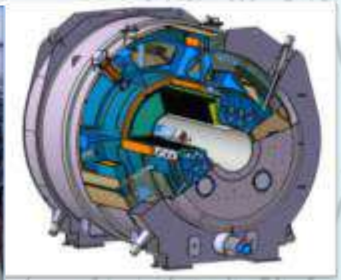
DE LA RECHERCHE À L'INDUSTRIE

New facilities around the World, where we stand where we go ?

Nuclear Physics a pillar of the Cosmological model.





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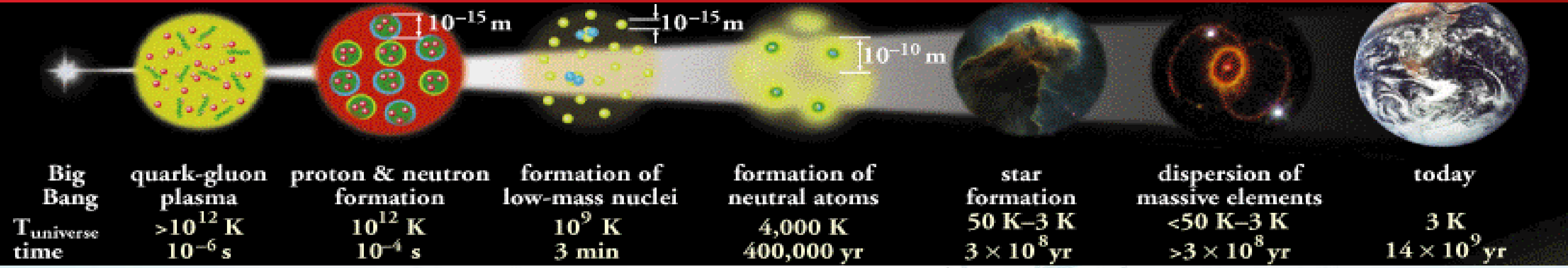
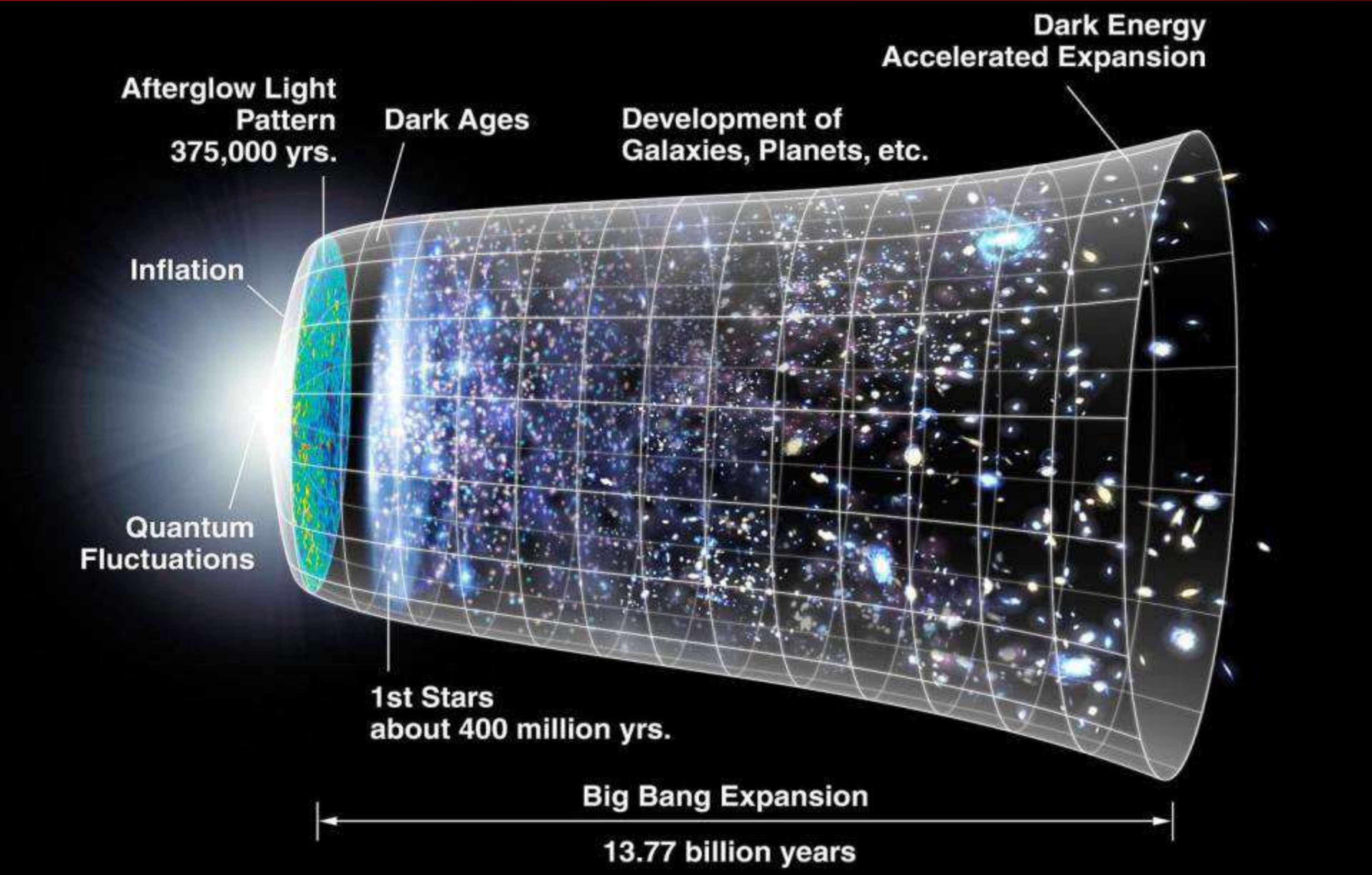
Nuclear physics is a pillar of the cosmological model



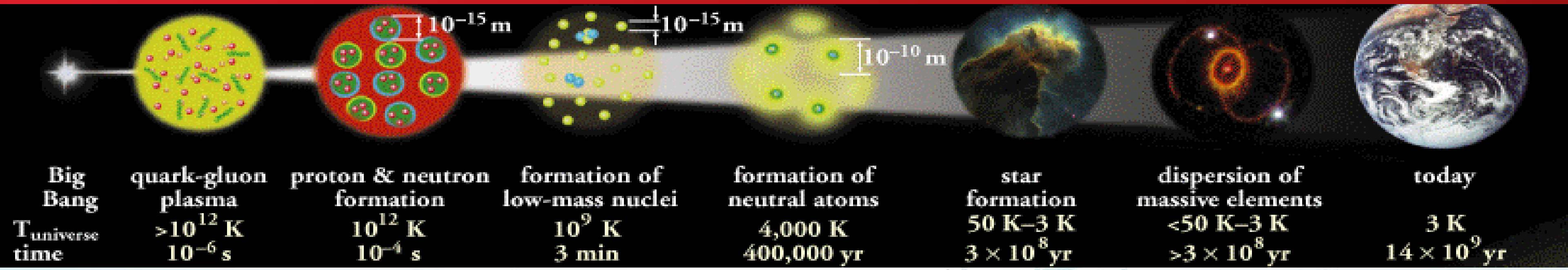
The aim of modern science is to understand the origin and evolution of the cosmos and to contribute to the well-being of our world.

Nuclear physics contributes to this intellectual adventure by attempting to understand : how matter was created, how it evolved in the history of the cosmos, how nuclear forces bind matter to form nuclei…

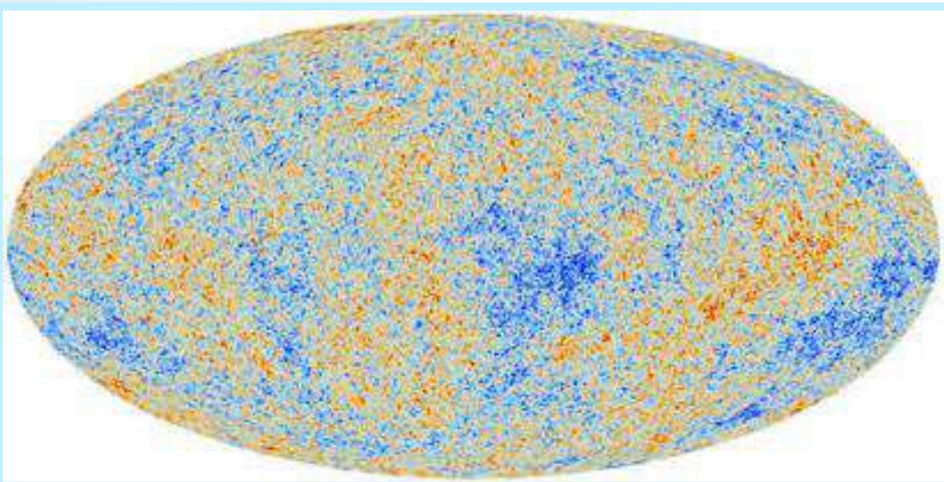
The cosmological model

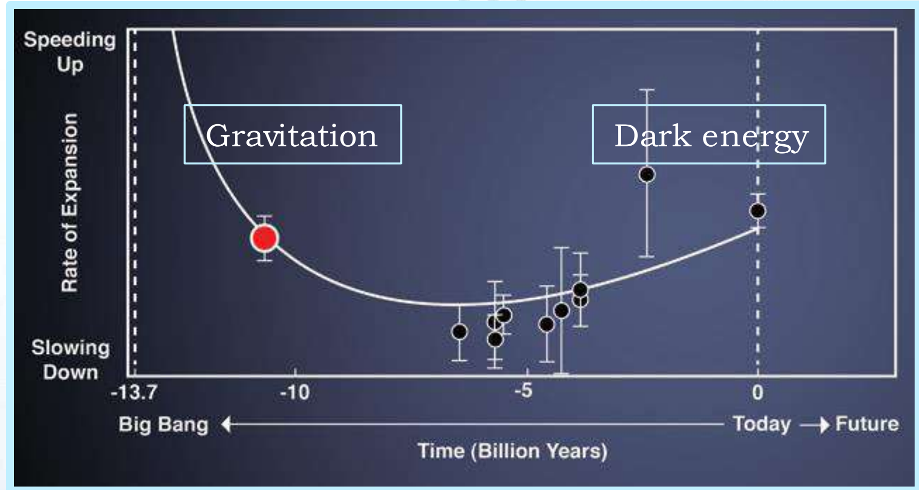


Among the pillar of the Cosmological model

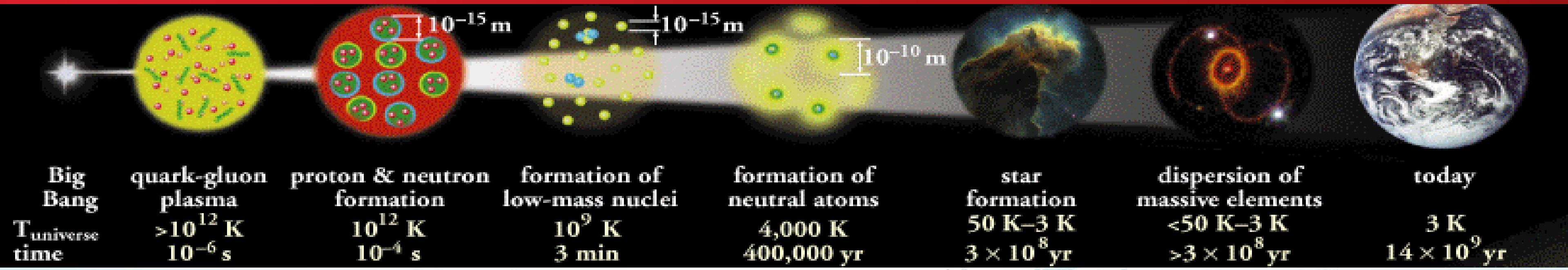


The primordial nucleosynthesis, together with the cosmic microwave background radiation (CMB) and the expansion of the universe, constitutes one of the three irrefutable pillars of the Big Bang theory.





AMONG THE PILLAR OF THE COSMOLOGICAL MODEL



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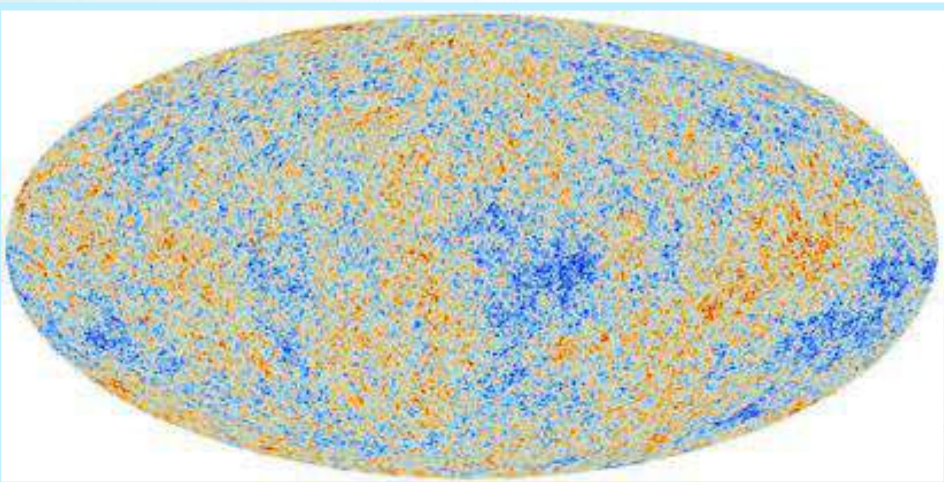
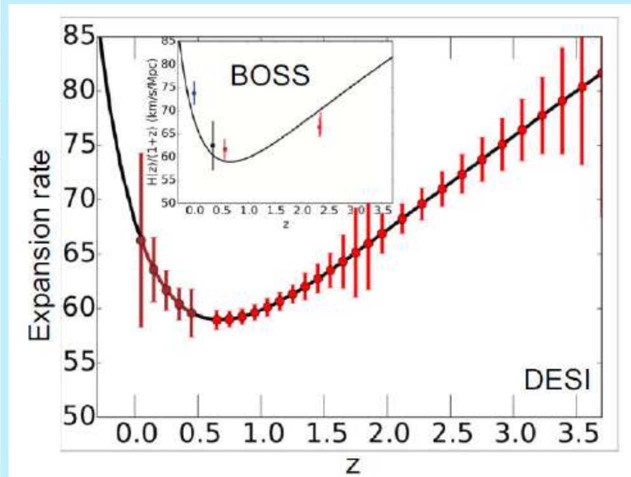




Nuclear physics a pillar of the cosmological model

Nuclear physics covers the whole history of the evolution of our universe, from the very first moments of its creation, when the universe was made of a liquid of quarks and gluons, to the creation of the first hadrons, the proton and the neutron, to the primordial nucleosynthesis, which will completely freeze out its content, to the creation of the nuclei that compose us.

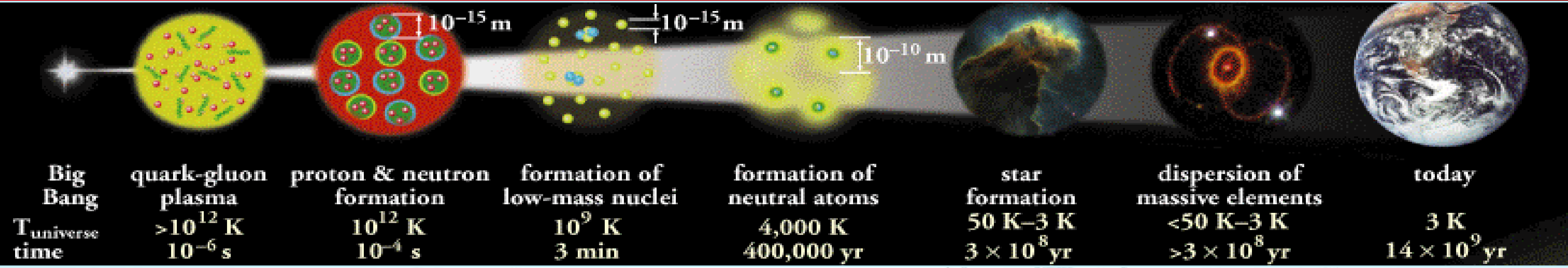
In this presentation, I will describe the new facilities under construction around the world. The objective is to invest the many fundamental questions that nuclear physicists are asking today.

Of course, nuclear physics has also a large number of societal applications, but this aspect will not be discussed today.

Future nuclear physics facilities around the world

- Hot QCD, or Quark Gluon plasma search, or Hadronic physics at T≠0
- Cold QCD – Hadronic Physics at T=0
- Nuclear Structure
  - Super-heavy elements
  - Exotic nuclei

Nuclear physics at the electroweak-era



At the beginning, 13.7 billion years ago, there was the Big Bang

Up to 10^{-6} seconds: The electroweak-era.

The universe is composed of a plasma of quarks and gluons at a temperature of a thousand billion of degrees.

Because of this high temperature, quarks cannot bind to form mesons and baryons. The universe is filled up with a soup of elementary particles including photons, neutrinos, electrons, gluons, quarks.

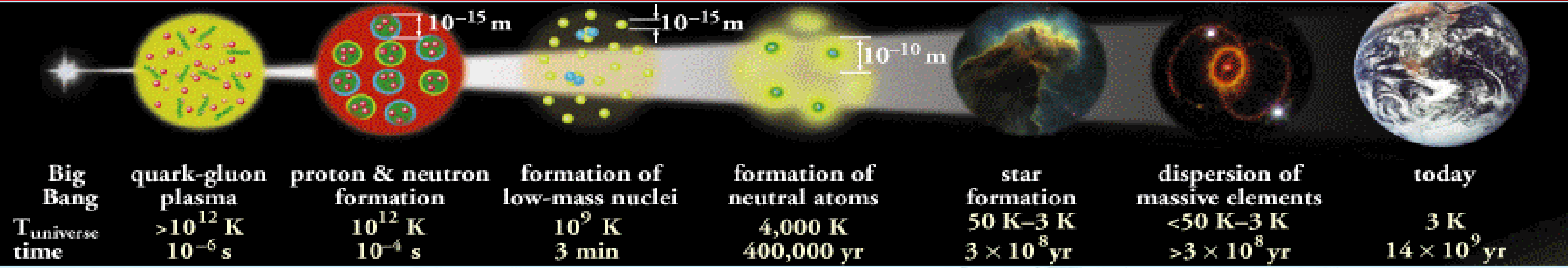
Study of hot and dense baryonic matter

The experimental approach to study “this phase of the universe” made by a strongly interacting matter at very high temperatures involves collisions of hadrons at very high energy. The target energy is 4 to 11 GeV at the center of mass.

To summarize …. after 30 years of research with five accelerators, RHIC at Brookhaven, which started operating in 2000, has discovered a new state of matter (QGP). The matter is an almost “perfect” liquid of quarks and gluons with a shear viscosity-to-entropy density ratio near the quantum limit.
The ALICE experiment at CERN started in 2010 and re-discovered this new state of matter.

Challenges in QCD mater physics – experiments at FAIR Eur. Phys. J. A (2017) **53**: 60

Many important questions about QCD can be accessed with these tools



Among the fundamental questions ?

- What are the phases of strongly interacting matter and what roles do they play in the cosmos?
- What is the role of gluons in nucleons and nuclei?
- How are the unique properties of QCD manifested in unusual properties of strongly interacting matter?

IUPAP Updated 2018, QCD and Quark Matter by Berndt Mueller (BNL)

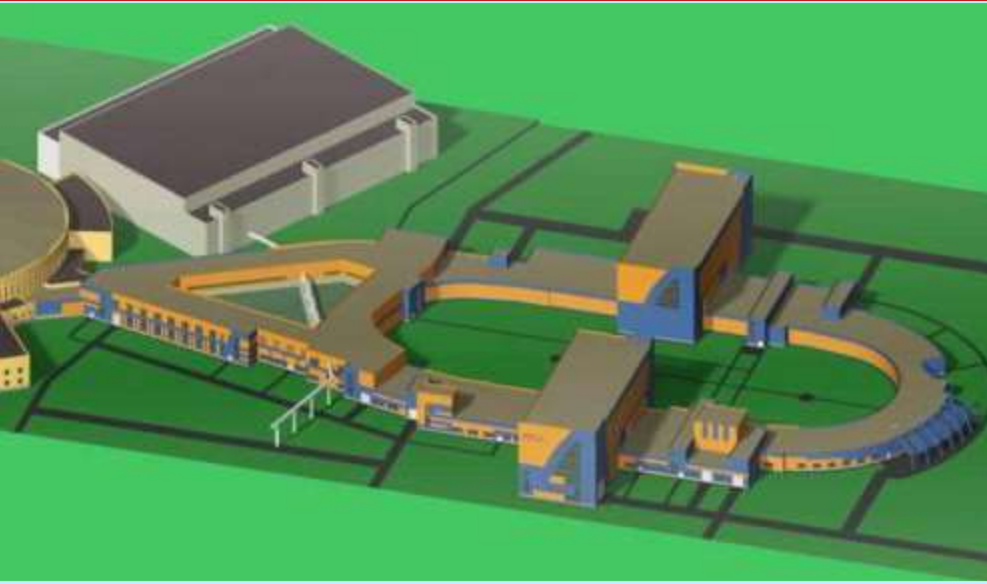
The **bold characters** are for the running facilities, *italics for those under construction*, and the gray cells for proposed facilities.

Subfield		America	Europe	Asia
Quark many body -Hot QCD-		**RHIC A+A**	**LHC (ALICE)** *FAIR(SIS100)* *NICA A+A*	
Quark many body systems Cold QCD-	hadron beam		**CERN SPS** *FAIR(SIS100)*	**J-PARC** **HIRFL**
	lepton beam	**JLAB-12GeV**	**CERN SPS μ** **MAMI**	**Spring-8** **ELPH**
	collider	**RHIC p+p**	*NICA p+p*	**(Bess-III)** **(Belle-II)**
		eIC e+A/e+p		*-eIC@HIAF*
Nucleon many body systems	Projectile Fragmentation RI beams	*FRIB*	*FAIR*	**RIBF** **HIRFL** *RISP* *HIAF*
	ISOL RI beams	*ARIEL/ISAC2*	**HIE-ISOLDE** *SPIRAL2* *SPES*	*BRIF2* *JUNA*
	Super Heavy	**High Flux Reactor**	**GSI UNILAC,** *Dubna SHE factory*	*Superconducting RIKEN RILAC*
Super ISOL		*FRIB upgrade*	*EURISOL*	*Beijing ISOL*

New facilities FAIR and NICA

The energy regions which FAIR and NICA are targeting are the region once covered by the SPS and low-energy scans at RHIC, however no experiments were done in this domain with high luminosity. FAIR and NICA will challenge the physics of dense QCD with a much higher interaction rate.

NICA (à DUBNA) E_{lab} < 60 GeV/n



FAIR/CBM E_{lab} ~ 34 GeV/n

A long-term vision

At RHIC the luminosity upgrade will extend the present experimental program. The heavy ion program at CERN will continue with the upgrade of the detectors. *RHIC and LHC (including ALICE and LHCb,….,) have another 10-15 years of productive research in studying the properties of QGP.*

FAIR and NICA will challenge the physics of dense QCD with advanced experimental technologies. However, today it is difficult to anticipate what the scientific output from these two new facilities will be ?

It the future, after 2030 the relativistic heavy-ion colliders may be replaced by electron-ion colliders like (EIC) (2030-2040) in the US or by the high energy electron-ion collider (LHeC)project under discussion at CERN?

Future nuclear physics facilities around the world

IFMIF

- Hot QCD, or Quark Gluon plasma search, or Hadronic physics at T≠0

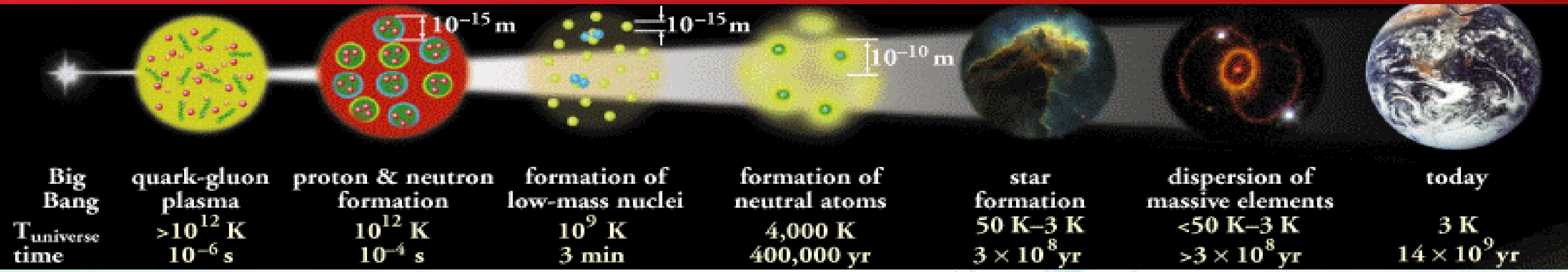
- Cold QCD – Hadronic Physics at T=0

- Nuclear Structure

  - Super-heavy elements

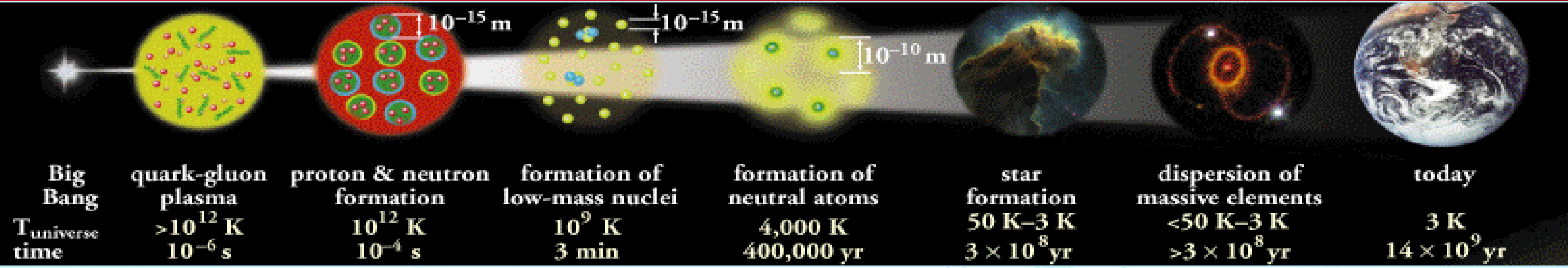
  - Exotic nuclei

From 10^{-6} seconds to 1 second, the hadronic era



From 10^{-6} seconds to 1 second, the hadronic era. The quarks are confined. They form baryons and mesons. Studying the internal structure of protons and neutrons is an essential step in understanding in a detailed way how the nuclear force, the one that binds protons and neutrons, emerges from QCD?

Cosmological model and Nuclear Physics

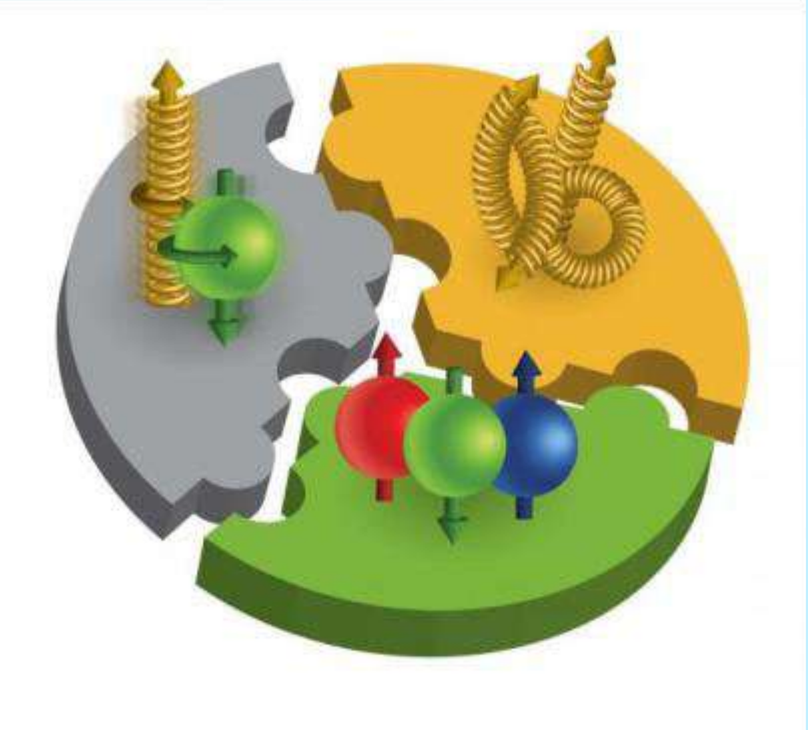


Among the fundamental questions ?

The question of confinement why free quarks have never been observed ?

The question concerning the origin of the mass and of the spin of the nucleons ? The Higgs mechanism provides mass to the mediators of the weak interaction, to the quarks and to the leptons. But the quarks contribute very little to the mass of the nucleons, which provide the mass of the universe.

An Example: The proton spin puzzle



IUPAP Updated 2018, Hadronic Nuclear Physics Cédric Lorcé

How different constituents of the proton contribute to its spin, a fundamental property that plays a role in how these building blocks give rise to nearly all visible matter in the universe. Pieces of the puzzle include the orbital angular momentum of quarks and gluons (top left), gluon spin (top right) and quark and antiquark spin (bottom). The latest data from RHIC reveal that the antiquarks' contribution is more complex than previously thought.

The bold characters are for the running facilities, *italics for those under construction*, and the gray cells for proposed facilities.

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Super ISOL		*FRIB upgrade*	*EURISOL*	*Beijing ISOL*

A long-term vision

Until FAIR and NICA and HIAF(*) become operational, J-PARC’s 30 GeV Proton Synchrotron in Japan will continue to play a leading for “Cold QCD” physics using hadron beams.

Among the lepton-photon beam facilities, Jefferson Laboratory (JLab) in the US is playing today and will play in the years to come (2020-2030) a leading role.

HIAF(*) is *The Chinese Heavy Ion Accelerator Facility (HIAF) project, was approved to be built at Huizhou, Guangdong Province (100km north-east of Hong Kong) as a nascent of the Heavy Ion Research Facility in Lanzhou (HIRFL),*

A long-term vision

EIC Is the first priority of the hadronic physics community.

It will be the world's first electron Ion Collider (eIC). It is proposed to be built either at BNL by adding an electron ring in the RHIC tunnel or by adding two ion-cooler rings to CEBAF at JLab.

The electron-proton colliding luminosity will be 100 times higher than at the former HERA collider.

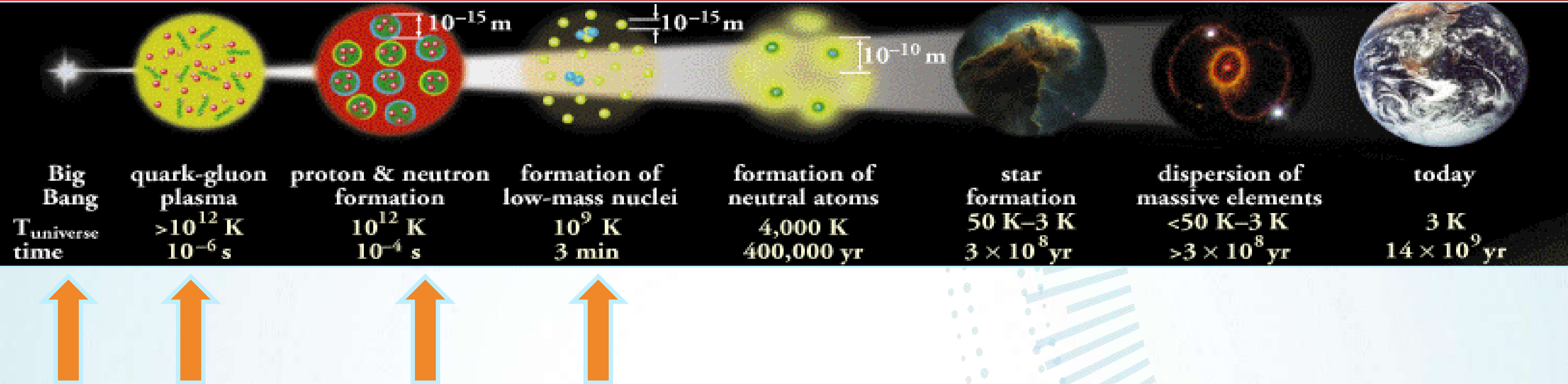
Similar option is also under consideration at CERN and HIAF (China).

Electron-Ion Collider: The next QCD frontier Understanding the glue that binds us all Eur. Phys. J. A (2016) 52: 268

IFMIF

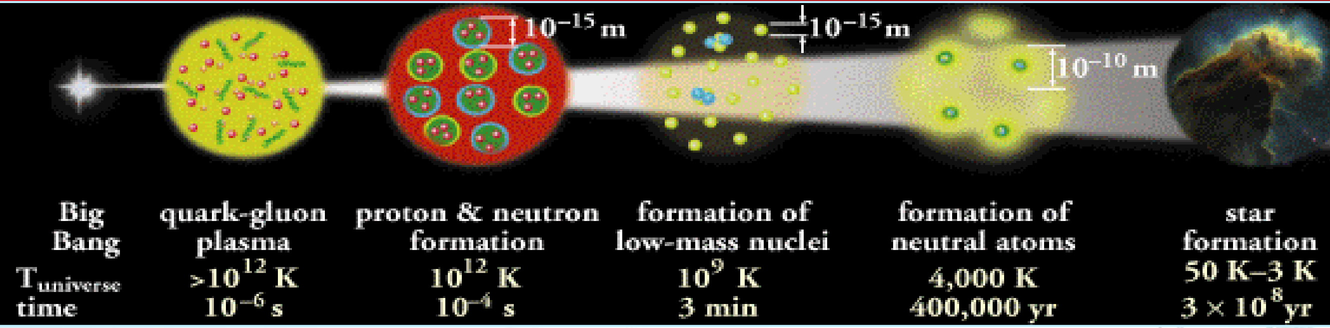
- Hot QCD, or Quark Gluon plasma search, or Hadronic physics at T≠0
- Cold QCD – Hadronic Physics at T=0
- Nuclear Structure
  - Super-heavy elements
  - Exotic nuclei

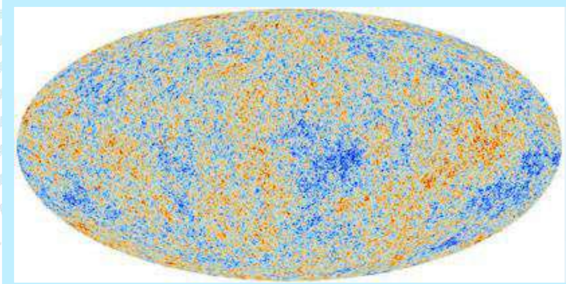
The Cosmological Model and N.Φ. The era of primordial nucleosynthesis: from 1 sec to 3 min



Protons and neutrons bind to form the first nuclei. They will interact via the reaction, $n + p \rightarrow d + \gamma + 2.226\,\mathrm{MeV}$ to create deuterons. The universe is now composed essentially of protons up to ~75% and alpha particles up to ~25% as well as deuterons, ^{3}He and traces of ^{6}Li and ^{7}Li. A real bottleneck!!!!!

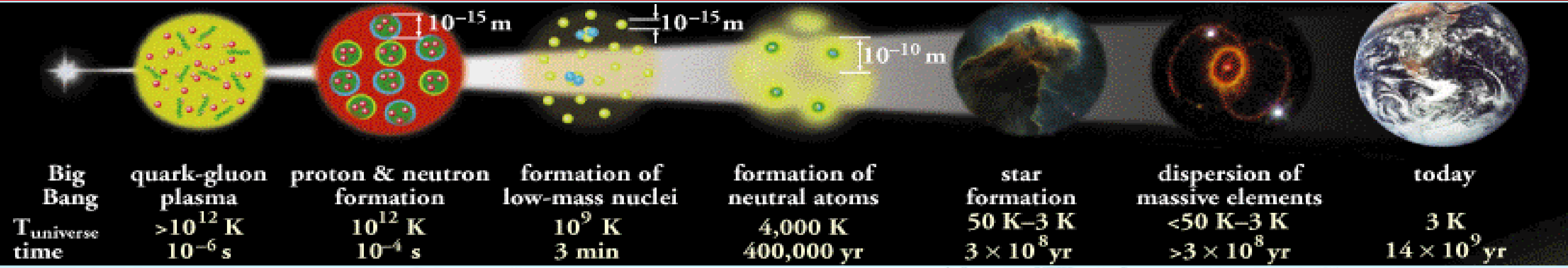
Decoupling of matter and light





The assembly of protons and electrons forms the first neutral atoms, the hydrogen atoms. When electrons were free, they interacted strongly with photons. Photons or in other words light could not escape because they were trapped by multiple collisions with electrons, so the universe was opaque. After the atoms have formed, the electrons are trapped and no longer interact with the photons.

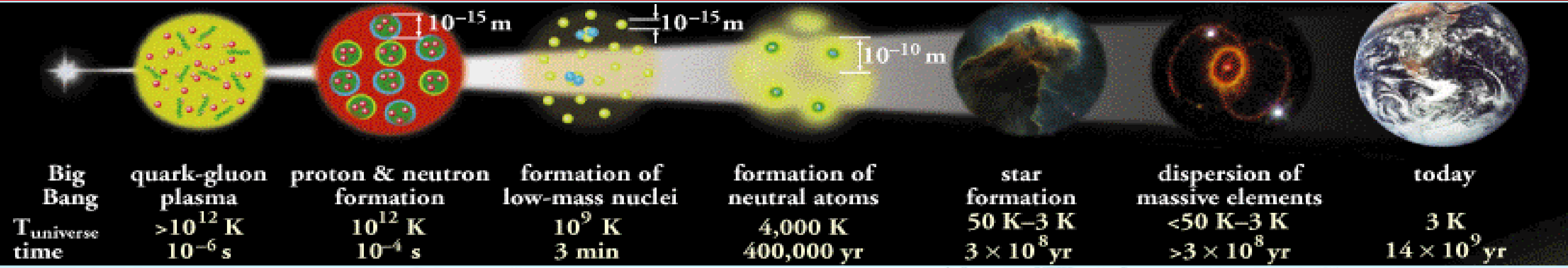
The Cosmological Model and N.Φ. From a million years after the Big Bang until today.

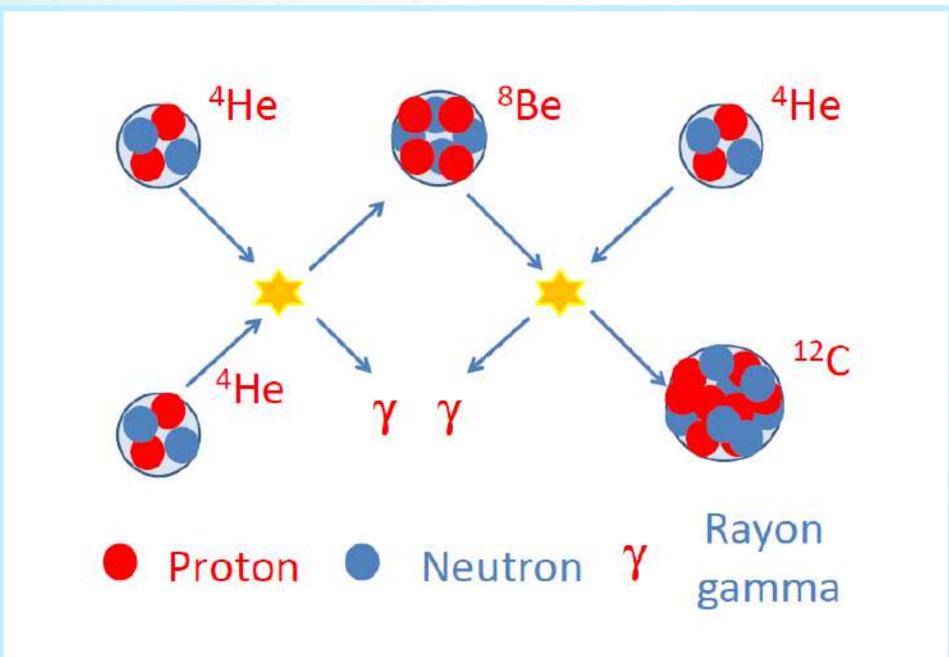


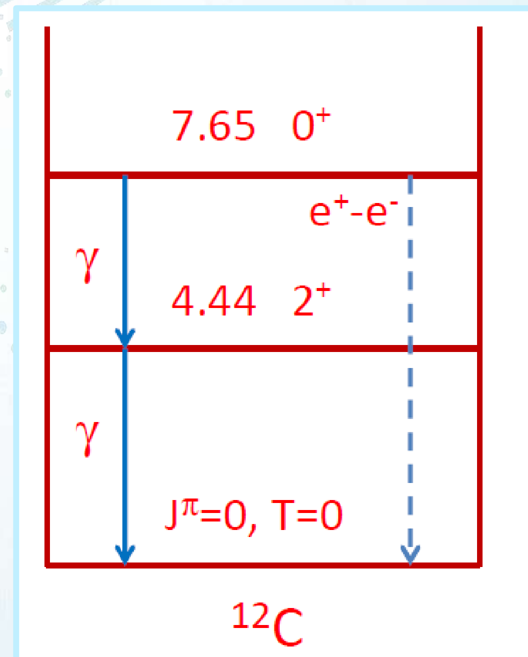
The clusters of matter form stars and proto-galaxies. Stars begin to synthesize heavier nuclei.

By what ingenuity does nature bypass this bottleneck to form nuclei like ^{12}C and then even heavier elements?

The Cosmological Model and N.Φ. From a million years after the Big Bang until today.

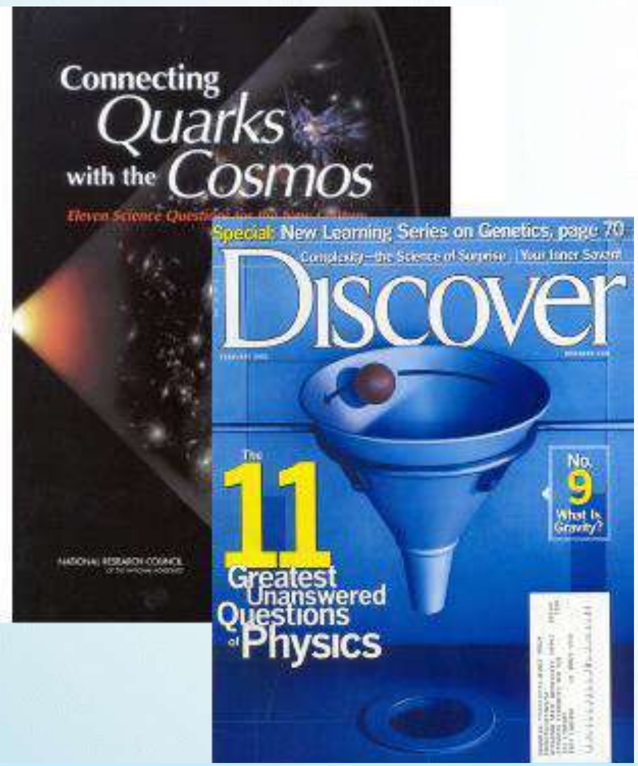


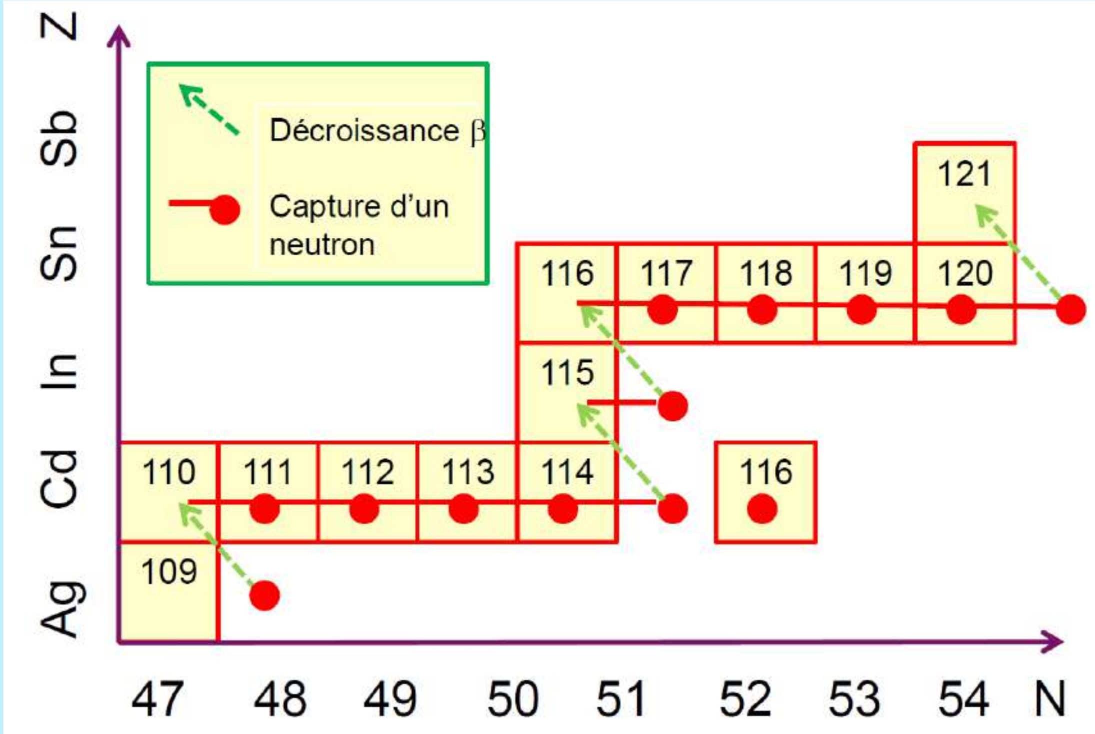




Neutron-capture process leading to elements heavier than iron

If fusion reactions are inefficient in producing elements heavier than Iron. Where and how these heavy elements are produced in the universe? This is one of the important Scientific Questions for the 21st century





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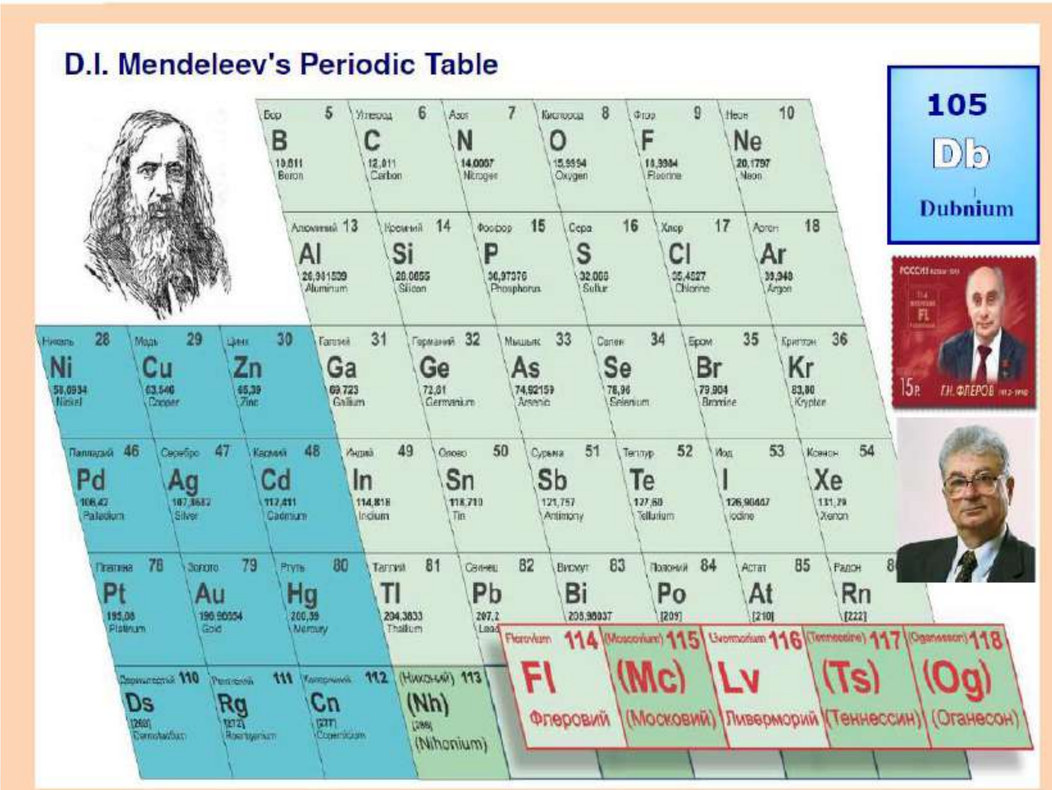
  - <u>Super-heavy elements</u>
  - Exotic nuclei

The Super Heavy elements.

During the last decade, six new super-heavy elements were added into the seventh period of the periodic table, with the approval of their names and symbols.

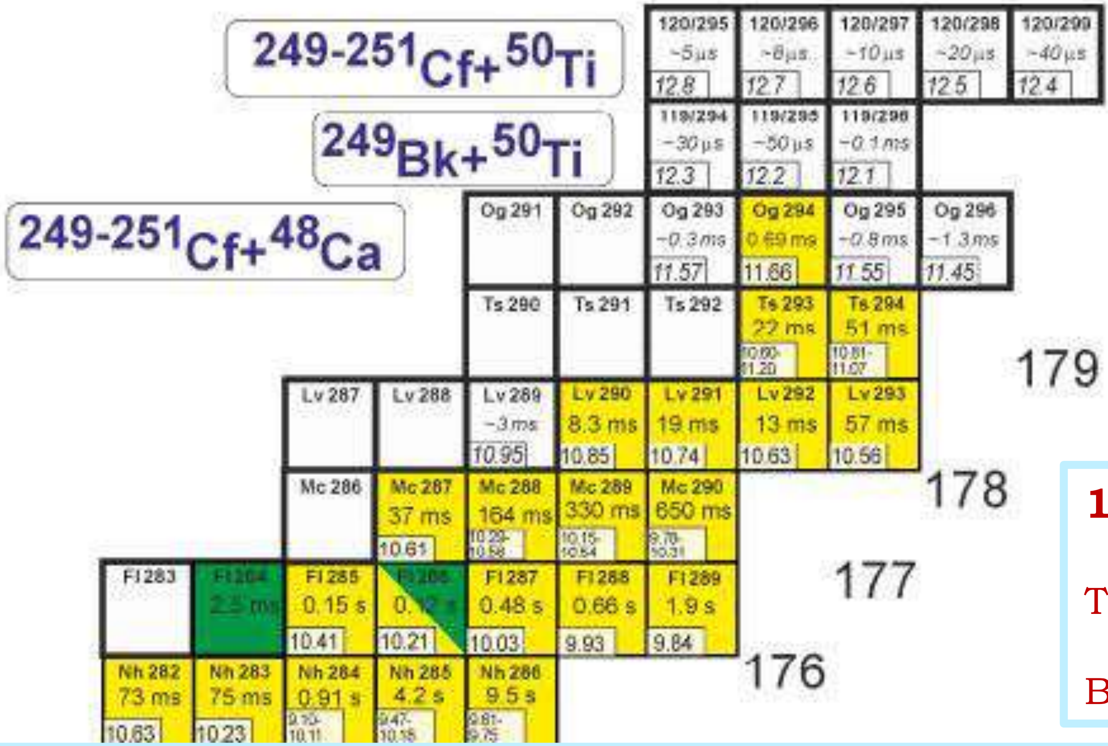


This milestone was followed by proclaiming 2019 the International Year of the Periodic Table of Chemical Elements by the United Nations General Assembly.

With Yuri Oganessian

Mr Element 118: The only living person on the periodic table

Synthesis of new elements 119, 120



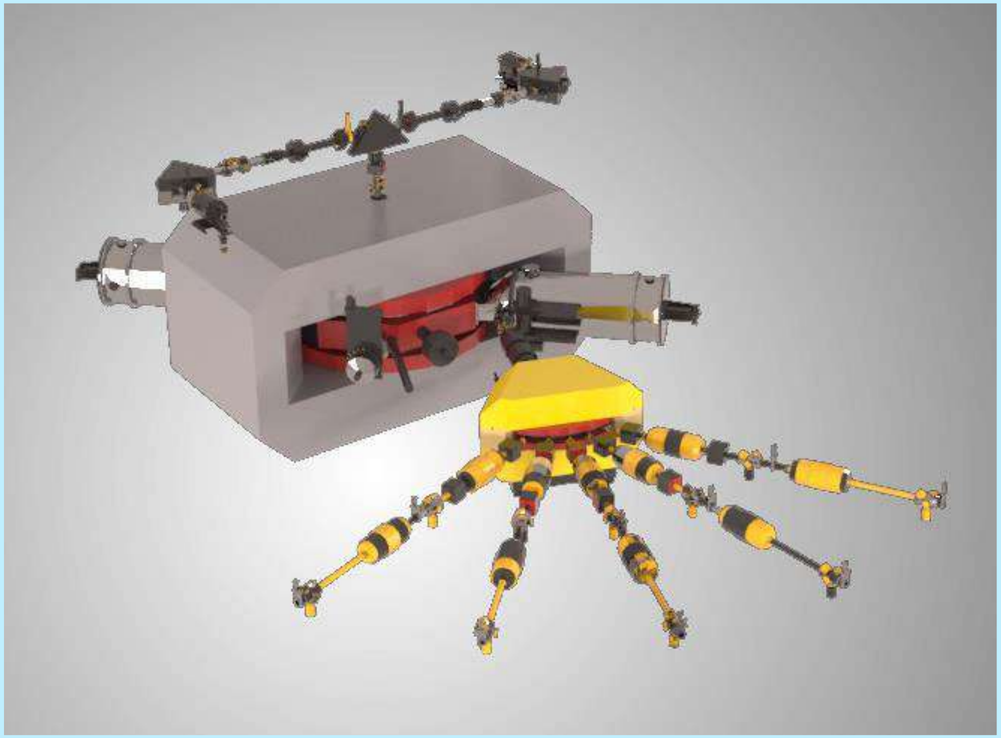
1gr of ^{248}Cm ~1million $

Targets: {Cf(98), Bk(97), Cm(96)}

Beams: {Ca(20), Ti(22), Cr(24)}

The future research for the 119th and 120th elements will continue at the SHE factory at Dubna and RIKEN.

DC-280 cyclotron – stand-alone SHE factory



- Synthesis and study of properties of superheavy elements.
- Search for new reactions for SHE-synthesis.
- Chemistry of new elements.

DC280 (expected) E=4÷8 MeV/A		
Ion	**Ion energy [MeV/A]**	**Output intensity**
^{7}Li	4	1×10^{14}
^{18}O	8	1×10^{14}
^{40}Ar	5	6×10^{13}
^{48}Ca	5	$0{,}6\text{-}1{,}2\times10^{14}$
^{54}Cr	5	2×10^{13}
^{58}Fe	5	1×10^{13}
^{124}Sn	5	2×10^{12}
^{136}Xe	5	1×10^{14}
^{238}U	7	5×10^{10}

With Yuri Oganessian - Dubna Octobre 2018

A long-term vision

Super-heavy element search : The search for the 119th and 120th elements will continue at the SHE factory at Dubna and RIKEN (introducing superconducting cavities to its linear accelerator). It should be noted that this future race requires actinide targets which can be delivered by High Flux Reactor like the ORNL.

The active search for super-heavy elements is expected to continue over the next decade. Thereafter, the field may gradually decrease, because of the complexity of the experiments, the lack of targets and retirement of experts.

It has to be noted that from the Shell model "point of view", information on the structure of Super-heavy nuclei can be inferred by studying the structure of heavy nuclei with similar active orbitals.

This may be one of the contributions of S3 at GANIL/France.

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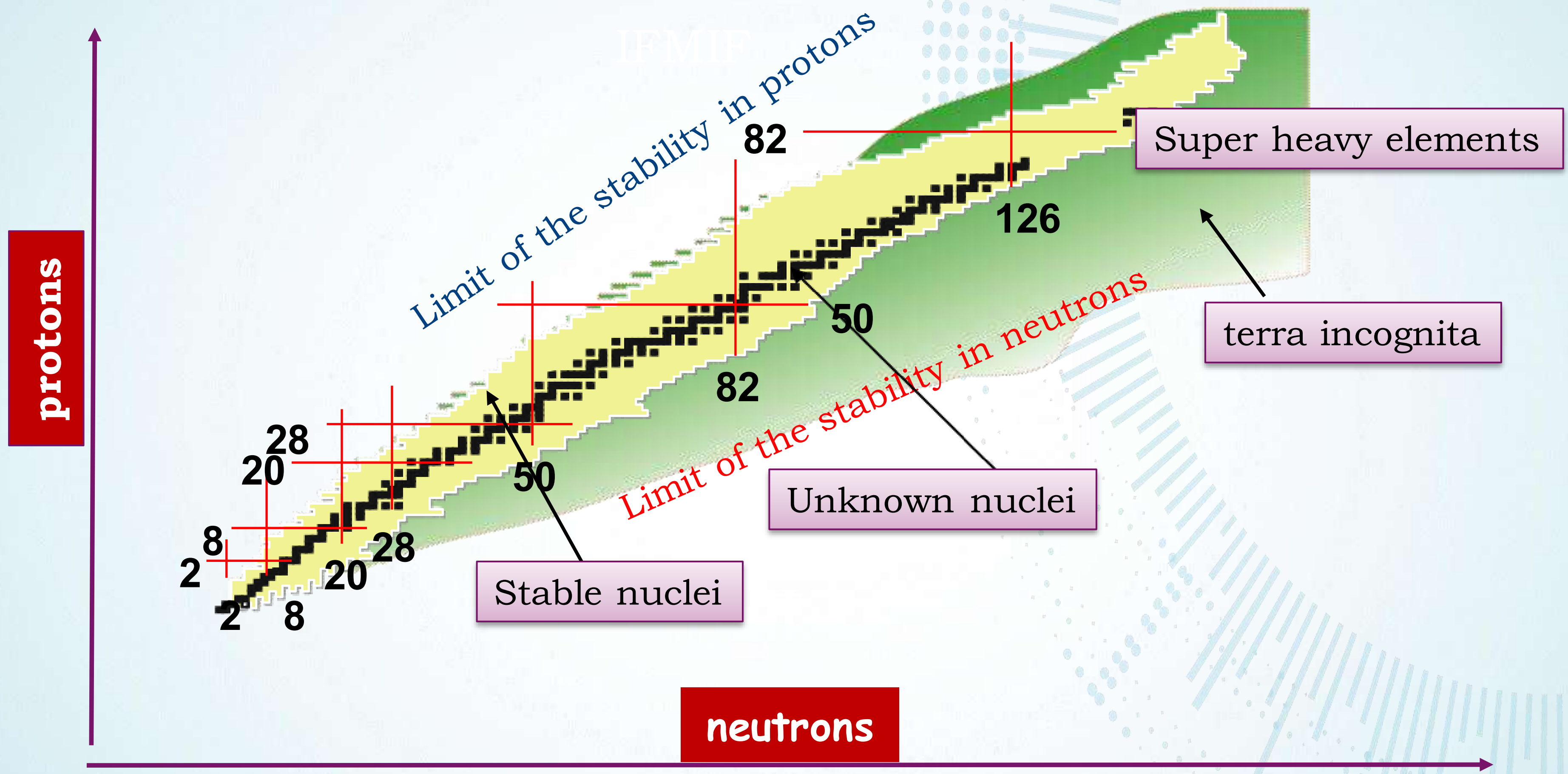
The landscape of the nucleus



IUPAP Updated 2018, Nuclear Structure, Nuclear Reactions, and Nuclear Astrophysics Alexandra Gade (Michigan State University)

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Super ISOL		*FRIB upgrade*	*EURISOL*	*Beijing ISOL*

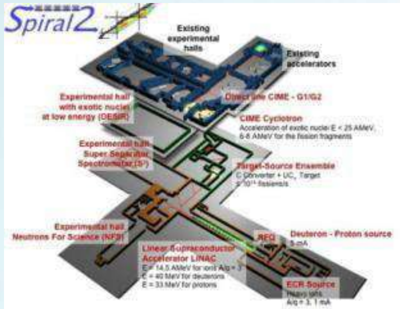
Production methodes

The projectile fragmentation method: The high energy primary beam interacts with a relatively thin target of p, ^{9}Be or ^{12}C and fragments into several nuclei. The fragments of interest are selected by appropriate methods (magnets, magnetic filters…). The radioactive beams produced in this way have energies typically ranging from 60 MeV/nucleon to 1 GeV/nucleon (about the same speed as the beam).

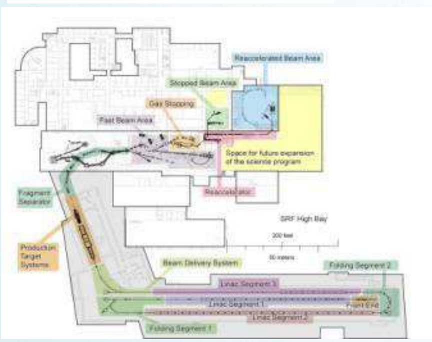
ISOL method: Radioactive beams are produced by nuclear reactions (fission, fusion - evaporation of a compound nucleus, transfer reactions) between the projectile (relatively low energy primary beam) and the target.

Radioactive beam facilities in the world (courtesy Grigorenko)

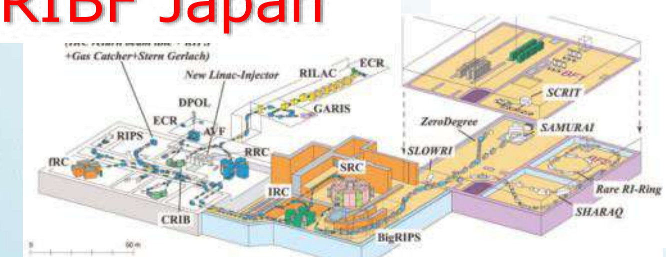
SPIRAL2 France



FRIB USA



RIBF Japan

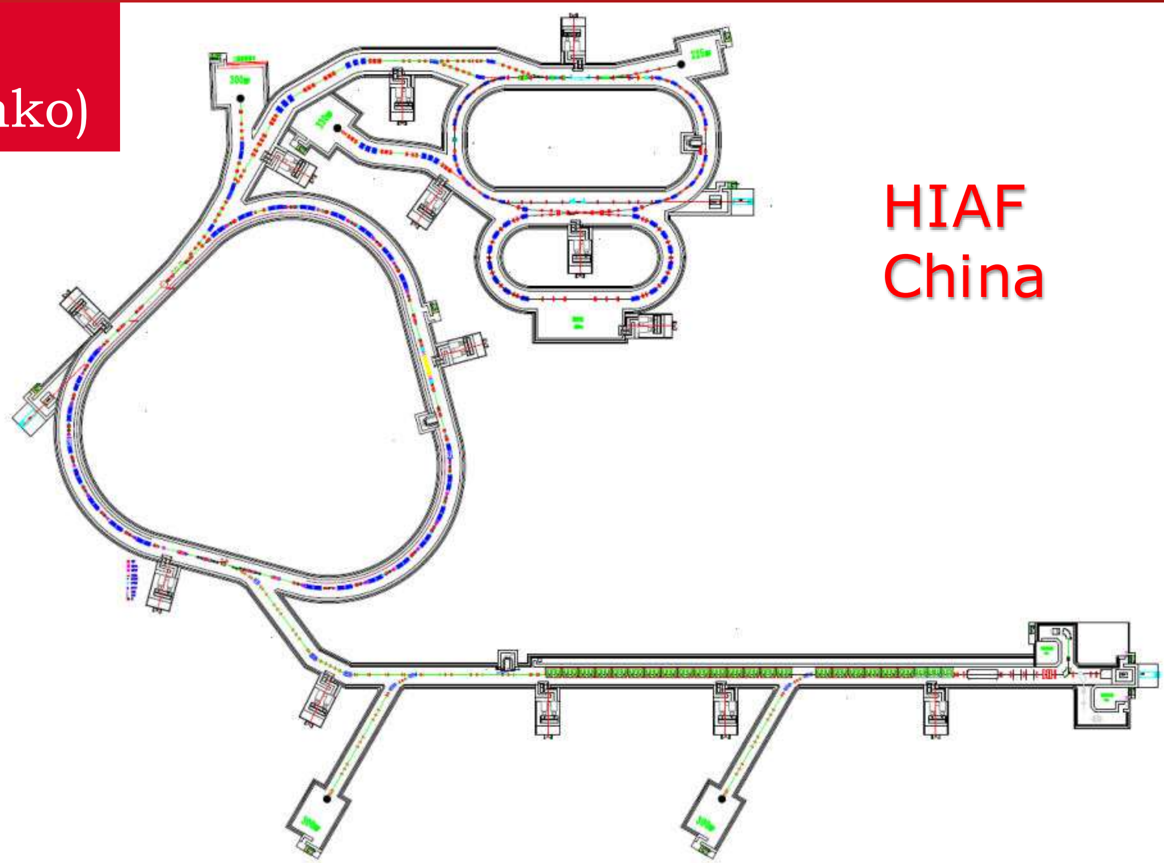


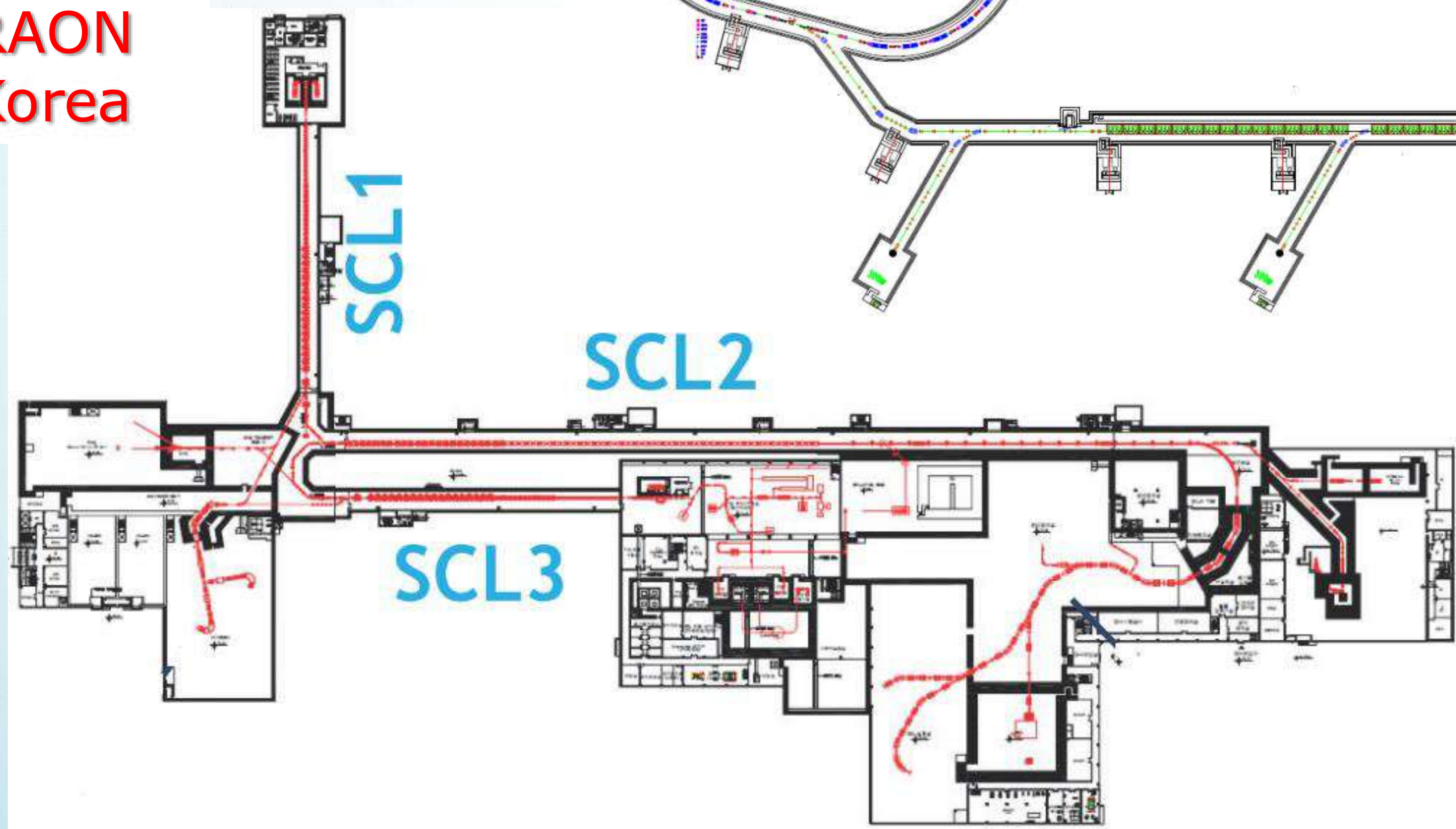
FAIR, Germany

100m

Even bigger (courtesy Grigorenko)

Horizontal scale of the slide ~1 km





ISOL facilities under construction or being planned and the anticipated ^{132}Sn production.

Type	Facility	Beam		Target(ISOL) or Beam current(PF)		Post acceleration		EXP Start
		Beam	Beam Power (kw)	Direct/ Conv/ PF	Fissions/s Beam pnA	MeV/A	^{132}Sn/s	
ISOL Coming	ARIEL	e 50MeV 10000mA p 500MeV 100mA	~100	Direct	$1*10^{14}$		$2*10^{9}$	2018
	HIE ISOLDE	p 1GeV 2mA	2	D&C	$4*10^{12}$	5-10	$2*10^{8}$	2017
	SPIRAL2	d 40MeV 5000mA	200	Conv	$1*10^{14}$	3-10	$2*10^{9}$	2018
	SPES	p 40MeV 200mA	8	Direct	$1*10^{13}$	10	$3*10^{8}$	2021
Super ISOL	EUR ISOL	p 1GeV 5000 mA	4M	D&C	$1*10^{15}$	20-150	$4*10^{11}$	?
	Beijing ISOL	Reactor	6M	reactor	$2*10^{15}$	>100	$5*10^{10}$	?
PF Coming	FRIB	U+33 200MeV	400	PF	8300 pnA	-	10^{8}~10^{9}	2020
	RISP	U+79 200MeV	400	PF	8000 pnA	-	10^{8}~10^{9}	2020
	FAIR	U+28 1500MeV	10	PF	50 pnA	-	10^{7}~10^{8}	2025
PF Running	RIBF 2015	U+86 345MeV	4	PF	100 pnA	-	$3*10^{6}$	running

Probably the beam Power will be limited at 30KW

Waiting for decision

IUPAP Updated 2018, NΦ Facilities around the World by Hideto En'yo (RIKEN)

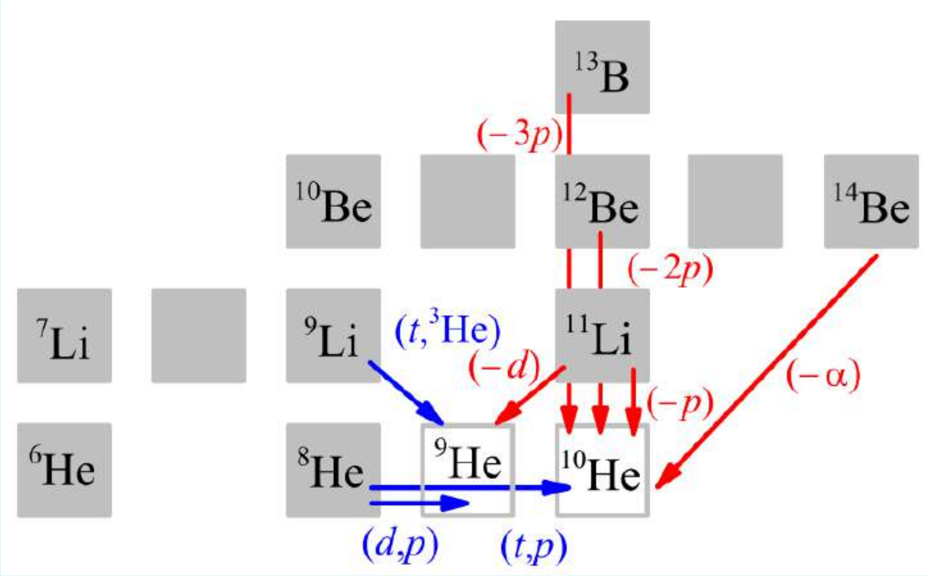
Future nuclear physics facilities around the world

IFMIF

- ACCOULINA-2 /DUBNA
- GANIL/SPIRAL2
- RAON
- ARIEL
- MSU
- DERICA
- MYRRHA
- SARAF/ISRAEL

HIE-ISOLDE, The project and the physics opportunities
M. J. G. Borge and K. Riisager Eur. Phys. J. A, 52 11 (2016) 334

Competitive scientific program at JINR



The ACCULINNA-2 project: The physics case and technical challenges

Eur. Phys. J. A (2018) 54: 97

G.M. Ter-Akopian, A.M. Rodin, A.S. Fomichev, 1996-Now

Structure of exotic light nuclei: Z=2,3,4
H. T. Fortune, Eur. Phys. J. A, 54 3 (2018) 51

FUTURE NUCLEAR PHYSICS FACILITIES AROUND THE WORLD

IFMIF

- ACCOULINA-2 /DUBNA
- GANIL/SPIRAL2
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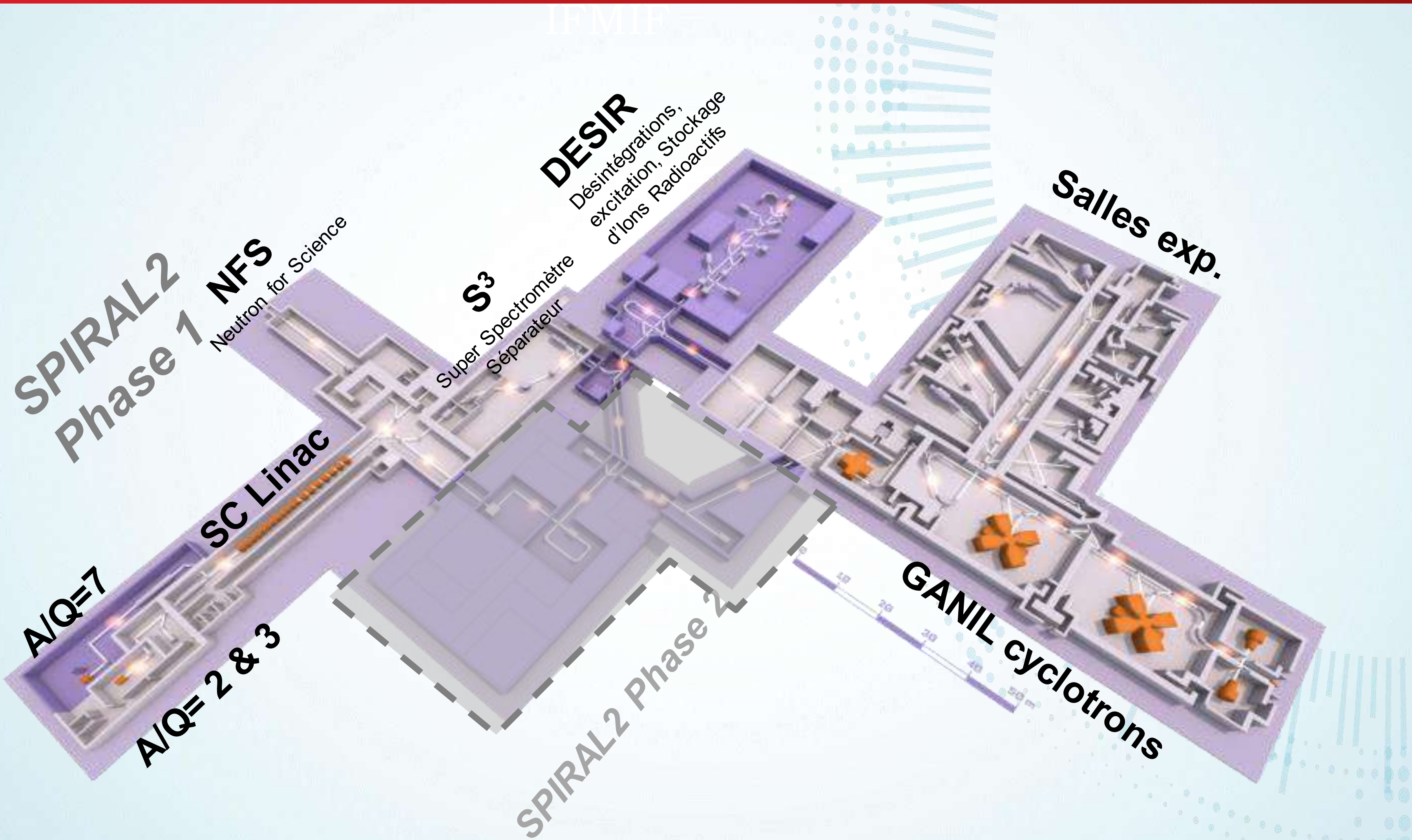
GANIL at Caen

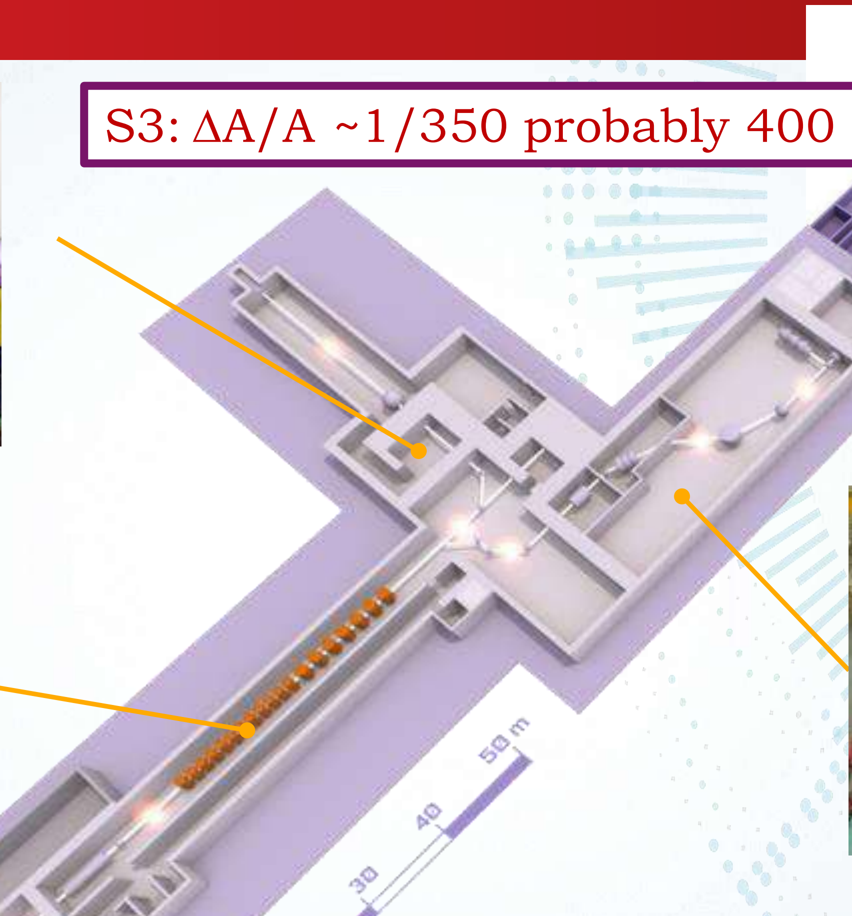


Installation of SPIRAL2 at GANIL

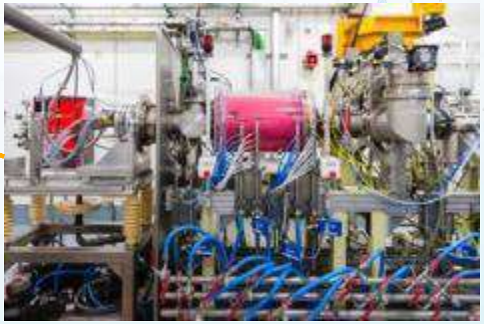
S3: ΔA/A ~1/350 probably 400

NFS

LINAC



S^3



Sources
A/Q=2, 3 et 7

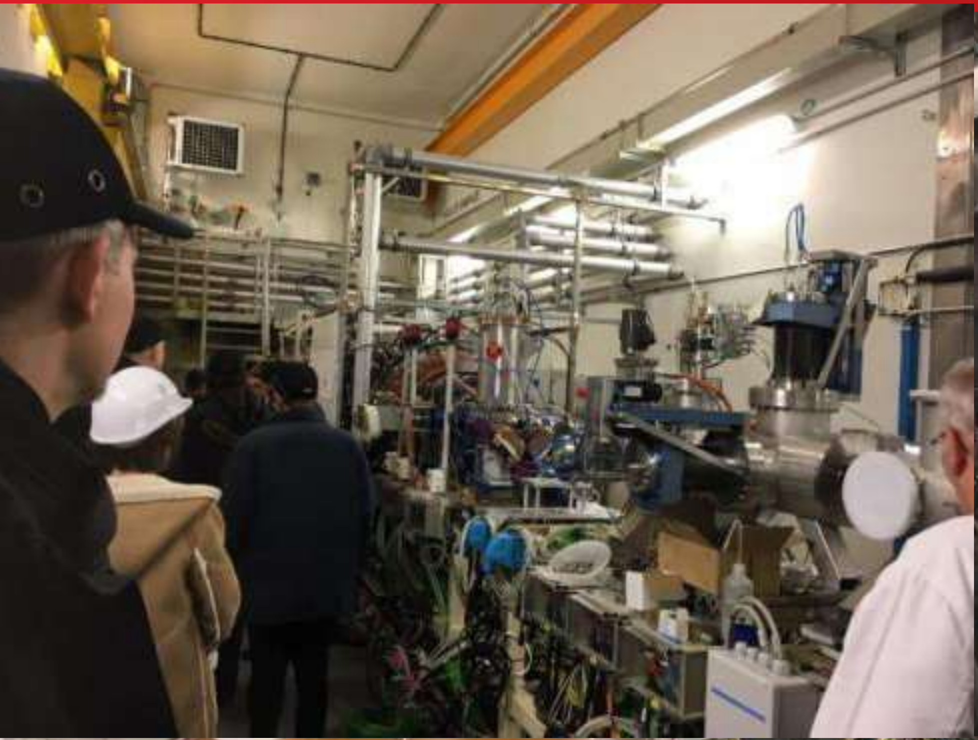
Expected beams of the DC-280 compared to CANIL

Maximum current on target

	GANIL		DUBNA
Source	Phoenix V3	Superc. ECR	Superc. ECR
Injector	A/q=3	A/q=6	SHE Factory
40Ar	3	120	25
48Ca	2,5	15	10
50Ti	2	10	5
54Cr	2	10	7
64Ni	1-2	11	7
136Xe	0	18	3,5

$1 p\mu A = 6.10^{12}$ part/s

GANIL Scientific council - January 2019



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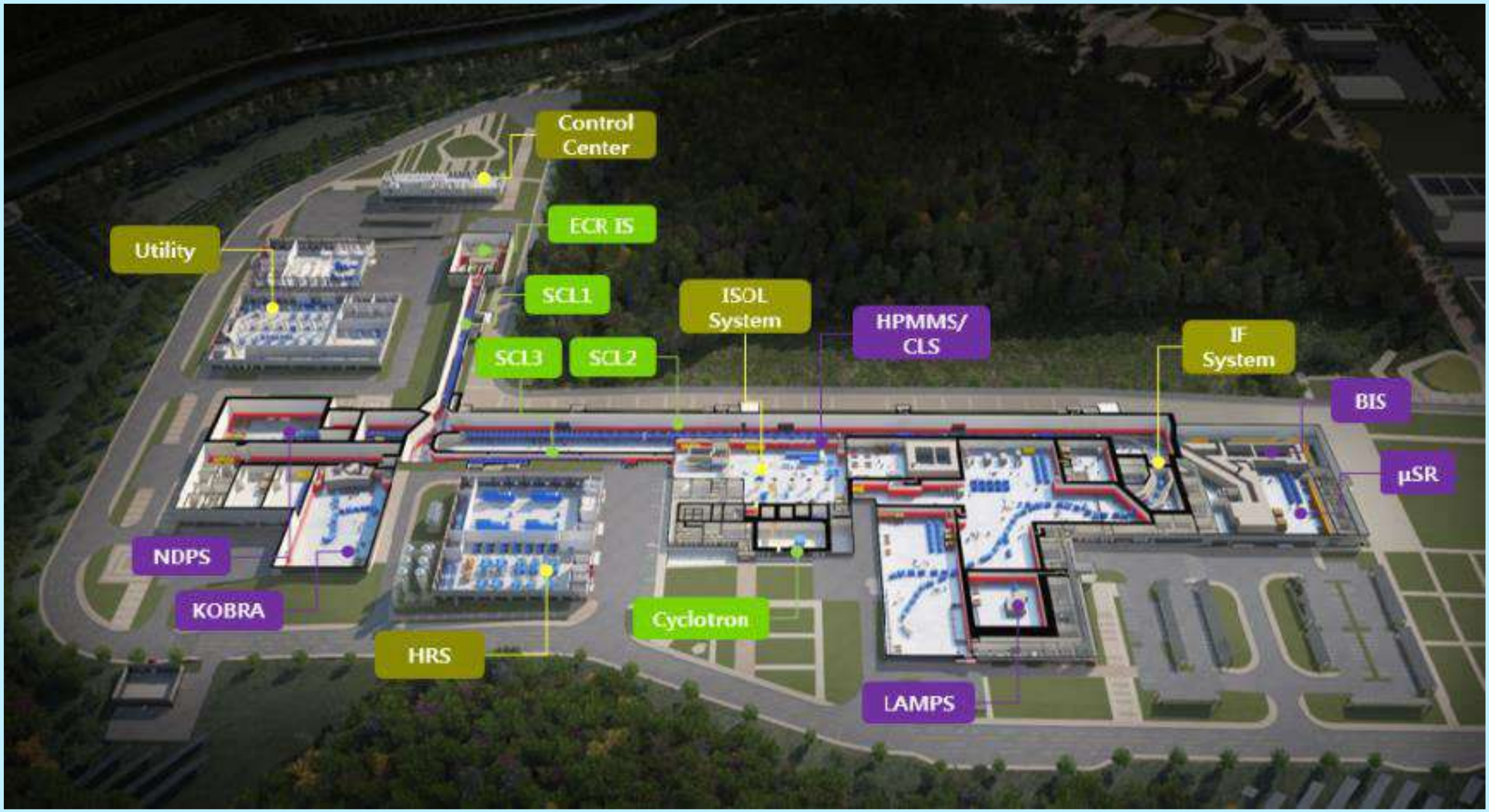
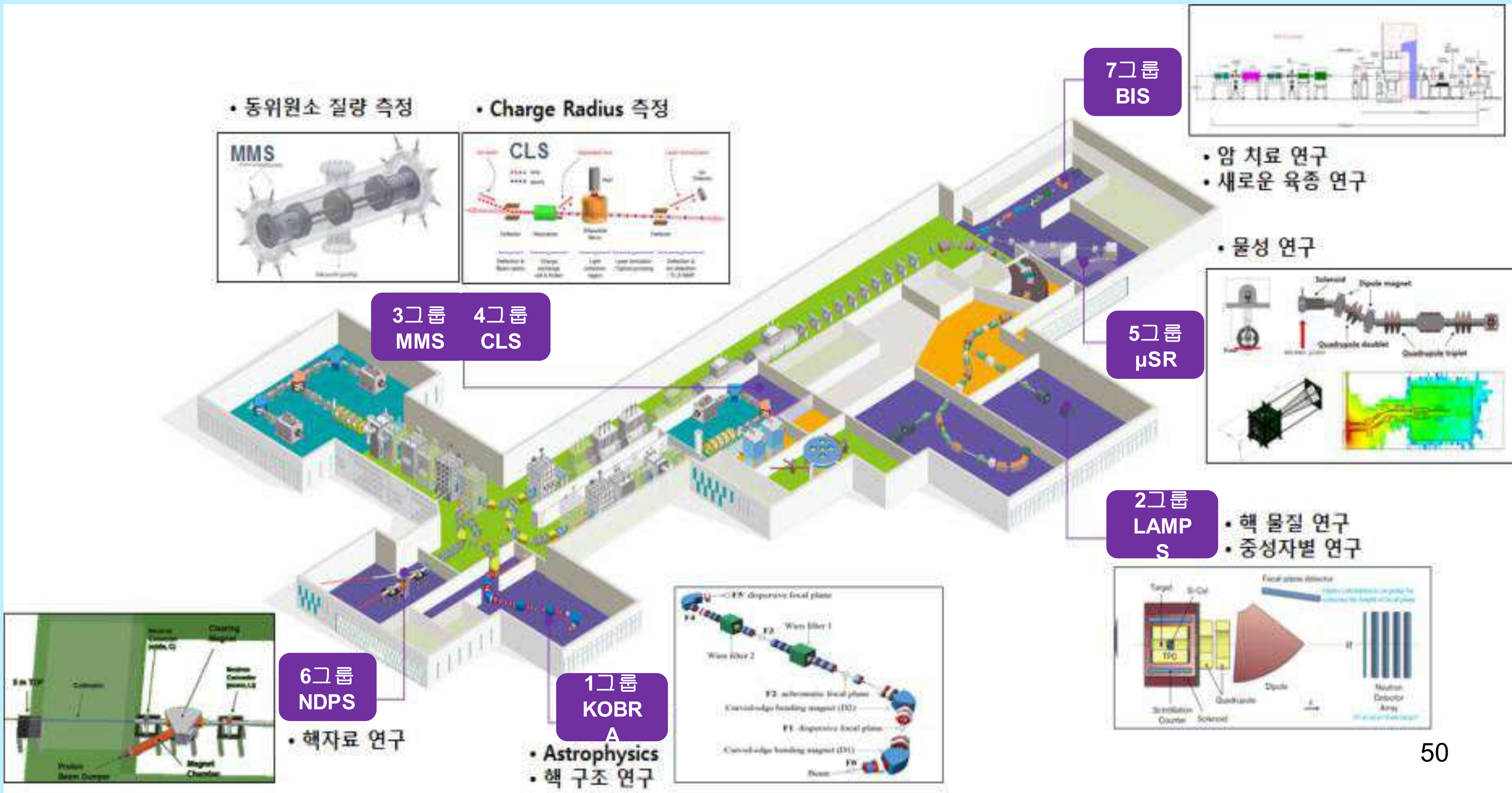
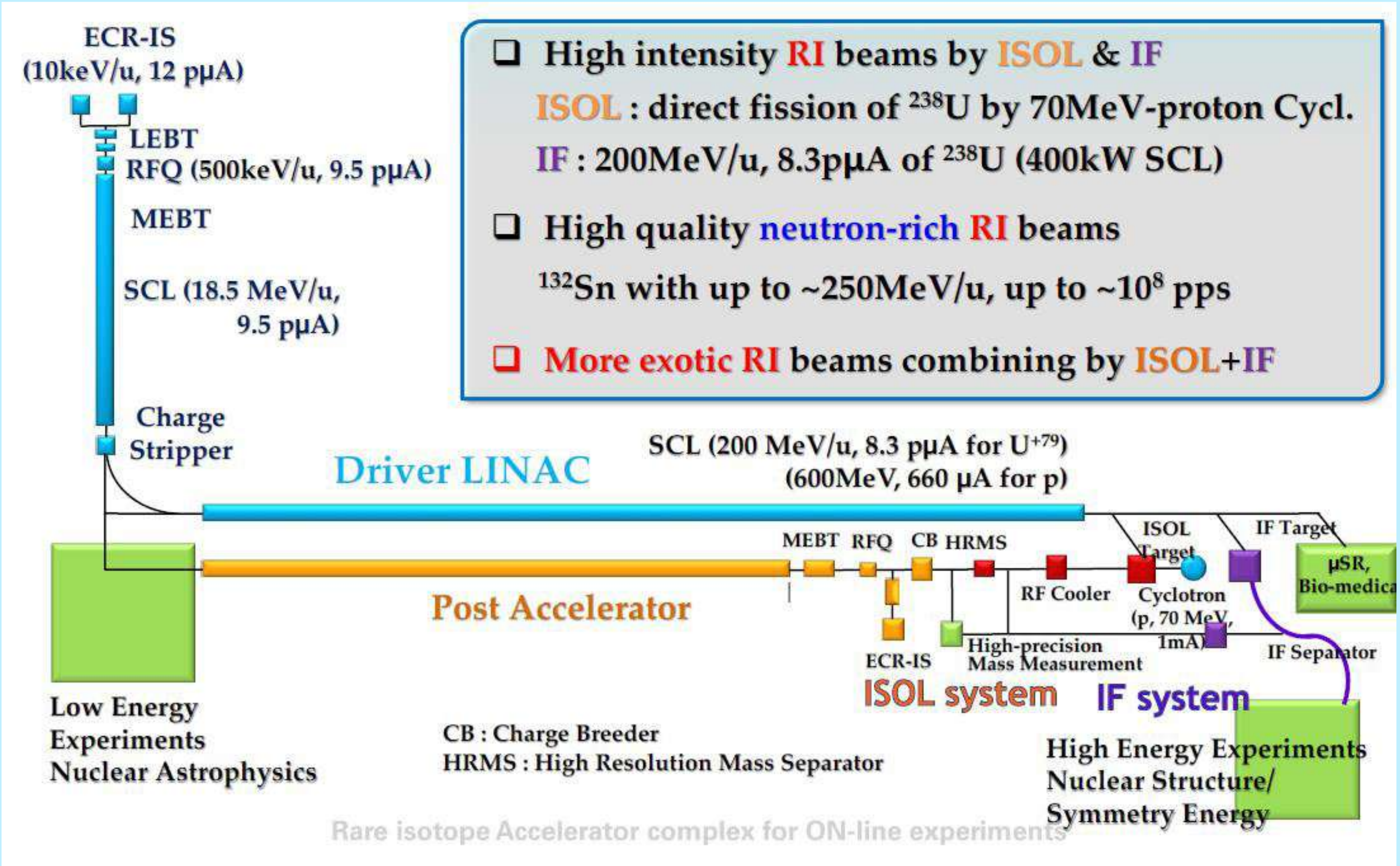
RAON Concept *(ISOLIF)*



RAON Concept *(ISOLIF)*



RAON Concept *(ISOLIF) from Kwon*



RAON – KOREA July 2018

FUTURE NUCLEAR PHYSICS FACILITIES AROUND THE WORLD

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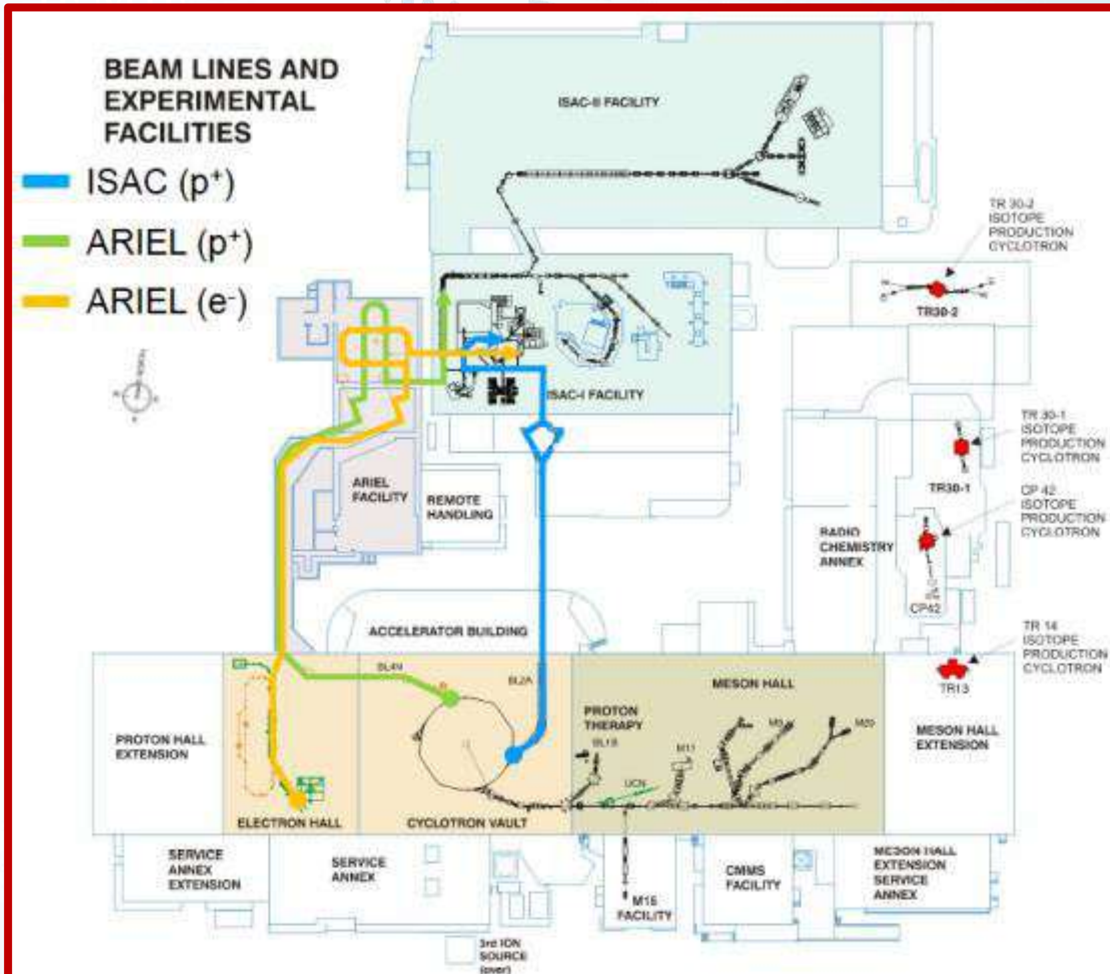
ARIEL : Isotopes for Science & Medicine

Simultaneous RIB production from 3 targets

- 50 kW existing ISAC proton target
- 50 kW new ARIEL proton target
- 100 kW new ARIEL electron target

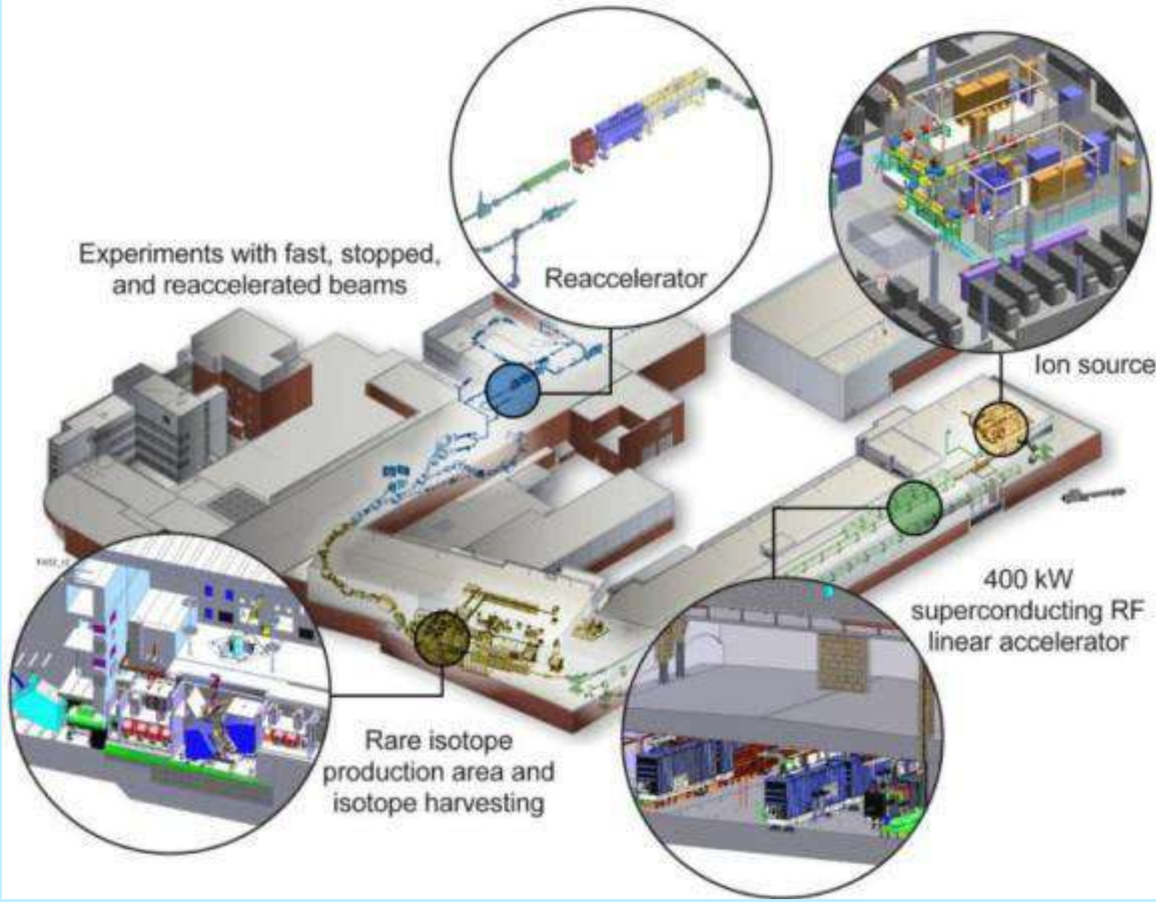
Multi-user capability



TRIUMF $292.7M investment in 2019

FACILITY FOR RARE ISOTOPE BEAMS

- Key Feature is 400 kW beam power (5 x10^{13} $^{238}U/s$)
- Separation of isotopes in-flight
  - Fast development time for any isotope
  - Suited for all elements and short half-lives
  - Fast, stopped, and reaccelerated beams



IFMIF

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- ARIEL
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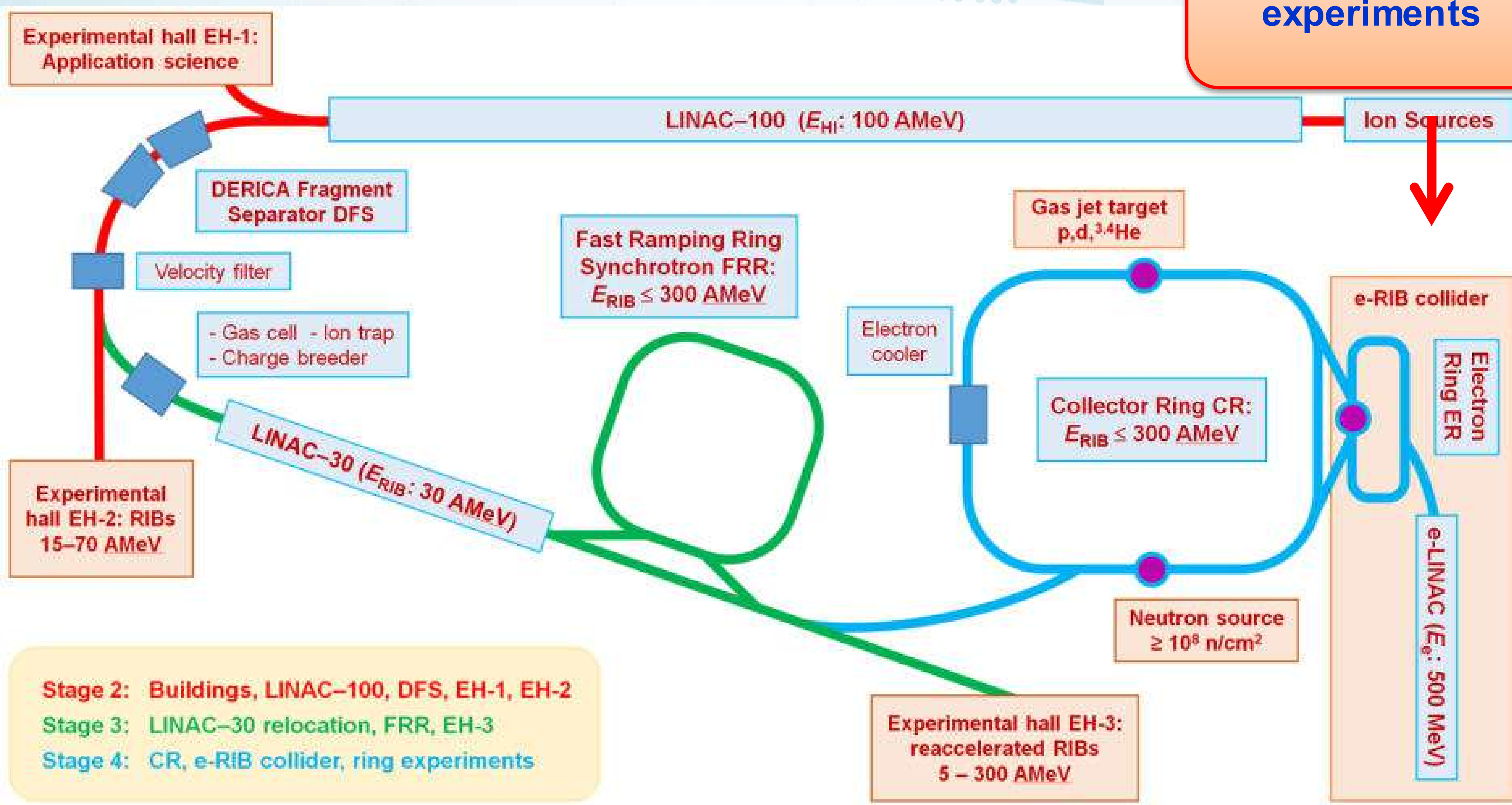
- MYRRHA
- SARAF/ISRAEL

DUBNA - DERICA stages 2 - 4

e-RIB collider experiments



FUTURE NUCLEAR PHYSICS FACILITIES AROUND THE WORLD

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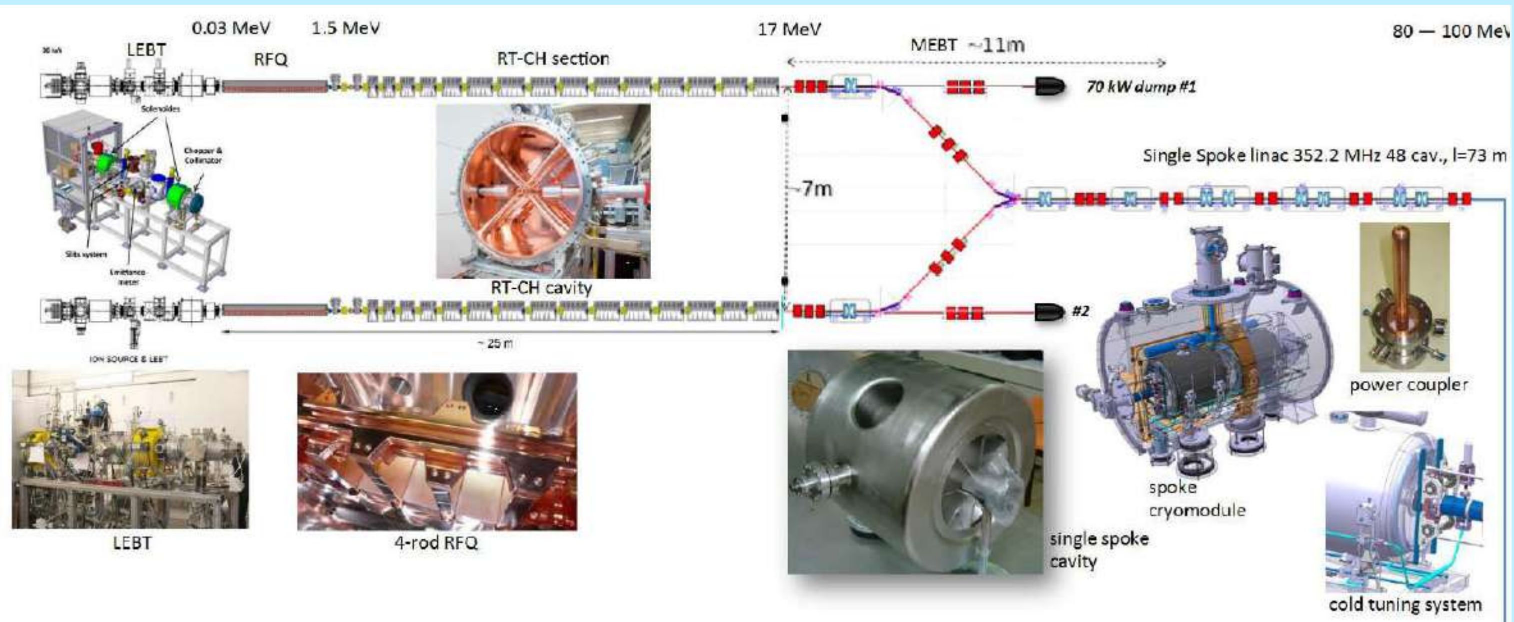
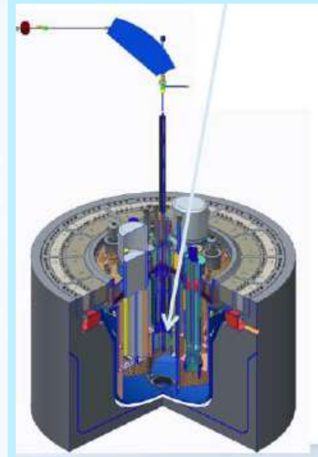
MYRRHA



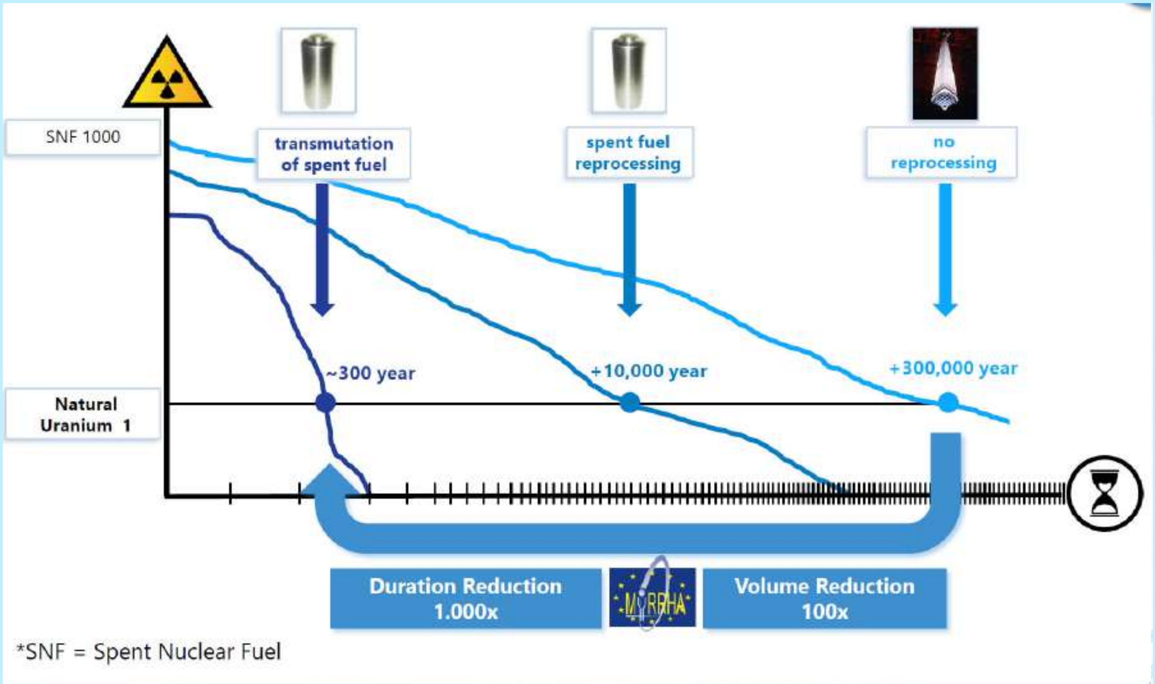


Phase 1 ('18-'24) – 100 MeV accelerator & ISOL Target Station

Phase 2 ('25-'30) – 600 MeV extension and Reactor

Approved: Phase 1, 100MeV Accelerator and ISOL Target station

Relative radiotoxicity on nuclear waste



Relative radiotoxicity on nuclear waste compared to natural uranium or as a function of time after unloading from the reactor, for spent fuel without recycling, with Pu recycling and after transmutation of minor actinides.

IUPAP Updated 2018, Nuclear Power, by Nicolas Alamanos and Sylvie Leray (Saclay)

FUTURE NUCLEAR PHYSICS FACILITIES AROUND THE WORLD

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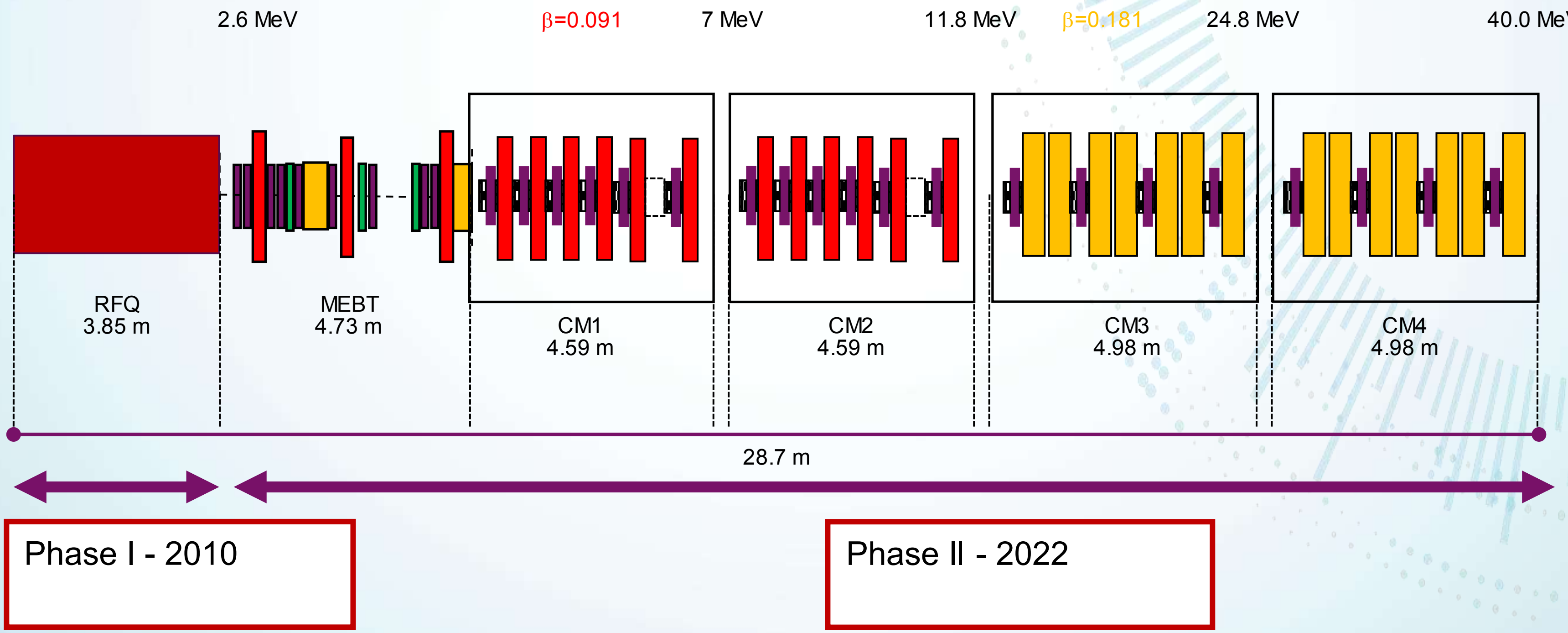
SARAF : Soreq Applied Research Accelerator Facility

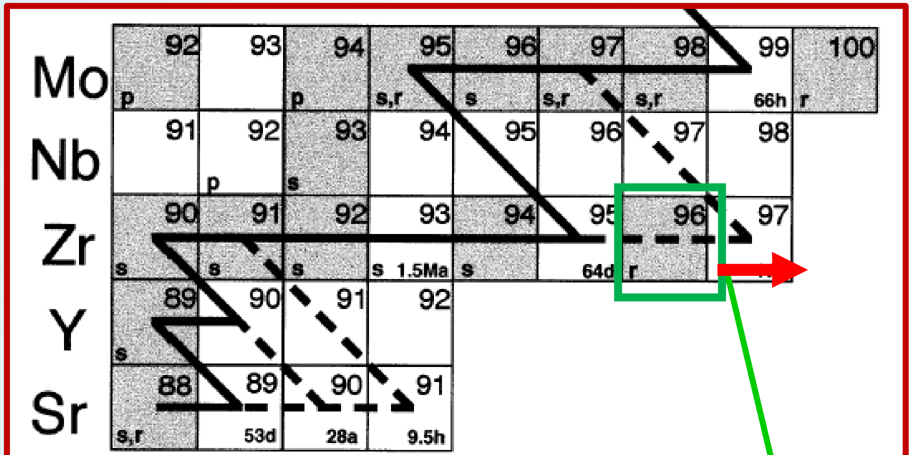
The high level requirements (proton/deuton energy: 35/40 MeV)

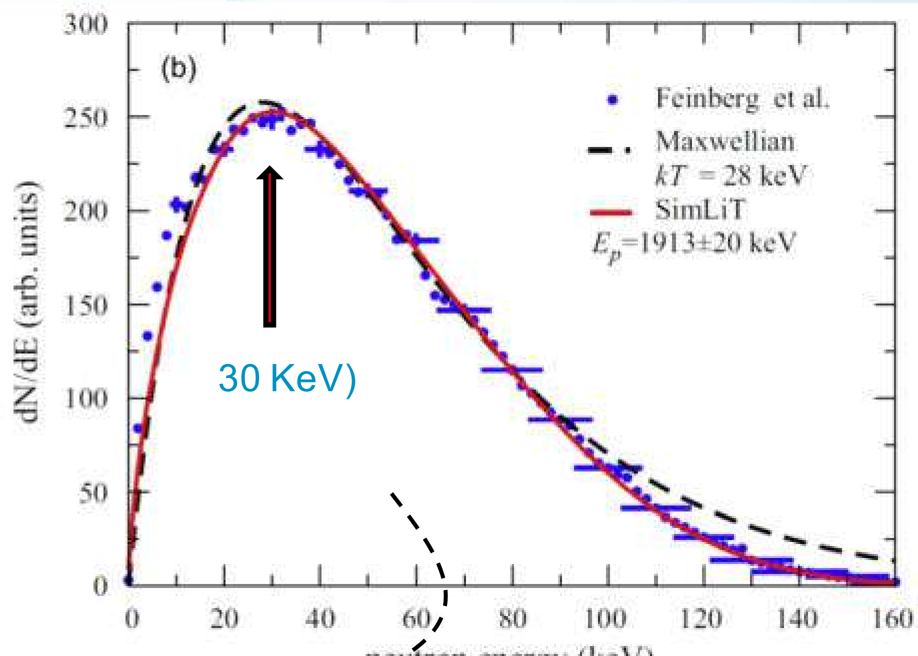
The scientific goal: nuclear physics, neutron science, medical applications

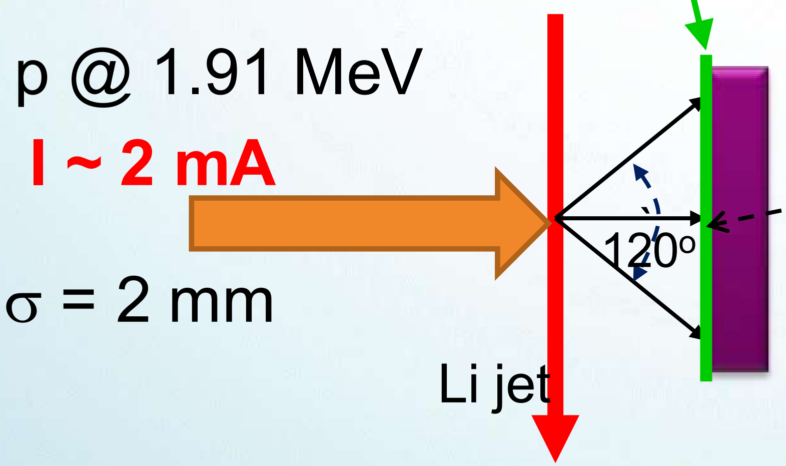


Lab Mimicking stellar nucleo-synthesis with a high-power liquid-lithium target

A 30 KeV quasi-Maxwellian neutron spectrum,



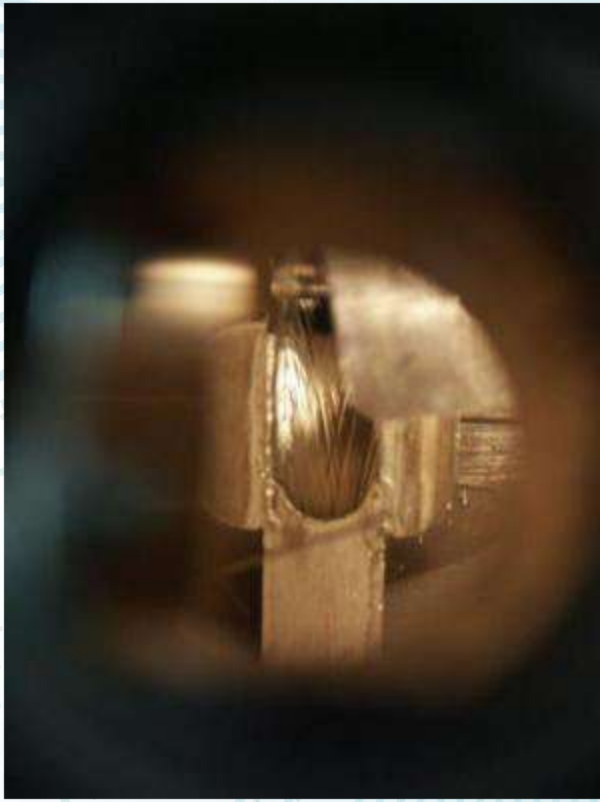




A 30 KeV quasi-Maxwellian neutron spectrum, with an intensity of 3-5 x10^{11}n/s More than a factor 10 than present ^{7}Li(p,n) neutron sources

LILIT

The free-surface LiLiT flow, photographed while bombarded by a ~ 3 kW continuous-wave proton beam from the SARAF linac. The liquid lithium jet, ~1.5 mm thick, forced-flown at a velocity of 2.5 m/s at ~ 195 °C and supported by a 0.5 mm thick stainless steel backing wall, serves both as a neutron producing target and the power beam dump. The target chamber pressure connected to the accelerator beam line is 1×10^{-6} mbar.



Reactions along the astrophysical s-process path and prospects for neutron radiotherapy with the Liquid-Lithium Target, Eur. Phys. J. A (2019) 55: 44

A long-term vision

Fragmentation Facilities

When FAIR will come on line, it will be the leading European nuclear physics facility covering "Hot QCD", probably "Cold QCD", and "Nuclear Structure" with RI beams via projectile fragmentation.

Fragmentation and ISOLDE Facilities

In the coming 5 years, FRIB in the USA will come also online. Future options of FRIB are to double the energy and to add an ISOL facility. FRIB is supported by a large and well organized scientific community.

Considerable scientific advances in the physics of exotic nuclei are expected in the coming years (2020 -2030) by the ensemble of the "national" facilities (SPES, ISOLDE, GANIL, CATANIA, ...) and the two flagships facilities FAIR and FRIB.

A longer-term vision

Until Beijing ISOL becomes available China will operate two facilities: BRIF2 (Beijing RI Facility) and Heavy Ion Research Facility in Lanzhou (HIRFL), and is starting to build Heavy Ion Accelerator Facility (HIAF) in Guangdong Province (100km north-east of Hong Kong).

In the coming 10 years, The RAON facility in Korea will come also online. One of the challenges of the RAON facility is to remediate to the "absence" of a "local" scientific community.

EURISOL (2030-2040) is the project of the European nuclear physics community. Its decision and construction will require a coordinate action of the ensemble of the European countries

DE LA RECHERCHE À L'INDUSTRIE

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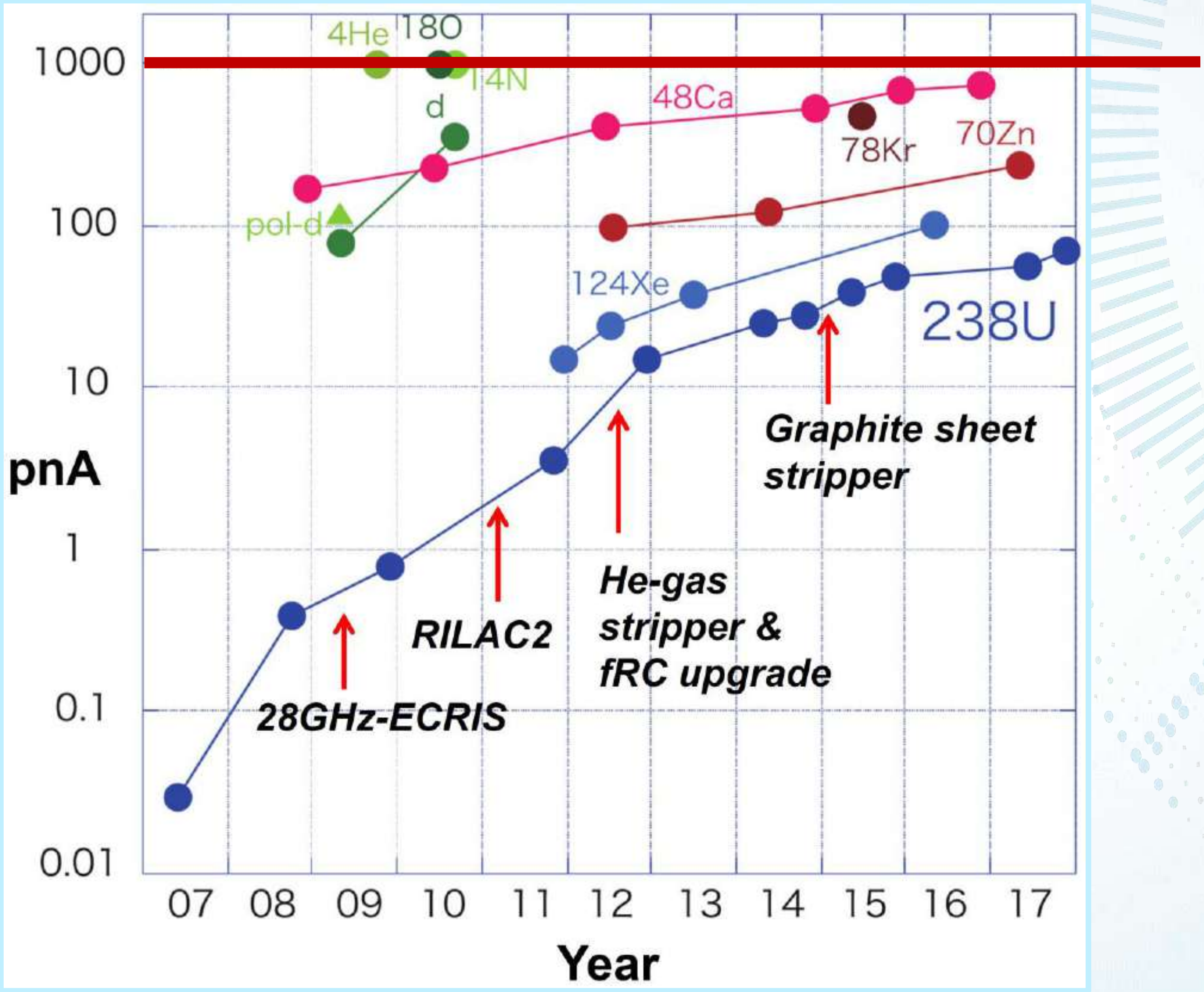
Thank you

FRAGMENTATION FACILITIES

Facility	Location	Injectors	Beams (MeV/A)	Power / Intensity	Energy of RIB's (MeV/A)	operation	
Riken	Japan - Tokyo	IRC and SRC Cyclotrons	Up to Uranium E=350	1 pμA	Energy from 200 up to 350	In operation	*
FAIR (Under construction)	Germany - GSI	Cyclotrons SIS 18 SIS 100	Up to Uranium E=	Uranium (~ 5 10^{11} U ions /s)	Close to 1000	2025	**
FRIB (Under construction)	USA-MSU	LINAC Supra	Up to Uranium E=200	400KW		2022	***

(*) OEDO => Energy-degrading system aiming to study nuclei with A>50 and 5 to 100 MeV/A
(**) CRYRING => store, cool and decelerate heavy, highly charged ions down to a few 100 keV/nucleon
(**) protons from 500 to 1 GeV and U from 200MeV/A to 400MeV/A

Increasing beam intensity of SRC for RI beam



Goal: 1 pμA

FRAGMENTATION AND ISOL FACILITIES

Facility	Location	Accelerator And beams	Power	Re-acceleration	Energy of exotics	operation	Remarks
FRIB	USA/MSU	LINAC Supra	400KW	"Rea heavy ion linac"	6 MeV/A	2022	Upgrade*

(*) from 6MeV/A up to 12MeV/A

ISOL FACILITIES

Facility	Location	Accelerator And beams	Power	Re-acceleration MeV/A	I of Rib's (p/sec)	operation	
ARIEL	Canada TRIUMF	p and electron Linac driver	p / 5KW	5.5 MeV/A			
HI-ISOLDE	CERN	(p) beam of E=1,4GeV (2,2µA)	3,1KW	10 MeV/A		In operation	*
MYRRHA	Belgium	Linear / (p) E=100MeV (4mA)	400KW CW			2024	**
SPES	Italy Legnaro	Cyclotron/ (p) E=70MeV (0,750 mA)	10KW (0,20mA 40MeV)	ALPI (5-15) MeV/A	~10^{13}	2019 (2021)	***

(*) With the LINAC4 and the foreseen increase in intensity, the expected power should be of 13,3KW
(**) ~2030 Increase of the energy from 100MeV to 600MeV
(***) E=10 MeV/A for A=130 and 2021 accelerated beams

SPIRAL2	France GANIL	Linear/ (d) E=40 MeV (5mA)	200KW	CIME E ~10 MeV/A	$\sim 10^{14}$		
BISOL	China Beijing	Linear/ (d) E=40 MeV (10mA)	400KW	??			
RAON	Korea Daejeon	Linear (p-U) E=600 MeV (p) (0,66mA)	~400KW				
SARAF	Israel SOREQ	Linear/ (d) E=40 MeV (5mA)	200KW	??			
SAIF	South Africa iThemba	Cyclotron/ (p) E=70MeV (0,150 mA ???)	10,5KW	??	$\sim 2x10^{13}$		

And many other facilities: ALTO France/Orsay, Notre dame, Sao-Paulo, ATLAS, LNS, ACCULLINA-2