RESEARCH AND INDUSTRIAL PROGRAMS ON ADS IN ITALY

G. Gherardi & S. Monti

ENEA Bologna

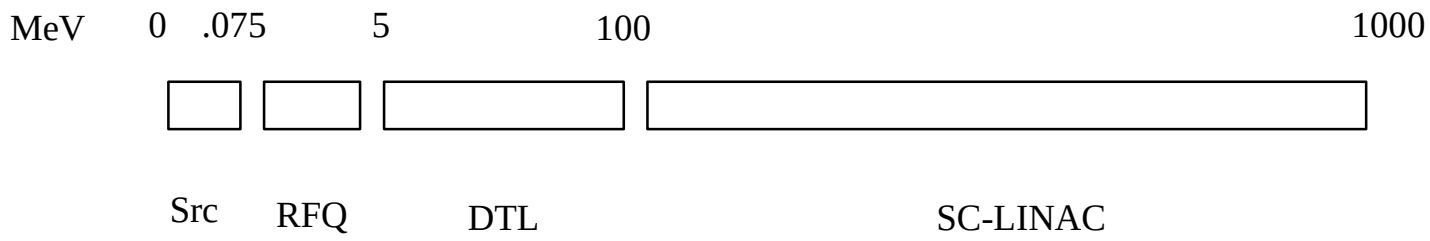
two main programs

- TRASCO: a basic R&D program (promoted by ENEA and INFN)
  - Aim: study physics & develop technologies to design an ADS for nuclear waste transmutation
  - Close reference to C. Rubbia proposal (EA)

- Industrial Program (an Ansaldo initiative in collaboration with CRS4, ENEA, INFN)
  - short term activities in the Italian context to issue a Reference Configuration Description of the ADS demonstration prototype for nuclear waste transmutation; main supporting R&D needs will also be assessed;
  - medium term activities in an European context with the aim to perform the detailed engineering design, the realisation phase and the commissioning of the demonstration prototype along with all the supporting parallel R&D deemed necessary.

program parts

- TRASCO-AC : Accelerator (managed by INFN):
  1 GeV-30 mA proton linac



- TRASCO-SS: Subcritical system (managed by ENEA): EA-like assembly

efforts and final goal

- All subsystems addressed, but, as resources are limited, efforts are concentrated on some significant and qualified activities, which can foster competitivity of Italian industrial and research system in the international context

- Final goal: participation in an international project for the construction of an ADS DEMO, like the EA, for waste transmutation

Main objectives of the research program

- Conceptual design of the 1 GeV - 30 mA proton LINAC.
- Design and construction of the proton source,the first section of the RFQ and prototypes of SC cavities.
- Development of methods and criteria for the neutronics, thermal-hydraulics and plant design for an EA-like sub-critical system, as well as specific aspects related to the safety analysis of this type of nuclear installation.
- Material technologies and development of components to be used in a plant in which lead or lead-bismuth will act either as primary target and coolant.
- Experiments to validate and verify proposed technology for material compatibility with Pb and Pb-Bi alloy.

participants, duration and costs

- participants
  - ENEA and INFN, jointly responsible
  - CINEL, CISE, CRS4, FN, ANSALDO, HITEC&SISTEC, SAES-GETTERS, ZANON
  - CIRTEN, INFM, University of Bologna

- duration: two years

- total cost: 17.1 GL (about 10 M$)*
  - 8 GL allocated by MURST
  - 9.1 GL provided by participants

  *additional funds (1.1 GL) and materials from INFN

subprograms

- Proton source
- Low and medium energy accelerator section
- High energy accelerator section
- Neutron production for material characterisation
- General design criteria and safety classification
- Neutronics and transmutation efficiency
- Thermal-Hydraulic analysis
- Beam window technology
- Material technology and compatibility with Lead and/or Lead-Bismuth alloy

INFN labs involved

- Laboratorio Nazionale del Sud (LNS)
  - proton source
- Laboratori Nazionali di Legnaro (LNL)
  - RFQ
  - DTL
- Sezione di Milano - Lab. LASA (MI)
  - SC linac
- Sezione di Genova (GE)
  - SC cavities
- Sezioni di Napoli (NA), Bologna (BO), Bari (BA)
  - halo studies

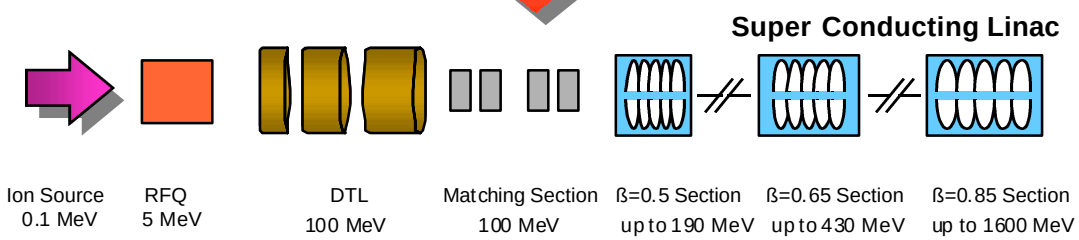
ENEA Labs involved

- Bologna
  - nuclear data (CDN), reactor physics, thermal-hydraulics, fuel cycle, safety and system analysis, plant design
- Brasimone
  - experimental facilities for Pb and Pb-Bi material compatibility tests
- Rome
  - neutron kinetics, pyrochemical treatment, material developments
- Frascati
  - MC analysis

The TRASCO accelerator

Approach Considered Here

- Ion Source
  - Existing Technology
  - Operated at 100mA
- RFQ acceleration to 5 MeV
  - Existing Technology @ 350 MHz
  - Tests at > 100 mA
- DTL-like acceleration to 100 MeV
  - Existing Designs @ 350 MHz
  - CW operation!
- SC LEP-like accelerator in 3 sections



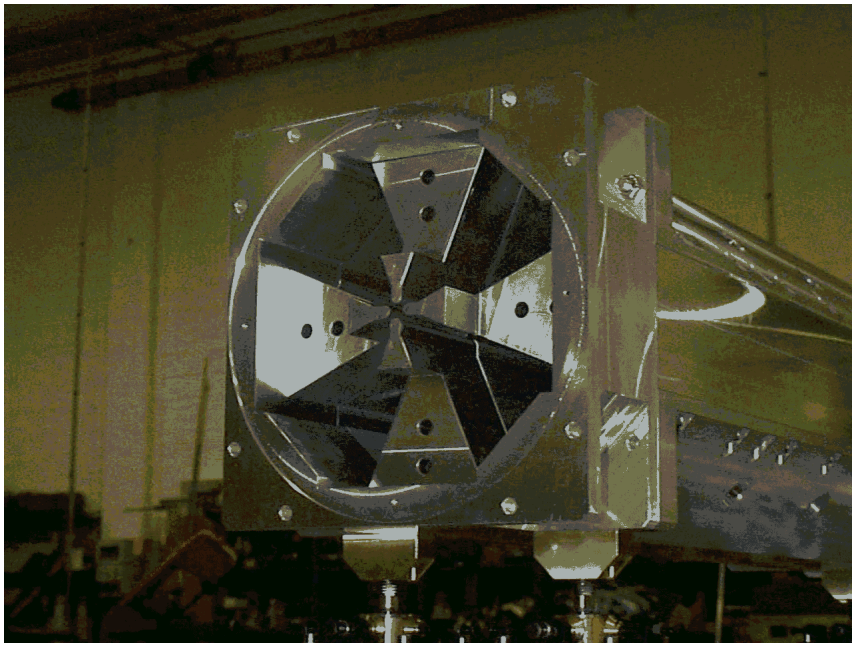
RFQ and DTL

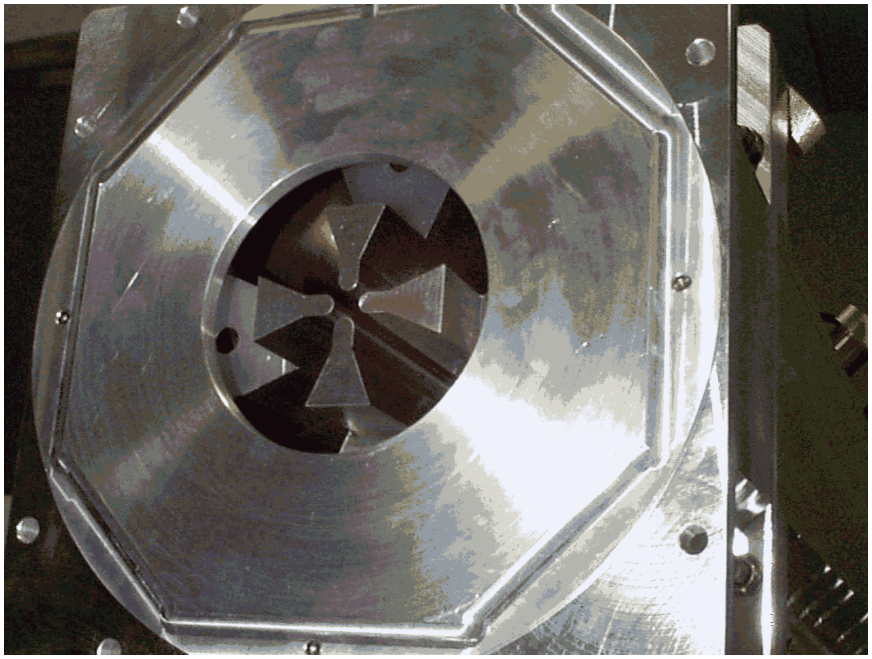
- A reference preliminary conceptual design of the medium energy section, which includes an RFQ and a DTL (352 MHz), has been determined since some time; 30 mA or more can be accelerated.

- A more detailed design work of the RFQ started from several months and a 3 m long aluminium model of the RFQ has been built for RF field stabilisation tests.

RFQ model

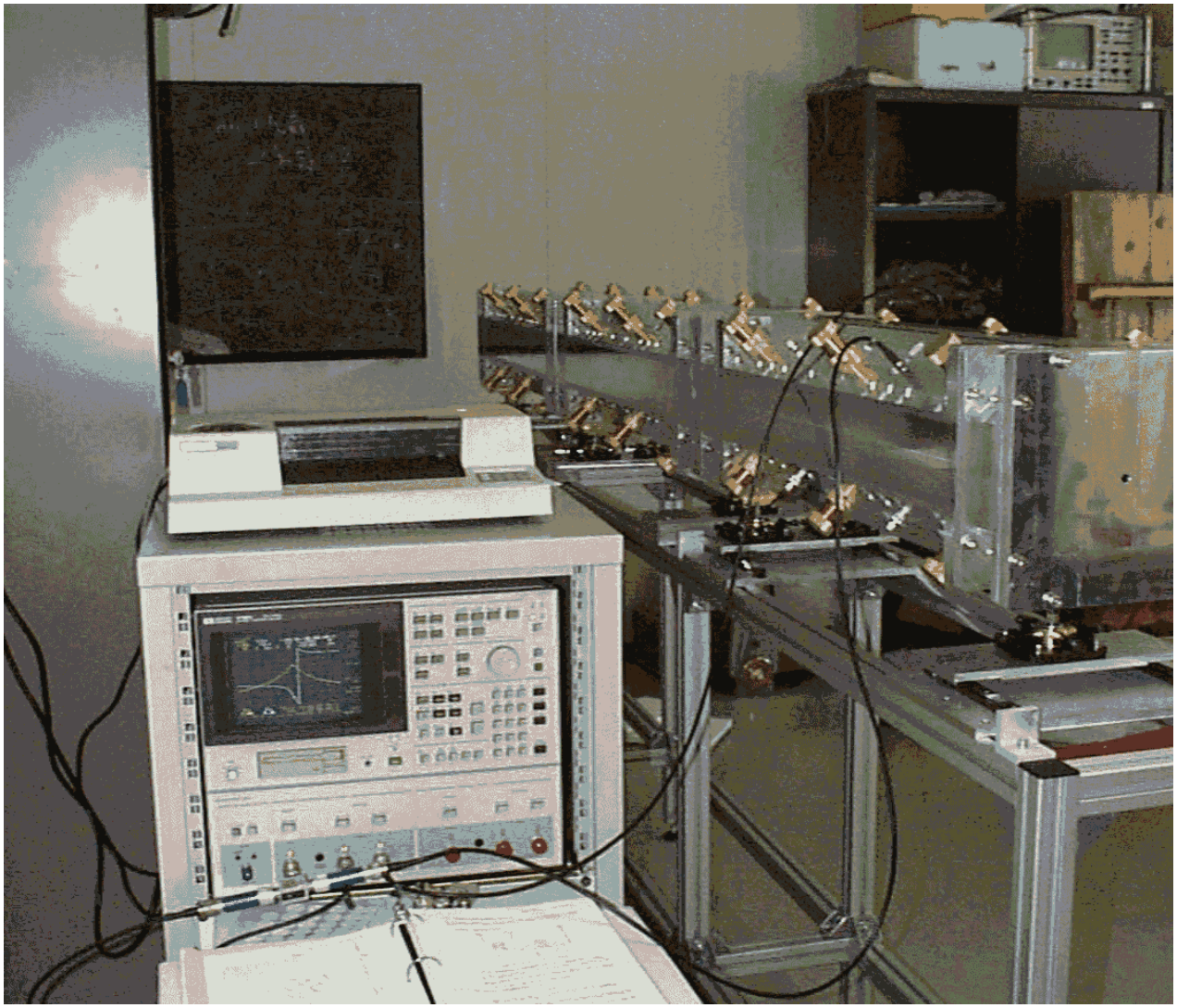
A 3 m long aluminum model of the RFQ has been built for RF field stabilization tests.





(RFQ cross-section and coupling cell)

Three segment RFQ during RF measurements



s.c. medium energy section

- Preliminary studies of an Independently Phased Superconducting Cavity Linac (ISCL) to be used instead of the traditional DTL have been also done.
  - The ISCL is an accelerator similar to those used for low energy heavy ion in several nuclear physics laboratory, like the Italian LNL. In the present case it has to be adapted to a much higher beam intensity and to a wider velocity range of the accelerated particles.
  - Various approaches have been checked, like single and double gap cavities, 176 and 352 MHz.
  - The most promising design [2] of a 352 MHz ISCL, able to accelerate a 30 mA proton beam from 5 MeV up to 100 MeV, is based on the so-called “reentrant cavities”, that are modified pillbox cylindrically symmetrical and, therefore, theoretically dipole free.
- Many points of this design work are very preliminary but can be used for cavity R&D.

SC linac

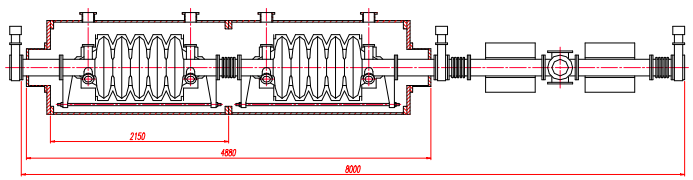
- Design of the high energy SC linac
  - criteria for the linac sectioning
  - section parameters (lattice length and parameters, cavity gradients, etc.)
- Design of the SC RF Cavities
  - electromagnetic design
  - structural behavior of low beta cavities
- Beam dynamics of the high energy section (100-1700 MeV)
  - linear beam dynamics completed
  - non linear space charge simulation tools developed and in use for emittance growth control

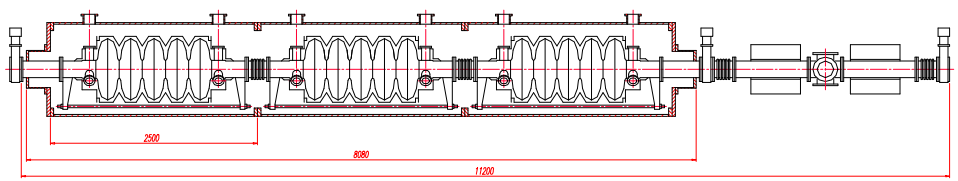
The SC High Energy section

- Main parameters:
  - From 100 MeV to 1.6 GeV
  - Operation at 352 MHz
  - Nominal current 25 mA (to deliver 40 MW)
- RF linac parameters:
  - 3 β-graded sections with β=0.5, 0.65, 0.85
  - E_p/E_{acc}~ 3.2-2.3, and keep E_p<16 MV/m and H_p<40 mT
    - → E_{acc}= 4.6/5.7/6.7 MV/m in the 3 sections
    - → Max power in the couplers 250 kW
  - 5 cell cavities, 2/3/4 cavities/cryostat in the 3 sections
- Focusing scheme:
  - Doublet focusing array, 1 doublet every cryotank
    - → Focusing cell: L=8.0/11.2/15.3 m

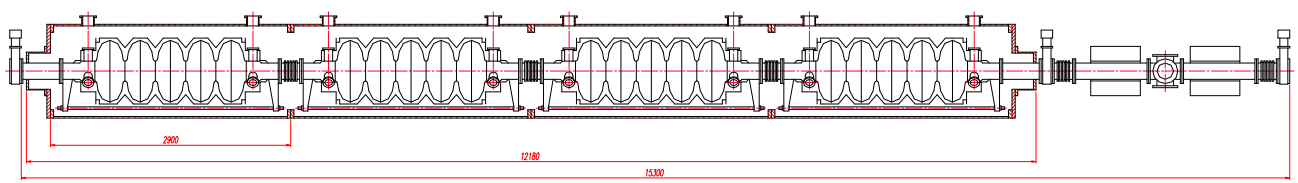
linac design

- The linac has been divided in three sections, with transition energies at 190 and 430 MeV, using RF cavities with a synchronous beta of 0.5, 0.65 and 0.85
- A doublet array structure, with the cavities placed in the long drift between the quadrupoles will provide the necessary transverse focusing





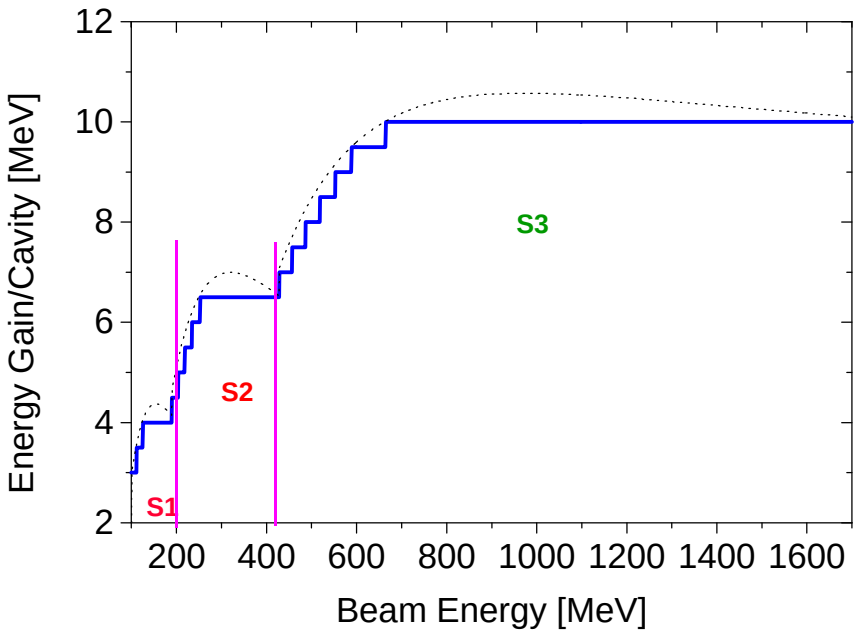
The three sections will employ 2,3 and 4 cavities per focusing period, respectively



Efficient use of the cavities

Criteria for linac sectioning and choice of cavity β:

- 5 cell structures represent a good compromize for velocity acceptance and active length per cavity
- Most of the cavities operate with a transit time factor of more than 0.95 (efficient use)
  - Only the first modules of each section operate at lower values of the transit time factor (0.80)
  - This results in an overall better efficiency for the whole machine
- A few cavities in each sections are used for velocity matching by operating them at lower RF power than the rest of the section cavities
- This approach allows the totality of each section cavities to operate close to the maximum accelerating gradient
- Furthermore, the best RF efficiency is set for the majority of cavities at the end of each section, which operate at a constant energy gain
  - constant power consumption per module



Transition energies at 190 MeV and 430 MeV:

S1: 100 ⇒ 190 MeV (β=0.5, i.e. 145 MeV)
S2: 190 ⇒ 430 MeV (β=0.65, i.e. 296 MeV)
S3: 430 ⇒ 1600 MeV (β=0.85, i.e. 843 MeV)

Click here to
continue to next section