Status of LHC collimators and implications on machine installation

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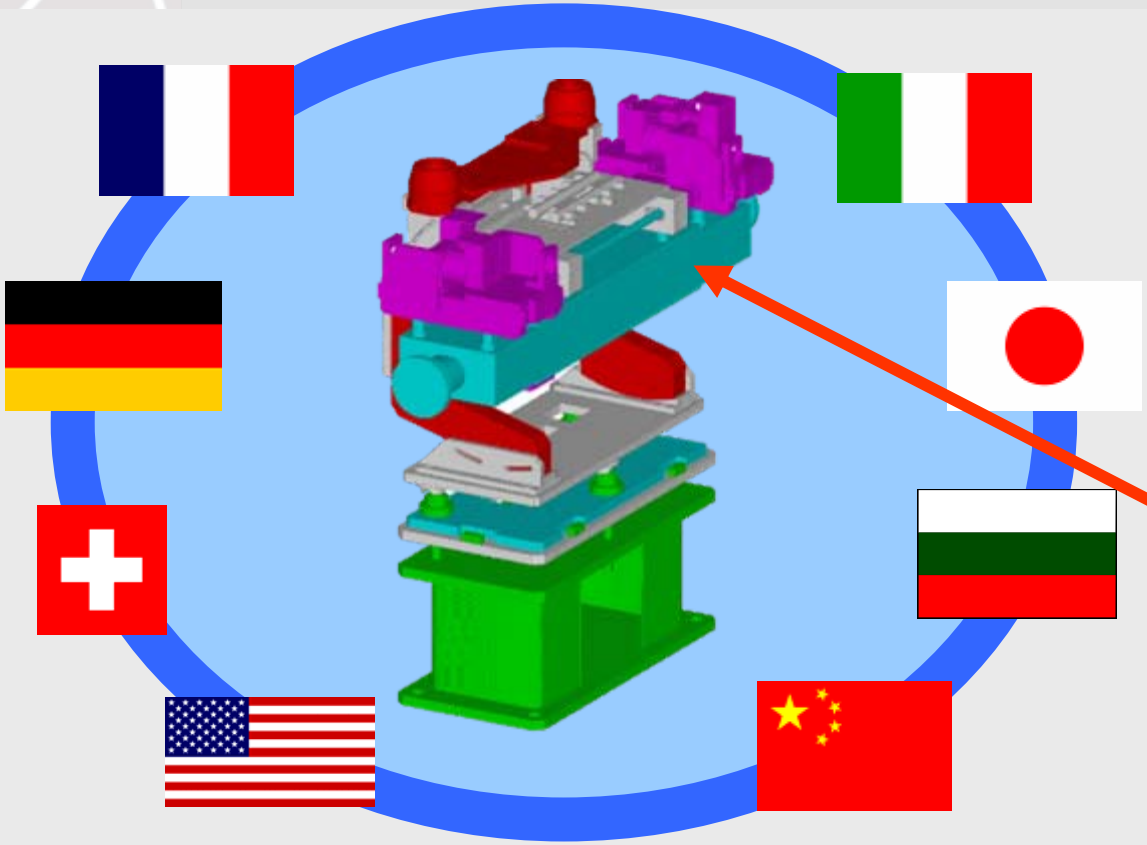
Collimator Production

- Collimation system is being implemented in a phased approach.
- Planning June 2006:

Collimation Phase	Number of collimators	Performance reach (ideal)	Database phase	Installation
1	82	10^{33} cm^{-2} s^{-1}	**1**	LSS planning
1	30	0.4 × I_{nom}	**2**	First shutdown
2	32	R&D	**2**	~2010

- Late production start due to re-design of LHC collimation starting in 2003!
- Production of all 125 phase 1 collimators (ring, TL, spares) signed with CERCA/AREVA in June 2005.
- CERCA/AREVA known from successful production of LEP2 cavities.

Overall Hardware Procurement...



Major contracts:

Collimators (FR)

Motors and sensors (D)

Position sensors (FR/China)

CFC (J)

Supports (Bulgaria)

Vacuum pumping ports (Italy)

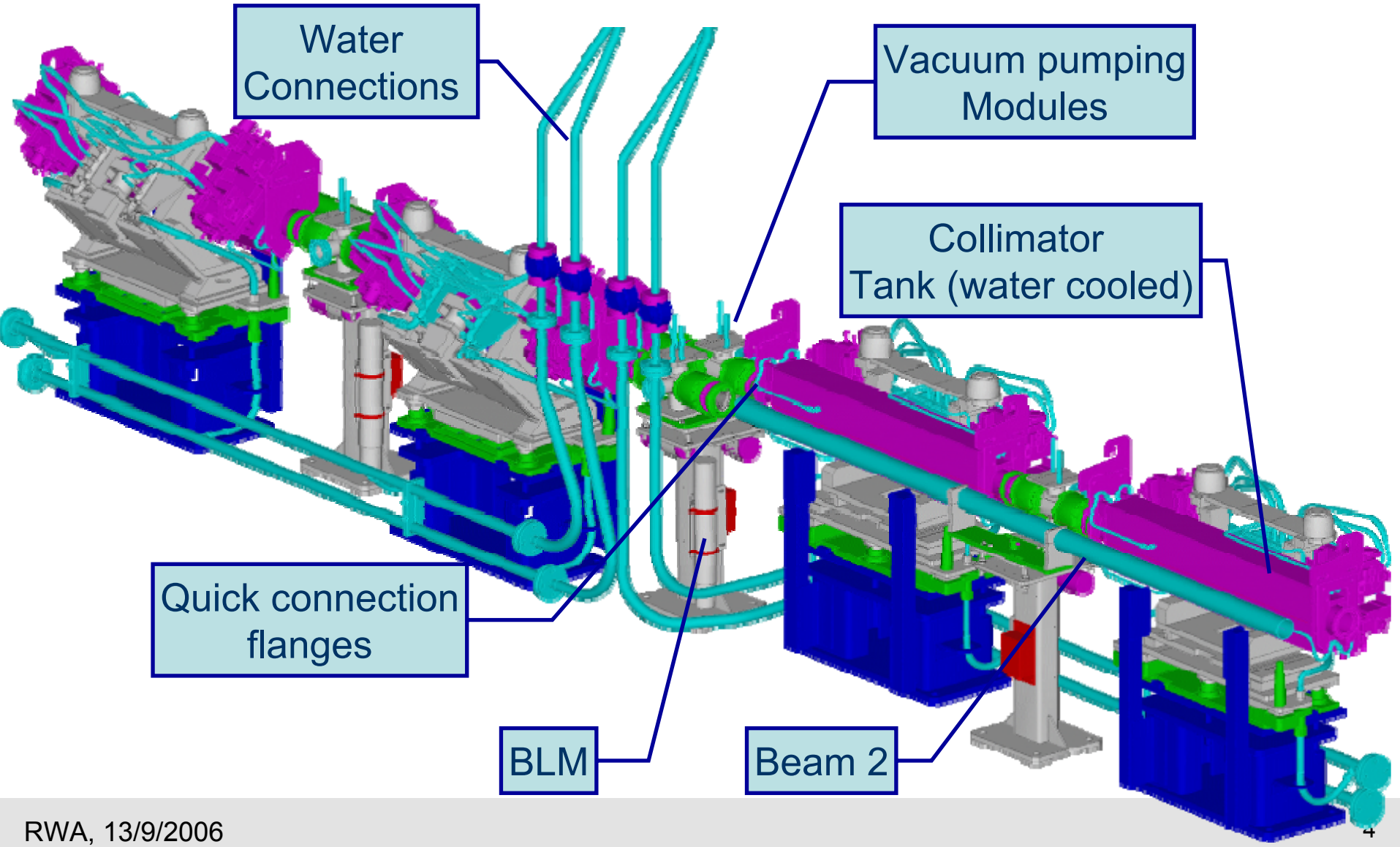
Material/screws (Switzerland)

Glidcop material (US)

➔ Only part of overall installation is affected by recent problems in production of collimator! Other things on track or not critical for schedule (motors).

Collimator General Layout

(vertical and skew shown)



Collimators in CERCA Production

Acronym	Description	Installed	Spares
TCP	Primary collimators	8	3
TCS	Secondary collimators	34	4
TCT, TCLA	Tertiary collimators, absorbers	30	3
TCLP	Absorbers for p-p induced showers	8	2
TCHS	Scraper	6	3
TCLIA	Injection protection	2	1
TCTVB	Tertiary collimator	4	1
TCDI	Transfer line collimators	14	2

➔ Operational spares are included into the production…

First LHC collimators produced and installed…

10 minutes installation: checking on quick-plugs…

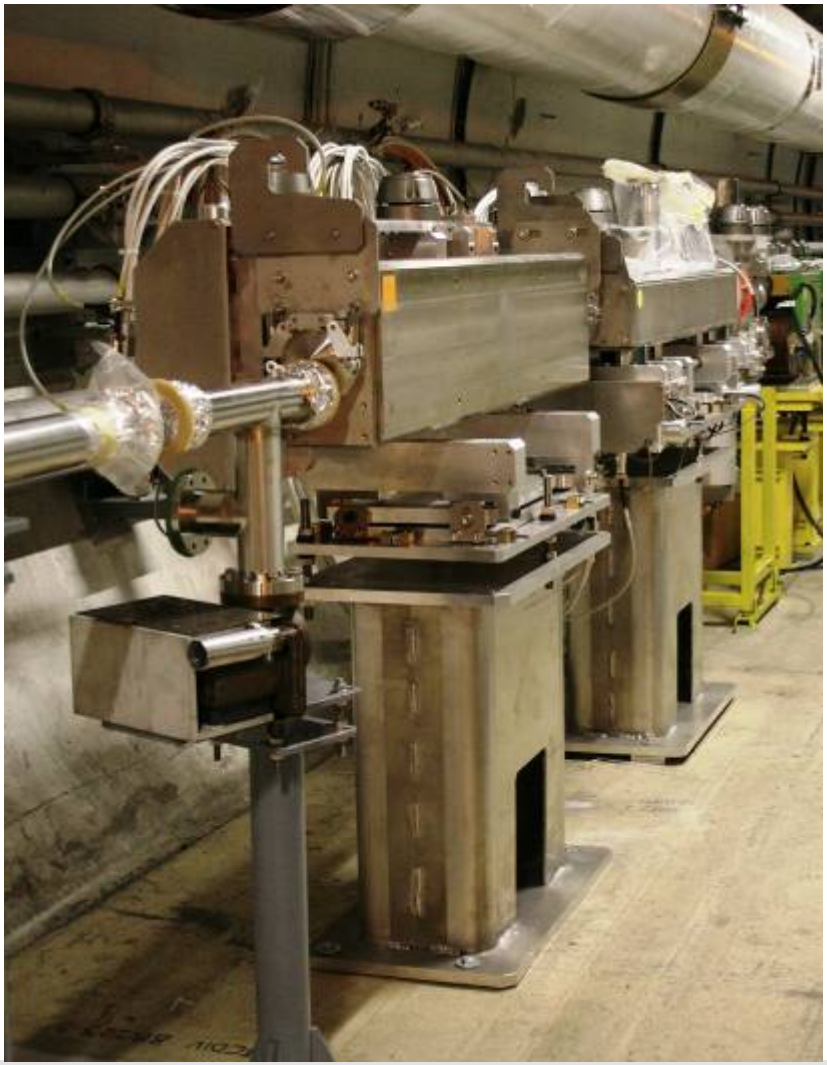
First ring collimator in 8L. (triplet protection for beam 1)

- June 14th -

First LHC collimators produced and installed…

Injection protection: Transfer line collimators in the ring, just before injection 8R.

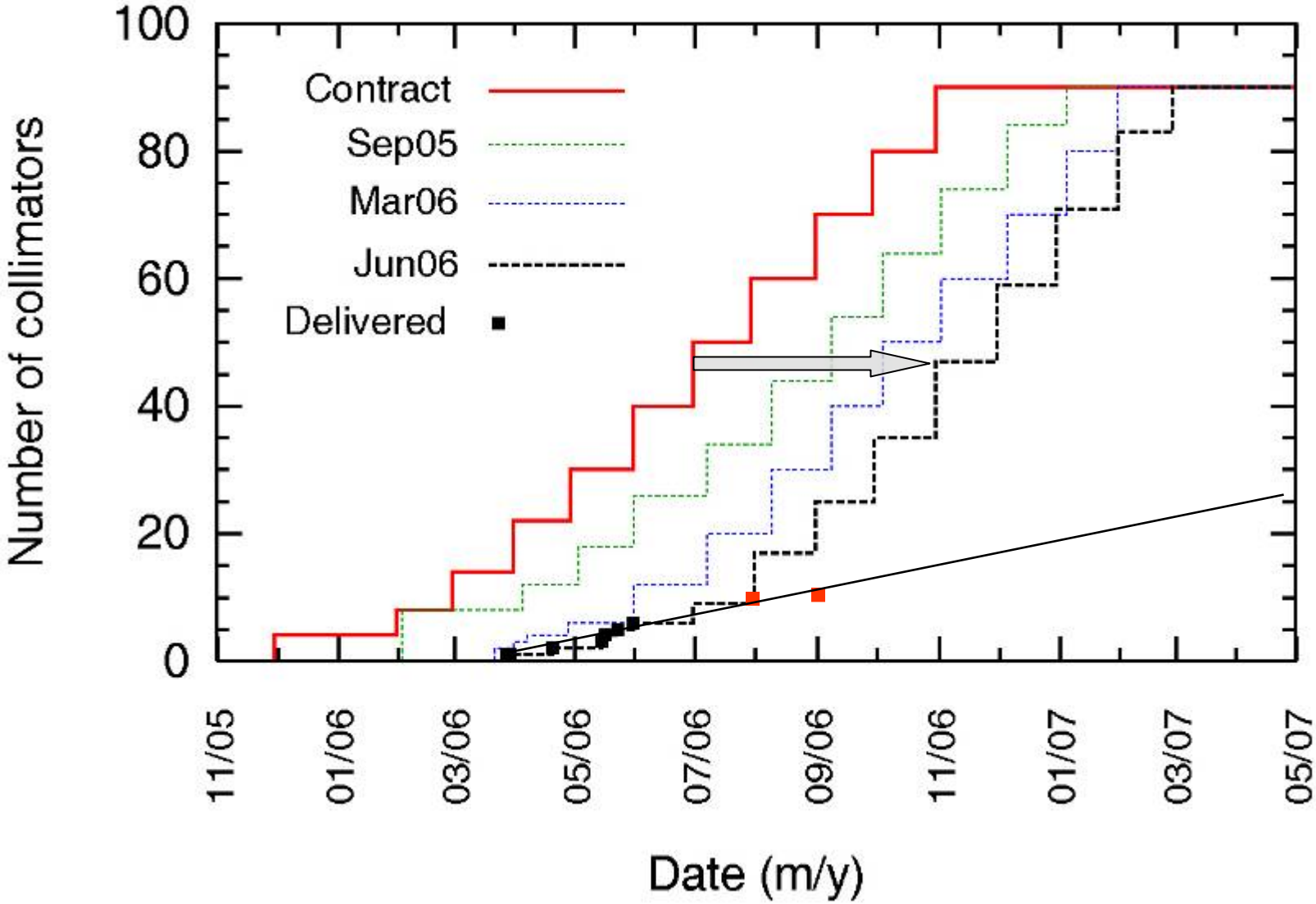
- May 31st -



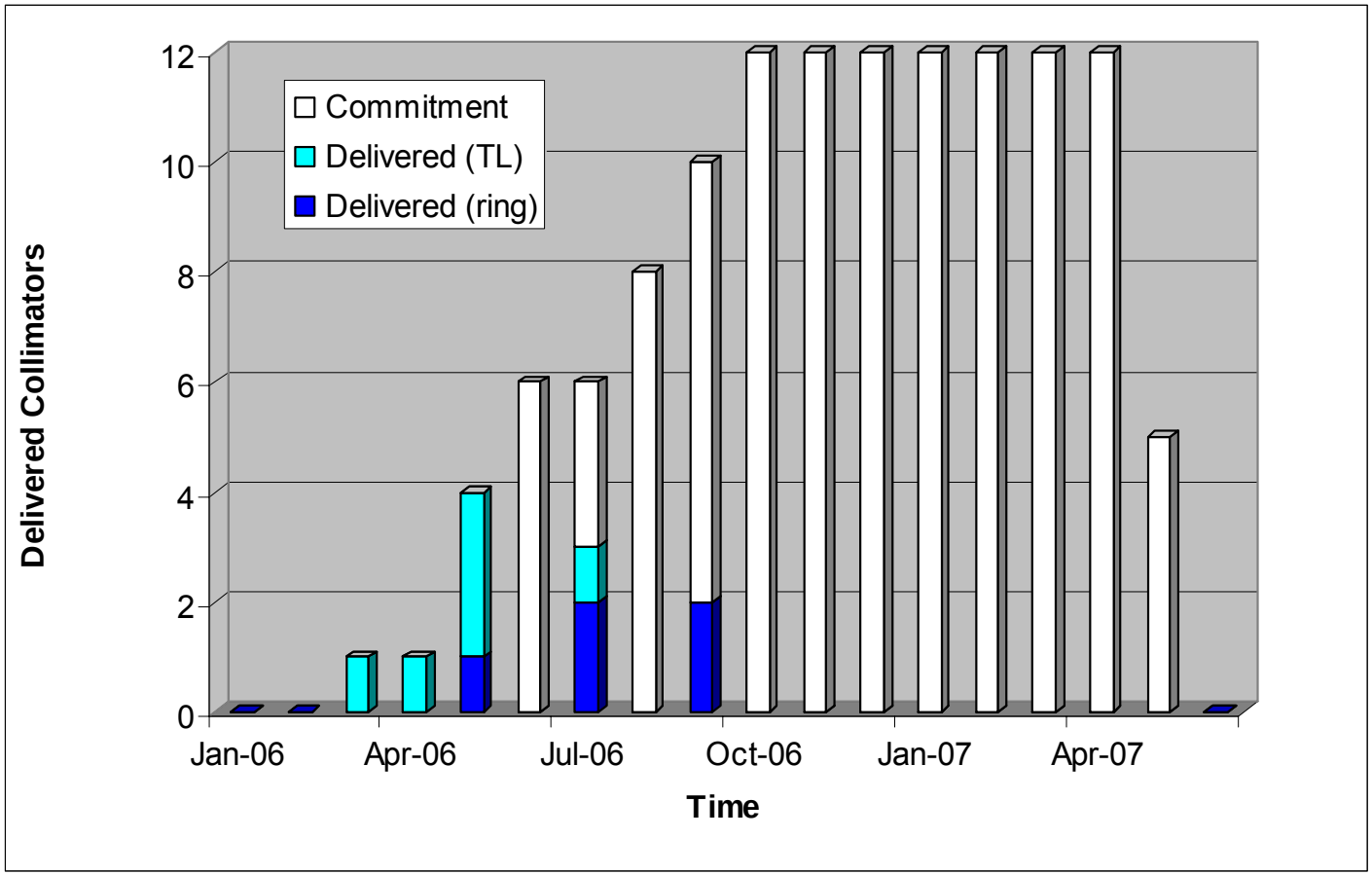
Fundamental Problem?

- There is no fundamental problem:
  - No major problems in design and drawings.
  - CERCA has built several fully conform collimators.
  - Major acceptance criteria are checked and fulfilled:
    - Jaw flatness: 40 μm tolerance fulfilled over 1.2 m long jaws. Each checked.
    - Heat conductivity: Brazing qualified for heat conductivity (Jan 2006).
    - Vacuum spectra: OK. Each checked.
    - Mechanical precision. 20 μm mechanical play. Micron alignment. Each checked.
- Problem are the delays:
  - Problem evident in March 2006 ➔ Top management meeting.
  - May 17th: CERCA DG at CERN. Commits on new schedule. Additional resources. A few technical issues resolved in weeks after meeting.
  - Agreement with CERCA: No fundamental technical issues!

Production Schedule Delays



Commitment and Reality



The schedule presented by H. Sztark (CERCA DG) at CERN on May 17th is completely obsolete!

Problems at CERCA

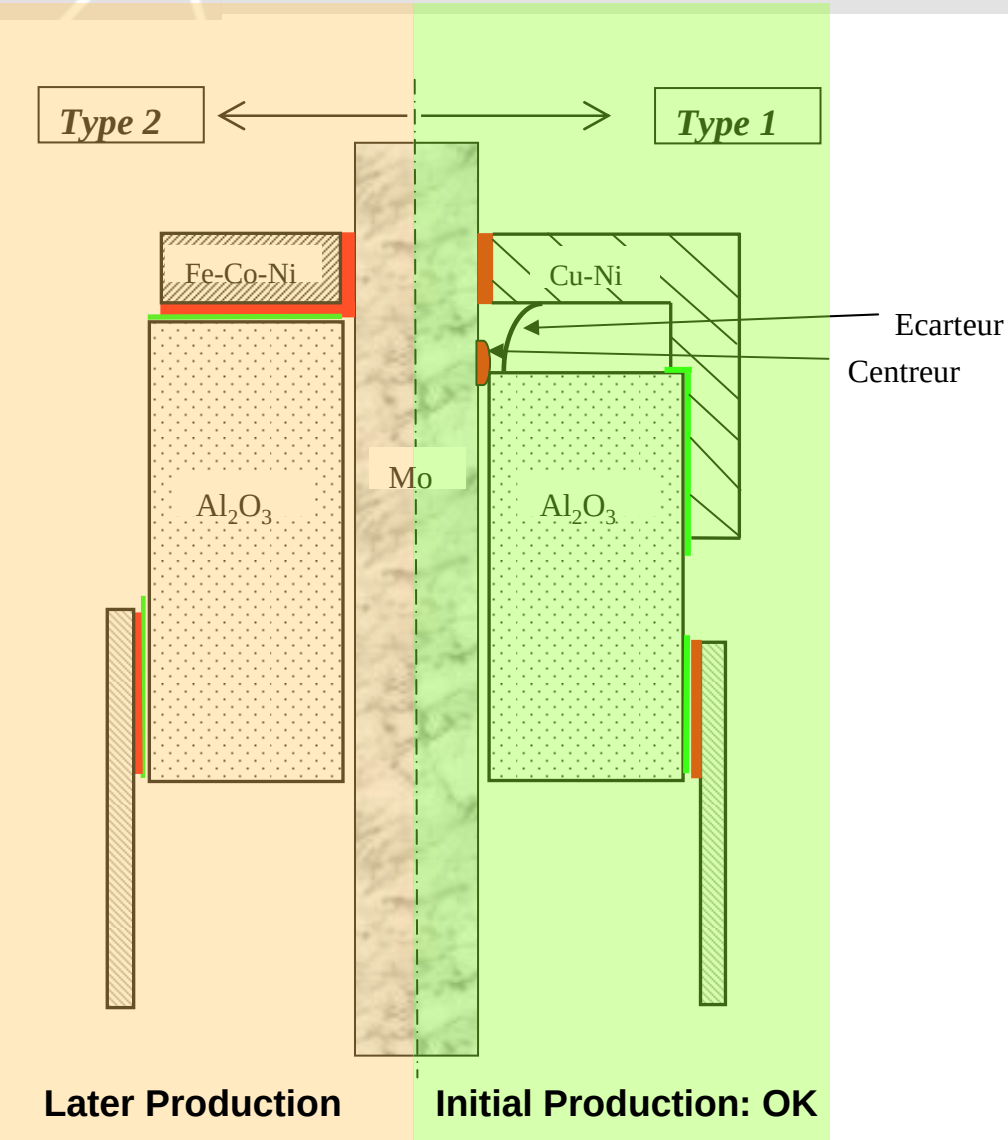
- **They work under intense pressure ($$$):**
  - Lot's of sub-contractors due to mis-interpretation of drawings, limitations at CERCA, … Brazing is also sub-contracted against qualification criteria!
  - They are **highly motivated to produce as fast as possible** to limit over-cost (collimators are worst project for them).
  - CERCA/AREVA **will complete the collimator job** (no signs of slow-down etc).
  - They do **big charges**: 16 jaws affected by latest production error. All feed-throughs ruined?
  - They tend to **cut corners** (vacuum tightness test of feed-throughs skipped because never problems encountered): more damage and delay.
  - **Manpower** maybe just sufficient for perfect production even after increase: Any problems result in lack of resources for normal production and effectively stop collimator production.
- **Problem encountered in ramping up production rate.** First trial failed ➔ "New brazing problem". Therefore this meeting today!
- **"New brazing problem":** Feed-through for temperature cables (Aug 06).
  - CERN delivered feed-throughs are more delicated but OK.
  - CERCA did not take care with a modified version and had trouble with the sub-contractor for coating ➔ Production error (as called by themselves)!
  - Vacuum leak at feed-through for 16 jaws, all feed-throughs damaged (coating), production stopped.

Brazing Status Summarized

	Number of ring jaws	Repairable	Comment
Totally brazed	**56**	n/a	
Rejected for cooling pipes	**4**	?	Old brazing problem
Rejected for feedthrough problem	**16**	16	New brazing problem (August 2006)
Installed into tanks	**14**	n/a	3 TCS delivered, 3 good TCS still at CERCA, 1 TCS rejected
Available for completing collimators	**22**	n/a	Brazed without feed-throughs

Maximum rate limited to 8 per month for next 3 months (present feed-through situation).

New Brazing Problem: Feed-through

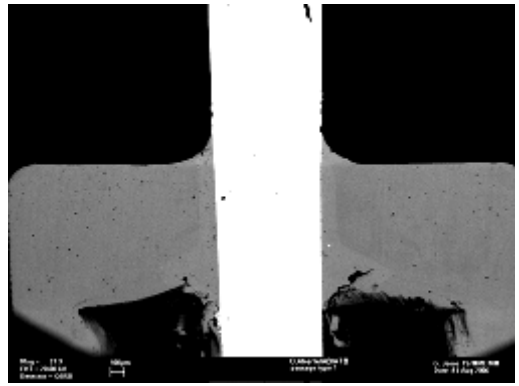


End of July 2006:

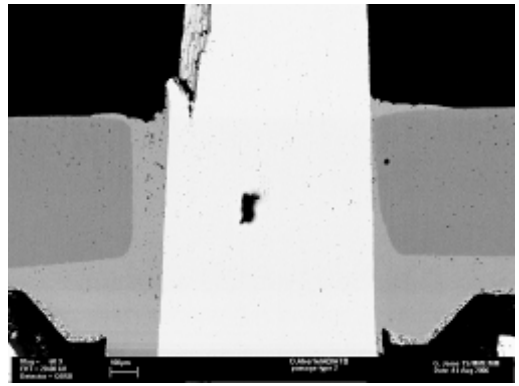
- Unexpected and new problem of vacuum leaks with 16 most recent jaws!
- Problem of feed-throughs which never made problems before at CERN and CERCA!
- Production stopped ➔ was looking OK until then.
- Problem investigated at CERN TS experts and CERCA (thanks to TS)!
- Two types of feed-throughs used (from the same company).

Feed-through Brazing Problem

- Feed-through type 1 not produced anymore ➔ type 2!
- TS and AB analysis still ongoing…
- Preliminary conclusions:
  - Type 2 tested OK at CERN, while being more delicate!
  - Problem of coating is being suspected at CERCA sub-contractor!
  - Investigation at company (TS experts) has revealed several problems that must be corrected!
- Recent brazing (end of last week) with feed-throughs type 1 failed!



Passage type 1 : brasure répartie de chaque côté du fil Mo



Passage type 2 : fil Mo décentré, brasure mal répartie

Consequences

- Plan for collimator installation must be changed.
- Collimators are an intensity-driven system: Take profit from low energy, low intensity start of the LHC!
  - No need to worry about missing collimators delaying the start-up of the LHC (no collimators needed at very low intensity).
  - New goal is to install the collimators which are really needed for the 2007 run.
  - Delayed collimators will be installed during the first shutdown.

Collimation Needs 450 GeV

Intensity	Primary collimation (TCP)	Secondary collimation (TCS)	Absorbers for collimation debris (TCLA)	Triplet cleaning and protection (TCT)	Dump protection (TCDQ +TCS)
$< 5 \times 10^{11}$	-	-	-	-	-
$< 4 \times 10^{12}$	5.7 σ	-	-	$a_{triplet} - 1\ \sigma$	7.0 σ
$< 1 \times 10^{13}$	5.7 σ	-	-	$a_{triplet} - 1\ \sigma$	7.0 σ
$< 3 \times 10^{13}$	**5.7 σ**	**6.7 σ**	-	$a_{triplet} - 1\ \sigma$	**7.0 σ**
$> 3 \times 10^{13}$	5.7 σ	6.7 σ	10 σ	$a_{triplet} - 1\ \sigma$	7.0 σ

≤ 42 foreseen for 2007

Not required if triplet is not aperture bottle-neck (as foreseen)

Proposed Collimator Delays and Impact

- Proposed **additionally delayed collimators**:
  - All **TCT's** for triplet protection and cleaning (except already installed IR8).
  - All **TCLA's** for shower absorption in IR3 and IR7.
  - Possibly *skew collimation in IR7* (details must be looked at).
- **Consequences** for 2007 low energy run: No additional limitations!
  - Triplets should not become the aperture bottle-neck (not the case with pre-squeezed injection optics with $\beta^* = 11$m, as foreseen).
  - Up to 3×10^{13} protons at 450 GeV and up to 1×10^{13} protons at 1 TeV with reduced collimation system.
  - Good: Only highly robust collimators installed for 2007 run (minimal risk to damage collimators).

New Plan for Collimation I

- A much reduced set of collimators is needed for the start-up in 2007!
- **Leave already installed collimators in, even if not needed. Install all infrastructure and collimator quick plug-in supports.**
- Do not install tertiary collimators (IR1/2/5) and absorbers (IR 3/7).
- Install sub-set of primary and secondary collimators in IR3/7. Keep IR6.

Collimation Phase	Number of collimators	Performance reach (ideal)	Database phase	Installation
1	36	~0.07 × I_{nom} at 450 GEV	**1**	LSS planning
1	76	0.4 × I_{nom}	**2**	First shutdown
2	32	tbd	**2**	~2010

- Out of 36 to be installed in minimal system:
  - 7 already installed
  - 3 at CERN available
  - 26 to be produced.

New Plan for Collimation II

- New dates for collimator installation, as agreed with K. Foraz:

LSS	Number of installed collimators	New baseline date	Final deadline	Old baseline date
6L	1	09/10/06	26/02/07	*09/10/06*
6R	1	23/10/06	02/04/07	*23/10/06*
3R	5	29/01/07	16/04/07	*06/11/06*
3L	5	05/02/07	14/05/07	*05/02/07*
7R	8	09/04/07	19/03/07	*09/07/07*
7L	8	09/04/07	06/08/07	*19/03/07*
1L	0	x	30/10/06	*06/09/07*
5L	0	x	27/11/06	*06/09/07*
5R	0	x	23/04/07	*05/02/07*
2R	0	x	21/05/07	*05/03/07*
2L	0	x	09/07/07	*08/01/07*
1R	0	x	06/08/07	*12/03/07*

New Plan for Collimation III

- All collimators to be installed still in 2006 are at CERN.
- **Minimal production goals** up to end of February 2006:
  - 6 months of production time (including Christmas).
  - 26 ring collimators.
  - Rate: **4.3 collimators/month**.
- CERCA/AREVA promise is 10 collimators in September and 12 per month afterwards.
- They maintain this expected production rate of 12 collimators per month ($$$).
- We believe that they should be able to steadily produce at a rate of 6 collimators per month if no major problems appear.
- **Other actions** we took:
  - **Help:** AB and TS review of critical production steps. TS help in critical production steps.
  - **Control:** Further tightened and formalized production control in AB with full time presence at company. Avoid that CERCA falls into other holes.
  - **Pressure:** Next top management meeting with CERCA requested for October to push on manpower and contractual issues.

Impacts for LSS Installation

- All collimator supports and external connections (quick plug-ins) installed and aligned as foreseen (dummy collimator for alignment). **No impact.**
- All infrastructure (cables, cooling, …) installed and connected as foreseen. **No impact.**
- Replacement chambers:
  - 36 (coated Cu) + 50 (stainless steel) replacement chambers of 1.48m procured
  - **Another 30 stainless steel replacement chambers to be procured (with spares).**
  - Production problems with mobile pumping ports (AT/VAC) can be treated with a longer replacement chamber + flexible bellow (total length 2.52m).
  - Proposal as discussed with M. Jimenez: **AT/VAC takes responsibility** for all missing replacement chambers, allowing flexible optimization with availability of pumping ports (minimizing number of replacement chambers).

Impacts for First Shutdown I

- 76 instead of 30 collimators to be installed/connected during first shutdown:
  - Transport: ~ 4 collimators per day.
  - Installation/connection of collimator: 0.5 h per collimator.
  - Installation of pumping ports (if missing): 0.7 h per collimator.
  - Alignment: Not required but at least point checks.
  - **Total time installation: ~ 4 weeks.**
- More important work load for vacuum work (bake-out).
  - Discussions with Miguel Jimenez.
  - Try to summarize in next slides.

Impacts for First Shutdown II

- Bake-out is essential close to experimental insertions: 16? vacuum sectors to be baked out (as in previous baseline).
- Bake-out could be skipped in cleaning insertions IR3 and IR7 (Chamonix 2006 + subsequent discussions).

	Adapted proposal		Previous baseline	
	Collimators to be installed	Vacuum sectors opened total	Collimators to be installed	Vacuum sectors opened total
LSS1	8	4?	4	4
LSS2	6	4?	4	4
LSS3	12	?	4	?
LSS5	8	4	4	4
LSS7	32	?	10	?
LSS8	4	4?	4	4
TI2	6	-	-	-

Impacts for First Shutdown III

- Wait for input from Miguel on bake-out time and resources…
- Required length of first shutdown to be estimated from Miguel's numbers.

Conclusion

Collimation Needs 1 TeV

Intensity	Primary collimation (TCP)	Secondary collimation (TCS)	Absorbers for collimation debris (TCLA)	Triplet cleaning and protection (TCT)	Dump protection (TCDQ +TCS)
$< 2 \times 10^{11}$	-	-	-	-	-
$< 2 \times 10^{12}$	8.5 σ	-	-	$a_{triplet} - 1\ \sigma$	10.4 σ
$< 5 \times 10^{12}$	8.5 σ	-	-	$a_{triplet} - 1\ \sigma$	10.4 σ
$< 1 \times 10^{13}$	**8.5 σ**	**10.0 σ**	-	$a_{triplet} - 1\ \sigma$	**10.4 σ**
$> 1 \times 10^{13}$	8.5 σ	10.0 σ	14.9 σ	$a_{triplet} - 1\ \sigma$	7.0 σ

≤ 42 foreseen for 2007

Not required if triplet is not aperture bottle-neck (as foreseen)