Machine-Detector Interface

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General Organization
LHC Experiment Machine Interface Committee (LEMIC)

- LEMIC provides a forum where those technically responsible for the LHC experiments meet and discuss with representatives of the machine project in AB, AT and TS Departments.

- The subjects treated cover everything of common interest to the machine and experiments and include the project status and planning, the coordination of infrastructure in the experimental areas, backgrounds and the status of the detector installation.
The LEA Group – Coordination of LHC Experimental Areas

- The liaison between the LHC accelerator and experiments as well as simulations of machine-induced backgrounds in the experimental areas is ensured by the Machine Physics Interface section.
  - The group provides such general support within its particular positioning at the interface between the LHC machine and experiments.

- The LEA group is represented on the following committees: LHCC (LHC experiments Committee), LEMIC (LHC Experiment Machine Interface Committee), LTC (LHC Technical Committee) and the TCC (LHC Technical Coordination Committee).
Machine-Detector Working Groups

- **LHC Experiment-Accelerator Data Exchange WG (LEADE)**
  - Coordination of parameter and signal exchange at the LHC.
  - Machine data production and their distribution to the experiments as well as information produced by the experiments on the machine running conditions and their communication to the LHC machine.

- **Machine-induced Background WG (MIB)**
  - Coordination of studies to keep machine-induced backgrounds down to an acceptable level and to ensure that detector protection and background shielding are adequate.
  - [http://cern.ch/lhc-background/](http://cern.ch/lhc-background/)

- **Radiation Monitoring WG (RADMON)**
  - Coordination of the development of radiation monitors to be installed in detectors, experimental areas, & accelerator tunnel
Additional LEA Representation on LHC Project Working Groups

- Machine Protection WG
- Injection WG (for ALICE ZDC)
- Collimation WG
- Hardware Commissioning WG
- LHC Collimation Control Specifications WG
Experiment – Machine Communications
experiment — machine data exchange

- LDIWG (LHC Data Interchange Working Group) defined single data exchange mechanism between all systems involved in LHC data operations

- Requires DIP (Data Interchange Protocol) bus supporting:
  - Publish/subscribe data exchange
  - DIM protocol selected due to lower cost and simpler maintenance
The LHC Logging System - Timber

- Data logging facility for LHC Controls System
- Input/Output Interface
  - Web-deployed GUI
  - Output
    - Graphical visualisation
    - File output
Data Flow from Experiments to Machine

<table>
<thead>
<tr>
<th>Entity</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrometer Magnets</td>
<td>Currents and polarity</td>
</tr>
<tr>
<td>Position of Moveable Detectors Components</td>
<td>LHCb Vertex Detector (VELO)</td>
</tr>
<tr>
<td></td>
<td>TOTEM and potentially ATLAS Roman Pots</td>
</tr>
<tr>
<td>Background Measurements in detectors</td>
<td>Spatial and temporal distributions</td>
</tr>
<tr>
<td>Beam condition monitors</td>
<td>Standardized background monitors used as reference for machine tuning</td>
</tr>
<tr>
<td>Beam Characteristics</td>
<td>Vertex position (x,y,z)</td>
</tr>
<tr>
<td></td>
<td>Luminous region</td>
</tr>
<tr>
<td>Absolute and Instantaneous Luminosity</td>
<td>Various sources for instantaneous (calorimeter currents, dedicated counters) TOTEM for absolute</td>
</tr>
</tbody>
</table>
Measurements on luminosity, beam-beam collisions, beam-related background & luminous region.

Essential to retain flexibility in data exchange mechanism as experience with experiment & machine operation develops
  - Number & choice of quantities exchanged, the production rate and hence the data rate

Additional rates, e.g. from calorimeters and muon detectors that are sensitive to the radial and φ distributions of beam-related backgrounds, should be developed in collaboration with the Machine Group.

<table>
<thead>
<tr>
<th>Producer</th>
<th>Measurement</th>
<th>Units</th>
<th>Production Volume (Bytes)</th>
<th>Production Interval (sec)</th>
<th>Data Rate (Bytes/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS/CMS</td>
<td>Total luminosity</td>
<td>cm⁻²s⁻¹</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ATLAS/CMS</td>
<td>Average rates</td>
<td>Hz</td>
<td>12</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>ATLAS/CMS</td>
<td>Luminosity per bunch</td>
<td>cm⁻²s⁻¹</td>
<td>14256</td>
<td>60</td>
<td>238</td>
</tr>
<tr>
<td>ATLAS/CMS</td>
<td>Rates for individual bunches</td>
<td>Hz</td>
<td>42768</td>
<td>60</td>
<td>713</td>
</tr>
<tr>
<td>ATLAS/CMS</td>
<td>Position and size of luminous region (average over all bunches)</td>
<td>cm</td>
<td>24</td>
<td>600</td>
<td>0.04</td>
</tr>
<tr>
<td>ATLAS/CMS</td>
<td>Total per experiment</td>
<td></td>
<td></td>
<td></td>
<td>966</td>
</tr>
</tbody>
</table>
## Machine Experiments

<table>
<thead>
<tr>
<th>Producer</th>
<th>Measurement</th>
<th>Data Type</th>
<th>Production Volume (Bytes)</th>
<th>Production Speed</th>
<th>Production Rate (kB/s)</th>
<th>Expected Accuracy</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-BDI</td>
<td>Total beam intensity</td>
<td>Protons</td>
<td>8</td>
<td>1 sec</td>
<td>0.008</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Individual bunch intensities</td>
<td>Protons</td>
<td>28.512</td>
<td>1 min</td>
<td>0.475</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Average 2D beam size</td>
<td>mm</td>
<td>16</td>
<td>1 sec</td>
<td>0.016</td>
<td>15%</td>
<td>For transport to IP will require knowledge of beta function</td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Average bunch length</td>
<td>ps</td>
<td>8</td>
<td>1 sec</td>
<td>0.008</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Total longitudinal distribution</td>
<td></td>
<td>285.120</td>
<td>1 min</td>
<td>4.752</td>
<td></td>
<td>Will be able to detect ghost bunches at the 0.1% level of nominal</td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Average HOR &amp; VER positions</td>
<td>um</td>
<td>32</td>
<td>1 sec</td>
<td>0.032</td>
<td>50um</td>
<td>From the BPMs located at Q1 either side of each IP</td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Luminosity</td>
<td></td>
<td>28.512</td>
<td>10 sec</td>
<td>2.851</td>
<td>1% relative</td>
<td>This is a relative measurement between bunches</td>
</tr>
<tr>
<td>AB-BDI</td>
<td>Average Beam Loss</td>
<td></td>
<td>16</td>
<td>10 sec</td>
<td>0.002</td>
<td></td>
<td>Average of up to 50 selectable BLMs</td>
</tr>
</tbody>
</table>
Beam Monitoring
Beam Monitoring –
Transverse Position of Collisions

LHC Machine
- The maximum transverse variation during a coast is expected to be <20% of the beam width ($\sigma_{x,y} = 16 \mu m$).
- The maximum transverse variation of the beam collision point between coasts is likely to be $<\pm 1 mm$.
- The transverse position of the beam can be re-aligned by the machine to within $<\pm 1 mm$.

ATLAS & CMS
- Plan to monitor the transverse position of the collision point by reconstructing tracks in the inner detectors.
- A measurement of this position to about 10 $\mu m$ accuracy could be provided within 10 s.
- Although such measurements will follow the movement of the detectors, a potential source of error is transforming the measurements from the experiment reference frames to that of the machine.
Luminous Region

- In order to preserve the assumed performance of ATLAS, it is requested that at least 95% of the integrated luminosity be within $z = \pm 112 \text{ mm}$

- Calculations
  - Bunch length increases by 30% in 10 hours (P. Baudrenghien)
    - Assume this is linear
  - Intensity falls off as $N = N_0 \exp(-t/10)$

\[ \phi = 300 \mu\text{rad}; \beta^* = 50 \text{ cm}, \text{ bunch l. 7.7 cm} \]

95% Lumi within ±90 mm

Good match between expected luminous region and acceptance of ATLAS & CMS trackers found.

Fast reconstruction in ATLAS & CMS will measure longitudinal position of collision to within ±2mm
Beam Monitoring –
Beam Position Monitor

- Total of 1166 BPMs needed for the LHC and its transfer lines.
- Includes timing pick-up for the experiments (BPTX)
- Located ~175m from the IPs
- One BPTX either side of the IP on the incoming beam
- Used exclusively by the experiments

Two applications of BPTX timing signals were identified by experiments
- Monitoring the phase of the clock of the two beams locally at the IRs
- Allows to determine whether the TTC system is synchronised with the actual arrival of the bunch.
- Identify the location of the gap in the LHC bunch train
- Especially useful during setting-up stage of the experiment
Anticipated Applications

- Initial beam finding & overlap maximization
- Manual maximization of collision rate for physics runs
- Equalization of the collision rates amongst the experiments
- Monitoring of the crossing angle
- Bunch by bunch measurement of the collision rate
Monitor to be installed in slot inside TAN Absorber at IR1/IR5

A major constraint on the choice is given by the required radiation hardness necessary to survive in IR1/IR5.

- Fast Ionization Chamber

What about IR2/IR8?

- Polycrystalline Cadmium Telluride?
## LHC Machine Collision Rate Monitor

### Functional Requirements

<table>
<thead>
<tr>
<th>Luminosity sub-range</th>
<th>particle</th>
<th>Resolution</th>
<th>integration time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.0 \times 10^{26} \rightarrow 1.0 \times 10^{28}$</td>
<td>p-p</td>
<td>beam</td>
<td>$\pm 10%$</td>
</tr>
<tr>
<td>$1.0 \times 10^{28} \rightarrow 3.0 \times 10^{34}$</td>
<td>p-p</td>
<td>beam</td>
<td>$\pm 1%$ (0.25%)</td>
</tr>
<tr>
<td>$1.0 \times 10^{33} \rightarrow 3.0 \times 10^{34}$</td>
<td>p-p</td>
<td>bunch</td>
<td>$\sim \pm 1%$</td>
</tr>
<tr>
<td>$1.0 \times 10^{24} \rightarrow 5.0 \times 10^{25}$</td>
<td>Pb-Pb</td>
<td>beam</td>
<td>$\pm 10%$</td>
</tr>
<tr>
<td>$5.0 \times 10^{25} \rightarrow 0.5 \times 10^{27}$</td>
<td>Pb-Pb</td>
<td>bunch</td>
<td>$\pm 1%$ (0.25%)</td>
</tr>
</tbody>
</table>
ATLAS Collision Rate Monitoring

- ATLAS proposes a dedicated detector - **LUCID**
  - **LUminosity measurement using Cerenkov Integrating Detector**

- There are 200 gas filled \((C_4F_{10})\) Cerenkov tubes per end.
- Use Al lined Carbon fibre Cerenkov tubes for heat resistance.
- The tubes are deployed in 5 layers of increasing diameter:
  - each row has 40 tubes.
- Tube orientation allows some position sensitivity.
CMS Collision Rate Monitor

Measure luminosity bunch-by-bunch

- Small angle (~1°) pointing telescopes
- Three planes of diamond sensors (8 mm x 8 mm)
- Diamond pixels bump bonded to CMS pixel ROC
- Form 3-fold coincidence from ROC fast out signal
- Located at $r = 4$ cm, $z = 170$ cm
- Total length 20 cm
- Eight telescopes per side

Count 3-fold coincidences on bunch-by-bunch basis

Rutgers/Princeton/UC Davis
Additional LHC Machine Monitors

- **Individual bunch currents**
  - Fast current transformers at Point 4
  - Updated every minute

- **Longitudinal bunch structure**
  - Luminosity Profile Monitors at Point 4
  - 50 ps resolution
  - Updated every minute

- **Beam loss monitors**
  - Gas ionisation detection in the arcs and straight sections
  - Secondary electron emission in the collimation regions
    - Loss rates 4 orders of magnitude higher than in arcs
The overall TTC system architecture provides for the distribution of synchronous timing, level-1 trigger, and broadcast and individually-addressed control signals, to electronics controllers with the appropriate phase relative to the LHC bunch structure, taking account of the different delays due to particle time-of-flight and signal propagation.
Timing, Trigger and Control (TTC)

OVERALL TTC System (with TTCex + TTCctx):

- RF signals generation: AB-RF
- Transmission to PCR: AB-CO
- VME CRATE: BST MESSAGE PROCESSOR, AB-CO
- TTC TRANSMITTER CRATE: TTCex + TTCctx provided by EP
- Implemented by Bruce Taylor. NOT SUPPORTED BY EP
- F.O. Network supported by IT-FO

EXPERIMENT AREA:
- TTC equipments provided by EP. Implementation and maintenance under responsibility of experiment.

MACHINE AREA:
- Only TTCrm cards provided by EP. Implementation and maintenance under responsibility of AB-BDI.
LHC Beam Synchronous Timing System (BST)
- BST used to synchronize LHC beam instrumentation
- Distribution of BST messages (once per orbit) uses TTC
- BST message: 32 bytes, of which 8 bytes for GPS Time

Usage in Experiments:
- GPS Time added to Event Record:
  - BST/TTC link to Central Trigger Control (1 link)
  - BST/TTC link to Local Trigger Controllers (10 links)
- GPS Time and LHC Data added to DCS Data:
  - BST/TTC link to central VME receiver (BOBR)
  - (complementary to access to LHC data via DIP)
LHC Machine Timing Signals & Distribution to the Experiments

- LHC RF Group will provide 3 clocks
  - **Stable reference clock**
    - 40.08 MHz delivered from the SR4 Faraday cage
    - Will serve as reference clock of the LHC machine
    - Can be used by the experiments to clock their electronics
  - **Two clocks which will drive the RF for the two beams**
    - Locked to the reference clock
    - But will vary since they are adjusted to follow the bunches in the machine
LHC Machine Timing & Distribution to the Experiments

- **Jitter** of reference clock 10 ps at origin

- **Experimental Considerations**
  - Experiments rely on collisions being as close as possible to the nominal IP \((z=0)\)
    - Example: CMS Calorimeter digitization requires a timing signal with < 50 ps jitter
  - Jitter affects the average time of collisions in the experiments with respect to the reference clock and the average collision point itself.

- Experiments would like to access reference signal from the closest beam pick-up at the insertion region
RF Timing Signals ➔ Experiments

- When machine is in colliding mode, the RF guarantees a clean, stable, non-interrupted 40 MHz well within range of experiment QPLL.
- During access, after beam dump, during shut-down or repairs the RF supplied bunch frequency can be (almost) anything (even missing)
  - Experiments need to implement a switch at the TTC input
    - Select either the RF-supplied 40 MHz or local reference
    - Switch driven by a timing that commutes on RF reference only when machine is in colliding mode
Radiation Monitoring
Experiment & Area Radiation Monitoring System - Introduction

- Radiation Monitoring System required to:
  - Provide on-line monitor for beam conditions, with possibility to request beam abort/injection inhibit/detector power ramp-down (Beam Condition Monitor - BCM)
  - Provide initial mapping of radiation field during first physics run (BCM + Active/Passive Monitors)
    - Check simulation results and check for shielding leaks
  - Provide mapping of the integrated radiation exposure (Active/Passive Monitors + RAMSES)
    - Diagnostic analysis in case of equipment failure
    - Corrective measures like shielding improvement
    - Activation levels for access
Beam Condition Monitor (BCM)

For nominal machine operation conditions, BCM is redundant system

BUT, machine protection group encourages implementation of BCM

Unsynchronised beam abort: $\sim 10^{12}$ protons lost in IP 5 in 260ns

Beam condition monitors
Looking for increase over normal rate
Monitors to be within CMS and feed to machine interlock
Sensors to be placed in the Pixel volume and after the Forward calorimeter

• Sensors under investigation: Polycrystalline Diamond
  • Fast signal response
  • Radiation hardness
  • Minimal services required ie no cooling necessary
CMS BCM Test Beam Programme

- 114 days of beam in PS East Hall
- Used Polycrystalline diamond
- Sensor irradiated to \( \sim 2 \times 10^{15} \) p/cm\(^2\)
- Linearity of PC CVD response
  - Good over \( \sim 9 \) orders of magnitude

Diamond Signal Amplitude
Sensor: 1 mm x 1 mm x 300 um
Sensor activity: 1 um
Amplifier gain: 15.8 (24dB)
Incident beam:
60:40 ratio 5 GeV n\(^\circ\), p\(^\circ\)

Single MIP signal
mean \( V_{\text{max}} = 16 \) mV
(After Gain of 15.8)
S/N \( \sim 0(100) \)

Amplitude of Amplified Diamond Signal (Volts)

CVD Flux per bunch (#/cm\(^2\))

- Fluence measurements with TLDs
- Fluence from particle counting in Scintillators
- Fluence from \(^{24}\)Na Dosimetry in Aluminium
- From direct single particle counting
- Sensor at 0.2V/mm (preliminary)

Testbeam programme:
Resources found from CMM and TS-LEA Groups

\[ y = y_0 + A \times x \]

\[ A = 0.318 \pm 0.004 \]
LHC Machine Beam Interlock Controller

Allows signals from the experiments to give the BEAM PERMIT, and a BEAM ABORT if the PERMIT is absent.
Functional Specification for describing the beam interlocking of the LHC experiments is under preparation.

- Includes description of LHC machine modes.
- Requirements for hardware & software interlocks.
- Special signals
  - Ready for high risk operation
  - Ready for beam abort
  - Normalized background signals
Active Radiation Monitors

**TID** ($Gy_{Si}$)
- mainly charged particles and photons

**$\Phi_{eq}$** (cm$^{-2}$)
- mainly fast hadrons

- RadFETs
- Optically Stimulated Luminescence (OSL)

- Forward biased $p$-$i$-$n$ diodes
- Reverse biased PAD structures
Passive Radiation Monitors

Polymer-Alanine (PAD) & Radio-Photo Luminescent (RPL) Dosimeters:

- Formation of stable free radicals/color center after irradiation;
- Readout by CERN SC/RP ("TIS");
- Well known dosimetry systems.


Gafchromic® Sensitive Films

- Formation of a stable dye polymer after irradiation;
- Optical readout (color density);
- Different sensitivities/ranges

Calibration campaign 2003 in the mixed $\gamma$/n field of CERN-PS IRRAD2 facility

24 GeV/c protons (HD-810)
LHC Machine Radiation Monitoring System

Installation also in experimental areas
e.g. alongside cryogenic electronics in UX85 cavern

- Radiation tolerant design (200 Gy)
- Remote readout via WorldFIP at 1 Mbit/s
- Up to 100 Hz Measurements of
  - Dose, Dose rate
  - 1 Mev Eq. Neutrons fluence
  - Hadron (E>20 MeV) flux and fluence

V3.1 Prototype Radiation Monitor

Development time: 3 years - first pre-series expected Q3 2005
RAMSES Project

- **Monitoring radiation variables (real-time)**
  - Measurement of dose rates during LHC operation around the accelerator, in experimental areas and their annexes, on the surface and in the environment (prompt radiation)
  - Measurement of radioactivity in released gases and fluids (radioactive nuclides)
  - Measurement of induced activity during LHC stop/shutdown
- **Generation of local radiation alarms and transmission of remote alarms**
- **Generation of interlocks**
- **Long term data storage**
  - Measured values
  - Events (radiation alarms, technical alarms, system faults, etc)
  - System configuration
Machine-induced Background
Background – General Introduction

- **Organization**
  - Work has been carried out particularly under the Collaboration Agreement No. K1141/TS (IHEP Protvino)
  - *Workshop on LHC Backgrounds* – *held at CERN in March 1996*

- The requested collision luminosities should be coupled with **low backgrounds** both from the experiments themselves and from the machine.

- Machine-induced background is proportional to the **machine beam current** while particle fluxes from proton-proton collisions scale with luminosity.
Machine-induced Background

- Secondary particle flux produced by proton losses upstream & downstream of the IPs (arc cells, dispersion suppressors and straight sections)

- Physics Processes
  - Inelastic scattering
    - Beam proton collisions with nuclei of residual gas giving secondaries with a resulting momentum significantly smaller than beam particles.
  - Elastic scattering
    - Collisions of beam particles with the residual gas nuclei giving final state energetic protons with a momentum close to the initial one.
  - Cleaning inefficiency
    - Proton out-scattering from the collimators followed not by absorption in the cleaning system but by subsequent proton loss downstream
  - Collisions at IPs
    - Proton-proton collisions in high luminosity IPs, giving energetic protons transported to and lost in next IR.
Machine-induced Background at IR8

Number of particles entering UX85 from IP1 side

LHC Project Note 258 (2001)
LHC Project Report 500 (2001)
Machine-induced Background at IR8

Number of particles entering UX85 from the injection side

Hadrons

Muons
Machine-induced Background at IR8

- **Cleaning Inefficiency**
  - For $\beta^* \geq 10 \text{ m}$, the contribution of the cleaning inefficiency is negligible.
  - To be checked with new loss distributions given the new C-on-C collimators

- **Collisions at IR1**
  - For $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ an integral loss rate of $10^{-2}$ particles/s is obtained for IR8
  - Factor of 100 lower for $\beta^* \geq 10 \text{ m}$.
  - Contribution of collisions at IP1 is therefore marginal
Machine-induced Background at IR8/IR2

- Integrated absolute rate of machine-induced background at IR8 (& IR2) is $4 \times 10^5$ particles/s.
- However, due to the relatively low luminosity, ALICE & LHCb are particularly sensitive to machine-induced background.
  - Shielding walls are being integrated into the tunnel lay-out.
  - Note that at P2 & P8 there is minimal space available for the installation of shielding between the detectors and the beampipe.
Machine-induced Background – Radiation Shielding at P1 & P5

- Protect experiments against machine-induced background emerging from the LHC machine.
- Therefore, for P1 & P5, radiation levels in the experimental caverns are low (1 Gy/yr) and both ATLAS & CMS will be rather insensitive to machine-induced background.
  - The rates for muons, which are the only particles that penetrate the shielding from the machine side, are estimated to be below 10 µ cm\(^{-2}\) s\(^{-1}\).
Machine-induced Background

- Newly-created Machine-Induced Background

WG is currently focusing on the following issues:

- Checking consistency of the machine optics, apertures, residual gas pressure estimates and operation scenarios.
- Evaluating up-to-date status of the various machine parameters used in the simulations.
- Studying contribution to the beam halo from the realistic distribution of the cleaning system inefficiency.
Event rates expected in ATLAS & CMS from beam-halo muons and beam-gas collisions during LHC single-beam period found to be significant and useful for commissioning experiment.

The ATLAS studies below assume a 2-month single beam period with 30% effective data-taking time.
ATLAS Commissioning: Beam-Halo

- Beam-halo
  - Leave signals essentially only in end-caps
  - Useful for calibration and alignment studies
- Beam-halo muon rates in the various sub-detectors are significant
- Use Thin Gap Chambers to trigger

<table>
<thead>
<tr>
<th>Detector</th>
<th>Rate (Hz)</th>
<th>Total number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDT (end-cap)</td>
<td>59</td>
<td>1.0x10^8</td>
</tr>
<tr>
<td>MDT (barrel)</td>
<td>29</td>
<td>5.2x10^7</td>
</tr>
<tr>
<td>TRT</td>
<td>15</td>
<td>2.7x10^7</td>
</tr>
<tr>
<td>SCT</td>
<td>29</td>
<td>4.9x10^7</td>
</tr>
<tr>
<td>Pixels</td>
<td>0.4</td>
<td>6.7x10^5</td>
</tr>
<tr>
<td>EM calorimeter</td>
<td>1.2</td>
<td>2.1x10^6</td>
</tr>
<tr>
<td>Tile calorimeter</td>
<td>1.3</td>
<td>2.3x10^6</td>
</tr>
<tr>
<td>HEC</td>
<td>0.3</td>
<td>5.3x10^5</td>
</tr>
<tr>
<td>FCAL</td>
<td>0.1</td>
<td>1.8x10^5</td>
</tr>
</tbody>
</table>
Beam gas collisions directly inside the Inner Detector cavity provide useful data for detector commissioning.

- e.g. for Inner Detector alignment since such beam-gas events resemble p-p collisions

Because of the soft $p_T$ spectrum of the produced particles need a dedicated detector for the trigger

- Scintillator telescope at ±3.5m from IP covering $1.9 < |\eta| < 3.9$ read-out by PMTs.

<table>
<thead>
<tr>
<th>Window (z)</th>
<th>Rate (Hz)</th>
<th>Total Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>±23 m</td>
<td>60</td>
<td>$1.1 \times 10^{11}$</td>
</tr>
<tr>
<td>±3.5 m</td>
<td>9</td>
<td>$1.7 \times 10^{10}$</td>
</tr>
<tr>
<td>±0.2 m</td>
<td>0.6</td>
<td>$1.0 \times 10^{9}$</td>
</tr>
</tbody>
</table>
## Experiment Requirements for Initial LHC Operation

The experiments will make use of any beam provided by the machine. Detector commissioning and for recording first pp collisions.

### PP OPERATION

<table>
<thead>
<tr>
<th>ATLAS &amp; CMS</th>
<th>LHCb</th>
<th>ALICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go as fast as possible to nominal conditions minimizing the number of overlapping events:</td>
<td>Go as fast as possible to nominal conditions minimizing the number of overlapping events:</td>
<td>Go to nominal conditions by tuning $\beta^*$ rather than with separated beam:</td>
</tr>
<tr>
<td>o 25 ns bunch spacing</td>
<td>o 25 ns bunch spacing</td>
<td>o $10^{29} \leq L \leq 5 \times 10^{30}$ cm$^{-2}$s$^{-1}$ (unsqueeze $\beta^*$)</td>
</tr>
<tr>
<td>o nominal energy</td>
<td>o nominal energy</td>
<td>o dipole polarity changed few times per year</td>
</tr>
<tr>
<td>o $L \geq 10^{33}$ cm$^{-2}$s$^{-1}$</td>
<td>o $\langle L \rangle = 10^{32}$ cm$^{-2}$s$^{-1}$ (squeeze $\beta^*$ as in IP1/5)</td>
<td>o if $L &gt; 10^{32}$ cm$^{-2}$s$^{-1}$ possible damage for the detectors</td>
</tr>
</tbody>
</table>

D. Macina
Experiment Requirements for Initial LHC Operation

D. Macina

- **PbPb Operation**
  - Three experiments (ALICE, ATLAS, CMS).
  - ALICE requires ~ 4 weeks PbPb run (early scheme OK) after the first long shutdown.

- **Special p Runs**
  - TOTEM - Few short 1-day runs with special optics ($\beta^*= 1540$ m, $L \sim 10^{28}$ cm$^{-2}$s$^{-1}$) and few short 1-day runs at injection optics($L \sim 10^{32}$ cm$^{-2}$s$^{-1}$)
  - Two projects encouraged by the LHCC:
    - ATLAS Roman Pots ($\beta^*= 2625$ m, compatible with TOTEM)
    - LHCf ($\beta^*= 10$ m (injection optics), $L \sim 10^{29-30}$ cm$^{-2}$s$^{-1}$, ~ 3 short runs in 2 years of operation, but not compatible with TOTEM ($N_b \leq 10$))

- **Low energy runs**
  - There is no request to run at lower energy during the first phase of the LHC operation with the exception of TOTEM ($\sqrt{s} \sim 8$ TeV to measure $\rho$)
Near-beam Systems

- **ALICE and LHCb Dipole Magnets**
  - Ramped up together with the 3 compensator magnets in step with the beam energy
  - Safety under discussion between PH/DT1 and MPWG.
  - Operation from CCC

- **LHCb VELO**
  - To be positioned at 50 $\sigma$ from beam axis
  - LHCb plans for operation from LHCb Control Room

- **Roman Pots (TOTEM, ATLAS)**
  - To be positioned at 10 $\sigma$ from beam axis
  - Operation (machine/experiment) under discussion

- **ALICE Zero Degree Calorimeter (ZDC)**
  - Does not enter into primary vacuum
  - ALICE proposes operation from CCC
Conclusions

- Good communication between the LHC experiments and machine is essential for the effective exploitation of the physics at the LHC.
- The LHC experiments, in close collaboration with the LHC Machine, are developing tools and mechanisms to exchange information and to monitor the LHC beams and collisions.
- Radiation monitoring in the intense and complex fields at the LHC are required from the outset.
- The experiments will make use of first beams provided by the machine.
  - Detector commissioning and for recording first pp collisions