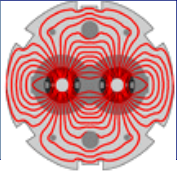


# LHC Software Interlock System

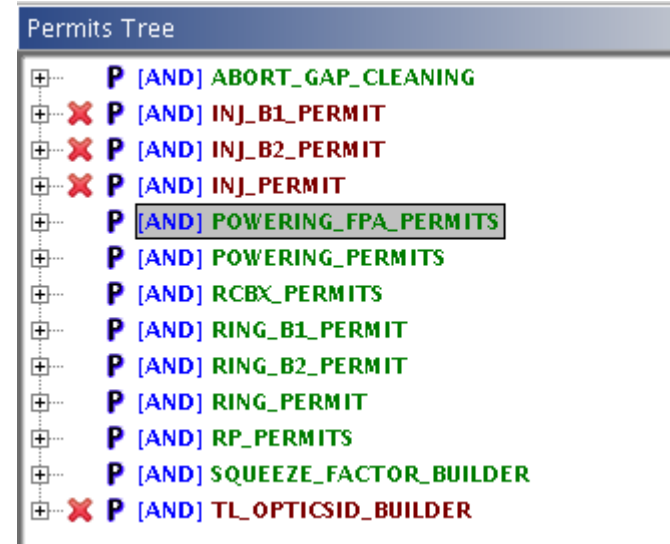
-

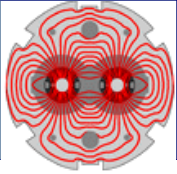
J. Wenninger, L. Ponce



## Mixed forest: new species introduced for 2015

- **3 INJECTION PERMITS:** exported to injection BICs for TI2 and/or TI8.
- **3 RING PERMITS:** exported to ring BICs (SR3 B1/2 and CCR) to abort the beam
- **RCBX PERMIT:** exported to BIC and PIC
- **POWERING\_FPA PERMIT:** exported to BIC and PIC
- **POWERING\_PERMIT:** exported to the PIC PVSS system to lock PCs.
- **RP PERMIT** taken out from RING PERMIT, only announcer
- **ABORT GAP CLEANING:** exported to abort gap cleaning controller
- **2 BUILDERS** exported to Telegram





## 3 tabs to analyze and debug a problem

Search parameters

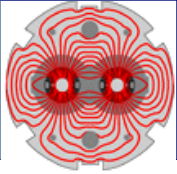
The screenshot shows the LHC SIS GUI interface. At the top, there's a menu bar with 'File', 'Operation', 'Unlatch all channels', and 'Help'. Below the menu bar, there's a toolbar with a search icon and a dropdown menu showing 'RBA: Ihcop'. The main interface is divided into several panels:

- Filtering Panel:** Contains 'Filtering Parameters' with a 'Pattern' and 'Search' input field. Below it are 'Extra Parameters' with checkboxes for 'Masked', 'Invalid', 'Latched', and 'Invalid for beam'. There are also 'Filtering Options' with checkboxes for 'Use RegExps', 'Invert filtering', and 'Flat view', along with 'Filter' and 'Clear' buttons.
- Permits Tree Panel:** Displays a tree view of permits. The root is 'Permits Tree'. The tree contains several entries, each with a status icon (green 'P' or red 'X') and a name: '[AND] ABORT\_GAP\_CLEANING', '[X] [AND] INJ\_B1\_PERMIT', '[X] [AND] INJ\_B2\_PERMIT', '[X] [AND] INJ\_PERMIT', '[AND] IPO\_POWERING\_PERMITS', '[AND] POWERING\_FPA\_PERMITS', '[AND] POWERING\_PERMITS', '[AND] RCBX\_PERMITS', '[AND] RING\_B1\_PERMIT', '[AND] RING\_B2\_PERMIT', '[AND] RING\_PERMIT', '[AND] RP\_PERMITS', '[X] [AND] SQUEEZE\_FACTOR\_BUILDER', and '[AND] TL\_OPTICSID\_BUILDER'. At the bottom of this panel, there are controls for 'Depth' (set to 1), 'Show', 'Expand All', 'Collapse all', and 'Font size' (+1, -1, Reset).
- Properties Panel:** Shows the 'Properties' tab for the selected permit 'RING\_B1\_PERMIT'. It includes fields for 'Id', 'Name', 'Description', 'Is maskable', 'Masking protection', 'Is latchable', 'Latching protection', and 'Mask effect' (highlighted in cyan as '(UNDEFINED)'). There are also sections for 'Counters' (Slot, Max Value, Policy, PPM?) and 'Exporters' (Id, Name, Class / Bean id, Description). The 'Exporters' section contains three tables, each with columns for 'Id', 'Name', 'Class / Bean id', and 'Description'. The first table has one entry: 'BicExporter'. The second and third tables have one entry each: 'pmLogExporter' and 'pmExporter'.

At the bottom of the GUI, there's a 'Console' panel showing running tasks and a 'Combined' view with log messages: '14:50:22 - LastPerformed login is: LOCATION' and '14:50:22 - Token is still valid (lifetime > 1 hour)'. The system tray at the very bottom shows the time '14:12:24' and the status 'All channels unlatched'.

Permit trees

AND/OR logic displayed



Properties \ Analysis \ Operations \

**Id:** INJ\_PERMIT.PC-CURRENTS.RB-CURRENTS.RB\_A12\_INTOL

**Name:**

**Description:** Checks that the PC current is within tolerance (defined range)

**Is maskable:** true

**Masking protection:** DEFAULT

**Is latching:** false

**Latching protection:** DEFAULT

**Mask effect:** **CRITICAL**

**Tags:**

**Counters:**

Slot	Max Value	Policy	PPM?
DEFAULT	1	RESET	true

**Exporters:**

**Condition:**

**Id:**

**Name:**

**Description:**

**Type:** SIMPLE

**Init value:** true

**Cycle aware:** false

**Acq window:** 6000

**Parameter id:** RPTE.UA23.RB.A12\_DATA

**Field:** I\_MEAS

**Index:** -1

**Operator:** IN\_RANGE

**Value:** [755;759]

**No value policy:** FALSE

**Class/Bean id:**

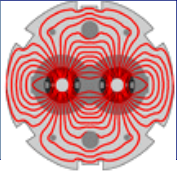
**Class config:**

**Factory class:**

**Script lang:** Groovy

**Script:**

- Details of the selected parameters:
  - Name, description
  - Attributes
  - Exporters list
  - Evaluation logic
  - No value policy
  - ....



Properties \ Analysis \ Operations \ Analysis (INJ\_B1\_PERMIT.MKI2\_STATUS.MKI2\_TEMP)

Actions Freeze

Events

- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1
- Event on LHC.USER.ALL.HX.BPNM-CT, counter=1

defined in configuration] UNLATCHED

[C.USER.ALL.HX.BPNM-CT]

TEMP\_MKI2 == <Click for value>

```
temperatureFW_D (float:1) -> 24.706251
temperatureDownTubeA (float:1) -> 21.0
temperatureTunnel (float:1) -> 24.8
temperatureRCP5_B (float:1) -> 25.3
temperatureRCP5_A (float:1) -> 25.0
temperatureSwitchMain_D (float:1) -> 38.40001
temperatureSwitchMain_C (float:1) -> 38.40001
temperatureSwitchMain_B (float:1) -> 37.700012
temperatureSwitchMain_A (float:1) -> 37.0
temperatureSwitchDump_D (float:1) -> 38.40001
temperatureSwitchDump_C (float:1) -> 39.100006
```

SISREF\_TEMP\_REF\_MKI2 == <Click for value>

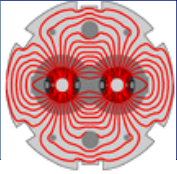
Result:

```
received from MKITempMagnetLimitsB1/Temp -> Header[acqSt
signature (String:1) -> 8d08cdd37ff4e3331b523163c855ee0c
imits (double[]:8) -> 52.0, 50.0, 52.0, 50.0, 52.0, 50.
```

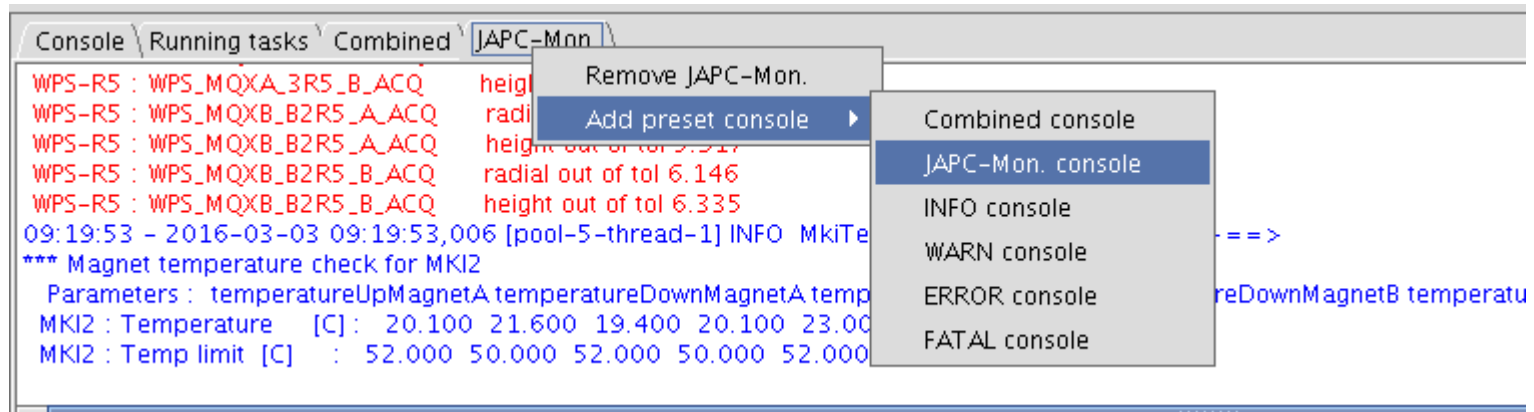
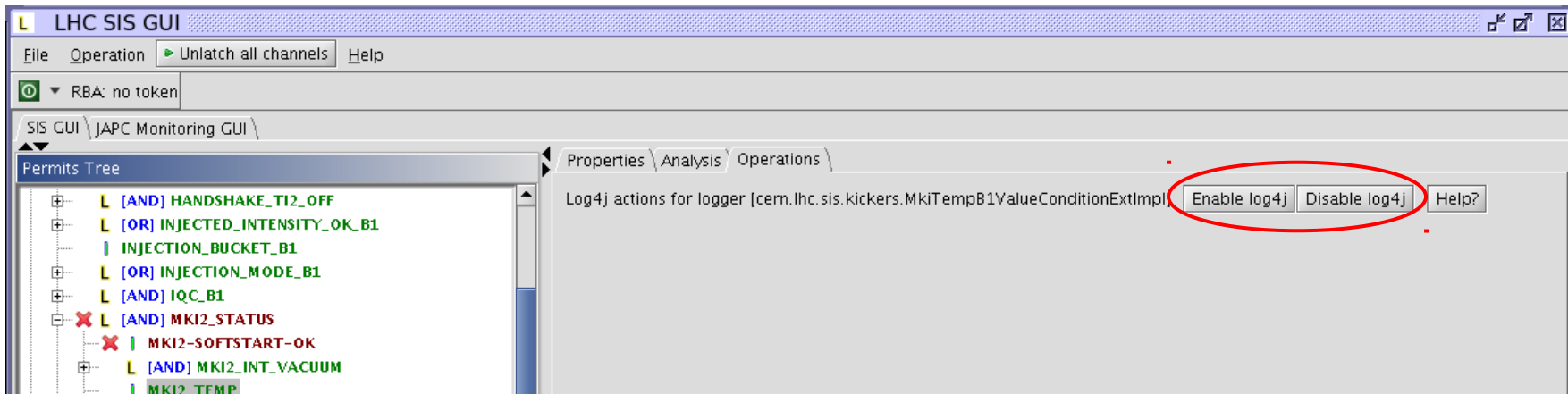
Parameter id = [TEMP\_MKI2]  
Parameter name = [null]  
Field name = [null]  
Array index = [null]  
Cycletstamp = [null]

Parameter id = [SISREF\_TEMP\_REF\_MKI2]  
Parameter name = [null]  
Field name = [null]  
Array index = [null]  
Cycletstamp = [null]

- ❑ Result of the evaluation
- ❑ Details of the read value for complex parameters
- ❑ History of the evaluation

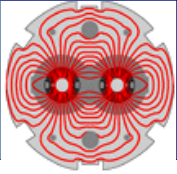


- Give more details on parameters evaluation for complex parameters if implemented in the code:
  - Appearing in the JAPC-console





# Parameter Monitoring



LHC SIS GUI

File Operation ▶ Unlatch all channels Help

Launch Monitoring GUI

Launch SIS GUI

Exit

Permits Tree

- [AND] HANDSHAKE\_TI2\_OFF
- [OR] INJECTED\_INTENSITY\_OK\_B1
- INJECTION\_BUCKET\_B1
- [OR] INJECTION\_MODE\_B1
- [AND] IOC B1

LHC SIS GUI

File Operation Help

RBAC response

SIS GUI \ JAPC Monitoring GUI \

Modules Status				Parameters Status										
Paramete...	Parameter name	Last up...	Cycle St...	Selector	SlotAwa...	pmCont...	logger	oscProtect	falseV...	checker	SIS	Updat...		
BA4.RQID	BA4.RQID.400100/interlock	16:22...	145.68...	SPS USE...										
BA4.RQID	BA4.RQID.400300/interlock	16:22...	145.68...	SPS USE...										
BA4.RQID	BA4.RQID.80100/interlock	16:22...	145.68...	SPS USE...										
BA4.RQID	BA4.RQID.80300/interlock	16:22...	145.68...	SPS USE...										
BA4.RQID	BA4.RQID.400200/interlock	16:22...	145.68...	SPS USE...										
BA4.RQID	BA4.RQID.400400/interlock	16:22...	145.68...	SPS USE...										
BA4.RQIF	BA4.RQIF.80200/interlock	16:22...	145.68...	SPS USE...										
BA6.RQID	BA6.RQID.61010													
BA6.RQID	BA6.RQID.61020													
BA6.RQID	BA6.RQID.61030													
BA6.RQIF	BA6.RQIF.61020													
BA6.RQIF	BA6.RQIF.61040													
BA6.RQIF	BA6.RQIF.61060													
BA7.RQID	BA7.RQID.20100													
BA7.RQID	BA7.RQID.20300													
BA7.RQID	BA7.RQID.20500													
BA7.RQIF	BA7.RQIF.20200													
BA7.RQIF	BA7.RQIF.20400													
BA7.RQIF	BA7.RQIF.20600													
BIC_ACCE	BIC_CCR.LHC.B1/E													
BIC_ACCE	BIC_CCR.LHC.B2/E													
BIC_INJ1	BIC.SP8.INJ1.2/B0													
BIC_INJ2	BIC.SP8.INJ2.2/B0													
BIC_SISACQ	BicSis.CCR/Hardw													
BPTDH.A	LHC.BPTDH.A4L1													
BPTDH.A	LHC.BPTDH.A4L2													
BPTDH.A	LHC.BPTDH.A4L5													
BPTDH.A	LHC.BPTDH.A4L6													
BPTDH.A	LHC.BPTDH.A4L8													
BPTDH.A	LHC.BPTDH.A4R1													
BPTDH.A	LHC.BPTDH.A4R2													
BPTDH.A	LHC.BPTDH.A4R5													

Stop parameter monitoring

Start parameter monitoring

Restart parameter monitoring

Check parameters for SlotAwareSIS

Uncheck parameters for SlotAwareSIS

Check parameters for pmController

Uncheck parameters for pmController

Check parameters for logger

Uncheck parameters for logger

Check parameters for oscProtect

Uncheck parameters for oscProtect

Check parameters for falseValueChecker

Uncheck parameters for falseValueChecker

Check parameters for checker

Uncheck parameters for checker

Check parameters for SIS

Uncheck parameters for SIS

Check parameters for UpdateEvent

Uncheck parameters for UpdateEvent

New parameter

Edit parameter

Delete parameter

Save configuration

Show date/timestamp

Filter: Module name Search Status

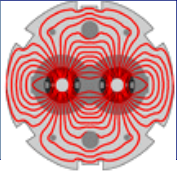
Module name	Status
SlotAwareSIS	OK
pmController	OK
logger	OK
oscProtect	OK
falseValueChecker	OK
checker	OK
SIS	OK
UpdateEvent	OK

Console \ Running tasks \ Combined \ JAPC-Mon. \

16:22:03 - New login context created, loginPolicy: DEFAULT

12:16:53 - Connection with the Core reestablished

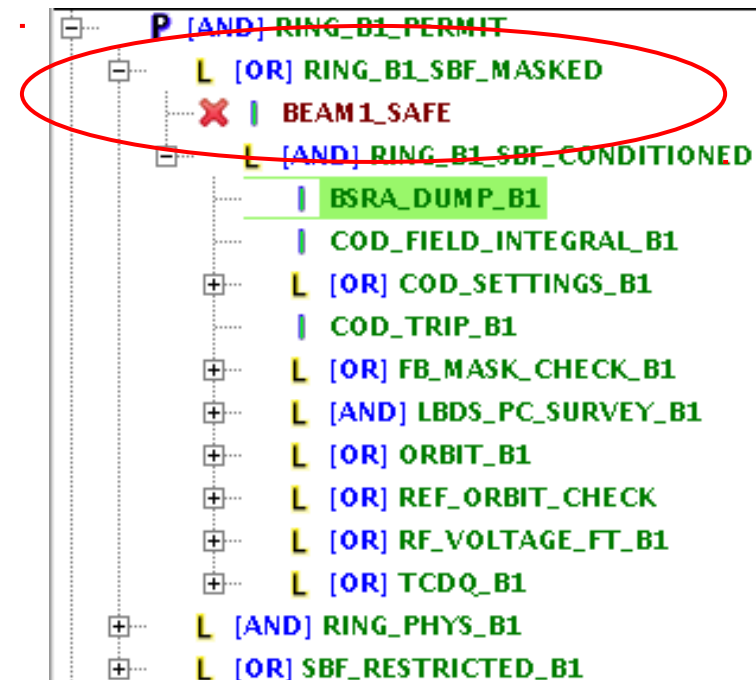
- Restart subscription:
  - RBAC protected in LHC SIS
- Many more options available



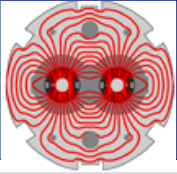
- ❑ 2 different masking “level” in SIS: from GUI or inside the logic
- ❑ GUI: each interlock test is declared **maskable** or **unmaskable** (hardcoded in the parameter configuration):
  - Masking done via the SIS GUI application :
    - **Independent of Set-up Beam Flag.**
    - Allowed for all holders of RBAC roles : LHC-EIC, MCS-SIS

- ❑ Interlocks combined by an OR logic with the **Setup Beam flag = true** conditions or **Beam mode**:
  - Allow to make interlocks unmaskable
  - All branches logic tested but active only for high intensity or in a given mode

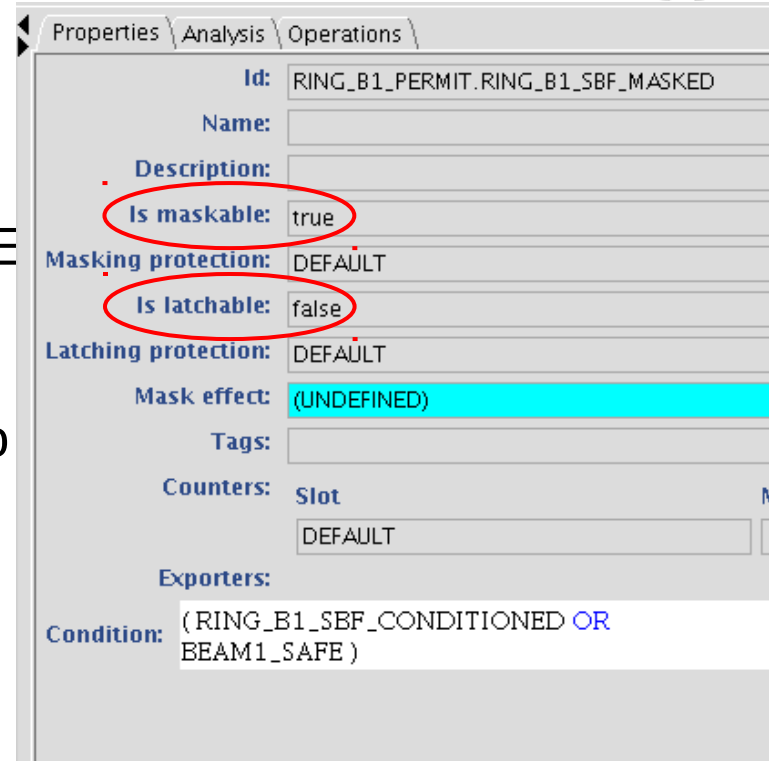
=> important not to force SAFE BEAM FLAG for loss maps...



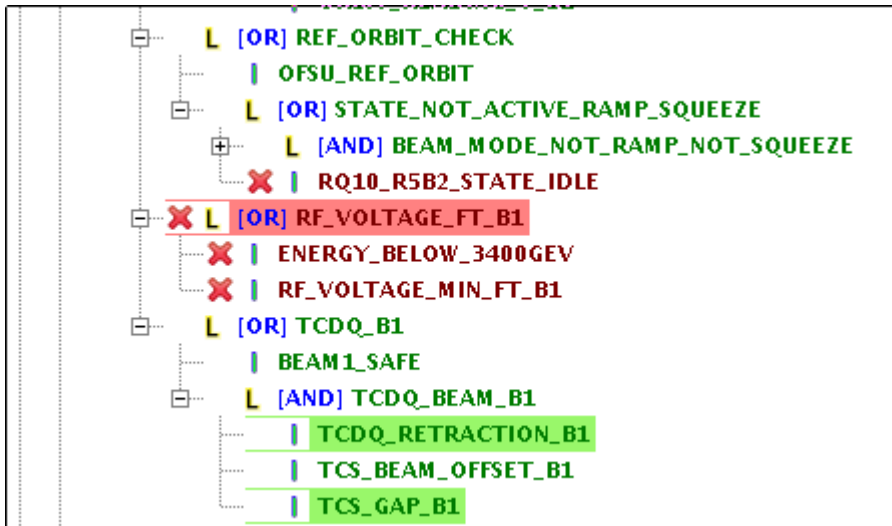


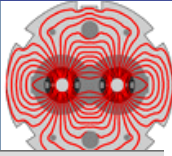


- ❑ 2 status declared inside the logic:
  - Is latchable = true/false
  - Is maskable = true/false
- ❑ A masked node is considered always TRUE
  - **GREEN background** in the display
- ❑ A node of the tree could LATCH:
  - Stay False after transition till OP action to unlatch (GUI or sequencer)
  - **RED background** in the display



Note: sequencer tasks available to unlatch/unmask tests automatically





- ❑ Can filter on masked/latched to see immediately all active
- ❑ Masking is protected by RBAC in the GUI:
  - Personnel login
  - Reason mandatory
- ❑ Possible to mask by family (TAG) predefined in the code:
  - Few available

**Action input dialog**

Please, specify a reason for the action:

User: null

Reason:

**Tags to select**

<input type="checkbox"/> QPS_OK	<input type="checkbox"/> TIM_SIGNAL	<input type="checkbox"/> RING_B2
<input type="checkbox"/> RING_B1	<input type="checkbox"/> SEQ_UNLATCH	<input type="checkbox"/> RQ_PERMIT
<input type="checkbox"/> RF_HOM	<input type="checkbox"/> ADT	<input type="checkbox"/> INJECTION
<input type="checkbox"/> ORBIT	<input type="checkbox"/> INJ_B2	<input type="checkbox"/> INJ_B1
<input type="checkbox"/> RCBX_PERMIT		

OK Cancel

SIS GUI | JAPC Monitoring GUI

### Filtering

**Filtering Parameters**

Pattern:

Search:

**Extra Parameters**

Masked  Latched  Valid  
 Invalid  Invalid for beam

**Filtering Options**

Use RegExps  Invert filtering  'Flat' view

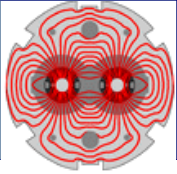
Filter! Clear

### Permits Tree

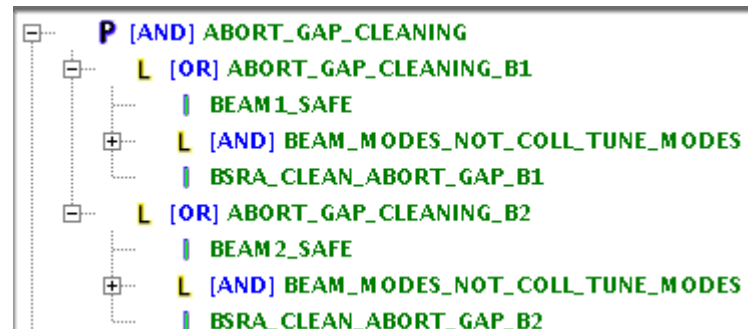
- ✗ P [AND] INJ\_B1\_PERMIT
  - L [AND] HANDSHAKE\_TI2\_OFF
    - ALICE\_HSH\_TI2\_OFF
- ✗ L [AND] PC-CURRENTS-B1
  - RU\_R4\_INTOL
- ✗ L [AND] PC-STATES\_B1
  - ✗ L [AND] PC-STATES\_S34\_B1
    - ✗ L [AND] RO-RCD-STATES\_S34\_B1
      - ✗ I RCD\_A34B1\_STATE\_PC
      - ✗ I RCO\_A34B1\_STATE\_PC
  - ✗ L [AND] WARM-MAG-PC-STATES\_B1
    - ✗ L [AND] RGMW-STATES\_B1
- ✗ P [AND] INJ\_B2\_PERMIT
  - ✗ L [AND] PC-STATES\_B2
    - ✗ L [AND] PC-STATES\_S56\_B2
      - ✗ L [AND] RS-STATES\_S56\_B2
        - ✗ I RSS\_A56B2\_STATE\_PC
    - ✗ L [AND] PC-STATES\_S67\_B2
      - ✗ L [AND] RO-RCD-STATES\_S67\_B2
        - RCD\_A67B2\_STATE\_OP
        - ✗ I RCD\_A67B2\_STATE\_PC
        - ✗ I RCO\_A67B2\_STATE\_PC
  - ✗ L [AND] PC-STATES\_S78\_B2

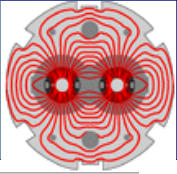
Depth: 1 Show Font size: +1 -1 Reset

**Expand All** Collapse all

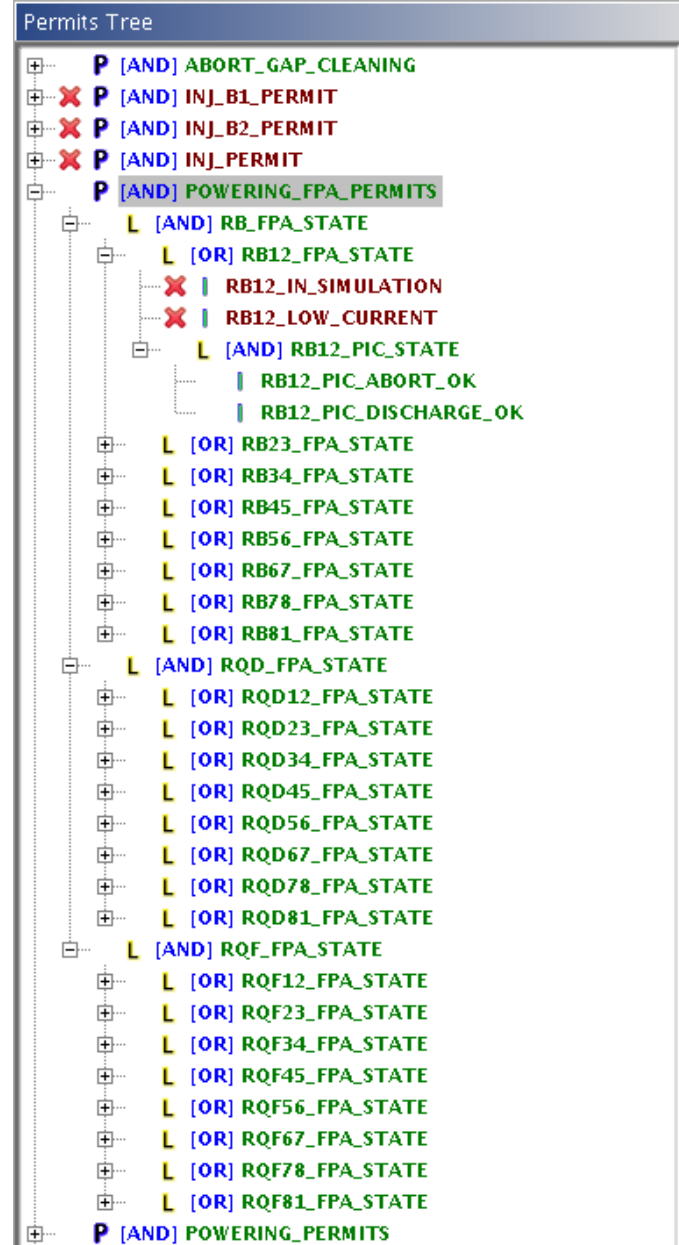


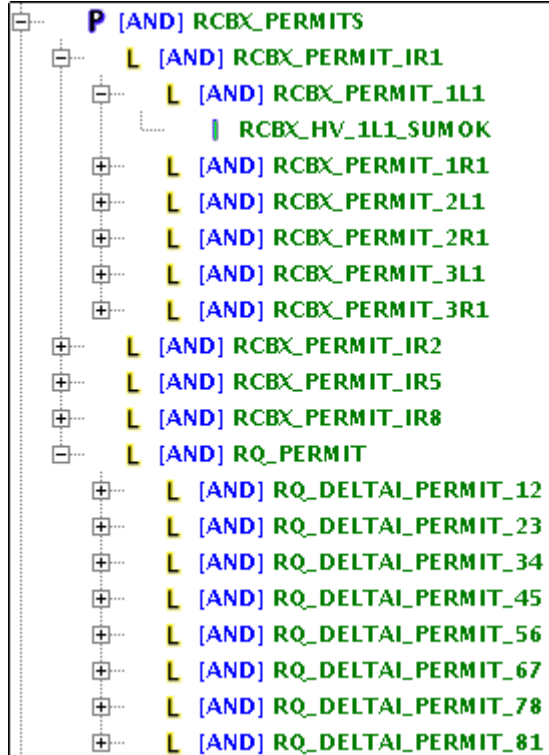
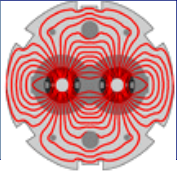
- ❑ Based on Abort Gap monitor, request to activate the cleaning sent by SIS
  - AG cleaning activated on change
  - Default cleaning settings used
- ❑ Logic conditioned by beam mode and beam intensity



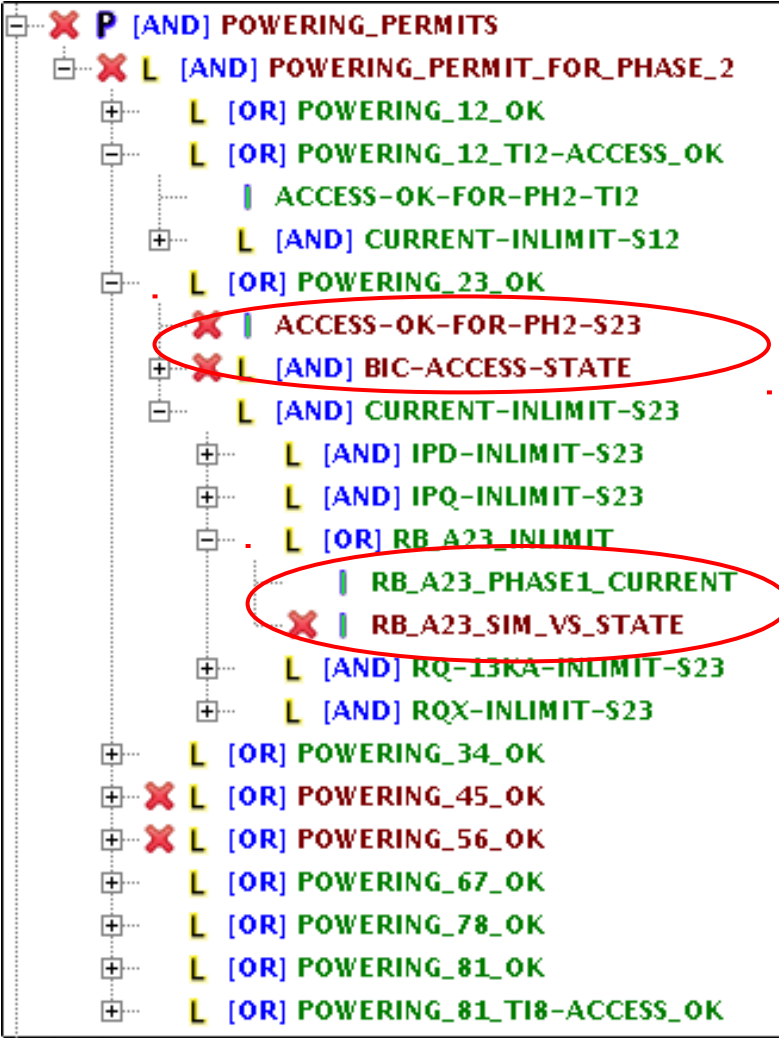
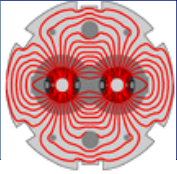


- ❑ New interlock introduced to cope with possible failure of the quench loop
- ❑ Export to BIC in point 7 to dump the beam and to PIC to open switches

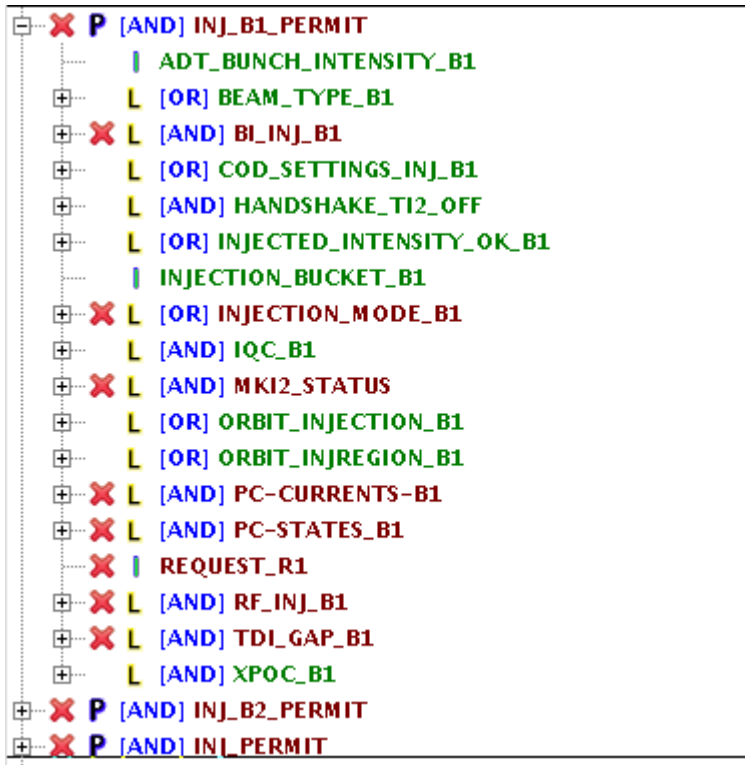
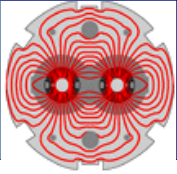




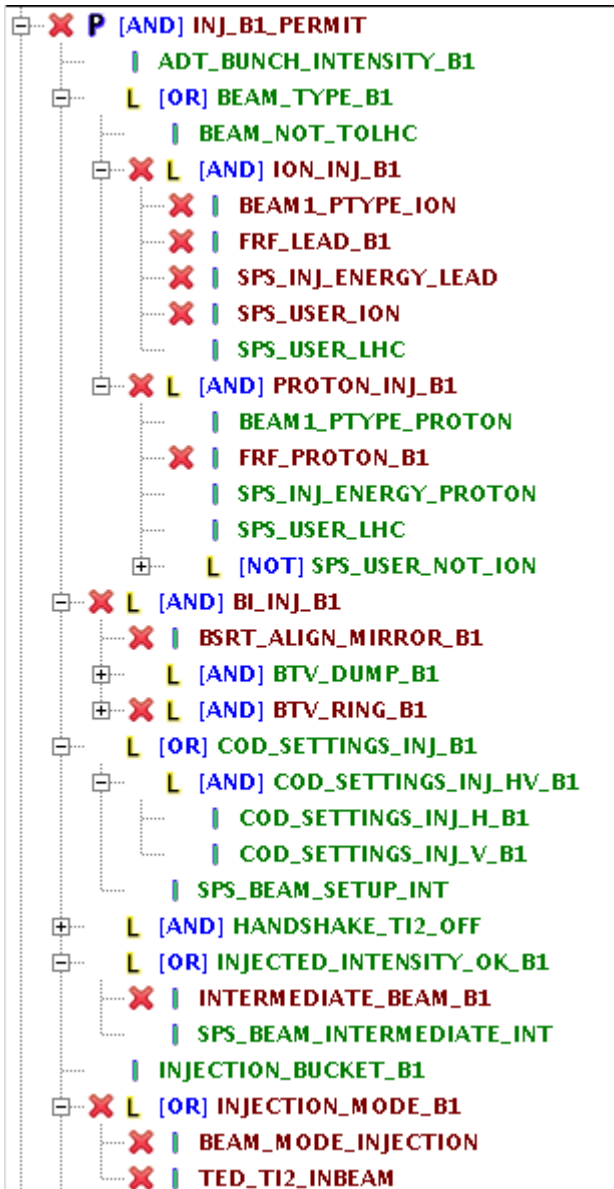
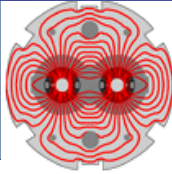
- ❑ Balanced powering of the circuits
- ❑ Export to PIC



- ❑ Abort powering if access conditions for powering phase 2 are broken
- ❑ One branch per sector
- ❑ Masking:
  - Global masking by the whole LHC closed signal (except TI2/TI8)
  - Also masked by PC in simulation mode for test
- ❑ Exporters to PIC at each branch level

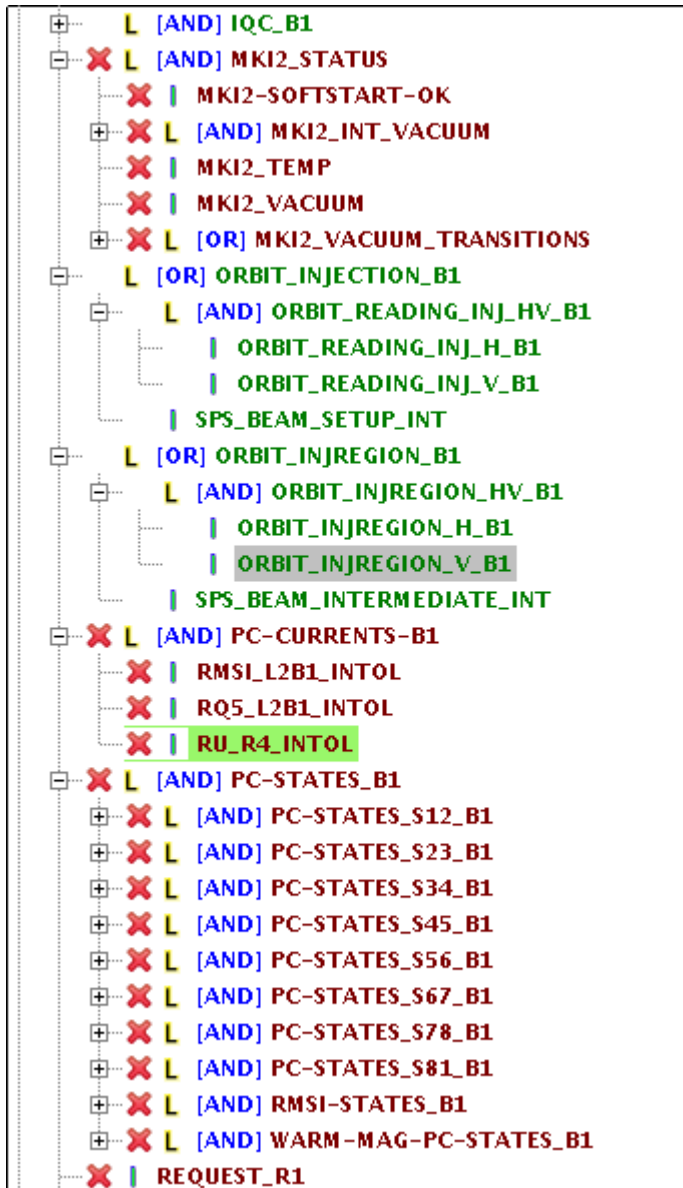
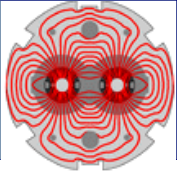


- ❑ Splitted in permits for B1, B2 and both beams
- ❑ Blocking injection → no beam dump

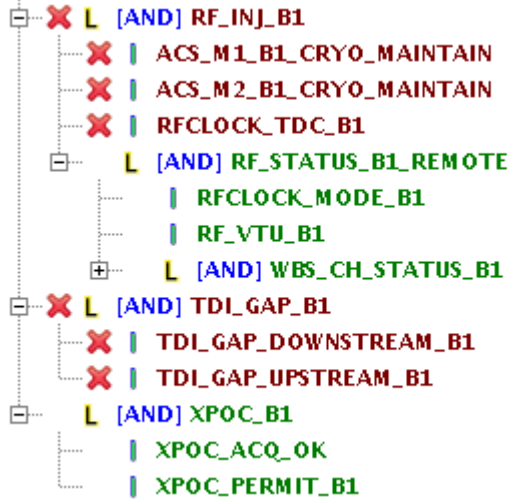
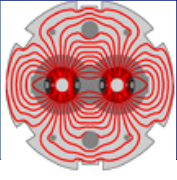


Test	Coverage	Comments
ADT bunch intensity		To protect ADT from too high intensity
Beam type	Telegram and TT10	Check ions/proton configuration
BTV position	Ring and dump line BTVs	
BSRT	Alignment mirror position	
COD settings	All CODs	Avoid injecting with large injection oscillation
TL handshakes	IP2 and IP8	Allow extraction till TED
Injected intensity		Cannot inject trains in empty machine
Injected bucket	over-injection protection	
Injection mode		Avoid injecting with wrong mode

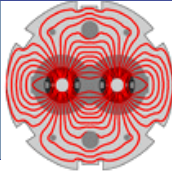




Test	Coverage	Comments
(Pre)-op checks	IQC	Latch + injection oscillation
MKI temperature	MKI magnets	Max values (MCS) per magnets
MKI vacuum	Magnets and interconnect	Problem of timeout on publication fixed
Injection orbit		Avoid injecting with large injection oscillation
Orbit in injection region	IP2 and IP8 spectrometers	
PC currents	MSI, RQ5 and RU	
PC states	All PCs	
Injection Request	CBCM request	Only true when request accepted



Test	Coverage	Comments
RF	Synchronisation Cryo maintain Status	
TDI Gap		Avoid injecting with TDI opened
(Pre)-op checks	XPOC	

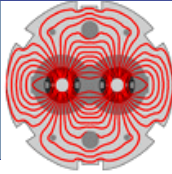


```

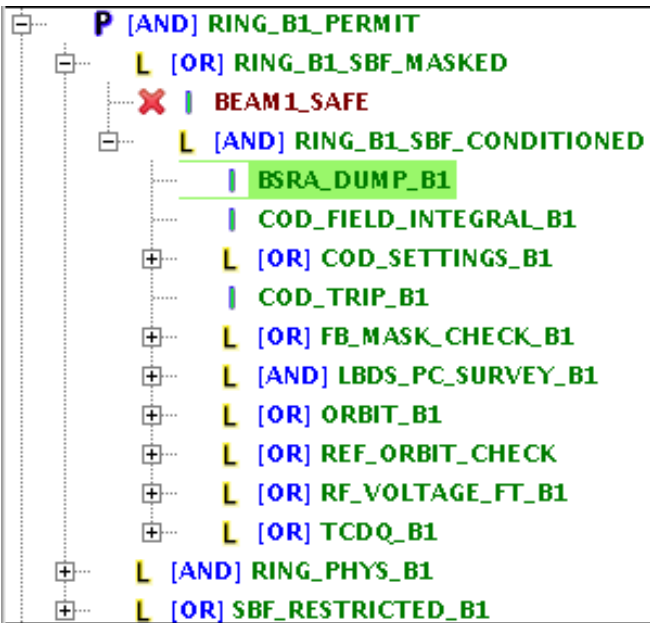
- [X] P [AND] INJ_PERMIT
  + [X] L [AND] BIC_PREOP_CHECKS
  + [X] L [AND] BLM_THRESHOLD_TABLE_STATUS
  + [X] L [AND] DP_TRIM_RT
  | INJECTION_BUCKET
  | INJECTION_ENERGY
  | MAX_BUNCH_REQUEST
  + [X] L [AND] PC-CURRENTS
  + [X] L [AND] PC-STATES
  + [X] L [AND] POST_MORTEM
  + [X] L [AND] QPS-STATE
  + L [OR] RF_INJ
  | SMP_PREOPS_CHECK
  + [X] L [AND] VENTILATION_DOORS_OK
  + [X] L [AND] WPS_IT
  
```

□ Max bunch request because of TDI limitations

Test	Coverage	Comments
(Pre)-op checks	BIC, BLM status, SMP	
RF RT trim	Radial modulation OFF	
Injection bucket	Abort gap protection	
Energy	Injection energy	
PC currents	RB, RQ, RD, MCBX	Extended to IPQ
PC states	All PCs	
(Pre)-op checks	Last postmortem	
QPS_OK	All circuits with QPS	Avoid injecting with wrong mode
RF Inj	RF diff between B1/b2	Masked by beam type
Ventilation doors	Non LASS interlocked doors	Include IP7 doors
Triplet alignment	WPS in all IRs	

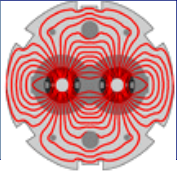


❑ Interlocks masked by SETUP BEAM flag

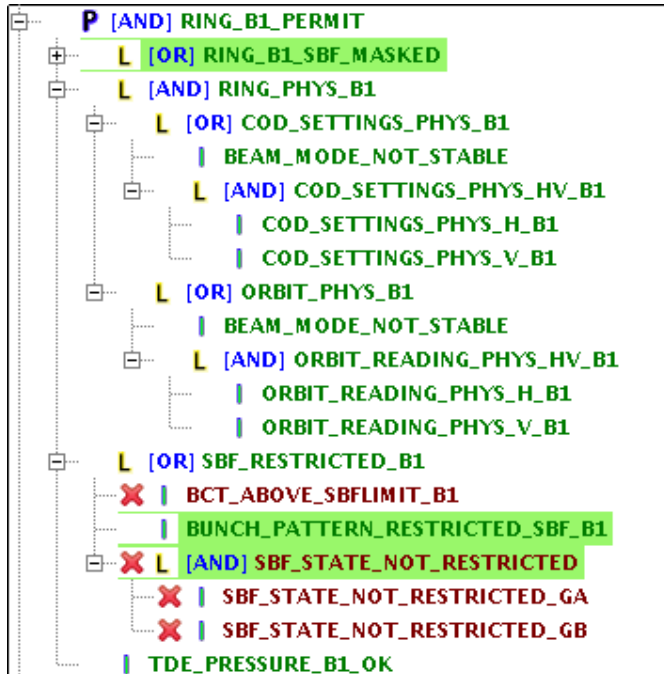


=> Maskable in green

Test	Coverage	Comments
BSRA DUMP	AG population	
COD integral	All arc Hor. CODs	$dp/p < 0.2\%$
COD settings	All CODs for ramp, squeeze and adjust	Achievable tolerances depend on orbit stability
COD trip	COD with larger kicks	Achievable tolerances depend on orbit stability
FB masks	RAMP & SQUEEZE	Dump if >25% of BPM disabled
LBDS (BETS)	Q4 and MSD in IR6	
Orbit	All ring BPMs	Achievable tolerances depend on orbit stability
Ref orbit		
RF voltage	Energy > 3.4 TeV	More strict for min limit that the internal interlock
TCDQ – beam	Beam center in TCSG, (TCSG gap, TCDQ-TCSG retraction)	Achievable tolerances depend on orbit stability

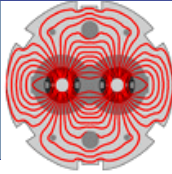


## ❑ Interlocks active in STABLE BEAMS

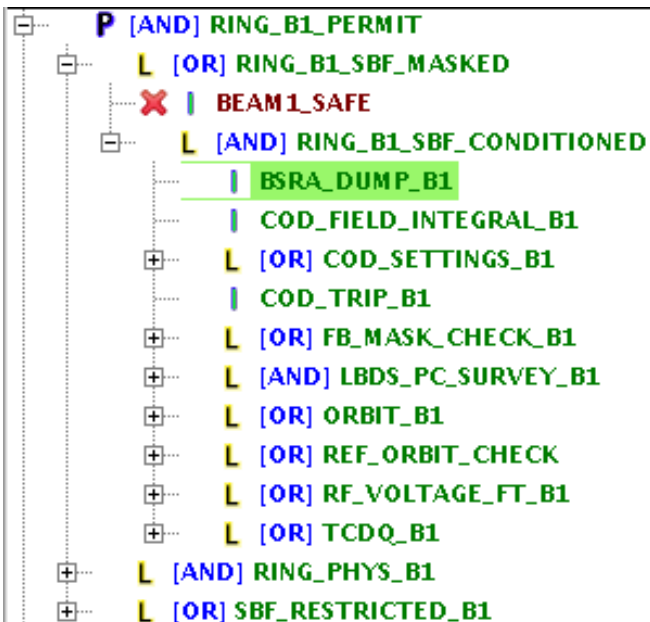


Test	Coverage	Comments
COD settings	All CODs in STABLE BEAMS	Achievable tolerances depend on reproducibility and variation in ramp & squeeze
Orbit	All ring BPMs	Achievable tolerances depend on orbit stability

- ❑ TDE pressure check added end of 2015
- ❑ Special logic for the SBF restricted limit depending on bunch pattern:
  - Not used yet

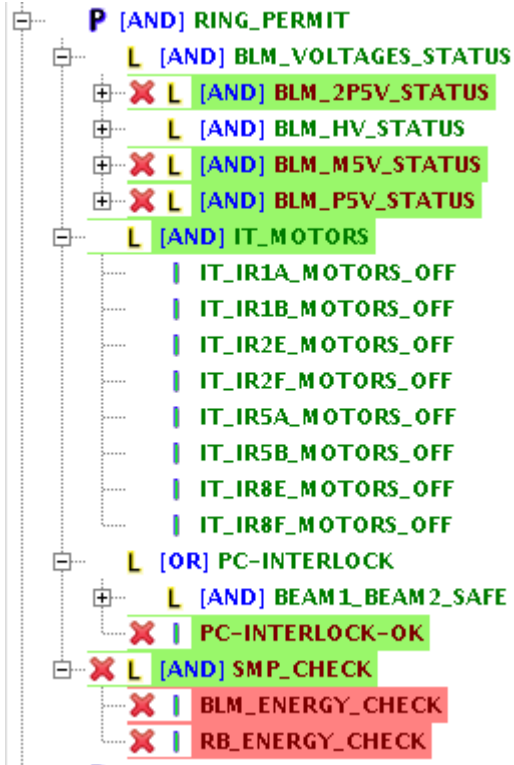
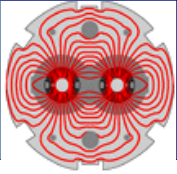


❑ Interlocks masked by SETUP BEAM flag



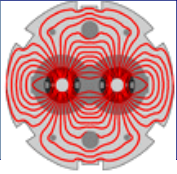
=> Maskable in green

Test	Coverage	Comments
BSRA DUMP	AG population	
COD integral	All arc Hor. CODs	$dp/p < 0.2\%$
COD settings	All CODs for ramp, squeeze and adjust	Achievable tolerances depend on orbit stability
COD trip	COD with larger kicks	Achievable tolerances depend on orbit stability
FB masks	RAMP & SQUEEZE	Dump if >25% of BPM disabled
LBDS (BETS)	Q4 and MSD in IR6	
Orbit	All ring BPMs	Achievable tolerances depend on orbit stability
Ref orbit		
RF voltage	Energy > 3.4 TeV	More strict for min limit that the internal interlock
TCDQ – beam	Beam center in TCSG, (TCSG gap, TCDQ-TCSG retraction)	Achievable tolerances depend on orbit stability



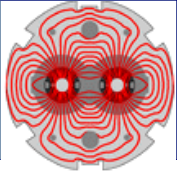
Test	Coverage	Comments
BLM HV	All BLM crates	Dump if HV link lost, complement for sanity checks
IT motors movement	All IPs	check motor status
PC interlock	All 60A CODs	Dump if 2 CODs out of tolerance
SMP energy distribution	All BLM crates	Verify energy across all BLM crates
SMP energy	All RBs, SMP energy	0.2% to 2% (ramp or not)

=> BLM HV only maskable at crate level



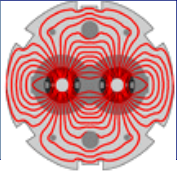
- Complex interlocking logic to limit global orbit excursion and catch undetected bumps (COD settings)
- Tolerances depend on beam modes and ring positions
  - For non-IR region:
    - $\pm 2$  mm for injection (2 BPMs trigger)
    - 1 mm for dump in all modes (15 BPMs trigger)
    - 0.6 mm for dump in stable beams (15 BPMs trigger)
  - In the IR (1+2+5+8): more complex because of specific conditions (VdM, low beta...)
- CODs settings checks is redundant with the PC interlock, will be replaced as soon as PC interlock is validated
  - For injection, tolerance is 15 urad
  - For dump logic, between 12 and 20 urad, but have to exclude Xing, sep and lumi CODs due to large change during cycle
- Still masked in 2015 to get more experience





- 15 dumps caused by SIS in 2015:
  - 7 caused by TGM timeout problem
  - 4 caused by communication problem with BLM crate
  - 3 due to subscription problems: Safe Beam Flag “blocked” to false without beam in the machine, IT motors surveillance
  - 1 due to real interlock
    - IR6 BPM faulty channel triggered the TCS-beam offset interlock

=> Nothing related to intensity



## ➤ TGM timeout problem:

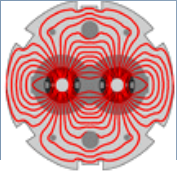
- Telegram signal is lost for long period (up to 25s) on SIS machine,
- Logic programmed such that after a programmed timeout, default energy value is 450GeV -> beam dump at 6.5 TeV by COD settings...
- CO experts working on finding a solution, In the meantime, timeout has been increased and default energy value is set to 6.5 TeV .

=> No news, still longer timeout

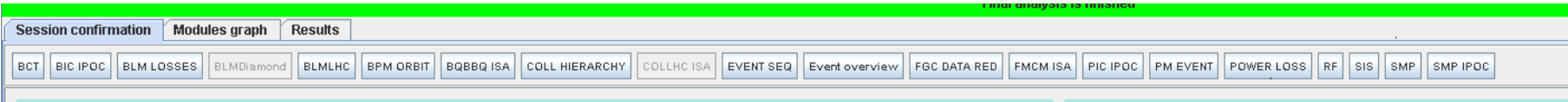
## ➤ BLM-SIS communication problem:

- Some BLM crates (in pt 6 and 7) are becoming unstable, when additional readout are coming (UFO buster, XPOC, IQC..) 1 Hz readout data is blocked and SIS triggered
- BI experts investigating, in the meantime, UFO buster disabled.

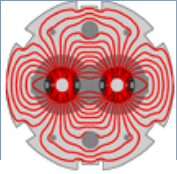
=> Fixed



- There is a new PM module for the SIS that decodes the information and presents it in graphical / readable form.



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st-  
Po  
SIS



- There is a new PM module for the SIS that decodes the information and presents it in graphical / readable form.

