The LHCb experiment at the Large Hadron Collider uses a silicon strip detector for the Upstream Tracker (UT), which is a part of its tracking system.

### The Upstream Tracker Detector for LHCb experiment

The upgrade of the LHCb detector will take place during the Long Shutdown 2 from 2019 to the end of 2020. It will extend significantly the physics reach of the experiment by allowing it to run at higher instantaneous luminosity with increased trigger efficiency for a wide range of decay channels. The LHCb upgrade relies on two major changes:

1. Firstly, the full read-out of the front-end silicon, currently limited by a Level-0 trigger to 1 MHz, will be changed to a readout at 40 MHz followed by a software-based event selection.
2. Secondly, the upgraded LHCb detector will be designed to cope with an increase of the nominal operational luminosity by a factor 5 compared to the current detector.

- Requires replacement of the tracking system, modification of detectors for higher luminosity, replacement of front-end electronics and integrated elements.

### Thermal requirements and detector cooling system

The detector cooling system has to:

- **extract the thermal power dissipated by read-out chips** => using CO₂ evaporative cooling system
- **prevent thermal runaway in presence of radiation damage by**
  - keep the ASICs temperature \( T_{ASIC} < 40 \text{ °C} \)
  - keep the temperature difference over the silicon sensors
  - prevent thermal runaway in presence of radiation damage by
  - extract the thermal power dissipated by read-out chips
- **obtain through a careful material choice and**

### Detector cooling system

**CO₂ cooling plant:**
- 2-Phase Accumulator Controlled Loop. Only passive systems in the unaccessible area.
- Common development with LHCb VELO detector
- LHCb UT Upgrade
- LHCb UT Upgrade
- LHCb Velo microchannel upgrade

**Power distribution**

There are different parallel evaporators

- 4 ASICs row
- 8 ASICs one

**Cooling design**

Energy balance

- Inlet: CO₂ liquid, near to saturation
- Outlet: 35% (max 50%) nominal vapour fraction, \( X_{OUT} \)
- \( H_{OUT} \) = enthalpy liquid to vapour – 280 kJ/kg, at the evaporation temperature of \( -25 \text{ °C} \)

**CO₂ flow-rate calculation**

\[
\Gamma_{CO₂} = \frac{POWER}{X_{OUT} \cdot H_{OUT}} = \frac{POWER}{0.3 \cdot 280 \text{ kJ/kg}} = 0.9 \text{ g/s}
\]

**CO₂ distribution system**

For thermo-hydraulic stability reasons:

- INLET connections MUST HAVE A BIG PRESSURE DROP, i.e. 5 times the evaporation channels.
- Using passive elements.
- Two options investigated:
  1. calibrated orifices: concentrated pressure drops inserted at the stave inlet.
  2. capillaries: distributed pressure drops, coiled or running between the staves and a common manifold.
- Both these options have been tested.

### CO₂ Cooling Test

**Mandatory to carry out the thermo-hydraulic characterization of the stave and the relevant detector components proposed in the design**

The cooling system operates in a stable region, and has been verified to accept 50% extra load, maintaining the stave temperatures inside an acceptable range, very near to the evaporation temperature, and having inlet-outlet temperature difference \( ~1 \text{ °C} \).

These measured ratios between the \( P \) of the circuit components should guarantee the stability from the thermal management point of view:

- the design and test of cooling related components for the UT detector (manifolds and distribution system) is well advanced
- the correct operation of the CO₂ cooling system for a single stave with a snake pipe has been demonstrated by simulations and measurements
- test are in progress to measure the detailed differences between stave types.