Machine Interlocks in the Injectors

Bruno PUCCIO (TE/MPE) IEFC workshop 22nd March 2011

Menu

Starter

Reminder on Machine Interlocks

Main course

Warm magnets Interlock system

Beam Interlock system

its Linac4 deployment

Desserts

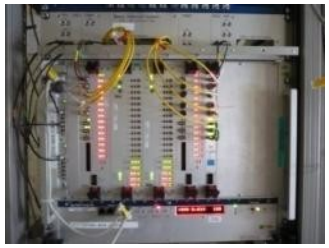
Wrap-up

What are the “Machine Interlocks”?

for protecting the Equipments for Beam Operation

Beam Interlock System

(VME based)



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BIS

WIC

Safe Machine Parameters System

(VME based)

SMP

PIC

FMCM

Fast Magnet Current change Monitor

for protecting Normal Conducting Magnets or Super Conducting Magnets

Warm magnet Interlock Controllers

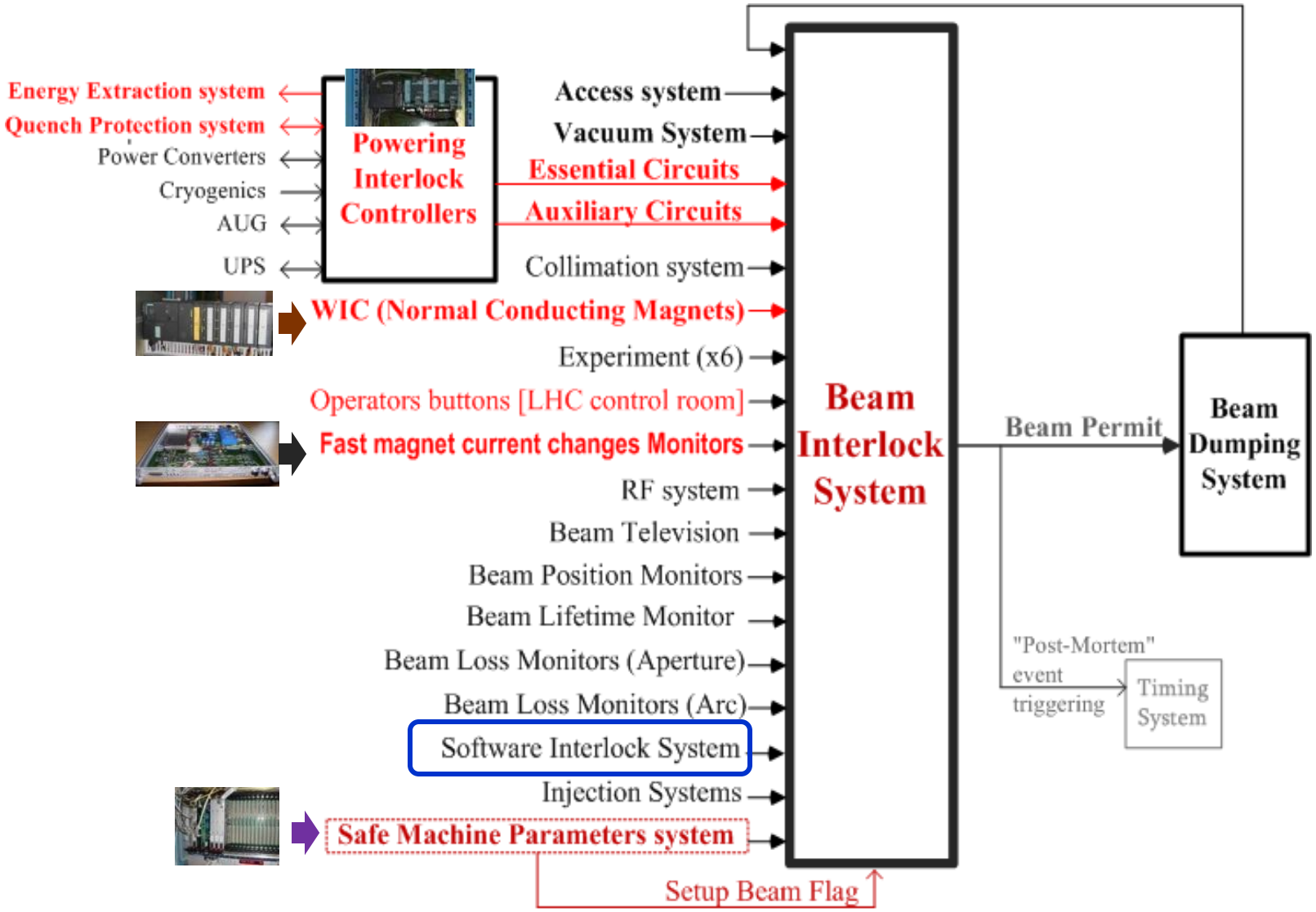
(PLC based)

Powering Interlock Controllers

(PLC based)

+

Machine Interlocks hierarchy (LHC case)



(TE/MPE systems are in red)

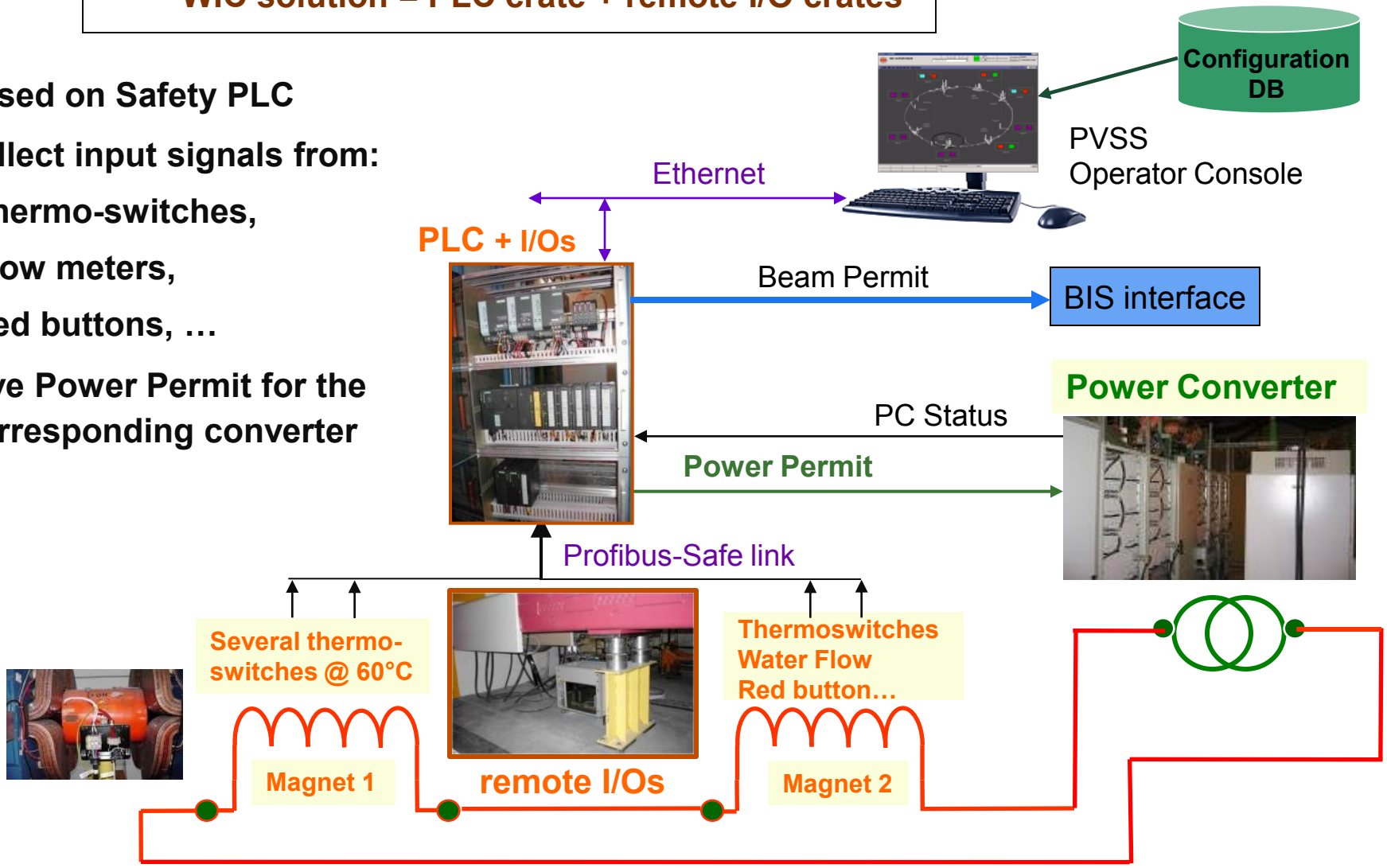
Warm Magnets Interlock (WIC system)

Pierre Dahlen (TE/MPE)

WIC system Overview

WIC solution = PLC crate + remote I/O crates

- based on Safety PLC
- collect input signals from:
  - thermo-switches,
  - flow meters,
  - red buttons, …
- give Power Permit for the corresponding converter



WIC systems currently in Operation

6 machines/zones

14 Controllers & ~ 300 I/O modules

~ 950 magnets are protected

WIC → LHC
(2007)

8 controllers

WIC → TT60 & Ti2
(2005)

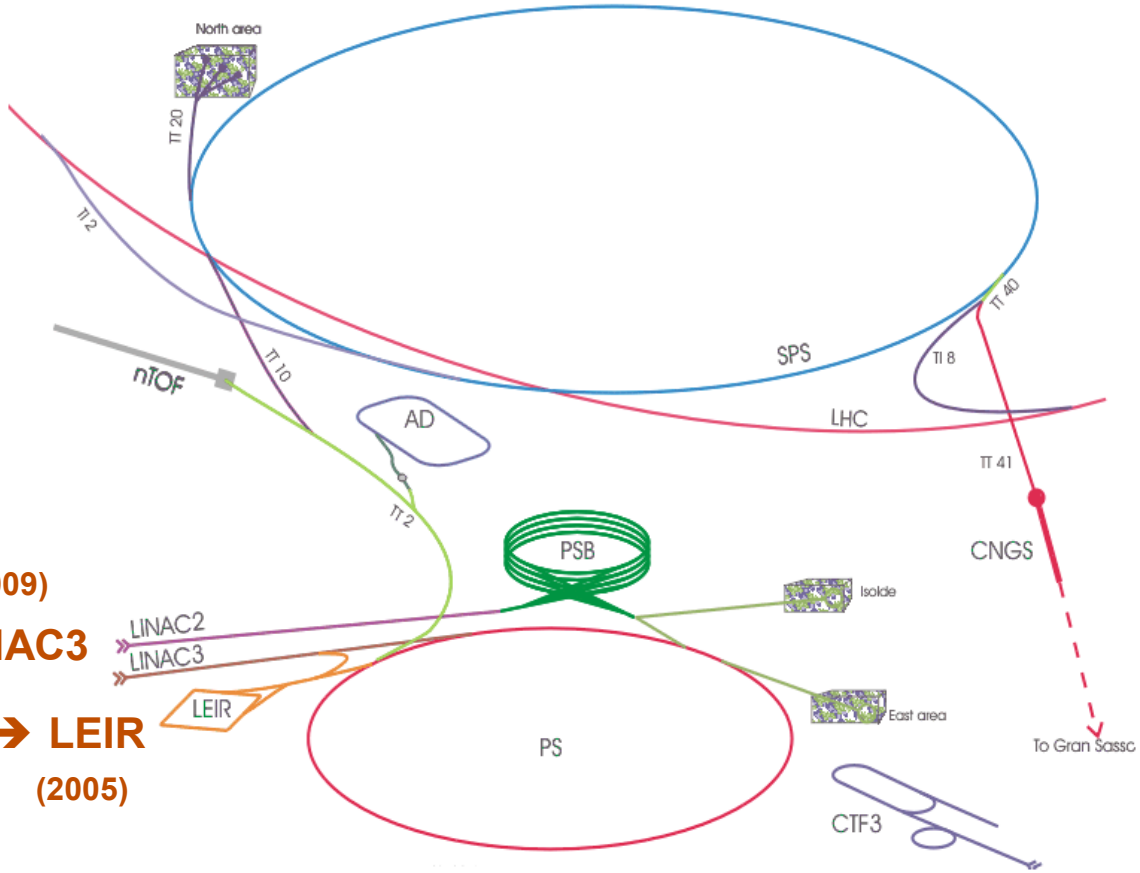
2 c.

(2009)

WIC → LINAC3

WIC → LEIR
(2005)

1 c.



WIC → TT40 & Ti8
(2004)

2 c.

WIC → TT41

1 c.

WIC system: the main features

- **Based of Safety PLC** (Siemens S7-300 F series)
- (on purpose) **Very simple process for PLC software**

Strong support from EN/ICE

- **Sensors/Magnets/Converters partition described in Configuration DB**

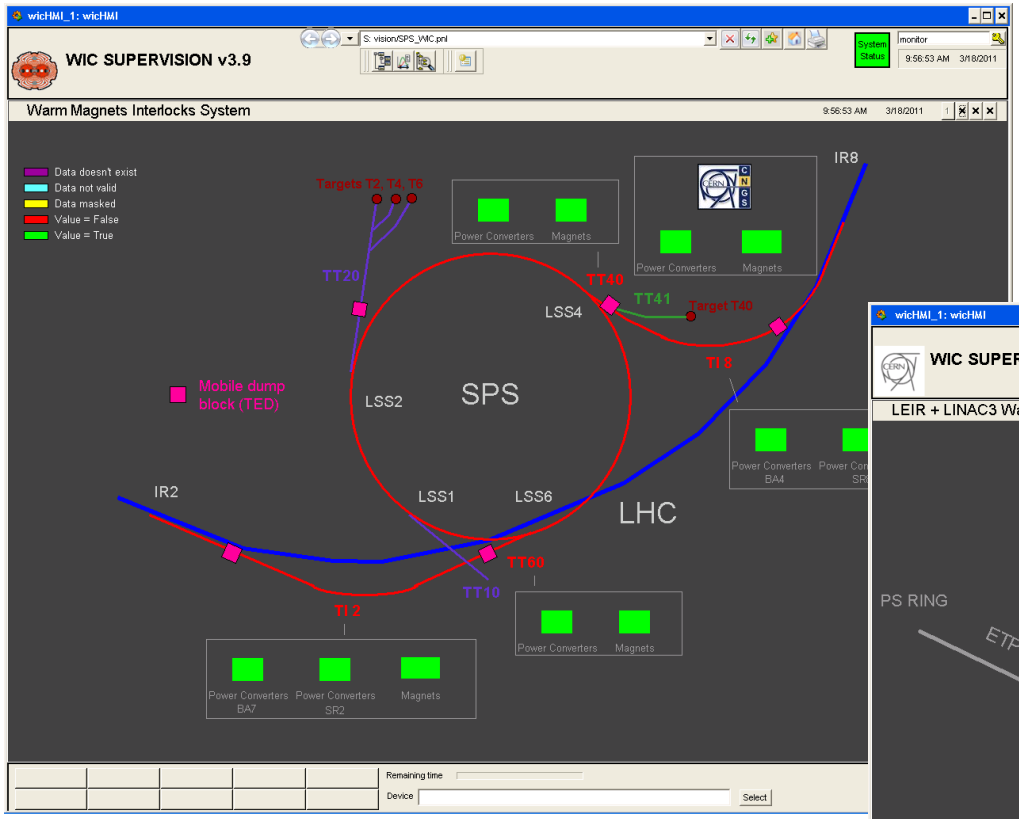
BE/CO

- **Reliable solution**
- **Remote test facility**
- **Generic solution to be deployed on any type/size of machine**
- **Dedicated PVSS application to allow supervision of:**
  - **Magnets & Power Converters Status**
  - **Interlock process (history buffer)**
  - **Communication state (Ethernet & Profibus)**

Developed & maintained by EN/ICE

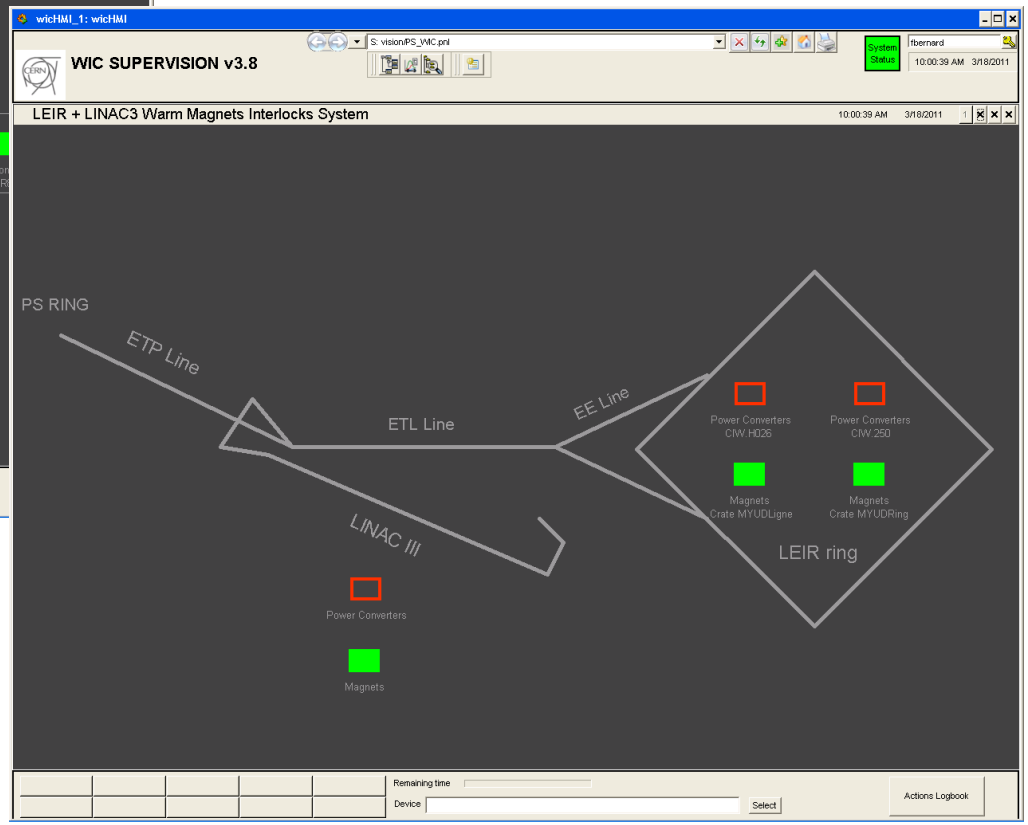
PVSS application: few screen-shots…

SPS Transfer Lines



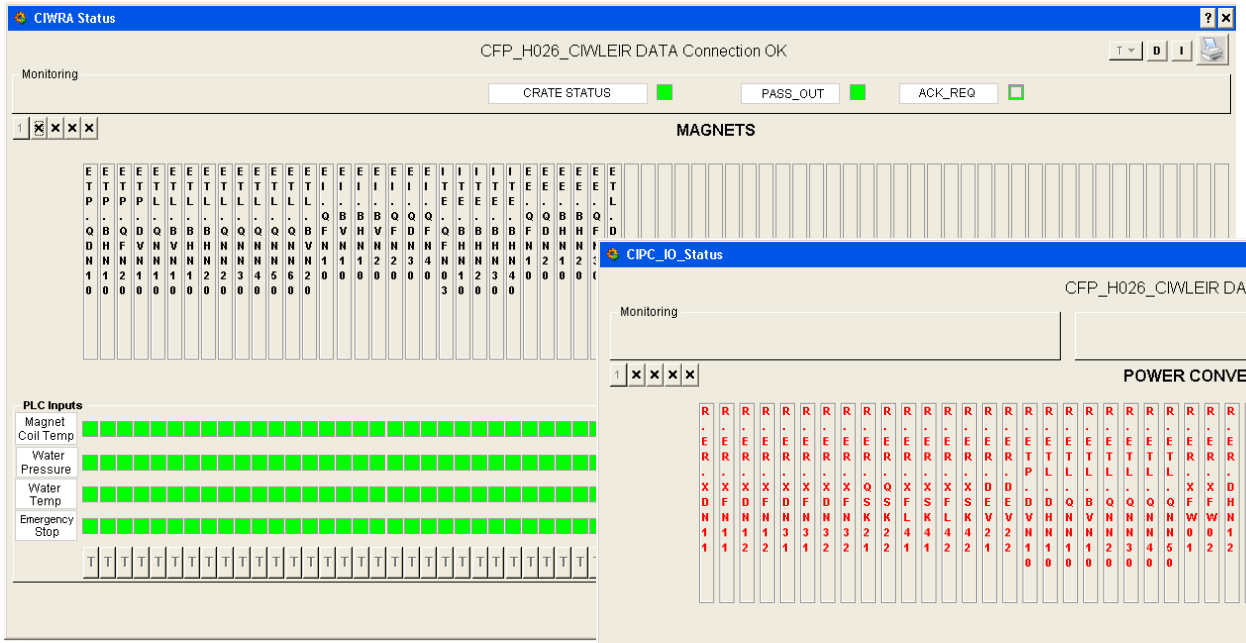
Courtesy of F. Bernard (EN/ICE)

LINAC 3 + LEIR

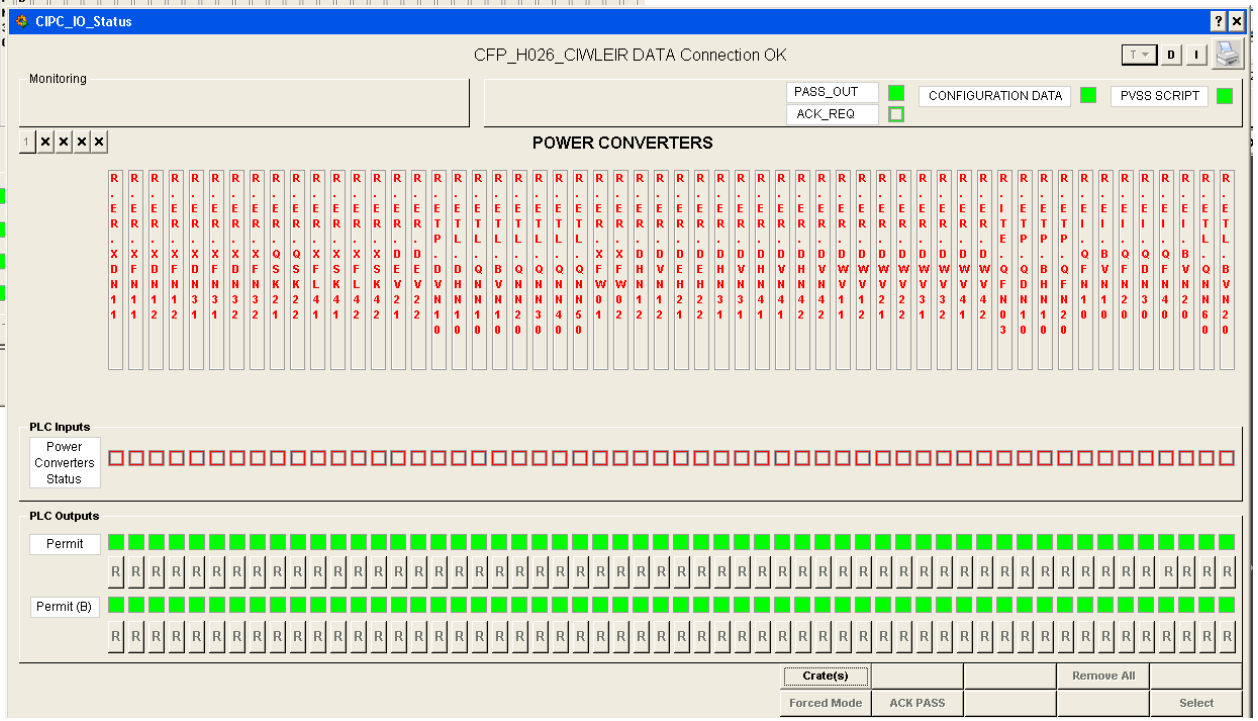


PVSS application: monitoring views…

Magnets status

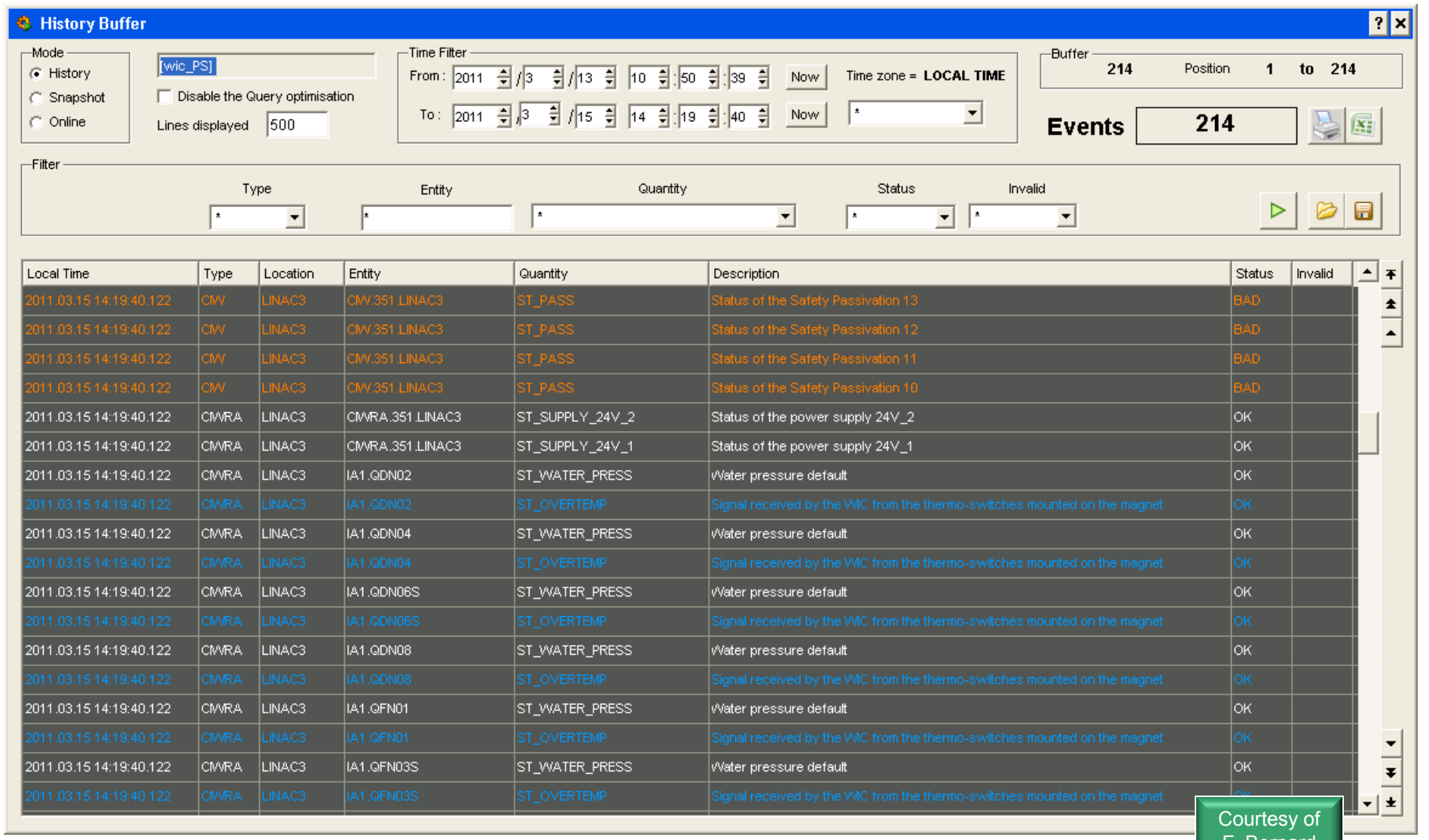


P.C. status



Courtesy of F. Bernard (EN/ICE)

PVSS application: History Buffer



Courtesy of F. Bernard (EN/ICE)

WIC system: future deployments



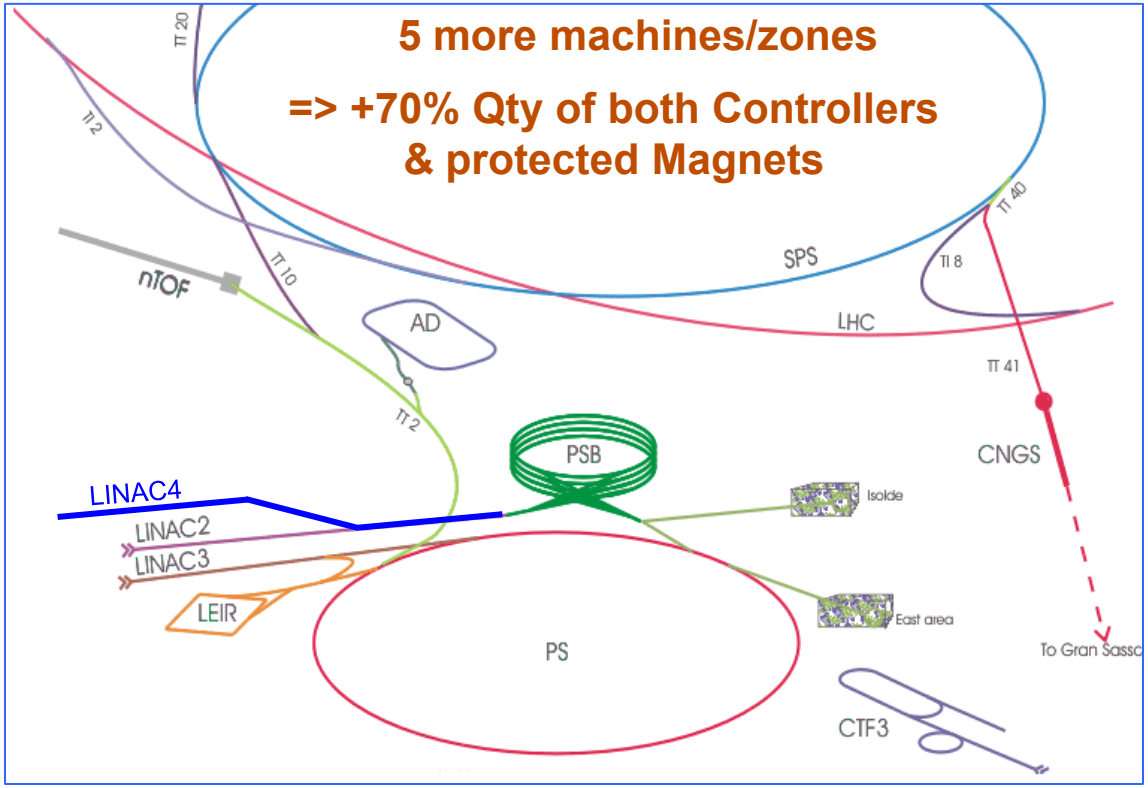
Machine	Number of Protected Magnets	Number of PLC crate	Number of Remote I/O crates	Installation date
HiRadMat	25	2	2	Q1/2011
Booster	172	4	53	during 2011 + Xmas 2011/12
Linac4 & Transfer line	98	2	6	2013

ready for 1st dry run (April 2011)

Isolde	50	1	1	2013
Elena ring	48	1	1	201x

should match corresponding schedules

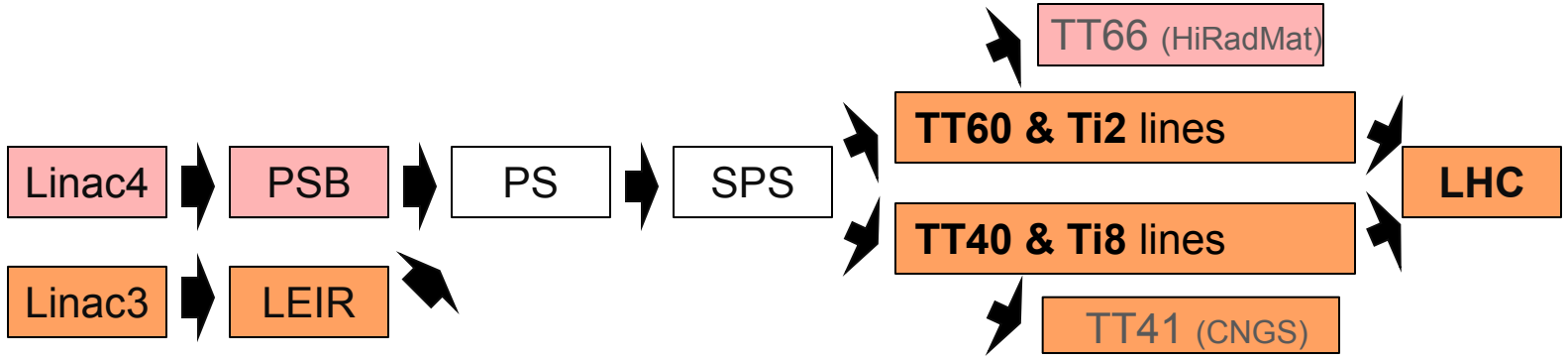
LHC chain status after planned deployments



WIC system

planned deployments

currently in operation



other WIC deployments…?

Machine	Protected Magnets	PLC crate	Remote I/O crates
PS main	~100	1	11
PS Auxiliary	~50	2	1
SPS ring +auxiliaries	~900	9	15

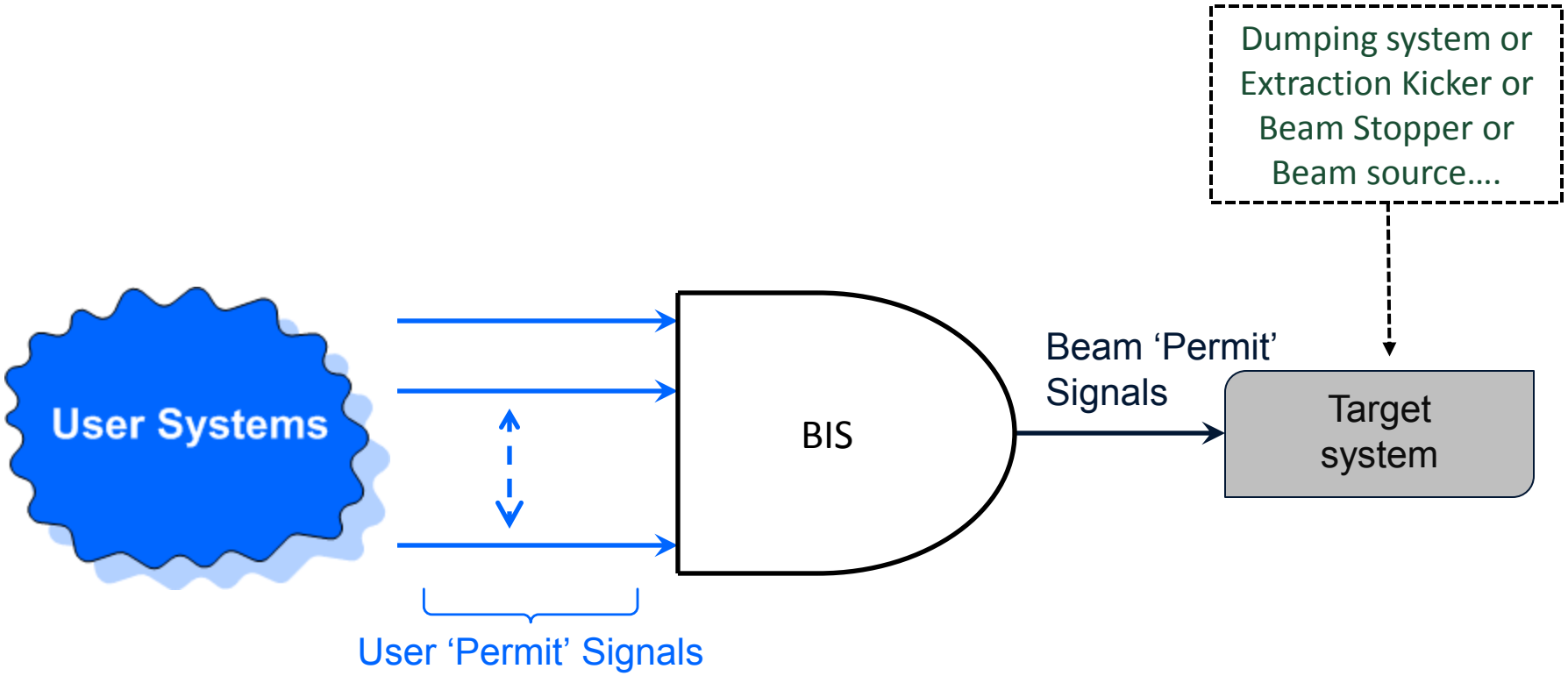
Not decided on (first study only)

(Due to lack of resources) **Not** possible to tackle so large installation….

Beam Interlock System

Benjamin Todd + Christophe Martin (TE/MPE)

Beam Interlock System Function

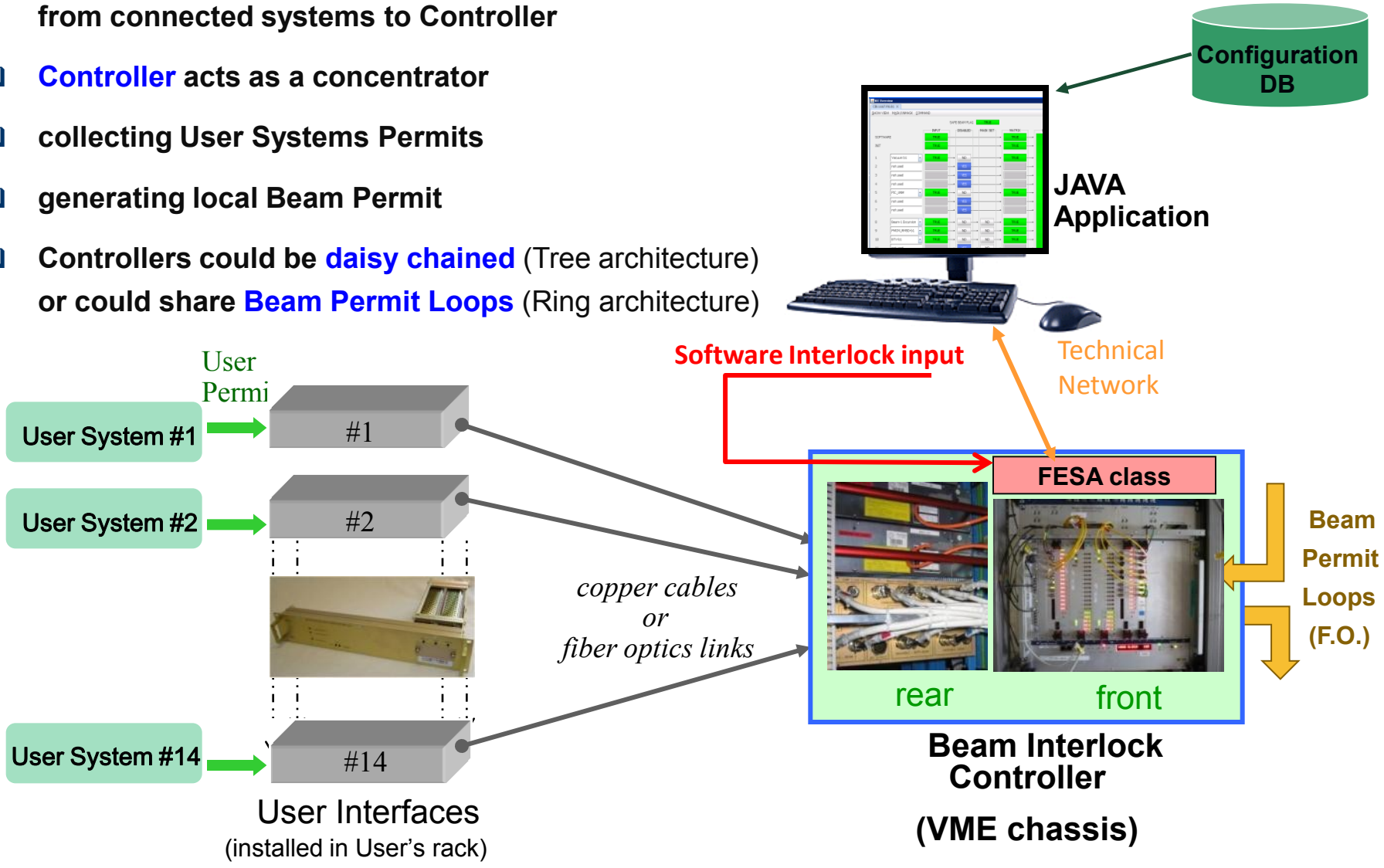


Σ(User Permit = "TRUE") => Beam Operation is allowed

IF one User Permit = "FALSE" => Beam Operation is stopped

BIS: simplified layout

- Remote **User Interfaces** safely transmit Permit signals from connected systems to Controller
- **Controller** acts as a concentrator
- collecting User Systems Permits
- generating local Beam Permit
- Controllers could be **daisy chained** (Tree architecture) or could share **Beam Permit Loops** (Ring architecture)



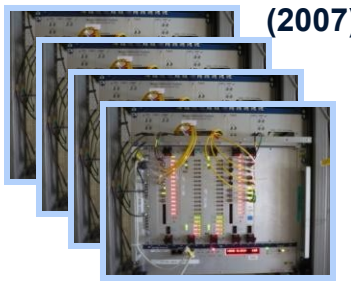
Software Interlock System (SIS)

- Currently used for interlocking: SPS extractions, LHC Injection regions and circulating LHC beams (=> dump)
- Subscriptions to thousands control system devices / parameters.
- Export (among other tasks) signals to the different BIS (update period 2 s)
- Interlock types:
  - *Initially*: used simple test logic comparison of acquired value to reference value (number or Boolean) – hardcoded into configuration.
  - *Now*: more and more complicated interlocks (JAVA) that pull together multiple signals and DB references. Very flexible, but complex interlocks that are less easy to test.
- Very high reliability given the number of signals.
  - The SIS processes of SPS and LHC have never failed during operation in the last 2 years.
  - In case of failure, the timeouts (20 sec.) on the SIS inputs to the BICs lead to beam dump/injection or extraction inhibit.

Courtesy of J. Wenninger

BIS (&SIS) currently in Operation

BIS ➔LHC ring (2007)



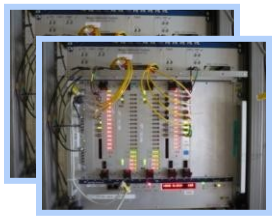
34 controllers

5 machines/zones

25 Controllers

~ 370 connected systems

BIS ➔ LHC Inj.1 region

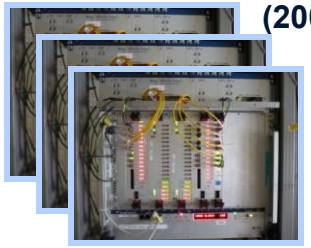


2 c.

BIS ➔ TT60/Ti2

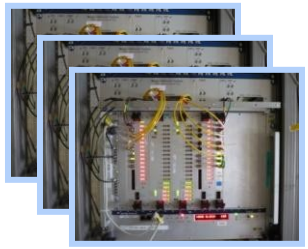
5 c.

BIS ➔SPS ring (2005)



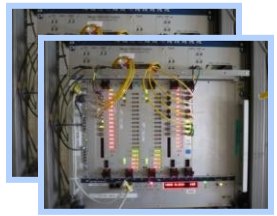
6 c.

BIS ➔ TT40/Ti8/TT41



7 c.

BIS ➔ LHC Inj.2 region

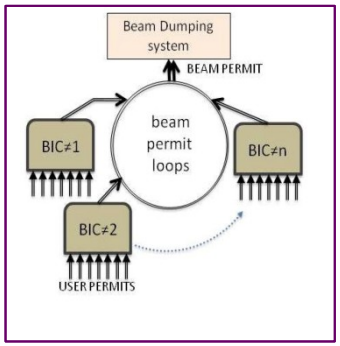


2 c.

BIS: main features

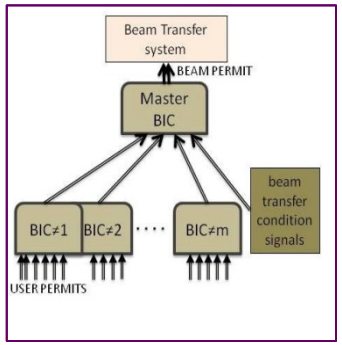
- Fast (~20µS reaction time from *User Permit* change detection to corresponding *Local Beam Permit* change)
- Reliable
  - Fully redundant HW process
  - Fail-Safe concept
- Available (Redundant Power Supplies)
- Maintainable
  - 100% Online Test Coverage
  - History buffer for recording I/O changes
- "Flexible"
  - half of *User Permit* signals could be remotely masked
    Masking conditioned by external signal (Safe_Beam Flag)
- Modular and Scalable
  - **Ring architecture** or **Tree architecture**
  - Daisy chain possible (BIC output connected to input of another BIC)
- Generic solution to any fast and reliable interlock requirement
  - Protect as much as small installation as large machine (27 km ring)
  - Based on BE/CO standard solutions (HW & SW)
- In operation in the SPS since 2005 with an extremely high availability

Manager board

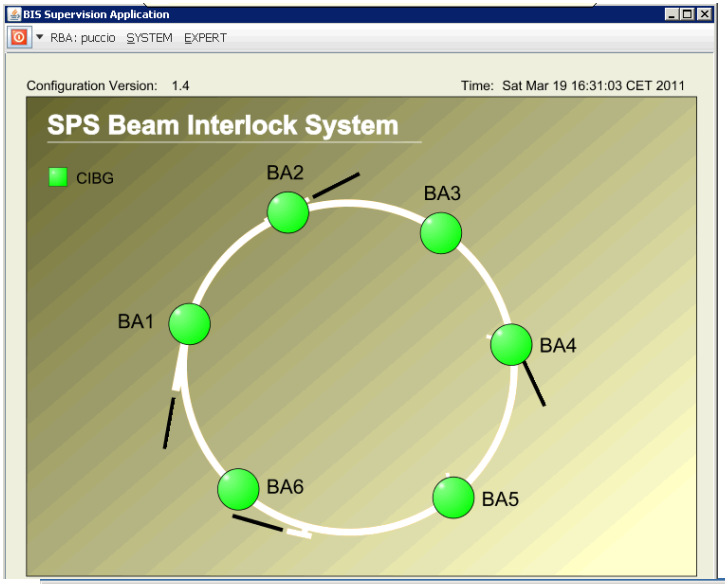


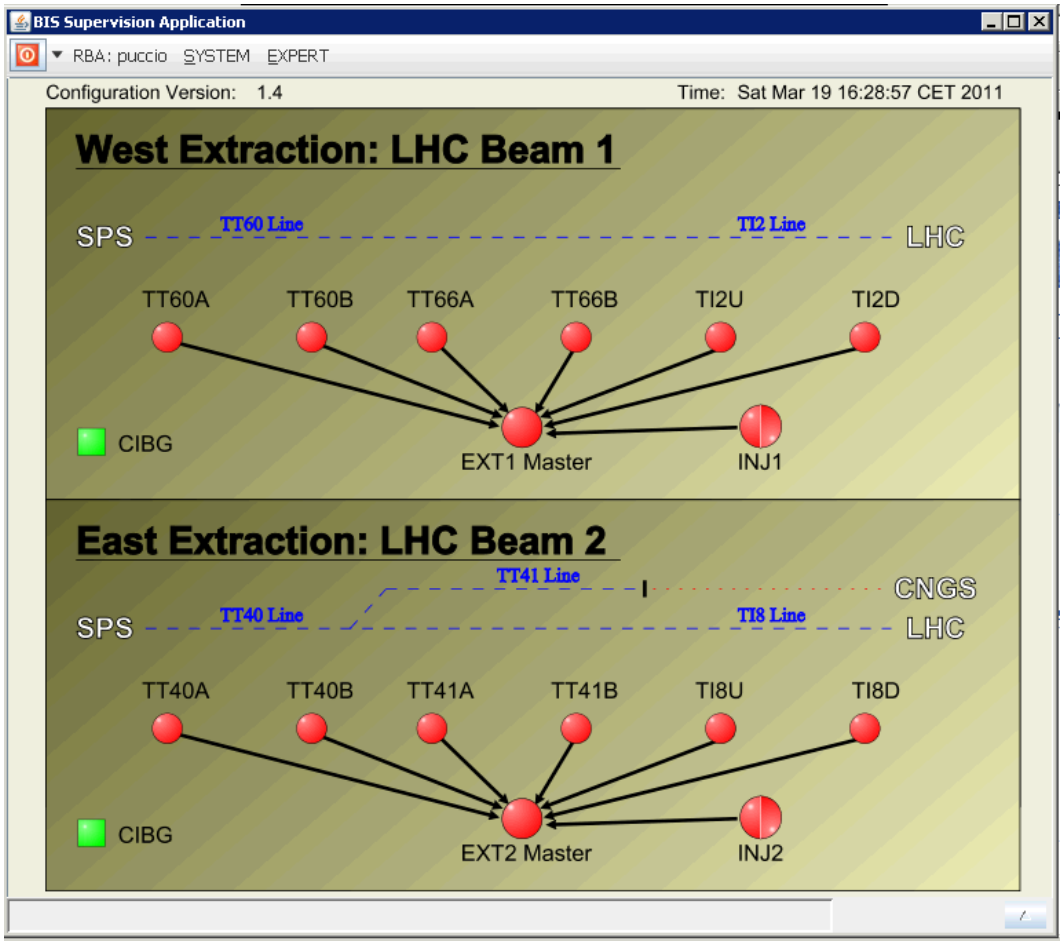
Ring Architecture

Tree Architecture

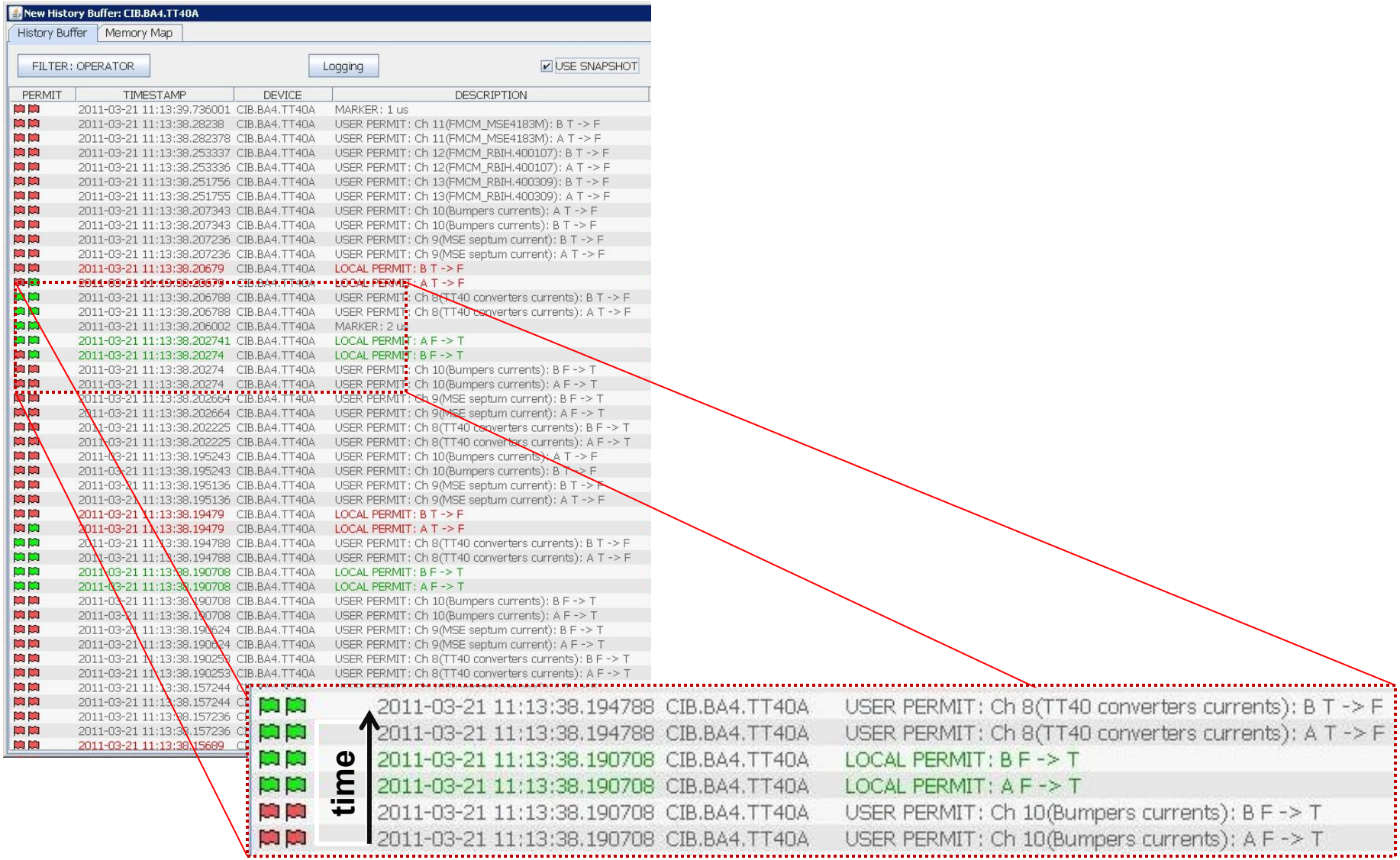


BIS Application for CCC

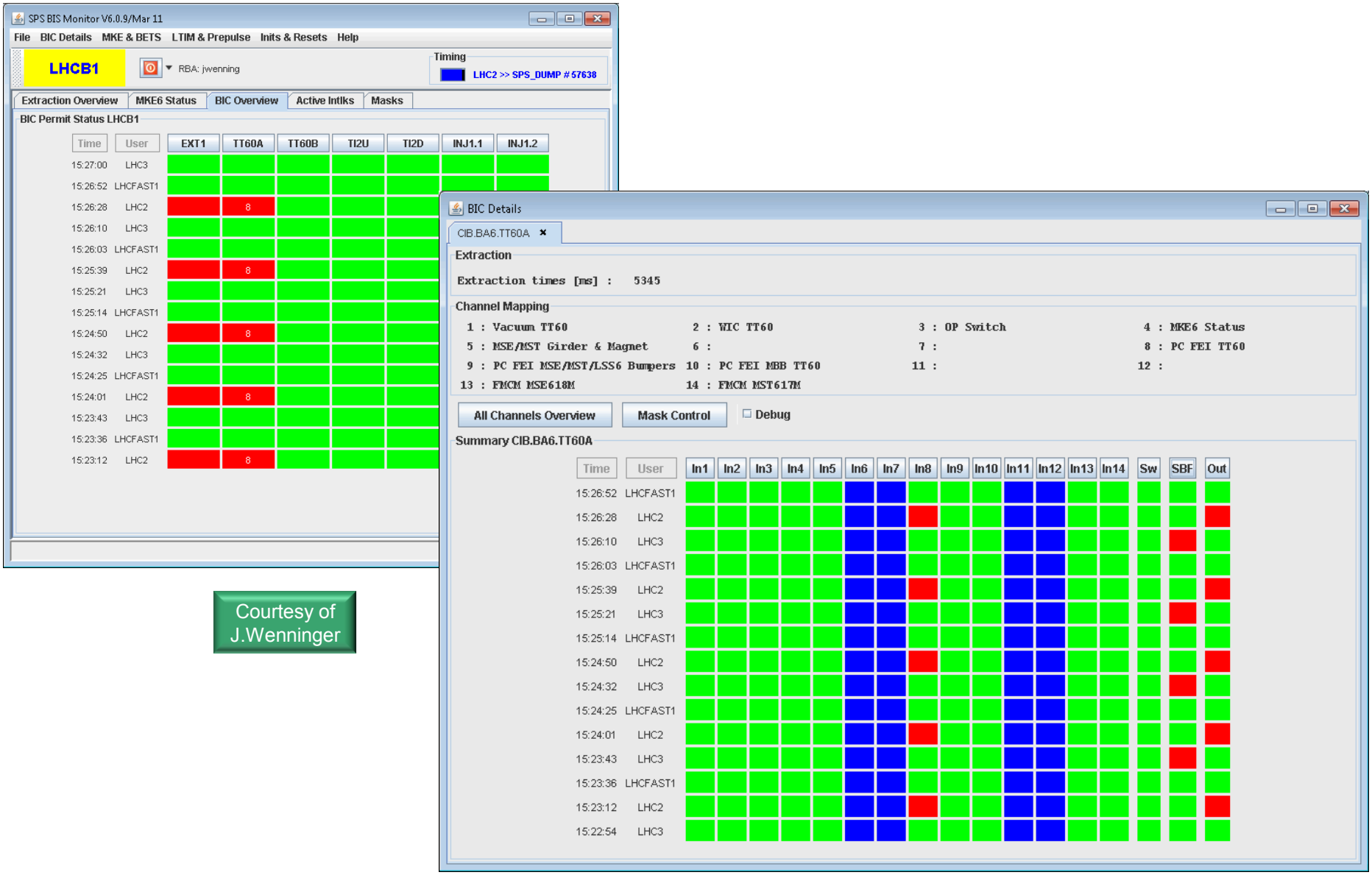




BIS Application: History Buffer

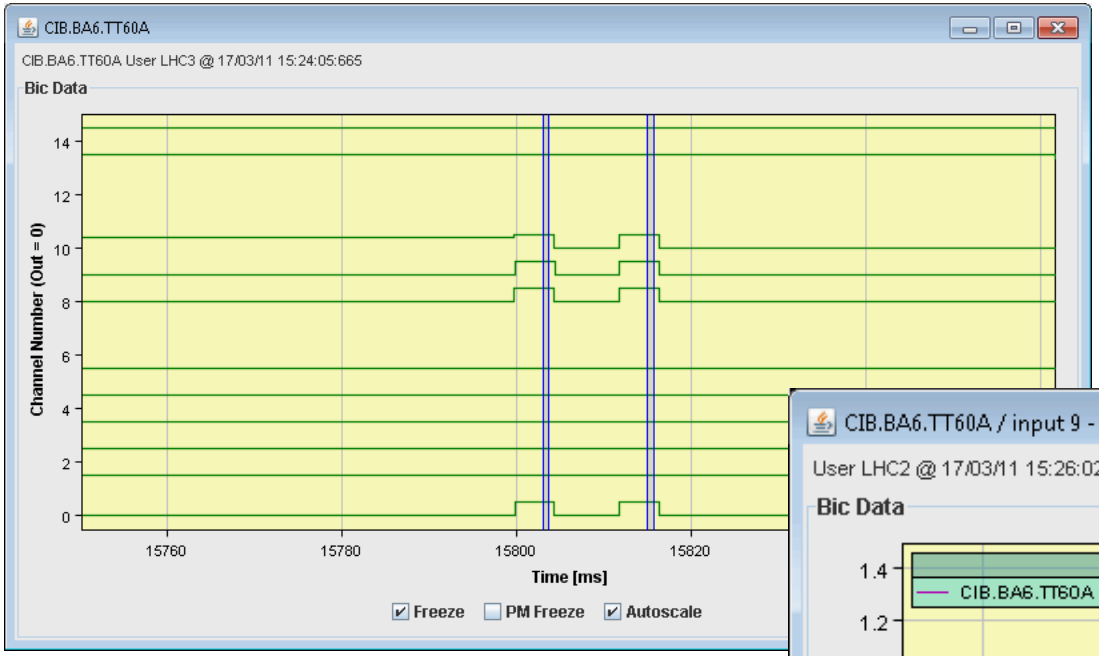


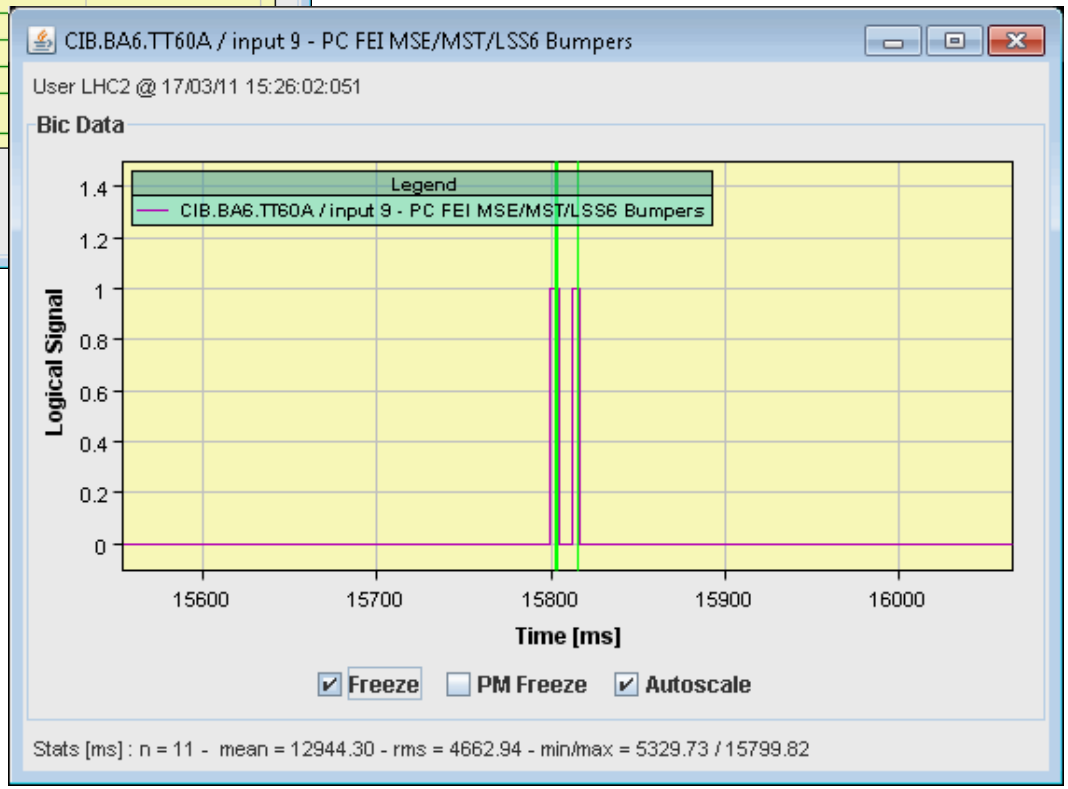
BIS Application: Extraction cycles view



Courtesy of J.Wenninger

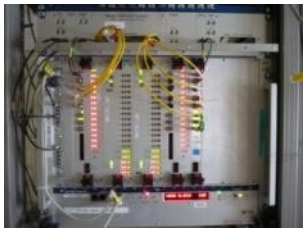
BIS Application: Timing Diagram





Courtesy of J.Wenninger

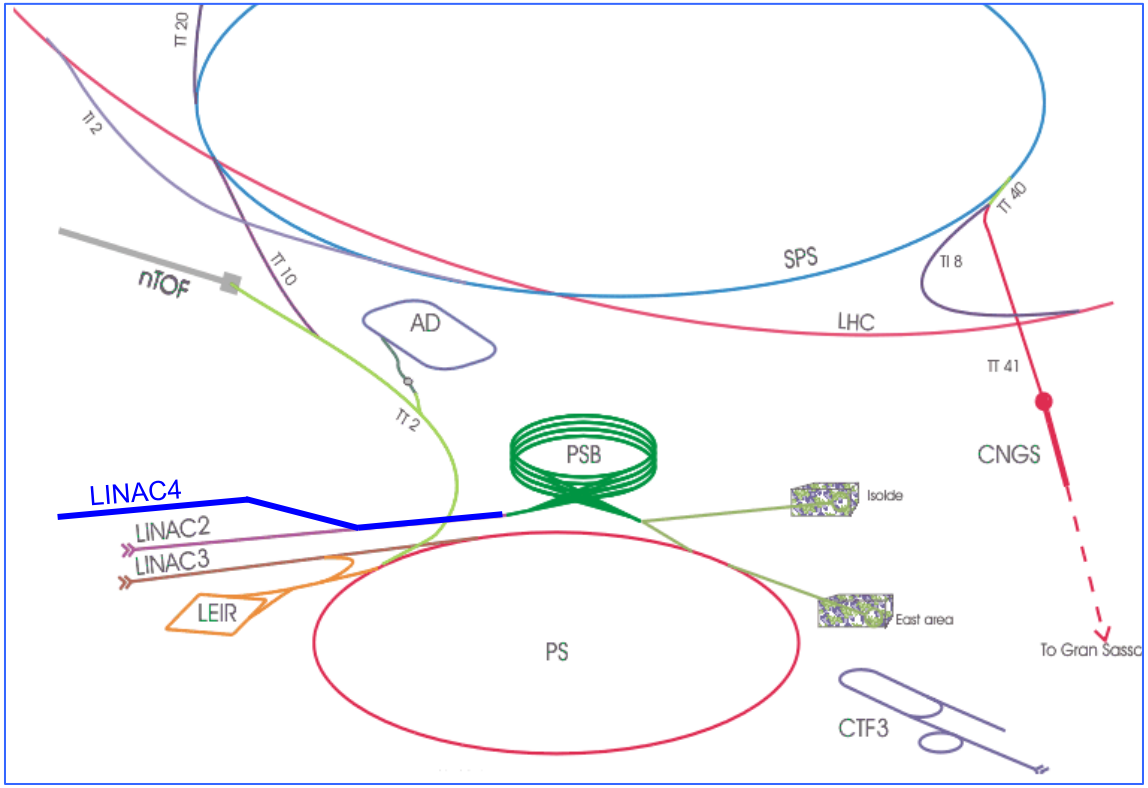
BIS: Future deployments



Machine	Number of		Installation date
	User Interface	Controller	
HiRadMat	10	1	Q1/2011
3 MeV Test Stand	7	1	Mid 2011
Linac4 & Transfer line	23	3	2013
Booster ring & ejection	24	2	2013

ready for 1st dry run (April 2011)

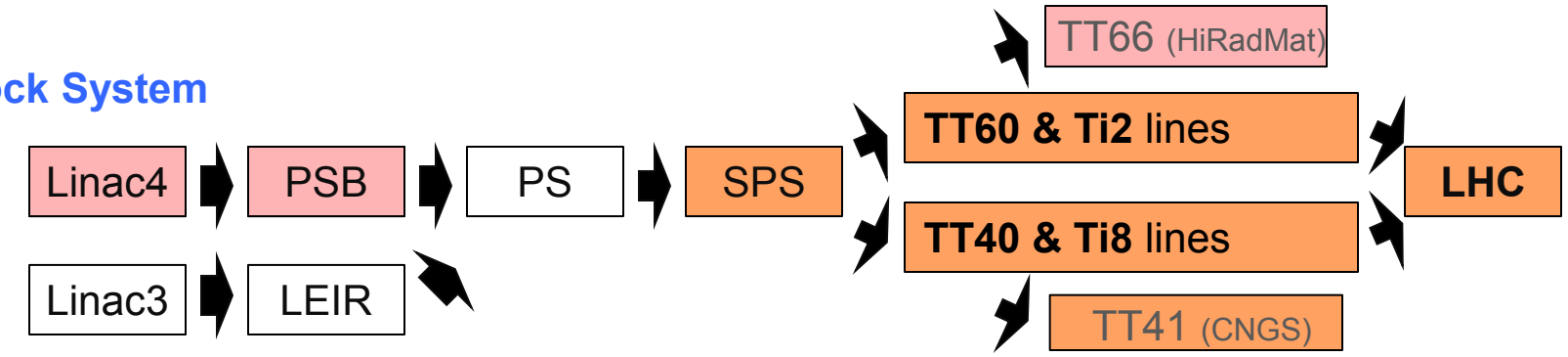
LHC chain status after planned deployments



Beam Interlock System

planned deployments

currently in operation



Beam Interlock System
for LINAC4 and PSB

BIS Engineering Specifications

CERN
CH-1211 Geneva 23
Switzerland

the Linac4 project

LINAC4 Project Document No.
L4-CIB-ES-0001 rev.0.3
CERN Div./Group or Supplier/Contractor Document No.
BE/OP
EDMS Document No.
1016233

Date: 2011-01-18

Engineering Specification

BEAM INTERLOCK SPECIFICATIONS FOR LINAC4, TRANSFER LINES AND PS BOOSTER WITH LINAC4

Abstract

The beam interlock system for Linac4 and its transfer lines to the PSB will be based on a mixed system comprising hardware interlocks provided via the BIS (Beam Interlock System), software interlocks based on the SIS (Software Interlock System) and the concept of External Conditions used currently in the PS complex. This document summarises the beam interlock specifications to safely operate Linac4, the Linac4-to-PSB transfer lines and the PSB with Linac4 injection.

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Distribution list: S. Myers, F. Bordry, R. Saban, P. Collier, R. Garoby, J. Wenninger, R. Schmidt

Linac4, Transfer Lines and Booster

CERN
CH-1211 Geneva 23
Switzerland

the Linac4 project

LINAC4 Project Document No.
L4-CIB-ES-0002 rev.0.2
CERN Div./Group or Supplier/Contractor Document No.
BE/ABP
EDMS Document No.
1106405

Date: 2011-02-08

Engineering Specification
ref. WP 2.14

BEAM INTERLOCKS SPECIFICATIONS FOR THE 3 MEV TEST STAND OPERATION

Abstract

Prepared by :	*Checked by :*	*Approved by:*
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Distribution list: S. Myers, P. Collier, F. Bordry, R. Saban, R. Garoby

3Mev Test Stand

BIS for LINAC4 & PSB: Design Principle (1)

Courtesy of B.Mikulec

- Main constraints:
  - Multiple 'interlock zones' due to several destinations
    - for Linac4: L4DUMP, LBE, LBS, PSB
    - for Booster: BDUMP, ISOGPS, ISOHRS, PS
  - PSB is (timing) master of Linac4
    - Maximize proton delivery to the experiments via '**External Conditions**'; the user (+beam destination) is calculated for the current cycle depending on some necessary conditions;
    - This analysis takes up to 3 basic periods and yields the decision if the 'normal' or 'spare' (or none) cycle should be executed
    - Beam stoppers and bending magnet rise-time too slow
- Must consider PSB and Linac4 interlock systems in parallel

  (also due to new PSB injection with Linac4)

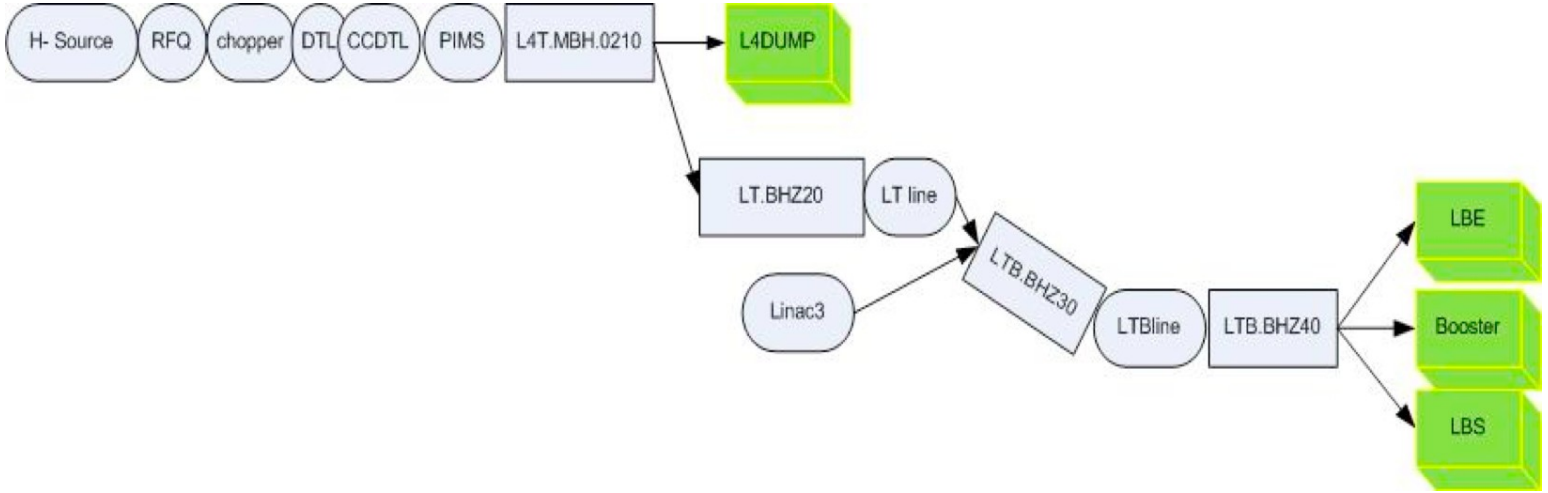
BIS for LINAC4 & PSB: Design Principle (2)

Courtesy of B.Mikulec

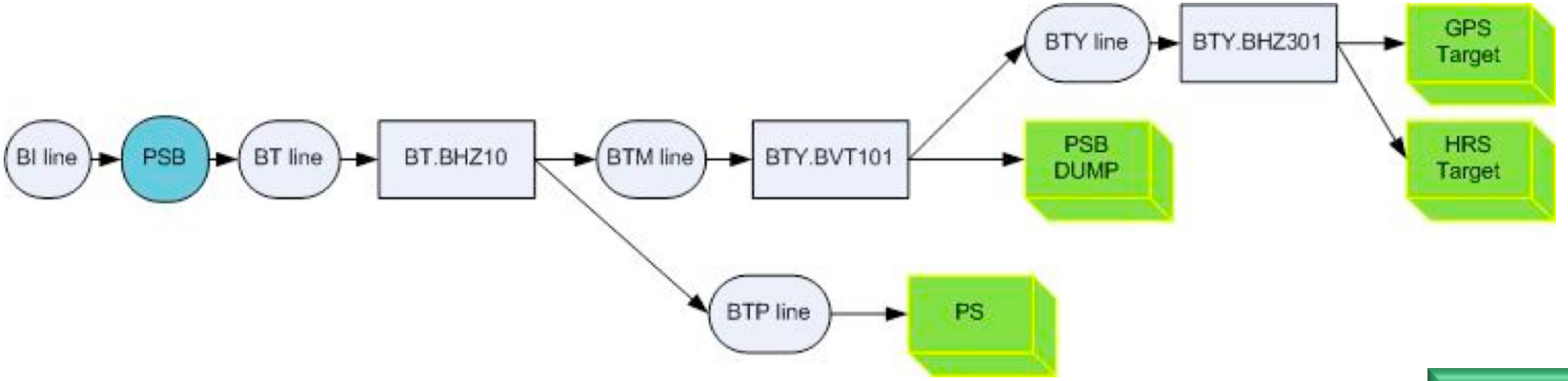
- Three actors:
  1. Hardware interlock system (BIS): reliable, fast
     - For fast reaction times
     - If considered useful to avoid machine activation
  2. Software interlock system (SIS): flexible
     - For slow-changing parameters
     - If some more complex logic needs to be adopted
  3. External conditions (EC): for proton optimization
     - Consider user requests
     - Method also useful for ring-specific interlocks

Interlock Zones

- Linac4 interlock zones

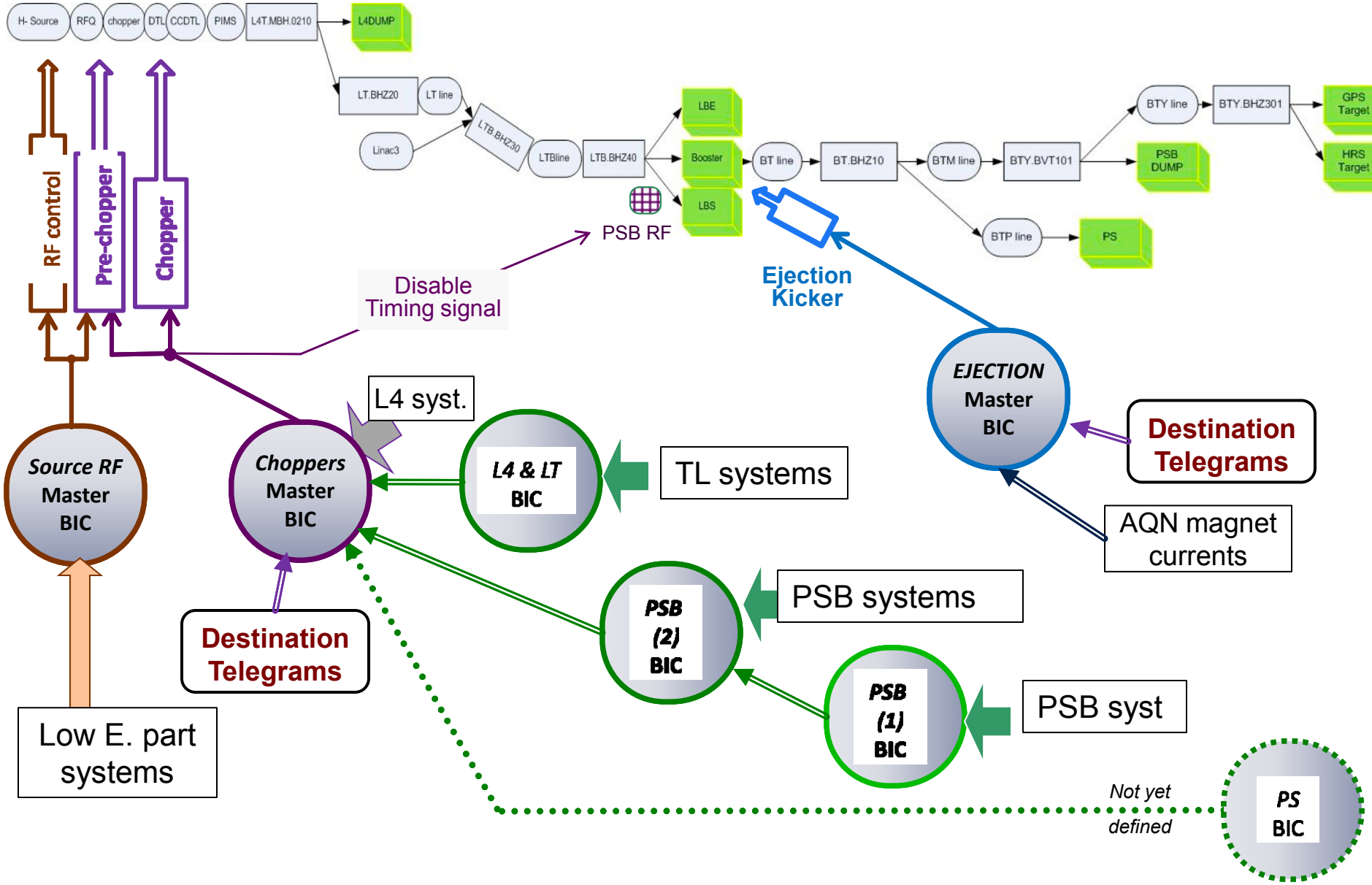


- PSB interlock zones



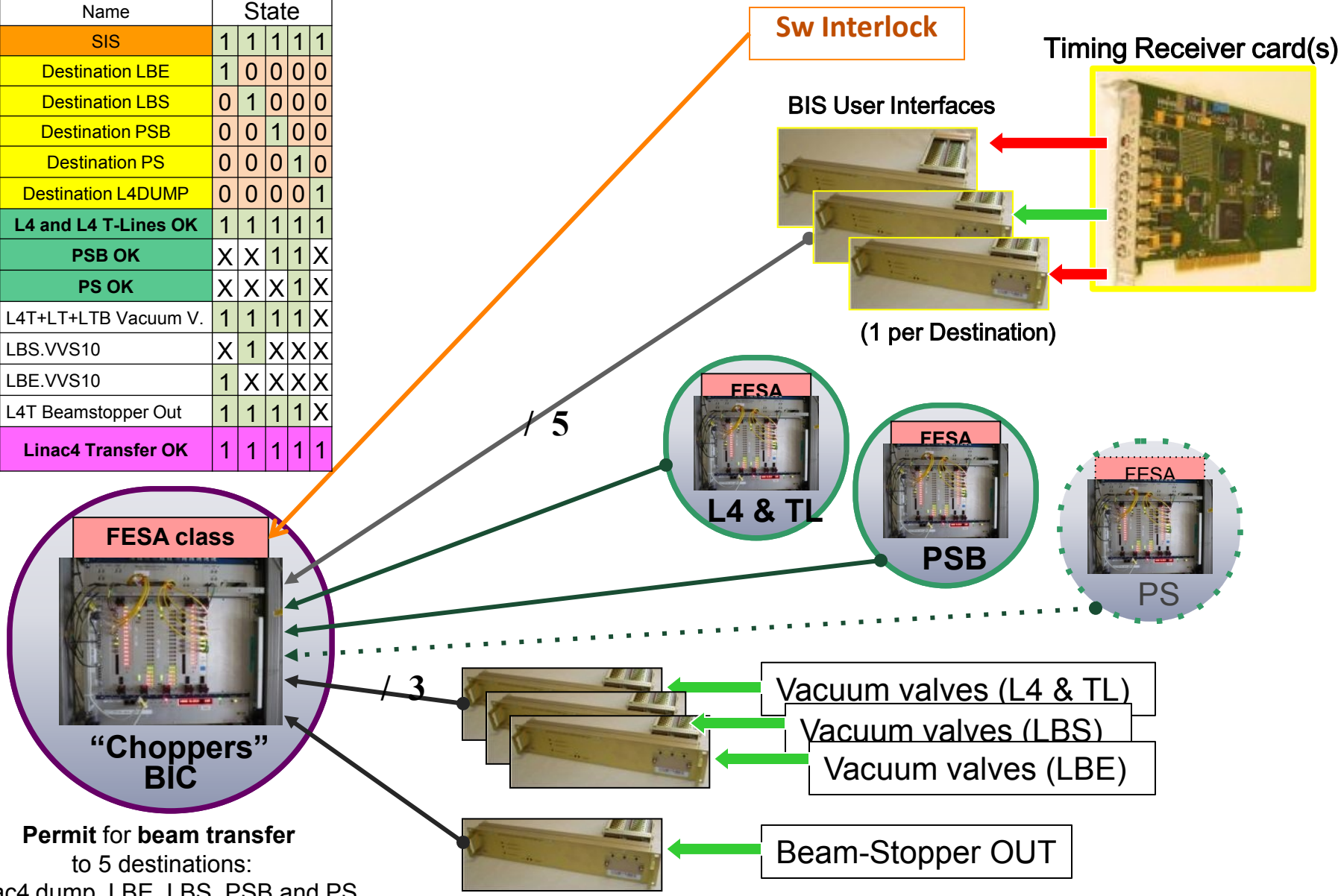
Courtesy of B.Mikulec

BIS Linac4 & PSB layout



Truth table example: “Choppers” BIC

In	Name	State				
1	SIS	1	1	1	1	1
2	Destination LBE	1	0	0	0	0
3	Destination LBS	0	1	0	0	0
4	Destination PSB	0	0	1	0	0
5	Destination PS	0	0	0	1	0
6	Destination L4DUMP	0	0	0	0	1
7	**L4 and L4 T-Lines OK**	1	1	1	1	1
8	**PSB OK**	X	X	1	1	X
9	**PS OK**	X	X	X	1	X
10	L4T+LT+LTB Vacuum V.	1	1	1	1	X
11	LBS.VVS10	X	1	X	X	X
12	LBE.VVS10	1	X	X	X	X
13	L4T Beamstopper Out	1	1	1	1	X
Output	**Linac4 Transfer OK**	1	1	1	1	1



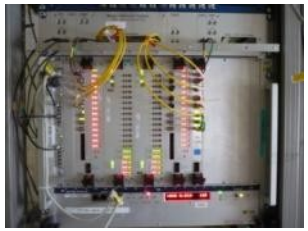
Permit for **beam transfer**
to 5 destinations:
Linac4 dump, LBE, LBS, PSB and PS

Wrap-up (WIC)

- WIC = improved system
- Generic solution to protect resistive magnets
- Rely on partnership with EN-ICE group
- After the long shutdown:
  - WIC system will be present in two ends of the LHC injectors chain
  - => Not deployed in PS & SPS
- Resources issue
  - Minimal level of staffing for coming deployments (and subsequently the Maintenance)
  - Not possible to tackle large installations in the near future

Wrap-up (BIS)

- Fast & reliable
- Modular & scalable


+


- BIS (&SIS) = CERN Generic solution
- For Linac4 & PSB: Timing provides more flexibility
- Maximize efficiency for Beam Operation
- After the long shutdown:
  - BIS installed in two ends of the LHC protons chain
  - No decision has been made for deployment to PS
- (f.t.b.) There are no plans to deploy BIS elsewhere…

Fin

Thank you for your attention