Alternative Conductor Concept for SIS-100 at the IAF-GSI

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Problem statement

- SIS-100 will be a pulsed machine with very heavy duty cycle
  - 2 T at 1 Hz, 4 T/s
  - 10^7 operation cycles . Present design *may* require additional optimization.
- performance and reliability of SIS-100 will affect the whole complex
  - 10^7 operation cycles
- Present design *may* require additional optimization

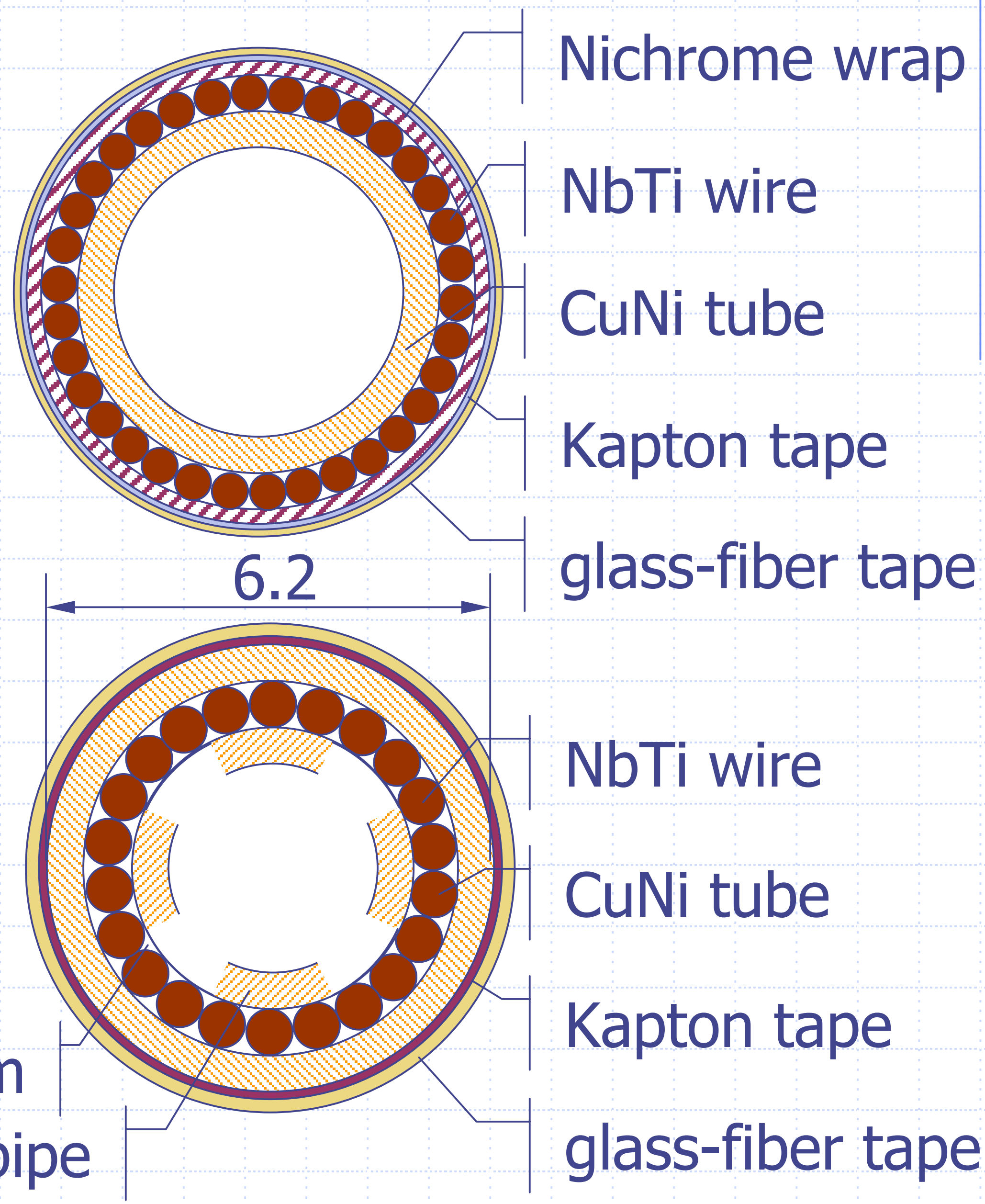
A proposal

bring strands close to He

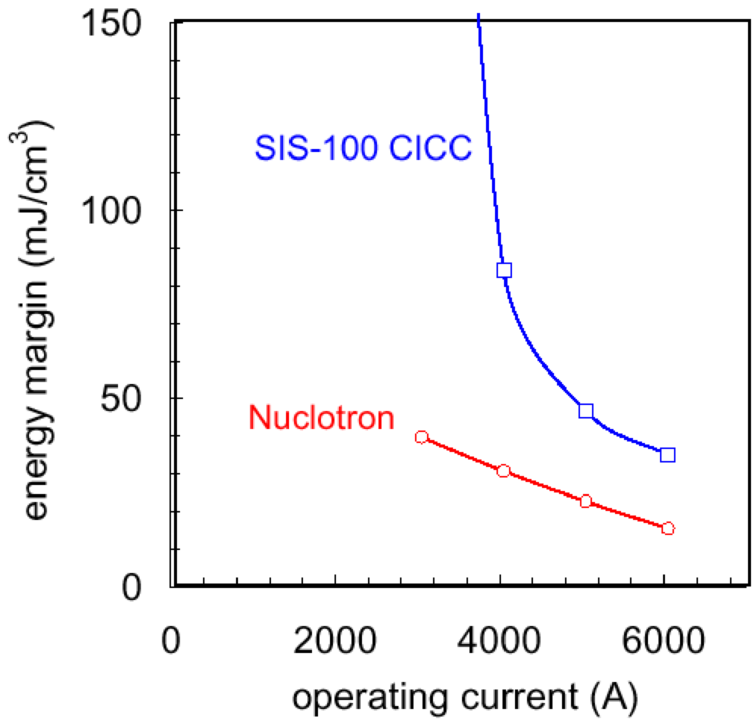
provide a low-impedance cooling path

use realistic strand data J_c=5200 A/mm^2

maintain operating conditions



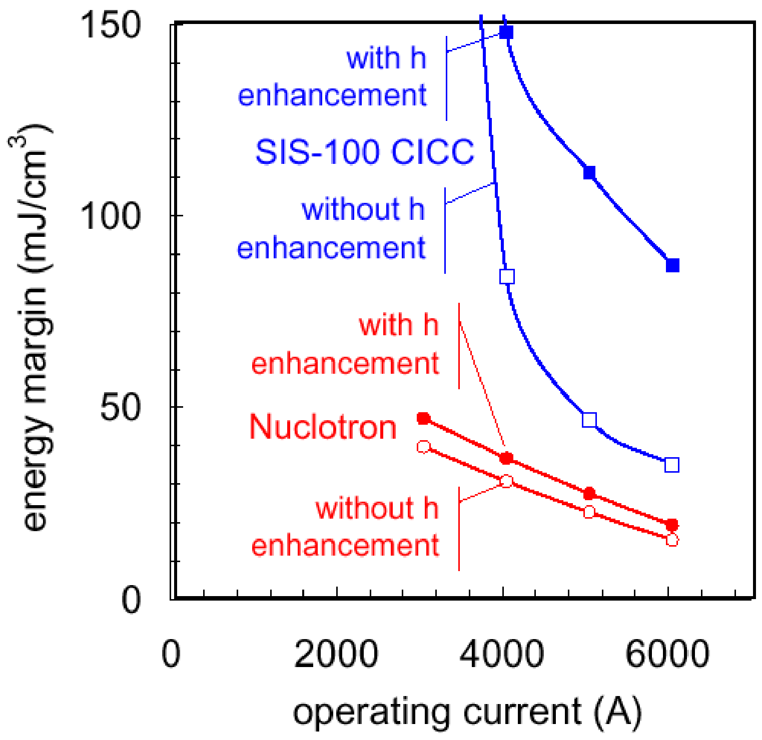
Stability analysis (1/3)



- analysis of stability margin as a function of the operating current
  - simplified simulation
    - supercritical helium at 3 bar, 4.22 K
    - no transient heat transfer
    - 1 ms perturbation time

clear gain in stability

Stability analysis (2/3)

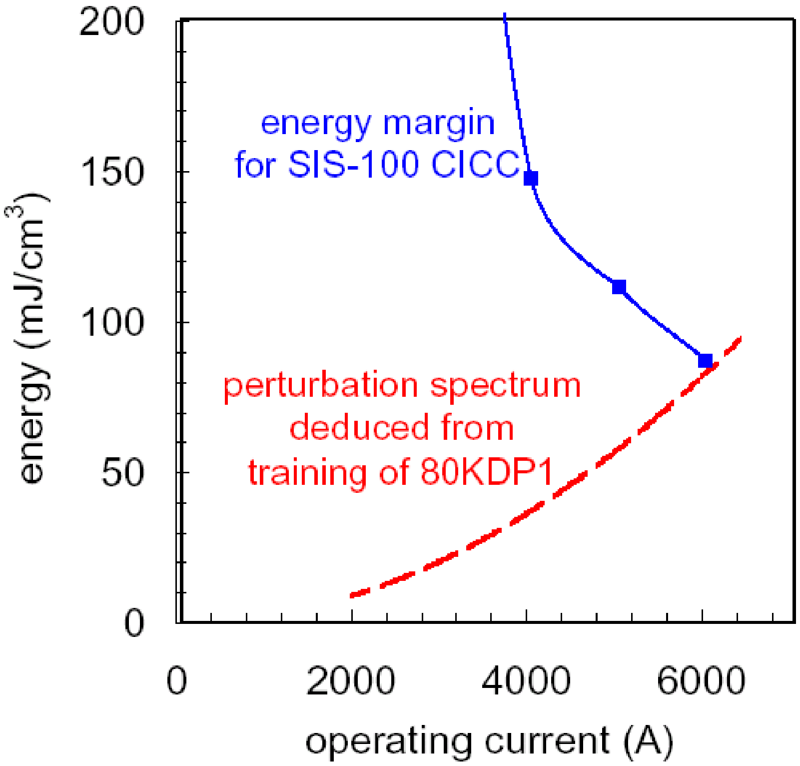


- effect of transient heat transfer important !
  - model as a boundary layer diffusion
    - supercritical helium at 3 bar, 4.22 K
    - 1 ms perturbation time
  - gain in stability is exceptional:
    - a factor 4.5 from 20 to 90 (mJ/cm^3)

Stability analysis (3/3)

- perturbation spectrum of the magnet:
  - first training quench of 80KDP1 at I_0=4 kA
  - computed stability margin Q_0=36.4 mJ/cm^3
  - estimated energy spectrum:

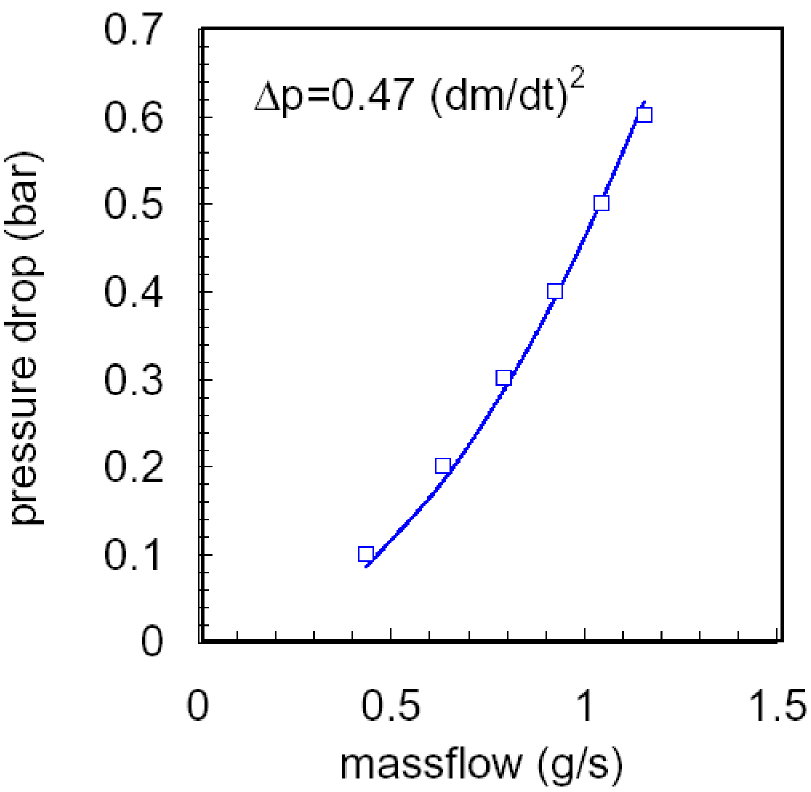
$$Q = Q_0 \, (I/I_0)^2$$



a SIS-100 CICC will have no training !

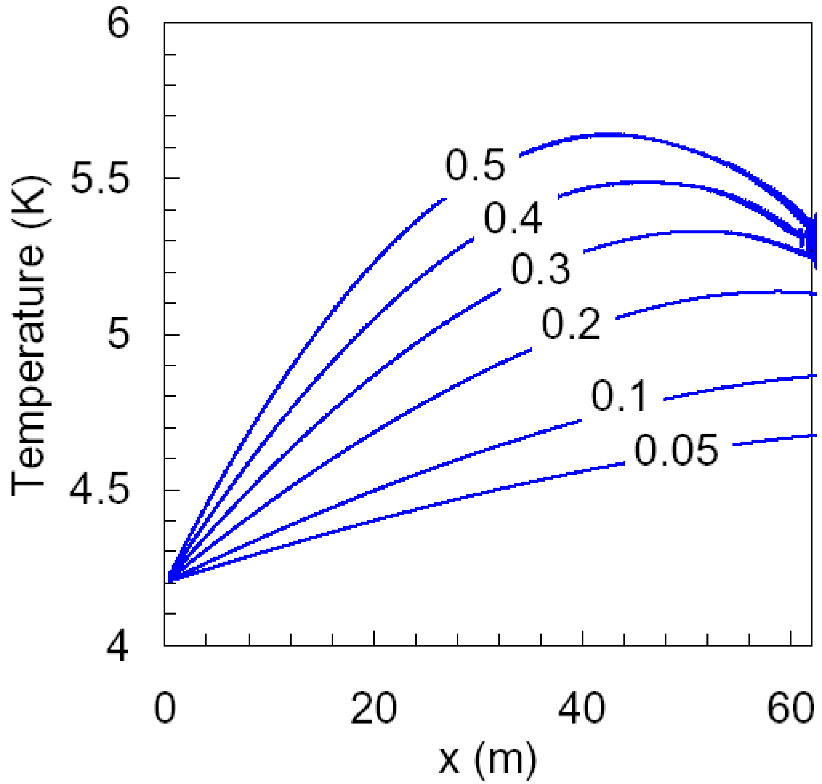
Flow and cooling analysis (1/3)

- supercritical helium analysis:
  - p_{in} = 3 bar
  - p_{out} = 2.4 … 2.9 bar
- modest pressure drop for the short conductor length as envisaged
  - L = 62 m
- the helium flows mostly in the central hole:
  - hole: 99…98 %
  - bundle: 1…2 %



Flow and cooling analysis (2/3)

p_{in} = 5 bar
p_{out} = 2.4 bar
dm/dt = 2.5 g/s

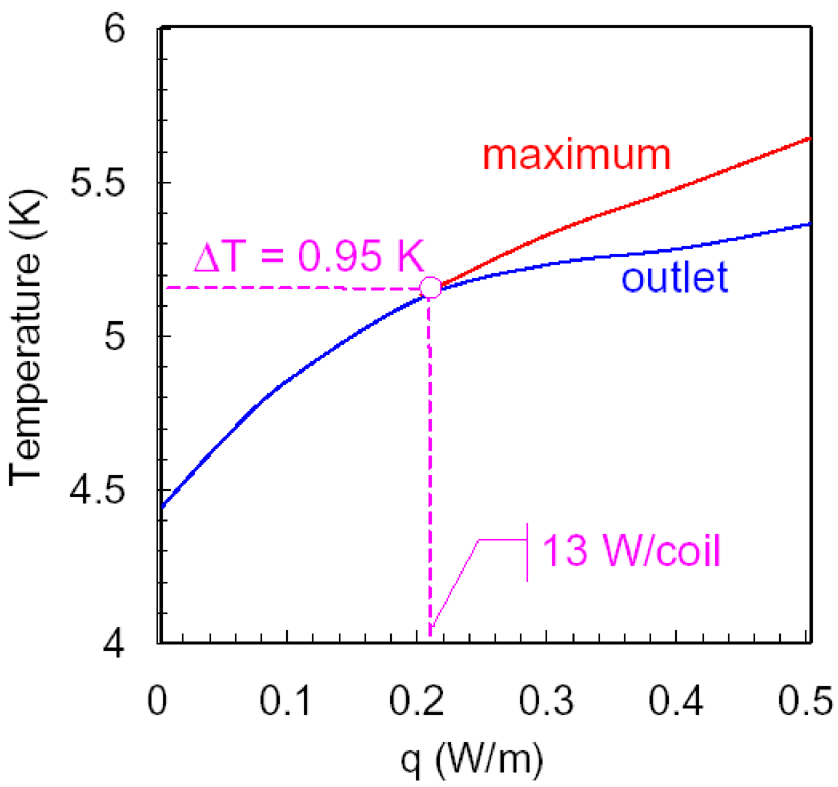


- maximum temperature is inside the coil for high heat load (above 13 W/coil) because of JT expansion along the cable

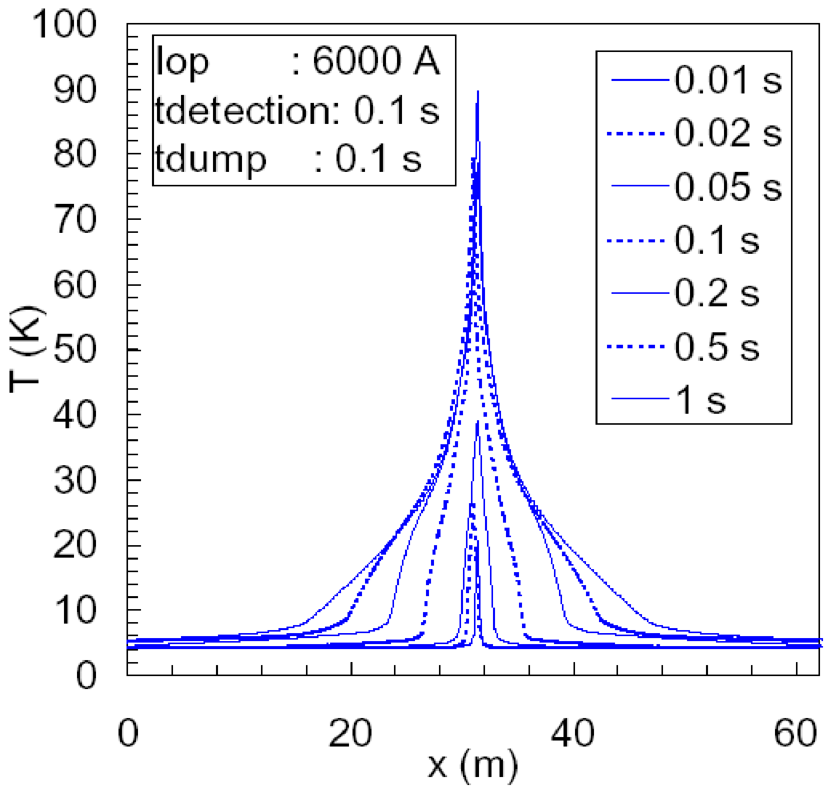
Flow and cooling analysis (3/3)

- working conditions are acceptable only if the heat load on the conductor is small (5…10 W)
- increase flow, or decrease hydraulic impedance to accommodate higher heat loads

p_{in} = 5 bar
p_{out} = 2.4 bar
dm/dt = 2.5 g/s



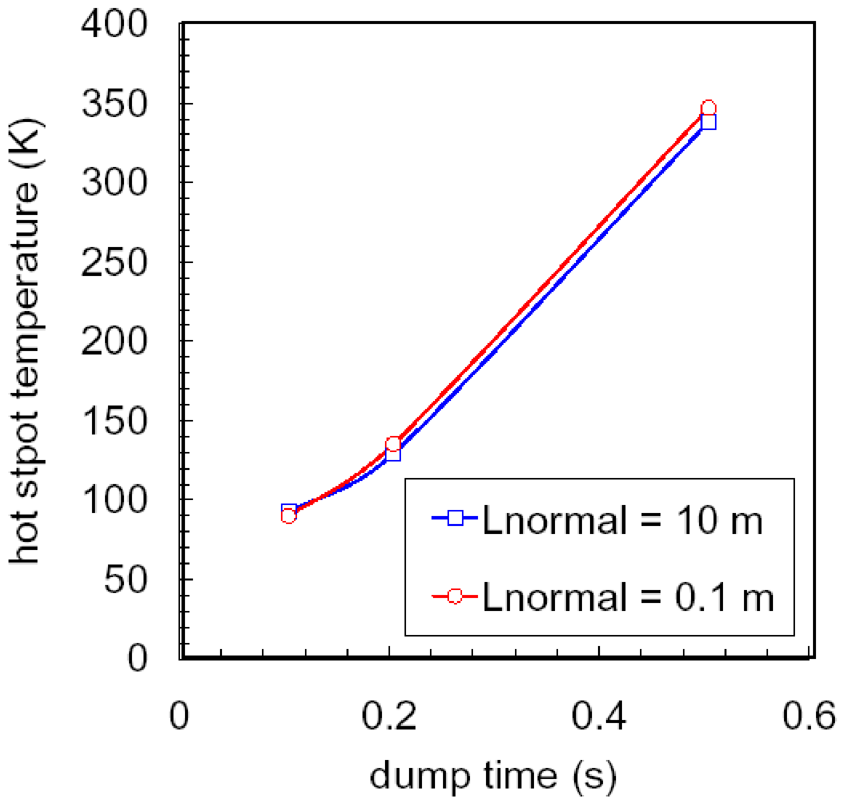
Quench analysis (1/3)



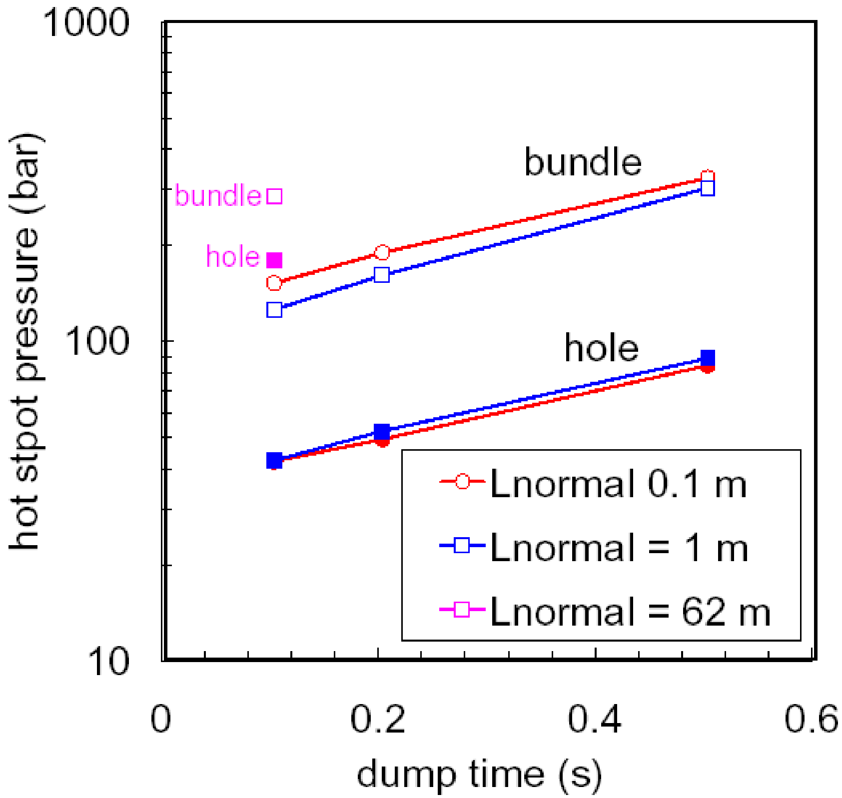
- quench propagation reaches THQB conditions
- average propagation speed in the time range 0 … 0.5 s is approximately 20 m/s

Quench analysis (2/3)

- hot-spot temperature safely below 150 K if:
  - detection within 0.1 s or faster
  - dump with a 0.2 s time constant or faster



Quench analysis (3/3)



- pressure increase is large (150 bar and more)
  - poor hydraulic coupling of bundle and hole (small dimensions)
  - can be improved by an increase of the effective transverse flow cross section

Conclusions

- the CICC technology is available and adapted to pulsed operation (low loss, high stability)
- a CICC conductor for SIS-100 appears to be feasible using present technology
- first analysis show that:
  - stability greatly enhanced, a CICC SIS-100 should have no training at all !
  - pressure drop is acceptable
    - 1 g/s $\rightarrow$ 0.5 bar
    - 2.5 g/s $\rightarrow$ 2.4 bar
  - supercritical cooling may be feasible
    - $\Delta T < 1$ K for 13 W/coil if dm/dt = 2.5 g/s
  - protection ($T < 200$ K, $p < 150$ bar) can be achieved with 0.1 s detection and 0.2 s dump time (approximately 60 V on a magnet) and can be improved with minor design changes