LHC commissioning phase A.10 - top energy, collisions

Presented by : H. Burkhardt

Procedures : Reyes Alemany-Fernandez

for the LHC Commissioning Working Group

with

W. Herr, T. Pieloni for separation, crossing angle, beam-beam

Simon White - PhD student, luminosity from machine parameters

and feedback from

Bernhard Holzer / HERA , Jerry Annala and Dean Still / Tevatron

Commissioning Phases

Phase	Phase	Procedures	LTC Presenter	Date	
injection and first turn	A.1	Magali	Brennan	7.03	✓
circulating beam, RF capture	A.2	Magali	Gianluigi	14.03	✓
450 GeV, intial commissioning	A.3	Verena	Rhodri	28.03	✓
450 GeV, optics meas	A.4	Stefano	Frank	11.04	✓
450 GeV, increase intensity	A.5	Laurette	Jan	25.04	✓
450 GeV, two beam operation	A.6	Walter/Verena	Ralph	4.07	
450GeV, collisions	A.7	Magali	Helmut	15.08	?
snapback and ramp	A.8	Reyes	Mike	9.05	✓
top energy checks with beam	A.9	Walter	Frank	6.06	✓
top energy, collisions (pilot physics)	A.10	Reyes	Helmut	20.06	←
+ squeeze	A.11	Stefano	Massimo	23.05	✓
top energy, physics runs	A.12				

Phase A

43 - 156 bunches, no crossing angle ; 4 - 9 × 10^{10} p / bunch

A.10 : $\beta^*_{1, 2, 5, 8}$ = 11, 10, 11, 10 m

+

A.12 physics runs after squeeze commissioning in steps down to β^* = 2 m (1/5)

Staged commissioning

Staged commissioning of high luminosity operation of LHC at points 1 and 5

$$L = \frac{N^2 k_b f \gamma}{4\pi \varepsilon_n \beta^*} F$$

$$Eventrate / Cross = \frac{L \sigma_{TOT}}{k_b f}$$

Machine parameters		**450GeV**	**Commission hardware for high energy operation**	**Stage A**		**Stage B**		**Stage C**		**Installation of phase II collimators and full beam dump diluters**	**Stage D**	
		Target		**Target**	**Limit**	**Target**	**Limit**	**Target**	**Limit**		**Target**	**Limit**
spacing	ns	2021		2021	566	75	75	25	25		25	25
bunch length	m	0.1124		0.0755	0.0755	0.0755	0.0755	0.0755	0.0755		0.0755	0.0755
crossing angle	urad	0		0	0	250	250	285	285		285	285
bunch intensity		4.00E+10		4.00E+10	9.00E+10	4.00E+10	9.00E+10	5.00E+10	5.00E+10		9.00E+10	1.15E+11
bunches		43		43	156	936	936	2808	2808		2808	2808
energy	eV	4.50E+11		7.00E+12	7.00E+12	7.00E+12	7.00E+12	7.00E+12	7.00E+12		7.00E+12	7.00E+12
F		1.00		1.00	1.00	0.96	0.92	0.90	0.84		0.90	0.84
normalised emittance	cm	3.75E-04		3.75E-04	3.75E-04	3.75E-04	3.75E-04	3.75E-04	3.75E-04		3.75E-04	3.75E-04
beta*	cm	1100		200	200	200	100	100	55		100	55
luminosity	/cm2s	7.16E+28		6.12E+30	1.12E+32	1.28E+32	1.24E+33	1.13E+33	1.91E+33		3.65E+33	1.01E+34
total inel cross section	cm2	6.00E-26		6.00E-26	6.00E-26	6.00E-26	6.00E-26	6.00E-26	6.00E-26		6.00E-26	6.00E-26
event rate per cross		0.01		0.76	3.85	0.73	7.09	2.14	3.63		6.94	19.18
protons per beam		1.72E+12		1.72E+12	1.40E+13	3.74E+13	8.42E+13	1.40E+14	1.40E+14		2.53E+14	3.23E+14
current per beam	mA	3.09E+00		3.09E+00	2.53E+01	6.74E+01	1.52E+02	2.53E+02	2.53E+02		4.55E+02	5.81E+02
energy per beam	Joules	1.24E+05		1.93E+06	1.57E+07	4.19E+07	9.43E+07	1.57E+08	1.57E+08		2.83E+08	3.62E+08
beam size	um	293.3		31.7	31.7	31.7	22.4	22.4	16.6		22.4	16.6

From R. Bailey, LHCCWG

LHC commissioning - top energy, collisions

- **Phase A.10**
  - **description (objectives)**
  - **entry conditions**
  - **procedure** **overview + detailed discussion**
  - **exit conditions**
  - **problems**
  - **questions**

http://lhccwg.web.cern.ch/lhccwg/Procedures/stageA/phaseA10/menu.htm

Description

This phase can be sub-divided into four steps / objectives

1. **Get beams into collisions**
2. **Optimise integrated luminosity with relative luminosity as the main performance parameter**
3. **Check / optimise experimental conditions - good lifetime, low background, no spikes ..**
4. **Get a rough calibration of the absolute luminosity from beam parameters**

Loop over increasing intensity

Loop over decreasing β^*

Entry conditions

- top energy (nominally Eb = 7 TeV)
- good beam lifetime (at least 1h)
- un-squeezed optics $\beta^*_{1,2,5,8}$ = 11, 10, 11, 10 m

  later also partially squeezed optics, limit is $\beta^*_{1,2,5,8}$ = 2, 2, 2, 2 (10) m
- nominal emittances (or smaller ~ 2.5 μm)
- no crossing angle
- 1+1 bunch of pilot intensity sufficient to see first collisions in 1/5 with few Hz in BRAN; better accuracy with few 10^{10}
- ramp up intensity to 4 ~ 9 × 10^{10} and number of bunches to 43 - 156
- beam modes ADJUST → STABLE BEAMS

Entry conditions; details (1/2)

	Entry condition
E.A.10.1	**Machine protection for 7 TeV** (already done in phase A.8)
E.A.10.2	**Good Vacuum for low background**
E.A.10.3	**Collimators: maximal cleaning efficiency**
E.A.10.4	**Power circuits**
.01	Correctors should be available and calibrated; bumps should be commissioned
.02	Octupoles ON (feedbacks OFF)
.03	Experimental magnets (solenoids and toroide) ON (coupling might be already corrected)
.04	Experimental dipoles OFF
.05	Online FiDeL magnetic model available via LSA for the correctors participating in the bumps
E.A.10.5	**High level controls**
.01	Separation scan application debugged and available
.02	Online FiDeL magnetic model available via LSA for the correctors participating in the bumps
.03	Online display of the beam parameters: current, lifetime, tune, chroma, orbit, etc.
.04	Online display of BLMs

Entry conditions; details (2/2)

E.A.10.6	**BI**
.01	BRAN detectors commissioned and available
.02	BPM (high resolution, non-directional button pickups) commissioned and good calibration
.03	Tune shift measurement available (for alternative beam-beam interaction lumi optimization). BBQ with tiny excitations or (better) Schottky
.04	BLMs commissioned and calibrated
.05	Synchrotron light monitor
.06	BCT commissioned and calibrated
E.A.10.7	**Beam parameters under control**
.01	Good beam lifetime
.02	Orbit
.03	Tune (collision tunes)
.04	Chromaticity
E.A.10.9	**Communication with experiments**
.01	DIP operational
.02	Regular schedule meetings
.03	TV-screen status page (pages 1)

Procedures - overview and detailed discussion

Procedure; overview (1/2)

Step	Activity	Who	Priority
A.10.1	**Get Beams into Collision in the X,Y plane**	OP	1
.01	At the end of the ramp or squeeze (depending on the phase) beams should be separated (~14σ)		
.02	Separator bumps at nominal 0 at all IPs (get settings from best knowledge; beams should be already pretty close)		
.03	Measure beam displacement at the IP using BPMs		
.04	Adjust beam separation such that the beam 1 and beam 2 difference left/right of the IP is the same. Do this for one IP at the time.		
.05	Monitor lifetime for all the bunches/empty buckets/abort gap; monitor beam losses. If OK continue, else separate beams.		
.06	"Watch" background		
.07	Change mode from ADJUST to STABLE BEAMS (if lifetime and background under control)		
.08	Start counting delivered luminosity; logging into database (~ Hz)		
A.10.2	**Measure and correct longitudinal position**	OP/RF	1
.01	Shift RF phase to monitor the longitudinal position		
A.10.3	**Monitor lifetime, beam losses and keep background low and stable (no peaks)**	OP	1

Procedure; overview (2/2)

A.10.4	**Optimize Luminosity: separation scans (simple orthogonal separation for commissioning)**	OP/ABP	2
.01	Scan the IP (x,y): 10 different values for the separation bumps strengths corresponding to 10 different beam separation within $\pm 2\sigma$.		
.02	Measure the position with the BPMs		
.03	Measure the luminosity with the BRAN detectors (Fig. 1)		
.04	Plot Lumi = f(nominal separation) and fit to get the maximum lumi		
.05	Once maximum lumi found, feedback the corrector strengths into to the system. Those values should be the nominal 0 next time (A.10.A.01).		
A.10.5	**Monitor luminosity during the fill provided by the experiments**	OP	2
A.10.6	**Waist measurement** (adjust quads in the triplets)	OP/ABP	If lumi asymmetry in the experiments
A.10.7	**Measure beta***	OP/ABP	If we have doubts
A.10.8	**Optimize Luminosity: alternative method; beam-beam interaction**	OP/ABP	Backup
A.10.9	**CALIBRATE absolute luminosity: Van de Meer[7-9]**	OP/ABP	Special runs

Get beams colliding

Luminosity with separation

$$\frac{\mathcal{L}}{\mathcal{L}_0} = \exp\left[-\left(\frac{\delta x}{2\sigma_x}\right)^2 - \left(\frac{\delta y}{2\sigma_y}\right)^2\right]$$

$\frac{\delta x}{\sigma_x}$	$\frac{\delta y}{\sigma_y}$	$\mathcal{L}/\mathcal{L}_0$
0	0	1.0000
0.1	0	0.9975
0.2	0	0.9901
0.3	0	0.9778
0.4	0	0.9608
0.5	0	0.9394
0.5	0.5	0.8825
1	0	0.7788
1	1	0.6065
2	0	0.3679
2	2	0.1353

Procedure and requirements :

- **End of ramp / squeeze, beams separated**
- **Turn off separation, based on BPM information**

required, roughly (values for x and y or radius, √2 better in each plane)

$\delta_r < 2\ \sigma$ to see collisions

$\delta_r < 0.5\ \sigma$ to optimise luminosity and equalise between experiments

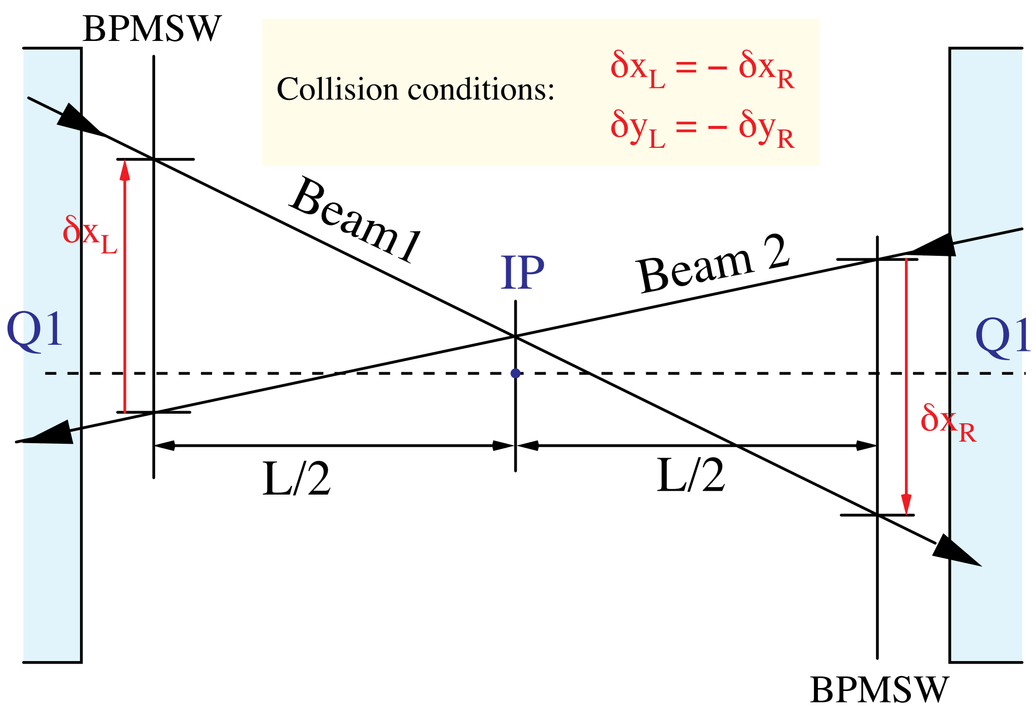
or in each plane x,y: $\delta_{x,y} < 1.4\ \sigma$ and $\delta_{x,y} < 0.35\ \sigma$

this implies at 7 TeV for nominal emittances :

un-squeezed, β^*= 11 m : $\delta_{x,y} <$ 133 µm and $\delta_{x,y} <$ 33 µm
squeezed to β^*= 2 m : $\delta_{x,y} <$ 44 µm and $\delta_{x,y} <$ 11 µm
squeezed to β^*= 0.55 m : $\delta_{x,y} <$ 23 µm and $\delta_{x,y} <$ 6 µm

Get beams colliding : BPM resolution, based on S. Fartoukh LCC 3/2001

Adjust orbits such, that the beam 1 and 2 difference left/right of the IP is the same.
measured with special (beam) directional stripline couplers BPMSW at about 21 m L/R from IP in front of Q1. There are 2 each in IR1 (Atlas), IR2 (Alice), IR5 (CMS) and IR8 (LHCb)
Beams must then collide. This is independent of mechanical offsets and crossing angles.



when both planes (x, y) are considered together

$$\delta_{\rm IP} = \sqrt{\left(\frac{\delta x_L + \delta x_R}{2}\right)^2 + \left(\frac{\delta y_L + \delta y_R}{2}\right)^2} = \sqrt{2}\,\sigma_{\rm BPM}$$

or simply **σ_{BPM} in each plane**

expected resolution for small separation and 0 crossing angle, each plane :
initially ~ 100 - 200 µm later (after k - modulation) **~ 50 µm**
mainly limited by electronics which is separate for b1 and b2

Request for improved BPM resolution

~ 100 - 200 μm BPM resolution should be (just about) sufficient to get beams close enough to see some collisions for un-squeezed beams at 7 TeV.

Request for an improved BPM system at the IP. Anyway needed for high-β Totem/Atlas (assume 5 and 10 μm resolution in their TDRs).

For operation with 0 crossing angle and a limited number of bunches, it should be possible to eliminate offsets using (non-directional) button pickups and electronics for beam1 and beam2, aiming for σ_{BPM} = 10 μm resolution needed for high-β which would also assure close to optimal collisions without need for frequent scanning.

Prelim. discussion with Rhodri : **appears to imply the design, construction and installation of a new combined pick-up system : stripline for normal operation with crossing angle and many bunches and button to measure the zero crossing angle angle and adjust collisions in early operation.**

Approve soon, to allow for installation before the zone gets too irradiated - and to be able to profit for early-physics !

Longitudinal position

Once we are in stable physics and see collisions, this can be monitored precisely by the experiments.

In principle not too critical in commissioning. First collisions will be without crossing angle and with rather large β^* (11 m). Even few ns resolution could be sufficient together with information from the experiments.

How to adjust in commissioning before experiments observe collisions ?

How to detect offsets later ? - no collisions with crossing angle and offset !

→ **Now solved : a new electronic card was developed. Uses BPMs around IP and existing infrastructure and allows to measure the relative beam arrival times with sub ns resolution.** Information from Rhodri

Comments on β* and waist measurements

see also Rogelio Tomas in LHCCWG#8 on β-beating/correction and Jörg Wenninger LHCCWG#9 on response matrix analysis

here : local β measurement , applied to β* at the IP

Principle :
a change of the quadrupole gradient Δk of a quadrupole at the beta function β_Q results in a tune shift of

$$\Delta Q = \frac{\Delta k \ \beta_Q}{4\pi}$$

β^* and β_Q at distance l from the IP
LHC l = 26.15 m from IP to centre of Q1

$$\beta_Q = \beta^* + \frac{\ell^2}{\beta^*}$$

numerical values for the LHC

β^* m	β_Q m	kqx 1/ m	ΔQ from $\Delta k = 10^{-5}$/m
11	73.165	$8.576824107 \times 10^{-3}$	0.00157
2	343.911	$8.730196766 \times 10^{-3}$	0.0082

measure with PLL

Luminosity from Machine Parameters

$$\mathcal{L} = \frac{N^2 f_{\rm rev} n_b}{4\pi\sigma^{*2}}$$

For head-on collisions of round beams and
N particles / bunch for n_b bunches
Gives **absolute** luminosity
Accuracy : knowledge of effective beam sizes (overlap integral) at IP

$$\sqrt{1+\left(\frac{\theta_c\sigma_z}{2\sigma^*}\right)^2}$$

Reduction by crossing angle. θ_c is the full crossing angle, nominally ~ 300 mrad

Not an issue for commissioning.

~ 1% or still rather negligible for 7 TeV, $\beta^* = 11$ m
only really significant (~ 20%) at 7 TeV squeezed.
σ_z is the r.m.s bunch length, 7.55 cm at 7 TeV

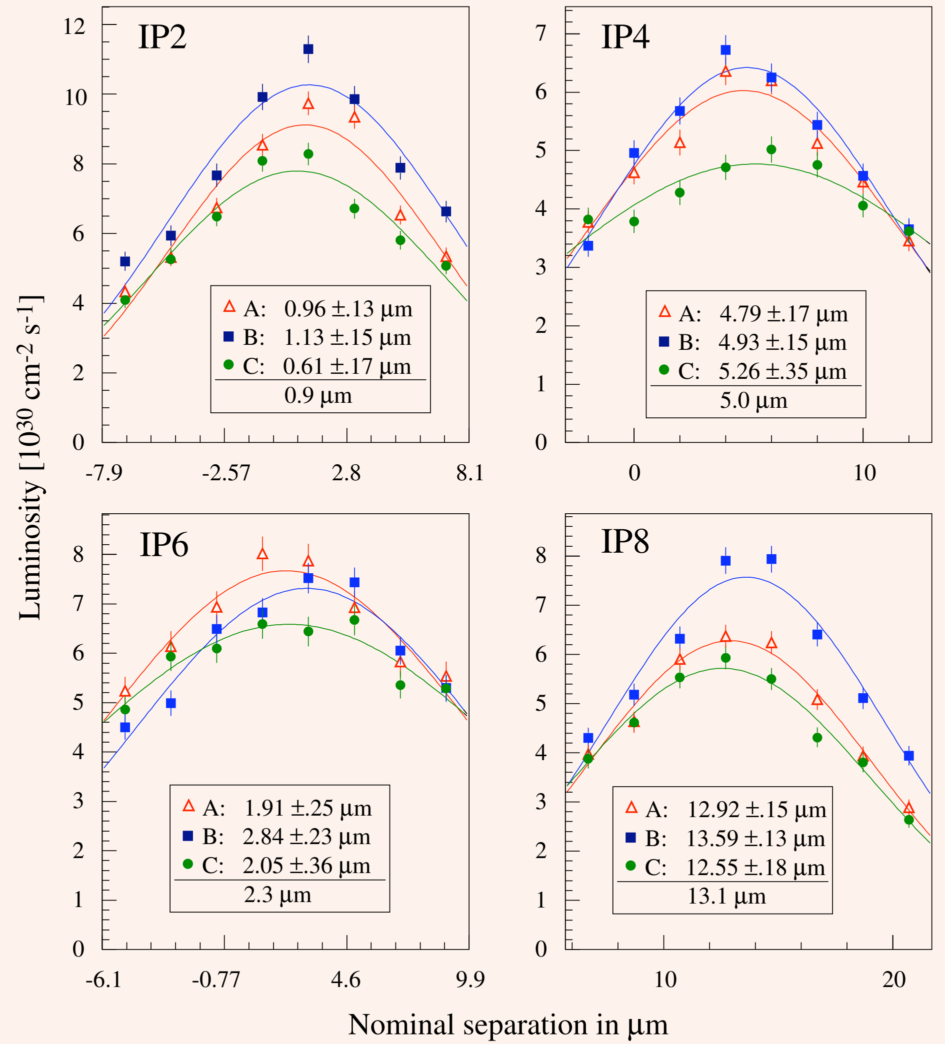
We expect to be able to predict absolute luminosities for head-on collisions based on beam intensities and dimensions, to maybe initially 20-30 % and potentially much better if a special effort is made.

LHC Machine luminosity determination - subject of a PhD thesis by S. White.

K. Potter, CAS 1992, CERN yellow report 94-01 in : THE VAN DER MEER METHOD OF LUMINOSITY MEASUREMENT
At the ISR this technique worked extremely well and with occasional calibrations of their monitors the experimenters always knew the luminosity to within a few per cent. For particular experiments such as the measurement of the total p-p and p-pbar cross section special care was taken and an error of less than 1% was achieved. In particular this required a calibration of the beam displacement (h) used in the luminosity measurement.

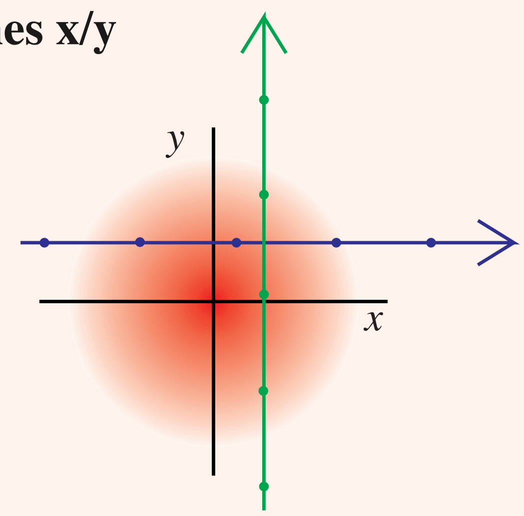
Separation Scan (pioneered by Van der Meer @ ISR)

LEP example:
vertical separation scans using LEP luminosity detectors in operation with 4 bunch trains of each 3 bunches
Time: about 5 min / IP



should be faster in the LHC
but needed in two planes x/y

Commissioning :
simple, orthogonal
x / y scan



different from LEP, the effect of one beam on the other is really small in LHC (negligible dynamic β effects)

Separation scans in the LHC should allow for reliable beam size measurements at the IPs.

Precise separation measurement : bump (and BPM) calibration (response matrix analysis)

Absolute Luminosity

Large Hadron Collider Project

LHC Project Report XX

Absolute Luminosity from Machine Parameters

H. Burkhardt [*,‡], P. Grafstrom [†]

Abstract

The expected rates for proton proton collisions in the LHC are rather high. Monitoring can be based on several detector components and different physics channels can be used together and should allow for a good accuracy in the relative luminosity determination. The accuracy in the absolute luminosity determination may soon be limited by the uncertainty in the knowledge of the proton proton cross section at the LHC energy.

Here we discuss the possibility to determine the absolute luminosity in the LHC from machine parameters which does not require the knowledge of particle cross sections.

Geneva, 23 May 2007

Experimental conditions

Experiments need good, or at least acceptable running conditions.
The goal is to optimise the accepted, integrated luminosity by the experiments

Efficient communication ; few clear normalised background numbers + detailed information.

Technically prepared (LEADE) and more recently followed up within LHC Background WG and LEMIC.

Summary on TV-screen status page
as for other CERN accelerators using the AB/CO teletext services **http://hpslweb.cern.ch/teletext.html**

By design : machine backgrounds ok at full intensity and $\beta^* = 0.55$ m
Gives (in theory) a large margin in background for commissioning.

Exit conditions

- **stable conditions -- good (luminosity) lifetime;   experiments happy**
- **43 - 156 bunches**
- **luminosity well optimised for the given condition**
- **phase A.10 (un-squeezed) : intensity ~ 9×10^{10} p / bunch**
- **phase A.12 (squeezed)   : β^* = 2m and intensity ~ 9×10^{10} p / bunch**
- **if we can expect to gain in $\int L\,dt$ by going to next step: increasing #bunches or decreasing β^***

Possible problems

- **Poor intensity lifetime : check / optimize working point**
- **Emittance growth : check nothings kicks the beam, vibrations (low freq. FFT), minimise RF-noise**
- **Backgrounds rising : check orbit / aperture; vacuum**
- **Poor luminosity : re-optimise - check / adjust separation**

Open Questions ; Concerns ; Follow up

- corrector transfer functions; hystereses
- bunch by bunch variations →
- beam-beam effects →
- high background →
- extended halo ; halo scraping →
- solenoid compensation ; small effect at 7 TeV, still do properly, when ? →
- going back to ADJUST, end of coast MDs →

questions related to scheduling and priorities :

Alice & LHCb spectrometers

displaced bunches for LHCb (+ crossing angle or extra collisions in other IPs)

Bunch by bunch variations

Our initially 43, 54, 108, 156 and later ~ 2000 bunches will have a spread in intensity and emittance

What is acceptable ? W. Herr at al:
For good lifetime and low halo aim for < 10% in intensity and ~ 20% in emittance and minimize separation < 0.1 σ
Matches about what is feasible from injectors (G. Arduini).

Long range b.b. negligible (≤156 bunches) - same orbits :
For optimising collisions and total integrated luminosity it is sufficient to take the sum from individual bunches.

For a full analysis and optimisation of lifetime, background and stability, measurements should be able to distinguish between bunches, for quantities like current, beam size (emittance), tune and luminosity

LHC collimation system and background

What can be done with the available system to optimise or at least check and diagnose background issues ? Which collimators could be moved ~ safely ?

Setting all (~100) collimators empirically is not realistic.

Operation will be based on full sets of predefined, commissioned collimator settings for a given operation mode - here 7 TeV collisions.

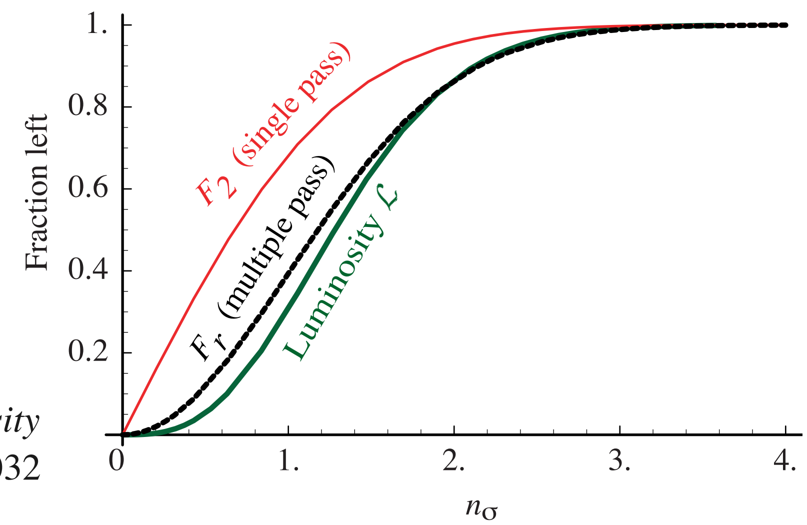
The following should be reasonably safe - to be verified at reduced intensity :

- **open slightly tertiary collimators from nominal ~ 8.3 σ ; check effect on experiments.**
- **prepare alternative settings; i.e. for reduced (~ 2.5 μm) emittances and more margin between prim/sec. collimators ; possible use as fine / coarse settings.**
- **move primary collimators closer to the beam from nominally study possible halo cleaning -- scraping with primary collimators ➙**

Halo scraping with primary collimators

Scraping a Gaussian beam (in multiple passages) at 3.5σ reduces the intensity by 0.22% and the Luminosity by 0.13%. Foreseen in the SPS before extraction of LHC beams, using fast scrapers, since the SPS is pulsed.

H.B., R. Schmidt, *Intensity and Luminosity after Beam Scraping*, CERN-AB-2004-032



LHC : move in primary collimators slowly, automatically stop if either

- **predefined position is reached**
- **intensity reduction by ~10^{-3}**
- **loss rates close to quench limit**

Potentially useful at various stages:

- **end of injection before ramp**
- **end of ramp before squeeze**
- **end of squeeze before physics**

Solenoids , Compensation

	ATLAS	ALICE	CMS
field [T]	2.0	0.6	4.0
length [m]	5.3	5.0	12.5
strength [Tm]	10.6	3.0	50.

largest is CMS. At 7 TeV c- = - 0.00034 i nearly negligible (priority 3)

mainly for completeness,

do whenever convenient at 450 GeV where effects should be well measureable :

33 mrad tilt, with crossing angle (here not an issue) reducing separation by 15 µm

and

$$c^-_{\text{CMS, 450 GeV}} = -\frac{i}{2\pi}\,\frac{B_s l}{B\rho} = -0.0053\,i,$$

see also A. Koschik, H. Burkhardt, T. Risselada, F. Schmidt, EPAC’06, WEPCH043

Back to ADJUST, end of coast MDs

why ?

can be a very efficient way to do certain MDs ; saves set-up time

how :

announce well before on page 1, ask experiments to turn off (safe)

Set mode to ADJUST and turn on > 6σ separation

that should be all - rest depends on MD

in some cases we may want to dump one beam or scrape beams

- **TEVATRON experience (by J. Annala, Tevatron machine coordinator)**:

  I. At Tevatron they go to MD mode often after Physics is over. The most common studies are fairly benign, but the experiments turn off most of their sensitive equipment. They often do things like crystal collimator studies, separation scans, collimator alignment, etc.

  II. They have unsqueeze beams and also decelerated protons, but this is not very commonly used. Their biggest problem is to have both protons and anti-protons in the same beam pipe.

Backup Slides

Parameter Range

and single bunch luminosities as relevant for lumi / separation scan statistics
Event rates for σ = 10 mb, which is about the cross section with high energy neutrons in the BRAN

ϵ_N μm	ϵ nm	p GeV/c	β^* m	σ^* μm	N_p	$\mathcal{L}$ cm^{-2}s^{-1}	$\dot{N} = \mathcal{L}\,\sigma$ Hz	$\frac{\dot{N}}{f_{\rm rev}}$	ξ
3.75	7.82	450	11	293.3	5×10^9	2.60×10^{25}	0.26	0.000023	0.000 16
3.75	7.82	450	11	293.3	4×10^{10}	1.66×10^{27}	16.64	0.0015	0.001 30
2.5	5.21	450	11	239.4	4×10^{10}	2.49×10^{27}	24.94	0.0022	0.001 95
3.75	7.82	450	11	293.3	1.15×10^{11}	1.37×10^{28}	138	0.0122	0.003 74
3.75	0.503	7000	11	74.36	5×10^9	4.00×10^{26}	4.00	0.00036	0.000 16
3.75	0.503	7000	11	74.36	4×10^{10}	2.56×10^{28}	256	0.0228	0.001 30
3.75	0.503	7000	11	74.36	9×10^{10}	1.30×10^{29}	1296	0.115	0.002 93
3.75	0.503	7000	2	31.71	1.15×10^{11}	1.11×10^{30}	11087	0.986	0.003 74
3.75	0.503	7000	0.55	16.63	1.15×10^{11}	3.54×10^{30}	35400	3.15	0.003 74

Commissioning Phase A aims for 43 - 156 bunches. No crossing angle

Nominal longitudinal LHC beam parameters V4.0 , LHC design report (frf = 400.8 MHz) :

V_{rf} = 8 MV σ_E / E = 4.716e-4 σ_Z = 11.24 cm σ_T = 0.375 ns 450 GeV

V_{rf} = 16 MV σ_E / E = 1.129e-4 σ_Z = 7.55 cm σ_T = 0.252 ns 7 TeV

HERA procedure on background optimization (by B. Holzer): reported by Reyes

1. First of all beams should collide as good as possible: central collisions, max. luminosity is crucial.

2. They optimize the angle of the two beams, again according to the best luminosity, but now also according to the lowest background.

3. Adjust collimators

4. Optimize the diffusion rate of the beams (crucial). In the case of HERA the ideal tunes are the ones close to the coupling resonance as they suffer even from 12 order resonances under collisions. And close to the diagonal in the tune diagram there is more free place.

5. Tune chromaticity (small values)

6. Optimize the coupling; if there is a measurable coupling the lifetime in HERA is easily reduced by a factor of 5.

7. The last step is an upstream orbit correction according to the drift chamber currents and background signals of the experiment.

At HERA, background tuning is in general done as a function of the overall loss rate, monitoring the BLMs. They could take the lifetime measurement, but find that loss rates are faster and much more sensitive

Waist position

- was an issue in LEP in 1991 to optimise and **equalise** luminosities between experiments. Assure β^* has the minimum at the IP. Steps of ±2e-4 in Qs0 strength resulted in 0.8 cm waist shift.

  LEP had typically σ_z = 1.2 cm, β_y^* = 0.05 m (β_x^* = 1.25 m). Distance IP to centre of 1st quad: 4.7 m

  What about the LHC ? All (length and β's) scaled up by 5 - 10 compared to LEP

- **LHC σ_z = 7.55 cm, β_x = 0.55 m, distance IP to centre of 1st quad 26.15 m**

  Quick check with mad : add same Δk = 1.e-5/m to triplet strength left and right. Moves waist position by about 10 cm at β^* = 0.55 m with about 3% relative increase of β at the IP.

  Should not be critical in commissioning. β varies only by 0.8 % over a length of ± 1 m from the IP for β^* = 11 m.

Check / optimise using beam-beam interaction

head-on b.b. tune shift

$$\xi_x = \frac{r_c \, N \, \beta_x^*}{2\pi \, \gamma \, \sigma_x \, (\sigma_x + \sigma_y)} \qquad \xi_y = \frac{r_c \, N \, \beta_y^*}{2\pi \, \gamma \, \sigma_y \, (\sigma_x + \sigma_y)}$$

calculated, using the classical particle radius, here for the proton $r_c = r_p = 1.5347 \times 10^{-18}$ m

In the LHC we have by design round beams with $\sigma = \sigma_x = \sigma_y, \; \beta^* = \beta_x^* = \beta_y^*$

so that $$\xi = \frac{r_c \, N \, \beta^*}{4\pi \, \gamma \, \sigma^2}$$

in terms of the normalised emittance $\sigma = \sqrt{\beta \epsilon_N / \gamma}$ we get simply $$\xi = \frac{r_c \, N}{4\pi \, \epsilon_N}$$

numerically

N	ξ
5×10^9	0.000163
4×10^{10}	0.00130
1.15×10^{11}	0.00374

independent of beam energy and β*
just a function of bunch intensity
which does not vary too much.

This is of the same order as the natural tune spread, $\delta Q/Q \approx 10^{-3}$ from $\delta p/p = 4.7 \times 10^{-4}$, $Q' = 2$ and should be observable. Was used successfully to optimise Luminosity in other machines :
Beam-beam transfer function, ISR, Hemery, Hofmann, JP Koutchouk et al. at PAC 1981
“Tune coupling” with excitation was used in HERA to steer collisions, S. Herb, Lauterberg 1992

LHC status summary page

	111	CERN AB	31-11-07	12:20:26	
LHC	Run 1234	data of	31-11-07	12:20:16	

— ** STABLE BEAMS ** —

E = 0.450 TeV	Beam	In Coast	0.5 h	
Beams	Beam 1	Beam 2		
#bun	43	43		
Nprot(t)	1.71e12	1.73e12		
tau(t) h	121	140		

Luminosities	ATLAS	ALICE	CMS	LHC-B
L(t) 1e28 cm-2s-1	5.23	6.23	7.13	1.21
/L(t) nb-1	0.78	0.68	0.78	0.12
BKG 1	1.20	0.52	0.90	0.33
BKG 2	0.85	0.82	0.50	0.60

From experiments

Comments 31-11-07 11:40:26

COLLIMATORS in coarse settings

Separation Scan in IR1/Atlas