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NUCLEAR ENERGY IN BRAZIL AND THE R&D STATUS ON FAST SYSTEMS
NATIONAL REPORT

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1. INTRODUCTION. ENERGY PROFILE

Brazil although a developing country, is a huge and rich country in natural resources. Table 1 illustrates general data of the country and its relation with energy.

Table 1: General Country Data and its relation with Energy

Data	*unit*	*2001*	*2002*	*%02/01*
Population	Millions	172.4	174.6	1.30
Gross National Product(GNP)	Billions US$/2002	444.1	450.9	1.52
Inflation	% year	10	26	160
Exchange Rate	R$/US$	2.35	2.92	24.6
Energy Internal Offer-OIE	10^6 TEP[a]	194	198	2.1
% structure OIE	%	100	100	-
Oil and Derivatives	%	45.4	43.1	-5.0
Natural Gas	%	6.5	7.5	15.8
Mineral Coal	%	6.9	6.6	-4.6
Uranium	%	2.0	1.9	-4.2
Hydraulic and Electricity	%	13.6	14.0	0.0
Wood and Vegetal Coal	%	11.6	11.8	2.8
Sugar Cane(alcohol)	%	11.8	12.6	8.6
Others	%	2.4	2.5	4.8
External Dependence	% OIE	21.1	14.4	-31.8

[a]1 kWh=860 kcal, Reference Petroleum=10000 kcal/kg

Highlights:

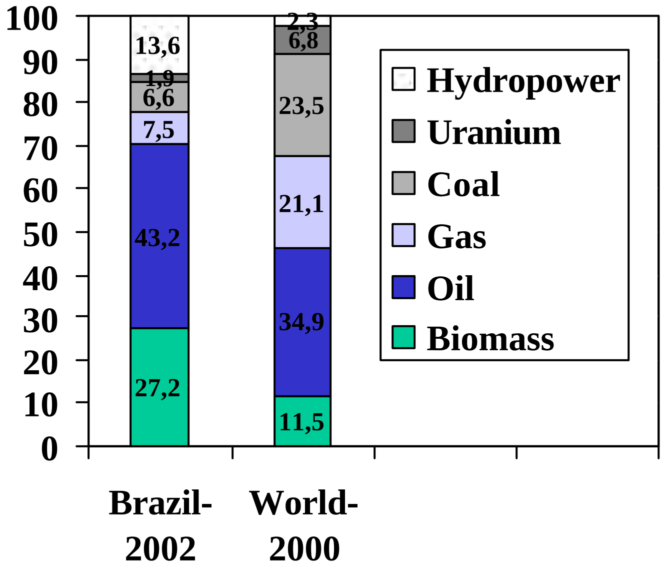
- The internal generation of energy (OIE), in 2002, was 198 millions of t equivalent petroleum (tep), 196% increased from 1970, and it is 2% of the world demand. This generation provides 86% of the national consume, the rest is imported(oil, natural gas, coal, and a small amount of electricity from the Itaipu a bi national, Brazil-Paraguay, hydro electric). The external dependence of energy in Brazil is decreasing, mainly due to the increase in the national oil production, mainly from off shore (the national reserves of oil increased from 283 millions of m^3, in 1979, to 2.1 billions of m^3 in 2002.

- In Brazil, around 41 % of the energy are from renewable sources (14% from hydro power, 27% from bio mass), against 14% in the world, and 6% in OECD countries. Alcohol, from sugar cane, is a one of the biggest energy source, mainly for transportation (In 1975, a program was created to substitute the gasoline used by cars by alcohol, with a great governmental support. Since this program was launched, the production of alcohol increased from 700,000 m^3(1975), to a maximum of 15.5 millions m^3 in 1997. Presently, the utilization of alcohol in cars is decreasing and consequently its production 12.6 millions m^3).

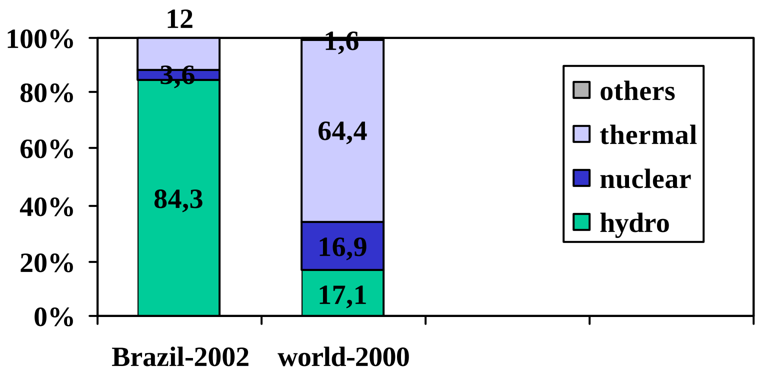
- The electrical energy is mainly hydro, and it has increased from 11 GW in 1970, to 82.5 GW in 2002(the hydro power installed in 2002, 65.3 MW represents around 25% of the total potential, mostly of them in the Amazon's region). Mostly of the electrical system is interconnected, and the extension of the transmission lines increased from 155,000 km, in 1979, to more than 220,000 km in 2002. Brazil, is following the international tendency of the energetic matrix, and is shifting for thermal power, mainly natural gas (the national reserves are 332 billions of m^3 in 2002, and gas are imported from Bolivia and Argentina). Nuclear, start contributing for electrical generation in 1985.

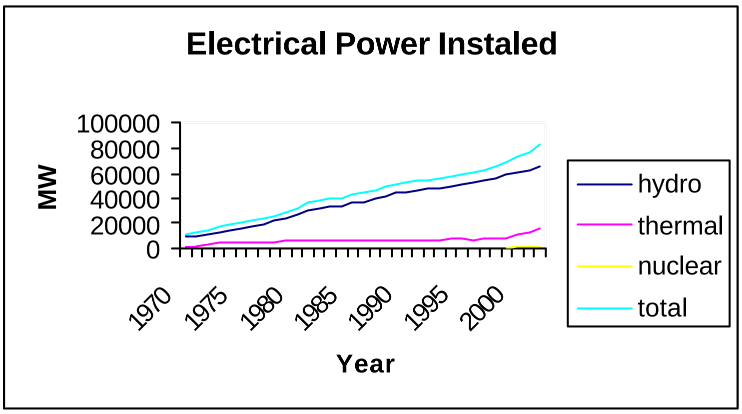
- Brazil has consumption per capita of 1.13 TEP, in 2002, below the world average of 1.65 TEP, and well below to developed countries like USA, 8.11 TEP. Also the electricity consumed per capita in Brazil (~2000 kWh), is well below of countries like German and France (~7000 kWh), or USA(12000 kWh), indicating that there is a potential demand to supply for the Brazilian population, in order to provide this commodity and improve their quality of life. Nuclear may have an space in such needed of growing of the internal energy offered, mainly due to the huge reserves of natural nuclear resources existing in the country, as it will be discussed in the next topic.

Illustrative Energy Data



Structure of Electrical Generation





2. NUCLEAR ENERGY

Nuclear Energy in Brazil is generated by 2 PWR, ANGRA I, a Westinghouse 657 MW_e, and ANGRA II, a SIEMENS, 1309(1350) MW_e. A third unity equal to unity II is under construction in the same site as the two other units (ANGRA III) as illustrated below:

- In 2002, ANGRA I and II produced a total of 13.8 TWh, which was less than 2001(14.3 TWh). Angra III is being considered in the decennial Governmental plan of expansion of the electrical sector (2002-2011) to be operating in 2009. In 2002, the National Council of Energetic Police gave authorization to the utility (ELETRONUCLEAR) to continue with efforts to conclude the enterprise, and presently the utility is working to obtain the needed environmental licensee. The main obstacle to continue with ANGRA III is financial.
- Another highlight in 2002-2003 was the decision of the utility to extended the lifetime of ANGRA I (more 20 years), and the main decisions was the opening of the international bid for the replacement of the two steam generators, forecast to happen in 2007. Also the utilization of advanced fuel elements is forecast in a joint project between the Westinghouse, Brazil and Korea.
- Besides the energy generation, there was progress in the Brazilian Nuclear Fuel Industry (INB), which provides the Fuel Elements for the NPP. As mentioned Brazil has the sixth world natural reserves of uranium, the location of the reserves and the installations are illustrated

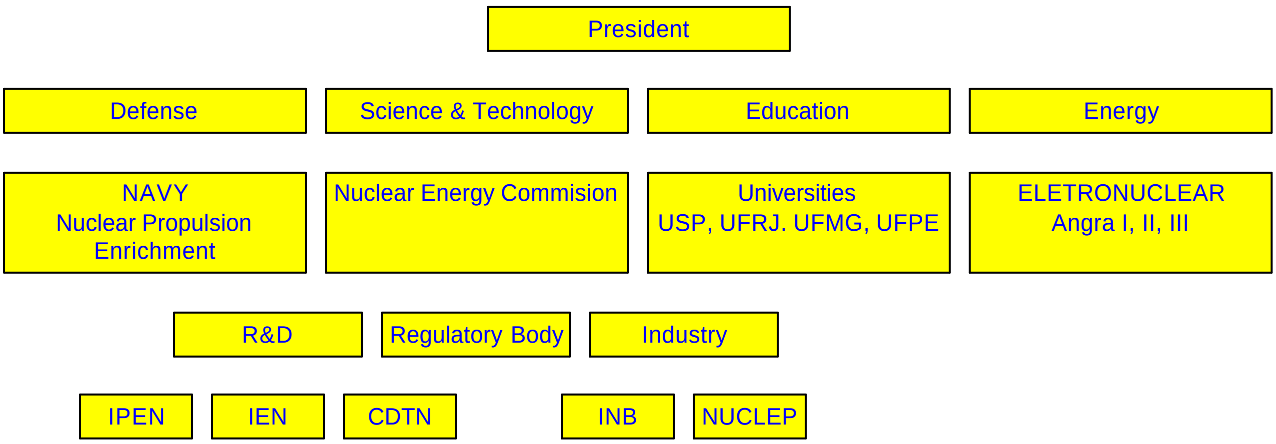
Uranium Mines and Reserves

- The INB is responsible by prospecting and mining uranium, and fuel fabrication. In its Industrial complex, INB has installations to convert enriched UF_6 to UO_2 (pellets), and assembly the fuel elements with Siemens and Westinghouse technology. Recently a contract was signed with the Brazilian Navy to install an enrichment facility by ultra centrifuge with capability to provide enriched Uranium for the 2 NPP. The highlights in the uranium prospecting was the consolidation of Itataia reserve (142,500 tons of uranium), and new reserves in the Amazon's region, with an estimated potential of 150,000 tons. Also the Lagoa Real/Caetité mine is operating with a capability to provide 400 tons/year. Related with Thorium resources, Table 2 illustrates the potential resources in Brazil. Also INB is processing Thorium from monazite sand, mainly to extract rare earths elements
- Besides generation of energy and the fuel cycle industry, R&D and products and services, mainly medical radioisotopes, are being conducted by the Research Institutes of the Brazilian Nuclear Energy Commission (CNEN), Universities, and the Navy develops a nuclear program aiming nuclear propulsion. The regulatory activities are under CNEN, however completely independent of the R&D branch. The structure of the Brazilian Nuclear sector is illustrated. It is important to emphasize that by constitutional law all nuclear activities are conducted by the State.

Table 2 . Thorium Potential Resources in Brazil

Occurrence	Associated Mineral	Average Content(%)	Measured, t ThO_2	Estimated, t ThO_2
Coastal deposits	Monazite	5	2,250	-
Morro do Ferro(MG)	Thorite and others	1 to 2	35,000	-
Barreiro, Araxa(MG)	Pyrochlore	0.09	-	1,200 000
Area Zero, Araxa(MG)	Pyrochlore	0.09	30,000	-
Aluvial and Pegmatite	Monazite	5	3,000	2,500
Total			73,500[a]	1,202,500

[a] Including 3,500 t of Monazite sand of INB



3. THE STATUS ON FAST SYSTEM R&D

Historical Background

- The interest on Fast System started in Brazil in the late sixties, when cooperation with France was established. In that time (1972) a small Na loop (150 KW) was constructed at IEN (Institute of Nuclear Engineering). Later on, in the beginning of the seventies IPEN had an agreement with General Atomic to develop gas cooled reactors (HTGR, GCFBR). From this cooperation a Helium loop was constructed, graphite ZPR split table was designed, and many components were developed (instrumentation, split table).
- In 1975 a huge technology agreement was signed with German, to construct 8 PWR(ANGRA II, III were the only reactors which still remained from this agreement), and a complete fuel cycle industry, including enrichment by Jet Nozzle , and reprocessing. INB was result from this agreement. Such plans and program deactivated many R&D programs, such the one described above.
- During the eighties given the focus of IEN in Fast Reactors, an agreement with Italy (ANSALDO) was signed. Such agreement resulted in an acquisition of a sodium loop (1981) that never had been assembled. Also a concept of a binary fast breeder reactor using a Th/U fuel cycle was developed, and a trial to initiate a national program (electrochemical reprocessing, HT-9 development,, U-Zr metallic fuel, a prototype of an experimental fast reactor,60 MW_{th}) was proposed.
- During the nineties a complete change in the Nuclear Police was implemented, and strategically the country abandoned programs and projects not related directly with short term social and economical interest. It is important to notice that such police was actually not restricted to the Nuclear Sector, and it was a consequence directly of a new globalization model, in which developing countries, like Brazil, put priorities in their economies, privatize many fields and the State concentrated in technological fields where they have international competition (such as agriculture and life science in the Brazilian case), or with high social demand(e.g. Application of Radiation and Radio isotopes) and leaving the other sectors with a low priority . Without judging such model, the direct consequence was that projects with long term life time (such as Fast Reactors) were aborted, and the Human Power and knowledge related with these fields declined, if not disappeared. We believe that such phenomena is not only restricted to developing countries like Brazil, but also an international tendency, and only those countries with vision and polices of medium and long term remain competitive(e.g. India, Korea, China).
- Nowadays, only academic activities still remain, and trials to convince the police makers to invest in such fields or to participate more actively in International Initiatives, even with a small degree of contribution. These activities will be reviewed in this paper. Finally, it is worthwhile to mention that although the low priority presently given by the government (CNEN) to projects and activities of long term, such as in fast reactors and ADS, the intention to follow up such innovative systems still remains, and Brazil is participating in international initiatives such as the IAEA INPRO, GENERATION IV, and still participating in the TWG-FR.

An Integral Fast Lead Reactor Concept for Developing Countries

- This study was performed by A. Santos and J. Nascimento, and it was a Ph.D thesis presented at São Paulo University. This work had been already presented at previous meetings of the TWG-FR and the main result published at NUCLEAR TECHNOLOGY, VOL 140, December, 2002.

- The concept was proposed to be used by developing country, and associated the best characteristics of the Russian and American Fast Lead Reactor. The reactor starts with metallic U-Zr and shifts cycle-by-cycle to the U-TRU-Zr fuel with an average burn up of 100 MWD/ Kg. Besides energy generation, the concept also proposes its utilization in high temperature industrial process.

- The main core parameters were evaluated in the first and in the equilibrium cycles as a function of the pin diameter(6.35-10.4 mm), pin pitch-to-diameter(p/d)[1.308 to 1.495], and reactor power (300-1500 MW_e), as illustrated in figure 1 and tables 3 and 4, using a calculation methodology illustrated in figure . The main results of the core neutronic characteristics were published in Nuclear Technology and will not be repeated here.

- Later on optimization was performed, and the concept converges for a 350 MW_e Integral Lead Reactor, and the results were presented at the GLOBAL 2003. Here only the main neutronic characteristics are illustrated in table 5, and the ILR-350 core is illustrated in figure 2.

- The study performed demonstrated that a lead-cooled metallic-fueled integral type reactor of 350 MWe named ILR-350 has very attractive safety characteristics such as negative void reactivity and burn up swing lower than the effective delayed neutron to mitigate the TOP accident. The loss-of-flow accident is protected by use of passive means like the gas expansion module and the ultimate safety device. Therefore, the ILR-350 has good inherent and passive safety characteristics. The integration of fuel cycle activities in one site guaranties a suitable environment safety and proliferation resistance. The efficient partition/transmutation scheme used possibilities a clean technology from the radioactive point of view. The question of a high peak fast fluence, that is characteristics of lead-cooled reactors loaded with low enriched fuel, is solved with an adequate fuel management strategy, that is, the fuel assemblies that are in a peak fluence position are shuffled to lower fluence positions. Finally, the necessary number of electro refining cells to make one fuel recharge is estimated and this number is six. The concept promises to be a sustainable energy generation center due to the use of fuel regeneration and reprocessing with minimum radioactive waste. Therefore, it is a suitable technology for the next generation reactor.

Power (MWe)	300	900	1500
	# Assemblies		
Inner core	66	204	342
Outer core	60	180	288
Control	13	25	43
Blanket	48	78	96
Neutron shield	114	174	210
Gamma shield	66	96	114

Table 3: Fuel Assembly Characteristics

Pin(mm)	6.35	6.35	6.35	8.12	8.12	8.12	10.4	10.4	10.4
p/d ratio	1.308	1.417	1.495	1.308	1.417	1.495	1.308	1.417	1.495
Pitch(mm)	149.5	160.6	169.1	188.2	202.9	213.9	238.4	257.4	271.6
Vol.fraction									
Fuel(%)	31.7	27.5	24.8	32.7	28.2	25.3	33.5	28.7	25.8
Structure(%)	21.8	19.6	18.1	20.4	18.2	16.7	19.1	16.9	15.5
Coolant(%)	46.5	52.9	57.1	46.9	53.6	58.0	47.4	54.4	58.7

Table 4:. ILR-350 Neutronic Characteristics for Three Batches Recharge Strategy

Cycle	First	Equilibrium
Enrichment IC/OC[a] (w/o)	14.3/21.0	14.2/19.3
Burnup reactivity(% Δk)	-4.21	-0.73
β_{eff} (10^{-3})	7.66	3.96
Breeding ratio	0.65	1.10
Peak Fast fluence (1023 n/cm2)	1.49	1.83
Doppler coefficient(10^{-3})	-3.10	-2.74
Core mass (t) BOC/EOC[b]		
$^{235}U + ^{238}U$	24.4/23.0	20.6/19.8
TRU	0/0.49	4.00/3.95
Pu	0/0.49	3.80/3.75
MA	0/~0	0.13/0.14
Blanket mass (t) BOC/EOCb		
$^{235}U + ^{238}U$	12.7/12.5	12.7/12.5
TRU	0/0.10	0/0.11

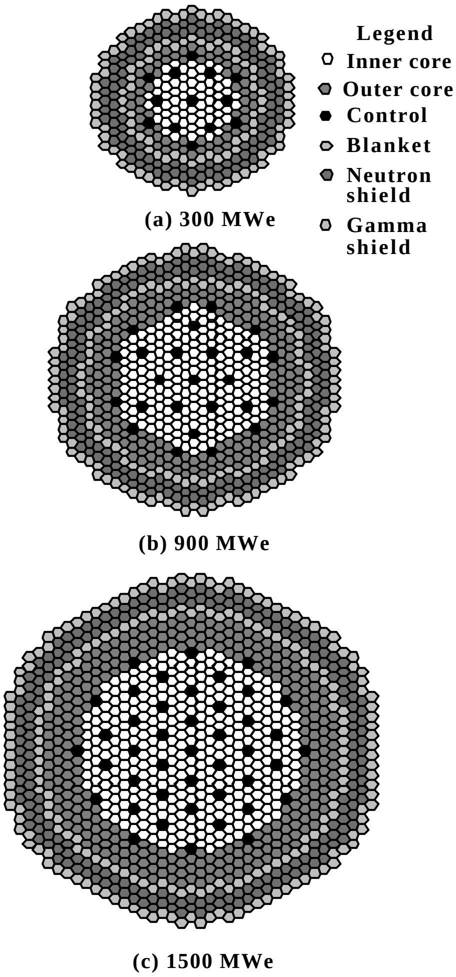


Figure 1: ILR Core Models

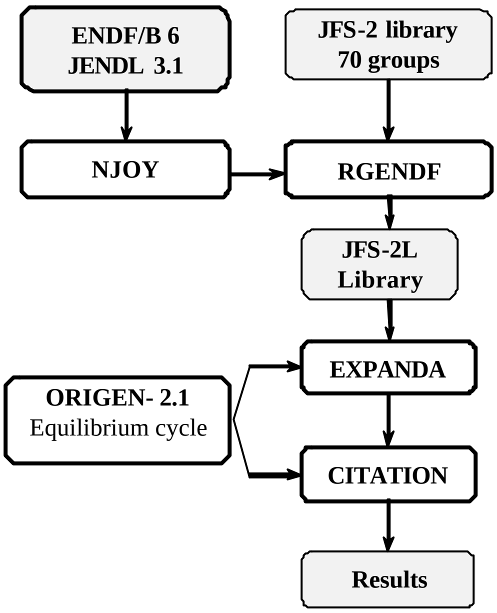


Figure 2: Calculation System Flow Chart

Region	# Assembly
Inner and outer cores	99 - 90
Blanket	102
Gamma shielding	120
Neutron shielding	144

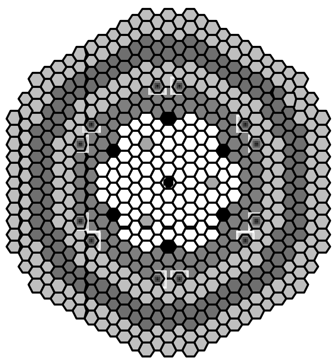
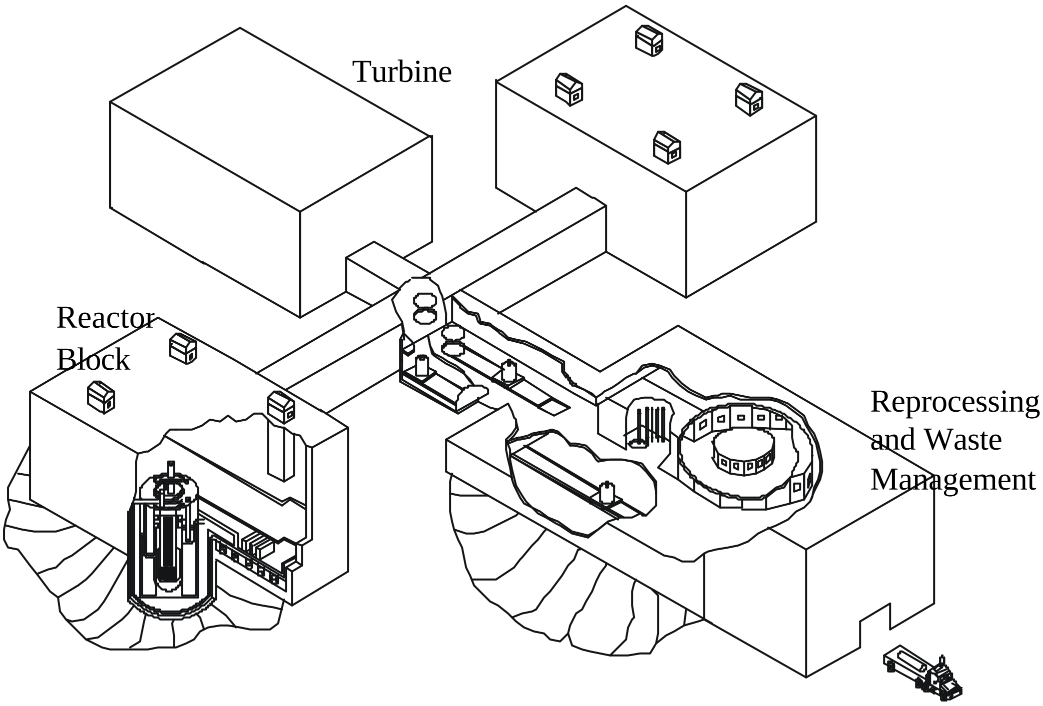


Figure 3: ILR-350 Core Model



Figue 4: ILR-350 Basic Module artistic conception

ADS Conceptual Studies, Calculation Methodology and Proposals of R&D programs and International cooperation

Motivation

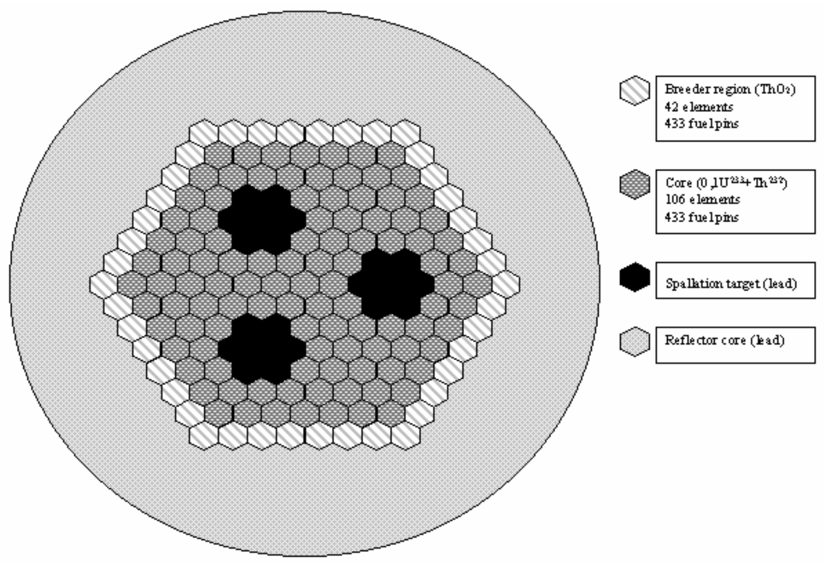
- To start in Brazil a R&D on ADS(motivated by Rubbia's visit in Brazil in the late 90)
- Utilization of Thorium and Gas cooled Reactors(previous studies already existed)
- To attract new students in innovative systems and keep the know how in Reactor Physics
- The nomination of the author as a Brazilian representative in the TWG-FR

ADS Conceptual Studies and Calculation Methodology

- To start activities on ADS, the first step was to propose an alternative concept on Rubbia´s concept. These preliminary ideas had been published in a Brazilian Journal , and in short they were:
  1. Alternative concept from Rubbia proposal includes more than 1 point of spallation to reduce Accelerator requirement, flat the power; Pb Solid cooled by He.
  2. Two lines: one using an hexagonal array of pins(with the same core as the Rubbia´s core,). and another using refueling on line similar of the CANDU.

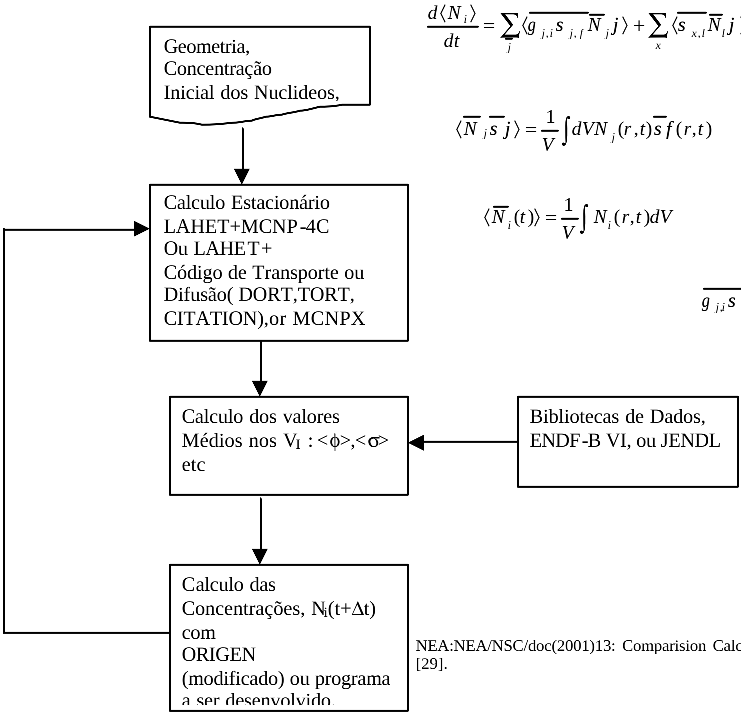
Both imbibed in a solid Pb cooled by He. These ideas had been reported in the TWG-FR 2001 (Kazakhstan), 2002 (Karlshure), and 2003 (Korea), and in conferences and papers .

- To demonstrate the feasibility of these ideas a Ph.D thesis was developed by Sergio Anefalos, and the first step were to introduce calculation methodologies not available in Brazil. So, the LAHET code system and its coupling with the available version of MCNP(4C) was introduced and the Rubbia´s results and some experimental Benchmark on Thorium-232 and Uranium-233 were performed. These results were presented at previous TWG-FR meetings, and demonstrate that conceptually the ideas were feasible (although later on we realize that at FZK the idea to utilize more than one point of spallation was also investigated, and there was some technological criticizes in the proposed concept). The results of Anefalos thesis was submitted for publication at Nuclear Instruments and Methods. Since these results were presented at several previous meeting (ADOPT 2003) here we just summarize the main results:



Power	105 MW_{th}
Accelerator	Cyclotron, E_p=500MeV, I_p=3 Ma
Multiplicity(n/p)	10.06
Source Criticality Factor, (M-1)/M	0.98
Target	Liquid Lead(windowless)
Multiplication Factor	0.97
Gain	70(E_p=500 MeV); 110(1GeV)
Radial Peak Factor	1.854
Specific Power(W/g)	2.58
Power Density(W/cm^2)	25.82
N_{233}/N_{232}	0.107
Fuel	$0.1^{233}UO_2 + {}^{232}ThO_2$

- Presently(2004), a Ph.D thesis(Ms Sara Mongelli) was initiated to introduce burn up and transmutation calculation and to demonstrated the in core fuel cycle of the MEA concept, and the calculation strategy is as illustrated bellow. The calculation methodology is going to be checked against the numerical NEA benchmark. Also a implementation and tests of MCNPX, recently received from RSICC, is being implemented by Anéfalos and Mongelli. Another activity is a home made code using Mathlab to solve the transmutation chain as illustrated in figure 5. Also the utilization of SCALE 4.4a, including the generation of the multi group microscopic cross section typical of ADS using BONAMI, NITAWL and XSDRNPM to be used by ORIGEN-ARP is planned to be a thesis of a undergraduate student (Mr. Thiago Carluccio) as an alternative calculation methodology and a study of the Th/U fuel cycle in a double strata. All these works are academics and intended to form students (a Scientific foundation, called FAPESP is providing support to develop these works).
- As we reported mostly of the activities are academic, and not related with a national program or project. Of course we are looking forward to participate in the planned IAEA CRP on "Benchmark Analysis on Data and Calculation Methods for Accelerator Driven System (ADS) Source Related Neutronic Phenomenology with Experimental validation", in order to qualify and inter compare our methods with the international community and join the effort leader by the IAEA by providing an international umbrella for information exchange and collaborative R&D in the area of advanced technologies and associated fuel cycles for transmutation of actinides and long lived fission products as a long term option for a sustainable nuclear energy development.



$$\frac{d\langle N_i\rangle}{dt} = \sum_j \langle \overline{g_{j,i} s_{j,f}} \overline{N}_j j\rangle + \sum_x \langle \overline{s_{x,i}} \overline{N}_i j\rangle + l_k \langle N_k\rangle - \overline{\langle s_{f,i}} \overline{N}_i j\rangle - \sum_y \langle \overline{s_{y,i}} \overline{N}_i j\rangle - l_i \langle N_i\rangle$$

$$\langle \overline{N}_j \overline{s}\, j\rangle = \frac{1}{V}\int dV N_j(r,t)\overline{s} f(r,t) \qquad f(r,t) = \int_0^\infty \Phi(r,E,t)dE$$

$$\langle \overline{N}_i(t)\rangle = \frac{1}{V}\int N_i(r,t)dV$$

$$\overline{g_{j,i} s_{j,f}} = \int_0^\infty g_{j,i}(E) s_{f,i}(E)\Phi(r,E,t)dE \Big/ \int_0^\infty \Phi(r,E,t)dE$$

$$\overline{s}_{x,i} = \int_0^\infty s_{x,i}(E)\Phi(r,E,t)dE \Big/ \int_0^\infty \Phi(r,E,t)dE$$

NEA:NEA/NSC/doc(2001)13: Comparision Calculation for na Accelerator Driven Minor Actinide Burner [29].

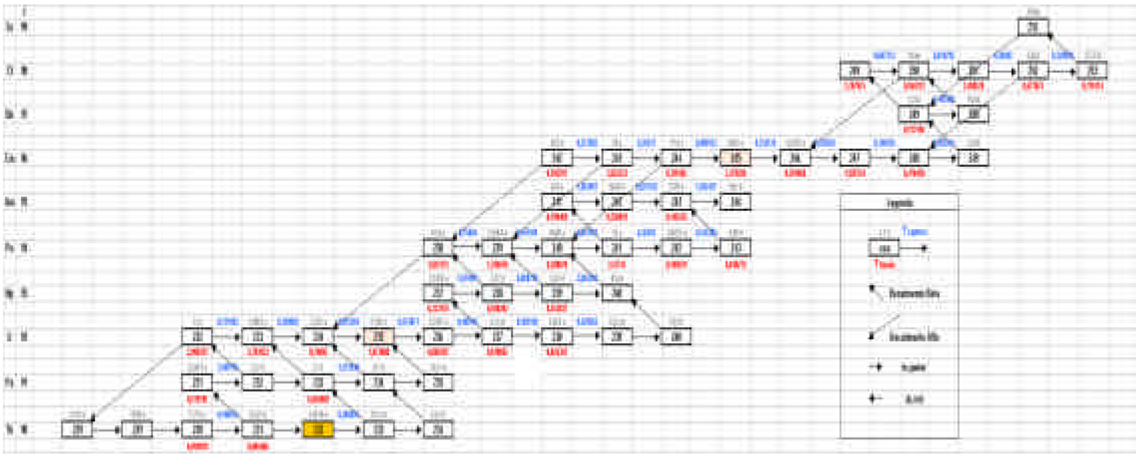
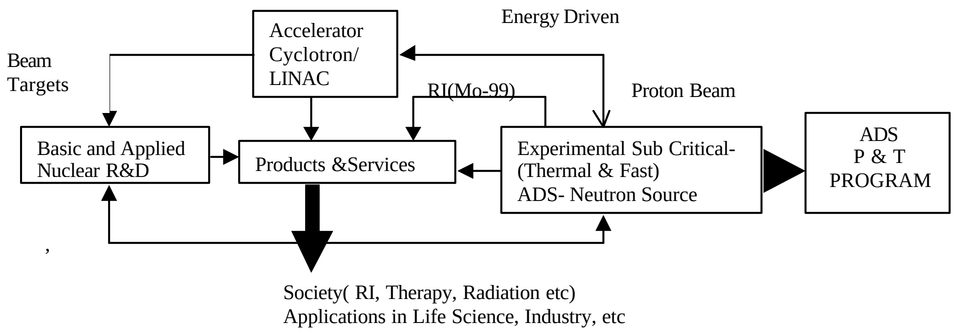


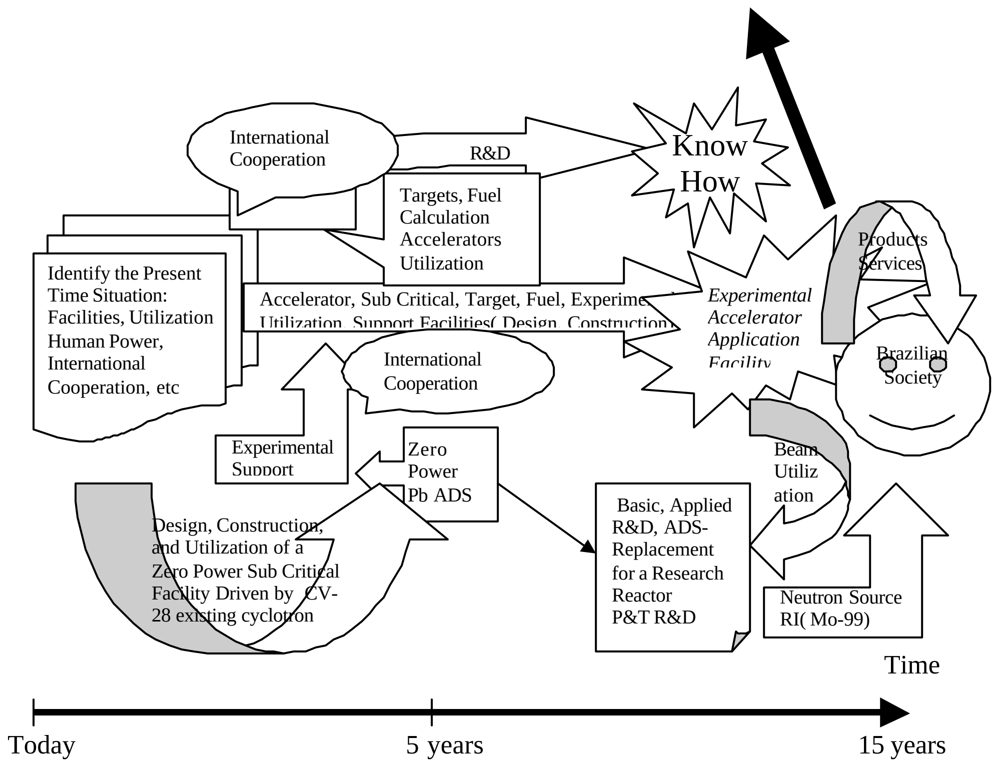
Figure 5: Transmutation Chain, U and Th.

Proposals of R&D programs and International cooperation

- A proposal of a program on accelerator utilization for basic and applied R&D, products and services (e.g. radio isotopes, proton therapy), and to drive a low power research reactor ADS were made together with IFUSP. This proposal includes a road map development, which had as a milestone a zero power ADS driven by small accelerators. Besides a document sent to the governmental institutions, papers were presented at the V Latin American Symposium on Nuclear Physics (2003), in the Brazilian Meeting on Nuclear Physics (2002), and a paper containing the proposal was published at the Brazilian Journal of Physics (2003) . Also, the Brazilian Status on ADS R&D were presented at ADOPT 2003 held at SCK-CEN, Belgium, and a paper to PHYSOR 2004 was accepted for publication **(**The utilization of a small accelerators to drive a zero power sub critical ADS**)**.
- International contacts were established through a scientific visit (National Consulting) supported by an IAEA TC Project (BRA/0/018-92-03). This visit included the participation in International Workshop on P&T and ADS Development (ADOPT 2003), and meetings with CEA-France personal in Paris Headquarters and in Cadarache to discuss topics of a bi lateral agreement between CEA and CNEN, including potential cooperation in ADS. Also a visit to MAZURCA facility (MUSE Experiment) was realized. The participation in the IAEA Workshop on “Technology and Applications of Accelerator Driven System (ADS), held at ICTP, Trieste, Italy, October 2003, and a Technical Meeting (TM) on “Review of Solid and Mobile Fuels for Partition and Transmutation Systems”, hosted by CIEMAT, Spain, in December, 2003 were also activities performed.

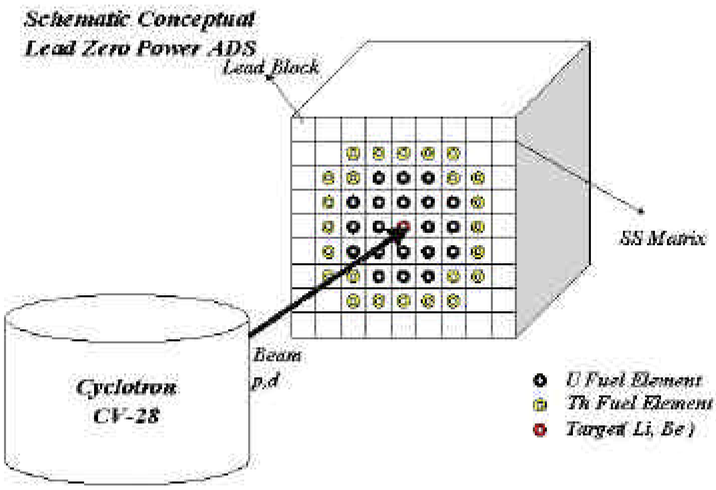
Accelerator Utilization Program
A preliminary Road Map

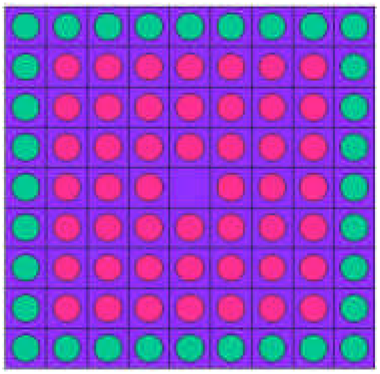




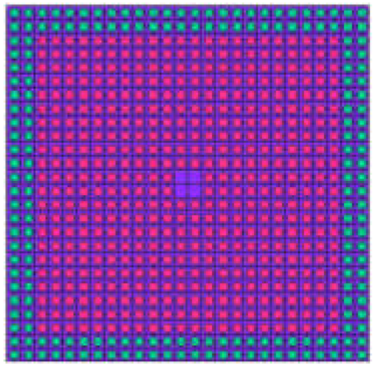
The utilization of a small accelerators to drive a zero power sub critical ADS

- Power and Waste Burner ADS are still on the stage of development, and although several concepts are underway, none of them have been built. R&D activities are being developed in several fields, such as in Reactor Physics, Nuclear Data, Target, Fuels, Thermal Hydraulics, Spallation Physics, Transmutation, etc .
- For Reactor Physics and Nuclear Data, experimental facilities operating at zero power (few watts) are being operating, or on planning, with the purpose to provide experimental benchmark on calculation methodology and nuclear data. Given the conceptual modified fast energy ADS under study, it is proposed a solid lead zero power ADS, using U/Th fuel and using as neutron source proton or deuterium from the CV-28 in a Be or Li targets, or 14 MeV neutron from a D-T reaction from a 400 KV existing Van de Graff. The proposed conceptual sub critical is illustrated, and in short it consist of lead blocks supported by a SS structure, containing holes in which the fuel elements are inserted. Given the low power, it is cooled by air natural convection.
- IPEN operates 2 cyclotrons; the CYCLONE 30, from Ion Beam, dedicated exclusively to RI production (e.g. ^{18}F, ^{123}I, ^{67}Ga, ^{201}Tl, ^{111}In), and CV-28, from USA Cyclotron Co., which is a compact, isochronous, multi particle radiation source where protons, deuterons, 3He++ and alpha particles can be accelerated with variable energies (current) up to 24 (40-60 μA), 14 (50-100 μA), 365 (5-50 μA) and 28 MeV (6-40 μA), respectively. Besides, IPEN also operates a 400 KV Van de Graff (VG) accelerator, which accelerates deuterons. The CV-28 or VG accelerators could be used as an external neutron source to drive a zero power ADS. Using the CV-28, fast neutrons (5-6 MeV) could be produced from the nuclear reactions of protons or deuterons with Beryllium or Lithium targets [10], with integrated intensities between $10^{11} – 10^{12}$ n/s and the VG can produce fast neutrons (14 and 2 MeV) from the D-T and D-D reactions with intensities $10^{8} –10^{9}$ n/s. Although both accelerators needs some refurbishing in order to reach full operational condition.
- Given the availability of these accelerators, a feasibility study to use them to drive a zero sub critical ADS was realized, and a conceptual project is underway. The zero power sub critical reactor would be used to simulate the conceptual ADS described before and provide experimental support for it.

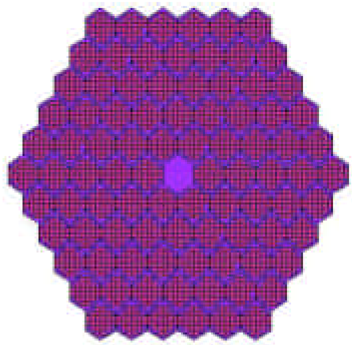




Case 1

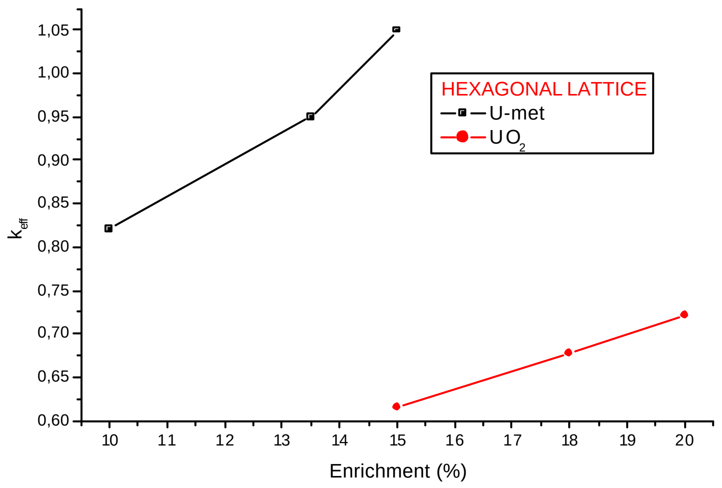


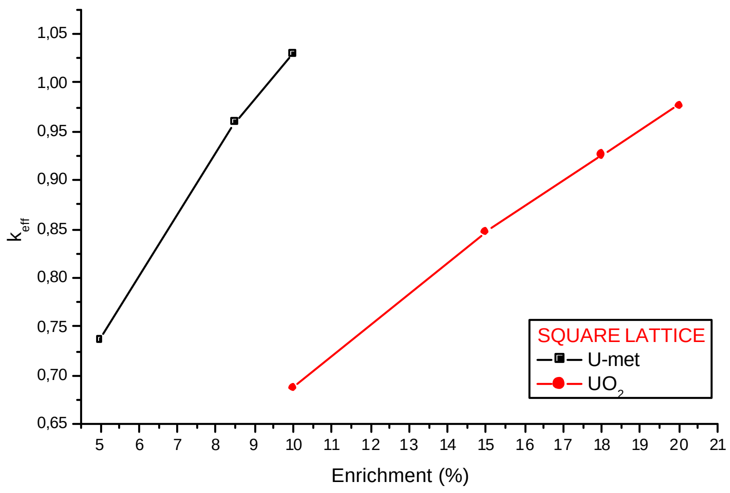
Case 2

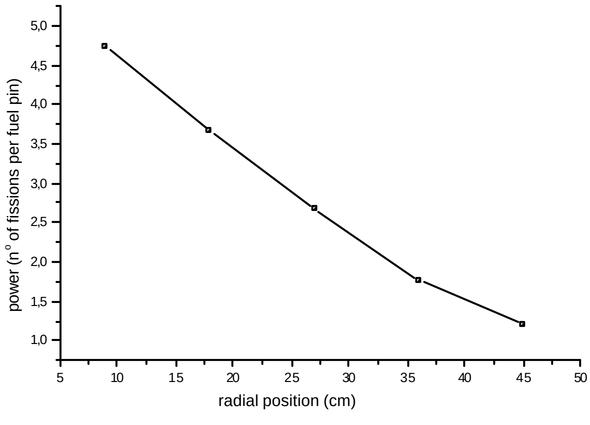


Case 3

	Lattice	k_{eff}		Fuel mass (ton.)		Enrichment (%)		Power (W/μA)	
		Umet	*UO_2*	*Umet*	*UO_2*	*Umet*	*UO_2*	*Umet*	*UO_2*
Case 1	square	0.95	0.93	7.2	3.8	9	20	0,1	0.02
Case 2	square	0.96	0.95	10	5.3	8,5	19	50	18
Case 3	hexagonal	0.95	0.71	6.5	3.4	13.5	20	2732	164







Radial power distribution simulated for Case 2.

MULTICOLLISION MONTE CARLO CODE FOR INTRANUCLEAR CASCADE AND EVAPORATION

THE CRISP PACKAGE

- As a result of a common effort of Brazilian research groups, IFUSP and CBPF, the development of ***MCMC*** (intranuclear cascade) and ***MCEF*** (evaporation) codes became a reality. These two codes utilize the Monte Carlo approach in order to study the nuclear reactions. The coupling between the MCMC and MCEF codes originates the **CRISP** (*Colaboração **RI**o – **S**ão **P**aulo*) package.

- The CRISP package utilizes an algorithm that describes a many-body intranuclear cascade and evaporation/fission competition process, considering dynamic evaluation of the fermionic multi collision process

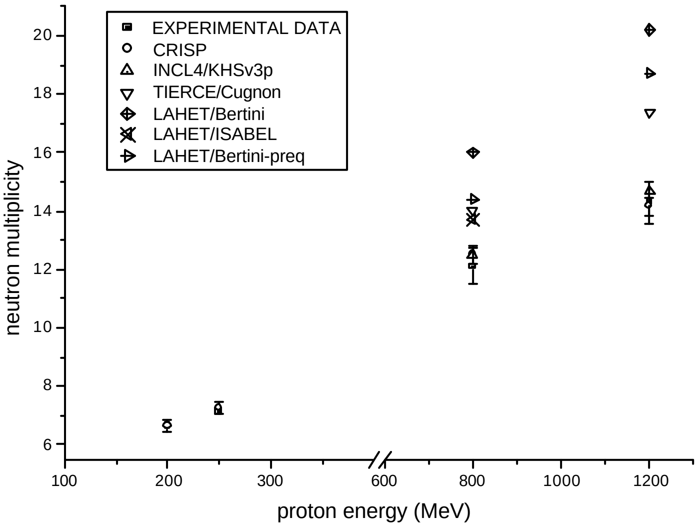
- The code takes into account the possibility of neutron, proton and alpha particle evaporation and gives information about neutron and proton multiplicities, angular distribution and energy spectra. Some applications of CRISP package are:

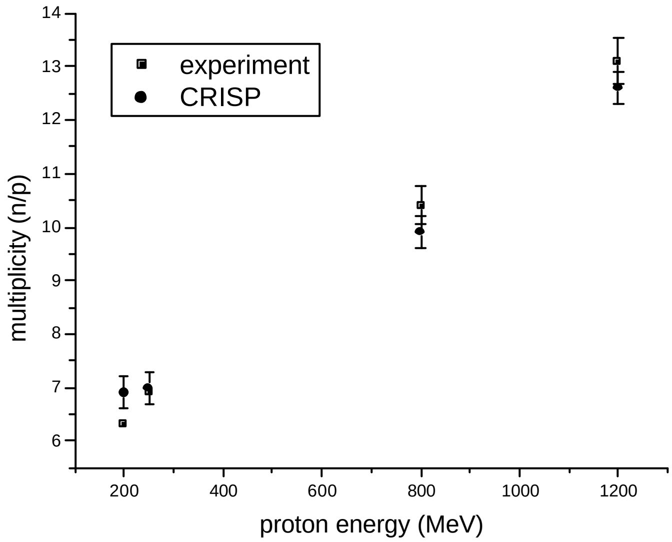
    - Study of spallation reaction;
    - Applications of nuclear reactions in the nuclear reactors development, particularly in the Accelerator Driven Systems;
    - Study of the properties of baryons;
    - Application in proton-therapy and BNCT.

- Some references about CRISP can be found in:

[1] A. Deppman et al., Phys. Rev Lett. 87 (2001) 182701.
[2] A Deppman et al., Nucl. Instr. Meth. B211 (2003) 15-21.
[3] A. Deppman et al., Comp. Phys. Comm., 145 (2002) 385.
[4] S. B. Duarte et al., Phys. Rev. Lett. 49 (1982) 538.
[5] M Gonçalves, S. B. Duarte et al. Phys. Lett. B 406 (1997) 1.
[6] A. Deppman et al., Phys. Rev. C66 (2002) 067601.

- Some preliminary results are shown:





Neutron multiplicities in ^{208}Pb for 200-1200 MeV protons (left). The CRISP result is compared to ICRU database (data for 200 and 250 MeV) and experimental data [A]. Neutron multiplicities in ^{184}W for 200-1200 MeV protons (right). The CRISP result is compared to ICRU database (data for 200 and 250 MeV) and experimental data [A].

Energy	**Expt.**	**CRISP**	INCL4 KHSv3p	TIERCE Cugnon	LAHET Bertini	LAHET ISABEL	LAHET Bertini-preq
			Pb T_{lab} = 800 MeV				
0 - 2 MeV		**4.24**	3.3	4.9	5.61	5.13	5.37
2 - 20 MeV	**6.5**	**6.36**	6.8	6.9	8.63	6.63	7.12
20 MeV - E_{max}	**1.9**	**2.06**	2.5	2.2	1.75	1.92	2.13
Total		**12.7**	12.5	14.0	16.0	13.7	14.04
			Pb T_{lab} = 1200 MeV				
0 - 2 MeV		**4.65**	3.4	5.8	6.35	--	6.02
2 - 20 MeV	**8.3**	**6.98**	8.1	8.9	11.44	--	9.86
20 MeV - E_{max}	**2.7**	**2.47**	3.1	2.8	2.45	--	2.83
Total		**14.1**	14.7	17.4	20.2	--	18.7

Neutron multiplicities in proton-induced reaction on Pb nuclei (second column) compared with the predictions of our model (third column) and those from other models [A].

[A] A. Boudard et al., Phys. Rev. C 66 (2002) 044615.

CONCLUDING REMARKS

- As concluding remarks, we notice that although the activities in development are academics and just in the beginning, in the last years (2002-2003) there was significant progress, by increasing the number of persons involved in the research field (Fast Systems), number of publications in international journals, participation in national and international conferences and meetings, and international contacts. The recent initiative of CNEN to open scientific forum to discuss topics of nuclear interest, including Advanced and Innovative Nuclear System, is a hope that in a near future we may have some official program. Also the participation in the IAEA CRP "Benchmark analysis on data and calculation methods for ADS source related neutronic methodologies" would be an opportunity for information exchange and international collaborative R&D.
- Finally we offer to our colleagues of the TWG-FR to host the 38th Annual Meeting of the TWG-FR in 2005.

"After all, three things remain: the assurance that we are always beginning…the assurance that we need to keep going…the assurance that we will be interrupted before finishing…Therefore, we must make: from every interruption, a new direction…from every fall, a dance…from the fear, a stair…from the dreams, a bridge…from the search, an encounter"

(Fernando Sabino, a Brazilian Writer, translated by Ting&Maiorino)