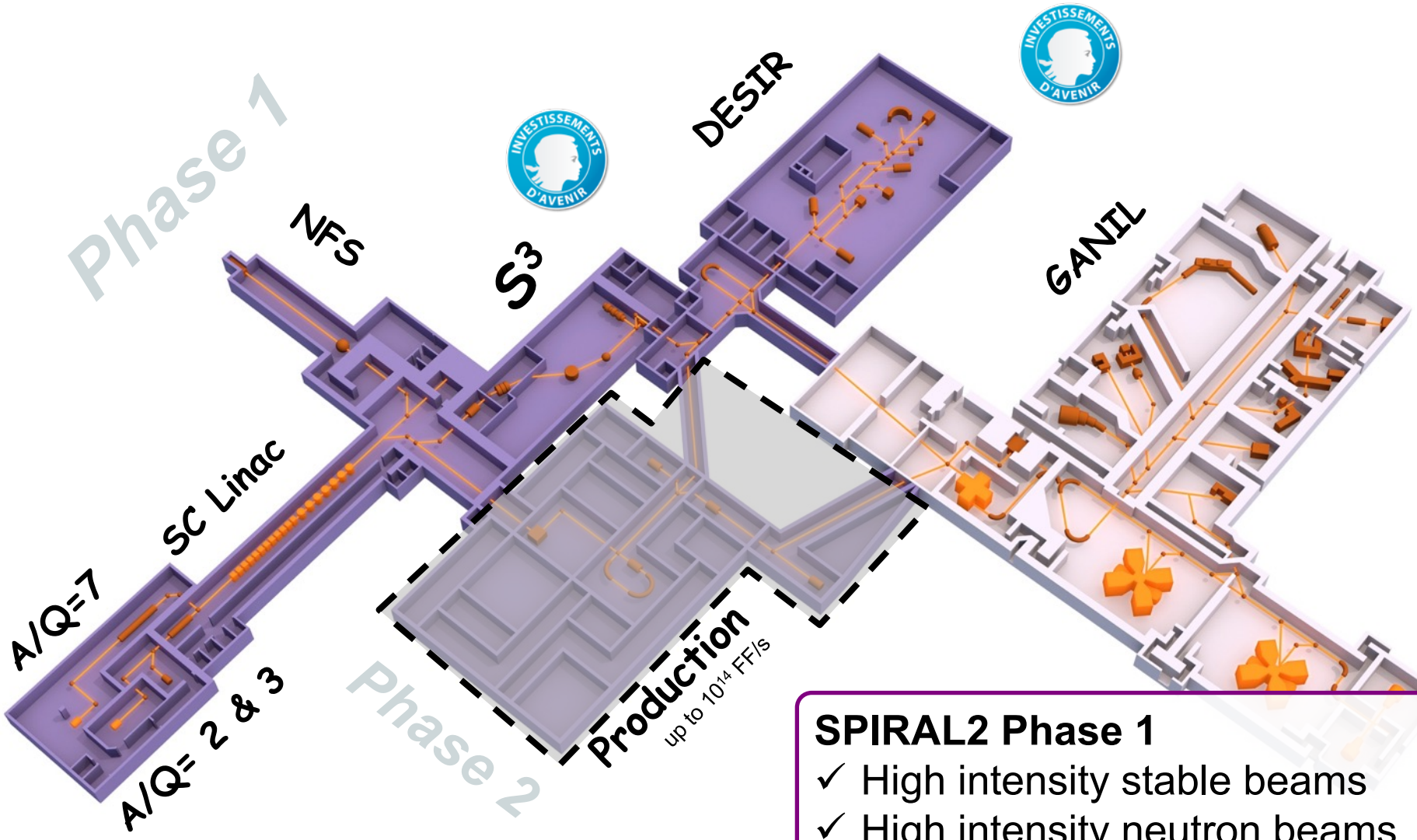
Super Separator Spectrometer

@ SPIRAL2

S3 – Workshop March 2017

H. Savajols (GANIL)

SPIRAL2 layout

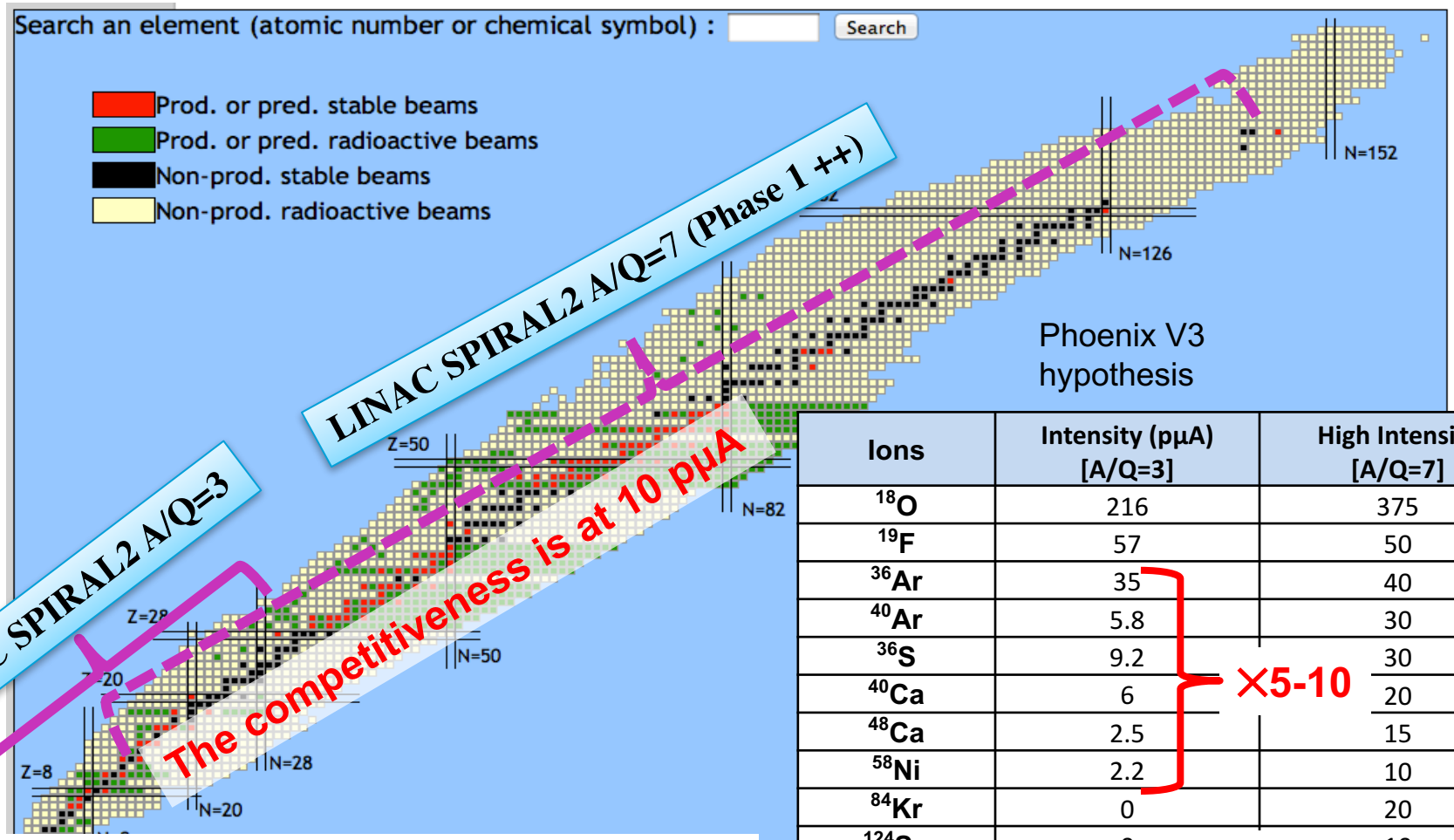


SPIRAL2 Phase 1

- ✓ High intensity stable beams
- ✓ High intensity neutron beams

High Intensity Stable beams @ SPIRAL2

- Reference project ≤ 10^{15} pps, p-Ni, 0.75 MeV/n – 14.5 MeV/n
- Phase 1++ ≤ 10^{15} pps, p-U, 0.75 MeV/n – 8.5 MeV/n



Ions	Intensity (pμA) [A/Q=3]	High Intensity [A/Q=7]
^{18}O	216	375
^{19}F	57	50
^{36}Ar	35	40
^{40}Ar	5.8	30
^{36}S	9.2	30
^{40}Ca	6	20
^{48}Ca	2.5	15
^{58}Ni	2.2	10
^{84}Kr	0	20
^{124}Sn	0	10
^{139}Xe	0	10
^{238}U	0	2.5

×5-10

×10^{x}

- Strengthen the phase 1+ scientific program
- Open new perspectives (Pb,U heavy beams)

SPIRAL2civil construction

May 2011 : Ground breaking

2011

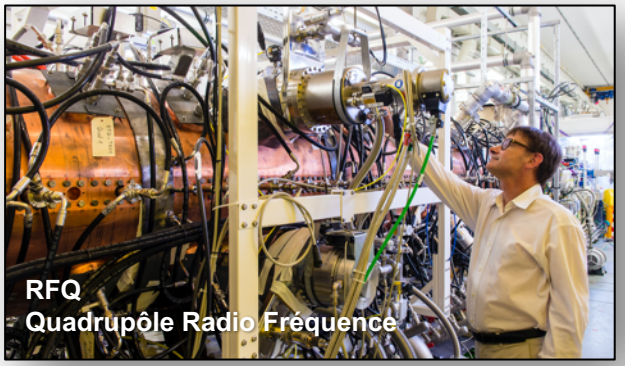
2012

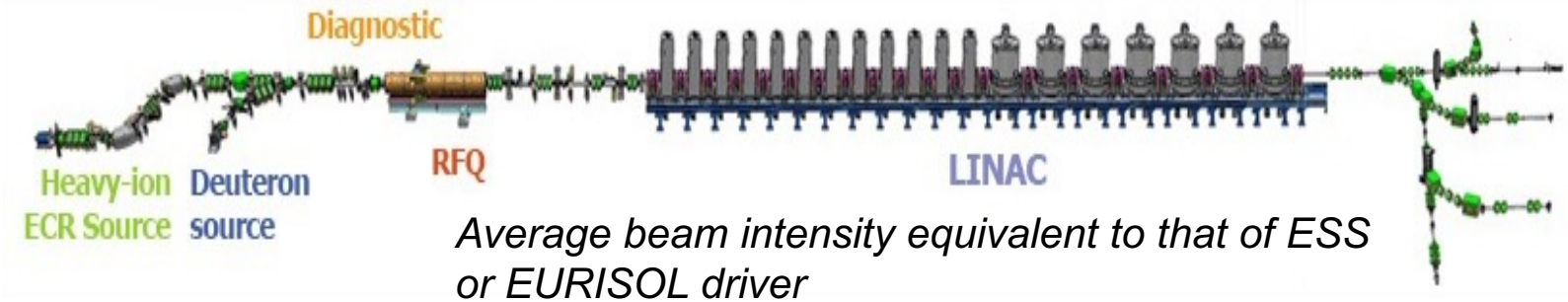
Sept 2014
Civil construction finished

2014

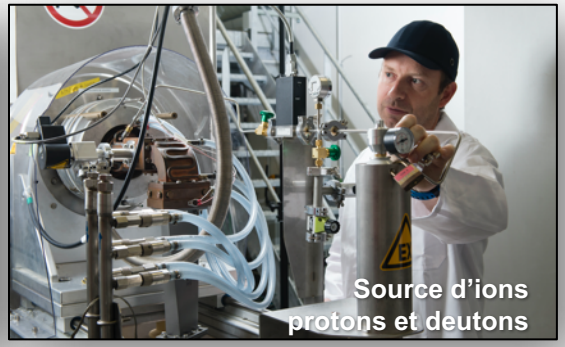
SPIRAL2 civil construction

SPIRAL2 accelerator





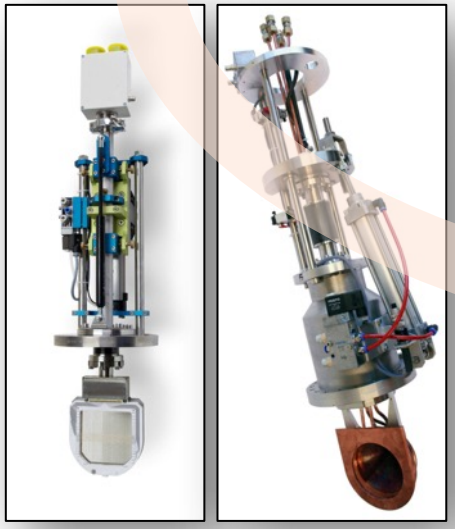
Average beam intensity equivalent to that of ESS or EURISOL driver



Installation is almost complete

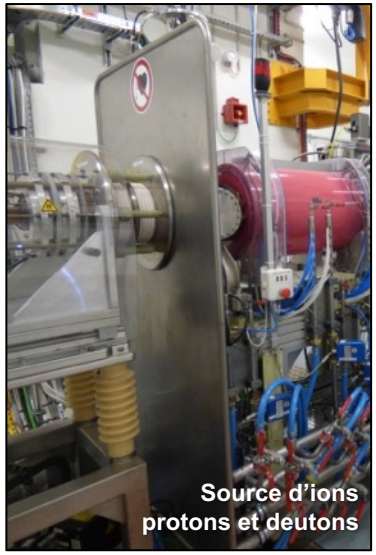
Infrastructure

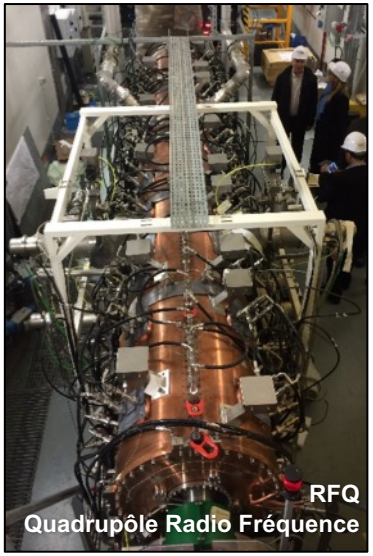
Beam monitors

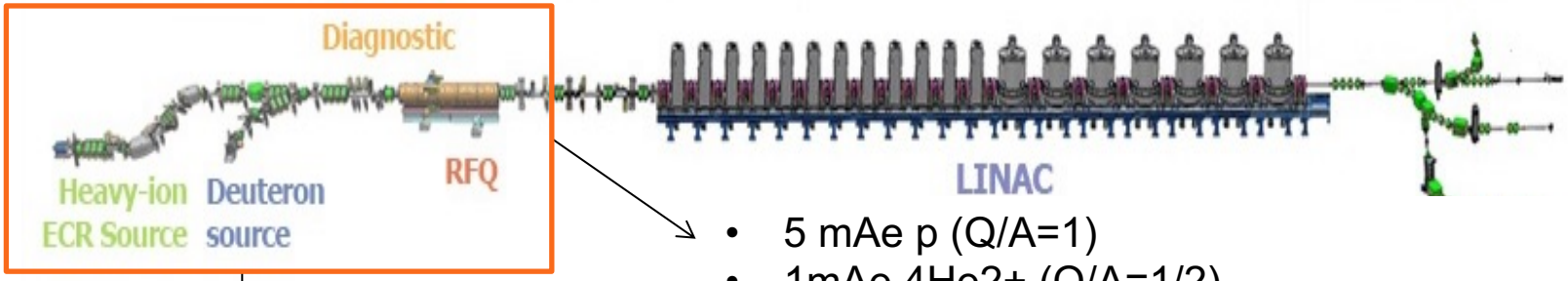


Control Room

First beams (Ions Sources & RFQ)







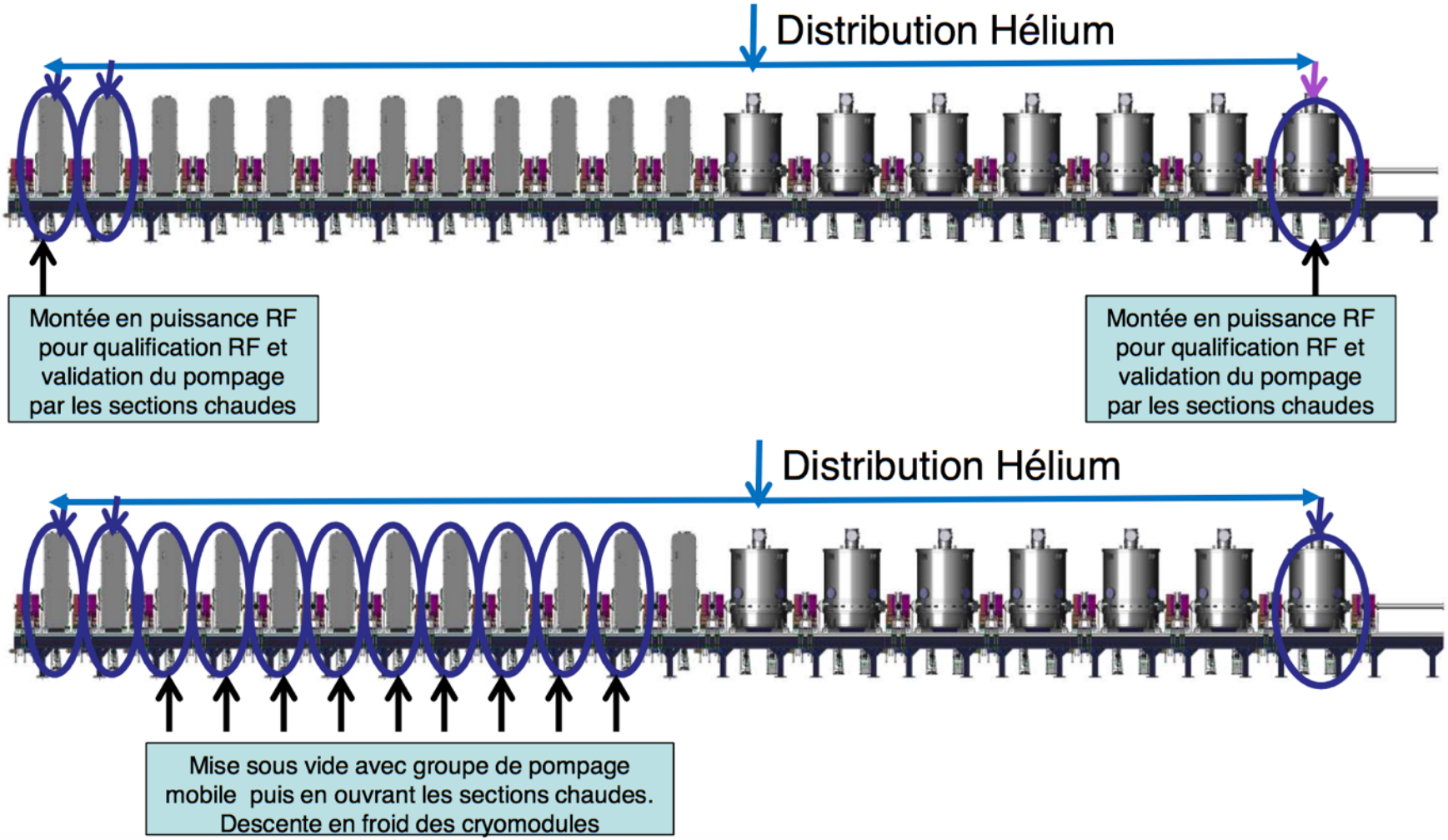
- 45 µAe 40Ar14+ (60 kV)
- 2 mAe 4He2+
- 0.9 mAe 18O6+

- 5 mAe p (Q/A=1)
- 1mAe 4He2+ (Q/A=1/2)
- 18O6+ (Q/A=1/3)

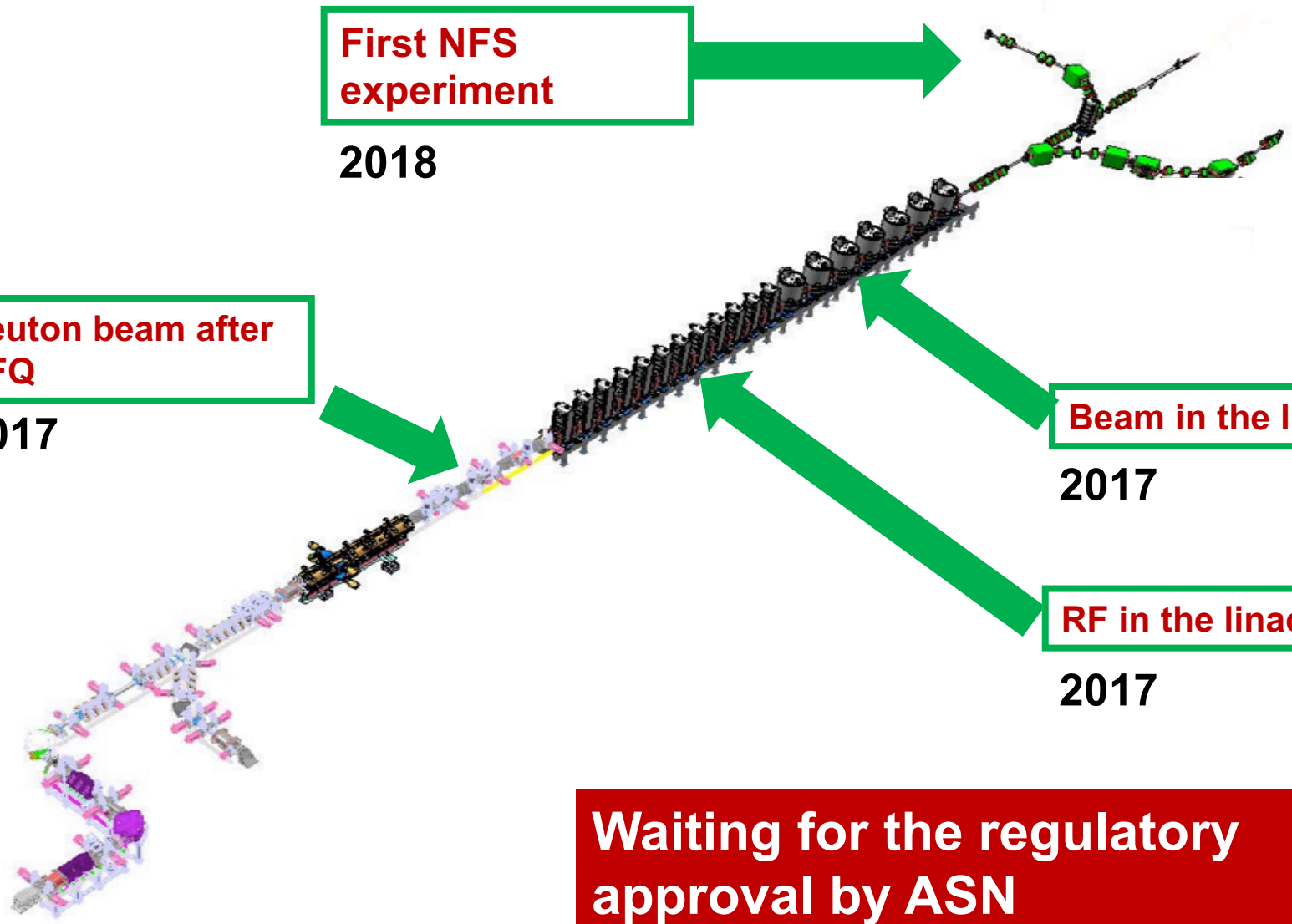
- Partial commissioning ongoing
- First beam injected in the LINAC planned in 2018

Cooled down the LINAC

Descente en froid semi complète à partir de mi mai jusque mi juillet



Accelerator next steps



First NFS experiment

2018

Deuton beam after RFQ

2017

Beam in the linac

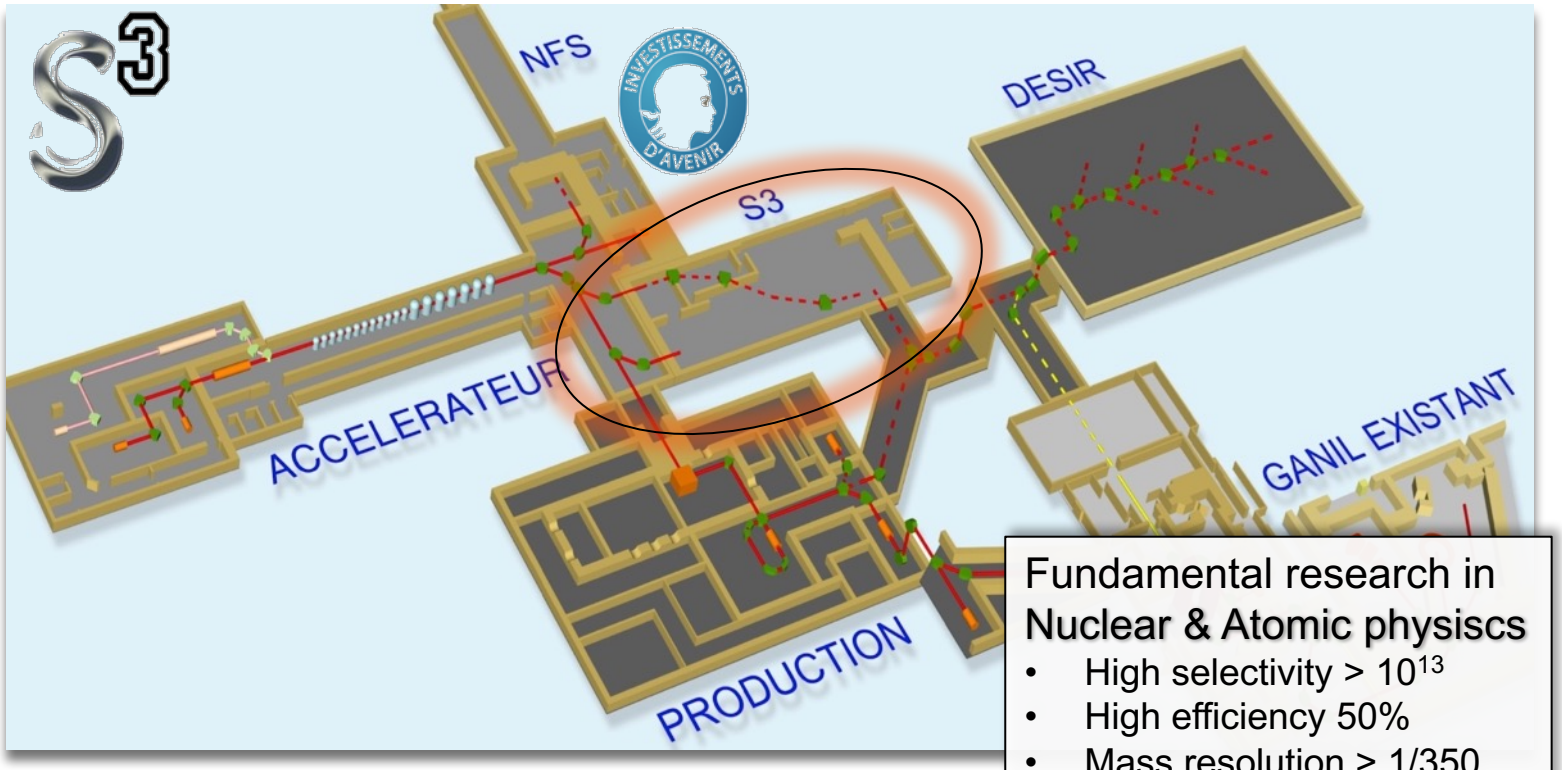
2017

RF in the linac

2017

Waiting for the regulatory approval by ASN

Super Separator Spectrometer



Fundamental research in Nuclear & Atomic physiscs

- High selectivity > 10^{13}
- High efficiency 50%
- Mass resolution > 1/350
- Versatility

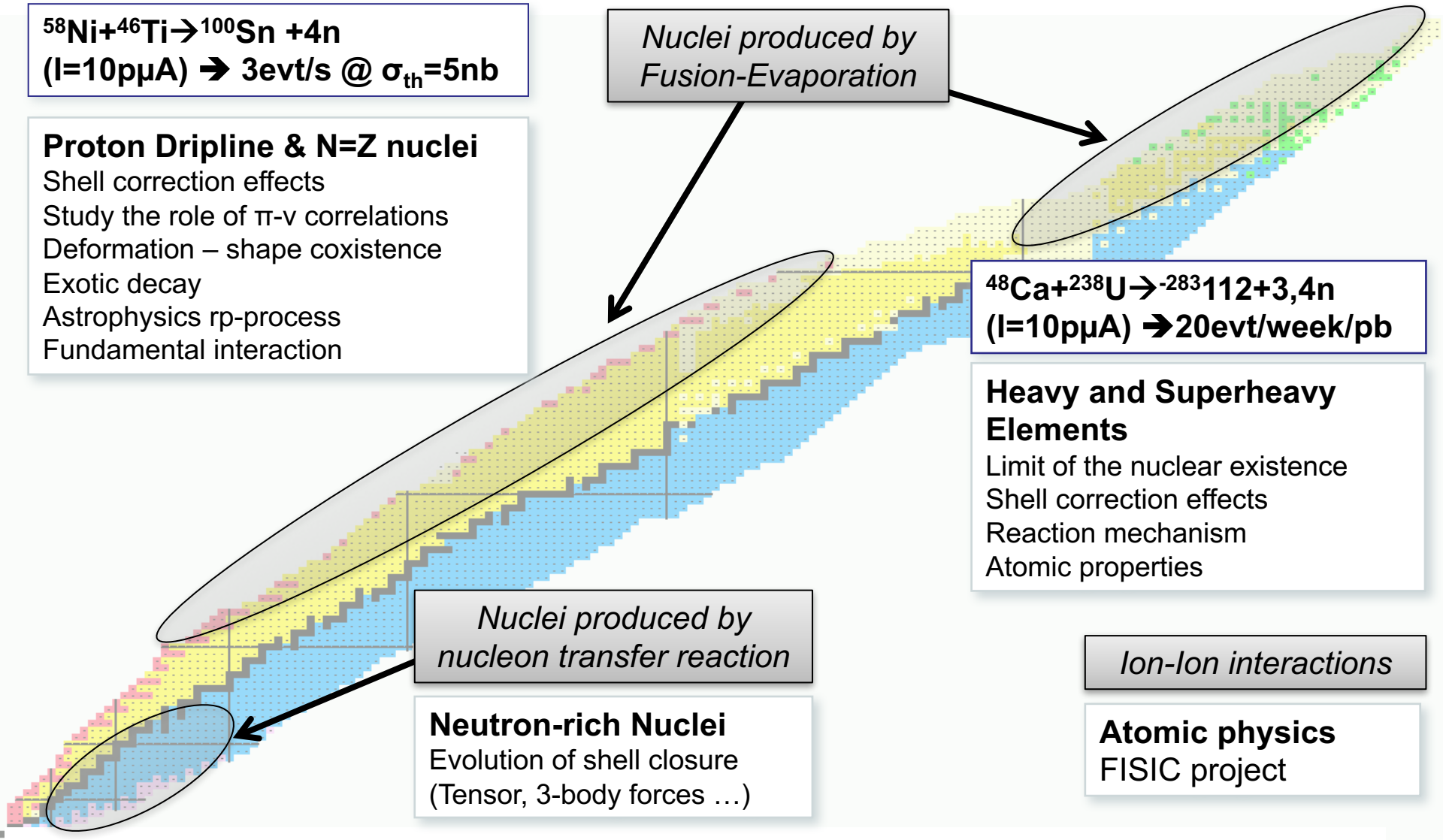
Physics goals

Study of rare events in nuclear and atomic physics

$^{58}Ni+^{46}Ti \rightarrow ^{100}Sn + 4n$
(I=10pμA) ➔ 3evt/s @ σ_{th}=5nb

Proton Dripline & N=Z nuclei
Shell correction effects
Study the role of π-ν correlations
Deformation – shape coxistence
Exotic decay
Astrophysics rp-process
Fundamental interaction

Nuclei produced by Fusion-Evaporation



$^{48}Ca+^{238}U \rightarrow ^{-283}112+3,4n$
(I=10pμA) ➔20evt/week/pb

Heavy and Superheavy Elements
Limit of the nuclear existence
Shell correction effects
Reaction mechanism
Atomic properties

Nuclei produced by nucleon transfer reaction

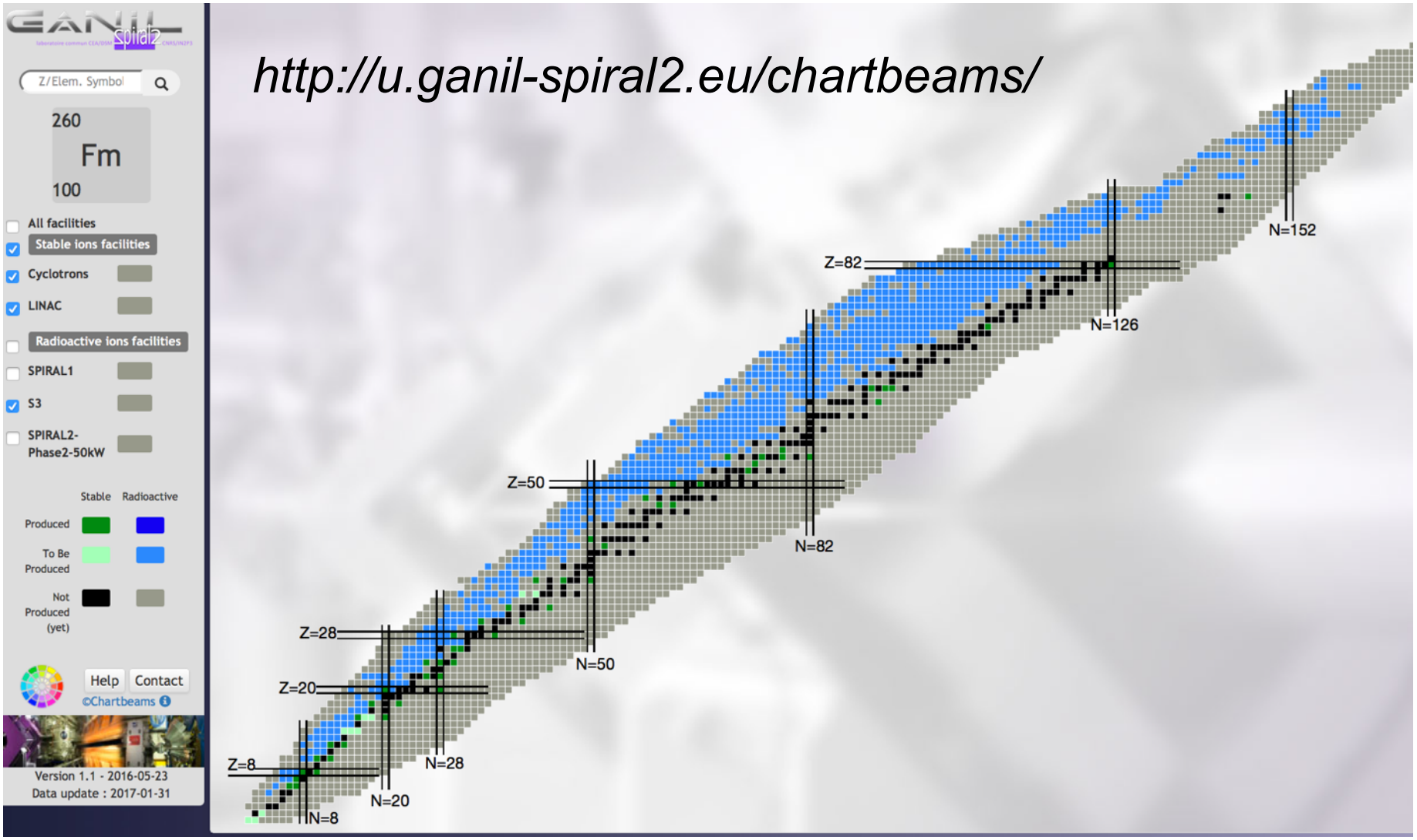
Neutron-rich Nuclei
Evolution of shell closure
(Tensor, 3-body forces …)

Ion-Ion interactions

Atomic physics
FISIC project

➔ **test nuclear and atomic models and guide new theoretical development**

S3 Beams


http://u.ganil-spiral2.eu/chartbeams/
Z/Elem. Symbol
260
Fm
100
All facilities
Stable ions facilities
Cyclotrons
LINAC
Radioactive ions facilities
SPIRAL1
S3
SPIRAL2-Phase2-50kW
Stable
Radioactive
Produced
To Be Produced
Not Produced (yet)
Help
Contact
©Chartbeams
Version 1.1 - 2016-05-23
Data update : 2017-01-31
Z=82
N=126
N=152
Z=50
N=82
Z=28
N=50
Z=20
N=28
Z=8
N=20
N=8

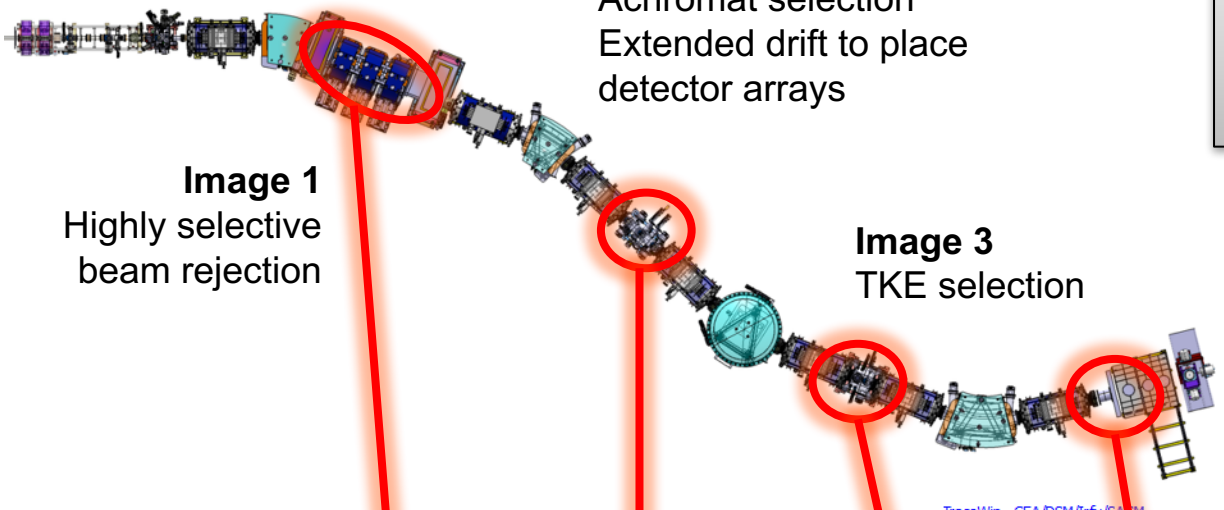
Optics

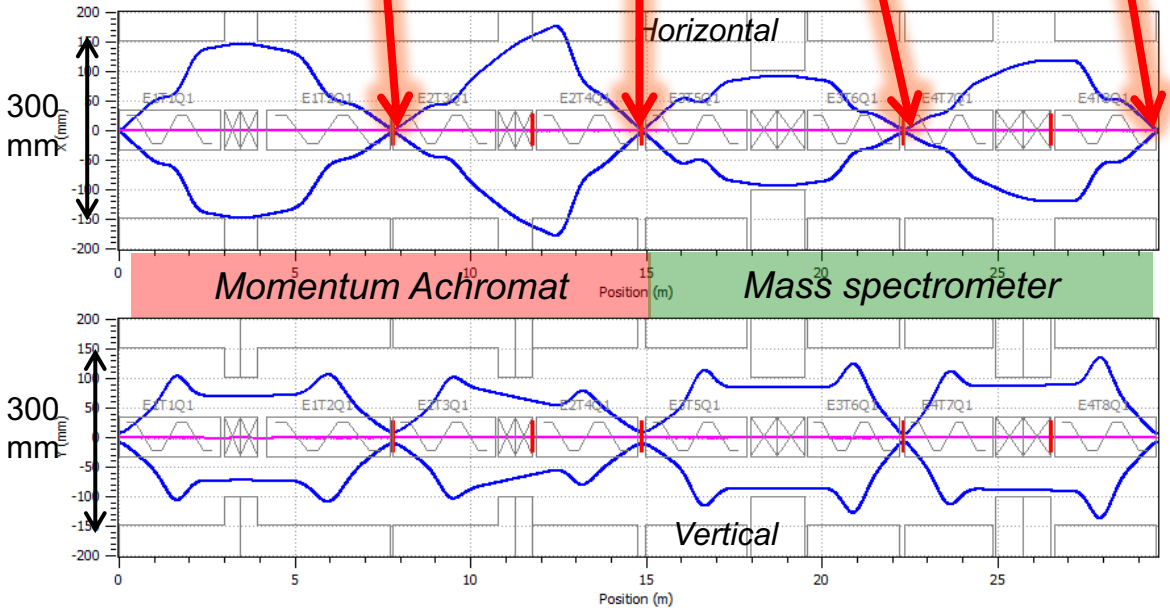
F. Déchery et al. NIMB**376** (2016) 125.
F. Déchery et al., Eur. Phys. J. A (2015) **51**: 66

Image 2
Achromat selection
Extended drift to place detector arrays

Image 1
Highly selective beam rejection

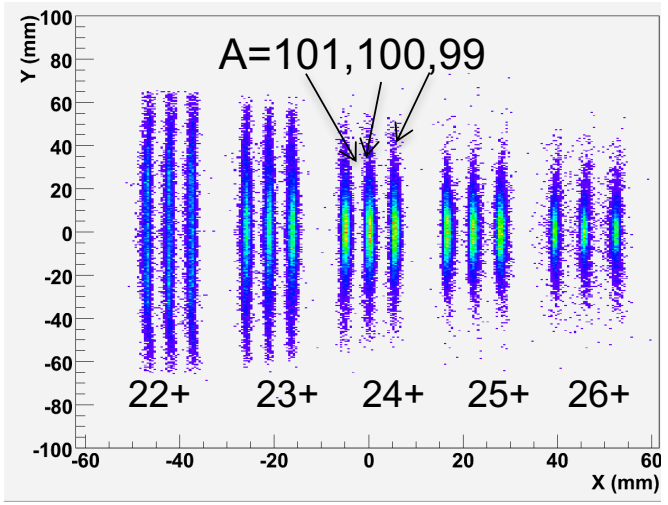
Image 3
TKE selection





- Multistep separation
- Large acceptance
- Variable modes
- Mass resolution (ΔM/M=460)

Image 4 : Mass selection



Optical design is complete
(Final report April 2017)

Commissioning plan is under progress

Bi-monthly meetings

Operational modes & performances

◎ High Resolution mode

- Designed for maximum selection
- Weighted mass resolution: **ΔM/M = 460**
- Folded transmission: 50% for $^{58}Ni + {}^{46}Ti \rightarrow {}^{100}Sn^{24+} + 4n$

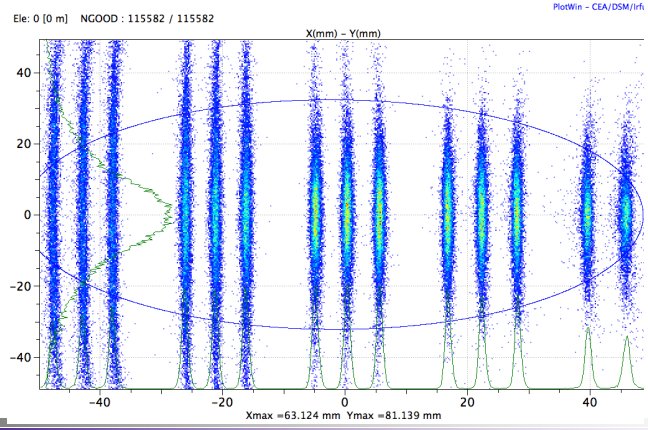
◎ High Transmission mode

- Designed for very asymmetric reactions
- Weighted mass resolution: **ΔM/M = 260**
- Folded transmission: 15-20% for $^{22}Ne + {}^{238}U \rightarrow {}^{255}No + 5n$

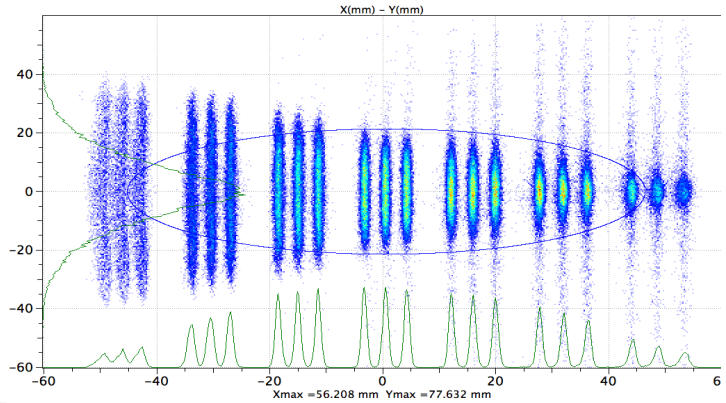
◎ Converging mode

- Designed for gas cell – Laser spectroscopy
- Folded transmission: 68% for $^{58}Ni + {}^{40}Ca \rightarrow {}^{94}Ag + p3n$

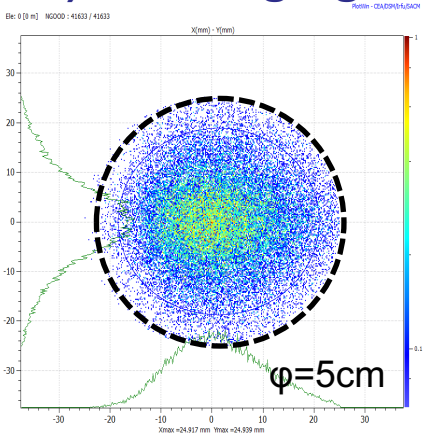
1) High resolution



2) High transmission



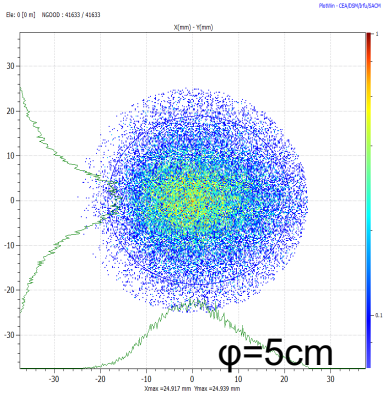
3) Converging



S3 Commissioning

Day one experiments : Converging optical mode

ex : Folded transmission: 68% for ^{58}Ni + ^{40}Ca ➔ ^{94}Ag + p3n



Optimisation requested:

- Primary beam rejection + high intensities (> 1pμA)
- Best possible transmission (80% of the nominal)
- ~~Mass Resolution~~

Which reactions for the commissioning ?

$^{116}Sn(^{40}Ar,4n)^{152}Er$ ($T_{1/2}$=10 s, α-branching = 91 %).

Oder Candidates : $^{144}Sm(^{36}Ar,4n)^{176}Hg$ - $^{160}Dy(^{36}Ar,4n)^{192}Po$

Which setup for the commissioning ?

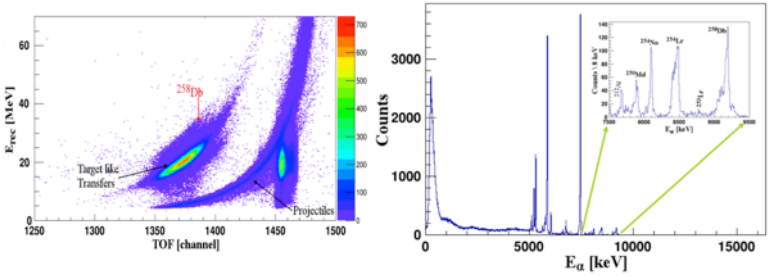
Stable Target station + MAMS + Multipurpose diagnostic box @ focal plane (Energy, TOF, Recoil Profile, Counting rates, Decay, …)

Prioritized beams : $^{36\text{-}40}Ar$, $^{40\text{-}48}Ca$, ^{58}Ni

Later : $^{32\text{-}36}S$, $^{26\text{-}30}Si$ … (TBC)

Ne ? O ? Ti ?

To be discussed @ workshop



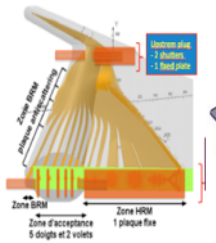
Main equipments

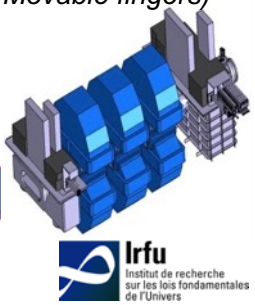
F. Dechery et al., Eur. Phys. J. A (2015) 51: 66
F. Dechery et al., in press NIMB

- Multistep separation
- Large acceptance
- Variable modes
- Mass resolution (ΔM/M=460)

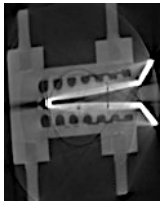
Dispersive zone

(beam dump & Movable fingers)



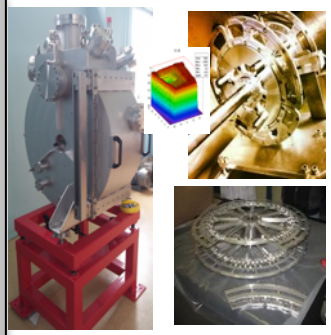


Irfu Institut de recherche sur les lois fondamentales de l'Univers



tested for 5kW/cm²

Target system



High power rotating targets (3000-5000 rpm)
Stable & Actinide systems

3 × M-dipoles

Large H & V gaps

E-Dipole

20 cm gap & +/- 350 kV
Epmax : 12-14 MeV
Open slit in the anode

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

(L=26m)

SC Multipoles

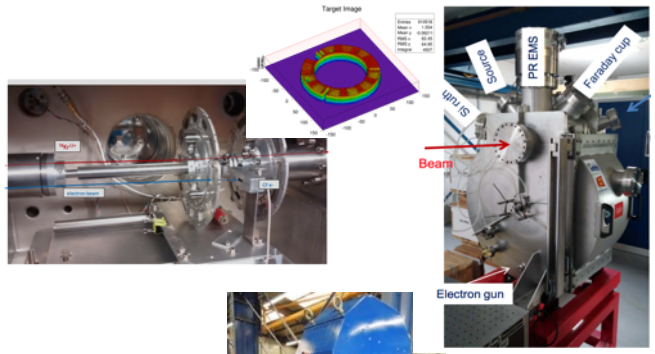
Q+S+O fields

PSS

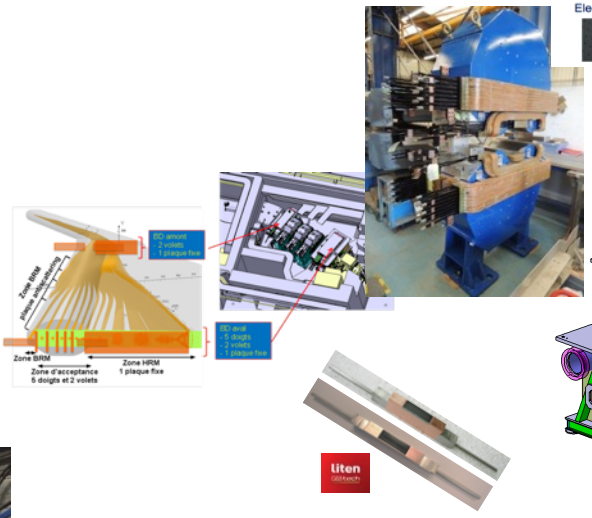
Cold Box

Main equipment status

- **Stable target station (Ganil)**
  - ✓ *Hardware completed (Chamber, wheel, diagnostics, …)*
  - ✓ *Wheel control & automation under tests*
  - ✓ *DAQ (diagnostics,…) under development ⟶ T1 2018*

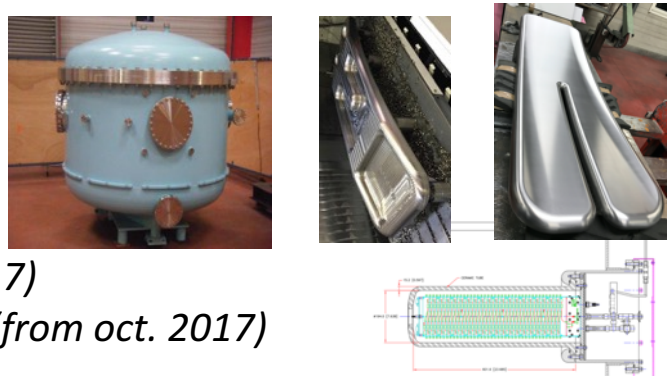


- **Dispersive zone (IRFU)**
  - ✓ *Open triplet delivered @ GANIL*
  - ✓ *Beam Dump*
    - *Design done, fingers commissioned*
    - *Chambers : delays with Sominex (June 2017)*
    - *Integration @ tests @ Saclay : S2 2017*
    - *Integration @ tests @ S³ : S1 2018*



- **Dipoles magnétiques (Ganil)**
  - ✓ *Delivered since 2013*
  - ✓ *Field mapping done*

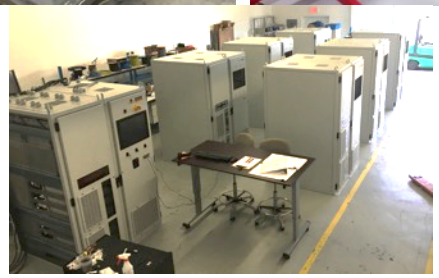
- **Electric dipole (IPNO-ANL)**
  - ✓ *Electrode delivered*
  - ✓ *Full mechanical assembly @ IPNO (March 2017)*
  - ✓ *Power supply : Design ok – assembly & tests (October 2017)*
  - ✓ *Final assembly & commissioning @ IPNO or GANIL (TBC) (from oct. 2017)*



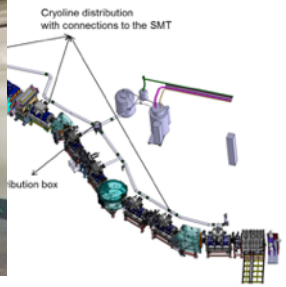
Main equipment status

- **SMT : Superconducting Multipoles Triplets (GANIL,ANL), Cryomagnetics**
  - ✓ *Tests of the first SMT @ CMI & ANL (From March 2017)*
  - ✓ *Delivery SMT2-7 @ GANIL (July 2017 - April 2018)*

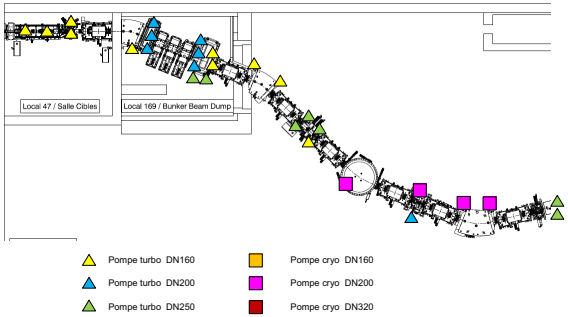

- **SMT Power Supply Systems (PSS) alims et protection Quenchs (GANIL, ANL, Irfu), AML**
  - ✓ *Manufacturing review (July 2016)*
  - ✓ *Tests of the first PSS @ ANL (May 2017)*
  - ✓ *Delivery of PSS1-7 @ GANIL (July 2017-October 2017)*



- **Cryogenic system (GANIL, ANL, Irfu)**
  - ✓ *Cold box commissioning (April. 2017)*
  - ✓ *Cryo line installation and tests (May 2017)*
  - ✓ *Commissioning SMTs @ GANIL (From September 2017) TBC*
  - ✓ *Full commissioning of the seven SMT-PSS (T3 2018)*

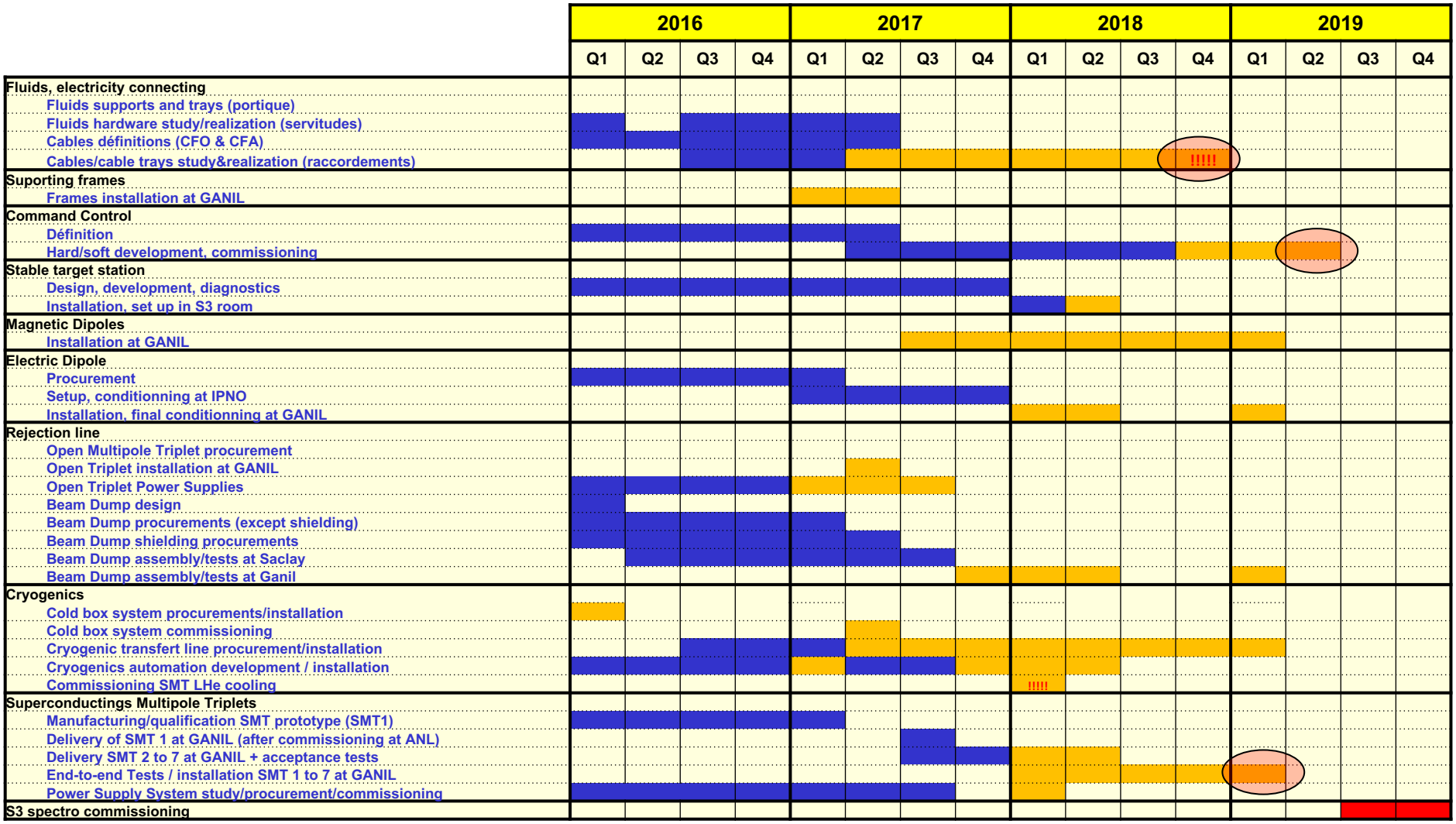
- **Vacuum system**
  - ✓ *Equipment ordered*
  - ✓ *Tests/commissioning @ GANIL (S1 2017)*



- **Vacuum chambers**
  - ✓ *Expected delivery (June 2017) TBC*

- **Servitudes et raccordements (Lots SPIRAL2)**
  - ✓ *Fluids (Jan. 2017), HV power (Oct 2017), LV power (T4 2018)*

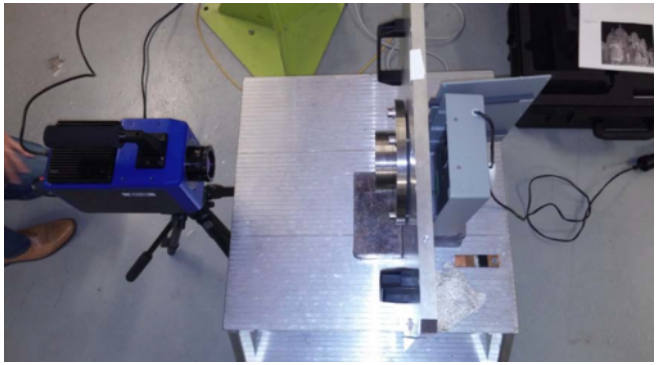
Planning nominal phase 0

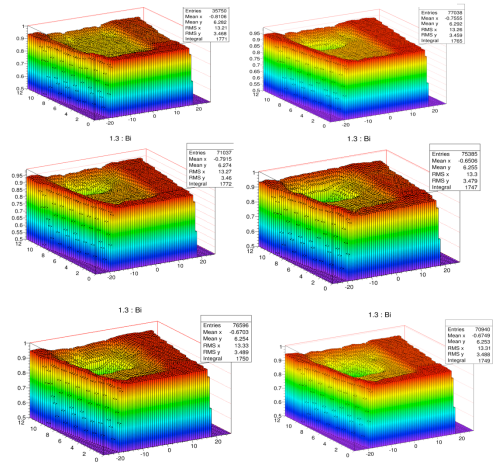


Critical paths

Target system developments

Stable target system

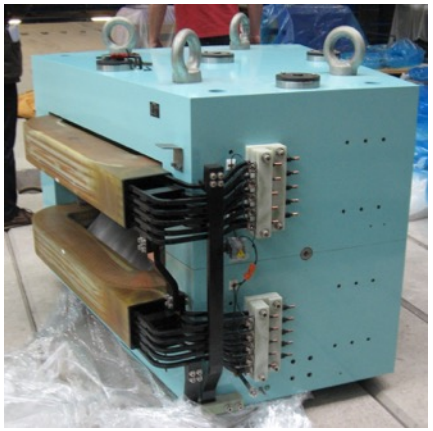




Ch. Stodel et al, Journal of Radioanalytical and Nuclear Chemistry, ***305*** *(2015)761.*

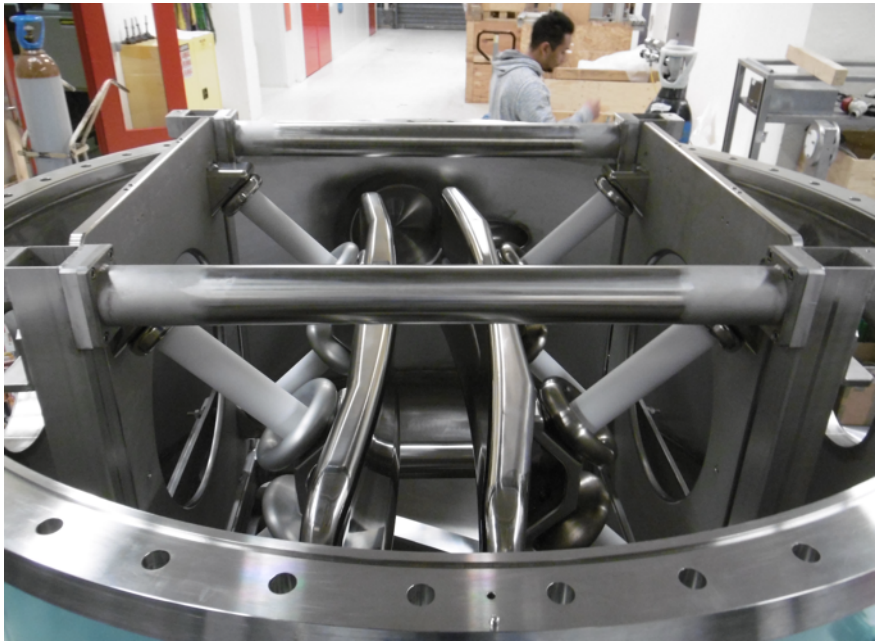
ANR PRCI TATTOO (Thin actinide target cooperation) pre-submitted

Magnets (Dipoles & Multipoles)

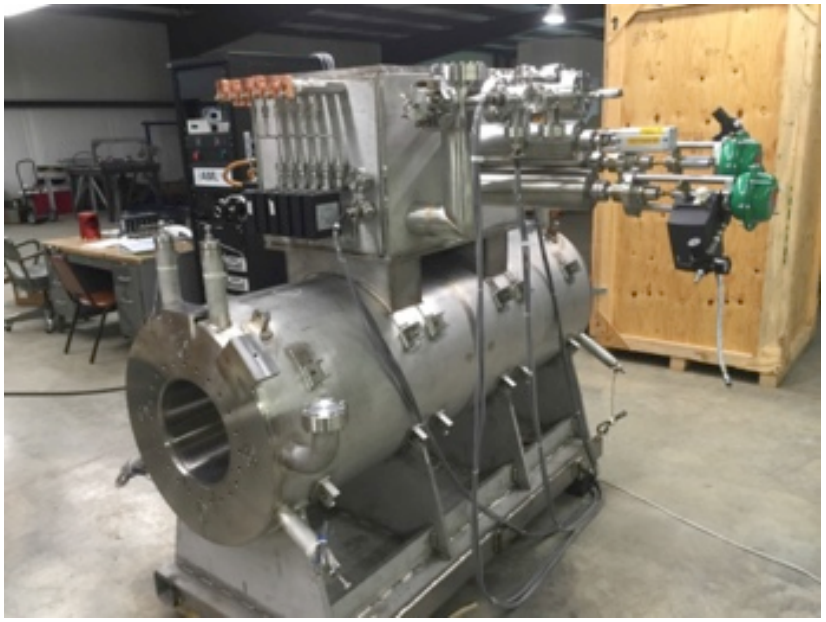


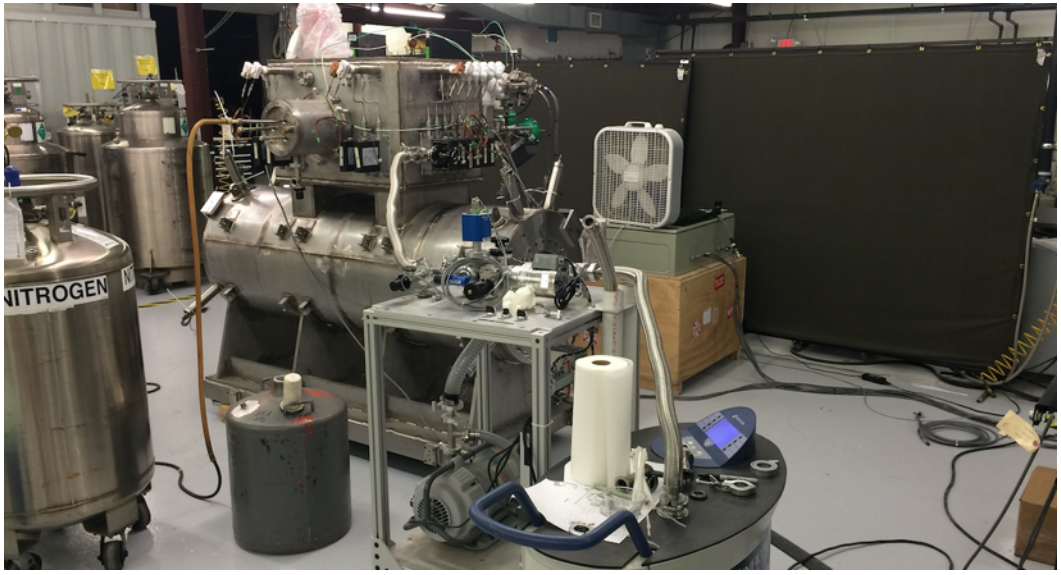
Waiting to be installed

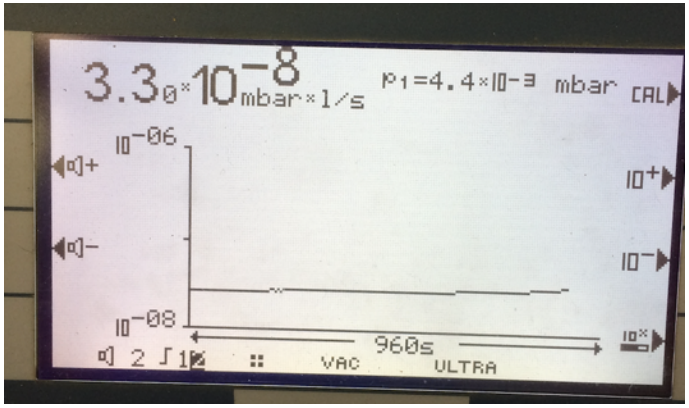
Electric dipole assembly @ IPNO



Superconducting Multipole Triplet @ CMI







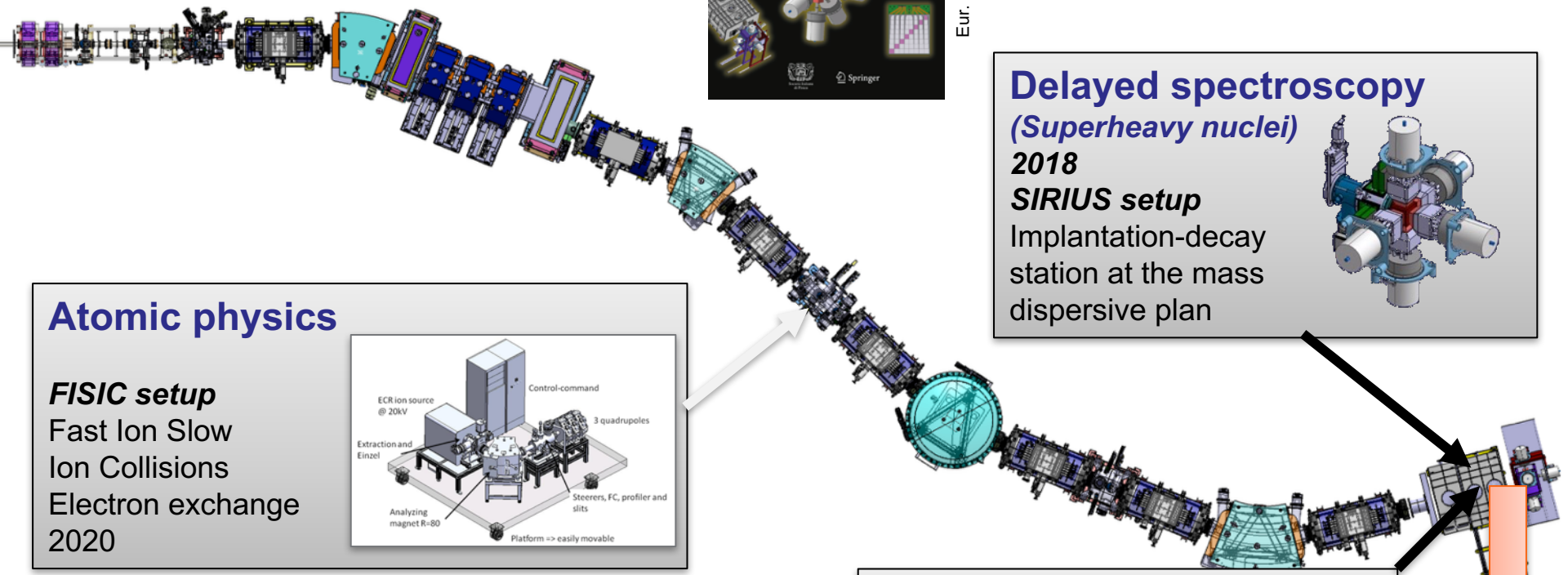
Power Supply System @ AML

S3 room …will be soon very crowded

Experimental techniques

S3 Physics case (26 LoIs)
- VHE-SHE nuclei
- Proton drip-line & N=Z
- Nuclear Astrophysics
- Atomic physics

Eur. Phys. J. A (2015) 51: 66



Delayed spectroscopy

(Superheavy nuclei)

2018

SIRIUS setup

Implantation-decay station at the mass dispersive plan

Atomic physics

FISIC setup

Fast Ion Slow Ion Collisions

Electron exchange

2020

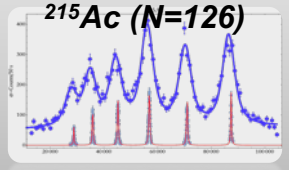
Ground state properties

(mass, size, moments, spins)

2018

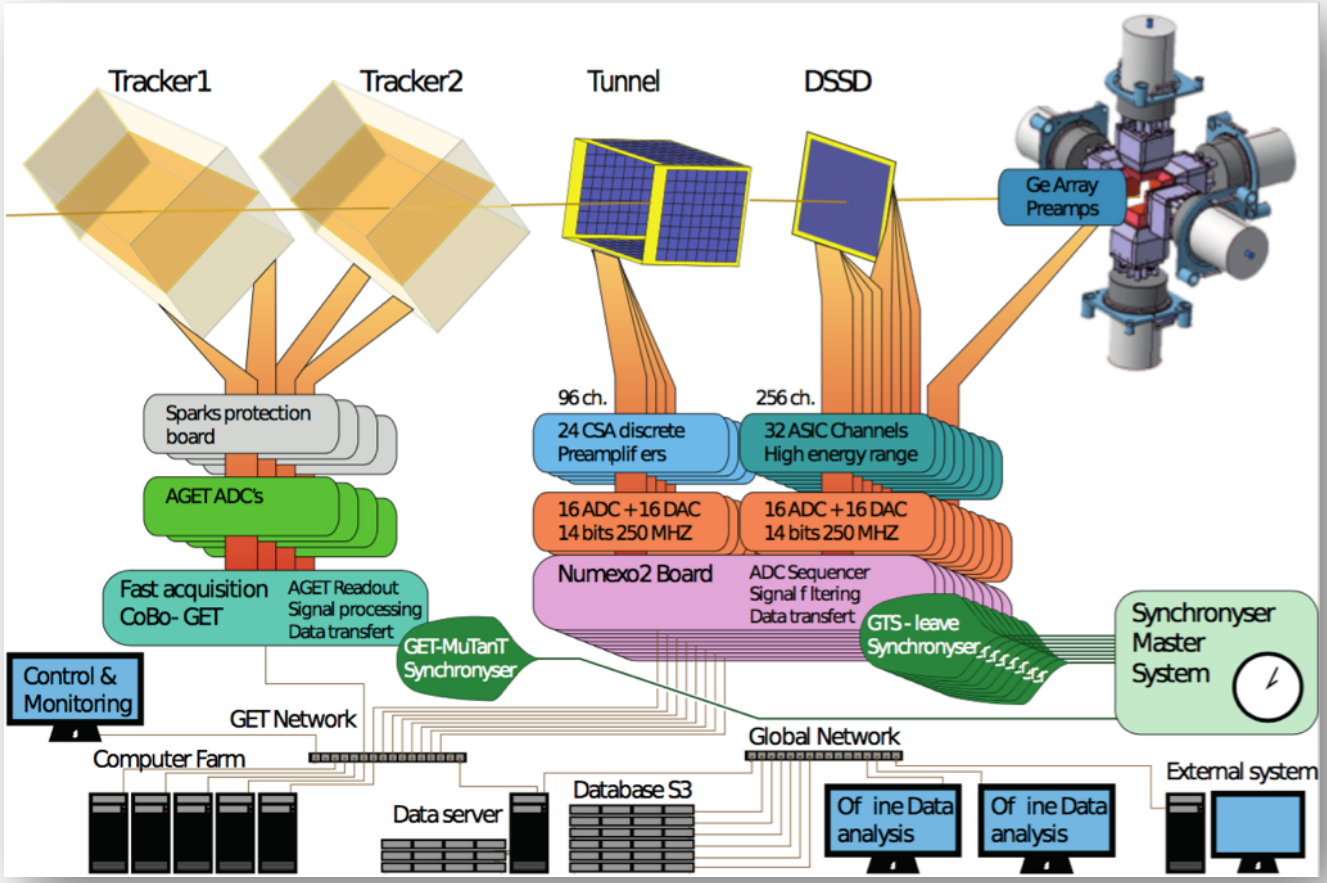
S3-LEB setup

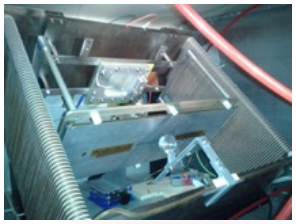
IGLIS + Mr-ToF

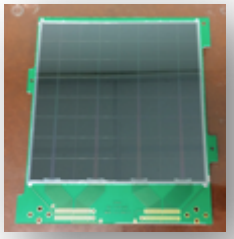


DESIR

SIRIUS (Spectroscopy & Indentification of Rare Ions Using S^3)







Full assembly & tests planned mid 2018

See talk B. Sulignano

F. Dechery et al., Eur. Phys. J. A (2015) 51: 66

Low Energy Branch (LEB)

R. Ferrer et al., NIM B 317 (2013) 570–581

KU LEUVEN (Gas cell, laser system)

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY (Gas cell)

lpc caen (RFQs)

GANIL spiral2 (mr-TOF-ms, laser system infractructure, safety, RFQsdetectors)

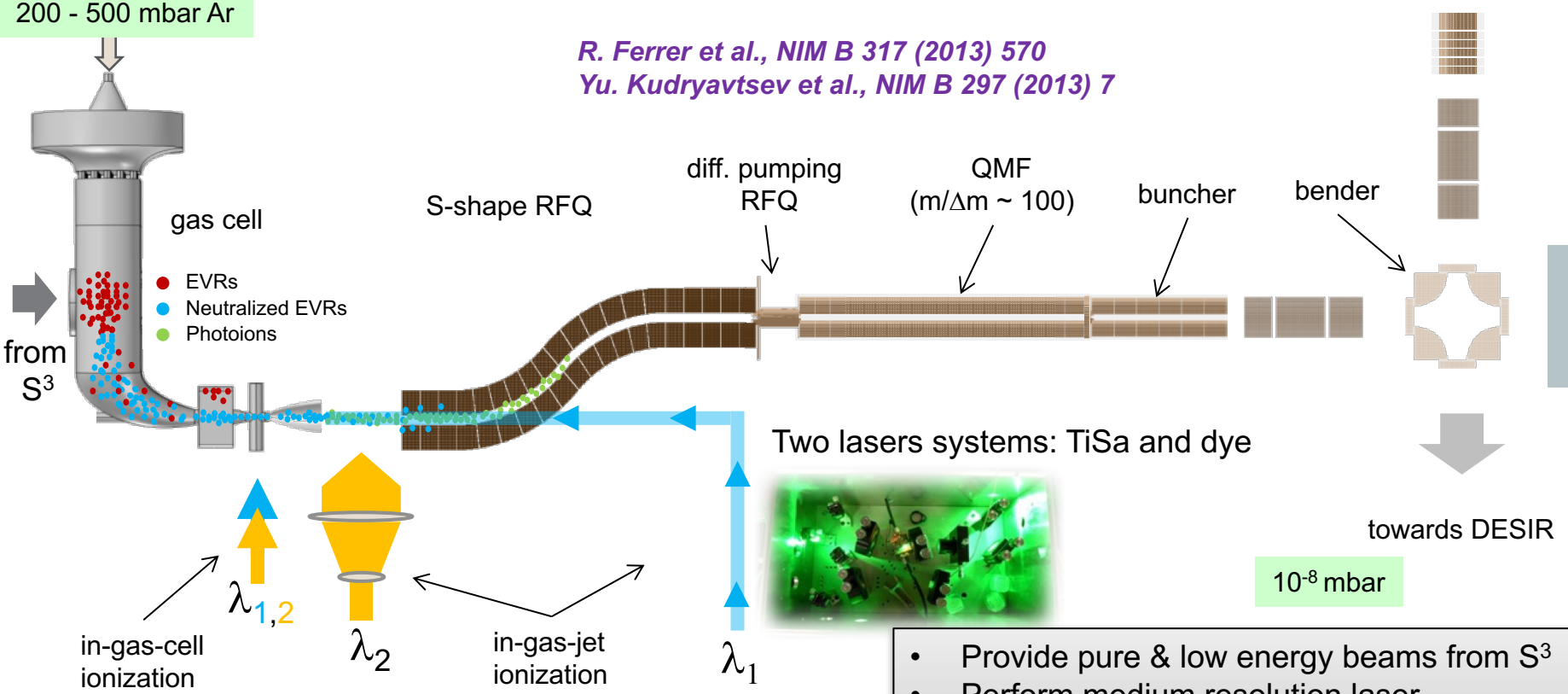
LARISSA JGU JOHANNES GUTENBERG UNIVERSITÄT MAINZ; UNIVERSITY OF JYVÄSKYLÄ (narrow band-width laser pre-studies at MARA)

MCP

MR ToF MS ($m/\Delta m \sim 10^5$)

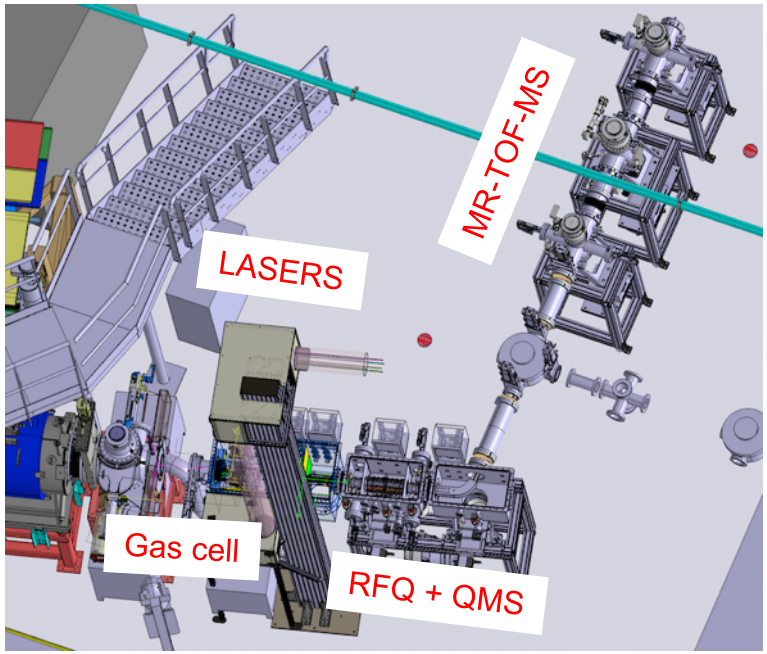
200 - 500 mbar Ar

R. Ferrer et al., NIM B 317 (2013) 570
Yu. Kudryavtsev et al., NIM B 297 (2013) 7

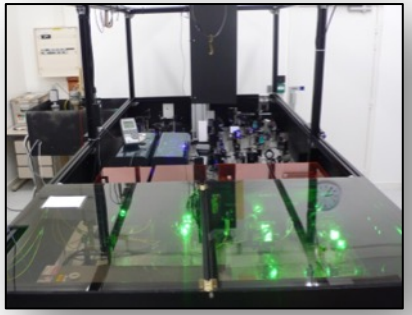


- Provide pure & low energy beams from S^3
- Perform medium resolution laser spectroscopy
  (charge radii, spin, magnetic dipole moment, electric quadrupole moment)

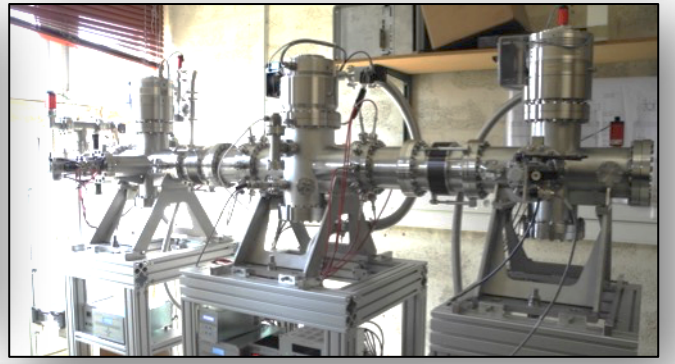
LEB equipment



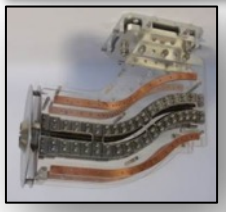
TiSa Lasers

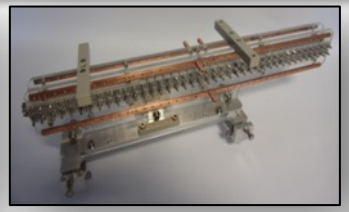


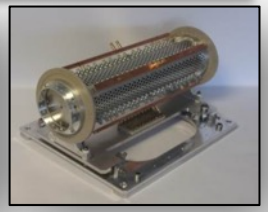
MR-TOF-MS (PILGRIM)



RFQ + QMS



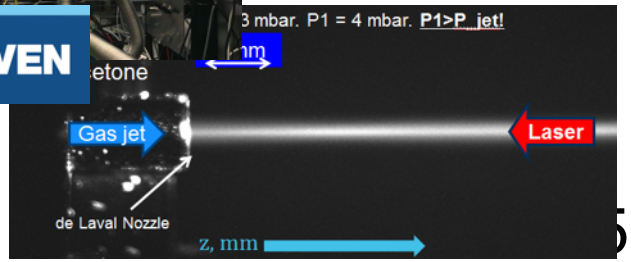




IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

KU LEUVEN

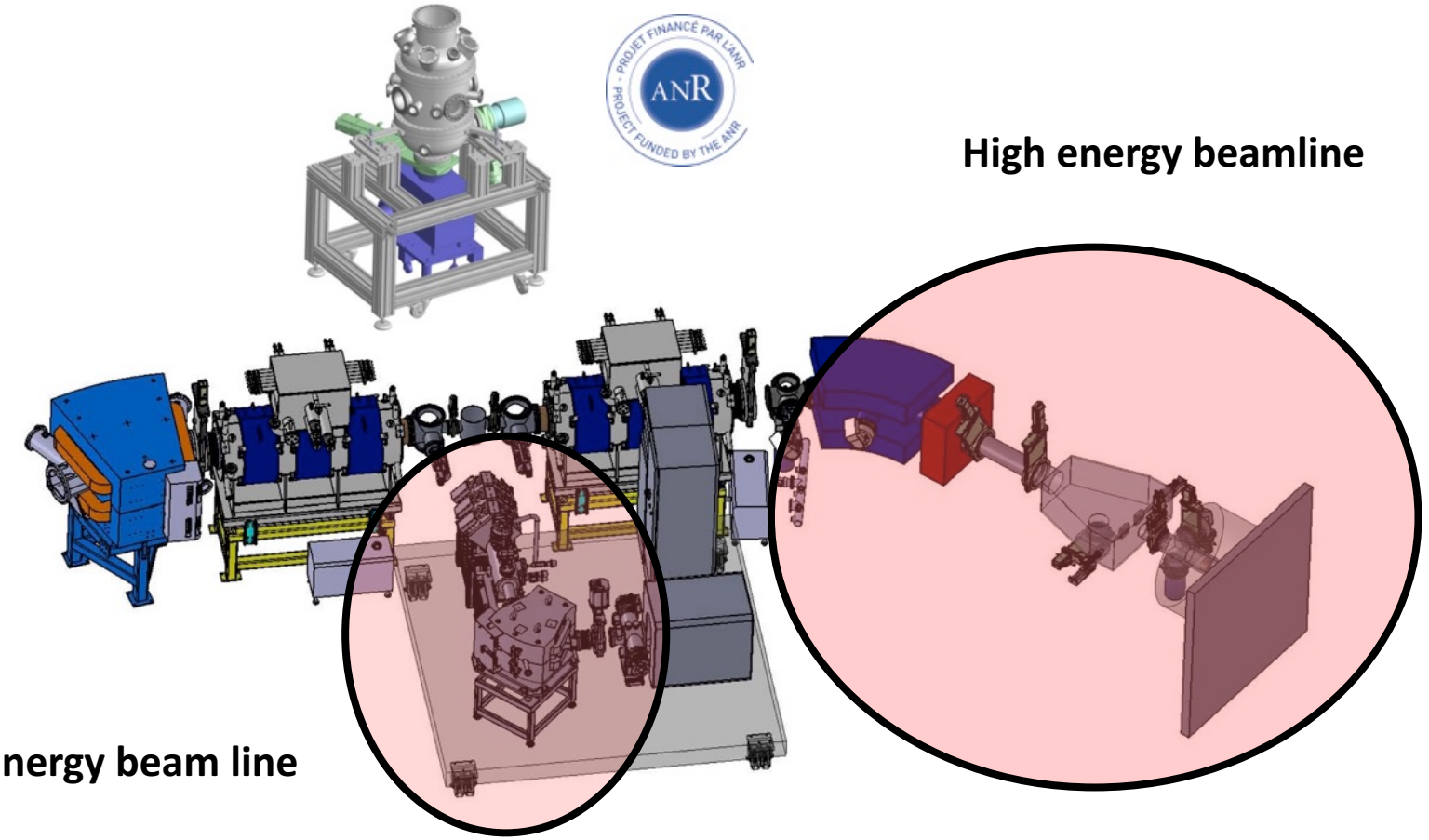
Leuven test bench
In-Jet Laser spec system



Full assembly & tests at LPC Caen in 2017 (except Lasers)
Full assembly & tests at GANIL planned end 2018

See talks P. VanDuppen & P. Delahaye

FISIC (Fast Ion Slow Ion Collision)



UPMC/INSP (Paris), GANIL (Caen), CIMAP (CAEN), Irfu (Saclay)

See talk E. Lamour

Conclusions

- **Start the scientific program with SPIRAL2 in 2018**
  - Commissioning of SPIRAL2 Phase 1 ongoing
  - First experiment with NFS in 2018
  - **Start the design study injector A/Q=7 expected in 2017**

- **S^3 is a low energy in-flight separator for the Spiral2 stable beams**
  - Fusion-evaporation, two-step reactions, rare channels, electron exchange…

- **Designed for the selection and identification of rare events**
  - 2 steps rejection and >350 Mass resolution
  - High transmission of evaporation residues
  - High versatility

- **Two basic detection set-ups**
  - Implantation-decay spectroscopy station (SIRIUS)
  - In gas cell laser ionization & spec. + MR ToF (LEB)

  ➔ First experiment in 2019

Conclusions