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# ***JEFF-3.1 LWR-Reactivity Qualification from EOLE Experiments***

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CEA

DEN/CAD/DER/SPRC/LEPh Bat 230

\*DEN/CAD/DER/SPEX/LPE Bat 238

13108 Saint Paul-lez-Durance

***JEFFDOC – 1143***



- EOLE facility : zero-power Research Reactor

*Slides made by latex (prosper)*



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- Residual Reactivity : Divergence Method



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  - UOX cores : EPICURE UH1.2 and MISTRAL 1
  - MOX cores : MISTRAL 2 and MISTRAL 3
  - UOX+MOX core : EPICURE MH1.2



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- Reactivity Calculations : TRIPOLI-4 M.C. code
- Nuclear Data Libraries : JEF-2.2 and JEFF-3.1

# UH1.2 Radial Cross Section

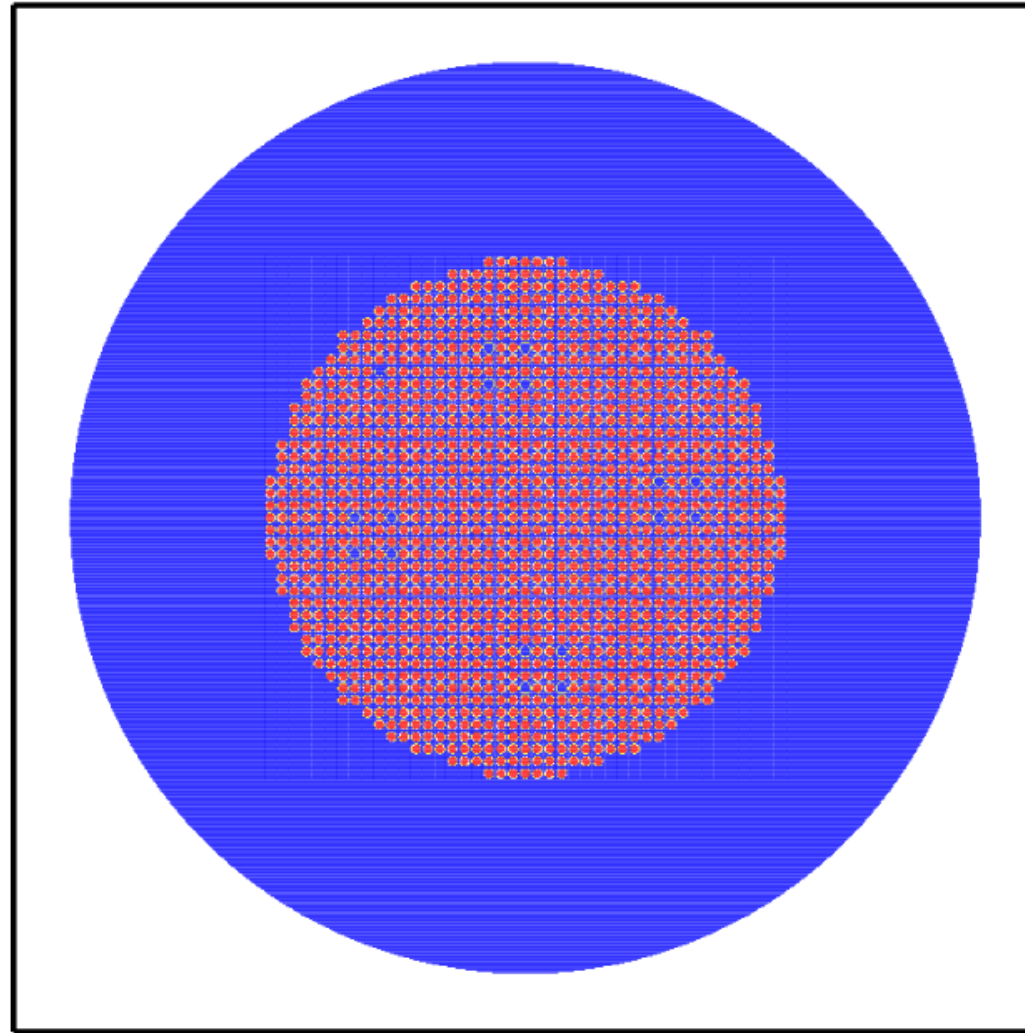


$\approx 1400$  cells

$UOX$  3.7%

$C_B \approx 600ppm$

$R_{mod} \approx 1.2$



# MISTRAL1 Radial Cross Section

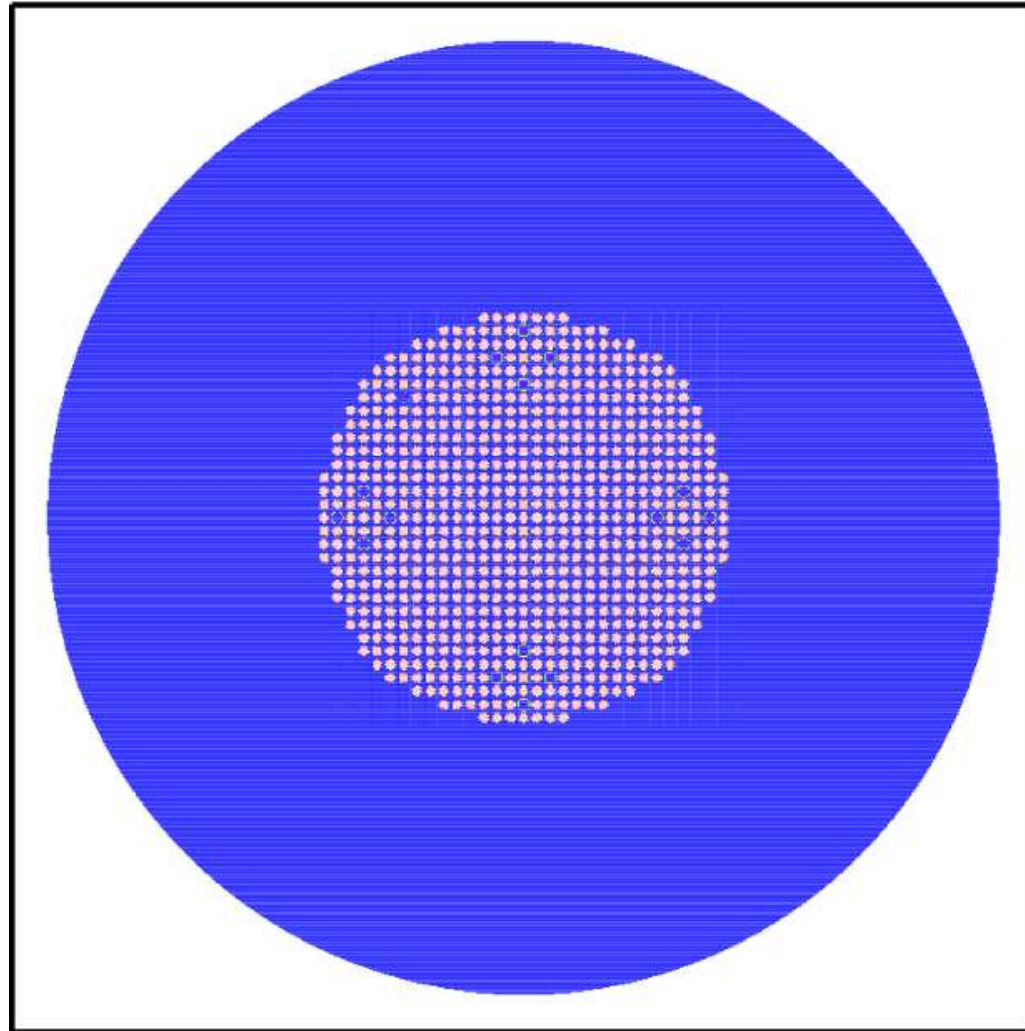


$\approx 750$  cells

$UOX$  3.7%

$C_B \approx 300ppm$

$R_{mod} \approx 1.7$





# MH1.2 Radial Cross Section



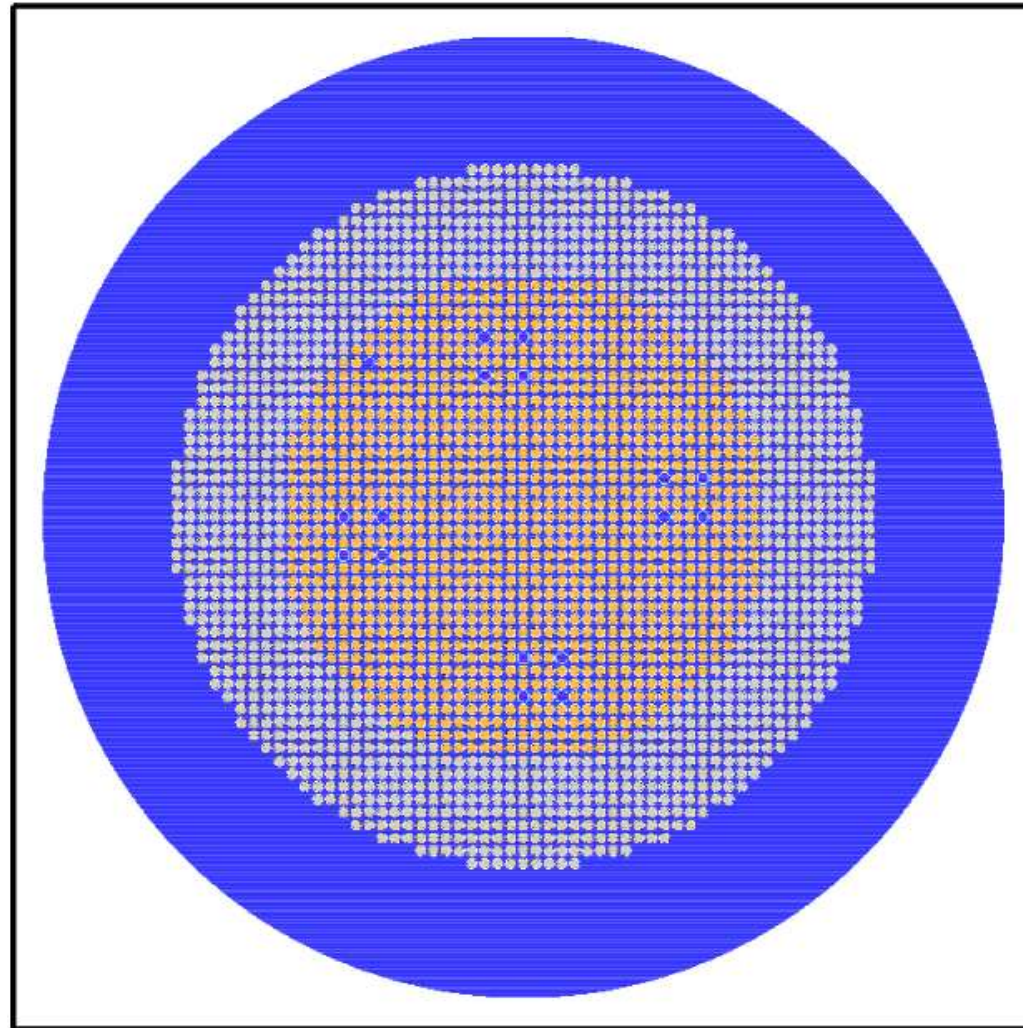
$\approx 2350$  cells

UOX 3.7%

MOX 7%

$C_B \approx 220\text{ppm}$

$R_{mod} \approx 1.2$



# MISTRAL2 Radial Cross Sections

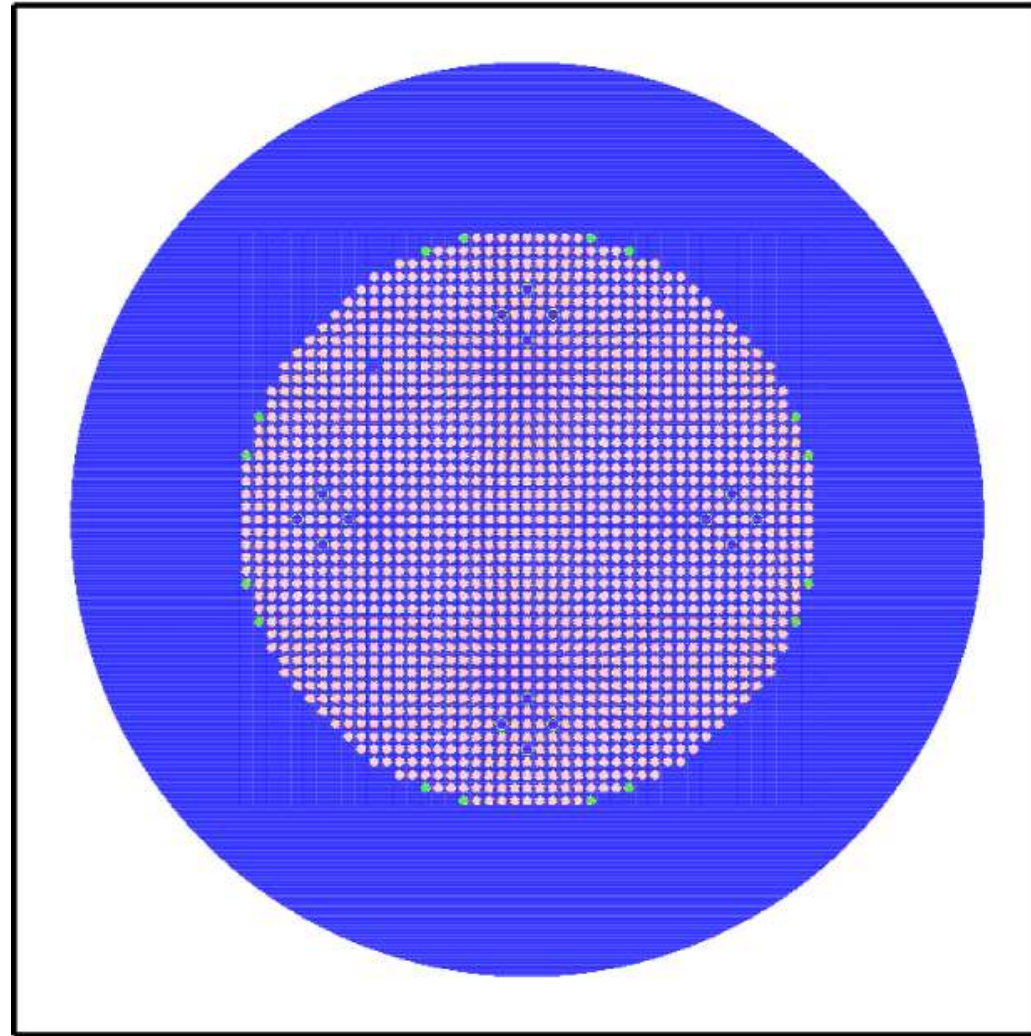


$\approx 1600$  cells

MOX 7%

$C_B = 0\text{ppm}$

$R_{mod} \approx 1.7$



# MISTRAL3 Radial Cross Sections

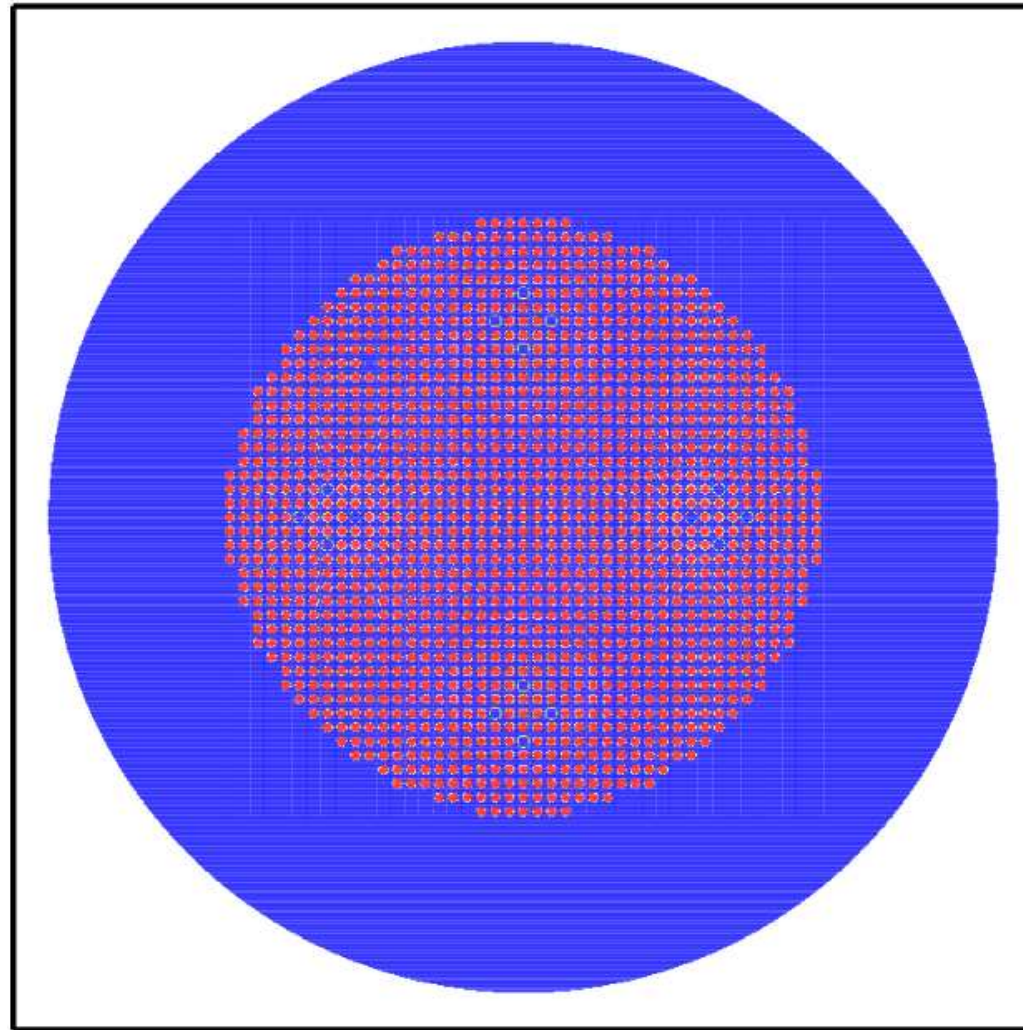


$\approx 1400$  cells

MOX 7%

$C_B \approx 200\text{ppm}$

$R_{mod} \approx 2.1$



# *from the element to the isotopes*

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Numerous natural elements in JEF-2.2  
are replaced by isotopes in JEFF-3.1

- $Zr \rightarrow {}^{90,91,92,94,96}Zr$

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- $Hf \rightarrow {}^{174,176,177,178,179,180}Hf$



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- $Mo \rightarrow {}^{92,94,95,96,97,98,100}Mo$

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- ...

mistral2 MOX core

$$\Delta\rho(Zr_{nat} \rightarrow Zr_i) = (-80 \pm 20) pcm$$

# $\Delta\rho$ in Cell calculations

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<i>Cells</i>		$C_B$ (ppm)	<i>pitch</i> (cm)	$\Delta\rho(J31 - J22)$ (pcm*)
<i>UH1.2</i>	( <i>UOX 3.7%</i> )	$\approx 600$	1.26	-271
<i>MISTRAL1</i>	( <i>UOX 3.7%</i> )	$\approx 300$	1.32	-161
<i>MISTRAL2</i>	( <i>MOX 7%</i> )	= 0	1.32	+ 35
<i>MISTRAL3</i>	( <i>MOX 7%</i> )	$\approx 200$	1.39	+ 2

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Expected effect in UOX cells  
Compensations in MOX cells

\* statistical uncertainty in cell calculation :  $1\sigma \approx 15$  pcm

# $\Delta\rho$ in Core calculations

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# $\Delta\rho$ in Core calculations



<i>Cores</i>	<i>pitch</i> ( <i>cm</i> )	$C^{J22} - E$ ( <i>pcm</i> *)	$C^{J31} - E$ ( <i>pcm</i> *)
<i>UH1.2</i>	1.26	+375	+225
<i>MISTRAL1</i>	1.32	+150	+140
<i>MISTRAL2</i>	1.32	+420	+650
<i>MISTRAL3</i>	1.39	+470	+740
<i>MH1.2</i>	1.26	+160	+280

$$\omega_{max} = 0.47$$

mixed core



# $\Delta\rho$ in Core calculations



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$$\omega_{\text{mix}} = 0.47$$

mixed core

The UOX Reactivity seems to be slightly overestimated.  
The MOX Reactivity is overestimated, but in Mixed core, the effect is not so important.

\* statistical uncertainty in core calculation :  $1\sigma \approx 20 \text{ pcm}$



## ***Isotopic Components from J22 to J31 in M2 MOX core***

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- Effect of  $H_2O$  :  $(+220 \pm 30) pcm$  (partly due to processing)



## ***Isotopic Components from J22 to J31 in M2 MOX core***

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- Effect of  $Zr$  :  $(-80 \pm 20)$  pcm

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- Effect of  $H_2O$  :  $(+220 \pm 30)$  pcm (partly due to processing)
- Effect of  $Zr$  :  $(-80 \pm 20)$  pcm
- Effect of  $^{241}Am$  :  $(-280 \pm 30)$  pcm

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- Effect of  $Zr$  :  $(-80 \pm 20)$  pcm
- Effect of  $^{241}Am$  :  $(-280 \pm 30)$  pcm
- Effect of  $^{241}Pu$  :  $(-170 \pm 30)$  pcm

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- Effect of  $^{241}Pu$  :  $(-170 \pm 30)$  pcm
- Effect of  $^{238}U$  (APOLLO2/CEA2005 calc.) :  
+230 pcm due to  $k_\infty$  (+120 from  $\sigma(n, \gamma)$  ; +70 from  $\nu$  ...)

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- Effect of  $^{240}Pu$  (APOLLO2/CEA2005 calc.) : +150 pcm
- Effect of  $^{239}Pu$  (APOLLO2/CEA2005 calc.) : +160 pcm

N.B: decrease by 1% of migration area  $M^2 = D/\Sigma_a \rightarrow +180\text{pcm}$  partly due to  $g(E, E', \mu)_{inel}^{U238}$

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- In EOLE PWR-UOX mock-ups, the reactivity seems to be slightly overestimated.
- 100% MOX core experiments point out a  $+700$  pcm reactivity overestimation.
- MH1.2 Experiment shows that the reactivity of LWR mixed-core loading is reasonably predicted using JEFF-3.1 library.