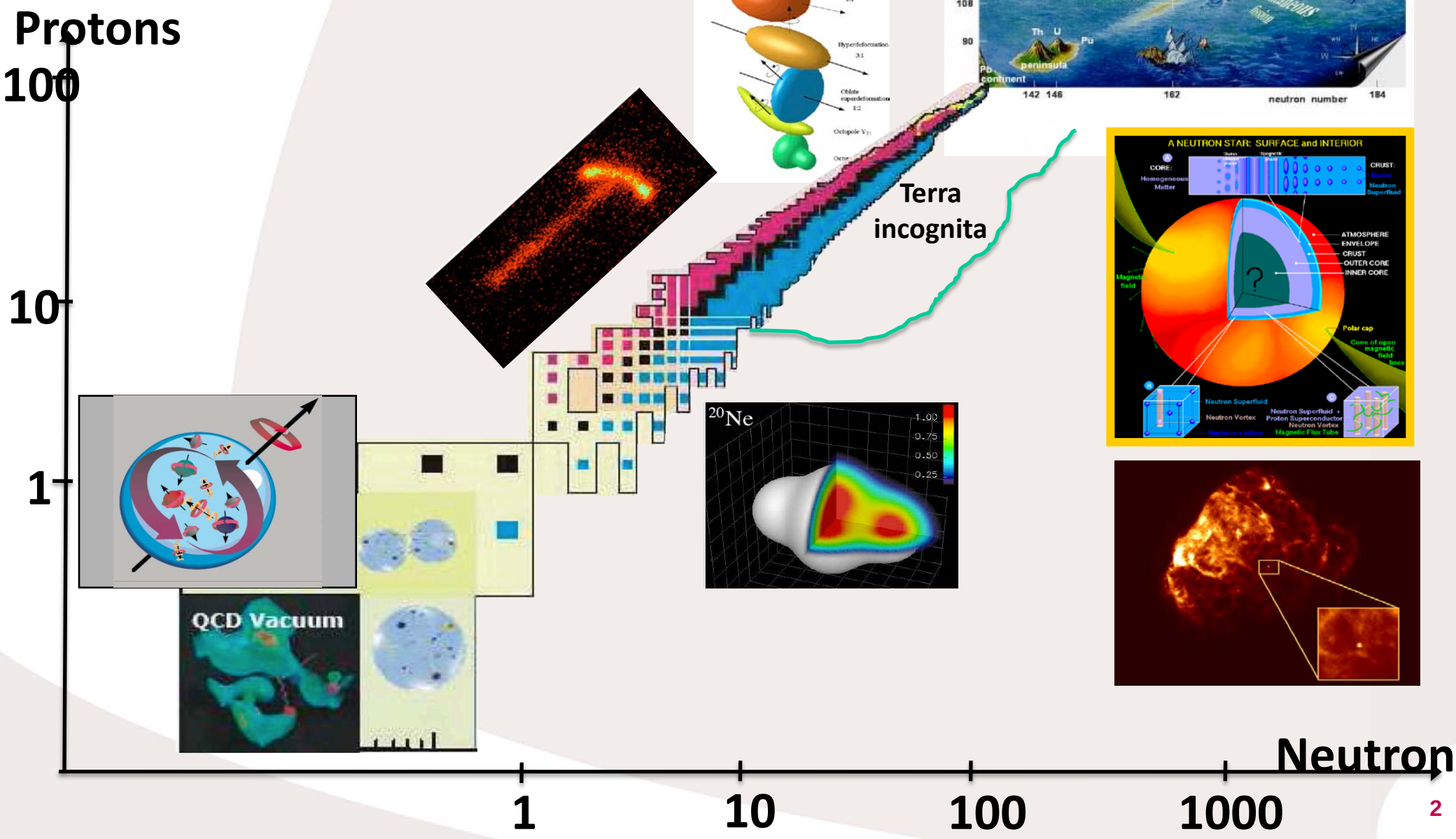
The European Collaboration for Stable Ion Beams – ECOS

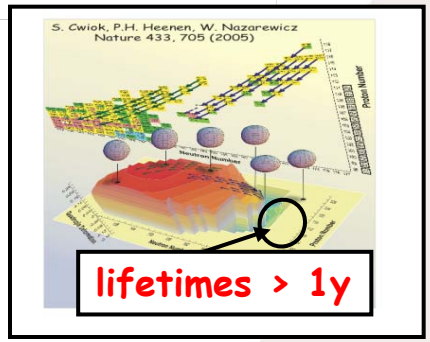
F. Azaiez

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

98% of the visible mass is due to the Stong interaction

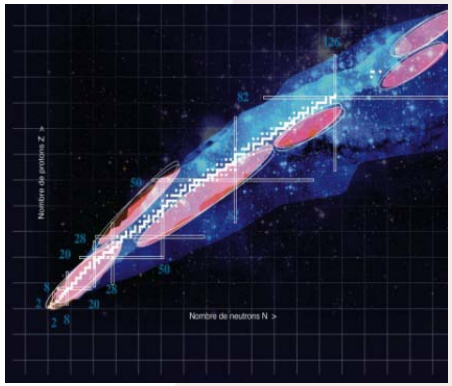


Science Key Questions

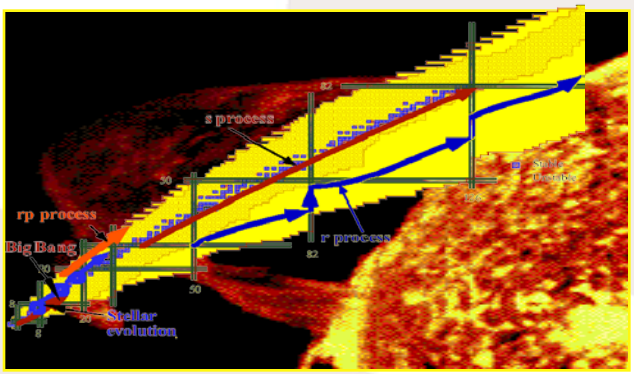


What are the limits of the heaviest elements?

SCIENCE Magazine- Top 125 Questions:
Are there stable high-atomic-number elements?



What are the limits of stability?



How the elements are made in the Universe?

3

After the NuPECC town-meeting (GSI-2004)

Letter to NuPECC:

…..We have been discussing such a project in many of the European countries and we are now in the process of forming a working group at the European level for finalizing the physics case and launching the design study related to this project. We believe that NUPECC should play an important role by endorsing the promotion and coordination of the project. While the European Long Range Plan document related to nuclear structure includes in some of its sections the need for a high intensity stable beam facility for the nuclear structure study, the recommendations elaborated during the last town-meeting did not mention this need at all. In order to preserve the vitality of the nuclear structure field and the nuclear physics community, we suggest the recommendations to be completed by including "direct support for new actions towards a European high-intensity stable beam facility", besides the presently expressed "strong support to maintain and develop the current stable beam facilities in Europe"…..

ECOS: European COnsortium for Stable (ion beams)

Marie-Helene Moscatello / M. Levitowicz (GANIL)
Annamaria Porcellato (Legnaro)
Uli Ratzinger (GSI)

Sigurd Hofmann (GSI)
Rauno Julin (JYFL)
Faisal Azaiez (IPN-Orsay)
Jacomo Deangelis (Legnaro)
Rolf-Dietmar Herzberg (Liverpool)

Task: Produce a document to NUPECC with:

--The Science with high intensity stable ion beams, Beam intensity limitations and technical developments for various types of research lines!

--Status and future developments of existing facilities

--Recommendations

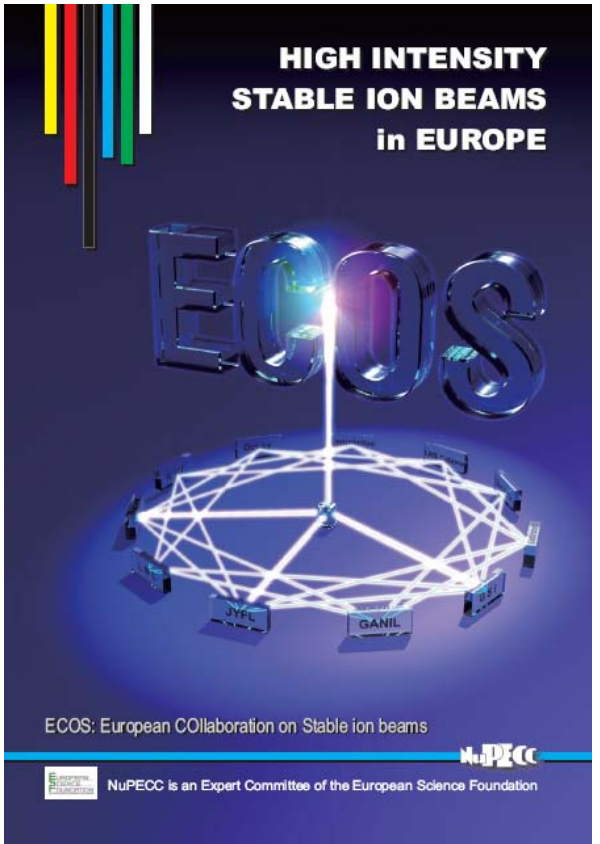
--The Science with high intensity stable ion beams, Beam intensity limitations and technical developments for various types of research lines!

N=Z nuclei (in–beam spectroscopy and decay studies) : *G. DeAngelis*
SHE search : *S. Hofmann*
Super heavy nuclei (in-beam spectroscopy and decay studies) : *R. D. Herzberg*
Neutron-deficient nuclei (in-beam spectroscopy and decay studies) : *R. Julin*
Exotic shapes and decay modes in nuclei : *F. Azaiez*
Neutron rich nuclei using DIC reactions : *F. Azaiez & G. DeAngelis*
Nuclear astrophysics*: S.V. Harissopulos*

--Status and future developments of existing facilities

LEGNARO : *A. Porcellato*
GANIL : *M. H. Moscatello/M. Lewitovicz*
GSI : *S. Hofmann&U. Ratzinger*
JYVASKYLA : *R. Julin*
KVI *: S. Brandenburg*
CATANIA:* *S. Gammino

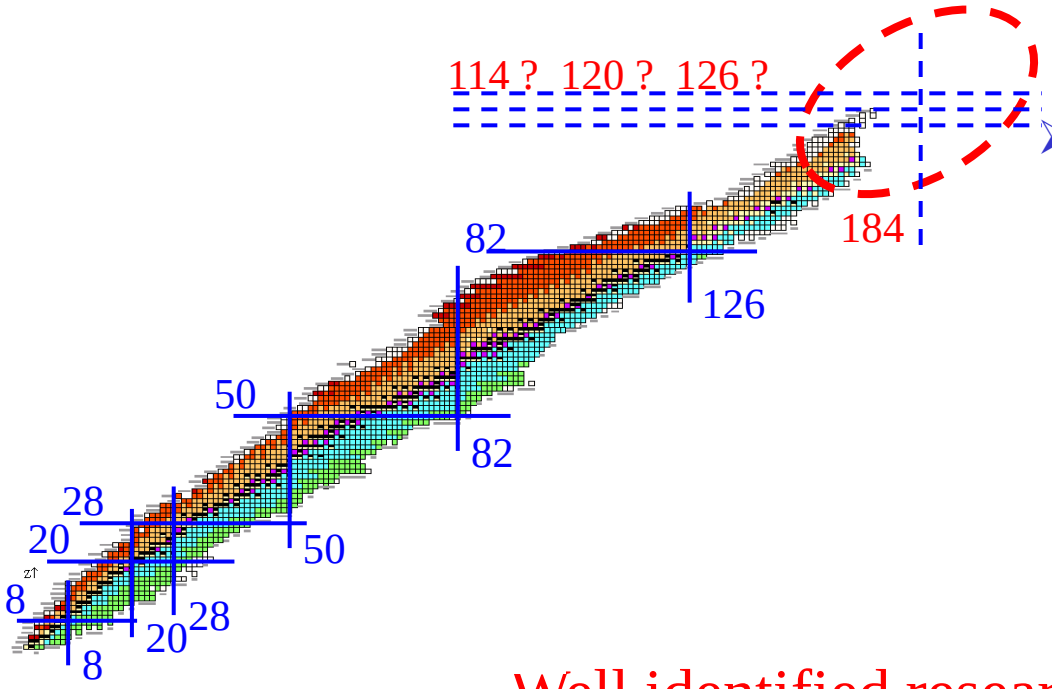
--Conclusions and Recommendations



Some of the key questions in the Nuclear structure field are and will remain for the coming 10 years well addressed using the state of the art detection systems and higher intensity stable beams!

SHE: Where the isle of stability is located?

what are the corresponding shell effects ?



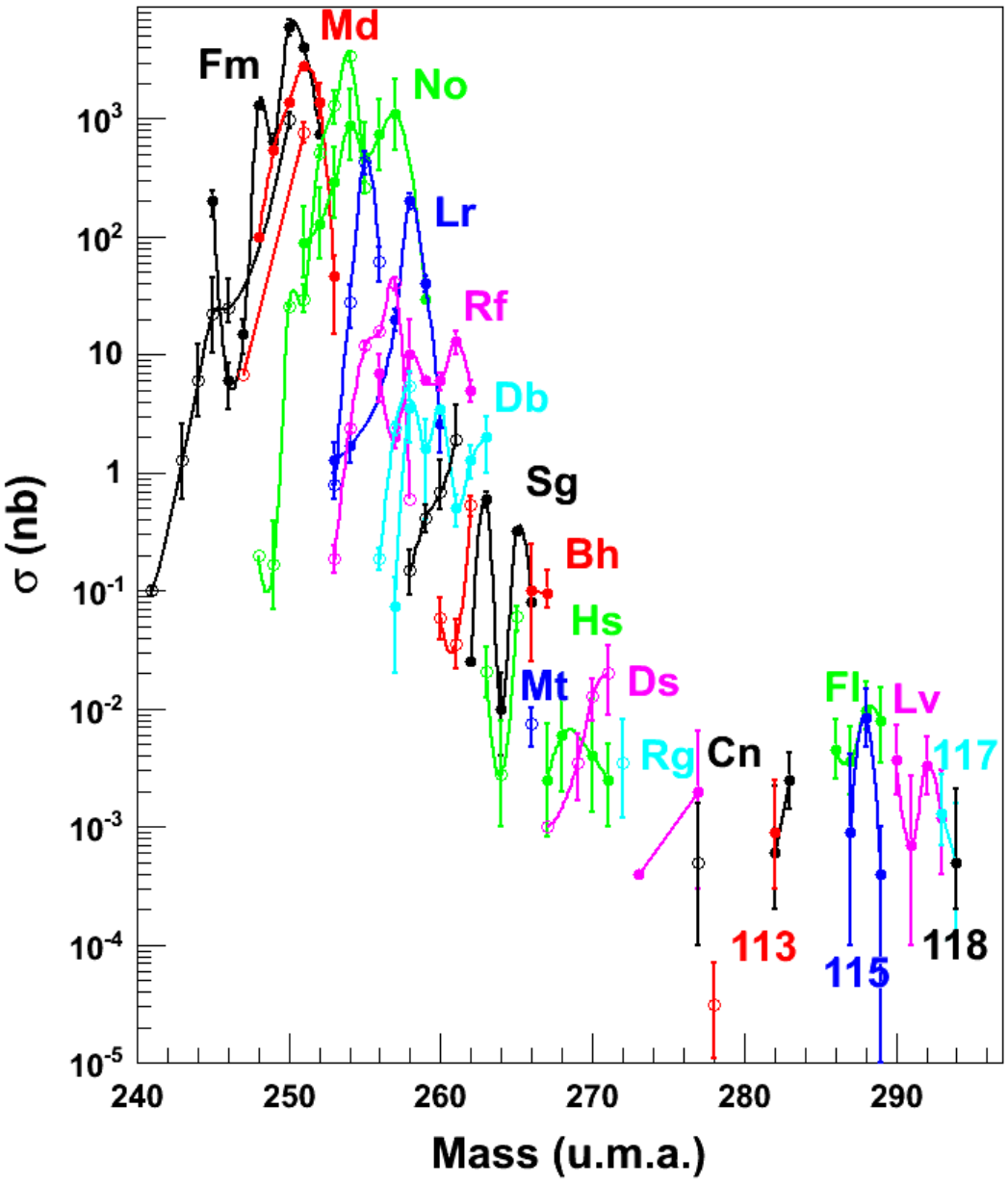
testing spin-orbit and more generally effective interactions at the extreme!

Well identified research program:

-Systematic search of SHE

-Study of the ‘stabilizing’ shell structure

-Study of complete fusion - fission processes


Fm
Md
No
Lr
Rf
Db
Sg
Bh
Hs
Mt
Ds
Rg
Cn
Fl
Lv
117
113
115
118
σ (nb)
Mass (u.m.a.)
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
240
250
260
270
280
290

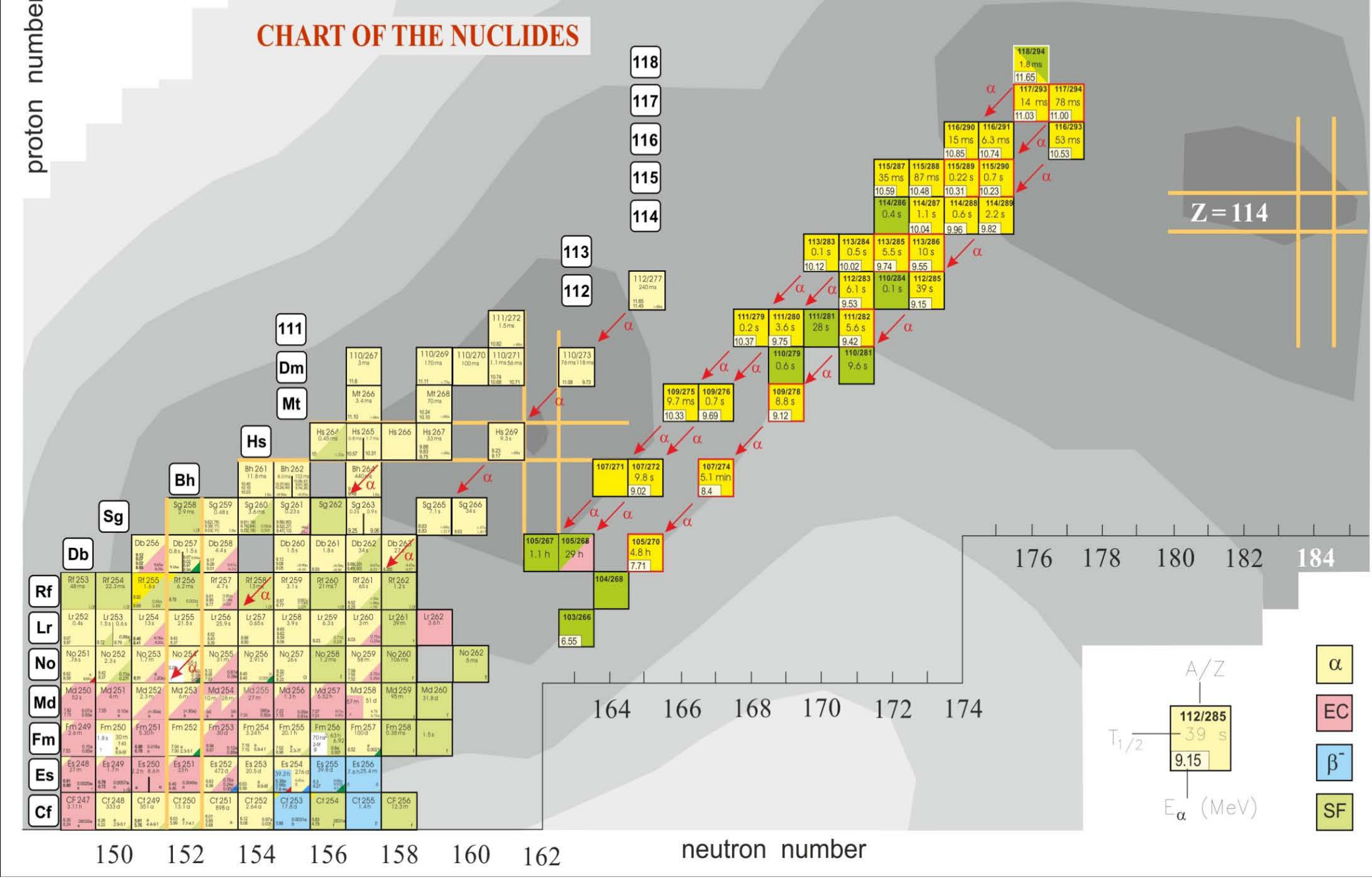
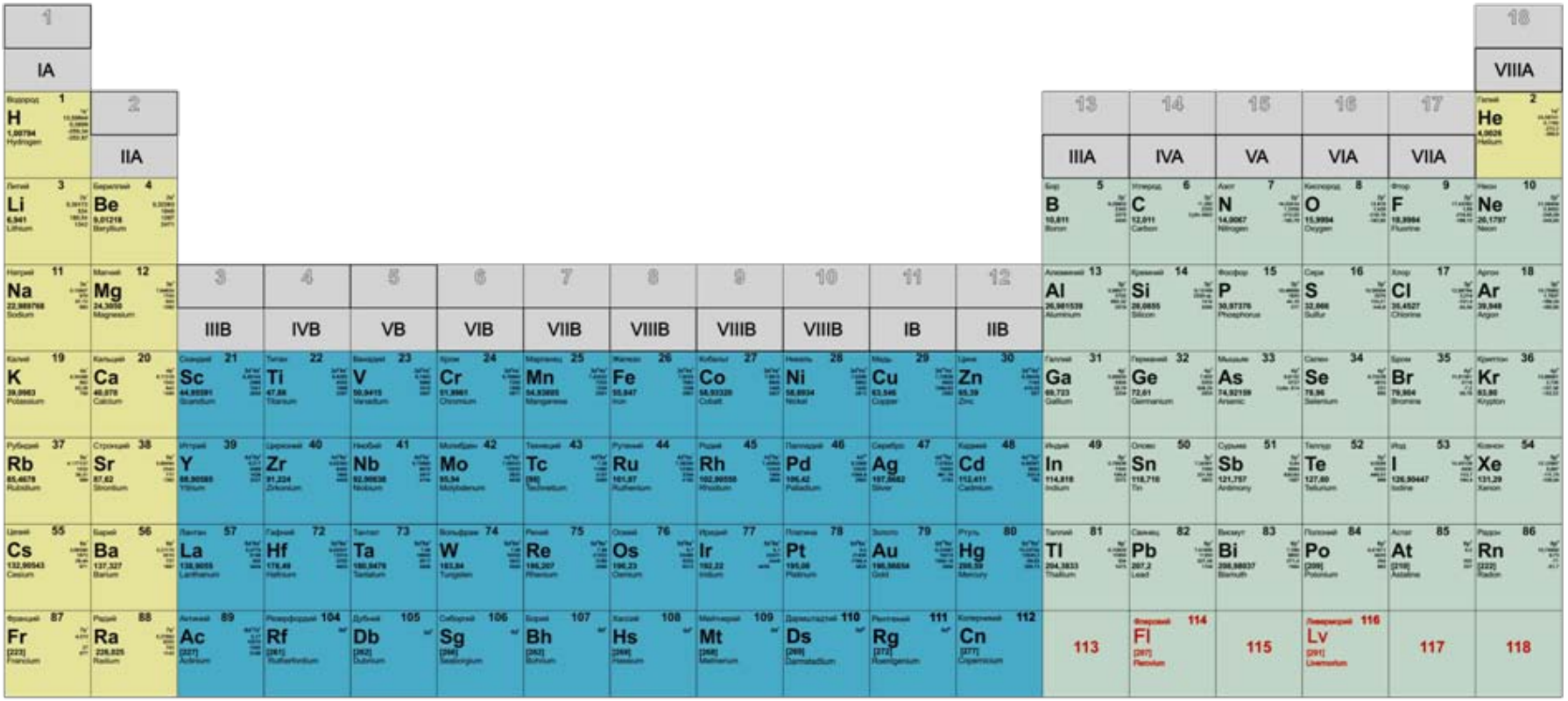
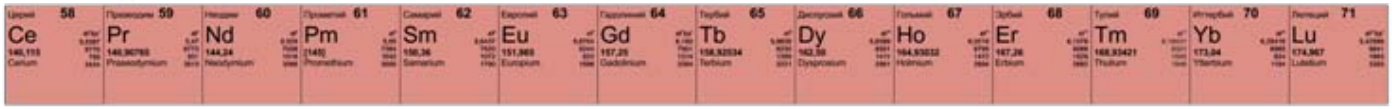


CHART OF THE NUCLIDES
proton number
neutron number
Z = 114
118
117
116
115
114
113
112
111
Dm
Mt
Hs
Bh
Sg
Db
Rf
Lr
No
Md
Fm
Es
Cf
150
152
154
156
158
160
162
164
166
168
170
172
174
176
178
180
182
184
α
EC
β⁻
SF
A/Z
T1/2
112/285
39 s
9.15
Eα (MeV)

Mendeleev Periodic Table of the Elements



Лантаноиды Lanthanides



Актиноиды Actinides

H - символ
1,00794 -атомный номер
1s¹ -электронная конфигурация
13,59844 - I-й потенциал ионизации, эВ
0,0899 - плотность кг/м³
-259,34 - температура плавления,°С
-252,87- температура кипения,°С

s-элементы
p-элементы
d-элементы
f-элементы

Recent highlights of ion source R&D (2011)

- **Metal ion beam production – first isotopic MIVOC ^{50}Ti beam**

19 μA $^{50}Ti^{11+}$ from 14 GHz ECRIS → 45 pnA on target

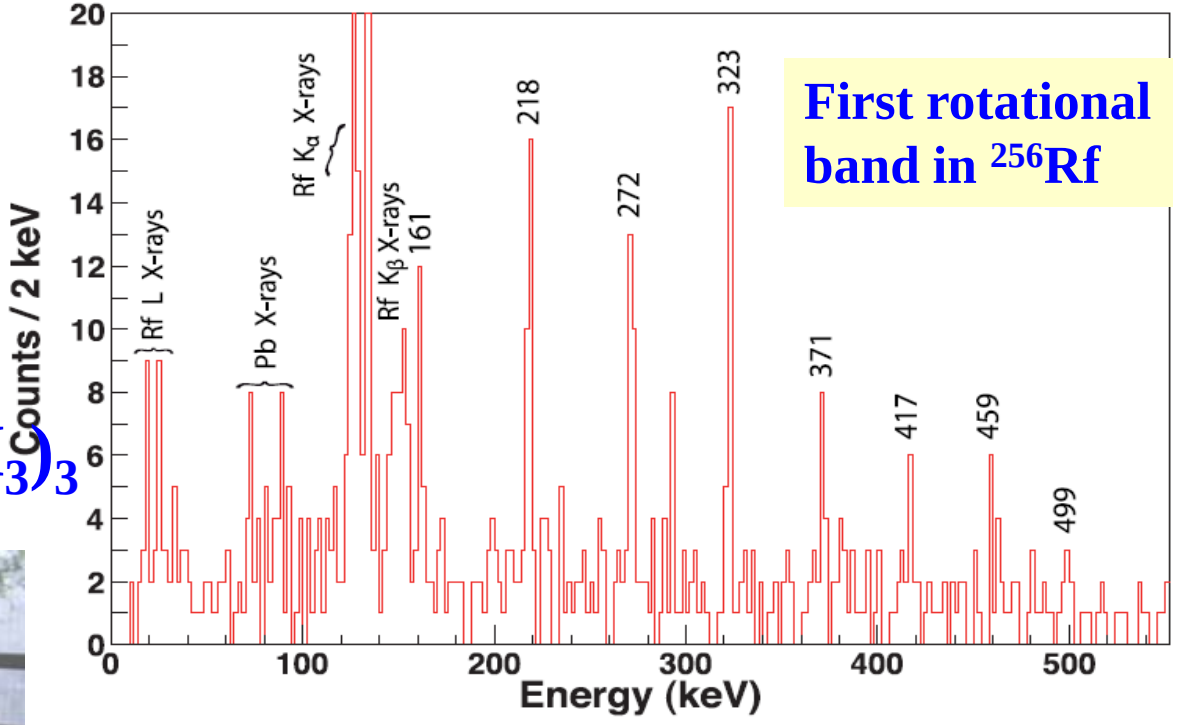
$^{50}Ti + {}^{208}Pb \rightarrow \boxed{^{256}Rf} + 2n$

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

0.2 mg/hr

$Cp^*{}^{50}Ti(CH_3)_3$

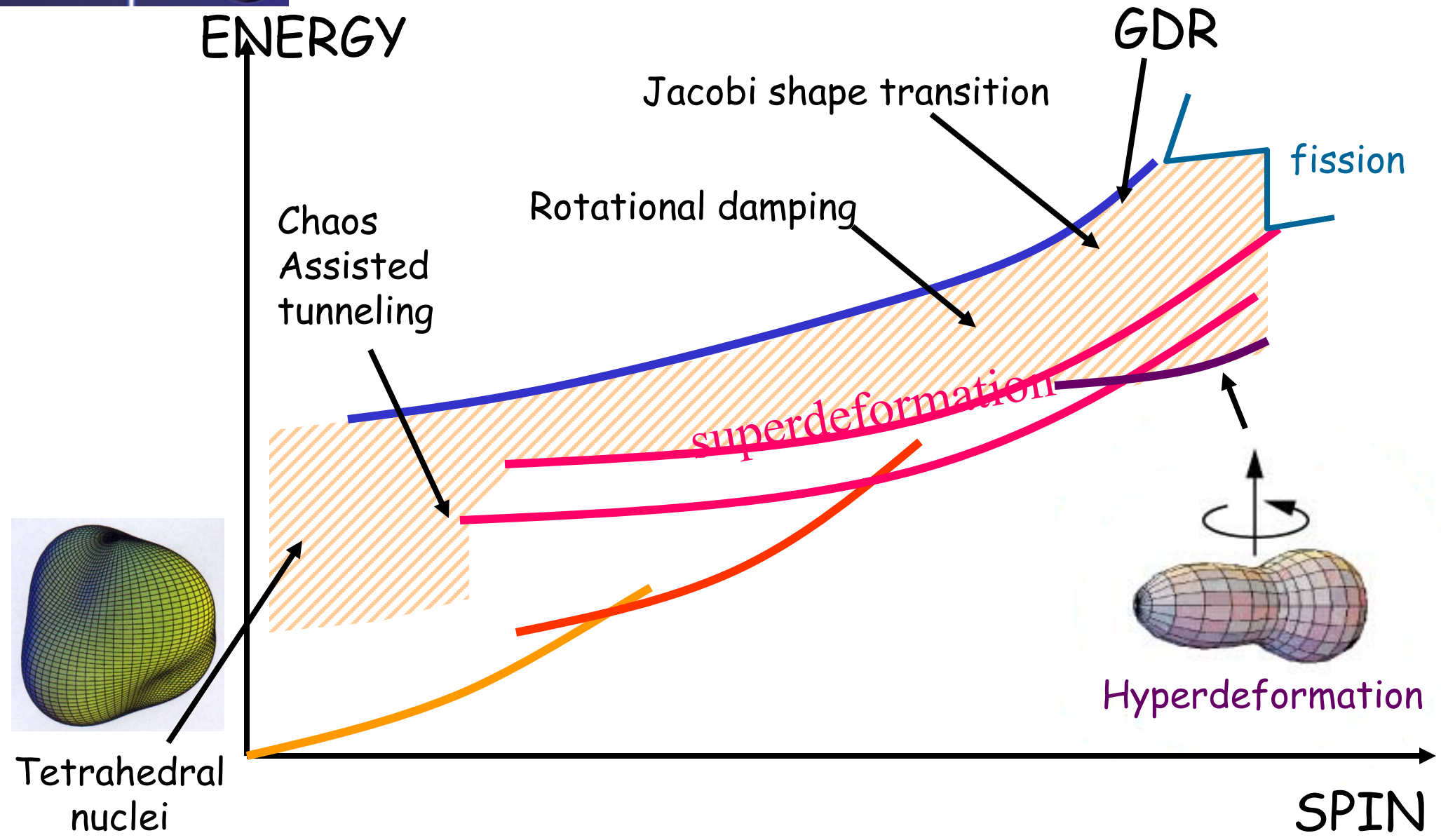
J. Rubert, J. Piot *et al*, NIMB 276 (2012) 33



First rotational band in ^{256}Rf

P.T. Greenlees, J. Rubert *et al*, accepted PRL (2012)

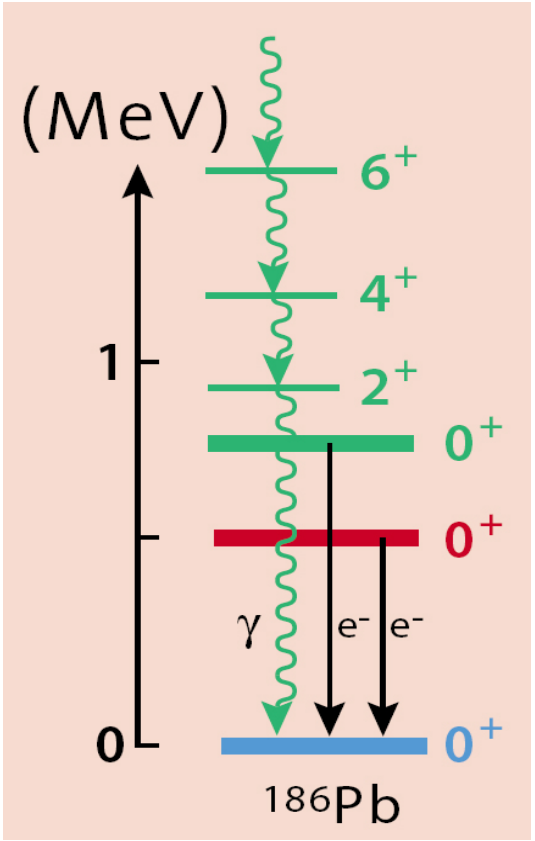
A domain rich of new exotic phenomena to be discovered

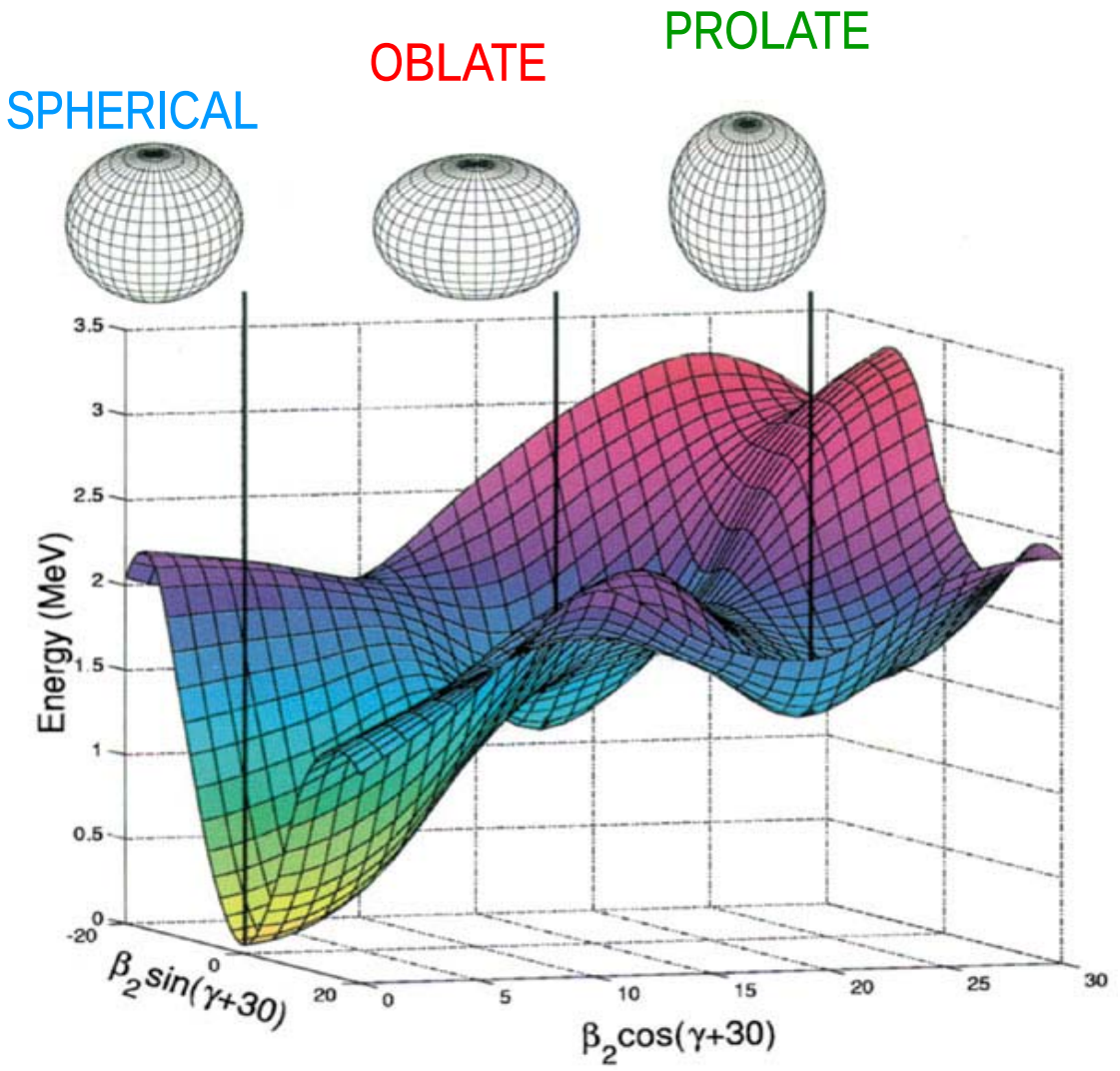


Decay- and in-beam spectroscopy of heavy nuclei at the proton dripline

Triple-shape coexistence

Where is the OBLATE band?





Three low-lying 0^+ states in ^{186}Pb observed in the alpha decay of ^{190}Po

A. Andreyev et al. Nature ***405 (2000) 430***

Nuclear astrophysics

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Our knowledge on key reaction rates has reached a high-level of accuracy but still crucial reactions relevant to the understanding of the structure and evolution of stars and galaxies deserve additional or completely new experimental approaches with stable beams.

An “ideal” stable beam facility for nuclear astrophysics should be able to provide **intense heavy-ion beams for indirect measurements**, mostly based on
transfer reactions or
Coulomb break-up, or
capture reactions in inverse kinematics

The low energy nuclear structure community has well defined and promising research programs for the future. Many of them are based on measurements to be carried out using higher intensity stable beams.

The in-beam studies will benefit from the high segmentation of new detection Systems and from digital electronics, in order to allow the increase of beam intensity by one order to two orders of magnitude (up to few 100pnA).

Other approaches using detection systems after a separator (focal plan) require a stable beam facility with very high intensities (up to 100pμA)

In all the cases a dedicated detection system is needed to run experiments with longer beam time.

Existing European facilities Legnaro, JYFL, GSI (unilac), Ganil (CSS1)

Projects of very high intensity injectors for SPES and SPIRAL2

A new project in Huelva

JYFL-Jyväskylä

Beams - E > 5 MeV /nucleon

Heavy and light ions available

>1pμA **p, He, B, C, N, O, Ar**

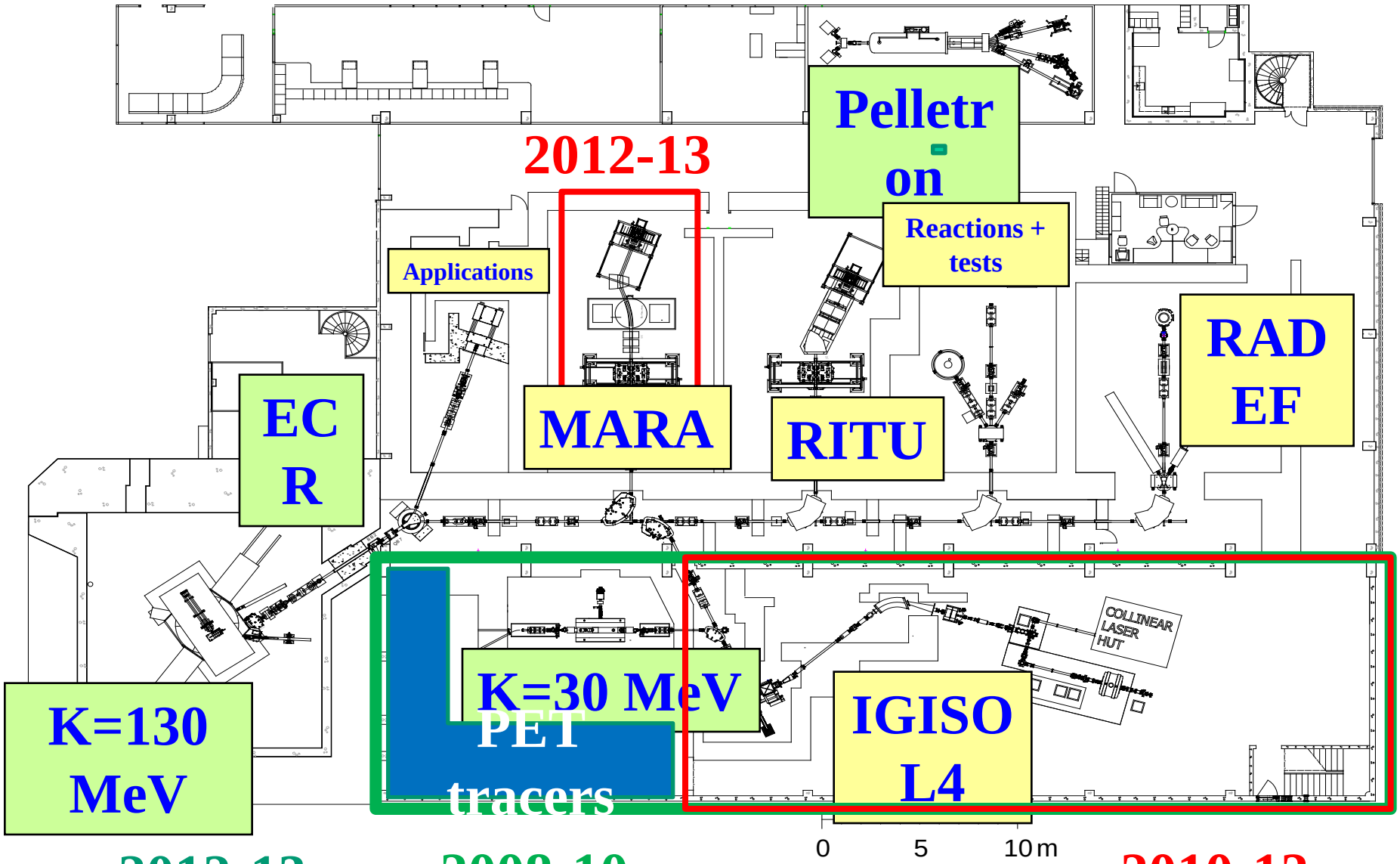
>100 pnA **F, Ne, Mg, Al, Si, S, Cl, Ca, Fe, Cr, Ni,Cu, Zn, Kr**

>10 pnA **Ti, Mn, Ge, Sr, Zr, Ru, Xe**

ECR developments for intensity upgrade

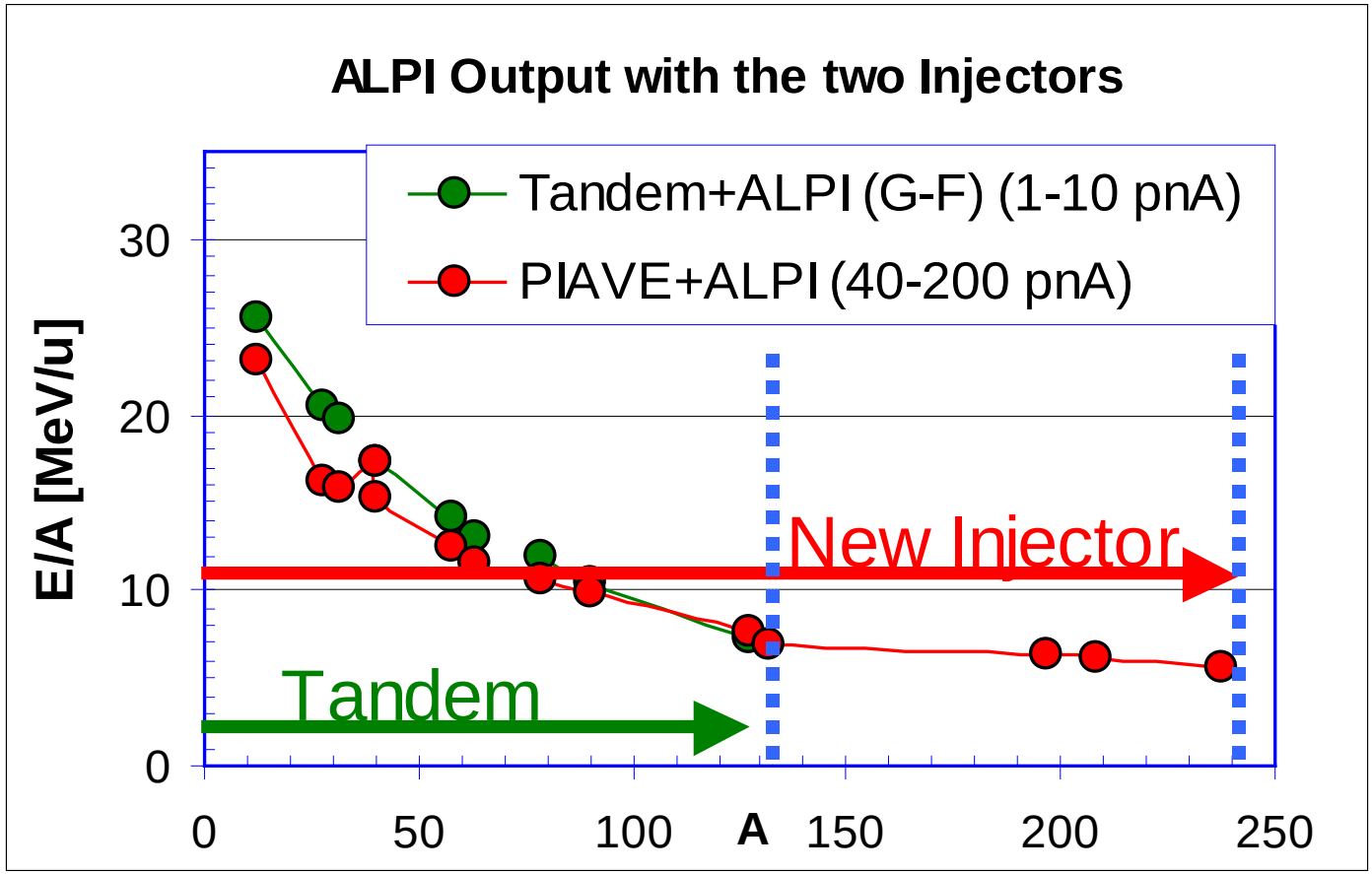
A second cyclotron has been installed

JYFL Acclab: present status and future



LEGNARO

Near future switching from a Tandem to a q+ injector (PIAVE)



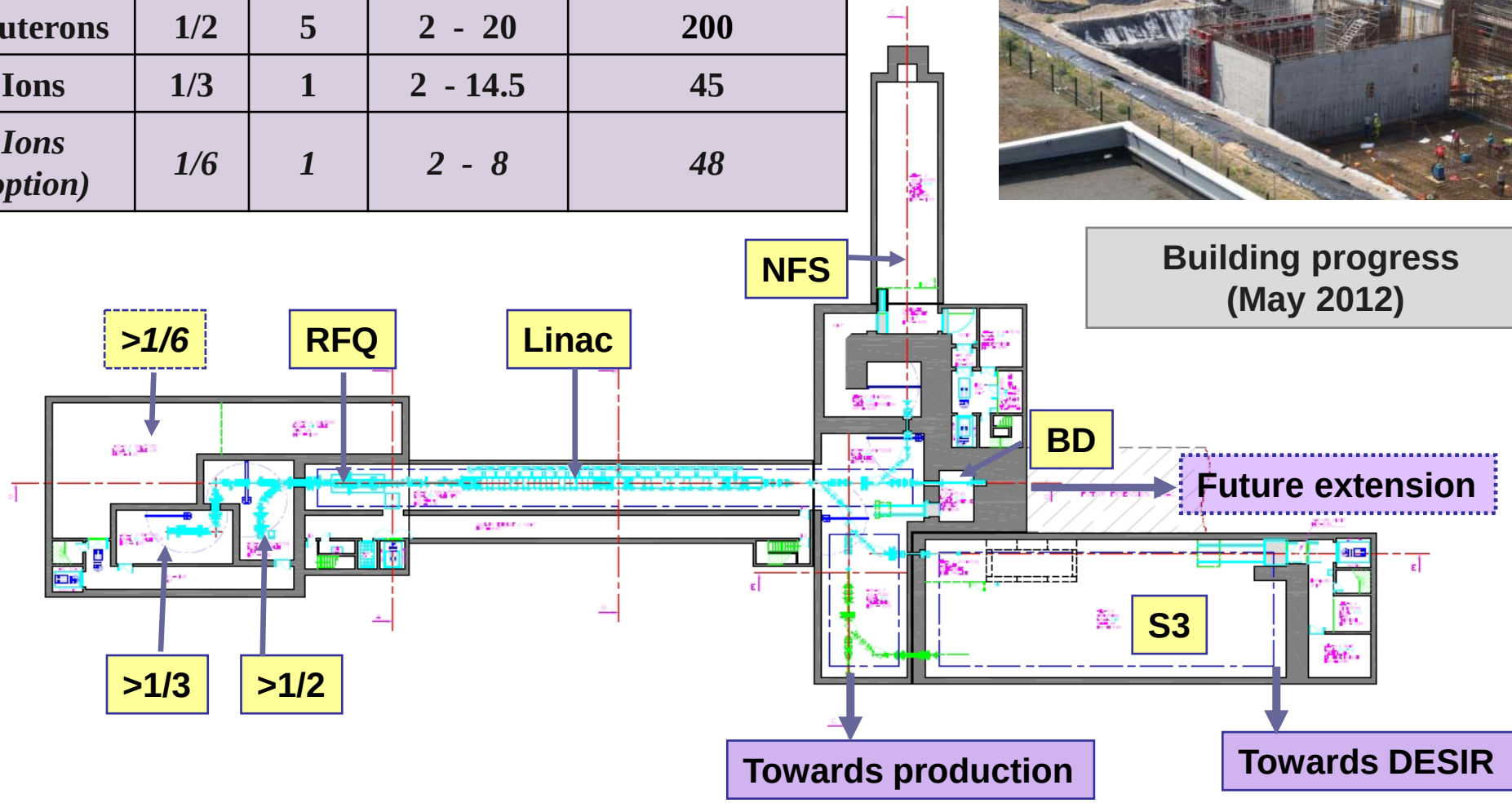
MORE CURRENT

HEAVIER MASSES

SPIRAL2 Driver Beam Characteristics

	Q/A	I (mA)	Energy (Mev/u)	CW max beam Power (KW)
Protons	**1/1**	**5**	**2 - 33**	**165**
Deuterons	**1/2**	**5**	**2 - 20**	**200**
Ions	**1/3**	**1**	**2 - 14.5**	**45**
Ions (option)	***1/6***	***1***	***2 - 8***	***48***

Building progress (May 2012)



LINAC cryomodules, couplers and amplifiers

A

IRFU/Saclay

GANIL/Caen

LPSC/Grenoble

B

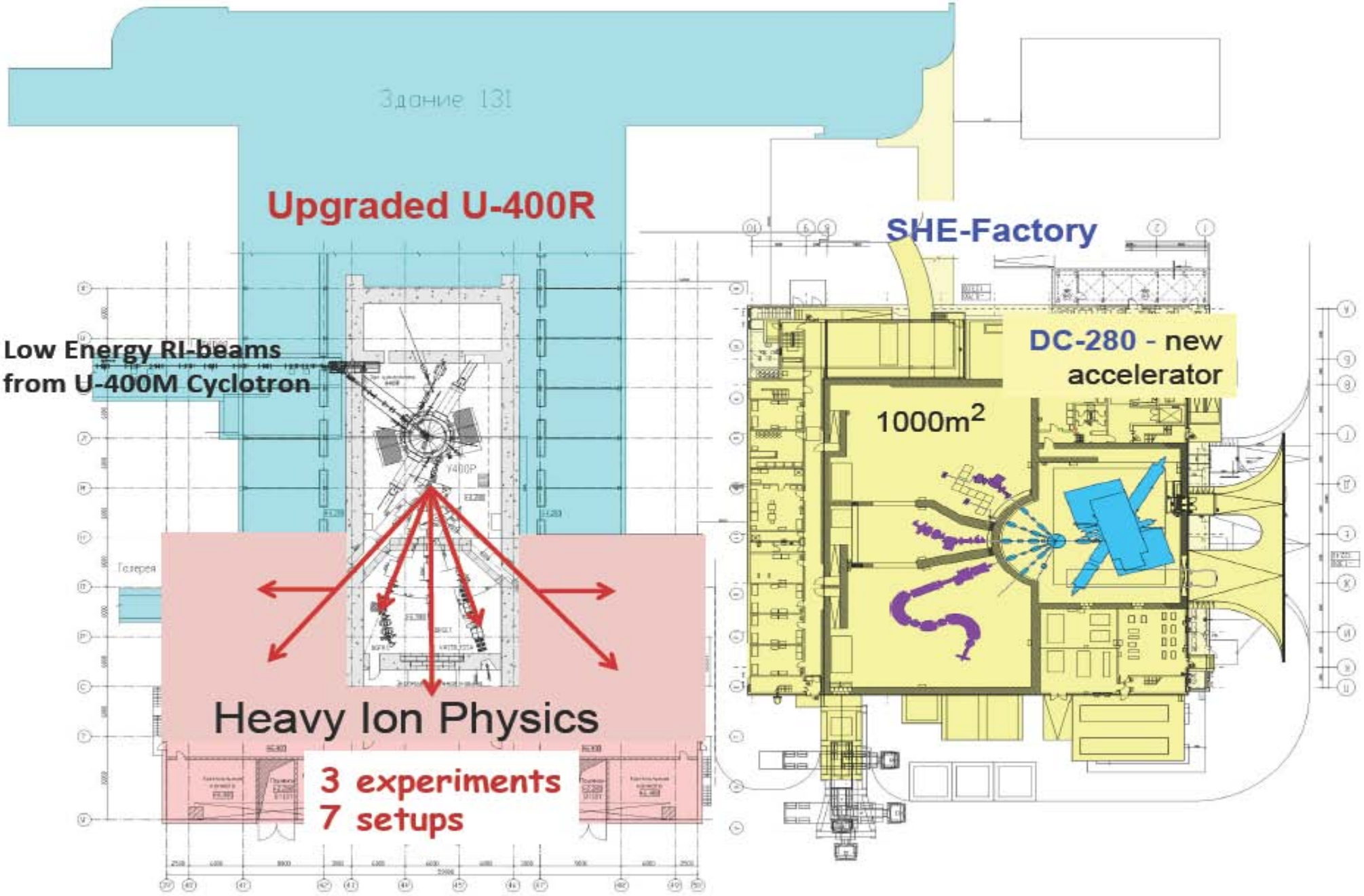
IPNO/Orsay

Other projects in Europe : Dubna SHE

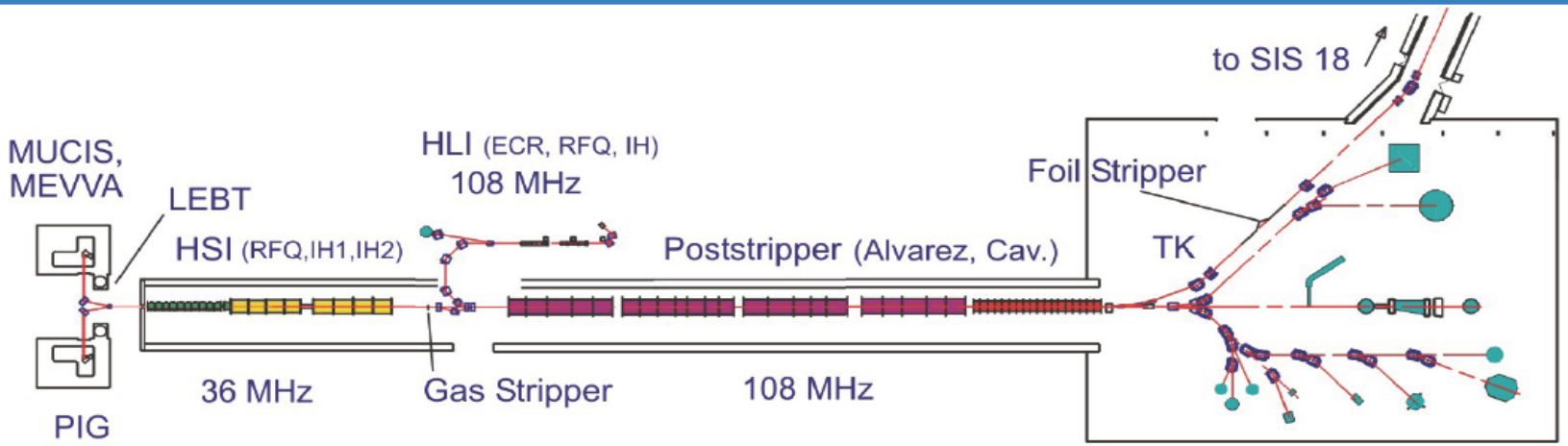
ACCELERATORS

Beam parameters	HI-Physics U-400R	SHE-Factory DC-280
Projectiles	Stable and RIB ($T_{1/2}$ > 0.1s)	Stable only
Projectile masses	4He – 238U	40Ar – 86Kr
Energy range	0.5 – 27.0 MeV/n	5 – 8 MeV/n
Energy resolution	0.5%	1.5%
Beam intensity (for 48Ca)	2.5 pμA	10-20 pμA
SHE-research program	≤30%	~100%
Registered decay chains of SHN (per year)	120 (now **30**)	**3000 - 5000**
State of readiness	75%	In course of design

From Yuri Oganessian, FUSHE 2012


Здание 131
Upgraded U-400R
SHE-Factory
Low Energy RI-beams
from U-400M Cyclotron
DC-280 - new
accelerator
1000m2
Heavy Ion Physics
3 experiments
7 setups

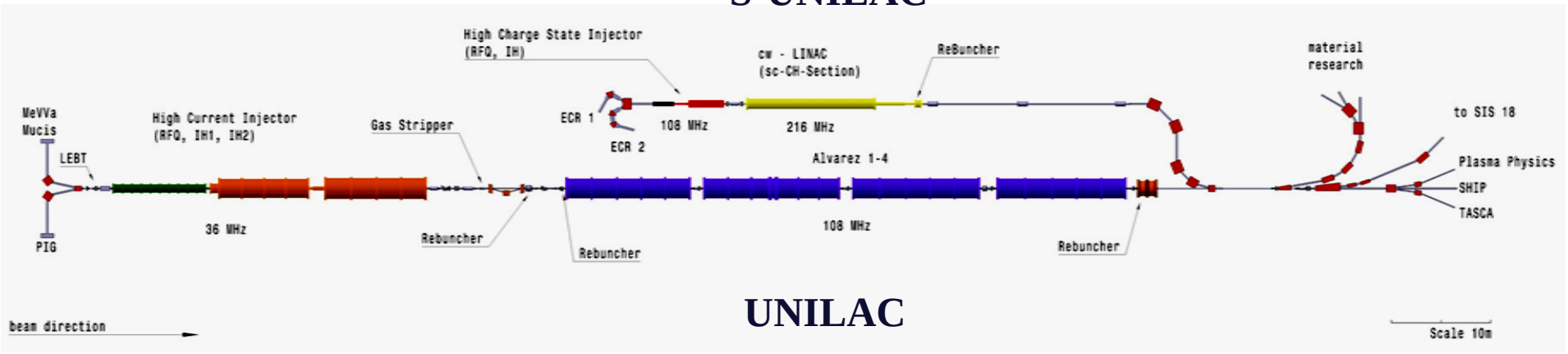
Overview/High duty factor upgrade



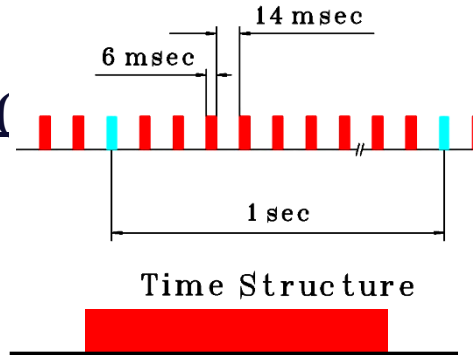
	Luminosity gain
• New RFQ: Duty cycle 25 -> 40%	x 1.6
• New MS-ECRIS: higher beam currents and	
• LEBT for new MS-ECRIS at HLI	x 5.0
• cw-linac	
– 100% duty cycle	x 2.5
– independent operation	x 2.0
	x 40

Design of a new super-conducting CW linac

S-UNILAC



UNILAC



present

DC-beam

S-UNILAC: Superconducting continuous wave (accelerator

- **High beam currents**
- **Permanent availability**
- **Low electricity costs**

U. Ratzinger, W. Barth, L. Dahl et al., 2004

A new life for ECOS: NA within ENSAR

Task 1: Organize the collaboration and exchange of expertise in high selectivity and high rejection power spectrometers.

Task 2: Organise the collaboration and exchange of expertise on the development of high power target technology

Task 3: Bring together the groups with activities on super heavy elements using high intensity ion beams for an exchange of ideas and techniques.

Task4: Promote and organize collaborative ventures between experimental researchers with special emphasize on the organization of common design and infrastructure studies between facilities that are aiming for the use of common detection systems (such as AGATA, PARIS, FAZIA etc...) at different stable ion beam

Task 5:oordination and Organization of the Network with the special duty of organising 3 annual workshops and one town meeting where all the ECOS collaboration will meet to discuss results and ideas related to the 4 tasks mentioned above.

ECOS-NA

8 Beneficiary

IN2P3, GANIL (France)

GSI-Darmstadt (Germany)

INFN, LNS (Italy)

University of Jyvaskyla (Finland)

Varsaw, Krakow (Poland)

28 associate partners

NIPNE-Bucarest (Roumania)
IN2P3 (France)
Department of Physics, University of Liverpool (UK)
KVI –Groningen (Nederlands)
CEA-Saclay (France)
LMU Munich (Germany)
IRMM Geel, (Belgium)
University of Sofia (Bulgaria)
Paul Scherrer Institute (Switzerland)
Royal Institute of Technology - Stockholm (Sweden)
University of Surrey (UK)
University of Paisley (UK)
University of Mainz (Germany)
Comenius University, Bratislava (Slovakia)
Nigde University (Turkey)
NCSR Demokritos (Greece)
Atomki- Bebrecen (Hungary)
HIL UW warsaw (Poland)
SAFE –University of Oslo (Norway)
CEA-Bruyeres-le –Chatel (France)
TU Munich (Germany)
INRNE-BAS, Sofia (Bulgaria)
Lund University (Sweden)
University of Bern (Switzerland)
University of Manchester (UK)
University of York (UK)
STFC Daresbury (UK)
University of Aarhus (Denmark)
Istanbul University (Turkey)
NR-Dubna (Russia)