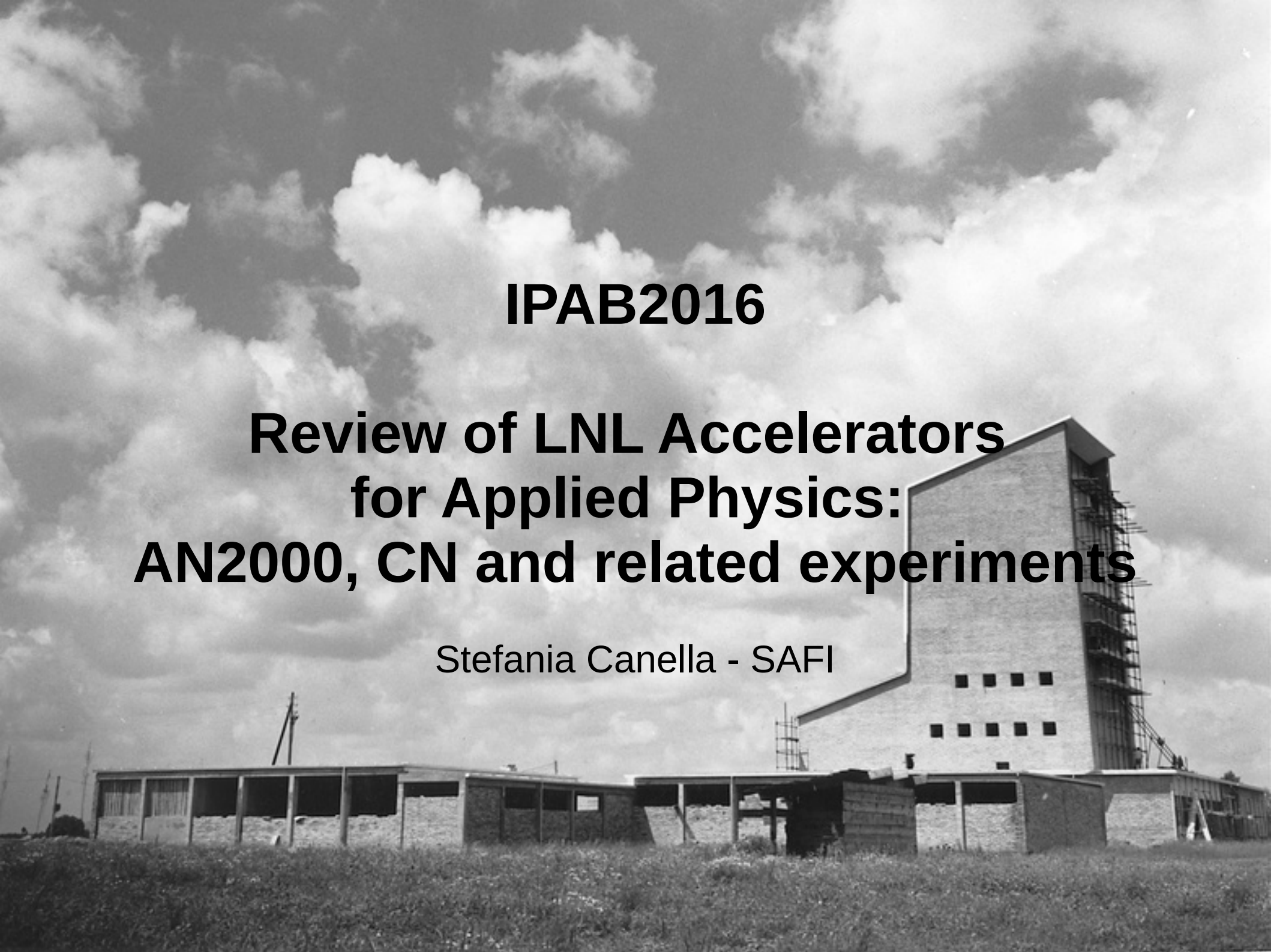

IPAB2016

Review of LNL Accelerators for Applied Physics: AN2000, CN and related experiments

Stefania Canella - SAFI

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Staff - SAFI

SAFI (Servizio Acceleratori Fisica Interdisciplinare)

- Enrico Munaron (University of Padova)
- Luca Maran (University of Padova)
- Leonardo La Torre (INFN – LNL)
- Davide Carlucci (INFN – LNL)
- Stefania Canella (INFN – LNL)

Accelerators

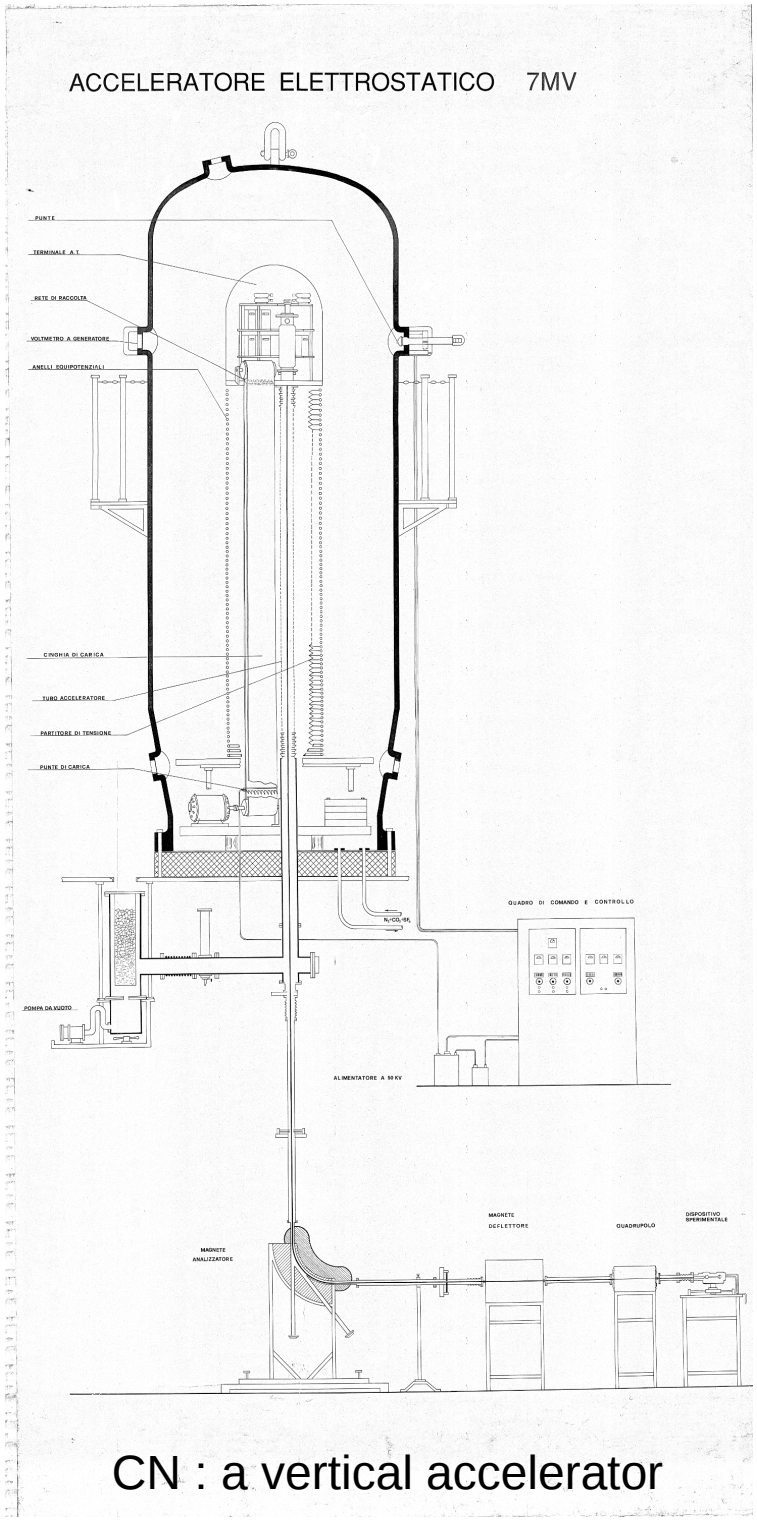
At SAFI there are 2 Van de Graaff electrostatic accelerators:

CN : a 7m high vertical machine, born for 5.5 MV (installed in 1961), upgraded to 7 MV, but now mostly limited to work below 5.8 MV with 3 days of conditioning, may supply 6 MV with three more days of conditioning, 6.2 MV with proper and longer conditioning;

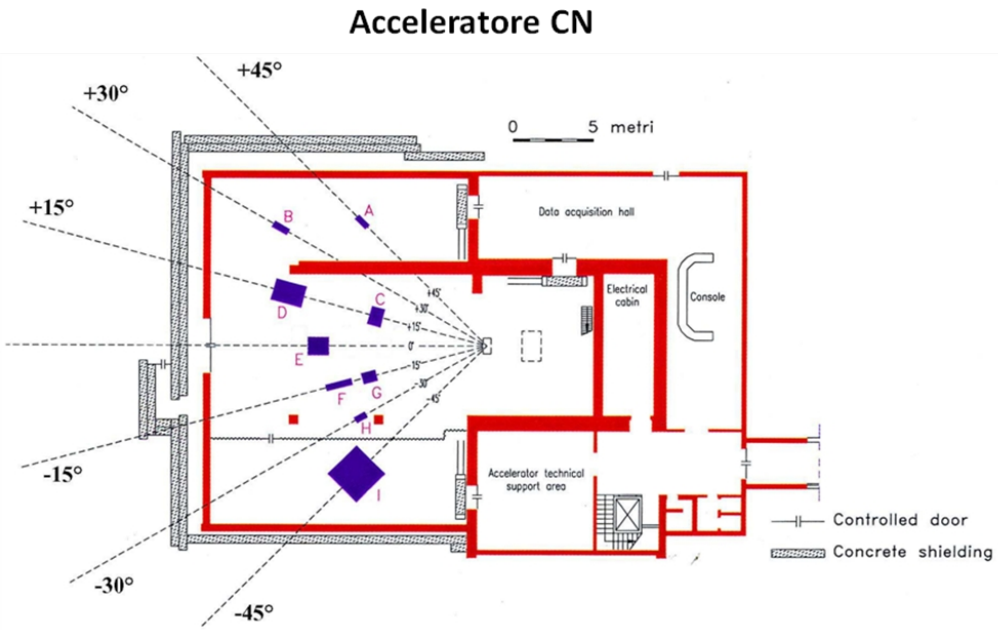
AN2000 : a 2 m long horizontal machine (installed in 1971), can supply a voltage up to 2.2 MV, but mostly limited to 2.0 MV.

Accelerators - CN

The CN "Van de Graaff" electrostatic machine was the first accelerator at LNL, in 1961. Its vertical structure is housed in a tower at the north-east border of the laboratory.
This was on of the first LNL building and it is now one of the symbols of the laboratory.
The whole accelerator structure is inside a metal tank, filled in with a high pressure gas: N_2 and SF_6.
The positive RF ion source (using light gases, H and He) is inside the machine, in the HV terminal, installed together with the necessary devices to extract and focus the ion beam in the accelerator pipe.

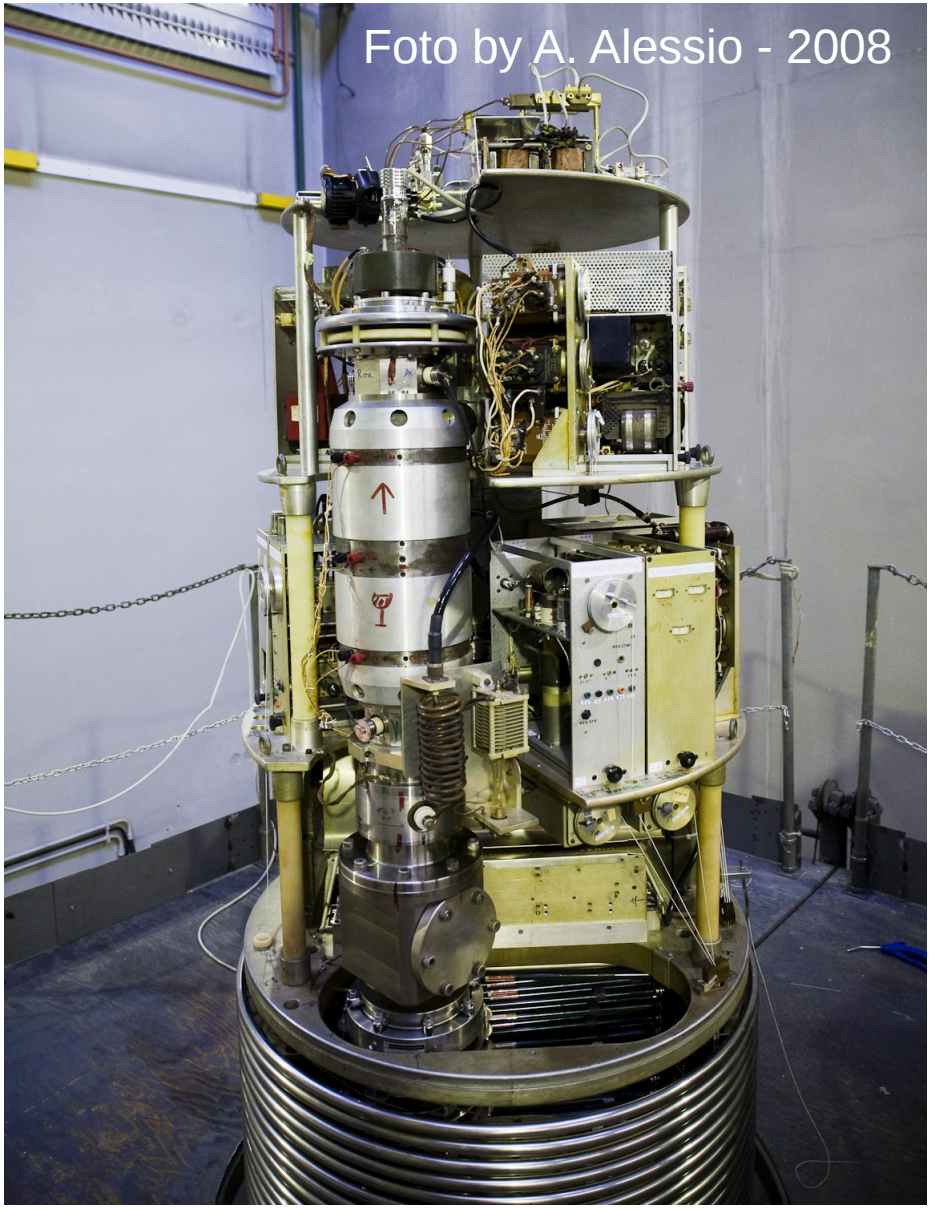


CN : a vertical accelerator



CN : the map of the experimental room with 7 beam lines

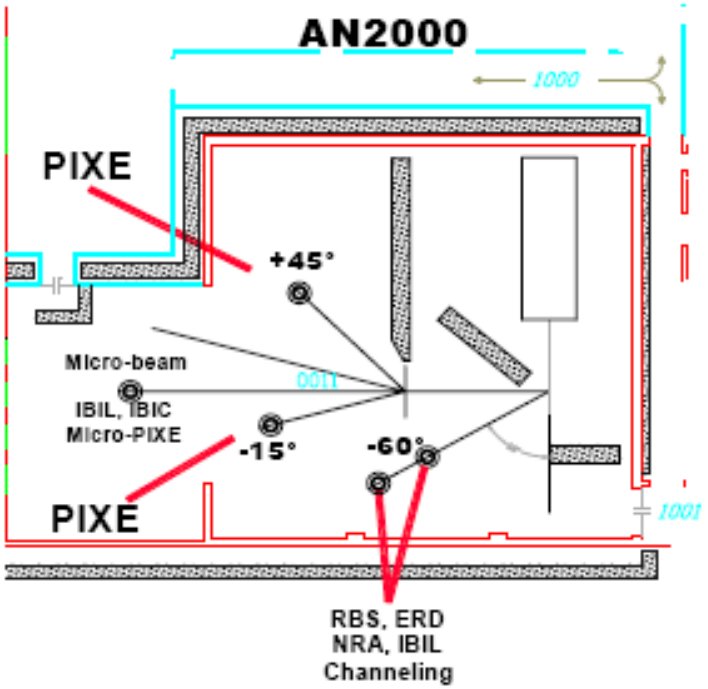
CN : open for maintenance

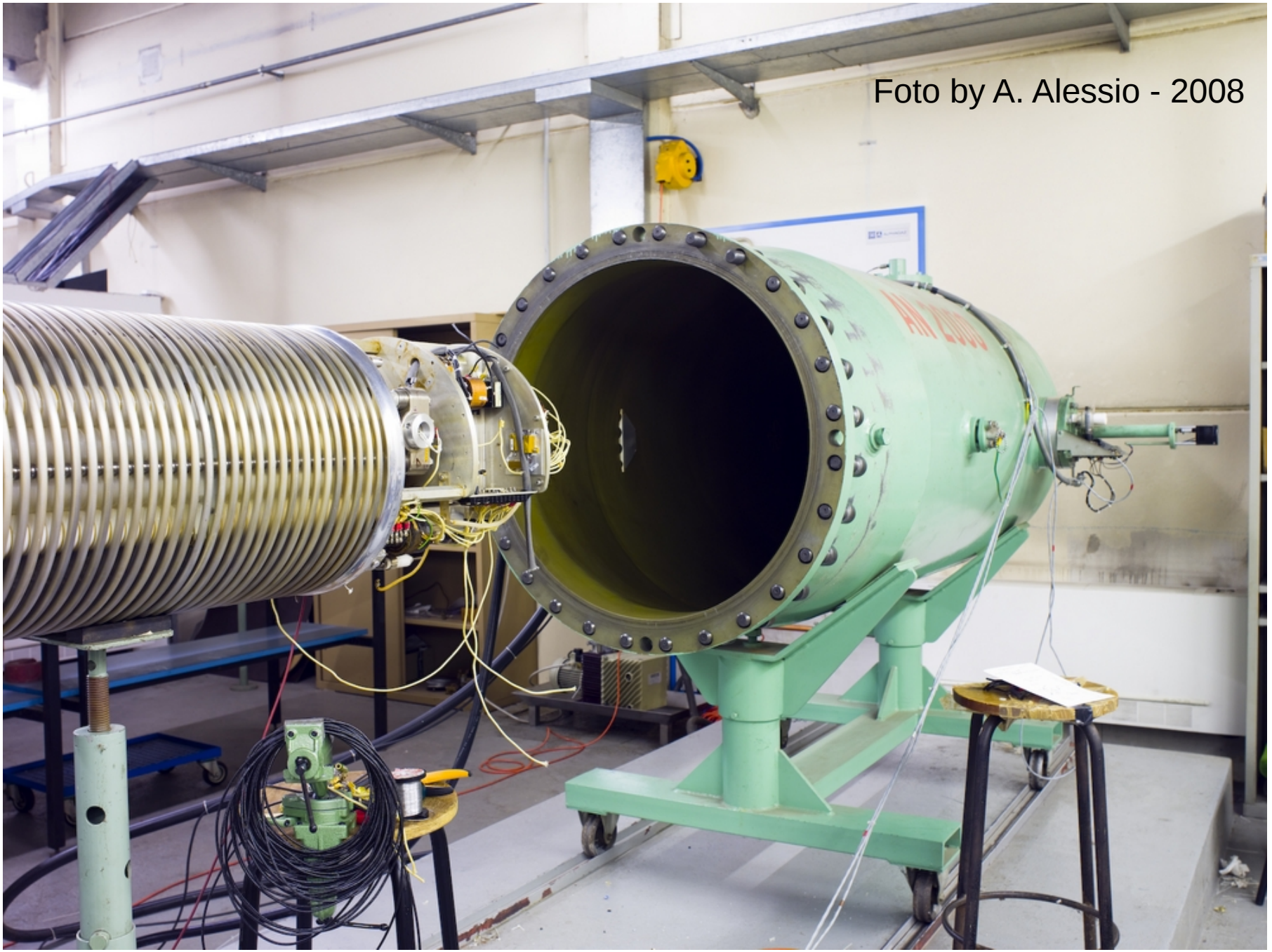


CN : the HV terminal

Accelerators - AN2000

AN2000 was installed at LNL in 1971.
This compact machine has an horizontal structure 2 m long, so the whole accelerator facility (the accelerator with its internal ion source, the beam lines and all measurements points) may be housed in a single experimental room.

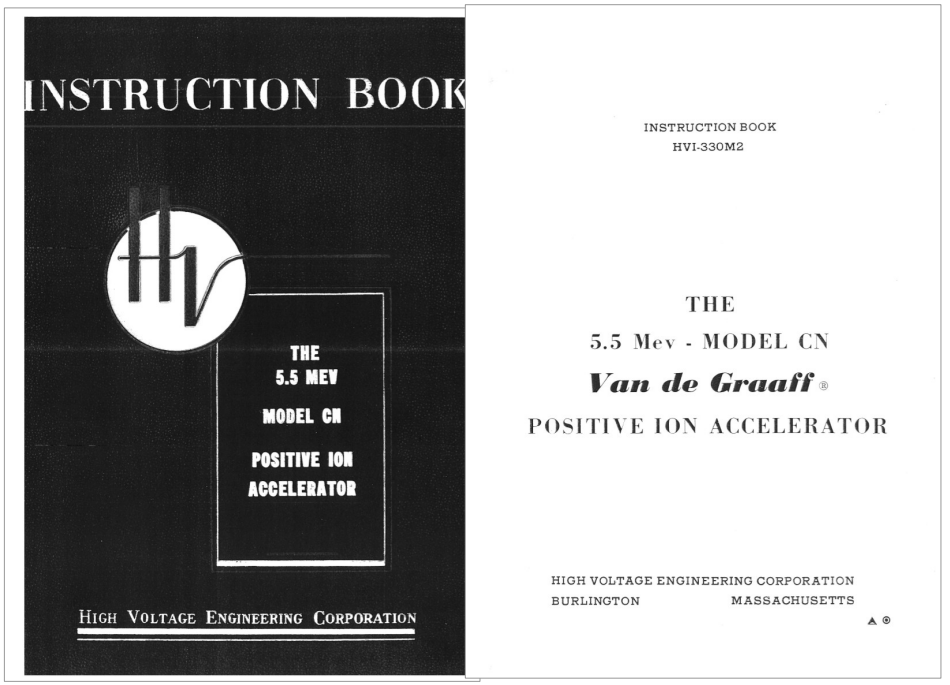


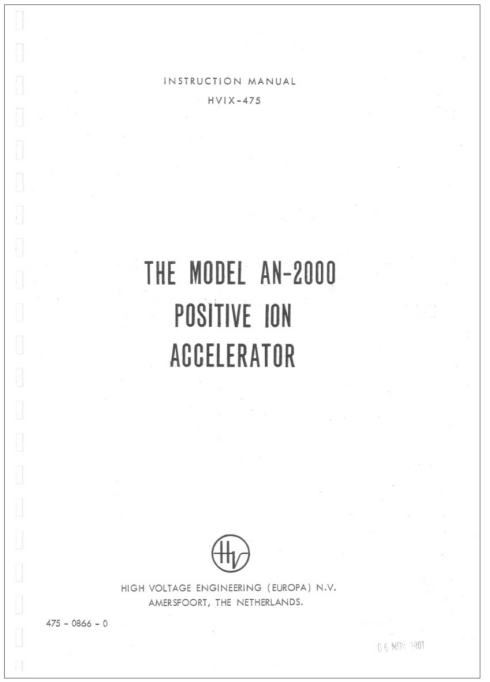


AN2000 : The accelerator open for maintenance

HV

Both CN and AN2000 accelerator were manufactured by HV





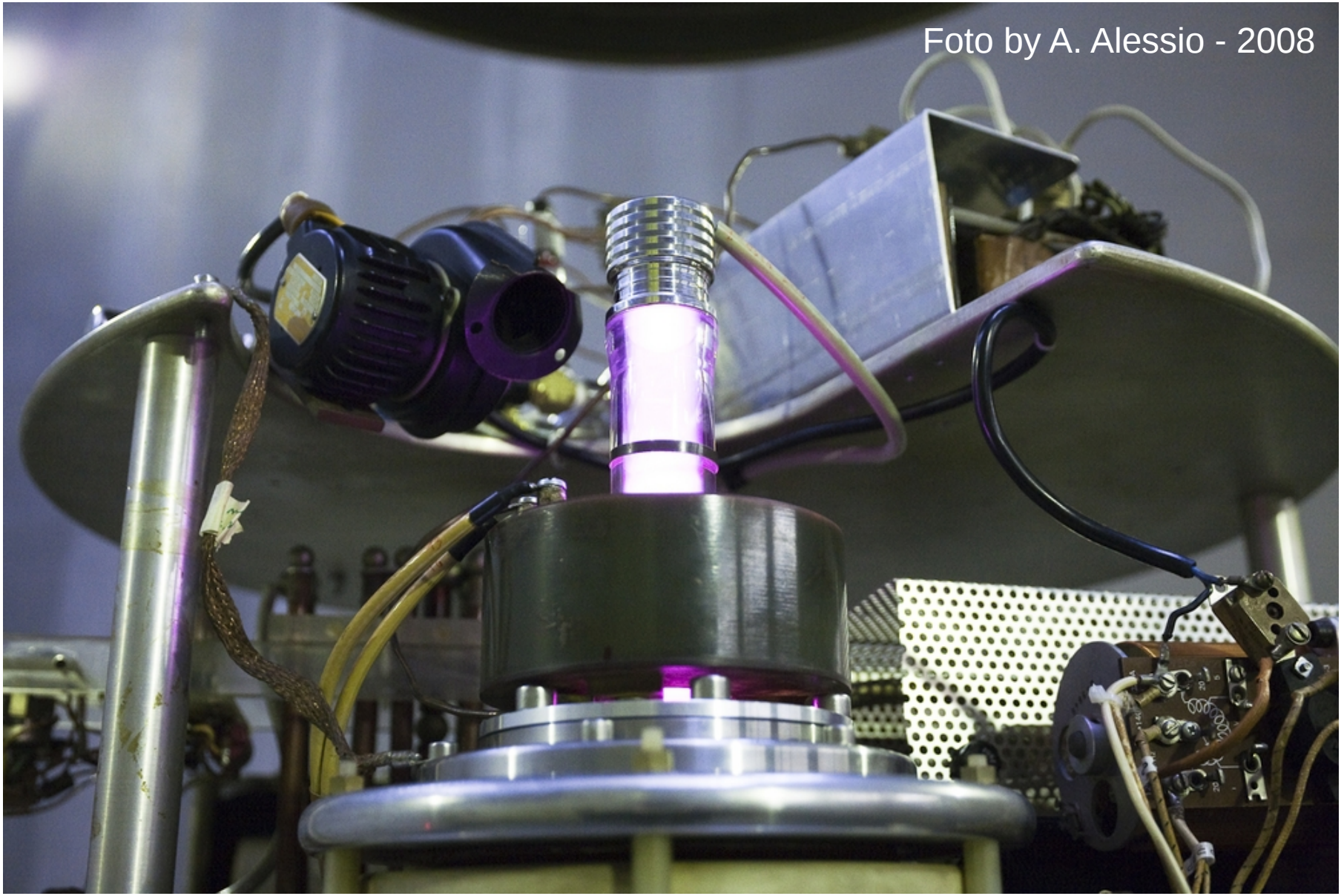
Beams

CN : $^{1}H+$, $^{2}H+$, $^{3}He+$, $^{4}He+$, $^{4}He++$; all in DC current mode (^{3}He must be supplied by the user);
$^{4}He++ \leq 20nA$ with two days beam preparation;

CN : pulsed beam is available on the 0° beam line at 3.3 MHz - should be properly planned, as a high current has to be extracted from the ion source;

AN2000 : $^{1}H+$, $^{4}He+$ in DC current mode;

AN2000 : the micro-beam facility is available on the 0° beam line



The CN ion souce on the HV terminal, switched on during a maintenance test

AN2000 : the micro-beam channel

Accelerators Performances (2015)

In 2015 the AN2000 and CN accelerators delivered beam according to users' requests.
For CN, 3 standard maintenance periods were necessary.
AN2000 had several short maintenance periods and the frequent change of insulation gas helped in the recovery of better performances after the substitution of the accelerating tube in 2014.

Year 2015 – CN	Number	Unit
Accelerator ON	1520	h
Conditioning	350	h
Time provided for user-op	1081	h

Year 2015 – AN2000	Number	Unit
Accelerator ON	1165	h
Conditioning & Maintenance	190	h
Time provided for user-op	975	h

Shift modes in 2015 – CN and AN2000

All SAFI personnel work in daily hours,
usually from 8:30 to 17:00.
Working days are from Monday to Friday.

Both the accelerators, **CN** and **AN2000,** must be started and the beams set by SAFI personnel.

On Friday afternoon both the accelerators must be stopped by SAFI personnel.

Shift modes in 2015 – CN and AN2000

Up to October 2015 CN has been operated only by the staff (start, tuning, stop), while for the whole 2015 AN2000 has experienced a partially self-service operation mode

Since November 2015 a partially self-service operation mode is allowed also at CN and now both the accelerators and the requested beam are started and tuned by the staff, but the machine may be left in charge to the users from Monday to Thursday for :
- stable operation (no changes in beam or energy)
- beam stop/restart and machine stop

This kind of operation is available to trained users (currently they are 11 at AN2000 and 12 at CN), who need stable beams for more than 8 hours per day.

Applied Physics at CN (1)

The CN accelerator has 7 beam lines and may be used in applied physics measurements for analytical purposes: EBS (Elastic Back-Scattering spectrometry) and NRA (Nuclear Reaction Analysis) are accomplished routinely spanning the entire available energy and particle range in the facility.

The CN laboratory is equipped with two dedicated experimental stations for radio-biology studies, one of them with beam in air to the target.

The shielding of the laboratory infrastructure allows the irradiation of Be and Li-based targets with high current proton and deuteron beams to produce well characterized fast neutrons beams.
The preparation of new interaction point to produce thermal neutrons is in progress (see poster P2).

Applied Physics at CN (2)

The original beam pulsing system of the CN accelerator is designed for a fixed 3MHz repetition rate. Recently a new system, coupled to the original system, has been installed on the beam-line 0 and successfully tested. It allows repetition rates at frequency lower than 3MHz by synchronous beam deflection: the supplementary pulsing system is able to suppress a fraction (1/2, 2/3, 3/4, 4/5...) of the main pulsed beam by deflecting the unwanted bunches toward a beam-dumper placed along the beam transfer line.

In such way it is possible to get a pulsed beam with several frequencies (1.5 MHz, 1 MHz, 750 kHz, 600 kHz and lower), well suited to avoid neutron TOF overlap in specific experimental conditions encountered in nuclear astrophysics.

Applied Physics at AN2000 (1)

The AN2000 Van de Graaff accelerator is used mainly for interdisciplinary studies in materials science, solid state physics, radiation and environmental physics. geology.

The AN2000 accelerator has 5 beam lines, one of them dedicated to the micro-beam facility (can focus 2.0 MeV proton beams down to 1 micron spot size in high vacuum).

The beam time is employed in experiments using elemental depth profiling with nuclear investigation techniques such as Rutherford and Non-Rutherford Backscattering (RBS) with proton and α-particles beams, Ion Channeling, Elastic Recoil Detection Analysis (ERDA), low energy nuclear reaction analysis (NRA) and Proton Induced x-ray Emission (PIXE) on crystalline and amorphous semiconductors, ceramic and glassy materials and on metal alloy thin films or on environmental city or marine aerosol samples.

Applied Physics at AN2000 (2)

Another important application exploited at LNL is Ion Beam Writing on diamond to obtain diamond-based micro-devices and to produce buried conductive paths in diamond with proton and alpha particles beams of variable energy.

Besides the micro-beam line, there are other 3 beam lines equipped with 2 broad beam PIXE chambers (used for archeology and environmental analysis) and two fully equipped IBA facilities dedicated to Ion Channeling, EBS, ERD, NRA and luminescence studies.

Perspectives for the next years

Light ions small accelerators have been extensively used for research in interdisciplinary fields since many years.

In more of 40 years of use of the 2 SAFI accelerators (CN since 1961, AN2000 since 1971) the interest of measurements performed with their beams has never decreased.

Recent developments in accelerator-based research fields, such as nuclear micro-probe techniques, are of growing interest to many research groups working in interdisciplinary fields like environmental physics, geology, radio-biology, detector and dosimetry science and technology.


Thanks for the attention.

Abstract

A review of the two LNL small accelerators mainly dedicated to applied physics (CN and AN2000) is given.

The experiments related to applied physics performed in the last 2 years at CN and AN2000 are also described, with special attention to those interesting for application of accelerator based analytical and diagnostic techniques (PIXE and others).

Perspectives for LNL small accelerators in this field will be also given.

Beams

CN : $^{1}H+$, $^{2}H+$, $^{3}He+$, $^{4}He+$, $^{4}He++$; all in DC current mode (^{3}He must be supplied by the user);
$^{1}H+$ up to 5μA ; $^{2}H+$ up to 0.5 μA ;
$^{4}He++ \leq 20nA$ with two days beam preparation;

CN : pulsed beam is available on the 0° beam line
3.3 MHz (300 ns) - should be properly planned, as a high current has to be extracted from the ion source;

AN2000 : $^{1}H+$, $^{4}He+$ in DC current mode;

AN2000 : the micro-beam facility is available on the 0° beam line

Typical beam currents at AN2000: 1-300 nA