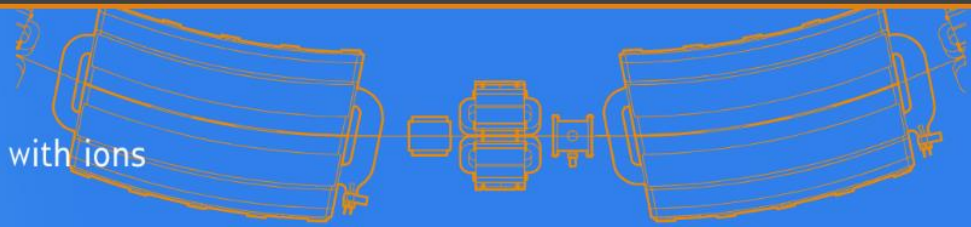




19-21 June 2018

Ideas and technologies
for a next generation facility
for medical research and therapy with ions
ESI, Archamps, France



The C400: the ARCHADE multi-ions cyclotron

Jacques BALOSSO

CFB at Caen and UGA at Grenoble



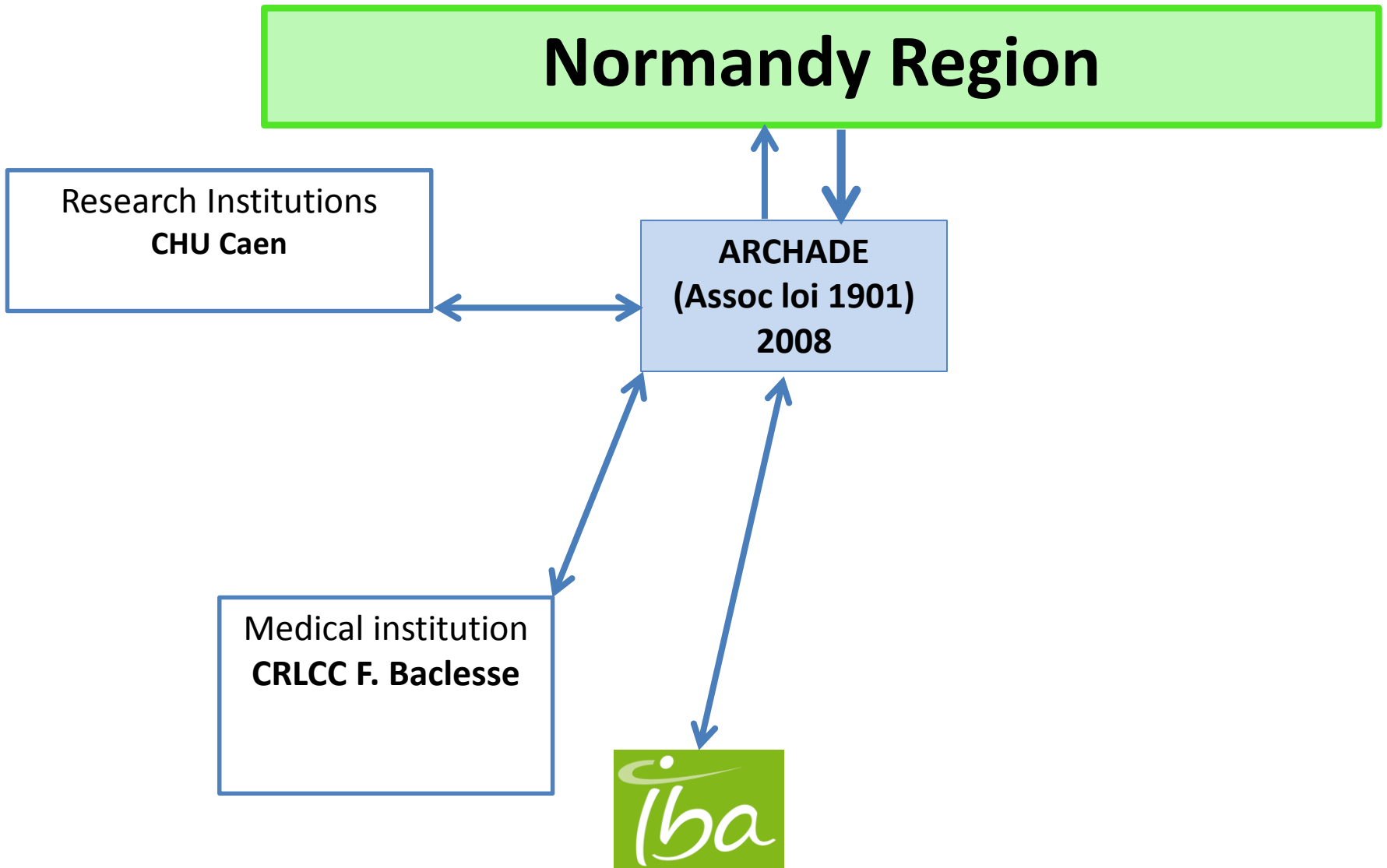
Outline

- History of the C400 project
- The ARCHADE project in Caen
- The CYCLHAD SAS in Caen
- The use of C400 in CYCLHAD
- The production of C400 by Normandy Hadrontherapy SAS
- Medical interest and constrains

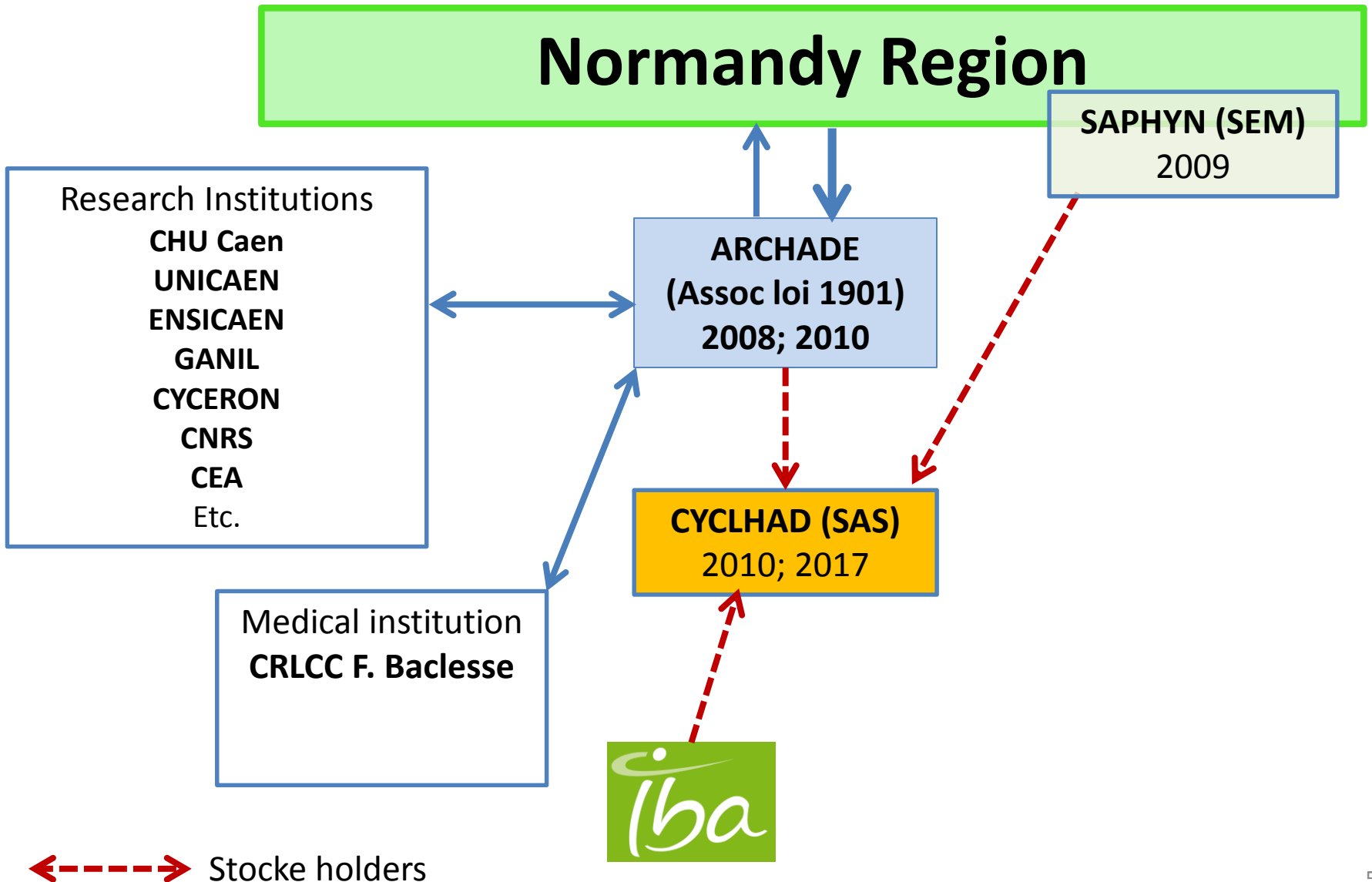
History of the C400 project

- After **ASCLEPIOS** (2005-2007) challenger of ETOILE ...
- **ARCHADE** was a pure scientific resource project (2008) with a unique industrial partner (**IBA**)
- But... **economically unsustainable**
- Introduction of the principle of a limited proton treatment production (2012) by a Proteus[®]One equipment
- **ARCHADE** progresses as a scientific project with mixed clinical/scientific activities
- A specific Co. and building are devoted : **CYCLHAD sas**
- The heart of the project is the development and the scientific use, mostly by **external users**, of the multi-ions superconducting cyclotron **C400**

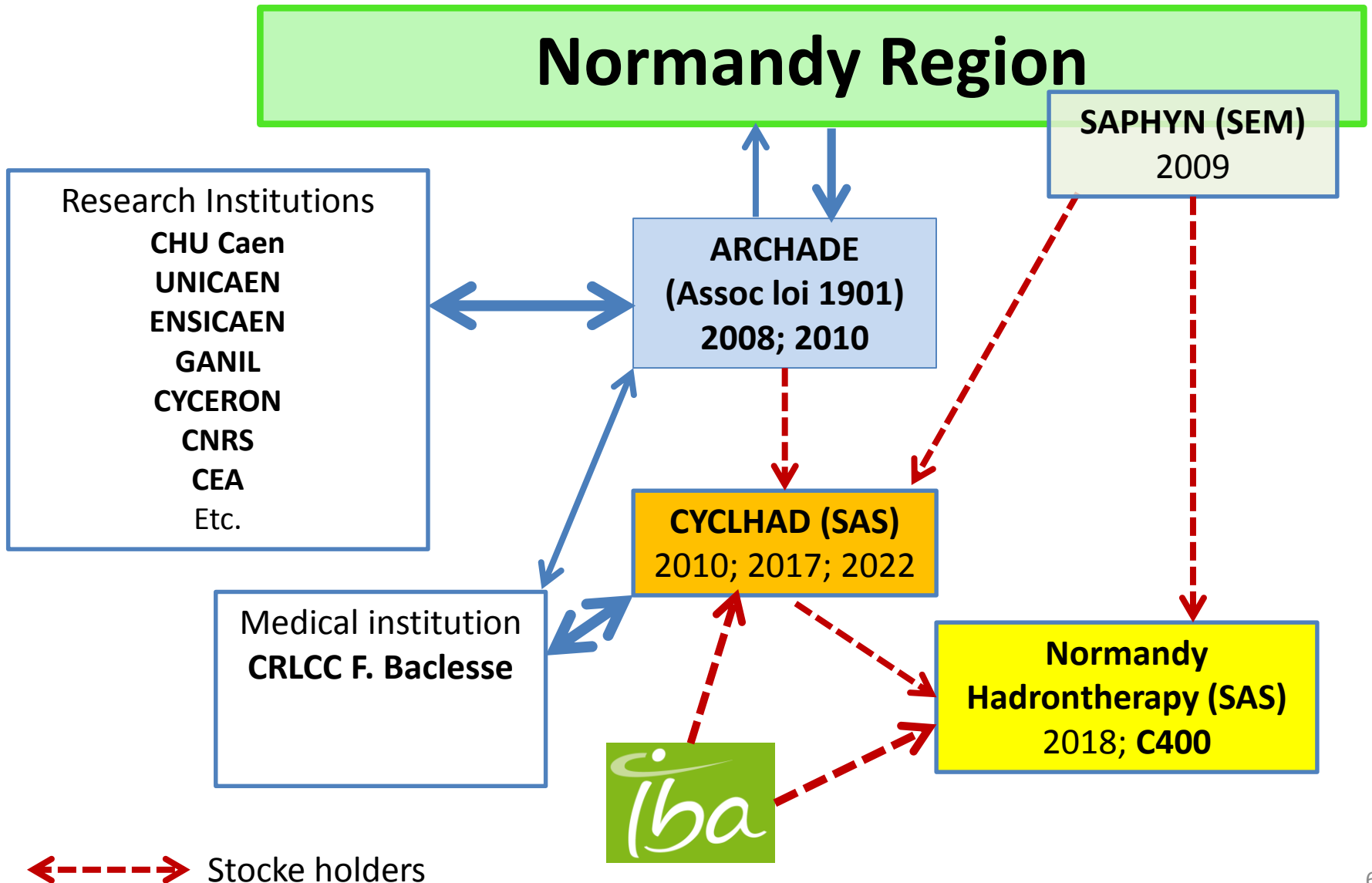
The ARCHADE project in Caen



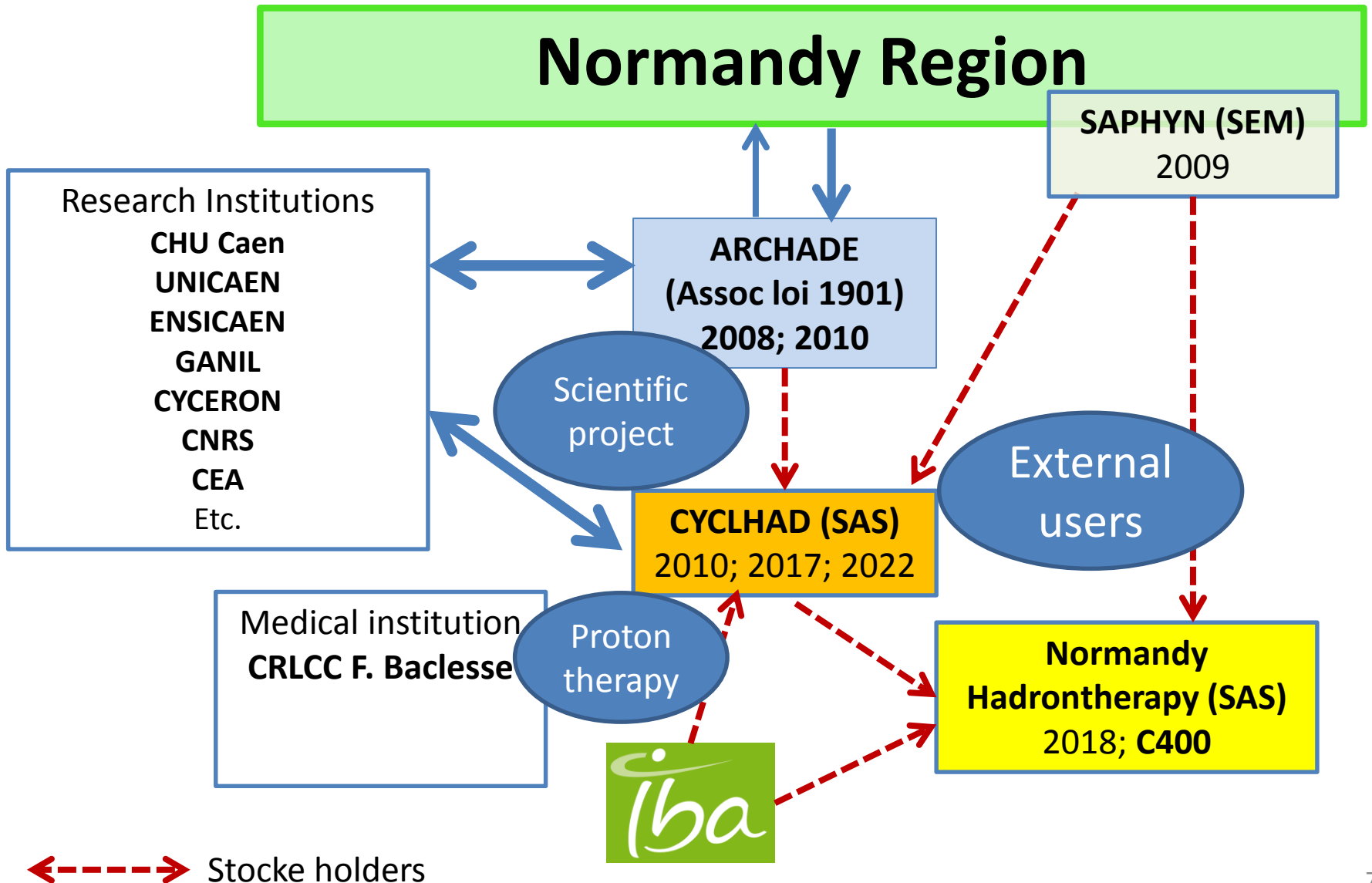
The ARCHADE project in Caen



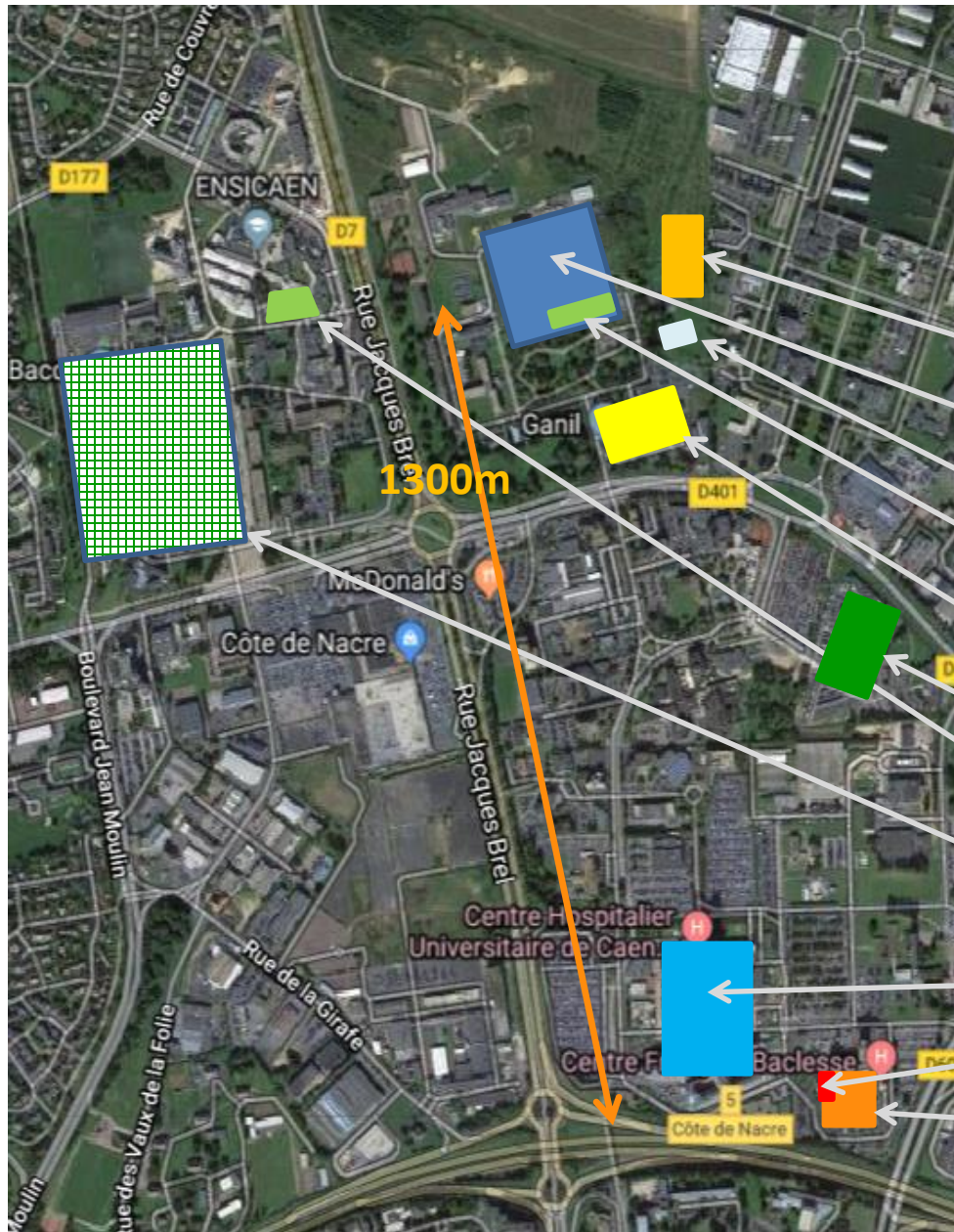
The ARCHADE project in Caen



The ARCHADE project in Caen



The ARCHADE project in Caen



ARCHADE partners are all located in the « North end » of Caen

CYCLHAD

GANIL

Guesthouse for external users

CIMAP-LARIA

CYCERON-ISTCT-CERVOxy

Medical School

ENSICAEN-LPCCaen-GREYC

Scientific Univ.

Univ. Hospital

ABTE-TOXEmac

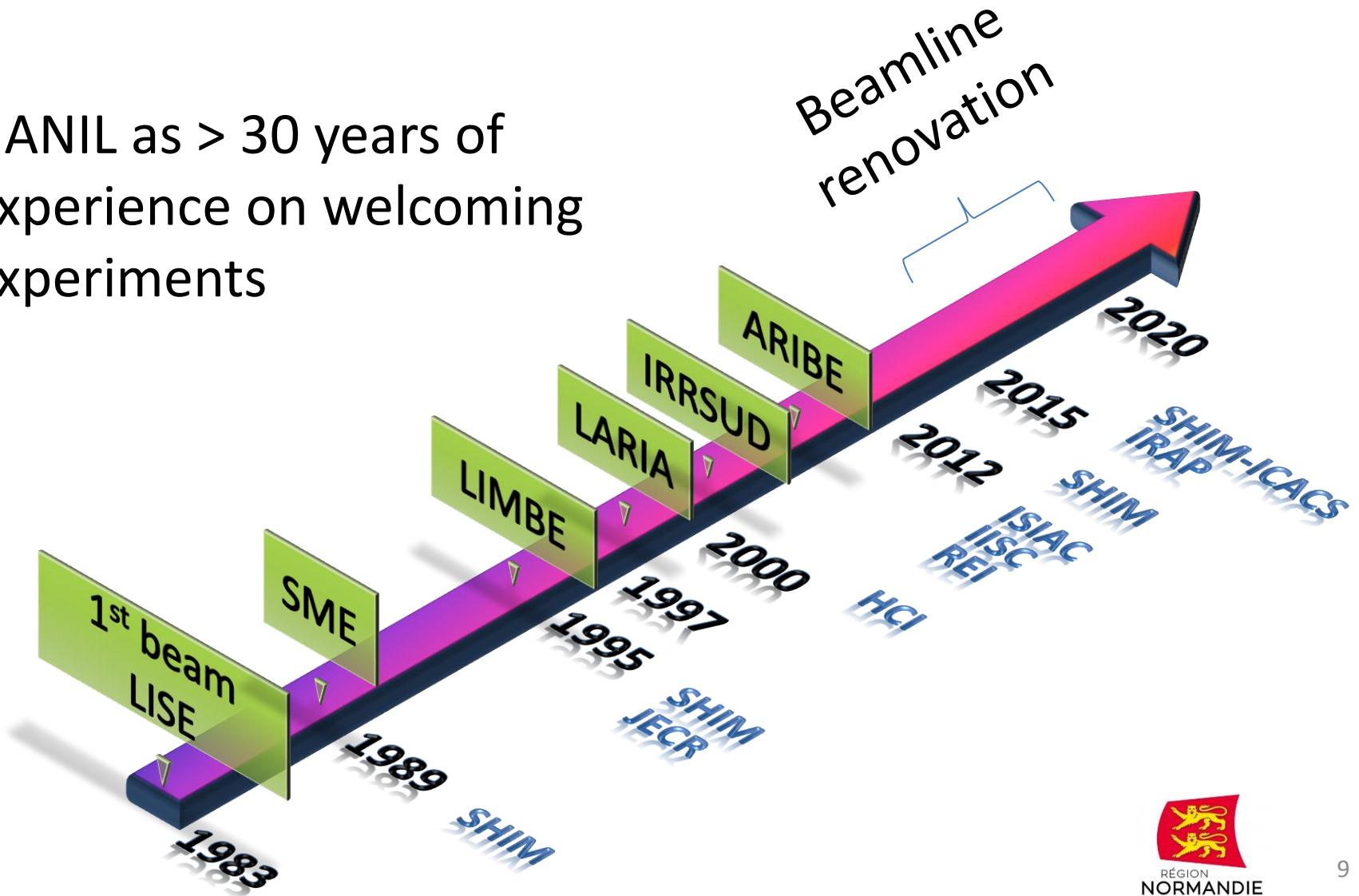
Centre Fr Baclesse



The ARCHADE project in Caen

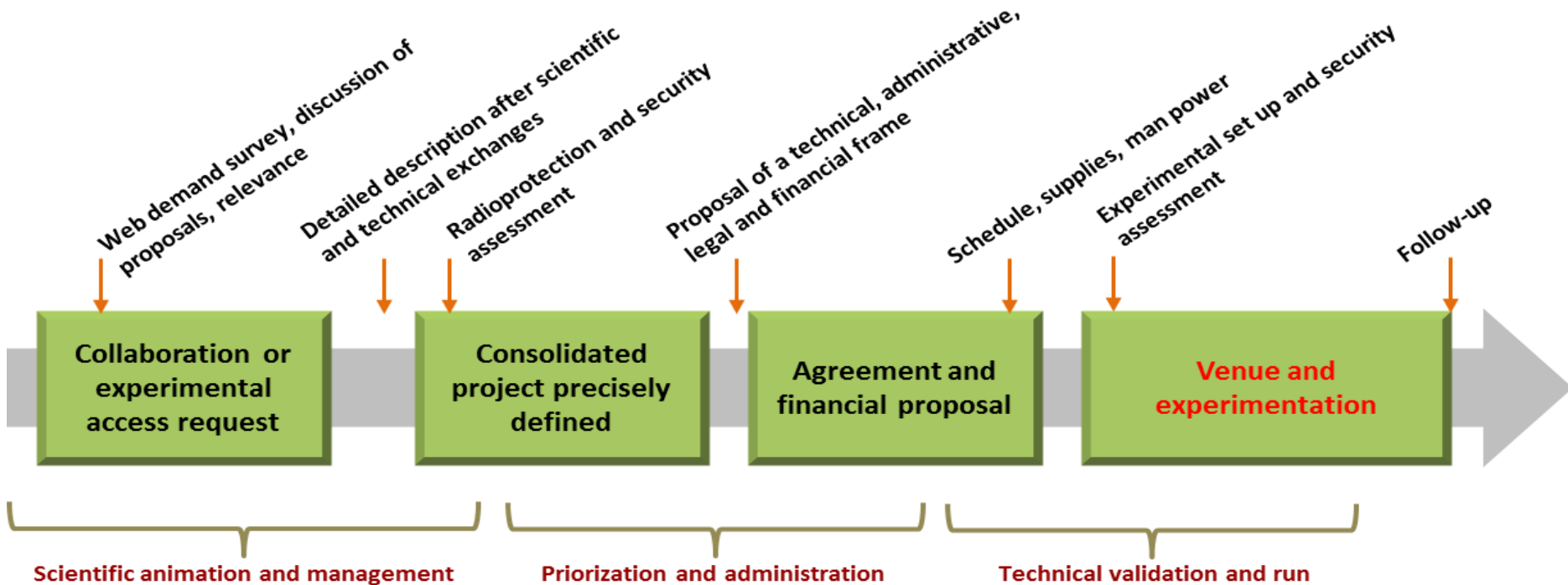
External users welcoming

GANIL as > 30 years of experience on welcoming experiments



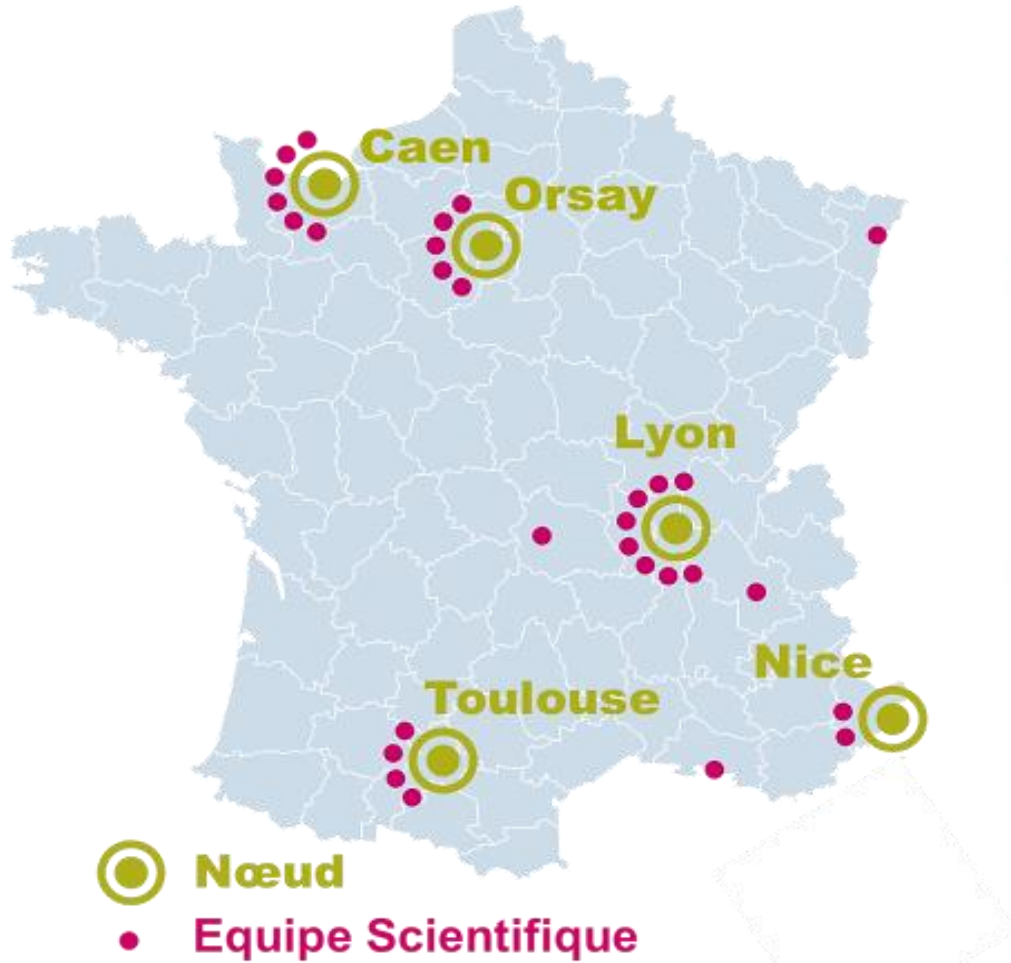
The ARCHADE project in Caen

Organization with a Proposal advisory committee



Practical organization

The ARCHADE project in Caen : position in France ...



... coming soon: RADIOTRANSNET

An exact correspondence of ARCHADE scientific program and *FrHA* project



- **WP1:** Clinical research in hadrontherapy
- **WP2:** Basic physicochemical data for hadrontherapy
- **WP3:** Radiobiology data for hadrontherapy
- **WP4:** Operational developments for improving the quality of treatments



The CYCLHAD sAs in Caen building completed in 2017



The CYCLHAD sAs in Caen

the treatment and experimental rooms



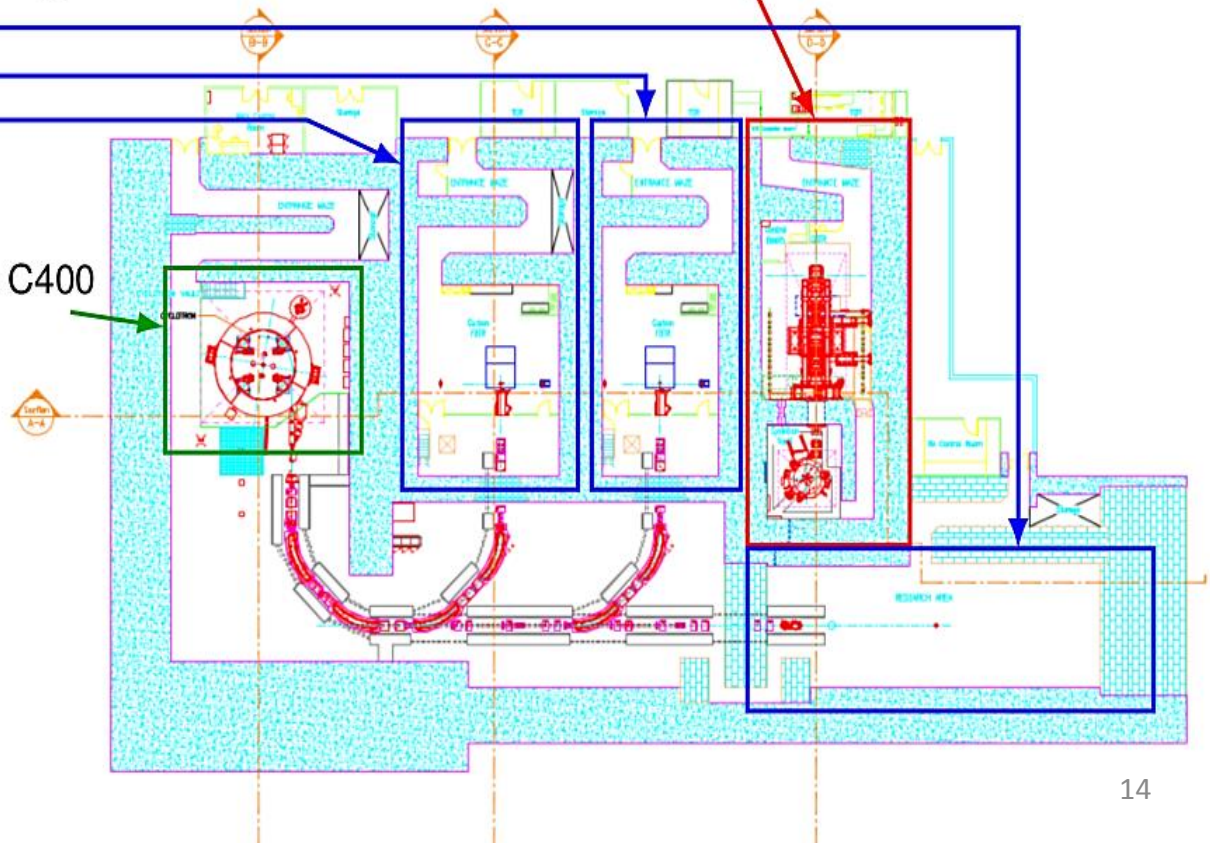
1

Hadrontherapy center :

- ▶ Protontherapy treatments
Proteus One (S2C2)
Protons at 250 MeV
- ▶ Research in carbon-therapy
 - Physics
 - Biology
 - Clinical testing

2

- Supraconducting Cyclotron C400
 ^{12}C at 400 MeV/u
Protons at 250 MeV
All light nuclei with $A/Z=2$



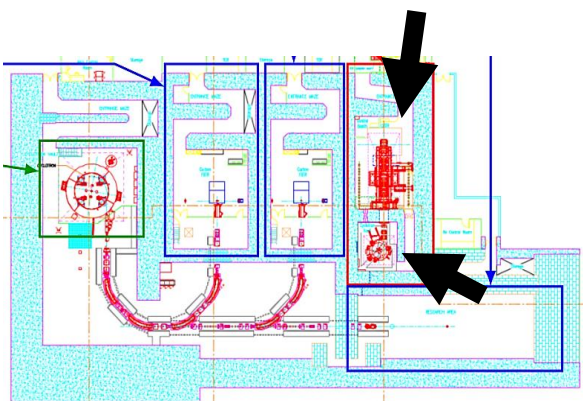
The CYCLHAD _{SAs} in Caen the surfaces for laboratories



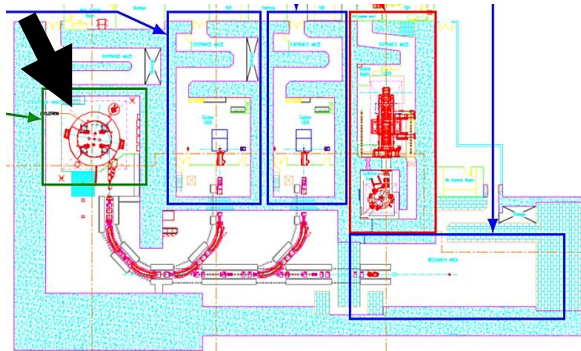
At the 2nd floor, 28 rooms devoted to science (researcher offices, laboratories, animal house, and logistic spaces) totalizing about 500 m²

The CYCLHAD _{SAS} in Caen

the installation of the Proteus[®]One in September 2017

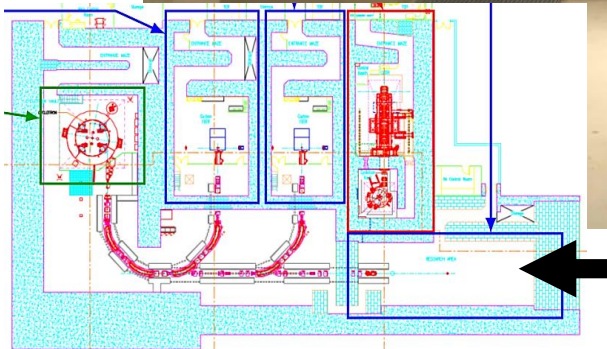


The
CYCLHAD
sas in Caen
the pillars to
receive the
C400 for its
assembly
starting in
2020



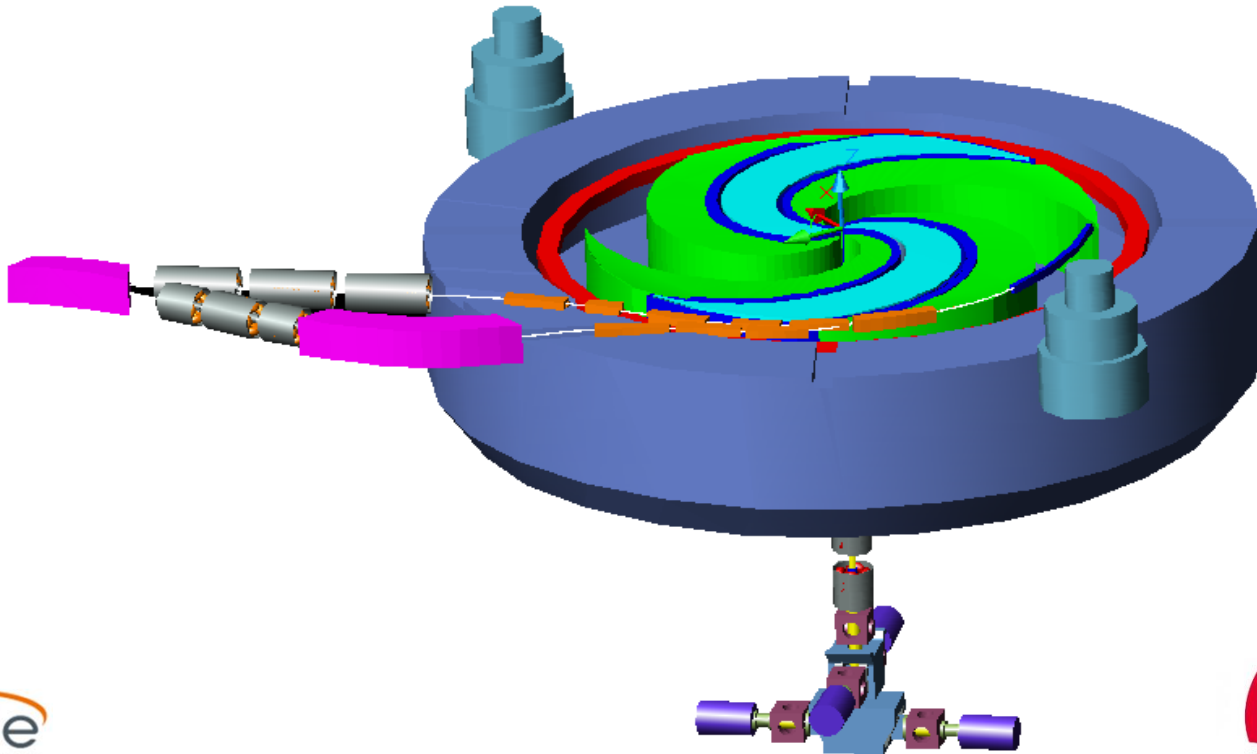
The CYCLHAD sAs in Caen

the beam lines hall seen from the physics exp. room



The production of C400 by NHa SAS

- The C400 has been designed by Russian teams of Doubna between 2006-2009 for IBA under the direction of Yves Jongen
- The PI is presently owned by the ARCHADE organization
- It will be an isochrone super conducting **cyclotron** able to accelerate **Protons, He, Li, B, C, N, O, Ne**



The production of C400 by NHa SAS

The main parameters of the C400 cyclotron for carbon ions

Energy (fixe)		400 MeV/u
Courant extracted beam →	Maximum	30 enA
	Minimum	0,03 enA
Emittance of extracted beam		
	maximum (1 σ) → (horizontal)	6 π mm.mrad
	(vertical)	8 π mm.mrad
External diameter of the magnet		628 cm
Total height of the magnet		340 cm
Total weight		694 tonnes

The production of C400 by NHa SAS

The main parameters of the C400 cyclotron helium ions

Energy (fixe)		400 MeV/u
Courant extracted beam →	Maximum	300 enA
	Minimum	0,3 enA
Emittance of extracted beam		
	maximum (1 σ) → (horizontal)	6 π mm.mrad
	(vertical)	8 π mm.mrad

The main parameters of the C400 cyclotron for protons

Energy (fixe)		260 MeV/u
Courant extracted beam →	Maximum	500 enA
	Minimum	0,5 enA
Emittance of extracted beam		
	maximum (1 σ) → (horizontal)	8 π mm.mrad
	(vertical)	9 π mm.mrad

The production of C400 by NHa SAS

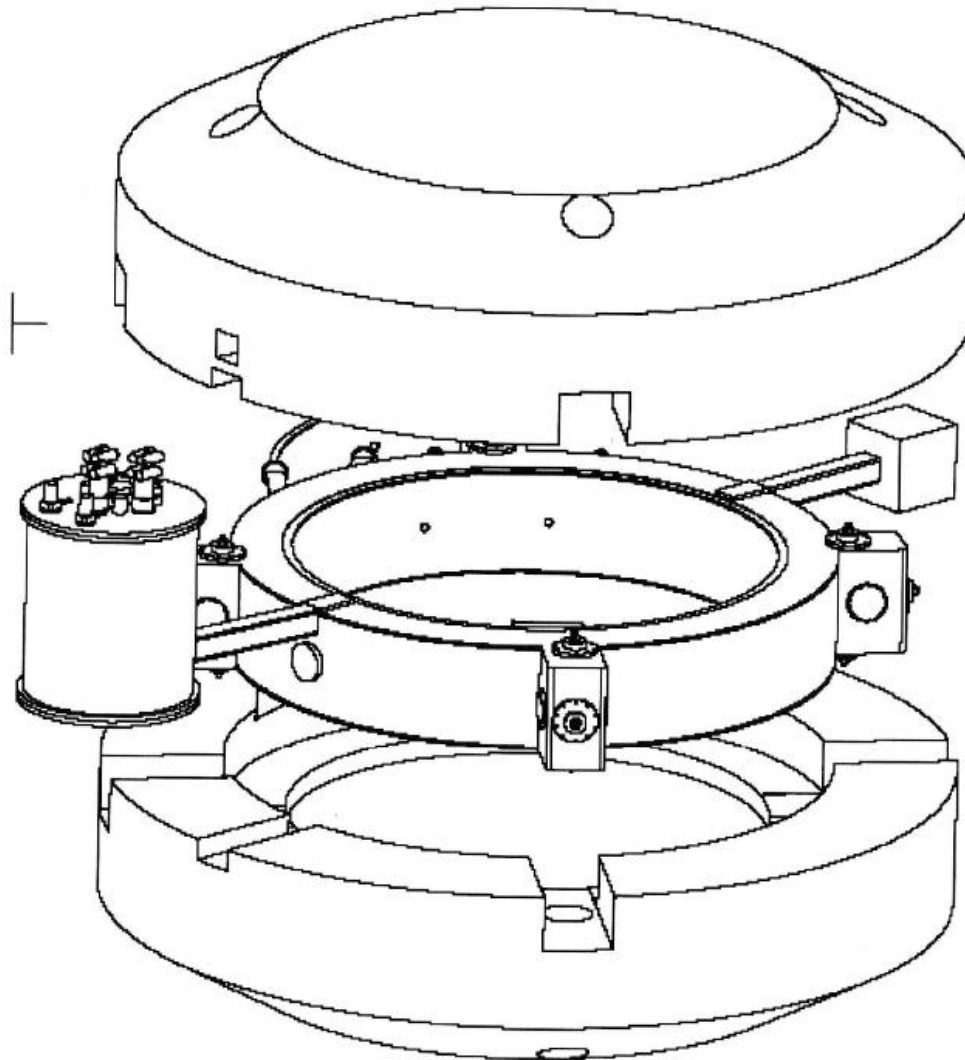


Fig.1.3.3. C400 magnet design

The production of C400 by NHa SAS

Table 1.3.1. Main parameters of C400 magnetic system

Outer diameter (m)	6.636
Height (m)	3.4
Total iron weight (t)	694
Pole radius (m)	1.87
Valley depth (cm)	60
Sectors gap (cm)	12/0.6
Sector angular width (max) (deg)	45
Sector spiral angle (max) (deg)	74
Bending limit	K=1600
Hill field (T)	4.5
Valley field (T)	2.45
A*turn (1 coil)	1 291777
Current density (A/mm ²)	28

C400 cyclotron

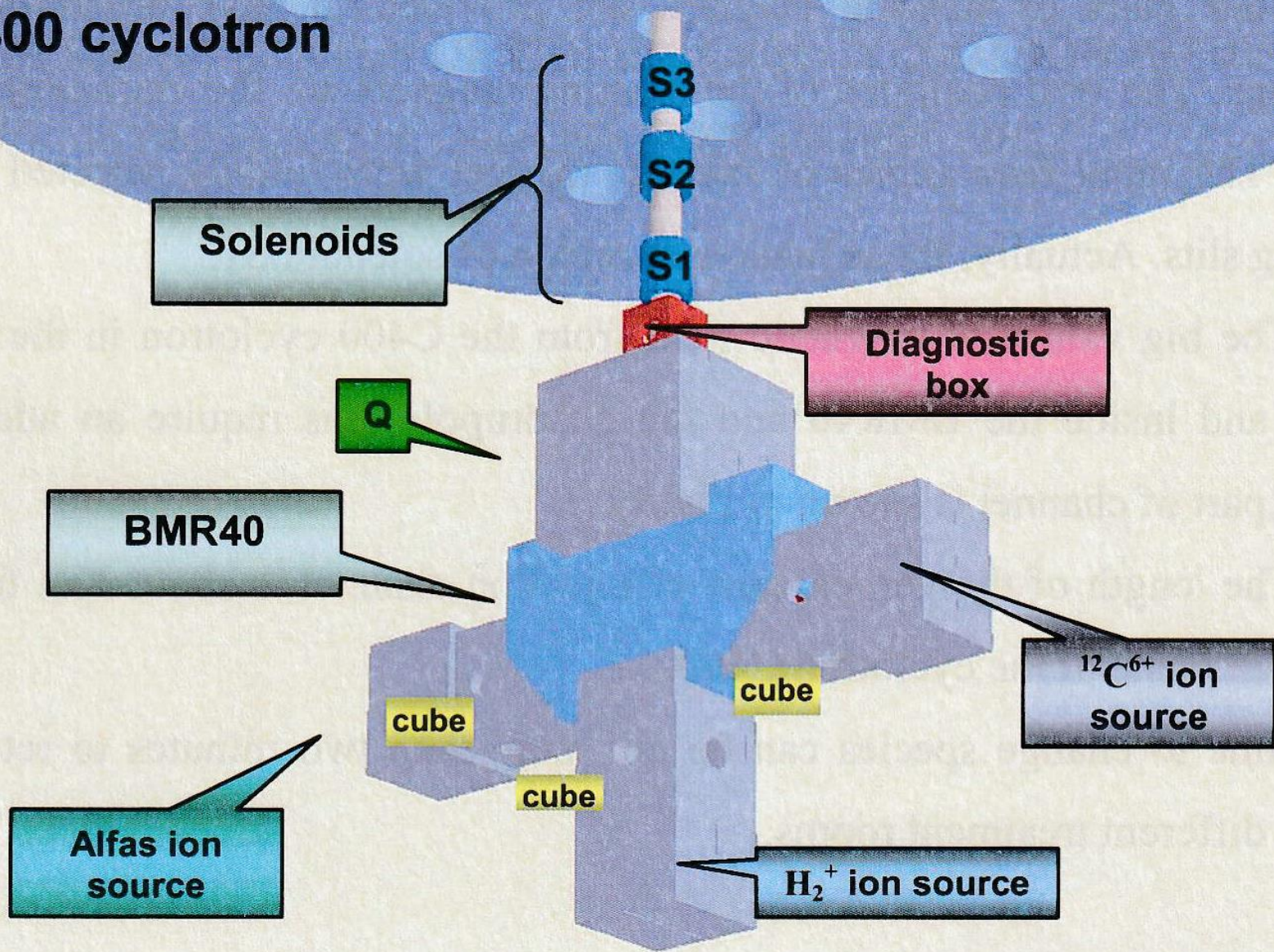


Fig. 5.1.1. General view of main elements of axial injection channel 24

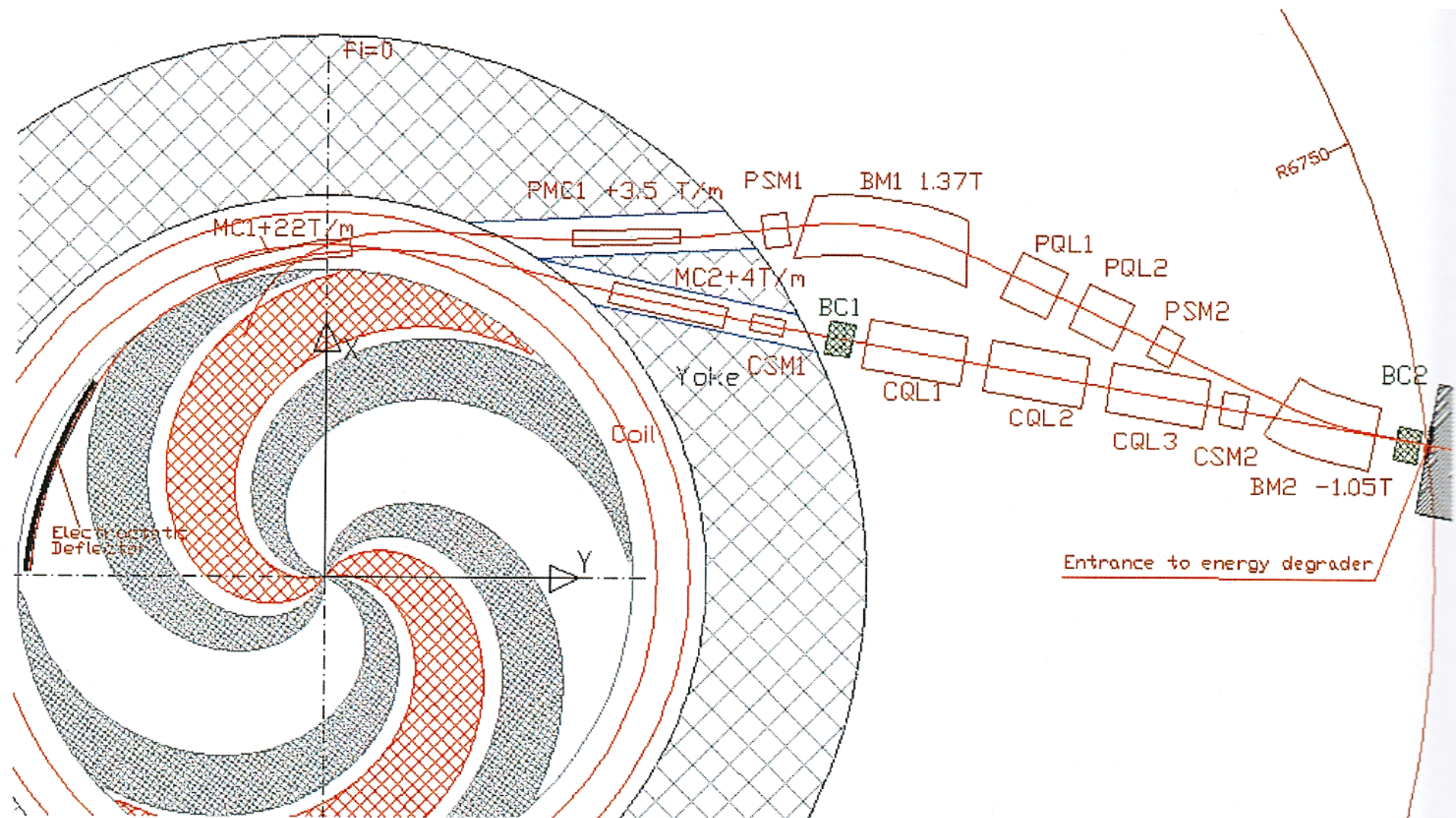
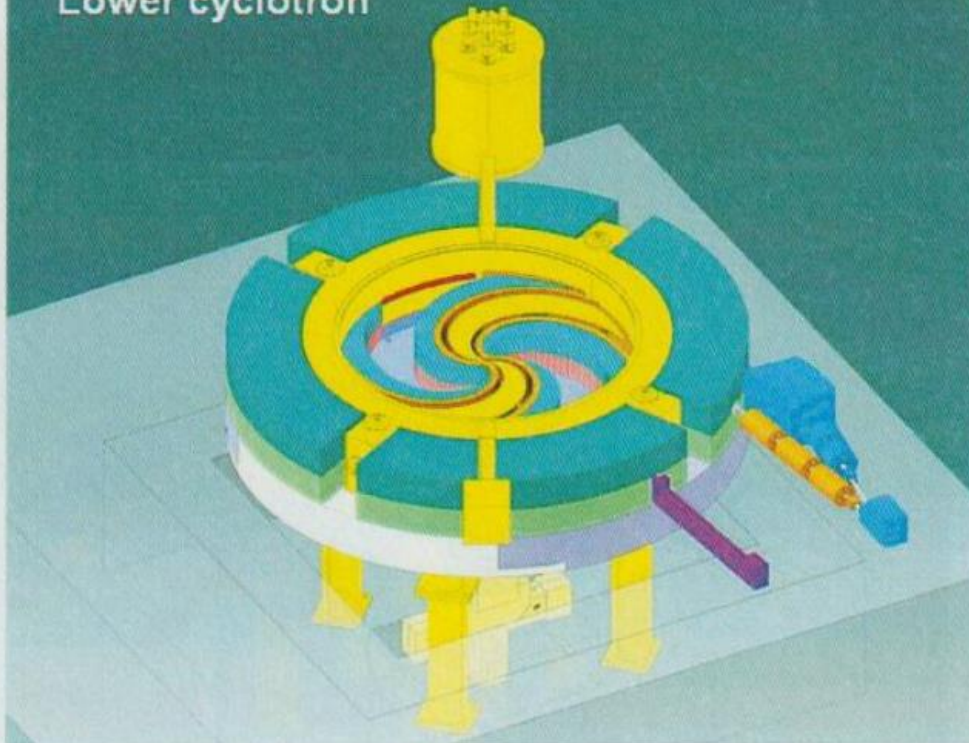


Fig. 6.4.1. Layout of the cyclotron C400 with two extraction systems (C400-360 map)

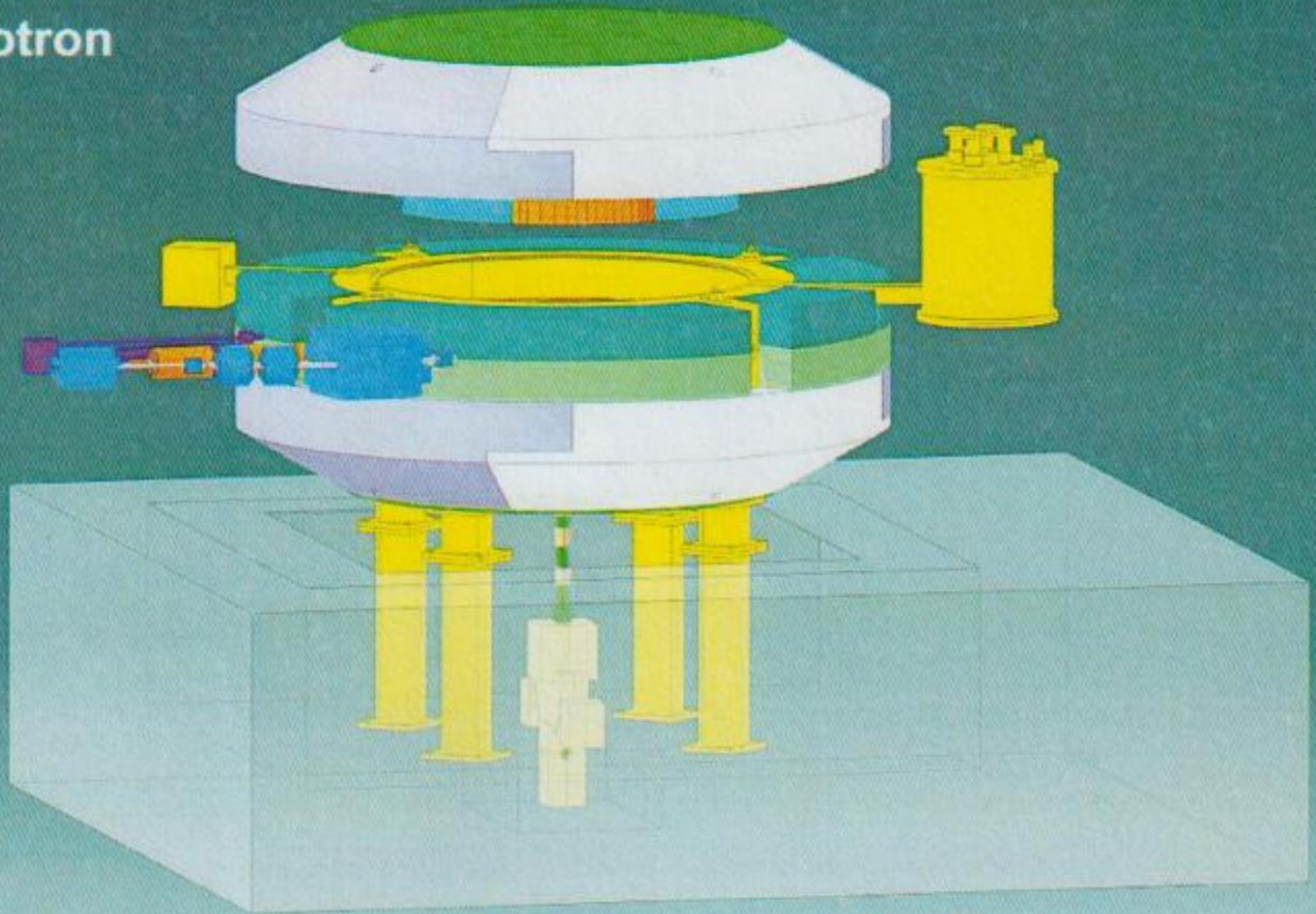
Upper cyclotron



Lower cyclotron



Full cyclotron



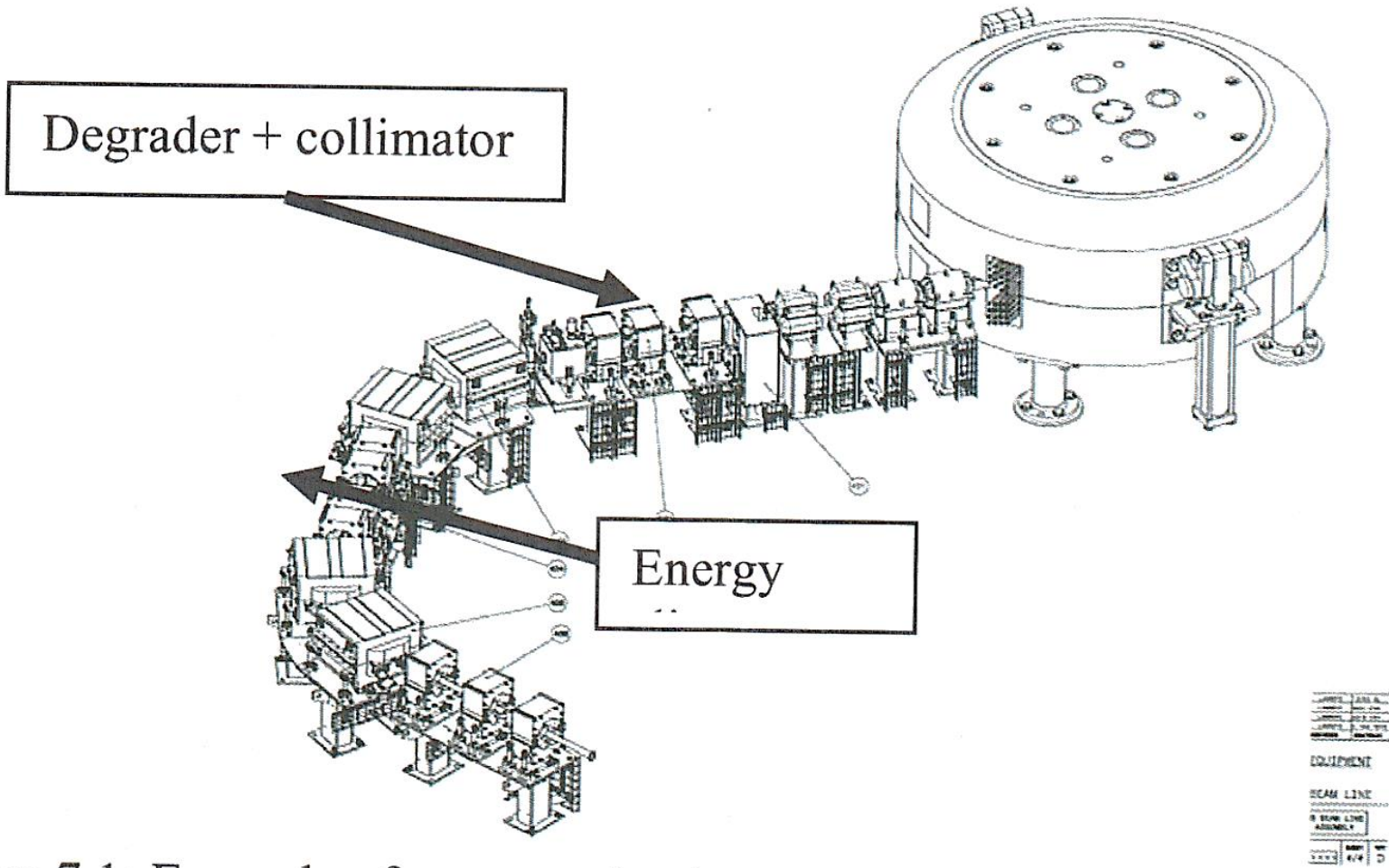


Figure 7.1: Example of energy selection system used in proton therapy system.

The production of C400 by NHa SAS

- 2010 the PI of C400 is sold to Normandie
- 2010 legal creation of Normandy Hadrontherapy (**Nha**)
- 2018 complete capitalization of Nha
- 2019 review of the specifications and design
- 2020 initiation of the construction on site in CYCLHAD
- 2022 starting the commissioning
- 2023 validation and beginning of use / test / upgrade

Medical interest and constrains

- From the C400 we are awaiting:
 - High dose rate for fast irradiation
 - Limited cost of running
 - Real multi-ions capacity in the same fraction...
 - Hight level of up time
- The use will be shared:
 - 50% for medical use
 - **50% for experimental use** including machine tests and upgrades.

Medical interest and constrains

The business model of CYCLHAD could be:

- 50% of the C400 beam time will be devoted to radiation oncology (protons and ions) and **sold** to the Centre Fr Baclesse (*as for the ProteusOne presently*)
- Up to 50% will be devoted, “free of charge” to non profit scientific users in the frame of **ARCHADE** scientific project **and external users**
 - However the access to CYCLHAD installation will not be “no cost” for ARCHADE: so the ARCHADE costs will have to be compensated.
 - We hope not to have to go beyond “marginal costs” but it will largely depend upon availability of running fundings...
 - Thus ion beam access in CYCLHAD will NOT be no cost!

To conclude... ARCHADE project is three folds

HEALTH



Starting July 2018, as a first step of the medical outcome of the **ARCHADE project**, protontherapy treatments will be available in Normandy at the **Centre François Baclesse** for cancer treatment. Protontherapy is a major progress in radiation oncology, especially for children and young adults since it is dramatically decreasing the normal tissue irradiation.

Adults and children will be treated for the following types of tumors:

ADULTS



- Meningioma
- Ependymoma
- Medulloblastoma
- Pituitary adenoma
- Skull base / paraspinal sarcomas
- Nasopharyngeal and HN Tumor
- Re-irradiation
- Orbital tumors
- and more...

CHILDREN



- Brain tumors (PNET)
- Medulloblastoma
- Craniopharyngioma
- Ependymoma
- Optic pathways glioma
- Neuro / Retinoblastoma
- Ewing sarcoma, other sarcoma

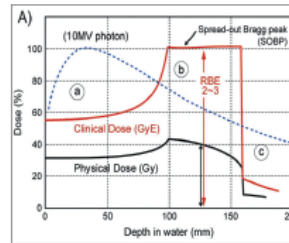
A treatment courses will last several weeks with daily treatment sessions, thus adapted housing will be available. Treatment sessions will be carried out in a devoted building called Cyclhad.

MEDICAL CONTACTS

For adults: Professor **Juliette THARIAT**
 For children: Professor **Jean-Louis HABRAND**
 Email: protonther.caen@baclesse.unicancer.fr

www.baclesse.fr

SCIENCE



Normandy is developing world class research in nuclear physics since decades at GANIL facility. More recently a comprehensive program of scientific research on hadrontherapy (the use of light ions beams for cancer treatment) has been initiated: the **ARCHADE project**. Several institutions are participating: Caen University, the National Center for Scientific Research (CNRS), the National Atomic Energy Commission (CEA), the François Baclesse Center for cancer treatment, etc.

Different types and scale of collaborations are possible in the frame of bilateral cooperation agreements:

- Short discovery training of 4 to 6 month in the frame of master degree in sciences
- Complete PhD program of 3 years
- Six months or longer medical training in protontherapy for junior or senior radiation oncologists
- Short stay for scientific teams for intensive experimental periods
- Faculty exchanges.

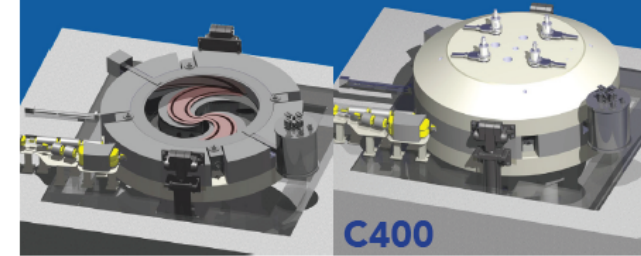
The different research domains are:

- Dosimetry, radiation-protection
- Particle fragmentation, radio-chemistry
- Treatment modelization;
- Beam control, on line quality assurance
- Tumor and normal tissues radiobiology
- Advanced molecular diagnosis
- Nuclear medicine
- Cancer epidemiology
- Clinical research in oncology

SCIENTIFIC CONTACT

Professor **Jacques BALOSSO**
 Coordinator of the Scientific project ARCHADE
 Email: j.balosso@baclesse.unicancer.fr

TECHNOLOGY



Hadrontherapy is a presently well-defined radiotherapy technology able to cure efficiently very radioresistant tumors.

However, important technological progresses are needed to make it more straightforward, less expensive and tedious to perform. These conditions are critical for its future development. In the frame of the **ARCHADE project**, Normandy backed by the world leader Co in protontherapy, is investing for technology development either for instrumentation development and breakthrough accelerator technology. For developing new accelerator technology, investments are needed and the devoted corporation backed by Normandy Region – **Normandy Hadrontherapy (NHa)** – is still looking for participation of new investors.

The immediate prospect is the development of a multi-ions superconducting cyclotron, as the entrance item of a new type of hadrontherapy system. Such equipment should be the next generation of accelerator for the future hadrontherapy centers making possible to offer several different types of light ions beams for the best adaptation of the tumor to treat.

Investments are warranted by the Normandy Region in case of failure.

A specific Society of Mixt Economy (SEM) has been set up to organize and manage these investments, the SAPHYN.

BUSINESS CONTACT

For more detailed information :
Mr Christophe LE FOLL
 c.lefoll@baclesse.unicancer.fr

Thank-you, questions ?