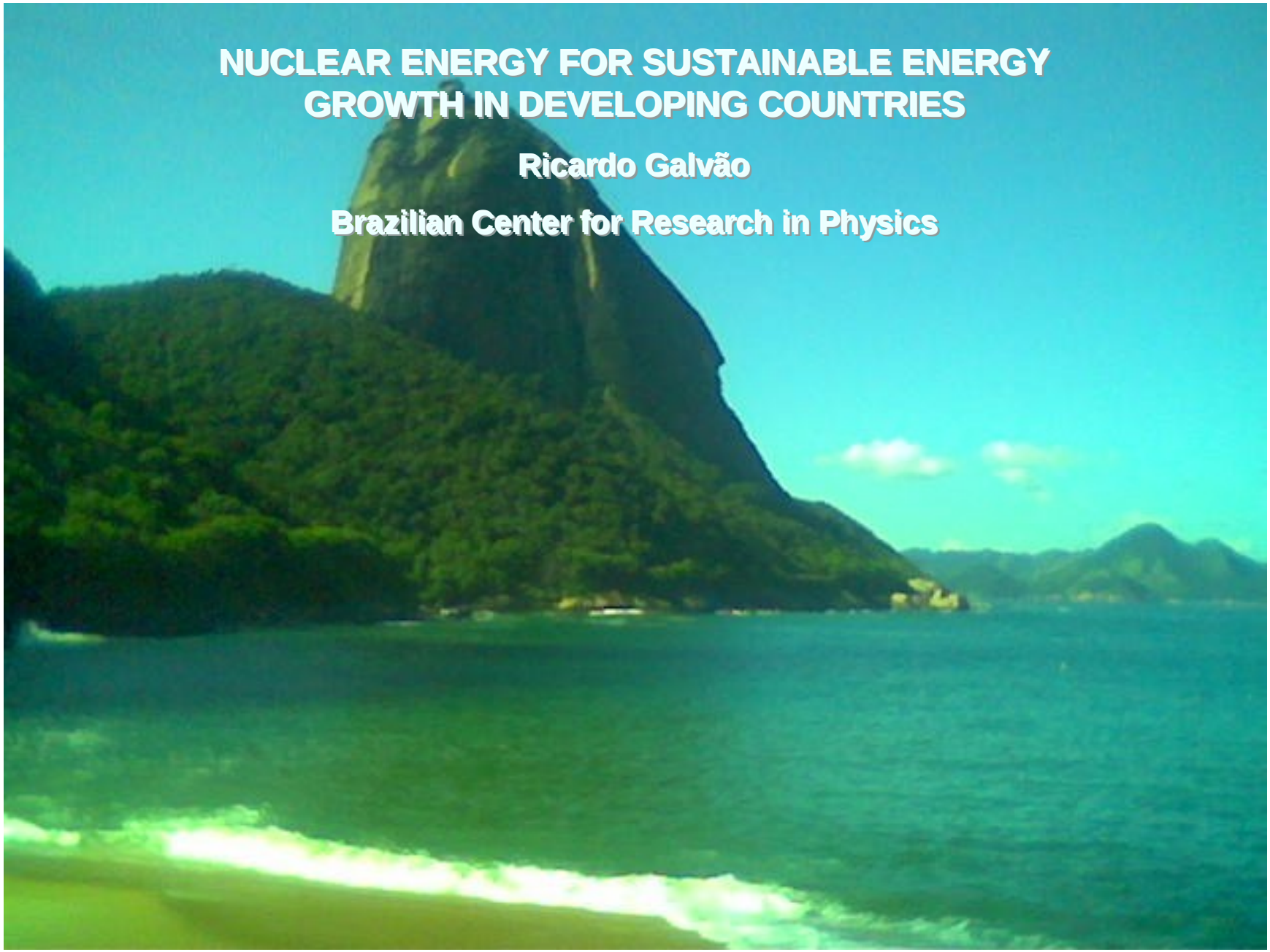


NUCLEAR ENERGY FOR SUSTAINABLE ENERGY GROWTH IN DEVELOPING COUNTRIES

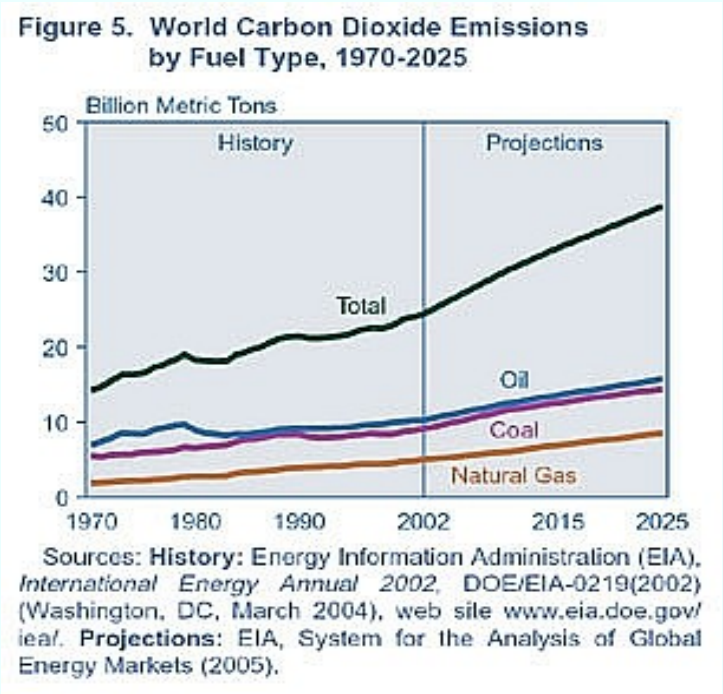
Ricardo Galvão

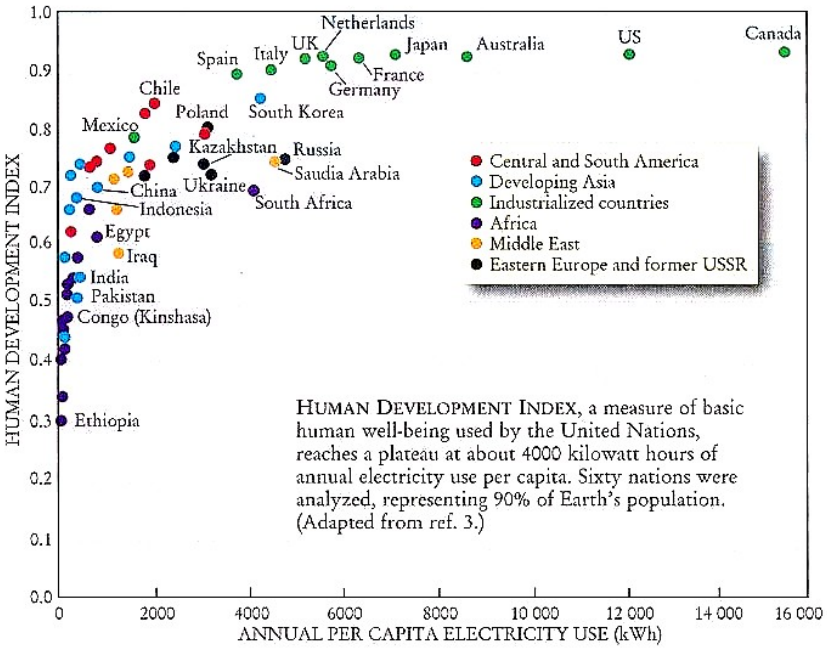
Brazilian Center for Research in Physics

PERSPECTIVES FOR NUCLEAR POWER

New energy sources are needed to

- **Replace fossil fuels**
- **Satisfy the demand of a growing world population**
- **Provide better share of economical growth and quality of life**





Meeting Energy Needs
IAEA - 2005

BARRIERS FOR NUCLEAR POWER BASED ECONOMY

Safety **Proliferation** **Waste** **Training and Expertise**

437 NPP

25 countries

≈11% energy production
(≈ 350GW)

1

2

2

Meeting Energy Needs
IAEA - 2005

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Meeting Energy
IAEA - 2005

A strategy to improve expertise and participation of developing countries, with due regard for safeguard policies, is needed

ADVANCED NUCLEAR ENERGY SOURCES

Next steps in the development and application of nuclear power pose significant challenges, but also open new possibilities for international collaboration, strengthening the participation of developing countries

- **Prototypes**
- **Current operating plants**
- **Advanced light-water reactors**

ADVANCED NUCLEAR ENERGY SOURCES

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Evolution of Nuclear Power Technology:

- **Prototypes**
- **Current operating plants**
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Evolution of Nuclear Power Technology:

- **Prototypes**
- **Current operating plants**
- **Advanced light-water reactors**
- **Revolutionary (intrinsically safe) concepts – Generation IV**
- **Fusion reactors**

Latter two activities will have to be based upon strong international collaboration in order to reduce costs and risk of proliferation, get wide acceptance, and yield economically and environmentally acceptable energy options

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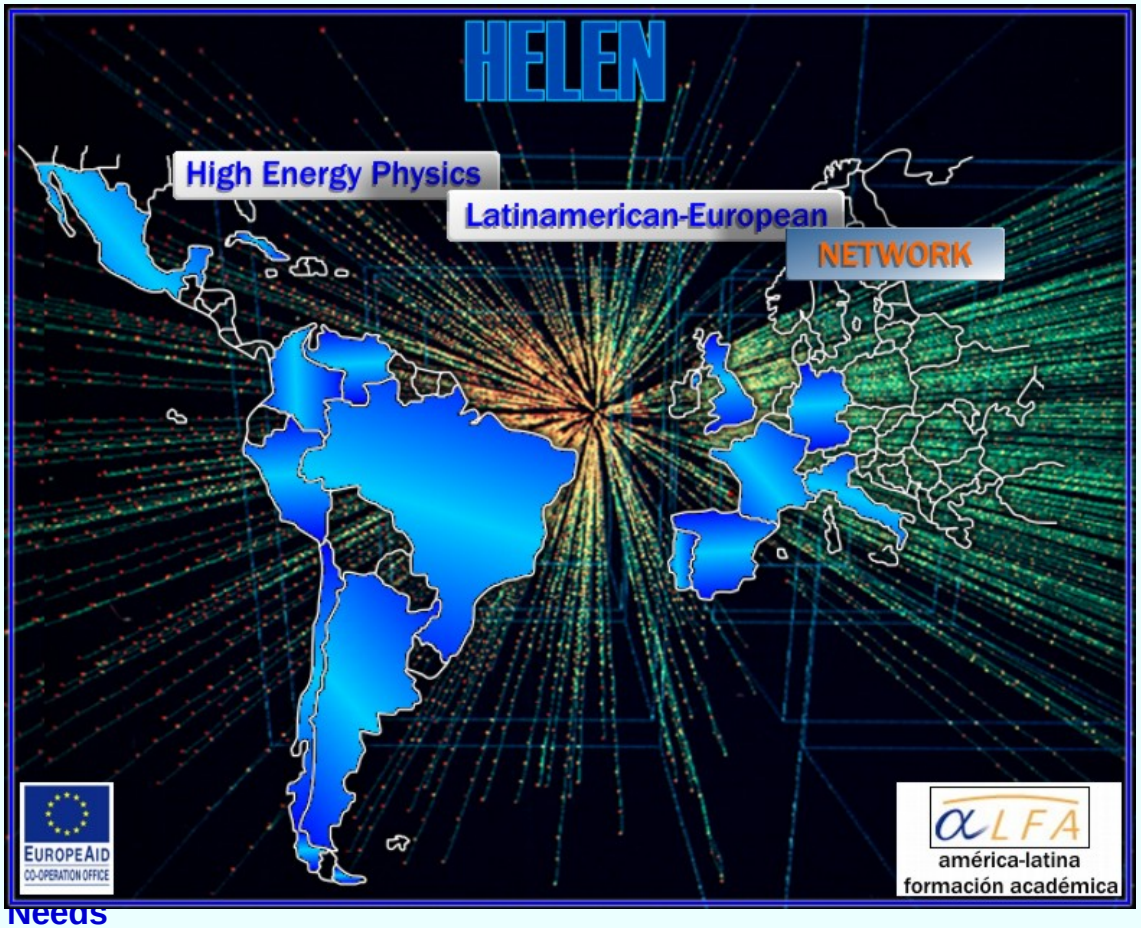
COLLABORATION SCHEMES OF OTHER SCIENTIFIC AREAS COULD BE EFFECTIVE

COLLABORATION SCHEMES OF OTHER SCIENTIFIC AREAS COULD BE EFFECTIVE

PARADIGM: HIGH-ENERGY PHYSICS



D0 EXPERIMENT - FERMILAB

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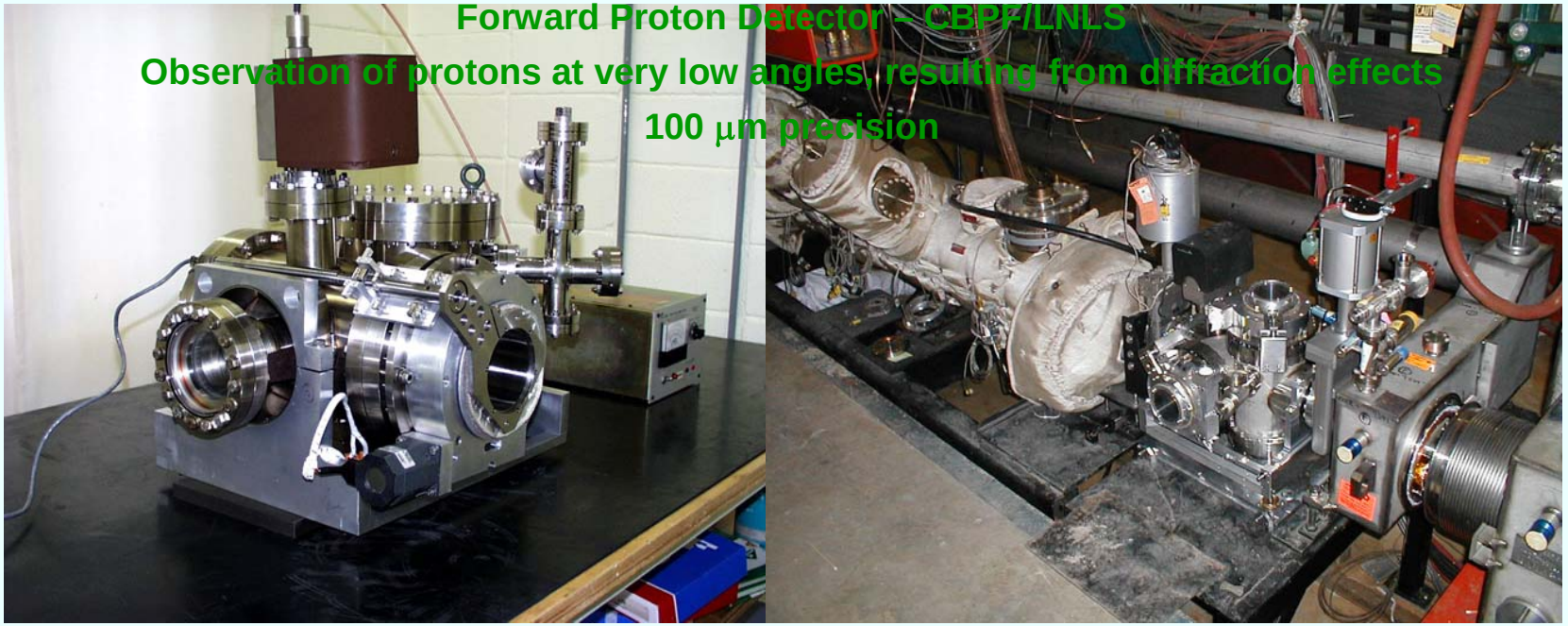
Meeting Energy
IAEA - 2005

D0 EXPERIMENT - FERMILAB

Forward Proton Detector – CBPF/LNLS

Observation of protons at very low angles, resulting from diffraction effects

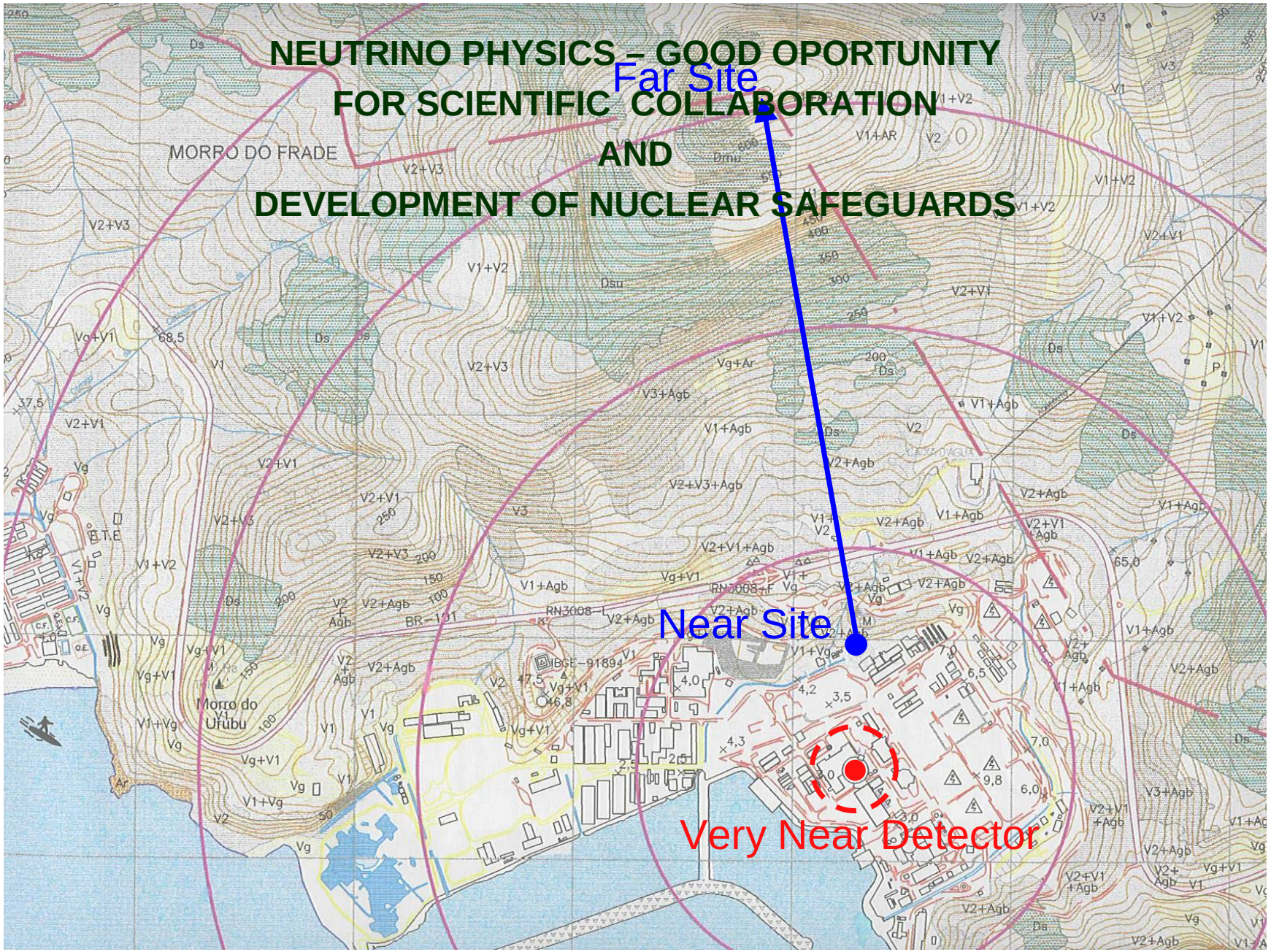
100 μm precision



NEUTRINO PHYSICS – GOOD OPORTUNITY FOR SCIENTIFIC COLLABORATION AND DEVELOPMENT OF NUCLEAR SAFEGUARDS

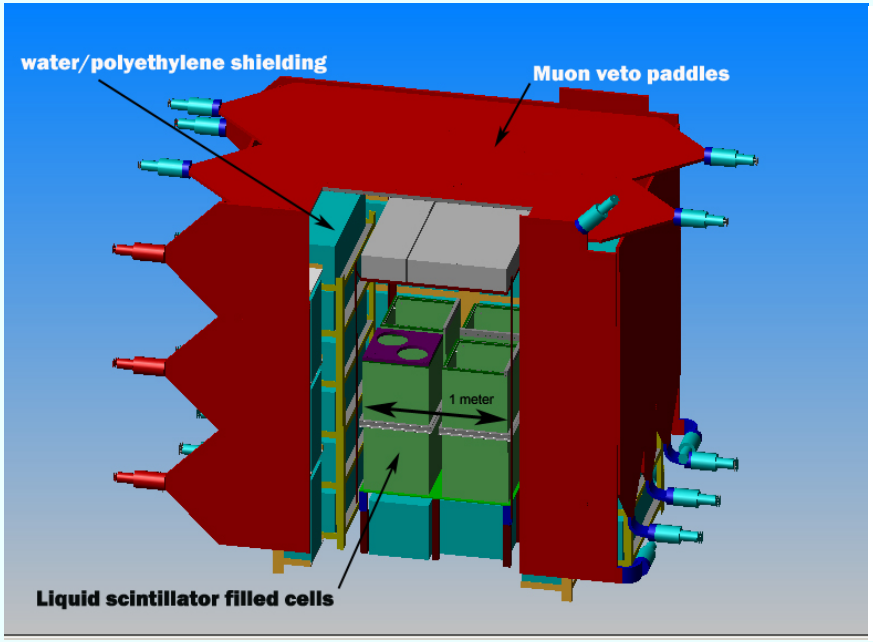
Meeting Energy Needs
IAEA - 2005

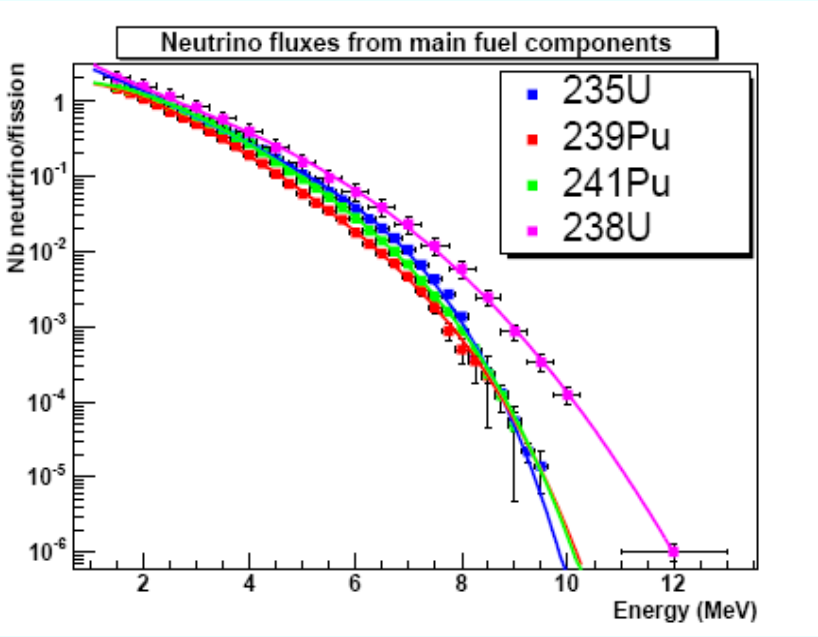

NEUTRINO PHYSICS – GOOD OPORTUNITY
FOR SCIENTIFIC COLLABORATION
AND
DEVELOPMENT OF NUCLEAR SAFEGUARDS
Far Site
L = 1500 m
Entrance
Near Site
depth = 100 m


NEUTRINO PHYSICS – GOOD OPORTUNITY
FOR SCIENTIFIC COLLABORATION
AND
DEVELOPMENT OF NUCLEAR SAFEGUARDS
Far Site
Near Site
Very Near Detector
MORRO DO FRADE
Morro do Urubu

NEUTRINO PHYSICS – GOOD OPORTUNITY FOR SCIENTIFIC COLLABORATION AND DEVELOPMENT OF NUCLEAR SAFEGUARDS

Near antineutrino detector that can be used to monitor the fuel composition in nuclear reactors.





Antineutrino energy spectra of the main components of the nuclear reactor fuel.

(^{238}U has not been measured, so the error bars are not shown)

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FUSION RESEARCH:

NO POLICY YET ESTABLISHED FOR WIDE-RANGE INTERNATIONAL COLLABORATION

Meeting Energy Needs
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Tokamak experimental papers published in Nuclear Fusion

FUSION RESEARCH:

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This type of scheme not usual in nuclear energy research, even in fusion

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NO POLICY YET ESTABLISHED FOR WIDE-RANGE INTERNATIONAL COLLABORATION

FUSION ENERGY PRODUCTION FROM A DEUTERIUM–TRITIUM PLASMA IN THE JET TOKAMAK

JET Team*
JET Joint Undertaking,
Abingdon, Oxfordshire,
United Kingdom

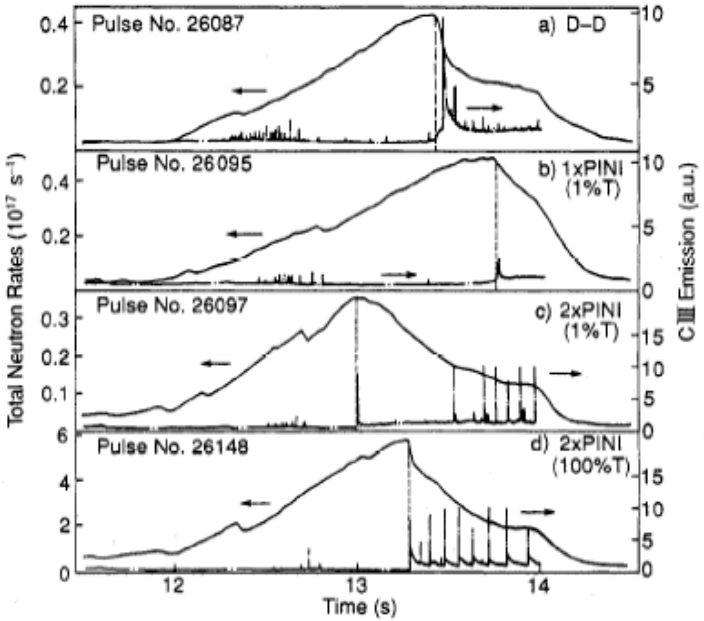

FIG. 15. Variation in the time of termination of the high performance phase of a number of similar discharges as shown by the fall in the neutron emission rate. The dashed vertical lines show the time of the 'carbon bloom' as characterized by increased emission of C III light from the plasma edge. In (a) and (b) this transition occurs 'naturally', in (c) it is triggered by an ELM, and in (d) it is triggered by a sawtooth collapse coupled to an ELM.

ANNEX

P.-H. REBUT, A. GIBSON, M. HUGUET, J.M. ADAMS[1], B. ALPER, H. ALTMANN, A. ANDERSEN[2], P. ANDREW[3], M. ANGELONE[4], S. ALI-ARSHAD, P. BAIGGER, W. BAILEY, B. BALET, P. BARABASCHI, P. BARKER, R. BARNSLEY[3], M. BARONIAN, D.V. BARTLETT, L. BAYLOR[5], A.C. BELL, G. BENALI, P. BERTOLDI, E. BERTOLINI, V. BHATNAGAR, A.J. BICKLEY, D. BINDER, H. BINDSLEV[2], T. BONICELLI, S.J. BOOTH, G. BOSIA, M. BOTMAN, D. BOUCHER, P. BOUCQUEY, P. BREGER, H. BRELEN, H. BRINKSCHULTE, D. BROOKS, A. BROWN, T. BROWN, M. BRUSATI, S. BRYAN, J. BRZOZOWSKI[3], R. BUCHSE[22], T. BUDD, M. BURES, T. BUSINARO, P. BUTCHER, H. BUTTGEREIT, C. CALDWELL-NICHOLS, D.J. CAMPBELL, P. CARD, G. CELENTANO, C.D. CHALLIS, A.V. CHANKIN[8], A. CHERUBINI, D. CHIRON, J. CHRISTIANSEN, P. CHUILON, R. CLAESEN, S. CLEMENT, E. CLIPSHAM, J.P. COAD, I.H. COFFEY[9], A. COLTON, M. COMISKEY[10], S. CONROY, M. COOKE, D. COOPER, S. COOPER, J.G. CORDEY, W. CORE, G. CORRIGAN, S. CORTI, A.E. COSTLEY, G. COTTRELL, M. COX[11], P. CRIPWELL[12], O. Da COSTA, T. DAVIES, N. DAVIES, H. de BLANK, G. de ESCH, L. de KOCK, E. DEKSNIS, F. DELVART, G.B. DENNE-HINNOV, G. DESCHAMPS, W.J. DICKSON[13], K.J. DIETZ, I.L. DMITRENKO, M. DMITRIEVA[14], J. DOBBING, A. DOGLIO, N. DOLGETTA, S.E. DORLING, P.G. DOYLE, D.F. DÜCHS, G. DUQUENOY, A. EDWARDS, J. EHRENBERG, A. EKEDAHL, T. ELEVANT[7], S.K. ERENTS[11], L.G. ERIKSSON, G. FAJEMIROKUN[13], H. FALTER, J. FREILINO[15], F. FREVILLE, C. FROGER, P. FROISSARD, K. FULLARD, M. GADEBERG, A. GALETSAS, T. GALLAGHER, D. GAMBIER, M. GARRIBBA, P. GAZE, R. GIANNELLA, R.D. GILL, A GIRARD, A. GONDHALEKAR, D. GOODALL[11], C. GORMEZANO, N.A. GOTTARDI, C. GOWERS, B.J. GREEN, B. GRIEVSON, R. HAANGE, A. HAIGH, C.J. HANCOCK, P.J. HARBOUR, T. HARTRAMPF, N.C. HAWKES[11], P. HAYNES[11], J.L. HEMMERICH, T. HENDER[11], J. HOEKZEMA, D. HOLLAND, M. HONE, L. HORTON, J. HOW, M. HUART, I. HUGHES, T.P. HUGHES[10], M. HUGON, Y. HUO[16], C. IDA[17], B. INGRAM, M. IRVING, J. JACQUINOT, H. JAECKEL, J.F. JAEGER, G. JANESCHITZ, Z. JANKOVICZ[18], O.N. JARVIS, F. JENSEN, E.M. JONES, H.D. JONES, L.P.D.F. JONES, S. JONES[19], T.T.C. JONES, J.-F. JUNGER, F. JUNIQUE, A. KAYE, A.E. KEEN, M. KEILHACKER, G.J. KELLY, W. KERNER, A. KHUDOLEEV[21], R. KONIG, A. KONSTANTELLOS, M. KOVANEN[20], G. KRAMER[15], P. KUPSCHUS, R. LÄSSER, J.R. LAST, B. LAUNDY, L. LAURO-TARONI, M. LAVEYRY, K. LAWSON[11], M. LENNHOLM, J. LINGERTAT[22], R.N. LITUNOVSKI, A. LOARTE, R. LOBEL, P. LOMAS, M. LOUGHLIN, C. LOWRY, J. LUPO, A.C. MAAS[15], J. MACHUZAK[19], B. MACKLIN, G. MADDISON[11], C.F. MAGGI[23], G. MAGYAR, W. MANDL[22], V. MARCHESE, G. MARCON, F. MARCUS, J. MART, D. MARTIN, E. MARTIN, R. MARTIN-SOLIS[24], P. MASSMANN, G. MATTHEWS, G. McBRYAN, G. McCRACKEN[11], J. McKIVITT, P. MERIGUET, P. MIELE, A. MILLER, J. MILLS, S.F. MILLS, P. MILLWARD, P. MILVERTON, E. MINARDI[4], R. MOHANTI[25], P.L. MONDINO, D. MONTGOMERY[26], A. MONTVAI[27], P. MORGAN, G. MORSI, D. MUIR, G. MURPHY, R. MYRNÄS[28], F. NAVE[29], G. NEWBERT, M. NEWMAN, P. NIELSEN, P. NOLL, W. OBERT, D. O'BRIEN, J. ORCHARD, J. O'ROURKE, R. ÖSTROM, M. OTTAVIANI, M. PAIN, F. PAOLETTI, L. PAPASTERGIOU, W. PARSONS, D. PASINI, D. PATEL, A. PEACOCK, N. PEACOCK[11], R.J.M. PEARCE, D. PEARSON[12], F. PENG[16], E. PEPE DE SILVA, G. PERINIC, C. PERRY, M. PETROV[21], M.A. PICK, J. PLANCOULAINE, J.-P POFFÉ, G. PÖHLCHEN, F. PORCELLI, L. PORTE[13], R. PRENTICE, S. PUPPIN, S. PUTVINSKII[8], G. RADFORD[30], T. RAIMONDI, M.C. RAMOS DE ANDRADE, R. REICHLE, J. REID, S. RICHARDS, E. RIGHI, F. RIMINI, D. ROBINSON[11], A. ROLFE, G.T. ROSS, L. ROSSI, R. RUSS, P. RUTTER, H.C. SACK, G. SADLER, G. SAIBENE, J.L. SALANAVE, G. SANAZZARO, A. SANTAGIUSTINA, R. SARTORI, C. SBORCHIA, P. SCHILD, M. SCHMID, G. SCHMIDT[21], B. SCHUNKE, S.M. SCOTT, A. SERIO, A SIBLEY, R. SIMONINI, A.C.C. SIPS, P. SMEULDERS, R. SMITH, R. STAGG, M. STAMP, P. STANGEBY[3], G. STANKIEWICZ[32], D.F. START, C.A. STEED, D. STORK, P.E. STOTT, P. STUBBERFIELD, D. SUMMERS, H. SUMMERS[13], A. SVENSSON, J.A. TAGLE[33], M. TALBOT, A. TANGA, A. TARONI, C. TERELLA, A TERRINGTON, A TESINI, P.R. THOMAS, E. THOMPSON, K. THOMSEN, F. TIBONE, A. TISCORNIA, P. TREVALION, B. TUBBING, P. VAN BELLE, H. VAN DER BEKEN, J. VLASES, M. VON HELLERMANN, T. WADE, C. WALKER, R. WALTON[31], D. WARD, M.L. WATKINS, N. WATKINS, M.J. WATSON, S. WEBER[34], J. WESSON, T.J. WIJNANDS, J. WILKS, D. WILSON, T. WINKEL, R. WOLF, D. WONG, C. WOODWARD, Y. WU[35], M. WYKES, D. YOUNG, I.D. YOUNG, L. ZANNELLI, A. ZOLFAGHARI[19], W. ZWINGMANN

Tokamak experimental papers published in Nuclear Fusion

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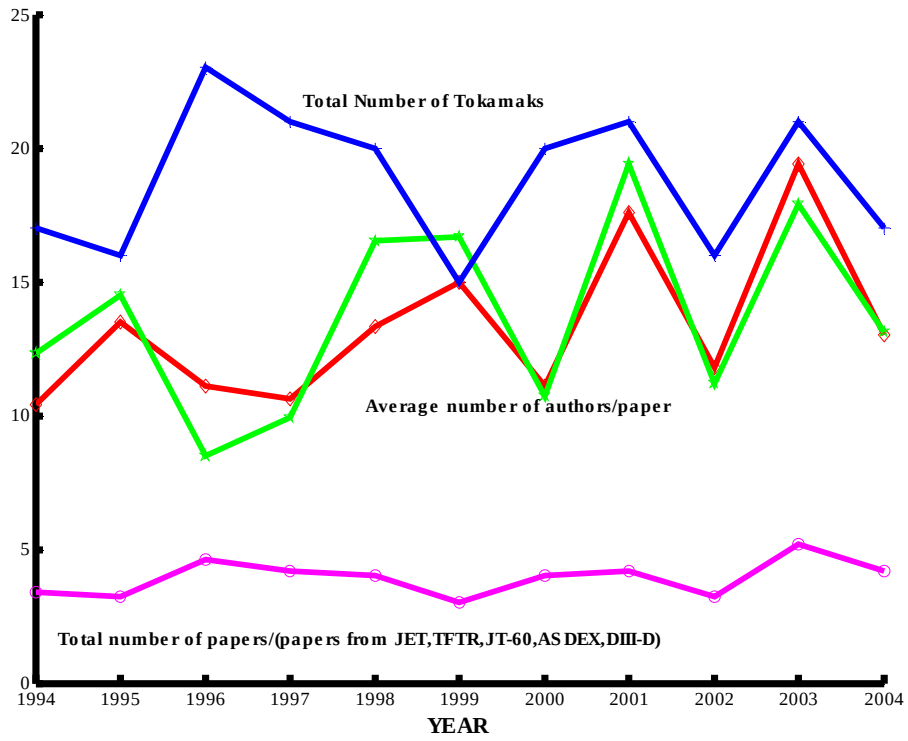

Meeting Energy Needs
IAEA - 2005

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POSSIBLE ACTIONS

Ex (CERN): Payment of maintenance and operational costs

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Establish mechanisms for secondary participation in major international nuclear energy projects

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Develop less expensive projects, complementary to the main stream ones, in which relevant participation would be possible without prohibitively high costs

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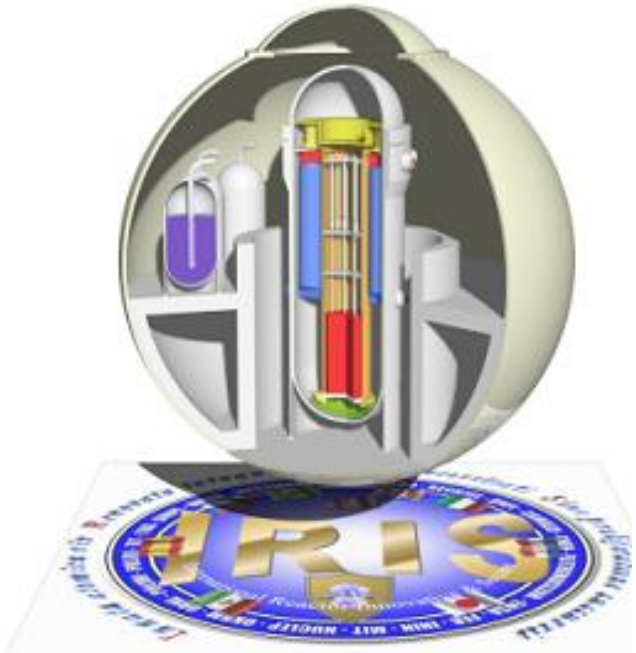
Ex: (Fission) IRIS Project



IRIS Partners

ANSALDO NUCLEARE · BECHTEL · BNFL · ANSALDO · CNEN · ENSA · FER · ININ · OKBM · ornl · TVA · Berkeley · UNIVERSITÀ DI PISA · Westinghouse Electric Company

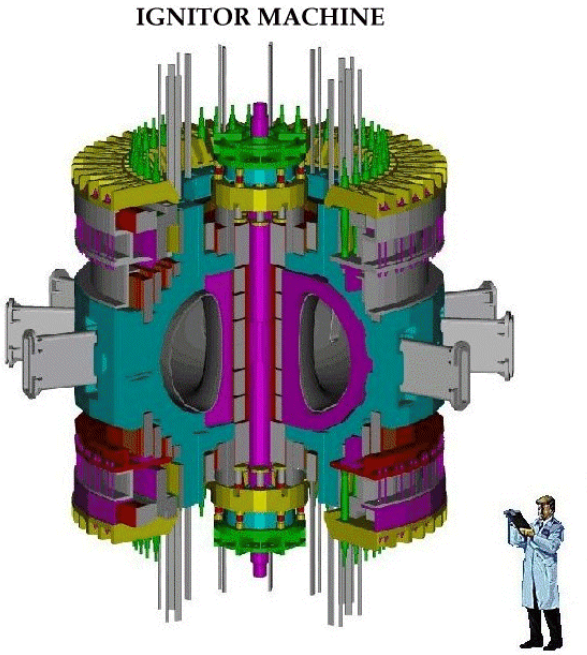
POSSIBLE ACTIONS

Establish mechanisms for secondary participation in major international nuclear energy projects

Ex (CERN): Payment of maintenance and operational costs

Develop less expensive projects, complementary to the main stream ones, in which relevant participation would be possible without prohibitively high costs

Ex: (Fusion) IGNITOR Project



IGNITOR Project not established as a broad international collaboration

However its cost, approximately one tenth of ITER, time to construct, estimated around five years, and main physical objective, i.e, a burning – plasma experiment, makes it very attractive for participation of developing countries.

REMOTE OPERATION AND DATA ANALYSIS

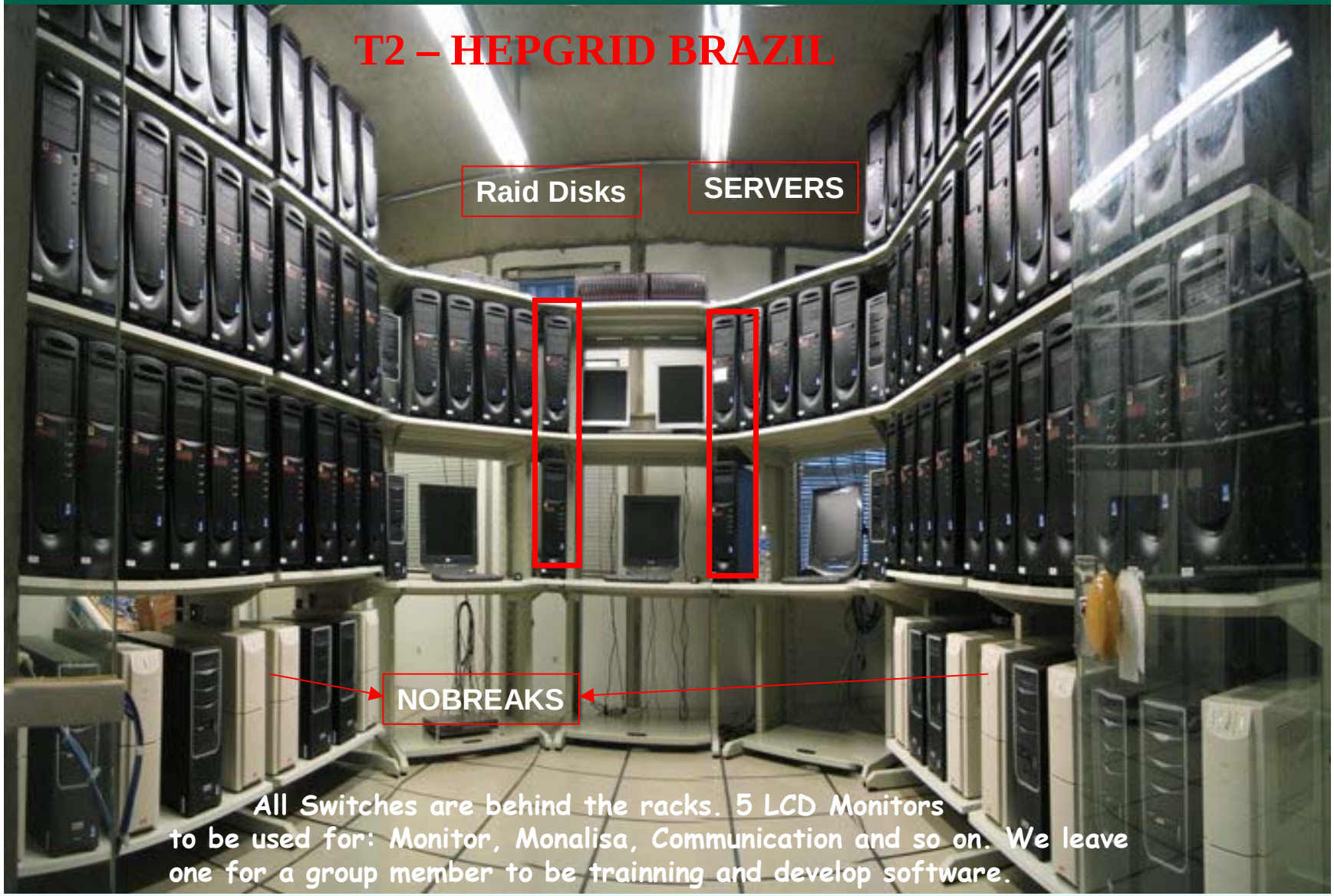
ITER GRID

- Real time interactions of large, geographically extended teams
- Real time interactions between small specialized groups
- Requirement of fast between – pulse analysis
- Simulations producing very large data sets (GB $\rightarrow$ TB $\rightarrow$ PB)
- Grid can be assembled with many small computers clusters
- Suitable for participation of low – budget groups
- Expertise available from high – energy phsics

STATE UNIVERSITY OF RIO DE JANEIRO – PROF. ALBERTOSANTORO

200 CPU 1GB/S

T2 – HEPGRID BRAZIL



All Switches are behind the racks. 5 LCD Monitors to be used for: Monitor, Monalisa, Communication and so on. We leave one for a group member to be trainning and develop software.