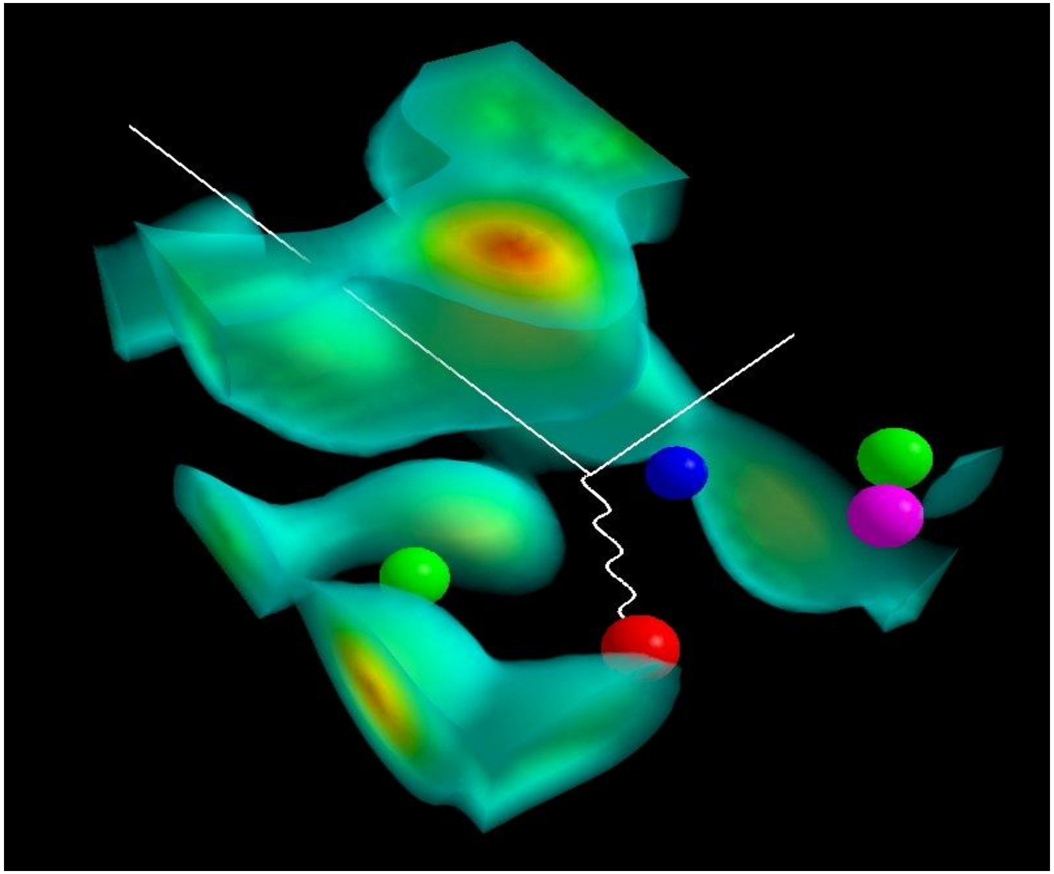
International Cooperation in Nuclear Physics



Anthony W. Thomas

Eurisol Town Meeting March 31st 2009

Overview

- Creation of IUPAP Working Group 9 on International Cooperation in Nuclear Physics
- First report on User Facilities world-wide
- OECD Global Science Forum
- Future

Origins

- Early 90s C12 (IUPAP Commission on Nuclear Physics - Chair H. Feshbach) discussed need for international cooperation but failed to produce a plan

- Only in 2003, under S. Nagamiya, was a sub-committee of C12 created (AWT Chair)

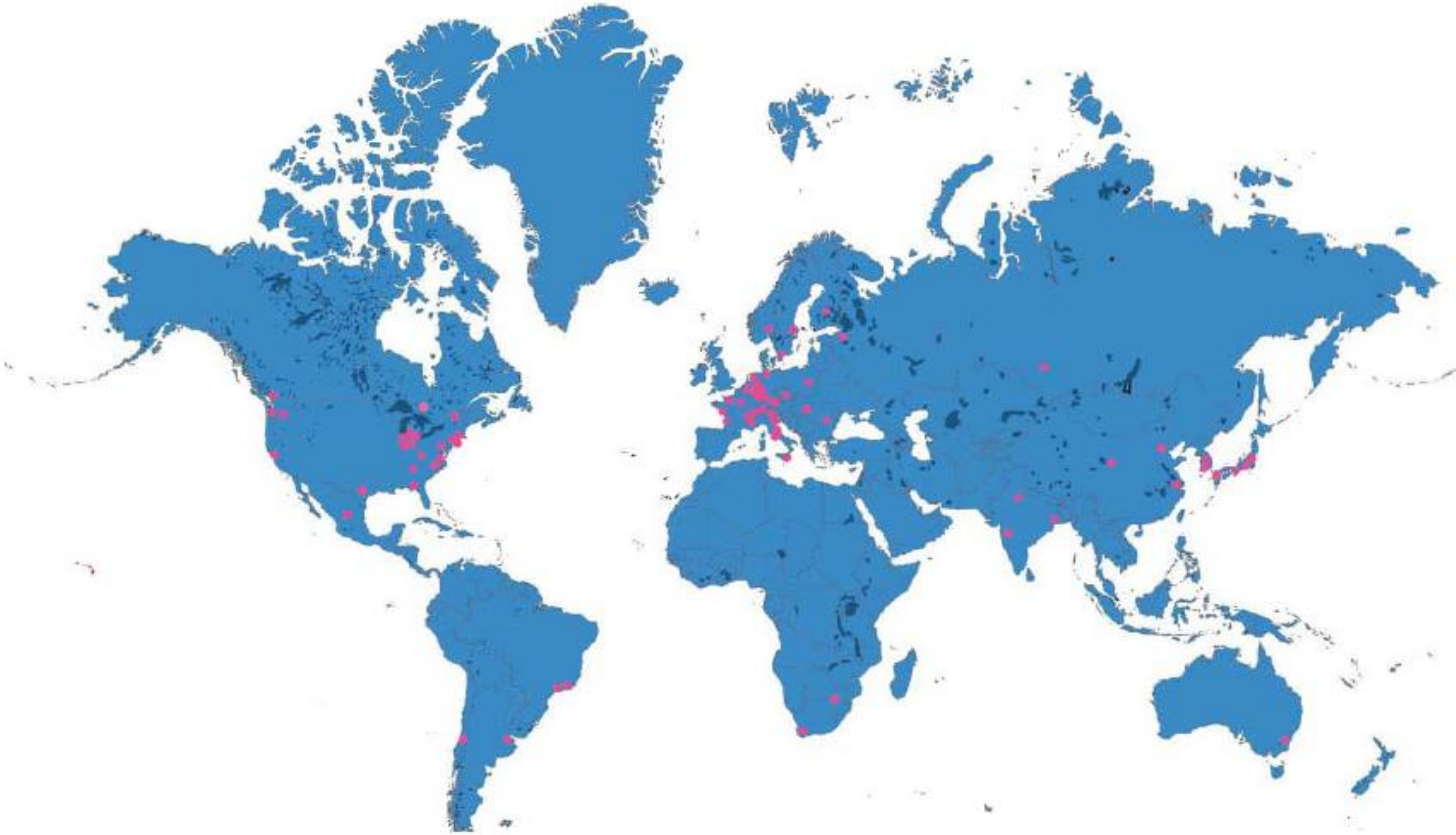
- At triennial IUPAP General Assembly in Capetown in 2005 this formally became the 9^{th} Working Group of IUPAP

- ICFA, created in 1960s (!) is WG.1

Initial 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)
- M. 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)

Nuclear Physics Facilities and Aims World-Wide



IUPAP Report 41: from Working Group 9
International Cooperation in Nuclear Physics

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?

Short summary (~20 pages) describing these and how facilities relate

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 / Location	Facility Name	Facility Characteristics
EUROPE				
	Belgium	Université Catholique de Louvain, Louvain-la-Neuve	Centre de Recherche du Cyclotron	Cyclotrons (K=30 & K=110) / p (30/70 MeV) / HI(A≤130 25-0.56 MeV/u / RIB (A < 20: 10 - 0.56 MeV/u)
	Czech Republic	Academy of Sciences of the Czech Republic, Rez	Nuclear Physics Institute	Cyclotron (K=40) / p He
	Finland	University of Jyväskylä, Jyväskylä	Accelerator Laboratory	Cyclotron (K=130) / p (130 MeV) / HI (A≤130 30 MeV/u – 5 MeV/u)
	France	Centre d'Etudes Nucléaires Bordeaux Gradignan (CENBG), Gradignan	AIFIRA	Singletron(3.5 MV) / p (3.5 MeV) / n (7 MeV)
		CNRS, Université de Nantes, École des Mines de Nantes, Nantes	ARRONAX	Cyclotron (K=70) planned; radioisotope production and nuclear medicine
		European Synchrotron Radiation Facility, Grenoble	ESRF GRAAL	Gamma Rays (Compton back-scattered polarized) (550-1500 MeV)
		GANIL Laboratory, Caen	GANIL	Cyclotrons (3 compact, 2 sep.sector) / SPIRAL ISOL / HI (95MeV/u)
		Institut de Physique Nucléaire de Lyon, Lyon	IPNL Van de Graaffs	Van de Graaffs (2.5/4 MV) / p (3.5MeV) / Au-clusters (2 MeV) / HI
		Institut Laue-Langevin, Grenoble	ILL	Research Reactor / n ($10^{15}s^{-1}$ cm^{-2})
		Institut Physique Nucléaire d'Orsay, Orsay	Tandem / ALTO	Tandem (15 MV) / 50 MeV e^- linac / ISOL / p (25 Mev) HI (8-1 MeV/u)
	Germany	Deutsches Elektronen-Synchrotron (DESY), Hamburg	HERA	Electron (30GeV)-Proton (920 GeV) Collider, pol. e^-
		Forschungsneutronenquelle Heinz Maier-Leibnitz, Garching	FRM II	Research Reactor / n ($8x10^{14}s^{-1}cm^{-2}$)
		Forschungszentrum Juelich (FZJ), Juelich	COSY	Synchrotron (acc.-cooler) / pl. p,d/0.27 - 3.7 GeV/c
		Gesellschaft fuer Schwerionenforschung (GSI), Darmstadt	UNILAC, SIS, ESR NP	Linac-Synchrotron-Storage Ring / p (4.7 GeV) / HI/RIBs (2 GeV/u)
		Technical University of Darmstadt, Darmstadt	S-DALINAC	Electron-Linac (S.C. / recirculating) / 2-130 MeV
		University of & Technical University of Munich, Garching	Maier-Leibnitz Laboratory	Tandem (14MV) / p (28 MeV) / HI (9-1.1 MeV/u)
		University of Bonn, Bonn	ELSA	Electron-Synchrotron/Storage-Stretcher Ring/0.5 - 3.5 GeV
		University of Cologne, Cologne	Tandem Accelerator	Tandem (10MV) / p (20 MeV) / HI (A≤80, 6-1.5 MeV/u)
		University of Mainz, Mainz	MAMI Accelerator	Microtron (e^- cw-race track) / 180-1500 MeV
	Hungary	Inst. of Nucl. Res. of the Hungarian Academy of Sciences, Debrecen	ATOMKI	Cyclotron (K=20) / p(20 MeV) / ^{3}He(27 MeV)
	Italy	European Centre for Theoretical Studies in Nuclear Physics, Trento	ECT*	Theory Institute
		National Institute of Nuclear Physics (INFN), Assergi	Laboratori Nazionali del Gran Sasso	Electrostatic Acc. 50 kV & 400 kV / deep underground facilities
		National Institute of Nuclear Physics (INFN), Catania	Laboratori Nazionali del Sud	Tandem (15 MV) p (28 MeV)/HI (14-1 MeV/u) SC-Cyclotron / p (80 MeV) / HI (80-20 MeV/u)

			Total	Theory (total)	Permanent	Temporary	Postdocs	PhD Students Onsite / Other Graduate Students	Undergraduates	Total user number	Internal (%)	National (%)	International (%)
AFRICA													
South Africa	ITHEMBA Laboratory, Faure / Cape Town	Cyclotron & Accelerator Facility	300	12	283	17	13	30/160	yes	445	0%	35%	65%
	NESCA, Pretoria	SAFARI-1/Van de Graaff	17		15		2	0/3	4	25	30%	95%	5%
ASIA													
China	China Institute of Atomic Energy, DNP, Beijing	Beijing Tandem Acc. Lab.	250	20	200	50	2	50/10	50	200	65%	90%	10%
	Chinese Academy of Sciences, IMP, Lanzhou	HIRFL	500	26	400	100	10	200/20	40	200	50%	90%	10%
	Chinese Academy of Sciences, SIAP, Shanghai	SLEGS (in planning)											
India	New Delhi University Grants Commission of India, New Delhi	Inter-University Accelerator Center	110	0	100	10	4	12/80	0	100	15%	95%	5%
	Variable Energy Cyclotron Centre, Kolkata	VECC	470	13			3	14/2		30	20%	80%	20%
Japan	Japan Atomic Energy Agency, Tokai	JAEA Tandem Facility	17	6	14	3	4	2/5	0	280	90%	80%	20%
	KEK and JAEA, Tokai	J-PARC (under construction)								480	10%	40%	60%
	Kyushu University, Fukuoka	KUTL	4	2	2	0	1	4/3	8	35	70%	100%	0%
	National Institute of Radiological Sciences, Anagawa	HIMAC	31		20	11	6	5/20	10	704	20%	90%	10%
	Osaka University, Osaka	Van de Graaff Laboratory	9		6	3	0	3/1	2	3	40%	90%	10%
	RCNP, Osaka University, Osaka	Cyclotron complex/back scattered photon facility	58	8	17	41	8	33/135	0	700	5%	90%	10%
	RIKEN, Wako	Nishina Center for Accelerator-Based Science	157	6	59	98	50	25/112	12	500	50%	81%	19%
	Tohoku University, Aoba	CYRIC	39		13	26	3	25/2	10	20	20%	95%	5%
	Tohoku University, Sendai	LNS Sendai	32		14	18	3	15/3	0	100	40%	100%	0%
	University of Tsukuba, Tsukuba	Tandem Accelerator Complex	21	0	13	8	1	7/3	0	60	90%	99%	1%
Korea	Korea Institute of Geoscience and Mineral Resources, Daejeon	Ion Beam Application Group	6	0	6	0	0	0	0	256	0%	100%	0%
	National Cancer Center, Goyang	Center for Proton Therapy	15	0	8	7	4	0/2	0	-	-	-	-
	National Centre for Inter-Universities Research Facility, Seoul	Electrost. Ion Acc./ AMS Fac.	11	0	8	3	1	1	0	500	75%	100%	0%
AUSTRALIA													
	Australia National University, Canberra	Heavy Ion Accelerator Facility	42	2	23	19	6	10/10	8	97	31%	52%	48%
EUROPE													
Belgium	Université Catholique de Louvain, Louvain-la-Neuve	Centre de Recherche du Cyclotron	19	0	19	0	2	0	1	145	7%	20%	80%

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 Acadamy 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	141	9	101	40	12	10/-	5	280		60%	40%

Facilities to Address the Major Questions in Nuclear Physics

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%

Update of IUPAP Report 41

- This is underway now.
- All laboratories which responded last time have been offered the chance to update their entry
- Response from Europe has been good
- Please support and especially any laboratory which is missing, encourage to participate

Agreed Actions

- 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" (AL-S, JMP, MM, WH)

- Develop 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: eg. Eurisol (SG, RC, BF ….)
  - Future electron-ion collider (SA, AT ….)

Agreed Actions (cont.)

- Support creation of organization analogous to NuPECC in Asia – currently China, Japan, Korea
- Similar move in South America – but will take longer
- Participate in OECD Global Science Forum Working Group - see following
- Promote the implementation of OECD GSF recommendation

OECD Global Science Forum

- In Autumn of 2005, Dennis Kovar approached the OECD Global Science Forum on behalf of the United States requesting that a Working group on Nuclear Physics be established.

- All 35 OECD countries invited, plus all other interested countries plus several international organizations.

- Established in March 2006 and final report published by the OECD in May 2008 – just 40 pages aimed at science administrators and funding agencies

- IUPAP WG.9 was asked to name three members to provide expert advice (AWT, W. van Oers & W. Henning) - the handbook of user facilities world-wide was very helpful

Appendix C: Participants

Country/ Organization	Name	Institution
Australia	John White	Australian Institute of Nuclear Science and Engineering
Belgium	Mark Huyse	Katholieke Universiteit Leuven
	Jean Sacton	Brussels Free University
Brazil	Alinka Lèpine-Szily	Instituto de Física, Universidade de São Paulo
Canada	Isabelle Blain	Natural Sciences and Engineering Research Council of Canada
	Alan Shotter/Nigel Lockyer	TRIUMF
CERN	Michael Doser	
	Mats Lindroos	
China	Wenlong Zhan	Institute of Modern Physics, Lanzhou
European Commission	Daniel Pasini	Directorate General for Research
France	Gabriele Fioni	CEA
	Sydney Galès	IN2P3/CNRS
Germany	Rainer Koepke	Federal Ministry of Education and Research (BMBF)
	Reiner Kruecken	Technical University of Munich
	Irene Reinhard	Gesellschaft fuer Schwerionenforschung
Italy	Angela Bracco	Istituto Nazionale di Fisica Nucleare- Milano
	Giacomo Cuttone	Istituto Nazionale di Fisica Nucleare- LNS
	Enzo De Sanctis	Istituto Nazionale di Fisica Nucleare- LNF
	Graziano Fortuna	Istituto Nazionale di Fisica Nucleare- Legnaro
IUPAP/ICNP	Anthony Thomas	Thomas Jefferson National Accelerator Facility
	Walter Henning	Argonne National Laboratory
	Willem van Oers	TRIUMF/University of Manitoba
Japan	Tohru Motobayashi	Rikagaku Kenkyusho
	Shoji Nagamiya	KEK
JINR Dubna	Mikhail G. Itkis	
	Alexey N. Sissakian	
Korea	Woo Young Kim	Kyungpook National University
Norway	Morten Hjorth-Jensen	University of Oslo
NuPECC	Brian Fulton	University of York
United Kingdom	Jane Nicholson/John Womersley	Engineering and Physical Sciences Research Council
United States	Dennis Kovar (Working Group Chairman)	U.S. Department of Energy
	Ani Aprahamian	National Science Foundation
	Donald Geesaman	Argonne National Laboratory
	Bradley Keister	National Science Foundation
	Jehanne Simon-Gillo	U.S. Department of Energy
	Robert Tribble	Texas A&M University
OECD	Stefan Michalowski	Global Science Forum

The Global Nuclear Physics Enterprise

Organisation for Economic Co-operation and Development (OECD)

Global Science Forum

Report of the

Working Group on Nuclear Physics

May, 2008

Table 1. Data on Estimated size of Nuclear Physics Workforce

Region	Theory Ph.D.	Experiment Ph.D.	Ph.D. students	Support	Totals
Europe	650	2260	1400	2210	6520
North America	350	1360	900	1150+	3760+
South America	70	100	120	100+	390+
Asia Pacific	~ 610	~ 1190	~ 520	300+	~2620
Total	~ 1680	~ 4910	~ 2940	3760+	13290+

~ indicates that some data has been estimate

+ indicates that only partial data existed for some countries (so a lower limit)

Total world-wide expenditure about $2B per annum

The Global Roadmap

There exists an international consensus on five key questions that motivate future research directions in nuclear physics, i.e., (1) Is QCD the complete theory of the strong interaction? (2) What are the phases of nuclear matter? (3) What is the structure of nuclear matter? (4) What is the role of nuclei in shaping the evolution of the universe? and (5) What physics is there beyond the Standard Model?

A global roadmap for nuclear physics emerges from matching the proposed new and upgraded facilities planned by the various countries and regions to the highest priority scientific opportunities. *The Working Group finds that this global roadmap reflects a high degree of coordination in optimizing the available resources for the world-wide nuclear physics programme.* The new facilities and upgrades that are now under consideration will ensure the continuing success of nuclear physics, with an estimated investment worldwide of $4 billion (US$) during the next decade.

The proposed new and upgraded facilities within the global roadmap for nuclear physics are well coordinated and will produce outstanding science and discoveries. Their implementation is recommended.

Accelerator Based Facilities

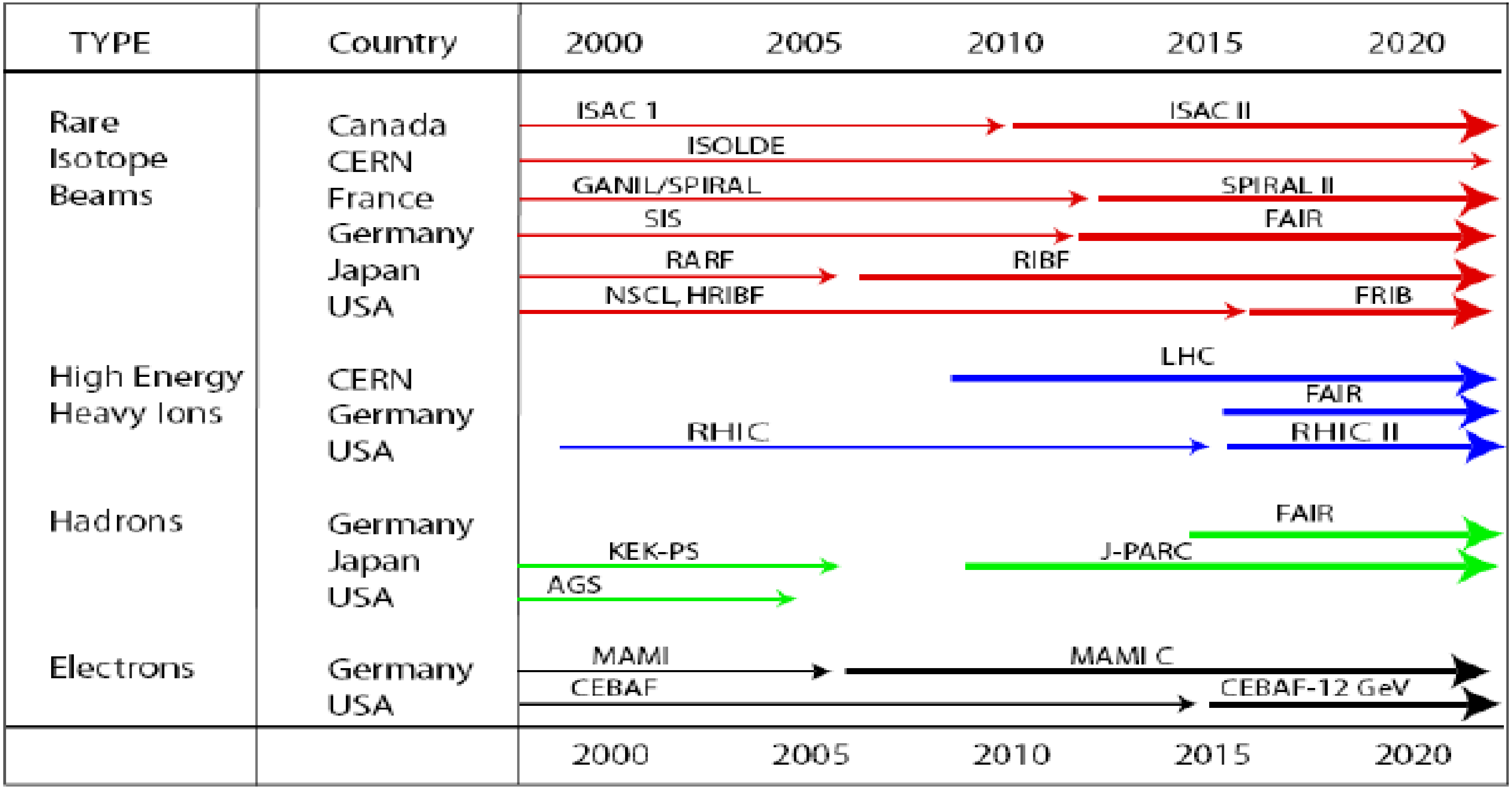


Figure 3: Summary of large-scale accelerator facilities in nuclear physics for the countries participating in this Working Group—existing, estimated starts of operation, or proposed starts of operation for the period 2007-2020.

Underground Laboratories

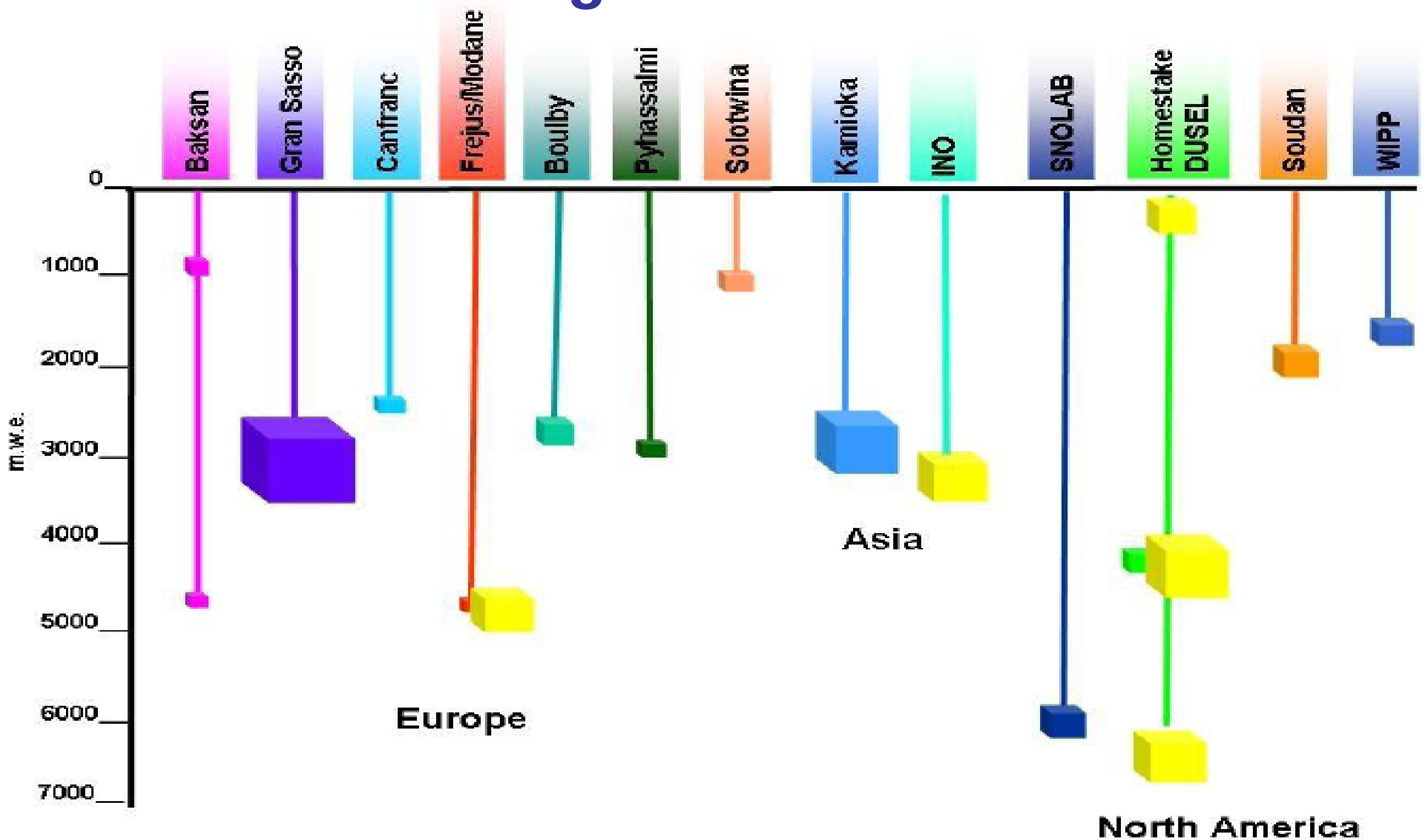


Figure 4: Volumes of existing and planned space in underground laboratories worldwide, as a function of depth (expressed in meter water equivalent, mwe). The laboratories shown are all above 400 m^2 in footprint area. The volumes shown in the graph are those exploited for research that is directly relevant to nuclear physics (thus, for example, existing spaces or planned extensions devoted to gravity wave experiments or geology experiments are not shown). At three facilities (Homestake/DUSEL, Fréjus/Modane, INO), new development or expansion projects are in advanced stages of authorisation, and are depicted in yellow. Additional plans and proposals are under discussion in other countries.

Projects Farther in the Future

These projects are discussed as potential future projects in national or regional plans but due to their longer time scale, are not included in Figure 3.

Electron Ion Collider: In the longer term, there is strong interest in the construction of a high-energy **Electron-Ion Collider** to study protons and nuclei at the shortest distance scales. Plans are being developed at BNL and JLAB in the U.S. and at CERN in Europe.

EURISOL: EURISOL is a very ambitious future project under consideration which would provide Europe with the world's leading ISOL facility. The driver accelerator envisioned for it is a several-megawatt superconducting linear accelerator, and a second superconducting accelerator would be used to accelerate rare isotope beams. The beam power projected for EURISOL is orders of magnitude beyond present capabilities. EURISOL has a very large collaboration drawn from across Europe and is the subject of an EU funded Design Study. It is intended to be an international European facility.

Global Planning & Coordination

The planning processes used by funding agency officials for priority-setting and decision-making (e.g., established national advisory mechanisms) have worked well for making decisions about the use of existing facilities, new facilities under construction, and proposed facilities. The processes have been instrumental for producing the global roadmap that reflects the worldwide consensus of the research community regarding the most challenging scientific questions and the experiments that can provide answers to those questions. *The Working Group finds, however, that given the desirability of ensuring a globally coherent and efficient evolution of nuclear physics beyond that which is currently foreseen, it would be useful for agency officials to be informed on an ongoing basis about future major facilities. The information and advice should come from a forum that involves the world-wide nuclear physics community.*

A forum should be established to discuss, on a regular and ongoing basis, national and regional science-based roadmaps and to articulate a global scientific roadmap for nuclear physics. It should be organised by the International Union of Pure and Applied Physics/Working Group 9 (IUPAG/WG9) and composed of representatives of WG9 itself, the major national and regional scientific planning bodies (e.g., Nuclear Science Advisory Committee [NSAC], Nuclear Physics European Collaboration Committee [NuPECC], Nuclear Physics Executive Committee of Japan [NPEC]) with proportionate participation from all other countries that are not members of one of the latter.

Large Scale Facilities

Looking beyond the timescale of the current roadmap, there is a possible need for large facilities that would be planned, designed, implemented, and utilized via a global-scale collaboration of interested countries.

The Working Group supports the OECD Global Science Forum's activities aimed at facilitating international consultations regarding the potential establishment of large-scale international facilities.

Cooperation Between Funding Agencies

Planning for the future of Nuclear Physics should be a globally-coherent response to recognized scientific challenges, using an optimal set of national, regional, and, if needed, global-scale projects. To achieve this goal, funding agency officials should consider establishing a venue where they can discuss the future of the field, with special emphasis on the role of large programmes and projects.

National, regional, and global planning should be done at the agency level among interested parties to optimize the science and international collaboration, taking into account the global scientific roadmap of the community. The establishment of a forum for nuclear physics funding agencies should be considered for discussing plans for new large scale facilities and for optimizing communication and cooperation at a global level.

Free Access to Facilities

Historically, the field of nuclear physics has benefited enormously from the application of the principle of free and open access to large-scale research facilities. According to this principle, the use of the facilities is allocated based on the importance and quality of the research proposed, regardless of nationality or institutional affiliation of the proposers. In addition, the operating costs of the facility are borne by the facility itself.

Free and open access to beam usage should continue to be the international mode of operation for nuclear physics facilities.

Funding agencies and research institutions are encouraged to create and support mechanisms that provide access to large-scale facilities by scientists from emerging or developing countries where no major facilities exist.

Summary

- **We are at an important beginning**

- **There are new opportunities for planning and coordination between scientists and administrators internationally**

- **This will not be easy BUT it has the potential to take our field to a new level**