Detector Control System TOTEM / LHC

J. Sziklai

On behalf of the TOTEM Collaboration

TOTEM DCS TEAM

Coordinator:	**Paolo Palazzi**
Steering Board:	**Ivan Atanassov**
	Federico Ravotti
	Fernando Lucas Rodriguez*
	Sami Heikki Sakari Stoeckell

*** "Design, Development and Verification of the Detector Control System for the TOTEM experiment at the CERN LHC" PhD thesis, Universidad de Sevilla, October 2009**

- The TOTEM DCS project follows the usual non-hierarchical, collaborative and informal style of HEP experiments, enhanced with a structured approach inspired by current practices in European Collaborative Space Projects [http://www.ecss.nl/]
- Using the Goal Directed Project Management (GDPM) as planning methodology
- Using the future Subversion based Software Version Control at CERN replacing the currently used CVS system.
- Using several tools based on Information Technology developments (Use case, UML State model, etc.)

TOTEM Hungary

TOTEM (1997-) és Totem-Hungary (2006-)

History:

Initiative:	**April 2006**
Acceptance byTOTEM Executive Commitee:	**May 2006**
TOTEM Spokesperson Budapest visit:	**December2006**
Hungarian research starts (TOTEM fund):	**January 2007**
OTKA és OTKA NKTH success in funding:	**March 2008**
TOTEM Coll. Board votes for full membership:	**April 2008**
TOTEM-Hungary MoU signature, LHC RRB:	**November 2008**

Main TOTEM Physics Goals:

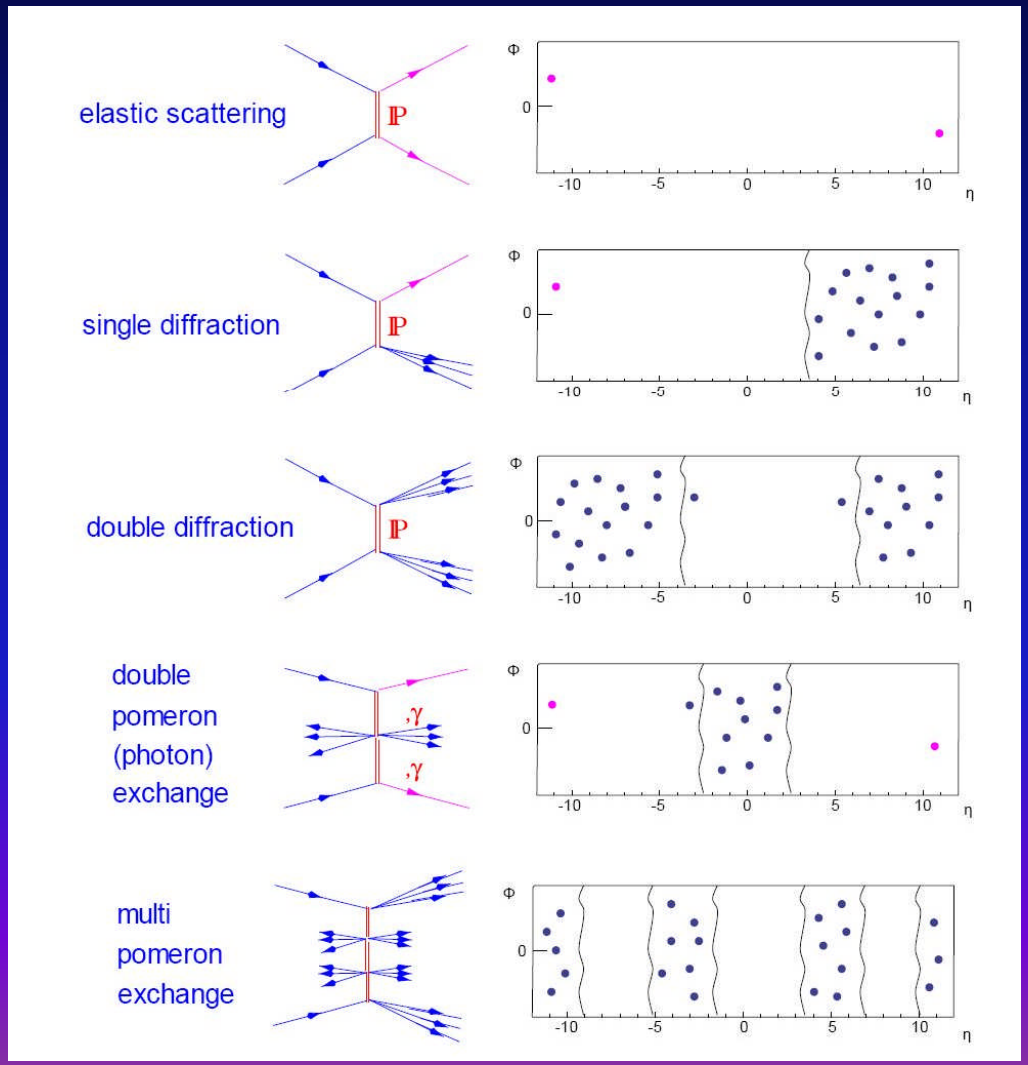
- **Measuring the total cross-section with an absolute error of 1 mb by using the luminosity independent method. This requires the simultaneous measurement of the elastic pp scattering down to the four-momentum transfer of $-t \approx 10^{-3}$ GeV^2 and of the inelastic pp interaction rate with an adequate acceptance in the forward region;**

- **Measuring elastic proton scattering over a wide range in momentum transfer up to $-t \approx 10$ GeV^2;**

- **Measuring diffractive dissociation, including single, double and central diffraction topologies using the forward inelastic detectors in combination with the CMS detector.**

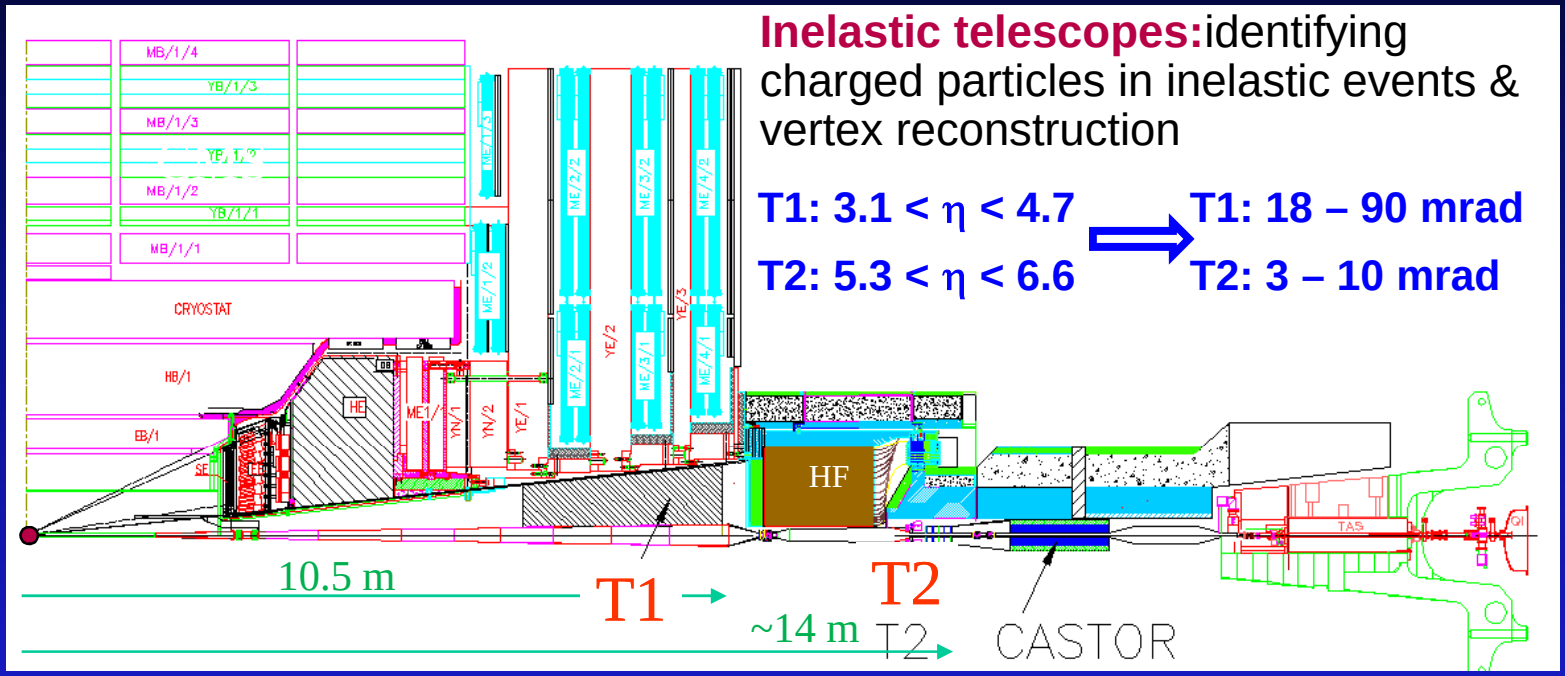
Diffractive processes

- **Diffractive process classes and cross sections**
  (Tevatron measured at 1.8 TeV, LHC estimated at 14TeV)

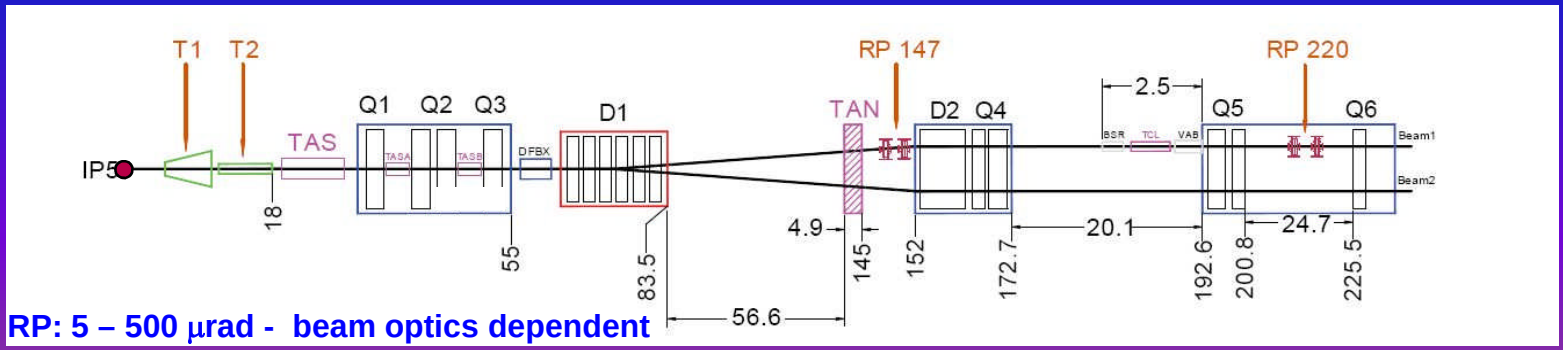


TOTEM Detectors @ IP5

Inelastic detector configurations no both side of IP5: all capable for tracking and trigger



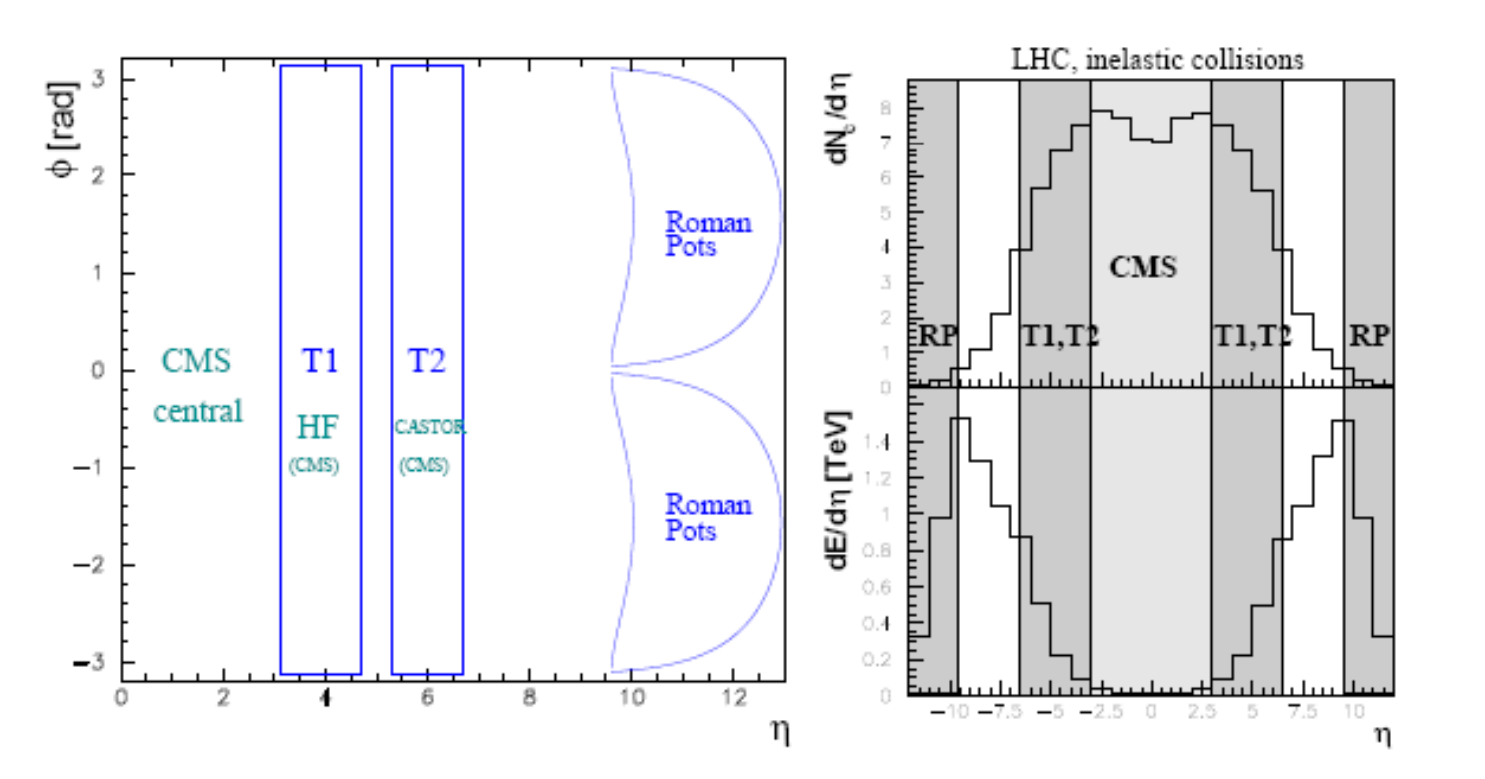
Roman Pots: measuring the elastic & inelastic protons closed to the beam



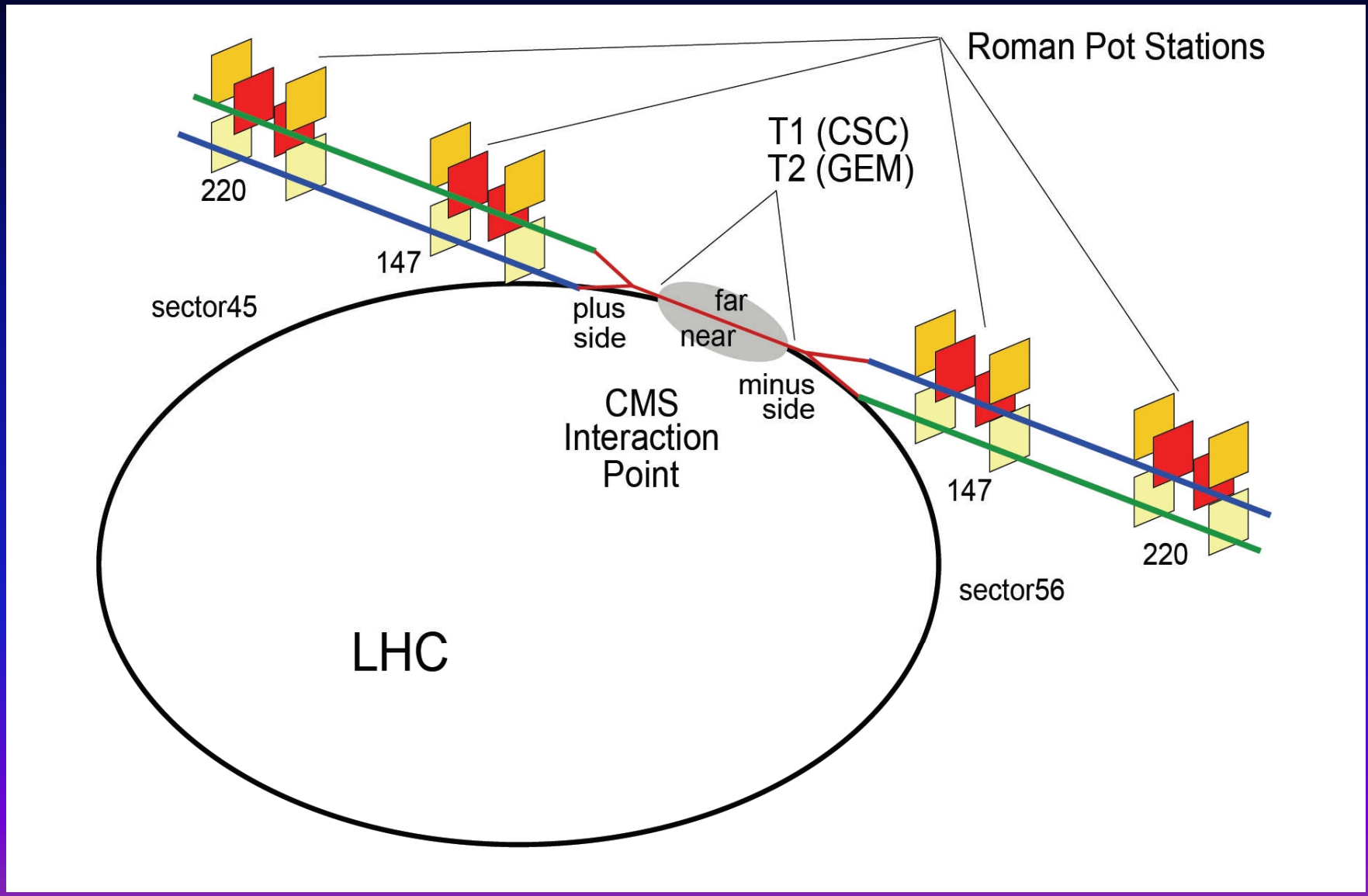
TOTEM capabilities

- Unique possibility of detecting charged particles with high pseudorapidity
- Ideal tool for studying forward phenomena (elastic & diffractive scattering)
- In case of inelastic events the energy flow and the multiplicity increases in forward angles

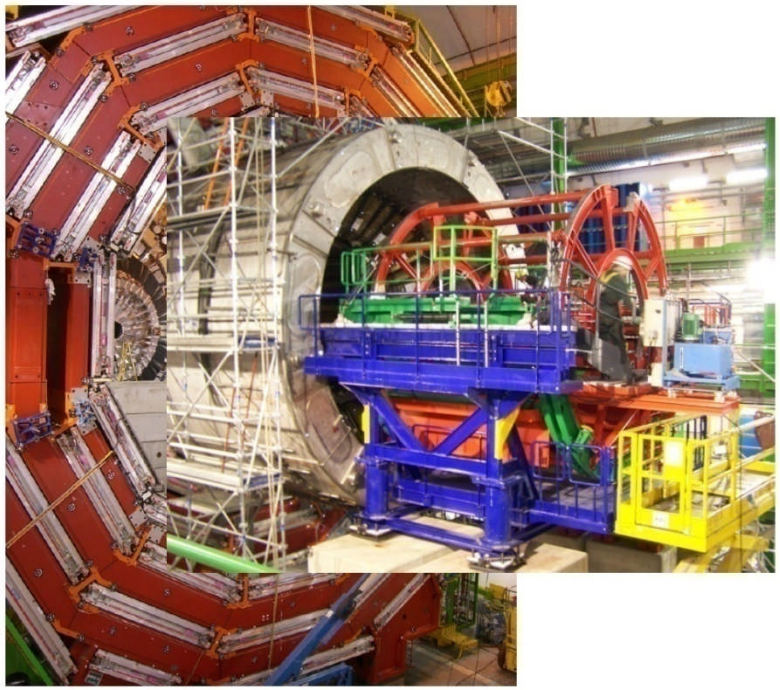
The acceptance coverage of the CMS and TOTEM experiment



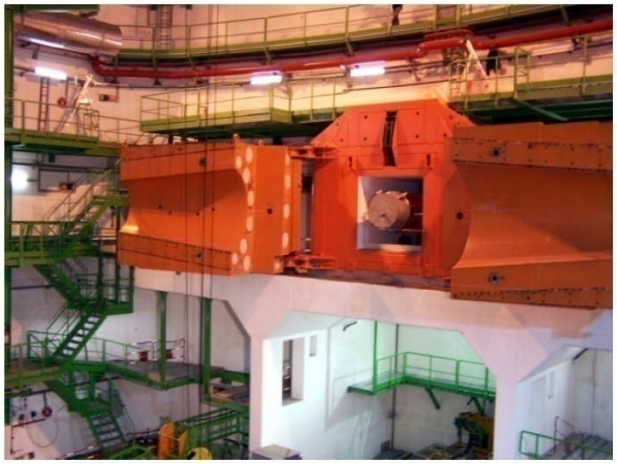
TOTEM Detectors



CMS & TOTEM



CMS experiment
pp interaction

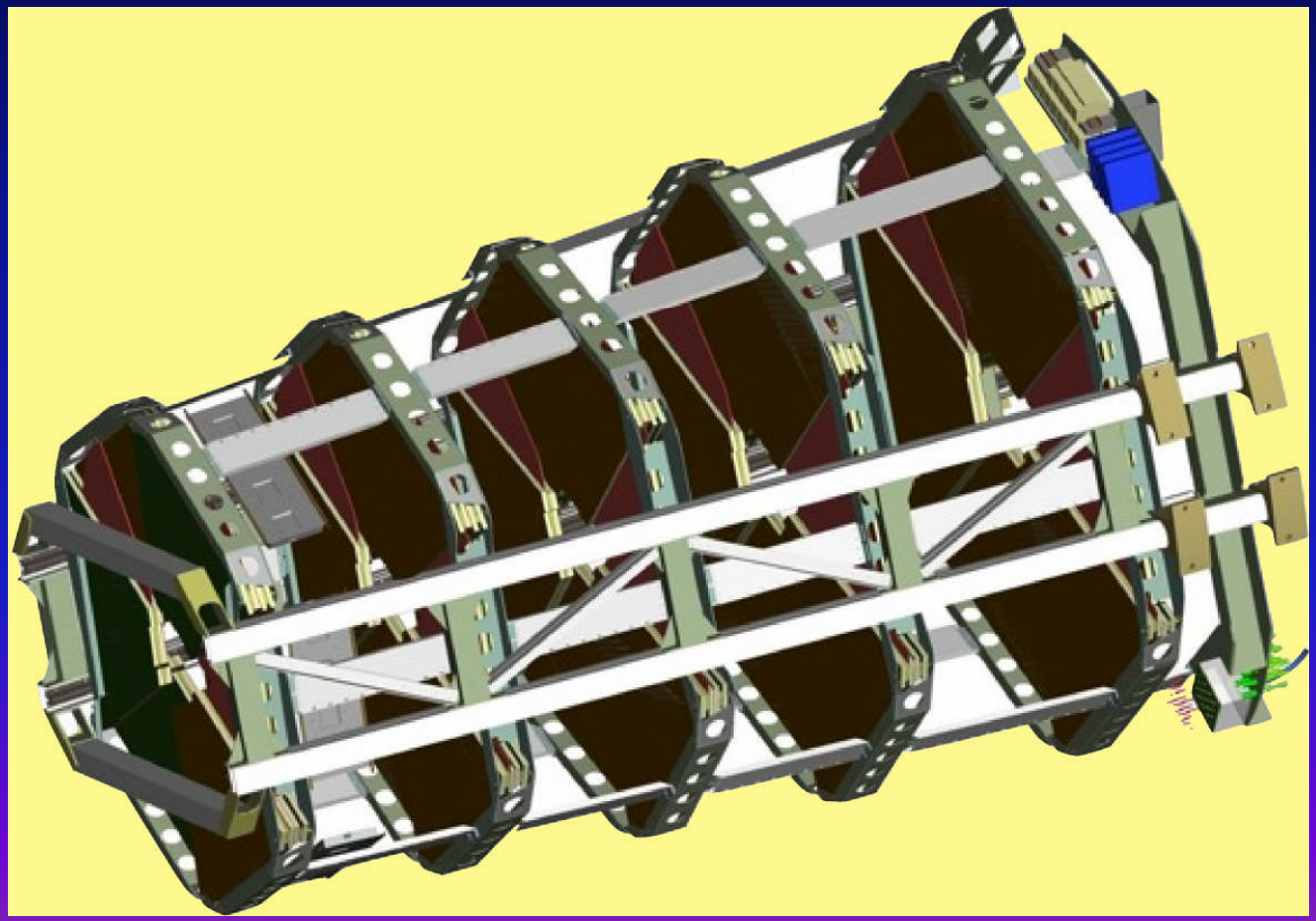


T1 and T2 detectors

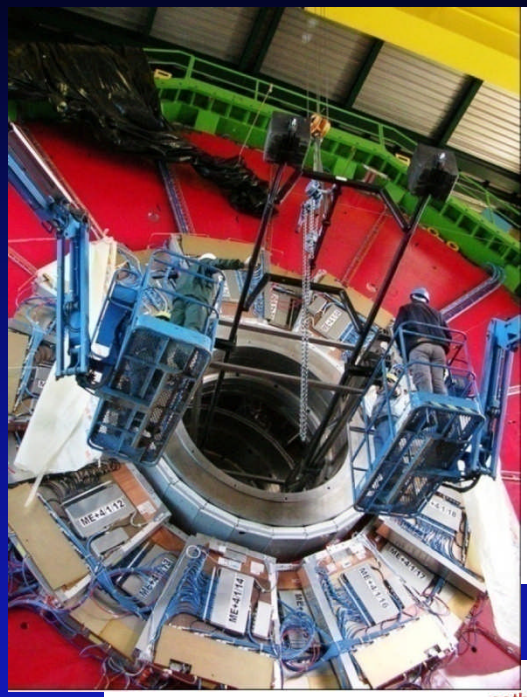
joint with the
accelerator pipe

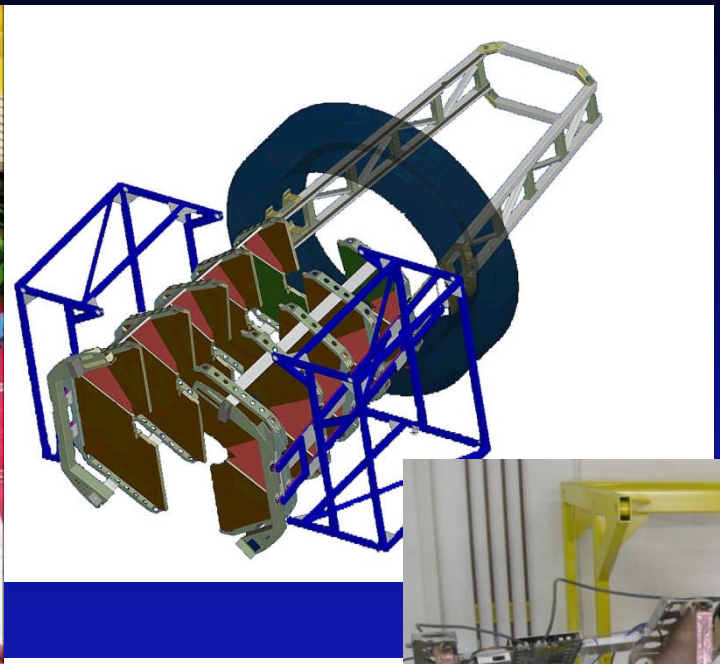
T1 telescope CSC (Chatode Strip Chambers)

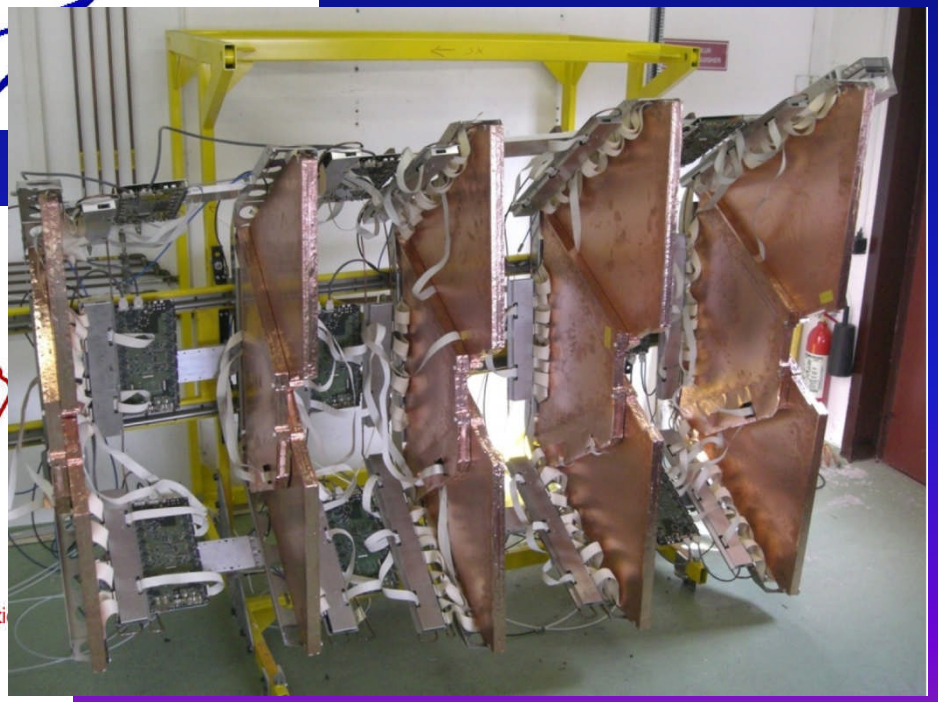
- 5 layers of CSC chambers with decreasing diameters
  - 2 x 3 trapezoid shaped CSC (Chatode Strip Chambers) detector elements

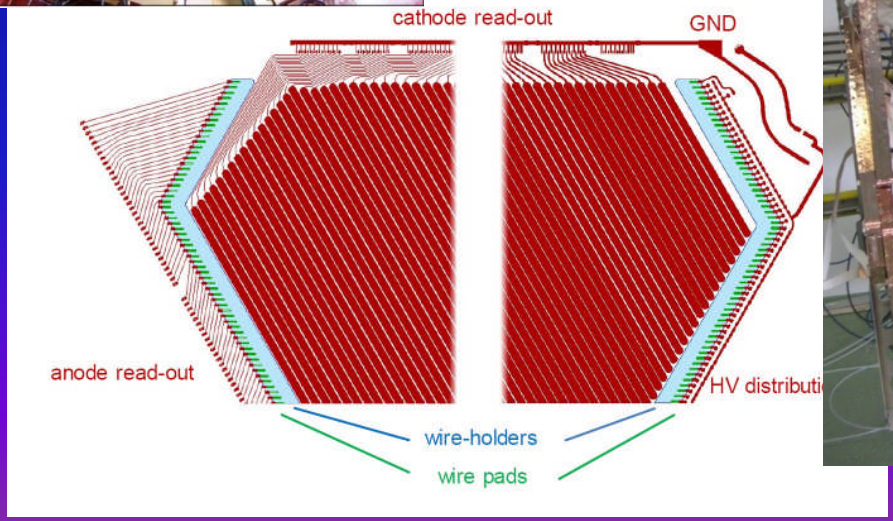


T1 telescope - details



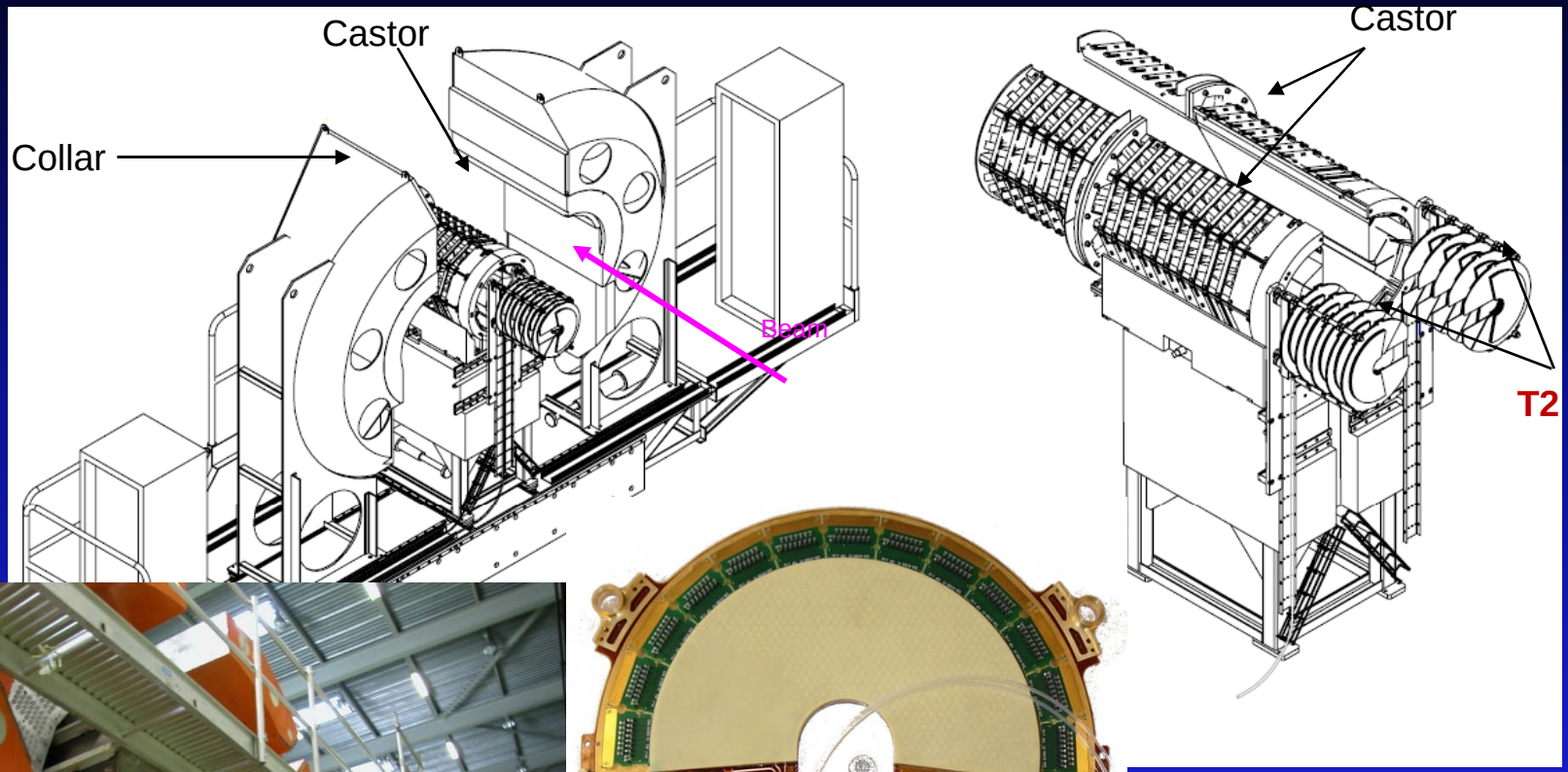






T2 Telescope GEM (Gas Elecron Multiplier)

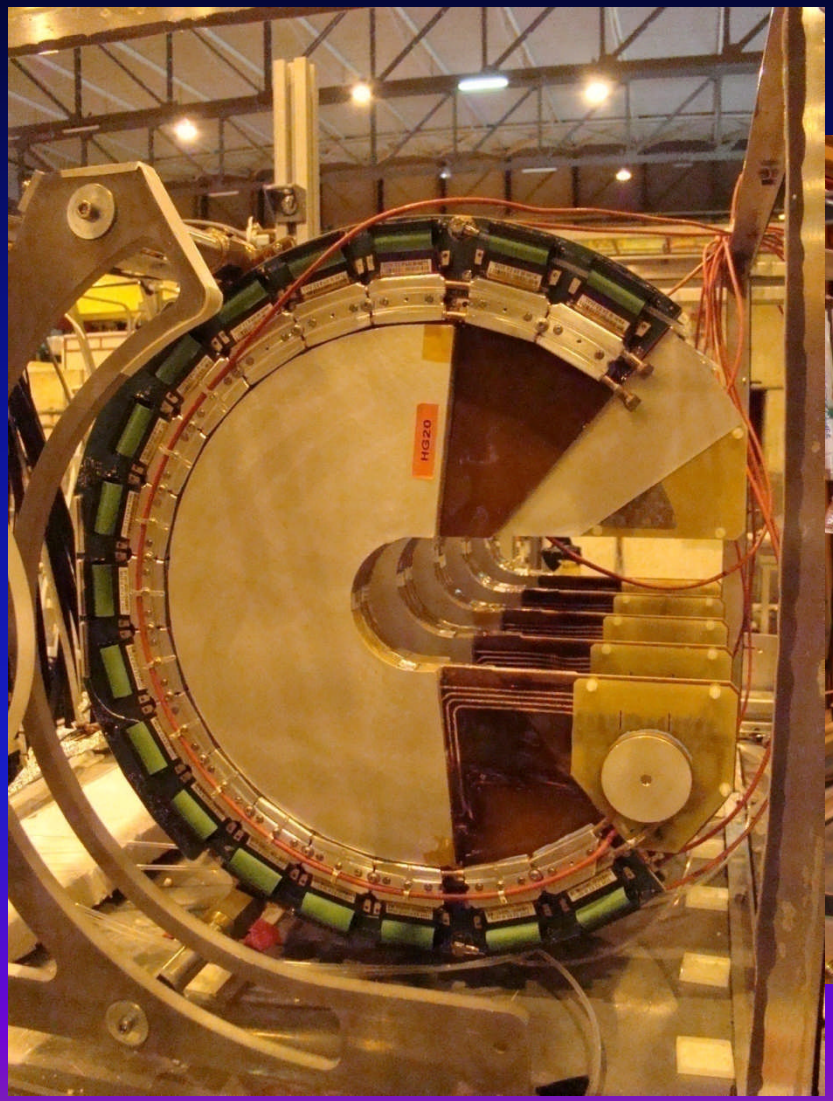
Design & installation together with CMS

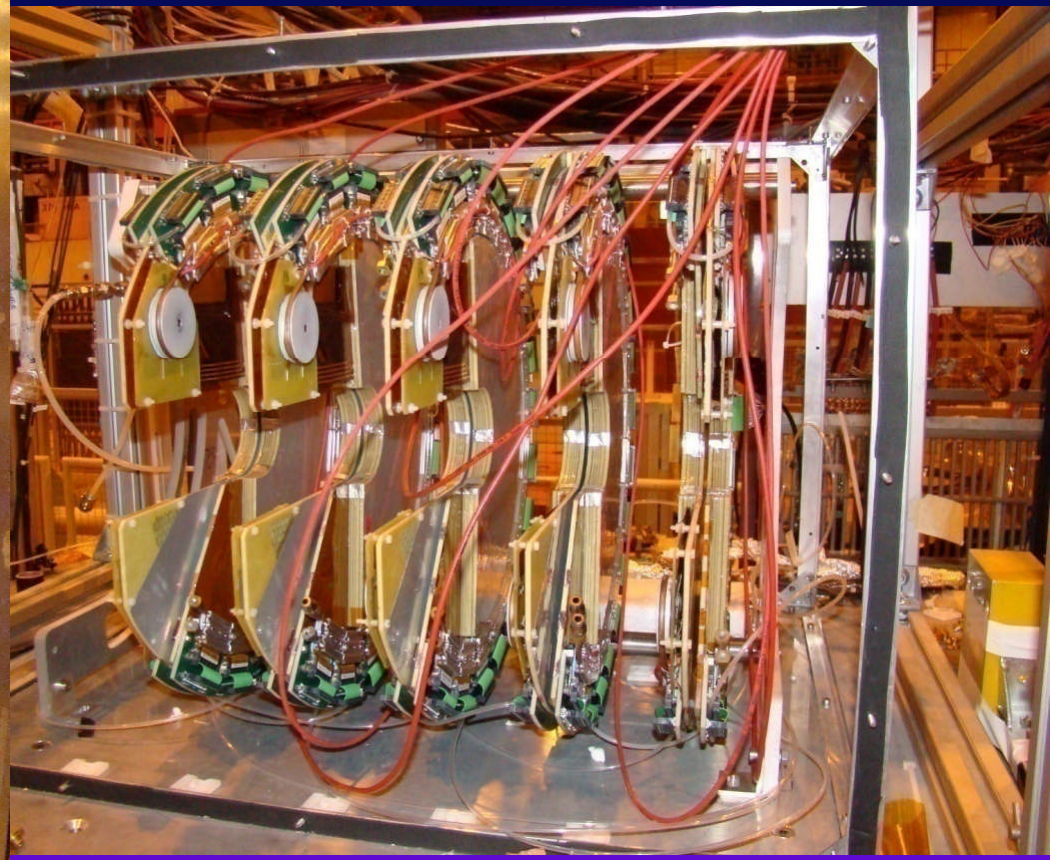


Final GEM chamber

10 tripple GEM layers on bothe sides of the IP to tolerate high particle fluxes in $5.3 < |\eta| < 6.6$ pseudorapidity range

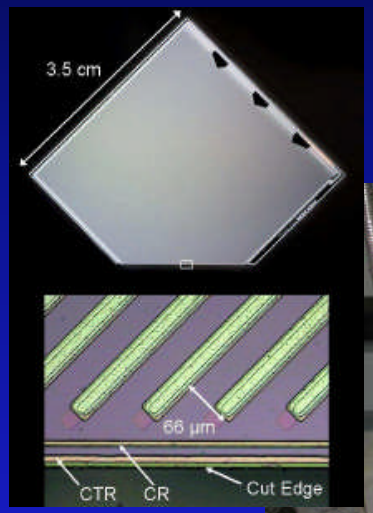
T2 Telescope in test beam

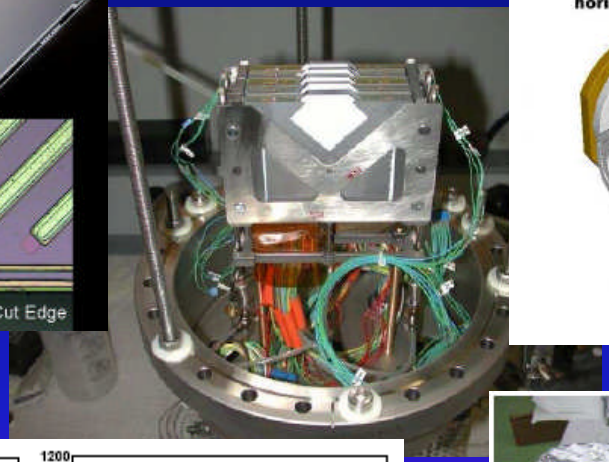


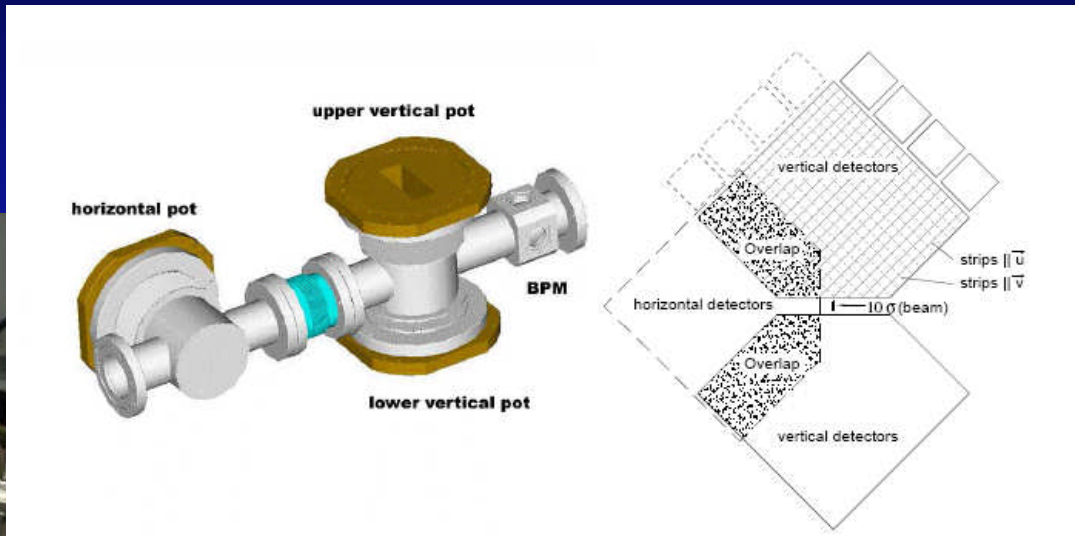


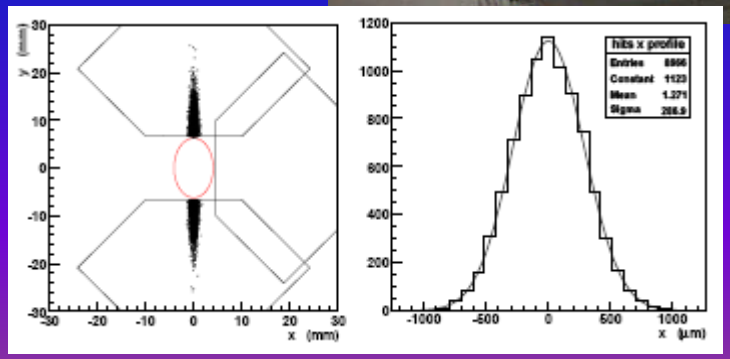
Roman Pot detectors

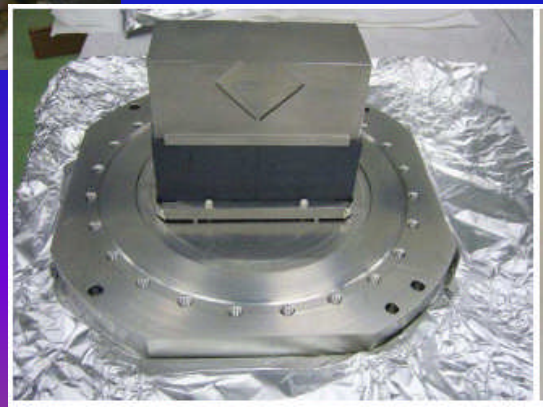
- Special movable detector assembly in its own separate vacuum space
- Roman Pot pairs at a distance of 4 meters at 147 és 220 m from IP

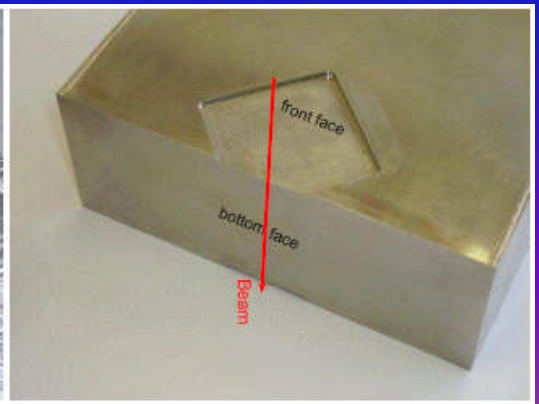




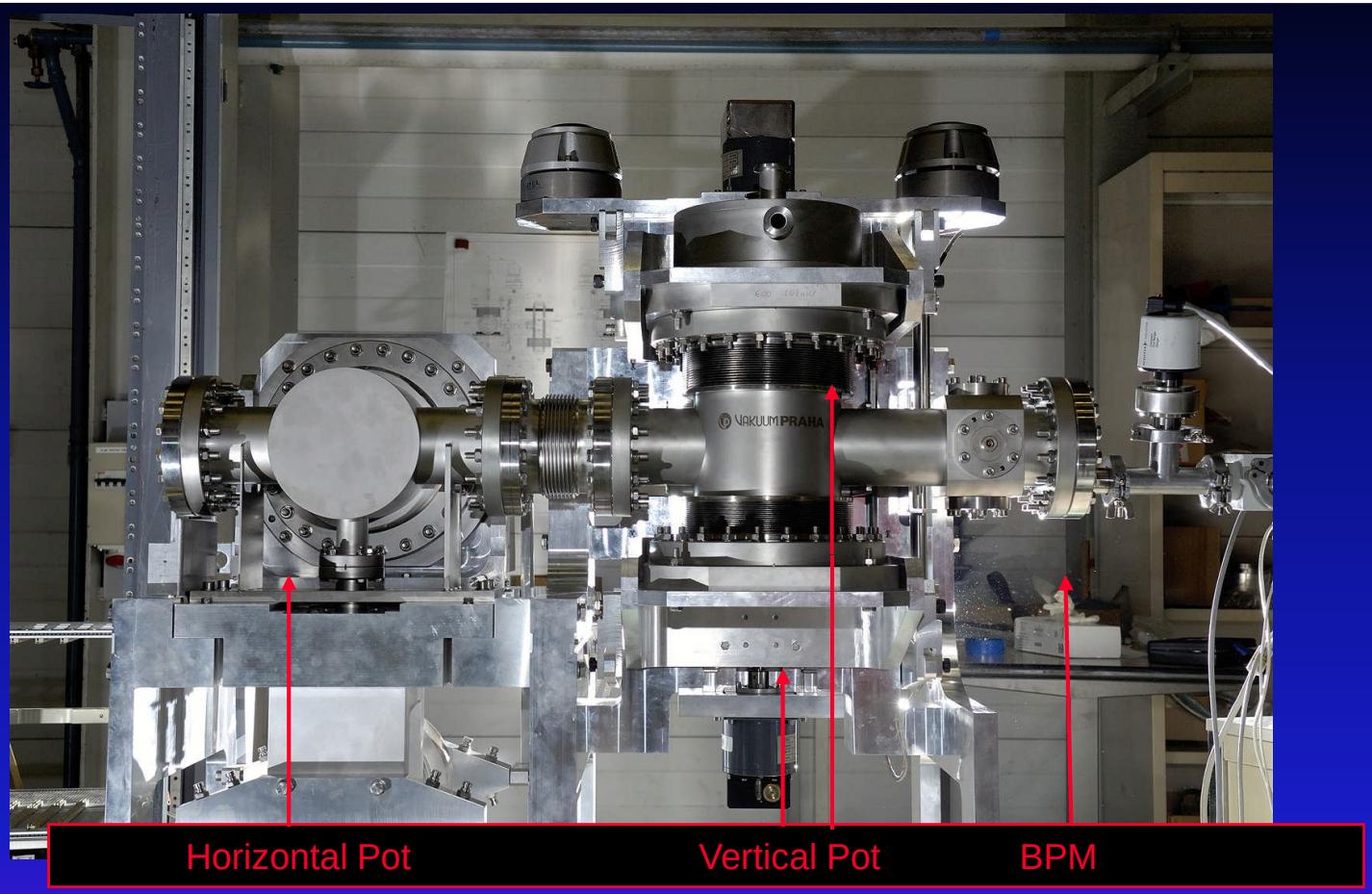






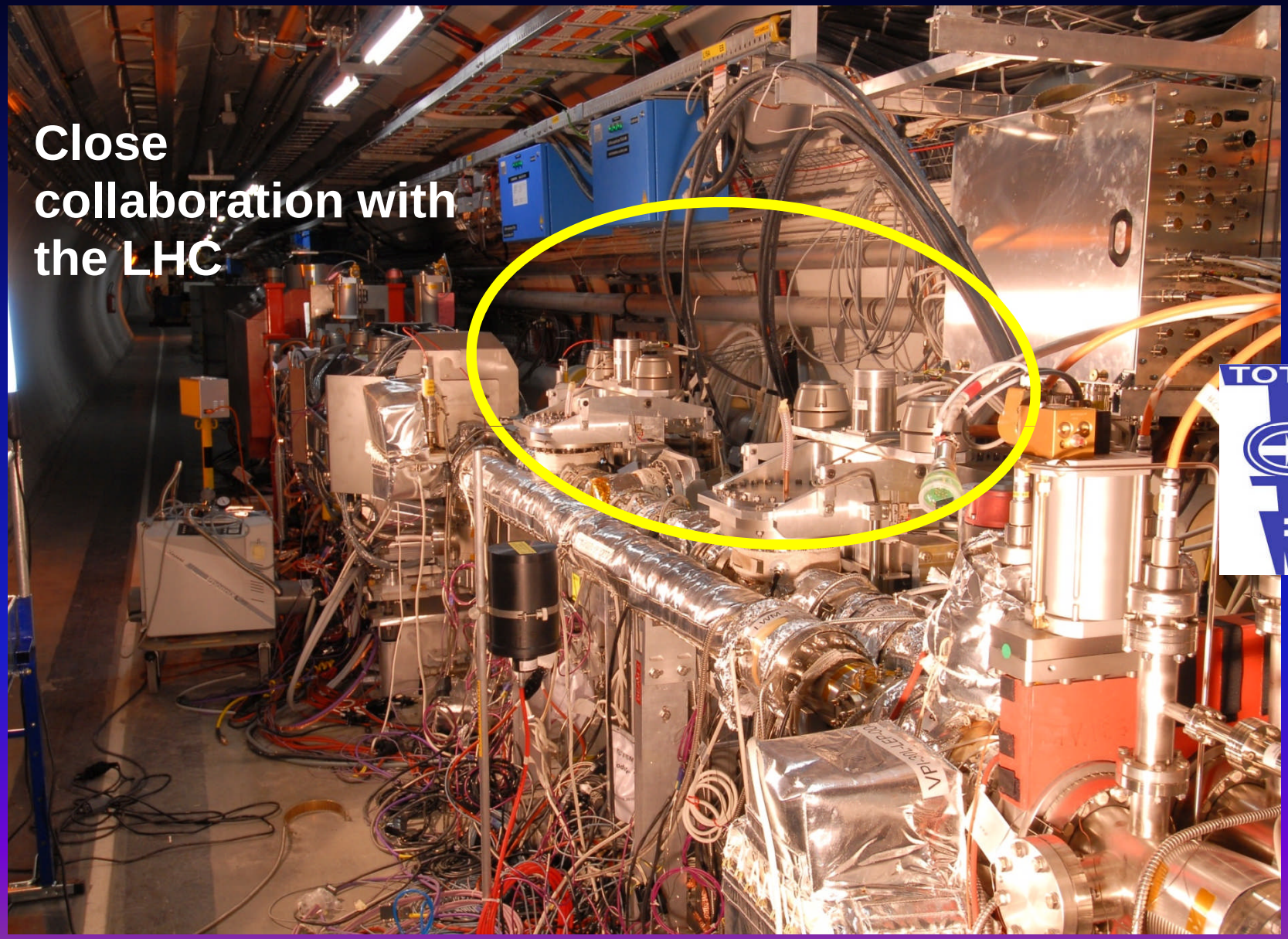


Roman Pots Motorization



- Developed by CERN
- Mechanical arm that moves towards the proton beams
- Its operation must be “safe” for the LHC accelerator
- An incident with Roman Pots shutdown Fermilab for 2 months in 2003

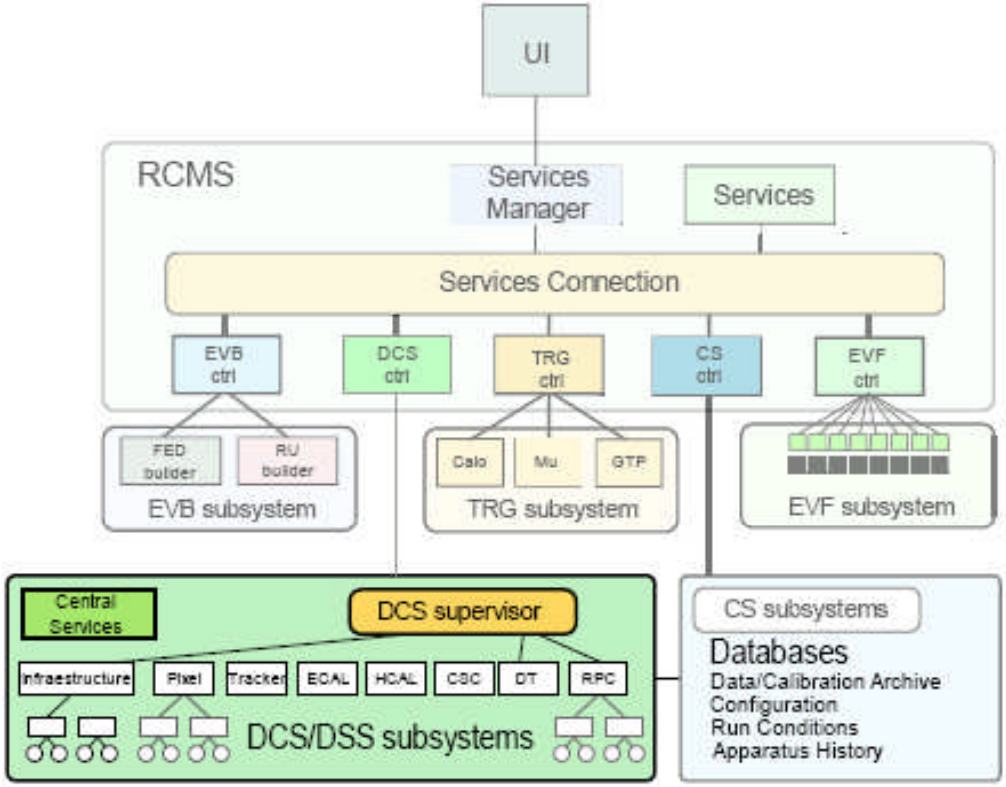
Roman Pots in the LHC tunnel

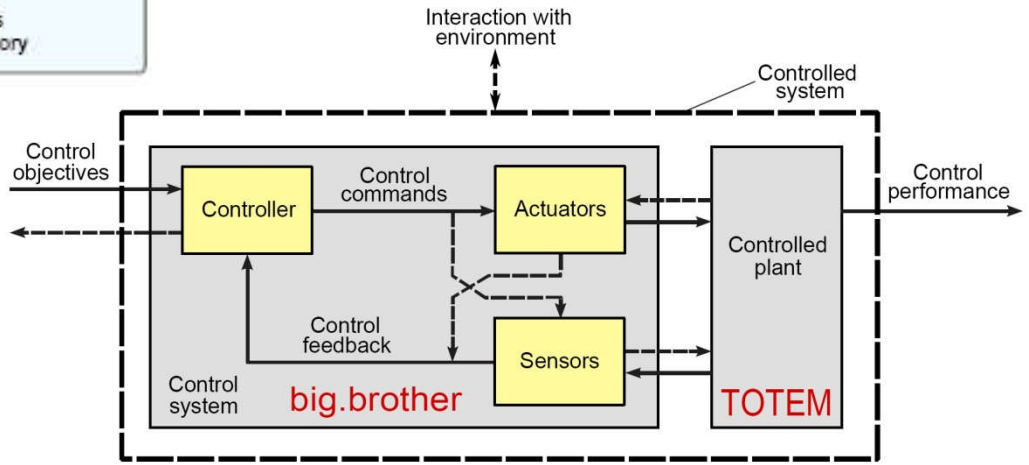


TOTEM DCS Objectives

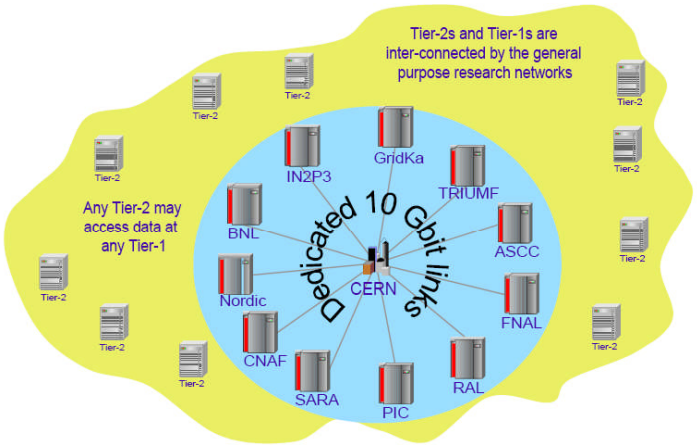
- The DCS will be a slave to the Run Control and Monitor System (RCMS) which will be in charge of the overall control and monitoring of the data-taking process
- The primary function of the DCS is the overall control of the detector status and its environment
- DCS has to communicate with external entities: the RCMS, the accelerator, DAQ, motorization, etc.
- DCS has to control and monitor the systems regulating the environment at the experiment, tasks traditionally referred to as “Slow Controls” e.g.:
  - Handling the supplies of electricity to the detector (HV, LV)
  - Environment monitoring (temperature, radiation, vacuum, humidity,../)
  - Other DCS-related detector electronics (e.g. calibration systems)
  - Control of the cooling facilities and the overall environment near the detectors
  - Supervision of all gas and fluid handling and cooling subsystems
  - Control of all racks, crates and access control

TOTEM DCS connections

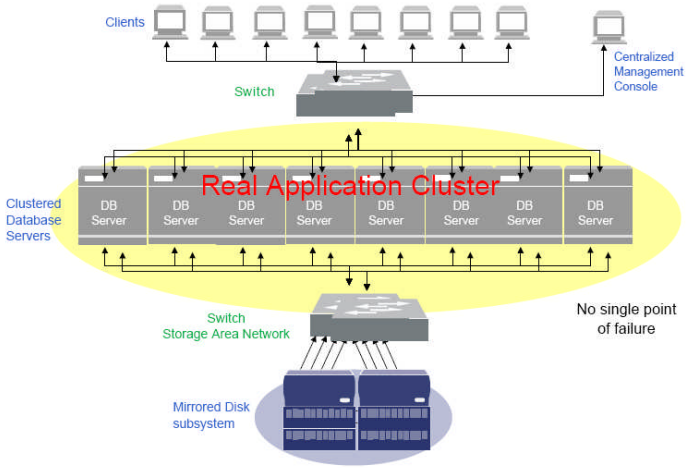


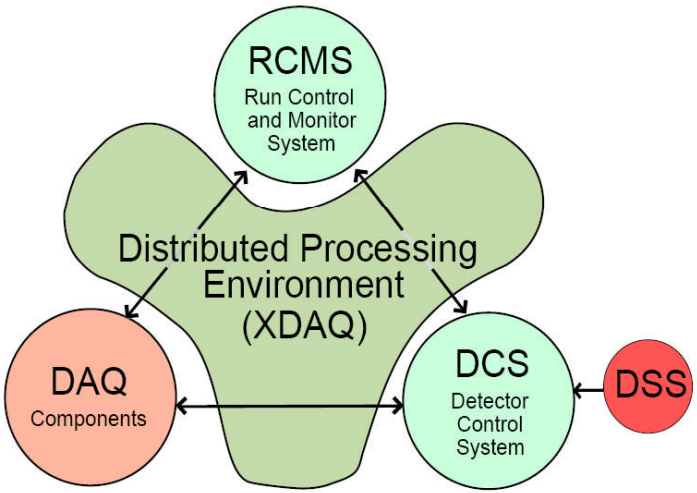


DATAFLOW



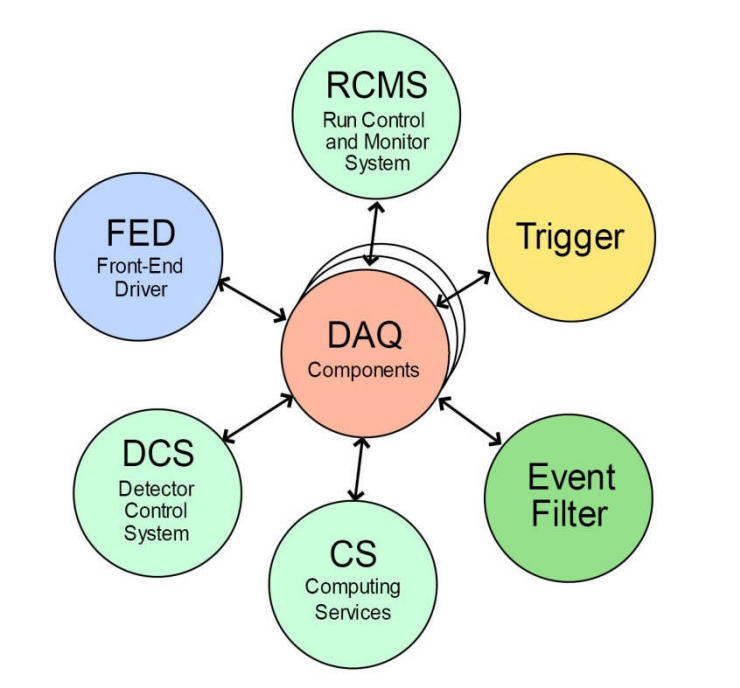
offline

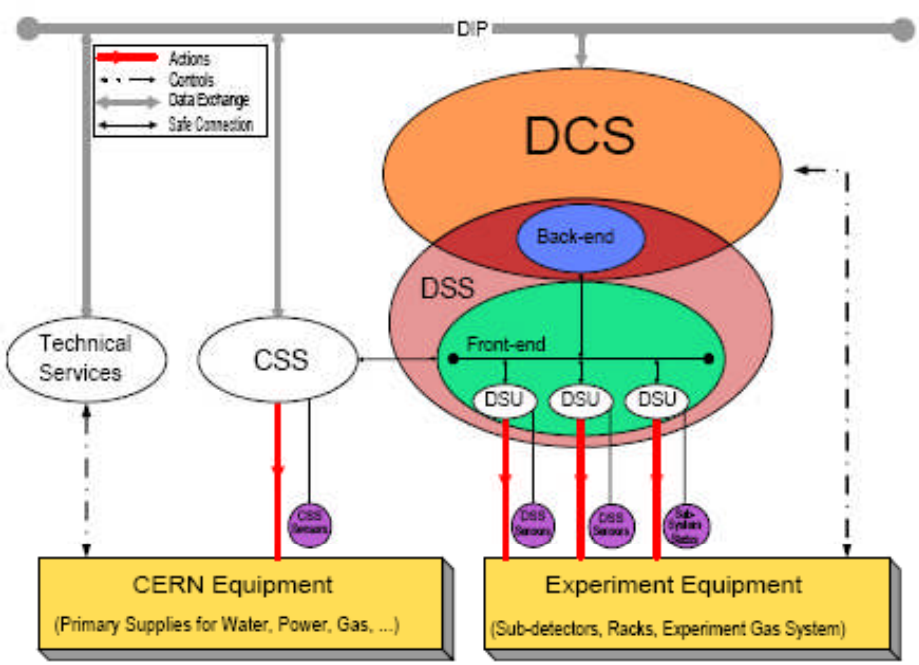


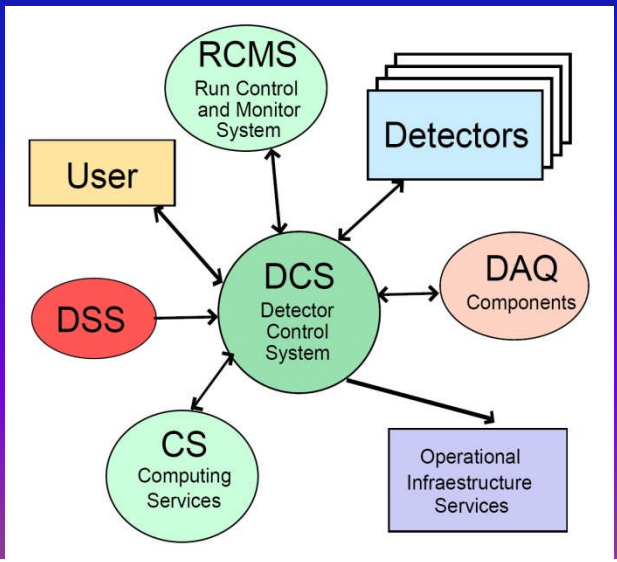


online

TOTEM DCS connections

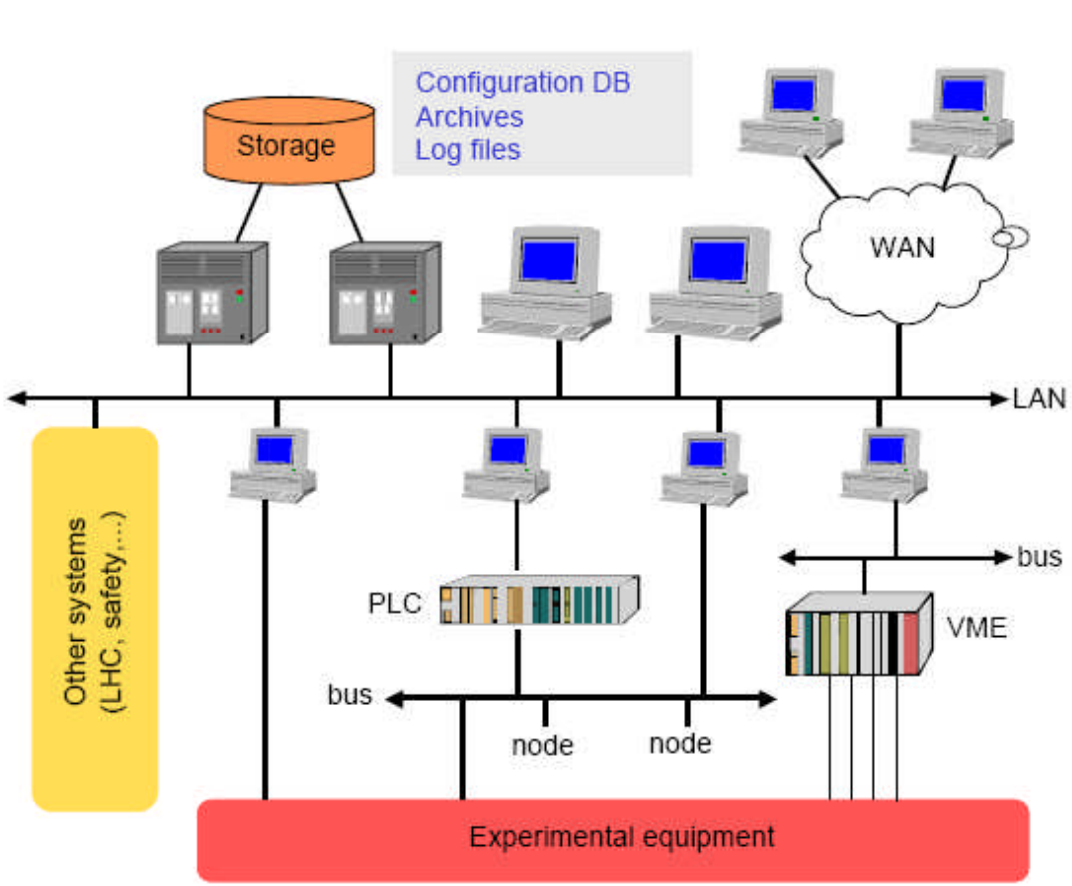


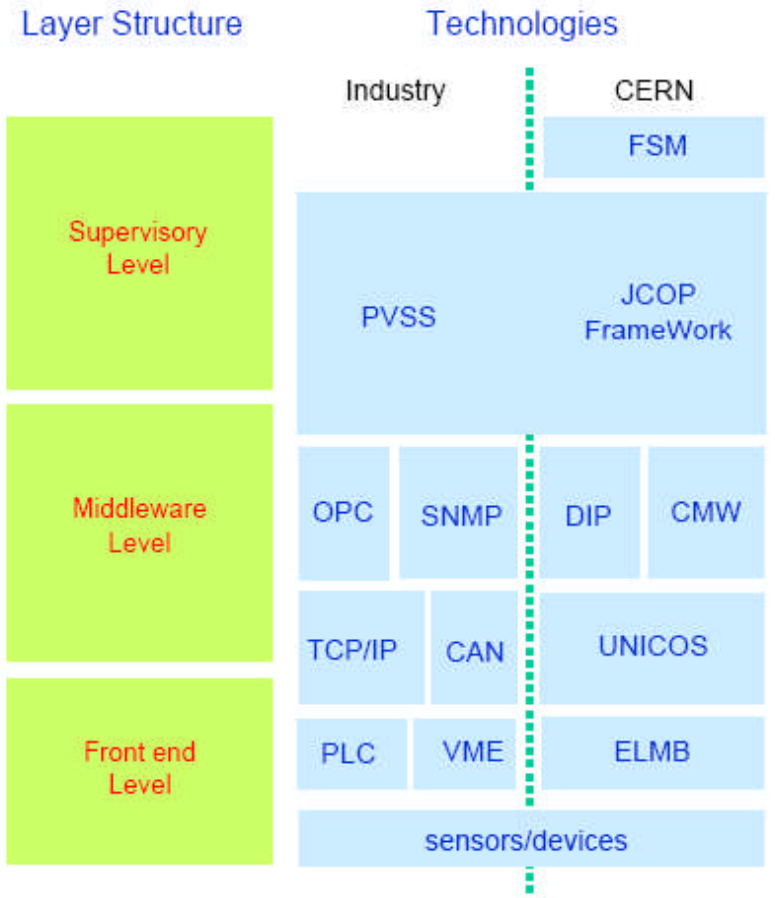




TOTEM DCS

Software/Hardware levels

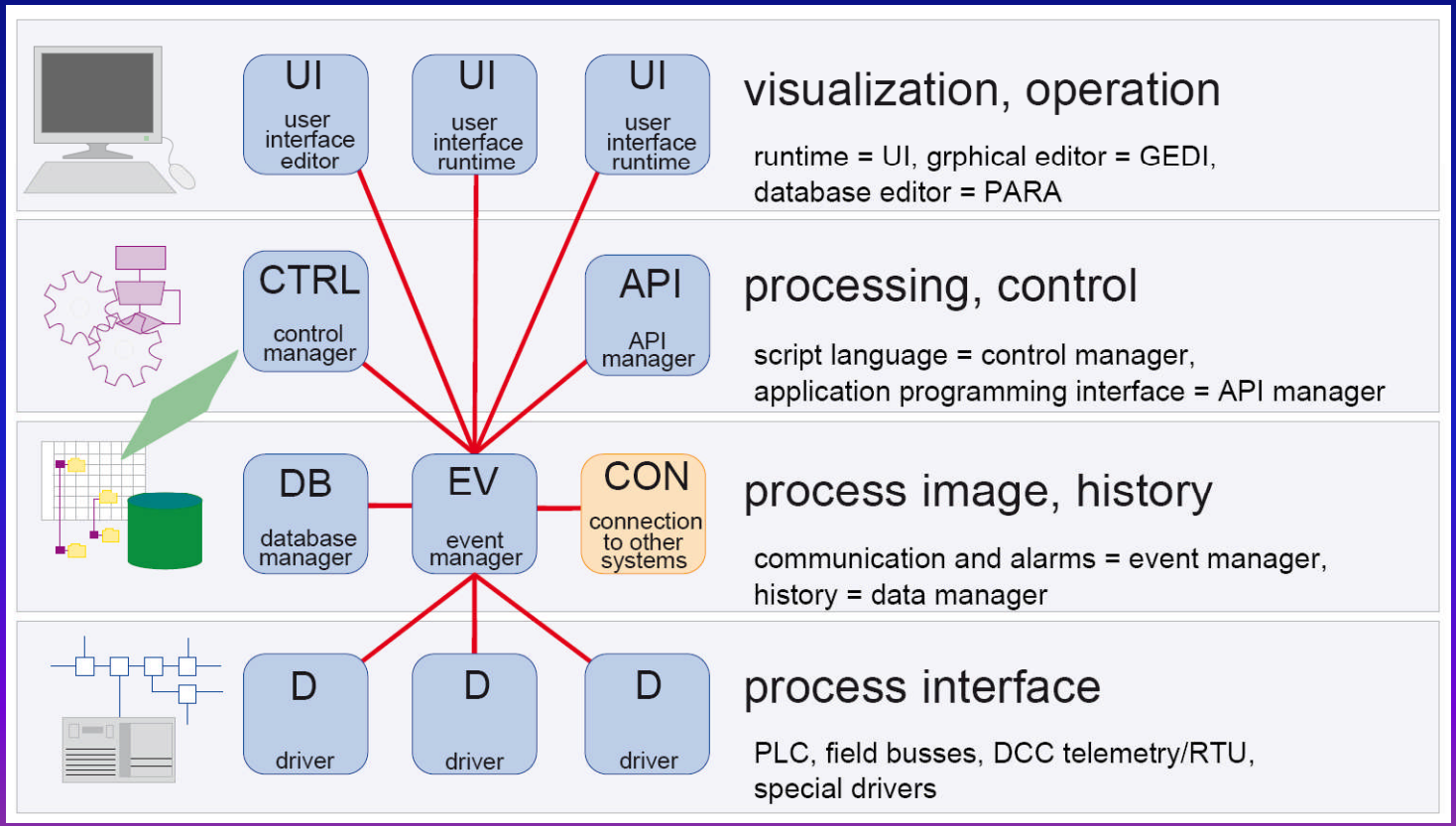




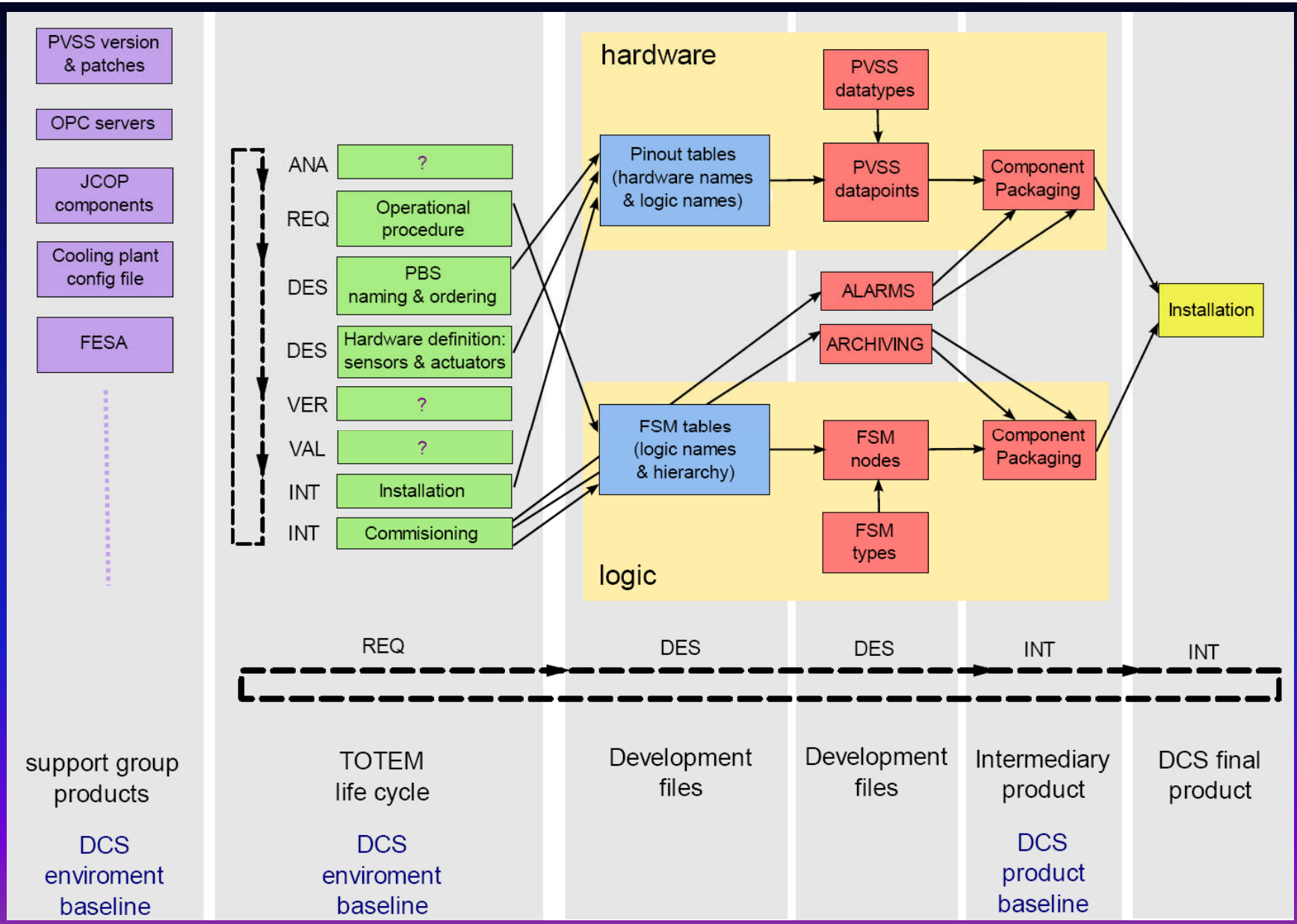
TOTEM DCS

PVSS II

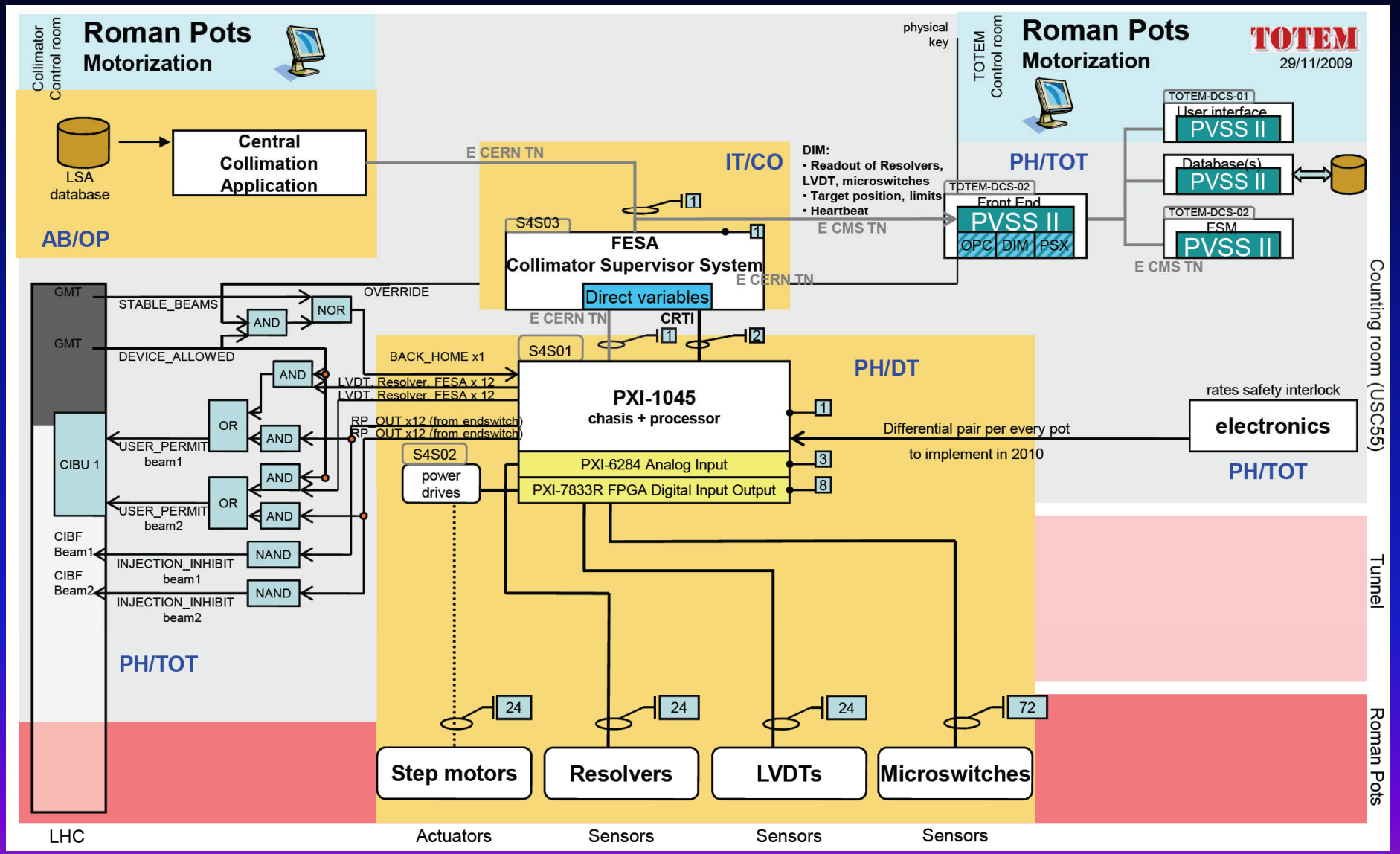
- Commercial SCADA (Supervisory Control and Data Acquisition) software for Windows and Linux
- Very scalable. Each process can run in a different computing node, mixing operating systems. Good performance on distributed systems.
- Can be extended using “scripts” and binary libraries.



TOTEM DCS Development process



TOTEM Hardware Overview Diagrams



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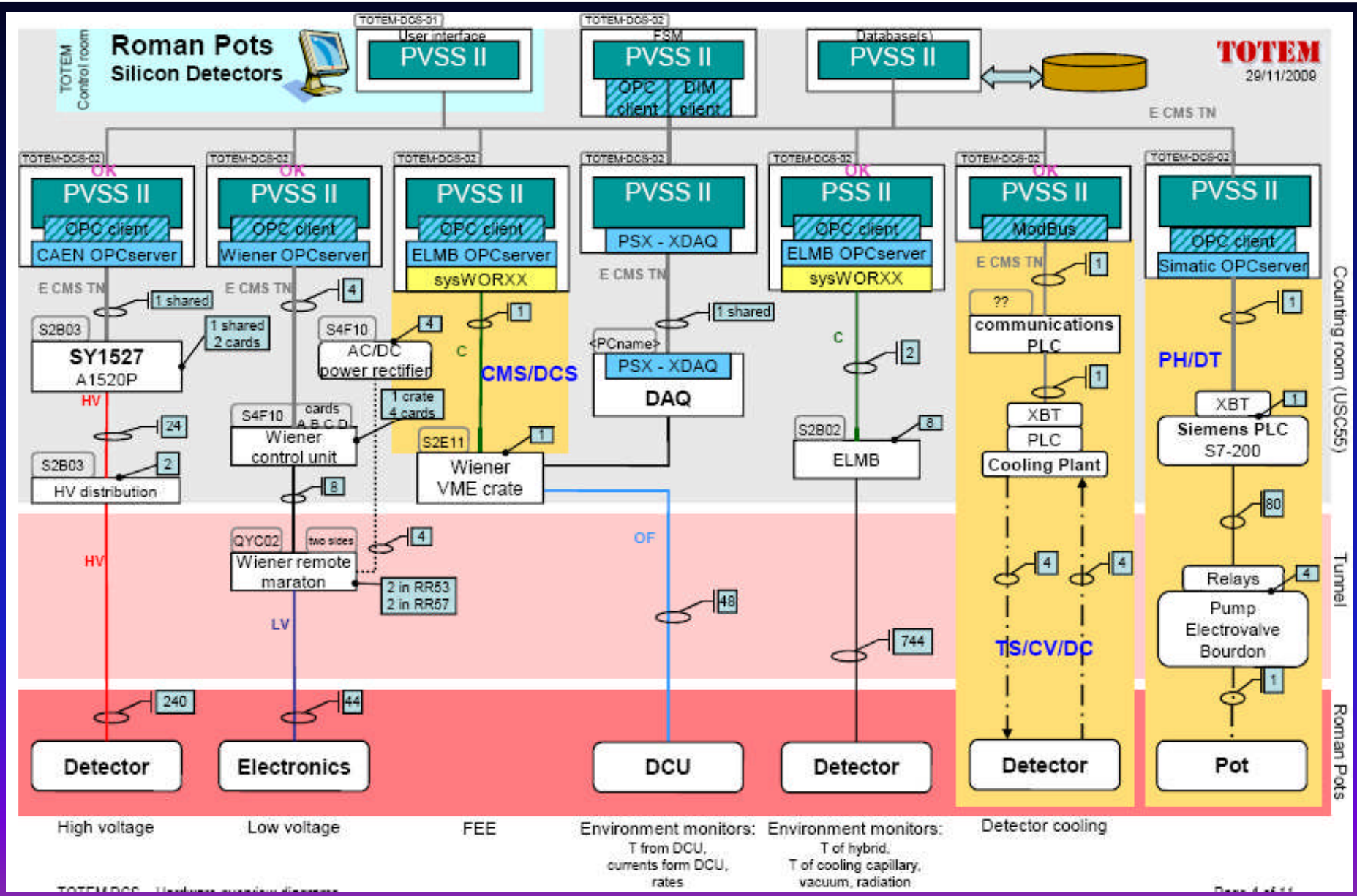

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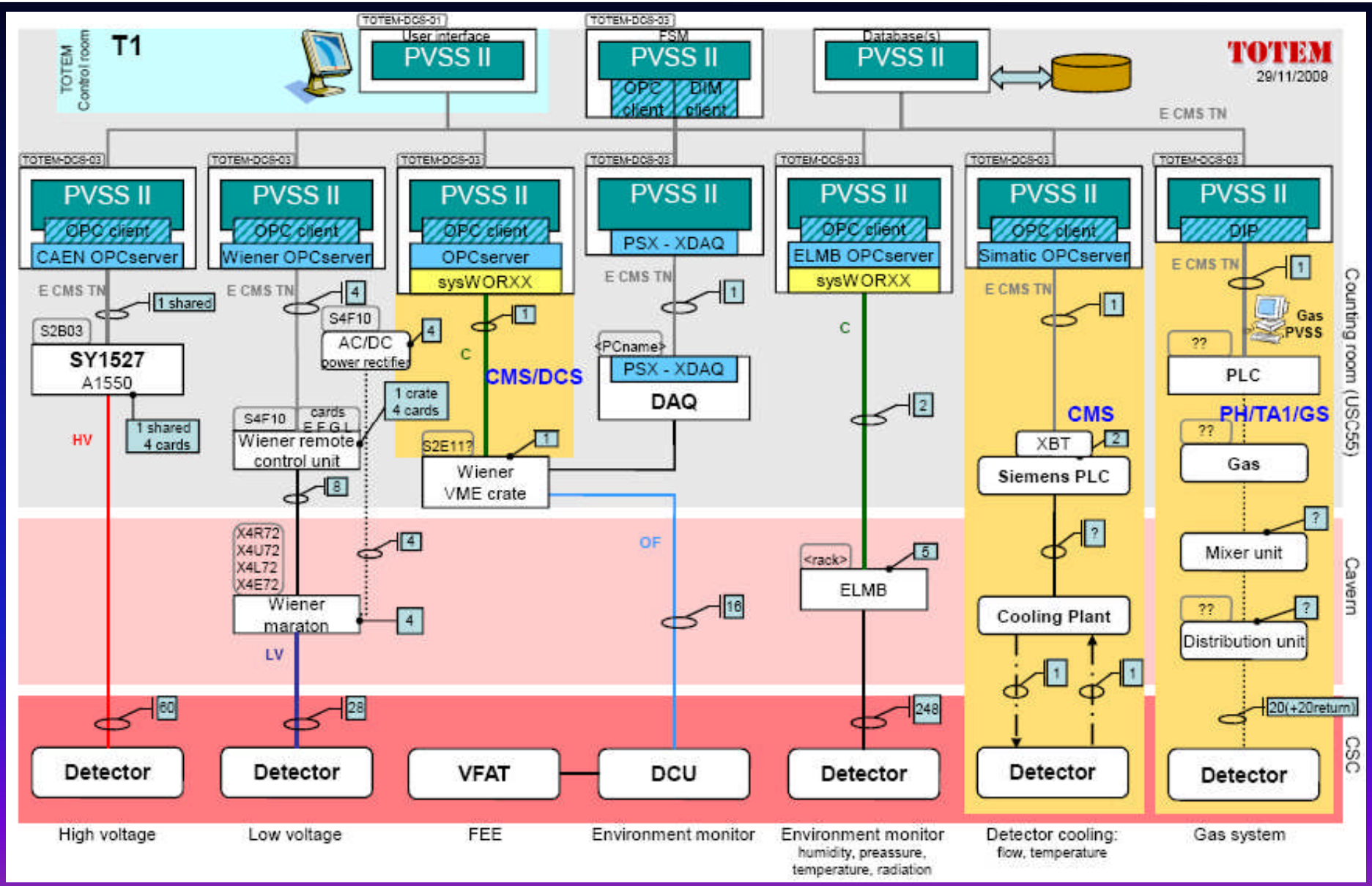
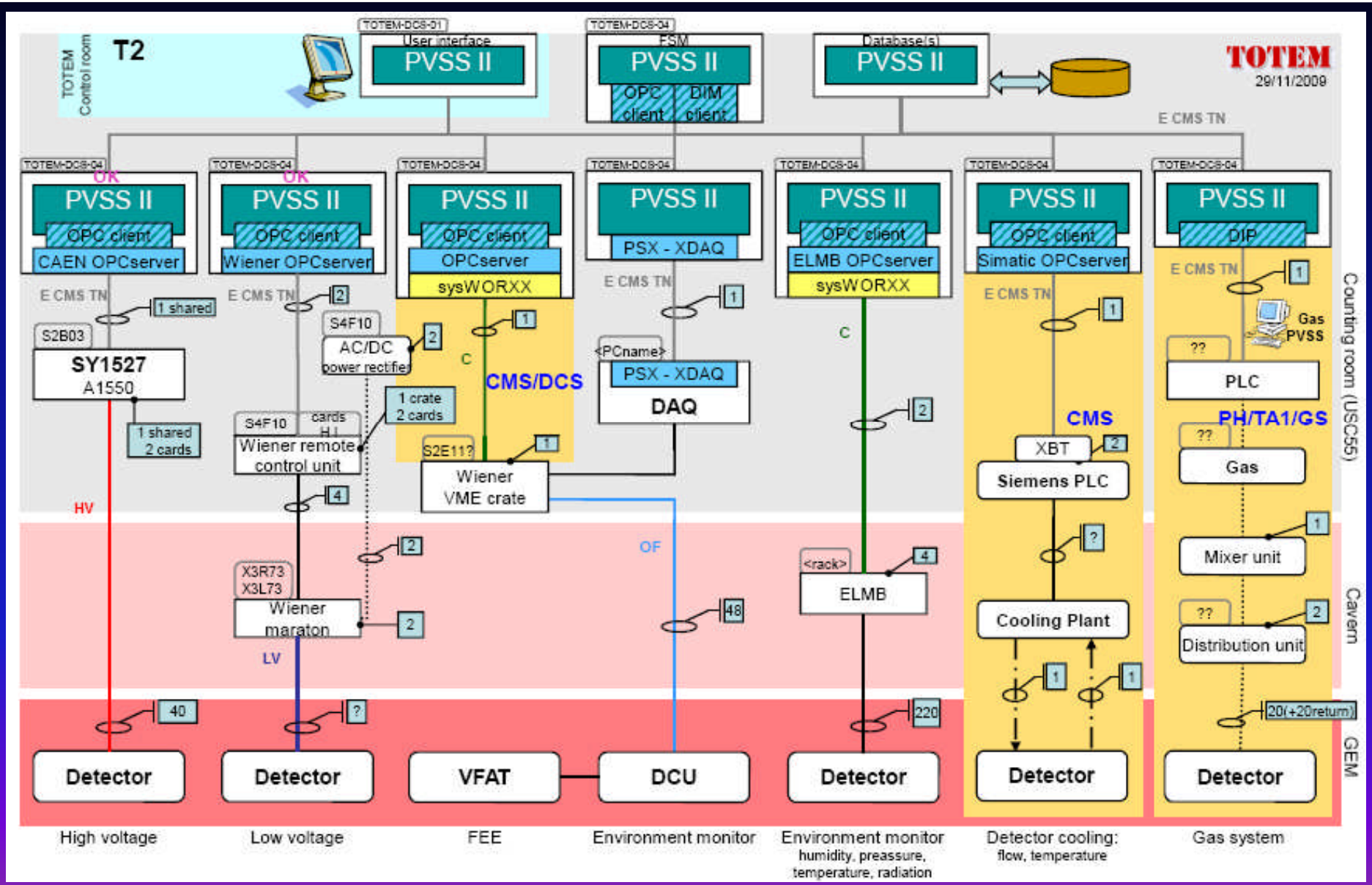


TOTEM Hardware Overview Diagrams



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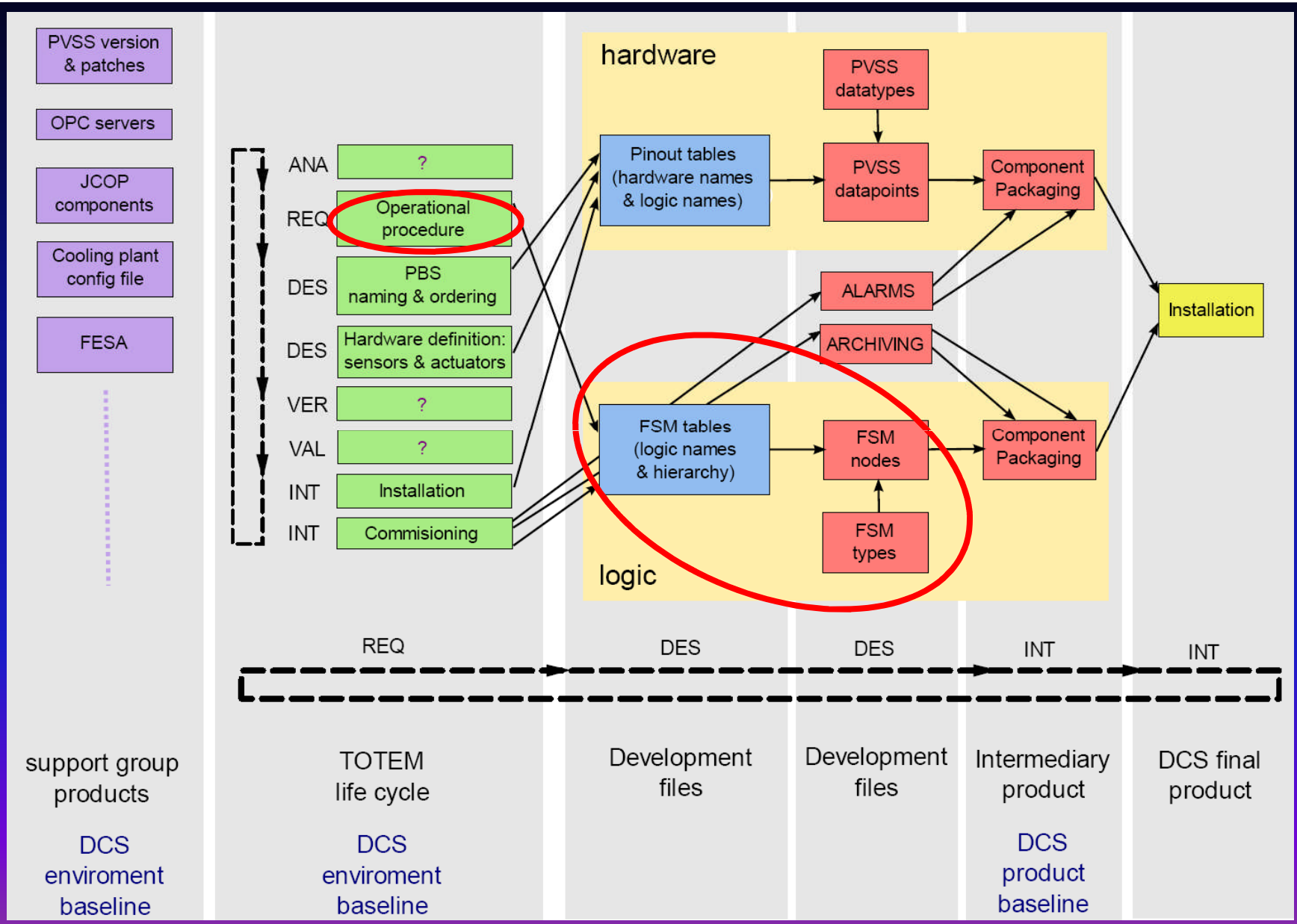
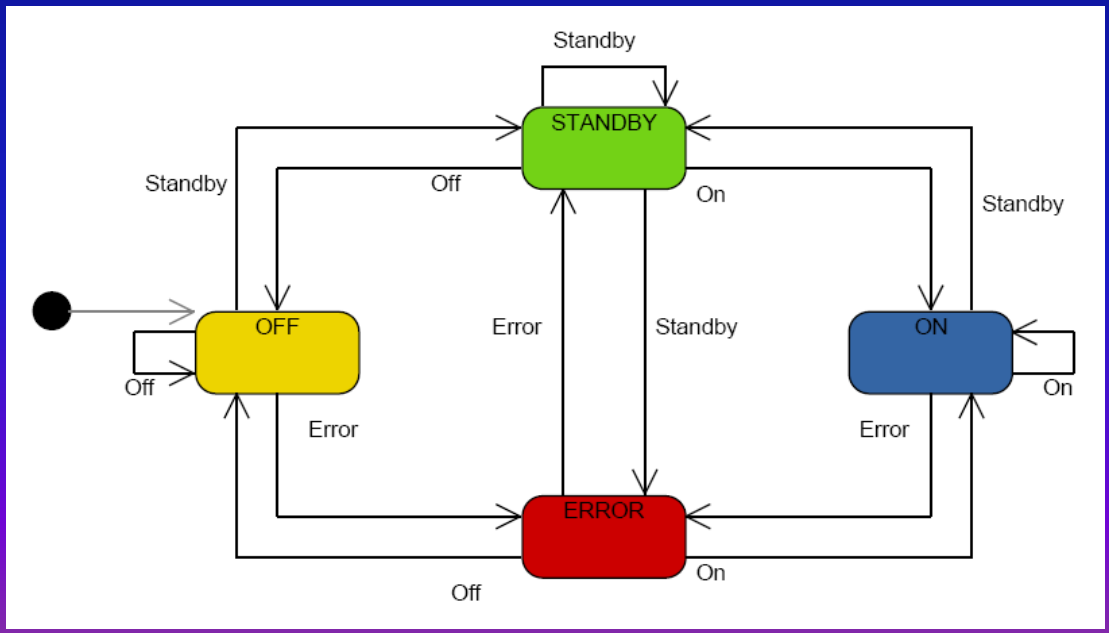


Operation Logic: FSM Low Voltage/UML

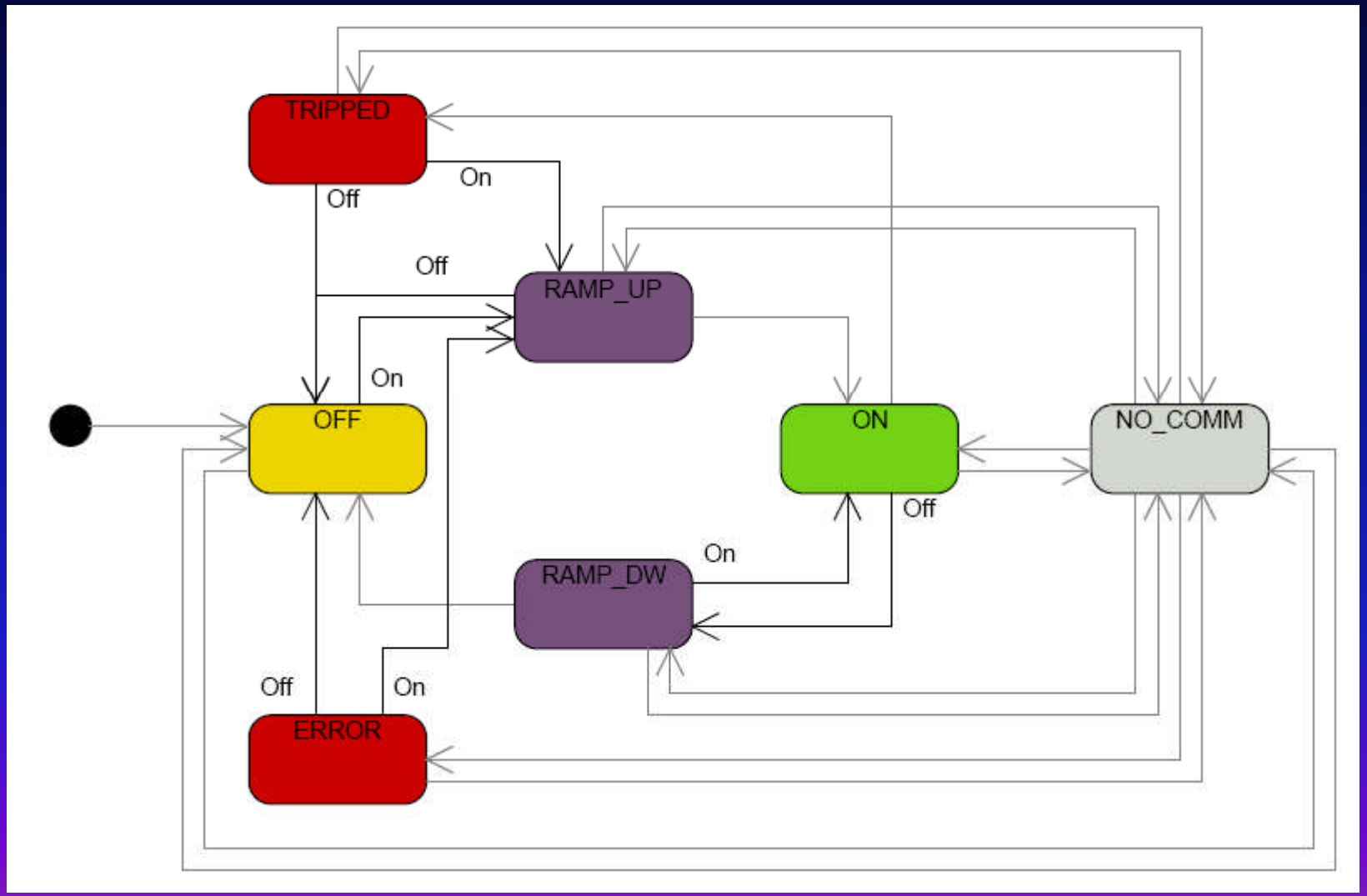
States	Commands
ON Low voltages channel is switched ON	OFF brings the low voltage channel to the state OFF
OFF Low voltages channel is switched OFF	ON brings the high voltage channel to the state ON
ERROR Manual intervention is required	OFF brings the high voltage channel to the state OFF
	ON brings the high voltage channel to the state ON
NO_COMM No connection to the Wiener Maraton Crate	



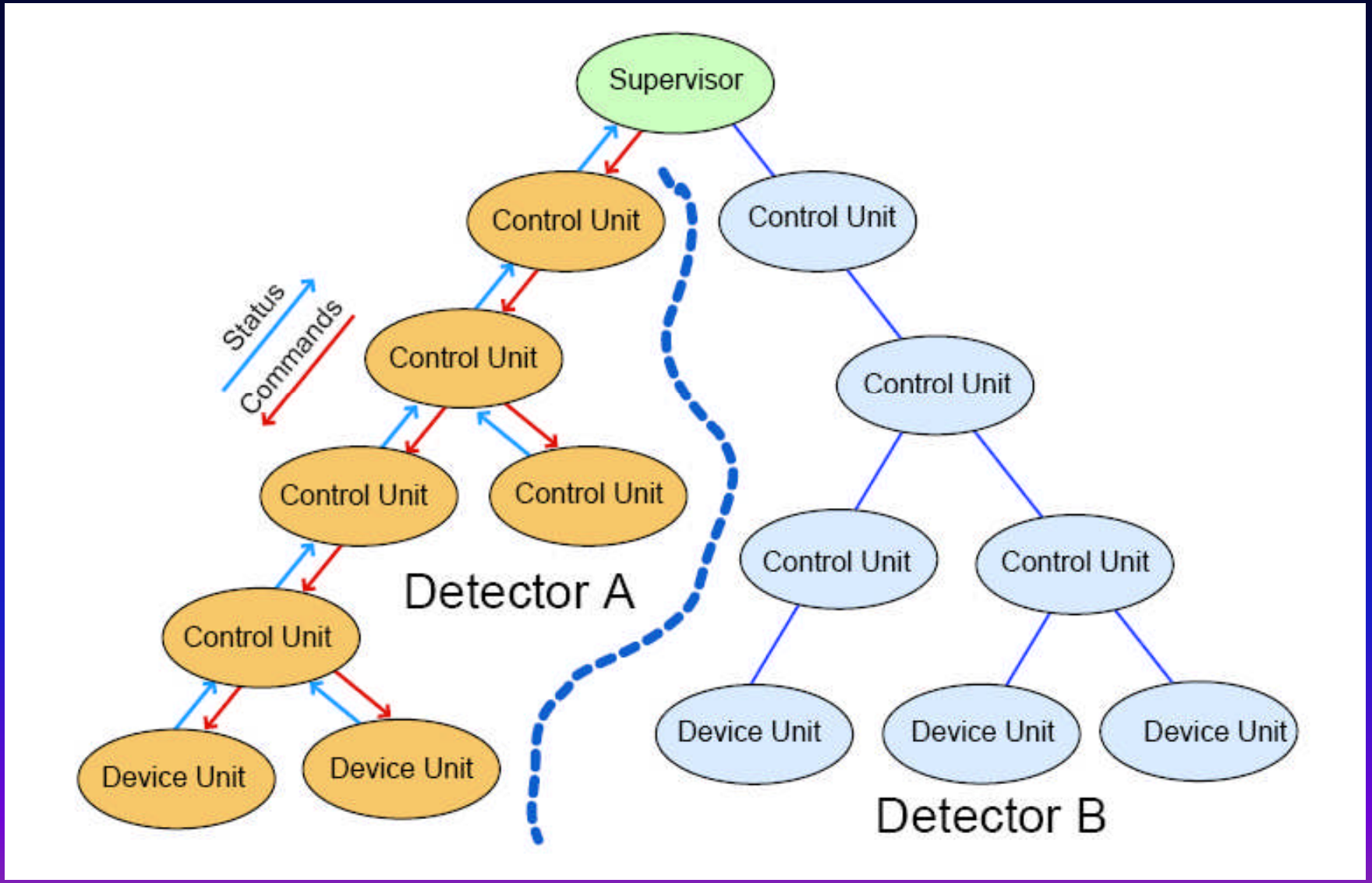
Operation Logic: FSM High Voltage

States	Commands
ON High voltages channel is switched on	OFF brings the high voltage channel to the state OFF
OFF High Voltage channel is switched off	ON brings the high voltage channel to the state ON
RAMP_UP High voltage channel is in RAMP UP	OFF brings the high voltage channel to the state OFF
RAMP_DW High voltage channel is in RAMP DOWN. The Roman Pot module is not ready for data taking.	ON brings the high voltage channel to the state ON
TRIPPED Manual intervention is required	OFF brings the high voltage channel to the state OFF
	ON brings the high voltage channel to the state ON
ERROR Manual intervention is required	OFF brings the high voltage channel to the state OFF
	ON brings the high voltage channel to the state ON
NO_COMM No connection to the Caen Crate	

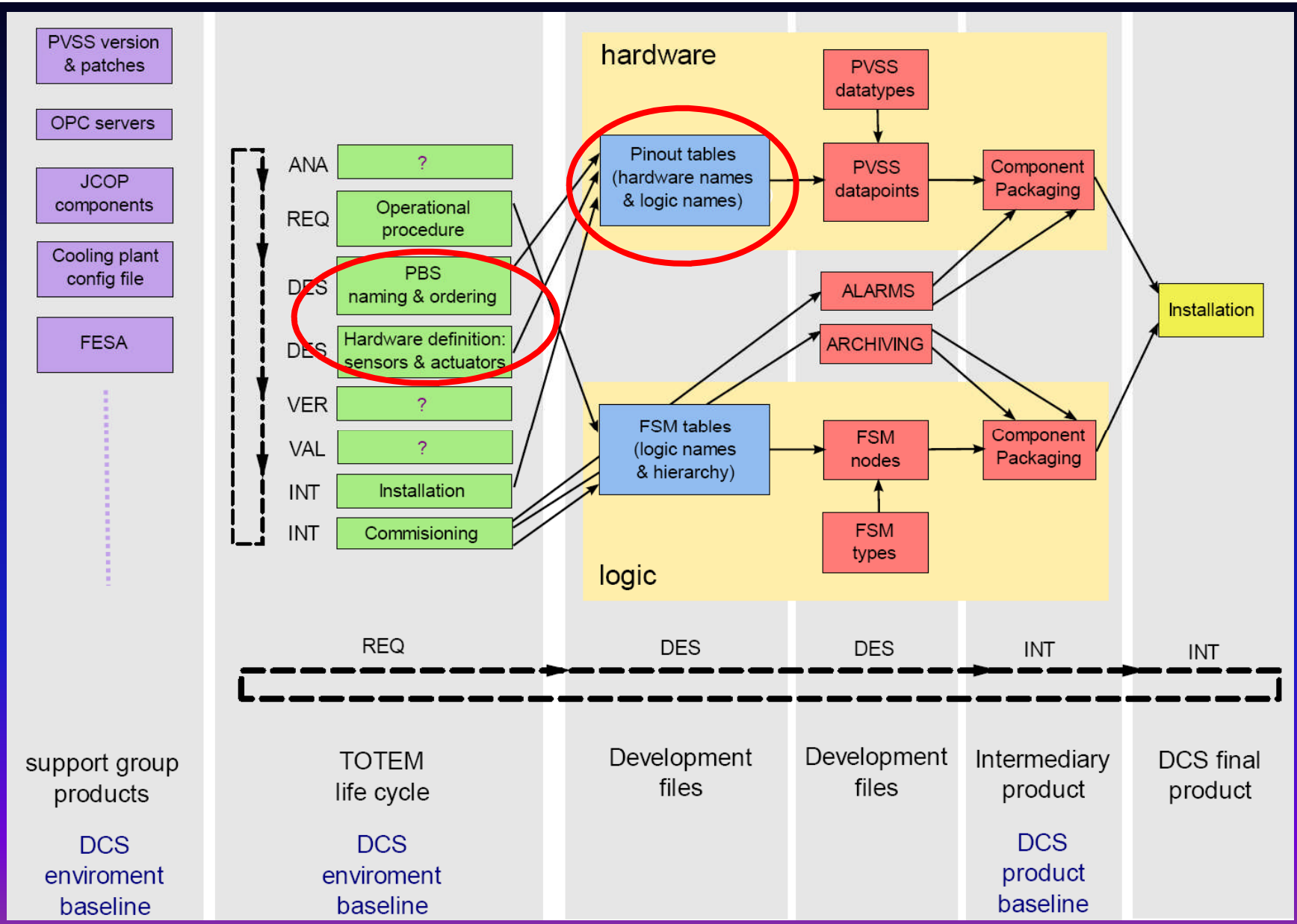
Operation Logic: FSM High Voltage/UML



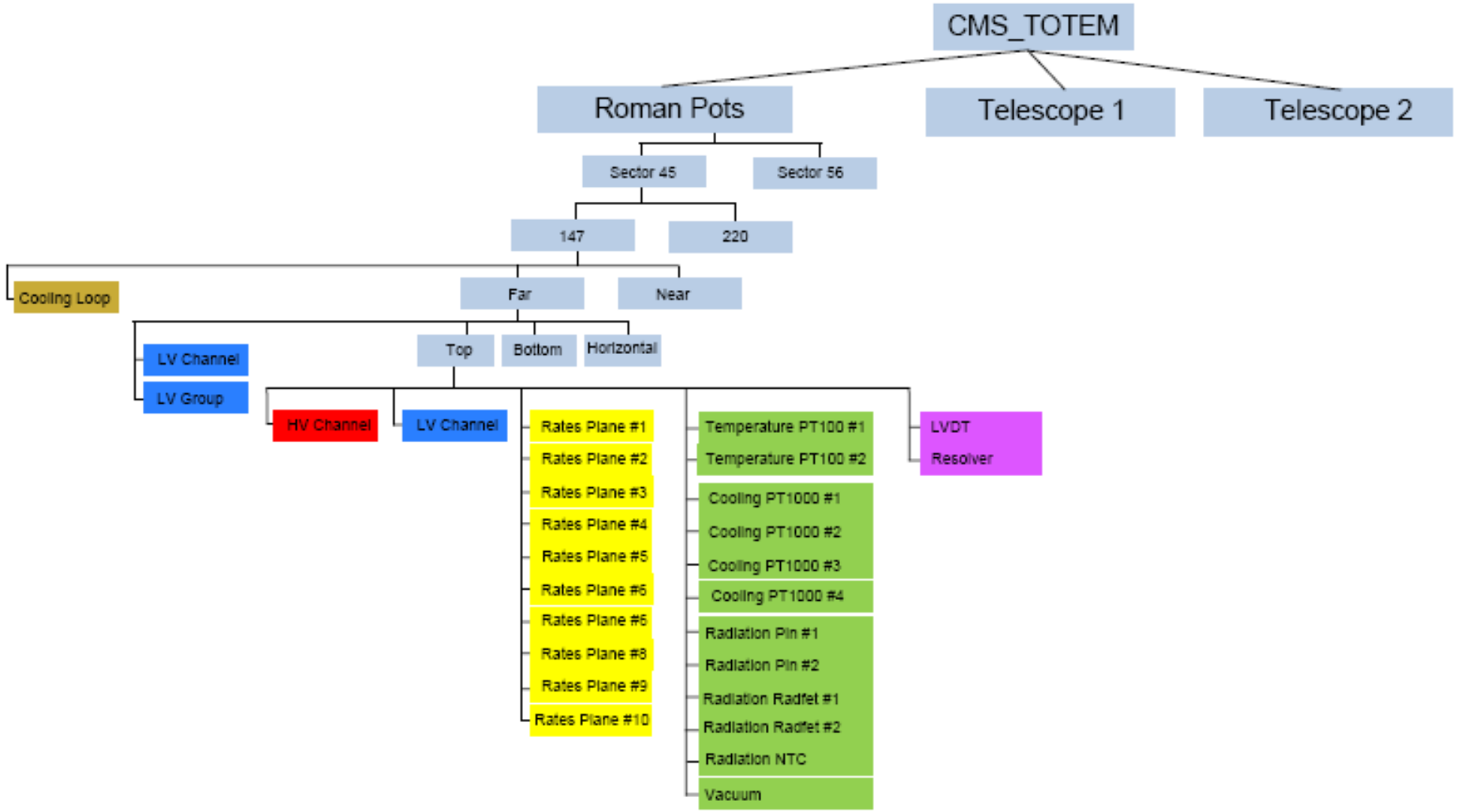
FSM State/Command Hierarchy



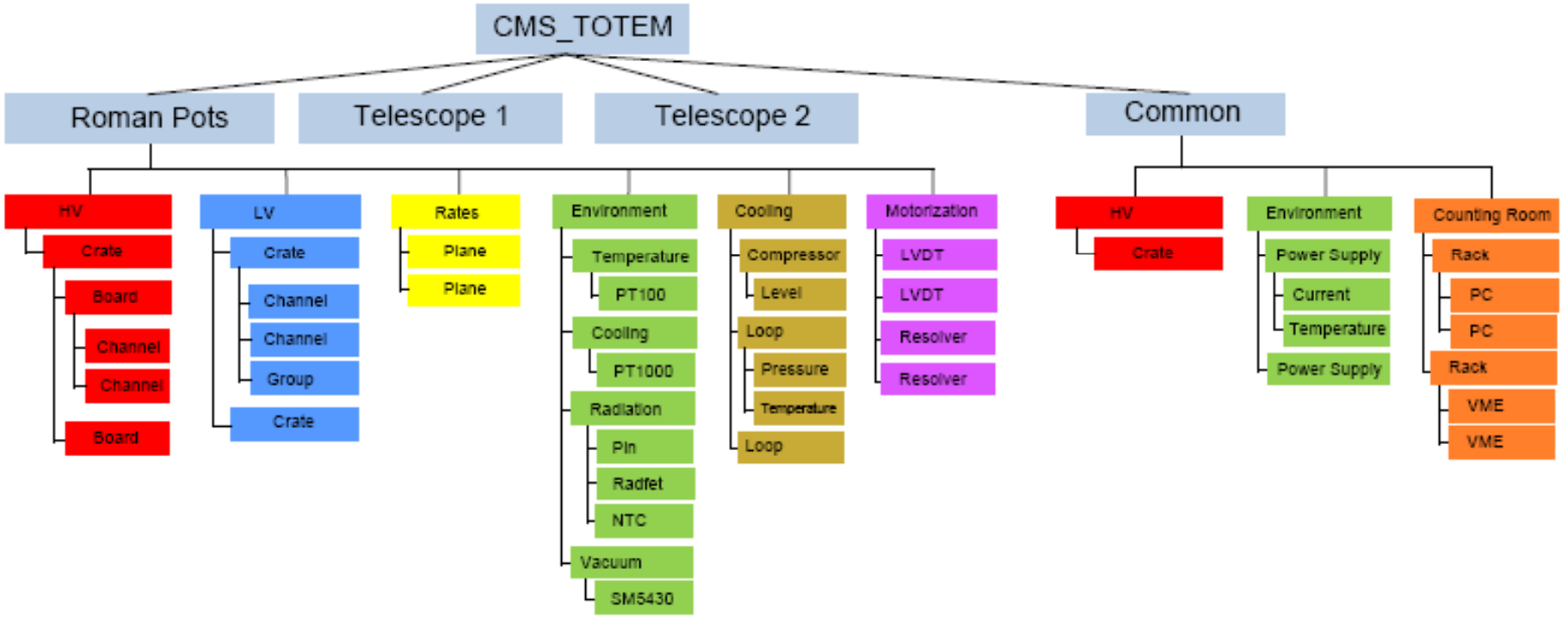
TOTEM DCS Development process



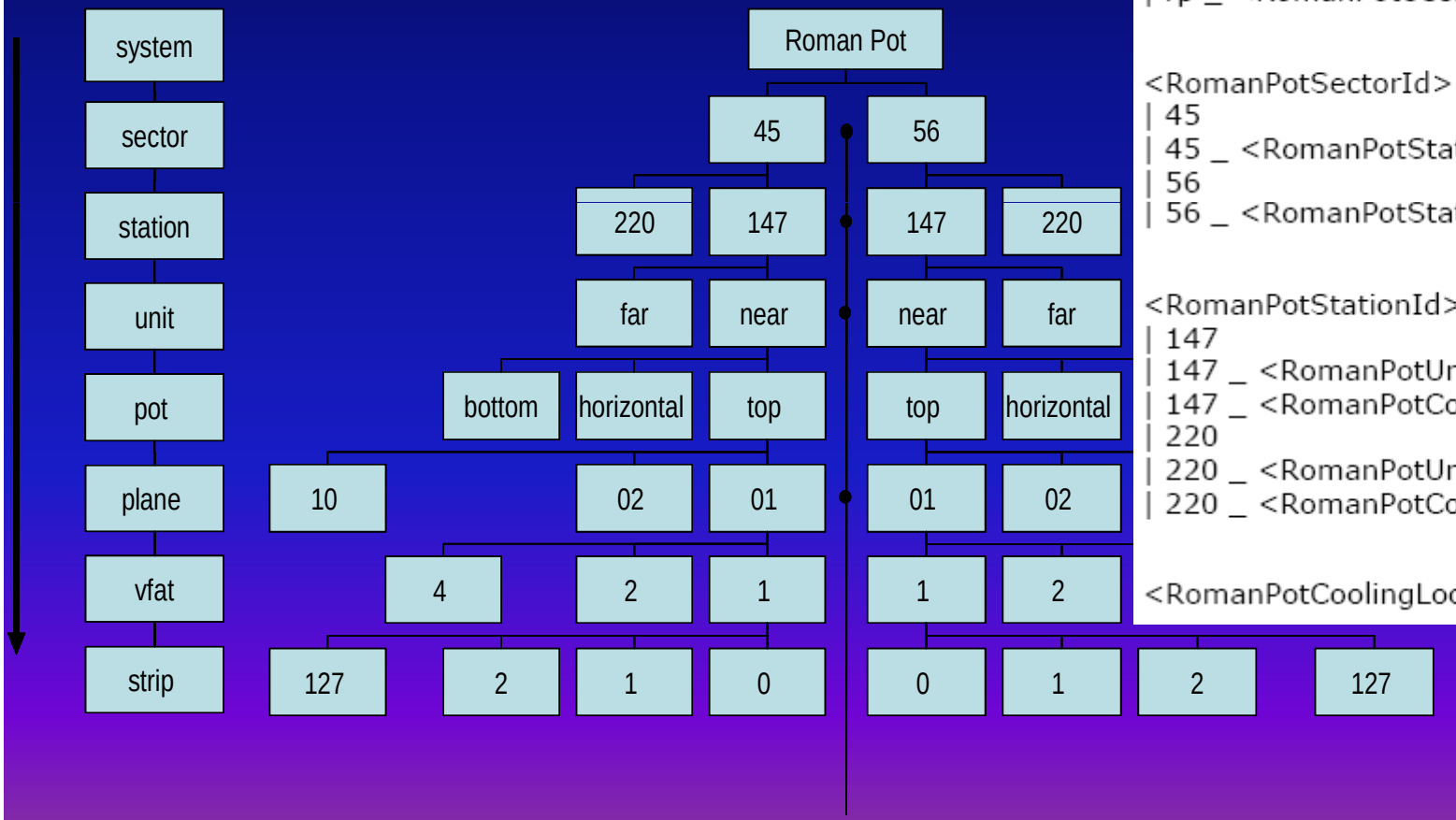
TOTEM Detector Tree



TOTEM Hardware Tree

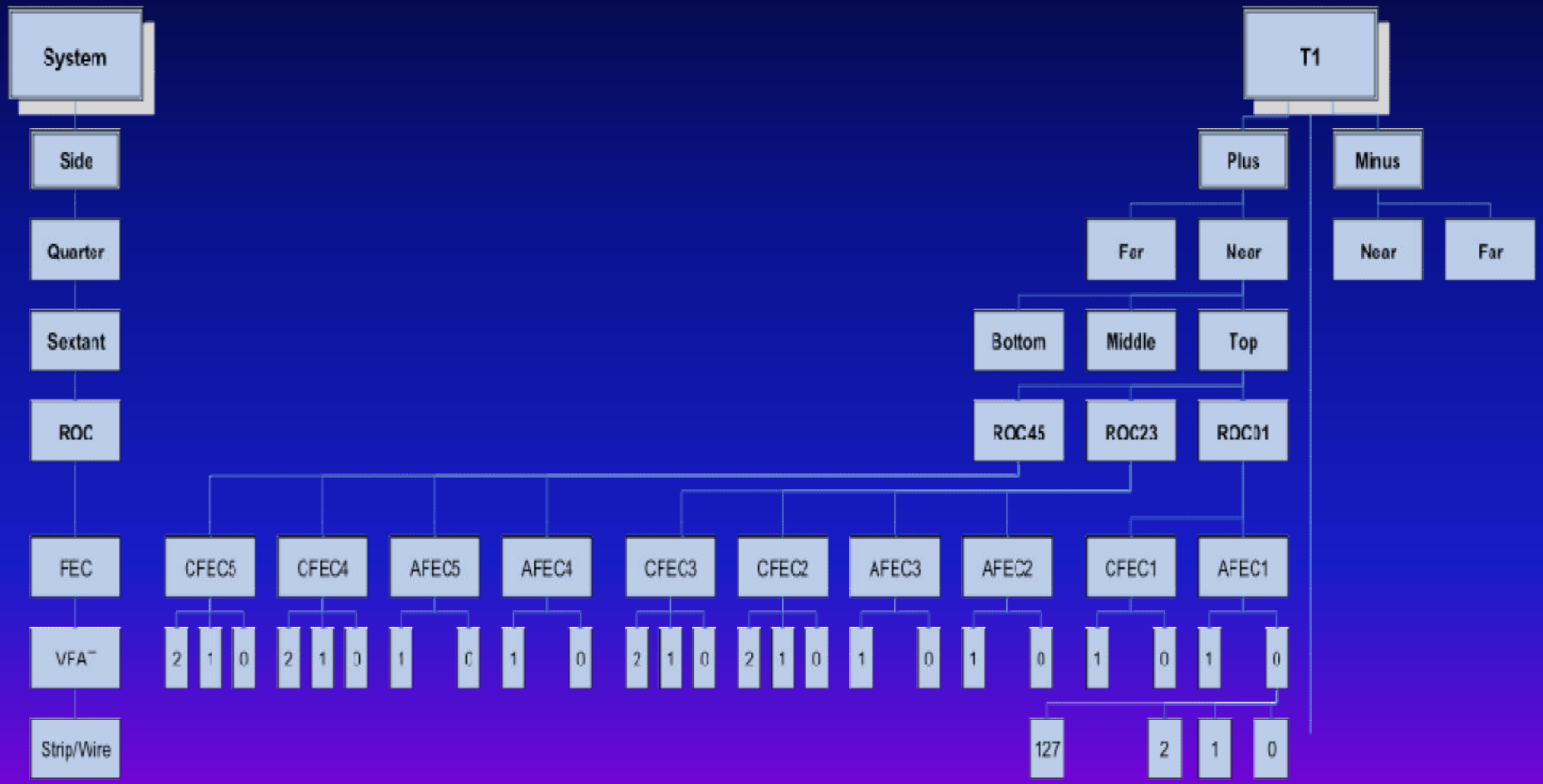


PBS & Naming Roman Pot

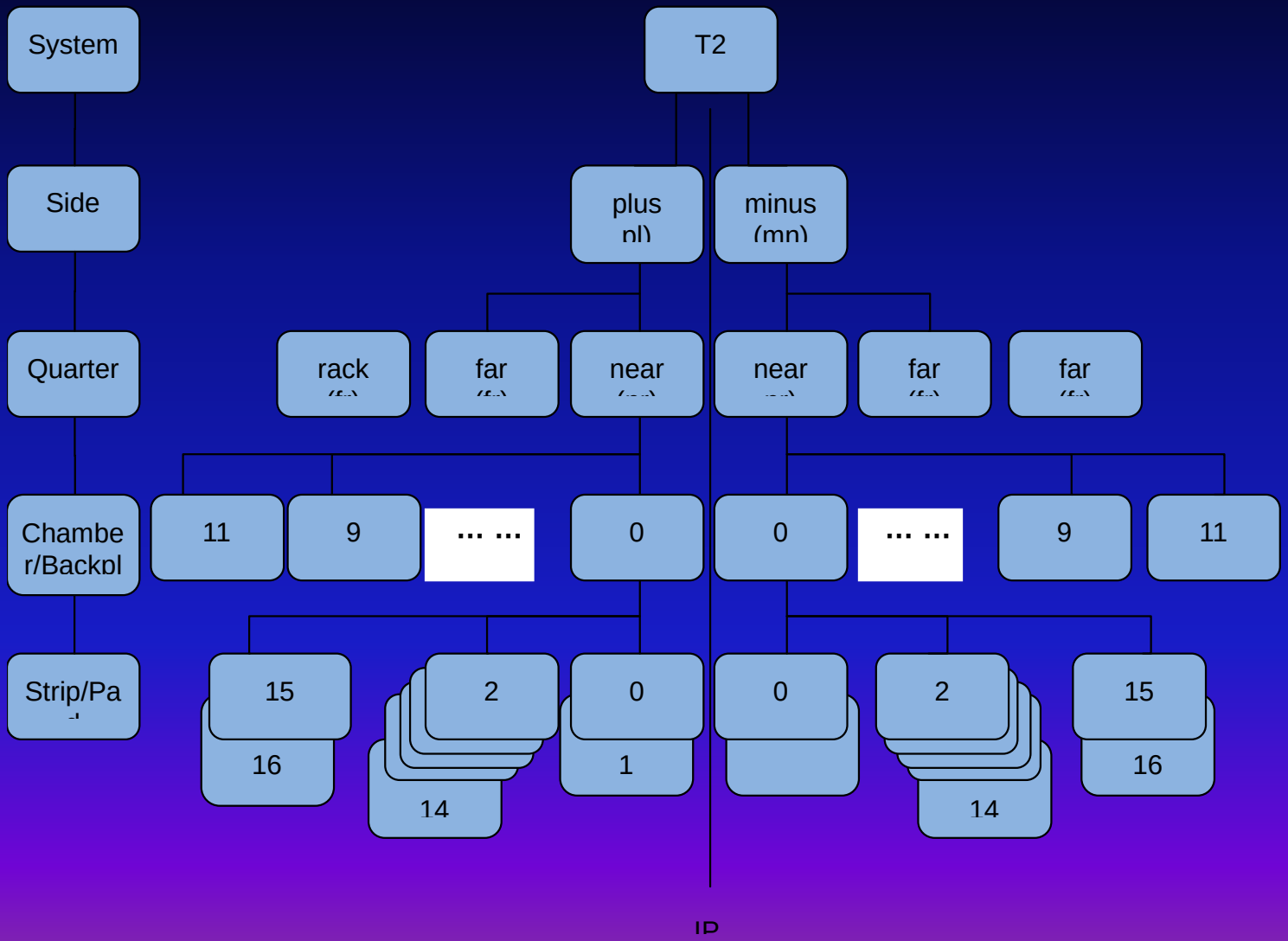



```
<TotemId> ::=
| tot
| tot _ <RomanPotId>
| tot _ <Telescope1Id>
| tot _ <Telescope2Id>
| tot _ <GeneralId>

<RomanPotId> ::=
| rp
| rp _ <RomanPotSectorId>

<RomanPotSectorId> ::=
| 45
| 45 _ <RomanPotStationId>
| 56
| 56 _ <RomanPotStationId>

<RomanPotStationId> ::=
| 147
| 147 _ <RomanPotUnitId>
| 147 _ <RomanPotCoolingLoopId>
| 220
| 220 _ <RomanPotUnitId>
| 220 _ <RomanPotCoolingLoopId>

<RomanPotCoolingLoopId> ::= CoolingLoop
```

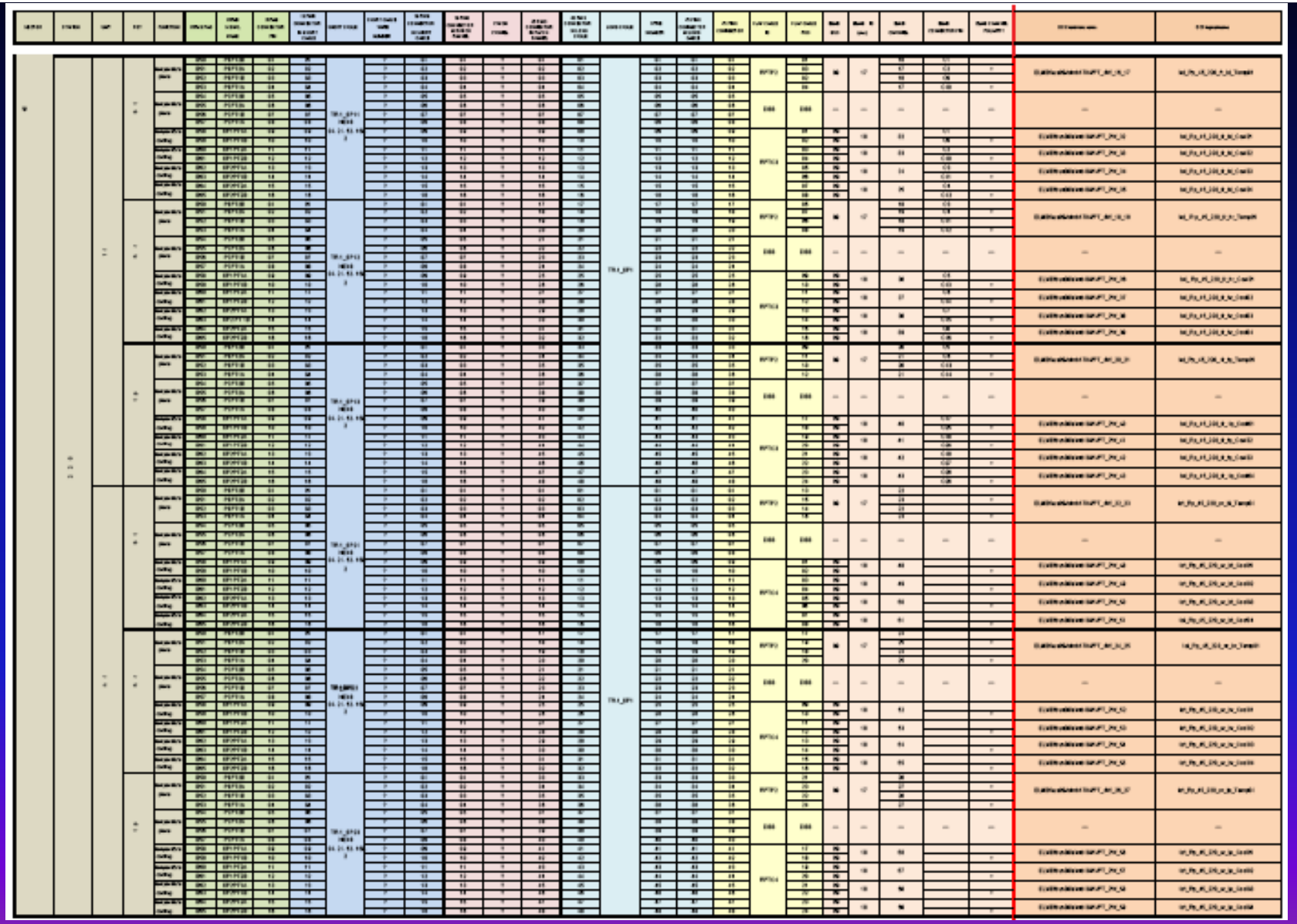
PBS T1


System
Side
Quarter
Sextant
ROC
FEC
VFAT
Strip/Wire
T1
Plus
Minus
Far
Near
Near
Far
Bottom
Middle
Top
ROC45
ROC23
ROC01
CFEC5
CFEC4
AFEC5
AFEC4
CFEC3
CFEC2
AFEC3
AFEC2
CFEC1
AFEC1
127

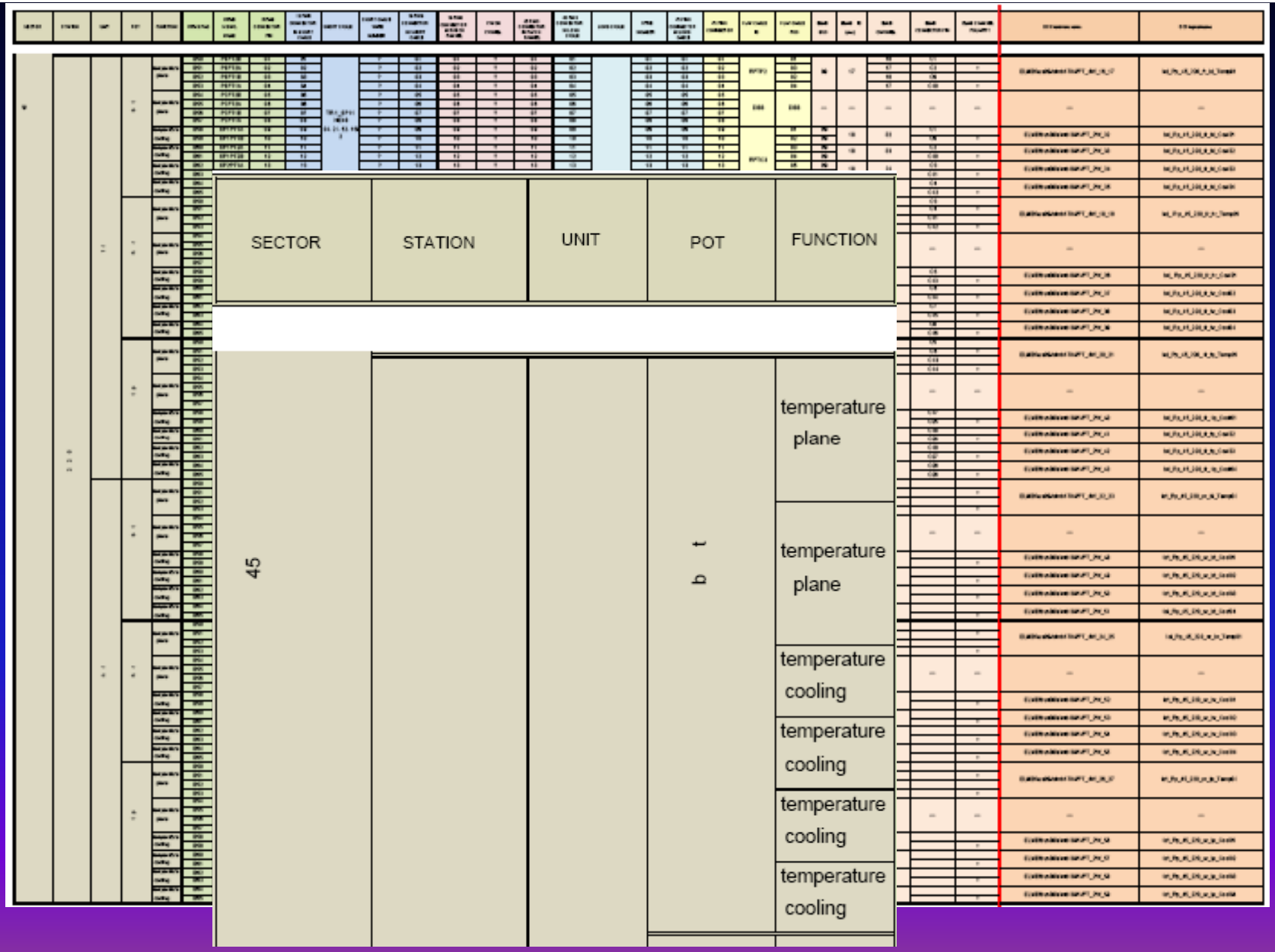
PBS T2


System
Side
Quarter
Chambe
r/Backpl
Strip/Pa
T2
plus
pl)
minus
(mn)
rack
far
near
near
far
far
11
9
... ...
0
0
... ...
9
11
15
16
2
14
0
1
0
2
14
15
16
IP

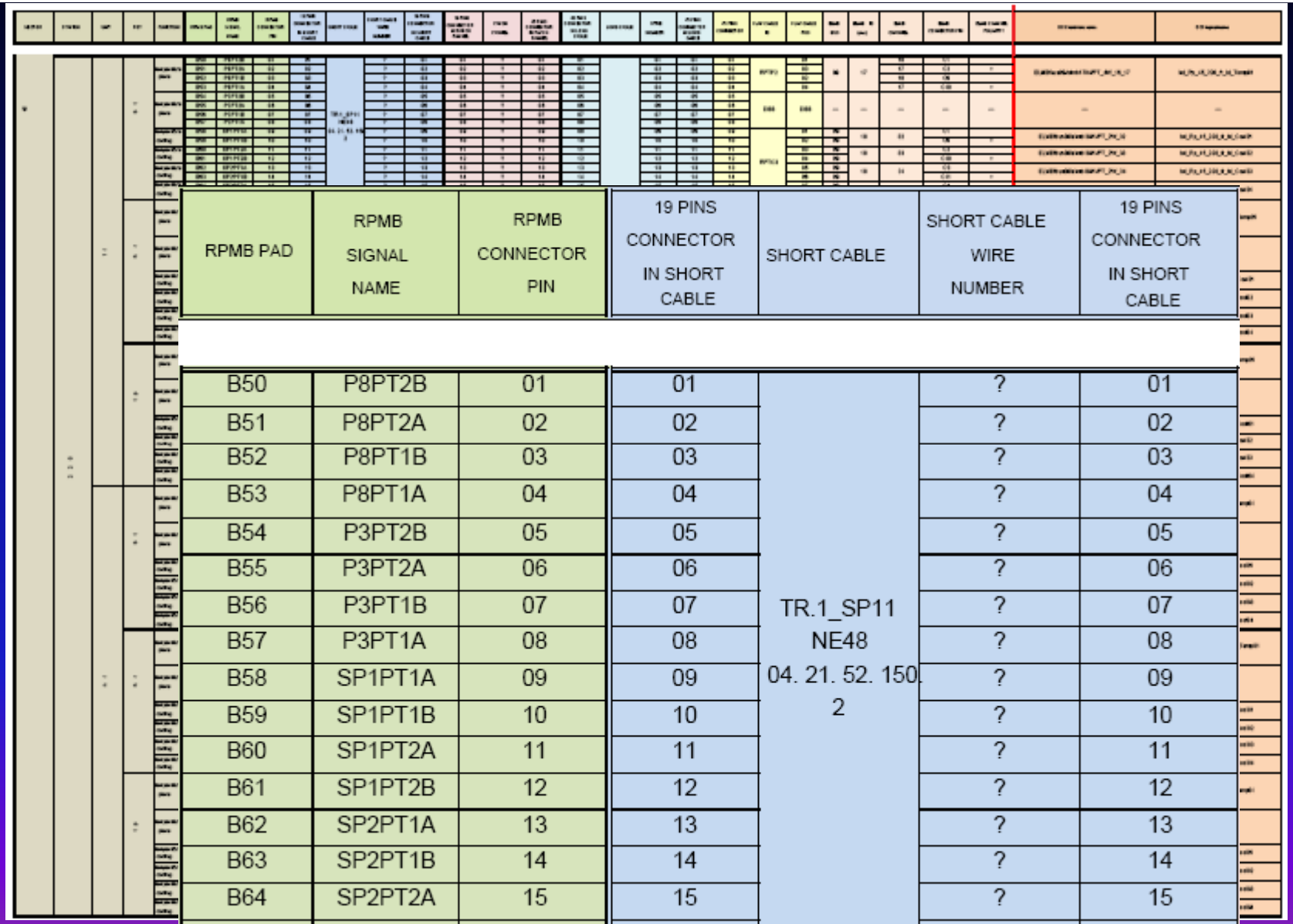
Pinout Tables Roman Pot



Pinout Tables Roman Pot

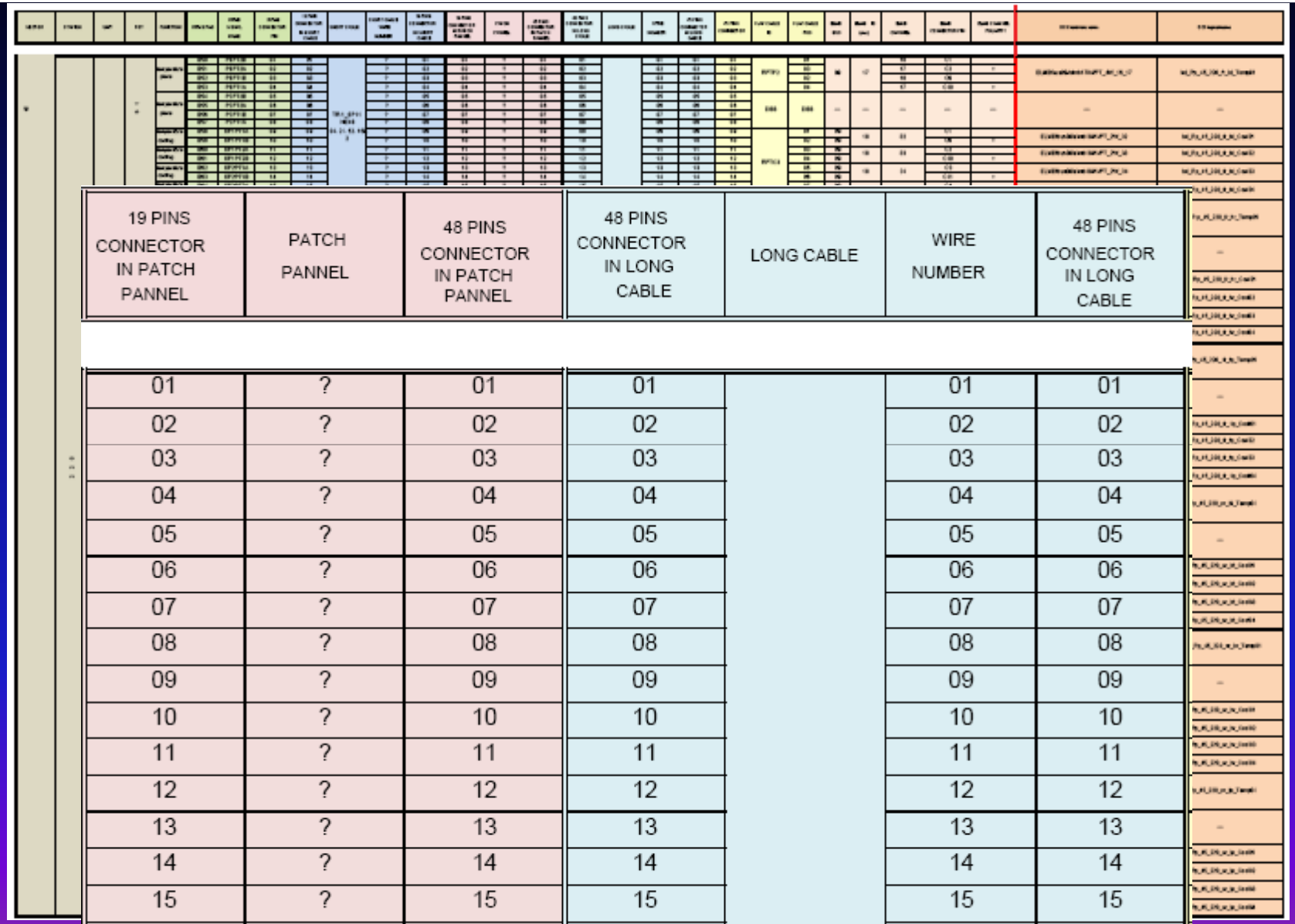


Pinout Tables Roman Pot



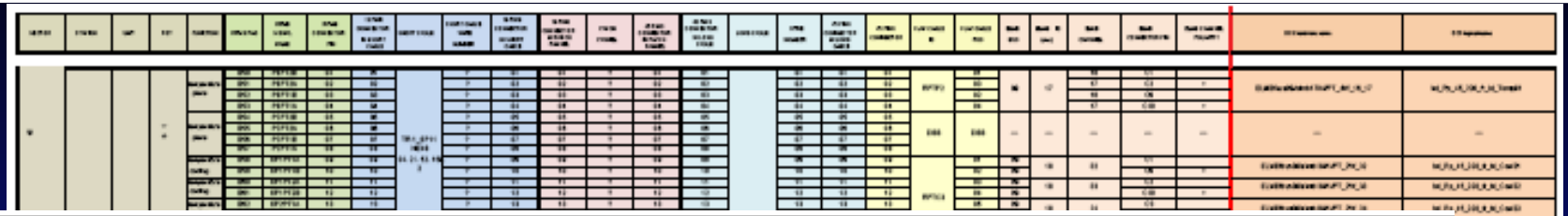
RPMB PAD	RPMB SIGNAL NAME	RPMB CONNECTOR PIN	19 PINS CONNECTOR IN SHORT CABLE	SHORT CABLE	SHORT CABLE WIRE NUMBER	19 PINS CONNECTOR IN SHORT CABLE
B50	P8PT2B	01	01	TR.1_SP11 NE48 04. 21. 52. 150. 2	?	01
B51	P8PT2A	02	02		?	02
B52	P8PT1B	03	03		?	03
B53	P8PT1A	04	04		?	04
B54	P3PT2B	05	05		?	05
B55	P3PT2A	06	06		?	06
B56	P3PT1B	07	07		?	07
B57	P3PT1A	08	08		?	08
B58	SP1PT1A	09	09		?	09
B59	SP1PT1B	10	10		?	10
B60	SP1PT2A	11	11		?	11
B61	SP1PT2B	12	12		?	12
B62	SP2PT1A	13	13		?	13
B63	SP2PT1B	14	14		?	14
B64	SP2PT2A	15	15		?	15
B65	SP2PT2B	16	16		?	16

Pinout Tables Roman Pot



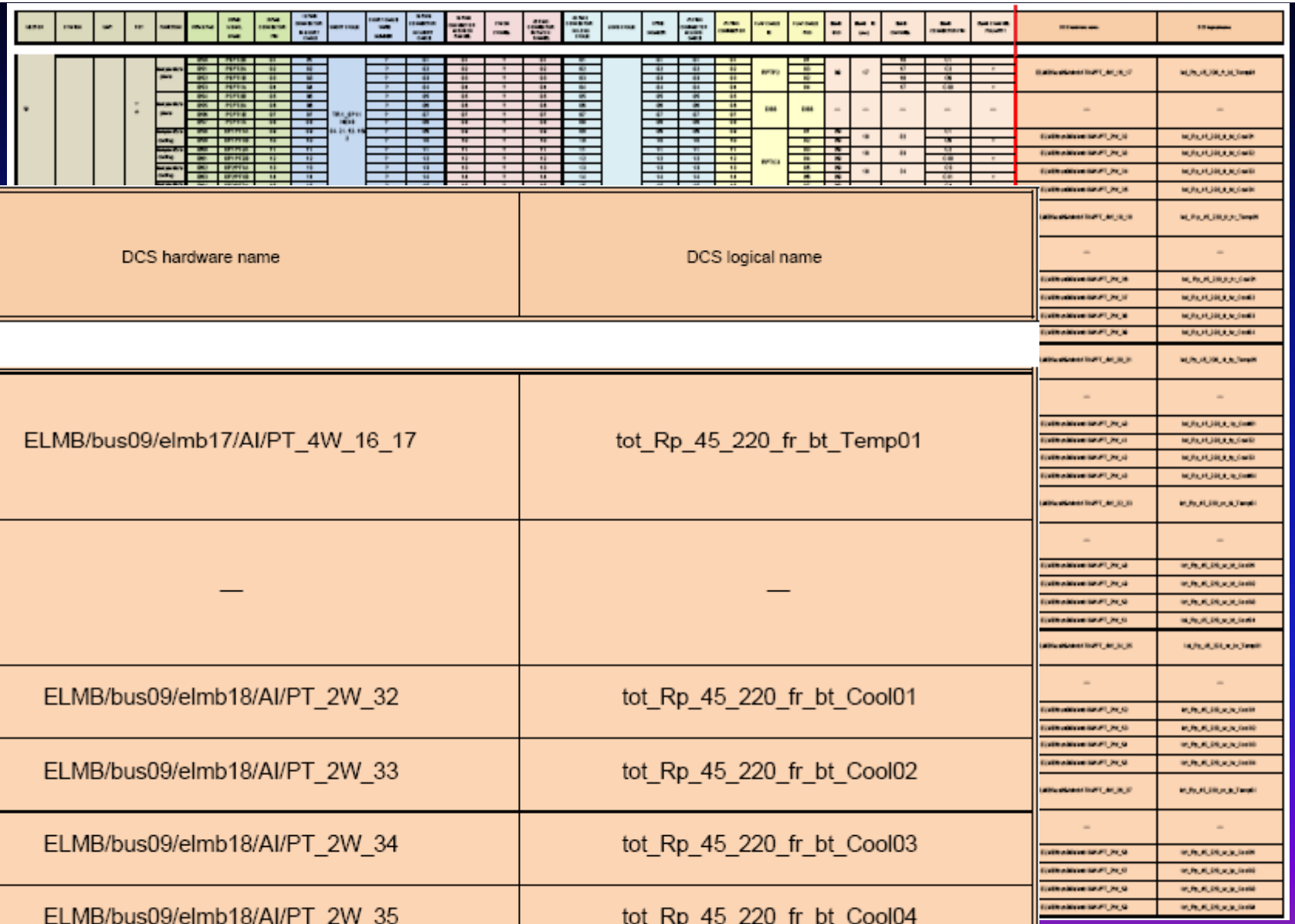
19 PINS CONNECTOR IN PATCH PANNEL	PATCH PANNEL	48 PINS CONNECTOR IN PATCH PANNEL	48 PINS CONNECTOR IN LONG CABLE	LONG CABLE	WIRE NUMBER	48 PINS CONNECTOR IN LONG CABLE
01	?	01	01		01	01
02	?	02	02		02	02
03	?	03	03		03	03
04	?	04	04		04	04
05	?	05	05		05	05
06	?	06	06		06	06
07	?	07	07		07	07
08	?	08	08		08	08
09	?	09	09		09	09
10	?	10	10		10	10
11	?	11	11		11	11
12	?	12	12		12	12
13	?	13	13		13	13
14	?	14	14		14	14
15	?	15	15		15	15
16	?	16	16		16	16

Pinout Tables Roman Pot



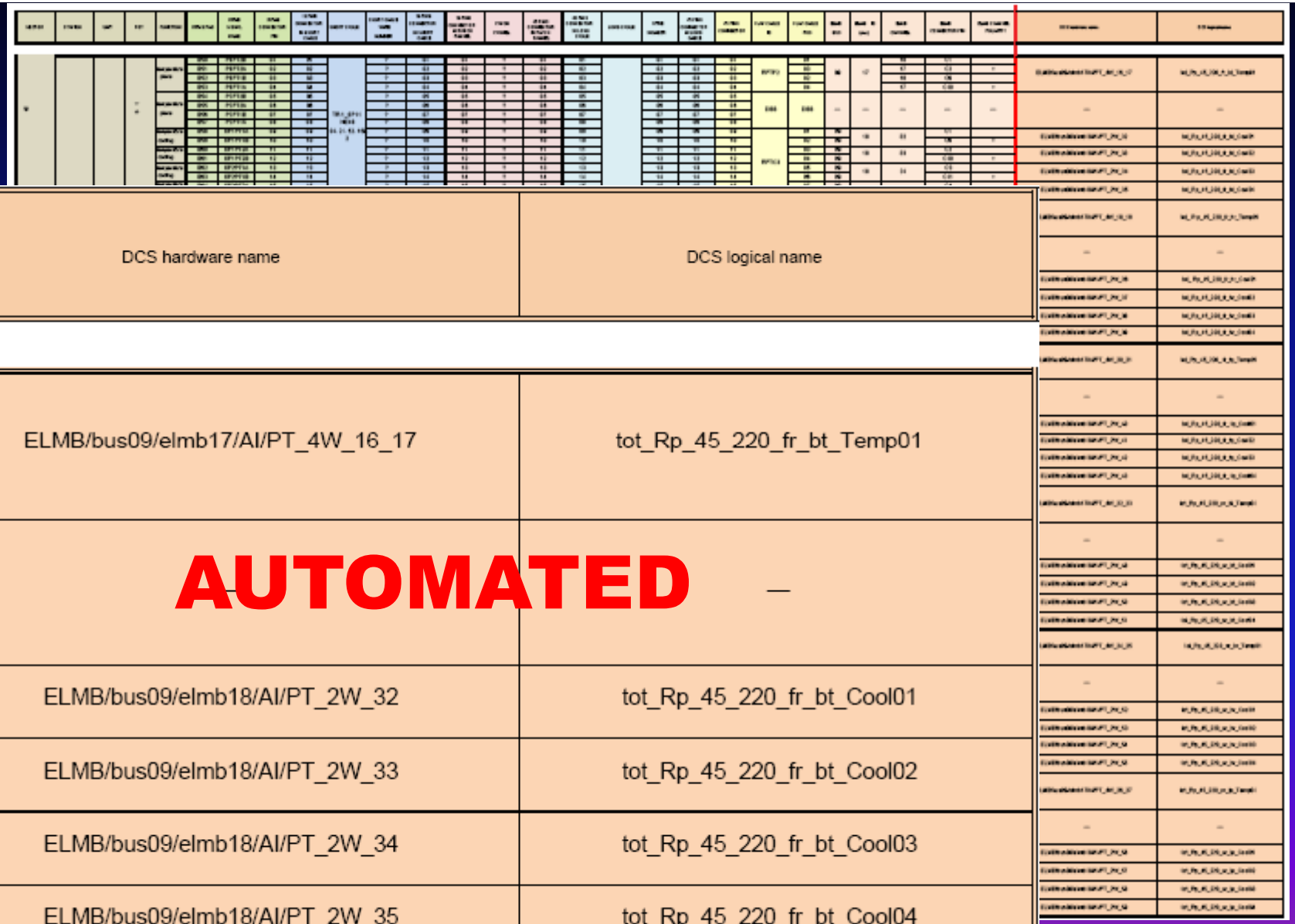
48 PINS CONNECTOR	FLAT CABLE ID	FLAT CABLE POS	ELMB BUS	ELMB ID (dec)	ELMB CHANNEL	ELMB CONNECTOR PIN	ELMB CHANNEL POLARITY
01	RPTP2	01	09	17	16	C1	
02		03			17	C2	+
03		02			16	C9	
04		04			17	C10	+
05	DSS	DSS	—	—	—	—	—
06							
07							
08							
09	RPTC3	01	09	18	32	C1	
10		02	09			C9	+
11		03	09	18	33	C2	
12		04	09			C10	+
13		05	09	18	34	C3	
14		06	09			C11	+
15		07	09	18	35	C4	
16		08	09			C12	+

Pinout Tables Roman Pot



DCS hardware name	DCS logical name
ELMB/bus09/elmb17/AI/PT_4W_16_17	tot_Rp_45_220_fr_bt_Temp01
—	—
ELMB/bus09/elmb18/AI/PT_2W_32	tot_Rp_45_220_fr_bt_Cool01
ELMB/bus09/elmb18/AI/PT_2W_33	tot_Rp_45_220_fr_bt_Cool02
ELMB/bus09/elmb18/AI/PT_2W_34	tot_Rp_45_220_fr_bt_Cool03
ELMB/bus09/elmb18/AI/PT_2W_35	tot_Rp_45_220_fr_bt_Cool04

Pinout Tables Roman Pot



DCS hardware name	DCS logical name
ELMB/bus09/elmb17/AI/PT_4W_16_17	tot_Rp_45_220_fr_bt_Temp01
AUTOMATED	—
ELMB/bus09/elmb18/AI/PT_2W_32	tot_Rp_45_220_fr_bt_Cool01
ELMB/bus09/elmb18/AI/PT_2W_33	tot_Rp_45_220_fr_bt_Cool02
ELMB/bus09/elmb18/AI/PT_2W_34	tot_Rp_45_220_fr_bt_Cool03
ELMB/bus09/elmb18/AI/PT_2W_35	tot_Rp_45_220_fr_bt_Cool04

TOTEM FSM Hierarchy Table

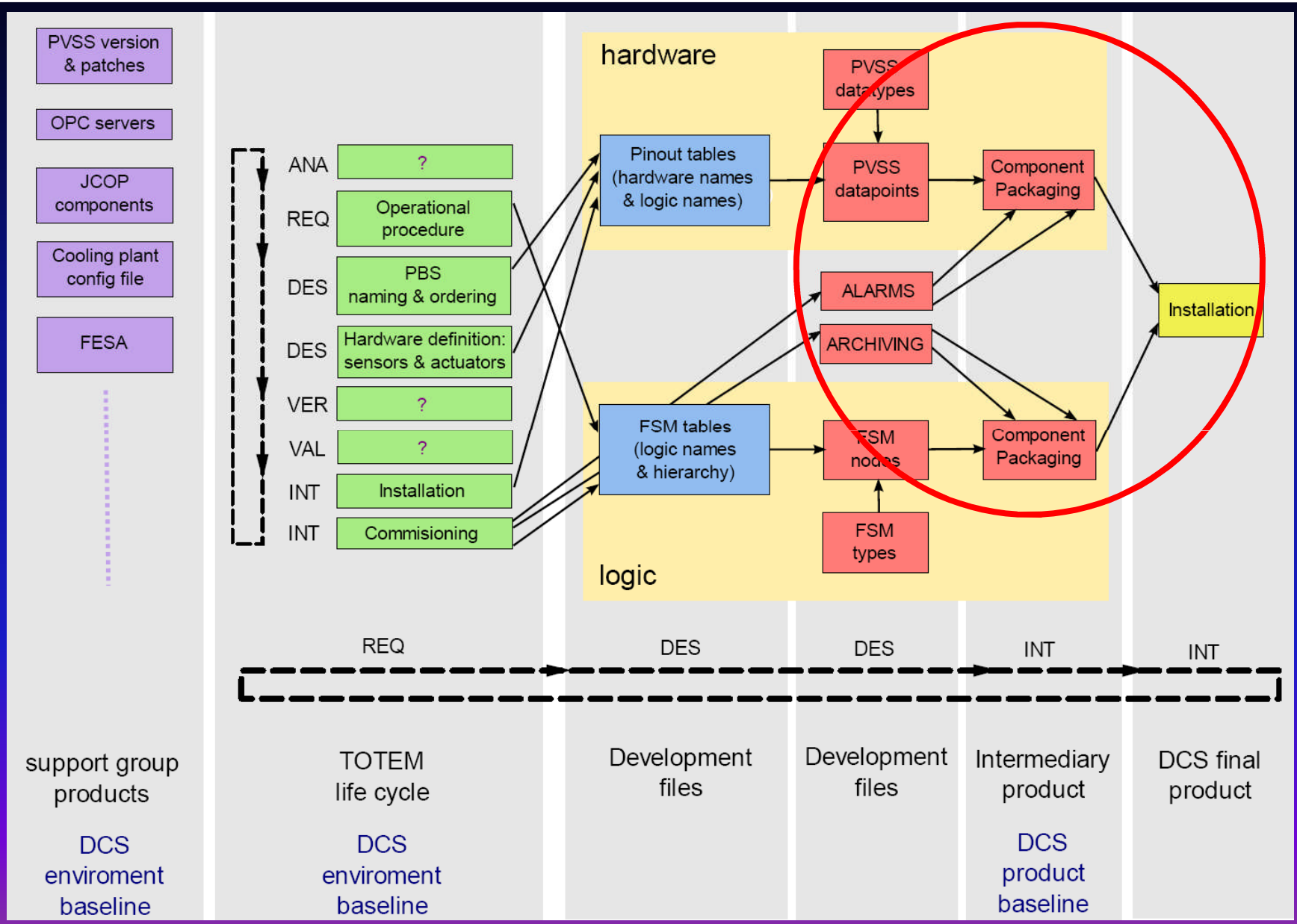
logic name and FSM name								parent override	FSM type: CU, DU or LU	PBS
level										
A	B	C	D	E	F	G	H			
tot_Rp								CMS_TOTEM	CU:tot_Rp_Sv	E.03.01
	tot_Rp_45								CU:tot_RpSide	E.03.99
		tot_Rp_45_220							CU:tot_RpStation	E.03.99
			tot_Rp_45_220_fr						CU:tot_RpUnit	E.03.99
				tot_Rp_45_220_fr_tp					CU:tot_RpPot	E.03.99
					tot_Rp_45_220_fr_tp_DssTemp				DU:tot_FwAiRpDss	E.03.09
#					tot_Rp_45_220_fr_tp_Lvdt				DU:	E.03.08
#					tot_Rp_45_220_fr_tp_Reso				DU:	E.03.08
#					tot_Rp_45_220_fr_tp_MicrIn				DU:	E.03.08
#					tot_Rp_45_220_fr_tp_MicrOut				DU:	E.03.08
					tot_Rp_45_220_fr_tp_Hv				DU:FwCaenChannelRpHv	E.03.01
					tot_Rp_45_220_fr_tp_LvG				DU:FwWienerMarathonGroupRp	E.03.02
					tot_Rp_45_220_fr_tp_LvA				DU:FwWienerMarathonChannelRp	E.03.02
					tot_Rp_45_220_fr_tp_LvD				DU:FwWienerMarathonChannelRp	E.03.02
#					tot_Rp_45_220_fr_tp_Temp01				DU:	E.03.05.03
#					tot_Rp_45_220_fr_tp_Cool01				DU:	E.03.05.03
#					tot_Rp_45_220_fr_tp_Cool02				DU:	E.03.05.03
#					tot_Rp_45_220_fr_tp_Cool03				DU:	E.03.05.03
#					tot_Rp_45_220_fr_tp_Cool04				DU:	E.03.05.03
#					tot_Rp_45_220_fr_tp_Vacc01				DU:	E.03.05.05

TOTEM FSM Hierarchy Table

logic name and FSM name level A B C D E F G H	parent override	FSM type: CU, DU or LU	PBS
tot_Rp	CMS_TOTEM	CU:tot_Rp_Sv	E.03.01
tot_Rp_45		CU:tot_RpSide	E.03.99
tot_Rp_45_220		CU:tot_RpStation	E.03.99
tot_Rp_45_220_fr		CU:tot_RpUnit	E.03.99
tot_Rp_45_220_fr_tp		CU:tot_RpPot	E.03.99
tot_Rp_45_220_fr_tp_DssTemp		DU:tot_FwAiRpDss	E.03.09
# tot_Rp_45_220_fr_tp_Lvdt		DU:	E.03.08
# tot_Rp_45_220_fr_tp_Resp		DU:	E.03.08
# tot_Rp_45_220_fr_tp_MicIn		DU:	E.03.08
# tot_Rp_45_220_fr_tp_MicrOut		DU:	E.03.08
tot_Rp_45_220_fr_tp_Hv		DU:FwCaenChannelRpHv	E.03.01
tot_Rp_45_220_fr_tp_LvG		DU:FwWienerMarathonGroupRp	E.03.02
tot_Rp_45_220_fr_tp_LvA		DU:FwWienerMarathonChannelRp	E.03.02
tot_Rp_45_220_fr_tp_LvD		DU:FwWienerMarathonChannelRp	E.03.02
# tot_Rp_45_220_fr_tp_Temp01		DU:	E.03.05.03
# tot_Rp_45_220_fr_tp_Cool01		DU:	E.03.05.03
# tot_Rp_45_220_fr_tp_Cool02		DU:	E.03.05.03
# tot_Rp_45_220_fr_tp_Cool03		DU:	E.03.05.03
# tot_Rp_45_220_fr_tp_Cool04		DU:	E.03.05.03
# tot_Rp_45_220_fr_tp_Vacc01		DU:	E.03.05.05

AUTOMATED

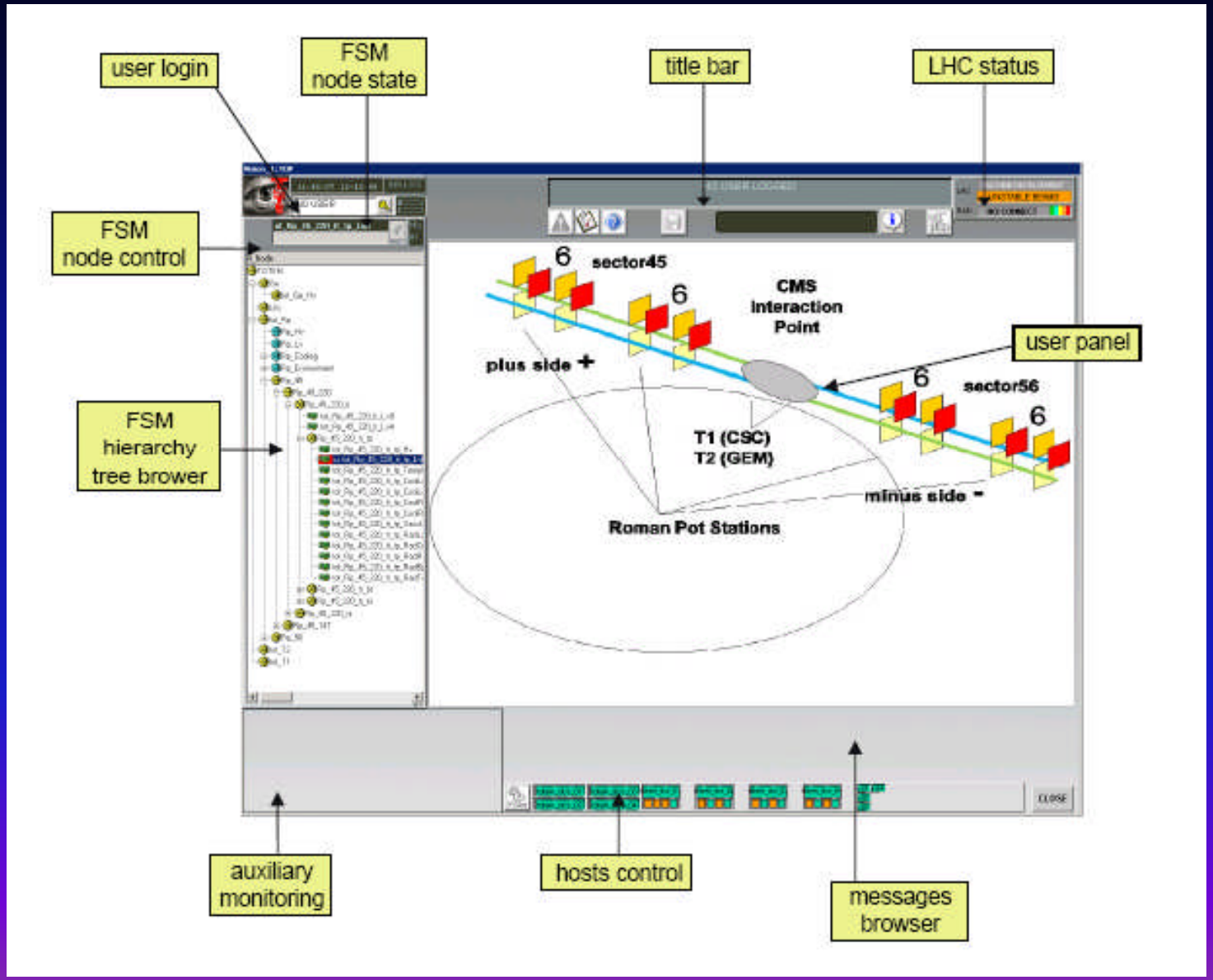
TOTEM DCS Development process



TOTEM DCS Conclusions

- Formalization for the hardware layout and operation logic
- This is allowing automatic developments, verification and establishing a software life-cycle.
- In this way all the front-end connectivity and FSM hierarchy is generated via automatic procedures.
- In case of development errors, it is only necessary to modify the automatic generation script. This saves months of work and human resources!

TOTEM Main Screen (Alice) Live DEMO



Questions