Decay vessel - alternative design

Piet Wertelaers / piet.wertelaers@cern.ch

SHiP Joint physics and detector meeting - vacuum vessel workshop

12 Feb. 2021

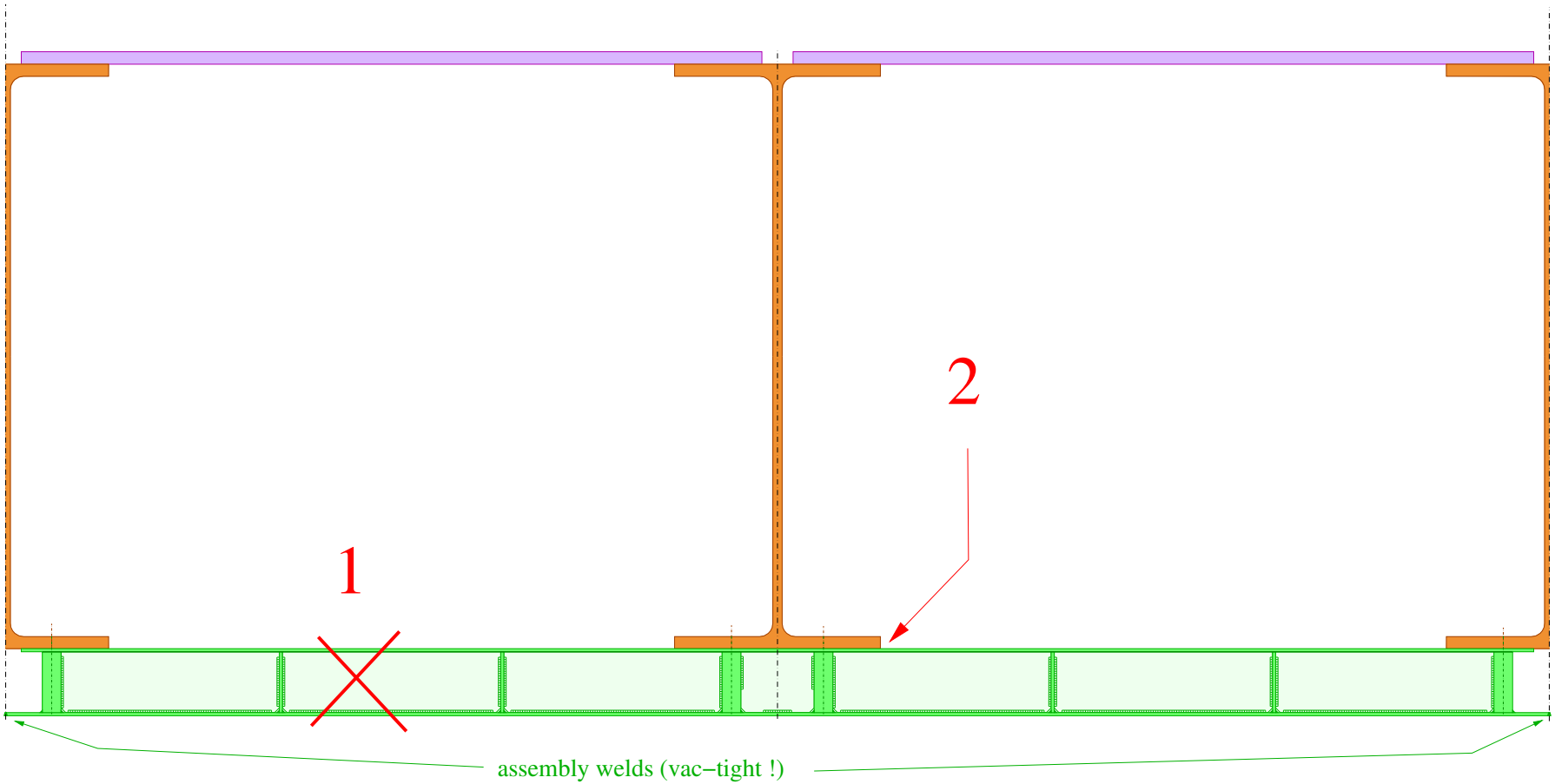
The worry

Tolerances - (weld deformations) - **Will it fit ?**

Due to (personal view) requirements/challenges :
* The bearing of a *liquid* scintillator
* Tank must be narrow (thus flexible, thus heavily loaded welds)

This talk : alternative design :
* Personal initiative ; unsolicited (.. and thus no CAD)
* Based on *hypothesis* : drop the 2 requirements
* Write-up : CERN-SHiP-INT-2021-002

Already some ideas in 2017 ; what has changed ?



1. Vacuum liner no longer as sandwich, but as monolithic sheet.

2. Liner now welded to beam (still some studs, to pull liner compact).

Philosophy

Sandwich of **sheets** to provide stiffness.

Skeleton of **beams** : starting base, spacing of sheets (shear-proof anchoring), corner moment.

Large spacing, generous stiffness : lower shear, connection to Spectrometer vactank.

Inner sheet = vacuum liner.

Void volume : for scintillator blocks/plates.

Outer sheet = cover, must be dismountable, so : bolted (to beams).

(Inner sheet connected to beam by – intermittent – welds.)

Portals (51 in total) of 4 beams erected in situ.

Frustum : portals increase in size , beams aligned "skew".

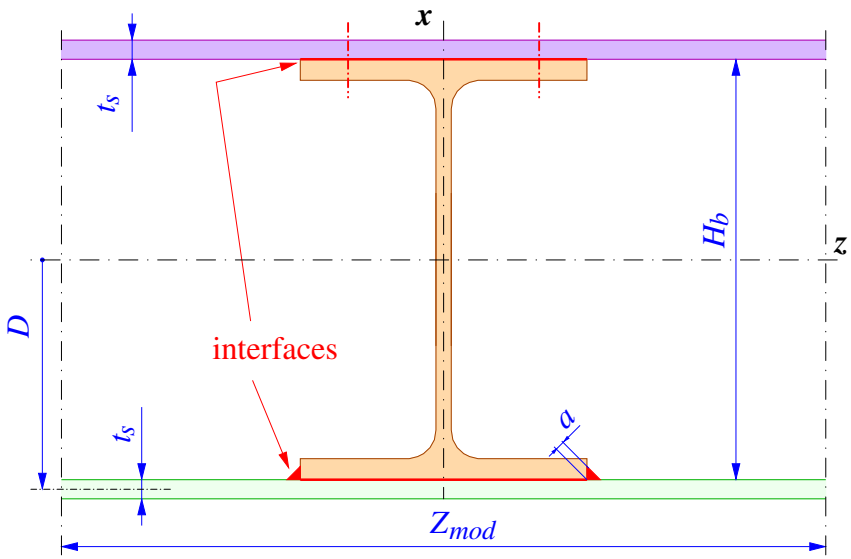
Vacuum liner sheet machined at edges , as wide as possible ($\approx$ 2 m).

Scint. cover sheet half as wide.

Cover sheets see unprecise beams : shimming, light tightness.

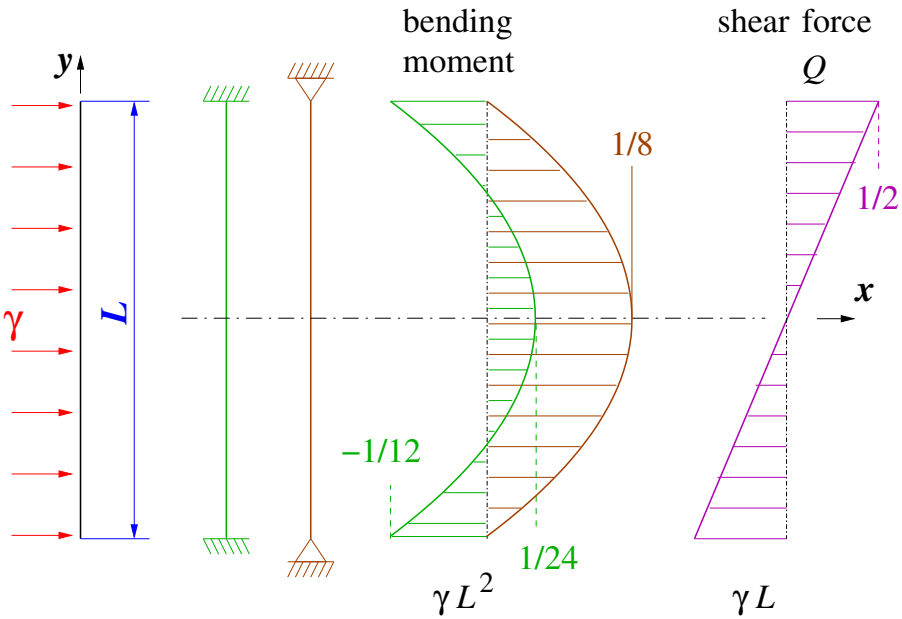
Vessel = **train wagon** on array of bogies : z-stroke , height adaptation, single z-constraining.

Dimensioning 1/6 : modular bit of (side) wall



outer sheet :
scintillator cover

inner sheet :
vacuum liner



mom. inertia : $I = I_b + 2\, Z_{mod}\, t_s\, D^2$

static moment : $S = Z_{mod}\, t_s\, D$

line load : $\gamma = p\, Z_{mod}$

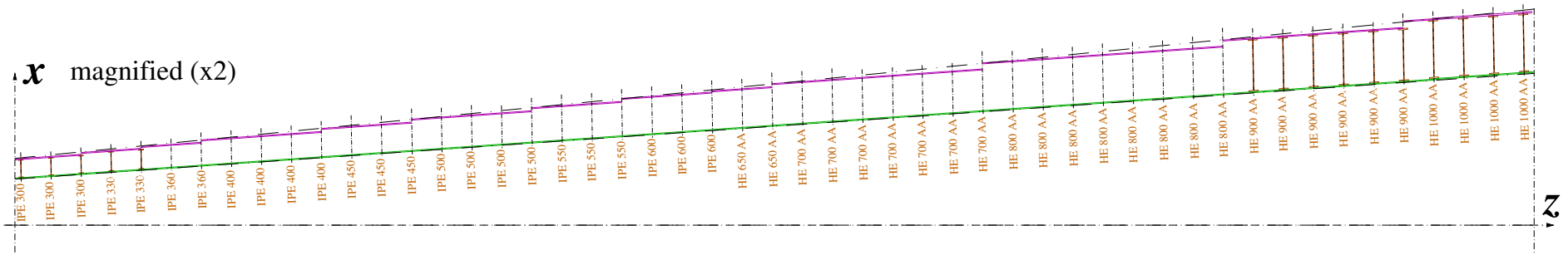
shear force : $Q(y) = \gamma\, y$

shear flux : $f_{sh}(y) = Q(y)\dfrac{S}{I}$

(hinged-end) sagitta $= \dfrac{5\,\gamma\, L^4}{384\, E\, I}$

Dimensioning 2/6 : side wall of frustum

$$Z_{mod} = 0.99 \text{ m}$$



aperture (inner envelope) : $x_{ap} = 0.0348\, z + 0.76$ m (traditional)

outer envelope : $x_{out} = 0.0492\, z + 1.10$ m (shocking !)

Careful ! $z = 0$ at start of vessel

Beams : standard I/H , but lightweight

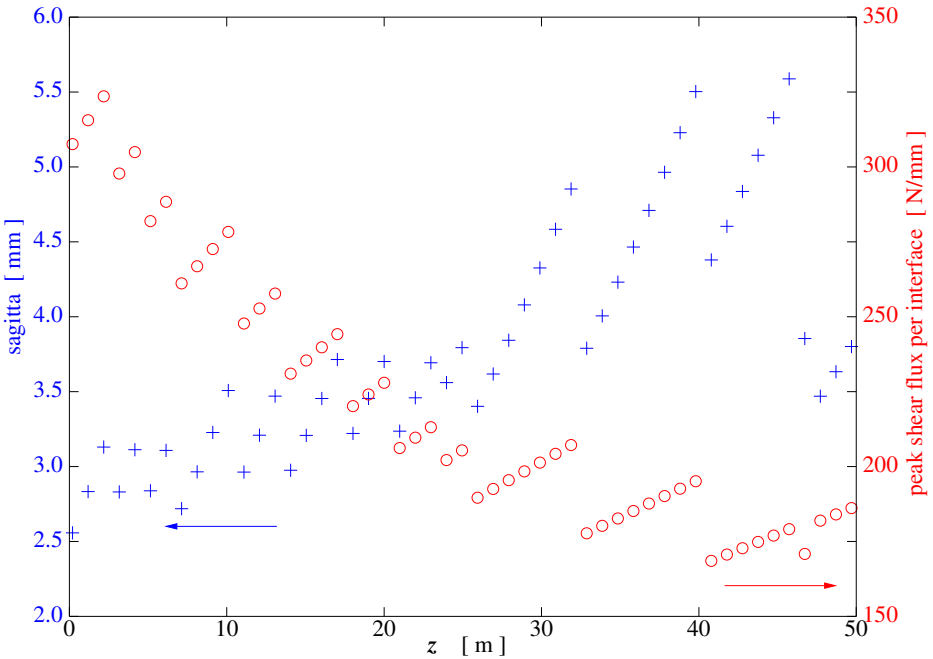
Sheets : $t_s = 16$ mm (25 in the last 3 units)

Dimensioning 3/6 : side wall : performance

Total free span L along y :

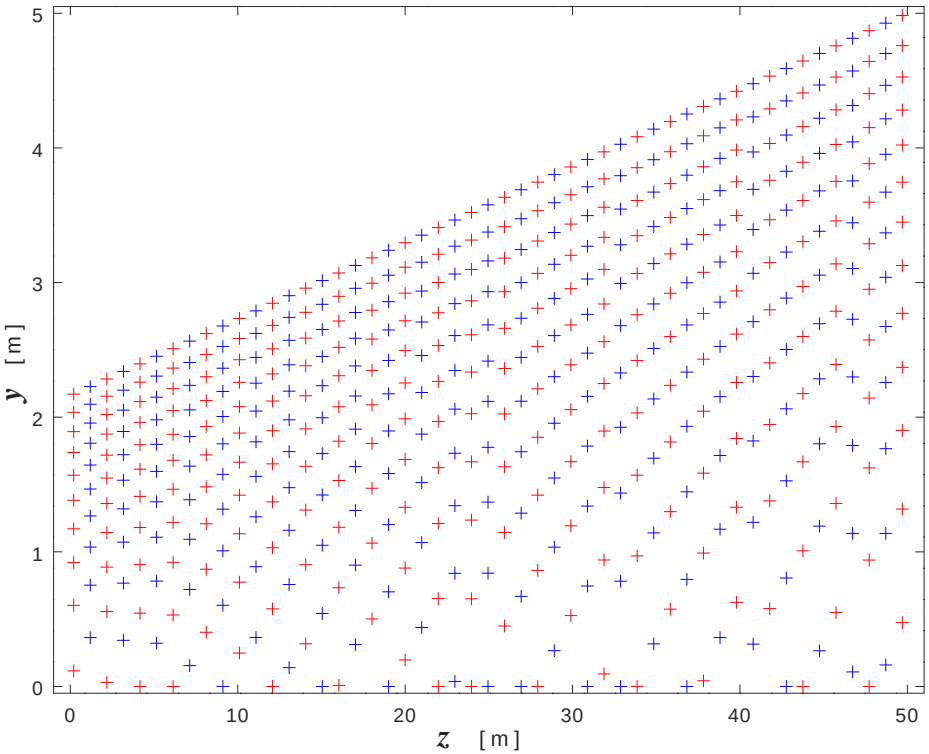
$$L = 2\,y_{ap} \qquad y_{ap} = 0.0568\,z + 2.16 \text{ m}$$

modules in isolation !

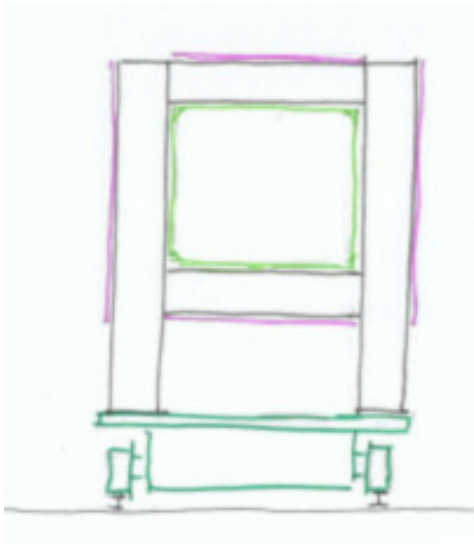


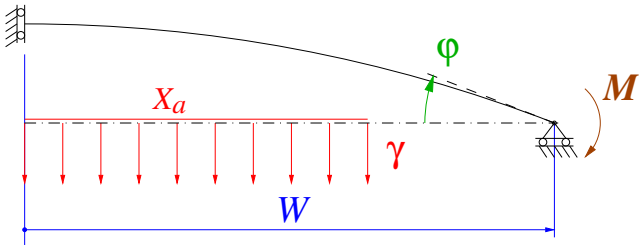
(300 N/mm is a meaningful shear flux !)

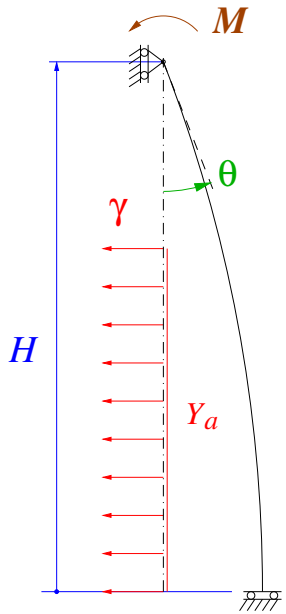
scintillator cover sheet : bolt pattern
(assumptions in Note)

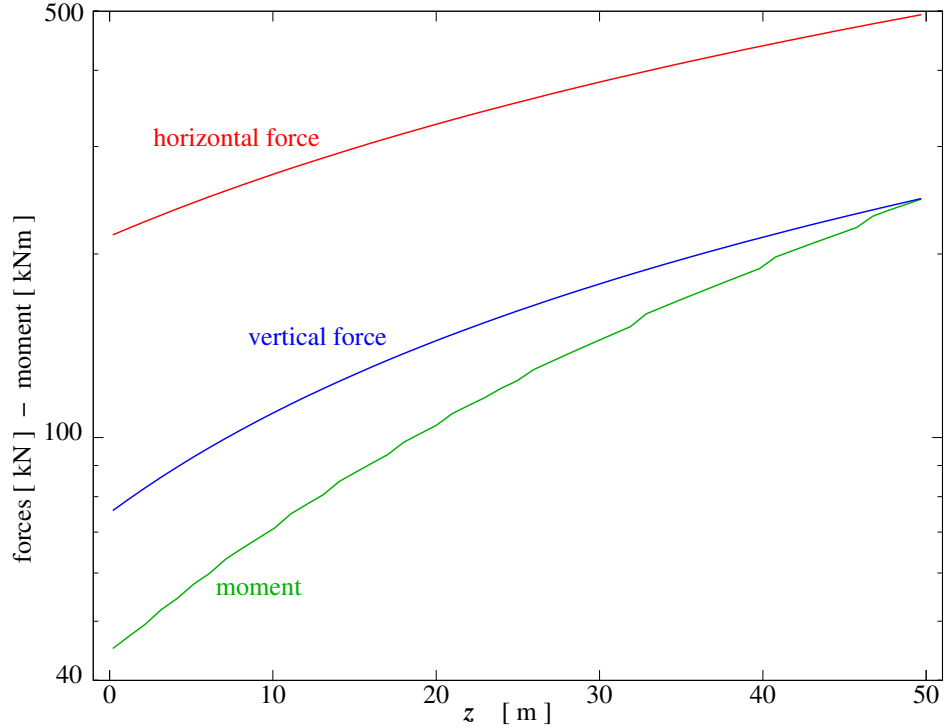


Dimensioning 4/6 : portal : corner forces and moment



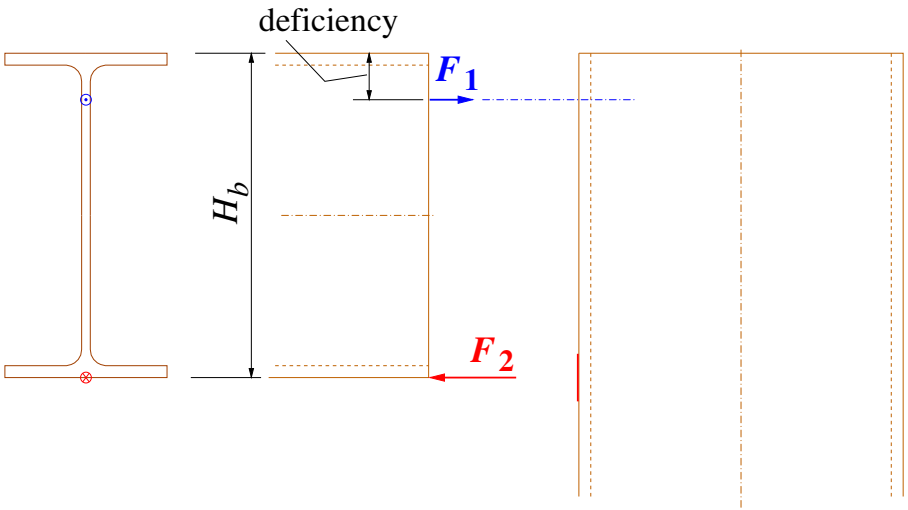


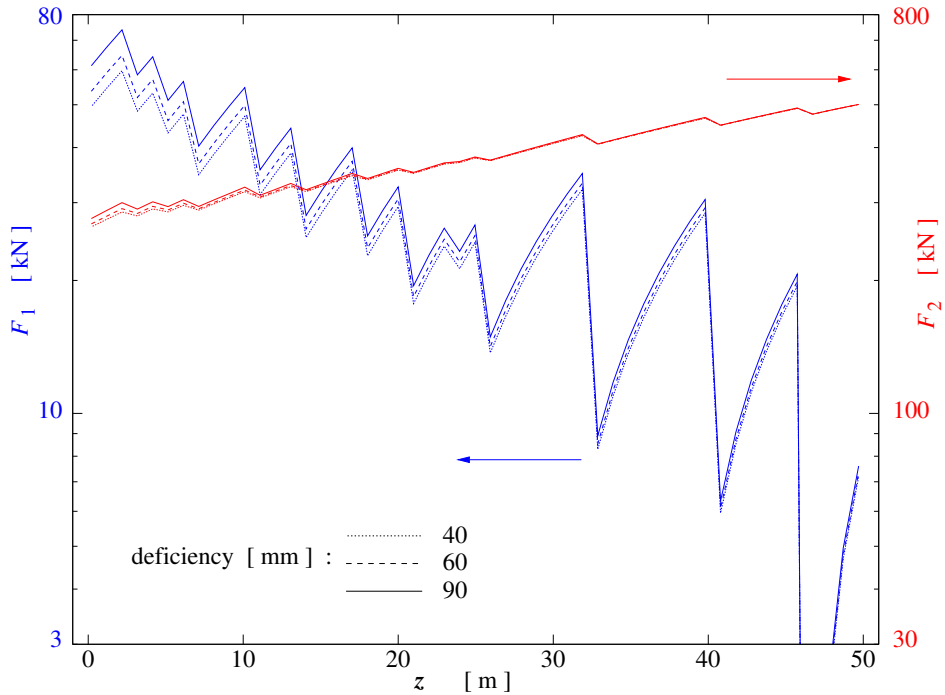




(should not have been polyline)

Dimensioning 5/6 : portal corner : connector forces



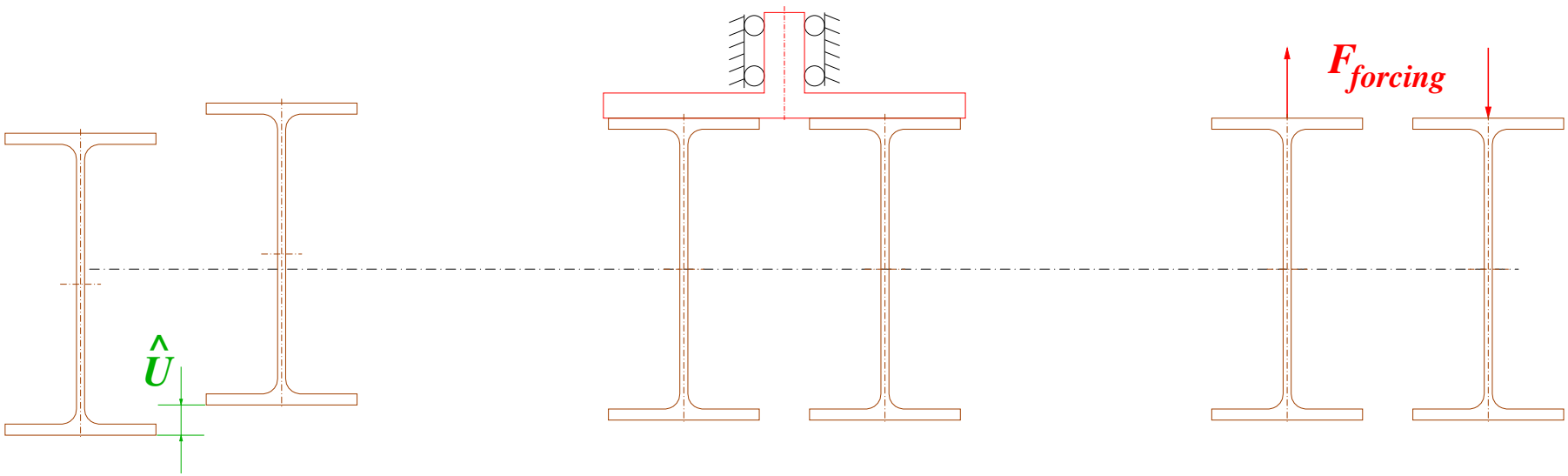


(should not have been polyline)

Dimensioning 6/6 : various

See Note for details

Elastic forcing (beams are not precise). Is possible, but tooling must be prepared.



Vacuum liner :

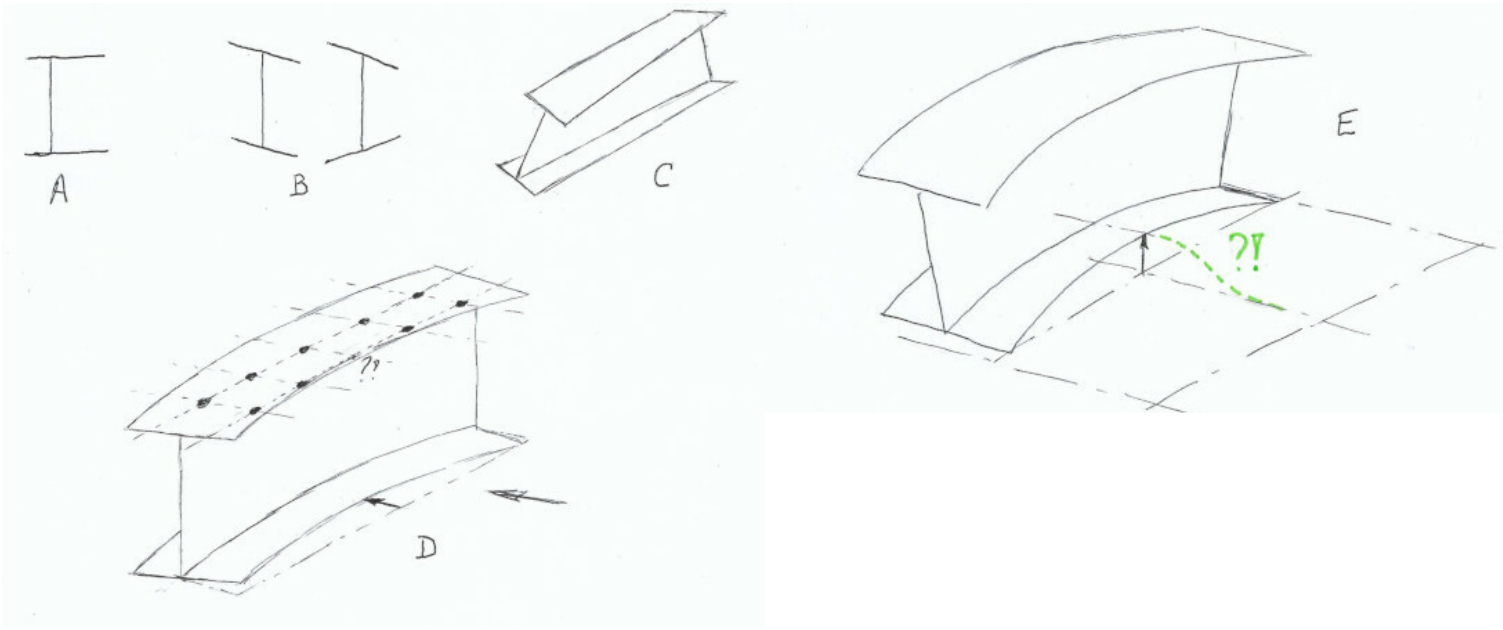
- tearing away fom beam under "vacuum" load ?
- risk of buckling under axial compression ?

Mild problems. No need for *intense* stiffening / cross-bracing.

Tolerances / machining

Sheets : machining (vacuum liner : welding lip!)

Beams : harmful : B, C, E



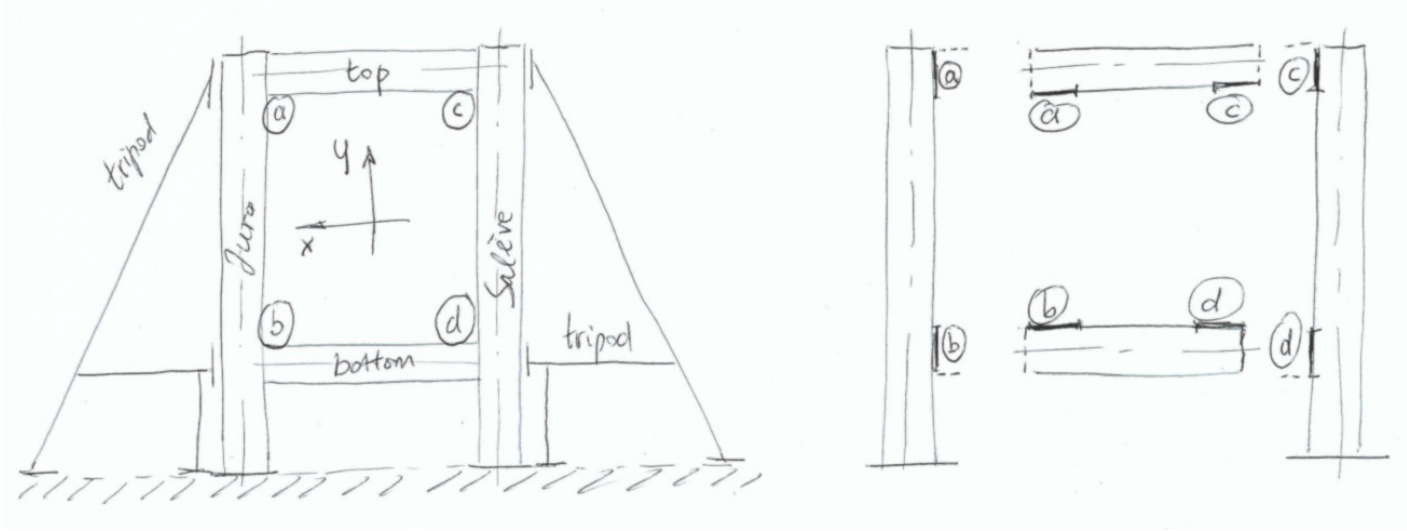
Portal preparation :

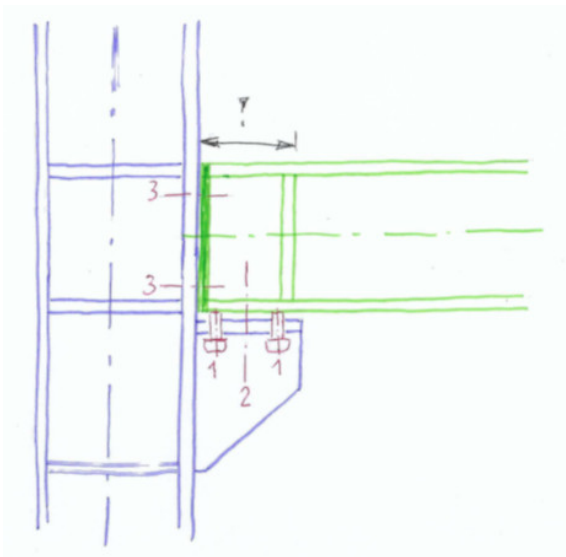
- Local stiffeners and flange plates : added by welding
- Machining : through holes (only ?? hopefully yes ; to be tested)

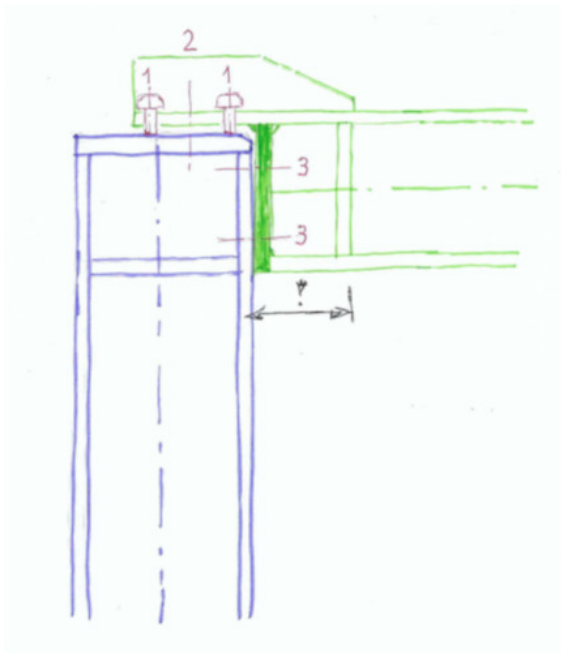
Assembly and welding :

- Items always positioned against absolute coordinates, by surveying. Never against arrest.
- Thus : no tolerance pile-up

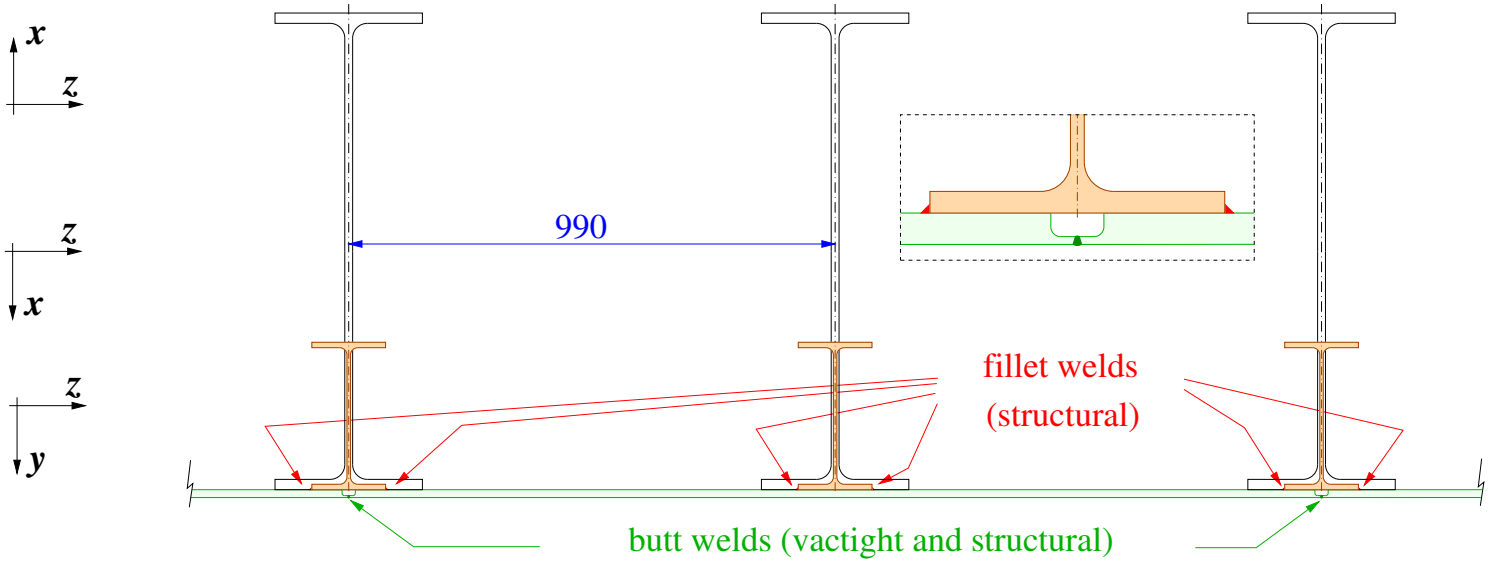
Assembly 1/3 : Portal erection

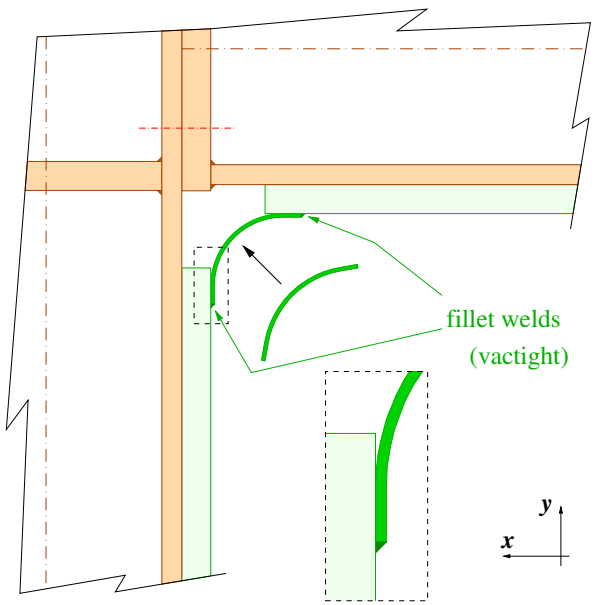


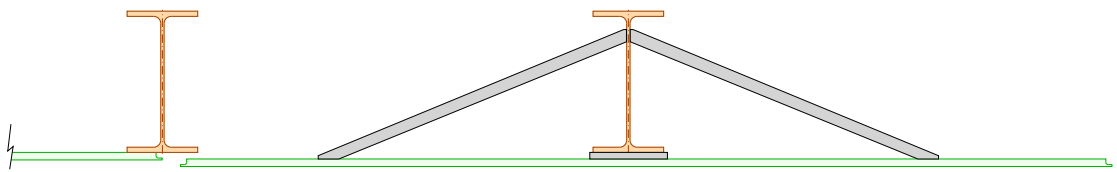




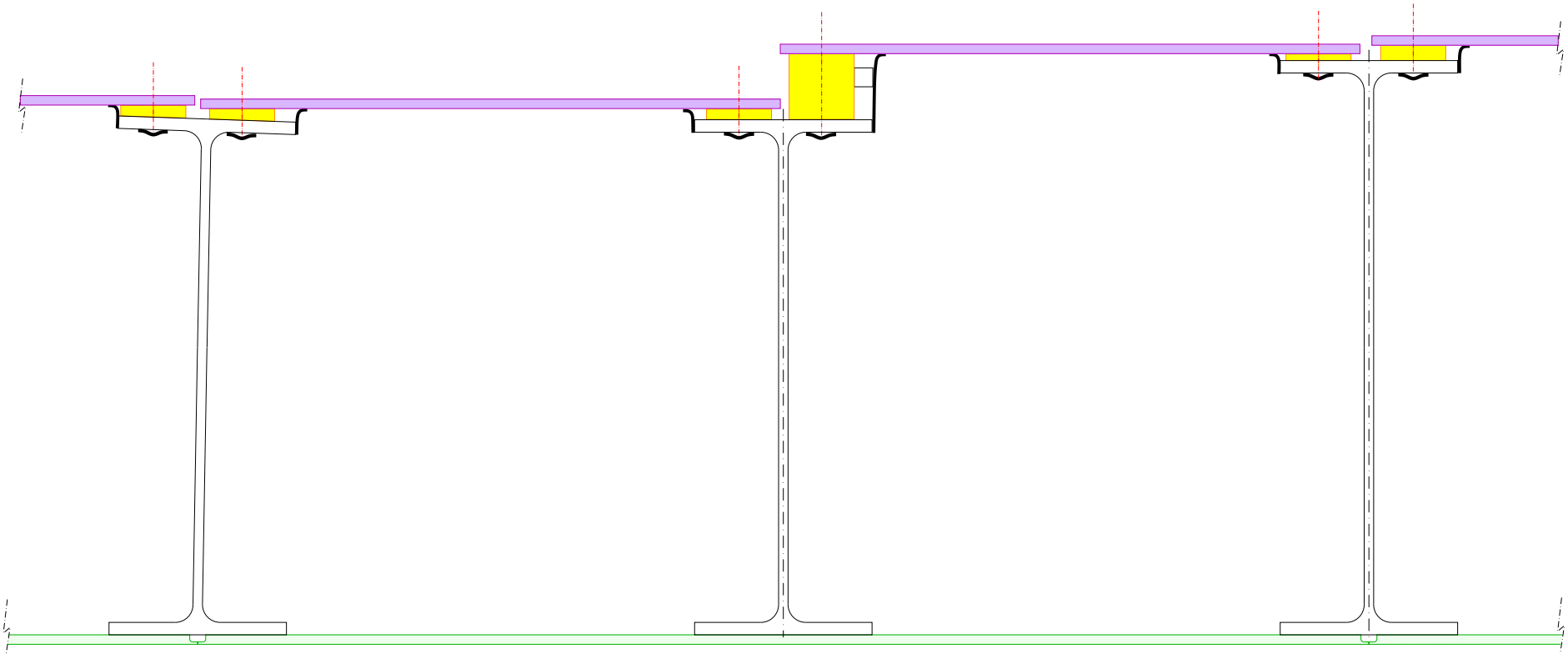
Assembly 2/3 : Vacuum liner



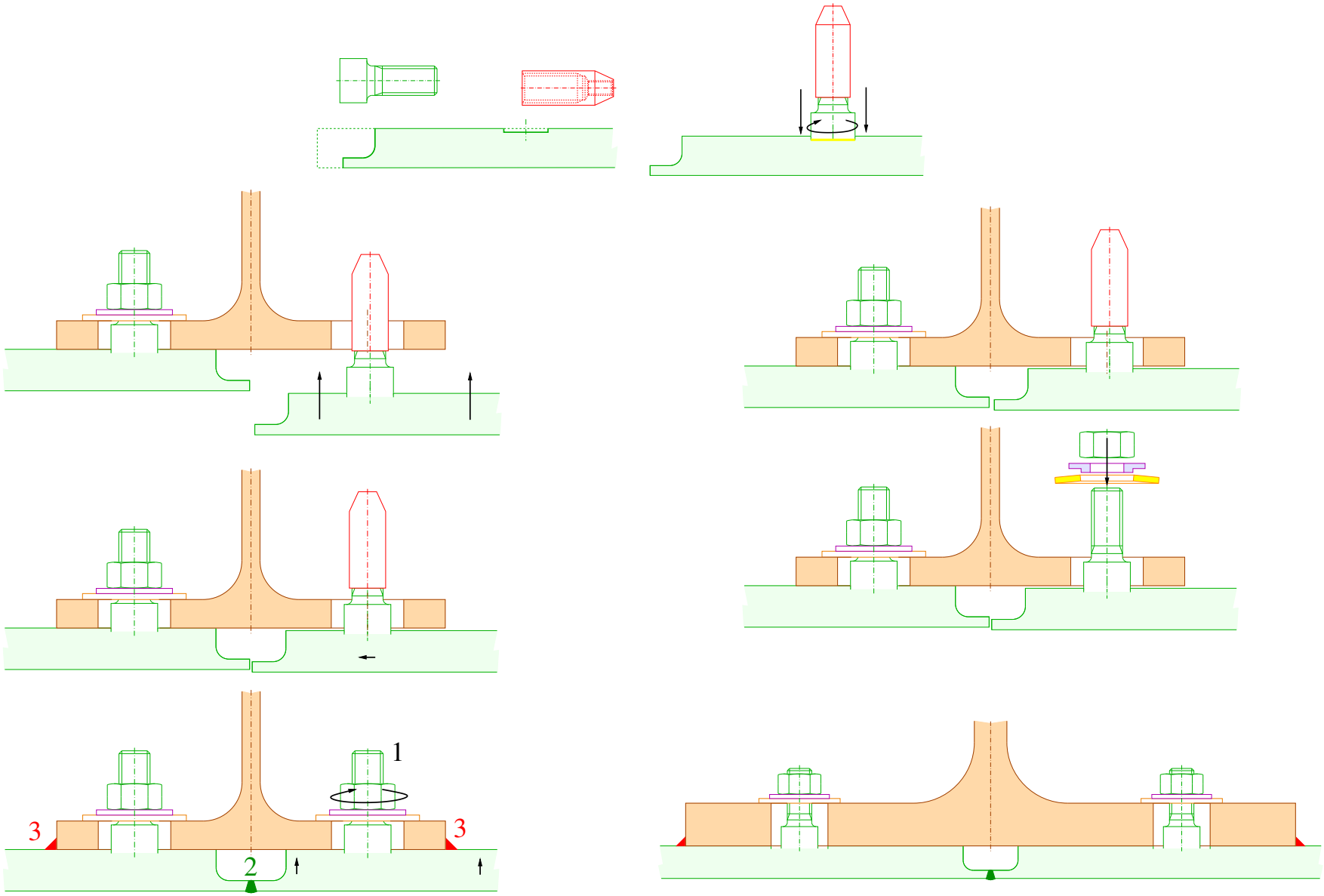




Assembly 3/3 : (Bolting of) scintillator cover

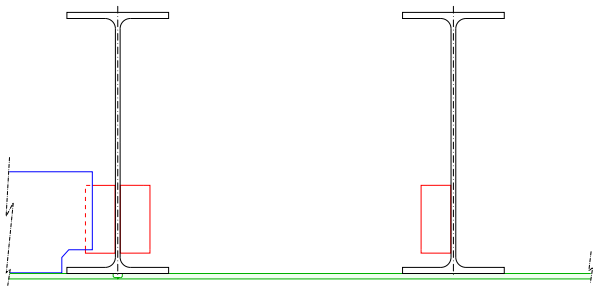


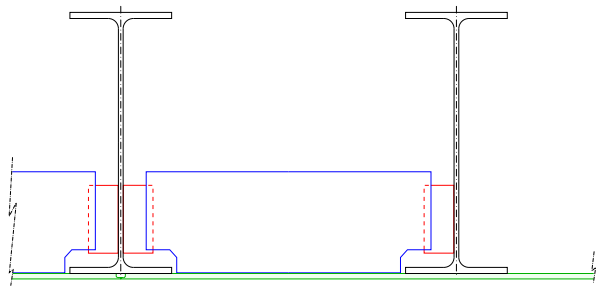
Special topics 1/4 : pull vacliner compact (before welding..)

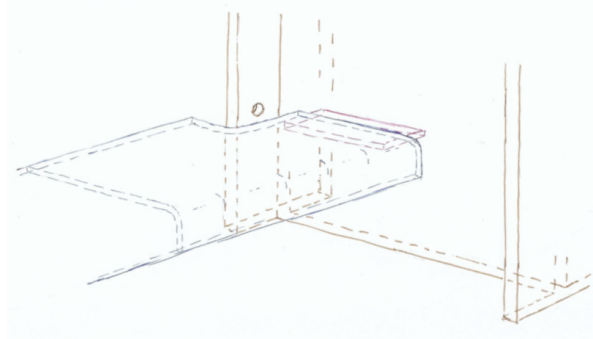


Special topics 2/4

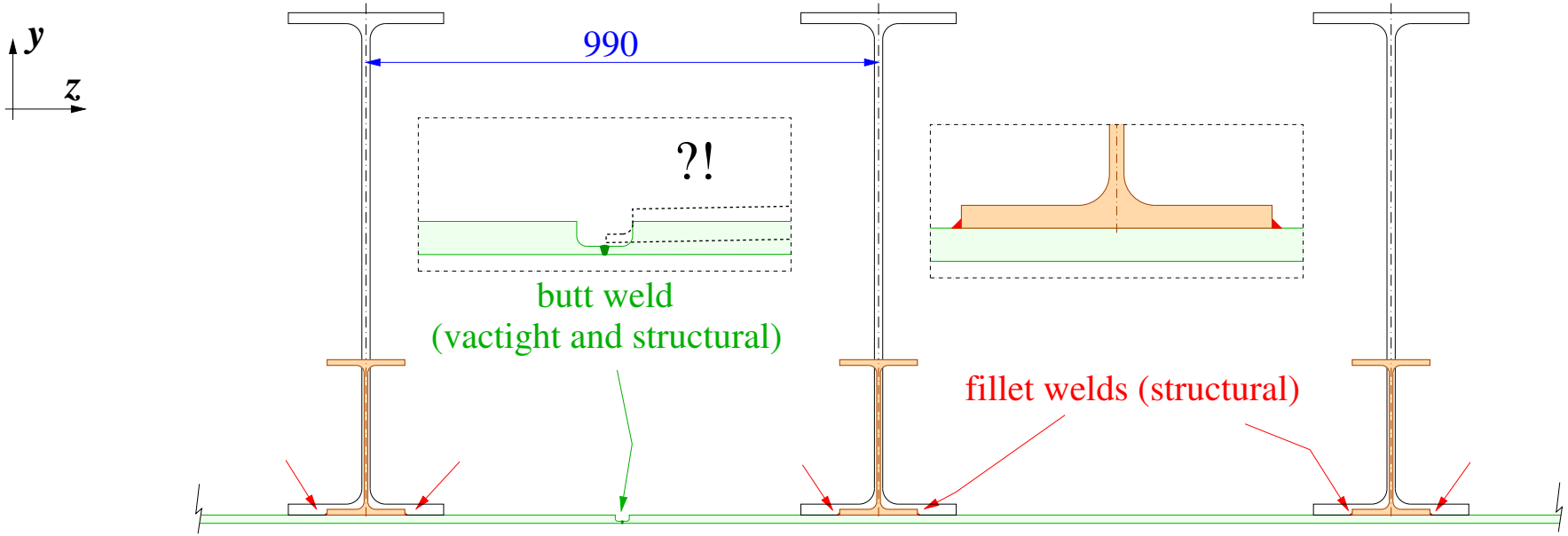
(some..) cross-bracing





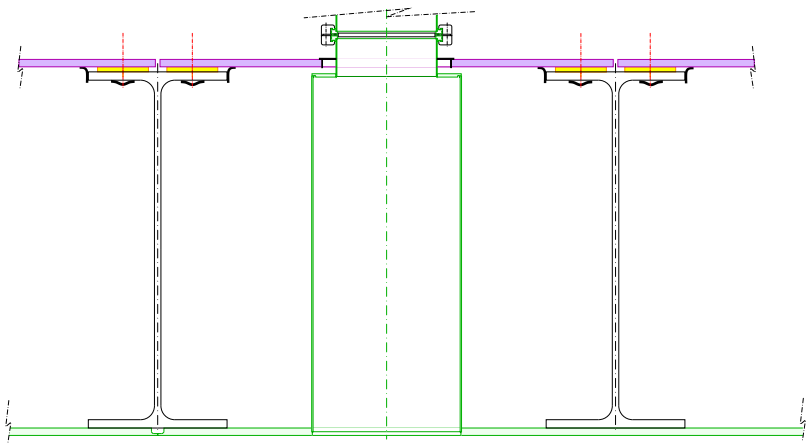


avoid over-the-head welding

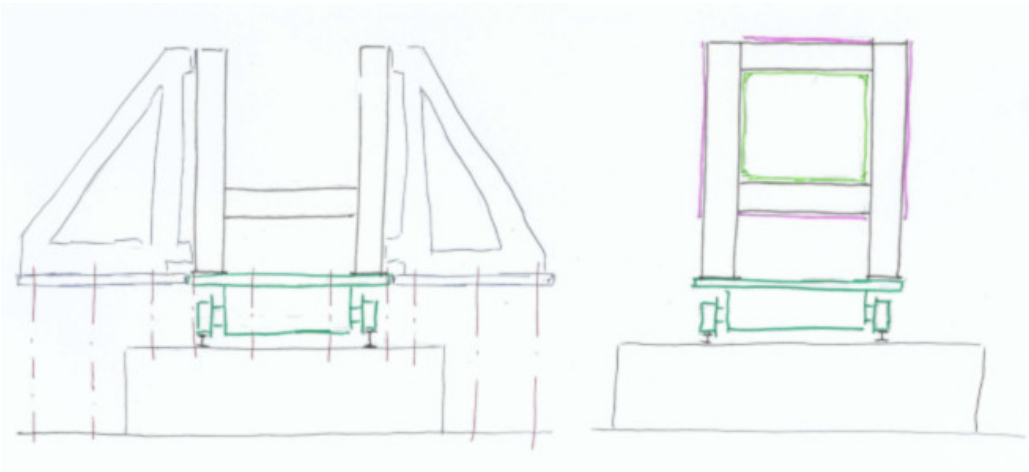


Special topics 3/4

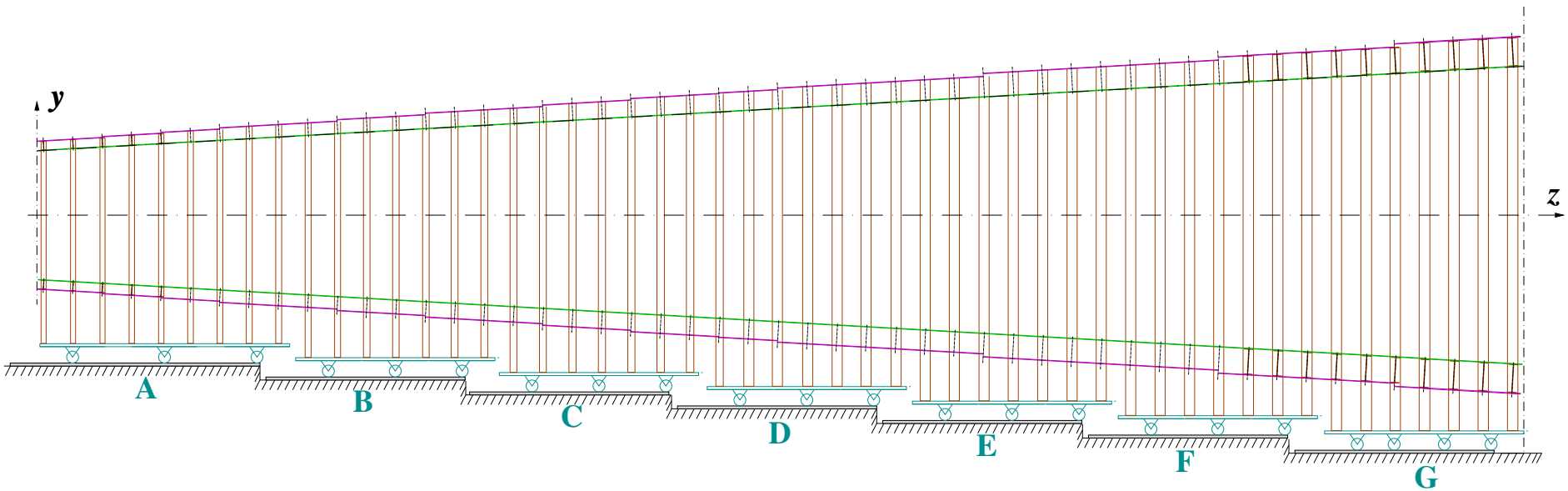
pumping stud (DN200)



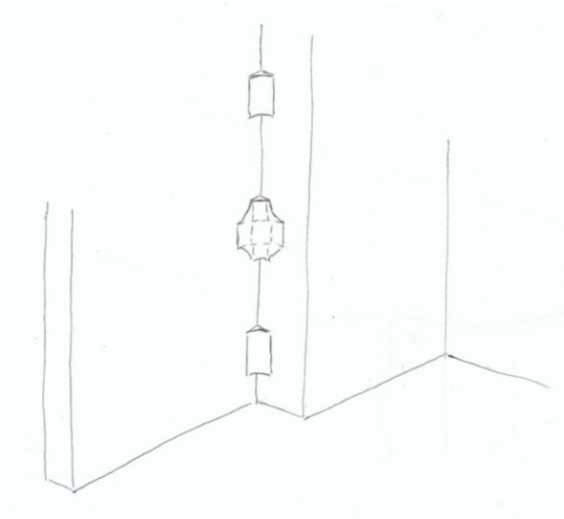
vessel parts on bogies (at height)

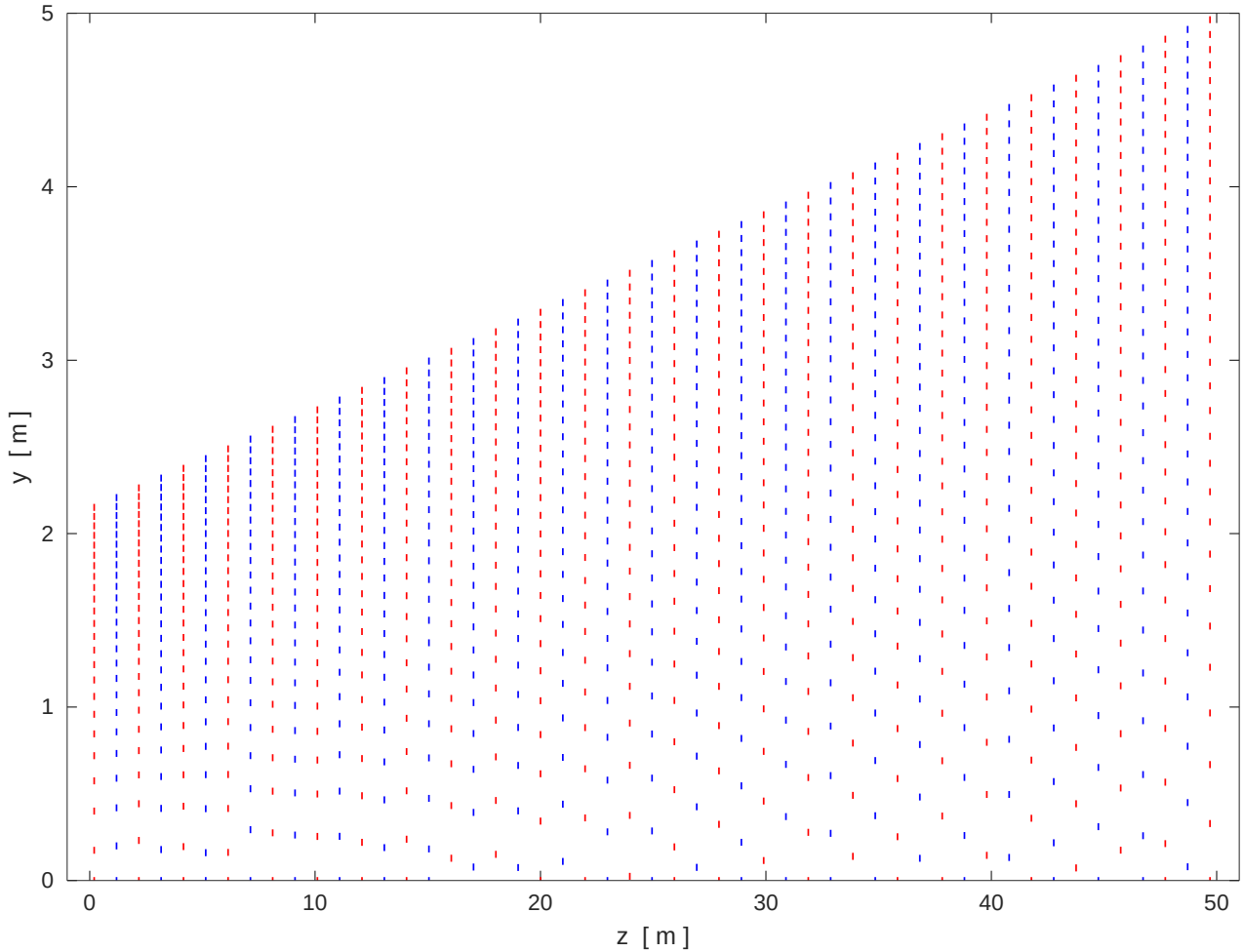


Special topics 4/4 : vessel as a train (wagon)



Appendix 1/3 : intermittent fillet welds vacuum liner to beam





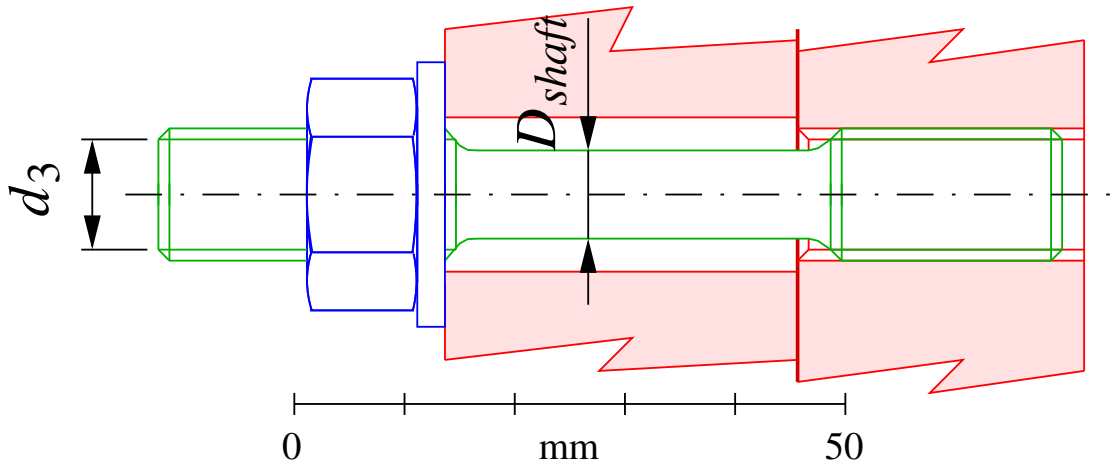
Appendix 2/3 : mass/size inventory

assigned to bogie :	y_{bogie} [m]	modules :	mass [t]
A	-4.30	1 - 9	39.8
B	-4.80	10 - 16	41.4
C	-5.29	17 - 23	52.5
D	-5.75	24 - 30	66.2
E	-6.25	31 - 37	78.0
F	-6.74	38 - 44	90.7
G	-7.25	45 - 51	122.1
grand total			**490.6**

Largest/heaviest items

item	module	notes	length [m]	mass [kg]
top/bottom beam	51	HE 1000 AA	4.98	1106
side beam	51	HE 1000 AA	13.26	2944
vacliner sheet, top/bottom	50 & 51	25 mm , 1.98 m	avg. 4.95	1936
vacliner sheet, side	50 & 51	25 mm , 1.98 m	avg. 9.91	3875
scint.cover, top/bottom	51	25 mm , 0.99 m	4.98	974
scint.cover, side	51	25 mm , 0.99 m	11.96	2339

Appendix 3/3 : pre-tensioned studs for scintillator cover



	M12 (× 1.75)	**M16** (× 2)	**M20** (× 2.5)
d_3 **[mm]**	9.853	13.546	17.933
D_{shaft} **[mm]**	8.4	11.5	15.2
$F_{n,stud}$ **[kN]**	44.3	83.1	145.2

Hydraulic tensioning cylinder :
click here for demo video (in Web browser)