A Three Stage Cleaning System with Improved Robustness and Impedance for the LHC

Collimation Working Group

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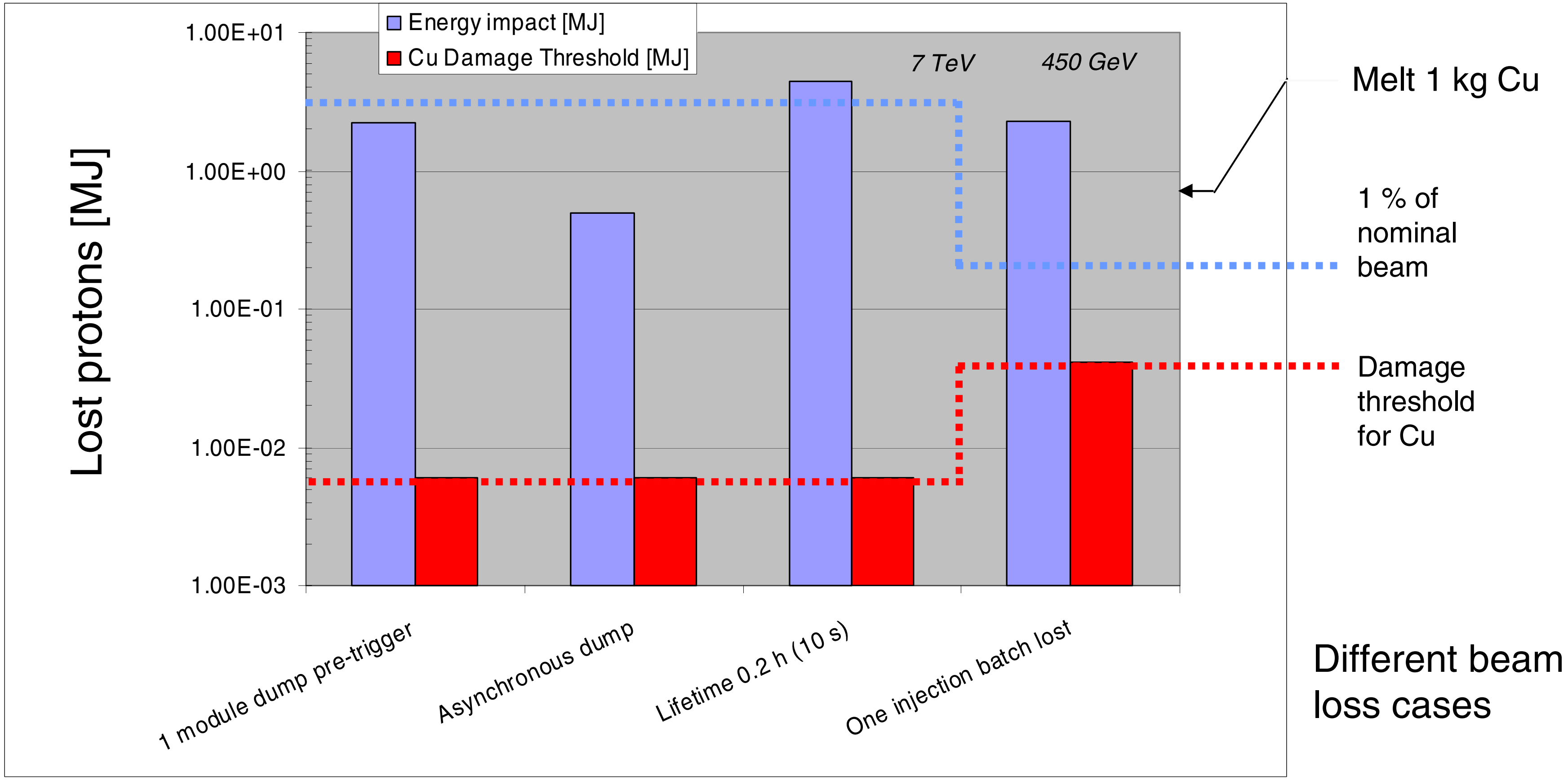
Most relevant cases of beam loss:



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?)

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 cannot avoid impact of one injected batch?)

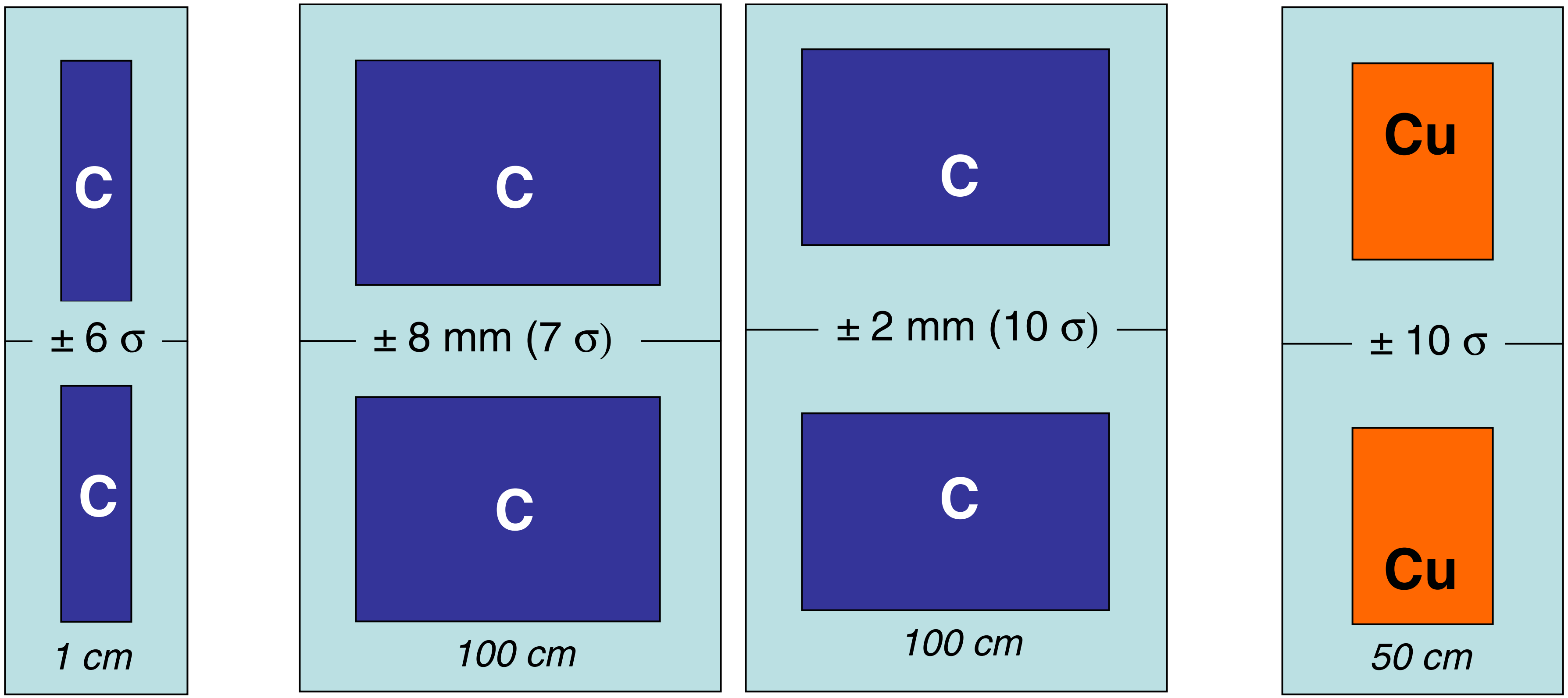
At 7 TeV: Use **short primary** (1 cm C) at 6 σ. Will be very robust!
Use **long secondaries** (1 m C) at 10 σ. In shadow of TCDQ.
Use **long tertiaries** (1m C) at 10 σ to clean 10 -13 σ secondary halo

Note: Ignoring cases at 450 GeV, we could go to short secondaries and tertiaries, made out of Cu (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.

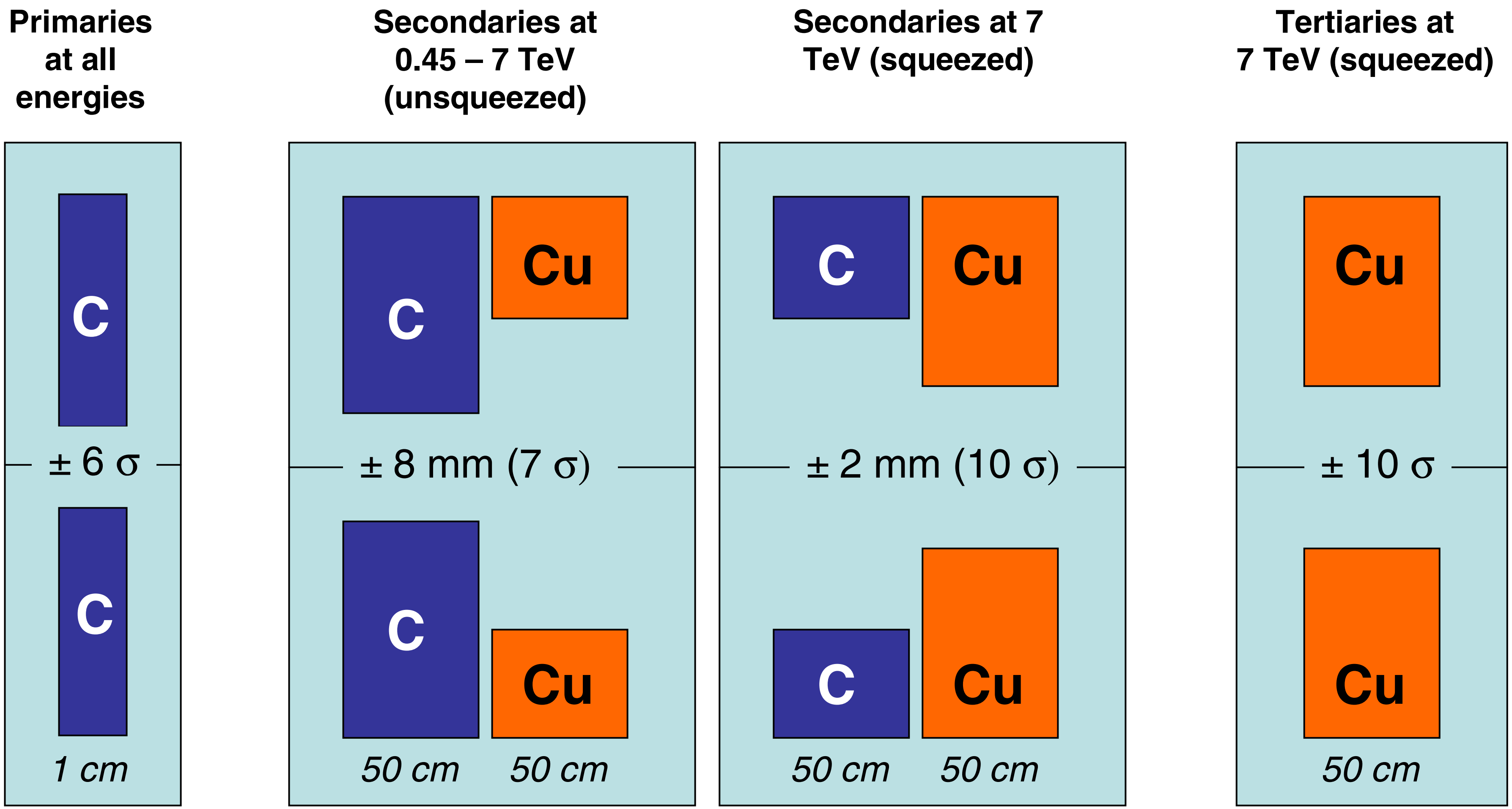
A robust, low impedance, high efficiency 3-stage system:

Primaries at all energies	Secondaries at 0.45 – 7 TeV (unsqueezed)	Secondaries at 7 TeV (squeezed)	Tertiaries at 7 TeV (squeezed)



Primaries almost indestructible, robust C secondaries, local cleaning at triplets, relaxed tolerances orbit and beta beat, good efficiency.
System fully based on C: Factor 3-4 improvement in impedance!

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.

Cleaning efficiency with short primaries:

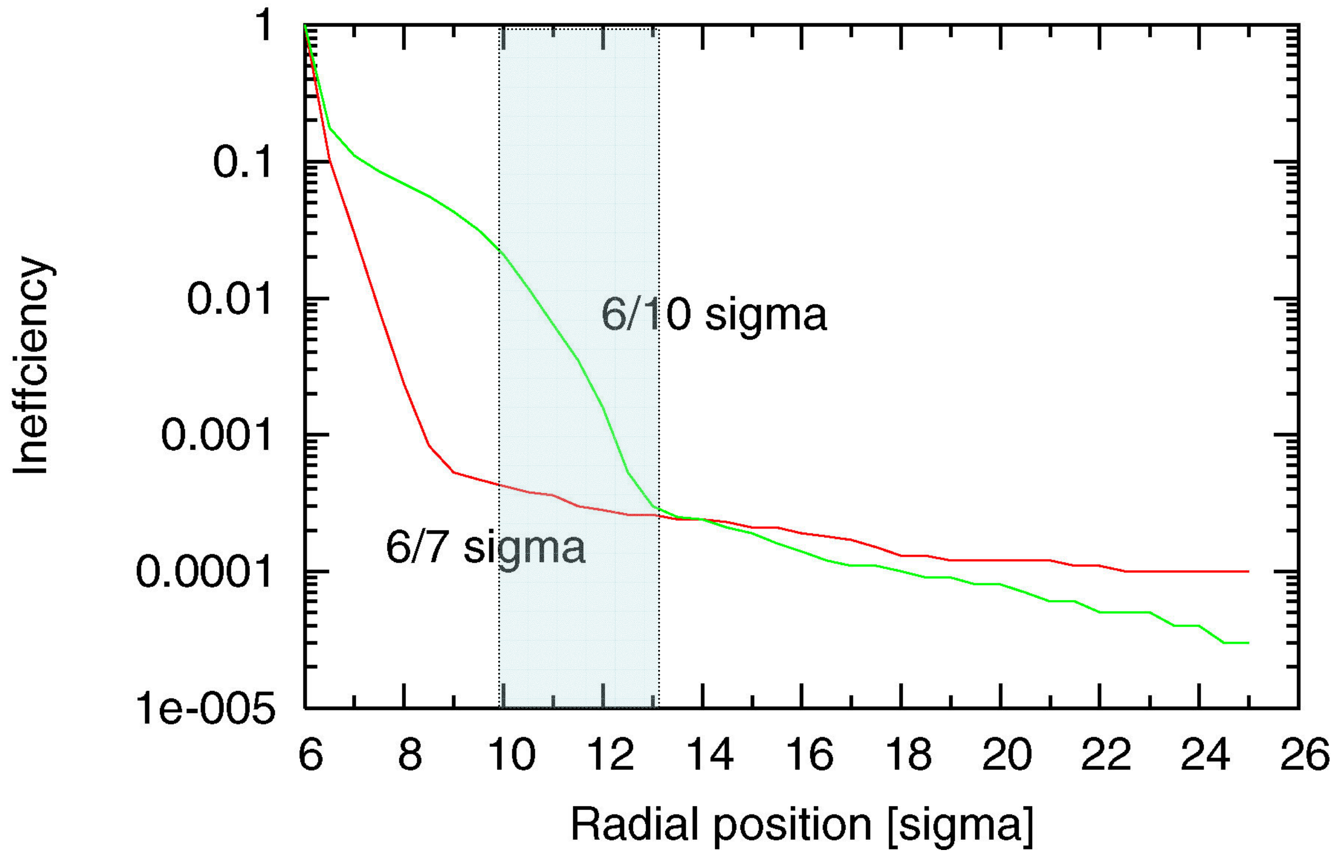
20 cm C:	**2.9×10^{-4}**	(>10 σ)
1 cm C:	**7.8×10^{-4}**	(>10 σ)

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).

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?**

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

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. 1/4.

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!

Conclusion:

- A three stage system is proposed.
- 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.
- A **full C based system** would reduce impedance by a factor 3-4, while offering maximum robustness.
- A **hybrid system C/Cu** 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).
- A three stage system 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).

If no show-stopper is discovered and if there is support for this idea:

Work out details (lengths, materials, settings, …).

Check possibilities for tertiary collimators at triplet/D1.

Determine whether Cu can be used in routine operation (low lifetimes)!

Get feedback from LTC (next Wednesday).

Get feedback from Collimator Project Meeting (engineering constraints).

…

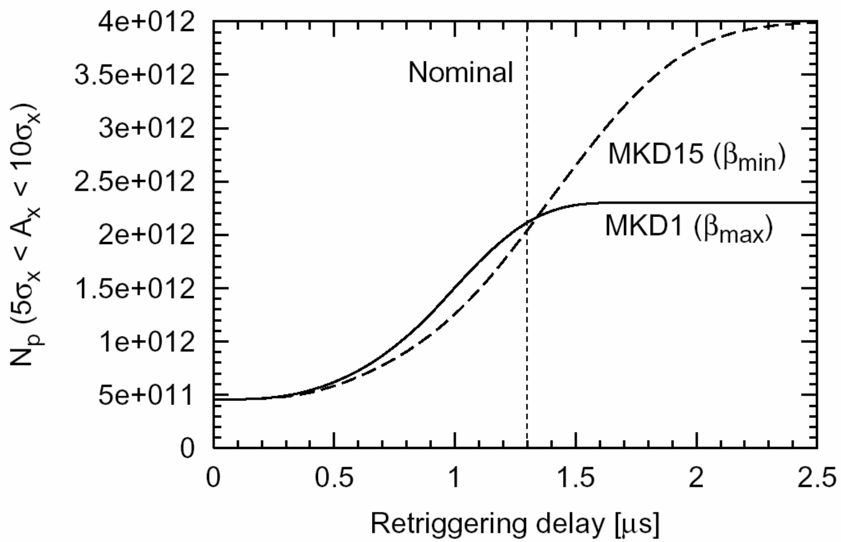
Propose to LTC, LHC Project Leader for a decision.

Impedance must be understood in any case!

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.