Physics opportunities and Status of the SPIRAL2 Project

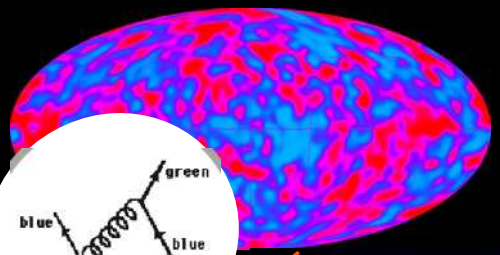
M. Lewitowicz
GANIL, CEA/DSM-CNRS/IN2P3, Caen, France

on behalf of the SPIRAL2 Project Group
&
Physics Collaborations

In the following:

1. *Introduction*
2. *GANIL and Physics Highlights*
3. *SPIRAL2 Facility*
    - *3.1 International Context*
    - *3.2 Beams and Detectors*
4. *Physics Opportunities with high-intensity stable-ion and RI beams*
5. *Status of the Construction of SPIRAL2*
6. *Conclusions & Long(er) Range Plan*

The origin of life



Creation of Matter

High Energy Physics

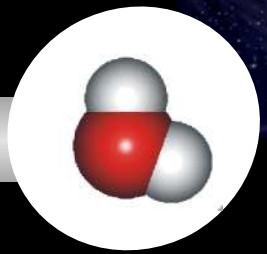
Elements

Nuclear Physics

Rare Isotope Beam Facilities

Planets

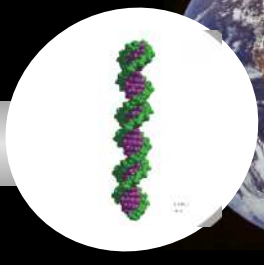
Chemistry



Life

Laboratory Experiments:
Understanding underlying physics

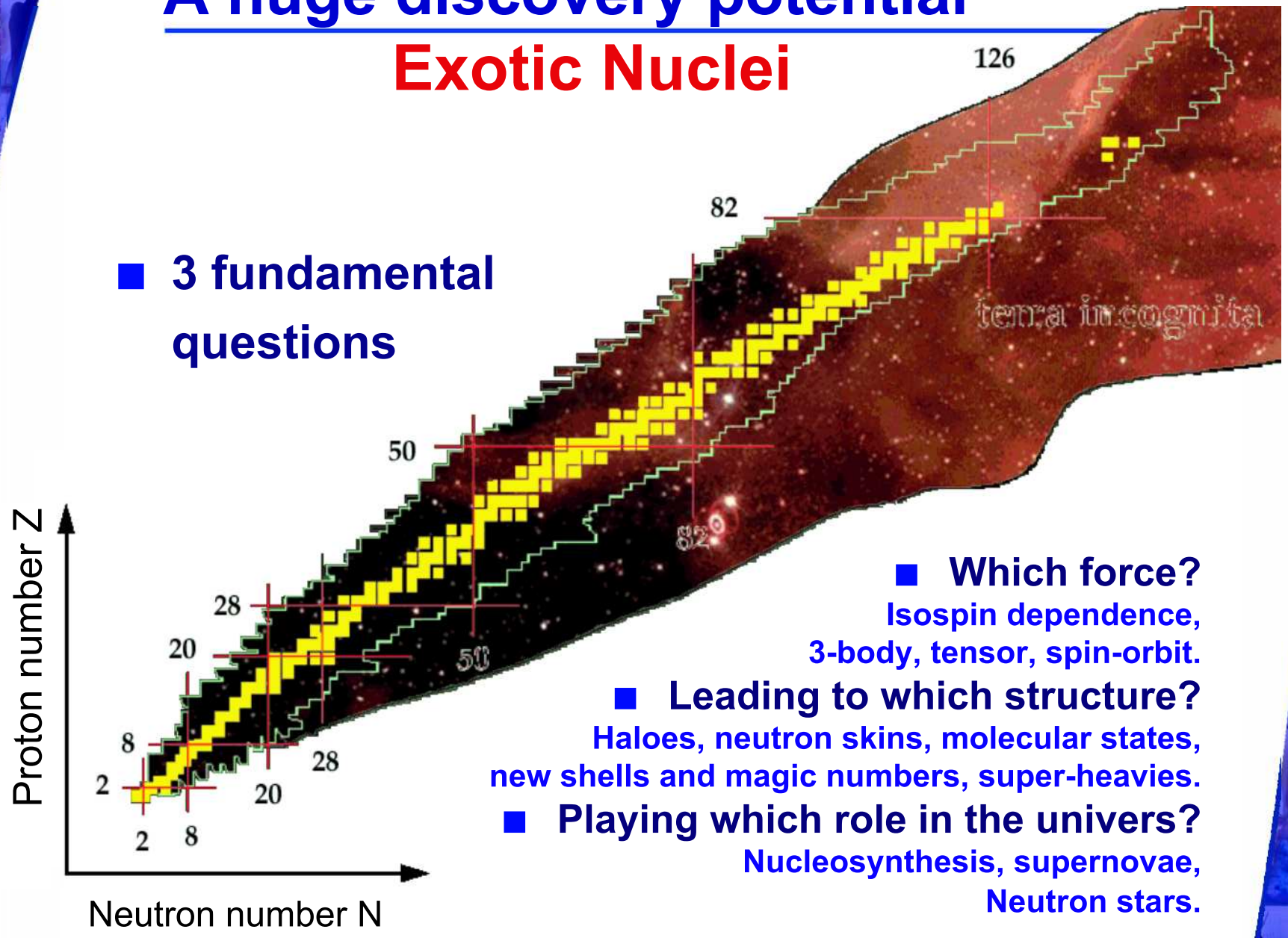
Biochemistry



A huge discovery potential

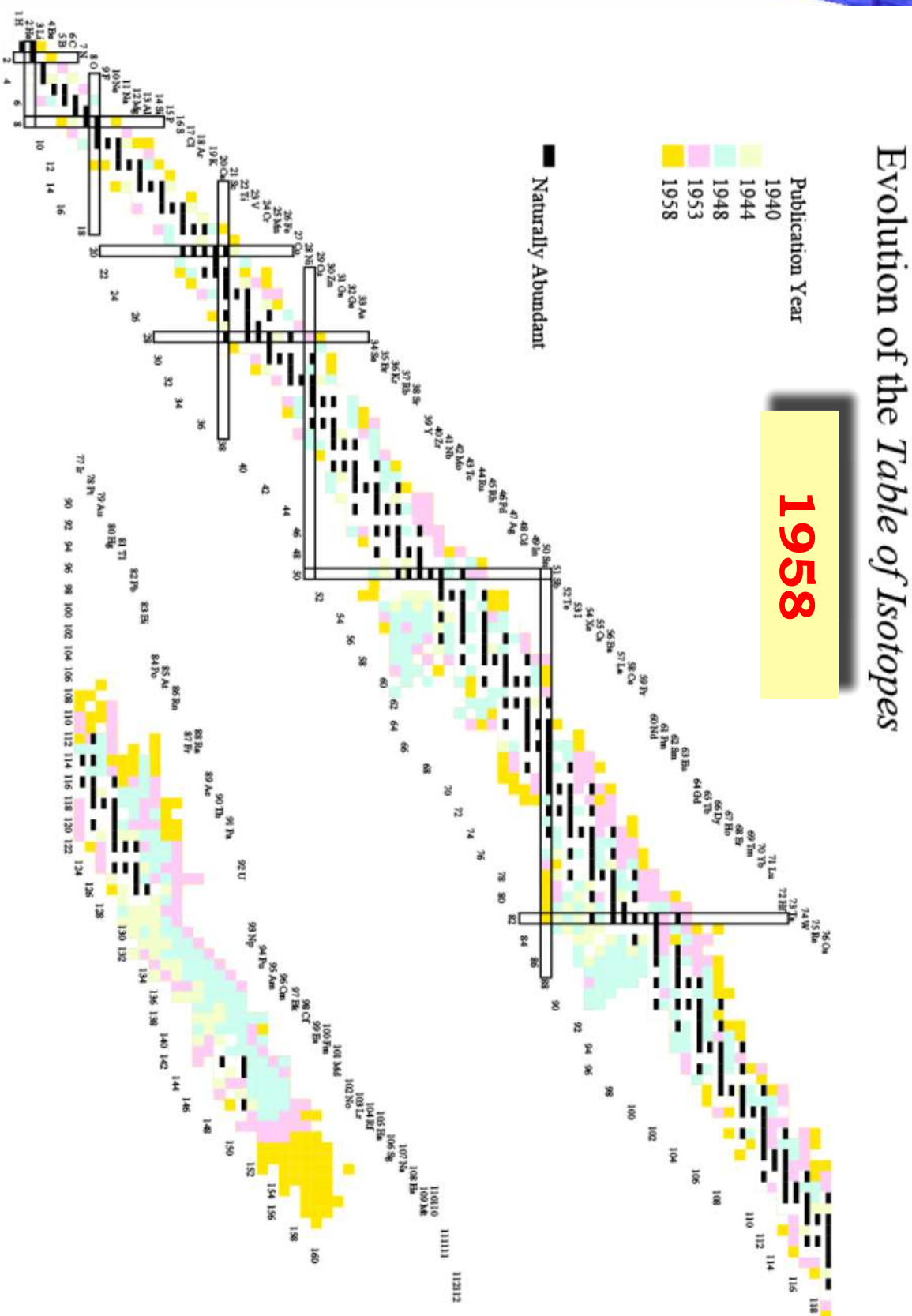
Exotic Nuclei

- 3 fundamental questions



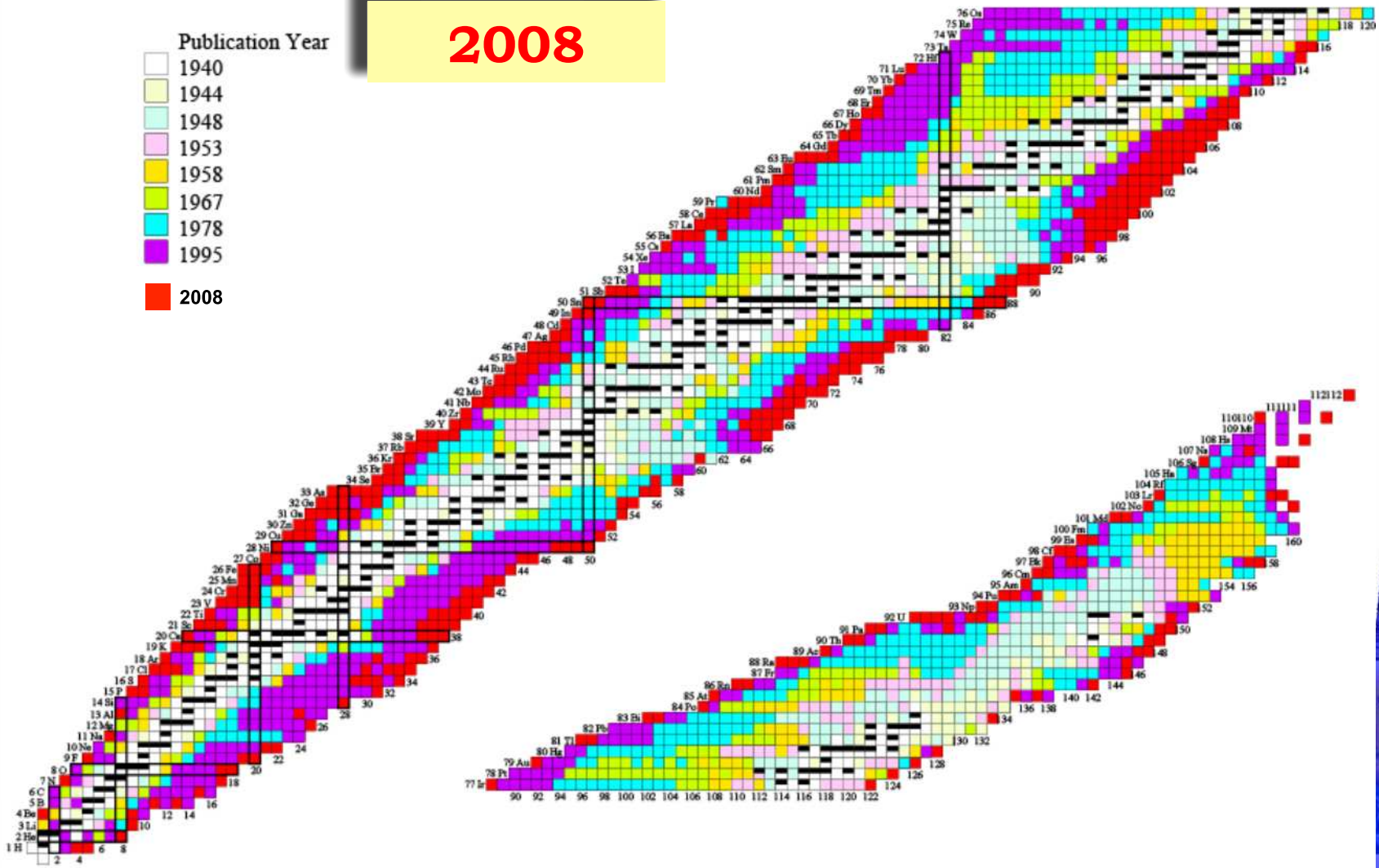
- **Which force?**
  Isospin dependence,
  3-body, tensor, spin-orbit.
- **Leading to which structure?**
  Haloes, neutron skins, molecular states,
  new shells and magic numbers, super-heavies.
- **Playing which role in the univers?**
  Nucleosynthesis, supernovae,
  Neutron stars.

Marek Lewitowicz


Evolution of the Table of Isotopes
1958
Publication Year
1940
1944
1948
1953
1958
Naturally Abundant

GANIL Spiral 2

Evolution of the *Table of Isotopes*



Marek Lewitowicz

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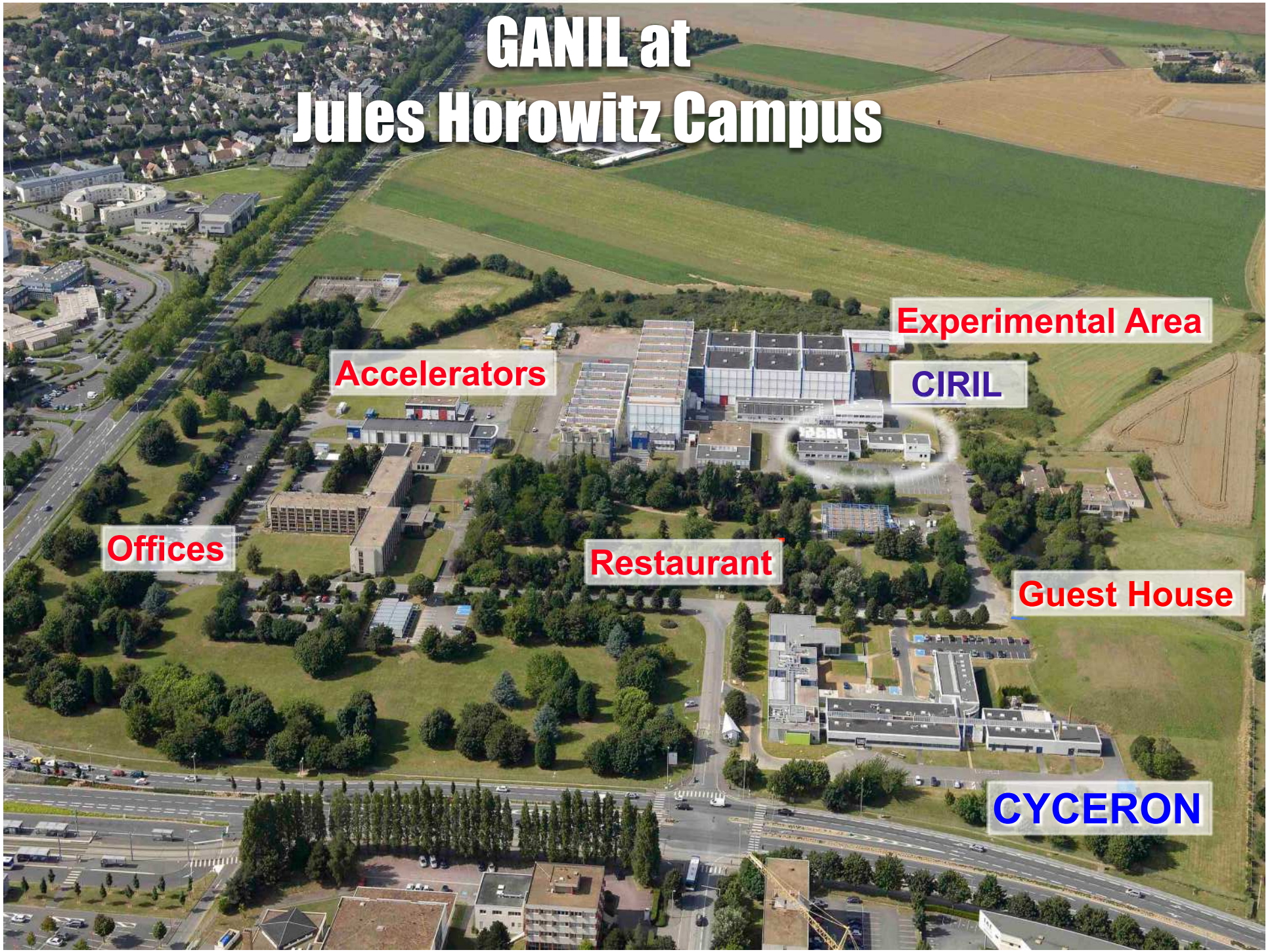
GANIL
CNRS/IN2P3-CEA/DSM
Caen, France
An Interdisciplinary Large Scale Facility
for the
French, European and International
Communities
CSS1
EXOGAM
CSS2
VAMOS
ECS
CIME
Nuclear Physics :
Nuclear structure far from stability
Nuclear dynamics
Nuclear Astrophysics
Applied Physics :
Irradiation of material (electronics, nuclear power plans, …)
Technological transfer (electronics, Ion sources, ...)
Interdisciplinary Researches :
Atomic and Molecular Physics
Surface - Ions Interaction
Material (polymers, organic molecules) - Ions Interaction
Radiobiology (Chromosomic instabilities)


London
Caen
Paris
CERN


Courseulles-sur-Mer
Luc-sur-Mer
GANIL, Caen, France
Caen
N
W
E
S
Image © 2006 TerraMetrics
© 2006 Europa Technologies
Image © 2006 DigitalGlobe
©2006 Google™
Pointer 49° 12'49.96"N 0° 21'37.35" W
Streaming 100%
Eye alt 15.96 km


GANIL at
Jules Horowitz Campus
Experimental Area
Accelerators
CIRIL
Offices
Restaurant
Guest House
CYCERON

GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS

First beam in 1983

STABLE BEAMS

- from C to U
- energies up to 95 A.MeV
- intensities up to 2.10^{13} pps (6 kW)

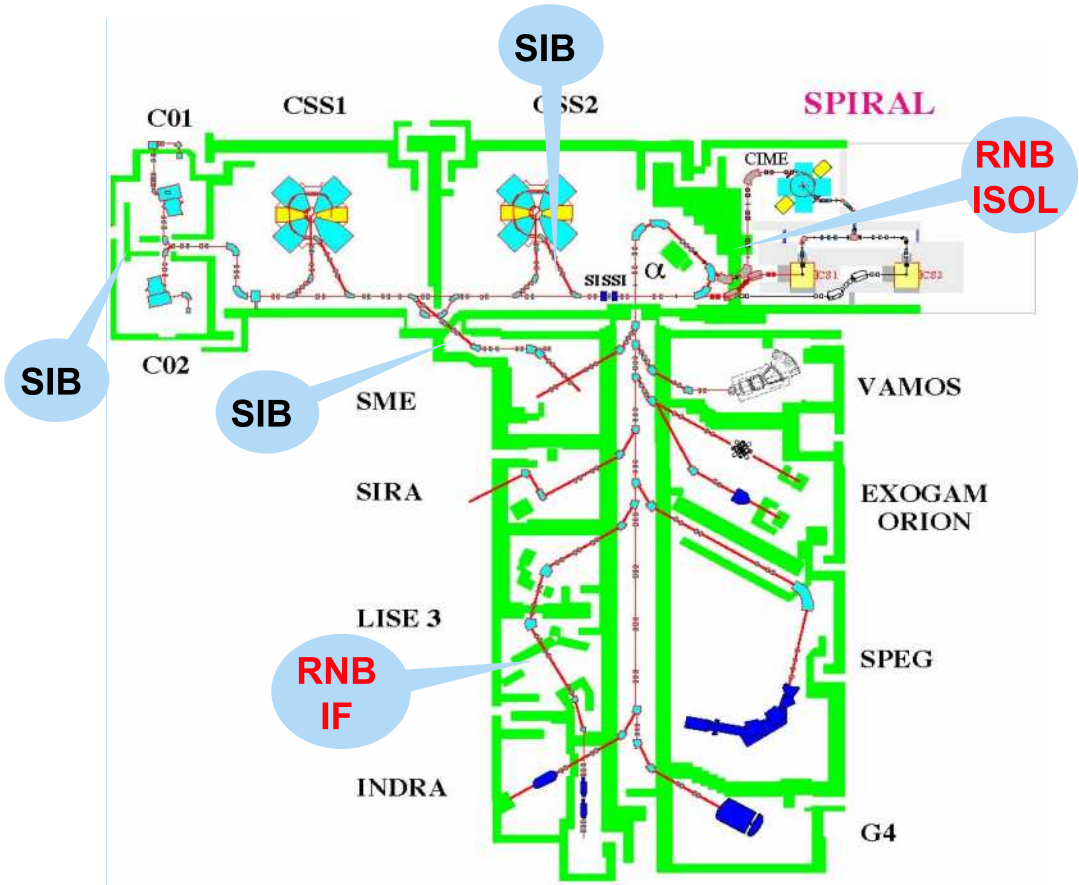
RIB production schemes

- in-flight method : SISSI, LISE
- ISOL method : SPIRAL (SIRA)
- Inverse kinematics: HI+C target

Up to 10000 hours of stable and radioactive beams per year
600 users/year (40% outside of France)

Operation budget (without salaries): 9M€/year

Staff 250 (10% physicists)



Primary Beams:

Ion:	^{12}C	^{36}Ar	^{86}Kr	^{238}U
Energy(AMeV):	95	95	60	24
Int. (pps) :	10^{13}	$3x10^{12}$	$5x10^{11}$	10^{10}


SPIRAL
Ion Source
CSS1
CSS2
Heavy-Ion Stable Beam
CIME
Heavy-Ion Radioactive Beam
Graphite Target
EXOGAM
VAMOS
ECS
CIME
CSS1
CSS2


ECRIS
Target & Ion Source
Container Target


O, Ne, Ar, Kr
1,5 kW


He
3 kW

Available SPIRAL beams

Isotopes

Krypton	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	...
Argon	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	...
Neon	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32		
Fluorine	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
Oxygen	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26				
Nitrogen	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
Helium	3	4	5	6	7	8	9	10											

Stable

Exotic

7 elements, 40 isotopes

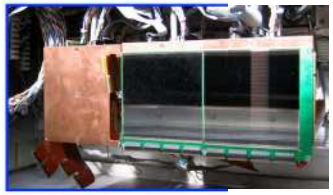
SPIRAL scientific production 2001 – 2008 :
70 physics articles
12 PhD Thesis
53 technical articles
7 PhD thesis

Recent overview article on physics at SPIRAL:
Navin Alahari et al.
J. Phys. G: Nucl. Part. Phys. 38 (2011) 024004.

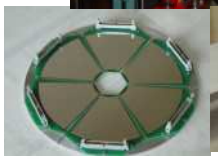
GANIL spectrometers and detectors

VAMOS

MUSETTE



TIARA



SPEG

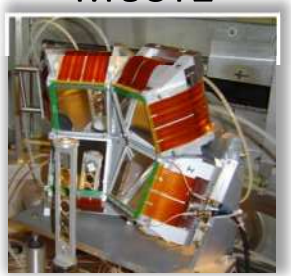
EXOGAM & n-wall

LISE 3

DIAMANT

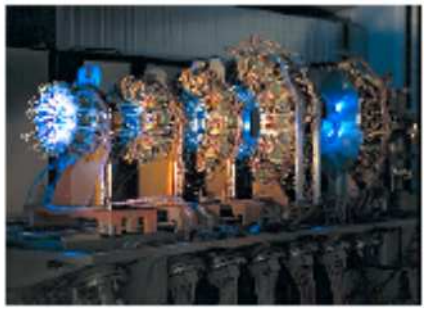
PLUNGER

MUST2

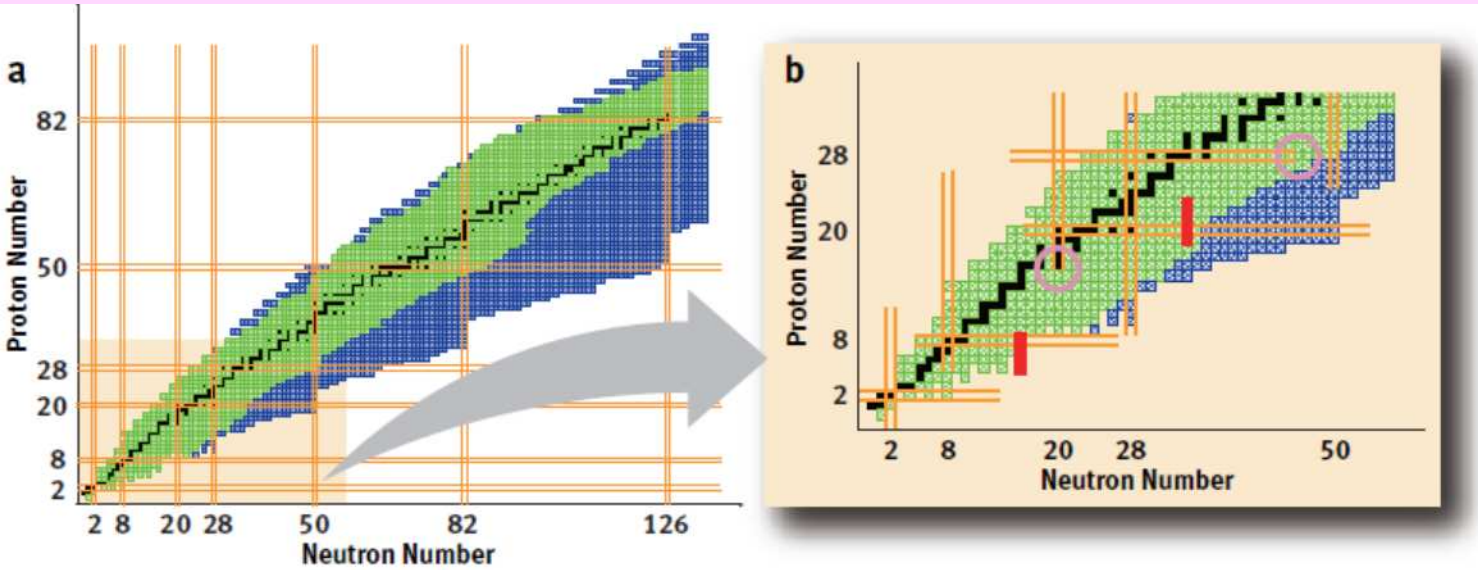


MAYA

INDRA



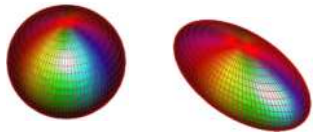
Universal Magic Numbers Mayer and Jensen (1949)



The study of the exotic nuclei revealed that the picture of "magic number" has to be refined…

At N=28 (20), the ^{48}Ca (^{40}Ca) is "magic" (spherical) but different experimental observations lead to the conclusion that the deformation plays an important role when Z≤20.

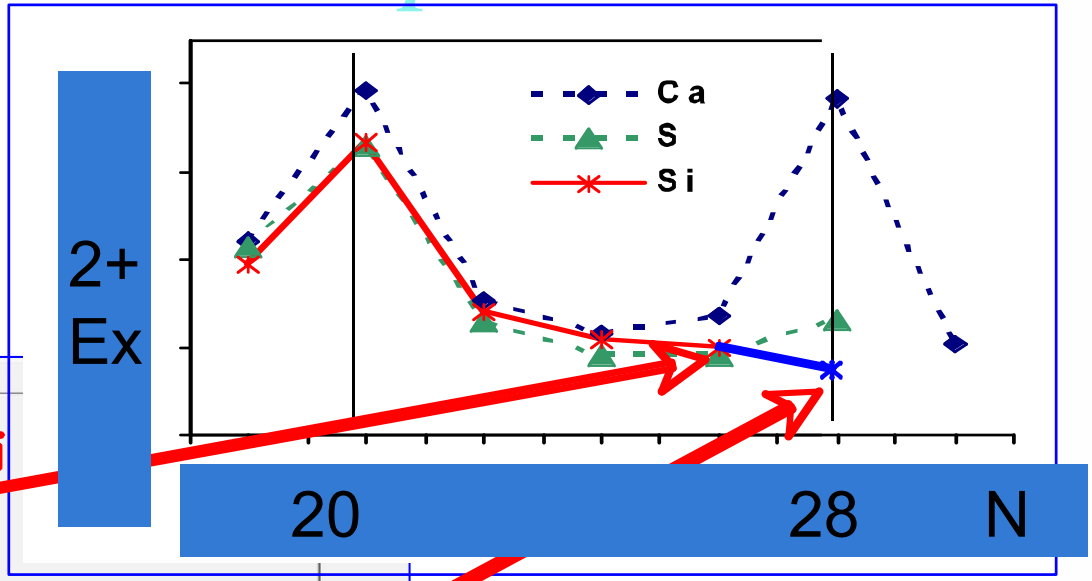
- **strongly deformed ^{42}Si**
- **spherical-prolate shape coexistence in ^{34}Si**

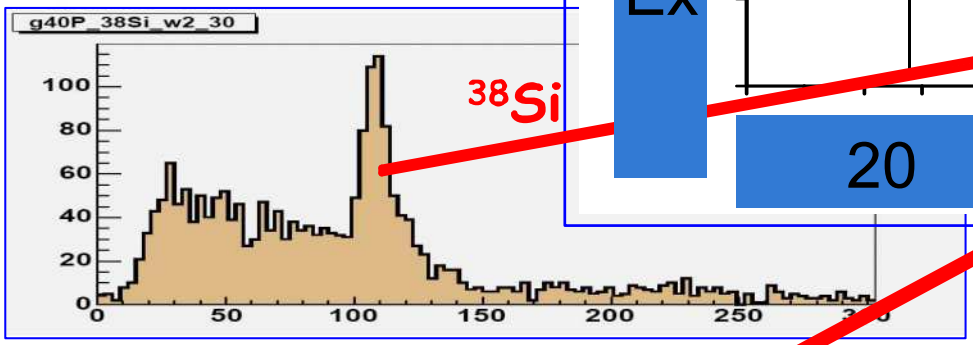


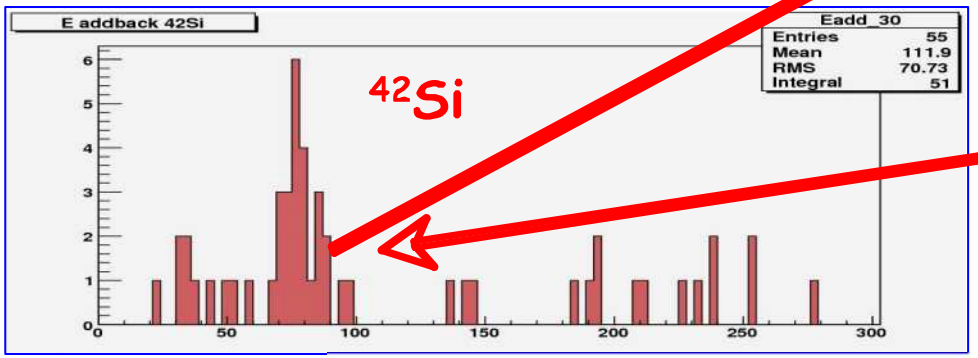
GANIL "in flight" ^{42}Si Results

One example N=28 shell

GANIL+SISSI
« In beam gamma Spectroscopy »







$E(2^+) = 765 \pm 25$ keV

B. Bastin *et al.*, PRL99(2007)022503

Search for the 0^+_2 state in ^{34}Si

N=20

^{40}Ca

^{38}Ar

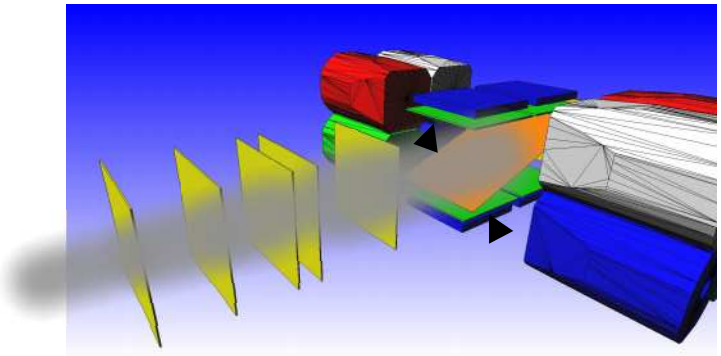
^{36}S

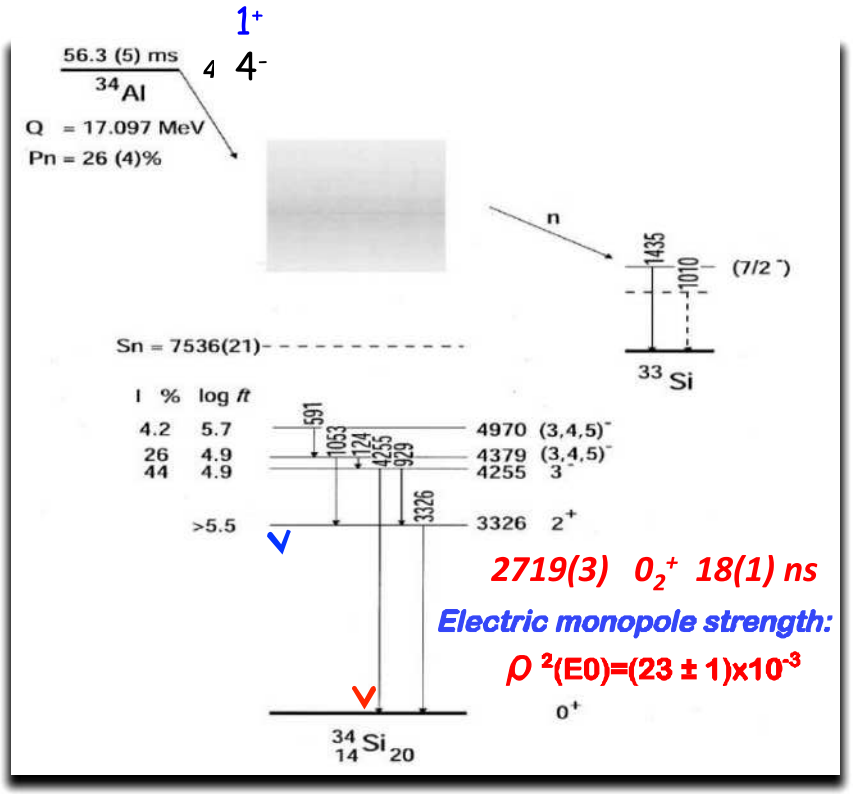
^{34}Si

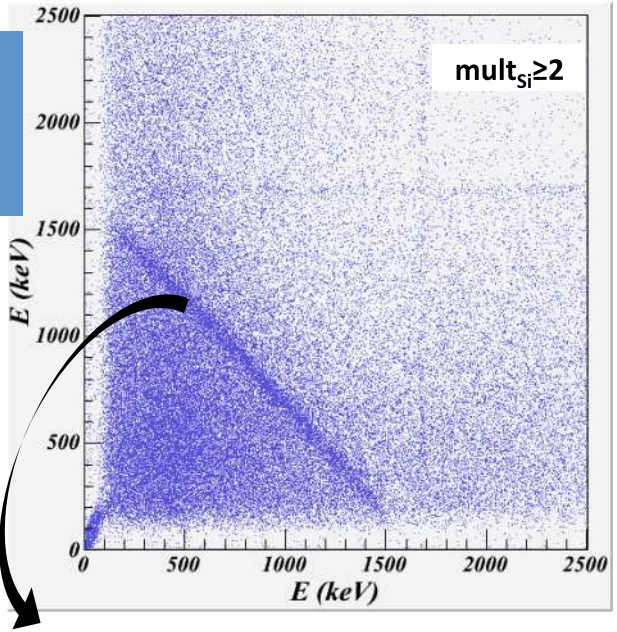
^{32}Mg

^{30}Ne

S. Grévy, F. Rotaru et al.

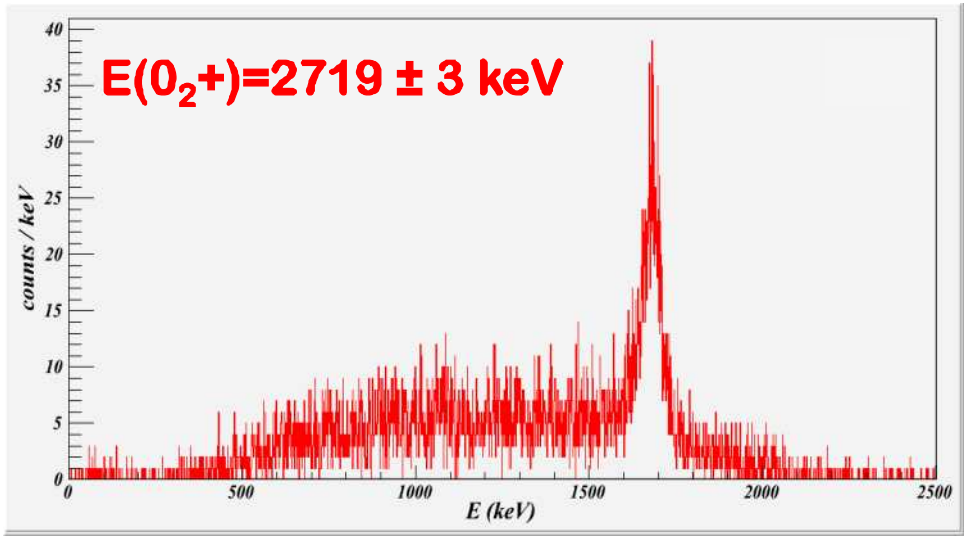






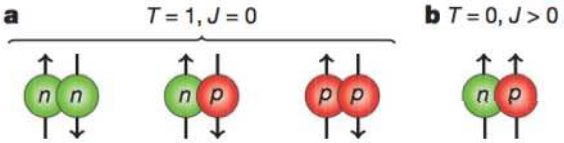
$E_{e1}+E_{e2}$ = cst = 1697(3) keV

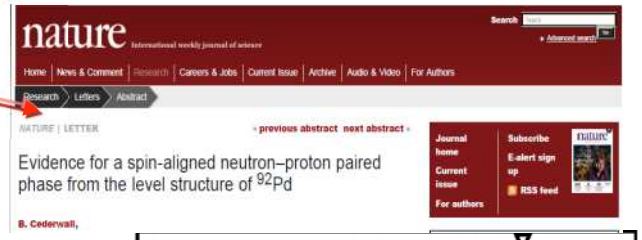
$E(0^+_2)$ = 1697 + 1022 = 2719(3) keV



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

*B Cederwall, et al.





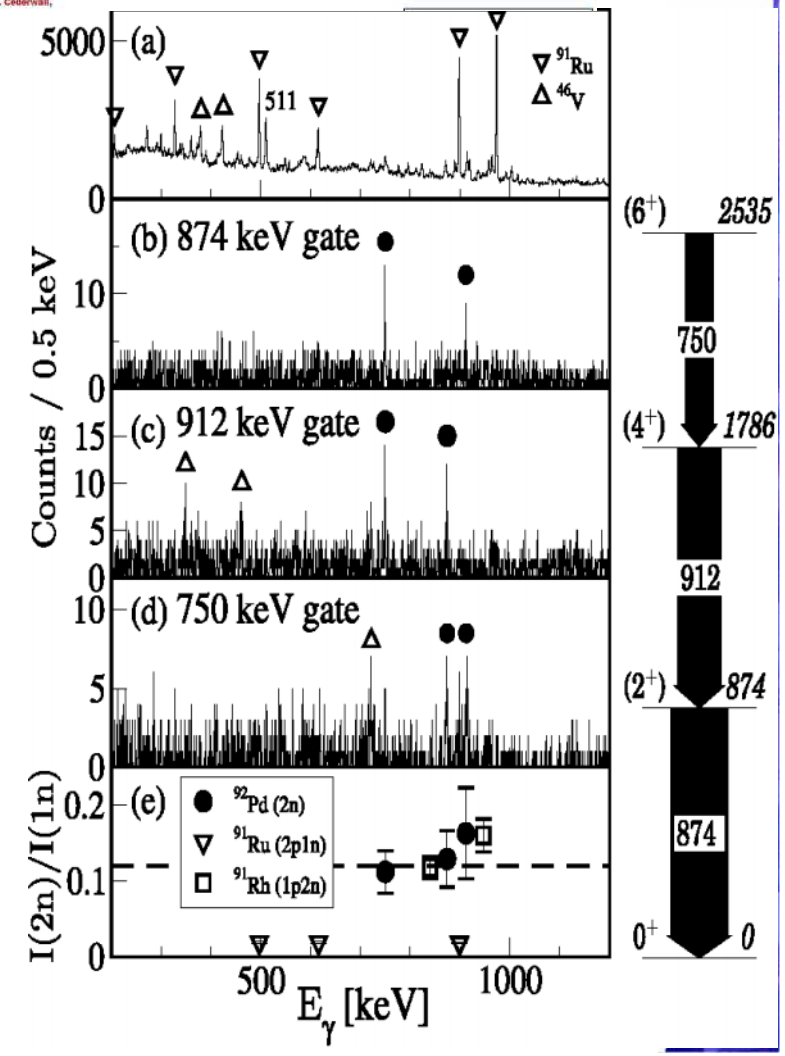
EXOGAM-NWall-DIAMANT:

The power of the coupling

- EXOGAM: 11 Clovers. $\varepsilon_p\omega$ ~ 10% for E_γ=1.3 MeV

- DIAMANT: 80 CsI(Tl) dets. $\varepsilon_{p \text{ or } \alpha}$ ~ 66%

- The Neutron Wall: 50 liquid scintillator detectors. ε_{1n} ~ 23%



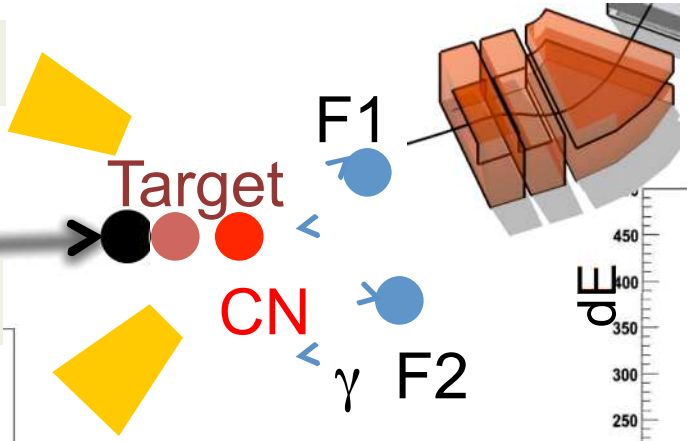
Prompt γ -spectroscopy of fully identified fission-fragments

A. Srivastava et al.

^{238}U (6.1MeV/A) + ^{12}C @ GANIL

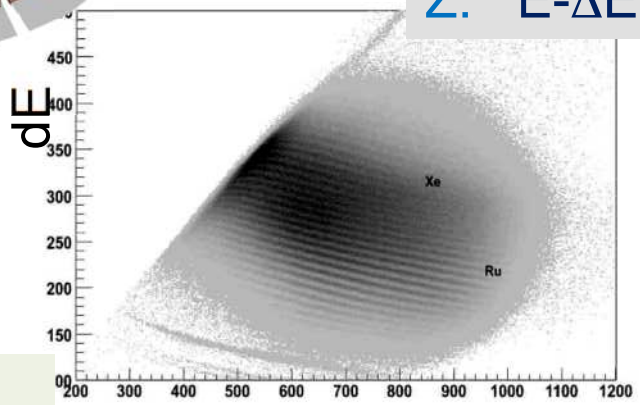
VAMOS

γ detection in Clovers

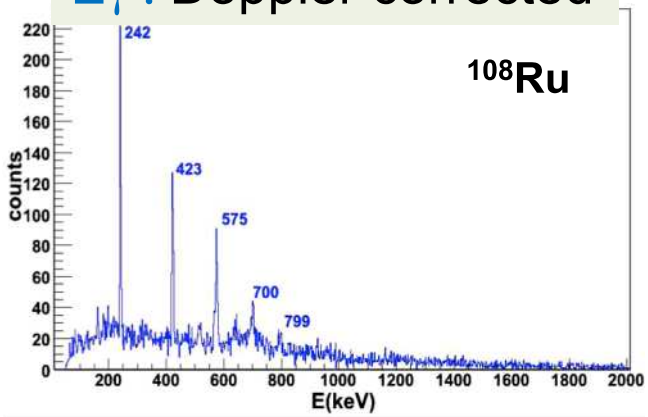


Fragment Identification (Z,M,Q)

Z: E-ΔE

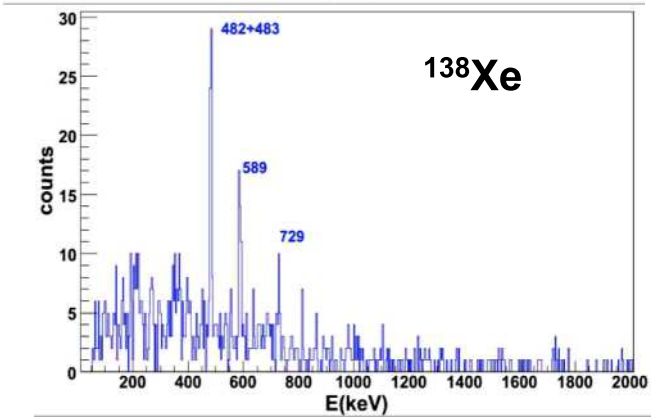


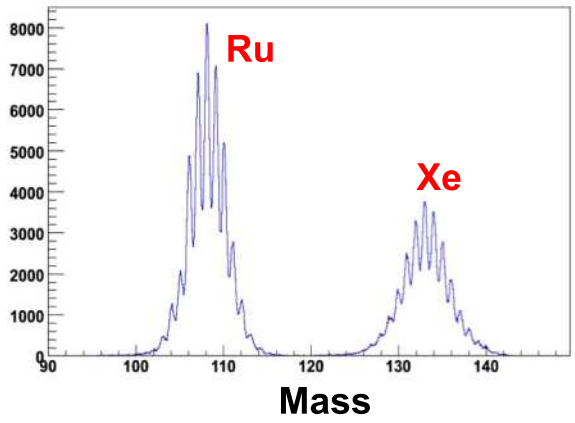
Eγ : Doppler corrected

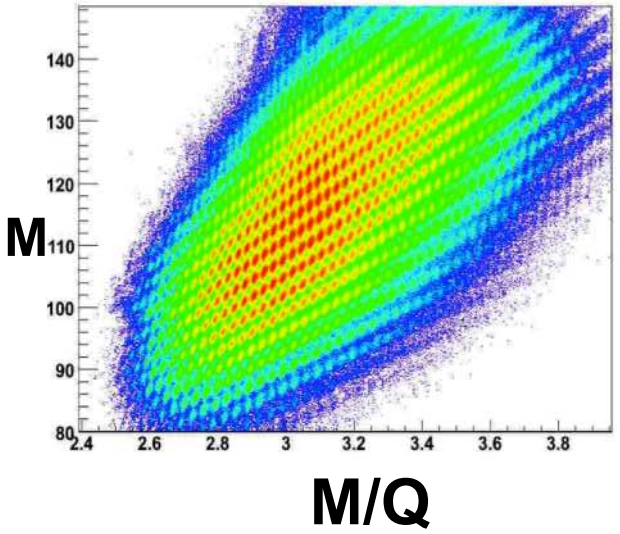


M → Total KE

M/Q → Bρ/velocity







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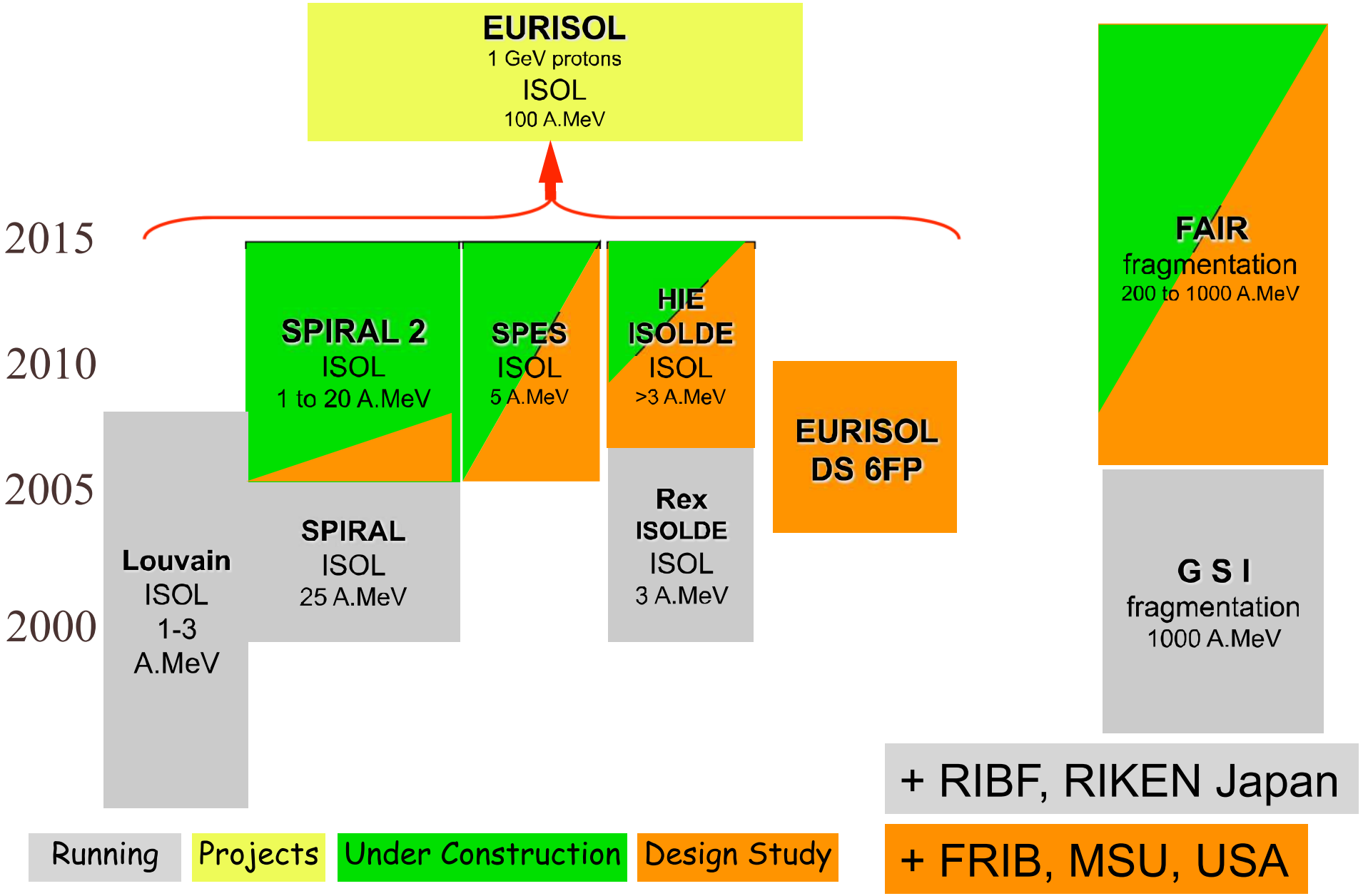
European RNB Facilities - NuPECC Road Map



European Roadmad - ESFRI Process 2006->

Nuclear Physics

FAIR &SPIRAL2

Selected!

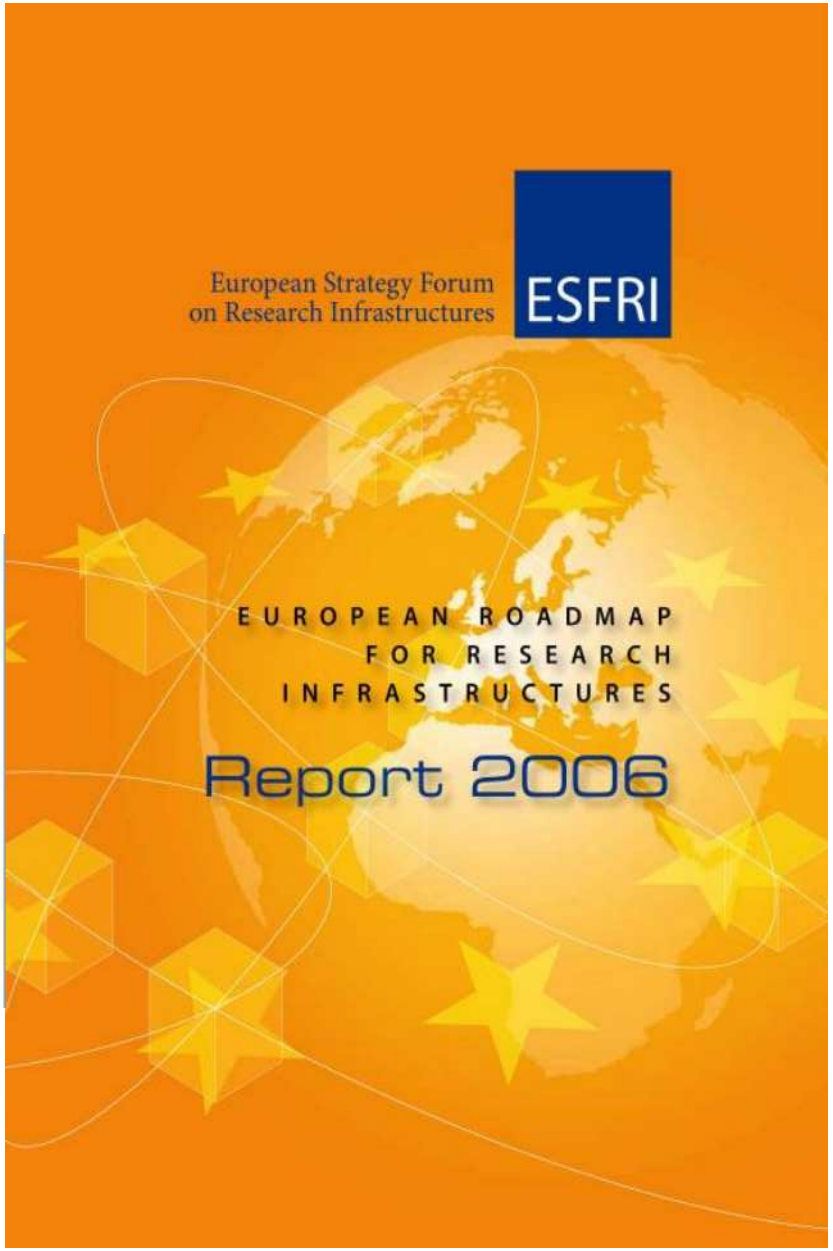
Two Complementary approaches:

=> FAIR @GSI - Darmstadt

Fragmentation at high energy

=> SPIRAL-2 @GANIL - Caen

ISOL-method – Very Intense RIB



NuPECC LRP 2010 Recommendations

- Complete **ESFRI** Facilities
  - **FAIR** with PANDA, CBM, NuSTAR and APPA
  - **SPIRAL2** at GANIL including S3 and DESIR
- Perform Major **Upgrades**
  - **HIE-ISOLDE** at CERN
  - **SPES** at INFN-LNL
  - **AGATA**
  - **SC Linac** at GSI
- Support **ALICE** at CERN
  - Upgrade the nuclear beams and the detector to expand physics reach
- Support **Theory**
  - RI **ECT*** in Trento
  - Projects for advanced studies related to the experimental roadmap
  - Dedicated high-performance computing facilities
- Fully exploit **Existing Facilities**
  - **Lepton beam facilities** ELSA in Bonn, MAMI in Mainz, COMPASS at CERN, DAΦNE at INFN-LNF, and **hadron beam facilities** COSY at FZ Juelich and GSI in Darmstadt
  - **Heavy ion beam facilities** JYFL, KVI, GSI, GANIL, IPNO, ISOLDE, INFN-LNL and INFN-LNS
  - **Underground labs** in Europe such as LUNA at INFN Gran Sasso
  - **AD** at CERN & upgrade **ELENA**
  - **Smaller scale national and university labs** across Europe dedicated to nuclear structure & astrophysics experiments, fundamental interactions and nuclear applications

GANIL/SPIRAL1/SPIRAL2 facility

Caen, France

GANIL Beam time: 35 weeks/y (600 users)
SP2 Beam time: 44 weeks/y
ISOL RIB Beams: up to 53 weeks/y
Up to 50 % more users: 800-900
First experiments 2013

LINAC:
33MeV p
40 MeV d
14.5 AMeV HI

Neutrons For Science

S3 separator-spectrometer

DESIR Facility low energy RIB

A/q=6 Injector option

GANIL/SPIRAL 1 today

A/q=2 source
p, d, ^{3,4}He 5mA

A/q=3 HI source
Up to 1mA

HRS+RFQ Cooler

RIB Production Cave
Up to 10^{14} fiss./sec.

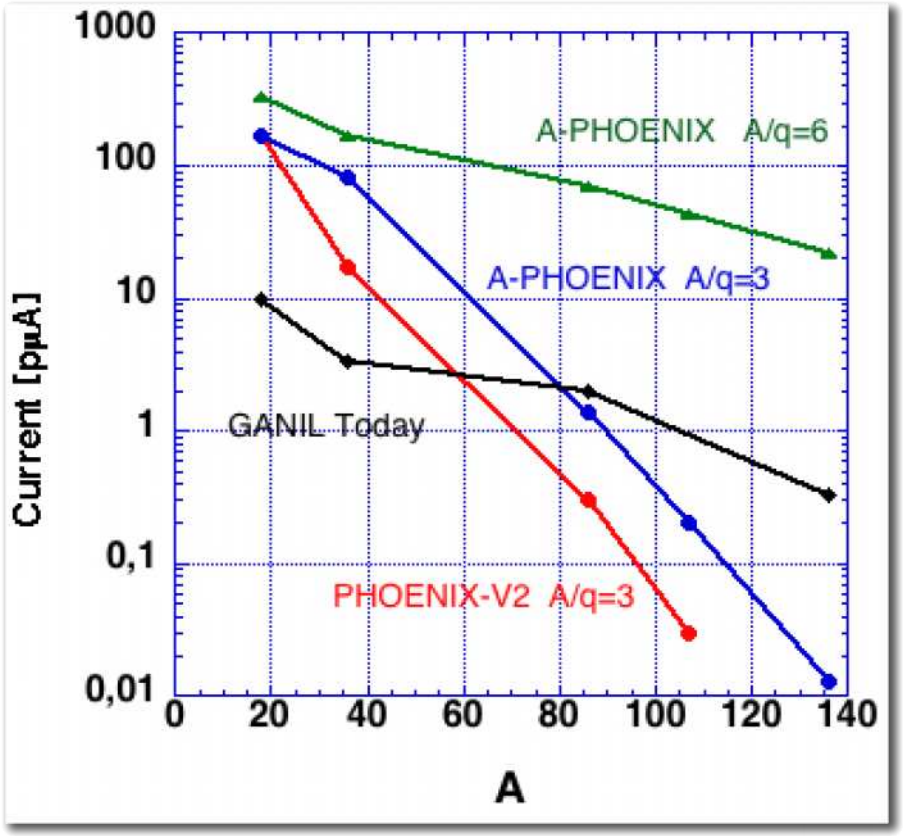
CIME cyclotron RIB at 1-20 AMeV
(up to 10 AMeV for fiss.fragments)

Cost: 200M€ Funded +
Detectors: Min. 8M€ – Max. 30 M€
(2011-2016)

2 RIB + 3 Stable-ion beams **-> 5 experiments in parallel**

LINAC beams for the Day 1 SPIRAL2 Phase 1 experiments*)
Based on the recommendations of SPIRAL2 SAC for the LoI

Energy = 0.75-15 *A.MeV*



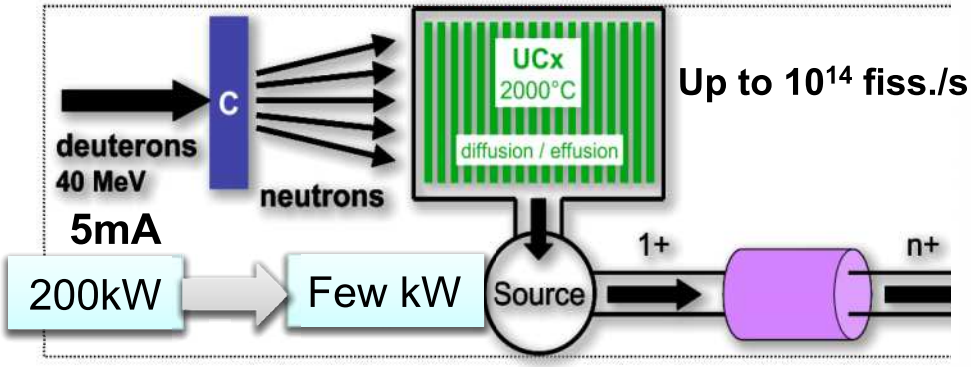
Ion(s)	Energy Range (MeV/nucleon)	Maximum Intensity (pμA)	Date of availability ***)	Remarks
$^{1}H^{1+}$	20-33	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{2}H^{1+}$	10-20	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{4}He^{2+}$	10-20	2-10	December 2012	NFS beam line; Intensity with fast chopper 1/100
$^{12}C^{4+}$	5-7	≥10 **)	February 2013	S3 beam line
$^{18}O^{6+}$	5-7	≥10 **)	February 2013	S3 beam line
$^{22}Ne^{8+}$	5-7	≥10 **)	February 2013	S3 beam line
$^{40}Ar^{14+}$	4-5	≥10 **)	February 2013	S3 beam line
$^{28-30}Si^{10+}$ or $^{32-36}S^{12+}$	5-7	≥10 **)	November 2013	S3 beam line
$^{40}Ca^{14+}$	5-7	≥10 **)	November 2013	S3 beam line
$^{48}Ca^{16+}$	5-7	≥10 **)	November 2013	S3 beam line
$^{58}Ni^{18+}$	4-14	≥1 **)	November 2013	S3 beam line

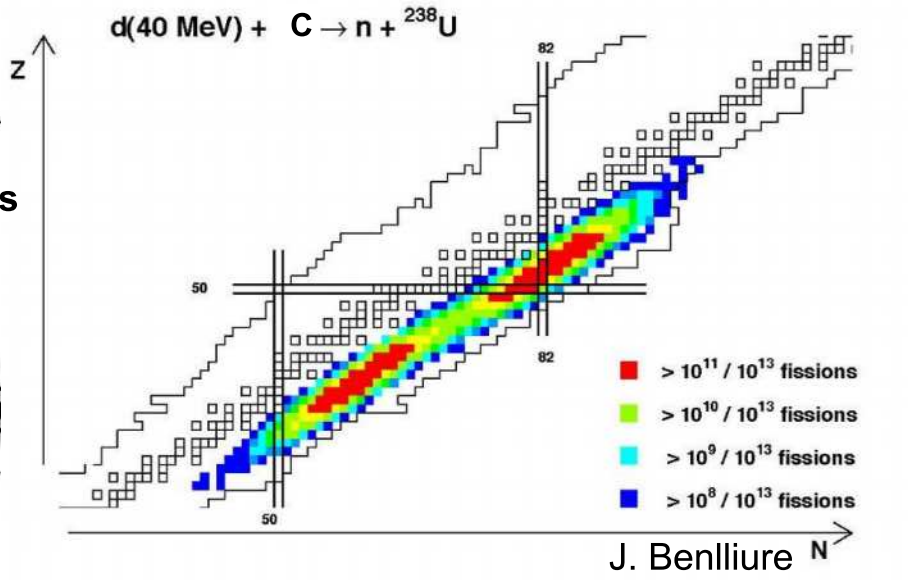
*) The parameters indicated in this table are the first and the best approximations that can be done today.
**) Based on the order of magnitude of the expected best currents extracted from a high performance, fully operational, 28 GHz ECR Ion source.

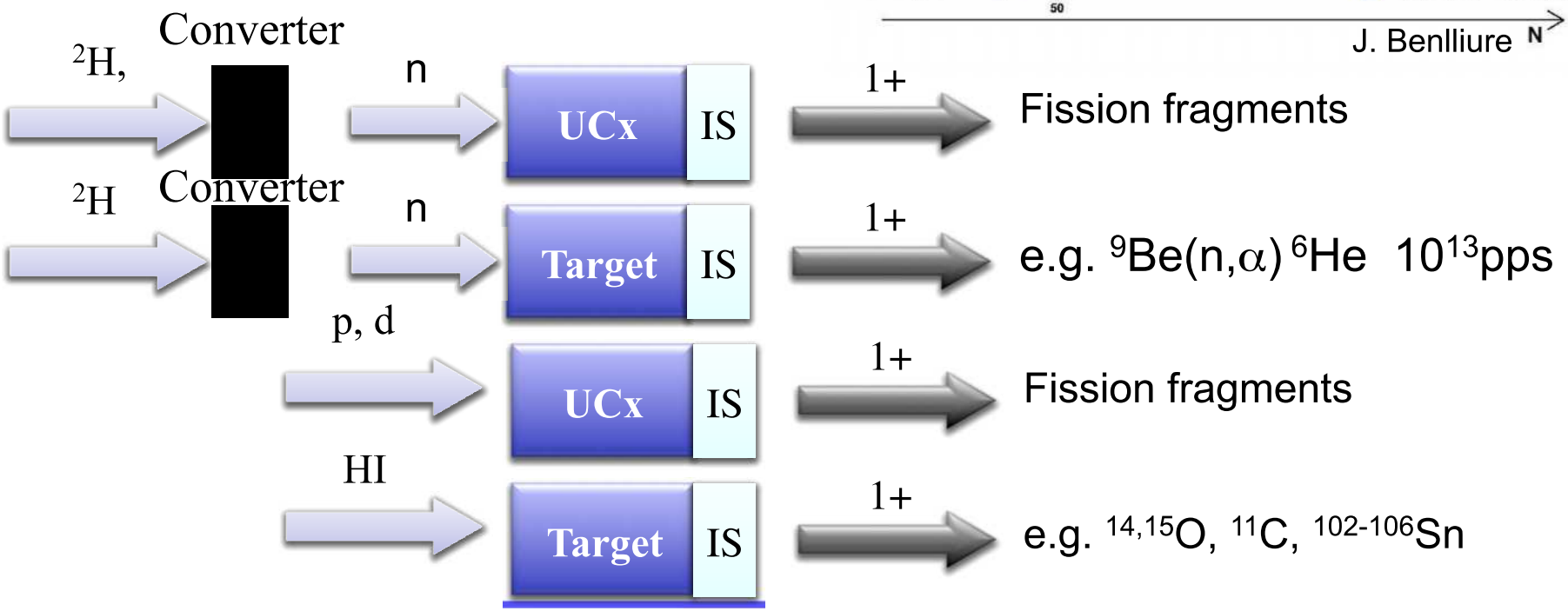
http://pro.ganil-spiral2.eu/spiral2/spiral2-beams

ISOL Rare Isotope Beams at SPIRAL 2

Up to 2.3 kg HD UC_2

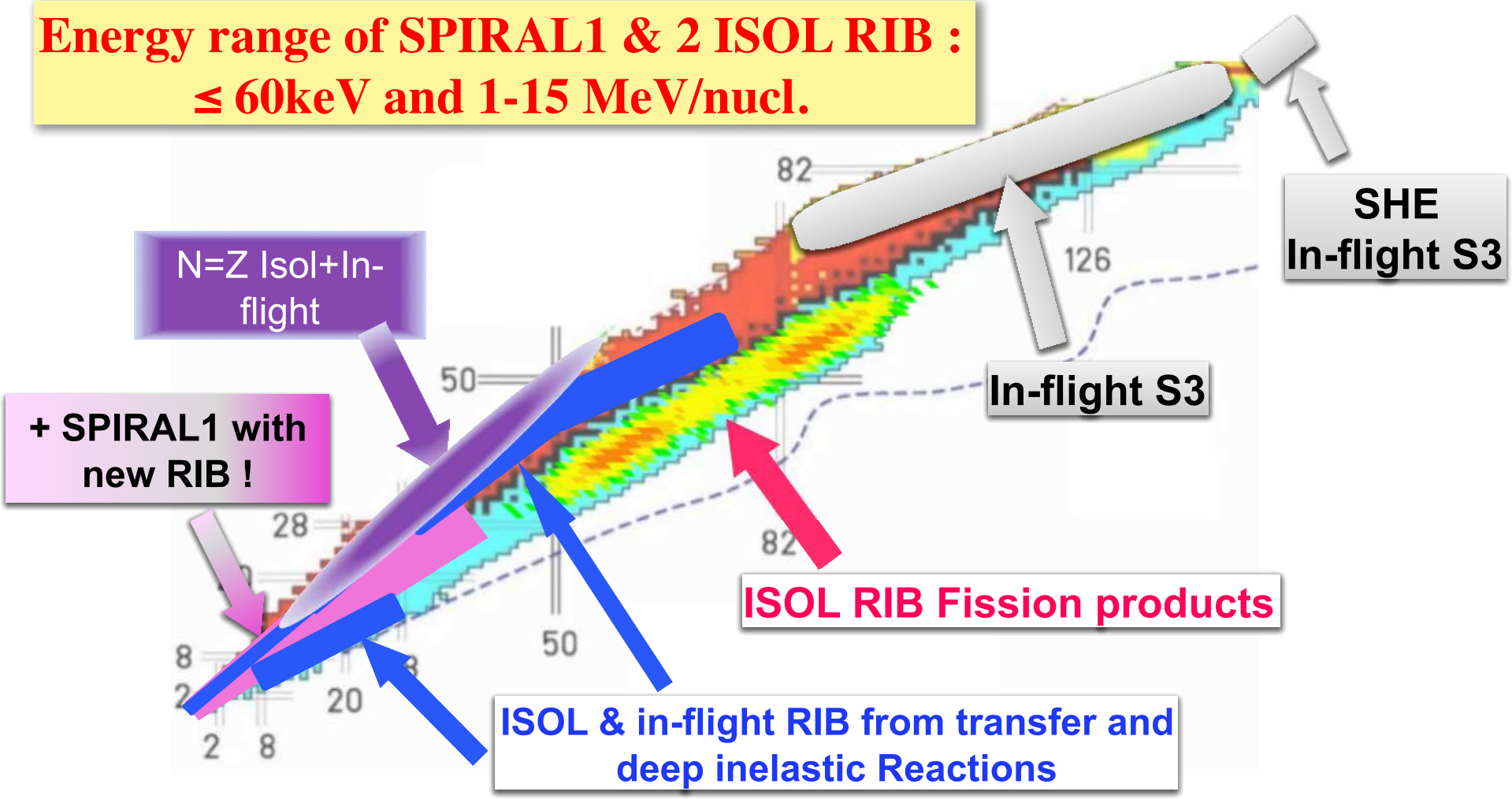






RIB and nuclei far from stability accessible with SPIRAL1 & SPIRAL2

Energy range of SPIRAL1 & 2 ISOL RIB : ≤ 60keV and 1-15 MeV/nucl.



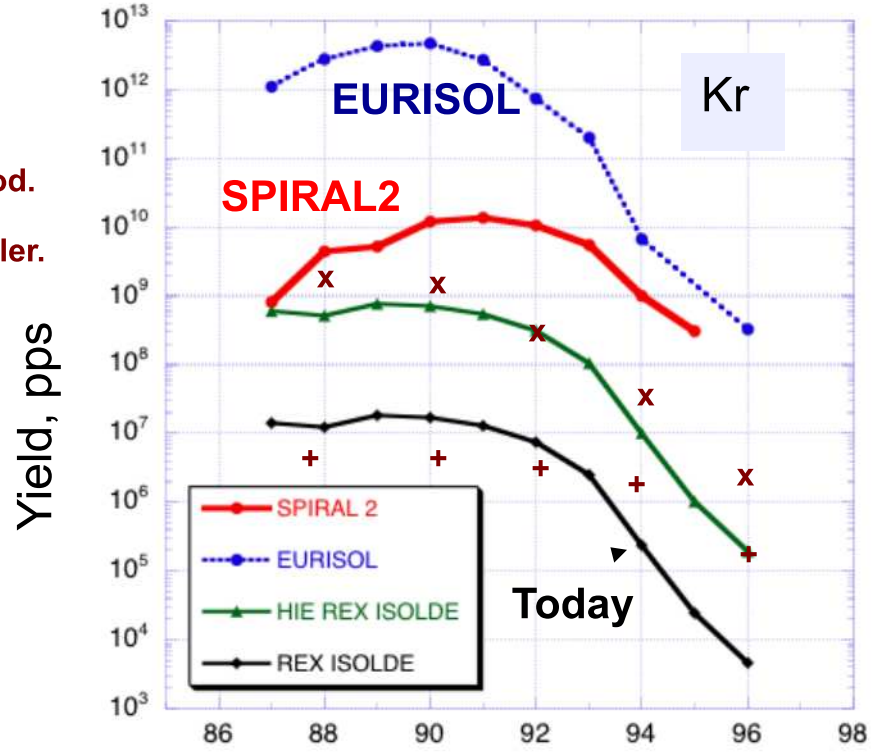
SPIRAL 2: Advanced ISOL RIB facility

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

FRIB

\+ Direct prod.

x Post-acceler.



1nb

1μb

1mb

Heavy Nuclei

Fusion- evap., DIC

Coulex, direct reactions

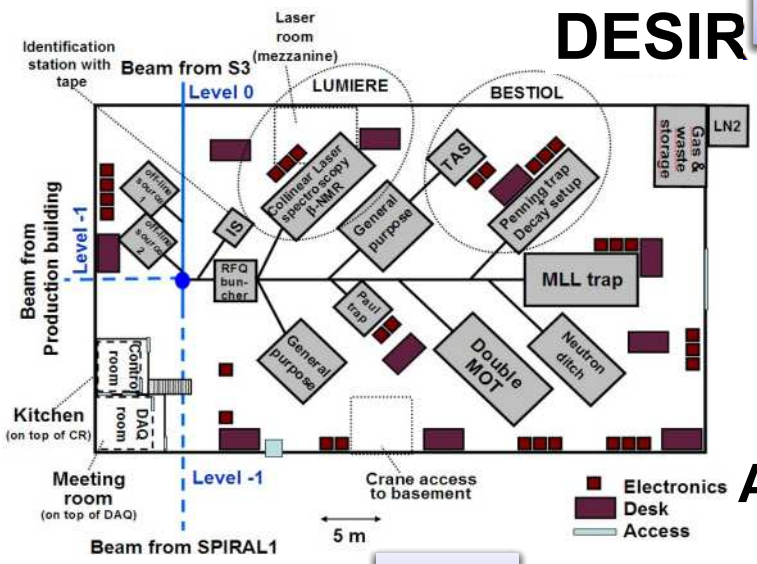
Ex.: At 1nb 1 nucl./day via fusion-evaporation

New detectors to be used at SPIRAL 2

Spiral2

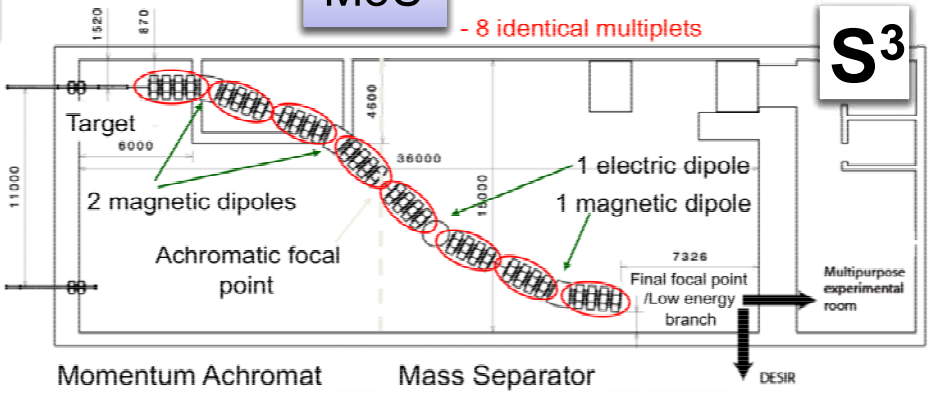
DESIR

MoU



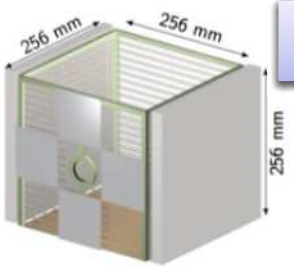
S³

MoU



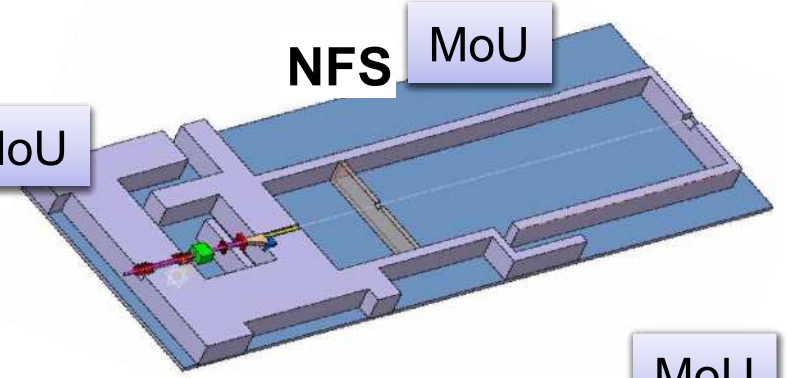
ACTAR & GET

MoU



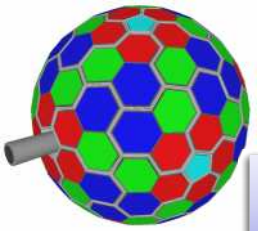
NFS

MoU

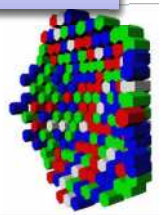


AGATA

MoU

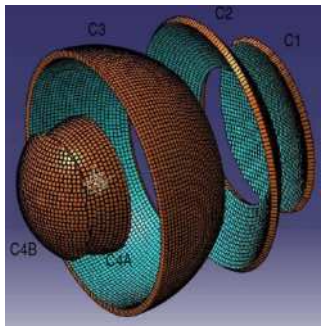


NEDA



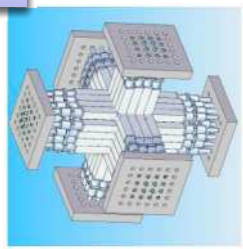
FAZIA

MoU



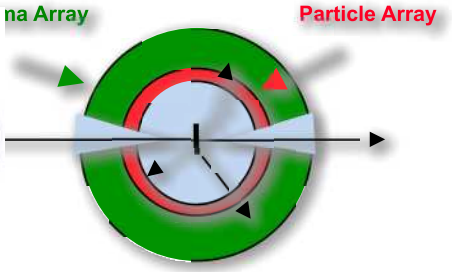
PARIS

MoU



HELIOS

GASPARD



EXOGAM 2

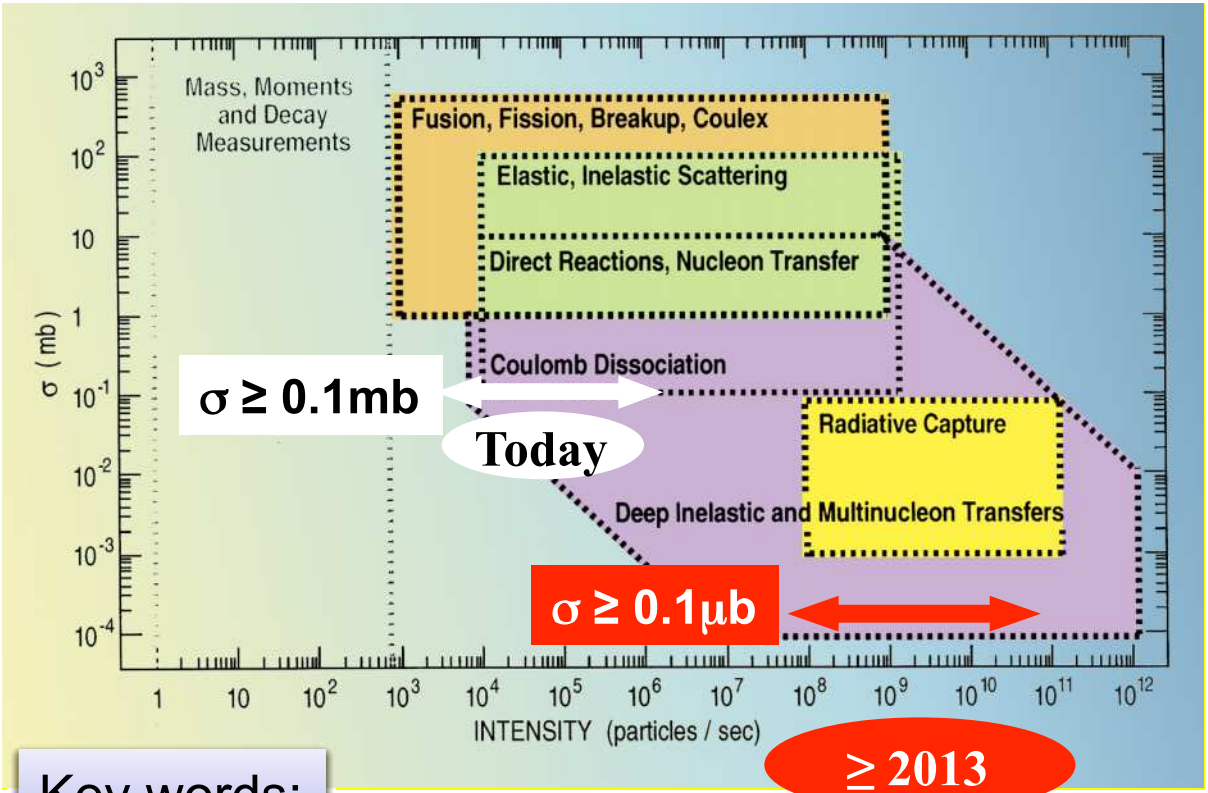
MoU

Detector cost: Min. 8M€ – Max. 30 M€ (2011-2016)

In the following:

1. *Introduction*
2. *GANIL and Physics Highlights*
3. *SPIRAL2 Facility*
   - *3.1 International Context*
   - *3.2 Beams and Detectors*
4. ***Physics Opportunities with high-intensity stable-ion and RI beams***
5. *Status of the Construction of SPIRAL2*
6. *Conclusions & Long(er) Range Plan*

Physics with Radioactive & Stable-ion High-intensity Beams at 1-20 MeV/nucl.



Physics:

- single-particle structure
- nuclear pairing
- structure of very-heavy nuclei
- nuclear clustering and nuclear molecules
- isospin in reaction mechanisms
- applications to astrophysics

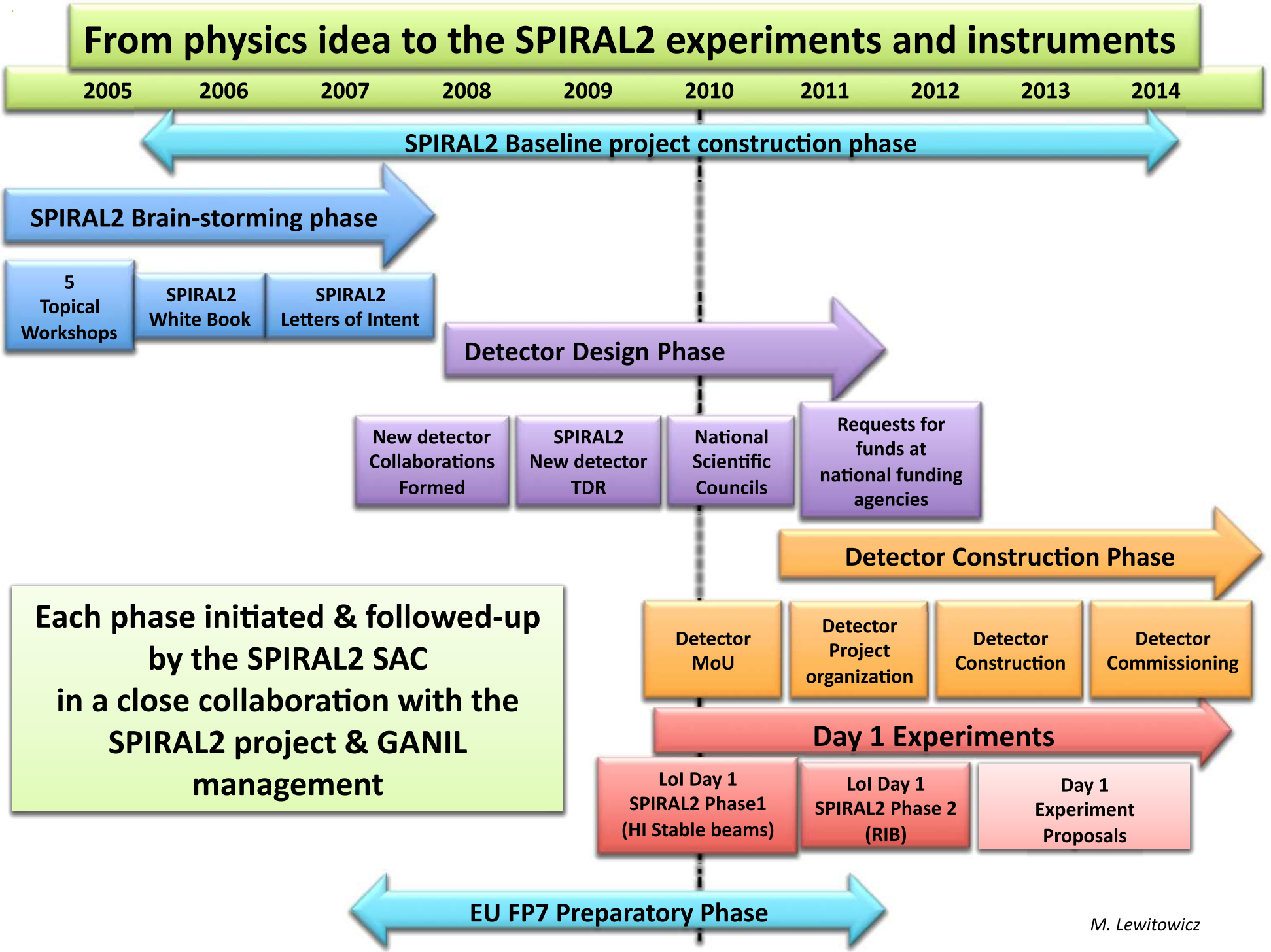
Reaction Types

- elastic & resonant el. (p,p) …
- inelastic (p,p'), (d,d')…
- transfer (d,p), (p,d), (p,t)…
- breakup
- fusion-evaporation
- deep-inelastic
- fission

+ "keV beam" physics !

Key words:

ISOL RIB beams:
- high intensity, optical quality & purity
Versatility:
- light & HI, high-intensity stable-ion & RIB
Multi-beam capabilities, months of beam-time
World-class arrays & detectors

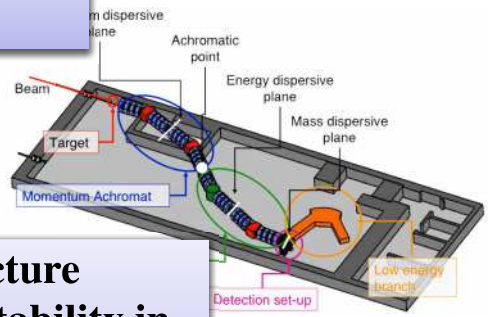

From physics idea to the SPIRAL2 experiments and instruments
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
SPIRAL2 Baseline project construction phase
SPIRAL2 Brain-storming phase
5 Topical Workshops
SPIRAL2 White Book
SPIRAL2 Letters of Intent
Detector Design Phase
New detector Collaborations Formed
SPIRAL2 New detector TDR
National Scientific Councils
Requests for funds at national funding agencies
Detector Construction Phase
Each phase initiated & followed-up by the SPIRAL2 SAC in a close collaboration with the SPIRAL2 project & GANIL management
Detector MoU
Detector Project organization
Detector Construction
Detector Commissioning
Day 1 Experiments
LoI Day 1 SPIRAL2 Phase1 (HI Stable beams)
LoI Day 1 SPIRAL2 Phase 2 (RIB)
Day 1 Experiment Proposals
EU FP7 Preparatory Phase
M. Lewitowicz

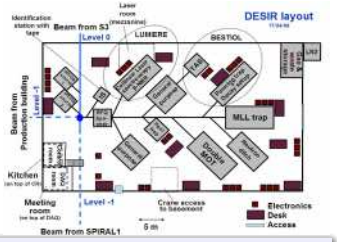
75 Letters of Intend (>1000 authors) for the Day 1 experiments at SPIRAL2

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

Heavy and Super Heavy Elements
3 LoIs

Atomic physics 1 LoI





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

p, 2p, α decay
3 LoIs

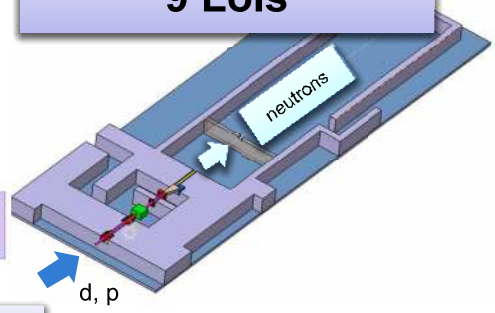
Shell structure very far from stability in n-rich nuclei
22 LoIs

N=Z
11 LoIs

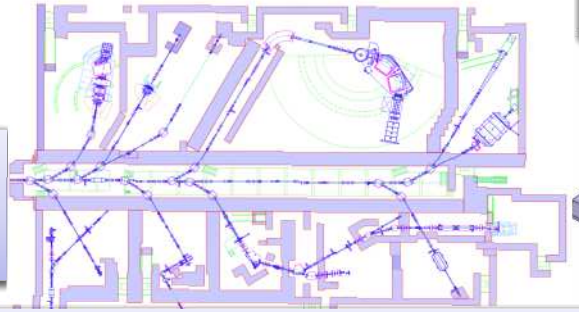
Astrophysics CNO, rp-process
10 LoIs

Astrophysics r-process path
2 LoIs

Neutrons for science
9 LoIs



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



Haloes & Structures in the Continuum
0 LoIs

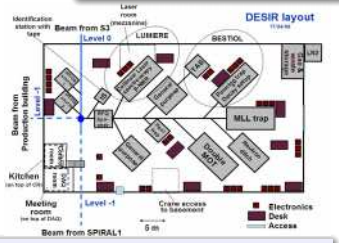
Fundamental Interactions – 2 LoIs

www.ganil-spiral2.eu

74 Letters of Intend for the Day 1 experiments at SPIRAL2

Spiral2

DESIR - ***21***



Equation of State, Role of Isospin in nuclear reaction
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Shell structure very far from stability in p-rich nuclei
13 LoIs

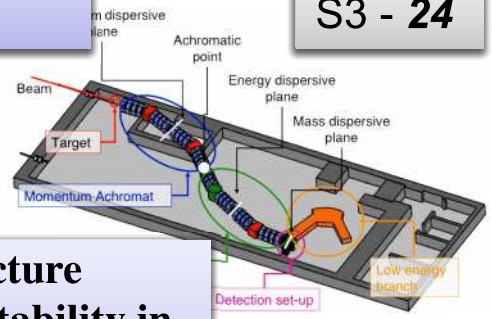
p, 2p, α decay
3 LoIs

N=Z
11 LoIs

Heavy and Super Heavy Elements
3 LoIs

Atomic physics 1 LoI

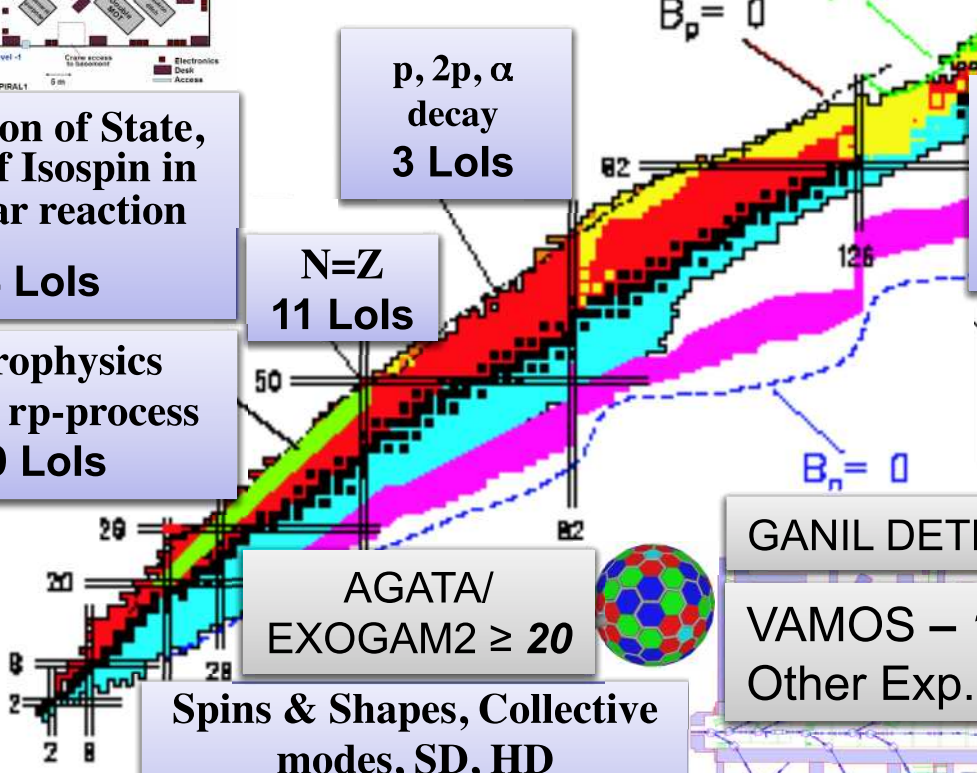
S3 - ***24***



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

Astrophysics r-process path
2 LoIs

PARIS ≥ ***10***
GASPARD - ***13***
FAZIA - ***2***
ACTAR - ***4***

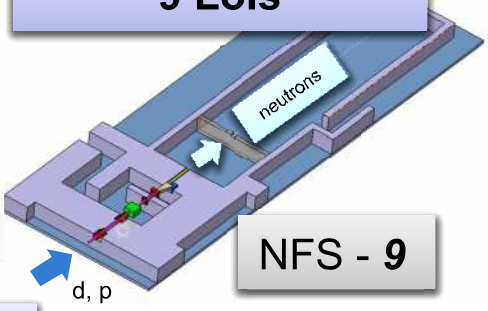


GANIL DETECTORS

AGATA/ EXOGAM2 ≥ ***20***

VAMOS – ***12***
Other Exp. Halls ≤ ***20***

Neutrons for science
9 LoIs



NFS - ***9***

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

Haloes & Structures in the Continuum
0 LoIs

Fundamental Interactions – 2 LoIs

Super Separator Spectrometer (S3)

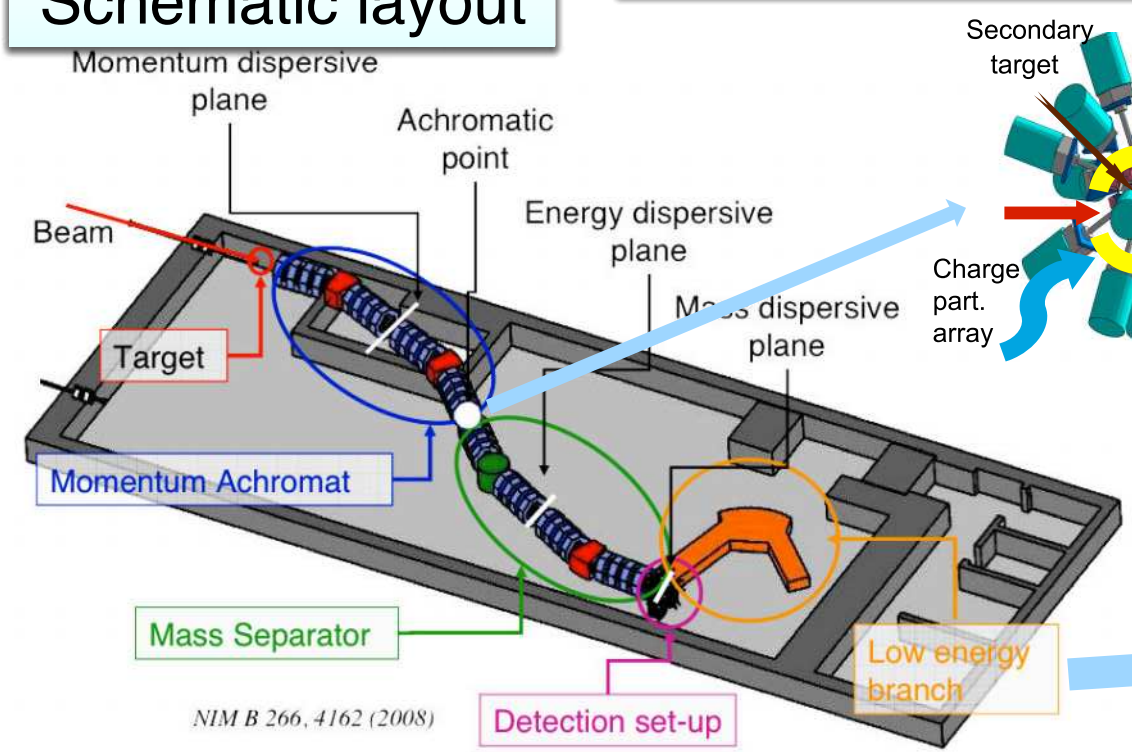
Collaboration

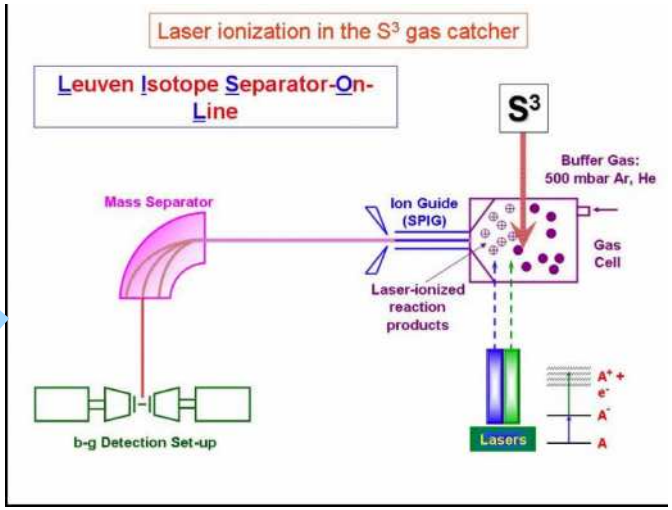
104 physicists, 30 institutions, 12 countries

Management Board

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

Schematic layout





- **Technically the project will be ready in 2011 to start the construction phase**
- **First experiment plan in 2013-2014**

S3 LoI Physics objectives

Proton Dripline & N=Z nuclei

LoI Day1 6, LoI Day1 8, LoI Day1 9
LoI Day1 11, LoI Day1 17

- Tests of Shell Model
- Single-Particle structure
- Development of Collectivity
- Shape coexistence

LoI Day1 3, LoI Day1 4, LoI Day1 18

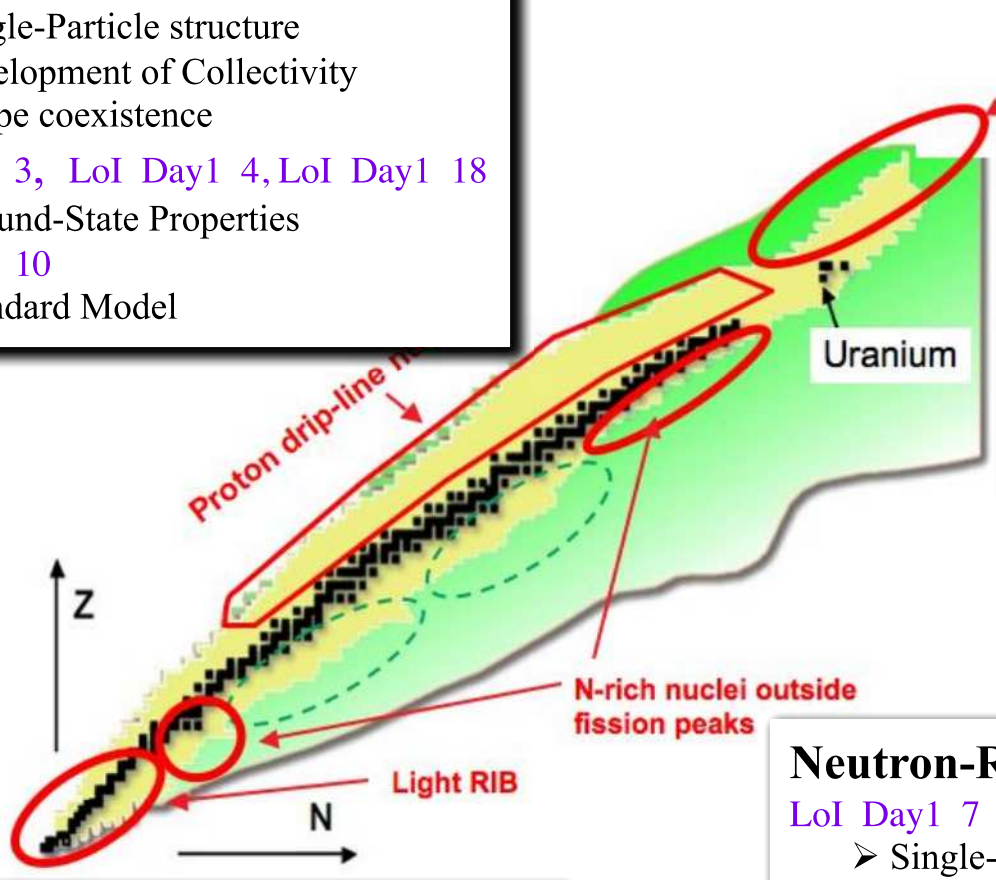
- Ground-State Properties

LoI Day1 10

- Standard Model

FISIC project

LoI Day1 1



Heavy and Superheavy Elements

LoI Day1 2

- Synthesis
- Spectroscopy and Structure

LoI Day1 5

- Ground-State Properties

Neutron-Rich Nuclei

LoI Day1 7

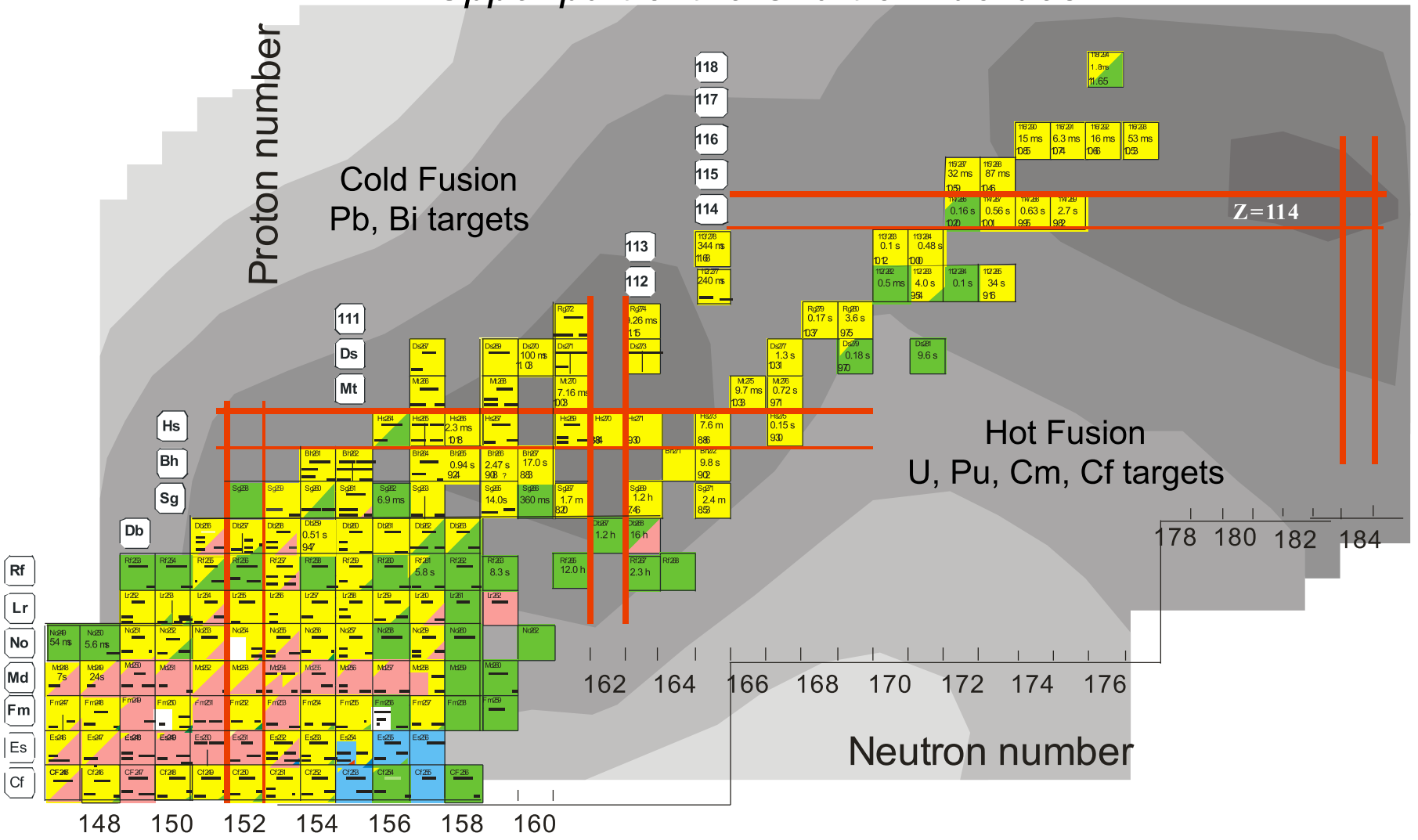
- Single-Particle structure
- Quenching of Shell Gaps

- 13 LoIs submitted
- LoIs signed by 170 physicists
- Requested beam time : 380 days !!!

Search for Heavy and Super-Heavy nuclei (New Elements)

GSI Darmstadt, FLNR Dubna, RIKEN, LBL Berkeley,…

Upper part of the Chart of Nuclides



The heaviest elements found in nature: Uranium (Z=92) and Plutonium (Z=94)

VHE-SHE

Production of SHE with Z=106-108-110-112

$^{40-48}Ca + {}^{238}U \rightarrow {}^{278-286}112^*$

$^{36-40}Ar + {}^{238}U \rightarrow {}^{274-278}Ds^*$

$^{32-36}S + {}^{238}U \rightarrow {}^{270-274}Hs^*$

$^{28-30}Si + {}^{238}U \rightarrow {}^{266-268}Sg^*$

Isotopic exploration

$^{40-48}Ca + {}^{238}U \rightarrow {}^{275-283}112 + 3,4n$

S³ (I=10pμA) ➔ 20evt/week/pb

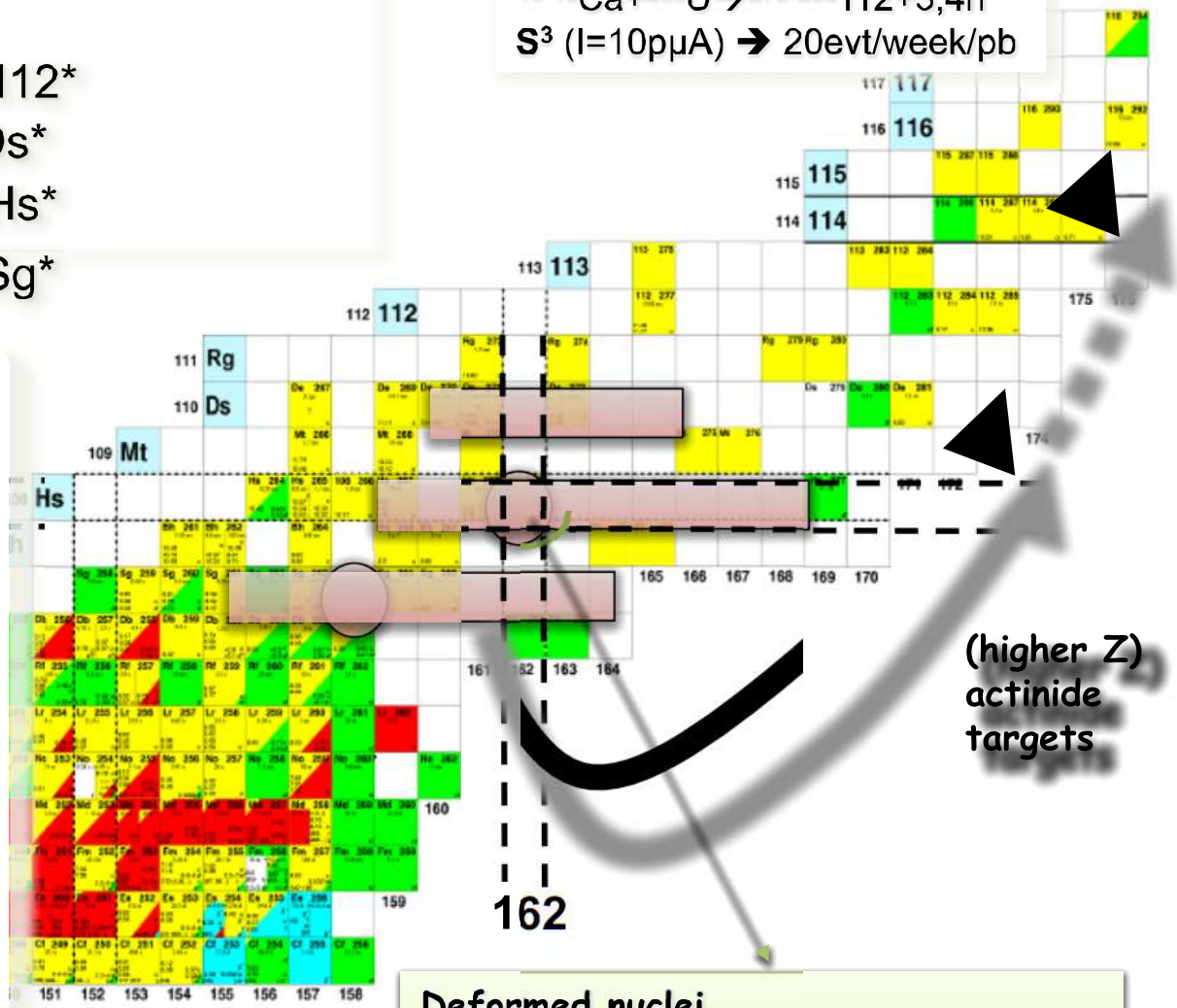
At the crossing road for

Reaction of synthesis :
- Link hot to cold fusion
- Isospin dependent reaction mechanism studies
- X-section systematics

Decay properties :
- K-isomers
- SF decay (T_{SF} half-lives)
- Alpha decays (Qα & half-lives)

Trans-actinide chemistry

GS properties
- Mass measurements …



Deformed nuclei

$^{40}Ar + {}^{238}U \rightarrow {}^{274}Ds$ (+4n) → $^{270}Hs + \alpha$

S³ (I=50pμA) ➔190evt/week@σ_{th}=2pb

Neutrons For Science (NFS)

Collaboration

50 physicists, 18 institutions, 8 countries

Spokespersons:

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

Stanislav Simakov, FZK, Germany

Physics topics

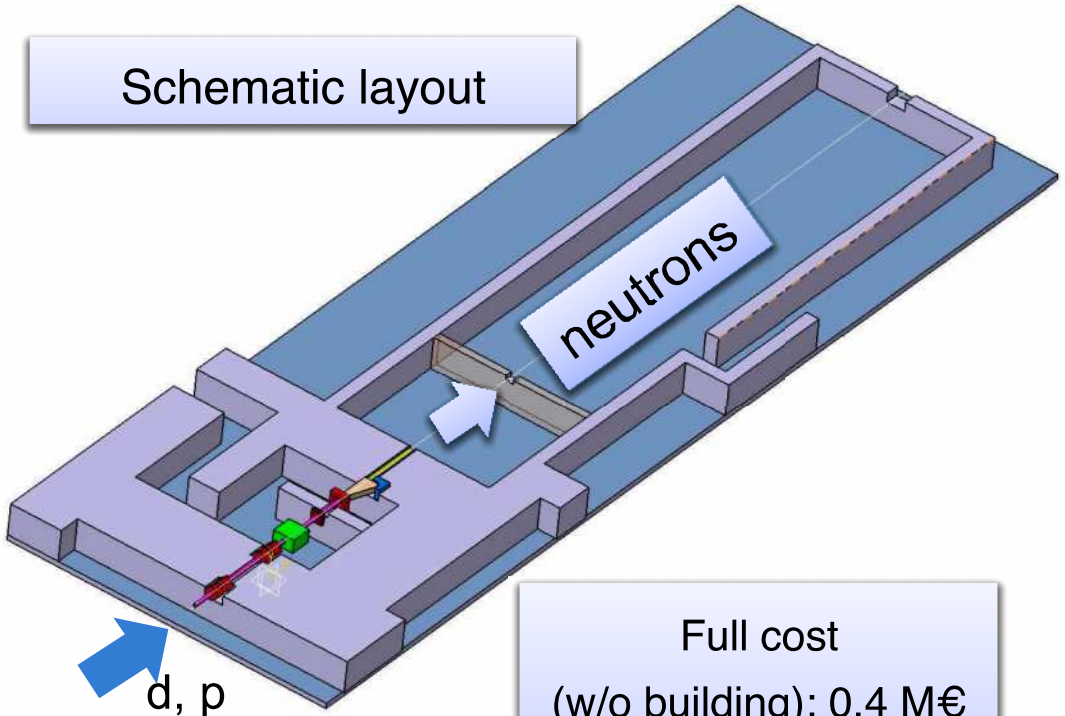
Fission
- **Minor actinides, main isotopes**
- **Cross section**
- **Neutron spectrum, multiplicity**
- **Prompt fission gammas**
- **Detailed A and Z distributions**
- **Delayed neutron yields and precursor characteristics**

Scattering
- **Secondary neutron energy and angle differential cross sections**
- **Inelastic scattering**

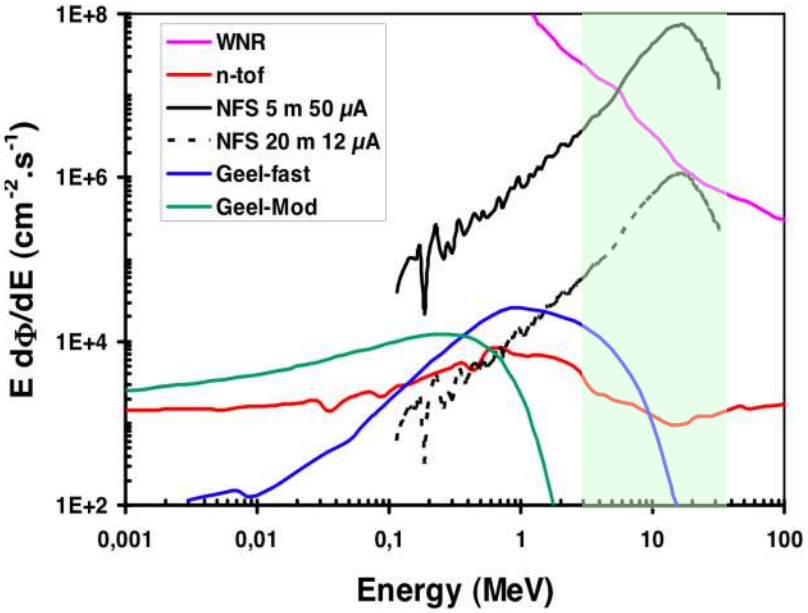
Fusion reactors

Astrophysics

Schematic layout



Full cost (w/o building): 0,4 M€



DESIR Facility

Collaboration

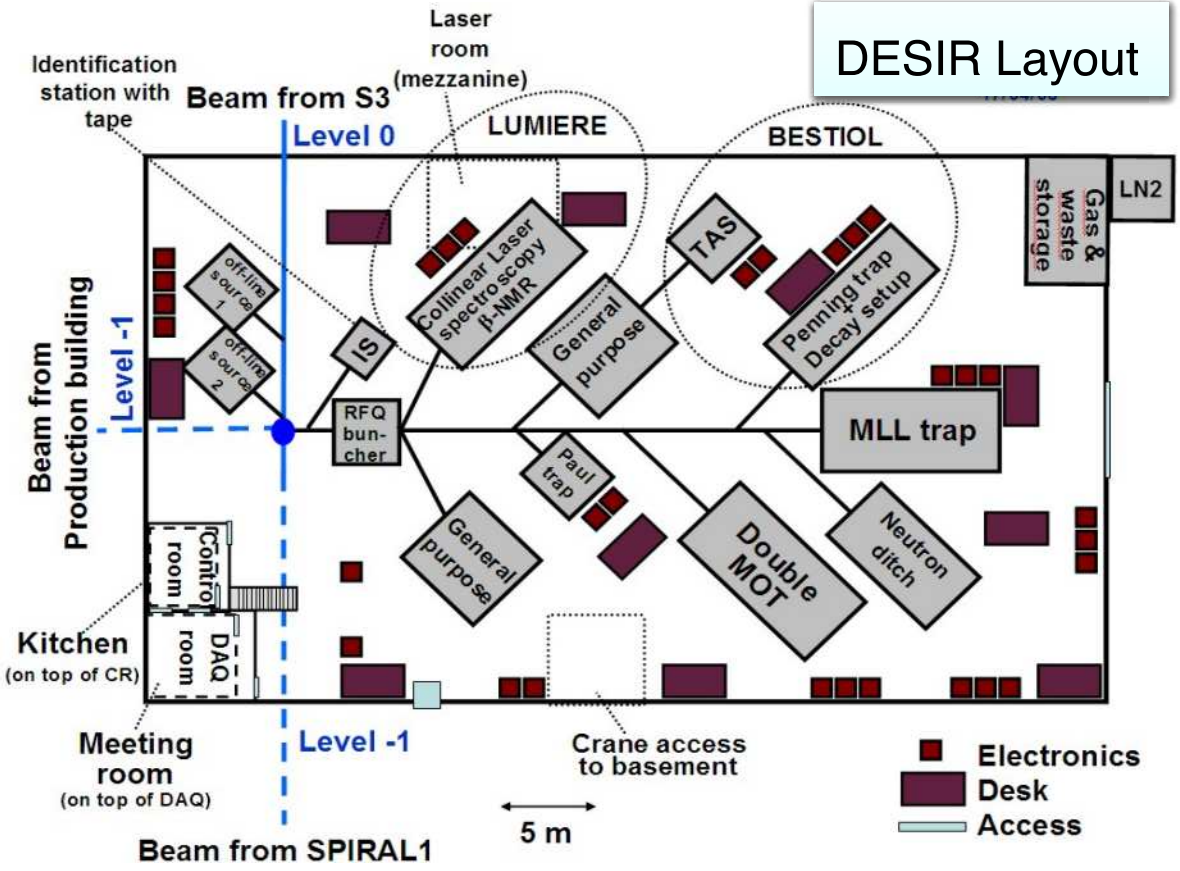
106 physicists, 34 institutions, 16 countries

Spokesperson:

Bertram Blank, CENBG, France

GANIL liaison: Jean-Charles Thomas

DESIR Layout



Topics:

- **nuclear fine structure**
- **charge radii & moments**
- **masses, ion-purification**
- **weak interaction studies**

Tools:

- **keV RI Beams**
- **decay spectroscopy**
- **laser spectroscopy**
- **ion / atom trapping**

DESIR time-line

- **design: 2007 - 2010**
- **construction: 2012-13**
- **commissioning: 2014-15**

PARIS Management board

A. Maj - project spokesman; IFJ Cracow

D.G. Jenkins, **J.P. Wieleczko**, J.A. Scarpaci - deputies

PARIS Steering *(Advisory)* Committee

F. Azaiez (F) -chairman, D. Balabanski (BG), W. Catford (UK), D. Chakrabarty (India), Z. Dombradi (H), S. Courtin (F), J. Gerl (D), D. Jenkins (UK) - deputy chairman, S. Leoni (I), A. Maj (PL), J.A. Scarpaci (F), Ch. Schmidt (F), J.P. Wieleczko (F)

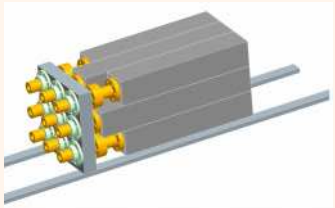
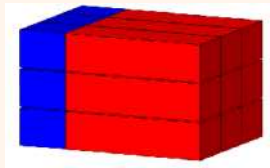
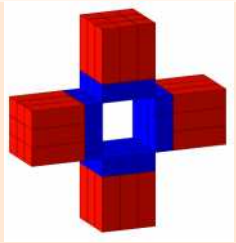
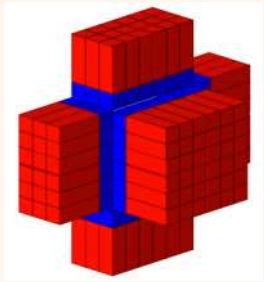
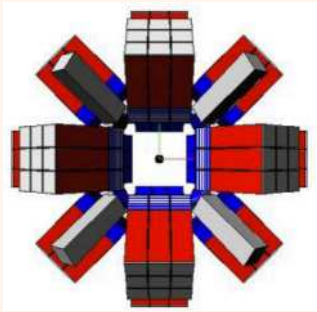
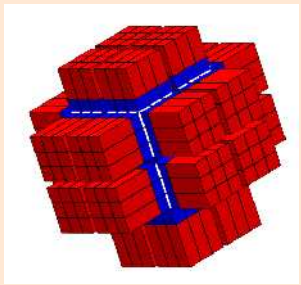
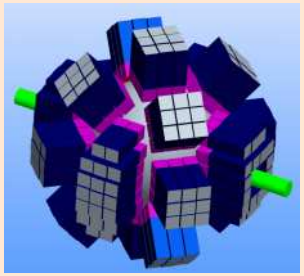
Active working groups

1. Simulations (O. Stezowski et al.)
2. PARIS mechanical design scenarios (S. Courtin, D. Jenkins et al.)
3. Physics cases and theory background (Ch. Schmitt et al.)
4. Detectors (O. Dorvaux et al.)
5. Financial issues (J.P. Wieleczko et al.)
6. PARIS in FP7 projects (A. Maj, F. Azaiez et al.)
7. Electronics (P. Bednarczyk et al.)
8. PARIS-GASPARD synergy (J.A. Scarpaci et al.)

J. Pouthas – PARIS liaison to SPIRAL2 project management

PARIS phases and costs*

Indicated costs are approximations only. Include cost of LaBr3+NaI phoswiches, PMs, HV, electronics and mechanics. It is assumed that phoswich solution will work.

Phase 1 **2011** **PARIS Prototype**	1 cluster: 9 phoswiches	 	**220 k€**	**Decided** Funds: SP2PP, ANR, Orsay, Strasbourg, Kraków, Mumbai Tests in-beam and with sources
Phase 2 **2013** **PARIS Demonstrator**	4 clusters: 36 phoswiches		**800 k€**	**Only if Phase1 validated** Funds: MoU Ph1Day1 exp@S3
Phase 3 **2015** **PARIS 2π**	12 clusters: 108 phoswiches	 	**2.2 M€**	**Only if Phase2 validated** Funds: MoU, PARIS consortium Ph2Day1 exp. with AGATA and GASPARD Other exp.
Phase 4 **≈2017** **PARIS 4π**	24 clusters: 216 phoswiches	 	**About 4 M€**	**Only if Phase3 validated** Funds: PARIS consortium Regular experiments in various labs

*) To be approved by PARIS MB in Jan.2011

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A large National & International Collaboration

French Partners

CEN de Bordeaux-Gradignan

Centre de Spectro. Nucléaire et Spectro. de Masse Orsay

Institut de Physique Nucléaire Orsay

Institut de Physique Nucléaire Lyon

Institut Pluridisciplinaire Hubert Curien Strasbourg

Laboratoire Accélérateur Linéaire Orsay

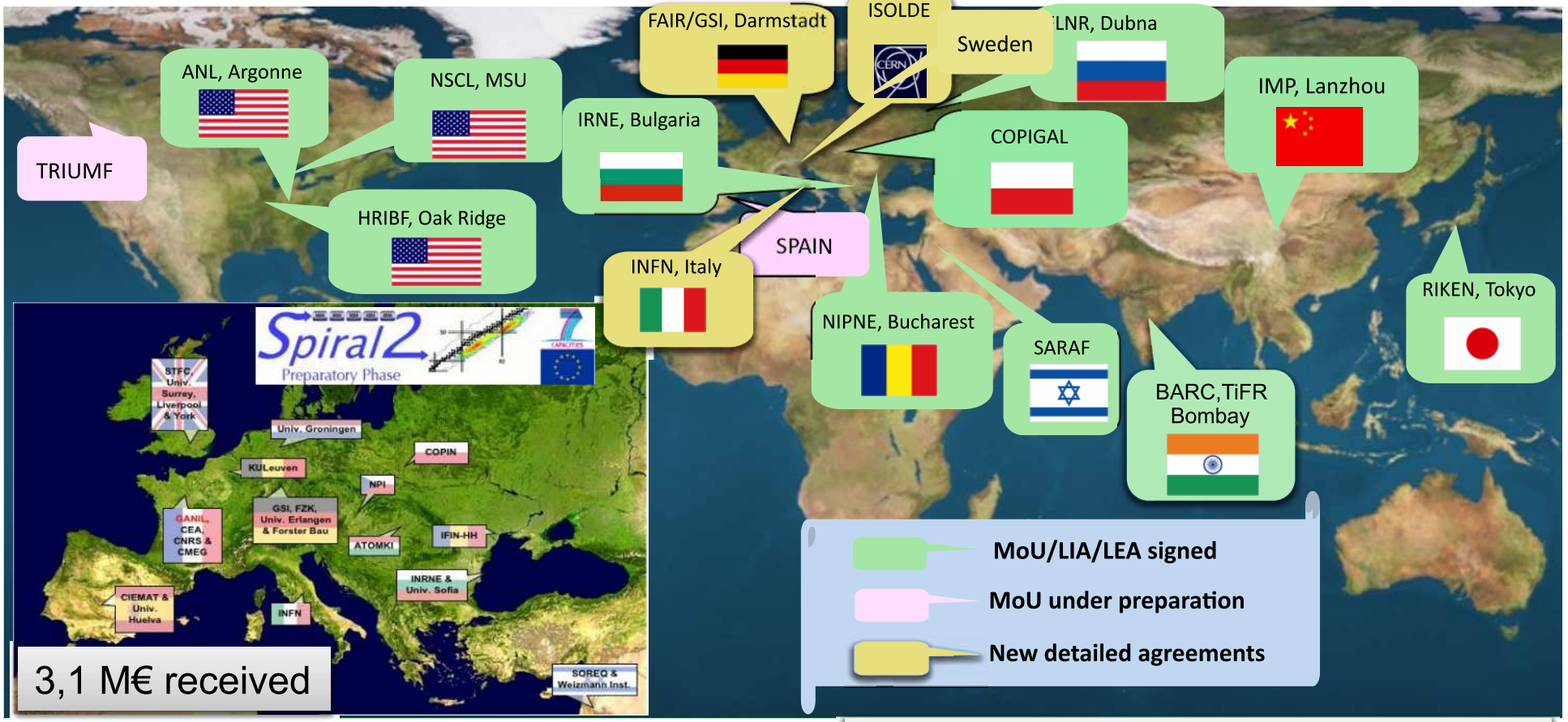
Laboratoire de Physique Corpusculaire de Caen

Laboratoire de Physique Nucléaire et de Htes Energies Paris

Laboratoire de Physique Subatomatomique et de Cosmologie Grenoble

DSM		Irfu/SPhN
		Irfu/SACM
DSM		Irfu/SIS
DSM		Irfu/SENAC
DSM		Irfu/SEDI
DSM – Saclay		Expertise
DAM	DPTA	DASE et DP2I
DEN		Expertise
DPSN		Expertise

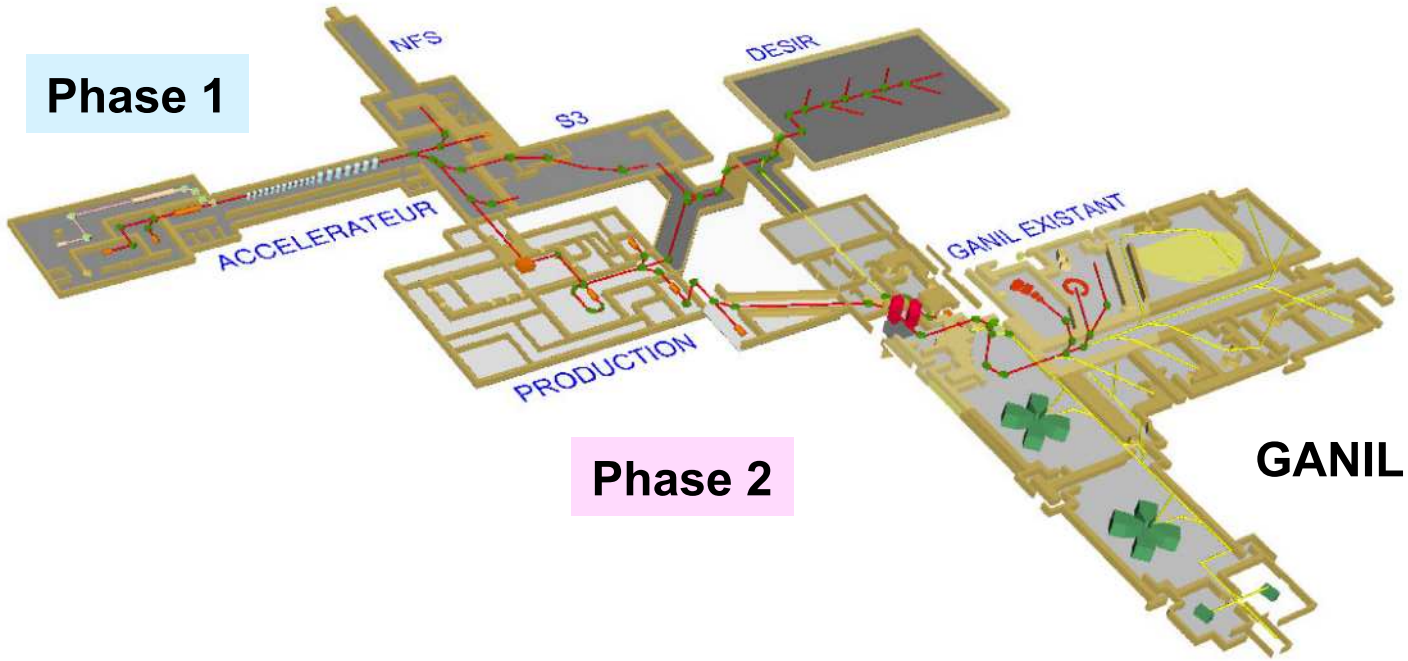
International Collaborations

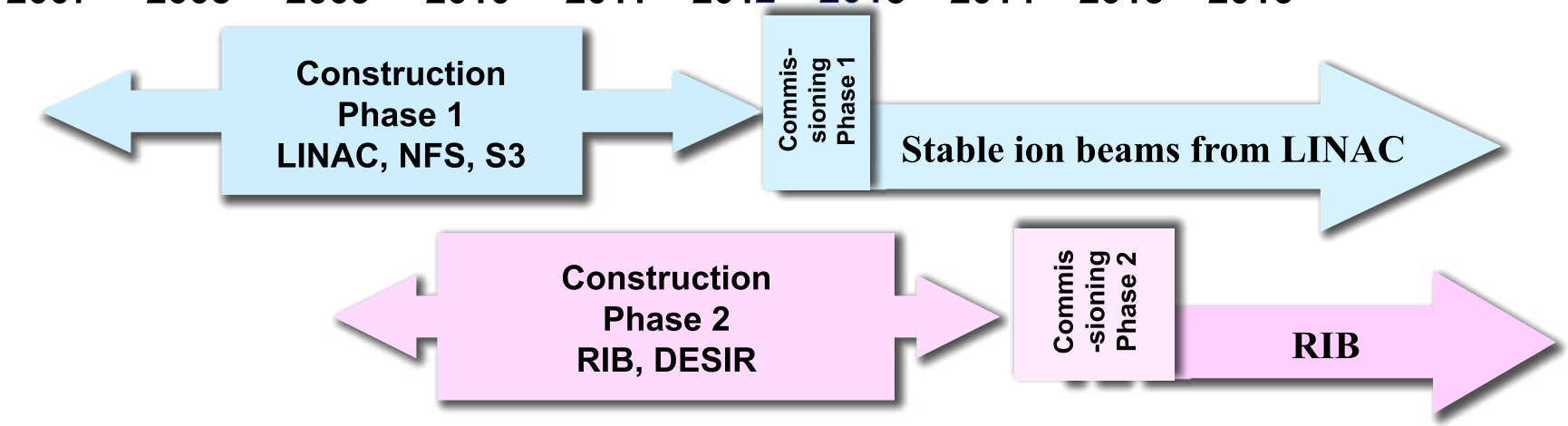


16 signed (LEA*, LIA**, MoU***) agreements
3 agreements under preparation:
- MoU with GSI (FAIR)
- MoU with Bilbao (RIB production module)
- MoU with Lanzhou (Dipoles for S3)

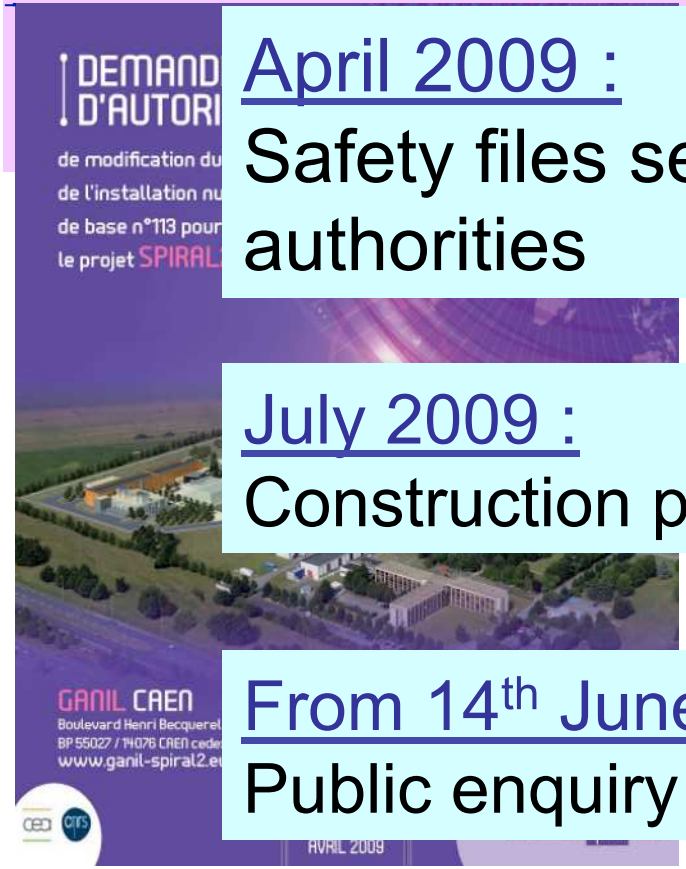
21-22/09/10 LIA Workshop with India
8-9/11/10 Workshop with Dubna
15-19/11/10 LEA Workshop with SPES
13/12/10 MoU with Sweden
5-8/01/11 LIA Symposium RIKEN

SPIRAL 2 timeline





Safety Aspects Construction



April 2009 :
Safety files sent to authorities

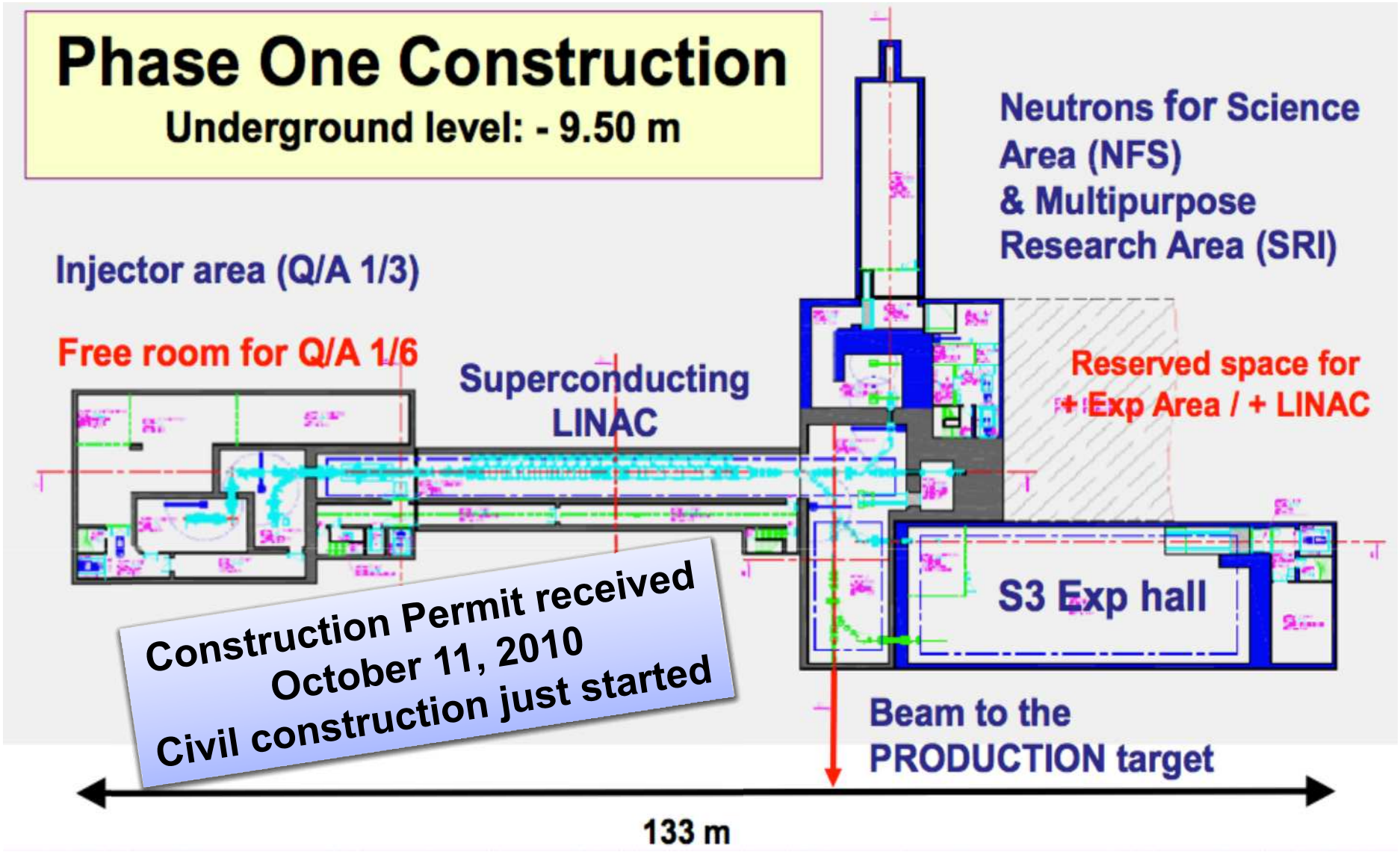
July 2009 :
Construction permit Phase 1 requested

From 14th June to 15th July 2010
Public enquiry

11th October 2010
Permit of construction delivered

Beginning of 2011
Site preparation – Ground breaking

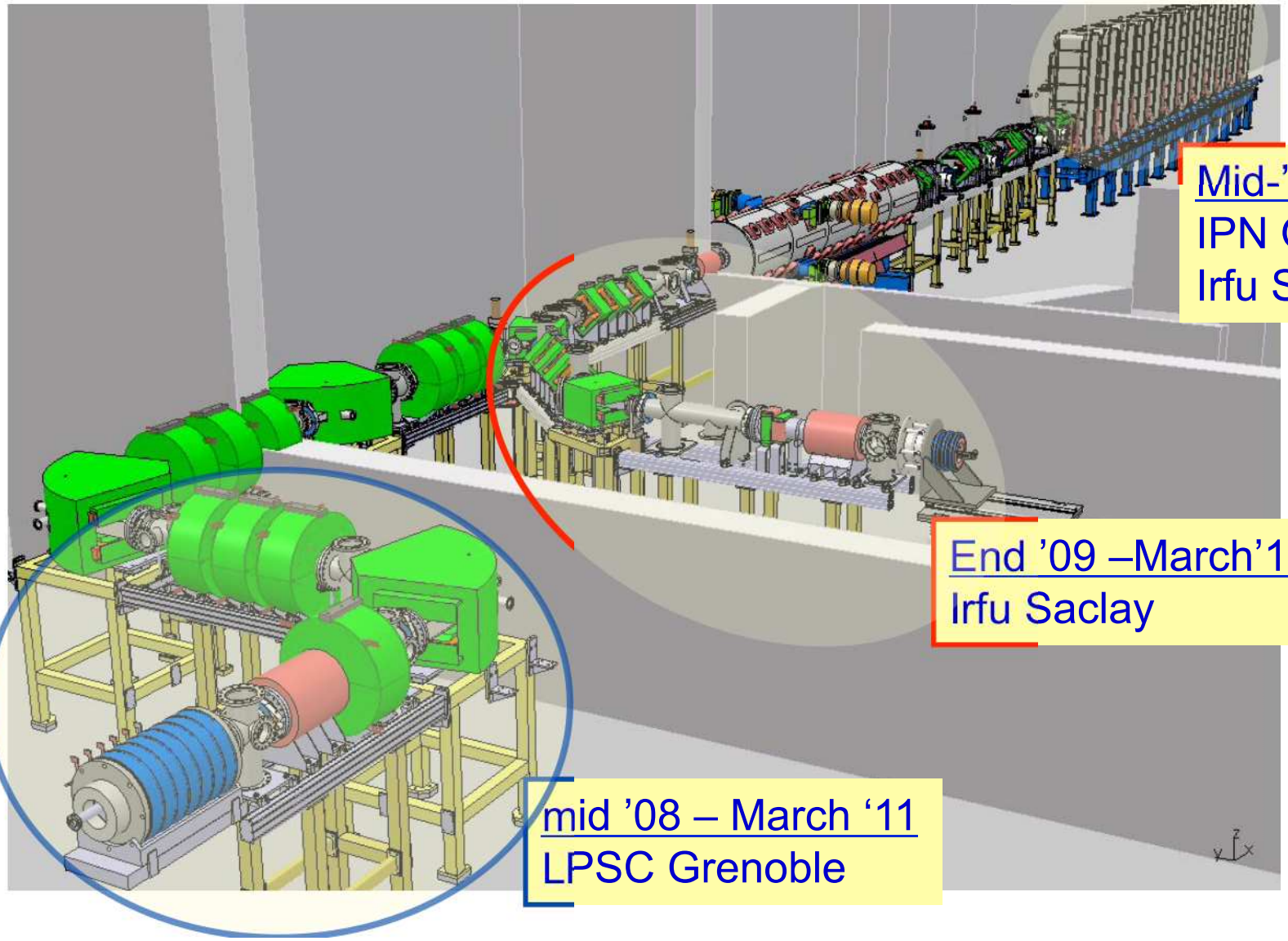
Layout of SPIRAL2 Phase 1



The first days of the civil construction of Phase 1

Dec. 2010

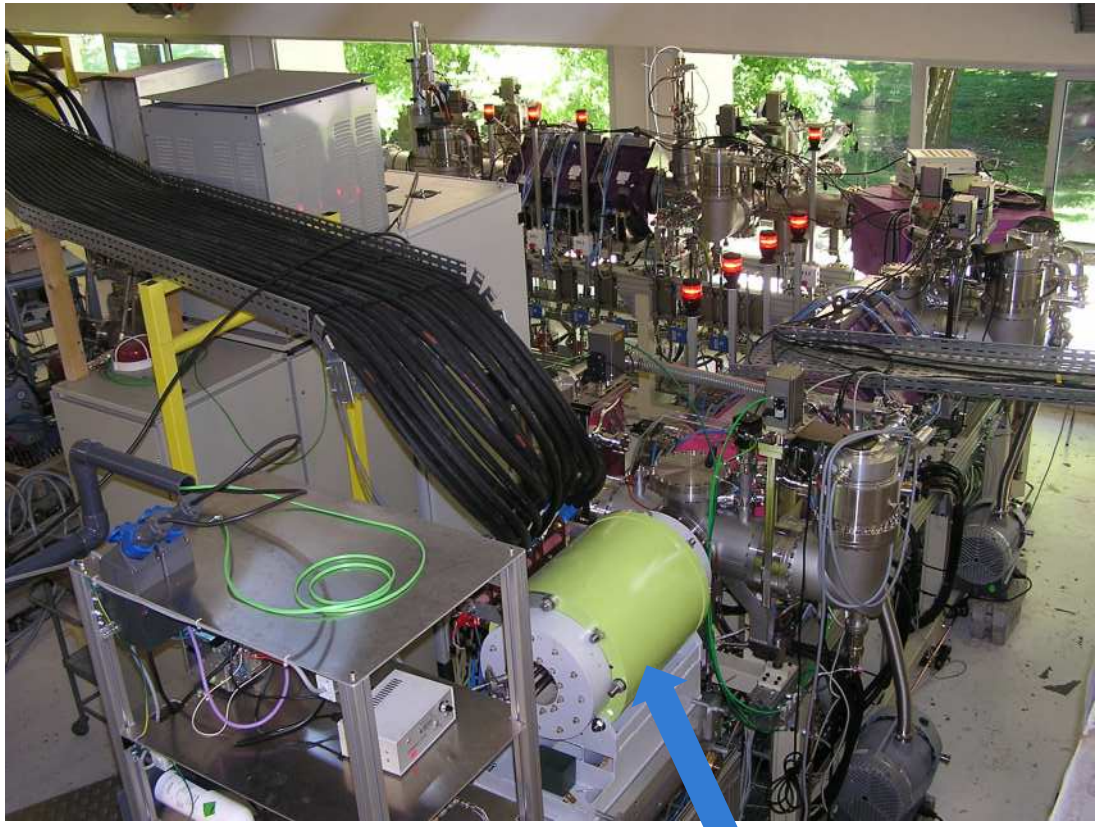
Accelerator



Heavy-ion injector of LINAC

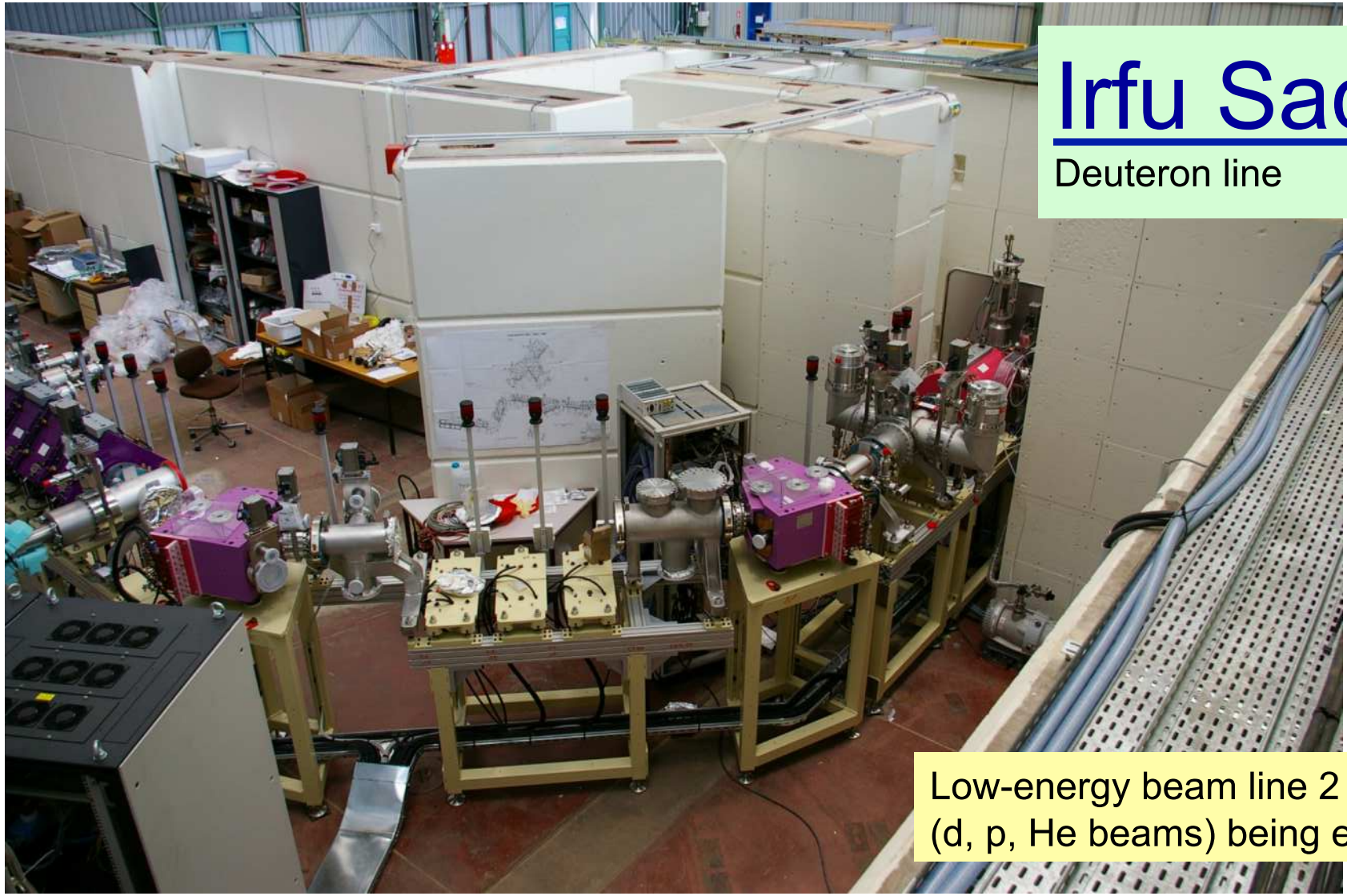
LPSC, IRFU
GANIL, IPNL

Tests in Grenoble



- **$^{18}O^{6+}$ and $^{36}Ar^{12+}$ beams reached Day 1 intensity (≥10pμA) at Phoenix V2 at LPSC Grenoble**
- **Tests of metallic beams (Ca, S, Si, Ni) started**
- **Tests of the new generation SC ECR A-Phoenix source in the coming months**

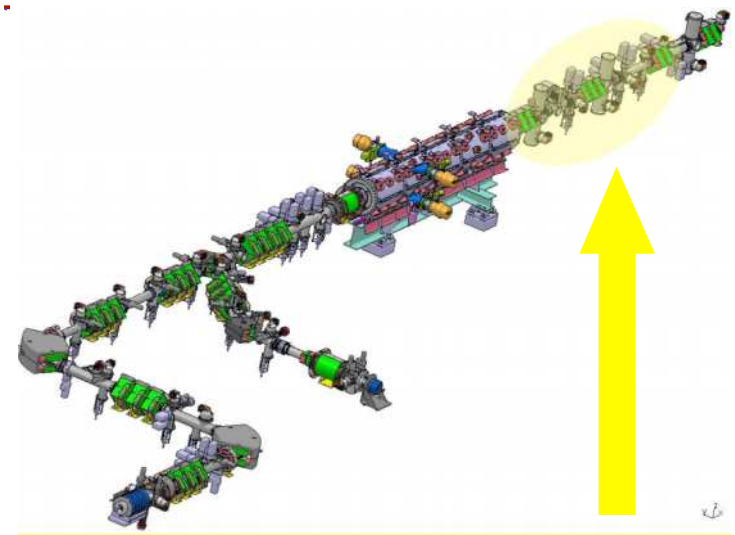
Accelerator



Irfu Saclay

Deuteron line

Low-energy beam line 2
(d, p, He beams) being equipped



Accelerator

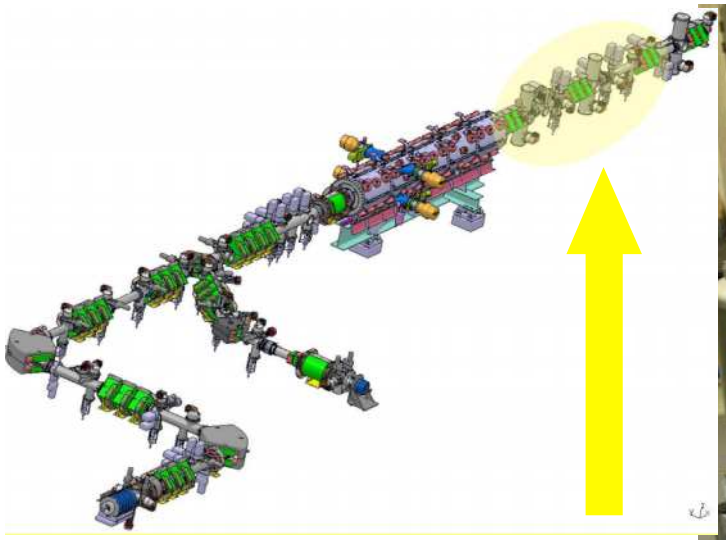
Ganil

Linac

Magnetic measurements

Series manufacturing by Tesla (UK)

Accelerator



IPN Orsay

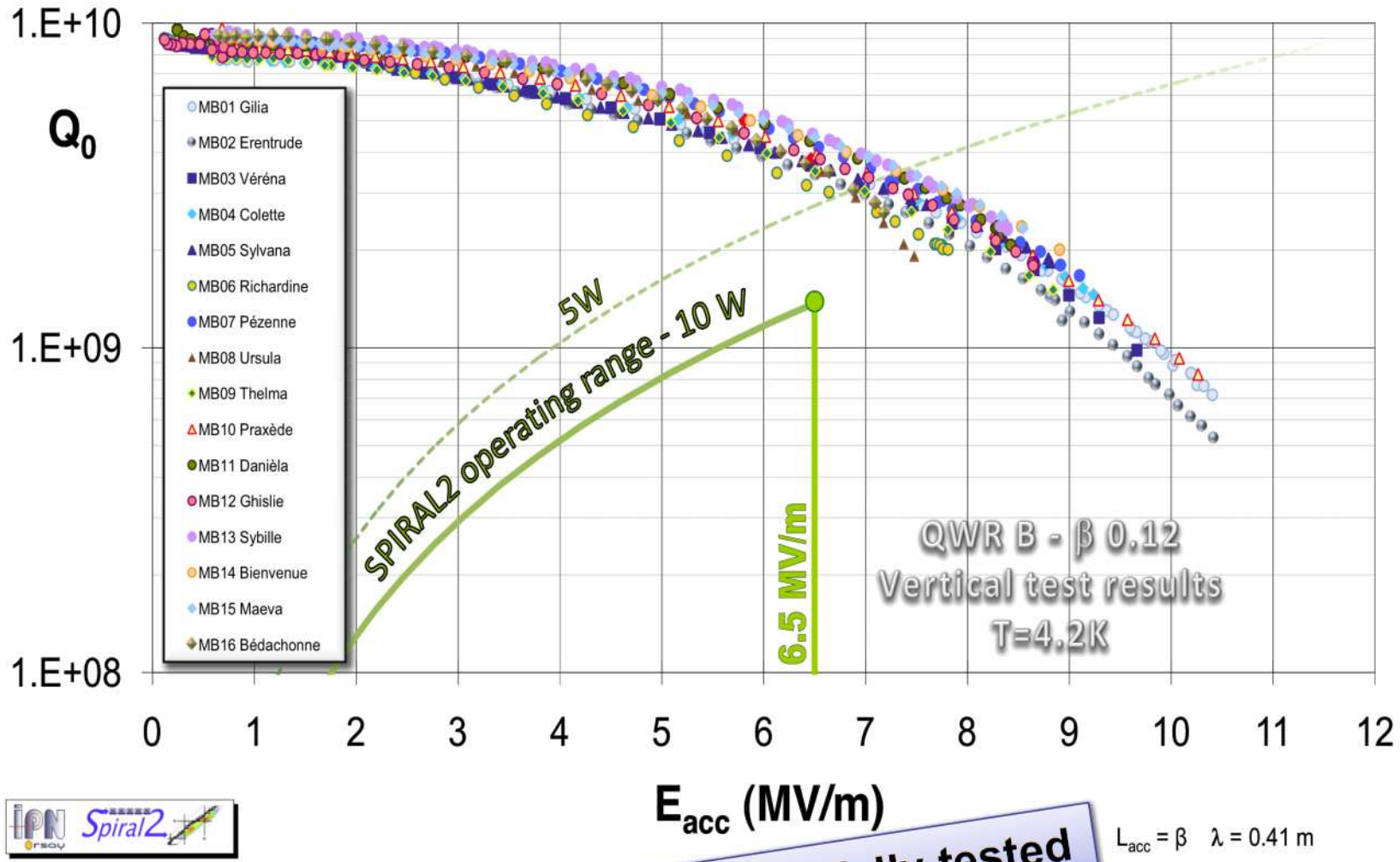
SC Cavities Type B

Status:

All cavities delivered and tested:

1st Cryomodule delivered in December

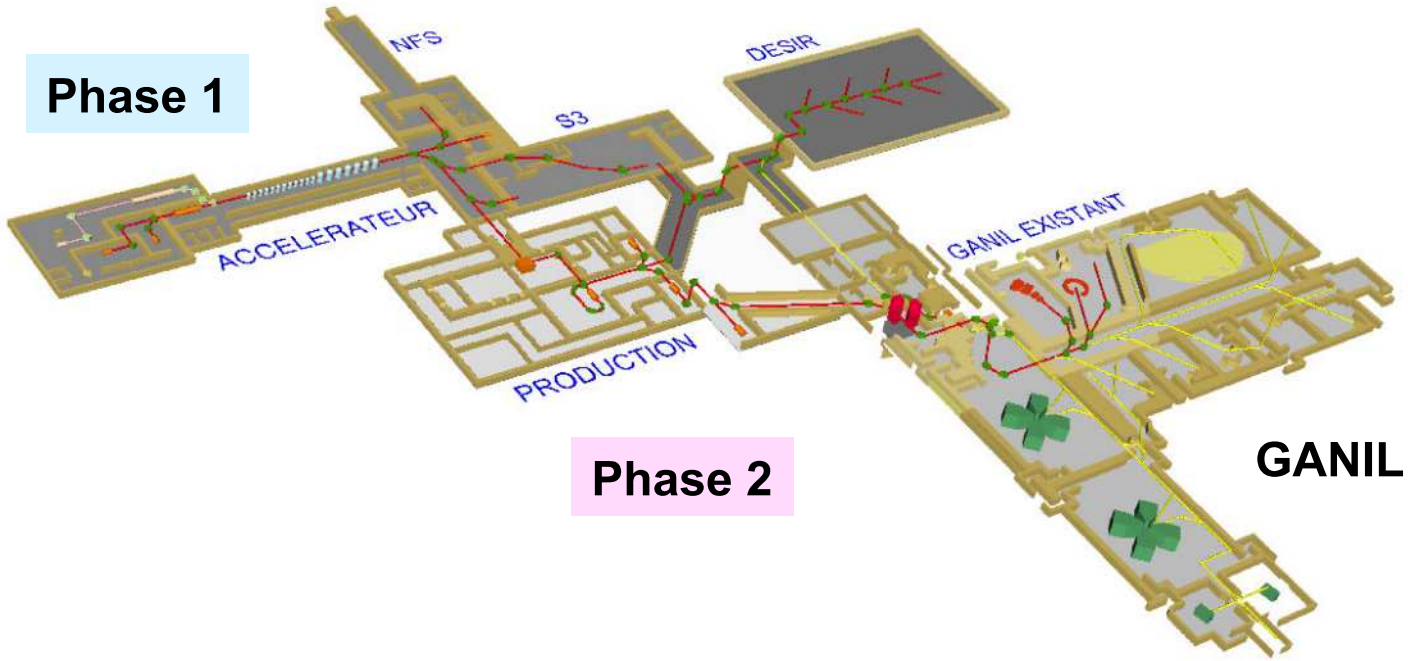
Tests of the SC cavities of type B at IPN Orsay

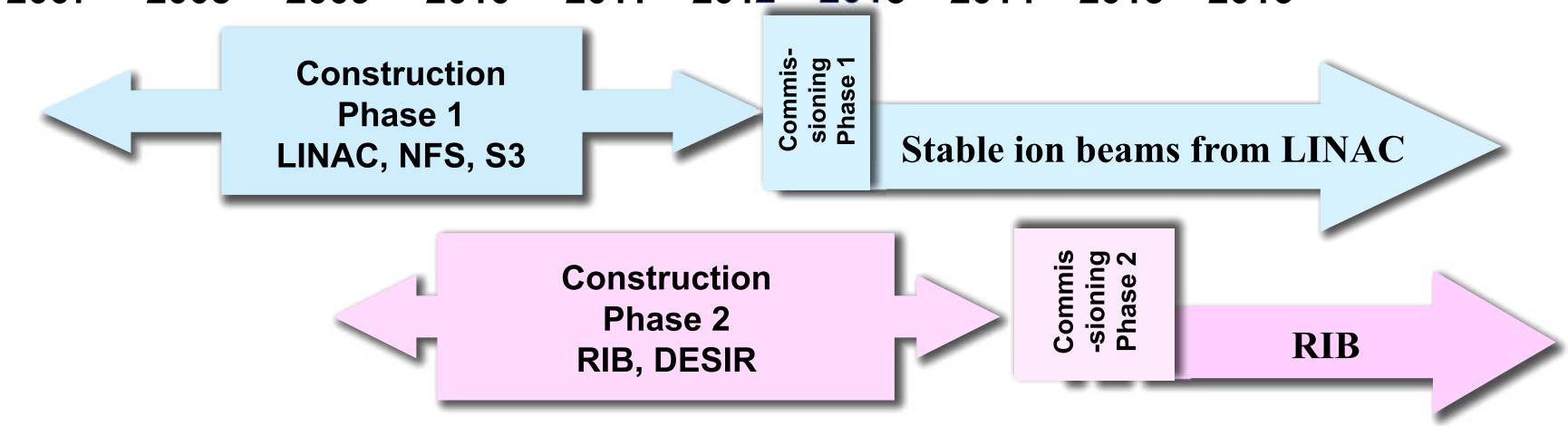


$L_{acc} = \beta \quad \lambda = 0.41$ m

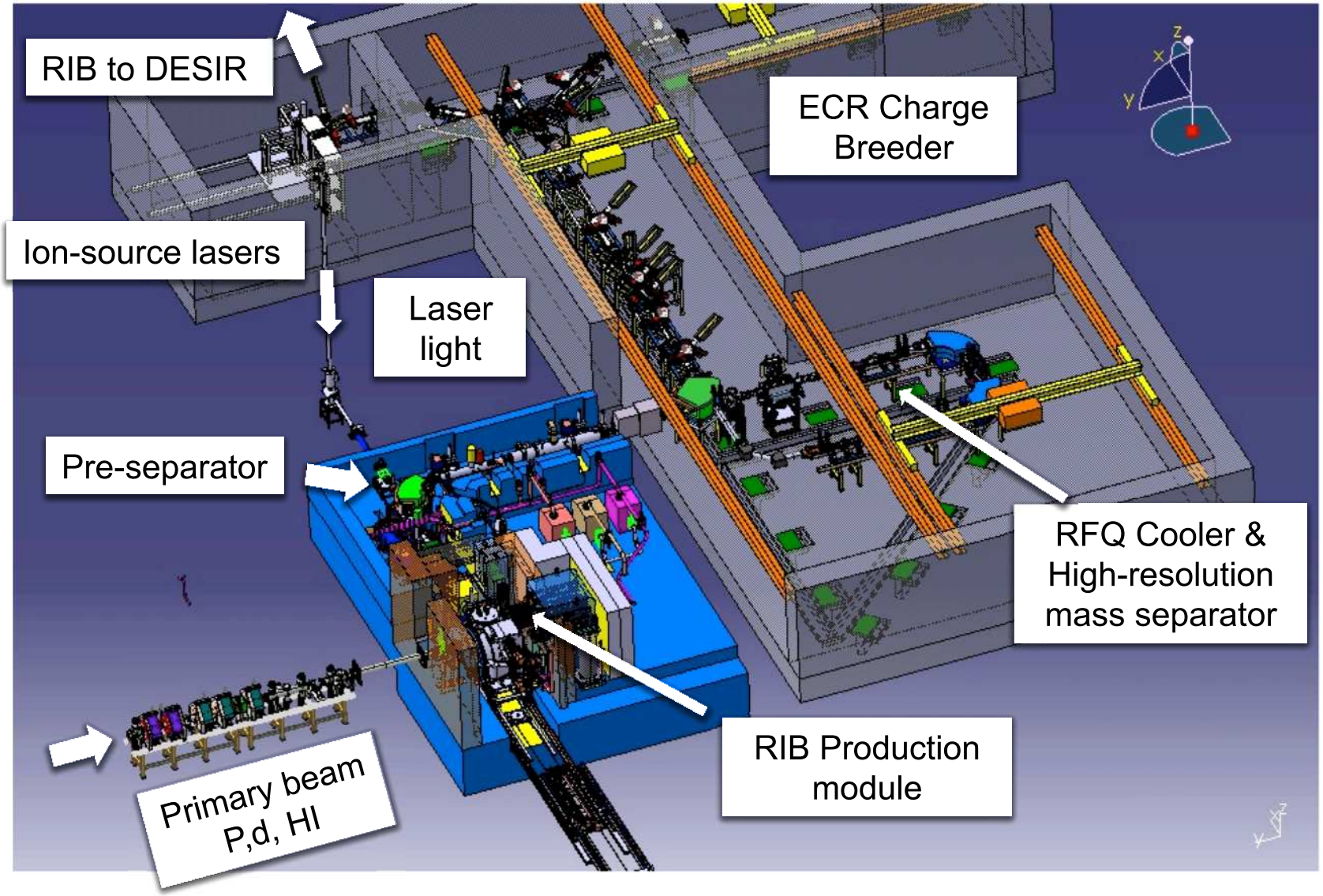
All cavities successfully tested

SPIRAL 2 timeline

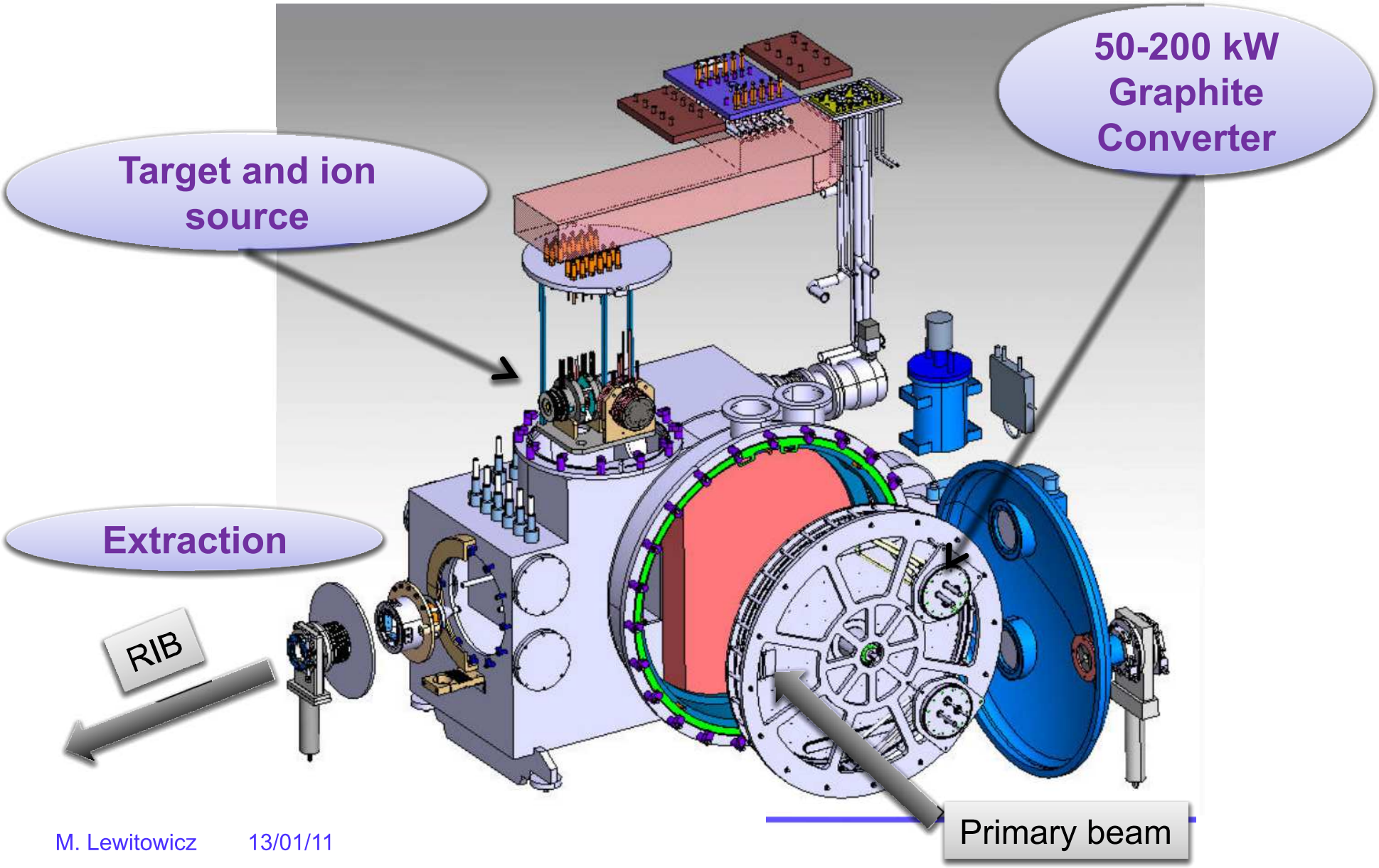




Detailed design of the RIB building



RIB production module



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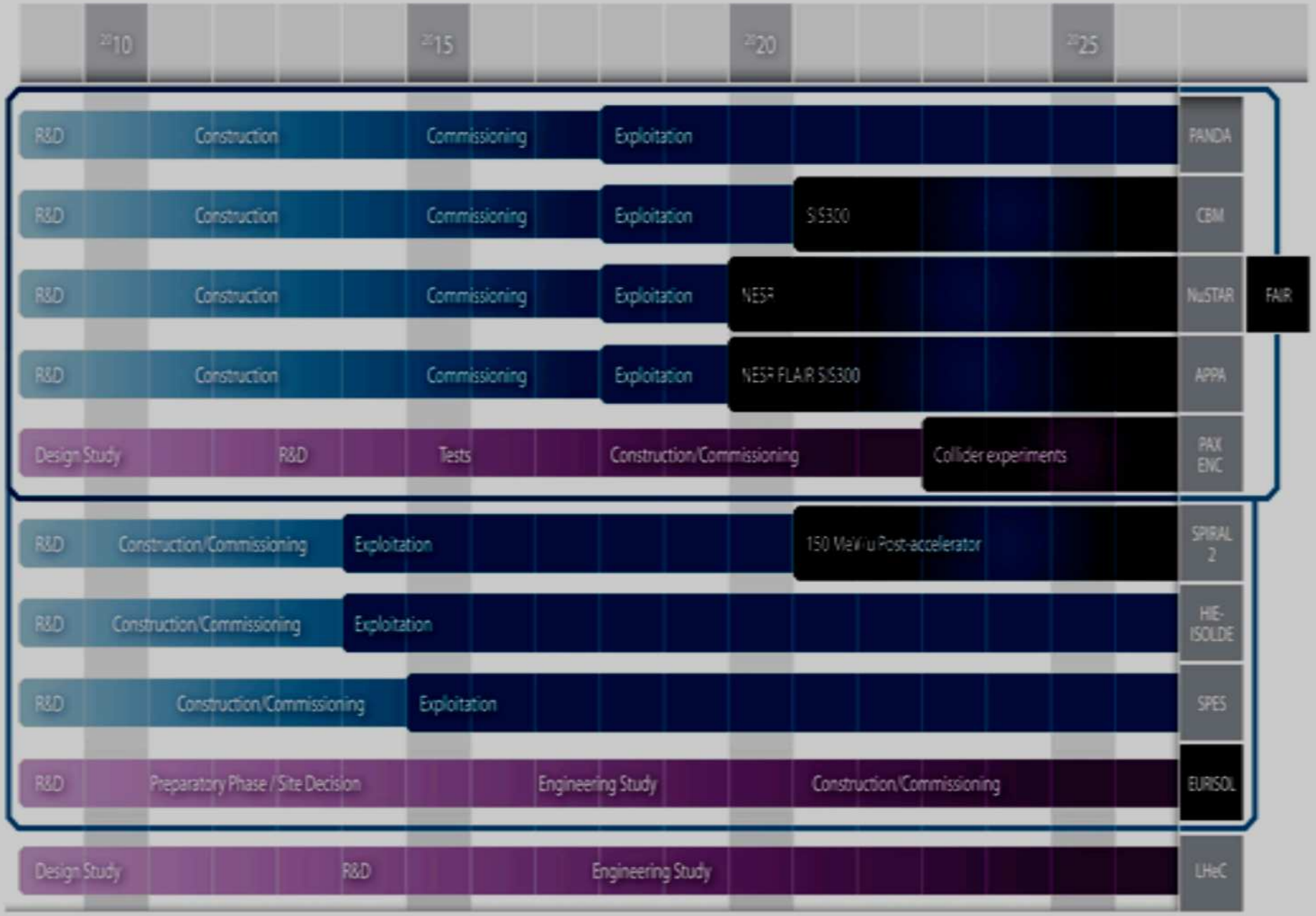
Conclusions (1/2)

- SPIRAL2 among the top priorities for the EU nuclear physics (NuPECC roadmap 2010)
- The civil construction of the SPIRAL2 Phase 1 started!
- Detailed design of the buildings SPIRAL2 Phase 2 to be ready in 2011.
- New detectors for SPIRAL2: R&D work and signatures of MoU entering in its final phase (to be accomplished by October 2011 as the EU SPIRAL2 PP deliverables)

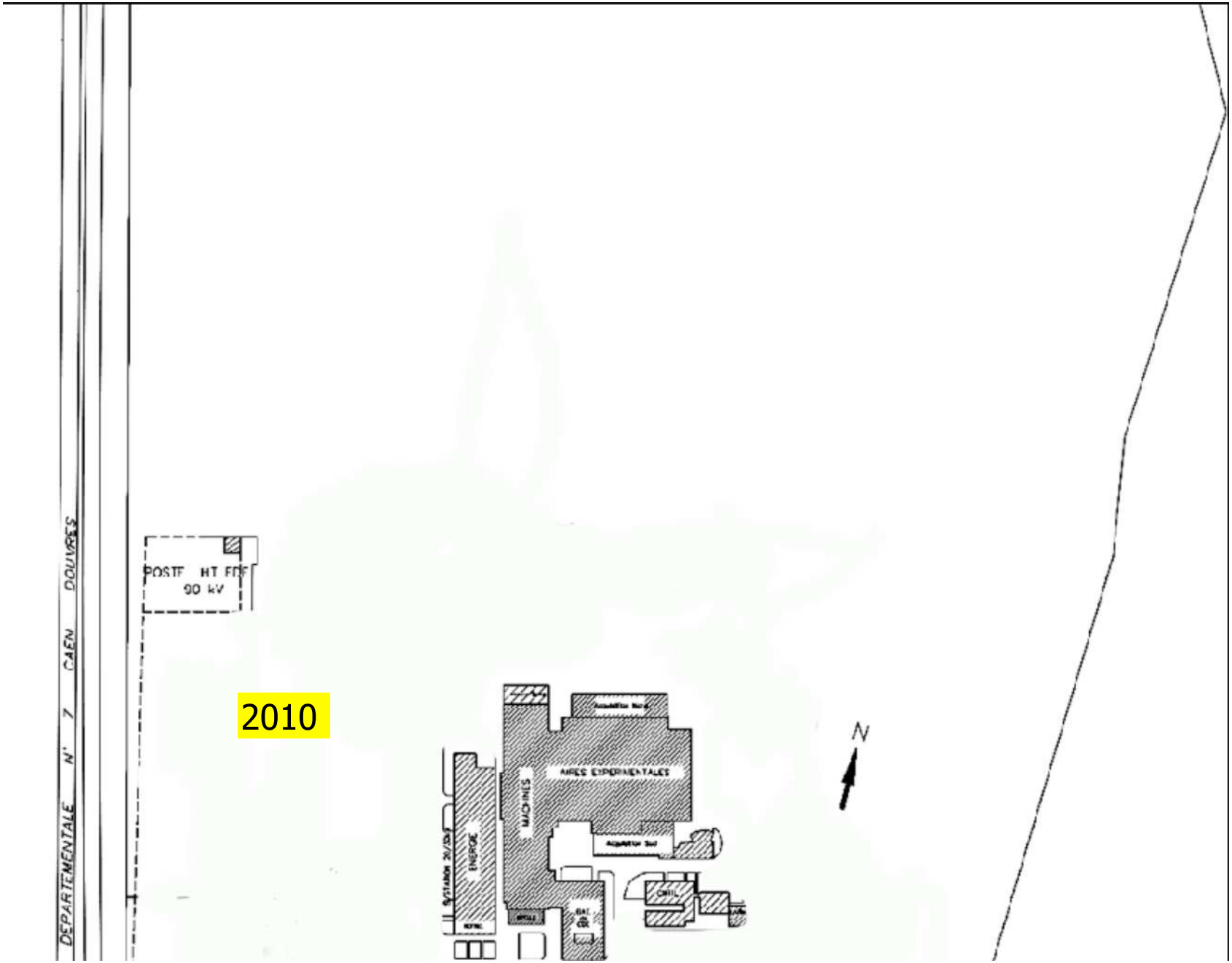
Conclusions (2/2)

- **The first years of physics at SPIRAL2 defined in:**
  - **22 Letters of Intent for Day 1 experiments with high-intensity stable-ion beams with SPIRAL2 Phase 1 (NFS and S3 facilities)** regularly updated & evaluated
  - **53 LoIs for Day One experiments at SPIRAL2 with RIB submitted recently (December 2010*)***
- ***Strong participation of Polish scientists in the SPIRAL2 Project***
  - ***COPIGAL Collaboration (F->PL 100k€),***
  - ***EU SPIRAL2 Preparatory Phase contract (EU->PL 250k€)***
  - FUSTIPEN (Theory US-France collaboration) started on 01/10/2010, inauguration & workshop January 18-19, 2011: M. Ploszajczak and W. Nazarewicz among the leaders
- SPIRAL2 Week 2011 Caen, Memorial 24-27/01/2011 (400 participants in 2010)

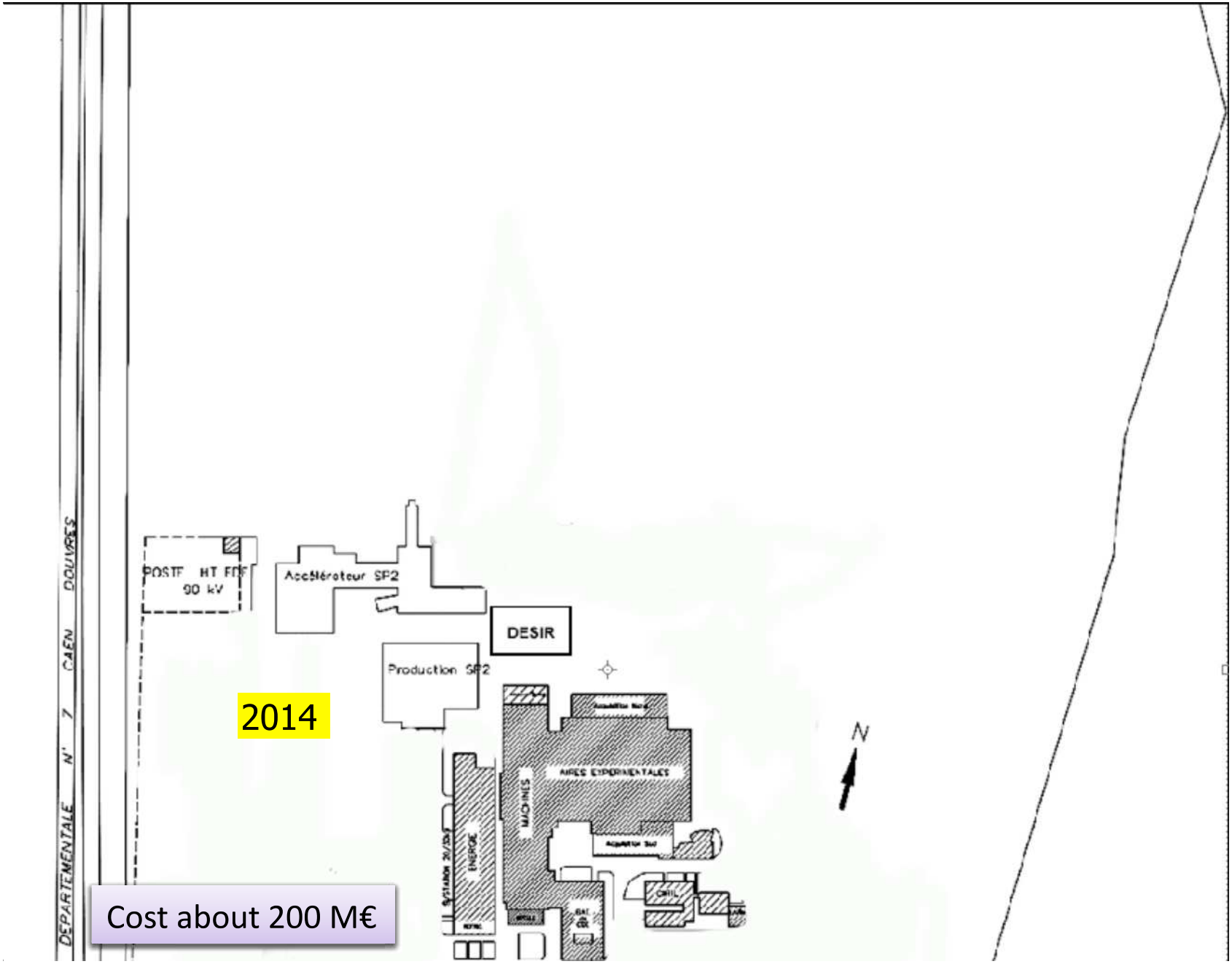
ROADMAP FOR NEW LARGE SCALE FACILITES



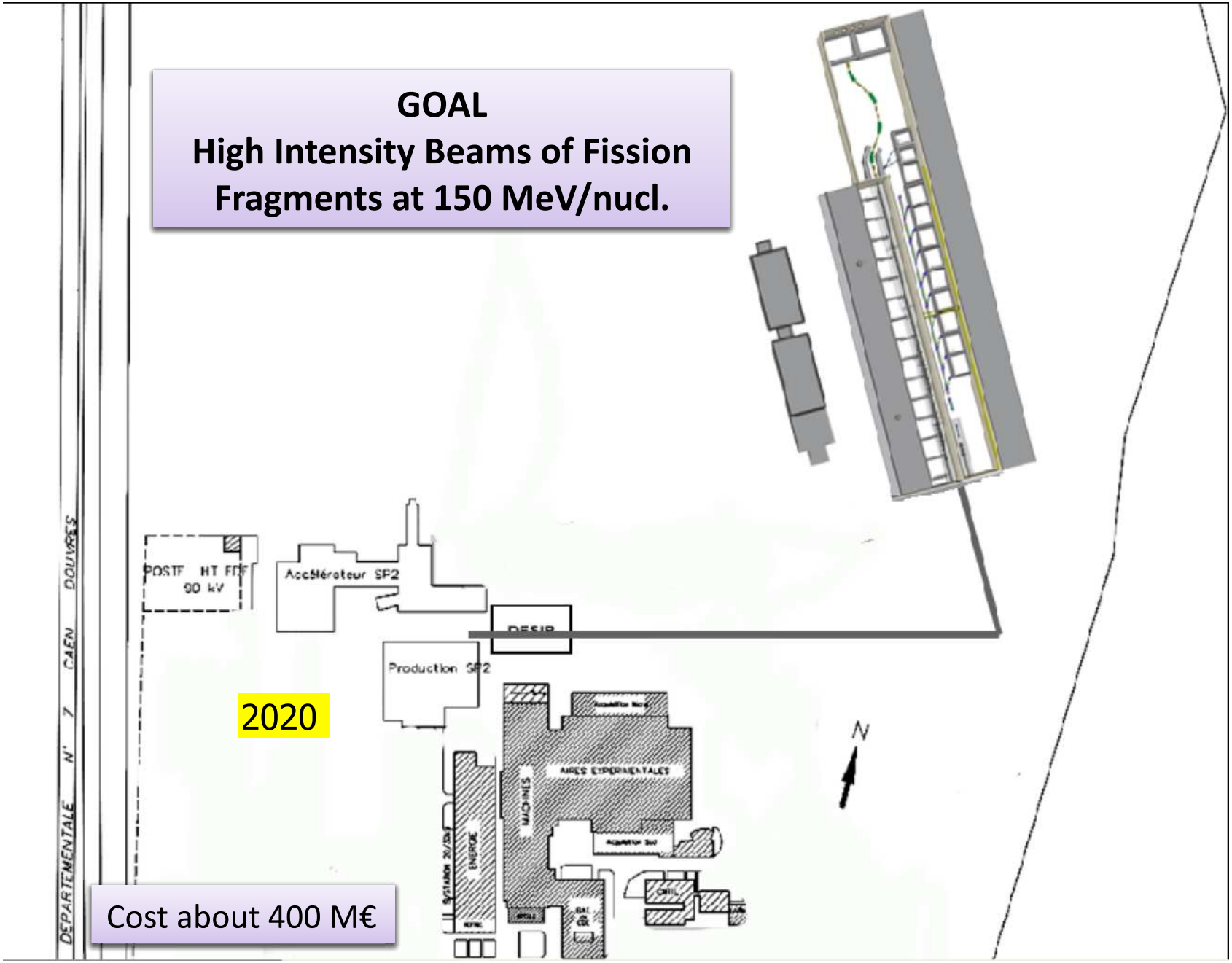
Future Upgrade of SPIRAL2- Scenario 1 → LINAG = driver of EURISOL



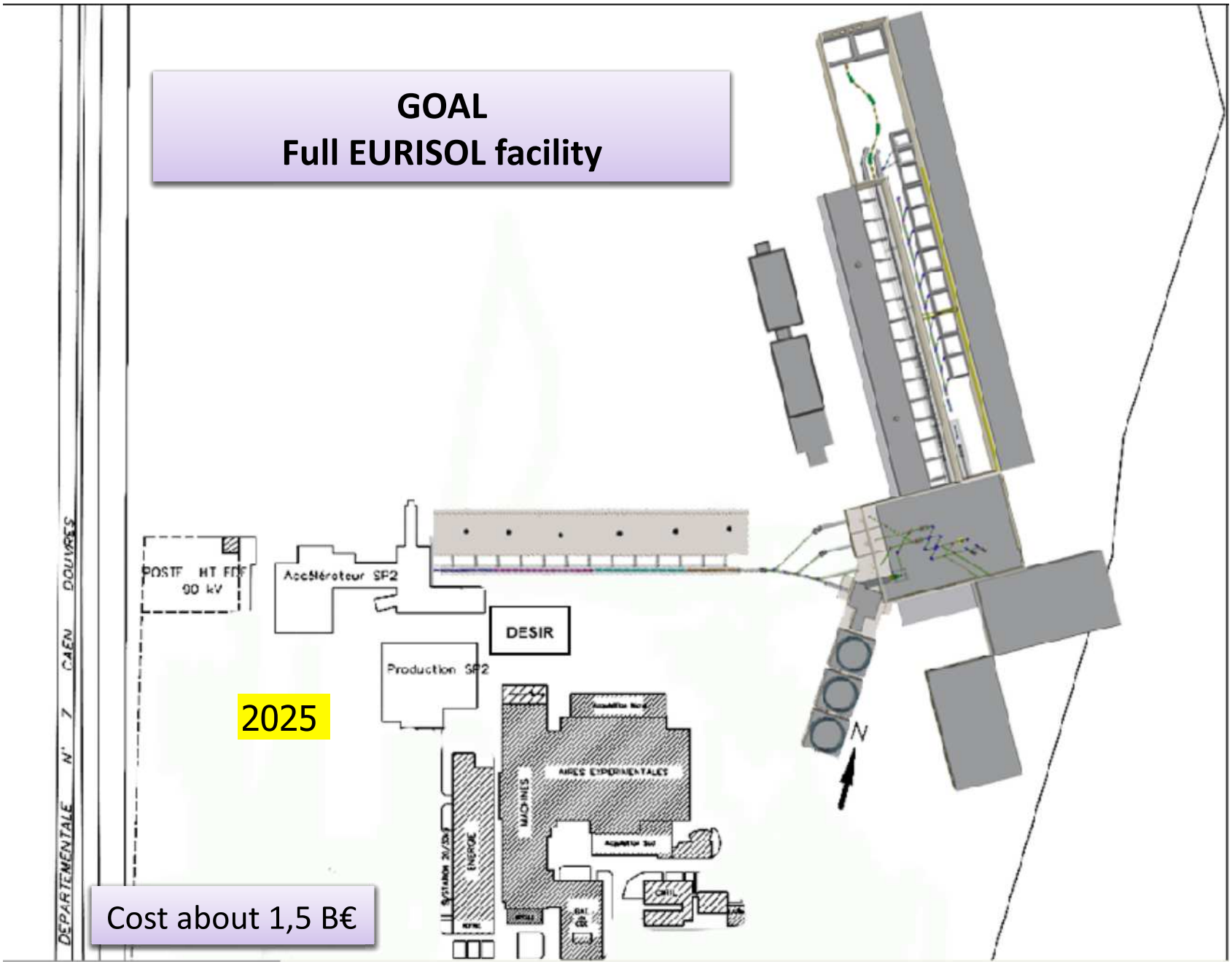
Future Upgrade of SPIRAL2- Scenario 1 → LINAG = driver of EURISOL



Future Upgrade of SPIRAL2- Scenario 1 → LINAG = driver of EURISOL



Future Upgrade of SPIRAL2- Scenario 1 → LINAG = driver of EURISOL



Discovery of POLONIUM and RADIUM 1898 Nobel Prize 1903 & 1911

„...the ability to radiate does not depend on the arrangement of the atoms in a molecule but it is related instead to the interior of the atom ...

..La capacité à irradier ne dépend pas de l'arrangement des atomes dans une molécule mais elle est plutôt liée a l'intérieur de l'atome..

Maria Skłodowska-Curie
1867-1934

THE END

Spherical-prolate shape coexistence in ^{44}S

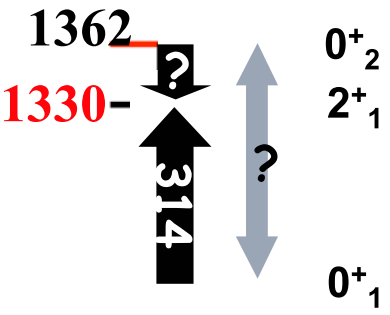
Method : isomer spectroscopy of ^{44}S

N=28 → Reduced Transition Probability B(E2;$0^+_2 \rightarrow 2^+_1$)

- Mixing of 0^+ states

→ Monopole strength ρ^2(E0;$0^+_2 \rightarrow 0^+_1$)

- Deformation of 0^+ states



^{48}Ca

^{47}K

^{46}Ar

^{45}Cl

^{44}S

^{43}P

^{42}Si

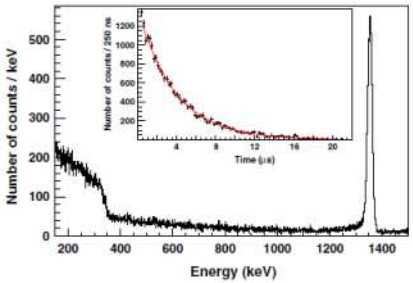


FIG. 1 (color online). Electron energy spectrum obtained from the Si(Li) detectors. The peak at 1362.5(10) keV corresponds to the $0^+_2 \rightarrow 0^+_1$ $E0$ transition. The low energy part is due to pair creation. Inset: Time distribution of the 1362.5 keV electron peak from which a half-life of 2.619(26) μsec is extracted.

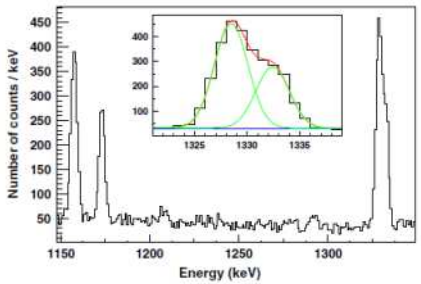


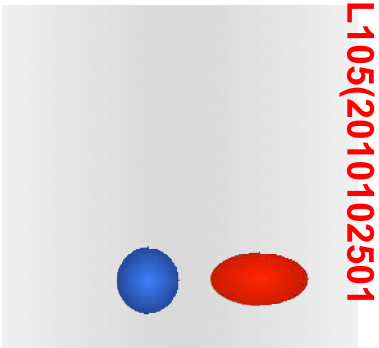
FIG. 2 (color online). Part of the delayed gamma energy spectrum. Peaks from the β decay of ^{44}K (1158 keV) and ^{60}Co (1173 and 1332.5 keV) are identified, the latter overlapping with the 1329 keV $2^+_1 \rightarrow 0^+_1$ transition of ^{44}S. The deconvolution of this doublet is shown in the inset.

B(E2;$0^+_2 \rightarrow 2^+_1$) = 42(13) e^2fm^4

→ **small mixing of 0.88(5) → 0^+ states are "pure"**

ρ^2(E0;$0^+_2 \rightarrow 0^+_1$) = 8.7(7) mu

→ **in agreement with prolate-spherical shape coexistence**



C. Force *et al.*, PRL105(201010250)1