Quench levels at 450 GeV

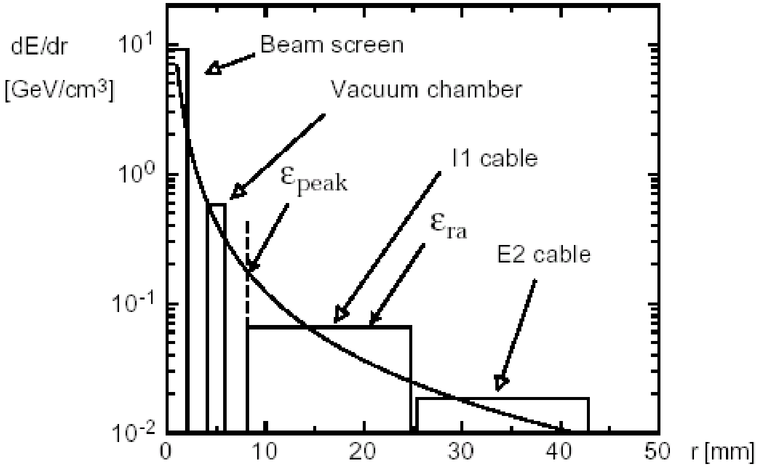
- Recall briefly LHC project report 44: “Quench levels and transient beam losses in LHC magnets” J.B. Jeanneret, D. Leroy, L. Oberli, T. Trenkler
  - In particular fast losses at 450 GeV

- Single proton impacting beam screen
- Hadronic/electromagnetic shower developing with an effective length of something like 1 m. with almost all incident energy converted to heat.

- CASIM simulations
  - Incident proton on beam screen with grazing angle x’ = 0.24 mrad in horizontal plane

Radial dependence

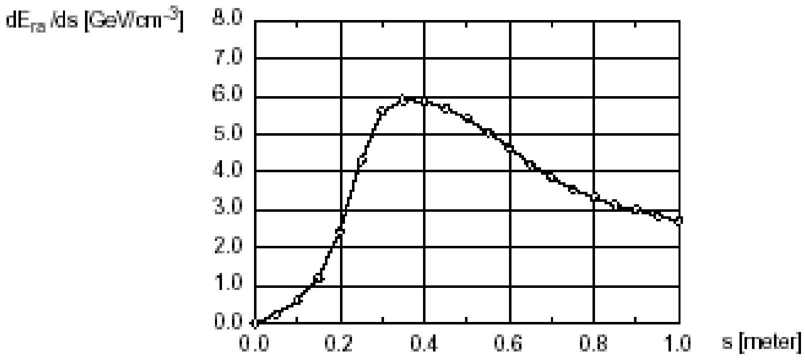
- **Estimate peak energy deposition in the cable**
- **Beyond the beam screen and the vacuum chamber the conductor closest to the impact point receives the maximum energy density**
- **For fast beam losses the Quench limit occurs at the edge of the cable facing the beam**
- **Maximum energy deposited per proton at that radial position is call ε_{peak}**



Longitudinal dependence

- **Calculate peak and radial energy densities for:**
  - **local losses**
  - **distributed losses**
- **Calculate the energy density ε_{dist} per proton per metre related to a longitudinally distributed loss of protons in the most exposed cable**

$$\varepsilon_{dist} = e_{peak} \times L_{eff}$$



- **L_{eff} at 450 GeV = 1 m. $\Rightarrow$**

$$\varepsilon_{peak,local} = 0.24\,\mathrm{GeV \cdot cm^{-3}} = 3.8 \times 10^{-11}\,\mathrm{Jcm^{-3}}$$

$$\varepsilon_{peak,dist} = 0.24\,\mathrm{GeV \cdot m \cdot cm^{-3}} = 3.8 \times 10^{-11}\,\mathrm{J \cdot m \cdot cm^{-3}}$$

Quench

- **Time duration of losses fast compare with thermal diffusion times, number of protons required to induce a quench is:**

$$n_q = \frac{\Delta Q_c}{\varepsilon}$$

- **Where ΔQ_c is the amount of heat per unit volume needed to raise the temperature to its critical value T_c**

- **Specific heat goes as:**

$$c_v = c(T) = 10^{-3}\varepsilon\left[\left(\frac{6.8}{\varepsilon}\right) + 43.8\right]T^3 + (97.4 + 69.8 \cdot B)T \quad [\mathrm{mJ/cm^3} \cdot K]$$

- **Use volumetric specific enthalpy – integral of the specific heat with respect to temperature**

- **Heat input needed to go from one temperature to another – difference in enthalpy between the two temperatures**

- **At 450 GeV with B = 0.56T, T_q=9 K,**

$$\Delta H_{wire} = 38\ \mathrm{mJcm^{-3}}$$

- **For very short loss duration, no temperature equalisation:**

$$\Delta Q_{critical} = \Delta H_w \quad \text{and} \quad \varepsilon = \varepsilon_{peak}$$

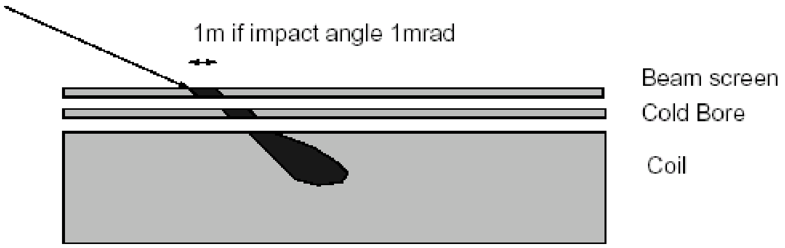
- **Local loss of 1.0×10⁹ protons**
- **or distributed loss dN/ds of 1.0×10⁹ protons/m**

- **JB assumes distributed loss with angle of incidence ≈ betatron angle**

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

$$\Delta s = \frac{2\sigma}{x'} \approx 11\,\text{m}.$$

$$\Rightarrow \text{n}_\text{q} = 10^9 \Delta s = 10^{10} \text{ protons}$$



Issues

- **Dangers – whether to quench or not?**
  - Even straight in, JBJ reckons destruction is 5.3 nominal bunches at 450 GeV (Further checks suggested)
  - Thermal stress?
- **How?**
  - We have the strength to stick the beam straight into a dipole

$$\delta_{\max}^{450} \approx 1.26\ \mathrm{mrad}$$

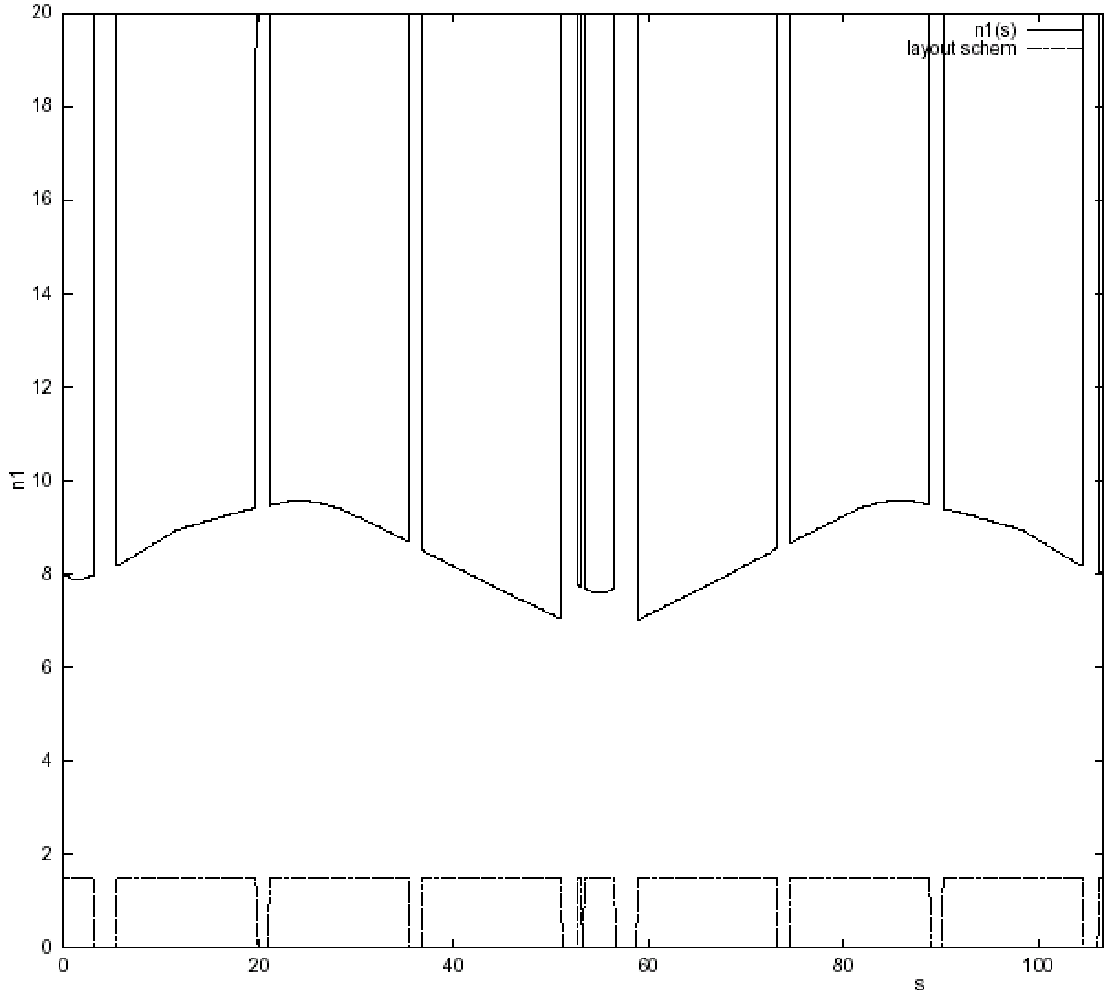
  - However a 3-bump is probably more judicious

- **Where?**
  - Horizontal
  - Beam losses inevitably near QF (max beta. max dispersion), with aperture limited by beam screen

Issues

- What?
  - Quad or dipole? Both?
- How many quenches?
- Requirements

- Simulations. Verification of simulations.


n1(s)
layout schem
n1
s
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100