PETRA IV.
NEW DIMENSIONS

PETRA IV Girder

Design, Test, Logistics

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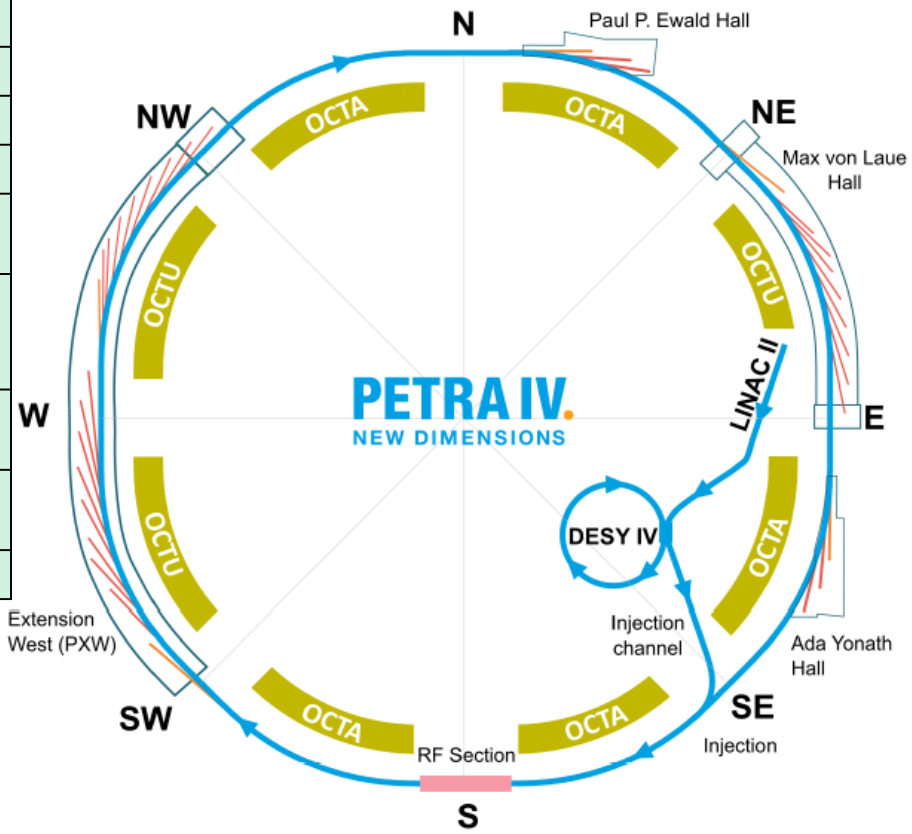
HELMHOLTZ

DESY.

The PETRA IV Ring

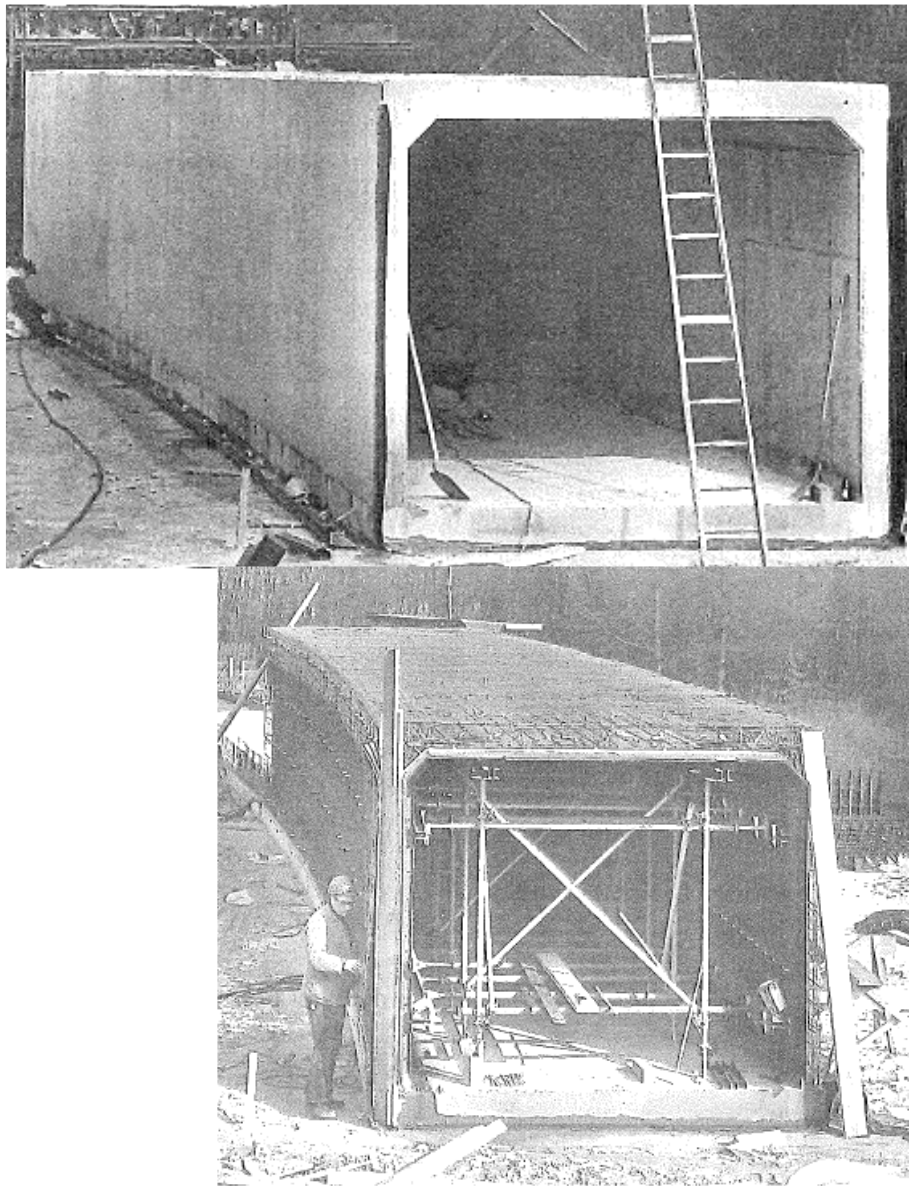
- Circumference 2300m (approx double of other rings)
- Two types of octants, 9 cells each, 4 girders per cell (288 total)
- Re-use PETRA tunnel (dates back to PETRA I)

	H6BA
Tunes ν_x, ν_y	135.18, 86.27
Natural chrom. ξ_x, ξ_y	-233, -156
Mom. comp. α_C	$3.3\ 10^{-5}$
U_0	4.17 MeV
Standard ID section	4.7 m - 4.9 m
Hor. Emittance w/o IDs, zero current	20 pm
Hor. Emittance with IDs, zero current	20 pm
Rel. energy spread with IDs, zero current	$0.9\ 10^{-3}$
Beta at ID	$\beta_x = 2.2\ m$ $\beta_x = 2.2\ m$
RF Voltage 1st / 3rd	8 MV, 2.4 MV



PETRA I Tunnel unstable

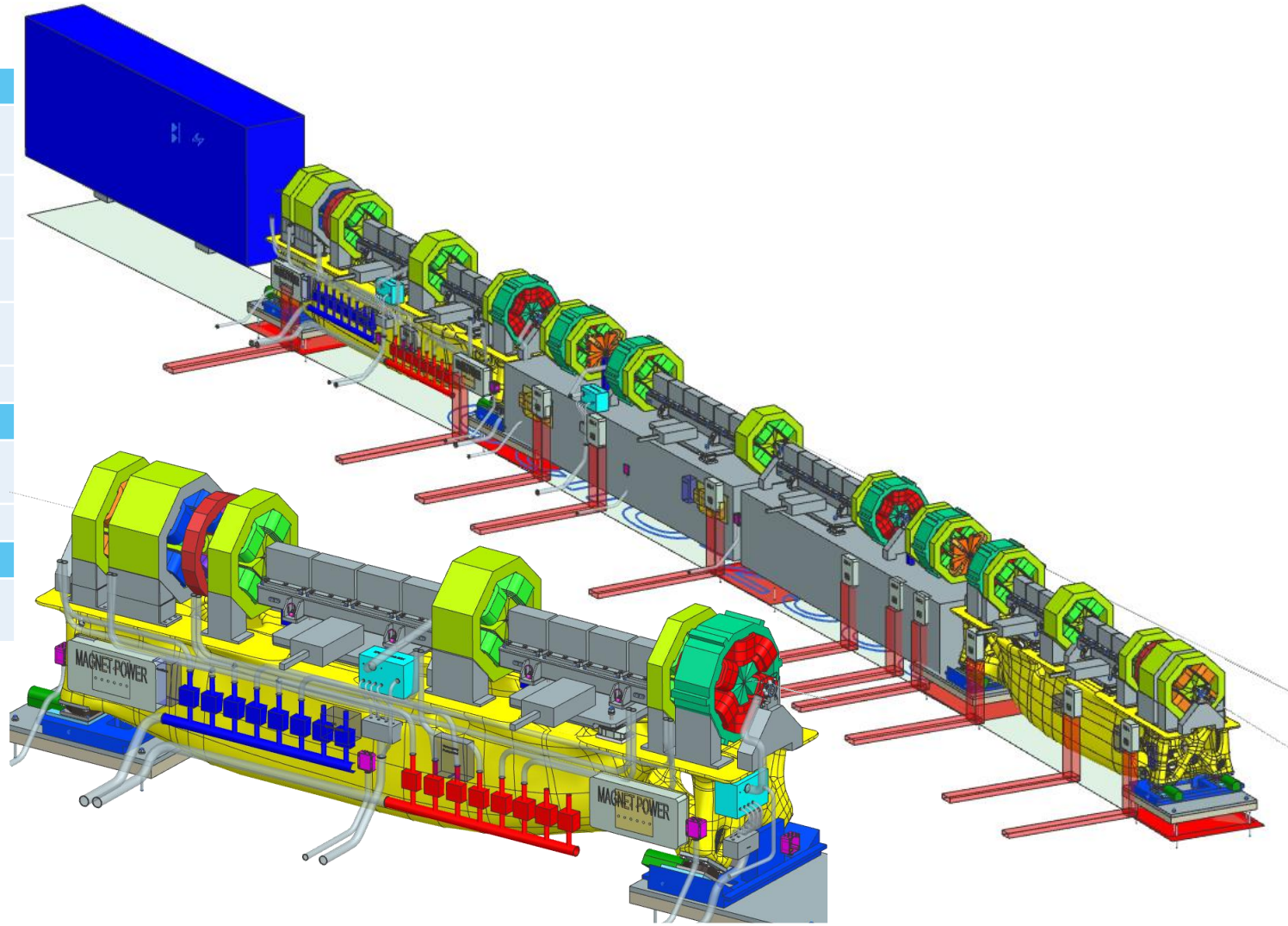
- The floor was prepared in long pieces, 5+25 cm thick.
- The tunnel was set on the floor in ~80 segments of 24 m each
- The tunnel walls are 20 cm thick, floor and ceiling 30 cm.
- The gaps between the segments are sealed with rubber.
- Today we se cracks at the joints and considerable movement between segments
  - Relative movements ~100µm (trans.) with extreme case ~700µm (entrance to extension hall)
- We decided to support the girders at their ends
  - movement of the tunnel will cause bends between girders – no offsets



Undulator cell with 4 girders

- Alignment tolerances

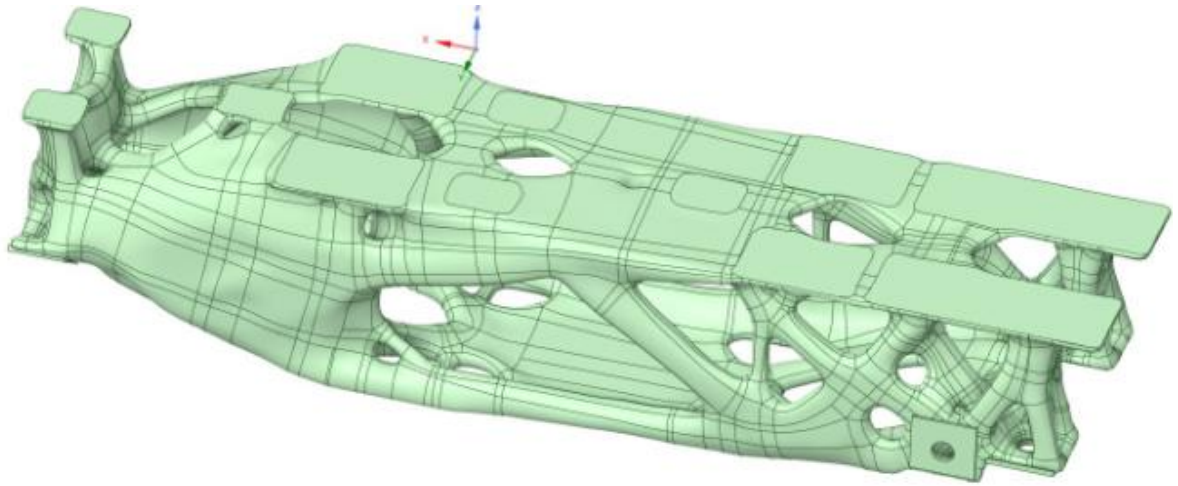
Magnets	Δx	Δy	Δs	roll
QD0, QF1, QD2, QF3, QD4, QF5, QF6, QD7, QF8	30 µm	30 µm	300 µm	200 µrad
SD SF	30 µm	30 µm	300 µm	200 µrad
O1, O2	30 µm	30 µm	300 µm	200 µrad
DLQ, DQ	30 µm	30 µm	300 µm	200 µrad
Girders	**Δx**	**Δy**	**Δs**	**roll**
all	100 µm	100 µm	500 µm	200 µrad
BPM alignment	**Δx**	**Δy**	**Δs**	**roll**
	500 µm	500 µm	500 µm	200 µrad

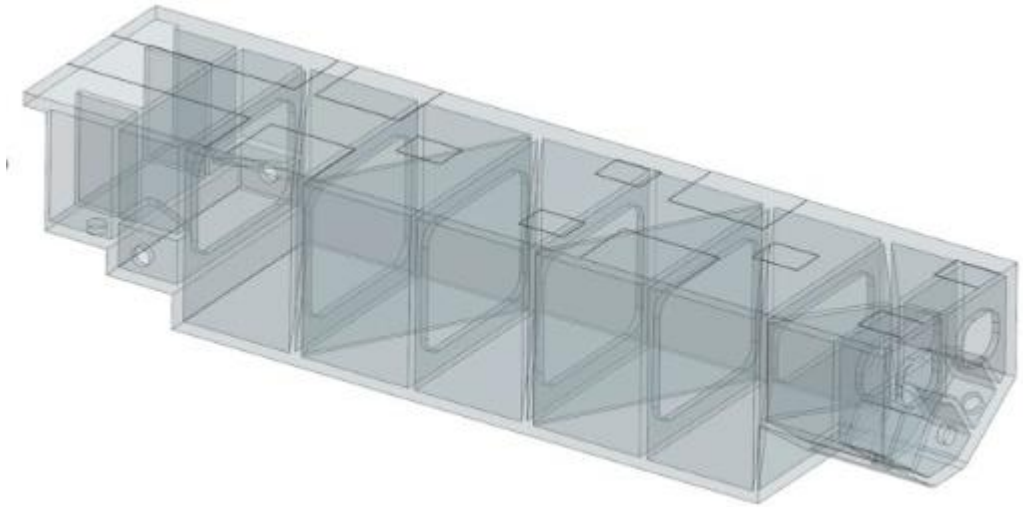


- First eigenmode above 50 Hz
- Support on movers (online adjustments)
- So far no online alignment measurement

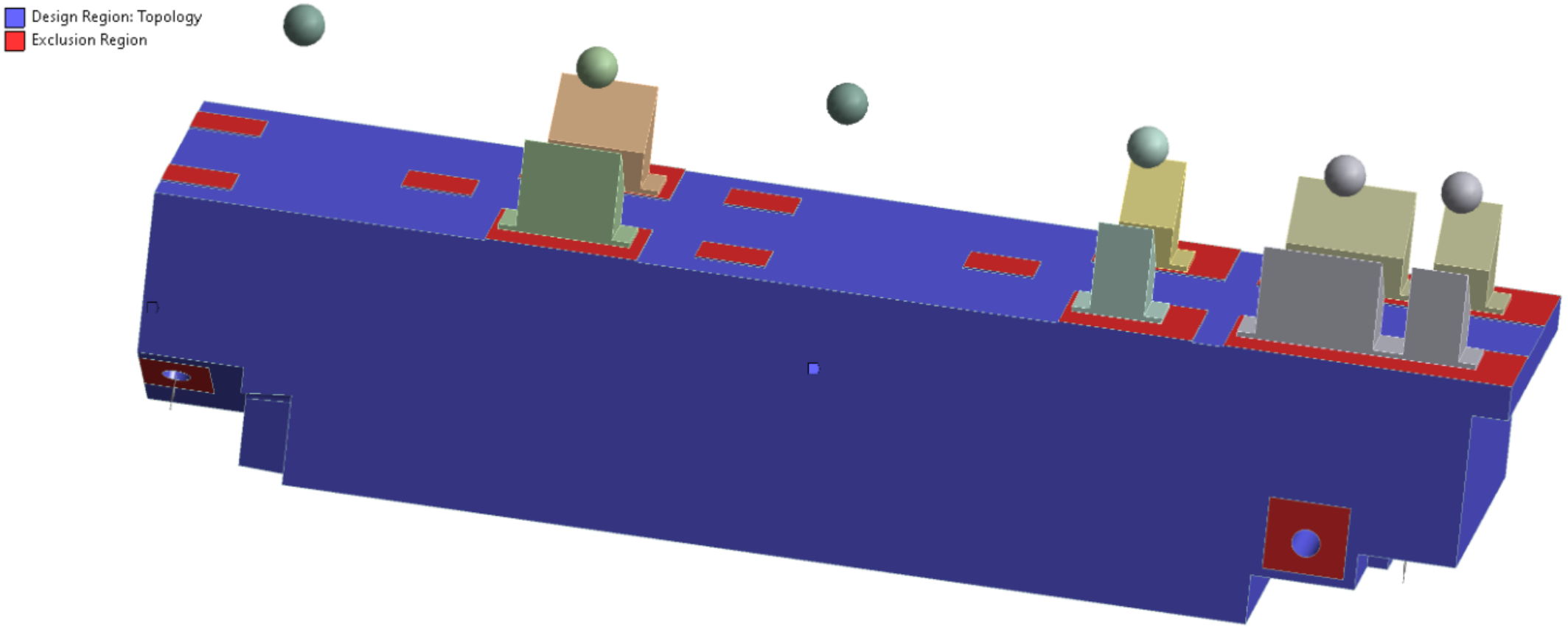
Topology optimized Girder

- With a given set of boundary conditions (loads, width, height, symmetry,…)
  optimize girder for eigenfrequencies, weight
- Call for tender for prototype(s) is out
  - 2 cast girders
    (2 materials with different hardness/damping)
  - 1 welded girder
- Expected cost of prototypes similar
- Eigenfrequencies (in theory) (52 resp. 46 Hz)

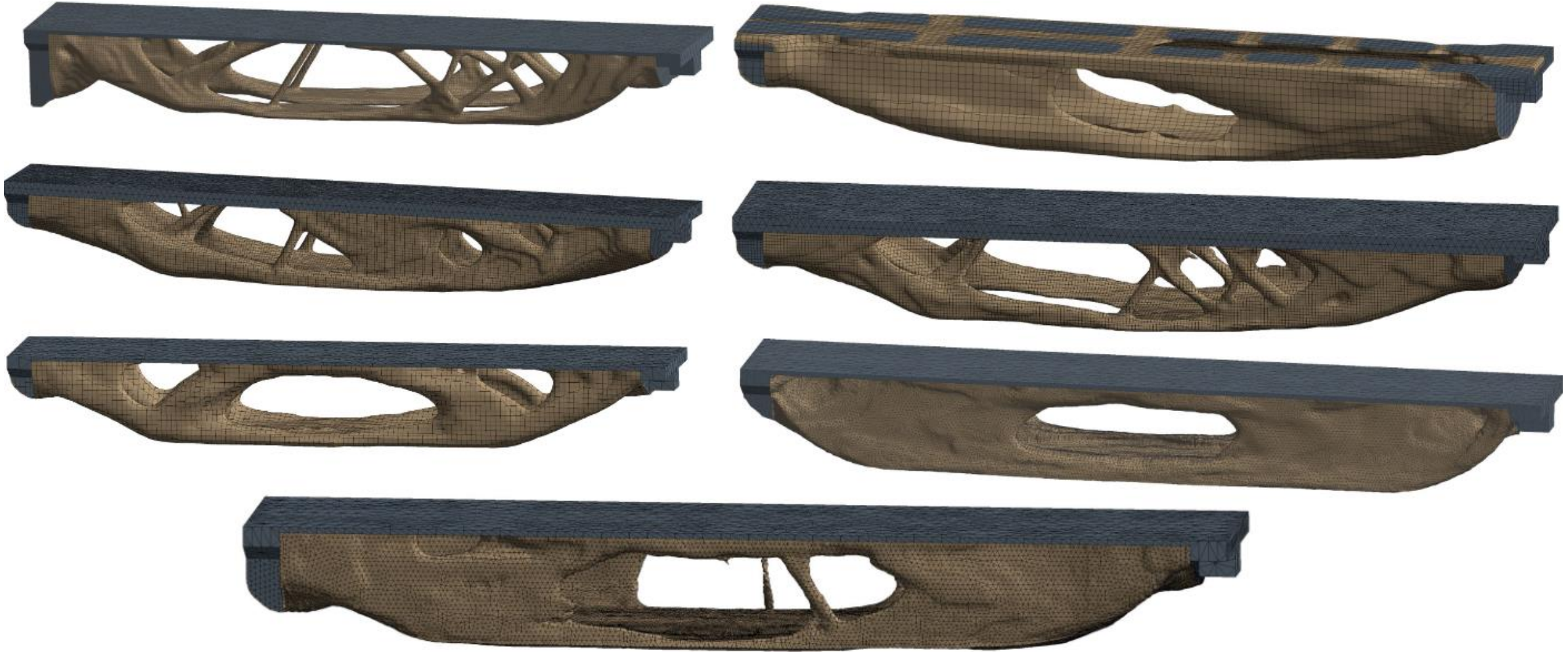




Topology Optimization

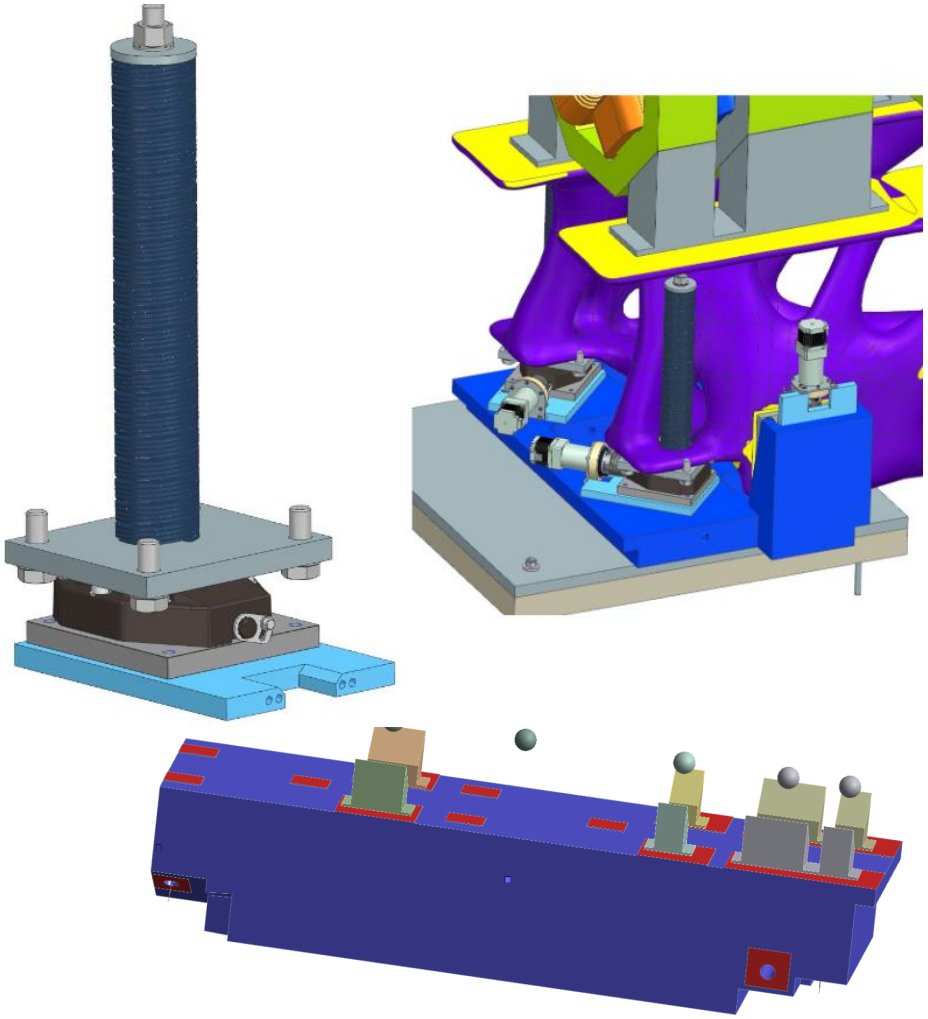


Example Results



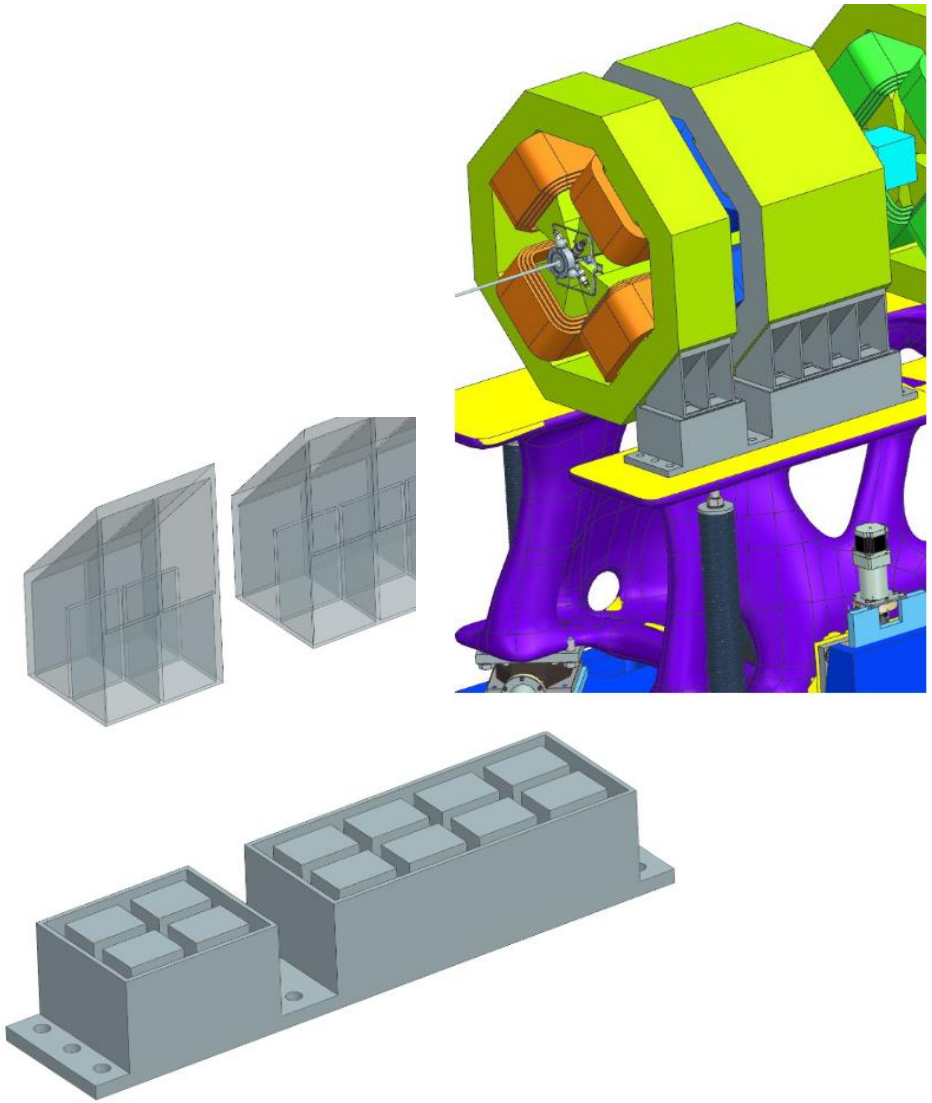
Girder Alignment

- Use motorized levelling wedges for online alignment
- 6 drives per girder
- 3½ point support to avoid torsion within girder while maintaining stability



Magnets fixed by gluing

- Alignment units used only during alignment process
  will be removed afterwards
- Magnet holders employ blades & sockets
  will be glued
- After curing no more movement (supposedly)
- Similar design employed in PETRA III
  (without removing alignment supports)



The PETRA III Solution

- Climatic hutch in experiment hall
- Fine alignment 4 days per girder, (overall time 21.7.-7.10.)
- Accuracy σ=22µm & σ=20µm from fiducialization
- Transport to final position one single craning
  - Suspend at same position as support points
  - No transport on ground (needed to test that for PETRA IV)

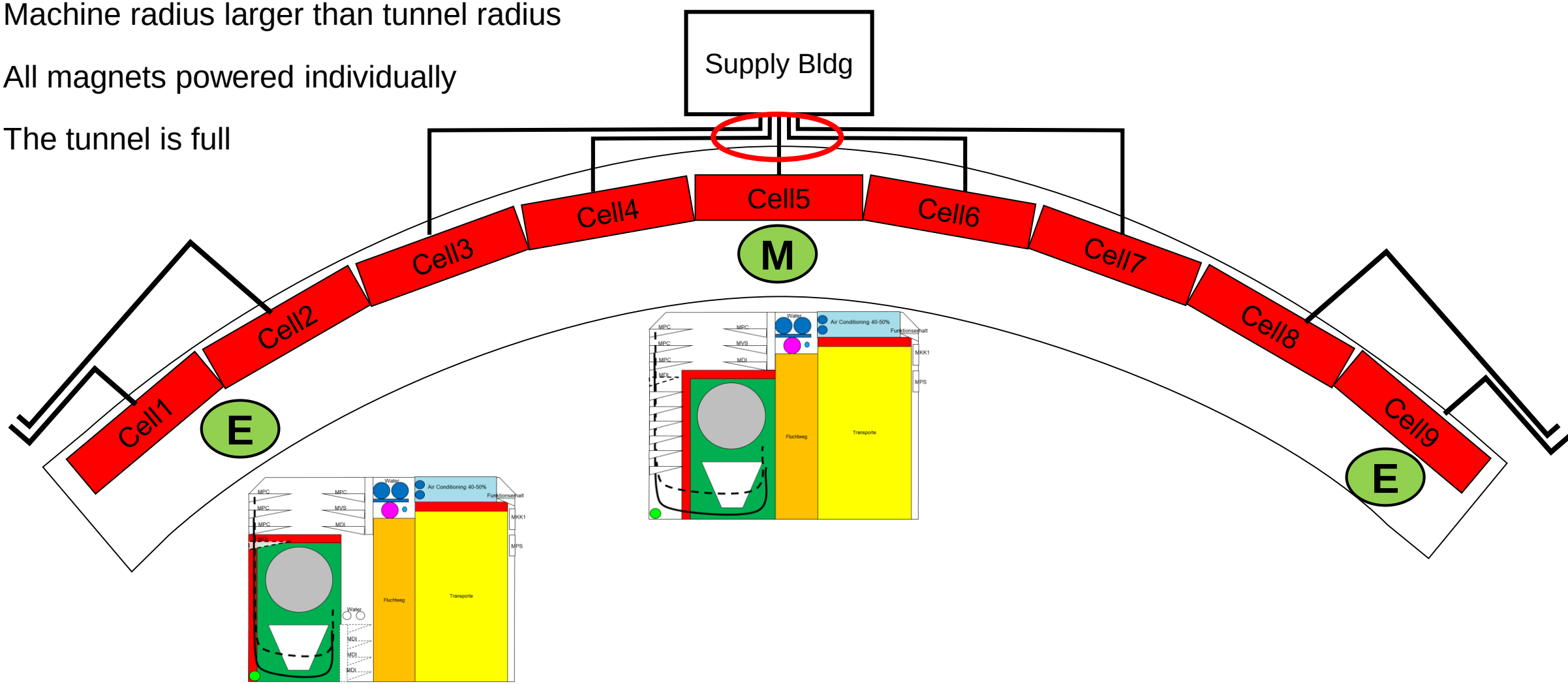
Transport Tests with glued Magnets

- Used a PETRA III girder
  (magnets larger and heavier)
- Tested moving the girder with ever increasing risk (acceleration)
  - Crane lifting
  - Crane transport
  - Truck transport on site (slow) flat road
  - Truck transport on site incl. Incline
  - Truck transport off site (normal speed)
  - Bumping
- So far alignment accuracy is maintained within an accuracy of 10µm (accuracy of measurement)

Space Restrictions in PETRA Tunnel

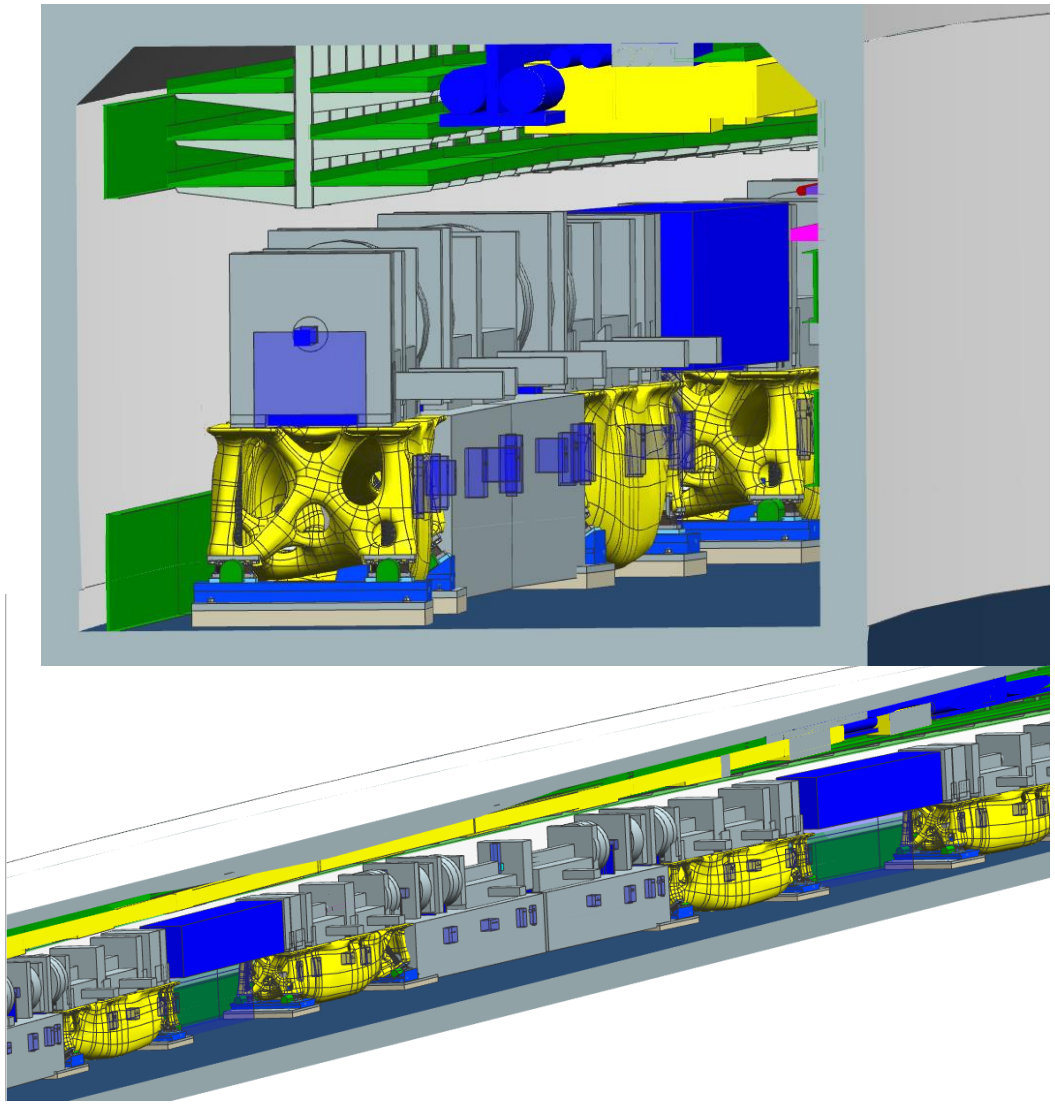
One Arc in the old Tunnel

- Machine radius larger than tunnel radius
- All magnets powered individually
- The tunnel is full



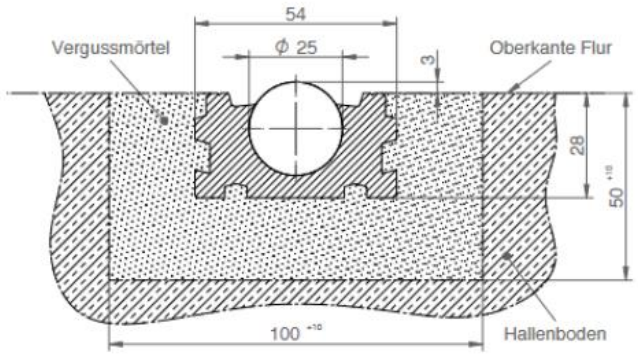
Tight Space Restrictions

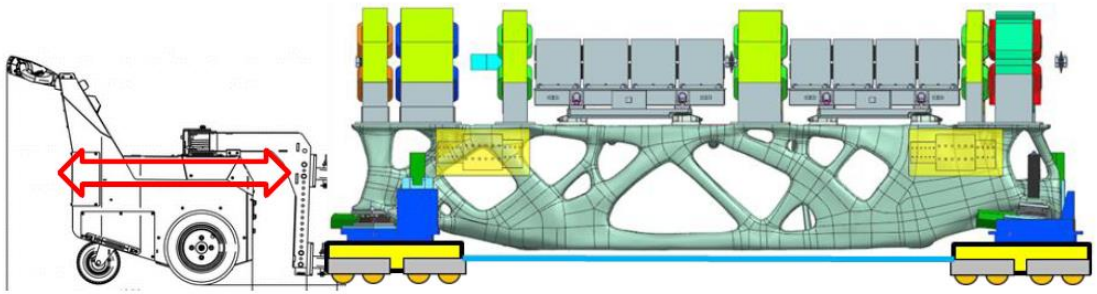
- Machine (incl. Girders) must not be wider than 1m
- Girder vehicle (incl. Girder) must not be wider than 1.1m
- Cable trays in place before girders
- Gap above machine 20cm
  (if the magnets stay smaller than allotted space)



Transport Concept

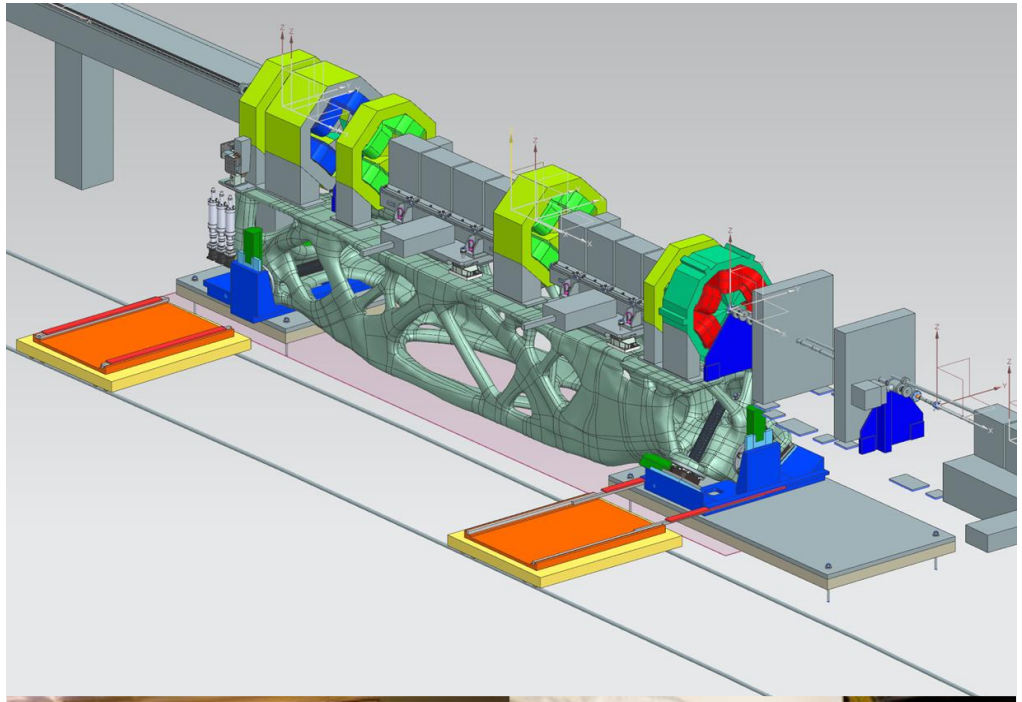
- Integrate a rail into tunnel floor
- Tendering for test installation underway
  - Check compatibility with old floor
  - Test bending of rails
- Expect the floor to bear load better than with dollies
- Directional stability is a given
- Investment is in the rails, vehicles are cheap





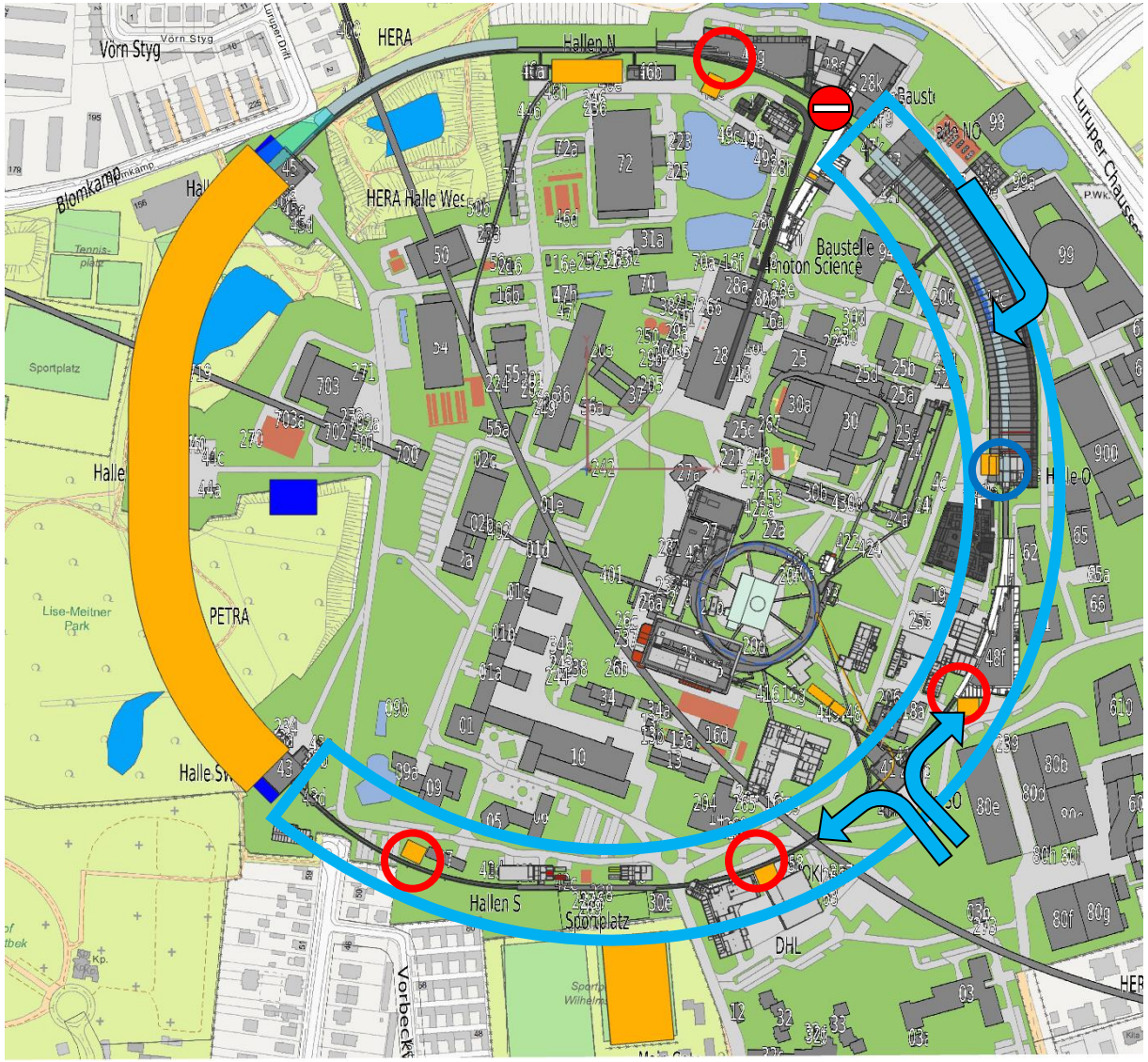
Installation Procedure

- Barely any lifting possible
- No space for counter-weights or supports
- Use the „egyptian method” for installation



Plan Installation around Boundary Conditions on Site

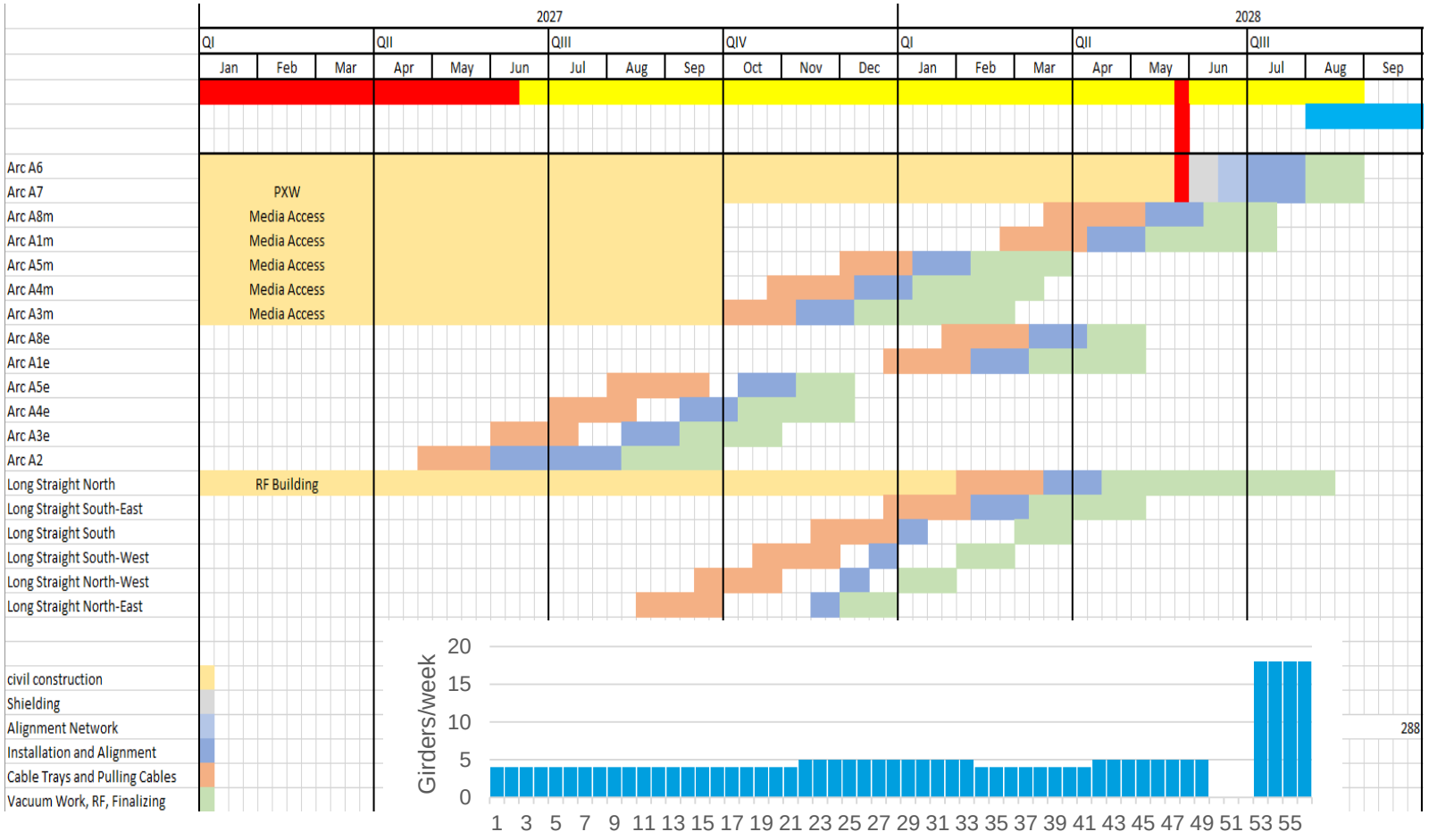
- ½ of the tunnel will be blocked by construction sites
- Need to wait for completion of 3 media access points
- Expect best accessibility through Max-von-Laue-Hall and hall SE
- Hall floor needs refurbishment in east and south-east halls → to be completed early on



Civil Construction of PXW dominates Installation Schedule

Expect fairly even Installation Rate except for Rush at the End

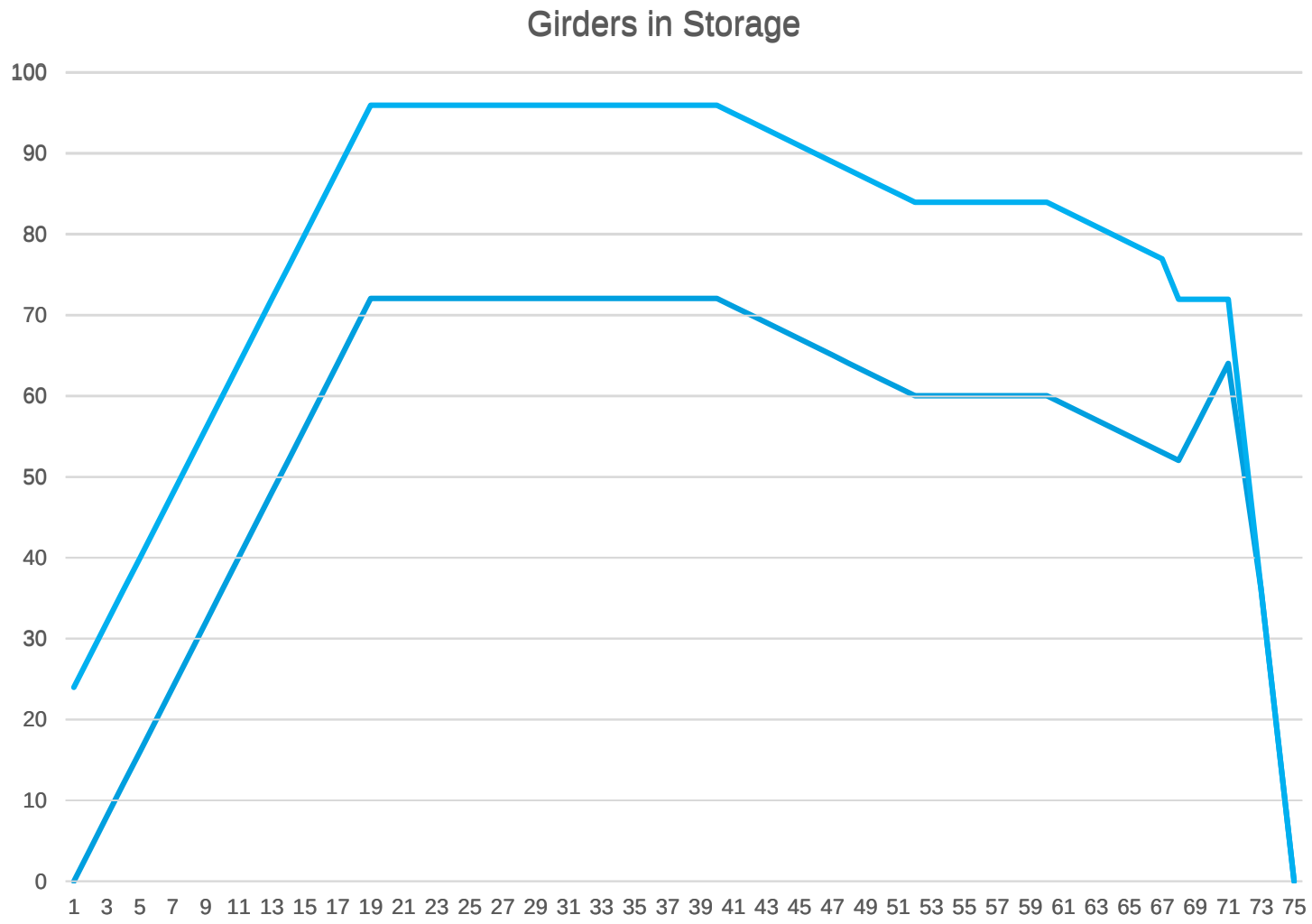
- Tight installation window in PXW necessitaes minimization of installation steps
- Maximum pre-integration of girders
- Evaluate gains at further trades (cable-trees, electronic racks,…)



Installation Scenario calls for Buffer of 72 Girders Minimum

Assembly rate of 4 girders per week

- With assembly going until the very end a stock of 72 girders is (barely) sufficient
- Would need to re-stock before end
- Increasing the stock to 96 avoids re-fill
  - allows for or earlier end of production (additional manpower for final rush?)
  - Contingency for hick-ups
  - Installation directly out of alignment (fewer transports)



Girder Assembly Lines Layed out

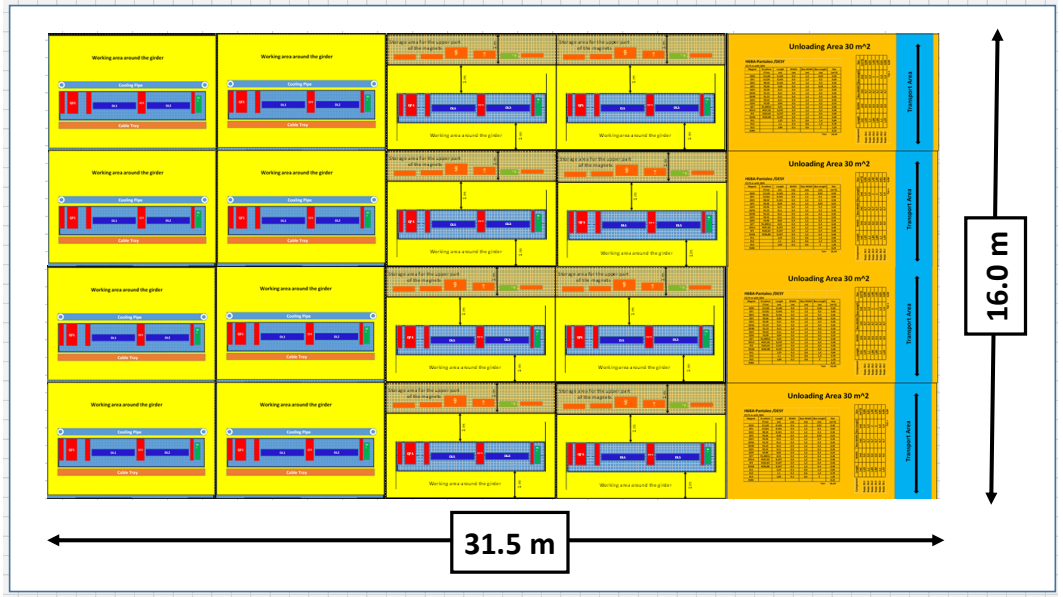
Plan for 4 Assembly Lines

- One assembly line puts out 4 girders every 2nd week
- Two assembly lines just fit to the installation plan without margin
- Therefore a third line is foreseen
- A fourth line is reserved for DESY4 girders
- The hours listed are DESY estimates but agree summarily with ESRF-EBS experience

PETRA IV - Assembling of 4 girders (June 2021)

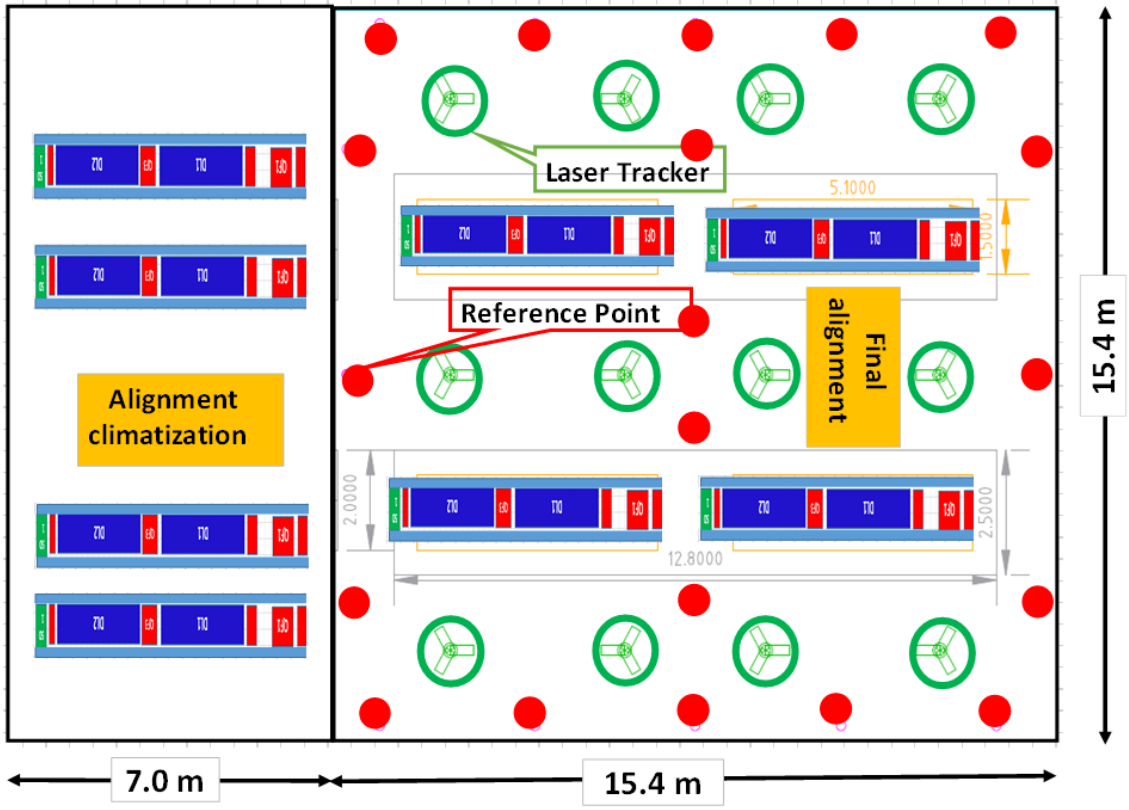
Groups: Mechanic-Group : Alignment-Group : Vacuum-Group

Group	Magnet installation	Hours		Hours	Days
	1.) Movement of 4 girders from storage to assembly area	4			
	2.) Fixation of alignment threads / positioning gauges	1,5			
	3.) Movement and fixation of 6 DL- supports to the girders	1,5			
	4.) Movement of 6 DL magnets to the girders	2		14	1,5
	5.a) Movement of 1 magnet on the girder (≈10 minutes)				
	5.b) Movement of 27 magnets on the girders	5			
	6.) Rough alignment of 33 magnets	24		24	3
	7.a) Opening the 1 magnet (≈ 20 minutes)				
	7.b) Opening of 27 magnets	9			
	8.) Moving the vacuum strings into the magnets	4		22	3
	9.a) Closing 1 magnet (≈ 20 minutes)				
	9.b) Closing 27 magnets	9			
	10.) Assembling of cooling pipe and connection of cooling circuits	8			
	11.) Mounting of cable trays and laying cables	8		20	2,5
	12.) Movement of the 4 assembled girders to the testing area	4			
	Sum =	80		80	10



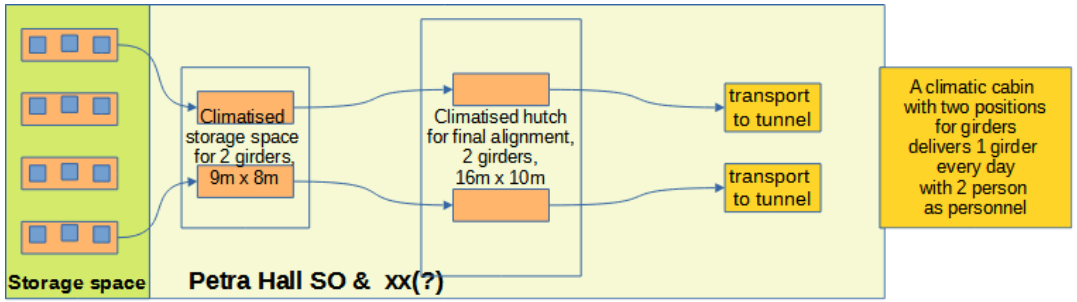
Precision Alignment performed in climatized Hutch

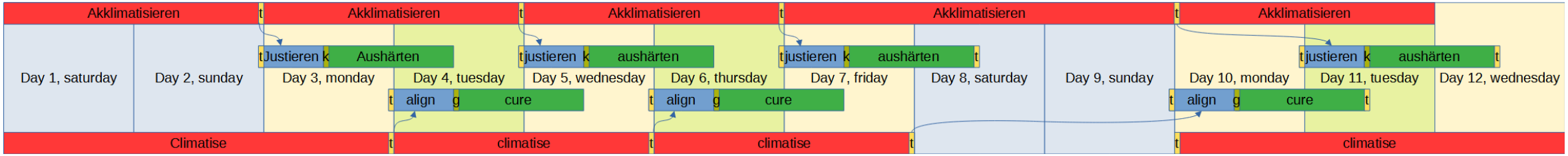
- Hutch will be operated at the same temperature as the PETRA tunnel
- To reach the required 30µm alignment accuracy a number of strict requirements apply to the alignment hutch
- Sufficient width and stability required for precision measurement (10x10m^2 for single 5m girder)
- Antechamber for the girders to reach temperature equilibrium
- After the alignment magnets will be fixed with glue
- Transports only with crane or special vehicles, support-points always the same as in tunnel



Alignment Hutch Throughput

- For PETRA IV a throughput of 5 girders per week is sufficient
- The setup with 4 measurement stands provides sufficiently reserve for 8 girders per week with a team of 2 surveyors
- The procedure for the individual girder takes 3.5days out of which 3 days consist of waiting
- The procedure as such was successfully applied for PETRA III (with single position)

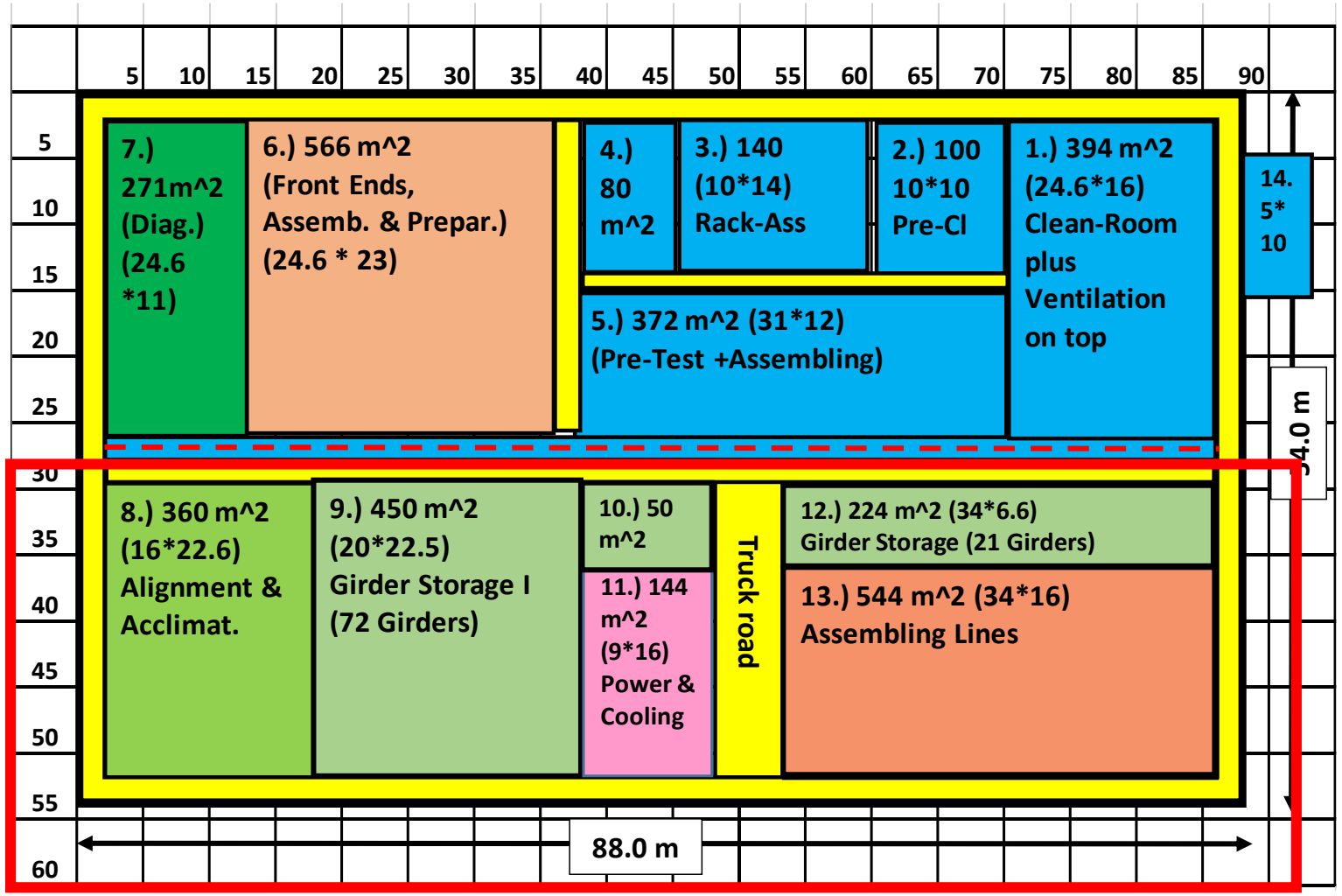




Functional Layout of Girder Assembly Building (GAB)

To be built to house major parts of the preparation and assembly of machine components

- A hall of 54*88m^2 is planned for the GAB
- The girder assembly and storage was compressed to fit into one segment (crane rail) of the hall
- Second segment assigned to
  - Vacuum clean room
  - String pre-assembly
  - Diagnostic components
  - Front-end assembly



Conclusion and Outlook

- PETRA IV demand on alignment precision can be met with pre-fabricated girders
- Sufficient buffer storage can help support tight installation schedule
- Pre-integration of girders has to be more thorough than in PETRA III
- First tests concluded with promising results
- Prototyping underway

Thank you

Contact

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