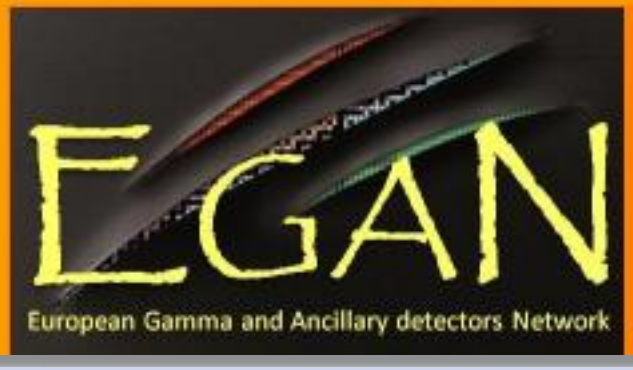




EGAN 2014 Workshop

23-26 June 2014

Europe/Berlin timezone

# AGATA Beyond 2016

# Presentation from LNL

**Presentation based on the letter from the LNL director, written in support to the Italian community request.**

Angela Bracco

# Outline

- **The LNL laboratory in the next years**

**The construction of the SPES facility for radioactive beams beams and installations**

- **The letters of intent for physics at SPES**

- **Hosting AGATA 2019-2012**

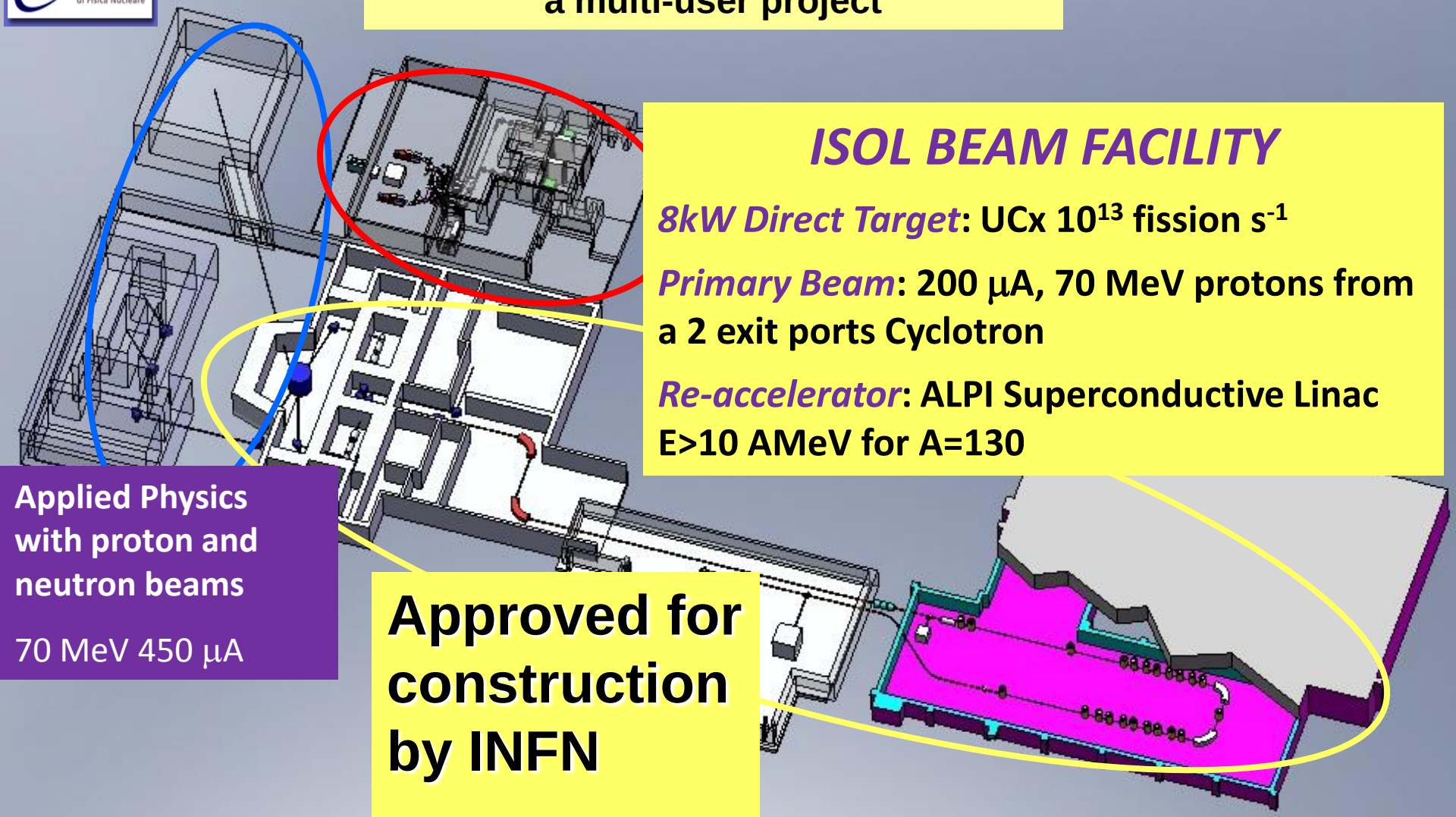
**Conclusions**

# The SPES Project @ LNL

## a multi-user project

# The SPES Project @ LNL

**a multi-user project**



## *ISOL BEAM FACILITY*

*8kW Direct Target*: **UCx $10^{13}$ fission $s^{-1}$**

*Primary Beam*: **200 μA, 70 MeV protons from a 2 exit ports Cyclotron**

*Re-accelerator*: **ALPI Superconductive Linac E>10 AMeV for A=130**

**Applied Physics with proton and neutron beams**

70 MeV 450 μA

**Approved for construction by INFN**

**First beams in 2017**

# The goal of SPES

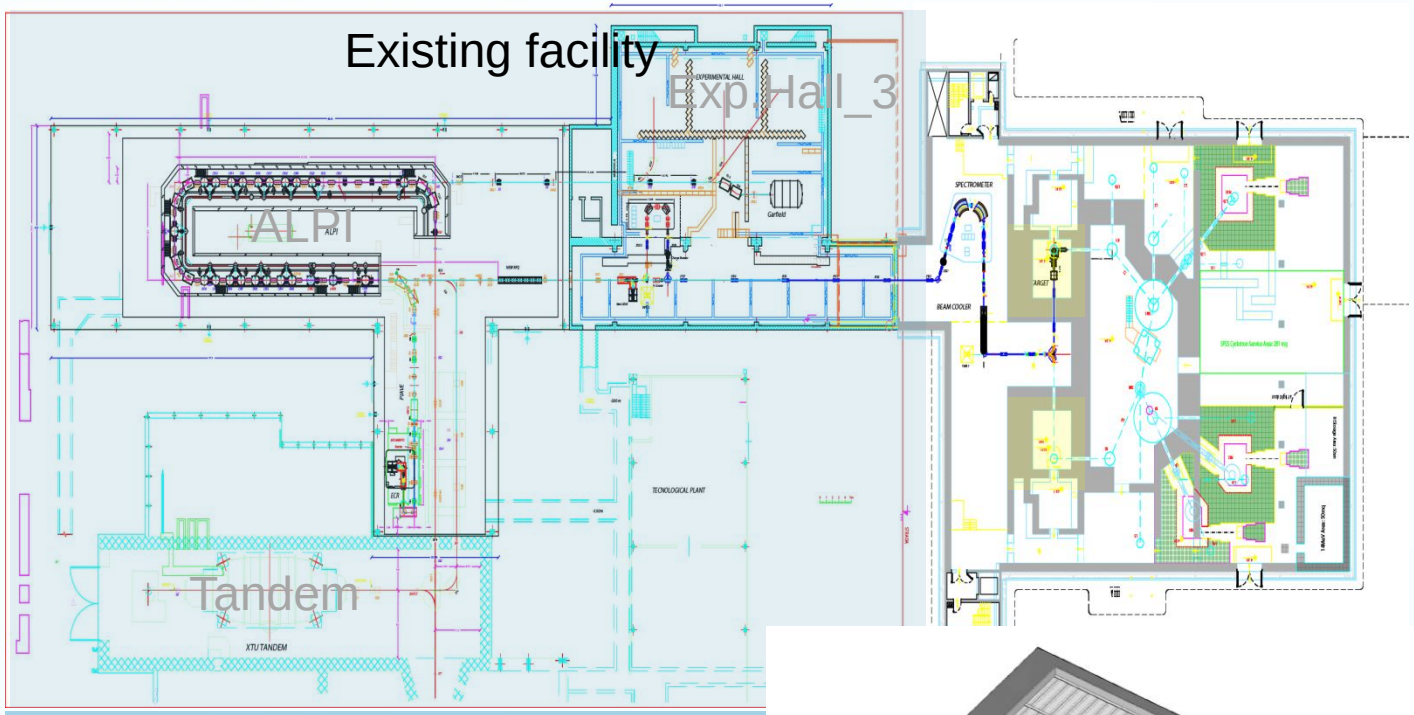
- **S**elective **P**roduction of **E**xotic **S**pecies
- Optimized use of the two exits high current proton driver

production of re-accelerated neutron-rich exotic beams
**$10^{13}$ fission/s in-target production, and re-acceleration at 10*A MeV (A=132)**

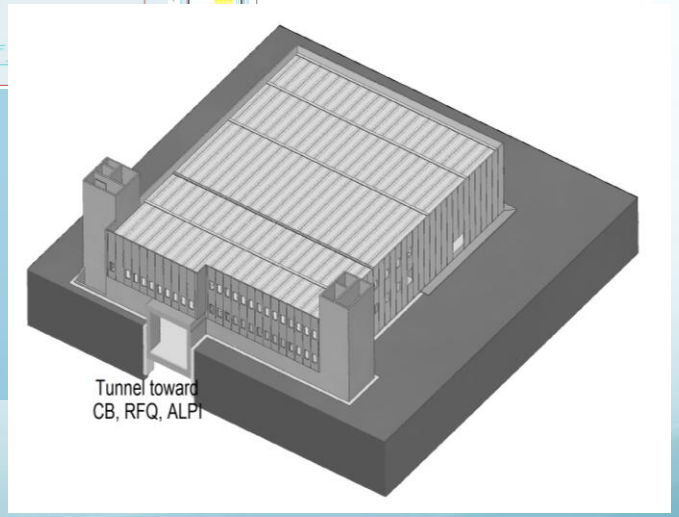
Radioisotope production & Medical applications
**innovative radiopharmaceuticals (e.g. Sr-82, Cu- 64, Cu-67)**

Fast neutron production & material applications: Atmospheric neutron spectra, QMN
**Single Event Effect, neutron capture**

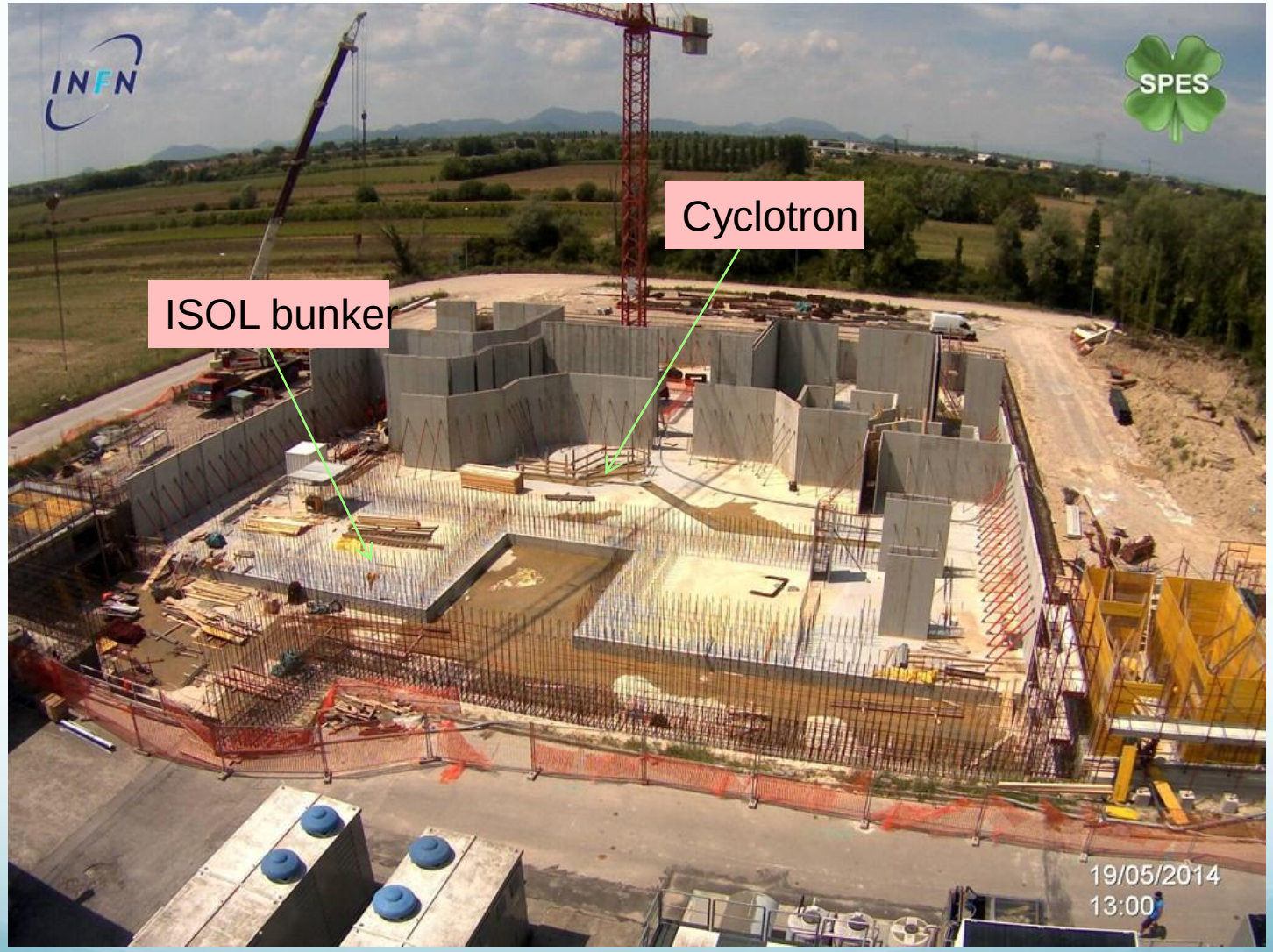
# SPES Facility Layout




- Accelerator system at **underground level** to match existing ALPI beam line
- **2 ISOL bunkers** for redundance and optimal operation



# SPES building under construction

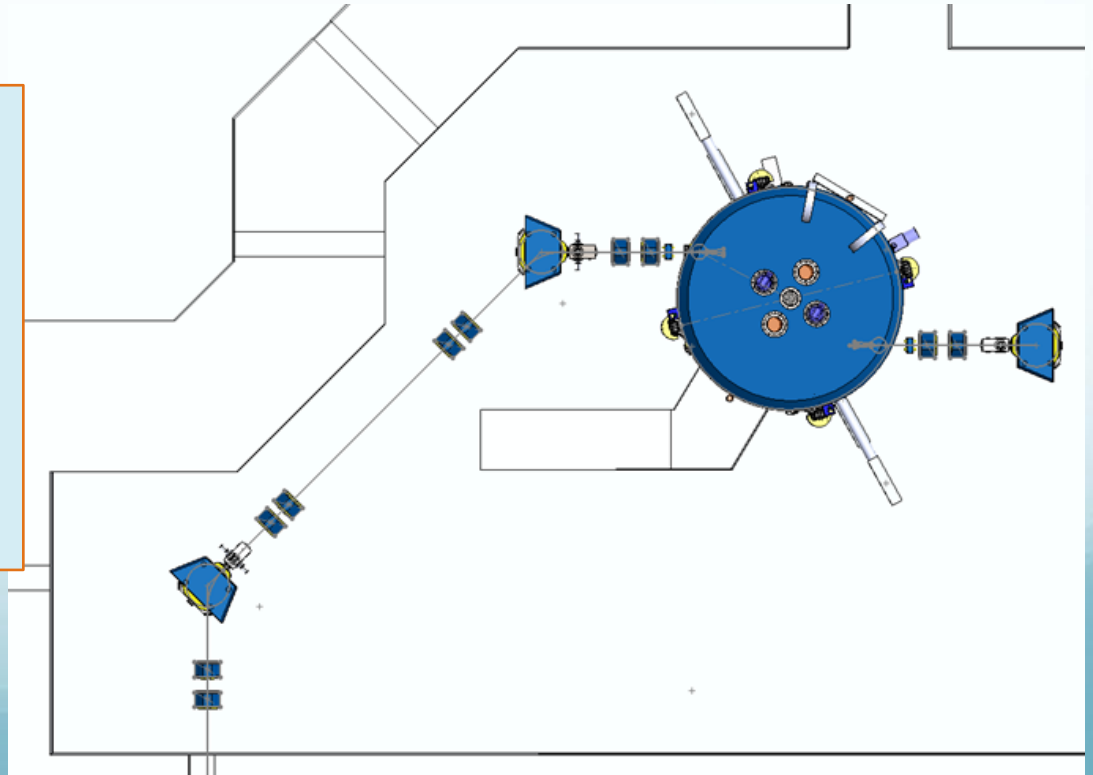


# Cyclotron Schedule

| | 2013 | | 2014 | | | 2015 |
|---|---|---|---|---|---|---|
| | II | III | I | II | III | |
| **Final Assembly and Testing** | | | | | | |
| **Factory Commissioning** | | | | | | |
| **Disassembly and Shipping** | | | | | | |
| **Installation at LNL** | | | | | | |
| **Commissioning at LNL** | | | | | | |

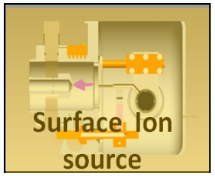
The Contract with BEST Theratronics provides for:

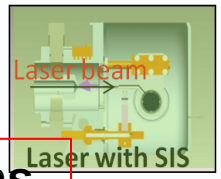
- Cyclotron
- Two exit channels
- High power beam transport line (up to SPES target)



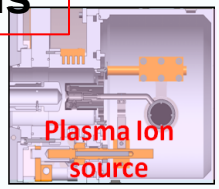
# SPES: Targets and beams

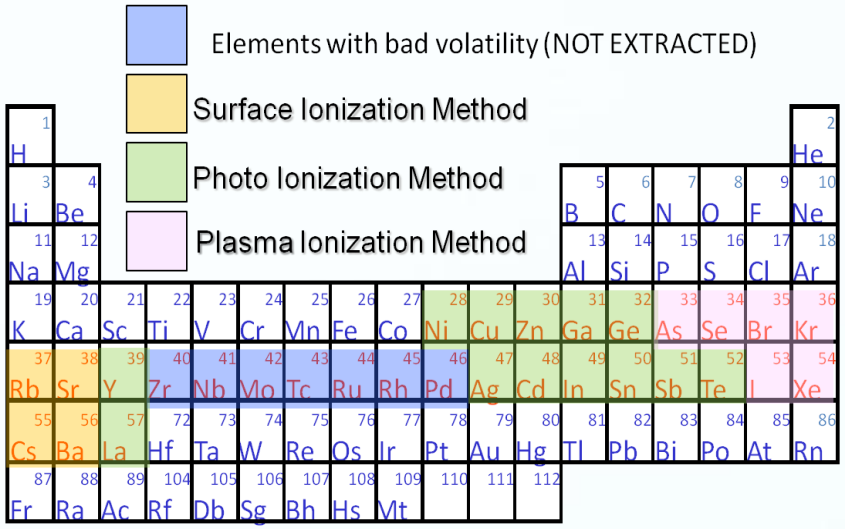
## UCx target



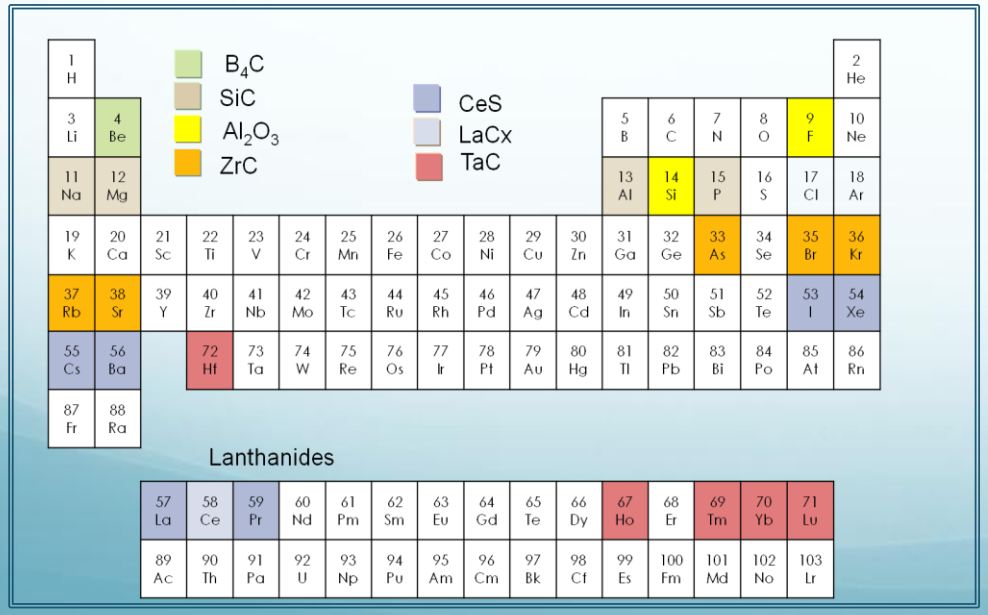

## Proton induced reactions




Main fission (p-> $^{238}$U) fragments

## Other target materials



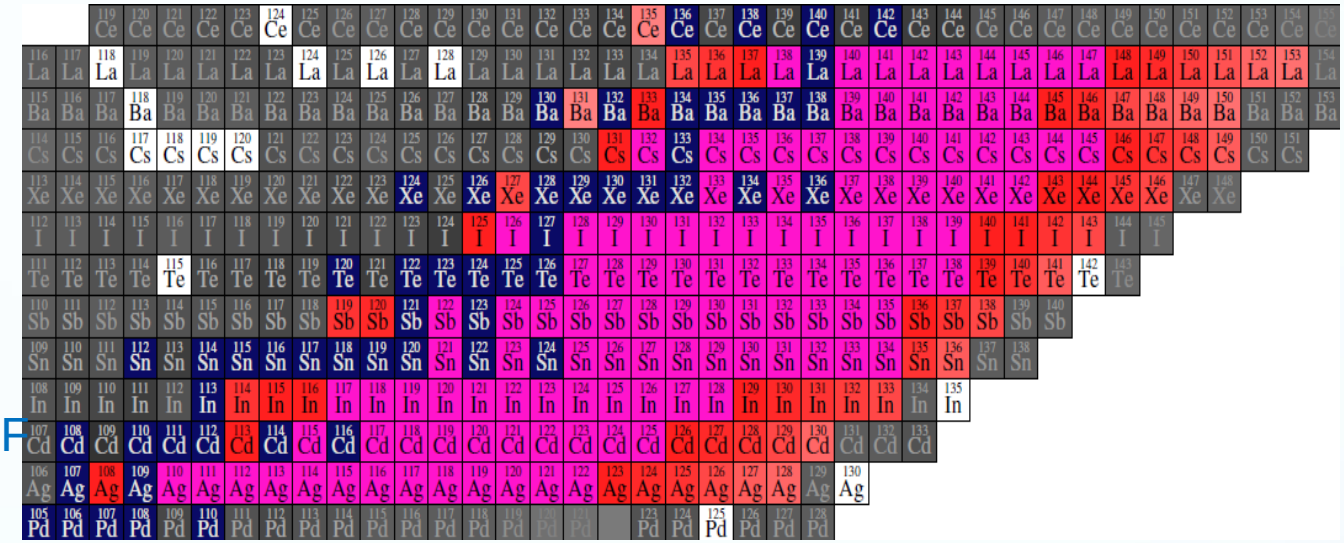

| | |
|---|---|
| 7 | Be* |
| 10 | Be* |
| 21 | Na* |
| 22 | Na* |
| 22 | Mg* |
| 23 | Mg* |
| 24 | Al* |
| 25 | Al* |
| 26 | Al* |
| 29 | P* |

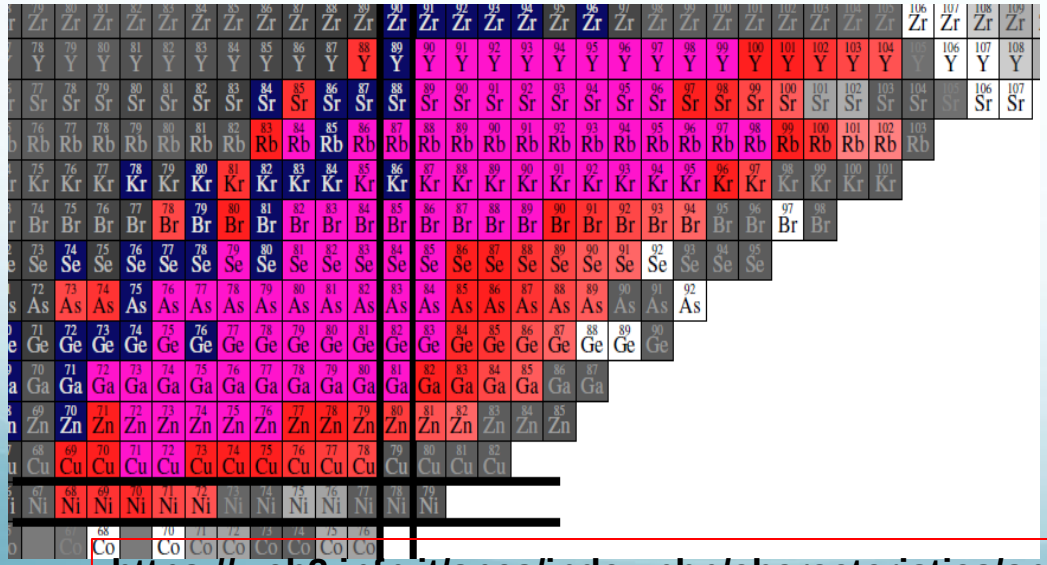
The target materials we are developing for the SPES ISOL facility, will allow to produce a variety of beams both in the neutron-rich and the neutron-poor area

# SPES beam intensities after the Ion Source ($1^+$)

Calculated with **MCNPX**
Considered the **release** and **ionization efficiency** in agreement and re-scaled on **HRIBF experimental values** and **currents** (**200μA/5μA**)

BERTINI – ORNL (FF
cross sections)





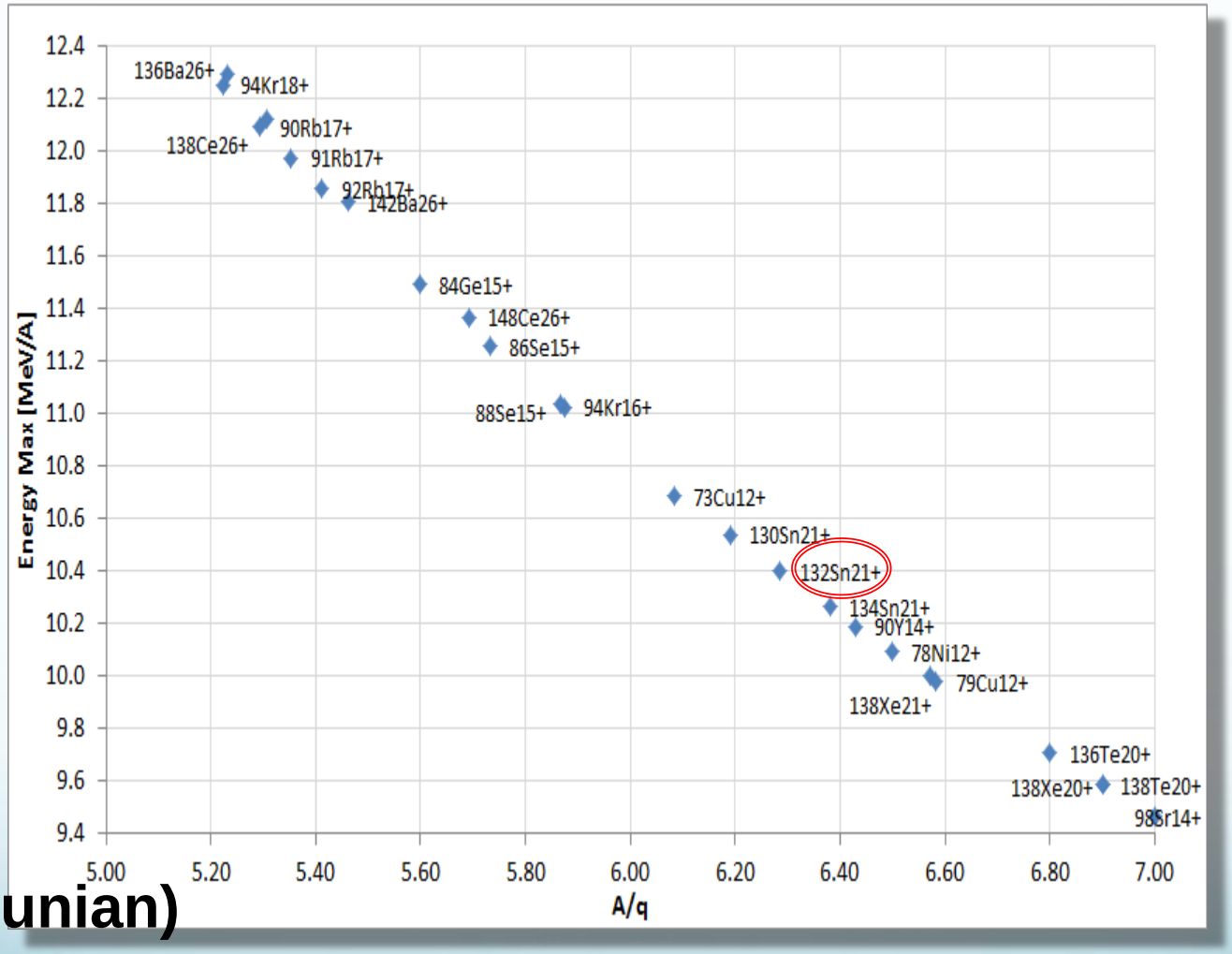
SPES beams after Ion Source

- $10^7$-$10^9$ pps
- $10^6$-$10^7$ pps
- $10^5$-$10^6$ pps
- $10^4$-$10^5$ pps
- $10^3$-$10^4$ pps
- 10 -$10^3$ pps
- 0 -10 pps

**https://web2.infn.it/spes/index.php/characteristics/spes-beams-7037/spesbeamstable**

Courtesy of F.Gramegna

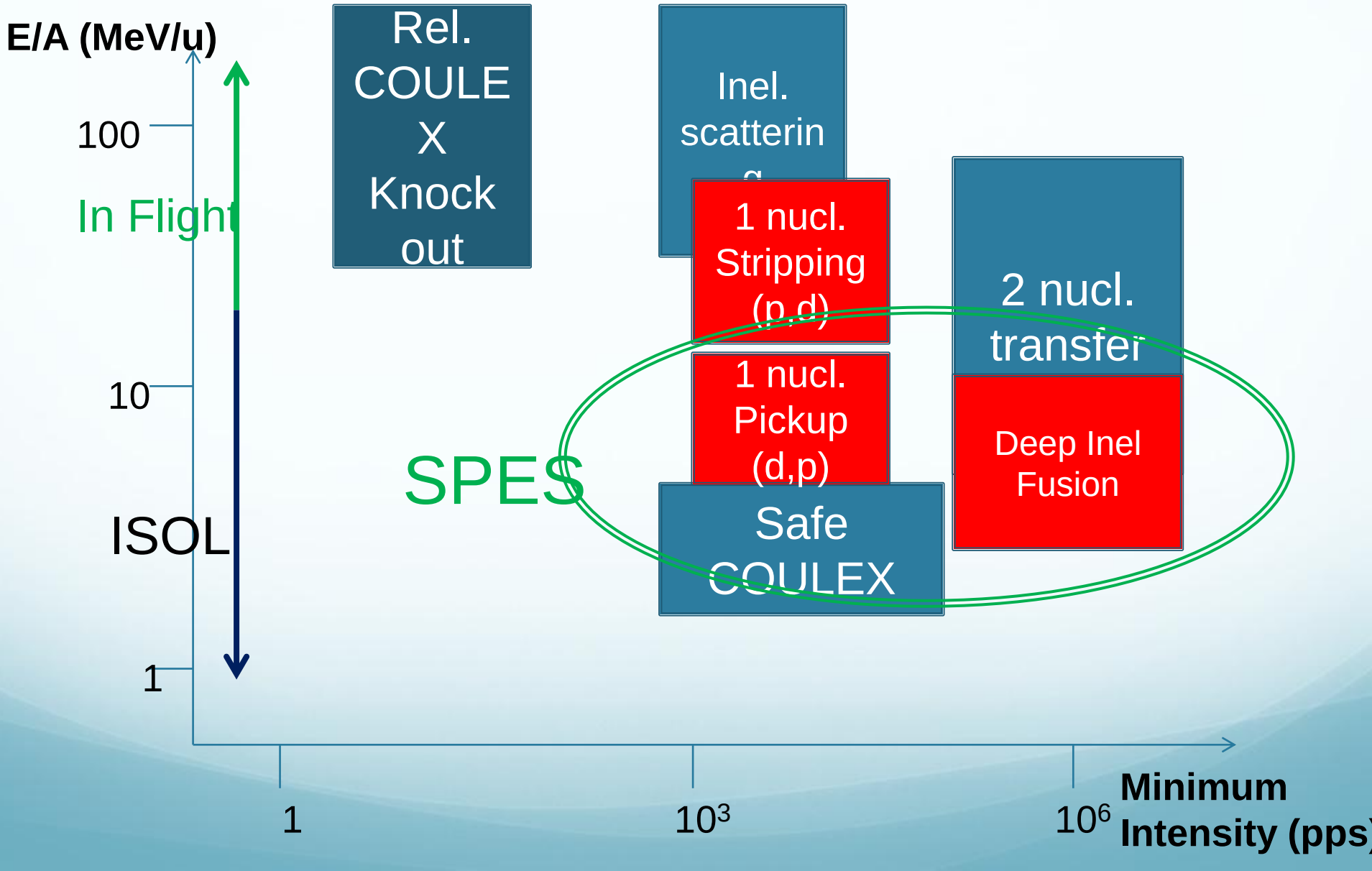
# Energy from SPES Post-Accelerator as function of A/q




(M. Comunian)

**Preliminary results from alpi performances with 2 cavities as margin, Low Beta=5 MV/m, Medium Beta=4.3 MV/m, High Beta=5.5 MV/m**

# Reaction domains



# SPES CYCLOTRON

## load work

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

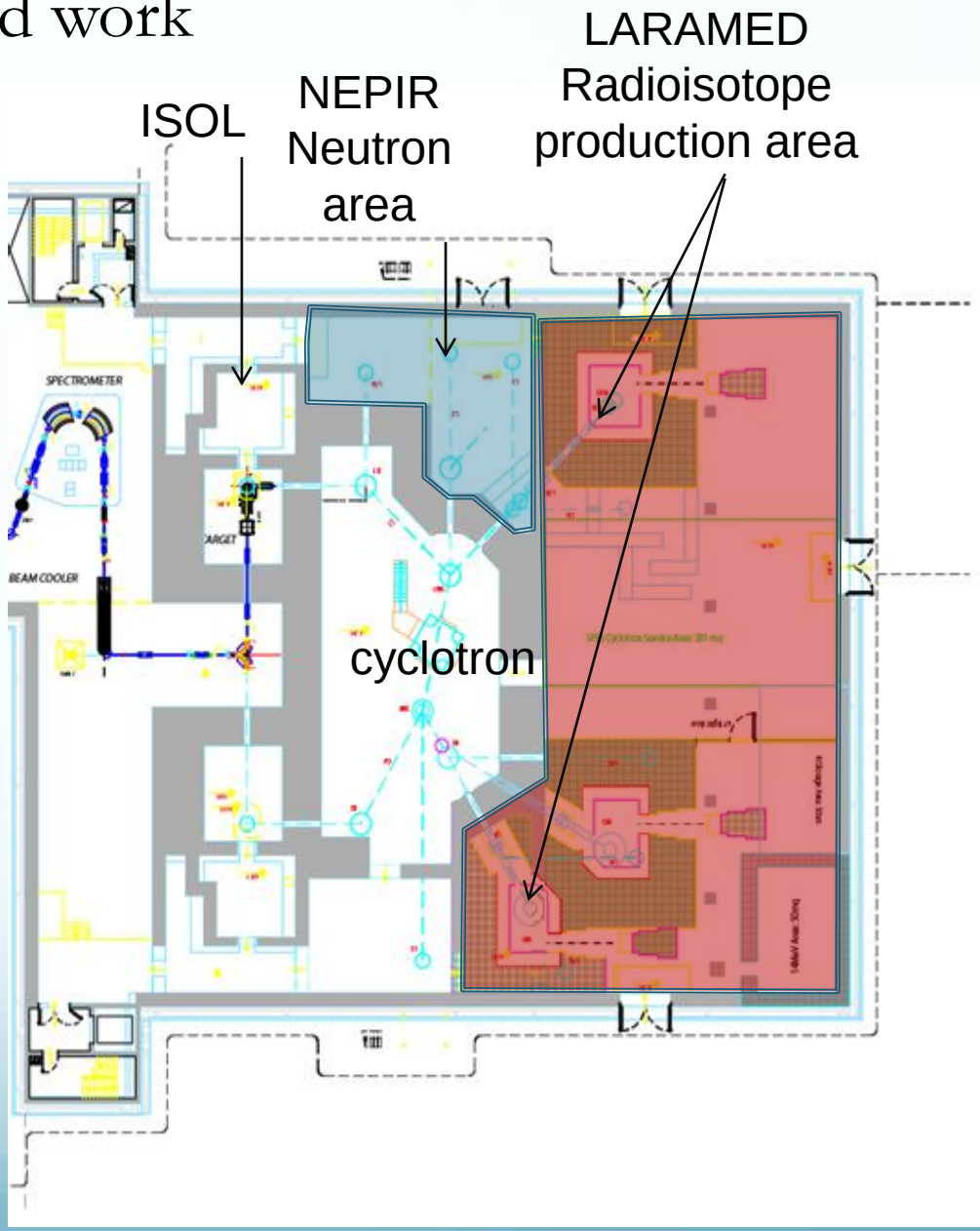
Beam on target →280 hours per shift

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

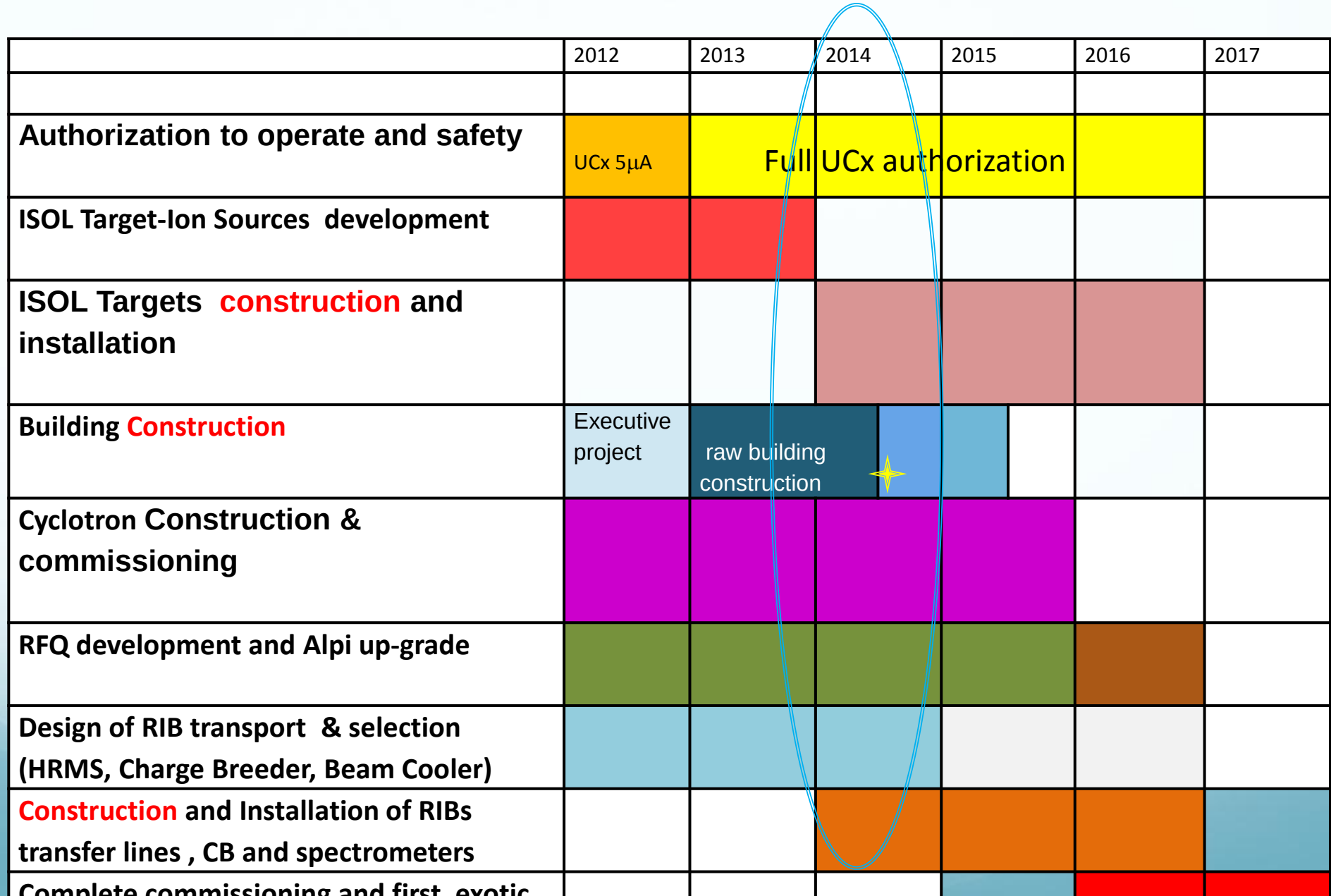
7 shifts for cyclotron maintainance

**Expected Beam on target**
**9000 hours per year**
**(final configuration with 2 ISOL targets):**

**≈4500 hours/year for Nuclear Physics**
**≈4500 hours/year for Applications**



# SPES Schedule January 2014



# Letters of Intent
# For
# The SPES Project @ LNL

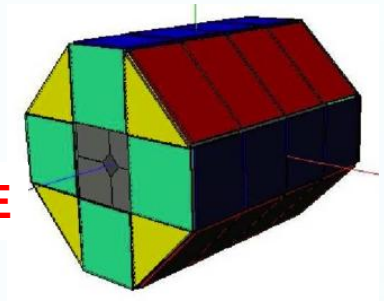
# LOIs at ISOL Facilities

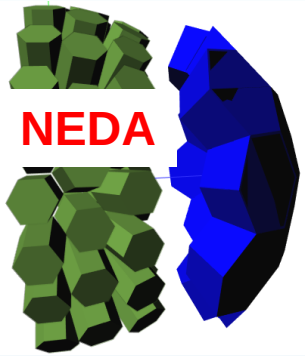
| | SPES | SPIRAL2 Phase 2 | HIE-ISOLDE |
|---|---|---|---|
| Decay Studies | 4 | 20 | Not Applicable |
| Elastic /Inelastic | 2 | 4 | 3 |
| COULEX | 7 | 2 | 13 |
| Transfer | 8 (3HI) | 7 | 16 |
| Deep Inelastic/ MNTR | 5 | 1 | 0 |
| Fusion/Fission | 11 | 3 | 2 |
| New instrumentation | 4 | NA | 5 |
| Astrophysics | 3 | 6 | 4 |

# γ-ray Spectroscopy at SPES

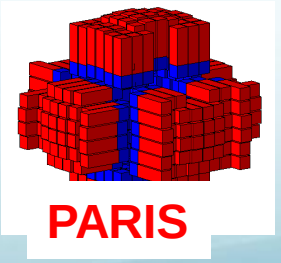
**~10 A·MeV, <u>In most cases gammas emitted by the beam-like particle</u>**
Doppler broadening limits resolution: tracking required

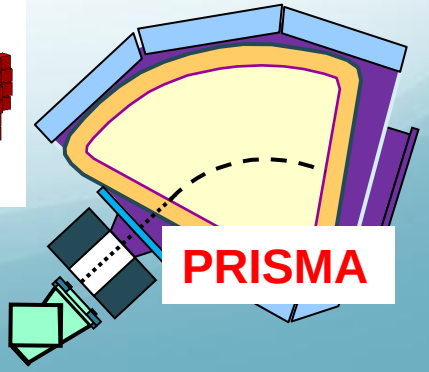
- **Coulomb excitation reactions**
- **Striping/Pickup cluster tranfer/Inelastic reactions**
- **Fusion-evaporation reactions**
- **Multi-nucleon transfer & DIC**







# Physics Reach- single particles

- In a first stage (5 μA p beam) (d,p) reaction to $^{70}$Ni and $^{135}$Sn
- In the final stage (200 μA p beam) (d,p) reaction to $^{72}$Ni and $^{137}$Sn.

**Use also cluster transfer,**

**Promising technique (ISOLDE experiment)**

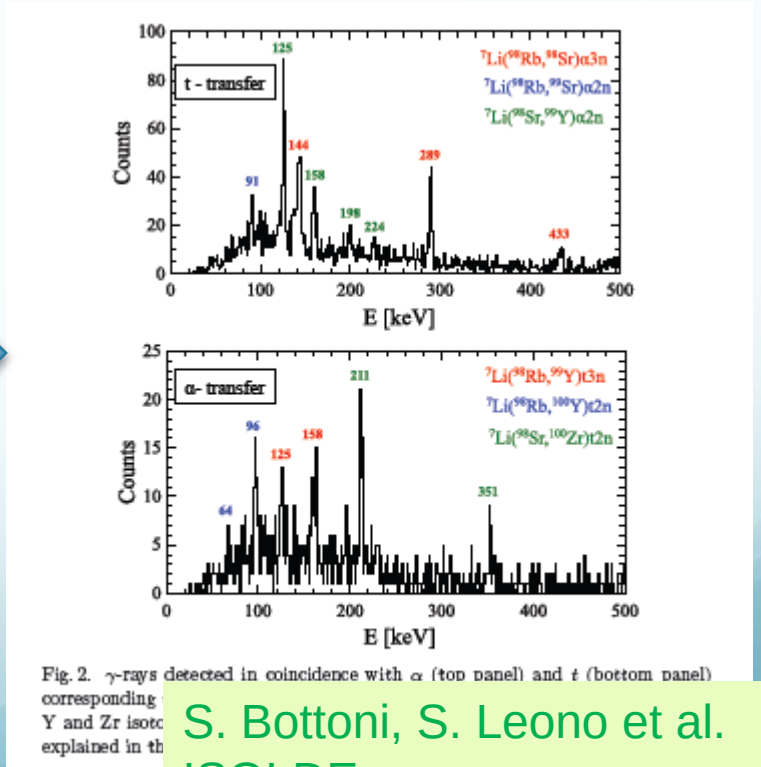
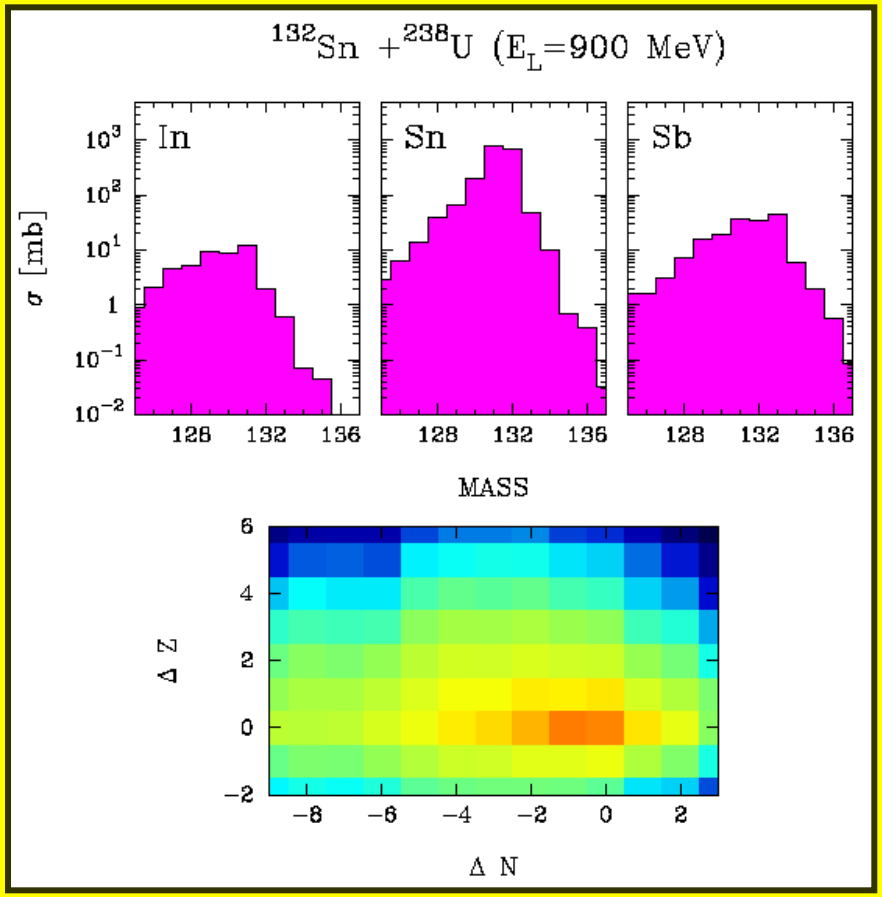



Fig. 2. γ-rays detected in coincidence with α (top panel) and t (bottom panel) corresponding
Y and Zr isotc
explained in th

S. Bottoni, S. Leono et al.
ISOLDE exp.

# Multinucleon transfer reactions with neutron-rich beams




GRAZING code calculations

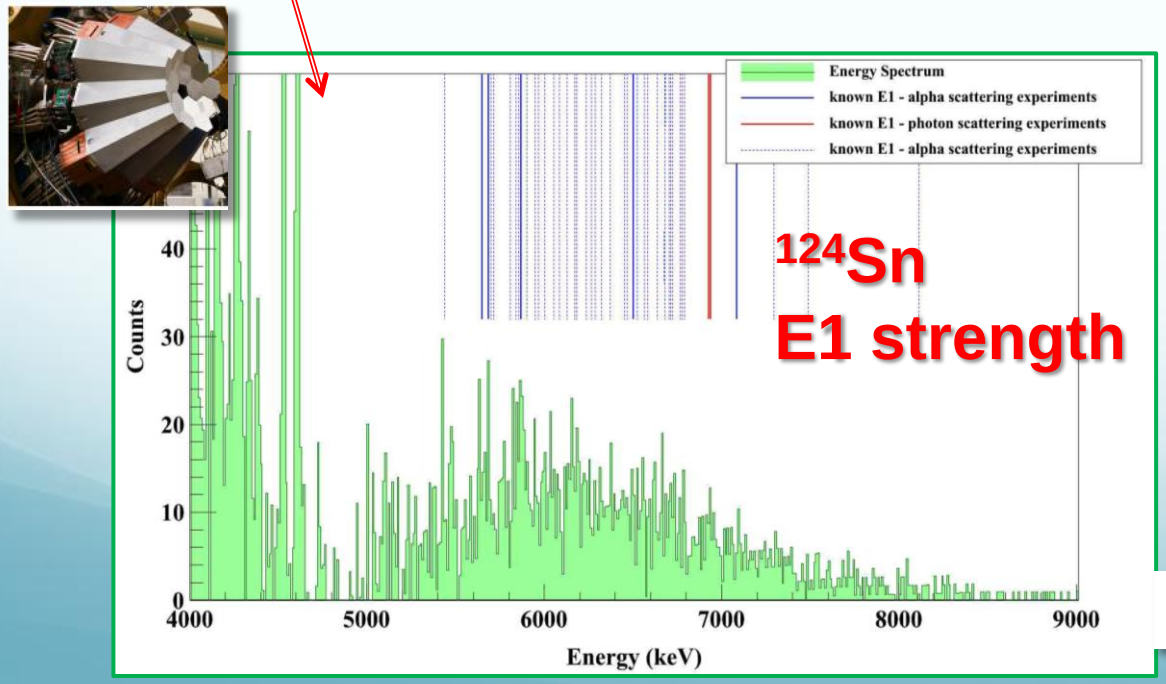
possibility to populate nuclei via pick-up and stripping of both neutrons and protons

probing (nn), (pp) and (np) correlations. Important for studies on pairing vibrations/rotations, nuclear superfluidity

production of neutron rich isotopes

# Collective modes

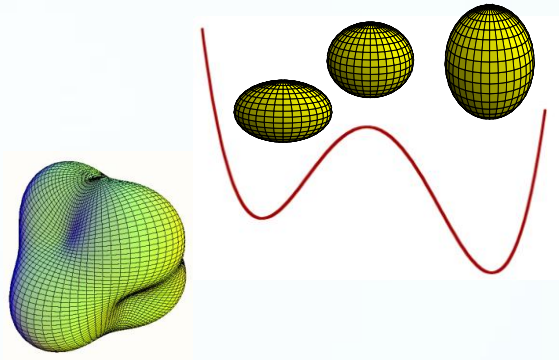
- **Pygmy resonances through inelastic scattering at 10 MeV/A**
- Dynamic dipole emission in fusion reactions with very large dipole moments in the entrance channel (large N-Z)
- Quenching of the GDR in hot nuclei: Isospin dependance of the liquid gas phase transition.




L.Pellegri et al.

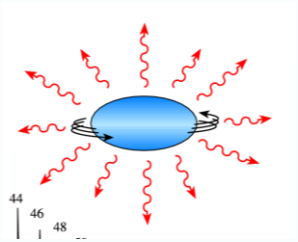
# γ-ray for fusion evaporation

- **Fusion-evaporation reactions**

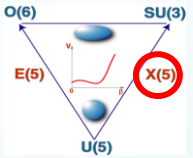


shapes- shape coexistance-deformations

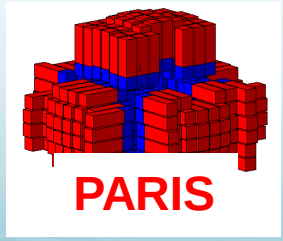
High spin states  and order-chaos transition



Dynamical symmetries




# AGATA with:

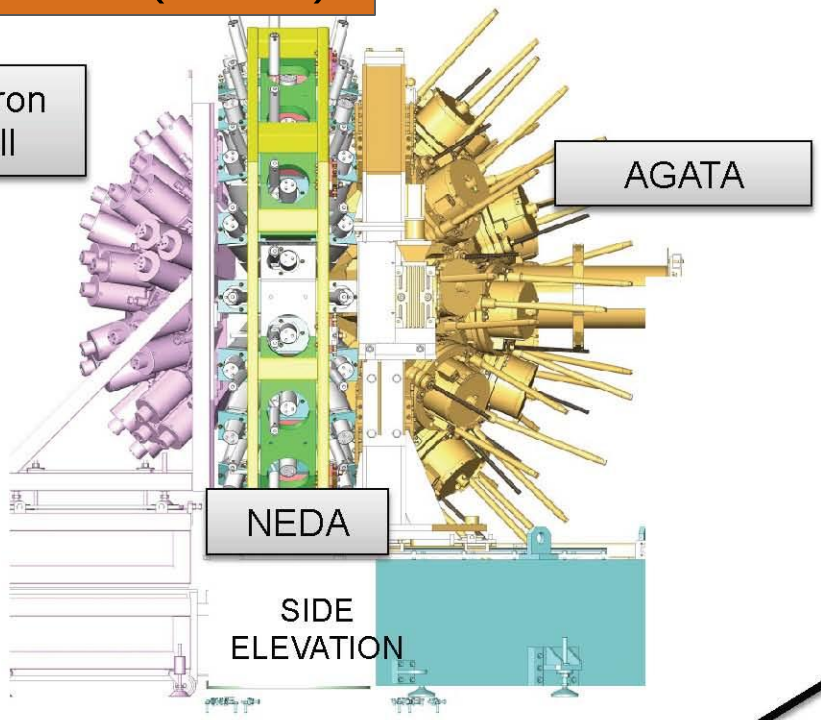



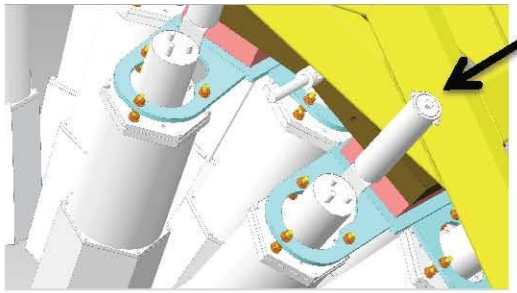


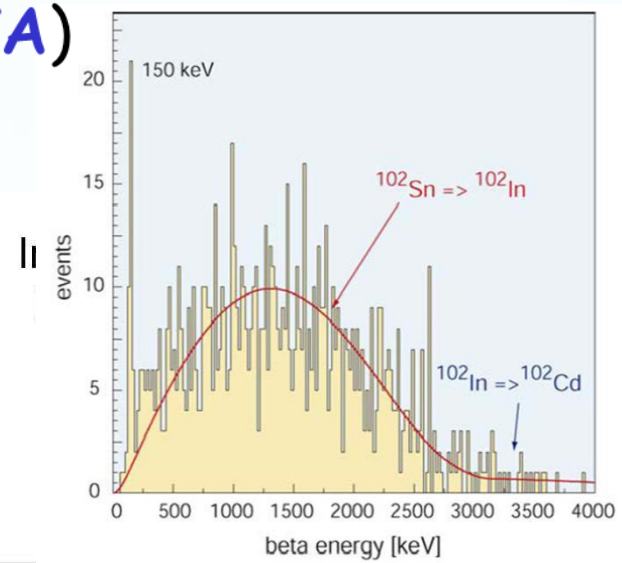
**Recoil Filter**

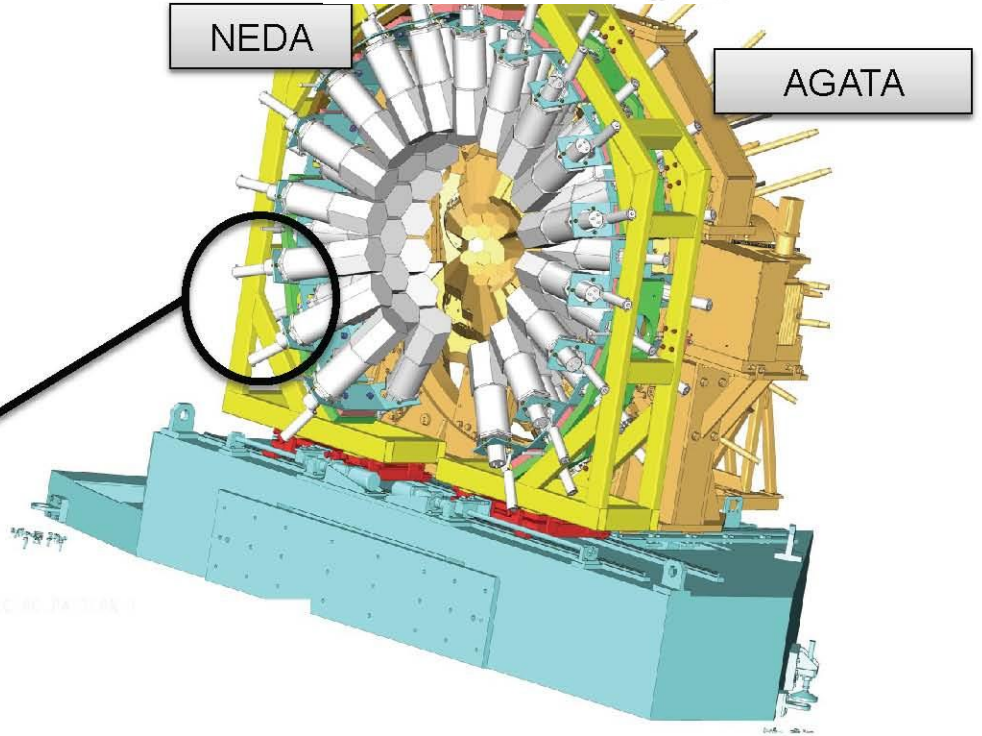
# Q-values from β-decay (NEDA+AGATA)

Vandle n det. (ORNL)






➔ Shortest half-lives, production rates << 1 min$^{-1}$

# Hosting Agata at LNL

# Hosting Agata at LNL

✓ An addendum of the AGATA@LNL host agreement is expected to be prepared in due time to commit the necessary involvement of human and financial resources.

✓ In this connection the past and successful experience with the AGATA demonstrator at LNL is very useful

# Hosting Agata at LNL

Based on the submitted letters of intent at this stage

## 3 different set-ups are proposed:

**1 - AGATA "stand alone" (2019)**

**coupled to SPIDER (Coulomb excitation), Recoil Filter Detector (Fusion residues), TRACE (Transfer reactions) or NEDA (neutron detection), PARIS (gamma ray calorimeter) etc.**

**2 - AGATA coupled to the PRISMA spectrometer - (2020)**

**3- AGATA coupled to particle hodoscopes (2021)**

# END