Possible Collimation Priorities
June 13th, 2005

• Collimation Project made significant progress for phase 1:
  – Successful tests of phase 1 collimator prototypes (Nov04)
  – Design and execution drawings for major collimators completed (Apr05)
  – Contract for series production for all 125 required collimators (May05)
  – Commitment on total budget and approval by management (May 05)

• Last major open point: Production & installation schedule

• This CWG: Should we define priorities and if so, what are these?

• Today’s meeting:
  – Don’t expect final decisions and installation plan (too early).
  – Expect detailed input on all relevant aspects for establishing a plan for collimator production and installation.
## What needs to be installed?

<table>
<thead>
<tr>
<th>Phase</th>
<th>Acronym</th>
<th>Material</th>
<th>Length [m]</th>
<th>Number</th>
<th>Locations</th>
<th>INJ</th>
<th>TOP</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>1</td>
<td><strong>Scrapers</strong></td>
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<td></td>
<td>TCHS</td>
<td>tbd</td>
<td>tbd</td>
<td>6</td>
<td>IR3, IR7</td>
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<td>tbd</td>
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<td><strong>Collimators</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TCP</td>
<td>C-C</td>
<td>0.2</td>
<td>8</td>
<td>IR3, IR7</td>
<td>Y</td>
<td>Y</td>
<td>Primary collimators</td>
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<tr>
<td>1</td>
<td>TCSG</td>
<td>C-C</td>
<td>1.0</td>
<td>30</td>
<td>IR3, IR7</td>
<td>Y</td>
<td>Y</td>
<td>Secondary collimators</td>
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<tr>
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<td>TCSG</td>
<td>C-C</td>
<td>1.0</td>
<td>2</td>
<td>IR6</td>
<td>Y</td>
<td>Y</td>
<td>Help for TCDQ set-up</td>
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<td>2</td>
<td>TCSM</td>
<td>tbd</td>
<td>tbd</td>
<td>30</td>
<td>IR3, IR7</td>
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<td></td>
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<td>4</td>
<td>TCS4</td>
<td>tbd</td>
<td>tbd</td>
<td>10</td>
<td>IR7</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>TDI</td>
<td>Sandwich</td>
<td>4.2</td>
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<td>IR2, IR8</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>TCLI</td>
<td>C</td>
<td>1.0</td>
<td>4</td>
<td>IR2, IR8</td>
<td>Y</td>
<td></td>
<td>Injection protection</td>
</tr>
<tr>
<td>1</td>
<td>TCDI</td>
<td>C</td>
<td>1.2</td>
<td>14</td>
<td>TI2, TI8</td>
<td>Y</td>
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<td>Injection collimation</td>
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<tr>
<td>1</td>
<td>TCDQ</td>
<td>C-C</td>
<td>6.0</td>
<td>2</td>
<td>IR6</td>
<td>Y</td>
<td>Y</td>
<td>Dump protection</td>
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<td><strong>Movable Absorbers</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TCT</td>
<td>Cu/W</td>
<td>1.0</td>
<td>16</td>
<td>IR1, IR2, IR5, IR8</td>
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<td></td>
<td>Tertiary collimators</td>
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<tr>
<td>1</td>
<td>TCLA</td>
<td>Cu/W</td>
<td>1.0</td>
<td>18</td>
<td>IR3, IR7</td>
<td>Y</td>
<td>Y</td>
<td>Showers from collimators</td>
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<tr>
<td>1</td>
<td>TCL/TCLP</td>
<td>Cu</td>
<td>1.0</td>
<td>4</td>
<td>IR1, IR5</td>
<td>Y</td>
<td></td>
<td>Secondaries from IP</td>
</tr>
<tr>
<td>3</td>
<td>TCL/TCLP</td>
<td>Cu</td>
<td>1.0</td>
<td>4</td>
<td>IR1, IR5</td>
<td>Y</td>
<td></td>
<td>Secondaries from IP</td>
</tr>
</tbody>
</table>
Series Production Overview

- Now included 6 different types for a total of 125 collimators:

<table>
<thead>
<tr>
<th>Design type</th>
<th># total</th>
<th># spares in total</th>
<th>Drawings</th>
<th>Mech. Table</th>
<th>Tank</th>
<th>RF contacts</th>
<th>Flanges</th>
<th>Jaw assembly</th>
<th>Jaws type</th>
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<tr>
<td>TCP/TCS (reference)</td>
<td>49</td>
<td>7</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>CC clamped</td>
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<tr>
<td>TCT</td>
<td>33</td>
<td>3</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>Cu/W screwed</td>
</tr>
<tr>
<td>TCLP</td>
<td>10</td>
<td>2</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>Cu screwed</td>
</tr>
<tr>
<td>TCDI</td>
<td>16</td>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>C not cooled</td>
</tr>
<tr>
<td>TCHS</td>
<td>9</td>
<td>3</td>
<td>no</td>
<td>similar?</td>
<td>similar?</td>
<td>similar?</td>
<td>no</td>
<td>yes</td>
<td>tbd</td>
</tr>
<tr>
<td>TCT/TCLI (2beam)</td>
<td>8</td>
<td>2</td>
<td>no</td>
<td>similar?</td>
<td>different!</td>
<td>different!</td>
<td>yes</td>
<td>yes</td>
<td>Cu/W and CC</td>
</tr>
</tbody>
</table>

- Baseline is start of production with TCP/TCS reference design (most difficult and most important) ➔ If we can build them all others are “easy”.
- All 3 CERN prototypes are of type TCS!
- TDI, TCDQ, TCDS, … are not affected by this production.
Original and New Approach

• Original production approach:
  – **Two different production sites for parallel production** of LHC collimators.
  – **European industry**: All TCP and TCS. Possibly other most important.
  – **Novosibirsk**: All other types (transfer line, tertiary, …).
  – Split production risk and avoid bottle-necks.

• New approach:
  – **Only one producer: European industry with twice peak production rate**.
  – Peak production rate is 10 collimators/month!
  – Two production lines but **common bottle-necks** exist!
  – Increased production risk!
  – New possibility and **requirement to define priorities**!

• General worries about possible problems similar to QRL!
Collimators Requirements

• LHC collimators are very different from magnets or QRL where all elements are required before start-up of the LHC!

• **LHC can be commissioned without any collimators or with missing collimators if intensity is restricted:**
  
  – 1 pilot bunch: No collimators.
  
  – ~46 nominal bunches @ 7 TeV: 60% of phase 1 collimators.  
    (~ 3 times Tevatron)
  
  – ~1000 nominal bunches @ 7 TeV: All phase 1 collimators.  
    (~ 65 times Tevatron)
  
  – 2808 nominal bunches @ 7 TeV: Phase 1 + phase 2 + phase 3.  
    (~200 times Tevatron)

• Even with delays we can support increasing LHC intensities with partial installations: Big difference to QRL and magnets!

• Ignoring installation schedule implies cost and additional work!
How to Produce?

• Two priorities are possible:
  1. Produce and install in order to optimize LHC performance reach at any time.
     – Advantages: LHC ready for first year operation after 60% of production and installation, most of production with 2 types, more time for equipping and testing collimators, …
     – Disadvantages: Increased installation effort, potential need for temporary installations, need for multiple interventions, …
  2. Produce and install according to the LHC installation schedule.
     – Advantages: Minimize installation effort, avoid temporary installations, avoid multiple interventions, …
     – Disadvantages: LHC ready for first year operation only after installation of last batch, production of up to 3-4 collimator types in parallel, reduced time for equipping and testing collimators, …

• Decision on approach will be taken at CERN: What is the preferred approach for us?
What needs to be installed?

- Vacuum pump
- Quick-connect flanges
- Collimator tank
- Beam 2
- Interconnect support
- Collimator support
- Survey reference points
- Motorization/sensors

R. Perret et al
Original “Collimator Installation Policy”

- Collimators are late and should **not be taken as a driving constraint for installation schedule**.
- There is **no interference of collimators with installation of “cold” machine parts**, which is highest priority and on the critical path.
- For **minimal impact** the following scenario was agreed (S. Weisz):
  - Installation of all infrastructure (cables, water connections, …) during the standard infrastructure installation campaigns. Still true to my knowledge: all input defined.
  - Installation of all collimator supports (including phase 2) during standard machine installation campaigns, including connection of quick plug-ins and alignment of supports.
  - Installation of phase 1 collimators (as soon as available) in quick plug-in fashion (for radiation optimization): __ hour per collimator!?  
  - In case required: **Installation of simple vacuum pipes (2 kCHF/piece) for missing collimators** to not hold up general progress.

- Now it is time to define details…
A general installation schedule has been established for the LHC.

A collimator installation plan has been drafted in order to fit into the general installation plan.

Production can barely fit the present installation plan for standard phase 1 collimator, assuming:

- No delays in production schedule.
- Just in time production of collimators of the 4 different types, according to installation plan.
- Reduction of time for equipping and testing collimators at CERN from 2 months to 0-1 month.

Possible installation-oriented production schedule is extremely critical:

- Delays will result in incompatibility with installation schedule.
- Delays can postpone the first LHC physics run!
- High risk and visibility, so we need accurate information and commitments!
Draft of Collimator Installation

• Based on presentation by K. Foraz on June 1st, 2005.
  Remarks:
  – Added transfer line collimators to the presented installation schedule.
  – Produced only in 2007: 6 TCHS and 6 TCT/TCLI (2-beam) designs (requires temporary installations in IR2, IR3, IR7, IR8).
  – Does not include the passive absorbers in IR3 and IR7 (2 per IR).
  – Does not include devices which are not produced by the collimation project: 8 TCDD, 2 TCLIM, 2 TDI.

• Production just in time for the sector to be installed next.

• Betatron cleaning completed after LSS7R installation in Nov 06:
  – Missing primary collimators, absorbers, secondary collimators before this date.
  – Not a functioning system for either beam before this date.

• Momentum cleaning completed after LSS3L installation in Jan 07:
  – Missing primary collimators, absorbers, secondary collimators before this date.
  – Not a functioning system for either beam before this date.

• Last collimators to be produced are among the most important of the LHC.

### Table: Installation Dates

<table>
<thead>
<tr>
<th>Section</th>
<th>Installation date</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSS8R</td>
<td>April-06</td>
</tr>
<tr>
<td>LSS1L</td>
<td>April-06</td>
</tr>
<tr>
<td>LSS5L</td>
<td>May-06</td>
</tr>
<tr>
<td>LSS8L</td>
<td>May-06</td>
</tr>
<tr>
<td>TI8</td>
<td>May-06</td>
</tr>
<tr>
<td>LSS3R</td>
<td>June-06</td>
</tr>
<tr>
<td>LSS6L</td>
<td>June-06</td>
</tr>
<tr>
<td>LSS6R</td>
<td>June-06</td>
</tr>
<tr>
<td>LSS5R</td>
<td>July-06</td>
</tr>
<tr>
<td>LSS7L</td>
<td>August-06</td>
</tr>
<tr>
<td>TI2</td>
<td>October-06</td>
</tr>
<tr>
<td>LSS1R</td>
<td>November-06</td>
</tr>
<tr>
<td>LSS7R</td>
<td>November-06</td>
</tr>
<tr>
<td>LSS2L</td>
<td>December-06</td>
</tr>
<tr>
<td>LSS2R</td>
<td>December-06</td>
</tr>
<tr>
<td>LSS3L</td>
<td>January-07</td>
</tr>
</tbody>
</table>
Just-In-Time Collimator Production with Contract

Installation and Production of Regular Phase 1 Collimators

Date

Number of collimators

- Installation
- Production
- Installation ready (+2 months)
- Installation ready (+1 month)

Only 1 month at CERN for testing and equipping!
Remarks on Company Schedule

• Previous slide presented the contractual production schedule.

• Company schedule proposes **6 weeks delay** for samples and **1 month delay** for all series production.

• Company schedule relies on some **optimistic assumptions**:
  – Approval of several 10 new **sub-contractors** in the next weeks (possible if no bad surprise?).
  – Approval to **start series production before qualification samples** have been received and tested by CERN.
  – All **material for first 10 collimators** to company in the next two weeks (1 month earlier than agreed).
  – Some **crucial production processes** (calibration & referencing) have not yet been defined in detail by the company (additional time required).
Installation and Production of Regular Phase 1 Collimators with Proposal from Company

No time at CERN for testing and equipping!
Version 1: Installation Optimized

Installation Optimized with Material Constraints

- Ready for LHC year 1
- All "regular" collimators
- All phase 1 collimators for machine installation

Delivery date:
- November 2005
- January 2006
- March 2006
- May 2006
- July 2006
- September 2006
- November 2006
- January 2007
- March 2007
- May 2007
- July 2007
- September 2007
- November 2007
- January 2008
- March 2008

Number of Collimators:
- Delivery date
- Operational spares

Metrics:
- TCHS
- TCT/TCLI(2beam)
- TCDI
- TCLP
- TCT
- TCP/TCS
### Important Dates for Version 1

<table>
<thead>
<tr>
<th>Date all delivered</th>
<th>Date all ready for installation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/10/06</td>
<td>31/12/06</td>
<td>Ready for LHC year 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Up to 3% of intensity (43 bunches OK)</em></td>
</tr>
<tr>
<td>31/10/06</td>
<td>31/12/06</td>
<td>All “regular” collimators</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Up to 40% of intensity but restricted $\beta^</em>$ in IR2/8*</td>
</tr>
<tr>
<td>31/03/07</td>
<td>31/05/07</td>
<td>All “phase 1” collimators</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Up to 40% of intensity with free $\beta^</em>$ in IR2/IR8 and no restriction for injected batches*</td>
</tr>
<tr>
<td>30/04/07</td>
<td>30/06/07</td>
<td>Phase 3 ready for nominal luminosity</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Up to 40% of intensity but allowing for nominal luminosity. Delayed installation.</em></td>
</tr>
<tr>
<td>30/04/08</td>
<td>30/06/08</td>
<td>All “phase 1+3” spares available</td>
</tr>
</tbody>
</table>
Version 2: Minimal “Ready for Year 1” System

- Detailed performance estimates need to be done. Numbers based on past experience and qualitative considerations.

- A system to be ready for LHC first year operation would consist of the 60 most important collimators (out of 125 total collimators)
  - 8 TCP collimators (all installed of phase 1).
  - 24 TCS collimators (2/3 of installed).
  - 22 TCT collimators (3/4 of installed).
  - 4 TCLP collimators (all installed of phase 1).
  - 2 TCDI collimators (1/7 of installed).

These collimators would allow to run the LHC in 2007 (first year) for 43 on 43 nominal bunches and without an expected limitation from the collimation system!

- Do such considerations make sense? What is the really required minimal system? Should we study and define a sub-system? Do we need all collimators in 2007? What are other critical collimators? …
Version 2: Performance Optimized

Performance Optimization + Material Constraints + 2 Early TCDI

- Ready for LHC year 1
- All "regular" collimators
- All phase 1 collimators for machine installation

Number of Collimators

Delivery date

- TCHS
- TCT/TCLI(2beam)
- TCDI
- TCLP
- TCT
- TCP/TCS

Operational spares

Phase 3

Ready for LHC year 1
All "regular" collimators
All phase 1 collimators for machine installation
## Important Dates for Version 2

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<thead>
<tr>
<th>Date all delivered</th>
<th>Date all ready for installation</th>
<th>Status</th>
</tr>
</thead>
</table>
| 31/07/06           | 30/09/06                        | Ready for LHC year 1  
  Up to 3% of intensity (43 bunches OK) |
| 31/10/06           | 31/12/06                        | All “regular” collimators  
  Up to 40% of intensity but restricted $\beta^*$ in IR2/8 |
| 31/03/07           | 31/05/07                        | All “phase 1” collimators  
  Up to 40% of intensity with free $\beta^*$ in IR2/IR8 and no restriction for injected batches |
| 30/04/07           | 30/06/07                        | Phase 3 ready for nominal luminosity  
  Up to 40% of intensity but allowing for nominal luminosity. Delayed installation. |
| 30/04/08           | 30/06/08                        | All “phase 1+3” spares available |

(These are are based on the contract, company schedule: + 1 month)
Version 3: TCDI First + Performance Optimized Later

TCDI first + Performance Optimized

- Ready for LHC year 1
- All "regular" collimators
- All phase 1 collimators for machine installation

Number of Collimators

Delivery date

- Nov-05
- Jan-06
- Mar-06
- May-06
- Jul-06
- Sep-06
- Nov-06
- Jan-07
- Mar-07
- May-07
- Jul-07
- Sep-07
- Nov-07
- Jan-08
- Mar-08

Operational spares

- TCHS
- TCT/TCLI(2beam)
- TCDI
- TCLP
- TCT
- TCP/TCS

All "regular" collimators for machine installation

Ready for LHC year 1

All phase 1 collimators for machine installation

Operational spares

Phase 3
Version 4: Some Mixture

Mix Performance Optimization + Early TCDI + Material Constraints

- Ready for LHC year 1
- All "regular" collimators
- All phase 1 collimators for machine installation

Number of Collimators

Delivery date

- TCHS
- TCT/TCLI(2beam)
- TCDI
- TCLP
- TCT
- TCP/TCS

Phase 3
Operational spares

RWA, 13/6/2005
General Remarks on Production

- We need to foresee production of **up to 3-4 collimator types in parallel**.
- We cannot finish one type before doing the next type (**spares at the end**).
- Installation-ready for **minimal “first year system” for the LHC** with contractual dates, ignoring for the moment delayed schedule from producer:

Note: Dates assume contractual peak production of 10 collimators/month in Summer 2006!
Successful sample production assumed for 31.07.05 (has not started yet)!
Steps towards a Decision

- June 1st: Input from the installation side.
- June 6th: Visit to company.
- June 10th: Visit of company at CERN.
- June 13th: CWG on possible priorities.
- June 15th: New proposal for production schedule from company.
- June 21st: Decision on first 10 collimators to avoid further delays.
- June 29th: LTC???
- July 4th: ABMB
- July 6th: Announcement of collimator production & installation plans.

→ Comments on process are welcome!
Questions for Brainstorming

• **Significant risks from collimator production exist!**
  – We rely on a single company without any margin in the production schedule!
  – We are already discussing bypassing of some quality assurance steps and delays before the production has started!
  – We can imagine strong future pressure to skip time-consuming quality checks and calibration procedures!
  – Strong risk to end up with sub-optimal collimators in the LHC (need 3 times better than Tevatron already for 43 on 43 nominal bunches!)

• **How to best address this risk?**
  – Define sub-system for first year? Minimize risk for performance?
  – Delay less important collimators? Acceptable? What are these?
  – Accept installation delays (plug-in of later collimators): cost of temporary pipes (2kCHF/pipe), second installations, break of vacuum for installing delayed collimators, ...
  – Insist on all collimators for 2007 and, if required, put additional money (if budget available)?
  – …

• Your input will have an impact on what collimators will be there in 2007! Feedback required from members of CWG, LHCOP, MPWG, …