2nd Meeting of the LHC Beam Cleaning Study Group 10.10.2001

Present: *R. Assmann (chairman), I. Baishev, H. Burkhardt, G. Burtin, B. Dehning, S. Farthoukh, C. Fischer, E. Gschwendtner, M. Hayes, J.B. Jeanneret, R. Jung, D. Kaltchev, M. Lamont, R. Schmidt, J. Wenninger*

1) Organization

JBJ asked RA to act as chairman of the beam cleaning study group.

2) The mechanical design of the collimators (G. Burtin)

(a) Mechanical tolerances

G. Burtin presented the present assumptions for the mechanical tolerances of the LHC collimators. He gave a first draft, based on the experience from the LEP collimators:

Parameter	LEP specified	LEP achieved	Limit
Flatness[1]	50 µm	120 µm	10-15 µm
Surface roughness[2]	0.8 µm	not measured (2 µm?)	-
Position set size[3]	uncritical	2.5 – 5.0 µm	-
Repeatability	uncritical	½ step ?	-

The collimators are referred with about 10 µm accuracy (at an ambient temperature of 20 °C) to an external reference line, which ideally goes parallel to the beam axis. The reference line is used to set both the horizontal and vertical orientations of the collimator jaw. The installation error is expected to be about 100 µm. The accuracy of the reference system and of the installation will determine the angle between the jaw surface and the beam axis (longitudinal tilt). A non-zero longitudinal tilt can add to the non-flatness of the jaw and can cause a further reduction of the active collimator length. The collimators are also referred into an external x-y reference plane that is important in order to obtain the correct x-y angle of the collimator surface (transverse tilt).

After installation, only the collimation depth can be adjusted (distance between jaw surface and beam). The longitudinal and transverse tilts cannot be adjusted and must be lived with.

There was a lively discussion about the presented tolerances and accuracies, especially contrasting the numbers with the 1 µm impact parameter of particles on the collimator (transverse distance between impact point and collimator edge). Would the collimation efficiency be drastically reduced, if the beam halo only passes through a small fraction of the collimator (due to the non-flatness and possible longitudinal tilts from installation)? JBJ asked about a possible smaller step-size of the movers. RA mentioned that magnet movers with 1 µm step size are in use at the FFTB at SLAC. DK asked about the hysteresis of the movers. HB pointed out the necessity to include the surface flatness into simulations of the cleaning efficiency. BD asked about the impact of the 60 cm high support pedestals on the temperature and mechanical stability. IB pointed out the importance to distinguish between primary and secondary collimators. The surface flatness might be acceptable for primary collimators, but not for the secondary collimators. JW mentioned that the beam position at the collimators is known within 10 µm, not better. SF pointed out that it is important to compare the collimator flatness

[1] The flatness is defined as the maximum deviation of the surface from an ideal plane.
[2] The surface roughness is defined as the average absolute value of measured surface variations.
[3] Position control is in 1D only per collimator jaw.

to the beam divergence at 6 σ offset amplitudes. SF quoted a change in beta beating of 5% during 0.5 hours, due to b3 decay.

G. Burtin asked about the effect of collimator heating on the mechanical properties of the jaw. He would welcome support on this topic. JBJ gave ~ 0.5 kW heating per collimator jaw. The heating issue is also important, as the collimators will be baked-out in-situ at high temperatures (300 °C for Cu and 150 °C for Al).

Action: Mechanical deformations due to collimator heating. (tbd)
Action: What do we know about expected heating? (JBJ)
Action: Is the surface flatness acceptable for collimation efficiency (collimation efficiency as function of active collimation length)? (RA)
Action: Is the longitudinal tilt that results from installation accuracy acceptable for collimation efficiency? (RA)
Action: Divergence of particles at given offset amplitudes (e.g. 6-7σ). (SF)

(b) Impedance issues

G. Burtin pointed out that the impedance of the collimator jaws has not yet been calculated. If any transitions are required to reduce the impedance, the overall length of the collimators might increase significantly. At the present time the geometry of the cleaning insertions takes into account only the nominal length of the collimator jaws and at many locations there is no free space available for additional transitions.

Action: Impedance calculation for the collimator jaws. Specification of eventual transitions (JBJ, RA: D. Brandt's team will be contacted)

3) First view of operation with collimators (M. Lamont)

M. Lamont presented a first view of operation with collimators. A copy of his slides is appended. A lively discussion centered on the expected level of injection oscillations. HB pointed out that collimation at the end of the transfer line will cut the beam at 8-9 σ. The TDI only collimates in one plane. Injection oscillations are then possible with amplitudes of 5-6 σ. Those oscillations could destroy the collimators of the cleaning insertions that sit at 6 or 7 σ. The present tolerance on injection oscillation is 1 σ. Questions were asked about the intensity variation from bunch to bunch and the emittance variation in the transfer line. RA pointed out that the start of the ramp is a potentially very dangerous part of the LHC cycle, as the non-linear fields change strongly and several accelerator parameters with them (chromaticity, betatron coupling feed-down, orbit feed-down). At the same time the collimators are still at 6-7 σ. It remains to be shown that the cleaning efficiency remains good enough to prevent quenches at the start of the ramp. There were questions about the performance of the beam instrumentation (BPM's etc) for different phases of LHC running (pilot, injection, ramp, physics).

Action: Bunch-to-bunch intensity and emittance variations in the transfer line and at LHC injection. (HB)
Action: Maximum level of injection oscillations and protection of the cleaning collimators against destruction. (HB, RA)
Action: Expected changes in beam and accelerator parameters during start of ramp. (MH)
Action: Expected performance of beam instrumentation as function of current, number of bunches, … (JW, ML)

4) Required simulations for the BLM system (B. Dehning)

B. Dehning shortly discussed the simulations that are required for the study and design of the BLM system. The list is given below and is also appended:

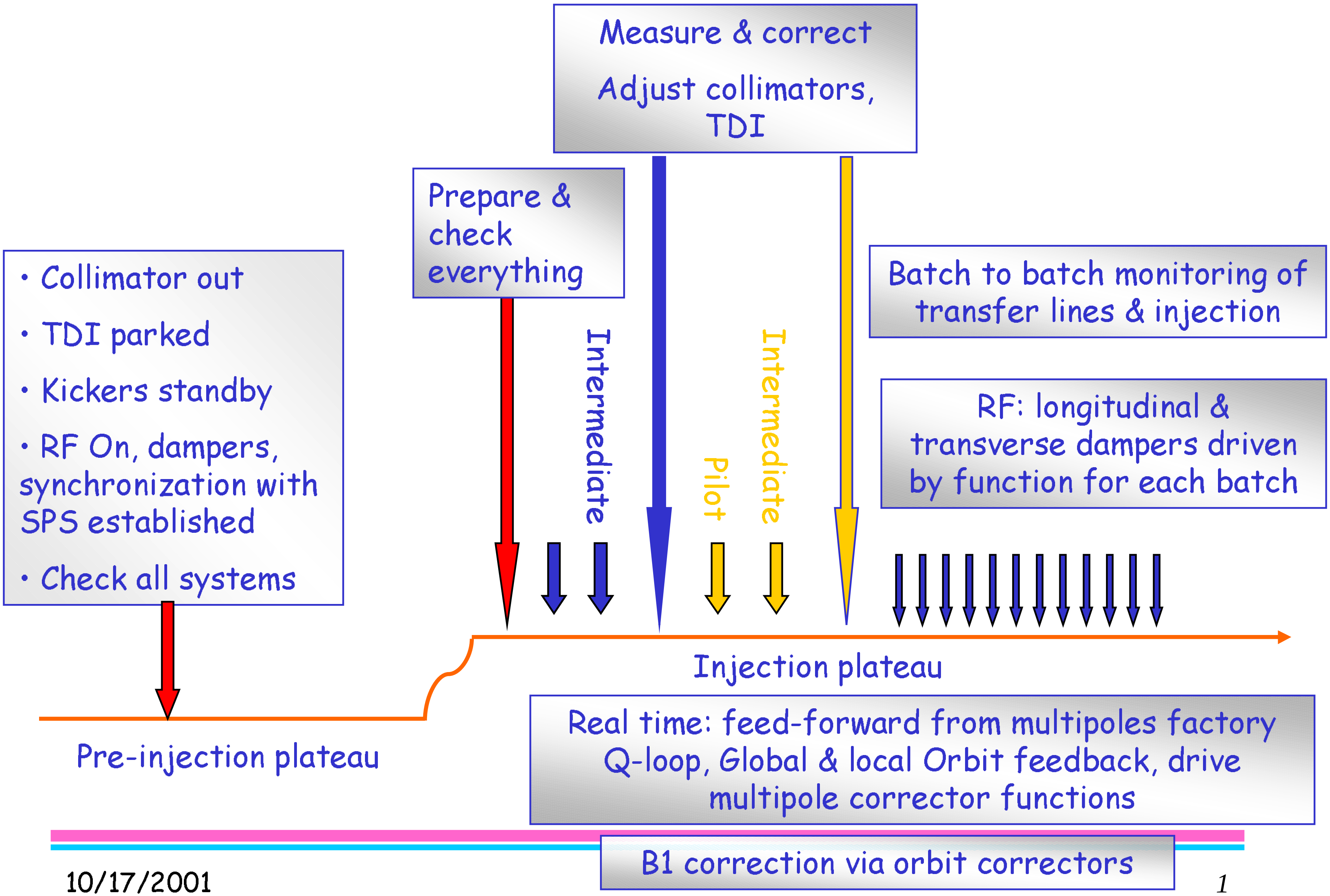
1. How to combine the ionisation chamber signals (and, or, ...)?
   - Between primary and primary chambers
   - Between secondary and secondary chambers
   - Between primary and secondary
   - Between betatron and momentum cleaning
2. What is the number of location where particle losses will occur (in the arc and in the long straight sections)?
3. At which location losses are expected?
4. What is the length of the losses (relevant for design of chambers)?
5. Do we need to combine signals from loss detectors in the arc (correlation of losses)?

The list and the required actions will be discussed in a future meeting.

5) Next meeting

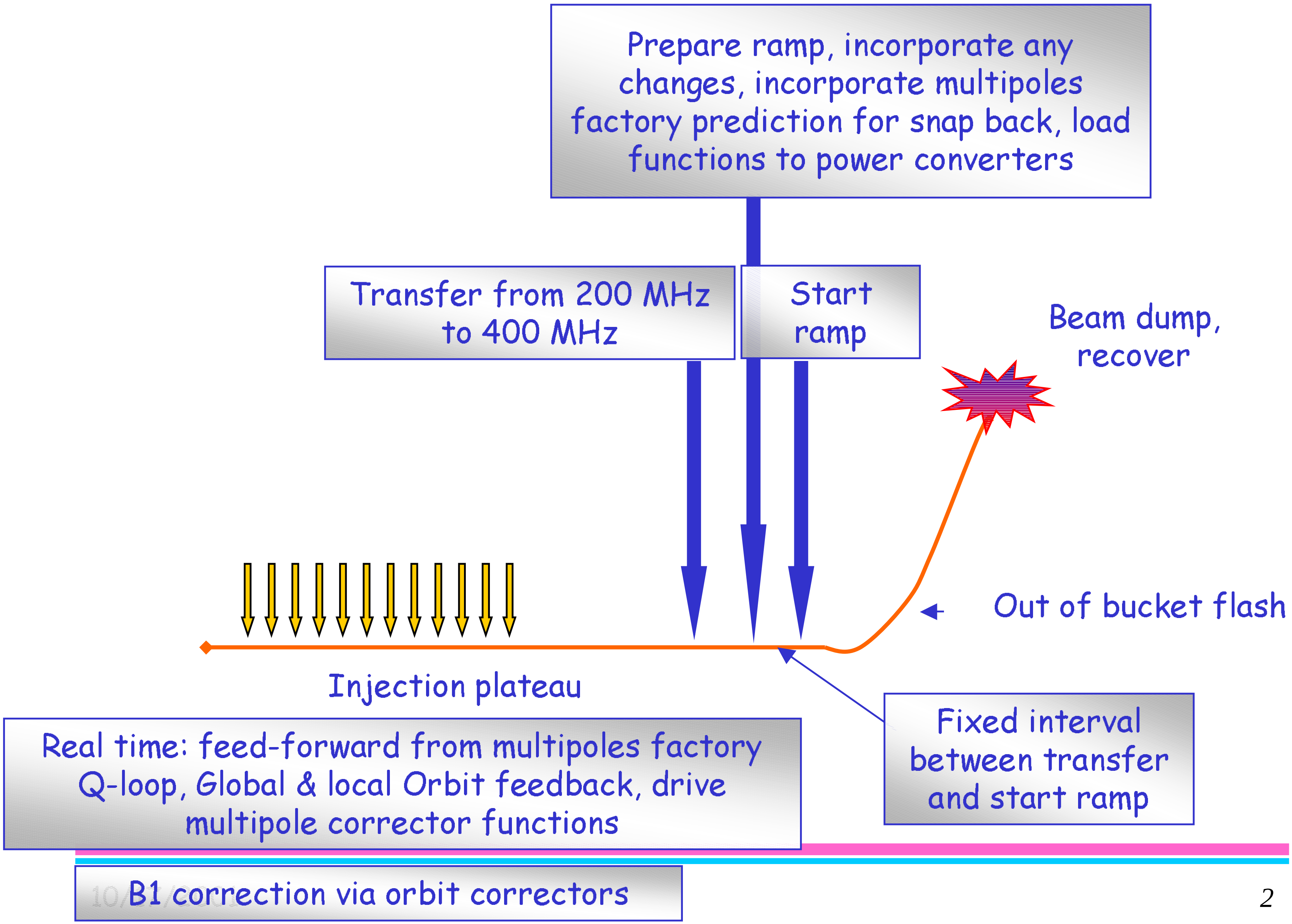
Next meeting will take place 10h30 October 24th, 2001. B. 112, 4C17.

Injection…



Measure & correct
Adjust collimators, TDI
Prepare & check everything
• Collimator out
• TDI parked
• Kickers standby
• RF On, dampers, synchronization with SPS established
• Check all systems
Intermediate
Pilot
Intermediate
Batch to batch monitoring of transfer lines & injection
RF: longitudinal & transverse dampers driven by function for each batch
Injection plateau
Pre-injection plateau
Real time: feed-forward from multipoles factory Q-loop, Global & local Orbit feedback, drive multipole corrector functions
B1 correction via orbit correctors

Injection...



Prepare ramp, incorporate any changes, incorporate multipoles factory prediction for snap back, load functions to power converters
Transfer from 200 MHz to 400 MHz
Start ramp
Beam dump, recover
Out of bucket flash
Injection plateau
Fixed interval between transfer and start ramp
Real time: feed-forward from multipoles factory Q-loop, Global & local Orbit feedback, drive multipole corrector functions
B1 correction via orbit correctors

Beams

	Bunch Spacing	Charges per bunch	bunches per batch
Pilot	25 ns	5×10^9	1
Intermediate	25 ns	3.4×10^{10}	72
Intermediate	75 ns	8.3×10^{10}	24
Commissioning	25 ns	1.8×10^{10}	216/288
Nominal	25 ns	1.1×10^{11}	216/288
Ultimate	25 ns	1.8×10^{11}	216/288
Nominal Lead	125 ns	5.6×10^9	608 per beam
Machine Studies	x	y	N
TOTEM		1.1×10^{11}	36

Pilot

- Here we assume the machine has been cycled and set to injection level. Something is taking care of the effects of persistent current decay. Orbit movements are clearly of importance in what follows and the impact of the plan to compensate the effect on energy of b1 drifts using the horizontal orbit correctors will have to be checked.

- Pilot is essentially "safe without protection". (5 10^9 per bunch is not able to provoke quench). Will need an intensity inhibit via SPS BCT. If mode = pilot and total intensity greater than x don't inject into LHC. Clearly needed to avoid equipment damage.

- The collimators will be "all out". What's out? Greater than 10 sigma or on the switches? This clearly might vary as experience grows.

Pilot II

- Acquire and correct closed orbit. Asynchronously position collimators at around 8 sigma with respect to closed orbit. Rough - first cut.

- What is beam size at collimators?
- How do we take care of the effects of beta beating?

Intermediate intensity

- Having acquired a pilot and positioned collimators and TDI, the pilot is dumped and preparation is made to accept a intermediate intensity beam.
- Although there's some discussion, this mode makes use of the increase resolution of the BPMs with intensity and number of bunches, this allows:
  - exploration of aperture > to be specified
  - adjustment of TDI - check optics > to be specified
  - fine adjustment of collimators > to be specified
- Prerequisites: Collimators in, TDI in and possibly some auxiliary collimators (2 secondary betatron and 2 secondary momentum).
- Note en passant: during commissioning will need bumps and BLMs to home on aperture limits...

Full intensity

- Prerequisites: All collimators in at specified positions. n1 = 6 sigma, n2 = 7 sigma (to be discussed). Positions with respect to average closed orbit.
- Ionisation monitors attached to collimators to monitor beam losses on the collimators.
- Closed orbit clearly. Orbit feedback as required in cleaning sections. What stability is required?
- Beam loss monitors
- TDIs in position
- Some discussion about possible emittance variation coming from transfer line mismatch, up to 100% could be expected. But assume here 50% instability in emittances. (Scraping in SPS... dump in SPS if too large.. variation in mismatch due to temperature variation in transfer line...) Whole issue to be followed up.

Full intensity

- At least some collimators will be able to action a beam dump if losses greater than a variable threshold are sustained. For example that incurred if the emittance are too large. Thresholds to be determined but figure of 1% beam loss mentioned. Thresholds will clearly have to be adjustable.

Ramp

- After injection process has finished, the momentum collimators will move in to finer settings and then stay where they are during the ramp.
- Secondary collimator movement has to shadow primary collimator movement.
- Orbit feedback will be required in cleaning sections (3 & 7) hold to hold collimator positions fixed with respect to closed orbit (average position of bunches). Detailed specification of requirements for feedback systems necessary
- Essentially collimators will stay where they were at the end of the injection process. Some question about emittance increase during snapback and possible tail formation. At 500 GeV or so the collimators could be brought in to chop the tails.

Squeeze

- The collimators have to track the squeeze. The ratio n1/n2 between primary and secondary has to remain fixed (wrt the closed orbit) and again the secondary collimator movement has to shadow primary collimator movement.
- The collimators need to move first and then the TDE to avoid the TDE becoming the aperture limit.
- The collimators need to be positioned to 0.1 sigma or 10 microns (1 sigma ~ 0.4 mm at beta ~ 200 m.) The 10 microns represents the most extreme resolution required. Step sizes of 1 micron will be required. To be discussed!

Control

- Some discussion about how to synchronise the movement of the collimators. Full synchronisation is not possible because the power is shared by up to four motors. Either force synchronicity at high level by asynchronously applying very small steps to each collimator in turn, or possibly command to low level controller (go from here to here in this time). Functional specification required.

- Synchronicity requirements between the 2 beams were also questioned.

Beam Loss Simulations

1. How to combine the ionisation chamber signals (and, or, ...)?
   i. Between primary and primary chambers
   ii. Between secondary and secondary chambers
   iii. Between primary and secondary
   iv. Between betatron and momentum cleaning
2. What is the number of location where particle losses will occur (in the arc and in the long straight sections)?
3. At which location losses are expected?
4. What is the length of the losses (relevant for design of chambers)?
5. Do we need to combine signals from loss detectors in the arc (correlation of losses)?