International Scientific Collaboration

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For a related, earlier talk on 'Regional and Global Collaboration in Big Science' see http://www.feast.org/conference2006/documents/FEAST_Conference2006_transcripts.pdf + *www.feast.org/conference2006/presentations.html*

La science n’a pas de patrie - Louis Pasteur

There is no national science, just as there is no national multiplication table; what is national is not science - A P Chekhov

The laws of nature are the same everywhere in the world* (indeed everywhere in the Universe as far as we can tell from light reaching us from distant galaxies)

International collaboration in science and technology is therefore natural, especially as many problems that need scientific/technological solutions *(e.g. pollution, spread of disease, climate change)* ***do not respect national frontiers***

*However - social and political factors influence what science gets done (agenda set in industrialised countries), and may bias conclusions when understanding is incomplete

International scientific collaboration has some obvious

Advantages
- progress fastest when it draws on all/the best sources of knowledge, wherever located
- may be needed to reach "critical mass" of *expertise* (especially for multi-disciplinary work) and/or *resources*
- sharing costs releases resources for other purposes
- whole > sum of parts

and

Disadvantages
- reduces diversity + spur of scientific competition
- tension between (commercial) competition and collaboration
- added complexity of decision making
- ...

Setting the Scene

- **Collaborations ~ many forms** (informal networks/sharing of results... joint institutions/construction projects), **and may involve many players** (government labs, charitable Foundations, universities, industry)

  Nature of collaborations changing, due to

  - the Web

  - demise of big corporate laboratories + blurring of boundaries between industries and universities

- **Will focus on government funded 'big science' projects,** *but first briefly give examples of*

- industrially driven collaborations
- dispersed but strongly co-ordinated collaborations
- networks

Examples of collaborations (1)

■ Industrially driven collaborations

• **'Horizontal'** (focussed on one topic) **collaboration** *e.g. oil industry* + *academia* $\Rightarrow$ *work on carbon sequestration*

• **'Vertical'** (through supply chain) **collaboration** *e.g. Alcan-motor industry-Ciba Cigy* $\Rightarrow$ *aluminium Jaguar*

• **'Horizontal' collaboration in R&D** $\Rightarrow$ **manufacture** e.g. airbus

• **Computer Grid based e.g.**

– **DAME** (**D**istributed **A**ircraft **M**aintenance **E**nvironment): Rolls-Royce + 2 companies & 4 universities $\Rightarrow$ diagnostic systems for aircraft: data taken in-flight $\Rightarrow$ 4 centres around world

– **Pharmagrid** (Novartis + others) $\Rightarrow$ reliable data bank+ *in silico* experiments

In the case of industrial collaborations the role of governments is to avoid creating barriers/facilitate (especially for collaborations involving public and private partners)

Examples of collaborations (2)

- **Dispersed, but strongly co-ordinated collaboration,** e.g. human genome
  - USA [6 universities; 4 national labs], UK, France, Germany,Japan:
  - funding from governments + Foundations in UK and France*
  - collaboration needed to provide resources and manpower:
  - obvious approach when result are (or should be) public goods

  *in parallel: Celera Genomics - funded by Perkin-Elmer (→ shop window for gene sequencers), used gene map from publicly funded project: welcome check of results, but intellectual property issue!

- **Networks**, e.g. International Technology Roadmap for Semiconductors

  Global collaborative effort of manufacturers, suppliers, government organisations, universities – assessment of semiconductor requirements/challenges for next 15 years

Examples of collaborations (3)

■ Networks/dispersed collaboration

- **IPCC WGI on anthropic climate change** [WG II ~ impacts, WG III ~ policy options]
  – ***ownership by scientific community****: transparency, peer review*
  – ***separation of science/policy***
  – ***cross-disciplinary integration of information***

- **ExternE*: external costs (environment/health) of different energy sources and transport**:** *30 teams in 9 European countries (economists, sociologists, environmental scientists, health specialists, atmospheric chemists and modellers, software experts)*

* *e.g. electric train is more friendly for environment than a barge*

Case Studies from Big Science

- **CERN**

- Aside on **SESAME** (**S**ynchrotron-light for **E**xperimental **S**cience and **A**pplications in the **M**iddle **E**ast): example of role of science in building political bridges

- **S**uperconducting **S**uper **C**ollider

- **L**arge **H**adron **C**ollider

- **A**ttacama **L**arge **M**illimetre **A**rray

- **I**nternational **T**okamak **E**xperimental **R**eactor

Note: not a comprehensive list (International Space Sataion, Auger…. missing)
Won't discuss lab-lab-groups collaborations in individual experiments

Preliminary Remarks on Case Studies

- **Advantages of collaboration clear in cases considered**, but there are disadvantages (complexity, lack of competition)
- **Treat generalisations with care.** *Differences between cases considered include:*

ITER - potential fusion industry $\Rightarrow$ issue of intellectual property and industrial know-how

SSC, LHC, ALMA - no potential industry

SSC, LHC - additional users $\Rightarrow$ better experimental detectors all benefit

ALMA - additional users $\Rightarrow$ less observing time for each group

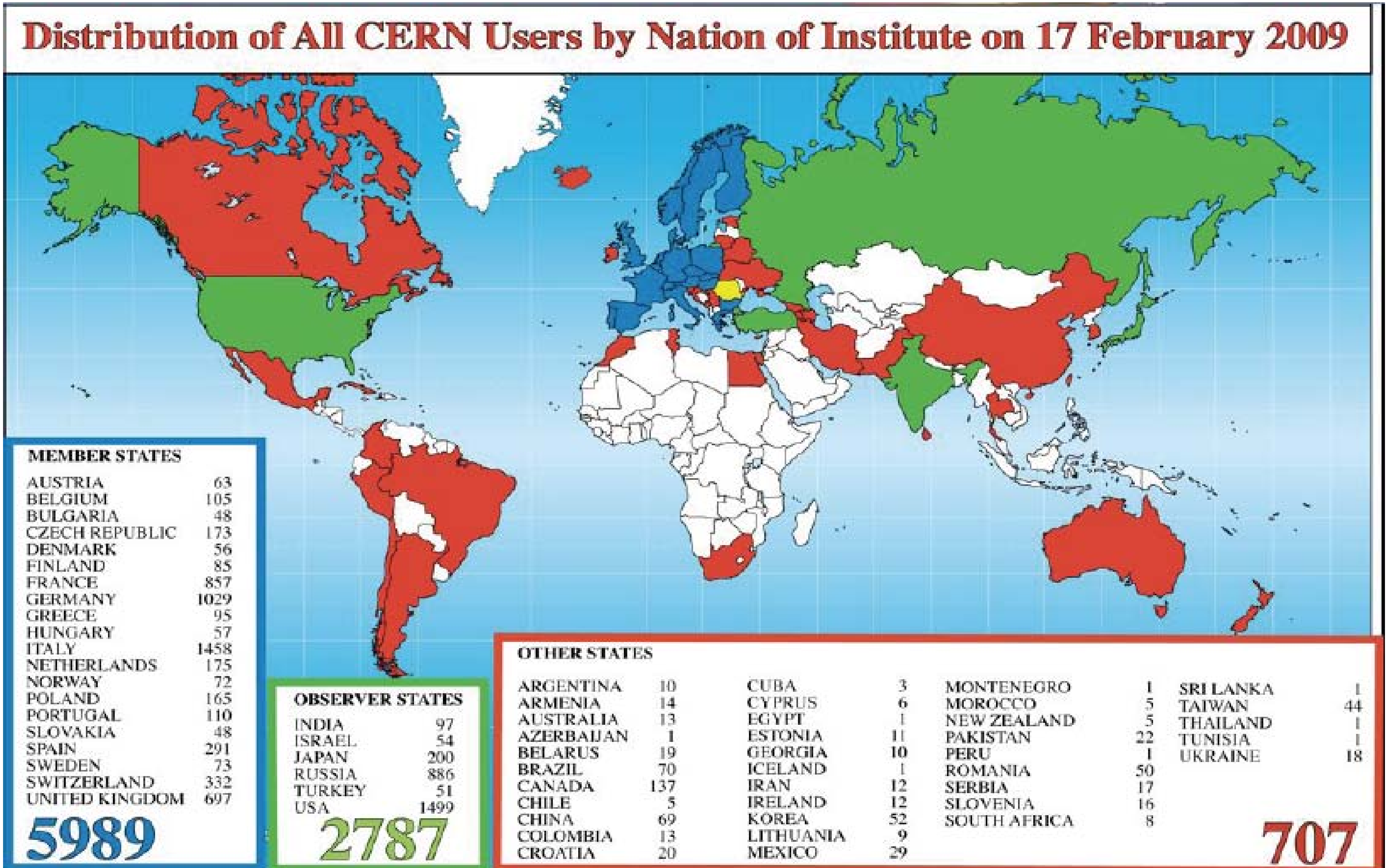
CERN – the scale and cost obviously make international collaboration necessary

The Twenty Member States of CERN

Member States (Dates of Accession)

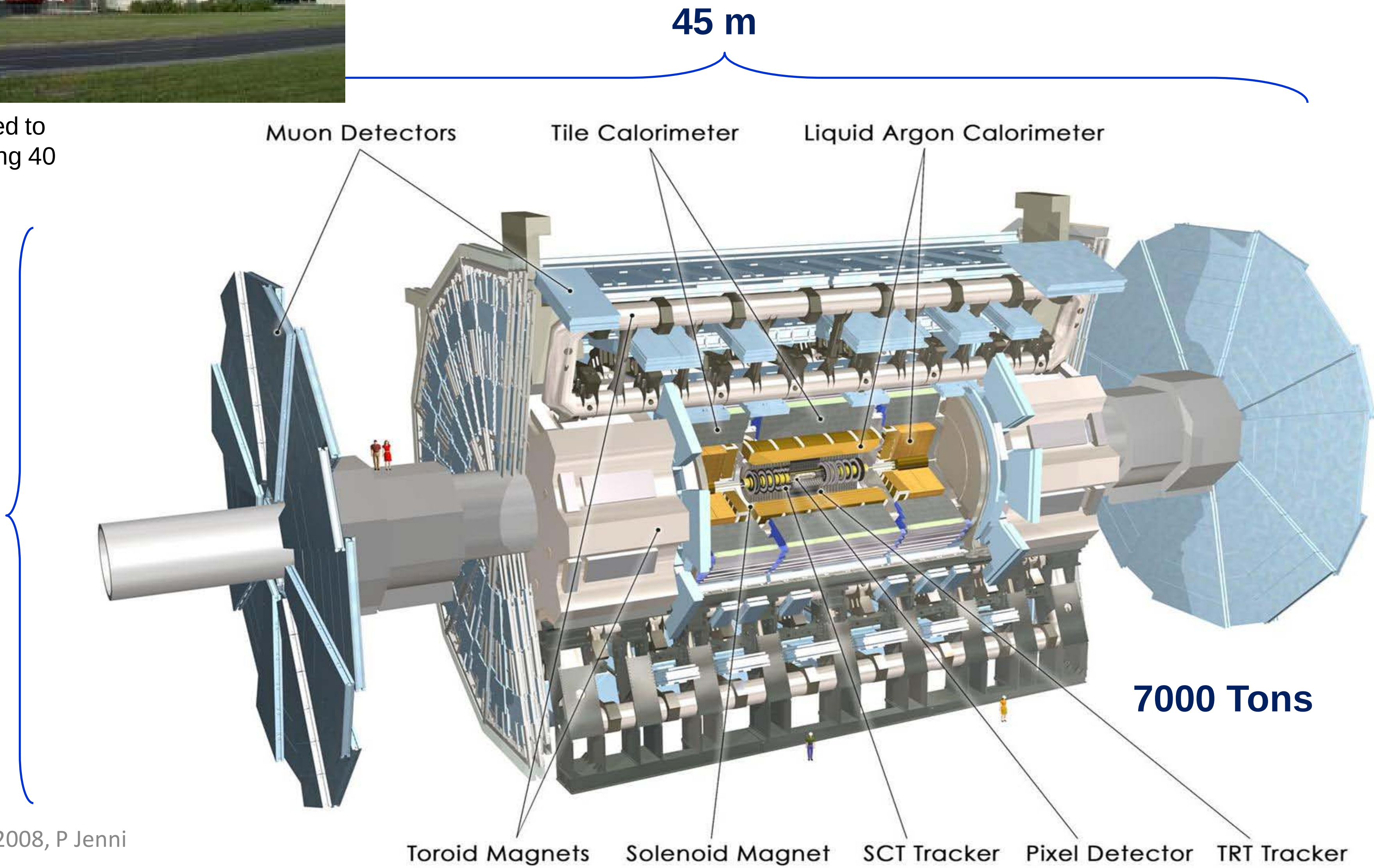
AUSTRIA (1959)	DENMARK (1953)	GREECE (1953)	NORWAY (1953)	SPAIN (1/1961-12/1968-1/1983)
BELGIUM (1953)	FINLAND (1991)	HUNGARY (1992)	POLAND (1991)	SWEDEN (1953)
BULGARIA (1999)	FRANCE (1953)	ITALY (1953)	PORTUGAL (1986)	SWITZERLAND (1953)
CZECH FR (1993)	GERMANY (1953)	NETHERLANDS (1953)	SLOVAK FR (1993)	UNITED KINGDOM (1953)

A Global Adventure: over 9000 Scientists from Around the World



ATLAS Detector

ATLAS superimposed to the 5 floors of building 40



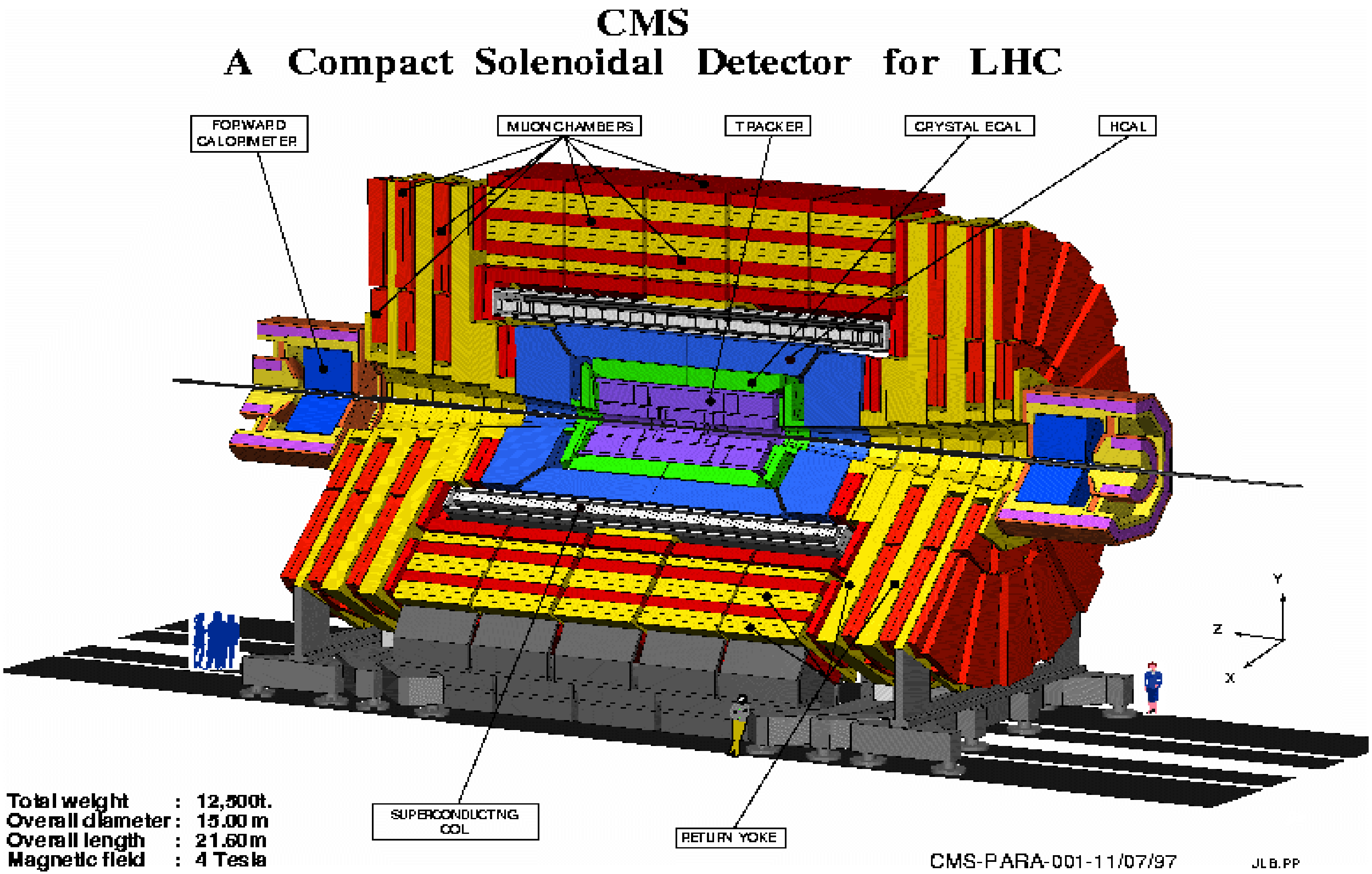
ATLAS Collaboration

(Status October 2008)

37 Countries
169 Institutions
2800 Scientific participants total
(1850 with a PhD, for M&O share)

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

Compact Muon Spectrometer



38 Countries , 180 Institutions, > 2500 Scientific Authors

***C**ompact **M**uon **S**olenoid*

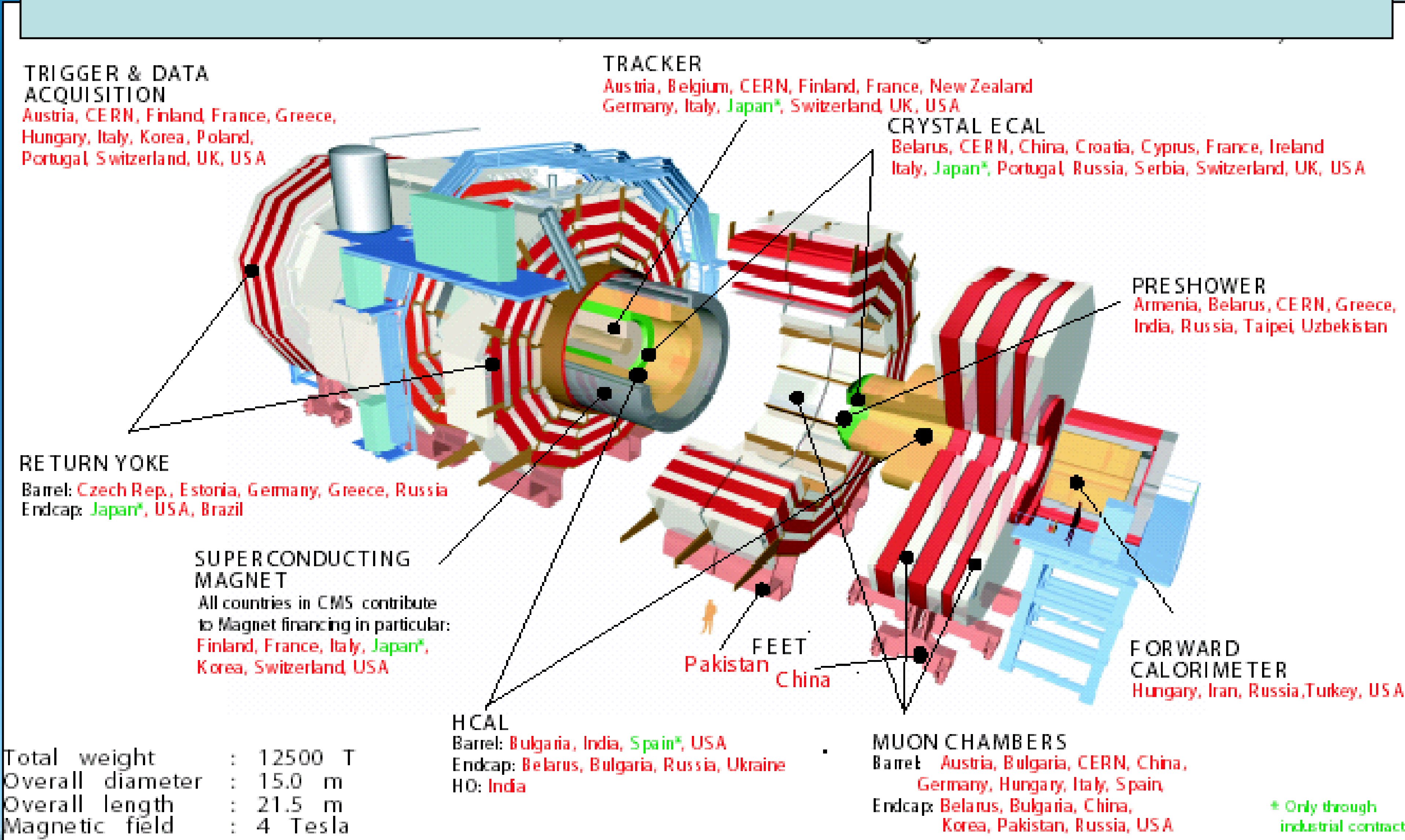
Forward Hadron Calorimeter (HF) collaboration between:
Hungary, Iran, Russia, Turkey, USA

Hungarian student inserting quartz fibres into steel wedges

CMS is a collaboration between ~over 2500 scientists from 180 institutes in 38 countries

CERN bridges many political divides:
US/Iran, Israel/Morocco, China/Taiwan, India/Pakistan, …

CMS Collaboration



Conclusions on CERN (LHC later)

It has worked scientifically – scientists with diverse backgrounds can work together on a ‘spiders web’ model

- it had to work, or world-class particle physics impossible in Europe

- stuck to one site

- few intellectual property issues

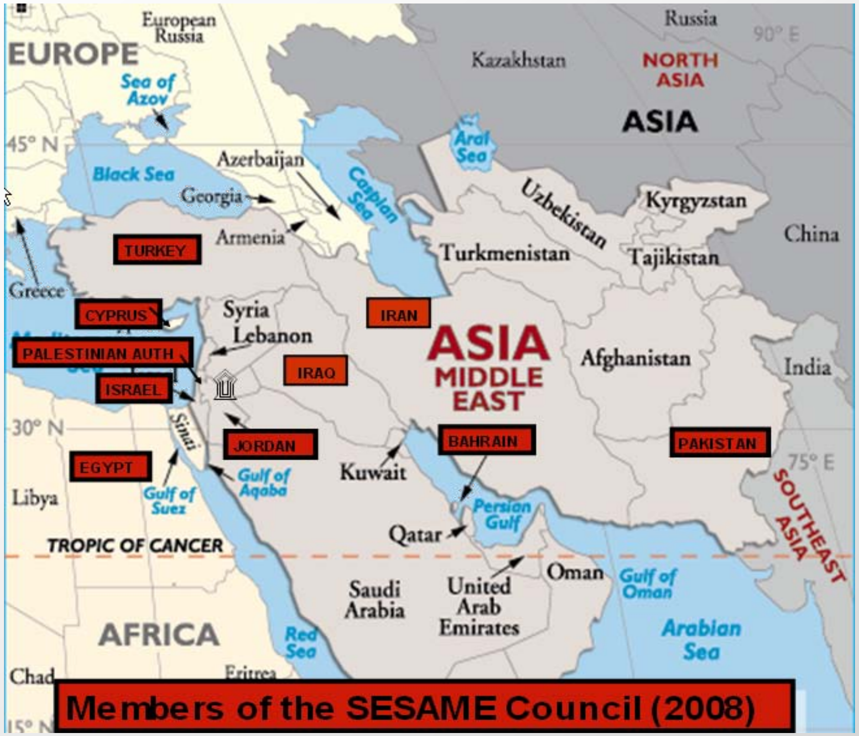
and politically

- model for EMBL, ESRF, ESO,…

- helped build bridges in post-war Europe, and with eastern block and rest of the world: model for **SESAME**

SESAME = **S**ynchrotron light for **E**xperimental **S**cience and **A**pplications in the **M**iddle **E**ast

- a 2.5 GeV light source, under construction near Amman.



Members: Bahrain, Cyprus, Egypt, Israel, Iran, Jordan, Pakistan, Palestinian Authority, Turkey. Pending: Iraq

Observers: France, Greece, Germany, Italy, Japan (to be confirmed), Kuwait, Russian Federation, Sweden, UK and USA.

Purpose: Foster excellent science and technology in the Middle East (and prevent or reverse the brain drain)

+ Build bridges between diverse societies

Very Brief History of SESAME

• Original idea (1997): rebuild old 800 MeV Berlin Synchrotron (BESSY), as basis for a new international organisation, modelled on CERN

• **2002: decision to build a new 2.5 GeV ring** (BESSY as injector)

To make a serious contribution to scientific capacity bulding *(for which synchrotron-light is ideal)* ***need a competitive device***

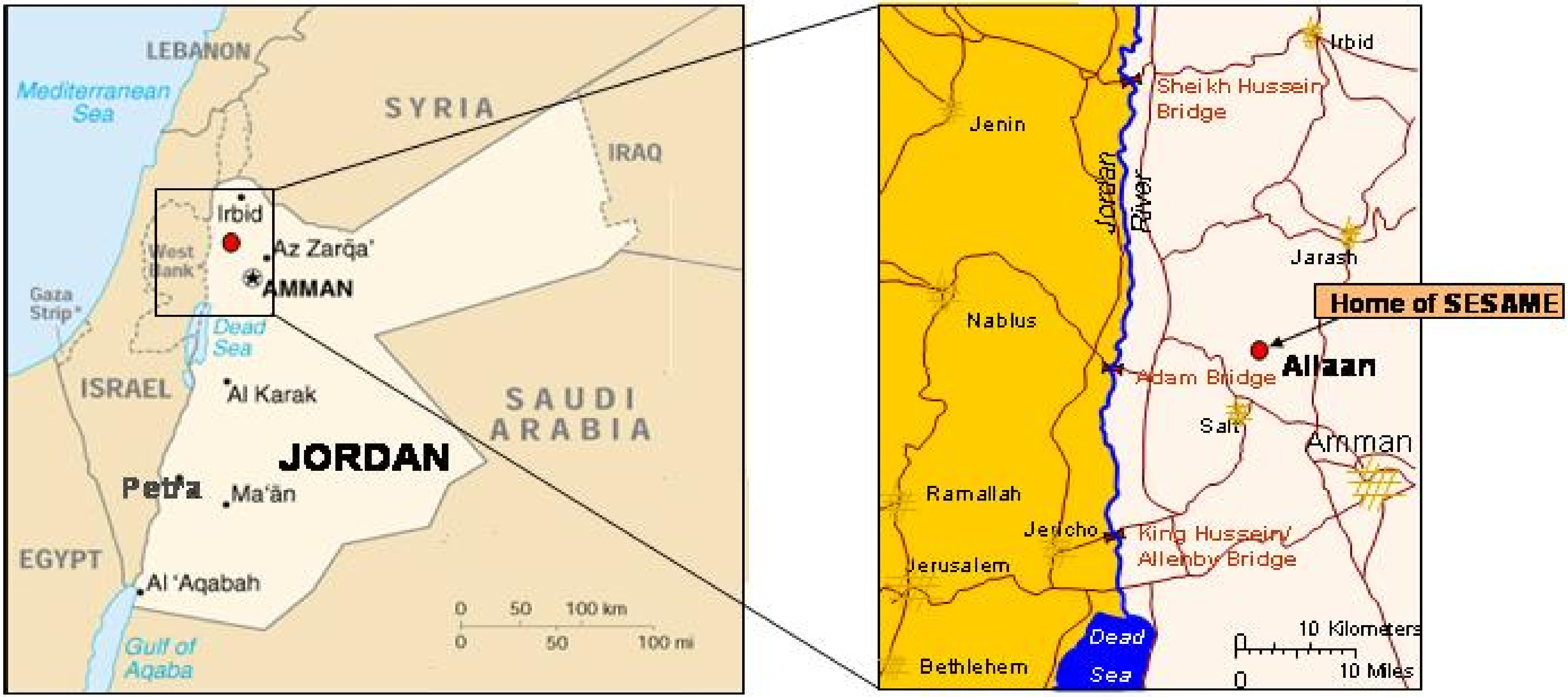
+ *firm scientific foundations essential for political bridges*

• From ground breaking (2003) to **completion of building (2008**) in record (?) time

BESSY partially installed; initial suite of donated beamlines (from Daresbury UK...) available

Vigorous training programme and growing potential user community

• **First experiments expected 2012**, ***assuming*** funding for main ring can be found



LEBANON
Mediterranean Sea
SYRIA
IRAQ
Irbid
Az Zarqa'
AMMAN
West Bank
Gaza Strip
Dead Sea
ISRAEL
Al Karak
SAUDI ARABIA
JORDAN
Petra
Ma'ān
EGYPT
Al 'Aqabah
Gulf of Aqaba
0 50 100 km
0 50 100 mi
Irbid
Sheikh Hussein Bridge
Jenin
Jordan River
Jarash
Home of SESAME
Nablus
Allaan
Adam Bridge
Salt
Amman
Ramallah
Jericho
King Hussein/ Allenby Bridge
Jerusalem
Dead Sea
Bethlehem
10 Kilometers
0
10 Miles

SESAME building, financed by Jordan and designed by civil engineers from Al-Balqa' Applied University, Jordan

Building can be used for high-level Arab-Israeli and Middle East Scientific meetings

3rd SESAME User Meeting
October 11-13, 2004
Antalya, Turkey

SESAME Accelerator Group; August 14, 2007

<u>First row left to right:</u> **Yara Zreikat, Mechanical Designer (Jordan), Adel Amro, Vacuum Assistant Engineer (Jordan), Adli Hamad, Radiation Officer (Jordan)**

<u>Second row Left to Right;</u> **Darweesh Foudeh, RF Engineer (Jordan), Firas Makahleh, Mechanical Engineer (Jordan), Mohammad Alnajdawi, Mechanical Designer (Jordan), Maher Shehab, Mechanical Engineer (Jordan), Hamed Tarawneh, Accelerator Physicist (Jordan), Maher Attal, Accelerator Physicist (Palestine), Ahed Aladwan, Control Engineer (Jordan), Arash Kaftoosian, RF Engineer (Iran) Seadat Varnasseri, Diagnostics Engineer (Iran)**

ANOTHER WORLD?

“As a string theorist, I work on parallel universes. I was always curious about what a parallel universe was like, and now I know. I’m living in one when I go to *SESAME* meetings”

Eliezer Rabinovici; Hebrew University and Israeli representative to the SESAME Council

Funding

Capital cost: Jordan (land, building and cash), donations (BESSY, beamlines), EU (€1.2M +..?)

New main ring not foreseen initially, and not budgeted by Members. Funding being sought for this and for adapting/upgrading the beamlines

Possible sources of funding: *special in-kind or cash contributions from members, new members, EU, other external donors, loan*

Operational cost - provided by Members: currently $1.5M, will rise to ~$(4-5)M

Training – initially mainly for machine builders, now mainly for users. Funded by IAEA and other organisations around the world (including APS), numerous synchrotron laboratories provide training opportunities. Workshops, Users' meetings, Fellowships…

SESAME

There are challenges

- Stable financial support
- Increasing the number of member countries in the Gulf as well as in the Mahgreb
- Compensating the differences in the human and financial resources of the member countries
- Solutions to some practical problems involving travel restrictions in the region
- Funding for main ring and adaptation/upgrading of beamlines

But the outlook is good with commissioning possible in 2012

thanks especially to HM King Abdullah II, Director Toukan, UNESCO, IAEA, and those who have donated equipment, especially BESSY1 and Daresbury

and SESAME should provide

A world class synchrotron radiation laboratory; non-discriminating scientific environment for collaborations, as well as individual development; interdisciplinary research, exploiting local advantages; advanced facility for training; place to which expatriates can return; contributions to development of local economy

Conclusion: science can help building political bridges, for which strong scientific foundations are essential

Superconducting Super Collider

Conceived 1982 [First (1984) detailed cost estimates - $2.7bn]

Approved 1987 [$4.4bn → $5.9bn with detectors]

Cancelled 1993 [Cost estimate - $11+ bn ; over $2bn spent]

Reasons for failing + lessons

- Cost increase !
- Project started *"to restore US leadership"*. Congress later made international contributions a condition (e.g. $2bn requested from Japan): start collaboration (real partnership) early
- Greenfield site did not attract enough key scientists and engineers (already at Fermilab, where existing infrastructure would have saved $2bn): consider locating big projects at/next to existing laboratories.

Large Hadron Collider

- Approved as **European project, but** initially for two stage construction - **other countries told their contributions would be used *"to speed up and improve the project***, *not to reduce the Member States' contributions".* This proved attractive, aided by offer of a voice in decisions + established nature of CERN as a multinational collaboration.
- Some tension over cash/in-kind contributions
- Despite long tradition of international collaboration in particle physics, negotiations with Non-Member States took a lot of time - necessary to establish mutual confidence of administrations and adapt to different ways of working
- Problems with USA - different culture; contributions *"subject to annual availability of funding"* – not a problem in practice; no independent arbitration + *"What number do I dial to speak to Europe?"*

LHC and Beyond at CERN

- **CERN has effectively become a world lab**

⇒ tensions in relations with the USA: 1499 users (more than any other country) seen as disproportionate relative to the contribution

(~ $550 M*****) which never looked generous, but was agreed when

- there were 'only' ~ 550 potential US users

- following cancellation of the SSC, the 'Drell panel' had proposed that the US should come on board the LHC with a contribution of $400 M***** *assuming* a bump in the HEP budget, *which did not happen*

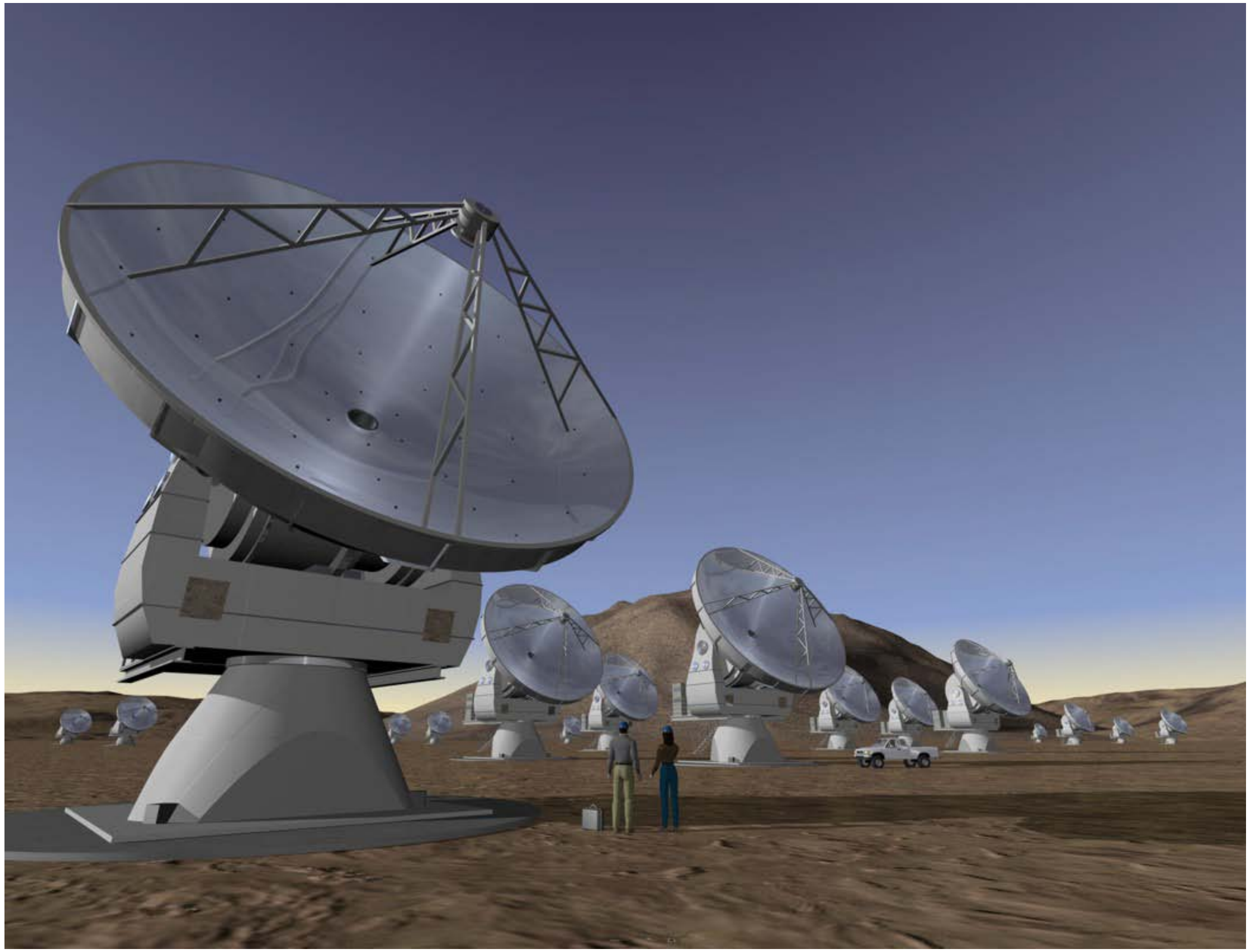
***** *to machine + detectors*

-Europe had hitherto been the net beneficiary of US open doors policies across science (although 'balance of trade' in HEP reversed with LEP)

- **CERN now considering opening the doors, as full members, to non-European countries** (Israel & Turkey have applied as have Cyprus & Serbia))

- **Question:** could CERN evolve into *the* world particle physics laboratory?

Atacama Large Millimetre-Array



Large telescope array in Atacama desert in Chile

Atacama Large Millimetre-Array

- **Inter-regional collaboration**, in co-operation with Chile, based on Agreement between

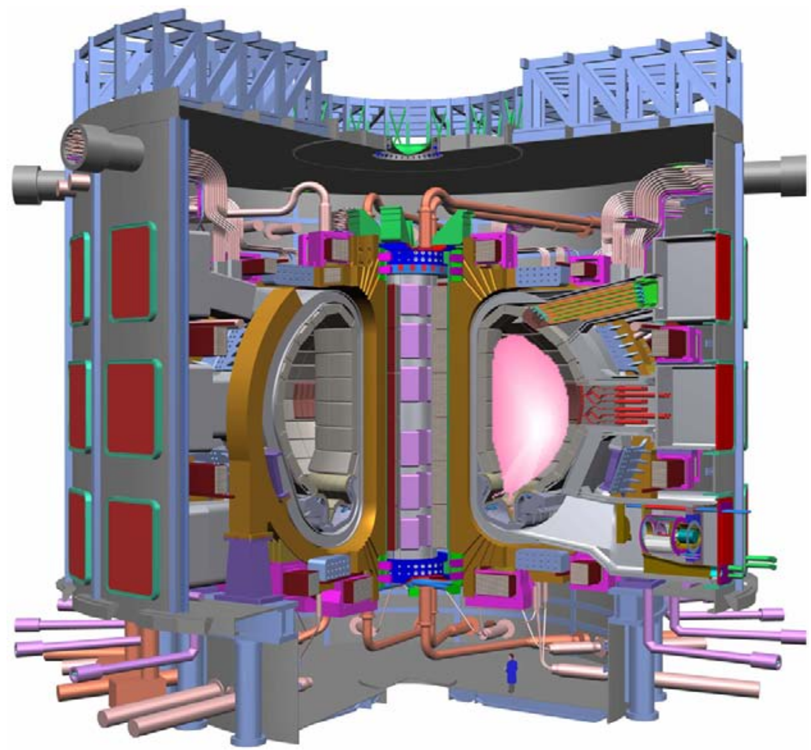
  European Southern Observatory + Spain

  US National Science Foundation + Canada +Taiwan

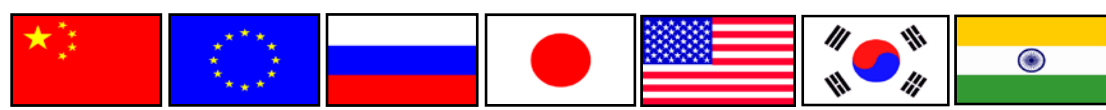
  Japan (NAOJ)**+ Taiwan**
- Agreement → Baseline programme: any other new members (who would join through ESO, NSF, or NAOJ) must enhance baseline programme
- Contributions during construction mostly in-kind, based on common costing model
- No problem with site choice (based on science). Host contribution not an issue - Chile not regarded as a host
- No *juste retour*

ITER (International Tokamak Experimental Reactor or *'The way'*)

- Aim is to demonstrate integrated fusion physics and engineering on the scale of a power station
- Key ITER technologies fabricated and tested by industry
- Construction beginning; over 5 Billion euro construction cost
- Europe, Japan, Russia, US, China, South Korea, India – home to over half the world's population
- Site at Cadarache, in S France



Talk by Steve Cowley at 8.30 tomorrow



- Also need to build International Fusion Materials Irradiation Facility (IFMIF)+ vigorously devlep fusion technologies - if done in parallel with ITER, **prototype fusion power stations could be supplying power to the grid in ~ 30 years**

ITER (1)

Some features that seem to be emerging as 'best practice' (e.g. in-kind contributions ~ common costing model)**, but various actual/potential problems** (although jury still out)**:**

- **Contributions**

  EU – 50%; Japan, Russia, USA, China, S Korea, India - 6x10% = 100% + 10% central contingency (Japan and EU both offered up to 50% as host)

  - not related to economic or scientific strength

  - Europe paying 50%: too asymmetric for real partnership/bad precedent**?**

  - Rising cost a much bigger problem for Europe – creating stress

- **90% in-kind contributions**

  - sub-optimal for engineering integrity of very integrated project?

  - governance problems (authority with ITER Organisation but Domestic Agencies, responsible for procurement, have $s) + management problems (balancing changes**)**

ITER (2)

- **Countries joined wanting a share in a large range of technologies, without realising implications**

  - Production costs bigger with (say) 5, rather than 1 or 2, partners building a system: all companies have to do R&D & tool-up, economies of scale lost

  - Increased work managing interfaces

- ***Juste retour*** for senior posts (all posts ~ contributions) - not necessarily optimal; global head hunting difficult

- **Difficulty of setting up an organisation from scratch**, with international boundary condition, under estimated

- **Intellectual property** is/will be a problem (exaggerated in my opinion)

- Issue of **terms for Associate members** not yet faced

- Some **confusion in site negotiations between roles of European Commission, Country holding EU Presidency, and France as potential host**

ITER (3)

- **Site** *(see also later)*
  – Cadarache next to large laboratory ✔ ✔ , but some argued this could vitiate ITER's international character (not true of JET)

  – Sites of LHC, ITER, Linear Collider linked in US Dept of Energy's view (+ view of US particle physicists, and Japan?). Connection not made in Europe: no mechanism*****. Good for fusion that trade-off ('Broader Approach') in fusion, but not necessarily optimal for science

  ***** **E**uropean **I**ntergovernmental **R**esearch **O**rganisations **Forum** (CERN, EFDA, EMBL, ESA, ESO, ESRF, ILL), created 2002, **should help communication**

- **USA** *(see also later)*

  Problems similar to those with LHC. Better in principle – the US signed up without reservations. Worse in practice – Congress reneged in year 1 by zeroing the budget

General Issues (1)

- **What is appropriate nationally/internationally depends on size of country/region**

- **Many candidates for future joint European projects, not so many for global projects or from US perspective**

-International Linear Collider; First Demonstrator Fusion Power Plant (DEMO)? (commercial/IPR issues…); successor to Auger; nextgeneration gratiataional wave experiment; next steps in space; carbon Capture and Storage trails: need variety (technology & geology), but commercial issues + likely to be done on regional scale (?); ……?

Question: how best to organise precursor organisations (planning, design…)?

- **Below a certain scale (large for the USA), mutually open access simpler than common ownership**

but conditions of access may be an issue (also for access to joint facilities by non-members); needs a balance of facilities, with no countries acting as parasites

General Issues (2)

- **Networks/information & work sharing more appropriate than joint facilities in many cases**

e.g. Energy R&D: global sharing of work load and results imperative

Some needs big/joint facilities (ITER, Gen IV,..); most does not

How this should best be done unclear (open books vs. protection of IPR…)

- **Need to ensure case for small science at large facilities is heard** (on national, regional and global scales)
  - 'Big' scientists (particle physicists, astronomers) are out of business without facilities – will make case/lobby
  - Small science needing big facilities with heterogeneous user communities – most not totally reliant on any one facility

Needs leadership + **Road Maps*** very useful on national and European scale:

- Force dispersed scientific communities unaccustomed to strategic planning to think ahead (and think big) and identify future needs (including funding of instruments)
- Put projects on radar screens of funders

* *e.g. European Road Map for Research Infrastructures produced by the European Strategy Forum on Research Infrastructures (ESFRI)*

Lessons & Issues Re Joint Facilities

- **Wide experience of European collaboration** (CERN, EMBL, ESA, ILL, ESO, JET, ESRF,...) - we know the advantages and the problems (from work permits/job opportunities for spouses to nature/size of contributions).
- **It took time, as is going global** – for negotiations, to build trust, to set up new organisations,….

  Worry that time needed for negotiations (and by increasing demands for accountability on national scale) **becoming longer than the time scale on which technology and needs change!**

- **Early exchange of information important**. ESFRI is doing this in Europe. OECD Global Science Forum provides mechanism on world scale? Utility not clear

Lessons & Issues Re Joint Facilities

- **Various lessons learned/good ideas**
  - start multilateral discussions early ($\rightarrow$ all on equal footing)
  - offer/demand added value to/from late-comers
  - agree ground rules early
  - try to minimise *juste retour* (posts, contracts, use: getting worse?)
  - if possible associate with existing laboratory
  - in-kind contributions ~ common costing model (politically necessary: dispersed construction $\rightarrow$ buy-in, but...). ITER will provide lessons.
  - idea of collaboration between regions is attractive
  - Europe must avoid confusion of roles of EU, Presidency, Host country.
- **Open questions**
  - organisation of precursor organisations?
  - appropriate level of Host contributions during construction and operation? Lessons from ITER?

Question of Choice of Site for Joint Facilities

- Illusion to think choice can be based on technical issues; political factors always dominant (and sometimes unexpected, e.g. site of Joint European Torus chosen as a result of capture of German hostages in Mogadishu)
- Generally an illusion to seek ‘detailed balance’ field by field*
- Basket approach (decide several projects in different fields simultaneously → all regions win) doomed to failure (too few projects, not in phase) + Europe has no mechanism

  but approximate medium-term balance across different scientific fields seems necessary (others are thinking in these terms and Europe must find a way to deal with this or be forced to follow an agenda set by others)

** fusion is a partial exception (Broader Approach partially balancing ITER)*

Question of USA as a Partner in Joint Facilities

Problem that one Congress cannot commit another

Physics Today (October 2008) ***"US falters on commitments to international science projects: ITER and the ILC are the latest in a series of big-ticket science collaborations to fall victim to the US political process"****….. "US shirking obligations"*

US normally only sign up *"subject to annual availability of funding"* and (unlike all others) never commits to independent arbitration of disputes, or signs the usual privileges and immunities agreements

Would a Treaty help? Needs Senate approval (~ time + outcome not guaranteed)
Anyway US has not ratified Vienna Convention on the Law of Treaties (case of UN)

Case of ITER

US (with encouragement of House Science Committee) in the end signed (November 2006) on the same basis as all others - specific obligations + no Member may leave for ten years (no escape clause). Agreement ratified October 2007, but in December 2007 the Congress (in a fight with the President) set the budget to zero!

Other problems, e.g. closure of BaBar; USA not the only culprit – UK pulled out of ILC, EU's slow decision making irritates others

Would others agree to the USA hosting a major joint facility?

Final Conclusions

- **International collaboration in S&T works**

- speeds up science, saves costs, whole> sum of parts, can help build political bridges

- **There are some problems and questions**

-scale at which European or global collaboration is desirable, possible loss of diversity, complexity of decisions, access, juste retour, host contribution, choice of site, USA as partner. **Danger** that **time needed for decisions may become longer than the time scale on which technology and needs change!**

- **Going global**

-takes time, but many lessons learned (start early, common costing, Europe needs to speak with a common voice..), and common confidence is building

Final remarks: **best scientific collaborations driven bottom-up:** need to balance getting projects on political radar screens vs. premature politicisation, and optimise for science. **Big need for technological collaborations on energy issues,** many involving industry with IPR etc. issues: **how best to share work & results?**