LHC Machine and Experiment Interface Issues

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CERN EST-LEA

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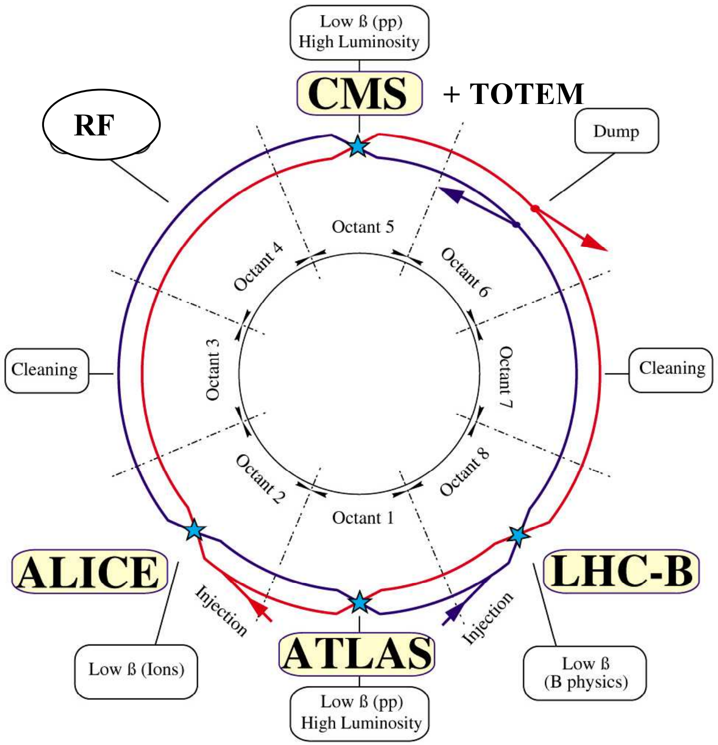
LHC LAYOUT



CERN AC _ EI2-4A_ V18/9/1997

LHC Machine Parameters

- Protons

Parameter	Units	Nominal	Ultimate
Number of Bunches		2808	2808
Bunch Spacing	ns	25	25
Protons per Bunch	10^{11}	1.1	1.7
Average Beam Current	A	0.56	0.86
Norm. Trans. Emittance	μm	3.75	3.75
Longitudinal Emittance	eV.s	2.5	2.5
Peak RF Voltage	MV	16	16
RF Frequency	MHz	400	400
r.m.s. Bunch Length	cm	7.7	7.7
r.m.s Energy Spread	10^{-4}	1.1	1.1
IBS Emittance Growth	hr	115	76
Beta at IP1-IP5	m	0.5	0.5
Full Crossing Angle	μrad	300	300
Luminosity Reduction due to Crossing Angle		0.81	0.81
Luminosity at IP1-IP5	10^{34} cm^{-2} s^{-1}	1.0	2.3

Satellite bunches from 400 MHz RF located 2.5 ns from nominal bunches

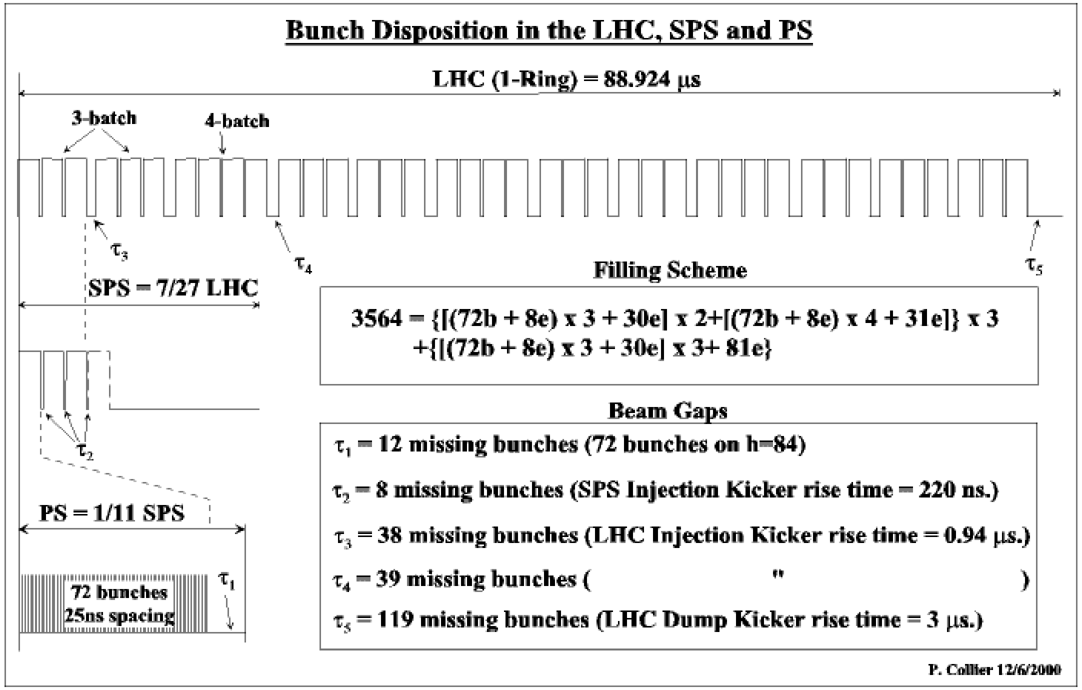
Luminosity from these bunches will be small - <1%

- Pb-ion

Energy per charge (^{82}Pb)	E = 7 TeV
Bunch intensity	N_{ions} = 7.0 × 10^7 ions
Emittance and β*	Same as for proton operation
Crossing angle	α = 200 μrad
Number of bunches:	N_b = 592
Total luminosity:	10^{27} cm^{-2} sec^{-1}
Luminosity lifetime:	τ_{lumi}= 8.4 hrs (limited by nuclear effects)
	scales with luminosity & number of experiments

LHC Machine Operation

- Protons



3-batch and 4-batch cycles from PS interleaved in the form 334 334 334 333

➢ Pb-ions

- Bunch spacing: 100 ns
- Harmonic Number = 891
- Total number of bunches = 592
- Gap between adjacent PS bunches = 225 ns
- LHC Beam Dump Gap = 3 μs

- Batches from the PS will be interleaved as

3x(13 12 12) + 1x(13 13 8)

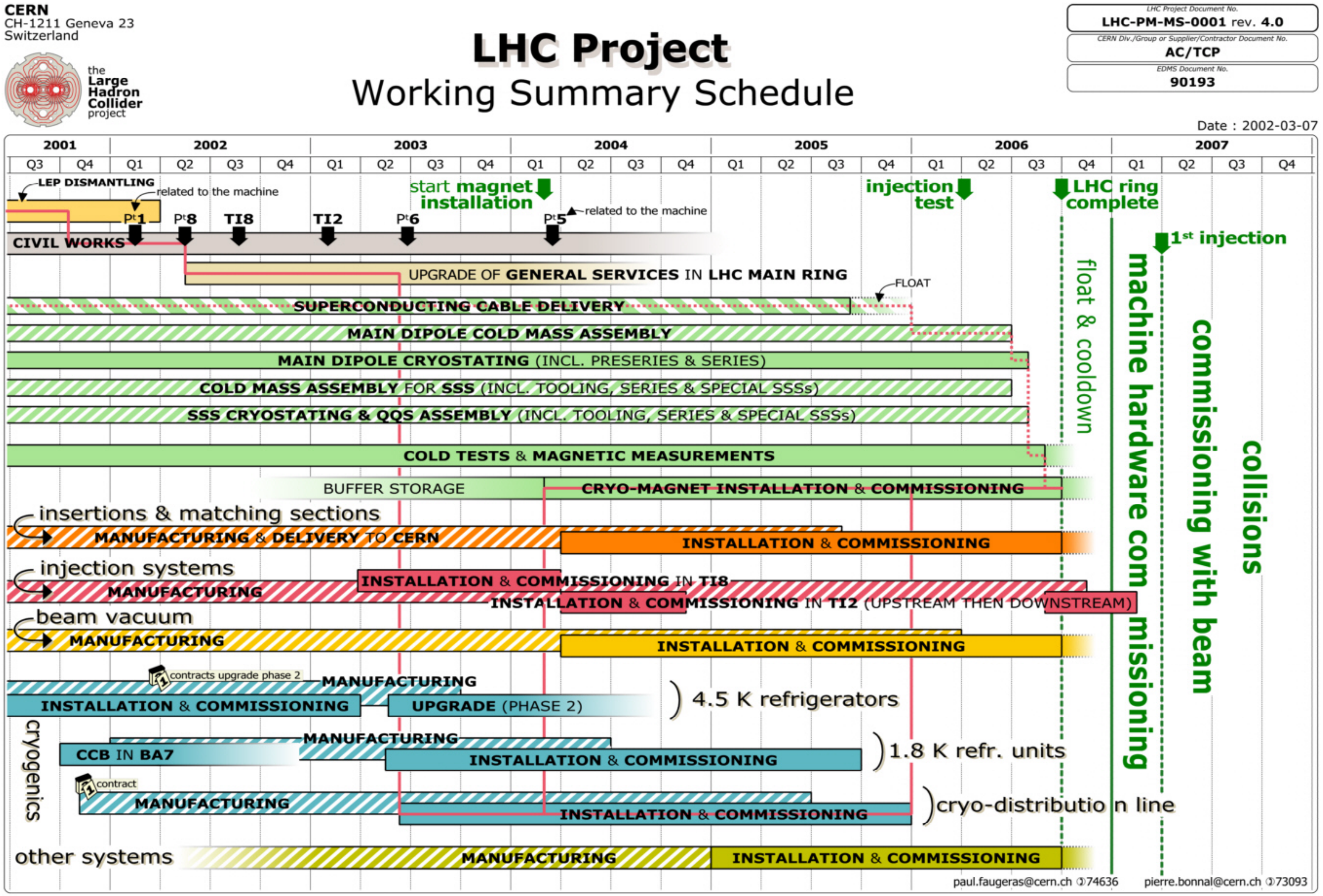
OR

3x[2x{13x[4b+1.25e])+7.75e}+(12x[4b+1.25e]+7.75e]+1x[2x{(13x[4b+1.25e])+7.75e}+(8x[4b+1.25e])]+28.75e

where

b= bunch

e = empty (x 100 ns)


CERN
CH-1211 Geneva 23
Switzerland
the Large Hadron Collider project
LHC Project
Working Summary Schedule
LHC Project Document No.
LHC-PM-MS-0001 rev. 4.0
CERN Div./Group or Supplier/Contractor Document No.
AC/TCP
EDMS Document No.
90193
Date : 2002-03-07
2001
2002
2003
2004
2005
2006
2007
Q1
Q2
Q3
Q4
LEP DISMANTLING
related to the machine
Pt1
Pt8
TI8
TI2
Pt6
Pt5
CIVIL WORKS
start magnet installation
injection test
LHC ring complete
1st injection
UPGRADE OF GENERAL SERVICES IN LHC MAIN RING
FLOAT
SUPERCONDUCTING CABLE DELIVERY
MAIN DIPOLE COLD MASS ASSEMBLY
MAIN DIPOLE CRYOSTATING (INCL. PRESERIES & SERIES)
COLD MASS ASSEMBLY FOR SSS (INCL. TOOLING, SERIES & SPECIAL SSSs)
SSS CRYOSTATING & QQS ASSEMBLY (INCL. TOOLING, SERIES & SPECIAL SSSs)
COLD TESTS & MAGNETIC MEASUREMENTS
BUFFER STORAGE
CRYO-MAGNET INSTALLATION & COMMISSIONING
insertions & matching sections
MANUFACTURING & DELIVERY TO CERN
INSTALLATION & COMMISSIONING
injection systems
MANUFACTURING
INSTALLATION & COMMISSIONING IN TI8
INSTALLATION & COMMISSIONING IN TI2 (UPSTREAM THEN DOWNSTREAM)
beam vacuum
MANUFACTURING
INSTALLATION & COMMISSIONING
contracts upgrade phase 2
MANUFACTURING
INSTALLATION & COMMISSIONING
UPGRADE (PHASE 2)
4.5 K refrigerators
MANUFACTURING
CCB IN BA7
INSTALLATION & COMMISSIONING
1.8 K refr. units
contract
MANUFACTURING
INSTALLATION & COMMISSIONING
cryo-distribution line
cryogenics
other systems
MANUFACTURING
INSTALLATION & COMMISSIONING
float & cooldown
machine hardware commissioning
commissioning with beam
collisions
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LHC Luminosity

➢ Pilot Run

- Single beam and single bunch
- Bunch intensity: $N_b \sim 0.5 \times 10^{10}$ protons
- Bunch length: $\tau < 5$ ns

➢ First Collisions

- As for Pilot Run but with both beams

➢ Commissioning Beam Parameters

- Reduce beam power
  - Reduce risk for quench and damage
  - 10% of beam power

    75 ns bunch spacing (940 bunches)
    ~1/4 of the nominal bunch current

- Reduce beam emittance
- Increase β^*

→ Commissioning Peak $L < 2 \times 10^{32}$ cm^{-2} sec^{-1}

➢ Initial Physics Run

- At initial physics run start-up
  - Start with the conditions of the commissioning run
  - Equivalent of 200 days with such parameters will yield L ~ 2 fb^{-1}

- Aim after optimisation
  - The aim is to reach a peak luminosity of ~2 × 10^{33} cm^{-2} sec^{-1}
  - Equivalent of 200 days with such parameters will yield L ~ 10 fb^{-1}

➢ LHC Machine Staging

- Install 8 of the 20 LHC dump dilution kicker elements for the initial run.
  - Limits maximum acceptable total beam intensity in each LHC ring to half of nominal beam intensity.
- In order to avoid potential problems due to electron cloud effects, LHC operation will start with 75 ns.
  - Electron cloud effect does not occur for such bunch spacing.
  - Use this set of parameters to condition the LHC vacuum (beam scrubbing)
- Delay installation of 200 MHz capture RF system

→ Reaching a peak luminosity of 10^{34} cm^{-2} sec^{-1} in the initial physics run is ruled out.

LHC Proton Operation Cycle

- Abort luminosity run after about 14 hours

- Turnaround time:

Ramp down all magnet currents from 7 TeV to 450 GeV	20 minutes
Ramp up to injection and system reset	5 minutes (?)
Inject new beams:	
Machine adjustments	4 minutes
Actual filling	7 minutes
Ramp up all magnet currents from 450 GeV to 7 TeV	20 minutes
Collision adjustments	5 minutes

➔ Minimum turnaround time of about 1 hour (access allowed!)

Luminosity Run and Integrated Luminosity

Assume: Intra-beam scattering — Beam blow-up with τ = 100 h (nom)
Beam-rest gas scattering — Intensity decay with τ = 85 h (nom)
Beam-beam interaction — Intensity decay with τ = 16 h (nom)
(1/2 value, 2 high luminosity IP's)

Neglect: Radiation damping, ripple blowup, dynamical β^* squeeze
Losses due to non-linearities, collective instabilities

Exponential beam lifetime: τ_{lumi} = 14.8 h (approximation)

Turn-around time Tturn
&
Lumi lifetime τ_{lumi}
→
Optimal length of physics run
Trun

T_{turn} \ τ_{lumi}	1	6	10	20	[hours]
6.5	3	6	9.5	11.5	T_{run}
10	4	9	11.5	15	
15	5	12	15	20	
19	5.5	13	16.5	22	

➢ Estimate of integrated luminosity (nominal parameters $1.0 \times 10^{34}\ cm^{-2}s^{-1}$)

- Assume 200 days of running
- Good turn-around time crucial for high integrated luminosity.
- Expect about **10 hours** turn-around time
- Integrated luminosity with nominal parameters: **~ 70 fb^{-1}**

T_{turn} \ τ_{lumi}	1	6	10	20	[hours]
15	122	78	65	47	L_{tot}
20	127	86	72	54	[$fbarn^{-1}$]

Luminous Region

- Calculation of Luminous Region ($\pm s$) → $\mathcal{L}(s) = \int L(s')\, ds'$

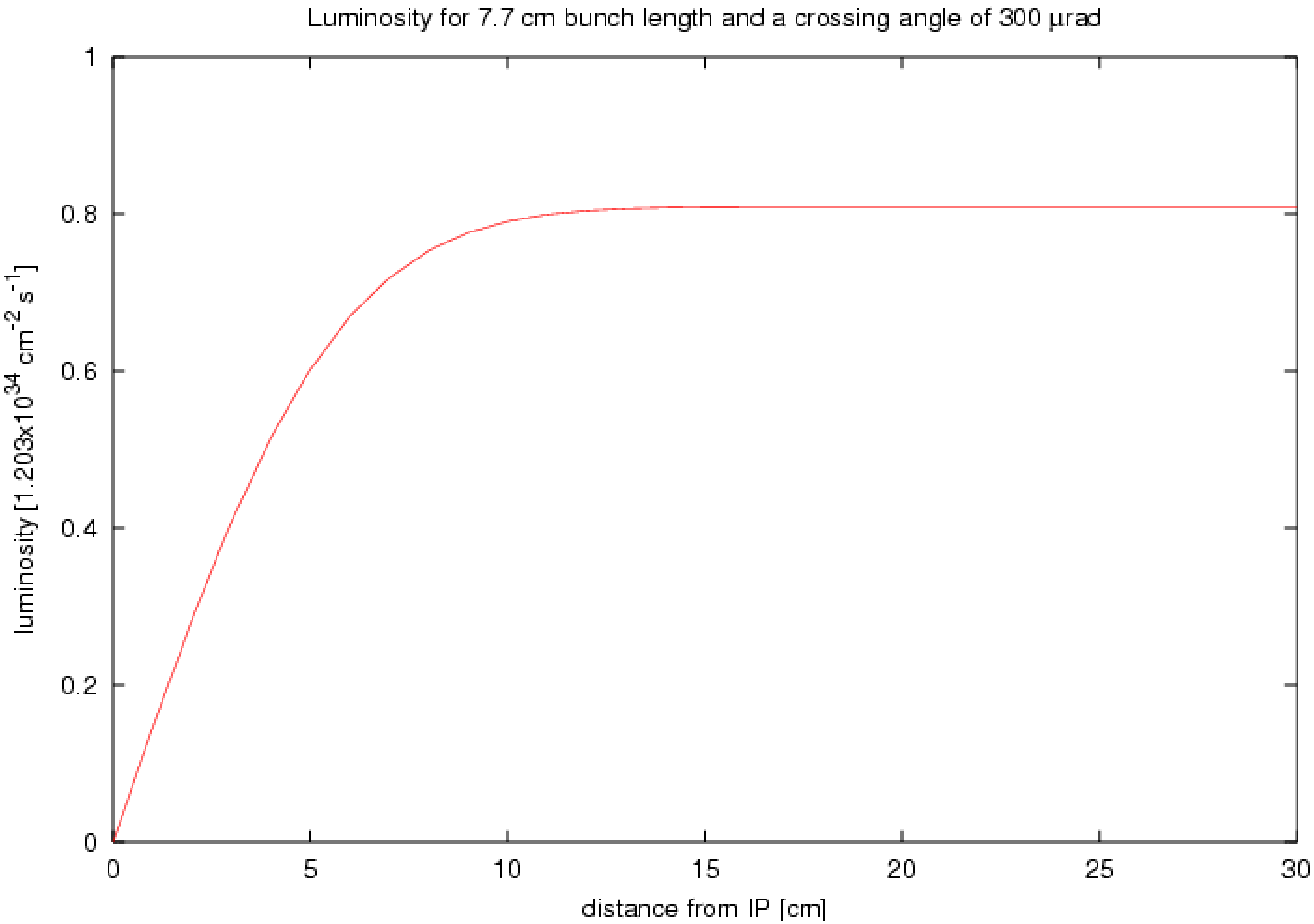
Time-integrated luminous region ($\pm s$) → $L(s) = \int L(s')\, ds'$

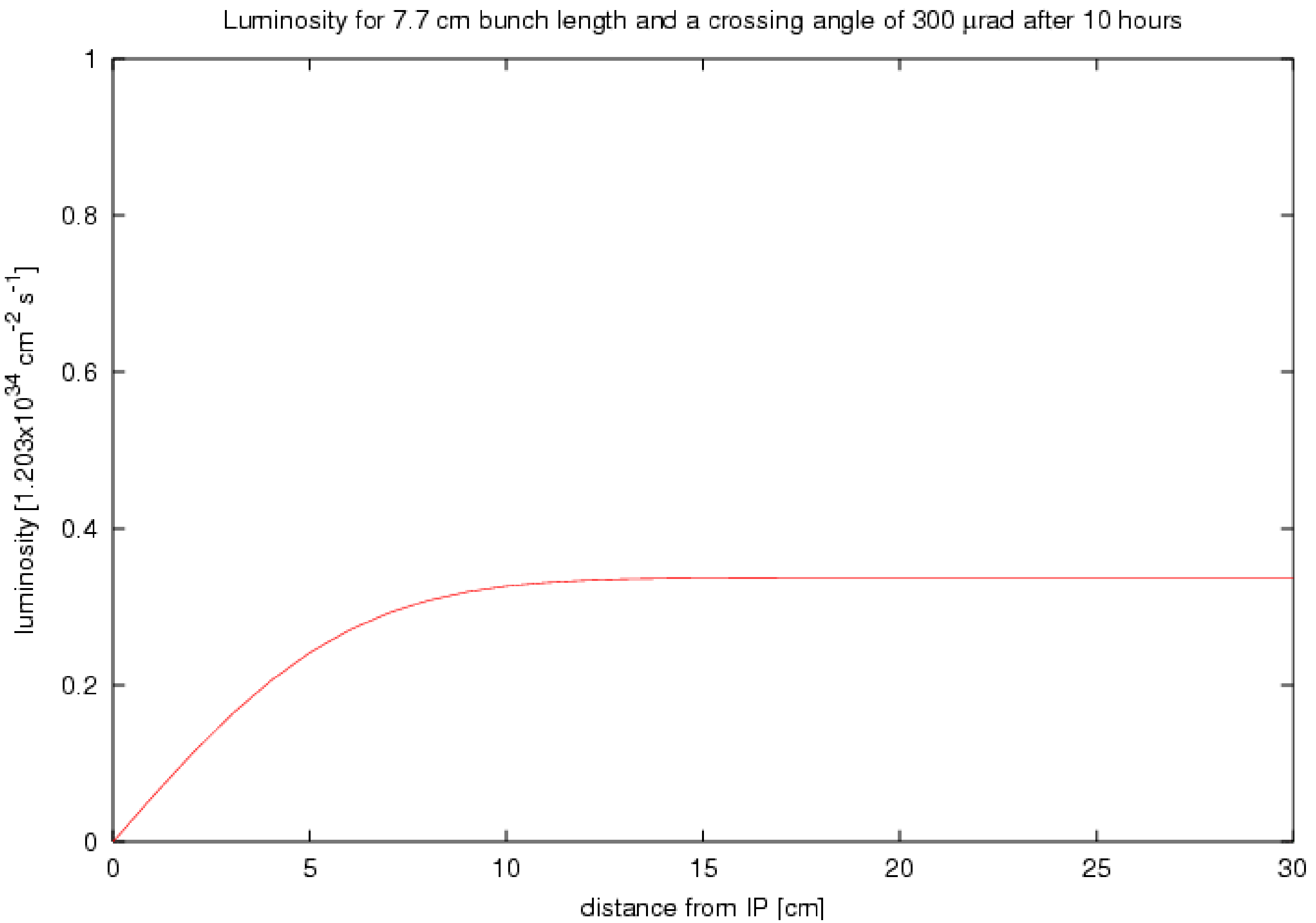
$$L_{av}(s) = 1/T \int \int L(s',t)\, ds'\, dt$$

➢ Results

- Luminosity reduces by ~20% for a crossing angle of 300 μrad
- Luminous Region

% of Luminosity	Luminous Region s [cm]
100	±12
95	±9
90	±8
85	±6.5
80	±6


Luminosity for 7.7 cm bunch length and a crossing angle of 300 μrad
luminosity [1.203x10^34 cm^-2 s^-1]
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
distance from IP [cm]


Luminosity for 7.7 cm bunch length and a crossing angle of 300 µrad after 10 hours
luminosity [1.203x10^34 cm^-2 s^-1]
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25
30
distance from IP [cm]

➢

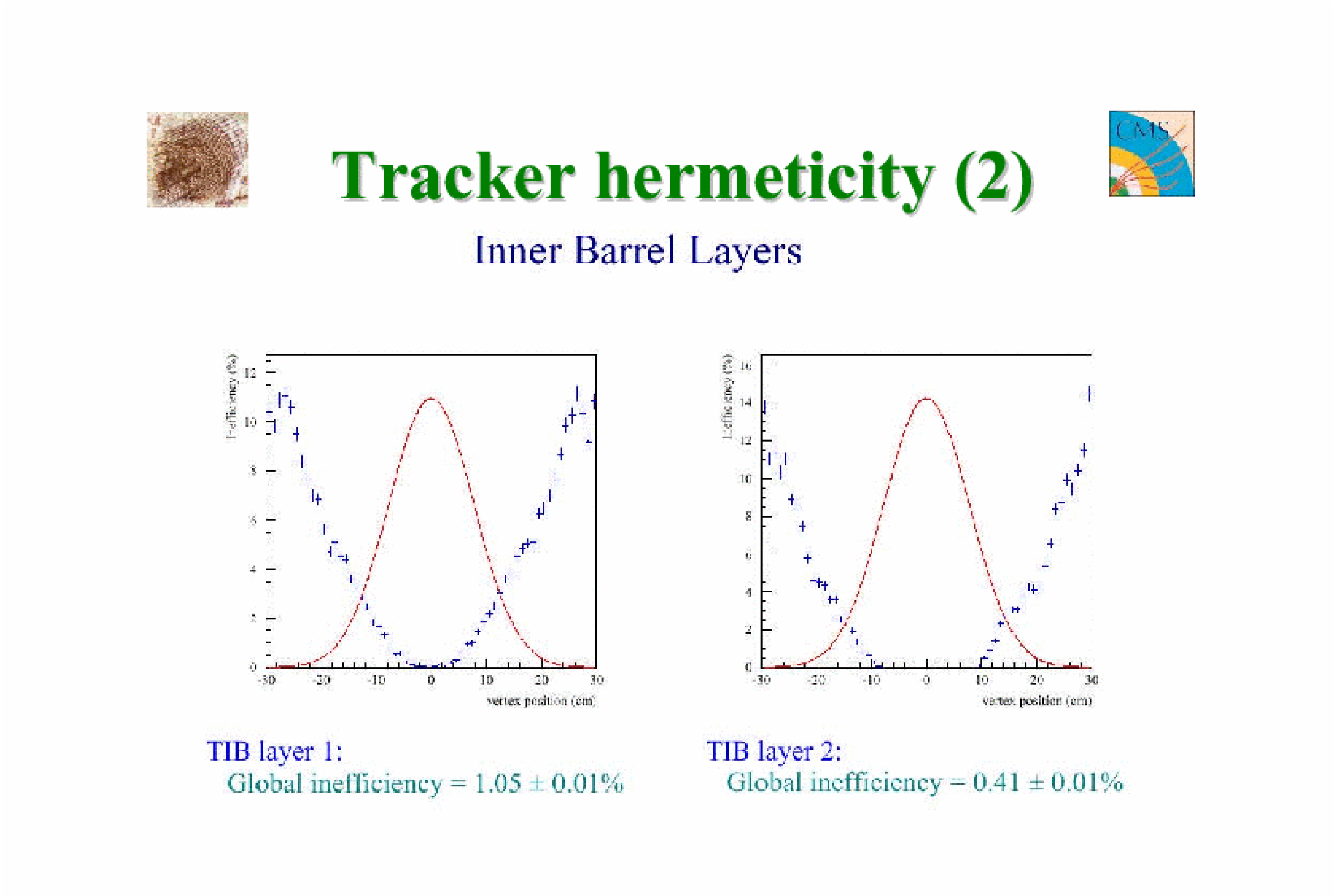
- Acceptable Size of Luminous Region for LHC Experiments

  - ATLAS

    - Studies for the ATLAS Inner Detector reconstruction have been made for a fiducial acceptance of z = ± 11.2 cm

    - In order to preserve the assumed performance of ATLAS, at most 5% of the integrated luminosity may be outside of z = ± 11.2 cm

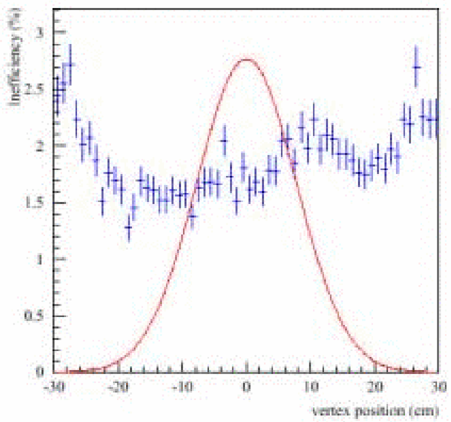
- CMS



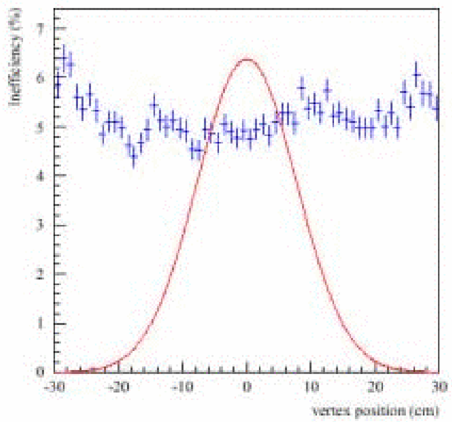
Tracker hermeticity (2)
Inner Barrel Layers
vertex position (cm)
vertex position (cm)
TIB layer 1:
Global inefficiency = 1.05 ± 0.01%
TIB layer 2:
Global inefficiency = 0.41 ± 0.01%

Tracker hermeticity (3)

Outer Barrel Layers



TOB layer 1:
Inefficiency of r−φ modules
= 1.76 ± 0.02%



TOB layer 1:
Inefficiency of r−z modules
= 5.00 ± 0.03%

Tracker hermeticity (4)

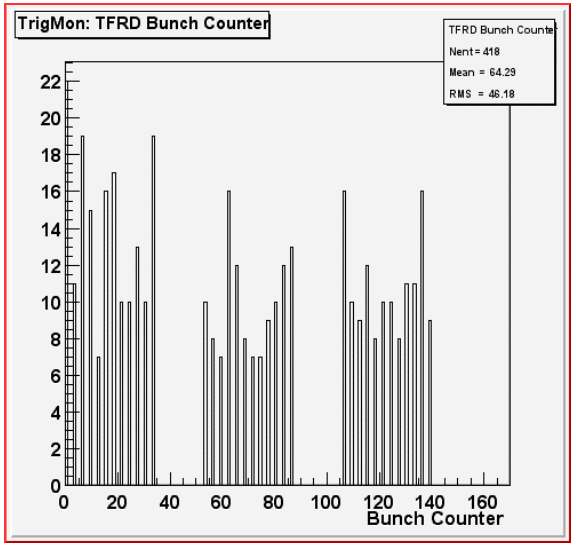
Barrel Hermeticity

Layer	Inefficiency		
	$r-\varphi$ modules	$r-z$ modules	Global
TIB 1	1.05%	3.41%	1.05%
TIB 2	0.41%	1.61%	0.41%
TIB 3	0.54%	–	0.54%
TIB 4	0.17%	–	0.17%
TOB 1	1.76%	5.00%	1.76%
TOB 2	2.88%	5.91%	2.88%
TOB 3	2.53%	–	2.53%
TOB 4	1.25%	–	1.25%
TOB 5	1.11%	–	1.11%
TOB 6	0.96%	–	0.96%

For a Gaussian collision point distribution with $\sigma = 7.72$ cm

Luminosity Monitoring

- Experiments require luminosity to be uniform across bunches
  - Detector performance depends on number of inelastic events in same bunch crossing
  - Monitored by experiments



CDF Trigger Rate/Bunch

- Machine Monitoring
  - Fast current transformers at Point 4
  - Updated every minute

Machine and Experiment Information Exchange

- Hardware and software level
  - When are stable conditions reached?
  - Are background conditions deteriorating?
  - Is the luminosity shared equally?
  - When to end a luminosity fill?
  - Are dangerous (for people / equipment) conditions approaching?

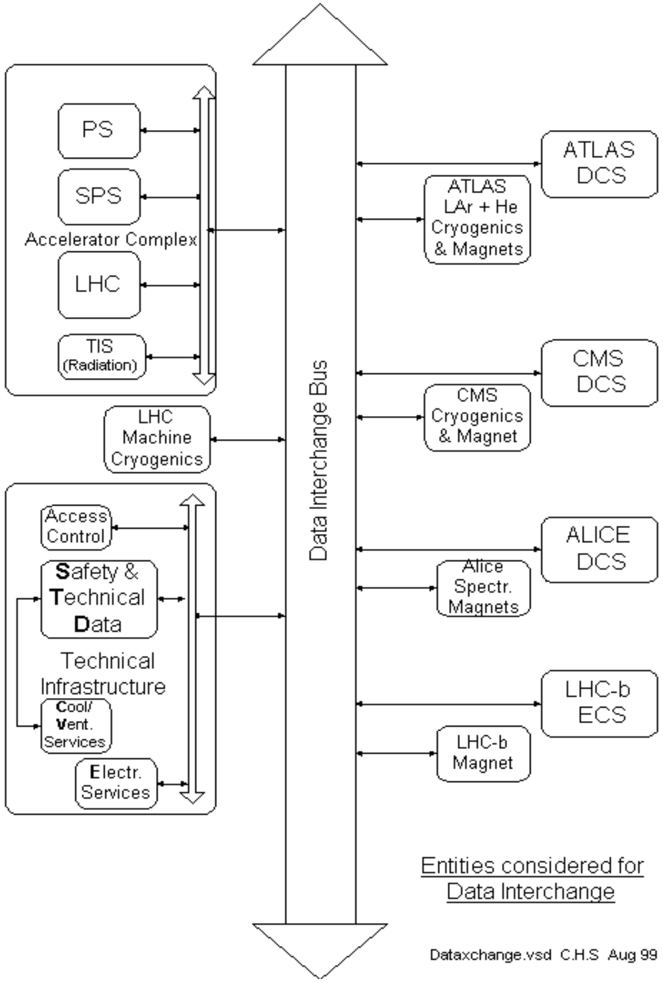
- Understand the causes of error symptoms
  - Have diagnostic information at hand
  - Need to be recorded as well for later analysis (history)
  - Try to prevent hazardous conditions

- Real time information provided by

  Experiments
    Including magnets and cryogenics
  Machine
    Accelerator complex
    Cryogenics
  Technical infrastructure
    Access control
    Safety

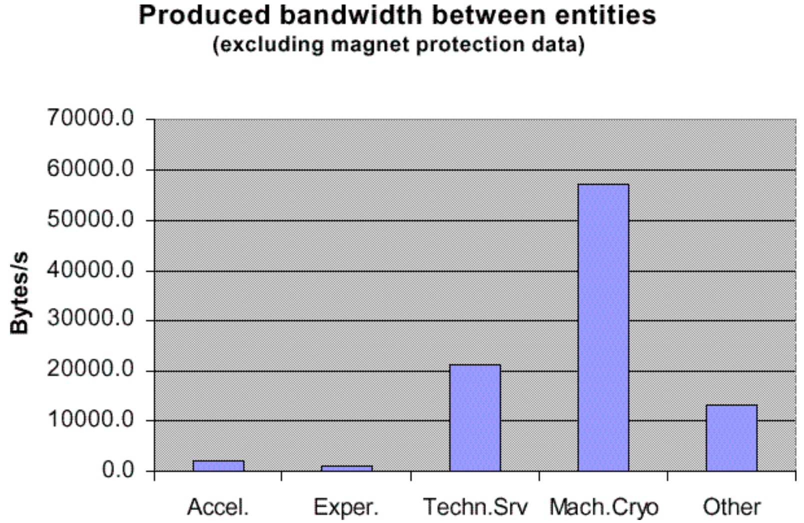
- Report on User Requirements from the LHC Data Interchange WG (LDIWG)

    Need standardised interfaces
    Flexibility to add new information



- Low frequency exchange
  - No bandwidth limitation
  - Latency of <1 s
  - Time-stamping 0.1 s precision
  - Protocol and implementation
    - To be defined
    - Commercial solution
- Level-3 alarms not included

\provider \ client \	Accelerator complex *provides* ▼	Experiments *provides* ▼	Technical, Electrical services & safety	Machine Cryogenics *provides* ▼	Other (various)	**Total received**
Accelerators *receive* <	------------	1050	19000 [20 (EL)]	57000	13000 (magnet protect, rad, SU)	**100 KB/s**
Experiments	2200	200	2800 [1400 (EL)]	----------------	125 (Cryomagnet) 5 (SU)	**5 KB/s**
Technical services & Safety	20	100	-----------	70		**0.2 KB/s**
Machine Cryogenics	15	-----------	5	-------------	-------	**0.02 KB/s**
Exp.magnets & cryo.	5	5	5	-------------	---------	**0.02 KB/s**
Total produced	**2.2 KB/s**	**1.4 KB/s**	**23 KB/s**	**57 KB/s**	**13 KB/s**	



➢ Machine to Experiments (update every second or minute)

- Operation status
  - Injecting, filling, ramping, colliding, optimising, physics, …
  - Operator comments
- Status of RF units, valves and gauges
- Settings of magnets close to experiment
- Settings of collimators
- Beam parameters
  - Currents (total and per bunch)
  - Energy
  - Beam position
  - Include also information from SPS (injector)
- Luminosity

➢ Experiments to Machine

- Data taking status
  - Interlock (e.g. injection inhibit)
  - Request of beam dump
- Magnet status
  - Currents and polarity
- Position of movable detector components
- Background measurements
  - Spatial and temporal distribution
- Radiation monitoring
  - Especially during injection and ramping
- Beam characteristics
  - As determined by the experiments themselves
  - vertex position, beam tilts, longitudinal size of interaction region

➢ Instantaneous luminosity

- Various sources (calorimeter currents, dedicated counters, …)

➢ Experiment to Experiment(s)

- Sub-set of the information provided by experiment(s) to the machine

- Concentrate on running conditions

  Status of experiment

  - Remove the injection inhibit promptly

  Background conditions

  - From various detector components
  - Indicate spatial and temporal distribution

  Luminosity summary

  - Get equal sharing (between IP1 and IP5)

Note: experiments will also receive information from Technical Services (electrical distribution, cooling water, ventilation,…

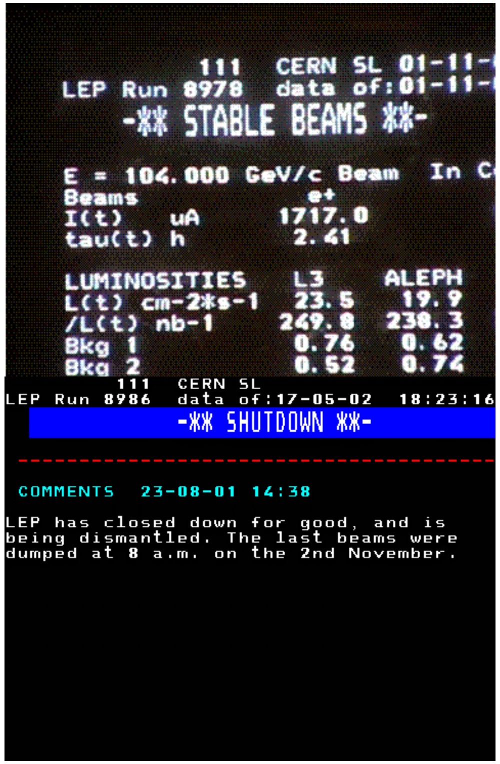
➢ Examples

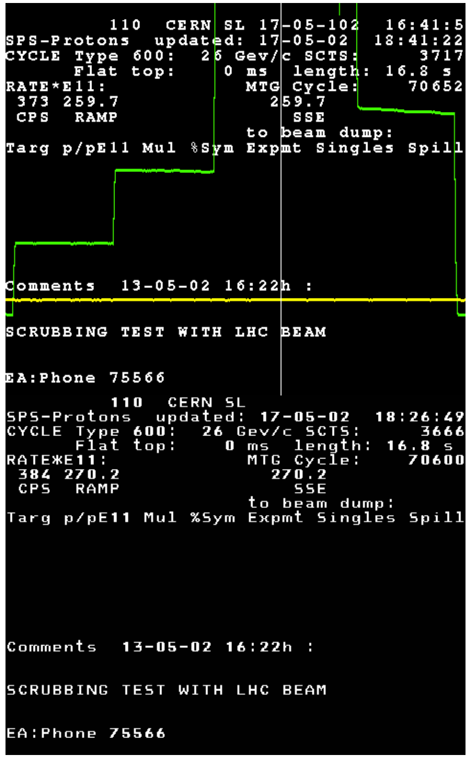
Page 1

A concise summary of the machine operation

Available on TV monitors throughout the laboratory

And also accessible via WWW

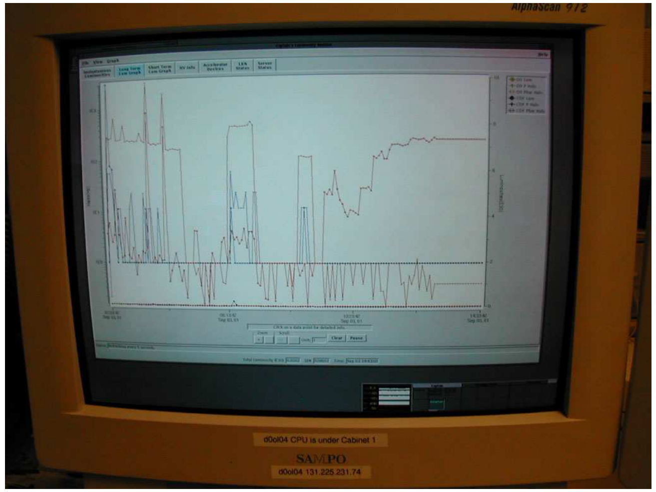




D0 Control Room (Tevatron)

'Interface' to the accelerator operation

- Time evolution of rates and luminosity
- Status information and parameters



Luminosity monitor display

Time evolution of the delivered luminosity

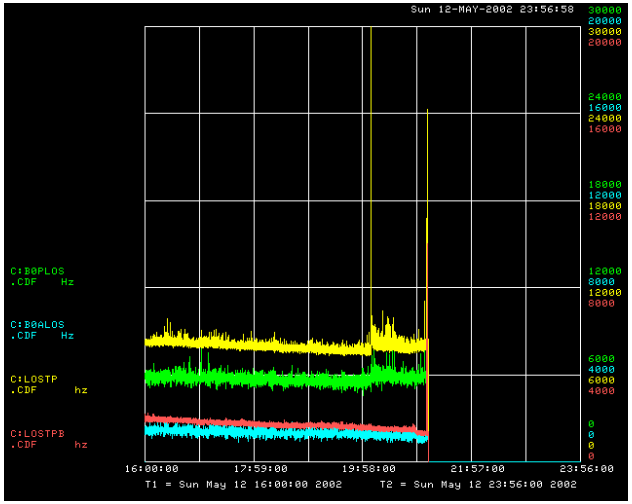
L-R coincidence counters for inelastic evts

$$L = N_{L-R} / \sigma_{tot}^{visible}$$

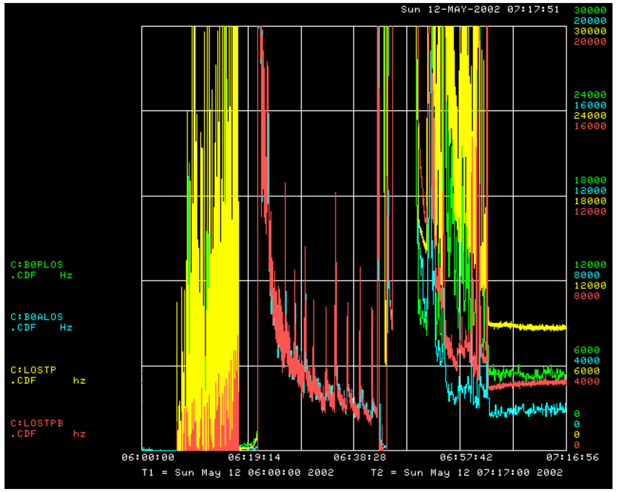
Beam loss rate for proton and anti-protons

Determined using the CDF beam shower counters (scintillators around the beam pipe at a distance of about 7 m from IP)

Stable Conditions

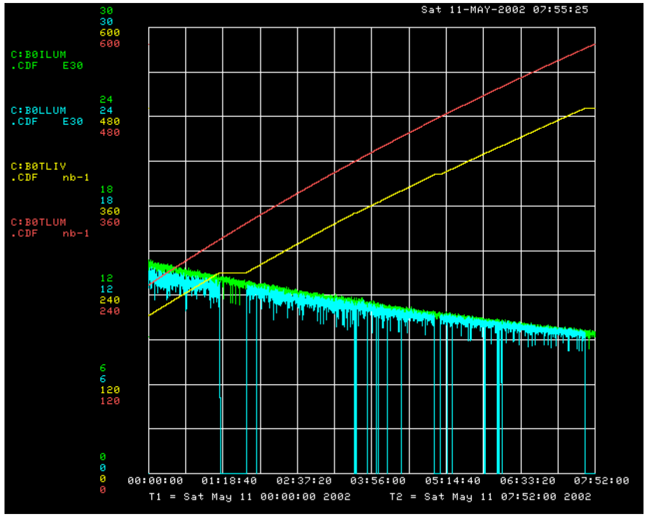


Unstable conditions

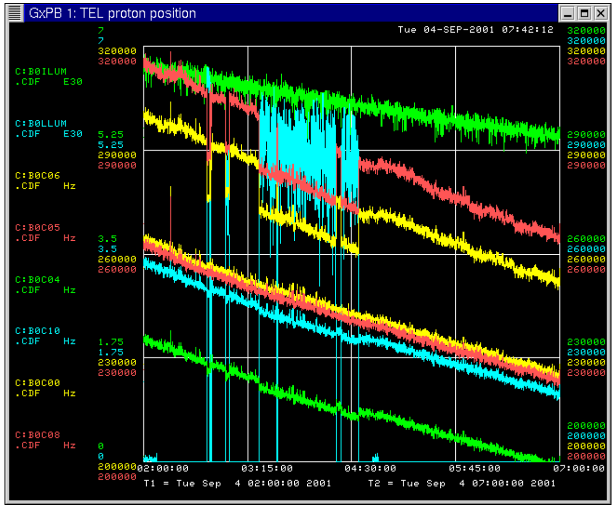


Luminosity monitoring and background rates

Instantaneous and integrated L

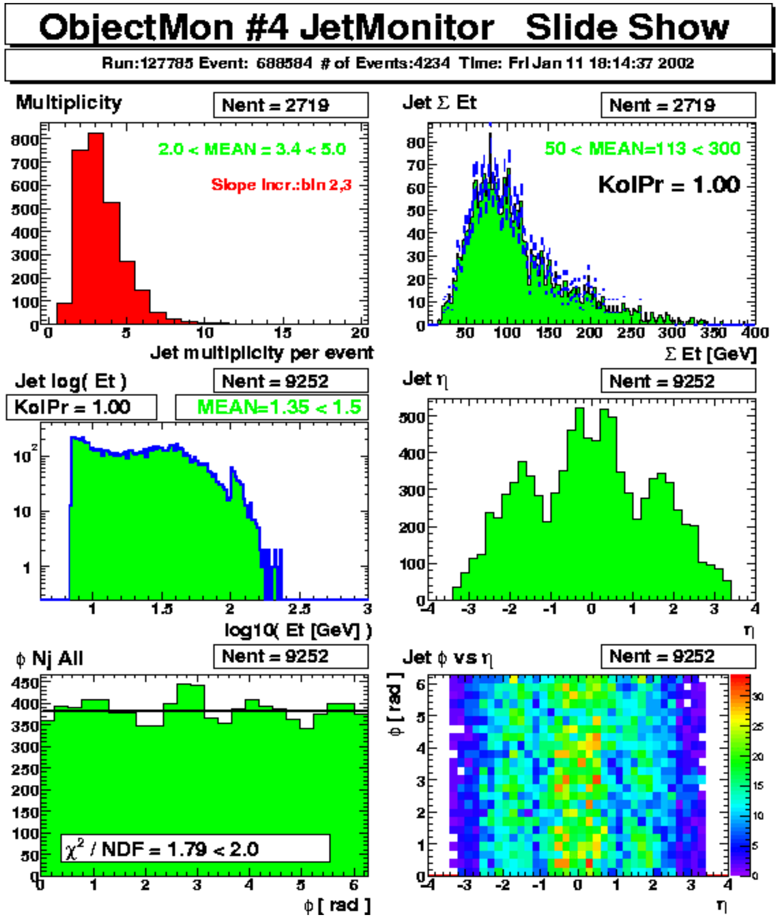


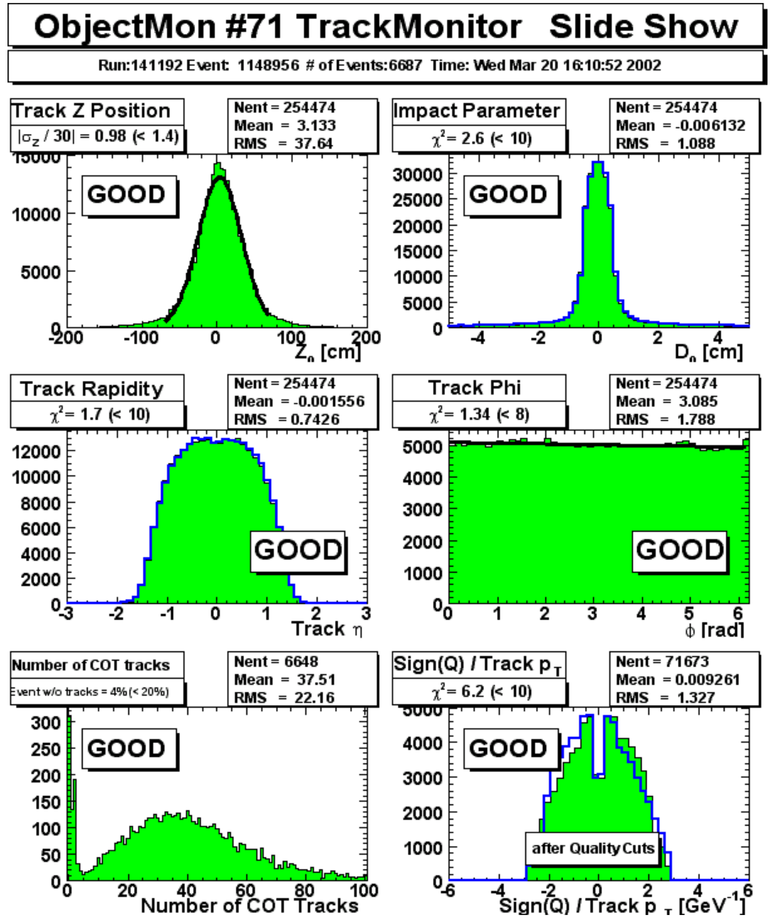
Instantaneous luminosity and rates at various scintillation counters outside the interaction point



CDF Online Monitoring

(objects reconstructed at LVL-3 trigger farm)





Experiment Measurements on Collision Quality

- ATLAS
  - Several trigger rates will be measured continuously in ATLAS
  - LVL-1 Trigger
    - Based on calorimeters
      - Rates of clusters of various kinds above thresholds
    - Based on muon trigger chambers
      - Rate of muon candidates above threshold

- HLT
    - More detailed information from calorimeters and muons
    - Inner Detector information

- Provision to monitor rates individually for all bunches

- Timescale on which rate information can be given to machine
  - Numbers integrated over all bunches
    - Sufficient statistics can be accumulated very quickly
  - Bunch-by-bunch statistics
    - Depending on trigger, timescale of minutes to collect sufficient statistics

- Fast Reconstruction of Collision Point
  - Beam position monitoring can be done by reconstructing Inner Detector tracks with the Event Filter processors
  - 10 μm transverse position accuracy and 2 mm longitudinal position and size accuracy within about 10 s.

    - Requires Inner Detector (including Pixels) powered and operational

    - Only possible once stable beams are established

- CMS
  - Information from Tracker
    - Z distribution and X,Y position

      Monitor Pixel detector hit rate and silicon Tracker every 10 ms

      HLT analysis of Pixel detector to provide vertex in x, y, and z with good accuracy.

      Possibility of eventual information on x and y width of luminous region (?)

- Relative Luminosity

  Vertex counting/event reported every second from Pixel

  Transmission of summary information at least every 100 s.

- Information from Muon System

  - Muon halo, size and distribution of neutron background

- Information from HCAL
  - Octant/Quadrant Occupancies

    Background `imbalance'

  - X,Y position using azimuthal energy flow
  - Possible Z information from forward/backward rate asymmetry
- Relative luminosity

  Information from forward rates

Transmission of summary information at least every minute

Radiation Field

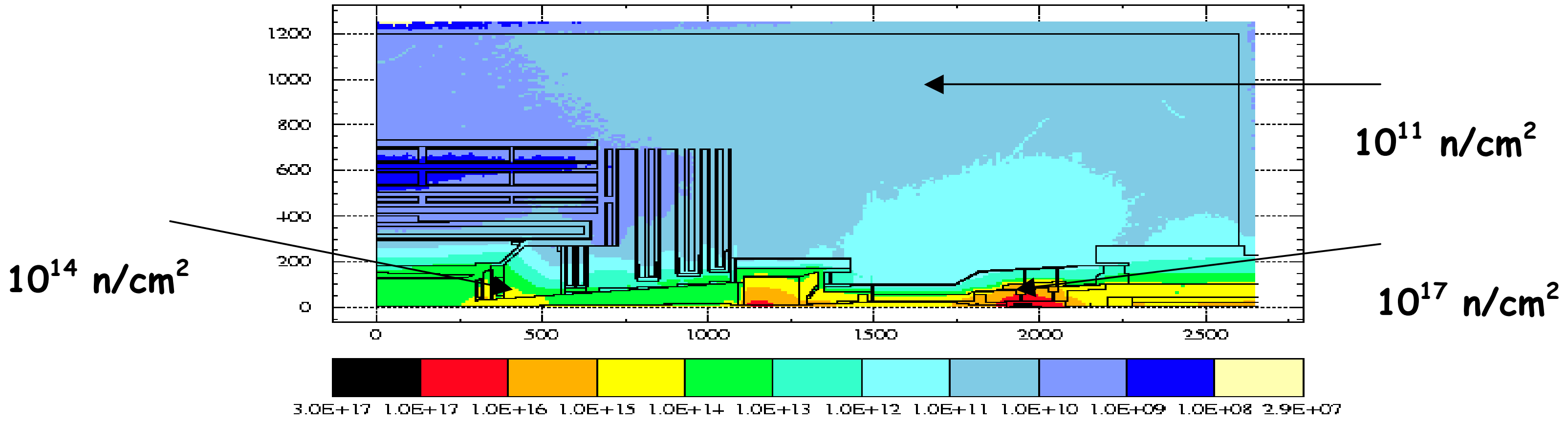
- Unprecedented hostile radiation environment.

- Secondaries from pp-interactions responsible for high radiation background.

    - Radiation damage of detectors, materials and electronics

    - Radiation safety issues

CMS Experimental Cavern

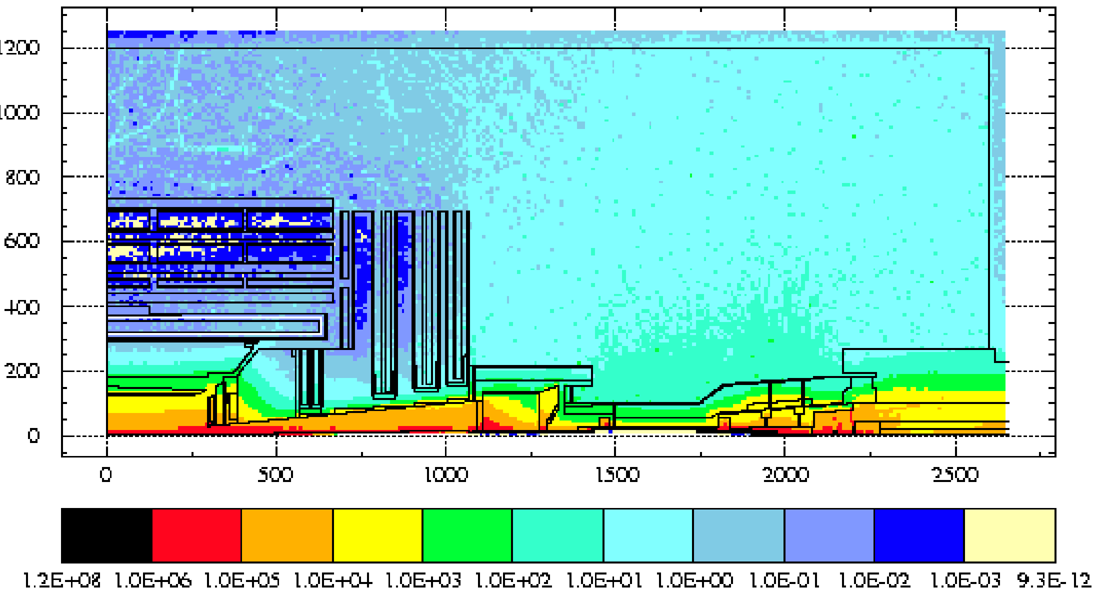


Neutron Fluence >100 KeV [n/cm^2 10 yrs LHC operation at L = 10^{34} cm^{-2} s^{-1}]

Results in bulk damage to bipolar devices

Mika Huhtinen
EP-CMM

CMS Experimental Cavern



Dose [Gy in 10 years of LHC operation at L = 10^{34} cm^{-2} s^{-1}]

Damage to electronics in cavern

Mika Huhtinen
EP-CMM

Radiation Shielding

- The CMS Central Detector (Tracker, EM Calorimeter, Hadron Calorimeter and Inner Muon Chambers) will be shielding efficiently by the mass of the CMS magnet yoke.

- However, additional shielding is required provide:
  - Effective shielding along the beam line and especially around the TAS absorber.
  - Reduce the background rates in the outer muon chambers (by up to 6 orders of magnitude).
  - Protect the electronics in the cavern against an excessive neutron flux and absorbed dose.

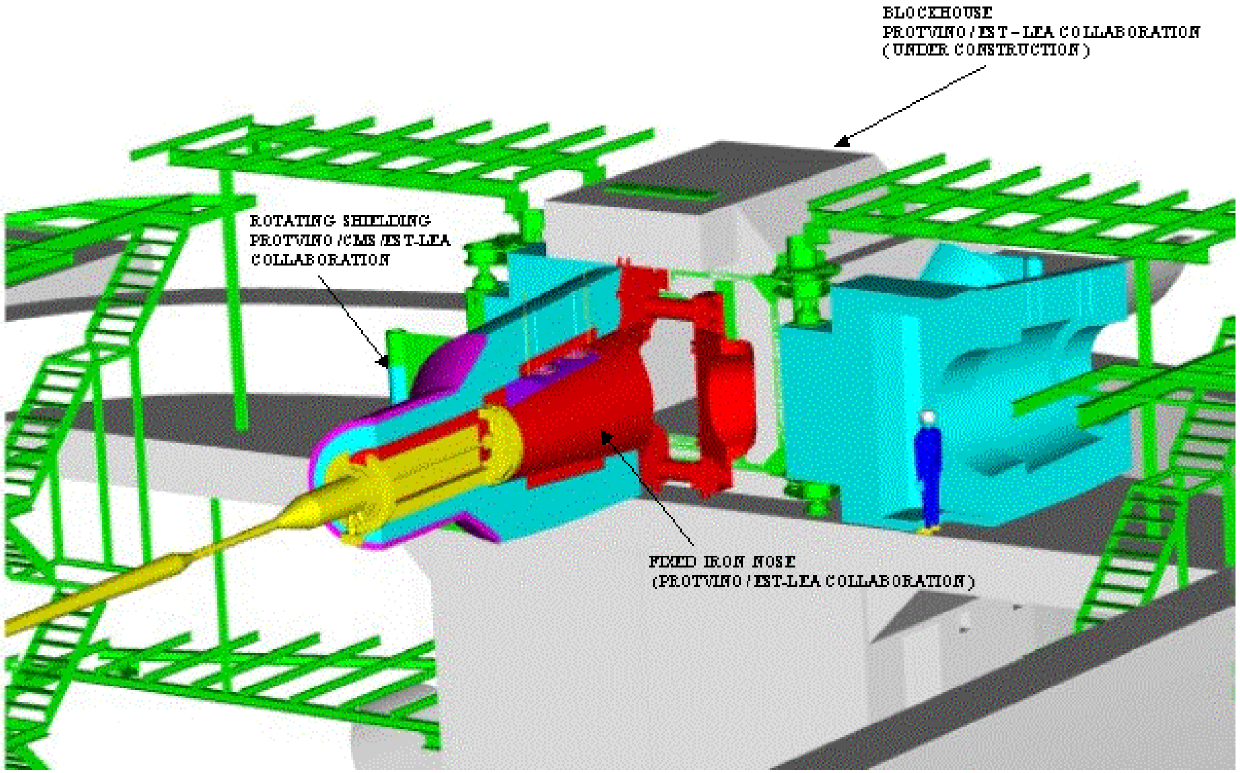
Moreover, the shielding provides three additional functions:

- Integral part of personnel shielding.
- Covers parts of experiment and machine that become highly radioactive.
- Protects experimental area against machine-induced background emerging from the LHC tunnel.

- As result, radiation levels in the caverns are low (1 Gy/yr) and both ATLAS and CMS will be rather insensitive to machine-induced background such as upstream beam losses.

- Muon rates, which are the only particles that penetrate the shielding from the machine side, are estimated to be below 10 muons cm^{-2} s^{-1}.

- However, the shielding makes access to detectors very difficult and completing the experimental detectors in short machine stops impossible.



THE C M S POINT 5 FORWARD SHIELDING

LHC Beam Abort

➢ General

- Abort on observing spurious behaviour in monitors.
  - Injection inhibit and beam abort.

- Use dedicated radiation detectors in the experimental areas.
  - Diamond detectors on beam pipe around the IP?
  - Independent of experiment sub-detectors.

- Response time on the order of machine response time (~2 orbits).

  RadFETs and $p^+/n/n^+$ diodes too slow.

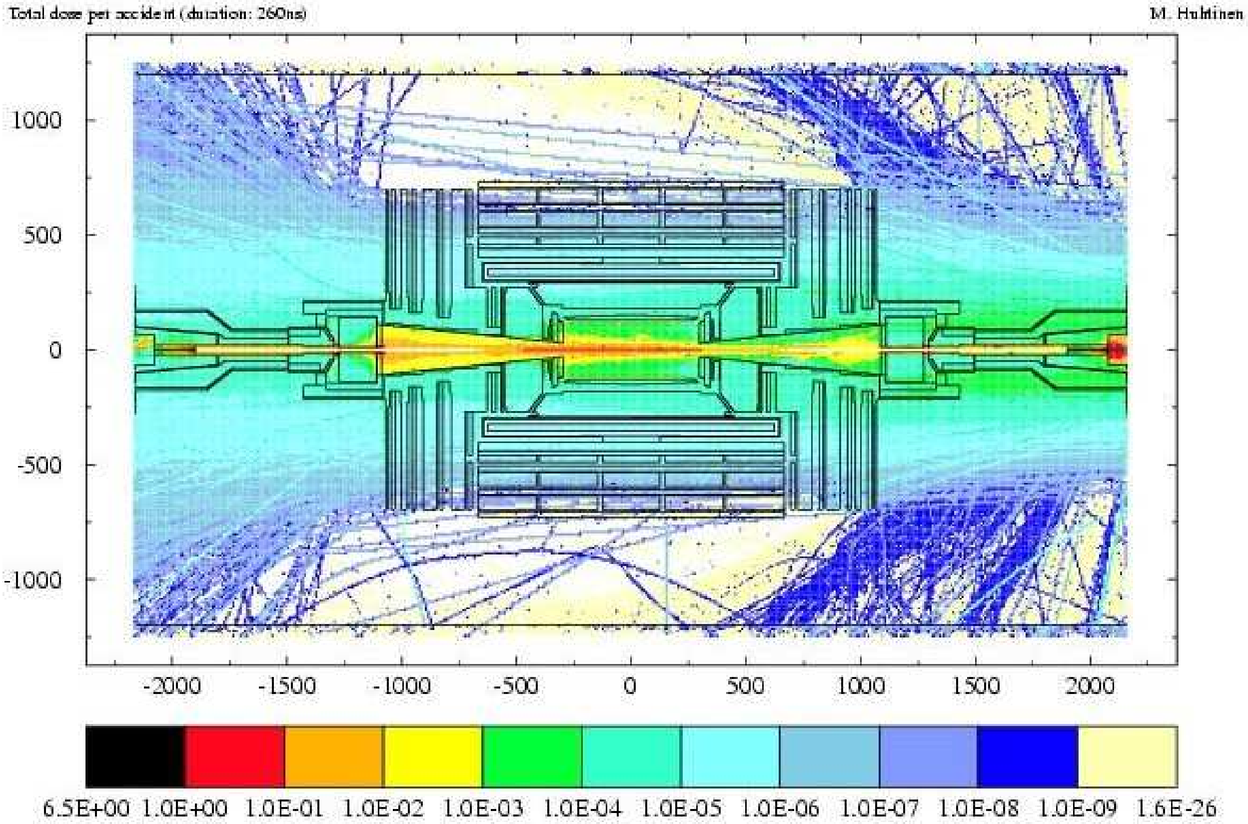
- Accident Scenarios
  - D1 Warm Magnet
    - Power converter trip
    - At collision energy
    - Loss location in quadrupole triplet/collimator
    - Time constant of 5 turns (~440 μs)
    - A fast beam abort could act on this time scale.

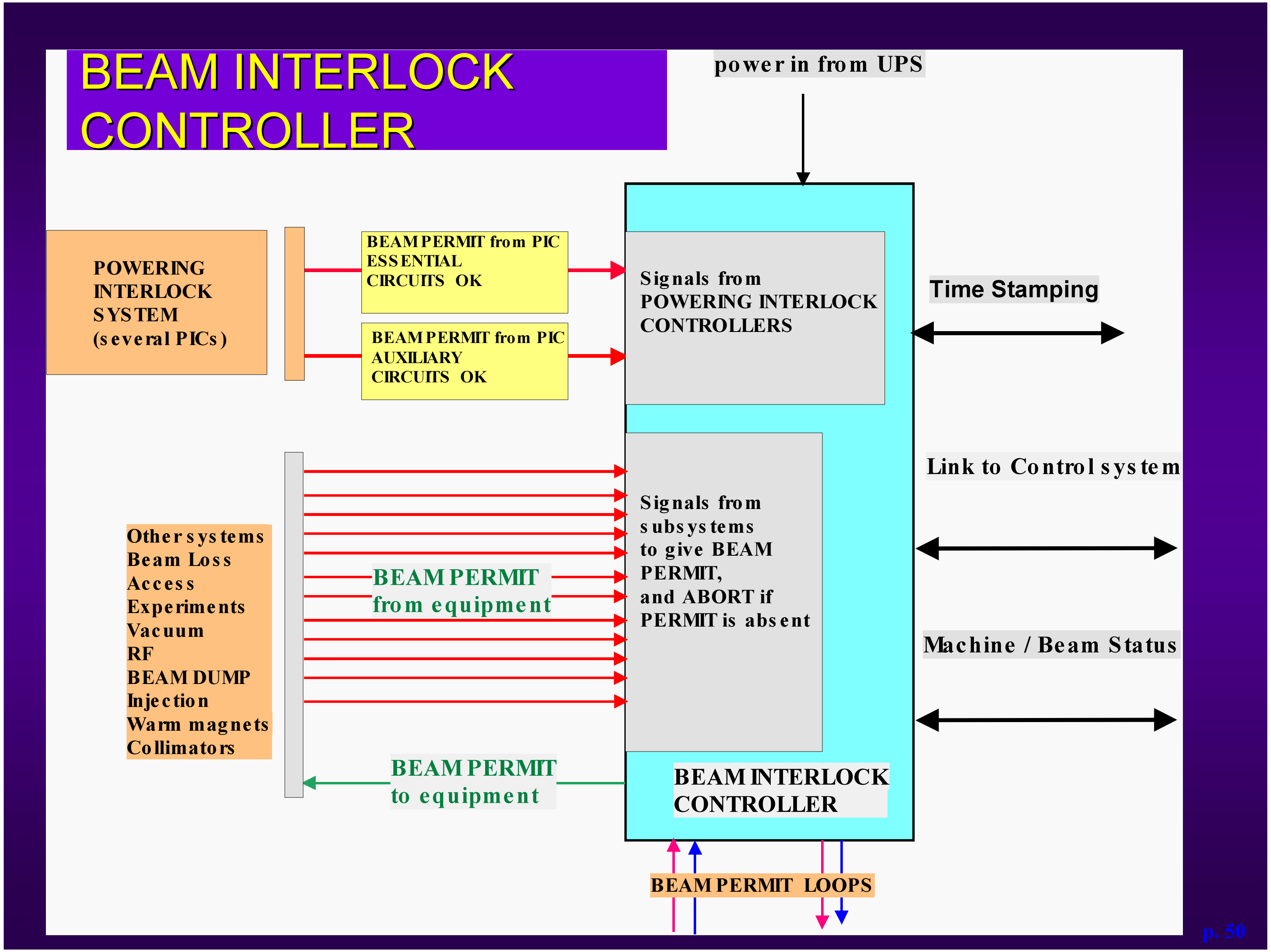
- Unsynchronised Abort

  - The dump kicker does not hit the abort gap
  - Some of the deviated bunches continue in the machine and are lost in the next limiting aperture
  - Accident duration: ~0.26 μs; 1×10^{12} protons lost in Point 5 (CMS)

- Beam dump malfunctions affect mainly CMS since it is the only experiment neighbouring the dump insertion IP6.
- Beam abort system would not be able to react in time.
- Such an accident may indeed happen.
    - Any timing or control loss could cause this
    - Occurred at the Tevatron.
- Absorber to be installed at IP6.
    - Would protect rest of the machine (including CMS)

Dose per unsynchronized LHC beam abort (Gy)




BEAM INTERLOCK CONTROLLER
power in from UPS
POWERING INTERLOCK SYSTEM (several PICs)
BEAM PERMIT from PIC ESSENTIAL CIRCUITS OK
BEAM PERMIT from PIC AUXILIARY CIRCUITS OK
Signals from POWERING INTERLOCK CONTROLLERS
Time Stamping
Link to Control system
Other systems
Beam Loss
Access
Experiments
Vacuum
RF
BEAM DUMP
Injection
Warm magnets
Collimators
BEAM PERMIT from equipment
Signals from subsystems to give BEAM PERMIT, and ABORT if PERMIT is absent
Machine / Beam Status
BEAM PERMIT to equipment
BEAM INTERLOCK CONTROLLER
BEAM PERMIT LOOPS
p. 50

LHC Timing Signals & Distribution to Experiments

- LHC RF Group is considering 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

- Clock Accuracy
  - Jitter of reference clock ~10 ps at origin
  - RF clocks are less accurate
    - Phase of reference clock and RF clocks could differ by up to 300 ps
    - RF clock phase can change rapidly on a time scale much less than the 88 μs LHC orbit period.
    - No guarantee that the variation in the phase of the two RF clocks will be correlated.

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.
  - A jitter of 300 ps implies significant displacements.
- Experiments would like to access reference signal from the closet beam pick-up at the insertion region

Absolute Time Tagging

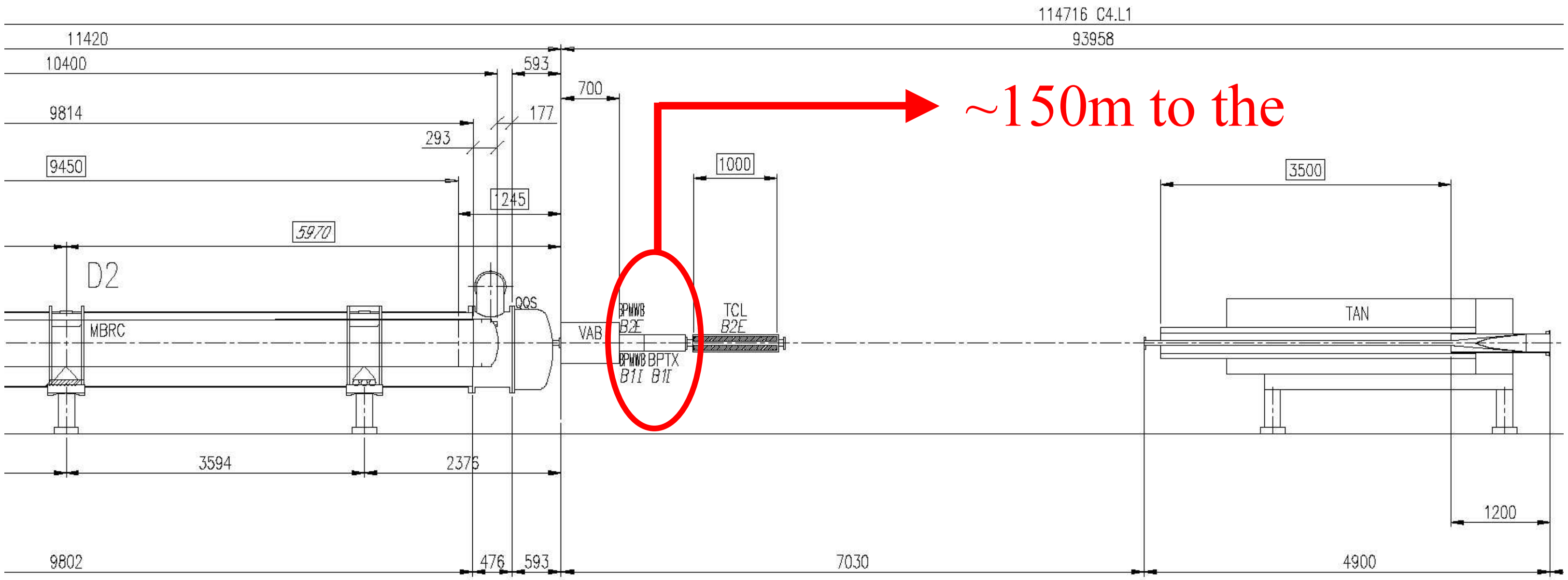
- LHC information (machine & experiments) will have absolute UTC time stamp

  - Derived from GPS module(s)
  - Located centrally in PS Complex with auxiliary modules at each other CERN accelerator and in each pit of the LHC.
  - Fibre may be connected to the experiments.

The LHC Beam Position System

➢ Timing Pick-up for the Experiments (BPTX)

- Located ~150m from the IP in front of the D2 Magnet
- One BPTX either side of the IP on the incoming beam
- Exclusively used by the experiments



➢ BPTX Technology

- Choice of Pick-up

  - Stripline Coupler

    Peak voltage (one button) ~20V after 200m of cable for nominal bunch
    Peak voltage (one button) ~1V after 200m of cable for pilot bunch

  - Button Electrode BPM

    Peak voltage (one button) ~5V after 200m of cable for nominal bunch
    Peak voltage (one button) ~250mV after 200m of cable for pilot bunch

  - Other Type of Pick-up

Applications

- Two applications of BPTX timing signals were identified by experiments
  - Monitoring the phase of the clock of the two beams locally at the IRs

    Allow 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

Both measurements performed by taking sum of BPTX quadrants

- Ancillary Systems

  - Cables

    - Choice of technology and location of front-end electronics will determine requirements for cables.

    - Procurred and installed by LHC Machine

    - Under the financial and logistical responsibility of the experiments

    - Experiments expressed interest to pull cables their galleries in the underground areas and thence to their underground counting rooms

- Front-end Electronics
    - Under the responsibility of experiments
    - Ensure radiation resistance (if required to operate in LHC tunnel)
    - Common development between all experiments and machine

Technical liaison group being created

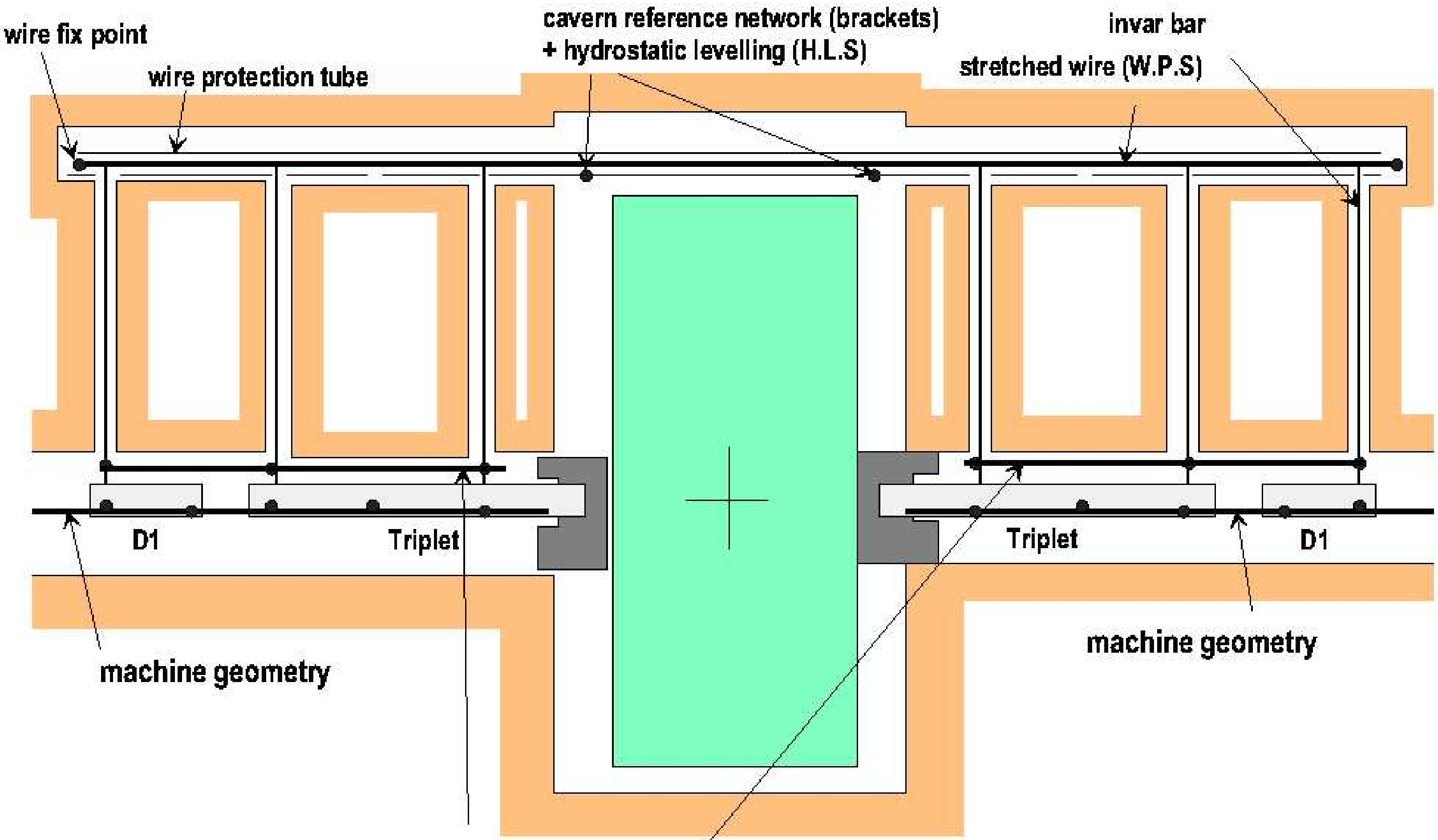
Transverse Centering of the IP

➢ LHC Machine

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

➢ Experiments

- 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 μm 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.



measure and control of the triplets

➢ Need for Re-alignment

- Cavern floors are expected to move:

  - Over time due to settling of the concrete (down) and due to the hydrology of the geology (up).

  - During extended access periods, during which major parts of the detectors are moved over the floor.

- Estimations for the ATLAS Cavern
  - 2 mm settling of the floor from the time the concrete is poured to the time ATLAS gets possession of their experimental cavern.
  - An additional 5.5 mm settling of the floor over the first 6 months thereafter due to the weight of the ATLAS experiment.
  - A 1 mm / year lift of the floor due to hydrostatic pressure.

- Re-alignment Process

  - ATLAS is not designed to be adjusted

    If above predictions are confirmed, an adjustment system for the ATLAS barrel may need to be implemented.

  - CMS includes adjustment mechanism based on jacks & grease pads.

    Lateral adjustment of ±20 mm and vertical adjustment of ±50 mm can be performed during machine shutdown periods.

  - LHC Machine

    Align the IRs with respect to the experiments and not the inverse.

    To within $<\pm 1$ mm

Conclusions

- Overview presented of issues relevant to the interface of the LHC machine and experiments.
- Common effort to ensure the highest quality data to be recorded.
- Must learn from & incorporate experience from previously and presently running facilities (ISR, SPS Collider, LEP, Tevatron, RHIC, HERA,…)
- These issues need to be understood and planned from now.

- With 5 approved experiments:
  - There will be compromises to be made & priorities to be fixed.
  - After initial operation there will be special requests for particular running conditions.
    - Lower energies (e.g. 1 TeV on 1 TeV) to make comparisons with Tevatron data.
    - Lighter ion species & various energies for ion programme.

Totally new experiments cannot be excluded (e.g. MOEDAL monopole search)

References

- Ad-hoc Working Group on LHC Experiment-Machine Parameter and Signal Exchange

  http://cern.ch/lhc-data-exchange

- LHC Experiment – Machine Interface Committee (LEMIC)

  http://lhc.web.cern.ch/lhc/lemic/lemic.htm

- LHC Commissioning Committee (LCC)

  http://lhc.web.cern.ch/lhc/lcc/lcc.htm