Description
<description>
For which monitor to calculate FFT
</description>
</property>

<property>
PROPERTY: <propertyName> FFT start </propertyName>
; → Data-
; → Direc

```

3.2. COMPONENTS

3.2.1. EQUIPMENT NAME: BINST-PUEqComp

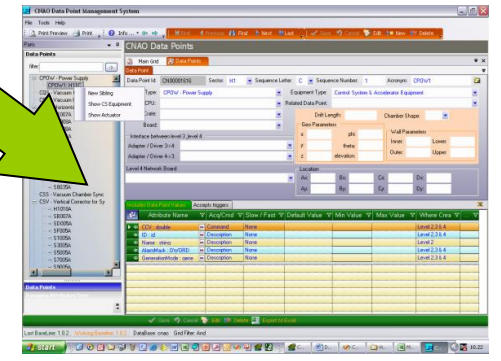
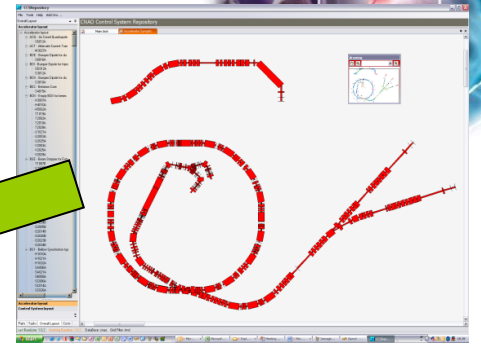
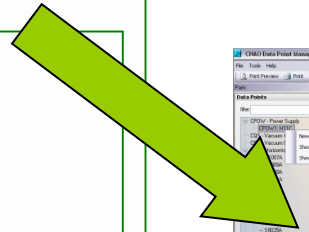
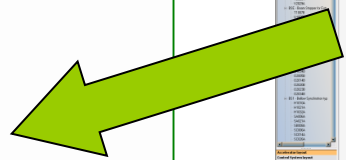
```

PROPERTY: FFT channel ; Data Type: String ; Direction: RW
Description
For which monitor to calculate FFT

PROPERTY: FFT start ; Data Type: Integer ; Direction: RW
Description
Offset in samples to beginning of FFT sub waveform

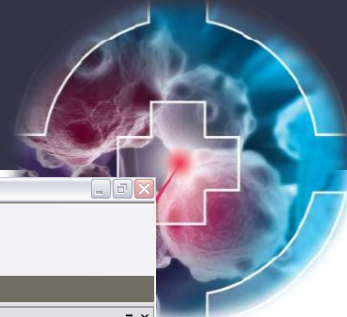
PROPERTY: FFT length ; Data Type: Integer ; Direction: RW
Description
Number of samples in FFT

```





Data Points Concept



CCSRepository

File Tools Help Add Ons ...

Print Preview Print Info ... First Previous Find Next Last

Save Cancel Edit New Delete Copy Fields

Parts

Data Types

filter: []

Attributes

Data Points

- SLA - BINST-SLEqComp
 - L1-0178-SLA: L10178
 - 01-0088-SLA: 010088
 - 01-0238-SLA: 010238
 - 02-0088-SLA: 020088
 - 02-0238-SLA: 020238
- SLB - BINST-SLEqComp
 - M2-006A-SLB: M2006A
 - M3-024A-SLB: M3024A
- SLC - SICoRFEqComp
 - S8-020B-SLC: S8020B
- SLE - Double movable Slit for E
- SU - Double movable Slit for Inj
- SL1 - PSLINAC-EqComp
 - L2-0198-SL1: L20198
 - 01-0028-SL1: 010028
 - 02-0028-SL1: 020028
- SL2 - Solenoid type 2
- SMA - Special Magnets Auxillar
- SMAg - Special Magnet
- SMS - Special Magnets Supervi
- SMT - Special Magnets Timing
- Soa - Sources Auxillar
- solenoid - spec_magnet_solenoid
- so - Sources Supervisor
- so - Sources Timing
- SD1 - Proton Source
- SD2 - Ion Source
- SPC - Special vacuum chamber
- SPU - Vertical Pick-up inside R
 - S8-023A-SPU: S8023A
- SSA - Synchrotron Vacuum Ch
- SSB - Synchrotron Vacuum Ch
- SSC - Synchrotron Vacuum Ch
- SSM - Septum Shadow Monitor

Data Types

Interface Types

Crates

Complex Data Types

System Info

Working Sets

Parts Tasks Overall Layout Costs

Save Cancel Edit Delete Export to Excel

Last BaseLine: 1.0.2 | Working Baseline: 1.0.2 | DataBase: cnao | Grid Filter: And

CNAO Control System Repository

Main Grid Accelerator Synthetic Control System Layout Addons **Data Points**

Data Point: Geometry Attributes Security Settings

Data Point Id: CN00003170 Sector: 01 Sequence Letter: B Sequence Number: 008 Acronym: 01-0088-SLA

Data Type: SLA - BINST-SLEqComp

Equipment Type: Accelerator Equipment

Related Data Point:

Level 3 CPU: L3CPU: FCA-BWS-SLA-HVP

Crate: Crate L3: FCA-BWS-SLA-HVP

Board:

Description:

Location

Ax: 323,647 Bx: 309,453 Cx: 309,183 Dx: 323,377

Ay: 319,004 By: 323,855 Cy: 323,064 Dy: 318,213

Layout

Interface between level 3 and level 4

Protocol: Data Socket

Adapter / Driver 3-4: OPCServer_FCA-BWS-SLA-HVP

Adapter / Driver 4-3: SWModule_L4_FCA-BWS-SLA

Adapter:

Datsocket for Reading:

Datsocket for Writing:

Datsocket for Operations:

Level 4 Network Board:

ETH-1010 with IP Address 192.168.40.3 in crate P4-1044 on rack Rack Beam DiagnosticsLEB1 at level 3 in room Electronics Room (Room B)

Clear Data Point Online State Show Settings

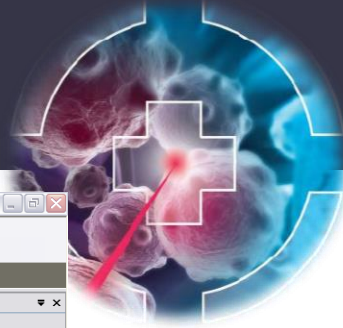
Includes Data Point Values Accepts triggers

Attribute Name	Acq/Cmd	Slow / Fast	Default Value	Min Value	Max Value	Where Crea
CompletionCode	comp	Acquisition	Slow			Level 2,3 and 4
Inhibition	boolean	Command	Slow	0		Level 2,3 and 4
ErrorCode	unsigned int	Acquisition	Slow			Level 2,3 and 4
ErrorString	string	Acquisition	Slow			Level 2,3 and 4
Busy	boolean	Acquisition	Slow			Level 2,3 and 4
CycleProg	unsigned int	Acquisition	Slow			Level 2,3 and 4
CycleCode	cyclecode	Acquisition	Slow			Level 2,3 and 4
WorkInProgress	unsigned int	Acquisition	Slow			Level 2,3 and 4
LV3Name	string	Acquisition	Slow			Level 2 and 3
SetInhibition	boolean	Operation	Slow			Level 2,3 and 4
Axis4_BeamRef	double	Description	None	31.21		Level 4
RightEmittanceGap	double	Description	None	0		Level 4
Axis1_BeamRef	double	Description	None	29.59		Level 4
Axis4_SlaRef	double	Description	None	0		Level 4
UpEmittanceGap	double	Description	None	0		Level 4
Axis2_BeamRef	double	Description	None	31.18		Level 4
FirstHoming	boolean	Description	None	True		Level 4
MotionDelay_AlterSTC	double	Description	None	0		Level 4
Axis3_BeamRef	double	Description	None	30.56		Level 4
InstStatus	unsigned int	Description	None	0		Level 4
DownEmittanceGap	double	Description	None	0		Level 4
Axis2_SlaRef	double	Description	None	0		Level 4
Homing	boolean	Description	None	False		Level 4
MotionTimeout	unsigned int	Description	None	10000		Level 4
Axis1_SlaRef	double	Description	None	0		Level 4
Axis3_SlaRef	double	Description	None	0		Level 4
InstanceStatus	PRBK	Acquisition	Slow			Level 2,3 and 4
MachineMode	PRBK	Acquisition	Slow			Level 2,3 and 4
Inhibition	PRBK	Acquisition	Slow			Level 2,3 and 4
SetMachineMode	boolean	Operation	Slow			Level 2,3 and 4

Single device Configuration



Working Sets Concept



Any Number of Working Sets built on demand for each Procedure

Any Working Sets can contain any defined device

Attributes	All Attributes	All Data Points	Seq Number
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	



Alarm Interface



Alarms ✕

Source	LEBT	Linac	MEBT	Synchrotron	HEBT
Room1O	Room2O	Room3O	Room3V	Room4G	Room5G

Date	Equipment Type	Equipment Number	Alarm ID	Description	Acknowledged	Active
10/10/2007 10.30	POW	45	OFF	The power supply cannot be set ON	10/07/2007 10.32	No
10/10/2007 10.35	POW	56	LOW	The current cannot reach nominal value	10/07/2007 10.38	No
10/10/2007 11.00	PUMP	12	NO START	The pump cannot be set ON	10/07/2007 11.05	No
10/10/2007 11.02	VALVE	23	DISABLED	cannot reach the valve on shut	10/07/2007 11.15	No
10/10/2007 11.12	VALVE	34	OFF	cannot reopen valve	10/10/2007 11.15	No
10/10/2007 11.18	MOTOR	44	SPEED	motor cannot reach nominal speed	10/10/2007 11.20	Yes
10/10/2007 11.33	BLOSS	16	HIGH	beam loss too high	10/10/2007 11.34	Yes
10/10/2007 11.48	INTLK	12	SHUT	interlock on power supply closed	10/10/2007 11.49	Yes
10/10/2007 11.52	MOTOR	18	REVERSE	cannot reset		Yes
10/10/2007 11.53	TIM	56	FAULT	no trigger		Yes

Overall | Source | LEBT | Linac | MEBT | Synchrotron | HEBT | Room1O | Room2O | Room3O | Room3V | Room4G | Room5G



Procedure for Sync Orbit Measurement



Closed Orbit Measurement for Synchrotron - Main Panel

New CycleCode SetReference Save Load Export About Close

Measure Identification Measure Description

ID: _____ Name: _____ Cycle Code: **fff05fab300** Date: **2014.10.05 00:29:42.**

User ID: **user** Supervisor ID: **<none>** Key 1: _____ Key 2: _____ Key 3: _____ Key 4: _____ Key 5: _____ Public

Input Area

Line	Parameter
1	S0-009A-PUH
2	S0-026A-PUH
3	S1-011A-PUV
4	S2-011A-PUH
5	S3-020A-PUV
6	S4-011A-PUH
7	S5-015A-PUV

Select All Deselect All

Selected Component: None
Cycle Prog: --

Resources Unlock Resources Lock

Output Area

Grid View Grid View Zero Trend Pos. Trend

Horizontal Set Y Autoscale Zoom All

Vertical Set Y Autoscale Zoom All

Name	Val
v S0-009A-PUH	
v S0-026A-PUH	
v S1-011A-PUV	
v S2-011A-PUH	
v S3-020A-PUV	
v S4-011A-PUH	
v S5-015A-PUV	
v S6-009A-PUH	
v S7-011A-PUV	
v S8-011A-PUH	
v S8-029A-SPU	
v S8-032A-PUH	
v S9-011A-PUV	
v SA-011A-PUH	
v SB-015A-PUV	
v SC-011A-PUH	
v SC-016A-PUH	
v SD-018A-PUV	
v SE-013A-PUH	
v SF-011A-PUV	

Set X Autoscale Export Cursor Cursor Position (ms) Set

Trend 3D H Reference Measure Details Reference measure not present

Trend 3D V

Accept Stop Freeze

Output Log

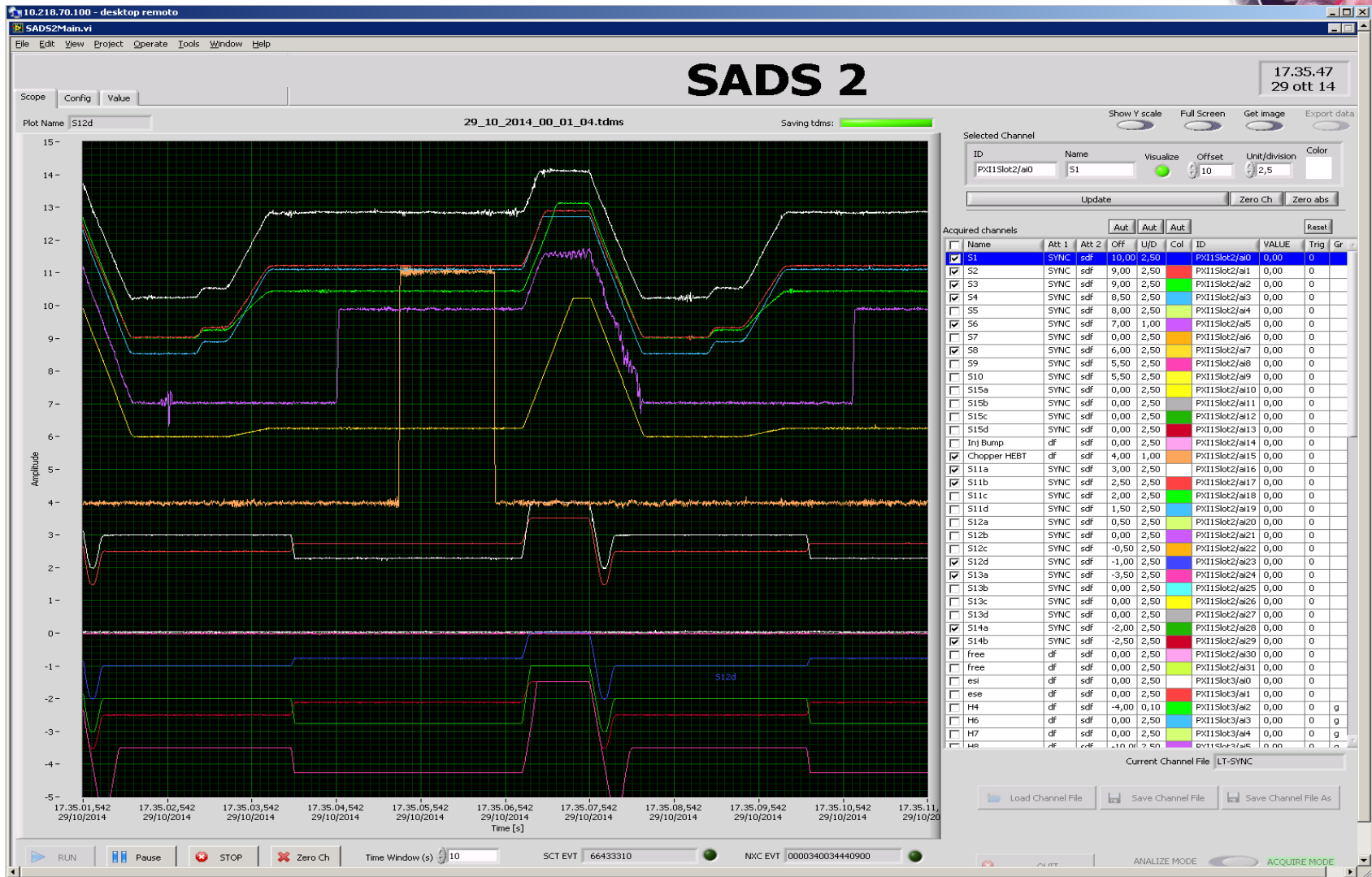
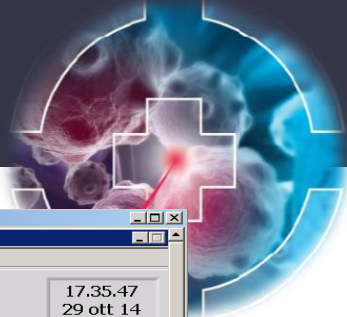
- Severe There are error in input data
- Severe Lock resources stopped.
- Info Start verify data.
- Info Settings: Freq: 1000; Samples 1000.
- Info Input data verified.
- Info Resources locked.
- Info Init procedure successfully.
- Info Init EC instance successfully.
- Info Parameter Saved
- Info Set new parameters
- Info Read PU values [Retrieve1]
- Info S0-009A-PUH: One Shot Measure
- Info S0-009A-PUH: One Shot Measure Completed
- Info Operation complete. Setting values.
- Info Parameter reloaded
- Info Procedure completed!

Measurement Navigation and Execution

Machine Settings Settings Name: _____

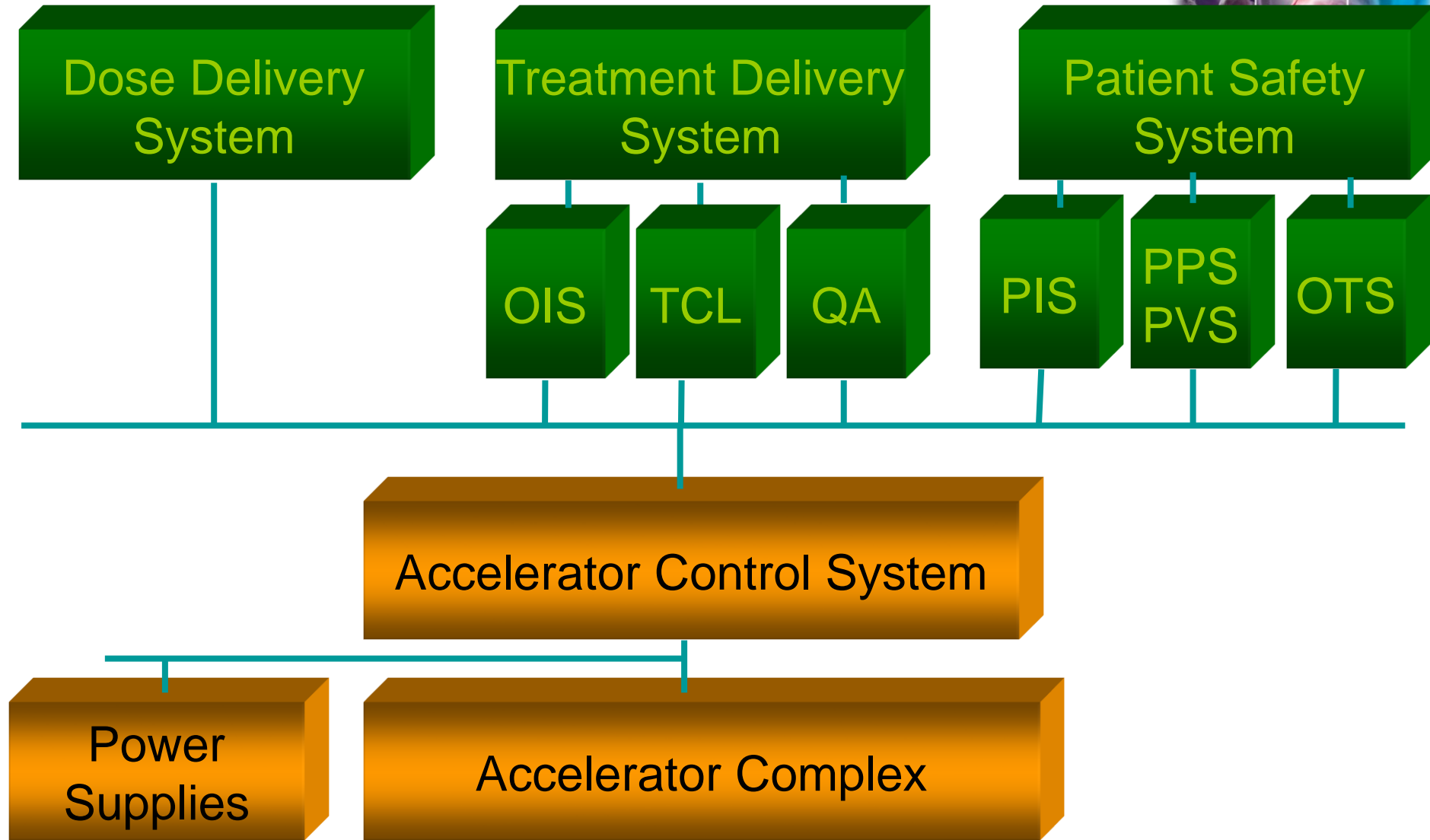
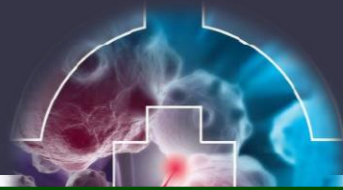


Signal Acquisition Interface



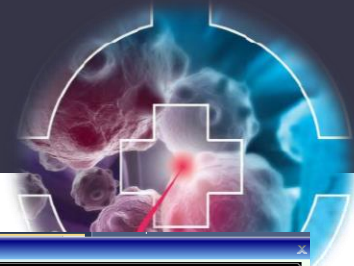


The Plant as a Complex Medical Device





Treatment Delivery Status



Room 1 ⁴

DELIVERY INFORMATION

Total Slice / Actual Slice

Total Dose / Delivered Dose

Dose Delivery

Patient Position

MTG Loaded

Beam Requested

Room 2

DELIVERY INFORMATION

Total Slice / Actual Slice

Total Dose / Delivered Dose

Dose Delivery

Patient Position

MTG Loaded

Beam Requested

Room 3 ^{>8}

DELIVERY INFORMATION

Total Slice / Actual Slice

Total Dose / Delivered Dose

Dose Delivery

Patient Position

MTG Loaded

Beam Requested

Accelerator State

Particle Carbon

Line 2H

Machine Available

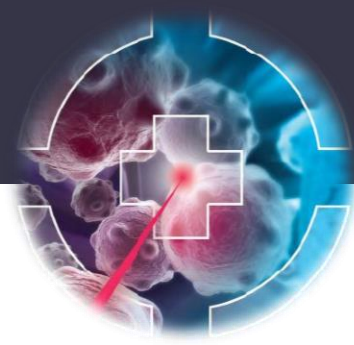
Patient

ID

Field

Following Patients					
Patient ID	Patient Name	Field Name	Line	Particle	Fields
A160458	SCACCHI LUCA	B1	2H	Carbonio	2/4
A160458	SCACCHI LUCA	B1B	2H	Carbonio	3/4
A160458	SCACCHI LUCA	B1C	2H	Carbonio	4/4
A170205	SEGALINI GIANMARIO	B1	1	Protoni	1/2
A170205	SEGALINI GIANMARIO	B2	1	Protoni	2/2
A170067	CAPPELLETTI MARTA	B2	3	Protoni	1/2

DataBase: Default Network Service Name: cnao Release Number: 1.0.0.112





Thanks for your attention