Fifth International Workshop on the
Utilisation and Reliability of High Power Proton Accelerator

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A-BAQUS

A multi-entry graph assisting the neutronic design of an ADS
Case study: EFIT

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EUROTRANS DM1 Task 1.2.4:
EFIT Core Design

- The **EFIT** (European Feasibility for Industrial Transmutation, VI FP, IP EUROTRANS) concept developed for the transmutation of MAs
- Neutronic design of a **Pb cooled sub-critical core** (ADS with k_{eff} (t) ≤ 0,97)

EFIT Pb Main features

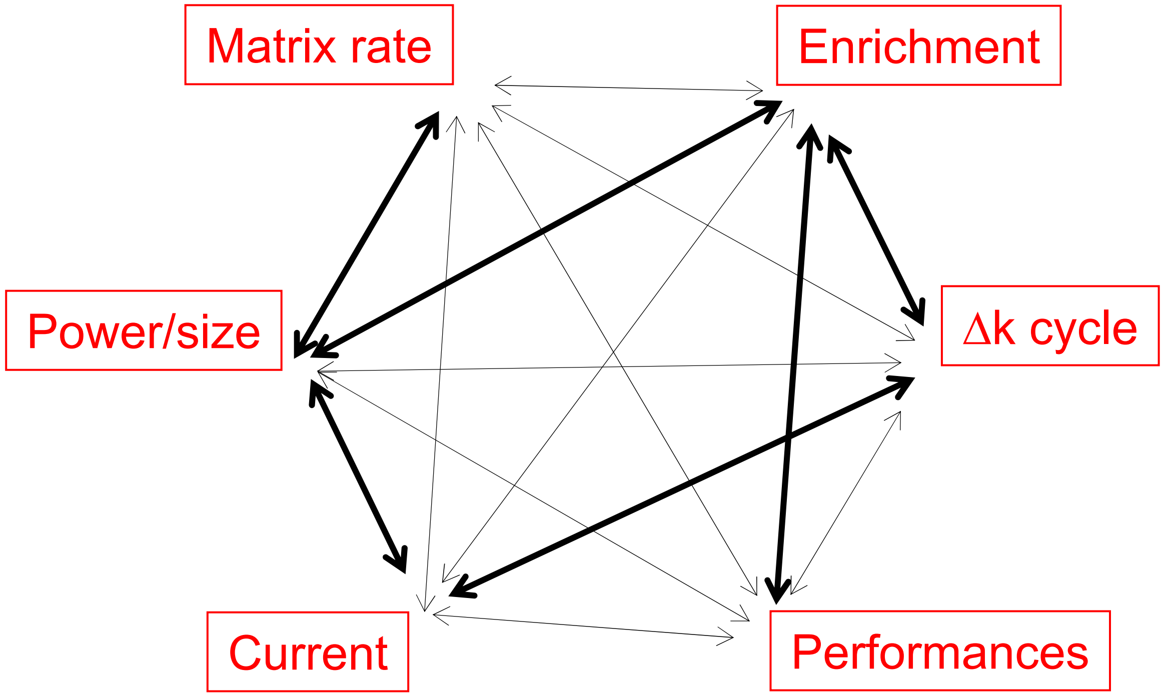
Goal:	fissioning MA
Fuel:	MA & Pu Oxide in inert matrix (MgO)
Coolant:	Lead, Tin=400 °C, Tout=480°C
Power:	several hundreds MW

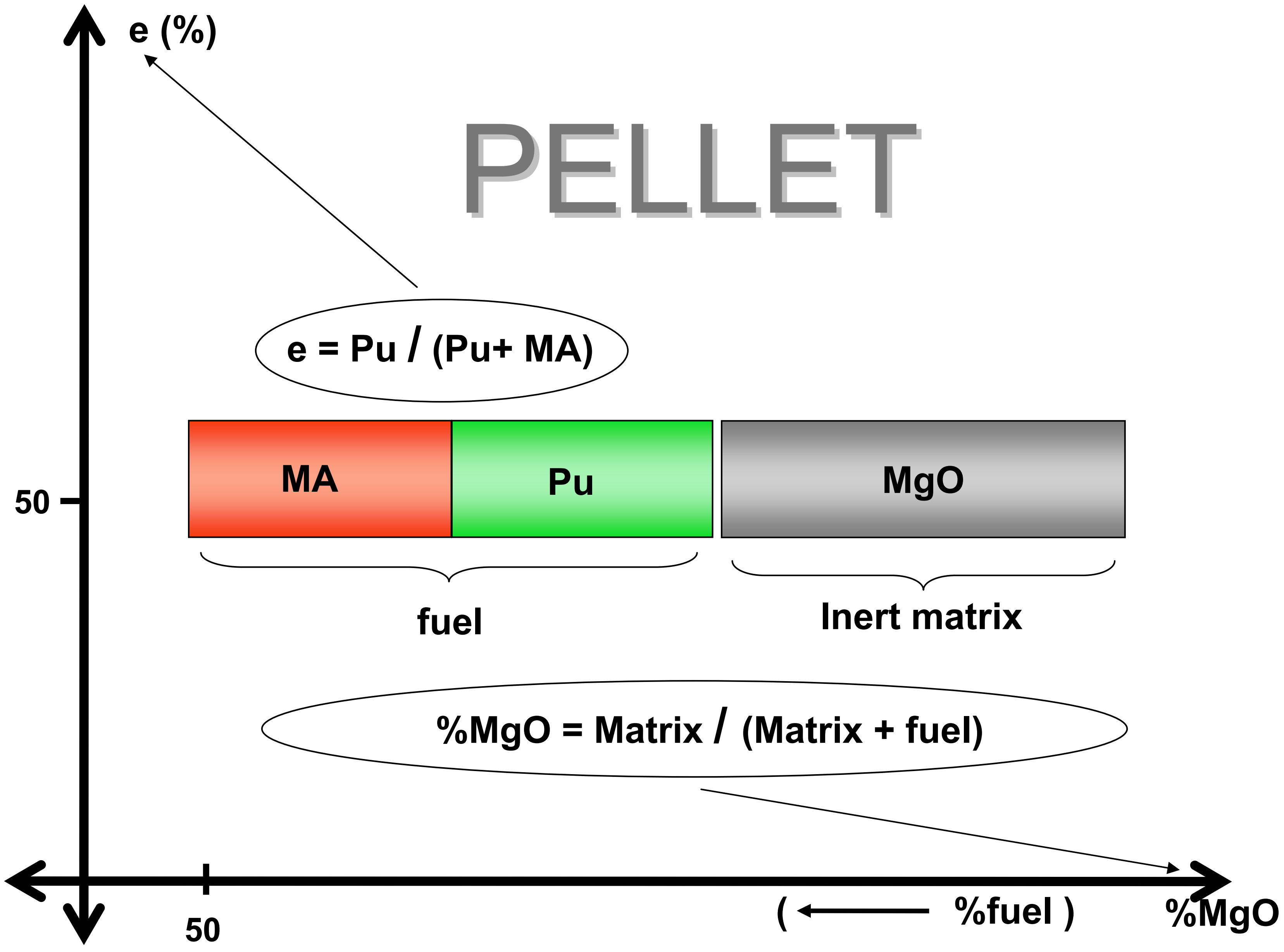
Main parameters to keep under control simultaneously in ADS neutronic design

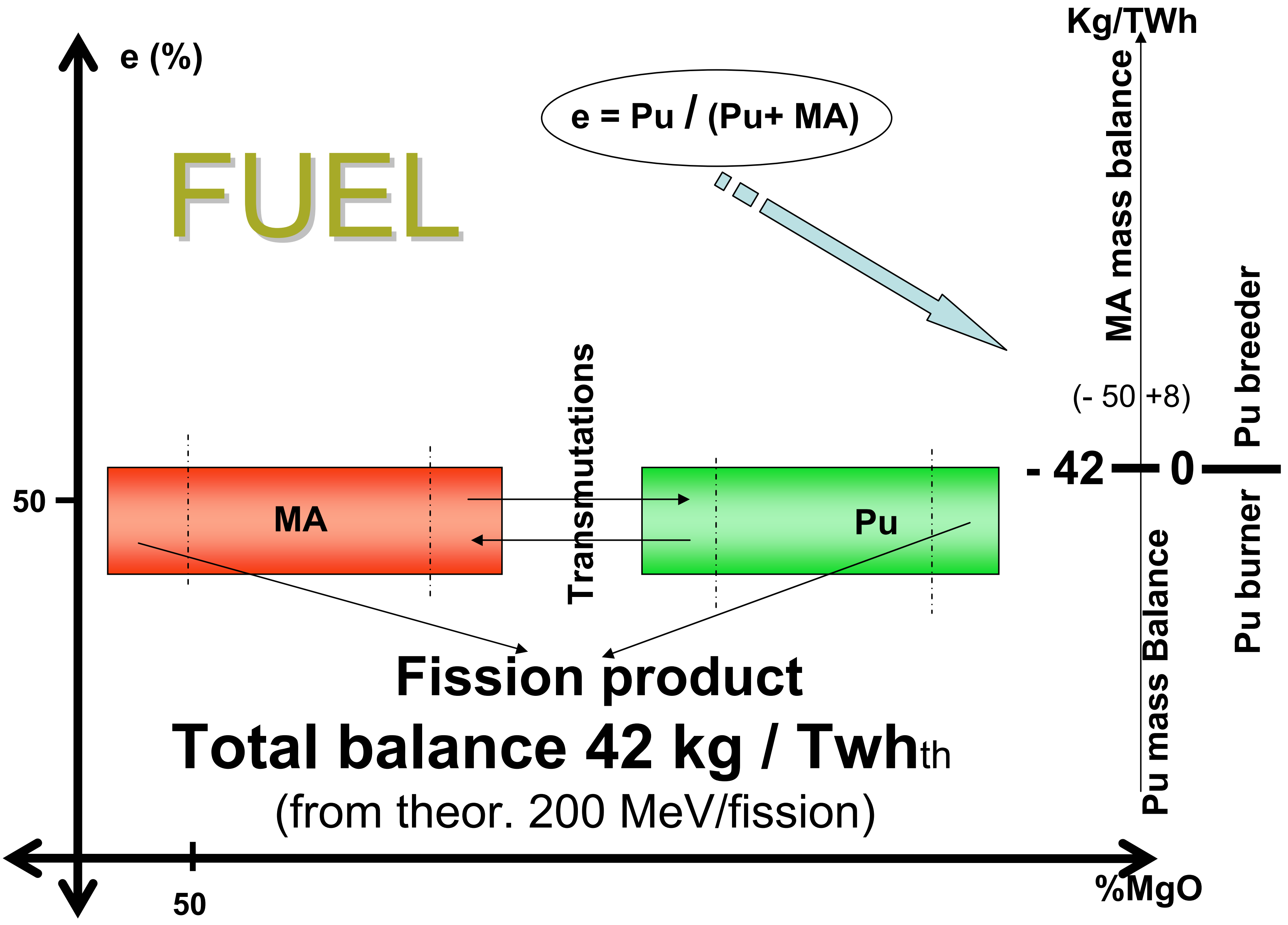
Provided:

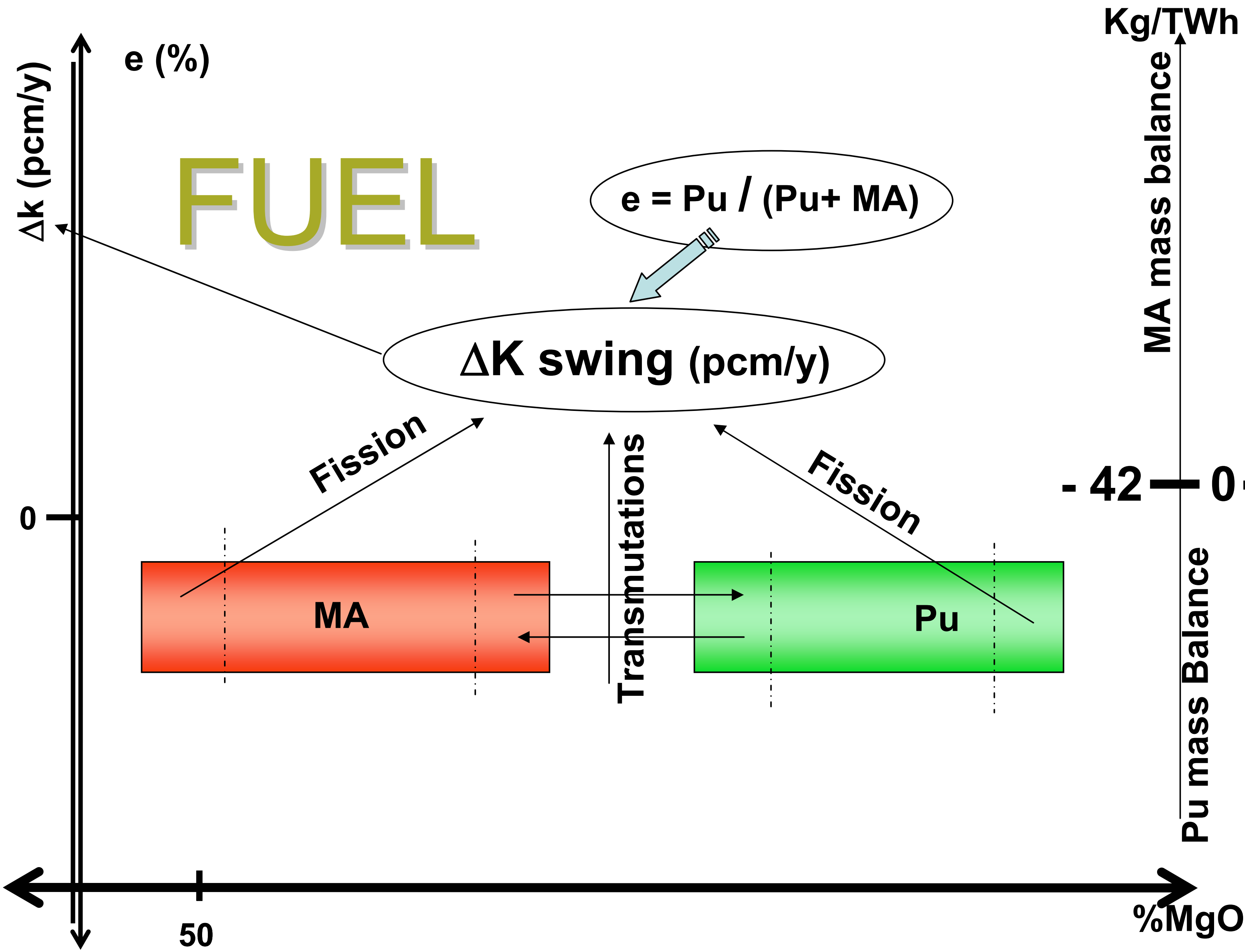
Subcriticallity → Keff

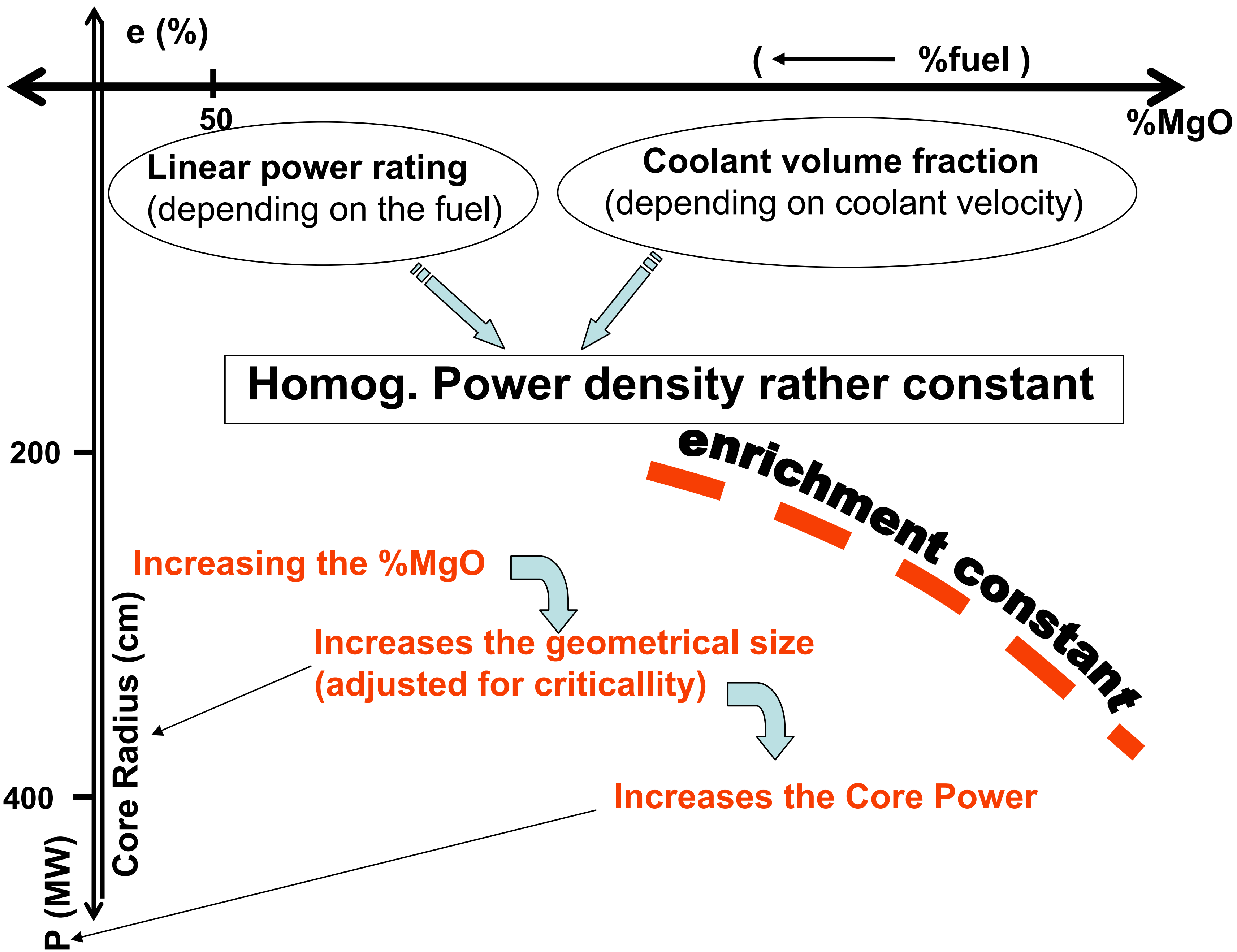
Fuel: T_{max}, conduction → Linear Power
Thermohydraulic constraints (ΔT, coolant velocity) } hom. power density



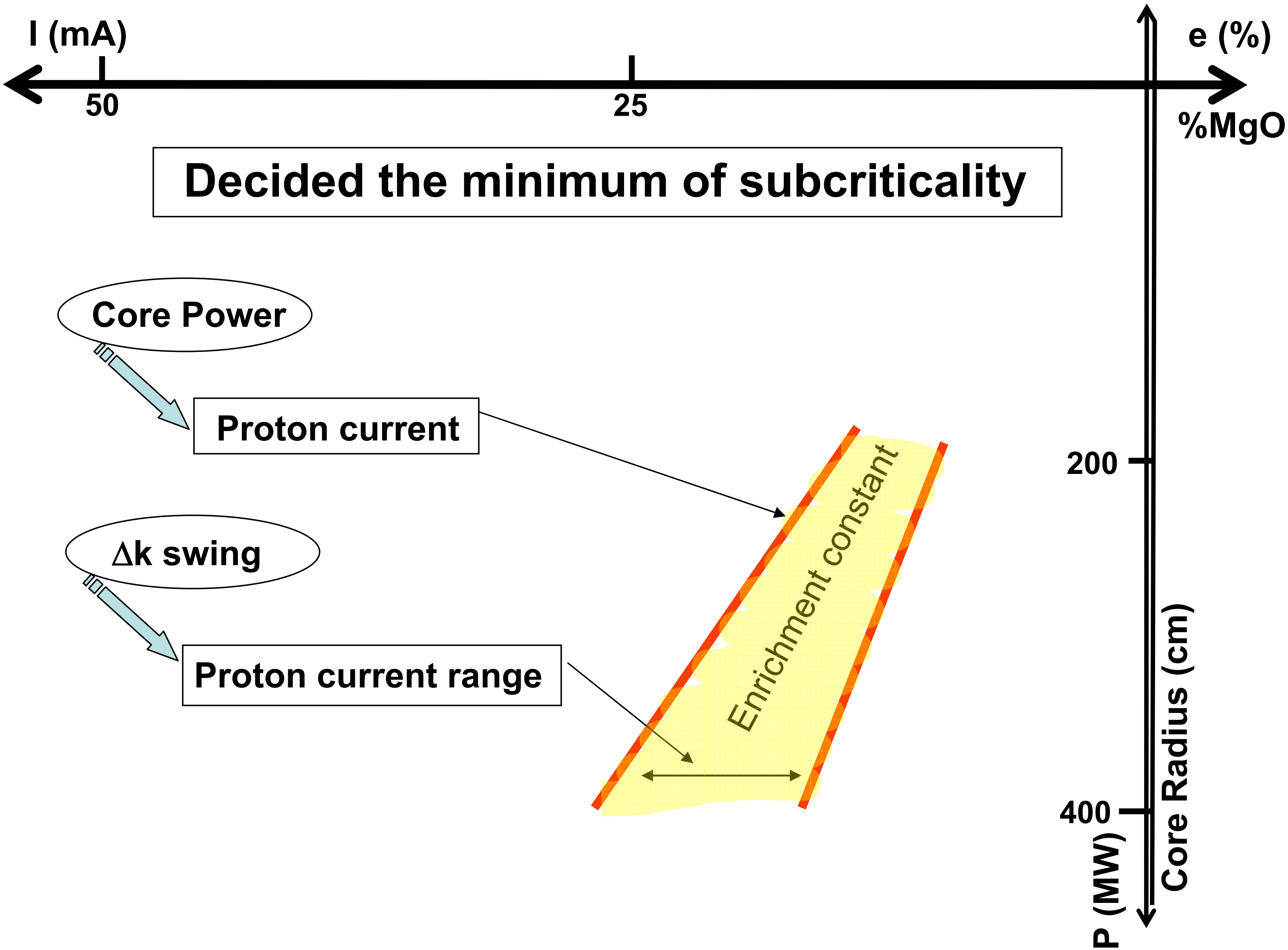

e (%)
PELLET
e = Pu / (Pu+ MA)
MA
Pu
MgO
50
fuel
Inert matrix
%MgO = Matrix / (Matrix + fuel)
50
(%fuel)
%MgO

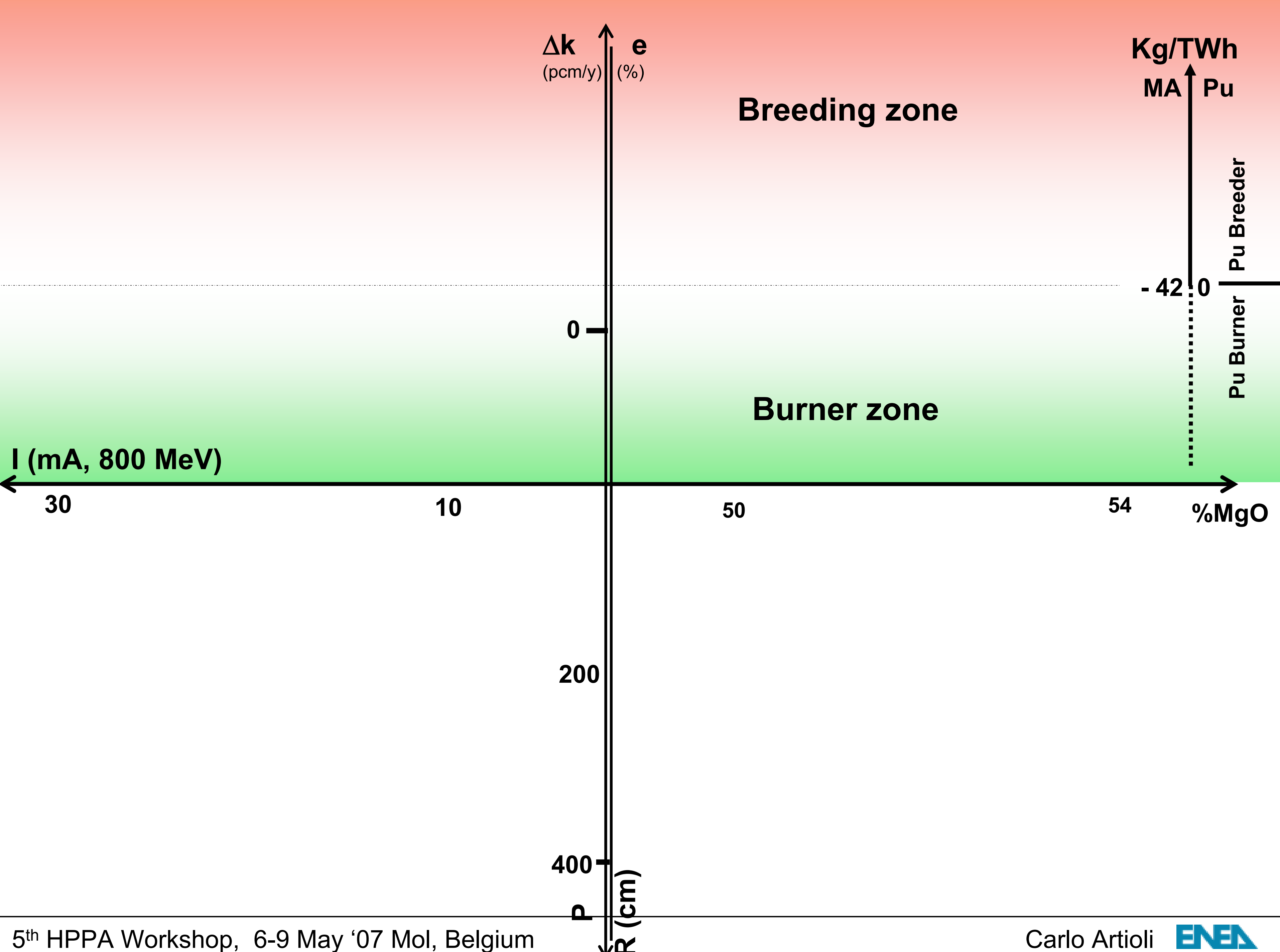

e (%)
e = Pu / (Pu+ MA)
FUEL
Kg/TWh
MA mass balance
(- 50 +8)
Pu breeder
- 42
0
Pu burner
Pu mass Balance
50
MA
Transmutations
Pu
Fission product
Total balance 42 kg / Twhth
(from theor. 200 MeV/fission)
50
%MgO


e (%)
Δk (pcm/y)
FUEL
e = Pu / (Pu+ MA)
ΔK swing (pcm/y)
Fission
Transmutations
Fission
0
MA
Pu
Kg/TWh
MA mass balance
- 42
0
Pu breeder
Pu burner
Pu mass Balance
50
%MgO



e (%)
(%fuel)
50
%MgO
Linear power rating
(depending on the fuel)
Coolant volume fraction
(depending on coolant velocity)
Homog. Power density rather constant
enrichment constant
200
400
Increasing the %MgO
Increases the geometrical size
(adjusted for criticallity)
Increases the Core Power
Core Radius (cm)
P (MW)


I (mA)
50
25
e (%)
%MgO
Decided the minimum of subcriticality
Core Power
Proton current
Δk swing
Proton current range
Enrichment constant
200
400
P (MW)
Core Radius (cm)


Δk
(pcm/y)
e
(%)
Kg/TWh
MA
Pu
Breeding zone
Pu Breeder
- 42
0
0
Pu Burner
Burner zone
I (mA, 800 MeV)
30
10
50
54
%MgO
200
400
P
R (cm)

ΔK zero approach

Flux flattening technique by different rate of matrix (min 50%)

ΔK zero → fuel enrichment → ΔMA and ΔPu (kg/TWh$_{th}$)

According to matrix rates (3 options)

↓

Core dimension for criticality (3 options)

↓

Core power (3 options)

↓

Proton current (3 options)

Δk cycle zero → proton current constant in the cycle

Δk (pcm/y) e (%)

Kg/TWh
MA Pu
Pu Breeder
- 42 0
Pu Burner
%MgO

I (mA, 800
30

400
P
R (cm)

ΔK zero approach

Flux flattening by rates of matrix

ΔK zero   e = 50%   -36/-6

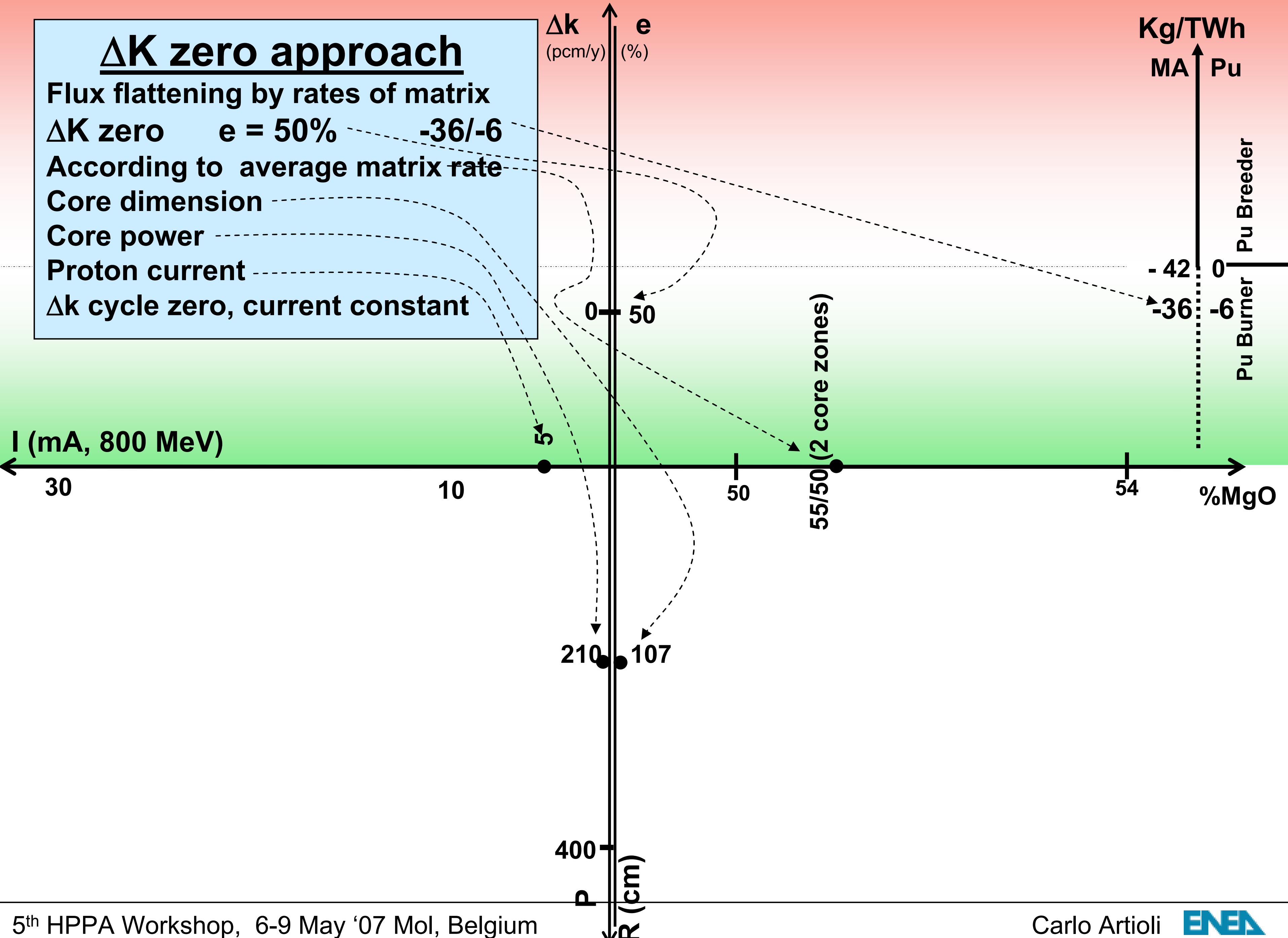
According to average matrix rate

Core dimension

Core power

Proton current

Δk cycle zero, current constant



ΔK zero approach

Flux flattening by rate of matrix

ΔK zero e = 50% -36/-6

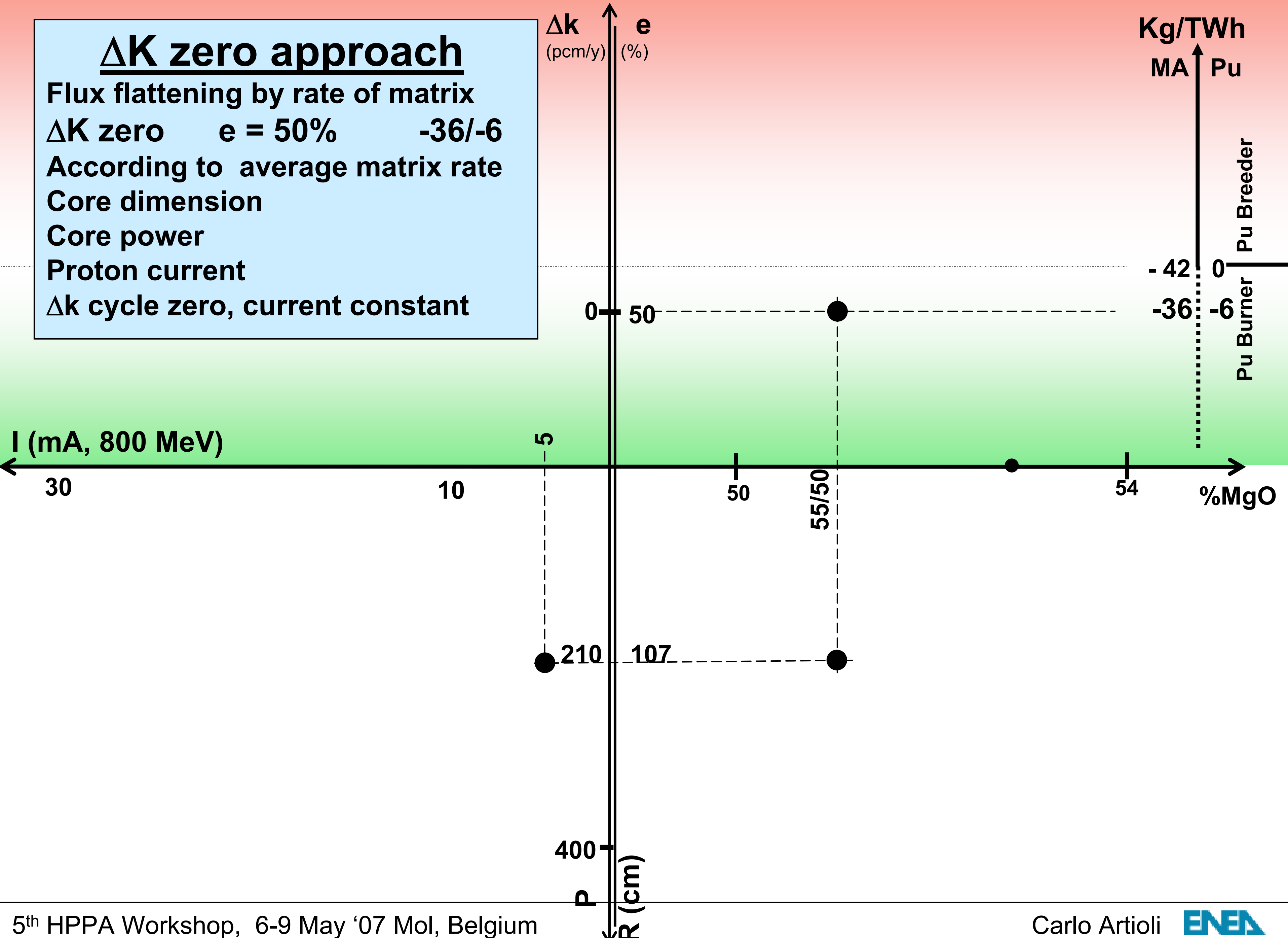
According to average matrix rate

Core dimension

Core power

Proton current

Δk cycle zero, current constant



ΔK zero approach

Flux flattening by content of matrix

ΔK zero   e = 50%   -36/-6

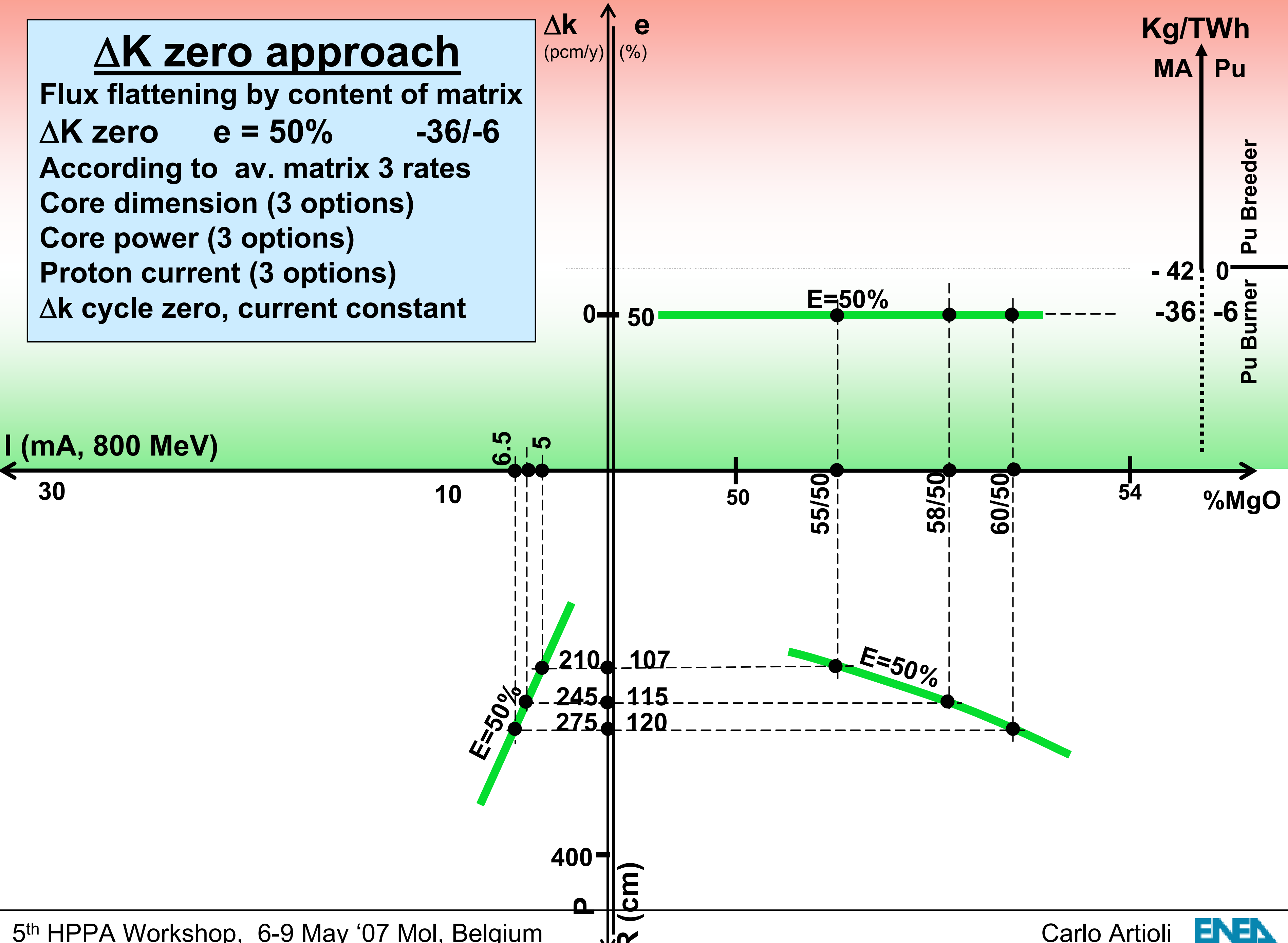
According to av. matrix 3 rates

Core dimension (3 options)

Core power (3 options)

Proton current (3 options)

Δk cycle zero, current constant



Δk (pcm/y) e (%)

Kg/TWh MA Pu

Pu Breeder
-42 0
Pu Burner

I (mA, 800

30

%MgO

<u>400 **MW approach**</u>

Flux flattening technique by different pin diameters (matrix rate = 50%)

P = 400 MW → pitch (coolability) → core dimension

↙

Enrichment for criticality

↓

ΔMA and ΔPu (kg/TWh$_{th}$)

↓

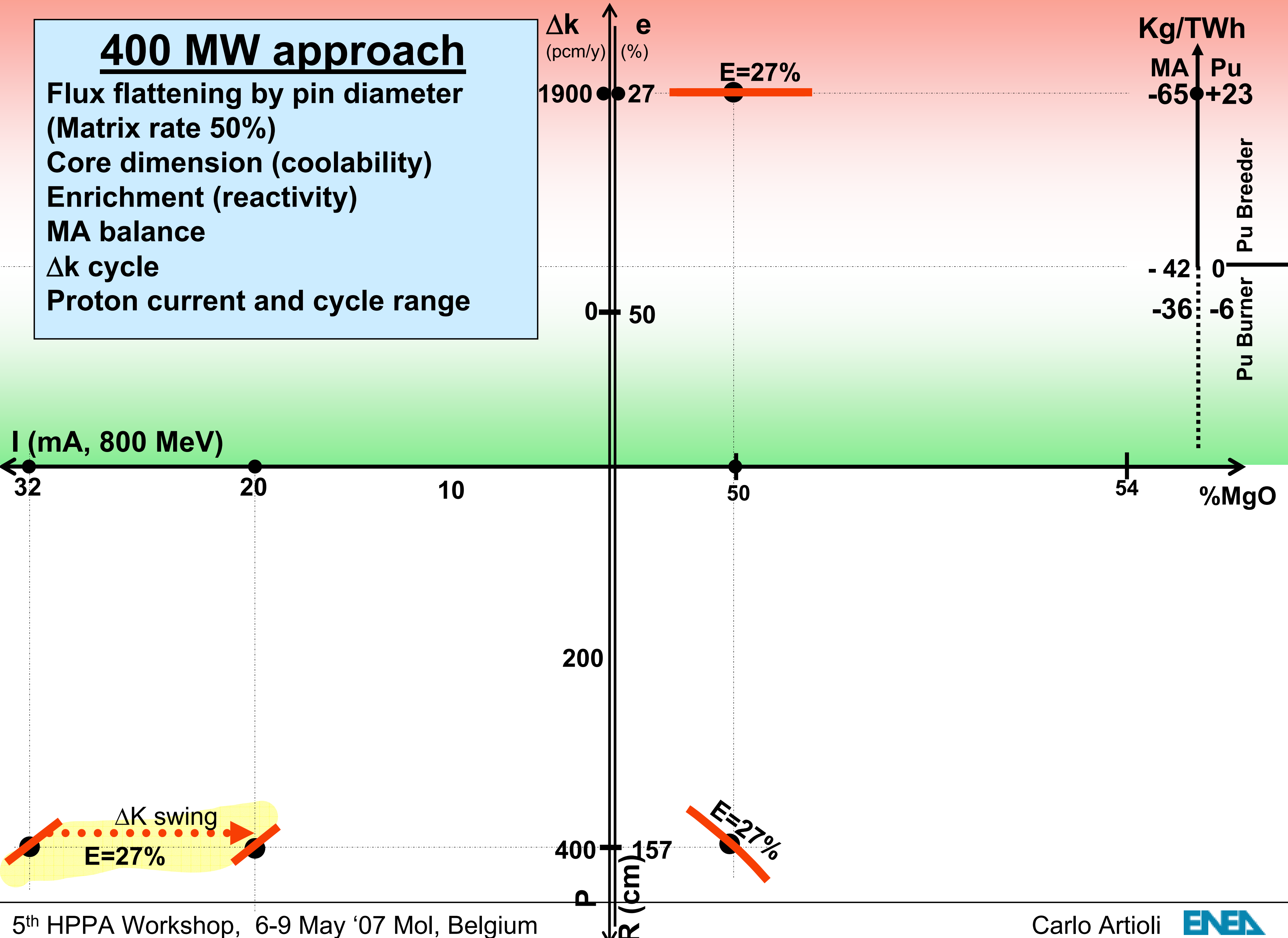
ΔK cycle

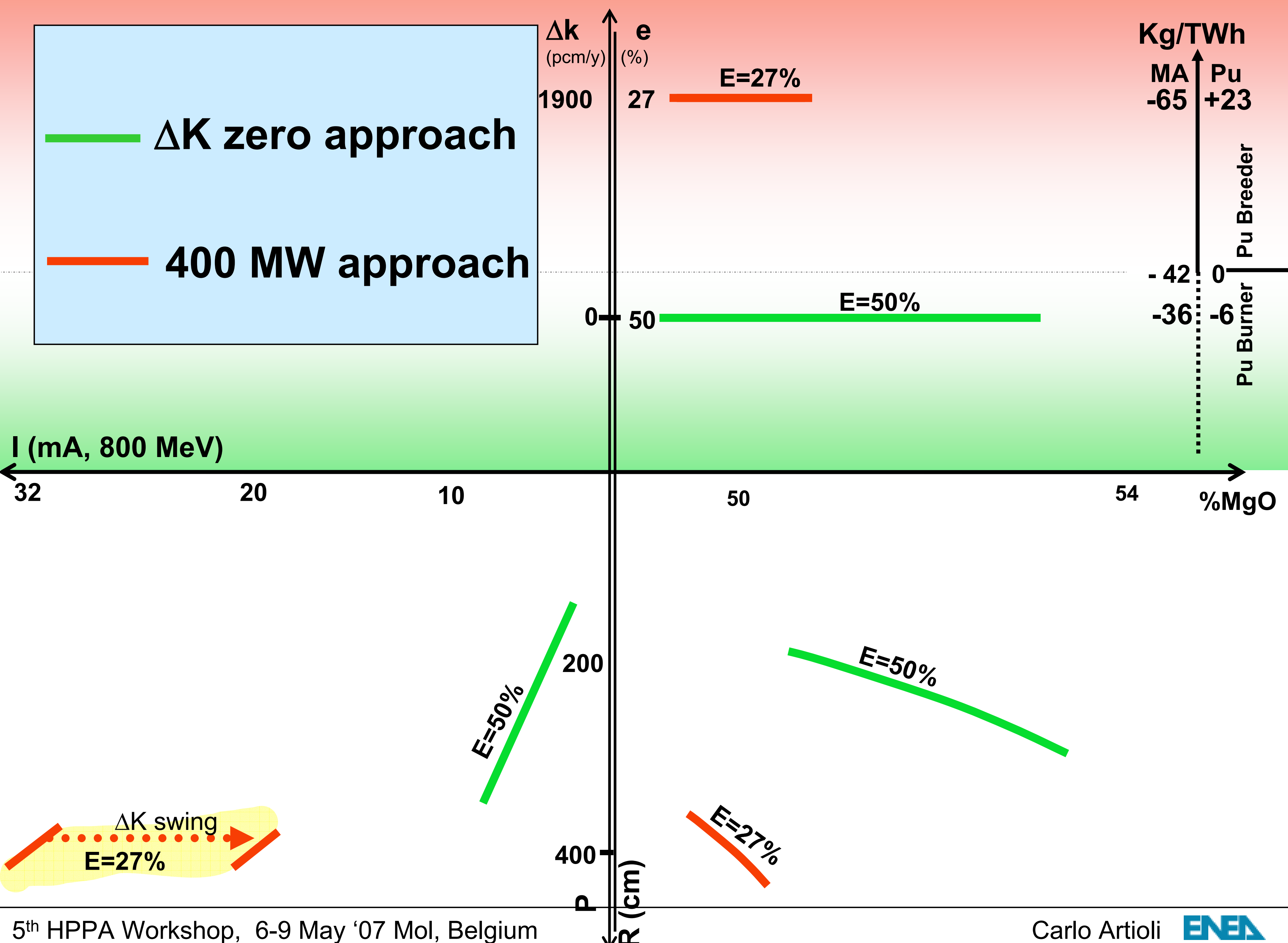
ΔK cycle not zero → proton current variable in the cycle

400 P R (cm)

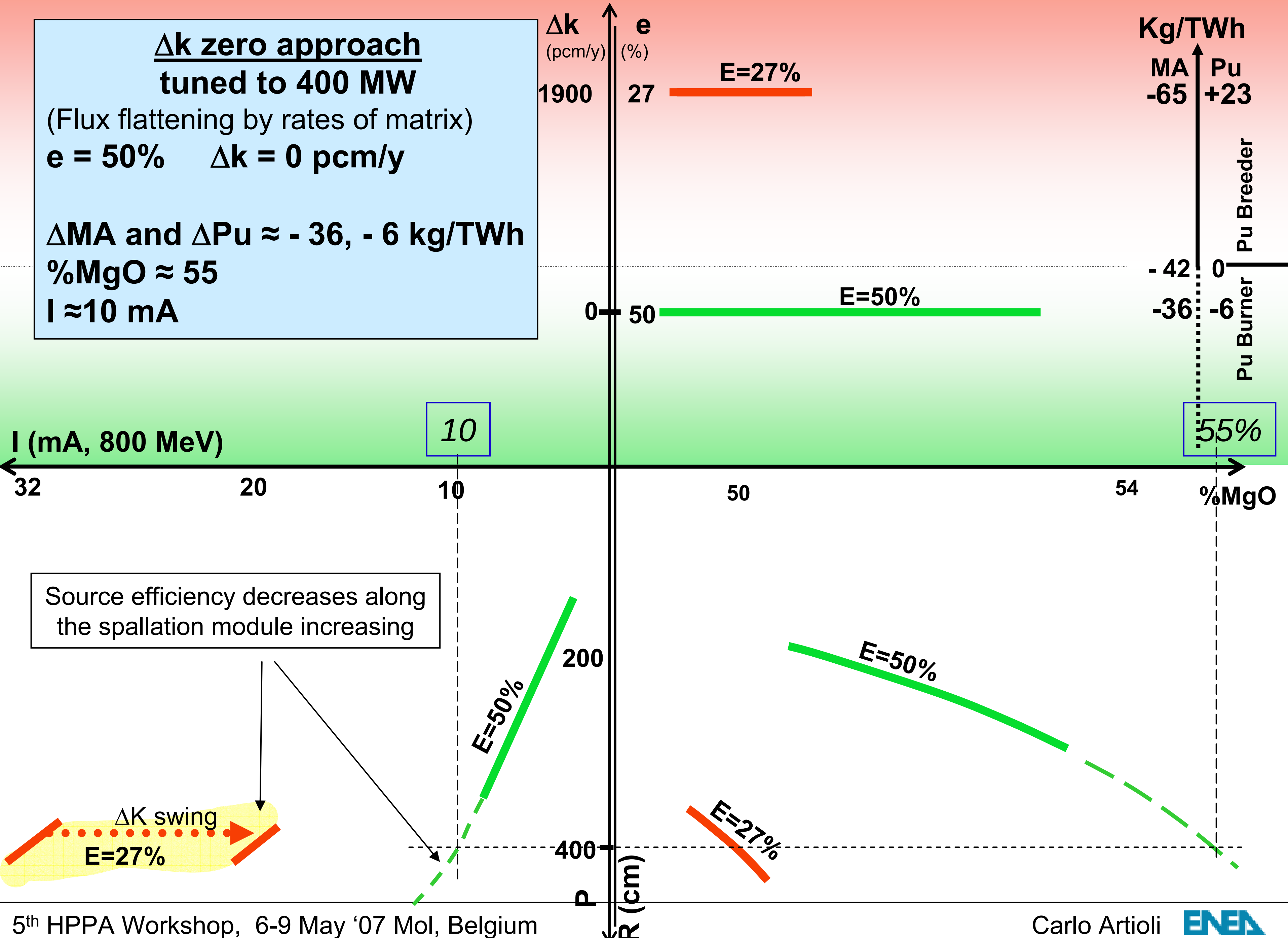
400 MW approach

Flux flattening by pin diameter
(Matrix rate 50%)
Core dimension (coolability)
Enrichment (reactivity)
MA balance
Δk cycle
Proton current and cycle range





ΔK zero approach
400 MW approach
Δk
(pcm/y)
e
(%)
1900
27
E=27%
0
50
E=50%
Kg/TWh
MA
Pu
-65
+23
Pu Breeder
- 42
0
-36
-6
Pu Burner
I (mA, 800 MeV)
32
20
10
50
54
%MgO
E=50%
200
E=50%
ΔK swing
E=27%
400
E=27%
P
R (cm)



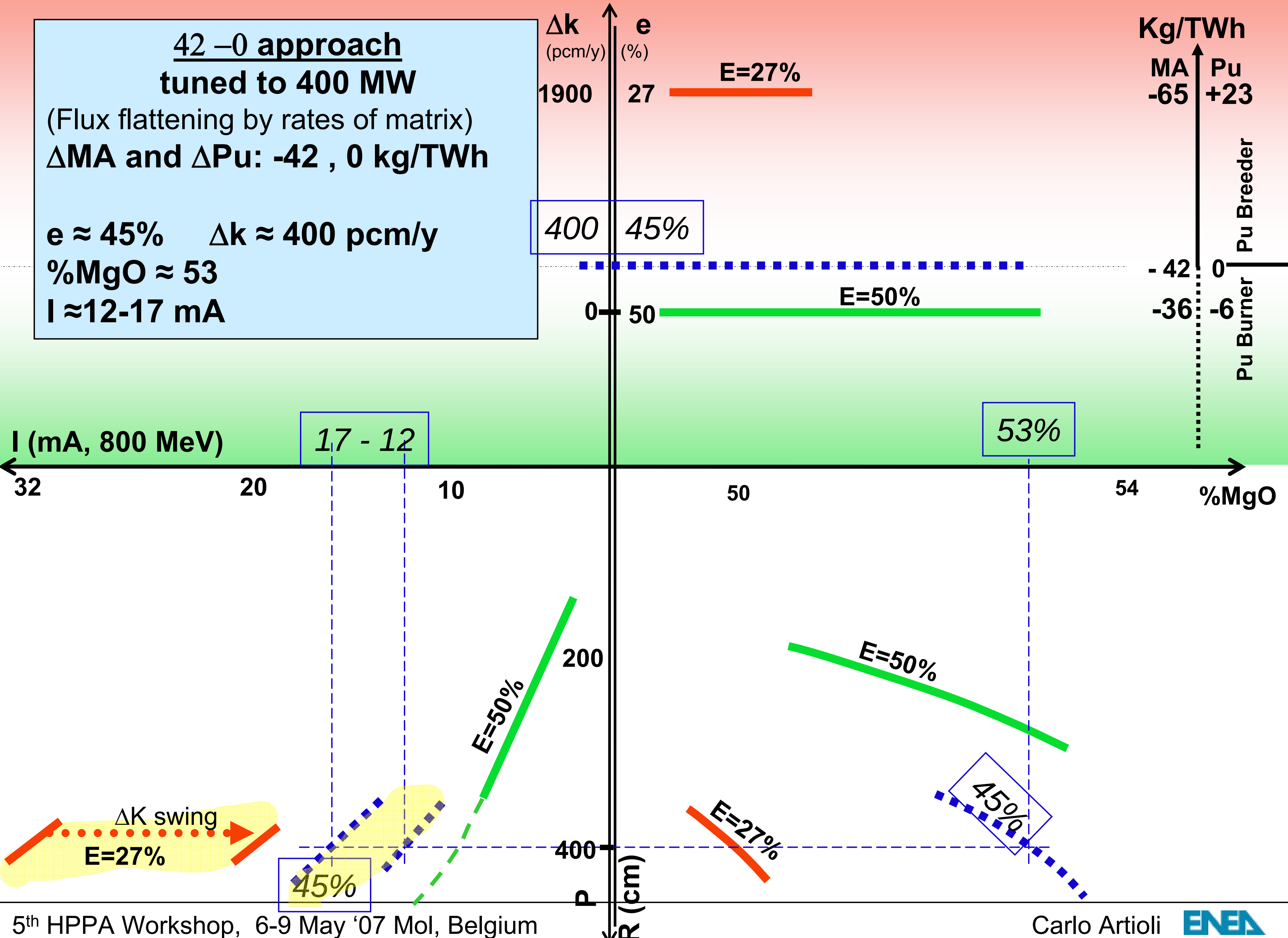
Δk zero approach
tuned to 400 MW
(Flux flattening by rates of matrix)
e = 50% Δk = 0 pcm/y
ΔMA and ΔPu ≈ - 36, - 6 kg/TWh
%MgO ≈ 55
I ≈10 mA
Δk
(pcm/y)
e
(%)
1900
27
E=27%
0
50
E=50%
Kg/TWh
MA
-65
Pu
+23
Pu Breeder
- 42
0
-36
-6
Pu Burner
10
55%
I (mA, 800 MeV)
32
20
10
50
54
%MgO
Source efficiency decreases along the spallation module increasing
ΔK swing
E=27%
E=50%
200
E=50%
400
E=27%
P
R (cm)

42 –0 approach
tuned to 400 MW

(Flux flattening by rates of matrix)

ΔMA and ΔPu: -42 , 0 kg/TWh

e ≈ 45%   Δk ≈ 400 pcm/y
%MgO ≈ 53
I ≈12-17 mA



42 – 0 approach

Flux flattening technique by different rate of matrix (min 50%)

42 – 0 ⟶ **enrichment** ⟶ **Δk cycle**

According to matrix rate (3 options)

↓

Core dimension for criticality (3 options)

↓

Core power (3 options)

↓

Proton current (3 options)

Δk cycle not zero ⟶ **proton current variable in the cycle**

42 –0 approach

Flux flattening by rates of matrix

42 – 0 e = 45.7%

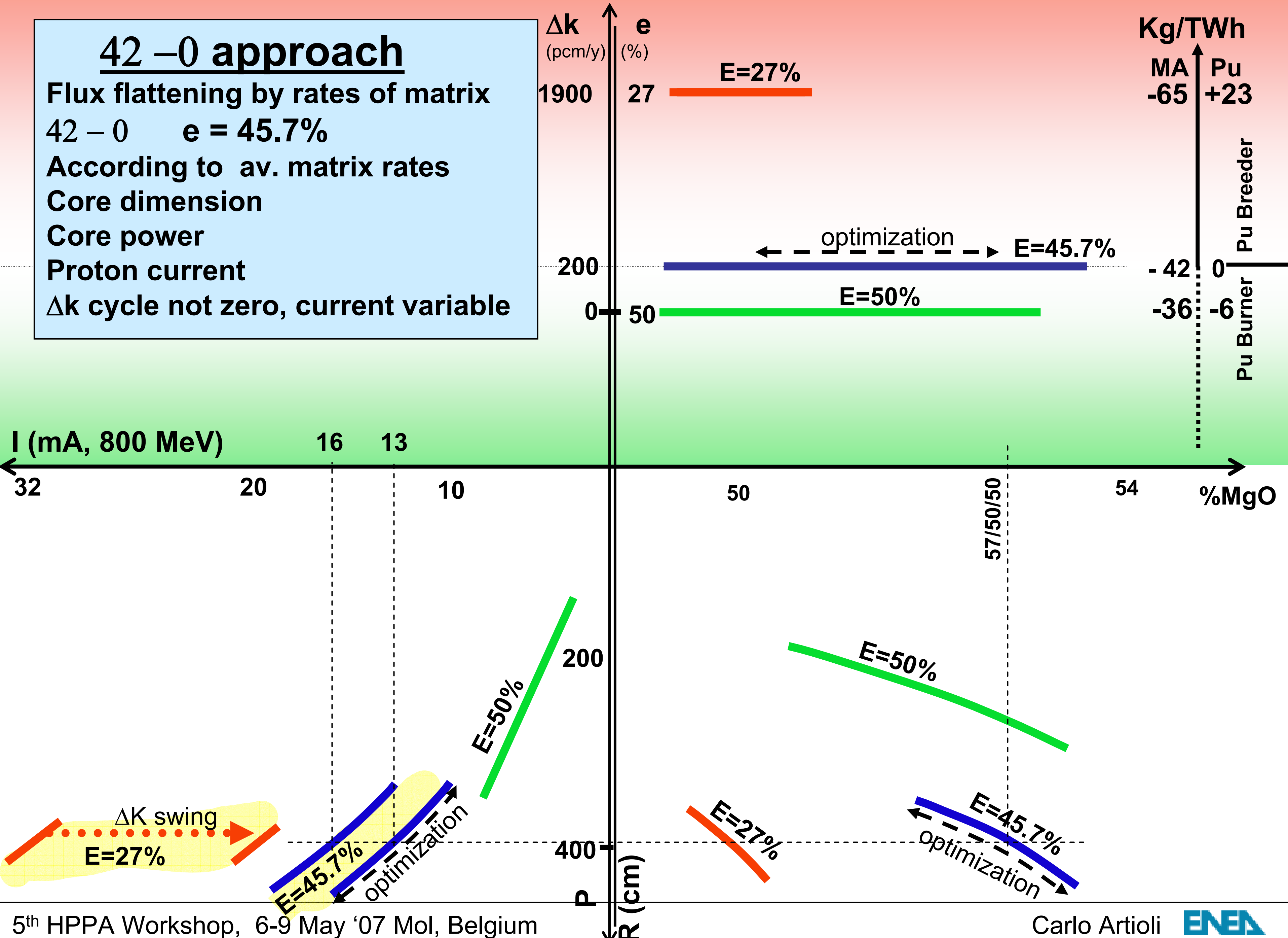
According to av. matrix rates

Core dimension

Core power

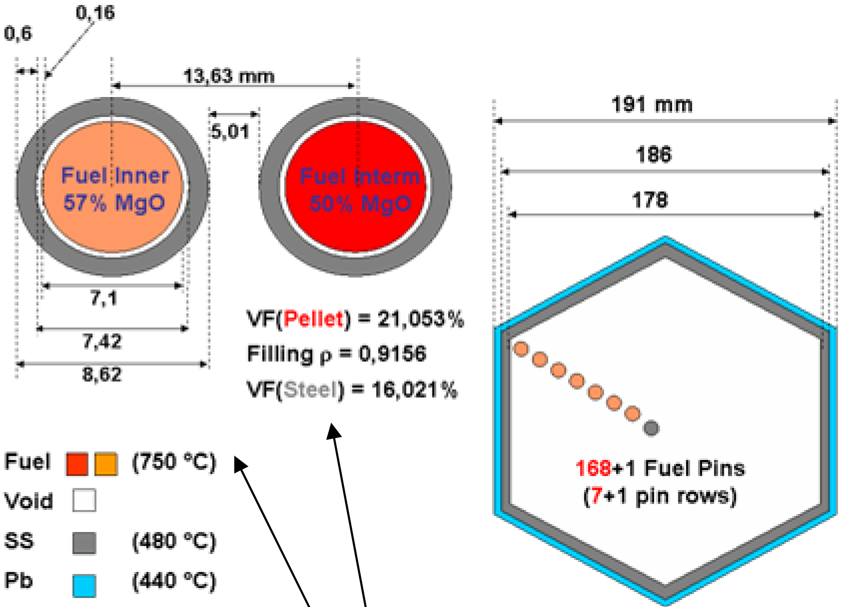
Proton current

Δk cycle not zero, current variable



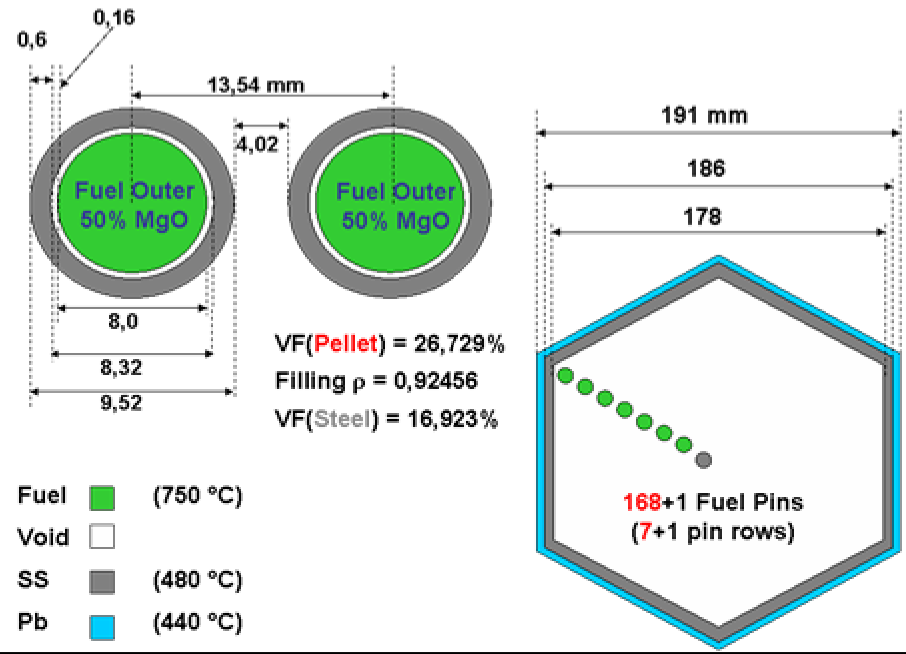
42-0 approach → fuel enrichment 45,7% (flattening by 3 radial zones)

(calculations: M. Sarotto)



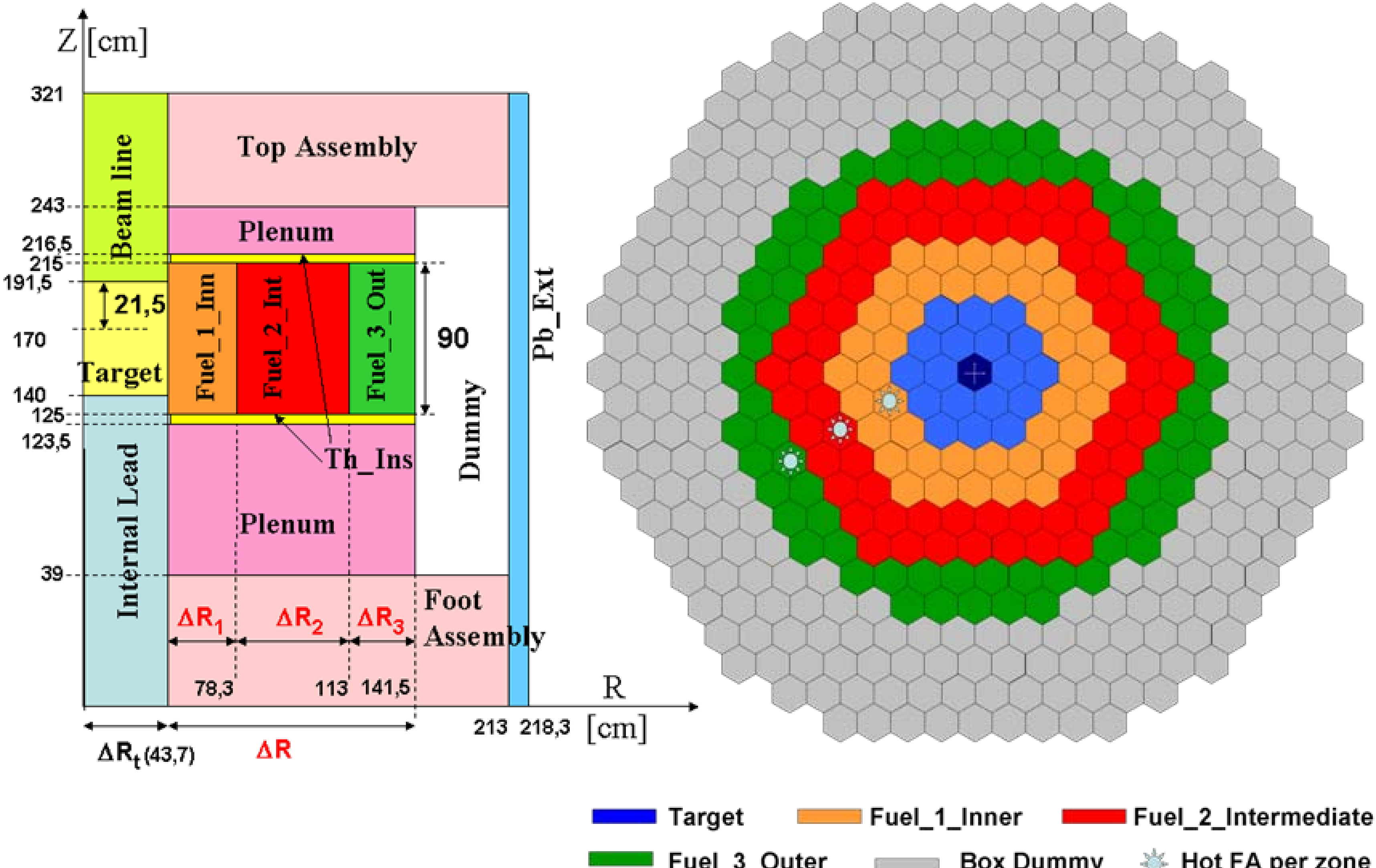
Inner and intermediate zones
(same pin diameter, different matrix rate)

Outer zone
(same pin number, larger pin diameter)



Size required to reach k_{eff} 0.97→ Core power

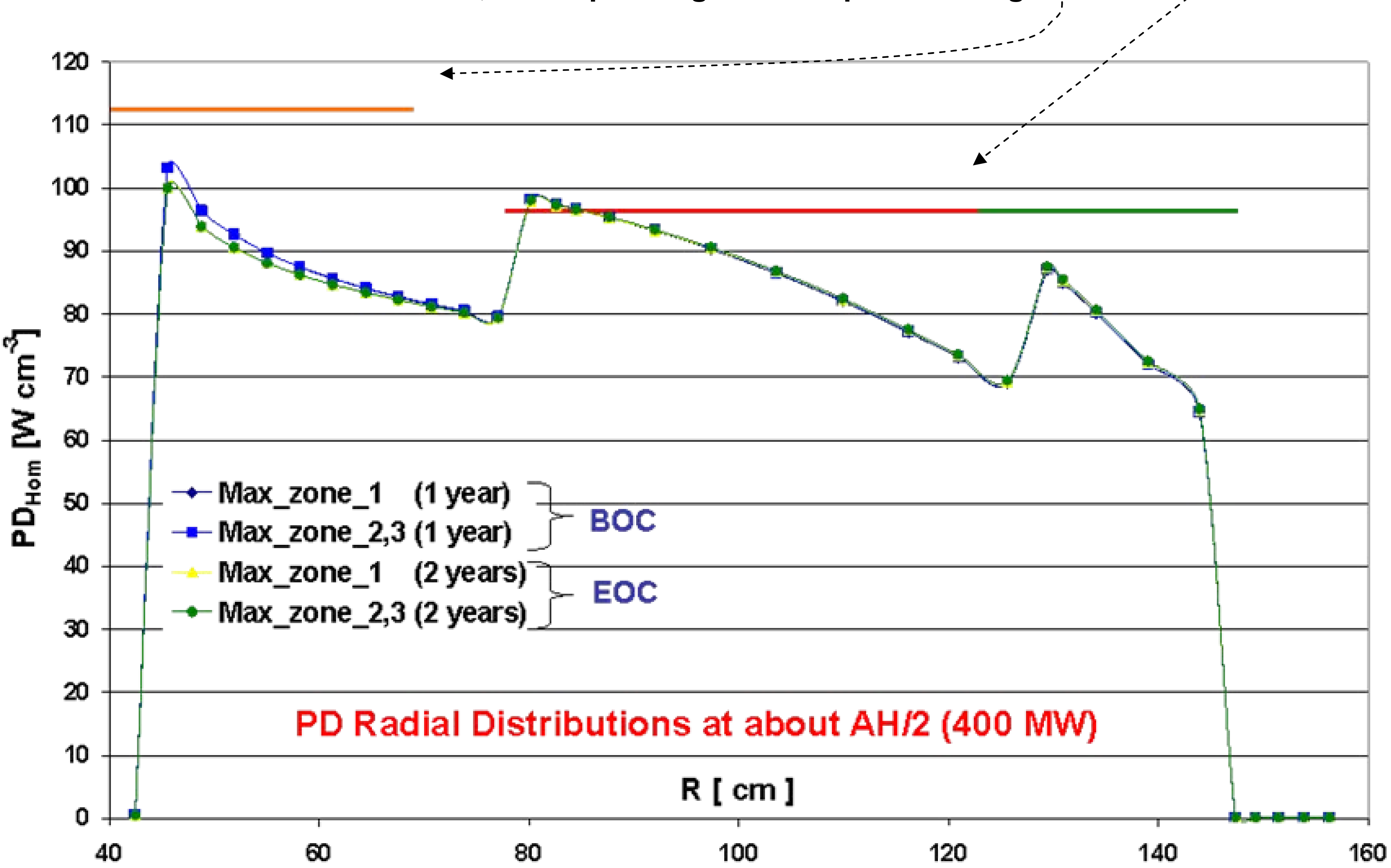
(calculations: M. Sarotto)



Hom. Power density at midplane

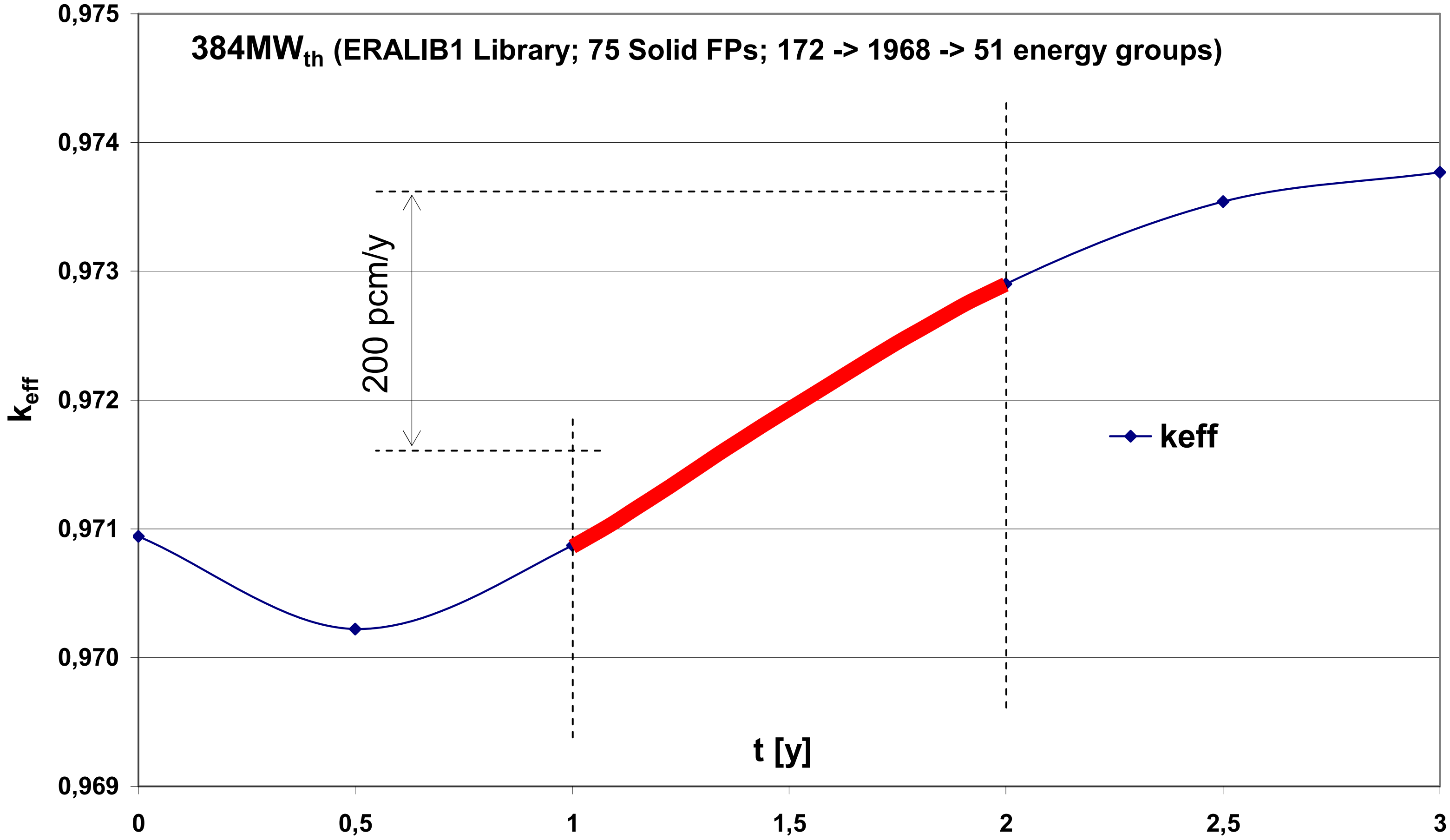
(calculations: M. Sarotto)

Maximum allowed, corresponding to linear power rating 207 and 180 W/cm



Δ k vs time: Δ k = 200 pcm/y

(calculations: M. Sarotto)



Mass balances

(calculations: M. Sarotto)

Pu & MA

MOX spent + 30 y cooling

Pu	[w %]
Pu238	3,737
Pu239	46,446
Pu240	34,121
Pu241	3,845
Pu242	11,850
Pu244	0,001

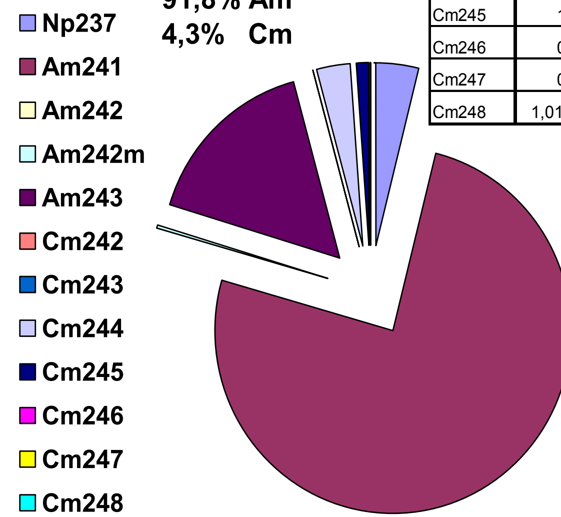
MA	[w %]
Np237	3,884
Am241	75,510
Am242	3,27E-06
Am242m	0,254
Am243	16,054
Cm242	2,3E-20
Cm243	0,066
Cm244	3,001
Cm245	1,139
Cm246	0,089
Cm247	0,002
Cm248	1,01E-04

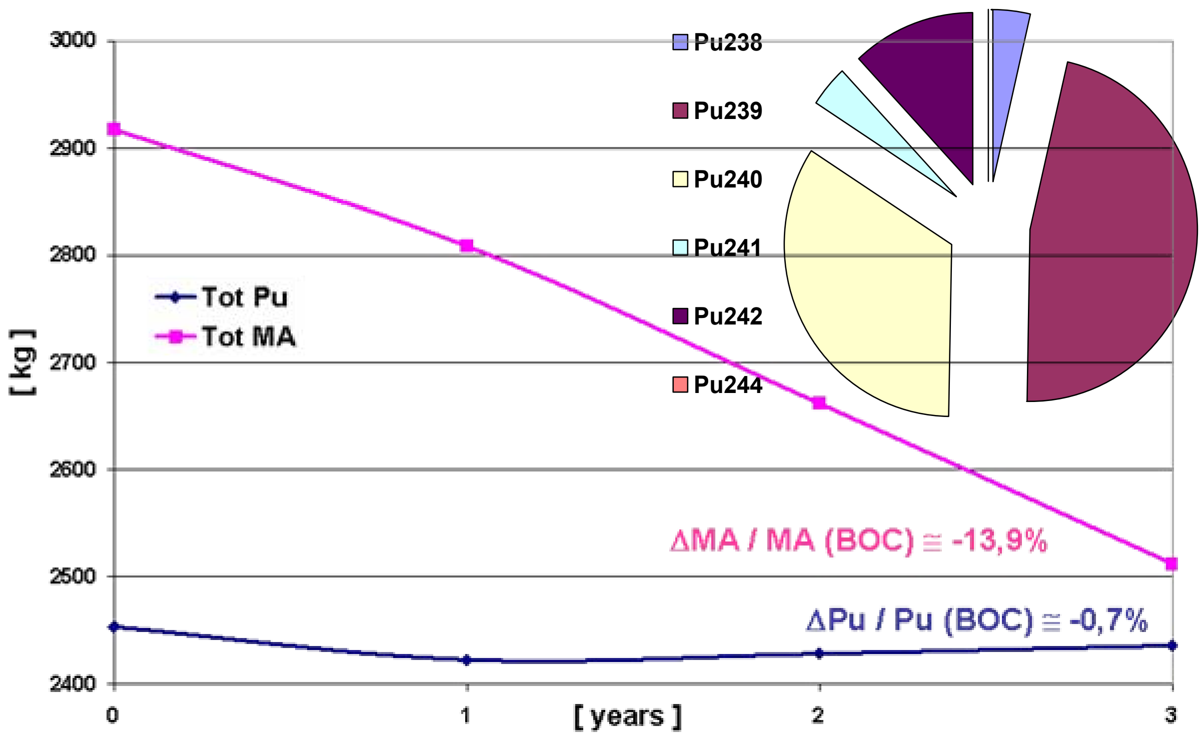
Pu Vector

MA Vector

91,8% Am

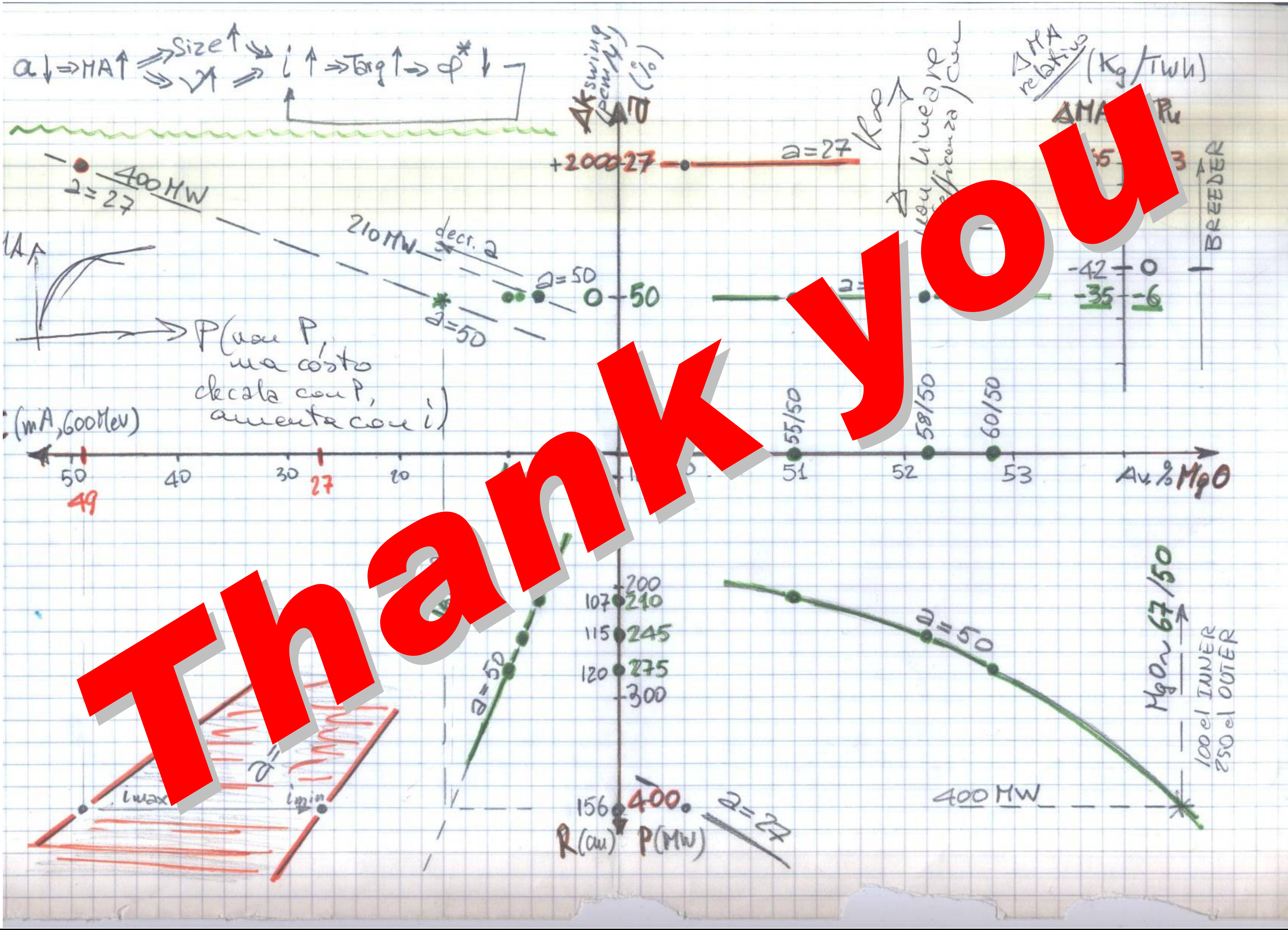
4,3% Cm





3 years { $\overline{BU}$ = 78,28 MWd / kg (HM) ; Total E = 10,0915 TWh_{th} } BU ➔ { -40,17 kg (MA) / TWh ; -1,74 kg (Pu) / TWh }

Thank you



400 MW
a=27
210 MW
decr. a
a=50
BREEDER
Av % MgO
R(cm)
P(MW)
100 el INNER
250 el OUTER