Target Materials

Study of prototype refractory ceramics (SiC and Al_2O_3) with open unidirectional porosity

Michal Czapski

Cathi Final Review Meeting
Barcelona, September 2014

WHY?

Target Materials

Study of prototype refractory ceramics (SiC and Al_2O_3) with open unidirectional porosity

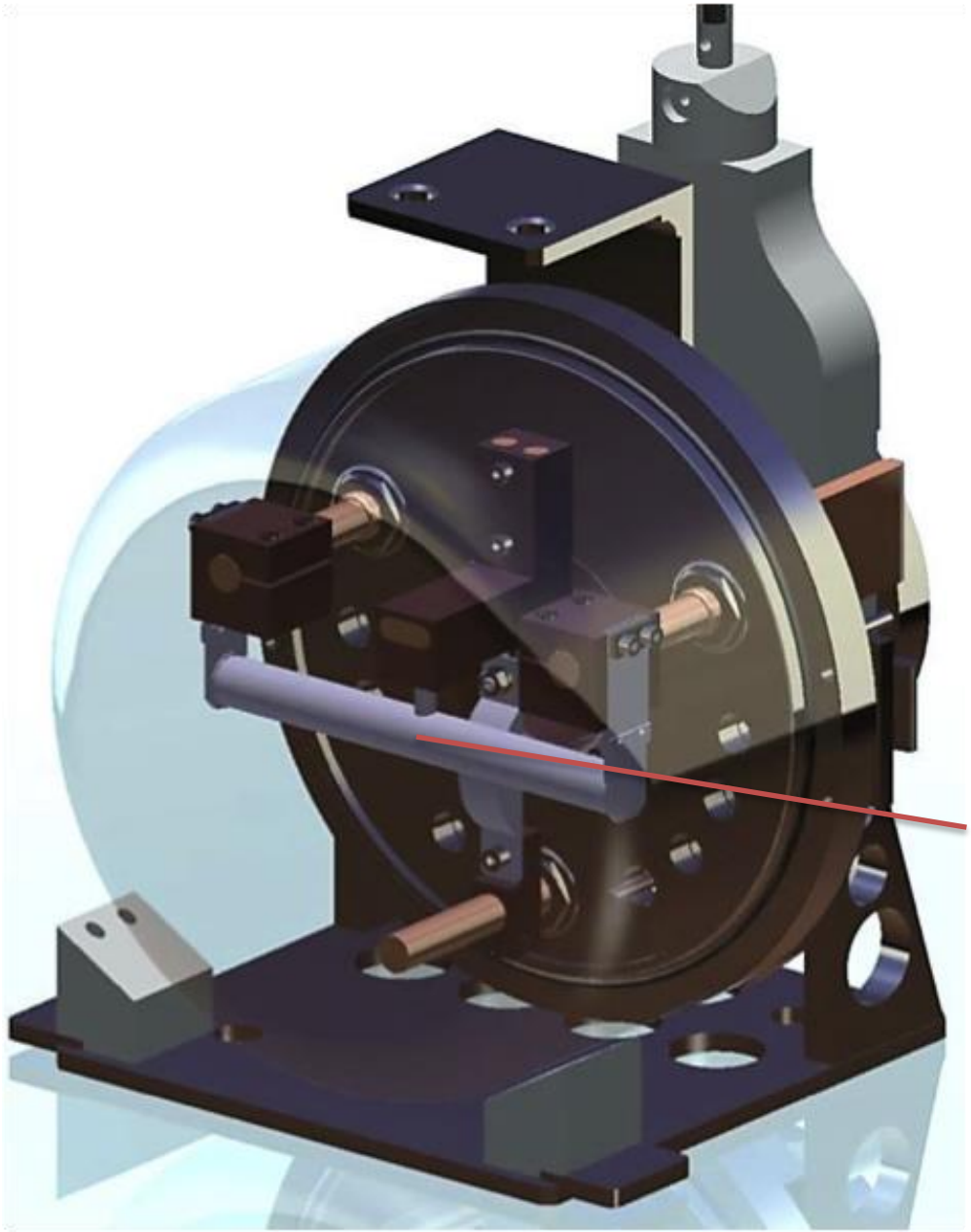
HOW?

WHAT?

WHEN?

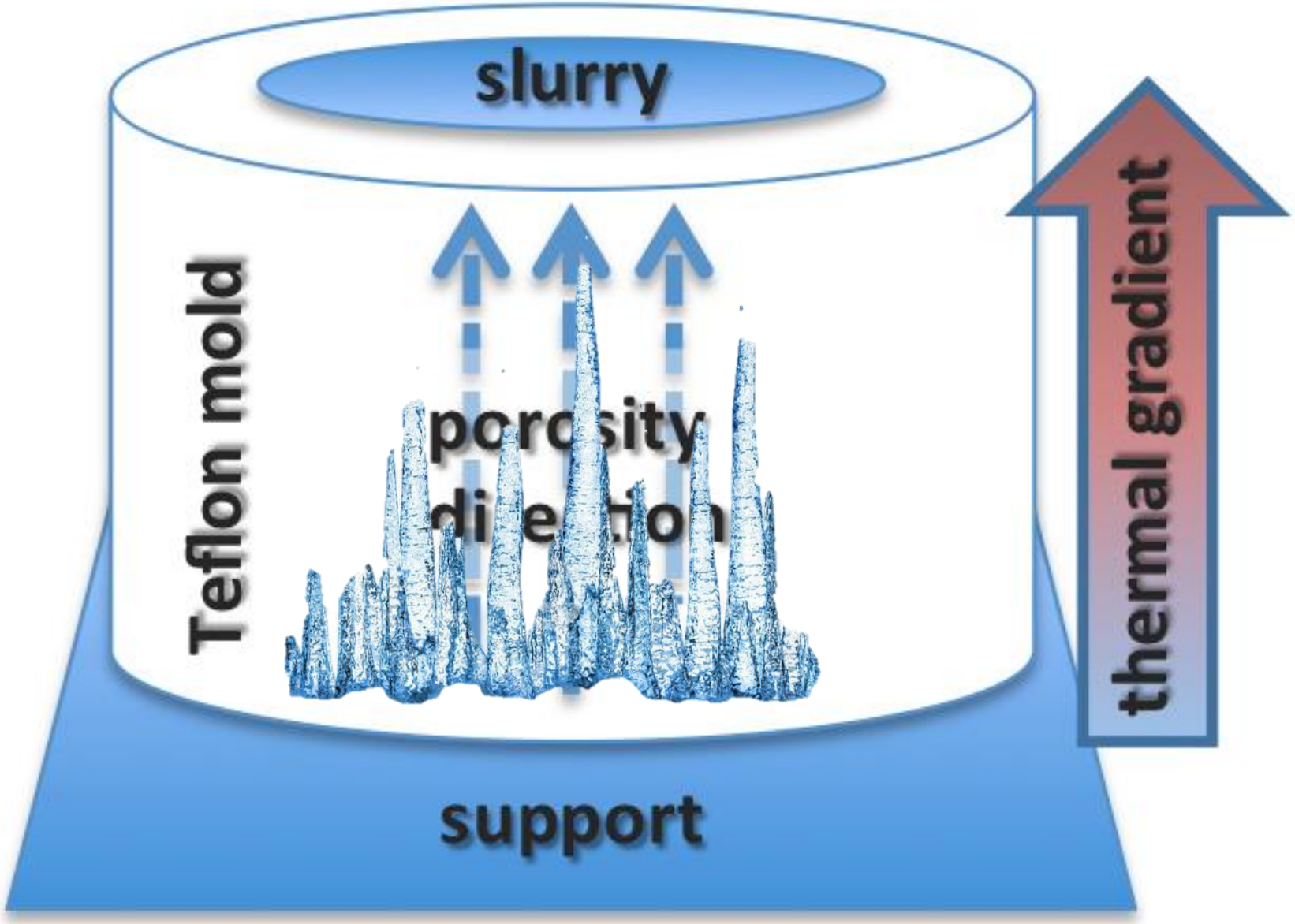
WHERE?

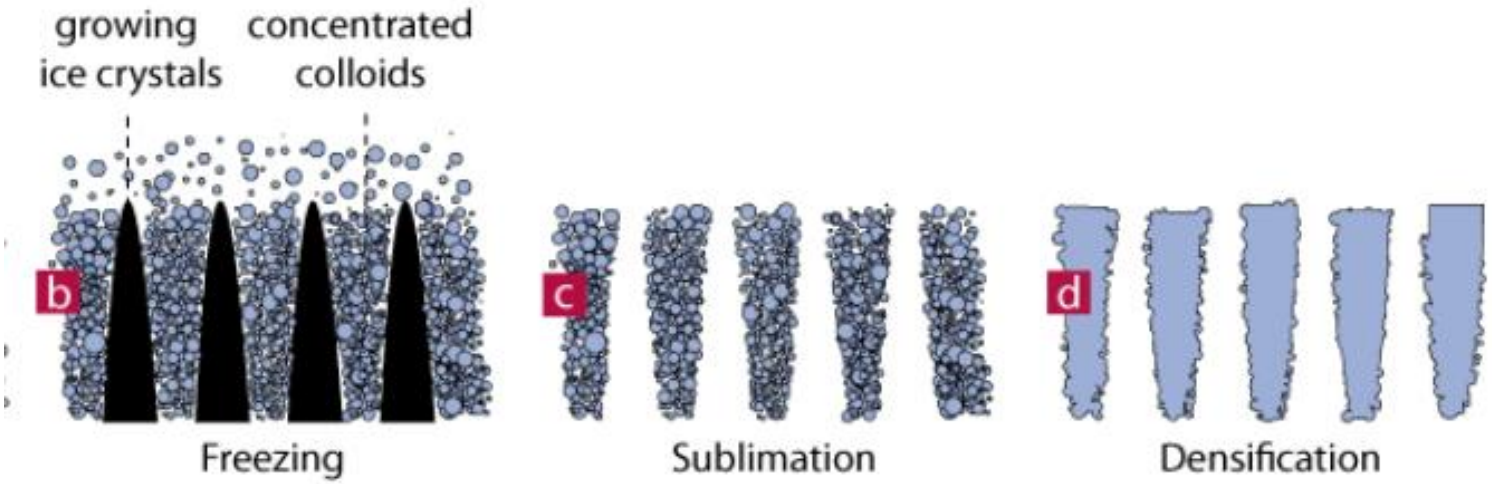
WHO?

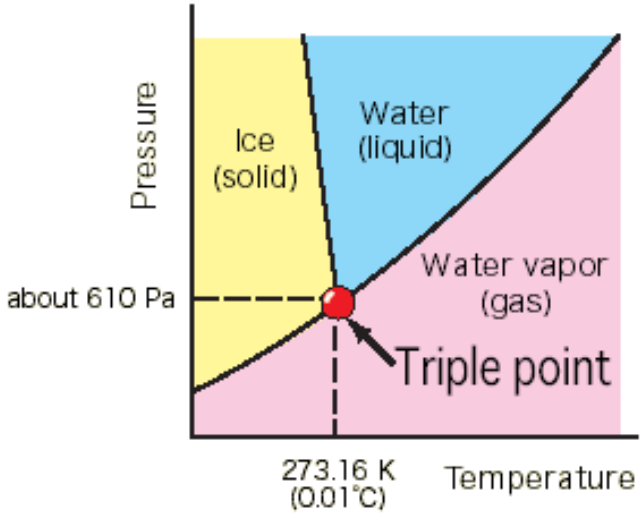


New target materials

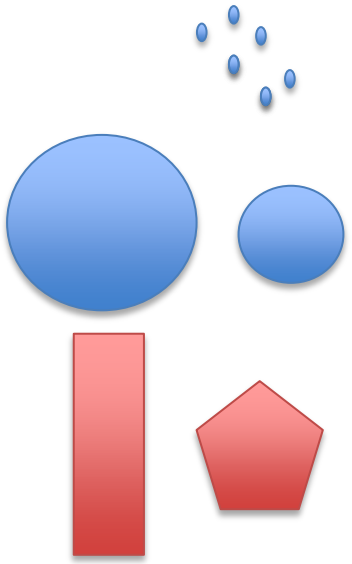
Ice-templating method


slurry
Teflon mold
thermal gradient
support

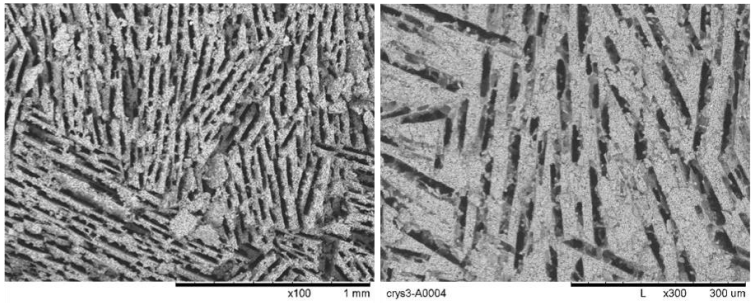

growing ice crystals
concentrated colloids
b
c
d
Freezing
Sublimation
Densification


Pressure
Ice (solid)
Water (liquid)
Water vapor (gas)
about 610 Pa
Triple point
273.16 K (0.01°C)
Temperature

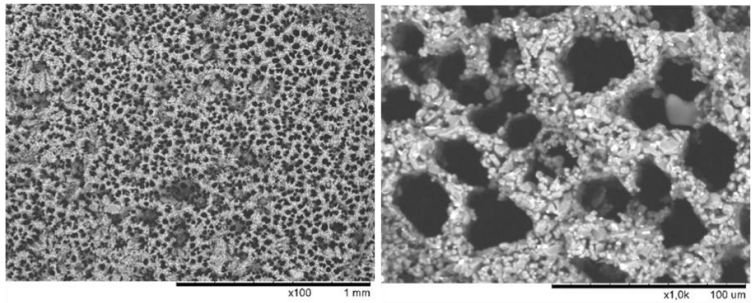
Parameter	Property
Powder fraction in slurry	Porosity fraction
Freezing speed	Pore size
Additivies	Pore structure



Powder volume ratio
25%



Powder volume ratio
25%
Zirconium Acetate



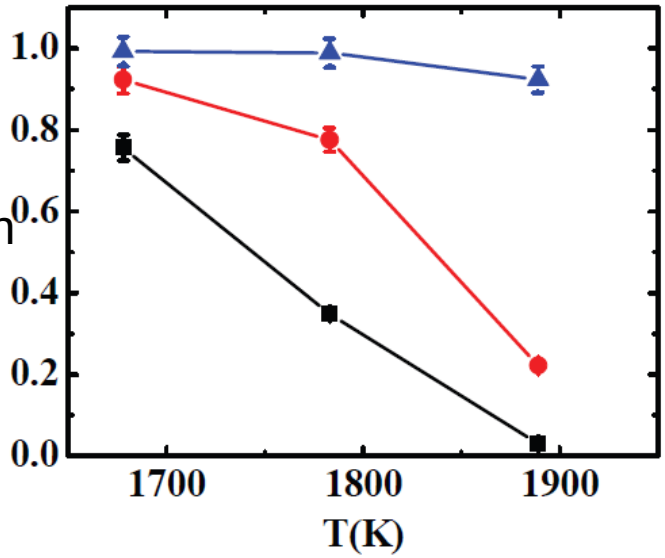
Macroporous structure preserved. No shrinkage during sintering.
Samples present unidirectional porosity (above 70%).

WHY?

GRAIN SIZE

POROSITY CONTENT

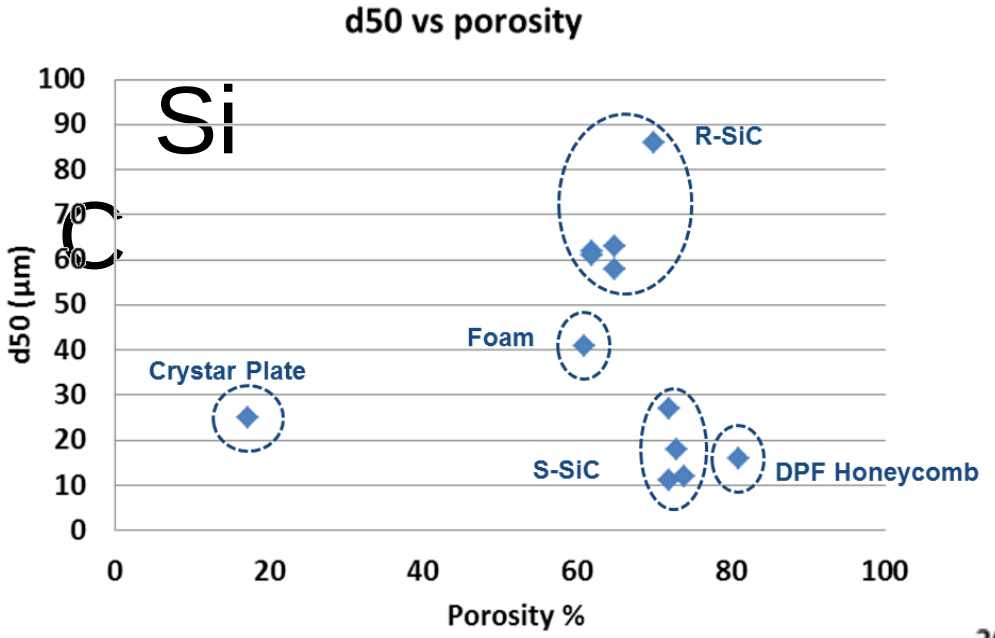
Remaining fraction
Material: Al_2O_3



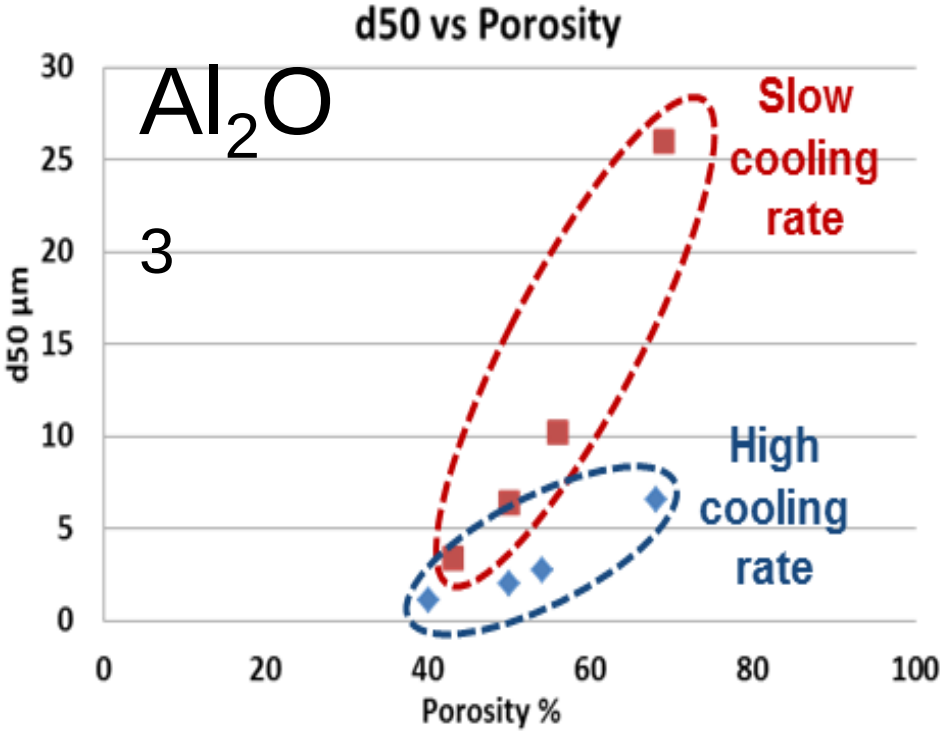
3.4 g/cm^3 1 micron
1.0 g/cm^3 30 micron
3.3 g/cm^3 0.3 micron

WHAT?

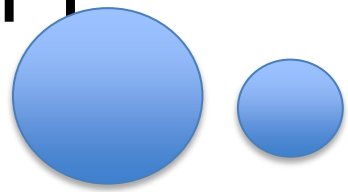
Powder	Compound	Characteristics of the bulk
Ceralox SPA 0.5	Aluminum Oxide (Al_2O_3)	high purity, porosity of 2%
Fine grains + 0.3 boron carbide	Sintered Silicon Carbide (S-SiC)	high hardness, compressive strength and light weight, high density structure (<5%)
Coarse (< 30µm) and fine grains (<10µm)	Reaction-Bonded Silicon Carbide (R-SiC)	optimum strength and oxidation resistance, porous walls (15 – 50 %)



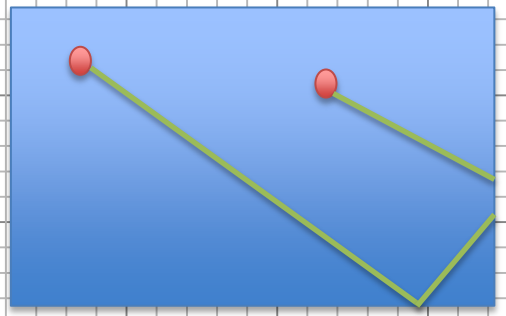
PORE SIZE VS. POROSITY



EFFUSI
VITY



EFFUSIVITY
He 1400 °C



Alumina, 6.3
Alumina, 6.6
Alumina, 8
Alumina, 11
S-SiC, 11
S-SiC, 12
S-SiC, 18
Crystar, 25
S-SiC, 27
Alumina, 29
Foam R-SiC, 41
R-SiC, 58
R-SiC, 61
R-SiC, 62
R-SiC, 63
R-SiC, 86

transit time [ms]

0.18
0.175
0.17
0.165
0.16
0.155
0.15
0.145
0.14
0.135
0.13

pore size D50 [µm]

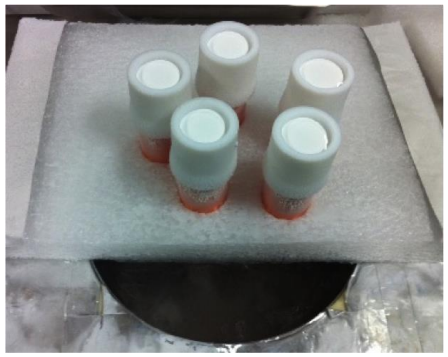
0
10
20
30
40
50
60
70
80
90
100

R-SiC
Crystar
Foam R-SiC
S-SiC
Alumina

Mechanical PROPERTIES ?

Mechanical PROPERTIES

	Hexoloy	Crystar	Ceralox
Density (g/cm^3)	3,1	2.7	3.8
Young modulus (GPa)	350	240	370
Flexural strength (MPa)	430	80	350
Thermal expansion (K^{-1})	4,5 10^{-6}	4,8 10^{-6}	8.2 10^{-6}
Thermal capacity (J/kg·K)	750	750	880



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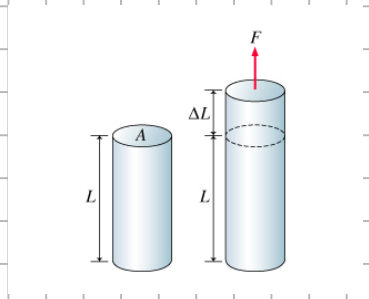

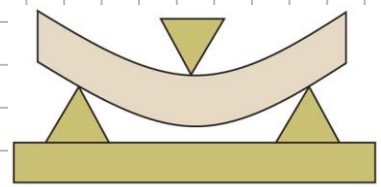

WHY?

HOW?

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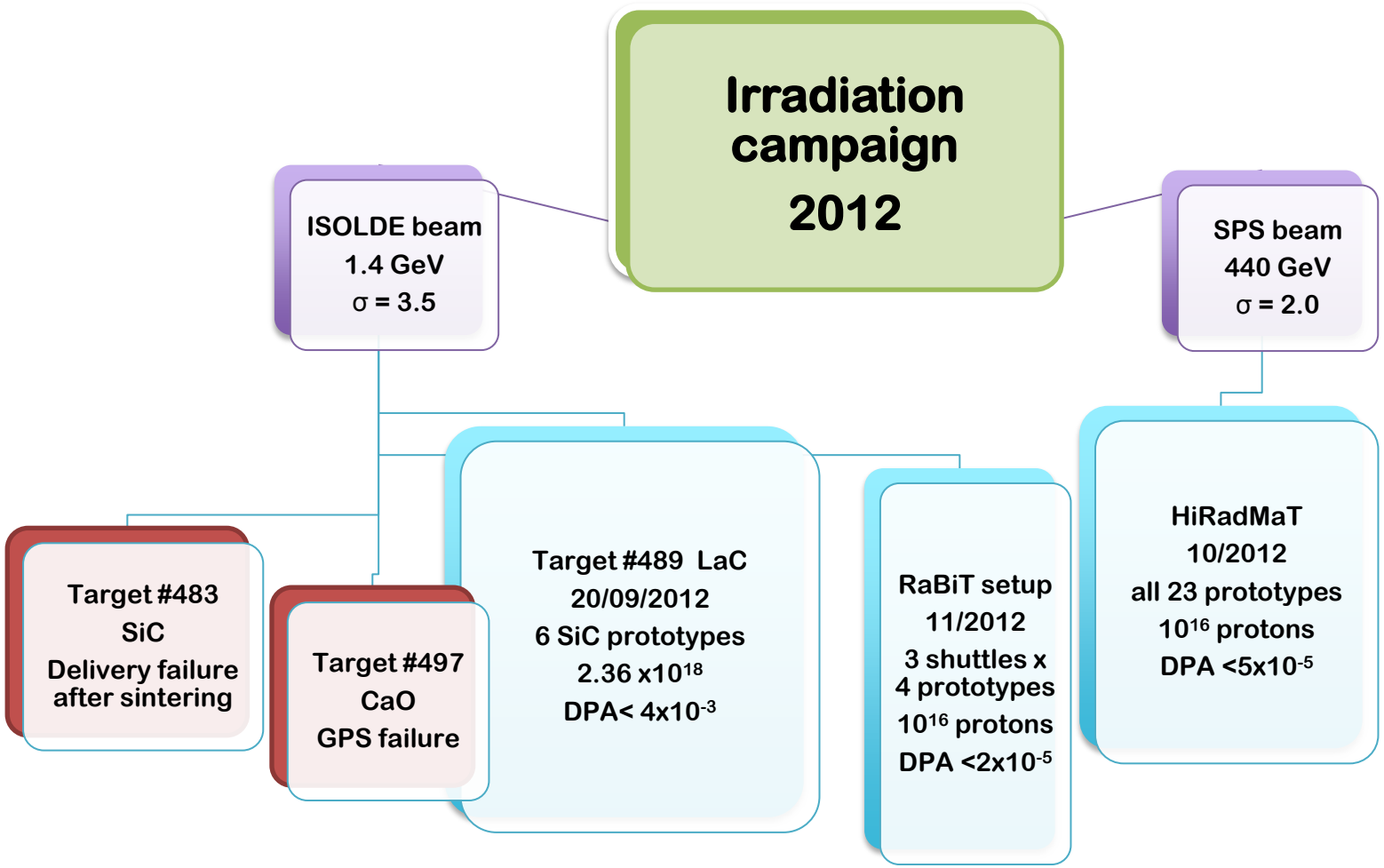
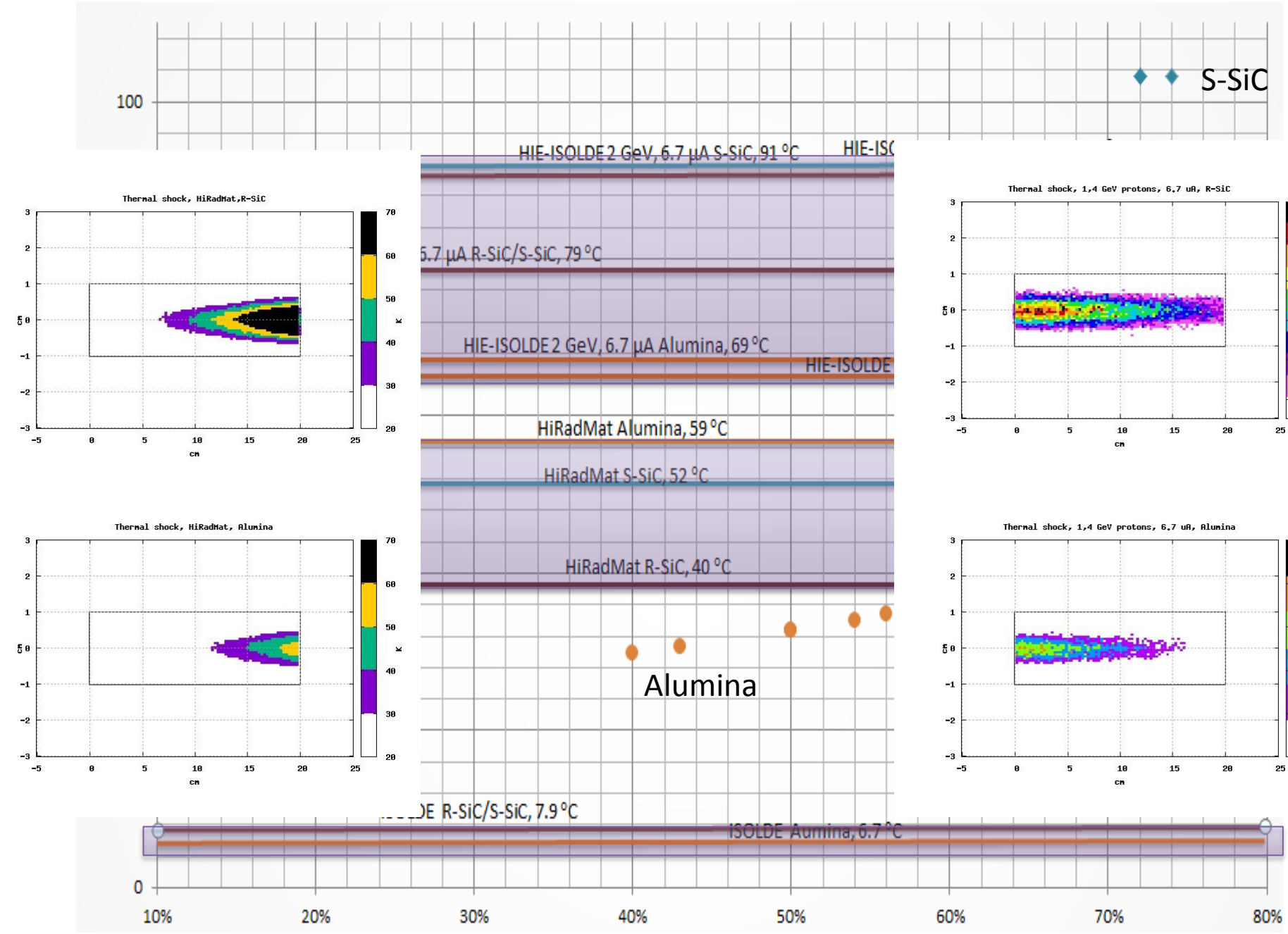
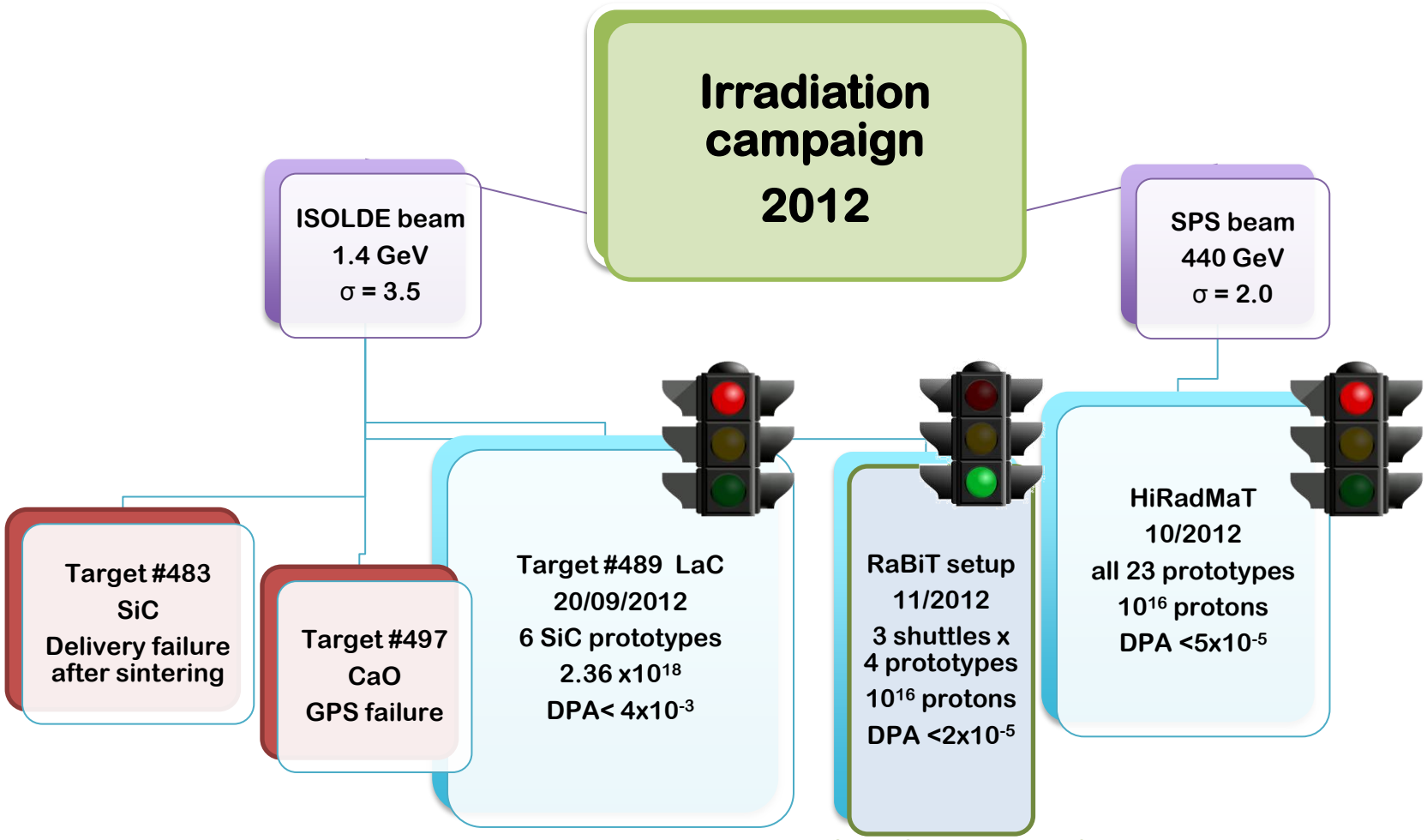

Irradiation campaign 2012
ISOLDE beam
1.4 GeV
σ = 3.5
SPS beam
440 GeV
σ = 2.0
Target #483
SiC
Delivery failure after sintering
Target #497
CaO
GPS failure
Target #489 LaC
20/09/2012
6 SiC prototypes
2.36 x10^18
DPA< 4x10^-3
RaBiT setup
11/2012
3 shuttles x 4 prototypes
10^16 protons
DPA <2x10^-5
HiRadMaT
10/2012
all 23 prototypes
10^16 protons
DPA <5x10^-5


100
S-SiC
HIE-ISOLDE 2 GeV, 6.7 µA S-SiC, 91 °C
HIE-ISC
6.7 µA R-SiC/S-SiC, 79 °C
HIE-ISOLDE 2 GeV, 6.7 µA Alumina, 69 °C
HIE-ISOLDE
HiRadMat Alumina, 59 °C
HiRadMat S-SiC, 52 °C
HiRadMat R-SiC, 40 °C
Alumina
DE R-SiC/S-SiC, 7.9 °C
ISOLDE Aumina, 6.7 °C
0
10%
20%
30%
40%
50%
60%
70%
80%
Thermal shock, HiRadMat,R-SiC
Thermal shock, 1,4 GeV protons, 6.7 uA, R-SiC
Thermal shock, HiRadMat, Alumina
Thermal shock, 1,4 GeV protons, 6.7 uA, Alumina
cm
K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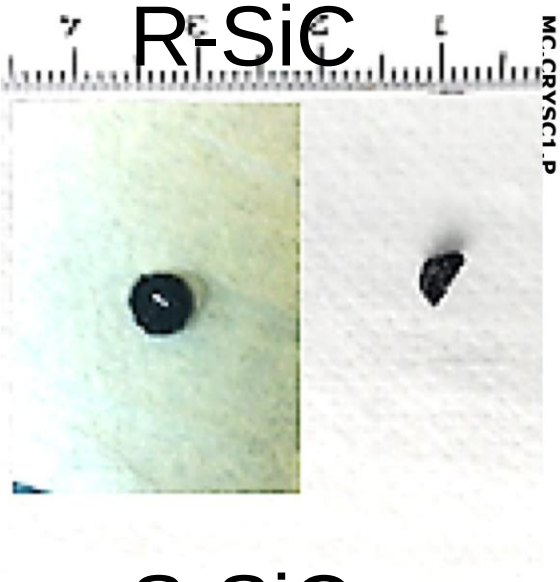
6 SiC prototypes
2.36 x10^18
DPA< 4x10^-3
RaBiT setup
11/2012
3 shuttles x 4 prototypes
10^16 protons
DPA <2x10^-5
HiRadMaT
10/2012
all 23 prototypes
10^16 protons
DPA <5x10^-5
At 10 cm
340 µSv/h
(01/2014)
Shuttles opened
Some pellets fractured
Activity < LE
Scheduled for SEM analysis
At contact
220 µSv/h
(10/2013)

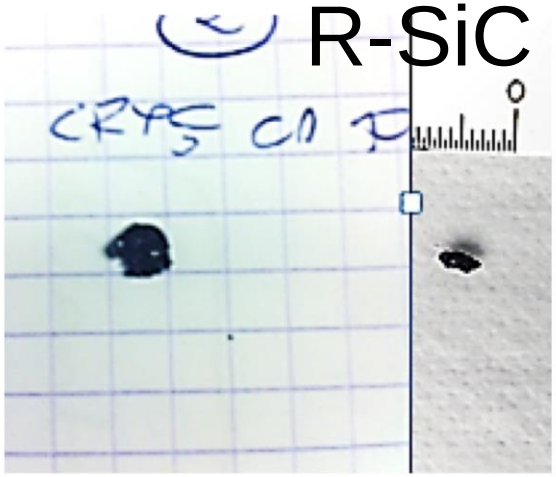
MC.CRYSA1.P

R-SiC



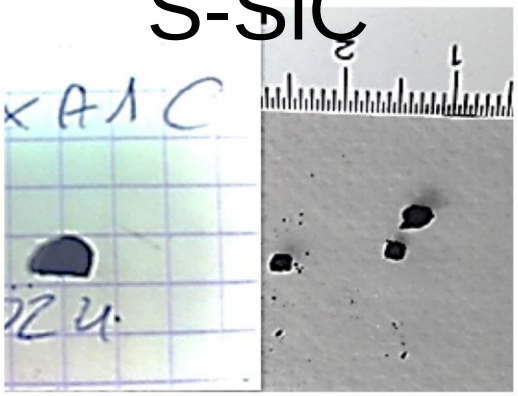
MC.CRYSC1.P

R-SiC



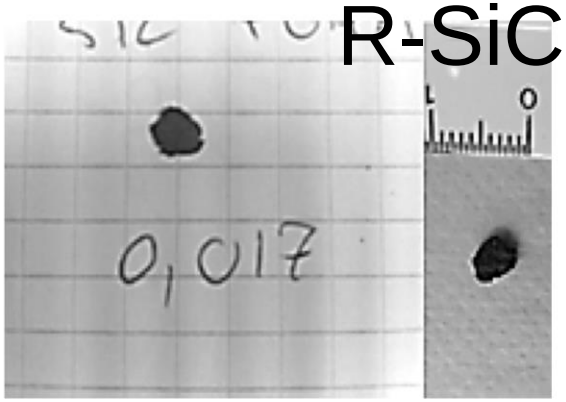
MC.HEXA1.C

S-SiC



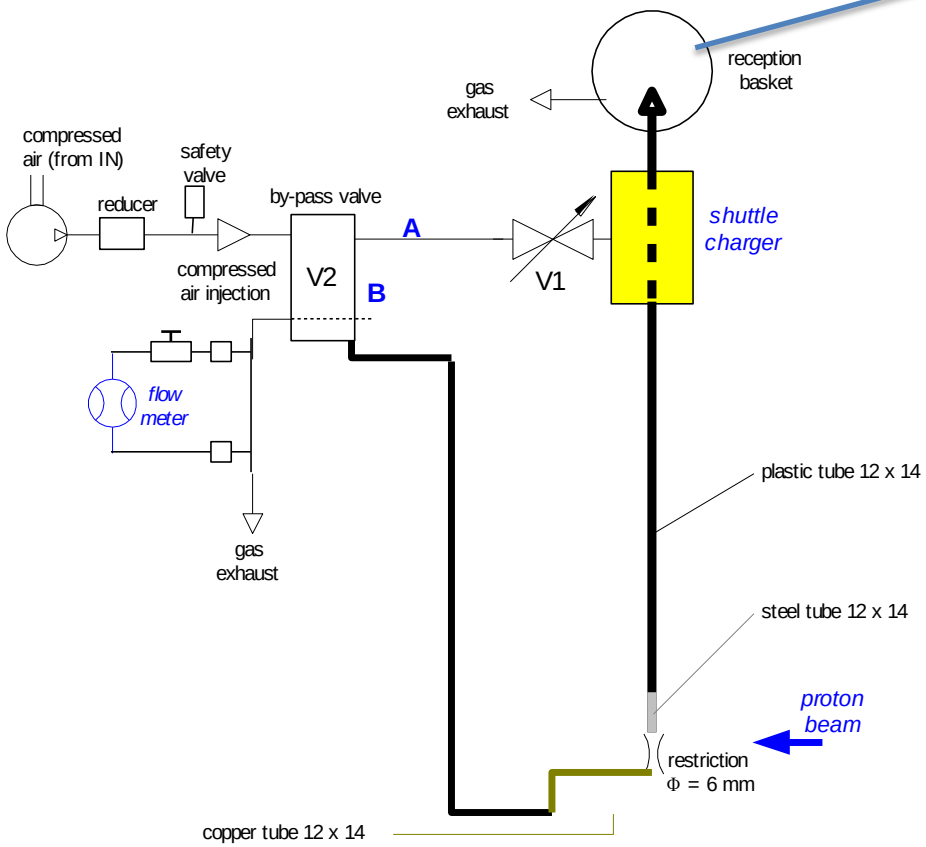
R-SiC Foam

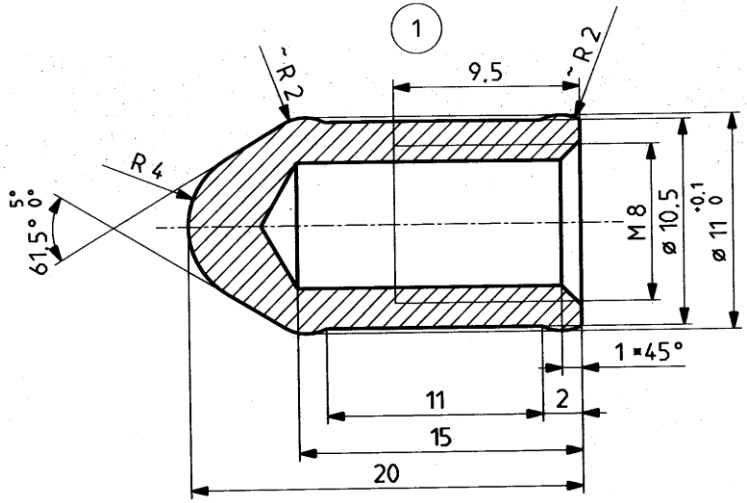
R-SiC foam



RaBIT

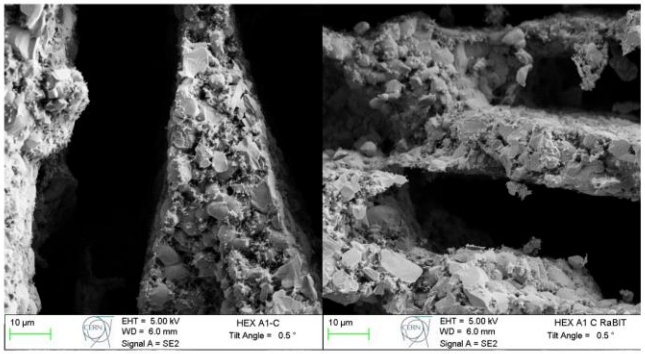
Rapid p-Beam IrradiaTion system



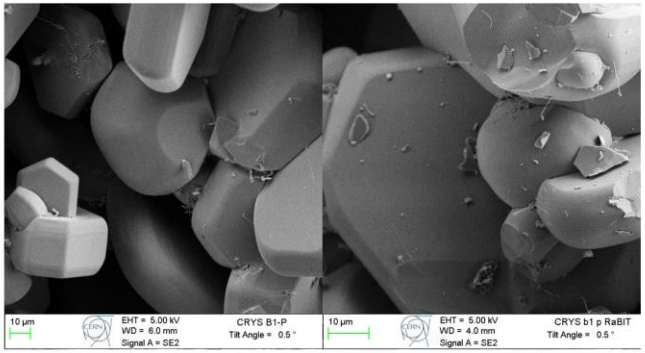


S-SiC

C.HEXA1.C



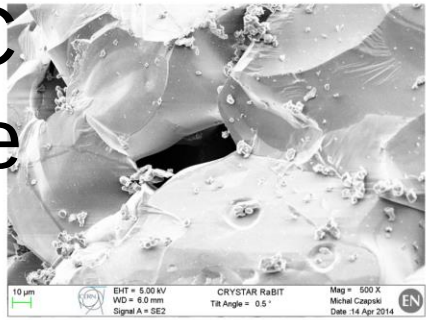
MC.CRYSB1.P

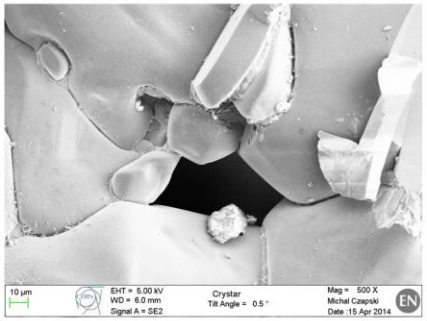


R-SiC

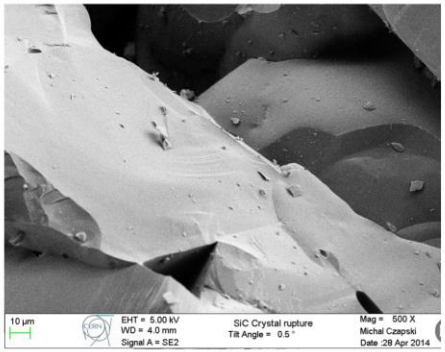
R-SiC dense

surface



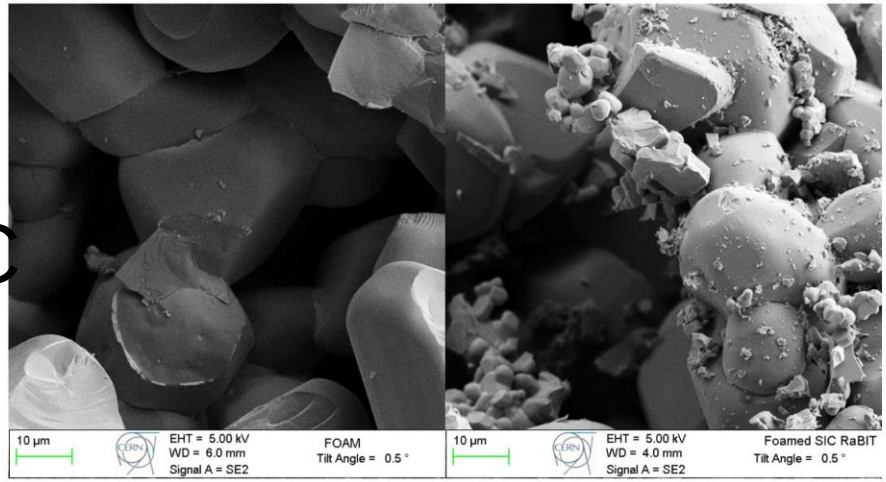


rapture



R-SiC Foam

R-SiC foam



CONCLUSIONS

Simple setup

Many structures

First tests – fractured pellets

No evident evolution of the structure

FUTURE STEPS?

Other samples…?

Mechanical testing

Micro-damages studies (continuation)

WHY?

HOW?

WHAT?

WHEN?

WHERE?

WHO?

WHO?


CERN


MARIE CURIE ACTIONS


ISOLDE


HIE-ISOLDE


SAINT-GOBAIN
MATERIAUX INNOVANTS


HiRadMat
High-Radiation to Materials

WHO?

Thank YOU