Linac-200: a new research facility of JINR

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Electron scattering at Netherlands

- In the mid-60ies Conrad De Vries went to Stanford to work at Bob Hofstadter’s group
- Elastic scattering to study nuclear structure, followed by the nucleon structure studes at SLAC
- After coming back to Netherlands, de Vries convinced the Instituut voor Kernfysisch Onderzoek to construct the electron accelerator

EVA and MEA

- First attempt (IKO + Philips) was not successful
- 90 MeV linac EVA (based on two spare SLAC sections) started operation 1968
- A higher energy linac, a copy of MIT-Bates machine, was ordered from Haimson Research Ltd in the United States
  - low cross-section = high current
  - precise measurements in coincidence = high duty factor
- Construction of 500 MeV linac **MEA** (Medium Energy Accelerator) started only in 1975 and the first measurements with MEA electrons were made in 1981.
- MEA could deliver up to 40 microamps at a duty factor of 1%. This was lower than the 10% originally aimed for, but much higher than the 0.02% of EVA.

C. De Vries (right) and P. Bruinsma (left)

@ CERN Courier

MEA structure

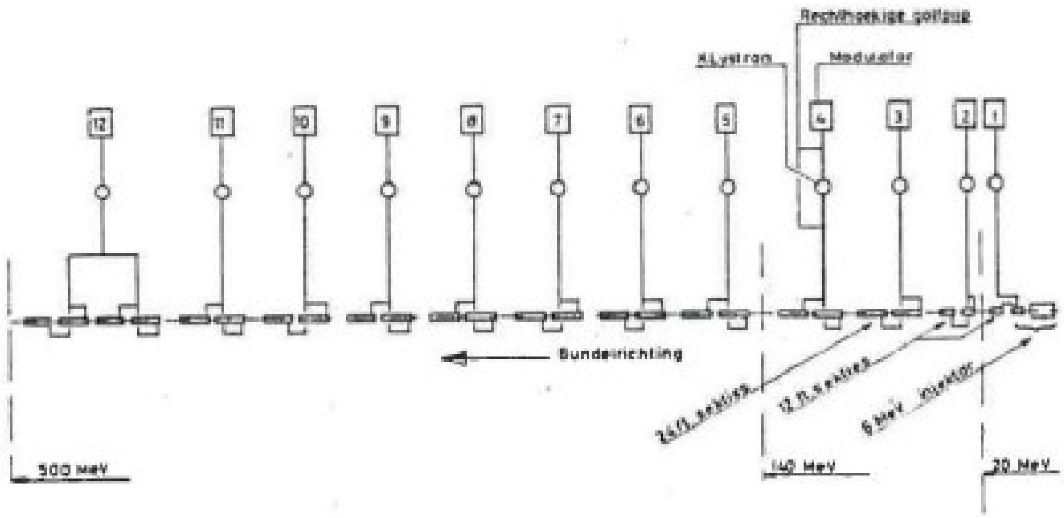


Fig. 1 Scheme of the main components of the 500 Mev electron accelerator

Injector

Buncher

12 klystron units (=accelerator stations)

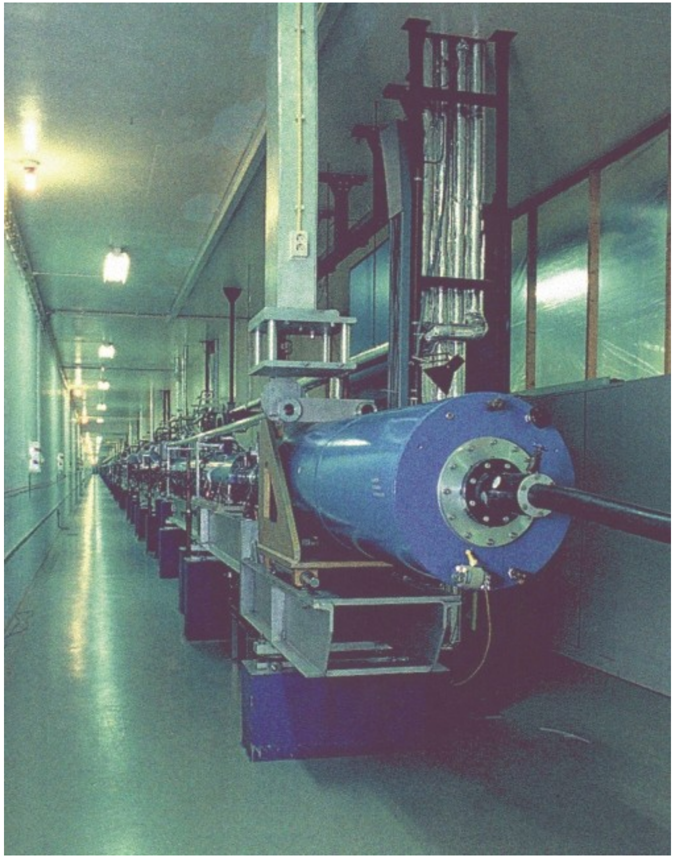
24 accelerating sections

Abundant beam diagnostics

Computer controlled

MEA research program

- Electron scattering
  - Two magnet spectrometers
  - Precision measurements of nuclei structure, nuclear spectroscopy, electronuclear and photonuclear reactions
- Radiochemistry
- Secondary beams of pions and muons



MEA at NIKHEF in 1998

MEA и AmPS

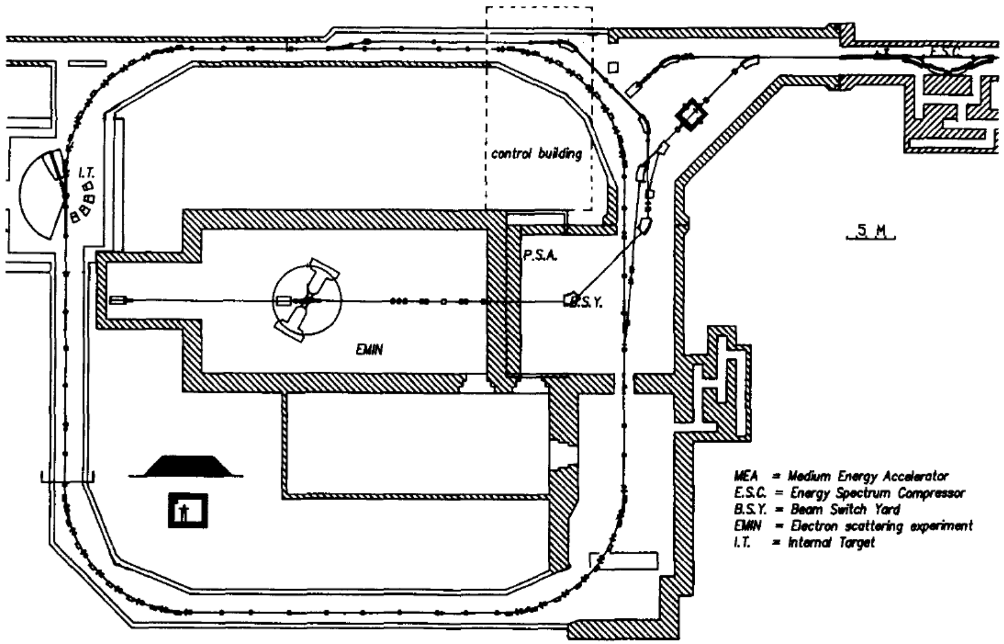


Fig.1 Layout of the ring; also shown are the end of the linac with the energy spectrum compressor (ESC), the beam switch yard (BSY), the electron scattering end station (EMIN) and the internal target hall (IT). The walls of the existing buildings are hatched.

- A major upgrade happened after 10 years of operations:
  - MEA energy 500 MeV → 800 MeV (new clystrons) →
  - A new 300-900 MeV storage ring AmPS (Amsterdam Pulse Stretcher) with a circumference of 212 m was constructed → ~100% duty factor

The AmPS was put in operation in 1992. Currents up to 150 mA have been stored and the maximum energy obtained was 630 MeV.

Due to high load on the Dutch budget, in 1998, NIKHEF phased out the electron scattering facility and offered to give its components to anyone who wanted them.

D E L S Y

Dubna ELectron Synchrotron

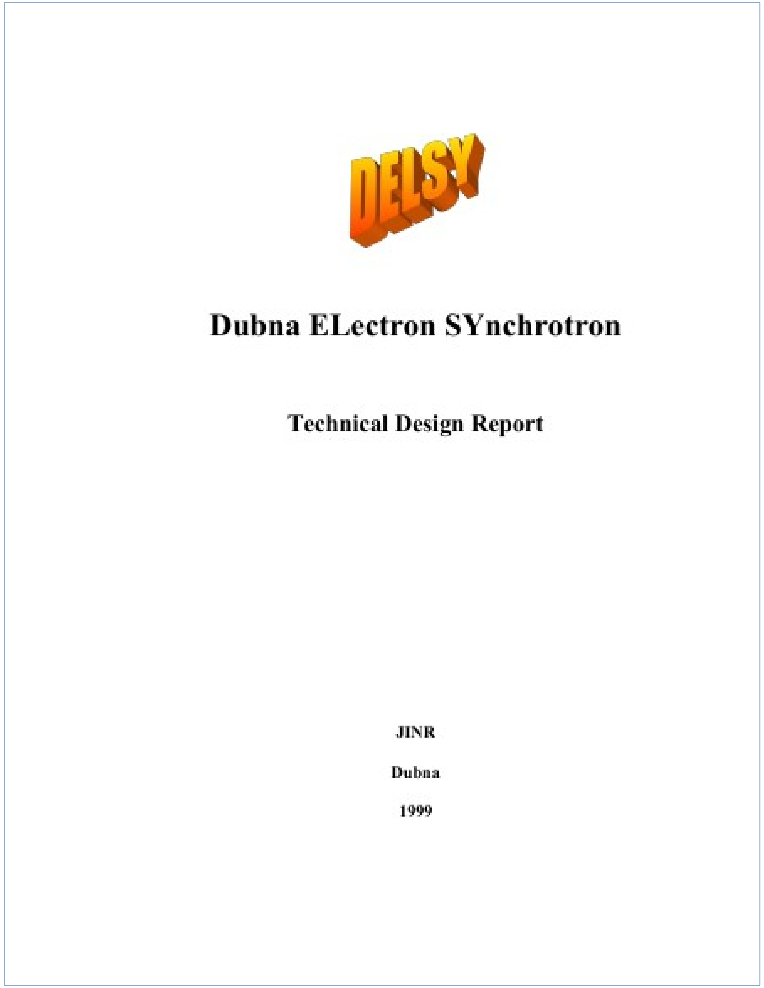
Дубна ЭЛектрон СИнхротрон

Synchrotron Radiation Source of the 3d Generation

Courtesy of I. Meshkov

DELSY

- The idea was to re-use MEA and AmPS parts to construct a new 3rd generation light source at JINR
- Phase 1: 800 MeV linac (LINAC-800) and UV FELs
- Phase 2: 1.2 GeV DELSY storage ring equipped with an undulator of the higher brilliance and a superconducting wiggler which generates hard X-ray radiation


DELSY

Dubna ELectron SYnchrotron

Technical Design Report

JINR

Dubna

1999

From Amsterdam

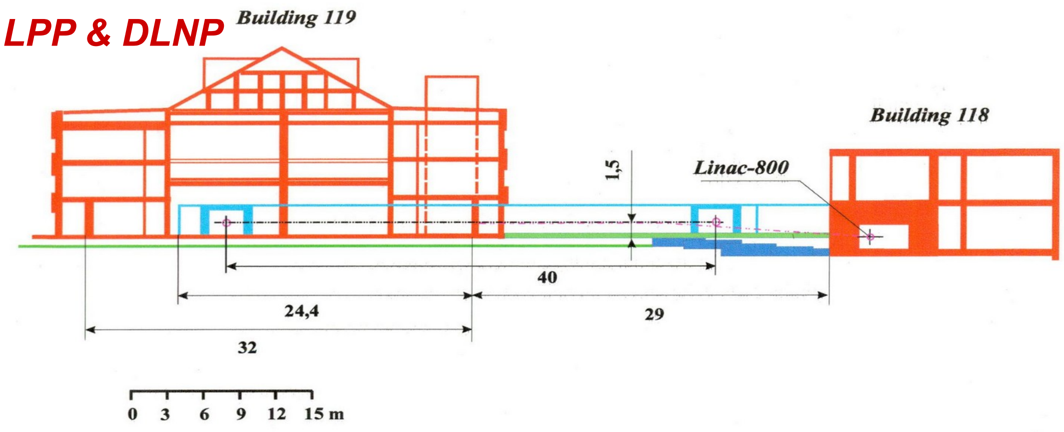
to Dubna, August 1999

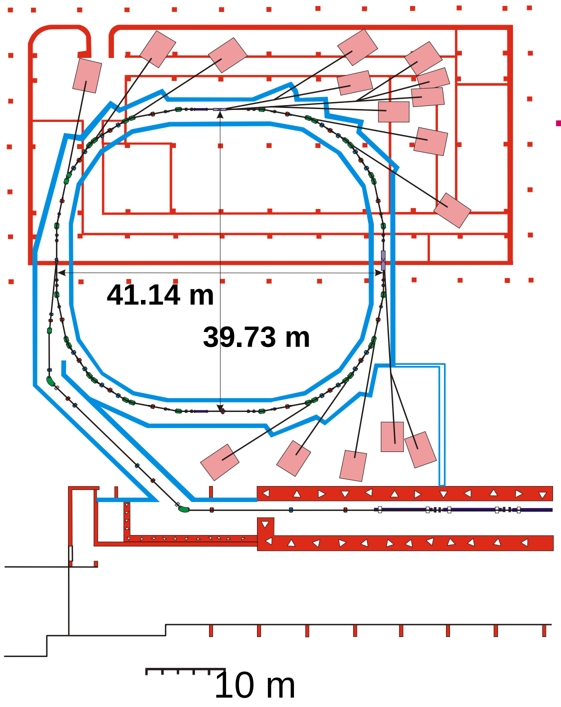
Last truck at Dubna

21 December 2000

Courtesy of I. Meshkov

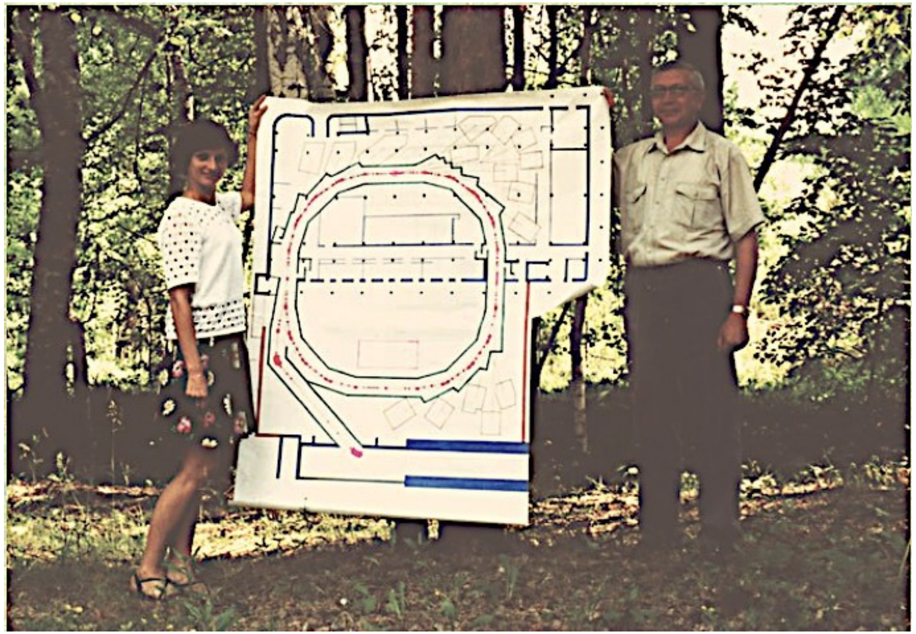
DELSY in the making





The DELSY Facility Layout

Location: Bldg 118 (former LIU-30 of IBR-2 complex) and Bldg 119



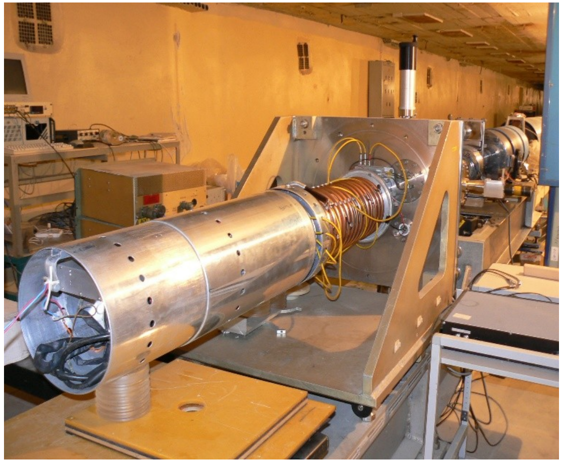
Courtesy of I. Meshkov

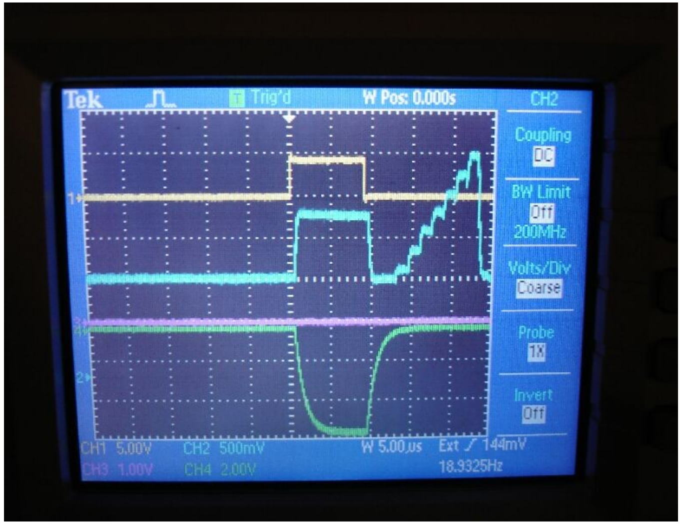
Bldg 119 (left) and 118 (right)

Modulator hall – 2002

Accelerator hall (2002)

December 2003



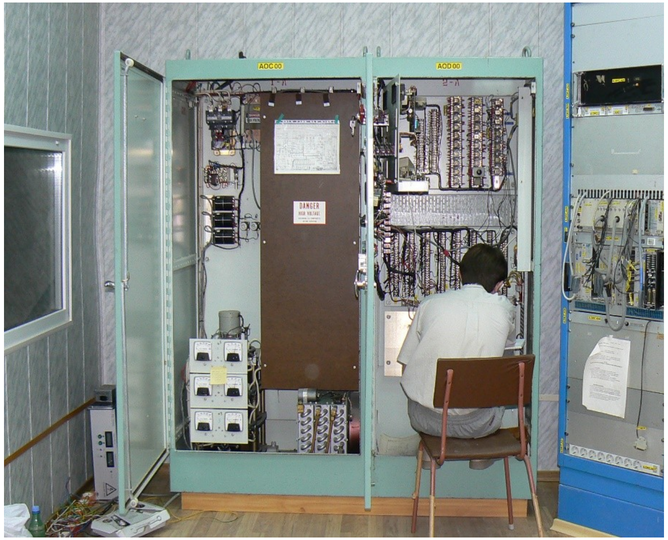


2007: Electron gun assembled and tested. The 30 mA current of 50 keV electrons achieved.

Courtesy of V. Kobets

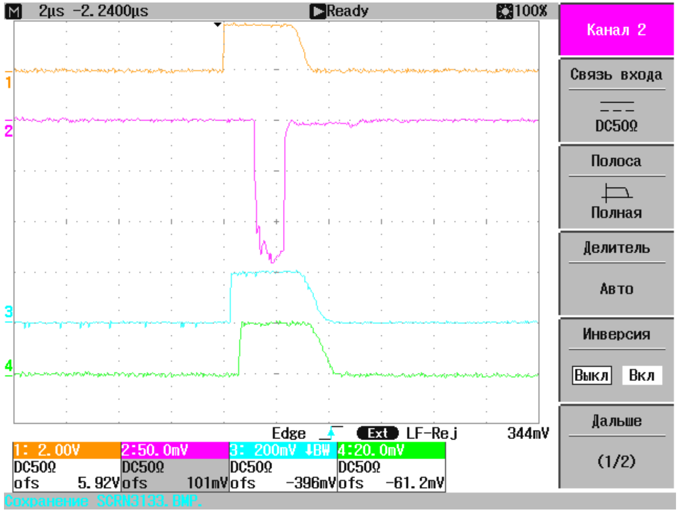
From DELSY to LINAC-200

- The DELSY project turned out to be too expensive for the JINR budget and was unable to attract additional third-party investment from JINR member countries.
- In 2004, the next generation of big machines of TeV scale was expected after the LHC. The **NLC** (Next Linear Collider), **GLC** (Global Linear Collider), and **TESLA** (Teraelectronvolt Energy Superconducting Linear Accelerator) projects were merged into a single project, the **ILC**, based on the use of superconducting accelerating resonators.
- In 2005, the GDE (Global Design Effort) team was formed to develop the technical design of the ILC. The JINR joined the project and expressed the interest to host the ILC.
- The linear accelerator continued to develop as a testbed for joint JINR-DESY R&D for ILC construction. The ring became an impossible task (although all the parts are still kept in storage).

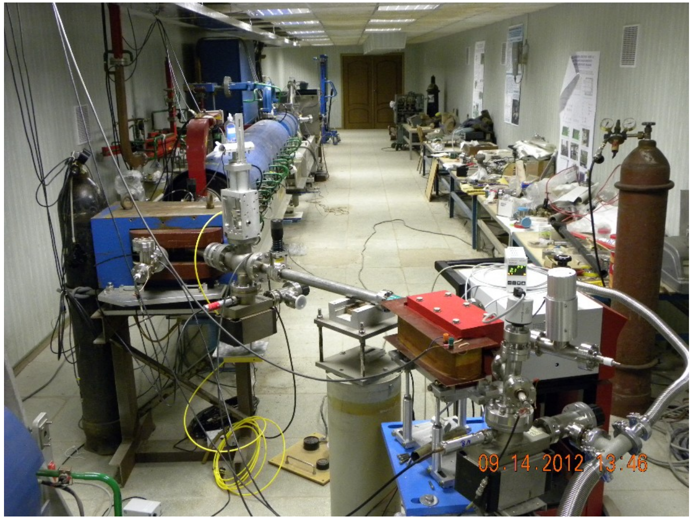


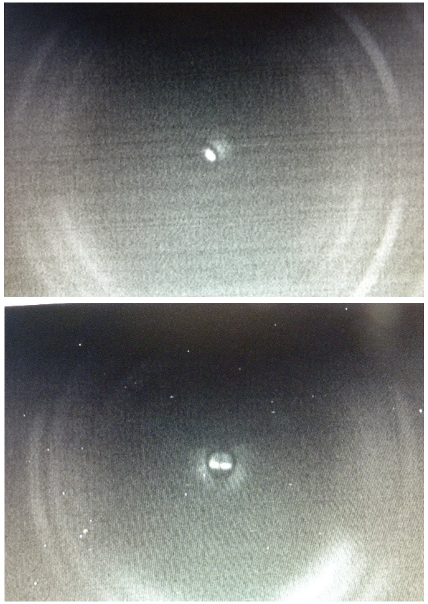
2008: Electron gun 400 kV power supply was commissioned

Courtesy of V. Kobets



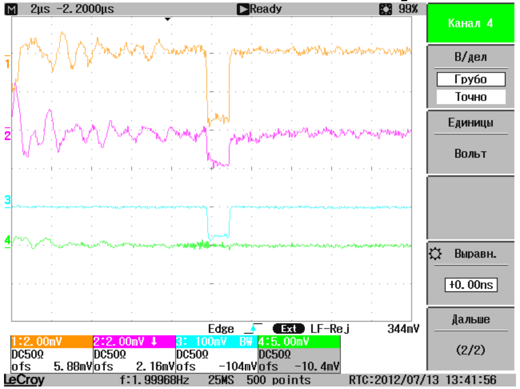
Beam current after the 1st section

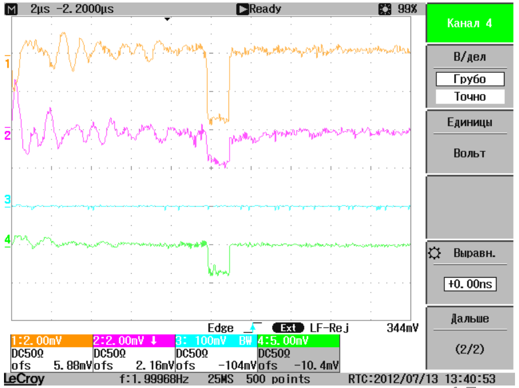




Beam spot after the 1st section and after the dipole

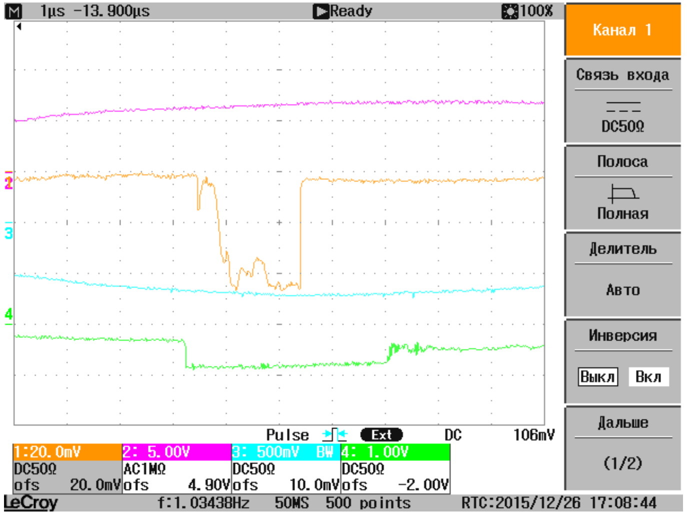
December 2011: the 1st section started operation. The dipole magnet allowed to extract the beam





Courtesy of V. Kobets

2015: The second accelerating station started operation

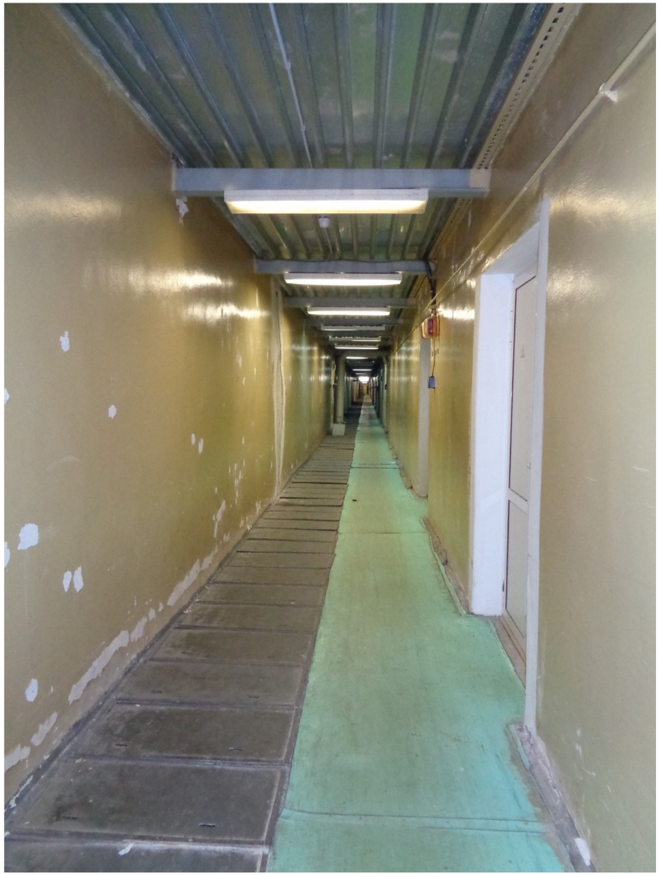


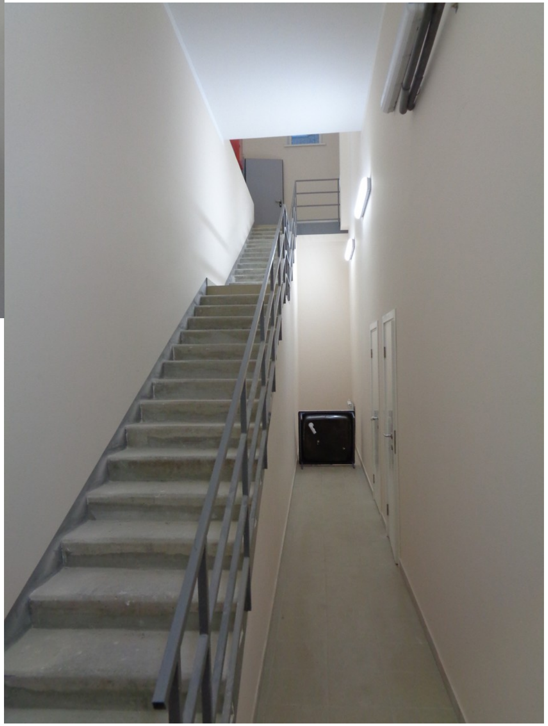
Courtesy of V. Kobets

Accelerator hall

before the renovation

after the renovation






Жолио-Кюри
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стр. 31
Здание
118

The accelerator control room

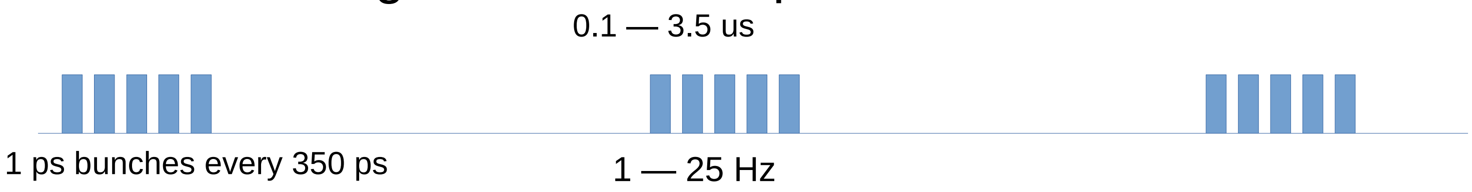
April 2012

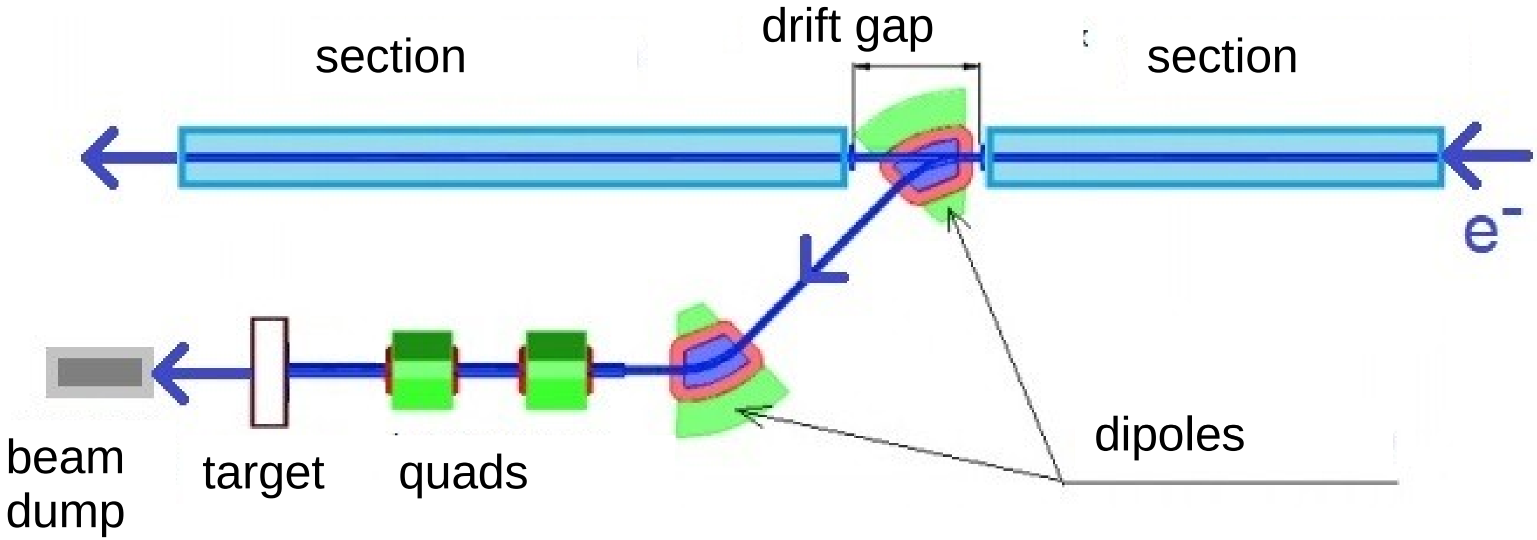
February 2021

April 2022

The machine

- Based on refurbished 800 MeV MEA (NIKHEF)
- LINAC-200 = Injector, buncher and 4 (of 13) accelerating stations — already operational and accelerates electrons up to 200 MeV
- LINAC-800 = Injector, buncher and 13 accelerating stations (800 MeV) — being constructed now
- The beam energy spread is about 1%
- The beam current in a pulse can be set in the range from practically zero values (single electrons in a bunch) to 80 mA (up to 10^{14} e^- / s)
- The maximum average current is 2.5 μA.





Beam lines	Beam energy [MeV]
T1 (after A01 station)	25
T2 (after A02 station)	60
T3 (after A03 station)	120
T4 (after A04 station)	200
T13 (after A13 station)	800

Research program

After 20 years or preparations, ILC seems to never happen. However, a strong request for electron testbeams has grown at JINR

MEA was designed for one specific purpose. LINAC-200 is going to be a multipurpose workhorse:

- Detector R&D
- Generaton of EM waves
- Nuclear physics
- Radiobiological studies
- Material irradiation
- Education and training

Detector R&D

Study of the detector response, determination of the efficiency, energy, time and spatial resolution, detector occupancy

- electromagnetic calorimetry and calibration in the 50-200 MeV energy range
- spatial resolution ≥200-300 um
- detector occupancy in a wide range
- electron identification
- calibration of photon and neutron detectors

Controllable generation of EM radiation by relativistic electrons using functional materials

Goal: study of the basics of electromagnetic interactions and new applications of controllable generation of electromagnetic radiation by relativistic electrons using functional materials

- Study of relaxation of EM response of materials based on topological insulators and Dirac semimetals with super-high electron mobility excited by bunched electron beam
- Explore the possibility of control of phonon response of metamaterials excited by bunched electron beams
- Investigation of polarization radiation generation by electron beam on surface structures with high local electron density
- Generation of intense ultra-monochromatic THz and sub-THz radiation. Construction of the THz radiation source for radiobiological research
- Study of the characteristics of Cherenkov radiation in radiation-resistant crystals (like corundum) for use in the diagnostics of relativistic beams in modern accelerators.
- Observation and study of the anomalous Doppler effect in the Smith-Parsell effect and resonant transition/diffraction radiation
- Application to the accelerator diagnostics R&D

FLAP Collaboration

Nuclear physics

- Study of photonuclear 209Bi(γ,xn) reactions produced by 100 MeV bremsstrahlung beam
- Study of the influence of the isospin effect on the splitting of the giant dipole resonance
- Study of multi-nucleon photo-nuclear reactions with up to 10 nucleons flying out
- Study of actinide nuclear photodisintegration
- Study of isomeric ratios in photonucleic reactions
- Reference testing of simulation codes such as Geant4, MCNP, and FLUKA against the experimental data

Radiobiological studies

- Irradiation of living organisms
- Investigation of the possibility of irradiation with short (1 ps) electron beam pulses and development of appropriate microdosimetry methods
- Testing and tuning of the dosimetric equipment
- Study of gamma and neutron radiation fields generated during irradiation of the head model of a 15 MV Siemens Primus therapeutic linear electron accelerator with fast electrons with energies ranging from 10 to 30 MeV

Material irradiation

- Study of the production of promising medical radioisotopes $^{186, 188, 189}Re$ on electron bremsstrahlung beams with an energy of 40 MeV
- Production of radionuclides ^{204m}Pb and ^{111m}Cd in samples containing natural cadmium and lead
- Study of the effects of pulsed electron irradiation on the crystal structure, as well as the electrical and magnetotransport properties of HTS tapes and other functional materials depending on the dose
- Study of radiation hardness of semiconductors (GaAs, SiC)

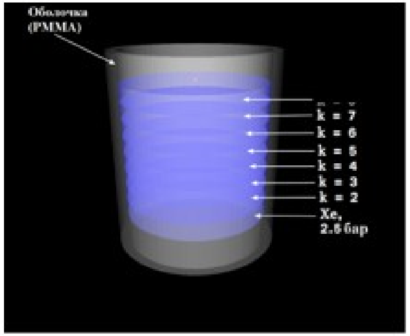
Education & training

LINAC200 is an excellent place to train young scientists and engineers:

- Accelerator physics and technology
- Particle detector characterization
- Toy experiments (e.g. measurement of nuclear form factors and GDR)
- Radiation material science, generation and registration of synchrotron and THz radiation, etc

Work together with the University Center

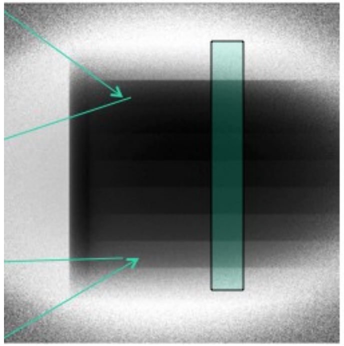
Electron radiography



Goal: Implementation of electron radiography technique, construction of the electron microscope with an energy of 200 MeV to measure the density distribution in dynamic and static objects with a linear density of up to 10 g/cm^2.

- Two radiography setups
  - Fast processes, FOV 20 mm and resolution 100 um
  - Static objects, FOV 10 mm and resolution 10 um
- Development of reconstruction methods and software
- Study of dynamic processes in porous materials and non-ideal plasma of shock-compressed inert gases
- Development of new structural materials
- Flaw detection research.

100x100 мм



Final remarks

Very often, our colleagues who are proposing accelerators and asking funds, are only speaking on the cost of the accelerator (in general accelerator, building, electrical power). But these machines are built to be used and we need experimental areas around the machine with a lot of magnetic spectrometers and other detecting systems.

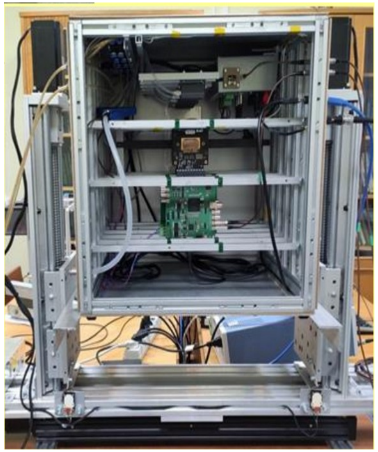
For this type of accelerator, a good approximation consists by multipying by a factor two the cost of the accelerator to have an order of magnitude of what we need to perform experiments. If you are not doing that, you will get a machine and nobody would work with.

Carl Schuhl from Saclay at the Conference on future possibilities for electron accelerators, Charlottesville, 8-10 January 1979

Test zone for detector R&D and applied studies

Goal: to construct an open access user facility for particle detector R&D and applied studies, including material science, radiobiology etc.

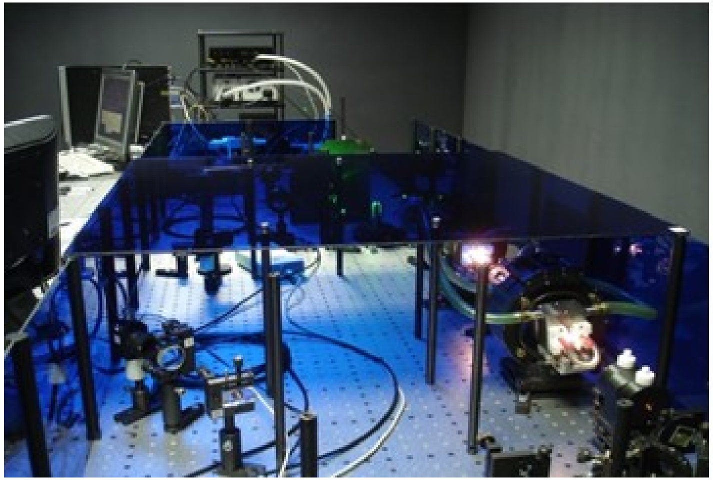
- Beam characterization
- Photon and neutron beam generation
- Precise dosimetry
- Infrastructure & Equipment

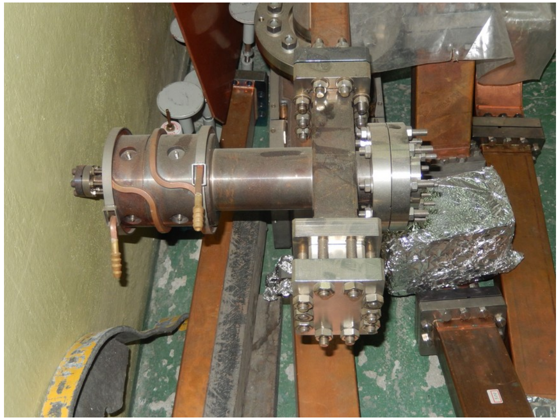


Setup for Alpide testing at Linac-200

Accelerator R&D and the upgrade plan

- Preparation of LINAC200 upgrade up to 800 MeV
  - Refurbishing old MEA parts
  - Upgrade of control and vacuum system
- Design and construction of the photoinjector
  - Possible replacement of the electron gun
  - R&D on generation of vortex electrons (together with ITMO)
- Proposals for the future
  - MEA construction goes back to 1975. Klystrons are 30 years old. What would be the next machine?





Summary

- A new electron accelerator is available at DLNP with the beam energy of 200 MeV and prospects to increase it up to 800 MeV
- Research program for the first years is compiled:
  - Detector R&D
  - Generaton of EM waves
  - Nuclear physics
  - Radiobiological studies
  - Material irradiation
  - Education and training
- Waiting for finalizing the licensing and approval process (hopefully in the second half of this year)
- More efforts are needed from the accelerator team and from users to achieve good beam conditions and to make the well-equipped and multifunctional testzone

Thank you!