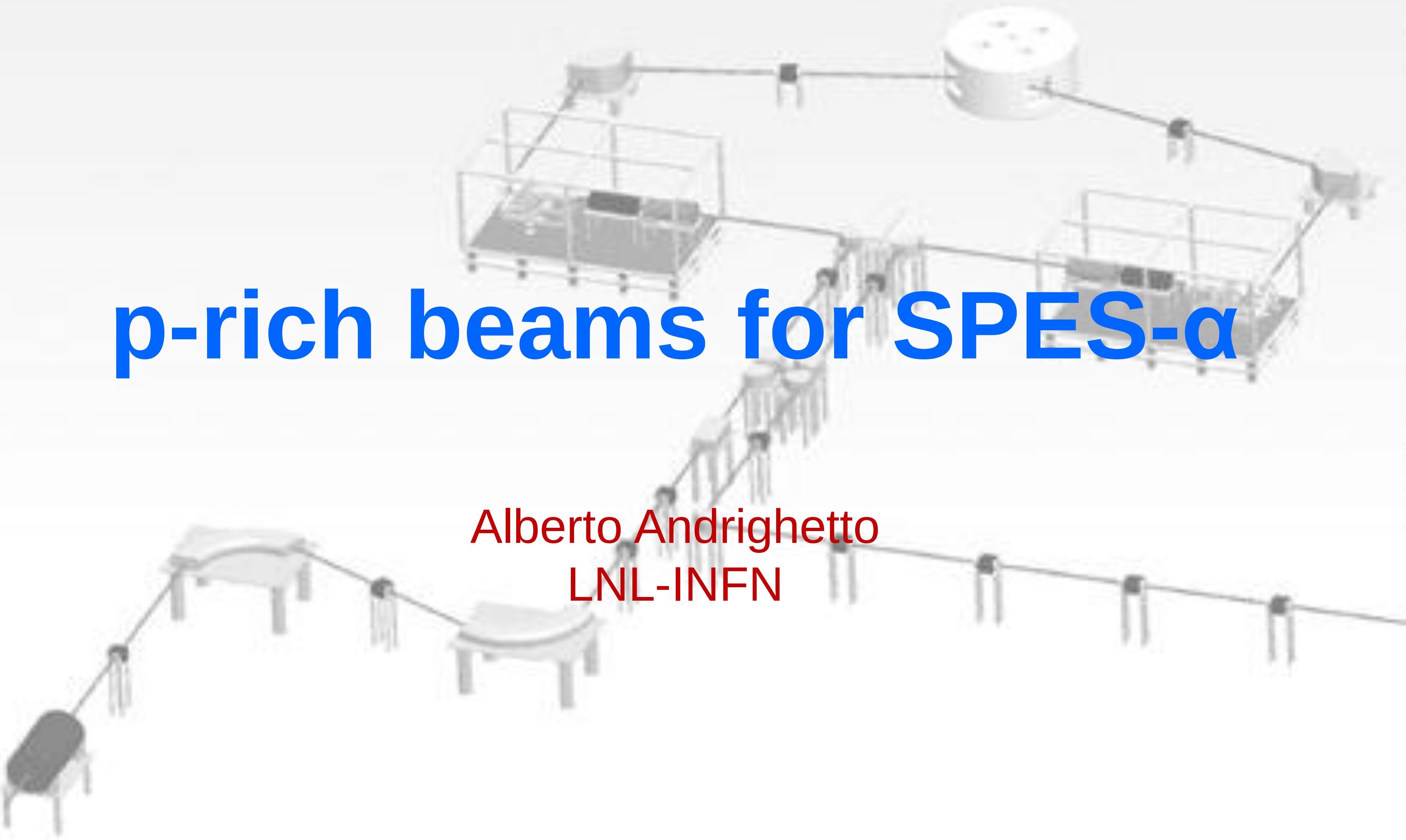
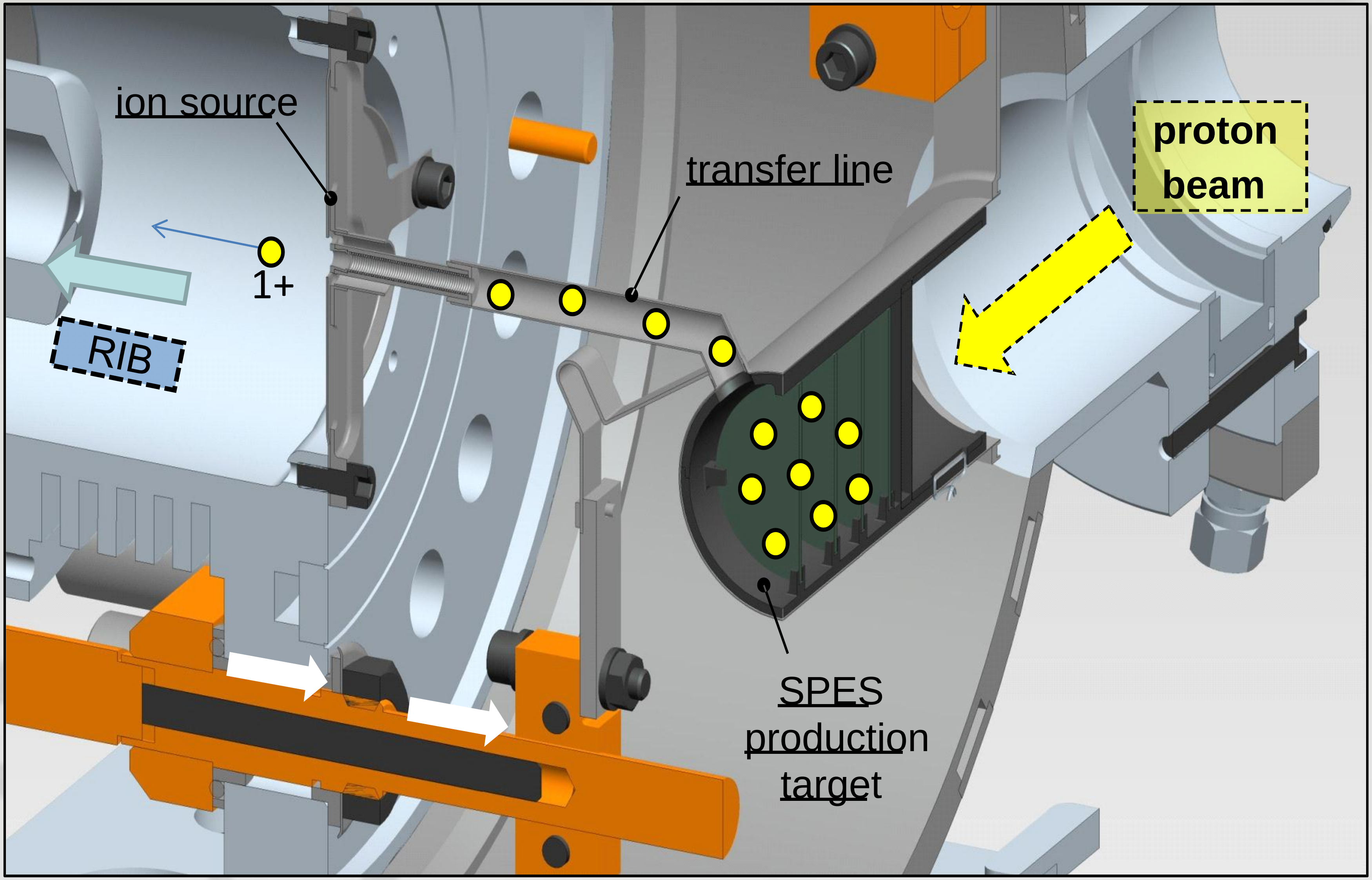
p-rich beams for SPES-α



Alberto Andrighetto
LNL-INFN

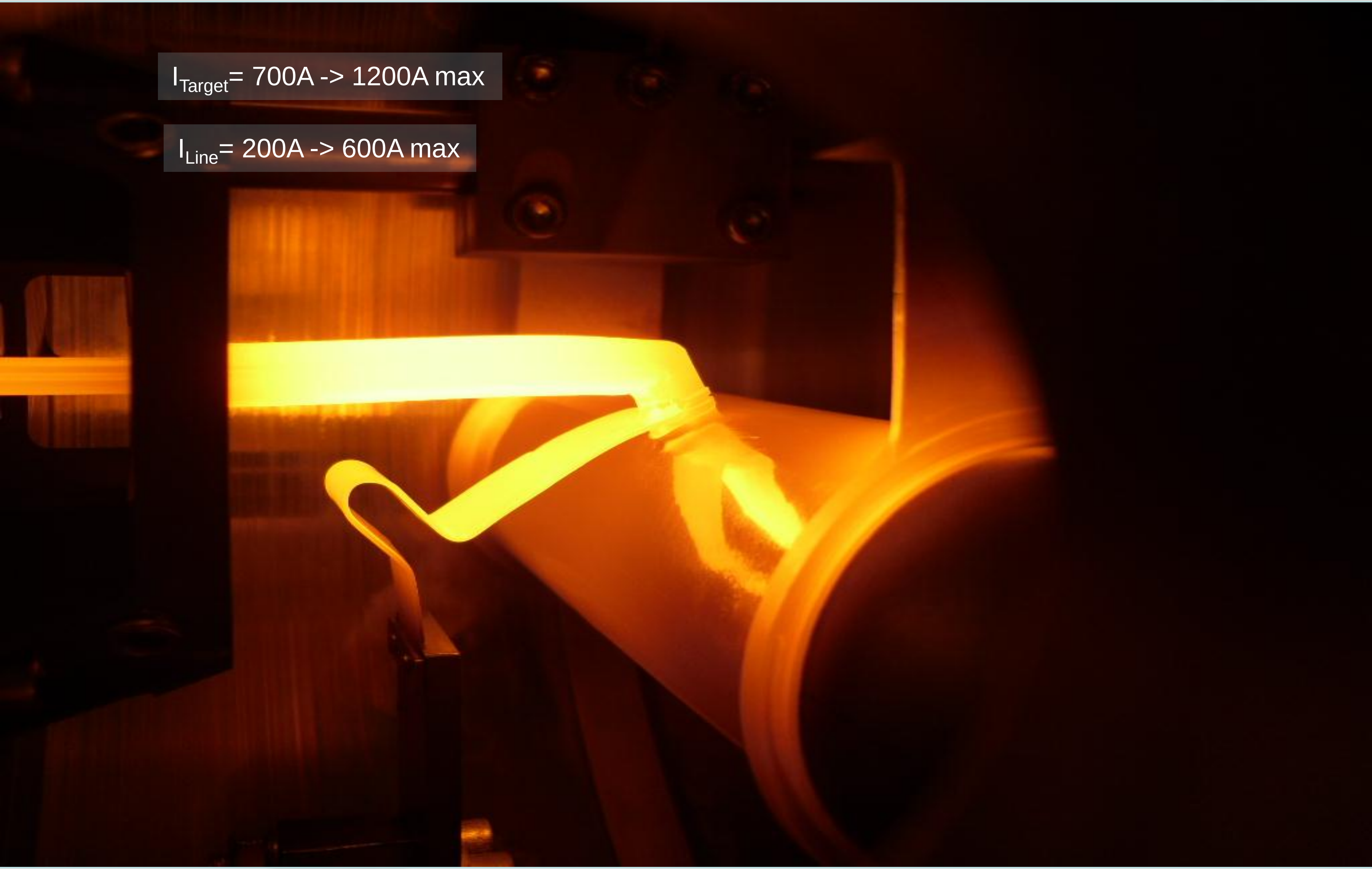
The SPES TIS complex



The Target: ready for irradiation…

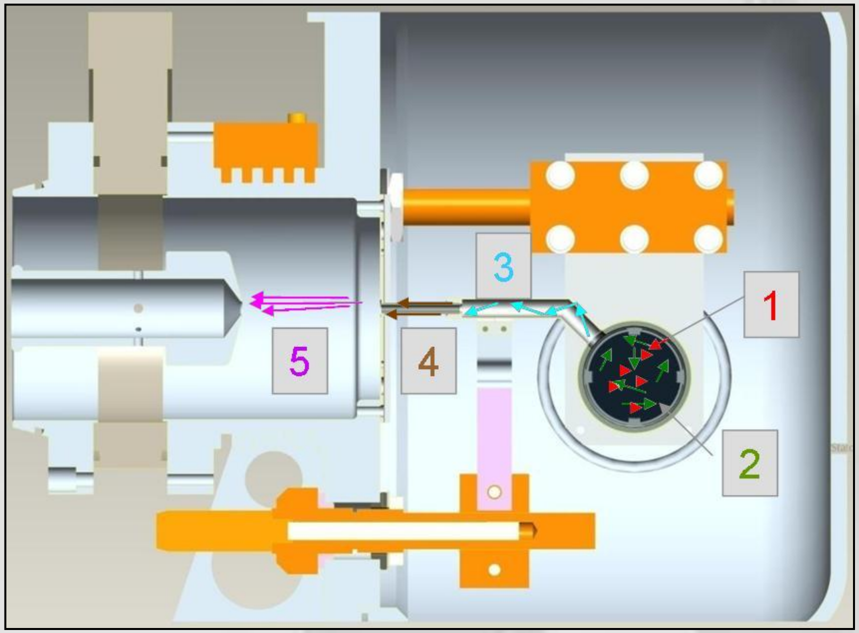
I_{Target}= 700A -> 1200A max

I_{Line}= 200A -> 600A max



The isotope release

Release of isotopes from a ISOL target: involved processes



1. **In-target reaction (fission)**
2. **In-target diffusion**
3. **Effusion from target to ion source**
4. **Ionization**
5. **Acceleration and transport**

The target yield and release efficiency

$$Y_{Target} = \Phi \cdot \sigma \cdot N \cdot \varepsilon_R$$

ϕ= Injector flux, σ = Cross section
N= Target thickness, ε_R= Release efficiency

ε_R takes into account the efficiencies of all the involved processes

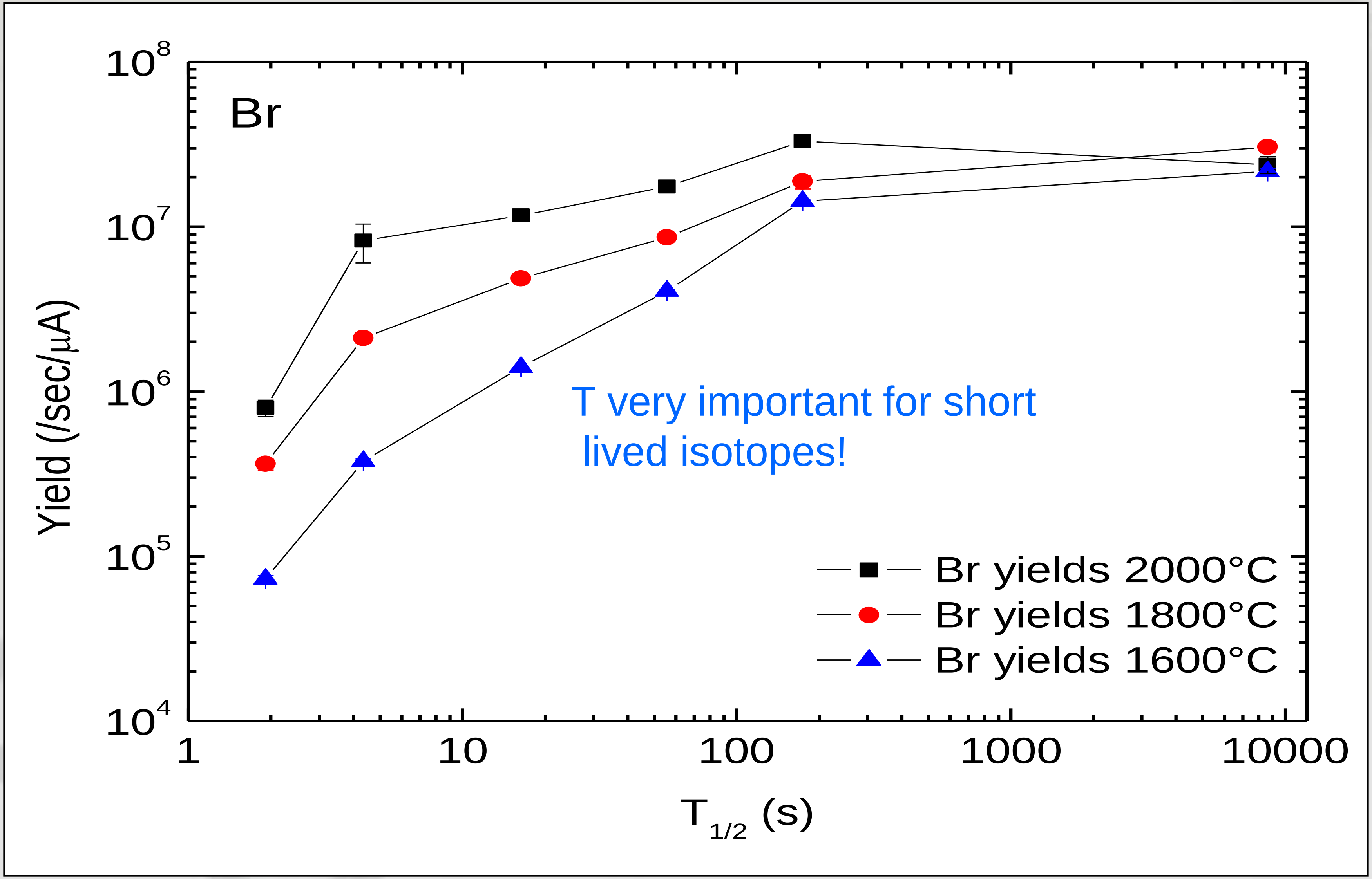
$$\varepsilon_R = \varepsilon_{diffusion} \cdot \varepsilon_{effusion} \cdot \varepsilon_{ionization} \cdot \varepsilon_{transport}$$

Most critical processes for release efficiency, they are affected by:

1) Material composition and density
2) Material microstructural properties (grain size,porosity, interconnectivity)
3) Working Temperature (use of high limiting temperature materials)

Temperature vs yield …

Spes data from HRIBF measurement



First conclusion…

Is necessary to produce for SPES RIB:

1) Target with high working temperature -> refractory carbides/oxides

2) Material with good characteristics in terms of release (grain and porosity) -> carefully R&D is mandatory!

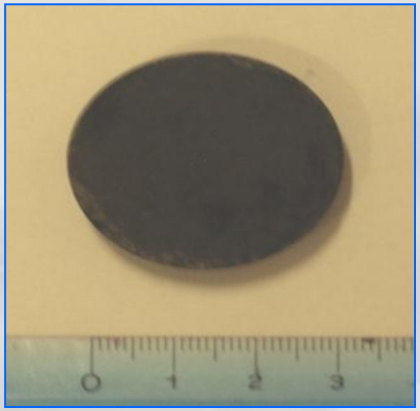
Target: n-rich vs. p-rich

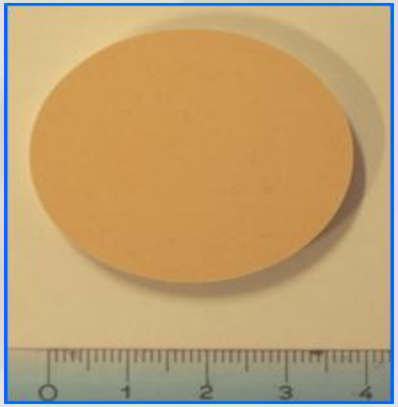
1 target material (UCx), & many isotopes produced on it

Main challenging

	2010	2011	2012
Density (g/cm^3)	4.25	2.59	6.38
Diameter (mm)	12.50	13.07	12.91
Thickness (g/cm^2)	0.41	0.41	0.41
Calculated porosity (%)	58	75	37

Dedicated material (carbides), & few isotopes produced in each

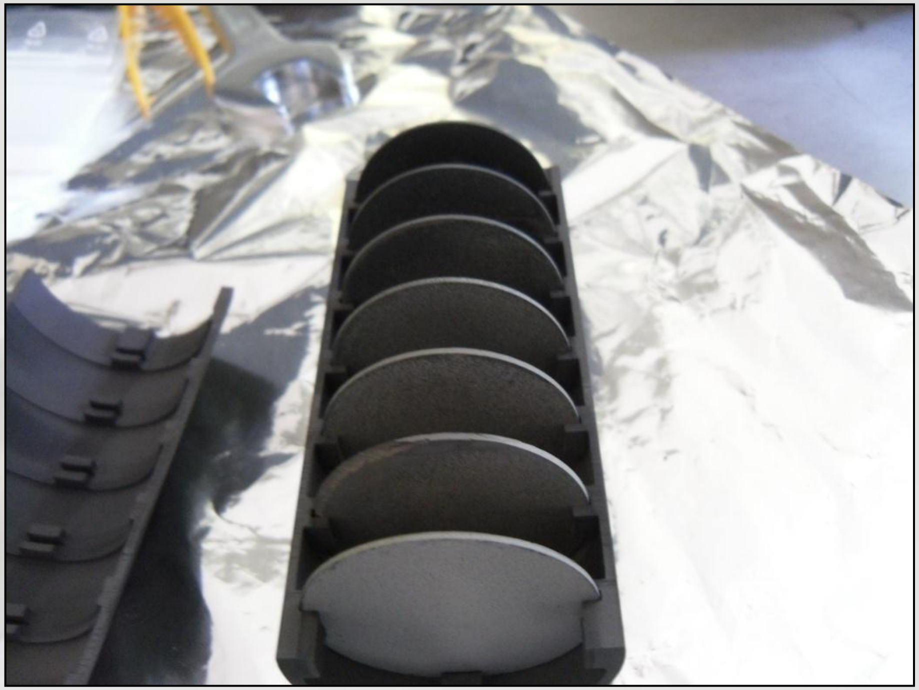




Lanthanum carbide synthesis

Vertical Carbothermic reduction (1600°C, high vacuum)

$$La_2O_3 + 11C \rightarrow 2LaC_2 + 4C + 3CO$$



OXIDE + GRAPHITE GREEN PELLETS → **CARBIDE/GRAPHITE (LaCx) PELLETS**

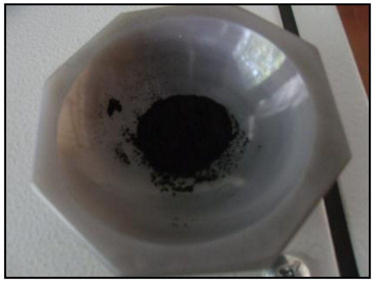
Boron carbide (B_4C) production

Boric acid $B(OH)_3$ + citric acid $C_6H_8O_7$

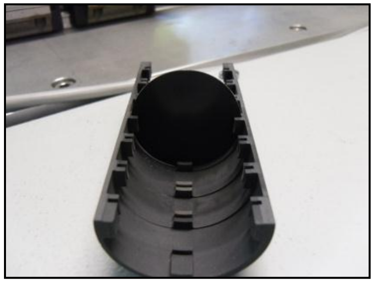
Solution of the acid

Gel formation

Grounding

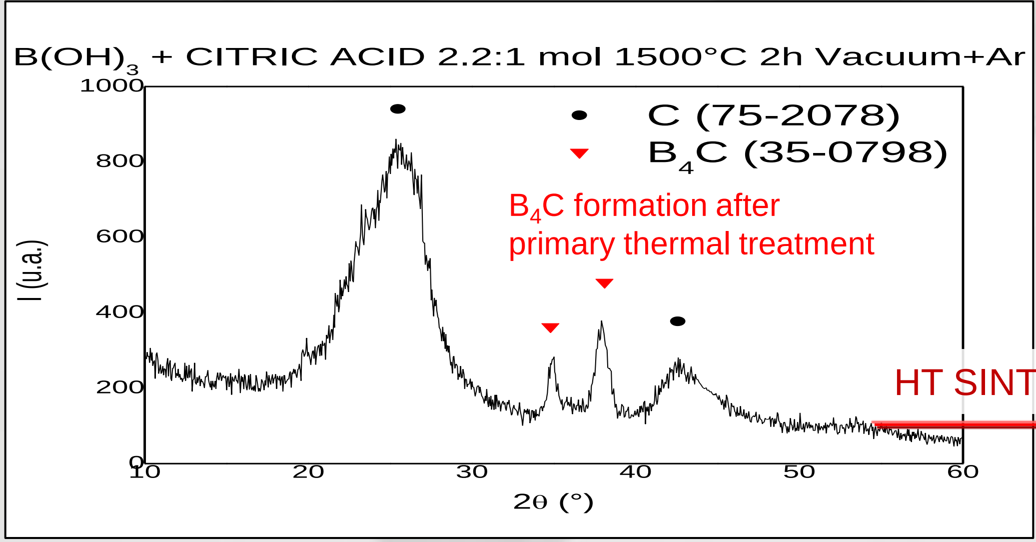


Thermal treatment

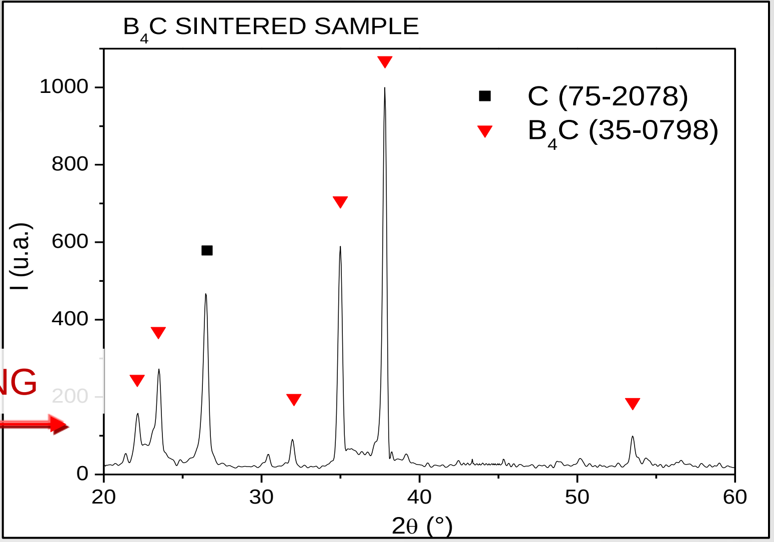


High T sintering

Thermal treatment :
- up to 800°C in low vacuum ($5*10^{-2}$mbar), 0.5 °C/min
- up to 1500°C in vacuum with Ar flow (1 mbar), 1÷3°C/min
- 2 hours at 1500°C



HT SINTERING



Possible p-rich beams for SPES-α

- Alkaline - Alkaline earth metals
- Post-transition elements
- Halogens
- Noble gases
- Transition metals

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra																

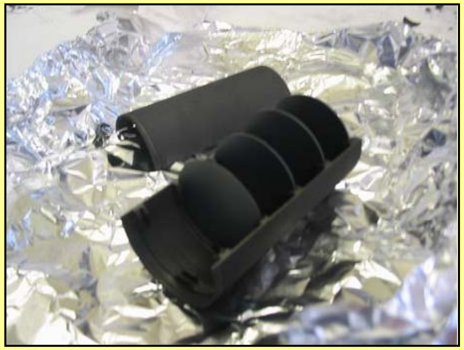
- Lanthanides

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Te	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Target for light isotopes

Elemento	A	Half Life	Target dedicati	Ionizzazione
Na	**21**	22.48 s	Al_2O_3 – SiC	SIS
Na	**22**	2.6 a	Al_2O_3 – SiC	SIS
Mg	**22**	3.86 s	Al_2O_3 – SiC	LIS-FEBIAD
Mg	**23**	11.3 s	Al_2O_3 – SiC	LIS-FEBIAD
Al	**24**	2.05 s	SiC	SIS-LIS
Al	**25**	7.18 s	SiC	SIS-LIS
Al	**26**	6.35 s	SiC	SIS-LIS
P	**29**	4.1 s	SiC - CeS	FEBIAD

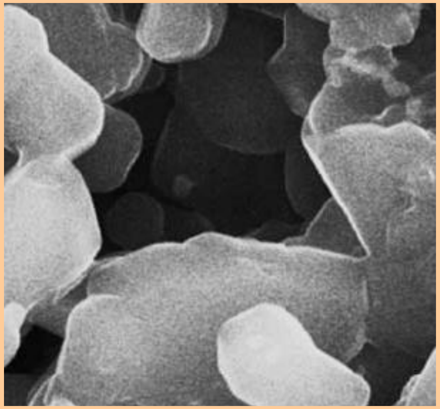
SiC (Saint Gobain)



$^{28}Si(p,\alpha)^{25}Al$ $^{28}Si(p,2pn)^{26}Al$

Elemento	A	Half Life	Target dedicati	Ionizzazione
Be	**7**	53.29 d	B_4C	LIS
F	**17**	64.8 s	ZrO_2 – HfO_2	FEBIAD
F	**18**	109.7 m	Al_2O_3	FEBIAD
Si	**26**	2.21 s	Al_2O_3	FEBIAD
Si	**27**	4.16 s	Al_2O_3	FEBIAD

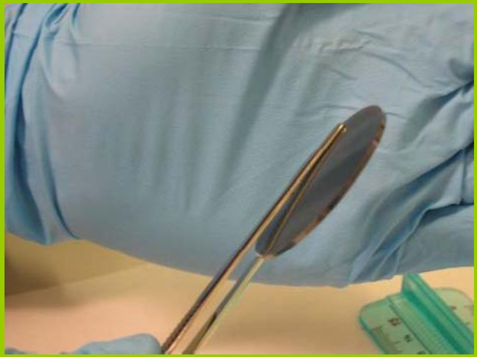
Boron Carbide



Target for heavy isotopes

Elemento	A	Half Life	Target dedicati	Ionizzazione
I	**126**	13.11d	LaCx - CeS	FEBIAD
Xe	**127**	36.4 d	CeS	FEBIAD
Cs	**129**	32 h	CeS	SIS
Cs	**130**	29.2 m	LaCx - CeS	SIS
Cs	**131**	9.69 d	LaCx - CeS	SIS
Cs	**132**	6.47 d	LaCx - CeS	SIS
Ba	**131**	11.5 d	LaCx - CeS	SIS

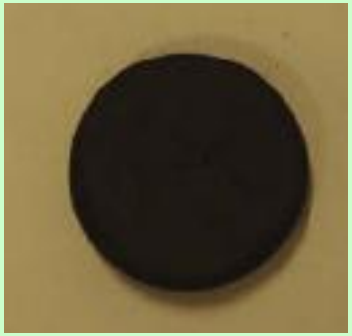
LaCx



$$La_2O_3 + 11C \rightarrow 2LaC_2 + 4C + 3CO$$

Elemento	A	Half Life	Target dedicati	Ionizzazione
Ho	**164**	29 m	TaC	SIS
Tm	**168**	93.1 d	TaC	SIS
Yb	**169**	32 d	TaC	SIS
Lu	**172**	6.7 d	TaC	SIS
Lu	**173**	1.37 a	TaC	SIS
Lu	**174**	3.31 a	TaC	SIS
Hf	**173**	23.6 h	TaC	FEBIAD

TaC foam



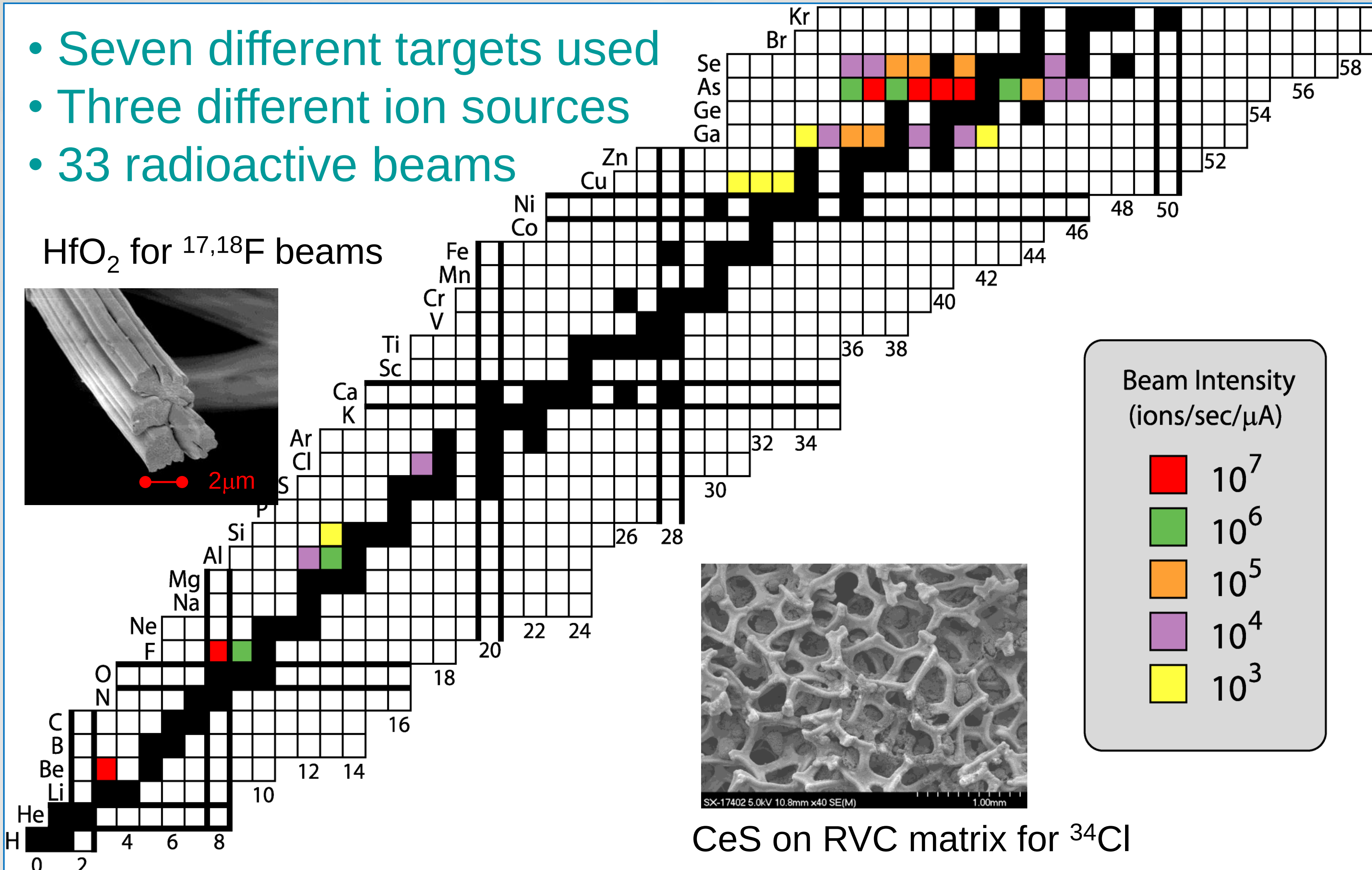
$$Ta_2O_5 + 7C \rightarrow 2TaC + 5CO$$

P-rich: production difficulty

Target material	Producible Elements	Ion Source	Material R&D effort needed	Beam quality
SiC	Al, Na, Mg, P	LIS-SIS-PIS	*	?
LaC_x	Cs, I, Ce, Ba	SIS-PIS	*	?
B_4C	Be	LIS-PIS	**	?
ZrC	As, Br, Rb, Sr	SIS-PIS	**	?
Al_2O_3	Na, Mg, Si	LIS-SIS-PIS	***	?
HfO2 – ZrO2	F	PIS	***	?
CeS	P, Cl, La	PIS	****	?

Proton-rich RIBS at HRIBF

- Seven different targets used
- Three different ion sources
- 33 radioactive beams



HfO_2 for $^{17,18}F$ beams

CeS on RVC matrix for ^{34}Cl

Extrapolations for SPES…

(to be checked using dedicated codes..)

p-rich light isotopes…

Elements	$T_{1/2}$	Ion Source	Yield (1/s)	Target material
^{7}Be	53 d	LIS-PIS	~10^9	B_4C
^{17}F	65 s	PIS	~10^9	HfO2 – ZrO2
^{18}F	110 m	PIS	~10^8	HfO2 – ZrO2
^{25}Al	7 s	LIS-PIS	~10^6	SiC
^{26}Al	6 s	LIS-PIS	~10^8	SiC
^{27}Si	4 s	LIS-PIS	~10^5	SiC
^{34}Cl	32 m	PIS	~10^6	CeS

What next for spes-alpha?

- Study of Isotope Yields from p->Targ$_{refractory}$
- Study of Release from p->Targ$_{refractory}$
- Yield Measurement of p->Targ$_{refractory}$ @ different T (LNS?)

The SPES-TIS group