Recent results and perspectives of the GANIL/SPIRAL2 facility

M. Lewitowicz
GANIL, CEA/DSM-CNRS/IN2P3, Caen, France

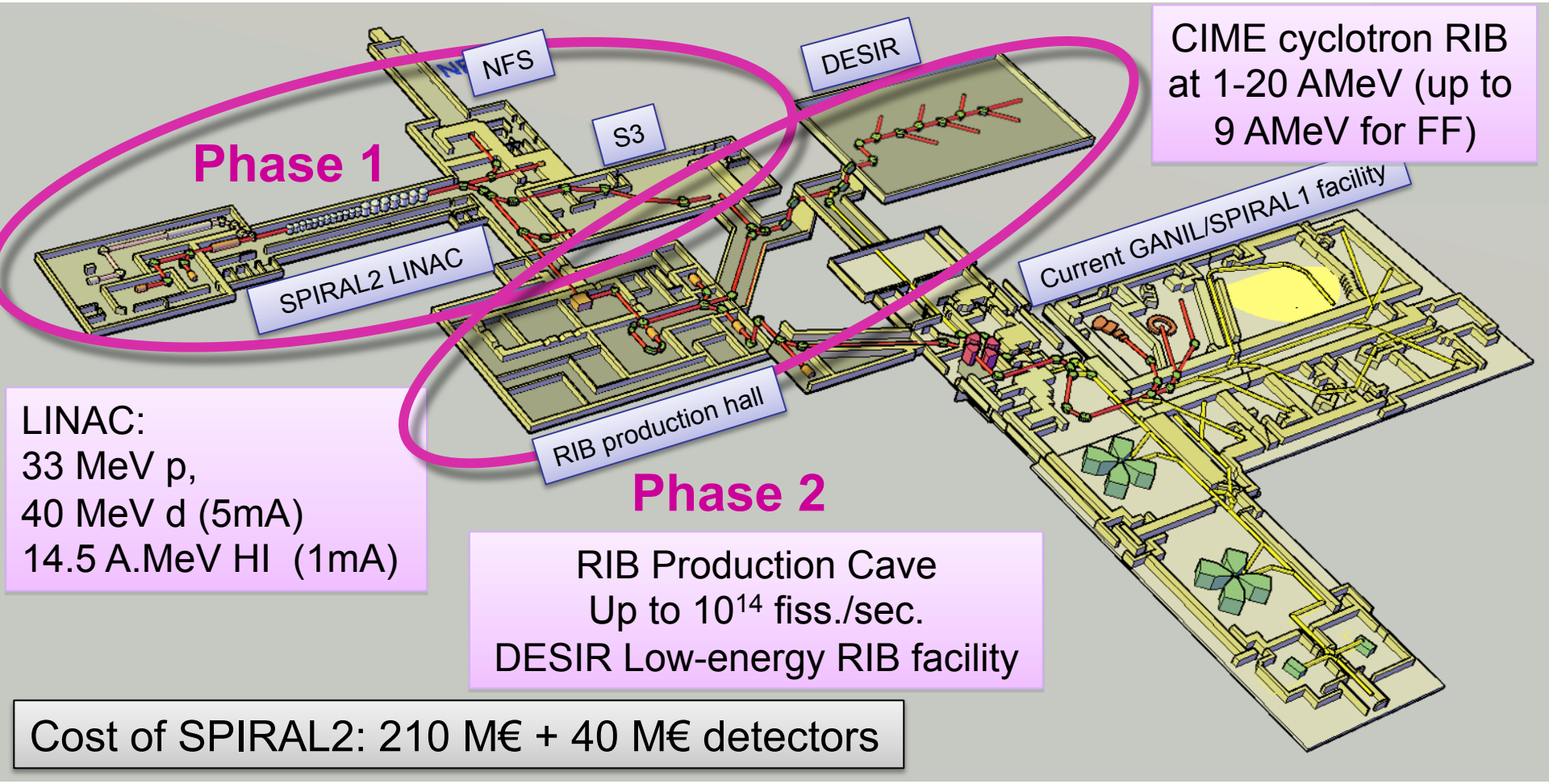
on behalf of GANIL, SPIRAL2 Project Group
&
Physics Collaborations

Existing GANIL facility &

SPIRAL2 under construction

Phase 1: High intensity stable beams + Experimental rooms (S^3 + NFS)

Phase 2: High-intensity low-energy (DESIR) & post-accelerated Radioactive Ion Beam facility



CIME cyclotron RIB at 1-20 AMeV (up to 9 AMeV for FF)

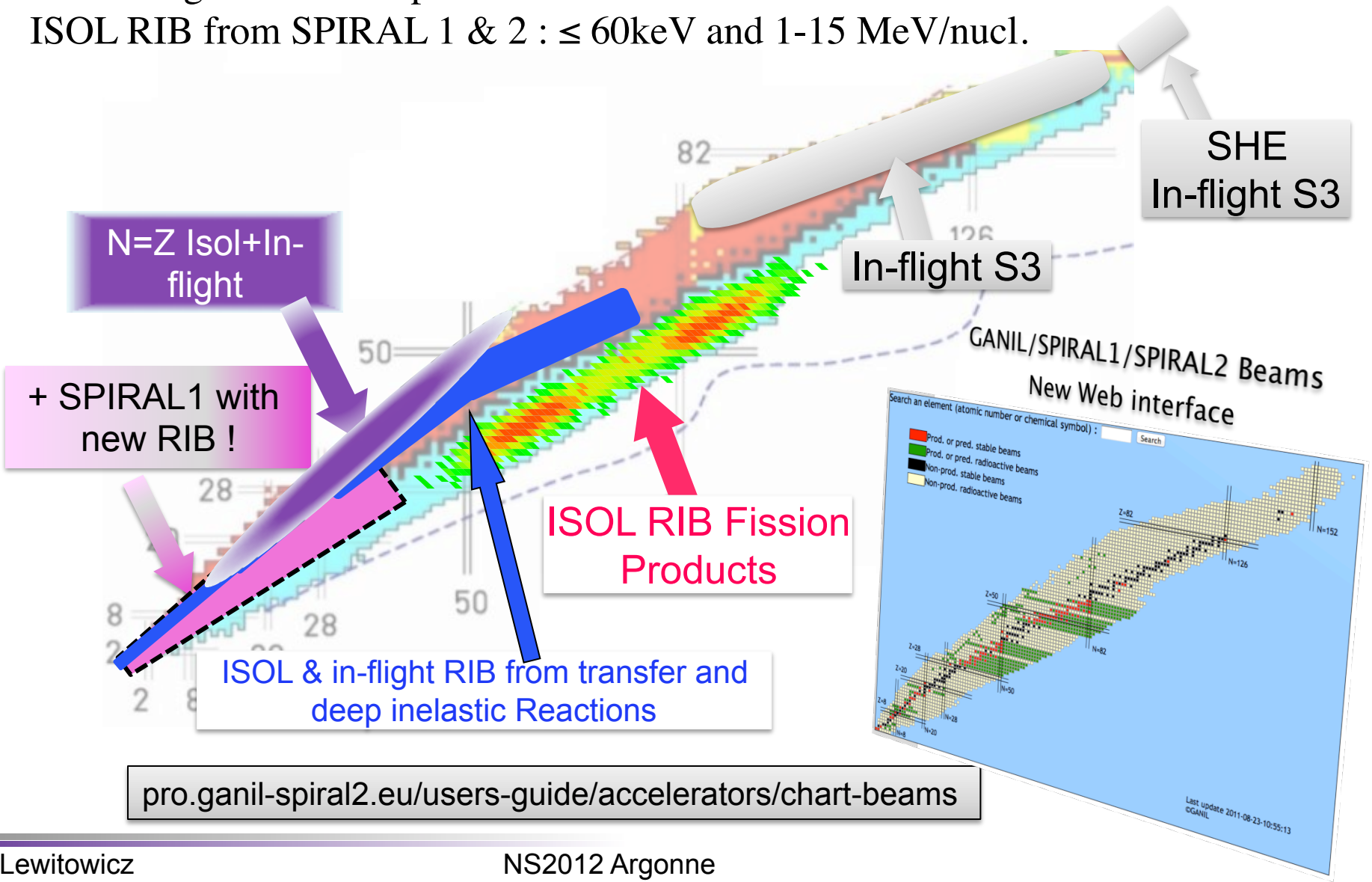
LINAC:
33 MeV p,
40 MeV d (5mA)
14.5 A.MeV HI (1mA)

RIB Production Cave
Up to 10^{14} fiss./sec.
DESIR Low-energy RIB facility

Cost of SPIRAL2: 210 M€ + 40 M€ detectors

Stable-ion & RIB at GANIL/SPIRAL2

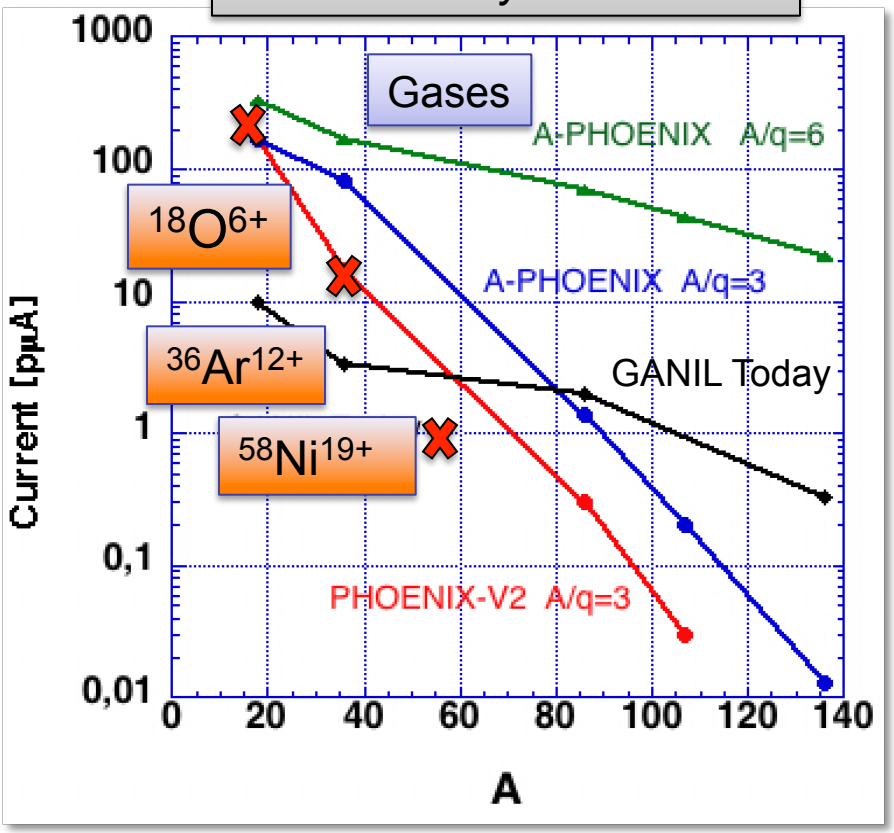
- High-intensity stable-ion beams (from C to U): from few keV to 95 MeV/nucl.
- RIB in-flight at LISE separator: from few to 50 MeV/nucl.
- ISOL RIB from SPIRAL 1 & 2 : ≤ 60keV and 1-15 MeV/nucl.



pro.ganil-spiral2.eu/users-guide/accelerators/chart-beams

Day 1 SPIRAL2 LINAC beams

Energy = 0.75-15 *A.MeV for Heavy Ions*



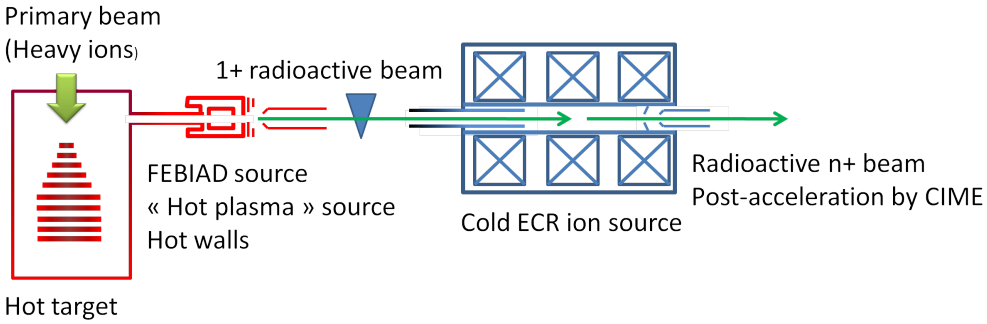
Ion(s)	Energy Range (MeV/nucleon)	Maximum Intensity (pμA)	Remarks
$^{1}H^{1+}$	20-33	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{2}H^{1+}$	10-20	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{4}He^{2+}$	10-20	2-10	NFS beam line; Intensity with fast chopper 1/100
$^{12}C^{4+}$	5-7	≥10 **)	S3 beam line
$^{18}O^{6+}$	5-7	≥10 **)	S3 beam line
$^{22}Ne^{8+}$	5-7	≥10 **)	S3 beam
$^{40}Ar^{14+}$	4-5	≥10 **)	S3
$^{28-30}Si^{10+}$ or $^{32-36}S^{12+}$	5-7	≥10 **)	m line
$^{40}Ca^{14+}$	5-7	≥10 **)	S3 beam line
$^{48}Ca^{16+}$	5-7	≥10	S3 beam line
$^{58}Ni^{18+}$	4-14	≥1 **)	S3 beam line

Beam Intensity Reached

✓Starting HI ECR source for commissioning and first experiments ➔ Phoenix V2

SPIRAL 1 upgrade – New RIB

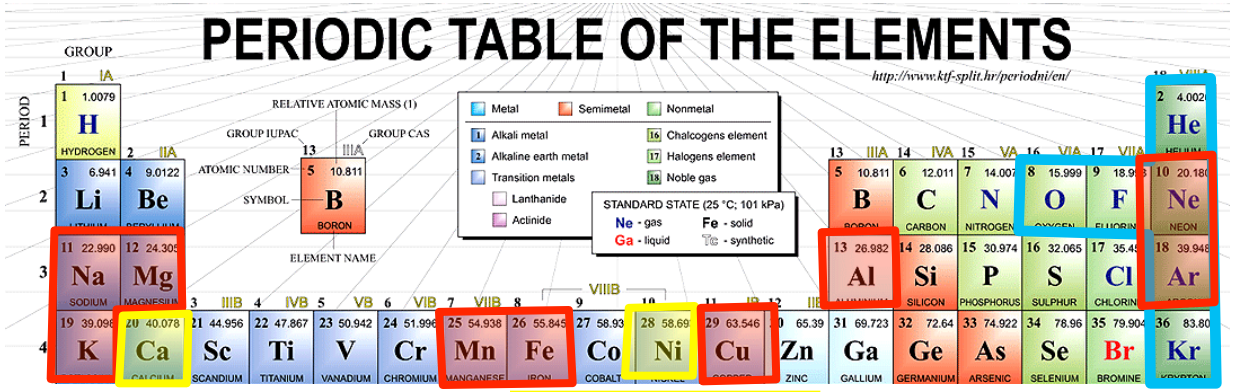
1+/n+ ionisation scheme



Metallic beams from a FEBIAD ion source

New FEBIAD source

SPIRAL Target



Ionised as **radioactive beams**

Ionized as **stable beams**

Existing beams at SPIRAL

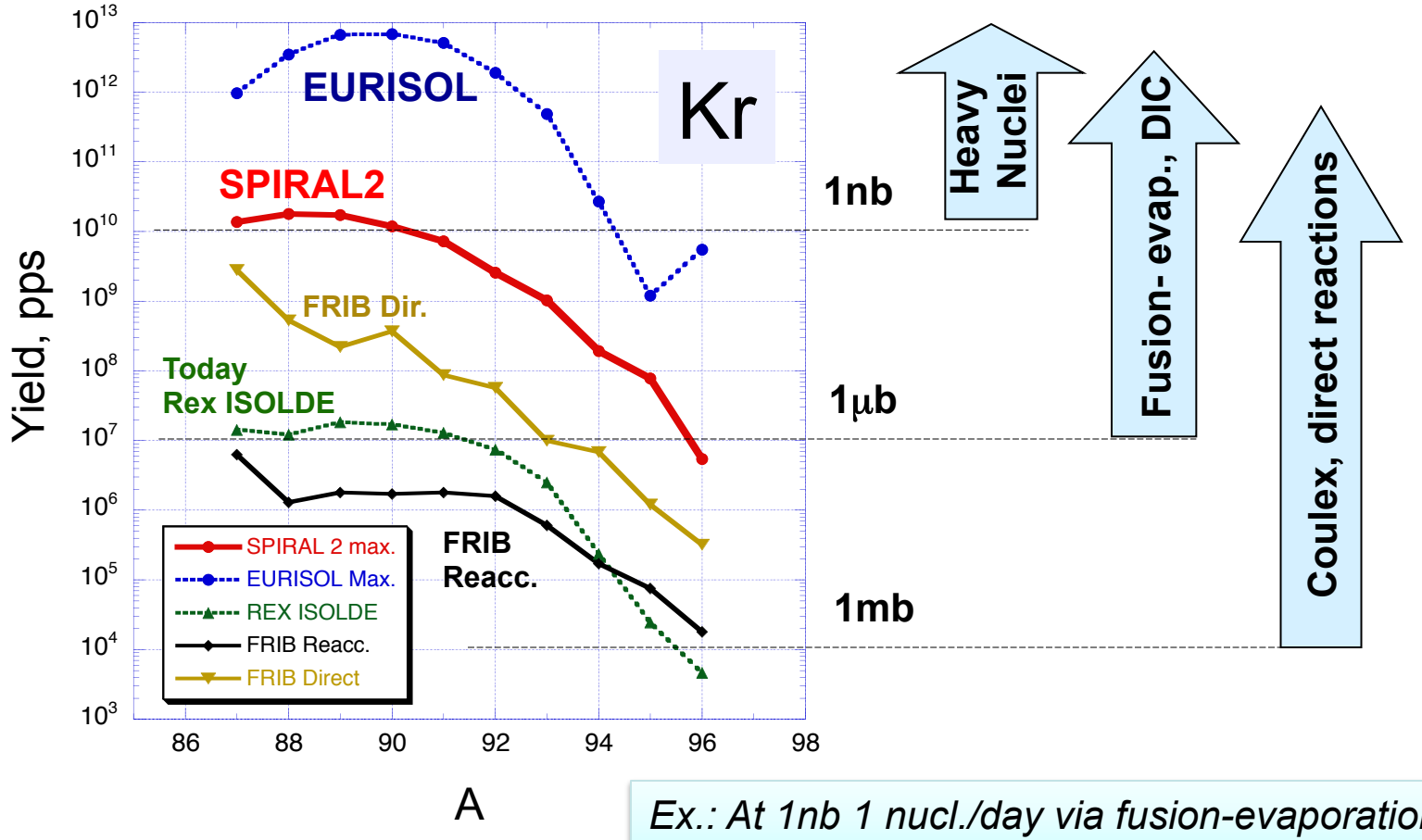
Most beams have projected intensities > **10^6 pps** for 1.5kW primary beam power

New **beams** from FEBIAD (LIRAT, IBE): **2014**
New **beams from Booster** (CIME energies): end of **2014**

P. Delahaye at al.

SPIRAL 2: Advanced ISOL RIB facility

SPIRAL 2: Experiments with RIB at low cross sections and very exotic nuclei at few MeV/nucleon



Ex.: At 1nb 1 nucl./day via fusion-evaporation

Recent results from GANIL/SPIRAL1
Nuclear structure, Fund. Int. & astrophysics 2012
Experimental works

X-Ray Fluorescence from the Element with Atomic Number Z = 120
M. O. Frégeau et al. PRL108 (2012) 122701

Discovery of a new isomeric state in ^{68}Ni: Evidence for a highly deformed proton intruder state
A. Dijon et al. PRC 85, 031301(R) (2012)

Astrophysical(α, γ) reaction in inverse kinematics; Electron screening effect in the beta-decay
P Ujic et al. JOP337 (2012) 012015

First g(2+) measurement on neutron-rich ^{72}Zn, and the high-velocity transient field technique for radioactive heavy-ion beams
E. Fiori, et al. PRC 85, 034334 (2012)

Resonances in 19Ne with relevance to the astrophysically important 18F(p,α)15O reaction
D. J. Mountford et al. PRC 85 (2012) 022801

First direct lifetime measurement of the 2+1 state in ^{72,74}Zn: New evidence for a shape transition between N = 40 and N = 42 close to Z = 28
M. Niikura et al. PRC 85, 054321 (2012)

Spectroscopy of ^{18}Na: Bridging the two-proton radioactivity of ^{19}Mg
M. Assié et al. PLB 721 (2012) 198-202

Evolution of the N = 50 gap from Z = 30 to Z = 38 and extrapolation toward 78Ni
M.-G. Porquet and O. Sorlin, PRC 85, 014307 (2012)

In-beam spectroscopic studies of the 44S nucleus
L. Caceres et al. Phys. Rev. C 85, 024311 (2012)

Low-lying neutron fp-shell intruder states in 27Ne
S. M. Brown et al. PRC 85, 011302 (2012)

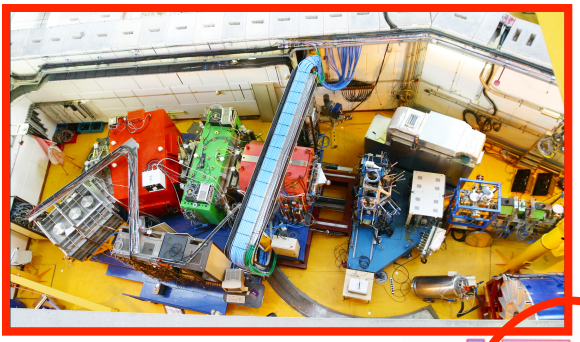
First Measurement of Pure Electron Shakeoff in the b Decay of Trapped ^{6}He+ Ions
C. Couratin et al. PRL 108 (2012) 243201

Spectroscopy of 26F
M. Stanoiu et al. PRC 85, 017303 (2012)

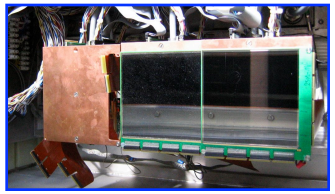
GANIL spectrometers and detectors

laboratoire commun CEA/DSM – CNRS/IN2P3

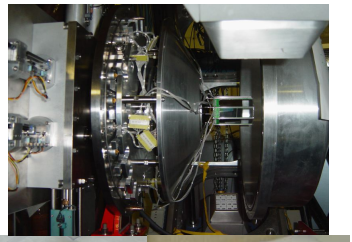
VAMOS

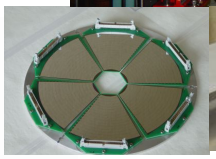


MUSETTE

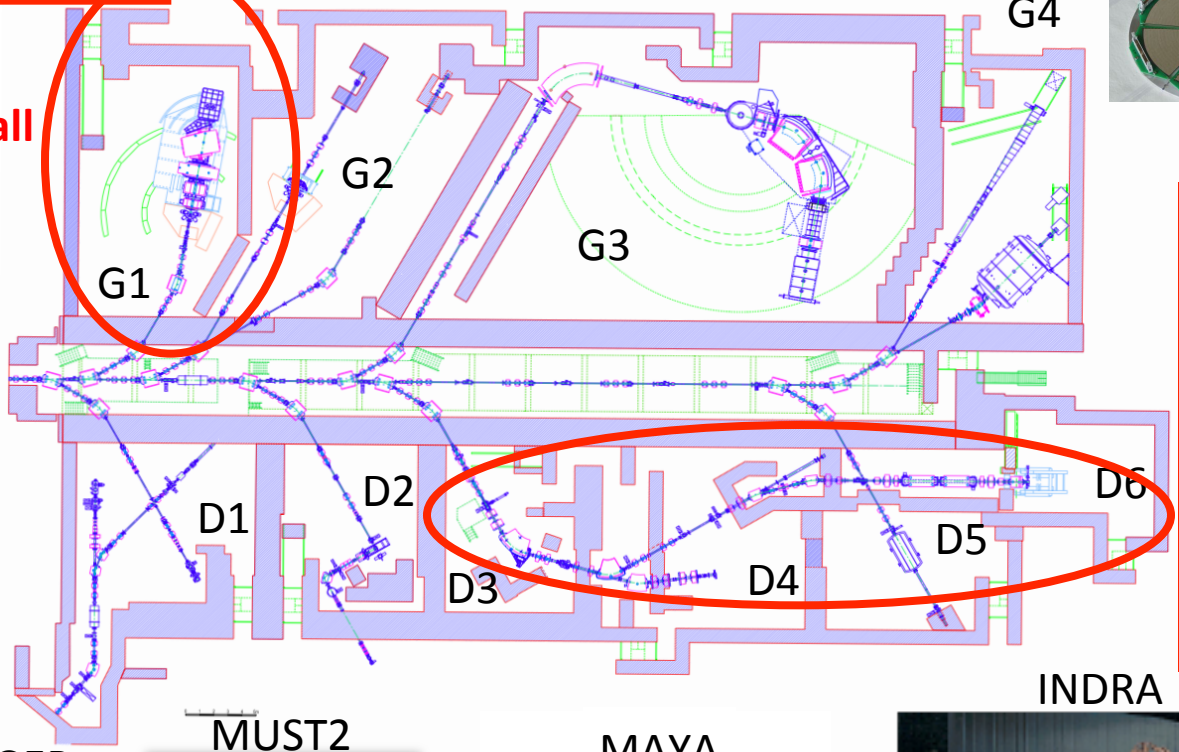


TIARA

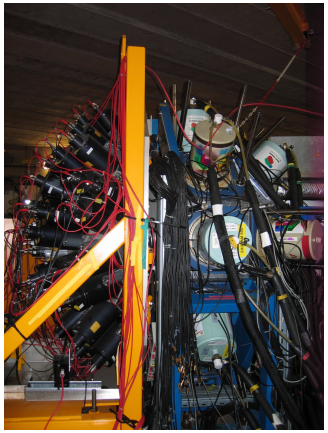




SPEG

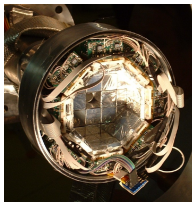


EXOGAM & n-wall

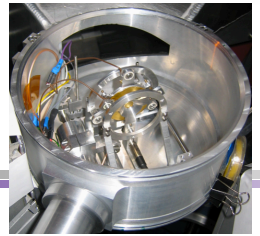


LISE 3

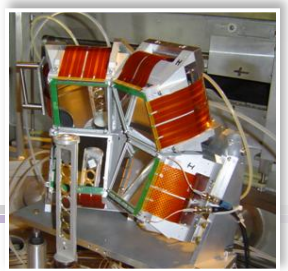
DIAMANT



PLUNGER

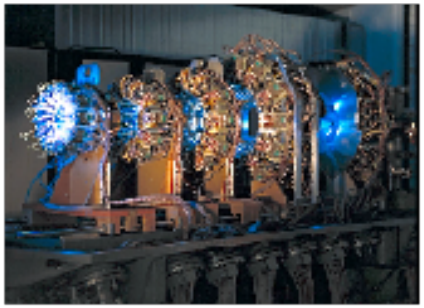


MUST2



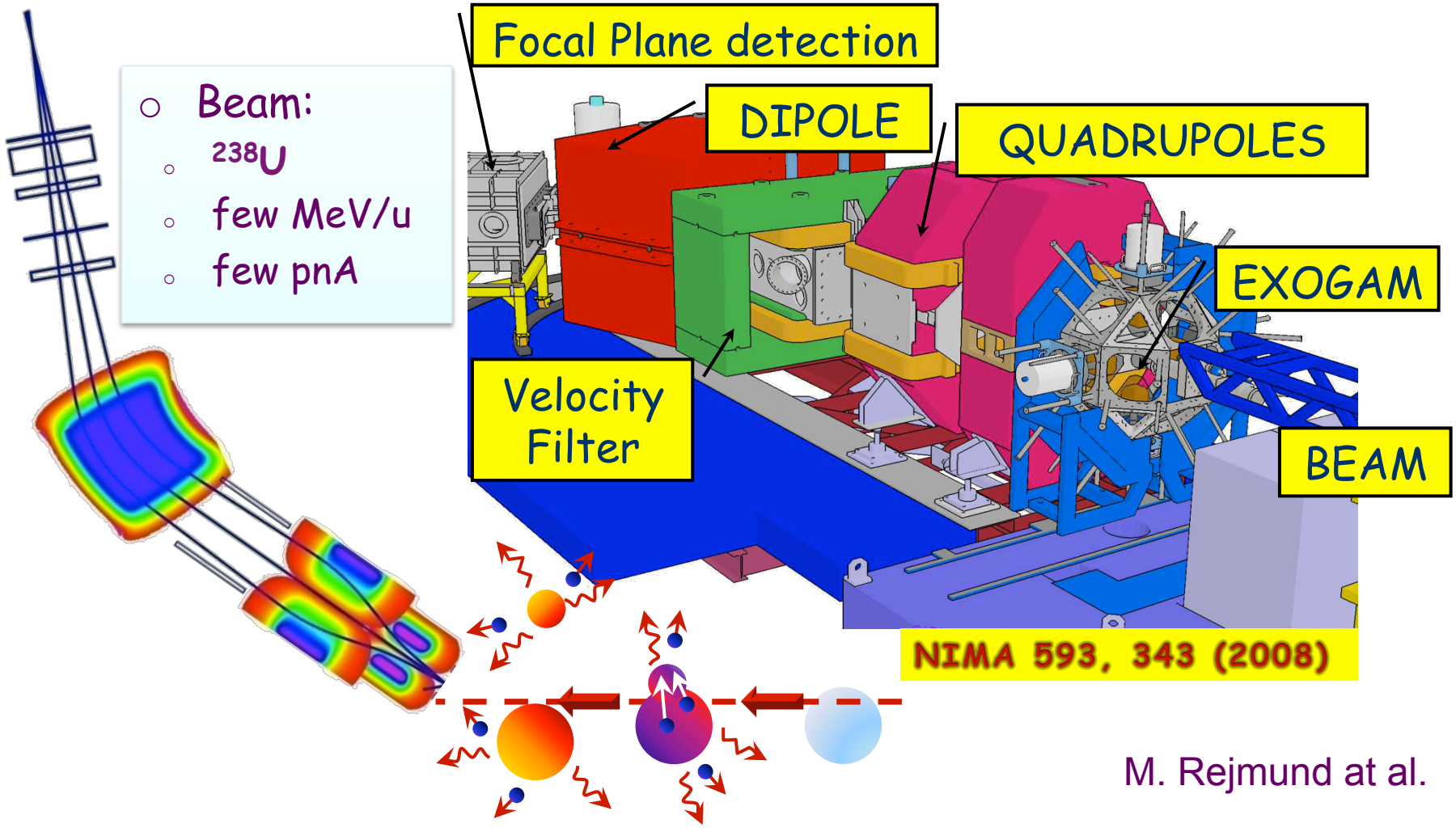
MAYA

INDRA



VAMOS Spectrometer

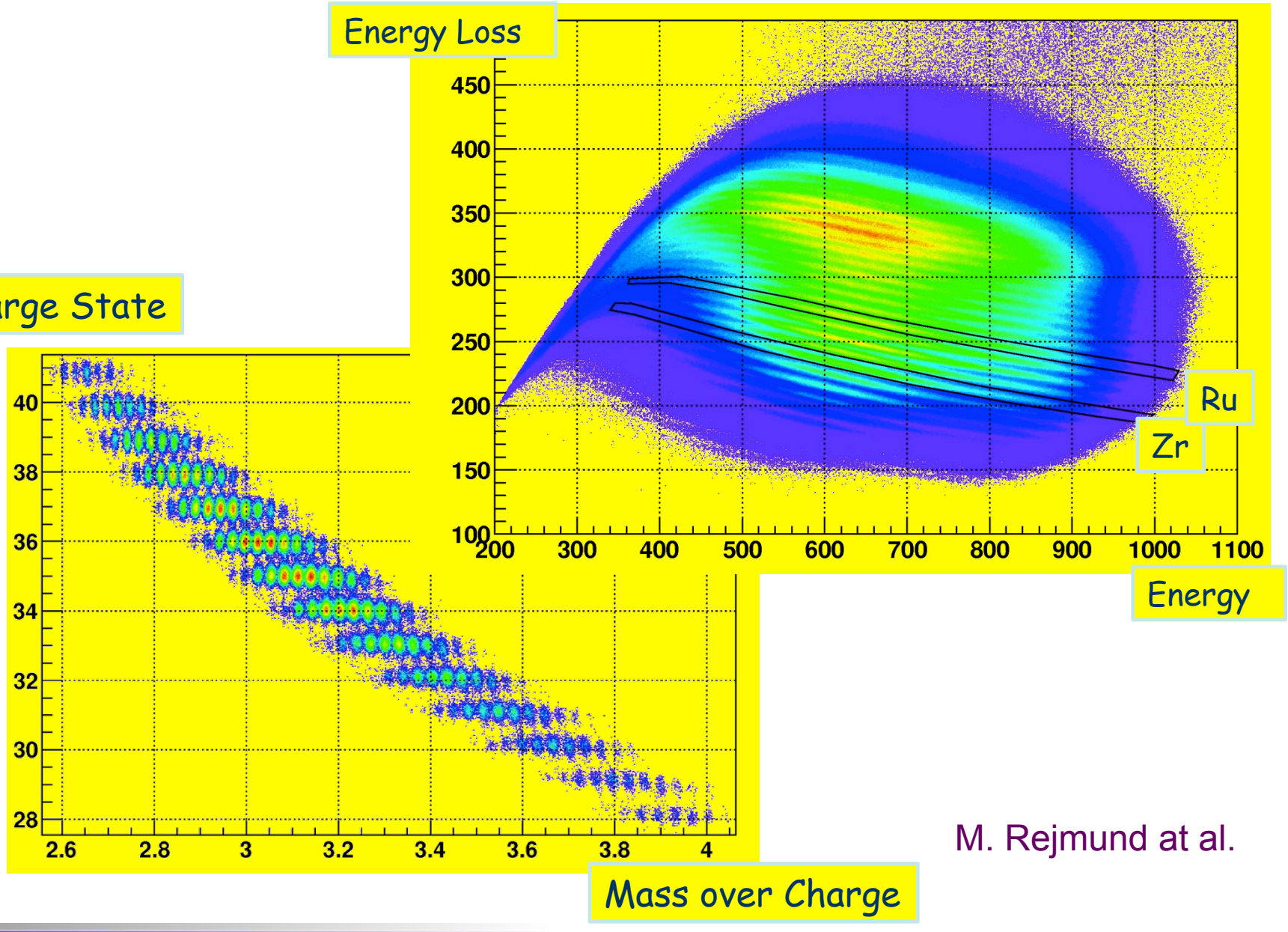
& Fusion-Fission, Multi – nucleon and Deep Inelastic Transfer Reactions



- Beam:
  - ^{238}U
  - few MeV/u
  - few pnA

M. Rejmund at al.

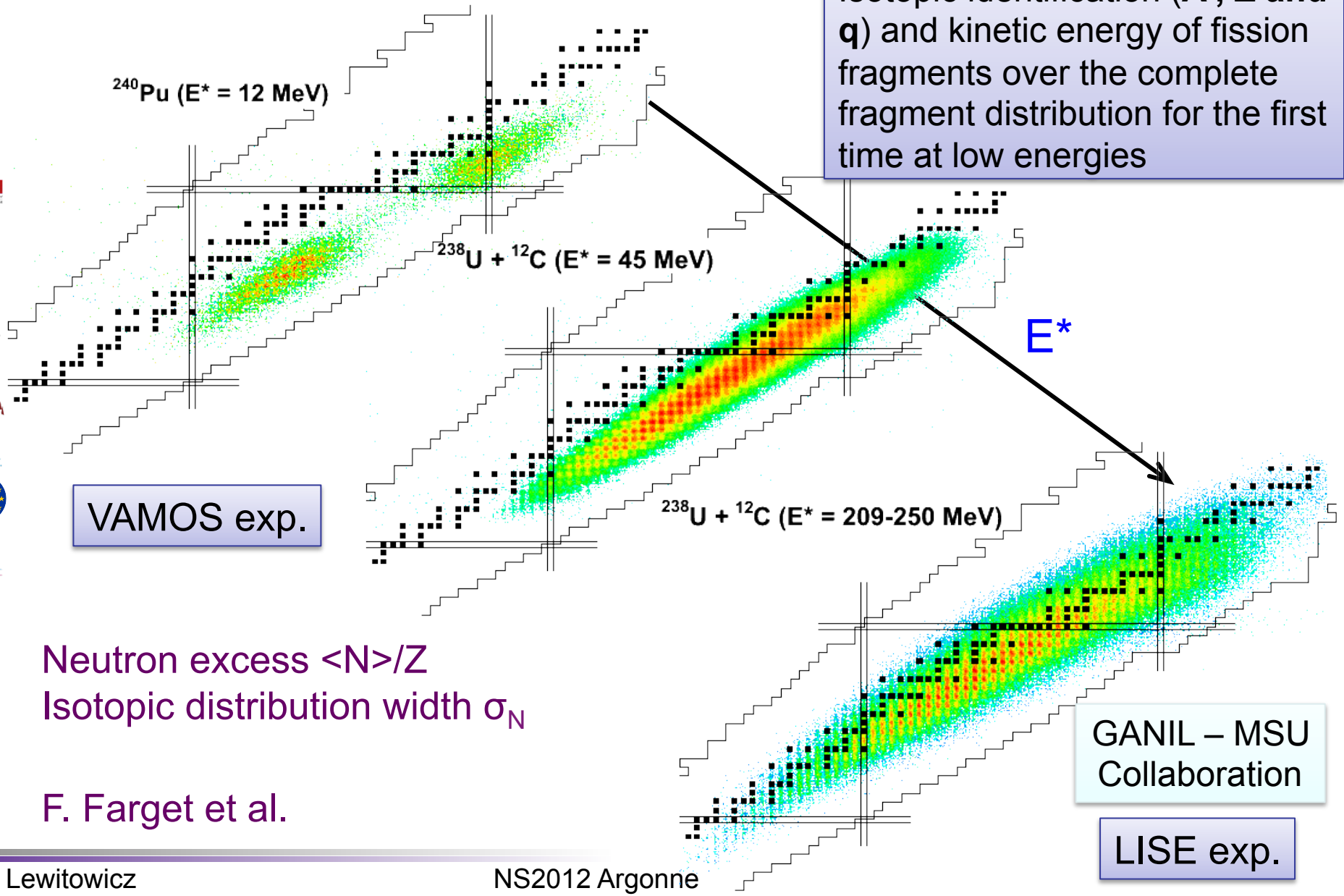
Z, A & q identification at few MeV/nucleon



M. Rejmund at al.

Evolution of isotopic distributions of fission fragments with excitation energy

Isotopic identification (**A , Z and q**) and kinetic energy of fission fragments over the complete fragment distribution for the first time at low energies



VAMOS exp.

Neutron excess <N>/Z
Isotopic distribution width σ_N

F. Farget et al.

GANIL – MSU Collaboration

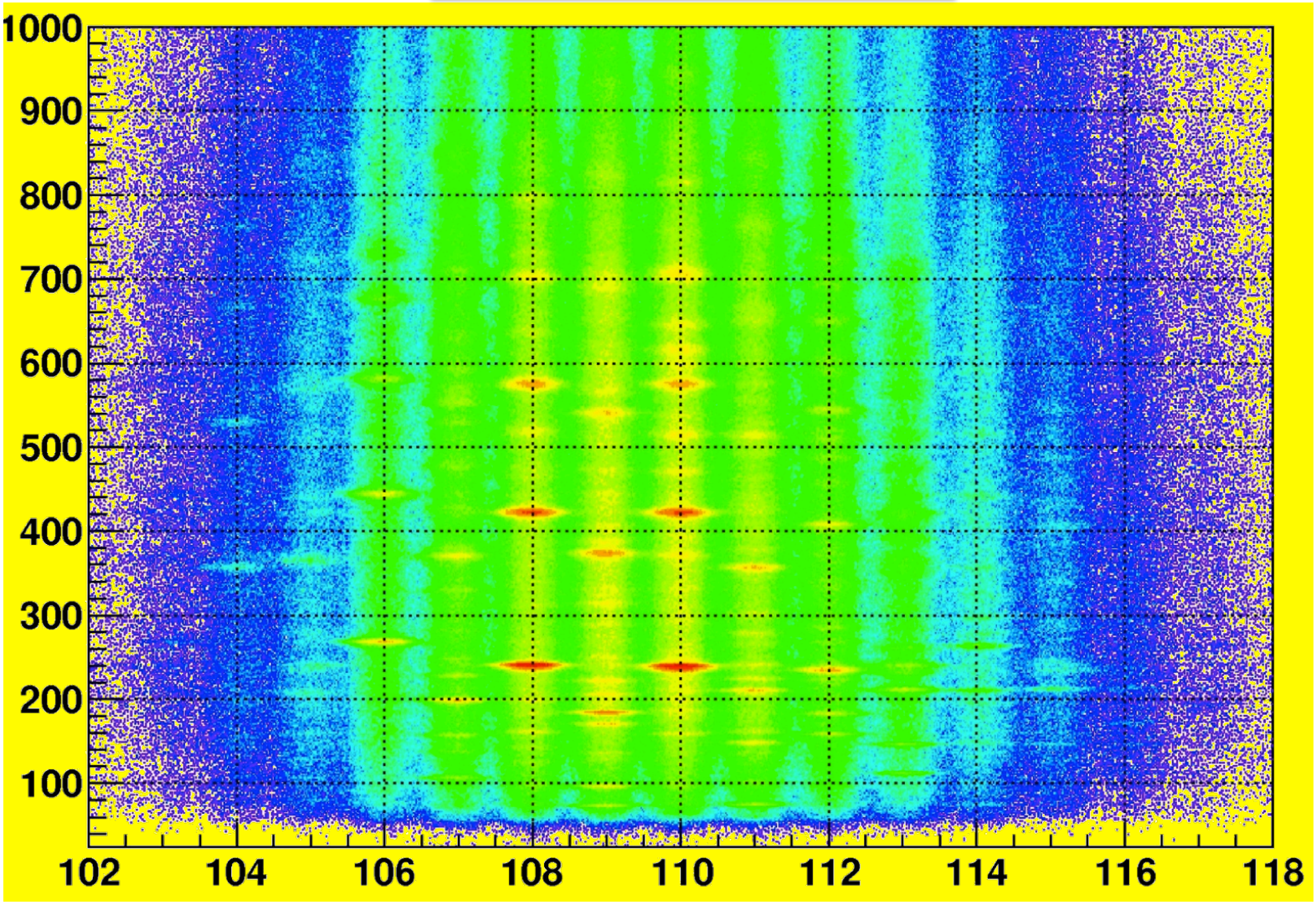
LISE exp.

Eγ vs A for Ru Z=44

Gamma-ray Energy, keV

VAMOS + EXOGAM

M. Rejmund at al.

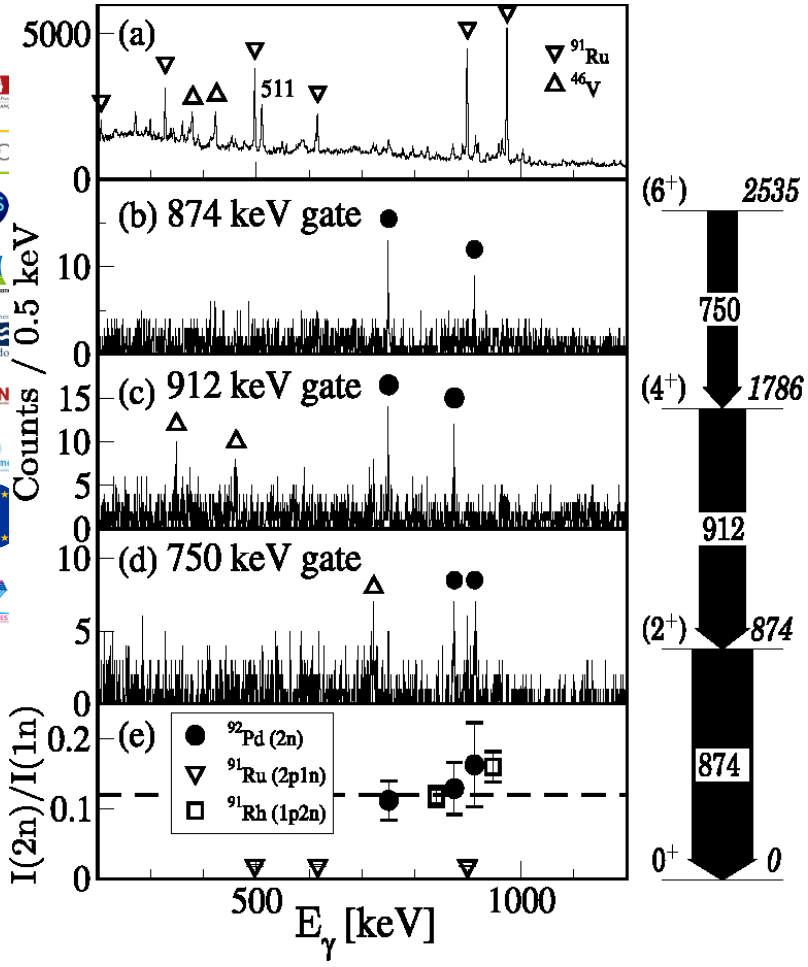


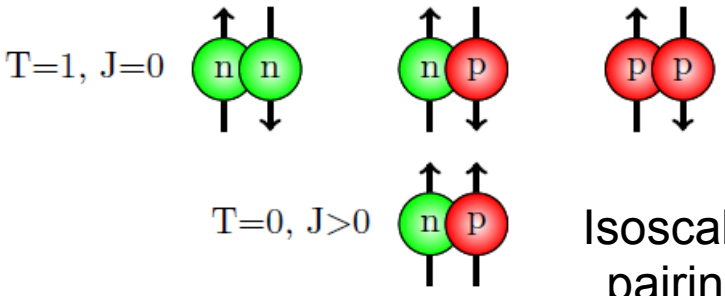
Mass

Isoscalar n-p pairing

^{92}Pd: evidence for a new spin aligned np coupling scheme

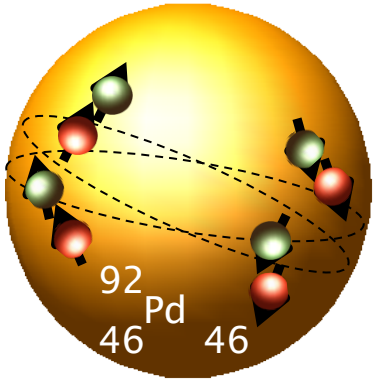
36Ar + 58Ni (fusion evap) N=Z=46





Isoscalar pairing

EXOGAM+n-wall+DIAMANT



B Cederwall, F. Ghazi-Moradi, T Back, A Johnson, J. Blomqvist, E Clément, G. de France, R Wadsworth et al,

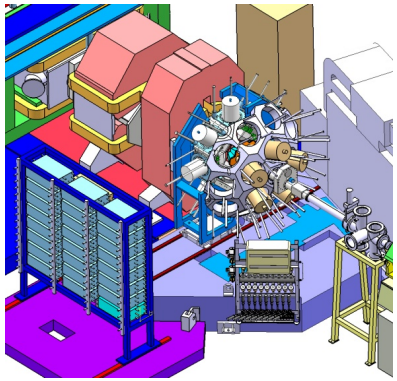
Nature (2010)

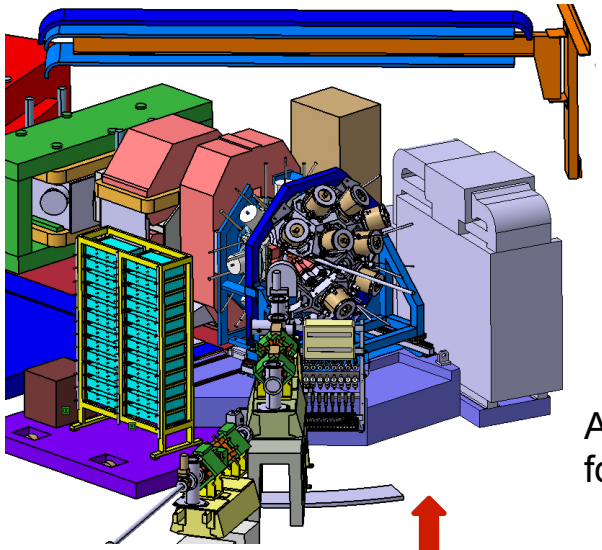
(Collaborations KTH Stockholm, York, ORNL, HIL and faculty of Physics Warsaw, ATOMKI, Uppsala, Legnaro, Ankara, INFN Napoli, Padova, CSIC Valencia, CENBG, NBI, TRIUMF).

AGATA 1π at GANIL 2014 →

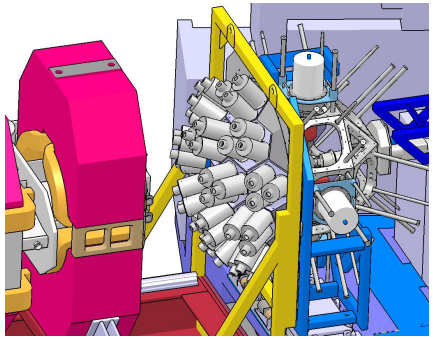
Total Eff. > 20% at 1.3 MeV

At 0° as separator (vaccum/gas-filled)

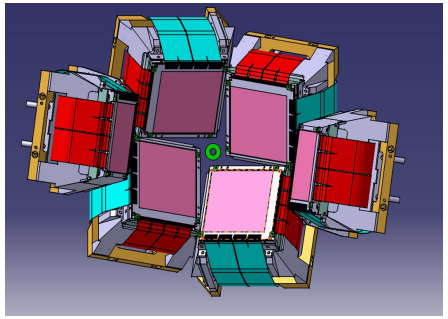




Angles >10 deg
for fission & MNT



MUST II

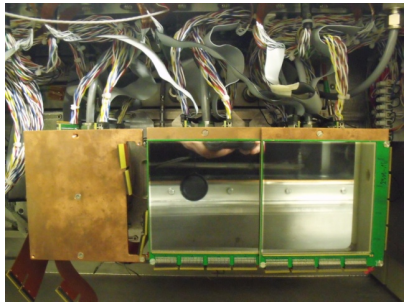


+ Cryogenic target

In G1 coupled to VAMOS (+ EXOGAM2): SIBs, RIBs

- *Charged particle array for transfer reaction MUST2/TIARA : (d,p) etc … program with SIB and RIB*
- *Charged particle array for prompt tagging : DIAMANT*
- *Charged particle array for Recoil Decay Tagging : MUSETTE*
- *Scintillators : BaF2 array, LaBr3*
- *Future detector : NEDA (n) , GASPARD (MUST2-like), PARIS (LaBr3)*

MUSETTE



E. Clément et al.

Gamow Shell Model: Shell Model for weakly bound and unbound states

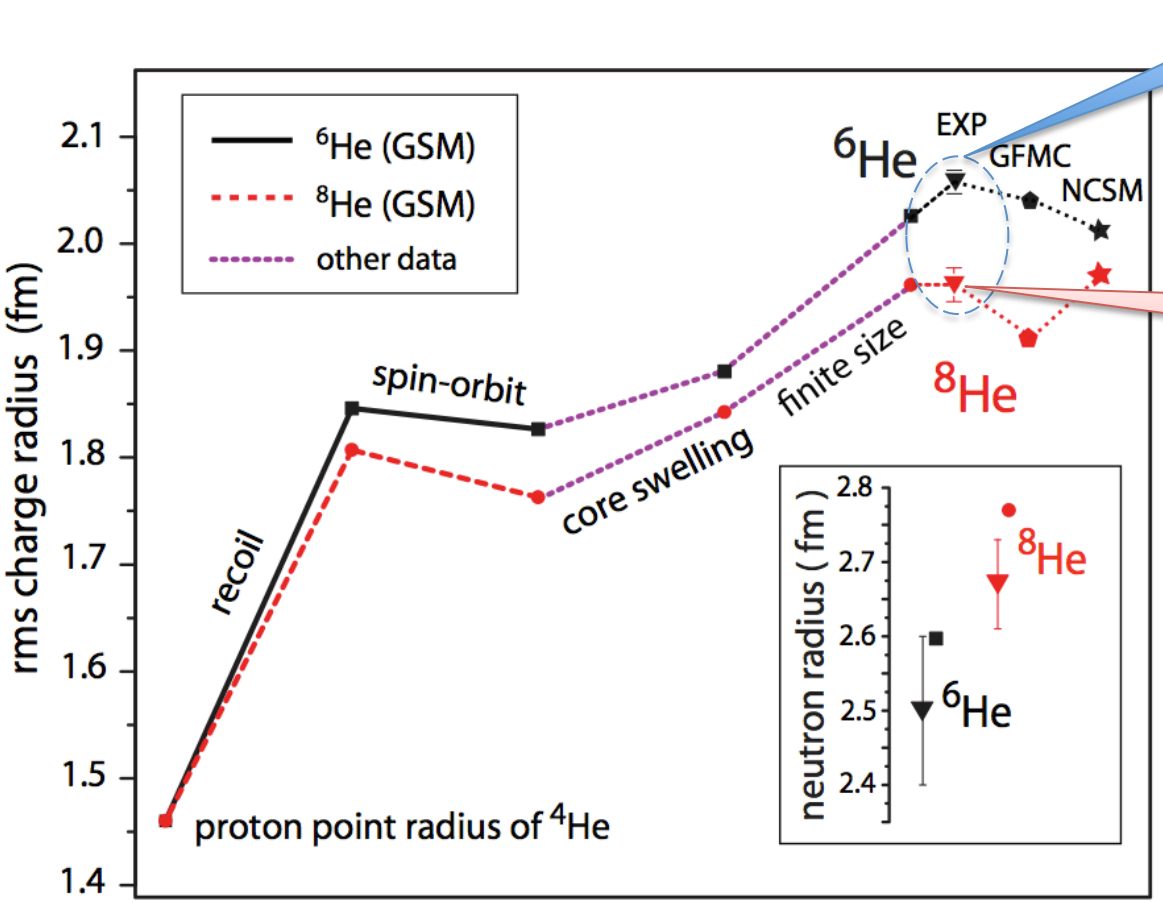
Offers a fully symmetric treatment of bound, resonance and scattering single-particle states in a many-body framework

GANIL – UT/ORNL Theory Collaboration

FUSTIPEN

Example: nn-correlations in ^{6}He and ^{8}He

G. Papadimitriou et al., Phys. Rev. C84, 051304(R)



Charge radii in He-isotopes depend mainly on:

(i) valence neutron correlations (core recoil)

(ii) spin-orbit contribution

(iii) polarization of the core by valence neutrons

Future at SPIRAL2 (Day 1 exp.)

82 Letters of Intend (>1000 authors)

Shell structure
very far from stability in
p-rich nuclei
13 LoIs

Heavy and Super
Heavy Elements
4 LoIs

Equation of State,
Role of Isospin in
nuclear reaction
5 LoIs

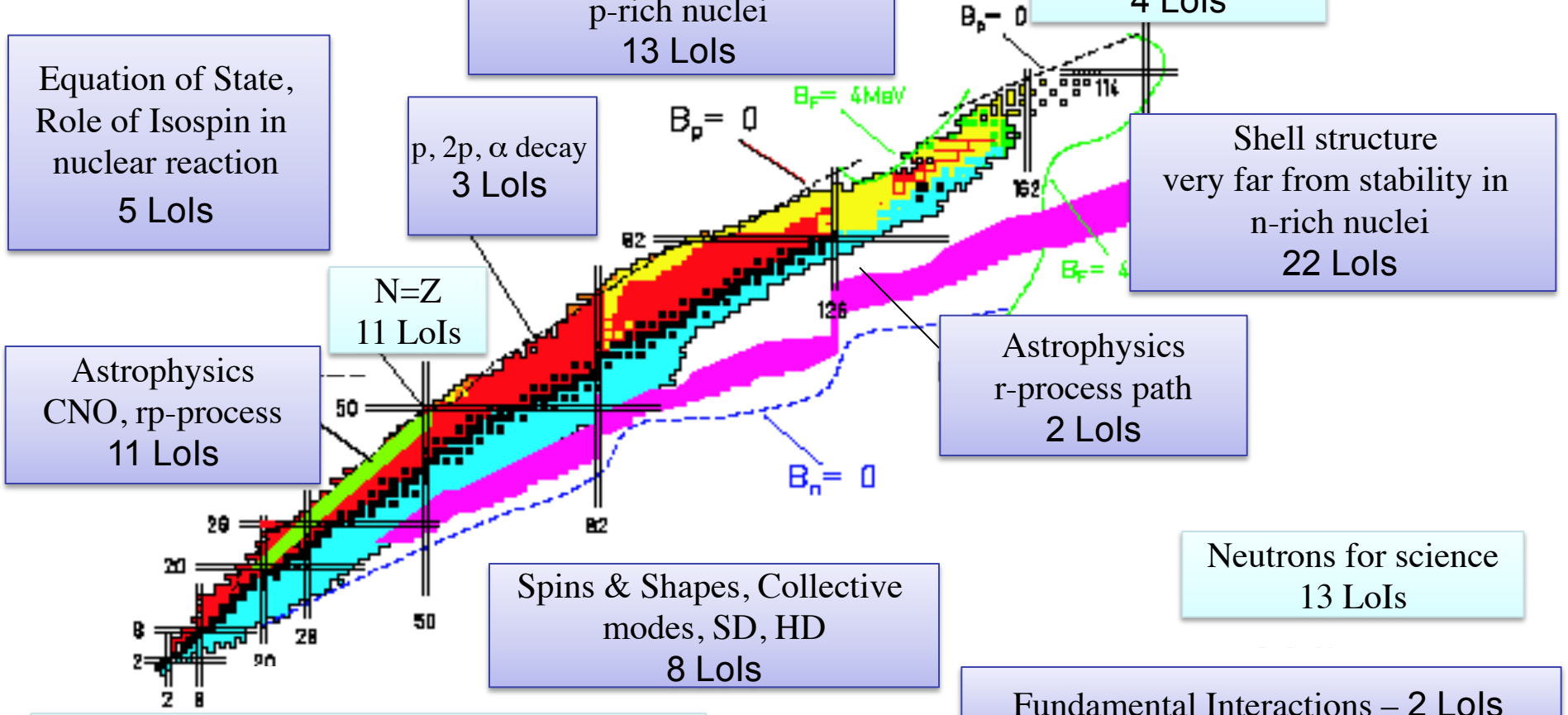
p, 2p, α decay
3 LoIs

Shell structure
very far from stability in
n-rich nuclei
22 LoIs

N=Z
11 LoIs

Astrophysics
CNO, rp-process
11 LoIs

Astrophysics
r-process path
2 LoIs



Spins & Shapes, Collective
modes, SD, HD
8 LoIs

Neutrons for science
13 LoIs

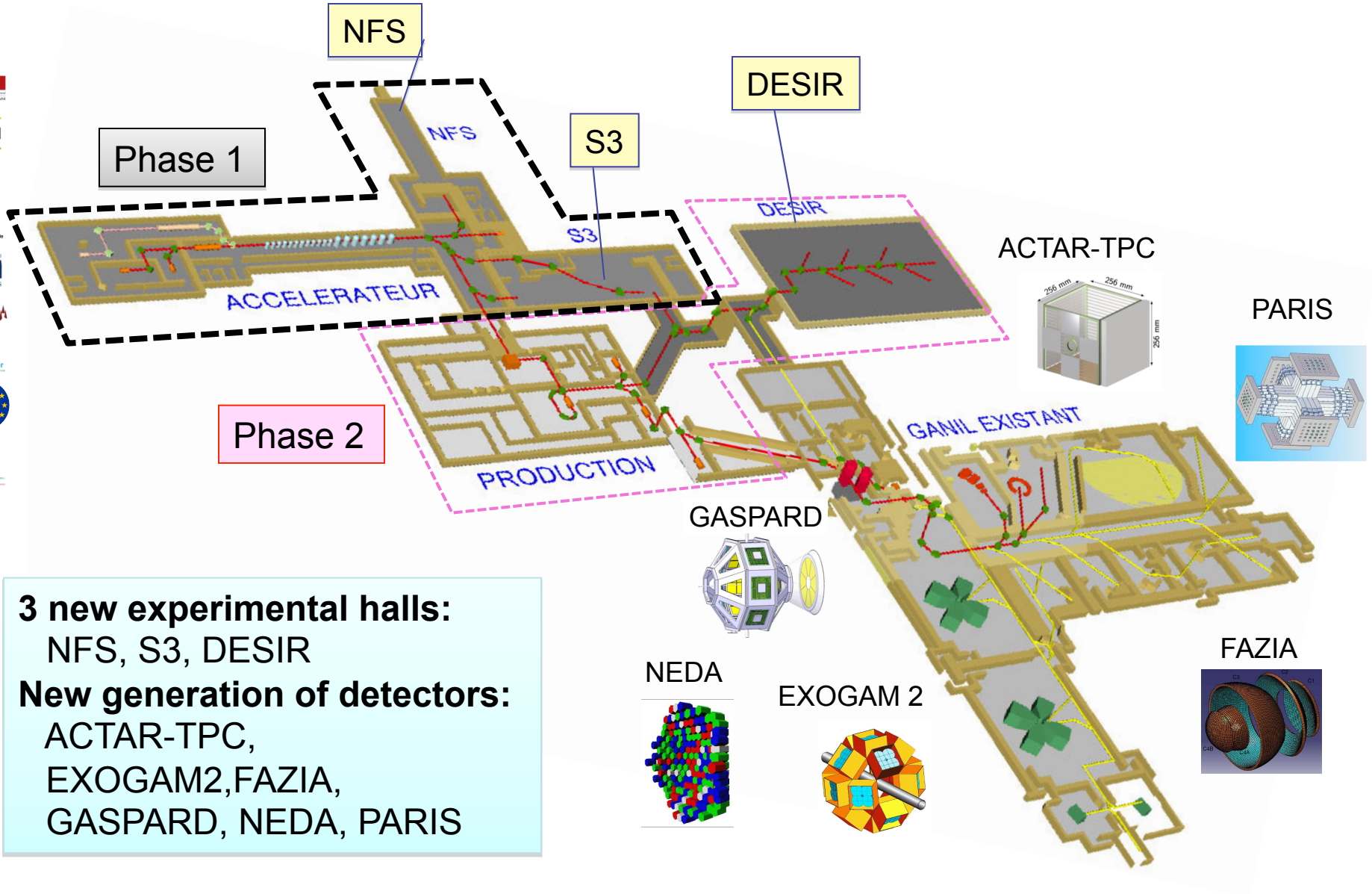
Fundamental Interactions – 2 LoIs

29 LoIs Phase 1 (16 for S3, 13 for NFS)

53 LoIs Phase 2 (21 for DESIR)

Atomic physics 1 LoI

SPIRAL 2 Layout



3 new experimental halls:
NFS, S3, DESIR

New generation of detectors:
ACTAR-TPC,
EXOGAM2,FAZIA,
GASPARD, NEDA, PARIS

SPIRAL2 phase 1 civil construction

SPIRAL2 phase 1 civil construction

SPIRAL2 phase 1 civil construction

SPIRAL2 phase 1 civil construction

- Decree (Authorization) of SPIRAL2 Phase 1 signed by Prime Minister on May 8th 2012
- Operation permit expected in the beginning of 2014

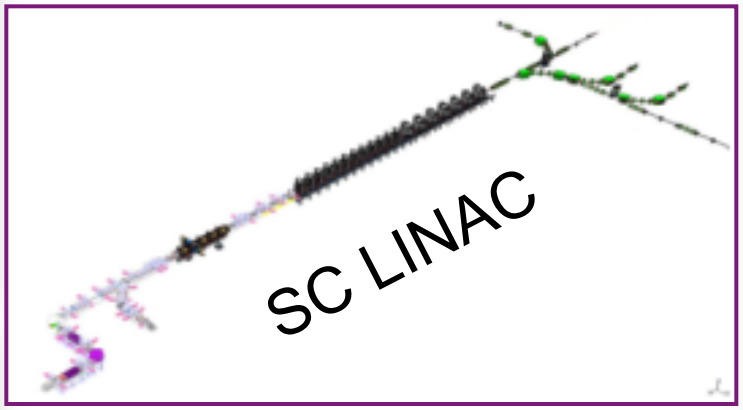
✓Installation of equipment ➔ Q3 2012 – Q4 2013

✓Commissioning ➔ Q4 2013

Phase 1

HI injector

SC LINAC



Cryomodule A

d & p injector

Cold Box

Cryomodule B

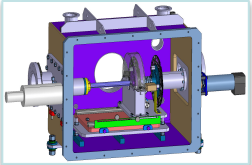
RFQ

S3

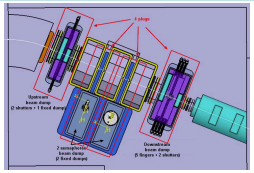
130 physicists, 30 institutions, 12 countries

Hervé SAVAJOLS – GANIL, France (Project leader)
Antoine DROUART – Irfu/CEA, France (Spokesperson)
Jerry A. NOLEN – ANL, USA (Spokesperson)
Martial Authier – Irfu/CEA, France (Technical Coord.)

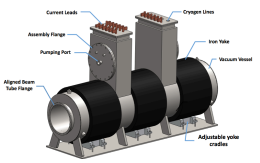
High power
Rotating targets
including actinides

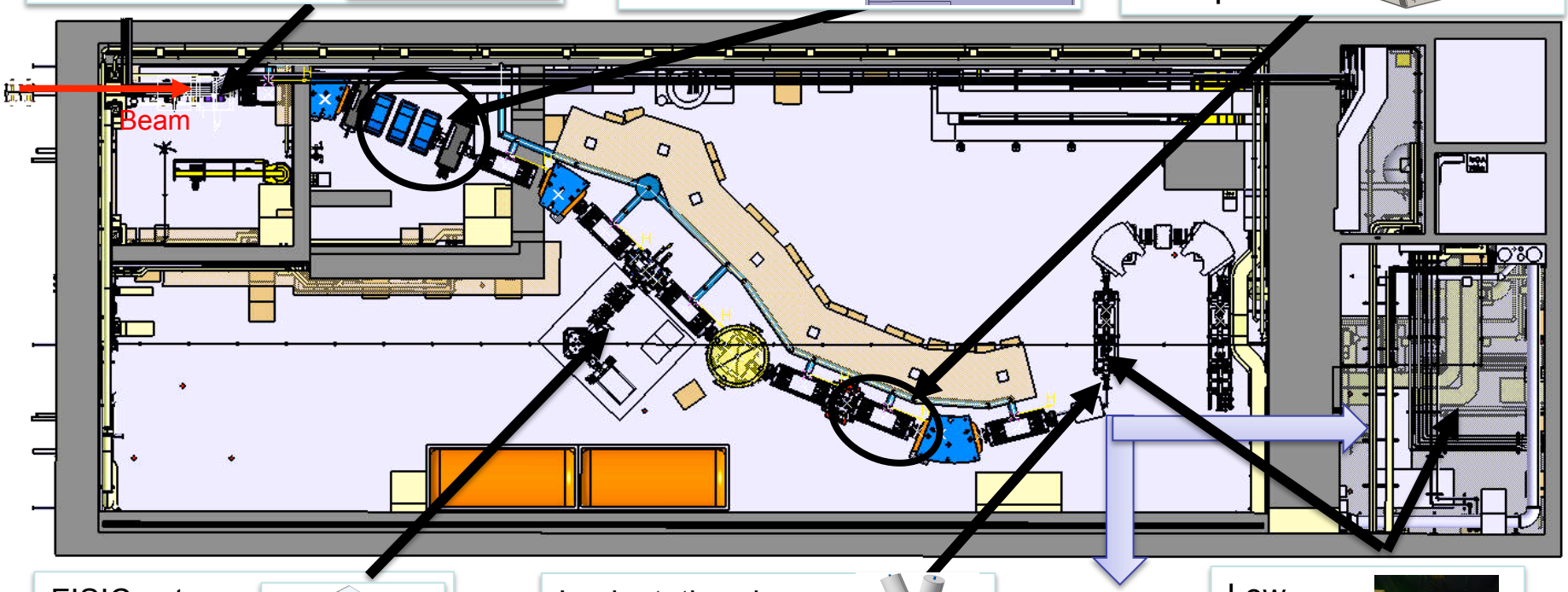


Beam dump
& Movable
fingers

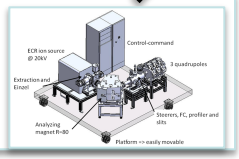


Large
acceptance
Multipoles

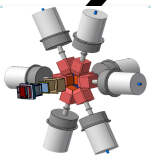




FISIC setup
Fast Ion Slow
Ion Collisions

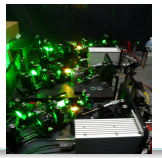


Implantation-decay
station at the mass
dispersive plan



DESIR

Low
Energy
Branch



130 physicists, 30 institutions, 12 countries
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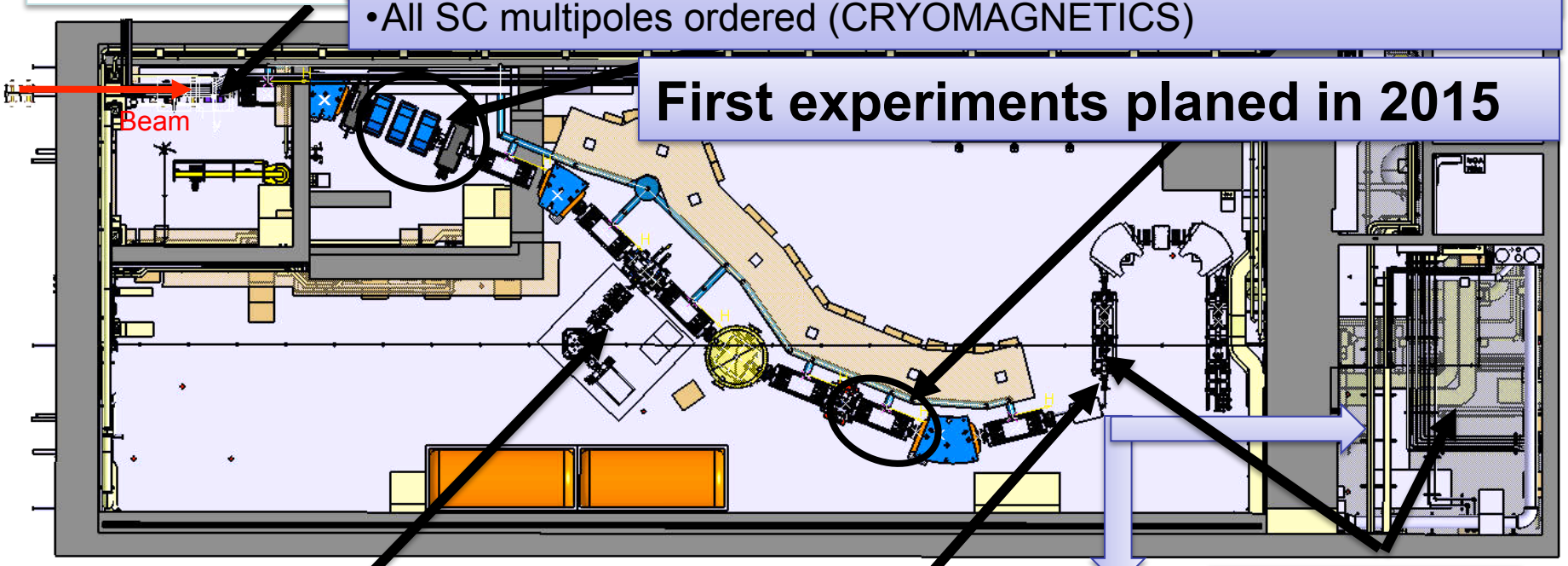
Jerry A. NOLEN – ANL, USA (Spokesperson)
Martial Authier – Irfu/CEA, France (Technical Coord.)

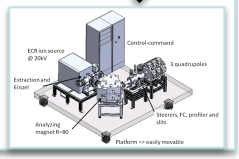
- Construction of S3 Phase 0 (separator-spectrometer with focal plane detectors) fully funded (10M€) and was launched
- All magnetic dipoles ordered
- All SC multipoles ordered (CRYOMAGNETICS)

High power
Rotating targets
including actinides

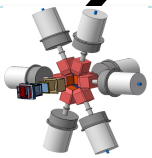


First experiments planed in 2015

FISIC setup
Fast Ion Slow
Ion Collisions

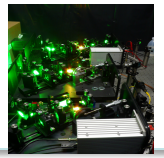


Implantation-decay
station at the mass
dispersive plan

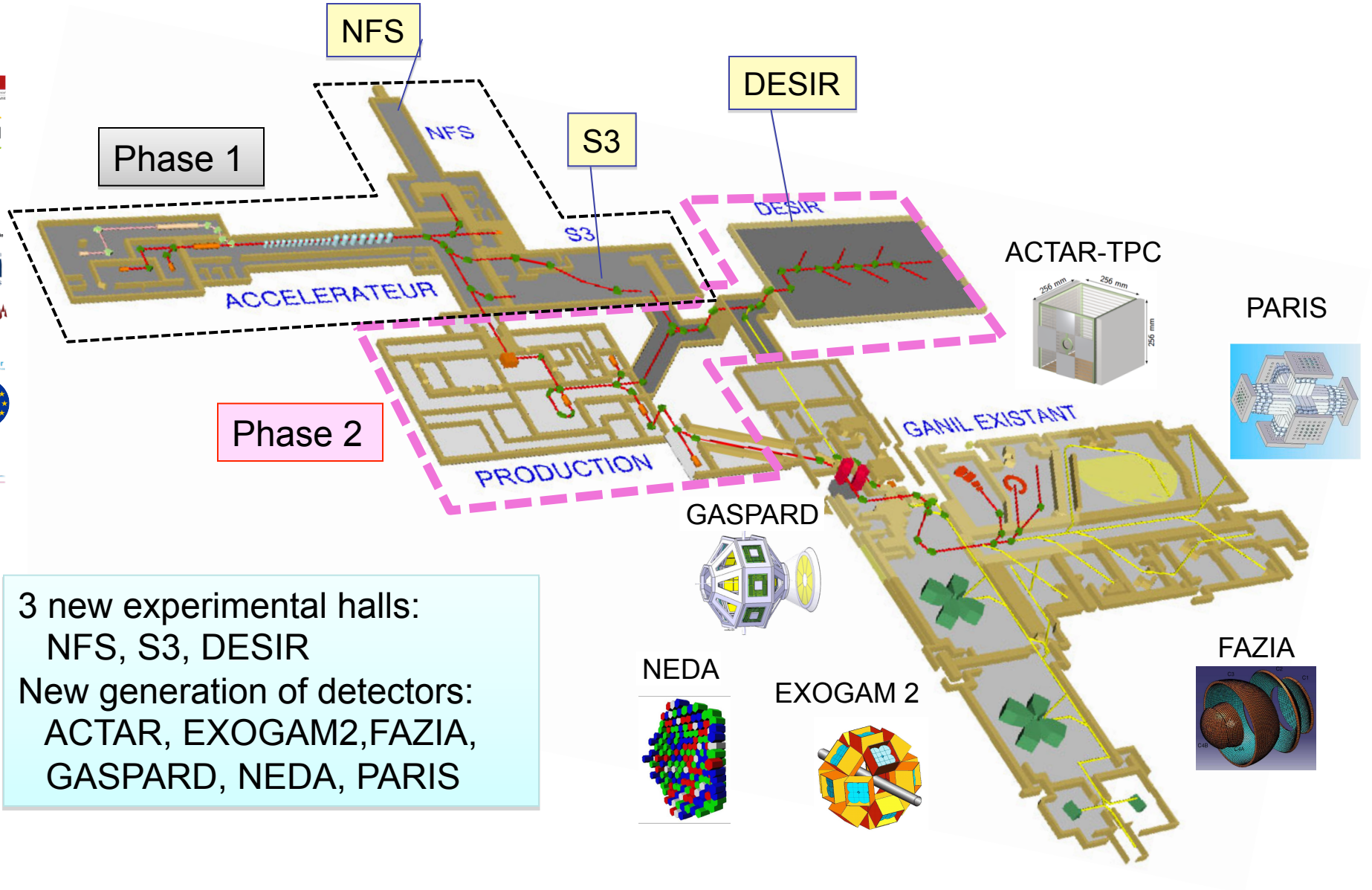


DESIR

Low
Energy
Branch



SPIRAL 2 Layout



3 new experimental halls:
NFS, S3, DESIR
New generation of detectors:
ACTAR, EXOGAM2,FAZIA,
GASPARD, NEDA, PARIS

RIB Production & transport

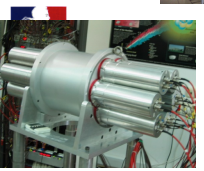
Phase 2

Intensive design work & prototyping is going on

DESIR experimental hall & associated detectors

DECA Agreement

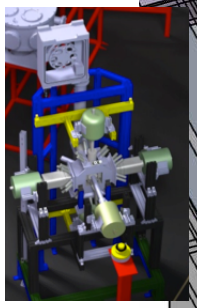
MLLTrap



PIPERADE+TAGS

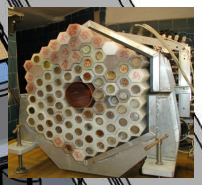
N -TOF detector

LPCTrap



BEDO

TETRA

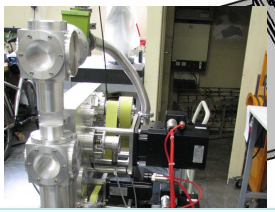


BELEN

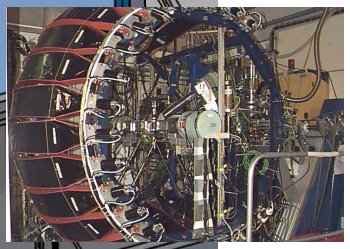
Silicon Cube

LUMIERE

TONNERRE

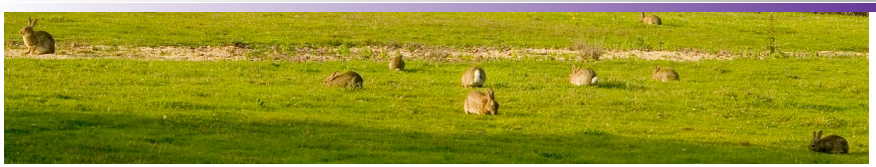


Identification station



Parties: 14 owners of DESIR experimental equipment
Commitment: ~5 M€ & 520 men.months

GANIL/SPIRAL 2 facility: status & outlook



SPIRAL2 Phase 1
Commissioning/
experiments
in 2014

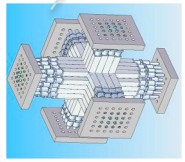
NFS MoU

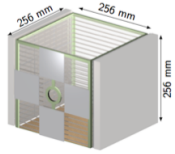
S3
Funds granted

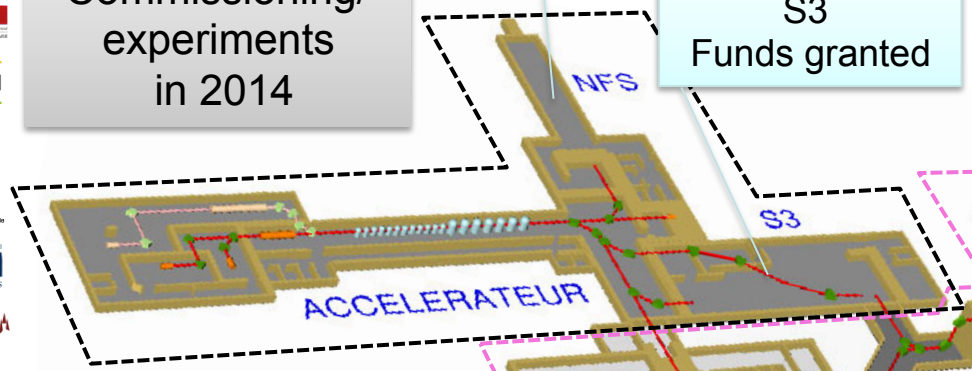
DESIR Coll. Agreement – DECA
Funds granted

ACTAR-TPC
Coll. Agreement

PARIS
MoU

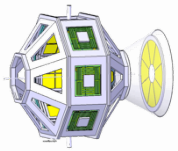






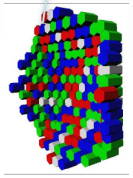
SPIRAL2 Phase 2 (RIB)
Civil construction
from 2015

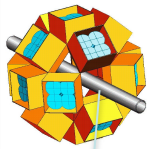
GASPARD



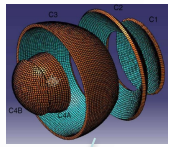
- ✓New RIB from SPIRAL1 by 2014
- ✓ AGATA 1 Π γ-ray tracking array (ε > 20%)
  2014-2015(6) @ GANIL

NEDA
MoU





EXOGAM 2
Coll.
Agreement

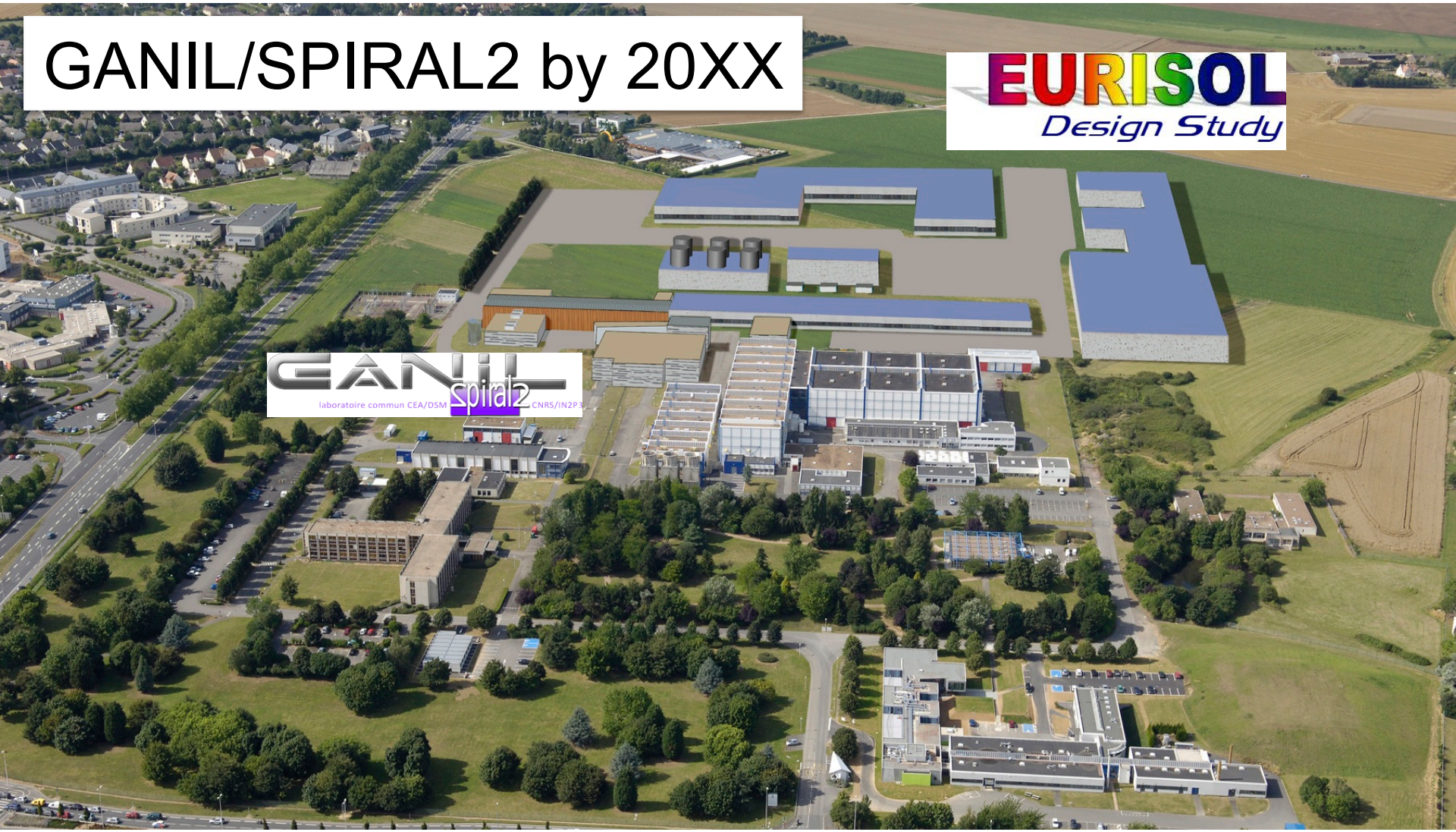


FAZIA
MoU

Nominal operation of GANIL/SPIRAL2:

- ✓up to 79 weeks/y of stable-ion beams
- ✓up to 53 weeks/y of RIB
- ✓up to 5 beams (2 RIB) simultaneously
- ✓800-900 users

EURISOL @ GANIL



NFS facility

Cost ≈ 523k€

50 physicists, 18 institutions, 8 countries

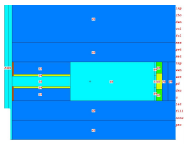
Spokespersons:

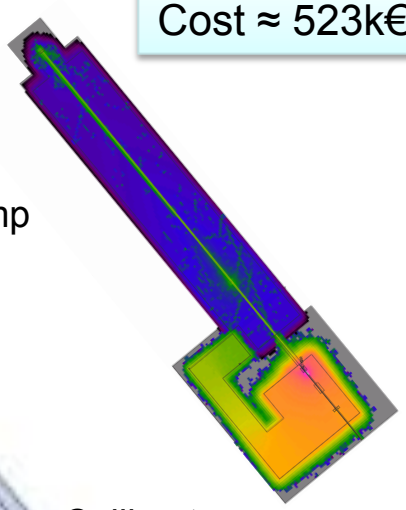
Xavier Ledoux, CEA/DIF/DPTA/SPN, France

Stanislav Simakov, FZK, Germany

GANIL contact person: Fanny Rejmund

Technical co-ordinator R. Hue GANIL



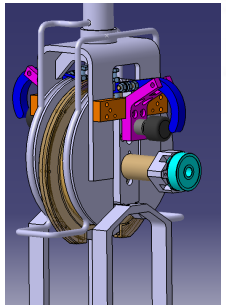


Neutron beam dump

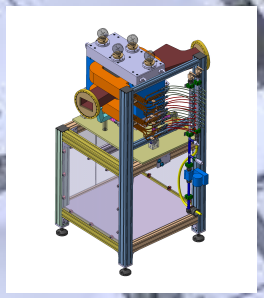
Time-of-flight area

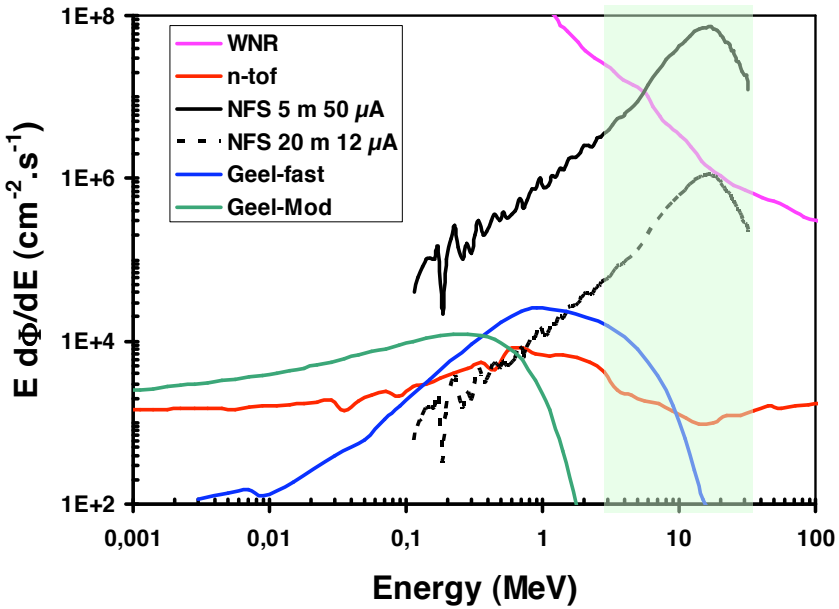
Collimator

D->n Converter
(Under Construction)



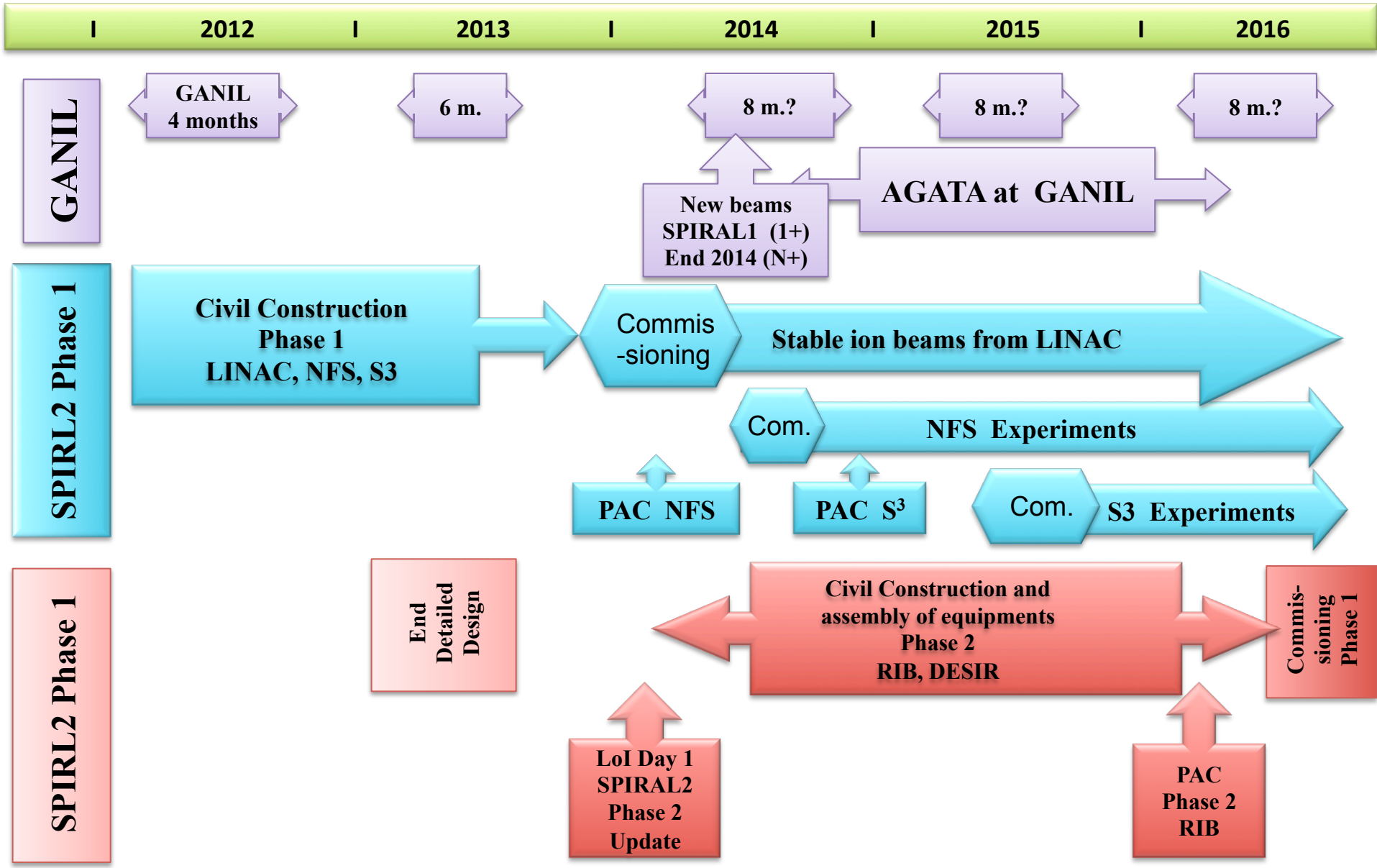
Clearing Magnet
(Ordered)



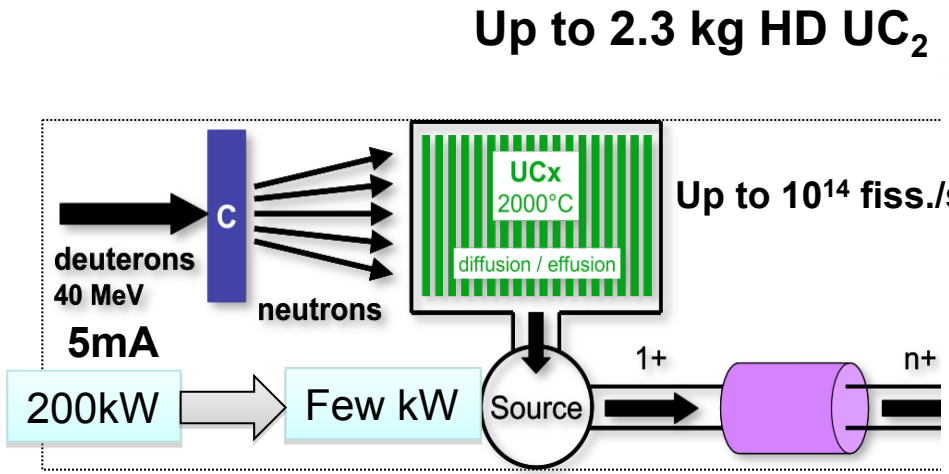


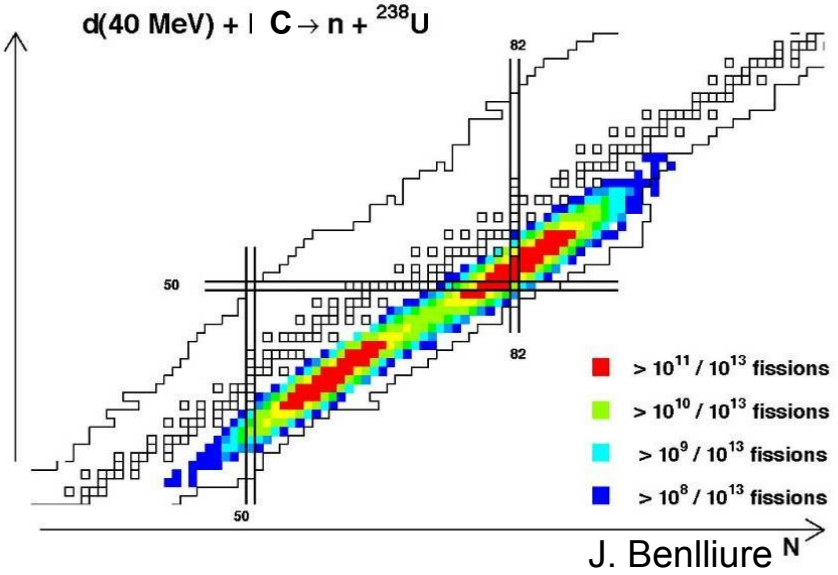
Goal: to be ready for commissioning of NFS in the middle of 2013

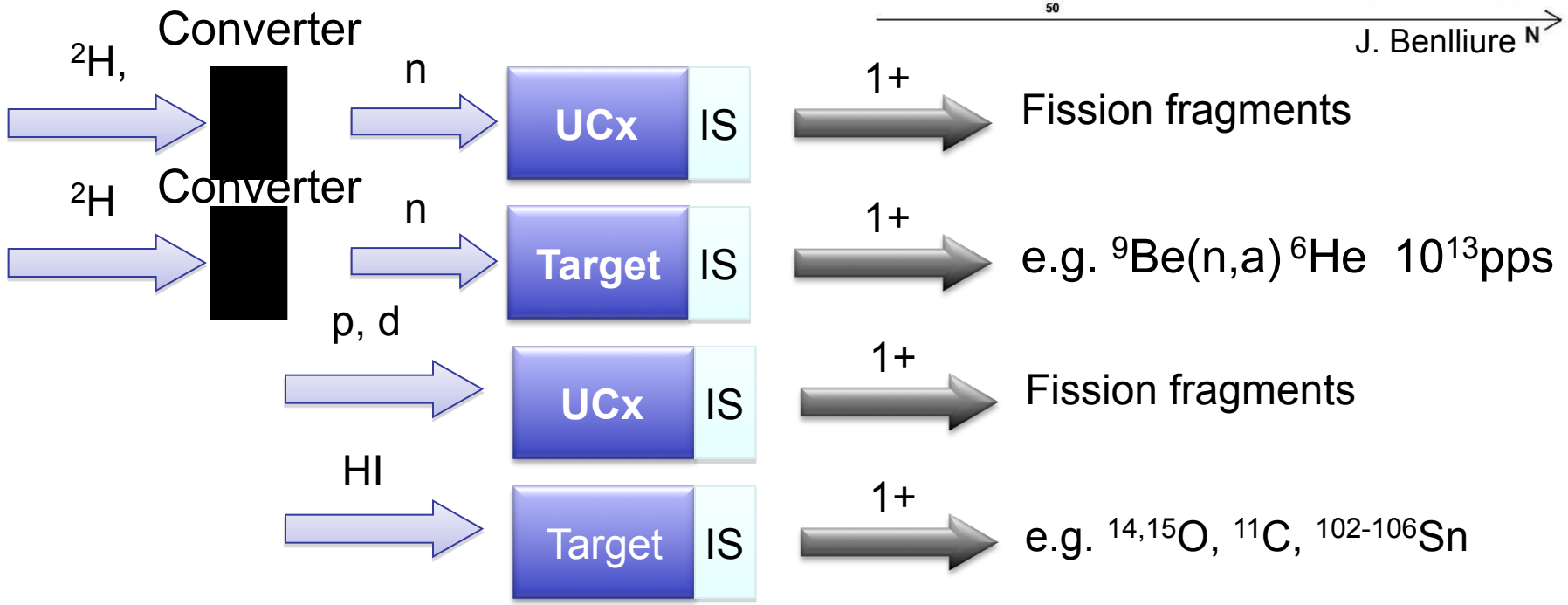
Timeline GANIL & SPIRAL2



ISOL Rare Isotope Beams at SPIRAL 2

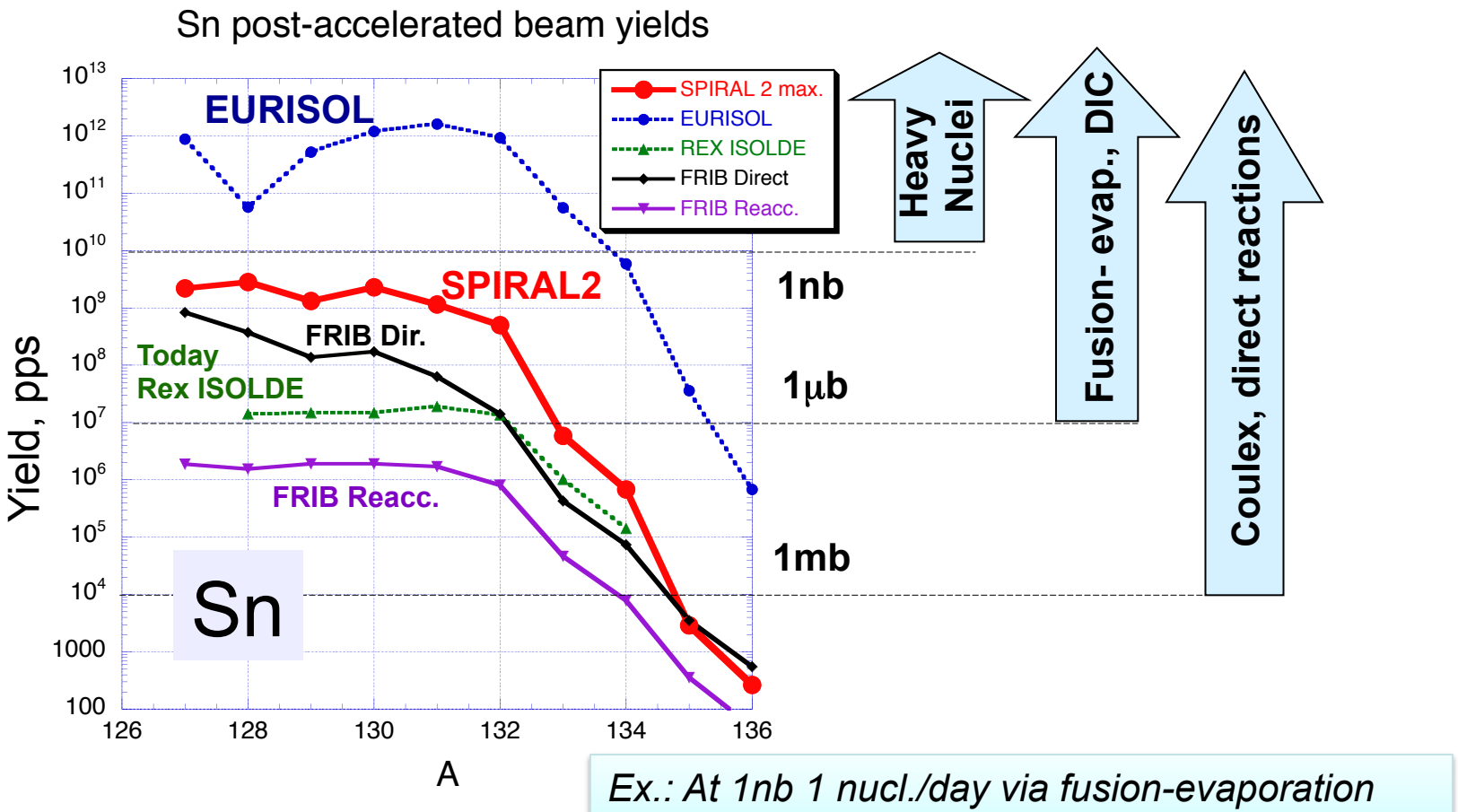






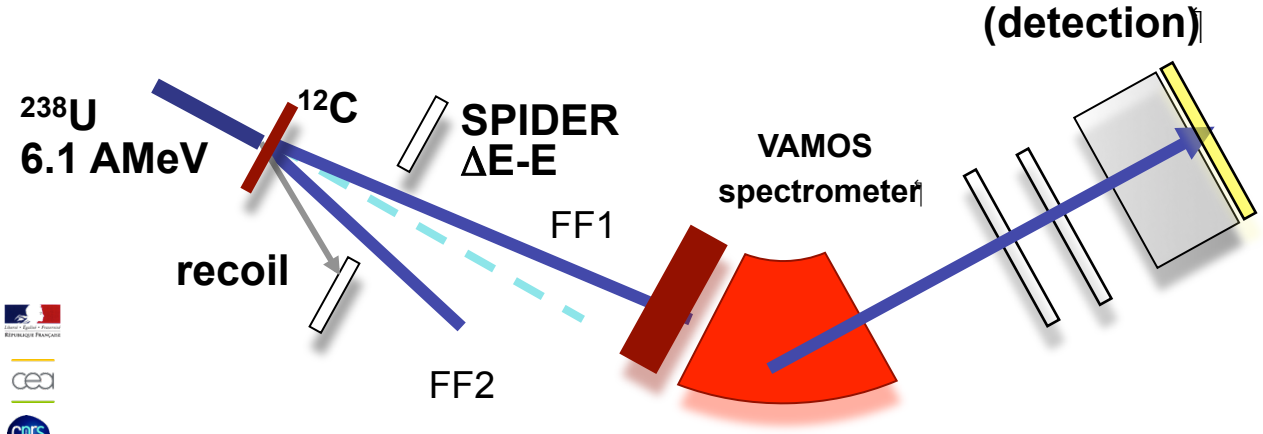
SPIRAL 2: Advanced ISOL RIB facility

SPIRAL 2: Experiments with RIB at low cross sections and very exotic nuclei at few MeV/nucleon



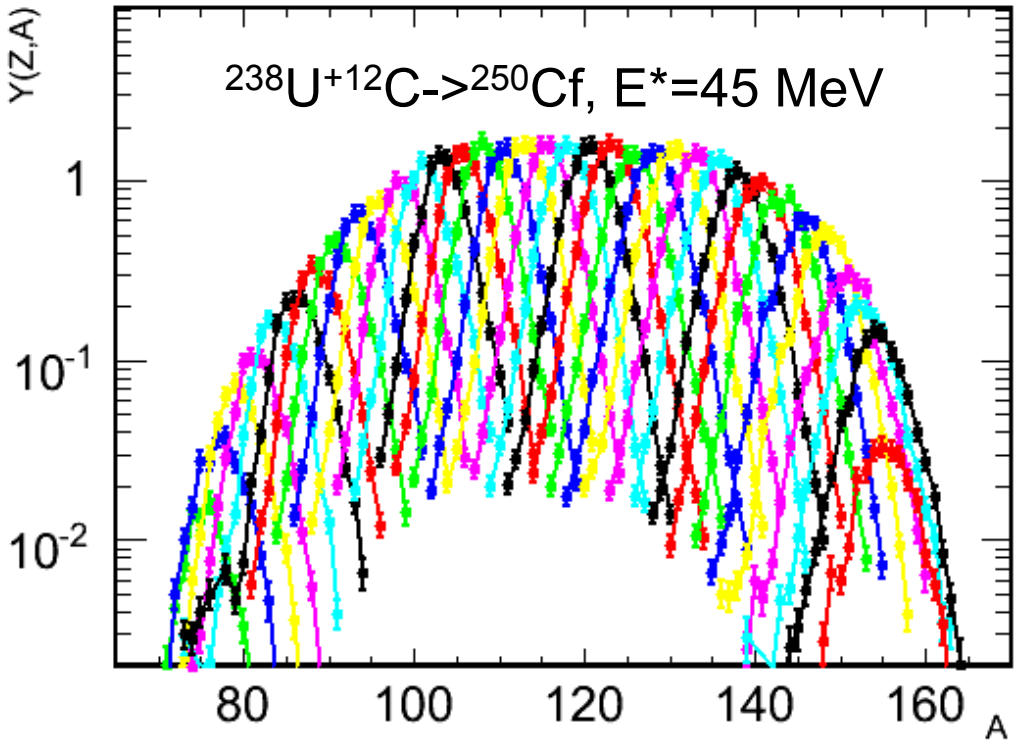
Ex.: At 1nb 1 nucl./day via fusion-evaporation

Transfer-induced fission in inverse kinematics



Transfer reaction
U, Np, Pu, Am, Cm
Low **E* =>** Shell Effects

Fusion reaction: ^{250}Cf
E*=45 MeV => LD Energy



Isotopic identification (**A , Z and q**) and kinetic energy of fission fragments over the complete fragment distribution is measured for the first time.

F. Farget et al.