Objects that can move into the Beams

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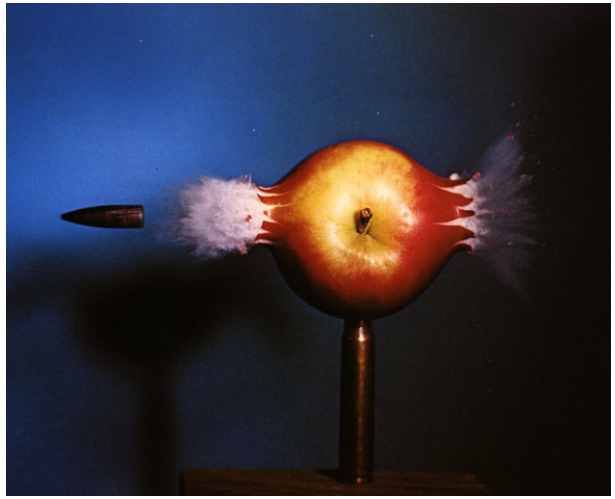
A mixture of:
Protecting the machine from the equipment and
Protecting the equipment from the machine …

- IN/OUT Devices: Transfer Lines & Ring
  - Valves, Stoppers, Screens and Dumps
- Mobile Devices
  - In the Transfer Lines
  - Beam instrumentation in the ring
  - Ring Collimators, Absorbers & Protection Devices
- Summary



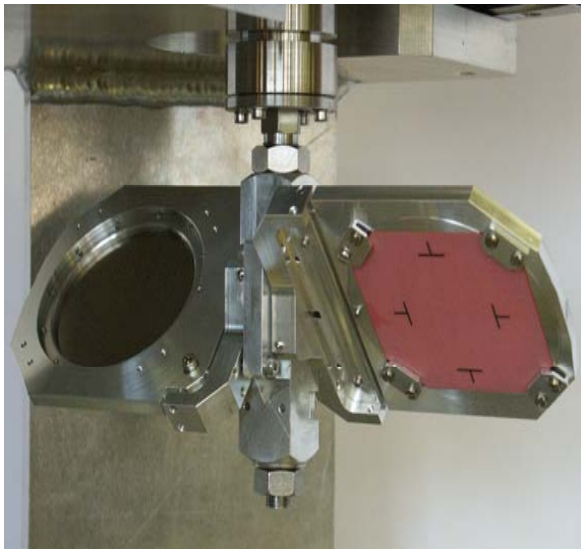
IN/OUT Devices: Transfer Lines

Stoppers/Dumps : 2 Mobile Beam Dump (Ted's)

1 Beam Stopper (TBSE, for access safety) per line

- No problem when IN, or OUT … (SAFE positions)
- Interlock needed when moving (82 seconds)
  - Ted IN permit signal
    - Used to mask interlock arising from equipments DOWNSTREANM of the Ted
  - Ted Not moving permit signal
    - Used to inhibit the beam in the region UPSTREAM of the Ted
  - Ted OUT permit signal

IN/OUT Devices: Transfer Lines



Screens : 9 screens in each line

- A screen in the line is SAFE for any beam
- Each screen has a position:
  - OUT (of beam)
  - OTR (10-100 microns thick)
  - AL oxide (1 mm thick)
- The interlock will be maskable with the Safe Beam Flag
- The interlock is generated directly from the FPGA that controls the screen motor and the access to the signals (switches).

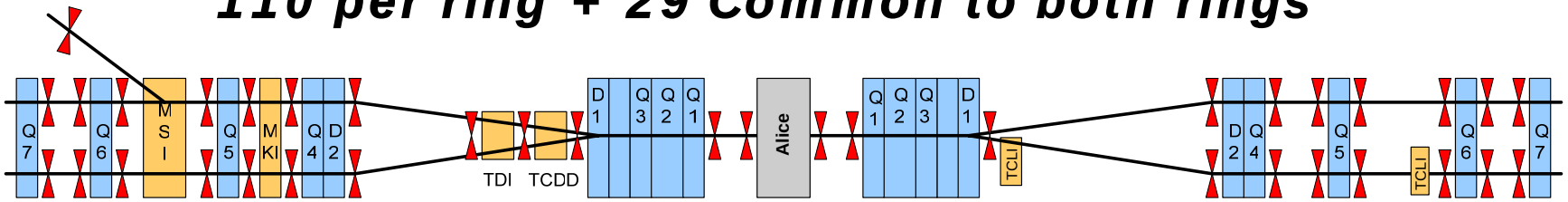
Vacuum valves: 7 per transfer lines

- Interlock extraction as soon a valve start to close.

IN/OUT Devices: Ring Vacuum Valves

249 Vacuum Valves in the LHC

110 per ring + 29 Common to both rings



Hardware

Activated by Compressed air shared with cryo valves

Mechanically locked open/closed

End switches connected in series to the valve chain interlock → BIC

Chain broken as soon as the valve starts to close …

Closing time ~3 seconds

Stop Press☹ (decision still pending)

2 fast valves around LHCb to close in 13ms

LHC-VVX-ES-0001 EDMS 351182

Via Software (Vacuum Controls):

For a pressure interlock the control system will fire the beam dump and wait for an OK status from it before closing valves…

We want to Veto valve manipulation with circulating beam

IN/OUT Devices : Ring Monitors

Screens:

- **5 Injection Screens per ring in IR 2 and IR 8**
  - **Interlock treated like in the transfer line via a FPGA**
- **1 Matching monitor for ring 2 in LSS3 + 1 per ring in LSS4**
  - **Must be used only in Inject & Dump mode, detailed implementation to be defined.**
  - **Limits for multi-turn monitors based on Intensity & Nº of turns.**
  - **We must be sure to dump reaching these limits:**

(max $2x10^{+12}$: 300 turns)

IN/OUT Devices : Ring Monitors

Wire-scanners

- Presently foresee 1 wire-scanner per plane and per ring (i.e. 4 total)
- The wire scanner must only be able to move if intensity is acceptable
  - The wire scanner must have access to a reliable intensity information
- Limits for use based on knowledge of beam energy and total intensity

  (8x72 nominal bunches @ 450 GeV … 2x72 at 7TeV)
- **No Interlock foreseen !!**

IN/OUT Devices : Others

RF Electron Stoppers

2 RF Electron Stoppers per beam in IR4

Access allowed only when stoppers IN

Must be IN for RF conditioning (no beam!)

Status monitored by the Access System

Behaviour otherwise is just like the vacuum valves

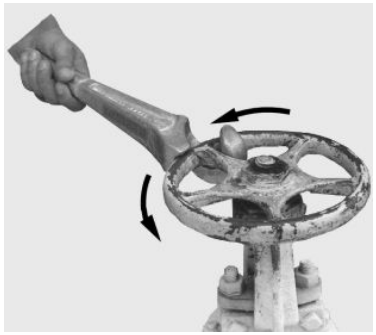
Access Safety Block

1 per ring. Planned for IR3 in front of primary collimators

Must be IN before giving access

Will go in as soon as triggered by the Access System

Connected to the vacuum control will inform BIC



Passive Valves

So far only under discussion for Alice

Manual operation only … but remote status available

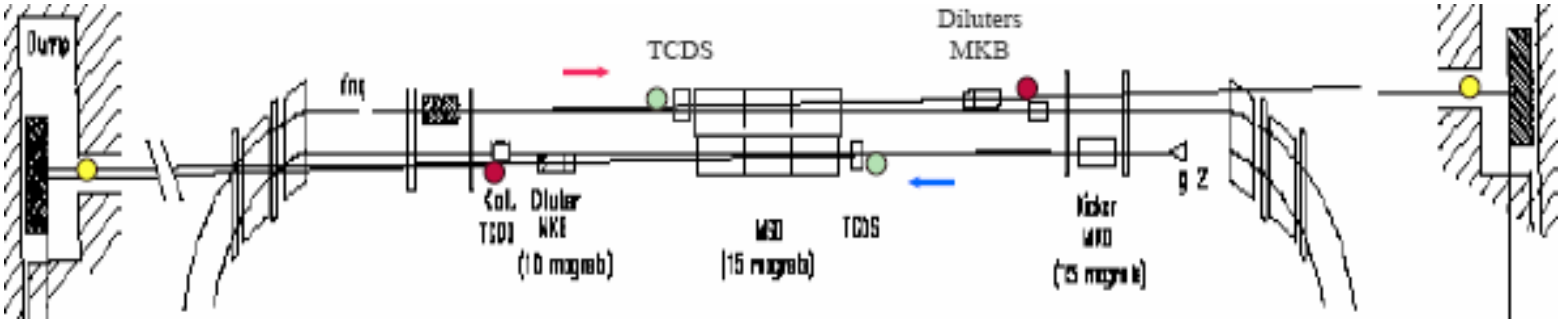
But will be attached to the valve interlock chain

IN/OUT Devices : Dump Lines

2 Vacuum Valves per line – same as others

3 Screens per dump line

- **Last one is fixed IN – beam painted on screen**
- **First 2 should not be IN for extraction of the full 7TeV beam.**
  - **These will be only used for low intensity operation**
  - **Replaced by BPM to steer the line at higher intensity**

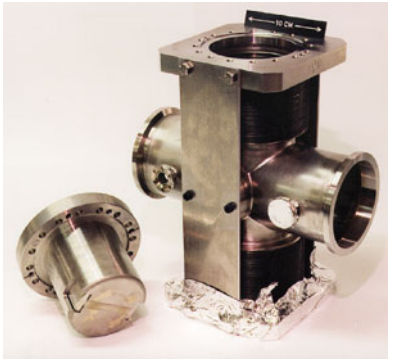


… a bit tricky since we can't interlock the beam dump!

Collimation & Protection : Conditions for Moving

- A total of 120 Collimators will protect the machine from the beam (amongst other uses)
- Some elements are only used during injection – the rest must be in position whenever there is beam
- The positions may change throughout the machine cycle – injection, ramp, squeeze, physics etc. – and form a coherent set – a file.
- The positions cannot be fixed exactly – must allow a window for optimization
- The size of the window will depend on:
  - The intensity/nº. of bunches, the energy, the optics (β^*), the mode of the machine etc.
  - Movement outside the specified window will have to be vetoed (with possibly an interlock if the window is exceeded for any reason).

Other Mobile Devices



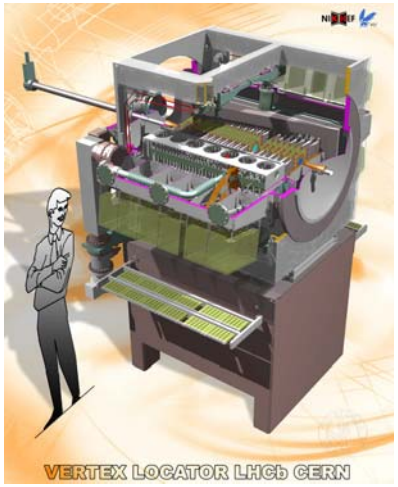
Experimental Detectors:

Roman Pots: **Special devices to move small detectors very close to the Beam.**
The distance to the beam may be as close as 10-15 sigma.

Totem Exp' (IR5) **Presently 6 stations, with up to 6 pots per station.** (*Put to 10σ*)
Atlas Luminosity (IR1) **2 Stations with 4 pots per station.**

They will be controlled together with collimators

LHCb Velo: **Two half detectors (*5 mm*).**
The detailed interlock strategy
is presently being finalized.



Possible movement to the beam
only when stable beam (experiment control).

Conclusions

- Some 500 objects are capable of moving into the aperture of either the LHC Ring, or the transfer lines
  - Ranging from passive valves up to very complex experimental detectors
  - Approx half are vacuum valves – adequate steps to prevent accident here
  - Screens, stoppers, wire scanners … interlocks soft and hard identified

- The movement of mobile devices is intimately linked with the different phases of LHC operation
  - Can't afford to allow free playing with any of these objects.
  - Movement outside specified ranges must be prevented.
  - The control should preferably be exercised from the Machine Control Room (CCC) – or in very close contact …

Mobile Devices : Collimation & Protection

Name	Number	Location	Description
TCP	8	IR3 & IR7	Primary Collimators
TCSG	30	IR3 & IR7	Secondary Collimators
TCT(a,b)	16	IR1,IR5,IR2	Tertiary Collimators
TCLP	8	IR1, IR5	Absorber – Physics region
TCLA	16-24(tbd)	IR3,IR7	Absorber – Cleaning region
TCSP	6	IR3,IR7	Scrapers {Special Use}
TCDQ	2	IR6	Bad Dump Protection
TCS	2	IR6	Bad Dump Protection
~~TCDS~~	~~2~~	~~IR6~~	~~Dump Septum Protection~~ Fixed
TDI	2	IR2,IR8	Protection During Injection
TCDD	2	IR2,IR8	Protection During Injection
TCLI(a,b)	4 (2+2)	IR2,IR8	Protection During Injection
TCDI	14	TI2, TI8	Transfer Line Collimators
Total	108-116		

Many with 2 jaws – Always in use

In use only during Injection

Only Phase 1 Collimators included

Collimation & Protection : Built in Fault Protection

- In case of a motor failure in a collimator the jaw will retract and generate an interlock which will dump the beam.
- The Mechanical design prevents excessive tilt of the jaw (>2mR).
- Hitting an end stop should (probably) also generate an interlock.

- Protection Devices should remain in place – not move. This means they will continue to provide the protection for the present machine mode.
- But should they still generate an interlock and hence a beam dump?
- Since when we try and move them and fail we will know there is something wrong.
- Changing the mode – e.g. trying to ramp with the injection protection elements still IN should not be allowed.

Machine Mode <-> Protection

Position Sets : {Files}

All elements are positioned with respect to the ring aperture (arc dipoles, or inner triplet)

$$a_{primaries} < a_{secondaries} < a_{tertiaries} < a_{protection} < a_{ring}$$

Must be maintained throughout the cycle - Primaries must always remain the Primaries!
This gives tight tolerances on the beam optics and stability.

a_{ring}	=	7.5 σ	Ring cold aperture
a_{prot}	=	6.8-7.0 σ	TDI, TCLI, TCDQ protection elements
a_{sec}	=	6.7 σ	Secondary Collimators – IR7
a_{prim}	=	5.7 σ	Primary Collimators - IR7
a_{TL}	=	4.5 σ	Traansfer Line Collimators (ring protection at 6.9 σ)

Injection Settings from Ralph

β-beating must be under control.

Static β-beating not really (much of) a problem. Must measure the β at each element and set the positions relative to the real β. Measure the β to ~20%.

Transient β-beating much more of a worry. More than ~10% and we run the risk of the secondaries becoming the primaries (especially with an orbit offset …)

- ↳ Severely limit the intensity until we have it under control
- ↳ Will also limit our ability to tweak the collimator positions for optimization

Machine Modes: Injection

- **Before first beam, put the collimators into positions determined during previous runs**
  - **The Protection elements are positioned to be in the shadow of the collimators …**
  - **All other objects moved out of the way**
- **Using a setup beam (Intermediate) the individual positions of collimators & protection elements may be optimized …**
  - **To reflect changes to the beam orbit, emittance, β-beating &so on.**
  - **A range of possible positions must be defined for each element**
- **During injection of the main beam the chosen positions will probably be fixed – or at least the window for movement restricted**
- **Before acceleration the injection must be inhibited – (change mode) – and the injection protection elements moved out**

Machine Modes Acceleration/Squeeze

During Acceleration do the collimators/protection elements need to move 'en masse'?

- **Under Discussion. In any case need orbit, machine parameters etc. under control. Feedbacks.**
- **β-beating during snapback is a worry – is there a possibility for a snapback set?**
- **Moving the protection elements (TCDQ) for high energy would also need a new file**
- **Is a 'window' for each collimator position still needed to allow for optimization? If so this may imply loading a new set of values during the ramp.**
- **Any change to a collimator position must always be limited by the need to maintain correct functionality – with errors. The allowed range for changing position might itself change with energy.**

The aperture to protect changes during the squeeze:

- **The collimators/dump protection system must be moved either in advance, or in synchronization with the squeeze. Several new file sets for the β* of the day**
- **A 'window' for each collimator position still needed to allow for optimization. This must always take into account the other collimator positions and the aperture!**

Any movement we don't like will have to be vetoed

Machine Modes : Physics

Will need to distinguish between: 'Data taking Period' == Stable Beams
and 'Non-data taking period' == Adjust (LEP)

Before Stable Physics:

- **The collimators may move again– for optimization of background?**
- **The allowed range for the collimator positions from this point onwards must be very small.**
- **If BBLR are installed they will move in before colliding the beams – powered as beams collide**

During Stable Physics:

- **The collimators should not generally be moved at all (no longer stable physics?)**
- **Permission can be granted to move the experimental detectors in to predefined positions ± some optimization tolerance.**
- **If we drop out of Stable Physics mode – these must retract (automatically?)**

Machine Mode <-> Machine Protection (again)

Summary : IN/OUT Devices

Vacuum Valves look OK – need software veto to stop putting them in with beam

Stoppers in the Ring will act in the same way as the vacuum valves.

Stoppers and screens in the transfer lines need an interlock to prevent extraction whilst moving – TED's take a long time. *SPS - IS*

Screens in the TL need a cross-interlocked such that we cannot inject into the LHC a high intensity beam that has passed through several screens ?

Screens in the Ring will need to get the intensity from the SPS, implement a turn count and a direct request to the beam dump… ?

In addition, must Veto their use when not at injection

Wire scanners need control based on measurements of beam conditions: Energy & total intensity. Veto use outside specified range. *BDI Front End?*

Putting the dump line screens IN must be vetoed when the intensity in the machine is high …

Conversely, injection of a high intensity must be vetoed when they are in. ?

Summary : Mobile Devices

Sets of positions (files) needed for operating the collimation/protection system

- At least one for injection, one or more for ramping (no injection protection), one for squeezing and (maybe one for physics)
- Put into the machine synchronized to maintain element functionality

Around these values a small window is needed to allow for optimization

- The size of this window will vary throughout the operational cycle
- Movement outside the specified window must be prevented.

'Permission/Veto Flags' will be needed for:

- Allowing the retraction of the injection protection elements – inhibit injection
- Veto of 'inappropriate' collimator/protection files.
- Allowing the experimental detectors to move into data-taking position
  - This probably corresponds to a 'stable beams' mode
  - The detectors must move out if this mode is cancelled.
  - Who actually moves them is (still) not clear.