PH-DT
Detector Technologies

CONCENTRIC VACUUM INSULATED TRANSFER LINES: FEEDBACK FROM ATLAS AND CMS NEWLY INSTALLED SYSTEMS

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30 June 2014- Forum on Tracking Detector Mechanics - DESY

Outline

Concentric transfer lines for CO2 cooling

- Why?
- How?

Insulation

Common approach: ATLAS & CMS choices

Overview of ATLAS Transfer lines

- Rigid transfer lines
- Flexible transfer lines

CMS Transfer lines

- On detector
- Off detector

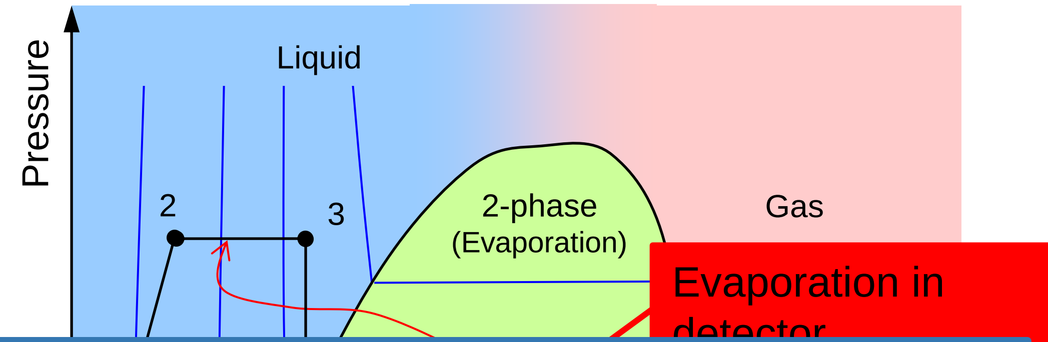
Common issues:

- Design
- Installation
- Testing

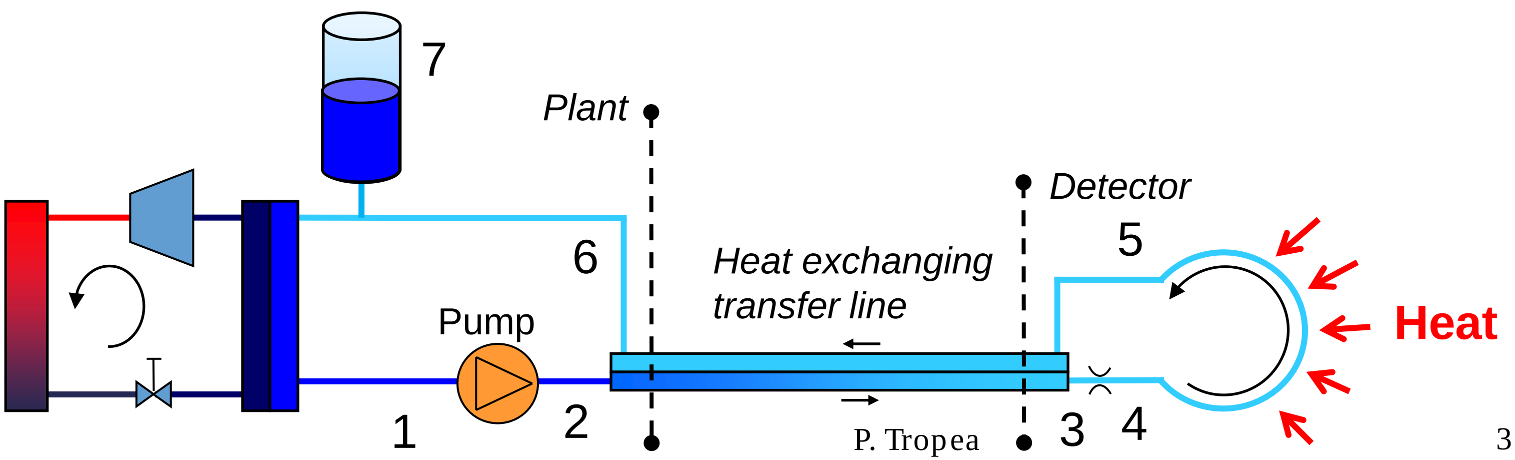
Conclusions

2PACL: 2-Phase Accumulator Controlled Loop

CO_2 evaporative cooling:
- Atlas IBL
- CMS Pixel Phase I

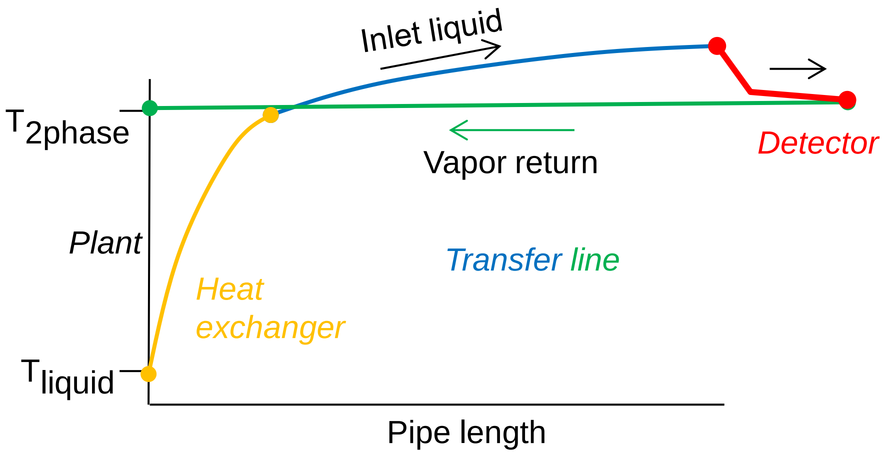


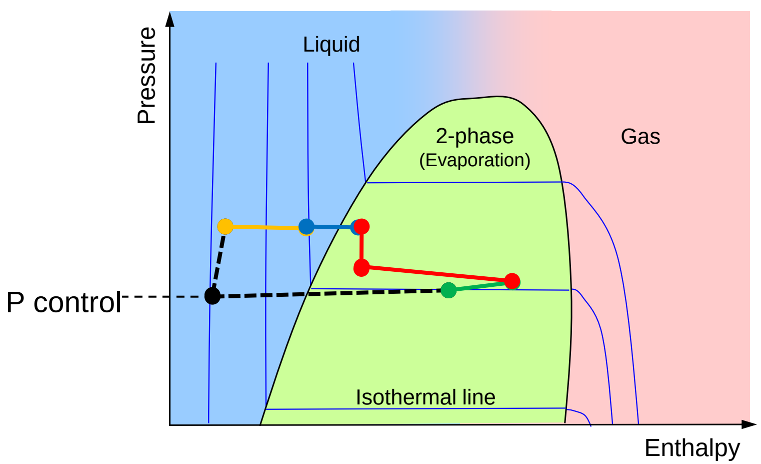
All very nice if evaporation starts at the detector inlet!
Need to ensure saturated liquid up to there, despite the long travelling!



Why do we need saturated liquid?

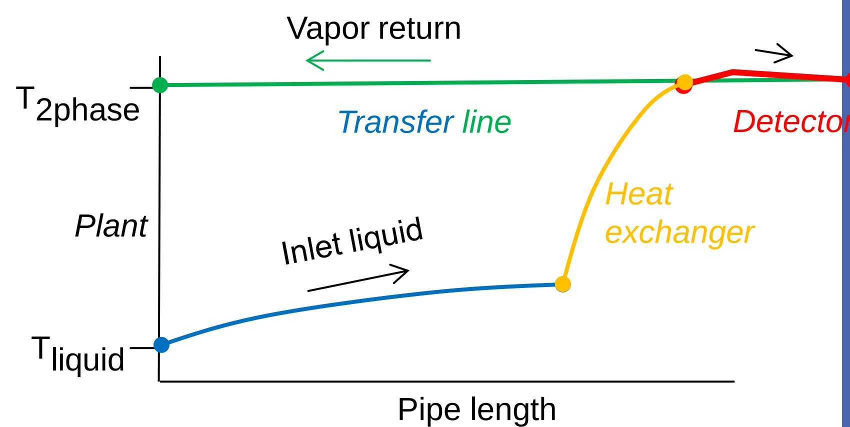
Heat exchange at the plant

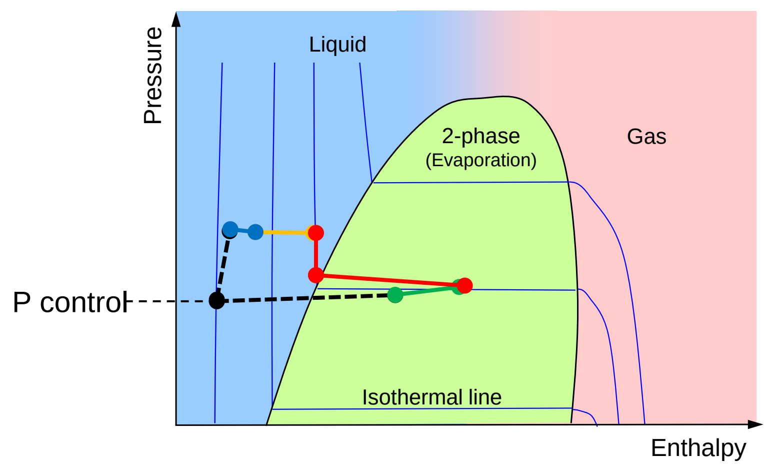




Detector inlet can be 2-Phase
(bad flow distribution)

Heat exchanger near detector

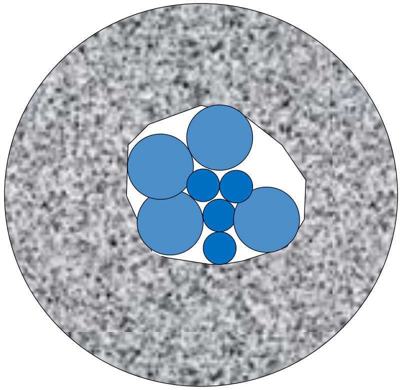




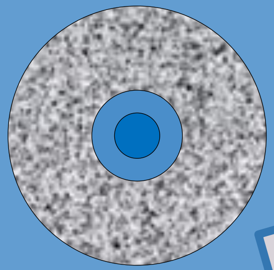
Detector inlet is saturated liquid

The possible solutions

Technology	Pro	Cons
Local heat exchanger at the detector inlet	Local control	Bulky, heavy, not accessible
Common insulation for inlet and return	Can be applied on existing pipes	Distribution of pipes in the bundle strongly influences the performances, heat from environment can still reach inlet, bulky
Concentric: inlet into return	Compact, full control of liquid no matter heat sources around	New installation (for CMS)



Bundled insulated tubes



Concentric insulated tube

Chosen!

Foam insulation?


LHCb-Velo system


CMS Tracker system

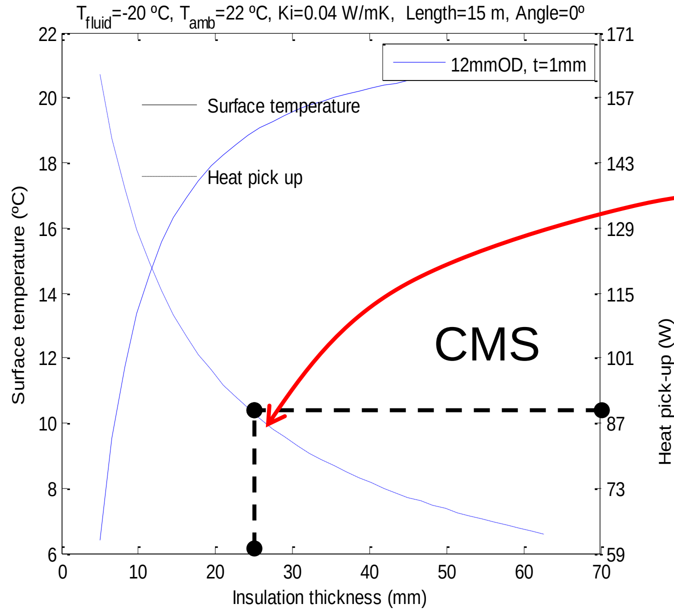
Armaflex: k=0.04 W/m*K

Dries out and looses flexibility, shall be carefully glued

Aerogel Spaceloft 9251: k=0.013 W/m*K

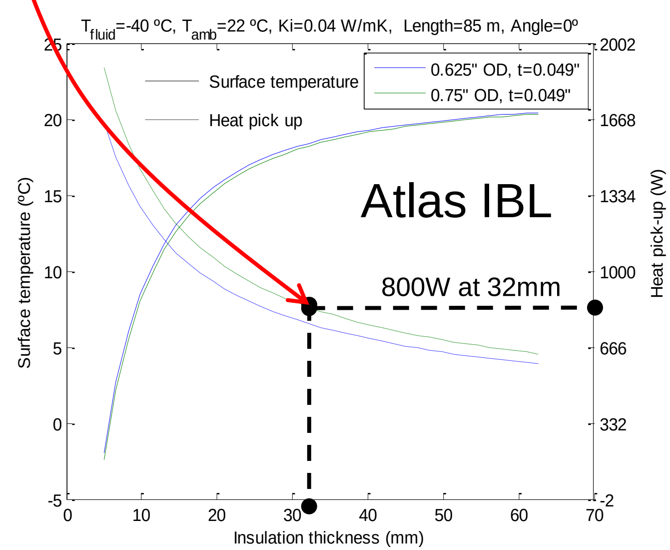
Dusty and difficult material to handle, but good performance if super well protected from humidity. All parts enclosed in polyethylene bags, sealed, then adhesive vapor barrier around: QA during installation shall be super strict…

What about vacuum insulation?



Pipe dimensions:

Pipe size	Process line [mm]	Vacuum jacket [mm]	Max.Capacity indication (L/h)	Heat in leak indication (W/m)
DN10	Ø12x1,0	Ø63,5x1,5	300	0,40
DN15	Ø18x1,0	Ø63,5x1,5	500	0,45
DN20	Ø23x1,5	Ø63,5x1,5	1000	0,55
DN25	Ø28x1,0	Ø63,5x1,5	2000	0,65
1″	Ø33.7x1,6	Ø76,1x2,0	3000	0,75
1½″	Ø48.3x1,6	Ø88.9x2,0	4500	0,85
2″	Ø60.3,1,6	Ø114.3x2,0	6000	1,0
2½″	Ø76,1x2,0	Ø139.7x2,0	11500	1,3
3″	Ø88.9x2,0	Ø154x2,0	16000	1,9
4″	Ø114.3x2,0	Ø168,3x3,0	27000	2,0
6″	Ø168.3x2,0	Ø219.1x3,0	60000	3,3



CMS

- 0.4 watt/m for -196’C for a vacuum jacket of 63mm (25.5mm insulation thickness)
- 6 watt with vacuum compared to 87 Watt with foam (but vacuum reference at -196’C)
- YB0 lines will have a reduced diameter (28mm)

Atlas IBL

- 0.55 Watt/m for -196’C for a vacuum jacket of 63mm (32mm insulation thickness)
- 55 watt with vacuum compared to 800 Watt with foam (but vacuum reference at -196’C)

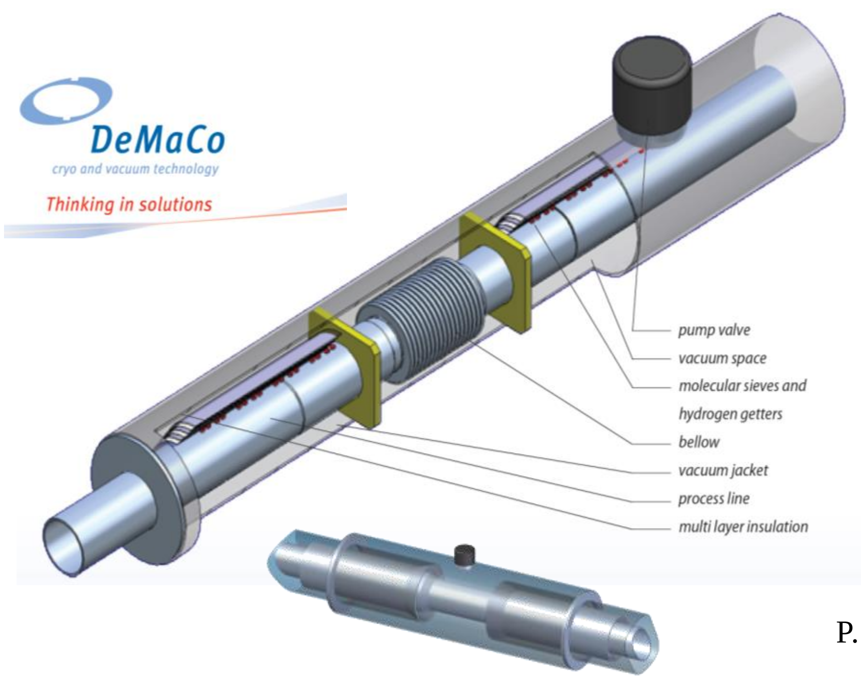
Vacuum insulation performs a magnitude better than foam, is more reliable and is smaller in diameter

Summary of pro & cons

Foam insulation:	Vacuum insulation:
Advantages	***Disadvantages***
In principle cheaper...	Expensive
Large heat leak: allowing high T set points with no additional load	Small heat leak: ask for additional load in order to operate at high T
Disadvantages	***Advantages***
Risk of leaking seals (Water condensation)	No seals
Large diameter (ex: -30 C /12mm pipe +2x32 mm insulation =76mm external envelope)	Small diameter (ex: -40 C/12 mm pipe - 28mm external envelope for vacuum jacket)
Hard to apply in crowded areas, access needed everywhere	Only access needed at welds
More heat leak (larger primary chiller)	Small heat leak (smaller primary chiller)

A common approach with different boundaries

- All paths concentric
- All passive vacuum insulated along main routing
- An industrial approach by cryogenic transfer line technology
- Customized design inside the detector for reduced diameter



ATLAS

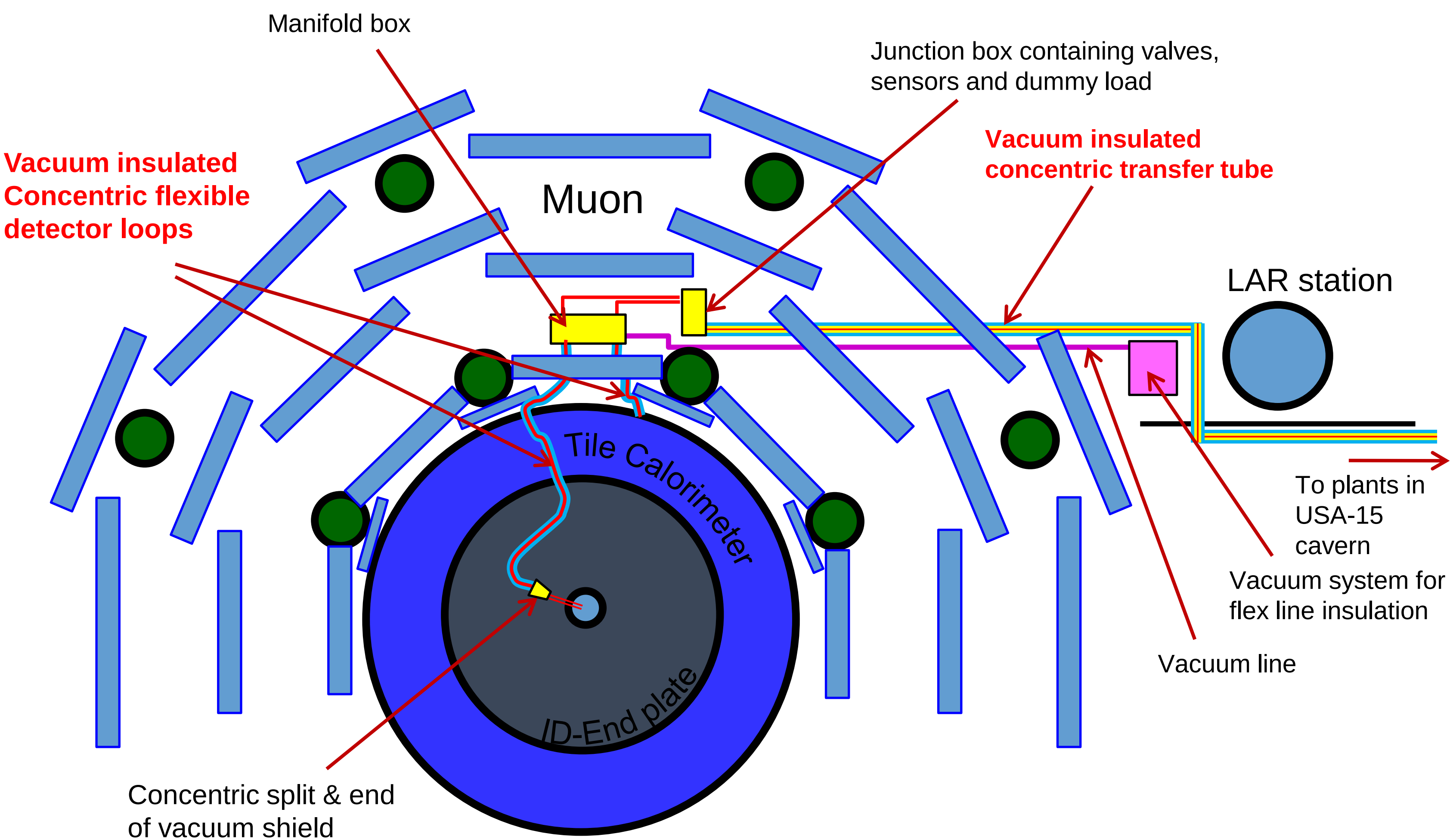
- CO_2 @ -40 C
- Main transfer line an industrial cryogenic solution
- Distribution to IBL an in-house development as only flexible lines were possible.
- Flex lines routing is as cabling
- Flex lines are actively pumped

CMS

- CO_2 @ -20 (but design of insulation for -40)
- 3 separate paths, different sizes and granularity
- all vacuum insulated, passive

ATLAS IBL Transfer lines

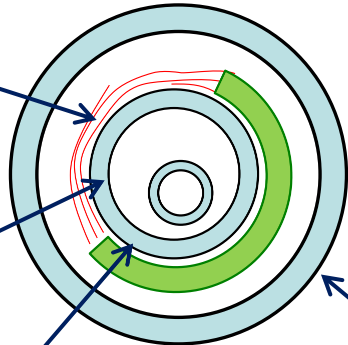
In Atlas 2 technologies:
1 Concentric main transfer line (21.3x2.11mm) in a 63.5mm stationary vacuum tube (100m)
14x Flexible concentric detector loops (1.6x0.3mm) in a 17mm flexible bellow tube (11m)



ATLAS IBL Main Transfer line

Industrial solution (Demaco)

MLI

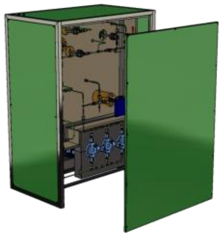


21.3mmOD /
17.08mmID CO2
vapor return tube

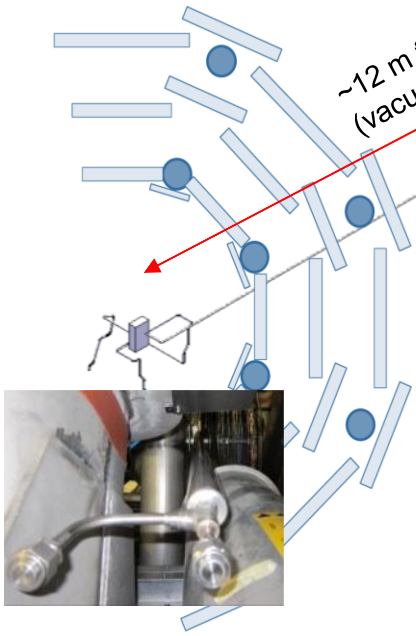
10mmOD / 8mmID
concentric CO2
liquid tube.

50mmOD / 47mmID Vacuum
tube for 12m section
63.5mmOD / 60.5mmID Vacuum
tube for 80m section

Cooling plant in USA15

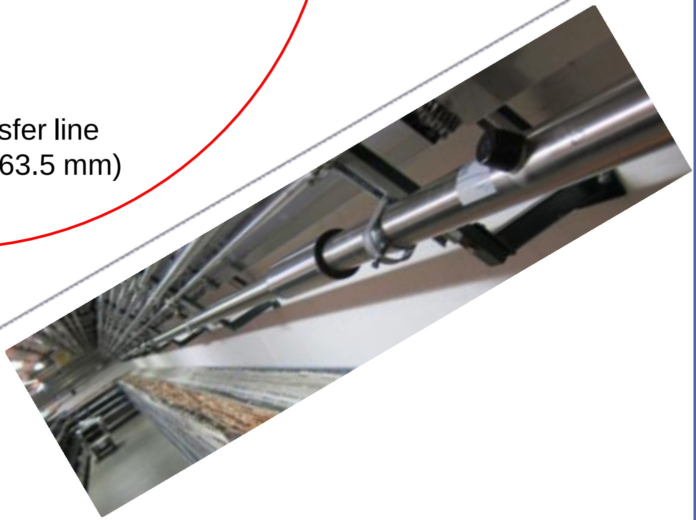


Detector



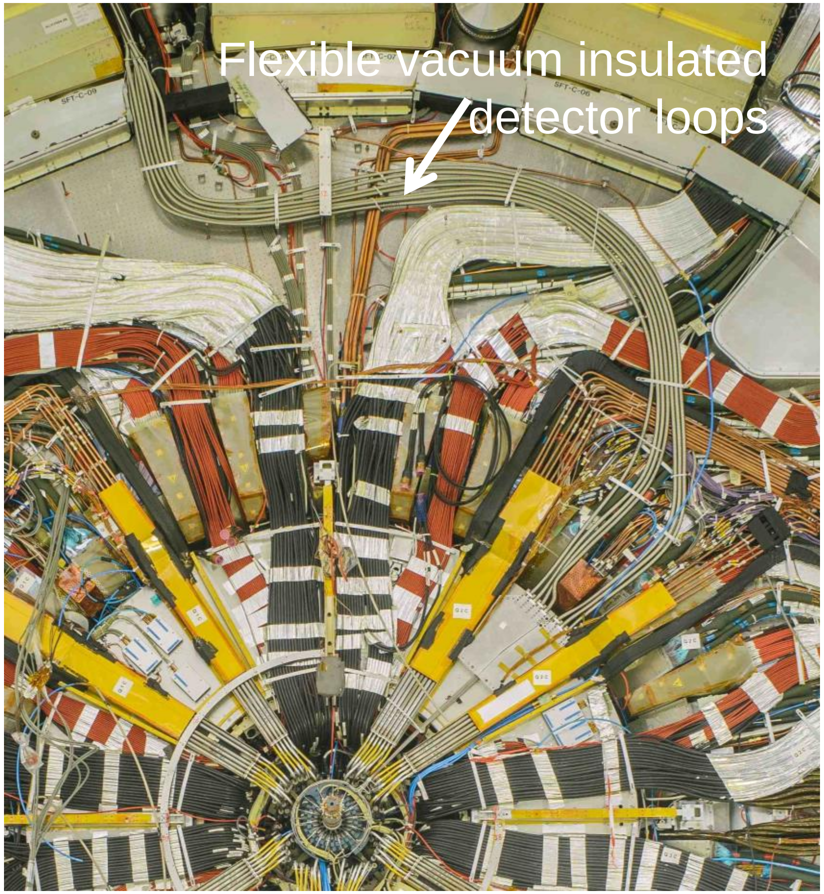
~12 m transfer line
(vacuum, D=50mm

~80m transfer line
(Vacuum, 63.5 mm)



ATLAS IBL flexible detector loops

- The routing towards the IBL has limited space in the Inner detector end plate.
- Need to be like cabling in order to fit.
- Routing through inaccessible areas
  - Only 1 solution: Flexible and Diameter < 18mm = Vacuum



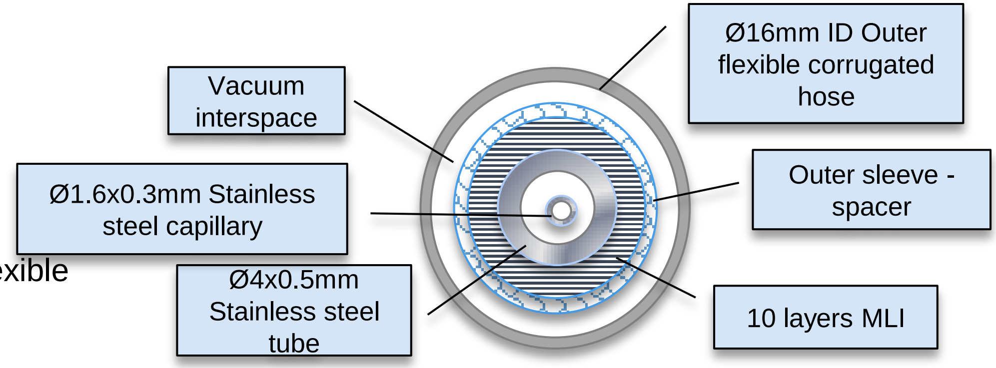
Purpose of the concentric flexible detector loop.

1. Prevent unwanted boiling of the flow distribution capillary
2. Make it flexible as a cable for integration purposes
3. Avoid condensation on outer surface

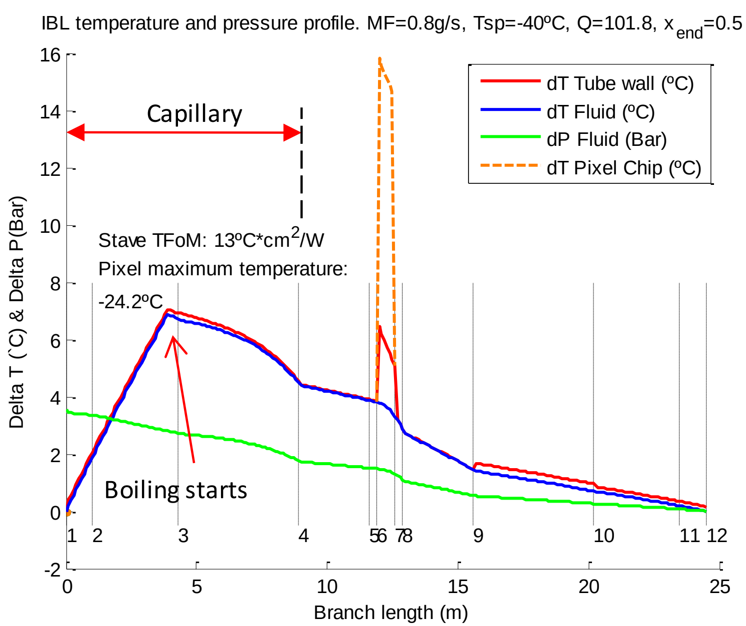
Concentric flex line considerations

Flex line dimensions:

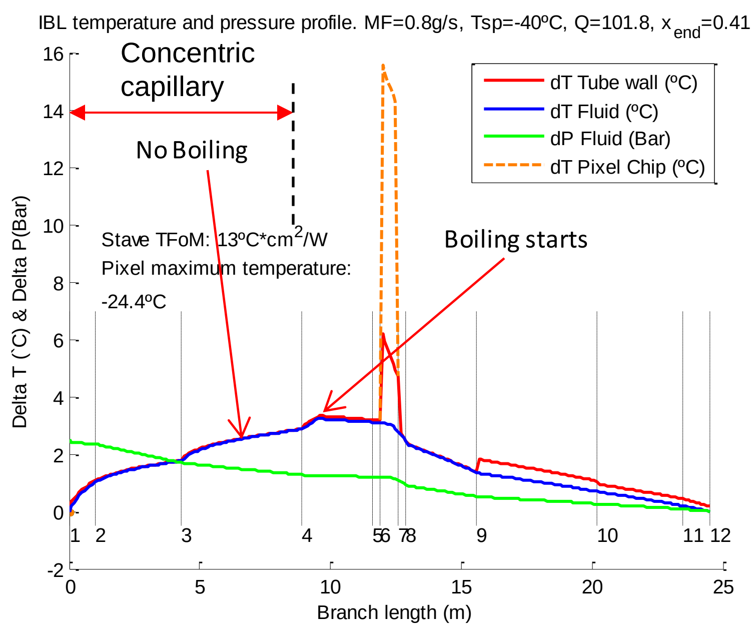
- A Ø1.6x0.3mm flow distribution capillary inside a Ø4x0.5mm tube.
- Length 11m long
- Vacuum hose Ø16mm bellow hose
- MLI inside glass fibre sleeve
- A 4mm stainless steel tube is considered as flexible



Simulation without concentric heat exchange



Simulation with concentric heat exchange

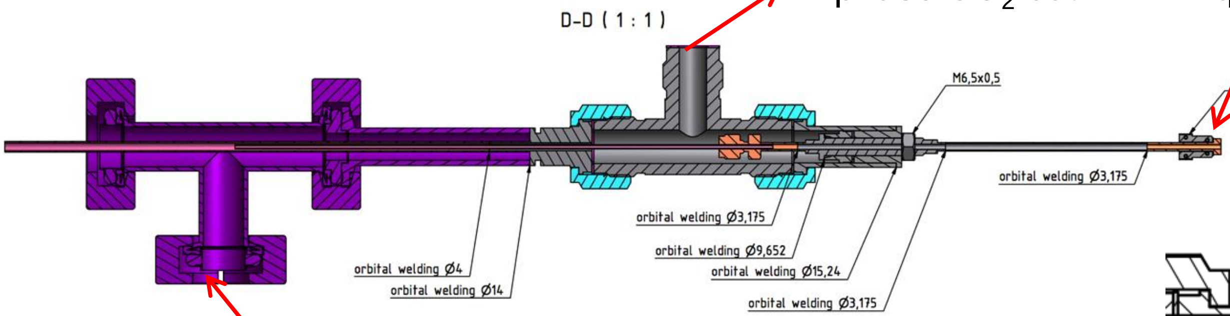


Flex line design

Rotatable joint to align connection to manifold box

2-phase CO_2 out

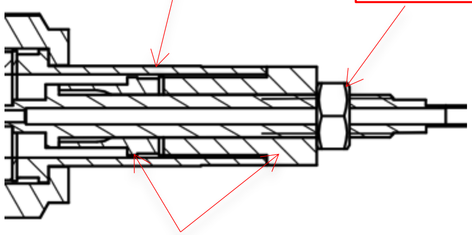
Liquid CO_2 in



Vacuum connection

Gasket

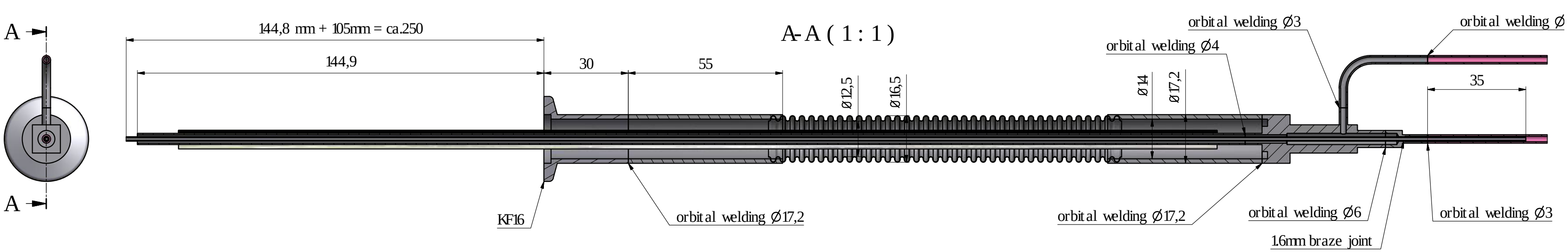
Nut



Sealing glands

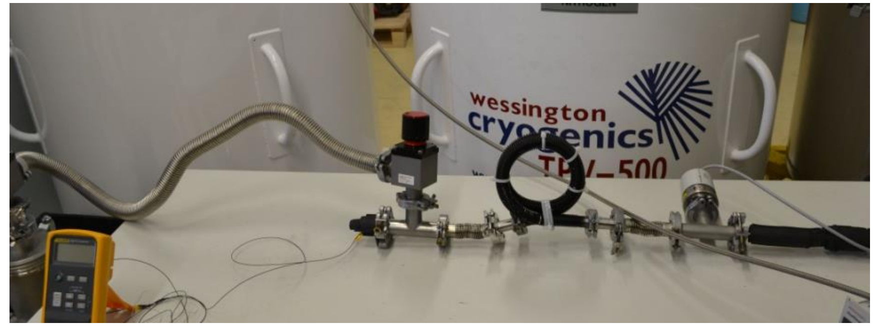
Special reversed VCR to disassemble concentric joints (outside of VCR pressurized)

Flex line dimension



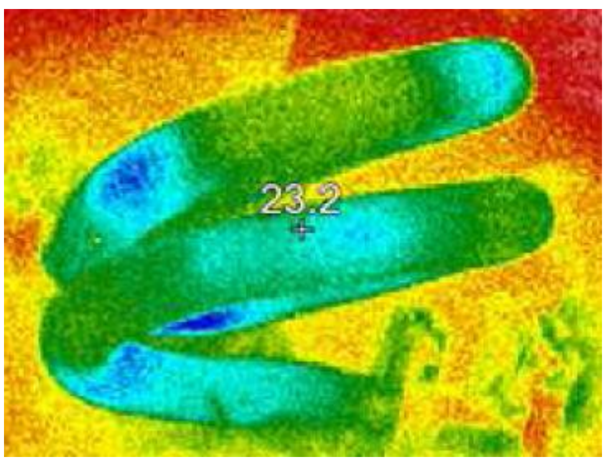
Laboratory testing

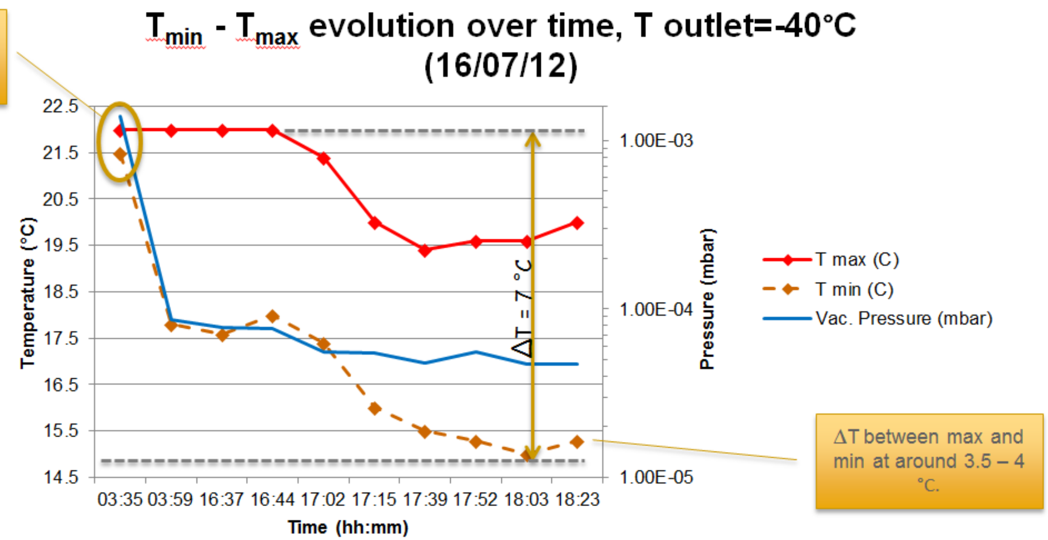
4mm tube with MLI and glass fibre as continuous thermal spacer



Test set-up with coiled hose (Maximum wall contact)

Surface temperature measurements to spot cold contact bridges





Goal of tests: see if surface temperature is above dew-point

Flex line production


Detector side splitting


Concentric weld

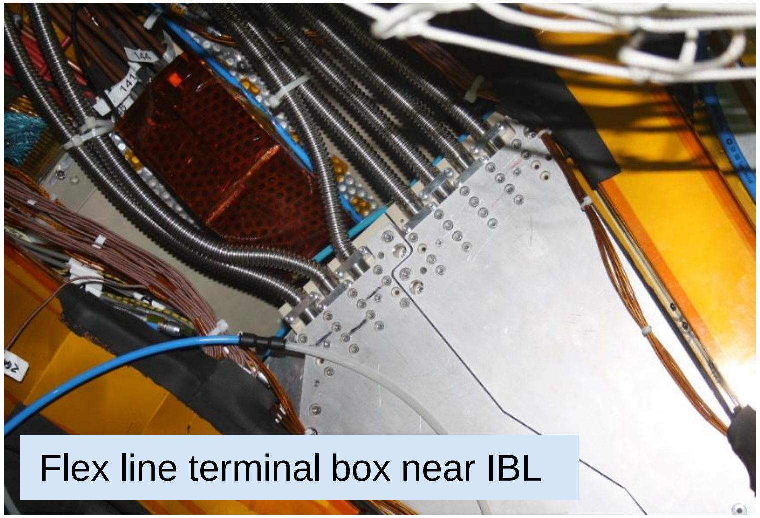

CO2 tubes with MLI


Prepared flexlines

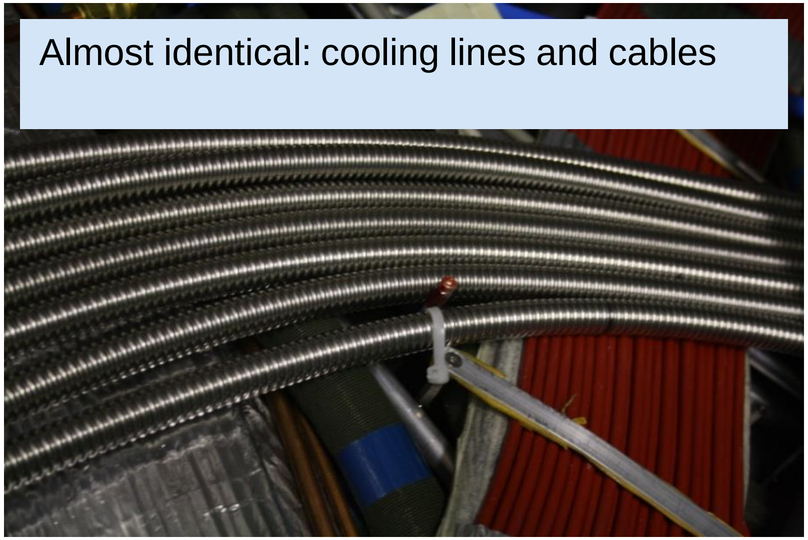

Ready for installation

Flex lines installed in Atlas (June 2014)

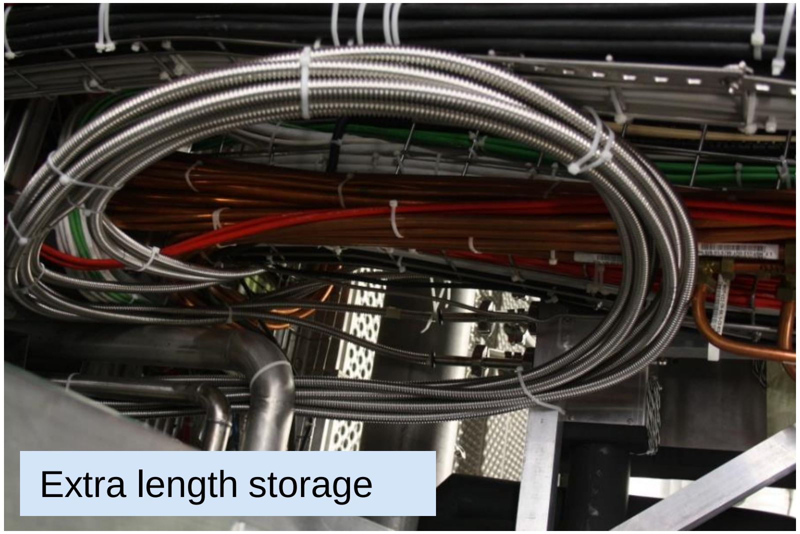
Flex line manifold in PP2 sector 5



Flex line terminal box near IBL



Almost identical: cooling lines and cables

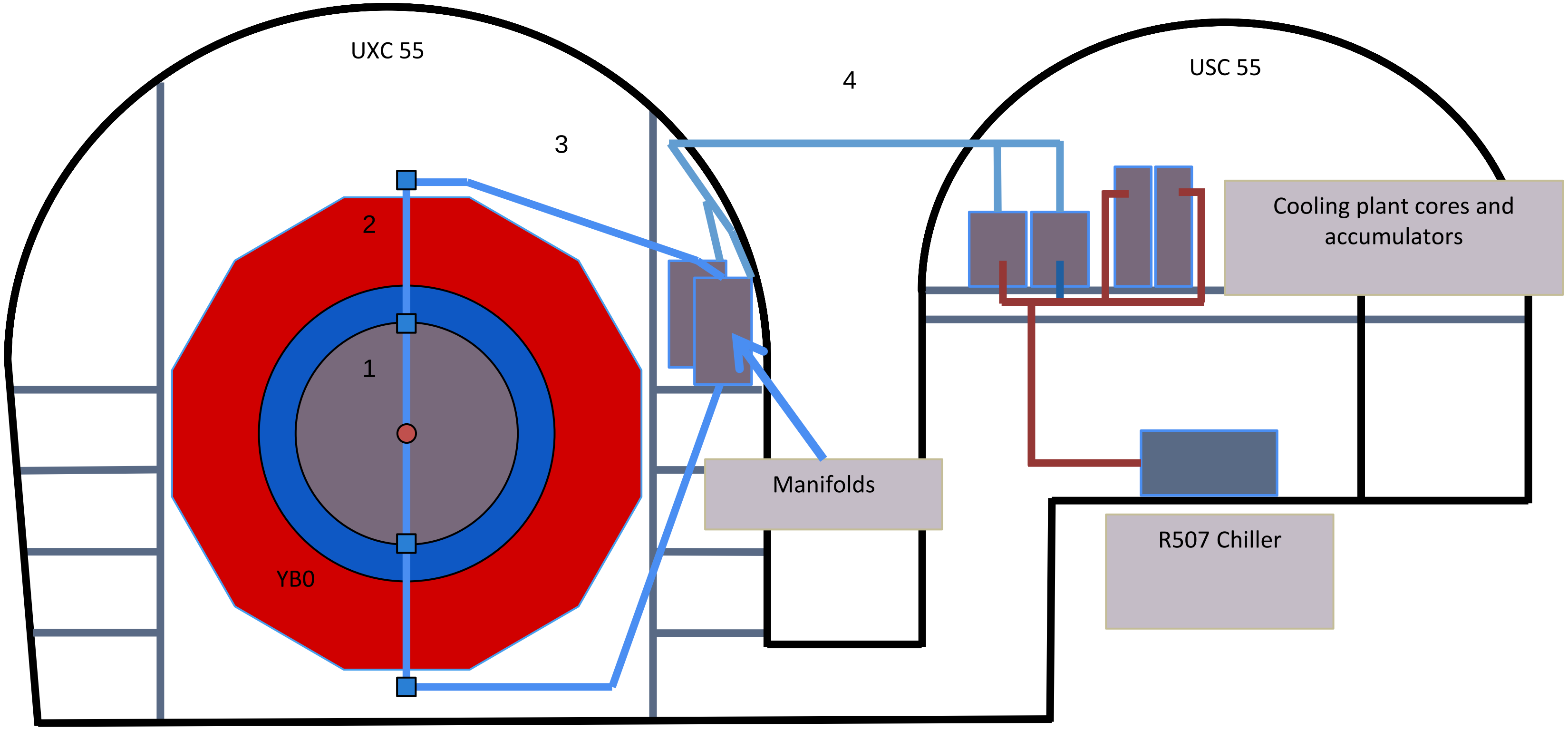


Extra length storage

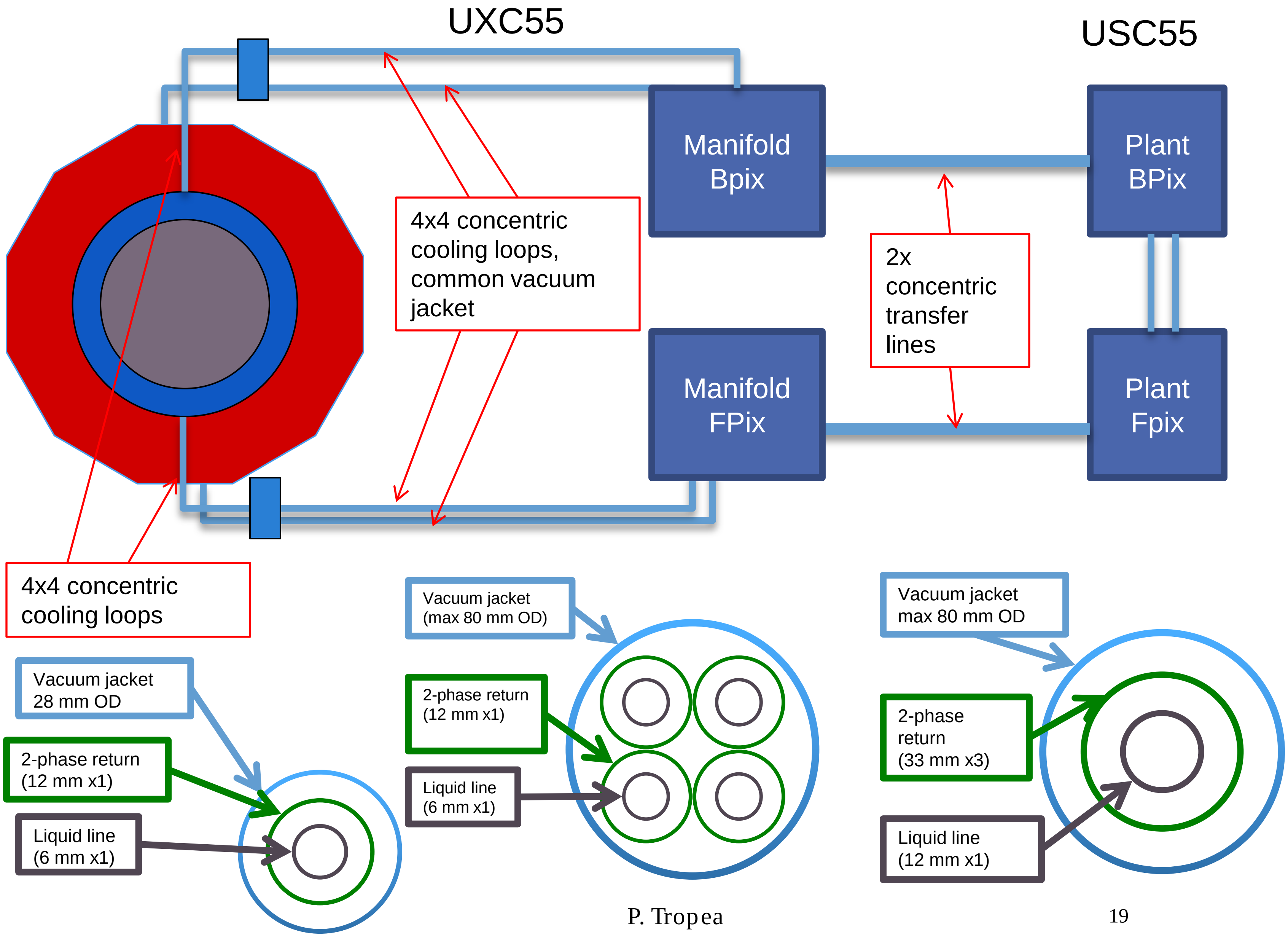
CMS Pix Phase I upgrade CO2 cooling

2 plants, 15 kW each, -20 C nominal

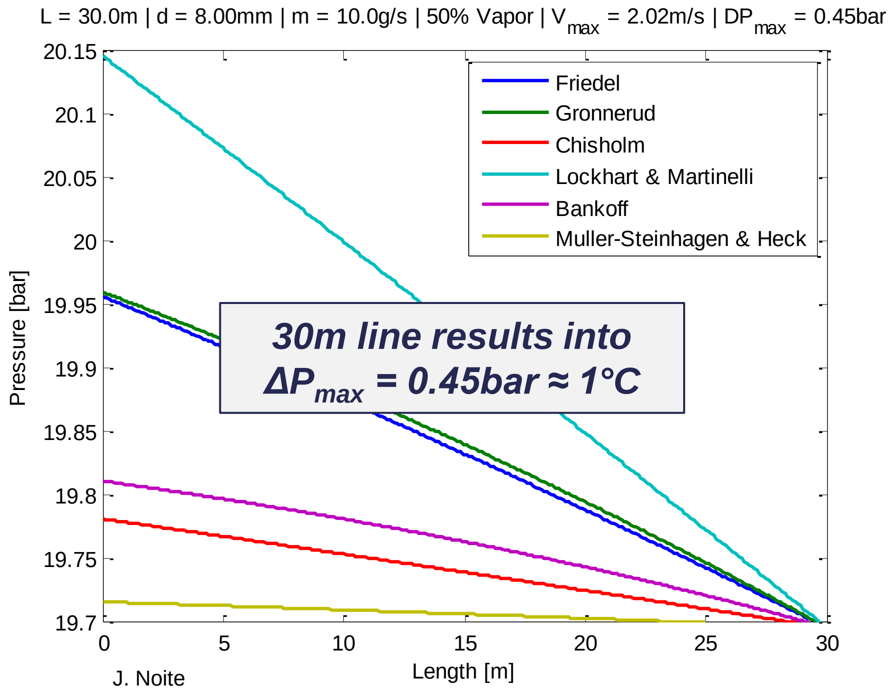
1) Preliminary layout done, to be installed with detector in YETS 2016
2) Installed in Jan 2014
3) In construction, installation August 2014
4) Design on-going, installation September 2014



CMS vacuum insulated transfer lines



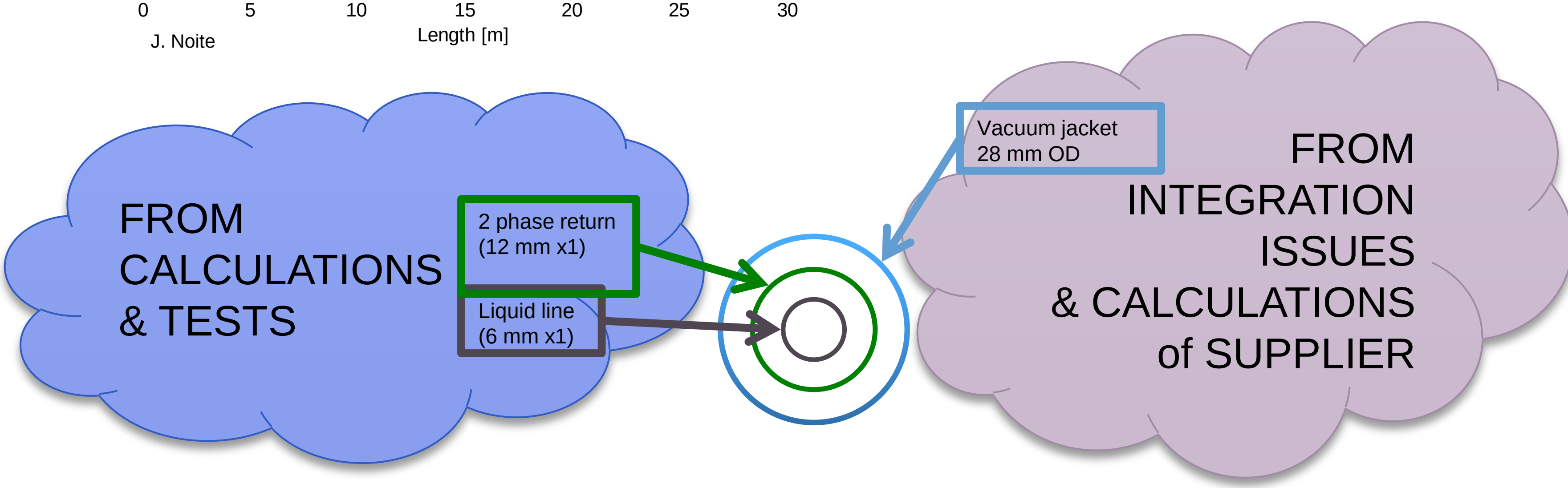
CMS on detector transfer line sizing



- *The CO_2 transfer line regulates the detector inlet liquid temperature via internal heat exchange with the detector's returning flow.*

MINIMIZING RETURN Δp IS THE GOAL

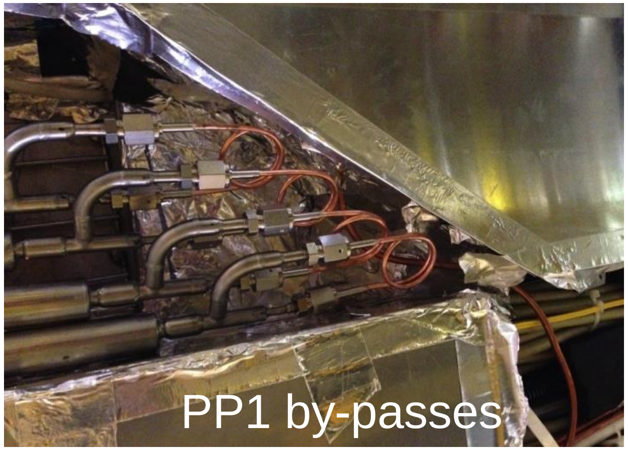
- *Max required mass flow up to 10g/s at main transfer line.*
- *2-Phase pressure drop models indicate loss of 1°C for max flow rate*



SIZING EXAMPLE: MINIMIZING RETURN ΔP

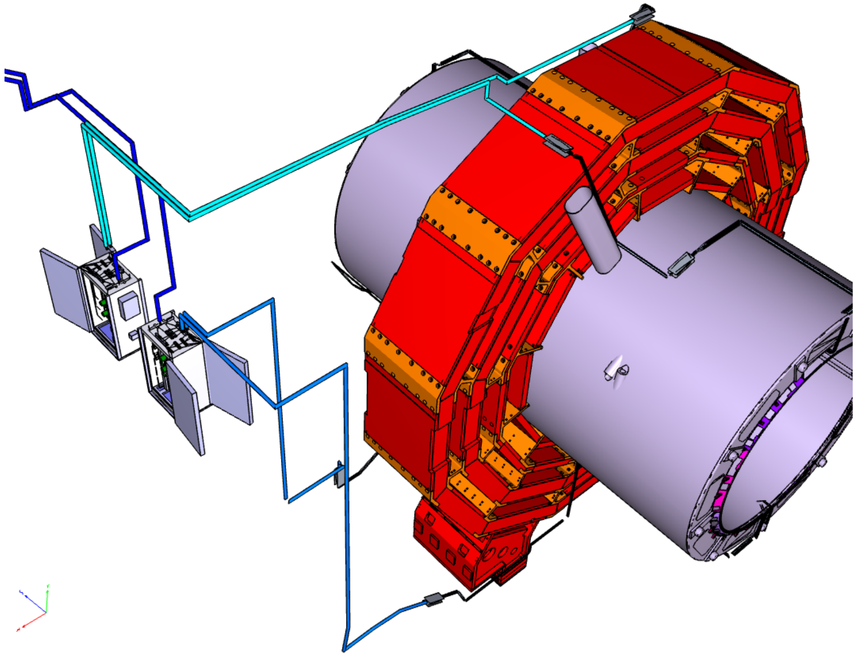
This was great!	Rather do differently…
3D model almost perfect on YB0	Verification with mock-up for zones outside detector
Swagelok VCRs: not a single leak	Small size vacuum ports in difficult locations
2 routings not needing on-site welds	2 routings needing on-site welds, included vacuum jacket…
Welding QA	Preparation of supports in advance

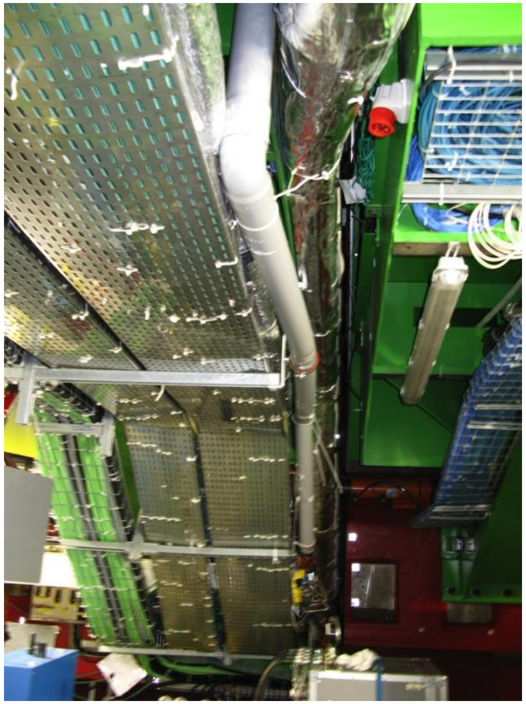
Installed in January 2014, pressure and leak tested



YB0 TO MANIFOLD TRANSFER LINES

…so we changed
Full scale mock-up with PVC pipes to update 3D model
Sections coming with pre-vacuumed jackets, only small volumes to be pumped on-site
High pressure leak testing test bench for pressure decay method being built



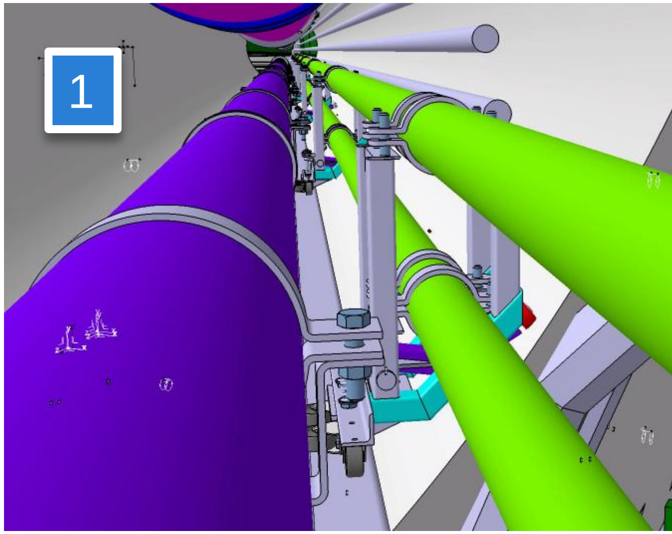


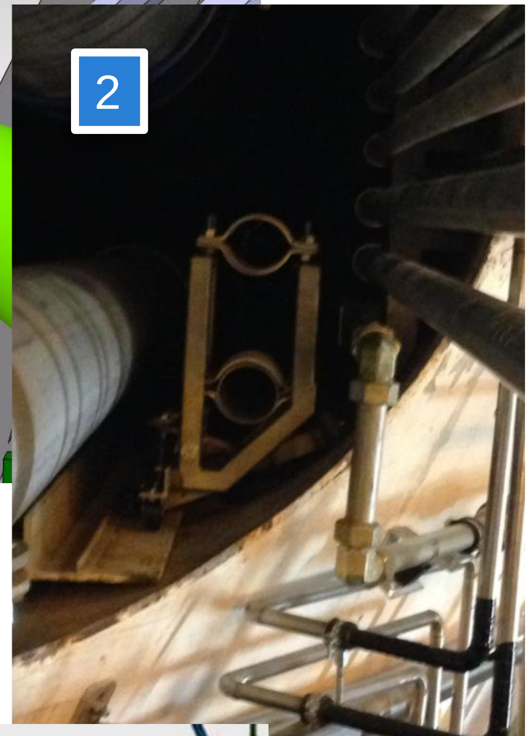
Construction on-going
Installation mid-August

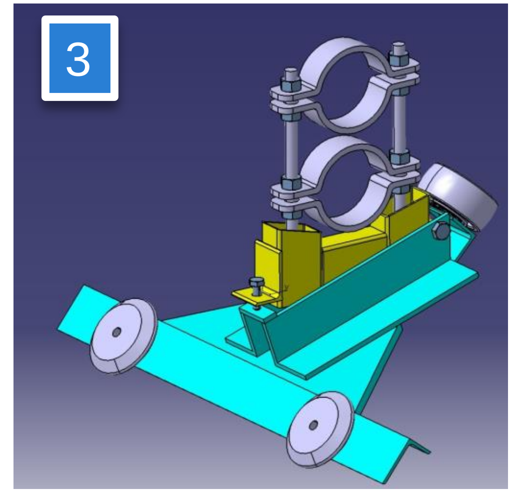
T. Pakulski, N. Smiljkovic

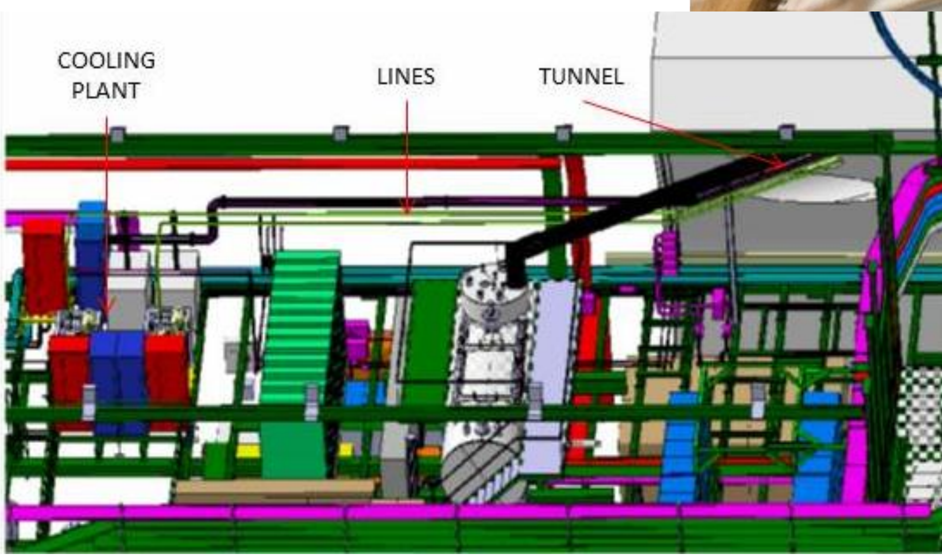
UXC55/USC55 – TR. LINES

PH-DT
Detector Technologies









Order placed last week
Installation mid-September

Integration

Mock-ups or 3D model or both?

- 3D model very precise in the proximity of the detector, looser precision at the interface cavern/detector in some cases
- Mock up with PVC piping super useful also for verification of handling procedures

Passive or active vacuum?

All parts installed so far in "big sizes", coming from industrial standards, passive vacuum

- 10 years theoretical guarantee, periodic check recommended
- Better not to rely on vacuuming on site, use bake-out and pre-vacuuming whenever possible
- No active components, no interlock

Atlas flex lines with active vacuum

- Constant performance monitoring
- Smaller envelope

Pressure and leak testing on site

CO_2 transfer lines are designed for high service pressure. CMS PS = 110 bar, ATLAS PS = 110 bar.

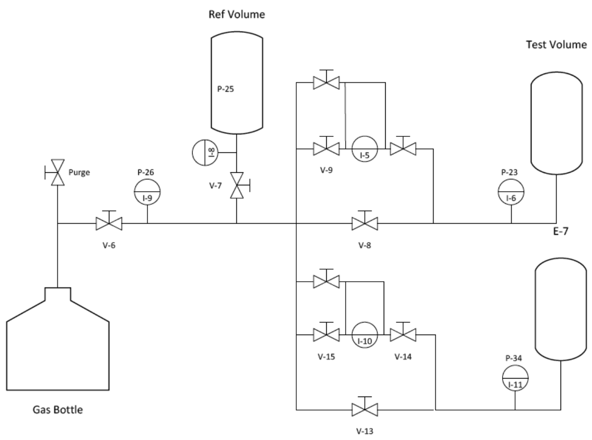
- PED: 1.43*PS = testing pressure

- CERN safety: pressure tests to be executed when pipework in their final destination

- Gas test: cavern evacuation (noise issues)
- Specific equipment needed (pressure reducer and gauges)

Leak detection

- He in sniffer mode (but test in vacuum rather than in pressure: VCR connectors not loaded properly!) – not always accepted
- Pressure decay: time consuming, need proper test bench



J. Daguin, N. Frank

CERN PH-DT Detector Technologies

Conclusions

Both Atlas and CMS have invested in vacuum insulated transfer lines for their CO_2 cooling systems

- Increased insulation capacity wrt volume
- Significant increase of reliability

“Industrial” solutions applied where possible, same cryogenic standards, no big surprises and good results!

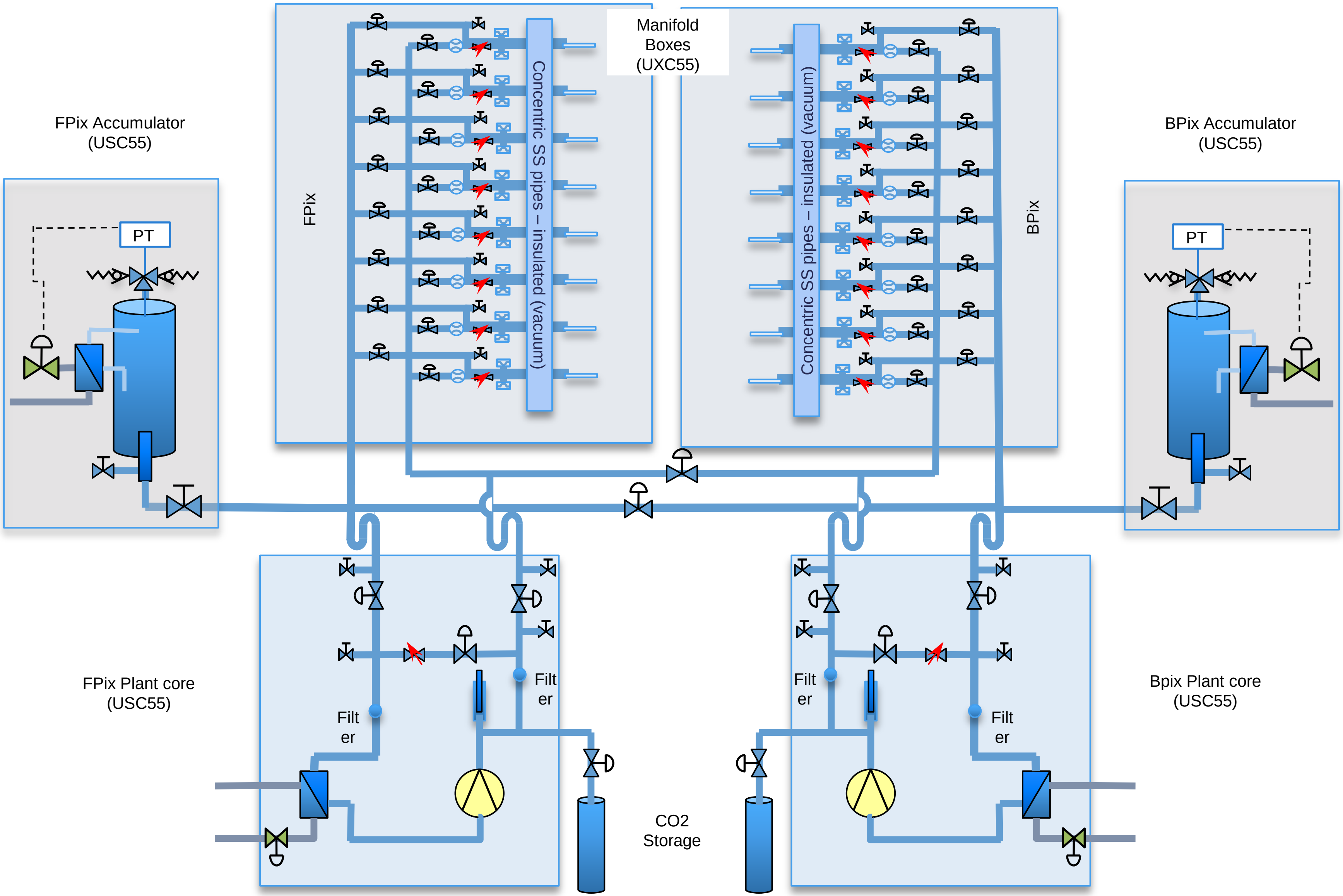
Some attention & innovative design (see flex lines) when routing is on detector (integration, accessibility of connections/vacuum ports).

So far only positive feedback!

Thanks for your attention!

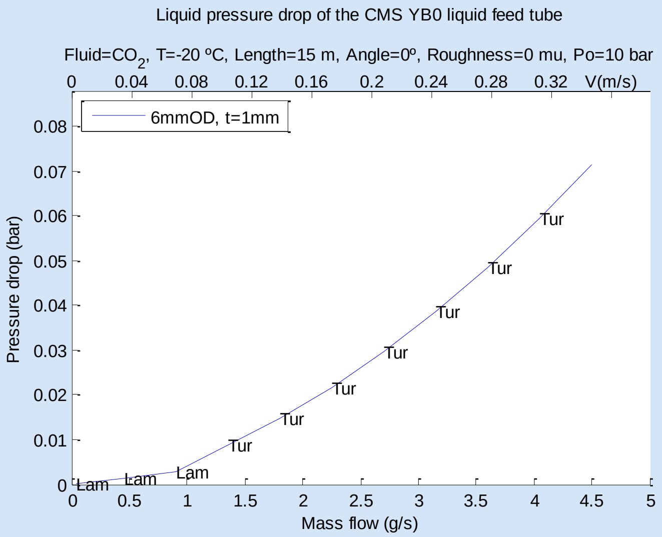
SPARE

CMS CO2 cooling

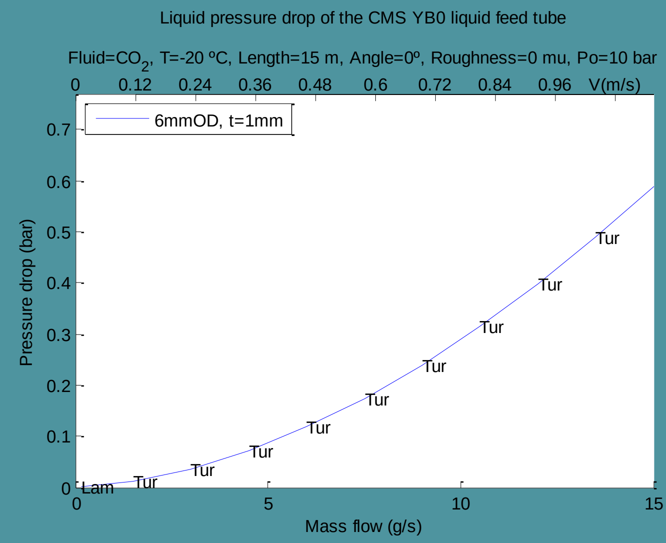


Details of pressure drops for YB0 concentric

Liquid feed



Low flow (3 g/s)



High flow (10 g/s)

Vapor return