Interaction Region Studies for a Linear Collider at CERN

- Detector ‘push-pull’ slab design

- Cavern assessment

Matt Sykes

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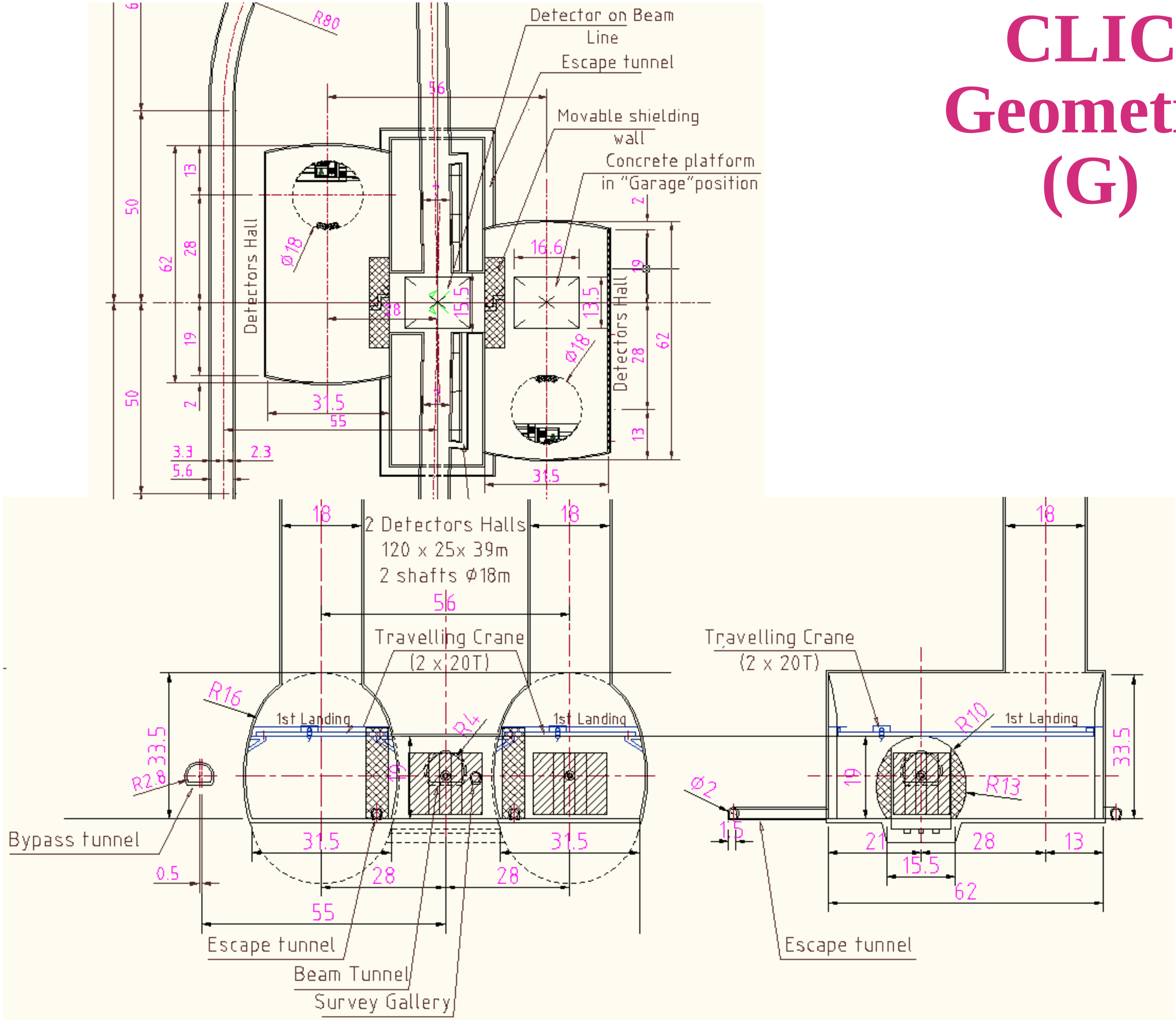
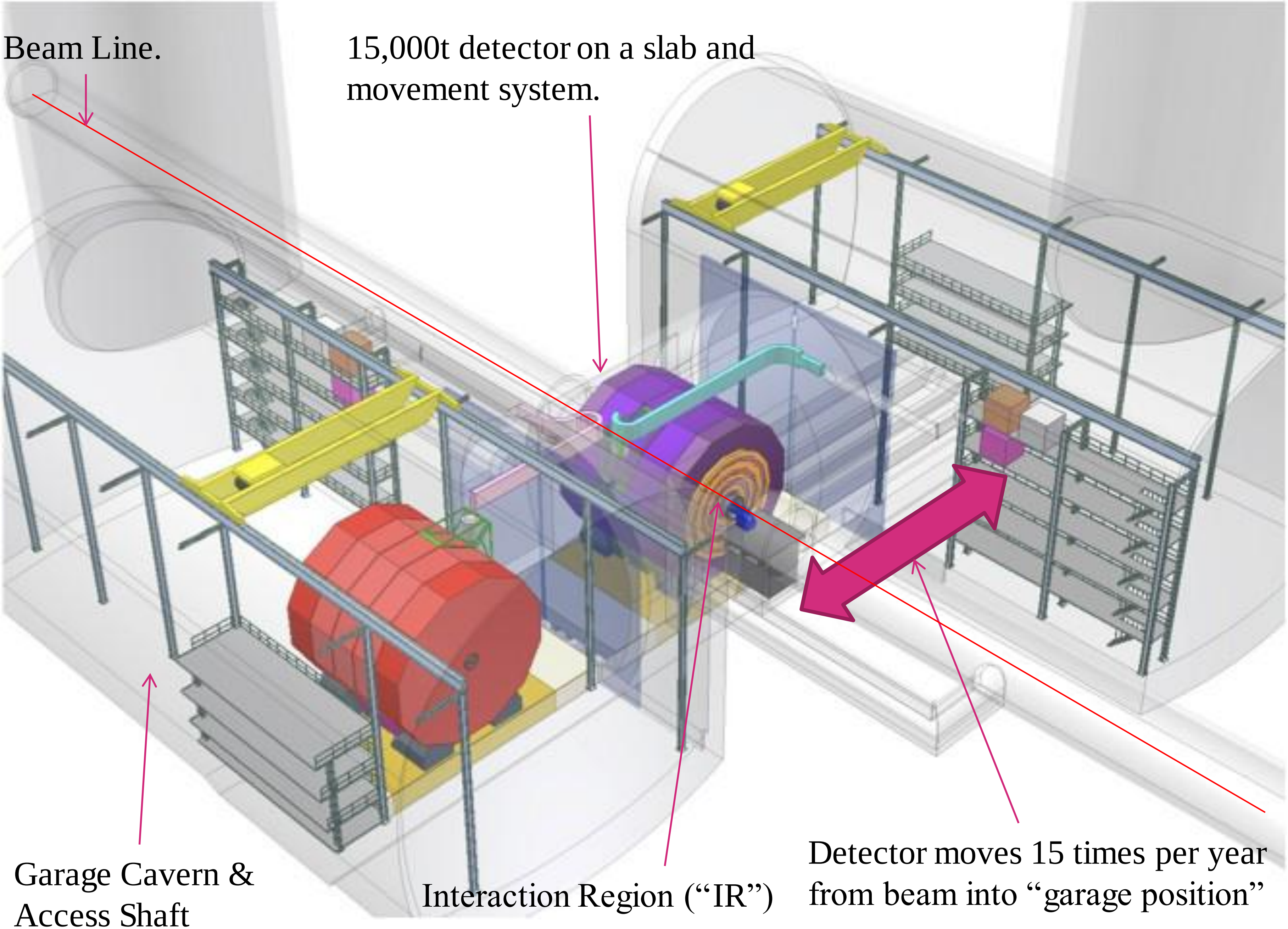
CLIC Geometry (G)




Beam Line.
15,000t detector on a slab and movement system.
Garage Cavern & Access Shaft
Interaction Region ("IR")
Detector moves 15 times per year from beam into "garage position"

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Summary of Requirements

4.1 Task 1 – Movement Platform

Platform Design Criteria		Value	Unit	Notes/assumptions
Detector		ILD		ILD is currently the most onerous system in terms of spatial and weight requirements
Detector Total Weight		15,500	tonnes	Fully installed weight including services and supply etc for movement to beam. It is assumed that additional weight is not added to the detector (and therefore the platform) once on the beam line, or at the garage
Detector Segment Weight	Door -Z	3,500	tonnes	An important design case for the platform will be when the detector is split for maintenance either on the beam line, or in the garage position. Weights provided by email (Oriunno-Osbourne 27th May 2011). The SiD and ILD have different combinations of slices when split. The worst loading case will be determined from the various combinations of ILD and SiD ring maintenance arrangements
	Barrel -1	2,500	tonnes	
	Barrel 0	3,500	tonnes	
	Barrel +1	2,500	tonnes	
	Door +Z	3,500	tonnes	
Slab Vibrations Modes	First Mode	20	Hz	Assumed feet and ground infinitely rigid with damping ratio of ~2%
	Further Modes			To be advised and informed by study, to include feet, invert slab and ground are expected to add compliance to the platform system
Magnetic field at top of platform		<1,000	gauss	It has been assumed that this is at the top of the platform
Operating Temperature Range		$20^{o}C \pm 2^{o}C$		

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Summary of Requirements

Platform Design Criteria (continued)		Value	Unit	Notes/assumptions
Movement System	Mechanism	Rollers or air pads		The platform design will be developed to be compatible with either roller or air pads. Should the design place any onerous performance requirement on one particular system this will be identified and where appropriate a mitigation measure identified. If a single platform design cannot service both systems clarification will be sought on the movement system to be used.
	Drive	Gripper jacks		
Platform	Concept	Single platform per detector		The design will be progressed on the basis that the two detectors are moved independently on separate platforms
	Material	Reinforced Concrete		A Steel support truss will not be considered further
	Footprint	20x20	m	
	Elevation	Study to confirm this		Beam to top of platform set by detector, platform depth below to be established during study. ILD to be used as greater beam to base distance (thinnest platform for same rail level)
Minimum distance between detectors		15	m	Minimum proximity of detectors at any location measured from exterior of iron

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Summary of Requirements

Platform Performance Requirement		Value	Unit	Notes/assumptions
Movement duration		5	hours	This is assumed to be the detector "speed" when travelling and would therefore not include preparation time to disconnect/connect detector or preparation of the movement system
Speed		>1	mm/s	(after acceleration). Assumed that the 5 hour requirement governs
Number of movements		10	$year^{-1}$	Assumed that both detectors will be moved an equal number of times
Limit of acceleration		0.05	g	This is a limit during movement
Maintenance allowances	On Beam	2	m	This is the between adjacent sections (end cap to centre section) when detector opened in the beam location
	In Garage	6	m	This is the between adjacent sections (end cap to centre section) when detector opened in the garage location
Static Deformation of platform		+-2	mm	In all locations, including during movement (as a single element or in sections)
Positioning relative to beam		+-1	mm	In relation to the beam location

Limited to under the footprint of the detector.
n/a when un-slicing

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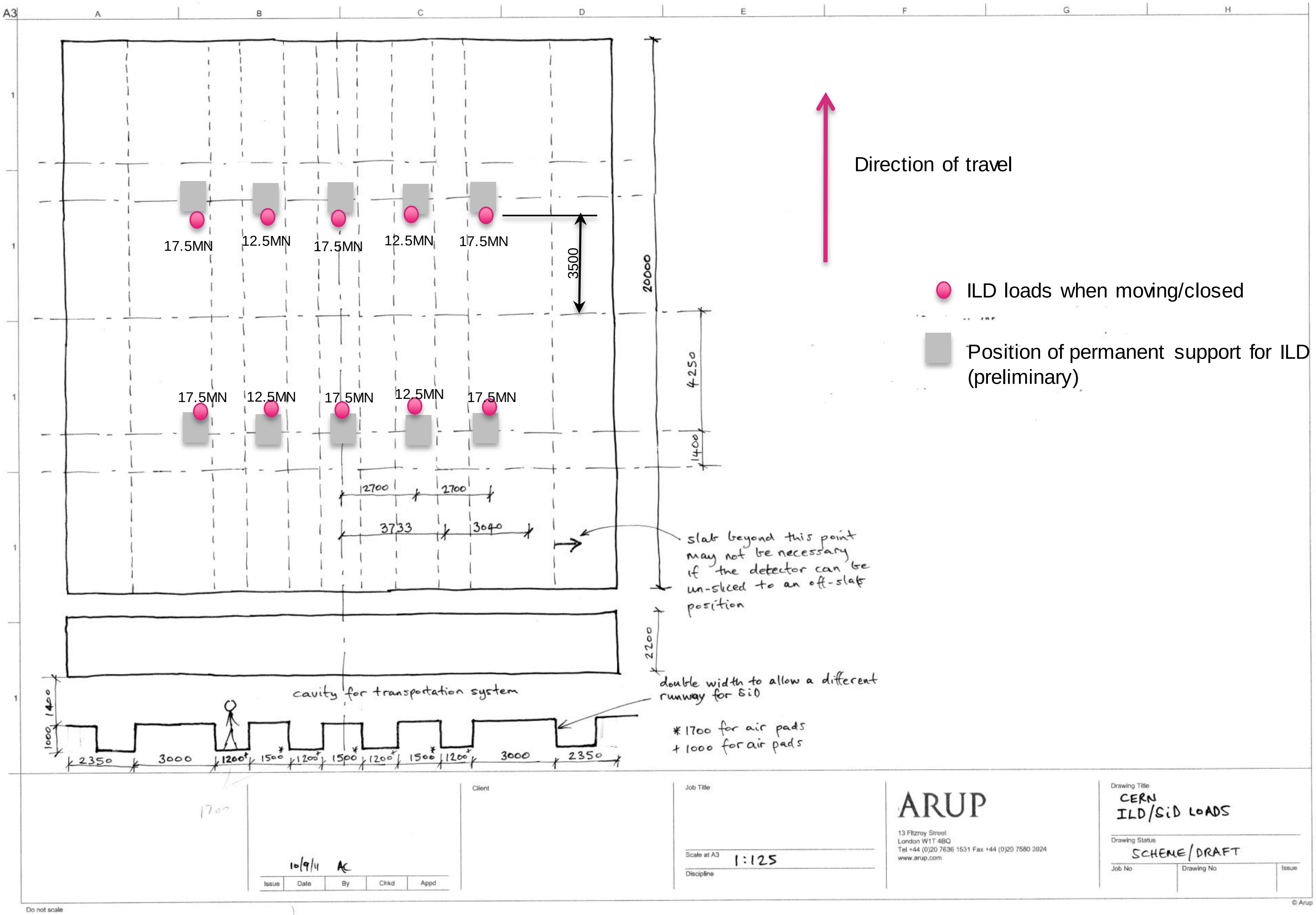
Slab flexure critical – but what is its definition?

- **Design using +/-2mm Under Detector**
- **Deflection limit Not applied during un-slicing**

ILD top loads when moving/closed



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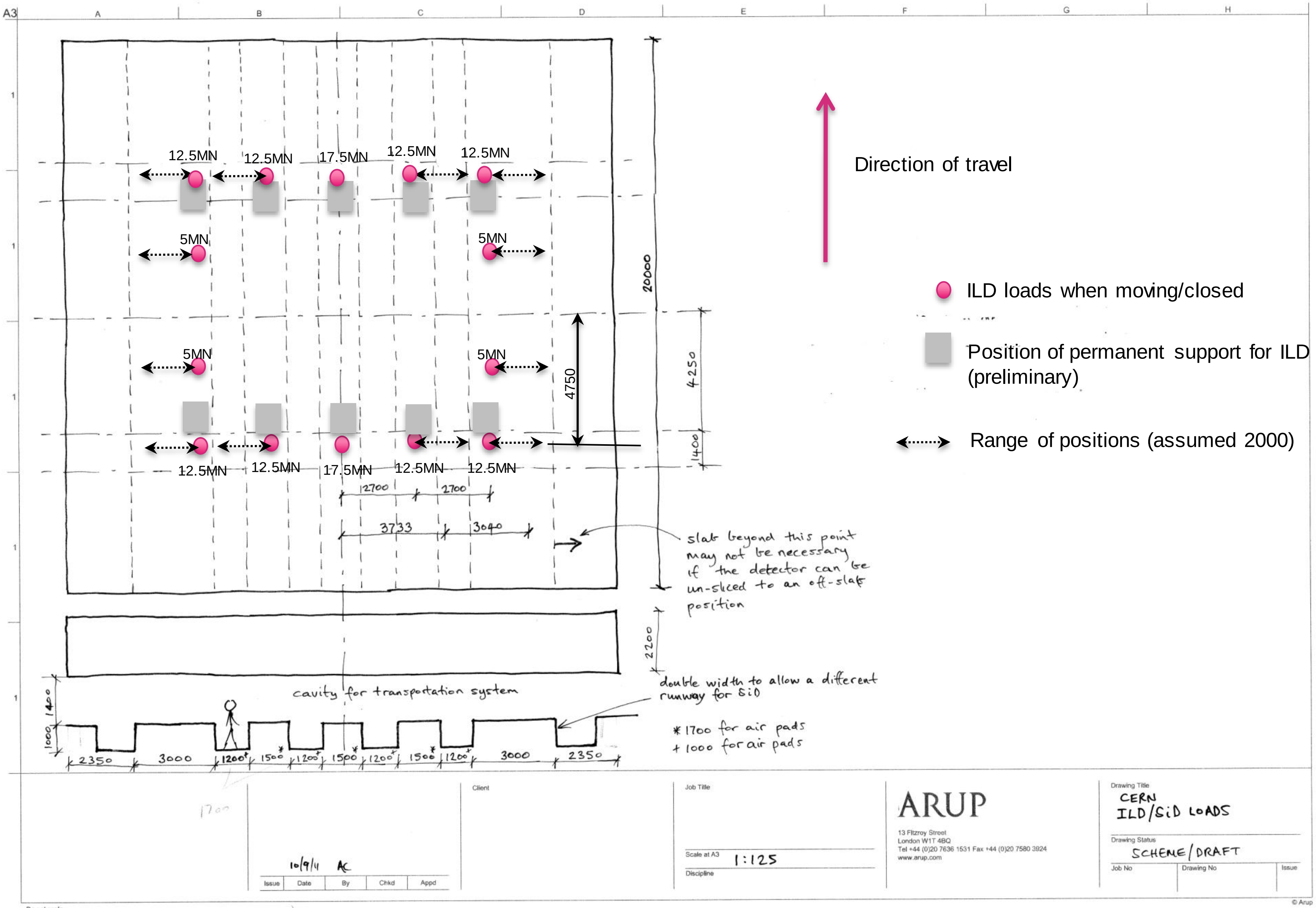
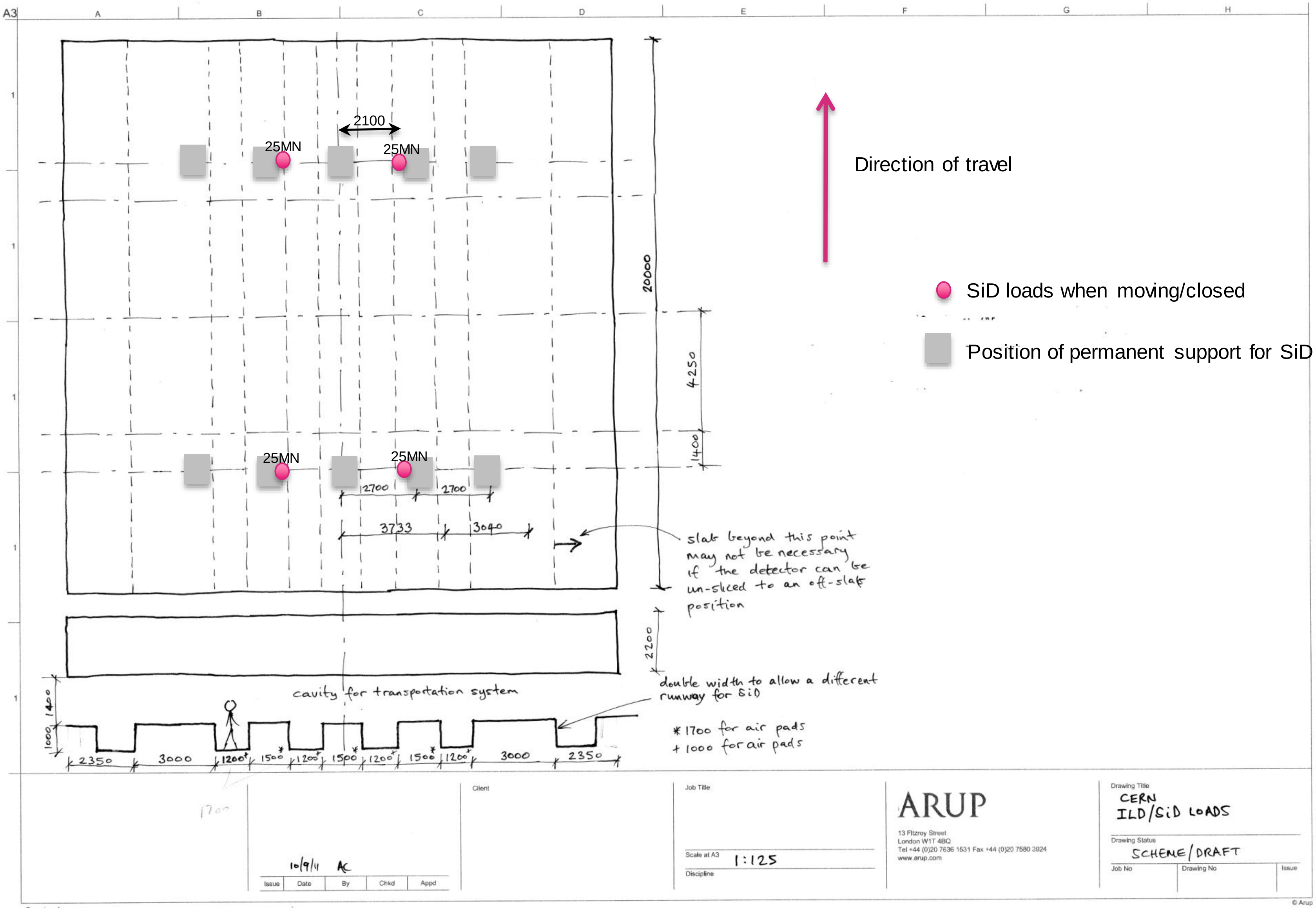
ILD top loads when un-slicing



SiD top loads when moving/closed



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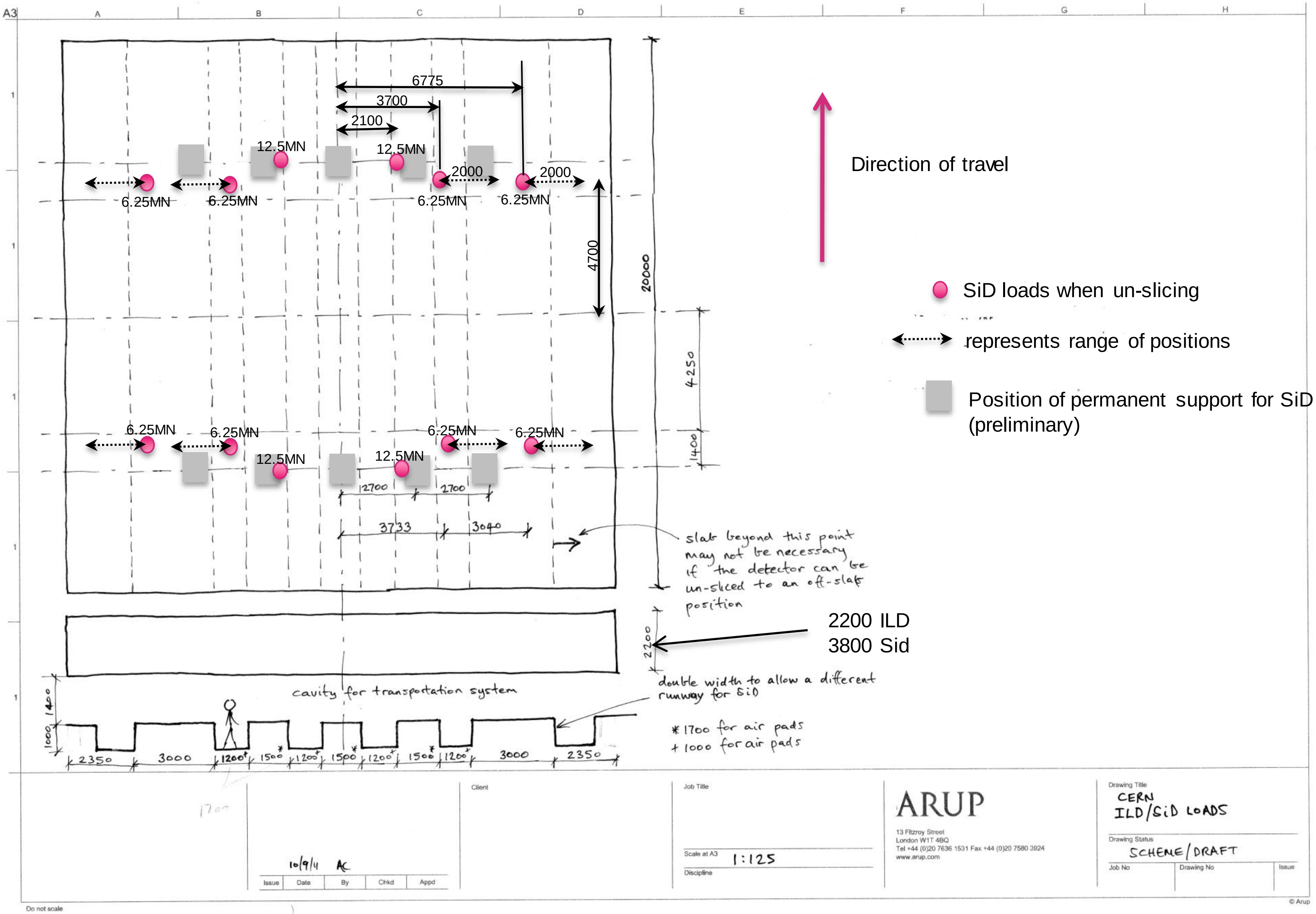
SiD top loads when un-slicing



A refined support system for ILD

- **Step 1: ILD Slab on permanent supports**
- **Step 2: Put ILD(closed) loads on top of slab**
- **Step 3: Jack onto transportation system**
- **Step 4: Consider un-slicing – not now subject to deflection limits**

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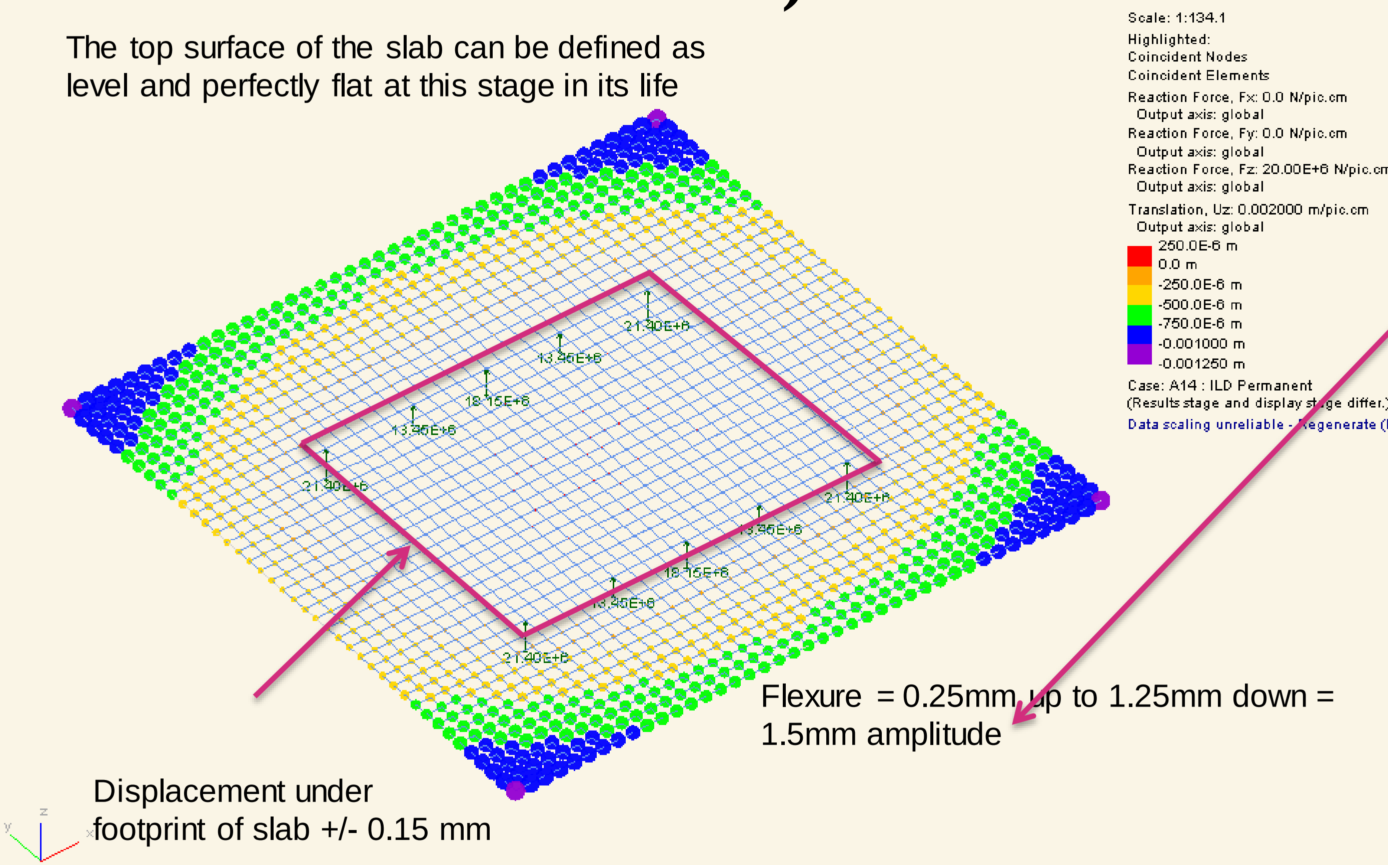
Step 1: ILD Slab on permanent supports

- **Slab on permanent supports (directly under the top loads for ILD closed)**

The top surface of the slab can be defined as level and perfectly flat at this stage in its life



But note this is a long term load case and the value will increase with creep - ongoing

Flexure = 0.25mm up to 1.25mm down = 1.5mm amplitude

Displacement under footprint of slab +/- 0.15 mm

Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = Slab self weight

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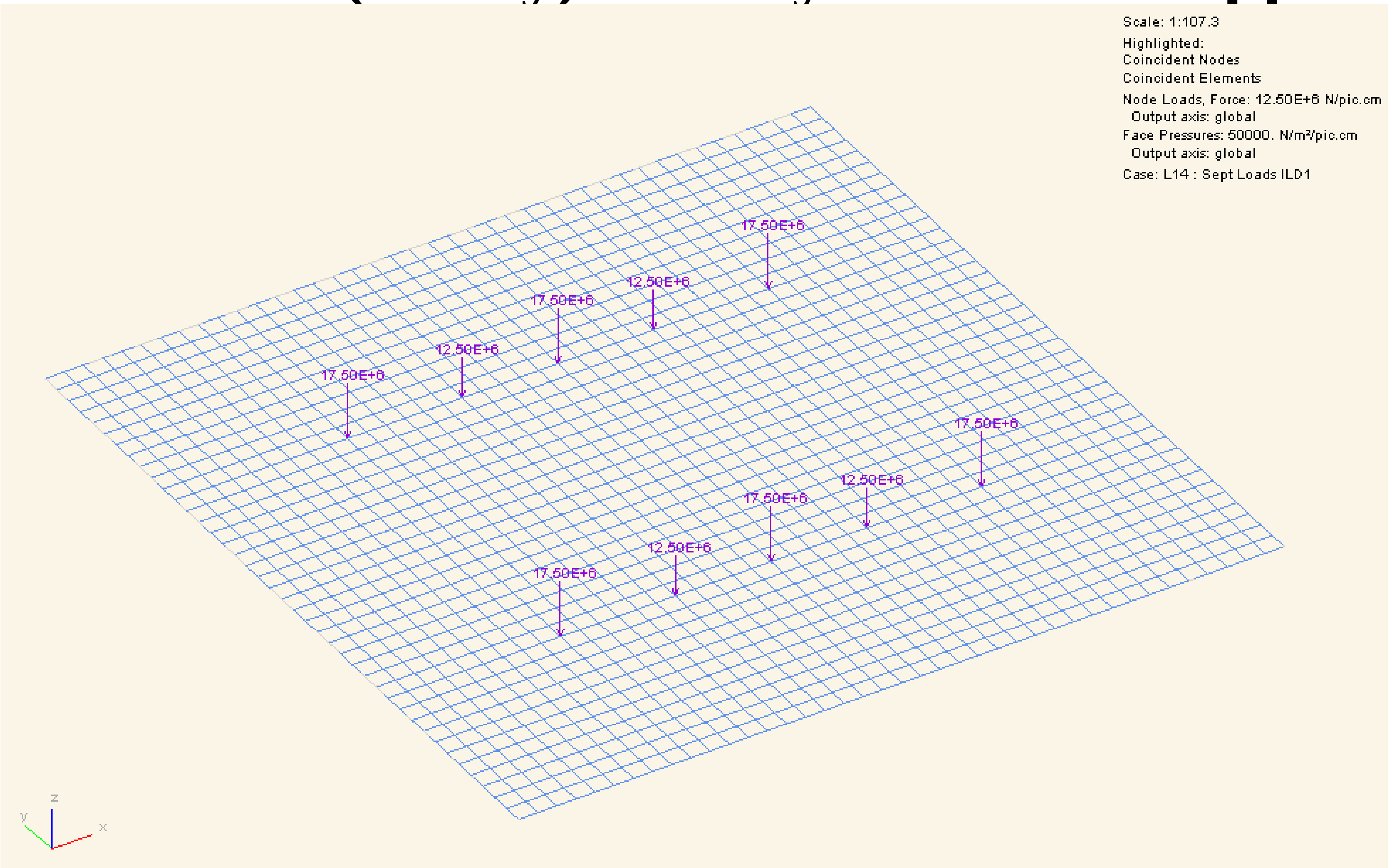
Step 2: Put ILD(closed) loads on top of slab

- **This has negligible displacement effect because the loads are (nearly) directly above the supports**



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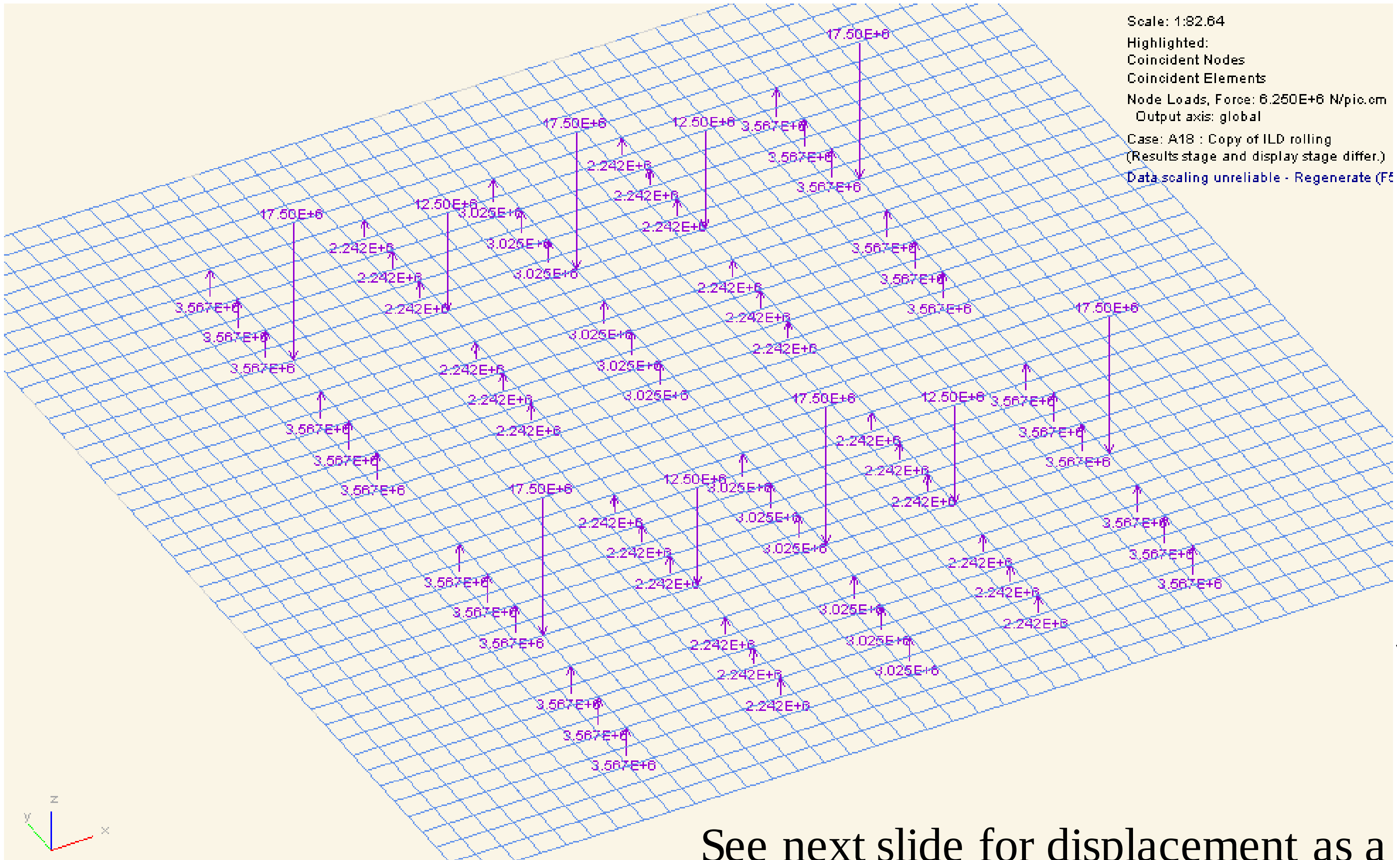
Step 3: Jack onto transportation system

- **ILD (closed) effect upon top surface of jacking onto the transportation system (jack config 1)**



Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = Slab self weight + ILD (closed) top loads

See next slide for displacement as a result of step 3

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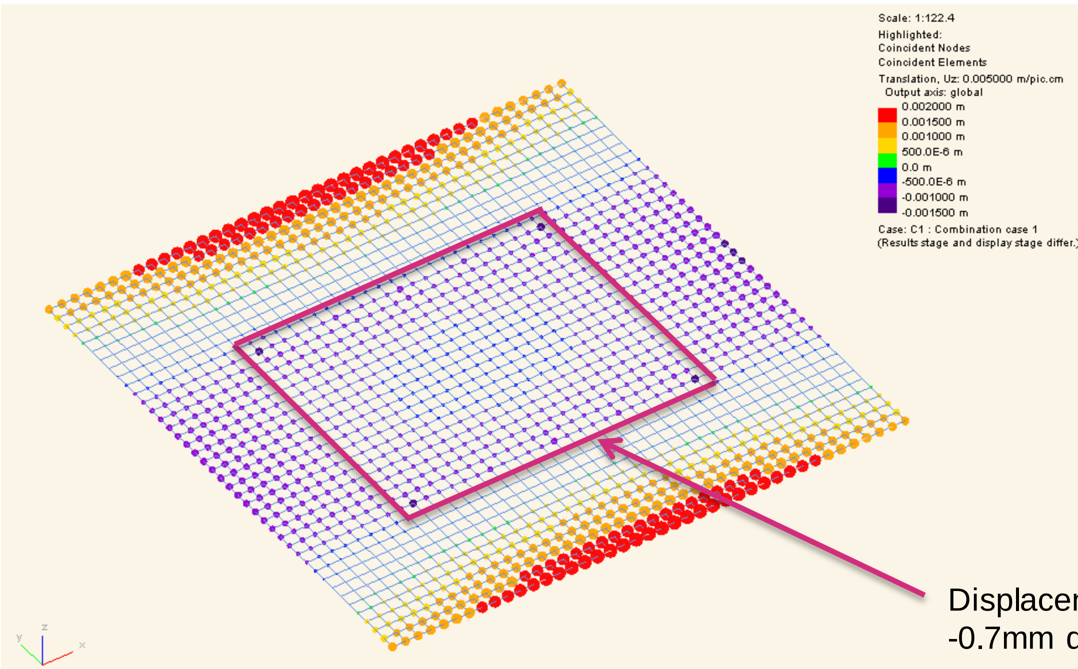
Step 3 (continued)

- **ILD (closed) effect upon top surface of jacking onto the transportation system (jack config 1)**



Flexure = +1.9mm to -1.0mm

This meets the +/- 2mm tolerance

Note if the slab were smaller the reported deflection would drop significantly.

Displacement under footprint of slab +0, -0.7mm down

Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = [Slab self weight + ILD (closed) top loads + jack supports] – [Slab self weight on permanent supports]

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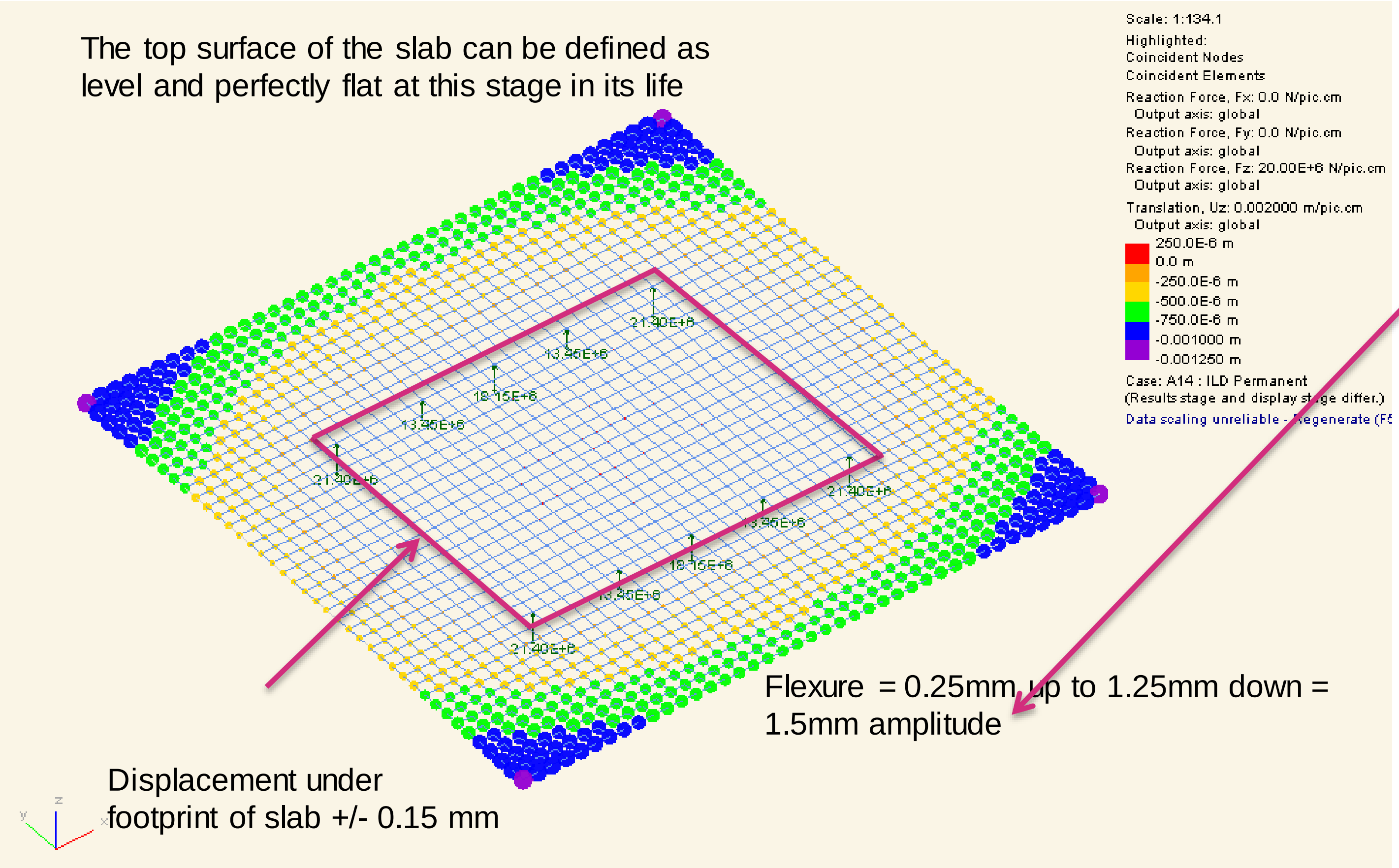
Step 1: SiD Slab on permanent supports

- **Slab on permanent supports (directly under the top loads for ILD closed – so we use same tracks as ILD)**

The top surface of the slab can be defined as level and perfectly flat at this stage in its life



Displacement under footprint of slab +/- 0.15 mm

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But note this is a long term load case and the value will increase with creep - ongoing

Model summary:
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Load = Slab self weight

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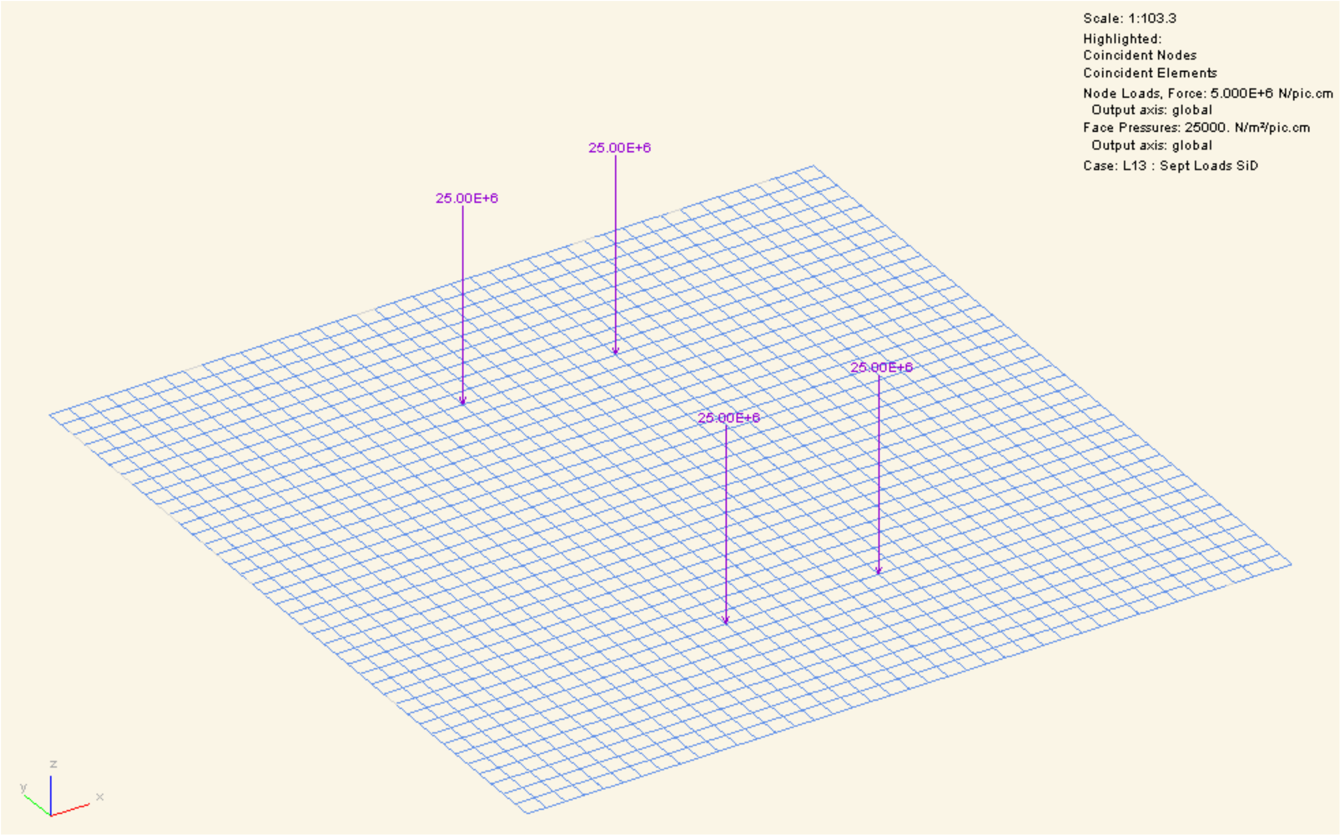
Step 2: Put SiD(closed) loads on top of slab

- **This has negligible displacement effect because the loads are (nearly) directly above the supports**



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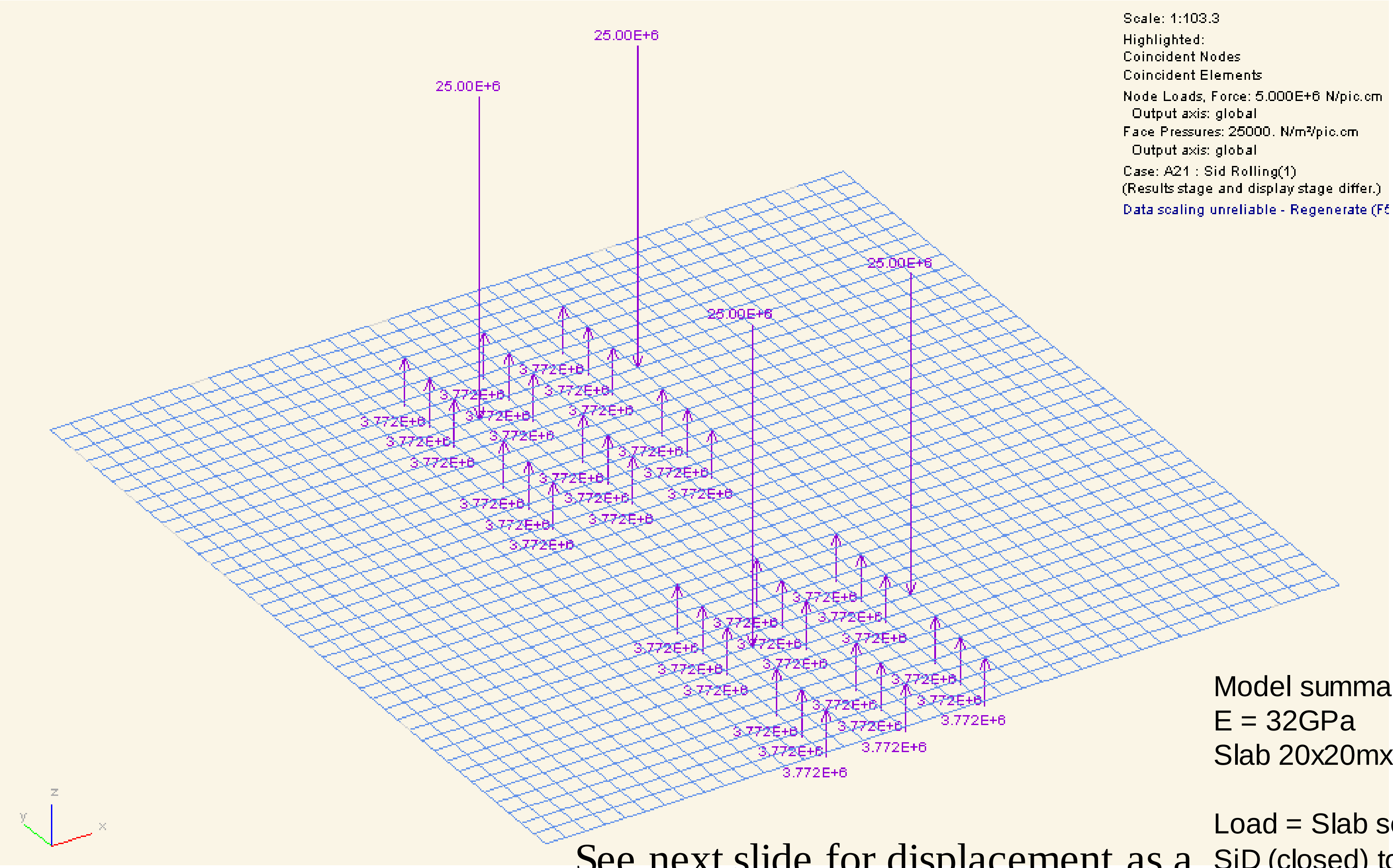
Put SiD(closed) moving on transportation system



See next slide for displacement as a result of these loads

Model summary:
E = 32GPa
Slab 20x20mx3.8m

Load = Slab self weight + SiD (closed) top loads

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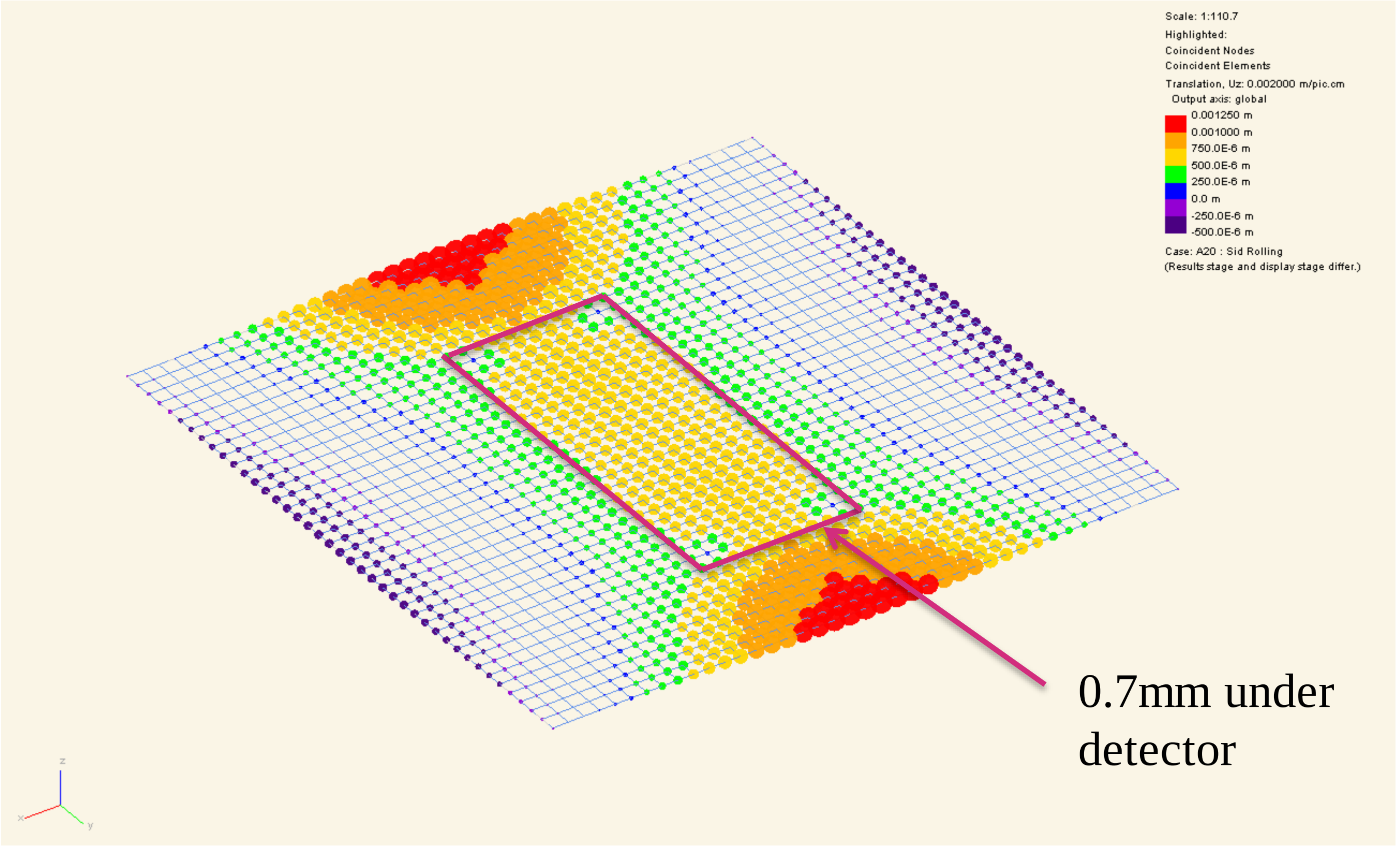
Put SiD(closed) moving on transportation system



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Un-slicing

- **Un-slicing causes top loads to move away from the permanent supports.**
- **Because of this, un-slicing would cause displacement limits to be exceeded if supported only by the permanent supports. Displacement limits N/A**

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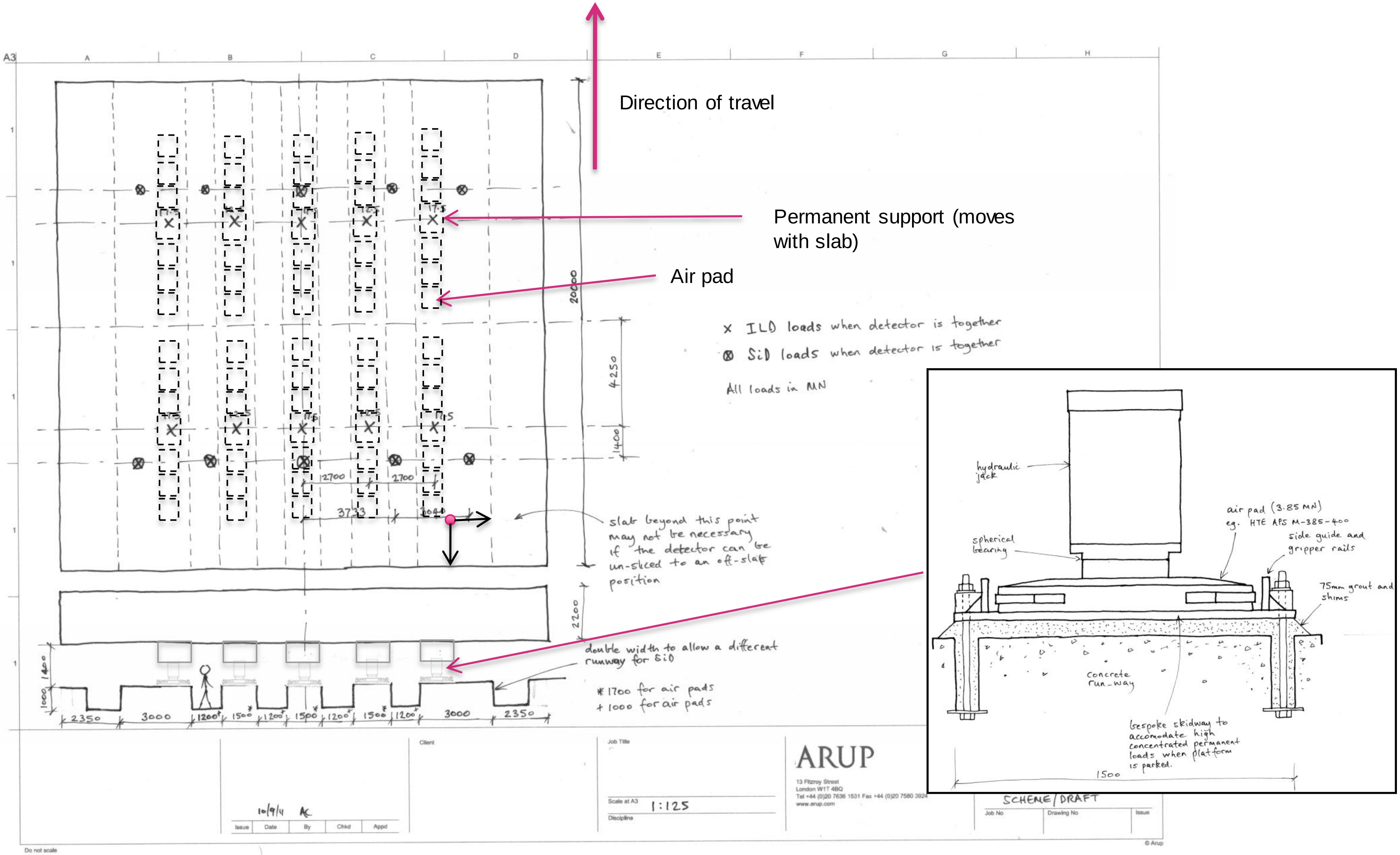
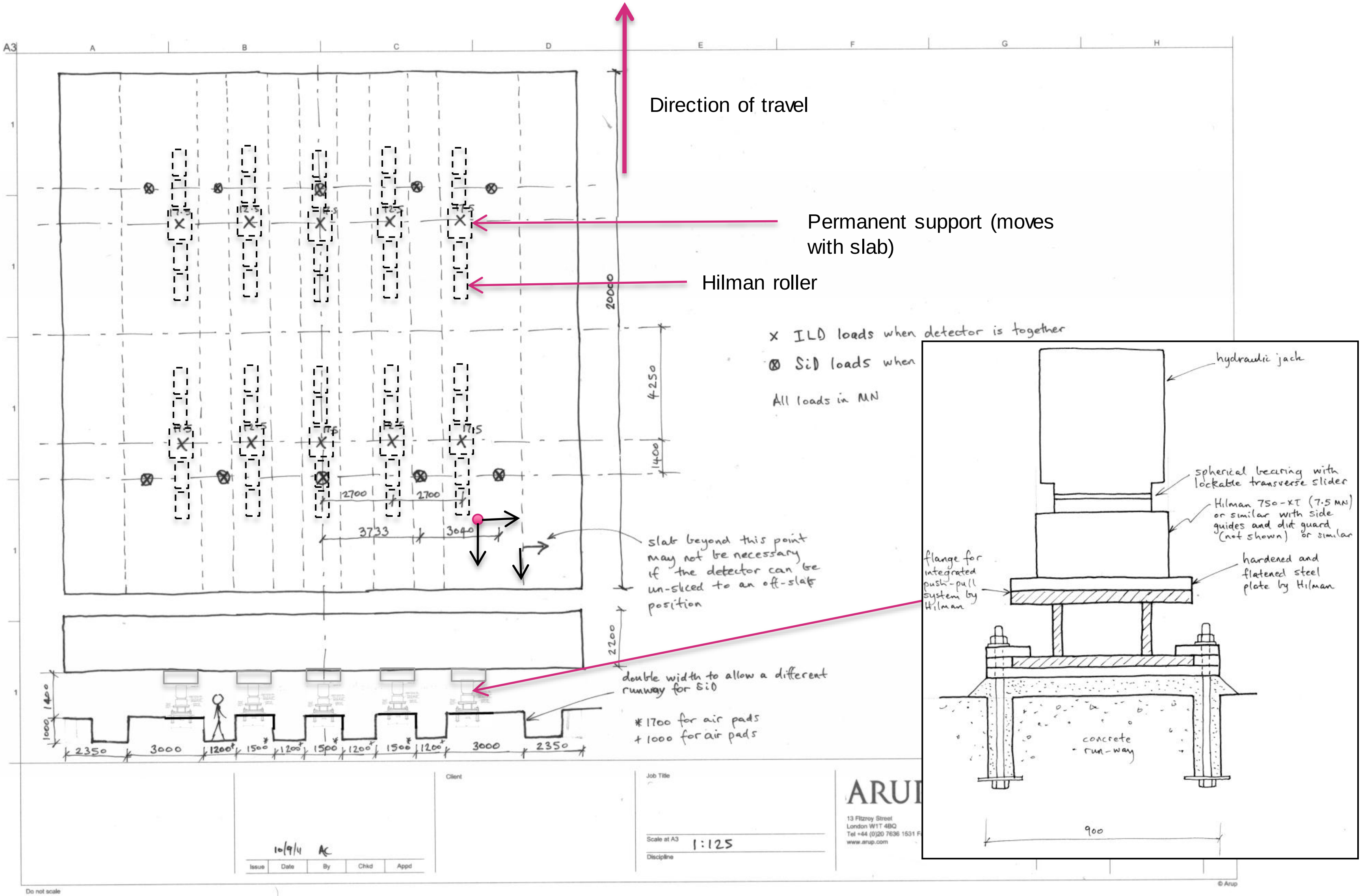
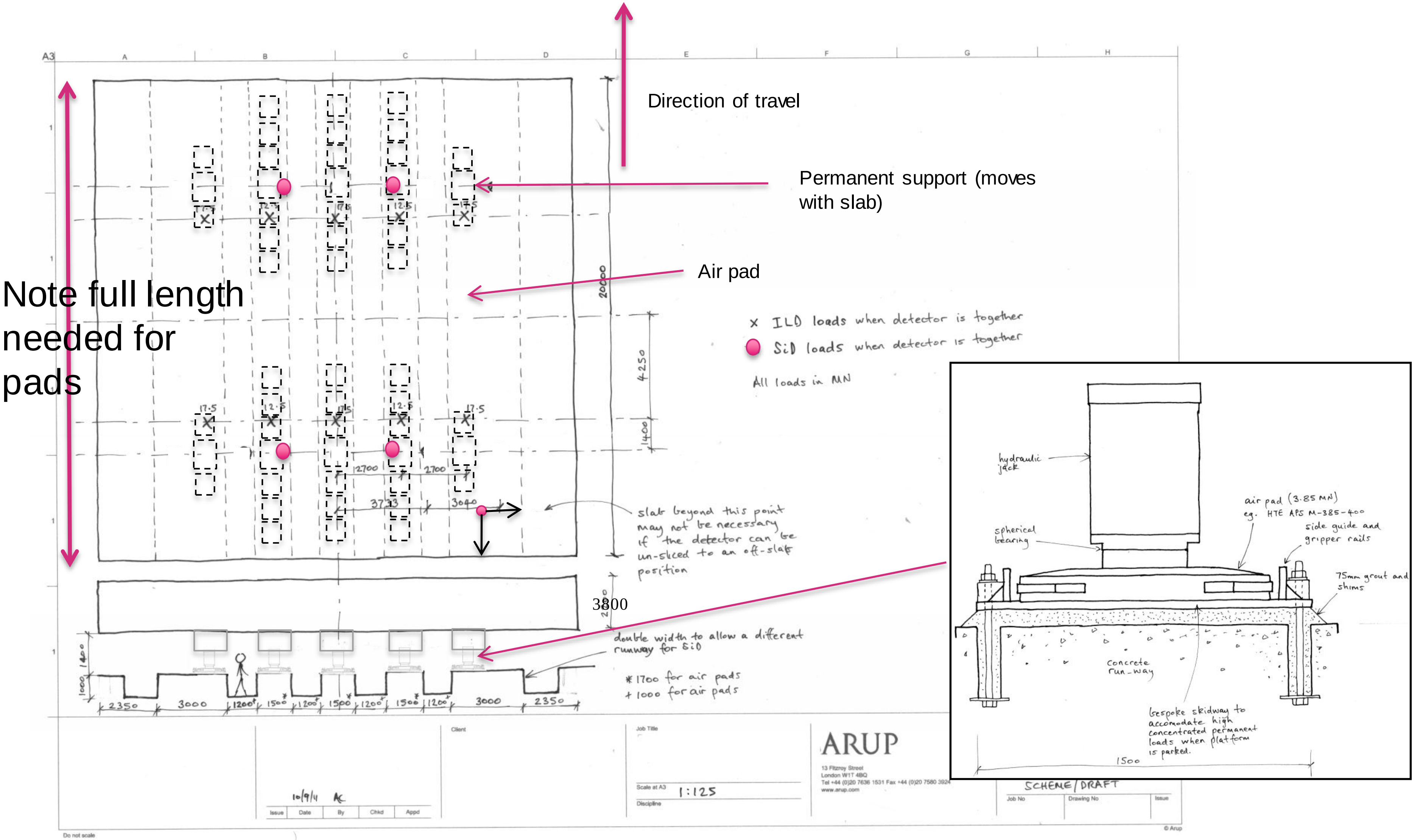
The movement support system – ILD, Airpads



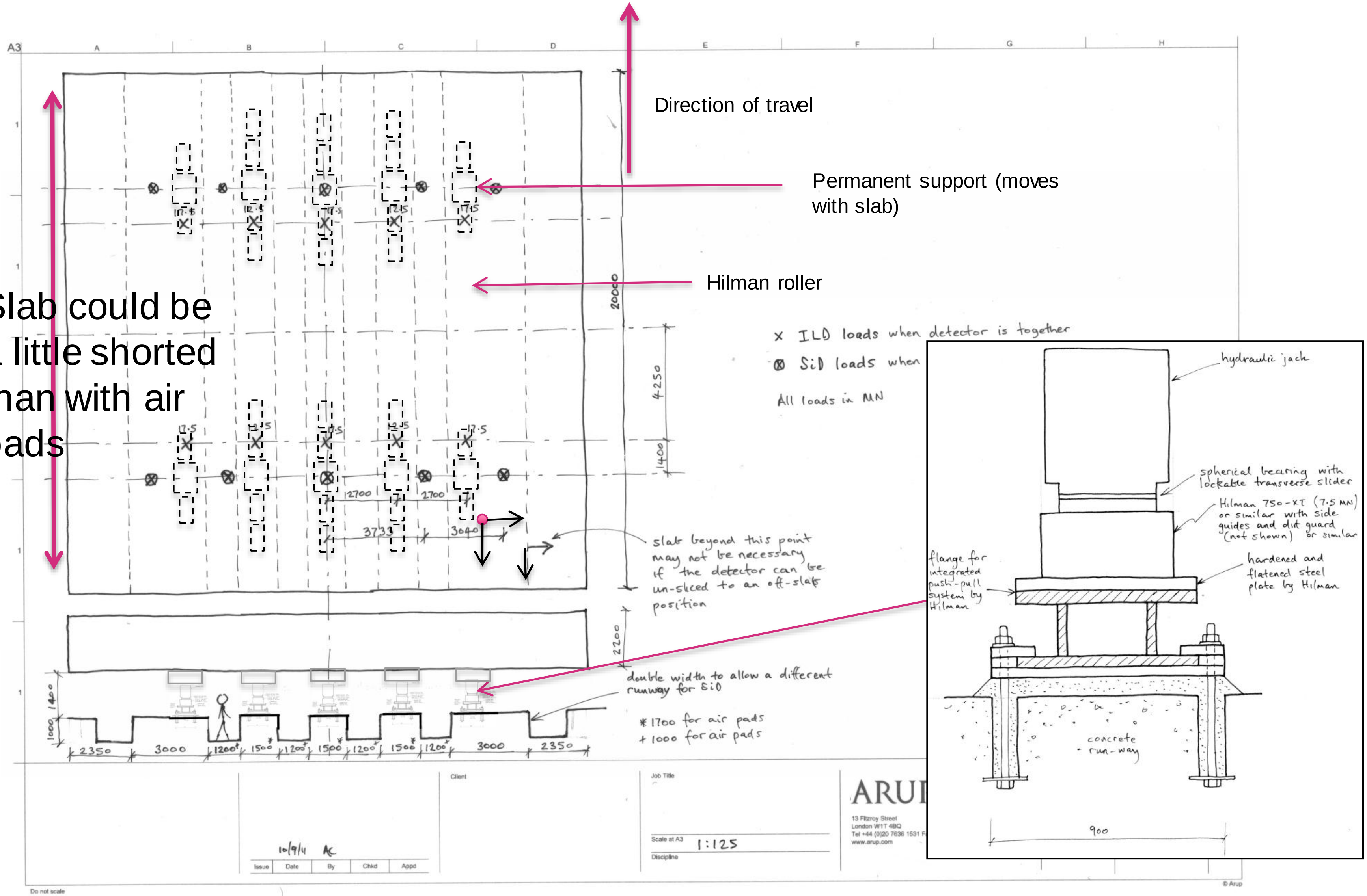
The movement support system – ILD, Rollers



The movement support system – SiD, Airpads



The movement support system – SiD, Rollers



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Conclusion on ILD movement

Moving the Detector

- **Can achieve disp limits of +/-2mm when moving**
  - ILD on 2.2m slab with pads or rollers
  - SiD on 3.8m slab with pads or rollers
  - Design works with pads and rollers, choice outside scope of assessment
- **Recommended Contingency/Studies**
  - Jacking and packing if the invert does flex (to keep the slab permanent supports plane)
  - Provide 50mm packing from the start to allow the height to be reduced
  - Evaluate slab final positioning systems (eg PTFE sliding surface)
  - Movement system not examined in detail (stick-slip accelerations require evaluation, $0.05m/s^2$)

Un-slicing

- **Limits exceeded when un-slicing…….but not applicable**
- **But props/shims will be needed under tracks when un-slicing to avoid a step**

BUT

- **Conclusions above dependent on invert flex ----- Displacement limit of ~0.5mm**

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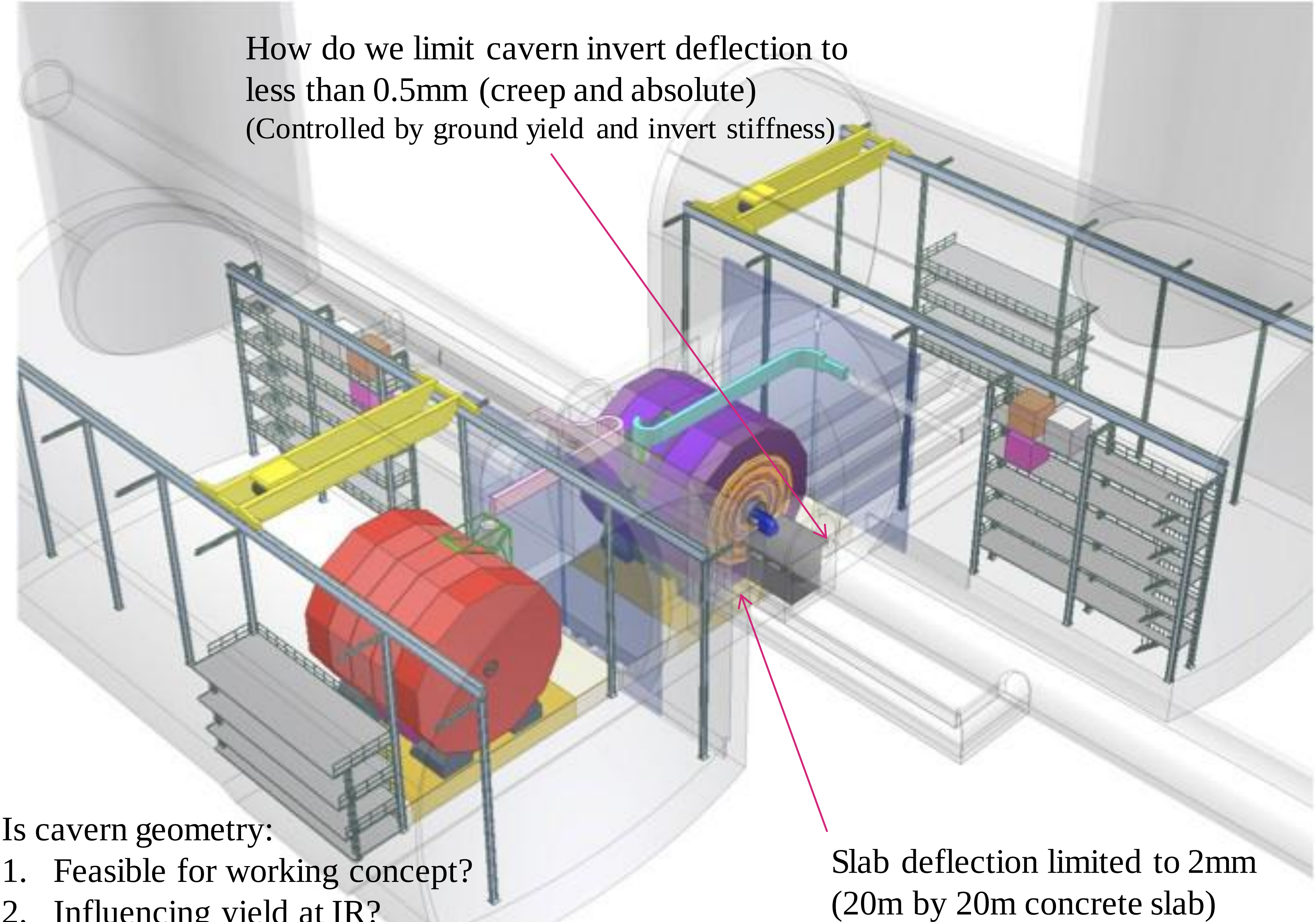
How do we limit cavern invert deflection to less than 0.5mm (creep and absolute)
(Controlled by ground yield and invert stiffness)



Is cavern geometry:

1. Feasible for working concept?
2. Influencing yield at IR?

Slab deflection limited to 2mm
(20m by 20m concrete slab)

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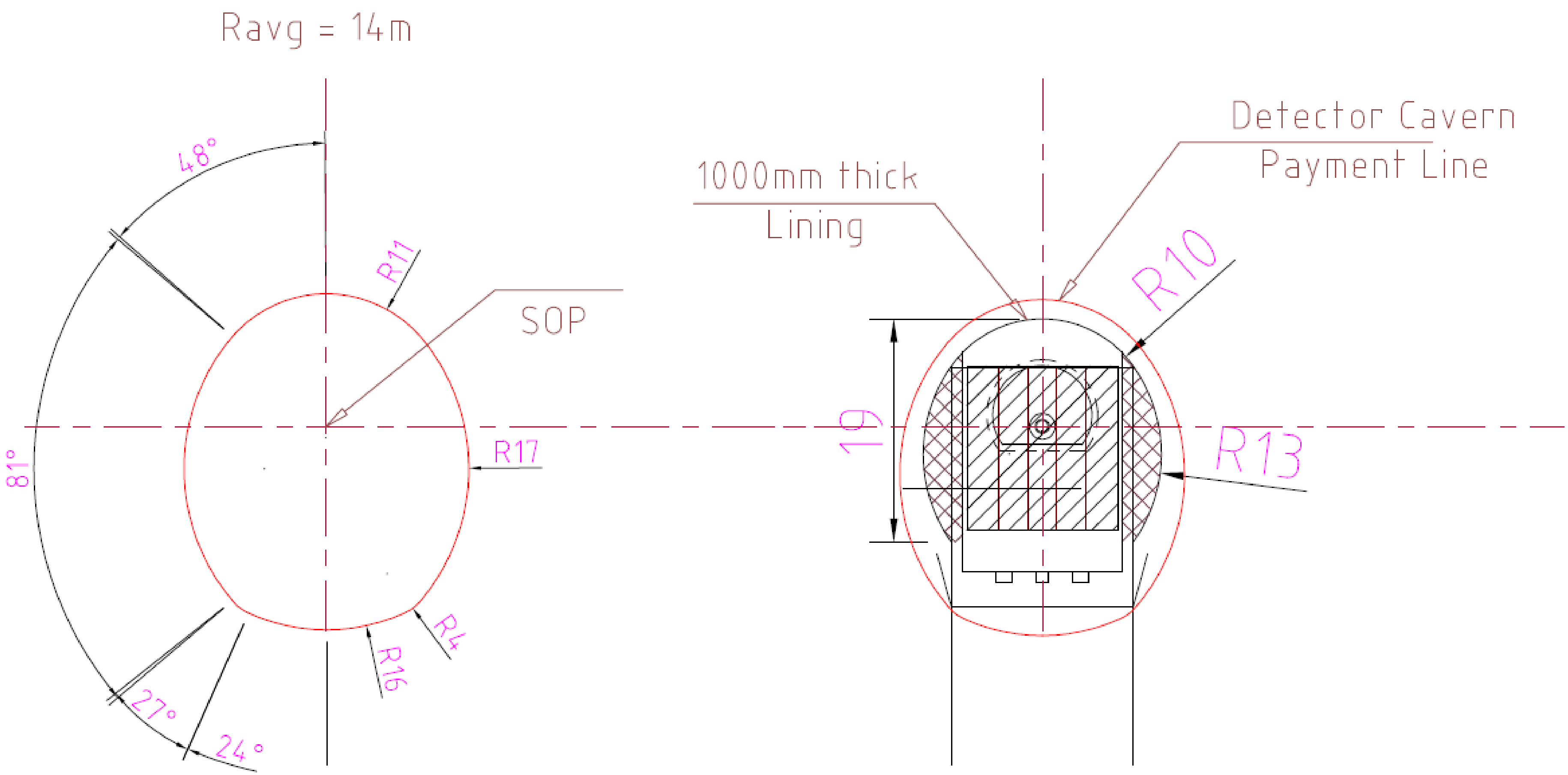
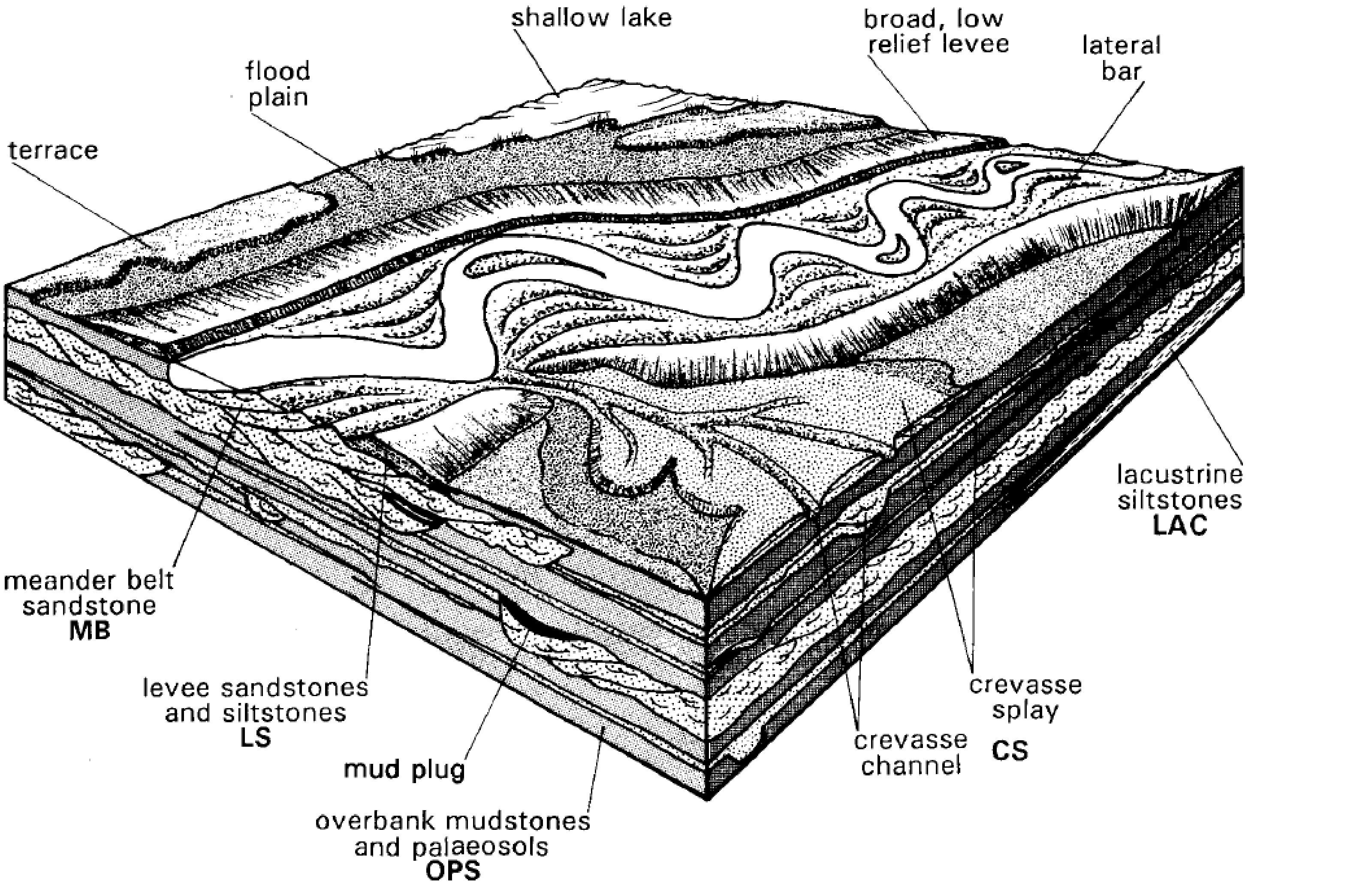
Key Issues for Invert Performance



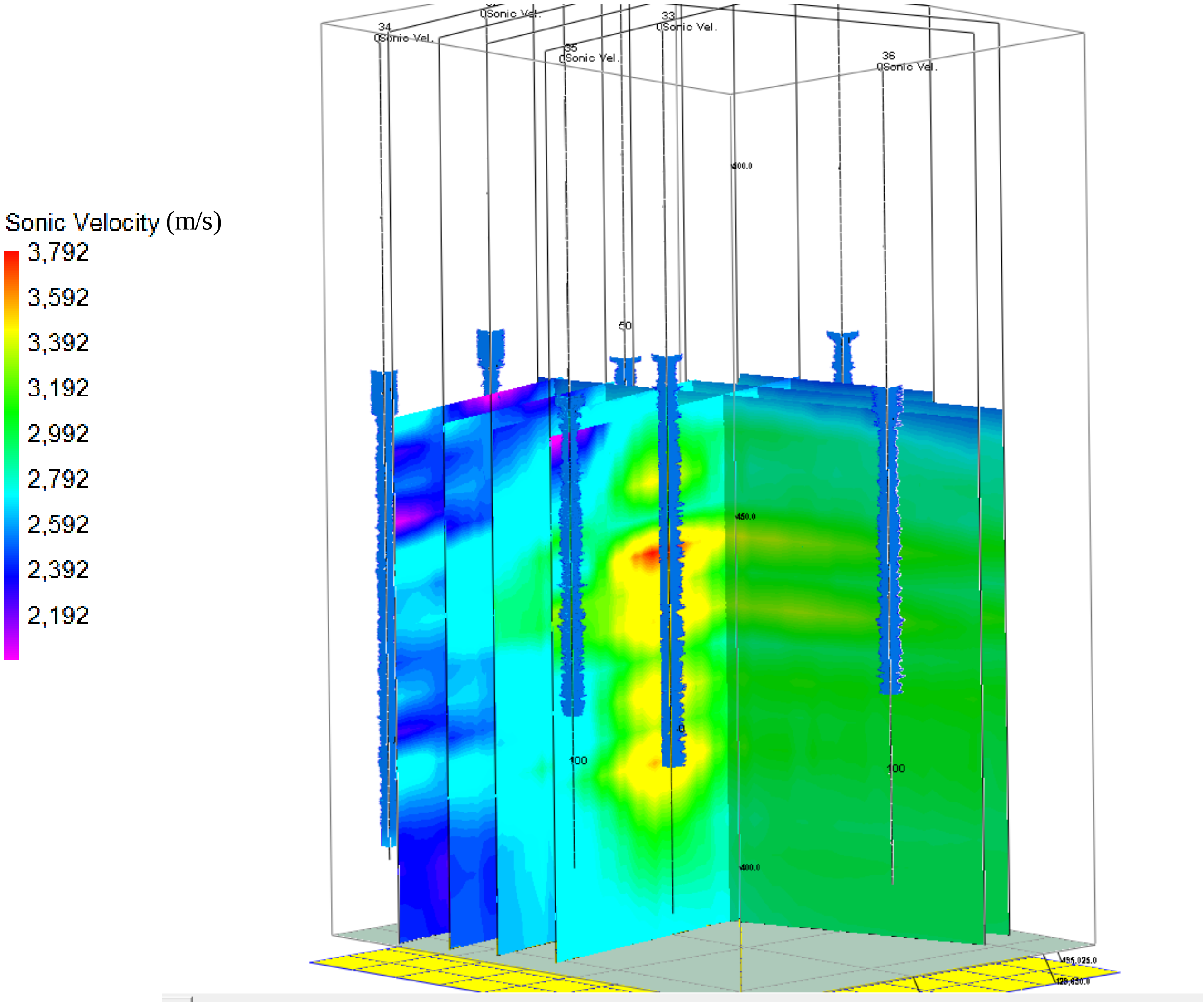
- What are the important characteristics of the ground?
- What is stress state in ground after construction?
- How will ground yield as a result?
- What are the invert displacements?

Depositional Environment

Lateral and vertical variability



New Assessment of Existing Information



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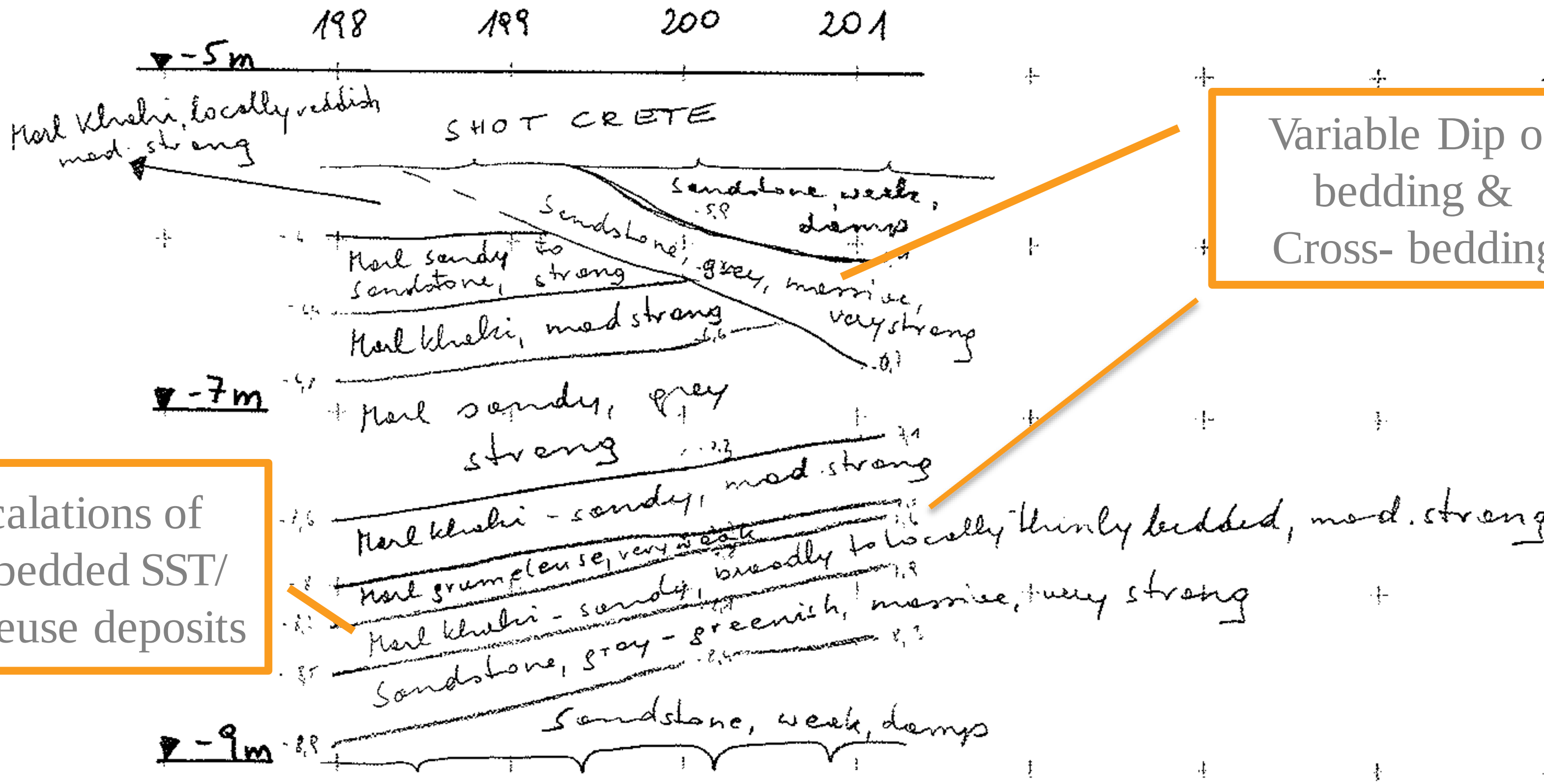
Confirmation of Depositional Features

- Examples from Point 5 GSG Face logs



Variable Dip of bedding & Cross- bedding

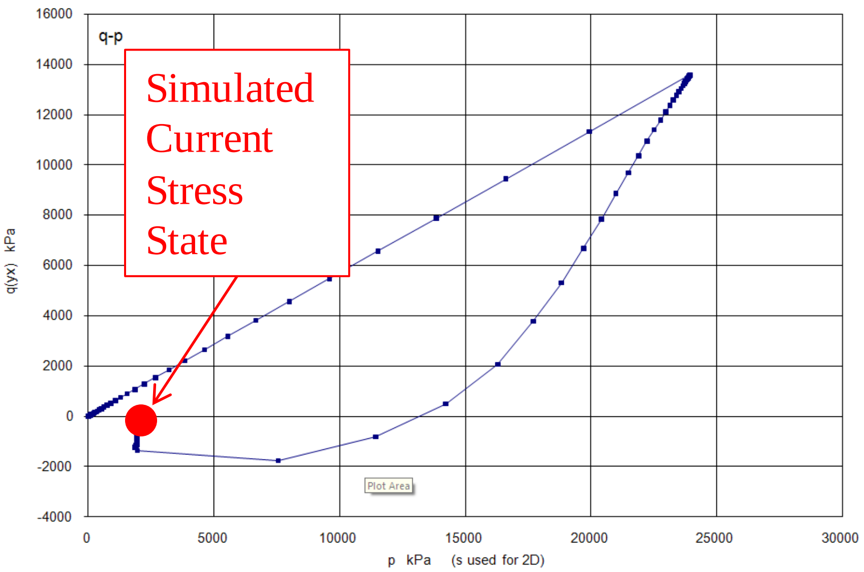
Intercalations of thinly bedded SST/ Grumeleuse deposits

Pillar Ch. 198-201m

Stress History and Ground Parameters

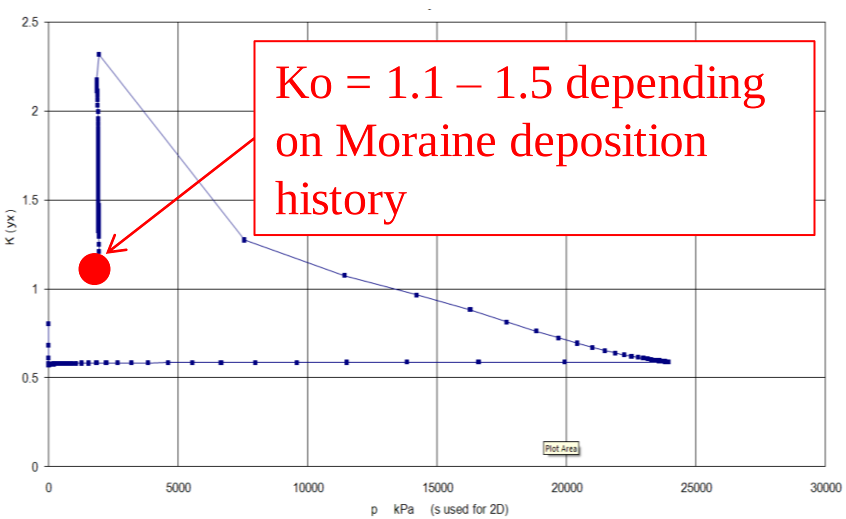
Assumed stress path:

Stage	Name	Cavern Depth (m)	Soil Effective Weight (kN/m^3)	Vertical Effective Stress (kPa)
1	Deposition of Molasse Rocks (2km)	2060	16	33000
2	Erosion	60	16	1000
3	Assumed deposition of 20m Moraine deposits	80	11	1200



Soil mass parameters:

Name	γ [kN/m^3]	k [m/s]	ν [-]	E_{mass} ‘(LB) [kN/m^2]	c' [kN/m^2]	ϕ' [°]
Molasse Rock Mass	23	1.00E-09	0.2	2800000	220	35
Moraine Gravel	23	1.00E-05	0.25	50000	0.01	35



Note: small strain stiffness/creep not known

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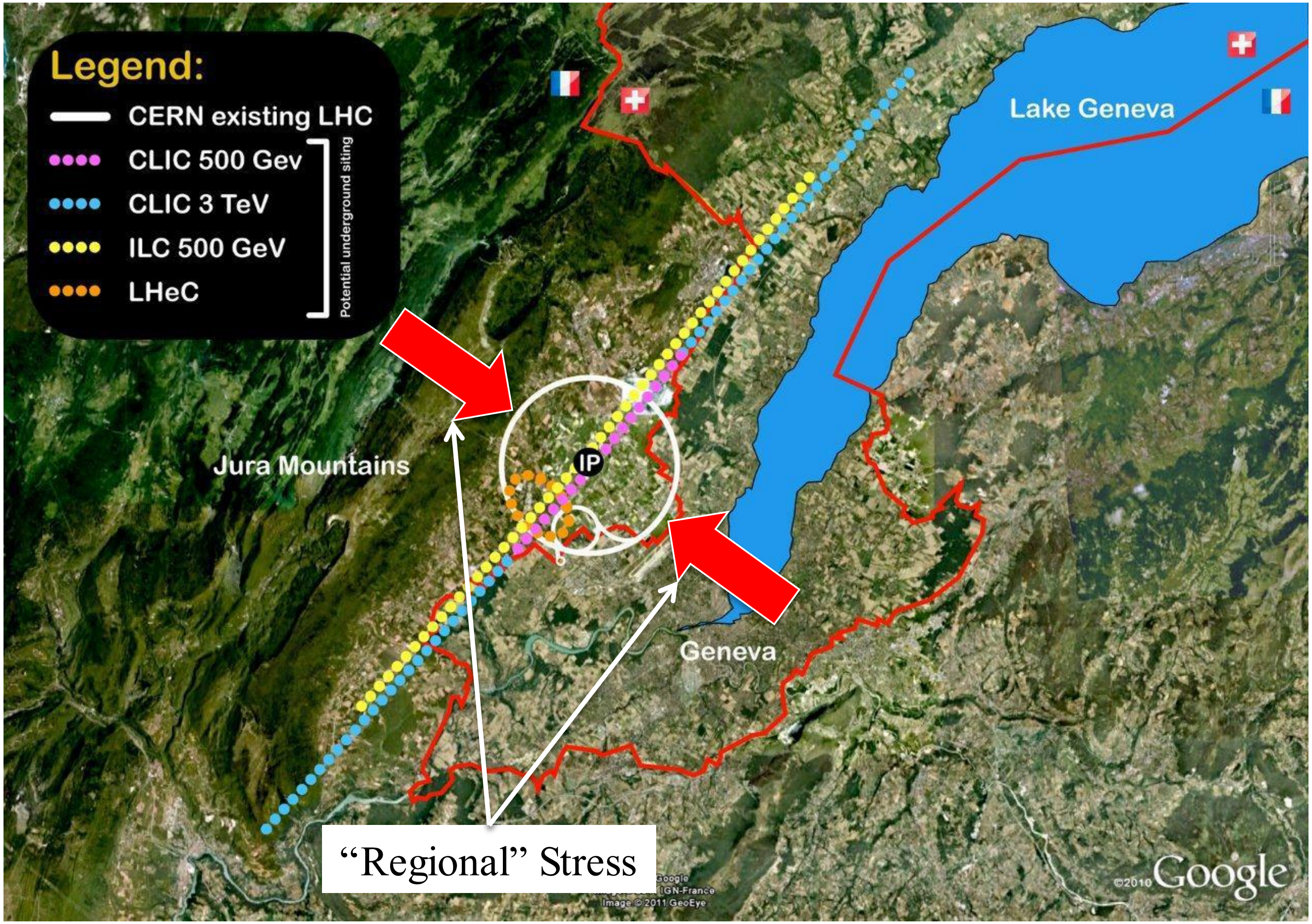
Regional Stress Regime



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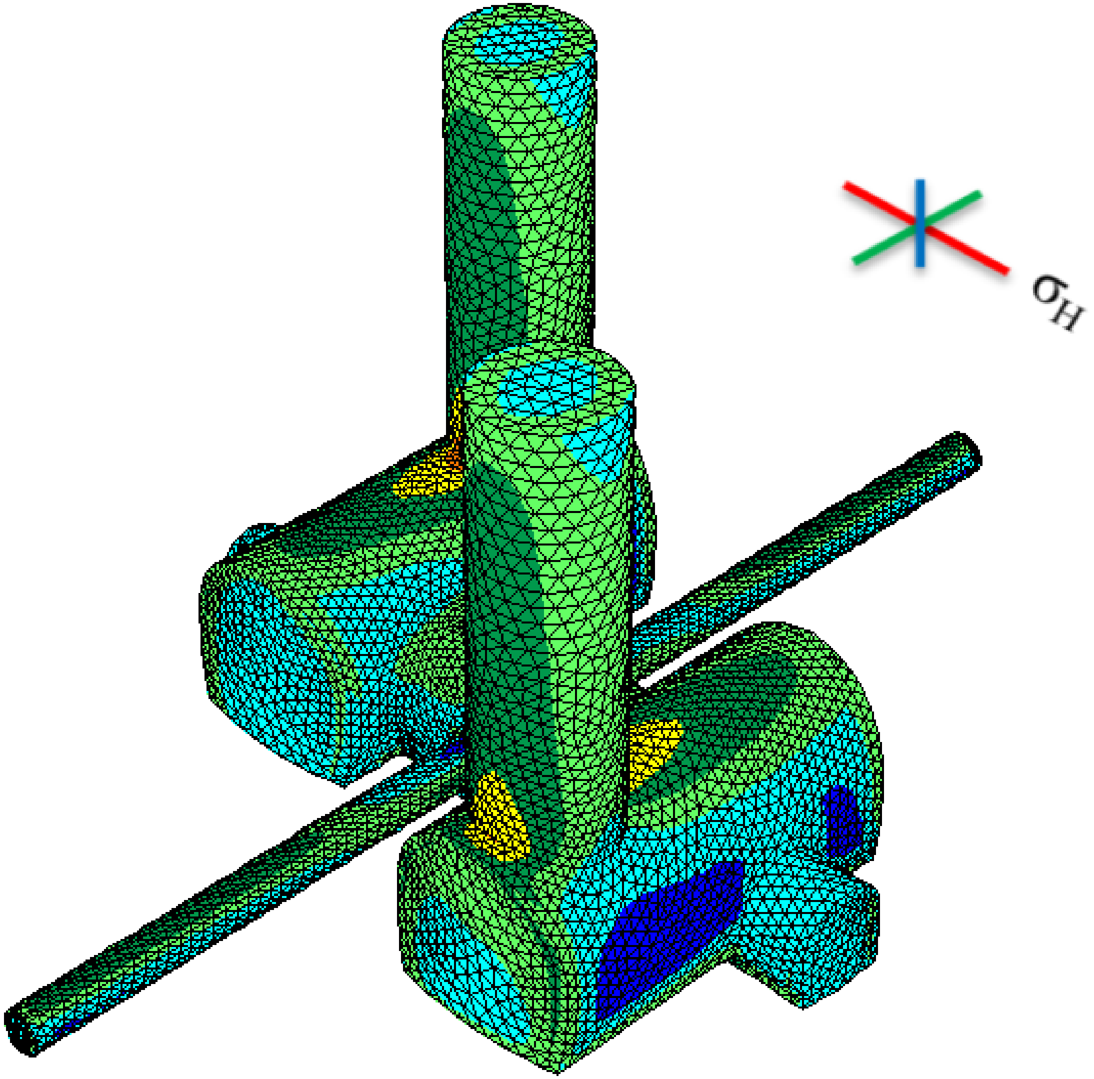
Likely Stress Trajectory at Cavern



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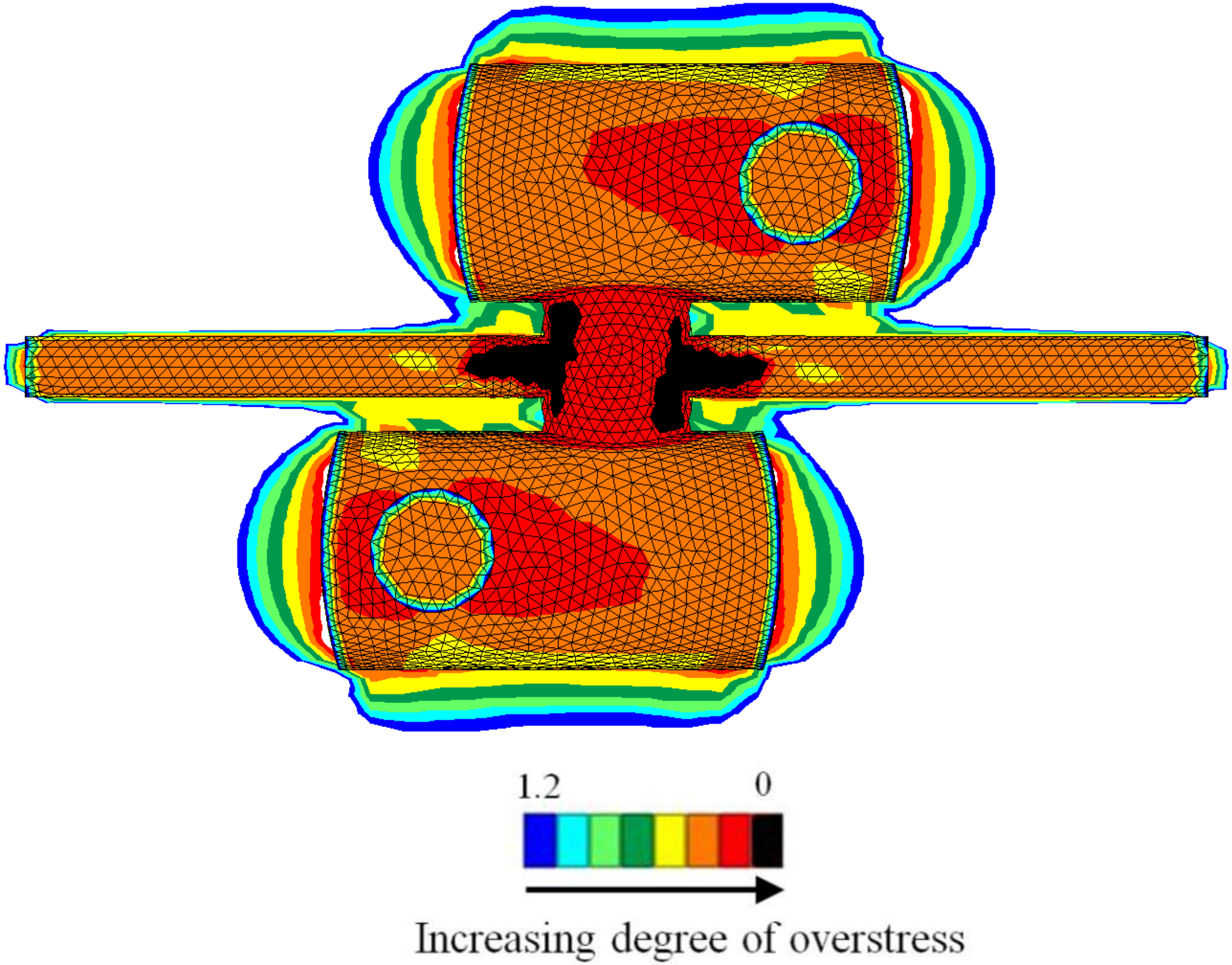
Layout G



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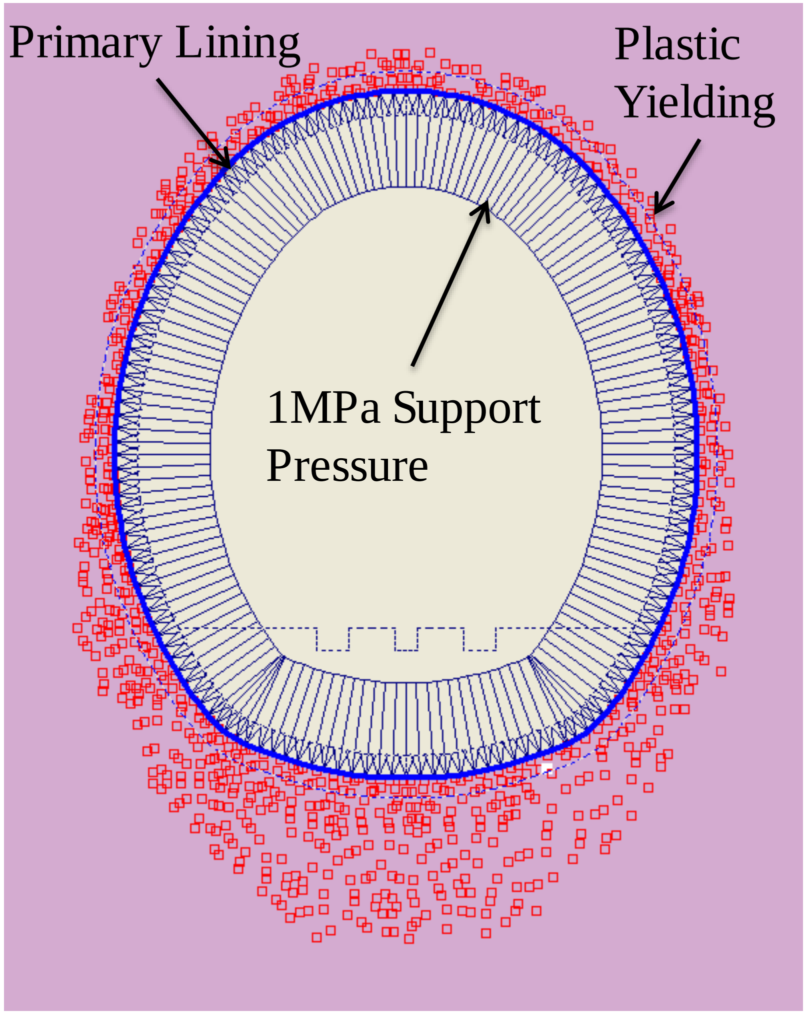
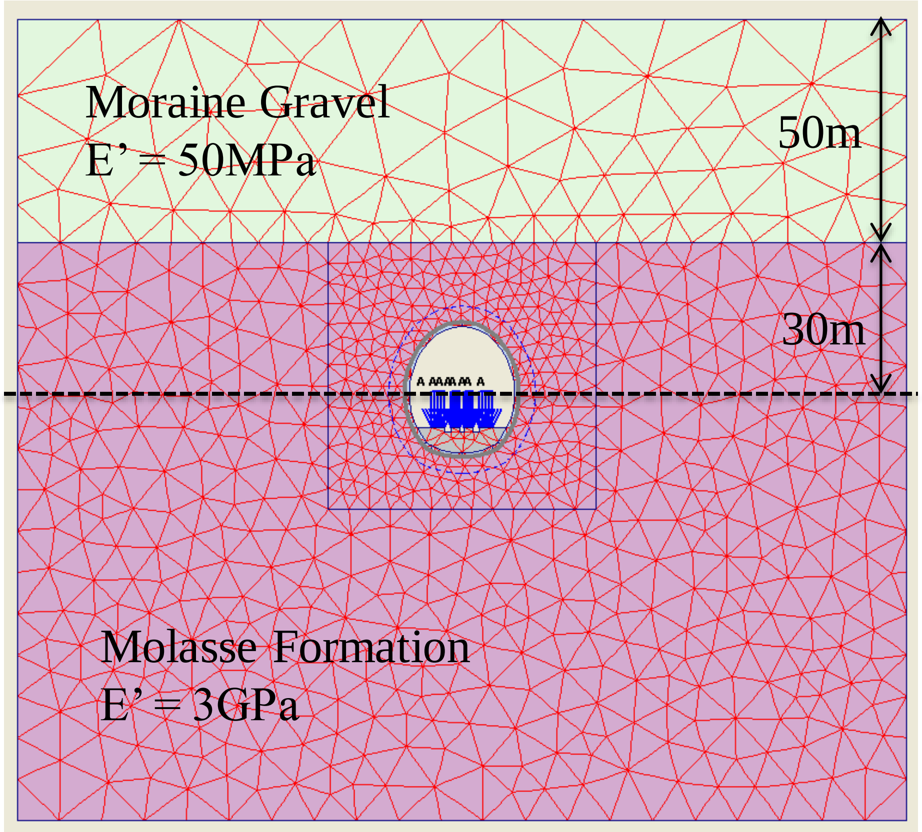
2D FE analysis





Lining support assumed to be same as UXC55 Cavern

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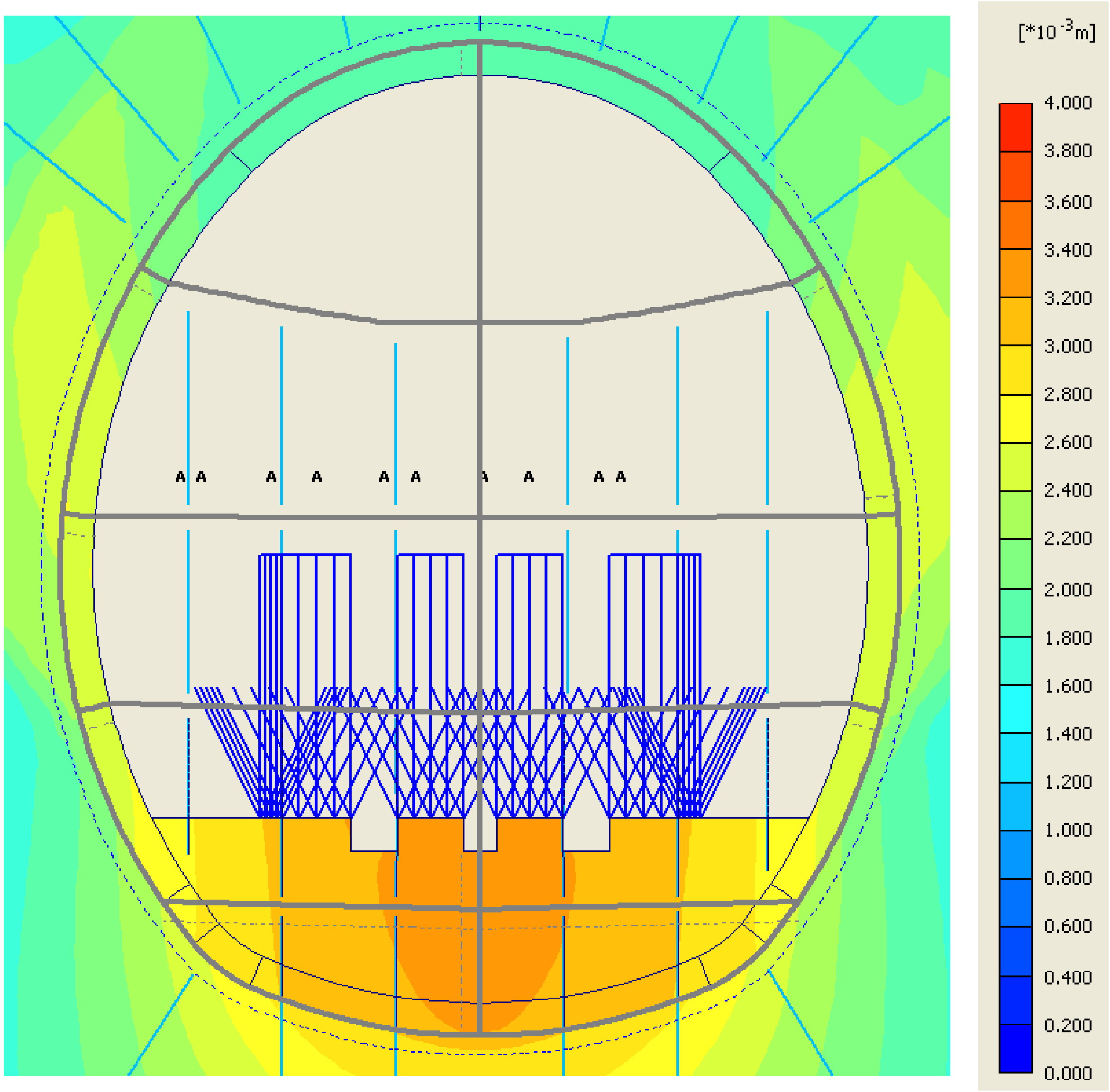
2D Invert Deformations



Longitudinal: 3.3mm / 16.6m = 0.2mm/m x 20m = **4mm/20m > 0.5mm/20m**.

Transverse: 3.3mm-3 mm / 13.5m = 0.023 x 20 = **0.45mm/20m < 0.5mm/20m**.

"Static" analysis carried out, existing data did not allow small strain stiffness, creep and cyclic deformation

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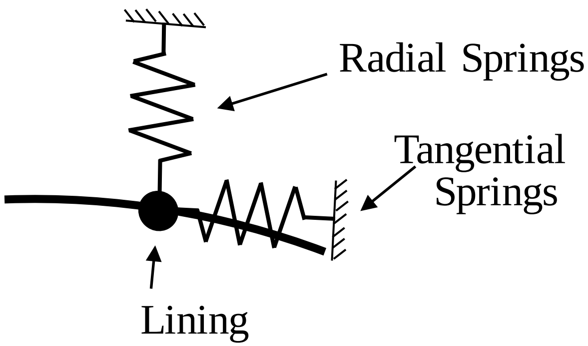
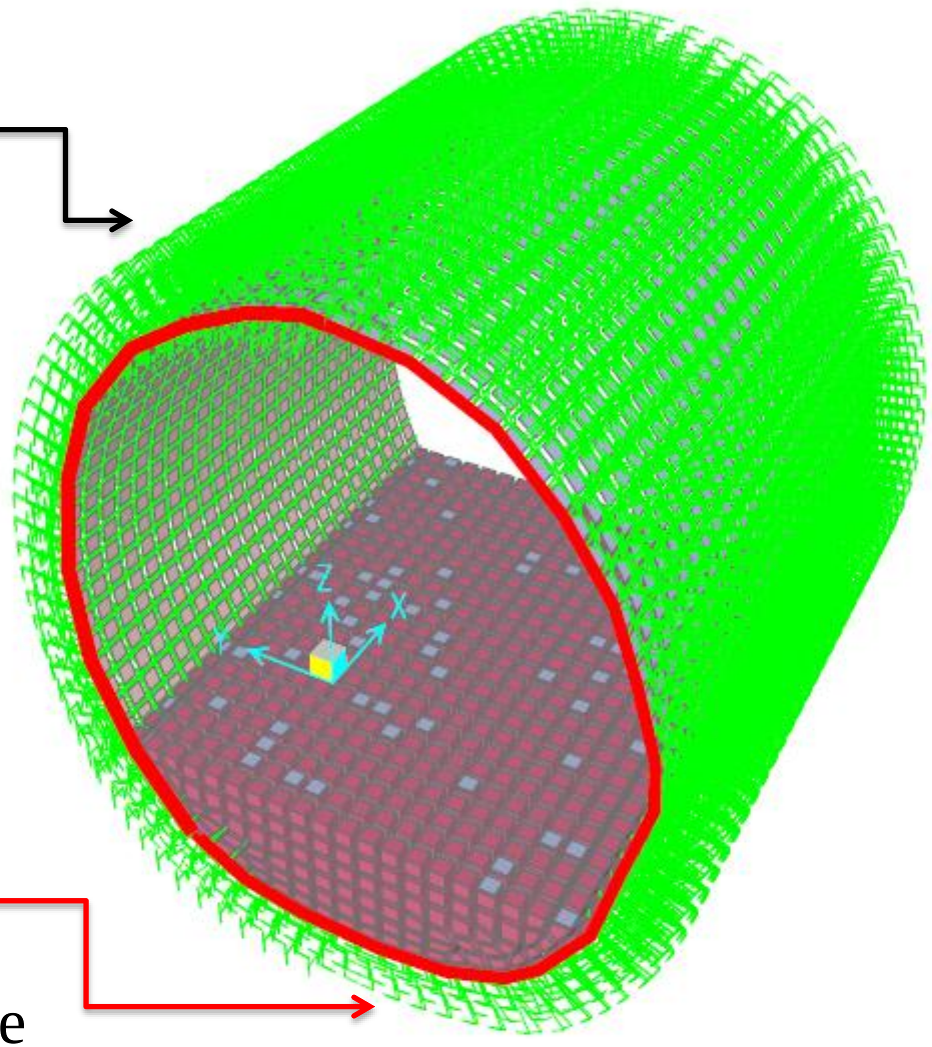
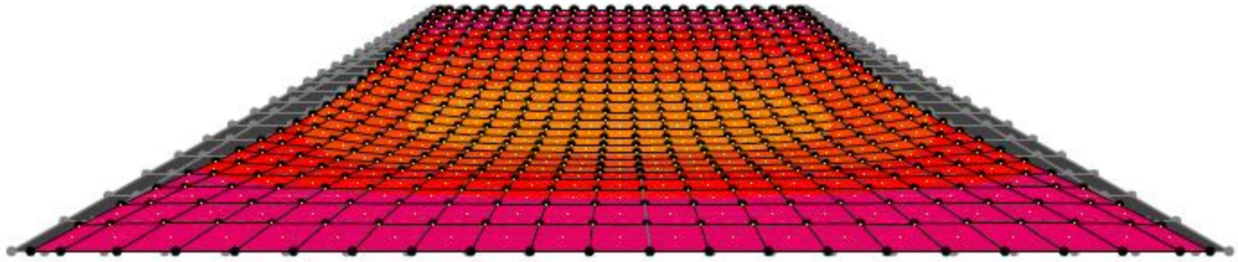
Boundary Conditions

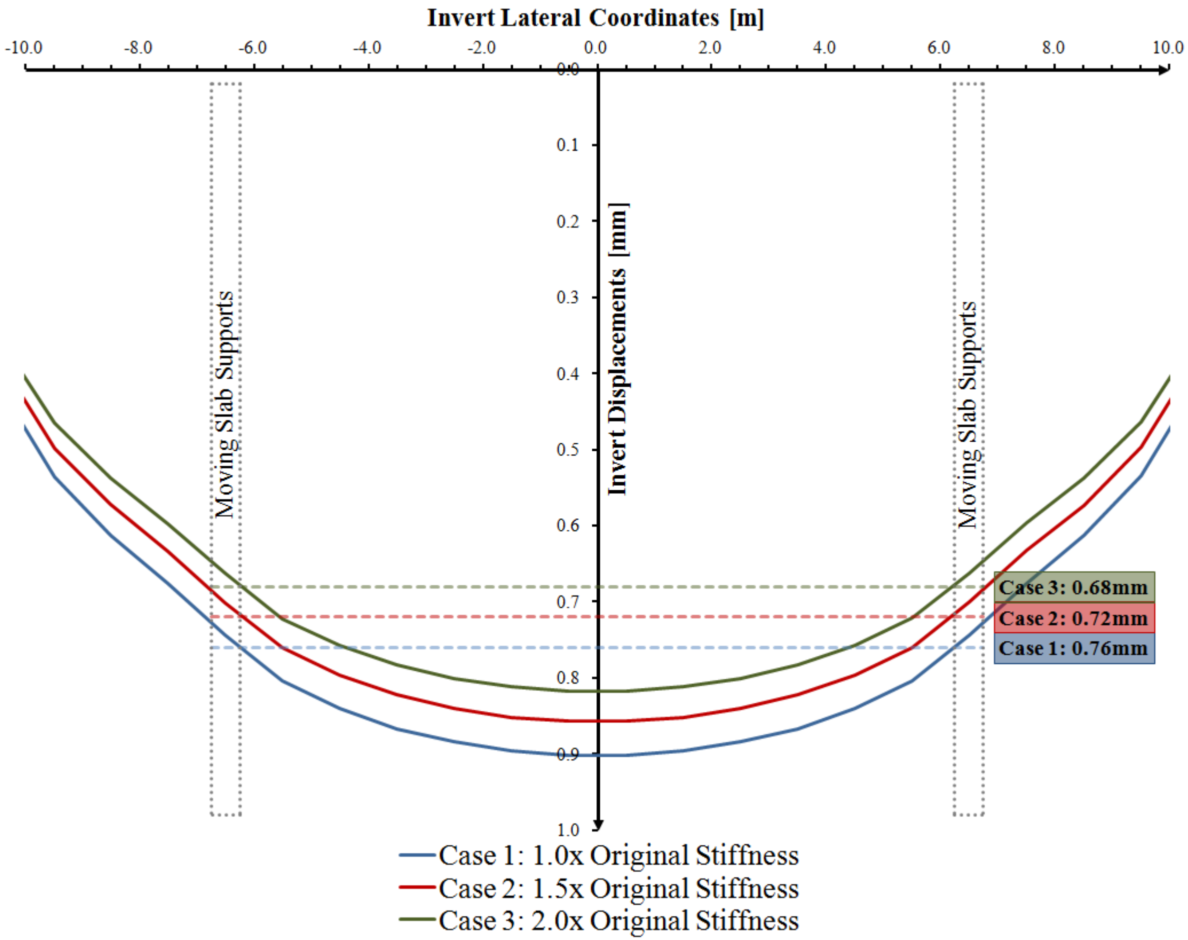
Springs represent ground stiffness





Pinned connection at interaction cavern and the service caverns interface




Invert Lateral Coordinates [m]
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
4.0
6.0
8.0
10.0
Invert Displacements [mm]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Moving Slab Supports
Moving Slab Supports
Case 3: 0.68mm
Case 2: 0.72mm
Case 1: 0.76mm
Case 1: 1.0x Original Stiffness
Case 2: 1.5x Original Stiffness
Case 3: 2.0x Original Stiffness

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Conclusions

Slab

- **Slab design for loads can be achieved for rollers and air pads**
- **Stick-slip accelerations need review for movements systems and slab final positioning**

Cavern

- **Performance of invert under loading is marginal in CERN geology, given sequence reviewed**
- **Invert performance highly dependent on:**
  - Geology – detailed and focussed SI required
  - In situ stress – verification of local variation
  - Construction sequence – to minimise disturbance
- **Long term and cyclic displacement and creep not yet understood**

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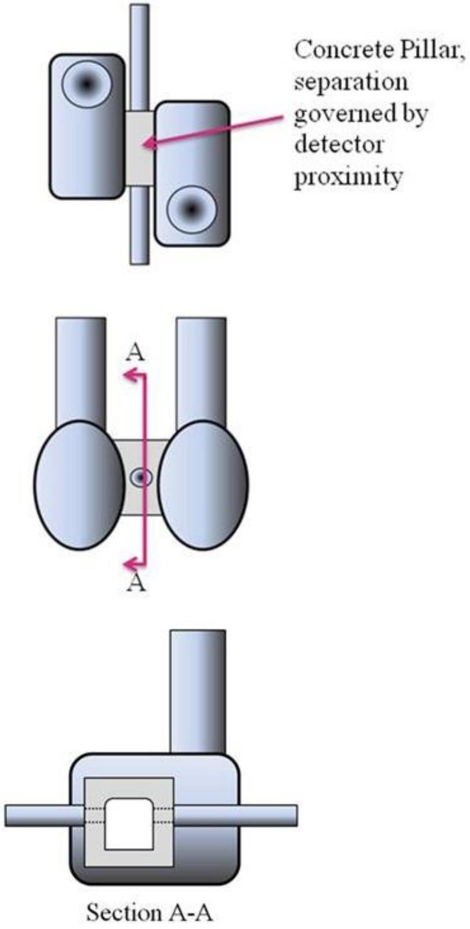
Recommendations

- **Focus investigations**
  - Seismic logging and 3d interpretation to select best horizon
  - Small strain stiffness
  - Sampling for creep evaluation
- **Provide contingency design for:**
  - Cavern support and sequencing (IR first)
  - Increase separation between Garage Caverns
  - Piling the cavern invert slab
  - Concrete pillar between caverns
  - Stiffer slab to allow more invert flex



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Further work

- **Ongoing commission with Fermilab**
  - Desk study
  - Cavern design Assessment
  - Costing
  - IR cavern performance assessment

- **Initiating internal dialogue with Arup's Tokyo Office**