Einstein Telescope – status
+
vacuum and beampipe summary

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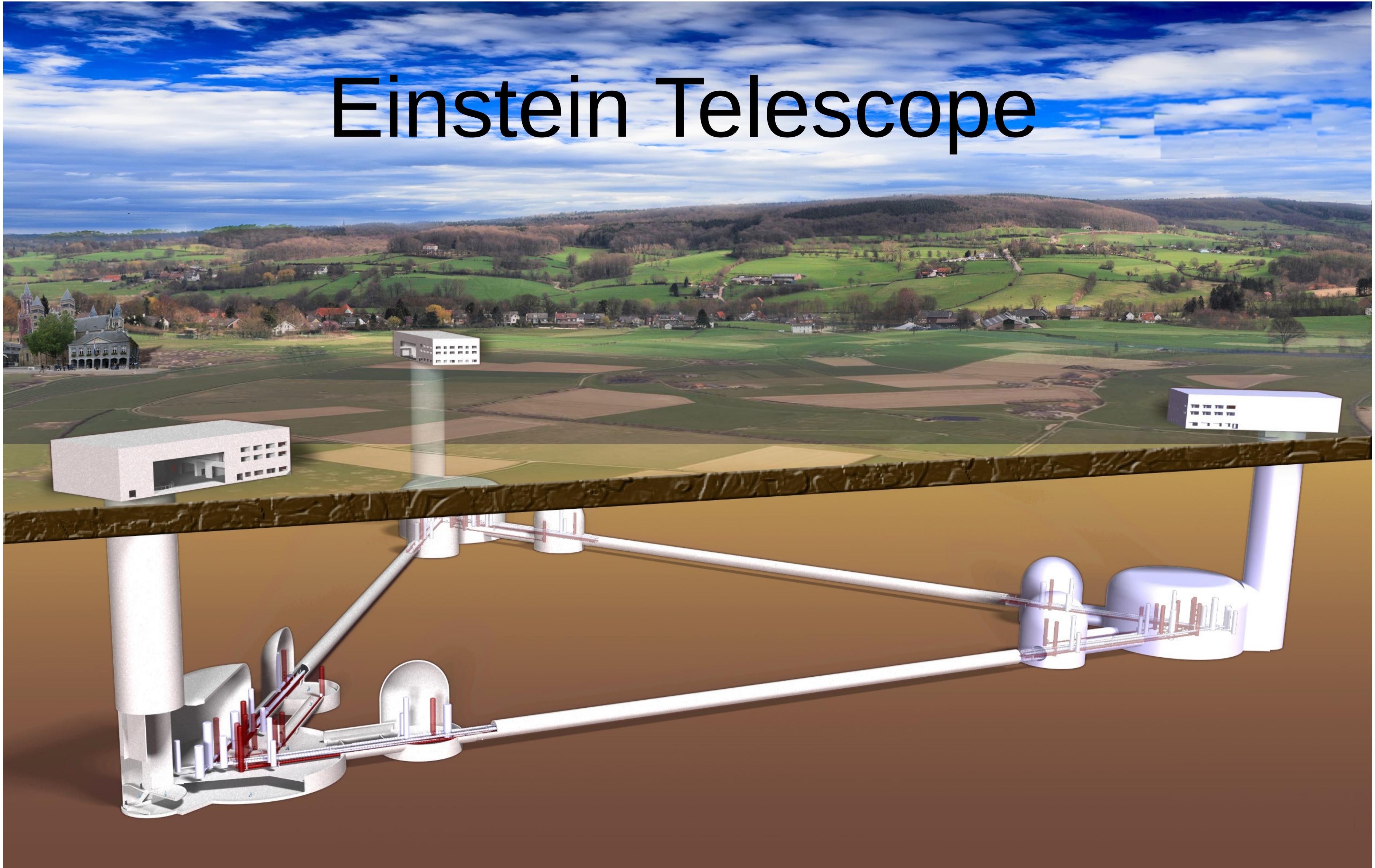
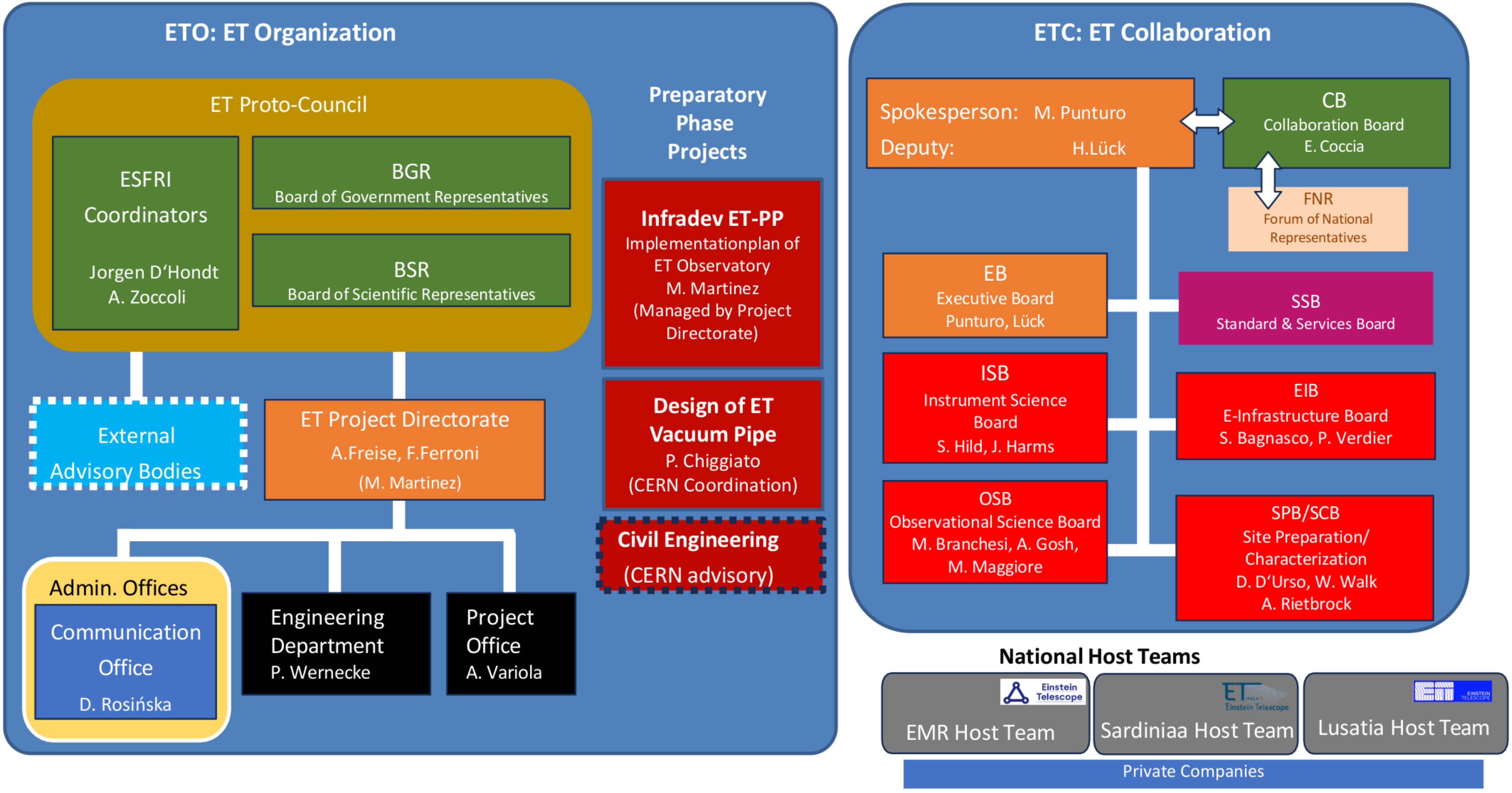
EINSTEIN TELESCOPE

Einstein Telescope



Collaboration

1876 members, 271 institutions, 31 countries



ETO: ET Organization
ET Proto-Council
ESFRI Coordinators
Jorgen D'Hondt
A. Zoccoli
BGR
Board of Government Representatives
BSR
Board of Scientific Representatives
Preparatory Phase Projects
Infradev ET-PP
Implementationplan of ET Observatory
M. Martinez
(Managed by Project Directorate)
Design of ET Vacuum Pipe
P. Chiggiato
(CERN Coordination)
Civil Engineering
(CERN advisory)
External Advisory Bodies
ET Project Directorate
A.Freise, F.Ferroni
(M. Martinez)
Admin. Offices
Communication Office
D. Rosińska
Engineering Department
P. Wernecke
Project Office
A. Variola
ETC: ET Collaboration
Spokesperson: M. Punturo
Deputy: H.Lück
CB
Collaboration Board
E. Coccia
FNR
Forum of National Representatives
EB
Executive Board
Punturo, Lück
SSB
Standard & Services Board
ISB
Instrument Science Board
S. Hild, J. Harms
EIB
E-Infrastructure Board
S. Bagnasco, P. Verdier
OSB
Observational Science Board
M. Branchesi, A. Gosh,
M. Maggiore
SPB/SCB
Site Preparation/ Characterization
D. D'Urso, W. Walk
A. Rietbrock
National Host Teams
EMR Host Team
Sardiniaa Host Team
Lusatia Host Team
Private Companies

About ET PP

- Et Preparatory Phase Project, https://etpp.ifae.es/
- Project to streamline Et preparations
- Documents at this website

WP 1: Management and Coordination

WP 2: Organization, Governance and Legal Aspects

WP 3: Financial Architecture

WP 4: Site Preparation

WP 5: Project Office & Engineering Department

WP 6: Technical Design

WP 7: Innovation and Industrial Engagement

WP 8: Computing and Data Access

WP 9: Sustainable Development Strategy

WP 10: Communication & Outreach

Potential locations

Italy: Sardinia

Netherlands, Belgium: EMR

Germany: Lusatia

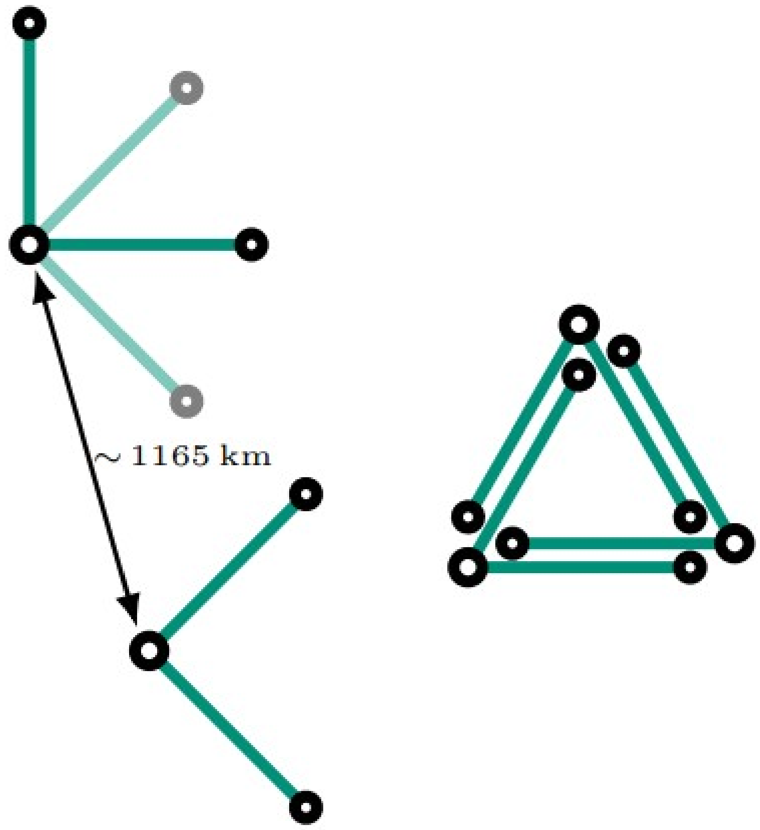
Layout: 2L vs Δ

Triangle

- 3(6) detectors of 10 km
- 30km of tunnels
- large diameter

2L

- 2 detectors with 15km arms
- 60 km of tunnels
- Small diameter



https://arxiv.org/pdf/2303.15923

Site selection process

Science case

The “Blue book”:

https://arxiv.org/pdf/2503.122


ET-0036E-25

The Science of the Einstein Telescope

Einstein Telescope collaboration

Fundamental Physics
Cosmology
Population studies
Multi messenger observations
Synergies with observatories

Subatomic physics
Stellar collapse ad NS
Waveforms
Tools
Data analysis

ET Pathfinder

ETPATHFINDER

ET experimental facility at the University of Maastricht

Testbed dfor Et technologies

-cryogenics
-quantum optics
- mirror testing
- laser technology (longer wavelength)

https://www.etpathfinder.eu/

Einstein Telescope meetings

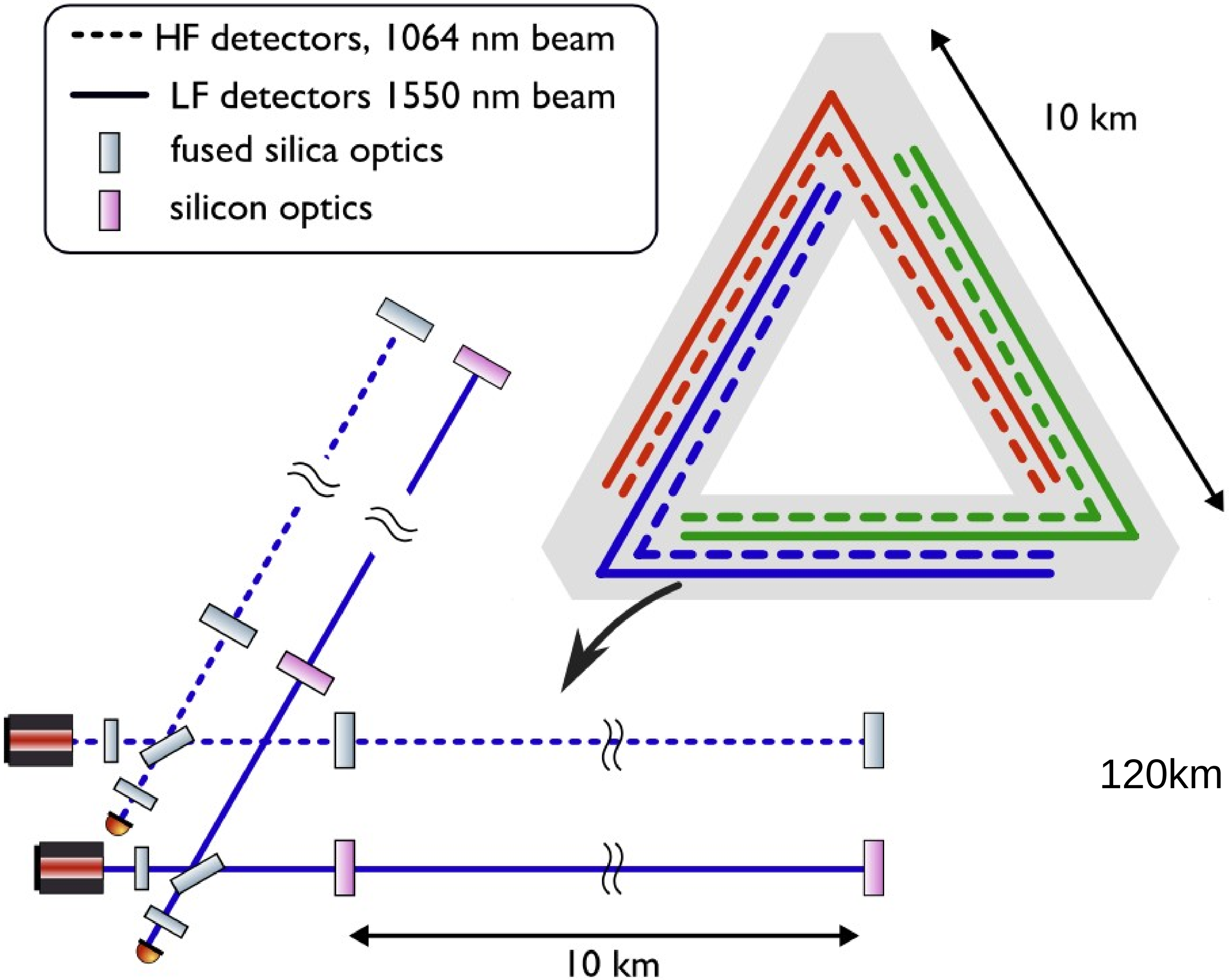
ET Meetings

- Held in the fall
- Internal meeting of the ET collaboration
- Next one in Croatia in November

ET Symposia

- Held in springtime
- Open to all
- Last in Bolonia
- Next TBD

Beampipe and vacuum work



120km of vacuum pipes

Documents

Einstein Telescope beampipe requirements

ET-0385A-24

Aniello Grado, Marije Barel, Tomasz Bulik, Marc Andres-Carcasona, Giacomo Ciani, Livia Conti, Julien Gargiulo, Stefan Hanke, Harald Lueck, Mario Martinez, Andrea Moscatello, Nick van Remortel, Carlo Scarcia, Emanuele Tofani, Patrik Werneke

Issue: 1

Date: June 10, 2024

Preparatory Phase for the Einstein Telescope Gravitational Wave Observatory

Deliverable 6.2

The Vacuum Pipe of ET

Groups of problems

- Scattering, baffles, dust, beampipie diameter
- Pressure fluctuations, residual pressure of different species
- Surface contamination
- Pump-down requirements, bakeout
- Conditions in the tunnels: Temperature, humidity,
- Acoustic noise, vibrations of the beampipe (modes)

- Lifetime
- Materials
- Supports
- Welding
- Vacuum control
- Maintenance and removal
- Risks
- Logistics and sustainability

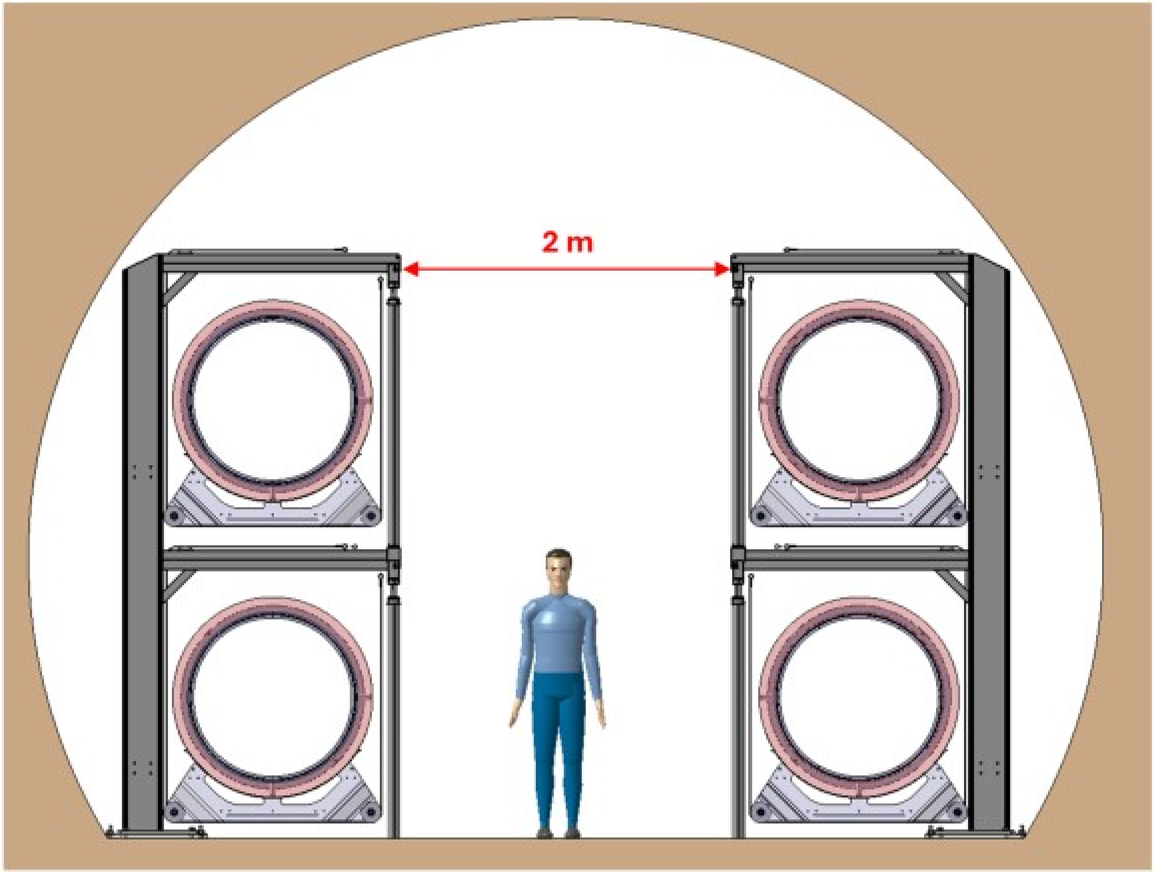
Basic parameters

FP optical cavity parameters				
Variable	ET-HF	ET-LF	Units	Description
m	200	211	kg	Mirror mass
L	10	10	km	Length of an arm
λ	1064	1550	nm	Wavelength of the laser
R_m	0.31	0.225	m	Radii of the mirrors
$\mathcal{R}_1$	5070	5580	m	Radius of curvature input mirror
$\mathcal{R}_2$	5070	5580	m	Radius of curvature end mirror
P_{circ}	3000	18	kW	Circulating power in the cavity
R	0.5	0.5	m	Radius of the vacuum pipe.

Materials for pipes

- Classical stainless steel
  - Needs bakeout
  - Significant outgasing
- Ferritic steel – an alternative
  - less hydrogen content
  - Lower cost
  - But magnetic properties to be taken care of

How to squeeze 4 pipes in a tunnel?



Pipe vibrations

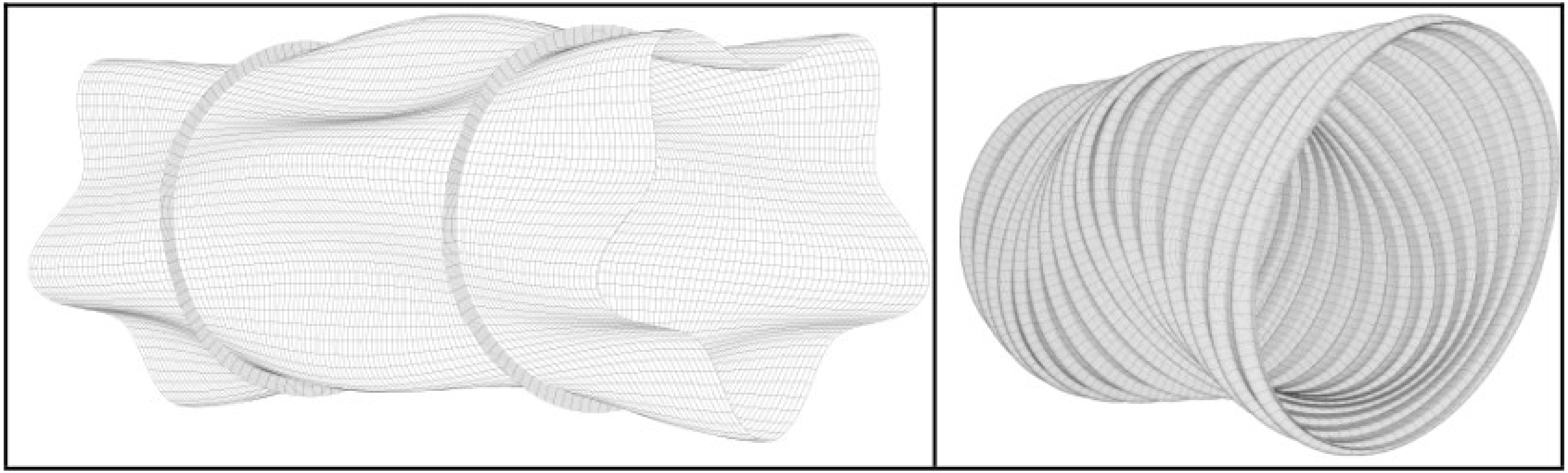
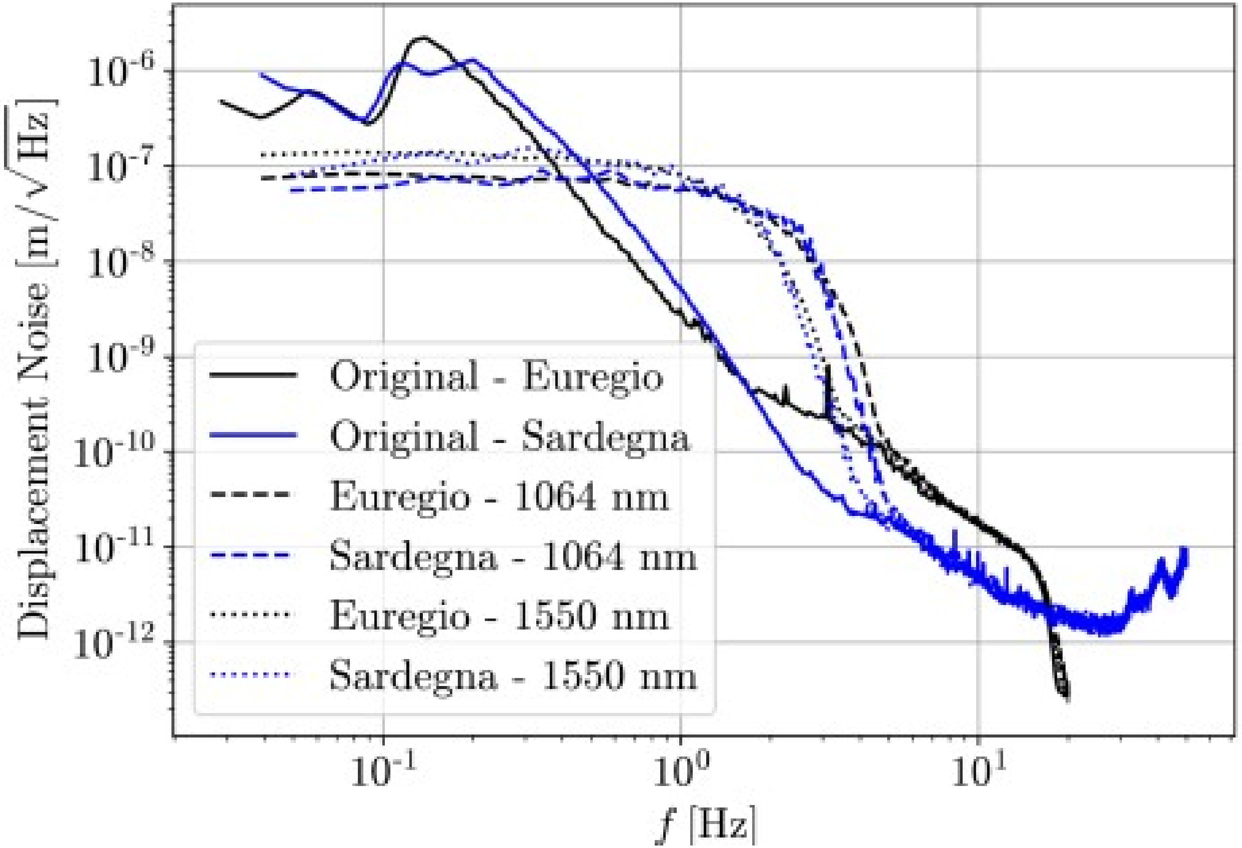


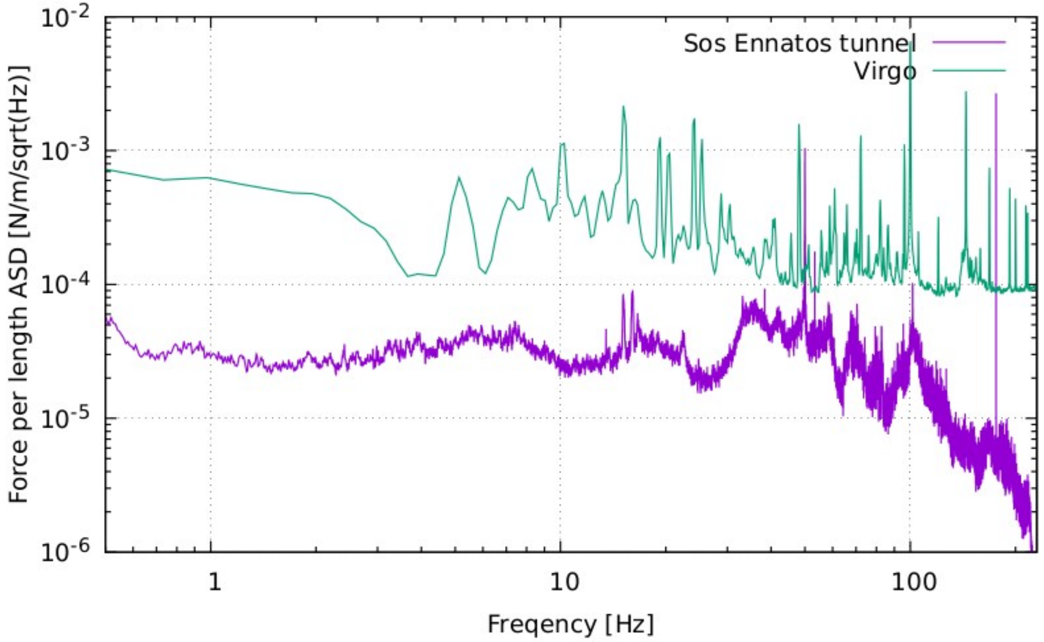
Fig. 7: *Main buckling mode of the smooth (left side) and corrugated vacuum pipes (right side).*

Seismic noise

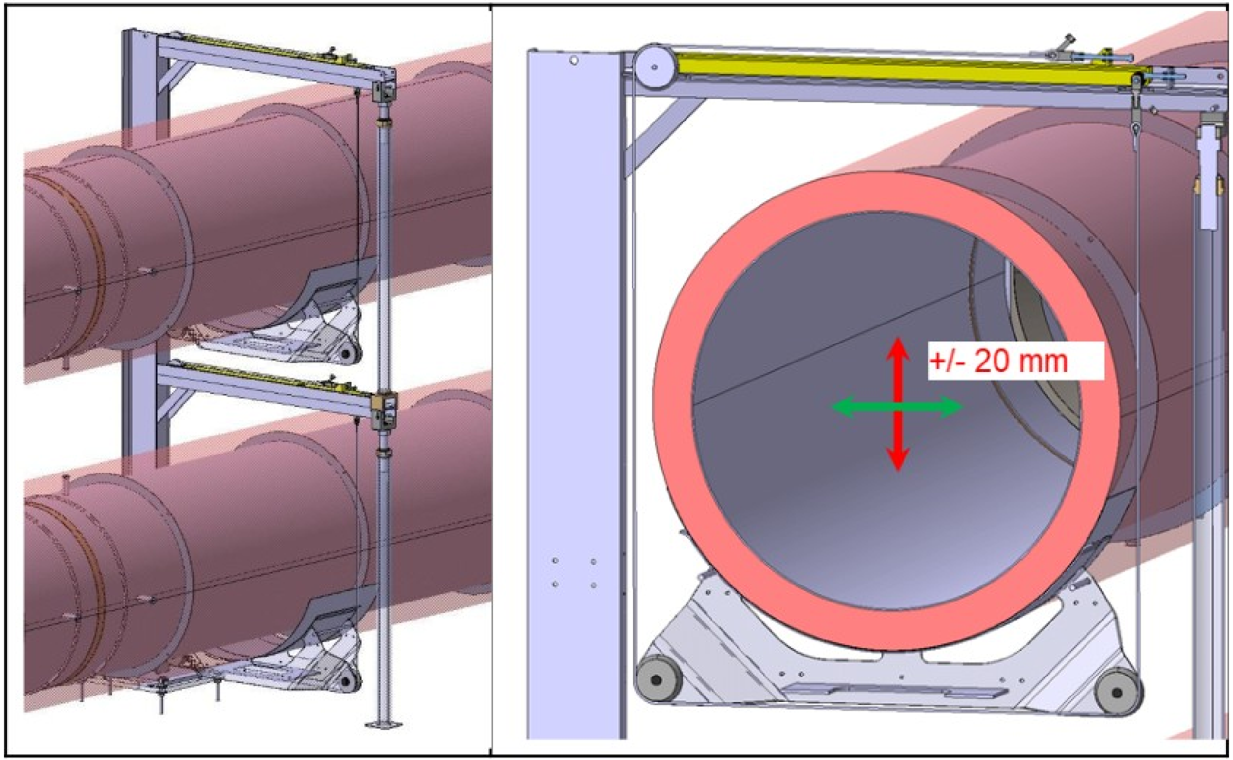


Beampipe vibrations

- Seismic noise
  - Transfer to the beampipe
- Infrasound noise
  - Force due to noise



Pipe mounting



Pipe construction

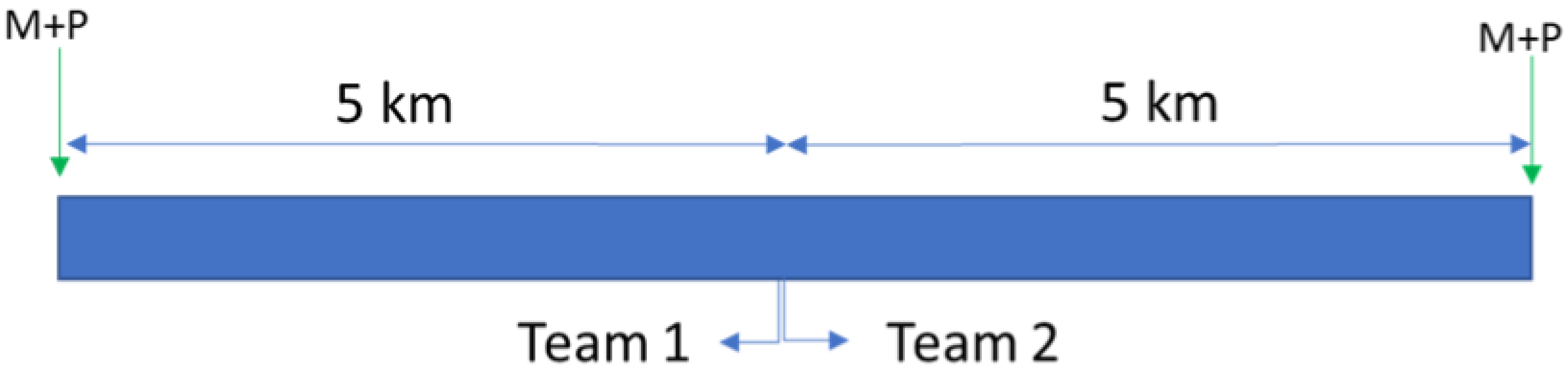
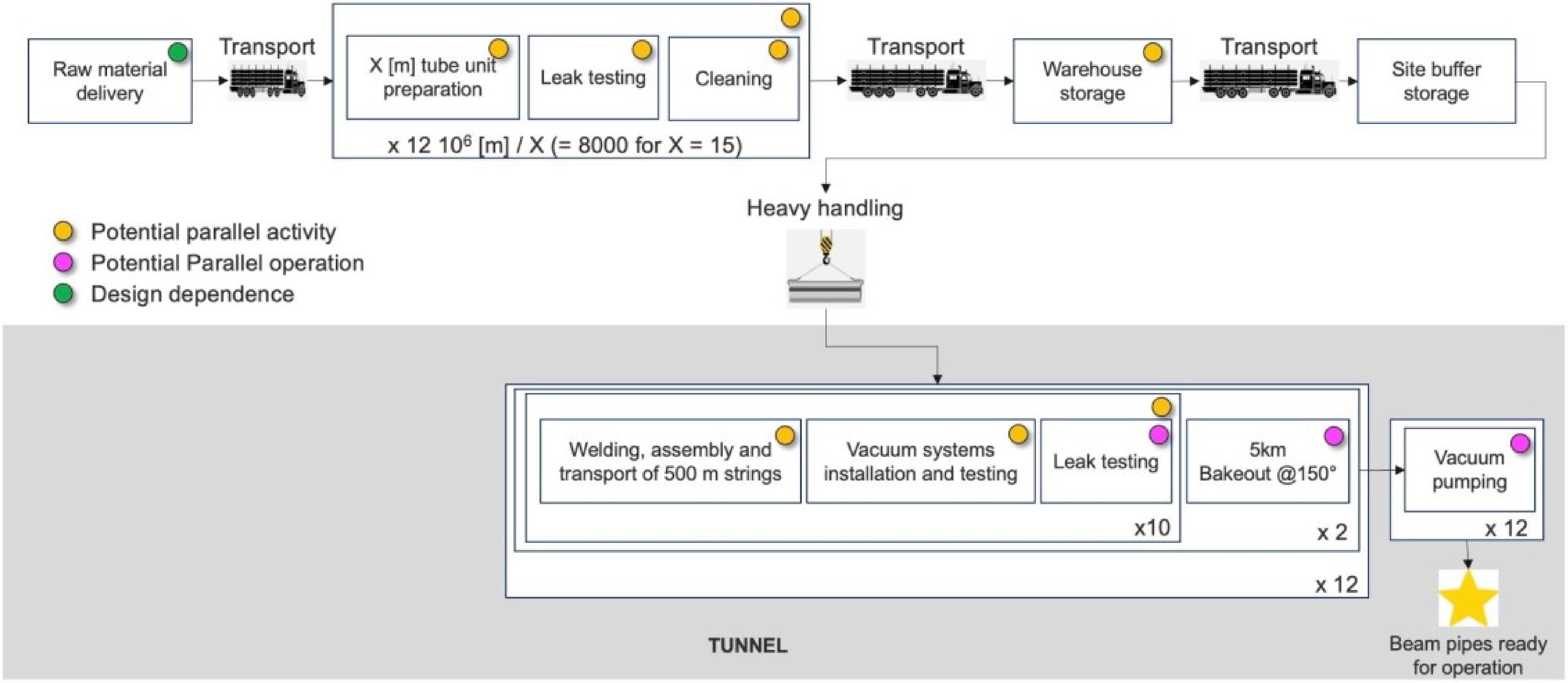


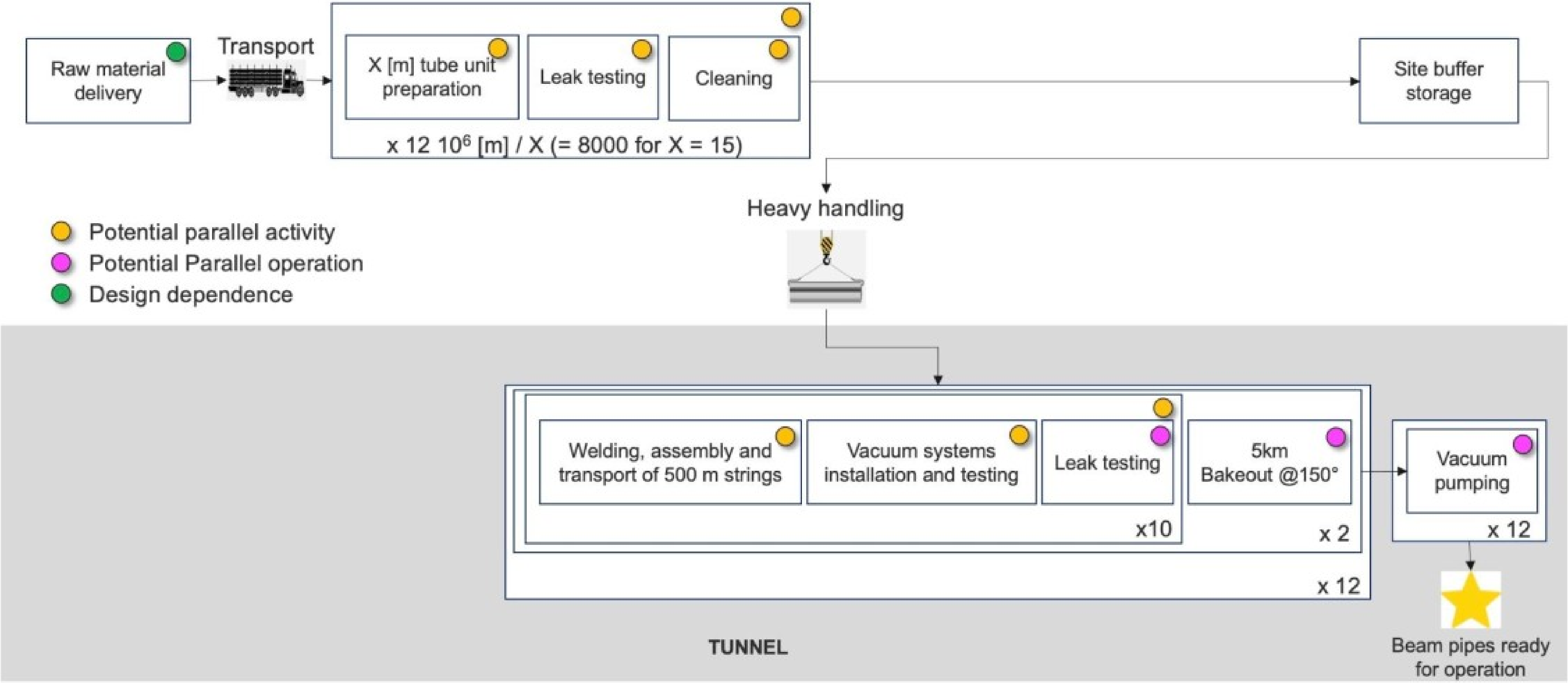
Fig. 23: *Schematic view of the tunnel (triangle version of ET) with the two installation fronts starting from the center. Personnel (P) and material (M) enter the tunnel from the extremities.*

Construction at about 10 units (of 15m length) per week.
Delivery of materials at night
Construction – approx 140 weeks

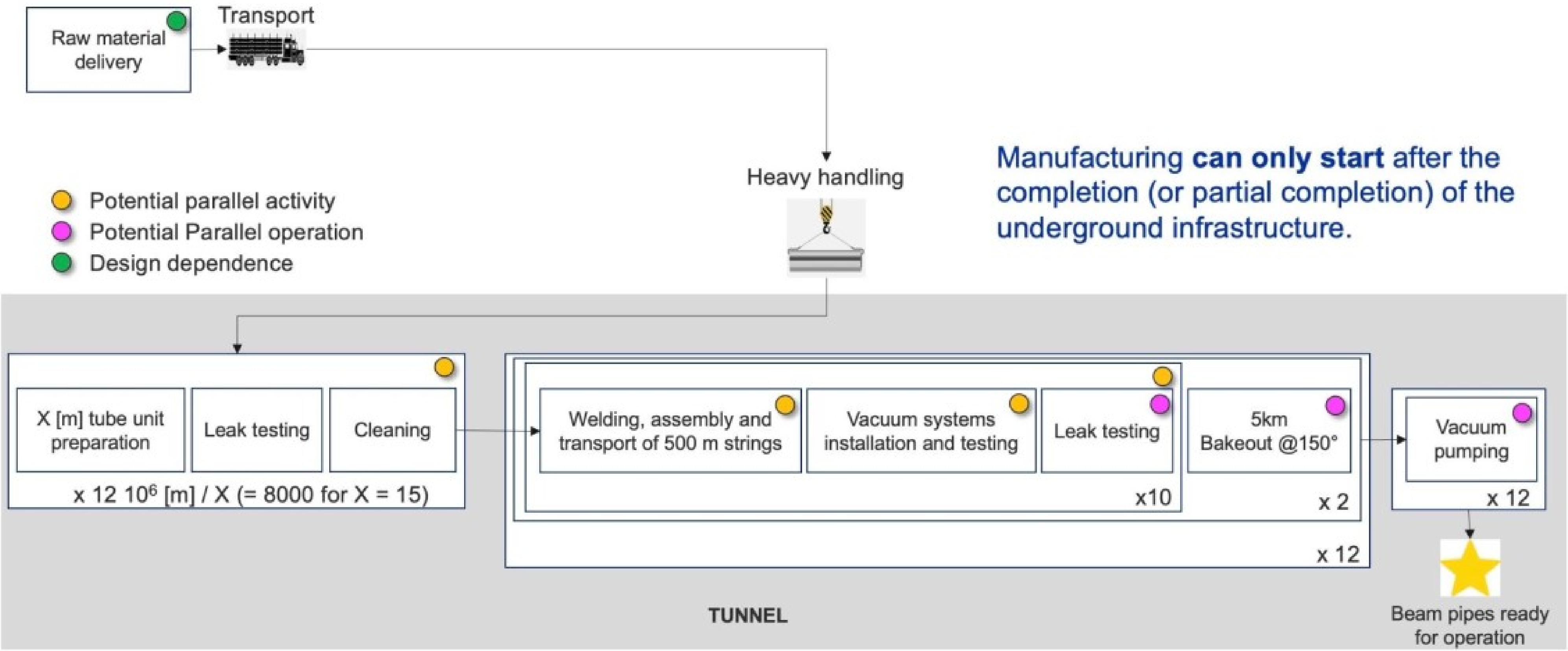
Manufacturing scenario: off-site



Manufacturing scenario: on site



Manufacturing scenario: in tunnel



Manufacturing **can only start** after the completion (or partial completion) of the underground infrastructure.

Pumpdown time and procedure

Rough pumping

High vac pumping

Bake out

Ultra high vacuum pumping

- t_{Rp} = 4.5 - 10 days.
- t_{HVp} = 7 - 15 days.
- $\alpha_{\text{bake-out}}$ = 120 - 48 °C/day (5 - 2°C/h).
- $t_{\text{bake-out}}$ = 7 - 30 days
- $\beta_{\text{bake-out}}$ = 120 - 48 °C/day (5 - 2 °C/h).
- $t_{\text{UHV scan}}$ = 2 days.

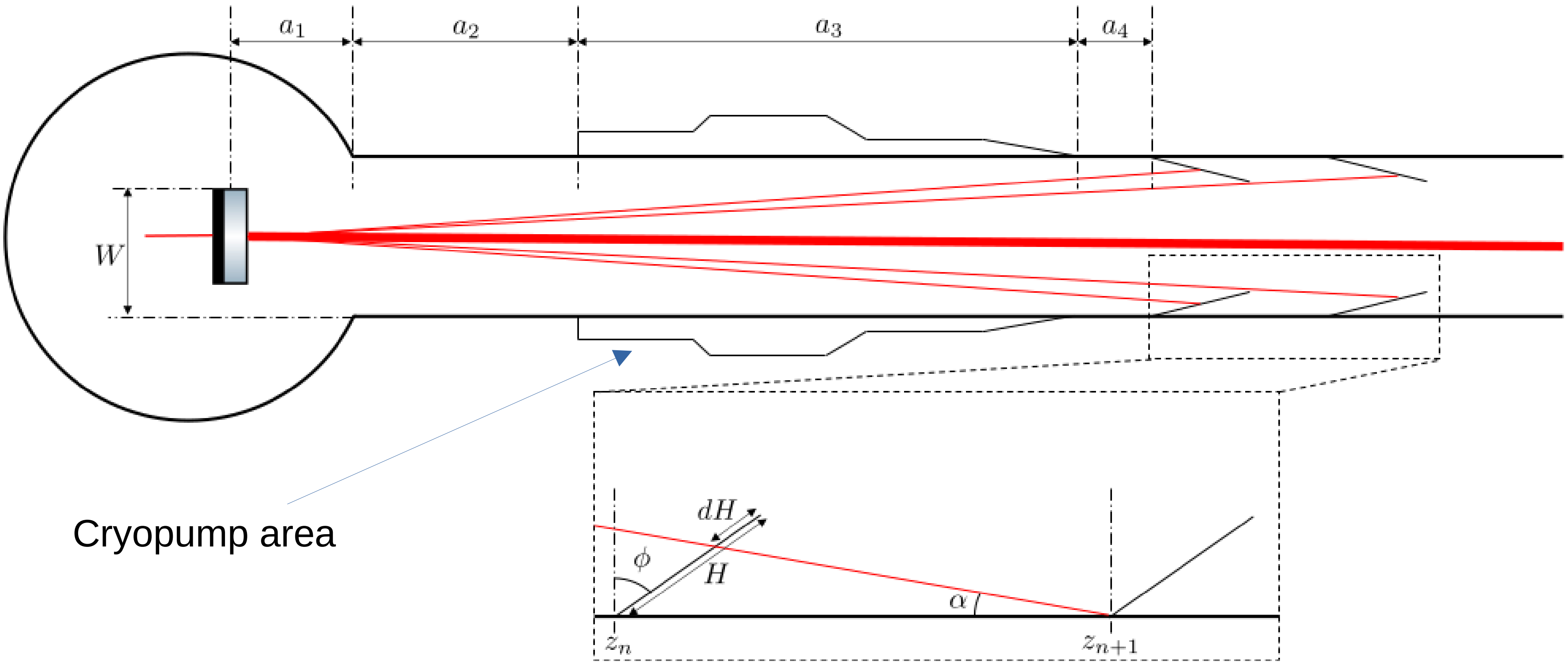
The minimum and maximum pump-down time for one 5 km long sector are 22 - 62 days.

Safety precautions during bake out

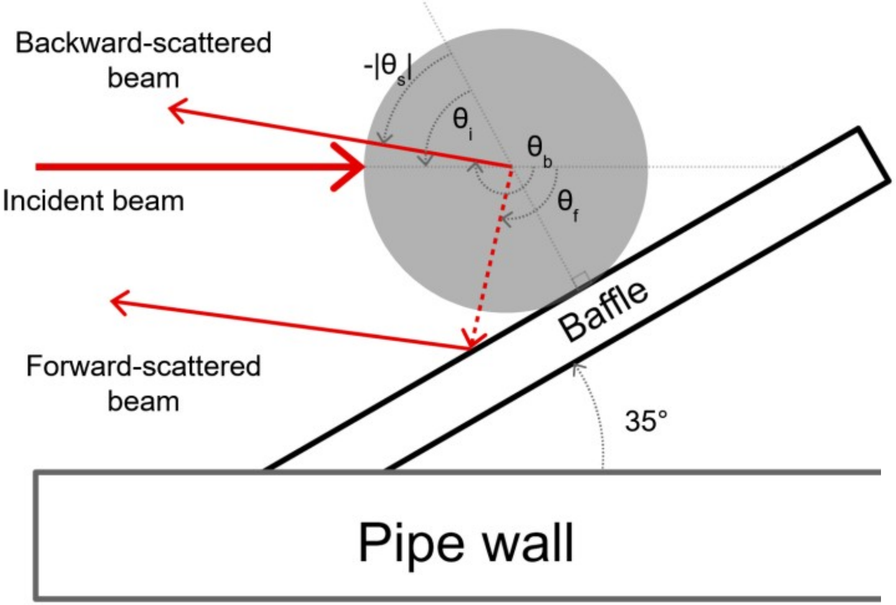
- Temperature in the tunnels <26C (30C)
- Humidity in the tunnels < 60%

- Tunnels must be reachable all the time

Baffles design



Scattering by particles

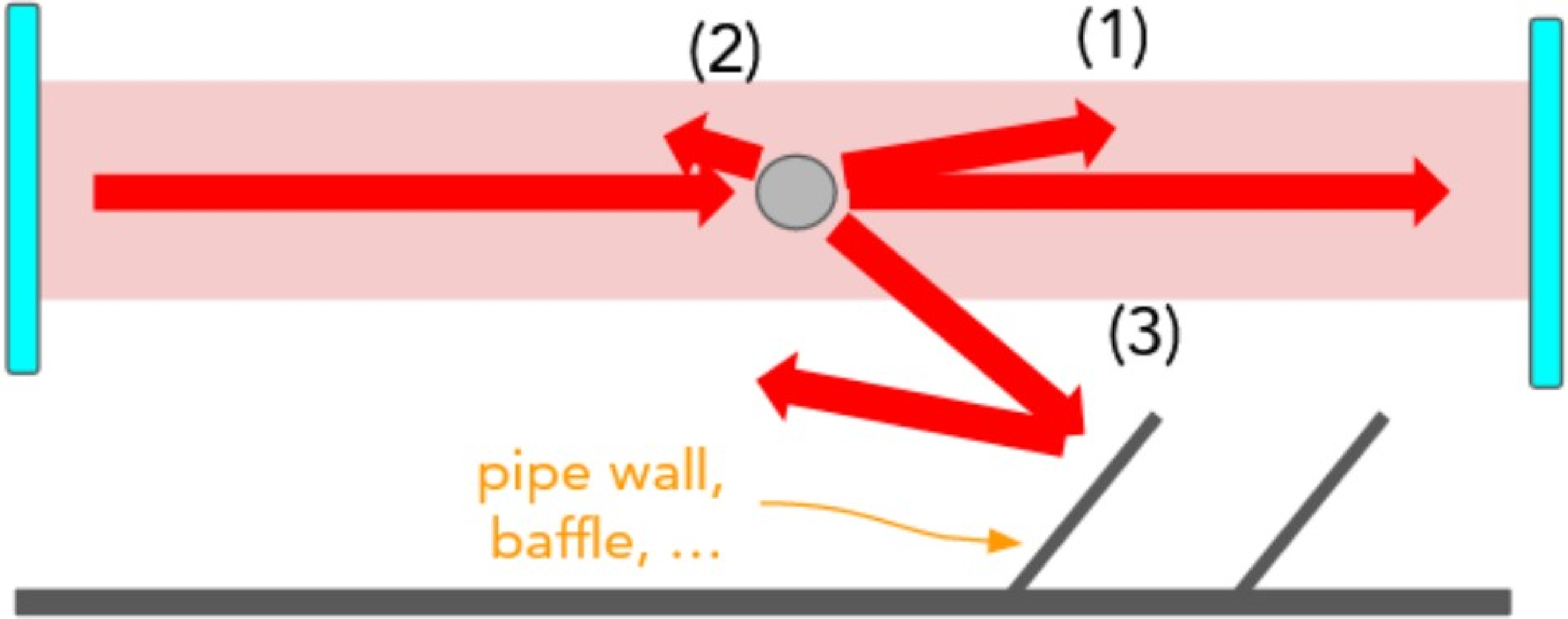


Mie scattering by particles on the baffles

	Density (particles/m^2)		
diameter range (μm)	50%	90%	$m = 1.5 + i\,10^{-3}$
(0.1 - 0.3)	$9.3 \cdot 10^{11}$	$6.2 \cdot 10^{11}$	$2.0 \cdot 10^{12}$
(0.3 - 1)	$1.5 \cdot 10^{11}$	$1.1 \cdot 10^{11}$	$5.7 \cdot 10^{10}$
(1 - 3)	$2.0 \cdot 10^{10}$	$1.4 \cdot 10^{10}$	$6.4 \cdot 10^{8}$
(3 - 10)	$2.1 \cdot 10^{9}$	$1.4 \cdot 10^{9}$	$1.1 \cdot 10^{8}$
(10 - 30)	$2.3 \cdot 10^{8}$	$1.5 \cdot 10^{8}$	$2.5 \cdot 10^{7}$
(30 - 100)	$2.2 \cdot 10^{7}$	$1.4 \cdot 10^{7}$	$4.5 \cdot 10^{6}$

Maximum allowed particle density on baffles

Dust crossing the beam



Will result in requirements for cleanliness during assembly, as yet to be determined

Residual gas pressure fluctuations

Gas will undergo fluctuations that will interact with laser light.

Gas pressure fluctuates and introduce noise in the laser beam

→

Requirements on partial pressure of different species in the gas

Gas pressure noise

Gas pumping example

23.9Hz

Gas species	Max pressure mbar	Noise HF $1/\sqrt{Hz}$
H_2	5.3×10^{-11}	1.7×10^{-26}
H_2O	9.6×10^{-12}	1.6×10^{-26}
N_2	5.6×10^{-12}	1.4×10^{-26}
CO	2.2×10^{-12}	1×10^{-26}
CO_2	2×10^{-12}	1×10^{-26}
$Hydrocarbon_{100}$	9.1×10^{-14}	1.5×10^{-26}

271Hz

Gas species	Pressure max mbar	Noise LF $1/\sqrt{Hz}$
H_2	5.3×10^{-11}	2.1×10^{-26}
H_2O	9.6×10^{-12}	2.1×10^{-26}
N_2	5.6×10^{-12}	1.8×10^{-26}
CO	2.2×10^{-12}	1.3×10^{-26}
CO_2	2.0×10^{-12}	1.6×10^{-26}
$Hydrocarbon_{100}$	9.1×10^{-14}	2.1×10^{-26}

Summary

- Status of ET: big effort, lots of activities
- Vacuum and beampipe work
  - Several steps taken
  - Basic requirements and procedures are set
  - Issues to be addressed: corrosion, support system, corrugated pipe design, dust management, thermal insulation, leak detection, safety analysis, assembly and storage requirements (and probably many more….)


CE/ET
jonrawlinson.com