

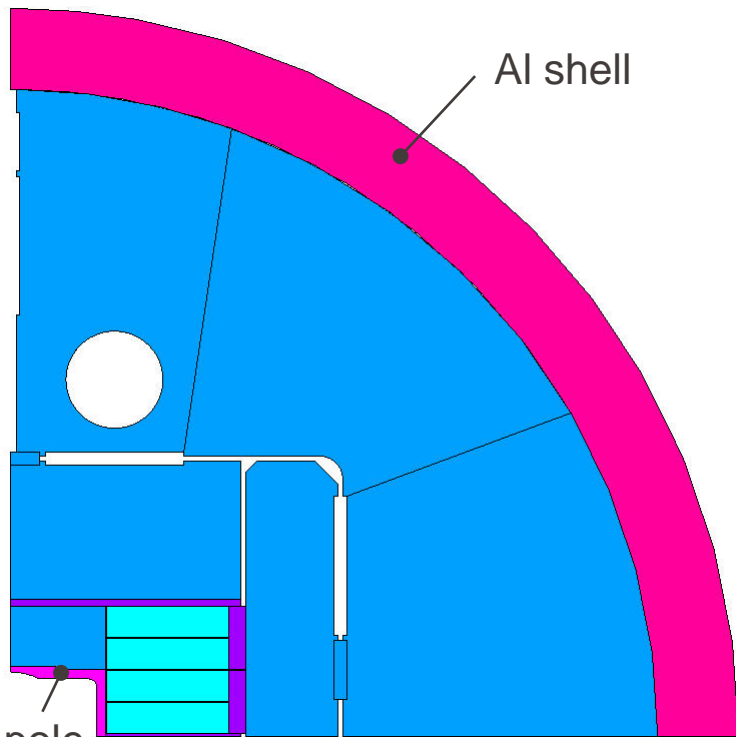
**EDIPO:  
Alternative design  
without Ti pole**

**X. Sarasola  
P. Bruzzone**

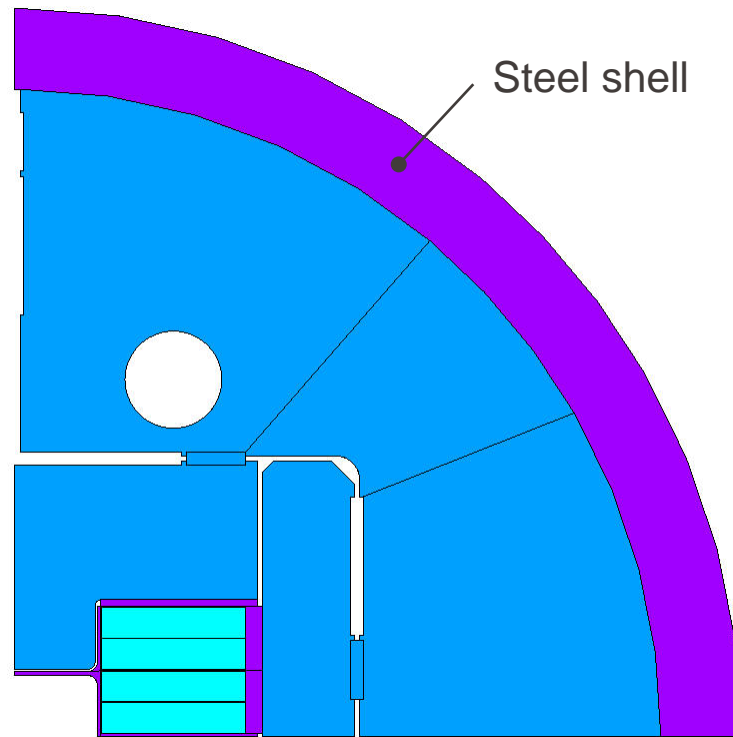
**May 8<sup>th</sup>, 2020**

# Alternative design without titanium pole

- 2018:
  - 4 coils (47 turns/pancake)
  - 14.5 T in the center aperture

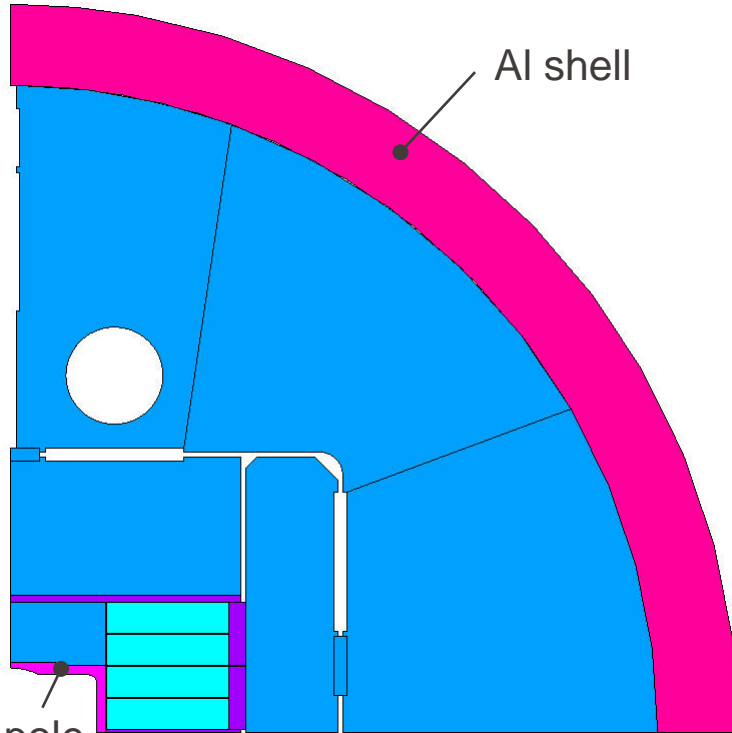


- H-shape test well, no Ti pole

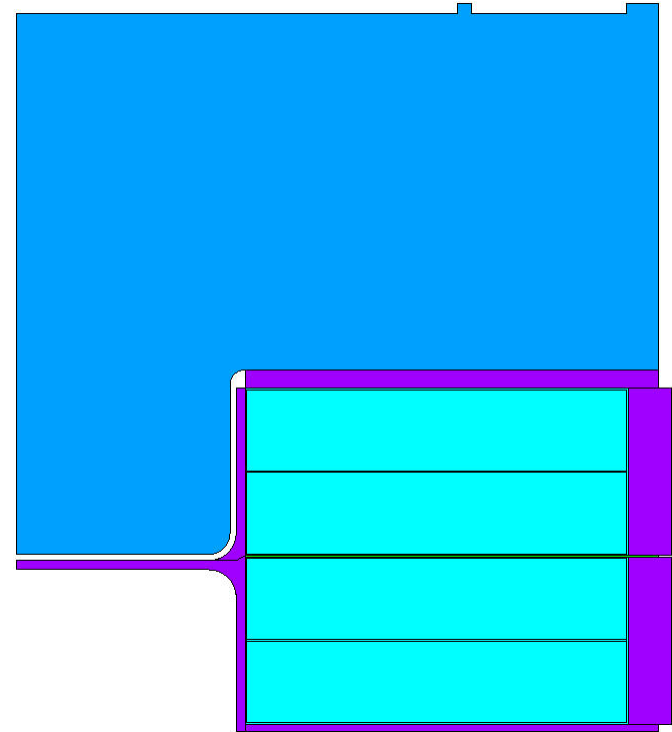


# Alternative design without titanium pole

- 2018:
  - 4 coils (47 turns/pancake)
  - 14.5 T in the center aperture

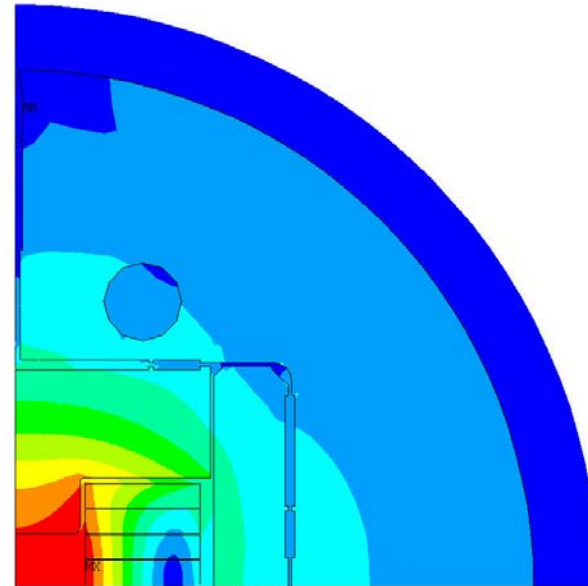


- H-shape test well, no Ti pole



- The conductor area required to reach 15 T in the center of the aperture is very sensitive to the thickness of the test well (i.e., location of WP)

Test well thickness (mm)	3.0	5.0	7.5
# turns/pancake	52	54	60
Ins conductor area (mm <sup>2</sup> )	12402	12879 (+4%)	14310 (+15%)
$I_{op} = 0.85 \times I_{ss}$ (kA)	11.66	11.46	10.87
$B_{coil}$ (T)	15.95	15.99	16.11
$B_{center\ aperture}$ (T)	14.97	14.96	14.99



```

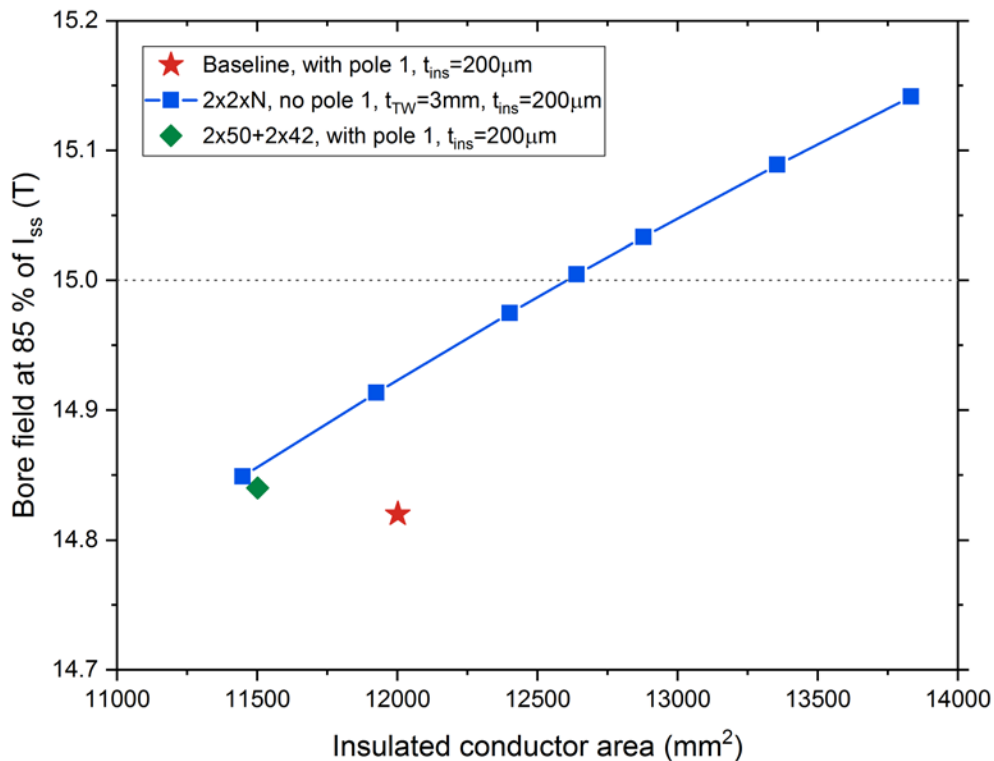
ANSYS Release 15
Build 19.0
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =5
TIME=1
BSUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =.005443
SMX =15.9722
1.77953
3.55362
5.32771
7.1018
8.87589
10.65
12.4241
14.1982
15.9722

```

EDIPO, magnetic model

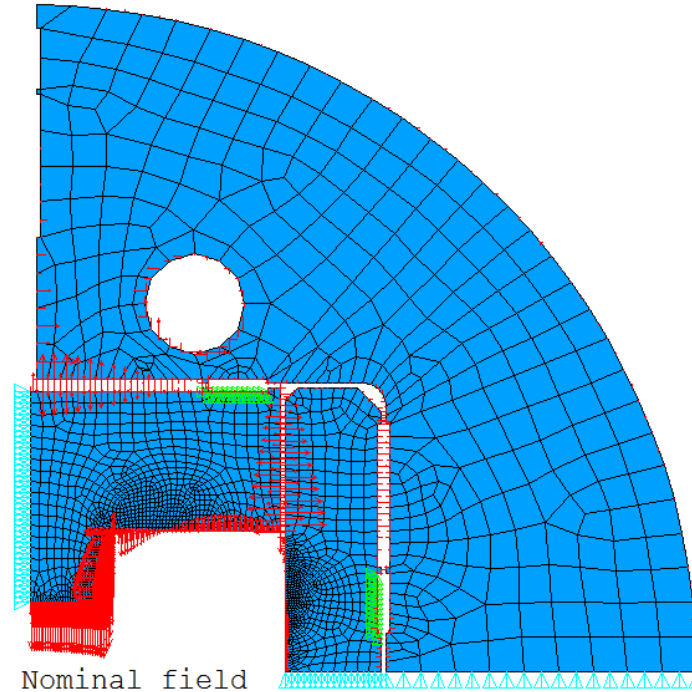
# Magnetic model

- For  $t_{TW} = 3.0$  mm, the alternative without Ti pole is **more efficient** than the current baseline and the 4-coil-design alternative



# Forces in the iron parts

- V pad and pole 2 are attracted towards the test well:
  - V pad:  $F_y = -2.5$  MN/m
  - Pole 2:  $F_y = -0.5$  MN/m

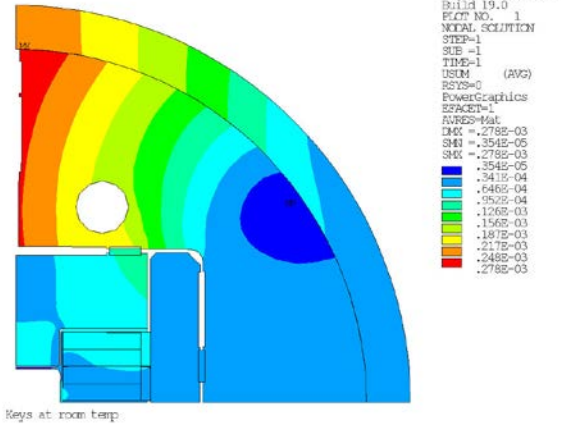


```
ANSYS Release 19.0  
Build 19.0  
ELEMENTS  
PowerGraphics  
EFACET=1  
MAT NUM  
U  
F  
CP
```

# Deformation

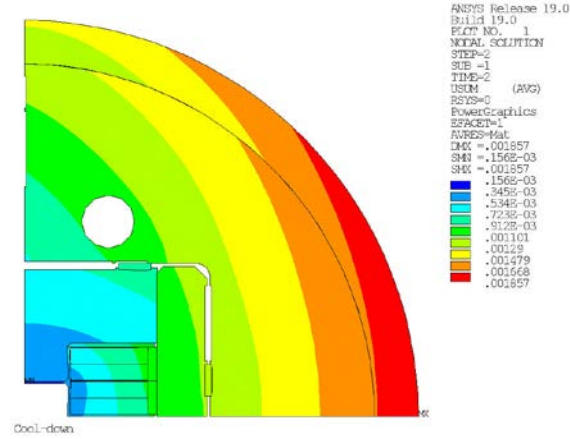
■ EDIPO: ALTERNATIVE DESIGN WITHOUT TITANIUM POLE

## 1. Room temp

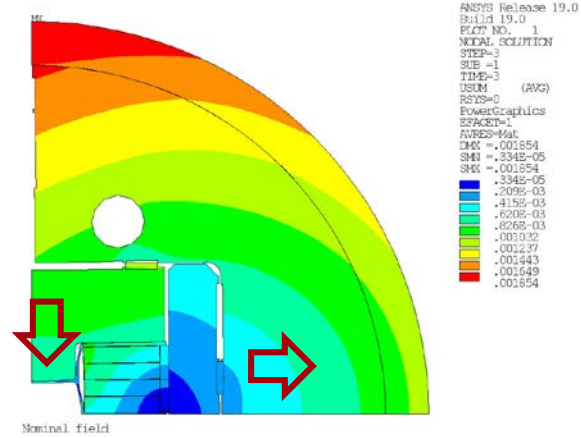


- During powering of the magnet, the iron parts experience forces in the directions highlighted by the arrows in the bottom right plot.

## 2. Cool-down

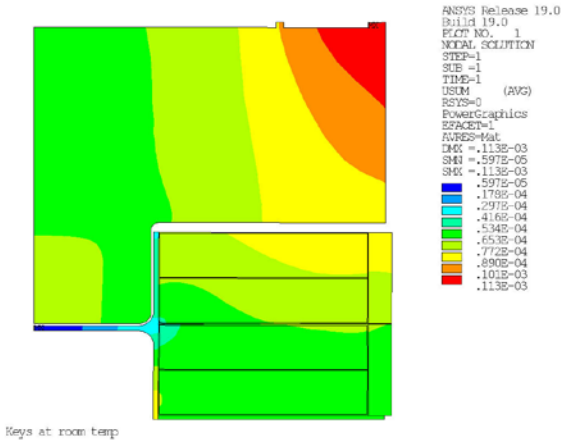


## 3. Nominal field

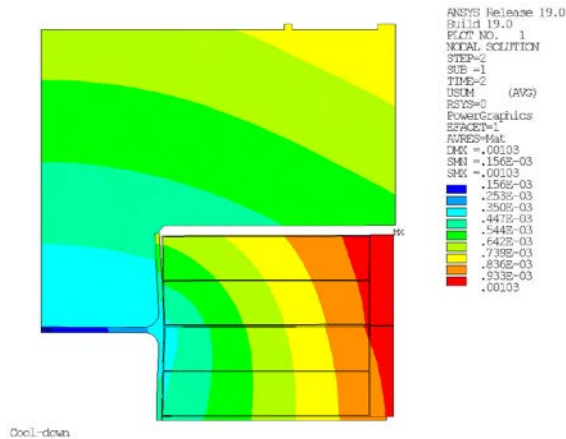


# Deformation (zoom)

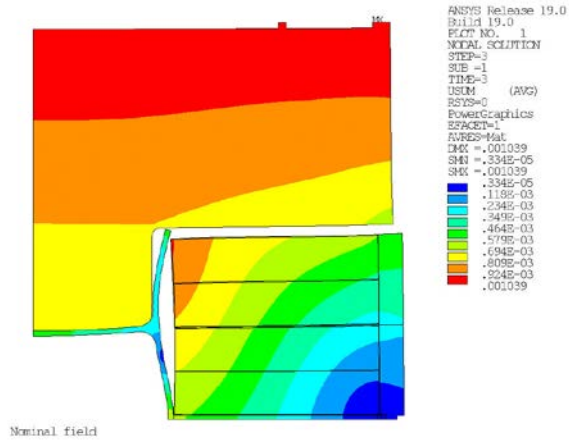
## 1. Room temp



## 2. Cool-down



## 3. Nominal field

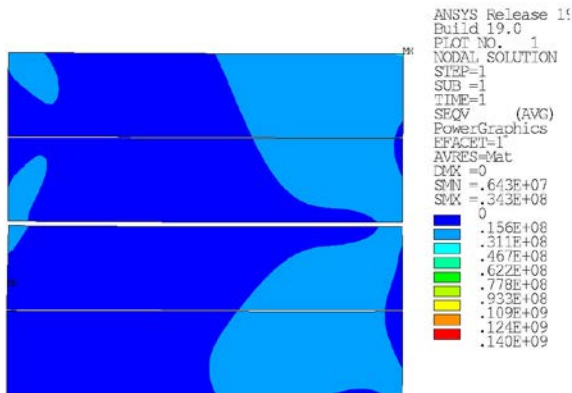




# Stress in the coils (von Mises)

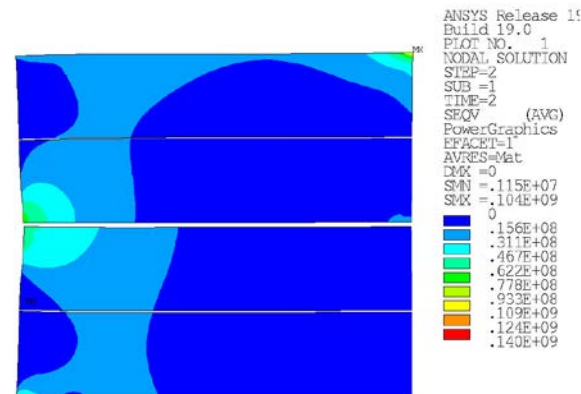
- Coils are essentially stress-free at room temperature (small lateral interference) and after cool down (shell is made of steel)
- After powering the stress remains below 120 MPa except in one corner in the low field region

## 1. Room temp



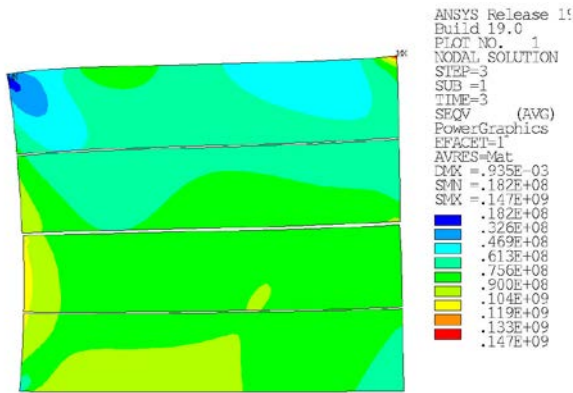
Keys

## 2. Cool-down



Cool-down

## 3. Nominal field

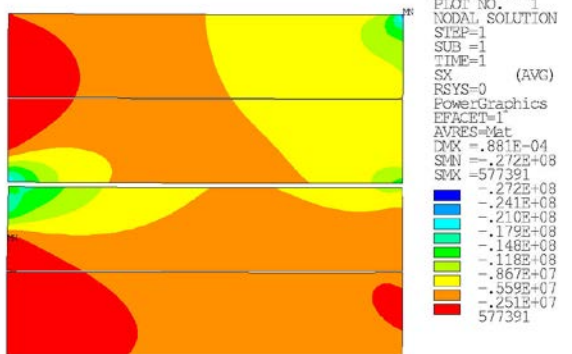


Nominal field

# Stress in the coils (horizontal)

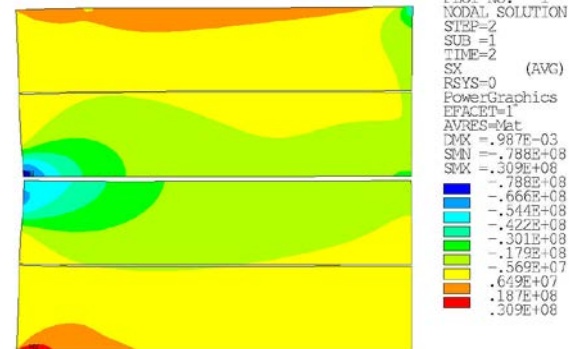
- Coils are essentially stress-free at room temperature (small lateral interference) and after cool down (shell is made of steel)
- After powering, the **horizontal stress remains below 110 MPa**

## 1. Room temp



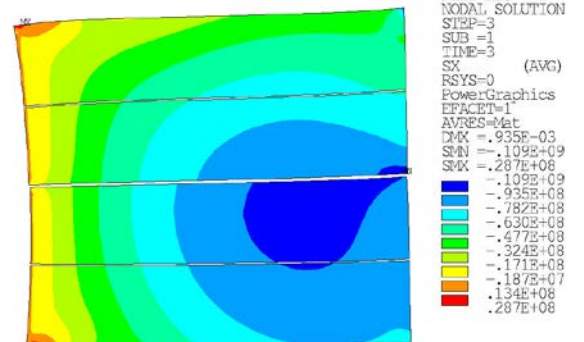
Keys

## 2. Cool-down



Cool-down

## 3. Nominal field



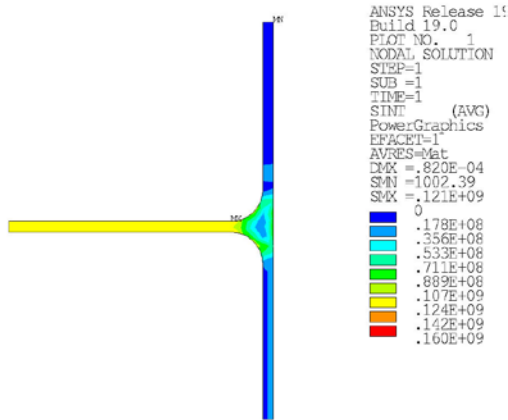
Nominal field

# Stress in the test well

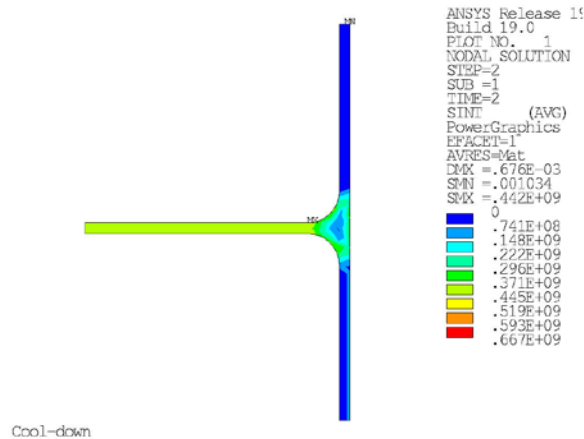
- Goal is to have a stress-free test well

Load step	Membrane (MPa)	Memb+bend (MPa)
Room temp	115	116
Cool-down	417	422
Nom. field	20	296

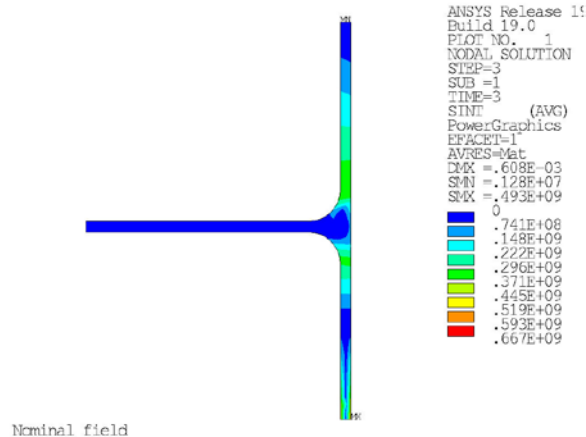
## 1. Room temp



## 2. Cool-down



## 3. Nominal field

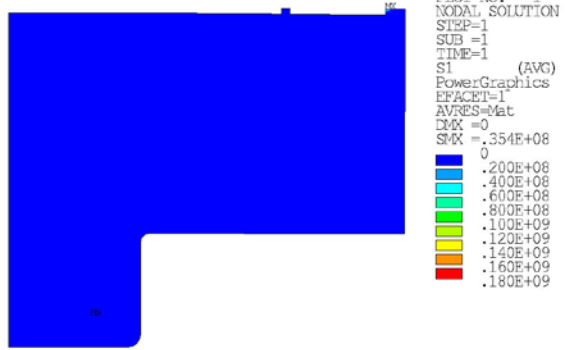


# Stress in the vertical pad + iron insert

- Vertical pad and iron insert satisfy stress criteria except in one corner

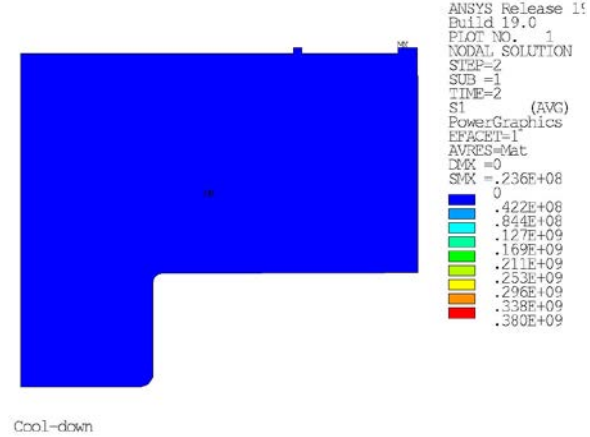
■ EDIPO: ALTERNATIVE DESIGN WITHOUT TITANIUM POLE

1. Room temp

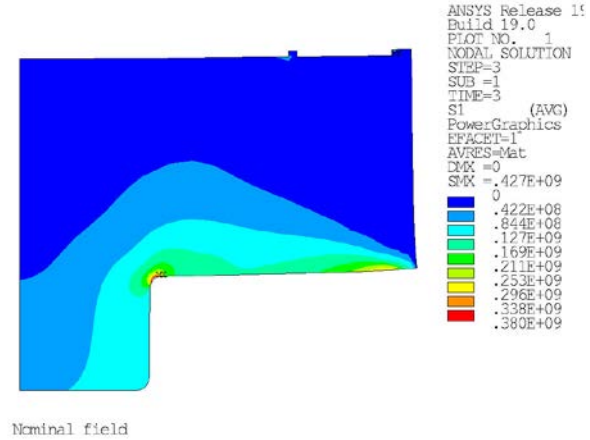


Keys

2. Cool-down



3. Nominal field

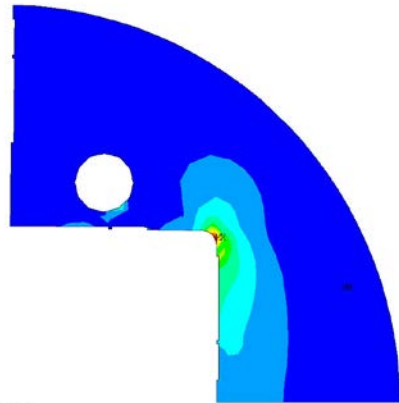


# Stress in the iron yoke

- Iron yoke satisfies stress criteria

EDIPO: ALTERNATIVE DESIGN WITHOUT TITANIUM POLE

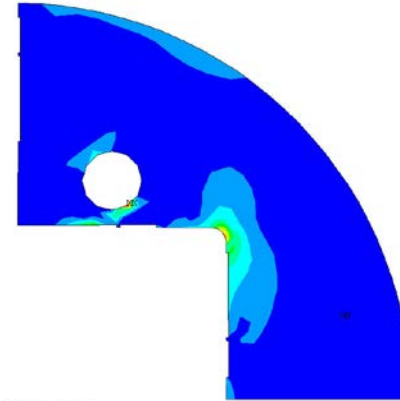
1. Room temp



```
ANSYS Release 15
Build 19.0
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
S1 (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.278E-03
SMX =.146E+09
0
.162E+08
.324E+08
.486E+08
.648E+08
.810E+08
.972E+08
.113E+09
.130E+09
.146E+09
```

Keys

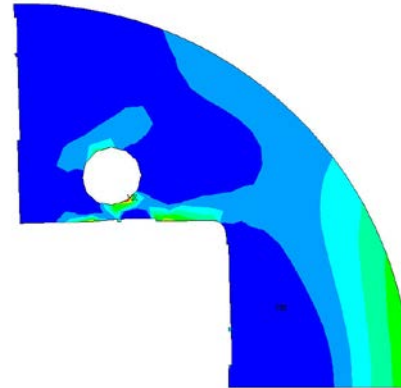
2. Cool-down



```
ANSYS Release 15
Build 19.0
PLOT NO. 1
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
S1 (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.001655
SMX =.549E+08
0
.610E+07
.122E+08
.183E+08
.244E+08
.305E+08
.366E+08
.427E+08
.488E+08
.549E+08
```

Cool-down

3. Nominal field



```
ANSYS Release 15
Build 19.0
PLOT NO. 1
NODAL SOLUTION
STEP=3
SUB =1
TIME=3
S1 (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.001703
SMX =.189E+09
0
.210E+08
.420E+08
.630E+08
.840E+08
.105E+09
.126E+09
.147E+09
.168E+09
.189E+09
```

Nominal field

# Conclusions

- The use of **detachable poles** and the **elimination of the Ti pole** result in a **more efficient coil design**
- The goal is to have a **stress-free test well**:
  - In practice, very moderate stress is applied to the test well
  - **A gap (<1 mm) opens** between coils and test well during powering
- **Stress in the coils is always very moderate**:
  - Everywhere below 120 MPa
  - Except one localized peak of 147 MPa (low field region)
- Only a peak of principal stress above the allowable limit is observed in the vertical pad + iron insert