Neutronic design of the XT-ADS core with In-Pile-Sections

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(on behalf of Task 1.2.3 of Domain 1 – Design)

Objectives of XT-ADS (1/2)

(see D1.1 in WP1.1)

- Demonstration of the ADS concept
  - Using conventional MOX-fuel
  - At reasonable power
  - Able to accept a certain number of MA assemblies
- Multi-purpose irradiation facility
  - Fast spectrum; $k_{eff} \approx 0.95$
  - Peak neutron flux: 10^{15} $n/cm^2.s$
  - Flexibility of operation

Objectives of XT-ADS (2/2)

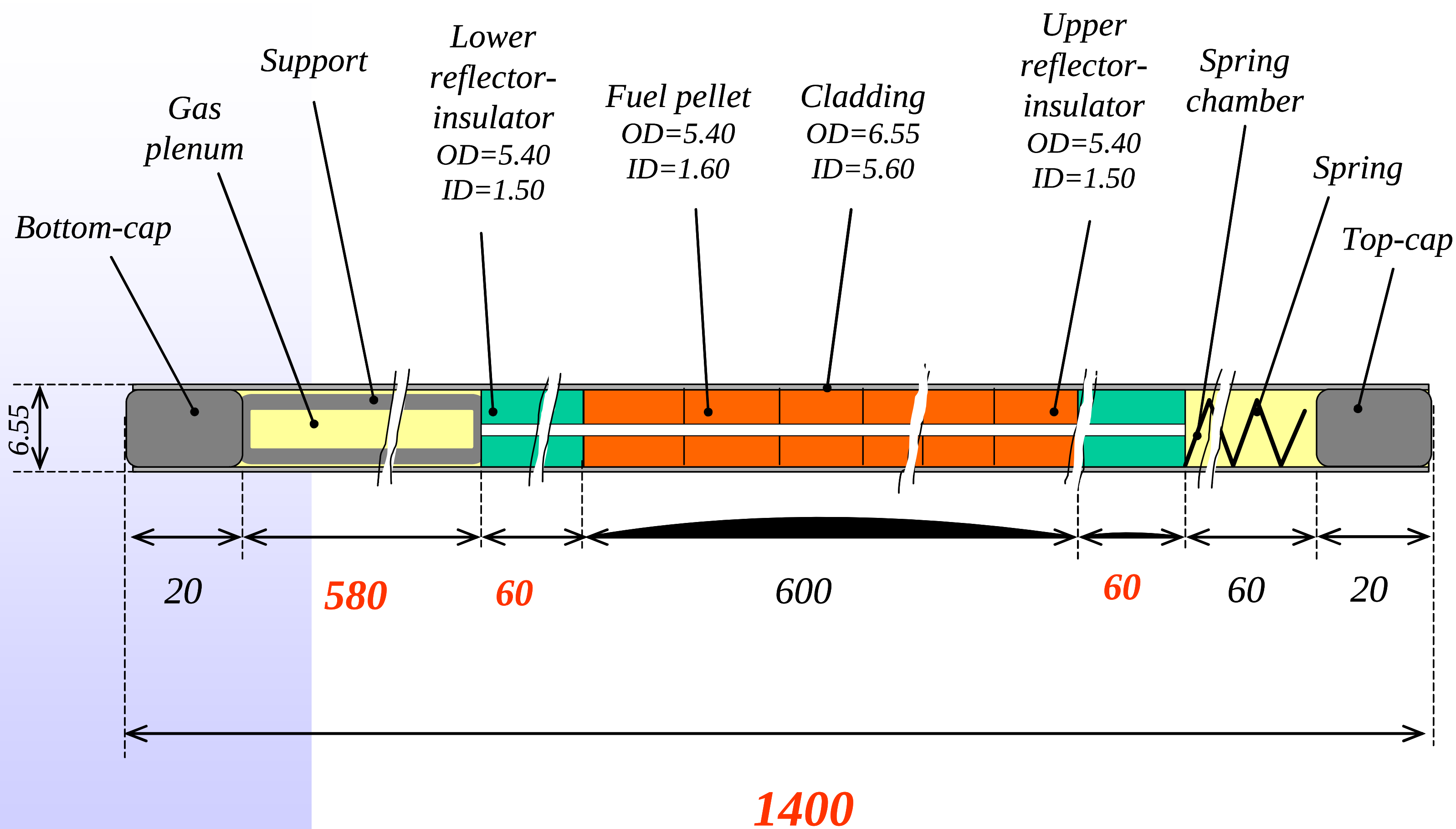
(see D1.1 in WP1.1)

- Transmutation studies in "EFIT conditions"
  - Important parameter: ratio of dpa in fuel cladding over burn-up of the fuel
  - Ability to load future EFIT fuel pins for testing and qualification

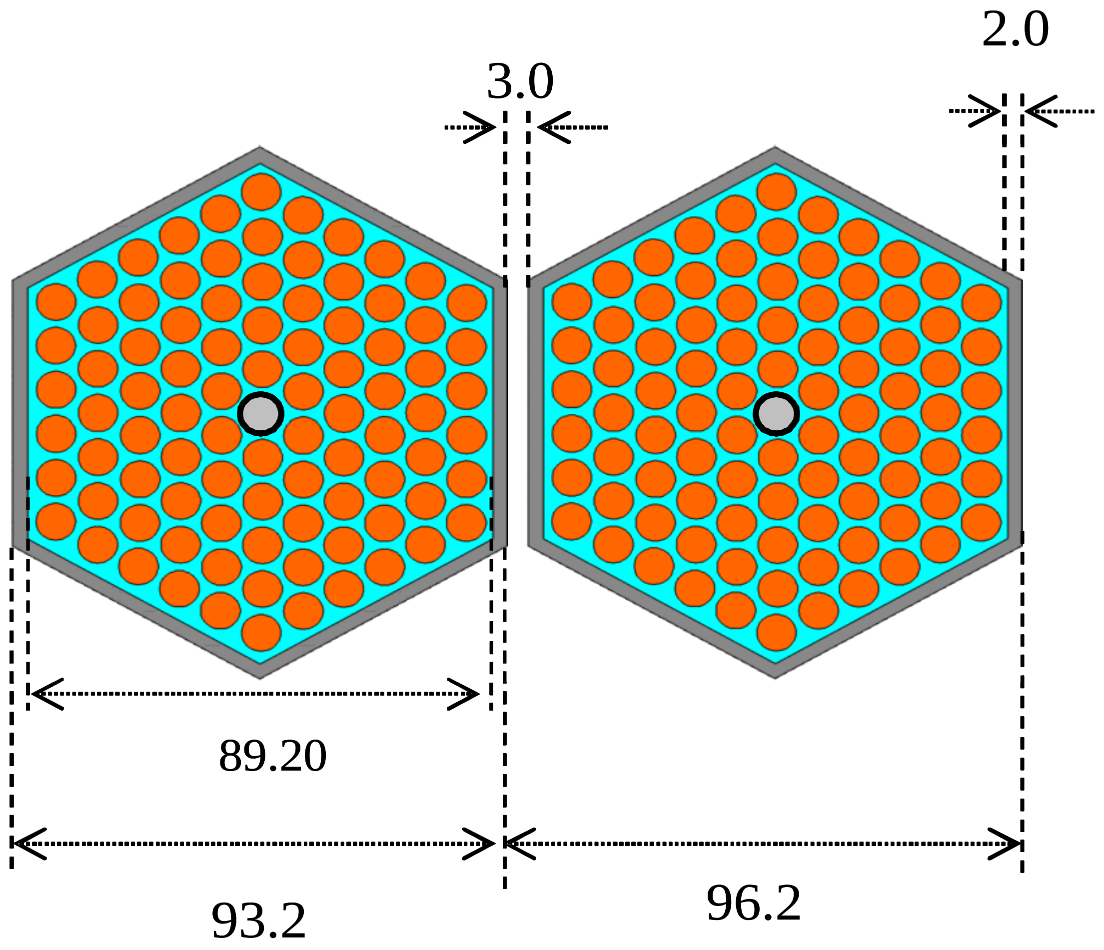
Core design
Computational route

- Start from MYRRHA Draft 2 file
- Constraints
  - 72 FAs, 90 active pins + 1 instrumentation pin
  - MOX vector from depleted UOX
  - Larger fuel pin pitch compared to MYRRHA Draft2
- Loss of reactivity compared to the original MYRRHA Draft 2
  - Increase of the Pu wt% to 31.5 wt%

Fuel pin


Support
Gas plenum
Bottom-cap
Lower reflector-insulator OD=5.40 ID=1.50
Fuel pellet OD=5.40 ID=1.60
Cladding OD=6.55 ID=5.60
Upper reflector-insulator OD=5.40 ID=1.50
Spring chamber
Spring
Top-cap
6.55
20
580
60
600
60
60
20
1400

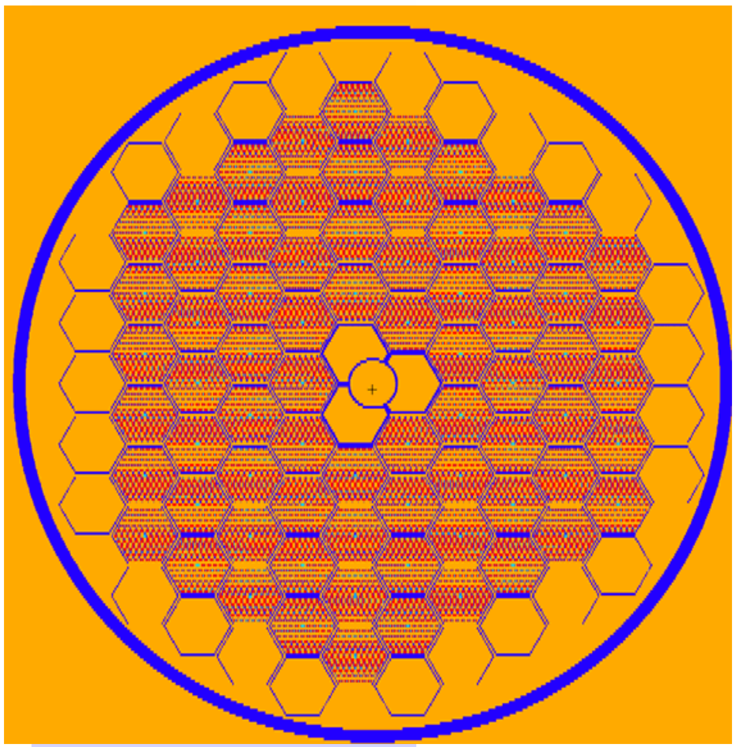
Fuel Assembly

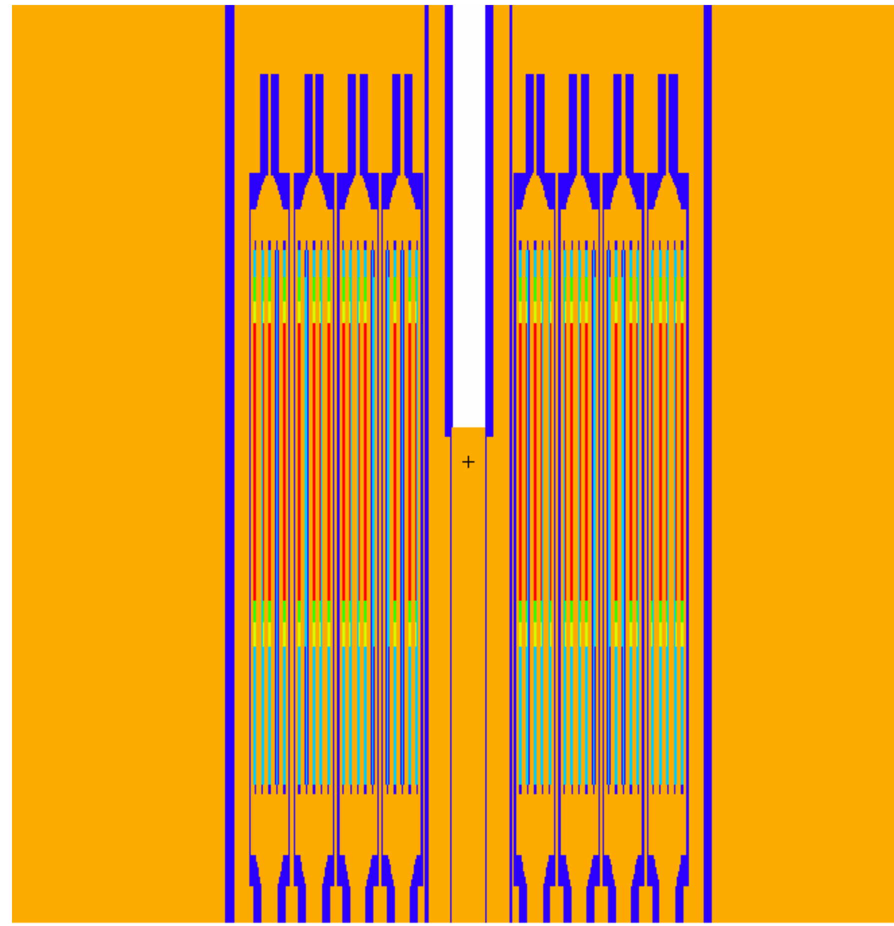


Tools used

- MCNPX 2.6c
- JEFF 3.1 XS
- Task 1.2.3 shares the same MCNPX input file to reduce "double work"

Reference core D1.7





Reference core D1.7

Parameter	Unit	XT-ADS Value	MYRRHA Value
Proton beam energy	MeV	600	350
Proton beam current	mA	2.33 †	5
Proton beam deposited heat	MW	1.40	1.75
Total neutron yield per incident proton		15.3	6.0
Neutron source intensity	10^{17} n/s	2.23	1.9
Initial fuel mixture	MOX	$(U\text{-}Pu)O_2$	$(U\text{-}Pu)O_2$
Initial (HM) fuel mass	kg	857	514
Initial Pu enrichment	wt%	31.5	30
k_{eff}		0.95324	0.95521
k_S		0.95711	0.96007
$MF = 1/(1-k_S)$		23.31	25.04
Source importance ϕ^*		1.095	1.127

Reference core D1.7

Parameter	Unit	XT-ADS Value	MYRRHA Value
Thermal power	MW	56.75 ‡	51.75 ‡
Specific power	kW/kgHM	66.22	101
Peak linear power (hottest pin)	W/cm	253	352
Average linear power (hottest pin)	W/cm	146	252
Max Φ_{total} in the core near hottest pin	10^{15} n/(cm2.s)	3.31	4.1
Max $\Phi_{>1MeV}$ in the core near hottest pin	10^{15} n/(cm2.s)	0.53	0.8
Max $\Phi_{>0.75\ MeV}$ in the core near hottest pin	10^{15} n/(cm2.s)	0.72	1.0

(†) Normalised to fuel power density of 700 W/cm^3 (‡) 210 MeV/fission

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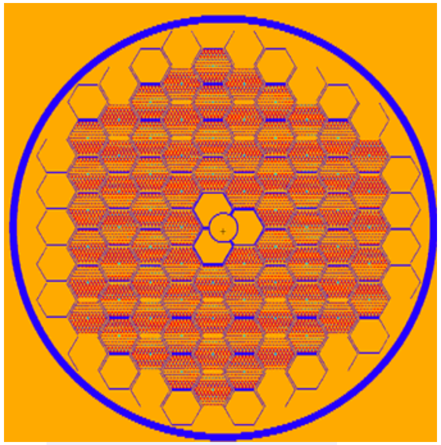
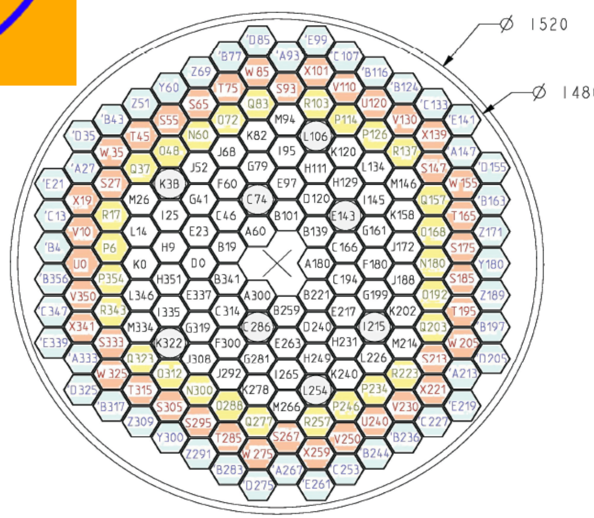
XTADS: core D1.7 → core C0



- Extended fission gas plenum
- Two extra rows added
- Core support plate taken into account in calculations
- New simplified target



$K_{eff} = 0.95057$

for

Pu wt% = 31.8

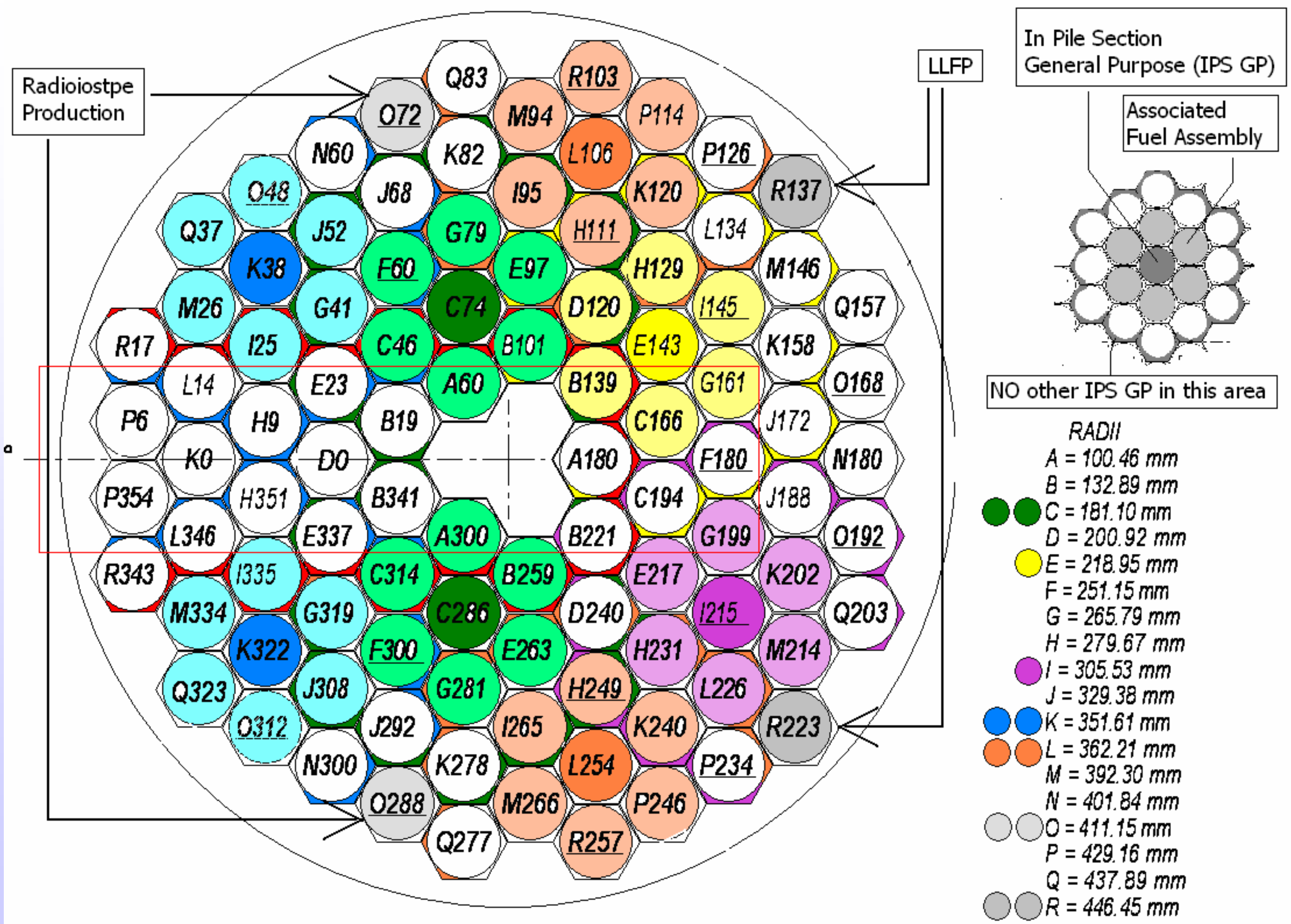
Proposed reference XT-ADS core - Option B

99 original positions
39 positions for assemblies filled with LBE and B_4C at ends (orange)
45 positions for assies filled with B_4C pins (light blue)
183 positions in total

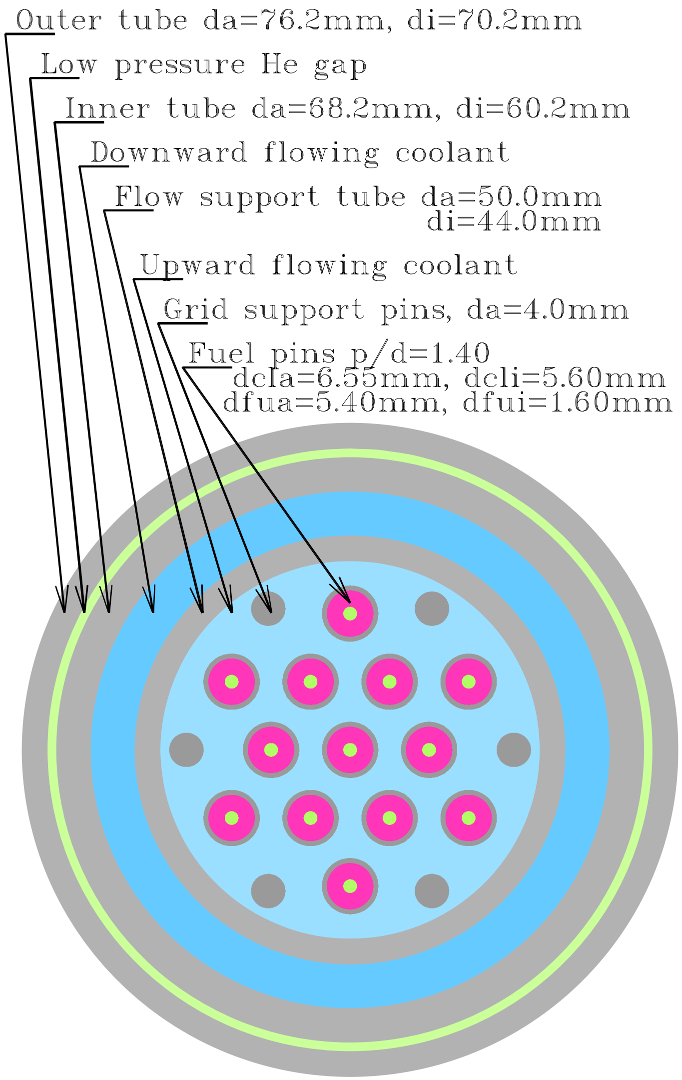
In-Pile-Sections

- 8 positions that are accessible from the top of the reactor are foreseen for experimental devices
- Each position is surrounded by at least 6 fuel assemblies
- Positions are chosen strategically
  - Close to the spallation target module
  - Far from the spallation target module

In-Pile-Sections

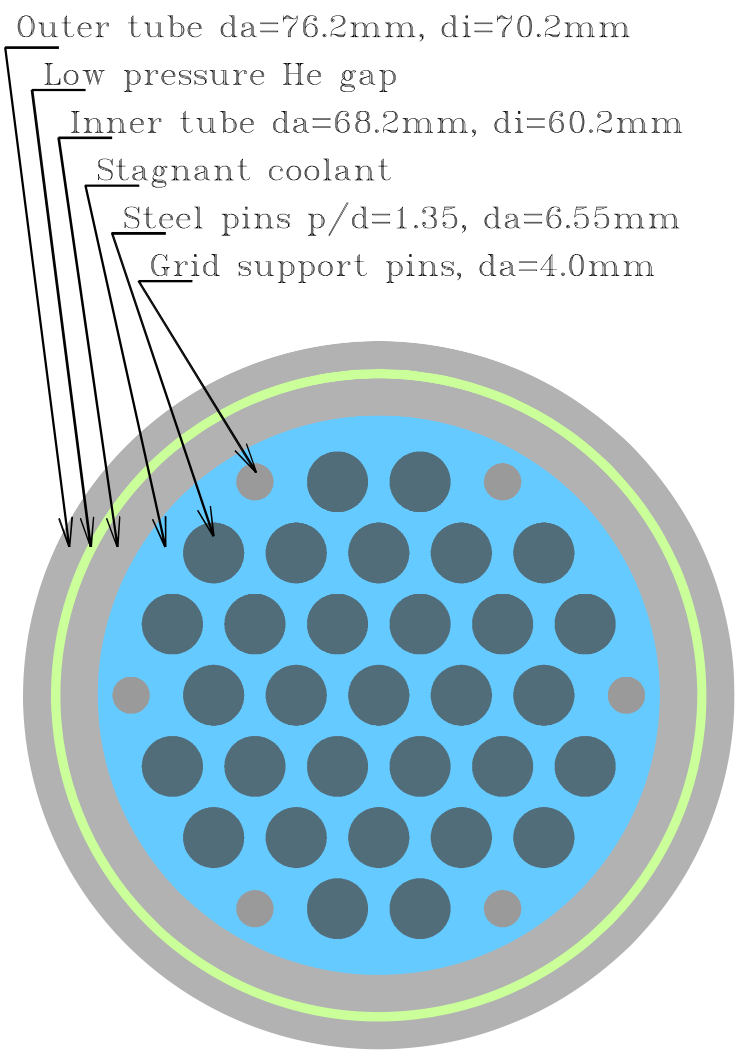


Four types of IPS



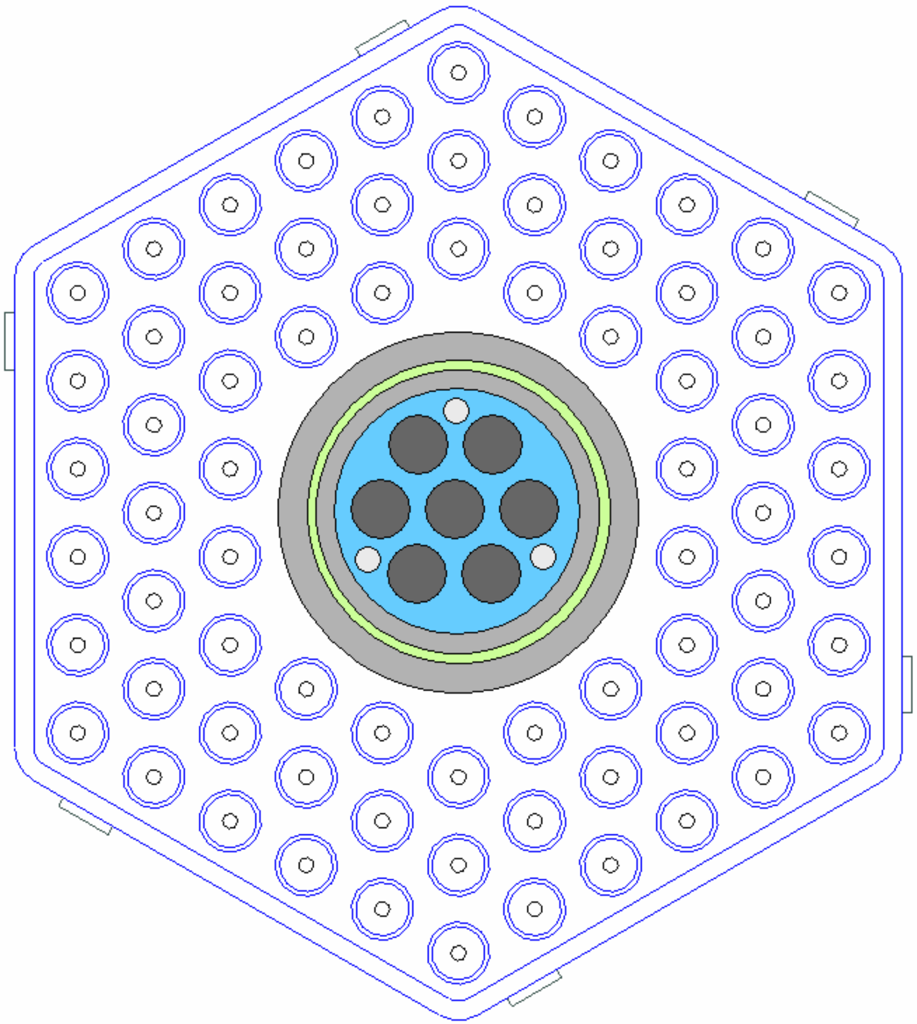
- P1, P2: irradiation of fuel pins
  - Currently we use the same pins as the core
  - EFIT pins in a later stage
  - Dedicated cooling circuit

Four types of IPS



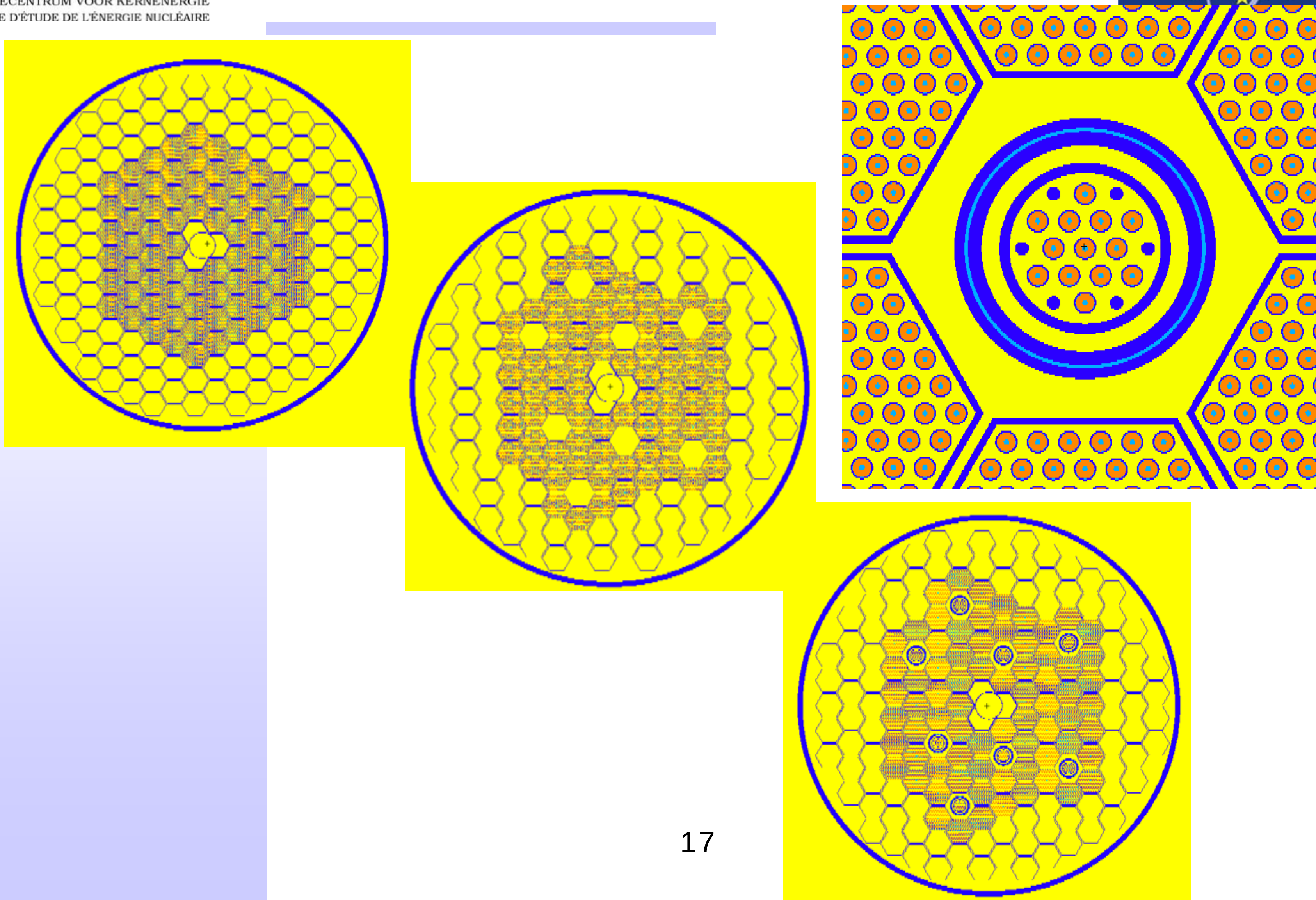
- P3: irradiation of structural materials
  - No fissile material in the hexcan
  - Stagnant coolant

Four types of IPS



- P4: irradiation of structural materials
  - Small-size IPS hosted in partially loaded fuel assembly
  - Loss of fissile material in the core is smaller
  - Higher fluxes inside the IPS

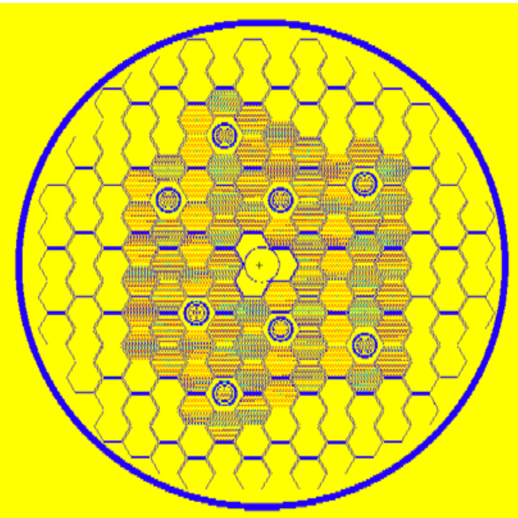
From C0 over P0 to P1

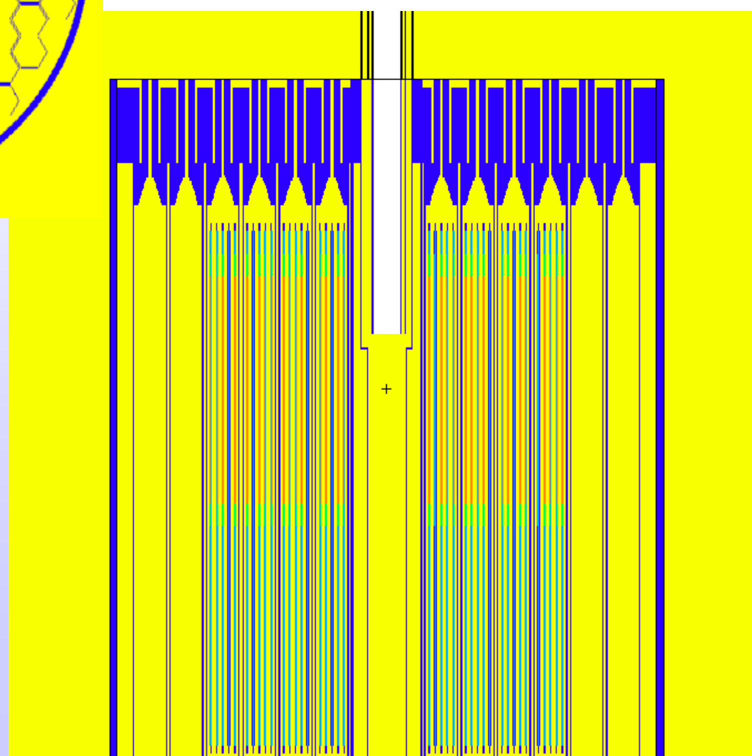


From C0 over P0 to P1

Core	Pu wt%	k_{eff}
C0	31.80	0.95057
P0	31.80	0.92594
P0	33.25	0.95177
P1	33.25	0.95418
P1	33.05	0.95035

Core P1 case



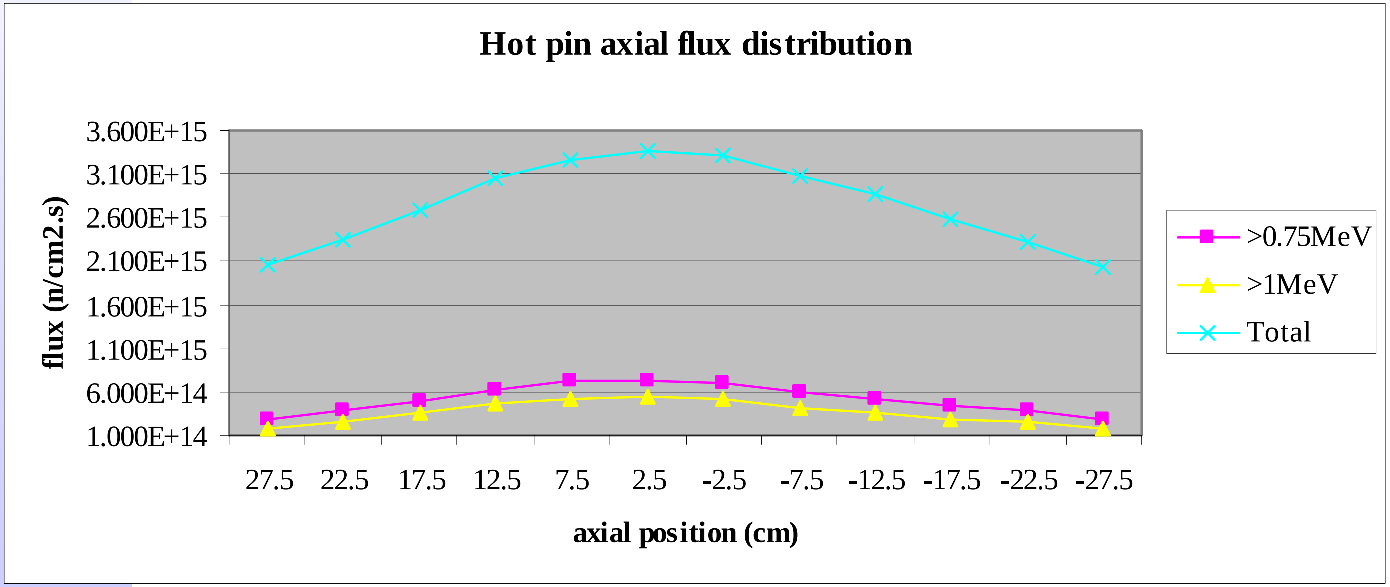


- Pu wt% = 33.05%
- k_{eff} = 0.95035
- K_s = 0.95598
- φ^*=1.13

- For I = 2.36 mA, P_{th} = 57 MW

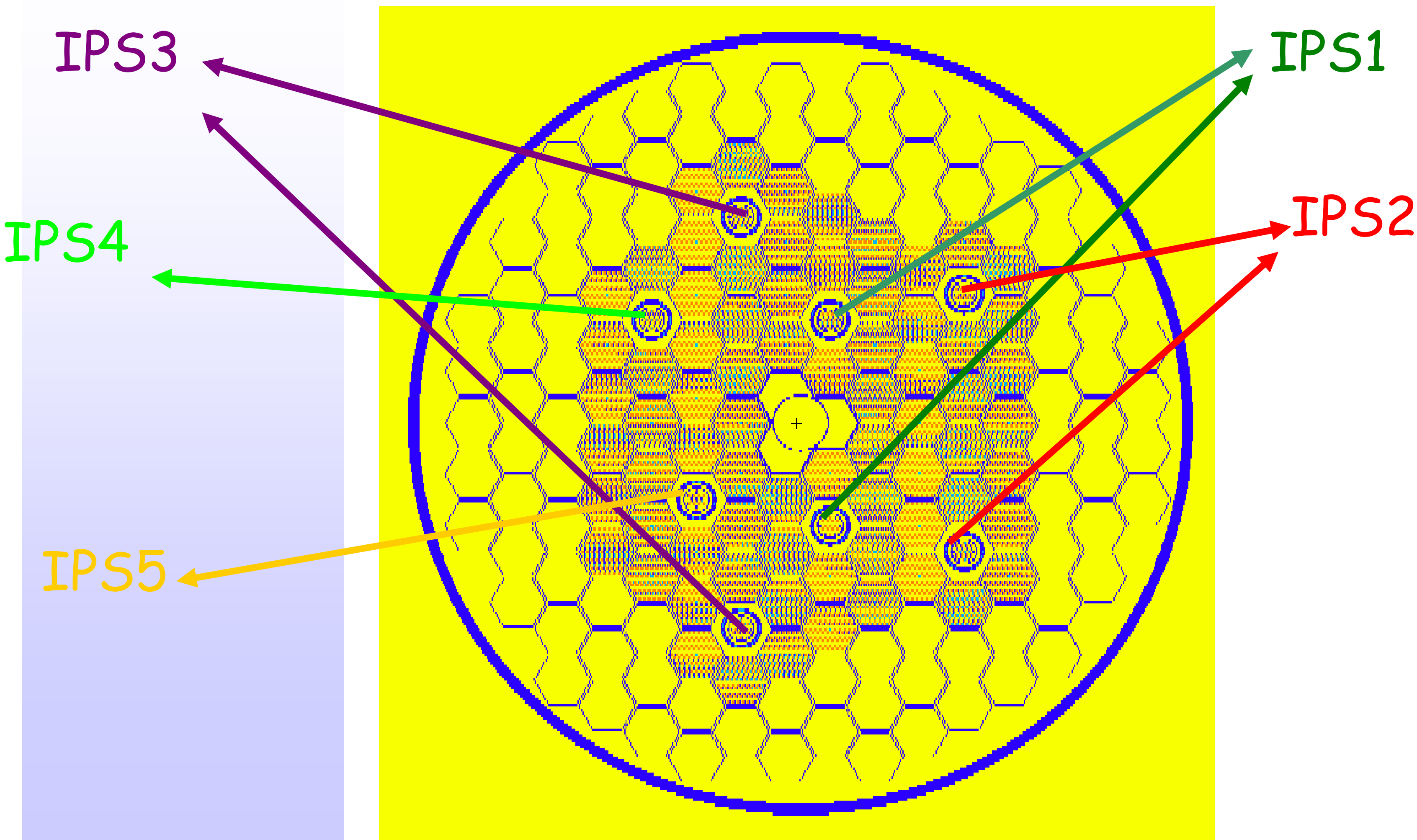
Core P1 case

- Fluxes in hot pin (midplane)
  - Peak fast flux $\Phi_{>1MeV}$ = 0.54 10^{15} $n/cm^2.s$
  - Peak fast flux $\Phi_{>0.750MeV}$ = 0.74 10^{15} $n/cm^2.s$
  - Total flux = 3.36 10^{15} $n/cm^2.s$



Core P1 case

- Fluxes in central pin of IPS elements (type P1) at midplane



Core P1 case

- Fluxes in central pin of IPS elements (type P1) at midplane

	$\Phi_{>0.75MeV}$ (10^{15} n/cm^2.s)	$\Phi_{>1MeV}$ (10^{15} n/cm^2.s)	Φ_{total} (10^{15} n/cm^2.s)
IPS1	0.43	0.29	2.63
IPS2	0.28	0.19	1.82
IPS3	0.26	0.18	1.74
IPS4	0.30	0.20	1.96
IPS5	0.43	0.30	2.46

Conclusions

- The reference core is fixed and described in Deliverable 1.7 of the EUROTRANS project
- Extension with two rows: core C0
- Simplified IPS models are put in the core: core P1 (ongoing work)
- Still room for optimisation of fluxes
  - Optimal position of spallation source
  - Margins on k_{eff}

One picture is better than a thousand words, we are in 2020