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Functional Specification

MEASUREMENT OF THE LUMINOSITY AND BACKGROUNDS AT THE LHC

Abstract

Draft Document of the LHC Beam Instrumentation Specification Working Group

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Approval group members:

To be defined

History of Changes

Rev. No.	***Date***	***Pages***	***Description of Changes***
	22/05/2002		1rst draft for the brainstorming 1 (M. Bozzo invited)
	04/06/2002		second draft for brainstorming 2 (E. Tsesmelis, D. Macina, K. Eggert invited)
	12/06/2002		Draft updated with the conclusions of the brainstorming 2.
	3/12/2002		Final draft for sections 1 to 6 following the meeting of the ad hoc WG on exp-machine data exchange + misc. updates

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1. SCOPE

This functional specification defines the requirements for the measurement of collision parameters in the four LHC interaction points. A basic set of parameters will be provided by the instruments of the AB/BDI Group. More detailed information of the collision parameters as seen by the experimental detectors will be provided by the experiments. This documents gives both an overall view and focuses on the specification of the machine luminometers.

2. BEAM OBSERVABLE AND DERIVED BEAM PARAMETERS

Depending on the technology of the instruments, the primary observables may be either counting rates of collision products or the beam-beam electro-magnetic coupling (beam-beam transfer function).

A second primary observable shall be the background to the experiment.

The derived beam parameters from the above are

- the relative luminosity, which is most important for this specification,
- the transverse residual separation of the beams/bunches,
- the position of the vertex in 3D space,
- the crossing angle.

Add accurate definitions of the above

3. STRATEGY AND RESPONSIBILITIES

3.1 LUMINOSITY

The discussion showed that the separation between absolute and relative luminosity monitors appear both artificial and counter-productive in view of the anticipated uses discussed in section 5. The machine `relative' luminometers can indeed be calibrated by the van der Meer method.

The proposed strategy is as follows:

- It is the responsibility of the experiments to measure their own absolute luminosity.
- Standardized, simple, fast and robust machine lumino-meters are necessary to set up the machine for physics, optimize its performance and compare it from run to run. The luminosity may be calibrated by comparison with the luminosity from the experiments and by the van der Meer method for internal machine use or as a cross-check.

3.2 BACKGROUNDS TO THE EXPERIMENTS

The minimization of the beam background to the experiments is an issue for LHC. The four insertions should be equipped with identical or similar detectors of forward particles under the control of the machine. They should provide information useful for the machine optimization, the ability to provide similar beam conditions from run to run and the understanding of pathologies. Their use to monitor single beam rates is mentioned.

It is proposed first that the implementation of standard meaningful background counters be discussed in the physics community (e.g. use or Roman pots) and provided by them or in collaboration with AB/BDI.

ACTION -> E. Tsesmelis, Daniela Macina.

4. BEAM AND MACHINE CONDITIONS

The luminometers and background monitors must cover a large range of beam and machine parameters defined hereafter.

4.1 RUNNING SCENARIOS

In addition to the baseline running scenarios [Scenarios] (initial, nominal, ultimate running) we have included in Table 1 a few cases that are important for set-up and optimisation of collisions.

Collision studies with single bunches and possibly large beam size at the interaction points (unsqueezed optics) would enable us to commission and optimise the collider in a very efficient and modular way. With single bunches the p-p collisions can be set-up in a selected interaction point with a separation bump in the opposite IP. Once well-controlled collisions and a good single-bunch orbit are established, the additional complications of the crossing bump, squeezed optics, multiple interaction points, and multi-bunch effects can be introduced one by one. We note that collision studies in this scenario are not time-critical, i.e. long integration times are acceptable for luminosity measurements.

Additional scenarios can be imagined, like special bunch patterns of a few bunches that collide simultaneously in all interaction points. These have not been included, as the luminosity in each interaction point is similar to the single bunch cases, which are listed.

4.2 RANGE OF BEAM PARAMETERS

4.2.1 INITIAL LUMINOSITY

The expected range of luminosity in the LHC is summarized in Table 1 for the different running scenarios. The different cases are not exclusive (the other experiments may be active in parallel) and are chosen to allow judging the expected range in luminosity.

Bunch population	Number of bunches	Bunch spacing	Mode	Experiment (not exclusive)	IP beta	Luminosity [$cm^{-2}\ s^{-1}$]
(a) Collision studies with single pilot bunch, no crossing angle						
5×10^{9}	1	n/a	p-p	ATLAS/CMS	18 m	2.0×10^{26}
5×10^{9}	1	n/a	p-p	ATLAS/CMS	0.5 m	7.2×10^{27}
5×10^{9}	1	n/a	p-p	ALICE	10 m	3.6×10^{26}
5×10^{9}	1	n/a	p-p	LHC-b	35 m	1.0×10^{26}
(b) Collision studies with single high intensity bunch						
2.75×10^{10}	1	n/a	p-p	ATLAS/CMS	0.5 m	8.7×10^{29}
1.1×10^{11}	1	n/a	p-p	ATLAS/CMS	18 m	9.9×10^{28}
1.1×10^{11}	1	n/a	p-p	ATLAS/CMS	0.5 m	3.6×10^{30}
1.1×10^{11}	1	n/a	p-p	ALICE	10 m	1.8×10^{29}
1.1×10^{11}	1	n/a	p-p	LHC-b	35 m	5.1×10^{28}
(c) Early p-p luminosity run (different scenarios)						

2.75×10^{10}	1260	50 ns	p-p	ATLAS/CMS	0.5 m	1.1×10^{33}
2.75×10^{10}	2520	25 ns	p-p	ATLAS/CMS	0.75 m	1.5×10^{33}
1.1×10^{11}	936	75 ns	p-p	ATLAS/CMS	0.75 m	2.2×10^{33}
(d) Nominal p-p luminosity run						
1.1×10^{11}	2808	25 ns	p-p	ATLAS/CMS	0.5 m	1.0×10^{34}
				LHC-B	35 m	1.0×10^{32}
				ALICE[1]	10 m	1.0×10^{30}
(e) Ultimate p-p luminosity run						
1.7×10^{11}	2808	25 ns	p-p	ATLAS/CMS	0.5 m	3.0×10^{34}
(f) TOTEM runs						
1.1×10^{11}	36	2.5 μs	p-p	TOTEM (7 TeV)	1100 m	1.0×10^{28}
				TOTEM (.9 TeV)	150 m	1.0×10^{28}
To be checked	2808	25 ns	p-p	TOTEM	18 m	$1.0\times10^{31-2}$
(g) Ion runs						
7×10^{7}	1		Pb-Pb	ALICE/ATLAS/CMS	0.5 m	1.7×10^{24}
7×10^{7}	592		Pb-Pb	ALICE/ATLAS/CMS	0.5 m	0.9×10^{27}

Table 1: Overview on expected initial peak luminosity in the LHC. The quoted values refer to different experimental conditions and to different periods in the LHC development. Different possible scenarios are listed for the initial p-p luminosity run.

The first scenario involving the collision of pilot bunches in the un-squeezed optics extends significantly the dynamic range. It should be noted that it is not strictly required but would greatly help the commissioning if this measurement is technically possible. The integration time is not constrained.

4.2.2 LUMINOSITY DECAY

We note that the quoted luminosity values refer to initial peak luminosity and that the luminosity will decay during a luminosity run. With the calculated luminosity lifetime of 15 hours [reference O. Bruning] and an assumed maximum run length of 20 hours it is expected that luminosity will decay to 25% of its peak value. We assume a decay factor of five, adding a safety margin for additional losses, for example intensity losses during ramp or squeeze. The effective range in luminosity measurement should then reach at least a factor of 5 below the specified range in initial peak luminosity. This required range is mostly relevant for the average beam luminosity at low intensities. Bunch by bunch measurements are expected to be most important for higher intensities, where it is expected that the luminometers offer enough dynamic range.

4.2.3 EXPECTED BACKGROUND RATES

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We have to decide whether we put luminosity and background in the same specification. If yes, this section has to be done some time.

[1] In p-p mode the beam-beam collision offset is adjusted such that the goal luminosity is obtained.

4.2.4 IONS

The initial peak luminosity for ion-ion collisions is low compared to the p-p collisions. Allowing for single bunch set-up of ion collisions with nominal bunch intensity will produce an initial peak luminosity of just 1.7×10^{24} cm^{-2} s^{-1}. As the cross sections for Pb-Pb are much higher than for p-p the event rates from ion-ion collisions will nonetheless be high. In view of the luminosity measurement one should therefore not directly compare the specified luminosity values for ions and protons.

4.3 RANGE OF MACHINE CONDITIONS

In addition to the beam parameters listed in Table 4.1 a number of other machine parameters are relevant to the measurement of the luminosity and background. Their nominal values and expected range are listed below [LHCPN315] [LHCPR367]:

1. *Value of the total crossing angle*: the total crossing angle between beam 1 and beam 2 (orbit bump and spectrometer bump) varies considerably. The angles and the planes of crossing are summarized in Table 2 for nominal p-p collisions. TOTEM runs have a nominal crossing angle of zero, which will also be employed for setting up collisions with a few bunches.
2. *Sign of the crossing angle*: the sign of the crossing angle must be left free for machine optimization or to leave the necessary freedom of the spectrometers' sign.
3. *Plane of the crossing angle*: In ALICE and LHC-b, the planes are fixed by the topology of their spectrometers. In CMS and ATLAS, the new requirement of a beam screen in the low-beta triplet is expected to fix the plane of crossing but leave the possibility to tilt it by up to ± 45 degrees with respect to the specified present situation. A decision on whether to fix the planes is expected by end 2002. The choice of whether the planes are H or V might come only end of 2003. The physics community asked that studies be carried out to free the crossing plane in a second stage some years after LHC starts.
4. *Transverse position of the vertex*: The transverse centering of the interaction point can vary due to orbit or alignment changes. The tolerances for changes in the transverse collision point are set from the experiments to be ± 1 mm for run-to-run and ± 3 mm for longer term movements. This tolerance refers to the experimental geometry; the IP must be centered in the experimental detector to within this tolerance. We note that the detectors are expected to experience significant movements and that the acceptable change from the machine side is then less than the ± 3 mm.
5. *Longitudinal position of the vertex*: The longitudinal position of the collision point is required to move less than ± 10 cm in order to stay within the luminous region of the particle detectors.

IR	Experiment	IP beta	Crossing angle plane	Half total crossing angle	Range for nominal cases
1	ATLAS	0.5 m	Vertical	±150 μrad	
2	ALICE	10 m	Vertical	±150 μrad	±(35-150) μrad
5	CMS	0.5 m	Horizontal	±150 μrad	
5	TOTEM	1100 m	Horizontal	0 μrad	
8	LHC-B	35 m	Horizontal	±285 μrad	±(200-285) μrad

Table 2: Magnitude and plane of the total crossing angle for nominal LHC. The sign of the crossing angle is not fixed, especially in IR2 and IR8 where the spectrometer polarity is

required to be reversed. The range is for nominal cases only and does not include special scenarios. For example, zero crossing angle should be foreseen in IR1 and IR5 for low luminosity running with a reduced number of bunches.

5. DESCRIPTION OF THE ANTICIPATED USES.

5.1 INITIAL BEAM FINDING & OVERLAP OPTIMIZATION

At first order the BPM's will be used to bring the beams close to each other. The residual beam separation Δy_{ip} at the IP depends on the BPM resolution δ_{res} and was estimated to be about [reference Fartoukh]:

$$\Delta y_{ip} \approx \sqrt{2} \cdot \delta_{res}$$

The BPM's are located in a difficult area (high background rates) and a conservative resolution of 200 μm is assumed. The expected residual beam separation is then about 200 μm, corresponding to 18 σ with β^*=0.5 m (squeezed optics) and to 3 σ with β^*=18 m (injection and ramp optics). The latter scenario is obviously better suited for commissioning. During this period, a maximum is expected to be carried out using a single bunch of moderate intensity or a pilot bunch.

The beams can then be put into full collision by maximizing the relative luminosity signal, assuming a constant background signal. The beam-beam separation knobs are changed in a systematic way in order to explore the transverse plane with both beams. Larger beam size (100 μm instead of 18 μm) allows employing larger steps during this possibly lengthy process, thus reducing the required set-up time, the tolerances on orbit drifts etc. This use requires a high-resolution luminosity measurement (resolution about 10^{28} cm^{-2} s^{-1} for one nominal bunch), which can be integrated over minutes, if required. A moderate accuracy of about 10% is sufficient.

5.2 LUMINOSITY OPTIMIZATION FOR PHYSICS RUNS

The main application of the luminometers will actually be the optimization of luminosity during physics running. The first phase in this optimization will be an initial tuning at the start of the fill, requiring fast response with good resolution and reproducibility (thus allowing to compare to the previous fill). The second phase will be more or less continual maximization during the luminosity production, often involving trial and error on several beam parameters. The success of tuning is always judged through the change in the luminosity signal. As the possible magnitude of changes is very much constrained in the LHC only small improvements can be expected and a good luminosity resolution is mandatory. We require a luminosity **resolution of better than 1% within a second for the full beam**. The reproducibility from fill to fill should be about 1%.

5.3 LUMINOSITY FEEDBACK

A procedure has been proposed [Wturner] to keep the beam in collision at a fraction (0.1 - 0.2) of sigma level by monitoring the average luminosity. The requirement in precision is identical to that of section xxx, i.e. a luminosity measured to the 1% level. The response time of the feedback loop need not be fast, as the phenomena leading to a beam separation are slow (e.g. local orbit drifts due to magnet motion). A correction rate in the range 0.1 to 0.01 Hz seems appropriate.

5.4 EQUALIZATION OF THE LUMINOSITY AMONGST THE EXPERIMENTS

Experience shows that issues such as unexpected discrepancies between the absolute luminosity measured by various experimental detectors occur. If differences on the few percent level are seen between the two high luminosity experiments (IR1 and IR5) machine tuning will be requested to equalize the delivered luminosities on a high level. The experiments will specify the required relative improvement for a given IP. A reasonably fast luminosity signal for machine tuning should be provided from the luminometers, requiring a luminosity **resolution of better than 1% for the full beam** with a time response that can in principle be as long as a minute or so (luminosity equalization is done during special machine tuning). It is important that the measured change in luminosity must not be affected by any changes in systematic errors, possibly arising from the machine tuning.

An absolute calibration for the luminometers can be inferred from the luminosity recorded in the experiments and from correlation studies between the machine and experimental luminosity signals. In case of large unexplained differences in reported luminosities between the experiments, an independent absolute calibration (e.g. van der Meer method) could also arbitrate discrepancies between experiment measurements. A level of 10% is felt sufficient for this purpose.

5.5 ADJUSTMENT OF THE LUMINOSITY FOR ALICE

ALICE requires the beams to be partly separated depending on the machine performance. The goal is to provide a pre-defined absolute luminosity. A rough absolute calibration of the machine luminometer would help as long as the detector cannot be switched on. If the absolute luminosity is already measured in another experimental point, simple calculations can be done to compute the required beam separation (assuming good knowledge of the local β^*). A relative luminosity measurement by the machine luminometer is then sufficient.

5.6 MINIMIZATION OF BEAM-BEAM EXCITATION

A small parasitic beam separation, of little or no practical consequence on the luminosity, has been identified as source of background and/or reduced lifetime [cornelis], [limberg]. Potentially too small for detection by IR BPM's, it could be detected by the luminometer. The tolerance for allowable beam-beam offsets is estimated to be about 0.1-0.3 sigma from the above-mentioned sources. Both the average offset between the beams and the offset in each bunch collision are important. The former can be corrected while the understanding of the latter may lead to better understanding of the machine performance. The luminosity with a beam-beam offset Δy_{IP} is given by:

$$L \approx L_0 \cdot e^{-\left[\Delta y_{IP}^2 / \left(2\sigma_y^*\right)^2\right]}$$

For a 0.2 sigma beam-beam offset tolerance we find a reduction in luminosity of 1%. In order to detect a parasitic separation, the resolution of the luminometer shall be better than 1%. The integration time shall be small as compared to the phenomena which lead to a beam separation of 0.1 sigma (e.g. orbit drifts for the whole beam, PACMAN effects from bunch to bunch). Orbit drifts typically occur over minutes (damped by feedbacks) and PACMAN effects are quasi-static. A 1% bunch-to-bunch resolution is required as well in order to allow analyzing and minimizing beam-beam offsets from bunch to bunch with the luminometer. It is noted that these subtle effects may also be studied via the beam-beam transfer function [bbtf1],[bbtf2] using electro-magnetic devices.

5.7 MONITORING OF THE XING ANGLE

The crossing angle is an important parameter for the LHC operation. It is crucial for the efficiency of the alternate crossing scheme. An estimate of the required accuracy for beam dynamics [LHCPN211] gives ± 7μrad. It will be measured with the BPM's in the IR region with an accuracy of down to 1.5 μrad *(or rather 10urad, to be verified)*. Its measurement with the luminometers potentially offers a redundancy which might prove valuable, especially as the BPM's must measure very precisely in the high background IR region (the BPM's at Q1 may be disturbed by the flux of charged secondaries). It is noted that the experiments might require an accuracy in crossing angle that is below the 7 μrad requirement for the machine.

5.8 MONITORING OF THE VERTEX POSITION

The experiments have a limited acceptance both in transverse and longitudinal position. The monitoring of the vertex position is thus necessary. It will be provided by the experiments (see Section **Error! Reference source not found.**)

5.9 BUNCH-BY-BUNCH MEASUREMENT OF LUMINOSITY

The limit of LHC performance is presently expected to be the long-range beam-beam effect. Not all bunches suffer the same perturbations. There is therefore a strong incentive to measure the relative luminosity bunch-by-bunch when the performance of the machine approaches about 50% of its nominal value. At a lower performance level, the anticipated electron clouds may produce similar effects. Together with the bunch-by-bunch measurement of the beam current position and emittance, the bunch-by-bunch luminosity measurement should help the diagnostic of selective blow-up, coherent oscillations,… The experience in the B-factories shows that indeed strong variations can be observed along long bunch trains, e.g. due to collective instabilities (e-cloud, …).

The luminosity resolution per bunch should be of the order of a few percent and less than 10%. The integration time is not really constrained. About 1 minute or less is convenient for operation. **It should be noted that a bunch-by-bunch excitor is needed to measure the beam-beam transfer function.**

5.10 MONITORING OF THE BACKGROUNDS

The low-beta insertions are rather complicated, making the machine optimization a possibly tedious process. The measurement of the background caused by beam-gas interactions or by the interactions of the halo particles with the surroundings can be expected to be valuable in optimizing the insertions for performance and for reproducibility. This was the case in the ISR where dedicated machine monitors were provided and is confirmed in RHIC. The monitoring shall be bunch-by-bunch to detect pathological bunches. The background signal is most suitable to center the vertex by minimizing the background. It is equally valuable to carry empirical machine optimization (tunes, orbits, coupling,…).

The integration time shall be less than or equal to 1 s for nominal machine performance to allow for efficient optimizations. In other scenarios, it would be convenient not to integrate for more than a few seconds. The only relevant component of the precision is the resolution. The background being a very sensitive signal, it does not seem easy to specify a useful resolution. A figure better than 10% and ideally of the order of 1% seems appropriate.

6. MACHINE AND EXPERIMENT INFORMATION EXCHANGE

Information to be communicated by the LHC machine and experiments is discussed in the LHC Data Interchange Working Group (LDIWG) [1] and the Ad-hoc LHC Machine-Experiment Parameter and Signal Exchange Working Group [2]. These communication links will be required to guide the interaction between the collider and experiments when operation of the LHC commences. Emphasis is placed on observables that can provide a measure of the LHC machine operating conditions for the experiments, and that can be used by the experiments to give feedback to the machine operation as well as to protect their detectors against damage from spurious operating conditions of the machine.

This chapter discusses the **subset** of exchanged information relevant to this specification. Figure 1 shows the conceptual lay-out of the entities considered for data exchange.

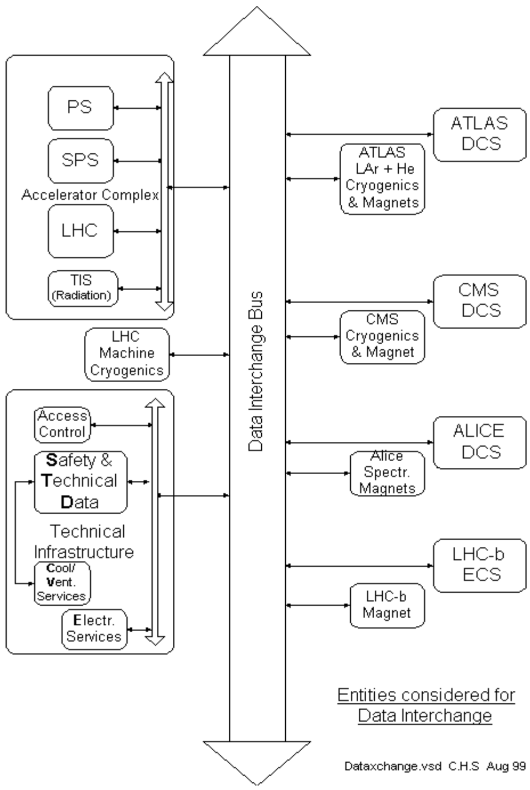

Figure 1: Entities considered for data exchange at the LHC

Details of the complete amount of information exchanged as well as the frequency may be found in Reference [1].

6.1 EXPERIMENTS TO MACHINE

Entity	Detail
Spectrometer Magnets	Currents and polarity
Position of Moveable Detectors Components	LHCb Vertex Detector (VELO) TOTEM Roman Pots
Background Measurements	Spatial and temporal distributions
Beam Characteristics	Vertex position (x,y,z) Luminous region
Absolute and Instantaneous Luminosity	Various sources for instantaneous (calorimeter currents, dedicated counters) TOTEM for absolute

The vertex position is measured in the reference frame of the experiment. A conversion to the machine reference frame shall be done before transmission. It will be based either on survey data measured during shut-downs or on continuous monitoring wherever available.

The relative luminosity can be measured from trigger rates and both the integral/average and bunch-by-bunch values will be provided. Transmission of the summary information from the experiments to the machine can be performed at least every minute. The bunch-by-bunch luminosity can be reported at a rate of 1 Hz. The expected accuracy is of the order of a few per cent. The same detectors are planned to measure the backgrounds and would deliver the data at the same rate.

This section summarizes the offer; from the machine point of view, the fast transfer rate of 1 Hz is only required for the background information.

6.2 MACHINE TO EXPERIMENTS

Entity	Detail
Relative Luminosity	

The information from the machine would be updated at least every minute and subsequently broadcast to the experiments.

In addition to the above information, a concise summary of the machine operating status, as has been the case for other accelerators, is required. This should be made available on TV monitors throughout CERN and also accessible via the WWW.

7. FUNCTIONAL REQUIREMENTS

THIS section is done done as yet. It will summarize in tables the requirements identified above in terms of parameters of the

luminometers. The issue of the background monitors has to be settled.

7.1 SAMPLING PERIOD

Average Lum., Bunch-by-bunch from beginning or…

7.2 DYNAMIC RANGES AND INTEGRATION TIMES

Summary of extreme requirements identified in the first 2 sections:

10^3 from detector for the bunch-by-bunch dynamics ⊗ 10^3 for the number of bunches (electronic processing)

7.3 PRECISION

Summary of requirements on absolute accuracy and resolution

7.4 DEPENDENCE ON THE GEOMETRY OF THE CROSSING

1rst brainstorming:

- *SIGN and Xing angle value are not a technical issue. Covered by the proposed layout.*
- *Plane is a major issue to be decided quickly ?!?! NOT Covered by the proposed layout.*

Small changes to the geometry of the beam Xing will occur during a run. The luminometer shall not be sensitive to them (precision guarantied) for the following range of changes:

- Transverse vertex position
- Xing angle

7.5 ROBUSTNESS AGAINST NOISE

Noise to the luminometer can be generated by:

- Ghost bunches if bunch data are averaged,
- DC fraction of the beam
- Halo collidung with aperture limits,…

A full list of possible sources would be valuable.

The detector should either be immune to this noise or able to detect an abnormal machine conditions.

7.6 DATA TO BE MADE AVAILABLE TO THE CONTROL ROOM

Data provided either systematically or on request are:

7.7 DATA TO BE MADE AVAILABLE TO THE EXPERIMENTS

It looks like the machine lum. Data is not required by the experiments beyond the global data block to be transferred incluuding intensity, ….

7.8 DATA AVAILABLE FROM THE EXPERIMENTS

To be defined: absolute luminosity is useful in case of optical error, long. And transverse vertex positions,…

7.9 POST MORTEM

Standard logging is required; probably nothing specific to post-mortem.

Action for the whole section 7: M. Placidi

8. DESIGN CONSTRAINTS

8.1 ALIGNMENT

8.2 RADIATION HARDNESS

As far as radiation is concerned, the location in LSS5 is the most stringent, IP5 being a high luminosity insertion point. The expected activity in the detector region has been evaluated [14] and [15]. A dose between 10 Gy/year and 100 Gy/year is expected.

8.3 INB CONSTRAINTS

The LHC has been classified as an "Installation Nucleaire de Base" by the French Authorities. CERN is therefore obliged to conform to their relevant regulations, guidelines and procedures. Within this context CERN has to establish traceability & waste management procedures and maintain a radiological and zoning system. In order to meet these requirements, information such as: material content, location history, sub-assemblies, etc…, shall be supplied by the Contractor and will be maintained in a CERN database. CERN has created a set of procedures and conventions as part of the Quality Assurance System for LHC, which will also be used to facilitate these INB requirements. The relevant quality documents are listed below and shall be applied by the Contractor during the production, testing and assembly of components: "The Equipment Naming Convention", "The LHC Part Identification", "The Manufacturing and Test Folder".

9. RELIABILITY, AVAILABILITY AND MAINTAINABILITY

Machine protection issues may also require for safety reasons that the continuous measure of the number of particles in the abort gap is not prevented while making any other type of acquisitions.

10. SAFETY AND REGULATORY REQUIREMENTS

The longitudinal profile monitor must meet the safety guidelines put forward by the CERN Technical Inspection and Safety Commission (TIS). TIS have issued safety documents in compliance with LHC-PM-QA-100 rev1.1, and the guidelines in these documents will be incorporated into the monitor design.

11. REFERENCES

[Scenarios] See web link "Beam Parameters - Design Performance" at the official web page of the LHC project (http://lhc-new-homepage.web.cern.ch/lhc-new-homepage).

[LHCPN315]

[LHCPR367]

[Bturner]

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[bbtf1] A. Hofmann, J.P. Koutchouk, The beam-beam transfer function, ISR Performance Report , 27/1/1981.

[bbtf2] D. Sagan et al., A luminosity monitor using the coherent beam-beam interaction, PAC93, 1993.

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[1] http://lhc-div.web.cern.ch/lhc-div/Controls/WG/LDIWG/Welcome.html

[2] http://cern.ch/lhc-data-exchange