LHCb VELO & UT CO_2 COOLING PLANT

P. Tropea, for the PH-DT cooling team

LHCb cooling EDR

3 Dec 2015

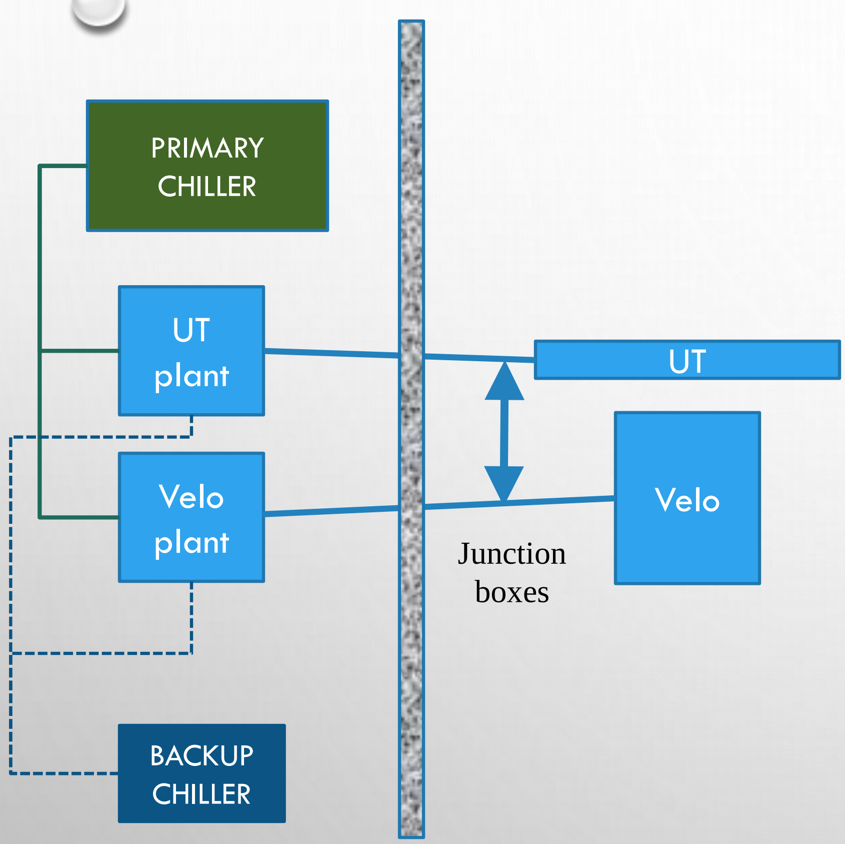
https://indico.cern.ch/event/450162/

COOLING PLANT: FOR REVIEW

1. The cooling system conceptual design:
   - P&I
   - basic functionalities
   - backup strategy
   - controls
   - commissioning strategy
2. Integration aspects
   - cooling plant
   - junction boxes
   - Interconnection
   - services
3. Cost estimate
4. Schedule
5. Work package between LHCb and PH-DT for plant construction

COOLING SYSTEM CONCEPTUAL DESIGN

LHCB VELO & UT CO2 COOLING SYSTEM



A. 2 CO2 cooling plants, one for Velo, one for UT

B. Each plant capable to cool both detectors together (7 kW @ -30C): i.e. if one plant fails, the second one can feed both detectors (Agreement on operating T needed when "swapping")

C. 1 primary chiller to condense CO2 **Q1**
   A. Local chiller for UT & Velo?
   B. Common to other LHCb systems? **Q2**

D. 1 backup chiller for both UT & Velo plants:
   A. limited power?
   B. Full power?

E. 2 PACL circuit with constant pressure drop regulation

F. Local junction boxes for swap between plants U & V: no balancing of levels required

Q1: PRIMARY CHILLER

LOCAL CHILLER

(-) Needs space & infrastructure in the alcove (water, power, etc..)

(+) Independency between subsystems

(+) Unique control system with CO2 process, easier to interface

(-) Cost (40 kCHF)

COMMON CHILLER (SCI-FI)

(-) Coordination btw subsystems for M&O

(+) Much simpler routing of basic services to the alcove (no water, less power…)

(-) Insulated pipe from common system to arrive to the alcove

(+) Time-scale for installation & commissioning to be coordinated (-)

(+) Can save 50% of primary system cost

Q2: SIZE OF THE BACKUP CHILLER

TO BE POWERED ON DIESEL, IN ORDER TO COPE WITH POWER CUTS!

FULL POWER

(+) Can be used for operation in case of:

- primary chiller failure
- water circuit failure

(-) Cost (300% baseline cost), complexity, size

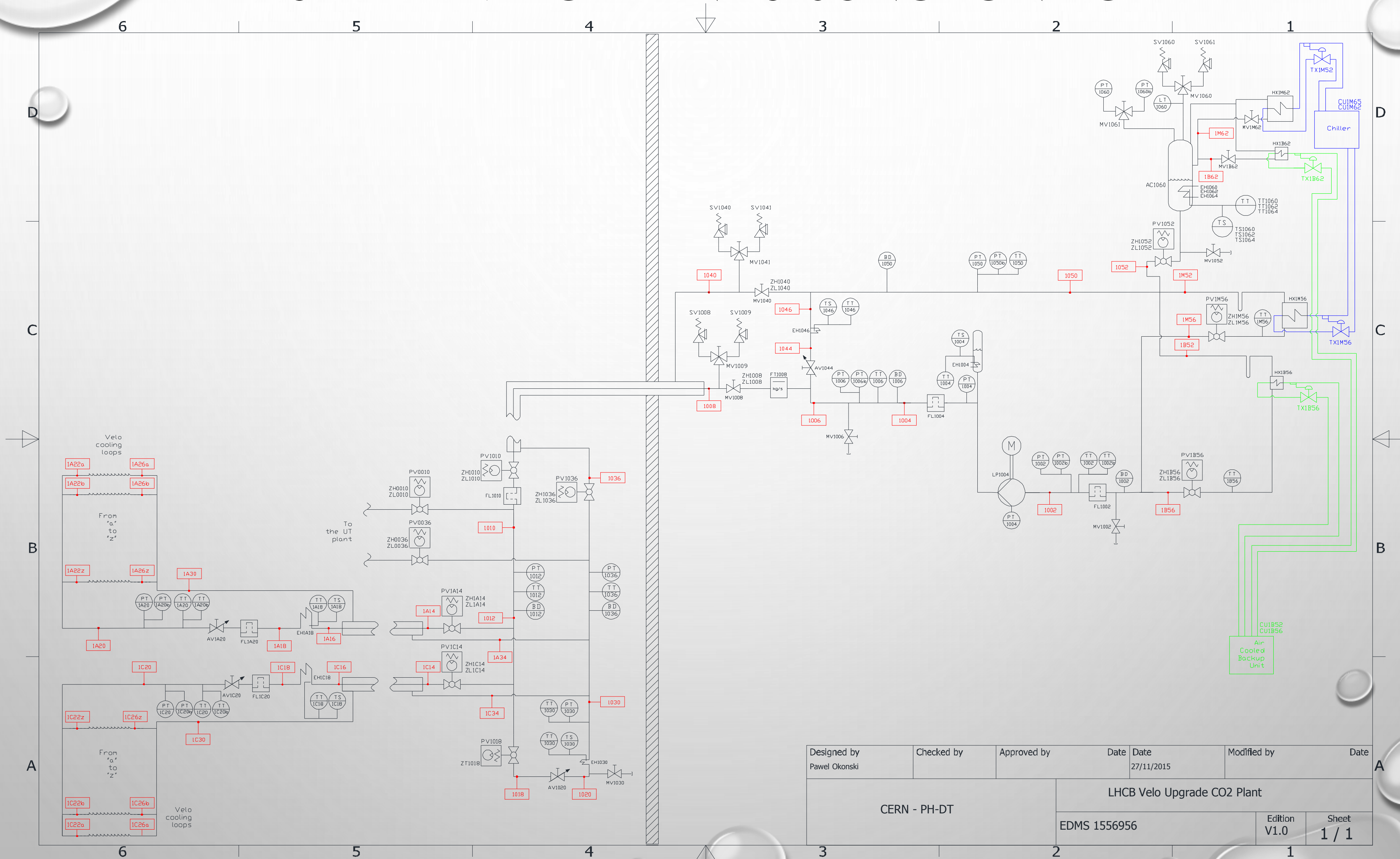
"KEEP IT COLD"

(+) Small, simple, cheap! (10 kCHF): the present Velo cooling works like this!

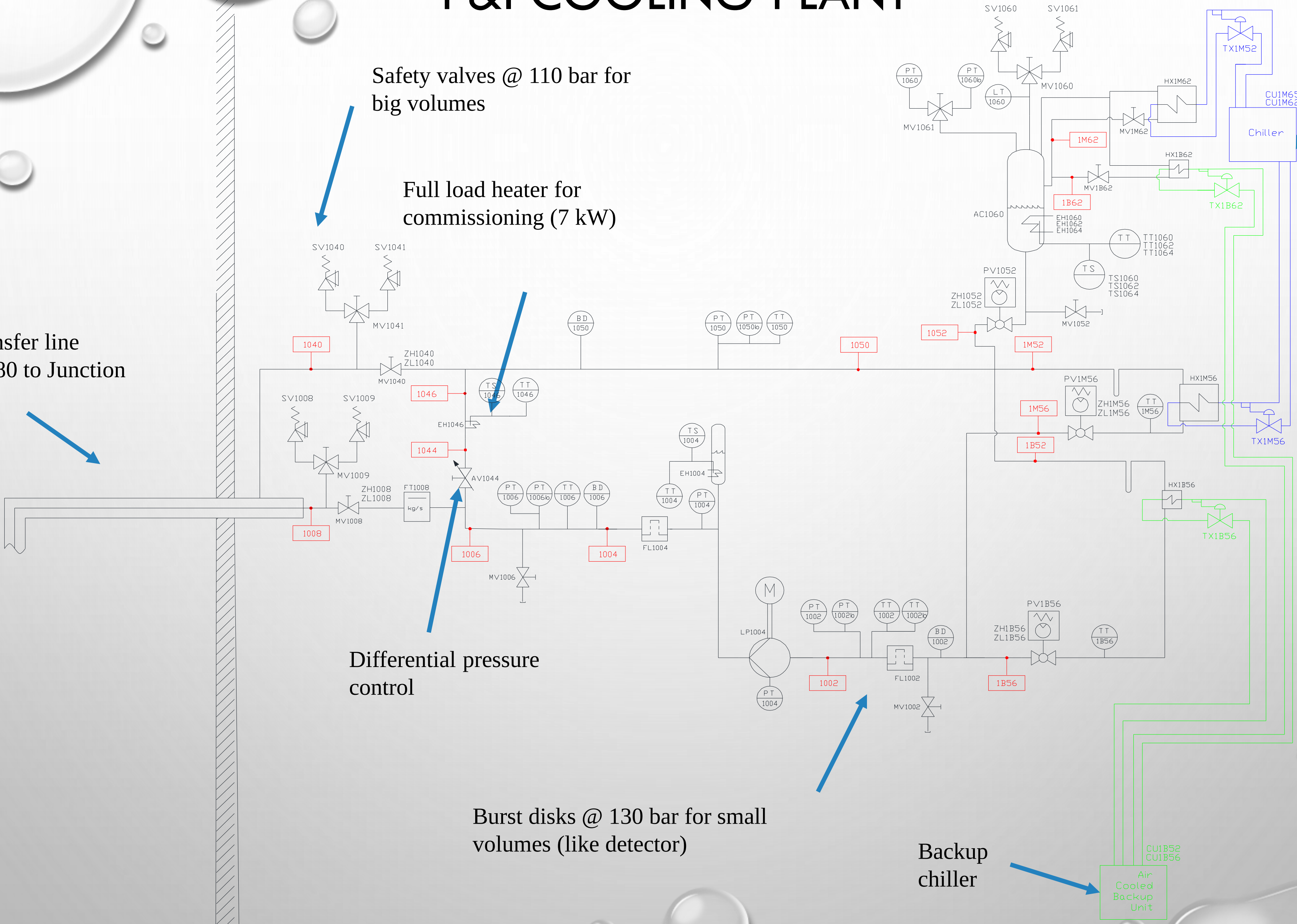
Need to define:

- the total power when detector off: 2-3 kW?
- What temperature shall be kept when the detector off? Same as with power or higher?

P&I – EX: VELO PLANT & JUNCTION BOX



P&I COOLING PLANT



Safety valves @ 110 bar for big volumes

Full load heater for commissioning (7 kW)

Transfer line DN80 to Junction box

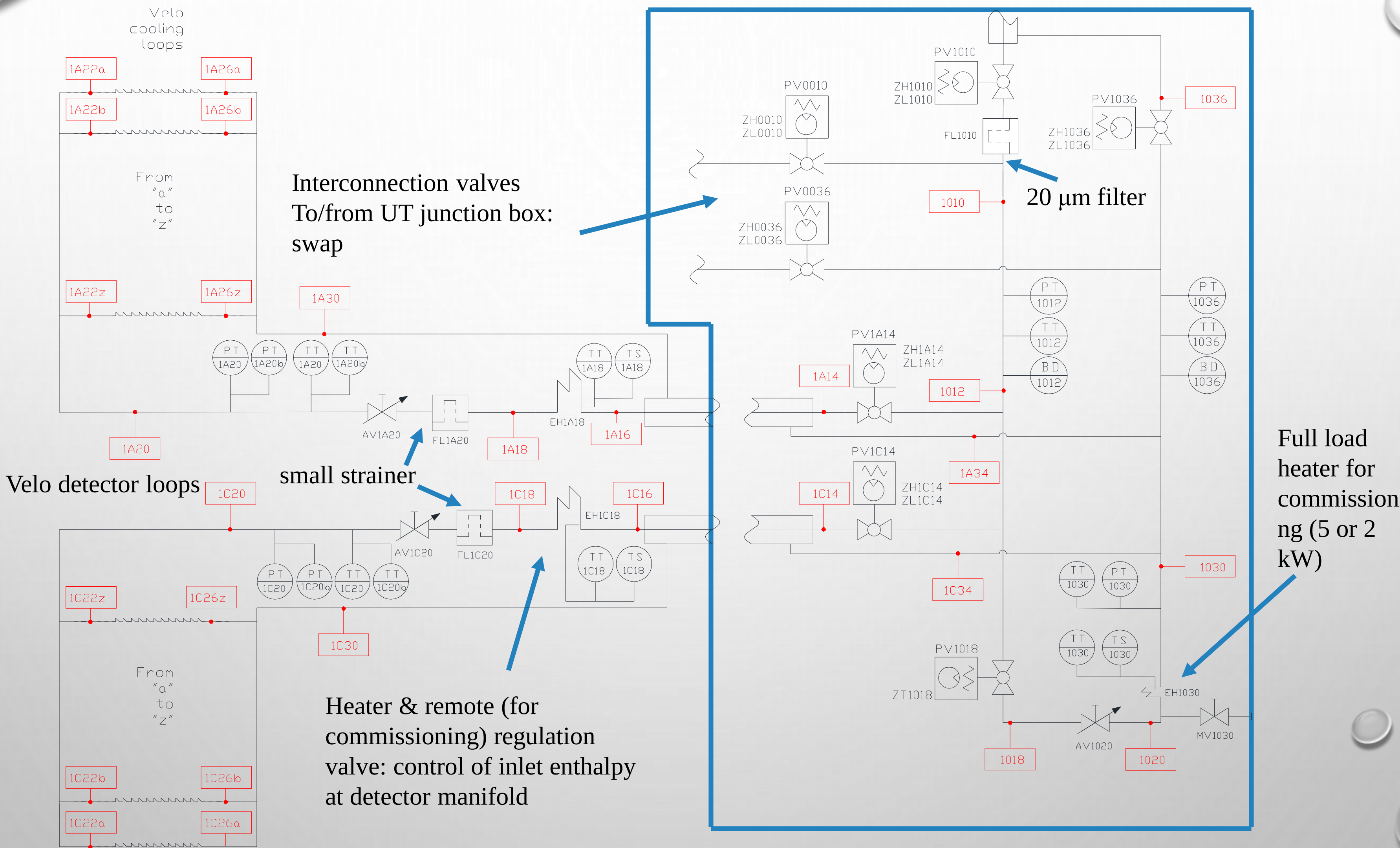
Differential pressure control

Burst disks @ 130 bar for small volumes (like detector)

Main Chiller

Backup chiller

JUNCTION BOX & DETECTOR DISTRIBUTION

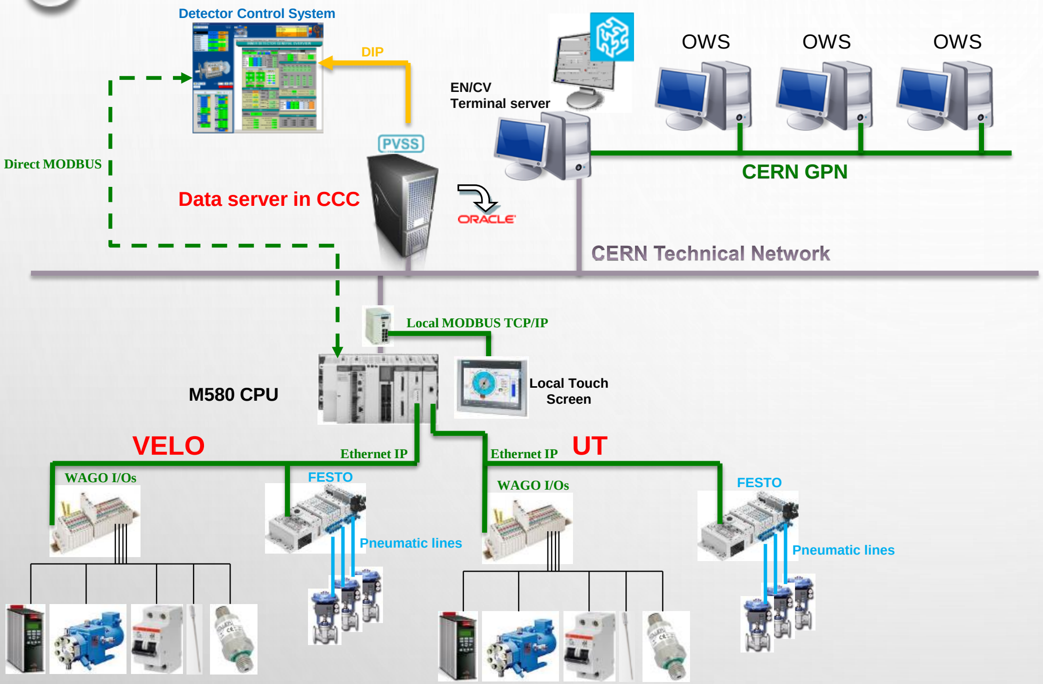


COMMISSIONING TOOLS & STRATEGY

1. **Electrical checkout** of separate parts: can be done on surface, ahead of installation
2. **Dummy loads at plant level**: help in commissioning the plant cooling power, can be used with no secondary system attached, eventually on surface (space, water/primary coolant, power, etc…): **feasible but COMPLEX and time consuming**
3. **Dummy loads at junction box**: allow for full commissioning & debugging, easy to build, can be ready in Jan 2017. In combination with transfer lines, shall be operated **at least for 6 months** in order to complete commissioning

Preparation of junction boxes, cables between underground areas & transfer lines allow complete decoupling from LS2 starting date, accessibility to the detector area, availability of resources during LS2….A BIG PLUS!

CONTROL SYSTEM KEY ELEMENTS



Controls:

- **Schneider** PLC: 1x M580 in technical network
- SCADA based on **Siemens WinCC OA 3.11**
- PLC and SCADA software based on **UN**ified **I**ndustrial **CO**ntrol **S**ystem (**UNICOS**) **C**ontinuous **P**rocess **C**ontrol **CPC6** of CERN
- **WAGO Ethernet IP** distributed I/Os in privet network
- **FESTO Ethernet IP** distributed I/Os in privet network
- Access control via e-groups
- Long term data storage in **LHC logging** data base
- Communication to the **Detector Control System** (DCS) uses Data Interchange Protocol (DIP)
- Additional direct MODBUS communication to DCS for critical data
- Hard wired signals connected to **Detector Safety System** (DSS)
- **local touch screen** used for the redundancy and safety needs

Electricity and power distribution:

- Standard industrial components (ABB, Siemens, etc.)
- 24V DC hot swappable redundant power supplies

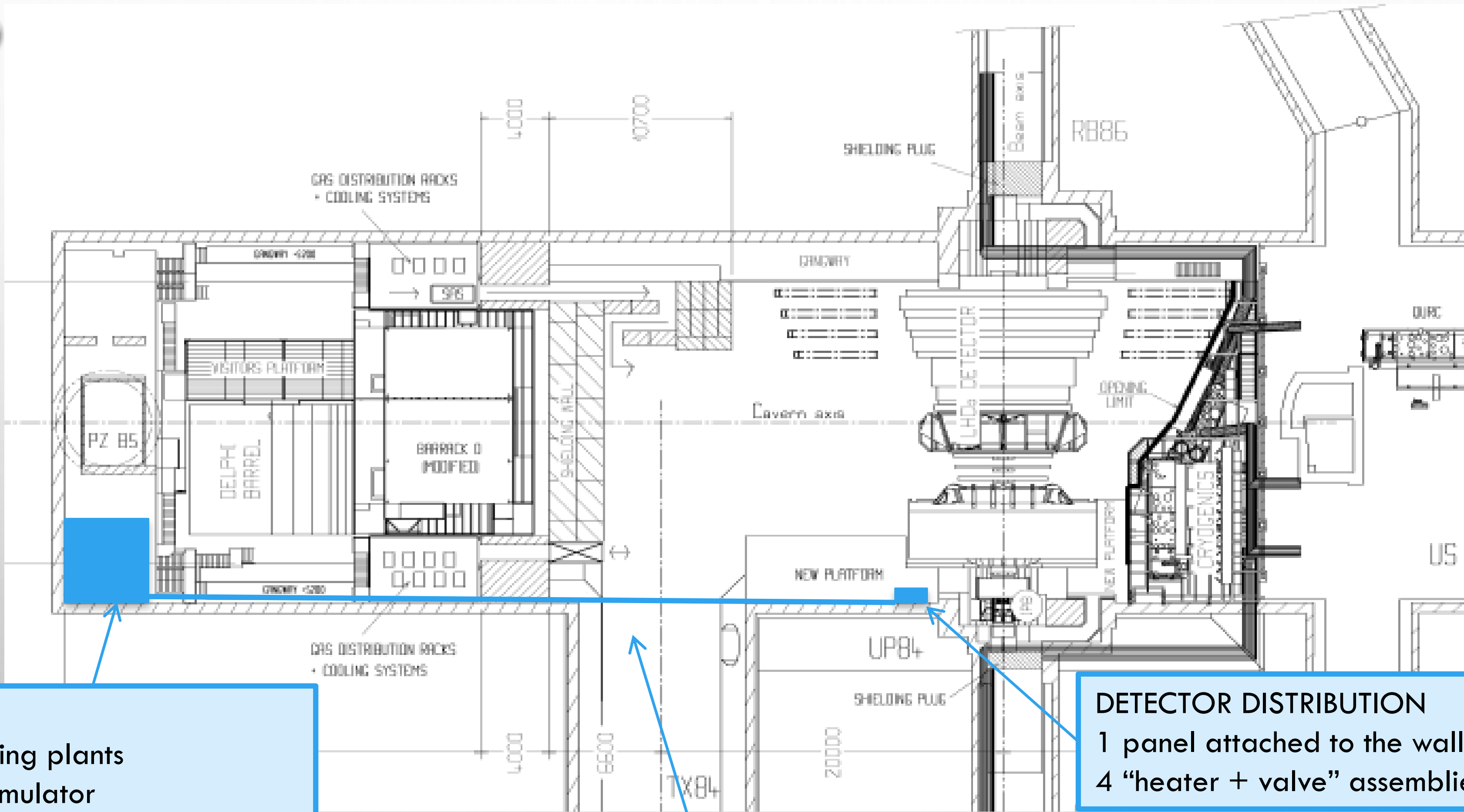
PH-DT standard

common for ATLAS and CMS CO_2 cooling systems

(including TIF and P5 of CMS)

INTEGRATION & SERVICES

INTEGRATION



ALCOVE
2 x Cooling plants
2 x Accumulator
1-2 Control/Pneumatic racks
1 Drier

BTW DETECTOR & PLANT
2 x DN80 vacuum insulated concentric transfer lines
1 x cable tray signal + pneumatic
1 x cable tray power

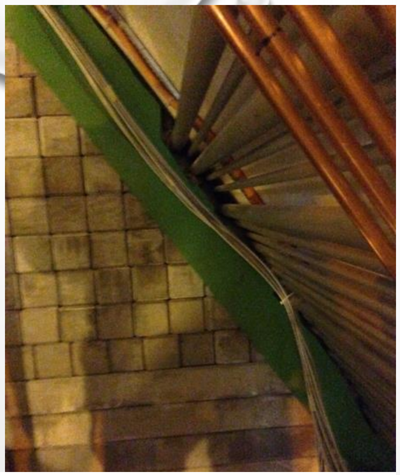
DETECTOR DISTRIBUTION
1 panel attached to the wall
4 “heater + valve” assemblies

ALCOVE: INFRASTRUCTURE NEEDS

- UPS Power supply for PLC & controls
- General power for:
  - Primary chiller (if it's there)
  - 2 plants
  - Dummy loads (at the plant or at the junction box)
  - Enthalpy rise heaters
- Diesel power for
  - backup chiller
  - drier
- Cooling water: 18 kW mixed water (14 C) – Only in case of independent chiller
- Dry air (dew point <-50 C) for flushing & valve piloting @ 7 bar, <20 Nm3/h
- Drier: on diesel power, 40 kW
- Ventilation
- CO_2 detection system

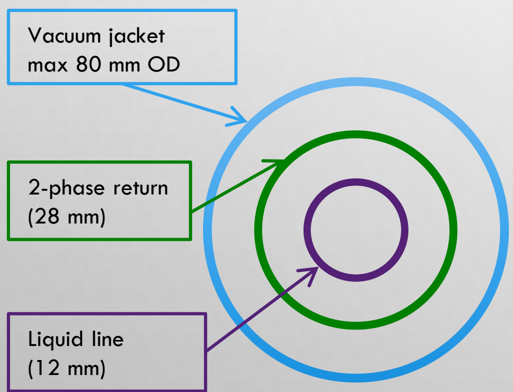
Detailed values after part selection (mid 2016)

FROM PLANT TO DETECTOR



Shielding wall passage

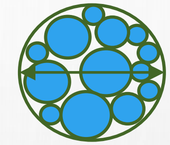
2 x TRANSFER LINES



SIGNAL CABLES

- Proximity of the detector 4xPT, 2xTT, 2xTC, 2xTS per detector
    - 28 wires + spares => 1x NE36 OD 18.5mm
    - 2x TC cables ~8.5mm + 2 spares
- Junction box 3xPT, 3xTT, 1xTS, 7x2 valve feedbacks, 1xTC per detector
    - 48 wires => 1x NE48 OD 21.0mm
    - 18 spare wires => 1x NE18 OD 13.5mm
    - 1x TC cables OD ~8.5mm + 1 spare

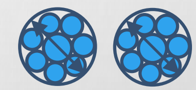
$\emptyset_{min}$=60.2mm



PNEUMATIC PIPES

- 2 multipipes with 12 pipes each, 6x4mm ⌀

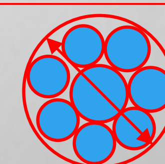
Ø= 28mm x2



POWER

- Proximity of the detector 2x2 monophase heaters => 4x 3x1.5mm2 +1 spare
- JB 1x2kW monophase heater => 1x 3x2.5mm2 +1 spare
- JB 1x5kW 3phase heater => 1x 5x4mm2

$\emptyset_{min}$= 46.8mm

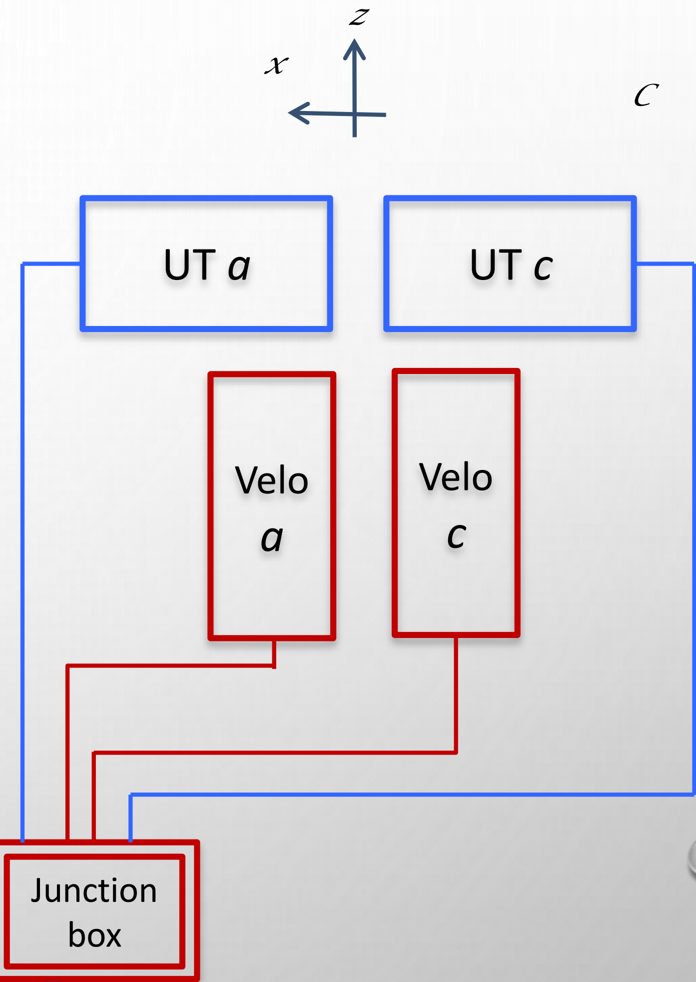


Verification of space & routing needed during YETS – courtesy LHCb integration

TRANSFER LINES SIZING & APPROACH

Transfer lines between plants and junction boxes

- Preliminary sizing based on commercial vacuum insulated product (80 mm OD) for long lines
- **Integration studies** necessary to determine correct path
- External company to produce (at least 6 months for purchase & production) – PH-DT can prepare the tender, LHCb team must take over with contract follow up and during installation
- Installation in a few weeks if routing is kept simple

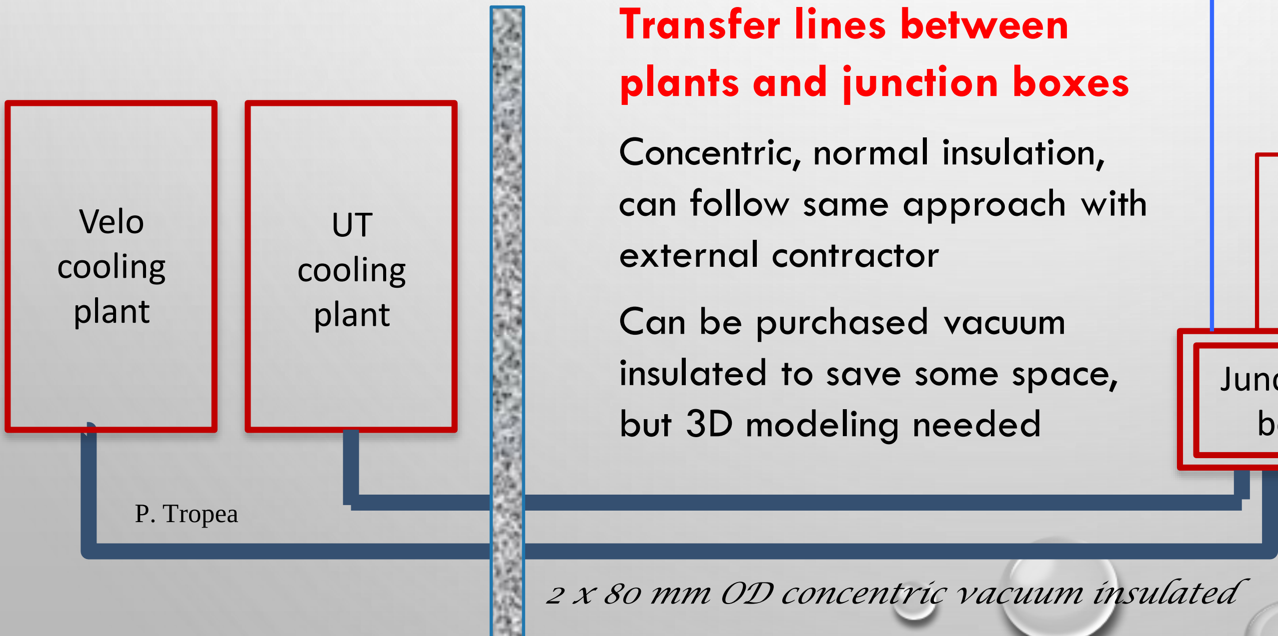


Both UT and Velo transfer lines to be designed

Transfer lines between plants and junction boxes

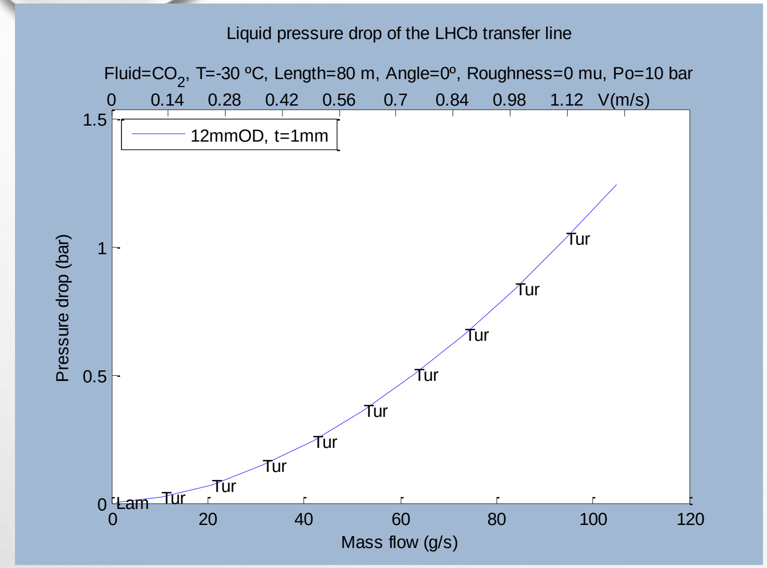
Concentric, normal insulation, can follow same approach with external contractor

Can be purchased vacuum insulated to save some space, but 3D modeling needed



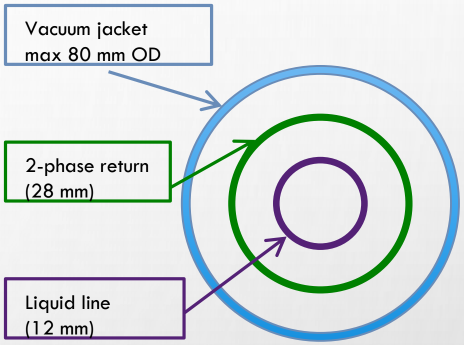
2 x 80 mm OD concentric vacuum insulated

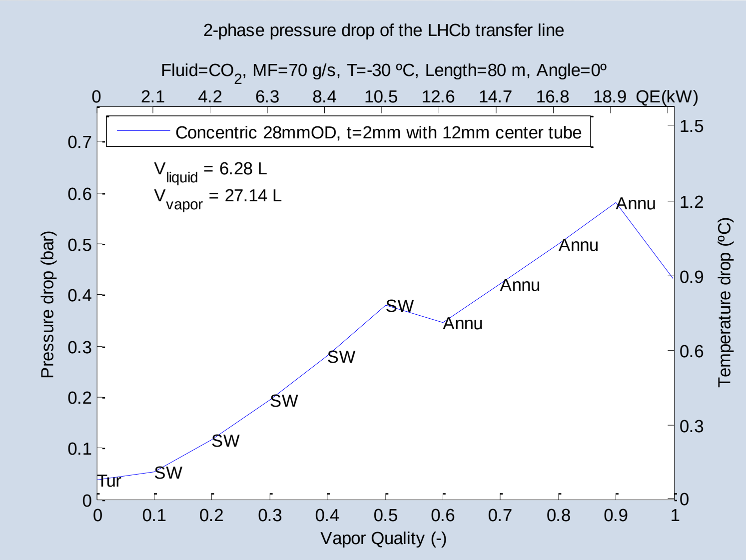
LHCB VELO & UT MAIN TRANSFER LINE

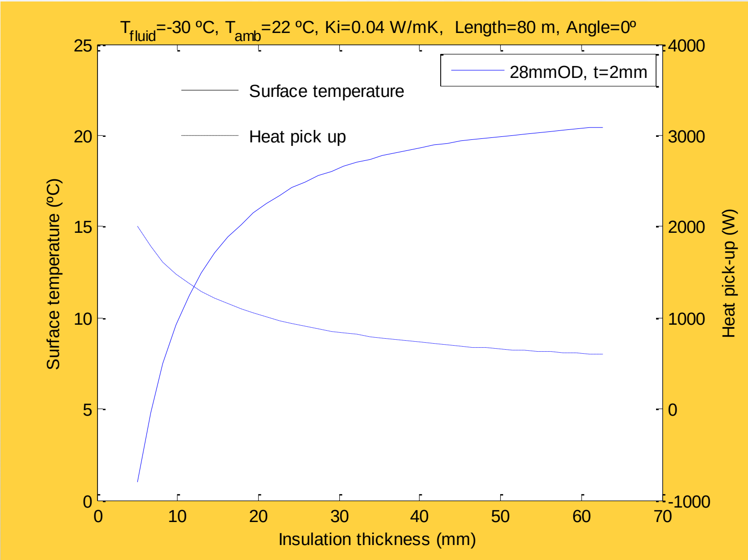


Transfer line from the plant to the Junction Box (2 of them, one per plant)

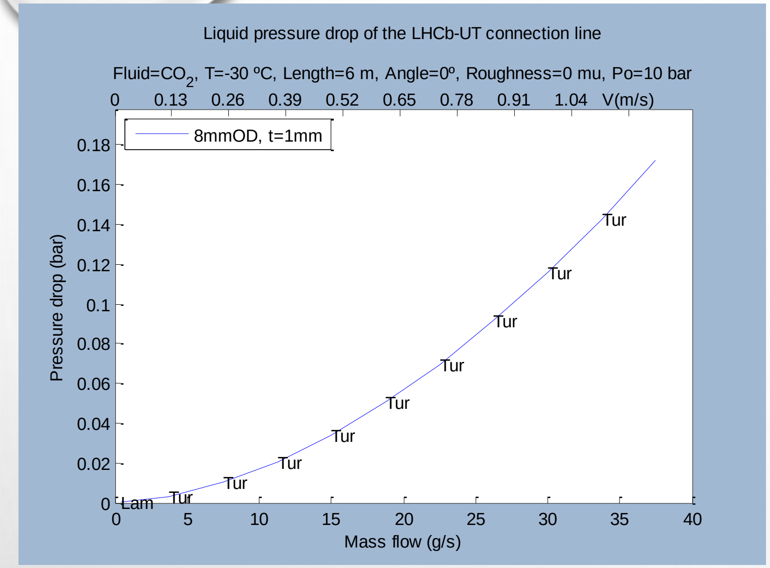
- Power 7000W
- Flow 70 g/s (VQ~0.3)
- Estimated length: 80m



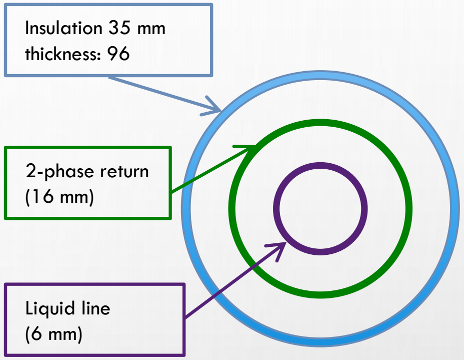


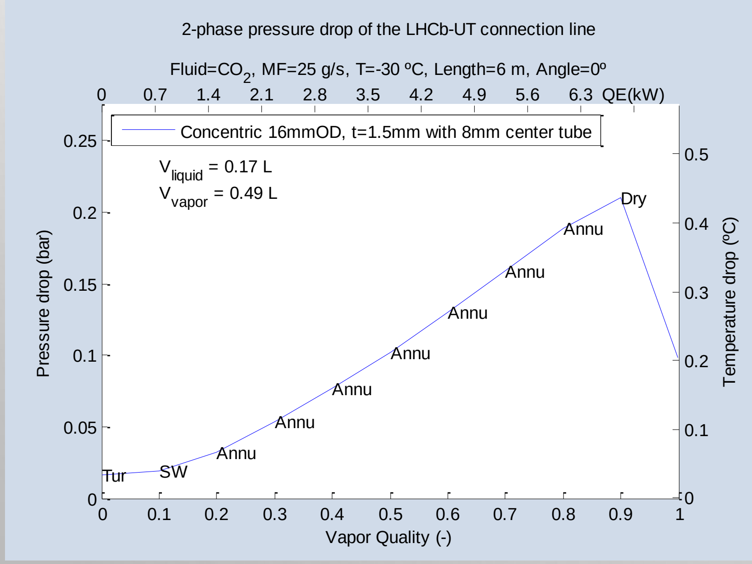


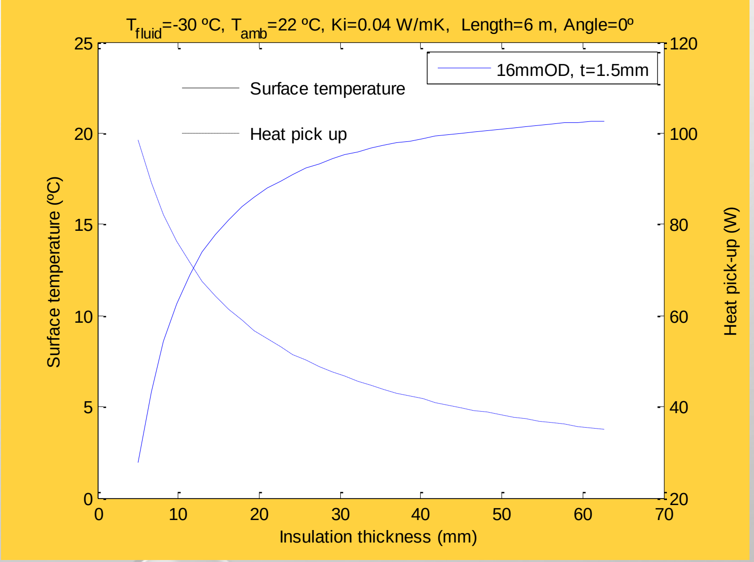
UT CONNECTION LINE



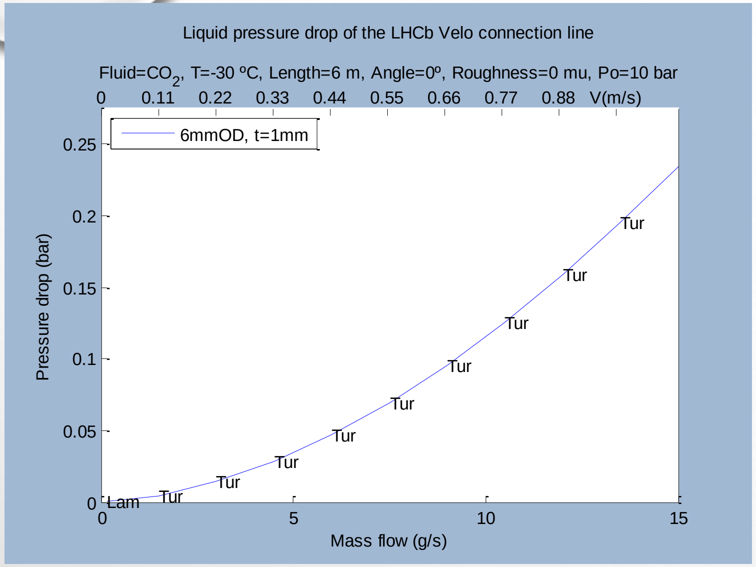
- Connection line from the Junction box to a UT detector half
  - Power 2500W
  - Flow 25 g/s (VQ~0.3)
  - Estimated length: 6m





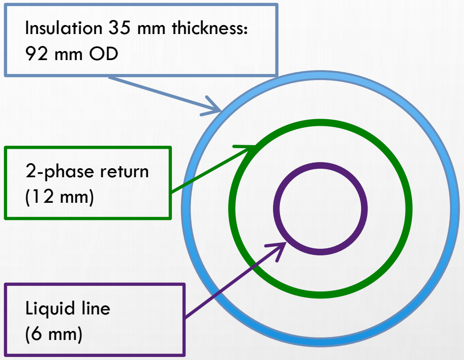


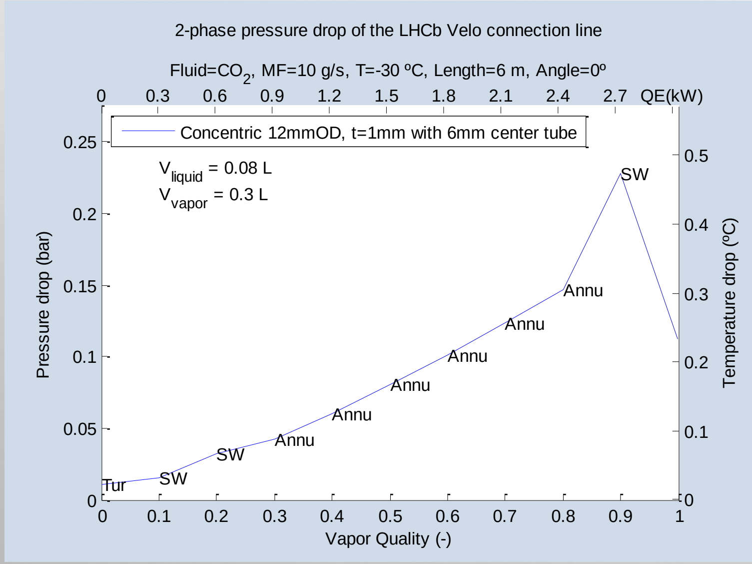
VELO CONNECTION LINE

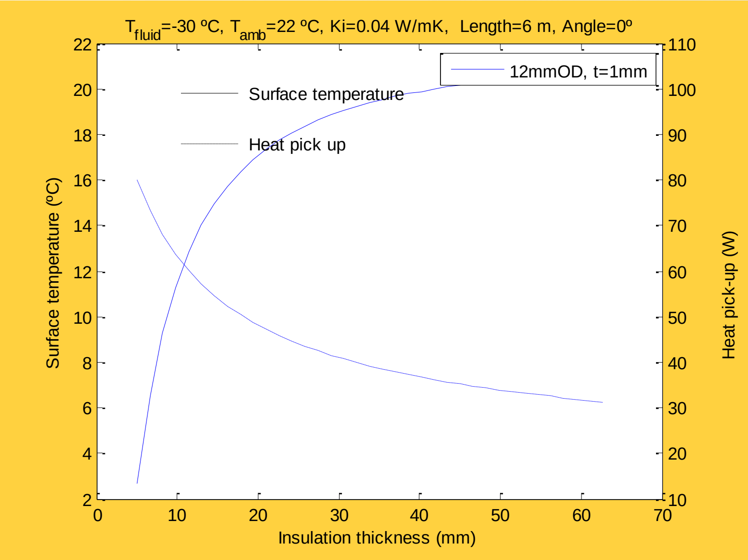


Connection line from the Junction box to a detector half

- Power 1000W
- Flow 10 g/s (VQ~0.3)
- Estimated length: 6m



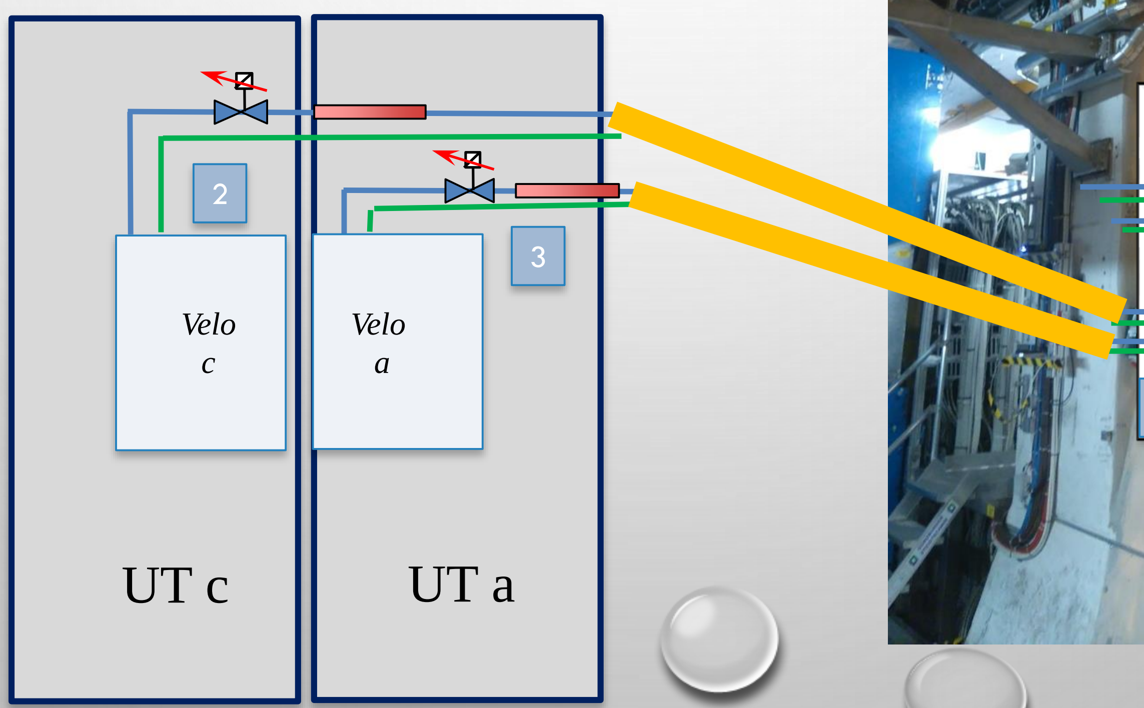




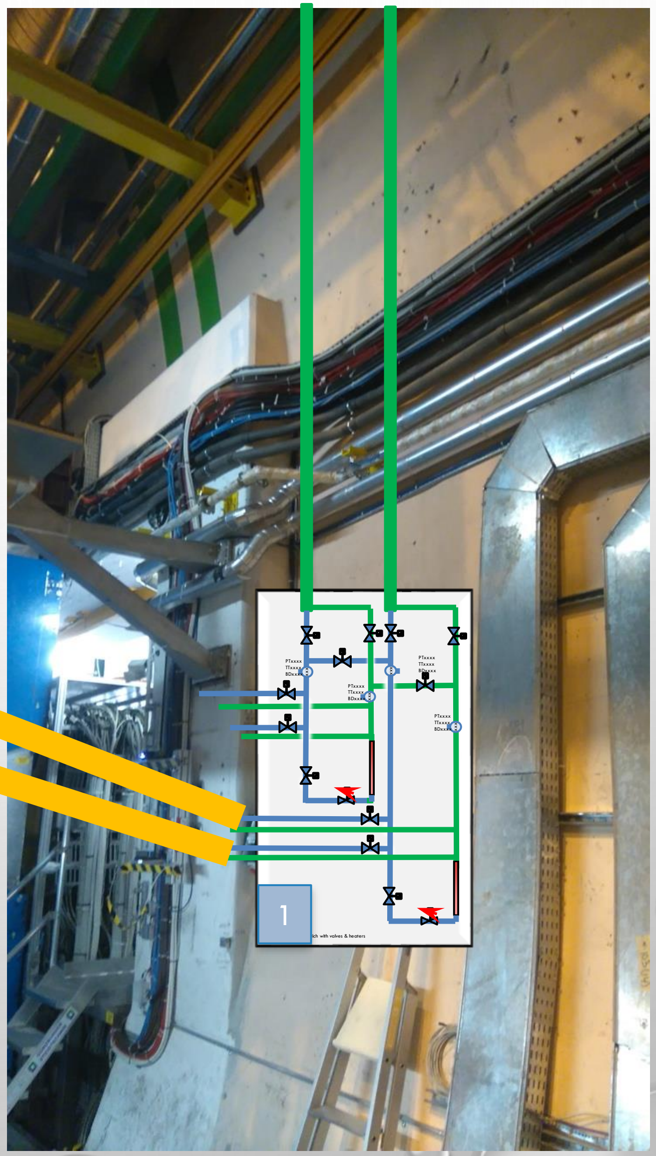
DETECTOR DISTRIBUTION - VELO

1) Junction box along the wall
2-3) heaters and manual regulation valves on top of Velo (where present cooling system distribution is)

Concentric transfer lines, normal insulation, rigid



Transfer lines & services from top of the cavern



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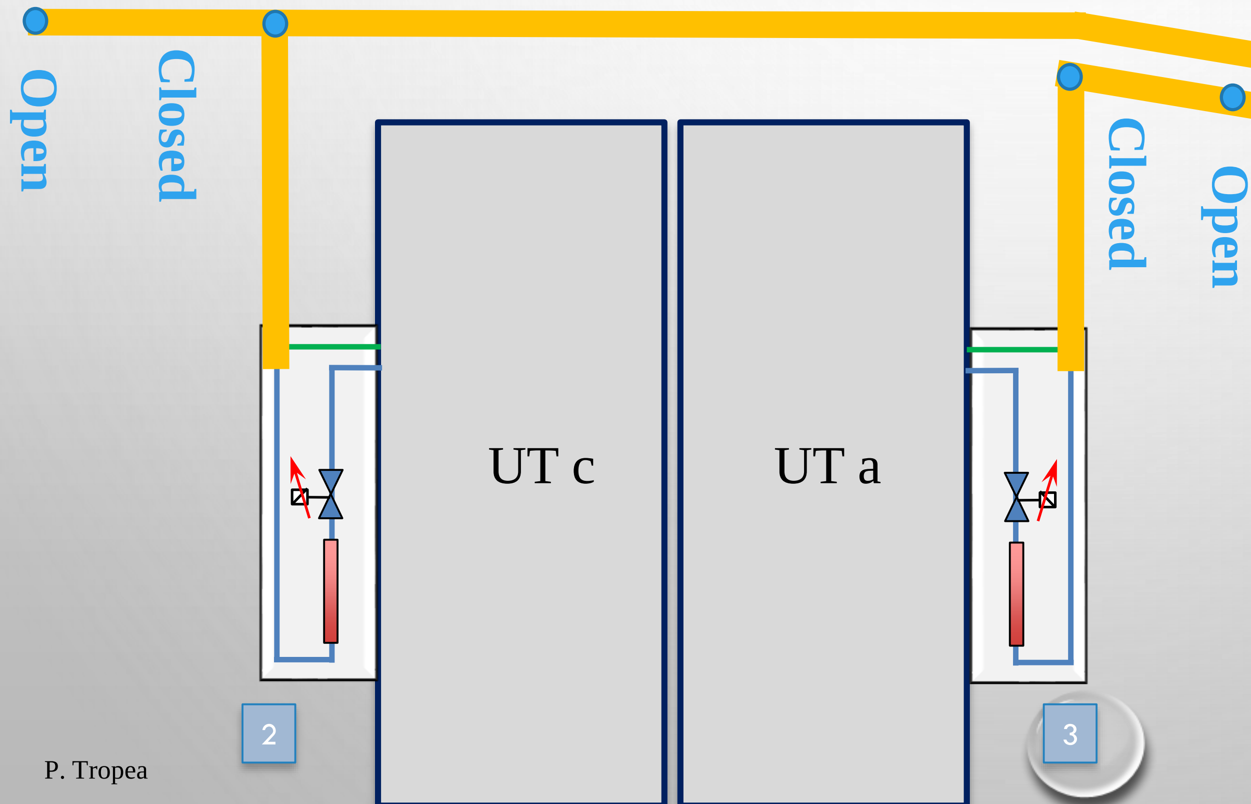
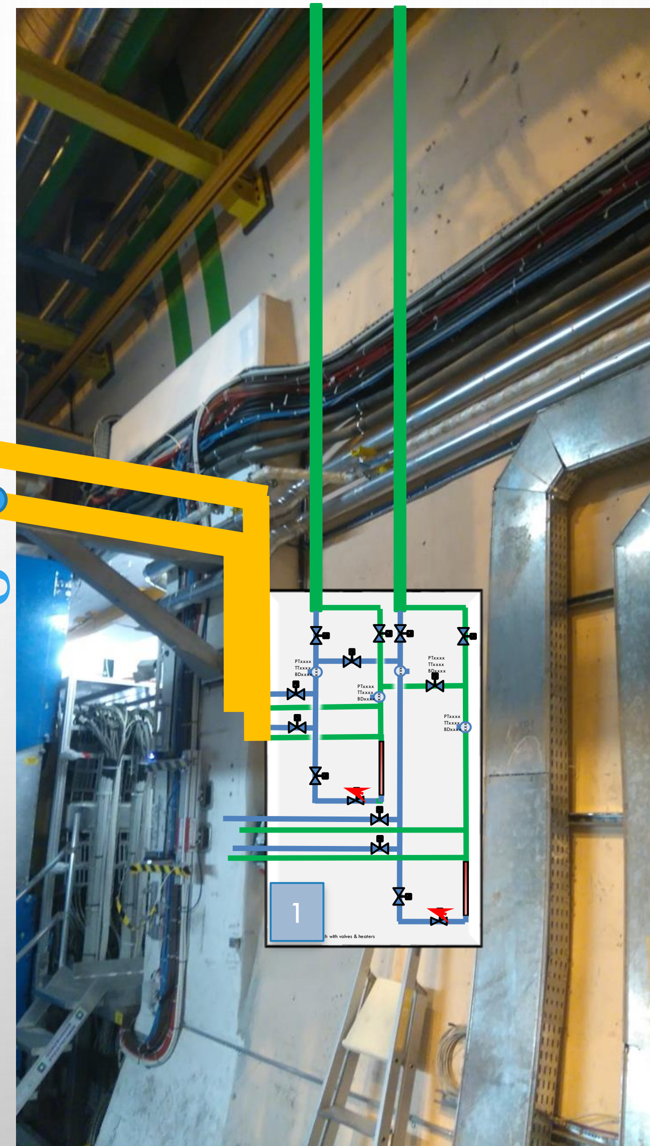
DETECTOR DISTRIBUTION - UT

1) Junction box along the wall
2-3) heaters and manual regulation valves on the two sides of UT

Concentric transfer lines, normal insulation, rigid
2 positions for connection to UT: roughly 1 hour operation to swap from "open" to "close" position



Transfer lines & services from top of the cavern



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COST & SCHEDULE

COST ESTIMATE - PLANTS

- Estimate based on previously selected components (CMS, ATLAS)
- Can expect 10% confidence

Main chapter	Detail	Unit price [kCHF]	Total QTY	Total price x 2 units [kCHF]
Hardware				
Primary				
	Main chiller	40.00	1	40.00
	Backup chiller	10.00	1	10.00
Hydraulics				
	Main components	100.00	2	200.00
	Pipework & structure	42.00	2	84.00
	Instrumentation	17.00	2	34.00
Controls				
	Control HW	40.00	1	40.00
	Cables & pneumatic pipes	10.00	1	10.00
Manpower				
	PH-DT Assembly Services	20.00	2	40.00
	PH-DT Cabling & programming	15.00	2	30.00
	QualificationServices	10.00	2	20.00
	Design	3.30	6	20.00
	Total 2 CO2 plants & primary system			*528.00*

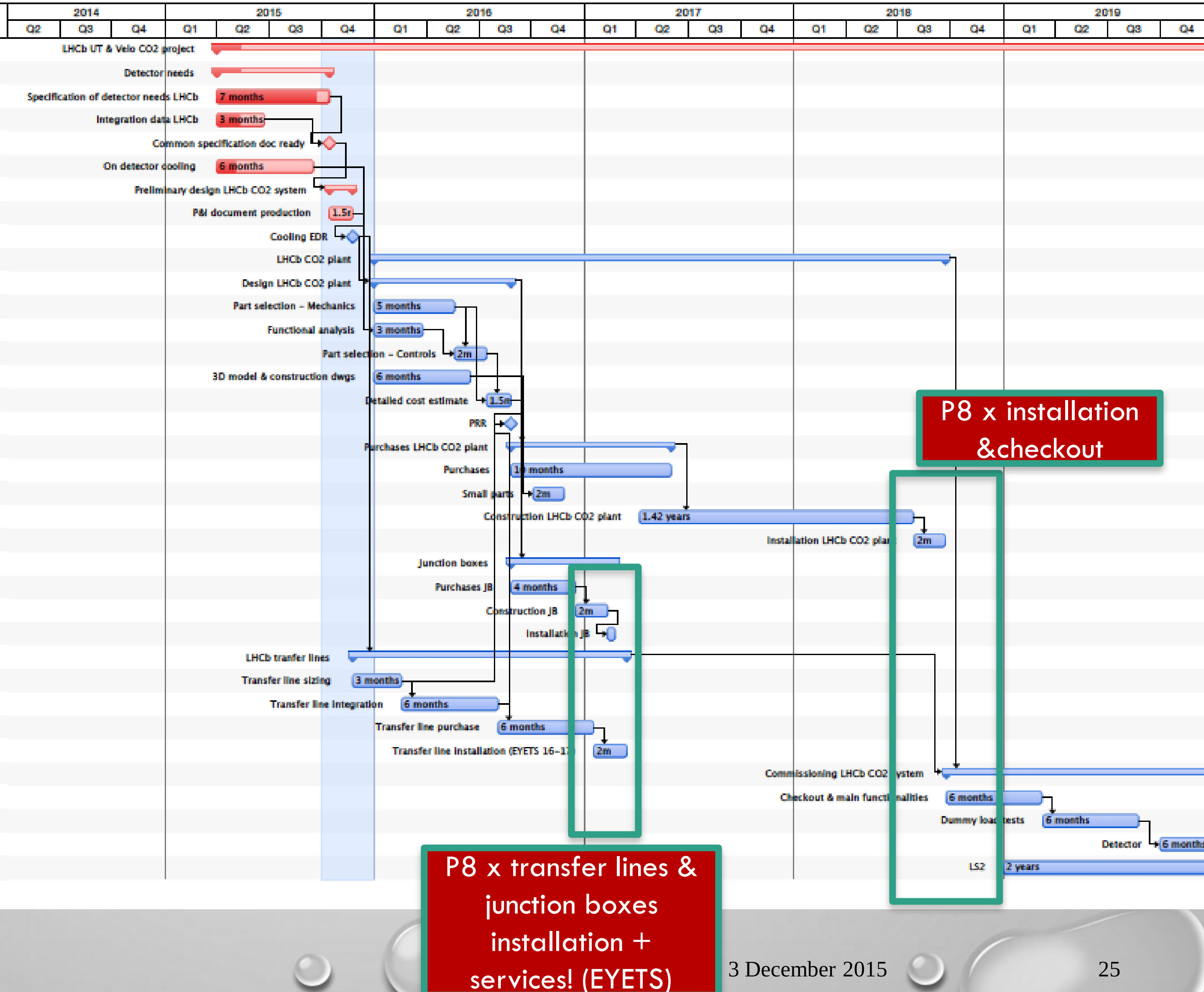
COST ESTIMATE - INFRASTRUCTURE

- Transfer line cost: vacuum jacket systems installed during LS1 on ATLAS & CMS, 450 CHF/m for standard sizing (20% confidence)
- Drier: as per last purchase Donaldson 80 Nm3/h, -70 C dew point
- Power distribution, water distribution: to be quoted, LHCb
- Cabling & pneumatic pipe installation between zones: LHCb

Main chapter	Detail	Unit price [kCHF]	Total QTY	Total price x 2 units [kCHF]
Infrastructure				
	Dry air system	16.00	1	16.00
	Vacuum-jacketed pipes plant to junction box	0.45	160	72.00
	Concentric lines junction box to detector	0.40	30	12.00
	Power distribution in alcove		not evaluated	
	Water distribution in alcove		not evaluated	
	Cabling & pneumatic pipe laying between cav		not evaluated	
	Total Infrastructure & transfer lines			*100.00*

PRELIMINARY SCHEDULE – DRAFT FOR DISCUSSION

#	Info	Title	Given Planned Duration
0		LHCb UT & Velo CO_2 project	
1		Detector needs	
2		Specification of detector needs LHCb	
5		Integration data LHCb	3 months
6		Common specification doc ready	
7		On detector cooling	
11		Preliminary design LHCb CO_2 system	
12		P&I document production	1.5 months
13		Cooling EDR	
14		LHCb CO_2 plant	
15		Design LHCb CO_2 plant	
16		Part selection – Mechanics	5 months
17		Functional analysis	3 months
18		Part selection – Controls	2 months
19		3D model & construction dwgs	6 months
20		Detailed cost estimate	1.5 months
21		PRR	
22		Purchases LHCb CO_2 plant	
23		Purchases	10 months
24		Small parts	2 months
25		Construction LHCb CO_2 plant	
30		Installation LHCb CO_2 plant	2 months
31		Junction boxes	
32		Purchases JB	4 months
33		Construction JB	2 months
34		Installation JB	2 weeks
35		LHCb tranfer lines	
36		Transfer line sizing	3 months
37		Transfer line integration	6 months
38		Transfer line purchase	6 months
39		Transfer line installation (EYETS 16–17)	2 months
40		Commissioning LHCb CO_2 system	
41		Checkout & main functionalities	6 months
42		Dummy load tests	6 months
43		Detector	6 months ?
44		LS2	24 months



WORK PACKAGE AGREEMENT

WORK PACKAGE PH-DT/LHCB
[HTTPS://EDMS.CERN.CH/DOCUMENT/1556960/1](https://edms.cern.ch/document/1556960/1)

PH-DT Detector Technologies	Work package between PH-DT and LHCb for the design, construction, installation and commissioning of the CO2 cooling plants for the Upstream Tracker and the upgraded Velo detector		
EDMS Id. 1556960		Created: 10 Oct 2015	Nb of pages: 7
		Last Modified: 1 December 2015	Version: 2.2

This document can be found at:
https://edms.cern.ch/document/1556960/1

Work package between PH-DT and LHCb for the design, construction, installation and commissioning of the CO_2 cooling plants for the Upstream Tracker and the upgraded Velo detector

Abstract

This work package defines the terms of the collaboration between the LHCb experiment and the CERN PH-DT group with respect to the construction, installation and commissioning of the cooling system for the LHCb UT and the Velo upgrade detector. It also summarizes the required resources.

The content of this note is intended for CERN internal use and distribution only

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Agreement between PH-DT & LHCb

- Scope: design, construction, commissioning
- Resources
- Costs
- Handover & future M&O perspective

WORK PACKAGE PH-DT/LHCB

[HTTPS://EDMS.CERN.CH/DOCUMENT/1556960/1](https://edms.cern.ch/document/1556960/1)

INCLUDES

- Design of the cooling system, selection and procurement of components (Technical specifications for all components will be made available in EDMS)
- Definition and implementation of a Quality Assurance plan
- Assembly and qualification of all the plants, accumulators and the junction boxes
- Preliminary sizing of the transfer lines
- Installation of all parts but the transfer lines in the LHCb underground area
- Connection of junction boxes to the transfer lines and to the detector and final leak tightness tests
- Control hardware and software (jointly with EN-ICE)
- System test and commissioning
- Engineering and management labor required to supervise and manage the construction, to procure components, and to conduct tests.

DOES NOT INCLUDE

- The production design of all the transfer lines (between plants and junction boxes, between junction boxes and detector manifolds)
- The procurement of all the transfer lines
- The installation of the transfer lines, along a path to be agreed with LHCb technical coordination and following the LHCb design
- The preparation of the electrical connection to the general network and/or any secured network requested by LHCb
- The preparation of the water network with the requested cooling power in the dedicated area
- The verification of the ventilation system in view of an air cooled primary chiller
- The preparation of the dry air/ dry gas supply for the electro-pneumatic modules and the flushing of the plants and junction boxes
- The detector cooling loops, manifolds and safety systems design, installation and testing
- Cabling between the different zones of the experimental site (from control [illegible] to junction boxes and detector, where needed)

Approval to be launched after EDR

OUTLOOK

Expect to receive by end January answers about:

- Primary chiller
- Backup chiller logic
- Final DP/flow of detectors
- Preliminary routing of transfer lines (with present sizing)
- Approval of Work package

Summary table of detector parameters in backup slides

CO_2 team work to continue with design phase: component selection, 3 D modeling in order to prepare PRR for mid 2016, with priorities:

- Selection & sizing of junction box components for integration studies

Thanks for your attention!

Questions?

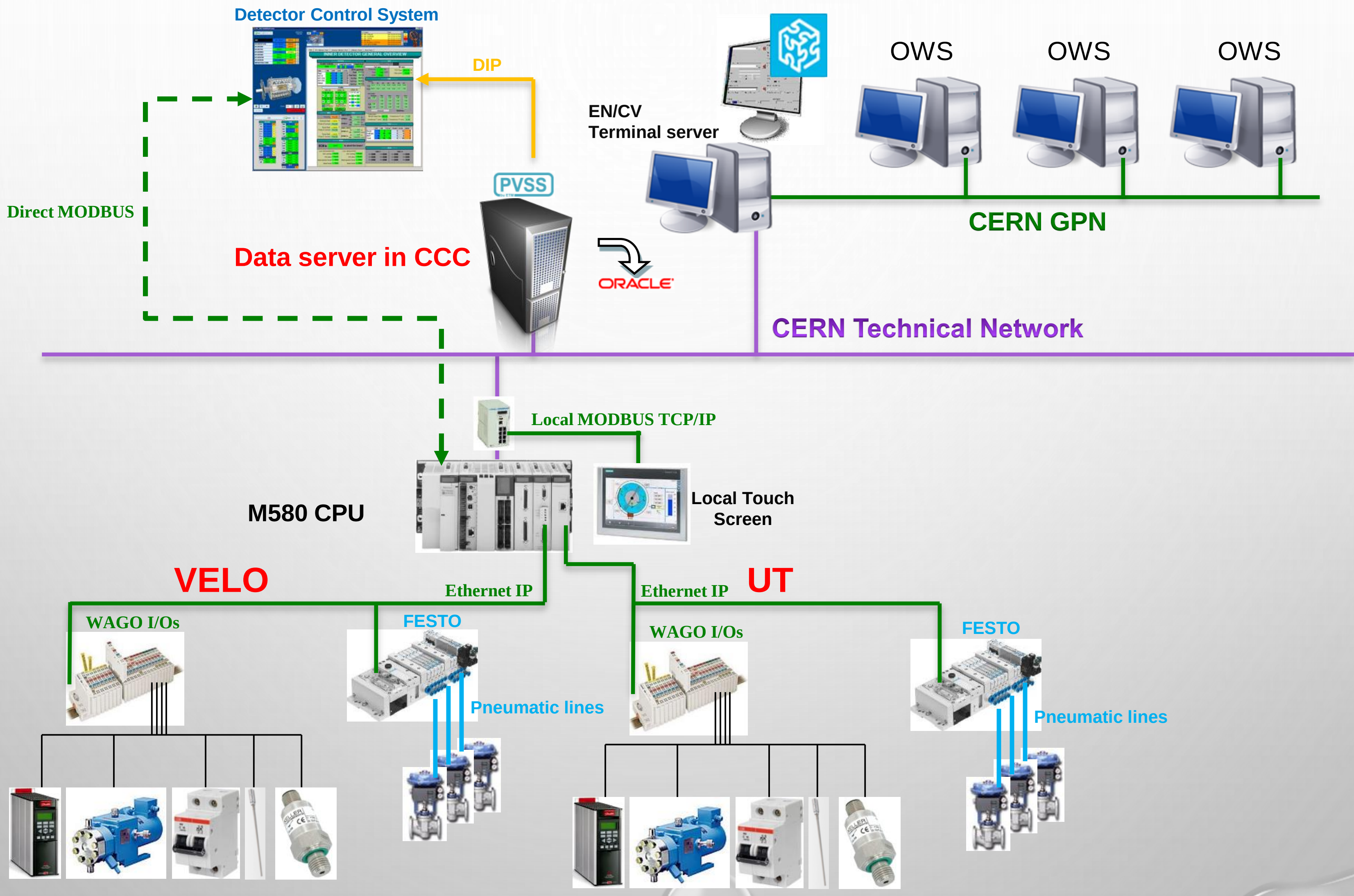
BACKUP SLIDES

INPUT NEEDED FOR PART SELECTION

Parameter/measure	*Unit*	*UT*	*Velo*
Request to CO2 cooling			
Accu Tmin	°C	-30	-30
Accu Tmax [°C]	°C	15	15
Geometrical constraints & thermal contact performances			
Detector cooling loops	#	34x2	26x2 (+/-x)
Parallel loops (each one of the 2 half	#	2 planes 8 channel parallel +	
		2 planes 9 channel parallel	
Transfer lines cooling plant to juncti	#	1	1
Transfer lines junction box to detect	#	2	2
Manifolding	#	4 inlet + 4 outlet	2
Power/Flow/pressure drop per detector cooling circuit on aged detector taking data at high lumi, low temperature			
Power /central stave – HLLT (MAX	W	76	28.4
Flow/central stave - HLLT @ -30	g/s	0.9	0.1-0.3
Dp central stave - HLLT@ -30	mbar	400 (measured)	?
Power / external stave – HLLT (MA	W	50	?
Flow/external stave - HLLT @ -30	g/s	0.6	?
Dp external stave - HLLT@ -30	mbar	measure in progress	?
Power/Flow/pressure drop per detector cooling circuit in case of operation at 15 C (commissioning phase when no dry volume): can be only a fraction of total detector			
Power /cooling loop - WARM @ 15	W	?	?
Flow/cooling loop - WARM @ 15 C	g/s	?	?
Dp cooling loop - WARM @ 15 C	bar	?	?
Power/Flow/pressure drop: full detector summary			
Max detector power	kW	5.472	1.5
Max total detector flow	g/s	61.2	15.6
Max detector Dp @ -30 (including c	bar	5*	?
		* including inlet pressure drop (t.b.d.)	

DP across detector (including capillaries/orifices) needed to size pump, control valve…
Inputs needed by **January 2016**

CONTROL SYSTEM DETAILED ARCHITECTURE



Lukasz Zwalinski

UT REGULATION VALVE POSITION