Accelerator Controls
Part2: CERN central timing system

CAS 2009@Divonne

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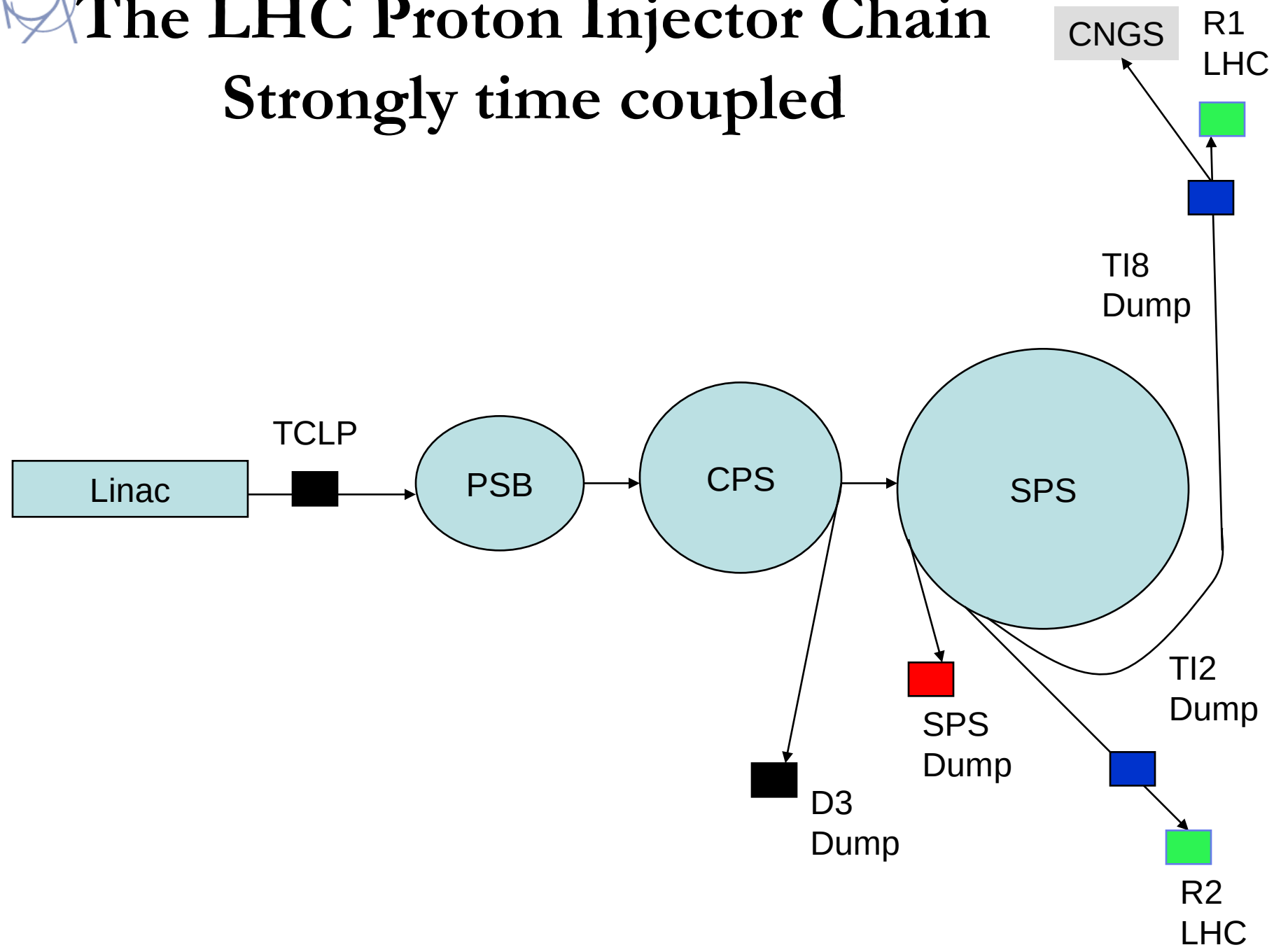
Outline Part 2

- Requested Functionality of the CERN timing system
- Implementation:
  Hardware Details
  Software Details:
  - definition of terms
  - applications
  - tools
- Summary

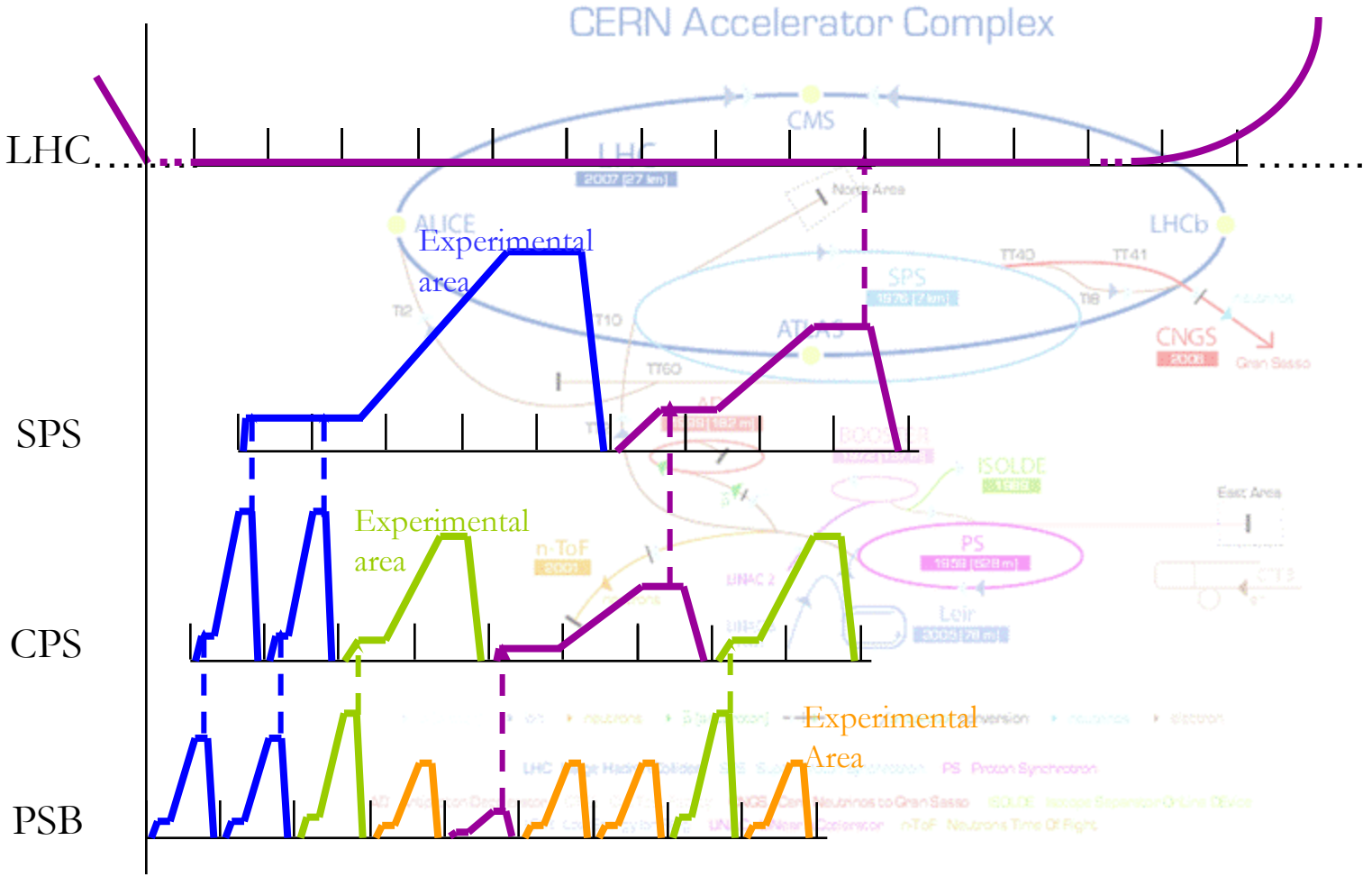
Demanded Functionality of the Timing System

- In general: Stimulate the creation of any particle beam type and assure the proper sequence of transport and acceleration througout the chain.
- In each machine or transport line:
  Sequence or synchronize the time development of every equipment down to the level of the micro-s.
- Provide absolute time information and time stamping of data down to the level of ns.
- Function as a unidirectional broadcast system for machine flags or safety information.

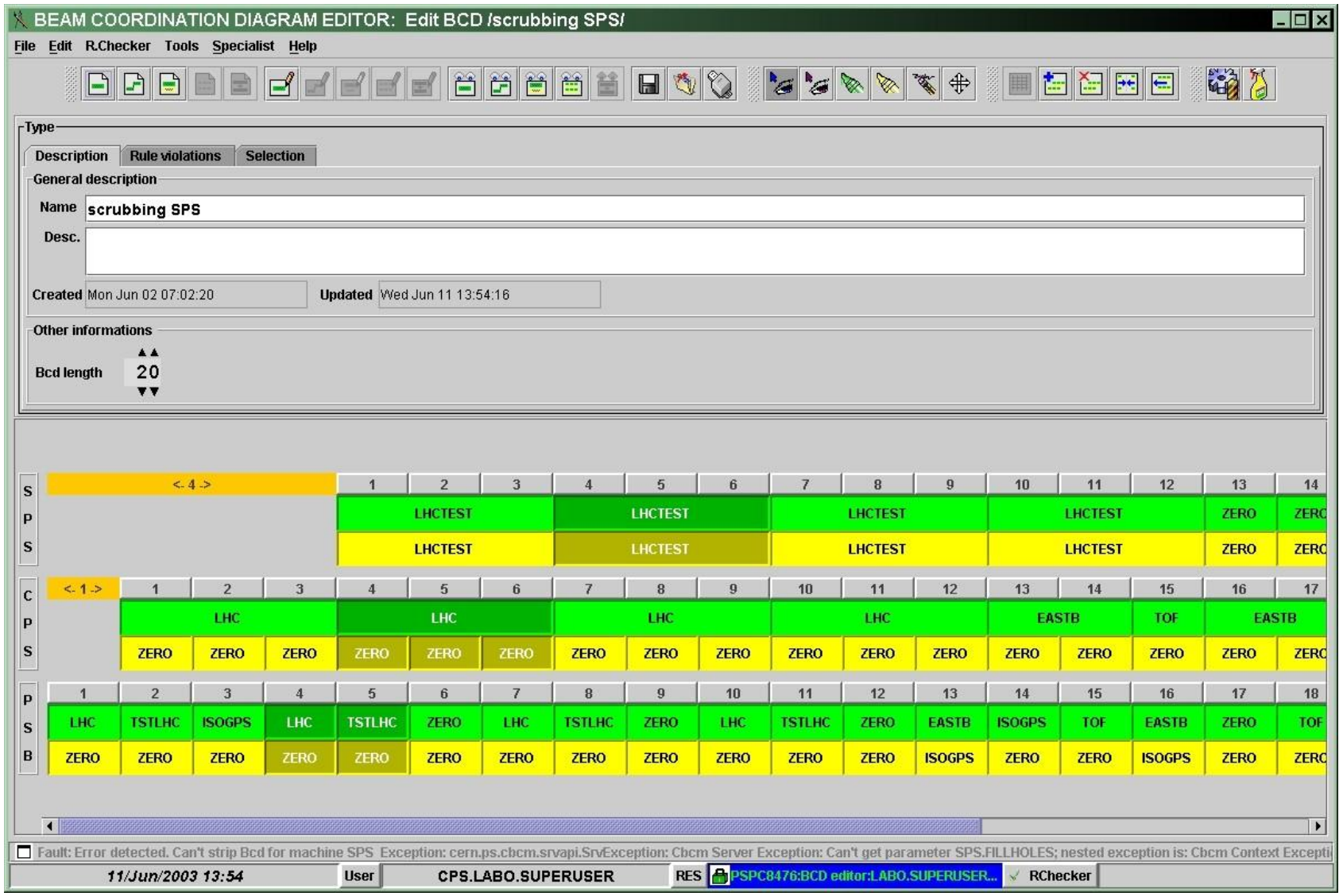
The LHC Proton Injector Chain
Strongly time coupled



CERN accelerator network sequenced by central timing generator

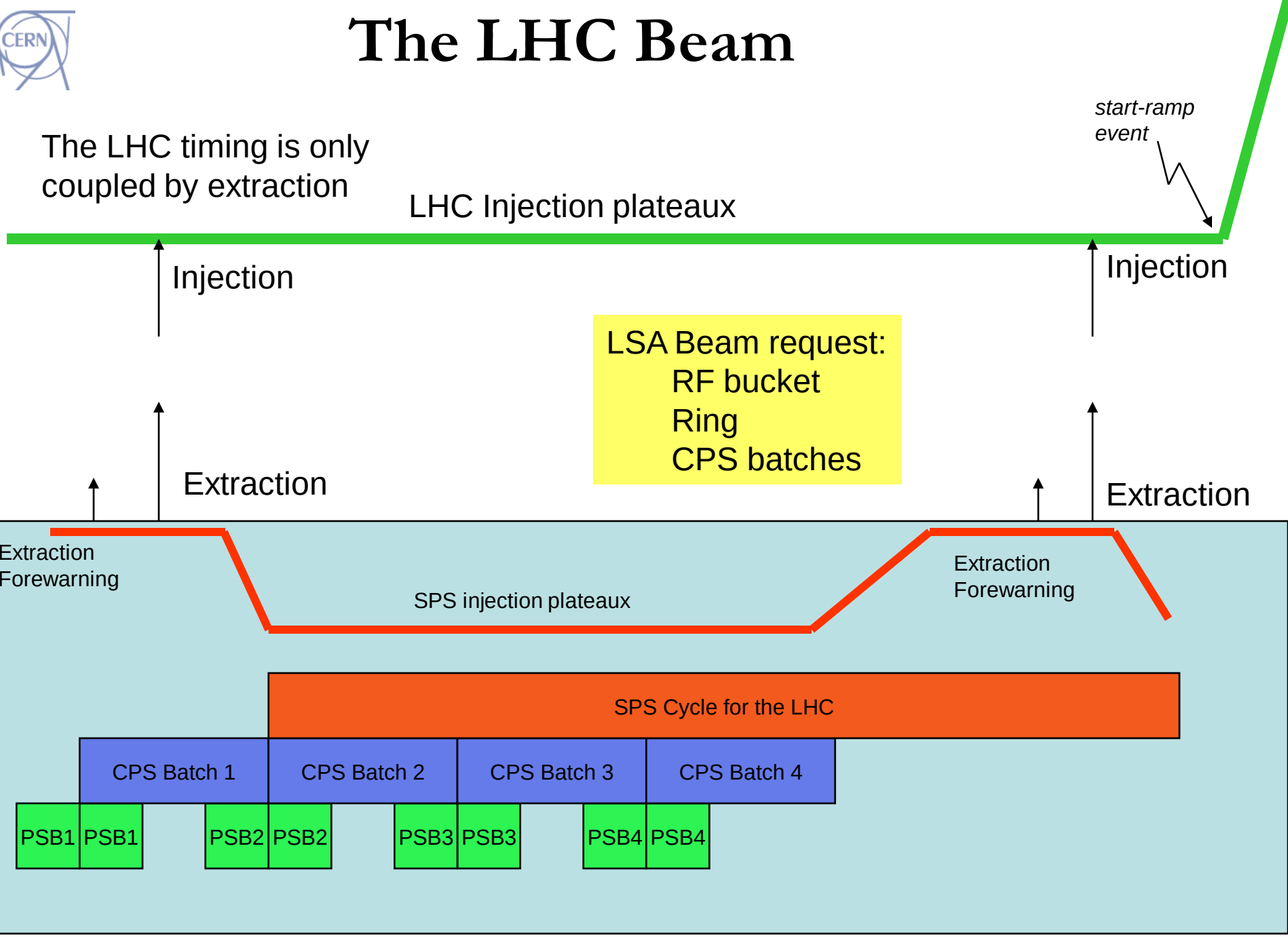


CBCM Sequence Manager



The LHC Beam

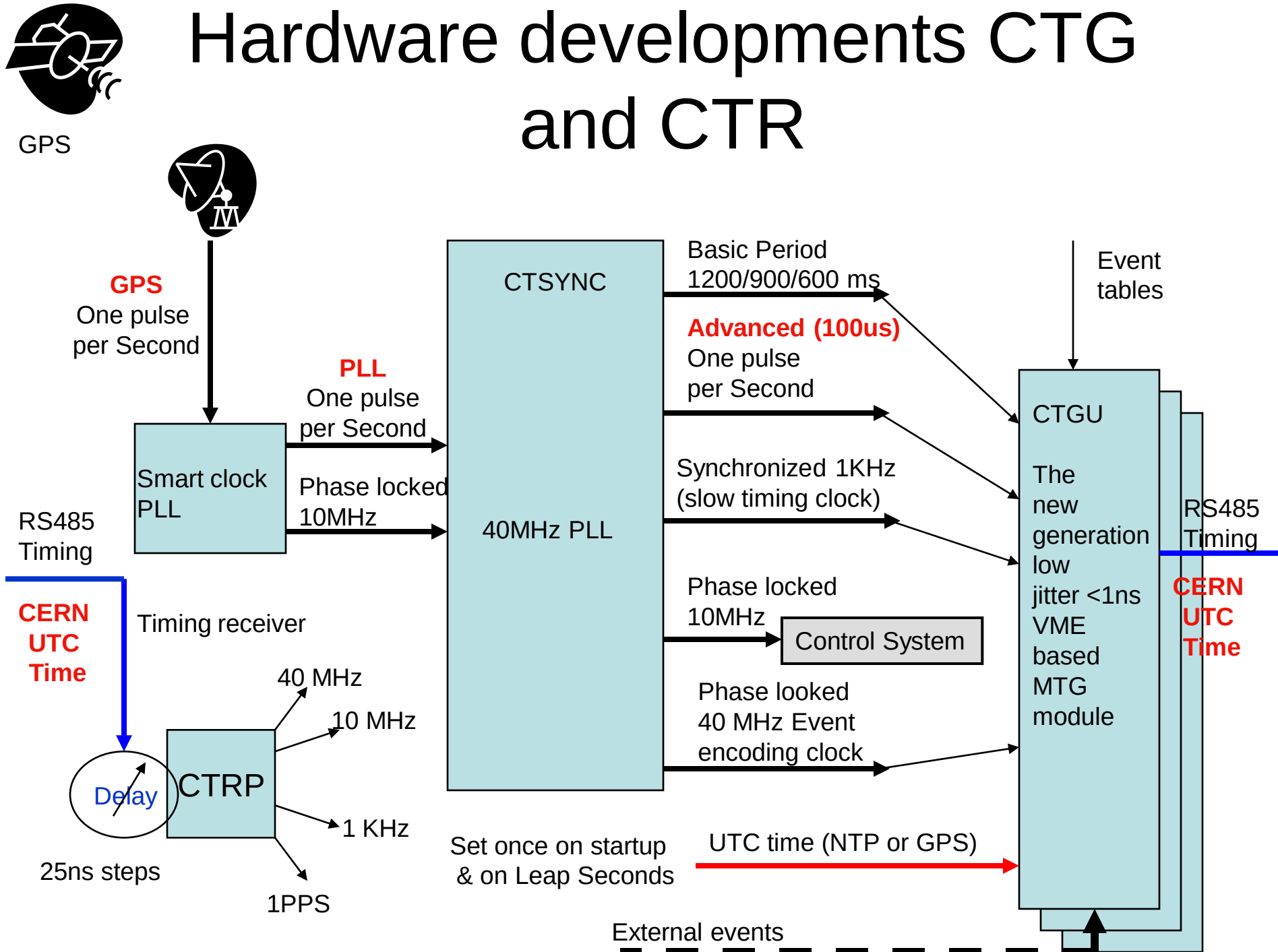
The LHC timing is only coupled by extraction



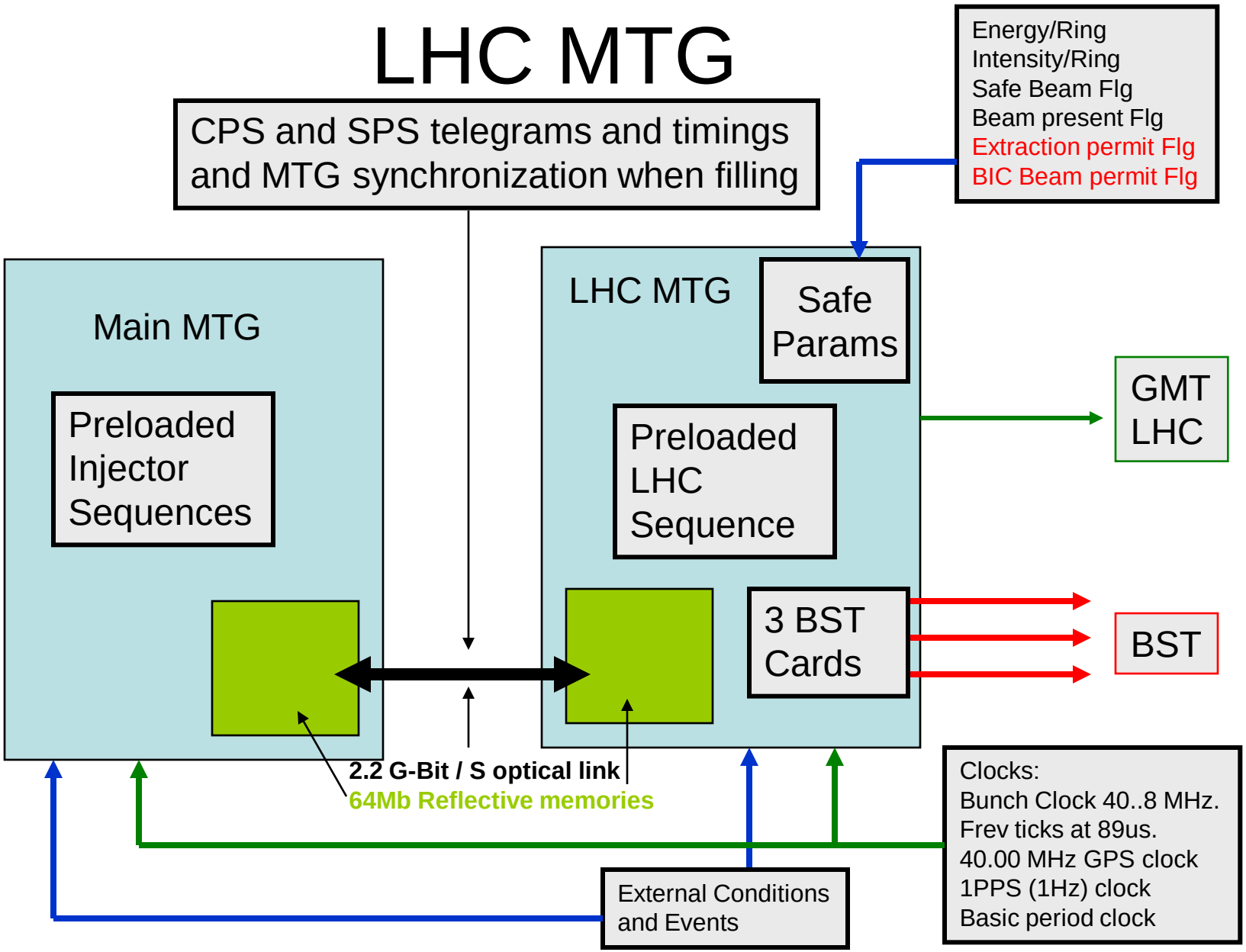
Hardware Implementation of CBCM

- At a single central place (CCR-Prevessin) we have the master timing generator (CBCM = central beam cycle manager), which generates the clock-beat and all relevant sequence information.
  There is a hot spare system running all the time.
- Through reflective memory the generated information is shared with the individual timing generator chassis for each machine.
- From these machine timing g
  cable/fibre optics links at a 1

Hardware developments CTG and CTR

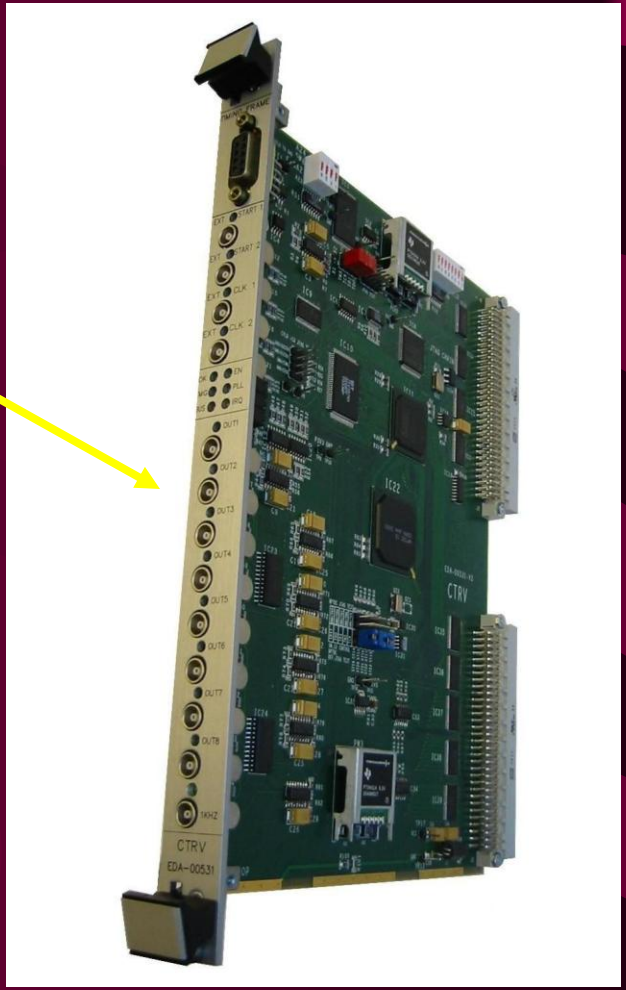


Hardware II
LHC MTG



Hardware Implementation

- …and at the other end of the timing cable:
- Receiver modules in different form factors; here shown in VME
  - reception of timing information
  - programmed reaction to specific timing events
  - reconstitution of clock references
  - programmable hardware outputs for integration into system
  - programmable software interrupts for system host



Outline Part 2

- Requested Functionality of the CERN timing system
- Implementation:
  Hardware Details
  Software Details:
  - definition of terms = lots of TLA or FLAB
  - applications
  - tools
- Summary

Terminology: The Telegram

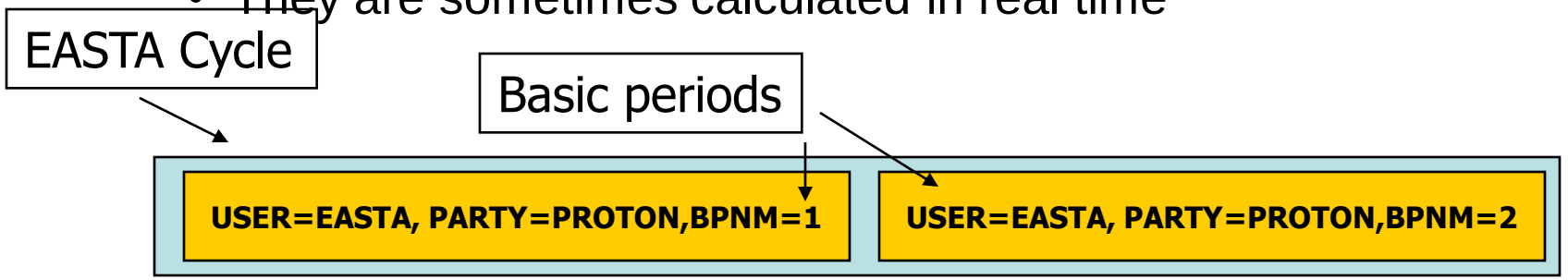
- It is a set of parameters group values (PARTY=PROTON, DEST=FTS,….) describing what each accelerator should do now.
- Each accelerator telegram layout is different
- Describe the present and the next cycle
- Telegrams drive the PPM/Multiplexing and SPS Multi-cycling
- They are delivered each basic period. (Currently 1BP = 1.2S)

Terminology: The basic period

- The basic unit of time use to define cycles. Characterized by :
  - a duration of 1.2s (Can be changed)
  - a telegram (32 parameters/groups maximum)
  - all cycle and super-cycle durations are a multiple of this time
  - is the heart beat of the central timing

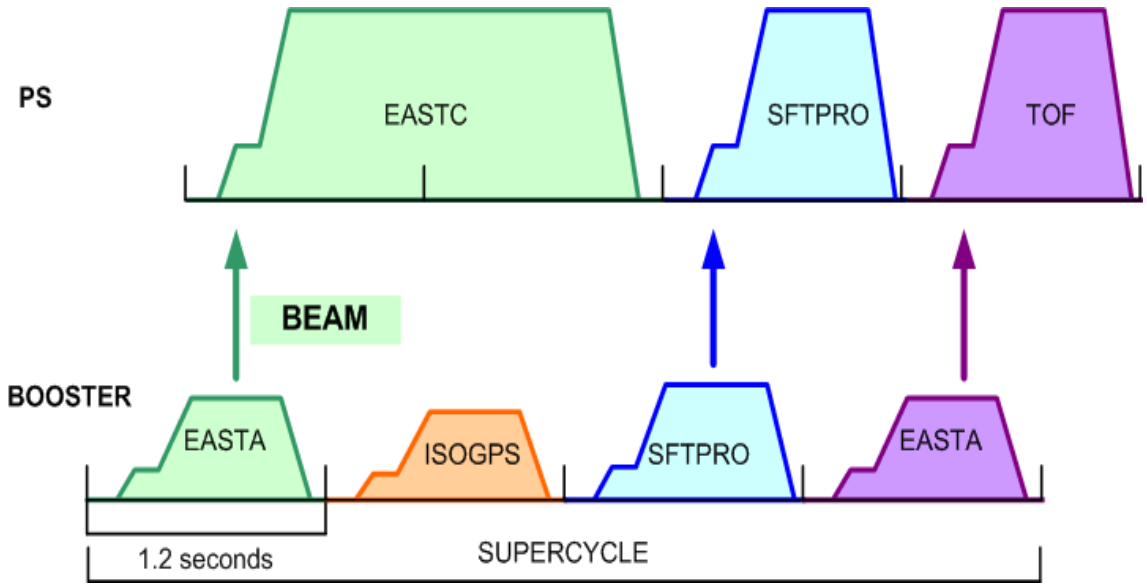
Terminology: The CYCLE

- Set of basic period
  - Length = N x Basic Period
  - Static telegram groups
    - Their values don't change within a cycle (USER=SFTPRO)
    - They are mostly calculated at BCD build time offline
  - Dynamic telegram groups
    - Their values can change from a basic period to another within a cycle (BPNM=1)
    - They are sometimes calculated in real time



Terminology: The BEAM

- Link cycles together (same/different accelerators)
  - When a beam is played by MTG, all cycles of the beam will be played.
  - The basic unit of work for the central timing
  - Decisions taken by the MTG on what to do next are based on beams
- Defined by :
  - Set of cycles
  - Phase between cycles



Strong and Loose coupling

Strong Coupling

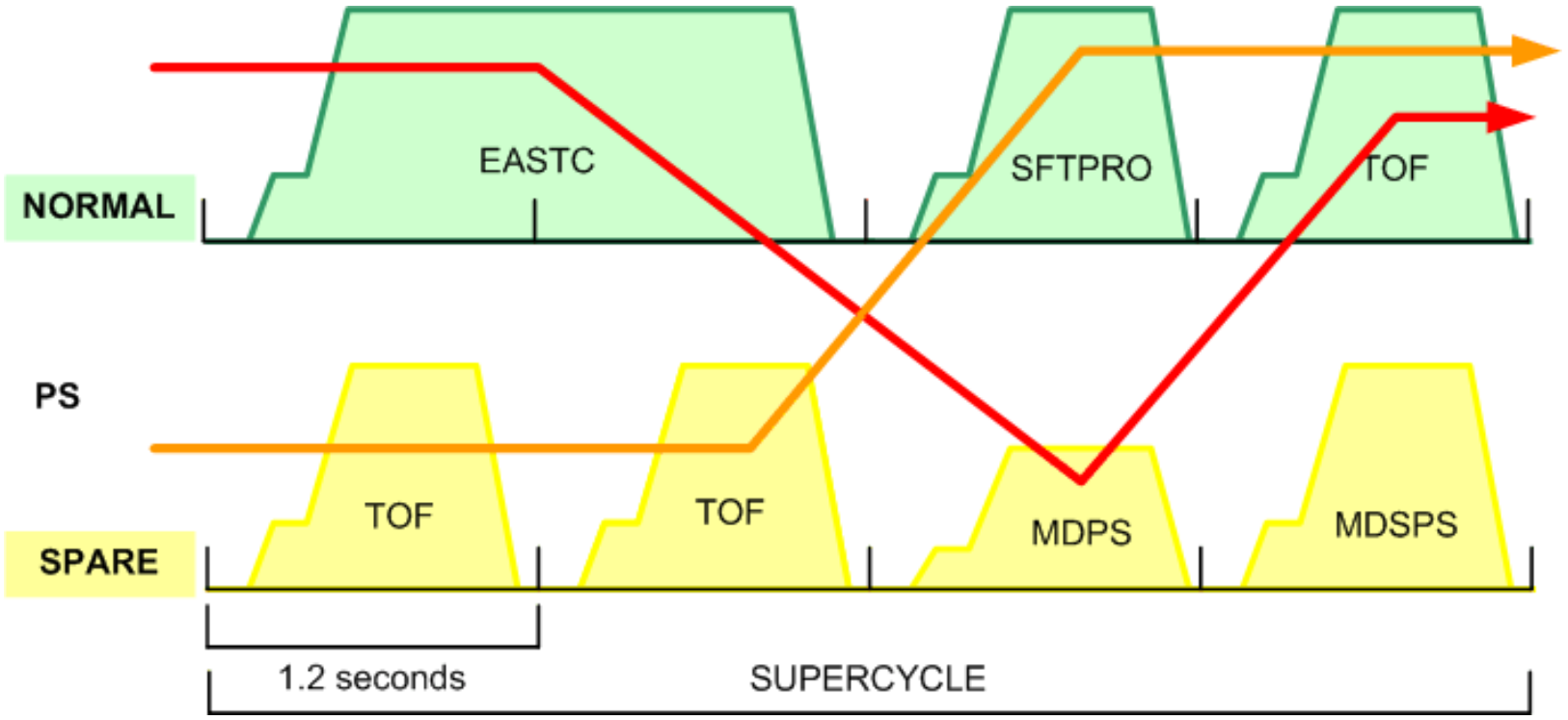
- Same supercycle length
- Cycles are strongly connected to create a beam
- Free supercycle phase

Loose Coupling

- Free supercycle length
- RT synchronization with machine in strong coupling for beam injection
- Supercycle can be stopped
- Occasional injection

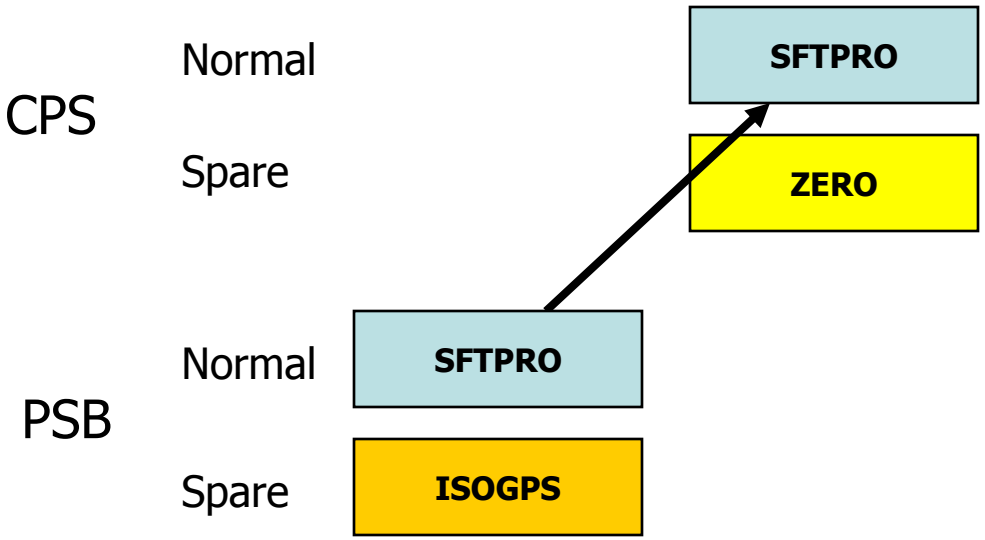
Terminology: NORMAL/SPARE

- Maximize accelerator up-time.

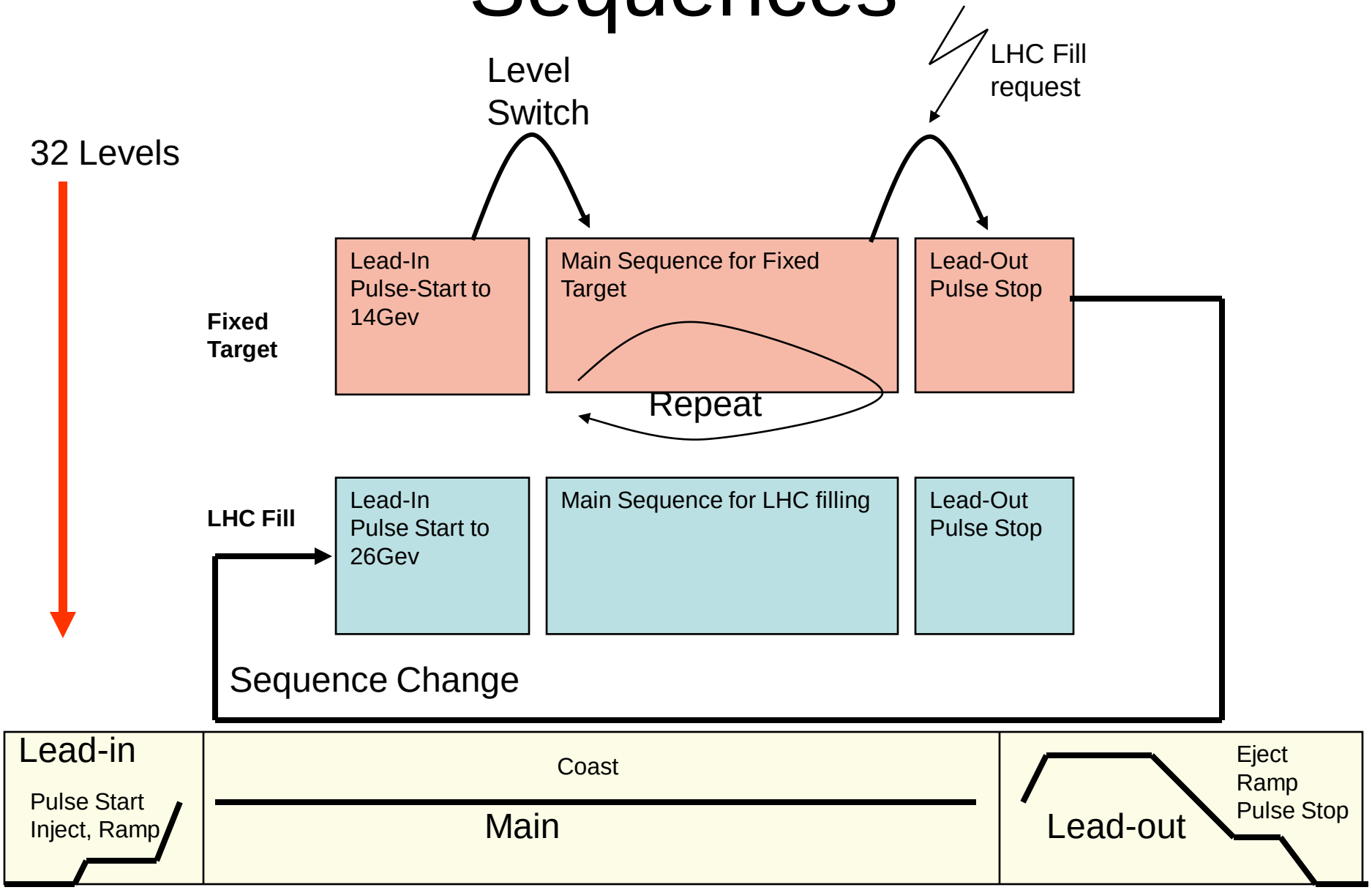


Terminology: NORMAL/SPARE(2)

- Representation in software tools



Sequences

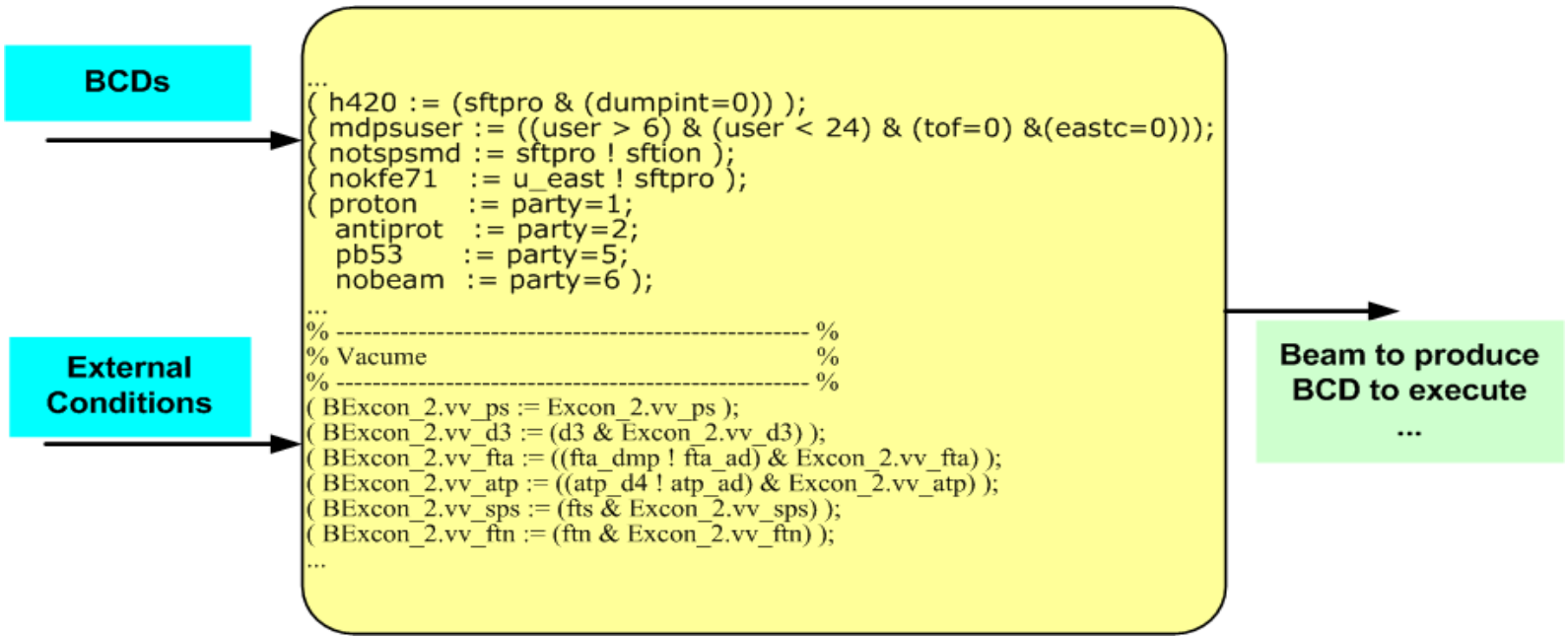

Level
Switch
LHC Fill
request
32 Levels
Fixed
Target
Lead-In
Pulse-Start to
14Gev
Main Sequence for Fixed
Target
Lead-Out
Pulse Stop
Repeat
LHC Fill
Lead-In
Pulse Start to
26Gev
Main Sequence for LHC filling
Lead-Out
Pulse Stop
Sequence Change
Lead-in
Pulse Start
Inject, Ramp
Coast
Main
Lead-out
Eject
Ramp
Pulse Stop

External Conditions

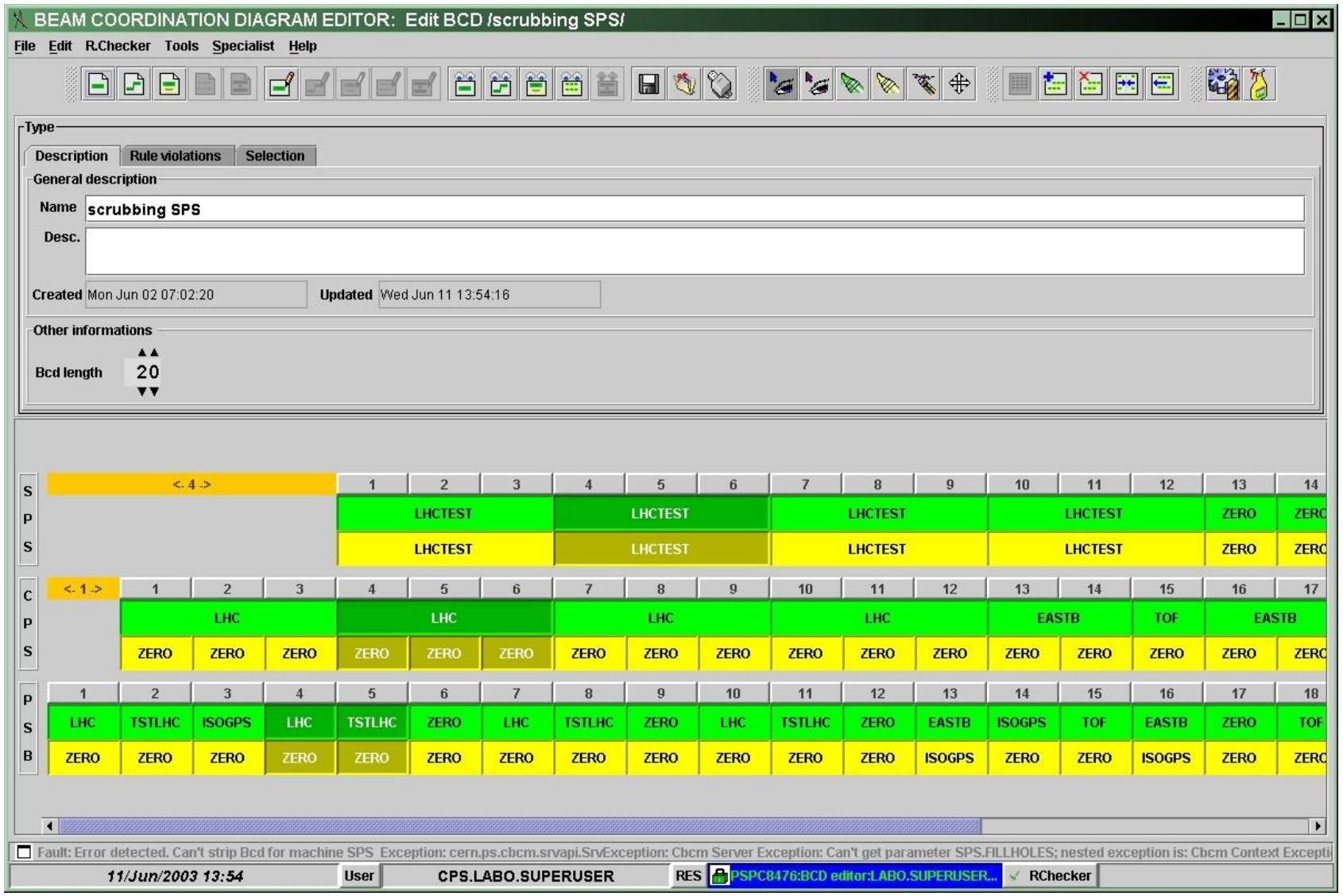
- Comprised of Requests, Inhibits, Interlocks.
- They are logic levels 1=Bad, 0=Good
- They control the CBCM
  - Normal <-> Spare
  - Sequence selection
  - BCD termination
- Can be either hardware or software
- Used By FIDO (= real time timing command interpretor) to make decisions on what to do next

FiDo programs

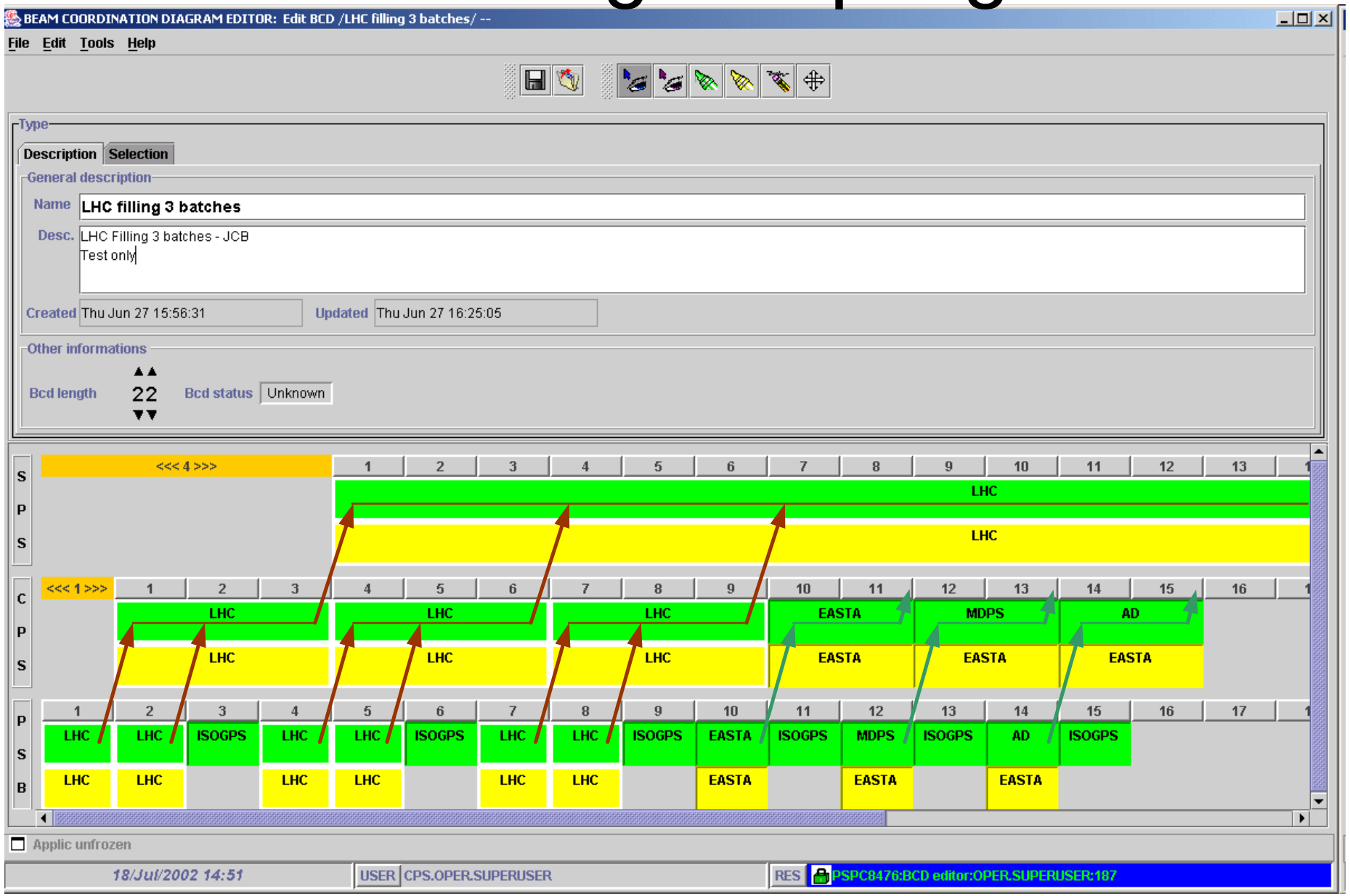
- MTG integrates the compiler and the interpreter.
- Can be downloaded in real-time



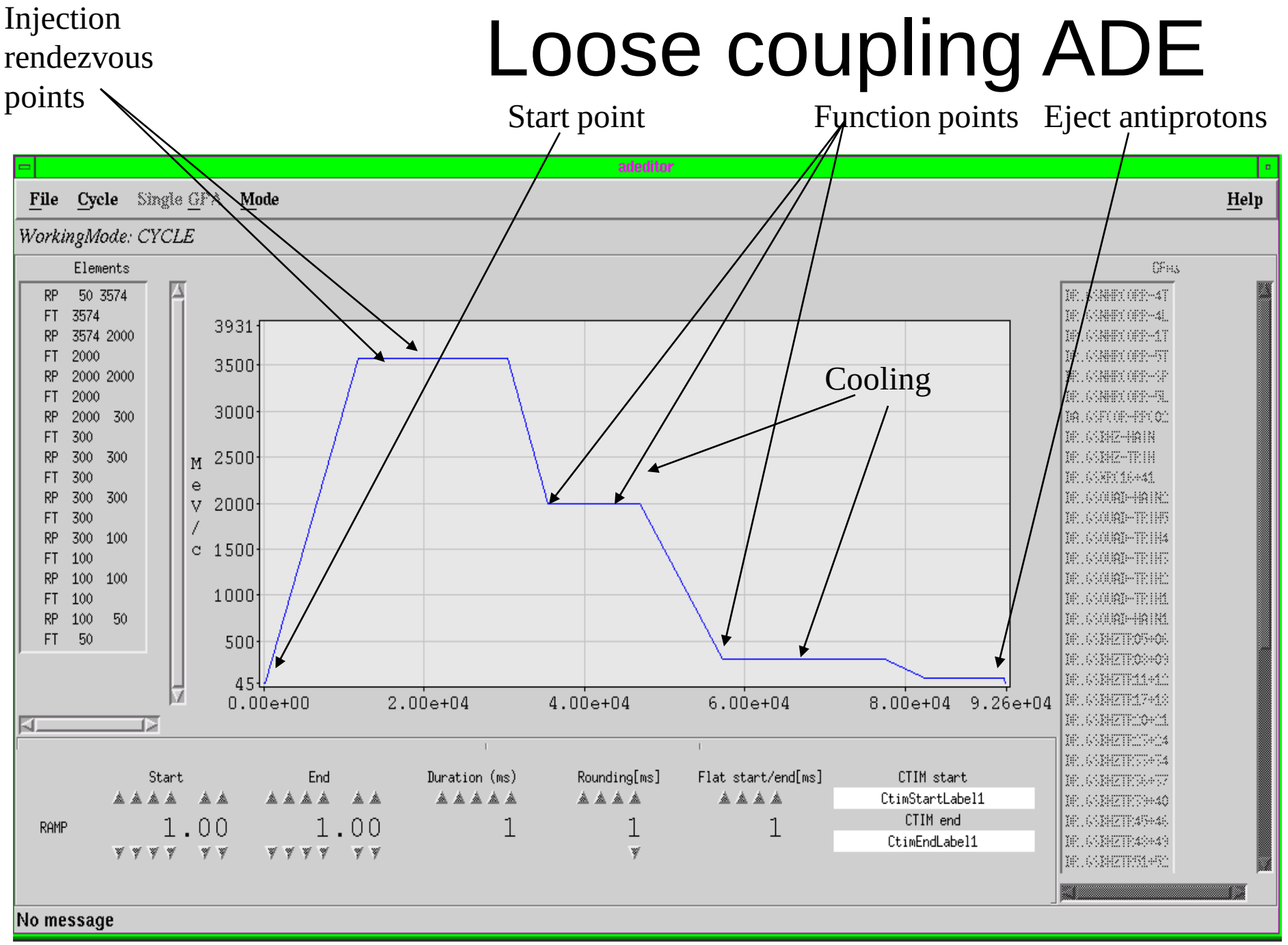
Beam Coordination Diagram editor



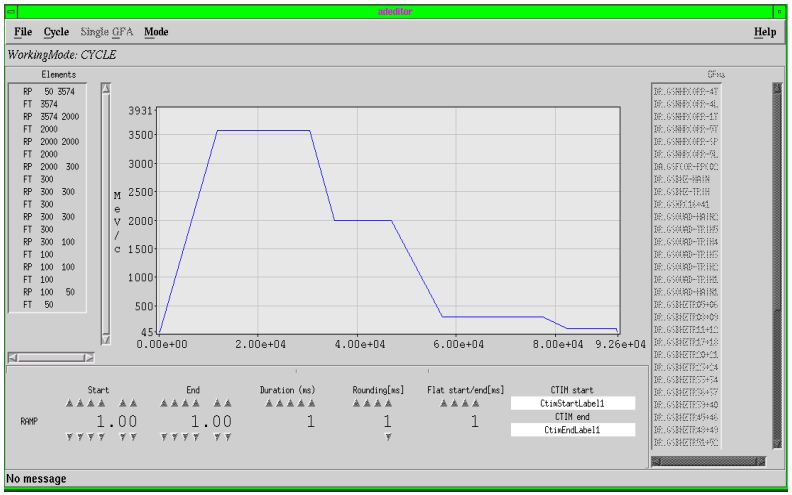
Strong Coupling

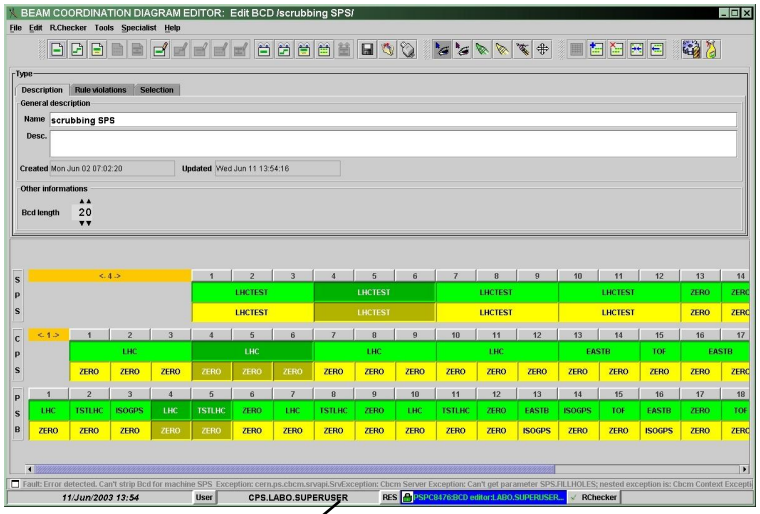


Loose coupling ADE



Make MTG table

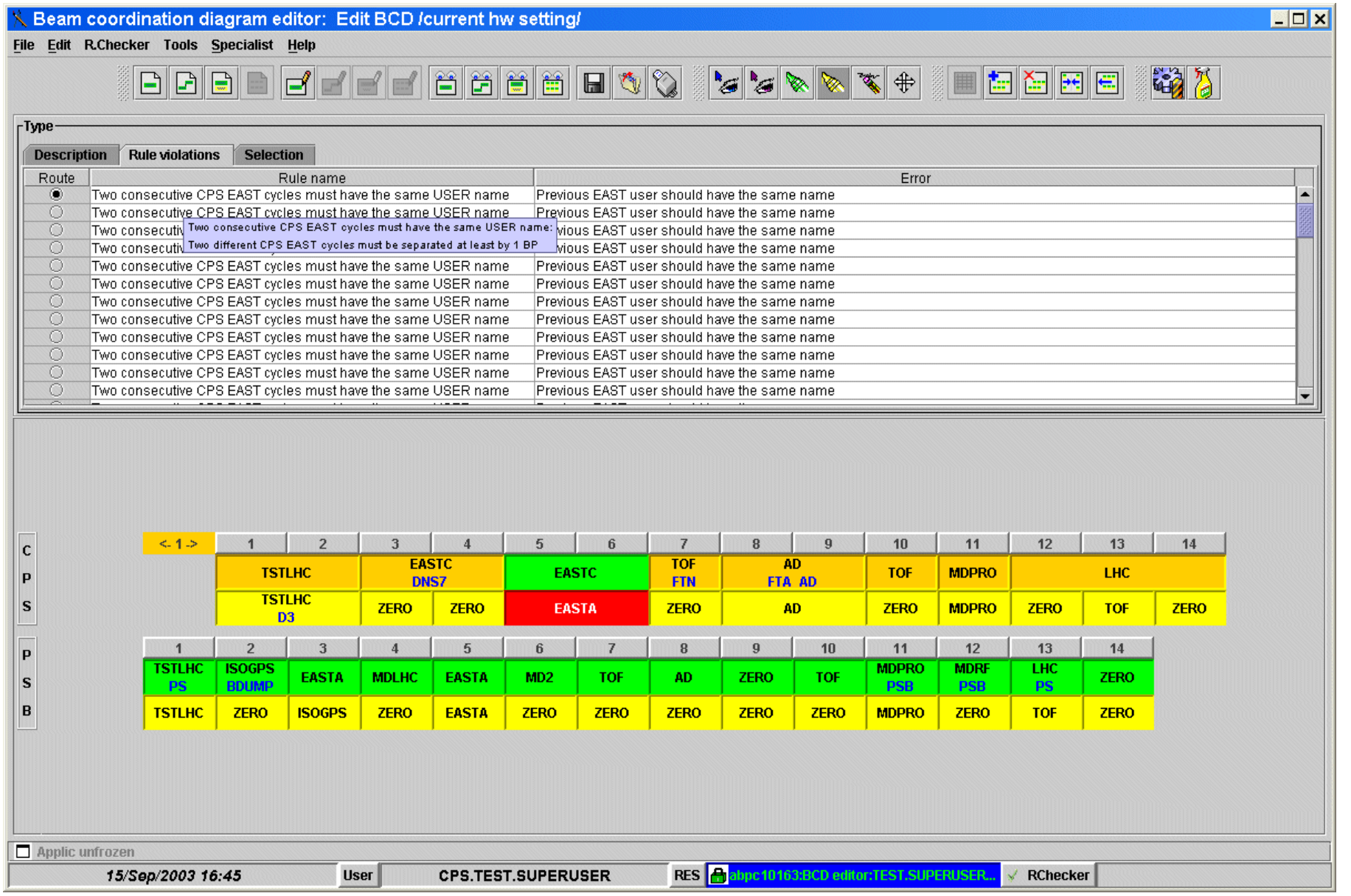




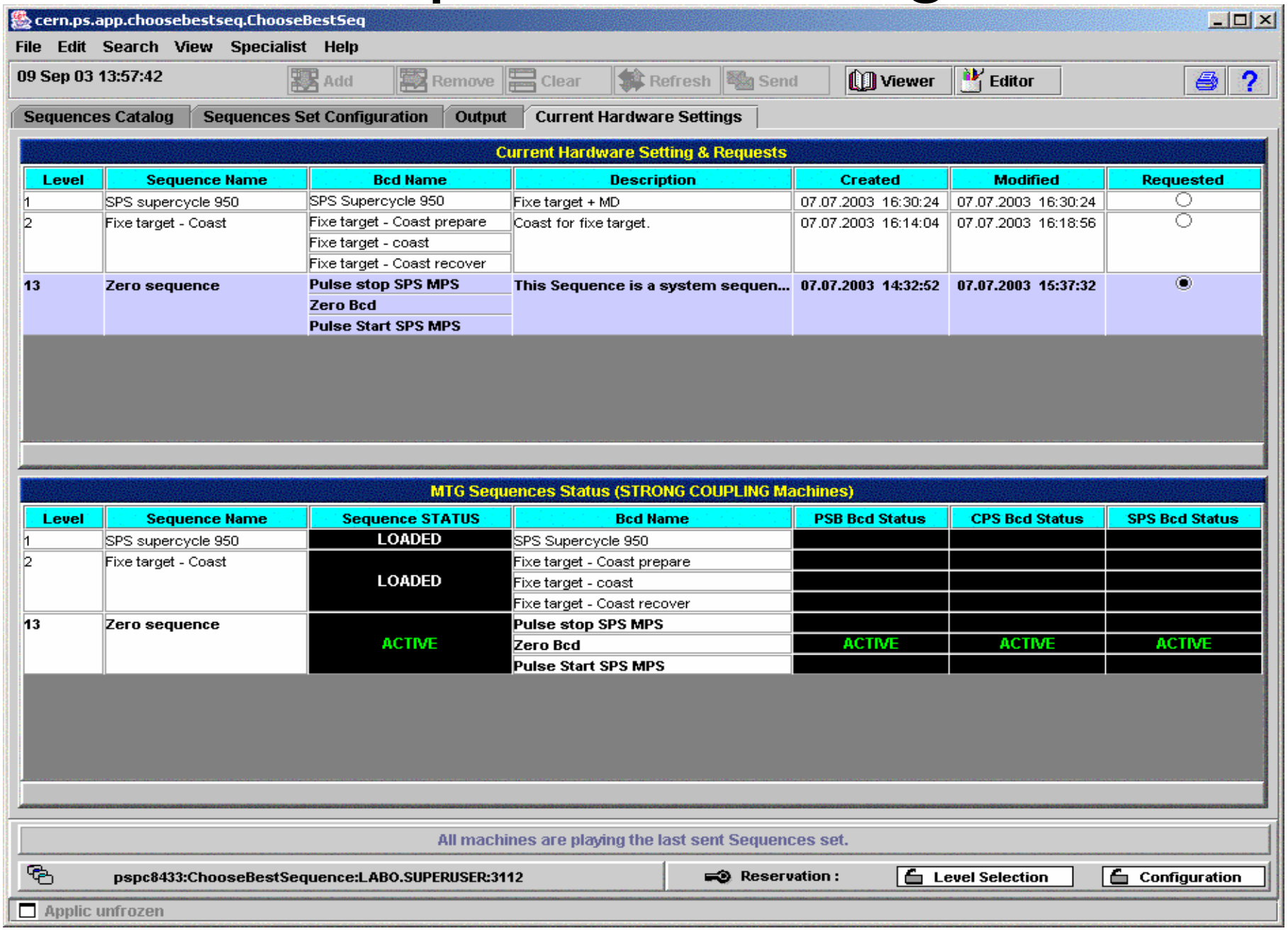
The BCD is the result of the merging of BCDs produces by the two editors.

BCD

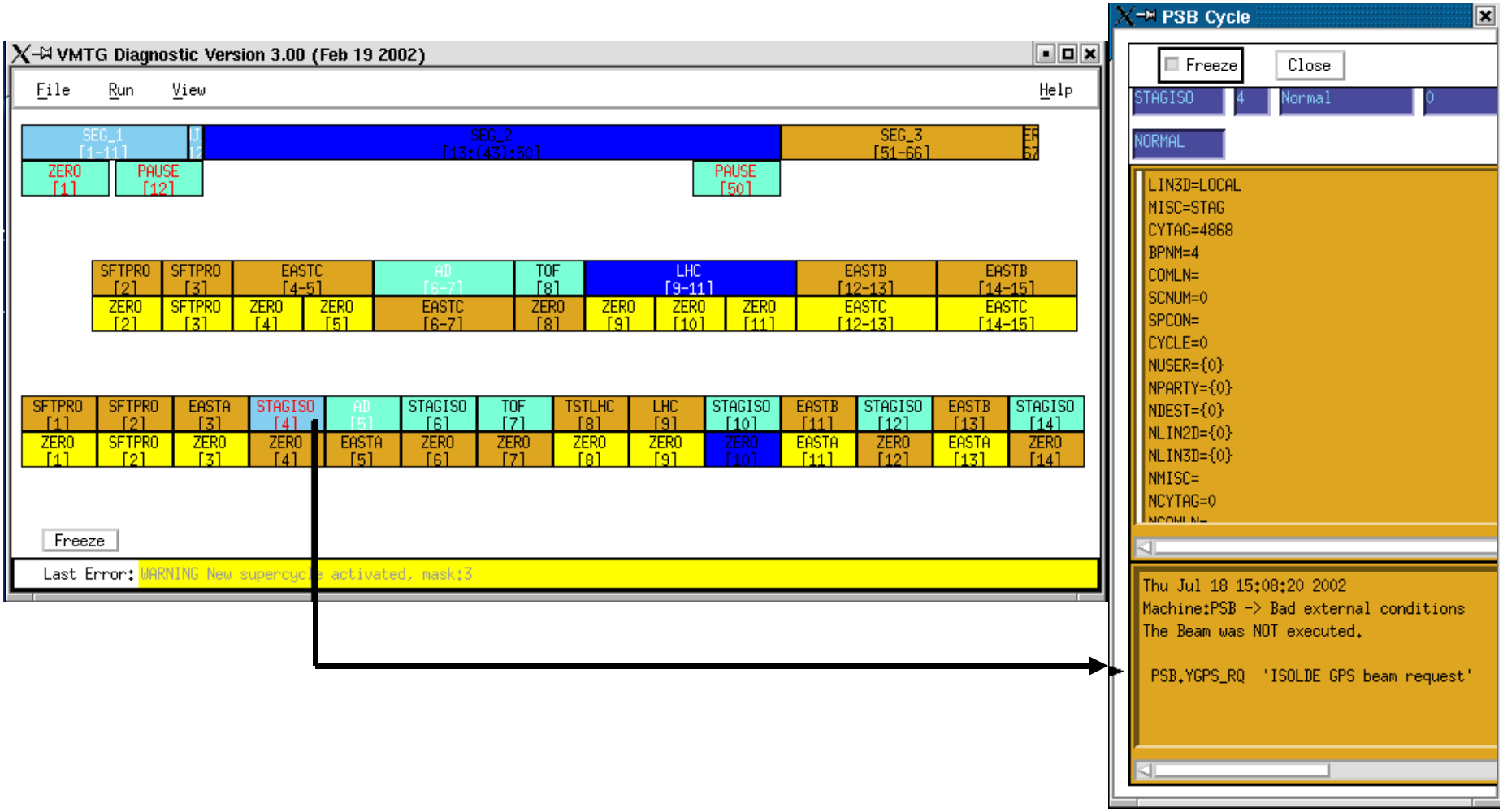
BCD Editor: Rule checker



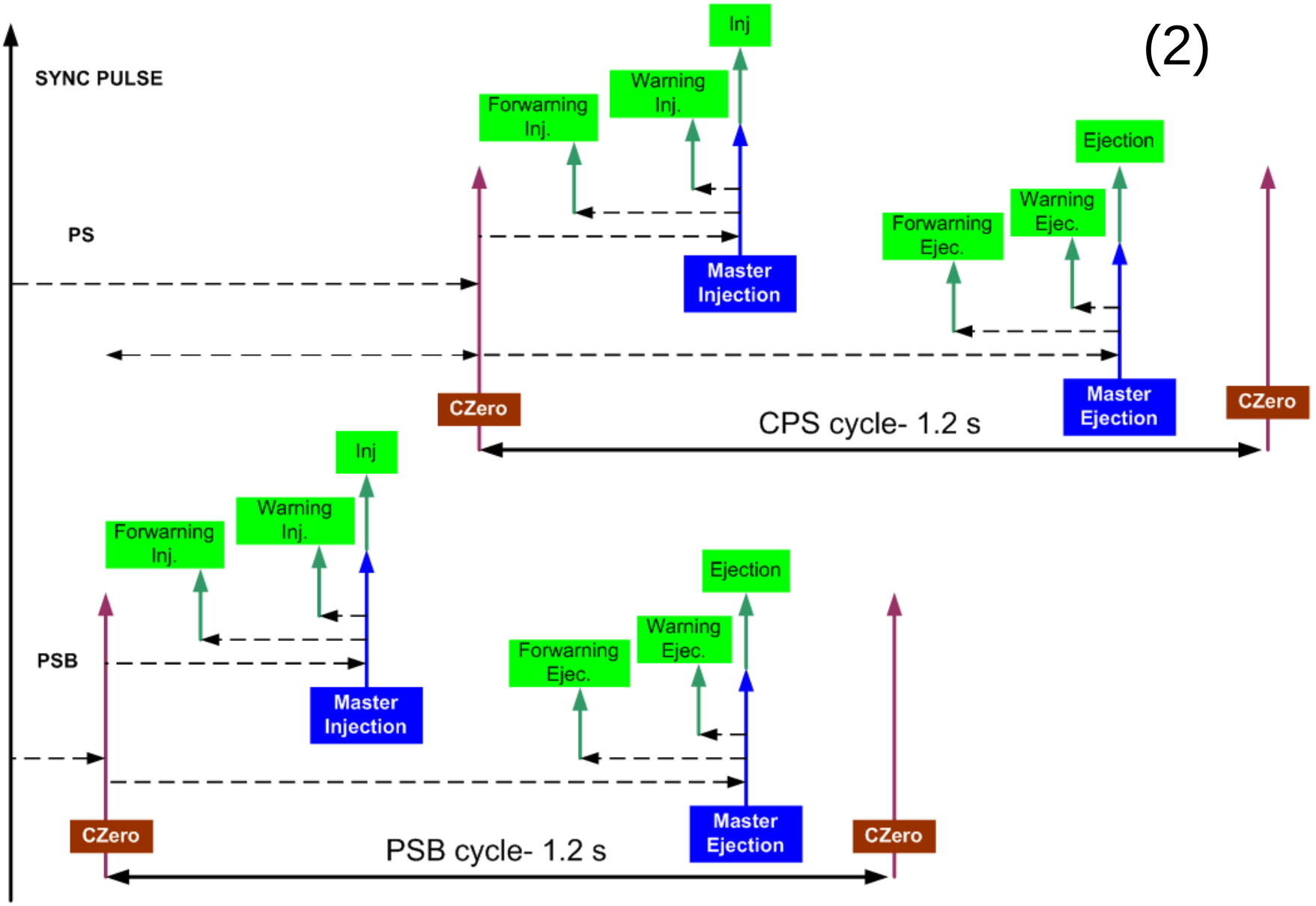
Sequence manager



MTG diagnostic

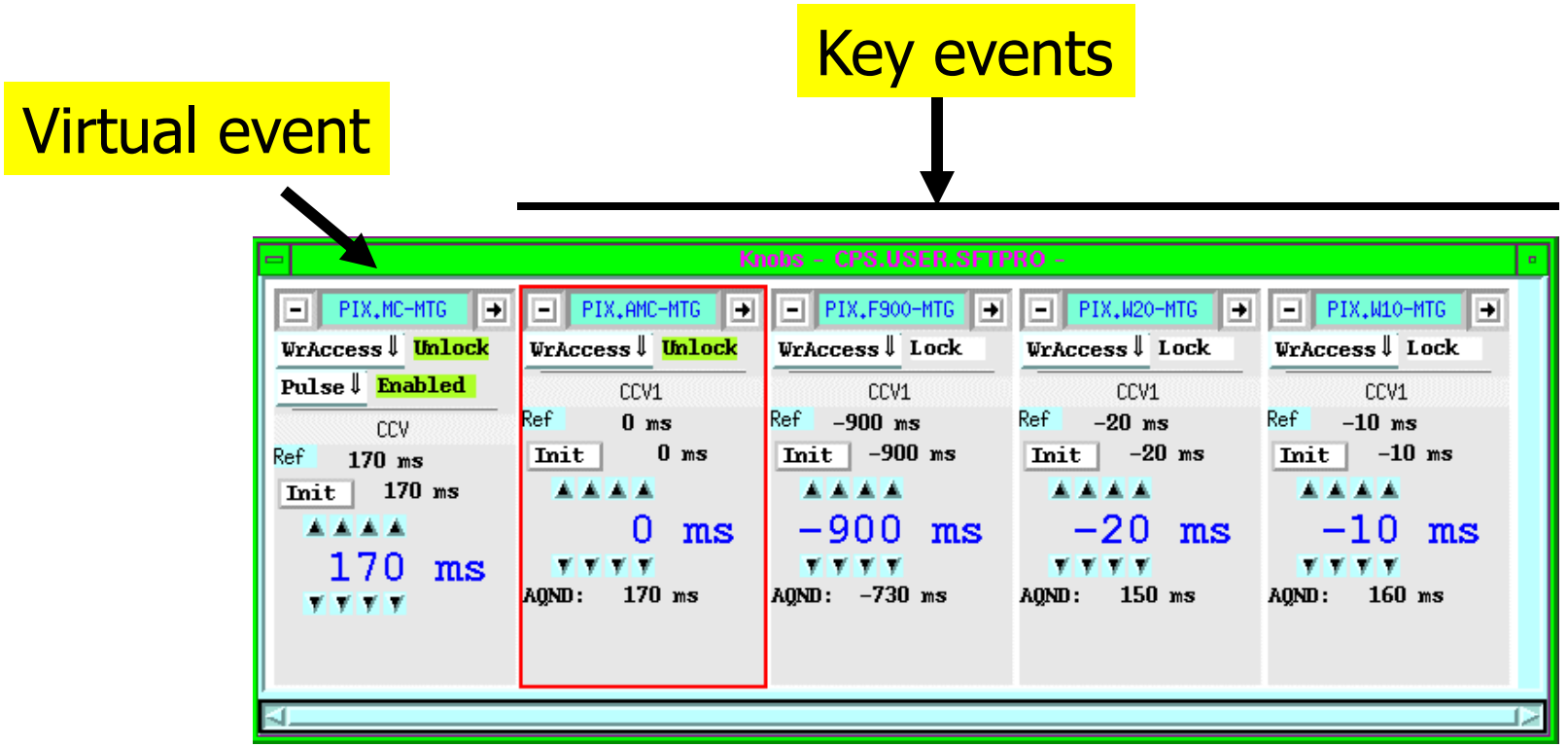


CTIM (2)


SYNC PULSE
PS
Inj
Warning Inj.
Forwarning Inj.
Master Injection
Ejection
Warning Ejec.
Forwarning Ejec.
Master Ejection
CZero
CPS cycle- 1.2 s
CZero
PSB
Inj
Warning Inj.
Forwarning Inj.
Master Injection
Ejection
Warning Ejec.
Forwarning Ejec.
Master Ejection
CZero
PSB cycle- 1.2 s
CZero

Timing events (CTIM) (3)

- Controllable by knobs in real-time



Summary Part 2

- The CERN timing system is an almost unique technical solution to a very complex timing/sequencing problem. Only a few accelerator centers in the world are confronted with its complexity of operation.
- The functionality/hardware implementation has evolved over the past decades. Lots of legacy equipment has still to be supported.
- Presently a project is under way in order to:
  - simplify hard- and software
  - increase functionality (higher resolution, bidirectional information)
  - name: White Rabbit → please visit BE-CO-HT webpages