lucasz.

Light Use Cooling Appliance for Surface Zones

Forum on Tracking Detector Mechanics 2017

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Cracow University of Technology: Tomasz Kuczek

Cornell University: Dionna O'Daniel, Peter Quigley, Jim Alexander, Anders Ryd, Julia Thom.

Outline of talk

- Introduction to the LUCASZ project *(Bart)*
- LUCASZ concept *(Bart)*
  - Requirements and specifications
- LUCASZ^{lite} (plant) technical overview *(Bart)*
  - Design and P&ID
  - Construction
  - Commissioning
- LUCASZ local box overview *(Bart)*
  - Design and P&ID
  - Construction
  - Commissioning
- Application of the LUCASZ plant *(Yadira)*
  - *CERN: phase 1, FPIX and BPIX commissioning*
  - *Cornell : USCMS FPIX phase 2 upgrade development*
- Looking forward *(Yadira)*
  - *Plant production at CERN*
  - *Construction at Cornell*
  - *Future systems*

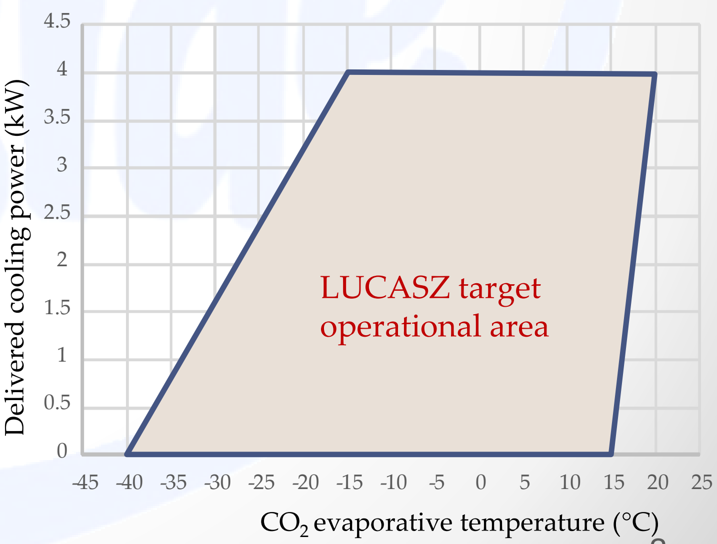
LUCASZ project

- **LUCASZ:**
  Light **U**se **C**ooling **A**ppliance for **S**urface **Z**ones

- LUCASZ is a plant for detector testing
  - Typical properties:
    - Easy to use, will be operated by non-cooling experts.
    - Full temperature operation range without special procedures -35°C to 20°C
    - Flow control range on set point demand 1-10 g/s per loop
    - 2 loops with individual flow control (same temperature)
  - LUCASZ will be controlled by the user via some basic commands
    - On-off
    - Temperature set-point
    - Temperature change speed
    - Flow set-point per loop
    - Connect piping (=vacuum & filling)
    - Disconnect piping (=emptying)
    - Interlock: go to warm (in case of humidity problems)
  - The PLC will take care of a safe operation behind the scenes

Feature	Performance
Cooling loop maximum flow	10g/s per loop
Total plant flow	20g/s
Min evaporating T	-30°C, depending on heat load, see graph
Max evaporating T	+18°C
Number of cooling loops	#2
Max DP across cooling loop	<15 Bar
Cooling loop max power	2000 W
Dimensions (LxWxH)	1125/1475* x 1300 x 1820 *Lite/Full version

Requirements from 1st clients: CMS and LHCb



LUCASZ project

- LUCASZ started from a request of CMS to commission the Pixel Phase 1 detector commissioning for the EYETS 2017 installation
  - Two units: 1 FPIX, 1 BPIX
  - Permanent installation in Pixel cleanrooms in P5 (Report by Yadira)
- LHCb has been added to the client list not far after for their UT and VELO commissioning for installation in LS2
  - 1 Fixed installation for UT commissioning in new assembly cleanroom in P8
  - 1 Mobile installation for VELO commissioning in Liverpool
- Cornell University (US) has joined the project and is building 1 unit in Cornell for FPIX–Phase 2 prototyping. (Report by Yadira)
  - Collaboration based on knowledge exchange vs commissioning involvement at CERN
- Status of today
  - 1 Unit in operation in CMS Pixel cleanroom
  - 1 Unit ready for commissioning in Cornell
  - 3 Units under construction in the EP-DT-FS workshop
- Eventual new units need to be outsourced in industry
  - Drawing package is made ready for this outsourcing

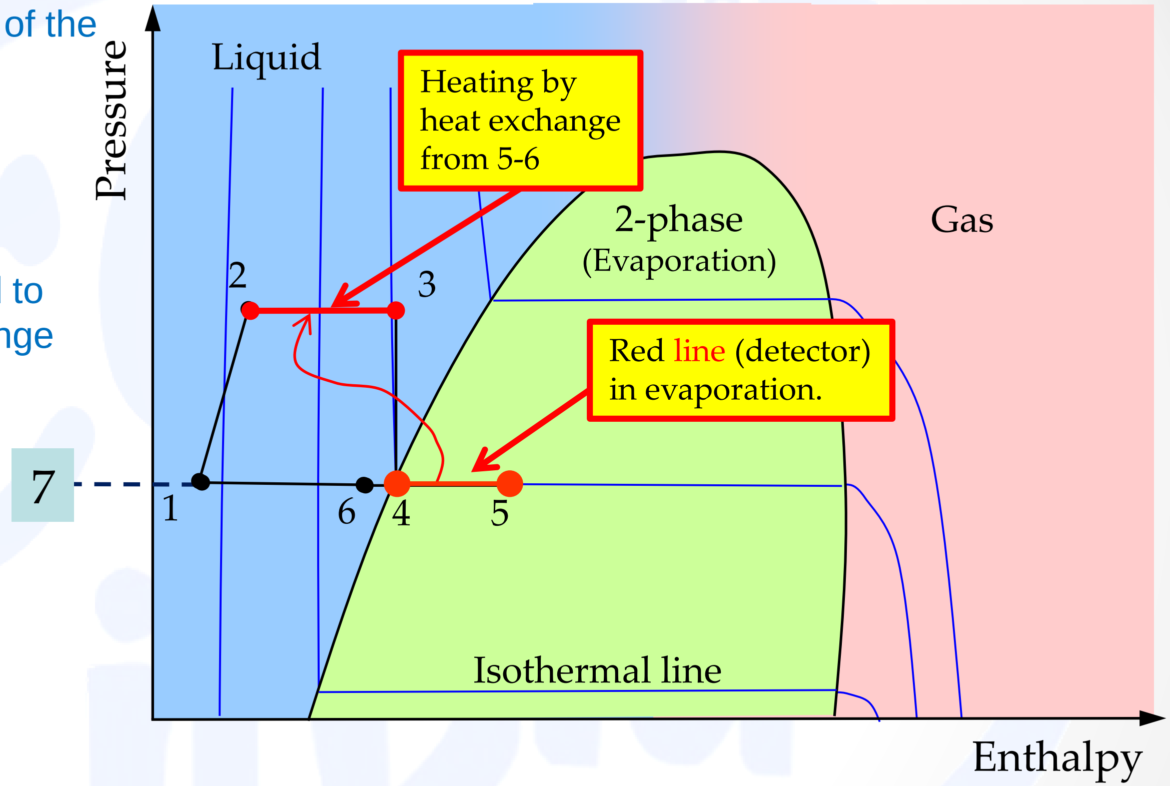
Traditional 2PACL cycle

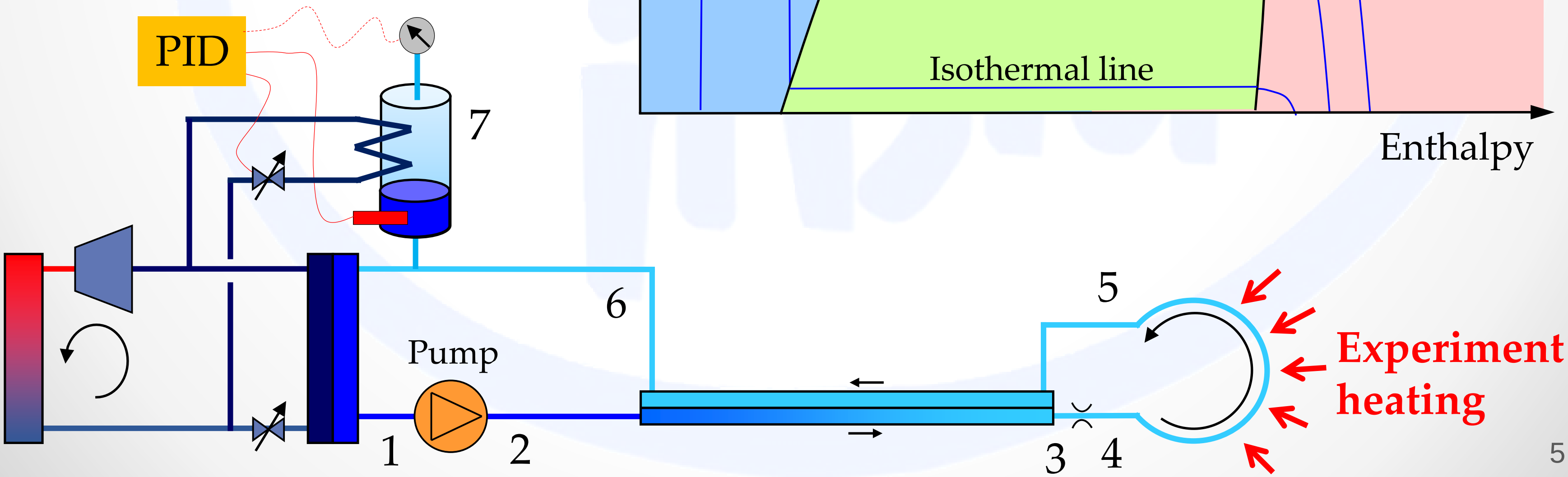
2-Phase Accumulator Controlled Loop

The cooling concept used in all HEP CO_2 cooling systems so far

- Advantages:
  - Perfect temperature control of the distant evaporators
  - Easy to control over a large temperature range
- Disadvantage:
  - Long transfer line is needed to obtain large temperature range

Not practical for test systems





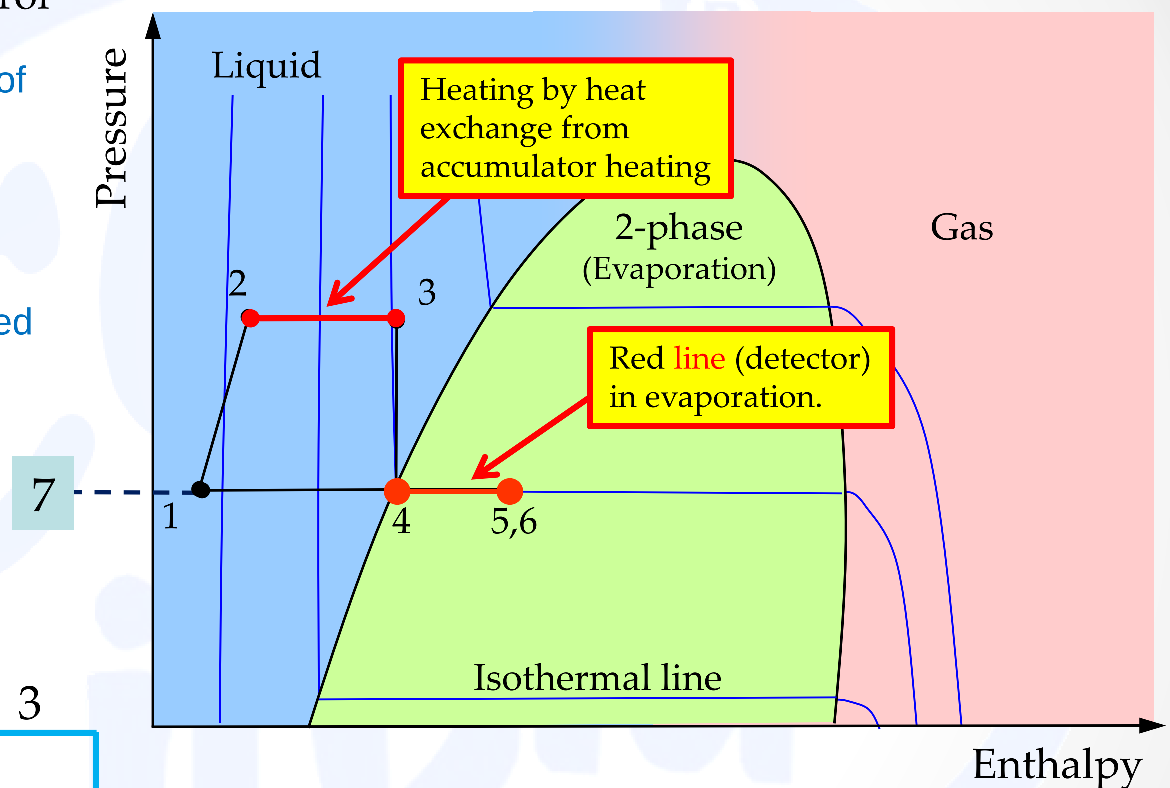
Patented I-2PACL cycle

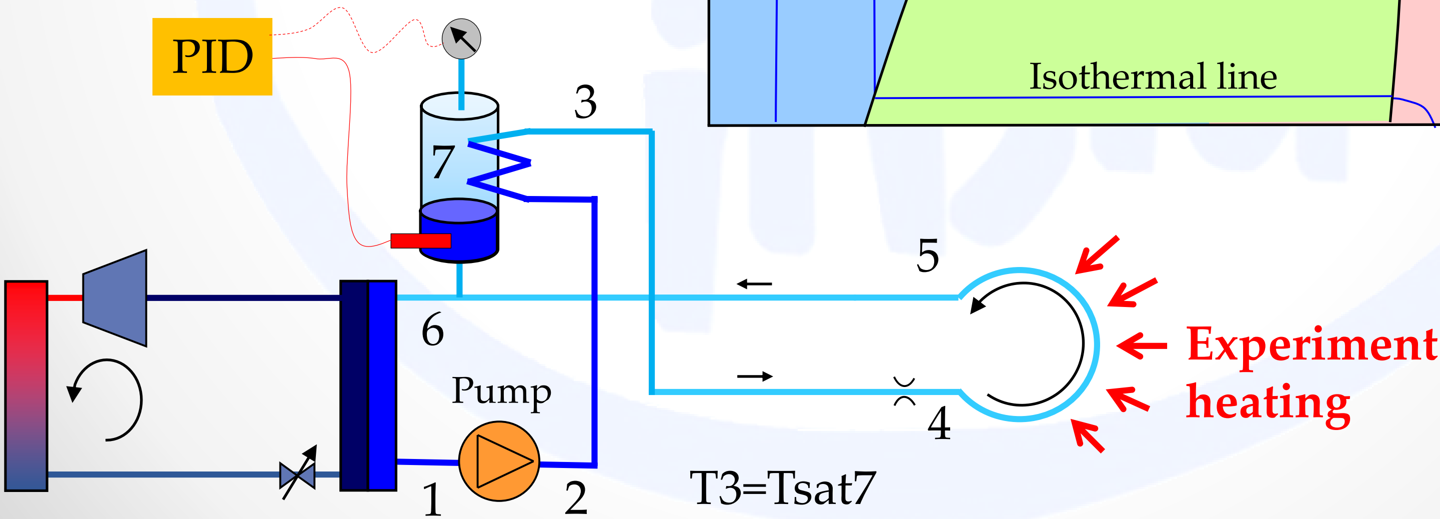
Integrated 2-Phase Accumulator Controlled Loop

Where the transfer line functionality is integrated in the accumulator control

- Advantages:
  - Simple design
  - Modular (strict separation of chiller and CO_2 system)
  - 1 controller for both saturation and liquid temperature
  - No long transfer line needed
- Disadvantage:
  - Less power efficient

  (Constant heating against cooling)





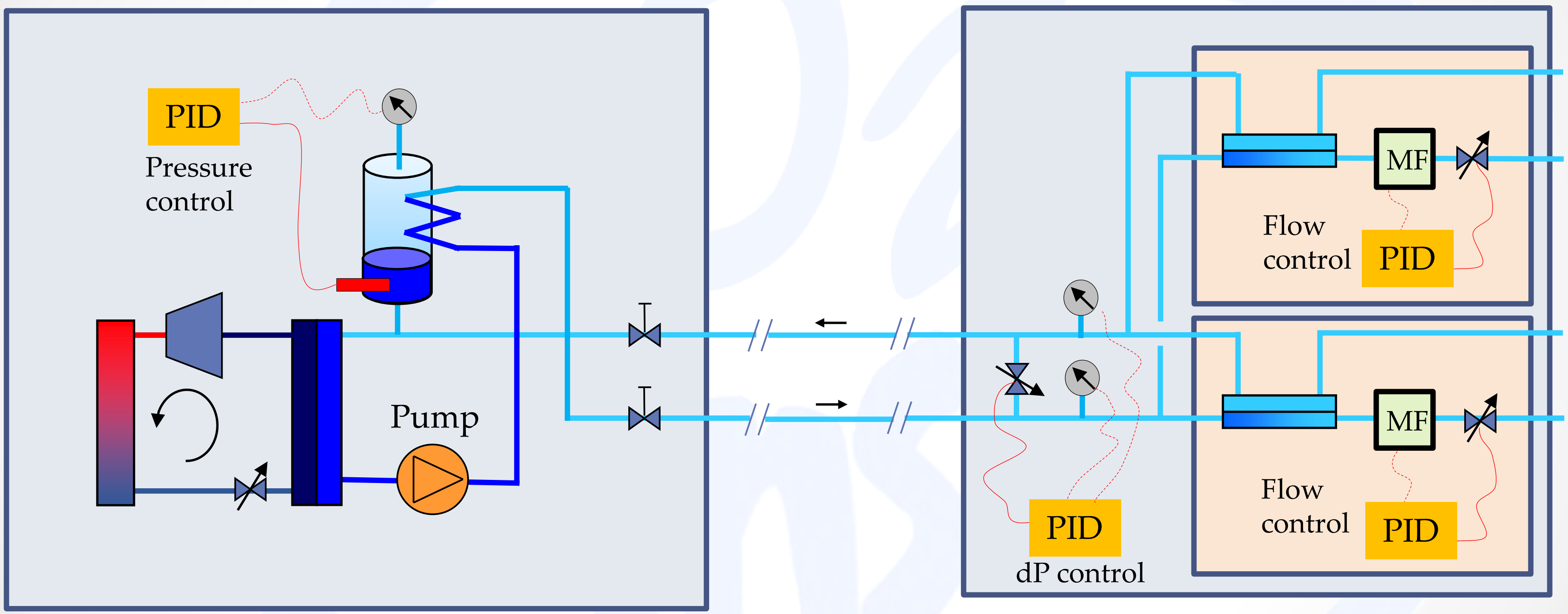
LUCASZ plant configuration

LUCASZ^{lite} Cooling Plant

- *Can be used stand alone*
- *Expert use needed*

LUCASZ Local Boxes

- *Providing 2 cooling branches with a controlled flow*
- *Providing automatic procedures for connecting and disconnecting experiments*
- *Designed for unexperienced users*

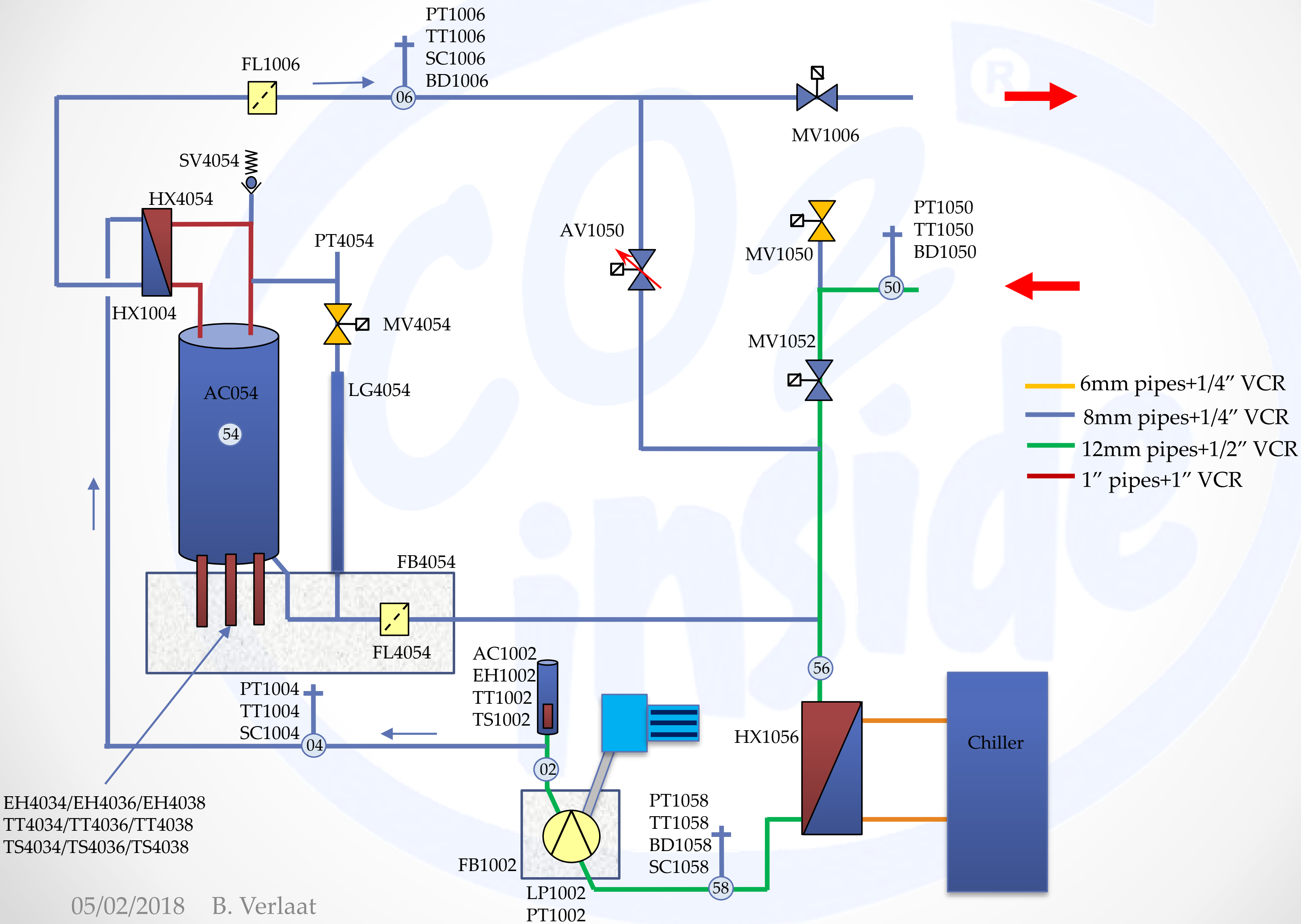


- Pressure drop regulation in by-pass
- 2x mass flow controlled out put

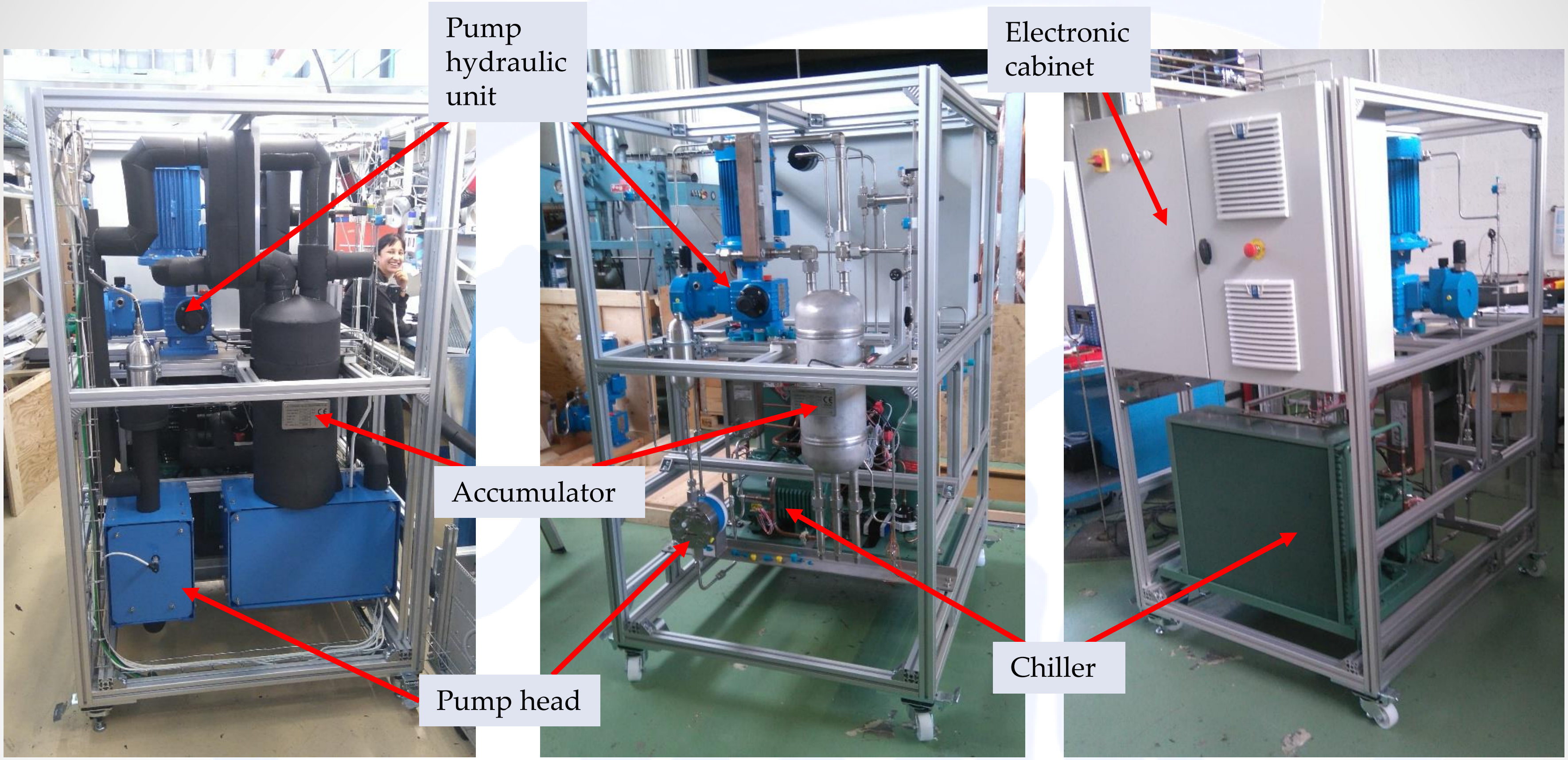
Fixed mass flow
(Manual setting)

Controlled temperature
(Liquid feed and 2-phase evaporation return)

LUCASZ^{lite} plant P&ID



LUCASZ^{lite} plant design

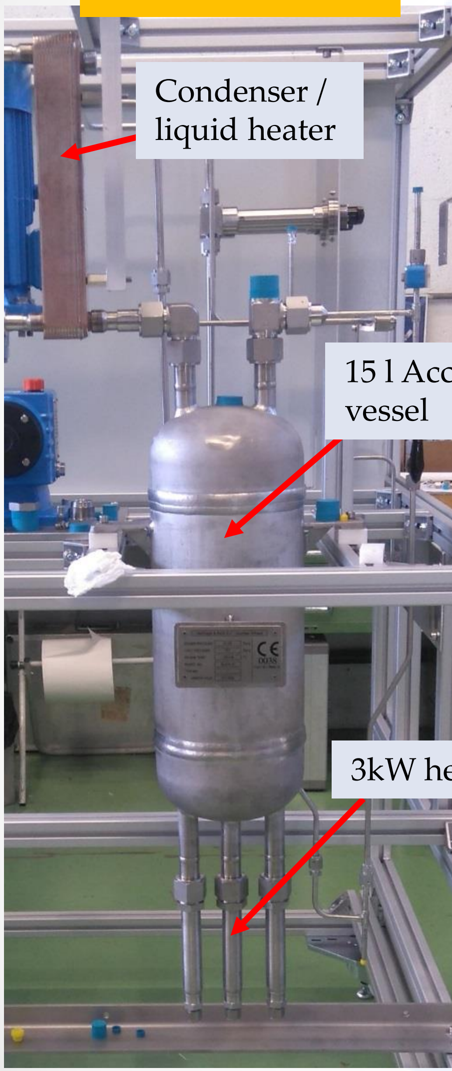


Insulated assembly | Before insulation | Electronic cabinet side

1st plant build at CERN

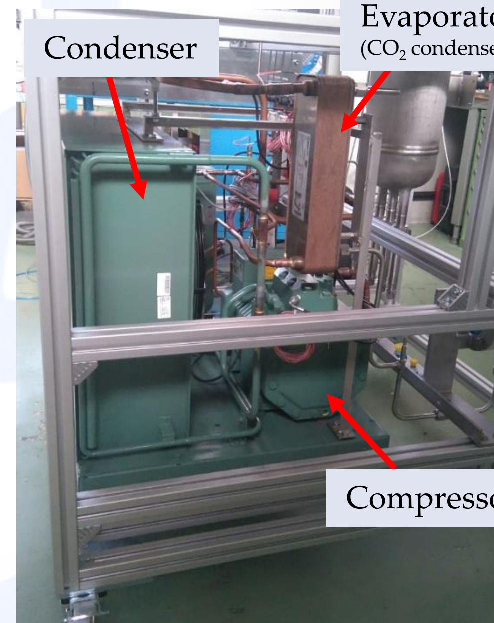
LUCASZ^{lite} main components

Accumulator



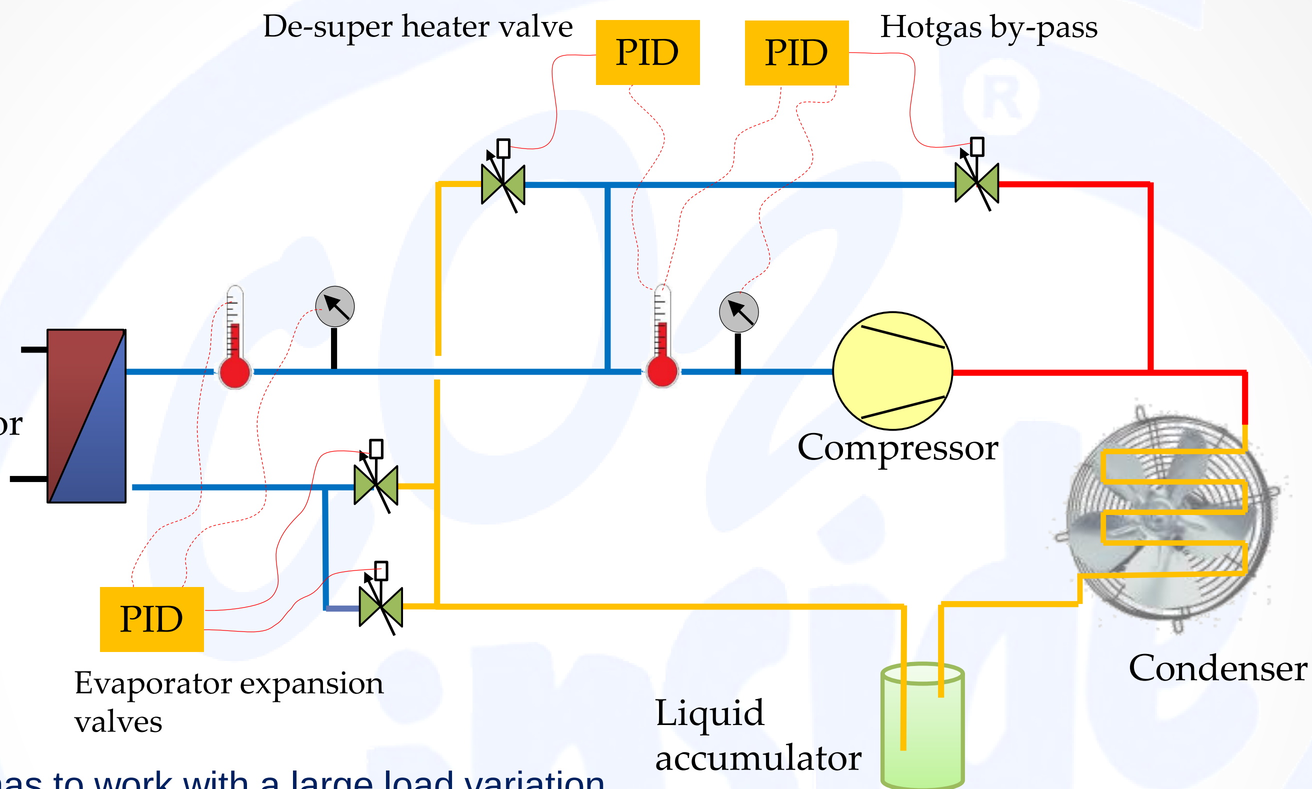
Pump

Electronic cabinet



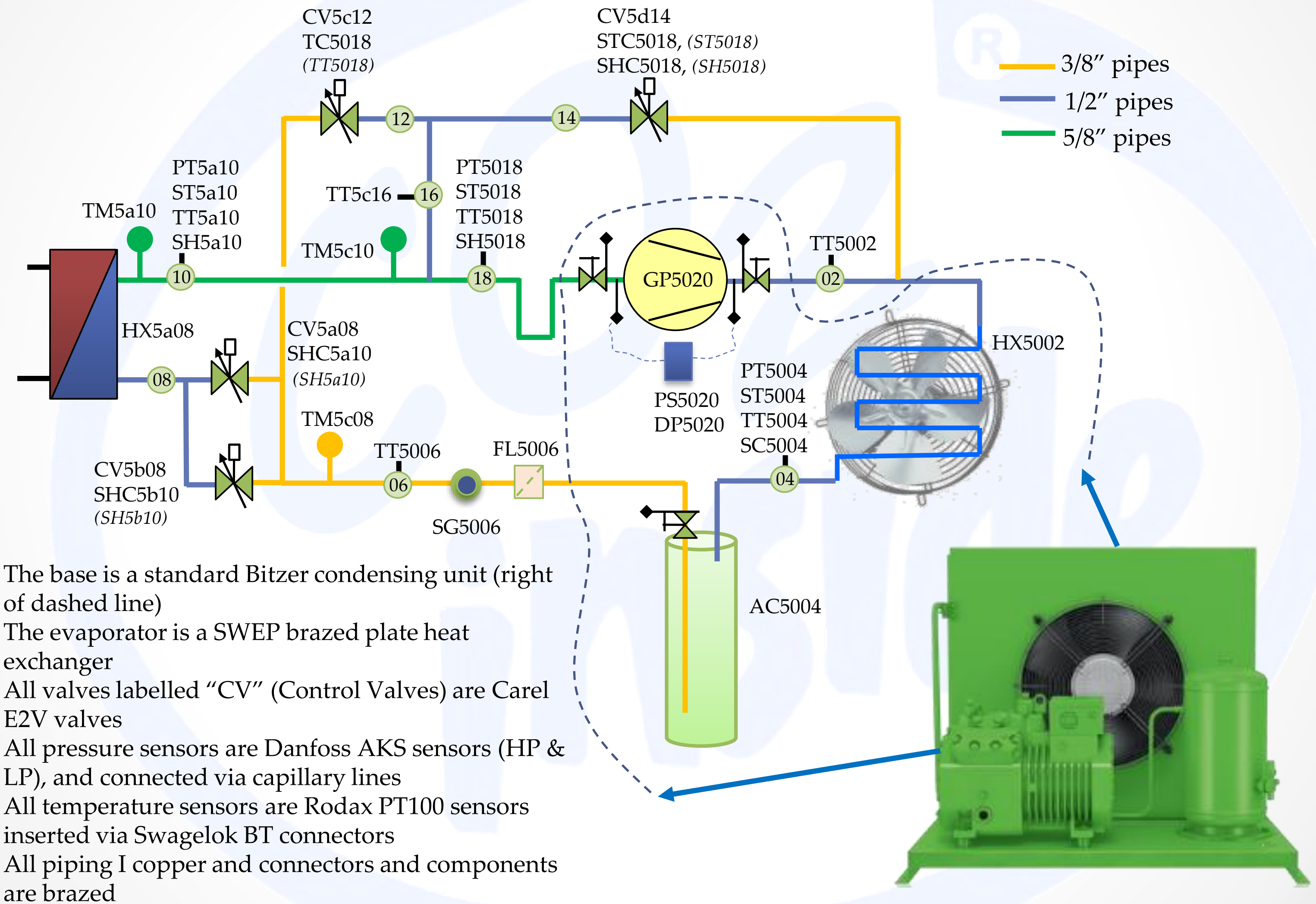
Chiller

LUCASZ chiller concept



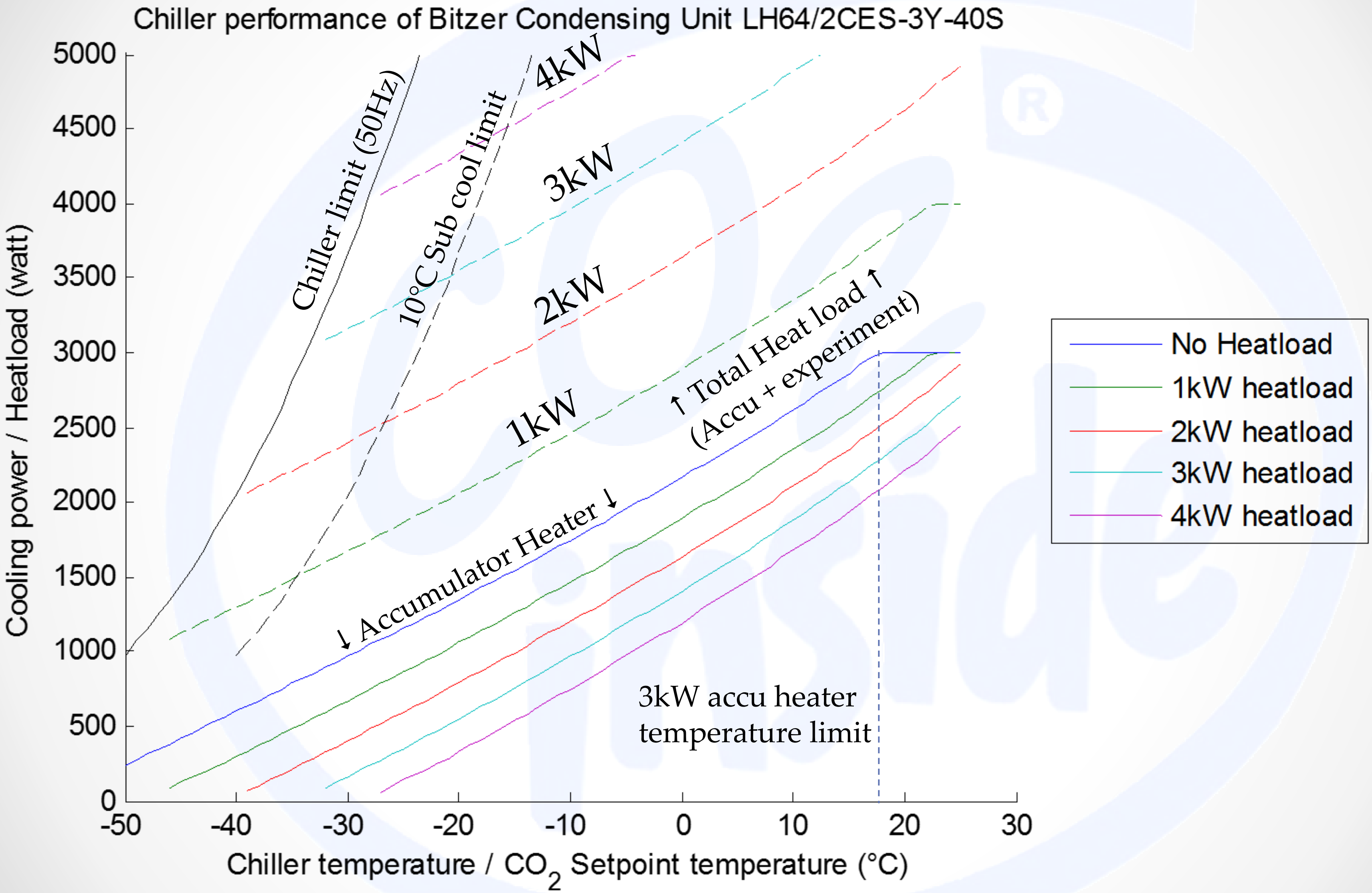
- The chiller has to work with a large load variation
  - Two evaporator valves to cover a large cooling power range
    - Regulated by evaporator outlet superheating
  - Hot gas by pass valve regulation
    - Regulates compressor suction pressure at low loads
    - Regulates compressor inlet superheating to avoid possible liquid suction
  - De-super heater valve regulation
    - Regulates compressor inlet temperature to avoid over heating due to hot gas injection
- Air cooled condenser for a mobile system

Lucasz chiller P&ID

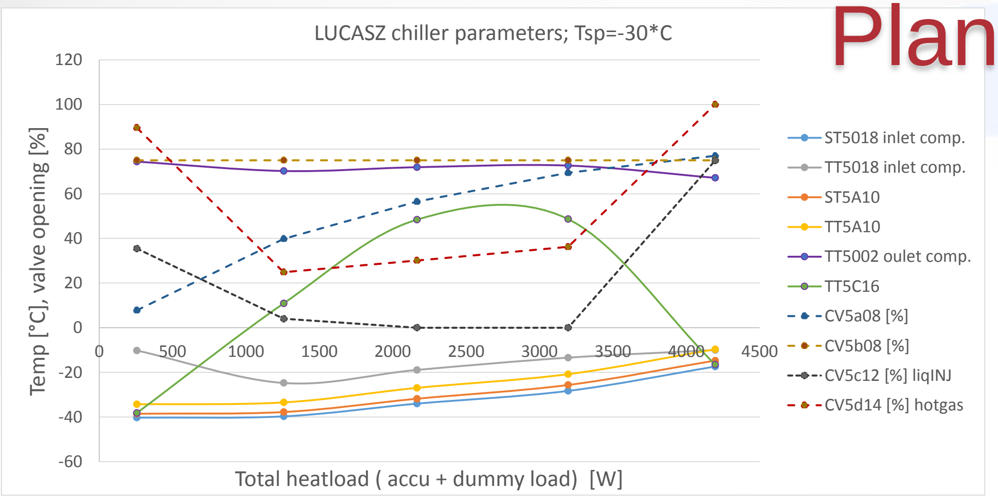


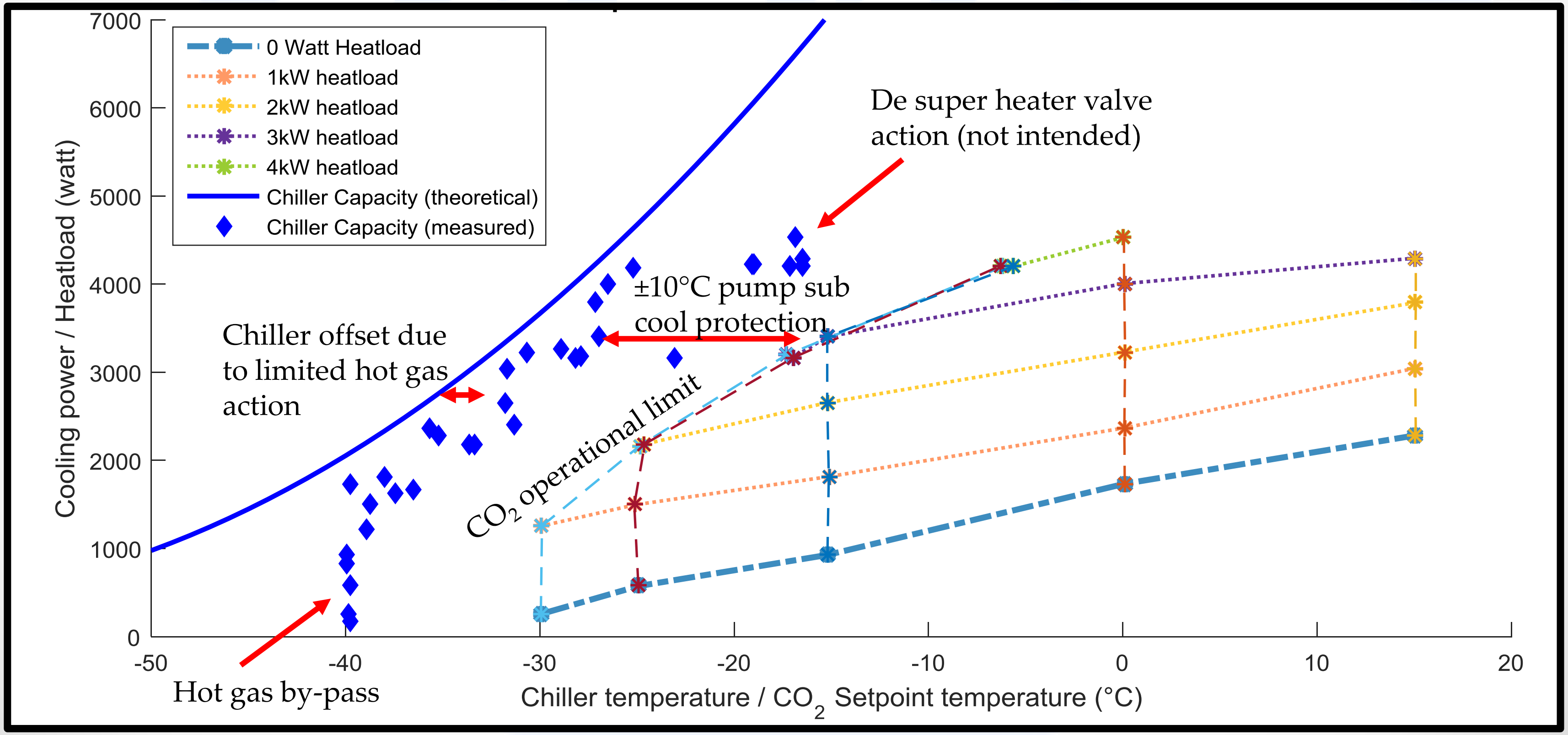
- The base is a standard Bitzer condensing unit (right of dashed line)
- The evaporator is a SWEP brazed plate heat exchanger
- All valves labelled "CV" (Control Valves) are Carel E2V valves
- All pressure sensors are Danfoss AKS sensors (HP & LP), and connected via capillary lines
- All temperature sensors are Rodax PT100 sensors inserted via Swagelok BT connectors
- All piping I copper and connectors and components are brazed

LUCASZ design performance

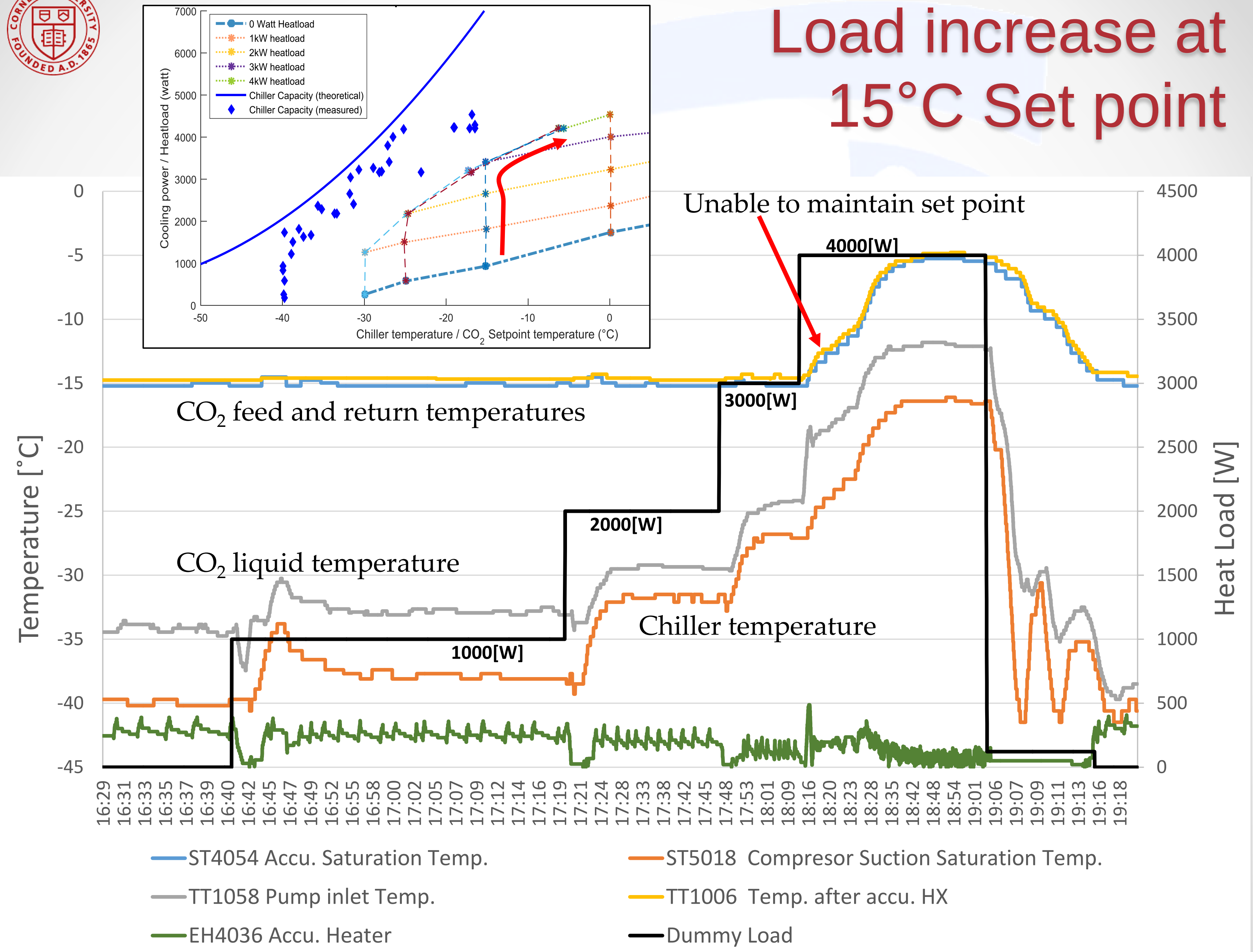


Plant commissioning results

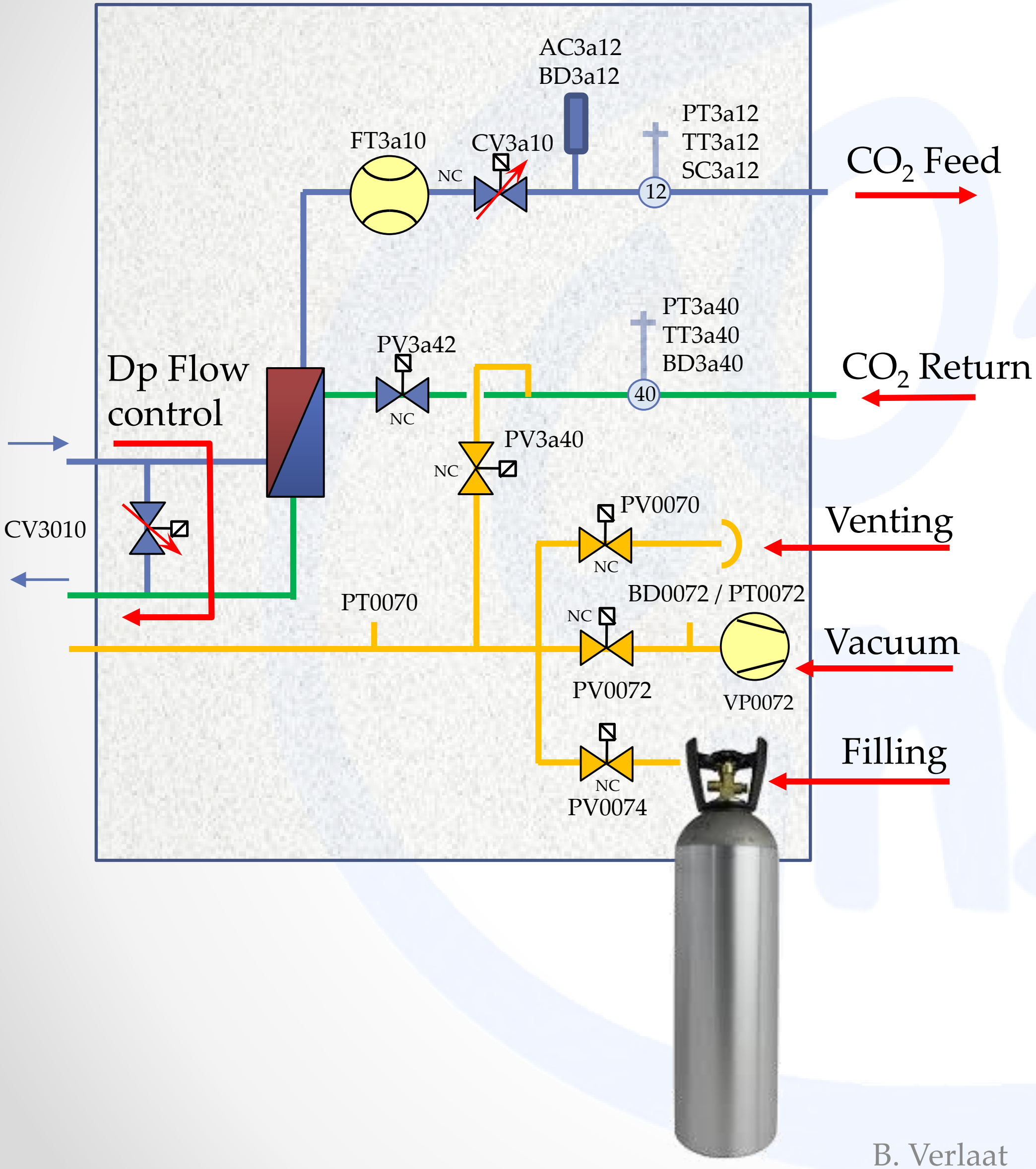




Load increase at 15°C Set point

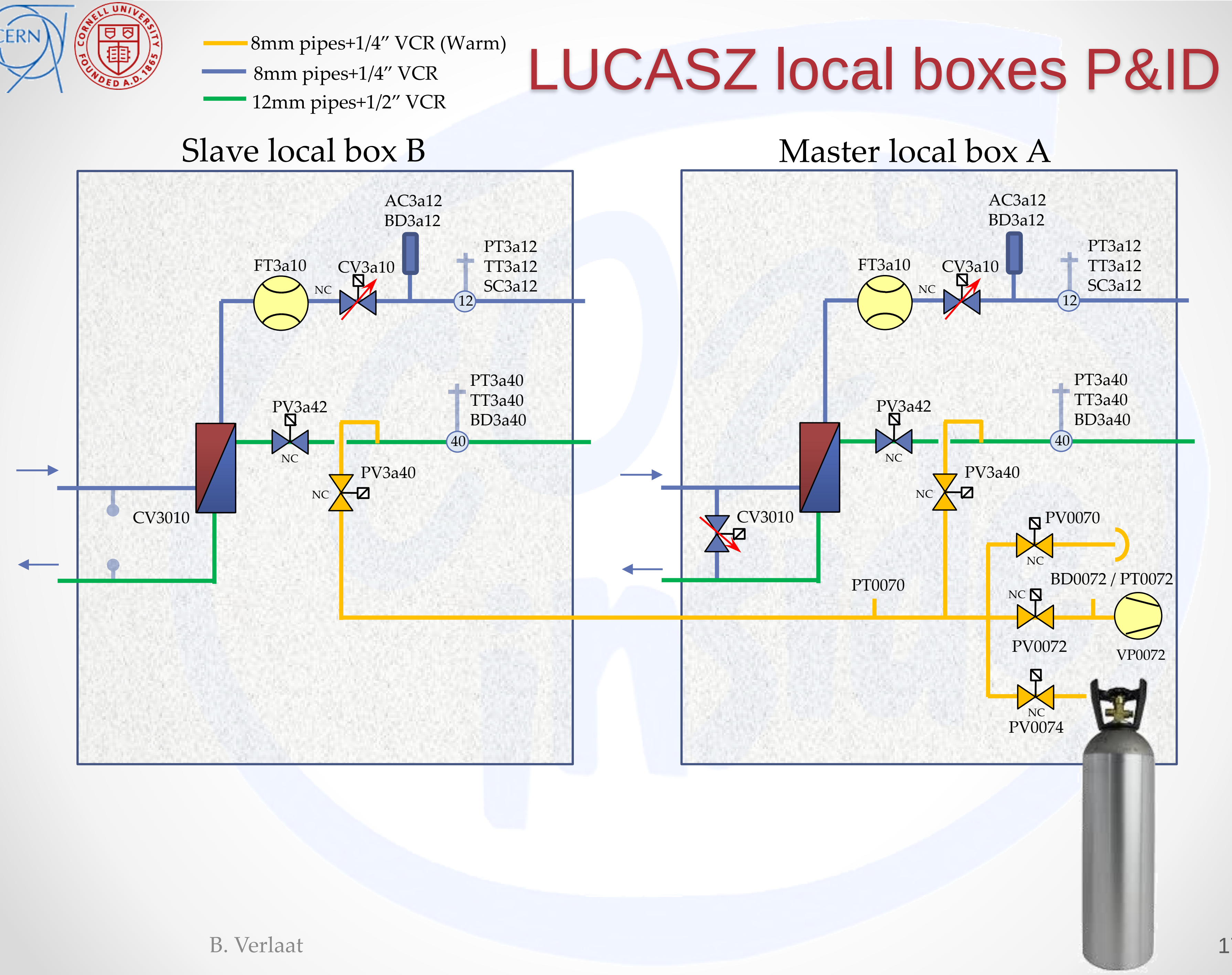


LUCASZ local boxes

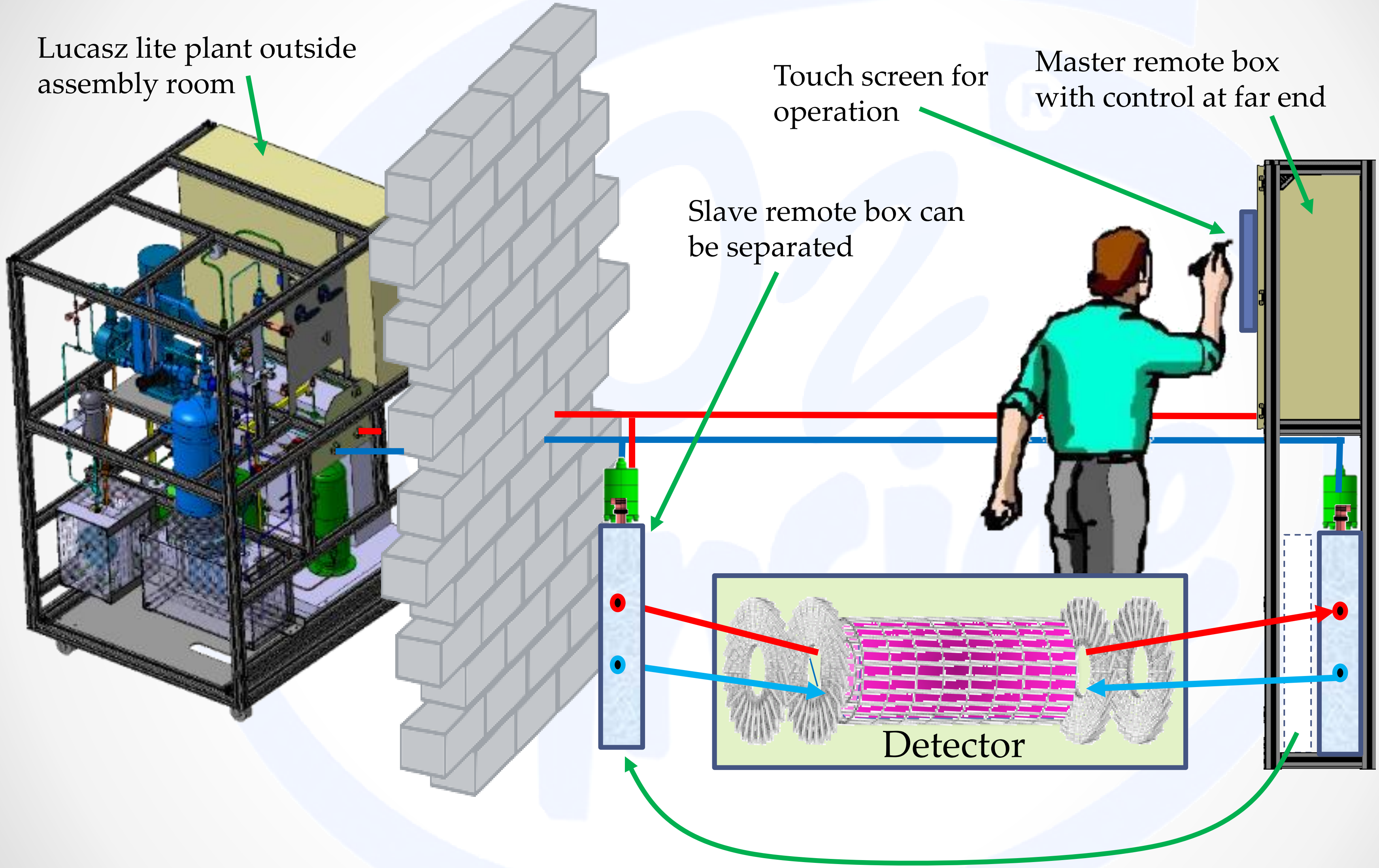


- Flow control per local box
- dP control of plant flow
- Heat exchanger to pre cool arriving liquid
- Touch screen operation
- Possibility to install the 2 boxes remote from plant and from each other
- Connection procedure
  - Vent
  - Vacuum
  - Fill 20 bar gas from bottle
  - Open valves to system
  - Ready
- Disconnecting procedure
  - Close inlet valve / open return valve
  - Cool accu to -20 °C (20 bar)
  - Experiment is emptied by evaporation
  - Once empty remaining 20 bar gas is vented
  - Ready
- A damper vessel is present at inlet
  - Acts as expansion vessel for liquid trap (2x NC valves)
  - Flush the experimental lines from eventual liquid during vent

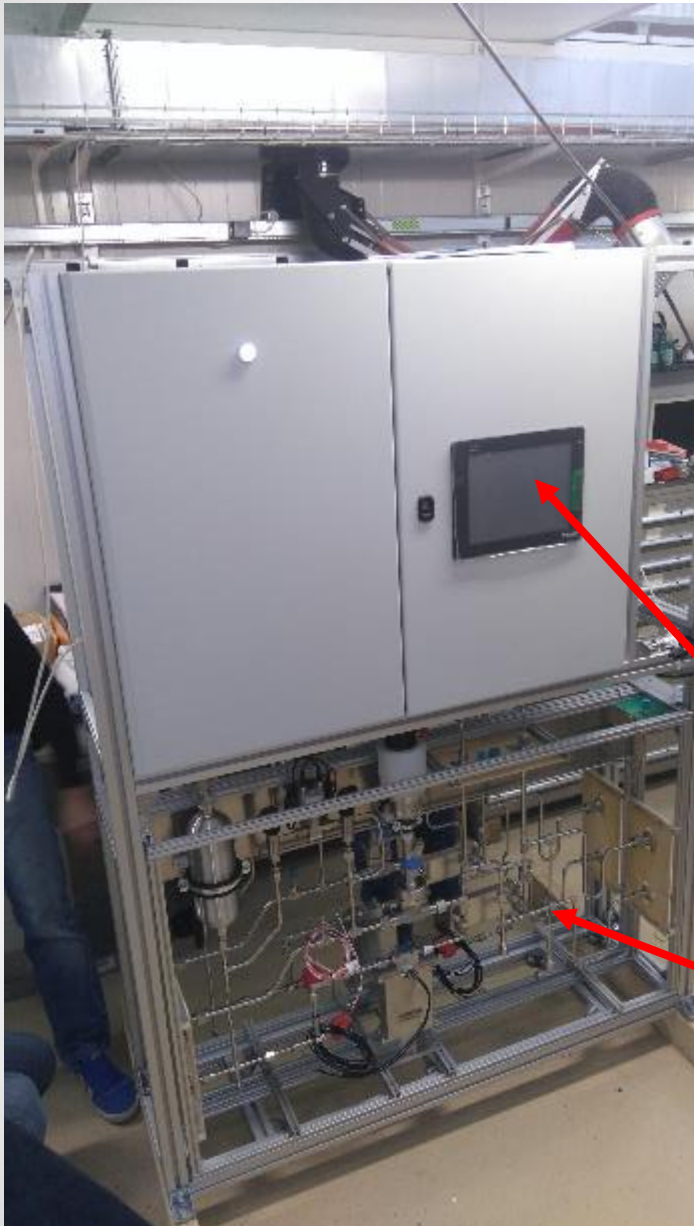
LUCASZ local boxes P&ID



LUCASZ remote configuration



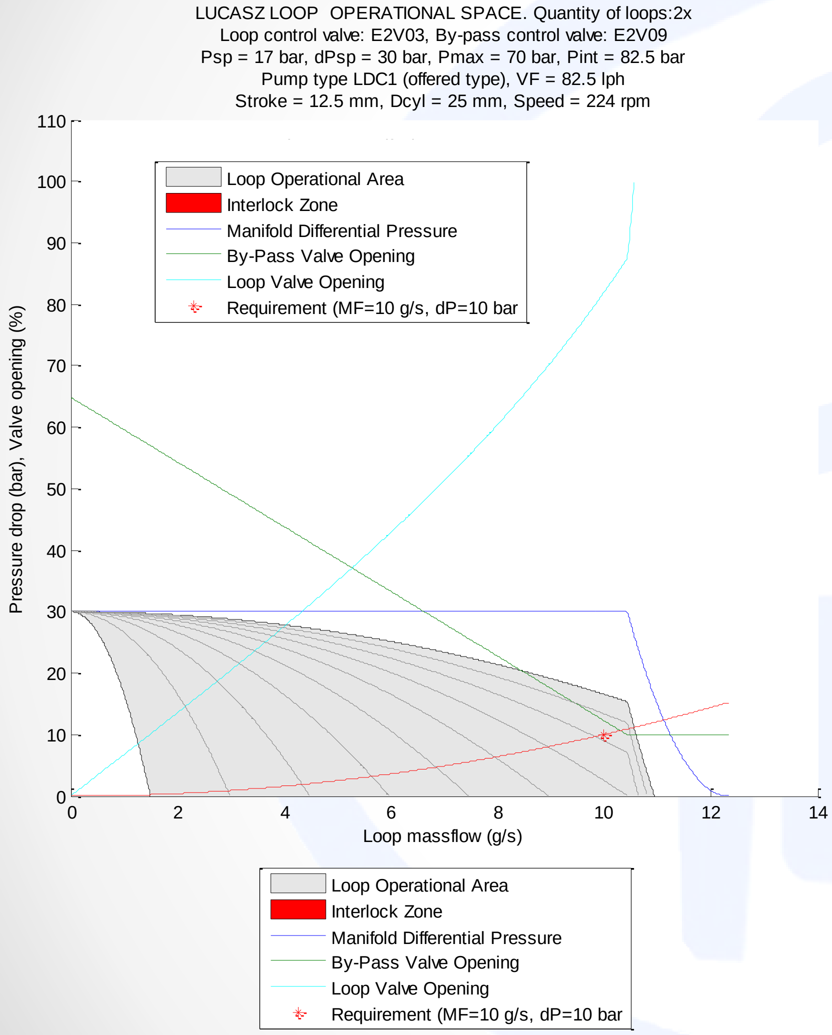
LUCASZ flow control box

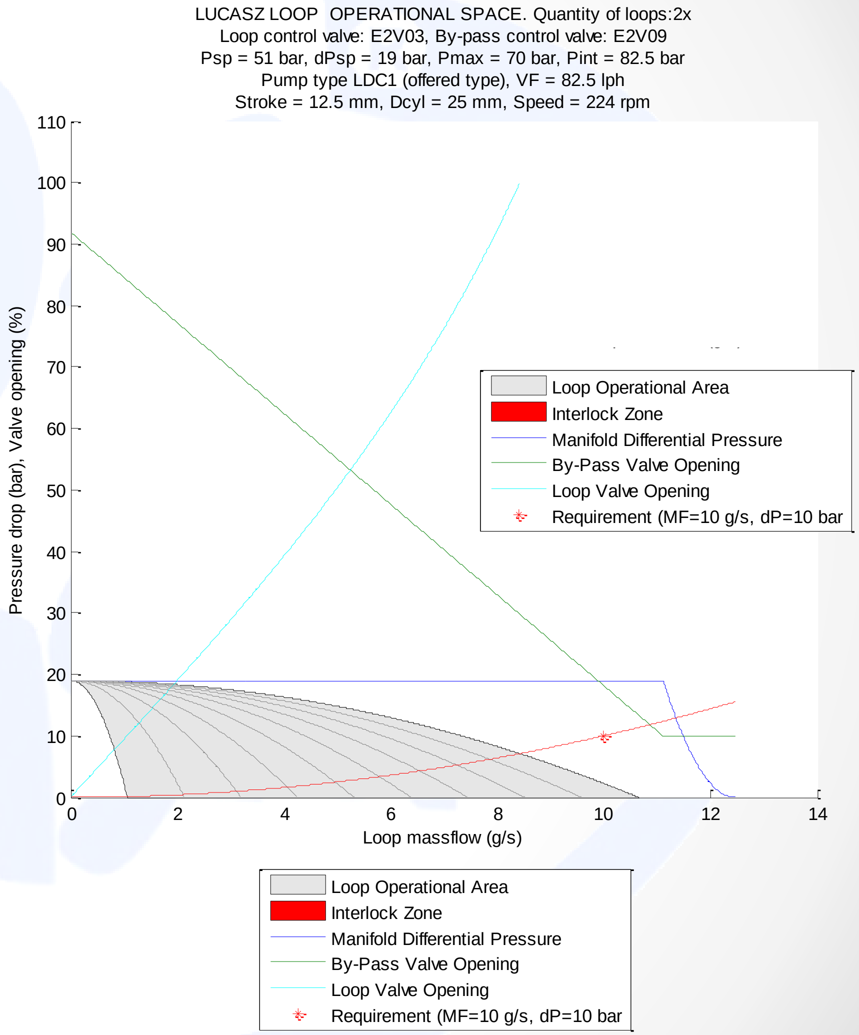


Electronic box with touchscreen control

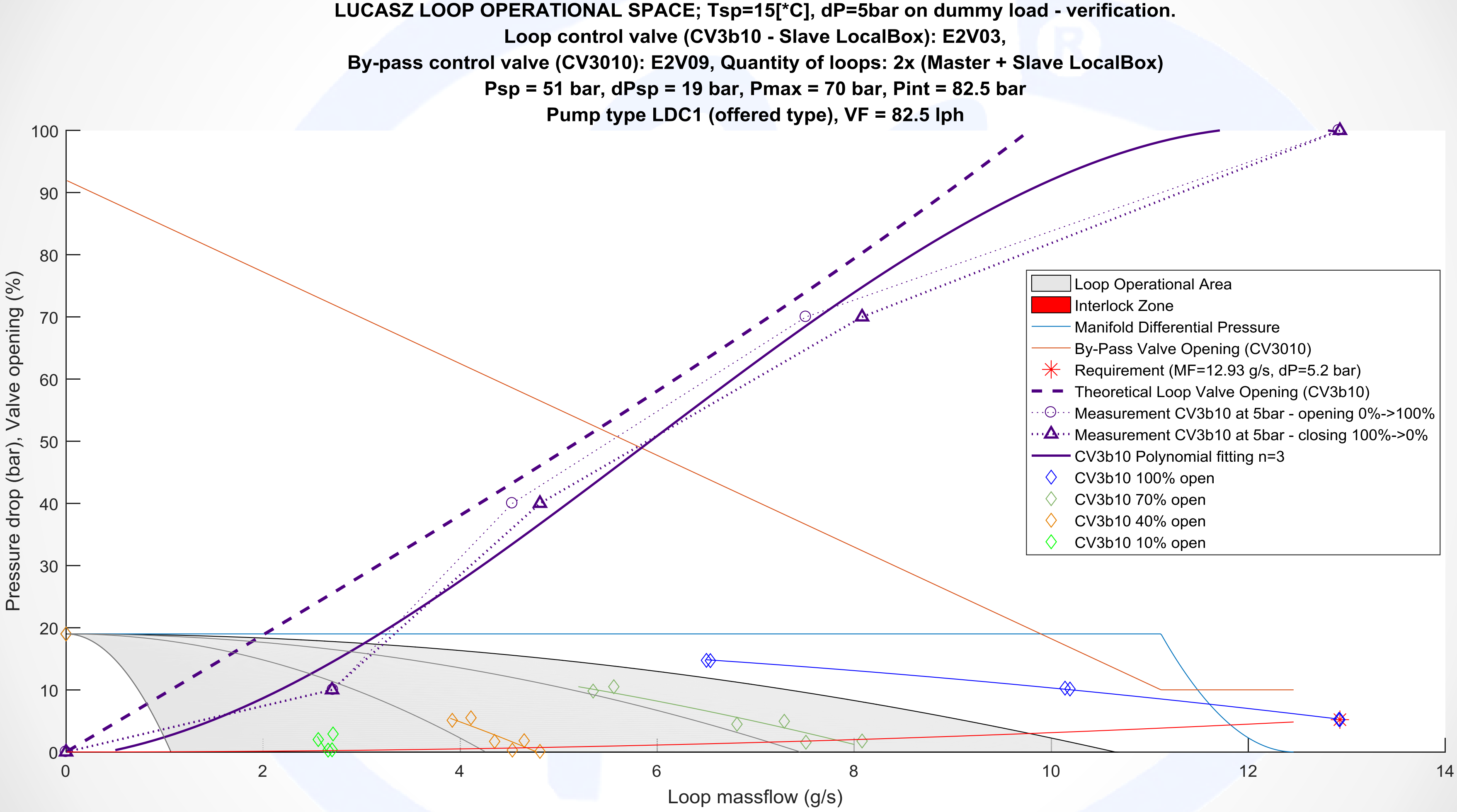
Piping

Flow performance per loop
(two loops operational)

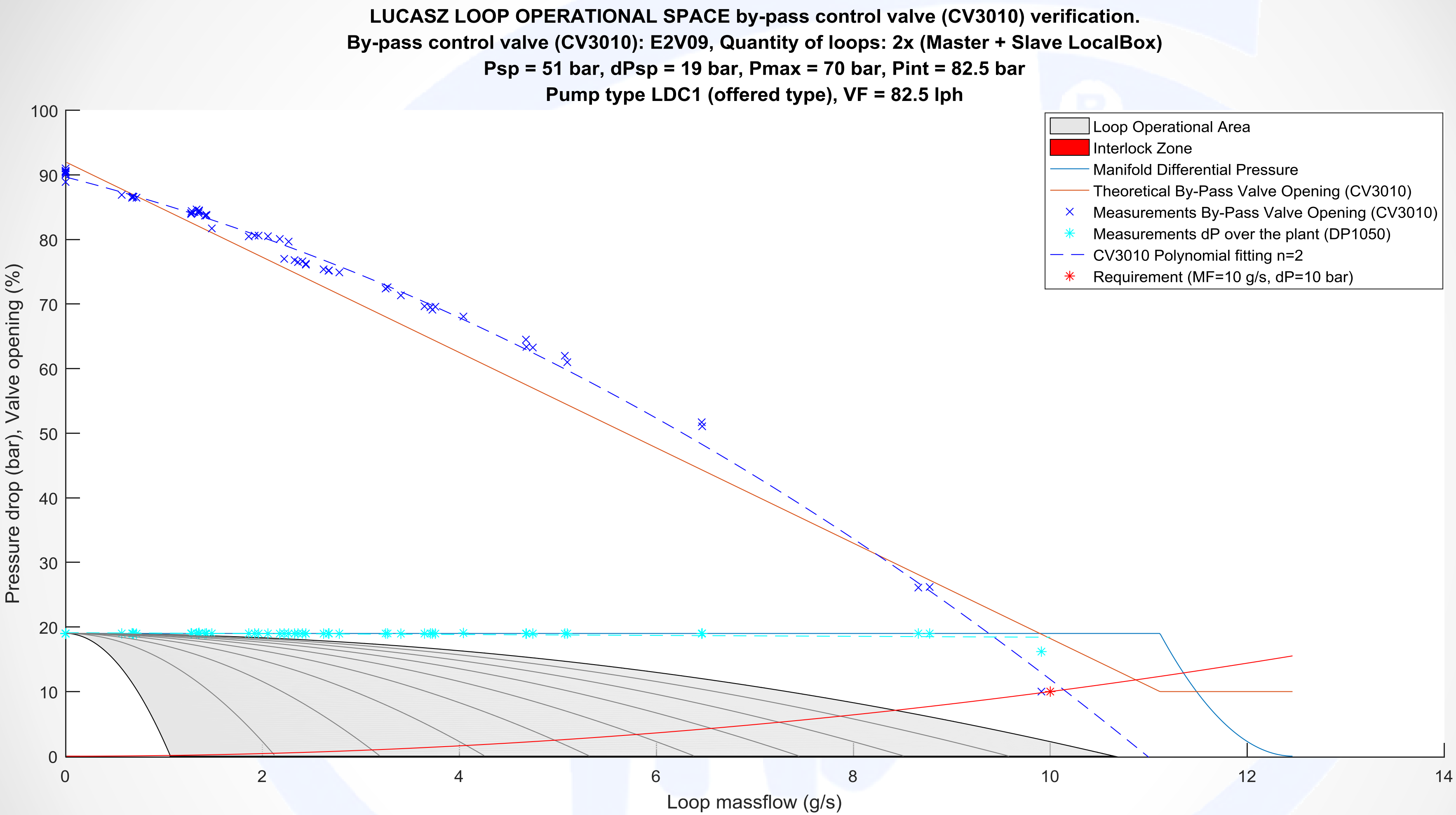




Local box flow capacity test results



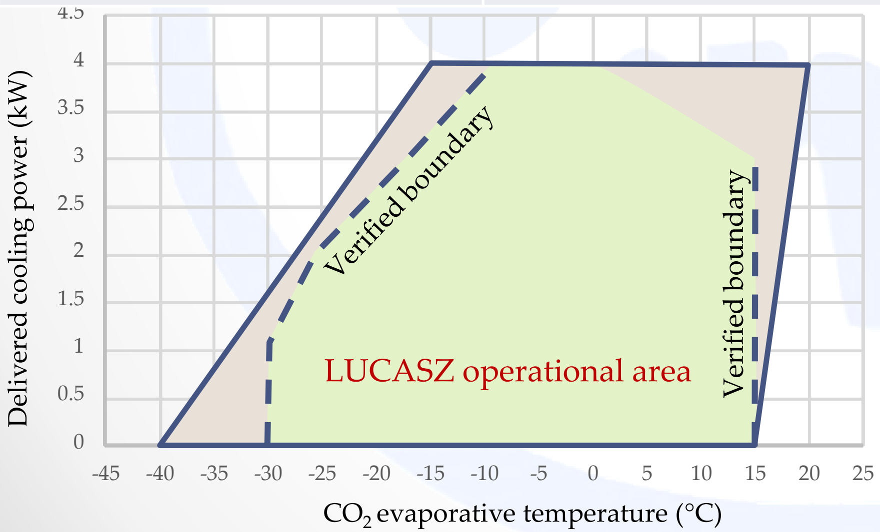
Local box by-pass flow control (fixed dP)



Design Specifications and Verification

Feature	Performance
Cooling loop maximum flow	10g/s per loop ✓
Total plant flow	20g/s ✓
Min evaporating T	-30°C, depending on heat load, see graph
Max evaporating T	+18°C ✓
Number of cooling loops	#2
Max DP across cooling loop	<15 Bar ✓
Cooling loop max power	2000 W ✓
Dimensions (LxWxH)	1125/1475* x 1300 x 1820 *Lite/Full version

The minimum temperature performance is not (yet) met. This needs further tuning of the chiller and a possible lowering of the sub cool control

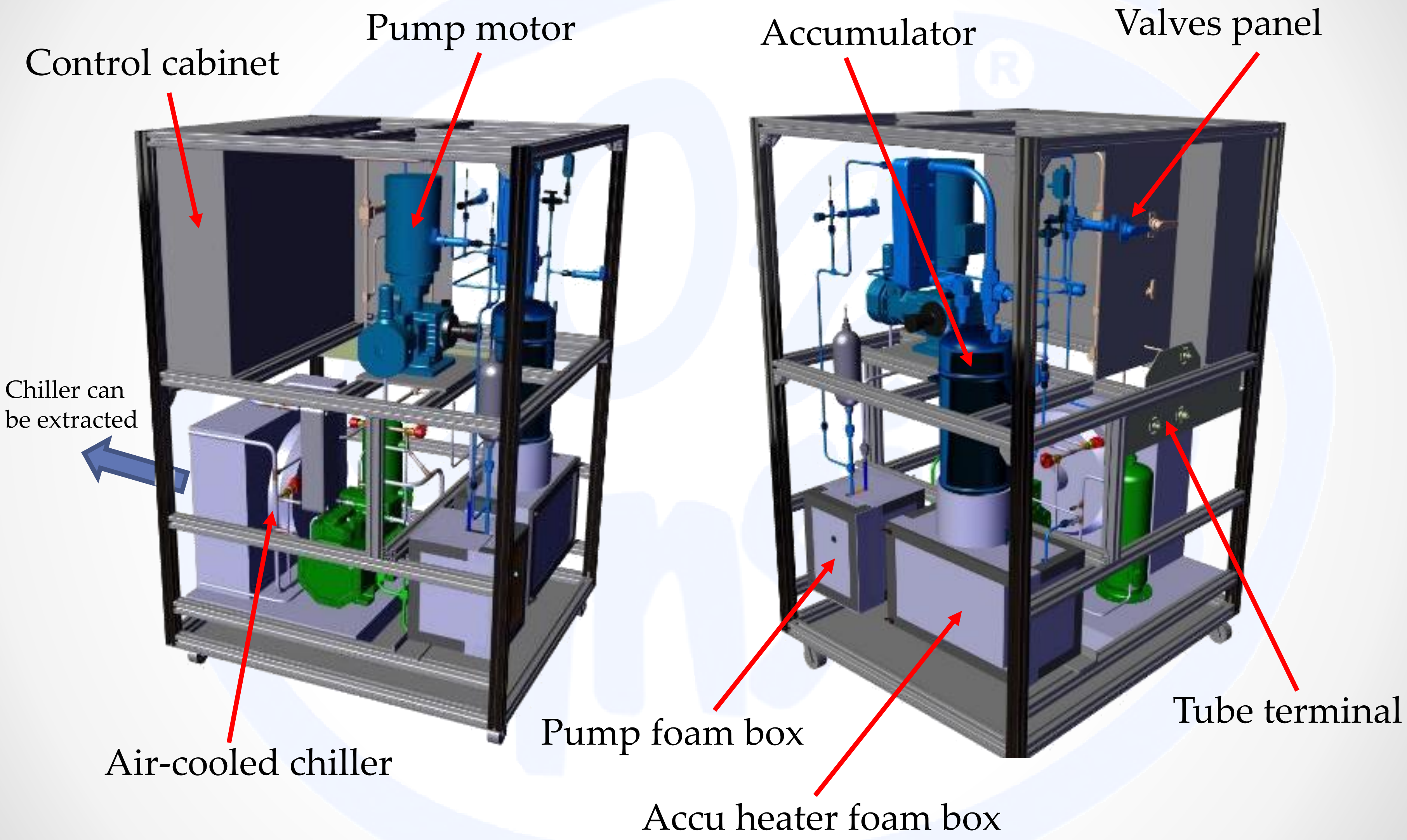


The LUCASZ commissioning was successful, measured performance close to design performance

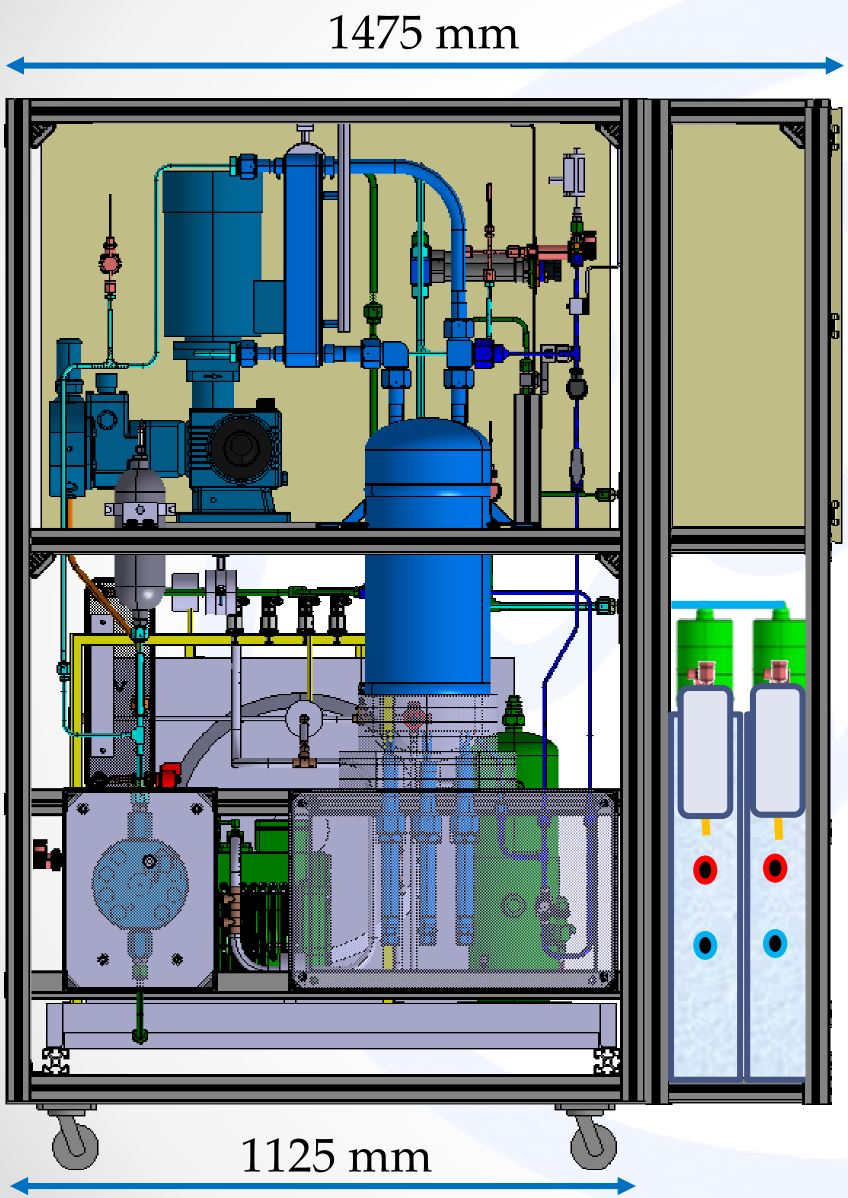
Here start Yadira's slides

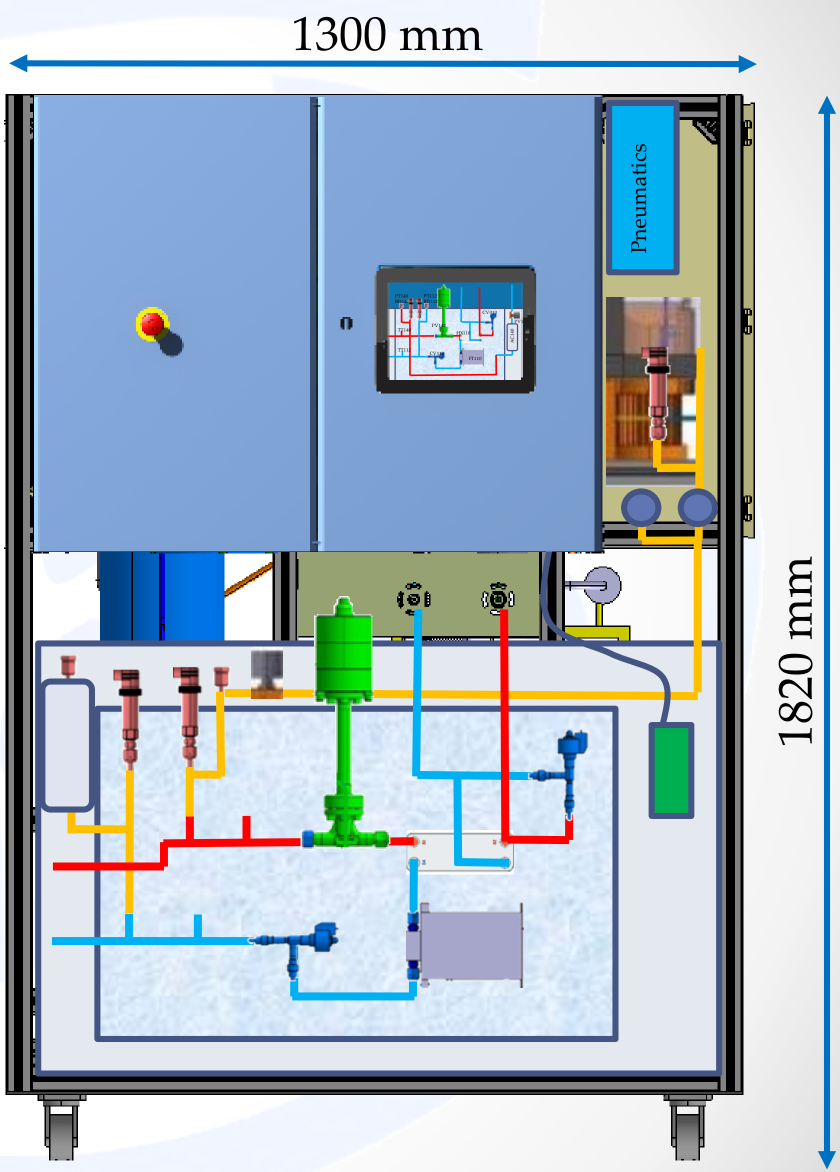
Backup slides

Lucasz plant core design



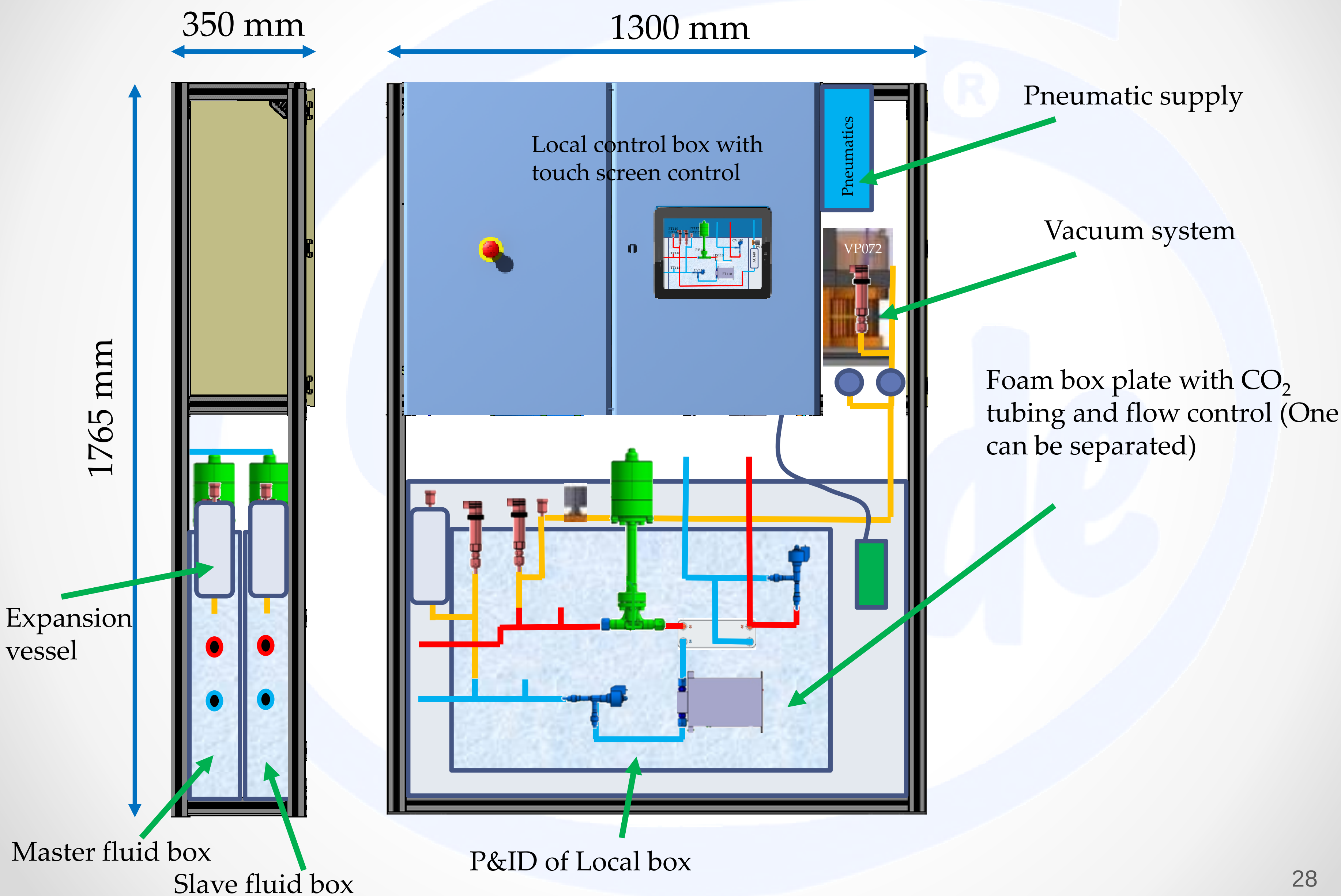
Lucasz$_{full}$ with local box attached



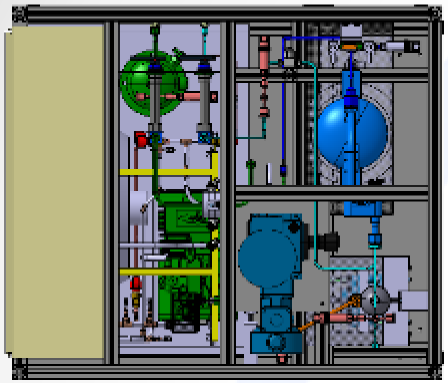


Lucasz$_{lite}$ + Local box = Lucasz$_{full}$

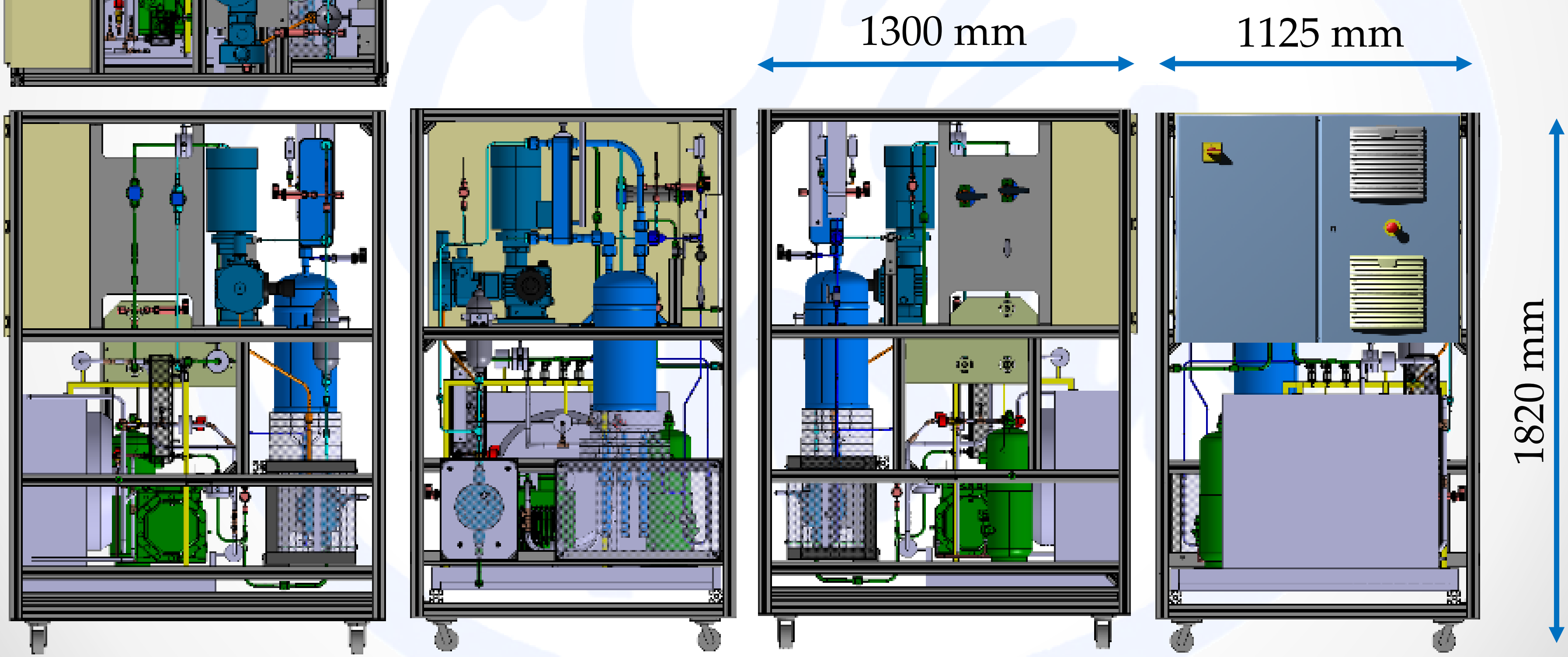
Local Control Box



Lucasz Cooling Plant



Lukasz $_{\text{Lite}}$ w*h*d=1300*1820*1125 mm
Lukasz $_{\text{Full}}$ w*h*d=1300*1820*1475 mm



Lucasz concept

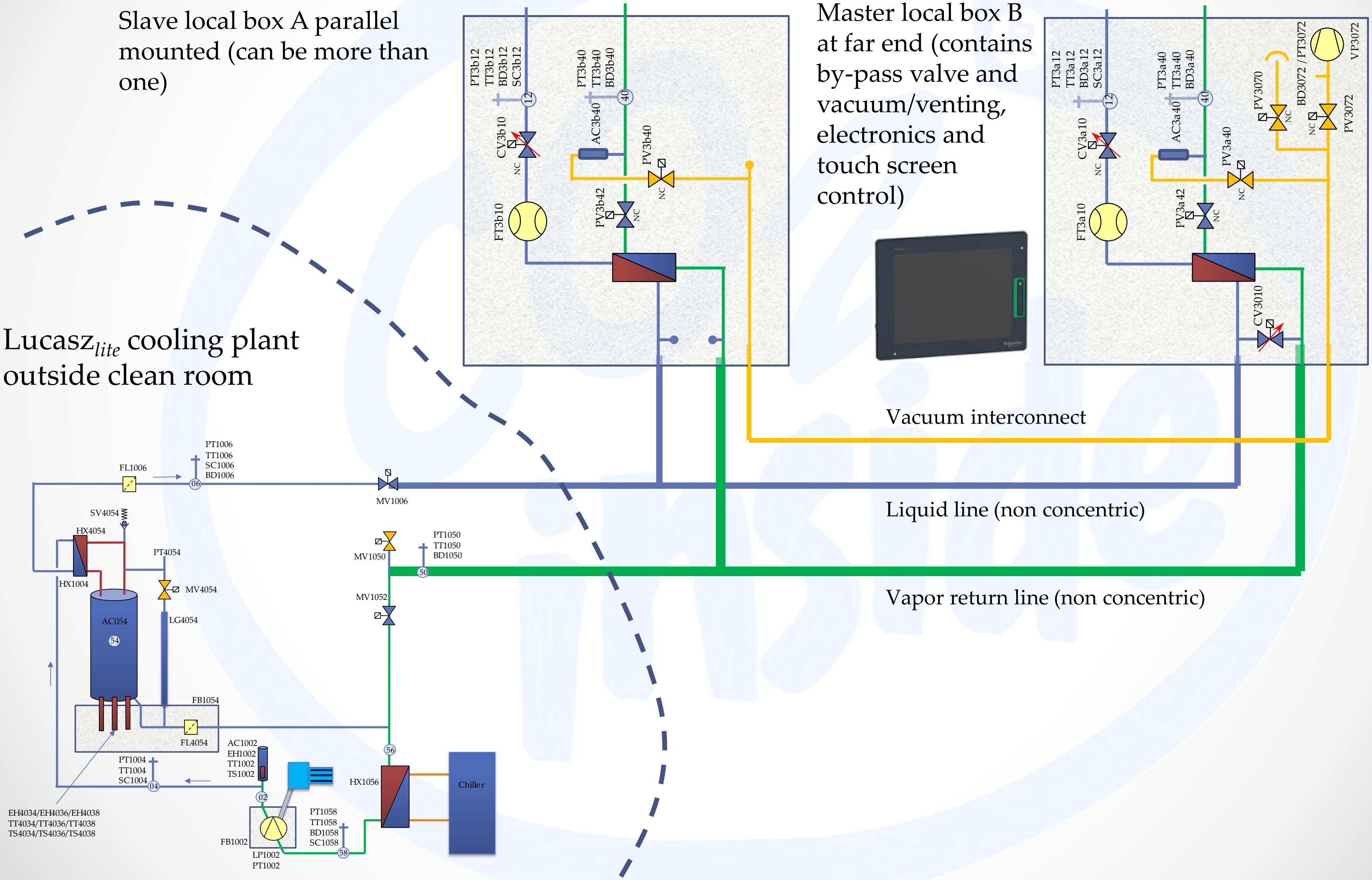
SLBaTo B-PIX1

MLBb to B-PIX2

Slave local box A parallel mounted (can be more than one)

Master local box B at far end (contains by-pass valve and vacuum/venting, electronics and touch screen control)

Lucasz$_{lite}$ cooling plant outside clean room



Lucasz unit cost

- 1st LUCASZ $_{full}$ prototype was foreseen to cost **CHF 135,117**
- Final expenditures after 1st prototype construction:
  - LUCASZ $_{full}$ = CHF 178,392
    - Where CHF 55,500 was FSU manpower cost @ CERN (40 CHF/hour)
  - LUCASZ $_{lite}$ = CHF 112,691
    - Where CHF 31,500 was FSU manpower cost @ CERN (40 CHF/hour)
- Currently using the second (and last phase) of prototyping we are bringing the documentation up to the quality needed for outsourcing. We are also actively searching for a reliable commercial partner for outsourced production.