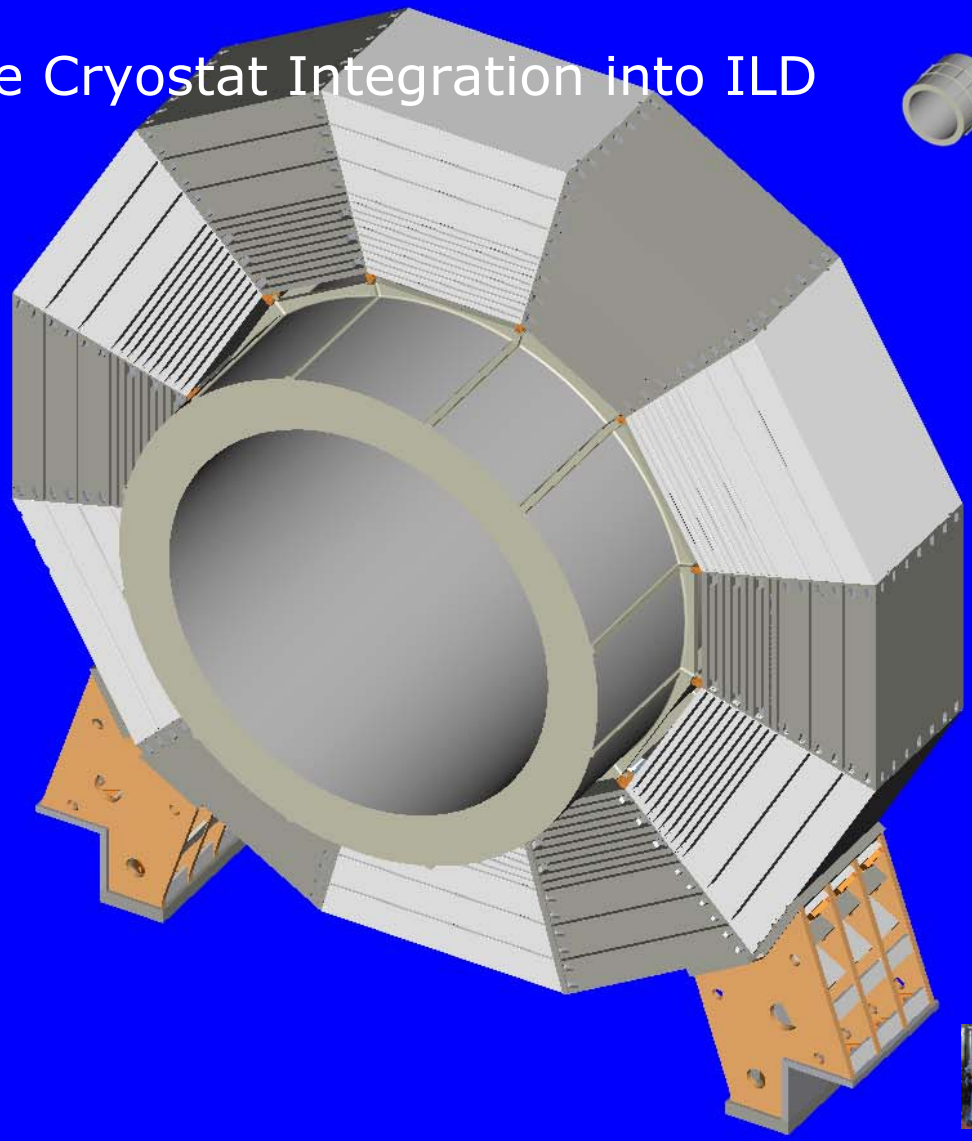
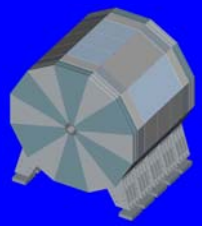
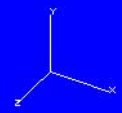
The Cryostat Integration into ILD







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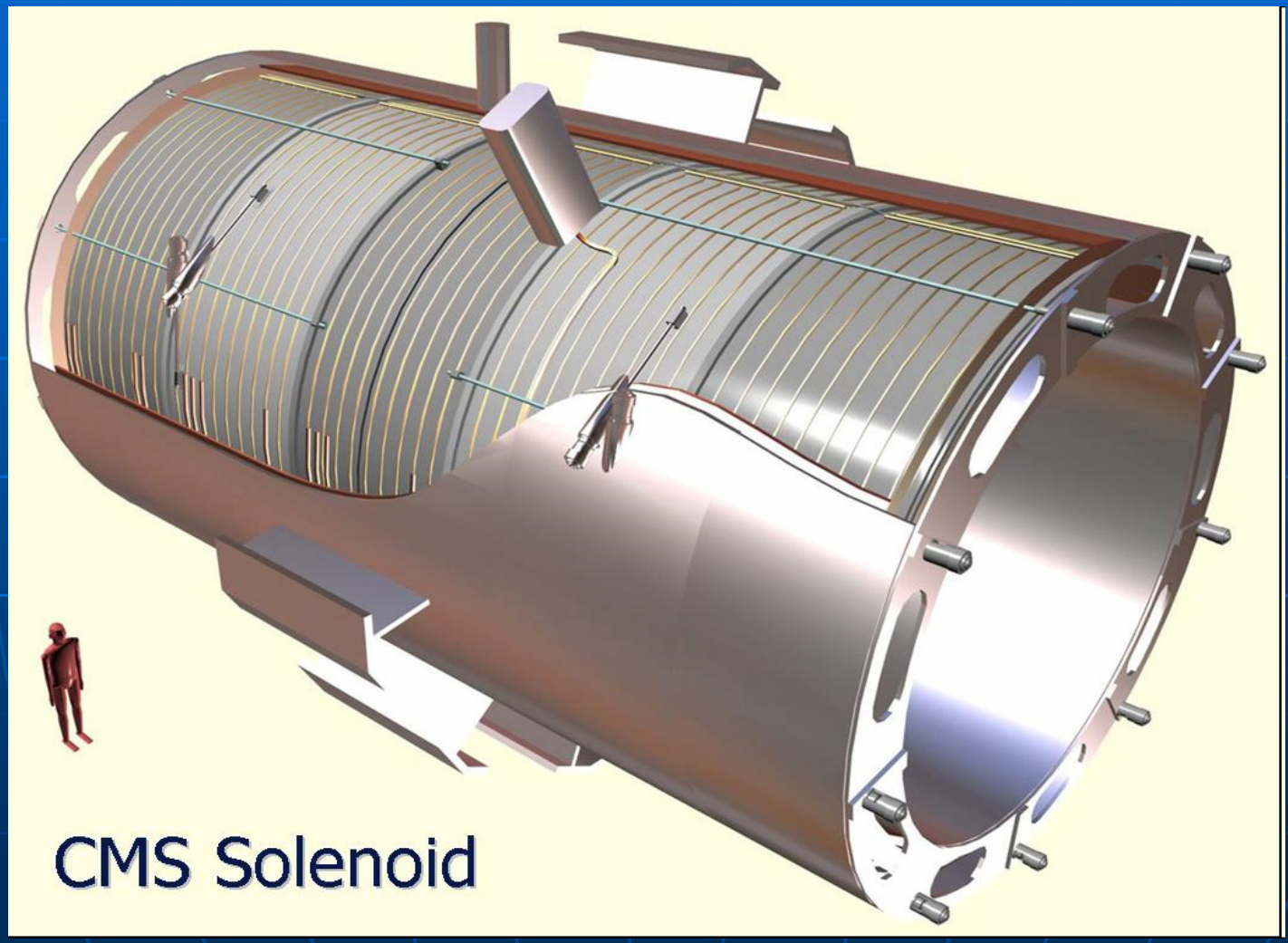
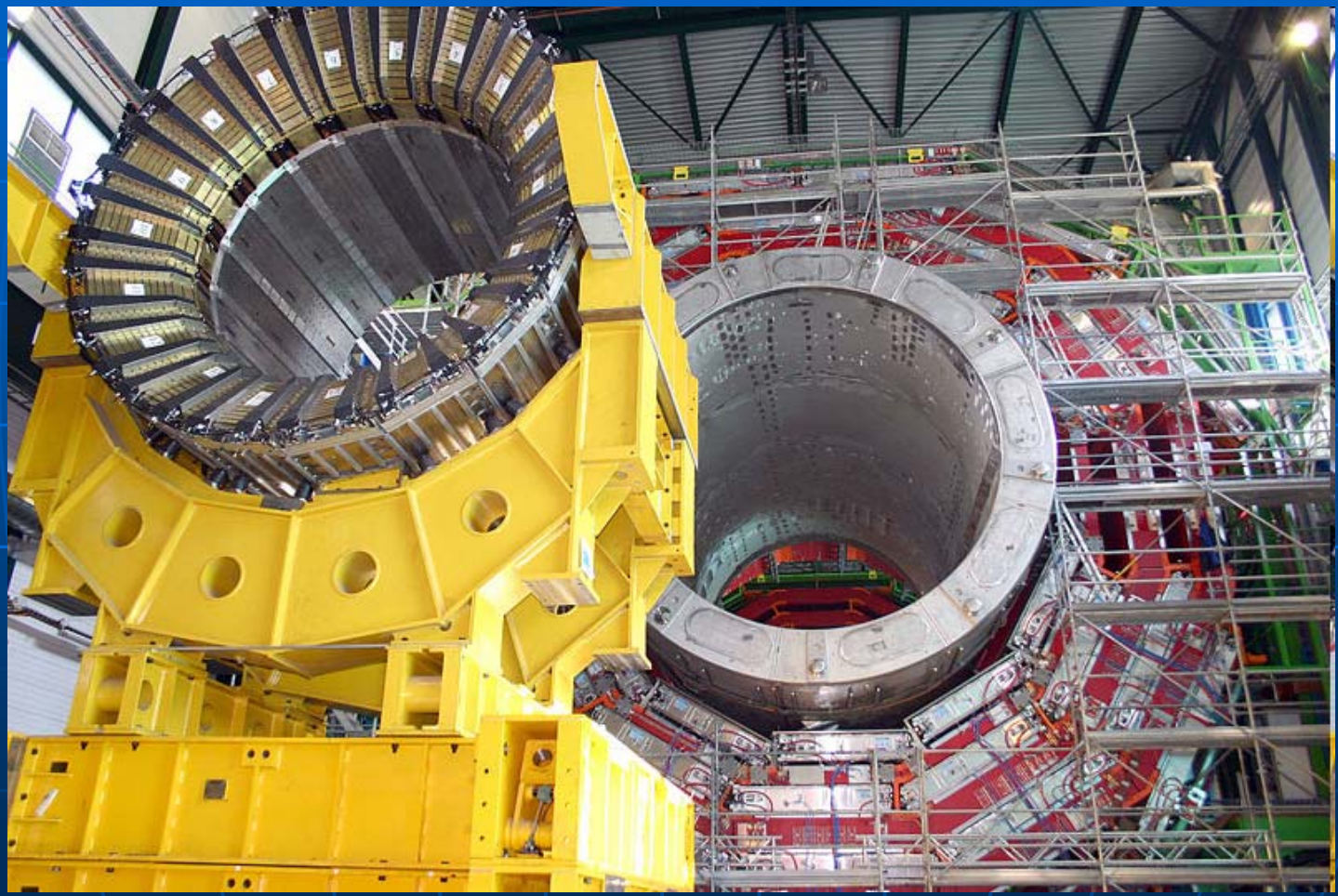
CERN CMS Solenoid schematic



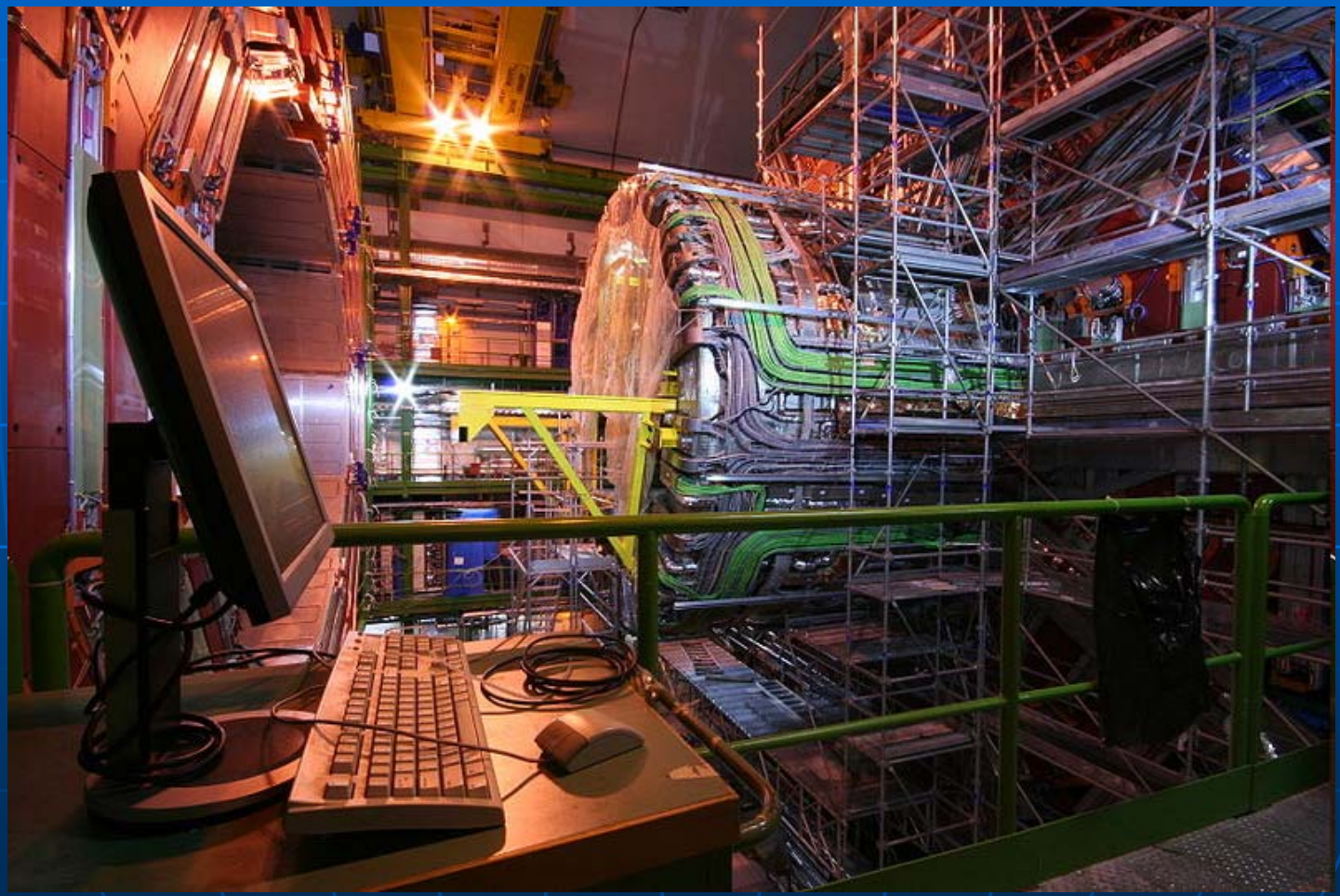
insertion of other vac-tank / CMC

the CMS centre part of the compact muon solenoid barrel with the vacuum tank

HCAL prepared for insertion / CMS



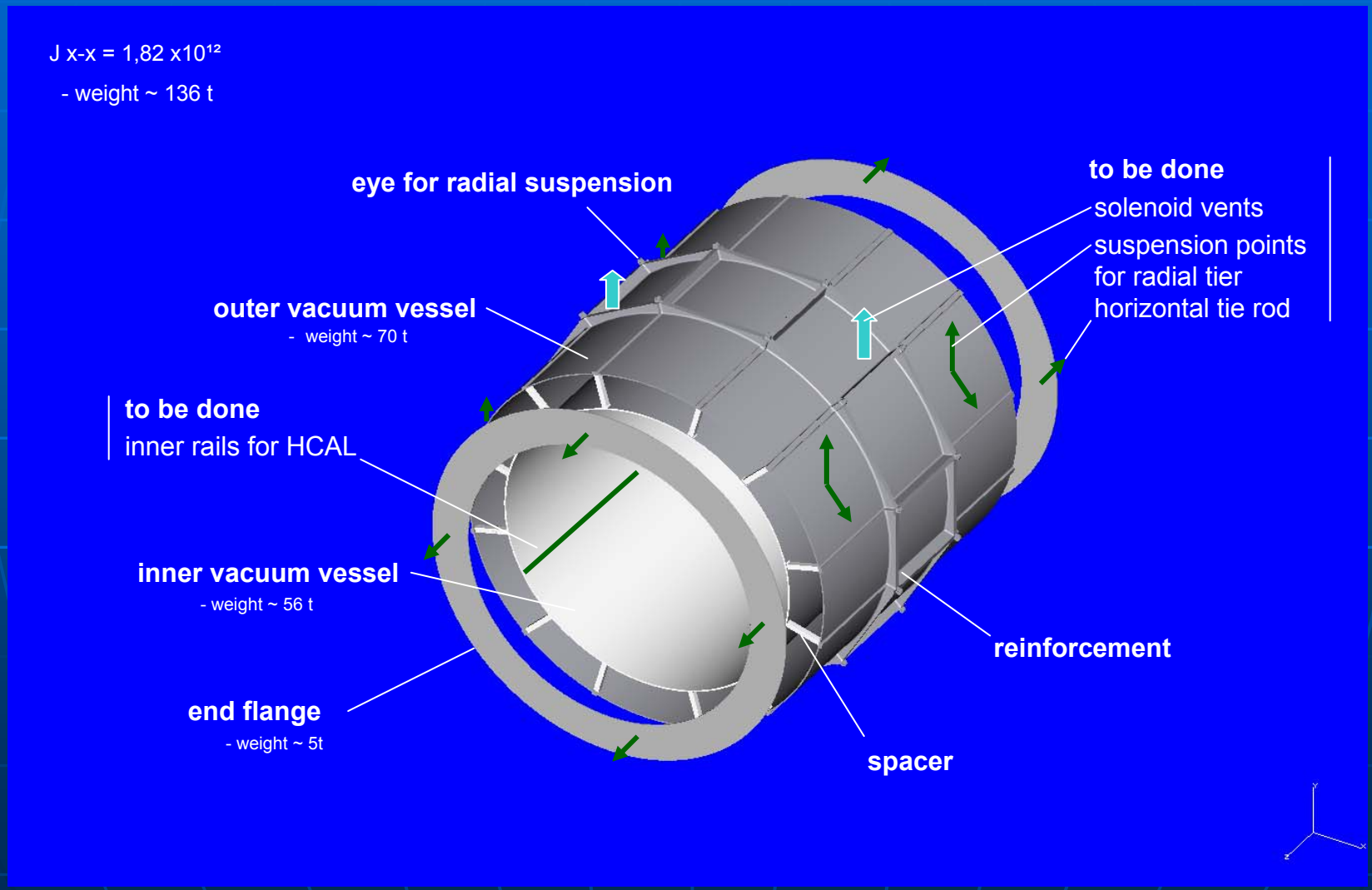
the centre part of the compact muon solenoid barrel with the vacuum tank, HCAL, ECAL, TPC and all connections



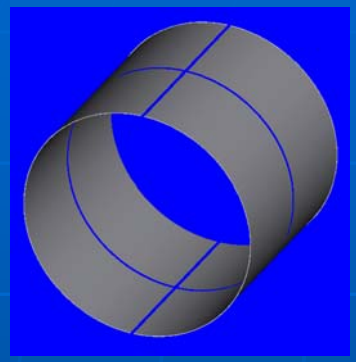
2.1 the ild cryostat structure proposal / all welded

J x-x = 1,82 x10¹²

- weight ~ 136 t

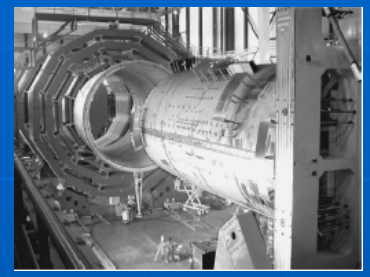


2.1.1 ILD Cryostat production schedule proposal



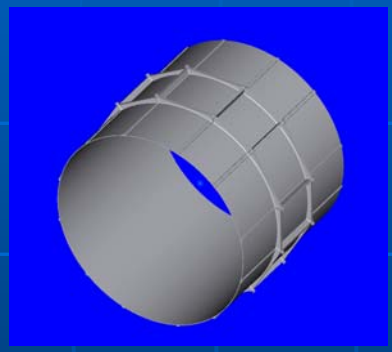
Outer-, and inner- vacuum vessel

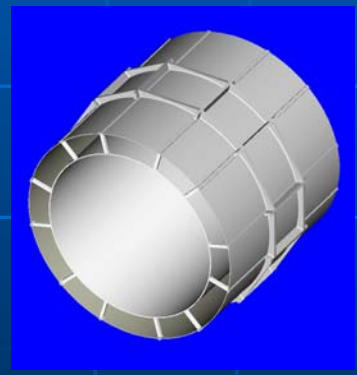
-sheet 4 or 8 (max. 13610 mm x 3905 mm, s= 30 mm)
segment rolled and welded



outer vacuum vessel

- prepared edge lined up and welded
- rotation symmetrical pilot hole diameter (ø 40 mm)
- outer reinforcements clamped to barrel and held in place by outer support
- aligned axis of ovv and barrel
- fixed ovv and welded brackets to the central barrel





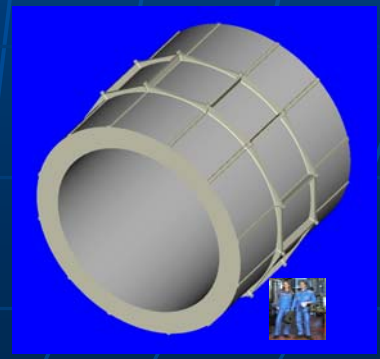
to be done

assembly cryostat to ovv

- solenoid completion and fixture

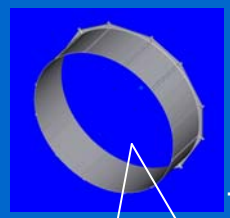
inner vacuum vessel

- sheet 4 or 8 rolled and outside scaffold
- aligned and welded
- lodge inner vv in outer vv, align rims and weld
- welding of end plate



2.1.2 Applied and resulting force, deflection line of Cryostat

-manual calculation-



outer ø 8680 / s = 30

inner ø 6880 / s = 40

(stainless steel)

7810

reaction force, resetting fixing

reaction force

reaction force, resetting fixing

F_L ~ 6000 kN

(active force)

f ovv ~ 0,5 mm

f oief ~ 0,3 mm

f oief ~ 0,03 mm

F ovv ~ 0,05 mm

F_R ~ 6000 kN

(active force)

f ovv ~ 0,5 mm

f oief ~ 0,3 mm

support

support

F_B ~ 6000 kN

(active force)

(active force)

F_A ~ 6000 kN

2868

2074

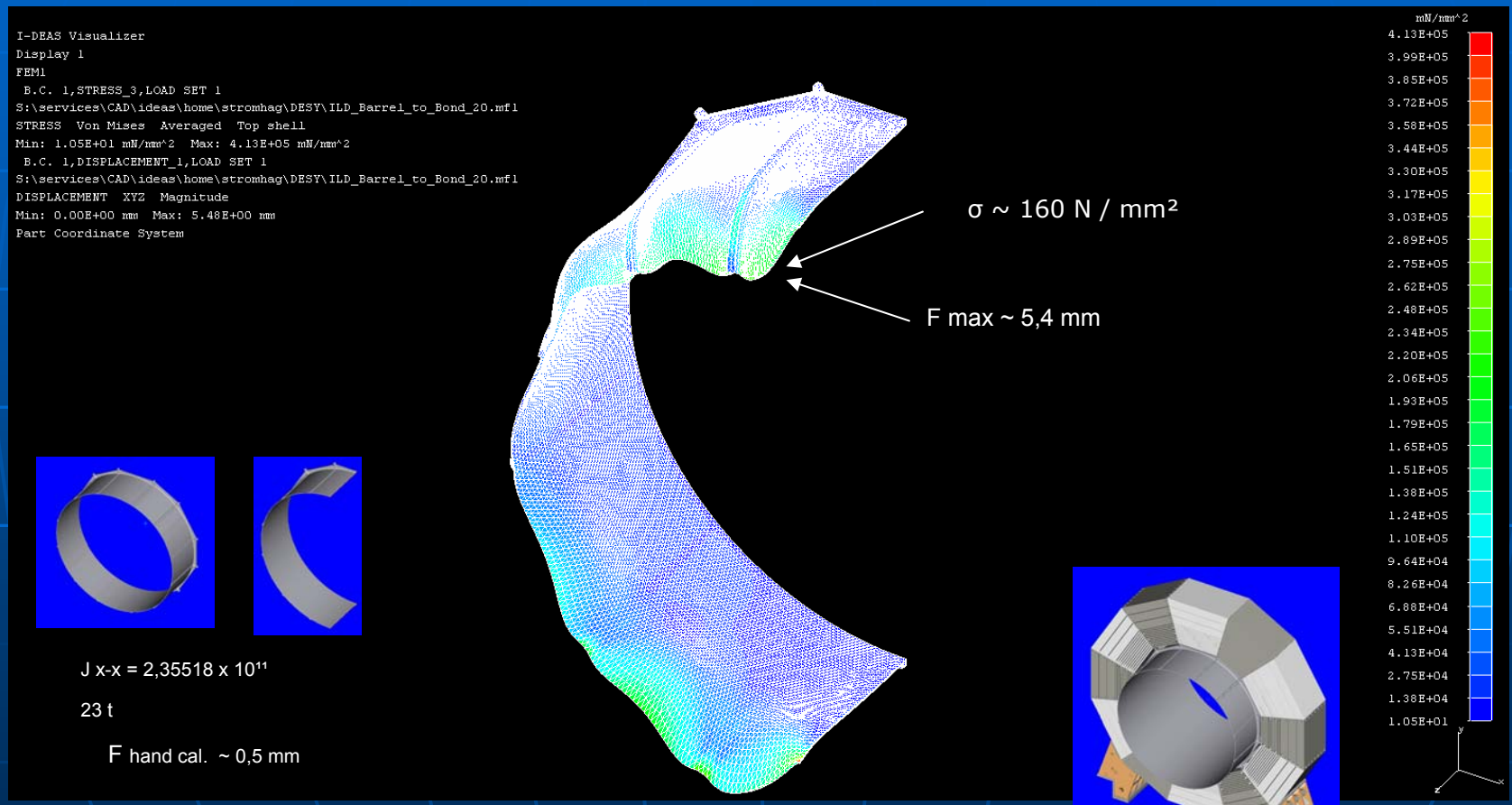
2868

1. outer vacuum vessel (ovv)
   - weight ~ 70 t
   - section modulus J x-x = 9,57 x 10^{11}
2. outer + inner + end-flanges (oief)
   - weight ~ 136 t
   - section modulus J x-x = 1,82 x 10^{12}
3. cryostat weight total ~ 360 t
4. HCAL, ECAL, TPC ~ 710 t

∑ ~ **1200 t**

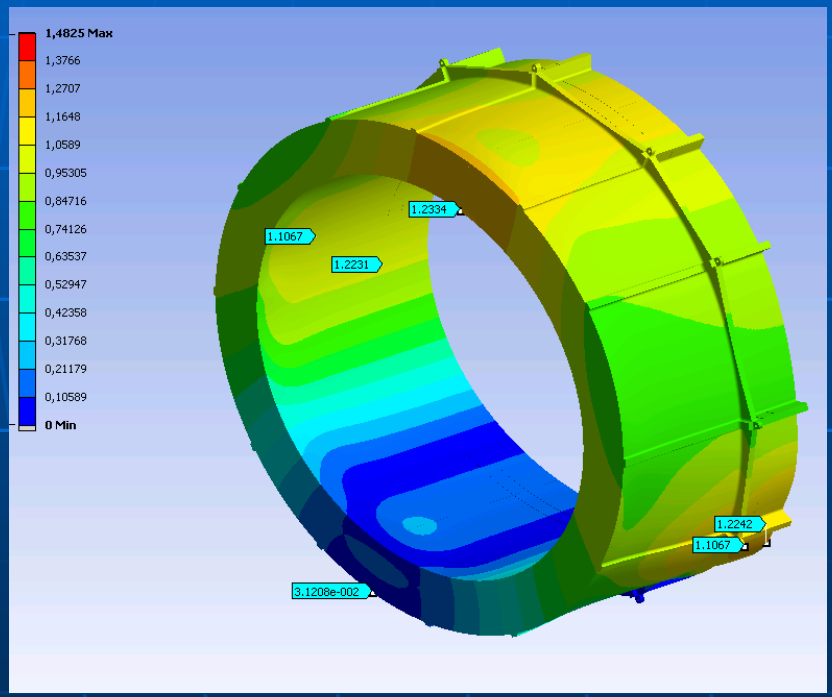
2.1.3 ILD Cryostat IDEAS FEM simulation

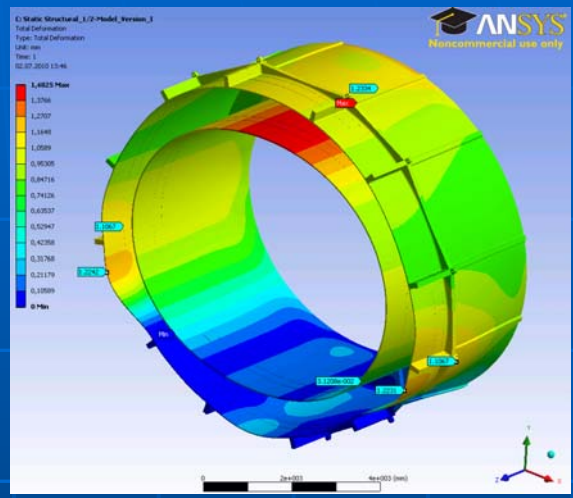
only end half part 2868 lg. / F = 3000 kN constant off-circumference

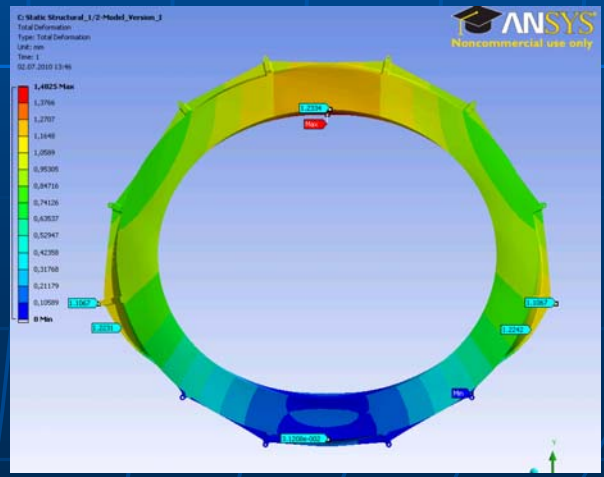


ILD Cryostat with “ANSYS” FEM simulation

max. deformation 1,3 mm



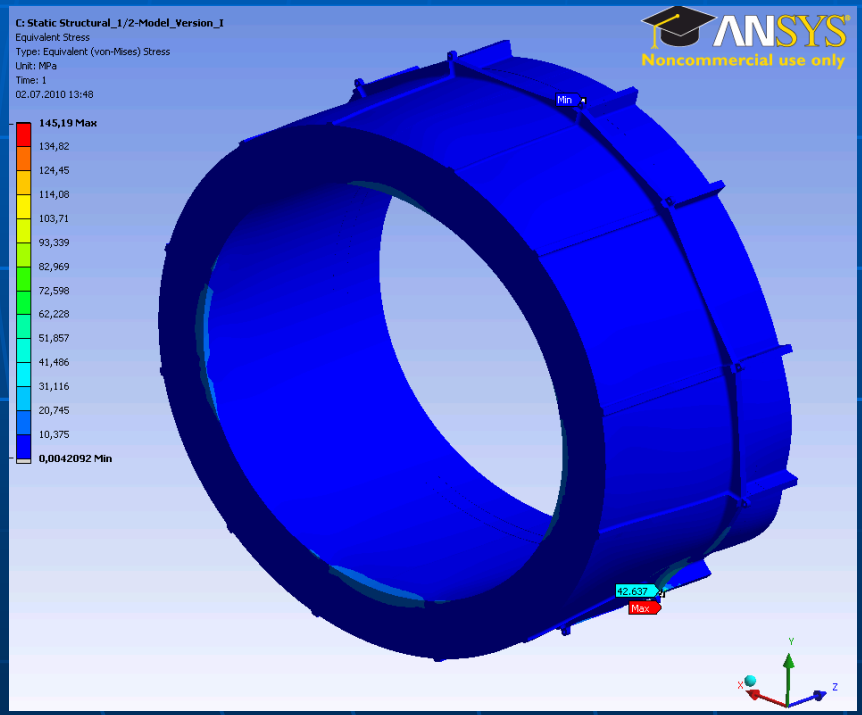


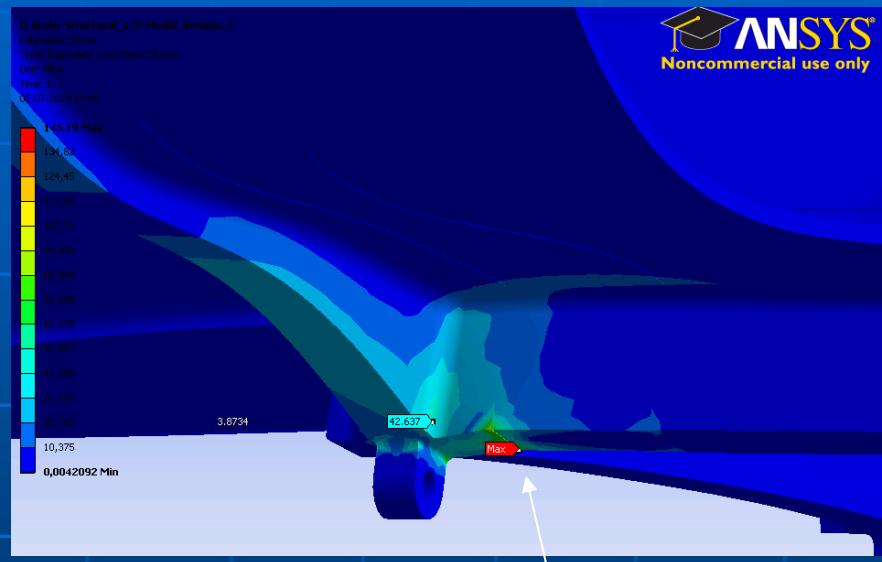


All deformation without + 30% safety factor,

- to be inaccuracy meshing.

ILD Cryostat total stress “ANSYS simulation”

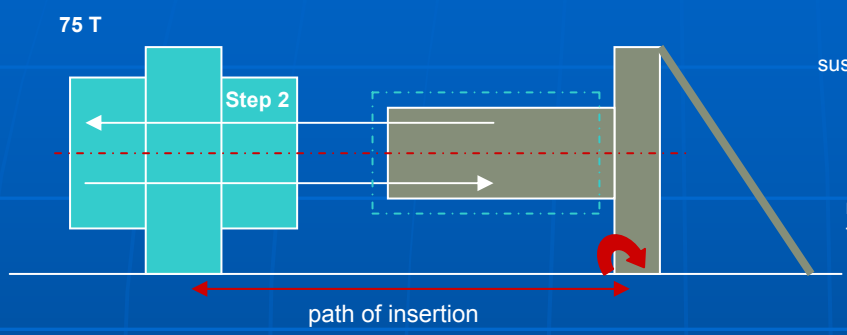


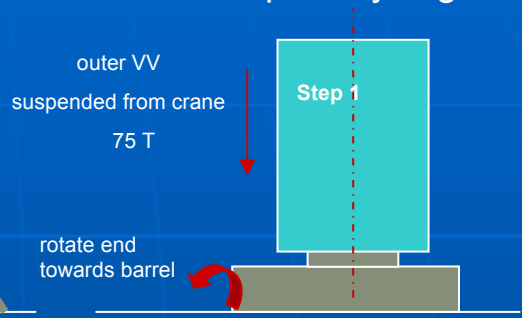


max. stress ~ 50 N/mm²

3.1 Solenoid assembly completion in ILD Central Barrel
- method similar to CMS -

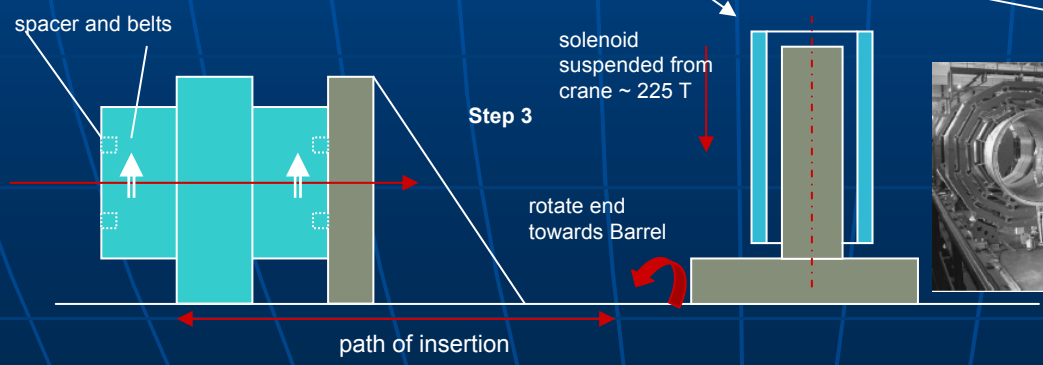
1. outer vacuum vessel (75 T.) with barrel after installation on turn table, primary alignment

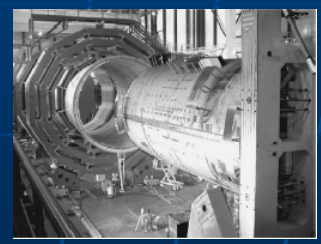


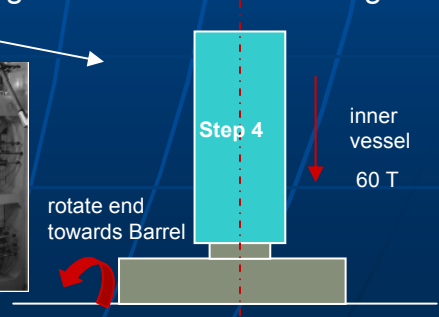


2. assembly and completion of the solenoid (~ 225 T)

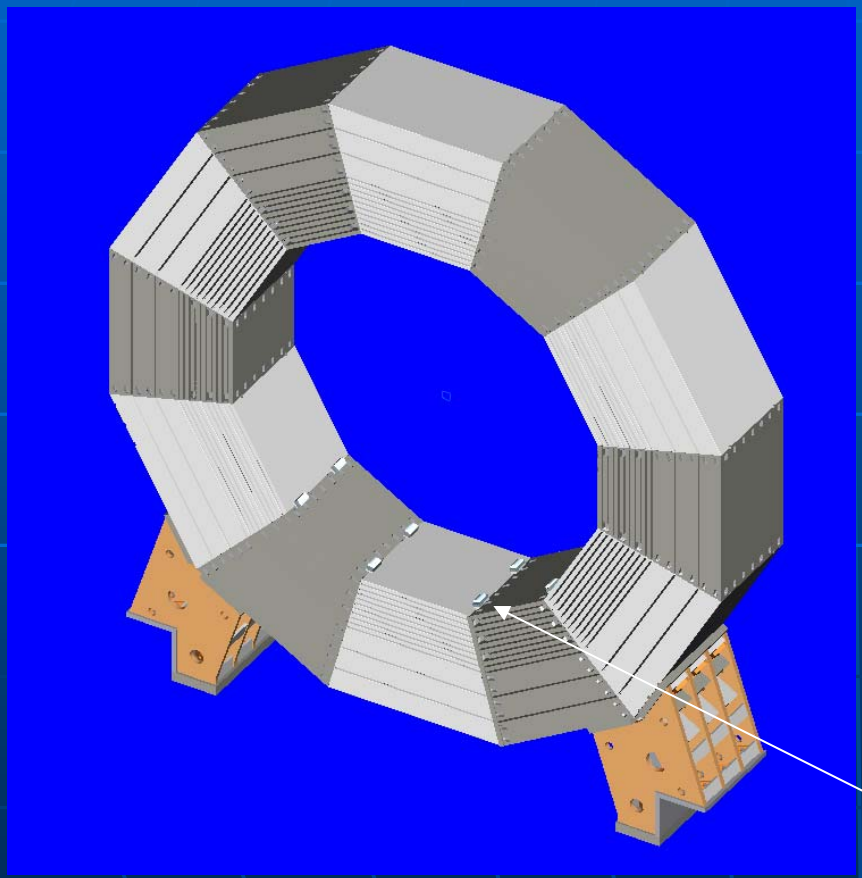
- rotate inner vacuum vessel into horizontal position => welded radial tiers and end flange
- vertical assembly of the inner vacuum vessel
- rotation of the Inner vacuum vessel in horizontal position
- welding radial tiers and end flange

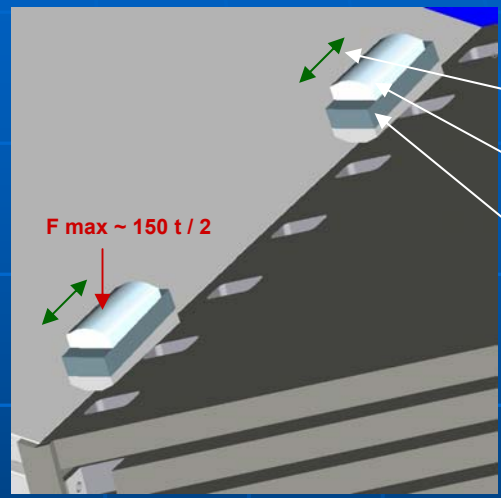






4.0 Operation schedule for Cryostat completion in ILD central barrel
- installation of adjustable integral key with 3 DEG angle bracket footings -





allowable pressure

S235JR (St37) R_{mN} ~ 360 N/mm²

yield point $Rp_{0,2N}$ ~ 235 N/mm²

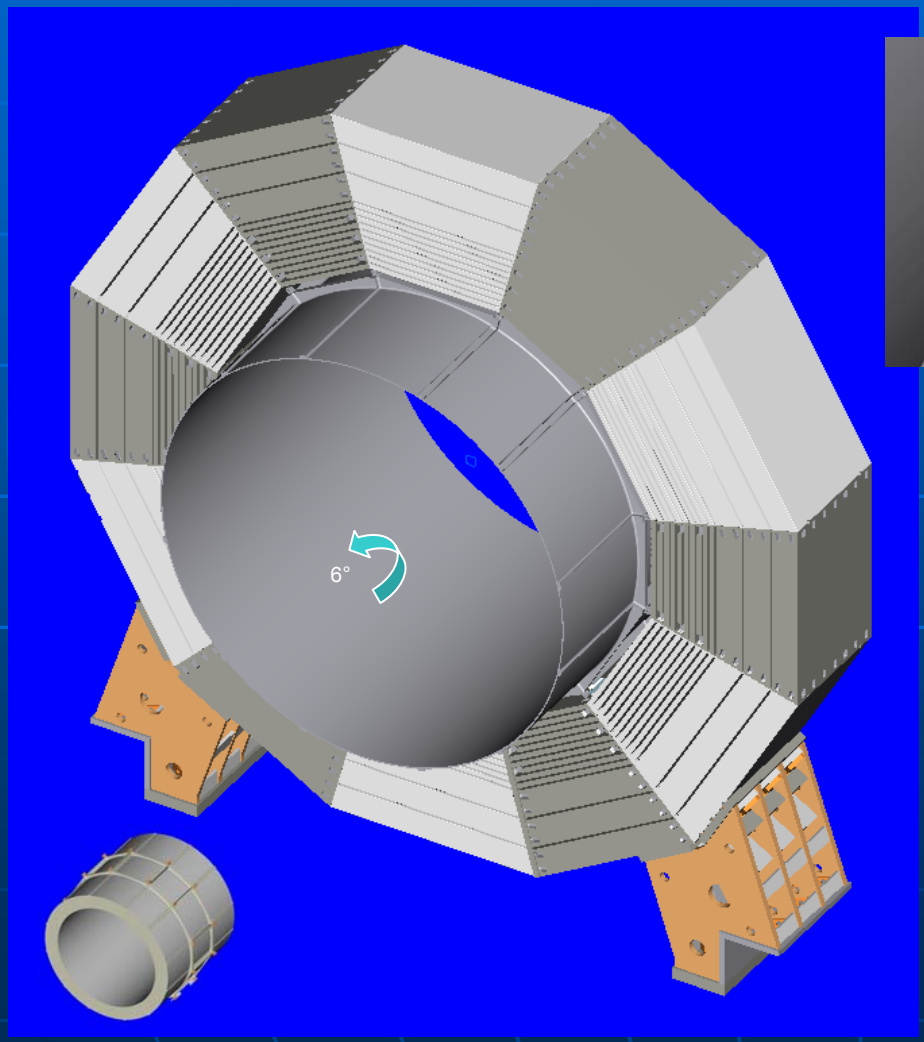
σ_{dB} ~ F / A ~ 75 000 0 N / 8 x 500 (mm) ~ 188 N/mm²

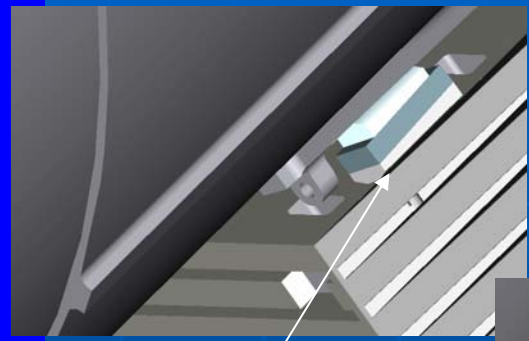
without preparatory work, full yield settling ~ 0,8 mm

Installation of "jacking up to line" keys with hardened plate to primary alignment (integral key ~ 3deg), shown in position (8 units)

4.1 Lifting outer vacuum vessel off jacks and final alignment in ILD Central Barrel

- alternative: each support is fitted individually and then welded to Barrel -





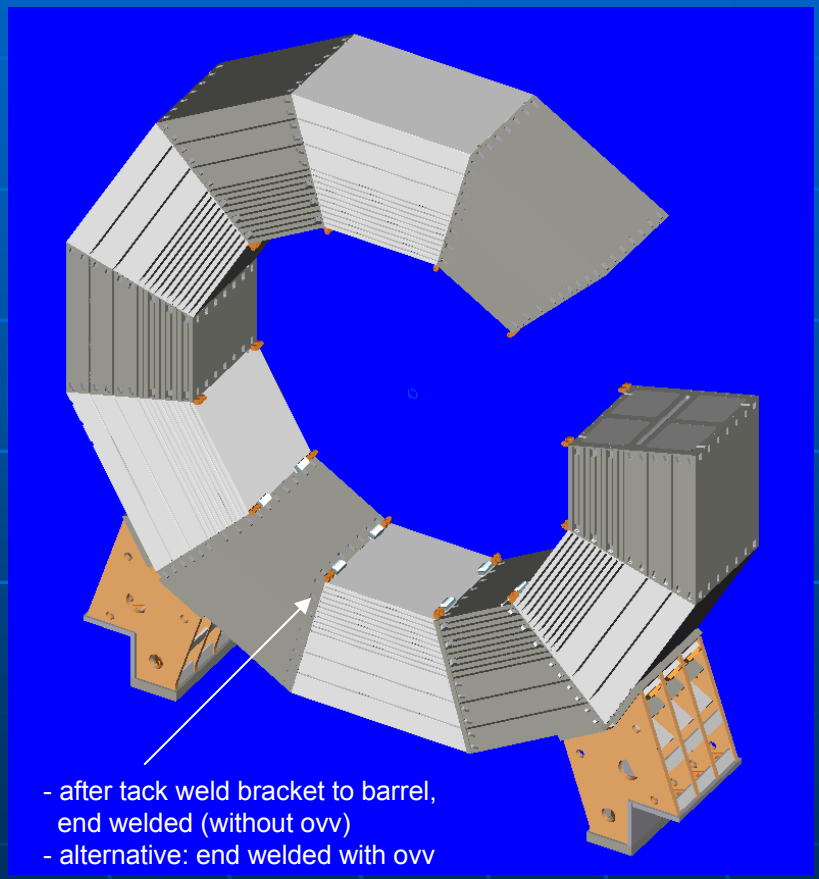
-after primary alignment

- tack weld each bracket to barrel individually,
- from point to point to fit and tack
- fit screw between barrel and ovv
- all bracket to barrel tack welding
- remove circular 6° ovv from barrel
- all bracket end welding

(alternative: welding without removal of ovv)

4.1.2 Bracket after adjustment- and tack welding,

- bracket after tack and final welding -

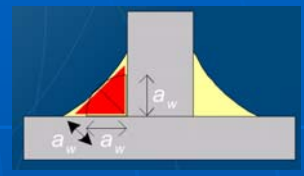


- after tack weld bracket to barrel, end welded (without ovv)
- alternative: end welded with ovv

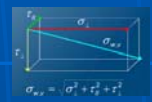
Reference is data sheet DVS 0705 / DIN 18800

welding seam: aw ~ 35 mm,

l = 80 mm, Aw = 2800 mm²

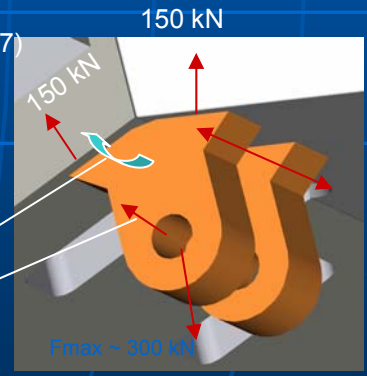


steel: S235JRG2
Rm ~ 360 N/mm²
Re ~ 215 N/mm²



stress reference value

σ ll ~ 18 N/mm²
σ ⊤ ~ 32 N/mm²
ζ ll ~ 32 N/mm²
ζ ⊤ ~ 32 N/mm²
σ exist ~ 48 N/mm² < σw ~ 207 N/mm² (St37)
(factor ~ 4)

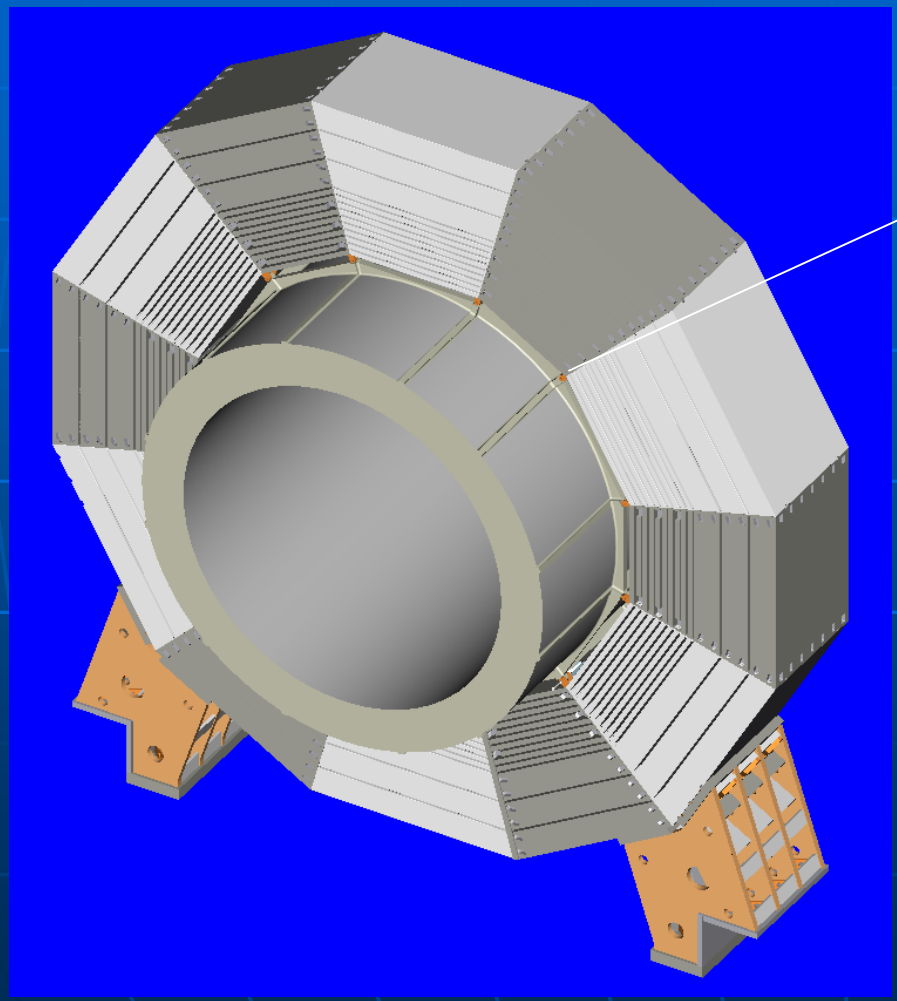


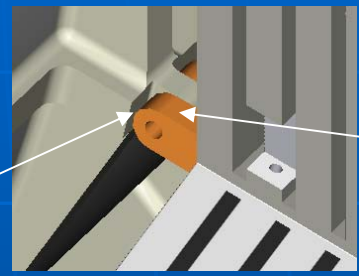
M bending moment ~ 19500Nm

F axial ~ 150 kN

σ normal stress ~ 152 N/mm² < σ tol. ~ 195 N/mm²

5.0 Cryostat integration in central barrel, final installation - outer vacuum vessel end fixing in central barrel -

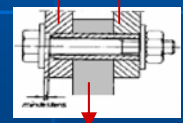




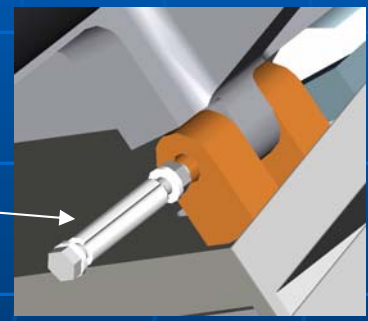
Assembly boring of ø 50H¹² mm bracket in combination with Cryostat eye

fix with friction bolt DIN 1481 - ø 50 x 240 lg. hexagon head bolts with large head (HV) DIN 6914 – M30 x 300 comply with washers and nuts

Fa ~ 300000 N Fb ~ 300000 N



Fr theory ~ 600000 N
Fr applied under 600000 N!
Surface pressure 65 N/mm²



shear stress factor ~ 2,5 (1,2 is ok)
surface pressure 125 N / mm²

S235JR ~ 235 N/mm² > 125 N/mm²

pressure factor ~ 1,8 (1,2 is ok)

friction bold DIN 1481
shearing force max ~ 1685000 N
Account: 20 friction bold to lift 1200 t

tightening screw condition:
hydraulically operated in sequence for 24 bold
DIN 6914 – M30 x 300
M ~ 1650 Nm, Fv ~ 350 kN

6.0 structural force / static

Manual calculation with neutral line (“Fp”) in parallel key to barrel segment

F_G centre of gravity = 11250 kN

F_C cryostat = 12000 kN / 2 = 6000 kN

F_A = 4300 kN

F_B = 13000 kN

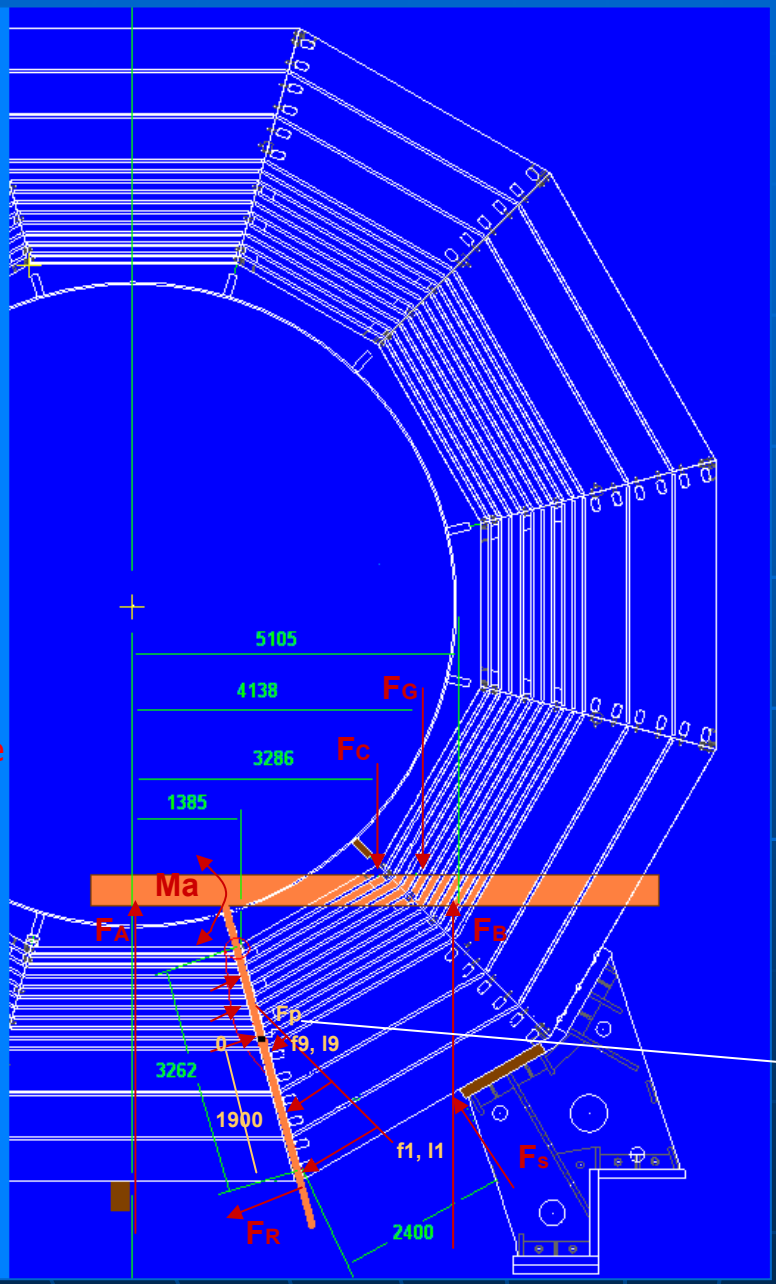
M_a moment = 6000 kNm

F_S = 12000 kN

F_R resulting force = 17000 kN

F_P fictitious pressure point (Roloff / Matek Kap.8.4.5)

Shows the Simplified external force acting on barrel and connecting screws

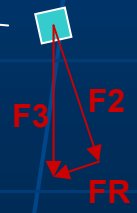


FR = 16300 kN

F2 = 15700 kN

F3 = 4200 kN

Parallel key (Fp)



6.1 The location of the neutral line from keys to barrel

the FEM simulation with CAD IDEAS and manual calculation

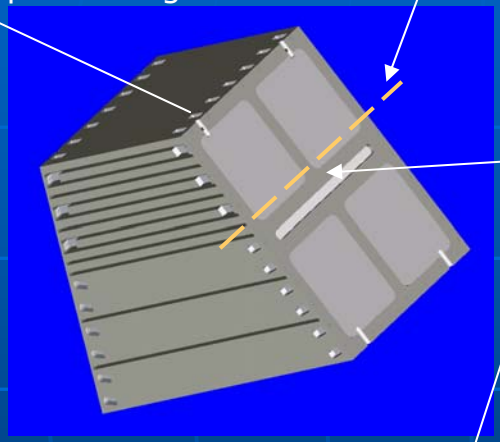
- 6.0 continues neutral line area “Fp” -

Transverse force support,

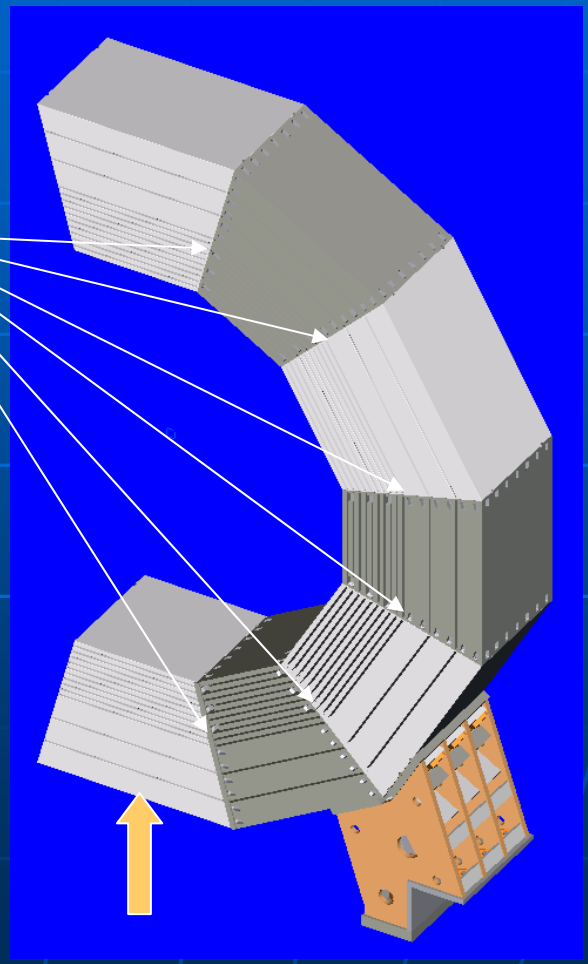
Bolt DIA 60 mm,

Assembly bore positioning

force neutral line “Fp”

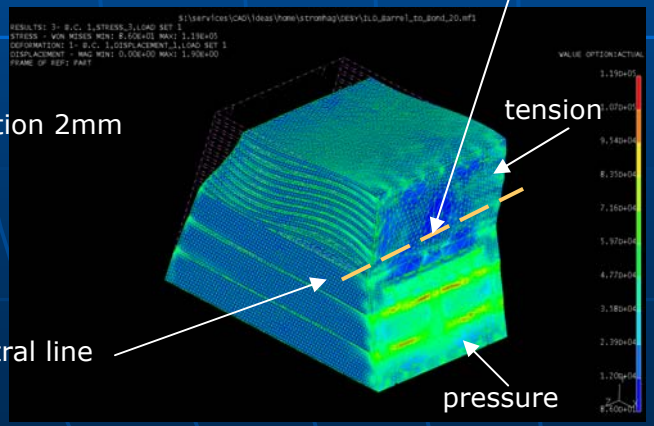


“Fp”



max. deformation 2mm

tension



force neutral line

pressure

7.0 Calculation for screw of Barrel, DIN 18800:

method: bracket connection (Roloff / Matek 8.4.5)
force, factors and dimension list (show 6.0)

external force	Fs	= 11917027 N
torque arm	La	= 2400 mm
number of threads	n	= 44
number of engaged threads	z	= 28
number of crack	m	= 1
minimum thickness	t min	= 65 mm
(part) safety factor - tensile strength	SM	= 1.2
(part) safety factor – shear force	SMq	= 1.2
(part) friction factor	μ	= 0,8 (Roloff / Mattek cap 4.1 / TB 4-1)
preload screw	Fv	= 560000 N
property mind. class		= 10.9 (d > M16)
tensile strength	Rm	= 1040 N/mm²
yield strength	Re	= 940 N/mm²
allowable flange pressure	σ zul	= 540 N/mm²

clearance (L) of tensile load screw to center of pressure

L1 = 1900; L2 = 1750; L3 = 1600; L4 = 1450; L5 = 1130; L6 = 980; L7 = 830; L8 = 680; L9 = 510

7.1.1 Appraisal and interpretation of results

- the screw calculation utilizes data from 7.0 -

1.	required bolt diameter		= M 36
2.	mean diameter	Ø	= 36,00 mm
3.	minor diameter	Ø	= 33.40 mm
4.	core diameter	Ø	= 31,09
5.	applied shear stress	τ_a	= 332 N / mm²
6.	applied flange pressure for t_{min} = 65 mm	σ_l	= 116 N / mm²
7.	bending moment bench mark center of pressure	Mb	= 28600000 Nm
8.	max. traction for bolt at distance l_1	$F_{o\ max}$	= 129526 N
9.	max. tensile strength for bolt at distance l_1	σ_z	= 159 N / mm²
10.	applied bolt shearing force	$F_{q\ exist}$	= 270842 N (not

mechanical characteristics of bolt M 36		interpretation	
nominal tensile strength	$\sigma_{z\ max.}$ = 693 N / mm²	≥ $\sigma_{z\ existing}$	= 159 N / mm²
nominal shear stress	$\tau_{a\ max.}$ = 381 N / mm²	≥ $\tau_{a\ existing}$	= 332 N / mm²
nominal applied flange pressure	$\sigma_{l\ max.}$ = 540 N / mm²	≥ $\sigma_{l\ existing}$	= 116 N / mm²
maximum bold friction grip / shear force	$F_{max.}$ = 324638 N	≥ $F_{q\ exist}$	= 270841 N
for 10 bolt at l1	$F_{R\ max.}$ = 2839941 N	≥ $F_{R\ existing}$	= 1169545 N

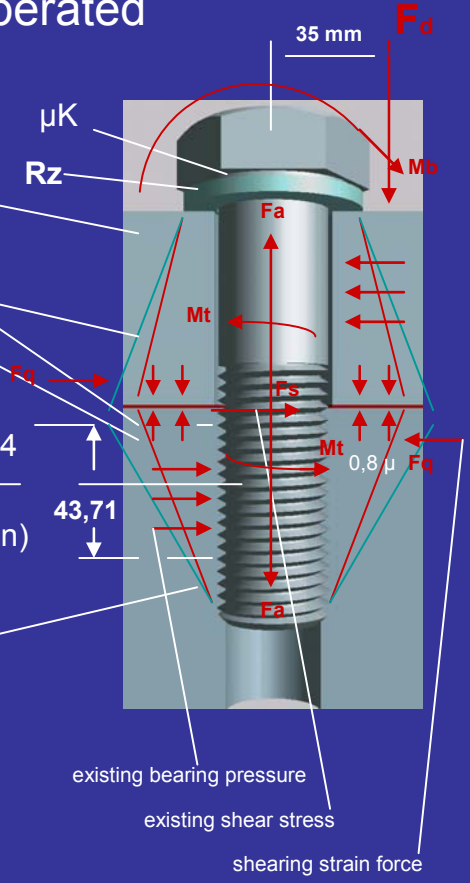
- Recalculation for screw DIN ISO 4014 - M36 x 140 – 10.9 / set VDI 2230
  - washers DIN 6916 - 37

tightening screw condition: hydraulically operated

Steel grade: Part 1. S235 JRG1 = 65 mm thickness
Part 2. S235 JRG1 = 100 mm thickness

max. shear resistance f_{BM} = 0.59
max. seating part stress factor f_G = 1,44 (VDI Tab. 5.5/1)
max. seating washers stress factor f_G = 0,87
washers average surface roughness Rz = 0,5µ
for screw elastic limit ~ 90% min. friction factor screw connecting surface μ_K = 0,14
for screw elastic limit ~ 90% min. friction factor screw thread μ_G = 0,14
friction grip / part friction factor 0,8 µ (connection with force transmission by friction)

stress cone inside slit ~ Ø 100 mm
stress cone outside slit ~ Ø 110 mm
distance pre-stressing area from transmission of screw force ~ 35 mm (F_d)
operating temperature ~ 20°C



7.1.3 Result for screw DIN EN ISO 4014 – M36 x 140 – 10.9 and washers DIN 6916 – 37

Ma - locking torque = 4,5 kNm

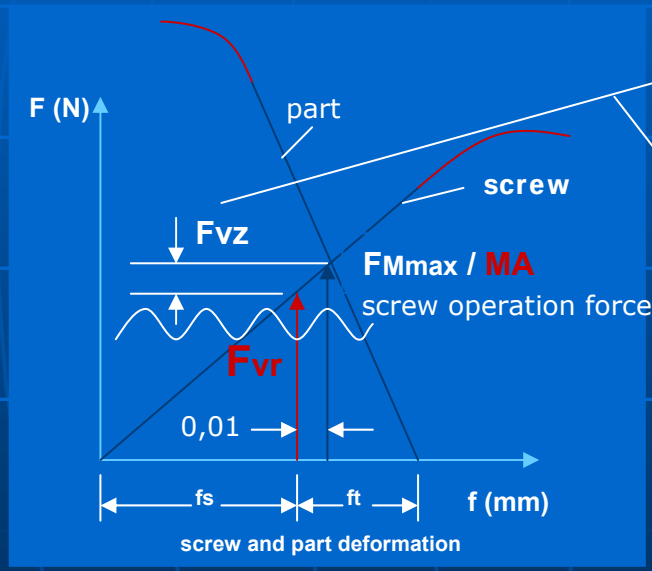
Fv - max. screw axial force = 420 kN

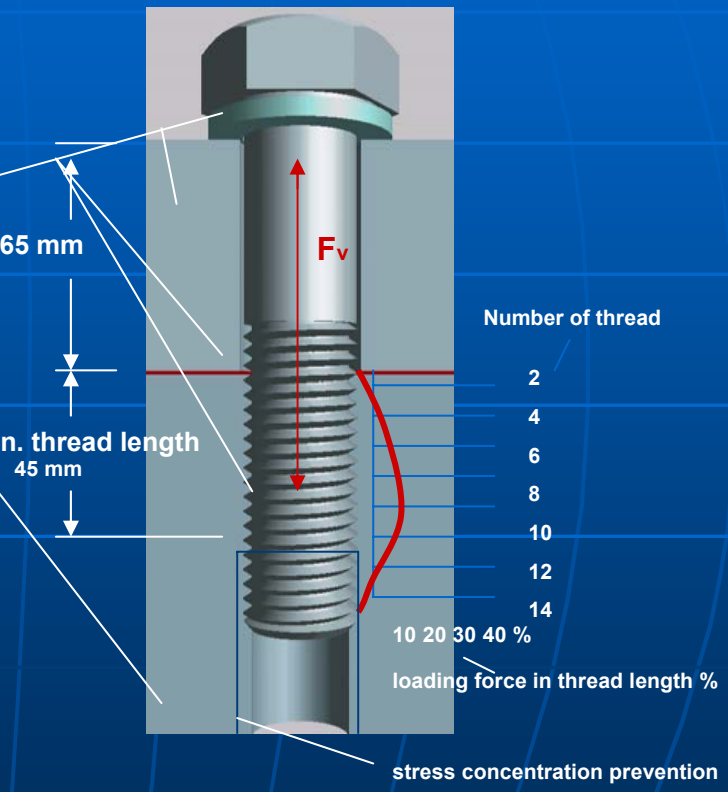
tol. screw-in depth = 44 + 4 mm

surface pressure	**mounting**	**operating after settling, - fz = 8,50 µ**
screw connecting surface	**= 830 N/mm²**	**= 821 N/mm²**
washers connecting surface	**= 453 N/mm²**	**= 448 N/mm²**

safety coefficient anti surface pressure		
screw connecting surface	**= 1,05**	**= 1,06**
washers connecting surface	**= 1,08**	**= 1,09**

7.1.4 Screw and washers lost of tension





loss of tension / loading force in thread length

8.0 conclusion

- In this note is described the status of the integration cryostat in central barrel.
- The design is only proposal, in detail with all calculation required and realistic.
- Insertion of ild cryostat in central barrel is adequate to CMS cryostat.
- strength analysis assumes "open-door design" (good safety factor)
- A lot of studies need to be performed:
- design of cryostat supporting system
- - all geometrical parameters
- - finish cryostat constructions concept
- - cryostat quench scenarios
- - cabling concept
- - power supply connection design
- - cryostat safety instruction sheet
- - scaffolding
- - gas-, cables-, water-, power-connection
- - escape rotes
- - safety periphery and risk assessment analyse
- - collaboration with other international ild interacting groups
- - peripheries transport equipment and devices

References:
CMS Technical Design Report - ISBN 92-9083-101-4
Roloff / Matek Maschinenelemente - ISBN 978-3-8348-0262-0
Schrauben Vademecum - ISBN 978-3-935326-46-7