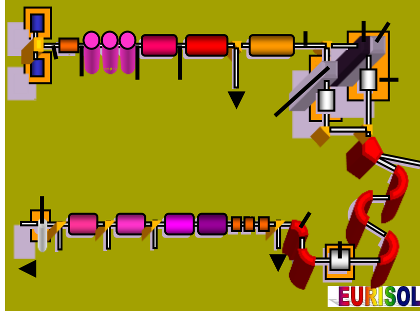
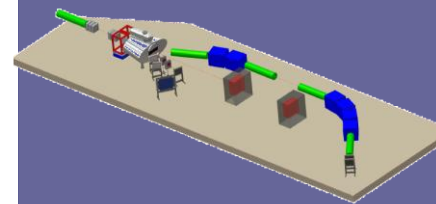
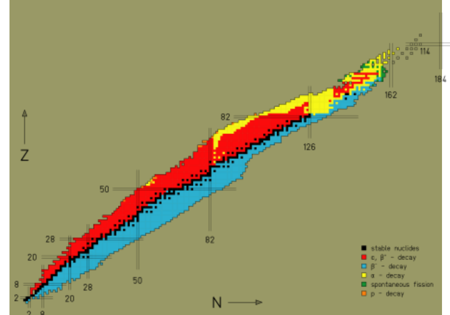
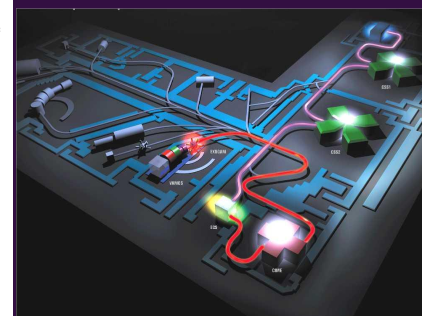








European RIB facilities - status and future

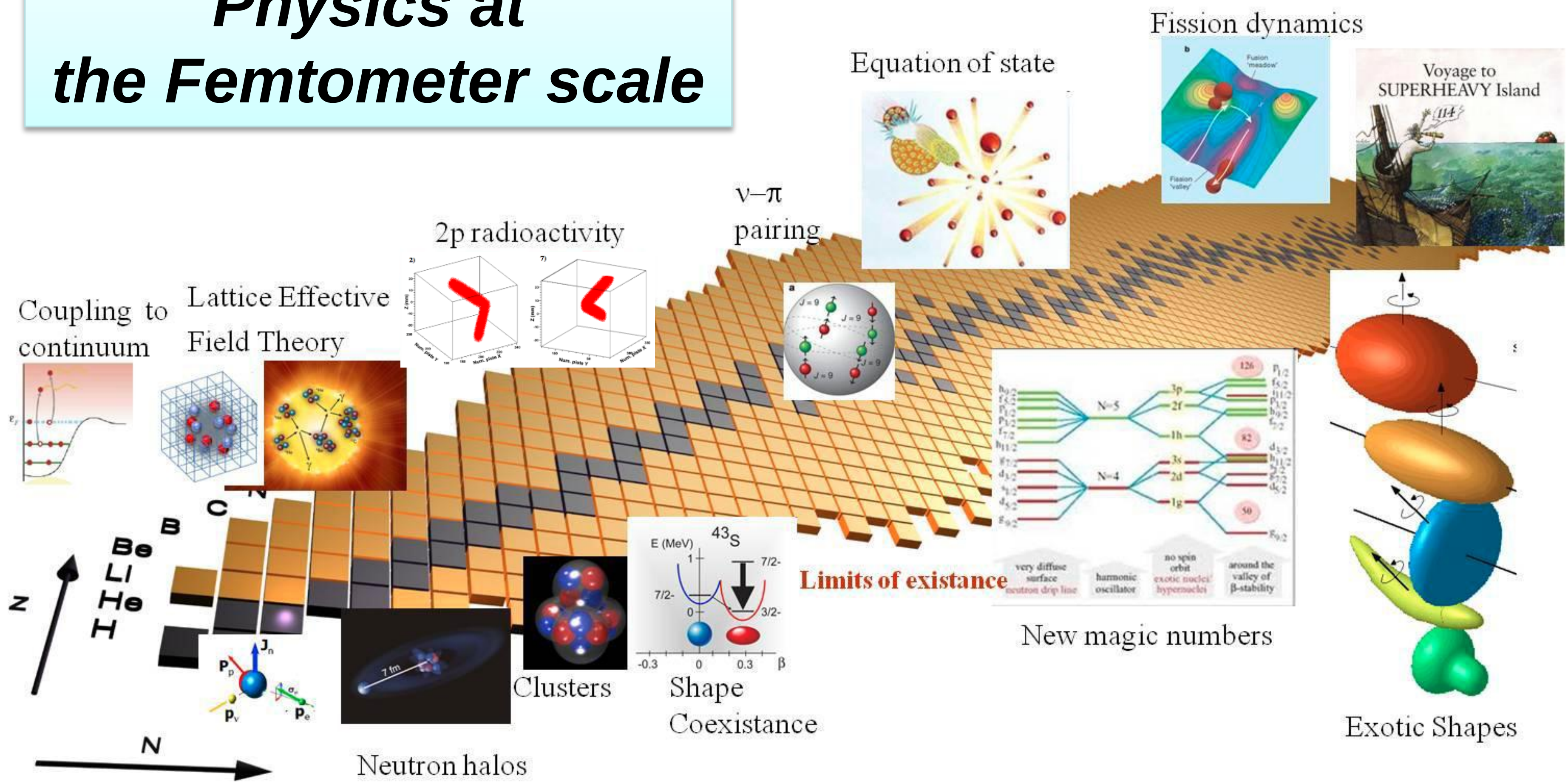
Thomas Nilsson

Fundamental Physics

Chalmers University of Technology

FAIR-NUSTAR BR

Physics at the Femtometer scale



GANIL/SPIRAL2: Nuclear Structure & reactions with high-quality, purity & intensity Stable-Ion and RIB in a perfectly suited energy range: from keV to 20 MeV/nucleon

NUclear STructure Astrophysics and Reactions

What are the limits for existence of nuclei?

- Where are the proton and neutron drip lines situated?
- Where does the nuclear chart end?

How does the nuclear force depend on varying proton-to-neutron ratios?

- What is the isospin dependence of the spin-orbit force?
- How does shell structure change far away from stability?

How to explain collective phenomena from individual motion?

- What are the phases, relevant degrees of freedom, and symmetries of the nuclear many-body system?

How are complex nuclei built from their basic constituents?

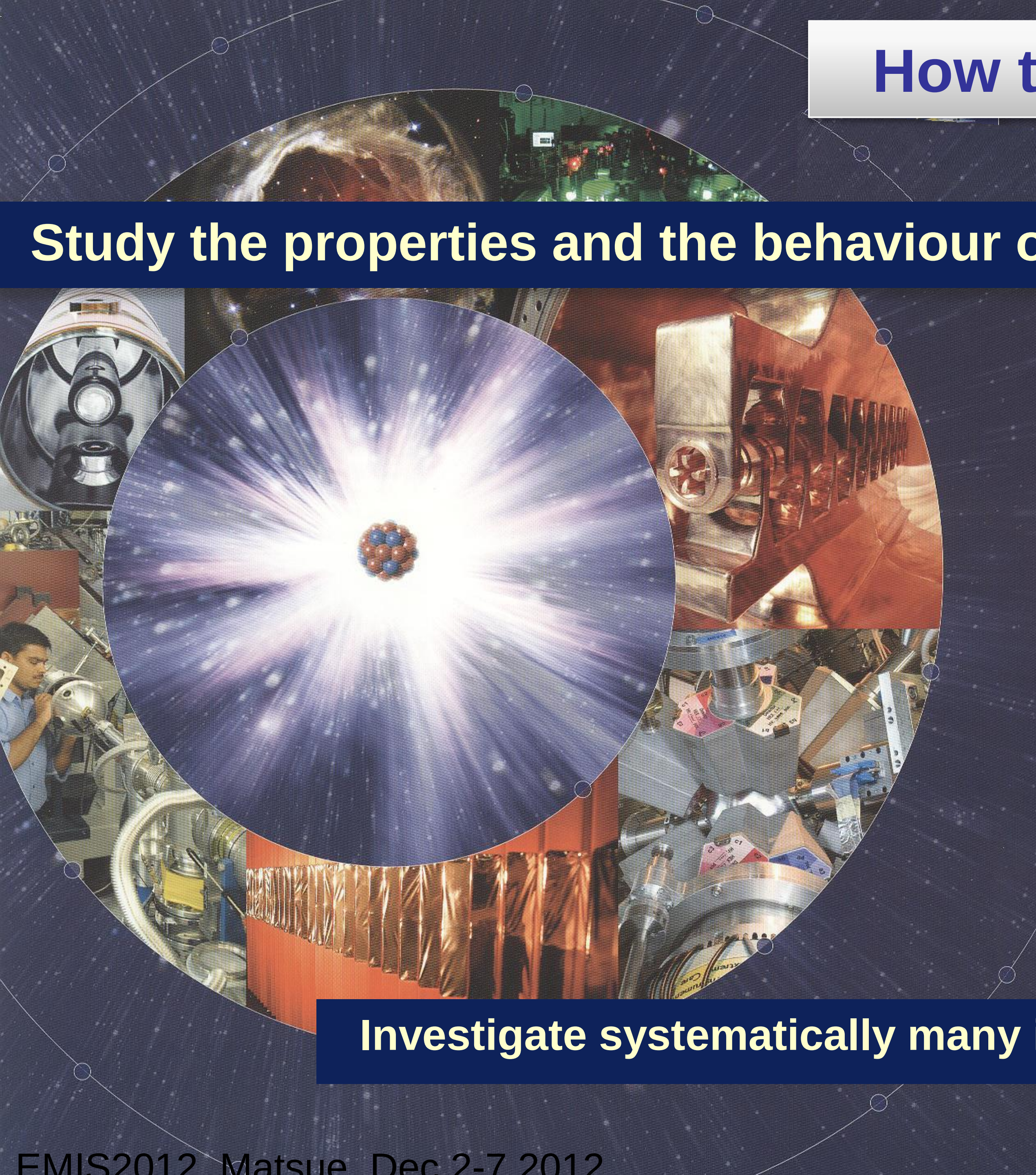
- What is the effective nucleon-nucleon interaction?
- How does QCD constrain its parameters?

Which are the nuclei relevant for astrophysical processes and what are their properties?

- What is the origin of the heavy elements?

A "buffet" of scientific questions common to RIB facilities worldwide!

How to get answers?



Study the properties and the behaviour of exotic nuclei!

Ground state

mass, binding energy, spin, parity...

Excited states
energy, spin, moments, transition probability...

Decay
lifetime, energy, modes...

Reaction
kinetics, energy, constituents...

Investigate systematically many isotopes far off stability

NuPECC Long Range Plan 2010

Perspectives of Nuclear Physics in Europe

Major Upgrades

Perform major upgrades of the following large-scale Nuclear Physics facilities, which complement each other regarding their physics scope and discovery potential:

- **HIE-ISOLDE** at CERN, including its radioactive beam experiments
- **SPES** at INFN-LNL in Legnaro, including its radioactive beam experimental set-ups
- **AGATA**, the γ-ray spectrometer consisting of semi-conductor detectors that will be used at the facilities SPES, HIE-ISOLDE, SPIRAL2 and FAIR
- The new **Superconducting Linac** for the provision of high intensity stable beams at GSI to search e.g. for superheavy elements

ESFRI Facilities

Complete in a timely fashion the construction of the Nuclear Physics facilities on the ESFRI list of large-scale research infrastructure projects in Europe:

- **FAIR** at the GSI site in Darmstadt, including its four pillars: the PANDA experiment using antiprotons to study the structure and spectroscopy of strongly interacting particles (hadrons), the NuSTAR radioactive beam facility to produce nuclei far from stability and investigate their structure, the CBM experiment to measure the properties of dense baryonic matter, and the atomic, plasma, and applied physics programme APPA.
- **SPIRAL2** at GANIL in Caen, including high intensity stable beams which will allow the study of unstable nuclei at the S3 spectrometer, and ISOL radioactive beams of very neutron-rich fission products and studied, for example, at the DESIR facility.

EURISOL in future updates of the ESFRI list, based on the successful EURISOL Design Study in FP6.

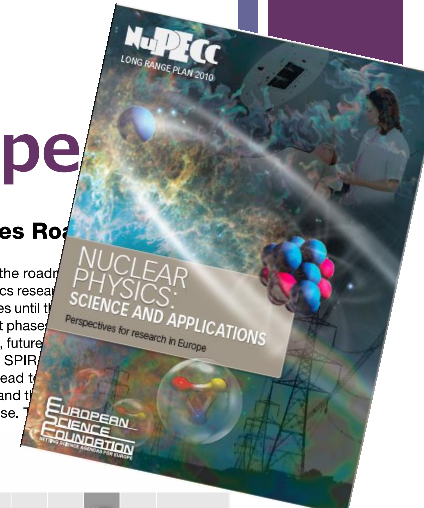
The Technical Design Study for a polarised proton-antiproton, **PAX**, and an electron-nucleon/ion collider, **ENC**, at FAIR.

The Technical Design Study for a high-energy electron-proton/ion collider, **LHeC**, at CERN.

The inclusion of Nuclear Physics programmes at the multi-purpose facilities **ELI** and **ESS**.

2.2 Facilities Roa...

We present below the roadm... scale Nuclear Physics resea... The time span ranges until t... Facilities whose first phase... are coloured in blue, future... The ISOL facilities SPIR... are designated to lead t... at FAIR, EURISOL and t... design or R&D phase.



The Nuclear Physics European Collaboration Committee is an Expert Committee of the European Science Foundation

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

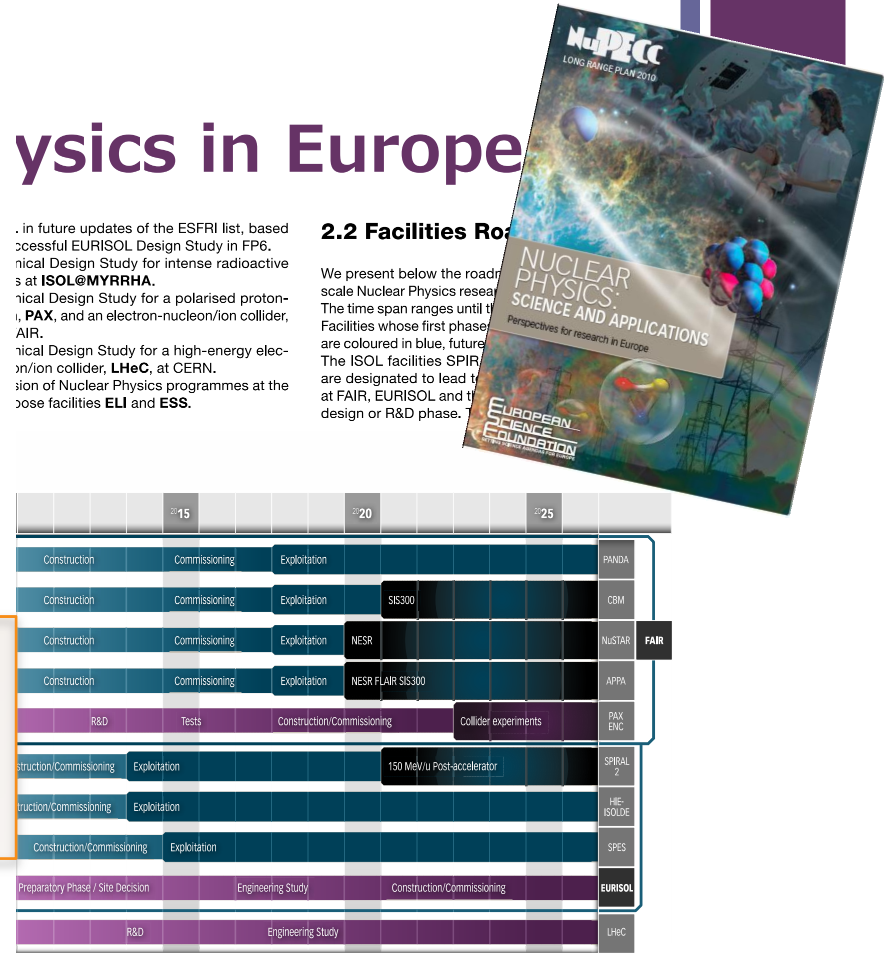
NuPECC

NuPECC Long Range Plan 2010

Existing Facilities

Fully exploit the currently existing large-scale research infrastructures (listed below in north to south order) and perform limited-size upgrades to ensure the best use of the large investments made in the past:

- The **lepton beam** facilities (electron/positron, muon beams) ELSA in Bonn, MAMI in Mainz, COMPASS at CERN, DAΦNE at INFN-LNF Frascati, and the **hadron beam** facilities COSY at FZ Jülich and at GSI to perform detailed studies of the structure of hadrons such as protons and neutrons.
- The **heavy ion beam** facilities JYFL Jyväskylä, KVI Groningen, GSI Darmstadt, GANIL Caen, IPN Orsay, ISOLDE at CERN, INFN-LNL Legnaro and INFN-LNS Catania to study the structure of nuclei and fundamental interactions.
- The nuclear astrophysics underground accelerator **LUNA** at INFN Gran Sasso, and the exploration of advanced new facilities.
- The **ELENA** upgrade of the Antiproton Decelerator at CERN to study antimatter.



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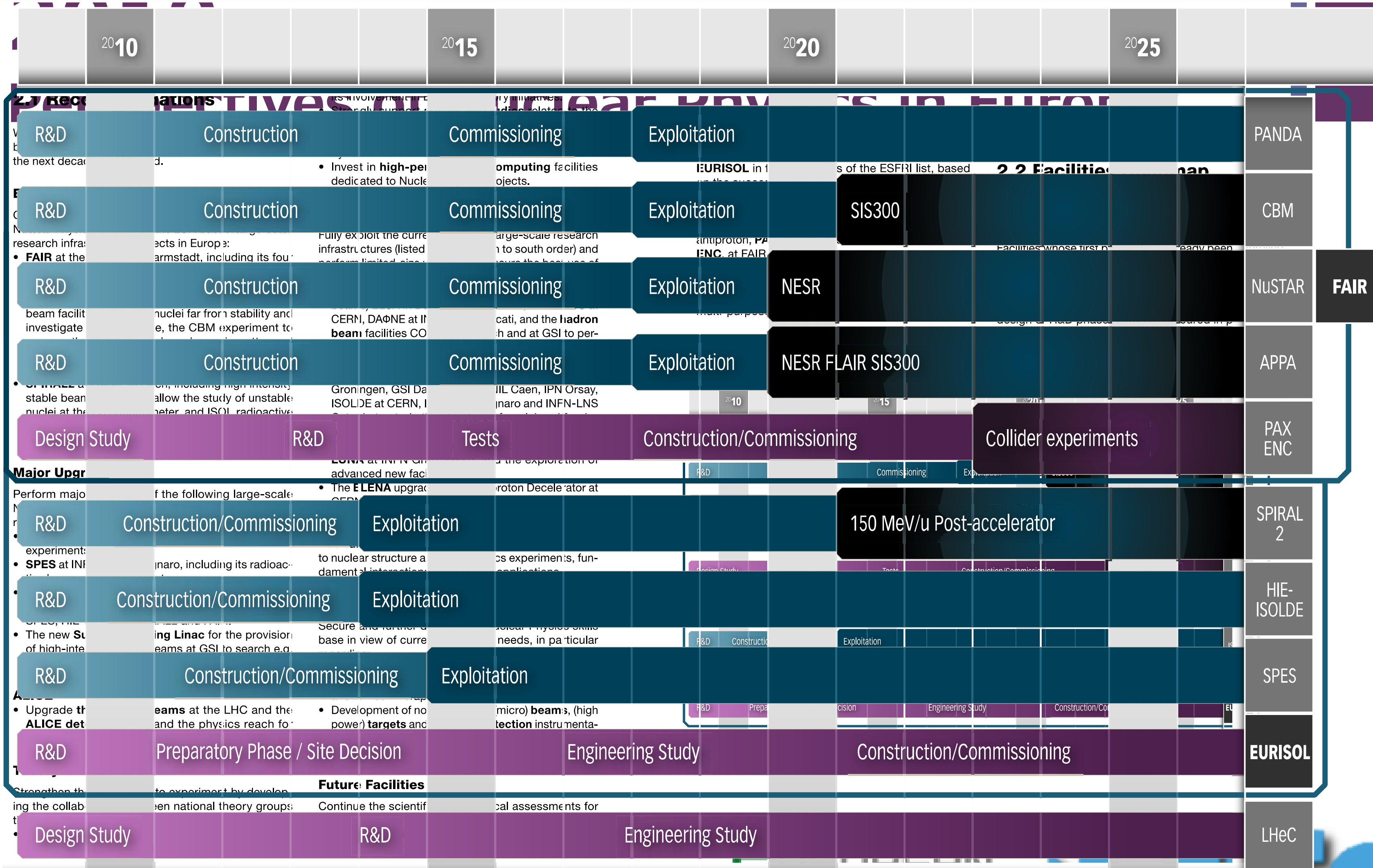
EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

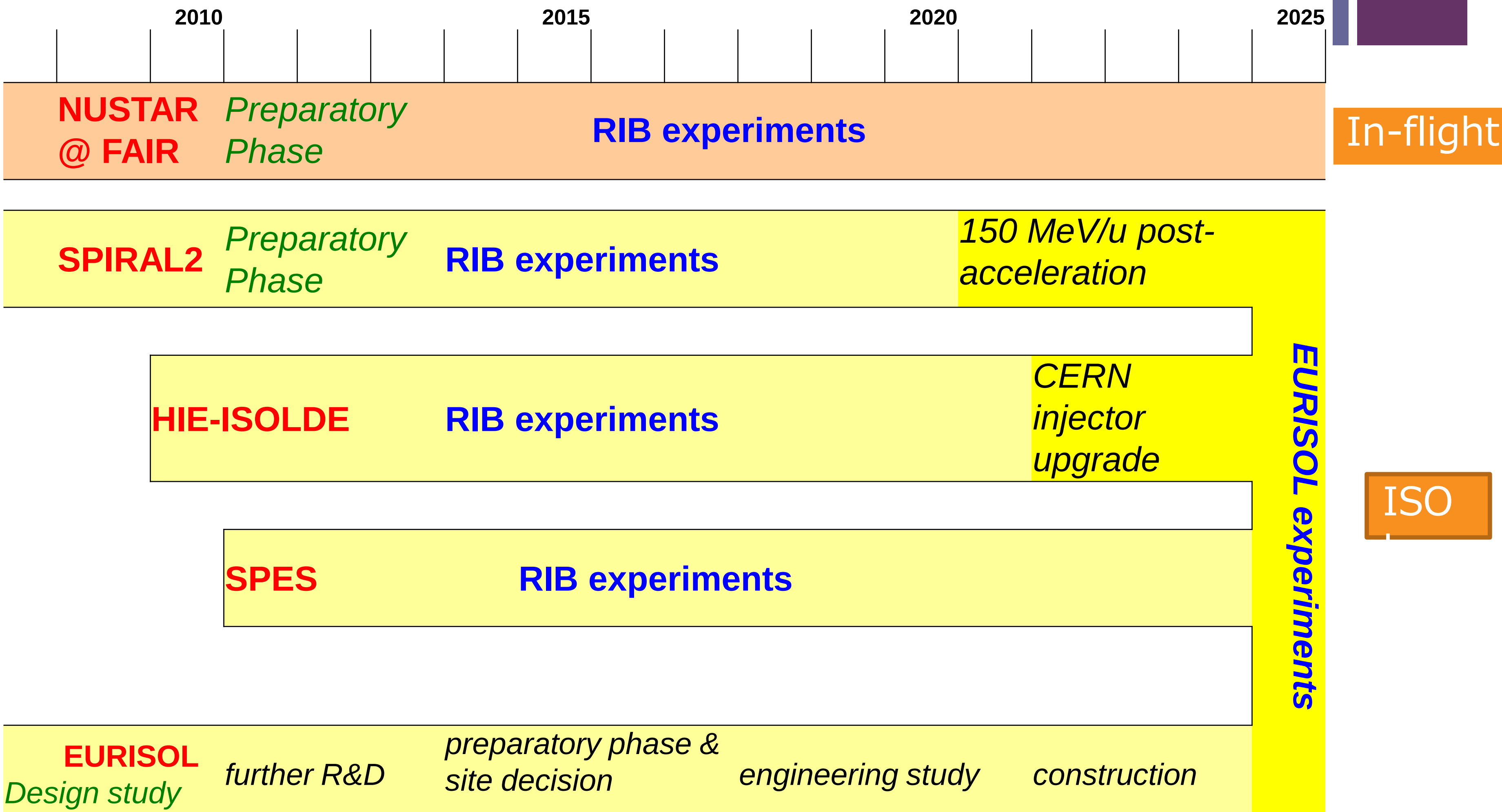
NuPECC

NuPECC Long Range Plan



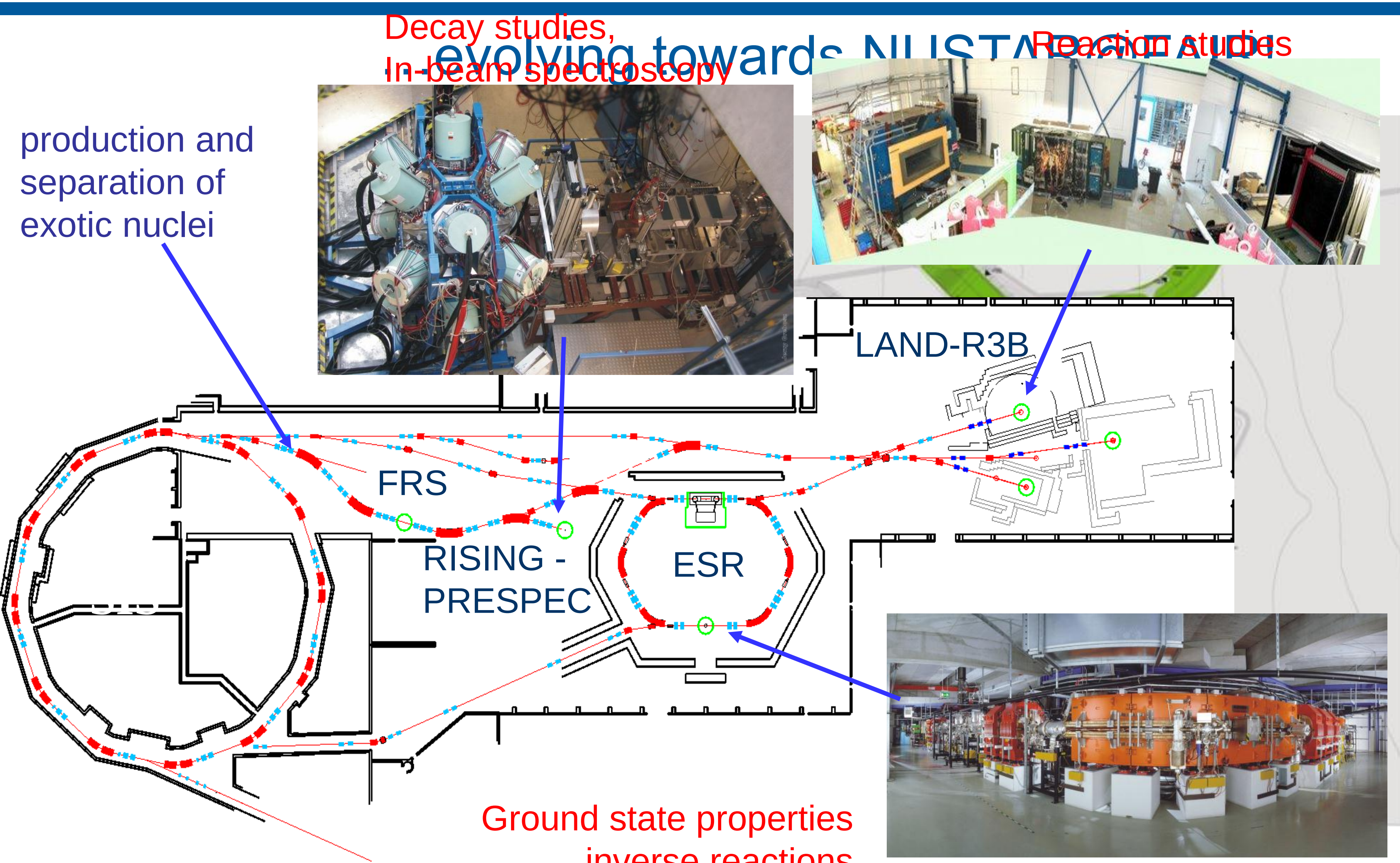
The Nuclear Physics European Collaboration Committee is an Expert Committee of the European Science Foundation

NuPECC Long Range Plan 2010 Timeline RIB Facilities



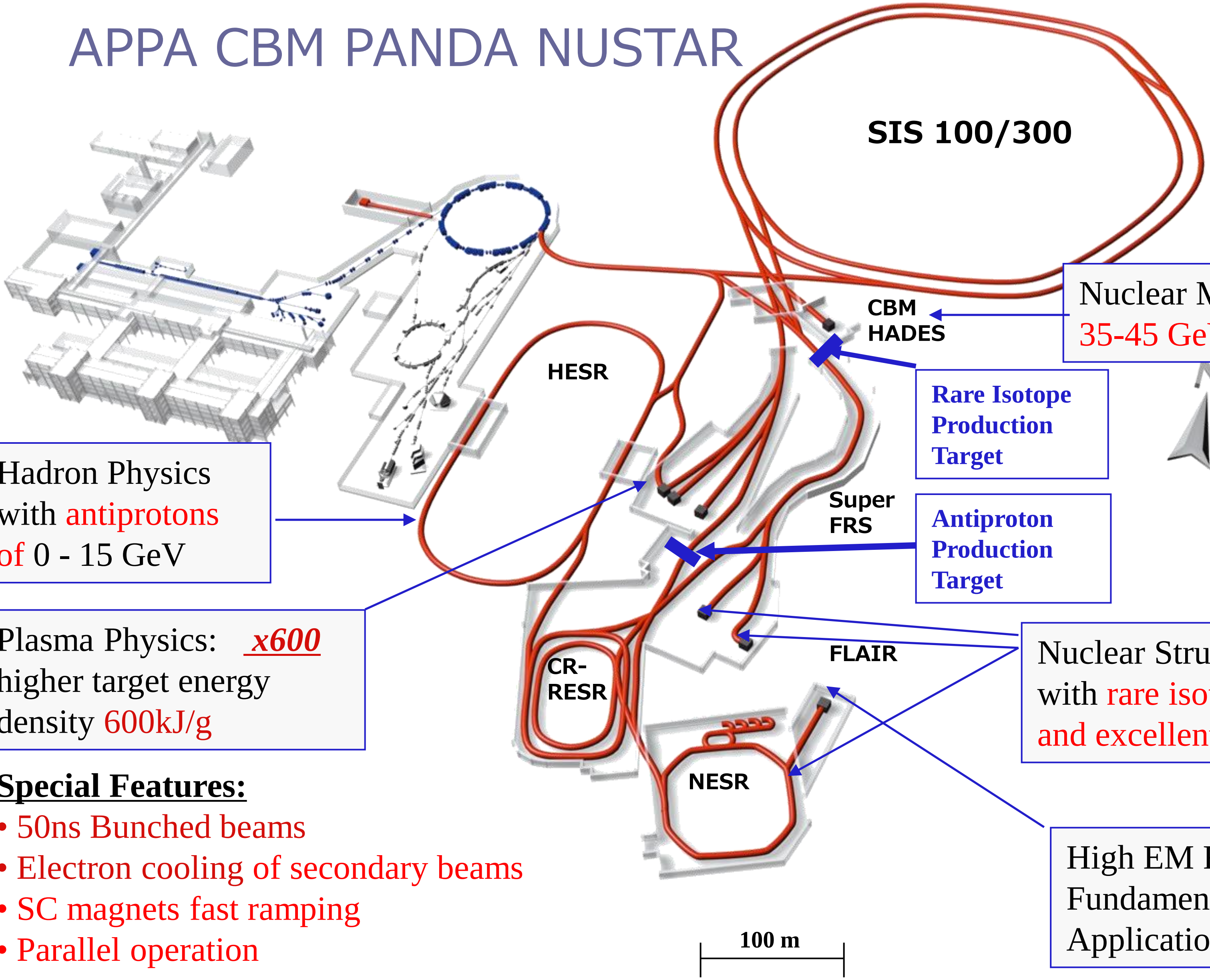
Y. Blumenfeld

Existing research opportunities at GSI



Research Communities at FAIR

APPA CBM PANDA NUSTAR



Nuclear Matter Physics with 35-45 GeV/u HI beams, ***x1000***

Rare Isotope Production Target

Antiproton Production Target

Hadron Physics with antiprotons of 0 - 15 GeV

Plasma Physics: ***x600*** higher target energy density 600kJ/g

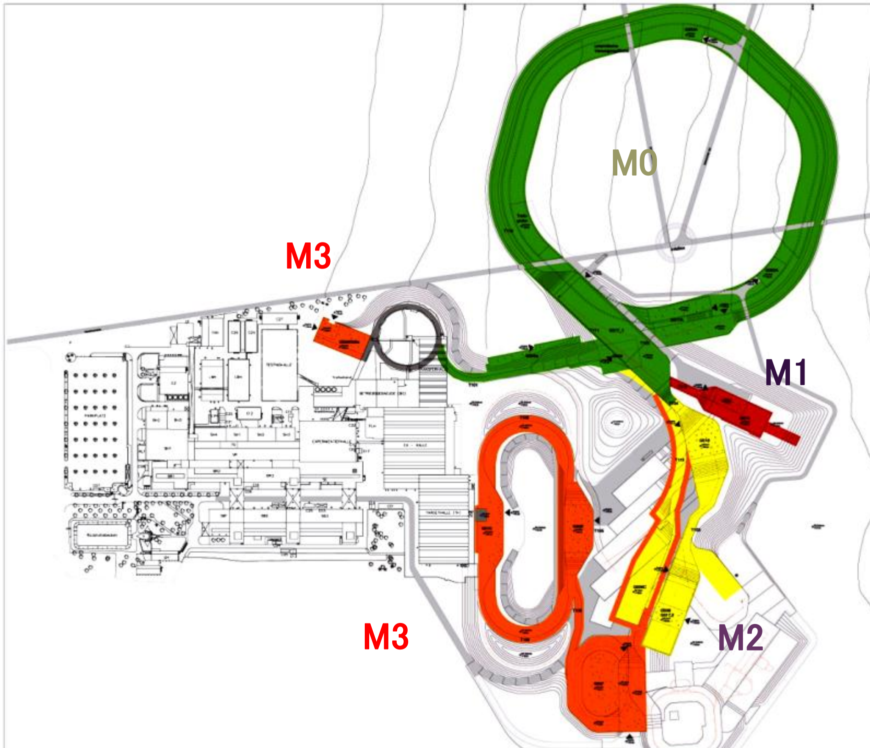
Nuclear Structure & Astrophysics with rare isotope beams, ***x10 000*** and excellent cooling

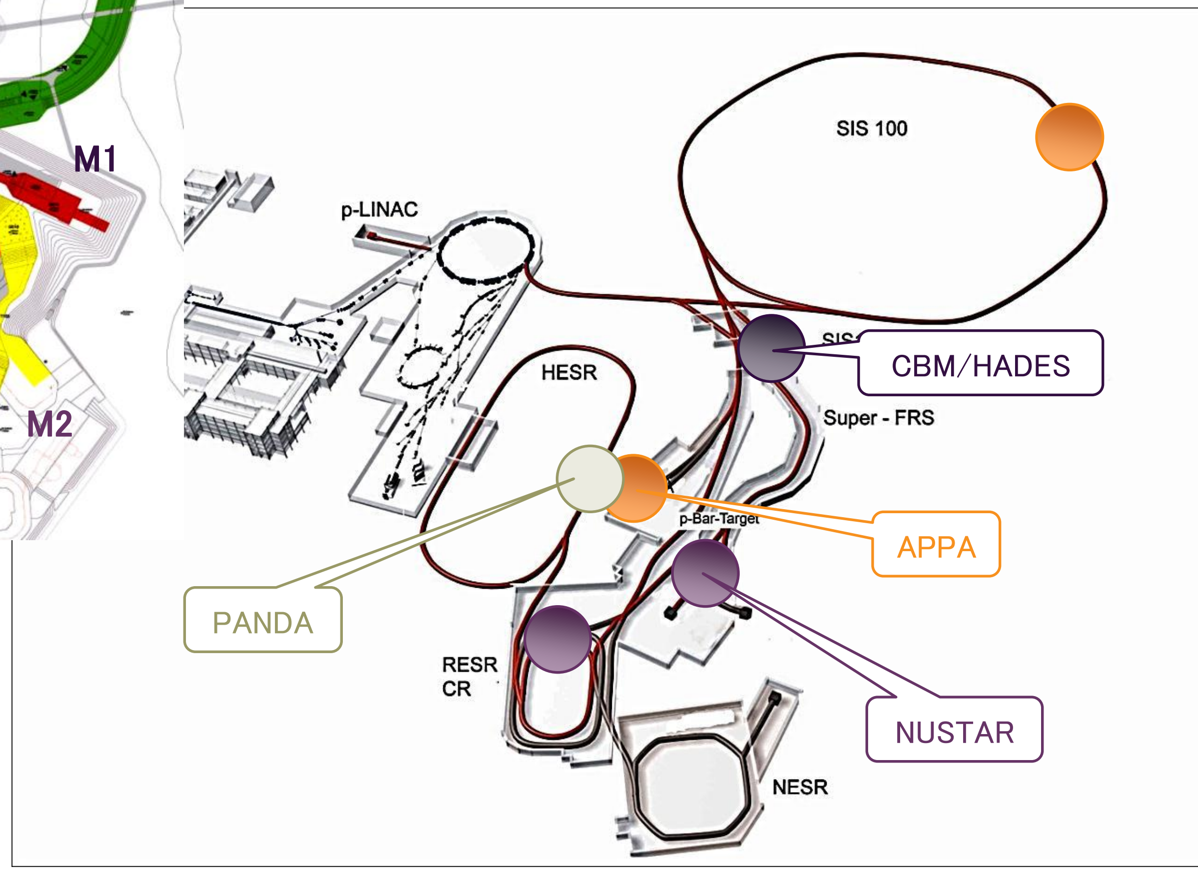
High EM Field (HI) _ Fundamental Studies(HI & p) Applications (HI)

Special Features:

- 50ns Bunched beams
- Electron cooling of secondary beams
- SC magnets fast ramping
- Parallel operation

Modularised Start Version





Experiments

M1: APPA

M1: CBM/HADES

M2: NUSTAR

M3: PANDA

NUSTAR - The Project

Super-FRS	RIB production, identification and spectroscopy
DESPEC	γ-, β-, α-, p-, n-decay spectroscopy
HISPEC	in-beam □ spectroscopy at low and intermediate energy
ILIMA	masses and lifetimes of nuclei in ground and isomeric states
LASPEC	Laser spectroscopy
MATS	in-trap mass measurements and decay studies
R^3B	kinematically complete reactions at high beam energy
ELISE	elastic, inelastic, and quasi-free e^{-}A scattering
EXL	light-ion scattering reactions in inverse kinematics

The Approach

Complementary measurements leading to consistent answers

The Collaboration

> 800 scientists

146 institutes

38 countries

The Investment

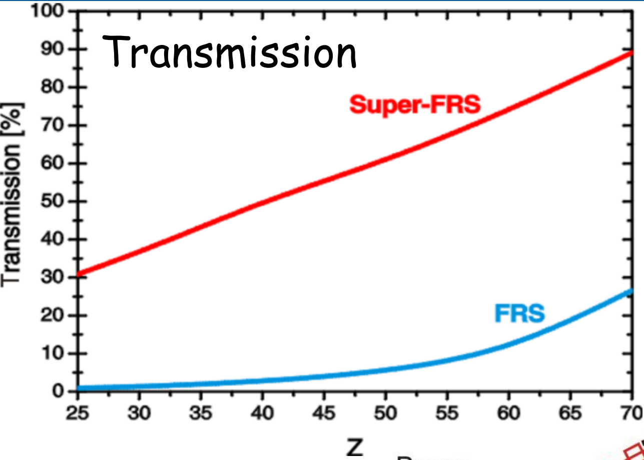
82 M€ Super FRS

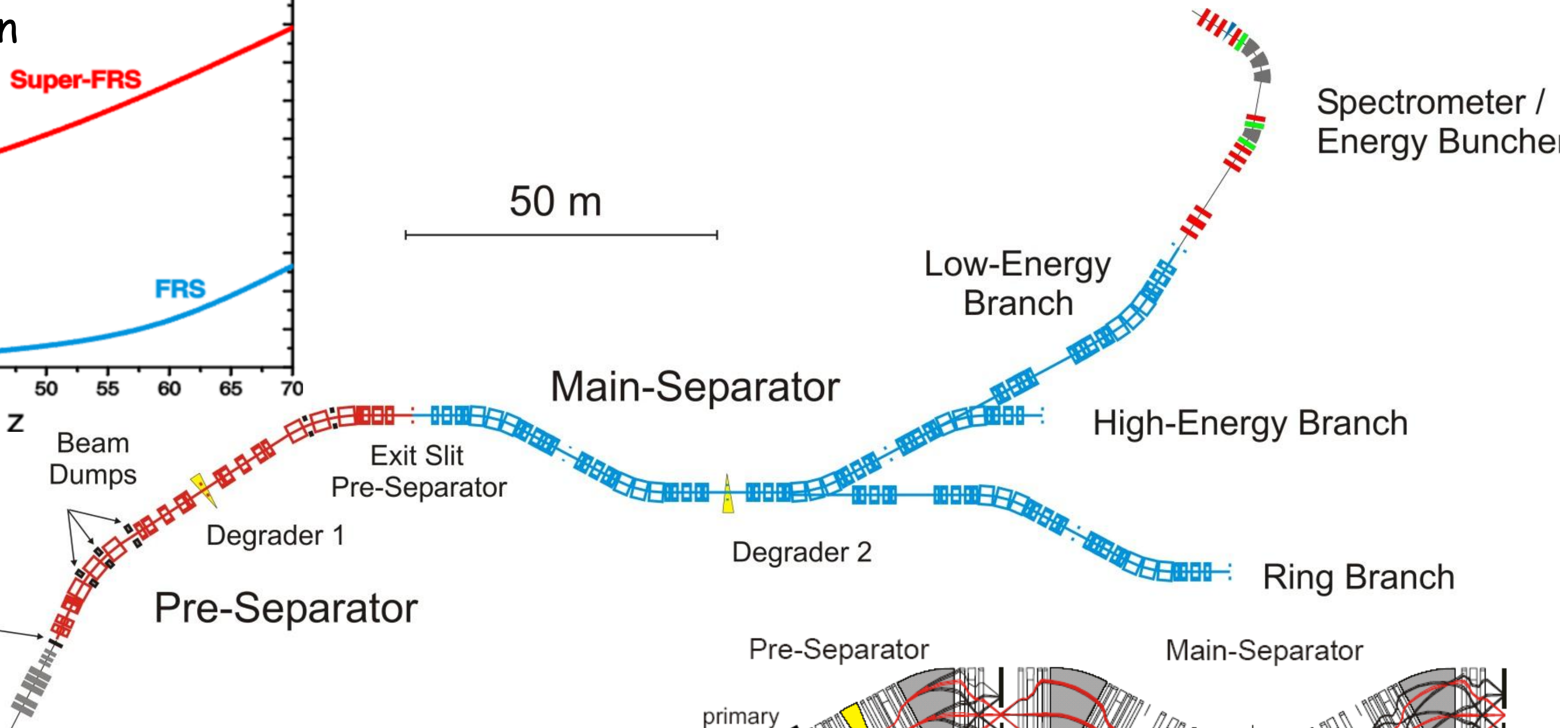
73 M€ Experiments

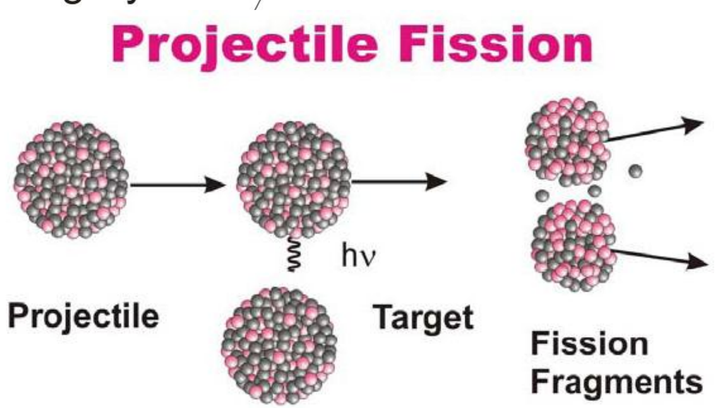
NUSTAR Week Kolkata Oct 2012

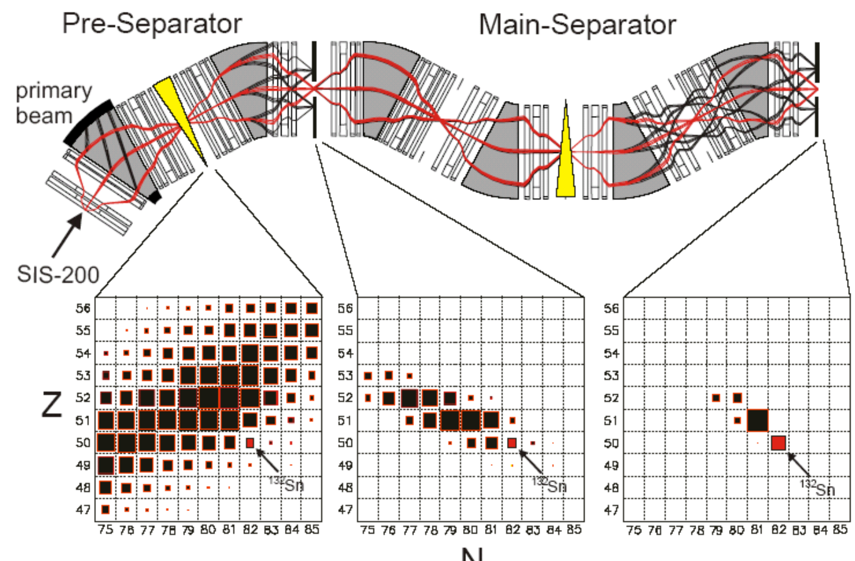
SUPERconducting FRagment Separator

Talk by H. Geissel session I



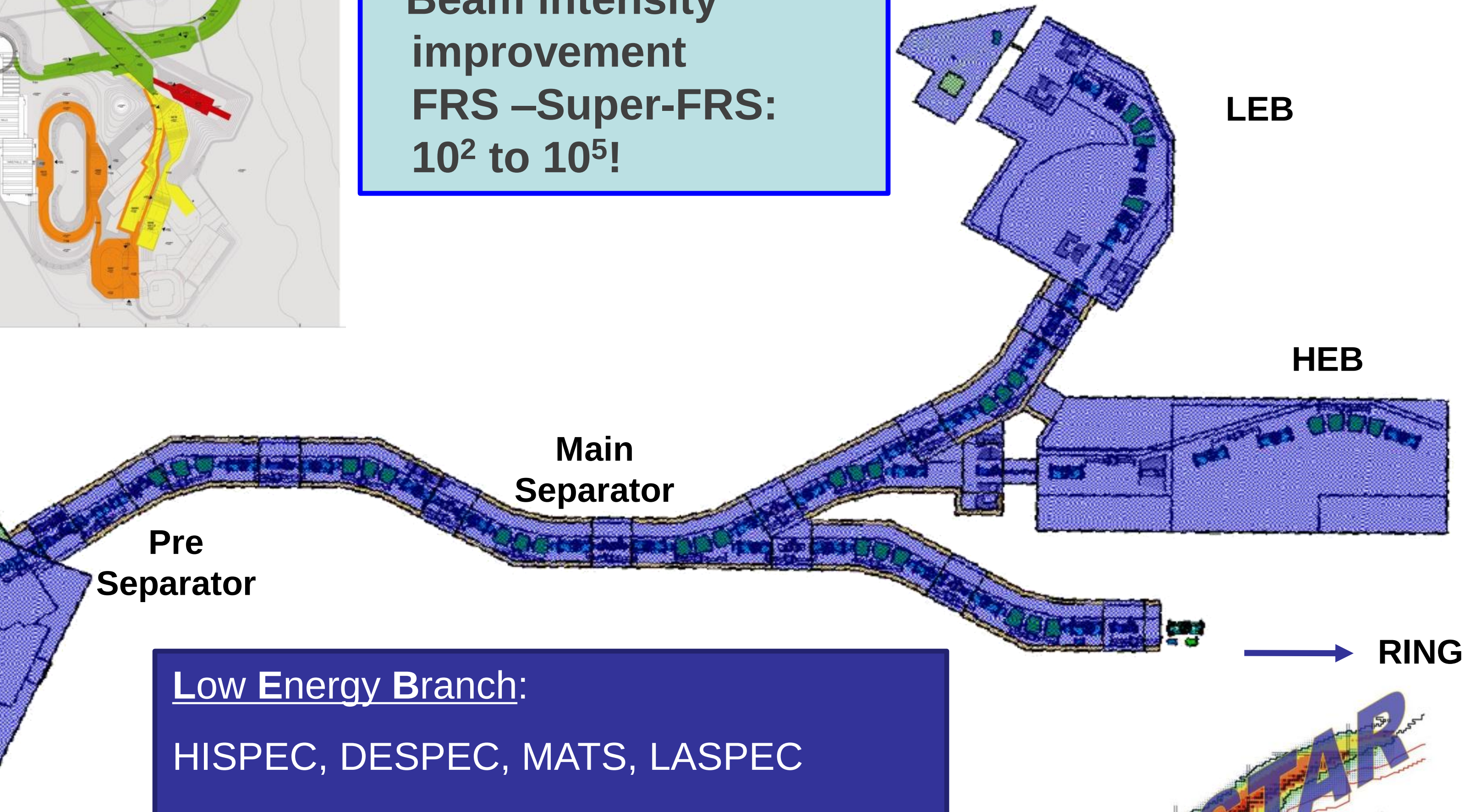






NUSTAR - The Facility

Beam intensity improvement FRS –Super-FRS: 10^2 to 10^5!



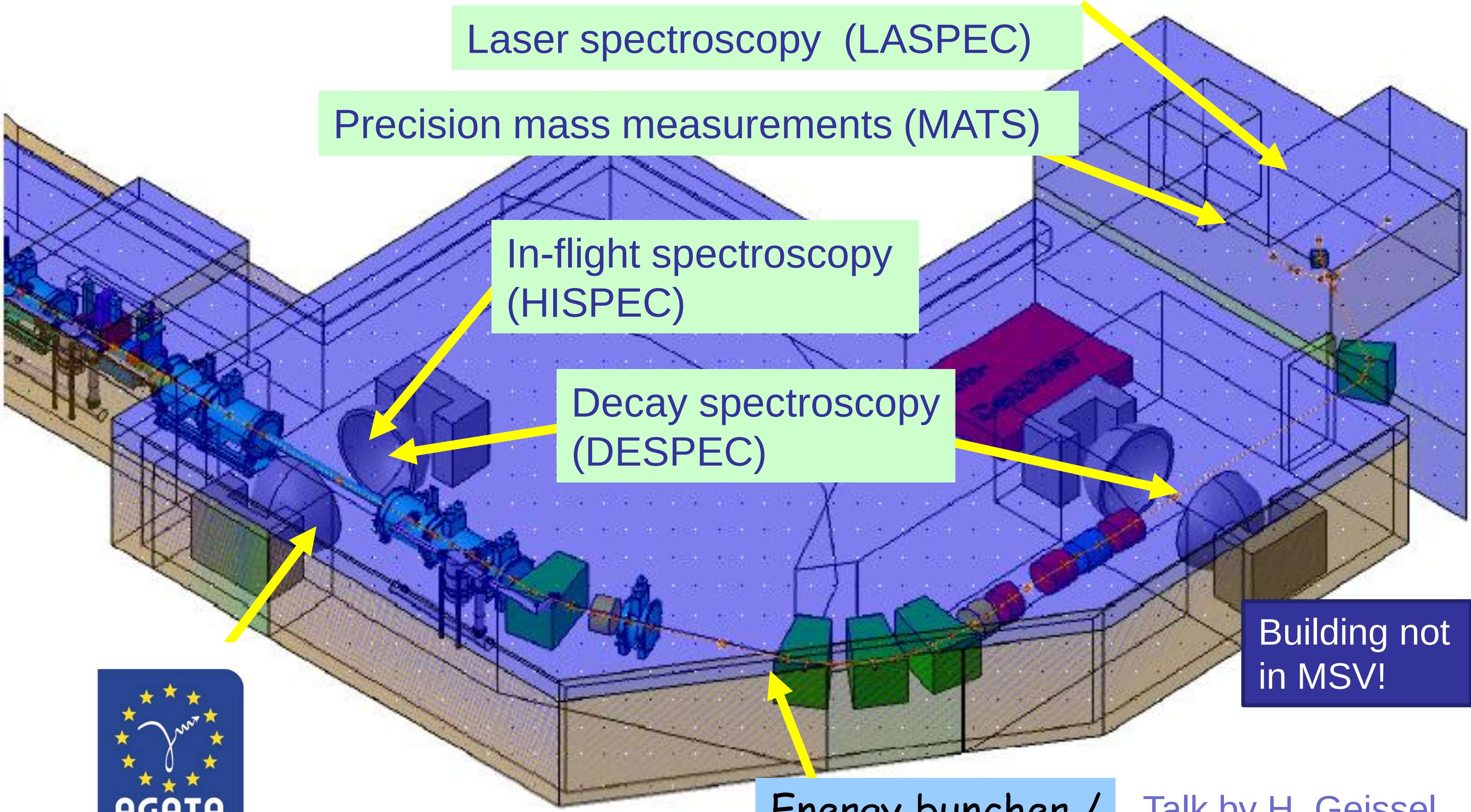
<u>**L**ow **E**nergy **B**ranch</u>:

HISPEC, DESPEC, MATS, LASPEC

<u>**H**igh **E**nergy **B**ranch</u>: R3B

<u>**Ring** Branch</u>: EXL, ILIMA, ELISE

LEB - Experiments with slowed and stopped beams (0 - ~150 MeV/u)



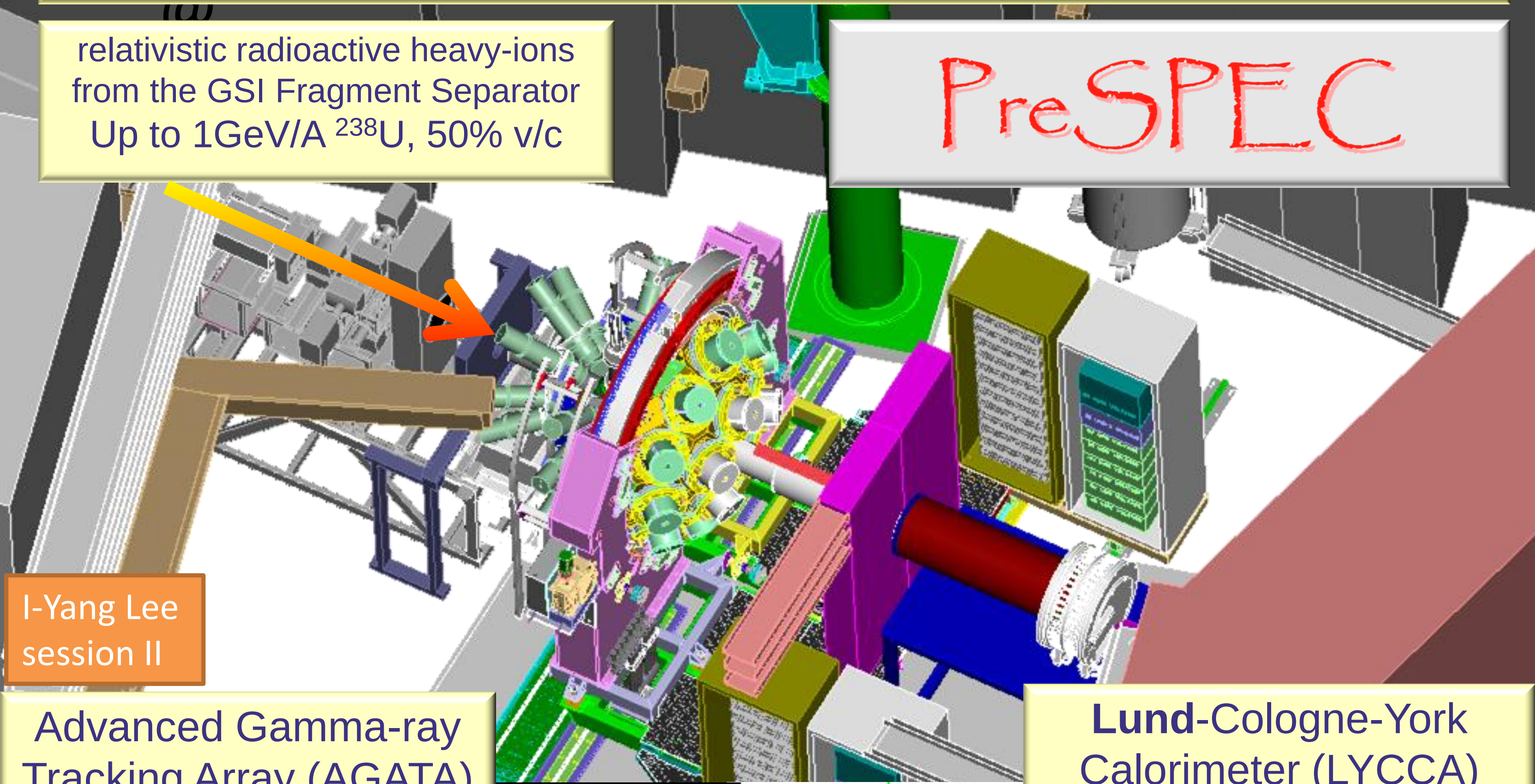
AGATA ADVANCED GAMMA TRACKING ARRAY

Talk by H. Geissel session I

PreSPEC-AGATA Set-up = Early Implementation of HISPEC

relativistic radioactive heavy-ions from the GSI Fragment Separator
Up to 1GeV/A ^{238}U, 50% v/c

PreSPEC



I-Yang Lee
session II

Advanced Gamma-ray Tracking Array (AGATA)

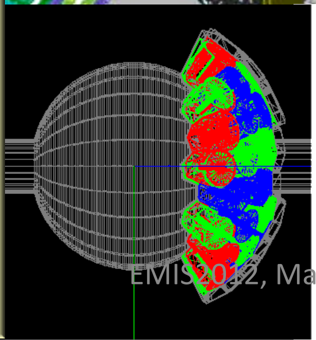
up to 5 x 2+10 x 3 = 40 segmented HP Ge-crystals

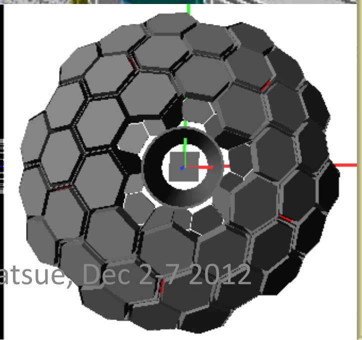
d ~ 20 cm

$\varepsilon_{Ph} \approx 17\%$

$\Delta E \approx 0.4\%$

AGATA ADVANCED GAMMA TRACKING ARRAY



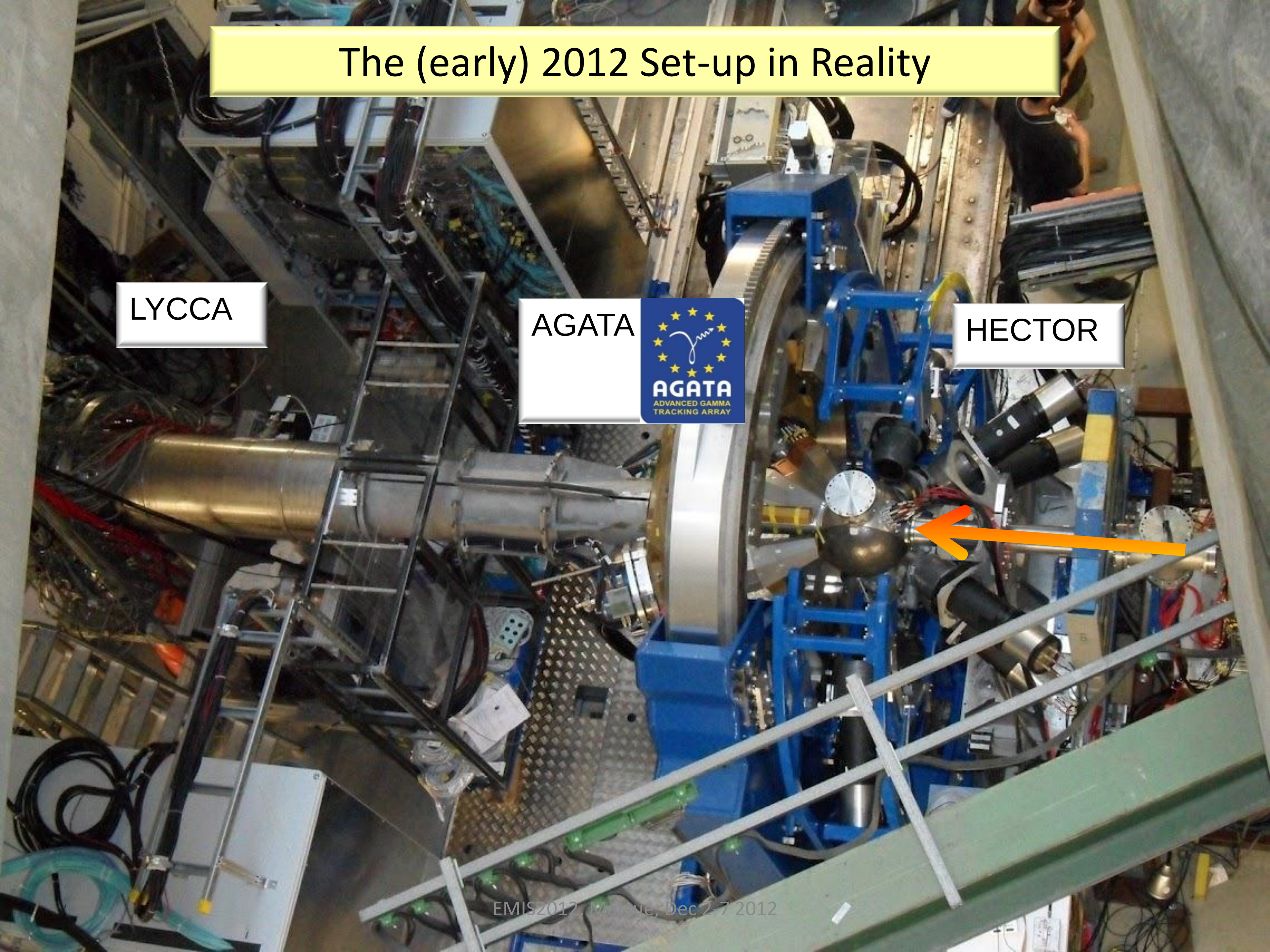


Lund-Cologne-York Calorimeter (LYCCA)

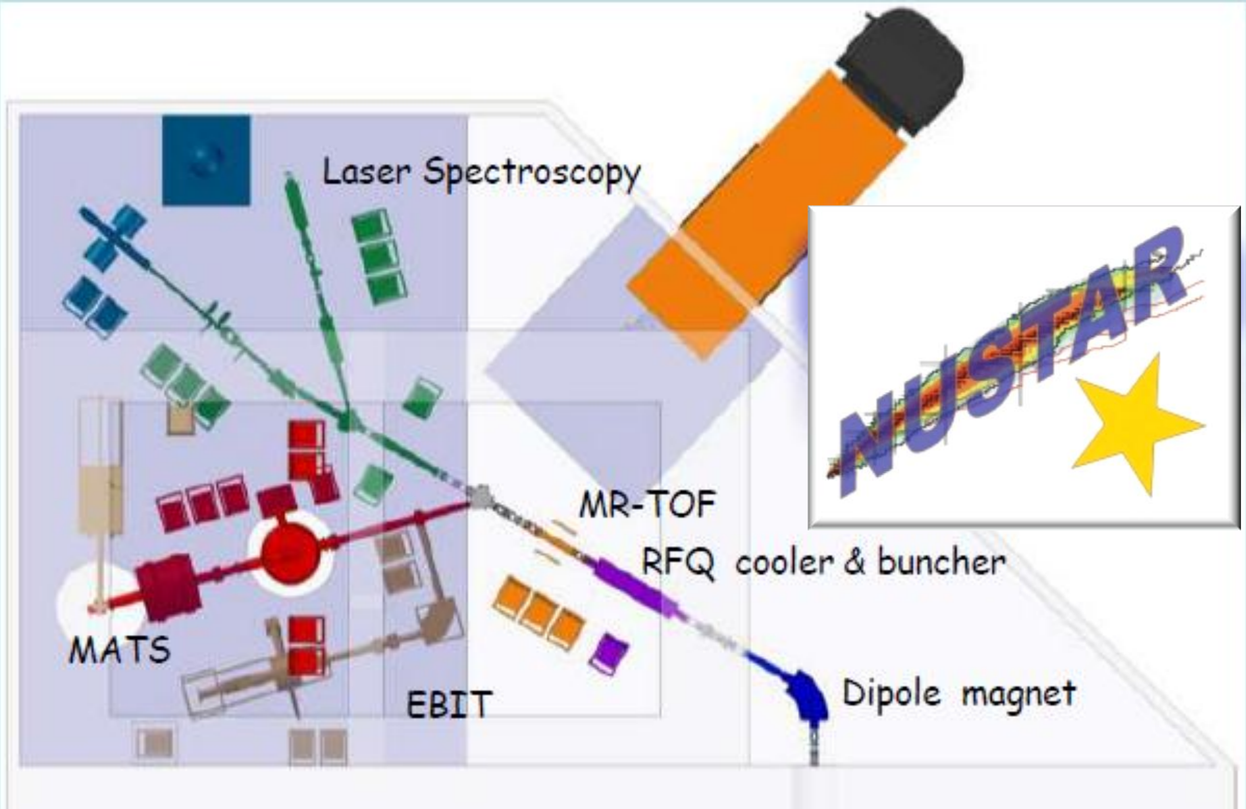
A and *Z* particle-ID after secondary target by means of

- x,y tracking
- Δ*E*-*E* (Si-CsI)
- Δt (plastic)

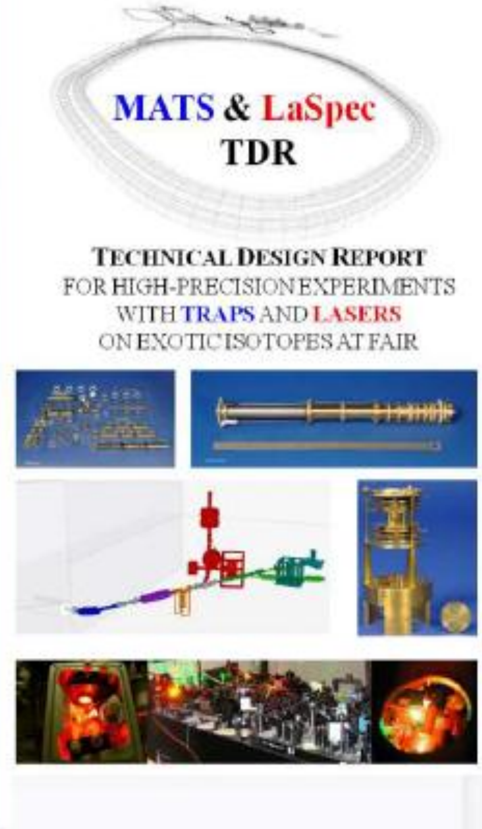
The (early) 2012 Set-up in Reality



MATS/LASPEC at the LEB



for more information see:
Technical Design Report of MATS & LaSpec:
D. Rodriguez, EPJ Special Topics 183 (2010) 1-123



Common beam line for MATS/LaSpec
Commissioning of the gas cell at the FRS (GSI)

On-line test using ^{238}U projectile fragments produced at 1 GeV/u at the FRS in October 2011 and July/August 2012

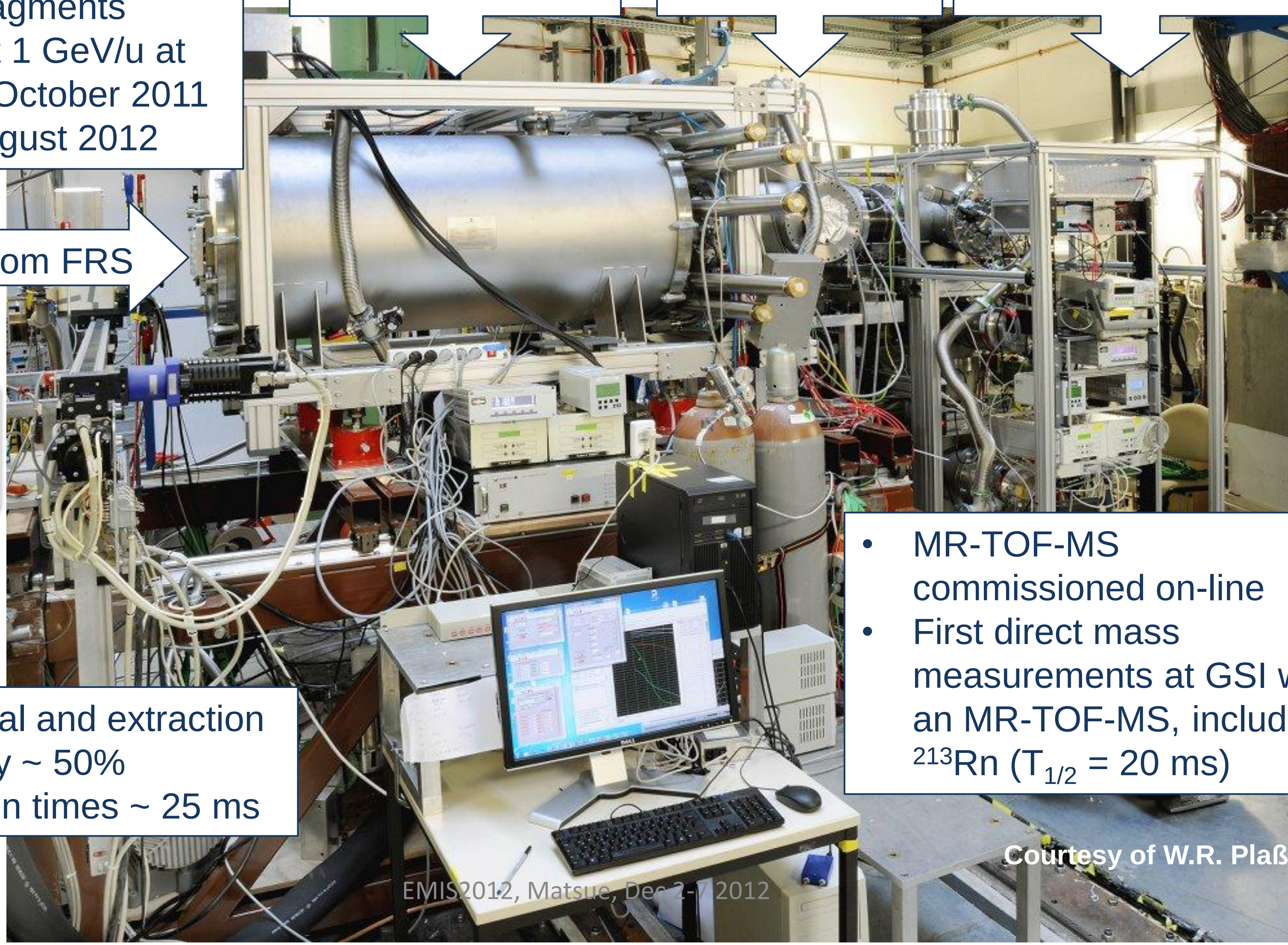
Cryogenic stopping cell

Diagnostics unit

Time-of-flight mass spectrometer

Beam from FRS

W. Plaß, session IV

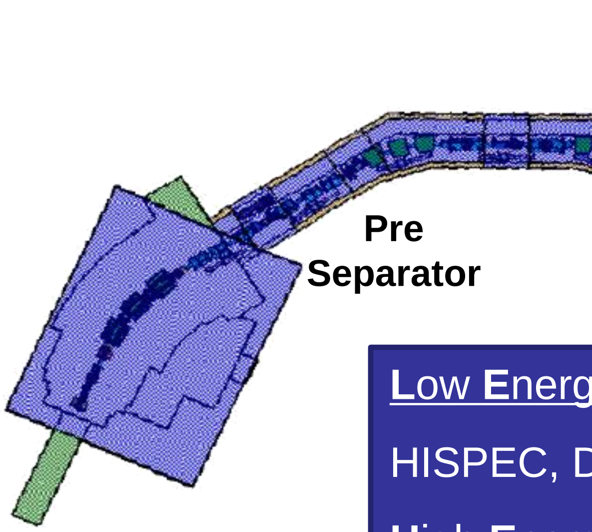


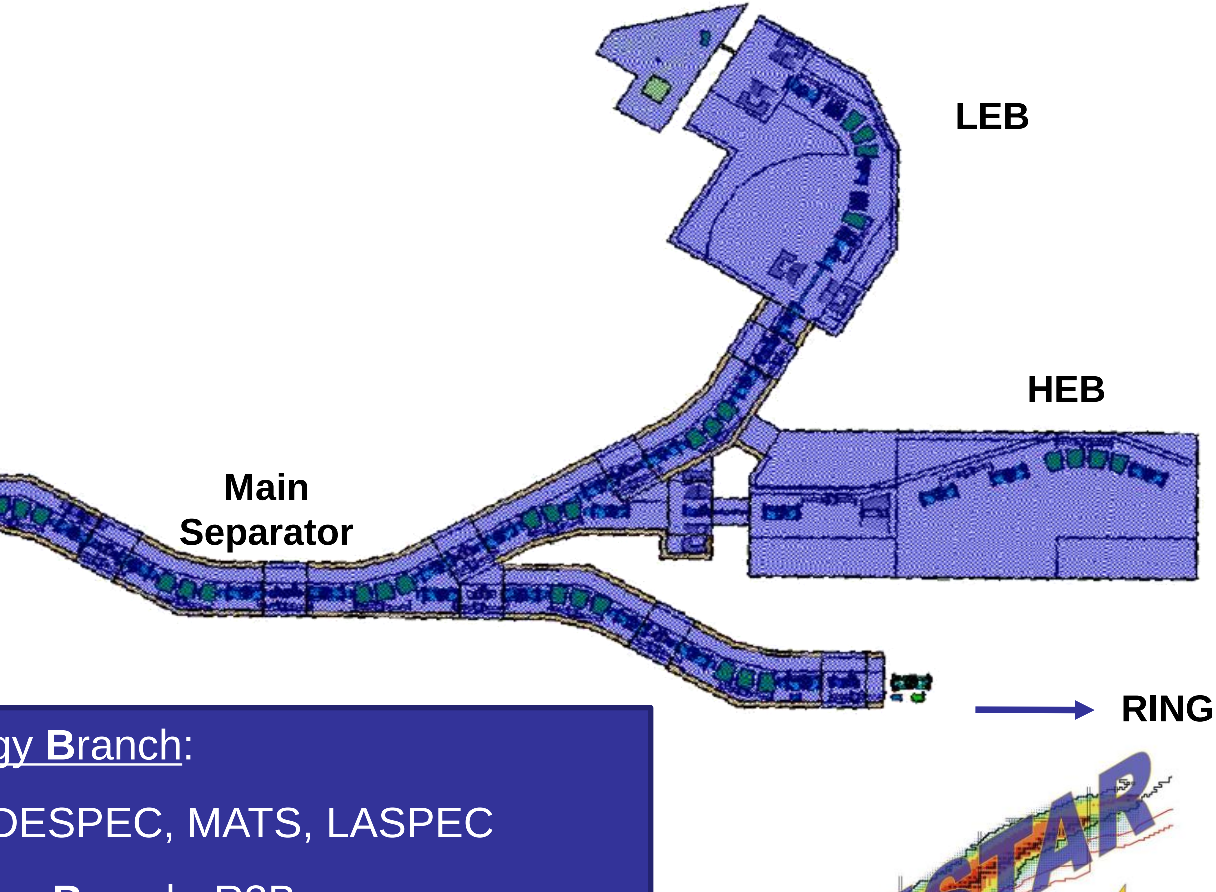
Courtesy of W.R. Plaß

- Ion survial and extraction efficiency ~ 50%
- Extraction times ~ 25 ms

- MR-TOF-MS commissioned on-line
- First direct mass measurements at GSI with an MR-TOF-MS, including ^{213}Rn ($T_{1/2}$ = 20 ms)

NUSTAR - The Facility – HEB ~0.3 – 1.5 GeV/u





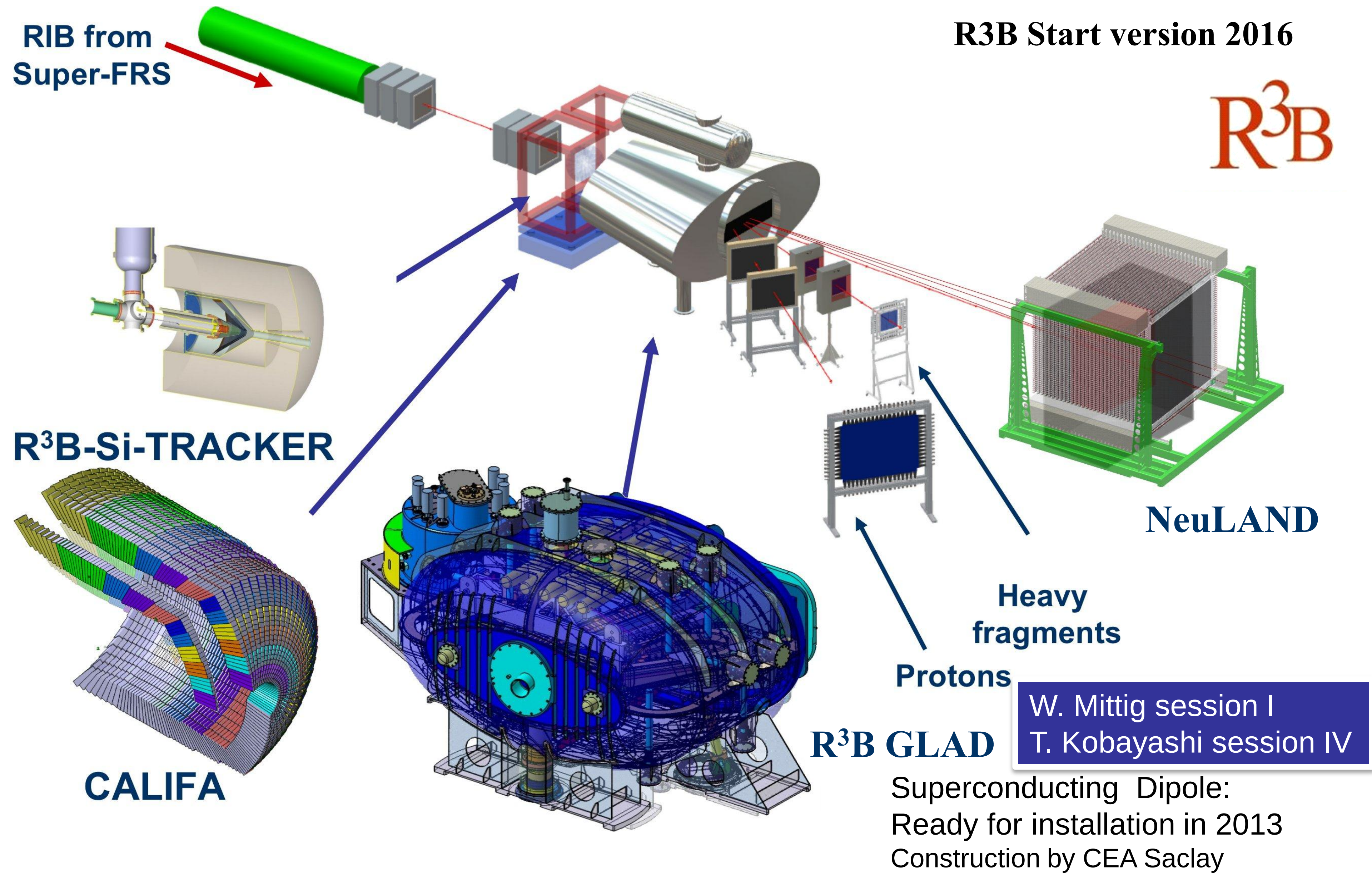
Low **E**nergy **B**ranch:

HISPEC, DESPEC, MATS, LASPEC

High **E**nergy **B**ranch: R3B

Ring Branch: EXL, ILIMA, ELISE

Reactions with Relativistic Radioactive Beams



Status

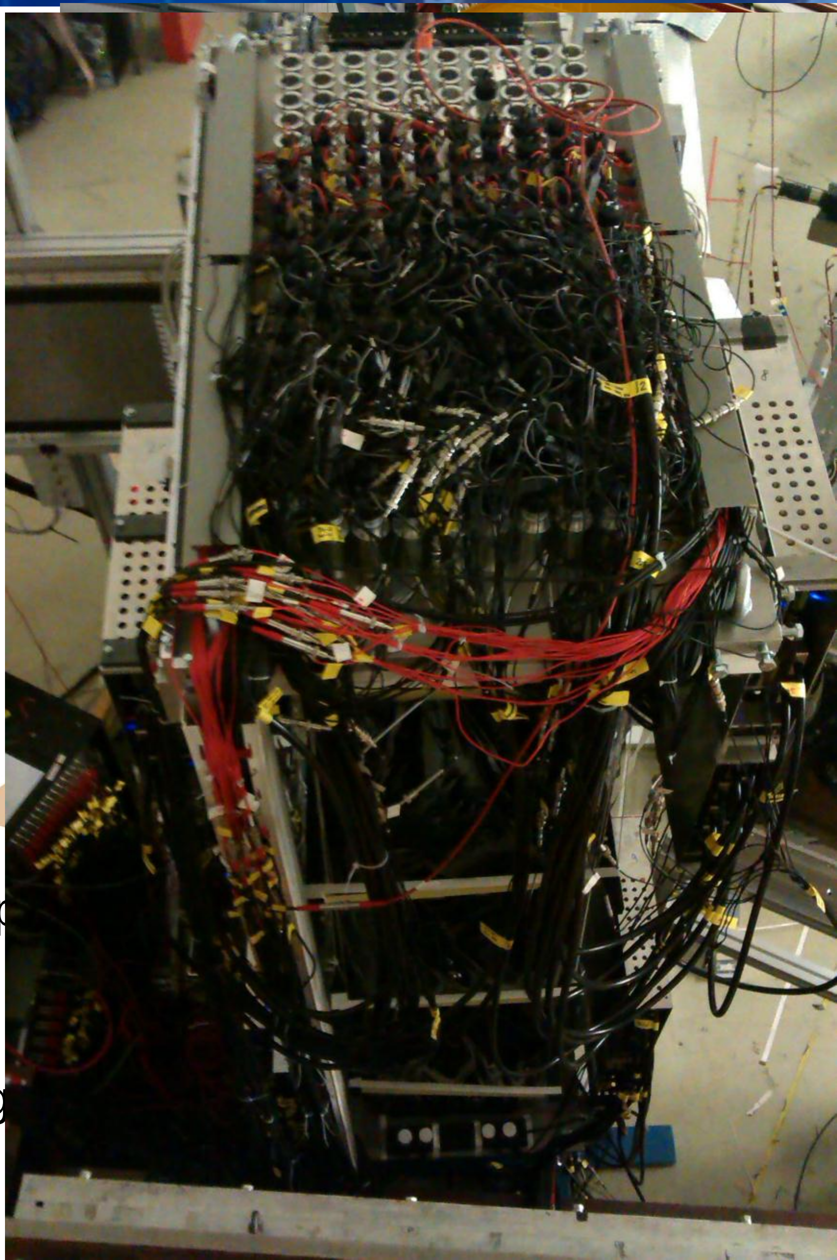
<u>Major achievements</u>

Large-acceptance dipole GLAD

- Cold mass ready and inserted in test cryostat at Saclay
- Final cryostat in construction
- Delivery of magnet to GSI end of 2013

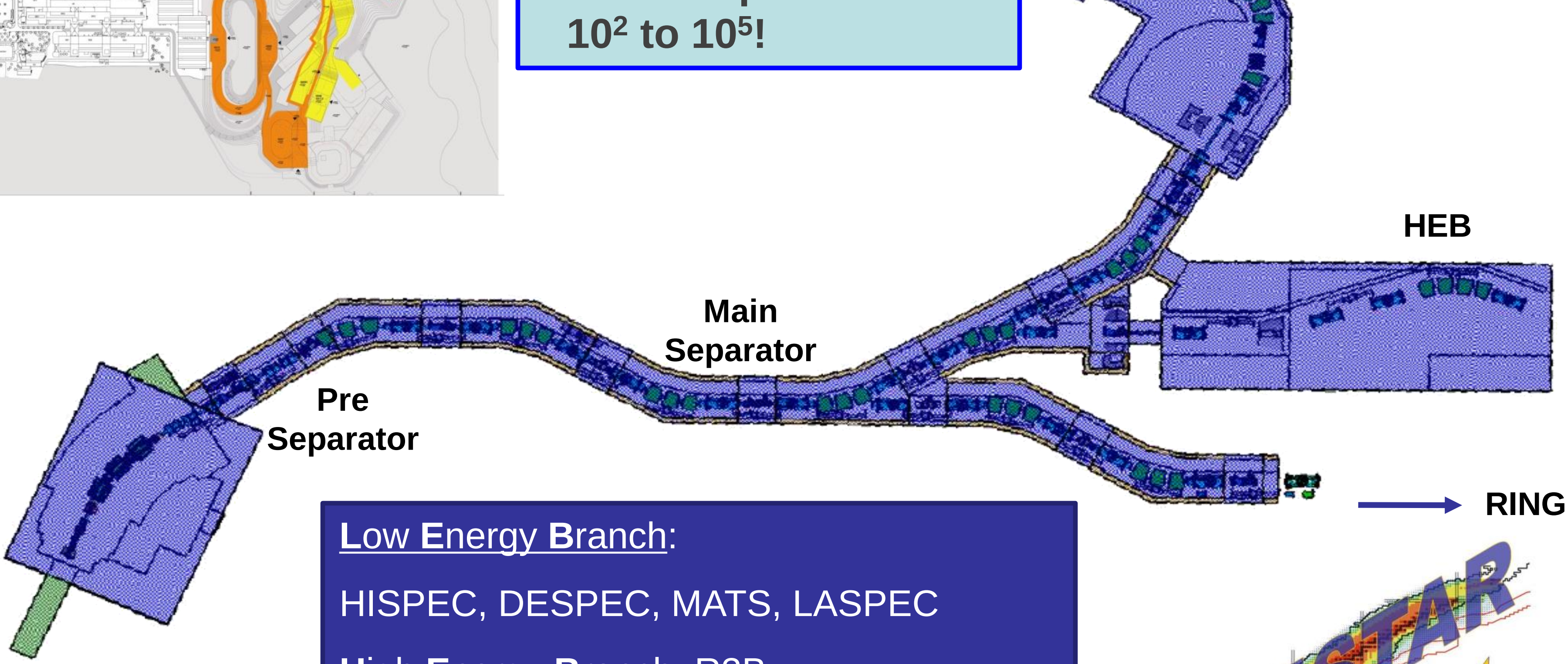
Neutron Detector NeuLAND

- Design finalized
  modular active detector of 3000 scintillator bars; 250x250x300cm^3 active volume
- TDR submitted to FAIR in Nov 2011 (in review p
- Experiment with mono-energetic neutrons from deuteron breakup in Nov 2012:
  200 modules (400 PM channels) in final desig
- Construction of 20% detector in 2013/2014



NUSTAR - The Facility

Beam intensity improvement FRS –Super-FRS: 10^2 to 10^5!



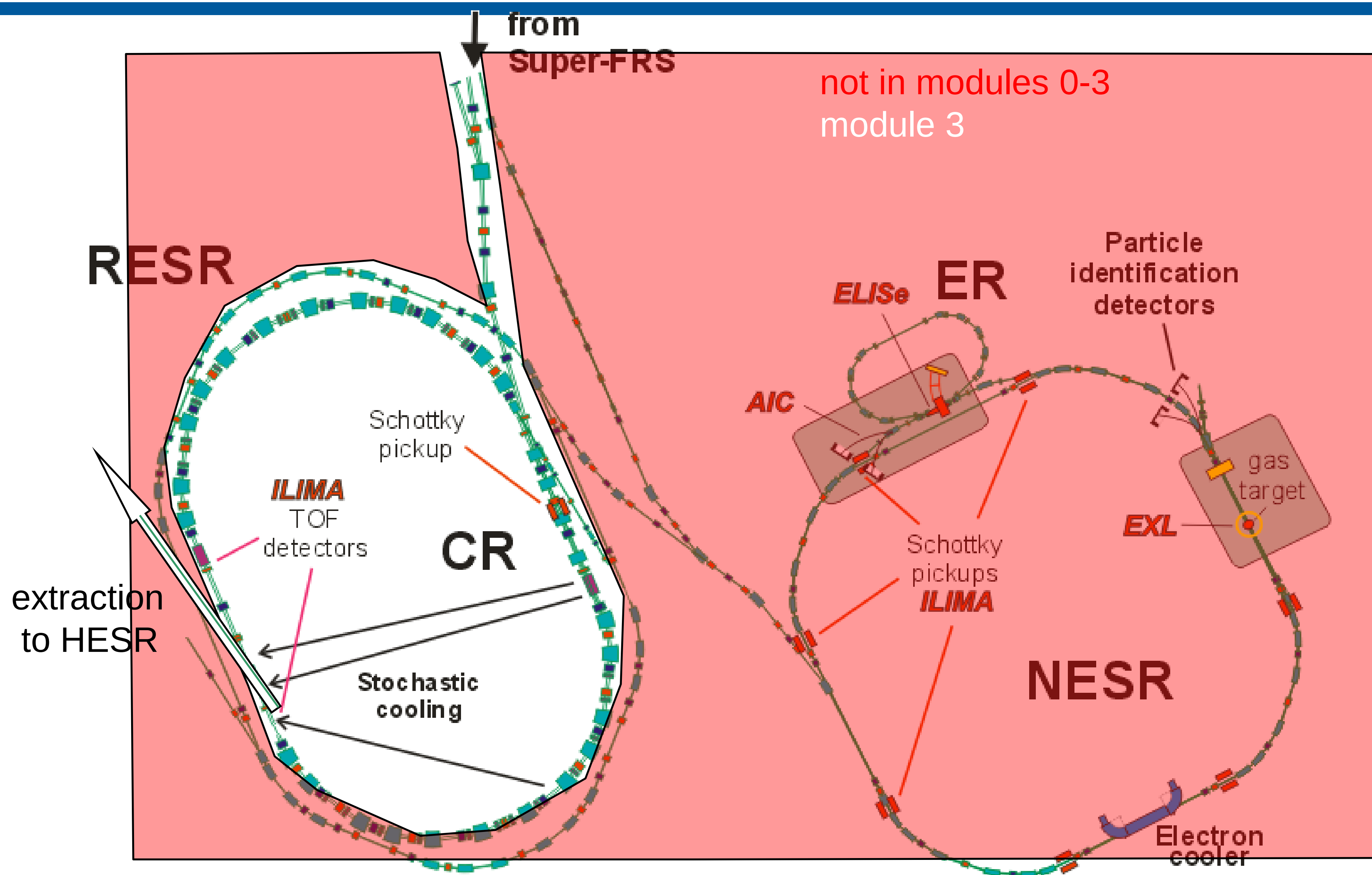
Low Energy Branch:

HISPEC, DESPEC, MATS, LASPEC

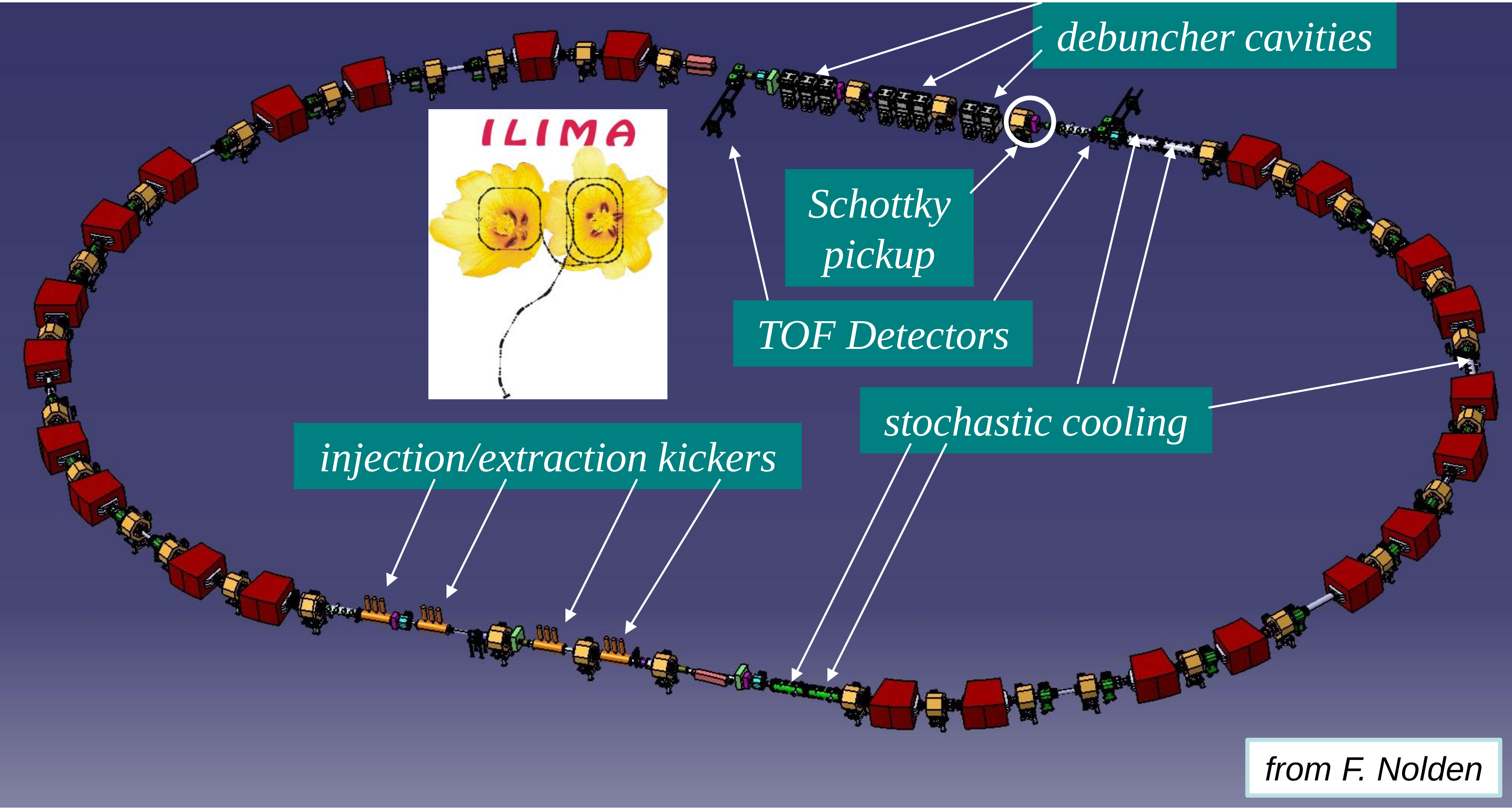
High Energy Branch: R3B

Ring Branch: EXL, ILIMA, ELISE

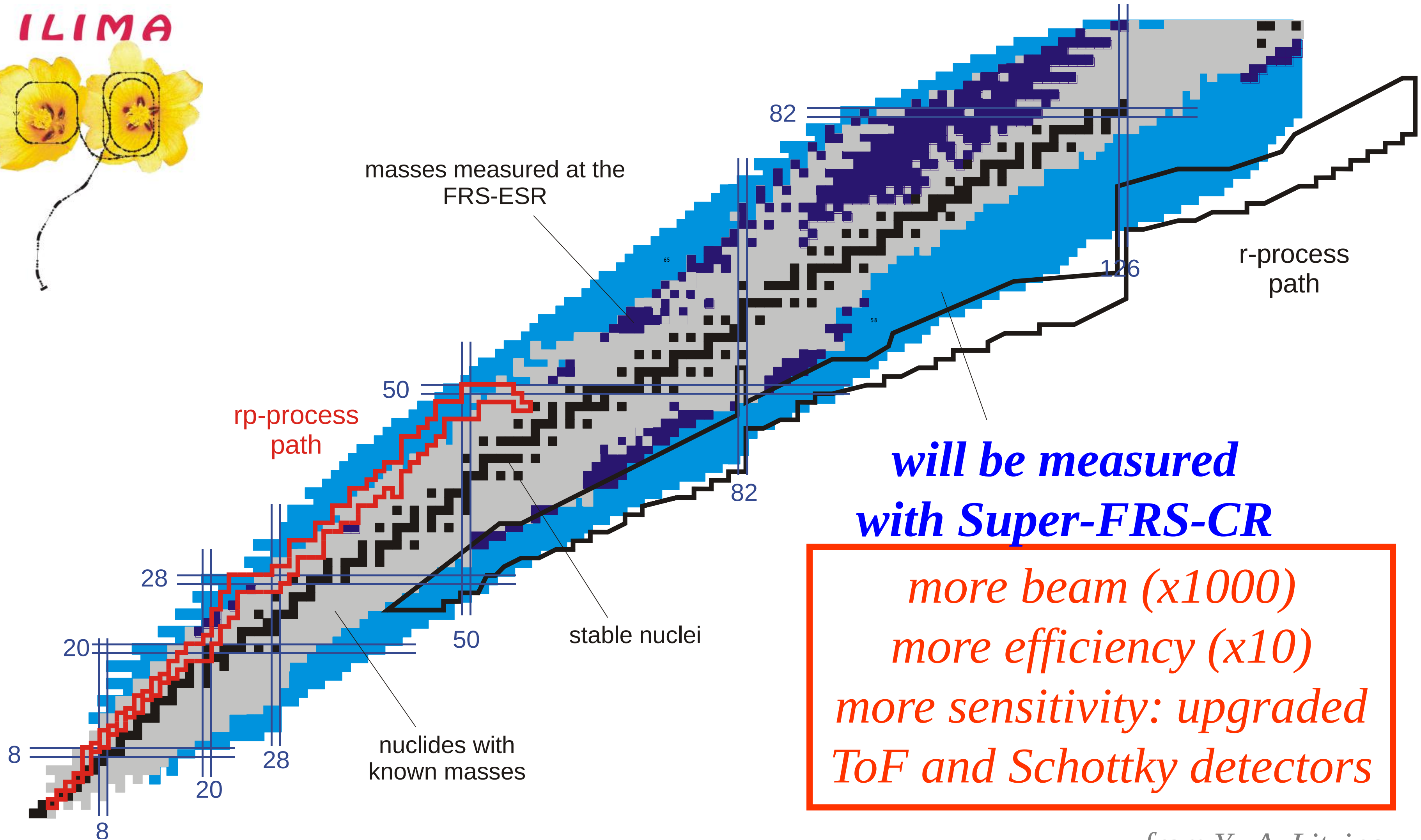
CR, NESR Storage Rings



CR perspective view



Potential for new masses with ILIMA

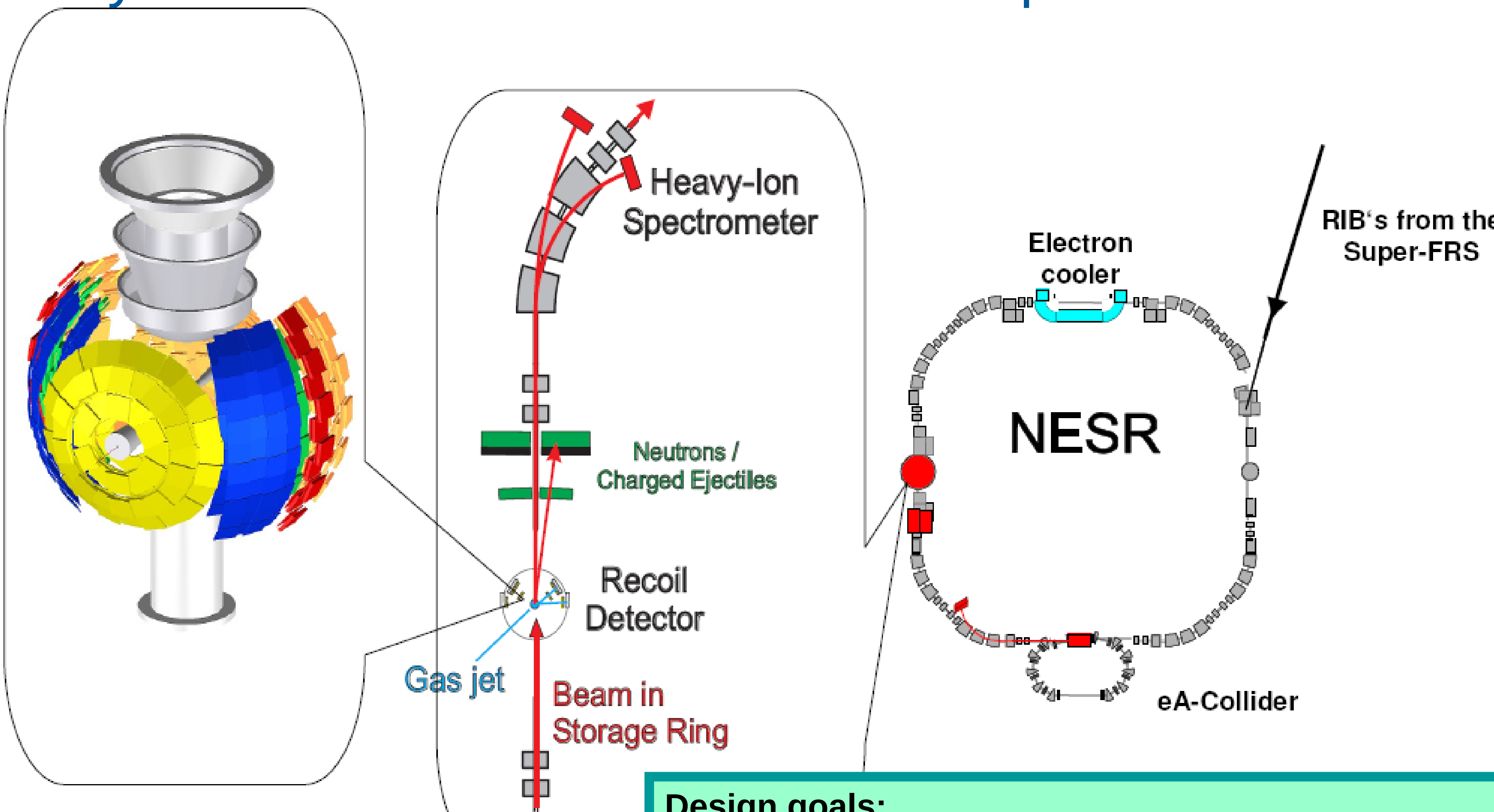


will be measured
with Super-FRS-CR

more beam (x1000)
more efficiency (x10)
more sensitivity: upgraded
ToF and Schottky detectors

from Yu.A. Litvinov

Beyond MSV: Details of the EXL setup



Detection systems for:

- Target recoils and gammas (p,α,n,γ)
- Forward ejectiles (p,n)
- Beam-like heavy ions

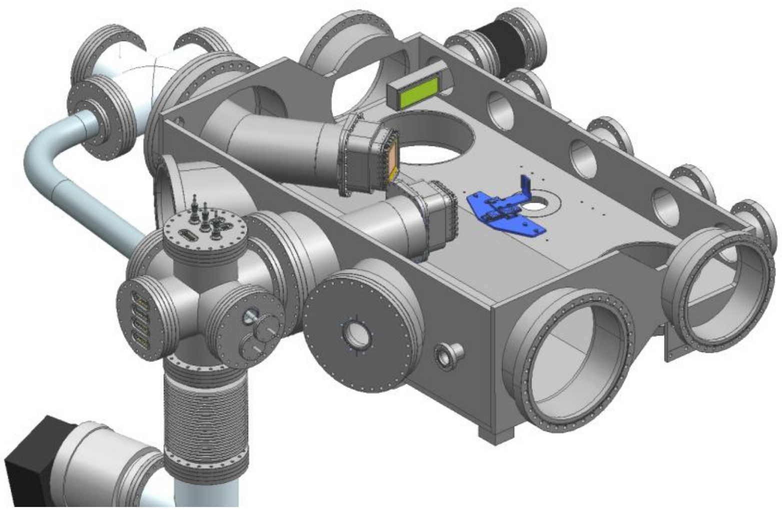
Design goals:

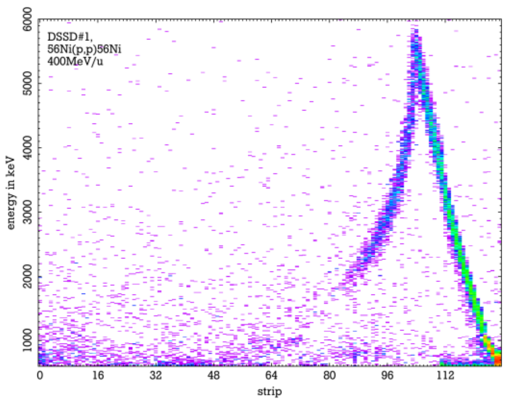
- Universality: applicable to a wide class of reactions
- Good energy and angular resolution
- Large solid angle acceptance
- Specially dedicated for low q measurements with high luminosity (> 10^{28} cm^{-2} s^{-1})

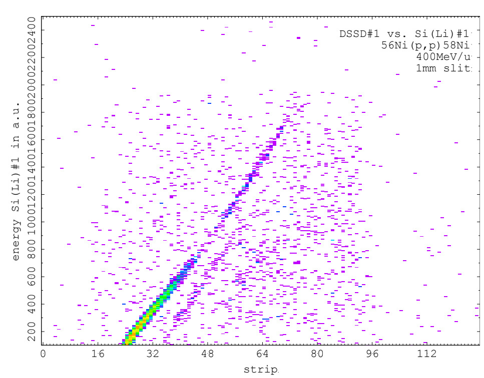
Intermediate storage ring activities/“Green Paper”

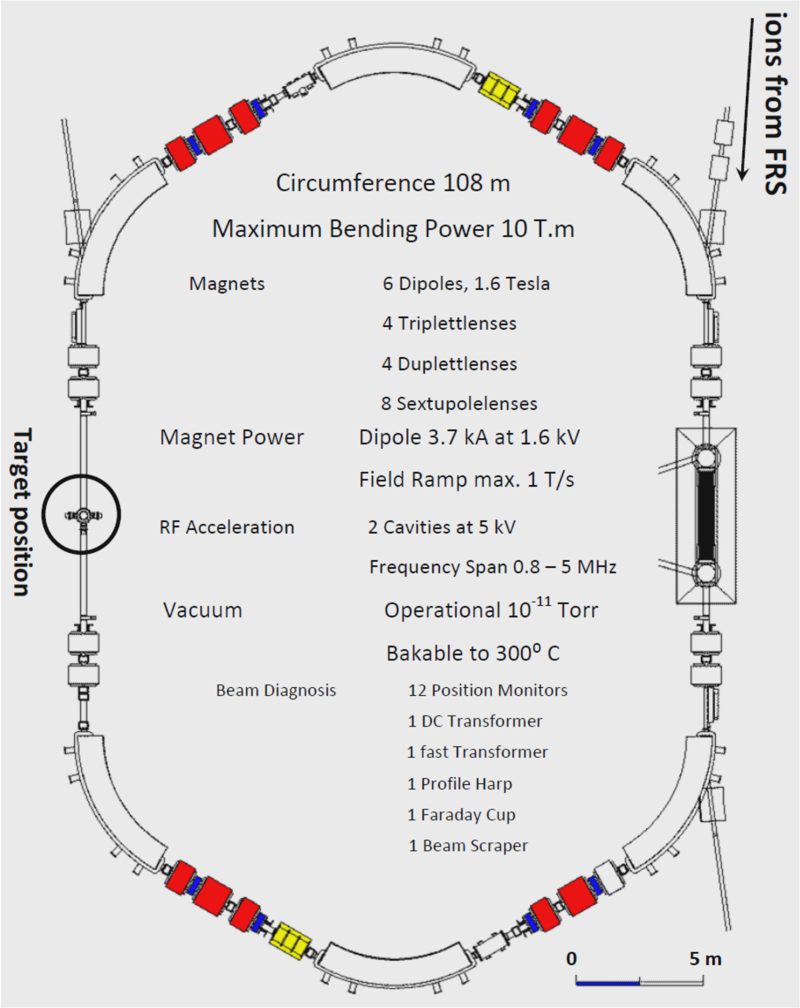
Elastic p-scattering off ^{56}Ni (proposal E105)

Y. Litvinov, session II





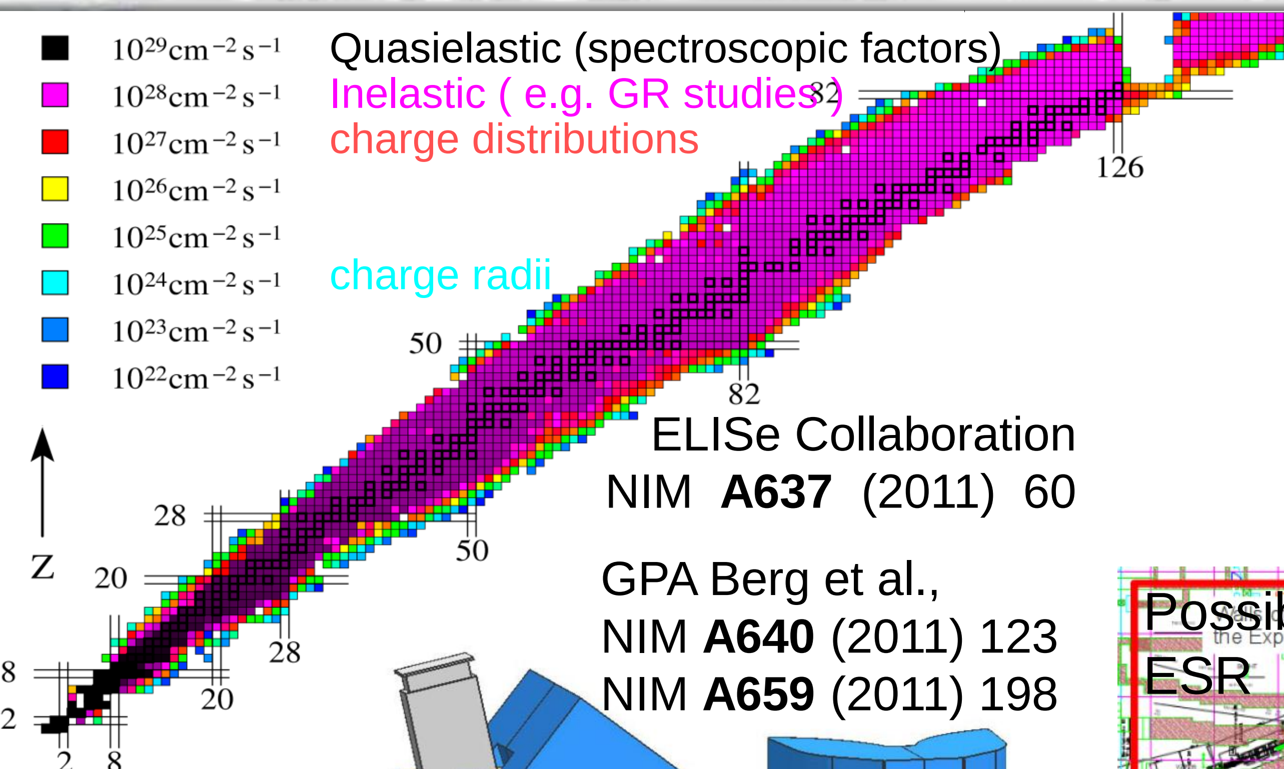


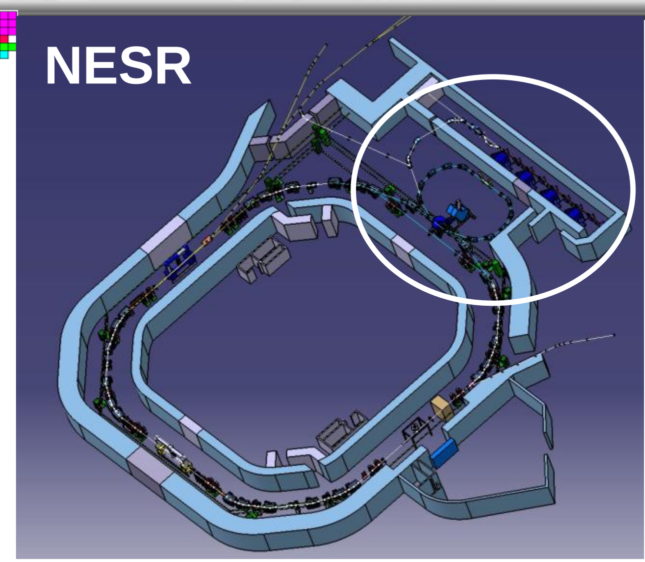


Realization of an RIB electron collider setup

The **ELISe** experiment

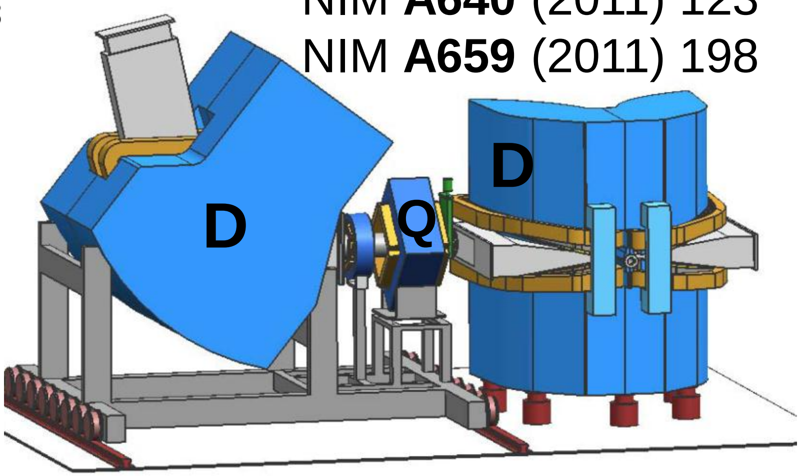
Haik Simon • GSI / Darmstadt

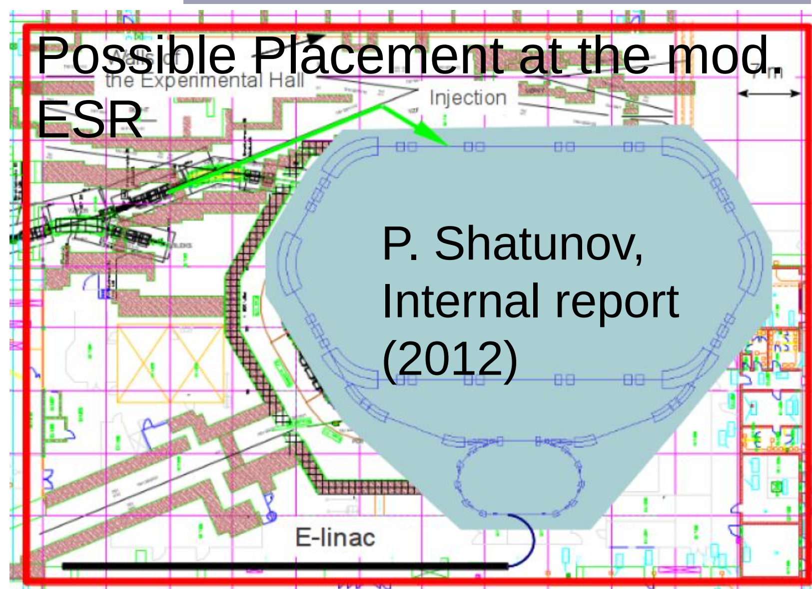




ELISe Collaboration
NIM **A637** (2011) 60

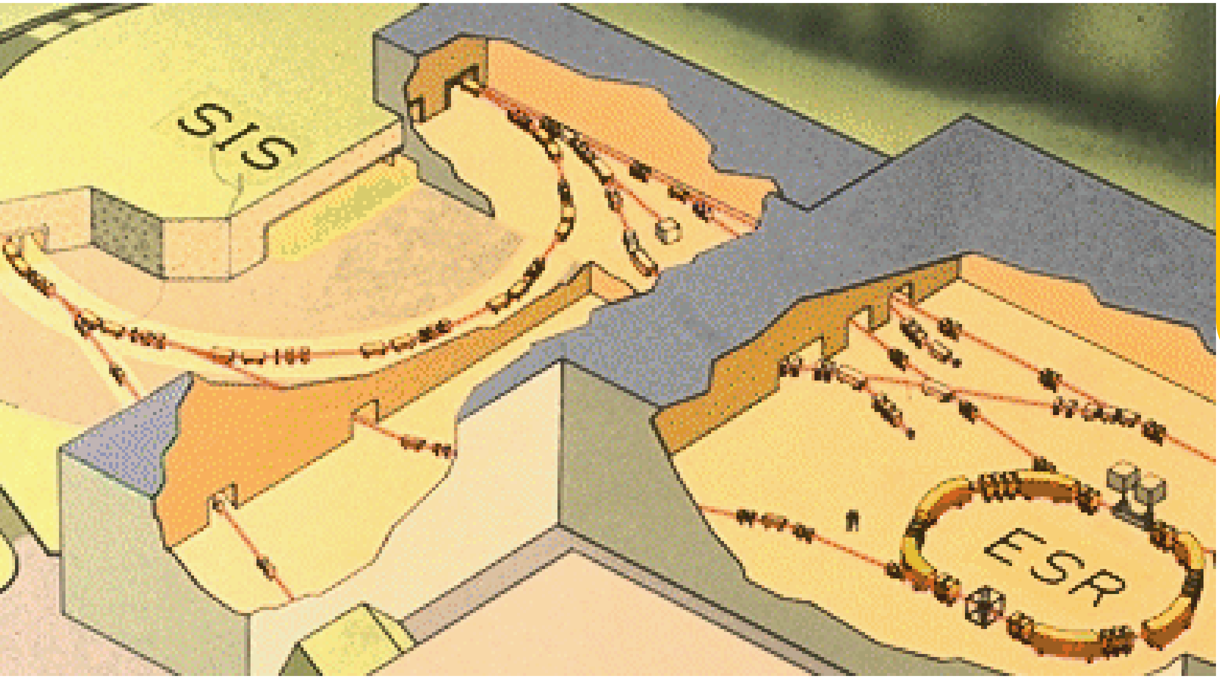
GPA Berg et al.,
NIM **A640** (2011) 123
NIM **A659** (2011) 198





E

Crying at the ESR



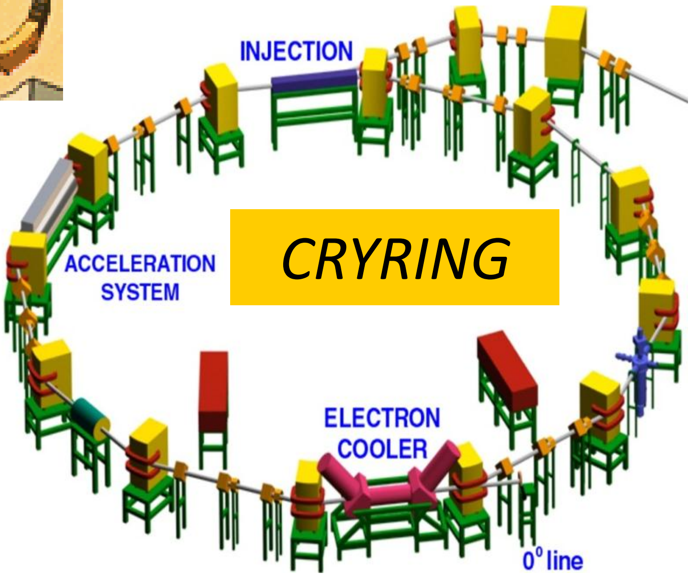
ESR:
Circumference
108 m

Bρ: 10 Tm

*Cryring+ESR: beam energies 0.1-1.0 MeV/u - reaction rates measurements in the Gamow window of the **rp-process***

Cryring
Circumference
54 m

Bρ: 1.44 Tm



Uniqueness of NUSTAR@FAIR — 2018-

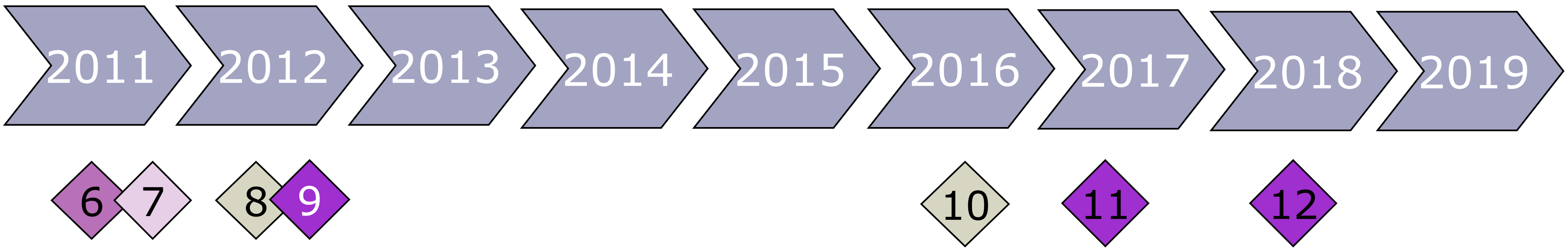
Synchrotron-based in-flight RIB production for:

- High-energy Radioactive Beams (≤1.5 GeV/u)
  - Efficient production, separation, transmission and detection aided by Lorentz boost
  - Chemical universality (wrt. ISOL)
  - Access to also the heaviest nuclei without charge-state ambiguities
  - Large range of attainable reaction mechanisms
- Storage rings
  - Mass measurements and beam preparation/manipulation
  - Isomeric beams
  - Novel experimental tools

Combined with:

- Wide range of state-of-the-art instrumentation
  - Strong evolution from existing programmes

Timeline



6 Building permits

7 Site preparation

8 Civil construction contracts

9 Building of accelerator & detector components

10 Completion of civil construction work

11 Installation & commissioning of accelerators and detectors

12 Start Data taking

G. Rosner

laboratoire commun CEA/DSM CNRS/IN2P3

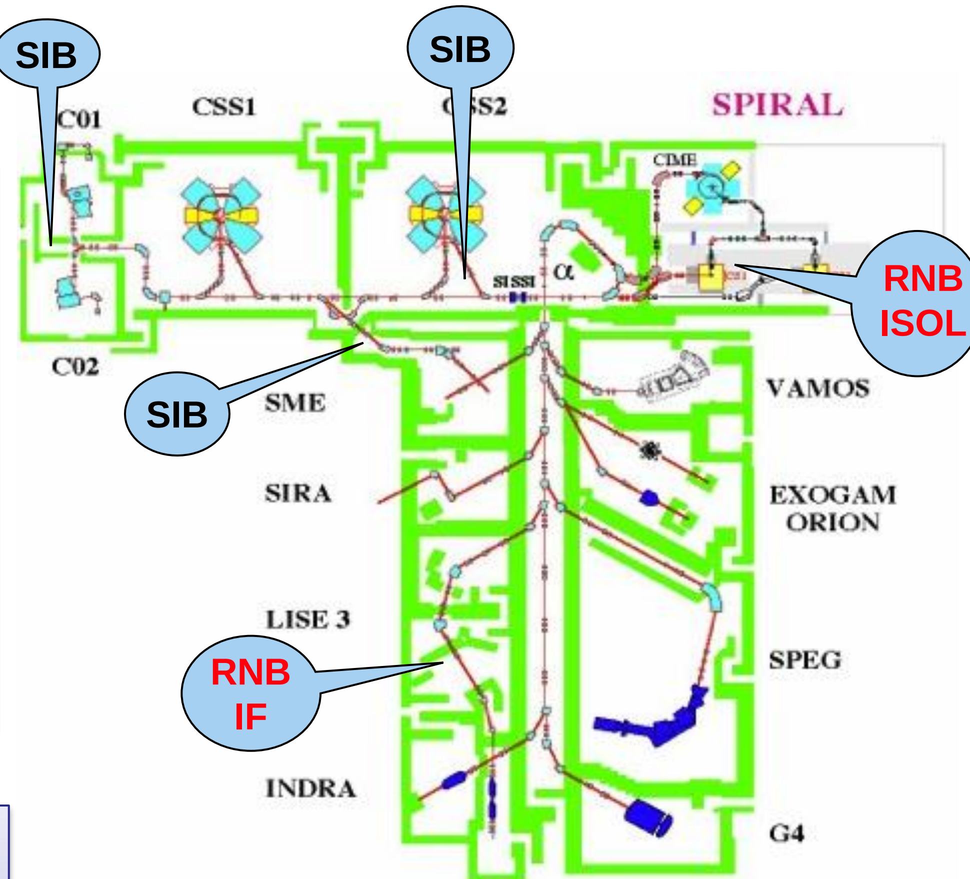
First beam in 1983

STABLE BEAMS
- from C to U
- energies up to 95 A.MeV
- intensities up to 10^{13} pps (3 kW)
- up to 4 beam simultaneously

RIB production schemes
- in-flight method : SISSI, LISE - since 1985
- ISOL method : SPIRAL 1 – since 2001

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

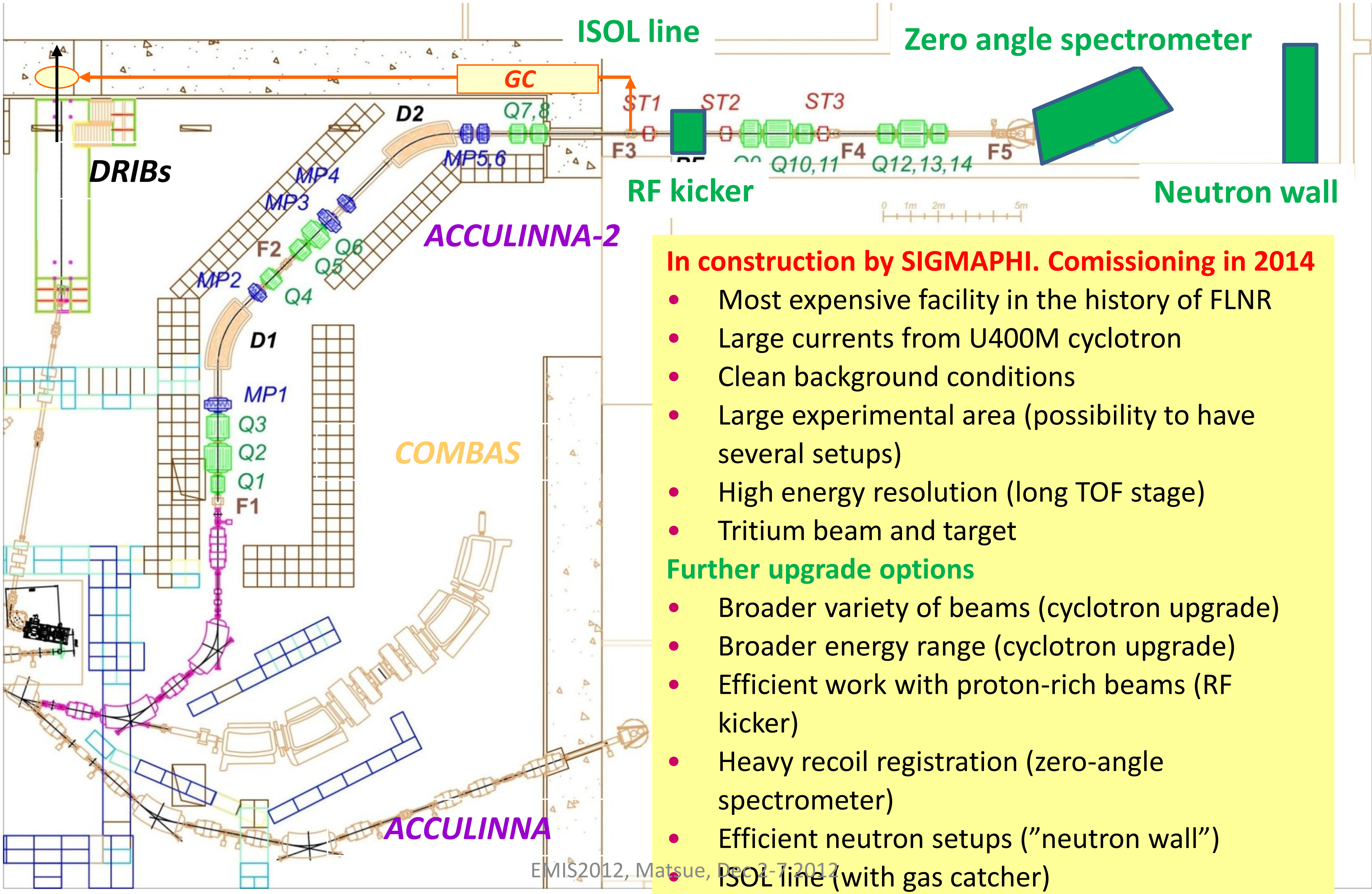
Staff 260 (29 physicists)



Primary Beams:

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

Flerov Lab (Dubna): ACCULINNA−2: a new in−flight separator at U−400M



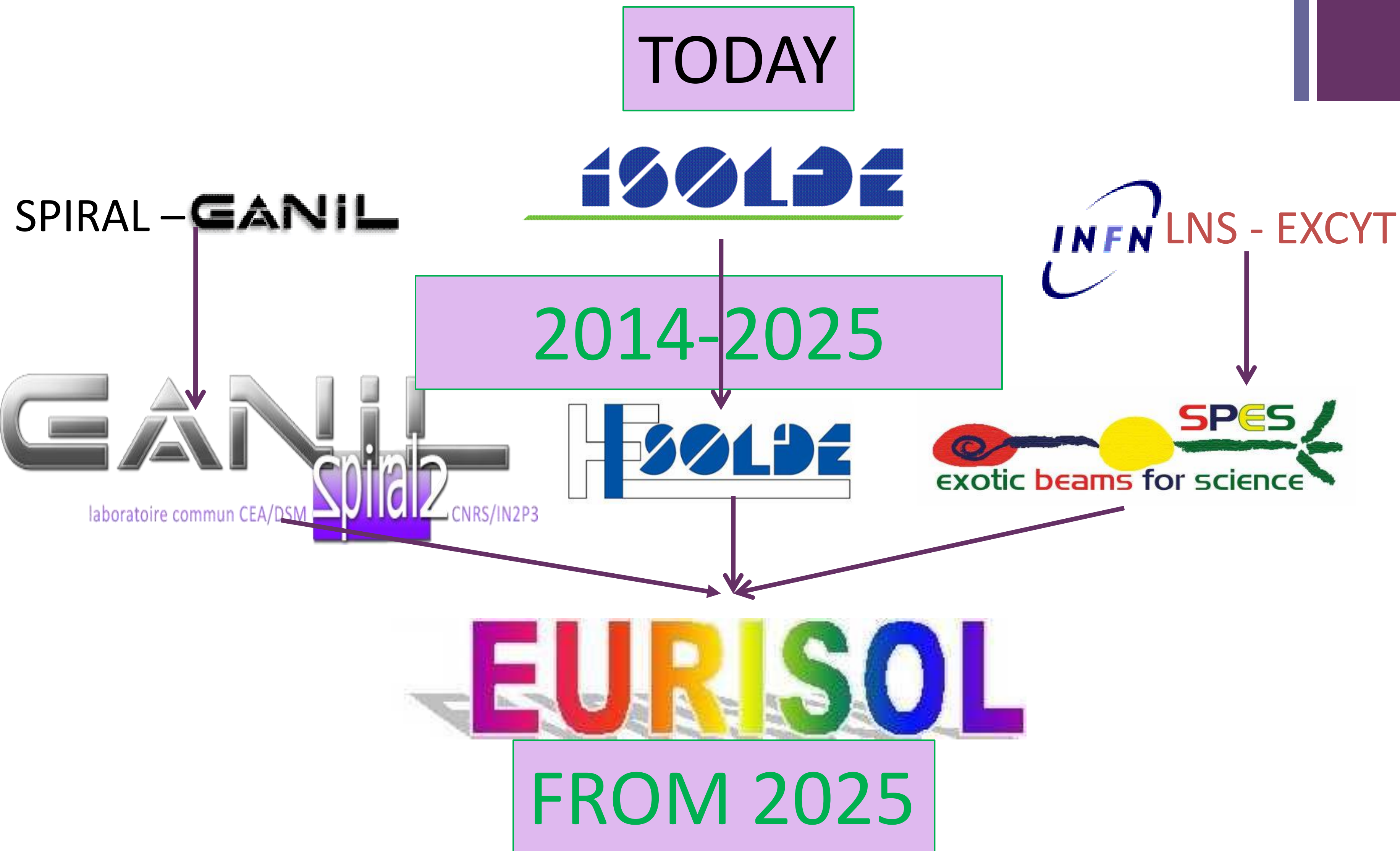
In construction by SIGMAPHI. Comissioning in 2014

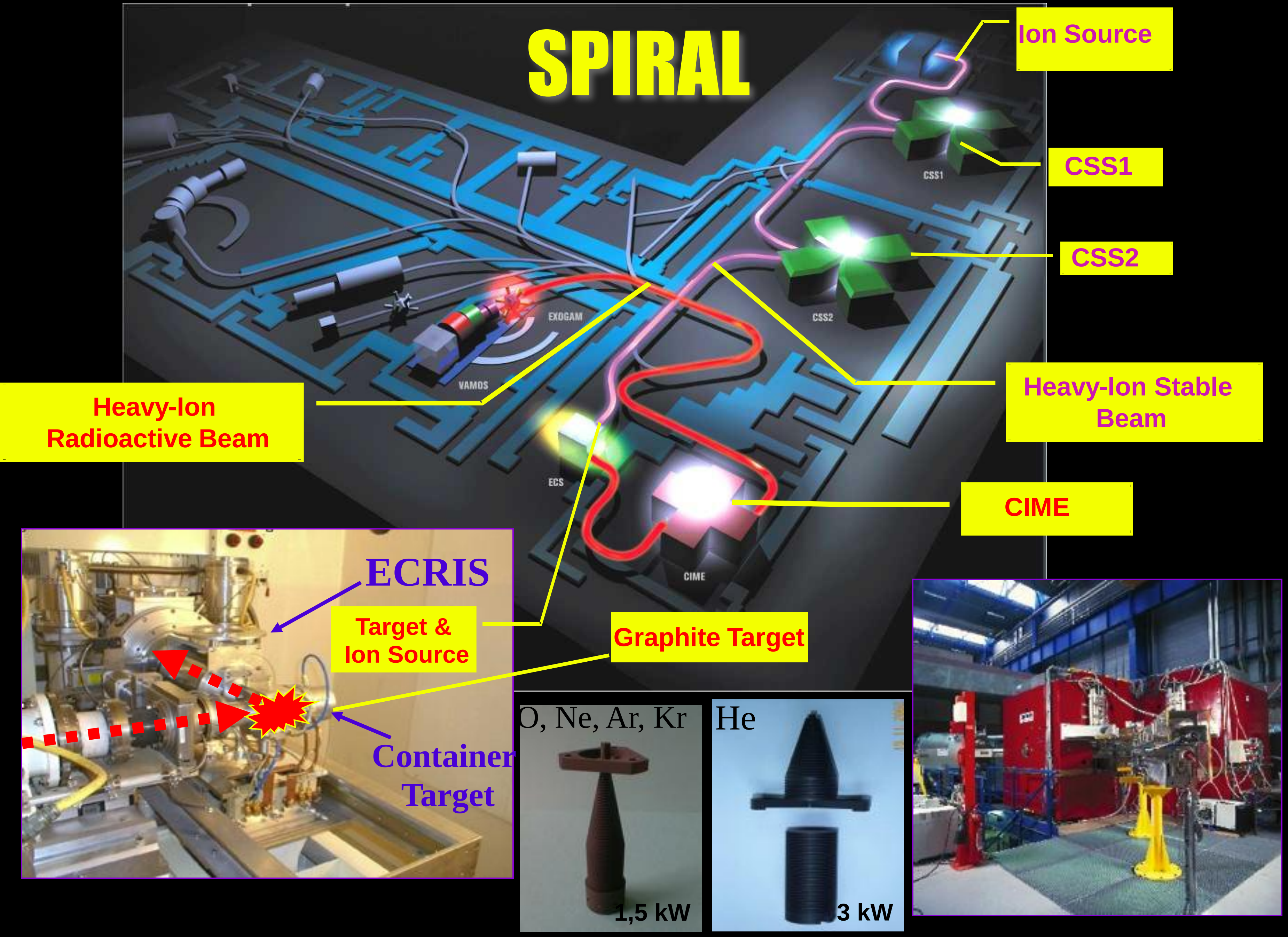
- Most expensive facility in the history of FLNR
- Large currents from U400M cyclotron
- Clean background conditions
- Large experimental area (possibility to have several setups)
- High energy resolution (long TOF stage)
- Tritium beam and target

Further upgrade options

- Broader variety of beams (cyclotron upgrade)
- Broader energy range (cyclotron upgrade)
- Efficient work with proton-rich beams (RF kicker)
- Heavy recoil registration (zero-angle spectrometer)
- Efficient neutron setups (”neutron wall”)
- ISOL line (with gas catcher)

ISOL Roadmap in Europe



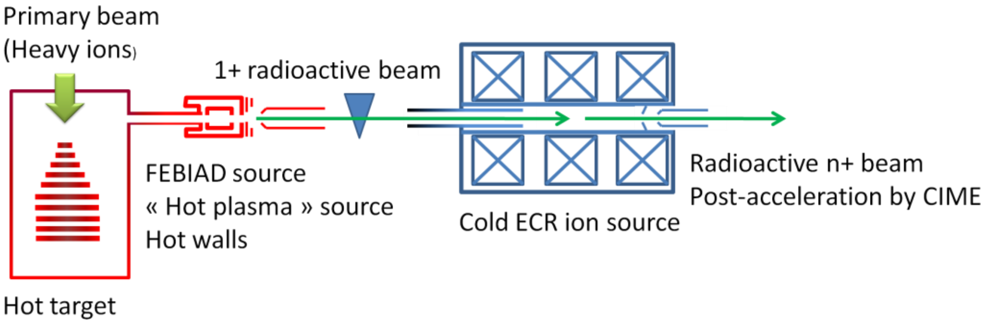

SPIRAL
Ion Source
CSS1
CSS2
Heavy-Ion Stable Beam
CIME
Heavy-Ion Radioactive Beam
EXOGAM
VAMOS
ECS
ECRIS
Target & Ion Source
Graphite Target
Container Target
O, Ne, Ar, Kr
1,5 kW
He
3 kW

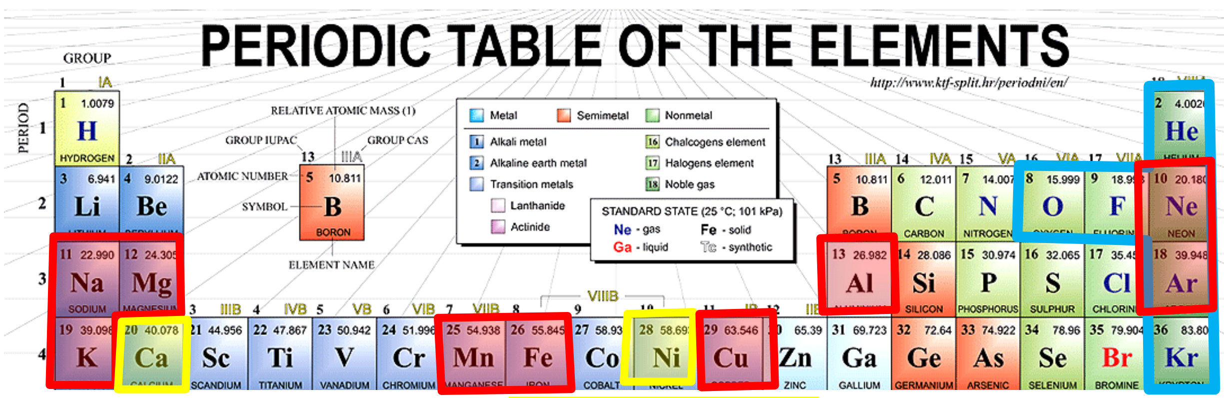
SPIRAL 1 upgrade – New RIB

laboratoire commun CEA/DSM CNRS/IN2P3

Metallic beams from a FEBIAD ion source

1+/n+ ionisation scheme





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**

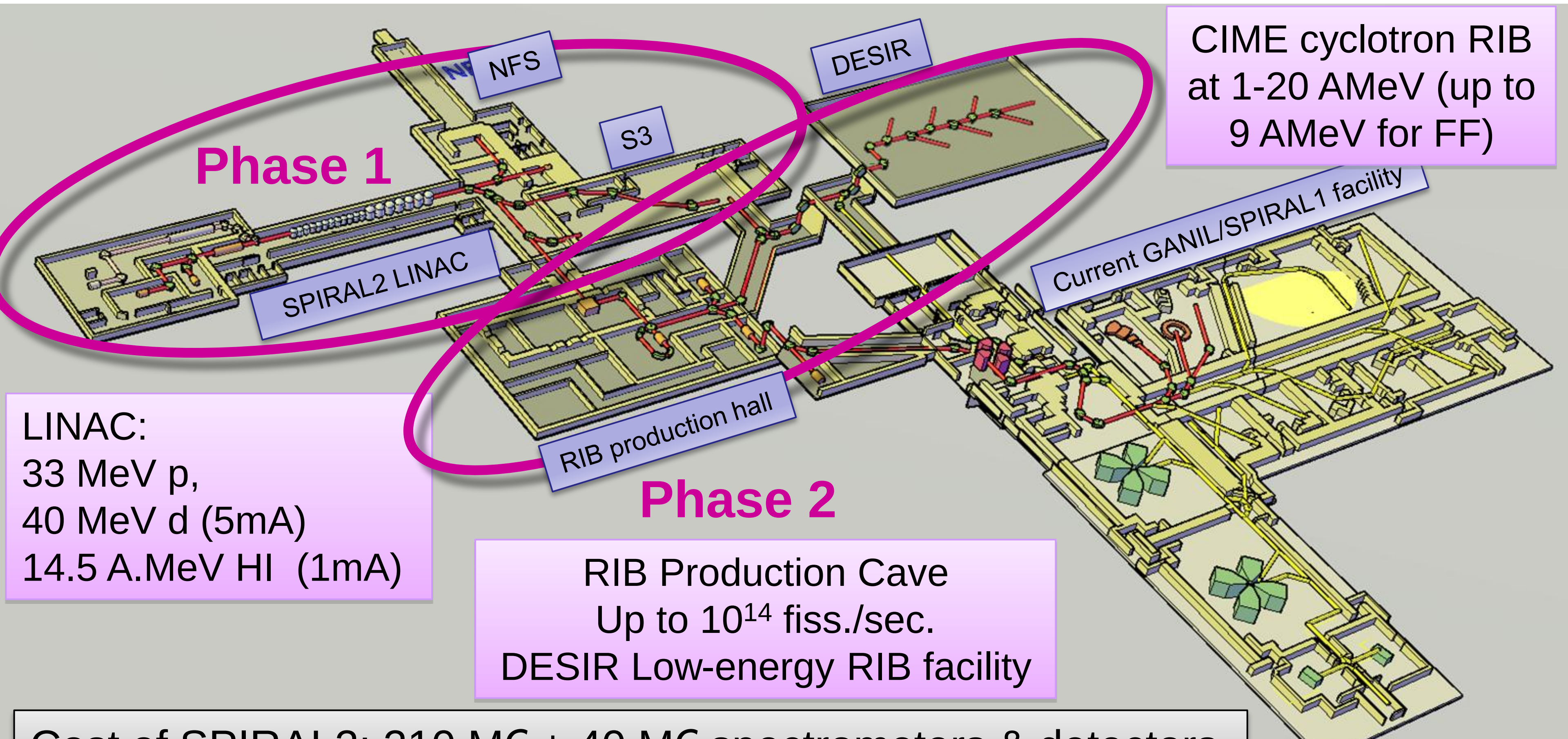
P. Delahaye, O. Bajeat, session III

Existing GANIL facility & SPIRAL2 under construction

Caen, France

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

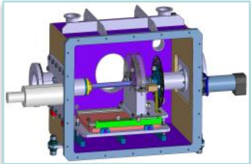
Cost of SPIRAL2: 210 M€ + 40 M€ spectrometers & detectors

T. Turkurtian
Nieto, session IV

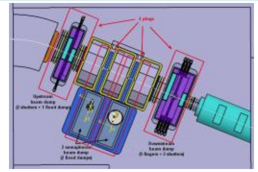
130 physicists, 30 institutions, 12 countries
Hervé SAVAJOLS – GANIL, France (Project leader)
Antoine DROUART – Irfu/CEA, France (Spokesperson)
Jerry A. NOLEN – ANL, USA (Spokesperson)
Martial Authier – Irfu/CEA, France (Technical Coord.)

First experiment in 2015

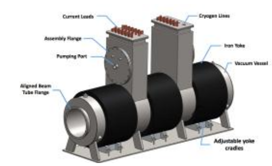
High power
Rotating targets
including actinides

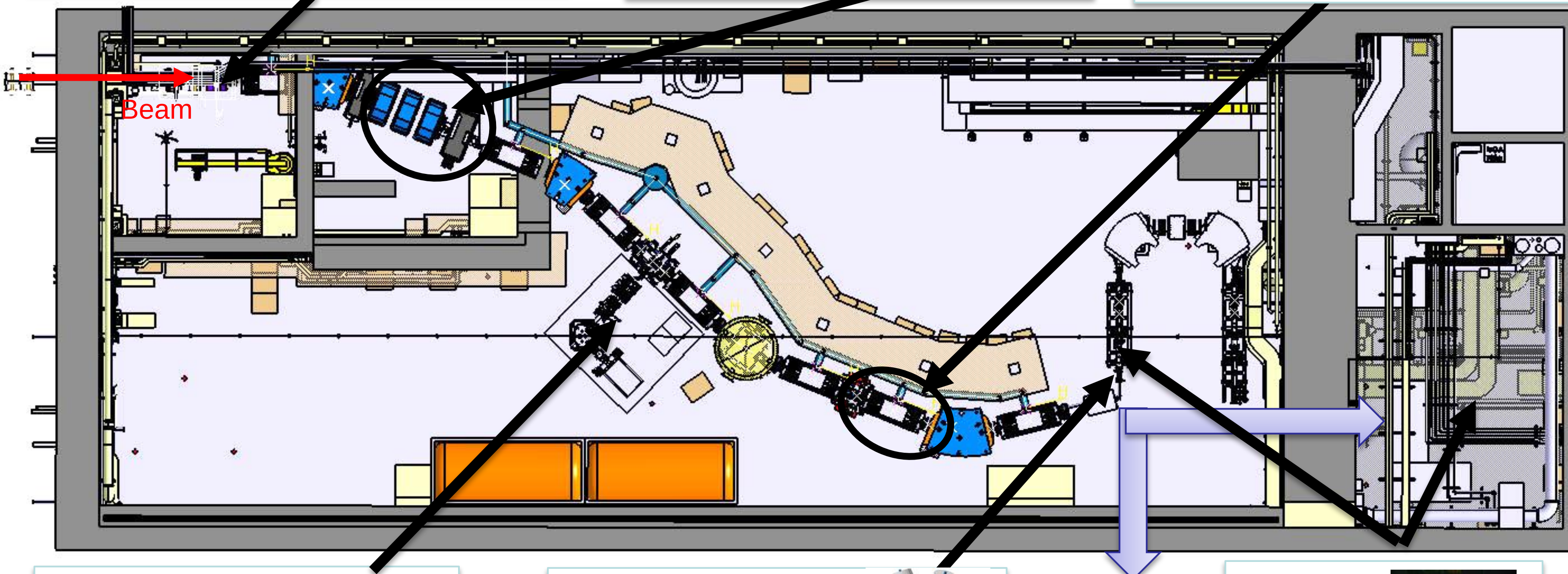


Beam dump
& Movable
fingers

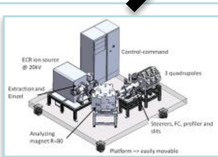


Large
acceptance
Multipoles

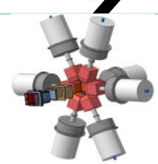




FISIC setup
Fast Ion Slow
Ion Collisions

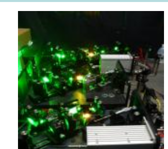


Implantation-decay
station at the mass
dispersive plan



DESIR

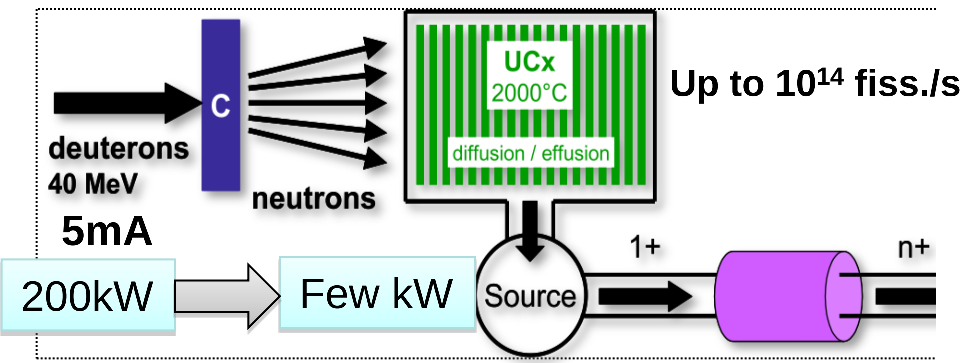
Low
Energy
Branch

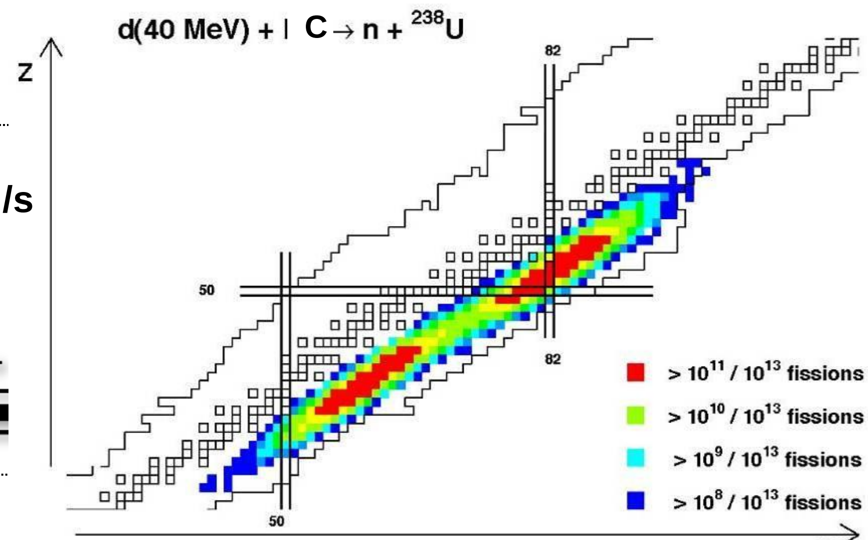


M. Huyse, session V

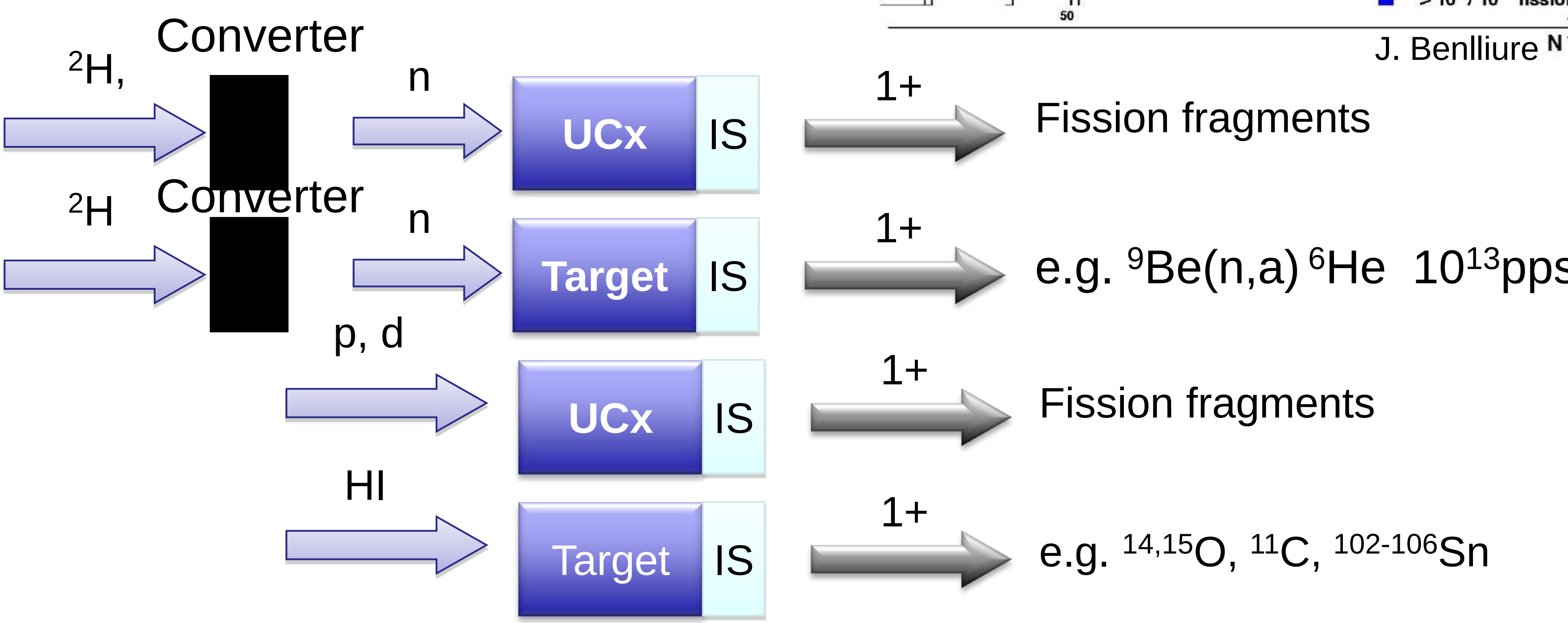
ISOL Rare Isotope Beams at SPIRAL 2

Up to 2.3 kg HD UC_2





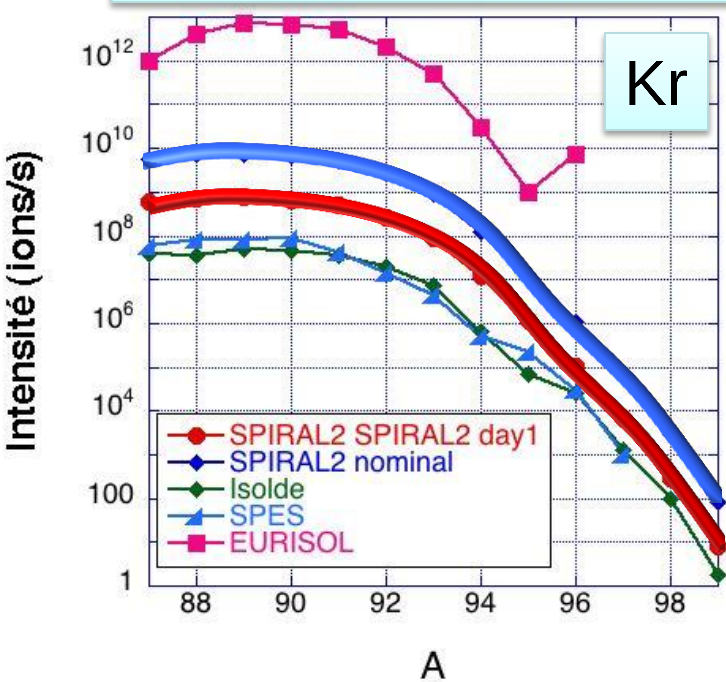
J. Benlliure



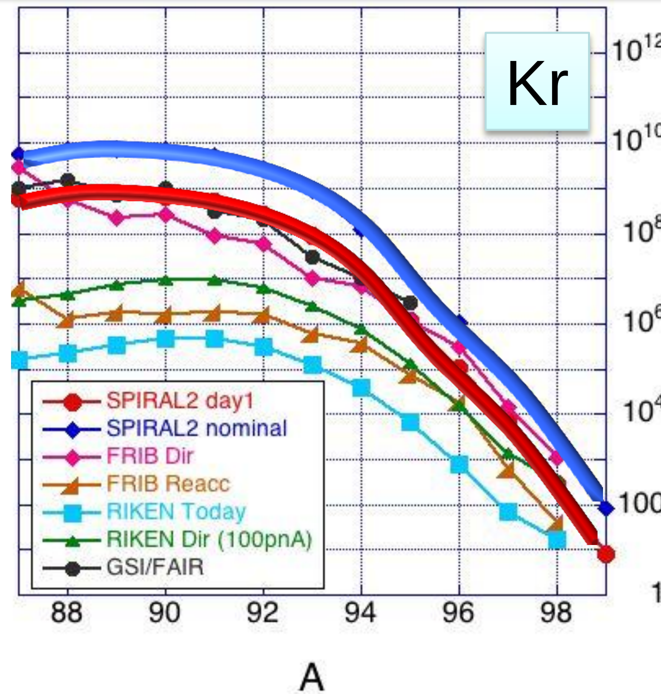
SPIRAL 2: Advanced ISOL RIB facility

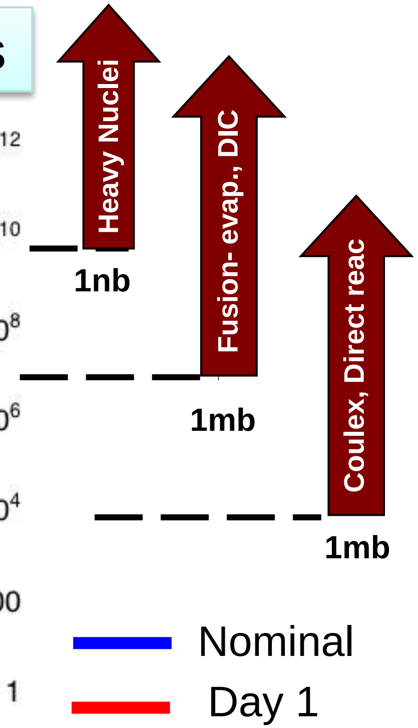
SPIRAL 2: Experiments with RIB at low cross sections and very exotic nuclei at few MeV/nucleon

SPIRAL2 – ISOL facilities



SPIRAL2 – In flight facilities





ISOL RIB beams:

- high intensity, optical quality & purity

Versatility:

- light & HI, high-intensity stable-ion & RIB

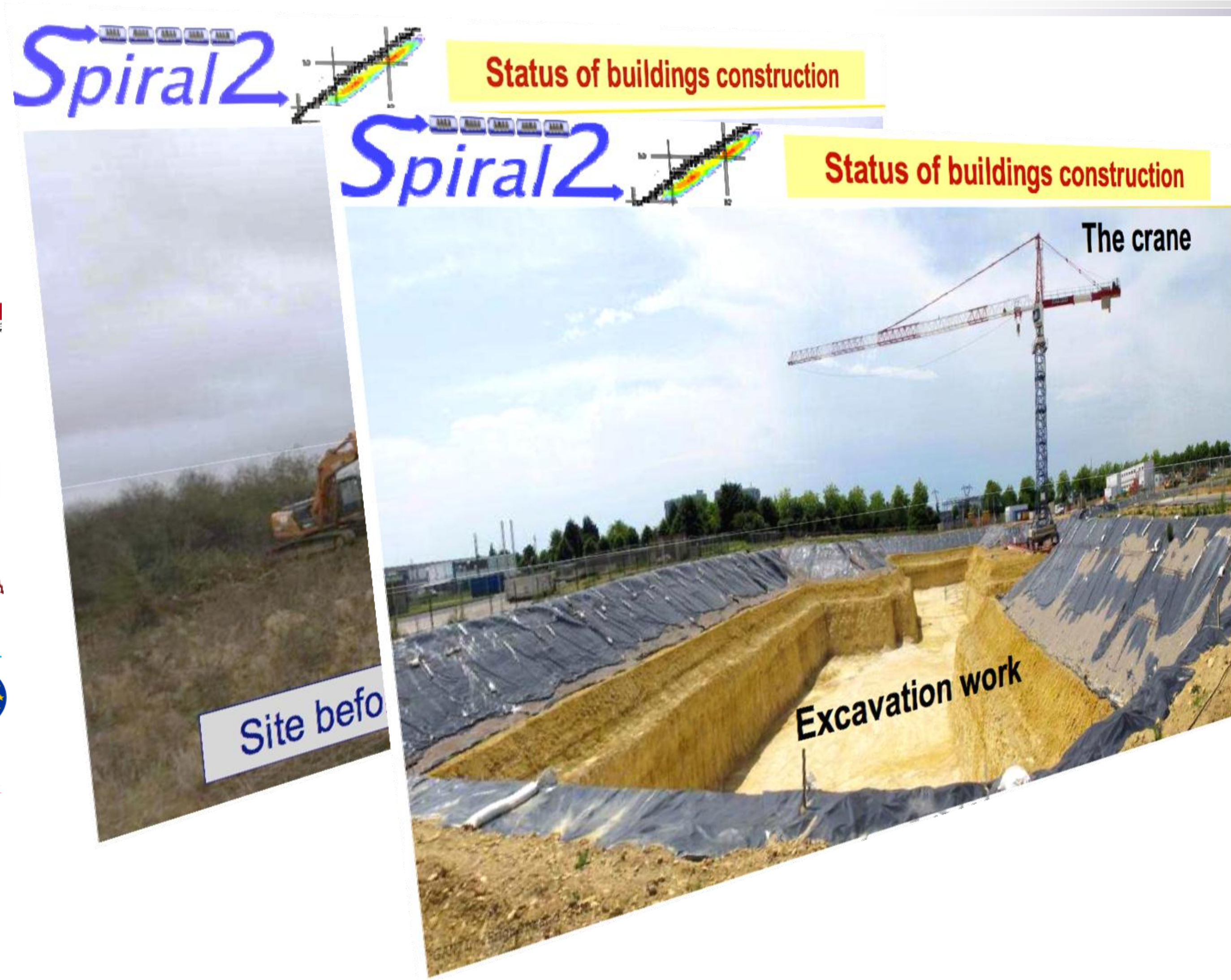
- Multi-beam capabilities,

- Months of beam-time

- World-class arrays & detectors

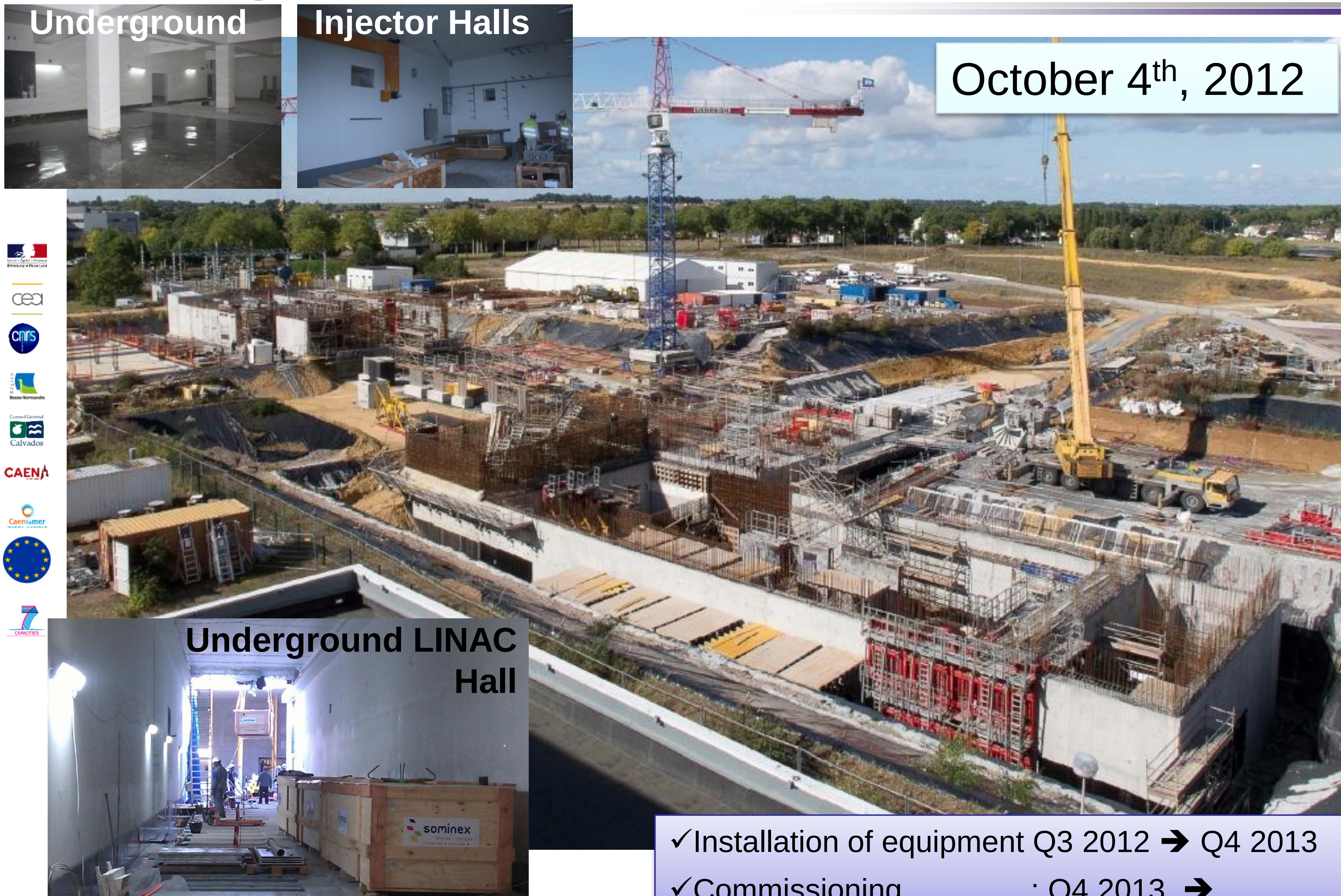
SPIRAL2 phase 1 civil construction

SPIRAL2 phase 1 civil construction



SPIRAL2 phase 1 civil construction

SPIRAL2 phase 1 civil construction



- ✓Installation of equipment Q3 2012 ➔ Q4 2013
- ✓Commissioning : Q4 2013 ➔

GANIL/SPIRAL 2 facility: status & outlook

SPIRAL2 Phase 1
Commissioning/ experiments in 2014

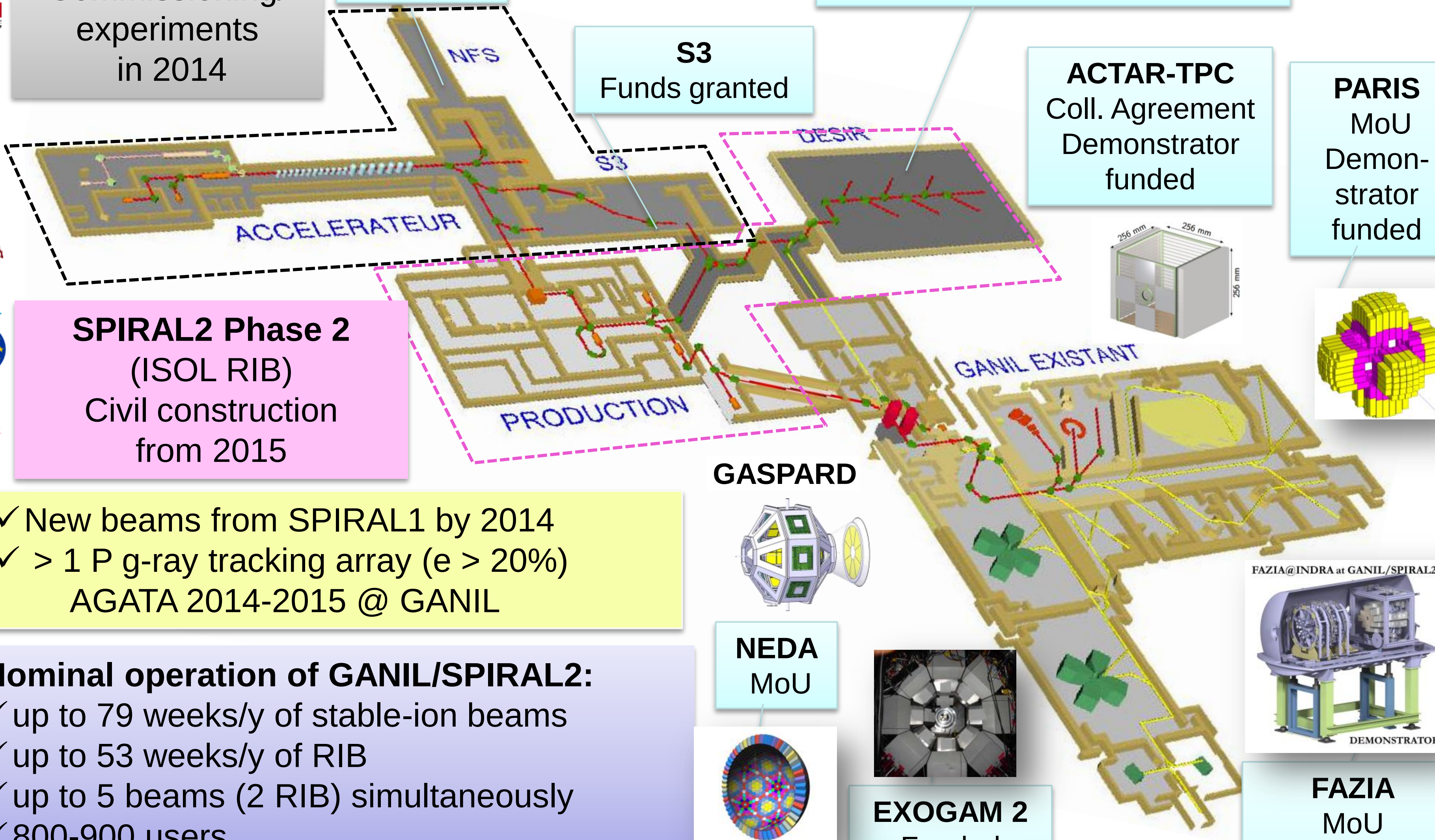
NFS
Funded MoU

DESIR Coll. Agreement – DECA
Funds granted

S3
Funds granted

ACTAR-TPC
Coll. Agreement
Demonstrator funded

PARIS
MoU
Demon-strator funded



SPIRAL2 Phase 2
(ISOL RIB)
Civil construction from 2015

- ✓ New beams from SPIRAL1 by 2014
- ✓ > 1 P g-ray tracking array (e > 20%) AGATA 2014-2015 @ GANIL

GASPARD

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

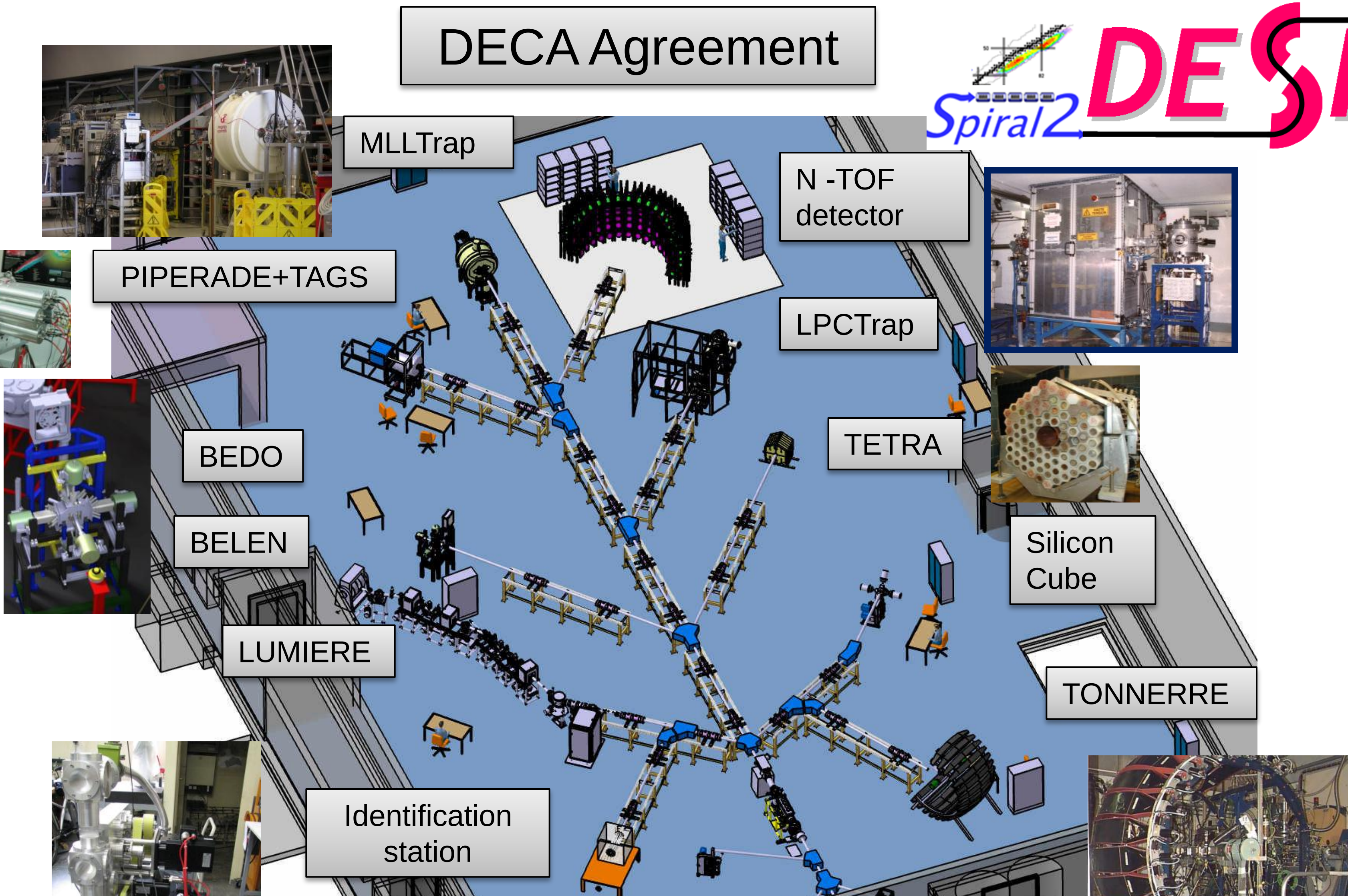
NEDA
MoU

EXOGAM 2
Funded MoU

FAZIA
MoU
Demonstrator funded

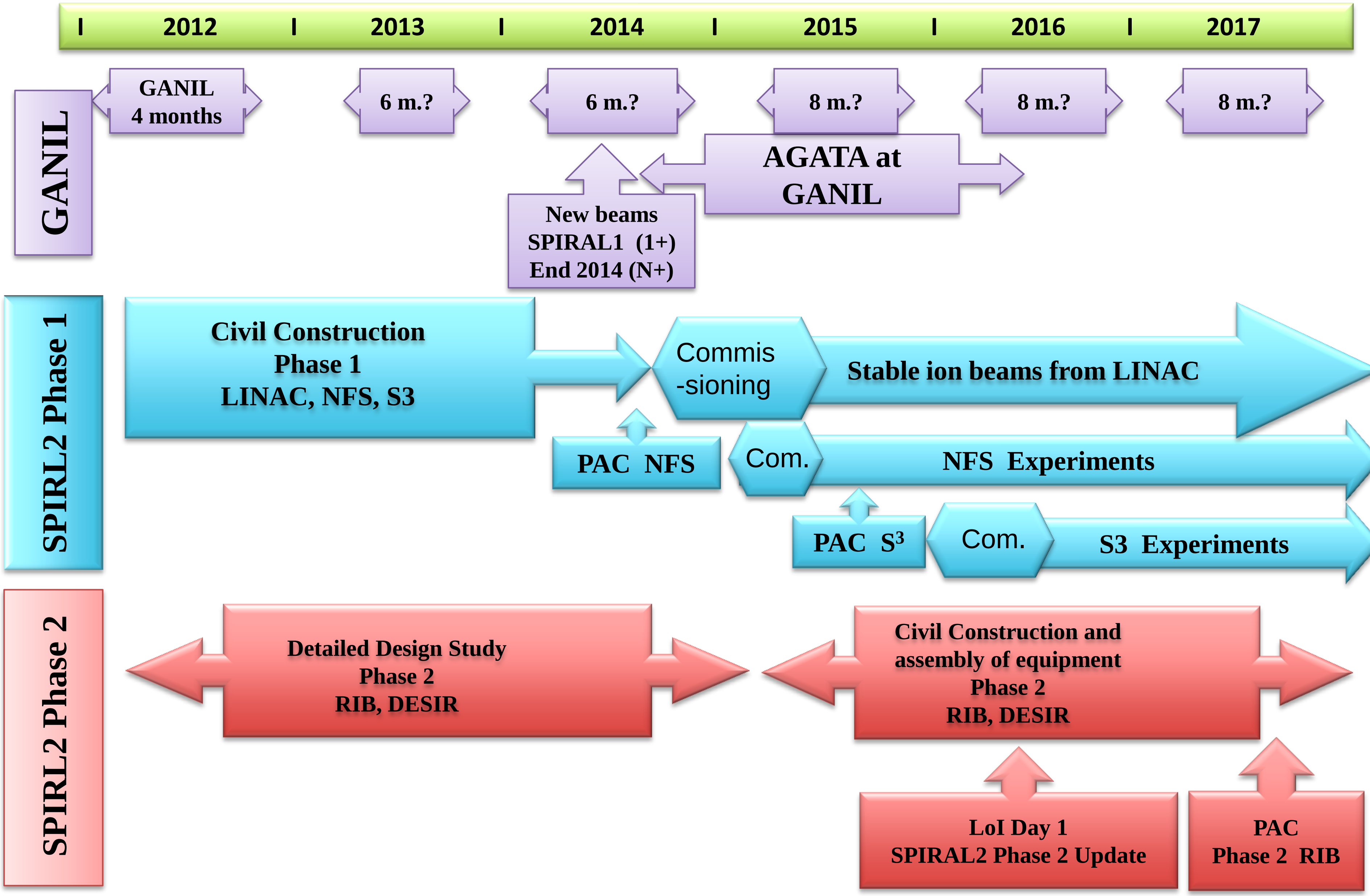
M. Lewitowicz

DESIR experimental hall & associated detectors



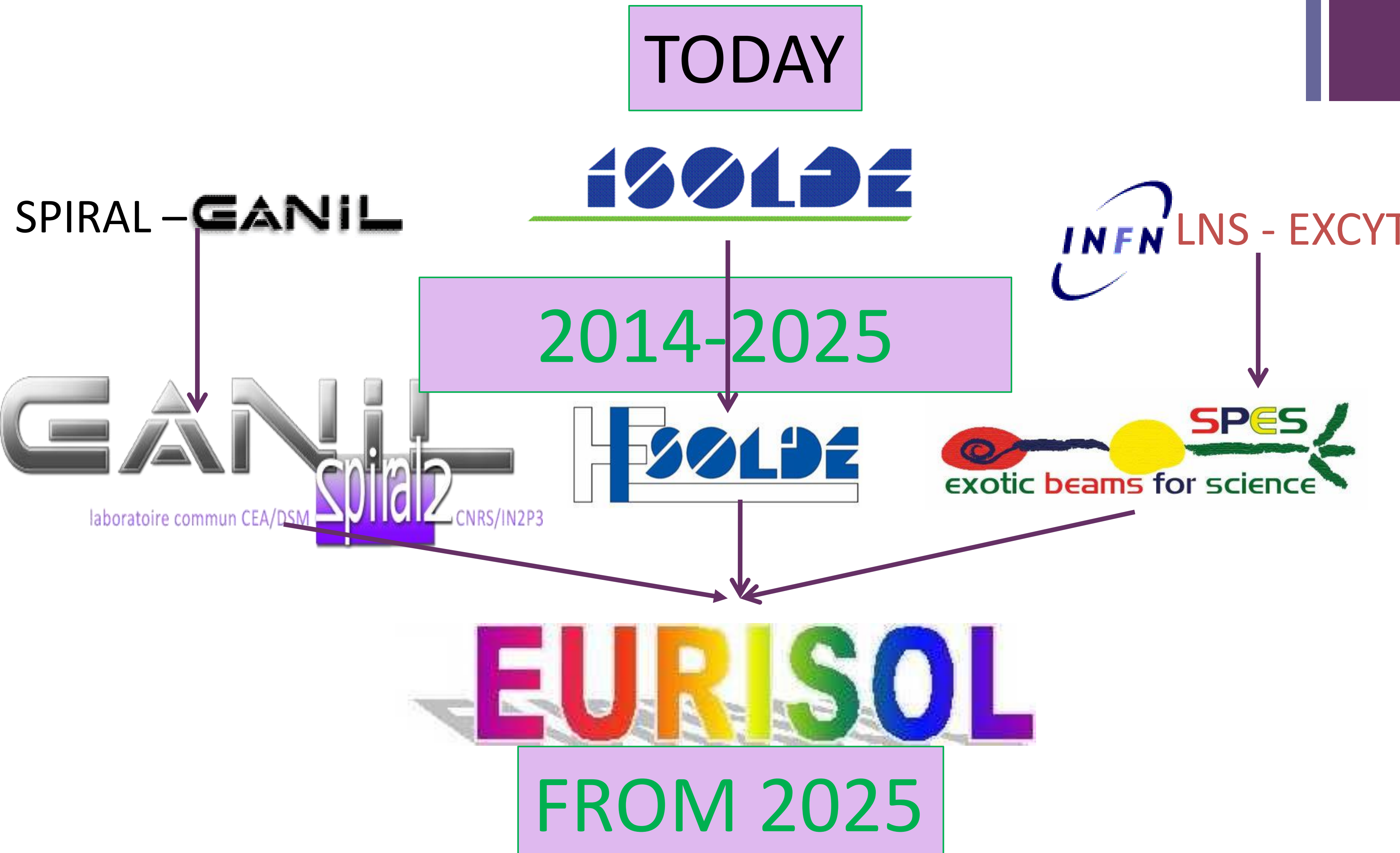
Parties: 14 owners of DESIR experimental equipment
Commitment: ~5 M€ & 520 men.months

Timeline GANIL & SPIRAL2



M. Lewitowicz

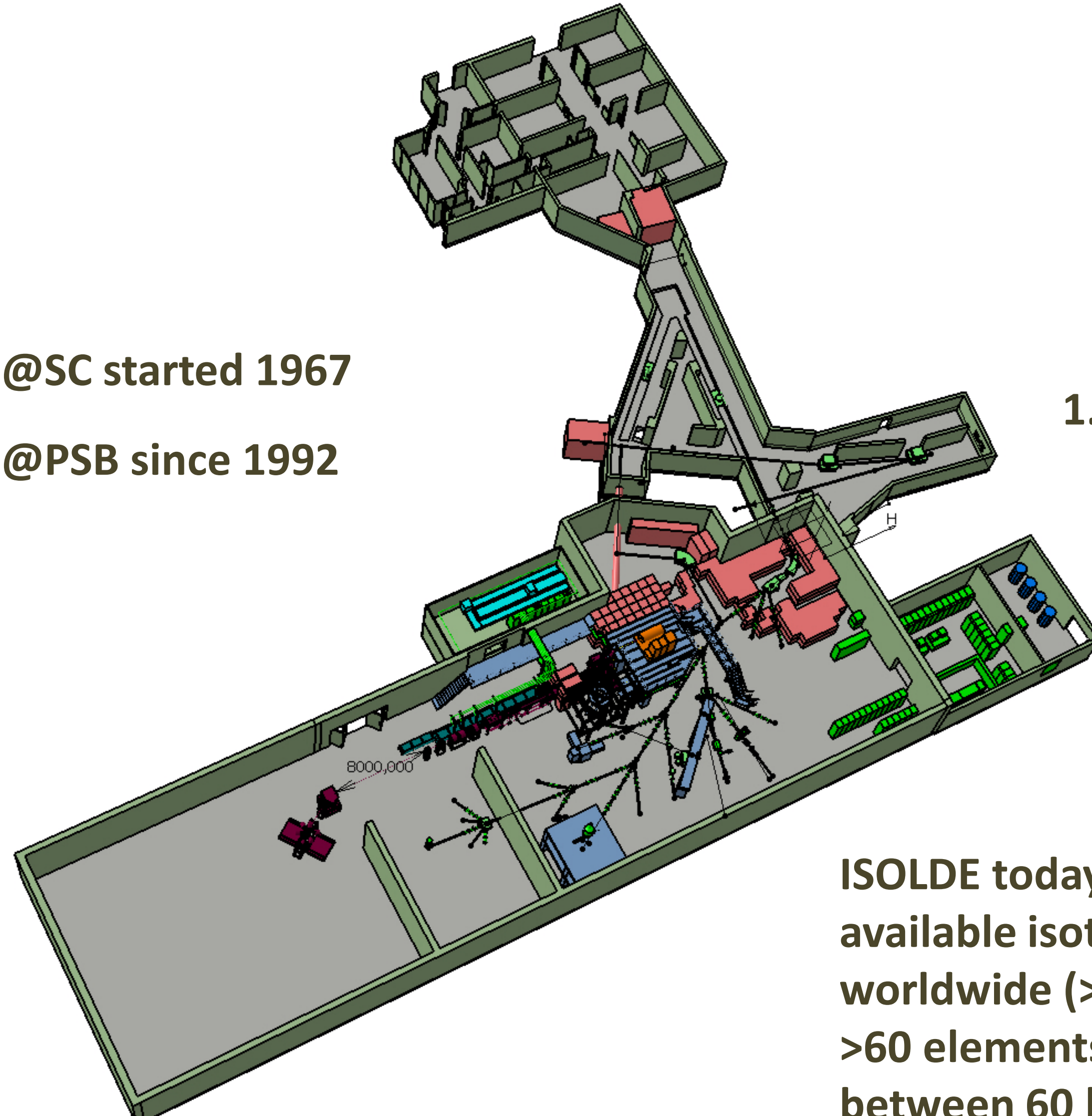
ISOL Roadmap in Europe



CERN-ISOLDE today

ISOLDE@SC started 1967

ISOLDE@PSB since 1992



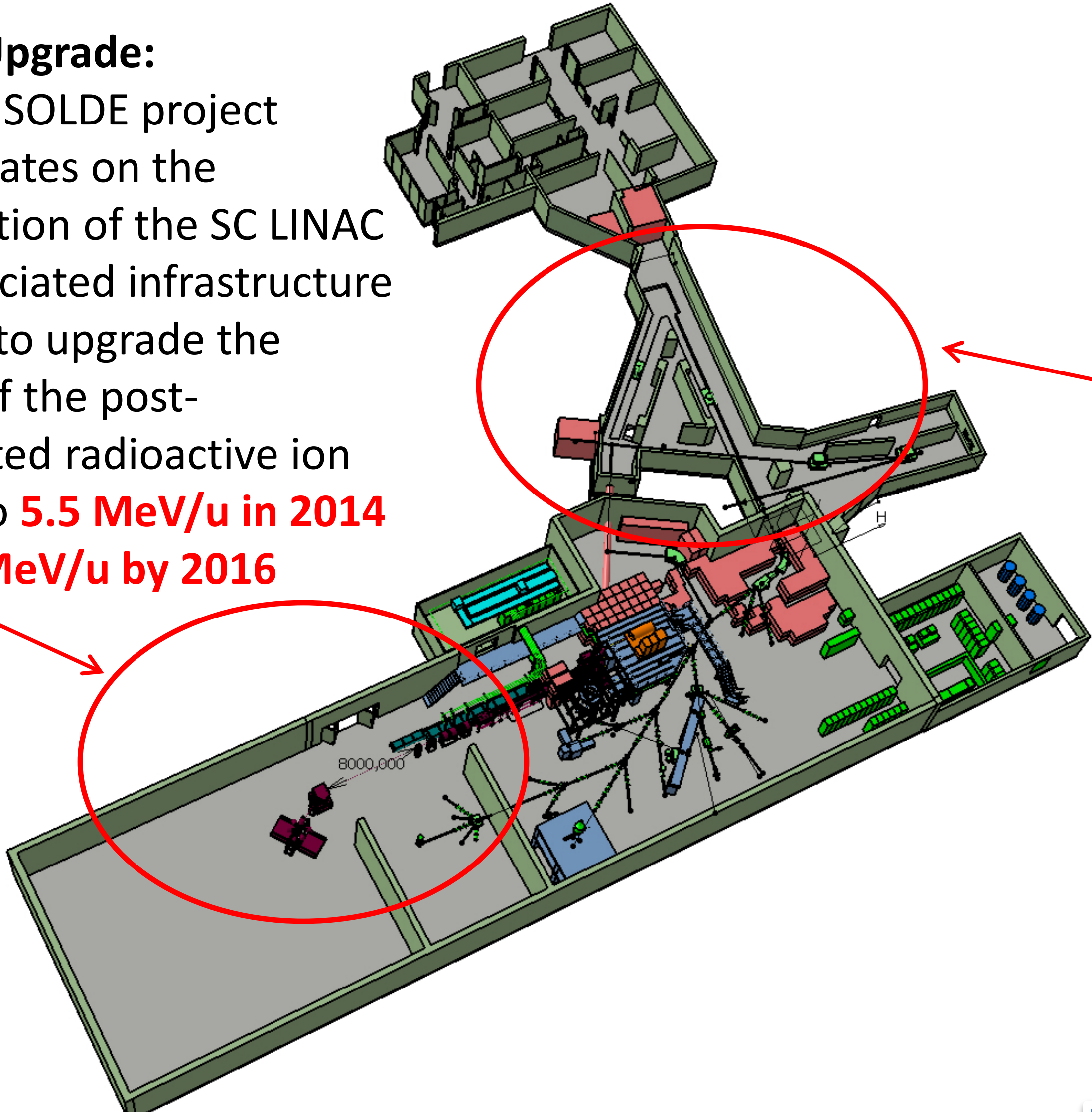
1.4 GeV p-beam from PSB, 2 μA

ISOLDE today offers the largest range of available isotopes of any ISOL facility worldwide (>600 radioactive isotopes of >60 elements) in an energy range between 60 keV and 3 AMeV.

Scope of HIE-ISOLDE

HIE-ISOLDE aims at increasing the energy of these RIB up to 10A MeV and their intensity by a factor 10

Energy Upgrade:
The HIE-ISOLDE project concentrates on the construction of the SC LINAC and associated infrastructure in order to upgrade the energy of the post-accelerated radioactive ion beams to **5.5 MeV/u in 2014** and **10 MeV/u by 2016**



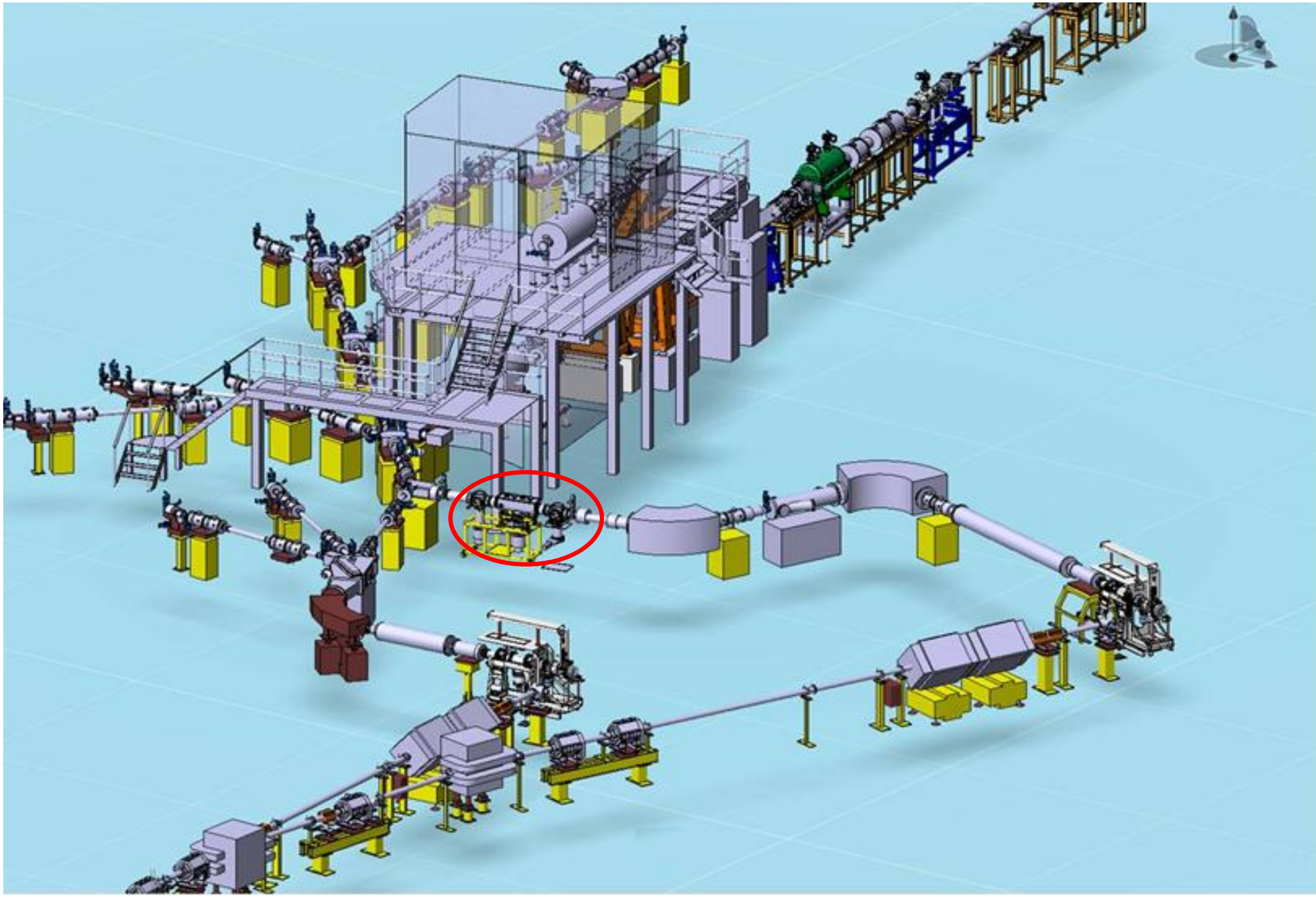
Continuous target – ion source development, improvement in ion-optical properties

T. Stora, session III
D. Fink, session III

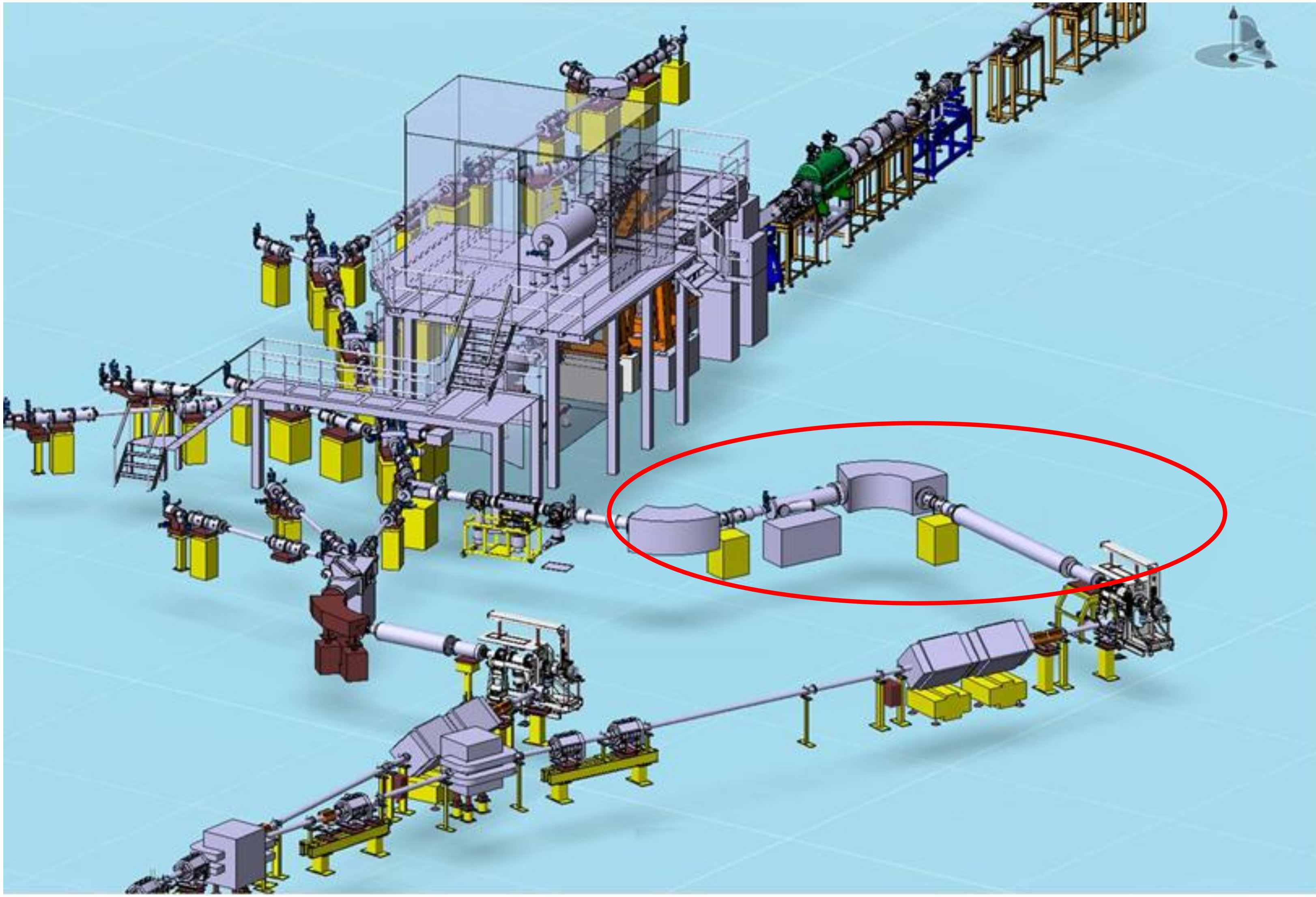
Intensity Upgrade:
The design study for the intensity upgrade, also part of HIE-ISOLDE, **starts in 2011**, and addresses the technical feasibility and cost estimate for operating the facility at **10 kW** once LINAC4 and PS Booster are online.

Talk by R. Catherall, session IX

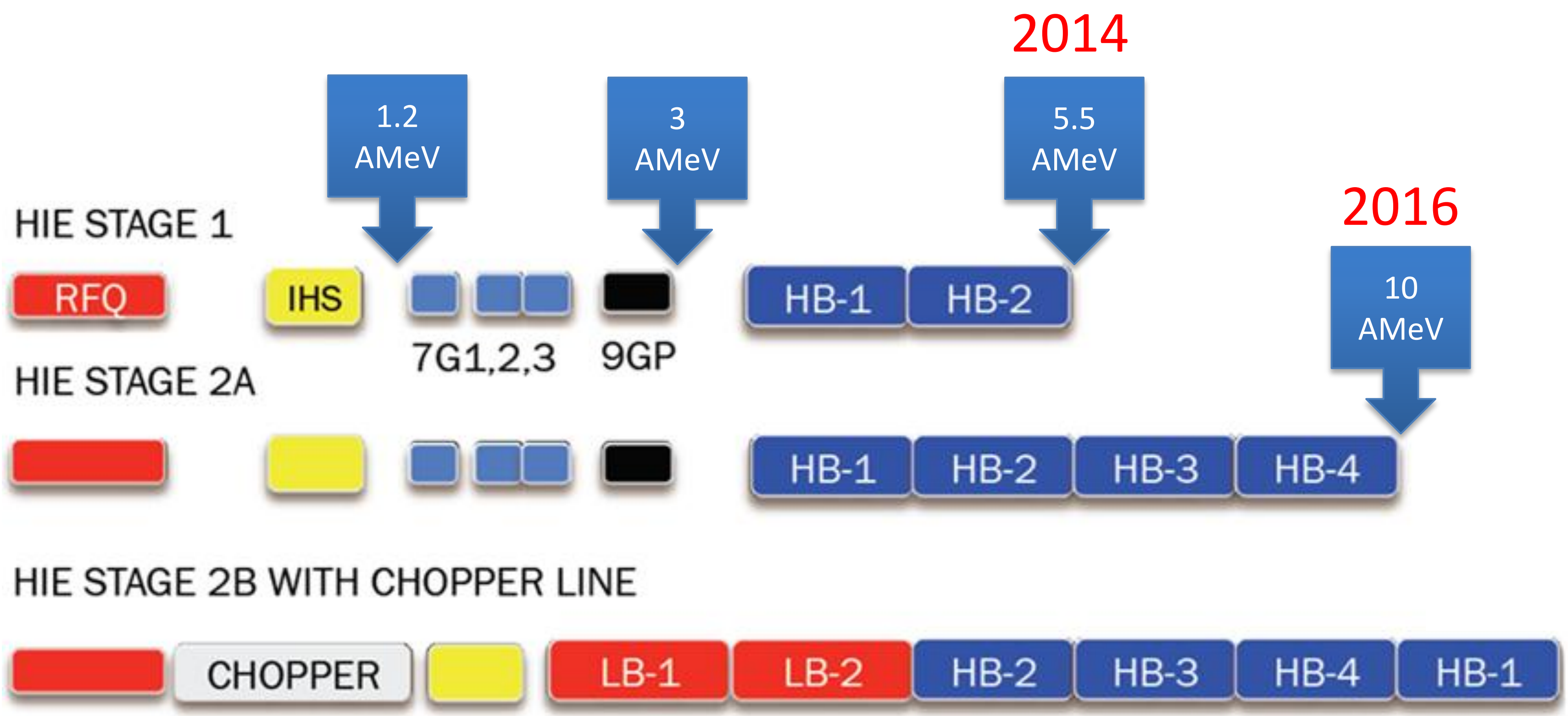
Increased beam quality: ISCOOL



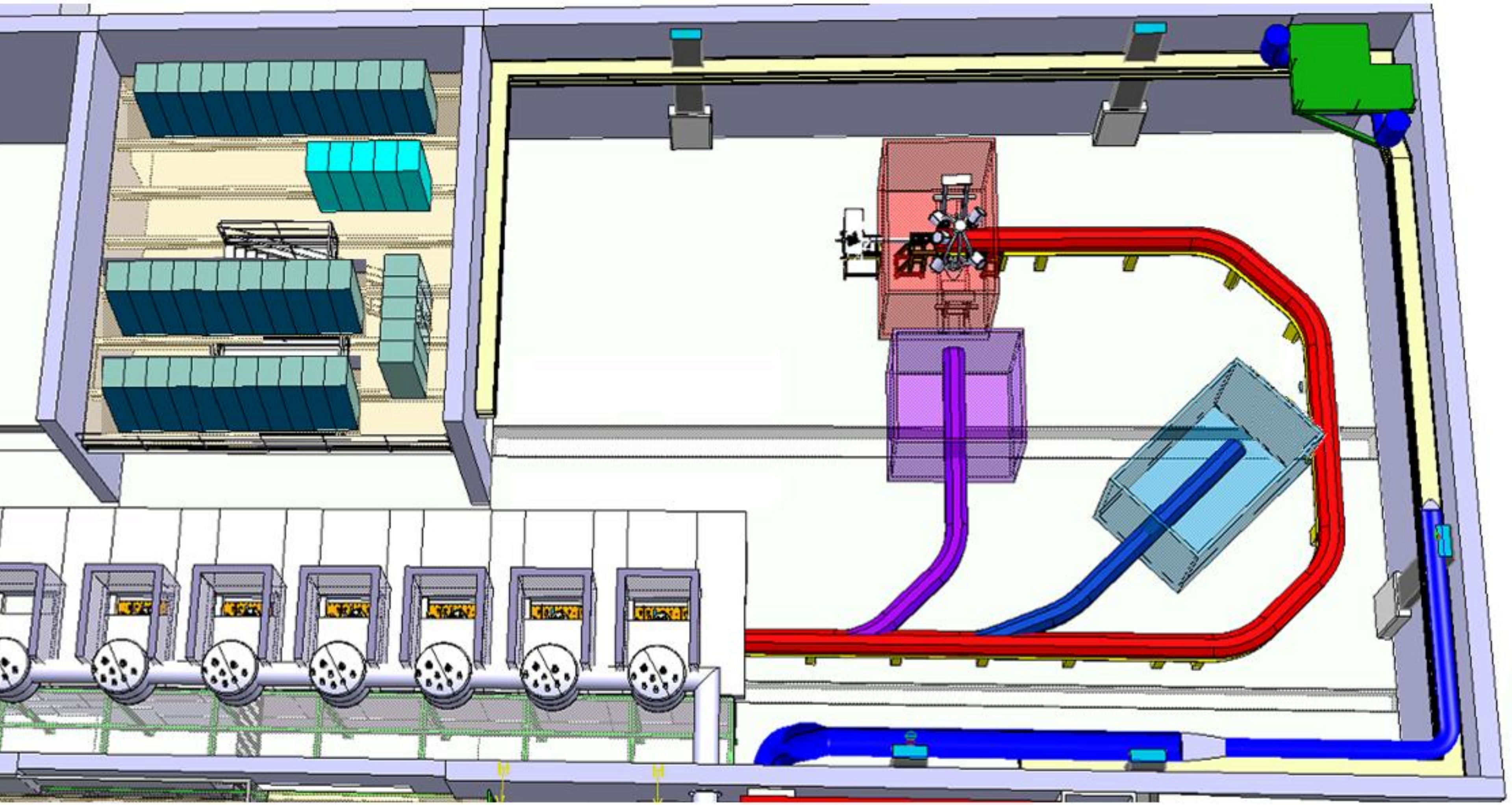
Increased beam quality: design studies for HRS

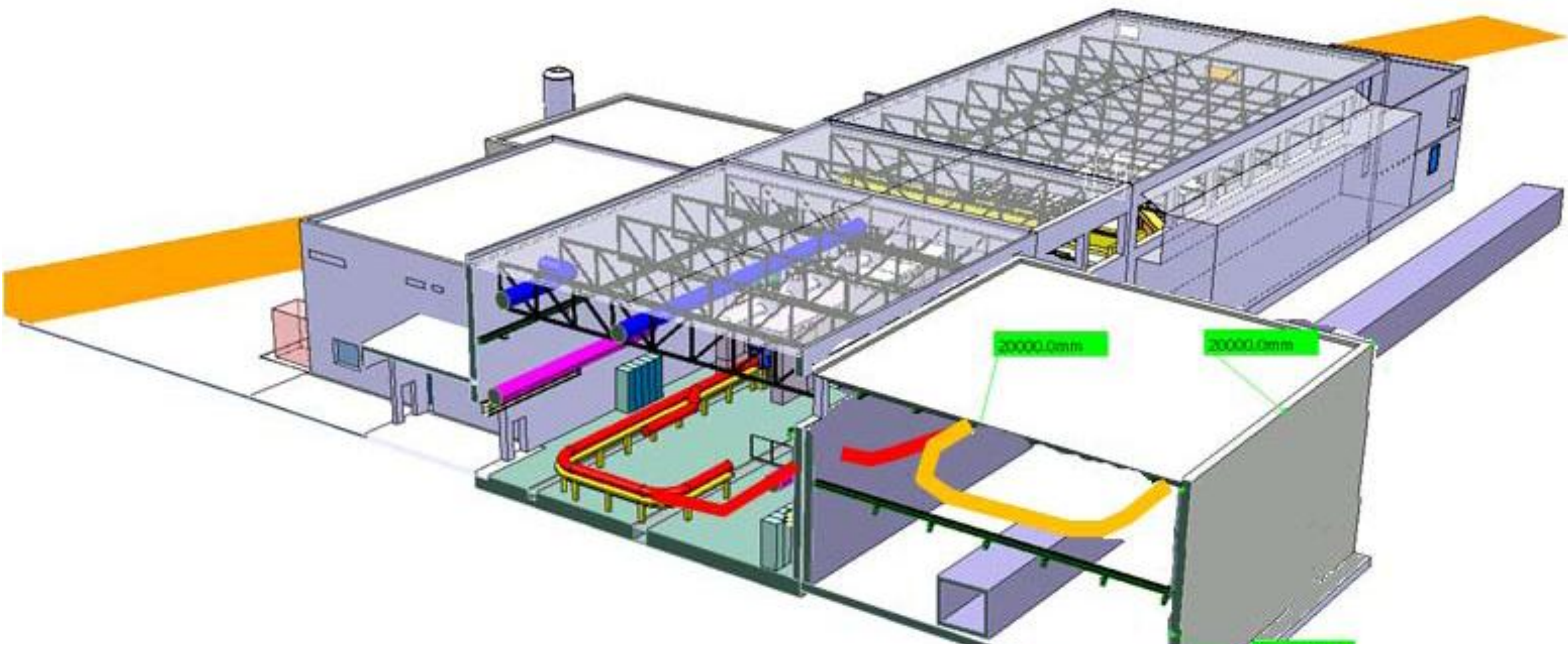


Staged energy upgrade



Phase 2: Experimental hall (10 AMeV 2016)





Installation of TSR@ISOLDE

	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Funding												
Building construction work												
Building infrastructure												
disassembly of TSR at MPIK												
Transport to CERN												
Assembly of TSR@ISOLDE												
Power and Electronics												
Begin Commissioning												

ISOL Roadmap in Europe

TODAY

SPIRAL – GANIL

ISOLDE

INFN LNS - EXCYT

2014-2025

GANIL spiral2

laboratoire commun CEA/DSM CNRS/IN2P3

HIE-ISOLDE

SPES exotic beams for science

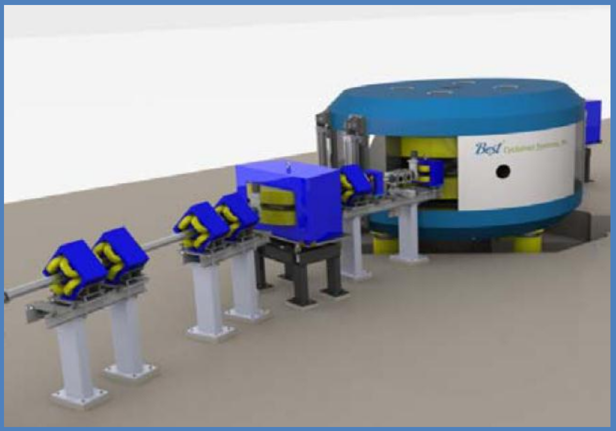
EURISOL

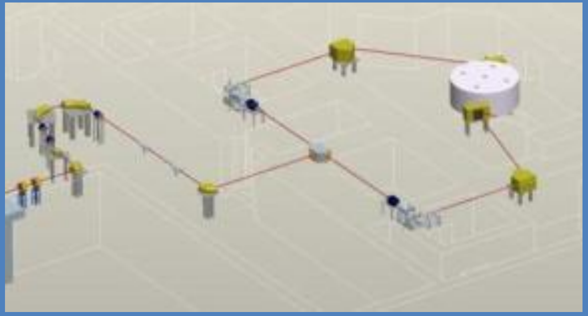
FROM 2025

The SPES choice for ISOL

Driver:

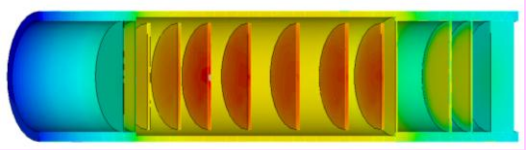
‘Commercial’ cyclotron

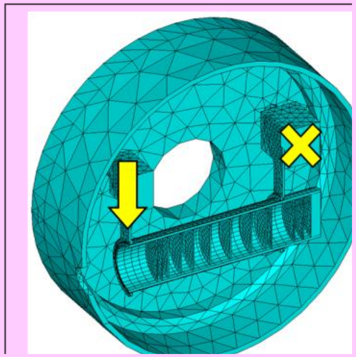




Production Target:

NEW CONCEPT
Multi-foil UCx direct target designed to reach 10^{13} f/s





Post Accelerator:

Normal conductive RFQ

(new development)

&

Alpi existing complex

G. Prete

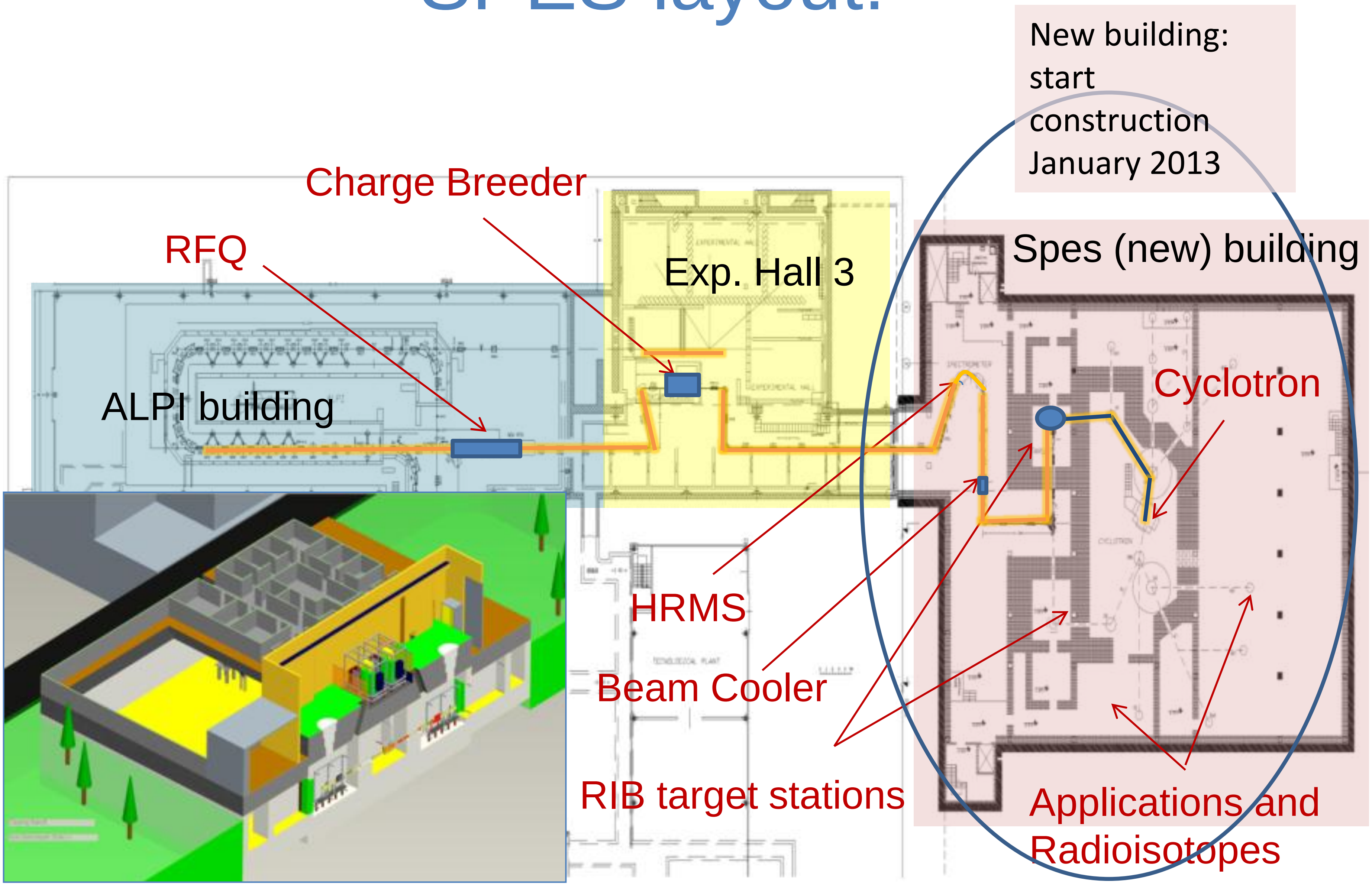
Second generation ISOL facilities in Europe (UCx target)

Production and study of neutron-rich nuclei

	Primary beam	Power on target	UCx target (UCx grams)	Fission s-1	Reaccelerator	Nominal energy AMeV A=130
HIE ISOLDE upgrade	p 1-1.4 GeV - 2 μA	0.8 kW	Direct (150g)	**$4\cdot10^{12}$**	SC Linac	5-10
SPIRAL2	d 40 MeV 5mA	200 kW	Converter (4000g)	**10^{13}** 10^{14}	CIME Cyclotron	5
SPES	p 40 MeV 200 μA	8 kW	Direct (30g)	**10^{13}**	ALPI SC Linac	10

G. Prete

SPES layout:


New building: start construction January 2013
Charge Breeder
RFQ
Exp. Hall 3
Spes (new) building
ALPI building
Cyclotron
HRMS
Beam Cooler
RIB target stations
Applications and Radioisotopes

SPES Schedule November 2012

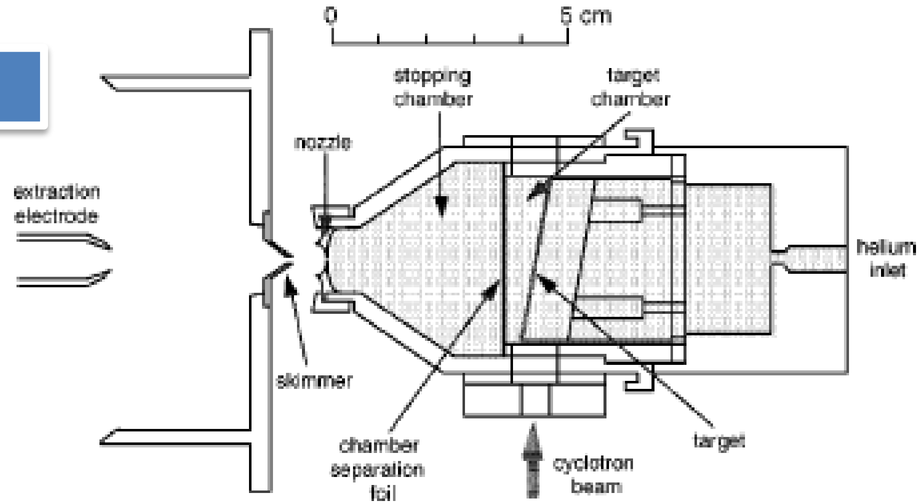
	2012	2013	2014	2015	2016	2017
Authorization to operate and safety		UCx authorization				
ISOL Targets construction and installation						
Building Construction	building project					
Cyclotron Construction & commissioning	in	schedule				
Alpi up-grade & pre-acceleration						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines and spectrometer						
Complete commissioning and first exotic beam						

A precursor to SPIRAL2: ALTO@IPN Orsay (F)

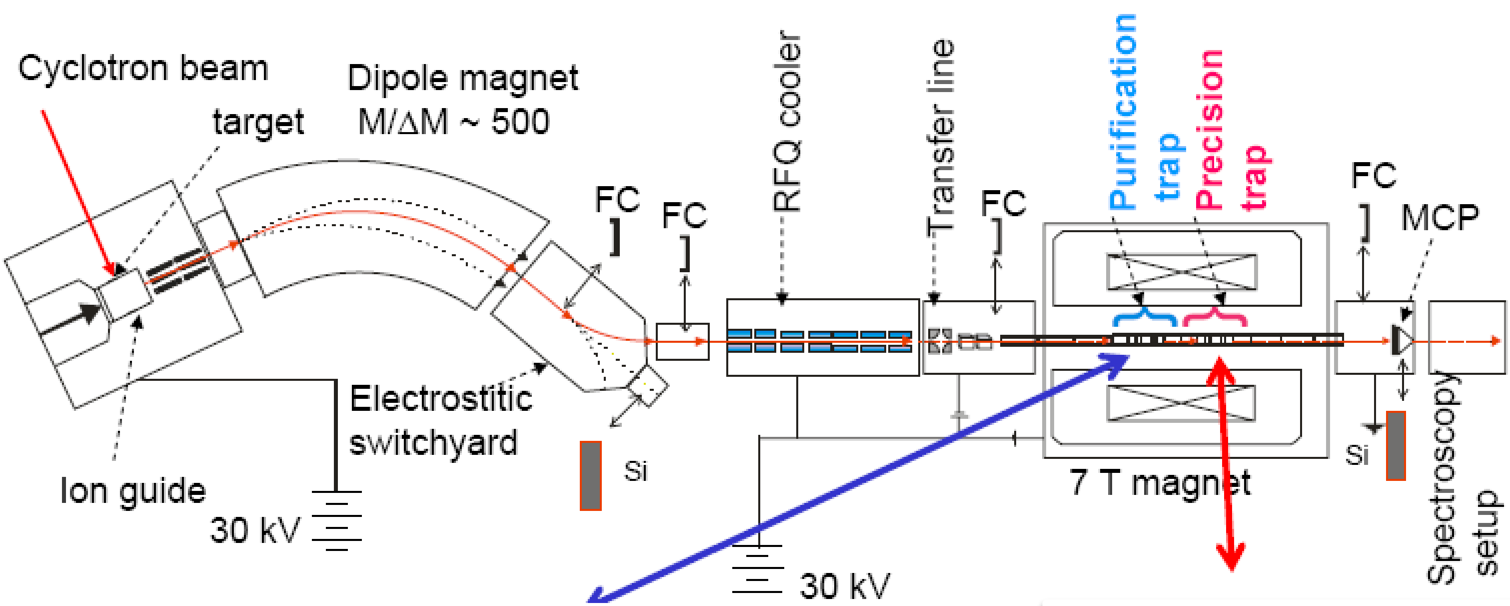
10 μA, 50 MeV electron beam on UCx target
Approved to run by safety authorities

Niche facility: IGISOL@JYFL (FI)

M. Wada, session IV



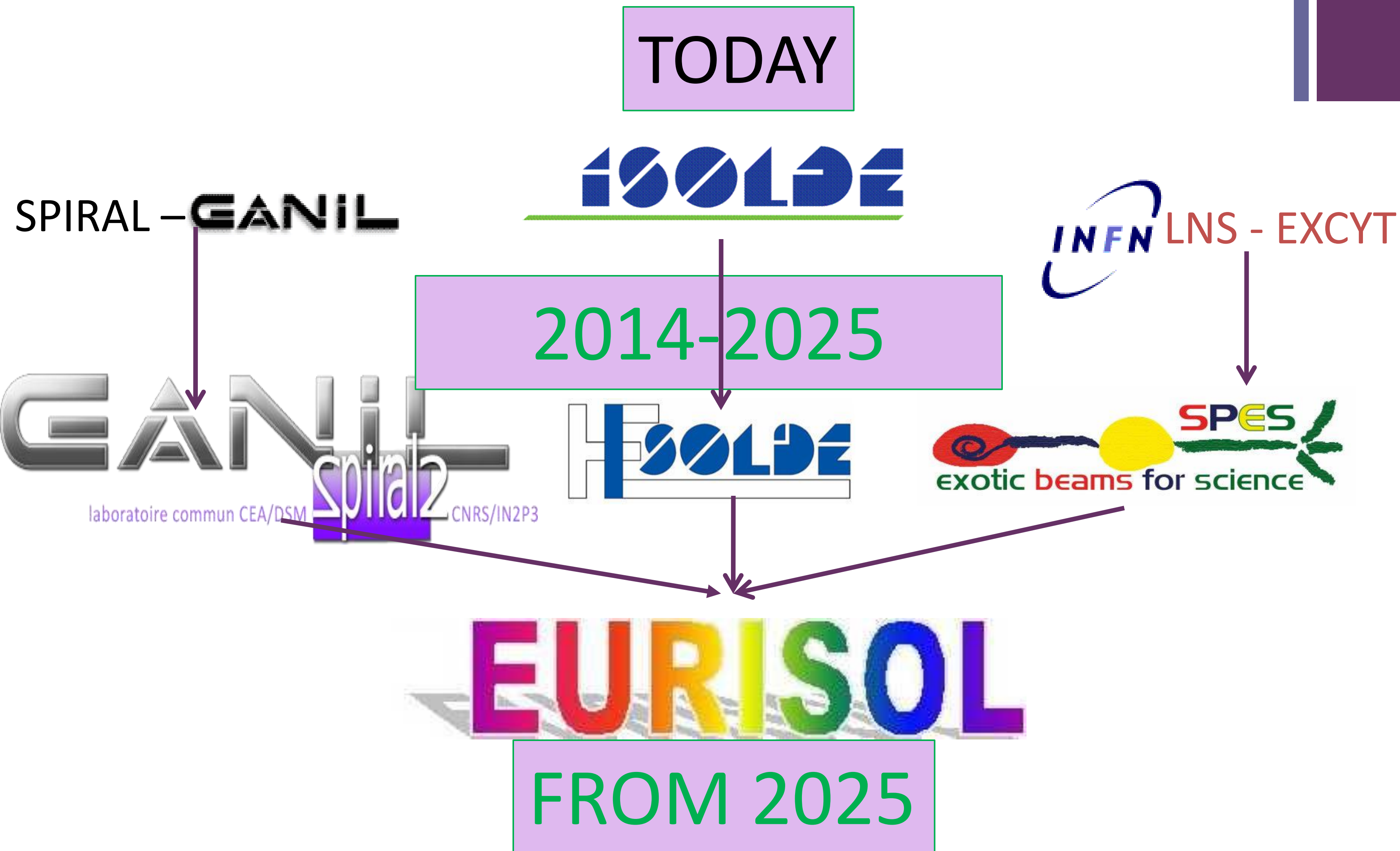
Now: IGISOL-4 with dedicated driver cyclotron
I. Moore session IV



V. Kolhinen, session VIII

The New MCC30/15 Cyclotron / JYFL

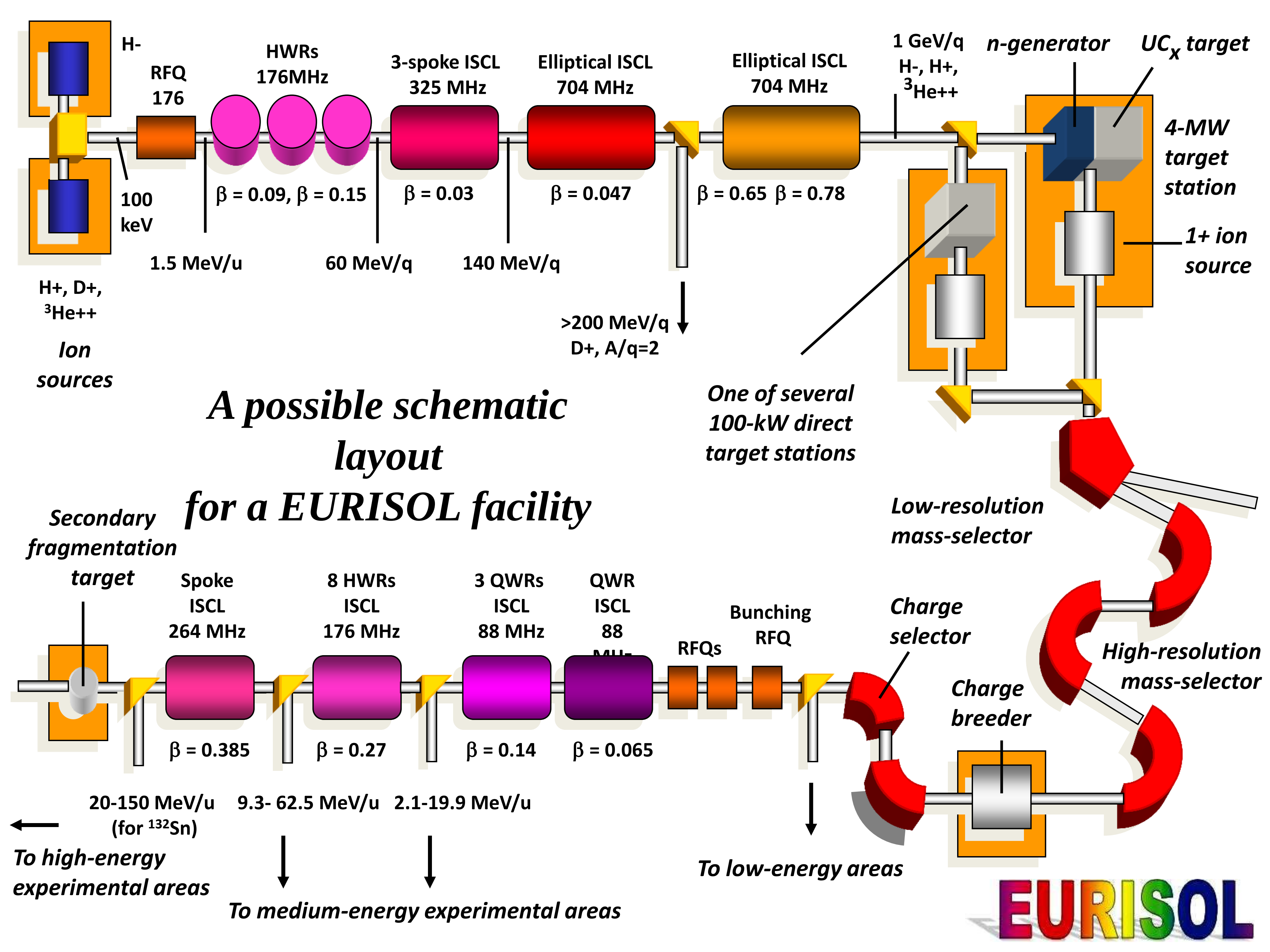
ISOL Roadmap in Europe



EURISOL: An Ultimate ISOL Facility for Europe
A Short History

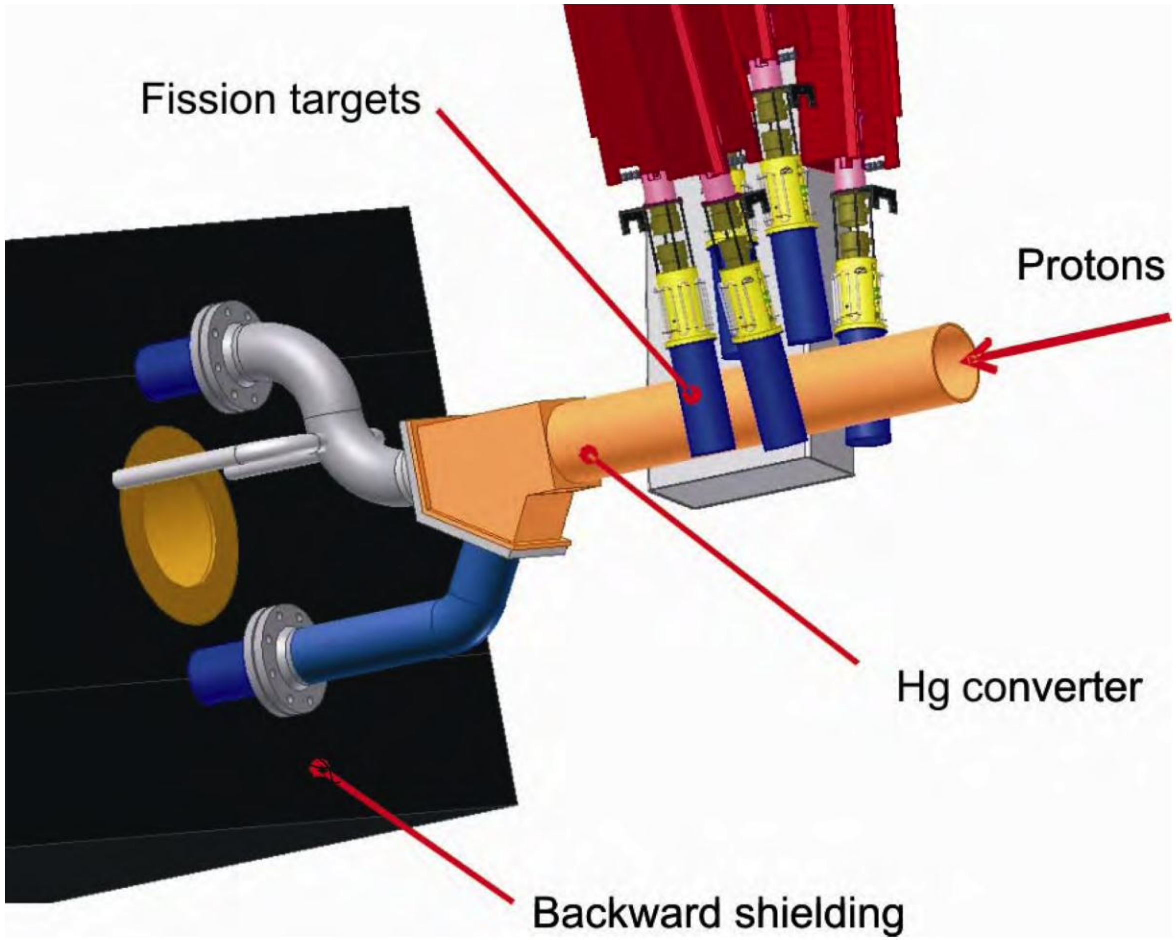
- 2000: The Idea to Build an Ultimate ISOL facility for EUROPE is born (B. Jonson-A. Mueller- J. Vervier)
- 2001-2004: EURISOL RTD led by J. Vervier in 5th framework program: Conceptual Design
- 2005-2009: EURISOL Design Study led by G. Fortuna and Y.Blumenfeld in 6th framework program
- 2010: Endorsed by NuPECC as highest long term priority for low energy nuclear physics in Europe.

EURISOL (Green field)



H-
RFQ 176
HWRs 176MHz
3-spoke ISCL 325 MHz
Elliptical ISCL 704 MHz
Elliptical ISCL 704 MHz
1 GeV/q H-, H+, ^{3}He++
n-generator
UC_x target
4-MW target station
1+ ion source
100 keV
β = 0.09, β = 0.15
β = 0.03
β = 0.047
β = 0.65 β = 0.78
1.5 MeV/u
60 MeV/q
140 MeV/q
H+, D+, ^{3}He++
Ion sources
>200 MeV/q D+, A/q=2
One of several 100-kW direct target stations
A possible schematic layout for a EURISOL facility
Low-resolution mass-selector
Secondary fragmentation target
Spoke ISCL 264 MHz
8 HWRs ISCL 176 MHz
3 QWRs ISCL 88 MHz
QWR ISCL 88 MHz
RFQs
Bunching RFQ
Charge selector
High-resolution mass-selector
Charge breeder
β = 0.385
β = 0.27
β = 0.14
β = 0.065
20-150 MeV/u (for ^{132}Sn)
9.3- 62.5 MeV/u
2.1-19.9 MeV/u
To high-energy experimental areas
To medium-energy experimental areas
To low-energy areas
EURISOL

Multi-MW fission target

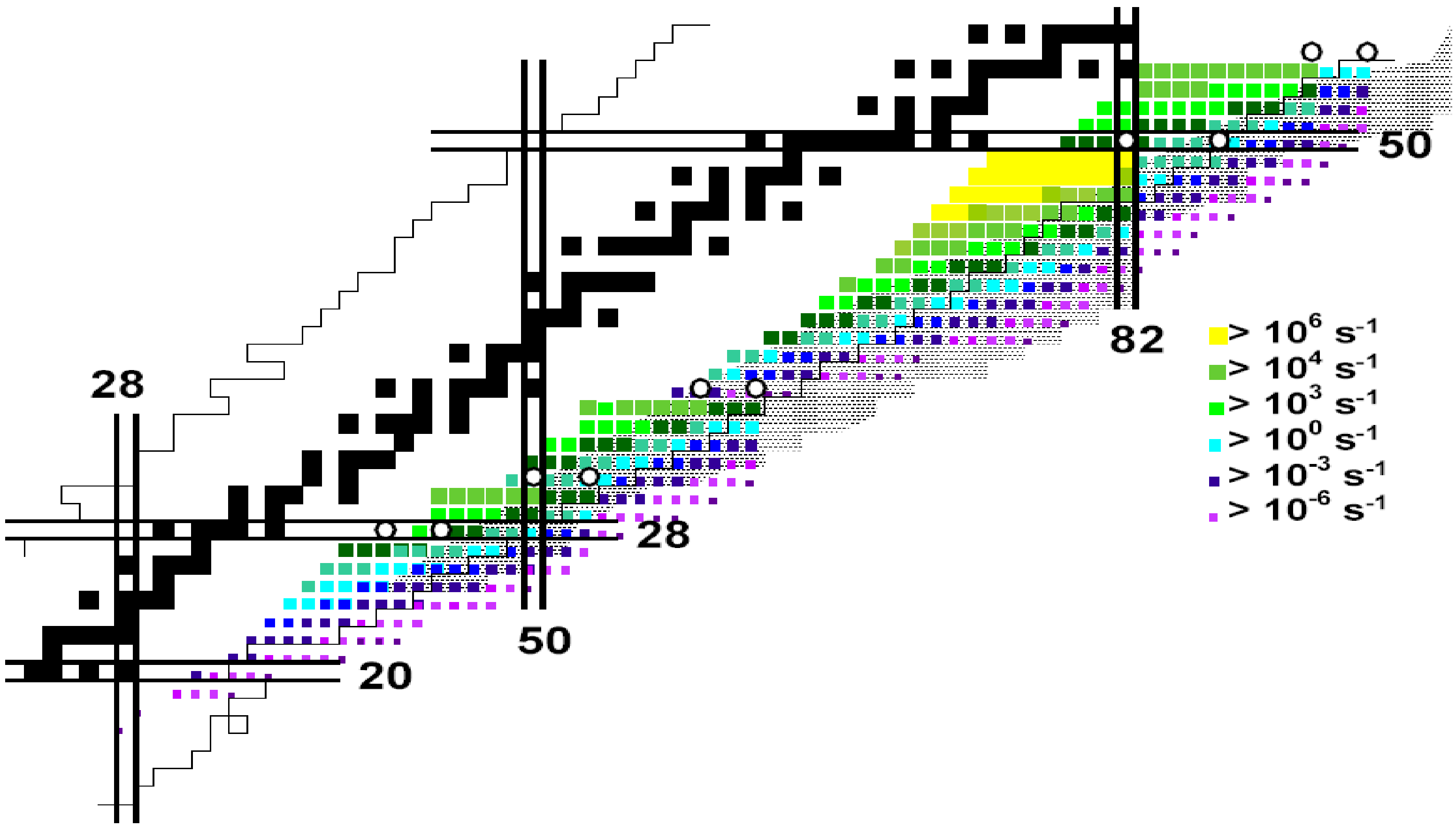


Accelerated ^{132}Sn yields (per second) *(fission factories only)*

HRIBF	10^5	4.5 MeV/u	(now)
REX-ISOLDE	10^6	3 MeV /u	(now)
CARIBU	5.10^4	10 MeV/u	(2010)
TRIUMF p-driver	10^7	5 MeV/u	(2010)
CARIBU phase 2	10^6	14 MeV/u	(2013)
HIE-ISOLDE	10^8	10 MeV/u	(2014)
TRIUMF e-driver	5.10^8	5 MeV/u	(2015)
SPES	5.10^8	9 MeV/u	(2015)
SPIRAL-2	2.10^9	7 MeV/u	(2015)
FRIB	3.10^7	100 MeV/u	(2019)
EURISOL	10^{12}	150 MeV/u	(2025)

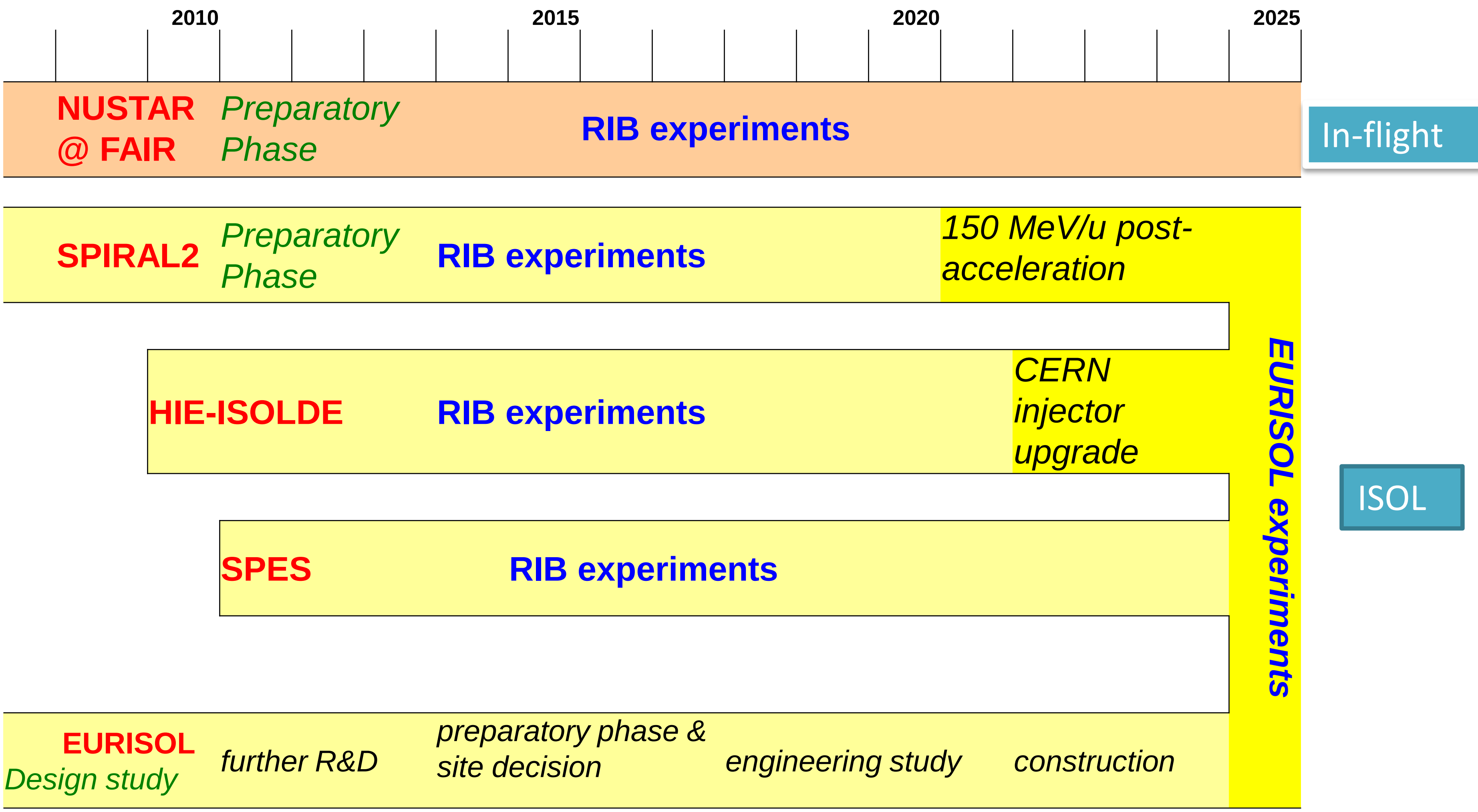
Y. Blumenfeld

Secondary Fragmentation of Fission Fragments at EURISOL



D. Loureiro, PhD thesis, Santiago

NuPECC Long Range Plan 2010
Timeline RIB Facilities



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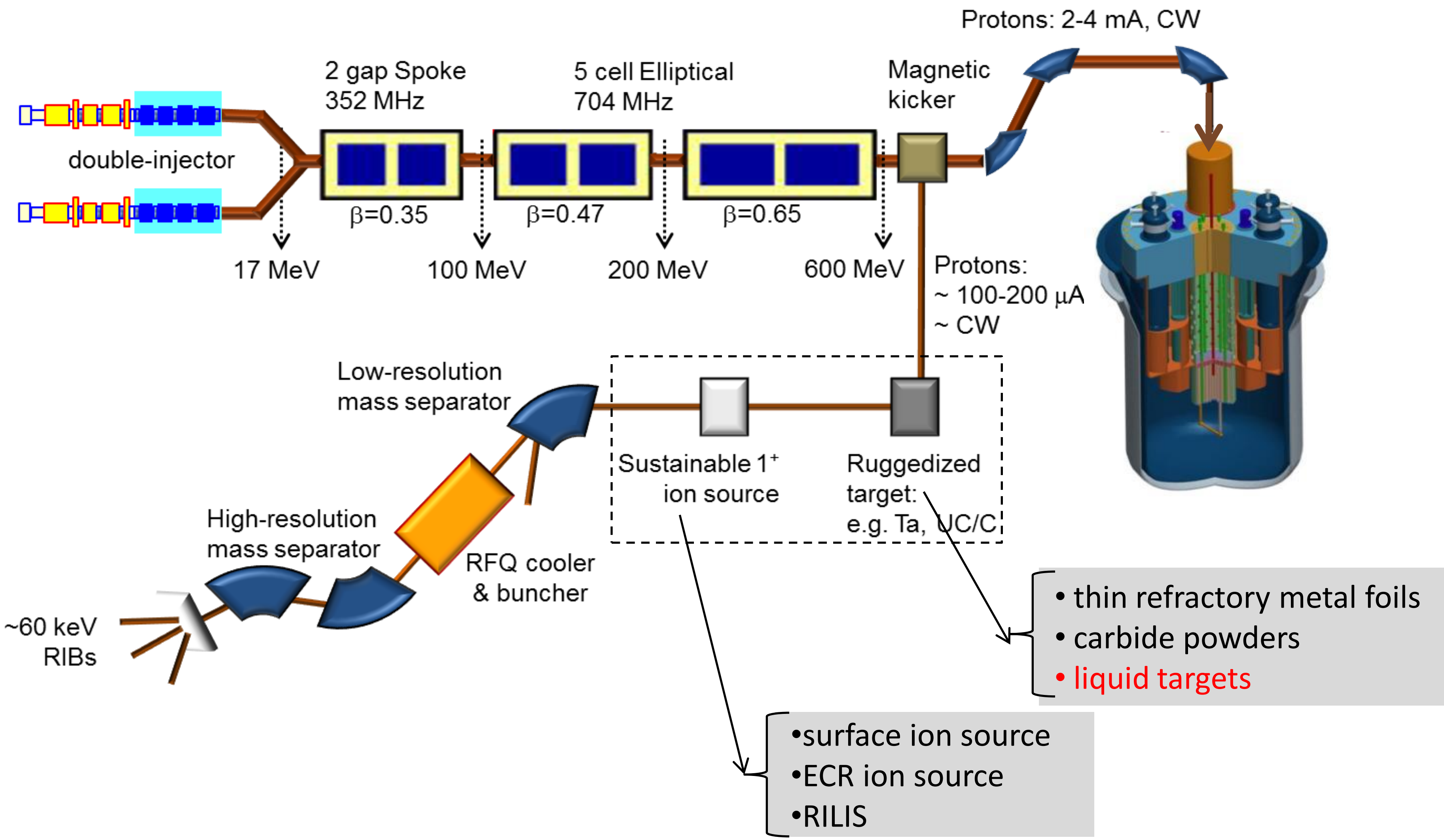
The MYRRHA ADS project at SCK•CEN

ISOL@MYRRHA - Concept



ISOL facilities – reality check…

- “Who said the yields are (only) a function of beam power?”
  T. Stora, session III

- “Develop two elements/year” J. Lassen, session V

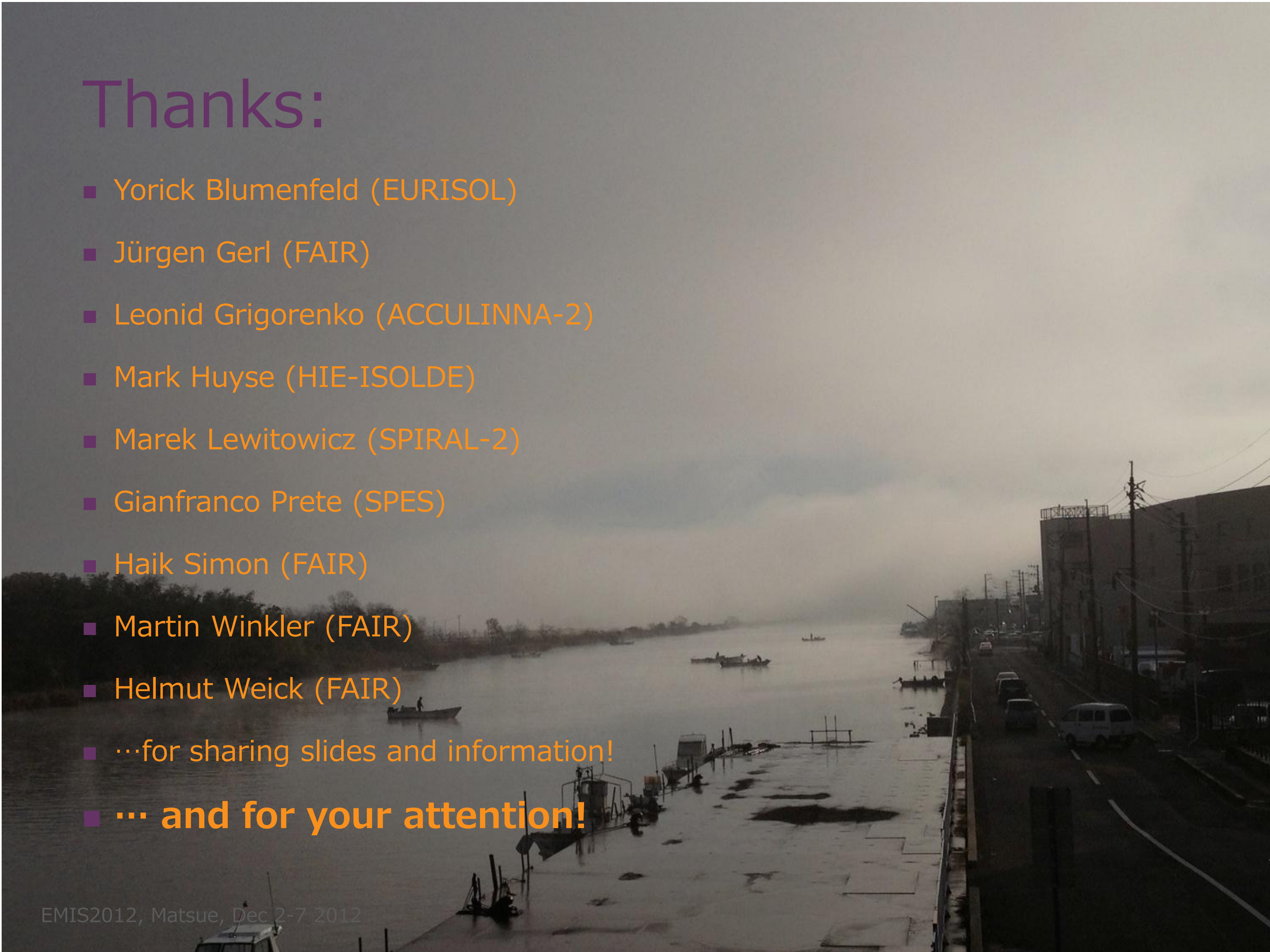
$$I = \sigma N_{target} \Phi \epsilon$$

ϵ_{delay}	probability of survival against radioactive decay during the time needed to extract the ion from the target-ion source system
ϵ_{ion}	ionization efficiency
ϵ_{trans}	efficiency of mass analysis and transport to the experimental set-up
$\epsilon_{cool-bunch}$	cooling and bunching efficiency
$\epsilon_{breeding}$	charge-state breeding efficiency
$\epsilon_{accelerator}$	efficiency of the post-accelerator
ϵ	total efficiency: the product of the above mentioned terms

Y. Blumenfeld, T. N., P. Van Duppen, Physics Scripta, acc. for pub

Conclusions

- The European landscape of RIB infrastructures is heterogeneous but coherent
  - Leading in-flight and ISOL will be available for decades
  - "Internally consistent" in long-range planning
  - Competitive and complementary on a global scale
  - Completion times an issue!
- Instrumentation efforts are matching



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