OTHER ISOL FACILITIES

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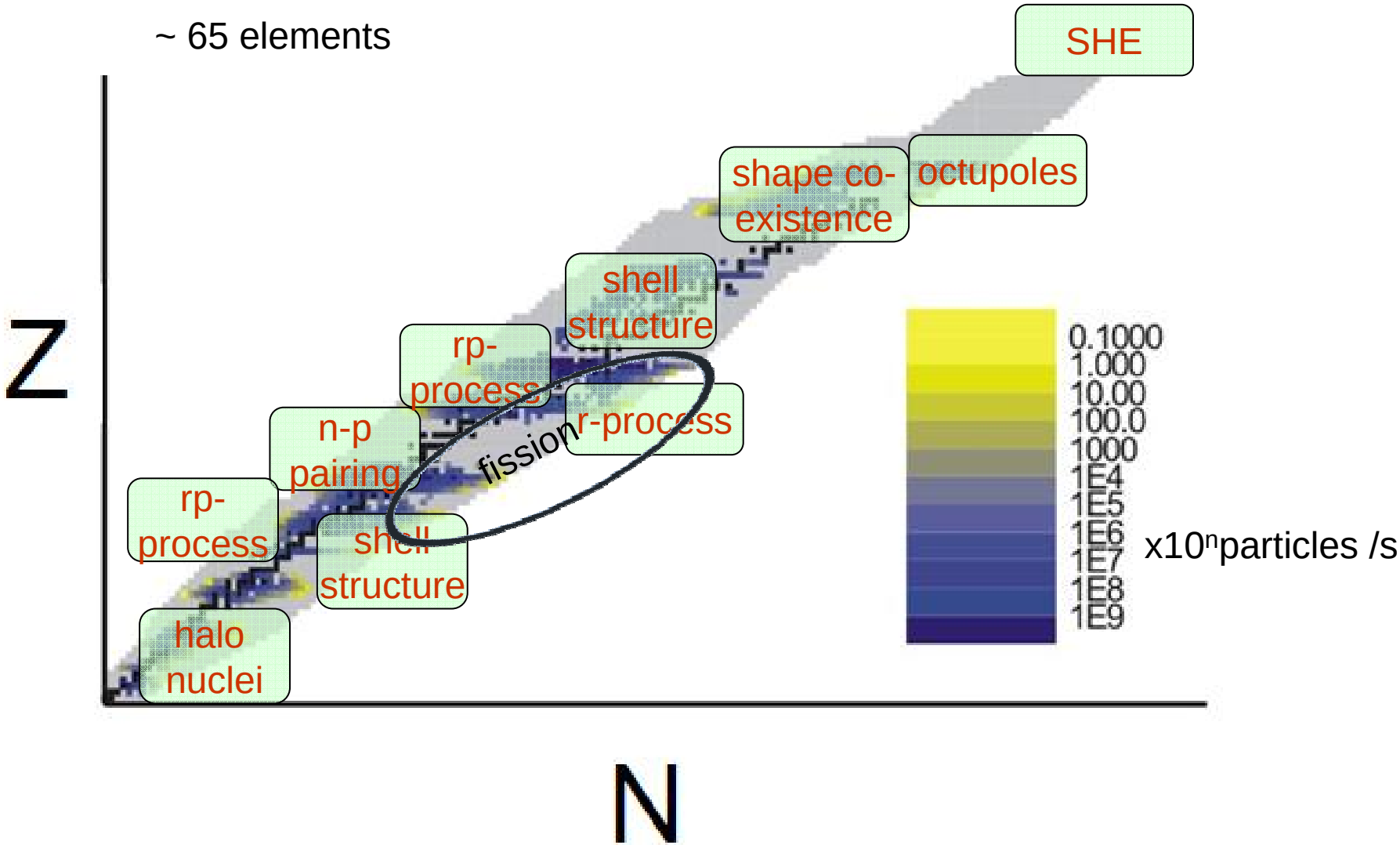
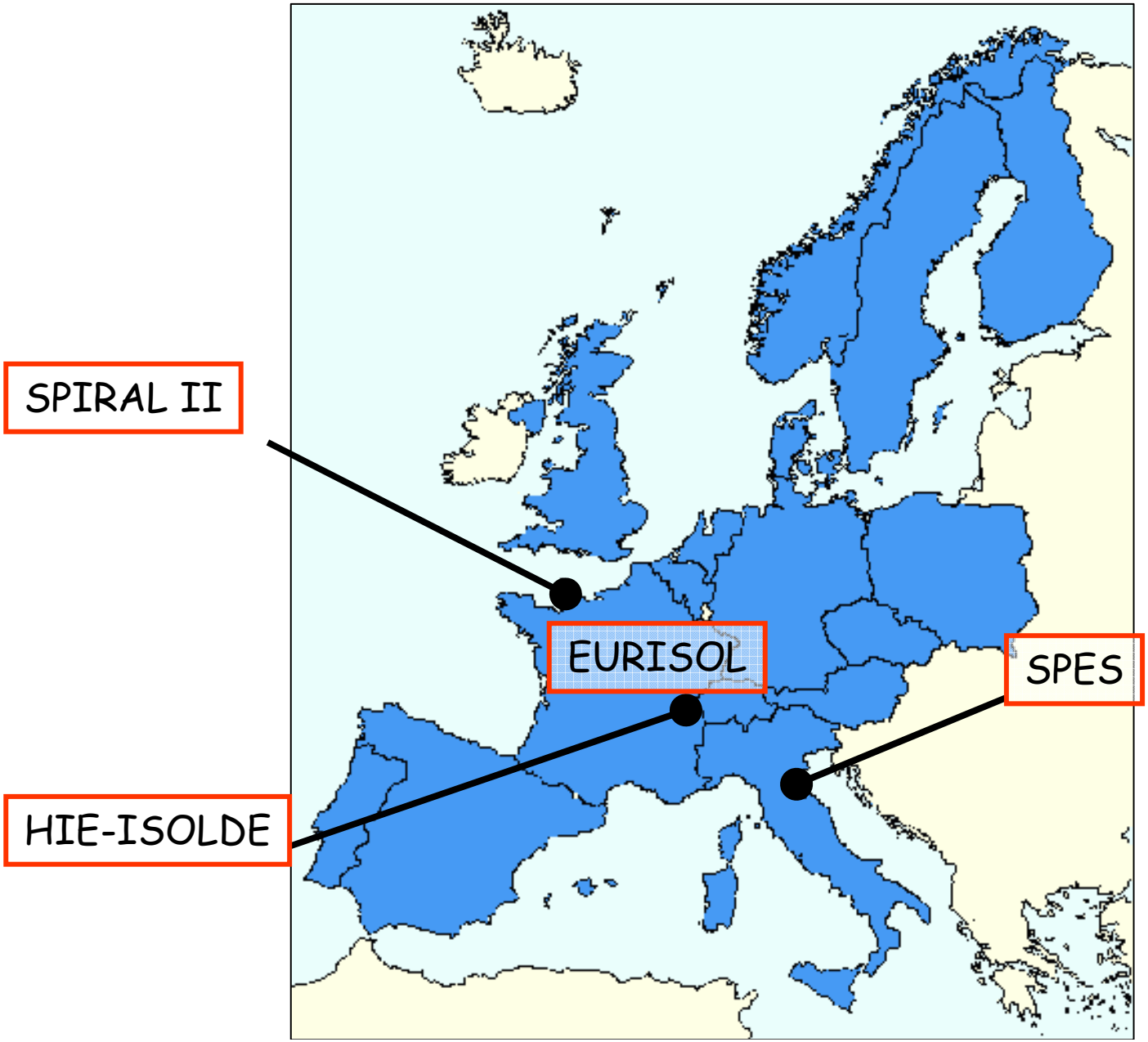
ISOL beams


~ 65 elements
SHE
octupoles
shape co-existence
shell structure
rp-process
r-process
fission
n-p pairing
rp-process
shell structure
halo nuclei
Z
N
0.1000
1.000
10.00
100.0
1000
1E4
1E5
1E6
1E7
1E8
1E9
x10ⁿparticles /s

World ISOL accelerated beams

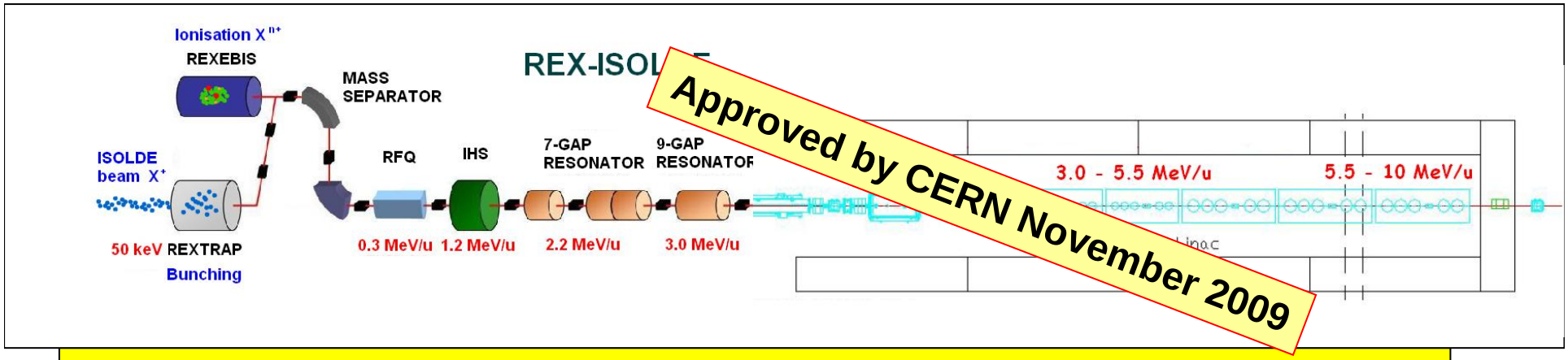
FACILITY	DRIVER	POWER	USER BEAMS ACCELERATED	MAX ENERGY
HRIBF **Oak Ridge** (USA) 1997	50-100 MeV p, d, α *(-ve ion source)*	1.5 kW	^{7,10}Be, ^{17,18}F, ^{26}Al, $^{76-79}$Cu, $^{67,83-85}$Ga, $^{78,80,82-86}$Ge, ^{69}As, ^{83,84}Se, ^{92}Sr, ^{117,118,120,122,124,126}Ag, $^{126,128,130-136}$Sn, ^{129}Sb, ^{129,132,134,136}Te **(44)**	5-15 MeV/u tandem
ISAC **TRIUMF** (CANADA) 2000	500 MeV protons	50 kW	^{8,9,11}Li, ^{10,11}Be, ^{18}F, ^{20,21,25,29}Na, ^{23}Mg, ^{26}Al **(12)**	14 MeV/u linac
SPIRAL **GANIL** (FRANCE) 2001	100 MeV/u heavy ions	6 kW	^{6,8}He, $^{14,15,19-22}$O, ^{18}F, $^{17-19,23-26}$Ne, $^{33-35,44,46}$Ar, $^{74-77}$Kr **(25)**	10-25 MeV/u cyclotron
REX ISOLDE (CERN) 2001	1.4 GeV protons	3 kW	^{8,9,11}Li, $^{10-12}$Be, ^{10}C, ^{17}F, $^{24-30}$Na, $^{28-32}$Mg, $^{61-63}$Mn, ^{61,62}Fe, ^{66,68}Ni, $^{67-71,73}$Cu, ^{74,76,78,80}Zn, ^{70}Se, ^{88,92,94,96}Kr, ^{96}Sr, ^{108}In, $^{106-110}$Sn, ^{100,102,104,122,124,126}Cd, ^{138,140,142,144}Xe, ^{140,142,148}Ba, ^{148}Pm, ^{153}Sm, ^{156}Eu, ^{182,184,186,188}Hg, ^{200}Po, ^{202,204}Rn **(72)**	3 MeV/u linac

Next generation ISOL facilities in Europe



HIE-ISOLDE

Increase in REX energy from 3 to 10 MeV/u (first step in increase to 5.5 MeV/u)



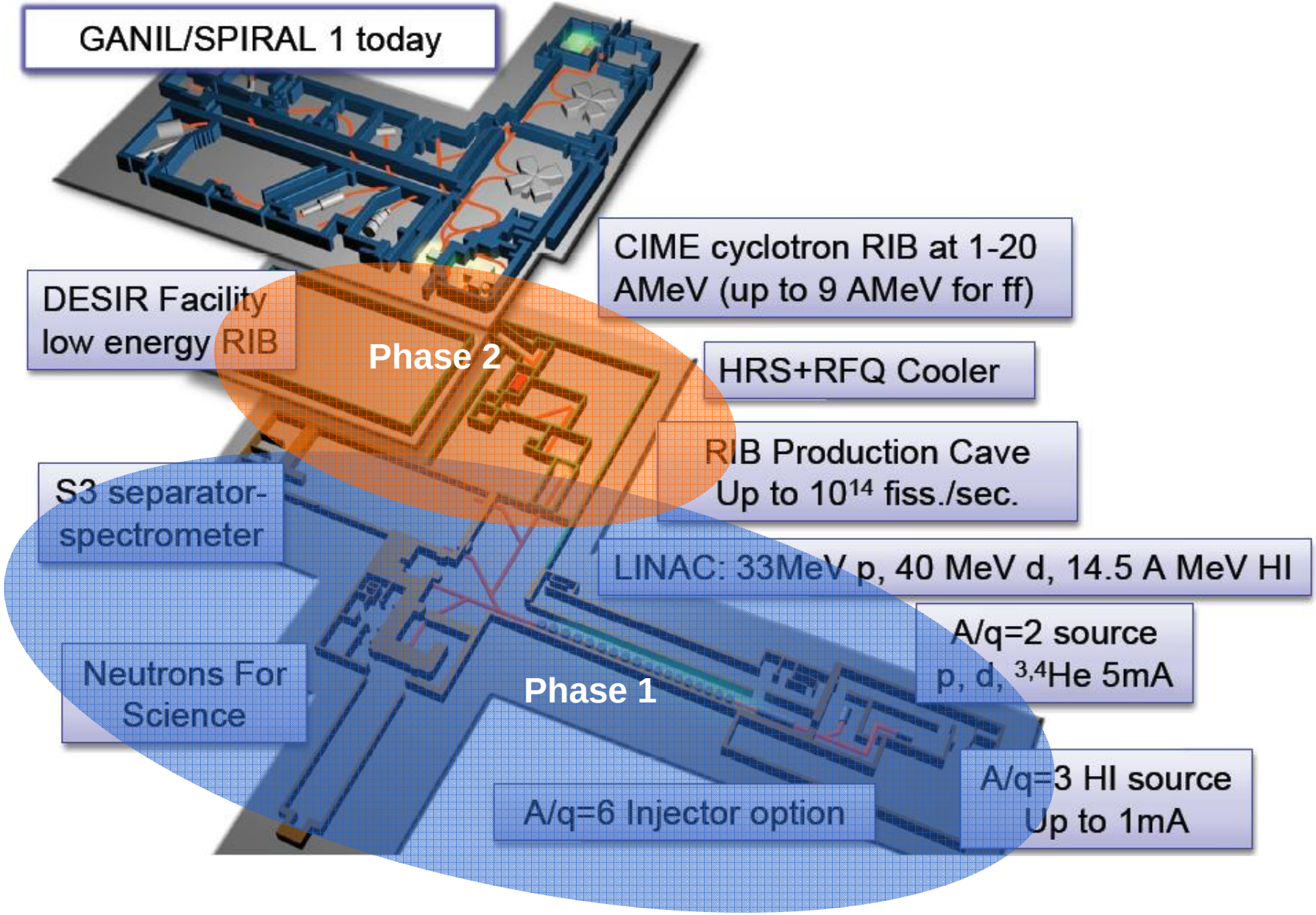
Increase proton intensity 2 → 6 μA (LINAC4, PSB upgrade); target + ion-source upgrade

Solid state laser ionisation ✓

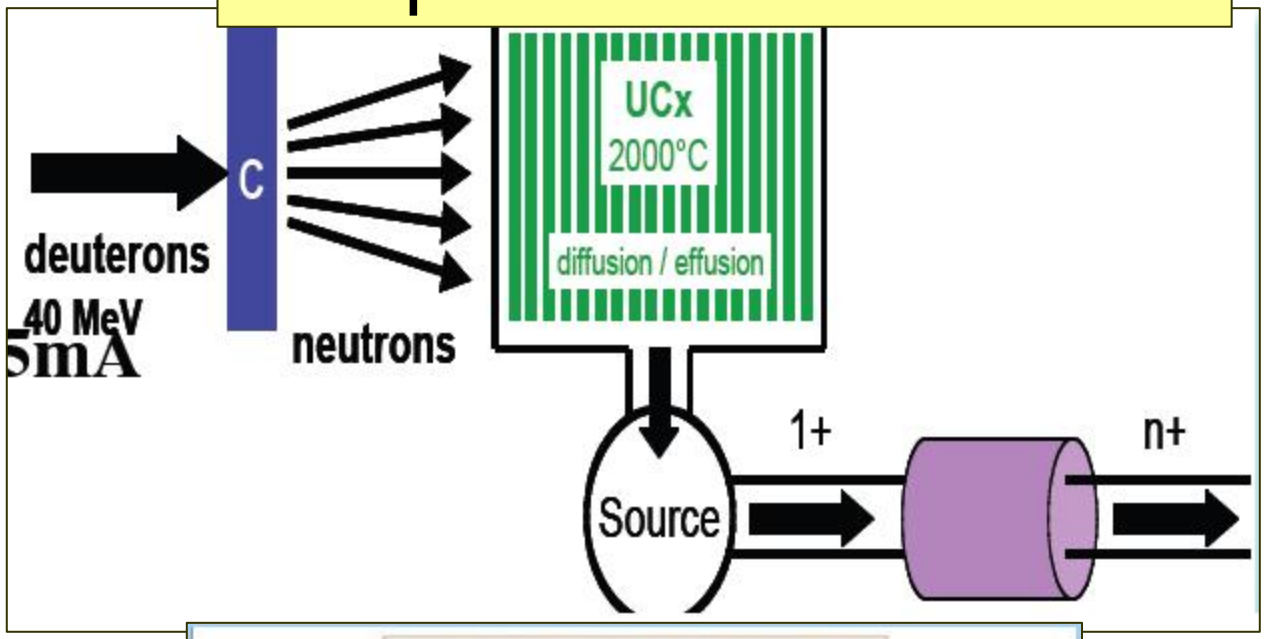
REX-TRAP, REX-EBIS upgrades

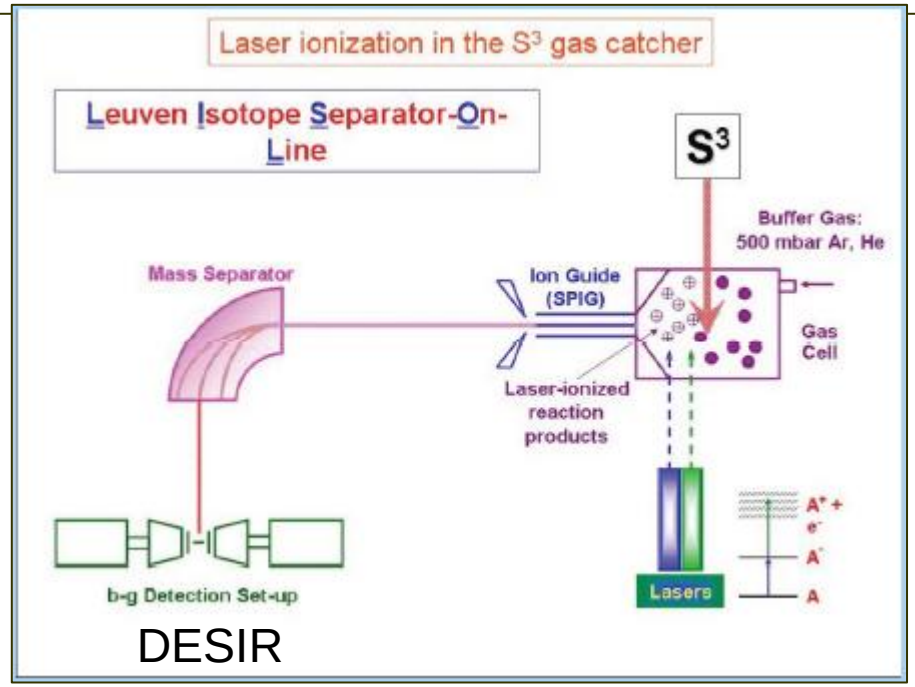
RFQ cooler ✓, Super-HRS for isobaric separation

SPIRAL-2 GANIL



RIB production SPIRAL-2





DESIR

Reference planning and phases

2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Reference Project Def.

Safety authorisation

Buildings construction

Construction of LINAG

Possible scenario

Phase 1
>10^{12} fiss./s

Stable ion beams from LINAG

RIB from non - fissile targets

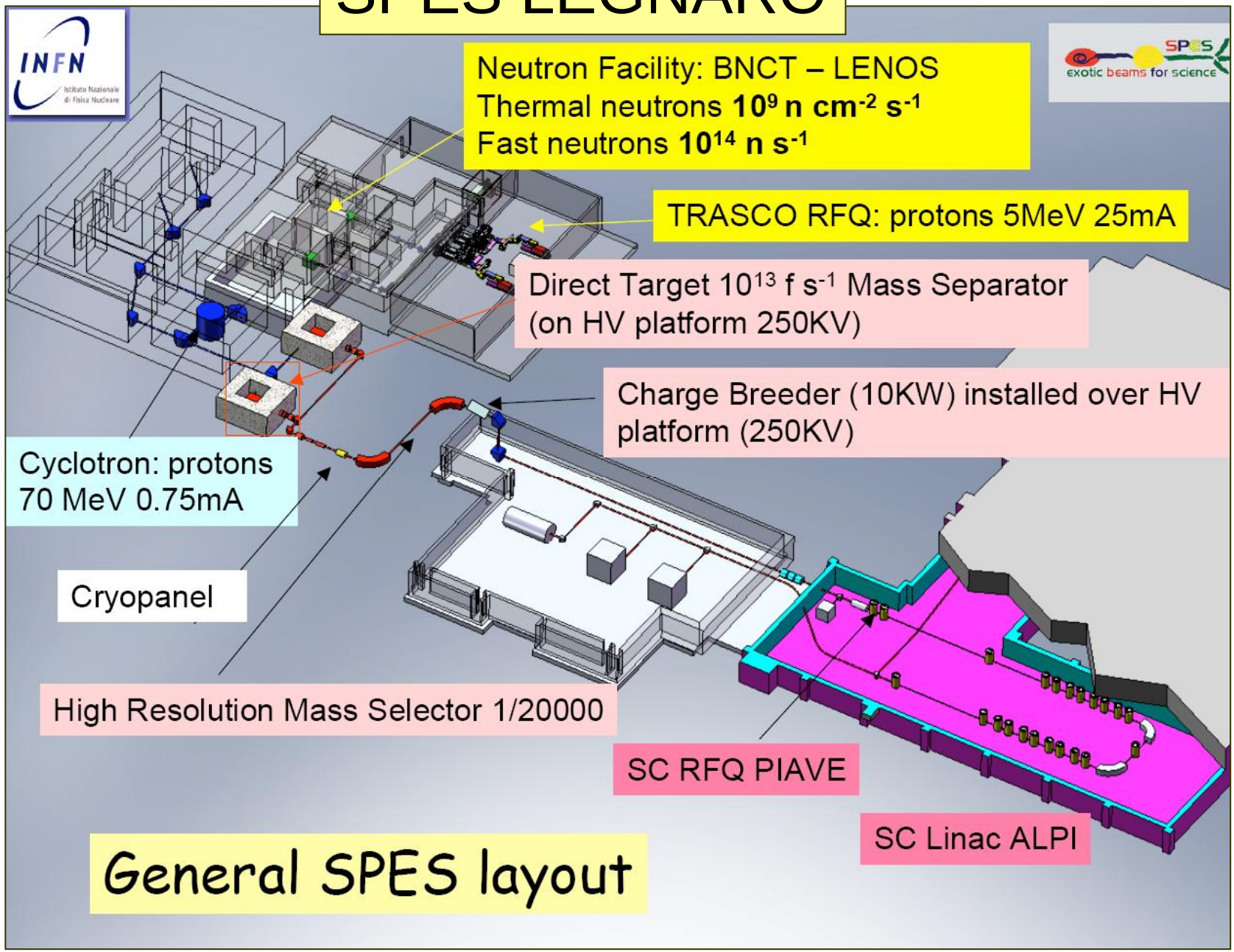
RIB of fission fragments > 10^{12} fiss./s

Phase 2
Goal: 10^{14} fiss./s

RIB of fission fragments
10^{14} fiss./s

Reference Planning

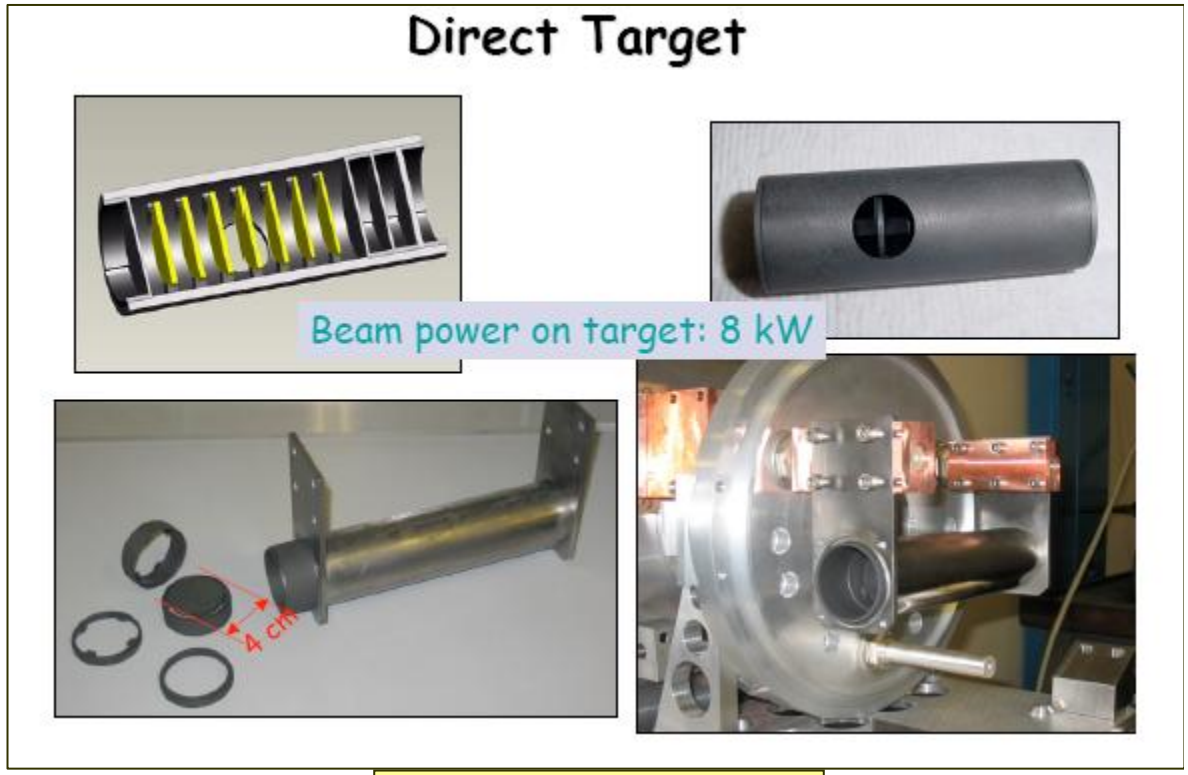
SPES LEGNARO



General SPES layout

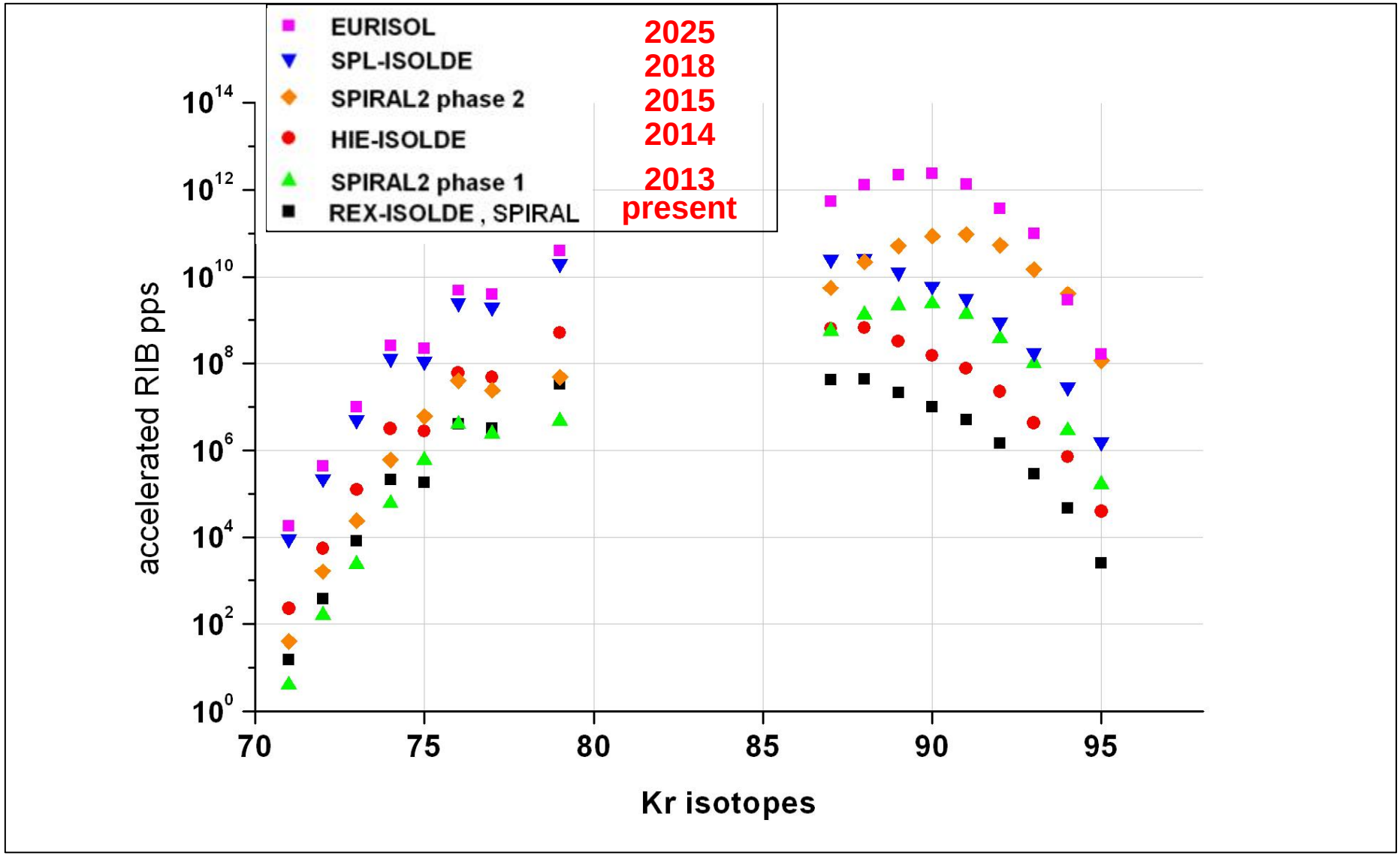
SPES

40 MeV p driver



UCx target

Radioactive ISOL beam yields

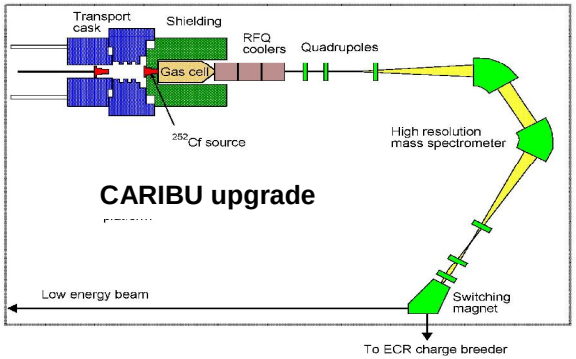


Future Upgrade Plans

- SPIRAL2 – post-acceleration to ~ 100 MeV/u
- HIE-ISOLDE – replacement of PS Booster by SPL (10 kW → 30 kW → 100 kW → …)
- EURISOL – 4MW Hg converter

ISOL in North America

CARIBU: Californium Rare Isotope Breeder Upgrade @ ATLAS



Isotope	Half-life (s)	Low-Energy Beam Yield (s^{-1})	Accelerated Beam Yield (s^{-1})
^{104}Zr	1.2	$1.5x10^3$ / $4.8x10^4$ / $6.0x10^5$	$5.3x10^1$ / $1.7x10^3$ / $2.1x10^4$
^{143}Ba	14.3	$3.0x10^4$ / $9.6x10^5$ / $1.2x10^7$	$1.1x10^3$ / $3.4x10^4$ / $4.3x10^5$
^{145}Ba	4.0	$1.4x10^4$ / $4.4x10^5$ / $5.5x10^6$	$5.0x10^2$ / $1.6x10^4$ / $2.0x10^5$
^{130}Sn	222.	$2.5x10^3$ / $7.8x10^4$ / $9.8x10^5$	$9.0x10^1$ / $2.9x10^3$ / $3.6x10^4$
^{132}Sn	40.	$9.3x10^2$ / $3.0x10^4$ / $3.7x10^5$	$3.5x10^1$ / $1.1x10^3$ / $1.4x10^4$
^{138}Xe	846.	$2.5x10^4$ / $7.8x10^5$ / $9.8x10^6$	$1.8x10^3$ / $5.8x10^4$ / $7.2x10^5$
^{110}Mo	2.8	$1.6x10^2$ / $5.0x10^3$ / $6.2x10^4$	$5.8x10^0$ / $1.8x10^2$ / $2.3x10^3$
^{111}Mo	0.5	$8.3x10^0$ / $2.6x10^2$ / $3.3x10^3$	$0.3x10^0$ / $9.6x10^0$ / $1.2x10^2$

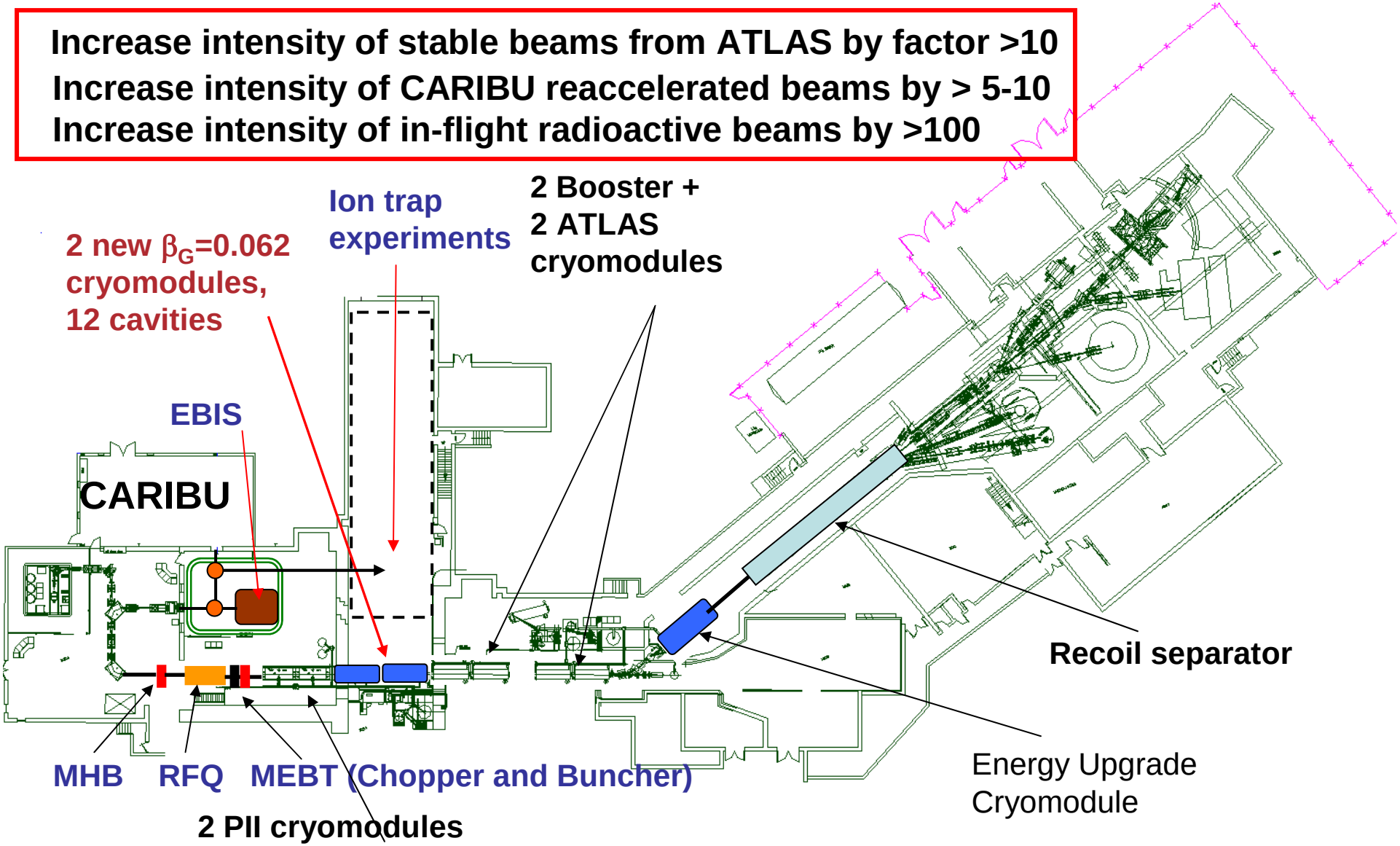
Fall 2009: 2 mCi source → tests & yields studies

Winter 2009 – Spring 2010: 80 mCi source → 1st expts.

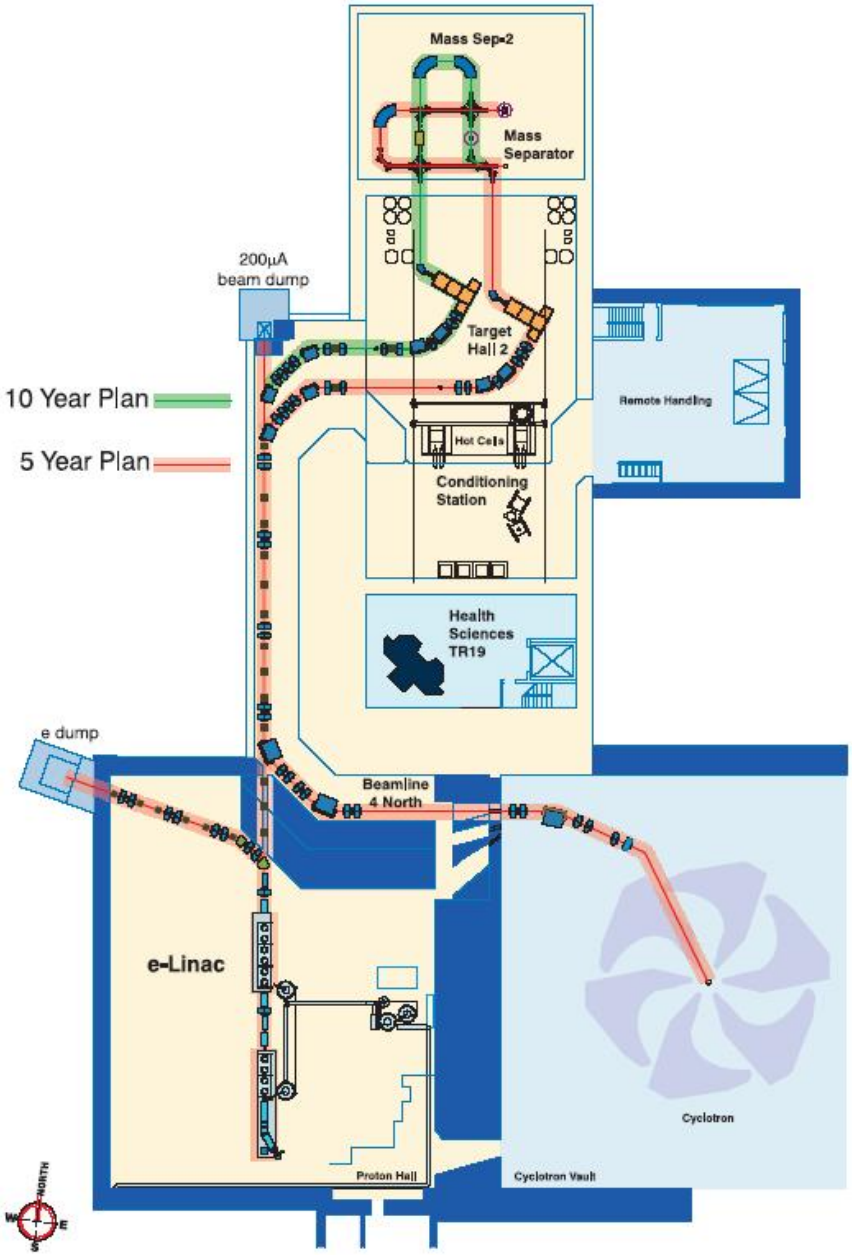
Summer 2010: 1 Ci source → Full research program

Proposed ATLAS efficiency and intensity upgrade

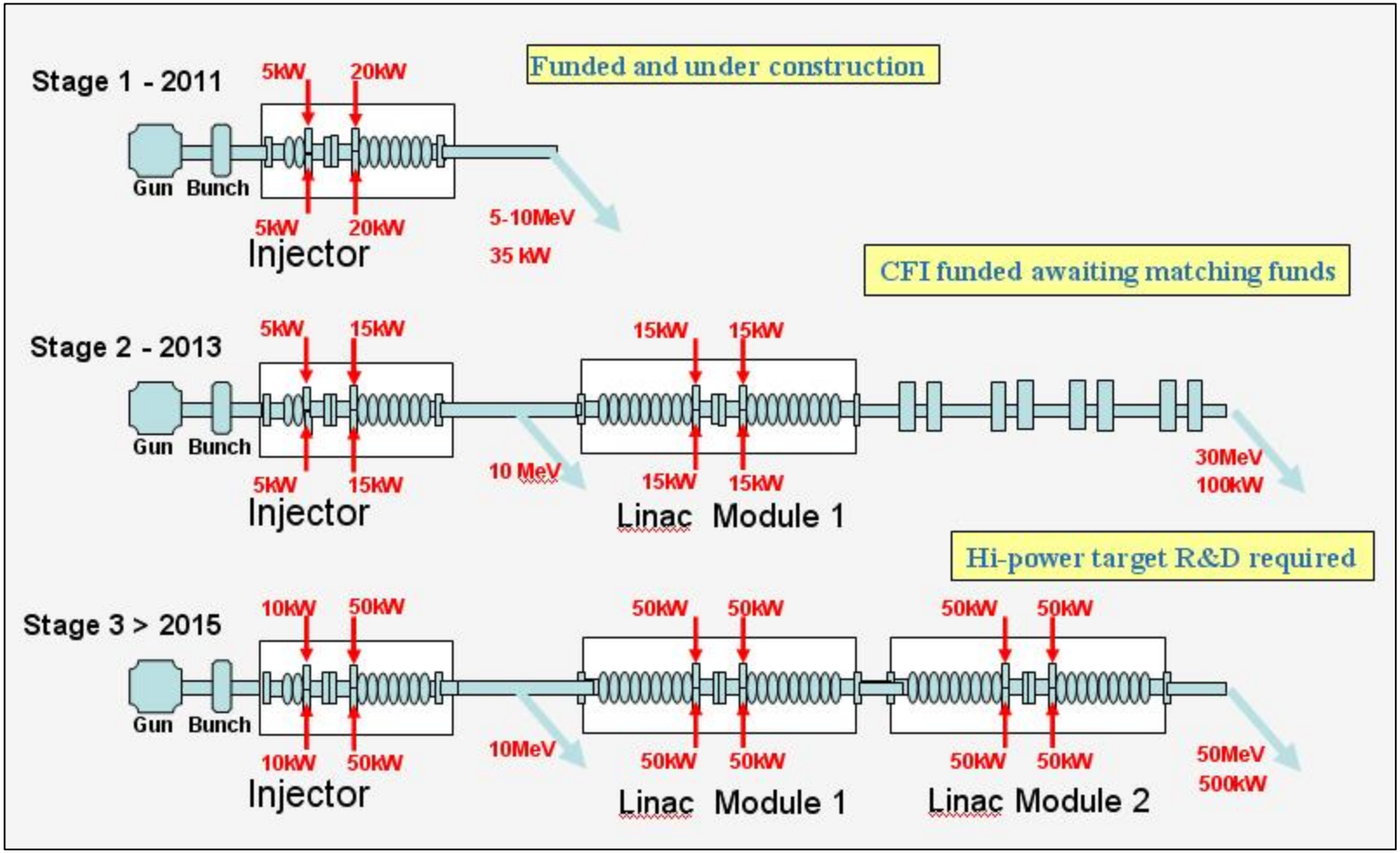
Increase intensity of stable beams from ATLAS by factor >10
Increase intensity of CARIBU reaccelerated beams by > 5-10
Increase intensity of in-flight radioactive beams by >100



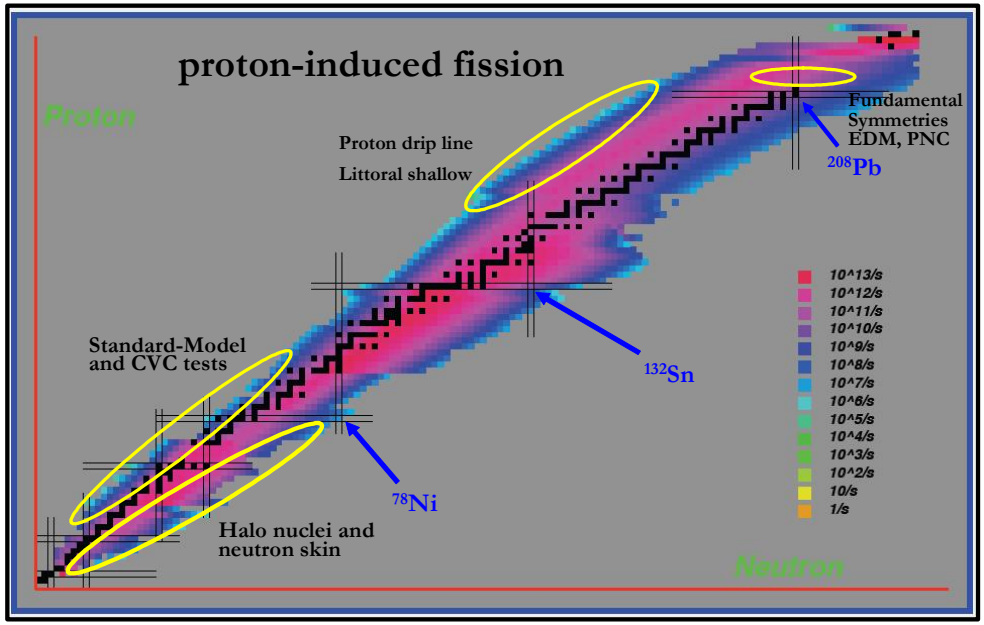
TRIUMF

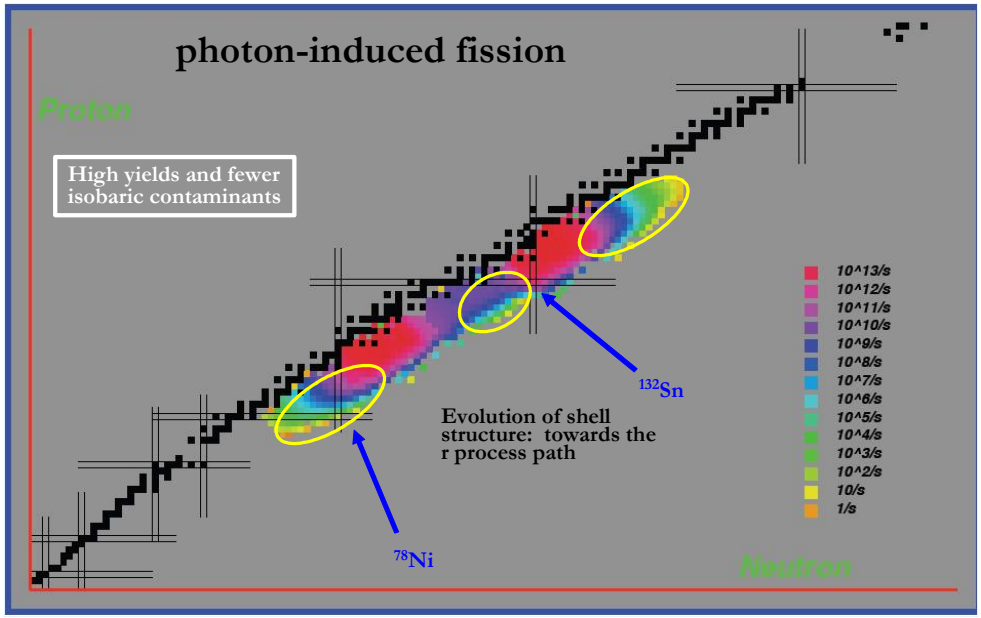

Mass Sep-2
Mass Separator
200μA beam dump
Target Hall 2
10 Year Plan
5 Year Plan
Remote Handling
Hot Cells
Conditioning Station
Health Sciences TR19
e dump
Beamline 4 North
e-Linac
Cyclotron
Proton Hall
Cyclotron Vault
NORTH

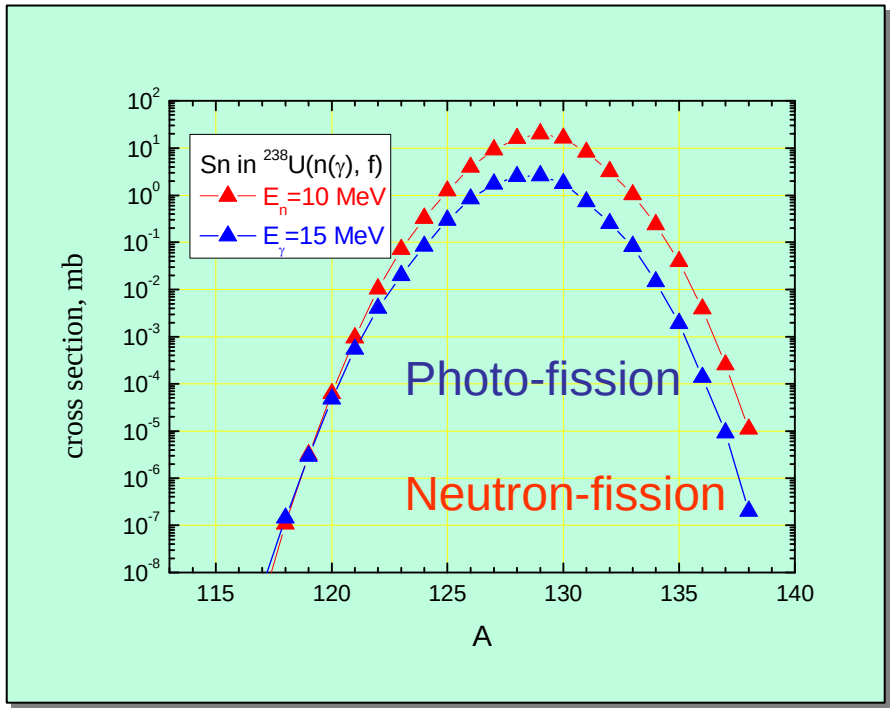
TRIUMF e-linac



Comparison of proton, photon and neutron-induced fission







Accelerated ^{132}Sn yields (per second)

(fission factories only)

HRIBF	10^5	4.5 MeV/u	(now)
REX-ISOLDE	10^6	3 MeV /u	(now)
CARIBU	5.10^4	10 MeV/u	(2010)
TRIUMF p-driver	10^7	5 MeV/u	(2010)
CARIBU phase 2	10^6	14 MeV/u	(2013)
HRIBF HDU	**2.10^8**	**4.5 MeV/u**	**(2013)**
HIE-ISOLDE	10^8	10 MeV/u	(2014)
TRIUMF e-driver	5.10^8	5 MeV/u	(2015)
SPES	5.10^8	9 MeV/u	(2015)
SPIRAL-2	2.10^9	7 MeV/u	(2015)
EURISOL	10^{11}	150 MeV/u	(2025)

Comments

- Only ISOLDE and HRIBF have accelerated fission fragments
- Maximum energy trade-off for intensity, particularly for ECR charge-breeder
- Issue of isobaric and charge-breeder background
- Issue of target size for extraction of short-lived radionuclides

FINIS