

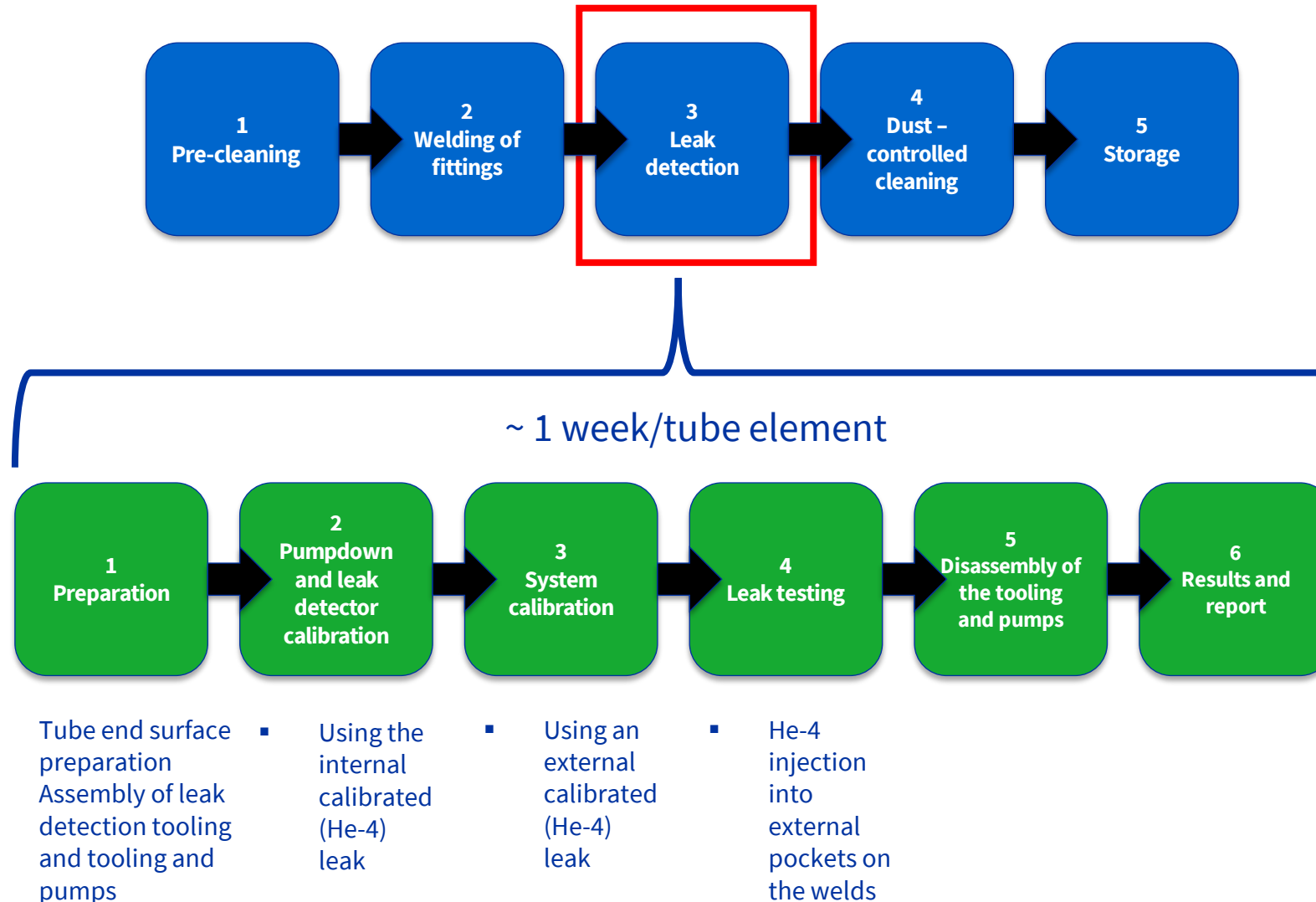


Leak detection of the ET Pilot Sector beam tubes

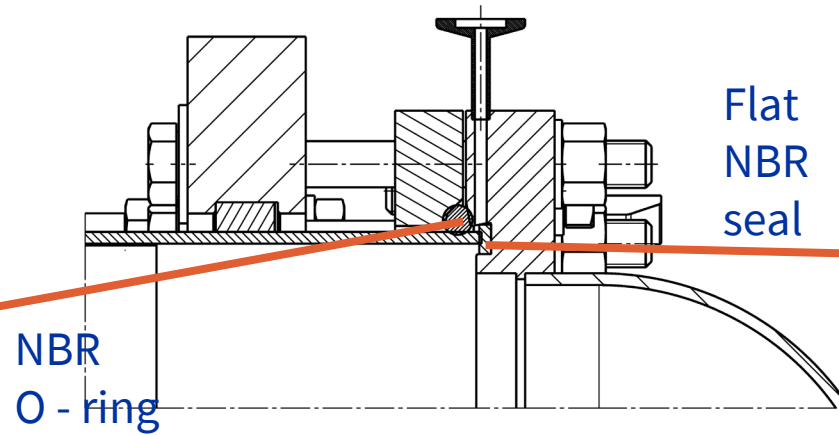
Purnalingam Revathi, Jan Hansen

ET Pilot Sector leak detection strategy

Tube element flow [DN1000 – 6 m] (AISI 441)

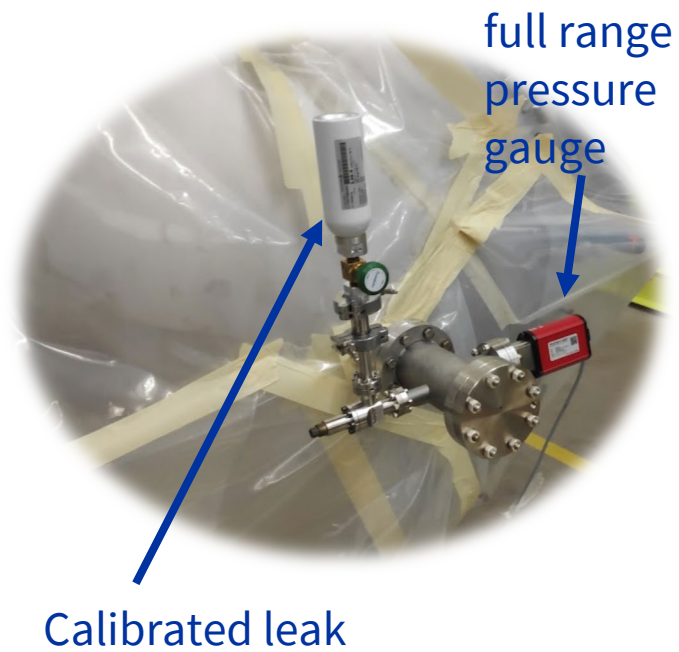


Leak detection of tube elements: Tooling

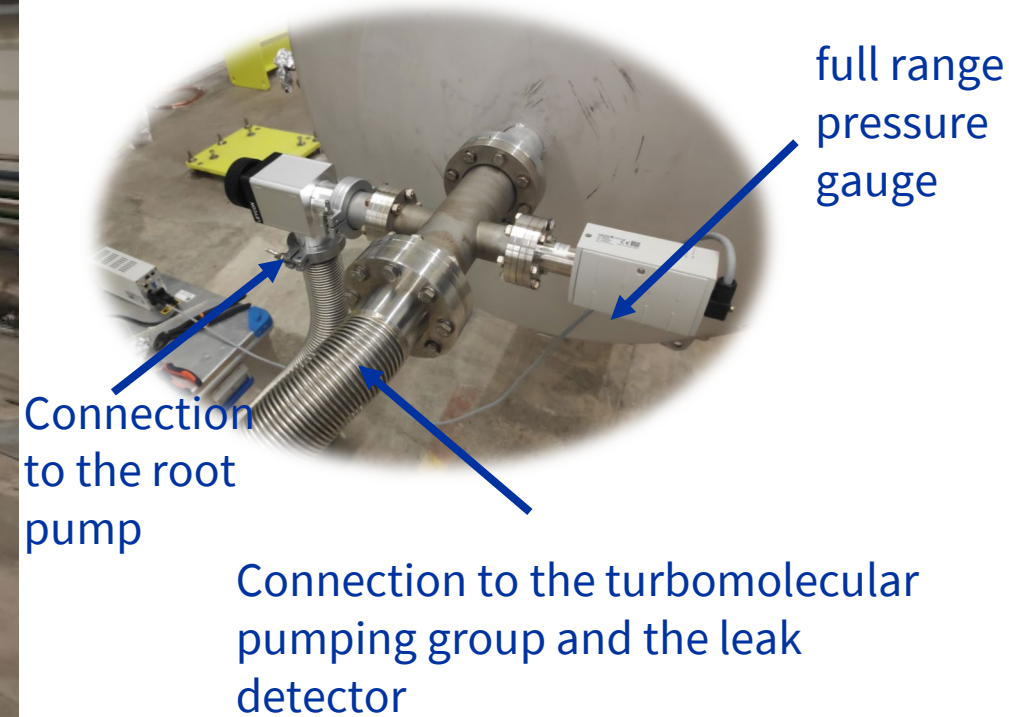
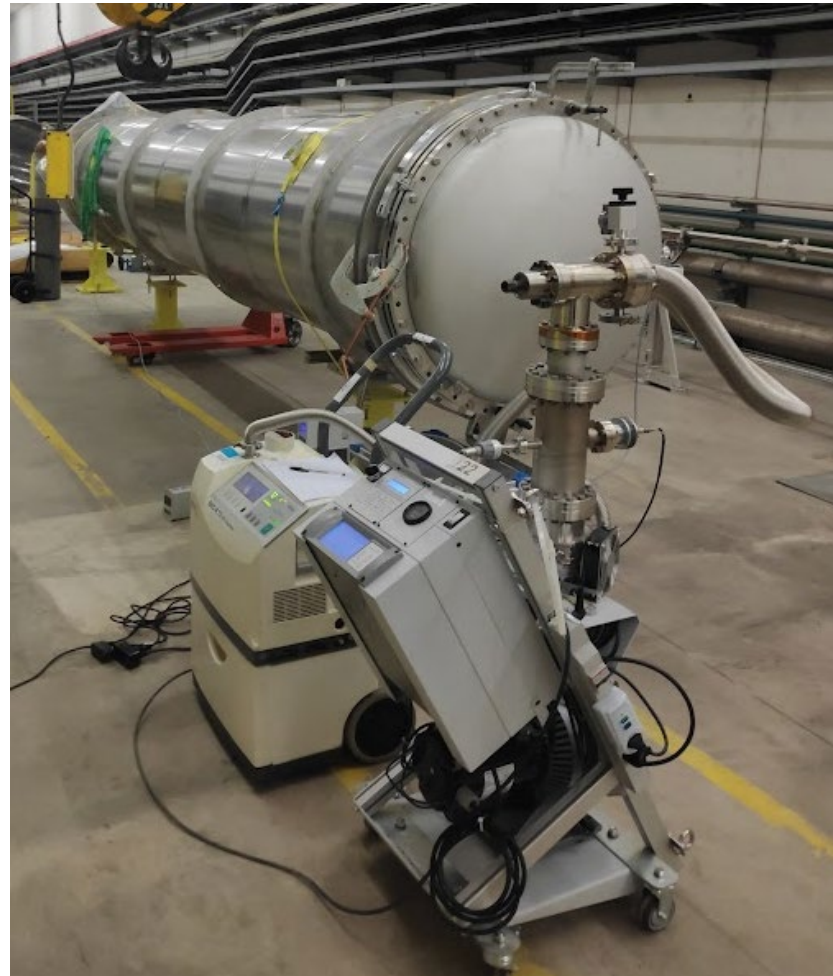


Test of the leak detection tooling
on the ET pilot sector bellows

Leak detection of tube elements: Assembly



Details of the calibration end



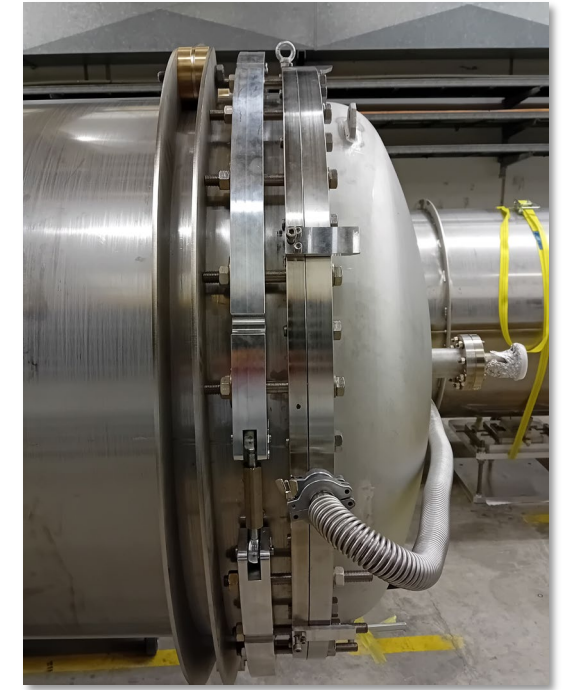
Details of the pumping end

Leak detection of tube elements: Leak testing

Plastic cover to protect the NBR O-rings



Plastic cover pockets over the welds for helium injection



*Double gasket (flat seal + o-ring) with differential pumping

100% external leak detection of the welds:
Testing of all 11 welds (3 circumferential welds, 4 stiffener welds, 4 longitudinal welds) for all 7 tubes = 77 welds in total

*If required when the first seal is not leak tight



Strategy for leak detection for Einstein Telescope

Purnalingam Revathi

Excerpts from Slides of Paul Cruikshank's presentation from Beampipes for Gravitational Wave Telescopes 2023 [1]

[1] [Beampipes for Gravitational Wave Telescopes 2023 \(27-29 March 2023\): Overview · Indico](#)

Leak Testing: What could leak ?

Ex-situ (components)

- 15m Pipe
 - longitudinal weld (spiral or straight)
 - circumferential welds (if any)
 - material through-wall defects (porosity, inclusions, damage, weld arc errors, ..)
- 1 m Pumping Module
 - welds, material defects, flange NC,...

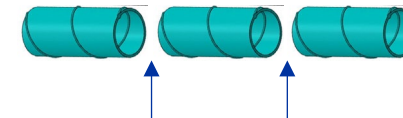
Components:
under vacuum tests, external helium



In-situ (x00 m Pipe Strings)

- Pipe to Pipe circumferential welds
- Degradation of validated components (transport, corrosion, etc)

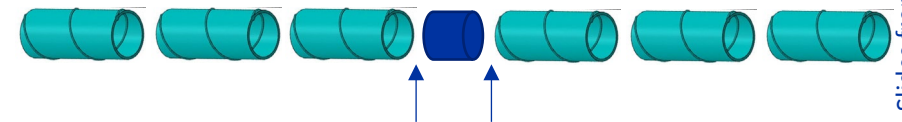
Pipe Strings: Pipe to Pipe
(under vacuum tests, external helium)



In-situ (5 km Vacuum Sector)

- Pipe to Pumping Module circumferential welds
- Vacuum Instrumentation CF flange connections

Vacuum Sector: Pipe String to Pipe String



Leak detection Strategy for Einstein Telescope

Leak Test Strategy	Fixed Costs (std tests)	Variable Costs (leaks)
‘Max’ Testing Strategy (classic, preventive approach)	Ex-situ: 100 % Component leak test (\$\$\$), In-situ: 100 % Subsector leak test(\$\$), In-situ: Vacuum Sector leak test (\$),	NC localisation, repairs & retest (\$) NC localisation, repairs & retest (\$) NC localisation, repairs & retest (\$)
‘Mid’ Testing Strategy	In-situ: 100 % Subsector leak test(\$\$), In-situ: Vacuum Sector leak test (\$),	NC localisation, repairs & retest (\$\$) NC localisation, repairs & retest (\$)
‘Min’ Strategy (corrective approach)	In-situ: Vacuum Sector test (\$)	NC localisation, repairs & retest (\$\$\$)

Component: pipe elements and pumping modules; **Subsector:** pipe elements welded between two pumping modules (“pipe strings”);

Sector: pipe elements/pumping modules welded between two sector valves

Assuming 2-year period, 400 working days, and going for ‘Max’ testing strategy.

Vacuum System Item	Qty	Leak tests (Factory)	Leak tests (On-site)
Arm Pipe (15 m unit length, Ø 1.0 m)	8000	20/day	—
Arm Pumping Module (1 m unit / 500 m)	240	~1/day	—
Arm Pipe String (500 m lengths)	240	—	~1/day
Arm Vacuum Sector (5000 m lengths)	24	—	~1/month

Leak detection Strategy: Cost estimate

Max Strategy:

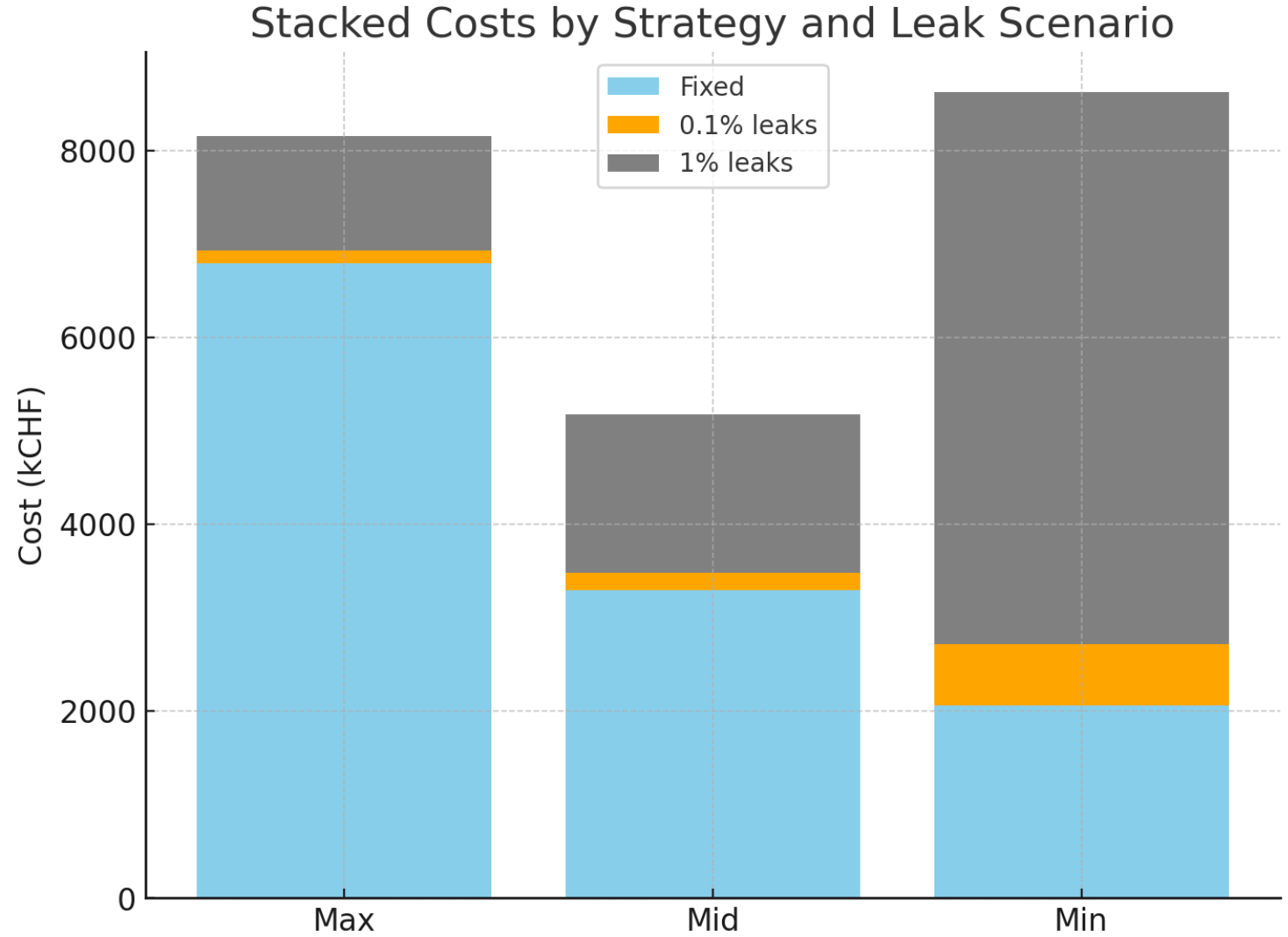
- Low risk
- Early warning of leak issues
- Dominated by component testing costs

Min Strategy:

- High risk (high confidence)
- Dependent on low leak occurrence
- Potential minimum cost

Mid Strategy

- Medium risk
- Higher leak occurrence can be tolerated w.r.t cost.
- Can review strategy dependent on field results.



1 CHF = 1 Euro = 1 USD

Leak detection Strategy for Einstein Telescope: Conclusions

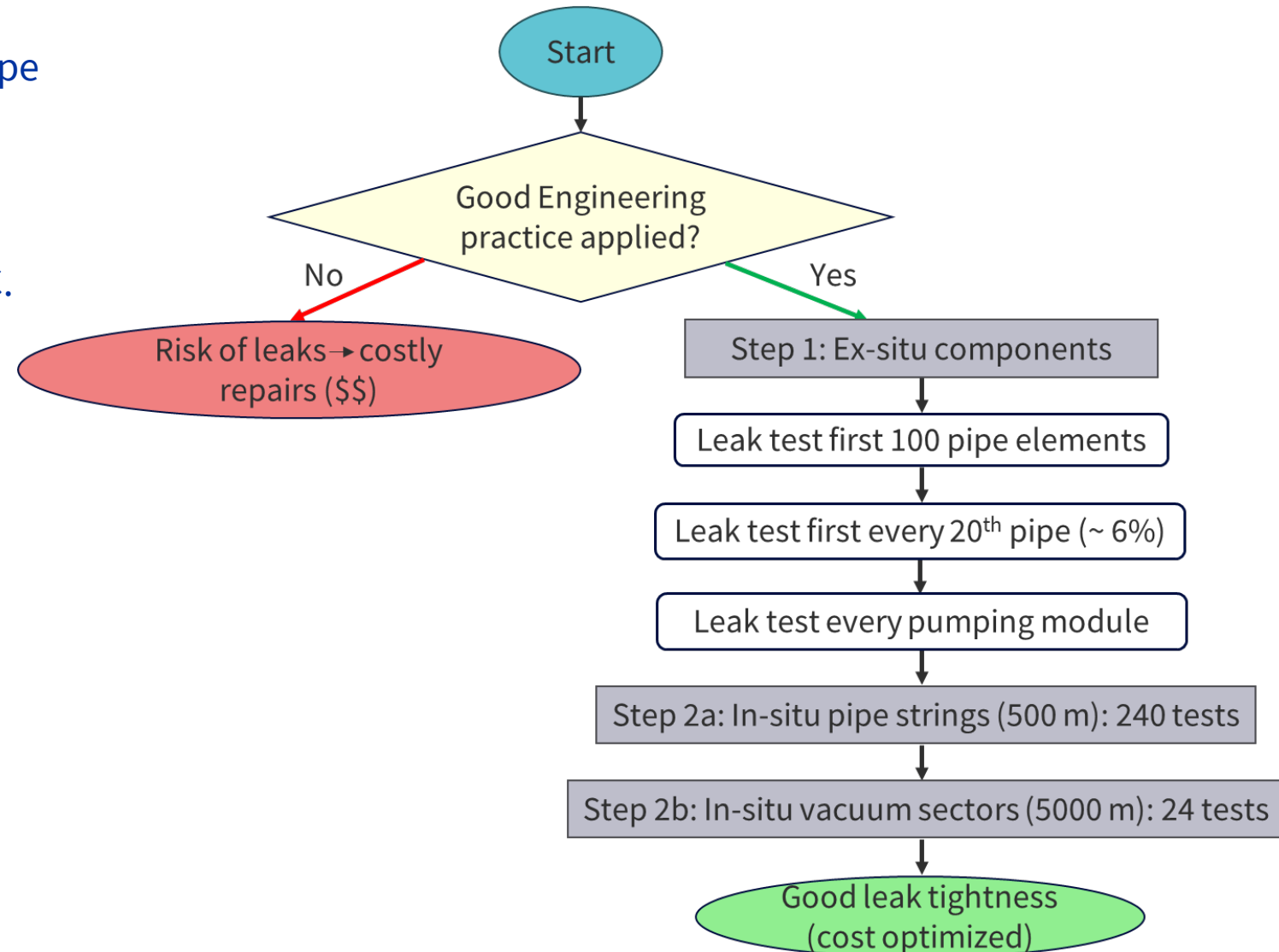
Adopting “**Mid Strategy**” with sampled testing of pipe elements ex-situ would be a way to go forward.

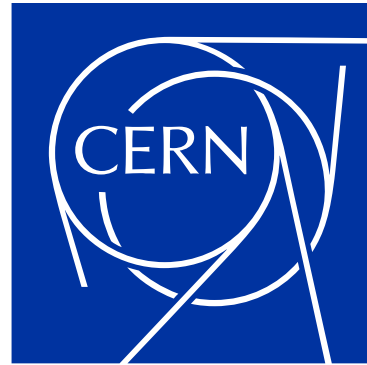
Good engineering practice:

Design, manufacture, assembly, commissioning, QC.
Vacuum engineer must be involved in all steps.

Solutions exist to close vacuum vessels
without **flanges**.

Different leak testing strategies can be
considered – each has its merits and
drawbacks with respect to **duration, cost,**
risk, etc.

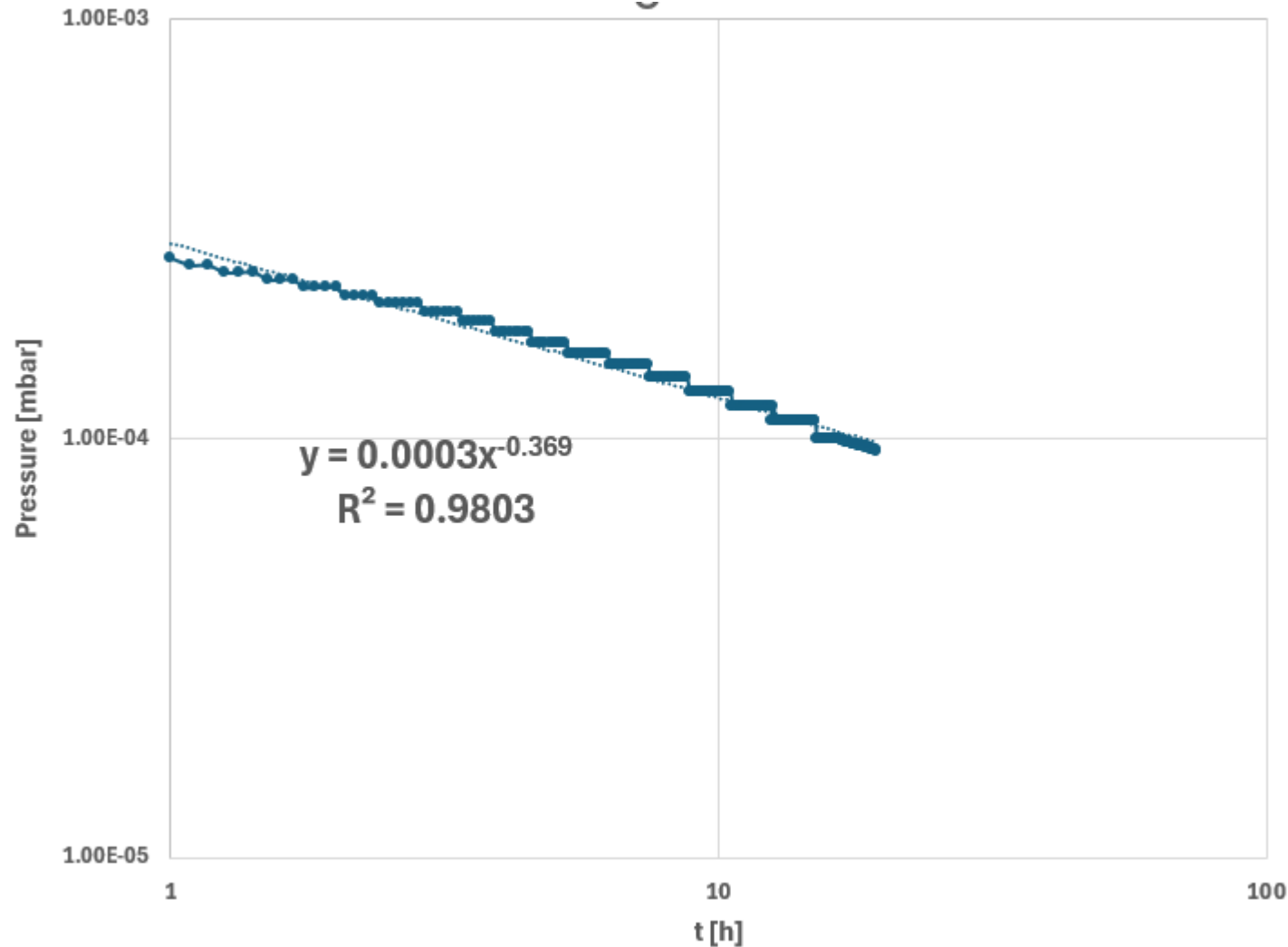




Thank you for your attention!

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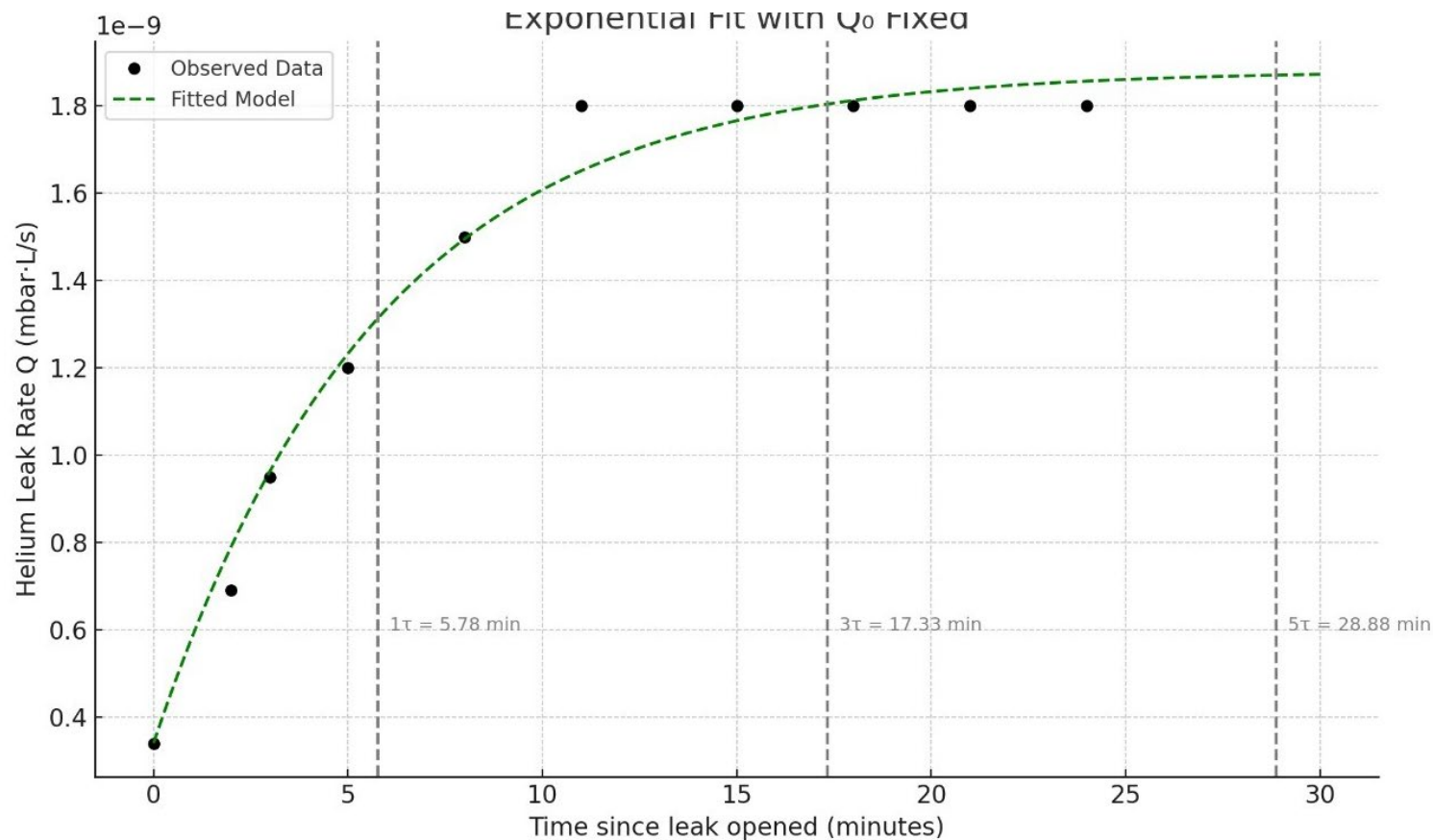
Leak detection of tube elements: Pumpdown



The pumpdown was slower with a time exponent of -0.369 possibly because of the NBR gasket

Confirmed by a separate pumpdown of an NBR gasket

Leak detection of tube elements: System calibration



The system calibration was done using a calibrated leak (Helium-4) on the end opposite to the pumping end.

This provides us the time constant (τ) of the system and the time to wait ($t > 3\tau$) after helium injection during the leak test.