

Date: 2004-09-03

Engineering Change Order – Class I

New Machine Layout in IR3 and IR7

Brief description of the proposed change(s) :

The layouts of the LHC cleaning insertions in IR3 and IR7 were adapted to an improved solution for the LHC collimation system. The new collimation layout addresses LHC requirements for cleaning performance, robustness, impedance, aperture, engineering, and schedule. Initial installation is minimized and space reservations are included for system upgrades. At the same time several optimizations are introduced: placement of dipole correctors and quadrupole connections out of particle showers, space reservations for absorbers and scrapers, increased inter-module distance for quadrupoles, consistent vacuum layout, and placement of BLM's.

<p>Equipment concerned : Beamline elements in warm regions of IR3/IR7. Infrastructure IR3/IR7.</p>	<p>Drawings concerned : LHCLSX__0005, LHCLSX__0006, LHCLSX__0013, LHCLSX__0014, LHCLSXG_0001, LHCLSXG_0003 (conceptual design)</p>	<p>Documents concerned : Reference database</p>
<p>PE in charge of the item : Ranko Ostojic</p>	<p>PE in charge of parent item in PBS : Paul Proudlock</p>	
<p>Decision of the Project Engineer :</p> <p><input type="checkbox"/> Rejected.</p> <p><input type="checkbox"/> Accepted by Project Engineer, no impact on other items. <i>Actions identified by Project Engineer</i></p> <p><input checked="" type="checkbox"/> Accepted by Project Engineer, but impact on other items. <i>Comments from other Project Engineers required</i> <i>Final decision & actions by Project Management</i></p>	<p>Decision of the PLO for Class I changes :</p> <p><input type="checkbox"/> Not requested.</p> <p><input type="checkbox"/> Rejected.</p> <p><input checked="" type="checkbox"/> Accepted by the Project Leader Office. <i>Actions identified by Project Leader Office</i></p>	
<p>Date of Approval : 2004-09-03</p>	<p>Date of Approval : 2004-09-03</p>	
<p>Actions to be undertaken :</p> <p>Modify the drawing concerned to reflect the changes described in this ECO.</p>		
<p>Date of Completion : 2004-09-03</p>	<p>Visa of QA Officer :</p>	

Note : when approved, an Engineering Change Request becomes an Engineering Change Order/Notification.

1. DETAILED DESCRIPTION

by R. Assmann

A review of the LHC collimation system was started in 2001 and the need for several improvements was established.

This ECR includes:

- The new layout in IR3 and IR7 with sufficient space allocated for the phased collimation approach with graphite collimators and collimator upgrades.
- An optimization of collimator locations for minimizing impedance while maintaining cleaning performance.
- A basic optimization of magnet positions for minimal impact of beam losses on equipment.
- An optimization of the vacuum system layout in IR3 and IR7.
- Definition of required infrastructure for the adopted collimation solution.
- Some preliminary space reservations for absorbers.

It does not include:

- The final number and positioning of absorbers in IR3 and IR7, which are required to protect equipment and to prevent shower-induced quenches. The detailed shower studies are still ongoing.
- Machine changes in IR3 and IR7 required for minimizing radiological impact of the LHC operation. Studies have not yet been finalized.
- The changes due to the placement of tertiary collimators in the other insertions of the LHC. Studies are almost completed.

Additional ECR's will introduce the changes required from the above listed studies. It is, however, expected that layout changes from these additional ECR's will be minimal with movements of machine elements on the scale of 1 m or less.

1.1 THE PHASED APPROACH OF COLLIMATION

LHC requirements for collimator robustness, efficiency and impedance were reviewed. It was found that the jaw material and length for LHC collimators had to be changed from the previously foreseen solution. The new solution would, however, limit the maximum performance reach of the LHC (limitations on beam current). Given the scheduling constraints it was decided to define a phased approach for collimation:

- Phase 1 (2007): Maximum robustness collimators with good cleaning efficiency and an impedance limitation. This system would be used always for injection and ramp, as well as for early years physics.
- Phase 2 (2008/9): Phase 1 is complemented with low impedance, high efficiency, but low robustness metallic collimators, located just downstream of each phase 1 secondary collimator. This system would be used only during stable physics and would provide low impedance and excellent efficiency during high current operation.
- Phase 3: Is of no relevance for IR3 and IR7, as this phase refers to the installation of additional TCLP collimators in IR1 and IR5.
- Phase 4 (only if required): Additional collimators can be installed for maximum cleaning efficiency, if required.

It is evident that the LHC layout in IR3 and IR7 had to be adapted to provide additional longitudinal space for a single collimator and the newly required placeholders. A detailed description of the new approach is included in the new LHC design report [1], including references to relevant publications.

1.2 LONGITUDINAL SPACE REQUIREMENT FOR AN LHC COLLIMATOR

The longitudinal space requirements per collimator were reviewed in detail, taking into account boundary conditions from cleaning performance, robustness, and engineering.

1.2.1 LOGICAL UNITS OF THE LHC COLLIMATOR

The collimator installation on the beamline is broken down in several logical units:

1. Collimator tank.
2. Quick plug-in, one half mounted on collimator tank, the other half on the support.
3. Support structure.
4. Interface with flexible bellows and quick exchange flanges for collimator-collimator or collimator-other element. The interface includes support, vacuum pumping and BLM monitors.

In addition infrastructure is required on the collimator (motors) and elsewhere (cables, electronics, cooling). The modular design of the collimators ensures a minimal installation time for the collimator tank, once the support with quick plug-in and the interfaces have been installed.

1.2.2 FLANGE-TO-FLANGE LENGTH OF THE COLLIMATOR TANK

The jaw material and length were decided as follows:

- Jaw material: Jaws will be made of Graphite materials for phase 1 collimators. Later phases remain to be defined in detail.
- Jaw length: The collimator jaws in phase 1 have a length of 0.2 m (primary collimators) and 1.0 m (secondary collimators), each plus 0.2 m for tapering.

A detailed engineering design was started and the flange-to-flange length of a tank for secondary collimator was fixed to **1.480 m**.

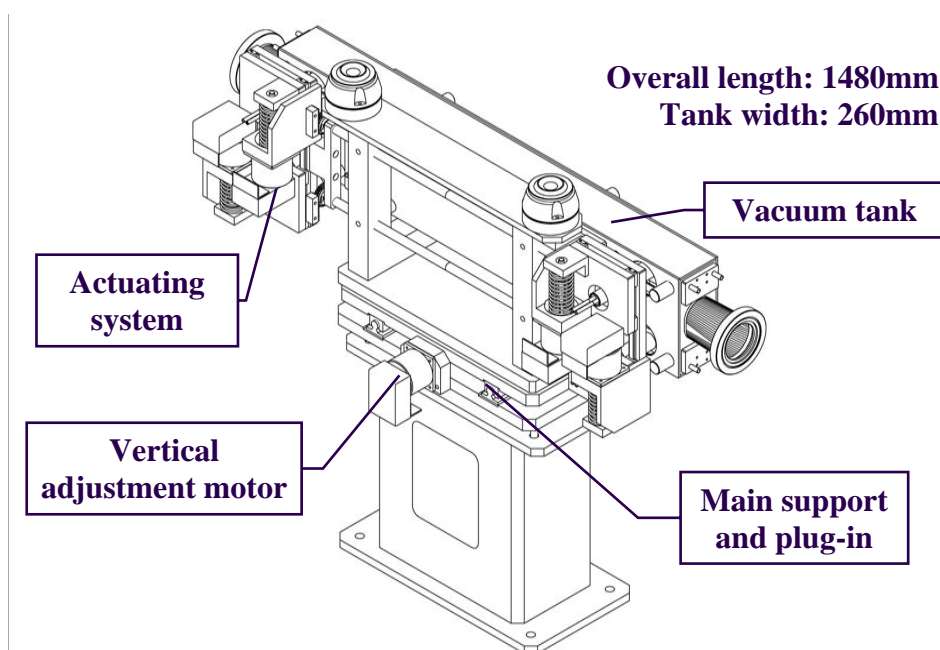


Figure 1: Sketch of the LHC secondary collimator, including dimensions.

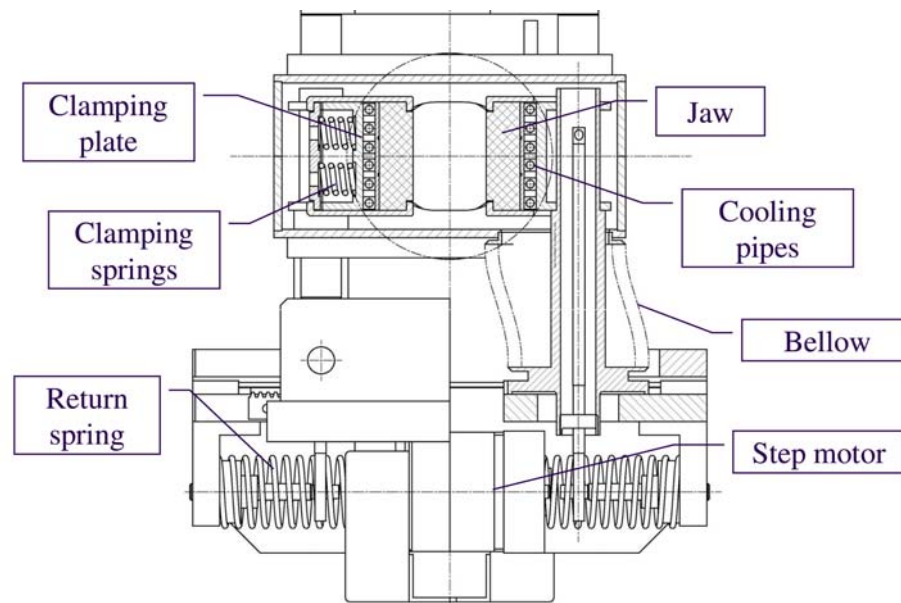


Figure 2: Secondary collimator mechanical assembly (cross-section of a horizontal TCSG).

1.2.3 LENGTH OF INTERFACE

The interface between two collimators or a collimator and another beamline element includes a separate stand, flexible bellows, quick exchange flanges, a vacuum pump, and BLM's. Its length was fixed to **0.520 m**. A special adaptation will allow for two of these inter-connects with some longitudinal overlap between beam 1 and beam 2.

For the detection of the particle loss of the adjacent collimator it is important that one type of detector is near to the vacuum pipe (<10 cm, see collimation working group talk 12.03.04).

1.2.4 TOTAL REQUIRED LENGTH PER SECONDARY COLLIMATOR (TCSG AND TCSM)

The total required length per secondary collimator (TCS) was fixed to be **2.00 m**, consistent with the detailed engineering design for a phase 1 secondary collimator (TCSG). It is assumed that the phase 2 secondary collimators (TCSM) require the same longitudinal space as the collimators for phase 1. This assumption is valid, because phase 2 collimators will have higher Z metallic materials and therefore shorter lengths than phase 1 collimators. The total length per secondary collimator then went from less than 1.0 m in the previous layout to **4.00 m** (for phase 1 and phase 2) in the new layout.

1.2.5 TOTAL REQUIRED LENGTH PER PRIMARY COLLIMATOR (TCP)

Primary collimators (TCP) can be shorter than secondary collimators. However, due to the small number of primary collimators it was decided to use the same (long) tank and mechanical construction as for secondary collimators. Only the design of the graphite jaw will be adapted to a shorter length. This allows for significant savings in design cost. The total required length per primary collimator was fixed to be **2.00 m**.

1.2.6 TOTAL REQUIRED LENGTH PER SCRAPER (TCHS)

The scrapers (TCHS) are specialized devices which cannot be copied from a secondary collimator. A new design is therefore required and can be optimized for short length. The total required length per scraper was fixed to be **1.20 m**.

1.3 COOLING REQUIREMENTS AND BAKE-OUT FOR COLLIMATORS

The cooling requirements for LHC collimators were specified as follows:

- Cooling capacity: 160kW (IR3) 420kW (IR7)
- Total flow rate: 36 m³/h (IR3) 96 m³/h (IR7)
- Pressure drop per collimator: 1.2 bars
- Collimator inlet temperature: ≤ 27 °C

The inlet temperature of the water was accepted to reach up to 27 °C, resulting in slightly higher peak temperatures on the graphite block and a slightly worse vacuum. Doing this the demineralised water circuit (27/42 degrees) can be used for collimator cooling. It was estimated that the contribution to activation of cooling water from the collimators in a given IR is about the same as the contribution from the warm magnets in the same IR.

After a vacuum intervention in a collimator region all collimators in the vented area must be exposed to a bake-out. It is required to empty the cooling water from the collimators beforehand. The bake-out procedure is basically foreseen as follows:

- Stop of cooling water flow through collimators with manual valve at collimator inlet. The outlet valve can be kept open until water is blown out in collimator.
- Blow-out of cooling water inside the collimator with pressurized gas. The water is blown into the cooling circuit.
- Closure of manual valve at collimator outlet, if required.
- Collimator bake-out at 250 °C.
- Opening of outlet and inlet valves.

This procedure minimizes the need for equipment. It was decided to equip the local collimator cooling circuits with manual valves. These valves will face the transport zone for easy accessibility and have a high reliability. A detailed study of the bake-out procedure will be performed later. It is noted that any activated water lost during collimator replacement should be collected and properly disposed.

1.4 CABLING REQUIREMENTS FOR A SINGLE COLLIMATOR

The collimators are equipped with complete motorization and extensive monitoring sensors. In particular we include:

- Two stepping motors per collimator jaws, such that position and angle can be controlled.
- One stepping motor per tank in order to provide spare surface on a given jaw.
- One resolver per motor for read-back of motor position.
- Independent monitoring of the collimator gap and centre of gap at each end of the collimator jaws.
- Switches for in/out/anti-collision.
- Sensing for shock impact, providing detection of any damaging event.
- Measurement of flow for cooling water.
- Survey of collimator temperature.
- Remote equipment on and close to the collimators is not defined in detail yet, but is likely required for limiting personnel exposure to radiation. Some basic cable support is included into the baseline.

This equipment will enhance the performance of the collimator, ensure safe operation at all times and provide detection of abnormal conditions. Table 1 analyzes the cabling need per single collimator. Note that wires have been grouped into cables for most efficient usage. An overhead of 6% can be used for spares. The following cables are

required for a single collimator: 2×NG28, 1×NG18, 1×NE26, 4×NE18, 1×NE6, 8×NE4 and 1×CKR50.

Table 1: An overview on elements per collimator is given. The wire needs are specified for each element. Wires are grouped into specific cables and totally required wires are specified.

Elements/Collimator	Elements	Wires/Element	Wires/Collimator*	Cable		Total	Free *
4	Motor: jaws	8	32	2	NG28	56	2
4	Switch: out	2	8				
4	Switch: in	2	8				
2	Switch: anti-collision	2	4				
4	interlock signal	2	8				
1	Motor: tank	16	16	1	NE18	18	2
1	Resolver: tank	6	6	1	NE6	6	0
5	Resolver: jaws	6	30	2	NE18	36	5
1	Communication	4	1				
6	Sensor: temperature	4	24	1	NE26	24	0
2	Sensor: gap size	4	8	2	NE4	8	0
2	Sensor: gap centre	4	8	2	NE4	8	0
2	Sensor: infrasonic	4	8	2	NE4	8	0
1	Flowmeter	4	4	1	NE4	4	0
4	Remote equipment	4	16	1	NE18	18	2
1	Remote pump	16	16	1	NG18	18	2
1	Level gauge	4	4	1	NE4	4	0
45			197	17		204	13
							6%

1.5 THE NEW COLLIMATION LAYOUT IR3

The layout in the momentum cleaning system in IR3 was adapted to provide the required space for collimators and to implement the changes explained in Section 1.2. The layout was optimized to avoid occurrence of small (~cm) drift spaces between collimators, magnets, etc. The design philosophy and criteria were not changed from the previous layout.

1.5.1 TYPES AND ORIENTATION OF COLLIMATORS

The collimators for momentum cleaning are listed in Table 2, also listing the angular orientation of the jaws and the phase in which collimators will be installed. In total 20 collimators and scrapers will be installed in IR3, from which 12 collimators are for phase 1 in 2007, the rest for phase 2.

Table 2: List of collimators in the momentum cleaning insertion IR3. Specified are the name, the collimator angle in degrees, the collimator type, the number of jaws per collimator and the phase in which the collimator will be installed.

Name	Angle	Collimator type	Jaws/collimator	Phase
IR3 beam1				
TCP.6L3.B1	0.0	Primary collimator	2	1
TCHSH.6L3.B1	0.0	Scraper	1	1
TCSG.5L3.B1	0.0	Secondary collimator	2	1
TCSM.5L3.B1	0.0	Secondary collimator	2	2
TCSG.4R3.B1	0.0	Secondary collimator	2	1
TCSM.4R3.B1	0.0	Secondary collimator	2	2
TCSG.A5R3.B1	170.4	Secondary collimator	2	1
TCSM.A5R3.B1	170.4	Secondary collimator	2	2
TCSG.B5R3.B1	11.4	Secondary collimator	2	1
TCSM.B5R3.B1	11.4	Secondary collimator	2	2
IR3 beam2				
TCP.6R3.B2	0.0	Primary collimator	2	1
TCHSH.6R3.B2	0.0	Scraper	1	1
TCSG.5R3.B2	0.0	Secondary collimator	2	1
TCSM.5R3.B2	0.0	Secondary collimator	2	2
TCSG.4L3.B2	0.0	Secondary collimator	2	1
TCSM.4L3.B2	0.0	Secondary collimator	2	2
TCSG.A5L3.B2	170.9	Secondary collimator	2	1
TCSM.A5L3.B2	170.9	Secondary collimator	2	2
TCSG.B5L3.B2	10.5	Secondary collimator	2	1
TCSM.B5L3.B2	10.5	Secondary collimator	2	2

1.5.2 LOCATION OF COLLIMATORS

The final locations of collimators are listed in Table 3 for beam 1 and beam 2. Note that collimators are interleaved for beam 1 and beam 2, such that no two collimators on the different beams are put at the same location. This is required in order to avoid transverse overlap.

Table 3: Locations of collimators in IR3 for beam 1 and beam2. The positions refer to the centre of the collimator.

Beam 1		Beam 2	
NAME	Distance from IP3 [m]	NAME	Distance from IP3 [m]
TCP.6L3.B1	-177.05	TCSM.B5L3.B2	-62.02
TCHSH.6L3.B1	-175.45	TCSG.B5L3.B2	-60.02
TCSG.5L3.B1	-143.68	TCSM.A5L3.B2	-56.20
TCSM.5L3.B1	-141.68	TCSG.A5L3.B2	-54.20
TCSG.4R3.B1	42.81	TCSM.4L3.B2	-44.81
TCSM.4R3.B1	44.81	TCSG.4L3.B2	-42.81
TCSG.A5R3.B1	54.20	TCSM.5R3.B2	141.68
TCSM.A5R3.B1	56.20	TCSG.5R3.B2	143.68
TCSG.B5R3.B1	60.02	TCHSH.6R3.B2	175.45
TCSM.B5R3.B1	62.02	TCP.6R3.B2	177.05

1.5.3 LOCATION OF MAGNETS

The normal conducting magnets had to be moved due to the various optimizations performed in the new layout. Table 4 lists the new magnet positions and summarizes the movements of the centre position and the magnet connectors (turning of some magnets, see 1.7.3 and 2.1). The correctors were moved up to 33.5 m and the quadrupole centres up to 2.9 m. Cable connection points are moved by larger values, up to 3.4 m for the dogleg bends, up to 6.0 m for the quadrupoles and up to 33.5 m for the dipole correctors. This is due to turning of some magnets.

Table 4: IR3 magnet positions (centre of magnet), movement with respect to V6.402, movement of the connectors with respect to V6.402 and orientation. U=connection side upstream, D=connection side downstream. (data 8/6/4)

Name	Distance from IP3 [m]	Centre movement [m]	Connection movement [m]	Magnet orientation
MBW.F6L3	-191.466	0.00	0.00	U
MBW.E6L3	-187.231	0.00	0.00	U
MBW.D6L3	-182.996	0.00	0.00	U
MBW.C6L3	-164.973	0.00	3.40	D
MBW.B6L3	-160.738	0.00	3.40	D
MBW.A6L3	-156.503	0.00	3.40	D
MQWA.E5L3	-150.548	-0.88	-0.88	U
MQWA.D5L3	-146.748	-1.78	-1.78	U
MQWA.C5L3	-138.708	2.56	5.66	D
MQWB.5L3	-134.908	2.66	5.76	D
MQWA.B5L3	-131.108	2.76	5.86	D
MQWA.A5L3	-127.308	2.86	5.96	D
MCBWH.5L3.B2	-123.653	3.23	3.23	U
MCB WV.5L3.B1	-121.323	31.76	33.46	D
MQWA.E4L3	-47.875	-2.49	-2.49	U
MQWA.D4L3	-39.835	-0.15	2.95	D
MQWA.C4L3	-36.035	-0.05	3.05	D
MQWB.4L3	-32.235	0.05	3.15	D
MQWA.B4L3	-28.435	0.15	3.25	D
MQWA.A4L3	-24.635	0.25	3.35	D
MCB WV.4L3.B2	-21.030	0.57	0.57	U
MCBWH.4L3.B1	-18.700	30.11	30.11	D
MCBWH.4R3.B2	18.700	-29.96	-29.96	U
MCB WV.4R3.B1	21.030	-0.43	1.27	D
MQWA.A4R3	24.635	-0.25	-0.25	U
MQWA.B4R3	28.435	-0.15	-0.15	U
MQWB.4R3	32.235	-0.05	-0.05	U
MQWA.C4R3	36.035	0.05	0.05	U
MQWA.D4R3	39.835	0.15	0.15	U
MQWA.E4R3	47.875	2.49	5.59	D
MCB WV.5R3.B2	121.323	-31.62	-31.62	U
MCBWH.5R3.B1	123.653	-3.09	-3.09	D
MQWA.A5R3	127.308	-2.86	-2.86	U
MQWA.B5R3	131.108	-2.76	-2.76	U
MQWB.5R3	134.908	-2.66	-2.66	U
MQWA.C5R3	138.708	-2.56	-2.56	U
MQWA.D5R3	146.748	1.78	4.88	D
MQWA.E5R3	150.548	0.88	3.98	D

MBW.A6R3	156.351	0.00	0.00	U
MBW.B6R3	160.586	0.00	0.00	U
MBW.C6R3	164.821	0.00	0.00	U
MBW.D6R3	182.844	0.00	3.40	D
MBW.E6R3	187.079	0.00	3.40	D
MBW.F6R3	191.314	0.00	3.40	D

1.5.4 COLLIMATOR CABLING AND RACK SPACE

About 360 cables with a total length of 106 km must be installed for the IR3 collimators phase 1 and phase 2. Sufficient space is available in the cable trays. Local cabling on and close to the collimator is not included in the above estimate and will be addressed separately.

In addition 4 cables of type NE4 should connect the racks in UJ33 to the surface SZU3, allowing direct access to selected collimator signals during beam operation.

A total of 2.5 racks are required in UJ33 for the collimator electronics. Sufficient rack space was identified and reserved in UJ33.

1.6 THE NEW COLLIMATION LAYOUT IR7

The betatron cleaning insertion IR7 underwent a major re-design. A new design philosophy was implemented, aiming at optimizing cleaning efficiency and impedance at the same time. The optics was only slightly changed and most of the gain was achieved by moving the collimators to better locations. Therefore, quadrupole movements are relatively small ($\sim m$) and collimator movements can be quite large ($\sim 40 m$). The layout was optimized to avoid occurrence of small ($\sim cm$) drift spaces between collimators, magnets, etc.

1.6.1 TYPES AND ORIENTATION OF COLLIMATORS

The collimators for betatron cleaning are listed in Table 5, also listing the angular orientation of the jaws and the phase in which collimators will be installed. In total 78 collimators and scrapers can be installed in IR7, from which 34 collimators and scrapers are for phase 1 in 2007, 22 (hybrid) collimators are for phase 2 in 2008/9 and 22 collimators are for phase 4 (only installed if required).

Table 5: List of collimators in the betatron cleaning insertion IR7. Specified are the name, the collimator angle in degrees, the collimator type, the number of jaws per collimator and the phase in which the collimator will be installed.

Name	Angle	Collimator type	Jaws/collimator	Phase
IR7 beam1				
TCP.D6L7.B1	90.0	Primary collimator	2	1
TCP.C6L7.B1	0.0	Primary collimator	2	1
TCP.B6L7.B1	126.9	Primary collimator	2	1
TCP.A6L7.B1	52.2	Primary collimator	2	4
TCHSV.6L7.B1	90.0	Scraper	1	1
TCHSH.6L7.B1	0.0	Scraper	1	1
TCHSS.6L7.B1	136.6	Scraper	1	1
TCSG.B6L7.B1	41.4	Secondary collimator	2	4
TCSM.B6L7.B1	39.9	Secondary collimator	2	4
TCSG.A6L7.B1	141.1	Secondary collimator	2	1
TCSM.A6L7.B1	142.5	Secondary collimator	2	2

TCSG.B5L7.B1	143.5	Secondary collimator	2	1
TCSM.B5L7.B1	141.6	Secondary collimator	2	2
TCSG.A5L7.B1	40.7	Secondary collimator	2	1
TCSM.A5L7.B1	42.7	Secondary collimator	2	2
TCSG.D4L7.B1	90.0	Secondary collimator	2	1
TCSM.D4L7.B1	90.0	Secondary collimator	2	2
TCSG.C4L7.B1	133.6	Secondary collimator	2	4
TCSM.C4L7.B1	134.5	Secondary collimator	2	4
TCSG.B4L7.B1	0.0	Secondary collimator	2	1
TCSM.B4L7.B1	0.0	Secondary collimator	2	2
TCSG.A4L7.B1	134.6	Secondary collimator	2	1
TCSM.A4L7.B1	135.7	Secondary collimator	2	2
TCSG.A4R7.B1	46.3	Secondary collimator	2	1
TCSM.A4R7.B1	45.2	Secondary collimator	2	2
TCSG.B4R7.B1	135.9	Secondary collimator	2	4
TCSM.B4R7.B1	136.4	Secondary collimator	2	4
TCSG.A5R7.B1	37.3	Secondary collimator	2	4
TCSM.A5R7.B1	39.2	Secondary collimator	2	4
TCSG.B5R7.B1	141.5	Secondary collimator	2	1
TCSM.B5R7.B1	139.6	Secondary collimator	2	2
TCSG.C5R7.B1	90.0	Secondary collimator	2	4
TCSM.C5R7.B1	90.0	Secondary collimator	2	4
TCSG.D5R7.B1	51.4	Secondary collimator	2	1
TCSM.D5R7.B1	53.3	Secondary collimator	2	2
TCSG.E5R7.B1	130.5	Secondary collimator	2	1
TCSM.E5R7.B1	128.5	Secondary collimator	2	2
TCSG.6R7.B1	0.5	Secondary collimator	2	1
TCSM.6R7.B1	0.5	Secondary collimator	2	2
IR7 beam2				
TCP.D6R7.B2	90.0	Primary collimator	2	1
TCP.C6R7.B2	0.0	Primary collimator	2	1
TCP.B6R7.B2	127.5	Primary collimator	2	1
TCP.A6R7.B2	51.0	Primary collimator	2	4
TCHSV.6R7.B2	90.0	Scraper	1	1
TCHSH.6R7.B2	0.0	Scraper	1	1
TCHSS.6R7.B2	132.2	Scraper	1	1
TCSG.B6R7.B2	41.2	Secondary collimator	2	4
TCSM.B6R7.B2	39.7	Secondary collimator	2	4
TCSG.A6R7.B2	141.3	Secondary collimator	2	1
TCSM.A6R7.B2	142.8	Secondary collimator	2	2
TCSG.B5R7.B2	143.6	Secondary collimator	2	1
TCSM.B5R7.B2	141.7	Secondary collimator	2	2
TCSG.A5R7.B2	40.6	Secondary collimator	2	1
TCSM.A5R7.B2	42.5	Secondary collimator	2	2
TCSG.D4R7.B2	90.0	Secondary collimator	2	1
TCSM.D4R7.B2	90.0	Secondary collimator	2	2
TCSG.C4R7.B2	133.6	Secondary collimator	2	4
TCSM.C4R7.B2	134.5	Secondary collimator	2	4
TCSG.B4R7.B2	0.0	Secondary collimator	2	1
TCSM.B4R7.B2	0.0	Secondary collimator	2	2
TCSG.A4R7.B2	132.1	Secondary collimator	2	1
TCSM.A4R7.B2	133.3	Secondary collimator	2	2
TCSG.A4L7.B2	42.1	Secondary collimator	2	1
TCSM.A4L7.B2	41.0	Secondary collimator	2	2
TCSG.B4L7.B2	135.6	Secondary collimator	2	4
TCSM.B4L7.B2	136.2	Secondary collimator	2	4

TCSG.A5L7.B2	37.3	Secondary collimator	2	4
TCSM.A5L7.B2	39.2	Secondary collimator	2	4
TCSG.B5L7.B2	141.5	Secondary collimator	2	1
TCSM.B5L7.B2	139.5	Secondary collimator	2	2
TCSG.C5L7.B2	90.0	Secondary collimator	2	4
TCSM.C5L7.B2	90.0	Secondary collimator	2	4
TCSG.D5L7.B2	51.4	Secondary collimator	2	1
TCSM.D5L7.B2	53.3	Secondary collimator	2	2
TCSG.E5L7.B2	130.5	Secondary collimator	2	1
TCSM.E5L7.B2	128.5	Secondary collimator	2	2
TCSG.6L7.B2	0.5	Secondary collimator	2	1
TCSM.6L7.B2	0.5	Secondary collimator	2	2

1.6.2 LOCATION OF COLLIMATORS

The final locations of collimators are listed in Table 6 for beam 1 and beam 2. Note that collimators are interleaved for beam 1 and beam 2, such that no two collimators on the different beams are put at the same location. This is required in order to avoid transverse overlap. Now 156 m in IR7 are reserved for collimators, up from about 28 m in V6.402.

Table 6: Locations of collimators in IR7 for beam 1 and beam2. The positions refer to the centre of the collimator.

Beam 1		Beam 2	
NAME	Distance from IP7 [m]	NAME	Distance from IP7 [m]
TCP.D6L7.B1	-204.98	TCSM.6L7.B2	-148.86
TCP.C6L7.B1	-202.98	TCSG.6L7.B2	-146.86
TCP.B6L7.B1	-200.98	TCSM.E5L7.B2	-114.26
TCP.A6L7.B1	-198.98	TCSG.E5L7.B2	-112.26
TCHSV.6L7.B1	-197.38	TCSM.D5L7.B2	-110.26
TCHSH.6L7.B1	-196.18	TCSG.D5L7.B2	-108.26
TCHSS.6L7.B1	-194.98	TCSM.C5L7.B2	-106.26
TCSG.B6L7.B1	-165.48	TCSG.C5L7.B2	-104.26
TCSM.B6L7.B1	-163.48	TCSM.B5L7.B2	-94.26
TCSG.A6L7.B1	-161.48	TCSG.B5L7.B2	-92.26
TCSM.A6L7.B1	-159.48	TCSM.A5L7.B2	-90.26
TCSG.B5L7.B1	-102.26	TCSG.A5L7.B2	-88.26
TCSM.B5L7.B1	-100.26	TCSM.B4L7.B2	-51.74
TCSG.A5L7.B1	-98.26	TCSG.B4L7.B2	-49.74
TCSM.A5L7.B1	-96.26	TCSM.A4L7.B2	-11.00
TCSG.D4L7.B1	-76.93	TCSG.A4L7.B2	-9.00
TCSM.D4L7.B1	-74.93	TCSM.A4R7.B2	5.00
TCSG.C4L7.B1	-47.74	TCSG.A4R7.B2	7.00
TCSM.C4L7.B1	-45.74	TCSM.B4R7.B2	9.00
TCSG.B4L7.B1	-7.00	TCSG.B4R7.B2	11.00
TCSM.B4L7.B1	-5.00	TCSM.C4R7.B2	45.74
TCSG.A4L7.B1	-3.00	TCSG.C4R7.B2	47.74
TCSM.A4L7.B1	-1.00	TCSM.D4R7.B2	74.93
TCSG.A4R7.B1	1.00	TCSG.D4R7.B2	76.93
TCSM.A4R7.B1	3.00	TCSM.A5R7.B2	96.26
TCSG.B4R7.B1	49.74	TCSG.A5R7.B2	98.26
TCSM.B4R7.B1	51.74	TCSM.B5R7.B2	100.26
TCSG.A5R7.B1	88.26	TCSG.B5R7.B2	102.26

TCSM.A5R7.B1	90.26	TCSM.A6R7.B2	159.48
TCSG.B5R7.B1	92.26	TCSG.A6R7.B2	161.48
TCSM.B5R7.B1	94.26	TCSM.B6R7.B2	163.48
TCSG.C5R7.B1	104.26	TCSG.B6R7.B2	165.48
TCSM.C5R7.B1	106.26	TCHSS.6R7.B2	194.98
TCSG.D5R7.B1	108.26	TCHSH.6R7.B2	196.18
TCSM.D5R7.B1	110.26	TCHSV.6R7.B2	197.38
TCSG.E5R7.B1	112.26	TCP.A6R7.B2	198.98
TCSM.E5R7.B1	114.26	TCP.B6R7.B2	200.98
TCSG.6R7.B1	146.86	TCP.C6R7.B2	202.98
TCSM.6R7.B1	148.86	TCP.D6R7.B2	204.98

1.6.3 LOCATION OF MAGNETS

The normal conducting magnets had to be moved due to the various optimizations performed in the new layout. Table 7 lists the new magnet positions and summarizes the movements of the centre position and the magnet connectors (turning of some magnets, see 1.7.3 and 2.1). The correctors were moved up to 32.1 m and the quadrupole centres up to 1.3 m. Cable connection points are moved by larger values, up to 3.4 m for the dogleg bends, up to 4.4 m for the quadrupoles and up to 33.9 m for the dipole correctors. This is due to turning of some magnets.

Table 7: IR7 magnet positions (centre of magnet), movement with respect to V6.402, movement of the connectors with respect to V6.402 and orientation. U=connection side upstream, D=connection side downstream. (data 8/6/4)

Name	Distance from IP7 [m]	Centre movement [m]	Connection movement [m]	Magnet orientation
MBW.D6L7	-214.413	0.00	0.00	U
MBW.C6L7	-210.178	0.00	0.00	U
MBW.B6L7	-174.6735	0.00	3.40	D
MBW.A6L7	-170.4385	0.00	3.40	D
MQWA.E5L7	-142.366	-0.30	2.80	D
MQWA.D5L7	-138.566	-0.20	2.90	D
MQWA.C5L7	-134.766	-0.10	3.00	D
MQWB.5L7	-130.966	0.00	3.10	D
MQWA.B5L7	-127.166	0.10	3.20	D
MQWA.A5L7	-123.366	0.20	3.30	D
MCBWW.5L7.B1	-119.761	1.23	1.23	U
MCBWH.5L7.B2	-117.431	30.07	30.07	D
MQWA.E4L7	-84.076	-1.10	2.00	D
MQWA.D4L7	-80.276	-1.00	2.10	D
MQWA.C4L7	-71.576	1.00	4.10	D
MQWB.4L7	-67.776	1.10	4.20	D
MQWA.B4L7	-63.976	1.20	4.30	D
MQWA.A4L7	-60.176	1.30	4.40	D
MCBWH.4L7.B1	-56.521	1.68	1.68	U
MCBWW.4L7.B2	-54.191	32.22	33.92	D
MCBWW.4R7.B1	54.191	-31.36	-31.36	U
MCBWH.4R7.B2	56.521	-1.52	-1.52	D
MQWA.A4R7	60.176	-1.30	-1.30	U
MQWA.B4R7	63.976	-1.20	-1.20	U
MQWB.4R7	67.776	-1.10	-1.10	U
MQWA.C4R7	71.576	-1.00	-1.00	U

MQWA.D4R7	80.276	1.00	1.00	U
MQWA.E4R7	84.076	1.10	1.10	U
MCBWH.5R7.B1	117.431	-29.21	-29.21	U
MCBWW.5R7.B2	119.761	-0.37	1.33	D
MQWA.A5R7	123.366	-0.20	-0.20	U
MQWA.B5R7	127.166	-0.10	-0.10	U
MQWB.5R7	130.966	0.00	0.00	U
MQWA.C5R7	134.766	0.10	0.10	U
MQWA.D5R7	138.566	0.20	0.20	U
MQWA.E5R7	142.366	0.30	0.30	U
MBW.A6R7	170.4385	0.00	0.00	U
MBW.B6R7	174.6735	0.00	0.00	U
MBW.C6R7	210.178	0.00	3.40	D
MBW.D6R7	214.413	0.00	3.40	D

1.6.4 COLLIMATOR CABLING AND RACK SPACE

About 1008 cables with a total length of 148 km must be installed for the IR7 collimators phase 1 and phase 2. Sufficient space is available in the cable trays. Local cabling on and close to the collimator is not included in the above estimate and will be addressed separately. In addition 4 cables of type NE4 should connect the racks in UJ76 to the surface SR7, allowing direct access to selected collimator signals during beam operation.

A total of 5.5 racks are required in UJ76 for the collimator electronics. Insufficient rack space is available. **An additional 1.5 racks must be provided in UJ76!** If the missing rack space cannot be found, cables must be brought to the surface where sufficient space is available.

1.7 ADDITIONAL CHANGES

The redesign for the cleaning insertions was used as an opportunity to introduce a few additional design optimizations at the same time.

1.7.1 INCREASE OF INTER-MODULE QUADRUPOLE SPACING

The space in the interconnects of the MQW magnets was increased from 300 mm to 400 mm at IR3 and IR7 (included in the layout lists given above). It was found that the standard ion pumps could not be integrated with the old spacing (strong infringement with the magnet). Additionally there is a magnet cover which reduces the space in the interconnect even more.

Even in the case that one could integrate two ion pumps there was still the problem of very poor access to the pump on the external beam line. To reduce intervention time as much space as available is required. Therefore an increase of the interconnect space by 100 mm was requested. As a consequence quadrupoles become 500 mm longer if no collimator is located inside the quadrupole.

1.7.2 RELOCATION OF DIPOLE CORRECTORS AND QUADRUPOLES

In the previous layout v6.402 of the beam cleaning regions IR3 and IR7, all normal conducting magnets except of some MCBWH (see Engineering Change Order LHC-MCBWH-EC-0001) are oriented with their connection side upstream.

In the new layout of IR3 and IR7 the magnets have to be oriented symmetrically around the IP with their connection side upstream (U) or downstream (D) with respect to beam1 according to the tables shown above in Sections 1.5.3 and 1.6.3. The downstream orientation is found from the upstream orientation by rotating the magnet by 180° around the vertical axis in the optical centre of the magnet. The turning of some of the magnets will require a change in the powering scheme to preserve its optical function.

2. REASONS FOR CHANGE

by R. Assmann

The proposed changes are required for the implementation of an improved collimation system for the LHC.

2.1 RELOCATION OF QUADRUPOLES AND DIPOLE CORRECTORS

Radiation and activation studies are relevant to predict the doses and consequently the mean life time of material. They are of equivalent importance for predicting the effective doses that will be later received by personnel during maintenance, repair and transport of the activated items. Modern Radiation Protection practice already requires an optimization of the machine layout during the design phase in order to minimize future exposure of personnel. As for the magnet modules, the main area for interventions is the connection side where thermo-switches are located and all water pipes and electrical power cables are connected and distributed to the coil windings. It has been shown that the remnant dose rate of a more than 3m long steel yoke is about 10 times higher on the side oriented towards the radiation source than on the side turned away from it [2, 3].

Certain MBW (D3, D4) and MQW (Q4, Q5) magnet modules have to be reoriented such that the main particle showers emerging from upstream collimators impinge on the magnets on the non-connection side. As a consequence series of magnets of the same type that are only separated by a vacuum ion pump will have to be oriented in the same direction, in order to guarantee access to the magnet connection during interventions and to reduce the number of variants of vacuum chamber fixations. The position of the supporting jacks is kept with respect to the magnet, one on the connection side, two on the non-connection side of the MBW and MQW magnets.

The orbit correctors MCBWH and MCBWV have been integrated with the vacuum ion pump such that a single universal setup can be used as a package at all required positions in both collimation regions (IR3 and IR7). The choice of orientation for the MCBWH magnets is limited as described in the Engineering Change Order LHC-MCBWH-EC-0001. This setup reduces the number of different vacuum items. Each of these corrector packages is placed on the side of the quadrupole groups with the lower radiation levels. This setup of correctors improves the layout with respect to vacuum and radiation. There is the additional benefit that each magnet type comes only in one variant. We will then have two identical spare magnets of each type and interventions can be shorter due to pre-equipped magnets.

3. IMPACT ON COST, SCHEDULE & PERFORMANCE

by R. Assmann

It is recalled that this ECR does not include machine changes in IR3 and IR7 which are required for minimizing radiological impact of the LHC operation. Consequently the impact of these possible further changes in IR3 and IR7 is not discussed here but will be addressed in an independent ECR.

3.1 IMPACT ON COST

The impact on cost was minimized to maximum extend. Different issues are discussed in the following.

3.1.1 IMPACT ON COST FROM PHASE 1 COLLIMATORS

The cost of the improved system is significantly increased already in phase 1, if compared to the original solution. This is due to longer tanks, more sophisticated materials, extended movement control and additional sensors. The cost of collimation is handled through the collimation project and is not discussed here.

3.1.2 IMPACT ON COST, SCHEDULE & PERFORMANCE FROM MAGNET MOVEMENTS

The power cables for the magnets have to be adapted. At the moment only the water cooled cables for the main magnet groups in IR3 are in place. These cables are already tested and commissioned. The changes in magnet position and orientation can be accommodated by changing the individual cable lengths of the flexible cables of 400 mm² cross-section by up to 7.5 m in IR3 and up to 4.4 m in IR7. The adaptation has no important impact.

The signal cables for magnet power interlocks have to be adapted. At the moment several signal cables have already been put in place and will have to be individually adapted in position and length by up to 7.5 m in IR3 and up to 4.4 m in IR7. The adaptation has no important impact

The supply of demineralised water for the magnets has to be adapted. Depending on the situation, additional taps have to be placed or the flexible tubes have to be longer. The adaptation has no important impact.

The position of the jacks for the MQW and MBW magnets will stay the same with respect to the magnets. This means for turned magnets (with connection side downstream) that two jacks will be placed upstream and one downstream, inverse to a magnet with connection side upstream. The jack positions at IR3 and IR7 have already been marked on the floor. This has to be redone. The adaptation has no important impact.

3.1.3 IMPACT ON COST FROM COLLIMATOR INFRASTRUCTURE

The prices for cabling and local water cooling circuits are included in the collimator budget and will be addressed with an updated collimation budget. Following the decision to connect collimators to the standard cooling water circuits in IR3 and IR7, about 50 kCHF additional costs are required for the adaptation of the demineralised cooling water circuit. The cost to provide additional rack space in IR7 remains to be addressed.

3.2 IMPACT ON SCHEDULE

There is no impact on schedule. The phased approach to collimation is fully compatible with the LHC schedule.

The modular design of the collimators allows full compliance with the **LHC installation schedule**. Support structures, interfaces and quick plug-ins are uncritical technologies. They will be ready by beginning of 2006 and will be included into the overall installation campaigns in IR3 and IR7. This also includes survey and alignment. The delicate collimators can then be later installed in short time (~ 1 h per collimator), taking advantage of the quick plug-in technology. If required, temporary vacuum pipes can be installed for vacuum commissioning before collimator installation.

The collimator installation at the end of 2006 will be sufficient for **beam commissioning** and the first physics run(s). System upgrades will support the natural evolution of the LHC performance.

3.3 IMPACT ON PERFORMANCE

The modified LHC collimation system should allow for a significantly improved LHC performance:

- Higher robustness should exclude or minimize collimator damage. Downtime due to collimator repair is avoided.
- The ultimately achievable cleaning performance is significantly better than the previous solution. Higher beam currents can be supported and higher peak performance is possible.

Initially, some limitation in maximum beam current due to impedance is accepted. However, this should not limit the practically achievable LHC performance. LHC performance will evolve naturally with time and will have to overcome various practical limitations. The impedance limitation from collimators will be resolved with phase 2 collimation before it becomes the overall limit in LHC performance. Several performance issues are discussed in more detail in the following text.

3.3.1 COLLIMATOR ROBUSTNESS

The new collimator solution is expected to have sufficient robustness such that expected LHC failures will not induce damage on the collimation system. The components are designed for the following driving failures:

1. A one-module pre-trigger of the LHC dump with retriggering of all other modules at 7 TeV and nominal beam intensity.
2. Impact of a full injected batch on a collimator.

The second case will be tested in 2004 in the SPS. Beam loss rates of up to $4e11$ protons per second can be sustained for 10 s, continuous losses can reach up to $0.8e11$ protons per second.

The much improved robustness should result in a minimal number of required repair. This minimizes downtime and personnel exposure to beam-induced remnant radiation.

3.3.2 CLEANING INEFFICIENCY

The cleaning inefficiency can be predicted by tracking programs that are also used in the design process of the cleaning insertions. The expected performances at injection and top energy of the betatron cleaning system in IR7 are shown in Figures 3 and 4. Almost a factor 10 better inefficiency can be reached with phase 2. It is noted that the results apply for an ideal system with some assumptions on the beam halo and cannot easily be used to estimate the allowable beam intensity in the LHC ring. Advanced halo tracking in a detailed aperture model must be used for this purpose, as discussed above.

Nevertheless it is stated that the design of the collimation systems achieved quite good cleaning inefficiencies that could not be optimized further, given the LHC

constraints. The predicted inefficiencies for the ideal betatron collimation at 7 TeV are about 12×10^{-4} for phase 1 and 2×10^{-4} for phase 2. Phase 1 performance is below the V6.402 performance ($\sim 5 \times 10^{-4}$), but phase 2 performance of the new system can be significantly better. The corresponding maximum amplitudes of the on-momentum secondary halo were independently estimated to be 9.3σ radially and 7.3σ and 7.4σ in the horizontal and vertical directions.

The performance of the momentum cleaning system was verified during the design process to be equivalent to the previously achieved performance.

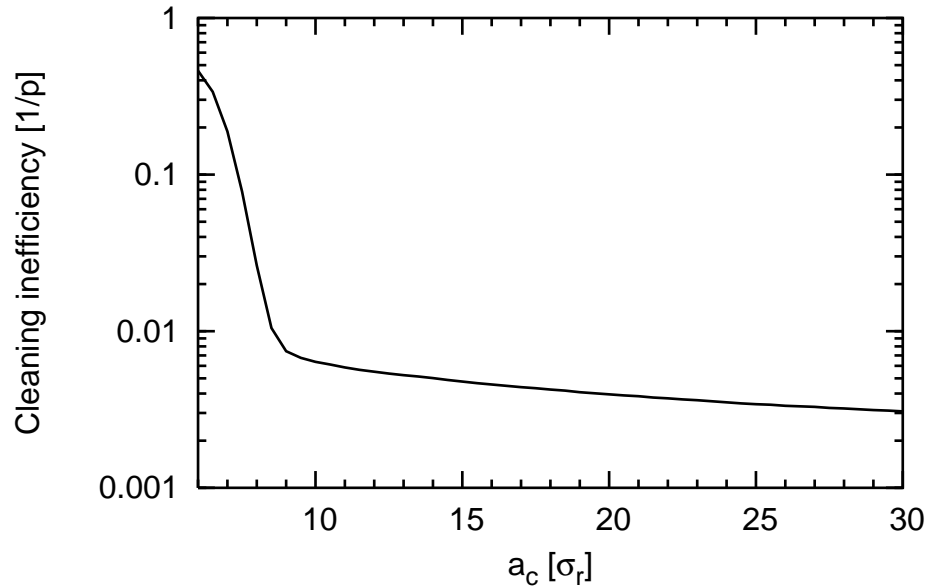


Figure 3: Predicted betatron cleaning inefficiency at injection energy. Note that a typical LHC value for a_c is 10σ .

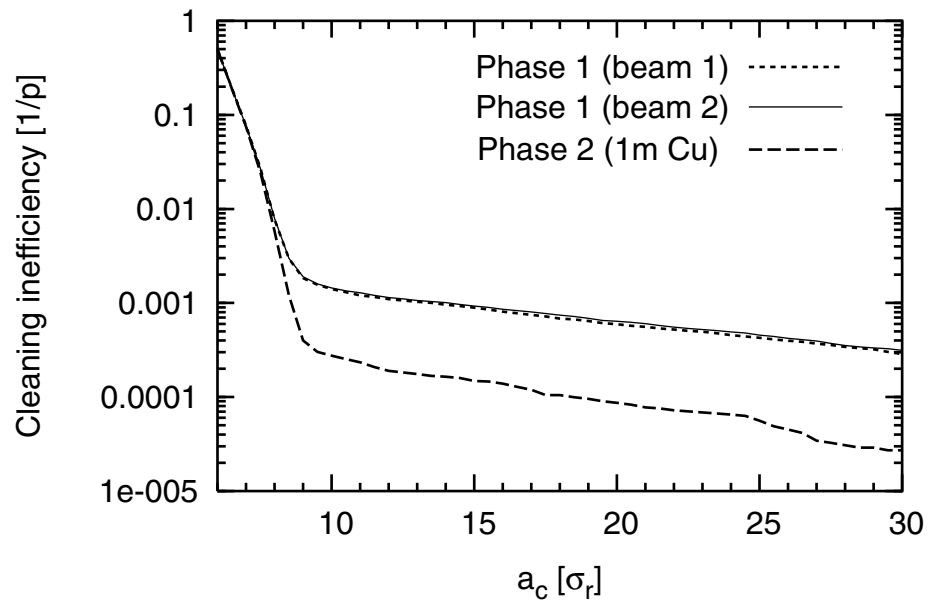


Figure 4: Predicted betatron cleaning inefficiency at 7 TeV, both evaluated for phase 1 graphite collimators (beam 1 and beam 2) and for phase 2, assuming 1 m jaws of Copper. Note that a typical LHC value for a_c is 10σ .

3.3.3 APERTURE IN IR3 AND IR7

The new optics solution provides the same aperture in IR3 and IR7 as the previous optics V6.4 (see presentation to the LTC by O. Brüning). It is noted, that local aperture restrictions exist in IR3 and IR7. These could not be removed during the re-design of IR3 and IR7. The aperture of the LHC is described in detail in the new LHC design report.

3.3.4 IMPEDANCE

The collimator impedance for an intermediate layout, with 20 collimators in IR7 and 7 collimators in IR3, has been discussed in the new LHC Design Report [4]. The resistive wall impedance for a single graphite collimator has been estimated analytically [5] and numerically using the code HFSS [6]. The thick-wall approximation with "inductive by-pass" has been used, since even at the lowest frequency around 8 kHz for the first slow wave the skin depth in graphite is about 2 cm and thus smaller than the 2.5 cm thickness of the collimator block.

The real part of the impedance for a single collimator varies approximately with the square root of frequency below the maximum and with its inverse for frequencies well above the maximum. The frequency corresponding to the maximum of the real part of the transverse impedance is proportional to the resistivity divided by the square of the collimator gap. The imaginary part of the impedance at low frequency tends to a constant value inversely proportional to the square of the gap. Also the maximum of the real part is proportional to the square of the gap. At injection the real part of the collimator impedance has a mild maximum around 0.2 MHz, while for the squeezed optics at 7 TeV the maximum is around 1 MHz. The "effective" impedances for the corresponding most critical coupled-bunch modes are $-11+55j$ M Ω /m and $-100+1400j$ M Ω /m, respectively.

The present baseline for Phase 1 includes only 4 primary and 15 secondary collimators per beam and the impedance is therefore reduced by about 30%. At 7 TeV with squeezed optics, about 60% of the nominal LHC beam intensity can be stabilized using the Landau octupoles. The heat load induced by the resistive part of the graphite collimators is about 160 W/m.

A thin Cu coating of about 1 micron thickness would considerably reduce both the real part of the coherent tune shift (improving beam stability) and the heat load. However such a thin coating may not survive during machine operation.

Further numerical estimates of the geometric collimator impedance are ongoing; the collimator design has been optimized to minimize trapped modes.

3.3.5 COMPONENT HEATING

The phase 1 graphite collimators absorb less energy than the previously foreseen Aluminium and Copper collimators. The Copper blocks absorbed about 50% of the shower energy, with the other 50% escaping the jaw. For the graphite collimators about 97% of the shower energy escapes. It is seen that heating of other components can be enhanced by about a factor of 2 with respect to the previously foreseen solution. This does not change the qualitative picture that component heating can be significant, requiring special absorbers or special component cooling (e.g. cooling of the vacuum pipes).

The need for cooled vacuum pipes has been addressed in a meeting of the Collimation WG on 13.02.04. Two independent studies (I. Baichev et al, V. Vlachoudis et al) concluded that cooled vacuum chambers are required in at least some locations in the cleaning insertions. It was recommended that cooled vacuum pipes should be foreseen for IR3 and IR7. More detailed and complete studies will tell how many cooled chambers are needed and in what locations.

3.3.6 RADIOLOGICAL ISSUES

The improved orientation of the magnets with respect to lower radiation and activation levels will reduce the number of interventions and the dose rate received during each intervention. The improved robustness of the collimators will as well reduce the number of required interventions and the dose rate to service personnel. The graphite jaws themselves will be less radioactive than copper jaws would be. However, the particles therefore will interact at other locations (e.g. possible absorbers), hence the situation with respect to radiation protection (maintenance, environment) will not change and is subject to detailed studies.

3.3.7 HANDLING OF COLLIMATORS

The concept of quick plug-ins and quick exchange flanges will limit the intervention time on collimators to a minimum. Handling problems for collimators are therefore minimized.

3.3.8 POWERING SCHEME

The turning of some of the magnets will require a change in the powering scheme to preserve its optical function. Impact is negligible but should not be forgotten.

3.3.9 EMC ISSUES

The electromagnetic compatibility (EMC) of the BLM detector system cables and the concentration of about 170 stepping motor cables in the same cable tray of IR7 (similarly in IR3) will need a special attention. It is proposed to set up a test stand with the prototypes of the stepping motor drivers and the LHC BLM acquisition system.

The EMC of collimator power supplies and other equipment in the electronics racks also requires detailed study, as some racks will be shared between collimation and other equipment.

3.3.10 FIRE SAFETY

The new collimator jaw materials (graphite/carbon-carbon) are inflammable materials. Nominally there is no risk of fire (collimator jaws in vacuum) but the possible accident scenarios must be considered in further studies, given the fact that there is no fire detection planned in IR3 and IR7 and that there is a certain heat load. It is noted that graphite is used in other movable elements in the LHC and that so far no serious risks were found.

4. IMPACT ON OTHER ITEMS

4.1 IMPACT ON THE VACUUM SYSTEM

by J.M. Jimenez, AT/VAC

The cost to completion (CtC) for the vacuum system in the collimation areas of IR3 and IR7 was based on the Optic version 6.401 and assumed standard 80/84 mm NEG coated copper chambers and standard interconnecting bellows. The recent studies on the robustness of the collimators and on the expected radiation levels with and without a radiation shielding require an optimization of the vacuum system. The impact of this new collimation scheme even though it took into account the space requirements, maintenance and radiation issues as requested by the Vacuum Group, shall not be neglected. The main changes are:

- **The supports for the second beam**

The overall size of the collimator does not allow the use of standard supports to support the NEG coated copper chamber of the second beam. A new version shall be designed.

- **The bake out**

A permanent bake out solution is preferred due to the high level of radiation expected around the collimators. An additional cabling will be required for this bake out equipment.

- **The number of electronic racks**

An increasing number of racks for the power supplies, vacuum control and bake out controllers.

- **The installation/removal scenarios for a new/faulty collimator**

The possible use of a local radiation shielding around the collimators will imply, for a collimator installed on the external beam, the removal of the beam vacuum chambers in front of it prior to the dismantling of the collimator. This scenario will increase the number of vacuum chambers since an adapted length (~ 1.5 m) will be preferred to the 7 m in length LHC standard. The baseline assumed that the second beam vacuum remained under vacuum while we remove the collimator from the top.

- **The interconnecting pieces**

The interconnecting pieces which allow the displacement of the jaws transversally or vertically for the vertical and horizontal collimator respectively are part of the collimators. These interconnecting pieces are mechanically more complex than the standard LHC interconnecting pieces initially foreseen in the same place. Therefore, an additional cost shall be considered for the manufacturing of these components.

- **The vacuum chamber downstream the primary and first secondary collimators and in the room temperature magnets**

The heat load deposited by the shower on the vacuum chambers downstream the collimators is still an issue since it could imply an active cooling of the vacuum chambers, drift space chambers and chambers inside magnets (compare Section 3.3.5 and Collimation WG on 13.2.04). The more detailed estimations of the power deposited on the chamber were expected by end of May. Any additional delay will have an impact on the delivery schedule of the chambers and on the installation schedule if actively cooled chambers have to be designed and manufactured.

Finally, the vacuum baseline assumes only the Phase 1 for the collimation system. Therefore, the CtC for the upgrade of the Phase 2 and 4 shall address the costs related to the vacuum system. However, some aspects of the future Phases have to be implemented already in Phase 1. This is the case of the cabling for the ion pumps, vacuum instrumentation and for the remote bake out. All the cables, including the one for the Phase 2 and 4 shall be pulled within the same campaign. The length and quantity of vacuum chambers which shall be adapted to make easier the future installation of the new collimators.

4.2 IMPACT ON MAGNET SORTING

by R. Assmann

In view of aperture restrictions in the dispersion suppressors (present also for the old solution) a sorting of magnets (matching of golden dipoles to aperture bottlenecks) is strongly supported.

5. CHANGE CLASS

by R. Assmann

Class I

6. COMMENTS (COMPULSORY)

by Project Engineer

7. COMMENTS (IF REQUIRED)

by other Project Engineers

7.1 COMMENTS FROM TS-EL (J. PEDERSEN)

TS-EL is aware that future ECRs issued by the collimator team may treat the points raised in the following. We do however state our points already here, as the points are of importance both financially and with respect to planning and operation.

7.1.1 IRRADIATION OF CABLE ISOLATION MATERIALS

The very high doses of radiation announced – admittedly still to be confirmed – will severely limit the lifetime of the isolation materials. If radiation resistant isolation materials are used the prospective lifetime is increased by a factor of maximum 10. The choice of isolation materials is limited to industrially available products with which it is possible to manufacture industrially applicable cable solutions. Otherwise the operational aspect, see below, becomes completely unmanageable.

7.1.2 IMPACT ON PLANNING: SEQUENCE OF THE INSTALLATION ACTIVITIES

The possibly required air treatment around IP 7 – ducts both in the collimation area and in the adjacent sectors – will render the installation of the cabling systems difficult. The sequence of installation is important in order not to block the access to other systems.

More serious is the lead time of the cable procurement. If radiation resistant materials are needed, the time needed for the specification and the procurement procedure, followed by a not negligible delivery time, must be taken into account. The estimated time to delivery from the moment the decision to use such materials is about 18 months.

7.1.3 IMPACT ON COST

The cost impact depends on the type of isolation material required. A factor of 5 between a radiation resistant and a conventional solution is not unrealistic.

The cabling cost of the collimation installations proper, in points 3 and 7 is estimated to 1.9 MCHF using conventional isolation materials. In the case radiation resistant materials are used the estimated cost is 5.6 MCHF

If it is deemed necessary to upgrade other, already installed systems to a radiation resistant solution the additional costs will be counted in millions as well.

7.1.4 IMPACT ON OPERATION

Due to the level of radiation it must be foreseen to change the most exposed part of the cables, even when using radiation resistant materials.

Most likely the work can only be performed after a cool down period. The duration of the work itself depends of course on the quantity of cables to change, but is likely to be of the order of 14 to 18 weeks, given the global quantity announced. This will have an impact on the shut down time, once the machine is fully operational.

7.2 COMMENTS FROM TS-SU (J.P. QUESNEL)

Given the high radiation and restricted space close to collimators in IR3 and IR7 the following alignment constraints should be taken into account:

- Automatic and remote system for survey of alignment stability.
- Alignment jacks for all elements, including collimators, should be easily accessible.

7.3 COMMENTS FROM TS-CV (J. INIGO-GOLFIN)

No specific requirements have been announced in this ECR for the ventilation and air conditioning. The problem has been addressed by the informal WG on optimization of radiation impact and will be submitted for approval in a separate ECR. Some preliminary comments are already given here:

Local air conditioning in the area between the ventilation doors on either side of the IP and the necessary modifications to avoid activation of the LHC sector air conditioning (textile duct by-pass of the IR areas) have been studied and quoted. None of these items are included in the CtC or in any of the group's contracts or foreseen tenders yet. Additional requests linked to the activation of the air have been made by the informal WG, which are not included in the ECR either. These include the installation of absolute filters at point 7 and the slowing of the flow in TZ76 to allow the decay of certain species in the air. This will entail the removal of ducts, the installation of booster fans and the painting of the TZ.

The adoption of the modifications for the by-pass of the IR areas by the LHC tunnel air will entail consequences on the smoke extraction system for the machine sectors concerned.

These items are important in terms of financial and schedule consequences and their not being mentioned in the ECR must not be understood as being part of the present baseline. These are all items linked to the IR areas and may need to be the object of additional ECR's in which the cost, schedule and future operation aspects are covered.

8. COMMENTS (IF ANY)

by PLO appropriate Committee

9. REFERENCES

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[6] H. Tsutsui, Resistive Wall Impedance of an LHC collimator, CERN LHC Project Note 318 (2003).