THERMAL MANAGEMENT OF SILICON DETECTORS: $\Delta T_{\text{fluid-sensor}}$ depends on the full chain of thermal resistances.

The thermal resistance can be exactly calculated if the properties and the thickness of all materials are known. Calculating the thermal resistance requires knowing the convective Heat Transfer Coefficient.
**Single-phase flow**: very reliable correlations available, only requiring $Re$ and $Pr$.

**Boiling flow**: Not much is changed from the foundational work of J.C. Chen (1962).

Determining the HTC value requires a large number of parameters and **FULLY EMPIRICAL exponents**, combined into two ADDITIVE factors (i.e. “non-similar” w.r.t. Buckingham theorem).

From 1962 to today, the efforts of the researches have been focused in producing experimental databases and adapt some “Chen-like” correlation to them.

The only different approach has been the one tried by the group of J.R. Thome at EPFL, linking the correlations to “flow maps”, i.e. to the specific phenomenology of boiling pattern (for CO$_2$: L Cheng, G Ribatski and JR Thome, 2008).

**CONVECTIVE HEAT TRANSFER COEFFICIENT**

HOWEVER ALL TWO-PHASE CORRELATIONS HEAVILY RELY ON THE AVAILABILITY OF RELIABLE EXPERIMENTAL DATA
PRODUCING RELIABLE MEASUREMENTS OF CO₂ BOILING IN SMALL CHANNEL IS UNFORTUNATELY VERY DIFFICULT

ONLY EXISTING Heat transfer and pressure drop database available in literature (trustable & established data) for CO₂ boiling flows in small channels (ID < 3 mm):

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Dₜ [ mm ]</th>
<th>G [ kg/m²s ]</th>
<th>Tₜsat [ °C ]</th>
<th>Heat flux [ kW/m² ]</th>
<th>data points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choi et al. 2007 [1]</td>
<td>1.5, 3.0</td>
<td>300 ÷ 600</td>
<td>-5</td>
<td>30 ÷ 40</td>
<td>471</td>
</tr>
<tr>
<td>Pamitran et al. 2011 [2]</td>
<td>1.5, 3.0</td>
<td>300 ÷ 600</td>
<td>1, 2, 3, 10</td>
<td>20 ÷ 30</td>
<td>2898</td>
</tr>
<tr>
<td>Yun et al. 2005 [4]</td>
<td>1.14, 1.54</td>
<td>200 ÷ 400</td>
<td>5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Ducoulombier et al. 2011 [5]</td>
<td>0.53</td>
<td>200 ÷ 1200</td>
<td>-10, -5, 0</td>
<td>10 ÷ 30</td>
<td>2710</td>
</tr>
</tbody>
</table>

> 8079 data points

↔ scattered
↔ limited in test range
↔ limited in test consistency
TWO PARALLEL APPROACHES

**LAPP (short term):**
1. focus on a well defined detector configuration (ATLAS ITk Pixel Local Support)
2. produce reliable measurements of $\Delta T_{\text{fluid-sensor}}$ for this configuration
3. precisely calculate the conductive component
4. adapt an existing HTC correlation to fit the experimental data
5. use the modified correlation for parametric performance forecast of that configuration

**CERN (medium-long term)**
1. focus on as much as possible simple and general configurations
2. produce systematic measurements of $\Delta T_{\text{fluid-sensor}}$ and $\Delta p$ as a function of varying parameters
3. create the largest possible empirical database to be used as “look-up table”
4. analyze in detail the physics of CO2 boiling as a function of varying parameters
5. work with world-wide boiling specialists to define new, more reliable, models