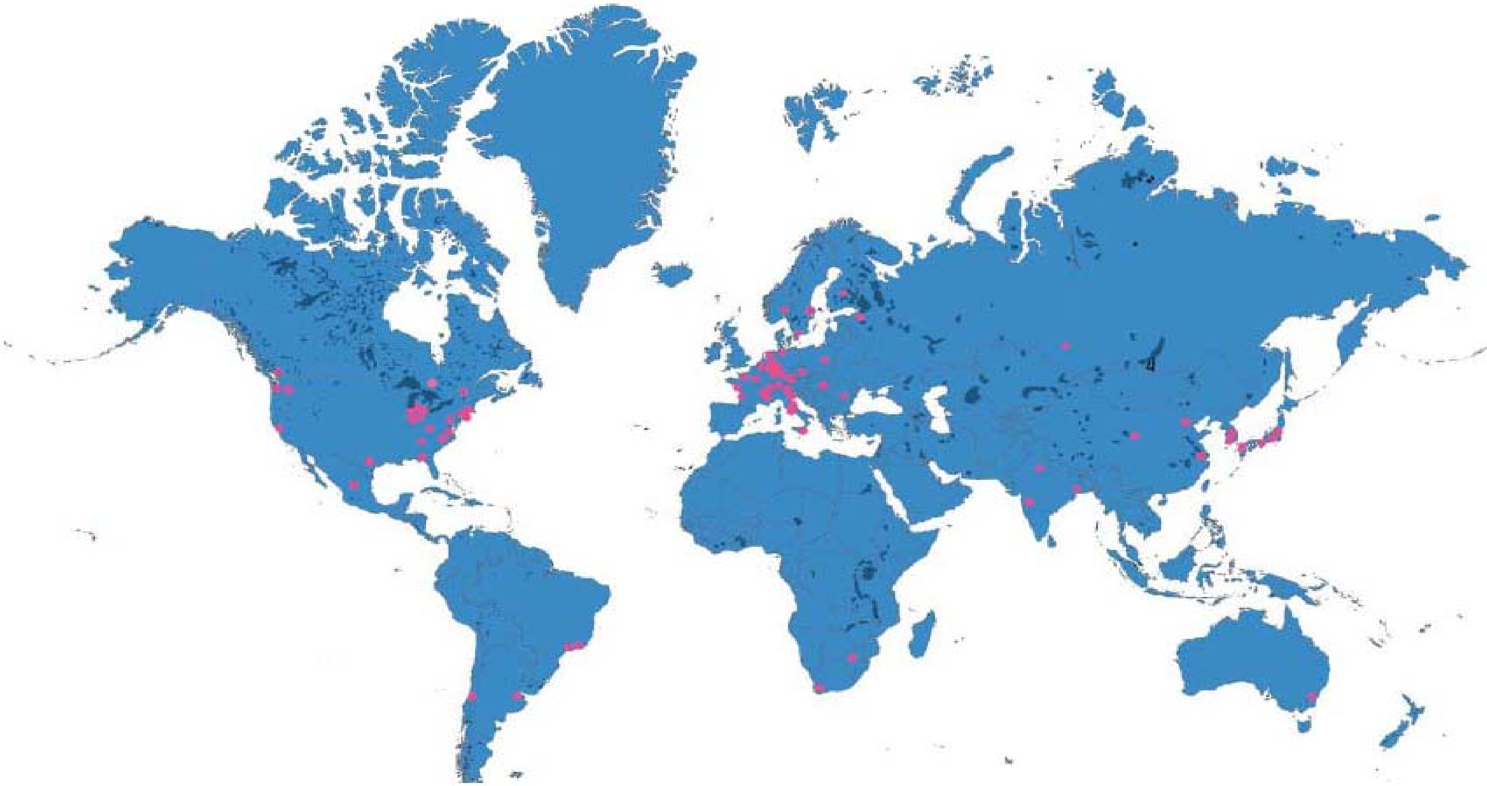
QCD and Hadronic Physics in the Context of Nuclear Physics Facilities and Aims World-Wide



Anthony W. Thomas

JLab Users Group : June 18th 2007

WG.9 IUPAP working Group on International Cooperation in Nuclear Physics

- Began as Committee on International Cooperation in Nuclear Physics (2003)

- A subcommittee of IUPAP Commission C12

- Followed earlier attempts beginning with Herman Feshbach, Erich Vogt and Bernard Frois (latter led to the last Global Science Forum report)

- Formally approved as a Working Group of IUPAP at the General Assembly in South Africa, October 2005

Mandate: IUPAP Council, October 2005

1) provide a description of the landscape of key issues in Nuclear Physics research for the next 10 to 20 years
2) produce (maintain) a compendium of facilities existing or under development worldwide
3) establish a mapping of these facilities onto the scientific questions identified above
4) identify missing components that would have to be developed to provide an optimized, comprehensive network of international facilities
5) explore mechanisms and opportunities for enhancing international collaboration in nuclear science
6) identify R/D projects that could benefit from international joint effort
7) serve as a source of expert advice for governmental or inter-governmental organizations in connection with efforts to coordinate and promote nuclear science at the international level
8) serve as a forum for the discussion of future directions of nuclear science in the broadest sense
9) document the cross disciplinary impact of Nuclear Physics and of nuclear facilities and identify mechanisms for expanding (fostering) cross disciplinary research

Membership of WG.9

- A. W. Thomas (Jefferson Lab, USA) Chair
- W. T. H. van Oers (Manitoba, Canada) Secretary
- S. H. Aronson (BNL, USA)
- R. F. Casten (Yale, USA) NSAC Past-Chair
- B. Fulton (York, Great Britain) NuPECC Chair
- S. Gales (GANIL, France)
- M. N. Harakeh (Groningen, The Netherlands) NuPECC Past-Chair
- W. F. Henning (GSI, Germany) Chair of C12
- A. Lepine-Szily (Universidade de Sao Paulo, Brazil)
- V. A. Matveev (Institute for Nuclear Research of Russian Academy of Sciences, Moscow, Russia)
- T. Motobayashi (RIKEN, Japan)
- S. Nagamiya (J-PARC, Japan) Past-Chair of C12
- J.-M. Poutissou (TRIUMF, Canada)
- R. Tribble (Texas A&M, USA) NSAC Chair
- Wenlong Zhan (Lanzhou, China)

First task…

- Prepare a report summarizing the facilities used by nuclear Physicists world-wide
- Explain the scientific issues that these facilities are designed to address

i.e. Mandates 1-3

Major Questions for Modern Nuclear Physics

- Can the structure and interactions of hadrons be understood in terms of QCD?
- What is the structure of nuclear matter?
- What are the phases of nuclear matter?
- What is the role of nuclei in shaping the evolution of the universe?
- What physics is there beyond the Standard Model?

Facilities to Address these Major Questions

WG.9 Report identifies 90 "User Facilities" world-wide

BUT many are relatively small with mainly local users

- **Play an important role in:**
  - **student training**
  - **applied nuclear science**

- **Frontiers <u>mainly</u> addressed by larger facilities**

Arbitrarily chose >300 users and $\geq$ 15% international users and exclude applied labs – e.g. ITHEMBA, ILL…)

$\Rightarrow$ much smaller number (13) of "Major Facilities"

Major Facilities

Facility	% NP Users	Total No. Users	% International
GSI (FAIR)	75%	1300	40%
Jefferson Lab	100%	1200	39%
RHIC	100%	1100	50%
CERN (LHC Alice)	100%	760	100%
GANIL	100%	630	36%
TRIUMF	100%	600	66%
RIKEN	100%	500	19%
J-PARC	100%	480	60%
ANL (Atlas)	100%	410	40%
Legnaro	100%	400	50%
COSY	100%	390	56%
CERN (Isolde)	100%	350	98%
DESY	10%	3000	47%

Region	Country	Institution / Location	Facility Name	Facility Characteristics
AFRICA				
	South Africa	ITHEMBA Laboratory, Faure / Cape Town	Cyclotron and Accelerator Facility	Cyclotron / p (227 MeV) / HI (A<136, 50-6 MeV/u) Accelerators (3-6 MeV)
		NECSA, Pretoria	SAFARI-1/Van de Graaff	Research Reactor / n(3-10Å, 10^7 s^{-1} cm^{-2}) / 4 MV VdG: p, d, ^{4}He, N
ASIA				
	China	China Institute of Atomic Energy, DNP, Beijing	Beijing Tandem Acc. Lab.	Cyclotron/p(100 MeV) under construction Tandem (15 MV)/p (30 MeV) / HI (15 MeV/q)
		Chinese Academy of Sciences, IMP, Lanzhou	HIRFL	Cycl.-Synchr.-Storage-R./ p (3.7 GeV) / HI (^{12}C 1.1 GeV/u, ^{238}U 520 MeV/u)
		Chinese Academy of Sciences, SIAP, Shanghai	SLEGS (in planning)	Gamma rays / 1-25 MeV 10^8-10^{10} s^{-1}
	India	New Delhi University Grants Commission of India, New Delhi	Inter-University Accelerator Center	Tandem - S.C.Linac HI (9-1 MeV/u)
		Variable Energy Cylotron Centre, Kolkata	VECC	AVF Cyclotron A<40, 20-7 MeV/u SC-Cyclotron, K=500, 10-80 MeV/u
	Japan	Japan Atomic Energy Agency, Tokai	JAEA Tandem Facility	Tandem-ISOL-S.C-Linac / p(20 MeV) / HI(A=15/200 20/5 MeV/u)
		KEK and JAEA, Tokai	J-PARC (under construction)	Synchrotron / p (30 /50) GeV >10^{14} s^{-1}
		Kyushu University, Fukuoka	KUTL	Tandem (9 MV) / p (18 MeV) / HI (A<60, 9 MeVq)
		National Institute of Radiological Sciences, Anagawa	HIMAC	Synchrotron / 6 MeV/u inj.-linac / HI (A<60 100-800 MeV/u) / medical
		Osaka University, Osaka	Van de Graaff Laboratory	Van de Graaff (5MV) / p-He (5 MeV/10 MeV)
		RCNP, Osaka University, Osaka	Cyclotron complex/back scattered photon facility	Cyclotrons (K140 + K400) / p (400 MeV) / HI (A<20, 100 MeV/u)
		RIKEN, Wako	Nishina Center for Accelerator-Based Science	Cyclotrons / RARF (<135 MeV/u) / RIBF (d-U / 350 MeV/u)
		Tohoku University, Sendai	CYRIC	Electron-Linac-SBRing (1.2GeV) / tagged photons (30-1150 MeV)
		Tohoku University, Sendai	LNS Sendai	Cyclotrons (K=10&110) / p(12/90 MeV) / HI (C 33 MeV/u, Kr 9 MeV/u)
		University of Tsukuba, Tsukuba	Tandem Accelerator Complex	Tandems 4MV (22 MeV) Bi (<1 MeV/u)
	Korea	Korea Institute of Geoscience and Mineral Resources, Daejeon	Ion Beam Application Group	Tandem (1.7 MV) / p-Au
		National Cancer Centre, Goyang	Center for Proton Therapy	Cyclotron / p (50-230 MeV)
		National Centre for Inter-Universities Research Facility, Seoul	Electrost. Ion Acc./ AMS Fac.	Tandem (3 MV) / p(6 Mev) / HI (^{14}C 10 MeV)
AUSTRALIA				
		Australia National University, Canberra	Heavy Ion Accelerator Facility	Tandem (15 MV)–SC-Linac / HI (Li 14 MeV/u Au ≤2 MeV/u)

Region / Country	Institution	Facility Name	Staff							Users			
			Total	Theory (total)	Permanent	Temporary	Postdocs	PhD Students Onsite / Other Graduate Students	Undergraduates	Total user number	Internal (%)	National (%)	International (%)
Czech Republic	Academy of Sciences of the Czech Republic, Řež	Nuclear Physics Institute	46	15	21	25	4	15	6	50	70%	10%	30%
Finland	University of Jyväskylä, Jyväskylä	Accelerator Laboratory	68	9	26	42	9	32	10	270	15%	25%	75%
France	Centre d'Etudes Nucléaires Bordeaux Gradignan (CENBG), Gradignan	AIFIRA	17	0	10	7	3	4/0	0	60	65%	95%	5%
	CNRS, Université de Nantes, École des Mines de Nantes, Nantes	ARRONAX											
	European Synchrotron Radiation Facility, Grenoble	ESRF GRAAL	35	0	25	10	2	0/15	3	30	40%	50%	50%
	GANIL Laboratory, Caen	GANIL	267	8	242	25	4	9/8	20	370	9%	64%	36%
	Institut de Physique Nucléaire de Lyon, Lyon	IPNL Van de Graaffs	29	0	20	9	0	6/1	0	30	95%	95%	5%
	Institut Laue-Langevin, Grenoble	ILL	452	5	382	70	18	28	5	1220	7%	26%	74%
	Institut Physique Nucléaire d'Orsay, Orsay	Tandem / ALTO	38	28	28	10	10	5	10	130	22%	64%	36%
Germany	Deutsches Elektronen-Synchrotron (DESY), Hamburg	HERA Note: Nuclear Physics about 10% of figures given	1695	50	1114	581	92	100/100	45	3000	5%	53%	47%
	Forschungsneutronenquelle Heinz Maier-Leibnitz, Garching	FRM II	220	0	140	20	40	15	5	814	0%	62%	38%
	Forschungszentrum Juelich (FZJ), Juelich	COSY	148	12	125	23	7	16/6	8	391	21%	44%	56%
	Gesellschaft fuer Schwerionenforschung (GSI), Darmstadt	UNILAC, SIS, ESR NP	1003	50	543	460	90	115/80	40	1300	20%	60%	40%
	Technical University of Darmstadt, Darmstadt	S-DALINAC	22	7	17	5	5	23	13	39	84%	25%	75%
	University of & Technical University of Munich, Garching	Maier-Leibnitz Laboratory	58	0	26	32	10	17/5		122	31%	75%	25%
	University of Bonn, Bonn	ELSA											
	University of Cologne, Cologne	Tandem Accelerator	35	0	6	29	5	12	0	75	40%	66%	34%
	University of Mainz, Mainz	MAMI Accelerator	216	20	103	113	36	93/10	0	150	50%	80%	20%
Hungary	Inst. of Nucl. Res. of the Hungarian Academy of Sciences, Debrecen	ATOMKI											
Italy	European Centre for Theoretical Studies in Nuclear Physics, Trento	ECT*											
	National Institute of Nuclear Physics (INFN), Assergi	Laboratori Nazionali del Gran Sasso											
	National Institute of Nuclear Physics (INFN), Catania	Laboratori Nazionali del Sud	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Region / Country	Institution	Facility Name	Staff							Users			
			Total	Theory (total)	Permanent	Temporary	Postdocs	PhD Students Onsite / Other Graduate Students	Undergraduates	Total user number	Internal (%)	National (%)	International (%)
	Michigan State University, East Lansing, MI	NSCL	280	14	155	125	23	55/10	30	170	27%	69%	31%
	National Institute of Standards & Technology (NIST), Gaithersburg, MD	NCNR	16	0	8	8	4	3/4	3	30	50%	80%	20%
	Nuclear Structure Laboratory, SUNY , Stony Brook, NY	Nuclear Structure Laboratory	13	-	5	8	1	7	4	20	80%	100%	-
	Oak Ridge National Laboratory (ORNL), Oak Ridge, TN	HIRBF	59	17	34	25	11	14/14	3	228	22%	90%	10%
	Pacific Northwest National Laboratory, Richland, WA	IGEX Detector	35	5	30	0	2	0	0	0			
	Texas A&M University, College Station, TX	Cyclotron Institute	82	11	50	32	13	22/0	10	140	60%	90%	10%
	Thomas Jefferson National Accelerator Facility, Newport News, VA	CEBAF	638	19	604	34	11	75/80	70	1206	5%	61%	39%
	Triangle Universities Nuclear Laboratory, Durham, NC	TUNL	65	0	25	40	10	30/0	15	60	90%	98%	2%
	University of Kentucky, Lexington, KY	Accelerator Laboratory	4	0	3	1	5	3/0	1	?	80%	95%	5%
	University of Notre Dame, Notre Dame, IN	Nuclear Structure Lab. (NSL)	32	-	4	28	6	22/11	7	40	25%	50%	50%
	University of Washington, Seattle, WA	CENPA	47		26	21	6	15/0	5	33	100%	-	-
	Western Michigan University, Kalamazoo, MI	Tandem Accelerator Laboratory	5	0	5	-	0	4/0	4	10	100%	100%	-
	Yale University, New Haven, CT	Wright Nuclear Structure Laboratory, (WNSL)	30	0	15	15	4	12/10	3	60	15%	65%	35%
SOUTH AMERICA													
Argentina	CNEA Physics Department, Buenos Aires	TANDAR Laboratory	52	15	44	8	3	5/0	10	25	90%	90%	10%
Brazil	Catholic University, Rio de Janeiro	Van de Graaff Laboratory	10	0	7	3	4	10/2	3	30	80%	100%	0
	University of São Paulo, São Paulo	LAFN	47	13	47	-	8	34/6	20	100	90%	100%	0
Chile	Comision Chilena de Energia Nuclear, Santiago	Centro Nuclear La Reina	6	9	5	1	1	0/1	2	15	100%	100%	_
	University of Chile, Santiago	Van de Graaff Accelerator Laboratory	8	-	7	1	1	1/2	20	8	90%	100%	-

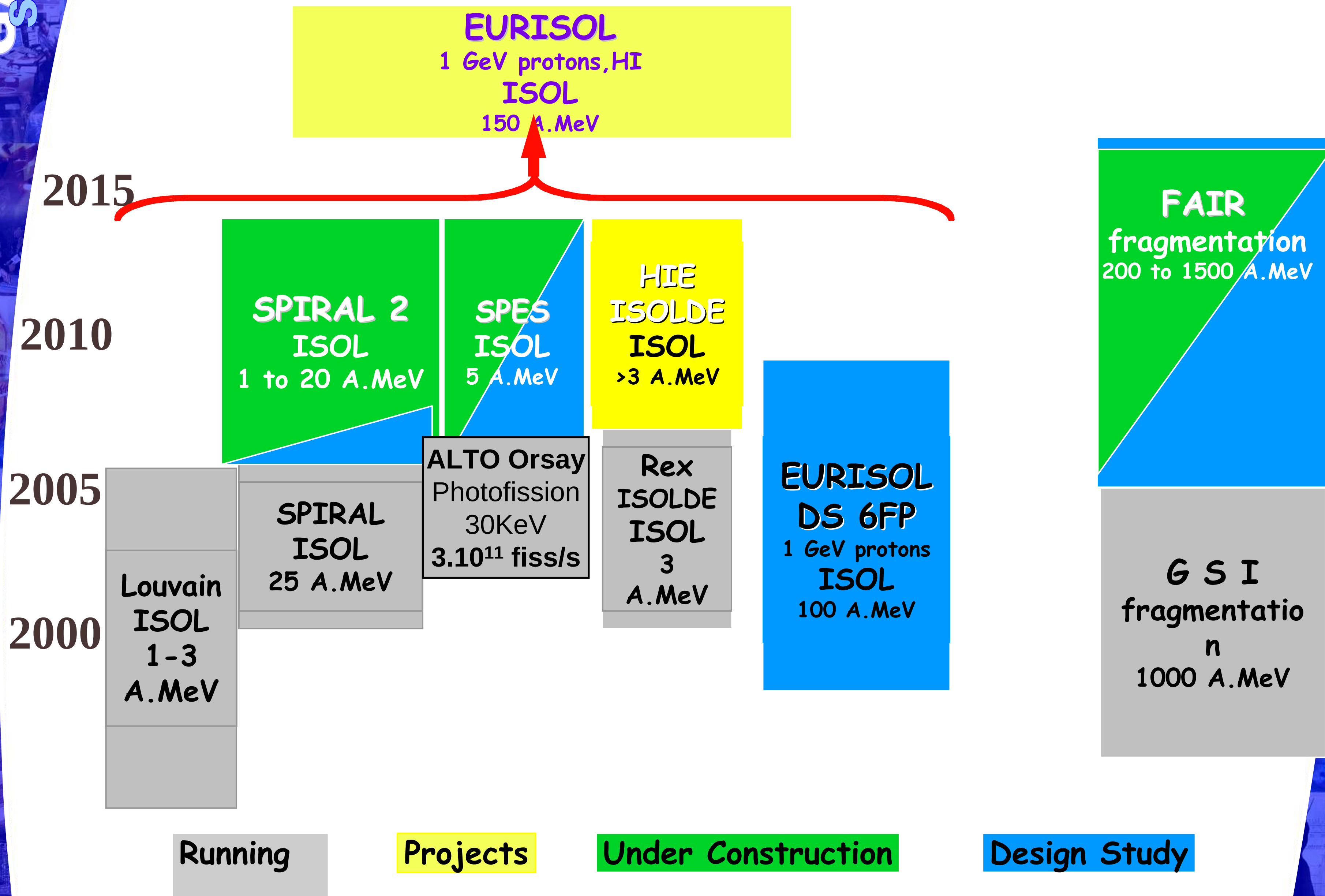
WG.9 is Providing Expert Advice to OECD Global Science Forum

(Mandate 7)

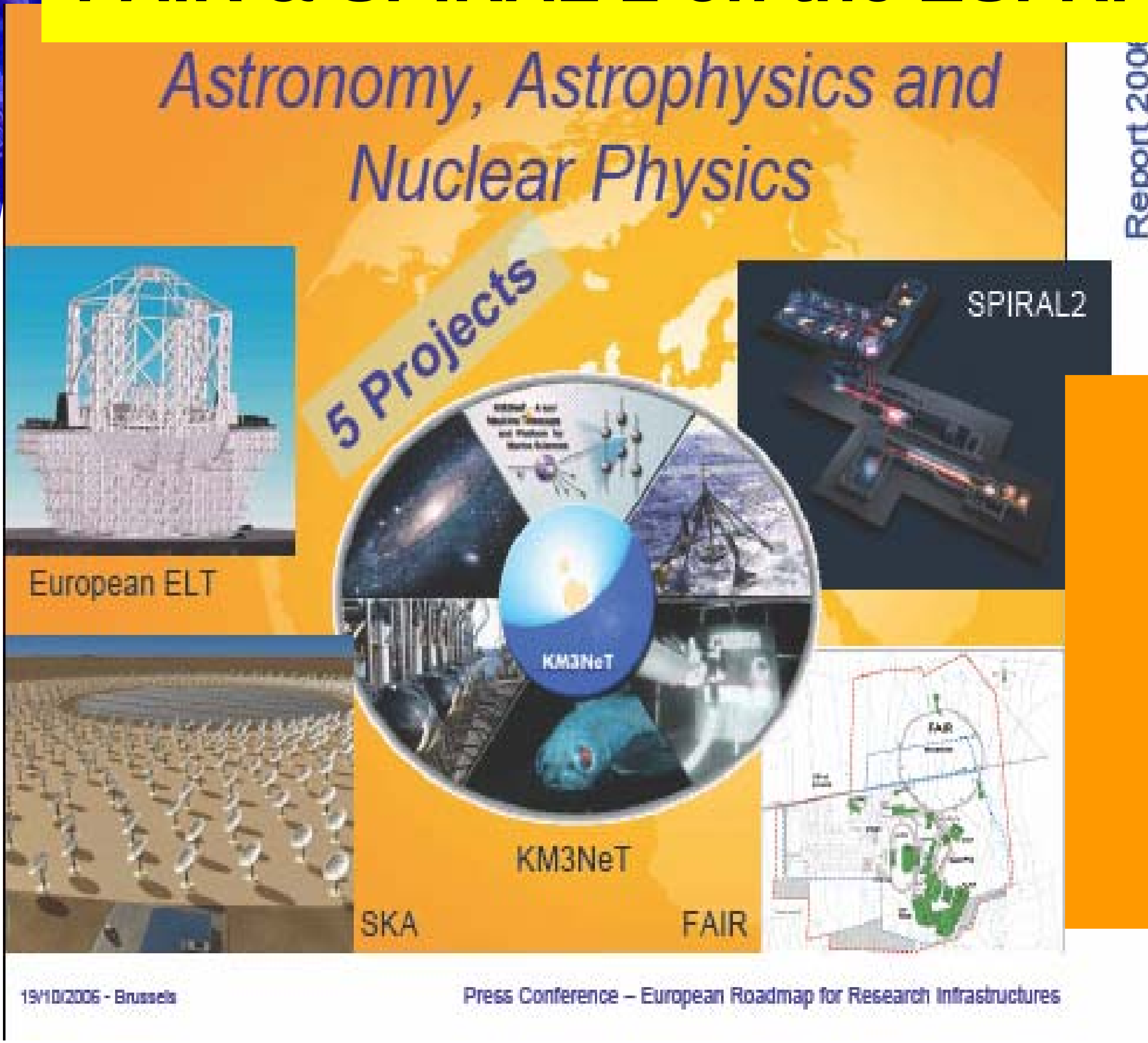
- **Provide IUPAP Report with International Landscape for NP**
- **AT, WvO, WH represent WG.9: provide expert advice**
- **Meetings in Washington, Rome, Tokyo; final meeting Nov. 4,5 in Paris**
- **Report serves as an important source of information for that group**

Europe

European RNB Facilities - Road Map

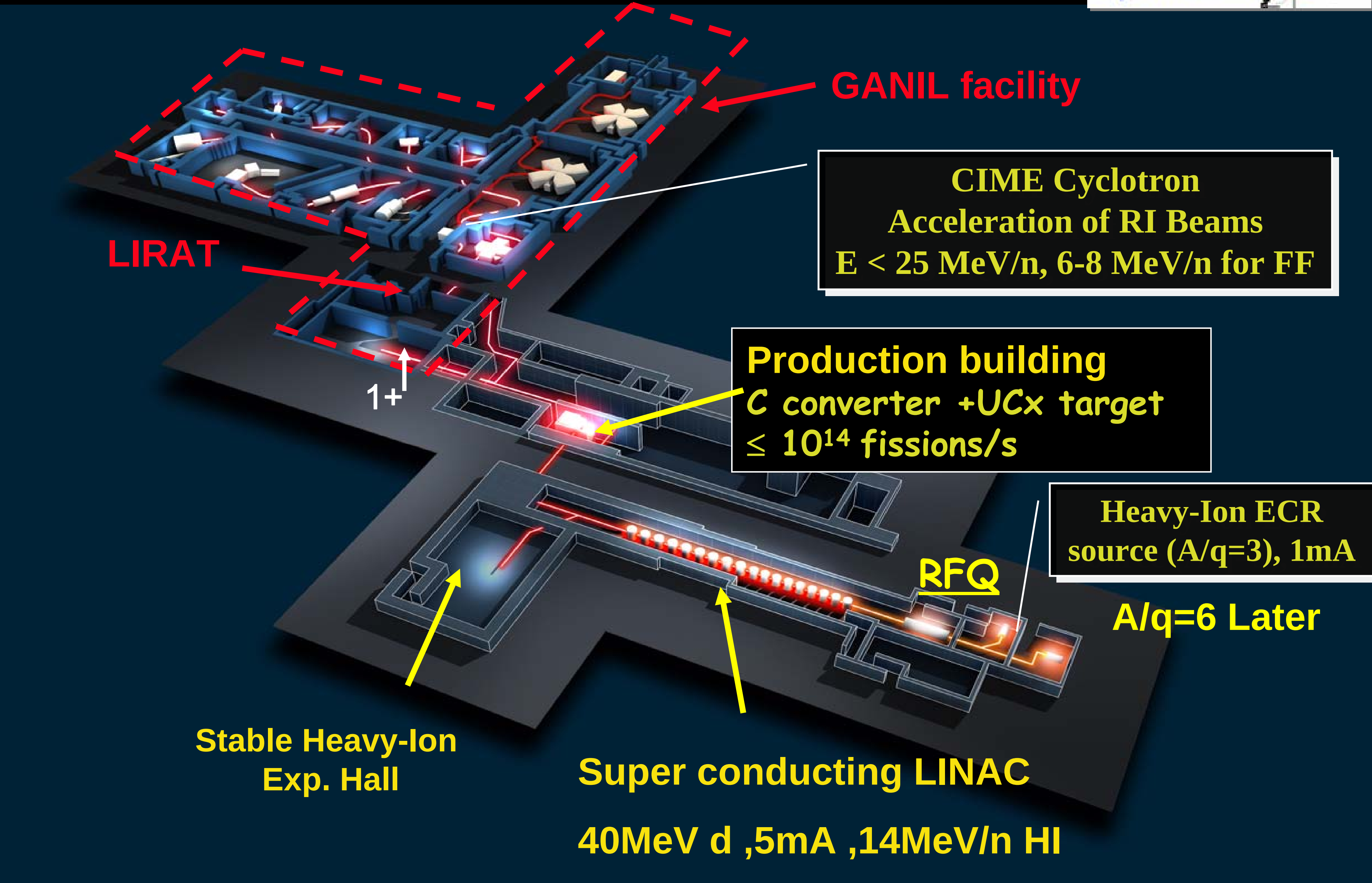


FAIR & SPIRAL 2 on the ESFRI list

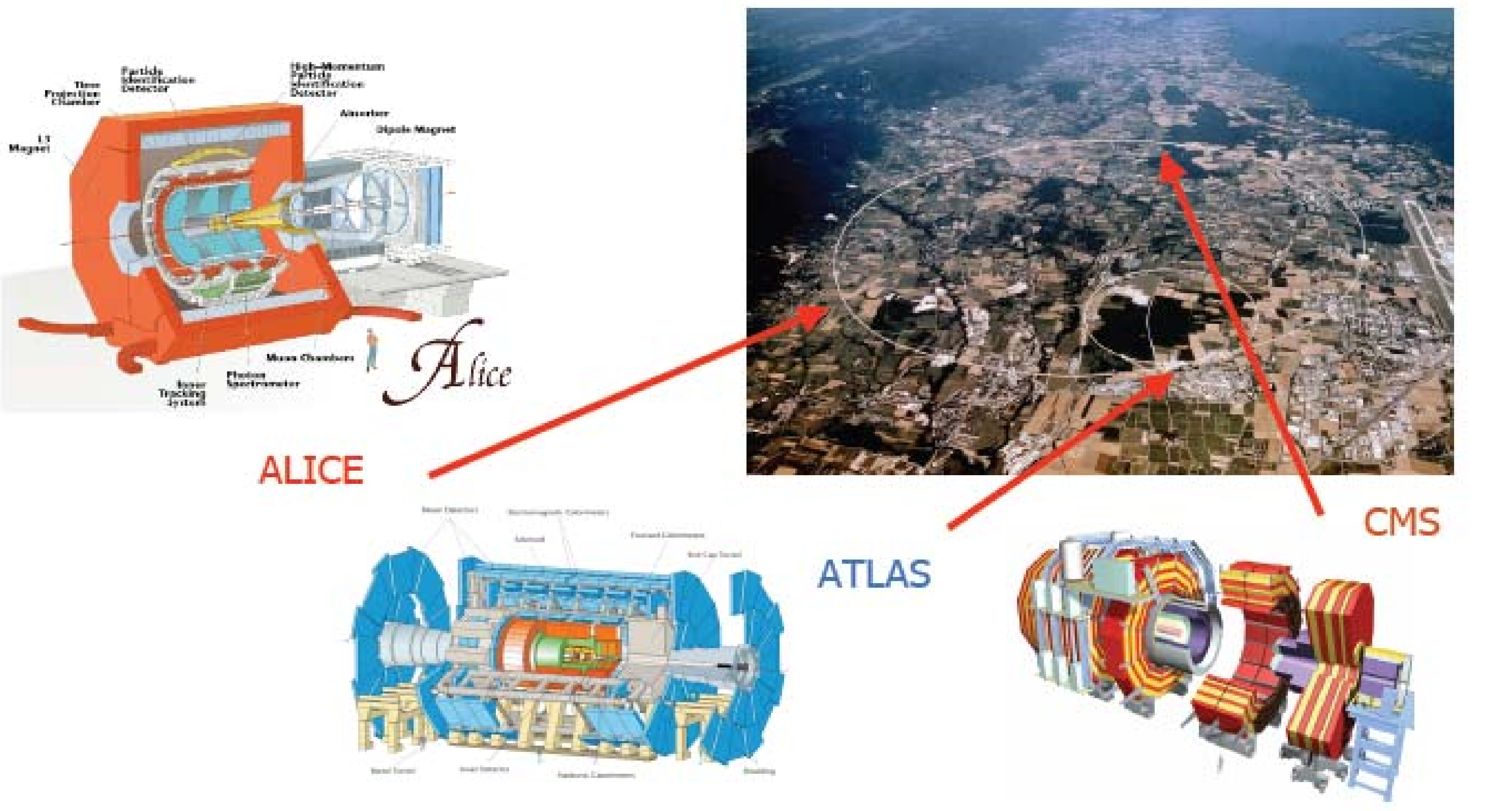


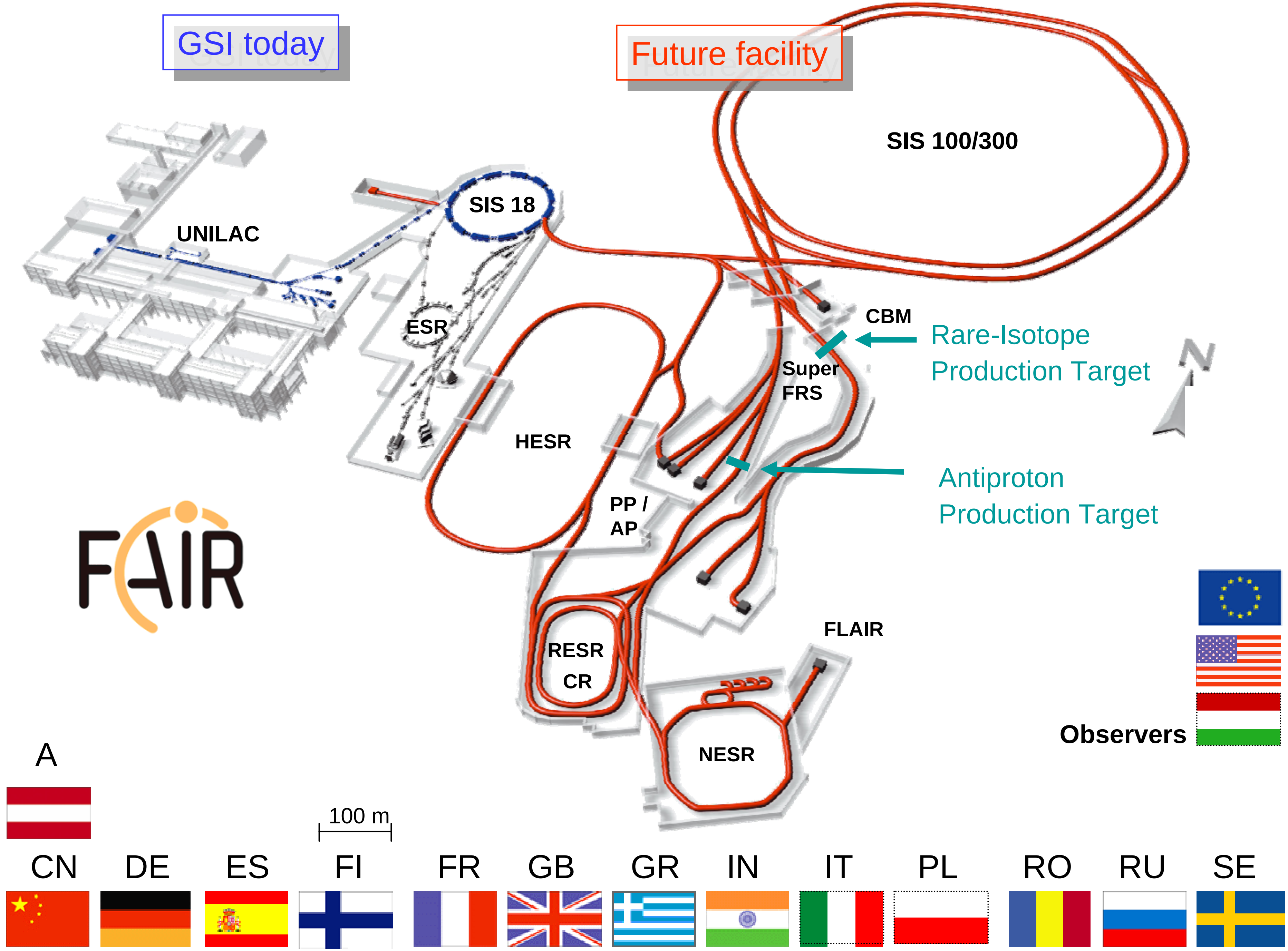
Brussels, 19 October 2006 European Research Infrastructures – ***The ESFRI roadmap identifies 35 large-scale infrastructure projects***

SPIRAL 2@GANIL - A world leading ISOL Facility



Heavy Ion physics at Large Hadron Collider





GSI today
Future facility
SIS 100/300
SIS 18
UNILAC
ESR
CBM
Rare-Isotope Production Target
Super FRS
HESR
Antiproton Production Target
PP / AP
FAIR
FLAIR
RESR
CR
NESR
Observers
A
100 m
CN
DE
ES
FI
FR
GB
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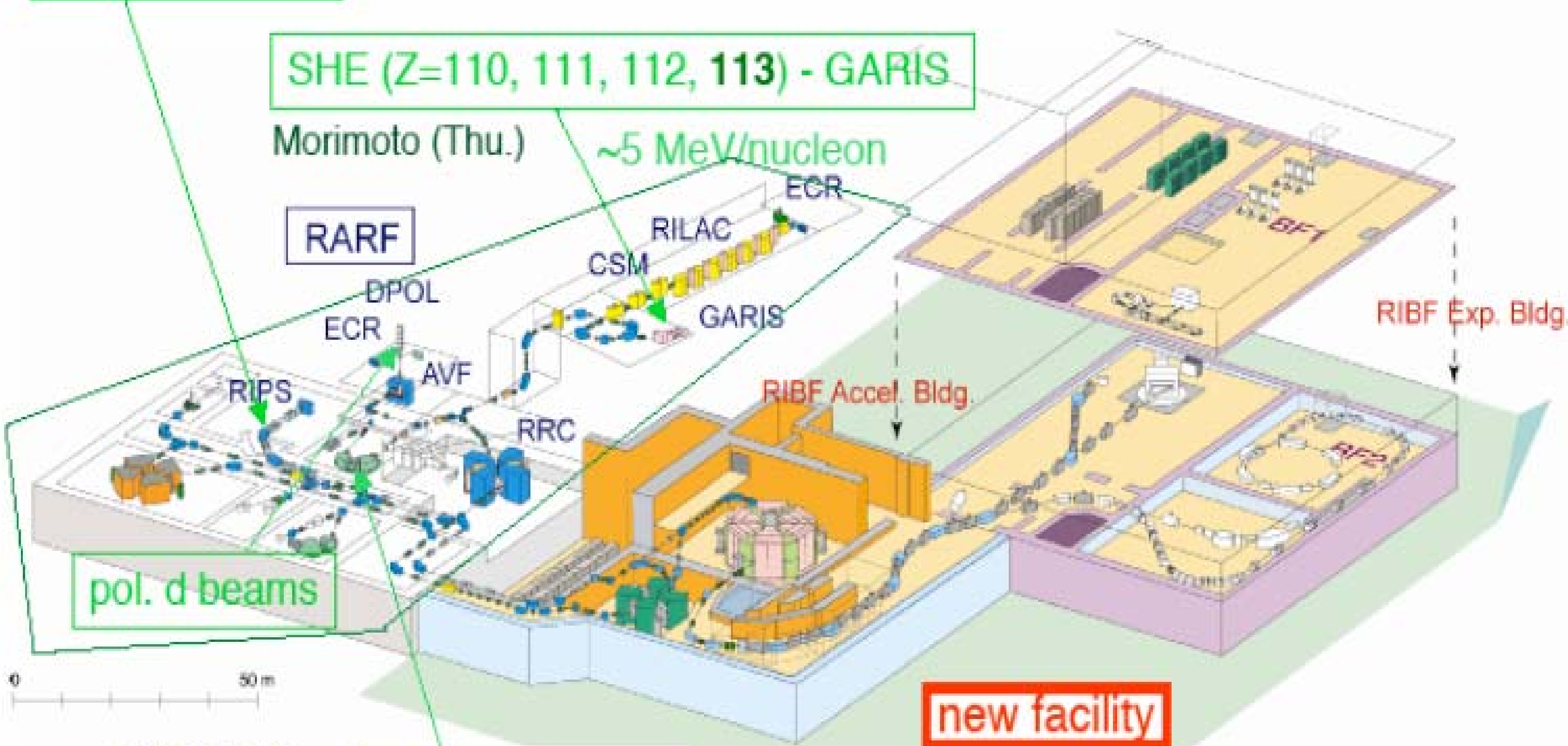
IN
IT
PL
RO
RU
SE

Japan

RIBF: Accelerator Complex in RIKEN Nishina Center

Fast RI beams - RIPS



0 135 MeV/nucleon for light nuclei (1986-)

RI beams (<5 AMeV) - CRIB

16 billion Yen (= $160 million if $1 = 100 Yen).

350 MeV/nucleon up to U

1st beam in 2006

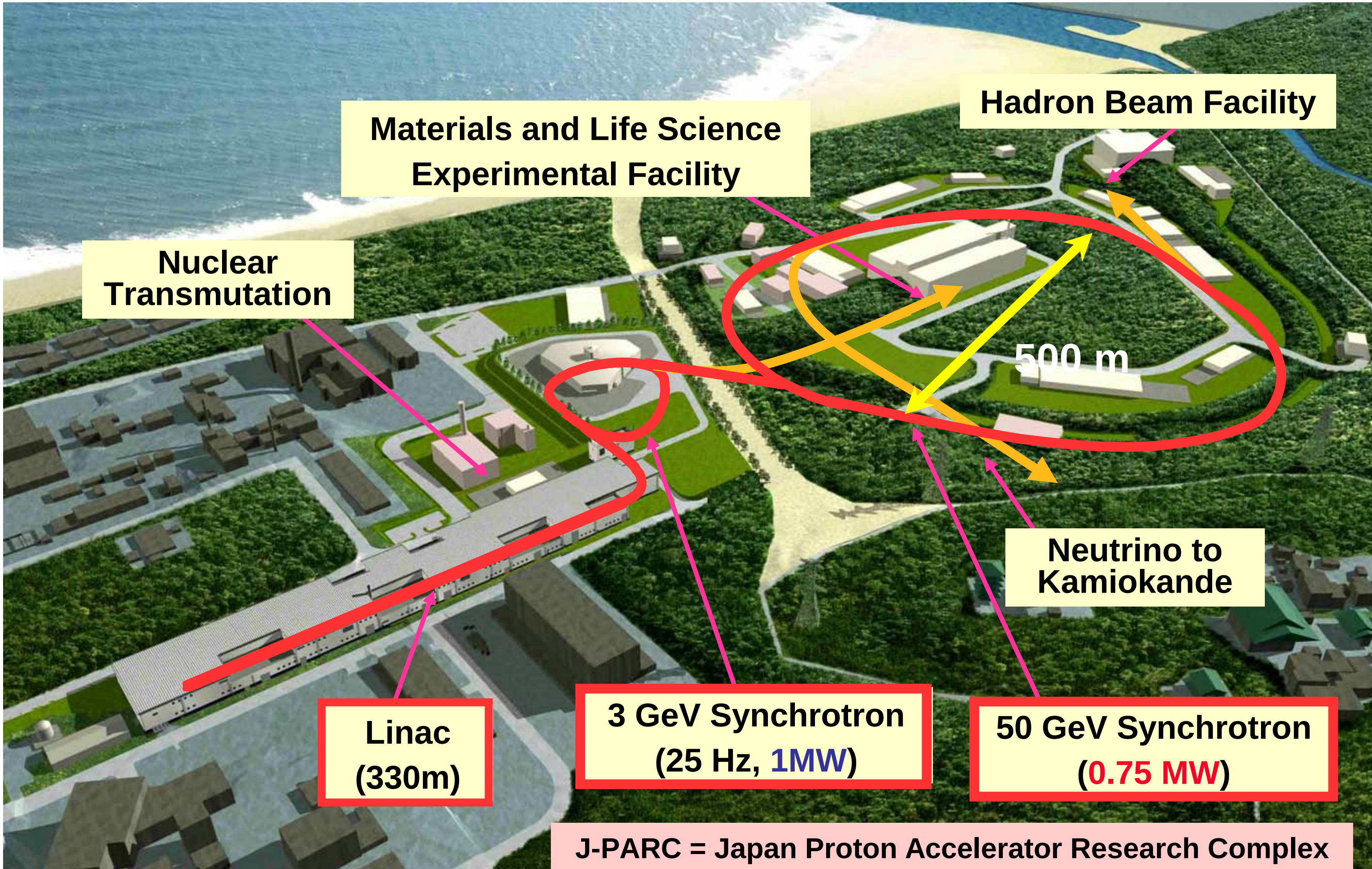
1 under construction

40 billion Yen (= $400 million)

2 to be built

5.6 billion Yen (= $56 million)

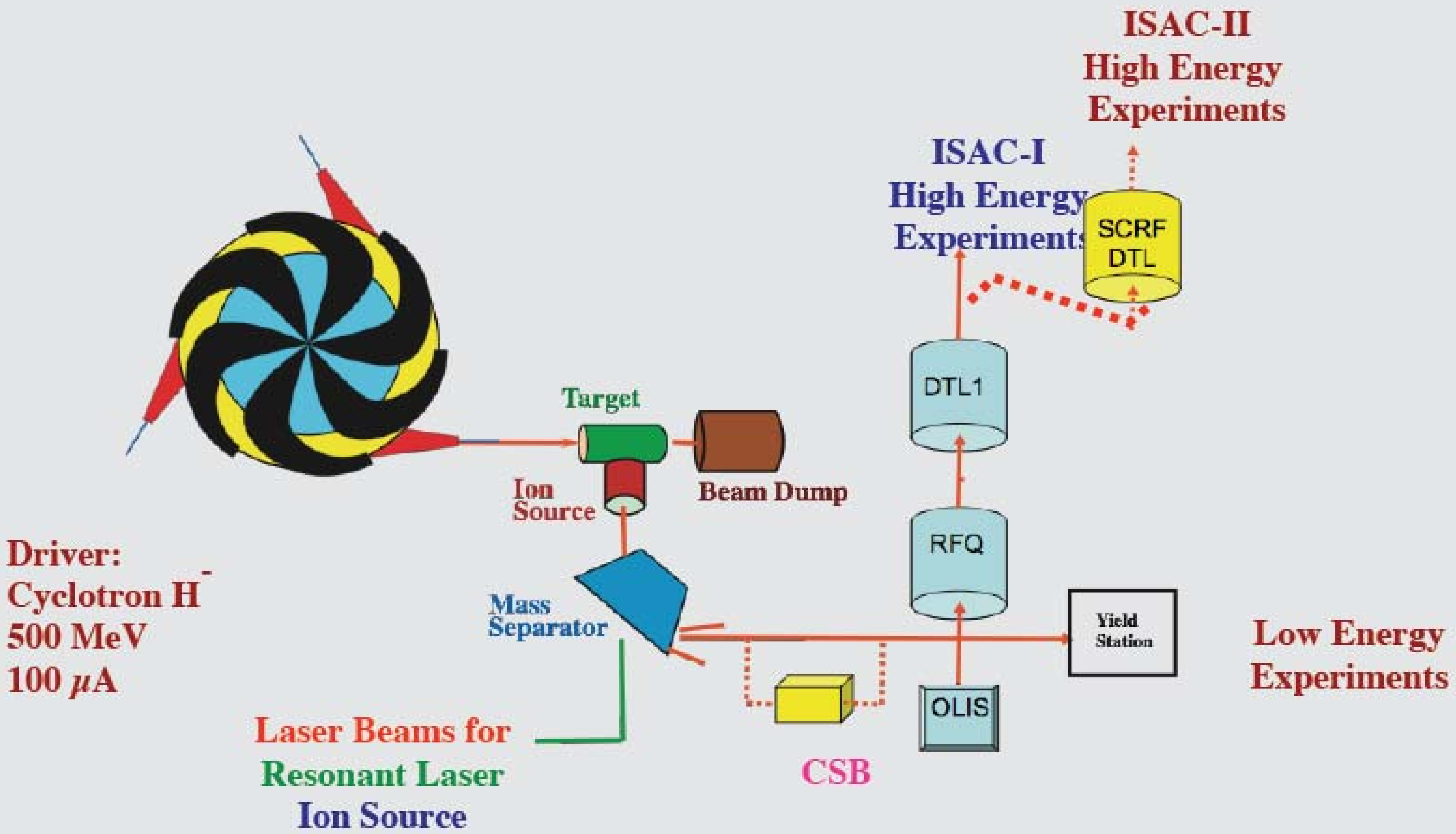
J-PARC Facility



Joint Project between KEK and JAEA

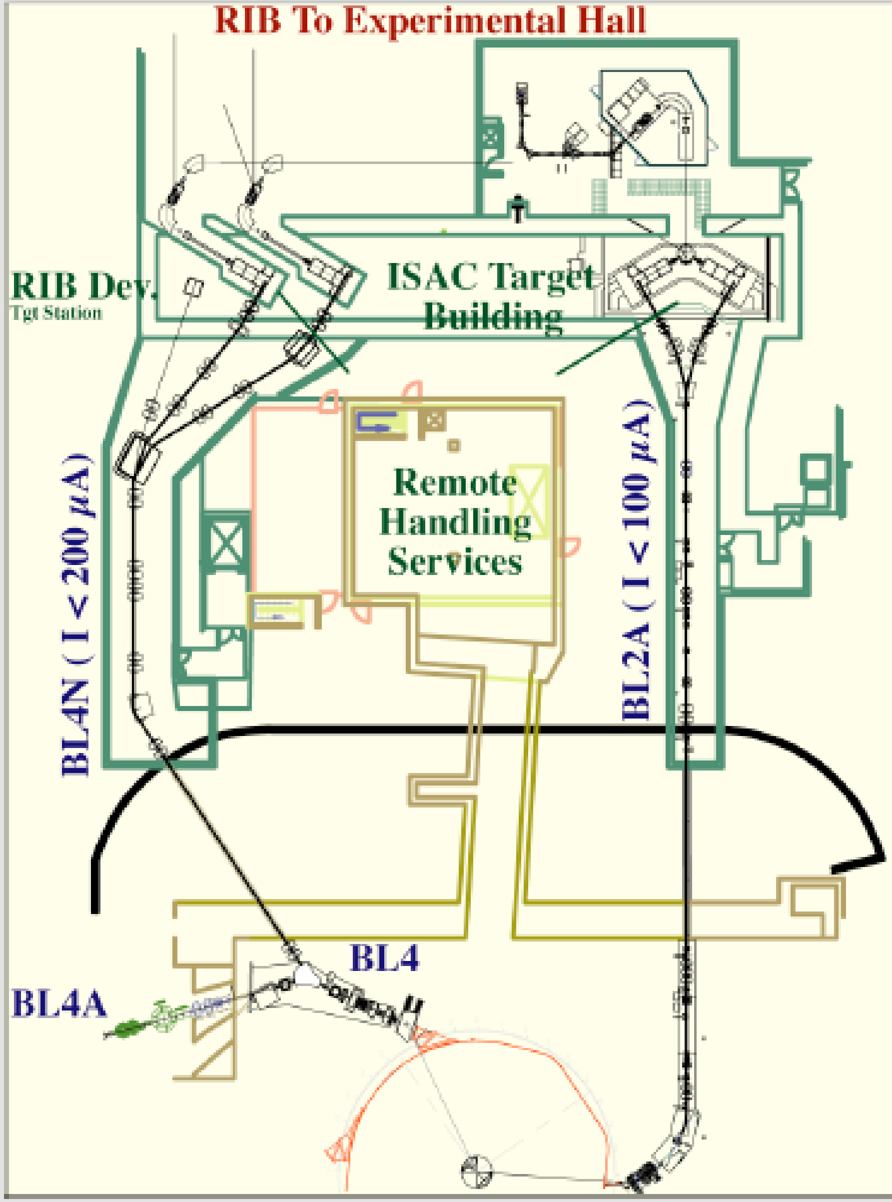
North America

Schematic Layout of TRIUMF/ISAC with H- Driver, ISOL Production & Post Accelerators



ISAC Future Plan

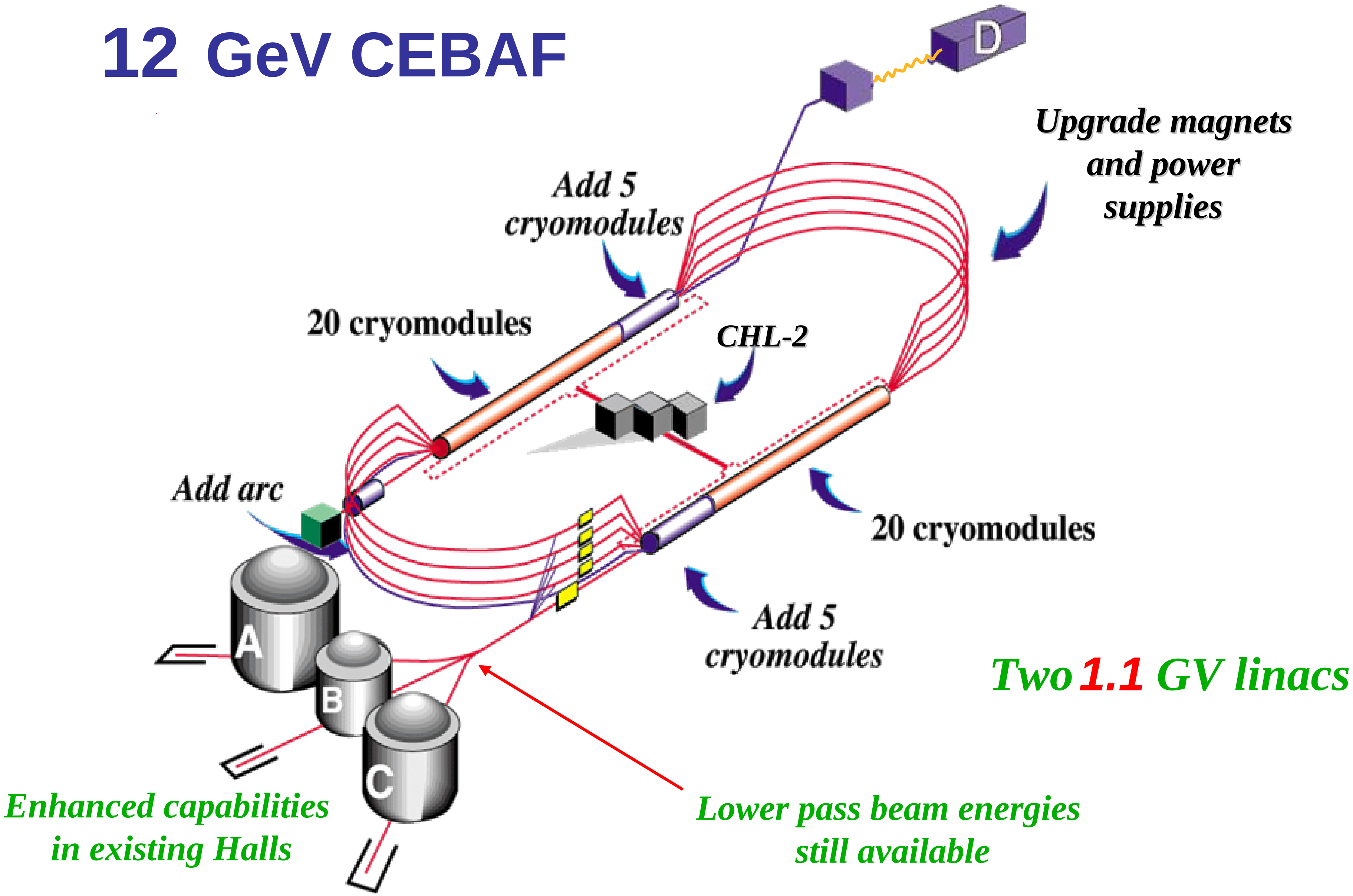
- The TRIUMF cyclotron driver could provide another proton beam (~ 200 - 400 μA) from a presently unused beam line (BL4AN) to new target stations,
- These target stations would then provide a place to perform systematic development of exotic beams,
  - Ion Source development,
  - Characterization of new targets
- An additional Radioactive Nuclear Beam could be simultaneously accelerated from these new target stations for experiment



United States - NSAC: LRP Recommendations

- **We recommend the completion of the 12 GeV Upgrade at Jefferson Lab. The Upgrade will enable new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of nuclei, and the nature of confinement.**
- **We recommend the construction of the Facility for Rare Isotope Beams, FRIB, a world-leading facility for the study of nuclear structure, reactions and astrophysics. Experiments with the new isotopes produced at FRIB will lead to a comprehensive description of nuclei, elucidate the origin of the elements in the cosmos, provide an understanding of matter in the crust of neutron stars, and establish the scientific foundation for innovative applications of nuclear science to society.**
- **We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet unseen violations of time-reversal symmetry, and other key ingredients of the new standard model of fundamental interactions. Construction of a Deep Underground Science and Engineering Laboratory is vital to US leadership in core aspects of this initiative.**
- **The experiments at the Relativistic Heavy Ion Collider have discovered a new state of matter at extreme temperature and density—a quark-gluon plasma that exhibits unexpected, almost perfect liquid dynamical behavior. We recommend implementation of the RHIC II luminosity upgrade, together with detector improvements, to determine the properties of this new state of matter.**

12 GeV CEBAF



D
Upgrade magnets and power supplies
Add 5 cryomodules
20 cryomodules
CHL-2
Add arc
20 cryomodules
Add 5 cryomodules
A
B
C
Two 1.1 GV linacs
Enhanced capabilities in existing Halls
Lower pass beam energies still available

Highlights of the 12 GeV Program

- Revolutionize Our Knowledge of Spin and Flavor Dependence of Valence PDFs

- Revolutionize Our Knowledge of Distribution of Charge and Current in the Nucleon

- Totally New View of Hadron (and Nuclear) Structure: GPDs
  - Determination of the quark angular momentum

Highlights of the 12 GeV Program….2

- **Exploration of QCD in the Nonperturbative Regime:**
  - **Existence and properties of exotic mesons**

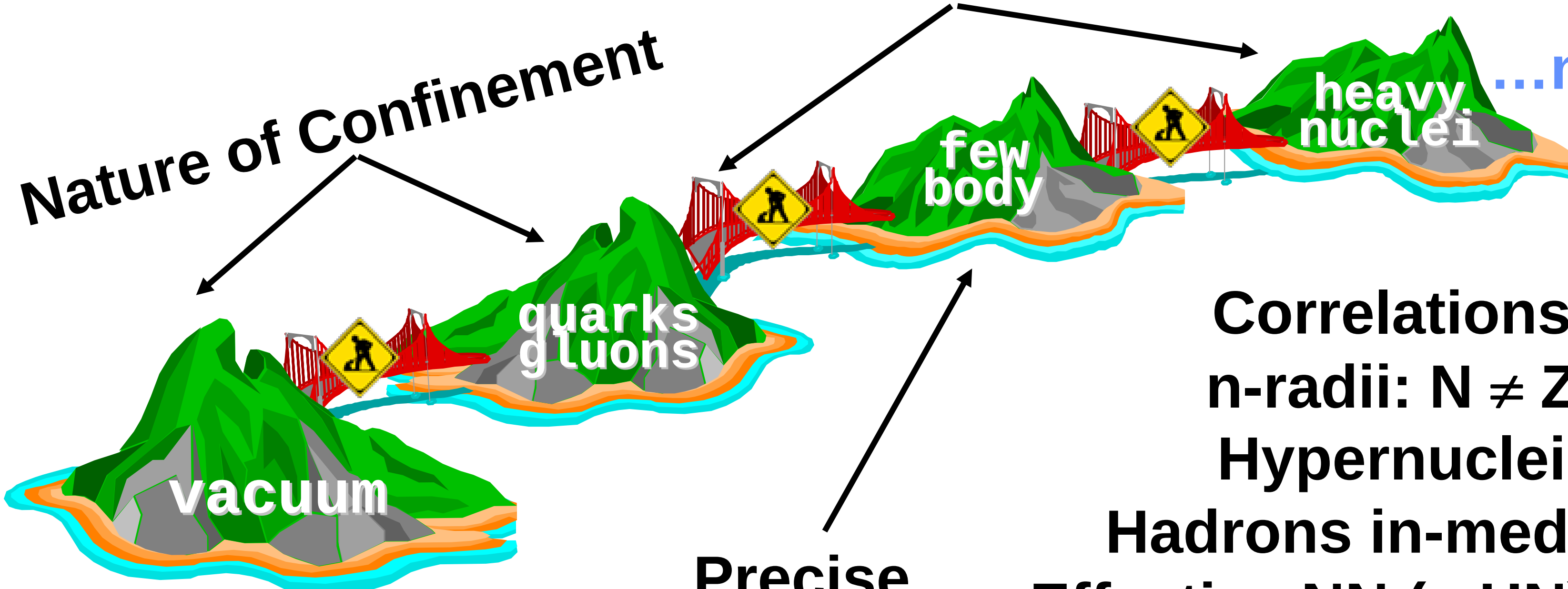
- **New Paradigm for Nuclear Physics:**
  Nuclear Structure in Terms of QCD
  - **Spin and flavor dependent EMC Effect**
  - **Study quark propagation through nuclear matter**

- **Precision Tests of the Standard Model**
  - **Parity Violating DIS & Möller**

The Program is Central to Nuclear Science

Quark-Gluon Structure
Of Nucleons and Nuclei

Nature of Confinement



…n-stars

Correlations
n-radii: N ≠ Z
Hypernuclei
Hadrons in-medium
Effective NN (+ HN) force

Exotic mesons
and baryons

Precise
few-nucleon
calculations

Recommendation 1

We recommend the completion of the 12 GeV Upgrade at Jefferson Lab. The Upgrade will enable new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of nuclei, and the nature of confinement.

A fundamental challenge for modern nuclear physics is to understand the structure and interactions of nucleons and nuclei in terms of quantum chromodynamics. Jefferson Lab's unique electron microscope has given the US leadership in addressing this challenge. Its first decade of research has already provided key insights into the structure of nucleons and the dynamics of finite nuclei.

Doubling the energy of this microscope will enable three-dimensional imaging of the nucleon, revealing hidden aspects of its internal dynamics. It will complete our understanding of the transition between the hadronic and quark/gluon descriptions of nuclei, and test definitively the existence of exotic hadrons, long-predicted by QCD as arising from quark confinement. Through the use of parity violation, it will provide low-energy probes of physics beyond the Standard Model complementing anticipated measurements at the highest accessible energy scales.

RISAC Report Science Drivers

- **Nuclear Structure**
  - Explore the limits of existence and study new phenomena
  - Possibility of a broadly applicable model of nuclei
  - Probing neutron skins (study of neutron matter)
  - Synthesis of Superheavy elements
- **Nuclear Astrophysics**
  - The origin of the heavy elements
  - Explosive nucleosynthesis
  - Composition of neutron star crusts
- **Fundamental Symmetries**
  - Tests of fundamental symmetries with rare isotopes
- **Other Scientific Applications**
  - Stockpile stewardship, materials, medical, reactors

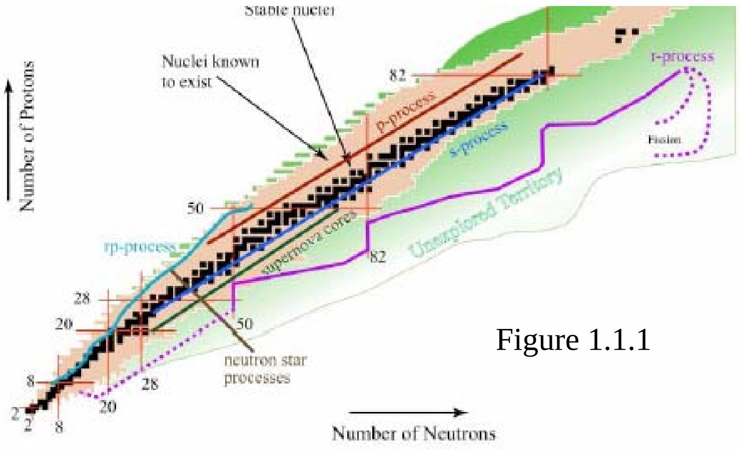


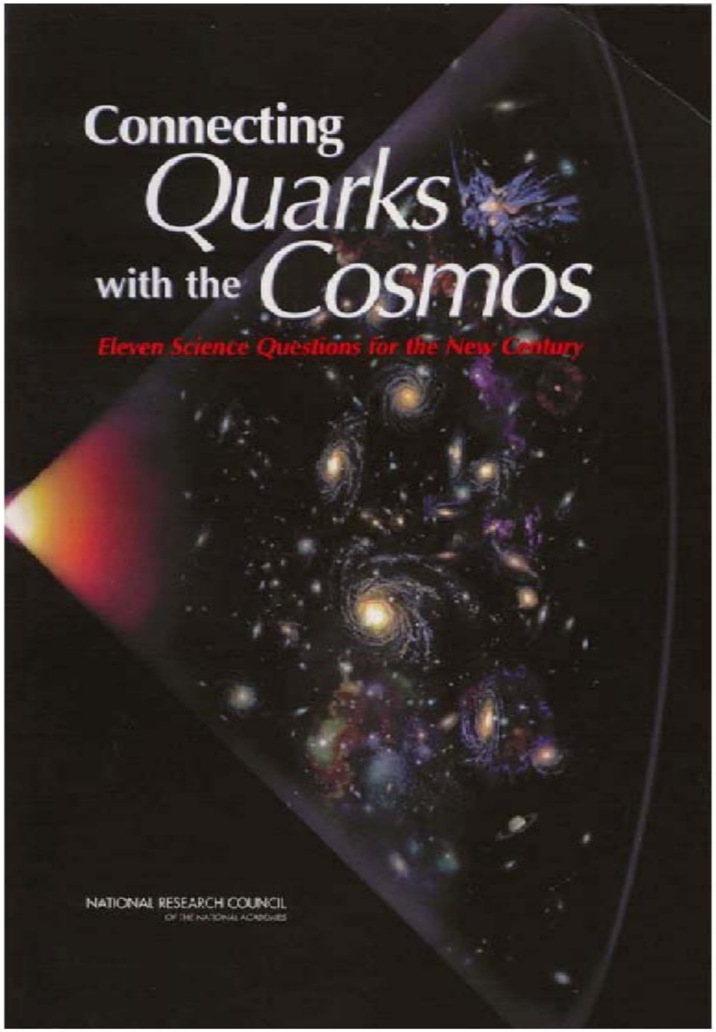
Figure 1.1.1

Recommendation 2

We recommend the construction of the Facility for Rare Isotope Beams, FRIB, a world-leading facility for the study of nuclear structure, reactions and astrophysics. Experiments with the new isotopes produced at FRIB will lead to a comprehensive description of nuclei, elucidate the origin of the elements in the cosmos, provide an understanding of matter in the crust of neutron stars, and establish the scientific foundation for innovative applications of nuclear science to society.

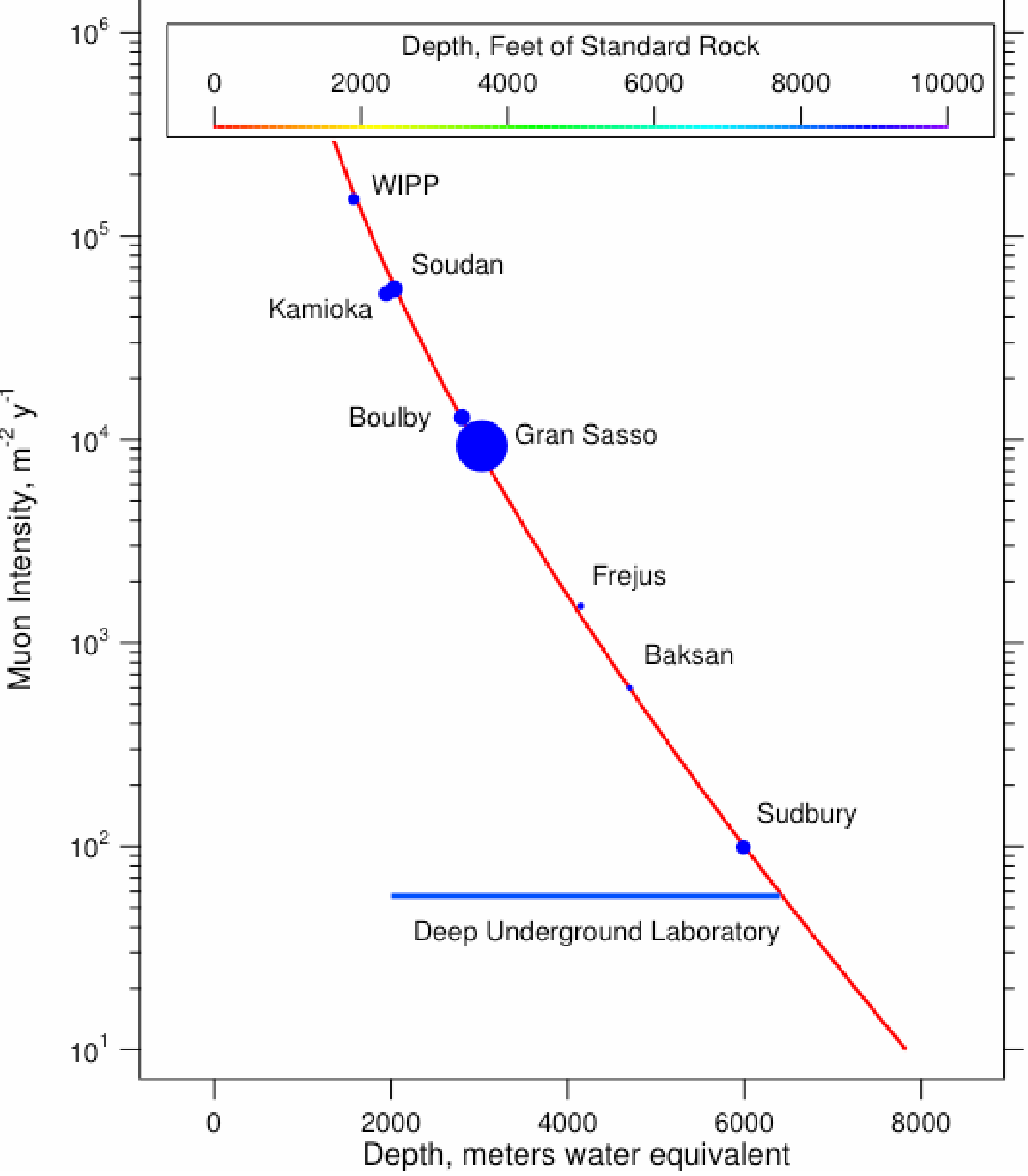
A roadmap has been delineated to achieve the goal of a comprehensive and unified description of nuclei. New data on exotic isotopes, that only FRIB will provide, are an essential ingredient of this approach as they will allow us to understand the nature of the forces that hold the nucleus together, to assess the validity of the theoretical approximations, and to delineate the path towards integrating nuclear structure with nuclear reactions. The study of rare isotopes is essential to explain the chemical history of the universe and the synthesis of elements in stellar explosions. Advances in Astrophysics and astronomy are driving the need for new and improved nuclear data on isotopes at the very limits of nuclear stability which will be available for the first time with suitable rates at FRIB. Rare isotopes also play a role in testing the fundamental symmetries of nature, and are essential for the many cross-disciplinary contributions they enable in basic sciences, national security, and societal applications. To launch the field into this new era requires effective exploitation of current User facilities, NSCL, HRIBF and ATLAS, and the immediate construction of FRIB with its ability to produce ground breaking research.

Scientific case has been established and validated by two National Academy Studies, two long-range plans and several community workshops



Determine the neutrino masses, the constituents of the dark matter and the lifetime of the proton. The Committee recommends that DOE and NSF work together to plan for and to fund a new generation of experiments to achieve these goals. We further recommend that an underground laboratory with sufficient infrastructure and depth be built to house and operate the needed experiments.

(3rd Turner Committee Recommendation, 2002)

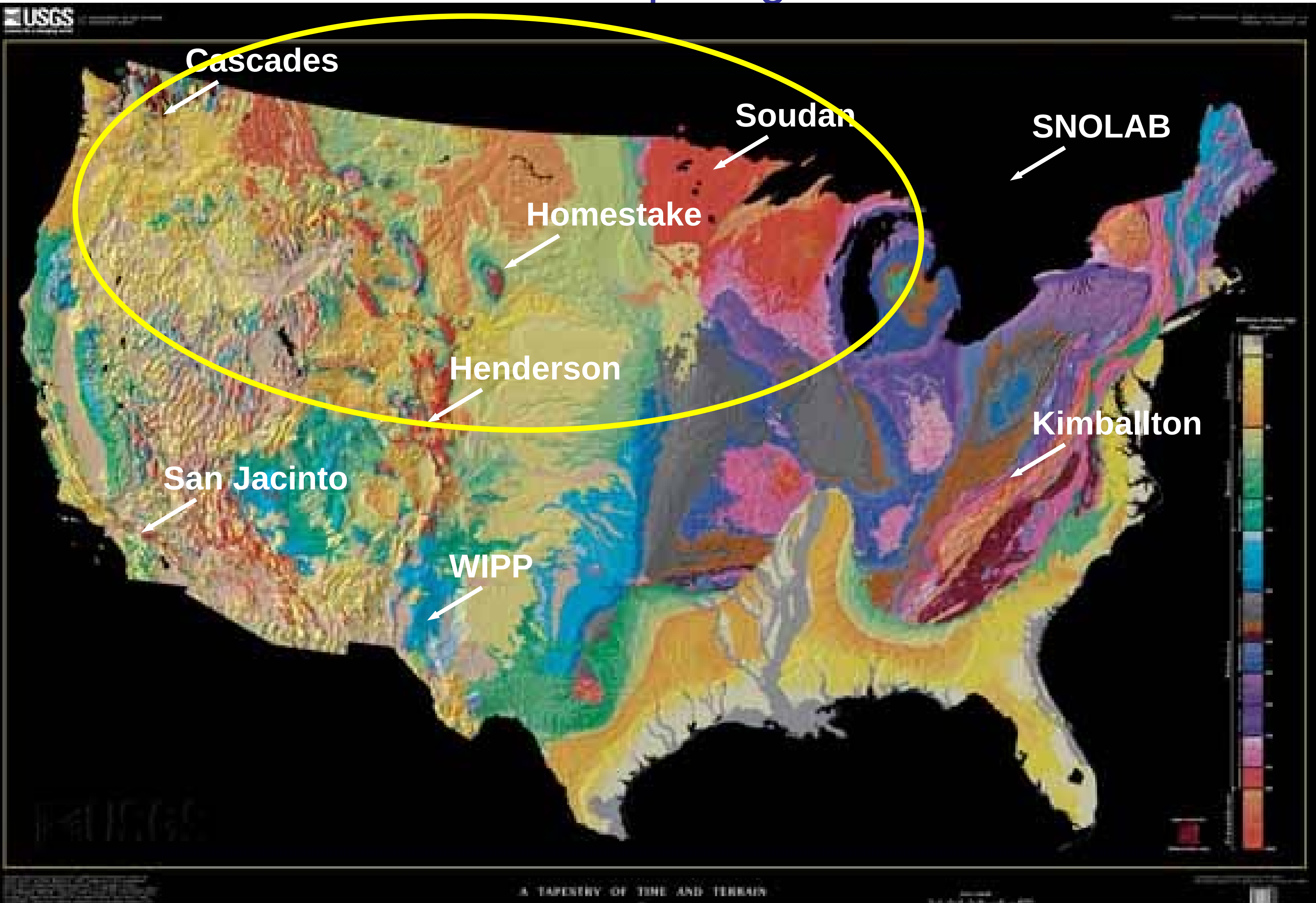


Data: Hime & Mei, astro-ph/0512125
Curve: Miyake, N.Cim. 32, 1505 (1964)

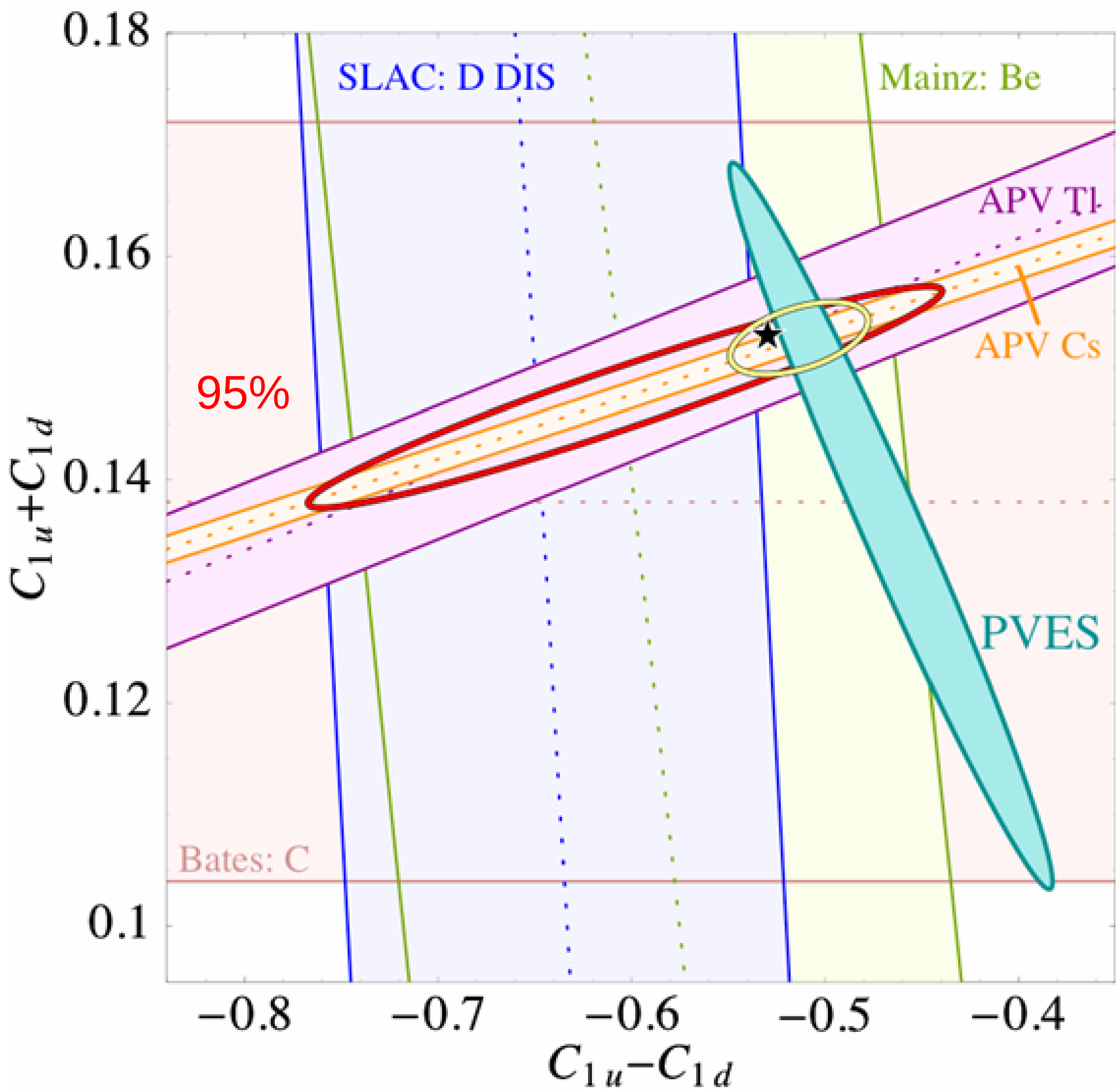
Physicists want:

- Cosmic-ray Shielding
- Seismic quiet
- Low radioactivity
- Access

DUSEL S3 competing sites



PVES ⇒ Major New Test of Standard Model



(Young et al., hep-ph/0704.2618)

Dramatic improvement in knowledge of weak couplings!

Factor of 5 increase in precision of Standard Model test

Recommendation 3

We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet unseen violations of time-reversal symmetry, and other key ingredients of the new standard model of fundamental interactions. Construction of a Deep Underground Science and Engineering Laboratory is vital to US leadership in core aspects of this initiative.

The discovery of flavor oscillations in solar, reactor, and atmospheric neutrino experiments – together with unexplained cosmological phenomena such as the dominance of matter over anti-matter in the Universe – call for a new standard model of fundamental interactions. Nuclear physicists are poised to discover the symmetries of the new standard model through searches for neutrinoless double beta decay and electric dipole moments, determination of neutrino properties and interactions, and precise measurements of electroweak phenomena.

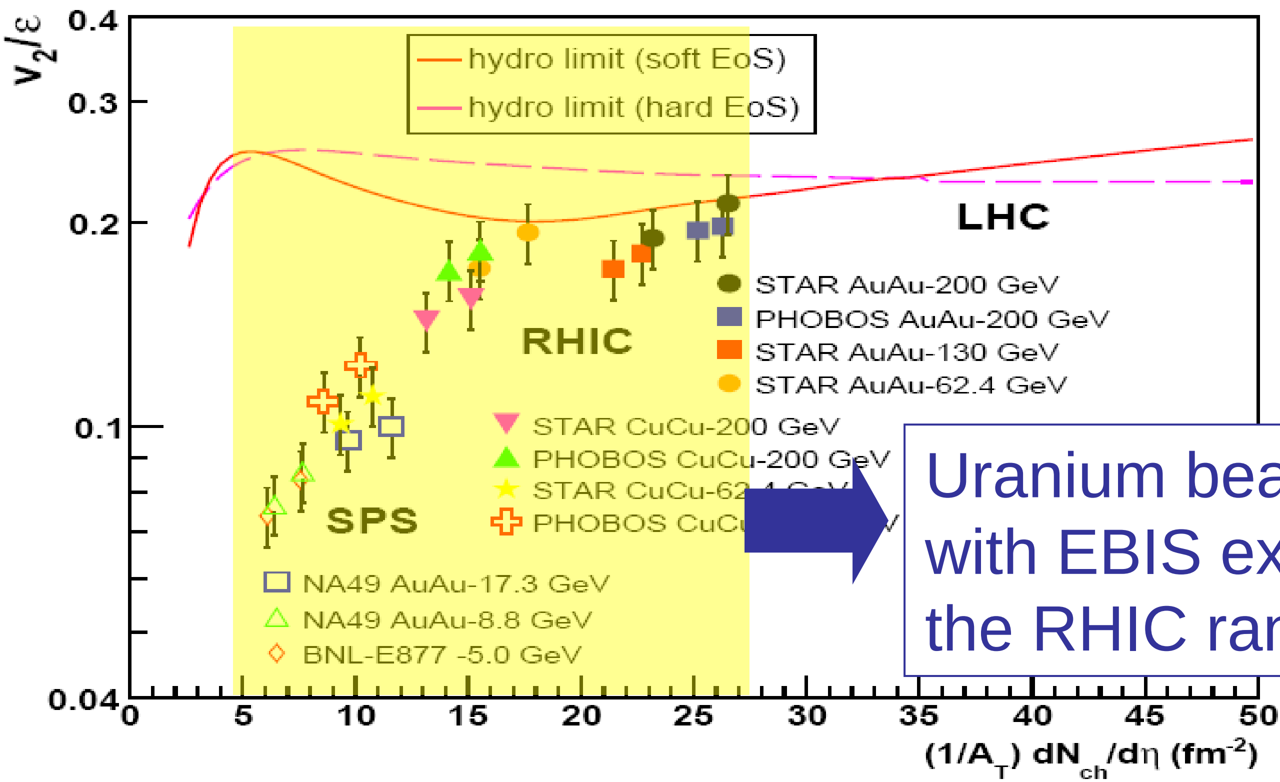
The Deep Underground Science and Engineering Laboratory will provide the capability needed for ultra-low background measurements in this discovery-oriented program. Experiments also will exploit new capabilities at existing and planned nuclear physics facilities. Assembling the new standard model using the breadth of new experimental results will require enhanced theoretical efforts.

RHIC II and LHC → Golden Age of Heavy Ions

RHIC II high luminosity and substantial energy range are critical to quantitative understanding and advances.

LHC highest energy achievable is also compelling.

One Example



Uranium beams with EBIS extend the RHIC range.

Recommendation 4

The experiments at the Relativistic Heavy Ion Collider have discovered a new state of matter at extreme temperature and density—a quark-gluon plasma that exhibits unexpected, almost perfect liquid dynamical behavior. We recommend implementation of the RHIC II luminosity upgrade, together with detector improvements, to determine the properties of this new state of matter.

The striking discoveries of the first five years at RHIC compel us to carry out a broad, quantitative study of the fundamental properties of the quark-gluon plasma. This can be accomplished through significant increases in collider luminosity, detector upgrades, and advances in theory, which also create further discovery potential.

The RHIC II luminosity upgrade, using electron cooling, provides a ten-fold increase in collision rate, which enables measurements using uniquely sensitive probes of the plasma such as energetic jets and rare bound states of heavy quarks. The detector upgrades make important new types of measurements possible and extend significantly the physics reach of the experiments. Achieving a quantitative understanding of the quark-gluon plasma also requires new investments in modeling of heavy ion collisions, in analytic approaches, and in large scale computing.

Top non-numbered recommendation: Accelerator and detector R&D related to:

A High Luminosity, High Energy Electron-Ion Collider: A New Experimental Quest to Study the Glue which Binds Us All

How do we understand the visible matter in our universe in terms of the fundamental quarks and gluons of QCD?

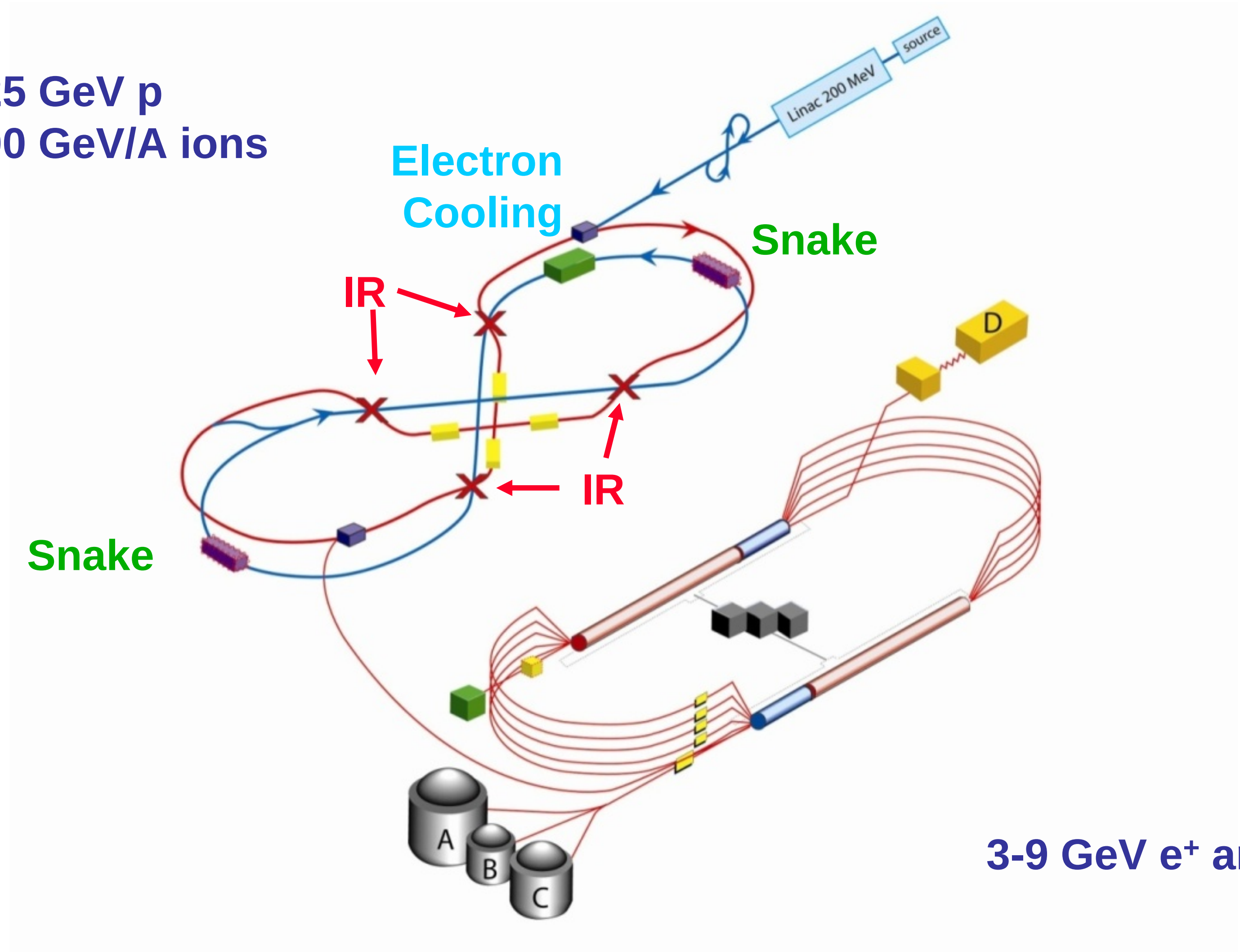
Explore the new QCD frontier: strong color fields in nuclei

Precisely image the sea-quarks and gluons in the nucleon

BNL, CERN, JLab….

At Jefferson Lab : ELIC

30-225 GeV p
30-100 GeV/A ions



3-9 GeV e^+ and e^-

Future Role of WG.9

WG.1 is ICFA – is there a similar role for WG.9?

Created to promote international cooperation in nuclear physics…

Are there projects in NP too big for a single country?

Series of workshops to stimulate discussion

Agreed Actions (Tokyo June 2007)

- Prepare a concise report on what it requires to operate an effective, truly international user facility
  - includes difficulty of access for users from "small countries" (ASL, JMP, TM, WH)

- Explore sources of funding for networking activities along lines so successfully employed by EC (WH, AT, ML, RT)

- Establish sub-committees to coordinate workshops/plans for facilities likely too large for single country/region
  - Future RIB facility (SG, RC, BF ….)
  - Future electron-ion collider (AT, SA ….)

- Pursue implementation of OECD recommendations…..