Status of the LHC Collimation System

R. Assmann
AB/ABP

For the Collimation Team

Problems we are facing:

1) Material robustness

7 TeV irregular dump: C marginally OK (factor ~4 missing)
Be not OK (factor ~10 missing)
Higher Z out of question

Other expected beam impact scenarios impose 4-10 times smaller robustness but still very critical (injection problems, low beam lifetime, …). Cu is out of question in present approach.

2) Impedance

FR, LV Feb 2003: Impedance from C betratron collimators is 10 times the rest of the ring (7 TeV squeezed).

Impedance from all movable devices? Resistive and geometric parts? Emittance blow-up? Impedance with C stripes? Acceptable impedance? Thresholds for instabilities?

3) Tight operational and mechanical tolerances

Tightest tolerances on beta beat and orbit occur at the collimators.

Additional correctors needed to ensure that tolerances are met, in view of problems with warm quadrupoles? (MG)

4) Collimator reliability and maintenance in high radiation area

Very tight schedule:

April 2003: **Choice of jaw materials and basic scheme**
April 2004: **Proto-type collimators**
2004-2005: **Production**
2006: **Installation**

- Very little room for delays.
- Judge constraints soon and decide (trade-off).
- The whole machine (not just collimation) must work: Discuss in the LTC to help in trade-off.

  - Can we choose a material without detailed understanding of impedance constraints?

  - For what level of details in theoretical studies should we wait (it is a difficult problem)?

  - Are experimental studies required and should we wait for them?

  - Is a factor of 10 increase in impedance acceptable?

Thinking about system design for collimation

Not just waiting for input, but also look for solutions on our side!

General goal: An efficient collimation system that does not limit the LHC performance (intensity, β^*, …) nor the operational flexibility (tune, phase advance, …) nor the luminosity uptime (cleaning efficiency, failure/damage rate, …).

Can we adapt the system to the three challenges (robustness, impedance, tolerances) without violating our goal?

Answer: This might be possible with a three-stage cleaning system.

Disclaimer: **Very preliminary thoughts, much too pre-mature for the LHC-MAC, for information of LTC, not ready for any decision! Work out over next weeks if no show-stopper!**

Price to pay: Additional collimators (tertiary) at the triplets (e.g. before D1).

Idea of a three stage system:

Relies on **adding tertiary collimator/triplet absorbers at triplets (before D1)**:

Good for machine protection (RS)
Good for cleaning efficiency (RA) → Use for relaxing tolerances and impedance…

Idea carried further to a three stage system:

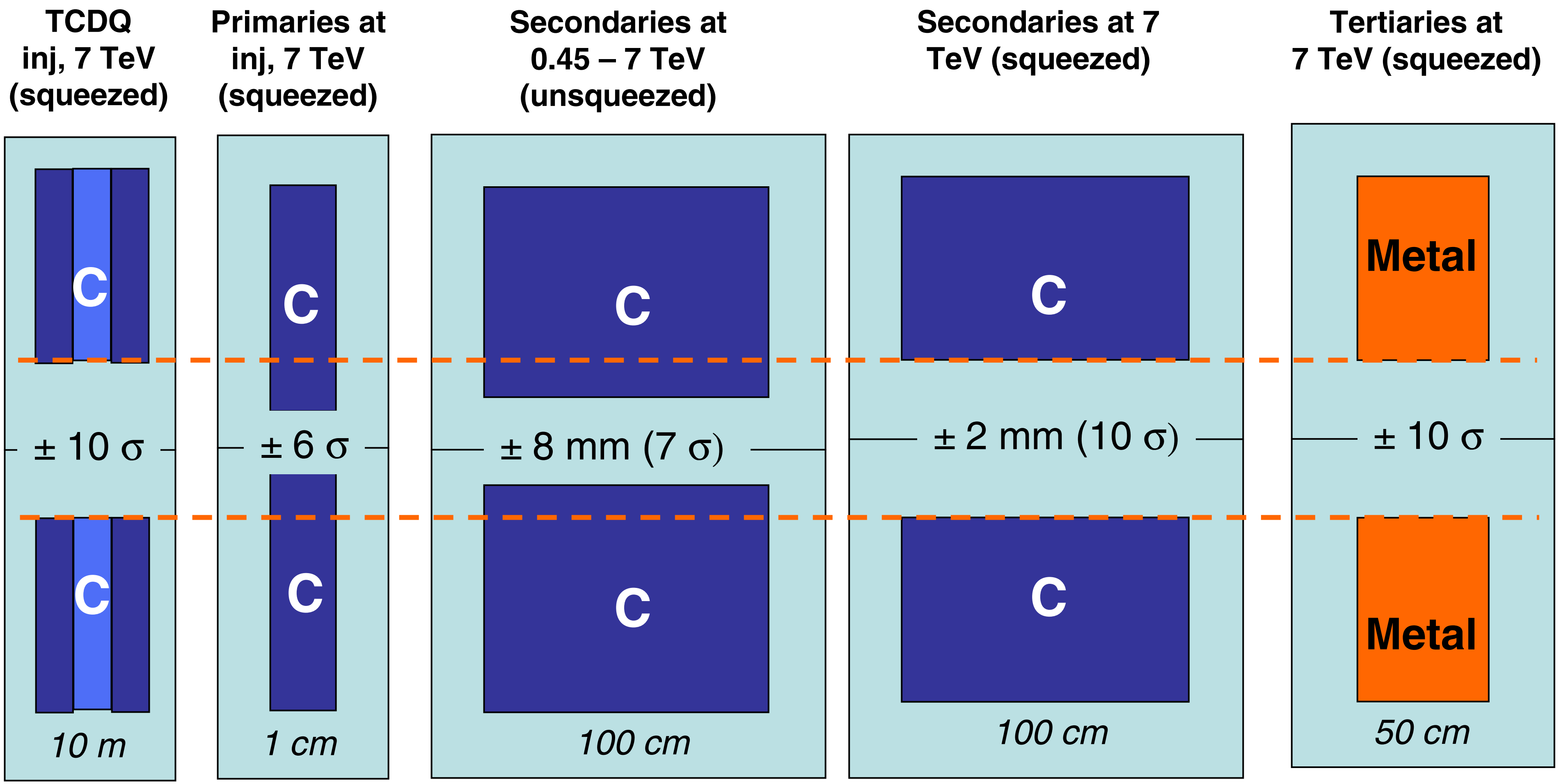
At 450 GeV: Use short primary and long secondary collimators in IR3/7.
No change of philosophy: 6/7 σ (protect downstream arc + DS)
No change of required robustness (use C for all collimators if we take into account impact of one injected batch)

At 7 TeV: (squeezed)
Use **short primary** (1 cm C) at 6 σ. Will be very robust!
Use **long secondaries** (1 m C) at 10 σ. In shadow of TCDQ (10 σ).
Use **long tertiaries** (1m C) at 10 σ to clean 10 -13 σ secondary halo.
Possibility to use Be?

Note: Ignoring cases at 450 GeV, we could go to short secondaries and tertiaries, made out of metal (no impedance problem). **Hybrid system:** 0.5 m C (inj) and 0.5 m Cu (top)?

Ideally: Put 4 primaries at 0, 45, 90, 135 degrees (not possible any more).

A robust, low impedance, high efficiency 3-stage system:

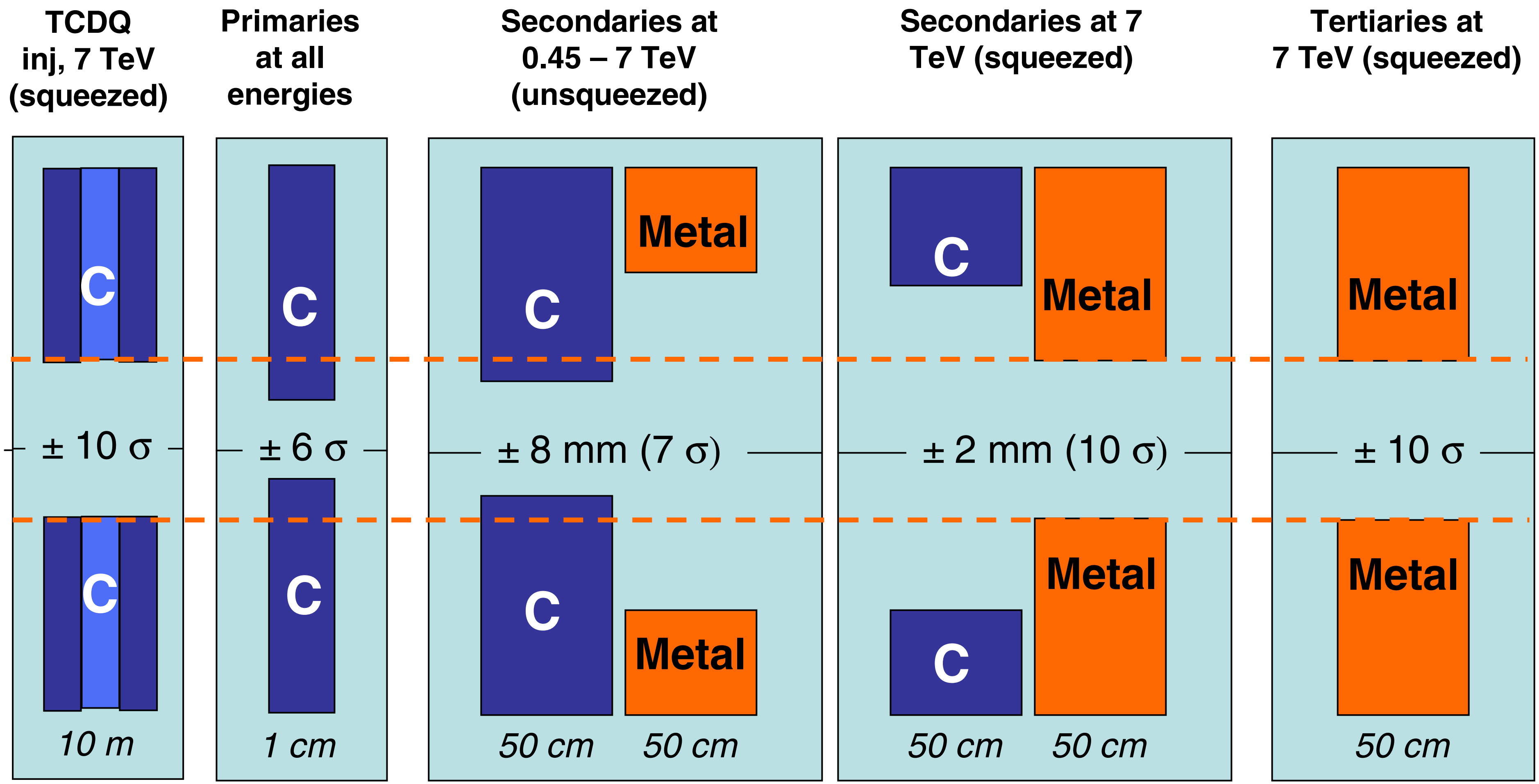


Primaries almost indestructible, robust low-Z secondaries, local cleaning at triplets, relaxed tolerances orbit and beta beat, good efficiency.

System fully based on C: Factor 3-4 improvement in impedance!

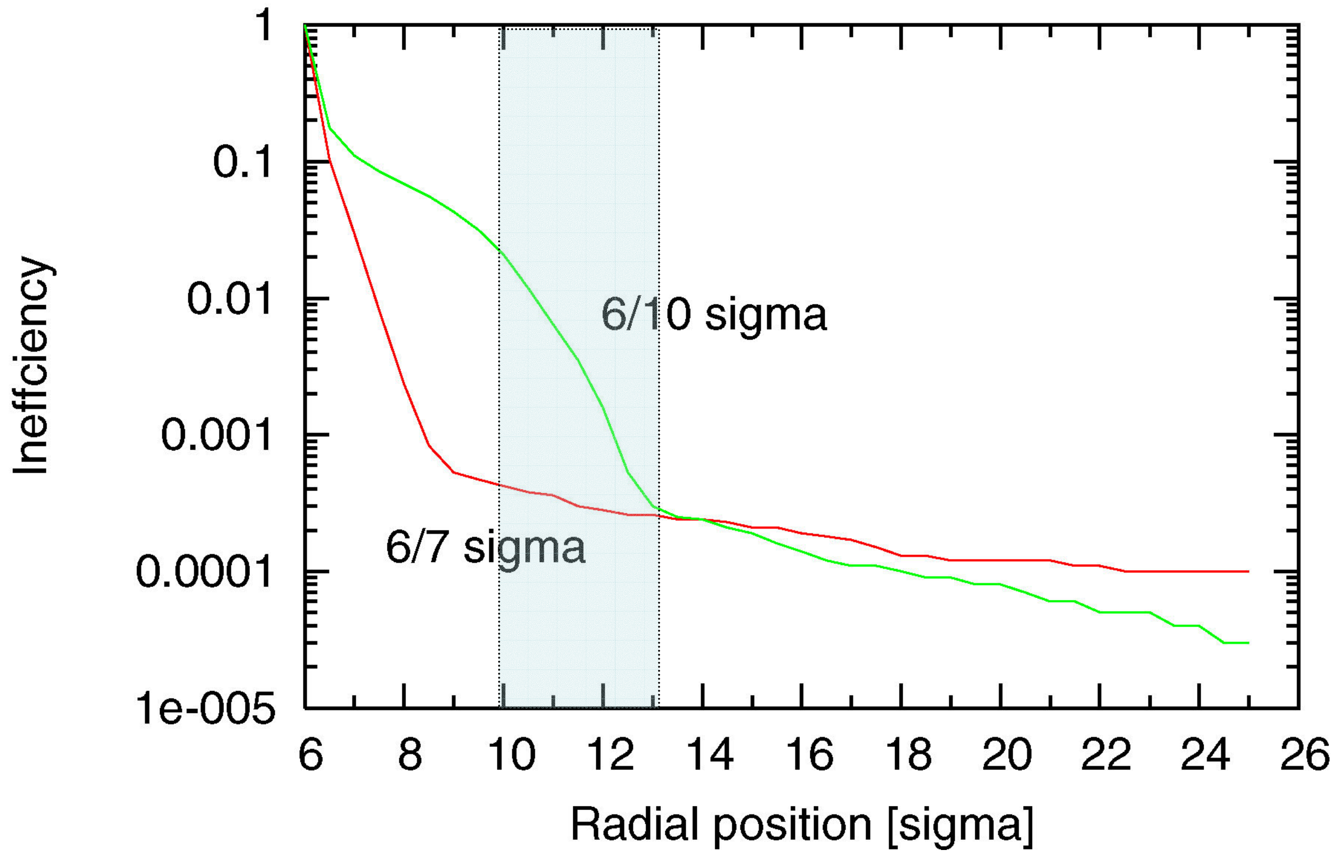
System with Be on C: Impedance problem avoided, but less robust and toxic materials!

A robust, low impedance, high efficiency, 3-stage hybrid system:



Primaries almost indestructible, robust C secondaries for injection (reduced cleaning efficiency), low impedance secondaries at 7 TeV (in shadow of TCDQ), local cleaning at triplets, relaxed tolerances orbit and beta beat, good efficiency. Same length as C system. Resistive impedance budget (20-30%) might be respected. Large flexibility (start with C at 7 TeV). No toxic materials.

Efficiency with secondaries at 10 σ (in shadow of TCDQ):



Open secondaries to 10 σ:

Secondary halo extends to 13 σ!

Install tertiary collimators before the triplets!

(protect triplet aperture bottle-neck)

Seems promising! **Can Cu withstand normal operation with low lifetimes?**

Cleaning efficiency with short primaries:

20 cm C:	**2.9×10^{-4}**	(>10 σ)
1 cm C:	**7.8×10^{-4}**	(>10 σ)

Cleaning efficiency is reduced factor 2-3!

However:
We might be able to accept this (goal is 1×10^{-3}).
Collimators are much more robust.
No adjustment of angle beam-jaw needed.
Particles will anyway see only a small part of jaw.

More studies required for optimal length (long tracking studies).

Tolerances with secondaries at 10 σ:

Significant operational gain with larger retraction!

Room until secondaries become primary collimators (quench):

1 σ retraction:

transient orbit change		1 σ	200 μm
transient beta beat		30 %	

4 σ retraction:

transient orbit change		4 σ	800 μm
transient beta beat		170 %	

Tolerance is a fraction of these values, e.g. ¼ (rough estimate).

Orbit:	**50 μm**	→	**200 μm**
Beta beat:	**8 %**	→	**40 %**

Much easier in operation! Much easier set-up! Much easier mechanical tolerances!
Details to be worked out!

Towards a three stage cleaning system?

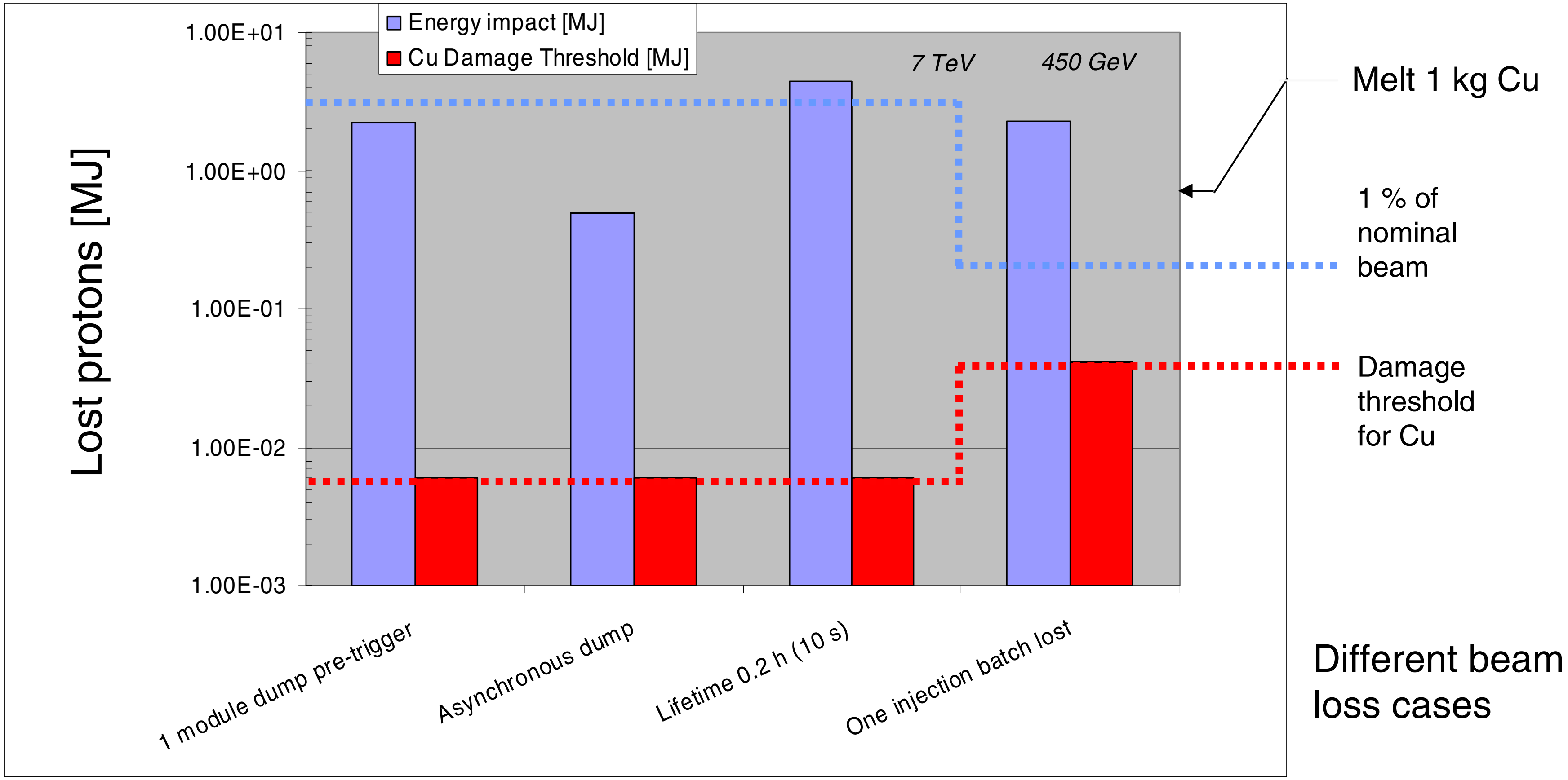
- A three stage system addresses our three biggest worries (impedance, robustness, tolerances). It involves **installation of tertiary collimators** before the triplets (50 cm Cu?).
- **Primaries** at 6 σ are short (~ cm), almost indestructible, and uncritical for set-up.
- **Secondaries** can be put to 10 σ at 7 TeV, into the shadow of the TCDQ.TCDQ impact rate in operation must be estimated.
- A **full C based system** would reduce impedance by a factor 3-4, while offering maximum robustness.
- A **system with Be surfaces** would reduce impedance further, however is less robust and introduces toxic material.
- A **hybrid system C/Metal** would offer full robustness at injection and very low impedance at top energy (taking advantage of protection by the TCDQ). Nice possibilities for optimization (robustness vs impedance vs efficiency vs vacuum vs experimental background).
- A three stage system with retracted secondary collimators would be much easier for set-up, operation, and mechanical tolerances. **Win factor 4-5 in tolerances!**
- **Full flexibility of the LHC is maintained** (tunes, β^*, …).
- Triplet absorbers are also required for **machine protection** (RS, MPWG).
- Experiments are **better protected** against failures, however, **experimental background** from beam might increase (to be studied), even though collimators are before D1 (showers are swept out).
- In operation we always can go back to the 2-stage system (no risk).

Conclusion:

- We are facing very difficult challenges.
- The **schedule for decisions** is very tight (major decision required end of April 03).
- Accurate **input and understanding of constraints** is very important for making a good decision.
- The collimation project cannot decide on **global LHC issues** (e.g. impedance budget). Guidance needed.
- Thinking is ongoing to propose a **system which relaxes problems** as much as possible while **fully maintaining LHC performance and flexibility**.
- A **three stage system addresses** three major worries (impedance/ robustness/ tolerances) and might relax requirements. Pre-mature to judge on feasibility.
- Other worries under consideration: Radiation and remote handling, experimental verification of assumptions, small impact parameters, vacuum, …

Additional Slides

Most relevant cases of beam loss:



Protect against: Beam dump irregularities at 7 TeV (horizontal)

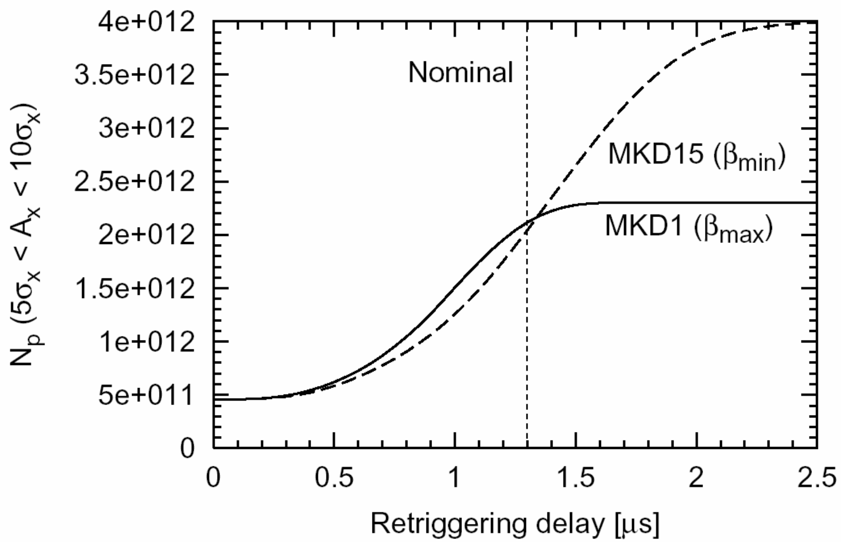
Losses from low lifetime at 7 TeV (any plane, any collimator)

Injection oscillations (mainly vertical, selected collimator?)

Other possibilities to relax requirements:

1. Shorten re-trigger time of dump (LHC PN 293)

Origin	450 GeV		7 TeV	
	ΔT [ns]	T_{sum} [ns]	ΔT [ns]	T_{sum} [ns]
Erratic switch No. 1	0	0	0	0
Re-triggering pick-up 10 V signal	400	400	200	200
Cable delay	180	580	180	380
Trigger unit delay	120	700	120	500
Cable delay + transformer delay	100	800	100	600
Turn delay GTO stack	400	1200	400	1000
Operational margin	300	1500	300	1300



2. Fix phase advance between dump and primaries (LHC PN 293)

	Beam 1		Beam 2	
Element	ψ_x [2π]	$\psi_x - N\pi$ [degree]	ψ_x [2π]	$\psi_x - N\pi$ [degree]
MKD kicker	0.	0.	0.	0.
TCDQ absorber	0.266	95.8	0.2653	95.5
Primary coll. (β-cleaning)	7.457	164.7	56.366	131.6

Optics V6.4

All beam should impact one primary horizontal collimator! Fix phase advance! Make short secondaries (injection?)
Beam 2: Fix phase advance to beta and momentum cleaning or freeze setting of momentum collimators.

3. Anti-kicker at the dump (BG et al)

4. Use TCDQ as primary hor. collimator for betatron cleaning at 6 σ (RS, BG).

Idea: Remove dump failures from our list of requirements for LHC collimators. Injection case stays.

Problems: One stage system has insufficient cleaning efficiency.

We do not win very much in impedance:
10 m long uncoated C jaw at 6 σ will create strong resistive impedance.
Win with square root of beta (sqrt(500/100) ~ 2.2).
However, secondary collimators will remain at 7 σ (triplet aperture).

Other collimators must remain robust for injection failures (no Al/Cu) and operation.