PAC for Condensed Matter Physics,
48th Meeting

Development of a facility for measurements with test electron beams at DLNP. LINAC-200.

in the framework of theme **04-2-1126-2015/2020**
Novel Semiconductor Detectors for Fundamental and Applied Research

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One of the main tasks of JINR is R&D of new types of particle detectors

- New collider experiments (ILC, CLIC, CEPC, HL-LHC, NICA)
- Search of neutrinoless muon conversion into electron (mu2e, COMET)
- Applied research: biology, material science and medicine

Sources of elementary particles

- Cosmic rays
- Radionuclide sources
- Beams of charged particles from accelerators

  Advantages:
- Tunable energy and intensity
- Possibility of their reliable identification
- Precise timing and coordinate information

- There are no any electron testbeams at JINR now!

Available electron test beams

Scientific center	Particles	Energy [MeV]	dP/P [%]	Number of lines
BTF (Frascati, Italy)	$e^{\pm}$	25-750	1	1
ELPH (Tohoku, Japan)	$e^{\pm}$	< 850	1	1
BEPC-II (China, Beiging)	e^{-} $e^{\pm}$ (sec.)	1100 - 1500 400 - 1200	1	3
FTBL (KEK, Japan)	e^{-}	500-3400	0,4	1
DESY-II (Germany)	e^{-}	1000-6000	1	3
CERN PS (Switzerland)	e, hadrons, μ	$(1\text{-}15)*10^3$		4
CERN SPS (Switzerland)	e, hadrons, μ	$(10\text{-}400)*10^3$		4
FTBF (FNAL, USA)	e^{-}, π^{-} , μ	$(1\text{-}66)*10^3$		1
SLAC (USA)	e^{-} e, hadrons (sec.)	$13{,}6*10^3$ $(0{,}1\text{-}13{,}6)*10^3$	0,1-1,3	1
IHEP (Protvino, Russia)	e, hadrons, μ	$(1\text{-}45)*10^3$		4
BINP SB RAS (Novosibirsk, Russia)	e^{-}	100-3500	1,8-2	1
PI RAS S-25R (Troitsk, Russia)	e^{-}	300-1300		0
EPI (Armenia)	e^{-}	75 6000		1

LINAC-200

History

- 1975 – Medium Energy Accelerator (MEA), energy 800 MeV have been done for NIKHEF by Haimson Research corporation.
- 1980 - commissioning at 700 MeV
- 1990 - modernization
- 1998 – decommissioning
- 1999-2000 moving to JINR as part of the project DELSY
- 2011 – a beam of 20 MeV was obtained
- 2014 – on behalf of the committee of plenipotentiaries, the JINR University center began to develop an educational program based on the accelerator
- August 2017 – physical start-up at 220 MeV.

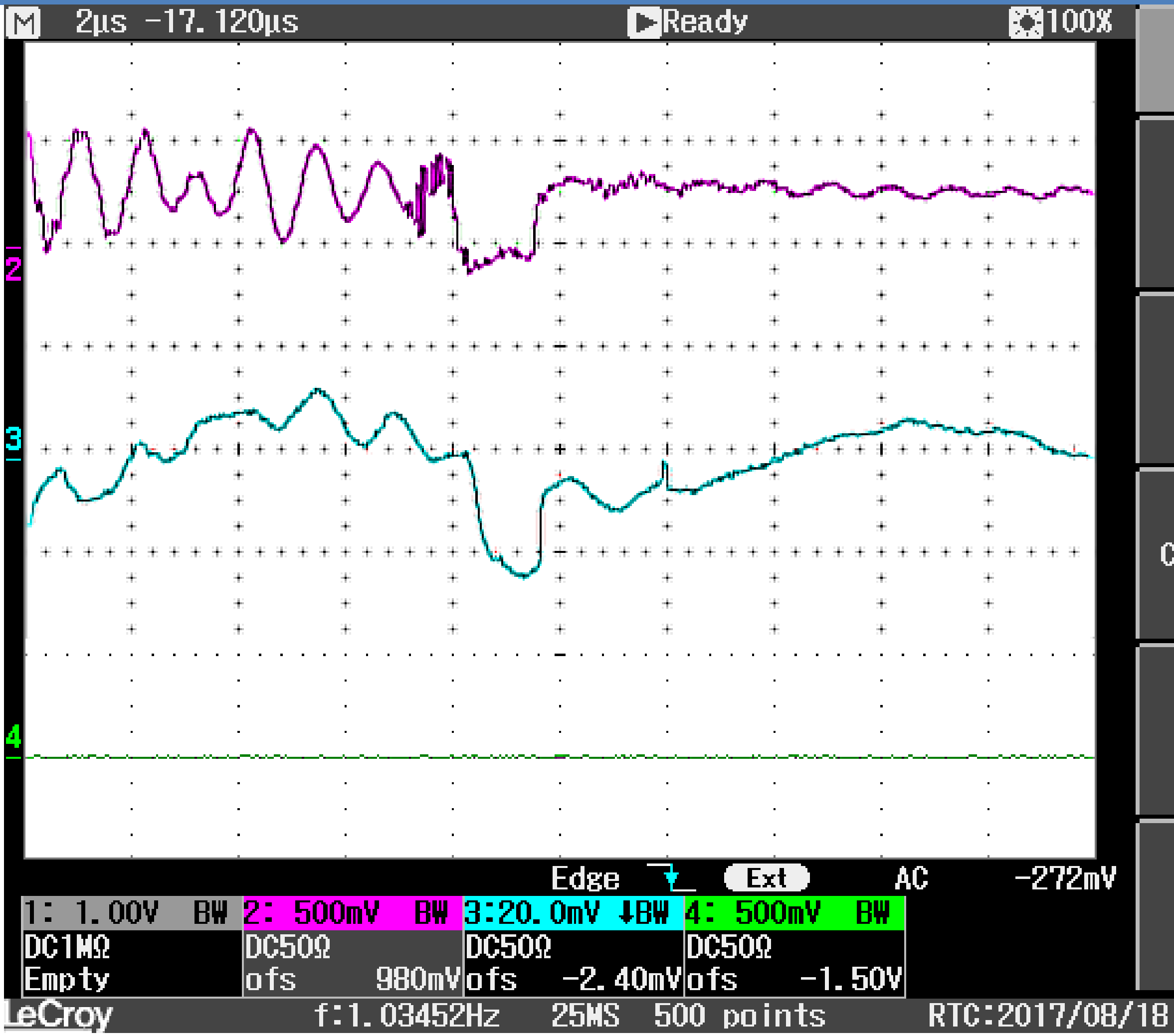
The linear electron accelerator LINAC-200

- an injector
- a buncher
- 12 accelerating stations

- Energy – up to 800 MeV (possible 2 GeV)
- The structure of the beam is pulsed, with pulse length of 0.1-3 μs
- The current in the pulse can be set in a wide range of values, from 60 mA to almost zero values
- The frequency of pulses is set in the range from ~10 to 100 Hz, which corresponds to the electron intensity from 1 to 10^{13} e^{-}/s

Physical start-up of A04 station

August 2017



upper line - current of electron beam after the 1st accelerator station, the energy of 20 MeV,

lower line – the current after the 4th accelerator station, the energy of 220 MeV.)

Project goal

physical start-up → test beams

- Finalize commissioning
- Tuning of the accelerator and development of test beams with energy up to 220 MeV
- The increase of energy up to 800 MeV and development of high-energy test beams

Status of the accelerator

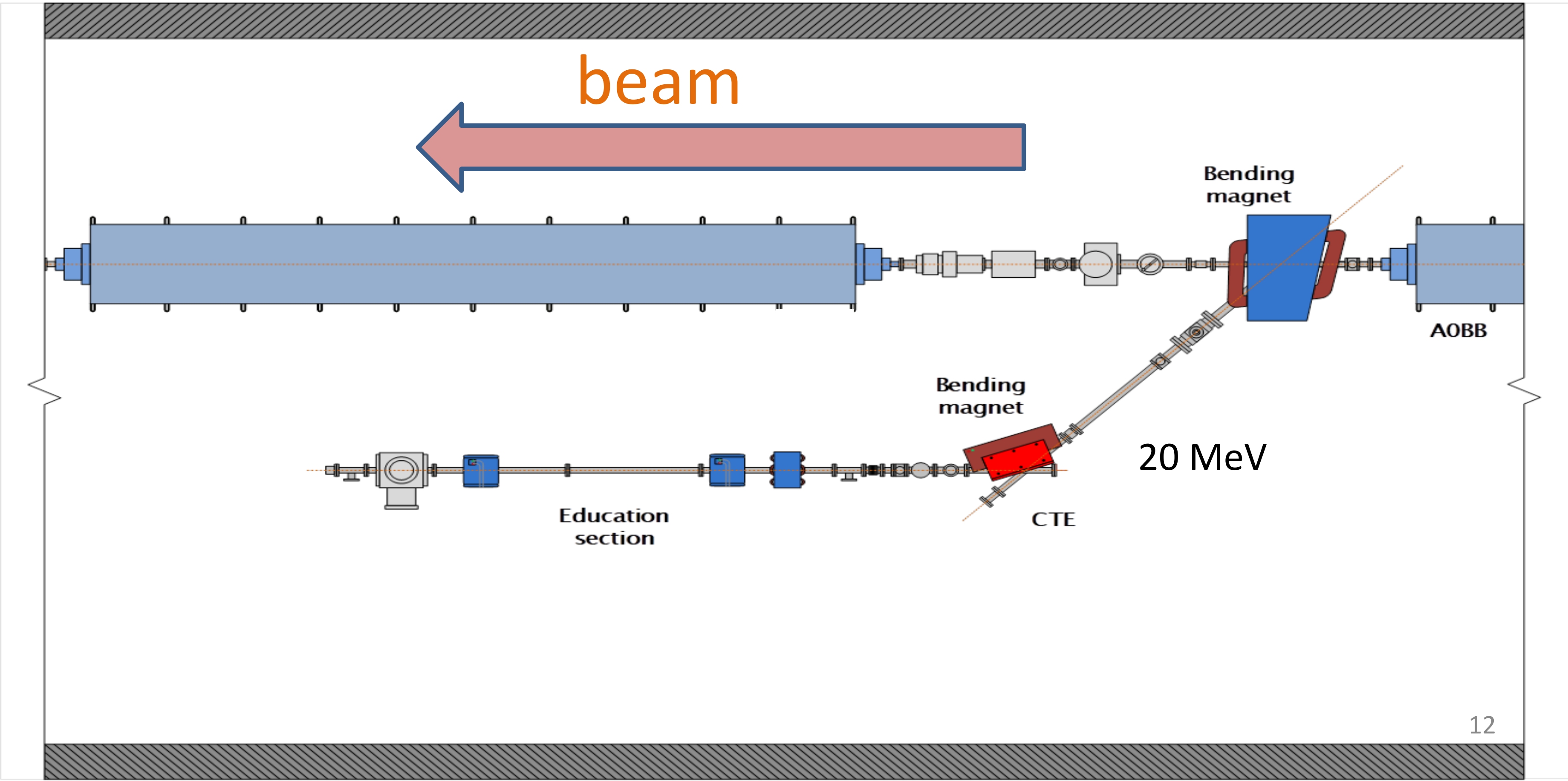
Main elements of the accelerator (accelerating structure, modulators, klystrons) is in good condition and has sufficient resource (>30000 hours) for long-term operation

Some technological systems need to be upgraded or replacement.

	cost (kUSD)
Vacuum system-pump replacement	240
The development of accelerator control system (ACS)	60
Beam diagnostics tools	30

Channels for output of the electron beam

- Currently, there are two channels for beam output from the drift gap after the A01 accelerator station (energy 5-20 MeV). One of these channels is intended for the implementation of educational programs. The second channel allows studies with a electron test beam.



Channels for beam output

after A01 station	20 MeV
after A03 station	130 MeV
after A04 station	200 MeV
after A06 station	350 MeV
after A08 station	500 MeV
«training» after A01 station	20 MeV

- The energy spread < 1%.
- Size of the focal spot < 1 mm
- Uniform illumination in the area of 20 cm x 20 cm
- The beam intensity from 1 to **10^{13} e^-/s**
- Beam stability < 5% when carrying out measurements

Testbeam equipment

- bending magnet
- quadrupole lenses to focus the beam
- horizontal and vertical collimators
- vacuum pipe with window for beam transportation and its output into the air
- necessary set of supporting structures and positioning system for irradiation of detectors
- local shielding for reduction of radiation loading and improvement of background conditions during the experiments
- the devices to measure and monitor the beam characteristics (energy, coordinates and direction, intensity, focal spot size, stability over time)

Testbeam construction (4 beams)	Cost (kUSD) (3 years)
Magnets and collimators	54
Detectors	36
Vacuum pipes, valves and windows	60

Short term plan of detectors R&D

The requirements for the beam depend on the problems to be solved:

- ❑ Research of radiation hardness of detectors, electronics, materials
  FCAL-collaboration, MEDIPIX, mu2e
  - high intensity
  - uniform illumination of a large area

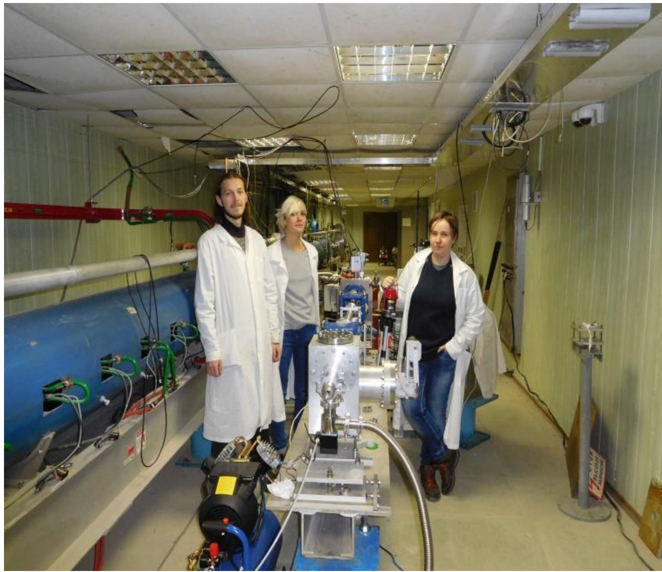
- ❑ Studies of crystals CsI, LYSO, BaF2, straw detectors, et al. - mu2e, COMET

- The low intensity, which allows to minimize the imposition of signals (pile up) and measure the response of the detector to single electrons. When working with crystals with a flash time of several tens of nanoseconds on LINAC-200 at a frequency of 50 Hz, it is necessary to work with a beam with an intensity of several tens of electrons/s, giving 10-20 triggers per second.
- The lowest possible background from scattered electrons, gamma rays, neutrons.
- Energy spread at the level of 1-3%

- ❑ R&D for NICA – semiconductor detectors, MPGDs etc.

Educational program.

- The following practical activities can be performed at the "training" beam of the LINAC-200 facility:
  - Operation of vacuum equipment;
  - study of magnetic optics (bending magnet, quadrupole lenses, sextupole);
  - beam diagnostics, emittance measurement.
- At the LINAC-200 facility it is possible to carry out trainings to study the response of various particle detectors.
- In future, laboratory classes to measure electron scattering on nuclei, research of giant resonances, etc. are planned.



Work plan.

- 2019
  - The upgrade of the vacuum system at A01-A04 stations.
  - The development and deployment of the ACS
  - Equipping the two existing testbeams with the standard set of detectors
  - Delivery of at least 200 hours of beam time for detector R&D
  - Start of practice at the "training" beam
- 2020
  - Installation and commissioning works at A05-A08 accelerating stations
  - Construction of the testbeams after A03 and A05 stations
  - Delivery of at least 300 hours of beam time for detector R&D
- 2021
  - Installation and commissioning works at A09-A12 accelerating stations
  - Construction of the testbeams after A08 and A11 stations
  - Delivery of at least 500 hours of beam time for detector R&D

	total	2019	2020	2021
Materials	75	25	25	25
Equipment	720	240	240	240
Travel costs	10	2	4	4
JINR budget (kUSD)	**805**	**267**	**269**	**269**

Equipment	**720**	**240**	**240**	**240**
A05-A12 station commissioning	240	80	80	80
clystron coils recovery	60	20	20	20
cooling and heat setting system	180	60	60	60
Accelerator upgrade	330	110	110	110
Vacuum pumps replacement	240	80	80	80
Monitoring and control	60	20	20	20
Beam diagnostics	30	10	10	10
Testbeam construction (4 beams)	150	50	50	50
Magnets and collimators	54	18	18	18
Detectors	36	12	12	12
Vacuum pipes, valves and windows	60	20	20	20

Conclusion

- Electron accelerator Linac-200 produced first 220 MeV beam in 2017
- We propose to use the machine as a base of the new testbeam facility, to enhance the detector R&D at DLNP and other scientific groups of JINR laboratories and from JINR Member States
- Several testbeams with the energy up to 800 MeV and wide range of beam intensity are planned
- Invaluable opporunity for practical training of young accelerator engineers and particle physicists

Thank you!

Financial Resources Needed for Project realization (Form №29)

No	TASKS	Total value	2019	2020	2021
	Direct costs of the Project.				
1	Accelerator, reactor	--	--	--	--
2	Computer	--	--	--	--
3	Materials	75	25	25	25
4	Equipment	720	240	240	240
5	R&D	--	--	--	--
6	Travel resources				
	a)) in non-ruble area	5	1	2	2
	b) in ruble area	5	1	2	2
	Total direct cost :	805	267	269	269