LHC Ring Collimation

– Overview –

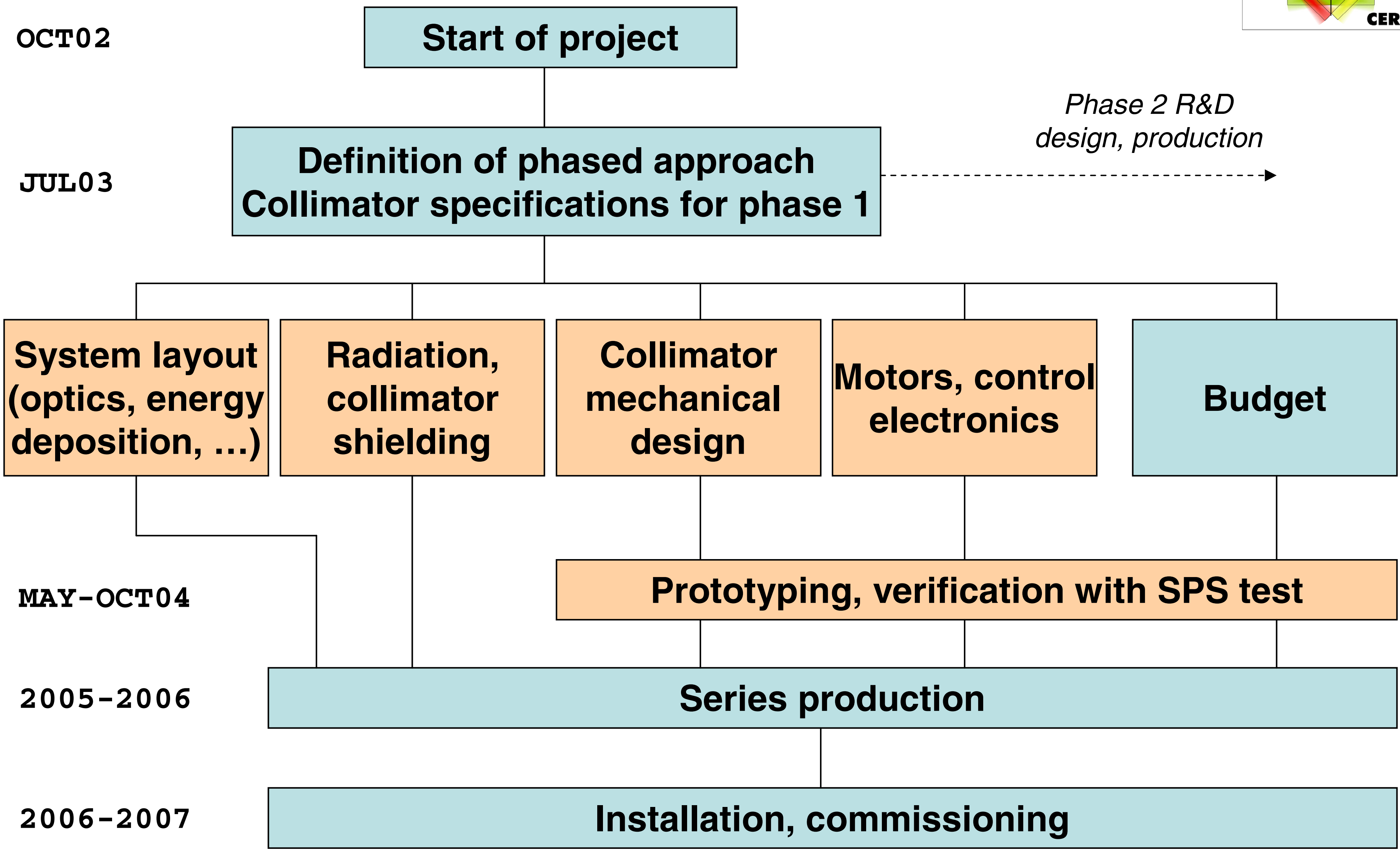
R. Assmann, AB/ABP

for the LHC Collimation Project

Included in overview

- Phases of LHC collimation with timeline
- Completing phase 1 collimation by 2007
  - Components with spares
  - Budget preliminary estimate and risks
  - Manpower
  - Schedule 2003/2004
  - IR7 layout: optics and cleaning design
  - Prototyping and tests
- Radiation and shielding
- Schedule beyond 2004

Main work flow



Logic behind the phased approach

No single collimator solution corresponds to all LHC requirements:

- High robustness (withstand LHC beam)
- Low impedance (don't disturb LHC beam)
- High efficiency (allow high beam intensities in SC ring)

Conflicting requirements ➔ More flexible approach required with specific sub-systems for **achieving nominal and ultimate performance** (hybrid sec. collimators)

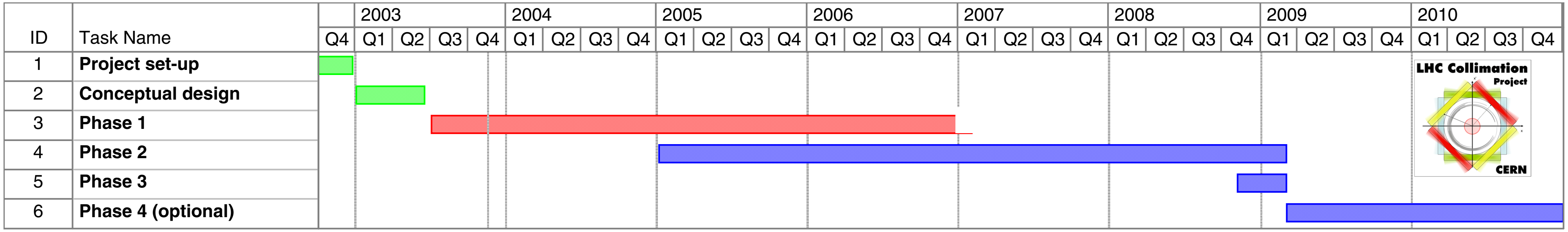
Benefiting from natural evolution of LHC beam parameters:

STAGE the design, production & installation of LHC collimators

Phase 1: Compatible with injection&ramping up to ultimate intensities and with requirements of commissioning and early 7 TeV physics run!
(accepting to run at the impedance limit at 7 TeV, fixed with phase 2)

Timeline for collimation phases

(without commissioning of the system – included in project mandate)



Timeline for phase 1 is on the critical path since start of the project: design, prototyping, production, installation of a big and challenging system in 4 years.

Phase 1 is being realized…

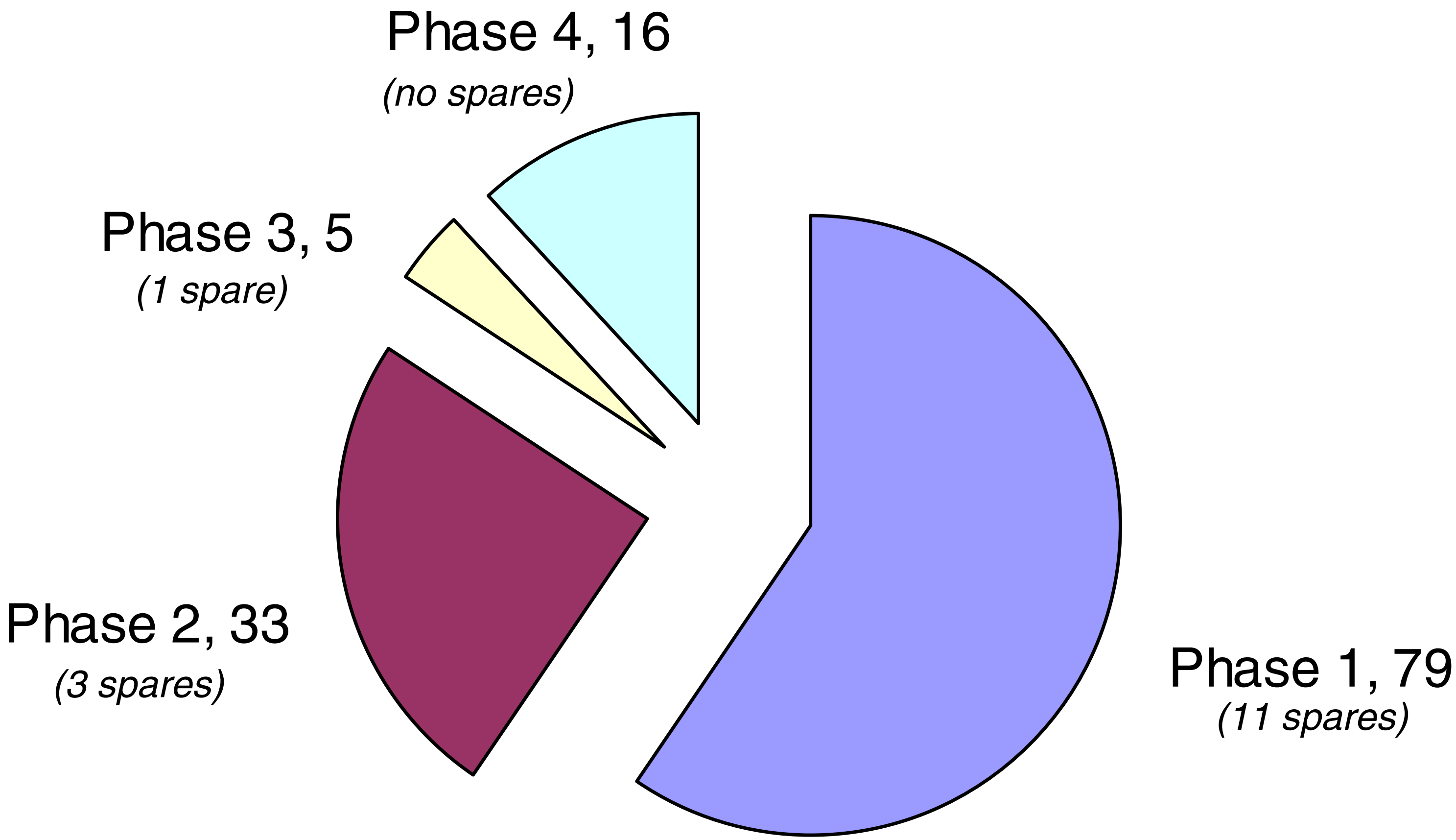
- with a collimator concept as **robust** as possible and as **simple** as possible
- relying as much as possible on available **experience**
- completed as **fast** as possible
- for a quite **low price**
- with **50 × better efficiency** than required at other machines (tighter tolerances)

Phased approach gives us **room for learning and developing the LHC collimation.**

Timeline for different phases extends until **2010/11**.

Start phase 2 design early to allow for nominal performance with advanced design (wait until phase is in series production)!

Phasing of ring collimators (including spares)



Size of system: Maximal **118 collimators** installed ➔ comparable to LEP system which had 200 blocks!

Ultimate efficiency: With **optional "Phase 4"** (not required for nominal – to be confirmed for new optics).

Completing Phase 1 collimation by 2007

Highest priority: **Compatibility with LHC schedule** without compromising the system performance (…too much)

(remember: in phase 1 we require 50× advancement in cleaning efficiency beyond requirements elsewhere)

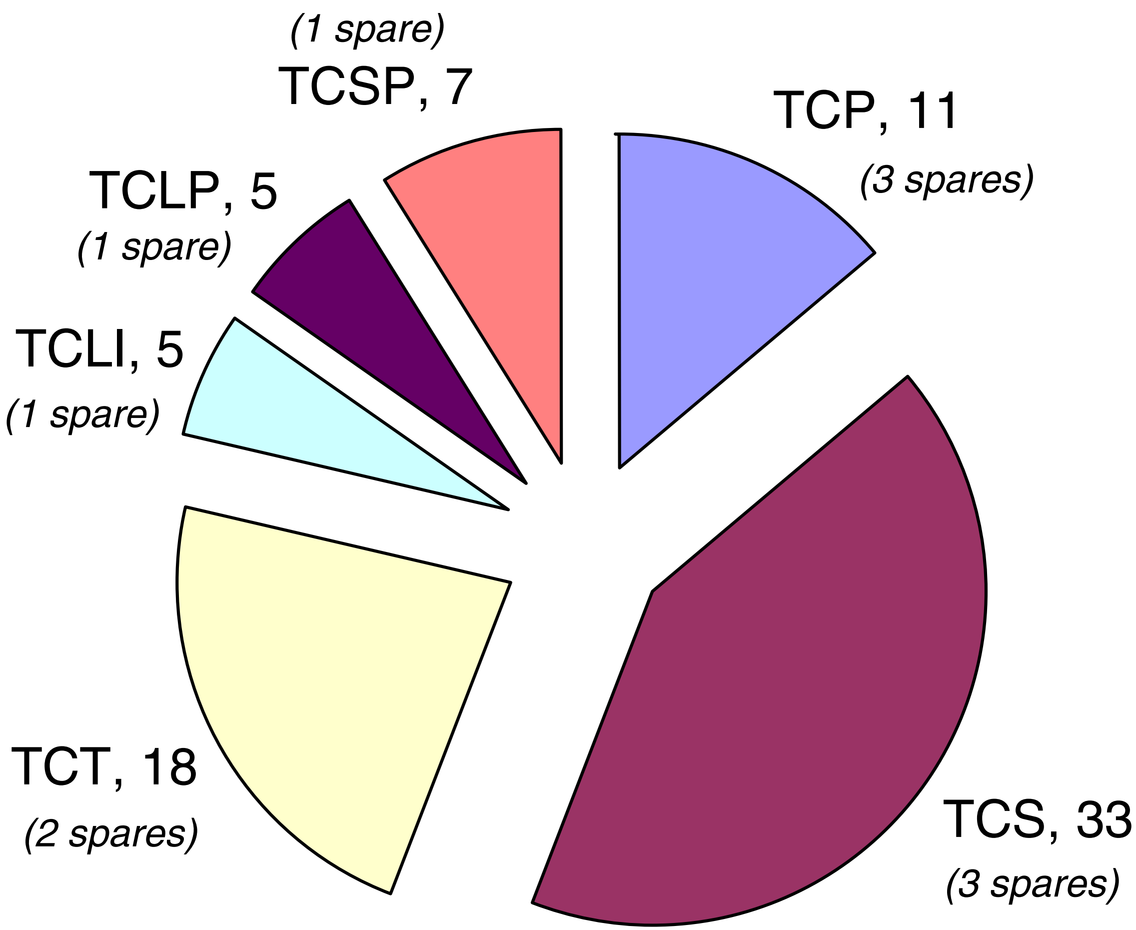
Strategy: **Rely on solutions that worked before** with similar mechanical specifications (resisting the temptation to just copy without verifying solutions are OK)!

➔ Use to maximum extent LEP solutions (no fancy stuff)
➔ EST leads mechanical design and prototyping (LEP designer)
➔ Strong support from AB division for mechanical design
➔ See O. Aberle for details…

Reserve sufficient time for experimental tests: jaw materials, vacuum, heating and cooling, flatness, prototype tests (SPS, TT40)

Quality assurance is crucial (0.2 mm deformations over 1m jaw ➔ useless secondary collimator ➔ factor 10 in allowable intensity easily lost)

Collimators for Phase 1 (including spares)



Phase 1 is a big system:

- Total 79 components (95 in worst unlikely case).
- Much work overhead: 6 different types, not counting different azimuthal orientations for TCS!

Concentrating on design of secondary collimators (TCS):
➔ most components and most difficult!

TCS design will serve as basis for TCP, TCSP, TCLP, and TCLI designs!

Collimation project for Phase 1

- Budget and risks
- Manpower
- Schedule

Budget LHC Collimation – Phase 1 –

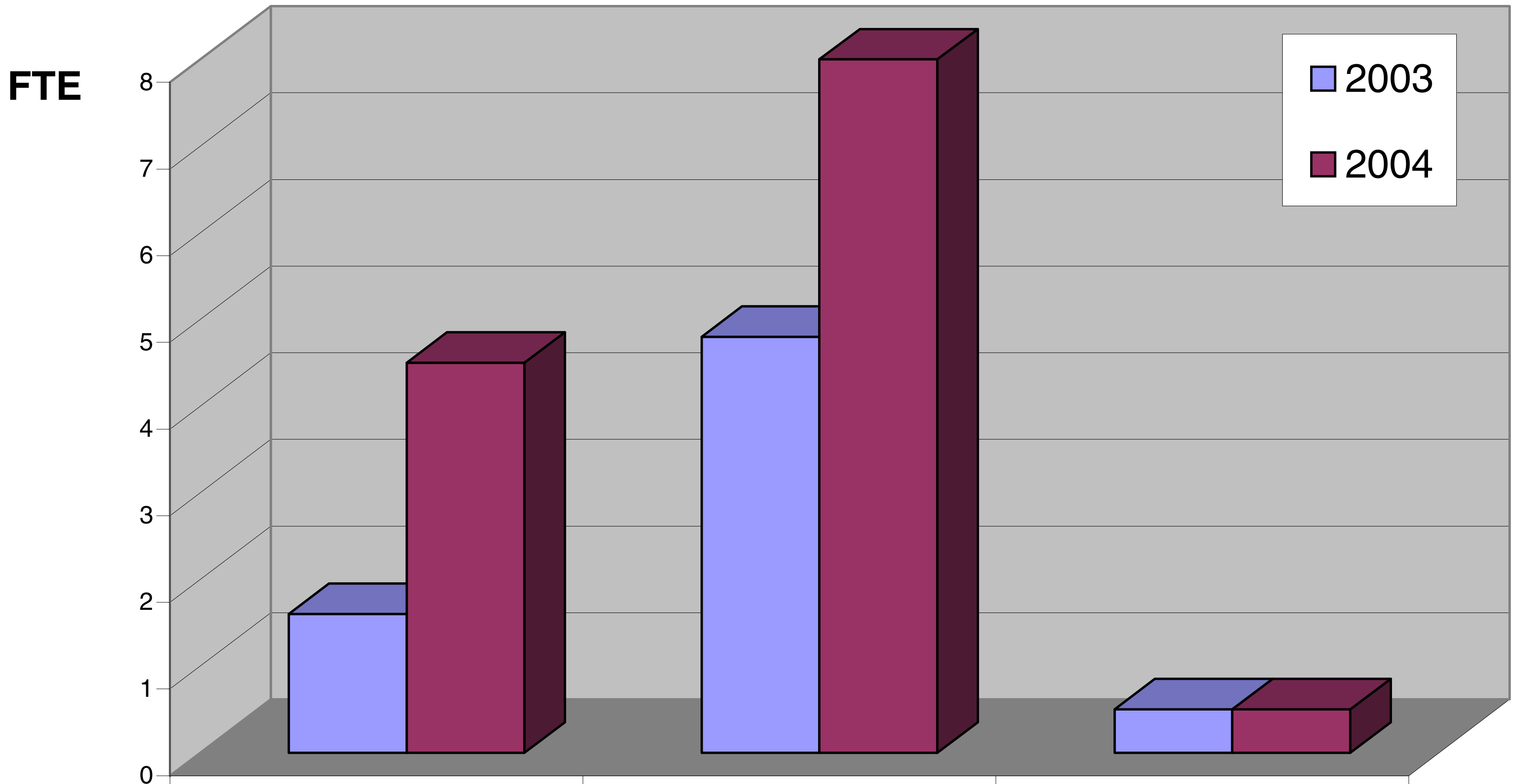
	Number of components		Cost/component	Total cost
	machine	spares	[kSFr]	[kSFr]
TCP	8	3	103	1133
TCS	30	3	133	4389
TCT	16	2	133	2394
TCLI	4	1	133	665
TCLP	4	1	133	665
TCSP	6	1	63	441
General costs				2247
Installation/alignm./transp./...	68		5	340
Total	**68**	**11**		**12274**

- Preliminary budget estimate (final estimate only after building prototype).
- Budget was allocated by LHC management (to be put into EVM).
- Prices appear favorable if compared with costs of existing (simpler) designs (SNS).

Budget risks phase 1

- The carbon jaws can be fixed on a metallic cooling support with a **technique of clamping**. If state-of-the-art techniques (as used for the ITER fusion project) need to be applied significant cost increase would result (on the order of 2-3MSFr).
- The cost for motors, electronics, and local control is **based on the LEP technology and prices.** If this technology cannot be used (e.g. due to higher radiation at LHC) significant cost increase can result.
- It is assumed that **no local shielding** is put at the collimators. Otherwise advanced handling tools for shielding and collimators might be required with a significant increase in budget.
- A **flexible collimator design** is assumed (collimators can be used for any plane), resulting in a minimum number of spares. More spares for less flexible designs would cause an increase in budget.
- It is assumed that 5 out of 8 prototypes to be built **can be installed into the LHC** as collimators. Prototyping cost therefore takes into account only 3 components.
- Significant **R&D for phase 2 collimators is done by SLAC** as part of the US-LHC collaboration (LARP) . Additional budget would be required if this R&D work would need to be performed at CERN.
- Production and installation cost for phase 2 and phase 3 collimators is not included. Phase 2 collimators need to be installed after one year of LHC operation. However, the **costs of services for phase 2 and 3 are included**, as they should be installed for day 1 of LHC (minimizing human intervention in IR3 and IR7).

Manpower Collimation Project



	HW	sim/design/exp	proj. management
2003	1.6	4.8	0.5
2004	4.5	8	0.5

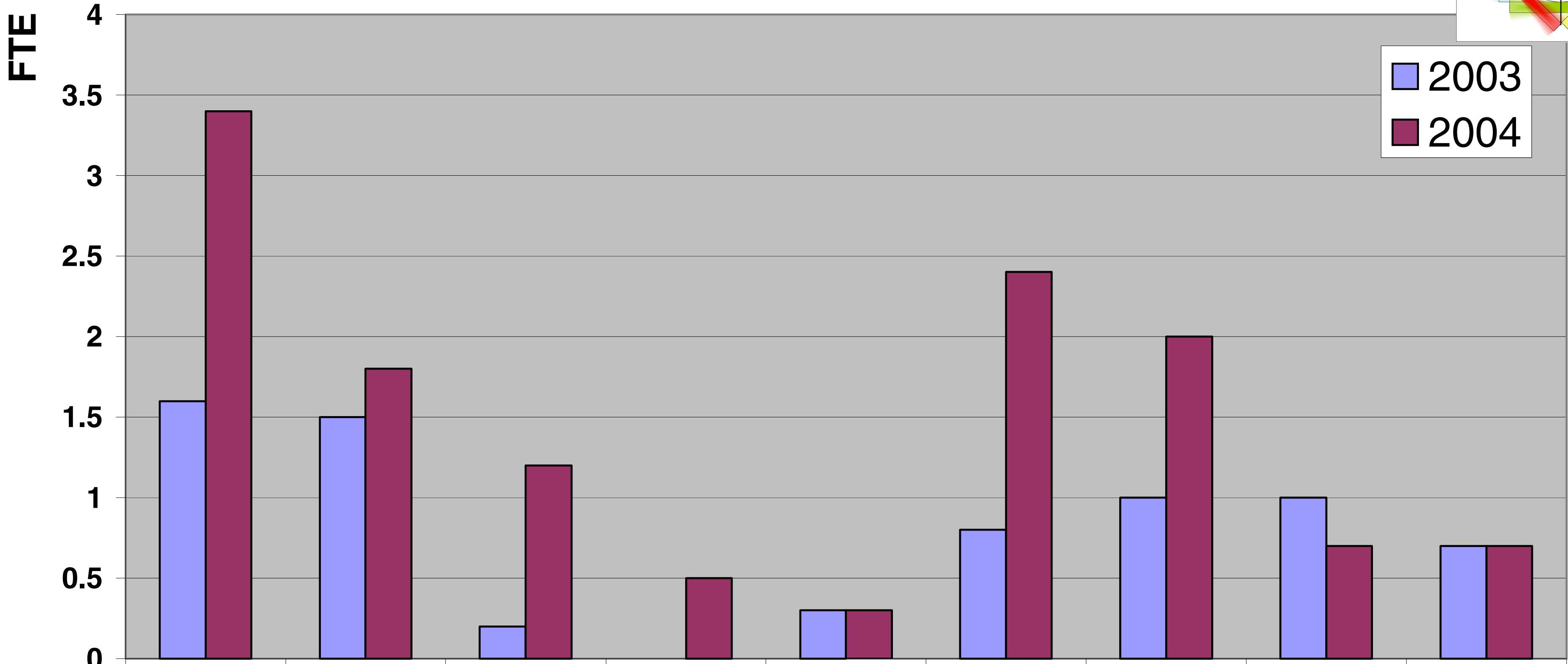
w/o ions

Manpower: **6.9** FTE (2003) ➔ **13.0** FTE (2004)

AB-division: 3.3 FTE (2003) ➔ 6.9 FTE (2004)

1.0 from PhD student

Manpower per group



	AB/ABP	AB/ATB	AB/CO	AB/RF	AT/MT	EST	IHEP	TIS/RP	TRIUMF
2003	1.6	1.5	0.2	0	0.3	0.8	1	1	0.7
2004	3.4	1.8	1.2	0.5	0.3	2.4	2	0.7	0.7

Total: **27 persons involved from 9 groups** in 2004

Average FTE/person: **0.3** (2003) ➔ **0.5** (2004)

Manpower status

- We are still **building up manpower** to tackle the collimation challenge (almost double in 2004).
- About 50% of manpower from AB.
- Still **most resources on simulation/system design**:
  This illustrates the big challenge of non-trivial beam loss signatures.
  2004: Shielding in IR3 and IR7 is a major work challenge (see later).
  Still not at all easy to meet deadlines!
- **Hardware resources tripling** next year (stronger increase than simulation). Healthy sign: Further increase might be required as we start to produce hardware!
- **Average FTE/person** goes from 0.3 to 0.5: Average person works 50% of its time on collimation! Healthy development! Still struggling with other priorities!

Schedule

- Collimation project **not in steady state**.
- Schedule must adapt to available manpower, free resources, priorities, encountered difficulties, ….
- **No time reserve in schedule**.

Emphasis in 2003:

- Put resources together to make **quick progress**
- Develop a **coherent picture of collimation** in the LHC rings
- Fix **basic technical design parameters** (materials, lengths, …)
- First round of new **layout in IR3 and IR7**
- **Get mechanical design going** on most difficult collimator

Schedule and tasks defined in detail until end of 2004…

ID	Task Name
1	Project set-up
2	Conceptual design
3	Optics & cleaning design IR7
4	Feedback from AT/VAC, EST/IC
5	Energy deposition IR7: Absorbers
6	ECR IR7
7	Optics & cleaning design IR3
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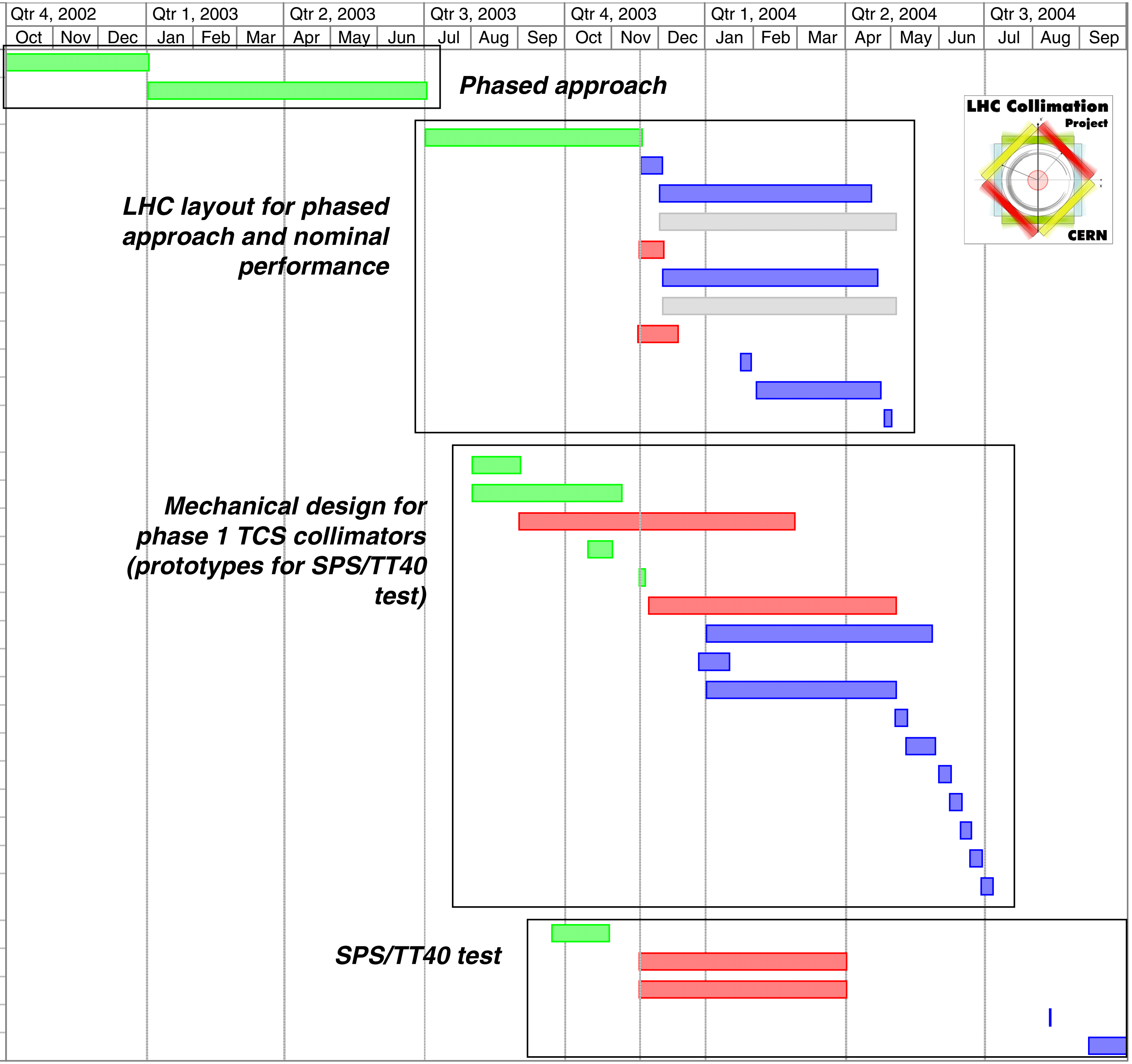
32	Pre-installation TT40
33	Test installation
34	SPS/TT40 beam tests



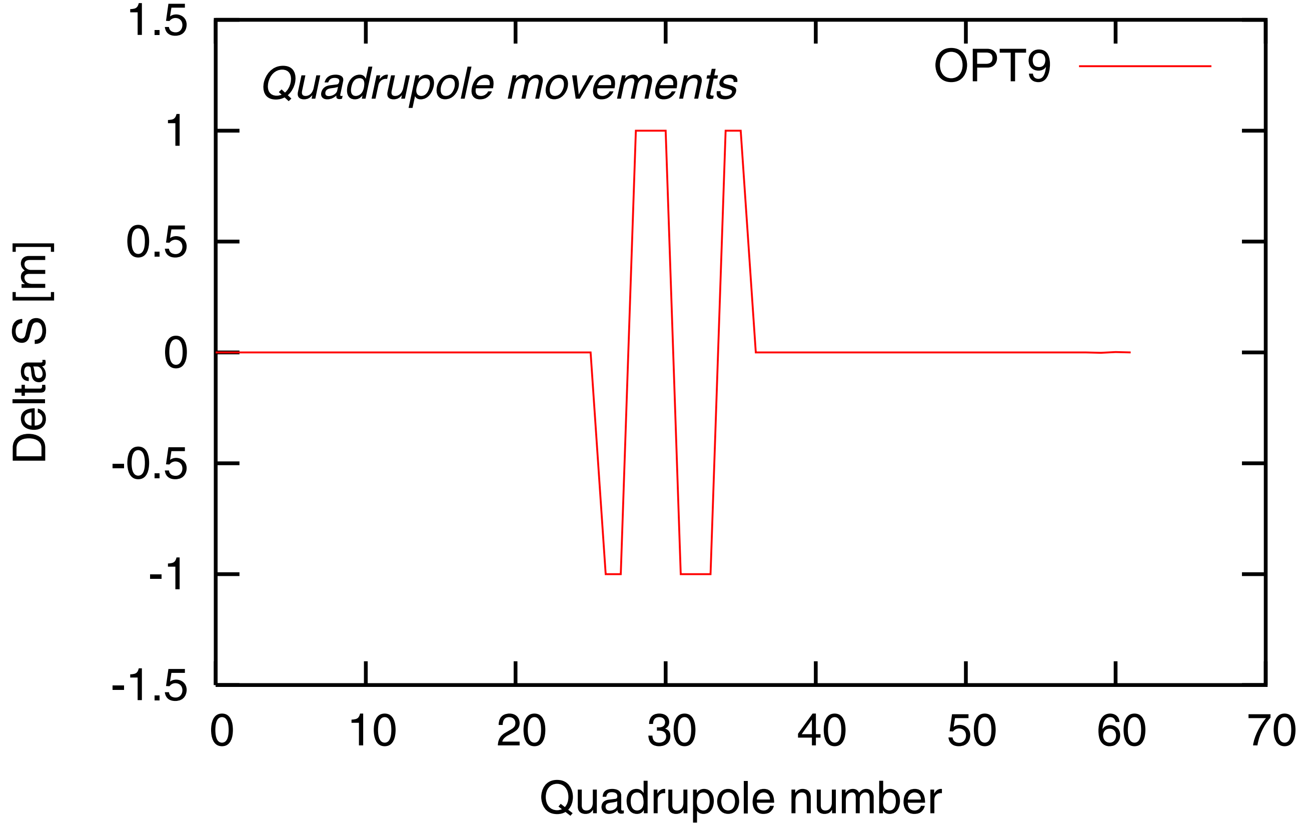
IR7 layout: Optics and cleaning design

Goal: Space allocations for secondary collimators (2 beams×16×2m), phase 2 hybrid collimators (2 beams×16×2m) with all upgrade phases.

Keep good cleaning efficiency.

Minimize impedance.

Decision for proposal: **Has been taken 14.11.03. Being finalized in optics team.**



Much larger movements for collimators!

Space in IR7

"RBEND"	"MBW.A6L7.B1"	376.7491258
2TCS + 1TCS = 12m	**24.7m**	
"QUADRUPOLE"	"MQWA.E5L7.B1"	405.1216258
"QUADRUPOLE"	"MQWA.A5L7.B1"	423.6216258
2TCS + 5TCS = 28m	**35.9m**	
"QUADRUPOLE"	"MQWA.E4L7.B1"	463.2116258
"QUADRUPOLE"	"MQWA.D4L7.B1"	466.9
1TCS = 4m	***5.0m***	
"QUADRUPOLE"	"MQWA.C4L7.B1"	475.6
"QUADRUPOLE"	"MQWA.A4L7.B1"	486.7116258
5TCS + 5TCS = 40m	**117.3m**	
"QUADRUPOLE"	"MQWA.A4R7.B1"	607.6636258
"QUADRUPOLE"	"MQWA.C4R7.B1"	618.8
1TCS = 4m	***5.0m***	
"QUADRUPOLE"	"MQWA.D4R7.B1"	627.5
"QUADRUPOLE"	"MQWA.E4R7.B1"	631.1636258
5TCS + 2TCS = 28m	**35.9m**	
"QUADRUPOLE"	"MQWA.A5R7.B1"	670.7536258
"QUADRUPOLE"	"MQWA.E5R7.B1"	689.2536258
1TCS + 2TCS = 12m	**24.6m**	
"RBEND"	"MBW.A6R7.B1"	717.6261258

Dogleg L
|
Q5 L
|
Q4 L
|
Q4 L
|
Q4R
|
Q4R
|
Q5
|
Dogleg R

All space included!

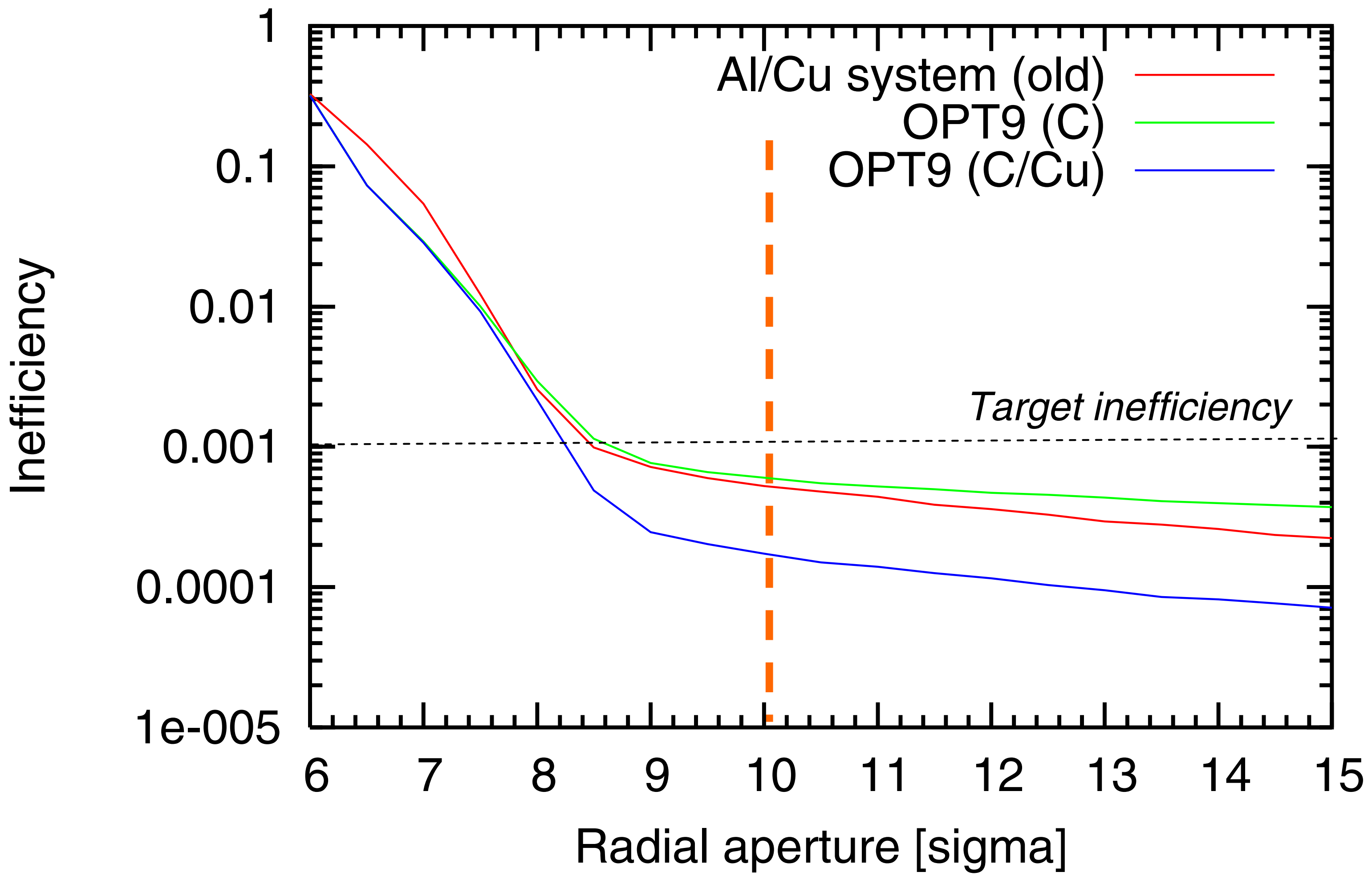
40% of space in IR7 reserved for collimation

Sufficient space for correctors, BPM's, …

Lowest free space between quads: **7.9 m**

Lowest free space with collimator in between modules: **1.0m**

Cleaning design IR7



Phase 1 with all collimators:	Roughly as good as old system…
Now to be done:	Remove collimators from phase 1!
Ultimate reach with Cu hybrids:	Factor 3-4 better in inefficiency!
Larger collimator gaps:	Expect factor 2-3 gain in impedance!

Radiation & collimator shielding

The LHC management has confirmed its policy to limit environmental impact of LHC operation to less than the low **10μSv/y limit**.

This implies that **shielding will be installed in IR3/IR7**, also on the collimators, if required to achieve this goal (also implementing ventilation changes).

Important trade-off in radiation protection in IR3/7:

Low personnel exposure	⟷	Low environmental impact
Less shielding		**More shielding**

Detailed shielding studies and proposals middle of next year between TIS/RP, collimation project, vacuum, …!

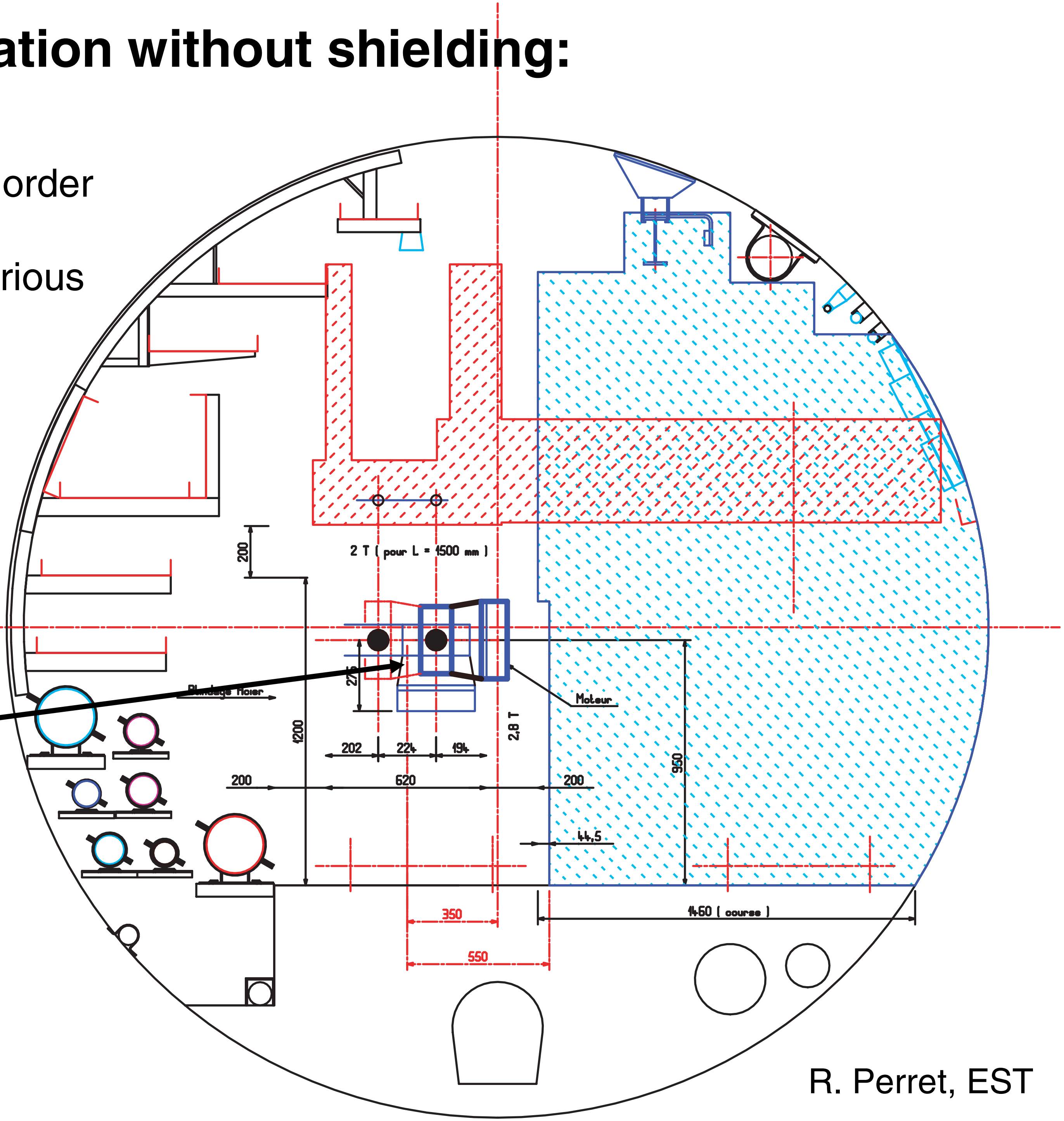
Just a few slides as a warning!

Collimator integration without shielding:

Compact dimensions in order to respect inter-beam distance and support various azimuthal orientations:

0° ➔ 90°
(all angles possible)

Details: O. Aberle



Collimator tank with motors (~100kg)

R. Perret, EST

Collimator integration with shielding:

Example of 20cm shielding
(illustrative only, no design)

Collimator design for SPS prototypes continues w/o shielding.

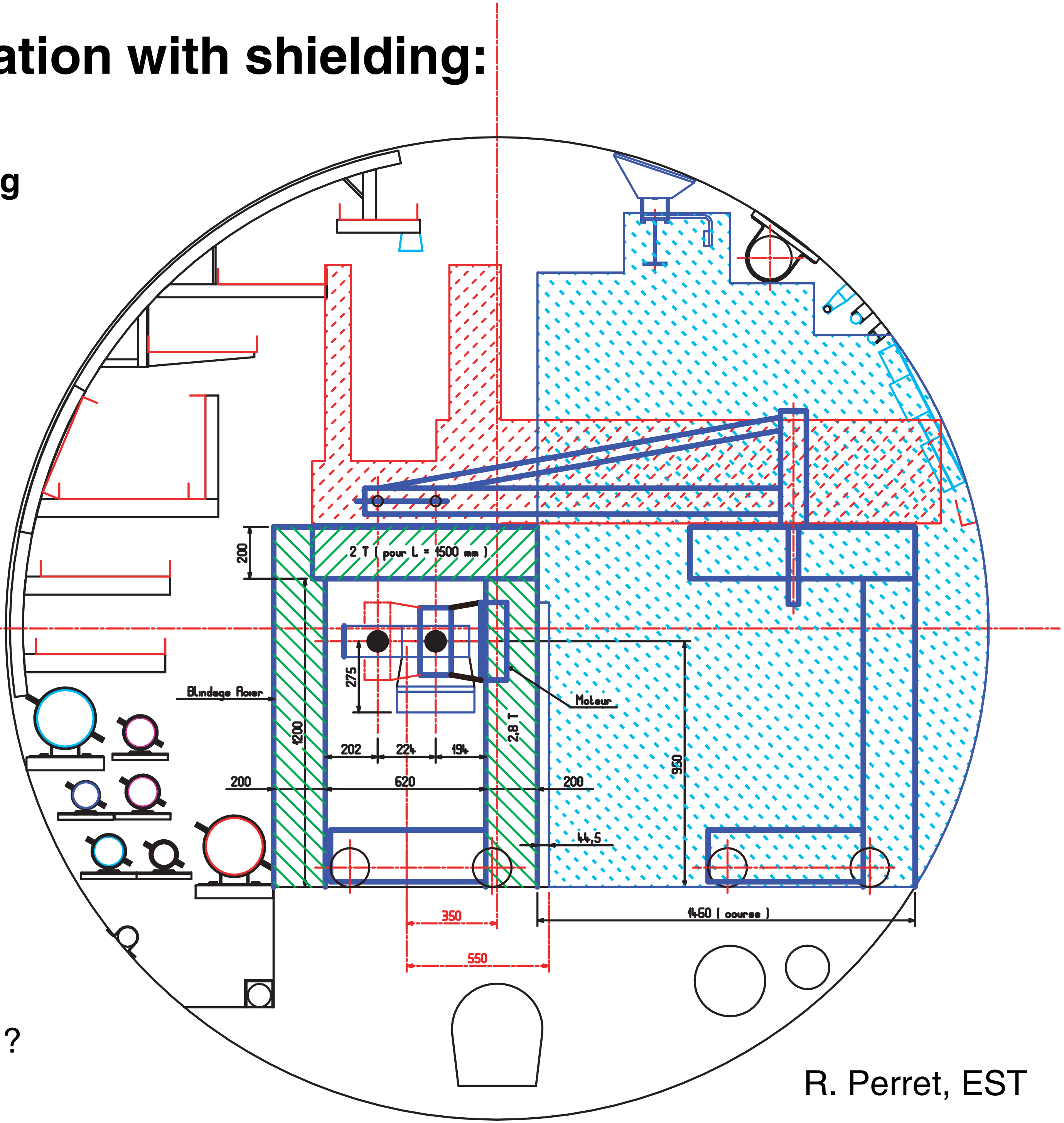
Start thinking about LHC design now:

- Motors (inside/ouside)
- Moving mechanism
- Handling tools (crane)

Decide about shielding details middle of next year! (start study Feb04)

Impact on collimator design and insertion layout! (integration)

➔ Next AB project review!?



R. Perret, EST

Prototyping & Tests

Prototyping and tests are very important in view of the challenges:

- Build a **prototype for every type of collimator**!
- Assume **8 prototypes** (already for TCS + 1 other overhead).
- Budget assumes that 5 of them can be installed into the LHC!

Biggest challenge tackled first (in terms of tolerances, dimensions, flexibility):

- Secondary collimators TCS with 1.2 m jaw (details O. Aberle).
- Two prototypes to be **completed in May 2004** (EST).
- **Thorough program of testing** and design verification for TCS prototypes:
  - Laboratory measurements (see planning)
  - Beam measurements (TT40: robustness, SPS: functionality/impedance)

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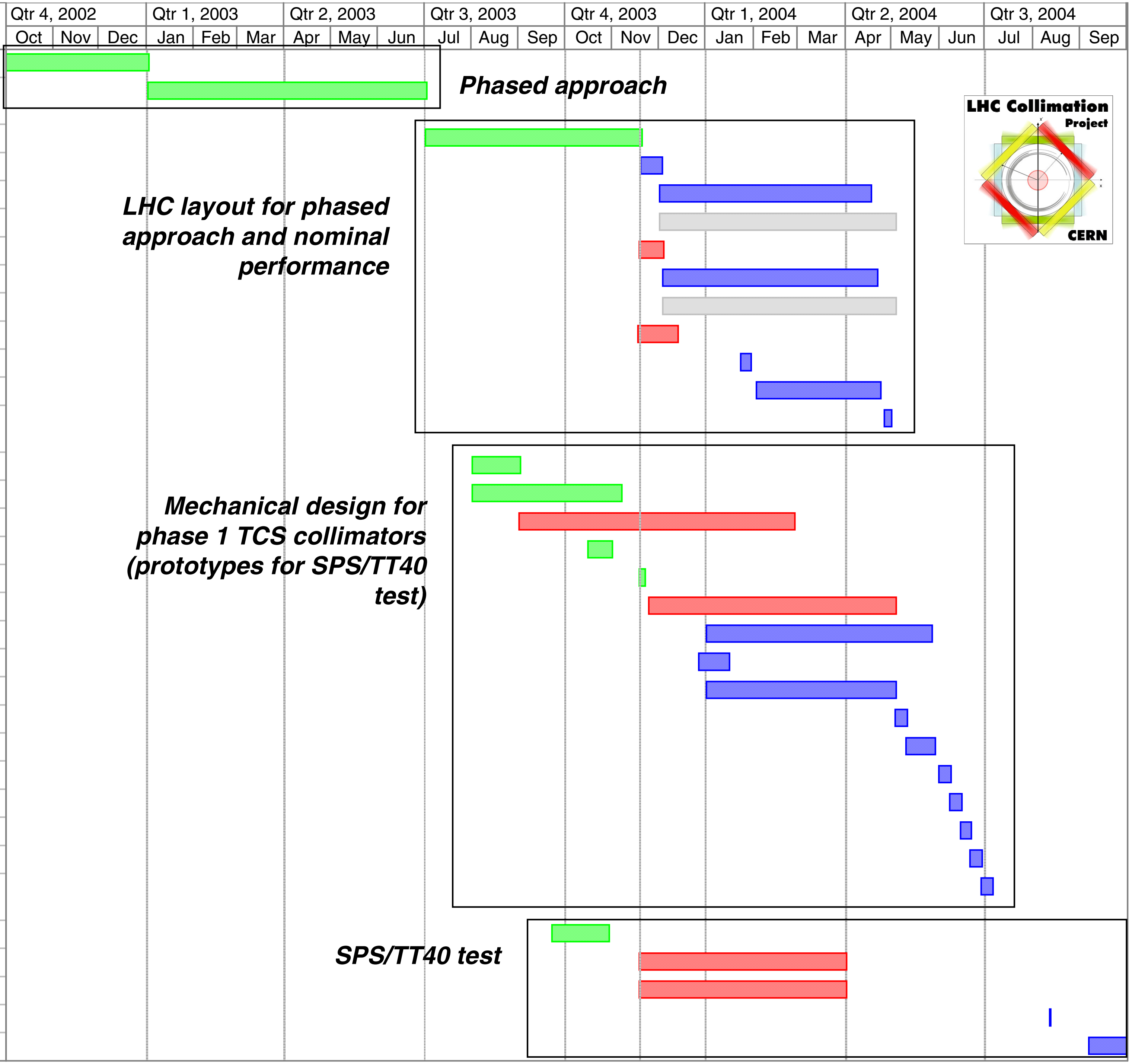

Schedule beyond middle 2004

More complete schedule will be prepared in January 2004:

1) **Mechanical design of TCP, TCSP, TCT, TCLI, TCLP**:
   Possible after completing design of TCS in 2/04…
2) **Prototyping beyond the SPS test requirements**:
   Possible after delivering TCS prototypes in 5/04…
3) **Feedback from TCS tests, design optimizations**
   After SPS tests in 11/04…
4) **Preparation for series production**:
   Starting in 1/04…

… later in 2004 (knowing about local shielding)…

5) Schedule for **ordering components, assembly**, …
6) Schedule of **test and quality assurance** for series production
7) **Installation** schedule

Still strong uncertainties until end of 2004:

- Delivery delays
- Assembly and testing
- **Shielding** and additional handling tools

Conclusion

- Project for LHC collimation is gathering momentum, relying on **good support from about 9 groups** at CERN.
- A **path to nominal LHC performance** has been defined.
- Project is not in steady state ➔ **dynamic process** (not everything is defined, scheduled, or documented in detail ➔ adjust to reality).
- However, documentation in **LHC design report**…
- Advancing on **freezing layout** (IR7 optics and cleaning design completed) with good LHC performance reach.
- Advancing on **mechanical design and prototyping**.
- Detailed **work tasks and schedule for 2003/2004** has been defined, including thorough testing without and with beam.
- **New budget** has been requested and allocated.
- **Local shielding** imposes risks for changes in design, budget, schedule.
- Next version of schedule (more complete) in Feb2004 and Nov2004?
- We will have a reasonably well performing Phase 1 collimation in 2007, but we cannot (yet) relax!

➔ **O. Aberle will present the engineering details…**