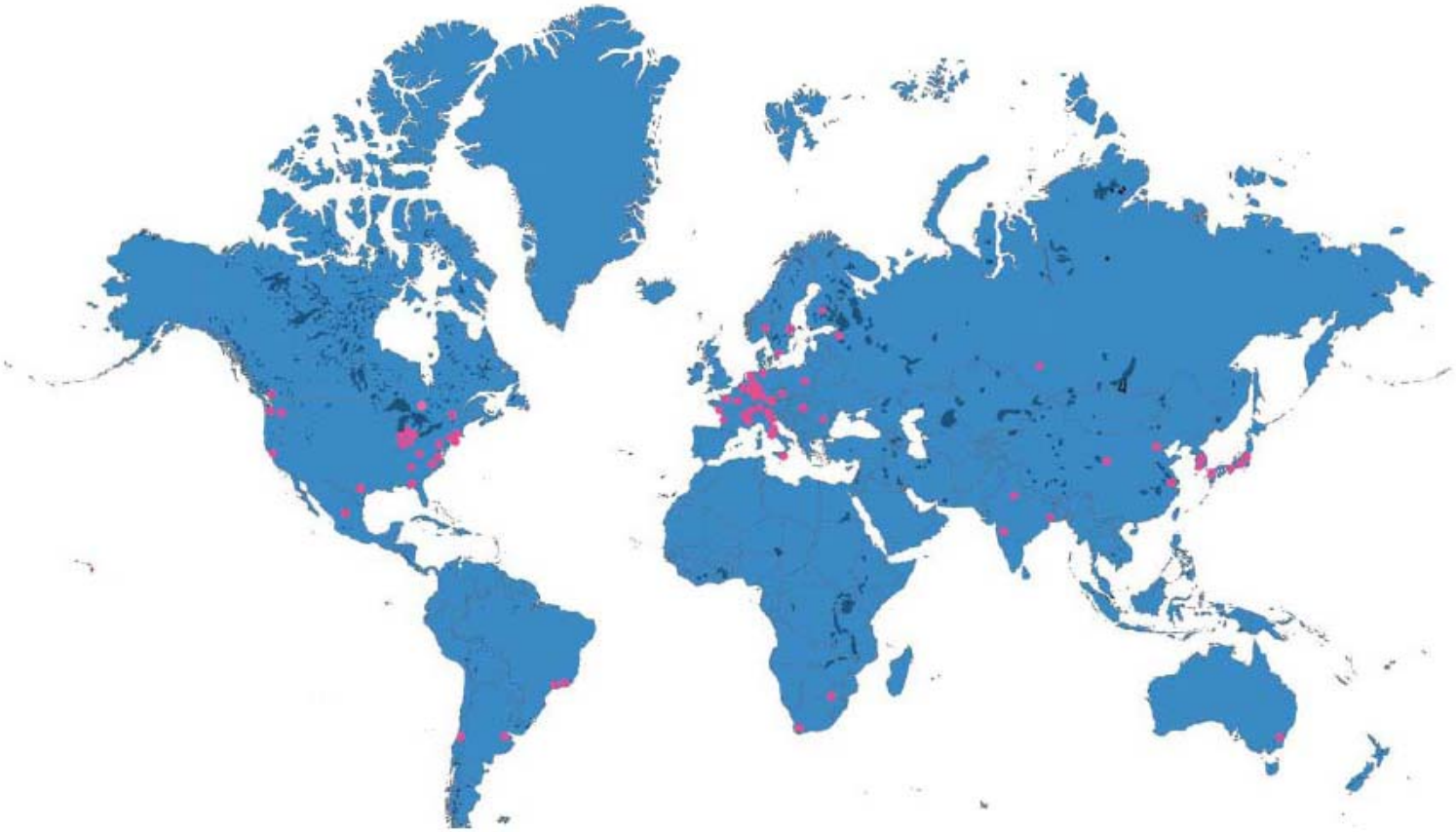
Nuclear Physics Facilities and Aims World-Wide



Anthony W. Thomas

IUPAP C12 : June 4th 2007

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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"

Expert Advice to OECD GSF

- **Prepare booklet 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 was important source of information for that group**

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.-Storege-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^{6}-10^{13} 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 Cyclotron 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 MeV/q)
		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, Reż	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 beck-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 Acadamy 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)

Region	Country	Institution / Location	Facility Name	Facility Characteristics
		Hope College, Holland, MI	HIBAL	Tandem (1.7 MV) / p (3.4 MeV) / ^{4}He (5.1 MeV)
		Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA	88-inch Cyclotron	Cyclotron (K=55) / p (55 MeV) / HI (6≤A≤209 32-4.5 MeV/u)
		Michigan State University, East Lansing, MI	NSCL	SC-Cyclotrons (coupled, K500, K1200) / HI RIBS (16≤A≤238 E=160-80 MeV/u)
		National Institute of Standards & Technology (NIST), Gaithersburg, MD	NCNR	Research Reactor / cold neutrons ($2x10^8 s^{-1} cm^{-2}$)
		Nuclear Structure Laboratory, SUNY , Stony Brook, NY	Nuclear Structure Laboratory	FN Tandem (9 MV) & SCLinac (12MV/xq) / p(20 MeV) / HI (A<60 12-7 Mev/u)
		Oak Ridge National Laboratory (ORNL), Oak Ridge, TN	HIRBF	Cyclotron-Tandem(25 MV) ISOL system / RIB (1≤A≤136 15-3 MeV/u)
		Pacific Northwest National Laboratory, Richland, WA	IGEX Detector	Enriched isotope double beta decay
		Texas A&M University, College Station, TX	Cyclotron Institute	Cyclotrons (K=150 K=500) / d – U (70 MeV/u – 15 MeV/u) / RIBs
		Thomas Jefferson National Accelerator Facility, Newport News, VA	CEBAF	Electron Facility (6 GeV CW SC-Linac recirculator) / 10 kW FEL
		Triangle Universities Nuclear Laboratory, Durham, NC	TUNL	Tandem (10 MV) & LEBAF/LENA (0.2 -1 MV) / p,d,He
		University of Kentucky, Lexington, KY	Accelerator Laboratory	Single-ended dc accelerator (7 MV) / ^{3}He (7-12 MeV)
		University of Notre Dame, Notre Dame, IN	Nuclear Structure Lab. (NSL)	Tandem (10.5 MV) & KN Van de Graaff (4 MV) / p(21 MeV) / HI (<100 MeV)
		University of Washington, Seattle, WA	CENPA	Tandem (9 MV)
		Western Michigan University, Kalamazoo, MI	Tandem Accelerator Laboratory	Tandem (6 MV) / p(12 MeV) / HI (A<60 3-0.7 MeV/u)
		Yale University, New Haven, CT	Wright Nuclear Structure Laboratory, (WNSL)	Tandem (20 MV) / p(28 Mev) HI (A=6-200 , 7-1.4 MeV/u)
SOUTH AMERICA				
	Argentina	CNEA Physics Department, Buenos Aires	TANDAR Laboratory	Tandem (20 MV) / p(28 MeV) / HI (A=6-200, 7-1.4 MeV/u
	Brazil	Catholic University, Rio de Janeiro	Van de Graaff Laboratory	Van de Graaff (4 MV, single-ended) / p (4 MeV) / HI (A≤40, 1 MeV/u)
		University of São Paulo, São Paulo	LAFN	Tandem (8 MV) (SC Linac u. constr.) / p(16 MeV) HI (A<30, 5-3 MeV/u)
	Chile	Comision Chilean de Energia Nuclear, Santiago	Centro Nuclear La Reina	Cyclotron (K=18) / p (18 MeV) / d (9 MeV)
		University of Chile, Santiago	Van de Graaff Accelerator Laboratory	Van de Graaff (3.75 MV) / p-Xe (3.5 MeV)

			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%

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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											

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	National Institute of Nuclear Physics (INFN), Frascati	Laboratori Nazionali di Frascati											
	National Institute of Nuclear Physics (INFN), Legnaro	Laboratori Nazionali di Legnaro	170	0	120	50	10	25/20	0	400	10%	50%	50%
Norway	University of Oslo, Oslo	Cyclotron Laboratory	25	0	10	15	3	8/0	0	30	50%	70%	30%
Poland	Warsaw University, Warsaw	Heavy Ion Laboratory	53	0	46	7	2	2/13	16	100	10%	80%	20%
Romania	National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele	FN Tandem Van de Graaff	54	4	49	5	11	10/3	7	60	90%	97%	3%
Russia	Budker Institute of Nuclear Physics, Novosibirsk	VEPP-4M / ROKK-1M	5	0	2	3	1	1/0	0	3	100%	100%	0%
	Budker Institute of Nuclear Physics, Novosibirsk	VEPP-3	11	2	7	4	1	2/0	2	20	70%	85%	15%
	Petersburg Nuclear Physics Institute, Russ. Acad. Sciences, Gatchina	PNPI Synchro-Cyclotron											
Sweden	Lund University, Lund	MAX-LAB	80		50	30	20	10/50	5	40	5%	15%	85%
	Uppsala University, Uppsala	The Svedberg Laboratory	29	0	24	5	0	0	0	150	2	25%	75%
Switzerland	CERN, Geneva	LHC – ALICE	85	1	33	8	14	-	22	761	-	-	100%
	CERN, Geneva	ISOLDE	26	0	12	14	4	7/50	15	350	2%	2%	98%
	Paul Scherrer Institute, Villigen	Isochroncus Cyclotron											
The Netherlands	Kernfysisch Versneller Institut (KVI), Groningen	AGOR	50	5	22	28	3	24/0	10	108	39%	50%	50%
NORTH AMERICA													
Canada	Snolab (Under construction), Sudbury, ON	SNOLAB	-	-	-	-	-	0/25	10	150	-	50%	50%
	TRIUMF, Vancouver, BC	TRIUMF / ISAC-I / ISAC-II	384	14	384		41	29/21	60	603	7%	34%	66%
Mexico	Universidad Nacional Autonoma de Mexico, UNAM, Mexico City	Van de Graaff Laboratory	18	0	8	10	0	0/0	1	24	25%	85%	15%
	Universidad Nacional Autonoma de Mexico, UNAM, Mexico City	Pelletron Accelerator Laboratory	11	0	7	4	0	6/12	15	14	85%	98%	2%
USA	Argonne National Laboratory, Argonne (ANL), IL	ATLAS	92	6	74	18	14	9/32	35	411	12%	54%	46%
	Brookhaven National Laboratory (BNL), Upton, NY	RHIC	523	8	473	50	20	10/60	20	1100	13%	50%	50%
	Florida State University, Tallahassee, FL	Superconducting Accelerator Laboratory	36	12	17	19	5	19/1	8	25	80%	90%	10%
	Hope College, Holland, MI	HIBAL	2	0	1	1	0	0	12	18	95%	95%	5%
	Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA	88-inch Cyclotron	57	0	35	22	9	8/1	9	147	29%	95%	5%

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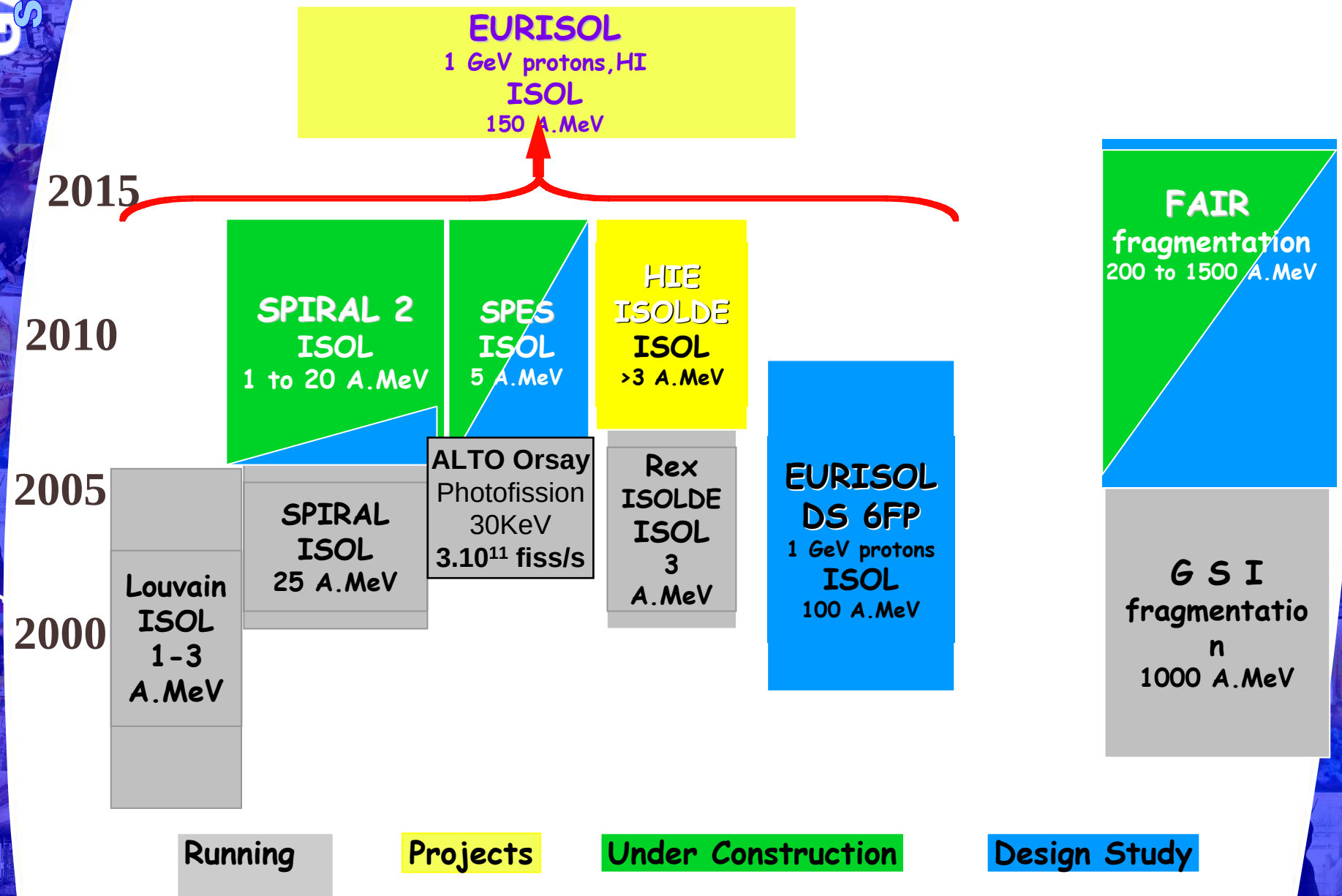
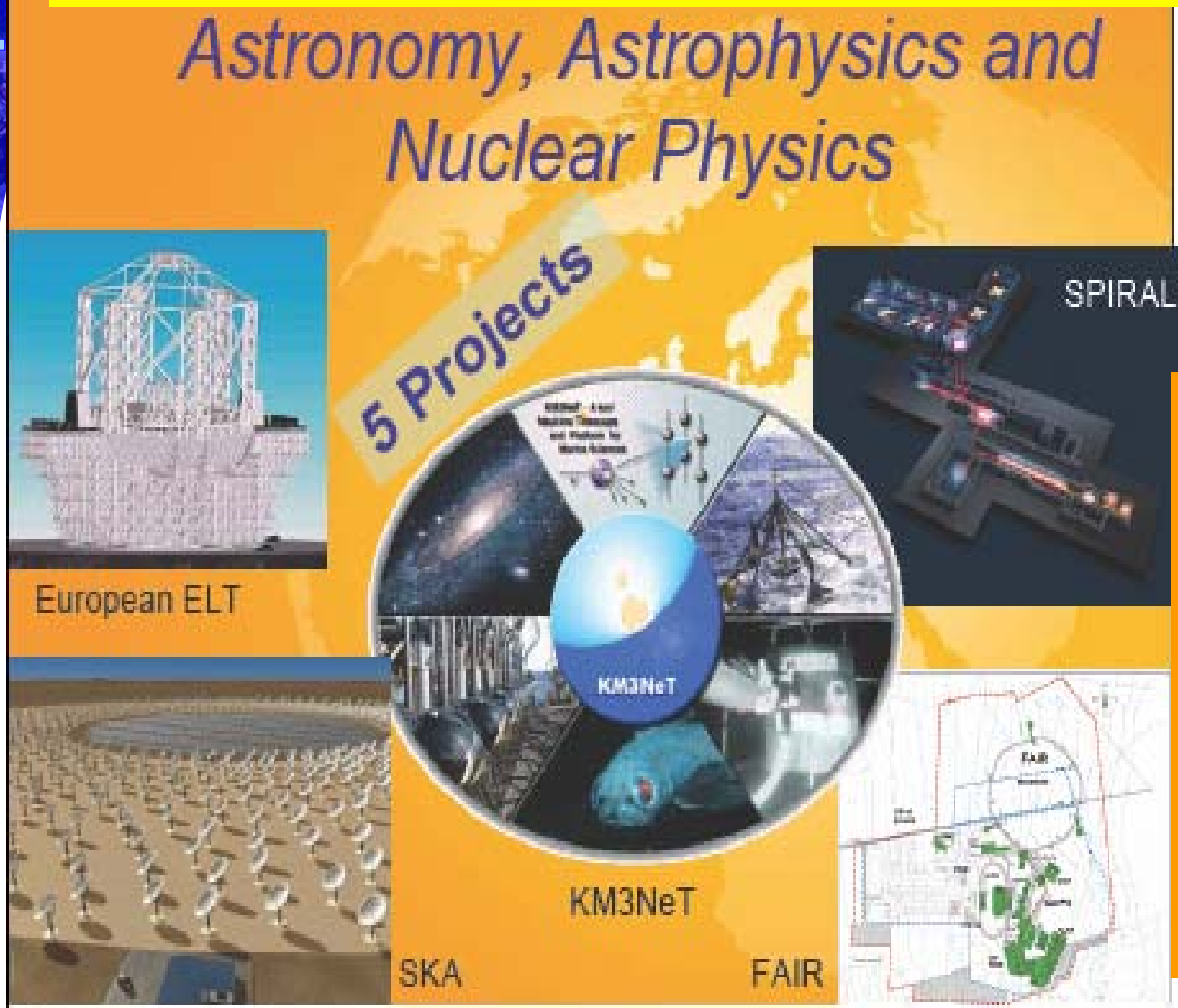
			Total	Theory (total)	Permanent	Temporary	Postdocs	PhD Students Onsite / Other Graduate Students	Undergraduates	Total user number	Internal (%)	National (%)	International (%)
	Michigan State University, East Lansing, MI	NSCL	280	14	155	125	23	55/10	30	170	27%	69%	31%
	National Institute of Standards & 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%	-

Europe

European RNB Facilities - Road Map

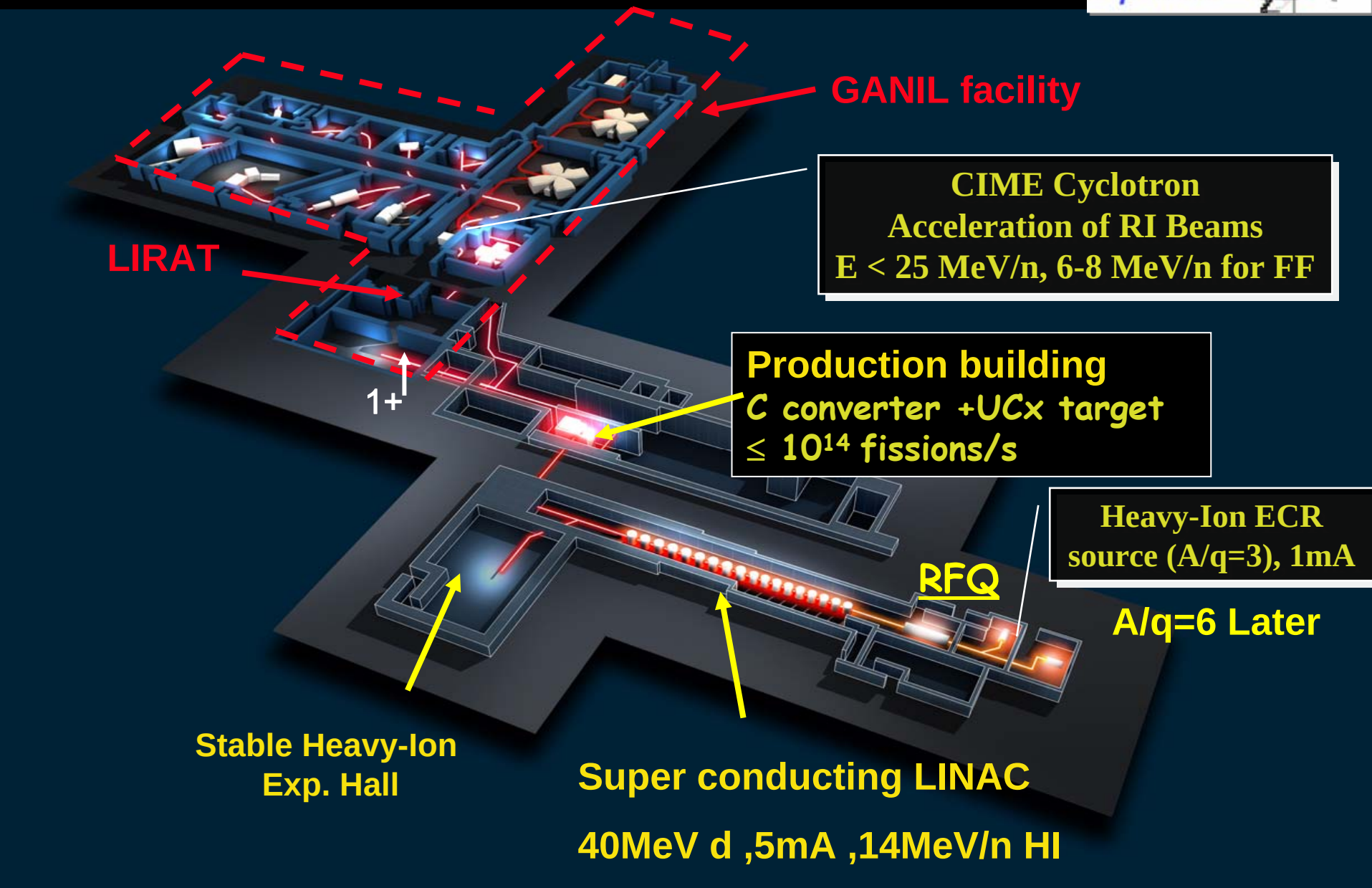


FAIR & SPIRAL 2 on the ESFRI list

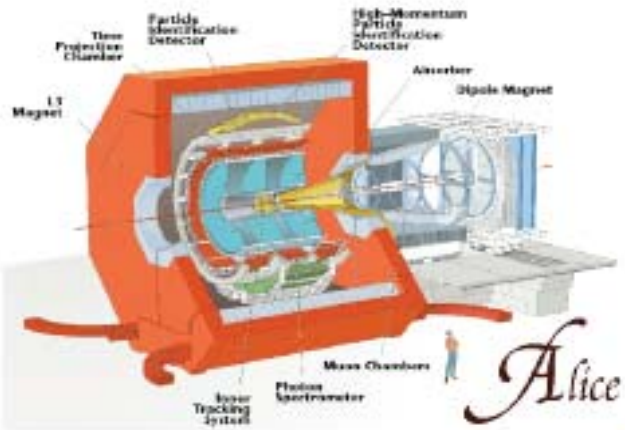


Brussels, 19 October 2006 European Research Infrastructures – *The ESFRI roadmap identifies 35 large-scale infrastructure projects*

SPIRAL 2@GANIL - A world leading ISOL Facility

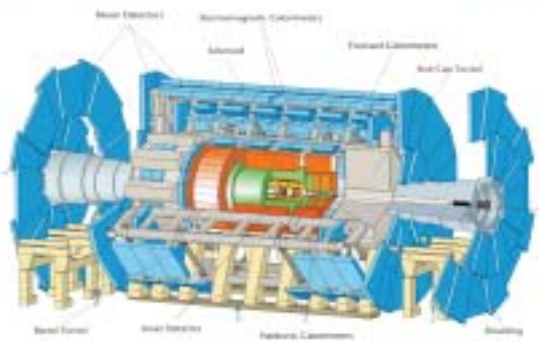


Heavy Ion physics at Large Hadron Collider

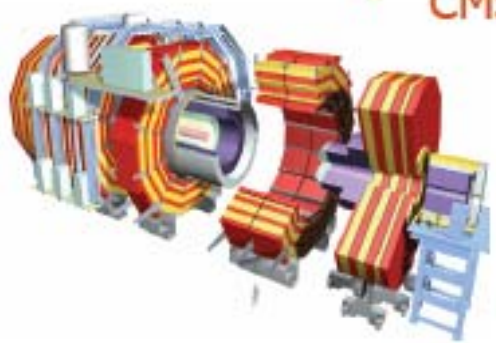


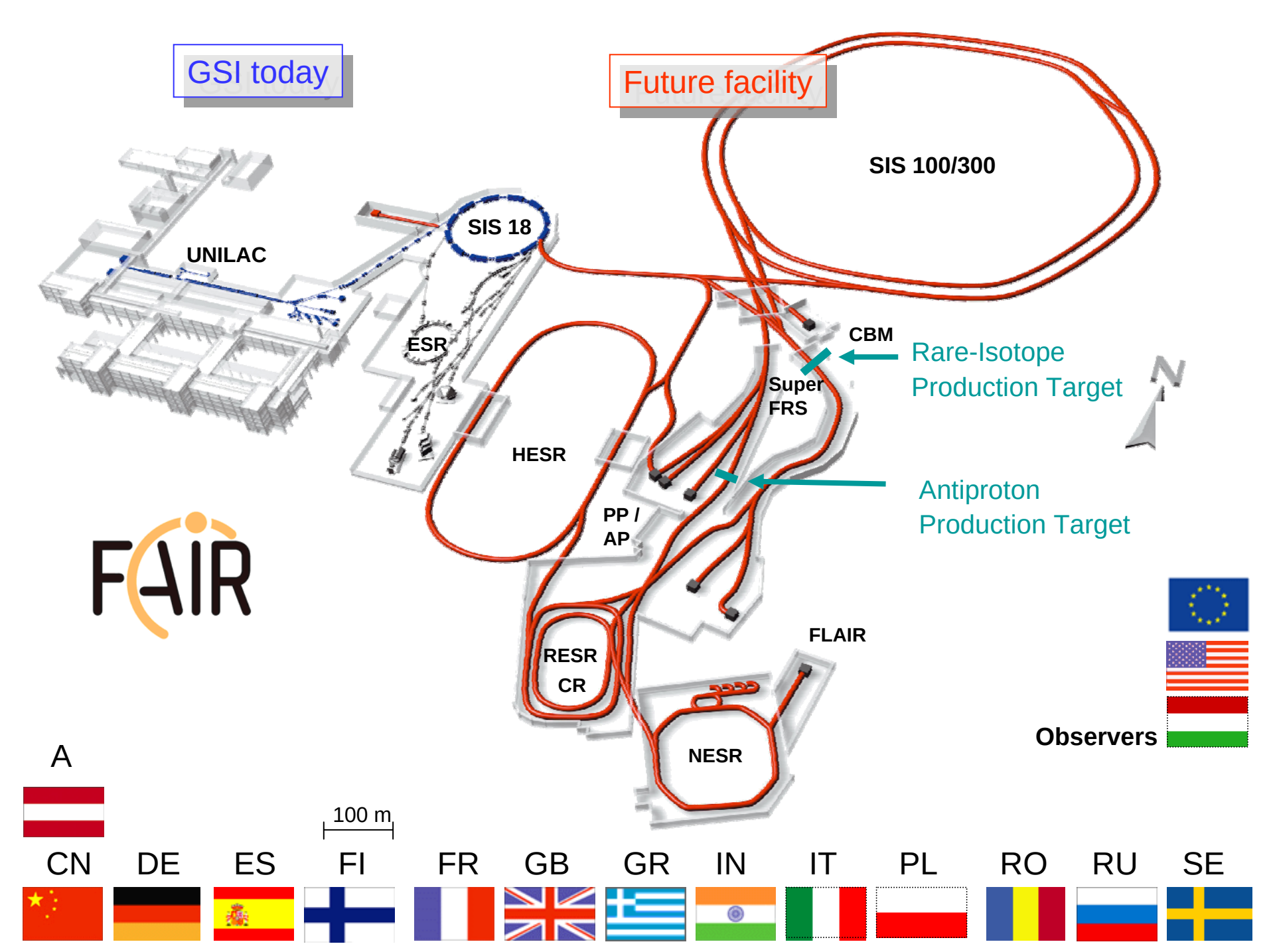
ALICE

ATLAS



CMS




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
GR
IN
IT
PL
RO
RU
SE

Japan

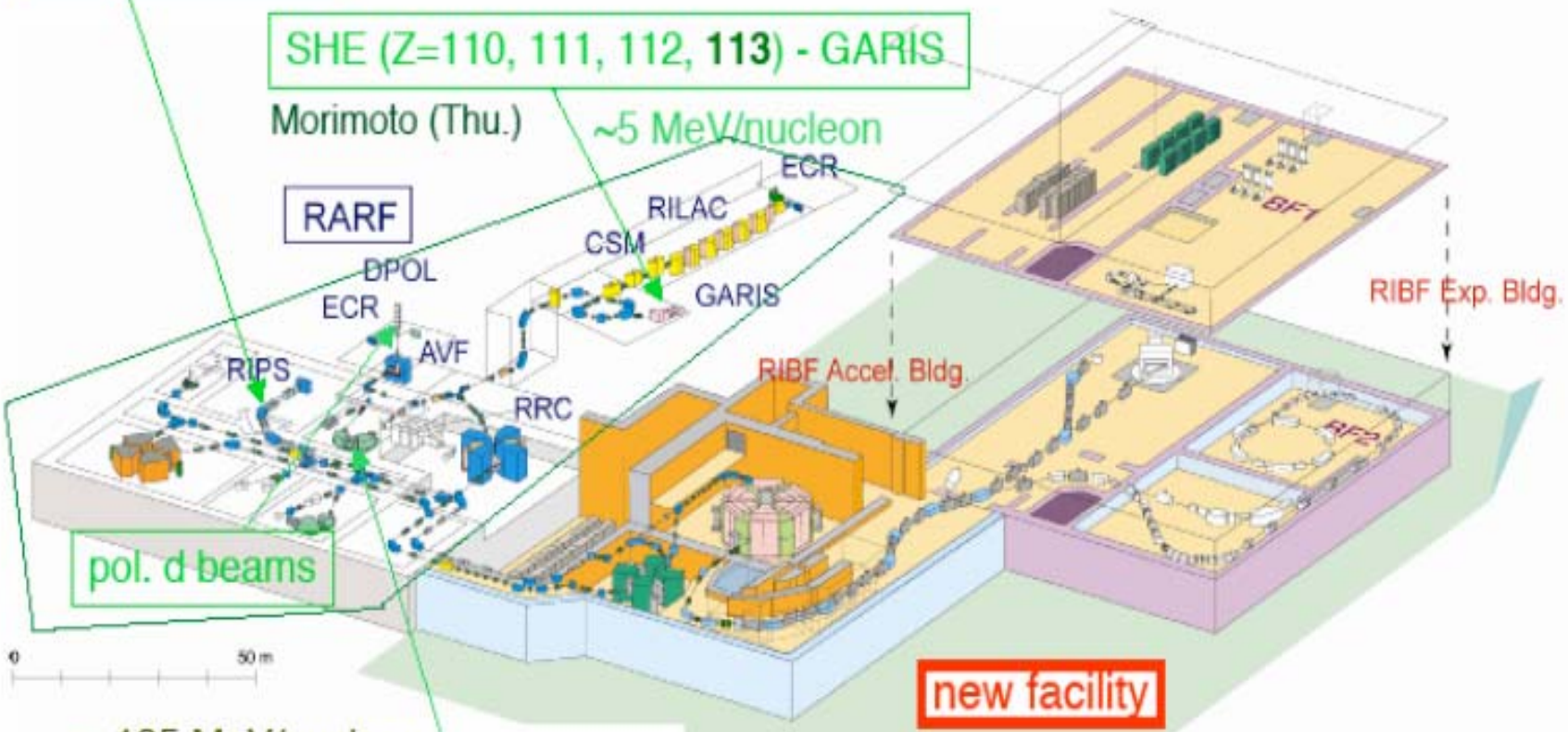
RIBF: Accelerator Complex in RIKEN Nishina Center

Fast RI beams - RIPS

SHE (Z=110, 111, 112, **113**) - GARIS

Morimoto (Thu.)

~5 MeV/nucleon



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

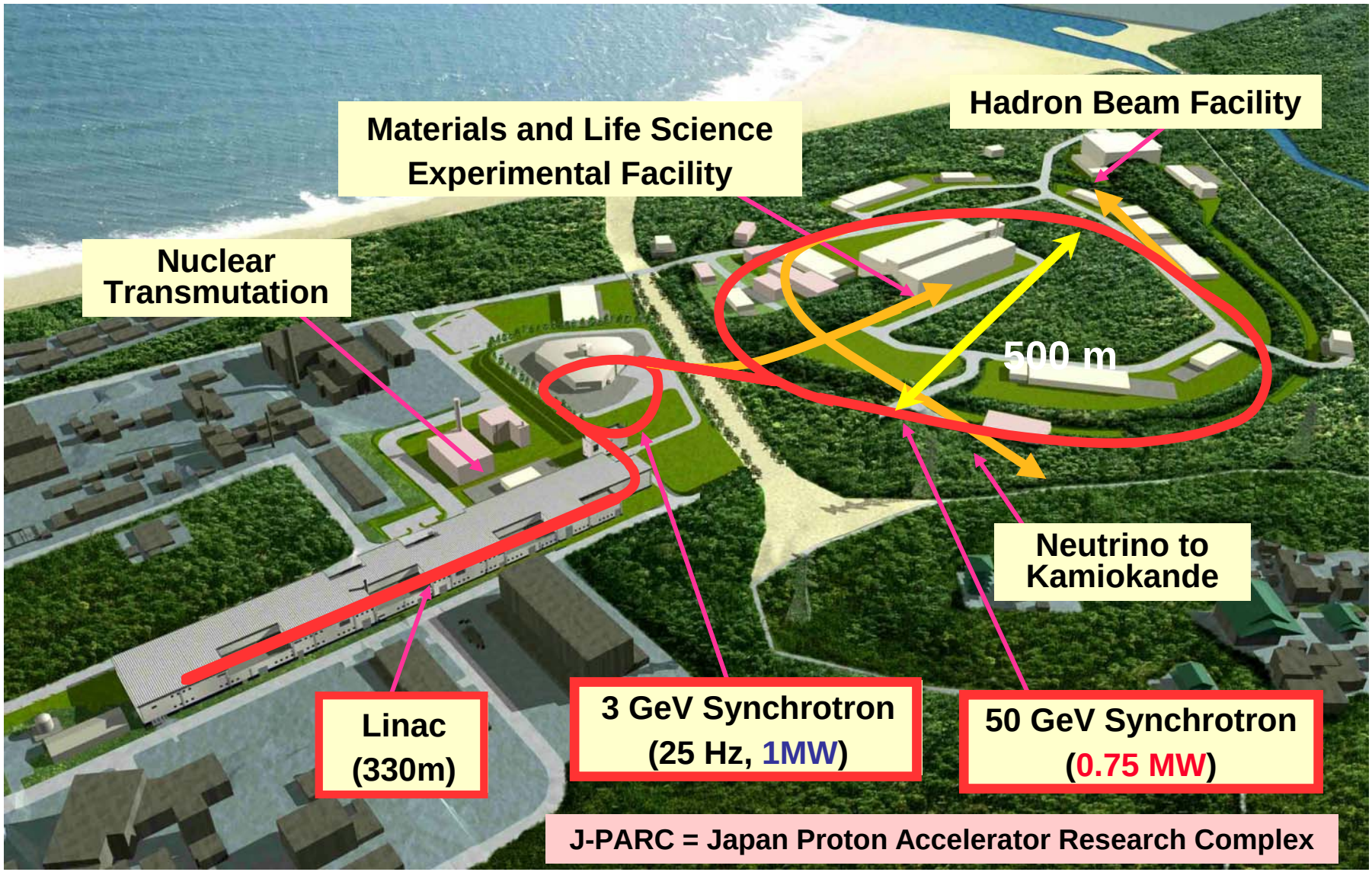
40 billion Yen (= $400 million)

2 to be built

5.6 billion Yen (= $56 million)

1 under construction

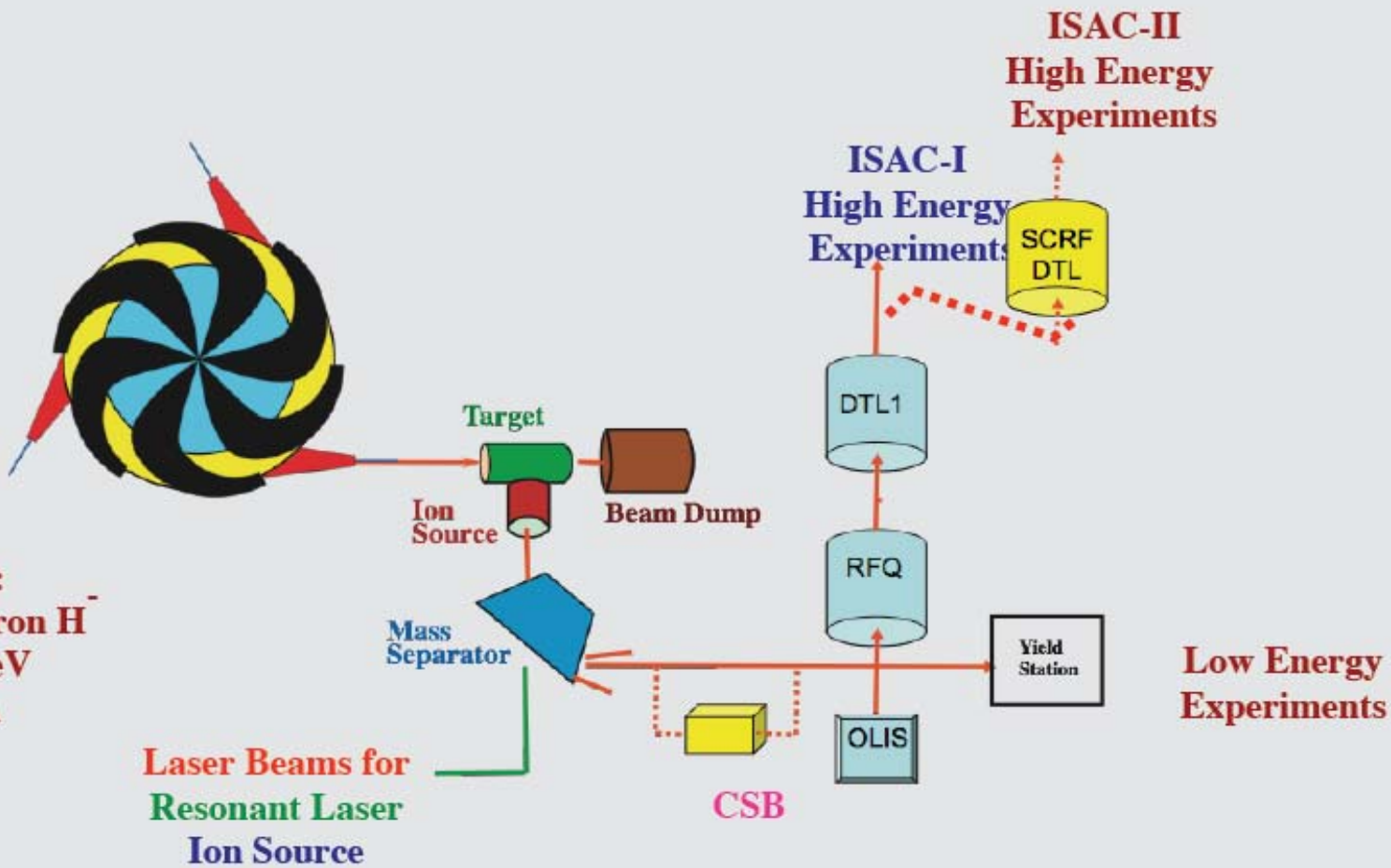
J-PARC Facility



Joint Project between KEK and JAEA

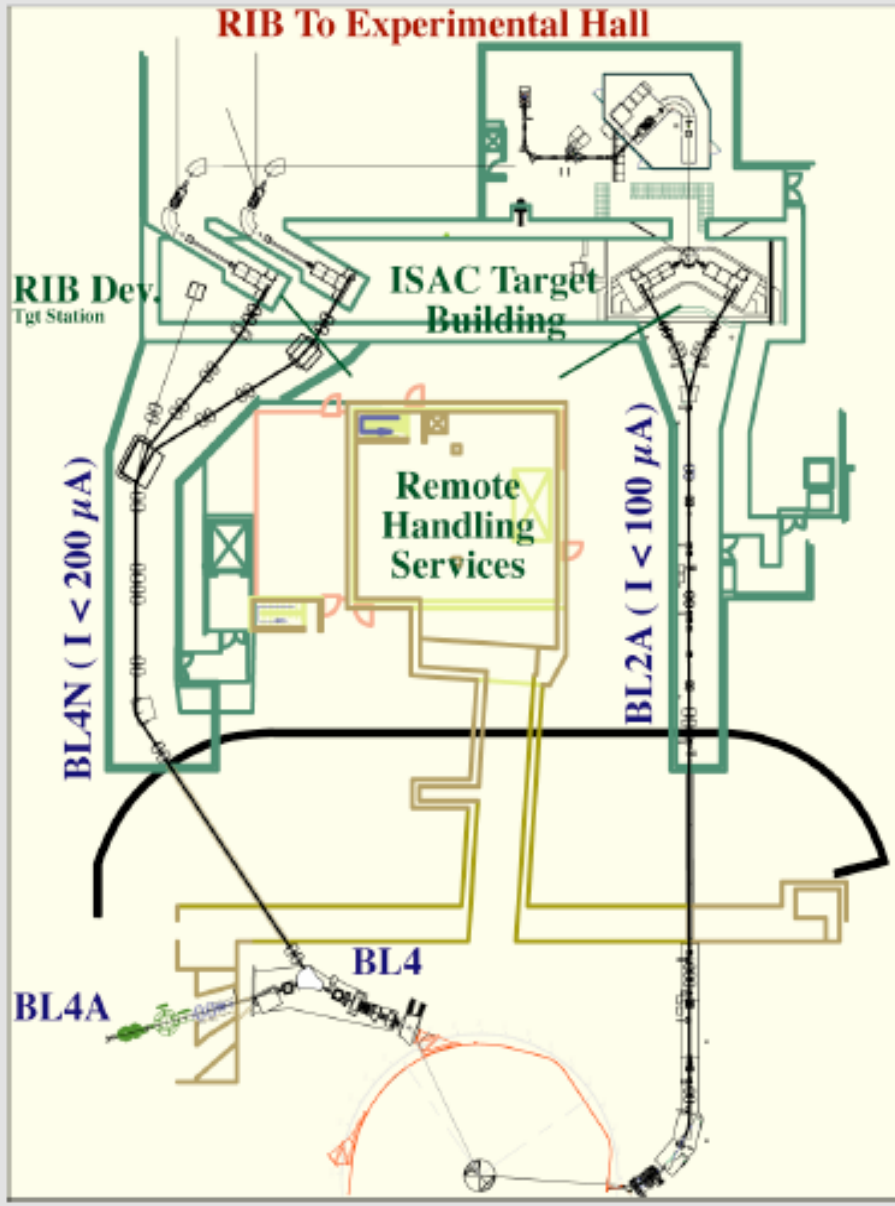
North America

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



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.**

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

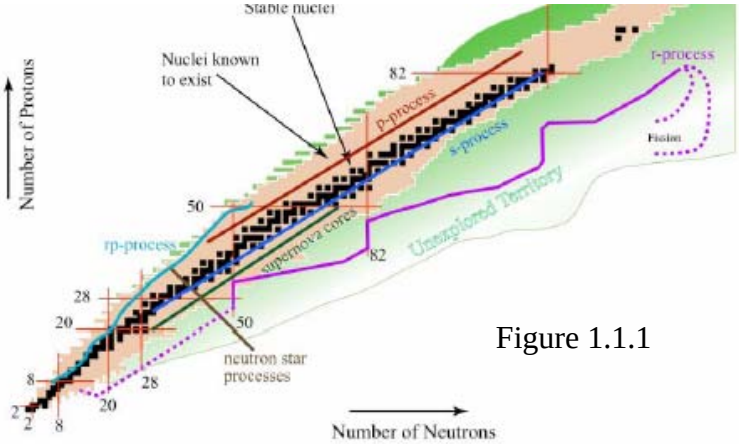
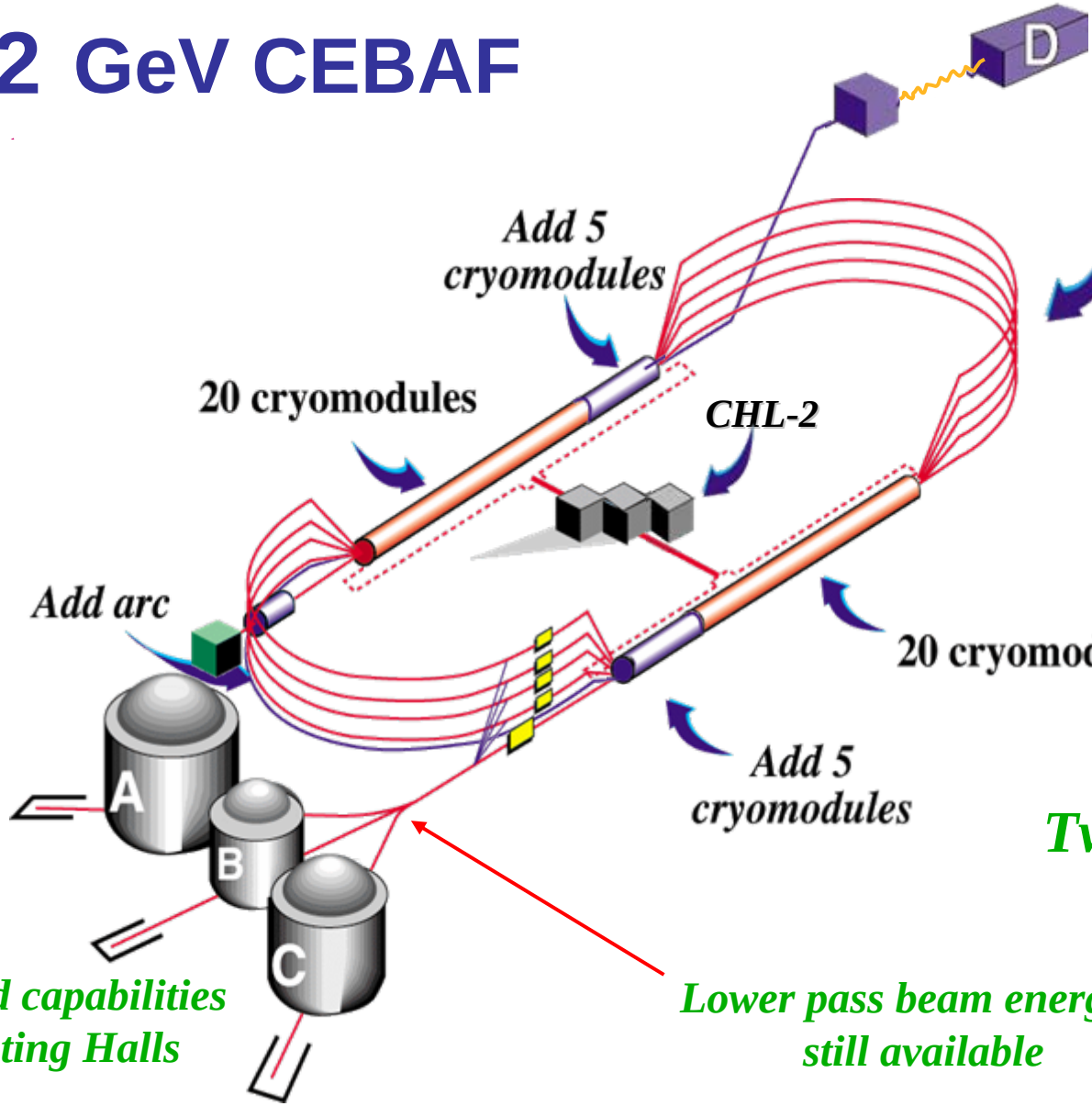


Figure 1.1.1

12 GeV CEBAF

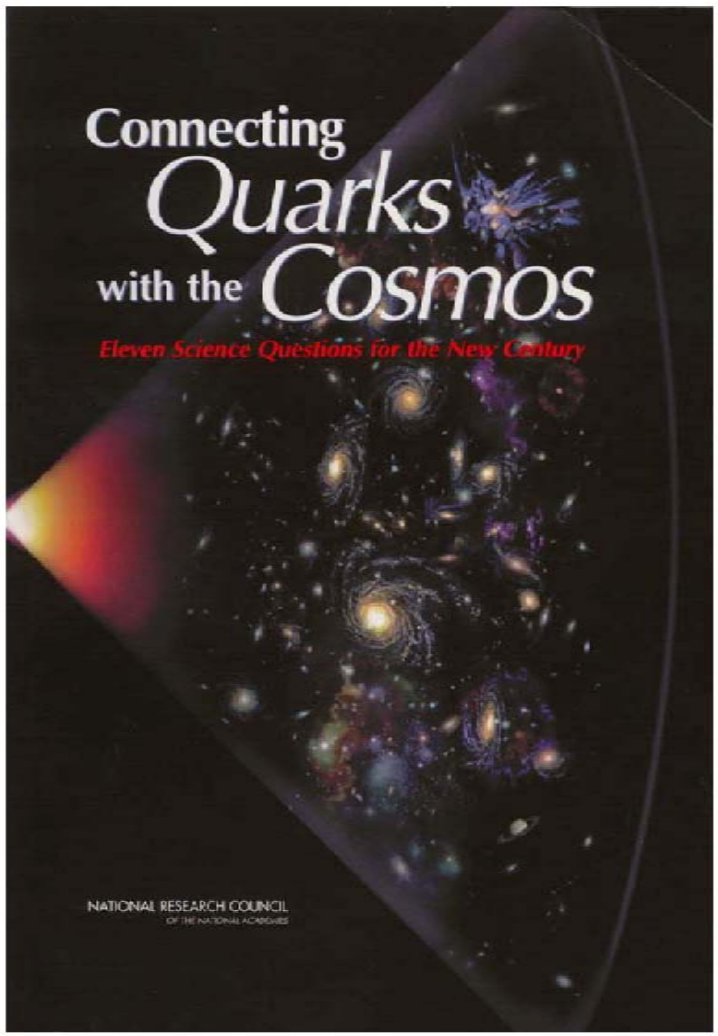


Two 1.1 GV linacs

Enhanced capabilities in existing Halls

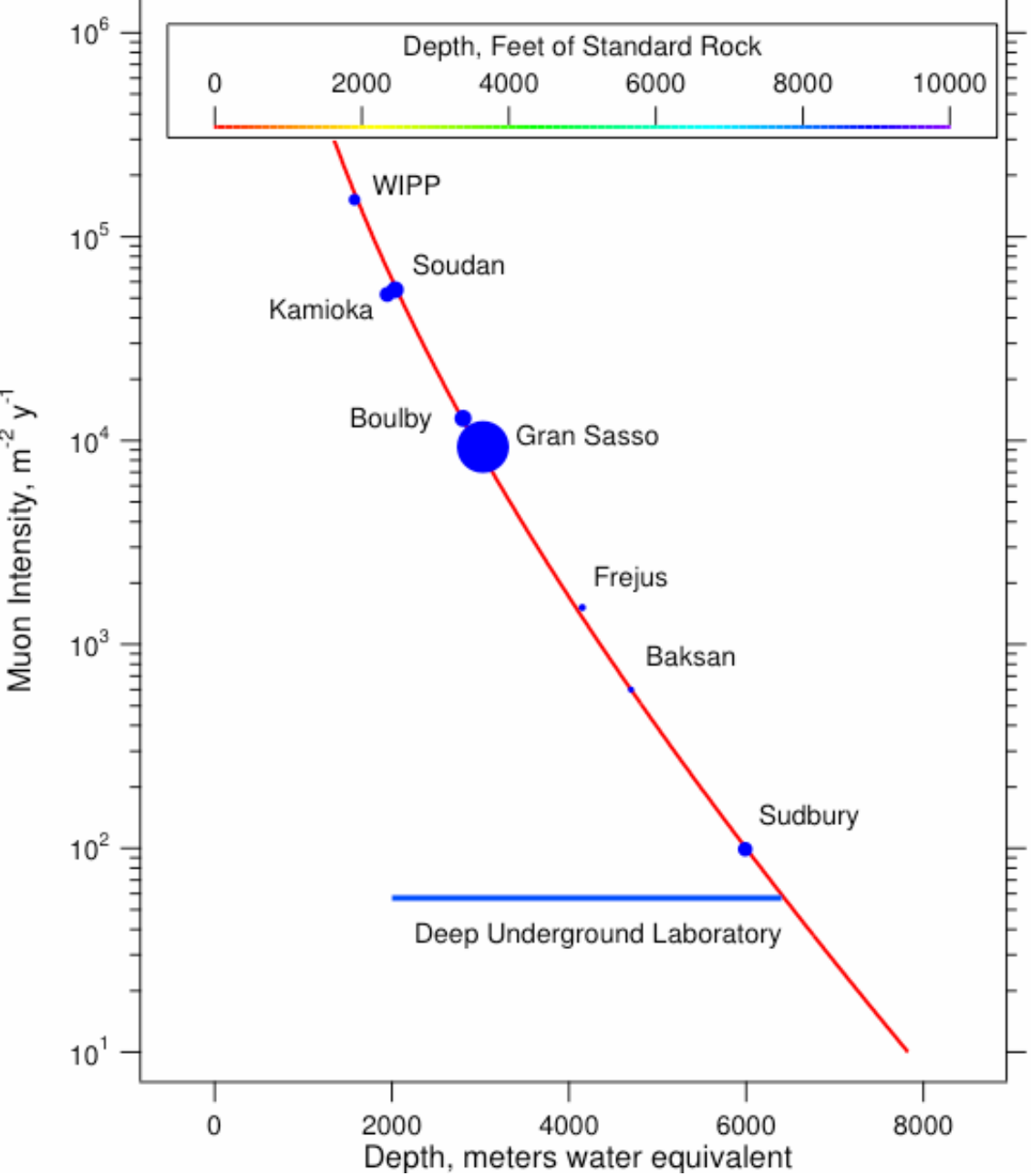
Lower pass beam energies still available

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)

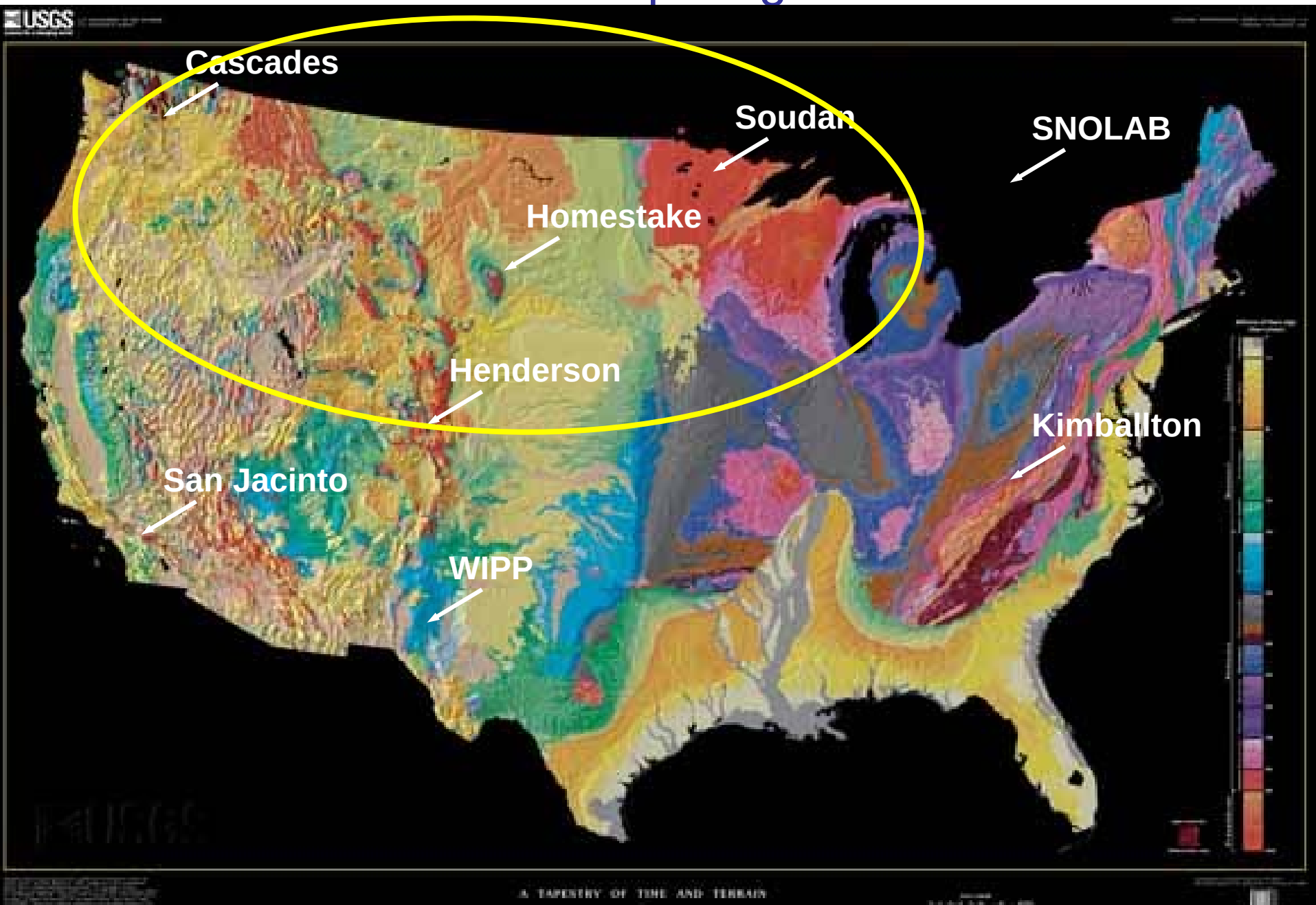


Data: Hime & Mei, astro-ph/0512125
Curve: Miyake, N.Cim. 32, 1505 (1964)

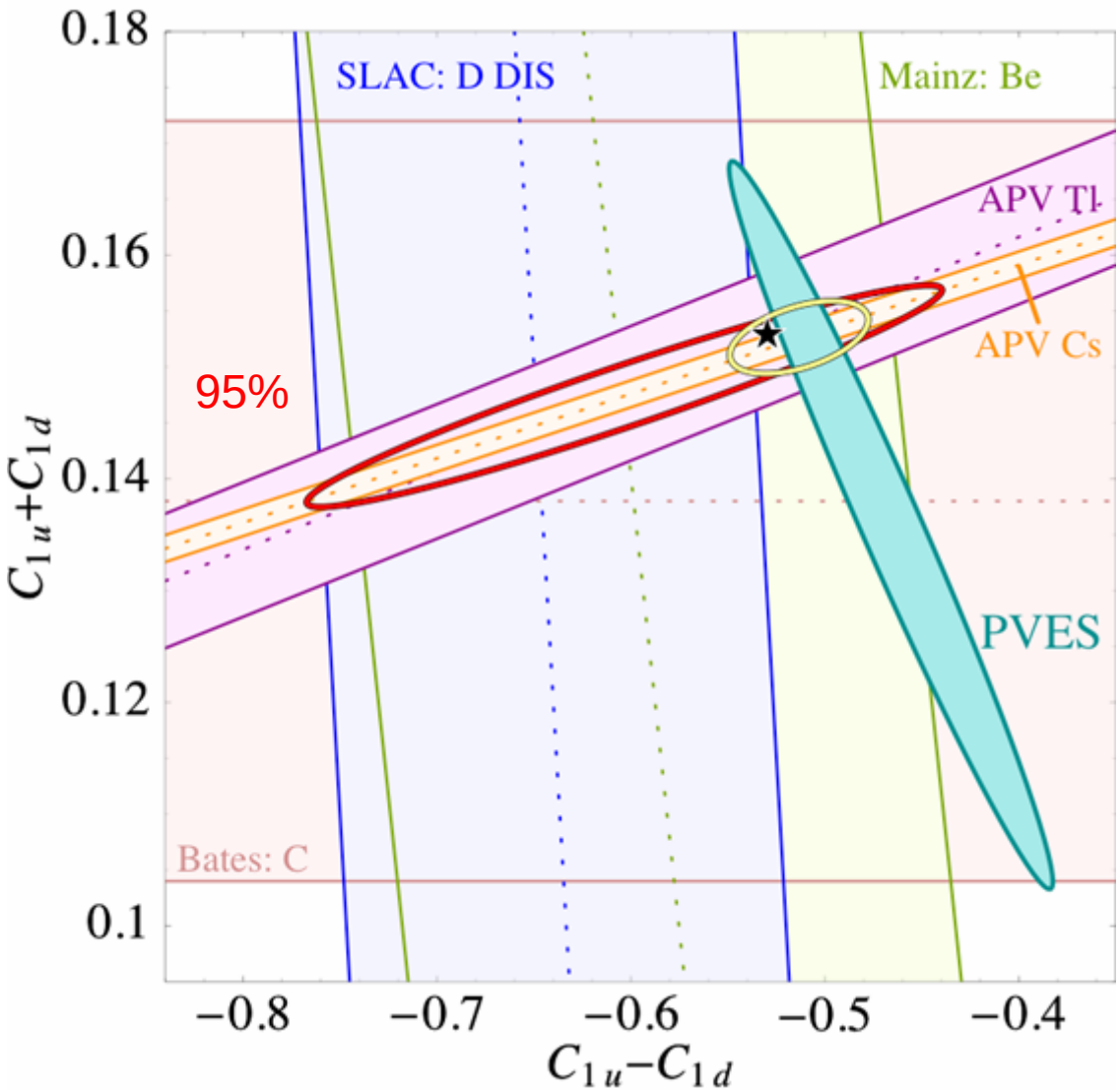
Physicists want:

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

DUSEL S3 competing sites



New update on C_{1q} couplings – Dec 2006



(Young et al.)

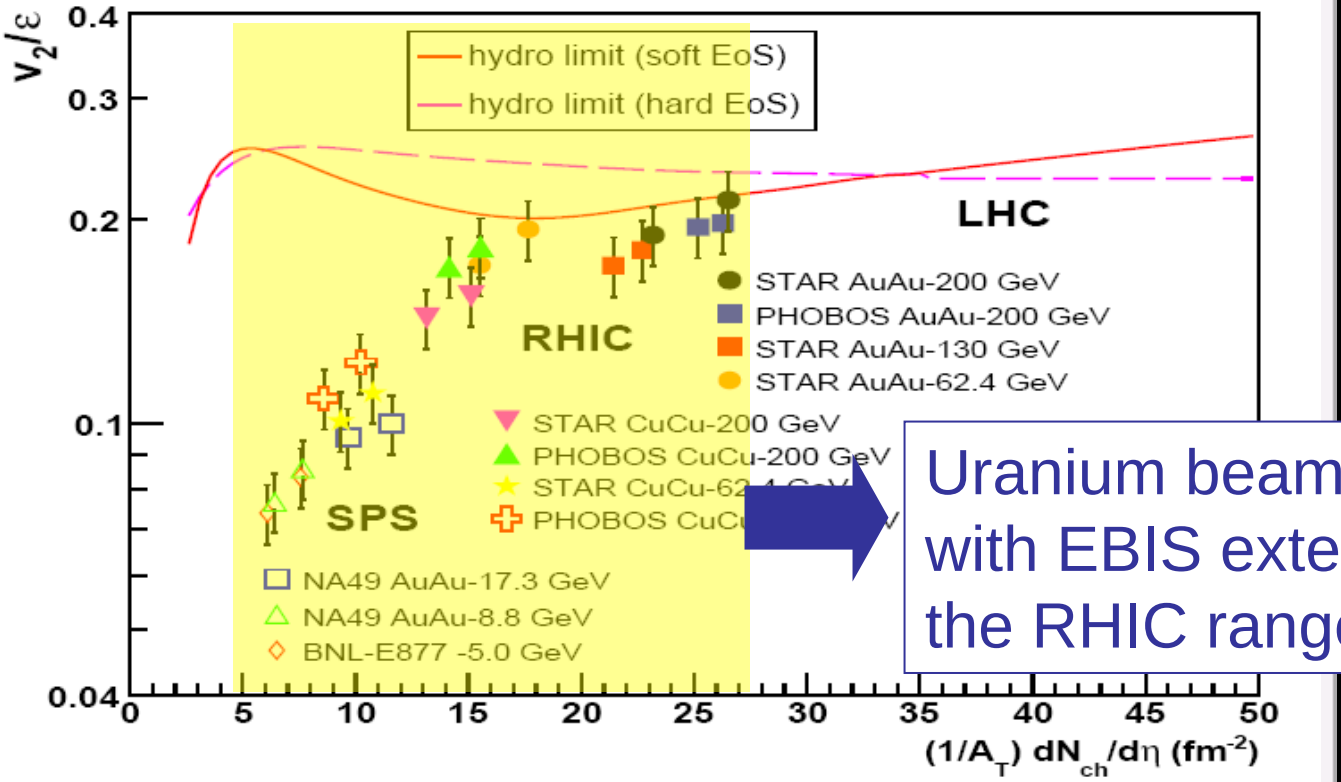
Dramatic improvement in knowledge of weak couplings!

Factor of 5 increase in precision of Standard Model test

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.

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….

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

- 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, 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 (SG, RC, BF ….)
  - Future electron-ion collider (SA, AT ….)

- Pursue implementation of OECD recommendations…..