Safe beams without collimation

LCC, Nov 2001

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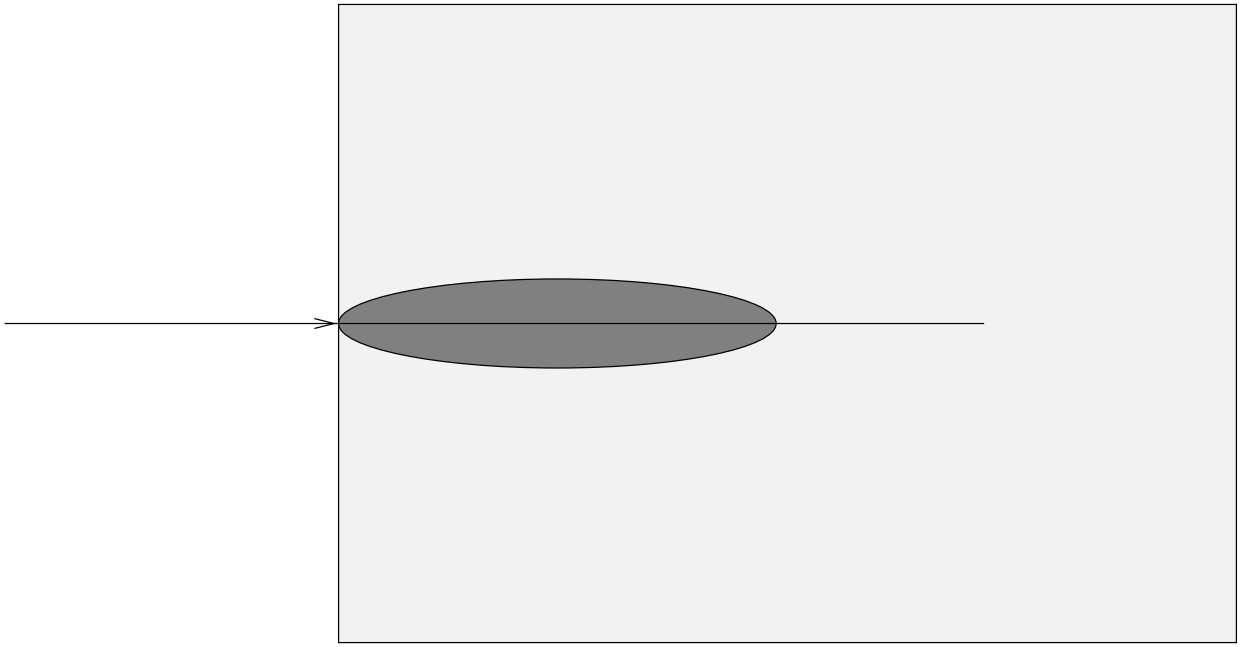
/Text/LHC/2001/lcc_7nov/slide

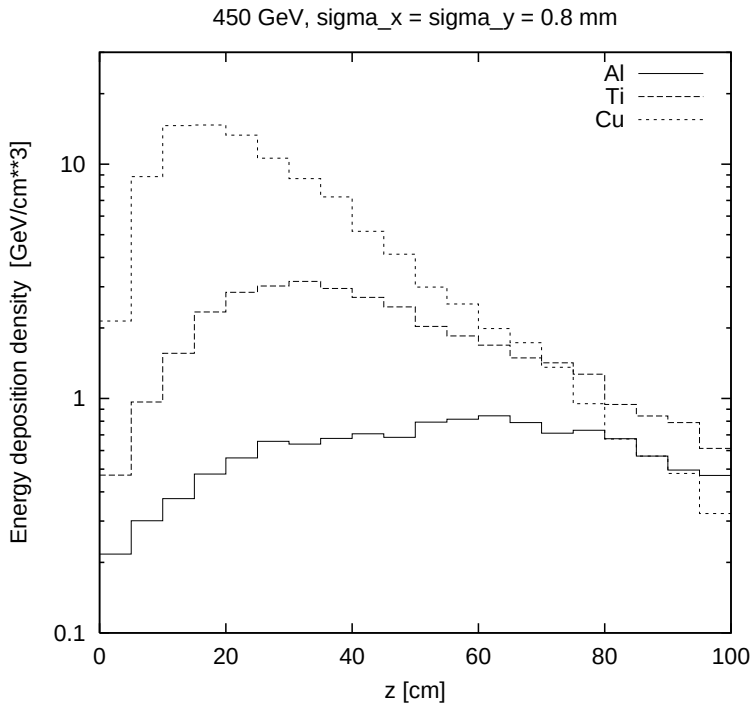
Calculations

- 1 - Worst case: straight on impact (simulation I.Baishev/IHEP)
- 2a- Intermediate: 1 mrad impact angle - beam screen
- 2b- Intermediate: 1 mrad impact angle - s.c. coil
- 3a- Regular: 0.25 mrad impact angle - beam screen
- 3b- Regular: 0.25 mrad impact angle - s.c. coil

Straight impact,Injection

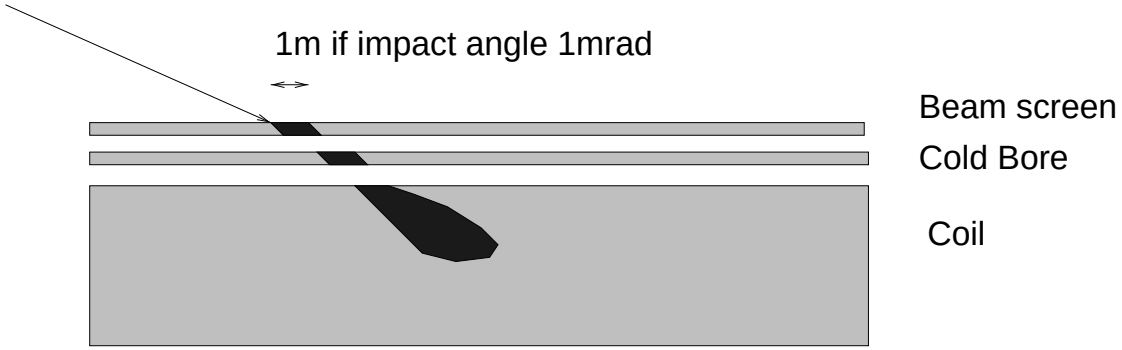


Straight impact,Injection



Regular case, Injection
maximum transverse energy density/proton

Impact angle : .25 mrad (22mm/100m=0.22mrad)



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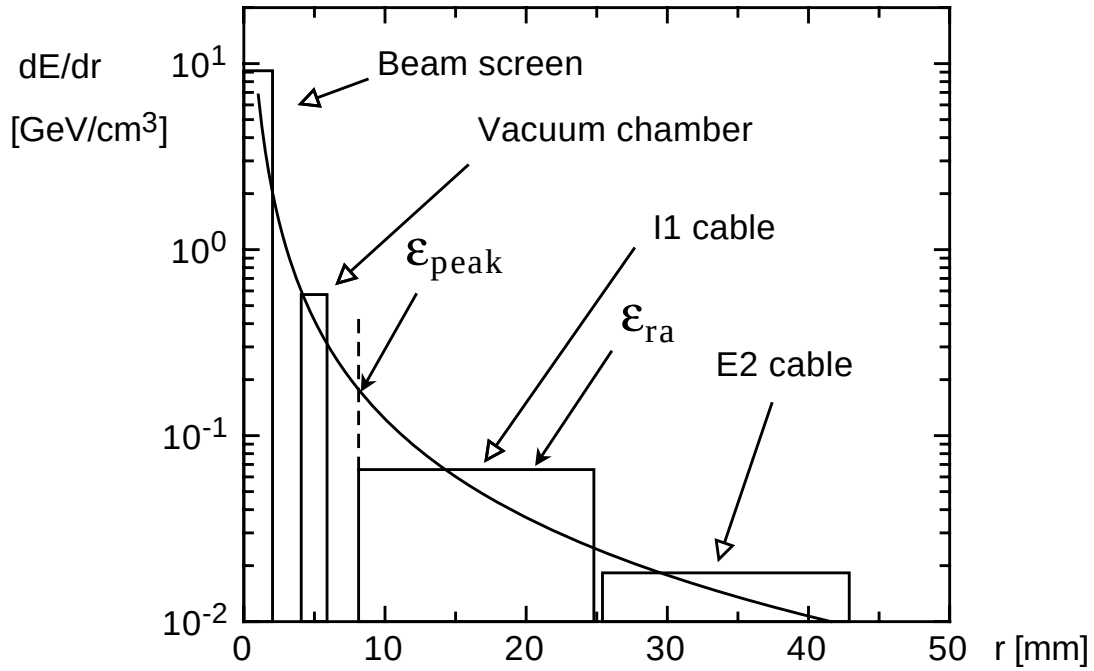

Thermal/mechanical criteria

Disclaimer: I am not an expert in metallurgy/s.c cable → Further checks?

pipe,passive elements

$$\Delta T = \frac{2}{3}(0.7T_{melt} - T_{room}) = 400\ \mathrm{K}\ \ (\mathrm{Copper}) \tag{1}$$

s.c. cable

$$aT^3 + bT^4 - (\frac{\Delta l}{l})_c = 0\ , (\frac{\Delta l}{l})_c = 4 \times 10^{-4}\ \rightarrow\ \ T_c = 104\ \mathrm{K} \tag{2}$$

$$\Delta Q = 9RT\frac{\rho}{m_A}(\frac{T}{\Theta_D})^3 \int_0^{\frac{\Theta_D}{T}} \frac{z^3 dz}{\exp(z) - 1} \tag{3}$$

$$\Delta Q_c = 87\ \mathrm{Jcm}^{-3}\ . \tag{4}$$

Straight results
Number of bunches at limit of destruction

	Case	injection	top	material
1	Straight on $x' = \pi/2$	5.3	0.05	Copper
2a	Intermediate $x' = 1.0$ mrad	7	0.2	Beam screen
3a	Regular $x' = 0.25$ mrad	8	0.4	Beam screen
2b	Intermediate $x' = 1.0$ mrad	12	0.4	s.c. coil
3b	Regular $x' = 0.25$ mrad	22	0.7	s.c. coil

Impact angles

- CO corrector $\alpha^{co}_{max,inj} = 1.2\,\mathrm{mrad} \Rightarrow$ 'intermediate' case
- $\alpha^{D's}_{max,inj} = 15 \times \alpha^{D's}_{max,top} \sim 30\,\mathrm{mrad} \equiv \pi/2 \Rightarrow$ Case 1

Therefore, the 'Regular case' can be considered if

- The 'pilot bunch in' strategy is made mandatory (proposal MPWG)
- The CO control between .45 and 7 TeV is secured (what does that mean: MPWG, LCC)
- Look further to quench limits

Summary

Margin on destruction case : $\sim 30\%$

	Destruction	Quench
Nb of bunches	N_b^d	N_b^q
Injection	8	10^{-2}
Top	0.4	10^{-5}

Number of bunches computed with 1 bunch $n_p = 1.05 \times 10^{11}$

What counts is $N_b \times n_p \rightarrow$ scaling allowed

Notice: at top energy, $N_b^d = BPMsens./5 \rightarrow$ *No safe mode*

(my) recommended additional precautions

- No collimation $\rightarrow$ Weak collimation ($8 - 10\ \sigma$)
- BLM system fully operational
- Strict secure operational procedures for full coast also applied (what does that mean: MPWG, LCC)
- Clean injection mandatory (collimation in transfer line still under design/discussion)
- pilot(5%) $\rightarrow$ 1 full bunch $\rightarrow$ 8 bunches highly recommended

Ion beam

- Ion hadronic shower have a shape nearly identical to protons
- But the density is Z times higher
- $\Rightarrow$ Scaling: Total $N_{ions} = N_{protons}/Z$
- Lead: $Z = 82$ $\Rightarrow$ destruction limit is

$$N_{inj} = 8 \times 1.05 \times 10^{11}/Z = 9.8 \times 10^{9} \quad (5)$$

$$N_{top} = 10^{-2} \times 1.05 \times 10^{11}/Z = 1.3 \times 10^{7} \quad (6)$$

- Yellow Book: $N_{stored} = 10^{10}$ ions
- $\Rightarrow$ Safe at injection

References

[1] Quench levels and transient beam losses in LHC magnets, J.B. Jeanneret, D. Leroy, L. Oberli and T. Trenkler, LHC Project Report 44, July 1996.

[2] Optics constraints imposed by the injection in IR2 and IR8, O.S. Bruning and J.B. Jeanneret, LHC Project Note 141, May 1998.

[3] S. Fartoukh, J.B. Jeanneret and J. Pancin. *Heat deposition by transient beam passage in spoilers*, CERN-SL-2001-012(AP), CERN, Geneva, March 2001, to be submitted to Physical Review.