

Accelerator Controls

Part2: CERN central timing system

CAS 2009@Divonne

Hermann Schmickler



Outline Part 2

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



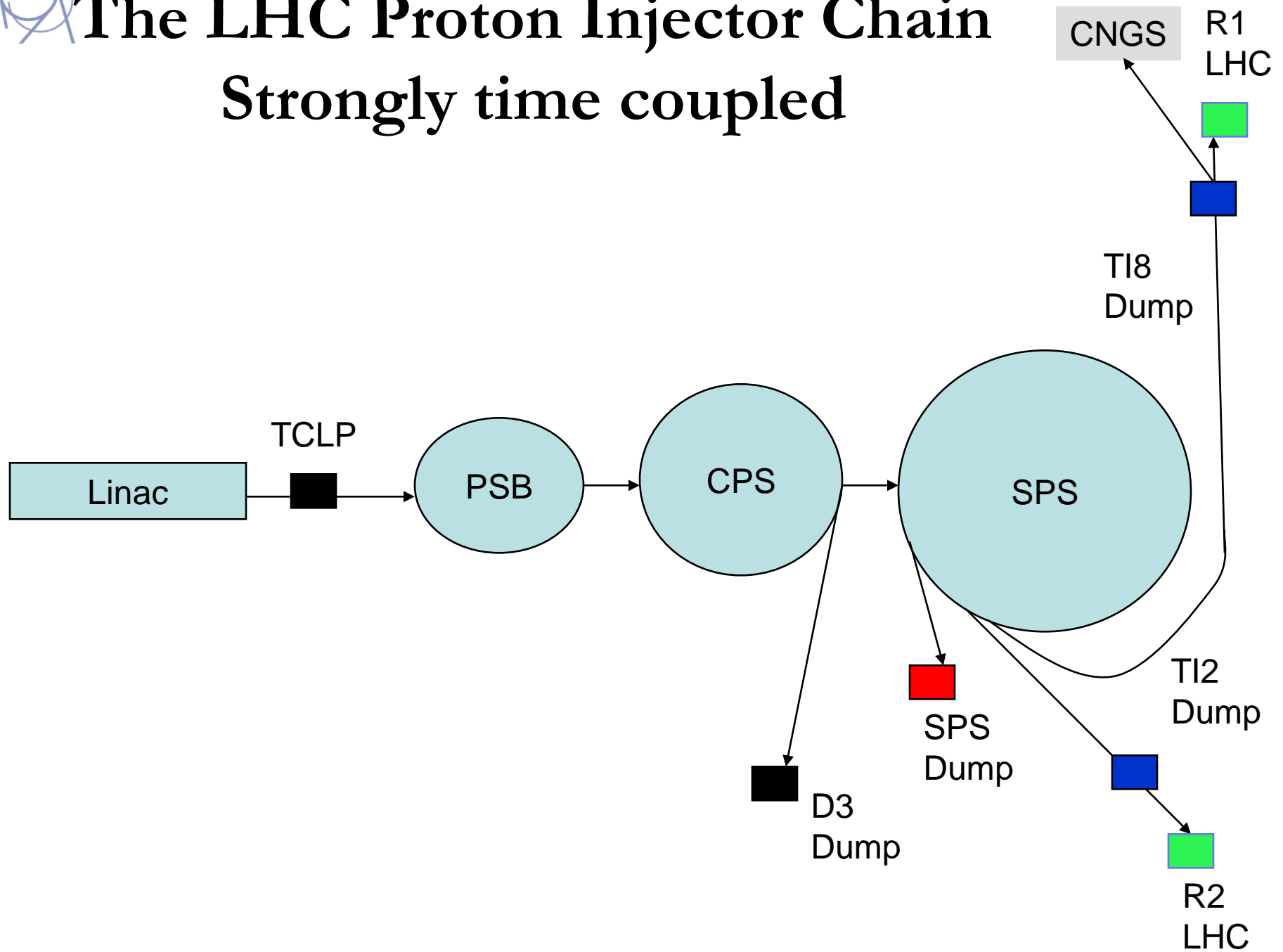
Demanded Functionality of the Timing System

- In general: Stimulate the creation of any particle beam type and assure the proper sequence of transport and acceleration throughout 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.



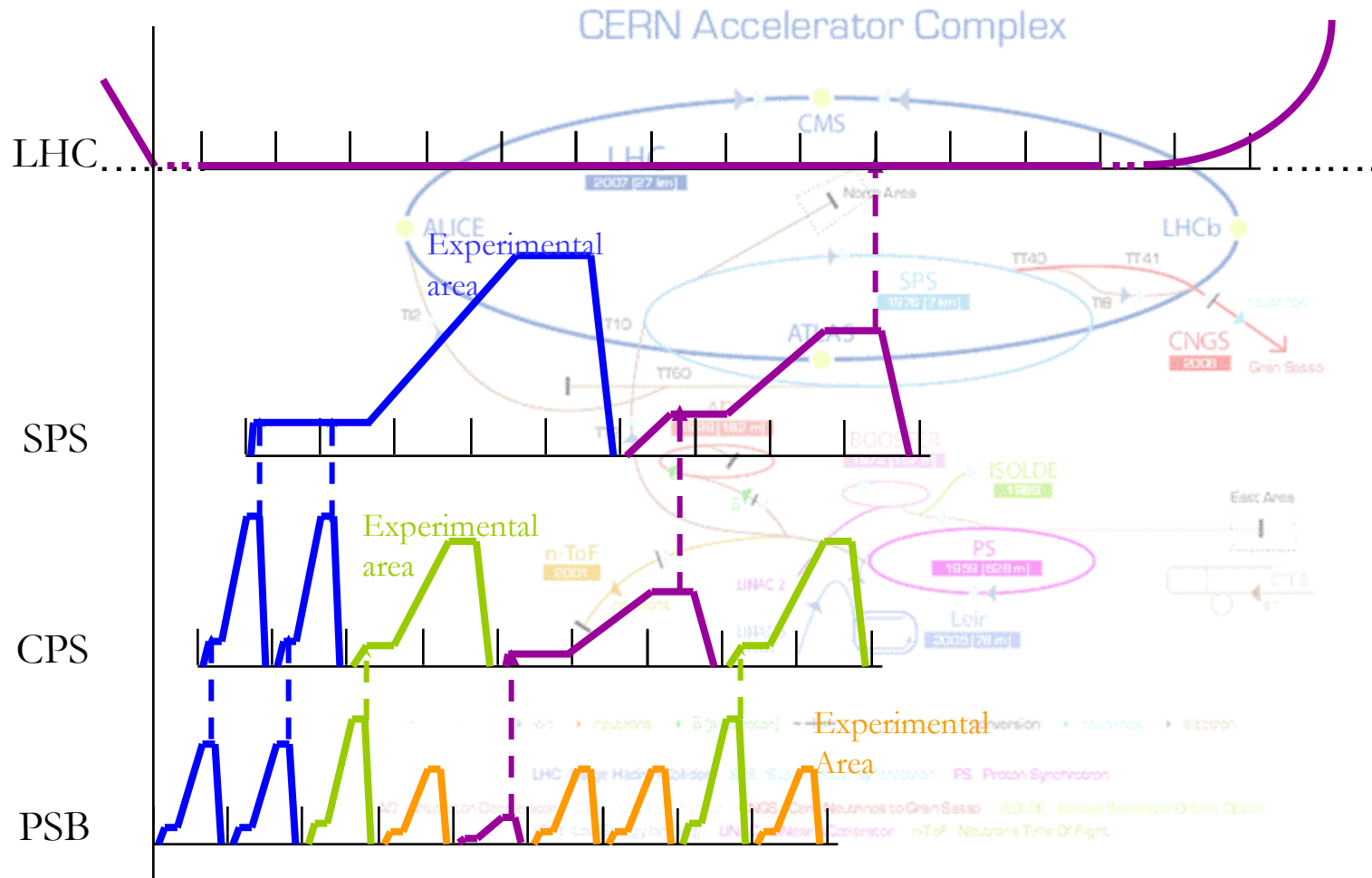
The LHC Proton Injector Chain

Strongly time coupled





CERN accelerator network sequenced by central timing generator





CBCM Sequence Manager

BEAM COORDINATION DIAGRAM EDITOR: Edit BCD /scrubbing SPS/

File Edit R.Checker Tools Specialist Help

Type

Description Rule violations Selection

General description

Name **scrubbing SPS**

Desc.

Created Mon Jun 02 07:02:20 Updated Wed Jun 11 13:54:16

Other informations

Bcd length **20**

S	< 4 >				1	2	3	4	5	6	7	8	9	10	11	12	13	14	
P					LHCTEST			LHCTEST			LHCTEST			LHCTEST			ZERO	ZERO	
S					LHCTEST			LHCTEST			LHCTEST			LHCTEST			ZERO	ZERO	
C	< 1 >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
P		LHC			LHC			LHC			LHC			EASTB		TOF	EASTB		
S		ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO
P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
S	LHC	TSTLHC	ISOGPS	LHC	TSTLHC	ZERO	LHC	TSTLHC	ZERO	LHC	TSTLHC	ZERO	EASTB	ISOGPS	TOF	EASTB	ZERO	TOF	
B	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ISOGPS	ZERO	ZERO	ISOGPS	ZERO	ZERO	

11/Jun/2003 13:54 User CPS.LABO.SUPERUSER RES PSPC8476:BCD editor:LABO.SUPERUSER... RChecker

Fault: Error detected. Can't strip Bcd for machine SPS Exception: cern.ps.cbcm.srvapi.SrvException: Cbcm Server Exception: Can't get parameter SPS.FILLHOLES; nested exception is: Cbcm Context Exception



The LHC Beam

The LHC timing is only coupled by extraction

LHC Injection plateaux

start-ramp event

Injection

Injection

LSA Beam request:
RF bucket
Ring
CPS batches

Extraction

Extraction

Extraction Forewarning

SPS injection plateaux

Extraction Forewarning

SPS Cycle for the LHC

CPS Batch 1

CPS Batch 2

CPS Batch 3

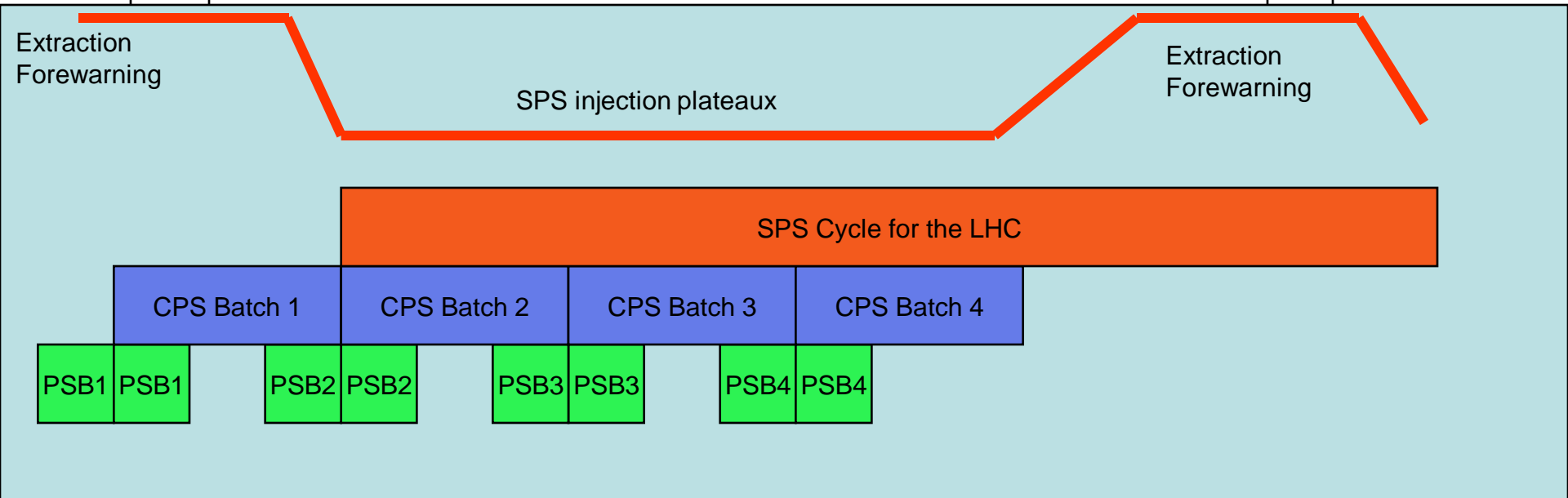
CPS Batch 4

PSB1 PSB1

PSB2 PSB2

PSB3 PSB3

PSB4 PSB4





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 generator chassis, the information is distributed to the machines via cable/fibre optics links at a 10 Gbps rate.





GPS

Hardware developments CTG and CTR



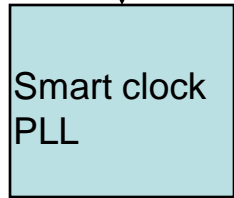
GPS

One pulse per Second

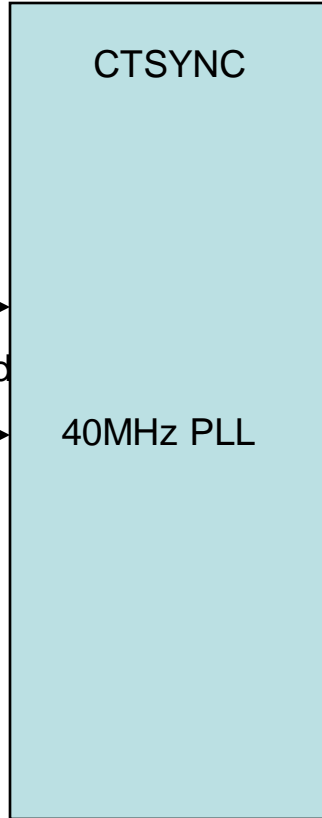
PLL

One pulse per Second

RS485 Timing



Phase locked 10MHz

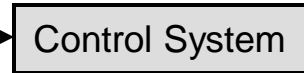


Basic Period 1200/900/600 ms

Advanced (100us)
One pulse per Second

Synchronized 1KHz (slow timing clock)

Phase locked 10MHz

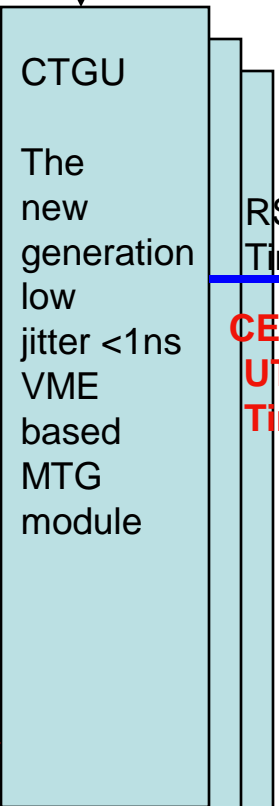


Phase locked 40 MHz Event encoding clock

Set once on startup & on Leap Seconds

UTC time (NTP or GPS)

Event tables



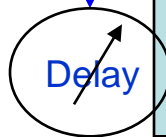
The new generation low jitter <1ns VME based MTG module

RS485 Timing

CERN UTC Time

CERN UTC Time

Timing receiver



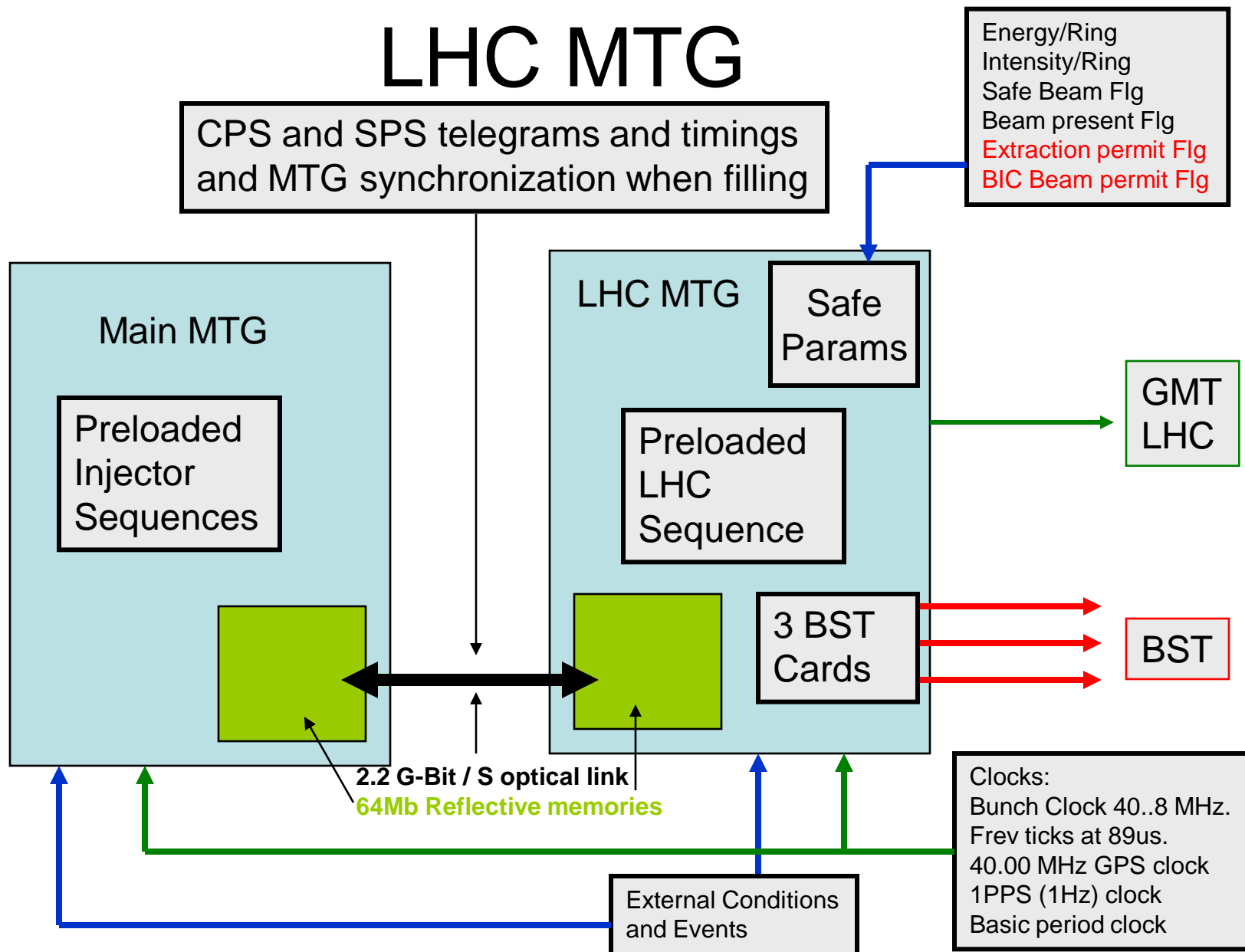
40 MHz
10 MHz
1 KHz
1PPS

25ns steps

External events

Hardware II

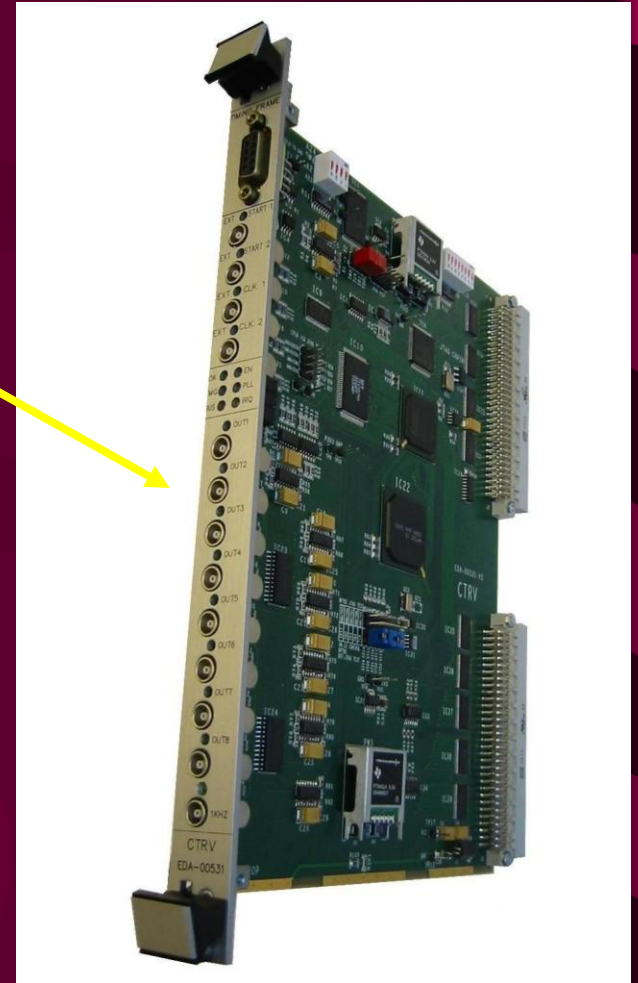
LHC MTG





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

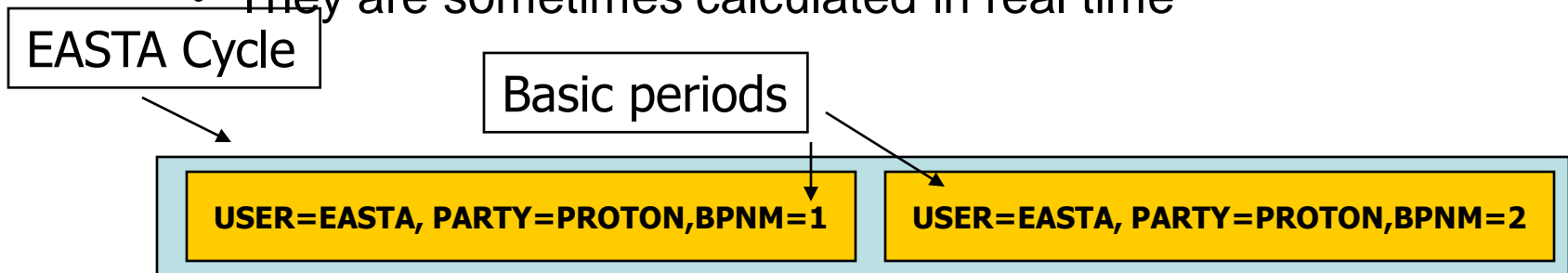
- It is a set of parameters group values (PARTY=PROTON, DEST=FTS,.....) describing what each accelerator should do now.
- Each accelerator telegram layout is different
- Describe the present and the next cycle
- Telegrams drive the PPM/Multiplexing and SPS Multi-cycling
- They are delivered each basic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

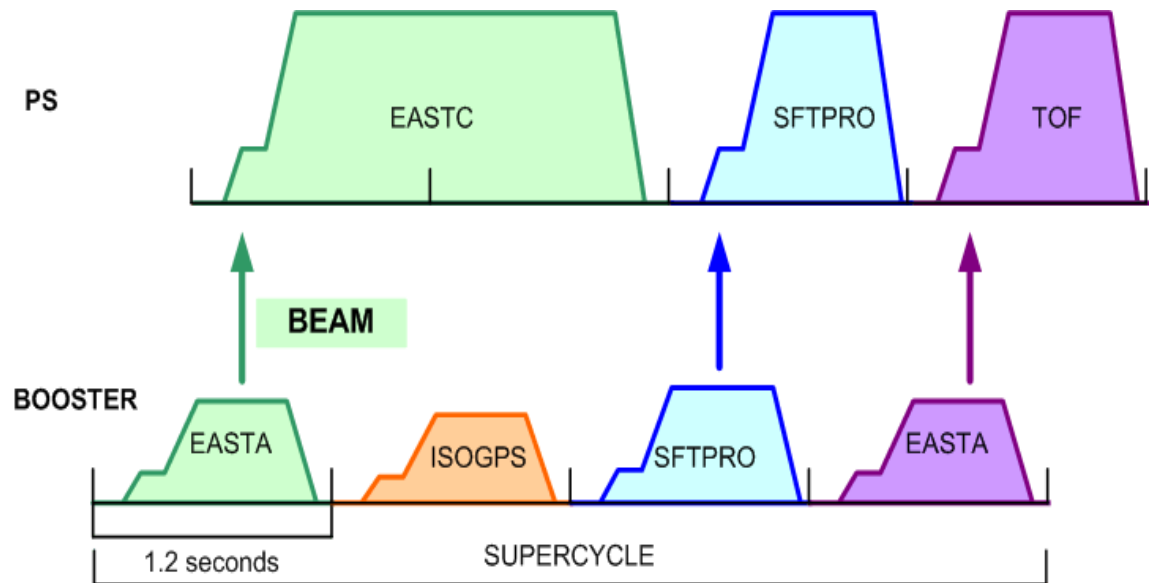
Terminology: The CYCLE

- Set of basic period
 - Length = $N \times \text{Basic Period}$
 - 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

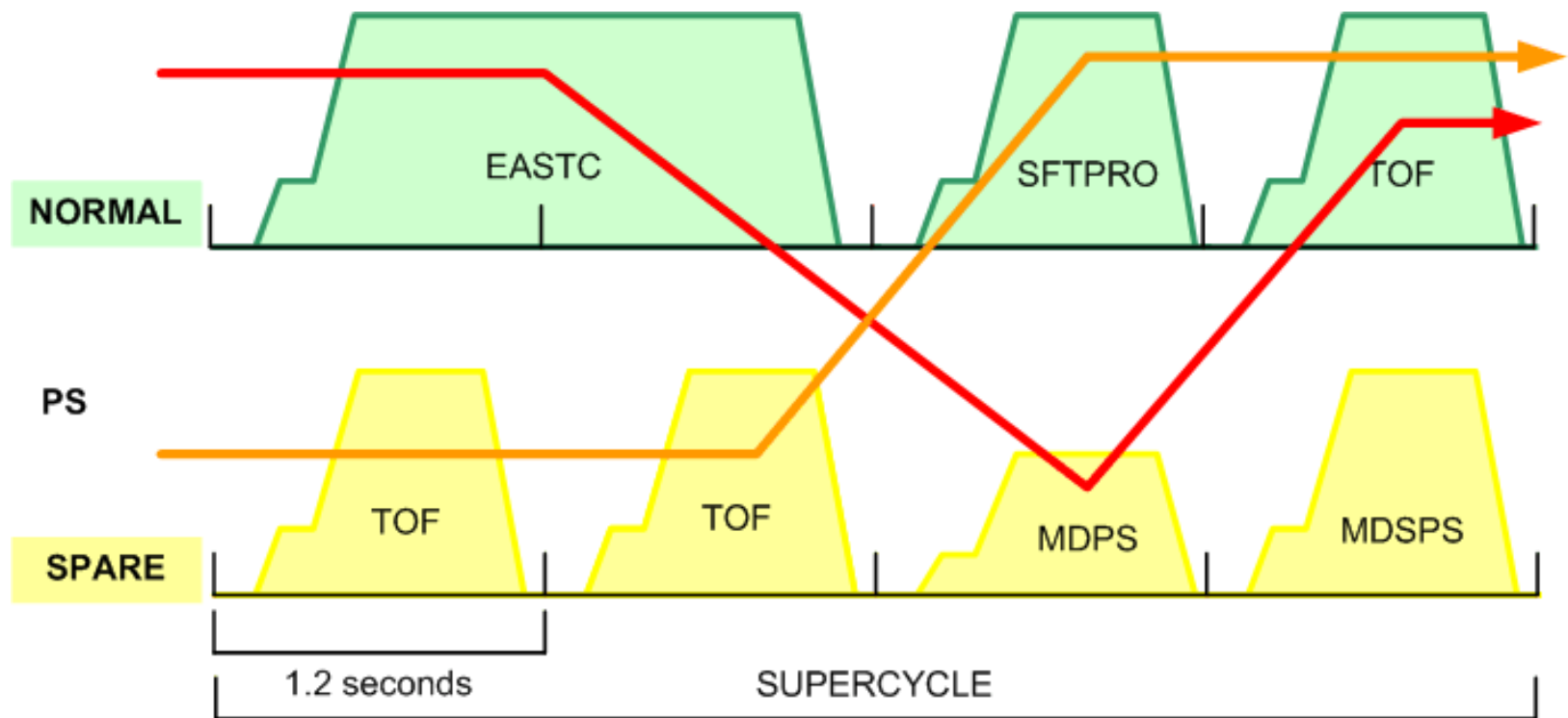
- Same supercycle length
- Cycles are strongly connected to create a beam
- Free supercycle phase

Loose Coupling

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

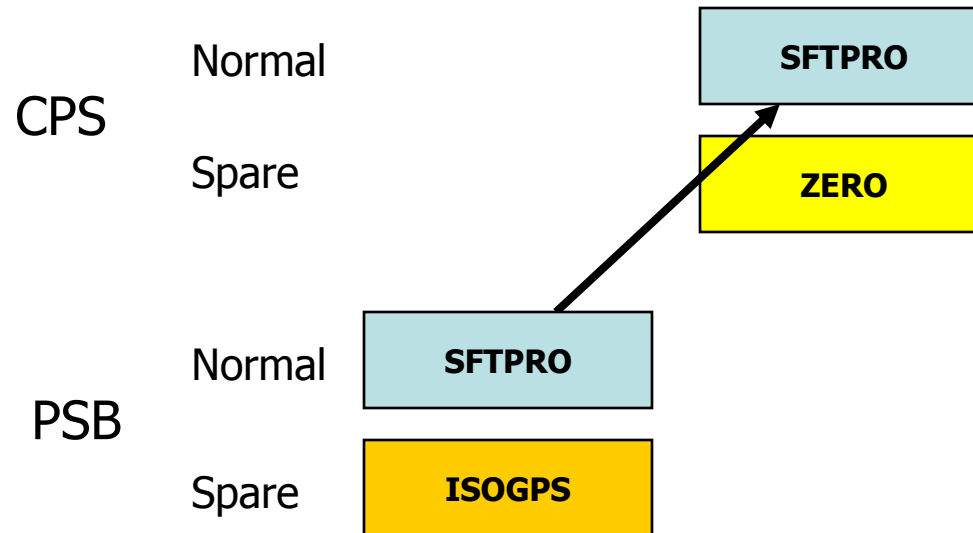
Terminology: NORMAL/SPARE

- Maximize accelerator up-time.



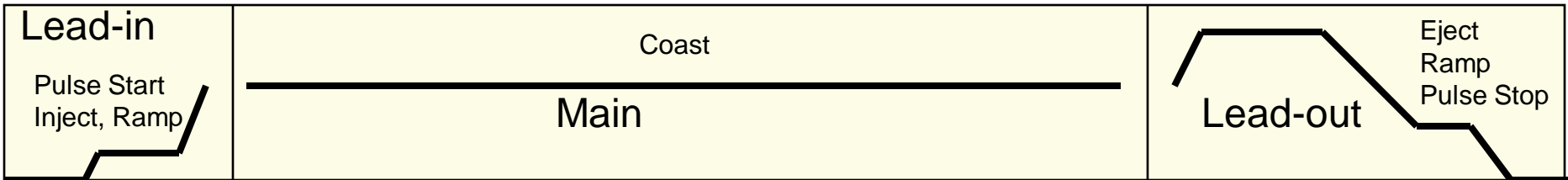
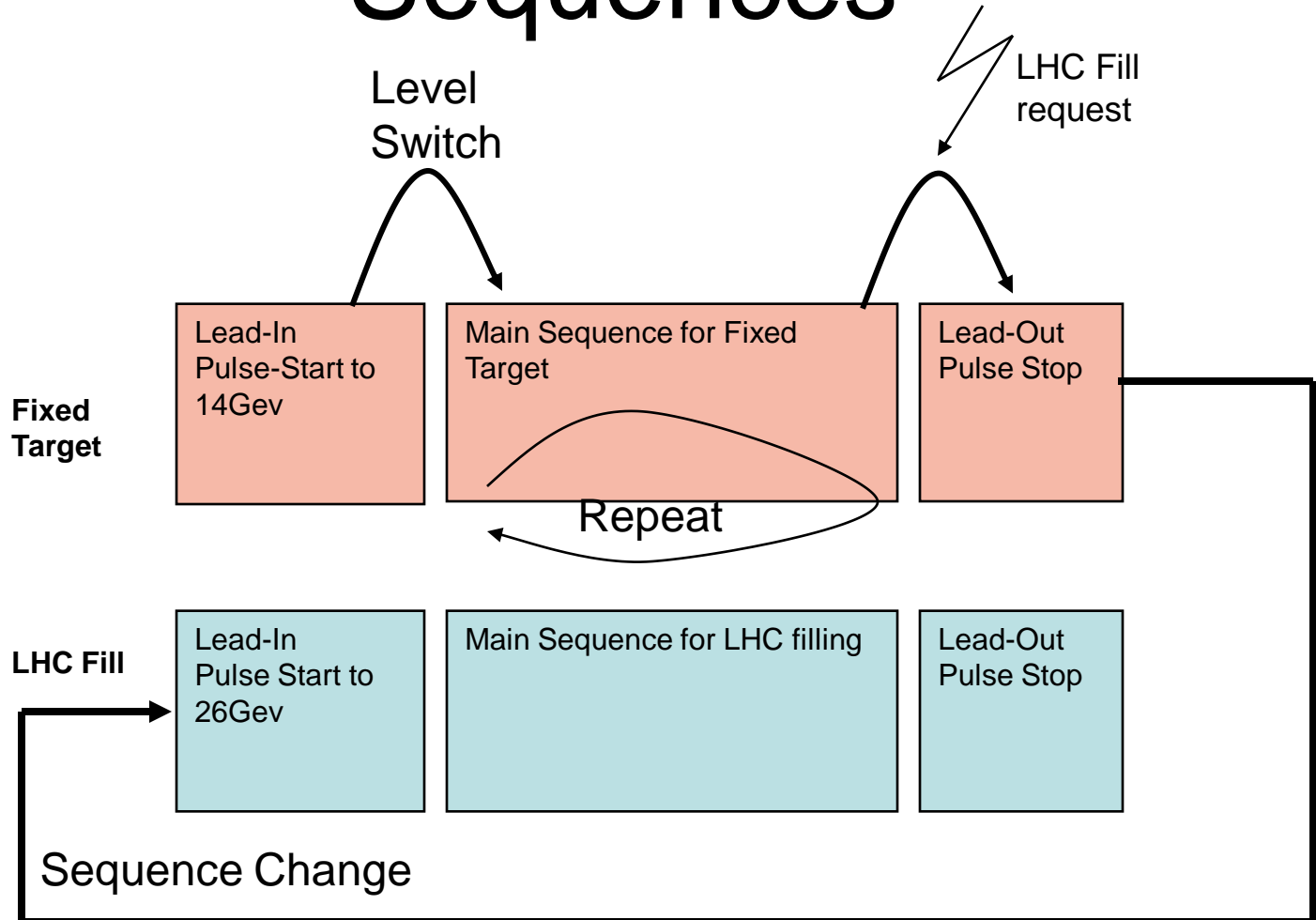
Terminology: NORMAL/SPARE(2)

- Representation in software tools



Sequences

32 Levels

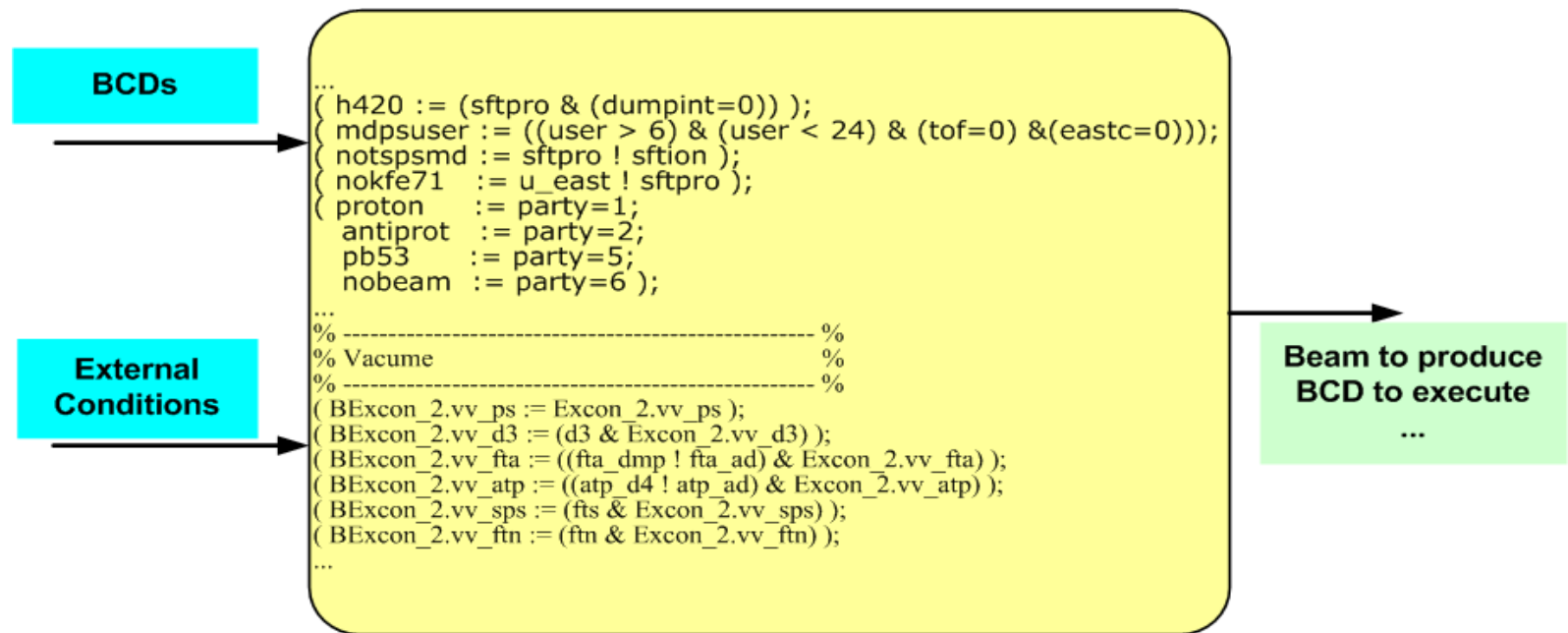


External Conditions

- 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 interpreter) 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

BEAM COORDINATION DIAGRAM EDITOR: Edit BCD /scrubbing SPS/

File Edit R.Checker Tools Specialist Help

Type

Description Rule violations Selection

General description

Name **scrubbing SPS**

Desc.

Created Mon Jun 02 07:02:20 Updated Wed Jun 11 13:54:16

Other informations

Bcd length **20**

S	< 4 >				1	2	3	4	5	6	7	8	9	10	11	12	13	14	
P					LHCTEST			LHCTEST			LHCTEST			LHCTEST			ZERO	ZERO	
S					LHCTEST			LHCTEST			LHCTEST			LHCTEST			ZERO	ZERO	
C	< 1 >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
P		LHC			LHC			LHC			LHC			EASTB		TOF	EASTB		
S		ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO
P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
S	LHC	TSTLHC	ISOGPS	LHC	TSTLHC	ZERO	LHC	TSTLHC	ZERO	LHC	TSTLHC	ZERO	EASTB	ISOGPS	TOF	EASTB	ZERO	TOF	
B	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	ISOGPS	ZERO	ZERO	ISOGPS	ZERO	ZERO	

11/Jun/2003 13:54 User CPS.LABO.SUPERUSER RES PSCP8476:BCD editor:LABO.SUPERUSER... RChecker

Fault: Error detected. Can't strip Bcd for machine SPS Exception: cern.ps.cbcm.srvapi.SrvException: Cbcm Server Exception: Can't get parameter SPS.FILLHOLES; nested exception is: Cbcm Context Exception

Strong Coupling

BEAM COORDINATION DIAGRAM EDITOR: Edit BCD /LHC filling 3 batches/ --

File Edit Tools Help

General description

Name: LHC filling 3 batches

Desc: LHC Filling 3 batches - JCB
Test only

Created: Thu Jun 27 15:56:31 Updated: Thu Jun 27 16:25:05

Other informations

Bcd length: 22 Bcd status: Unknown

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SPS	<<< 4 >>>				LHC												
CPS	<<< 1 >>>			LHC													
	LHC			LHC			LHC			EASTA			MDPS		AD		
	LHC			LHC			LHC			EASTA			EASTA		EASTA		
	LHC	LHC	ISOGPS	LHC	LHC	ISOGPS	LHC	LHC	ISOGPS	EASTA	ISOGPS	MDPS	ISOGPS	AD	ISOGPS		
	LHC	LHC		LHC	LHC		LHC	LHC		EASTA		EASTA		EASTA			

Applic unfrozen

18/Jul/2002 14:51 USER: CPS.OPER.SUPERUSER RES: #SPC8476:BCD editor:OPER.SUPER@USER:107

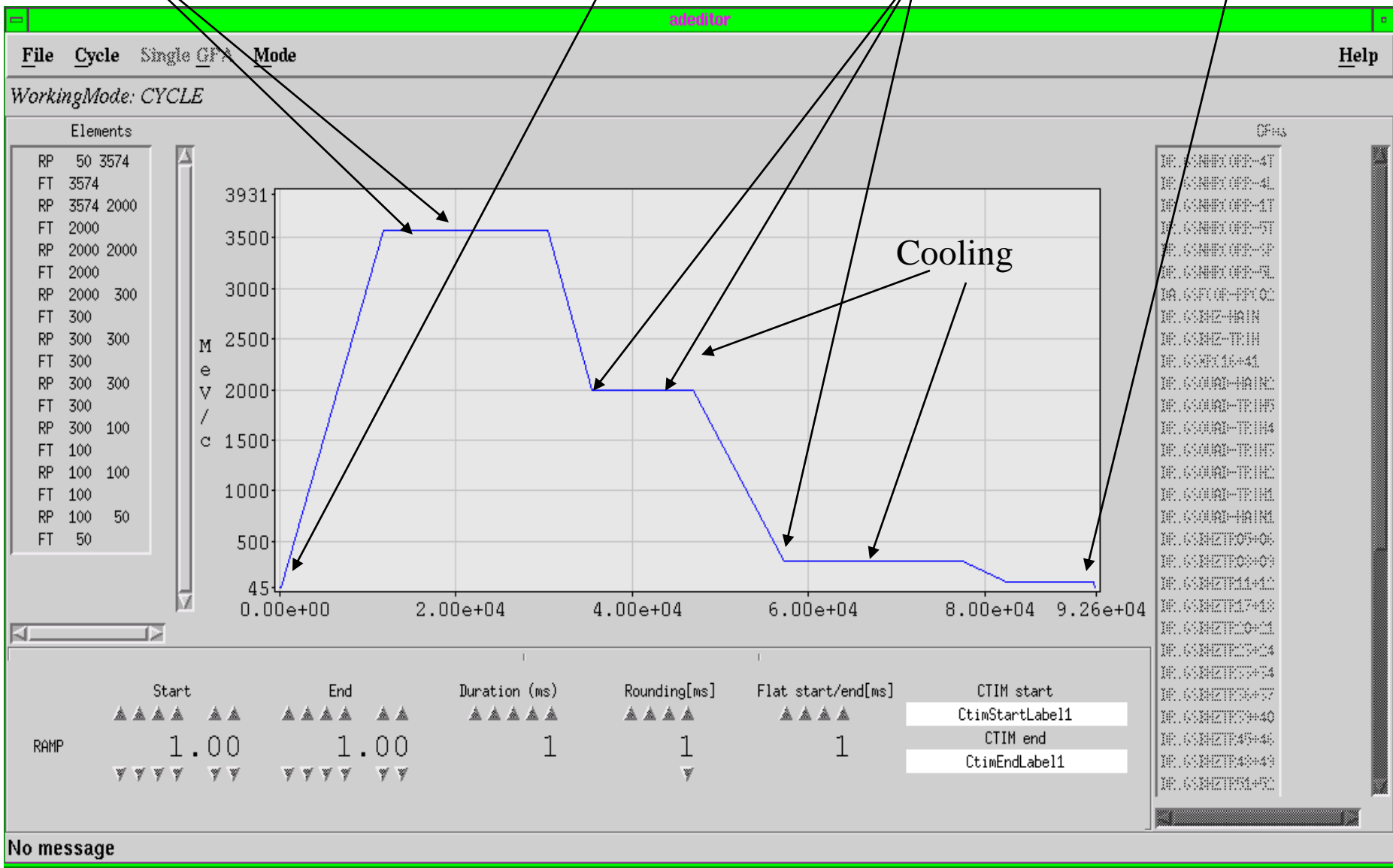
Loose coupling ADE

Injection
rendevous
points

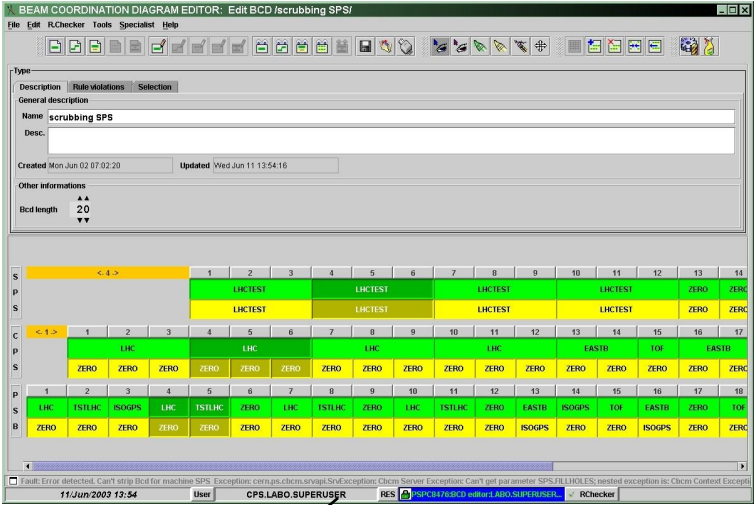
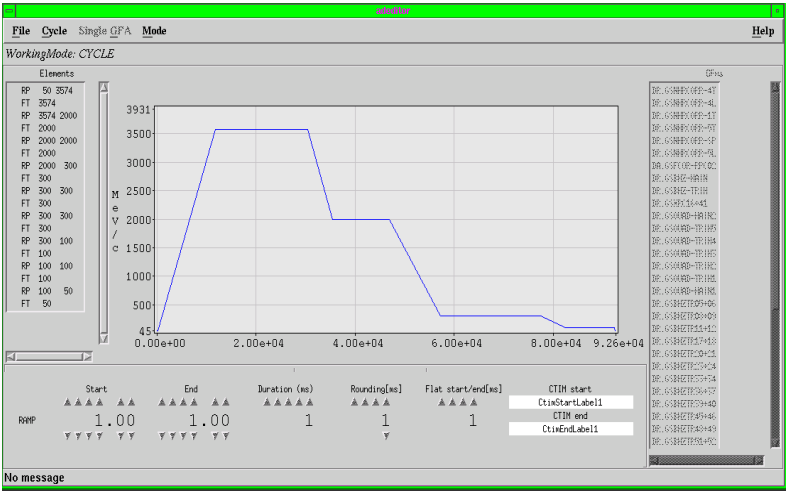
Start point

Function points

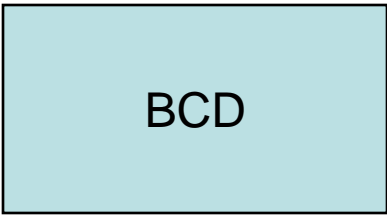
Eject antiprotons



Make MTG table



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



BCD Editor: Rule checker

Beam coordination diagram editor: Edit BCD /current hw setting/

File Edit R.Checker Tools Specialist Help

Type

Description Rule violations Selection

Route	Rule name	Error
<input checked="" type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two different CPS EAST cycles must be separated at least by 1 BP	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name
<input type="radio"/>	Two consecutive CPS EAST cycles must have the same USER name	Previous EAST user should have the same name

< -1 ->																												
C P S	1		2		3		4		5		6		7		8		9		10		11		12		13		14	
	TSTLHC				EASTC DNS7				EASTC				TOF FTN		AD FTA AD				TOF		MDPRO				LHC			
TSTLHC D3				ZERO		ZERO		EASTA				ZERO		AD				ZERO		MDPRO		ZERO		TOF		ZERO		
P S B	1	2	3	4	5	6	7	8	9	10	11	12	13	14														
	TSTLHC PS	ISOGPS BDUMP	EASTA	MDLHC	EASTA	MD2	TOF	AD	ZERO	TOF	MDPRO PSB	MDRF PSB	LHC PS	ZERO														
TSTLHC	ZERO	ISOGPS	ZERO	EASTA	ZERO	ZERO	ZERO	ZERO	ZERO	ZERO	MDPRO	ZERO	TOF	ZERO														

Applic unfrozen

15/Sep/2003 16:45 User CPS.TEST.SUPERUSER RES [shpc10163:BCD editor:TEST.SUPERUSER...](#) ✓ RChecker

Sequence manager

cern.ps.app.choosebestseq.ChooseBestSeq

File Edit Search View Specialist Help

09 Sep 03 13:57:42 Add Remove Clear Refresh Send Viewer Editor

Sequences Catalog Sequences Set Configuration Output Current Hardware Settings

Current Hardware Setting & Requests

Level	Sequence Name	Bcd Name	Description	Created	Modified	Requested
1	SPS supercycle 950	SPS Supercycle 950	Fixe target + MD	07.07.2003 16:30:24	07.07.2003 16:30:24	<input type="radio"/>
2	Fixe target - Coast	Fixe target - Coast prepare	Coast for fixe target.	07.07.2003 16:14:04	07.07.2003 16:18:56	<input type="radio"/>
		Fixe target - coast				
		Fixe target - Coast recover				
13	Zero sequence	Pulse stop SPS MPS	This Sequence is a system sequen...	07.07.2003 14:32:52	07.07.2003 15:37:32	<input checked="" type="radio"/>
		Zero Bcd				
		Pulse Start SPS MPS				

MTG Sequences Status (STRONG COUPLING Machines)

Level	Sequence Name	Sequence STATUS	Bcd Name	PSB Bcd Status	CPS Bcd Status	SPS Bcd Status
1	SPS supercycle 950	LOADED	SPS Supercycle 950			
2	Fixe target - Coast	LOADED	Fixe target - Coast prepare			
			Fixe target - coast			
			Fixe target - Coast recover			
13	Zero sequence	ACTIVE	Pulse stop SPS MPS			
			Zero Bcd	ACTIVE	ACTIVE	ACTIVE
			Pulse Start SPS MPS			

All machines are playing the last sent Sequences set.

pspc8433:ChooseBestSequence:LABO.SUPERUSER:3112 Reservation : Level Selection Configuration

Applic unfrozen

MTG diagnostic

VMTG Diagnostic Version 3.00 (Feb 19 2002)

File Run View Help

SEG_1 [1-11]		SEG_2 [13:(43):50]						SEG_3 [51-66]		ER 07
ZERO [1]	PAUSE [12]							PAUSE [50]		

SFTPRO [2]	SFTPRO [3]	EASTC [4-5]		AD [6-7]	TOF [8]	LHC [9-11]			EASTB [12-13]		EASTB [14-15]	
ZERO [2]	SFTPRO [3]	ZERO [4]	ZERO [5]	EASTC [6-7]	ZERO [8]	ZERO [9]	ZERO [10]	ZERO [11]	EASTC [12-13]	EASTC [14-15]		

SFTPRO [1]	SFTPRO [2]	EASTA [3]	STAGISO [4]	AD [5]	STAGISO [6]	TOF [7]	TSTLHC [8]	LHC [9]	STAGISO [10]	EASTB [11]	STAGISO [12]	EASTB [13]	STAGISO [14]
ZERO [1]	SFTPRO [2]	ZERO [3]	ZERO [4]	EASTA [5]	ZERO [6]	ZERO [7]	ZERO [8]	ZERO [9]	ZERO [10]	EASTA [11]	ZERO [12]	EASTA [13]	ZERO [14]

Freeze

Last Error: WARNING New supercycle activated, mask:3

PSB Cycle

Freeze Close

STAGISO 4 Normal 0

NORMAL

```

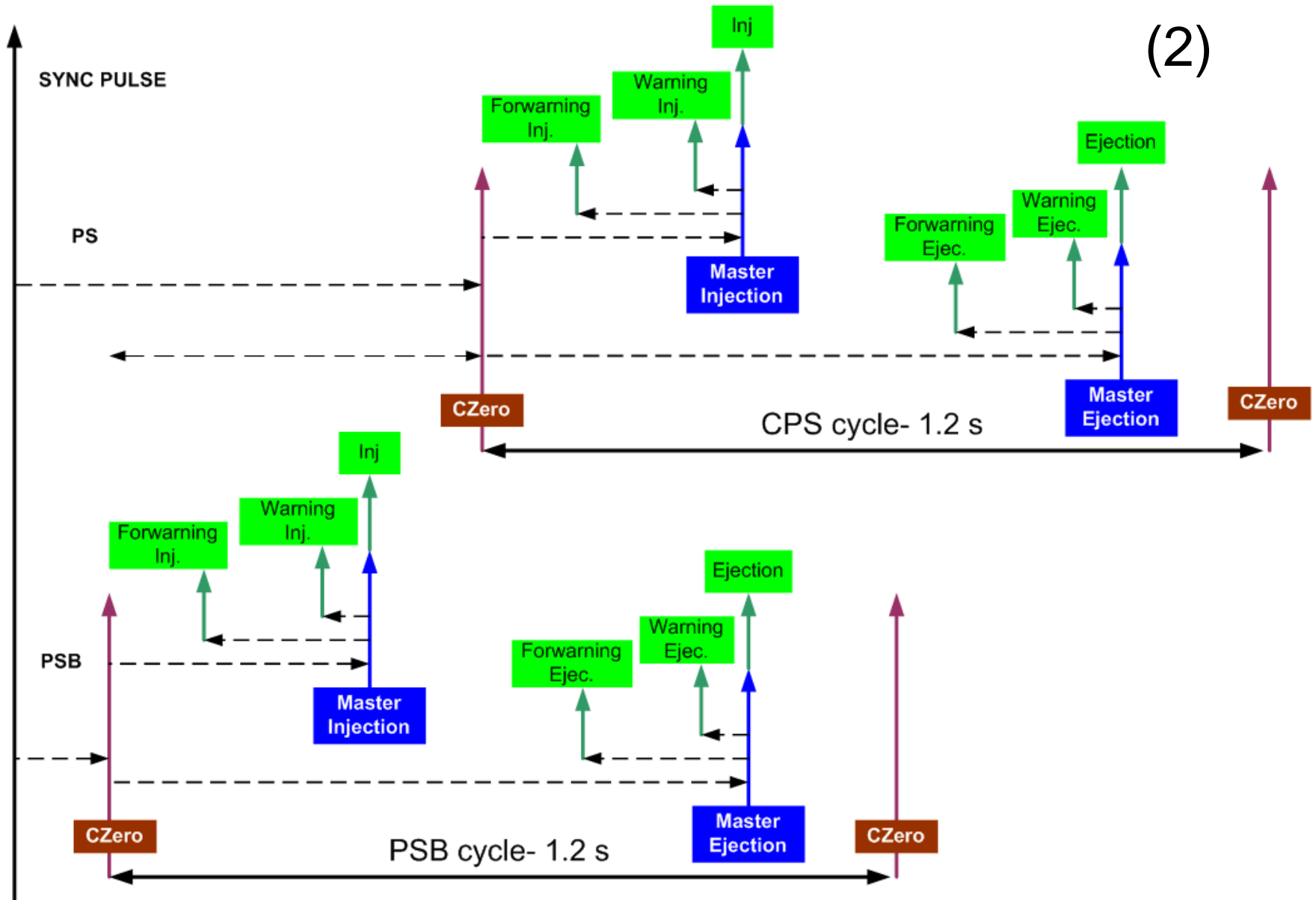
LIN3D=LOCAL
MISC=STAG
CYTAG=4868
BPNM=4
COMLN=
SCNUM=0
SPCON=
CYCLE=0
NUSER={0}
NPARTY={0}
NDEST={0}
NLIN2D={0}
NLIN3D={0}
NMISC=
NCYTAG=0

```

Thu Jul 18 15:08:20 2002
Machine:PSB -> Bad external conditions
The Beam was NOT executed.

PSB.YGPRS_RQ 'ISOLDE GPS beam request'

CTIM (2)

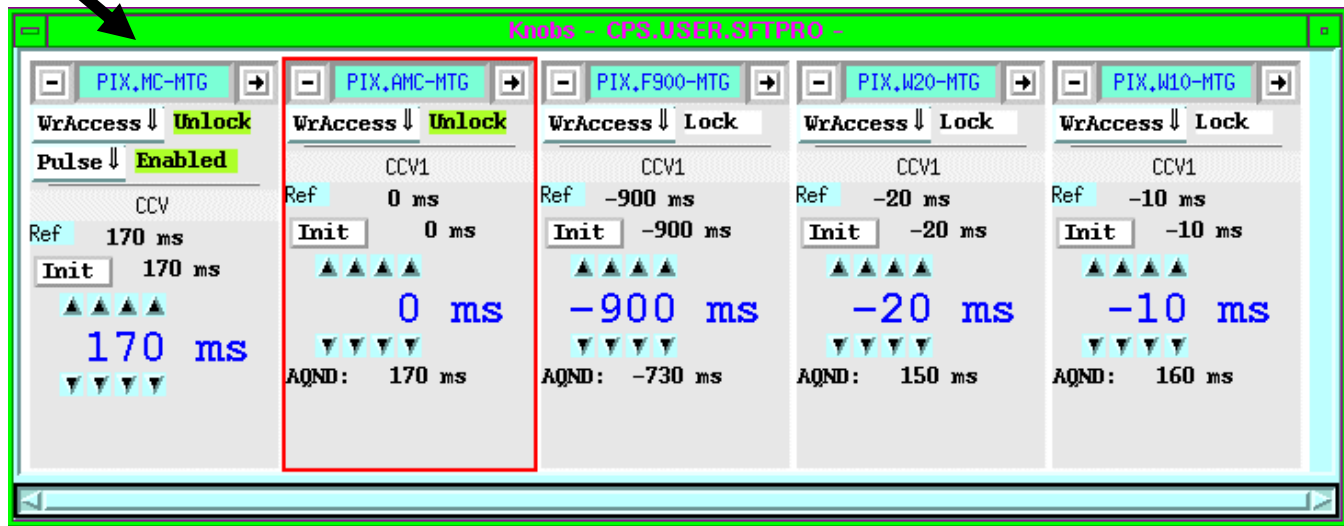


Timing events (CTIM) (3)

- Controllable by knobs in real-time

Virtual event

Key events





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