Increasing the particle energies to reveal more secrets of matter, the Large Hadron Collider (LHC) is about to reach its limits. For future experiments colliders of a new magnitude are planned; among others the future Circular Collider (FCC) with an circumference of 100 km and a centre of mass energy of 100 TeV.

Due to the high particle energies the proton beams emit a large amount of synchrotron radiation and generate image currents in the beam tube containing the beams and located in the center of the superconducting magnets. Despite of the thermal insulation a large heat load from the ambience is expected, caused by the sheer size of the machine. Heat load unavoidable to drive the beam screen cooling system.

The exergetic efficiency of the beam screen cooling system (without Nelium cycle) is the ratio of the exergetic benefit (energy of the extracted heat) and the exergetic input: \( \eta = \frac{\dot{Q}_\text{ex}}{\dot{Q}_\text{in}} \). The circulation power has to be extracted at cryogenic temperature level.

**Influence of the pressure drop and warm circulation scheme**

1. The circulation power has to be extracted at cryogenic temperature level. With increasing pressure losses in the beam screen cooling system, the increasing circulation power can only be extracted with a very high energetic effort at low temperature.

2. The major part of the power of a circulator working at ambient temperature can be extracted at a much “cheaper” temperature level. The terminal temperature difference of the internal heat exchanger though allows a certain energy to “pass” – this heat has to be extracted by the Nelium cycle.

3. If the cold circulator power exceeds the heat passed the internal heat exchanger by the terminal temperature difference in the warm cycle, the cold circulation cycle becomes more expensive.

**Summary and discussion of results**

1. The sector dimensions, the beam screen design and the heat loads are determined and define the basic energetic effort to keep the beam screen cooling cycle at the necessary temperature level.

2. Increasing pressure drop in the hydraulic scheme calls for additional circulation power. Although the circulation power of a cold circulator is smaller compared to a warm circulator, in the cold circulation scheme the power has to be extracted at cryogenic temperature level.

3. In the warm circulation scheme the major part of the compression power can be extracted very cheaply at ambient temperature level. The necessary internal heat exchanger though cannot transfer the entire heat and allows a certain heat energy to pass to low temperature.

4. Cold circulator power of a cold circulator is smaller compared to a warm circulator, in the cold circulation scheme the power has to be extracted at cryogenic temperature level.

5. The compressors losses are higher for the cold circulator, because of the cryogenic temperature level, the compression heat is deposited on the cold circulator. The main energy loss of the warm circulation cycle is caused by the terminal temperature difference of the internal heat exchanger. The energetic losses of the beam screen cooling cycle are much lower if a cold circulator is used.

6. Also the total energy consumption including the Nelium cycle is larger for the warm circulation cycle for the given pressure drop. From the progress of the total energetic effort curves, the stronger dependency of the cold circulation scheme on the pressure drop can be recognized.

**Conclusions**

The energetic advantage of large headers and short magnet strings is accompanied by an increasing effort of capital costs, controlling effort and possible downtime due to component failures. The energetic performance of the warm circulation scheme leads to an improved energetic performance of the warm circulation scheme, due to the pressure drop sensitivity of the cold circulator. Technical advantages of the cold circulator, for example easier handling, less errors proneness and the possibility of multipurpose use (e.g. during cool down and warm up) and a possible better performance during transient modes could make it a better choice, despite of the higher operational costs.