

Package

„The Protector“

for the Transport of UF₆

NRC meeting June 02, 2011

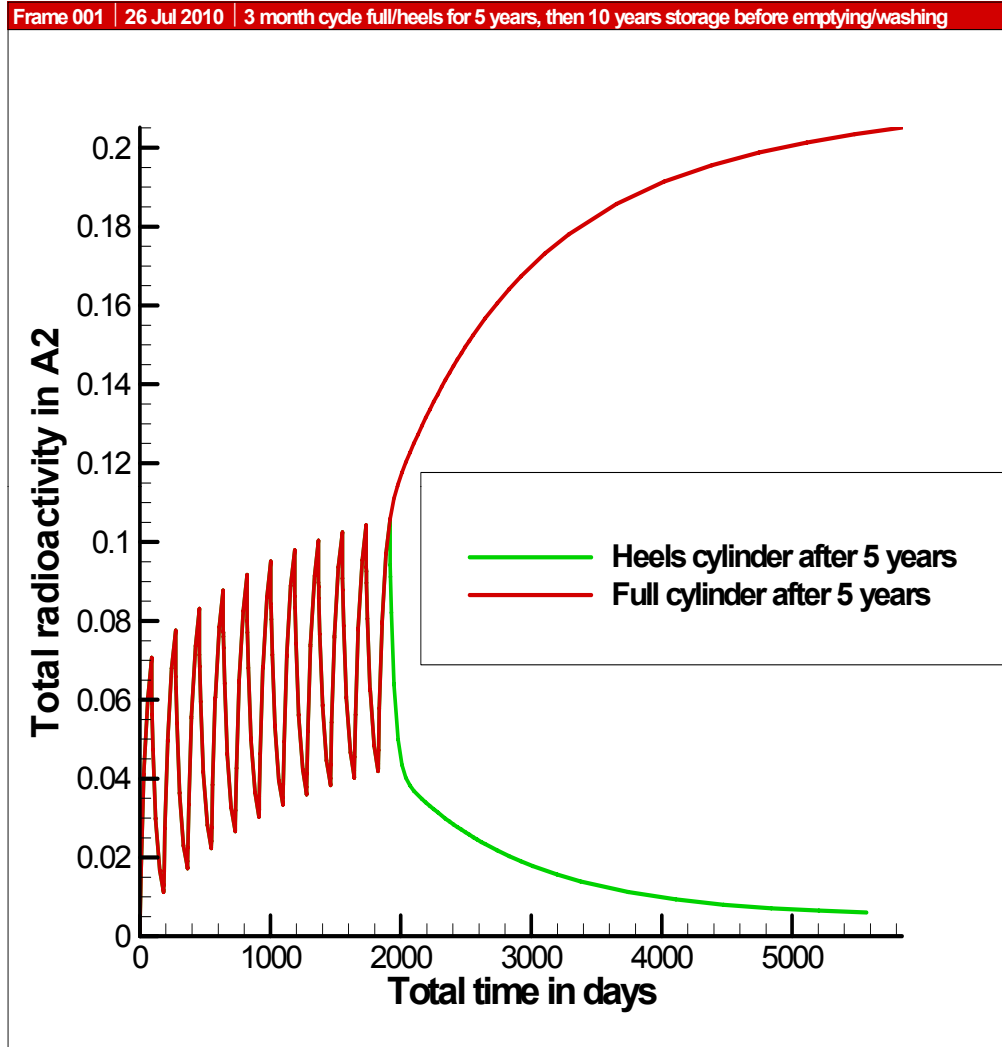
Content of the Presentation

- Definition of content and package type(s)
- Package design of the Protector
- Mechanical analysis
- Thermal analysis
- Drop test program
- Shielding analysis
- Criticality analysis
- Application status and way forward

Definition of the content

- Enriched commercial grade UF6
 - compliant with ASTM C 996
 - max. 5 wt.% enrichment
 - filled cylinders 11.34 – 2277 kg UF6
 - cylinders containing heels
 - 30 B cylinders wall thickness ≥ 11 mm
 - type AF

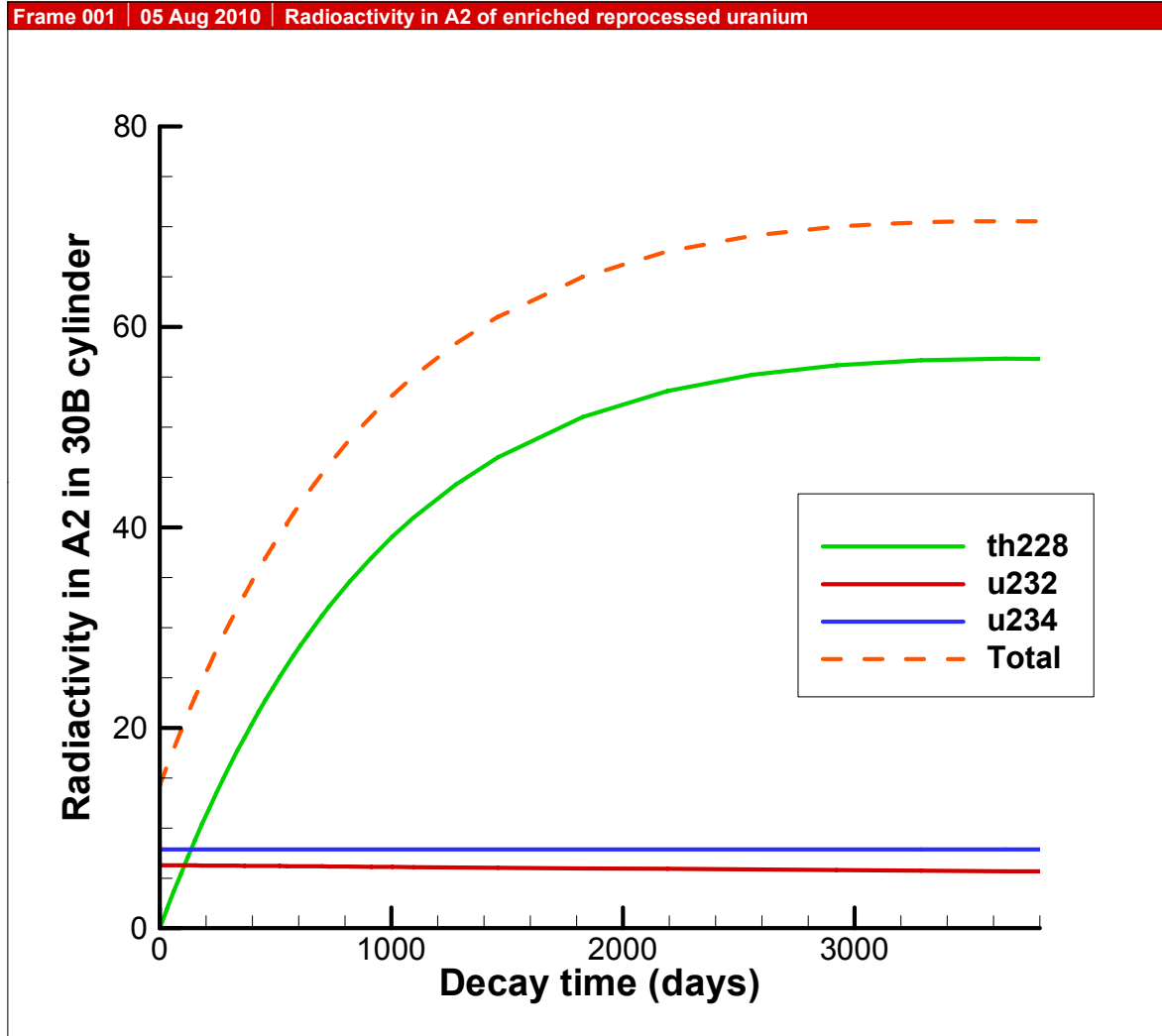
Radioactivity ASM C 996 commercial



Definition of the content

- Enriched reprocessed UF6 (product)
 - compliant with ASTM C 996
 - max. 5 wt.% enrichment
 - filled cylinders 11.34 – 2277 kg UF6
 - 30 B cylinders wall thickness ≥ 11 mm
 - dose rates of U-232 decay!
 - no time constraints for U-232 l.t. $2E-2 \mu\text{g/gU}$
 - “immediate” trp. for U-232 l.e. $5E-2 \mu\text{g/gU}$
 - type B(U)F / type IF (ADR-countries)
-

Radioactivity ASTM C 996 reprocessed



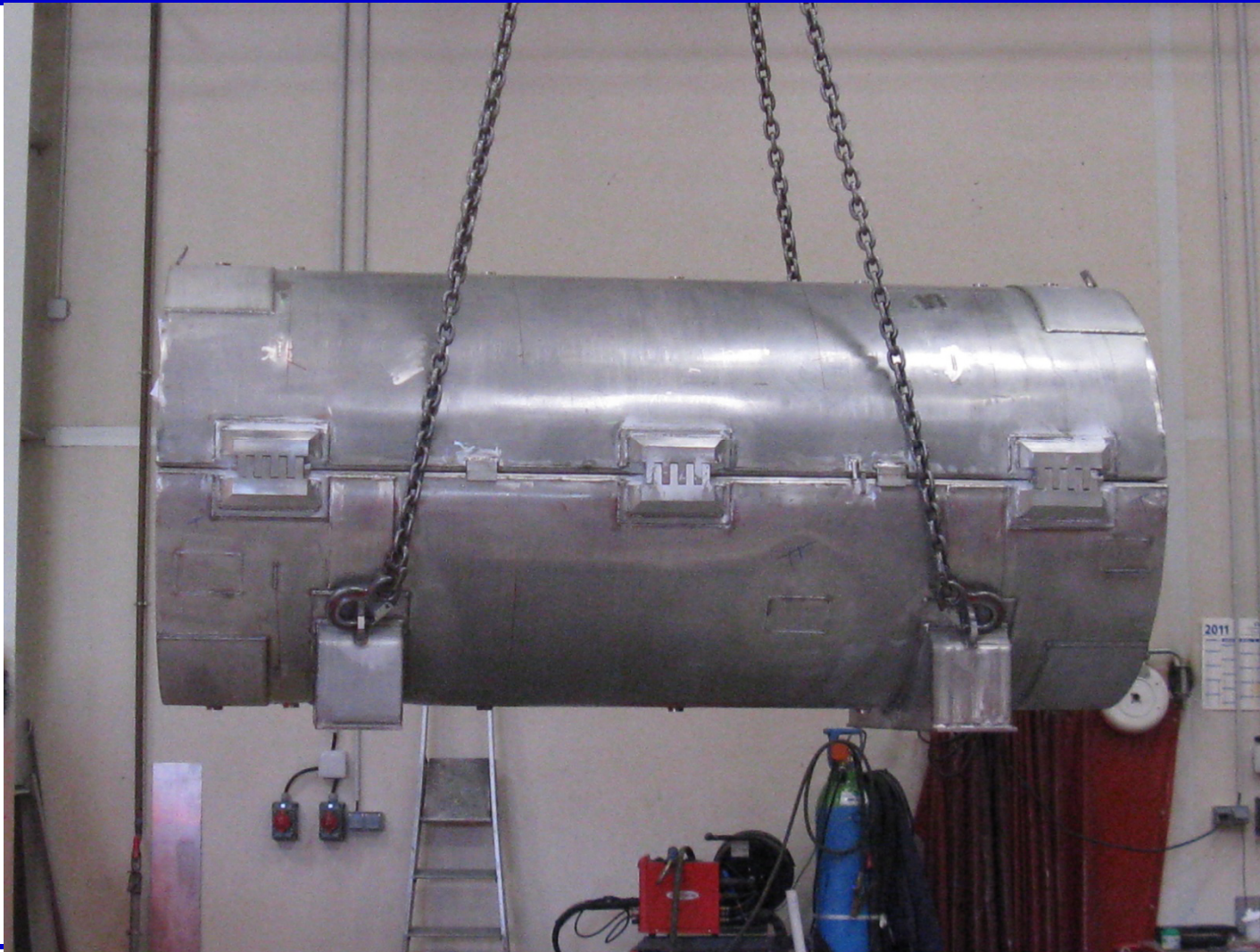
Definition of the content

- Enriched reprocessed UF6 (heels)
 - max. 5 wt.% enrichment
 - cylinders containing heels
 - dose rates of U-232 decay!!
 - intermediate storage after emptying
 - dose rate measurements
 - type B(U)F

Package Design „The Protector“



Package Design „The Protector“



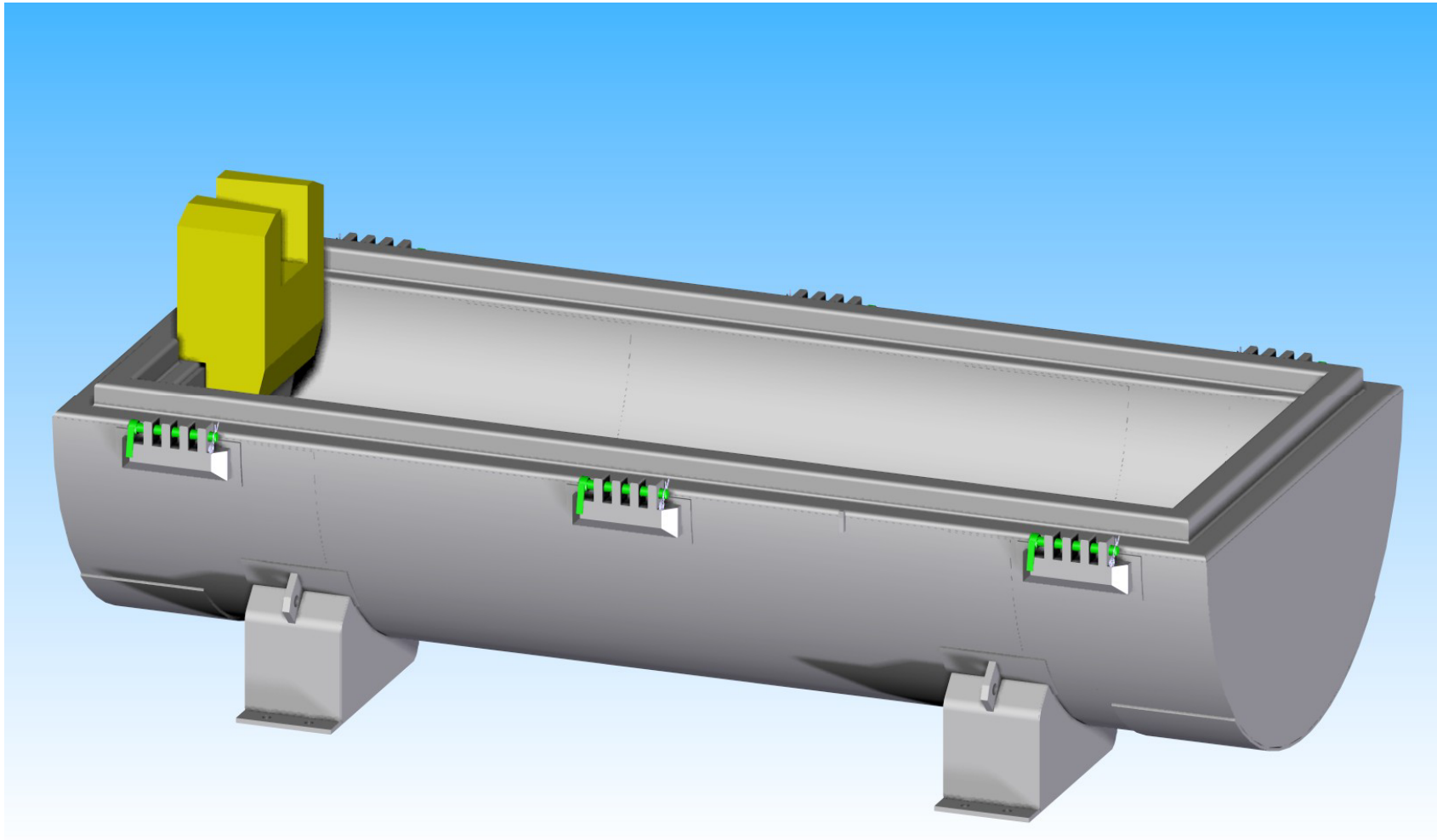
Package Design „The Protector“



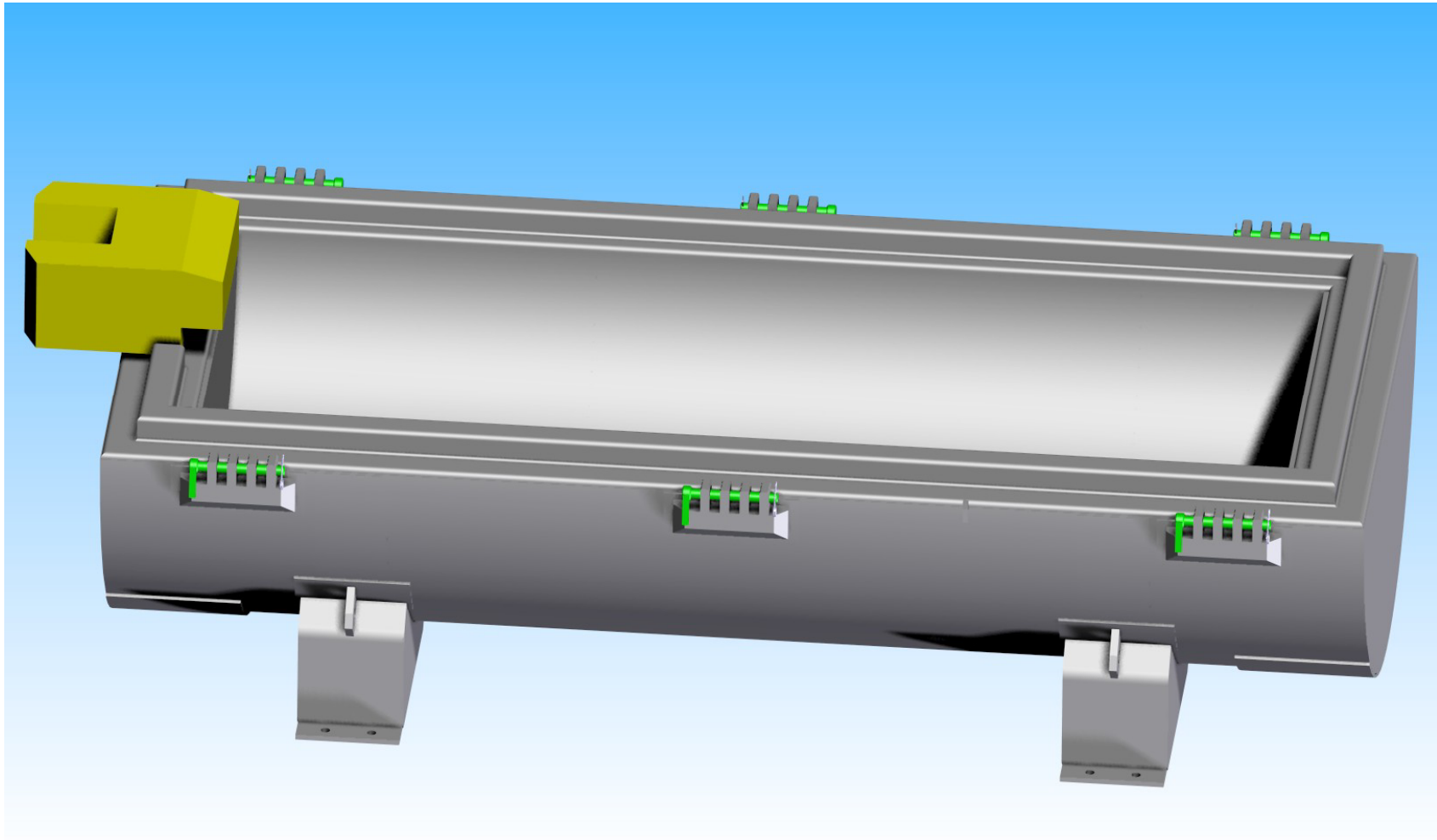
Package Design „The Protector“



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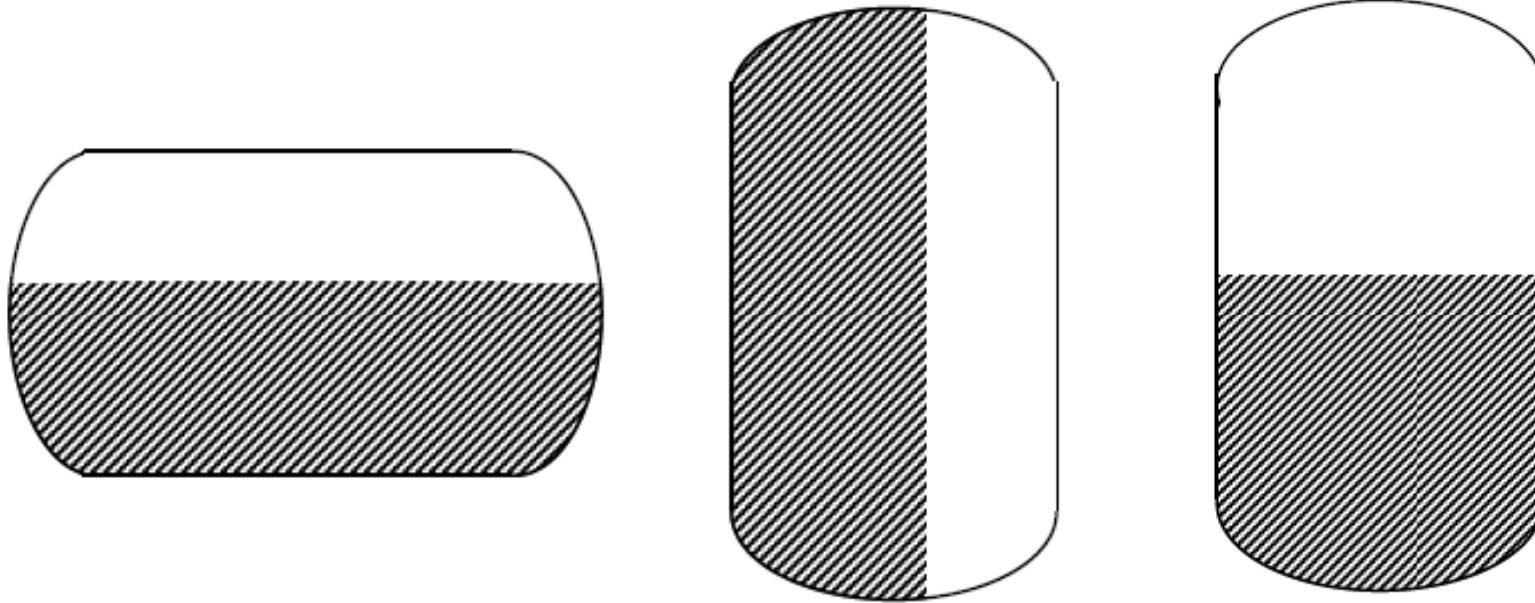
- Stainless steel shell and phenolic foam
- Hinged valve protector: steel box with foam
- Housing for plug
- Double step flange
- 6 comb like robust closures
- Welded stainless steel feet
- Mass approx. 1100 kg

Mechanical analysis

- FEA calculations with LS-DYNA
- Two UF₆ configurations
- NCT free drop test 1.2m
- ACT 9 m drop test
- ACT 1 m drop test onto the bar
- Two calculation temperatures:
 - max. temperature NCT
 - -40°C/F

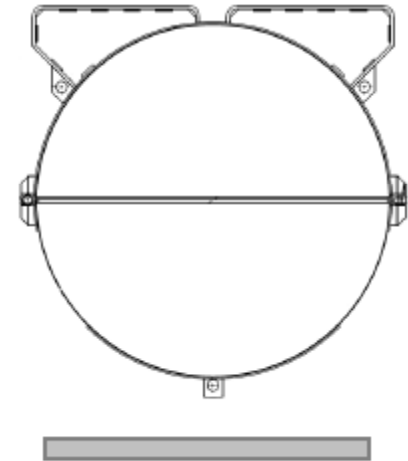
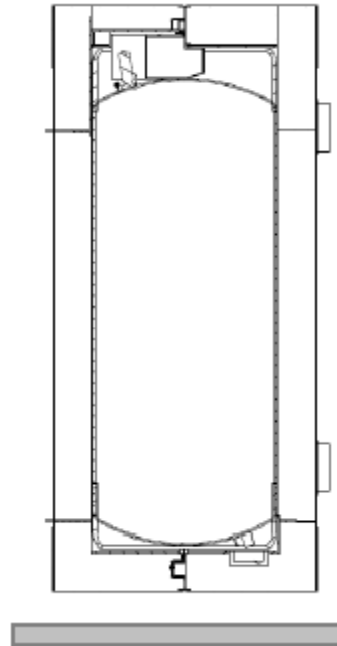
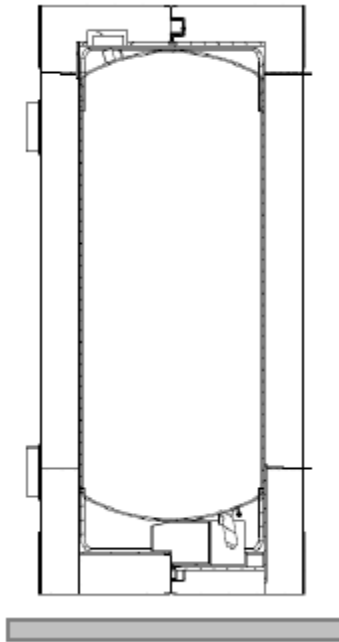
Mechanical analysis

UF₆ configurations



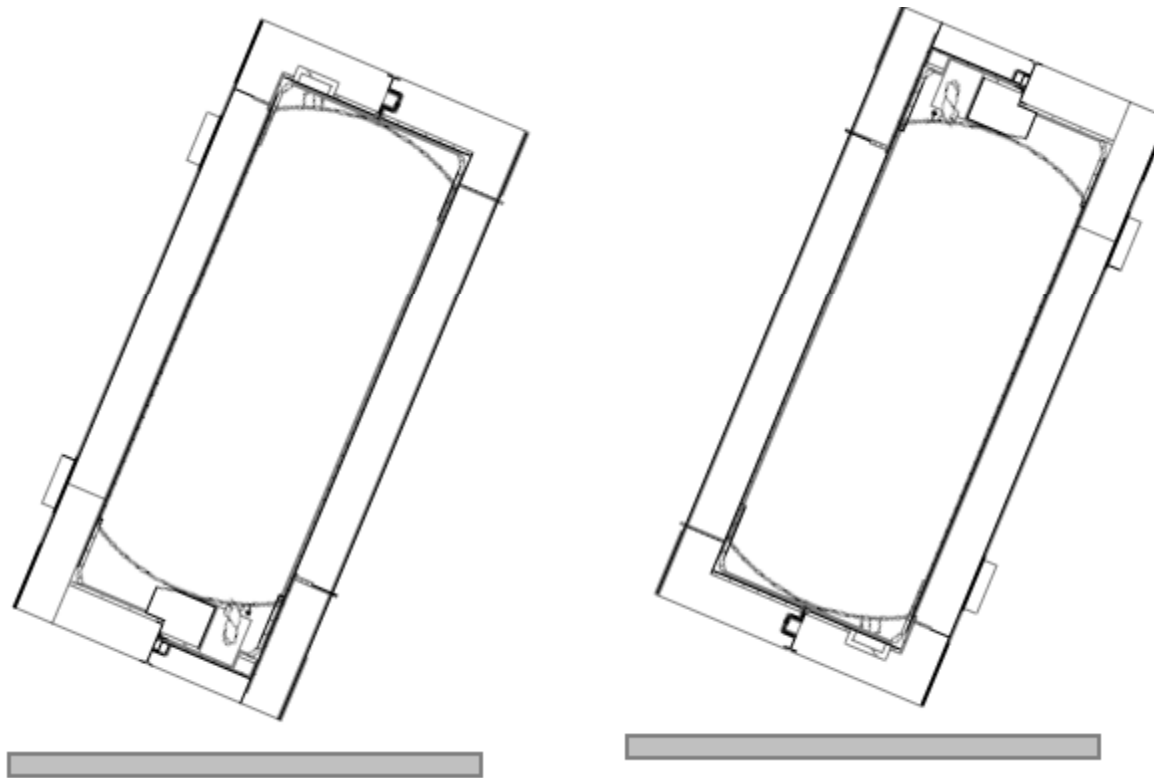
Mechanical analysis

Drop test configurations



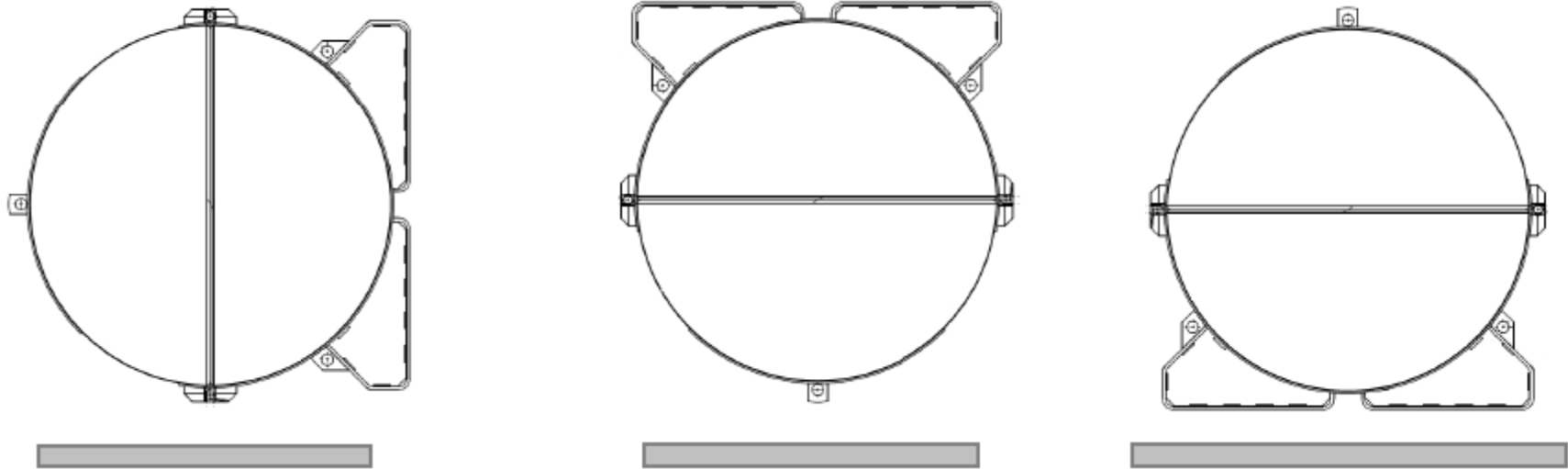
Mechanical analysis

Drop test configurations



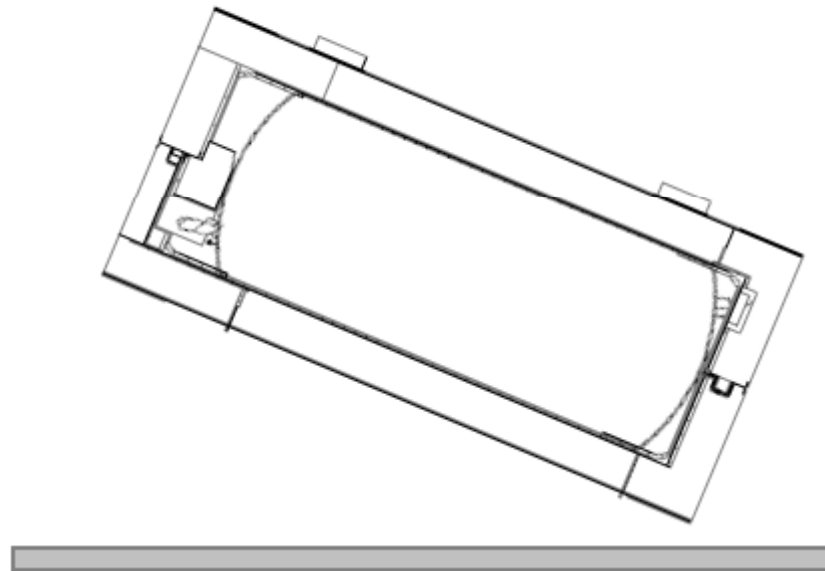
Mechanical analysis

Drop test configurations



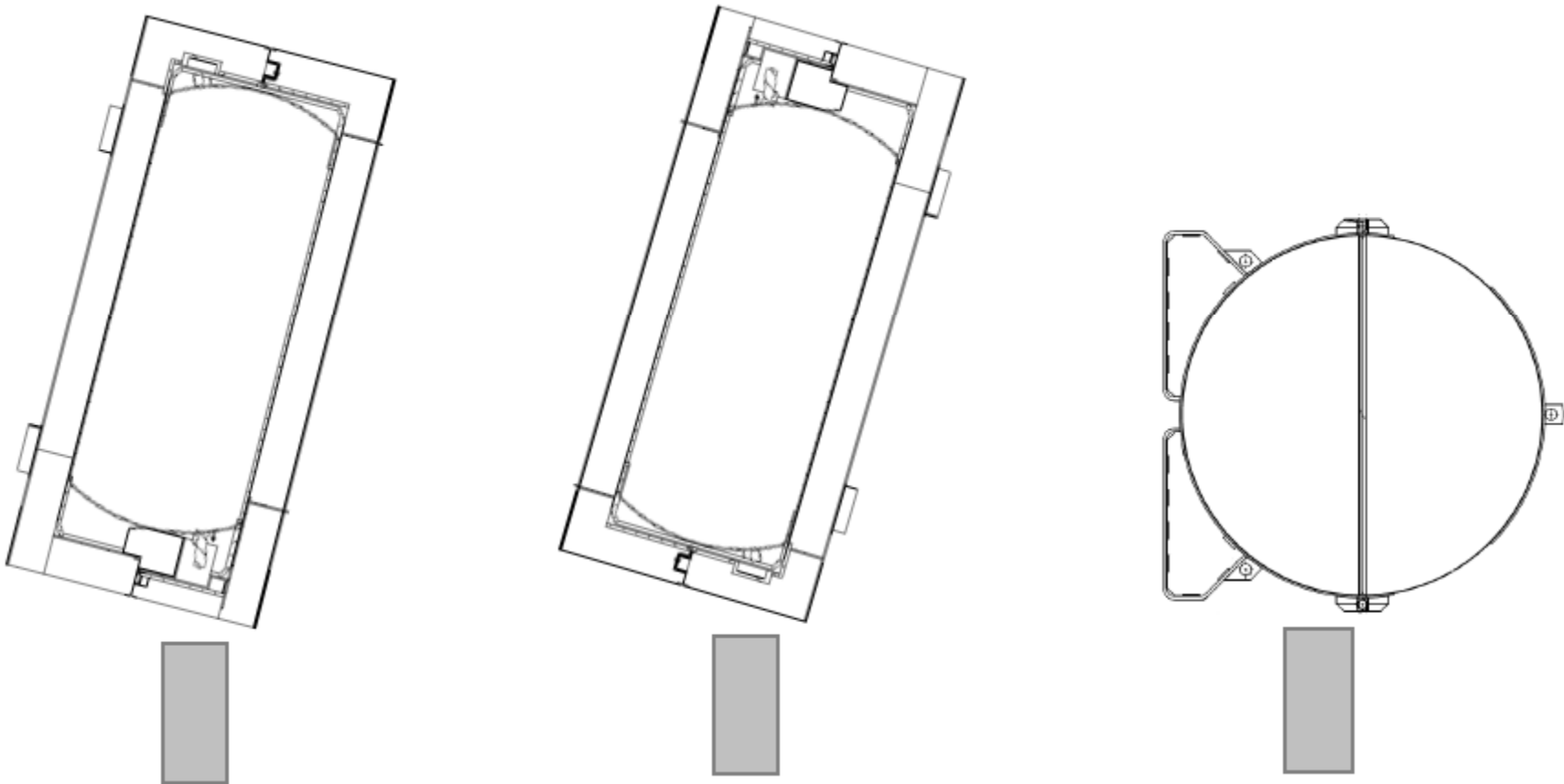
Mechanical analysis

Drop test configurations

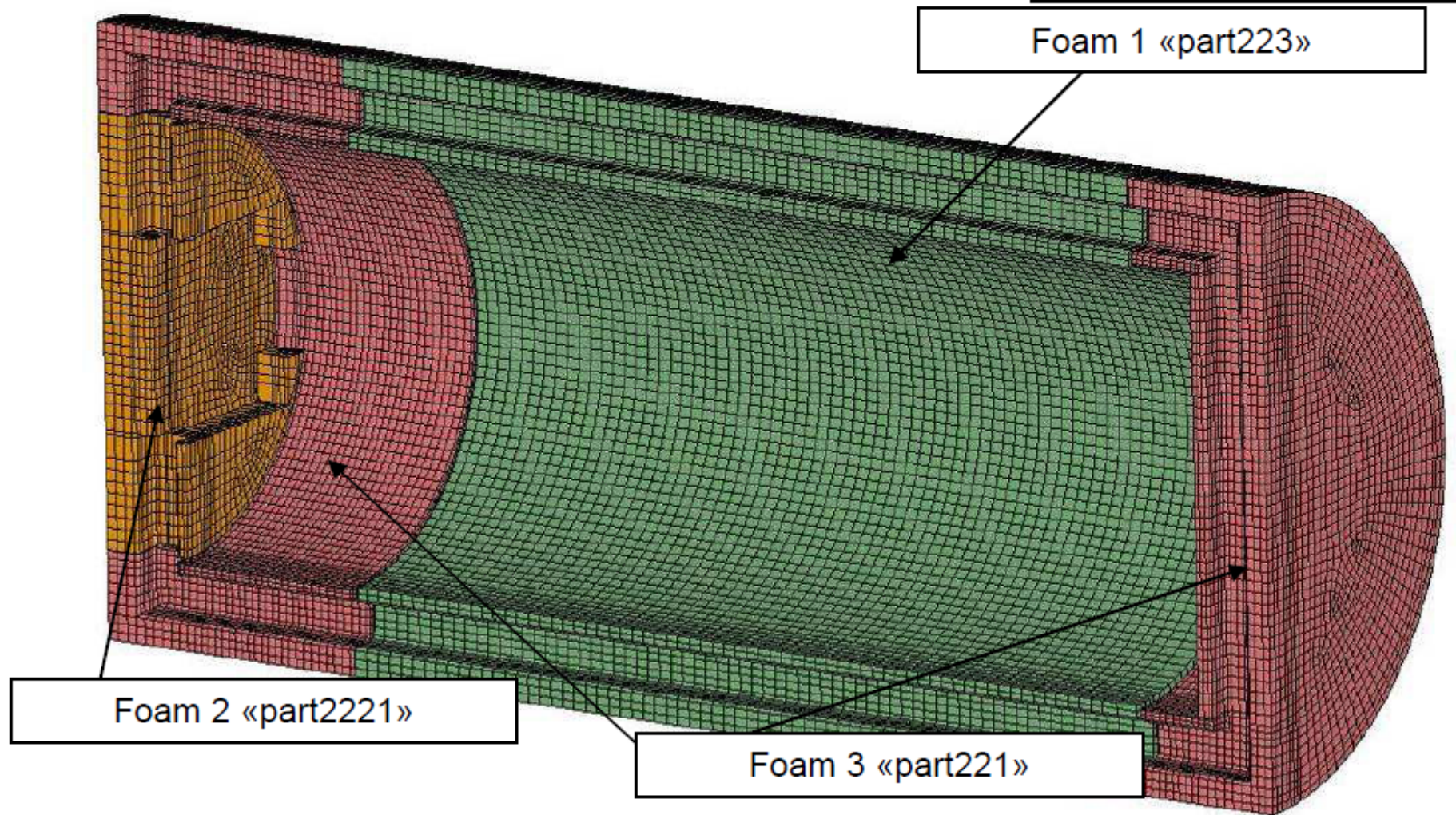


Mechanical analysis

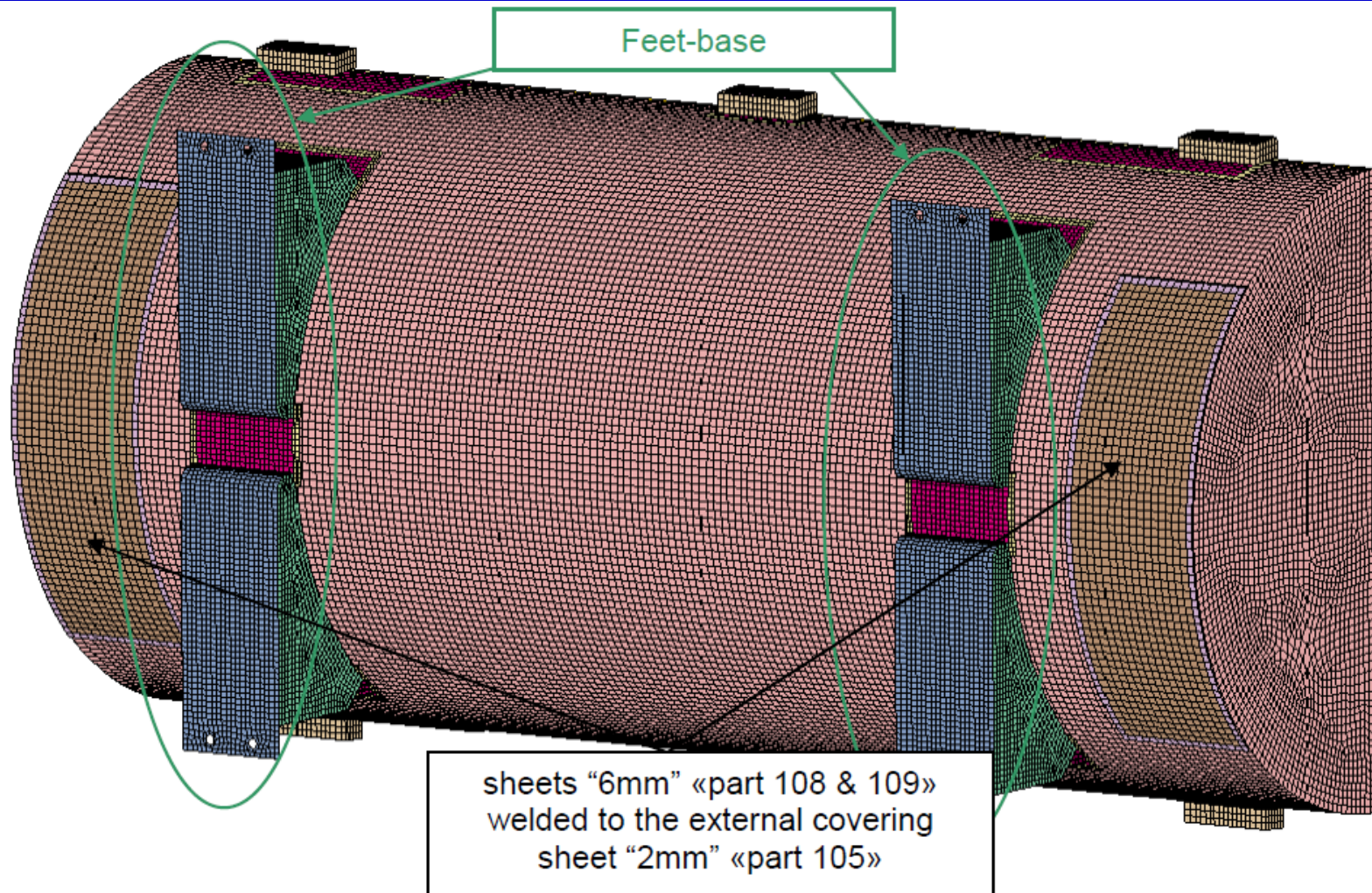
Drop test configurations



Mechanical analysis



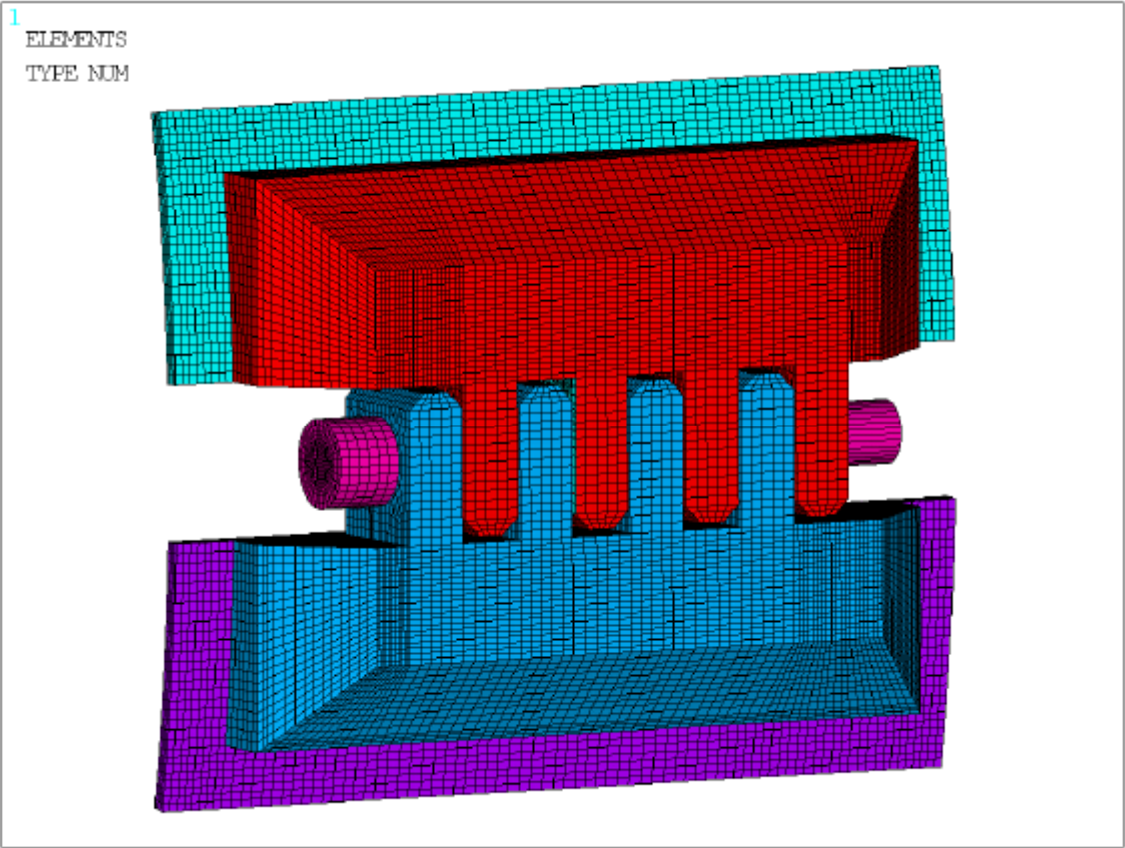
Mechanical analysis



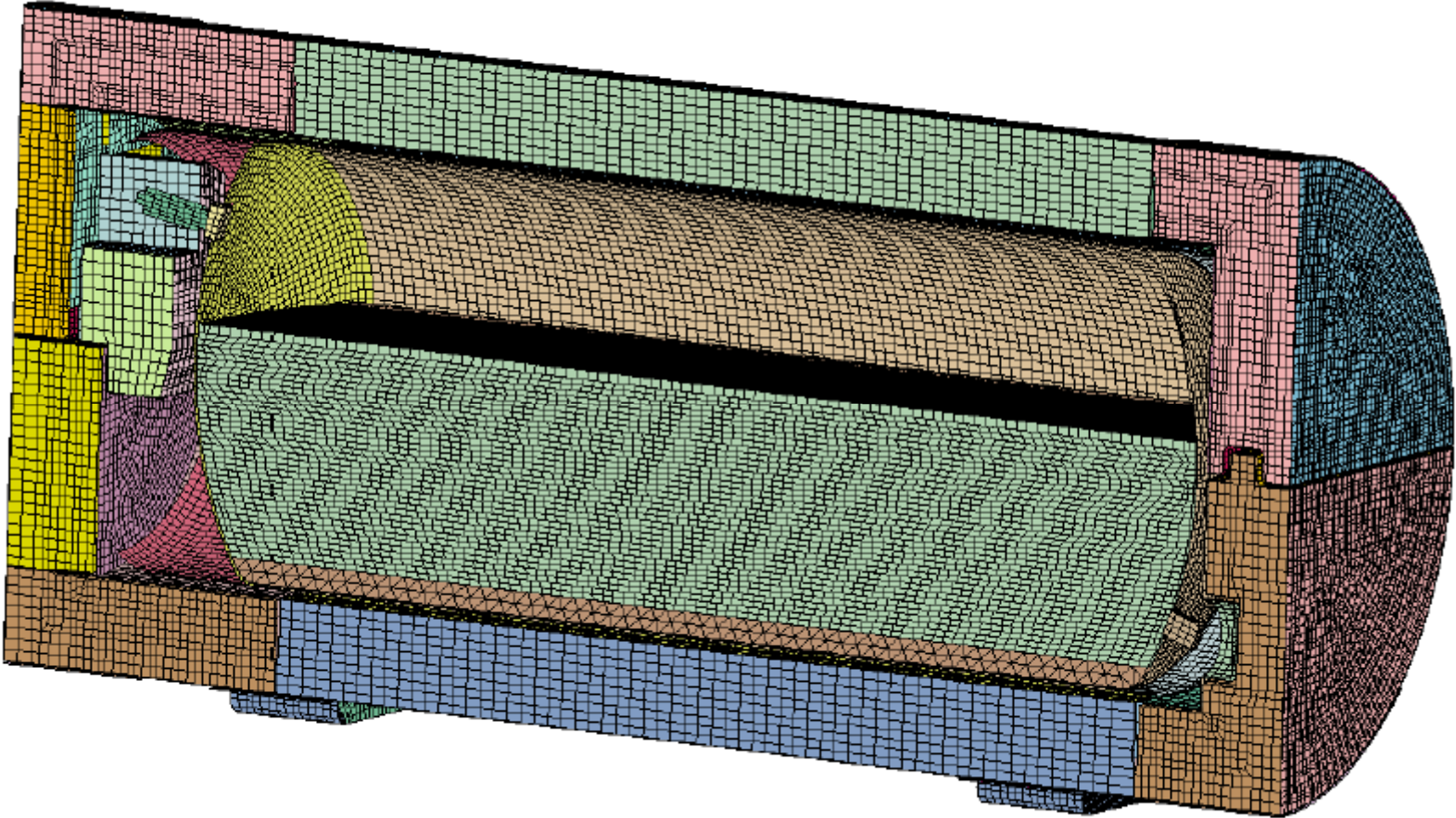
Mechanical analysis



Mechanical analysis

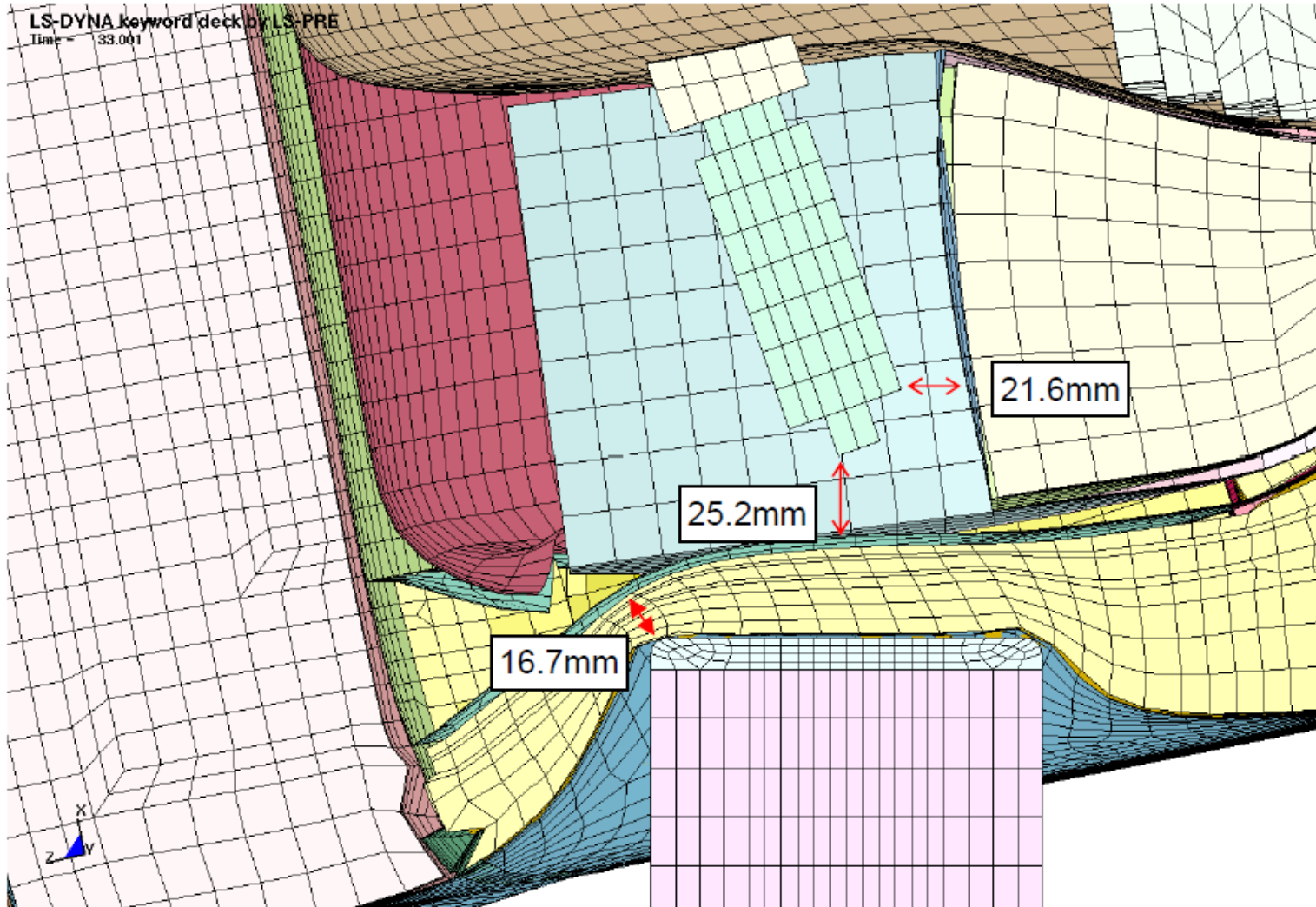


Mechanical analysis



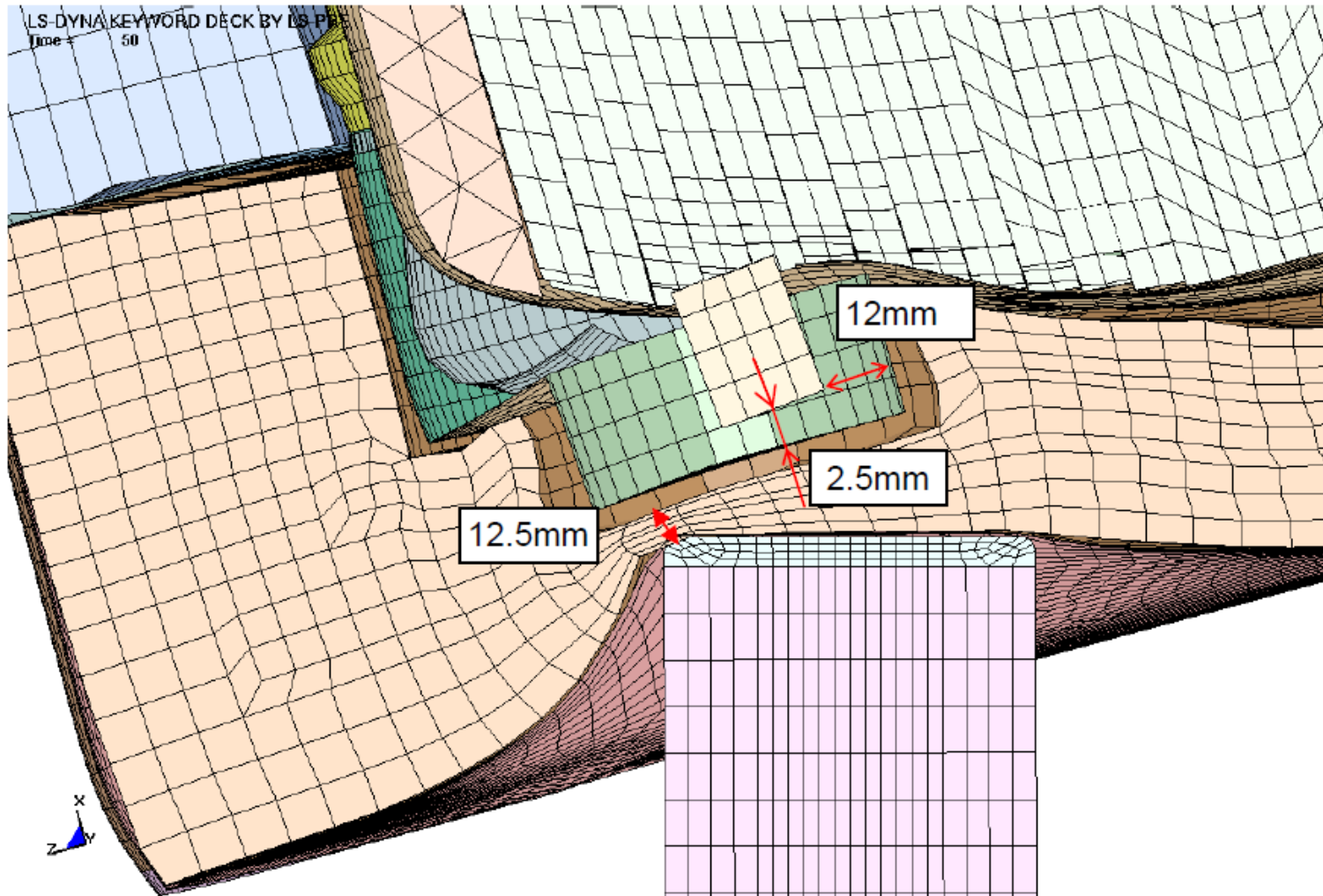
Mechanical analysis

1.2 m drop, 9 m drop and 1 m drop (bar) onto valve side



Mechanical analysis

1.2 m Fall, 9 m Fall und 1 m Fall (Dorn) auf die Stopfenseite

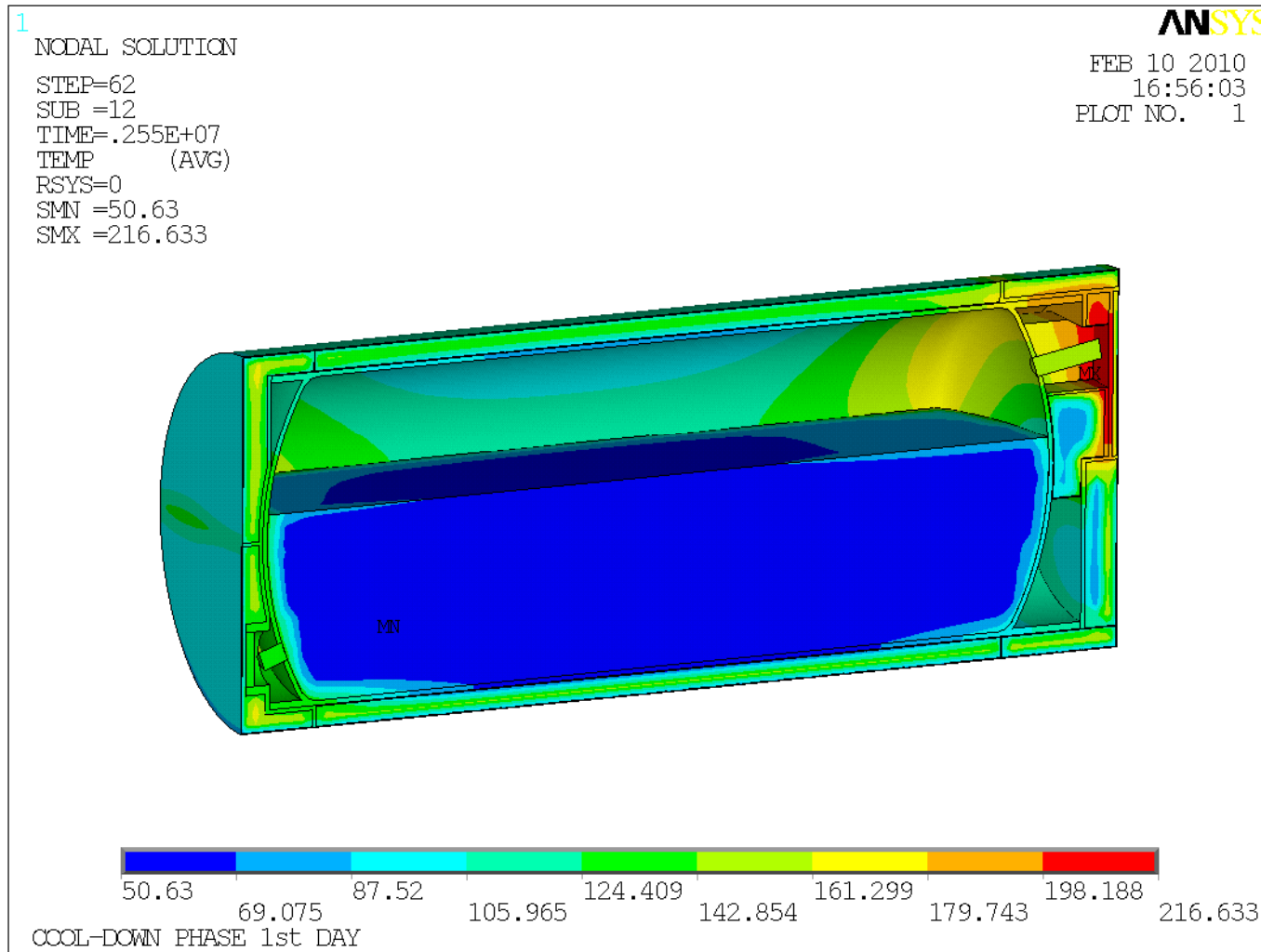


Thermal analysis

- FEA calculations with ANSYS
- NCT according to TS-R-1
- ACT horizontal and vertical
- ACT for 0 – 60.4% filling ratio (60.4% = 2277 kg UF₆)
- Max. temperature valve 160°C
- Max. temperature UF₆ 70°C (100°C for empty cylinder)
- Max. pressure 0.5 MPa

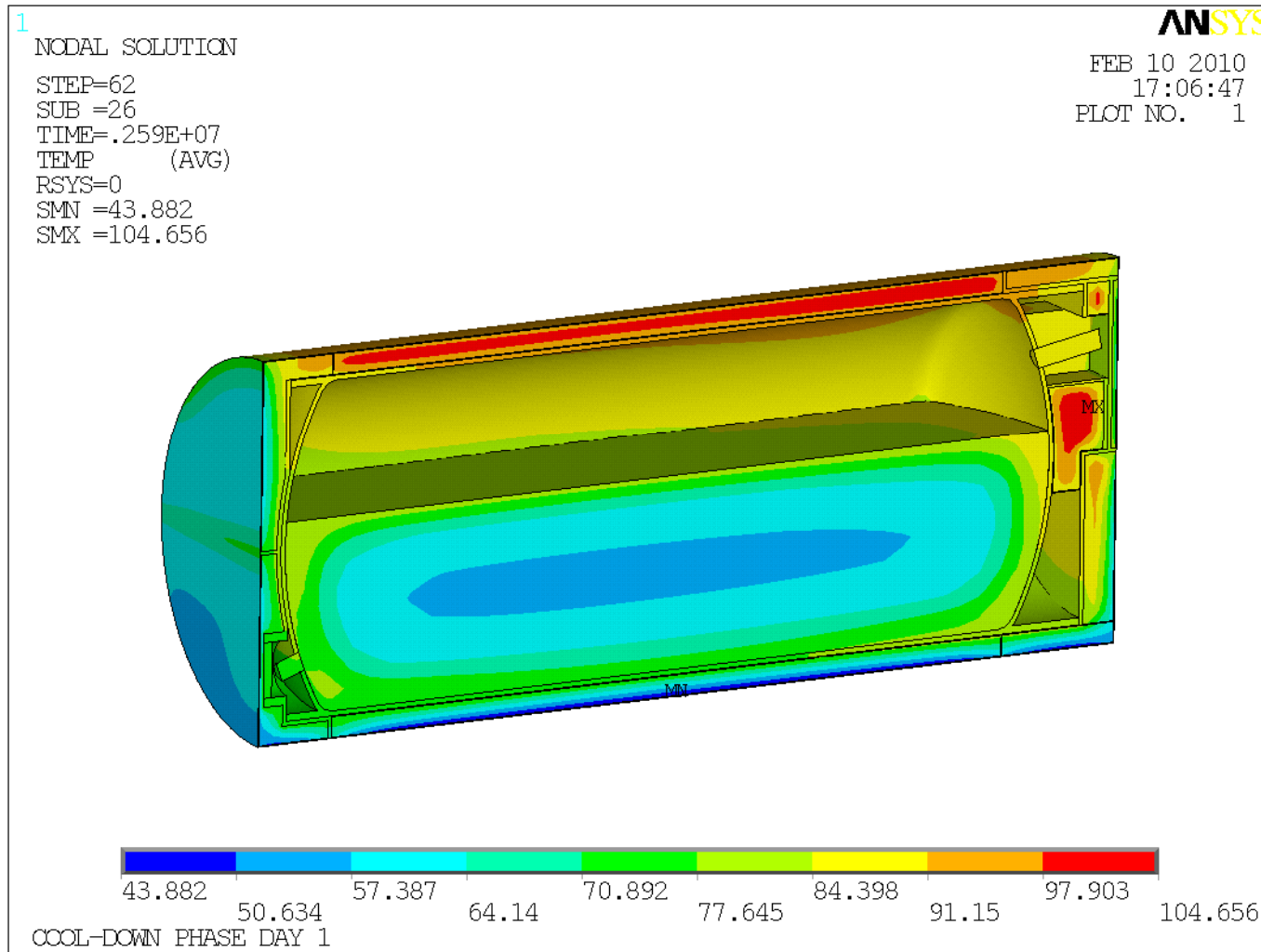
Thermal analysis

Max.
valve
temp.



Thermal analysis

Max.
UF₆
temp.



Drop test program

- 5 prototypes
- Drop tests at BAM/Horstwalde test site
- Drop tests at RT, benchmarking
- Nominal dimensions of overpack
- Conservative material properties
- ASTM A516 grade 60 for cylinder
- Content simulation steel balls

Drop test program

- Sequence 1 (prototype 1):
 - 1.2 m oblique valve side (63°)
 - 9 m oblique valve side (63°)
 - 1 m bar oblique valve side (78°)
 - 1 m bar mantle side (25°)
 - 1 m bar onto most damaged closure

- Sequence 2 (prototype 2):
 - 1.2 m edge plug side (63°)
 - 9 m edge plug side (63°)
 - 1 m bar plug side (63°)

- Sequence 3 (prototype 3):
 - 1.2 m flat valve side
 - 9 m flat valve side
 - 1 m bar valve side

- Sequence 4 (prototype 4):
 - 1.2 m horizontal onto closures
 - 9 m horizontal onto closures
 - 1 m bar horizontal onto closures
 - 1 m bar onto the joint between upper/lower half

Drop test program

- Sequence 5 (prototype 5):
 - 1.2 m mantle slap down drop (15°)
 - 9 m mantle slap down drop (15°)

Drop test program

- At each test:
 - accelerations
- After each test:
 - measurement of the external deformations
- After each sequence:
 - measurement of the internal deformations
 - Helium leak test cylinder
 - Visual check valve, plug; check of torque

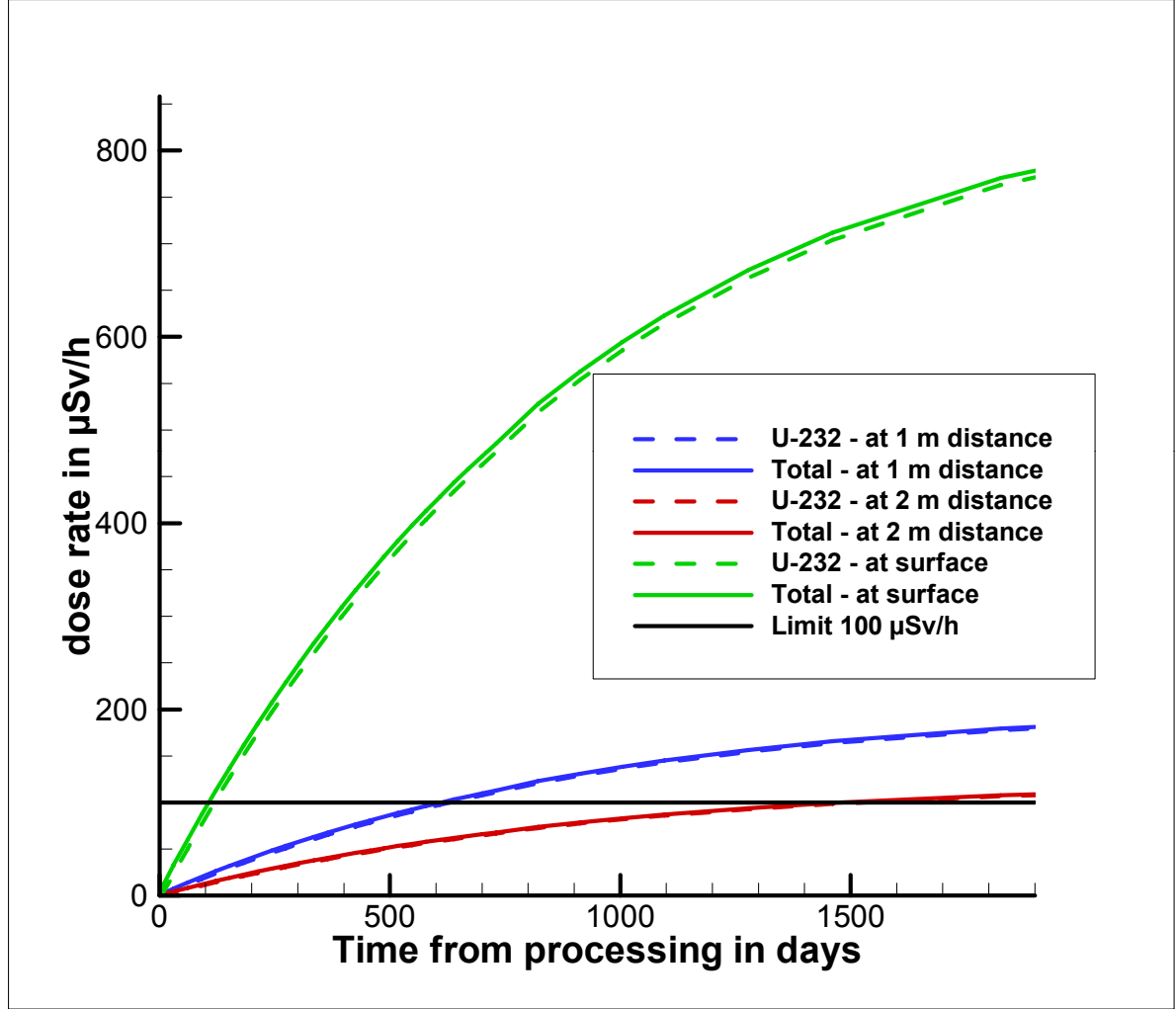
Shielding analysis

- TI < 10 (non exclusive use)
- TI > 10 only for heels of reprocessed UF6
- Surface max. 2 mSv/h
- 2 m distance max. 0.1 mSv/h
- NCT: max. 20% DL increase, NCT deformations
- ACT: max. 10 mSv/h in 1 m distance, assumption 100% loss of foam
- (Only ADR: proof LSA-II max. 10 mSv/h in 3 m distance)

Shielding analysis

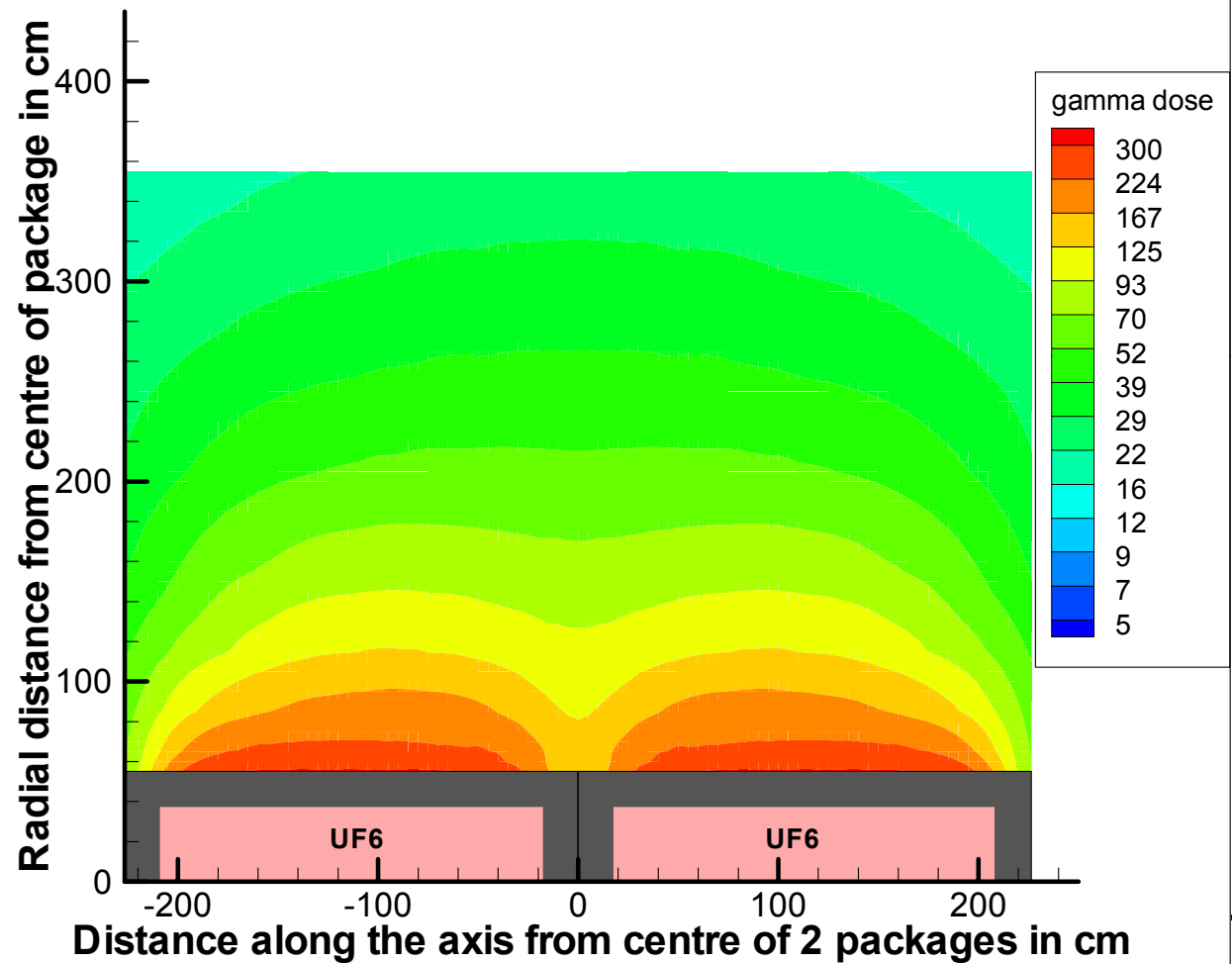
Frame 001 | 17 Aug 2010 | Gamma dose rates at a typical PSP surface/1m from package/2m from vehicle

U-232 = 0.05 $\mu\text{g/gU}$



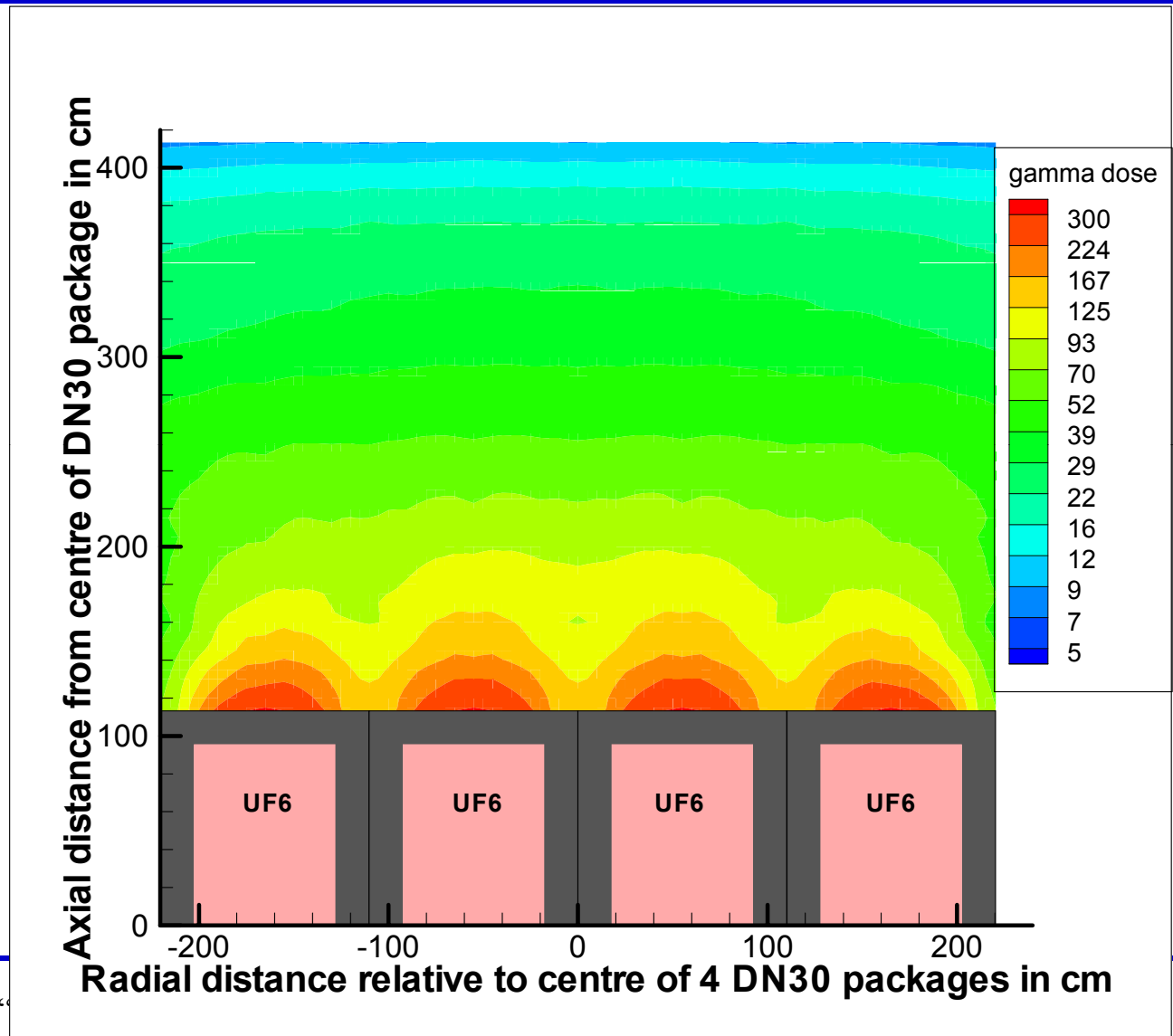
Shielding analysis

U-232 = 0.05 $\mu\text{g/gU}$
600 days after
processing
TI = 10



Shielding analysis

U-232 = 0.05 µg/gU
600 days after processing
TI = 10

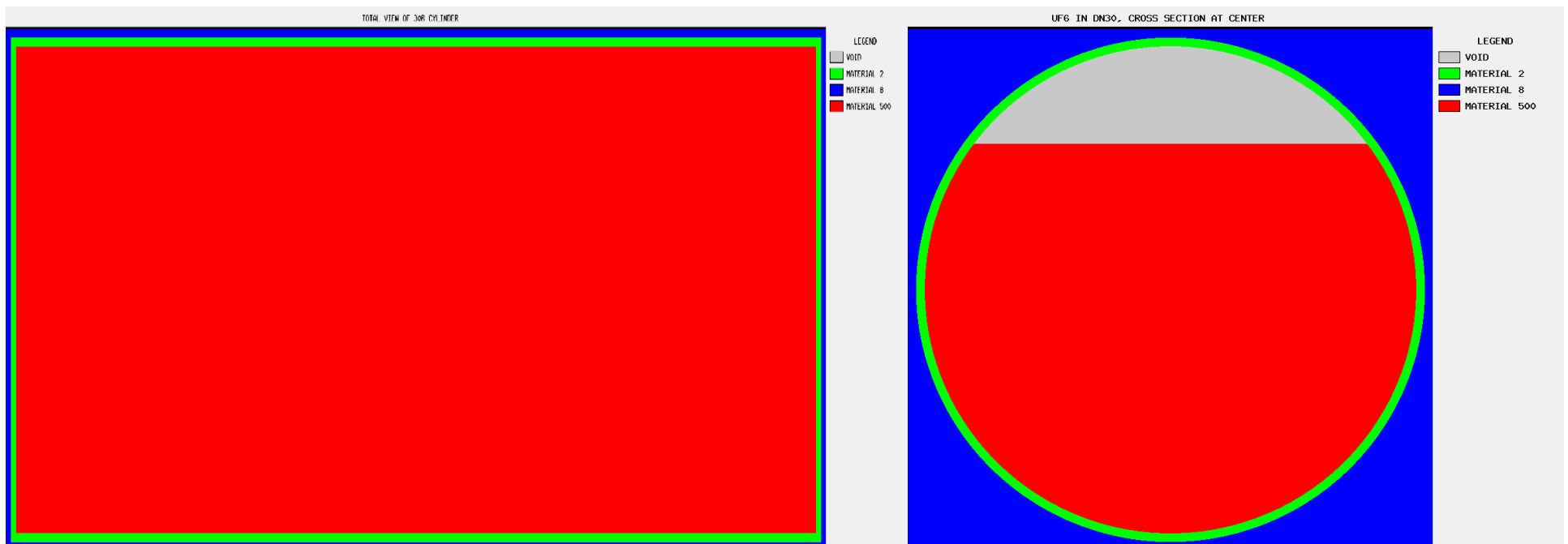


Criticality analysis

- $k_{\text{eff}} + 3 \text{ sigma} < 0.95$
- Impurities 0.5 wt.% HF
- Variation of UF6 density 3.1 – 5.5 g/cm³
- Skirts, valve, plug neglected
- NCT: cylinder without/with overpack, 20 cm water
- ACT: cylinder without/with overpack, CSI = 0

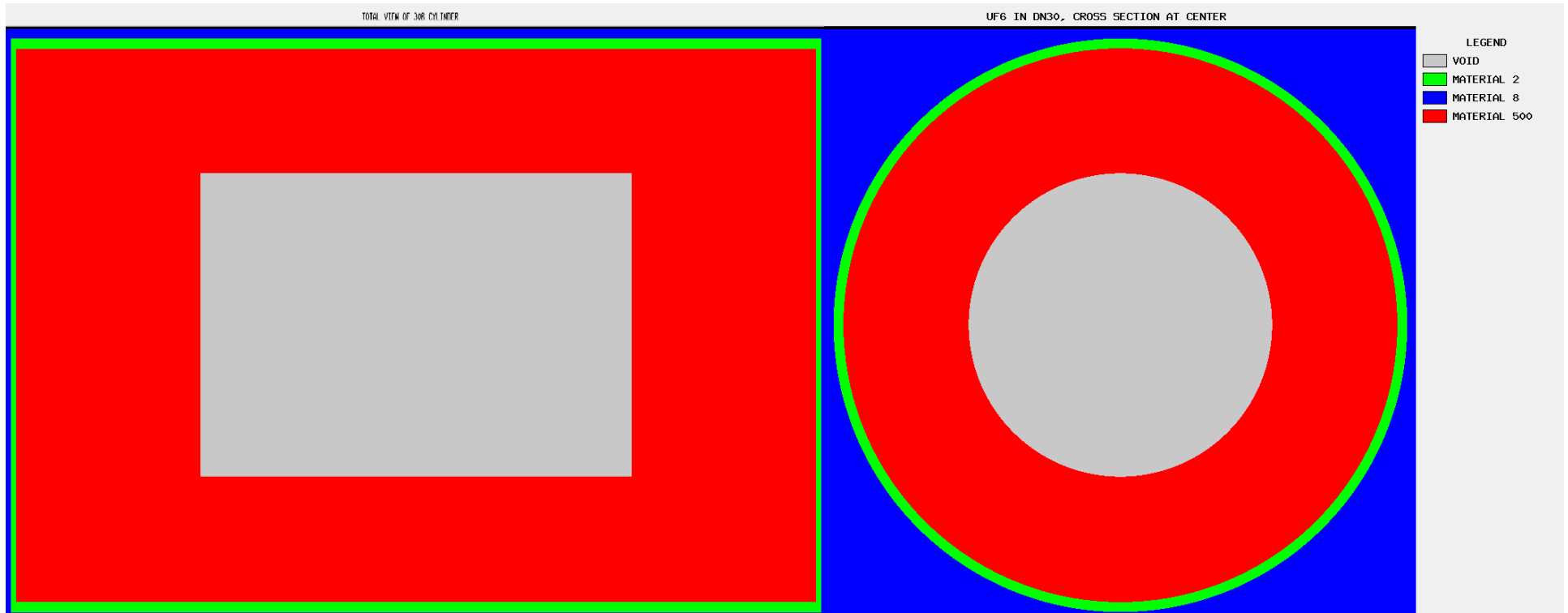
Criticality analysis

Calculation models



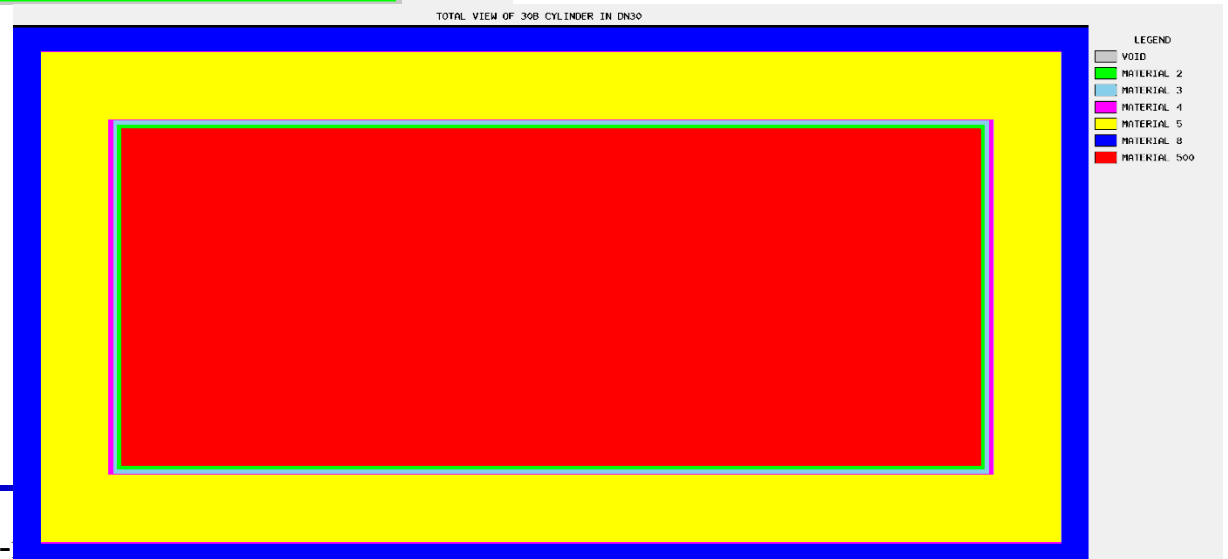
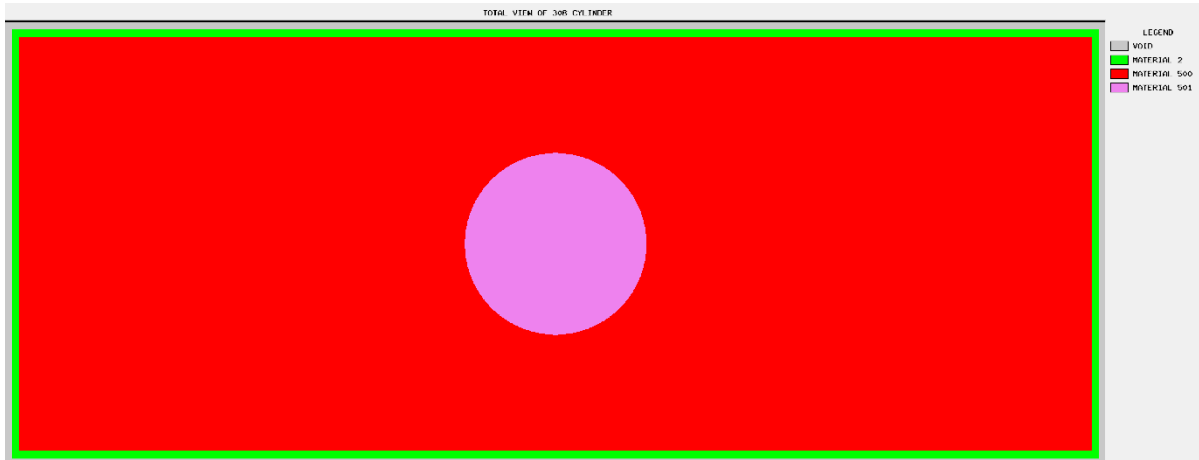
Criticality analysis

Calculation models



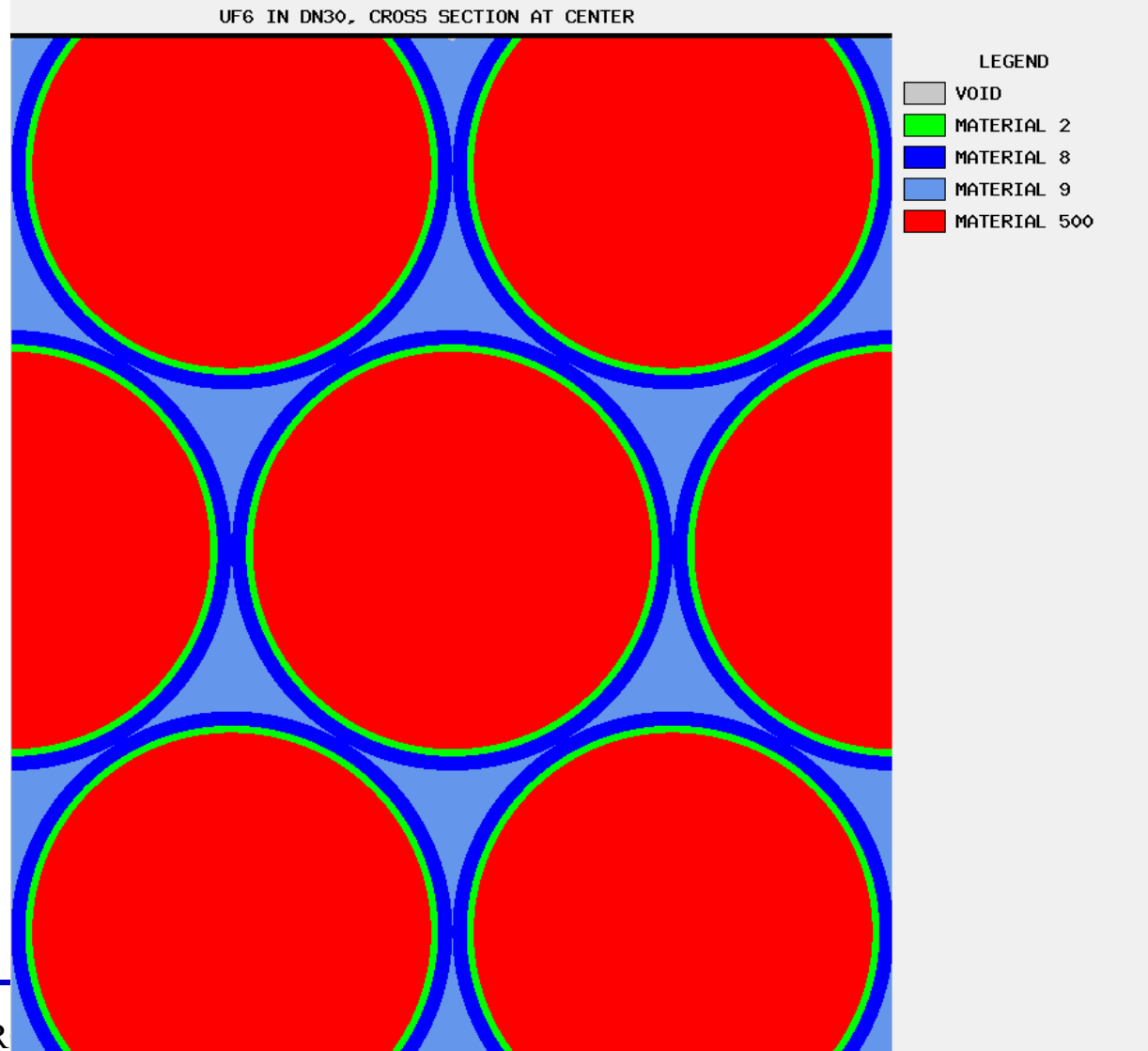
Criticality analysis

Calculation models



Criticality analysis

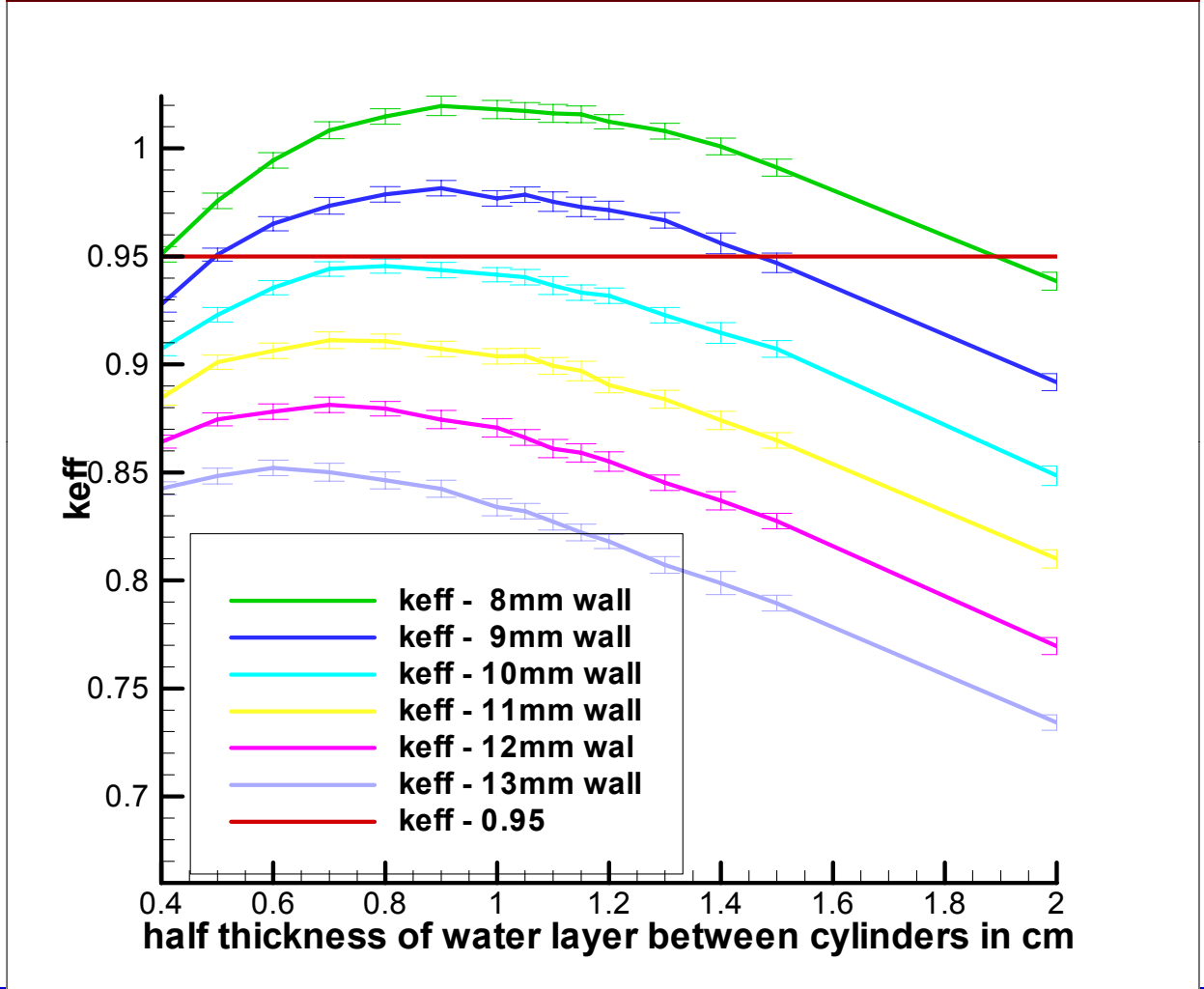
Most reactive
calculation model
for ACT



Criticality analysis

ACT
Most reactive model
Bare cylinder
Infinite arrangement
Max. UF6 density
Variation of cylinder
wall thickness
7.94 – 13 mm

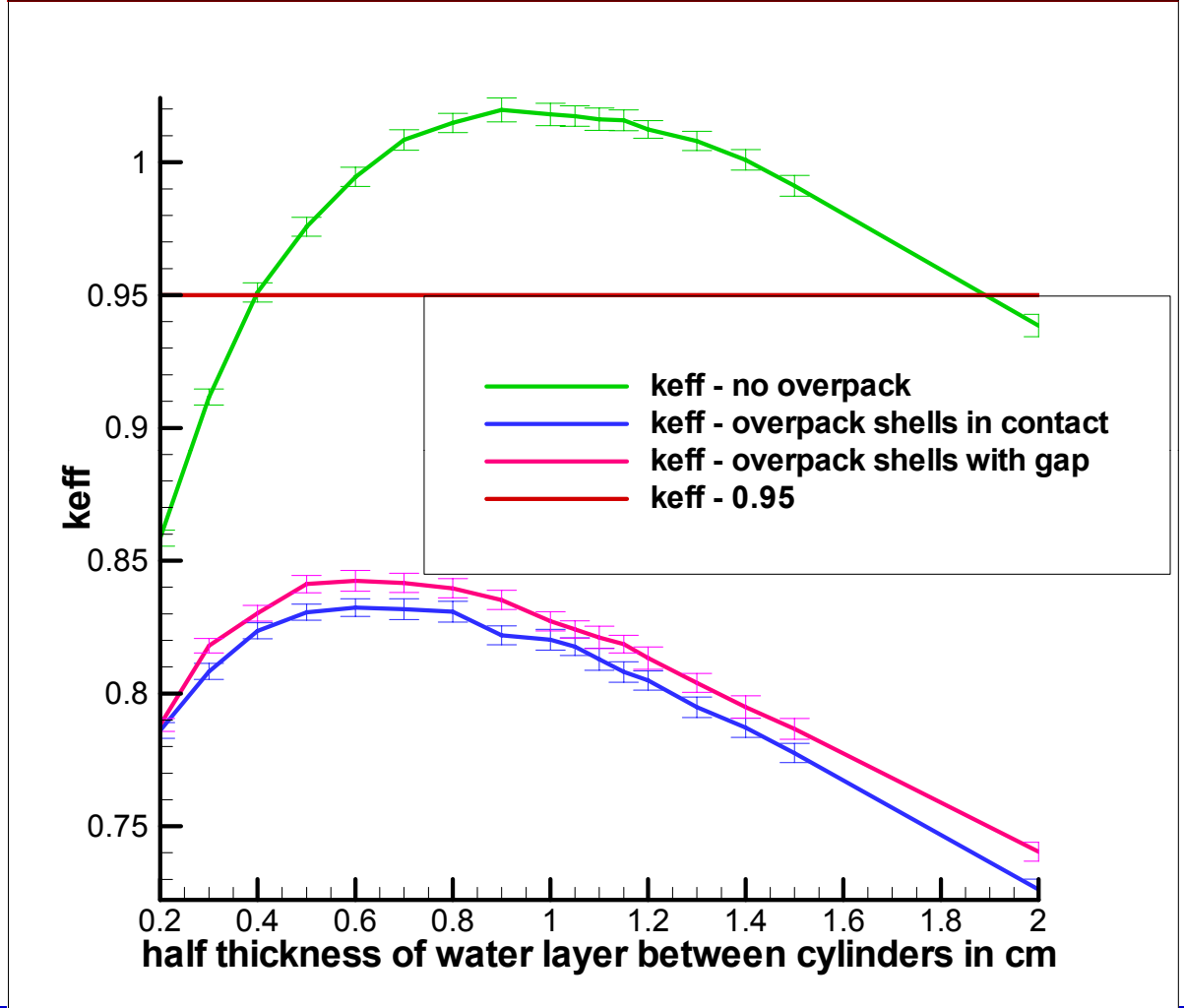
Frame 001 | 08 Oct 2009 | keff for bare 30B cylinder, ACT, 8 - 13mm wall thick., max. dimen., UF6 density 5.5 g/cm**3,



Criticality analysis

ACT
Most reactive model
Cylinder without/with
overpack
Infinite arrangement
Max. UF6 density
Cylinder wall
thickness 7.94 mm

Frame 001 | 09 Oct 2009 | keff for bare 30B cylinder, ACT, 8mm wall thick., max. dimen., UF6 density 5.5 g/cm**3, varia



- Application in France (country of origin)
- Release of drop test program expected this July
- Drop test to start immediately (BAM, Germany)
- Target: French package approval March 2012
- Application for validation in relevant countries
- 2 – 3 months expected for validations
- **How shall we proceed in the USA?**