SPES Project

a second generation ISOL facility

Gianfranco Prete LNL-INFN
On behalf of the SPES Collaboration

SPES exotic beams for science

INFN Istituto Nazionale di Fisica Nucleare

The Second Meeting of
The Union for Compact Accelerator-Driven Neutron Sources

UCANS-II

Indiana University, Bloomington
July 5-8, 2011

Istituto Nazionale di Fisica Nucleare
(National Nuclear Physics Institute)

I.N.F.N. is strongly connected to University

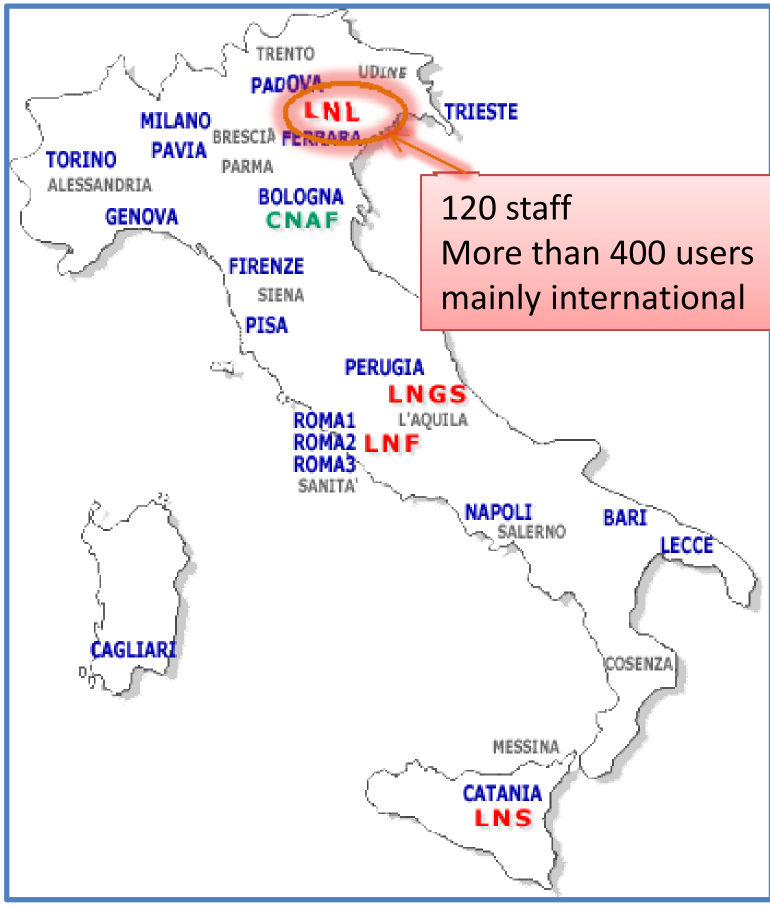
4 National Laboratories

19 Divisions located inside Italian Universities

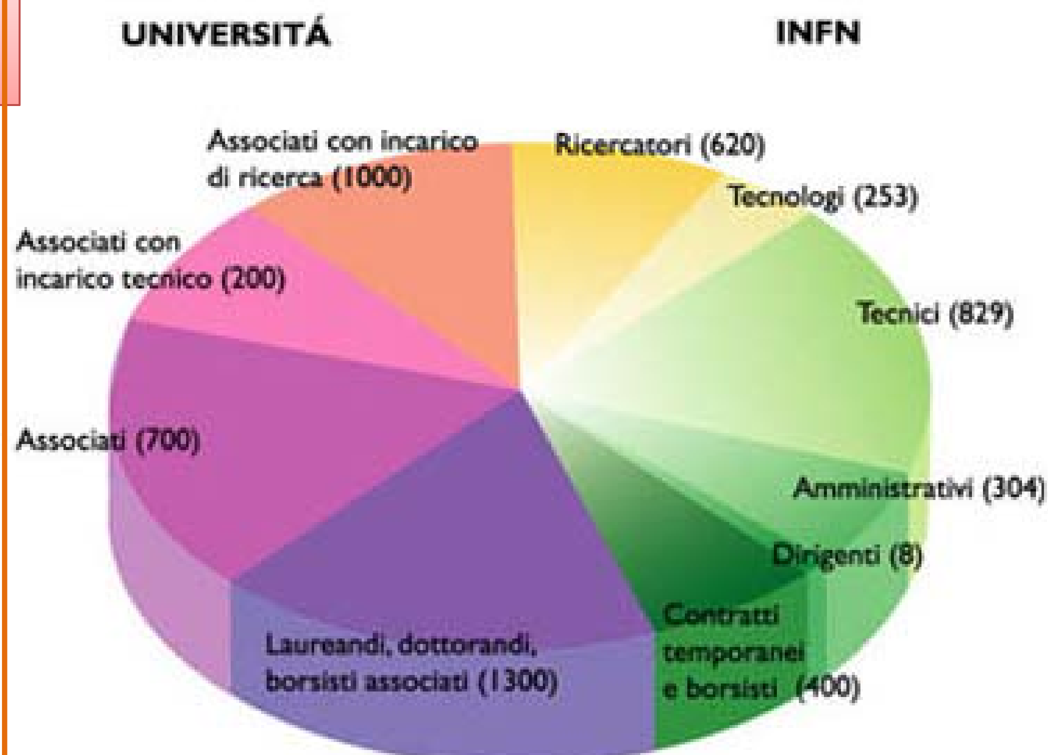
Personnel: I.N.F.N. ~ 2000 persons

Associated from University ~ 2000 persons

Students, PHD, temporary positions ~ 1700



120 staff
More than 400 users
mainly international



Accelerators at LNL

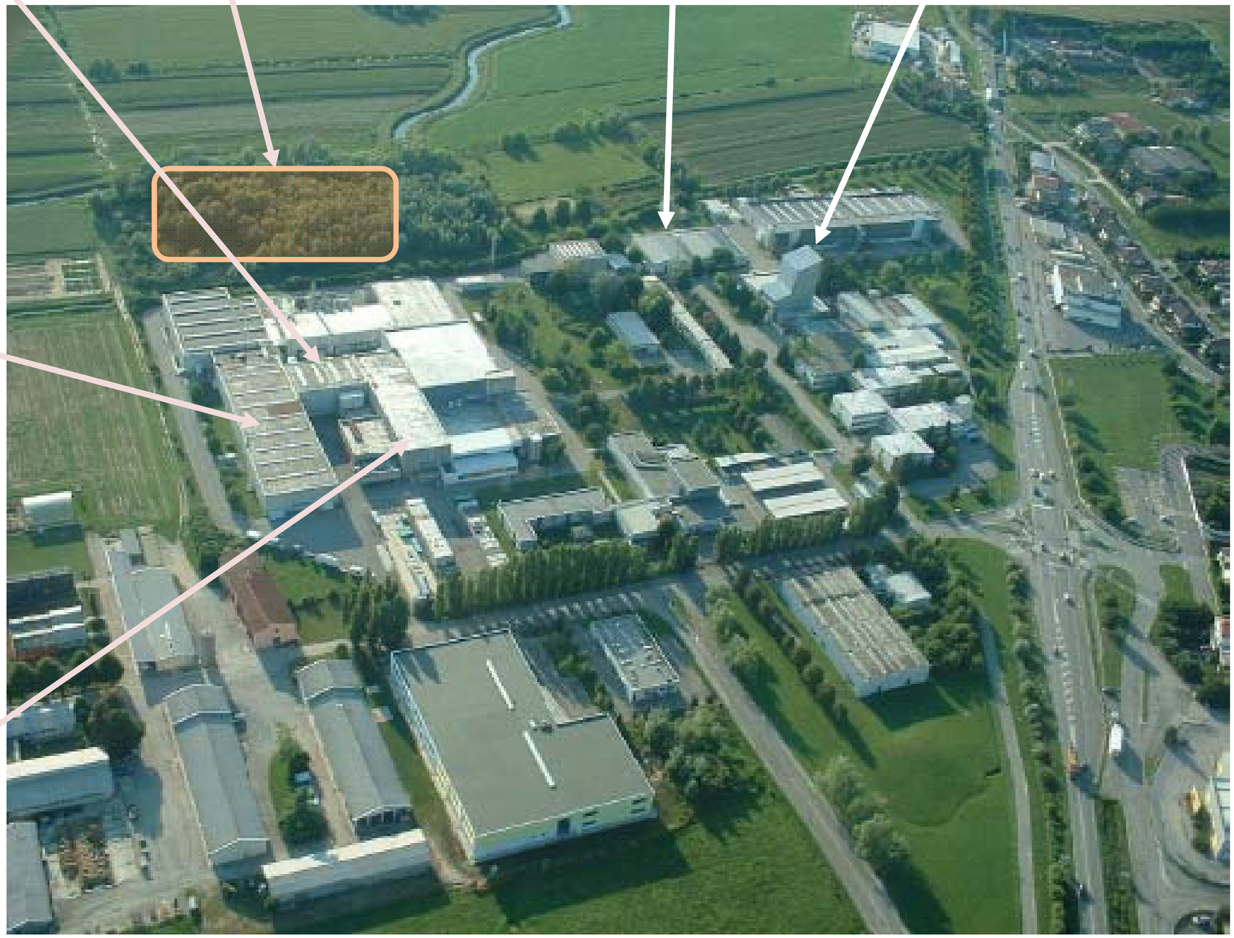
Laboratori Nazionali di Legnaro

**Superconductive RFQ
PIAVE HI Injector**

**Superconductive Linac
ALPI 40 MVeq**

Tandem XTU 15 MV

SPES AREA



AN2000 2 MV

CN 7 MV

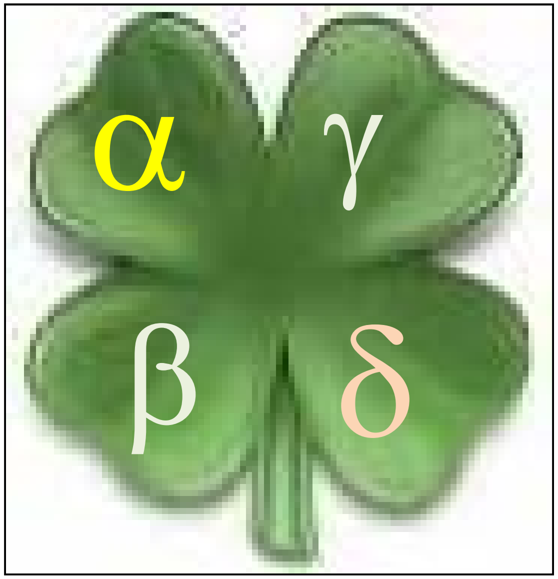
SPES project strategy

1. Develop a Neutron Rich ISOL facility delivering Radioactive Ion Beams at 10AMeV using the LNL linear accelerator ALPI as re-accelerator .
2. Make use of a Direct ISOL Target based on UCx and able to reach 10^{13} Fission/s.
3. Develop an applied physics facility based on the technology and the components of the ISOL facility. Applications in neutron production and medicine.

Exotic nuclei

ISOL facility for
Neutron rich nuclei by
U fission 10^{13} f/s

high purity beam
Reacceleration up to
$\geq$10 MeV/u

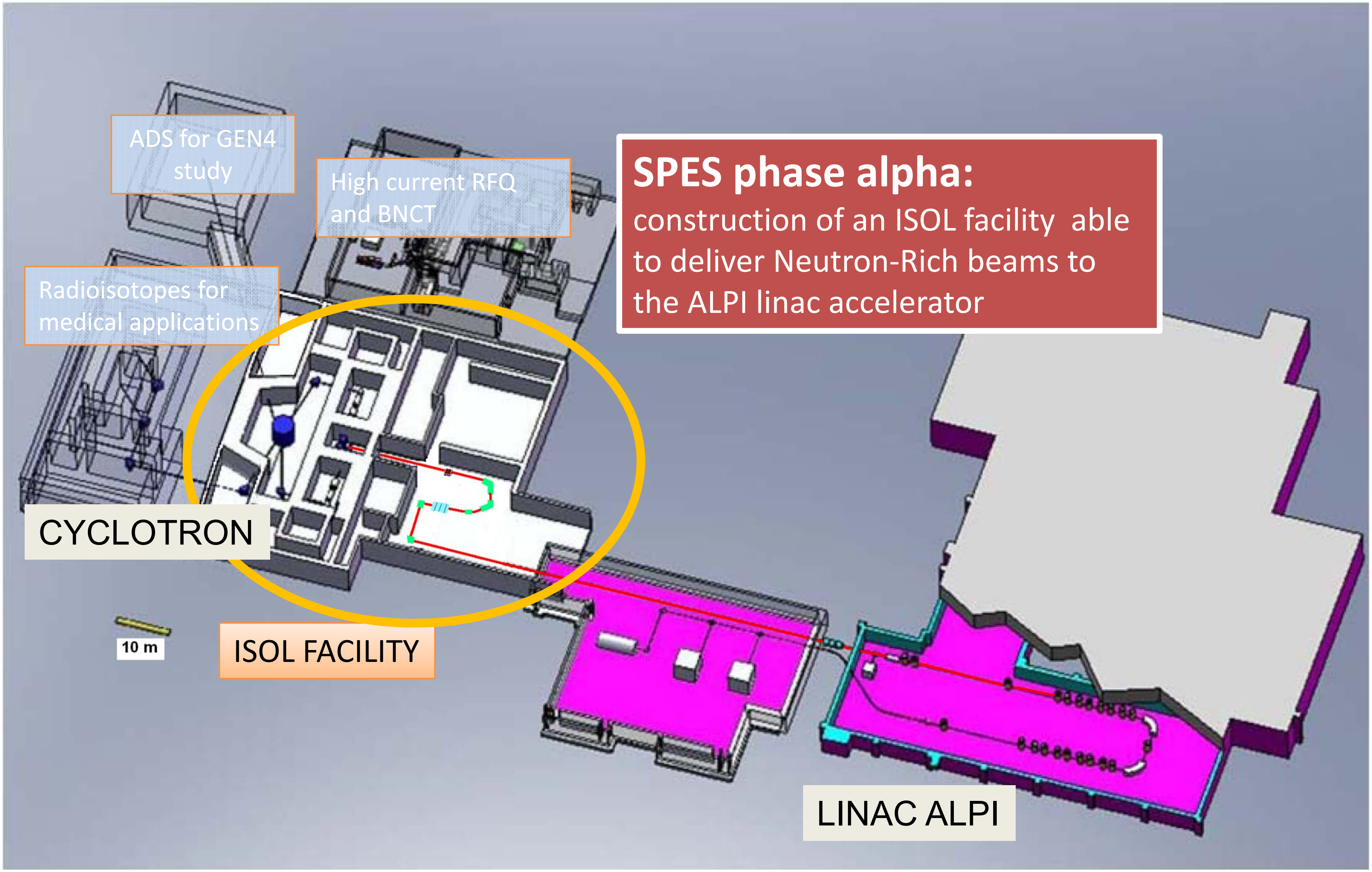


Applications

Proton and neutron
facility for applied
physiscs

Radioisotope
produduction
& Medical
applications

SPES layout



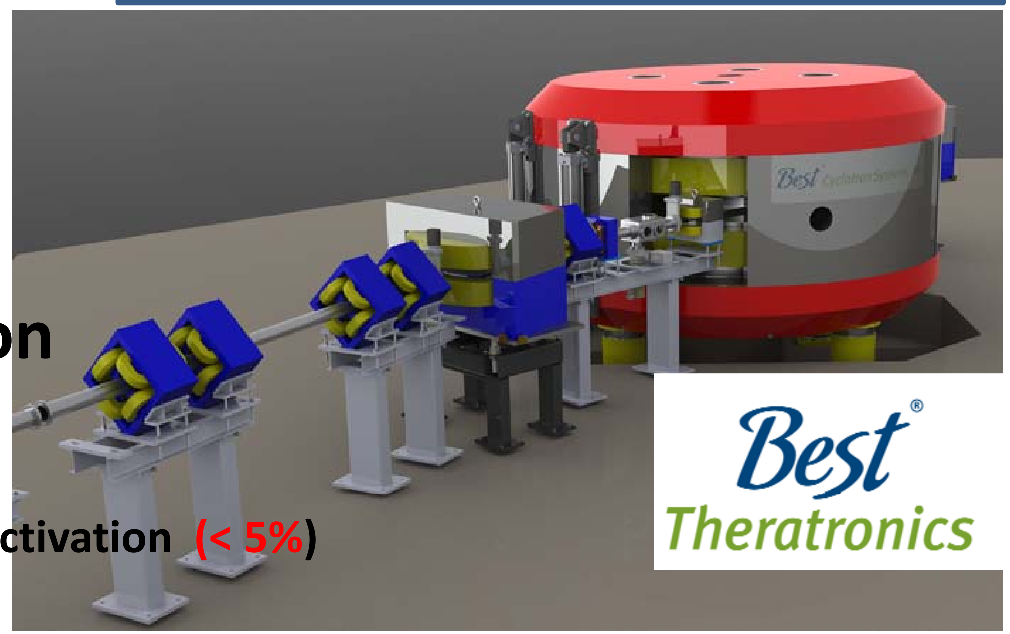
SPES phase alpha:
construction of an ISOL facility able to deliver Neutron-Rich beams to the ALPI linac accelerator

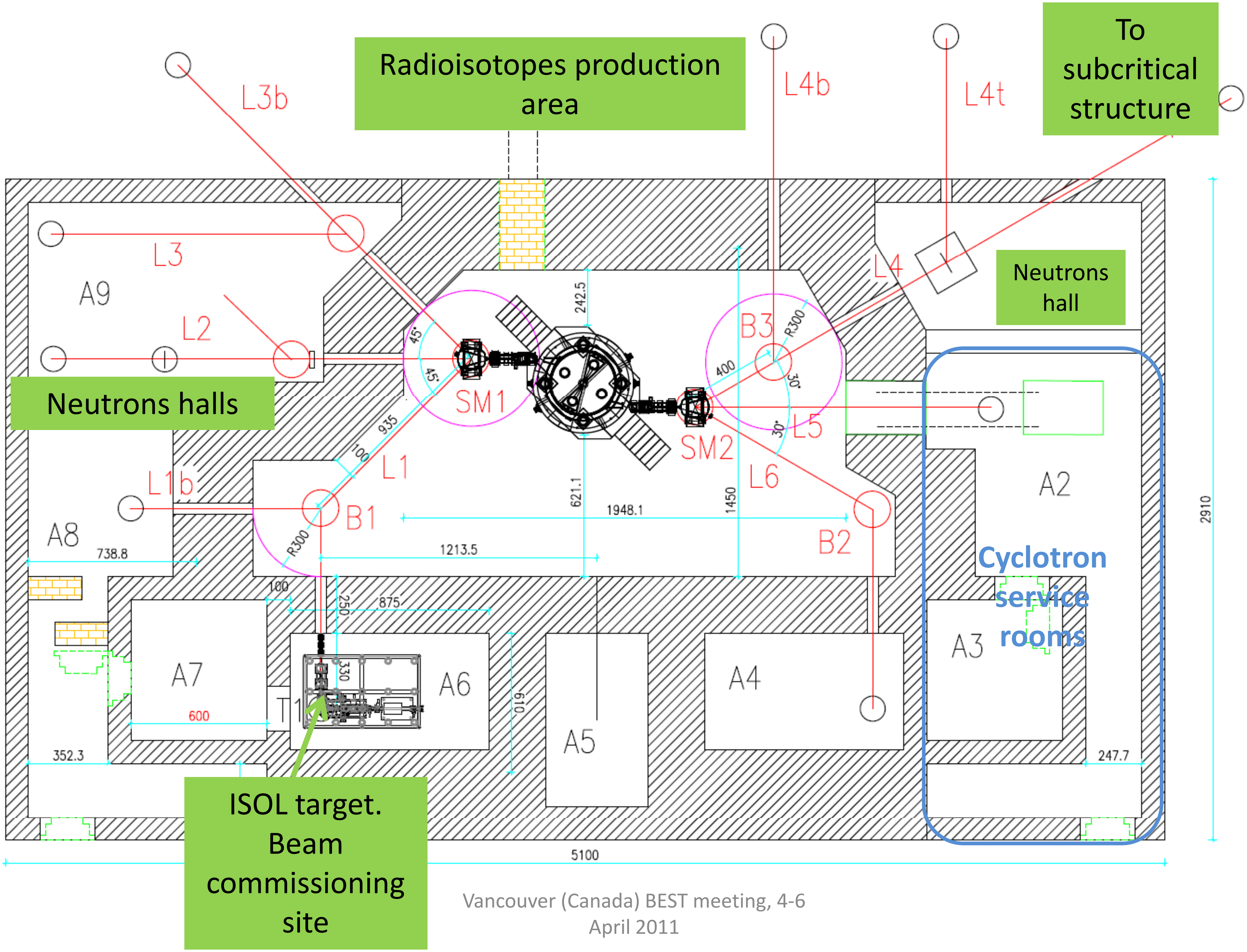
The SPES Cyclotron: main data

- Accelerated particles: **H^-**
- Variable Energy: **35 MeV - 70 MeV**
- Maximum beam current accelerated **>700 µA**
- Maximum beam current at the exit port **500 µA**
- Extraction system:
  - **Stripper → H^-**
  - **Beam shared on two exit ports**
- Performances:
  - exit1: **300µA H^- 40MeV**
  - exit2: **400µA H^- 70MeV**
  - **Dual beam operation**
  - **Running time > 5000 h/year**
  - **Minimum Beam Loss to avoid activation (< 5%)**

CONTRACT started 28 October 2010
COST: 10,5Meuro (IVA included)

Actual status: executive project evaluated on June 2011.
Construction started.
DELIVERY 3-4 years (shedule to be fixed according to building)





Radioisotopes production area
To subcritical structure
Neutrons hall
Neutrons halls
Cyclotron service rooms
ISOL target. Beam commissioning site
L3b
L4b
L4t
L3
L2
L4
L1b
L1
L5
L6
A9
A8
A7
A6
A5
A4
A3
A2
SM1
SM2
B1
B2
B3
T1
242.5
935
100
621.1
1948.1
1450
1213.5
738.8
R300
400
875
250
330
600
610
352.3
247.7
2910
5100

SPES CYCLOTRON
load work per year

2 weeks per shift
Beam preparation 2 days
Beam on target 12 days

Beam on target →280 hours per shift

Each bunker will cool down for 14 days after target irradiation.

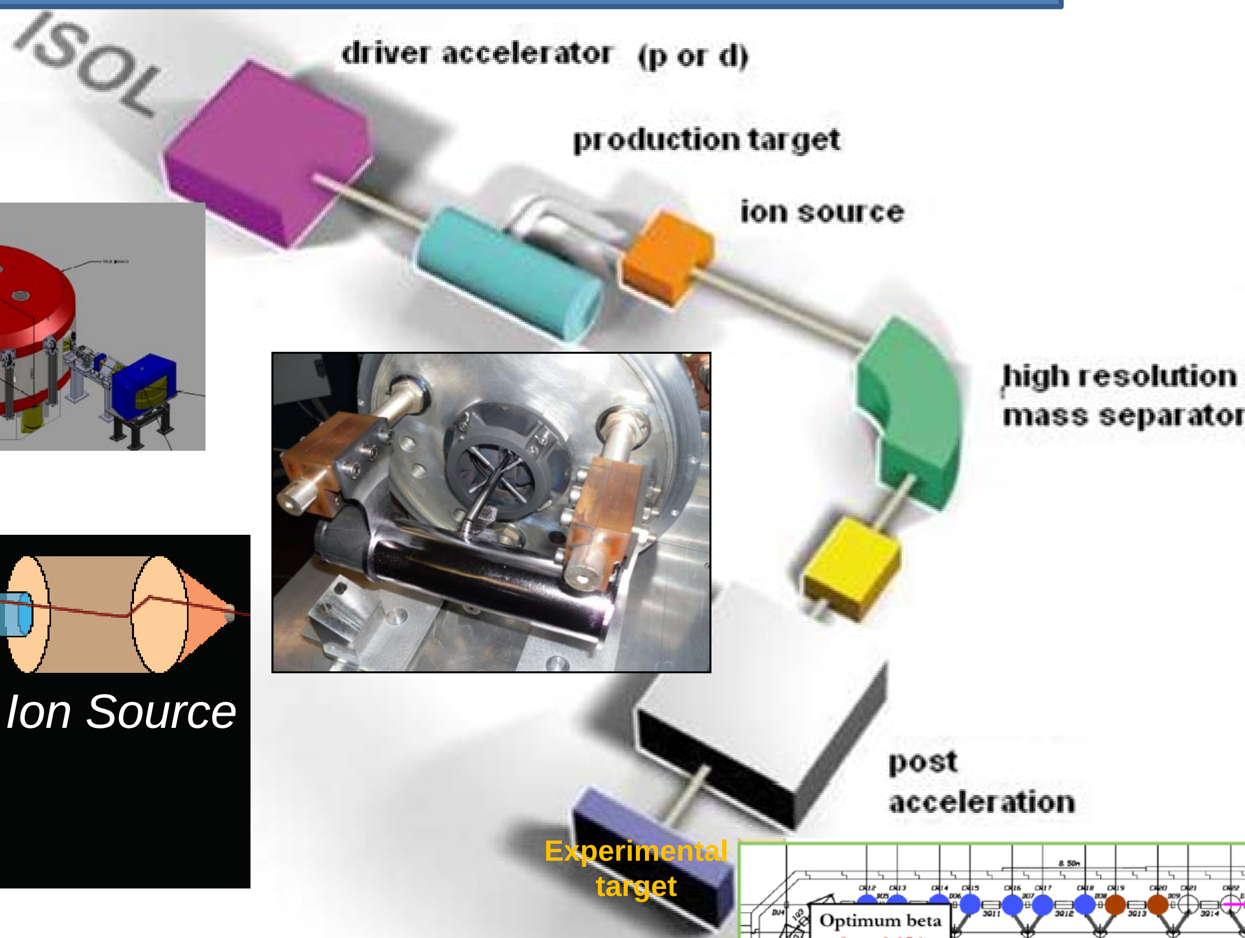
Expected Beam on target:
10600 hours per year

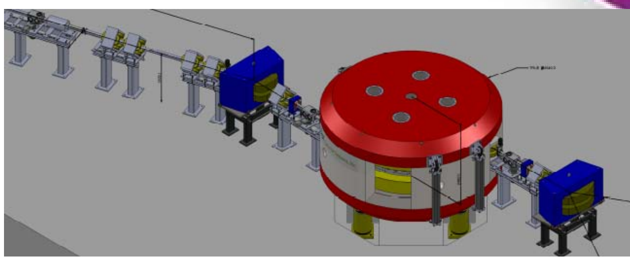
Over 5000 hours/year of proton beam available for applications

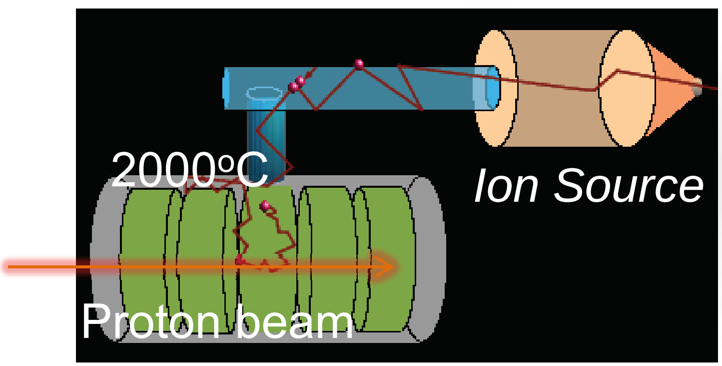
Beam sharing

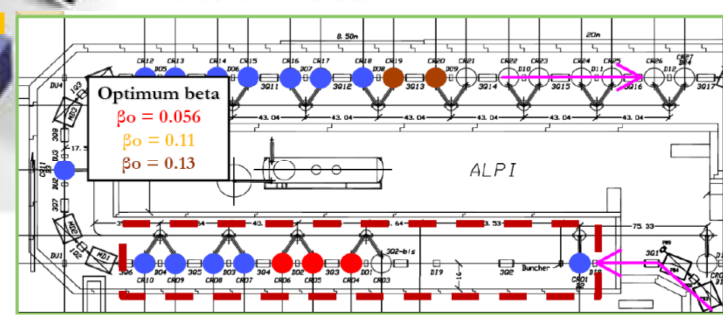
	Proton beam	N.rs of SHIFTS	Beam on target: Total 10600 hours
ISOL 1	300µA 40MeV	10	2800
Irradiation 1	500 µA 70MeV	9	2500
Irradiation 2	500 µA 70MeV	10	2800
ISOL 2	300 µA 40MeV	9	2500
Maintanance		7	7x14x24= 2350
Cyclotron Operation		19	19x12x24= 5462 esperiment 19X2x24= 912 beam preparation

ISOL Radioactive Ion Beam production method









SPES: *DIRECT TARGET ISOL facility*

SPES ISOL facility at LNL

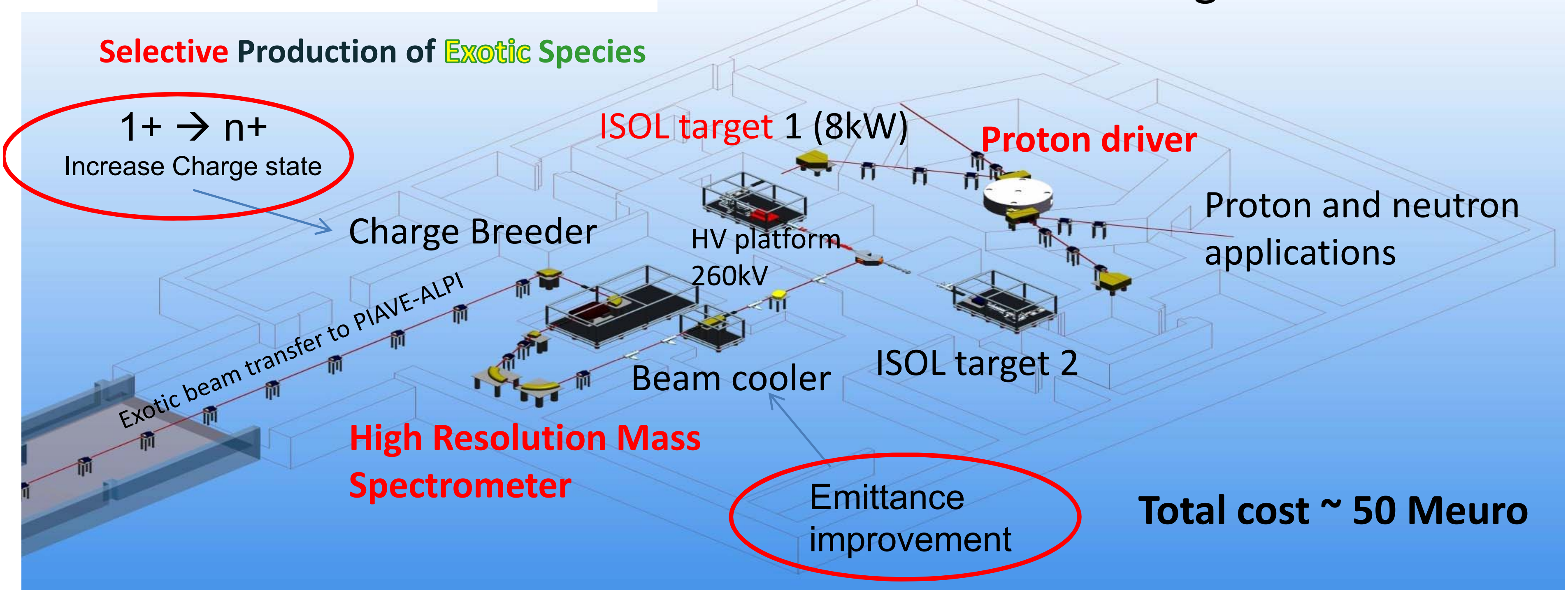
A second generation ISOL facility for **neutron-rich** ion beams and an interdisciplinary research center

SPES exotic beams for science

Proton induced fission on UCx

10^{13} fission/s

8 kW on direct target



ISOL Roadmap in EUROPE

TODAY

10^{12} fission/s ,
2 MeV/n (A=130)

SPIRAL GANIL

ISOLDE CERN

INFN LNS - EXCYT

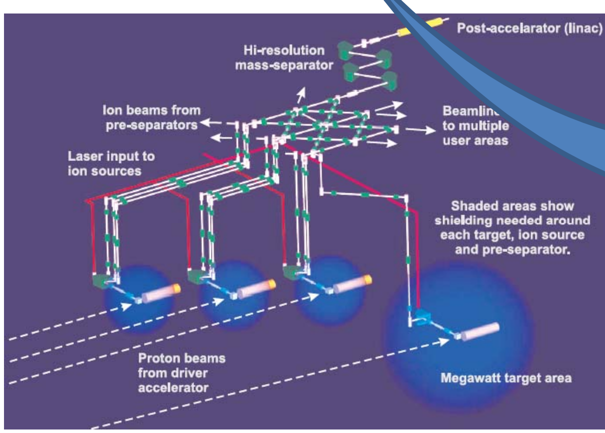
2014-2025

10^{13-14} fission/s
10 MeV/n (A=130)

GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3

HIE ISOLDE

SPES exotic beams for science



EURISOL

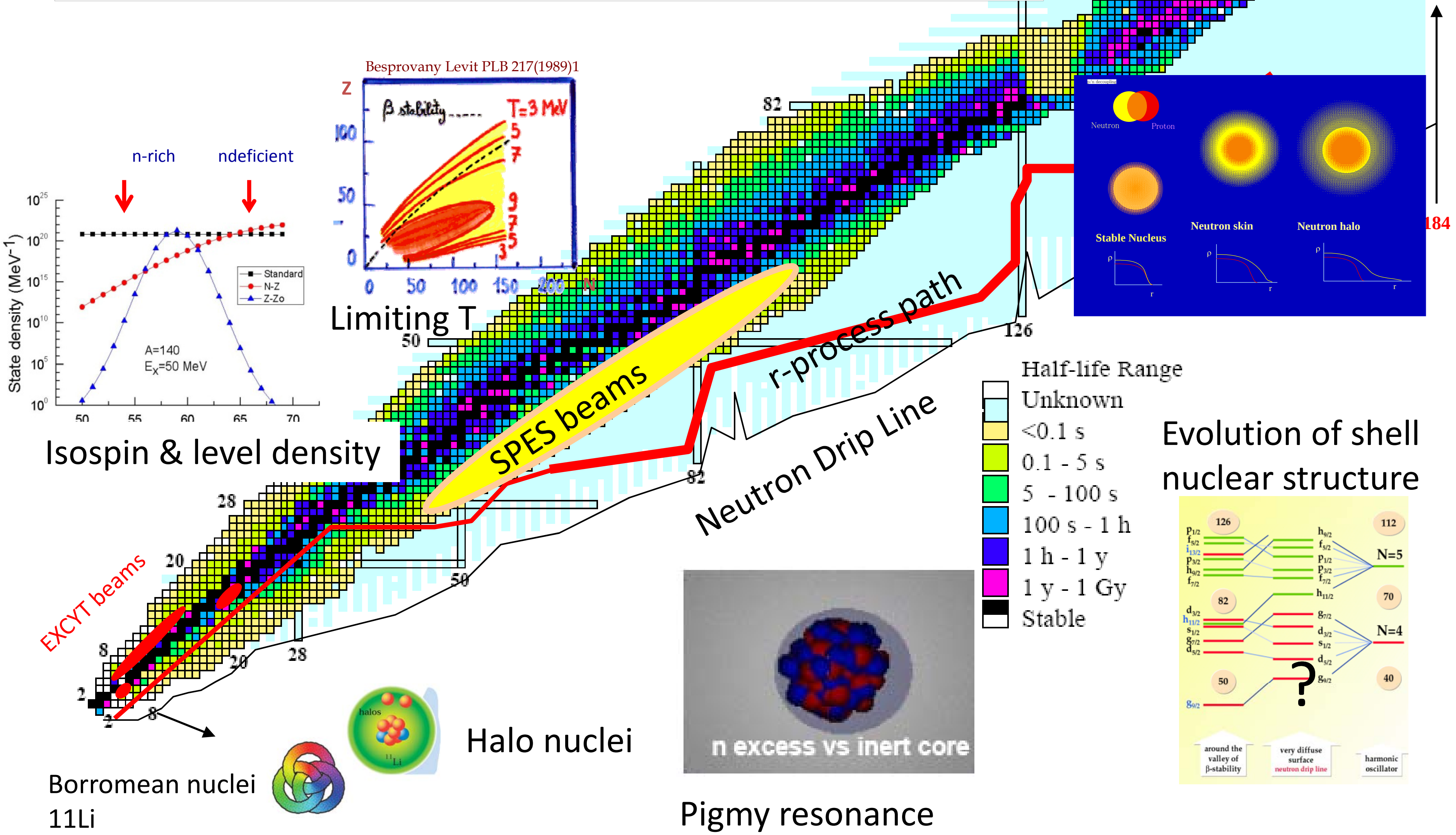
FROM 2025

> 10^{15} fission/s
100 MeV/n (A=130)

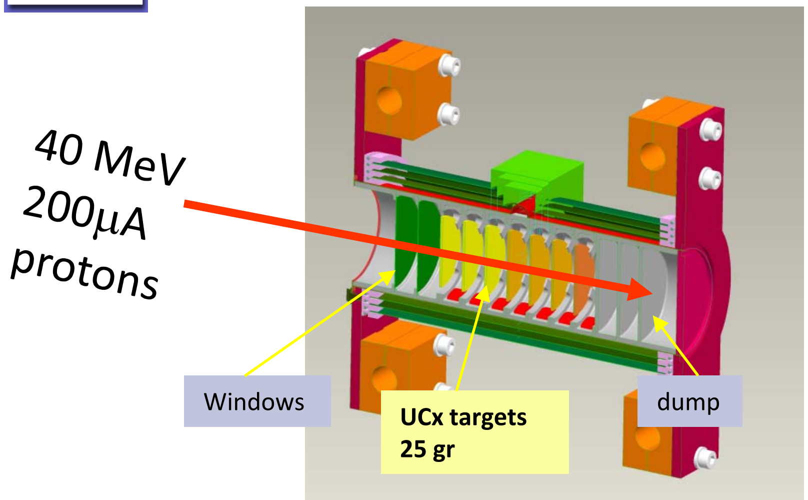
3x 100 kW direct target
1x 5 MW 2-step target

Neutron Rich Isotopes are fission fragments products

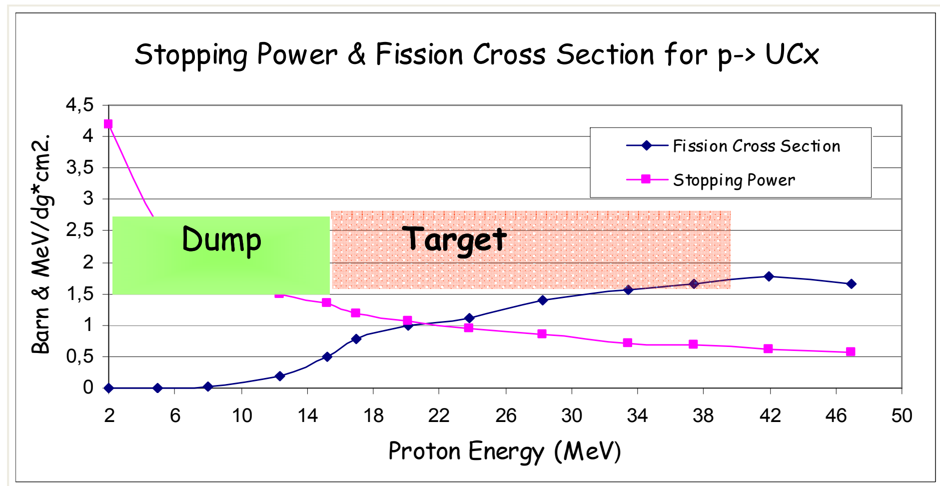
A: 80-160 with UCx target

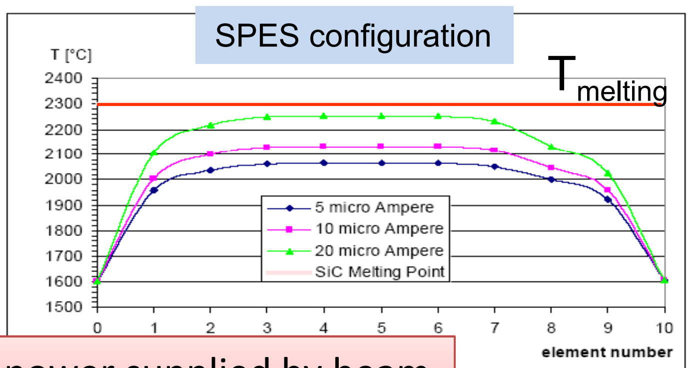


SPES target: operation principle



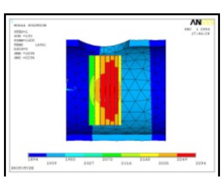
Fission efficiency → 100p per 1.5 FF
~ 200 μA → 10^{13} fissions/sec
Beam power = 40 MeV p x 200 μA = 8 KW

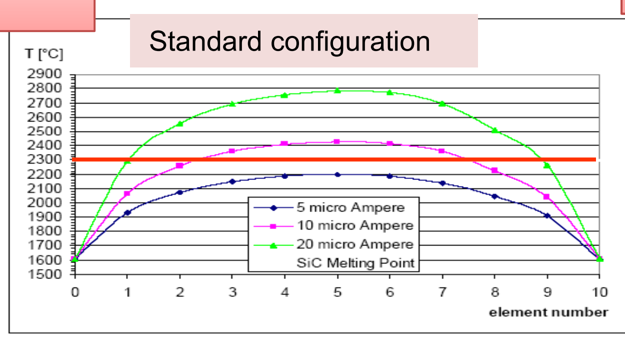




60% power supplied by beam
40% power from heater

© 7 UCx SLICES (ρ=2.5 g/cm3) (active material)
diameter 4cm
1.3 mm thick each (~30gr of UCx)
Power density in UCx = 200W/gr



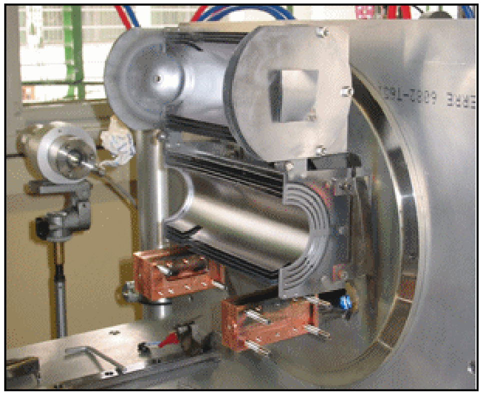


© 3 graphite DUMP
(slowing down protons with low fission cross section and high power density)

Thermal test performed at HRIBF-ORNL

Carbide developments

[Ultra High Temperature Furnaces]



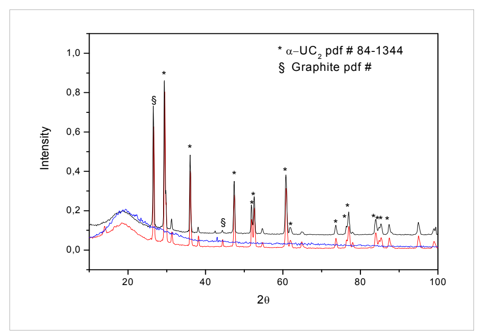
[Carbides production and characterization]

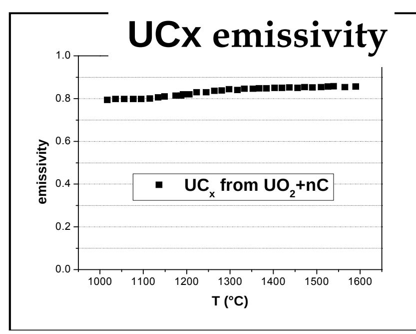
1) Carburization and sintering of carbides
2) Carburization and sintering of UC_x
3) Off-line tests on materials (UHT behaviour)
4) Development of measurement systems i.e. thermal conductivity and emissivity

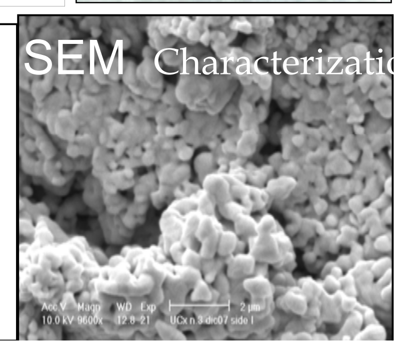
UCx with nanotubes.
Next experiment at HRIBF
October 2011

LabView software controlling the heating/cooling schedule

Engineering the shielding system







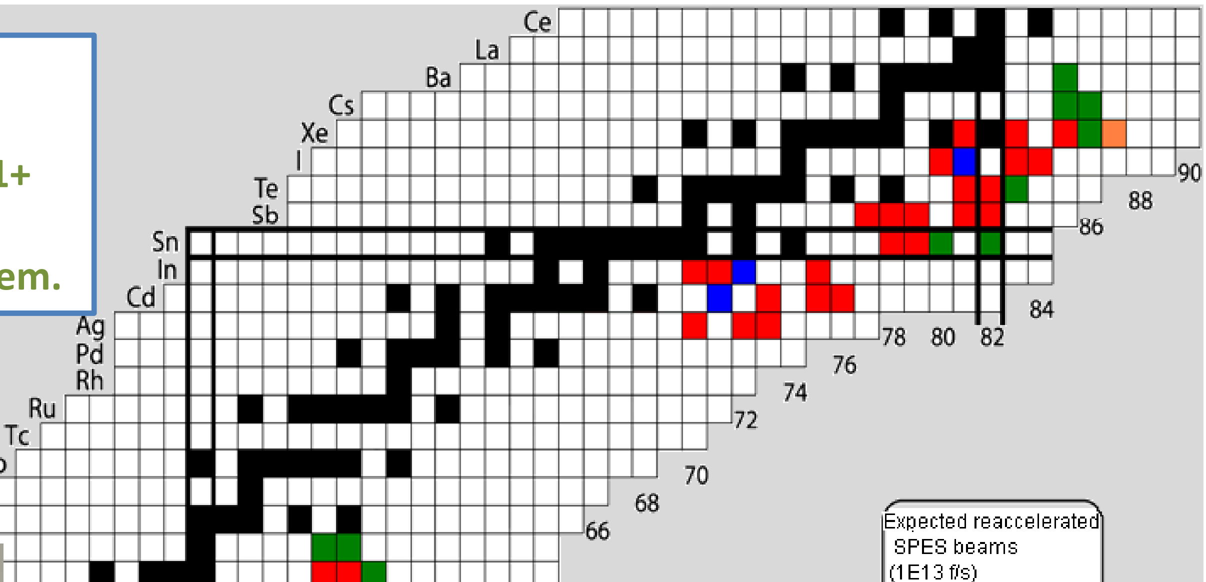
SPES Target
On-line Test experiment at HRIBF

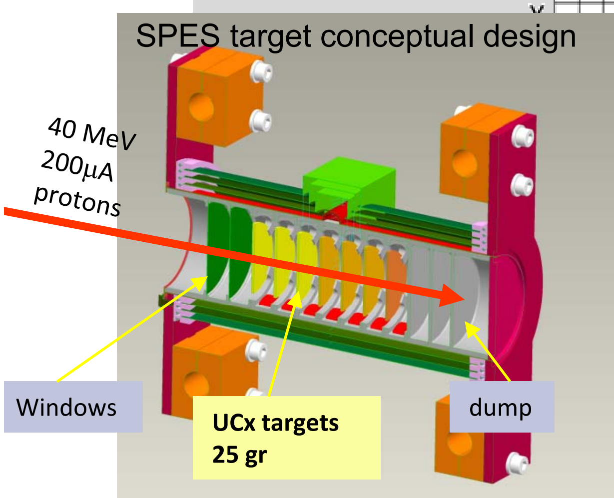
Eur. Phys. J. A (2011) 47: 32 DOI: 10.1140/epja/i2011-11032-5

Neutron-rich isotope production using the uranium carbide multi-foil SPES target prototype

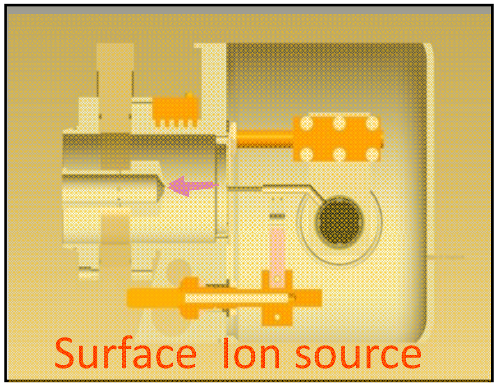
For **expected beam on target,** data are scaled to:
200 microA proton current
2-5% transport efficiency

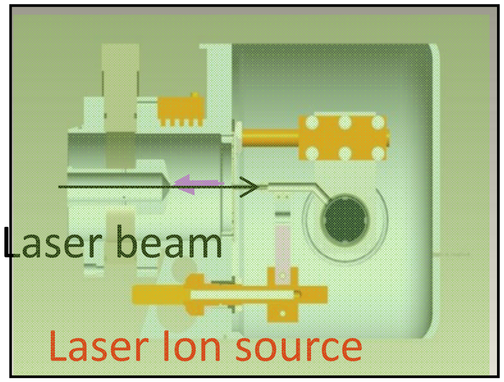
Proton energy = 40MeV
ISOL target operated at 2000°C.
Ionization and extraction with 1+ Plasma Source.
Isotopes measured at tape system.

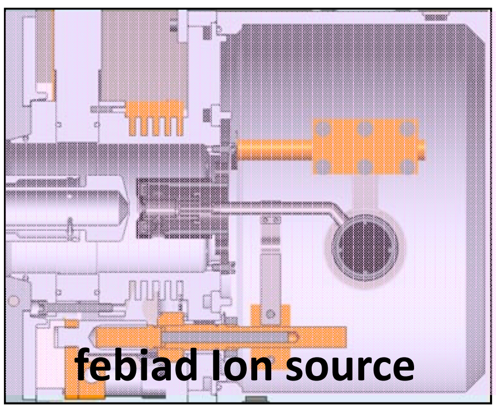




ION sources







Elements with bad volatility (NOT EXTRACTED)

Surface Ionization Method (Alkaline)

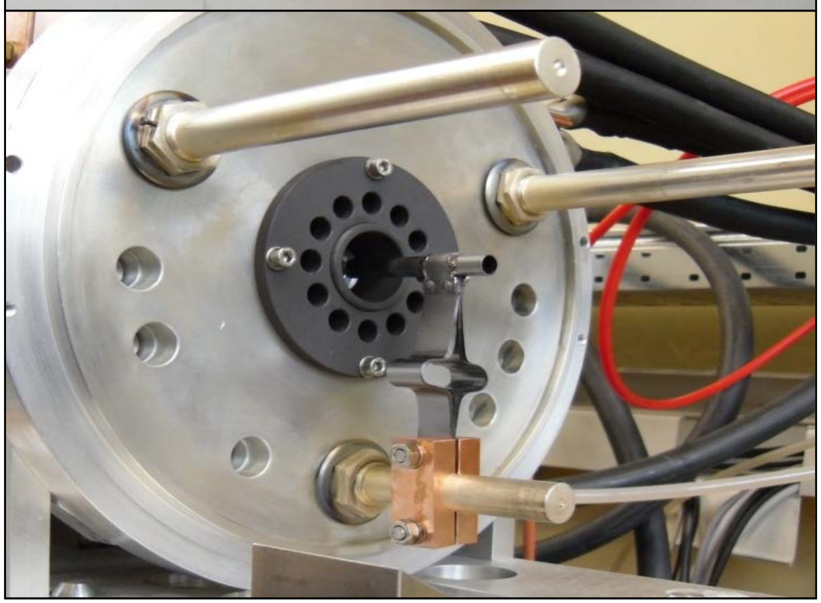
Photo Ionization Method

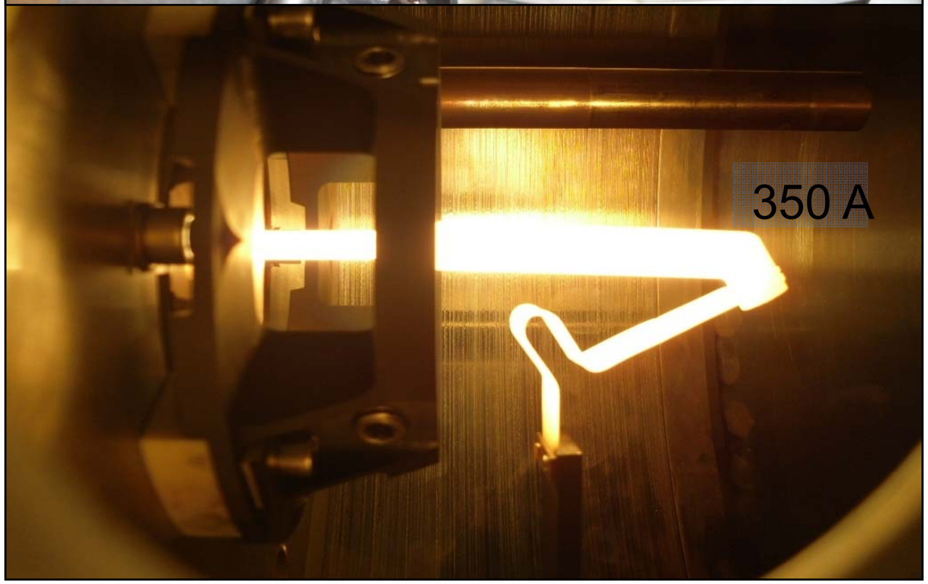
Plasma Ionization Method (Halogen)

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	57 La	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	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112						

Main fission 238U fragments

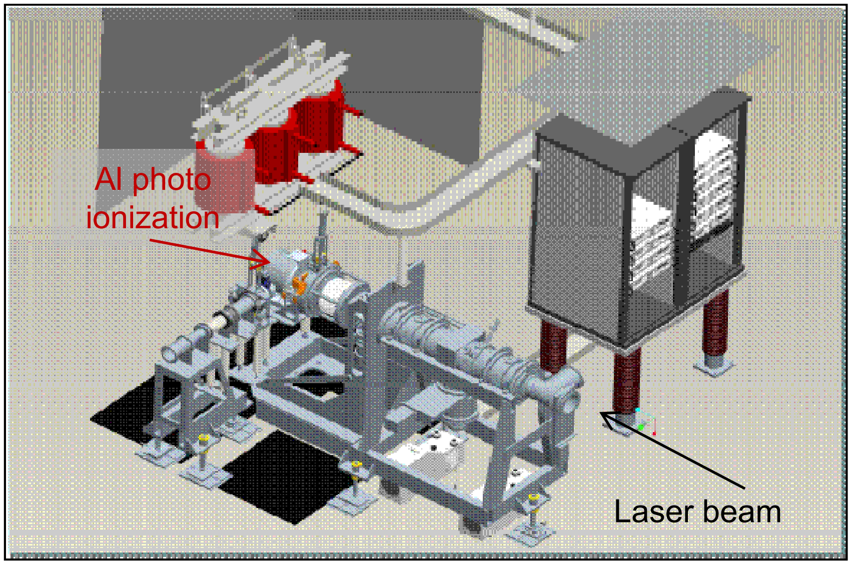
The SPES Ion Sources

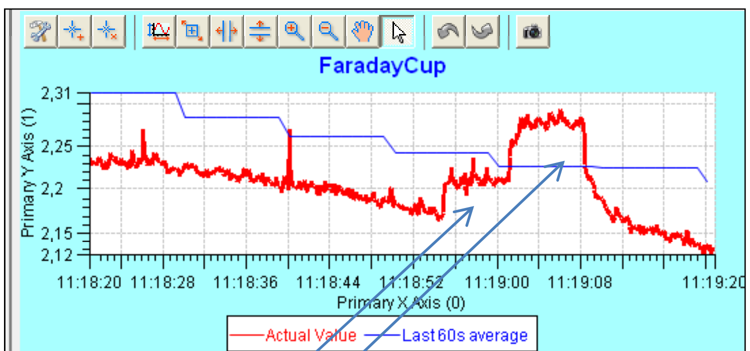




Next laser test at LNL with excimer

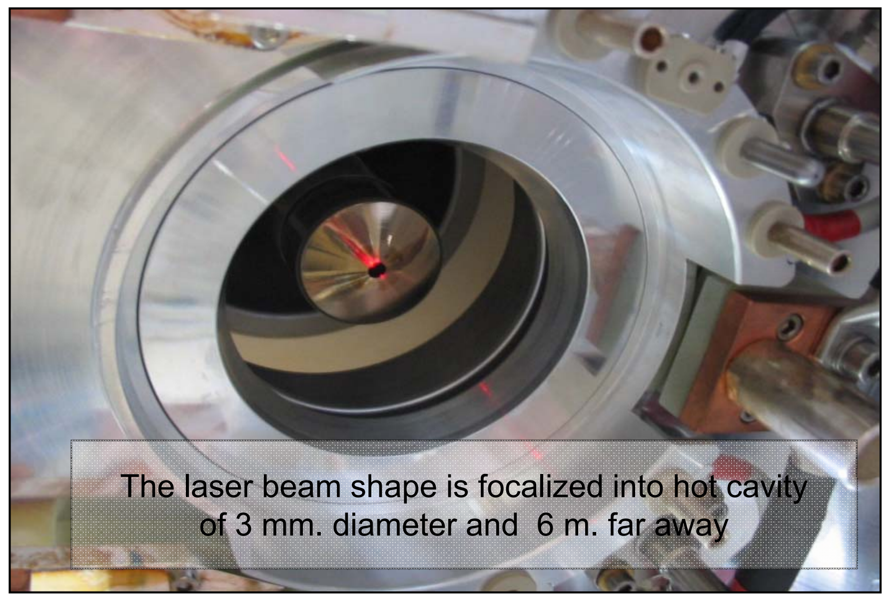
Selective Aluminum ionization with a single wavelength





20 Hz ; 12 mJ per pulse

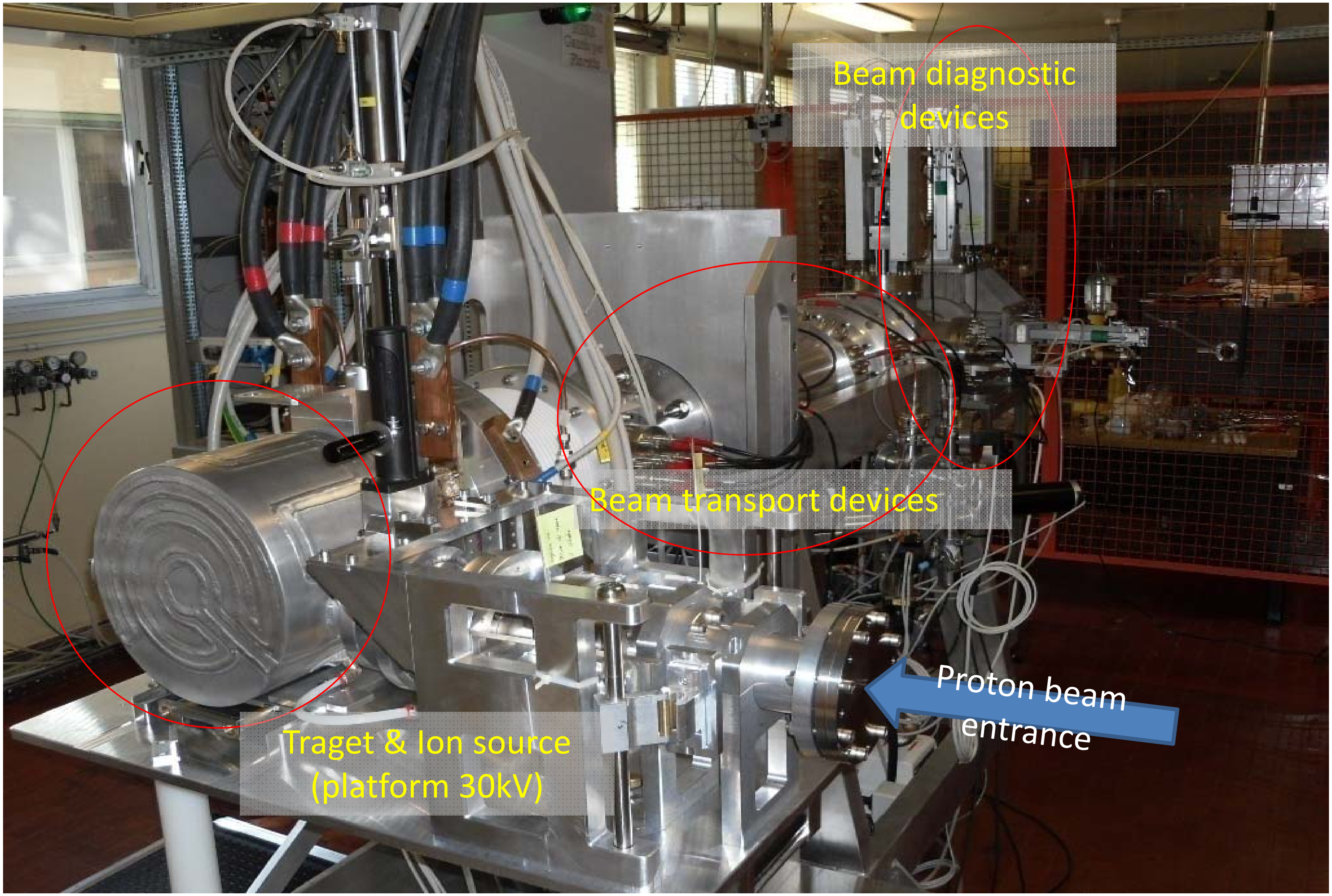
20 Hz ; 20 mJ per pulse



Preliminary results

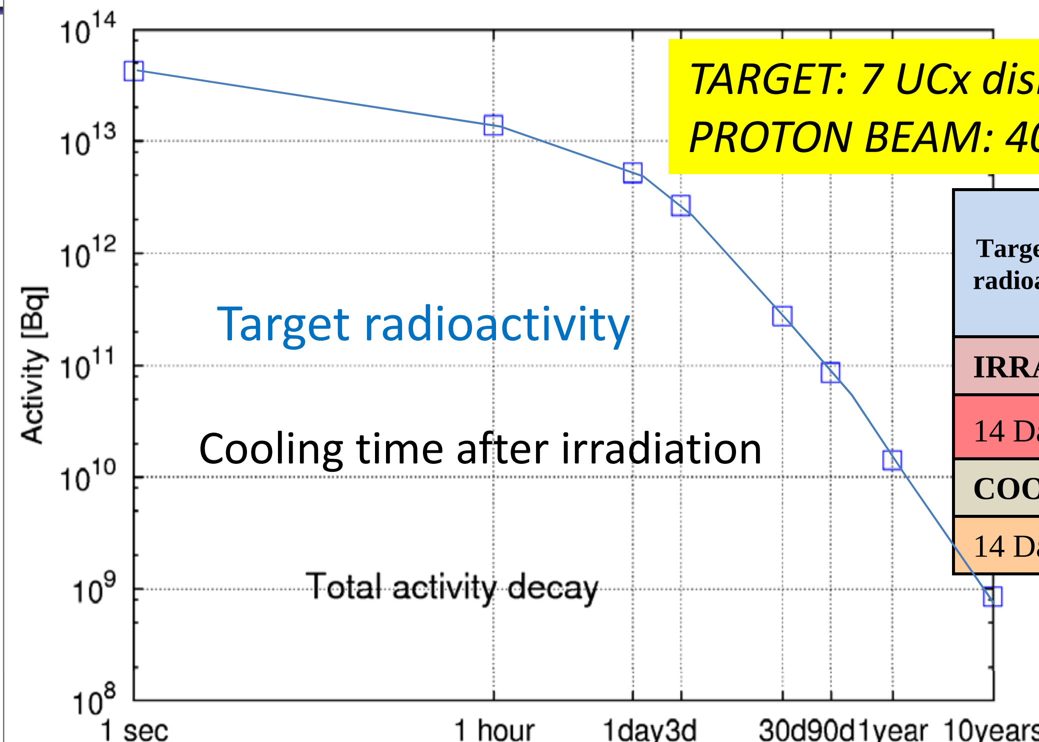
WP03: Ionization measurements

Front end running since June ‘10

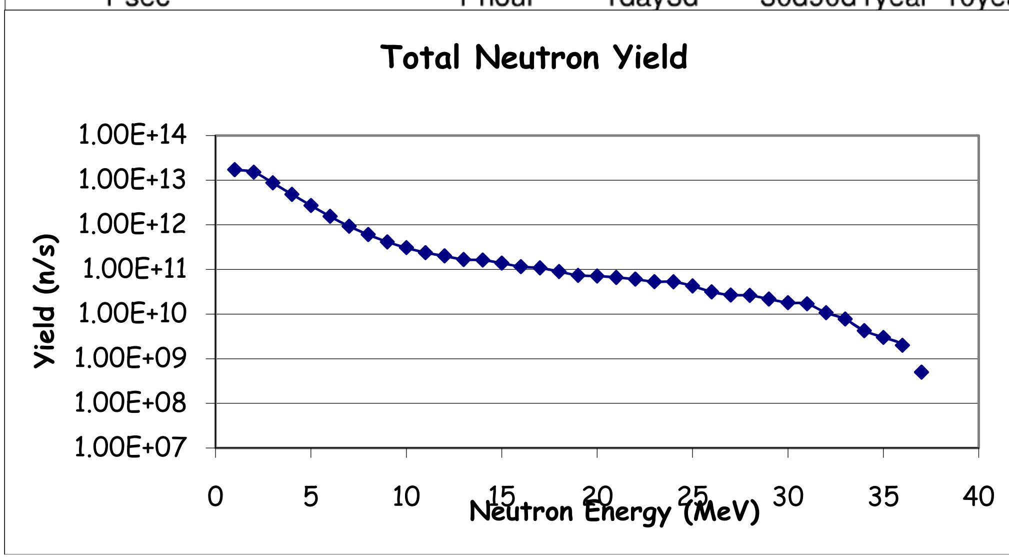


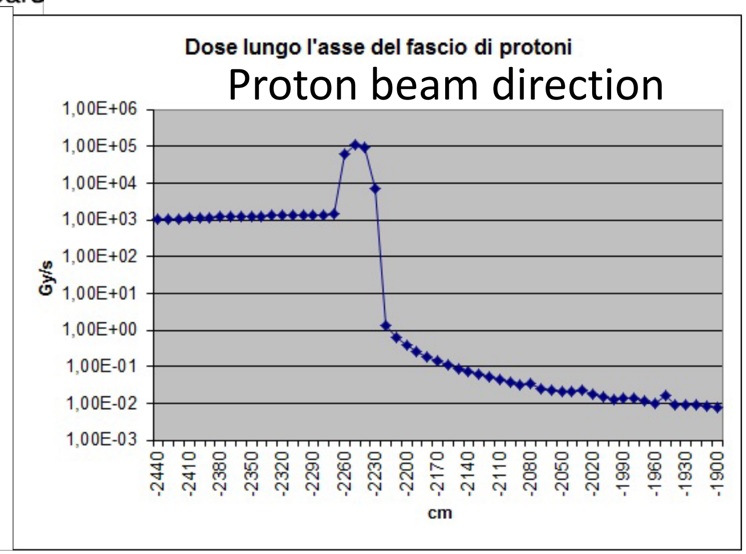
Target activation and neutron production

TARGET: 7 UCx disks + 3 graphite
PROTON BEAM: 40 MeV, 200 μA



Target radioactivity	Activity (Bq)	Total Dose (Sv/h) at 1 m	Total Dose (Sv/h) at 2 m	Total Dose (Sv/h) at 2 m with 2cm of lead
IRRADIATION				
14 Days	2E+13	2.1E+00	5.2E-01	
COOLING				
14 Days	7E+11	4.1E-02	1.0E-02	**1 E-03**





Spettri di neutroni prodotti dal fascio di protoni a 70 MeV su diversi bersagli "spessi"

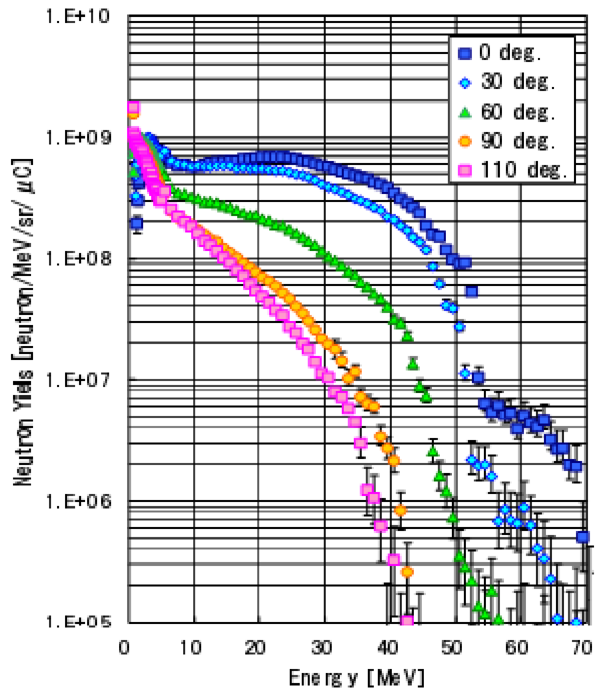


Figure 4: Thick target yield for C(p,xn) at 70 MeV

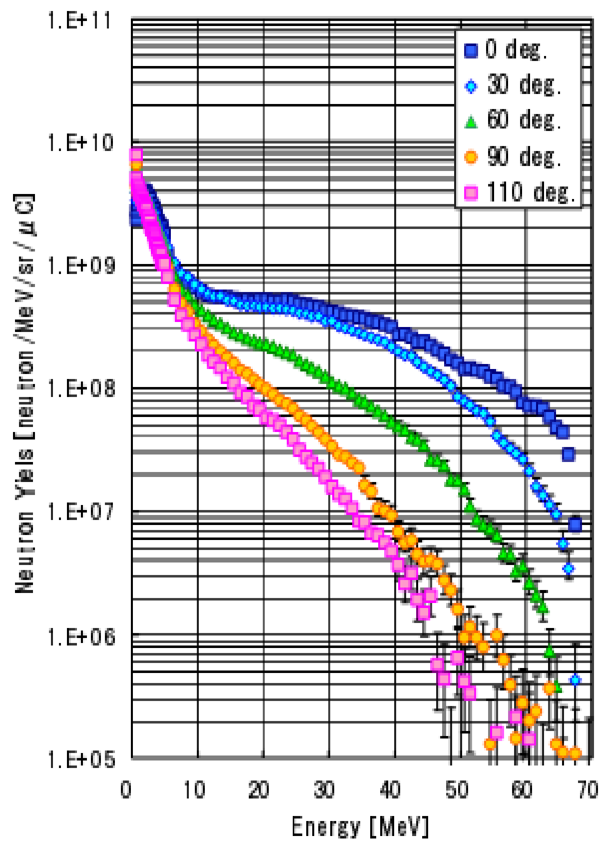


Figure 8: thick target yield for Al(p,xn) at 70 MeV

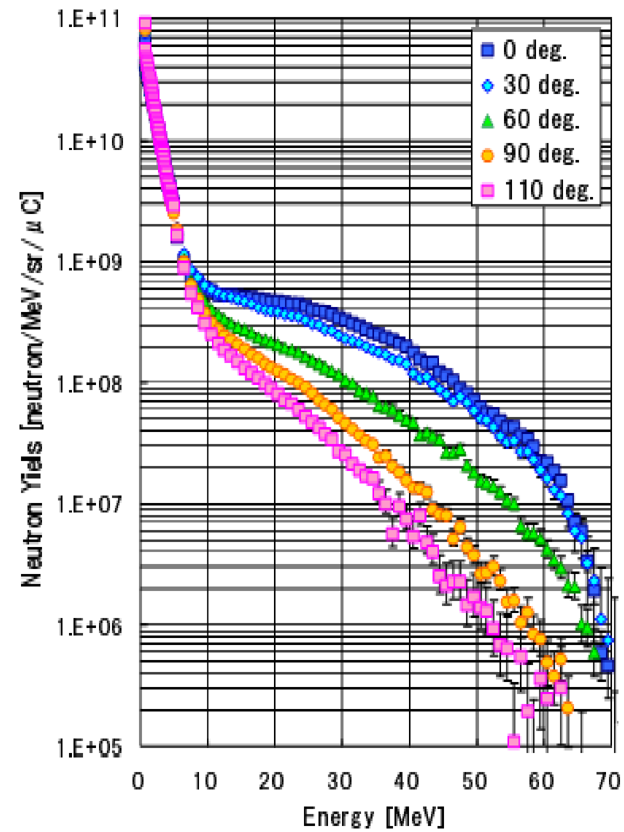


Figure 14: Thick target yield for W(p,xn) at 70 MeV

Neutron facility at the SPES Cyclotron

exotic beams for science

Integral neutron production at SPES Cyclotron

Proton beam= 70 MeV, 500 μA

Target = W 5mm

Energy region (MeV)	Sn (n/s) $\sim 6 \cdot 10^{14}\ s^{-1}$	**Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)**	**Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)**
1 < E < 10	$\sim 5 \cdot 10^{14}\ s^{-1}$	5×10^{8}	3×10^{13}
10 < E < 50	$\sim 1 \cdot 10^{14}\ s^{-1}$	1×10^{8}	$6x10^{12}$

LIFAN: **Single Event Effect** and DIRECT proton irradiation facility

FARETRA: Moderated neutron facility with Neutron spectra similar to Gen IV reactors

Research Accelerator Driven System:
fast neutrons subcritic system based on LEU and lead moderator. 200kW. Proposal under discussion.

UCANS

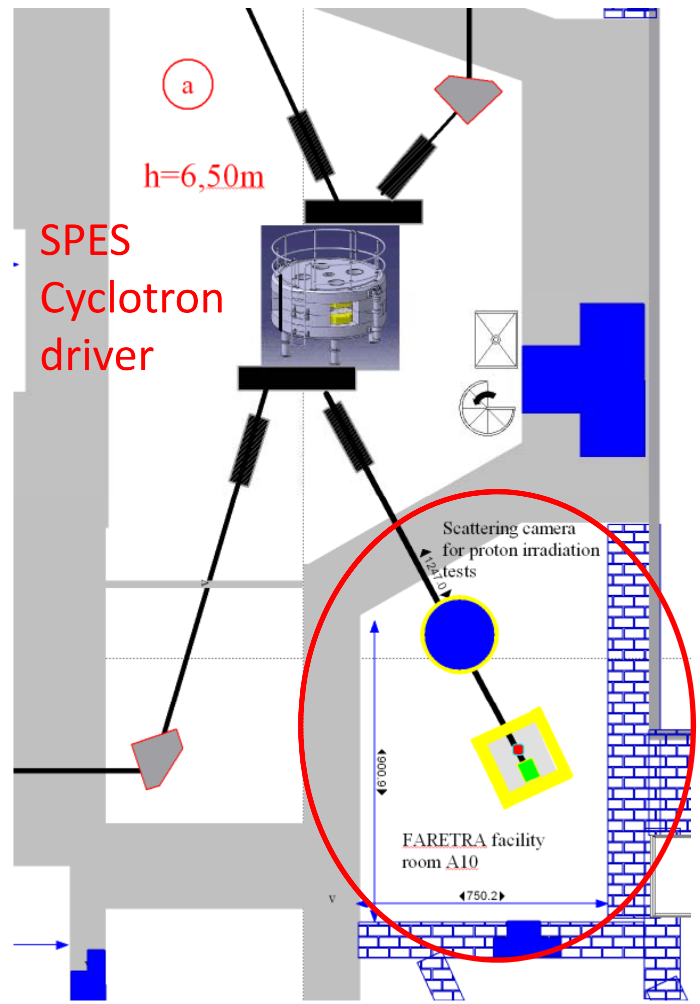
Union for Compact Accelerator-based Neutron Sources

Second Meeting:
Indiana University, Bloomington
July 5-8, 2011

FARETRA

FAst **RE**actor simulator for **TRA**nsmutation studies

Proposal: making use of the SPES cyclotron proton beam (40-70 MeV) on a (Be,W o Pb) neutron converter and of a proper neutron spectrum shifter system , produce a GenIV-like fast neutron spectrum to start cross sections integral measurements on actinides fission fragments and structural materials.

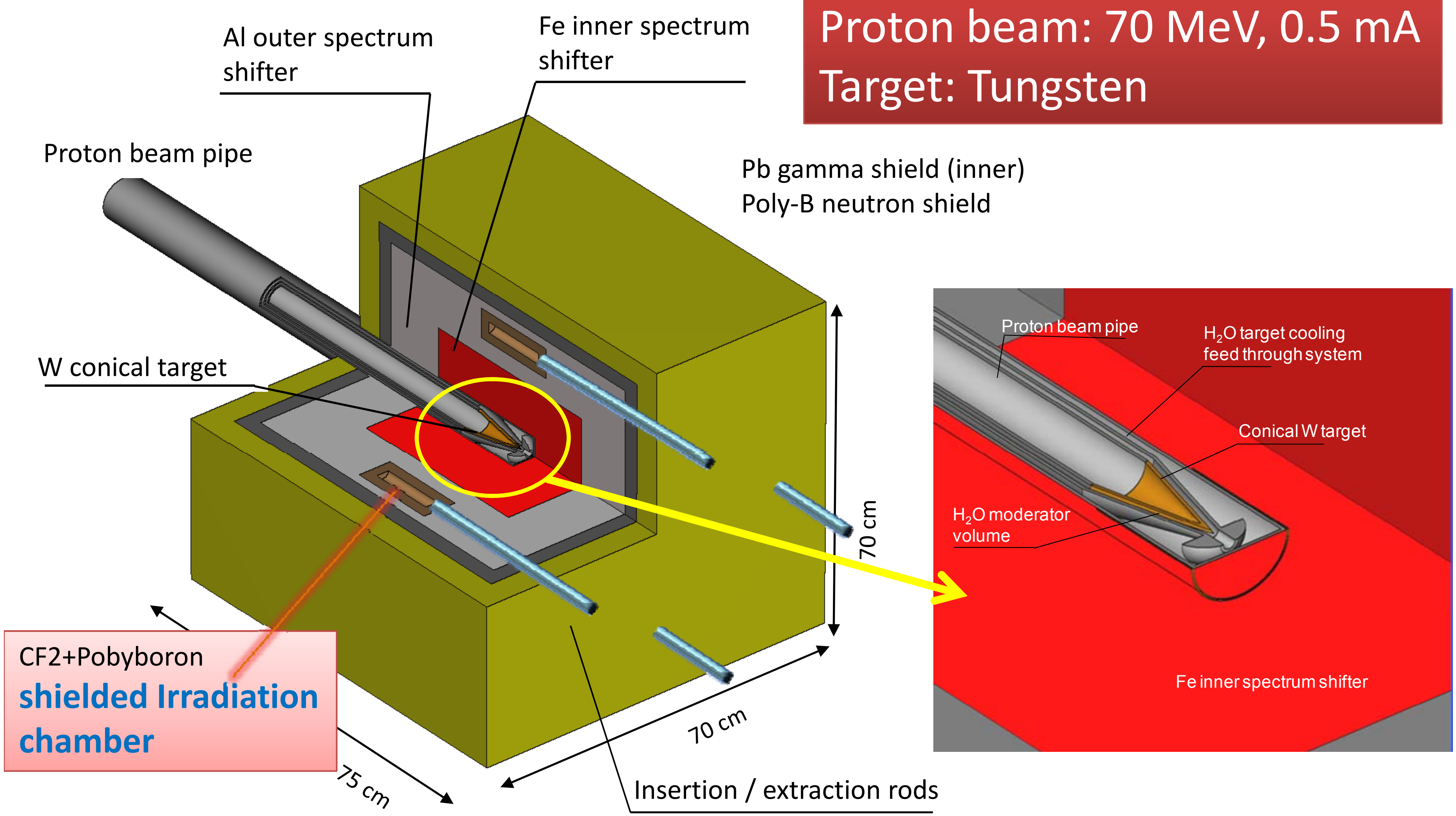


1 μgr ^{238}Pu (87 y, 0.6 MBq) σ(n,f) ~ 1 b

Expected Transmutation Rate = 20 c/s

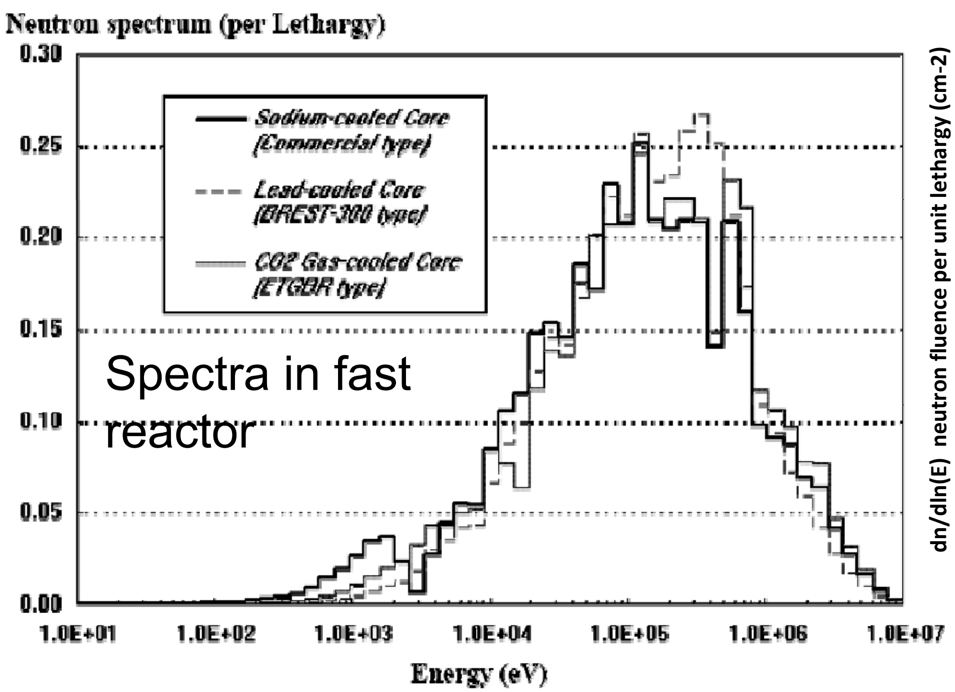
Preliminary modeling of FARETRA facility

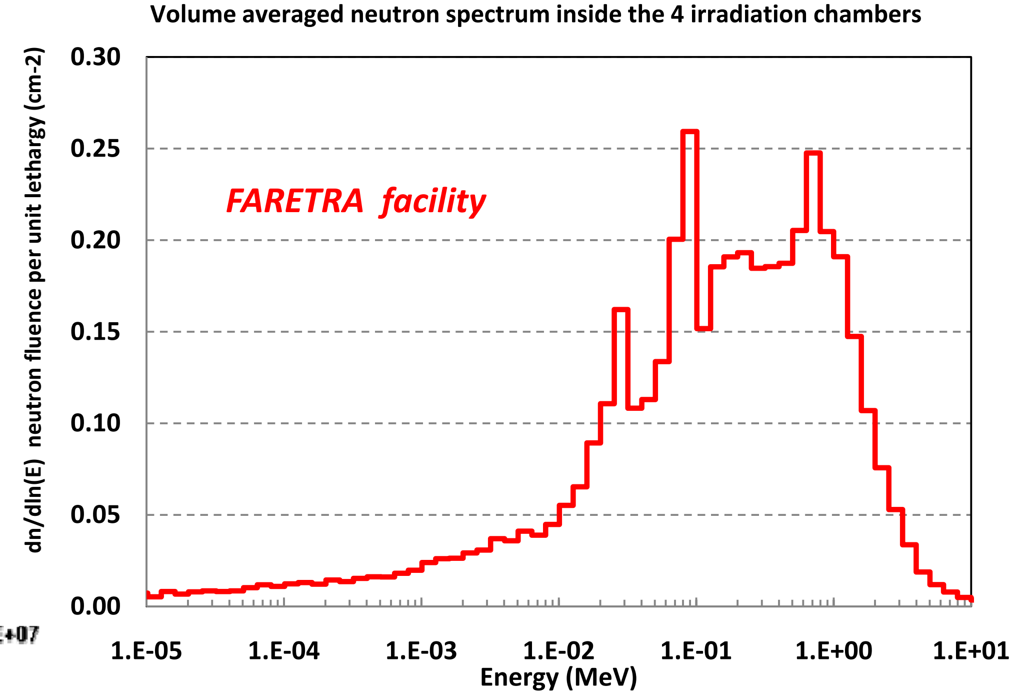
Proton beam: 70 MeV, 0.5 mA
Target: Tungsten



Neutron spectrum inside irradiation chamber MCNPX calculation results (Preliminary)

Accelerator-driven Systems (ADS) and Fast Reactors (FR) in Advanced Nuclear Fuel Cycles: A comparative study
NEA-OEDC, 2002





Moderation Efficiency (10 eV -10 MeV) : ~ $5\cdot10^{-4}$

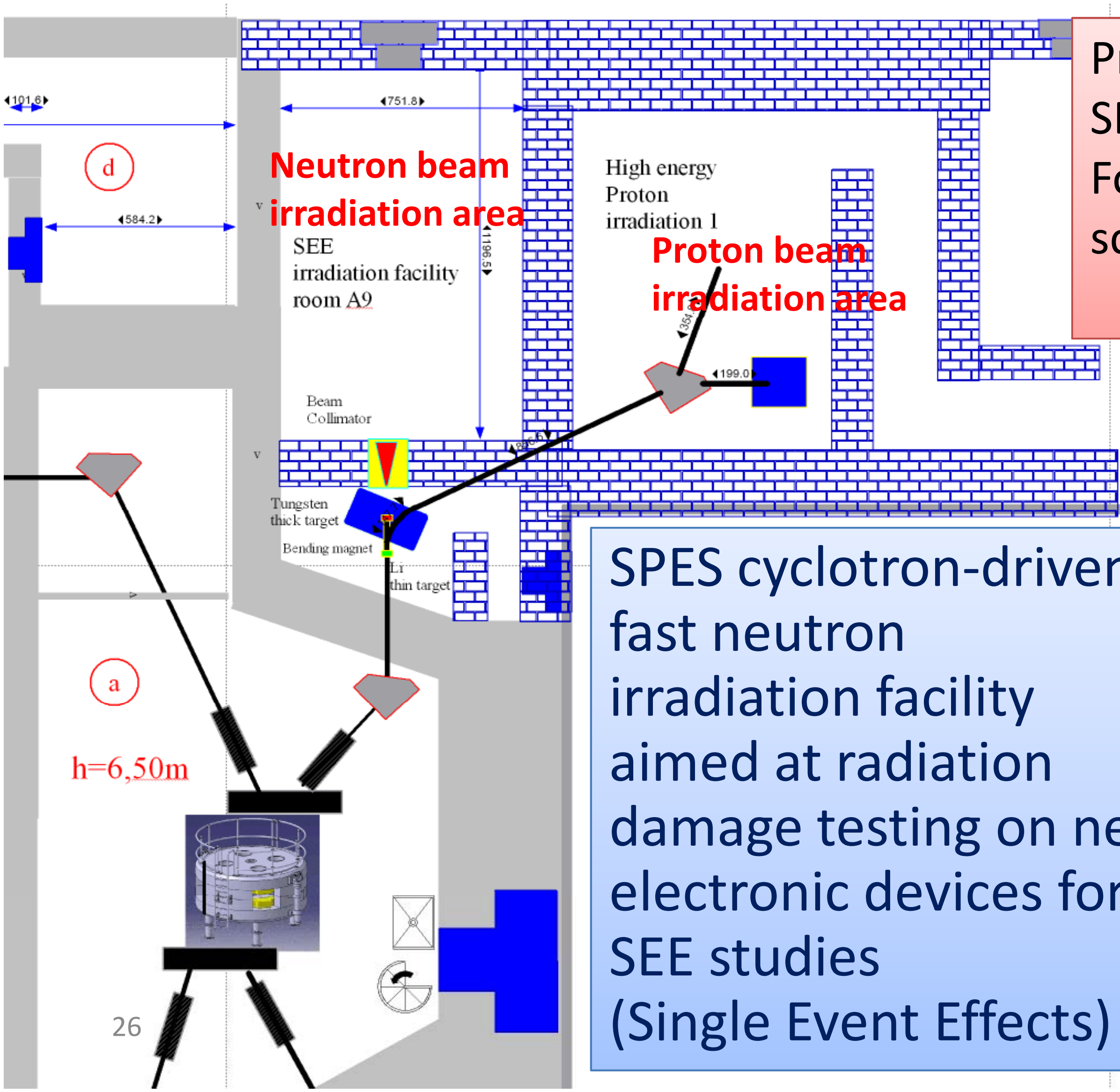
Integral neutron flux: Φ_n= ~ $1.0\cdot10^{10}cm^{-2}s^{-1}$

See details on J.Esposito POSTER 13

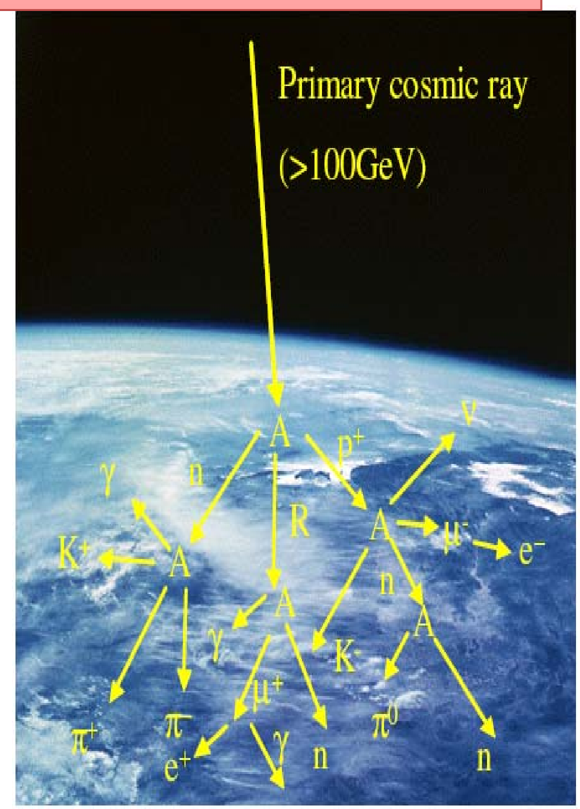
The LIFAN PROJECT

The **L**egnaro **I**ntense **FA**st **N**eutron Facility

Preliminary studies on a SEE irradiation facility at LNL Following the ANITA facility scheme at Zveldeberg

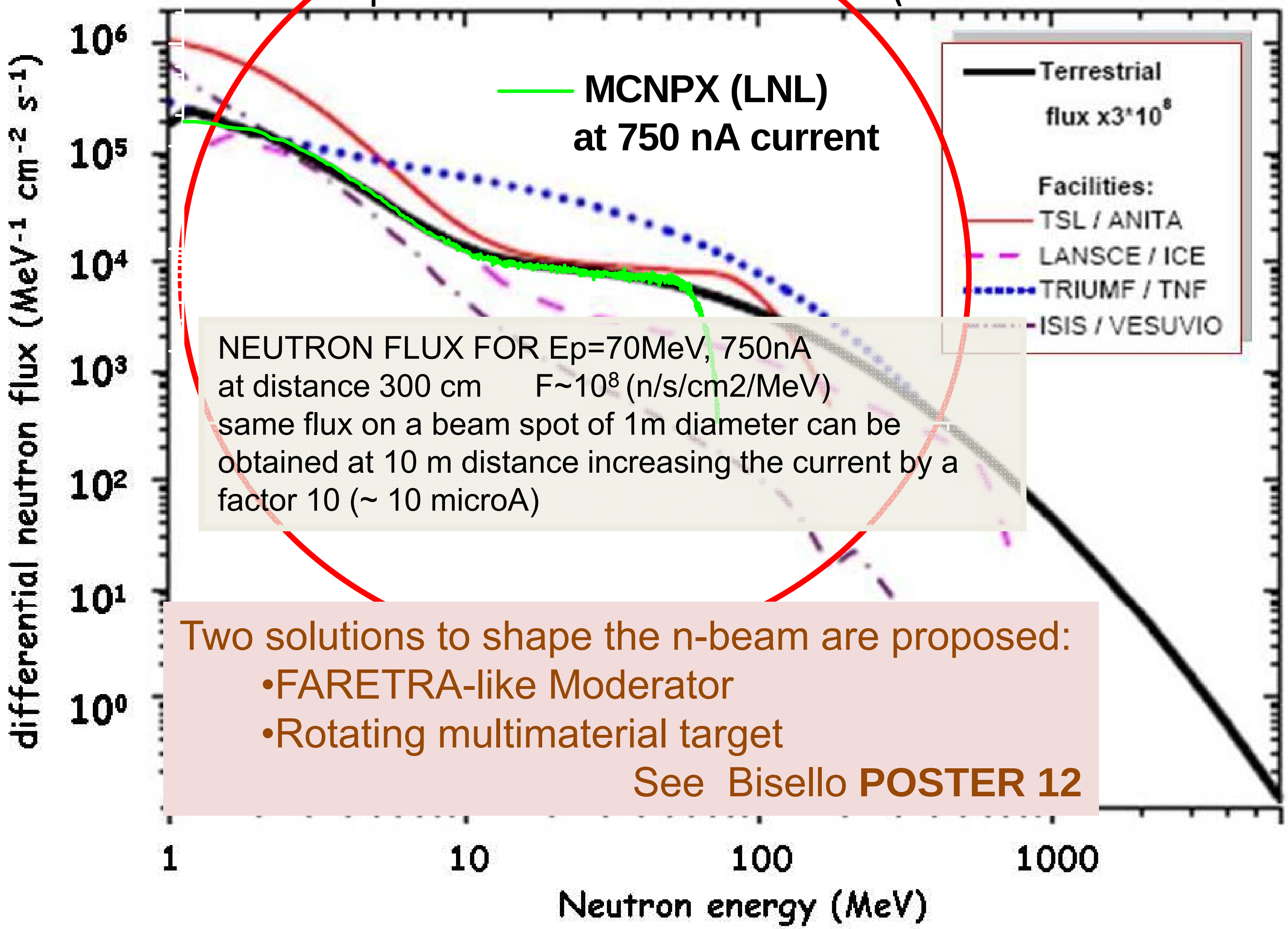


SPES cyclotron-driven fast neutron irradiation facility aimed at radiation damage testing on new electronic devices for SEE studies (Single Event Effects)



The LIFAN PROJECT

Flux comparison with other facilities (3 m distance from the target)



NEUTRON FLUX FOR Ep=70MeV, 750nA
at distance 300 cm F~10^8 (n/s/cm2/MeV)
same flux on a beam spot of 1m diameter can be obtained at 10 m distance increasing the current by a factor 10 (~ 10 microA)

Two solutions to shape the n-beam are proposed:

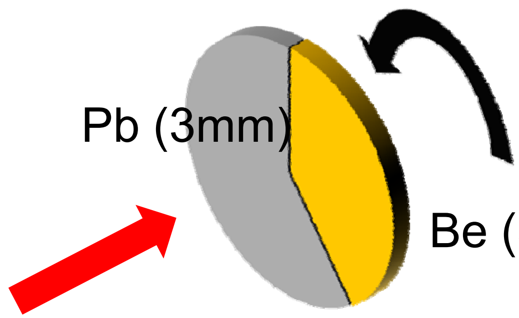
- FARETRA-like Moderator
- Rotating multimaterial target

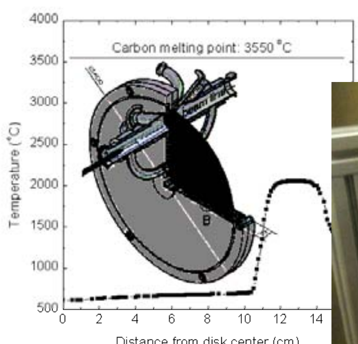
See Bisello **POSTER 12**

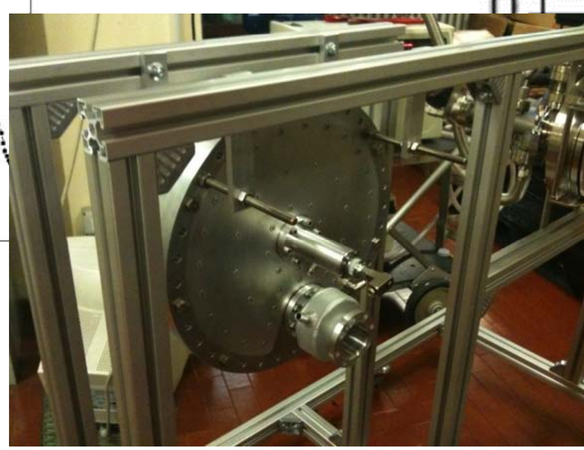
The White Spectrum Neutron Source

Our method: the desired neutron spectra is composed by adding neutron spectra coming from different target materials

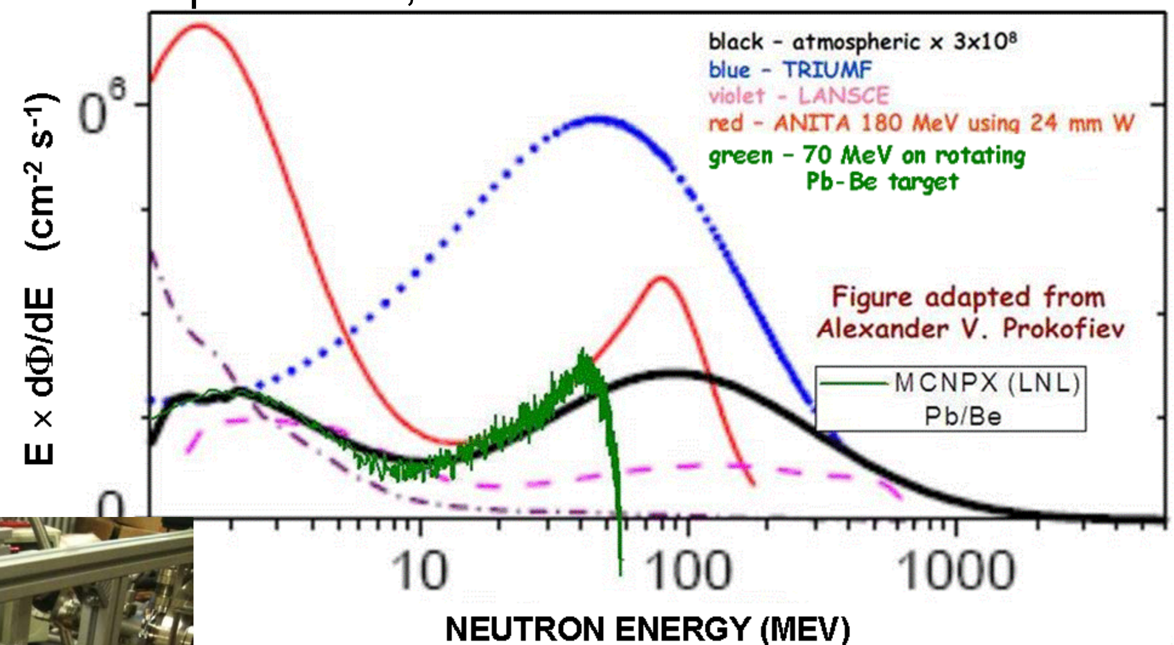
- rotating Pb/Be *thin* production target: no moderator needed







Neutron spectrum calculated at 3 m distance
Ep=70 MeV, 750nA



P.F.Mastinu

conclusions

- The SPES project is in the construction phase. Commissioning is expected for 2015.
- The proton driver accelerator allows to operate two targets at the same time
- Both the ISOL facility and an applicaion facility can run in parallel
- SPES project will offer the possibility to develop an accelerator based neutron facility at LNL
- UCANS is the right reference community
- We hope to become an “operative” partner soon.