Review Movement & Motorization

November 4th, 2005

Program

- Introduction & Charge – R. Assmann
- Mechanical design & SPS results – O. Aberle
- Mechanical calculations – A. Bertarelli
- Motorization – R. Losito
- Closing of open session – S. Myers
- Closed discussion

All talks on the collimation web site: http://www.cern.ch/lhc-collimation-project

Thanks to everybody for coming and helping us, especially to Dave Gassner from BNL and the colleagues at SLAC (Tom Porter, Tom Markiewicz, Eric Doyle, Doug McCormick) for getting up so early…

Why this review?

- Collimation is so critical for the success of the LHC that we are always trying to get advise on important decisions.
- 07/2004: **External review of the full collimation project**. At this time still LEP solution for motorization. No review possible on movement and motorization.
- Planned: Another **full review of the collimation project** once first series collimators arrive (next spring).
- Decision to do a **special review on movement and motorization**:
  - Decision required on procurement of stepping motors (decide before next week). High risk: 555 motors, ~1.5 MCHF, reliability risk for the LHC.
  - Take maximum time to understand and solve the problems. Then present status and take a decision!
  - We must take some risk because not everything can be tested in the available time.

Why are motors critical?

- Some general collimation challenges for the LHC:
  - Small beam size at the collimators: ~200 μm
  - Small collimator gaps: down to 2 mm in standard operation and down to 1 mm in special low emittance conditions
  - High damage potential of the beams.
  - Large fraction (~50%) of 106 collimators must respect set-up tolerances around 20-40 μm at 7 TeV. Lengthy set-up!
  - Excellent reproducibility of jaw settings required for reestablishing reference settings without new set-up!
  - Hostile conditions of the LHC cleaning insertions (~MGy/y dose rates, heating from beam losses or bake-out, elevated levels of Ozone, …).
  - 106 installed phase 1 collimators will be driven with **466 stepping motors**. Worry about precision, reproducibility and reliability.
- Much effort has been put on the design of a **precise and fail-safe mechanical movement system**.
  - The system has been made fail-safe by including the feature of auto-retraction: the jaws are opened by mechanical springs in case of motor failures.
  - Auto-retraction of jaws will in most cases allow LHC operation to continue and to repair the problem during a planned intervention period. This is possible with the built-in redundancy in the collimation system (2 opposite jaws).

Decisions on movement & motorization have direct consequences for…

- **Operational efficiency** of the LHC:
  - Possibly we must exchange a whole collimator if a motor fails (takes 1-2 weeks including bake-out).
  - High number of motors requires high reliability.
  - Problems in reproducibility will require retuning of collimator during each fill (loose time while not achieving best possible performance).
- **Architecture of the control system:**
  - For reasons of simplicity we avoid feedback on motor commands during the movement based on read positions.
  - Position read-out is just a check for rare problems which would always lead to a beam dump.
- **Schedule:**
  - More studies and tests would lead to delays (install motors a posteriori, limited hardware commissioning, …).

➔ Panel members selected to advise also on these risks!

Scope

Table 1 Summary of the different stepping motors required for the LHC both in the rings and the transfer lines. Motors on the support are used to remotely adjust the spare surface.

Type	Number collimators		Motors (jaws)		Motors (support)	
	installed	spares	installed	spares	installed	spares
TCP/TCS	42	7	168	28	42	7
TCLP	8	2	32	8	0	0
TCT	12	1	48	4	0	0
TCLA	18	2	72	8	0	0
TCDI	14	2	56	8	0	0
2-beam	6	2	24	8	6	2
TCHS	6	3	12	6	6	0
Total	106	19	412	70	54	9

Specifications

Table 2 Summary of requirements for stepping motors and mechanical movement. The tolerances must be achieved for any concerned collimator under any foreseen orientation.

Parameter	Requirement
Minimal possible step size	< 10 μm
Accuracy of movement	1 step
Reproducibility	the motor may not loose steps regularly: sensors are used as cross-check after movement and not as feedback information
Nominal speed	1 mm/s
Range in speed	0.5 – 4 mm/s
Synchronicity of motors	20 μm (or 20 ms for 1 mm/s)
Overall mechanical play	< 20 μm
Auto-retraction	jaw retracts if motor power is cut or if a motor fails

Project proposal

The members of the collimation project have agreed on a common proposal, based on our present knowledge:

1. Go ahead with the **procurement of the 555 motors, as specified**.
2. Do **not increase detent torque beyond the specified 80 N mm** but compromise on the maximum torque at the 20% level, if required.
3. Accept the **risk that auto-retraction does not fully work in a few collimators** but we expect it works in most.
4. Take care of **proper matching of mechanical system and motor during series production**.

This agreement is the result of hard and excellent work of all involved, making the system work in the lab over the last 4 weeks:

O. Aberle, R. Losito, R. Chamizo, A. Masi, P. Gander, A. Bertarelli, R. Perret, …

Thanks to them and collaborators for their impressive efforts!

Charge to the reviewers

The movement and the motorization for the LHC collimators shall be reviewed:

- Review the specifications and the achieved results of collimator motion for the various types of collimators and the various collimator orientations.
- Assess the overall status of the collimator mechanical actuation system and possible risks.
- Based on the above assessment, advice on the procurement of the LHC stepping motors.

The decision on motor procurement (~1.5 MCHF) is time critical as we are planning to go to the December CERN Finance Committee for approval of the contract. Alternatively we can opt for the Finance Committee in March, inducing a delay in motor installation on many collimators (many collimators will be installed into the tunnel without motors). Any further delay would not be possible.