



VACUUM

INNOVATION PROJECT

ET2SMEs – On-Site production of quasi-continuous UHV pipes

“Beampipes for Gravitational Wave Telescopes 2023”

Dr. M. Purrio

CERN, 27.03.2023

Project in a nutshell

4 project partners

4 mm stainless steel

Quasi-continuous production of
500 m pieces

120 km beampipe length

1 m beampipe diameter

7 month duration

in-situ production 300 m underground

49350 € funding



- Provider of services with cross-industry activities in the field of joining technology – Project lead

- Welding concept, feasibility and necessities for an optimal welding process



- Metalworking engineering company; total solutions in Engineering and Industrial contracting

- Overall production concept, calculations and drawings as well as feasibility and efforts



- 100% recyclable stainless steel products; high-performance solutions and local technical assistance

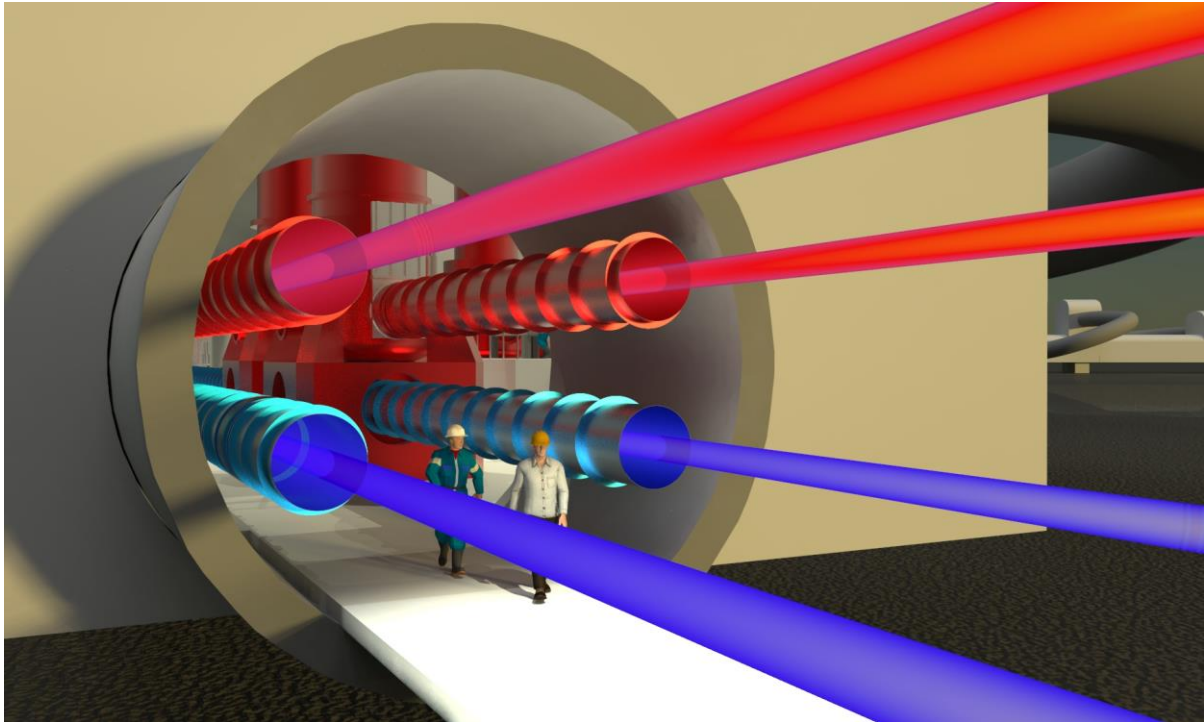
- Material and logistics, production and treatment of raw material and material behavior during and after the production



- experimental particle and astroparticle physics; design of international experiments at the world's largest particle accelerator and observatories for cosmic particles.

- Clarification of boundary conditions and physical conditions, expert knowledge on former projects

Why are we investigating in a continuous underground production?



12 beampipes of
10 km each

20 m pieces

500 pieces per
beampipe

weight per piece ~ 2t



120 km of pipes

6000 pieces

499 junctions per beampipe
/ 5988 junctions in total



§ 29 Straßenverkehrsordnung

- Total length of the vehicle must be smaller than 18,75 length x 2,55 width x 4 m height
- Gross vehicle weight is 40 tons
→ approx. 25 tons payload
- Otherwise it is a „special transport“

Source: Author: Marco Kraan, <https://www.nikhef.nl/pub/departments/mt/projects/EinsteinTelescoop/Artistic/2020/020> (nikhef.nl), 23.03.2023

Why are we investigating in a continuous underground production?

one 20 m piece per day transported, put in place, joined

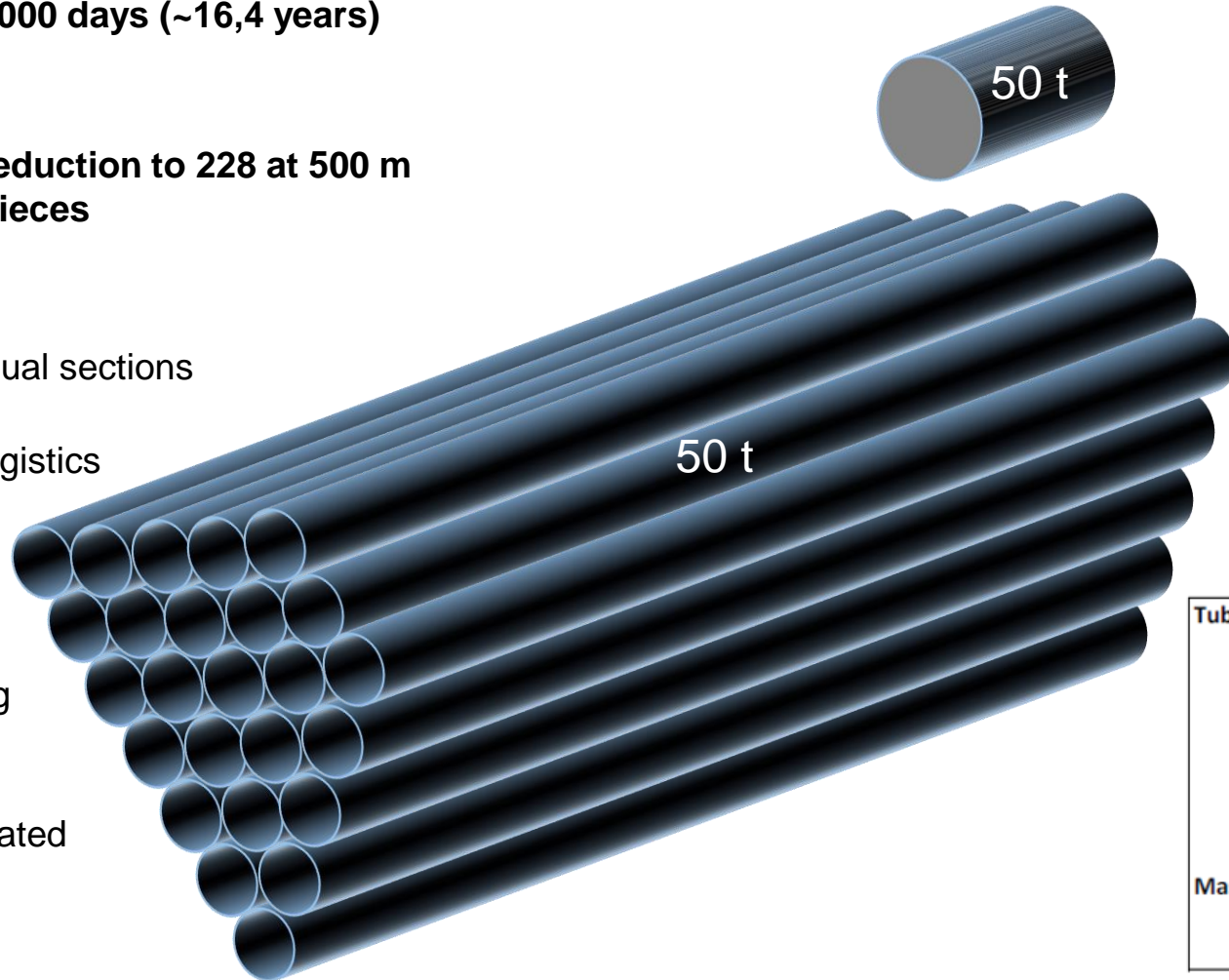
5988 manual joints at 20 m pieces



6000 days (~16,4 years)

reduction to 228 at 500 m pieces

- Less effort to connect the individual sections
- Significantly reduced effort for logistics
 - To the underground
 - Inside the tunnels
- Lower risk for defects by continuous automatic processing (in particular welding)
- Pipe sections get to their designated location faster



Coil :			
with :	mm		3.140,00
thickness :	mm		4,00
length :	m		510,00
Weight appr. :	Ton		50,80

Coil Ton:			
			50,80
with :	mm		3.140,00
inner diameter	mm		610,00
outer diameter	mm		1.715,00

Tubing :			
with :	mm		3.140,00
thickness :	mm		4,00
- double sheet -			
diameter :	mm		1.000,00
Mass:			
running meter:	kg/m		99,60

Our findings – Part 1: Bending

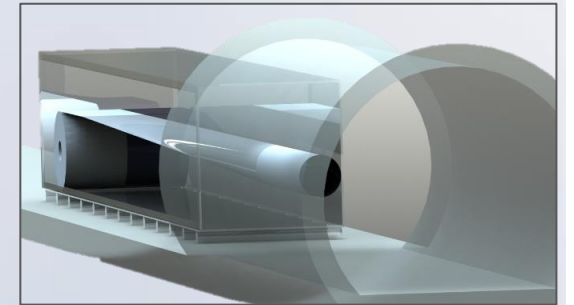
Bending top to bottom

- Welding in flat position
- Welding on the inside

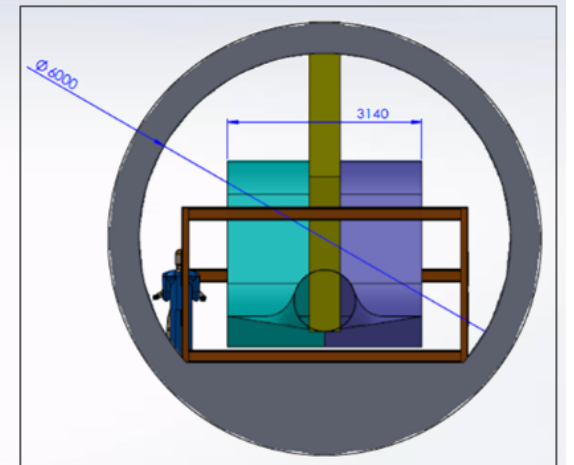


Prewelded coil

- max. coil width = 2 m
- welding on two positions & both PA
→ larger machinery in length & height



Coil Ton:		50,80
with :	mm	3.140,00
inner diameter	mm	610,00
outer diameter	mm	1.715,00

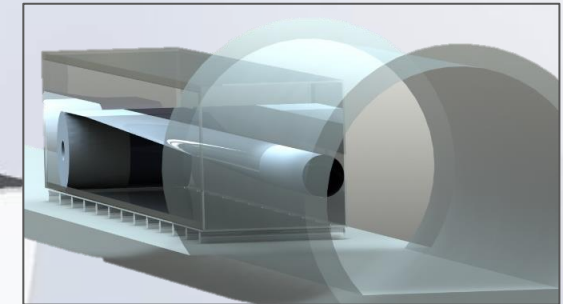
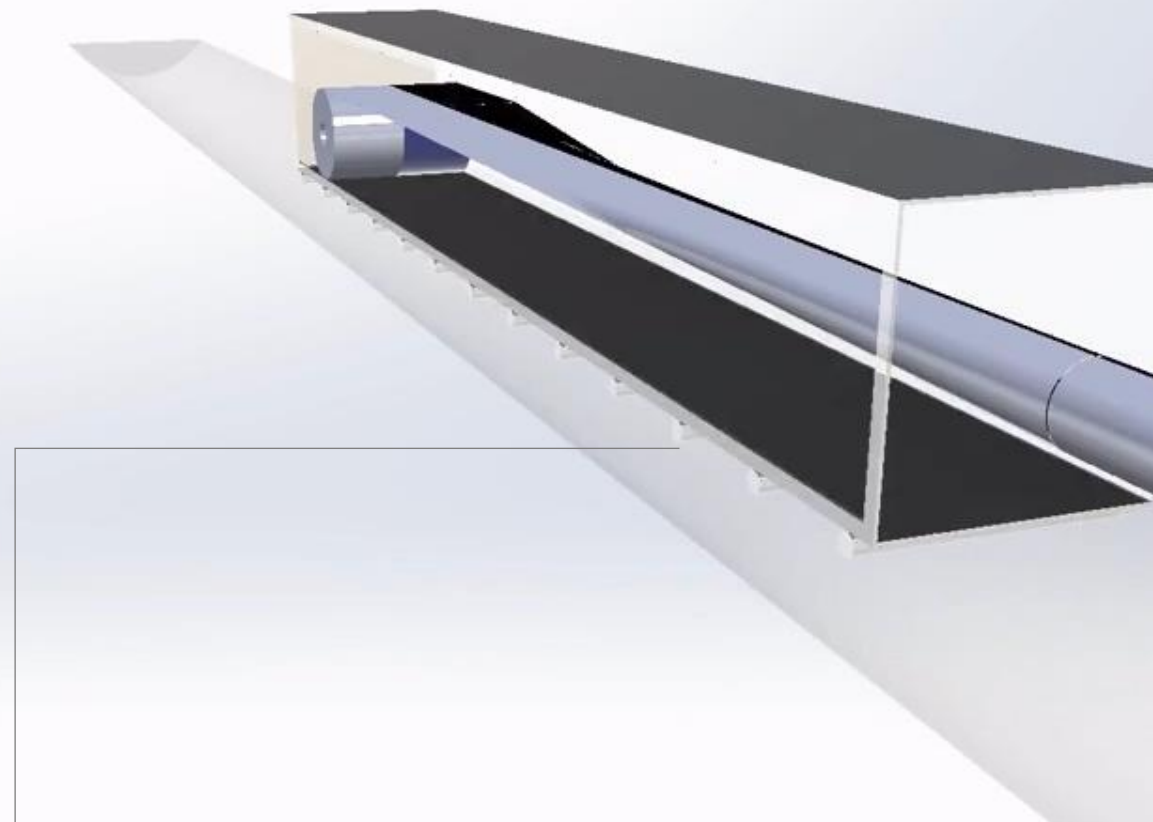


Source (all images and videos): Author: Jef Hoste, Werkhuizen Hengelhoef, 23.03.2023

Our findings – Part 1: Bending

Bending top to bottom

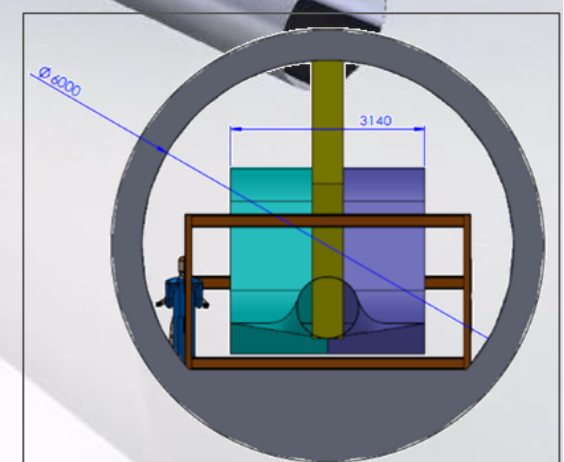
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Mobile equipment

- move either pipe section (500 m) or machines (~20 m)
- Assumption: rails in tunnels from tunnel construction

Source (all images and videos): Author: Jef Hoste, Werkhuizen Hengelhof, 23.03.2023

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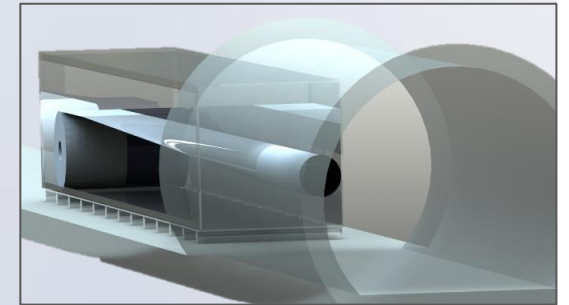
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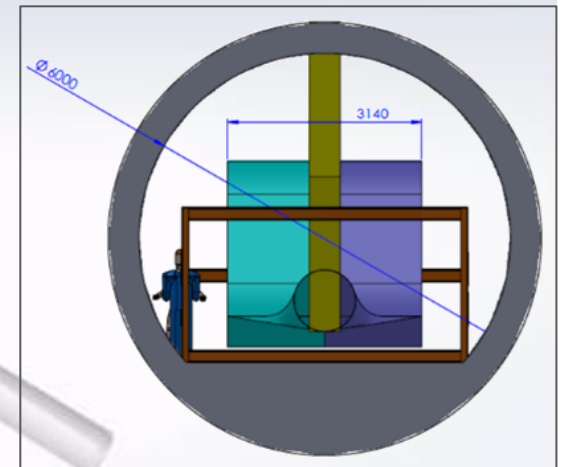
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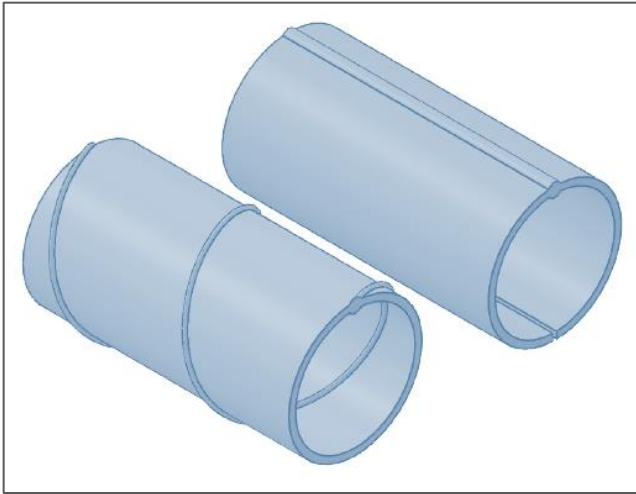


Coil Ton:			50,80
	with :	mm	3.140,00
	inner diameter	mm	610,00
	outer diameter	mm	1.715,00



Source (all images and videos): Author: Jef Hoste, Werkhuizen Hengelhof, 23.03.2023

Our findings – Part 2: Welding



Source: Author: Jef Hoste, Werkhuizen Hengelhoef, 23.03.2023

- less weld seam
- possibility to weld in PA from the inside

Pro:

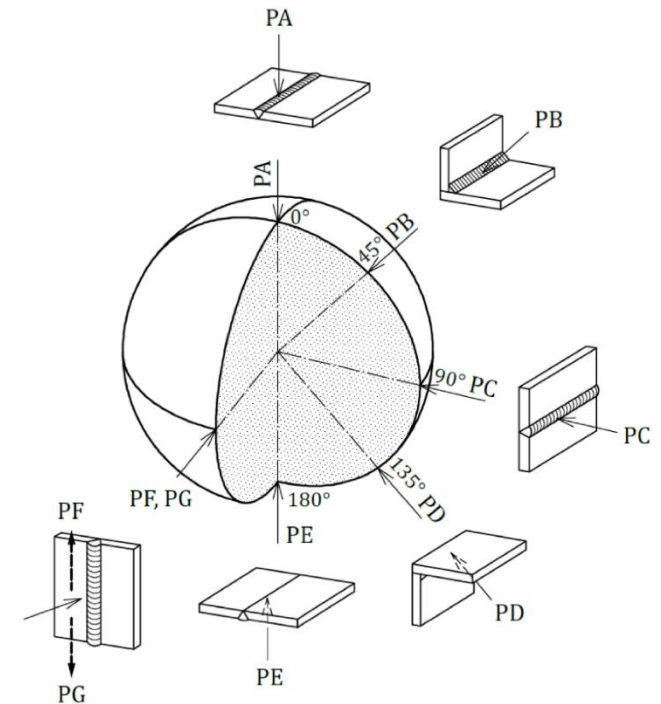
- higher surface quality on the inside
- contamination & pollution is on the outside
- easier to repair

Con:

- Bending process must be adapted

Dependencies:

- Cantilever ist needed (but common)
- If coils are joined, sheet must be turned to weld in PA inside again



Source: Beuth, DIN EN ISO 6947 Welding and allied processes - Welding positions (ISO 6947:2019);

Our findings – Part 2: Welding

Arguments for laser beam welding:

- Effective energy input
- Very stable process
- Fewer residues and contamination

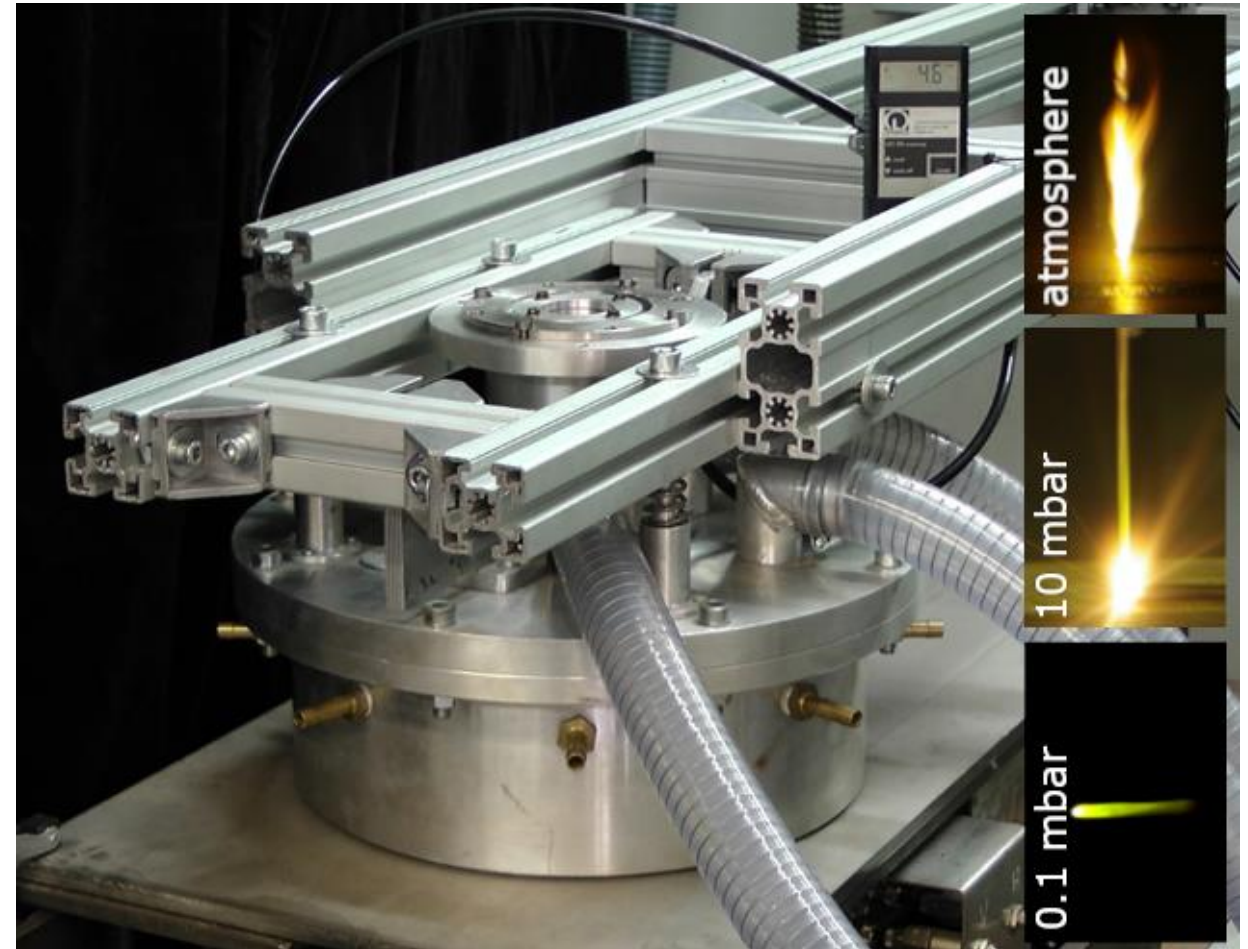
Arguments for the use of vacuum:

- Stable weldpool
- Less vacuum requirements than electron beam welding



How to create vacuum at the laser process at continuous production?

Make it mobile! (about 30 mbar could be reached)



Source (right image): U. Reisgen, S. Olschok, N. Holtum, S. Jakobs: "Laser beam in mobile vacuum". Proceedings: Lasers in Manufacturing - LIM 2017, Munich, Germany

What could possibly go wrong?

Strong arguments

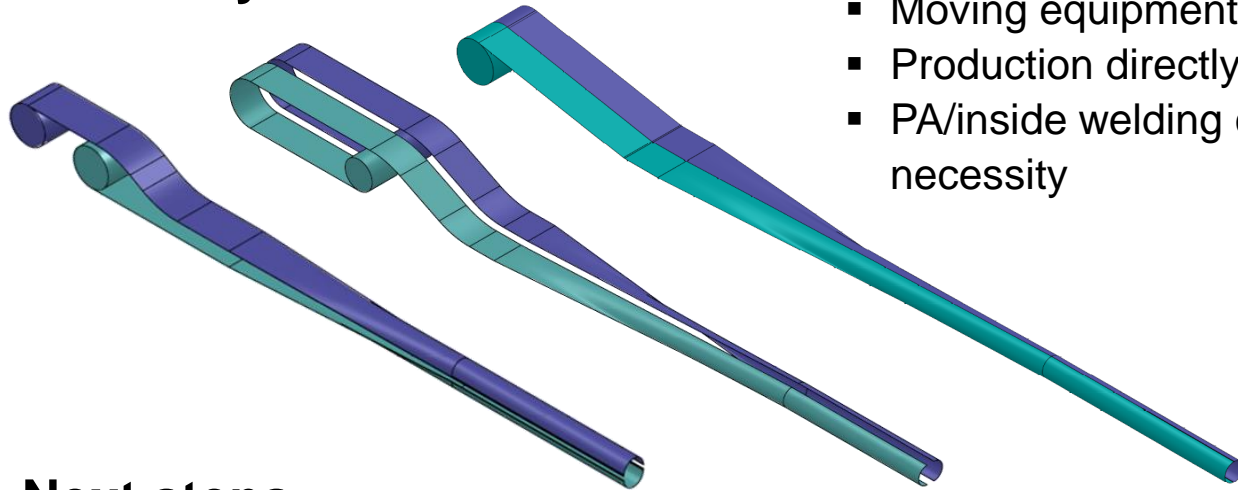
- Longer section length
 - Less weld seam
 - Less effort to connect the individual sections
 - Less logistical effort
- Quasi-continuous process
 - Better weld seam quality
 - Lower risk for defects
- In-situ processing
 - Significantly reduced effort for logistics
 - Estimated production speed limited by welding at 1 m/min
- Less time & less work → lower costs

To be discussed

- Production estimation needs a final design
 - Integration of stiffeners, baffles, vacuum pumps, etc.
 - Material type and thickness
- Realisation of moving equipment needs a final design of the tunnels
 - Location of the beampipes
 - Rails, Space, Placement order
- Welding process & process parameters must be tested
 - Tolerances of the bending process (technical zero gap)
 - Cleaning and testing necessity
 - mobile vacuum needs to be adapted
- Underground production set-up must be calculated
 - One-time effort to set-up machinery
- Risk analysis (product and machines)

Summary & next steps

Summary



- Moving equipment
- Production directly in the tunnels
- PA/inside welding considered as necessity
- 500 m pieces are realistic
- Concept is considered feasible
- Open questions must be discussed
- Pre-welded coils due to limited coil width
- Custom bending process needed

Next steps

Source: Author: Jef Hoste, Werkhuizen Hengelhof, 23.03.2023

- Welding parameter study
 - most stable parameters
 - ramp-up and ramp-down
- Adaption & testing of the mobile vacuum
- Tolerances & edge preparation at bending
 - pre- and post-treatment of the sheets
- Adjustment / modification of material
 - optimizing bending & welding properties
 - robustness to the prevailing underground conditions.



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Thank you for your attention

Do you have question?

