Beam Wire Scanner - answers

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Result presented in June - reminder

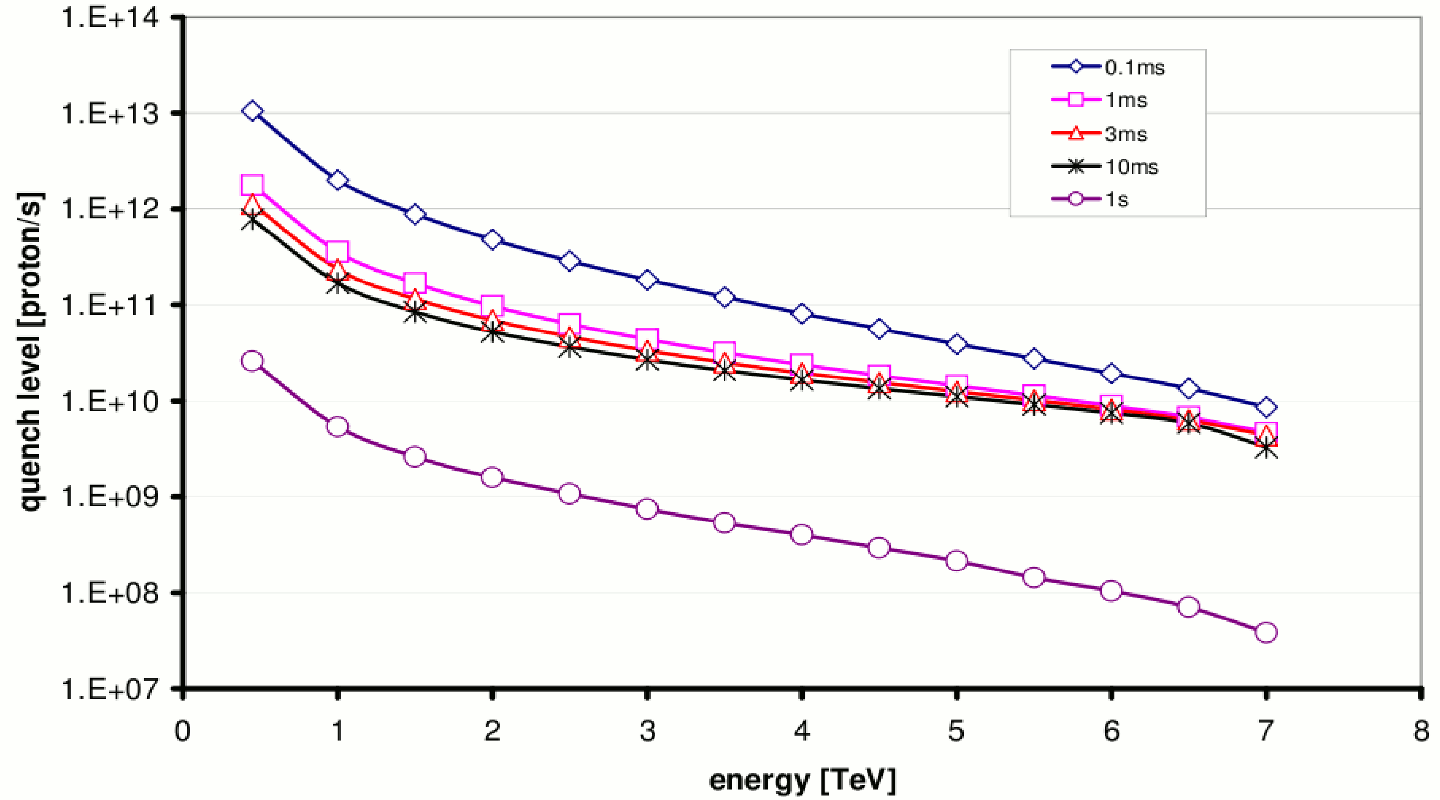
- The scan deposits energy in SC magnets downstream – more affected is Q5 (46 m) than D4 (33.7m)
- The “hot” zone is at the entrance to Q5
- At 7 TeV the Q5 will quench already at about 2% of the nominal beam
- This estimation has a large error (1-7%)

4 questions after presentation on June 7th

- What are theoretical limits on beam intensity in case of 450 GeV (quench and wire breaking) and 7 TeV (wire breaking)?
- What is the impact of the wire speed on quench and wire breaking at different energies? Can we slow down the wire to have more points for 7 TeV?
- What is the time necessary to recover (cool down) Q5 magnet between 2 scans
- Is there anything influenced after Q5?

Quench level at injection

- Comparing with beam losses
  - – there is factor 10^2 -10^3 difference



Therefore there should be no quench during scanning of injection beam

Model of carbon wire heating in accelerator beam

beam heating

Heat capacity

radiative cooling

heat conduction

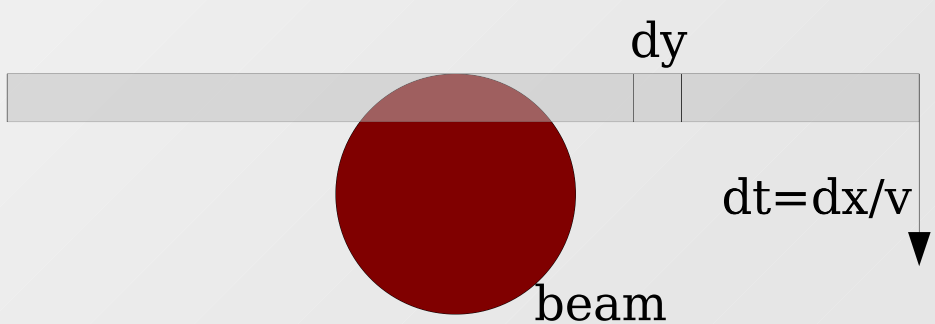
$$\Delta E \frac{dN_{hits}}{dt} = \rho_C V c_p(T)\frac{dT}{dt} - A_{rad}\epsilon\sigma(T^4 - T^4_{amb}) - \lambda(T)A_d\frac{dT}{dy}$$
$$- A_{rad}\left(\phi + \frac{2k_BT}{q_e}\right)J_{th} + C(y)J_{th} - \Delta H_{sub}\frac{dn}{dt}$$

thermionic current

heating by current compensating thermionic

sublimation heat

nonlinearity -> numerical solution

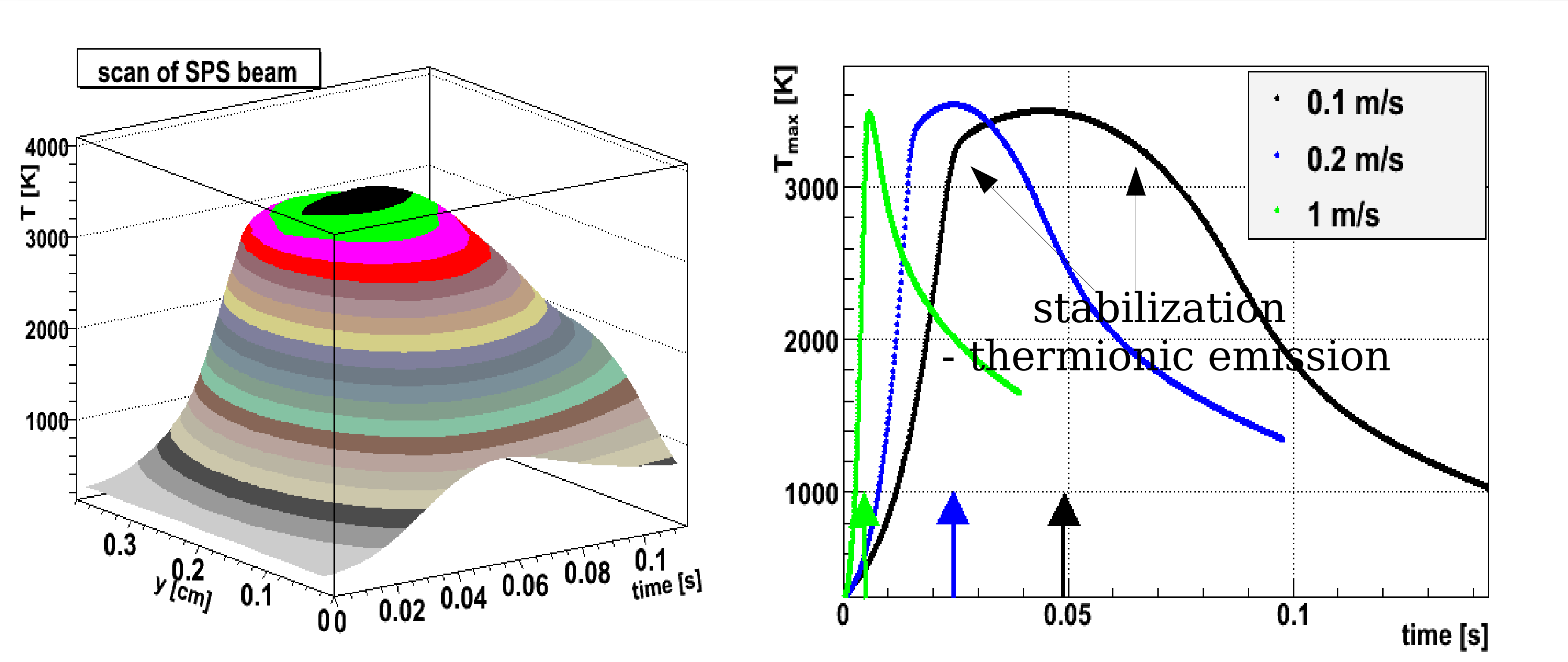


+ RF-heating simulation (Tom Kroyer)

+ simple sublimation model

Model test

- Results of 1988 experiment on wire breaking on SPS
- V=10 cm/s, $2*10^{13}$ protons, σ=1.6 mm

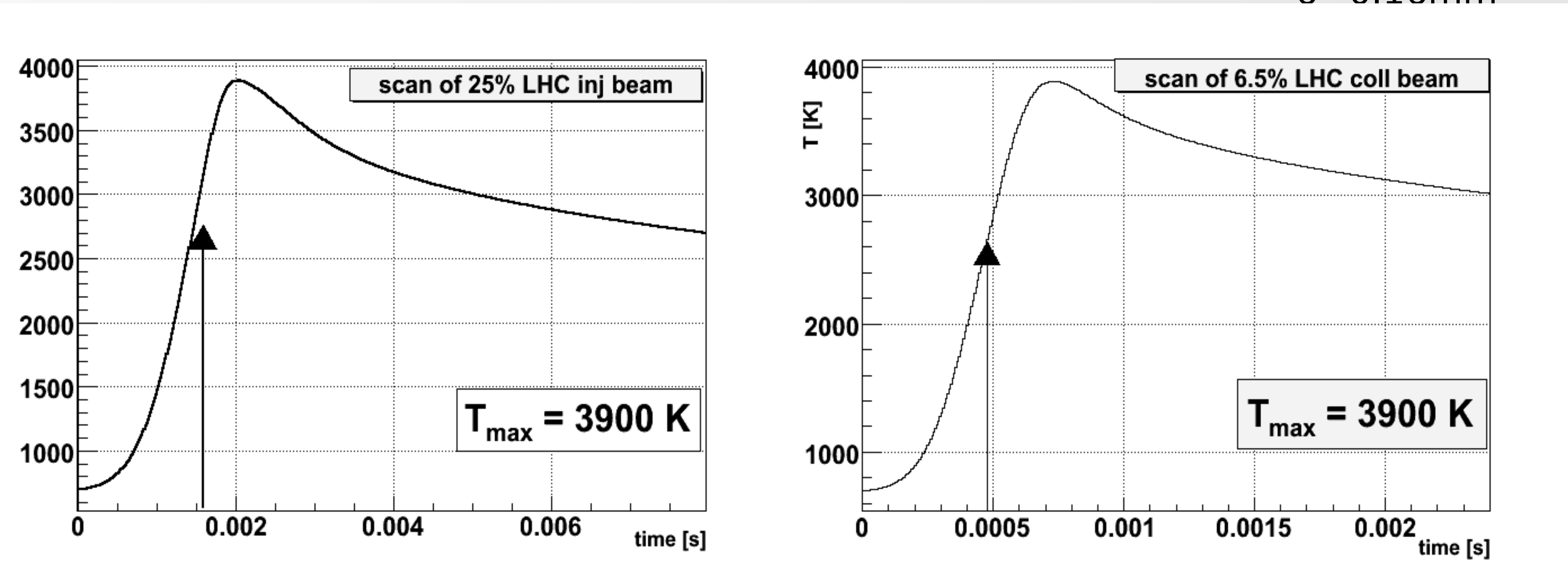


Total Edep about 0.25 J (central bin),
more than a half of the wire radius sublimates
Tmax = 3500 K, thermionic cool. dominant above 3200 K

Results for LHC

•Beam energy is not important, σ
•Already for σ=0.5 mm and wire speed 1m/s the cooling precesses have no time to react
•In this case the maximum temperature is a criterium

•σ=0.16mm



- 25% of injection beam (sigma=0.53 mm)
- 6.5% of collision beam (sigma=0.16 mm)

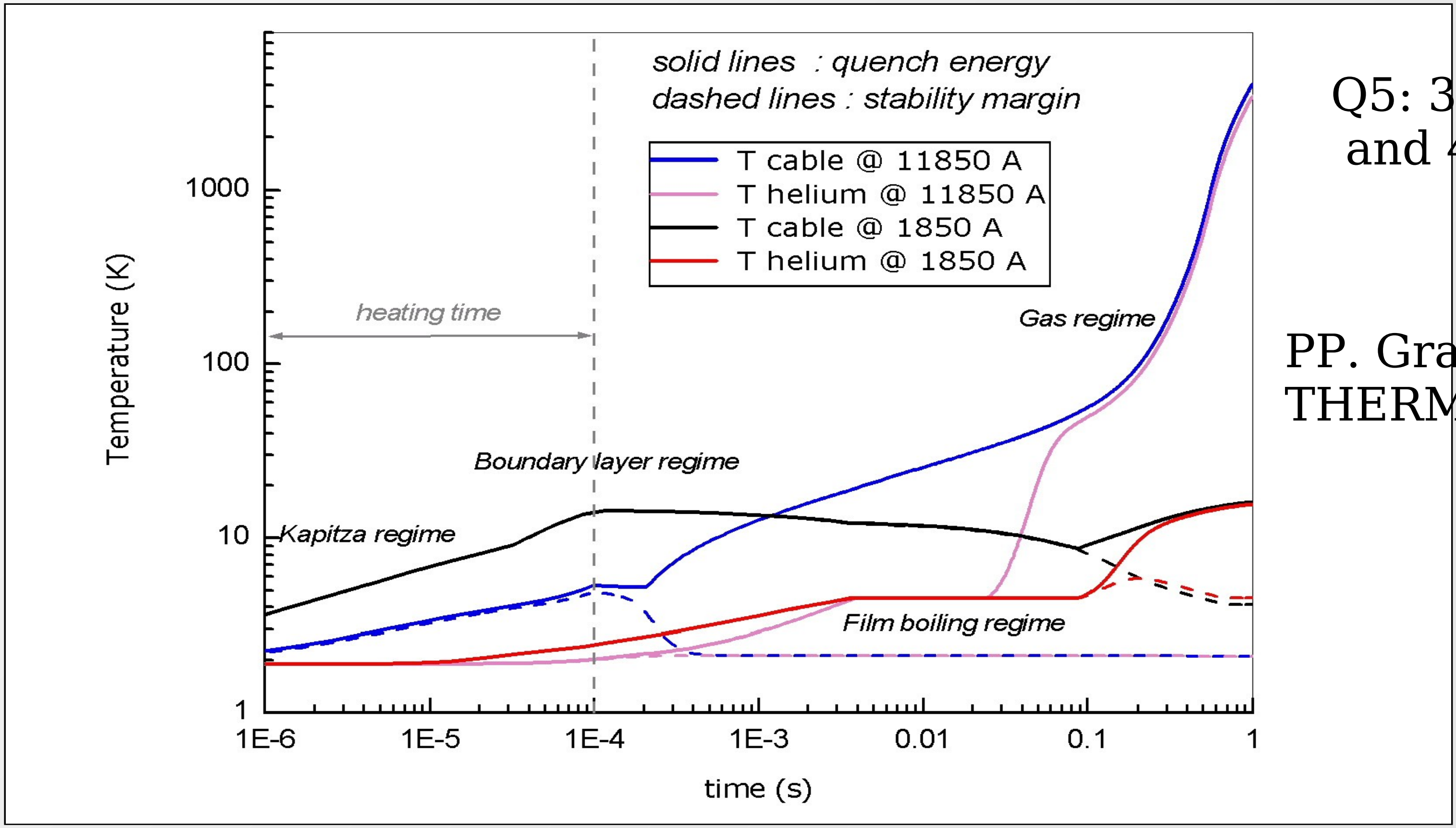
Can we slow down the wire to have more points on the beam profile curve?

According to above results the correct strategy would be rather to increase the electronics sampling frequency – there will be enough signal in the PMTs. Slower scan means lower beam intensity which can be scanned.

Slowing down the wire has sense in case of a single bunch.

How fast Q5 cools down

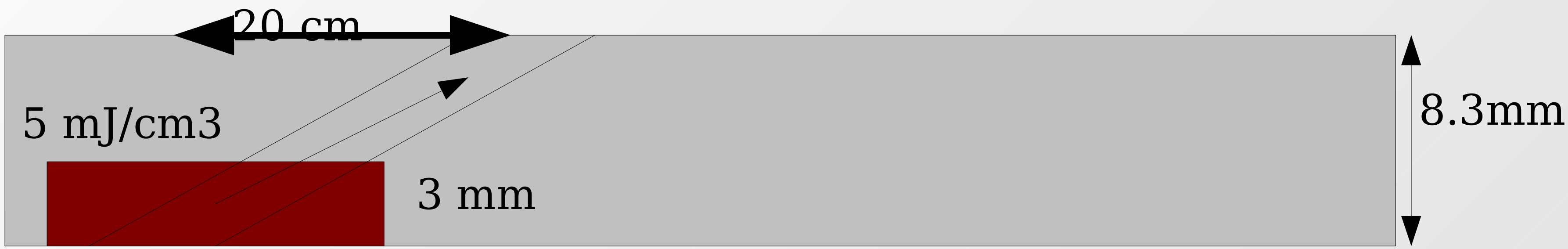
after heating there is a “decision time” when cable waits to quench or not, after that it cools down. The actual calculation for 4.5 K cable is not yet available, but we can conservatively say that after 1 sec Q5 comes back to its initial state.



Q5: 3610 A
and 4.5 K

PP. Granieri
THERMOMAG 07

How fast the Q5 cools down?



Heat transfer from hot zone (Tc = 10 K)
to cold zone (T=4.5 K) along the strand

$$\mathbf{V\, c_v\, dT/dt = K\, A\, dT/ds}$$

strand thermal conductivity

strand cross section

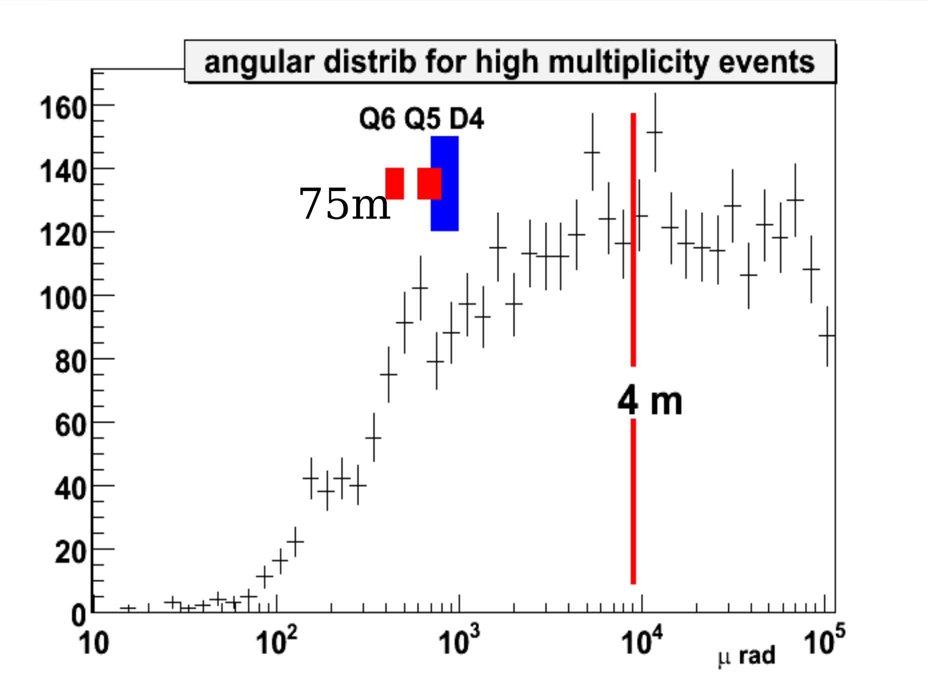
temperature gradient along strand

assuming: dT/ds = const
K = 1.8 W/cm/K
d = 0.735 mm

$$dT/dt = K\, dT/ds\ / (V\, c_v)$$
$$= \text{about } 10\ K/s$$

→ next scan after about a few seconds

Does wire scanner influences magnets after Q5?



No deviation due to magnetic field included
but
lower angle = higher energies

These is angular distribution of particles leaving the wire, 'tertiary' particles produced by the interaction with D4, Q5 etc are not included

It is difficult to judge but Q6 is safer than Q5 because there should be slightly less secondary particles. A proper tracing algorithm should be used.
Using numbers from collimators it can be said that the influence after about 50 meters decreases.