Improved anchoring of SSS with vacuum barrier to avoid displacement

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LHC Performance Workshop - Chamonix 2009, 3 February 2009

Overview

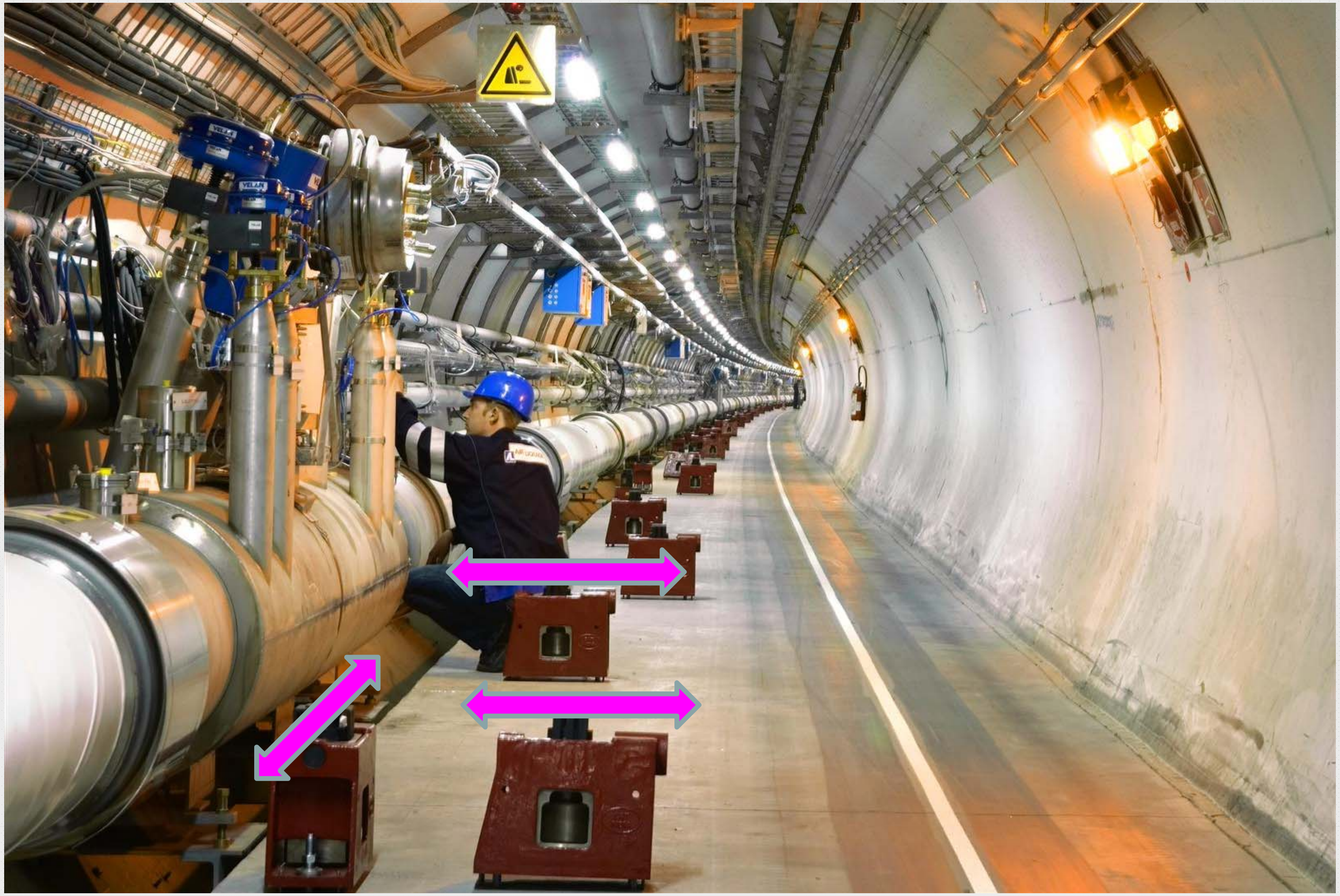
- Introduction
- Initial requirements and actual SSS supporting
- Updated requirements and improved supporting design
- Planning and costs
- Next weak point?
- Conclusion

Introduction

- Incident on 19th of September 2008 => failure of some supports of SSS in sector 3-4 due to longitudinal loads

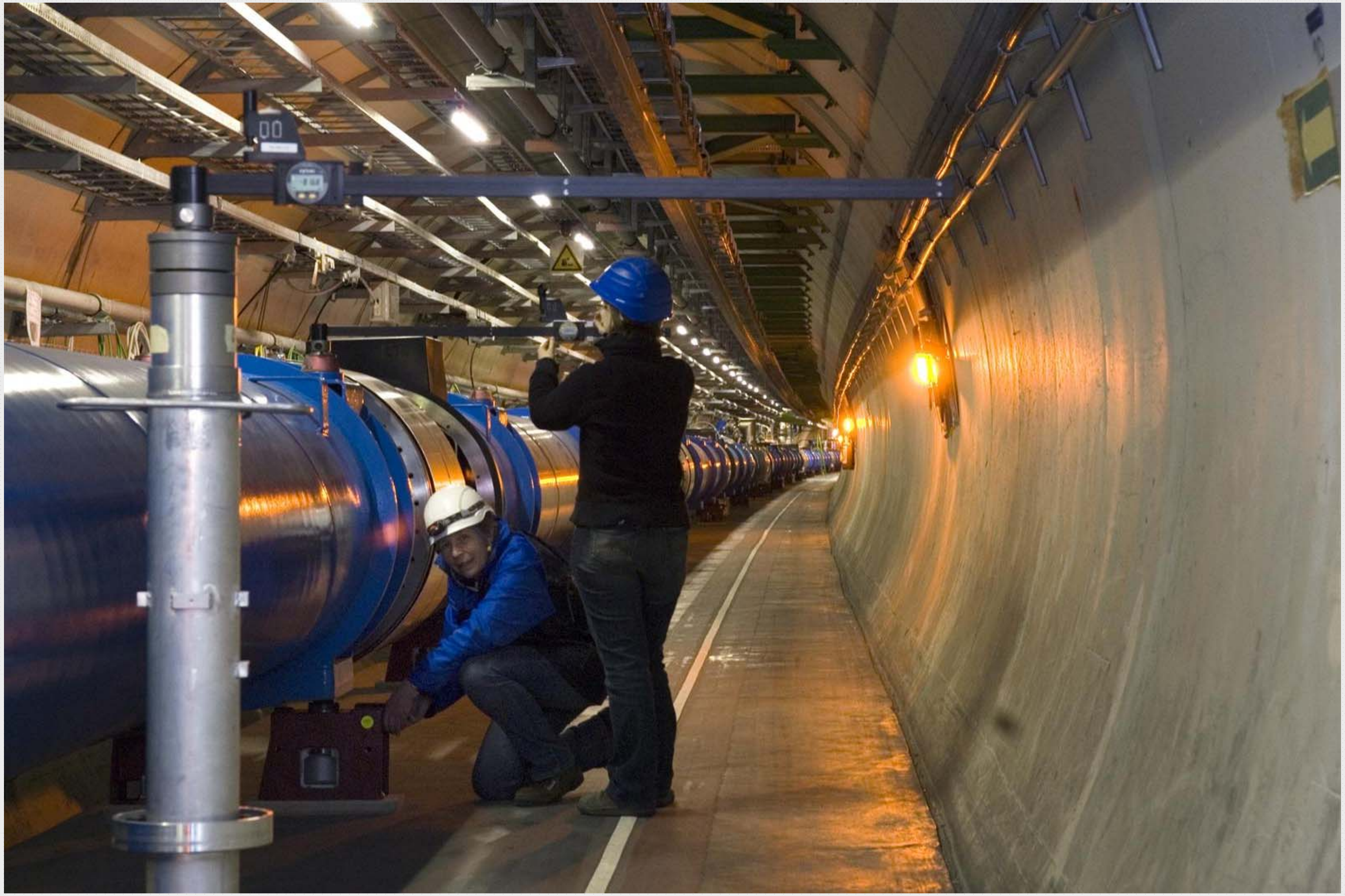
Initial requirements and actual SSS supporting

- Each SSS is installed on 1 jacks for longitudinal alignment + 2 for transversal alignment; The 3 jacks are used for vertical alignment



Initial requirements and actual SSS supporting

- Alignment done by geometers after installation



Initial requirements and actual SSS supporting

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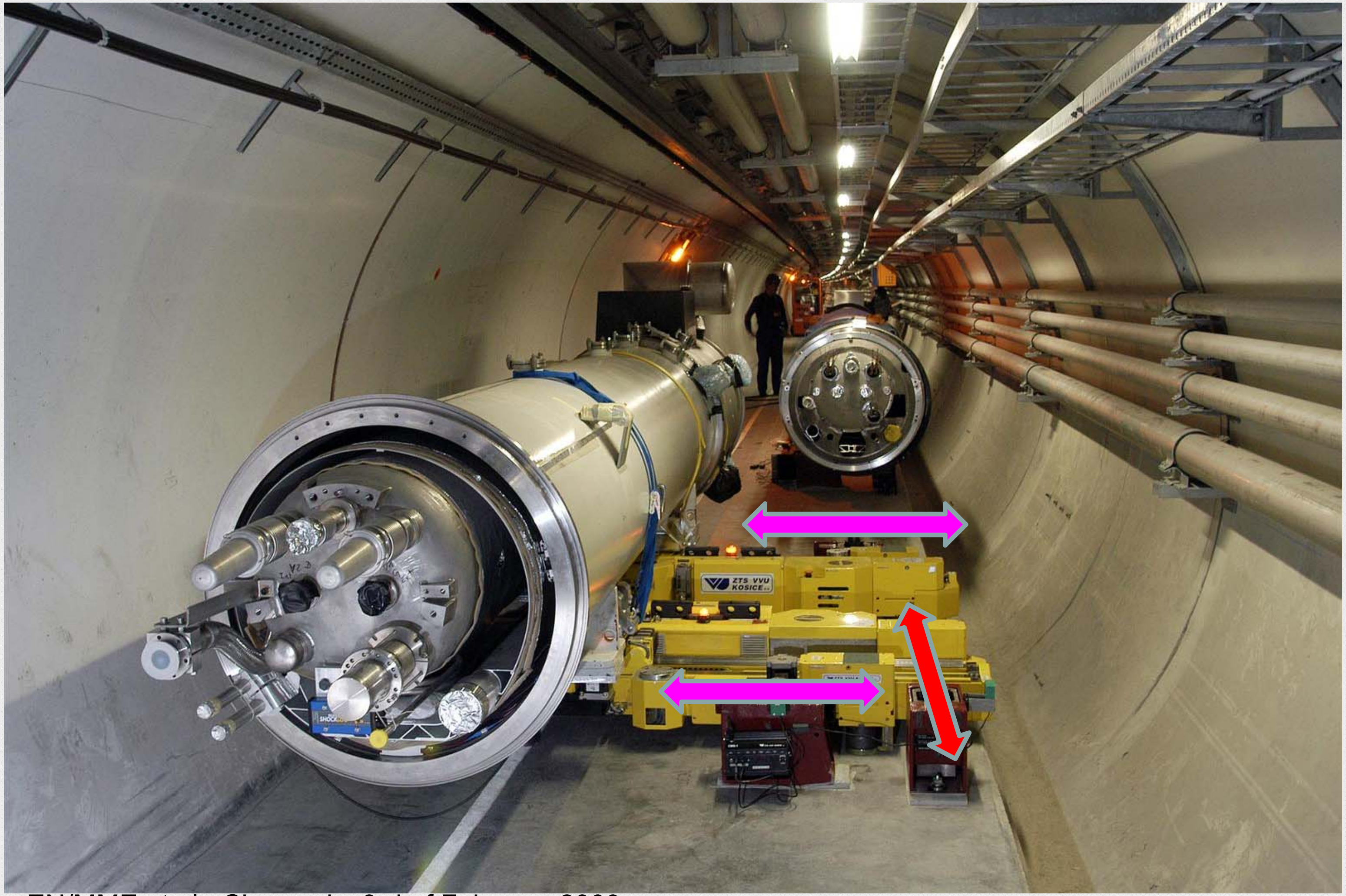
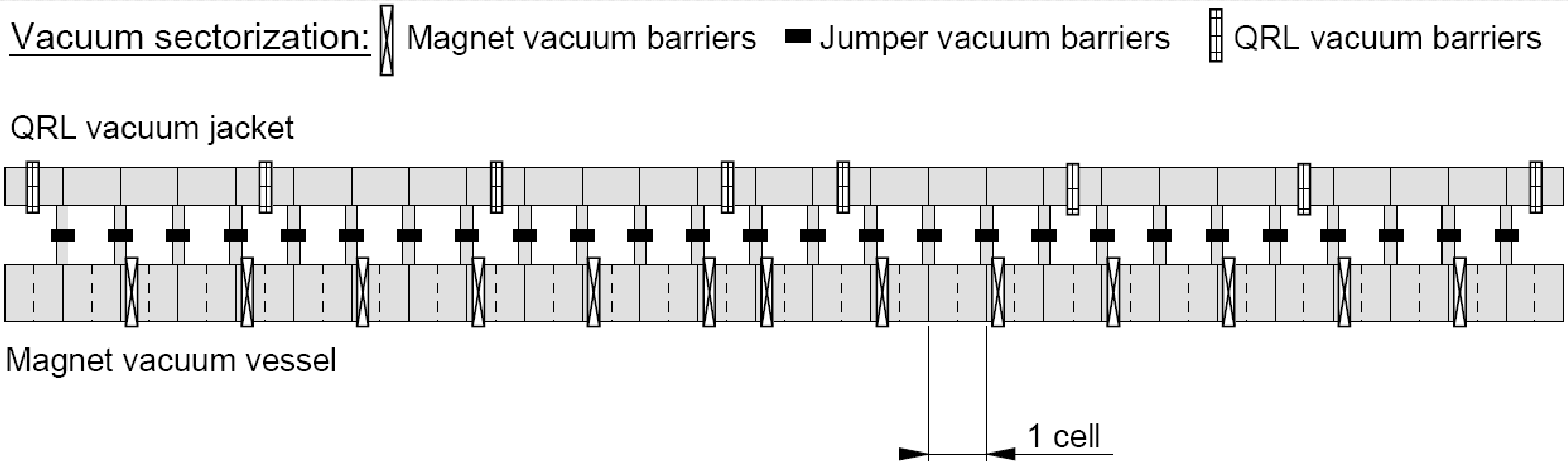


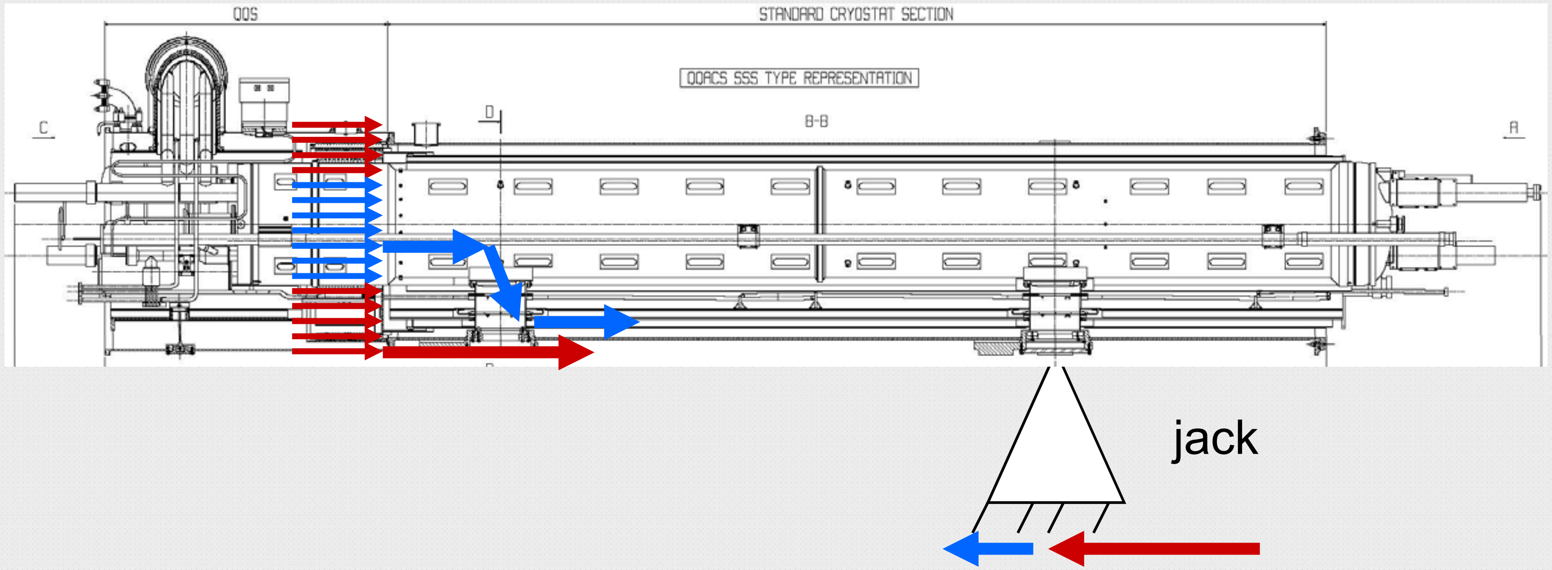
Initial requirements and actual SSS supporting

- Vacuum sectorisation for one LHC sector



- Vacuum barrier in 13 SSS / sector (Q11R&L, Q15R&L, Q19R&L, Q23R&L, Q27R&L, Q31R&L, Q33R)
- A total of 104 SSS with vacuum barrier

Initial requirements and actual SSS supporting

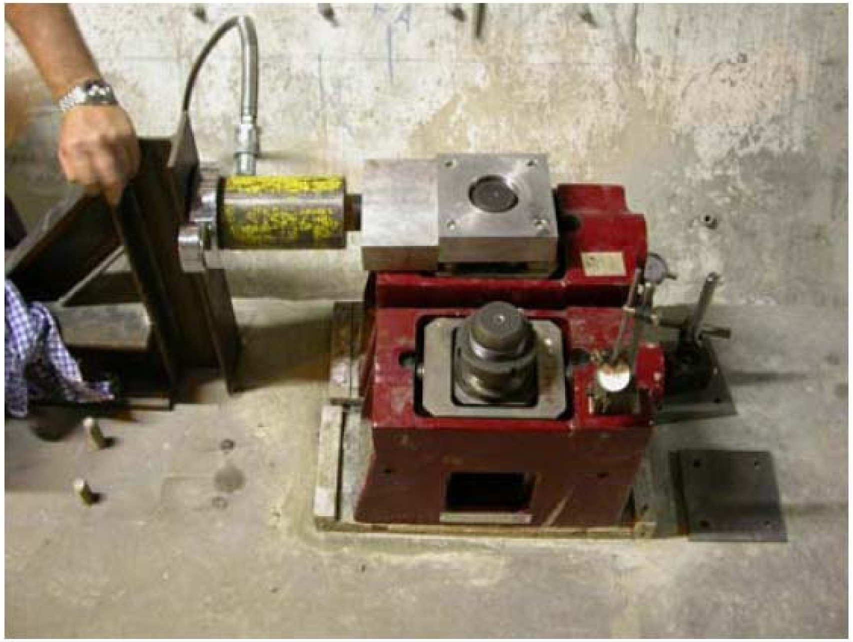


- Vacuum vessel/vacuum barrier designed for 0.15 MPa internal pressure
- Supporting system should withstand loads induced by differential pressure on both sides of vacuum barrier:
  - Nominal operation: up to Δp = 0.1 MPa
  - Exceptional : up to Δp = 0.15 MPa

- Δp = 0.1 MPa across vac. Barrier → 80 kN at the jacks (tested value)

Initial requirements and actual SSS supporting

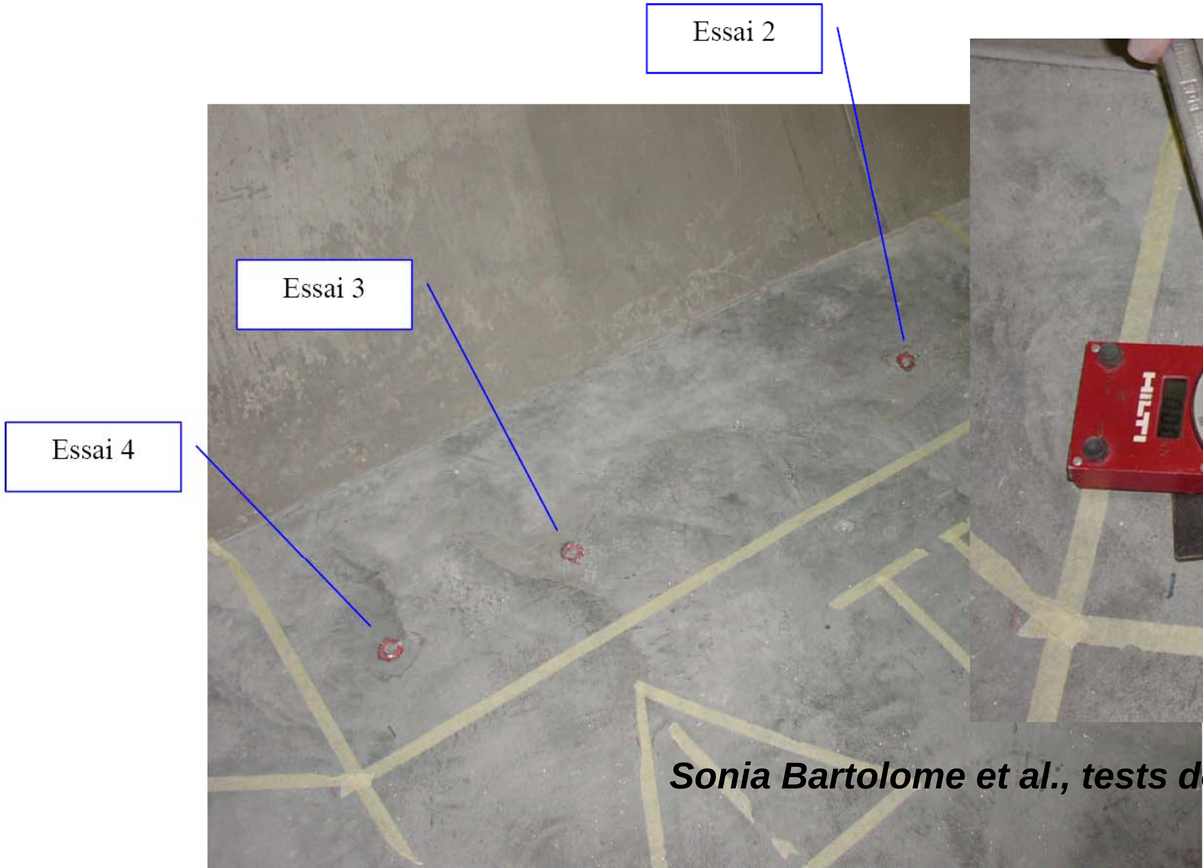
- Supporting system should withstand
  - Nominal operation up to 80 kN longitudinally (≡ 0.1 MPa)
  - Exceptional operation up to 120 kN longitudinally (≡ 0.15 MPa)
- Actual SSS supporting system:
  - Designed for 80 kN and tested in the tunnel for a longitudinal load up to 90 kN
  - Test done once in surface building up to 120 kN (not documented)



Sonia Bartolome et al., tests done in the LHC tunnel, June 2003

Initial requirements and actual SSS supporting

- Actual SSS supporting system:
  - Tested failure tensile loads of anchors 120 kN to150 kN
    - Ok for nominal operation
    - Failure limit for exceptional conditions (~ 150 kN)
    - No concrete damage observed



Sonia Bartolome et al., tests done in the LHC tunnel, June 2003

Updated requirements and improved SSS supporting

- Sect.3-4 incident: estimate *(see pres. Ph. Lebrun session 01)* pressure inside vessels (on one side of vacuum barrier): 0.7 MPa (x 4.6 design pressure)

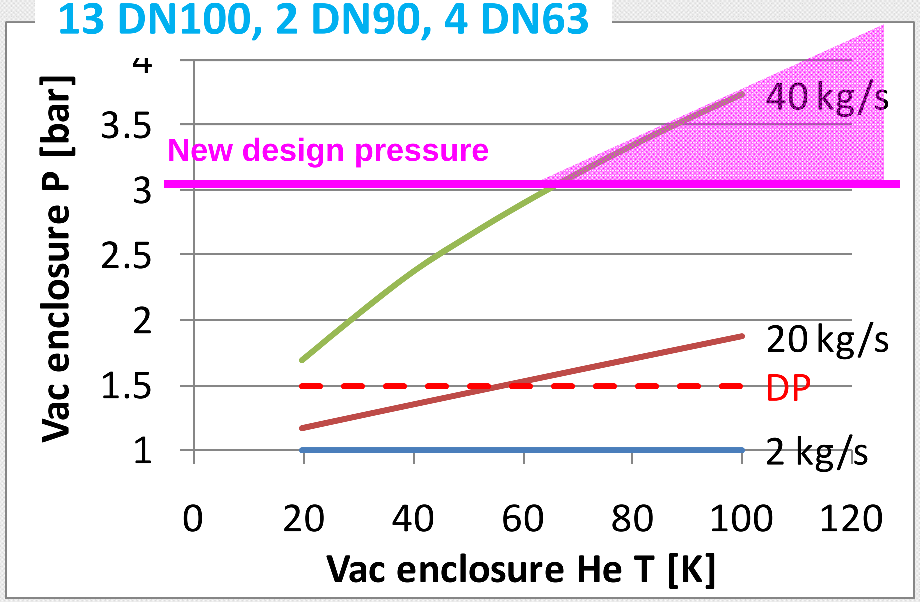
  => Improvements of security relief valves proposed *(see pres. V. Parma session 04)* different form warm / cold sectors

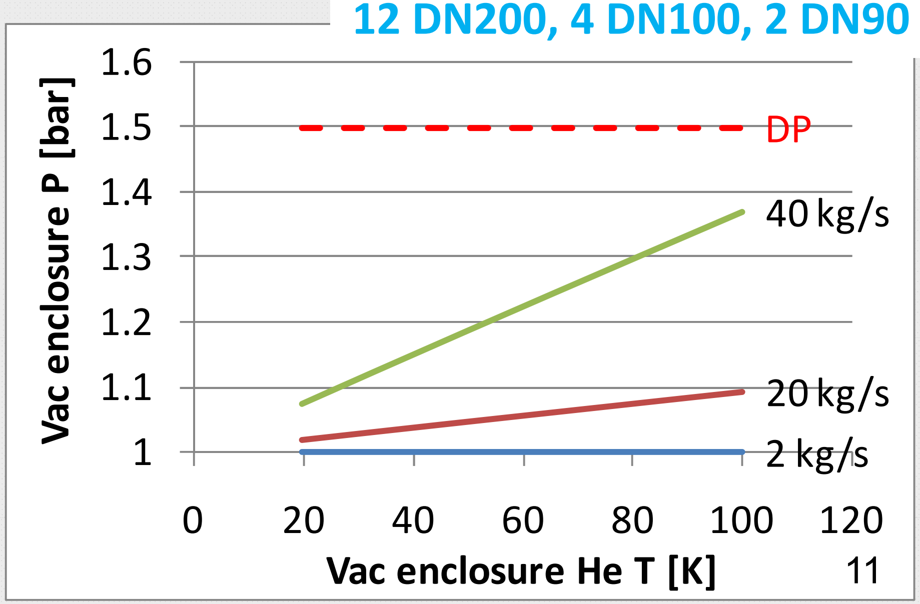
- Updated design pressure *(see pres. V. Parma session 04)*

New configuration on cold sectors: 13 DN100, 2 DN90, 4 DN63

(DP: Design Pressure)

New configuration on warm sectors: 12 DN200, 4 DN100, 2 DN90

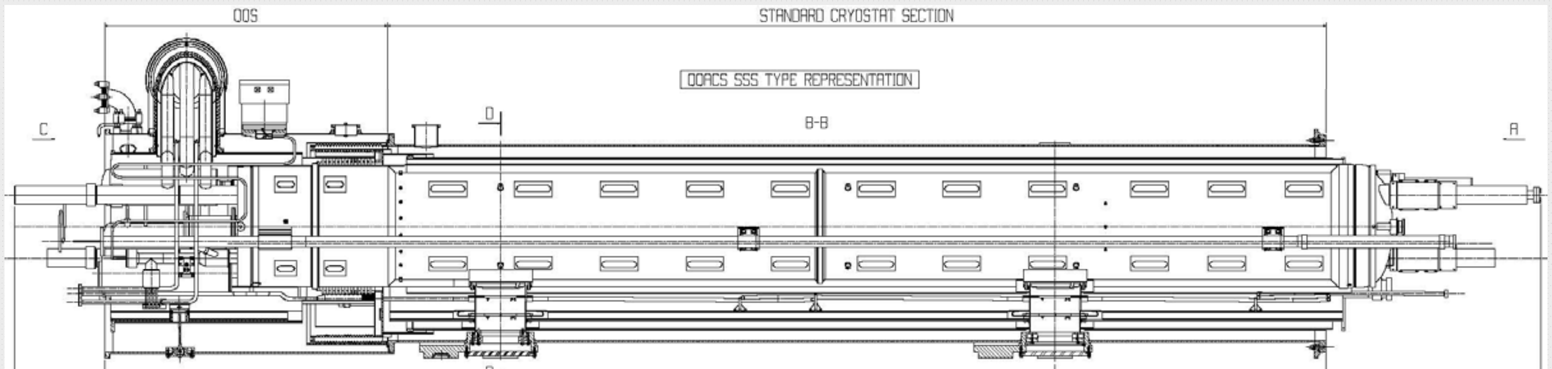


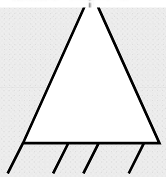


L. Tavian

Updated requirements and improved SSS supporting

- Updated design pressure 0.3 MPa for SSS anchoring. Why?
  - Covers an important area of possible events
  - Very high but feasible value of longitudinal loads to be considered for the new anchor design - 240 kN;
  - The chain of elements **vacuum barrier / cold foot / jack** should be equilibrated
    - Design of vacuum barrier for 0.15 MPa with security factor 3 => confident that it withstands 0.3 MPa
    - Cold foot tests showed no failure up to 70 kN equivalent to 0.3 MPa





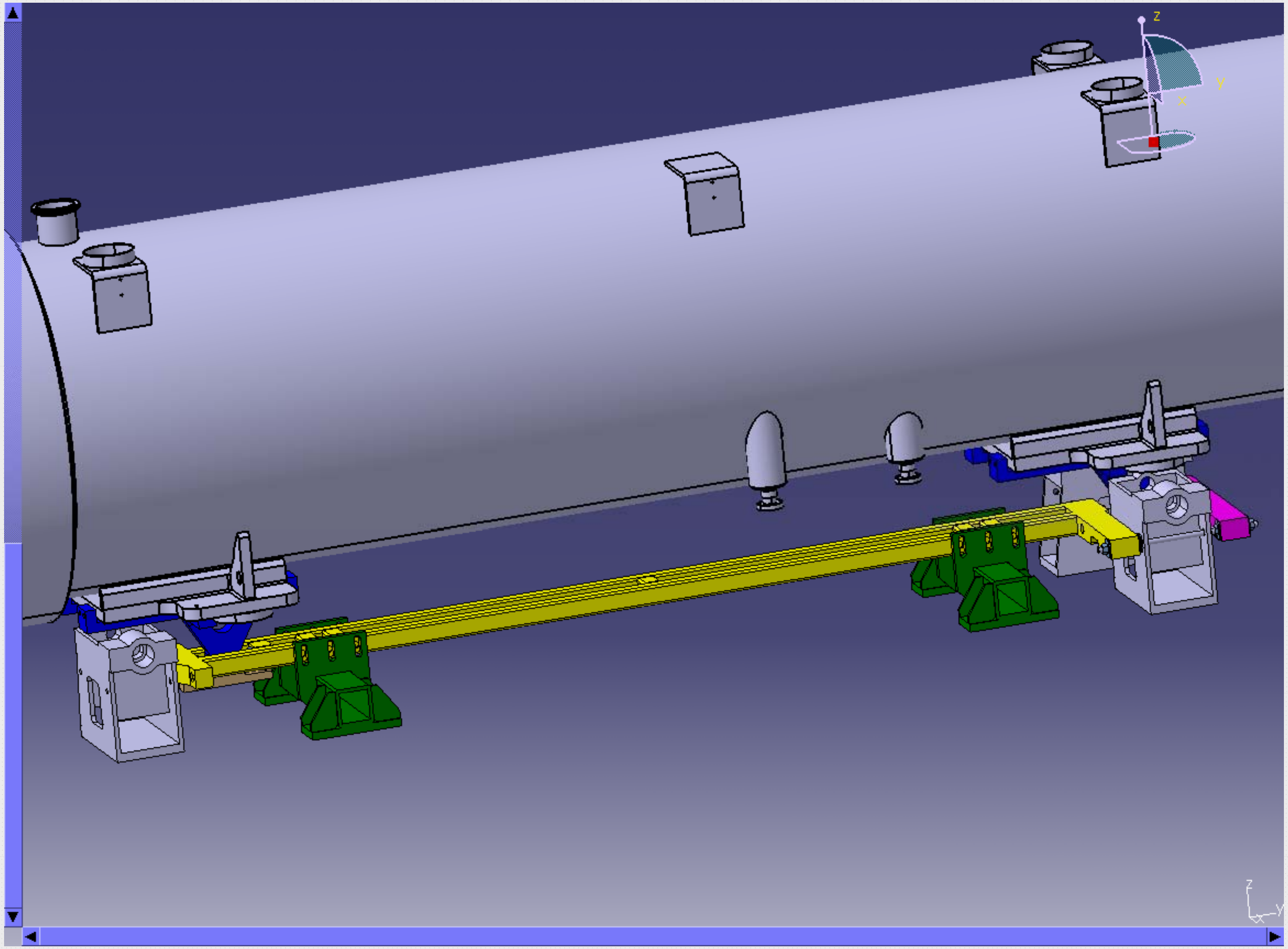
jack

Updated requirements and improved SSS supporting

- Requirements for the design of the improved SSS anchors
  - Withstand longitudinal load of 240 kN
  - Possibility to install the system on SSS already on jacks
    - Reduced space under the SSS – very difficult for drilling
  - Accessibility for alignment
    - Estimation of realignment every year
  - Allow thermal contraction of vacuum tank in case of accident
  - Allow space for other foreseen equipment under the SSS
  - Uninstalling the system should allow SSS removal if needed
    - Transport / installation zones to be taken into account
  - Optimize price
  - Feasibility within general planning

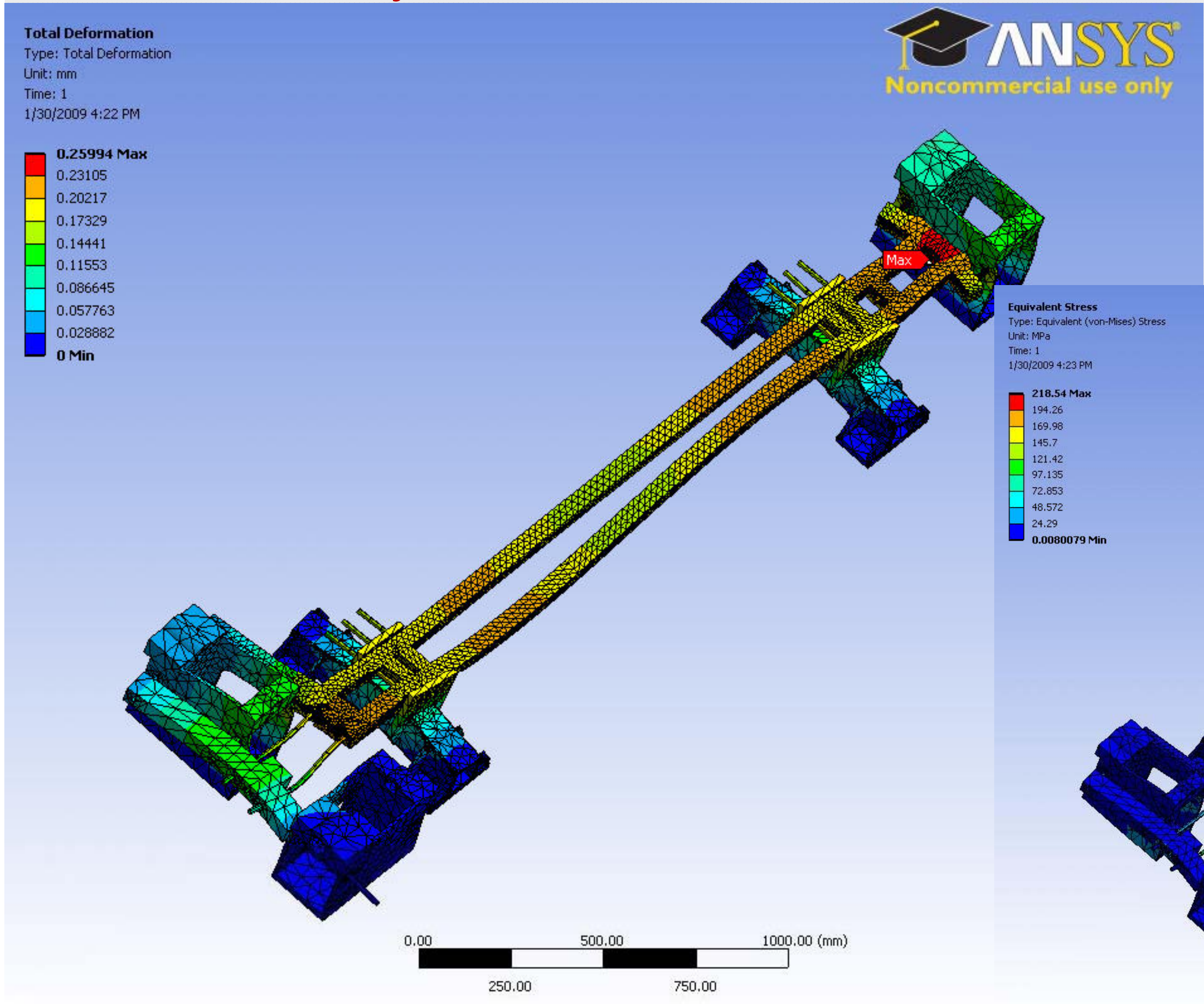
Updated requirements and improved SSS supporting

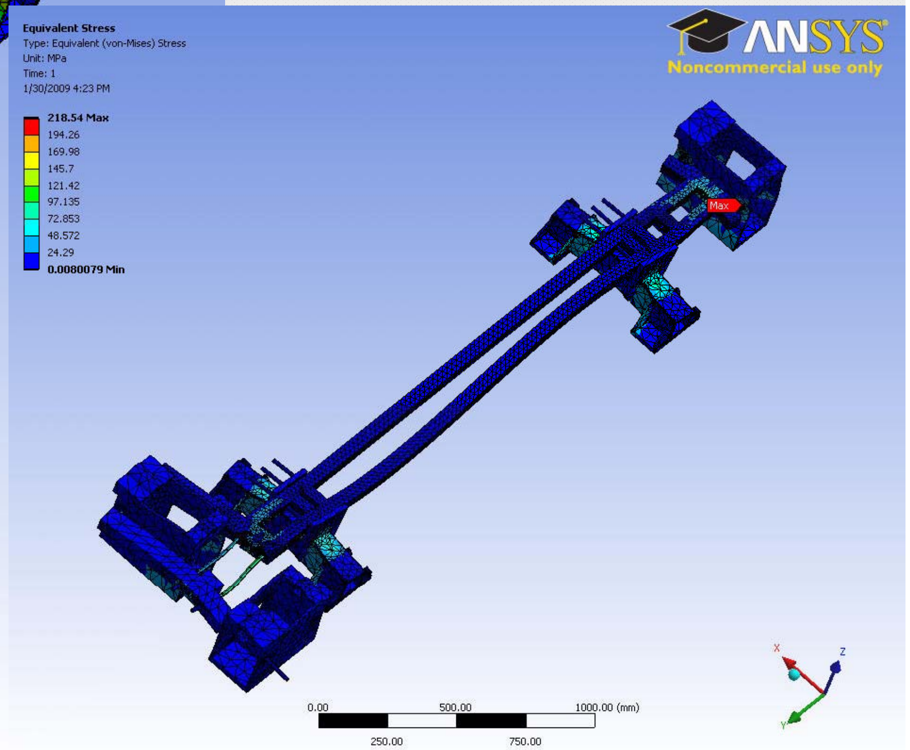
- Several solutions have been studied
  - 1st solution – distribution of the longitudinal load among the 3 jacks



Updated requirements and improved SSS supporting

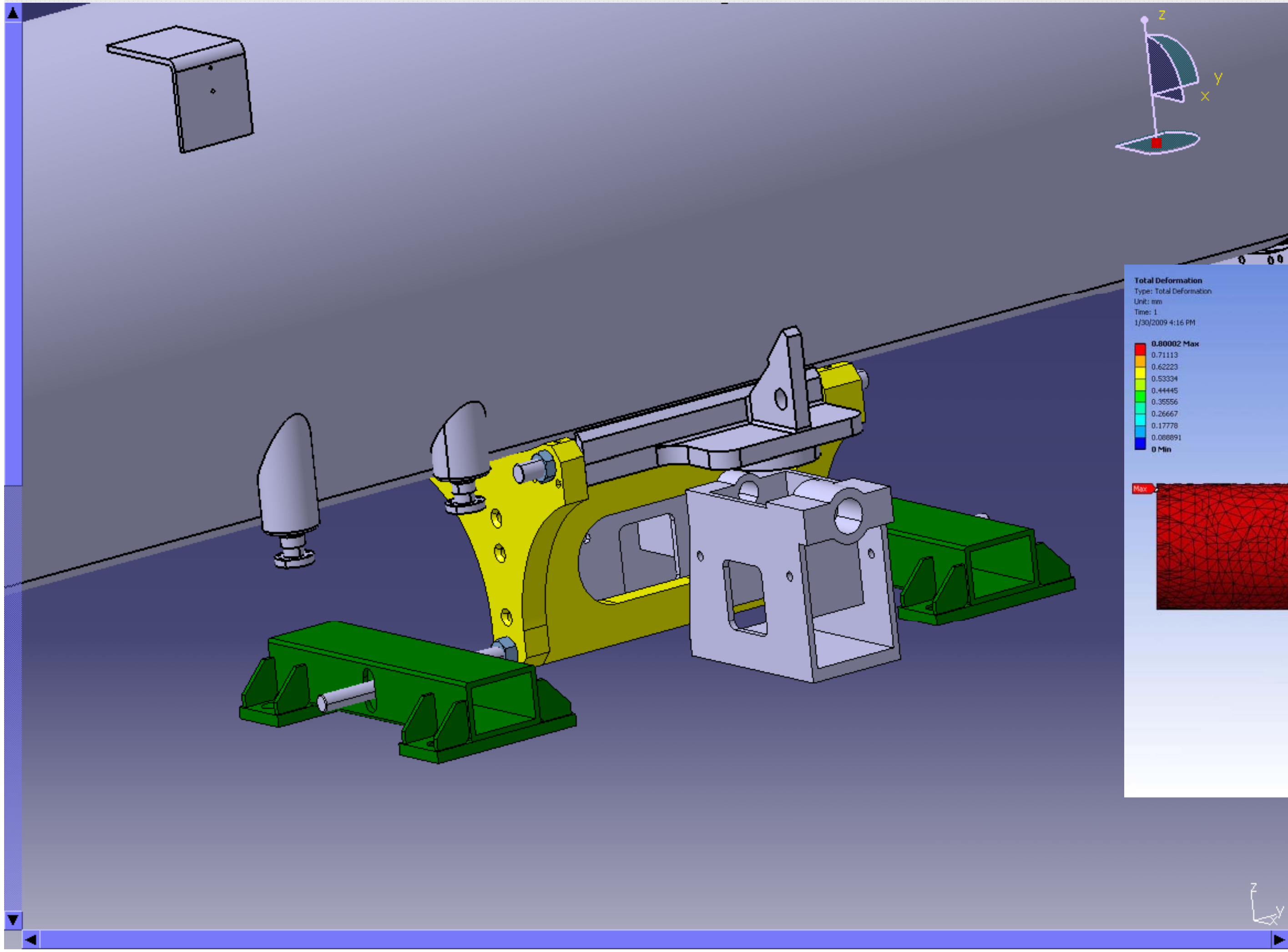
- Several solutions have been studied
  - 1st solution – distribution of the longitudinal load among the 3 jacks
  - No cryostat thermal contraction allowed

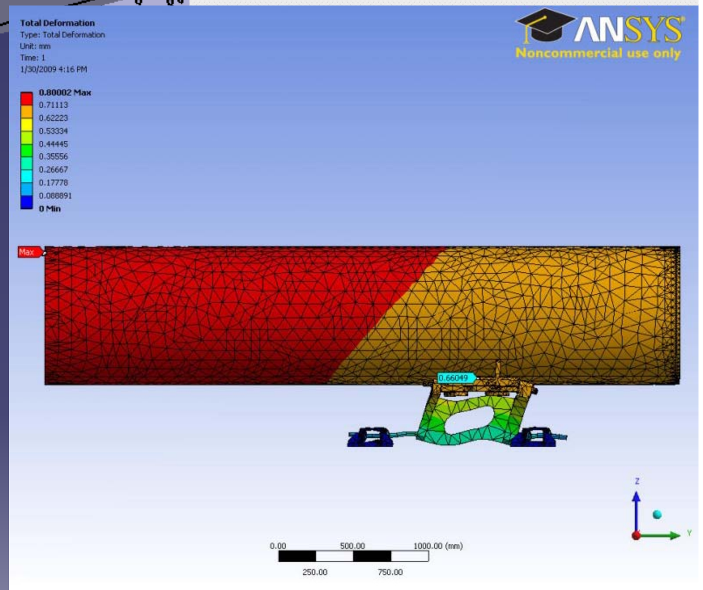




Updated requirements and improved SSS supporting

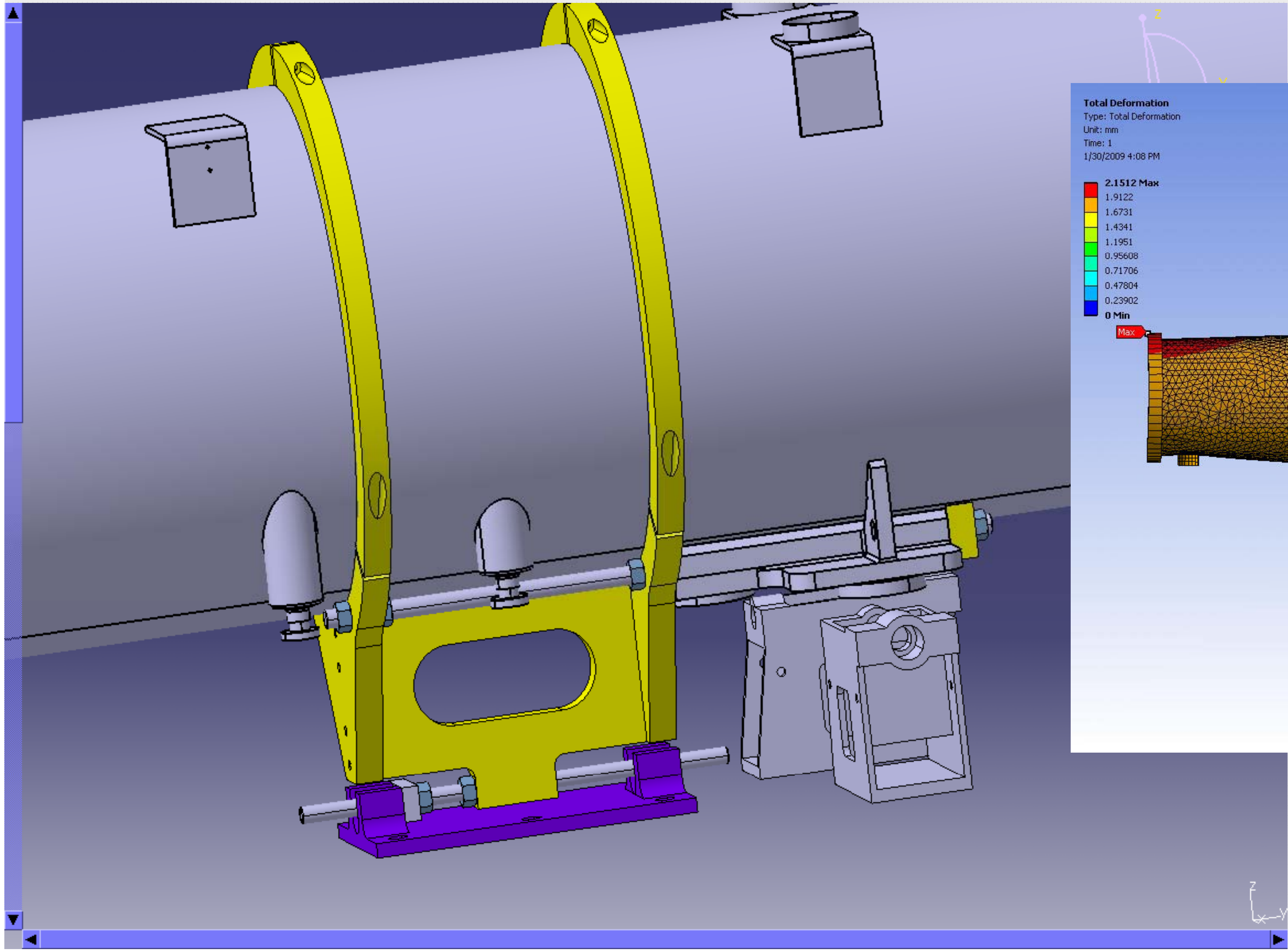
- 2nd solution – bloc additional fixation to the ground – only shear loads transmitted to the floor
- Poor accessibility to jacks for alignment

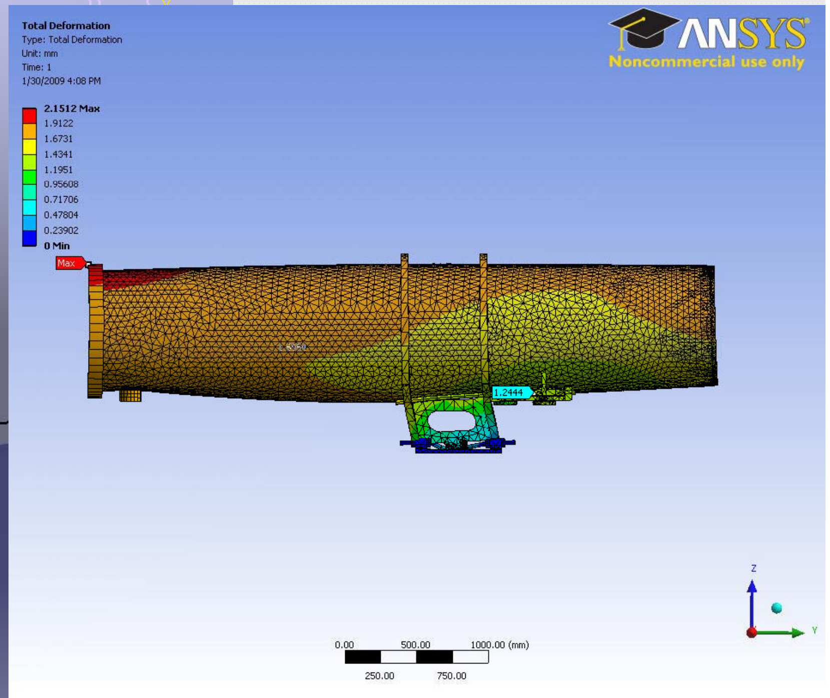




Updated requirements and improved SSS supporting

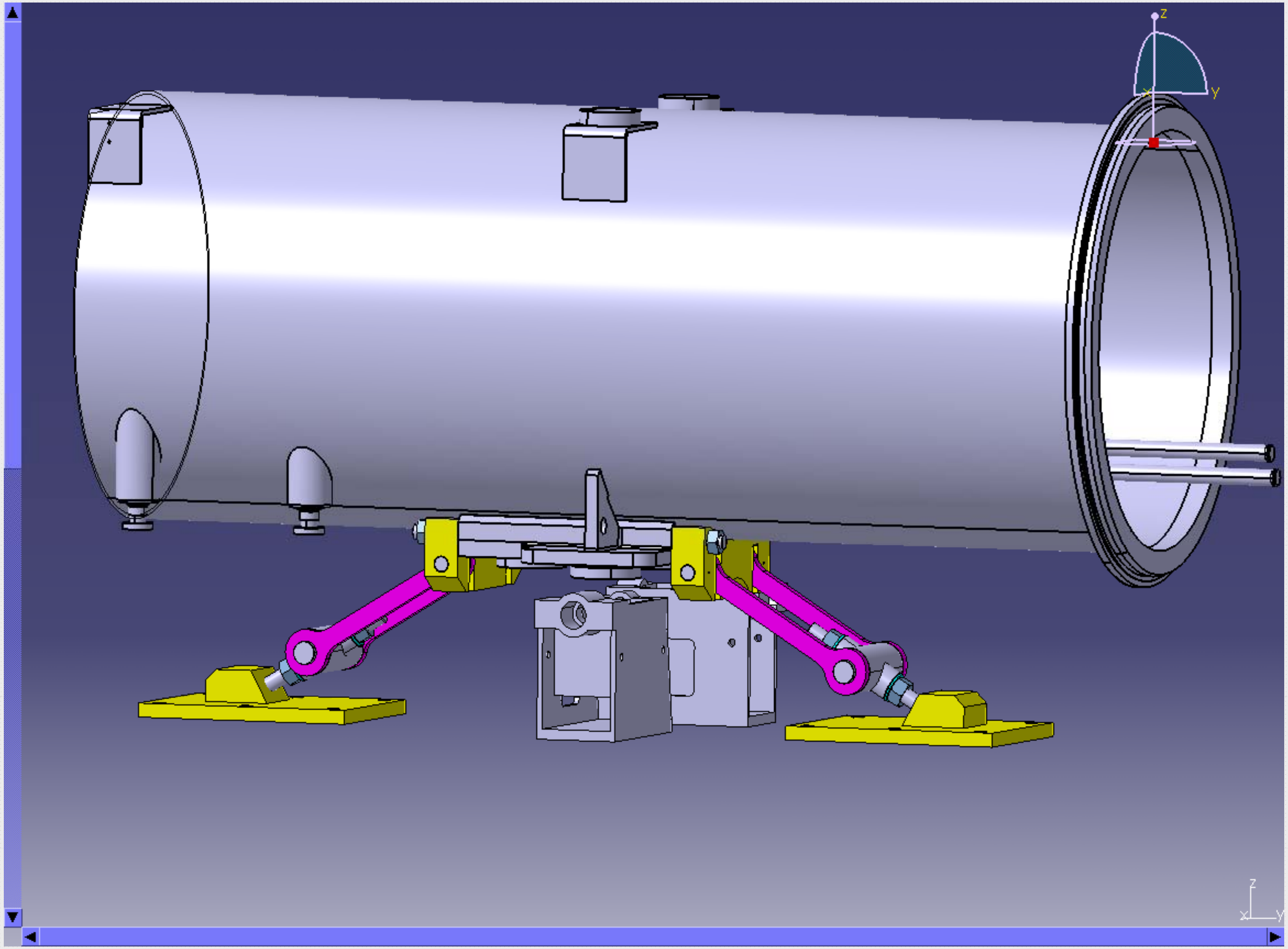
- 3rd solution – bloc additional fixation to the ground and to the cryostat – only shear loads transmitted to the floor
- Necessitates special installation procedure (monitored by geometers) to avoid vacuum tank deformation





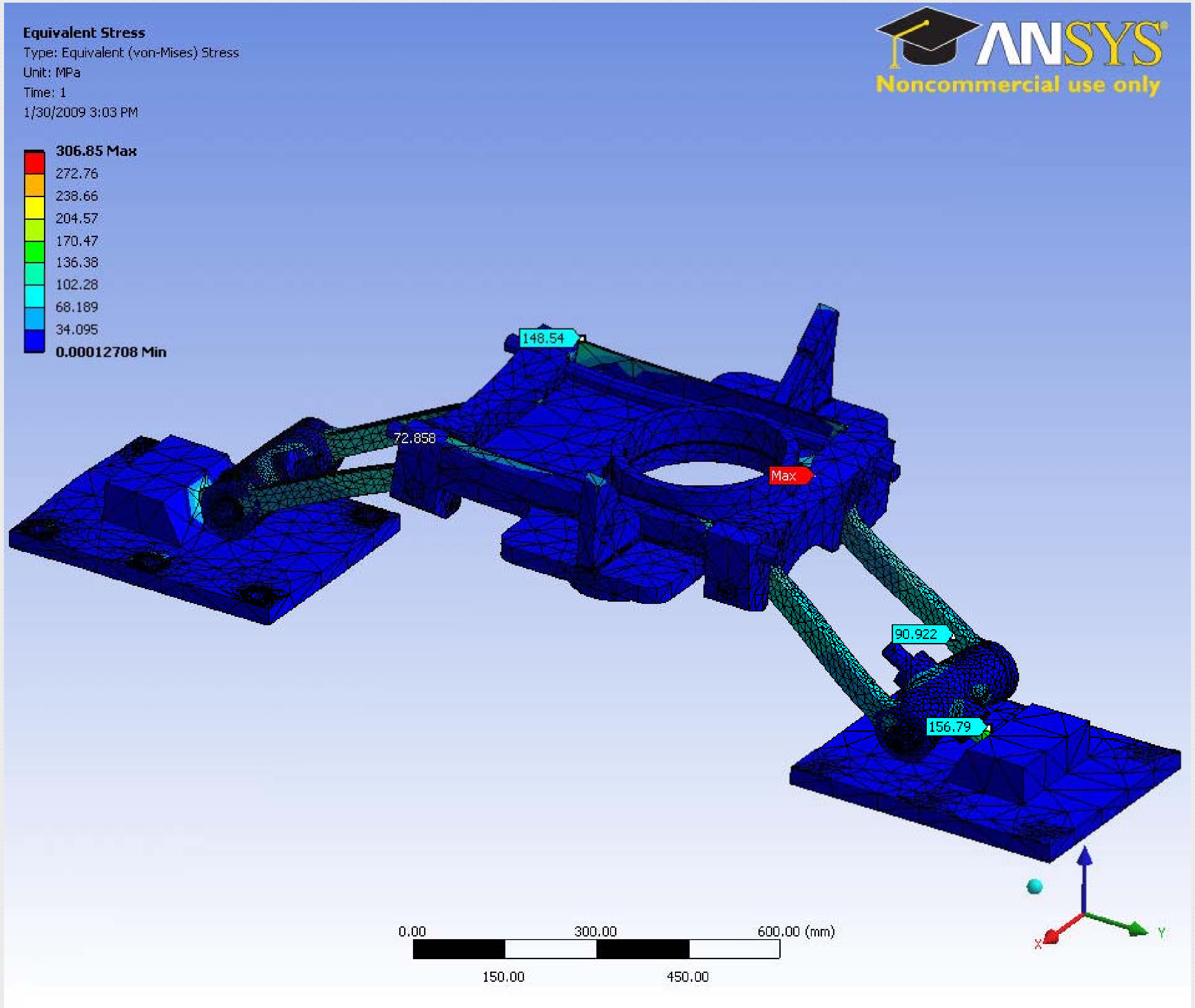
Updated requirements and improved SSS supporting

– 4rd solution – the final one



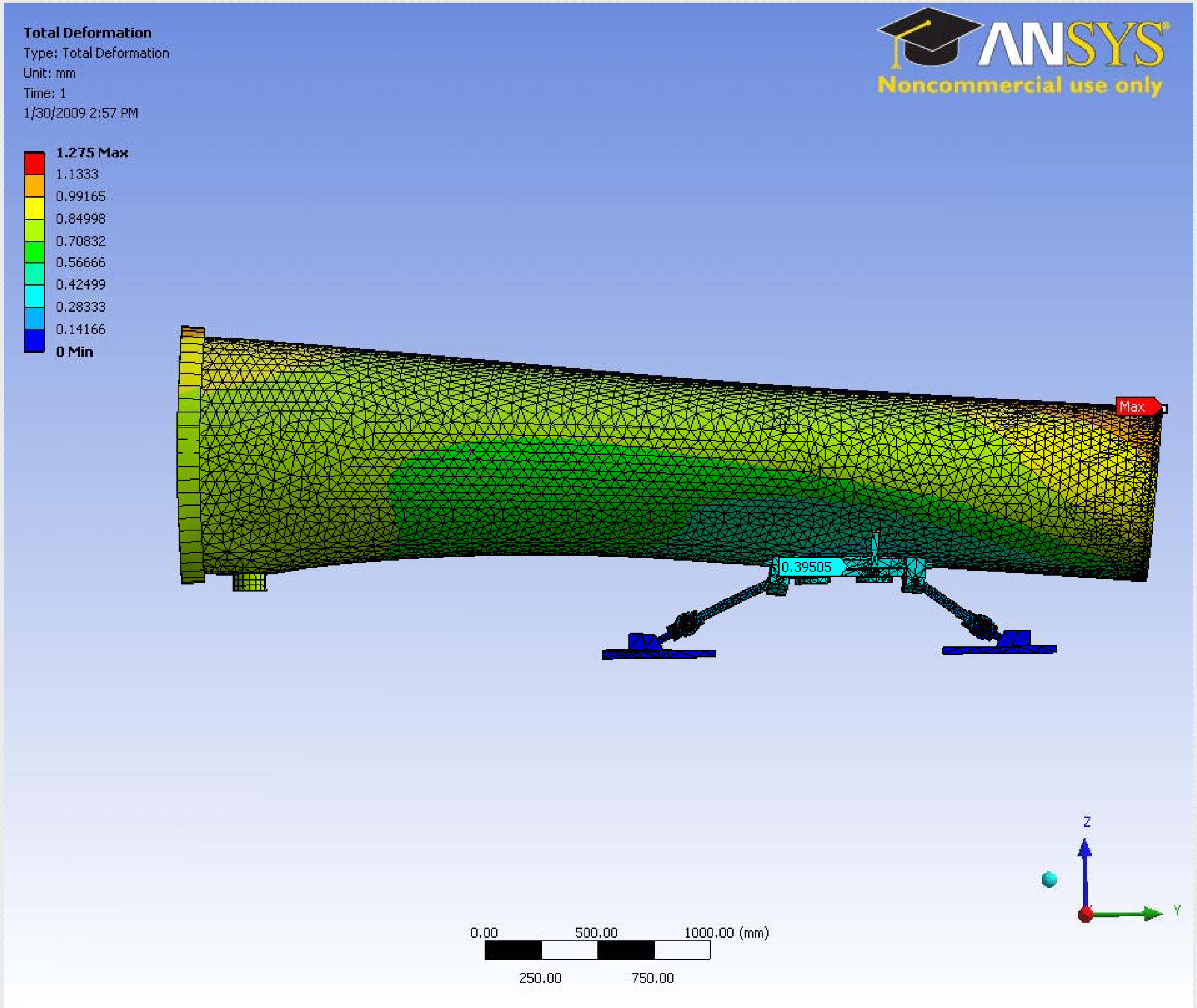
Updated requirements and improved SSS supporting

– Final solution – equivalent stress



Updated requirements and improved SSS supporting

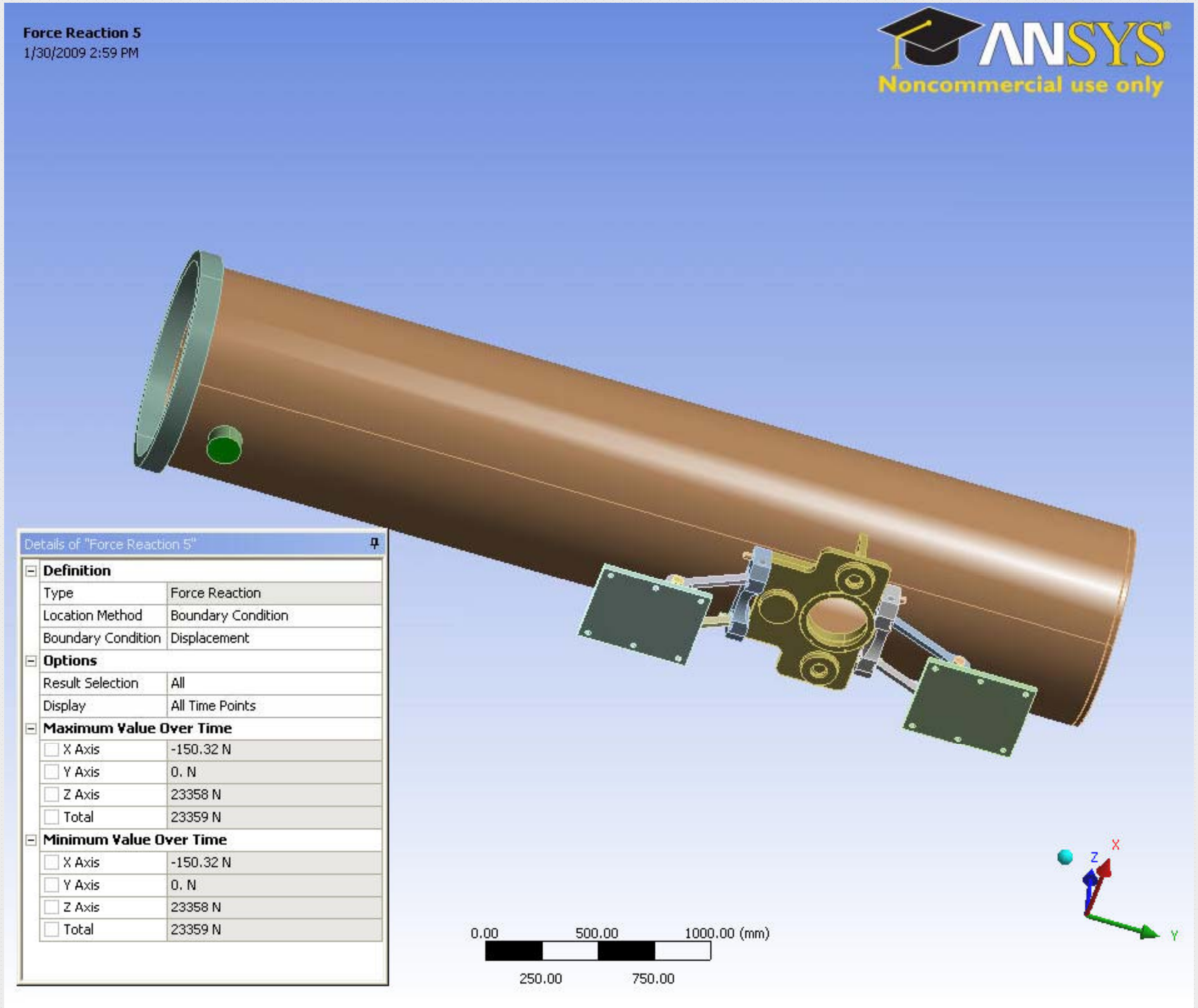
– Final solution – deformation



Updated requirements and improved SSS supporting

– Final solution – reaction loads

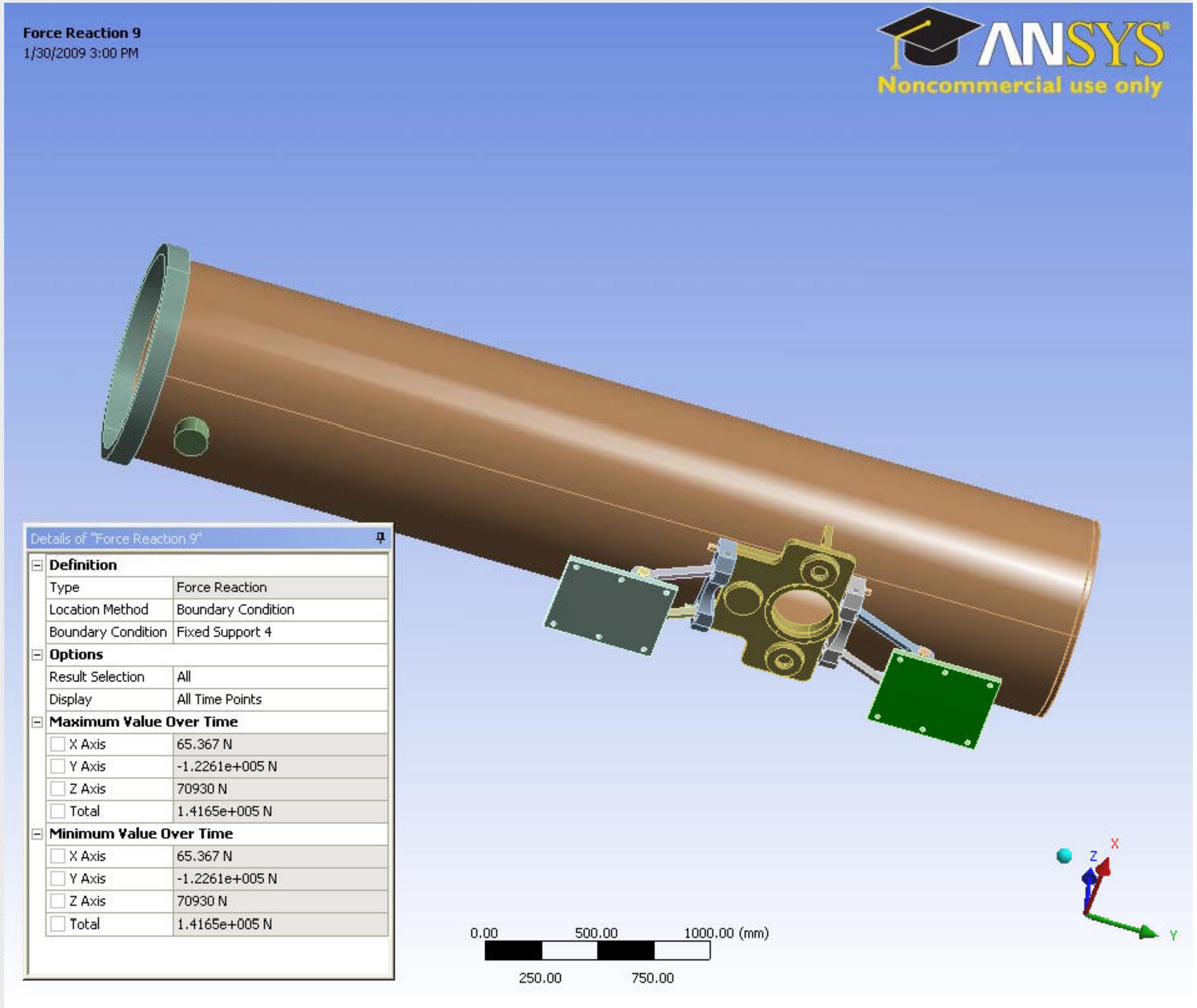
– Contact on single jack guaranteed



Updated requirements and improved SSS supporting

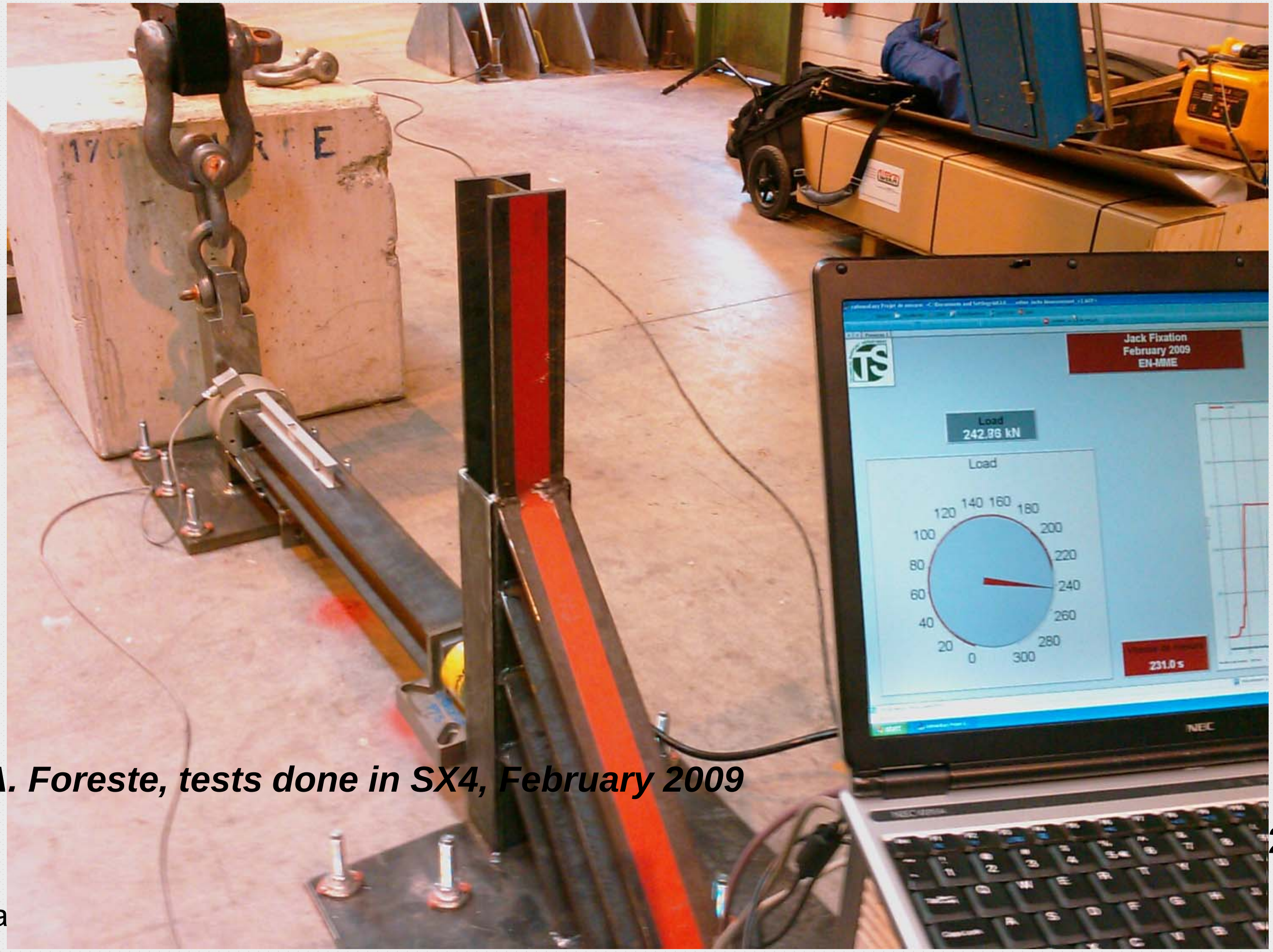
– Final solution – reaction loads

– Ground fixation system tested this morning in SX4



Updated requirements and improved SSS supporting

- Final solution – one ground fixation system tested in SX4
- Up to 380 kN applied longitudinally and 230 kN applied vertically (traction) during 10 min (1.5 x design load if only one side charged) => no visible damage observed



M. Guinchard and A. Foreste, tests done in SX4, February 2009

Planning considerations

- Prototype
  - Manufacturing complete prototype w7-8
  - Test prototype w9

- LHC installation
  - Hypothesis
    - Conservative hypothesis that drilling not allowed when liquid helium
    - Installation = same risk as alignment operations (ok with liquid helium)

  - Drilling 2 weeks / sector starting in week 11 for sector 2-3
  - Overall installation 2 weeks / sector within the general planning
  - Alignment check of SSS after system installation: a total of 25 days ok with general planning

Costs

- 104 systems to be manufactured and installed
  - System: 104 x 5'000 CHF — 520'000 CHF
  - Ground fixation: — 42'000 CHF
  - Manpower
    - Drilling: 104 x 4 x 6 x 62 CHF — 155'000 CHF
    - Installation: 104 x 2 x 8 x 62 CHF — 103'000 CHF
  - Equipment for drilling and installation: — 27'000 CHF
  - Alignment: — 20'000 CHF

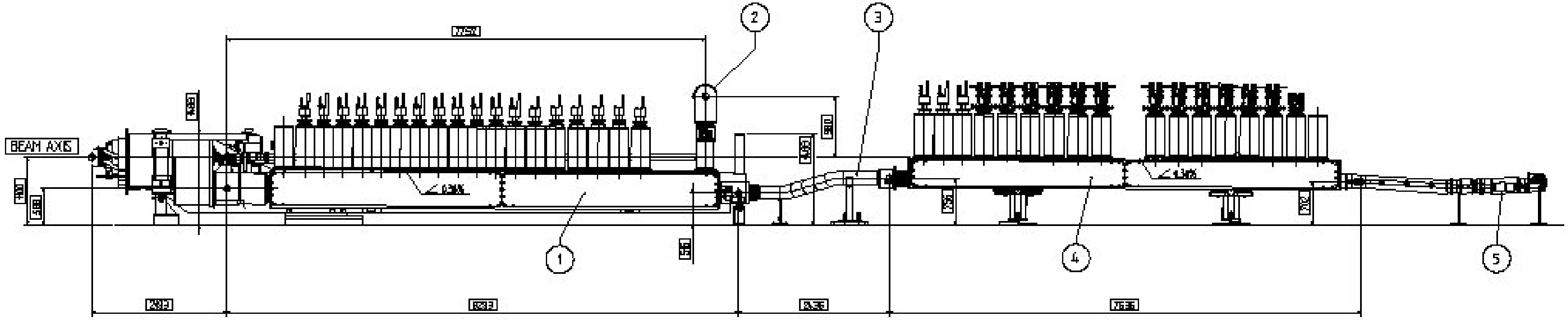
  - Total for 8 sectors — 867'000 CHF

- *Rmq transport operations not included*

Next weak point?

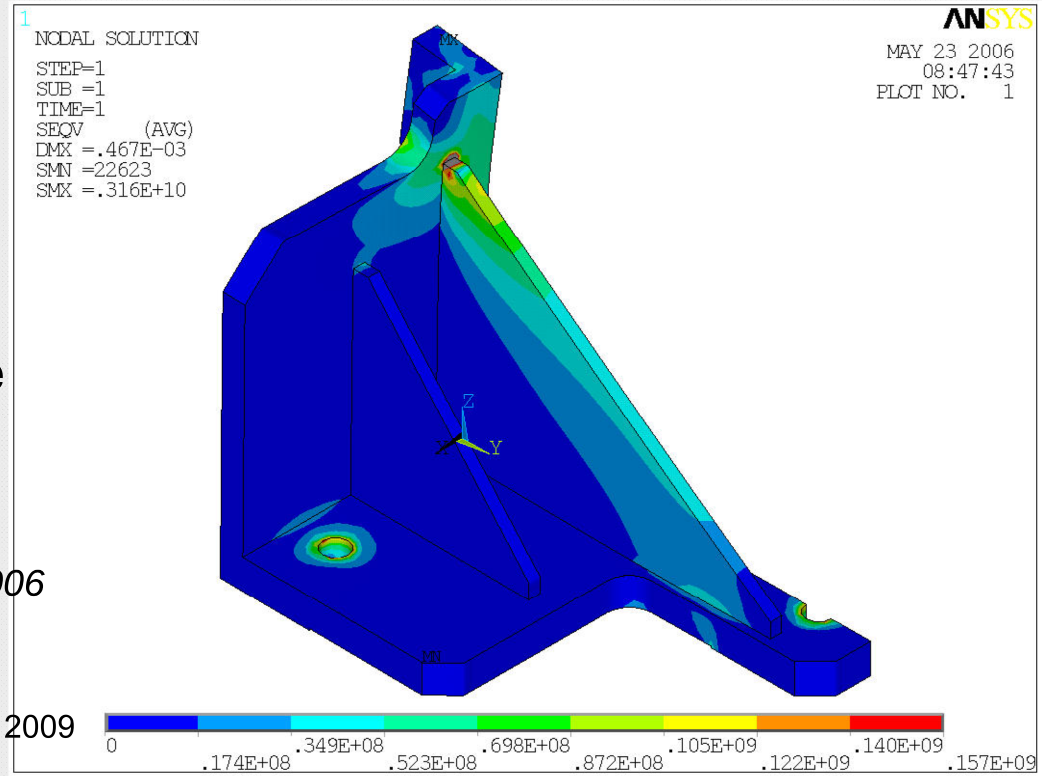
- The anchoring of SSS with vacuum barrier have been discussed
- If new cryostat design pressure 0.3 MPa instead of 0.15 MPa, what about the other equipments?

- DFBA



Next weak point?

- DFBA
  - Calculations done by A. Bertarelli in 2006 for a vessel design pressure of 0.15 MPa absolute (0.05 MPa relative)
  - The new design pressure of 0.3 Mpa (0.2 MPa relative) multiplies the applied loads by a factor 4
    - Shuffling module vacuum vessel – with the new design pressure the tank will plastify locally but should not get to failure
    - The "negative fixator" (external support) will fail
    - Fixation very difficult to improve due to lack of space



Alessandro Bertarelli
DFBA calculations done in 2006

Conclusions

- The design of the improved anchoring of SSS with vacuum barrier has been presented
- It was designed to withstand 240 kN longitudinally, equivalent to 0.3 MPa of differential pressure on both sides of the vacuum barrier
- The system is foreseen to be installed in “warm” sectors too as an additional safety device
- The installation of the equipments will be within the global planning
- The total cost will be of about 867’000 CHF, transport not included
- <u>Open questions</u>
  - What happens if $\Delta p > 0.3$ MPa ? : cold foot, vacuum barrier damaged before external anchoring damage…
  - We are very confident that vacuum barrier and cold foot withstand the load equivalent to 0.3 MPa but it has never been demonstrated
  - Next week point could be the DFBA…
  - What about other elements (such as all “special” cryostats of the LSS, jumper vacuum barrier …)?

Thank you !

… in particular Lucio for his patience and advices