

Centrum výzkumu Řež s.r.o.

Post-irradiation inspections on TVSA-T fuel assemblies at Temelín NPP

VVER 2013

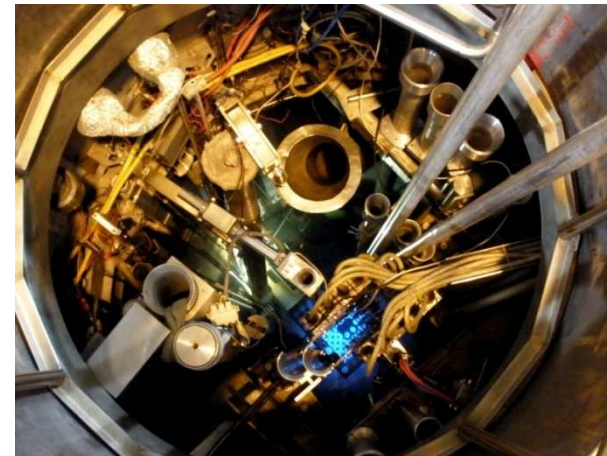
Martina Malá

12.11.2013

Scope



- **CV Rez**
- PIIP at Temelín NPP
- PIIP in 2013
- evaluation of FA changes with irradiation
- FR growth
- corrosion situation



Background



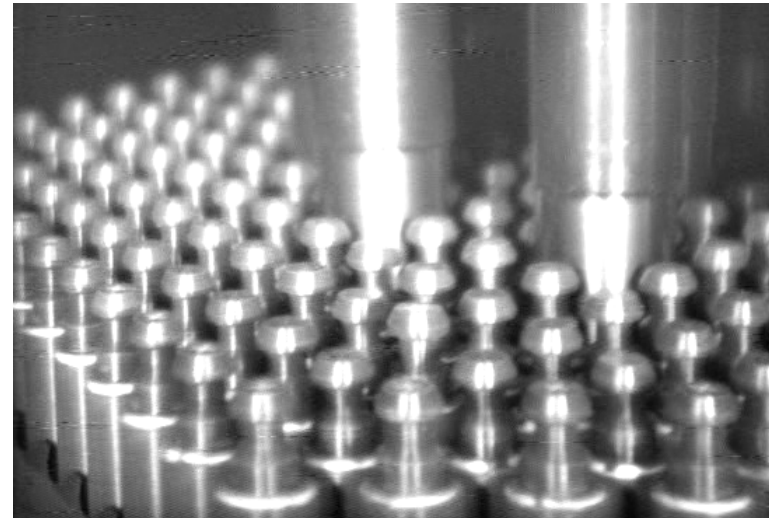
■ CV Rez:

- Centrum výzkumu Řež s.r.o.
- member of UJV Group
- independent fuel inspector (in parallel with JSC TVEL) since 2011
- participant of PIIP since 2008





- CV Rez
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Post-Irradiation Inspection Program on TVSA-T includes:

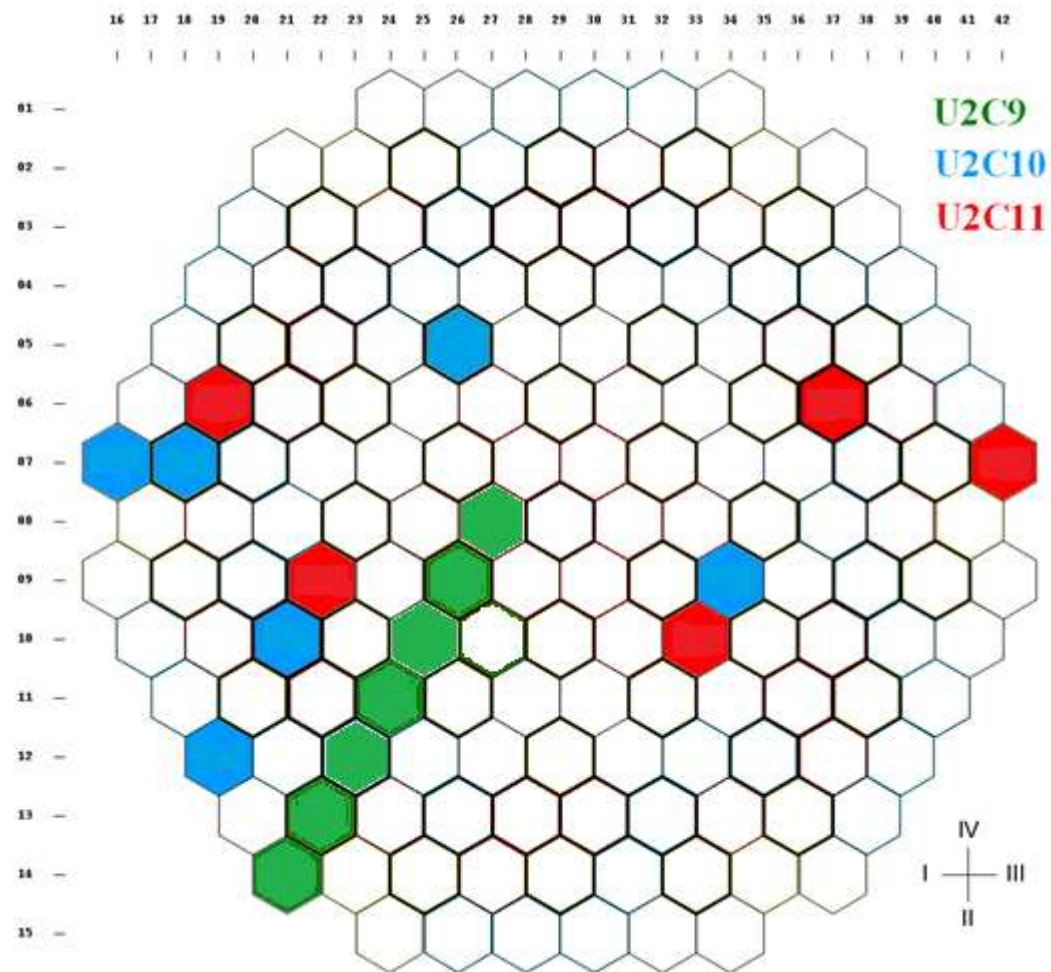
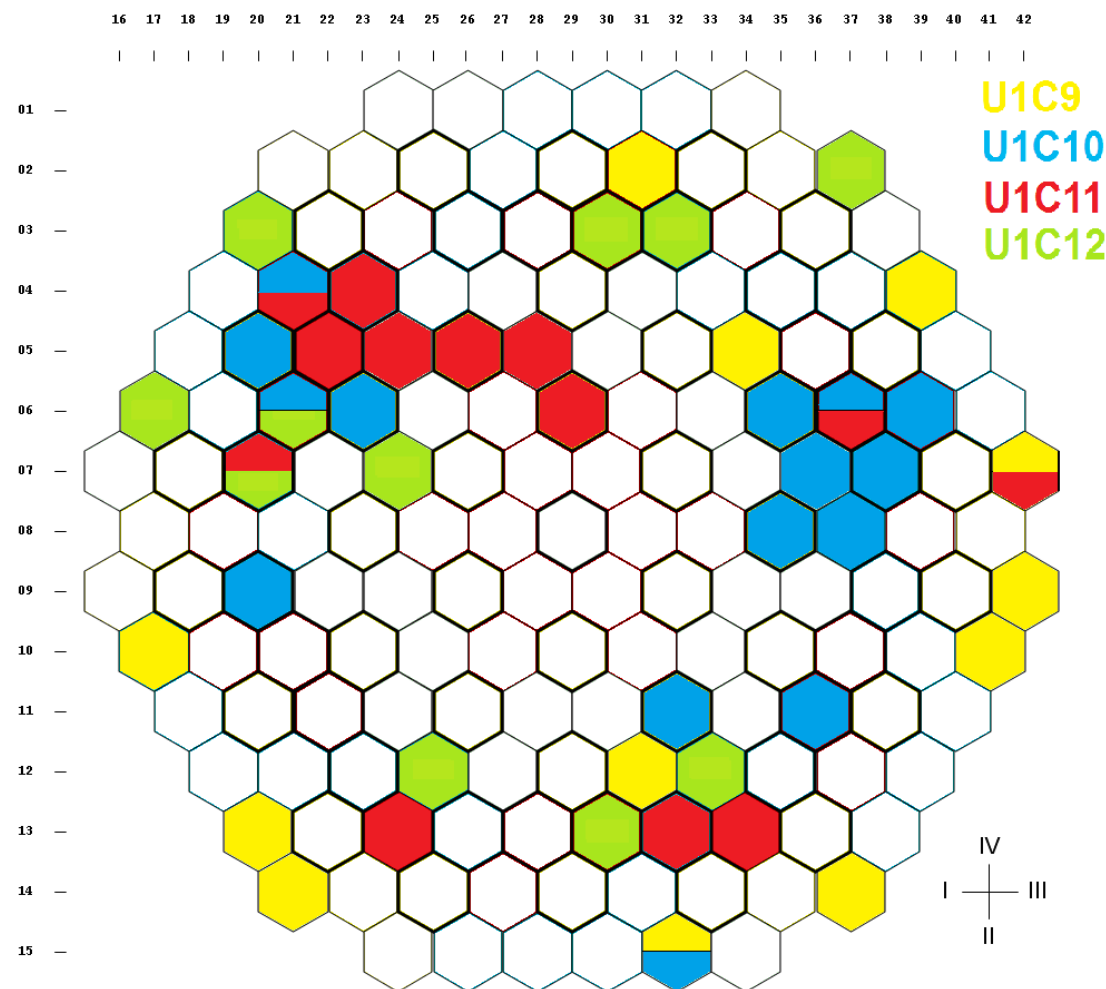
- **visual inspection of:**
 - whole FA – peripheral FRs, spacer grids, angles, upper nozzle, bottom nozzle
 - half-face
 - full-face
- **measurements:**
 - FA twist
 - FA bow
 - FA / FR growth
- **UT inspection to identify the leaking FRs**



PIIP at Temelín NPP (2)



- selected FAs measured at U1 and U2 in 2011 – 2013 and 2014 (not all selected FAs yet)



Scope



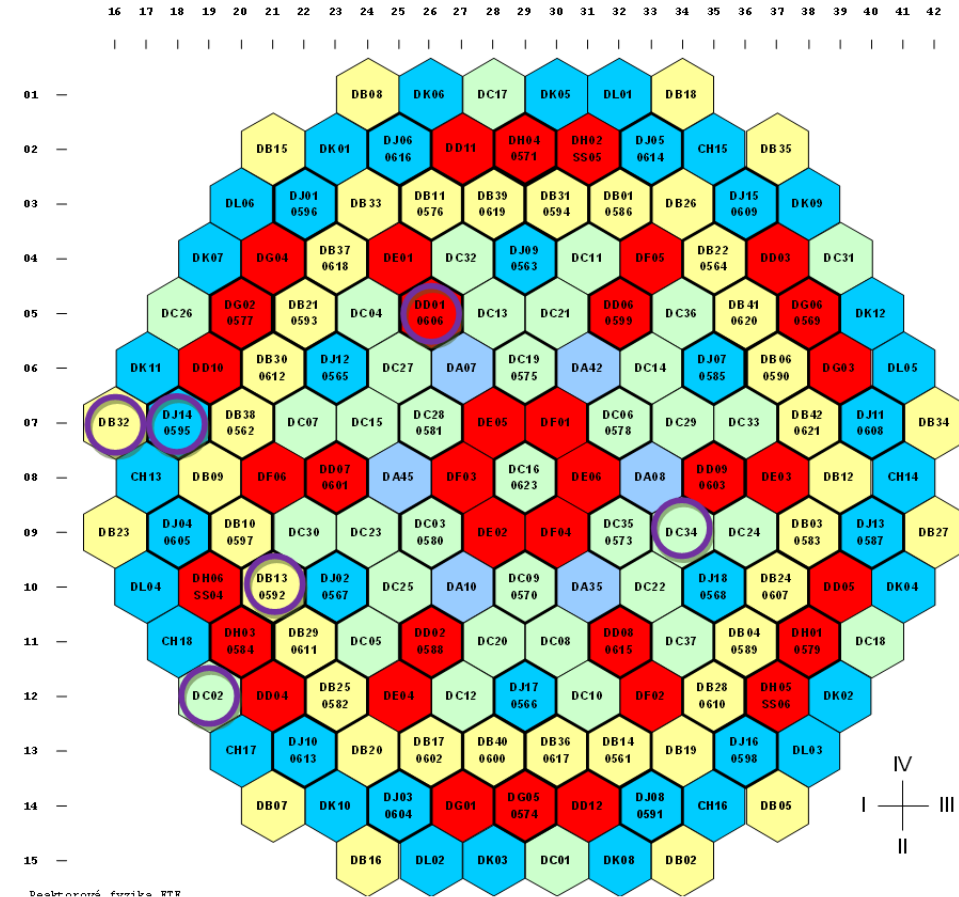
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PIIP after U2C10



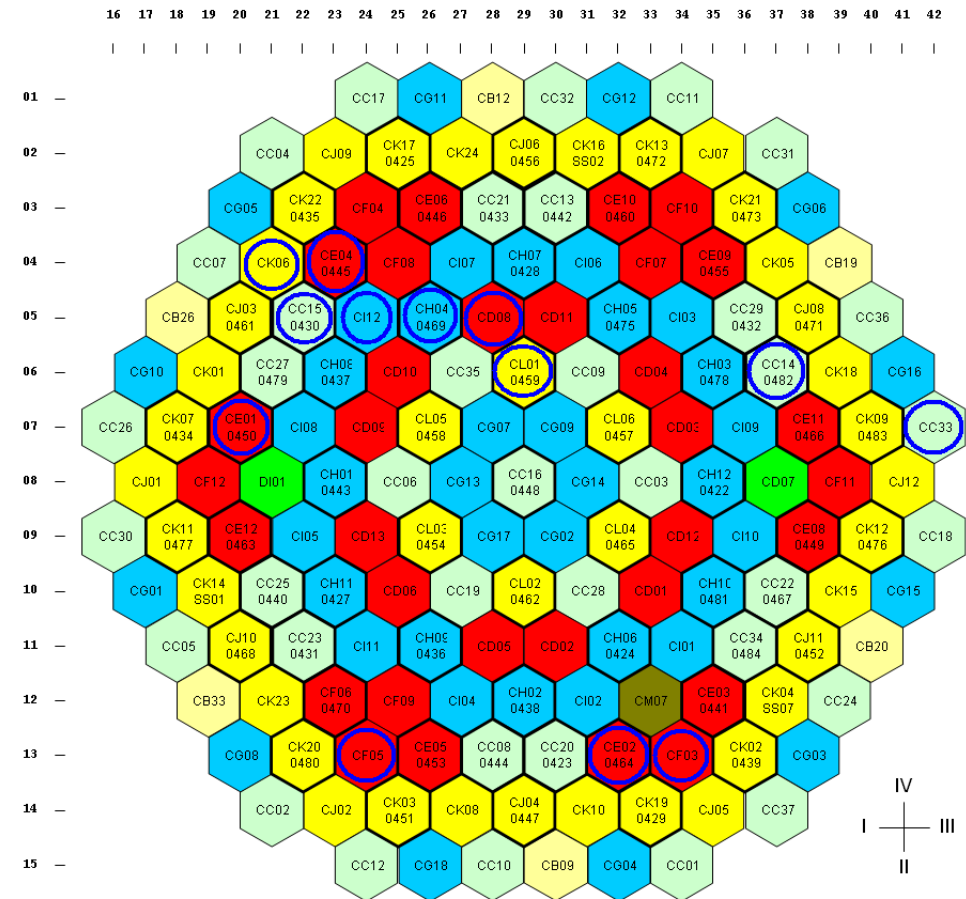
- Spring 2013
- after 2nd cycle with TVSA-T
- 1 one-year* and 5 two-year FAs
- BU: 15* – 25 MWd/kgU
- no leakers
- measurement of 6 FAs:
 - twist $\leq 1^\circ$
 - bow ≤ 5 mm (1 FA: 8 mm)
 - small difference of FA bow between U2C9 and U2C10
 - FA growth ≤ 2 mm
 - FR growth $\rightarrow 3 - 8$ mm



PIIP after U1C11



- July 2013
- after 3 cycles with TVSA-T
- BU: 16 – 37 MWd/kgU
- 9 three-year FAs, 2 two-year and 2 one-year FAs
- no leakers
- measurement of 13 FAs:
 - twist → immeasurable
 - bow ≤ 4 mm (1 FA: 8 mm)
 - small difference of FA bow between U1C9, U1C10 and U1C11
 - FA growth ≤ 3.5 mm
 - FR growth → 3 - 14 mm



Results: U2C10 and U1C11



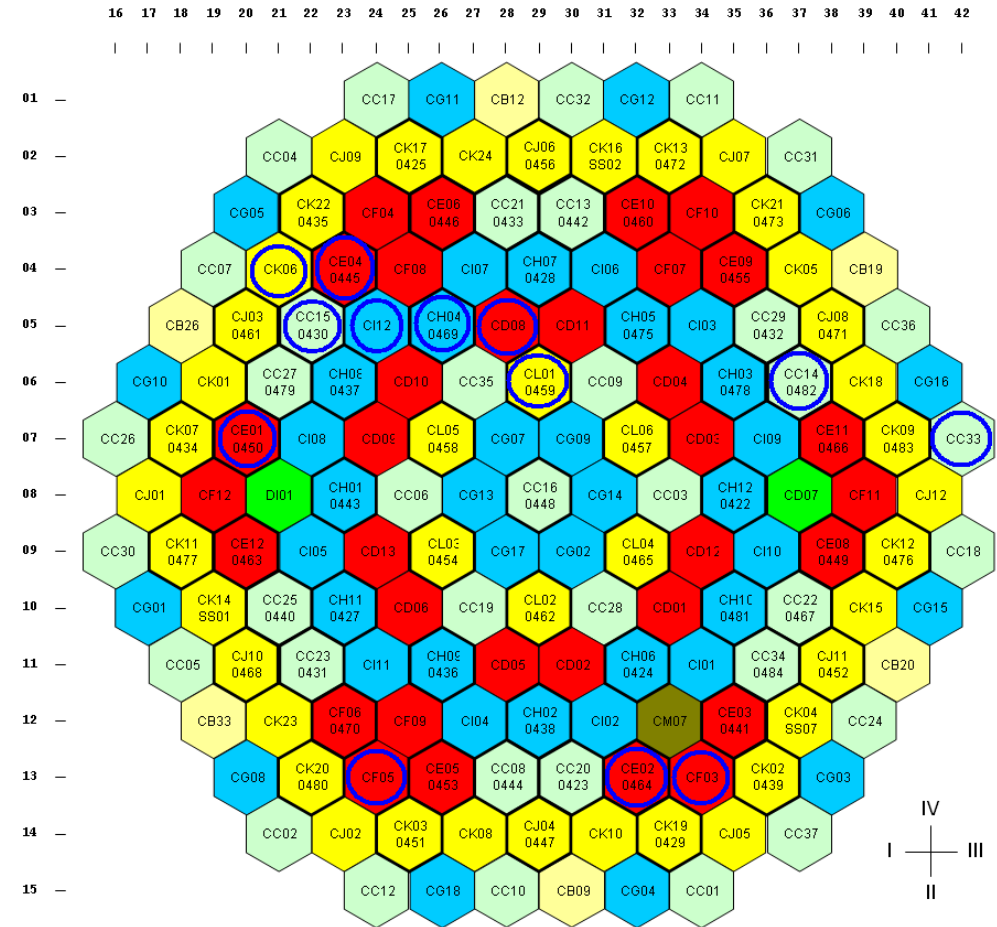
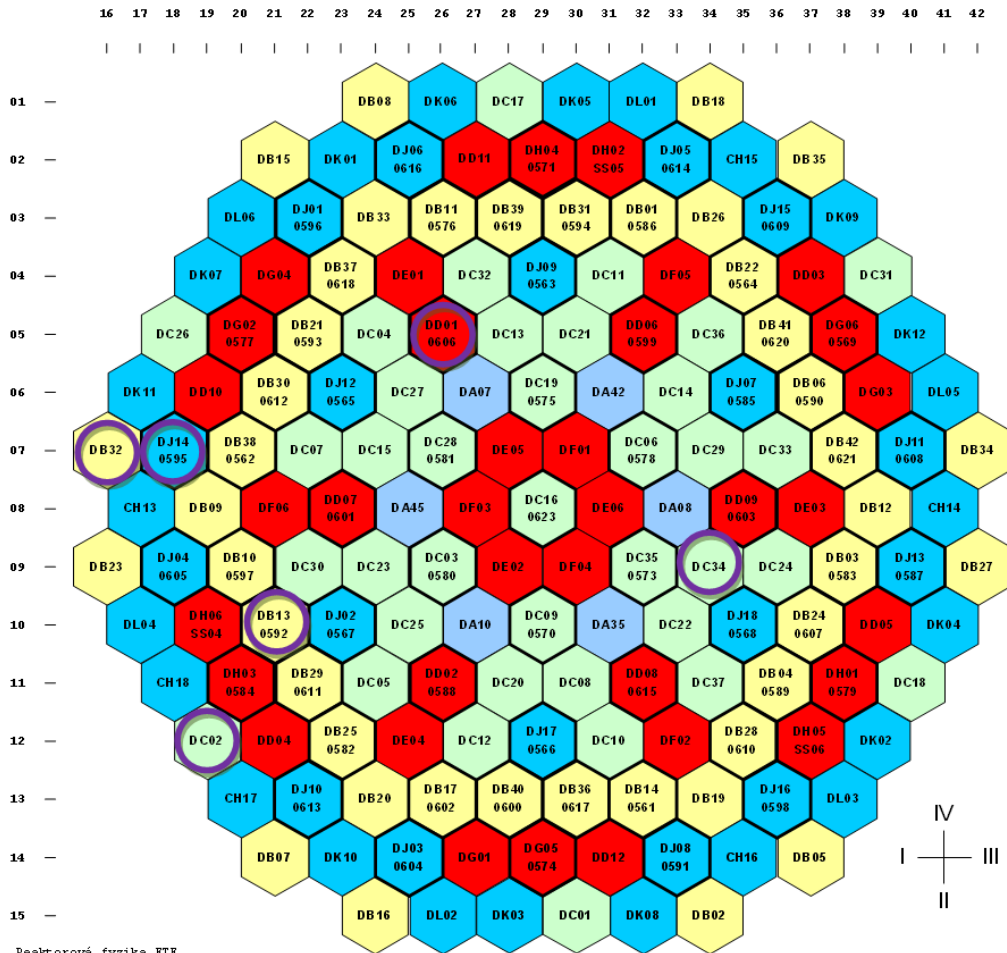
	U2C10	U1C11
FA age (years)	1 – 2	1 – 3
BU (MWd/kgU)	15 – 25	16 - 37
leakers	no	no
twist	~ 1°	~ 1°
bow	≤ 5 mm (1 FA: 8 mm)	≤ 8 mm
FA growth	≤ 2 mm	≤ 3.5 mm
FR growth	3 – 8 mm	3 – 14 mm

Results: U2C10 and U1C11 (2)



U2C10

U1C11



Dezember 2014



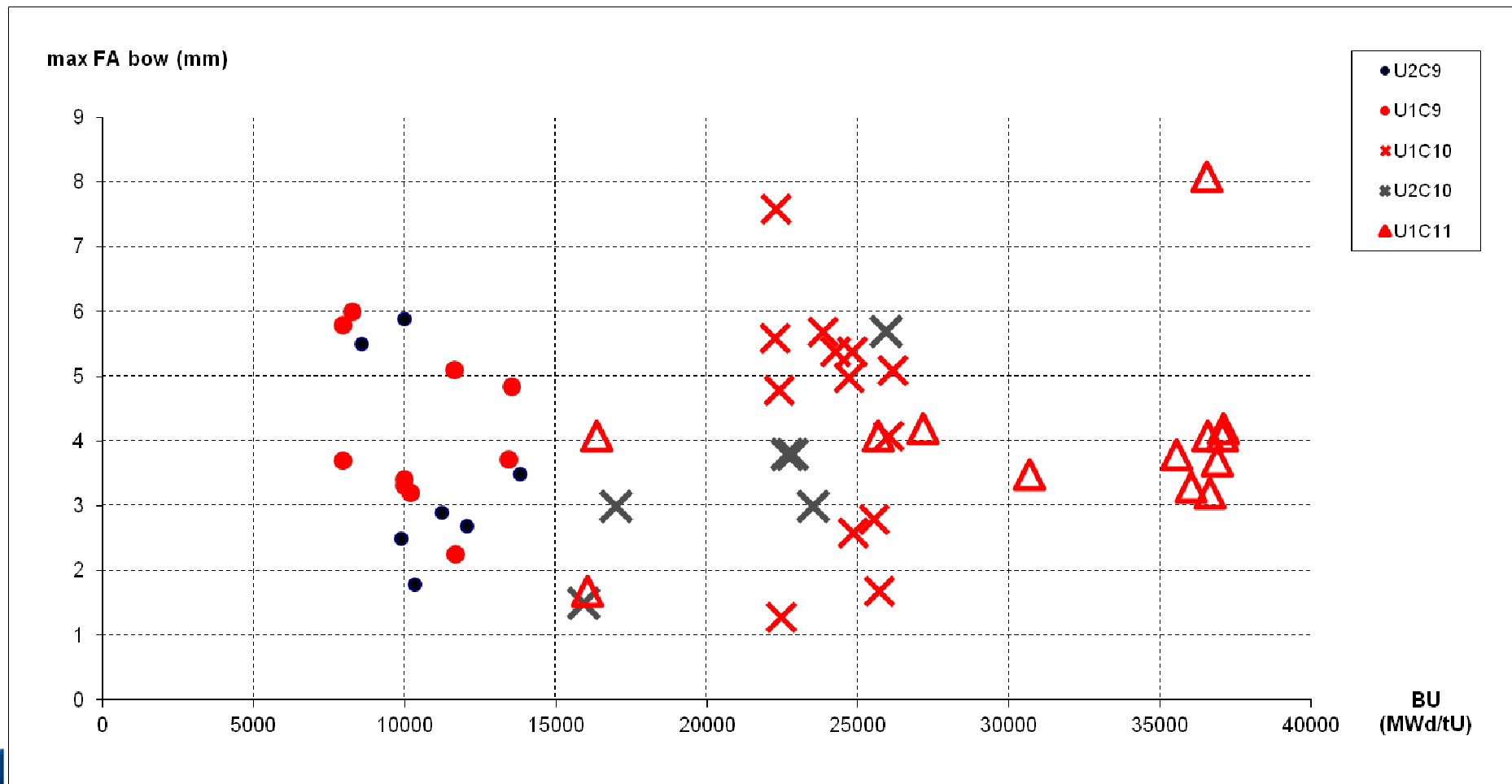
- CV Rez
- PIIP at Temelín NPP
- PIIP in 2013
- **evaluation of FA changes with irradiation**
- FR growth
- corrosion situation



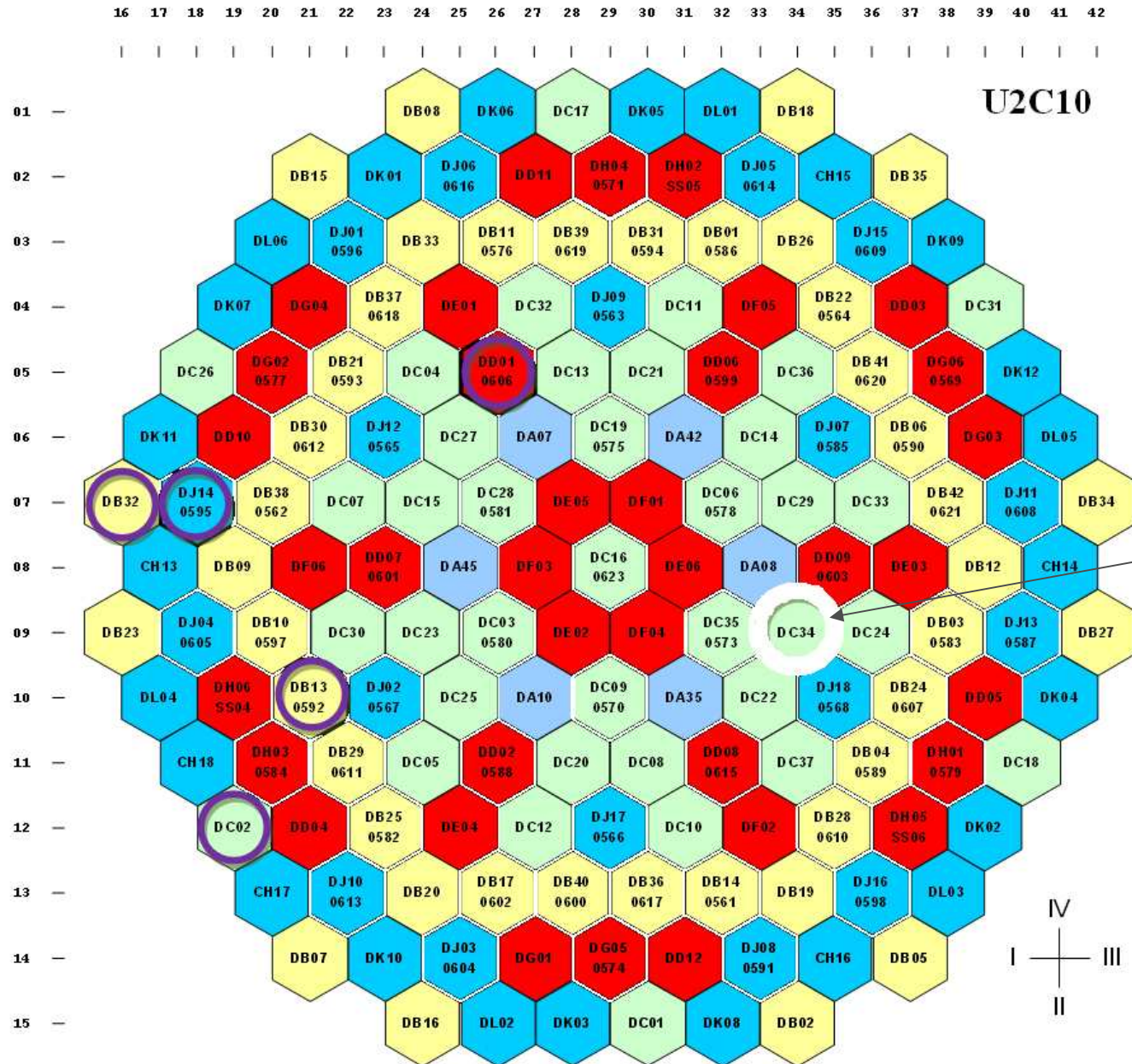
Evaluation of FA changes with irradiation (2)



- FA bow meets the expectations and does not develop with burnup



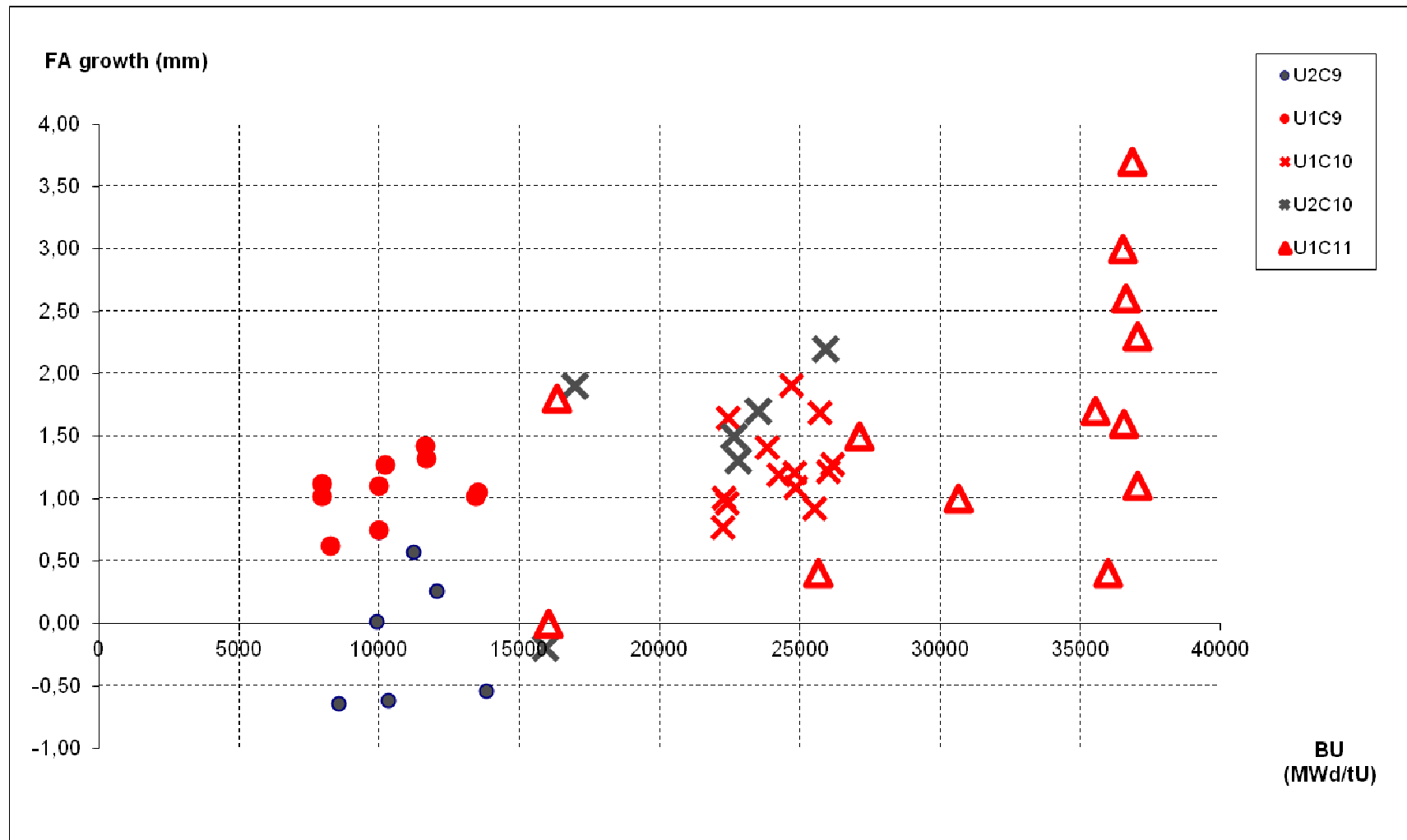
U2C10



Evaluation of FA changes with irradiation (3)



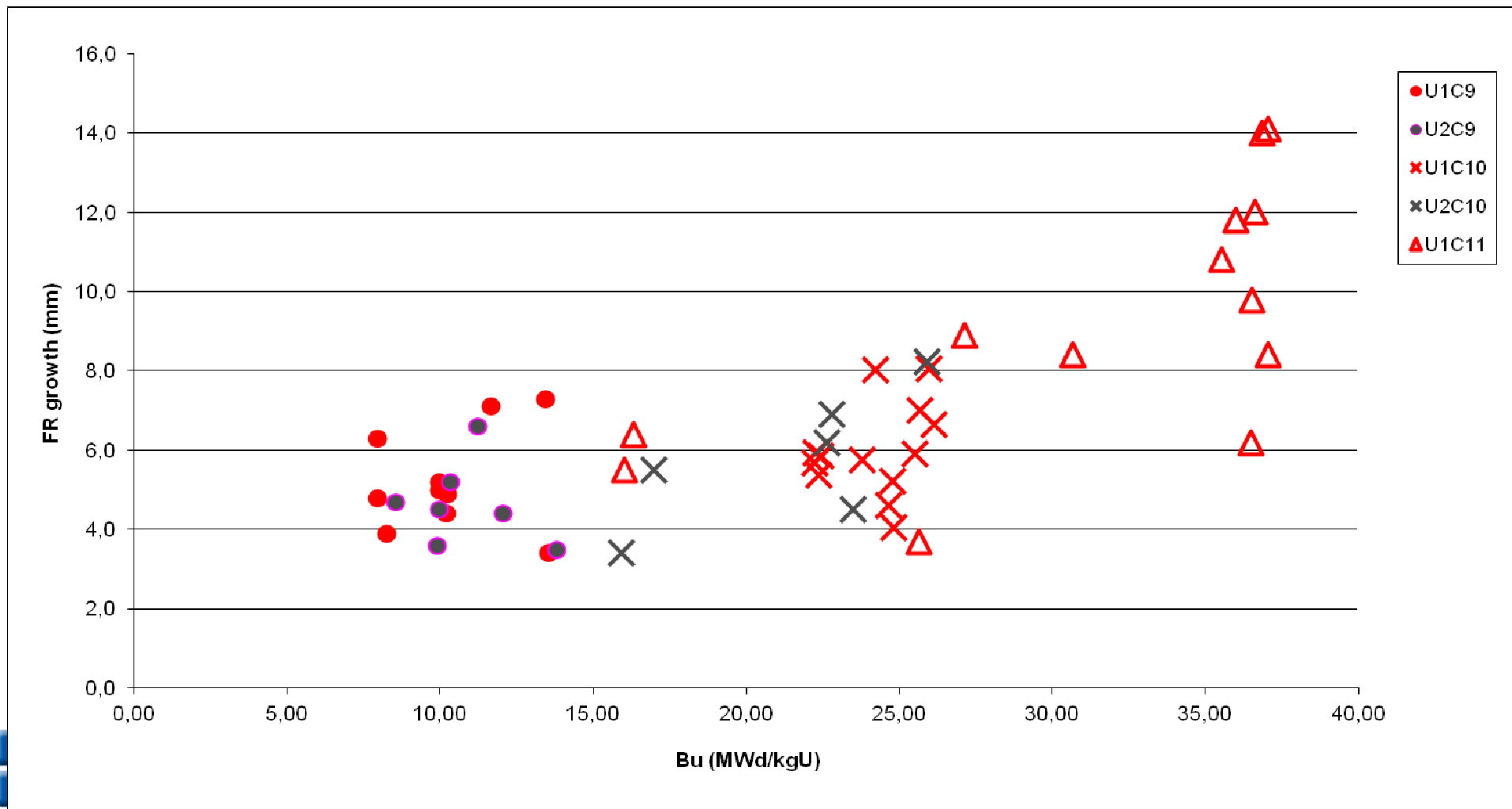
- FA growth seems to be affected by the position of upper core internals (BOT)



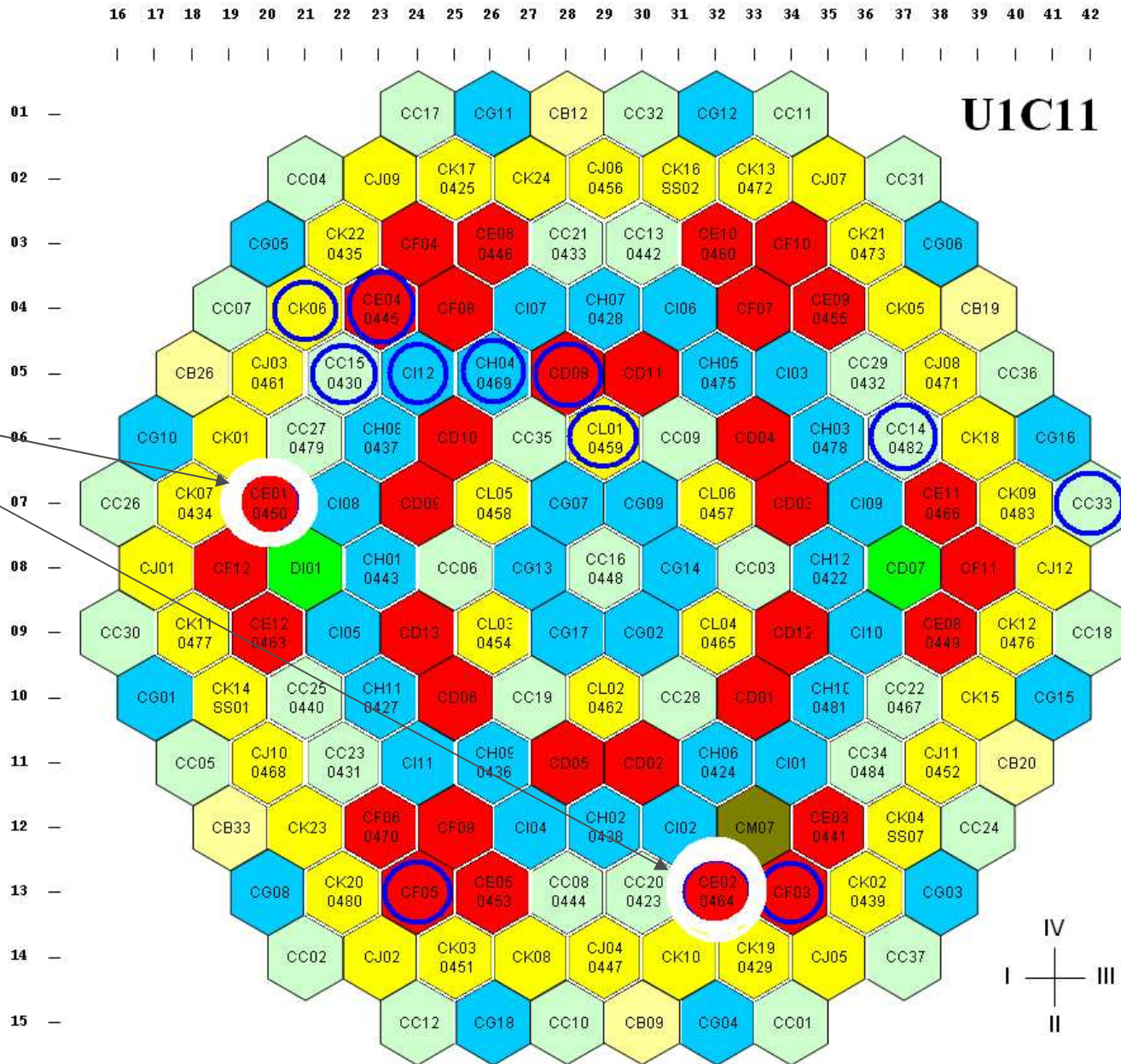
Evaluation of FA changes with irradiation (4)



- FR growth is near the predicted value (0.1% / 10 MWd/kgU)
- Larger scatter after 3 cycles due to pellet-cladding contact



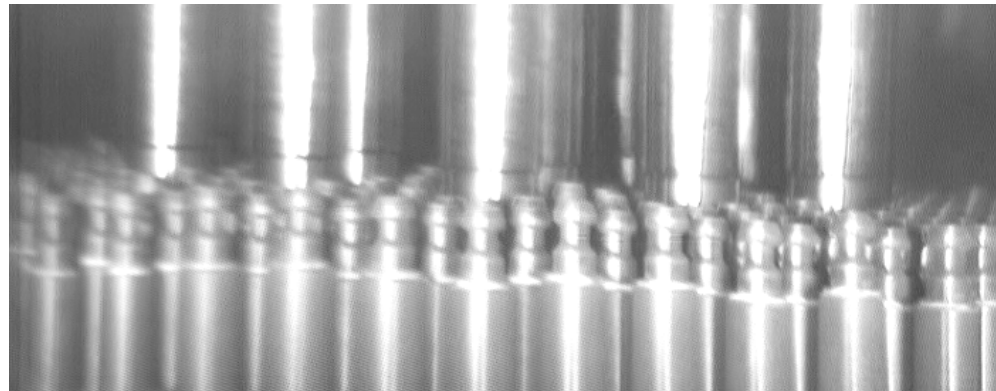
U1C11



Scope



- CV Rez
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- PIIP in 2013
- evaluation of FA changes with irradiation
- **FR growth**
- corrosion situation

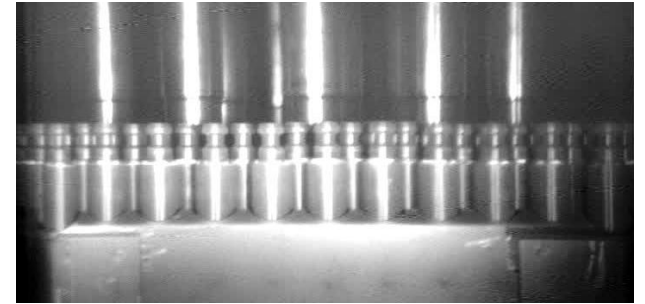


Fuel rod growth – tvel (UO₂ rods)



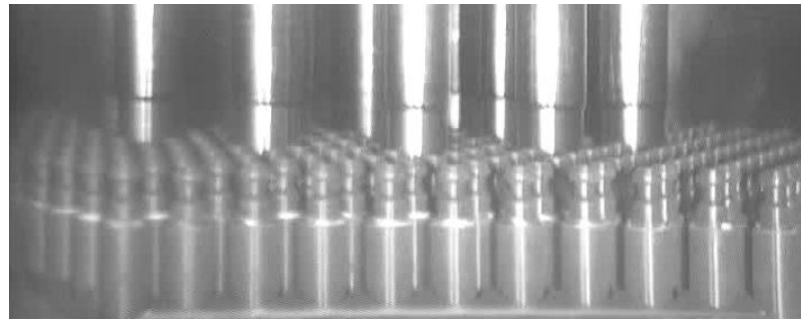
- **U1C9**

- 3 – 8 mm



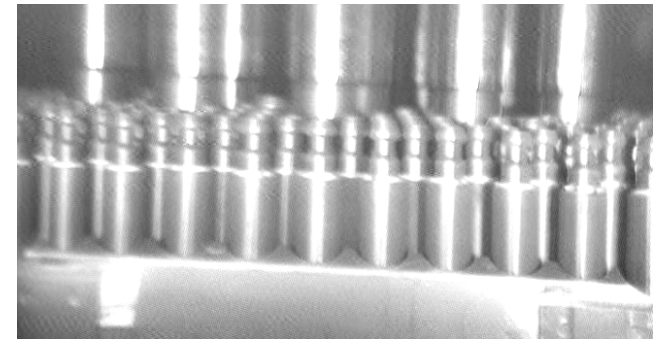
- **U2C9**

- 3.5 – 7 mm



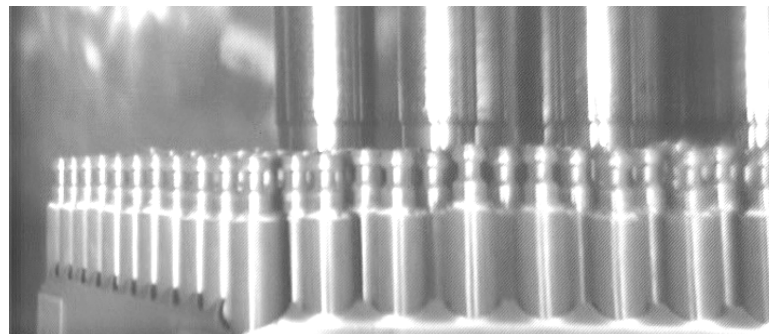
- **U1C10**

- 4 – 8 mm



- **U2C10**

- 3 – 8 mm



- **U1C11**

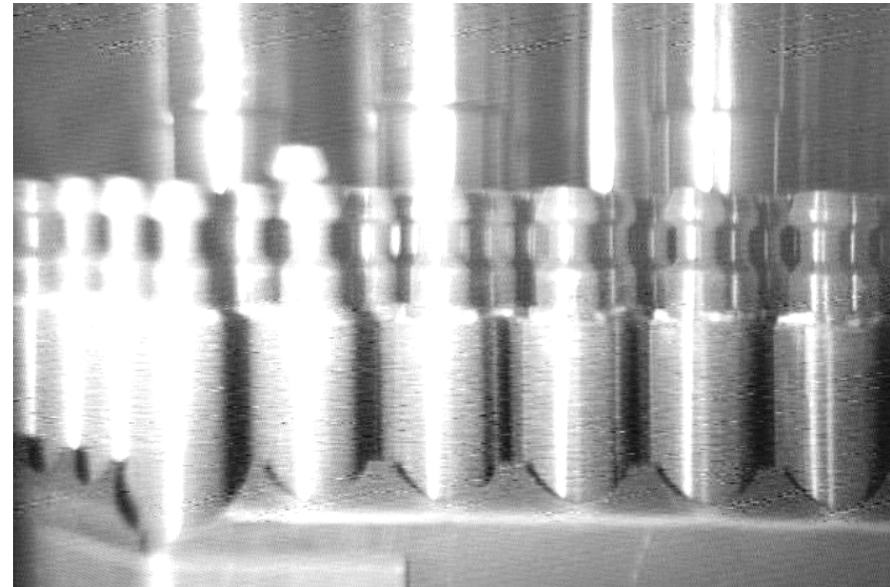
- 3.5 - 14 mm



Fuel rod growth – tveg



- $\text{UO}_2 + \text{Gd}_2\text{O}_3$ rod
- small but noticeable difference between tvel and tveg growth observed already after 1st cycle at both units
- does not pose any safety or operational problem, but contradicted predictions
- observed only for some assemblies
- not common behavior of all tvegs



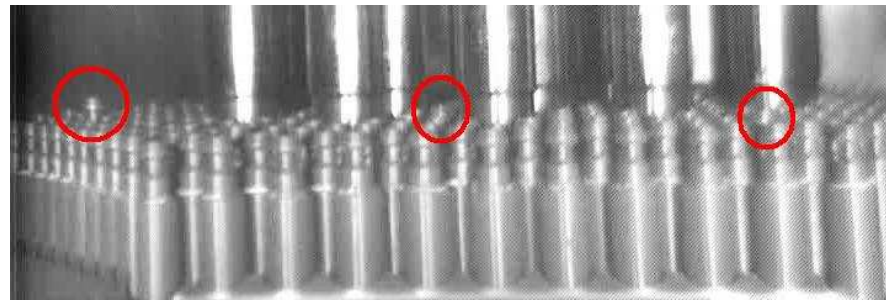


■ Discussion – considered but dismissed possible causes:

- different tveg length from the manufacture
- lower helium pressure under cladding and faster cladding creep
- different chemical composition or metalurgic properties of cladding tubes of certain batch
- lower end-plug release from the FA support grid
- pellet batch with higher content of hydrogen, or contamination of pellets or cladding tubes by organics leading to the hydriding of cladding

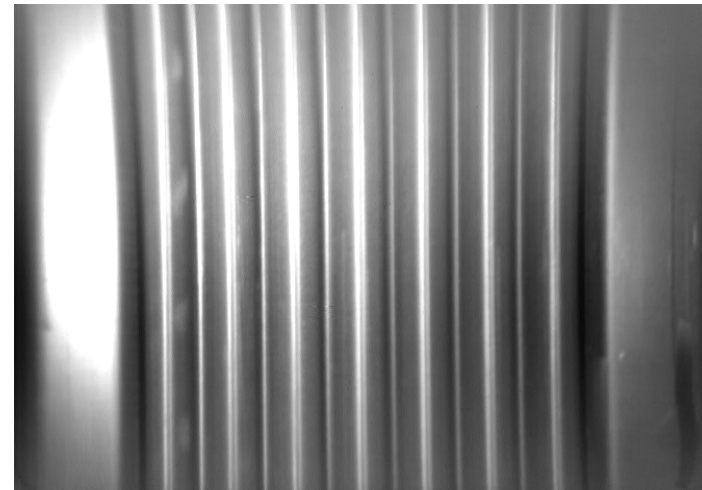
■ Most probable reason:

- Difference in pellet-clad contact moment between tvel and tveg
- According to calculations the the contact should occur slightly sooner in tveg, but not during the 1st cycle
- After 1st cycle the growth could be caused if the fuel column is not fully centered





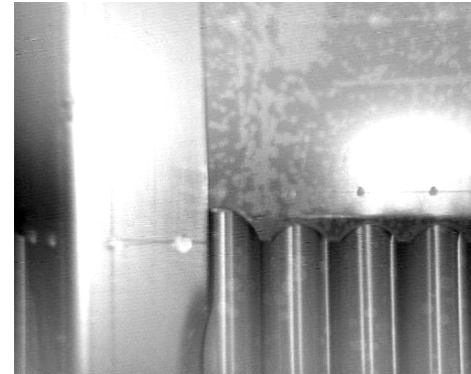
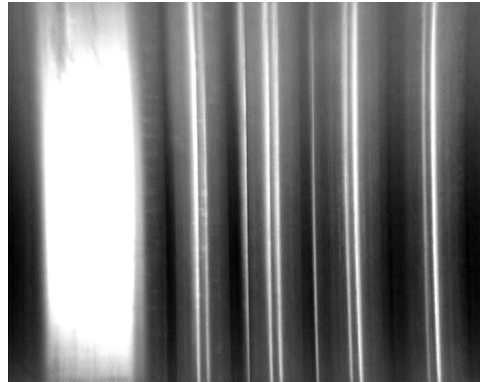
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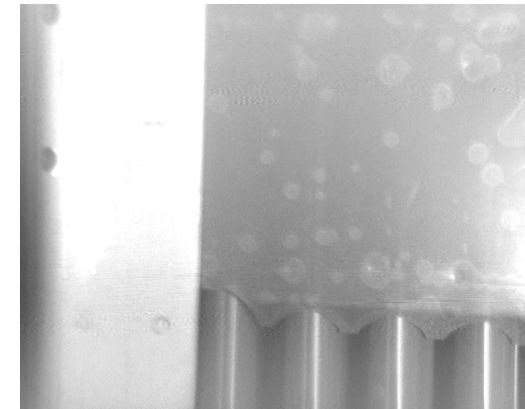
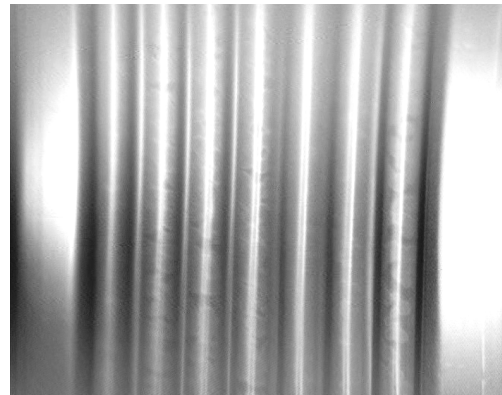
Corrosion situation



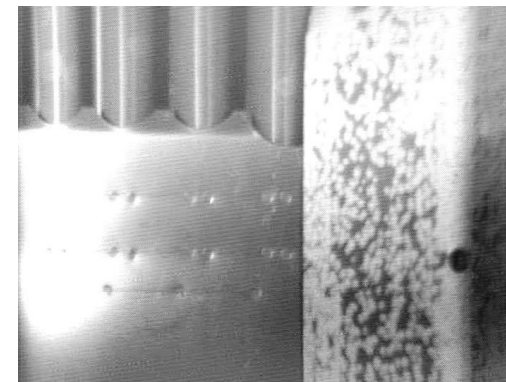
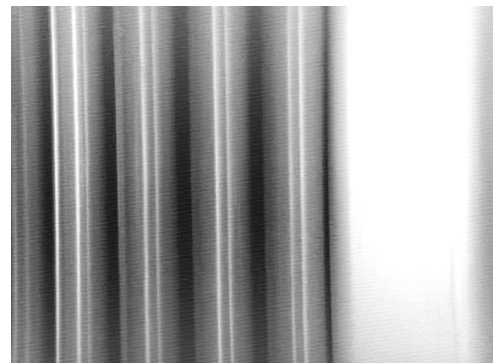
- 1 year



- 2 years



- 3 years



Conclusion



After 1, 2 and 3 cycles there are:

- no anomalies that would limit safe reactor operation
- no traces of handling damage found
- no defects of FA skeleton
- no significant FR growth
- mechanical stability

- FA behavior meets the predictions





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