Test beam facilities at BINP

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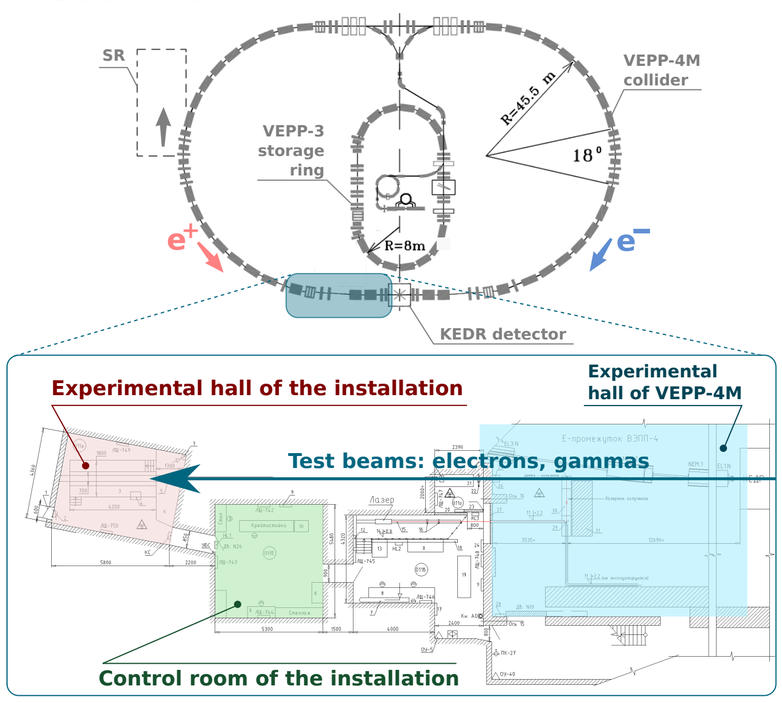
Introduction

- Detectors for High Energy Physics are developed in steps, including testing of detector prototype on specialized test beams.
- For this purpose an installation for generation of test beams of electrons and gammas was designed at BINP.
- The installation uses the infrastructure of VEPP–4M electron–positron collider.

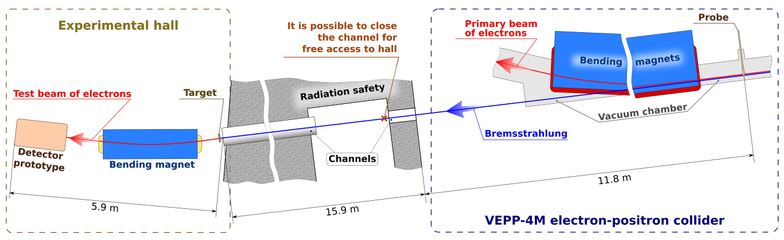
VEPP–4M main parameters	
Perimeter	366 m
Beam energy	1.5 ÷ 5.5 GeV
Number of bunchs	2×2
Peak luminosity (1.5 ÷ 3.0 GeV)	$2 \times 10^{30}\,\mathrm{cm^{-2}s^{-1}}$
Design luminosity (6.0 GeV)	$4 \times 10^{31}\,\mathrm{cm^{-2}s^{-1}}$

- Location of the installation



Test electron beam

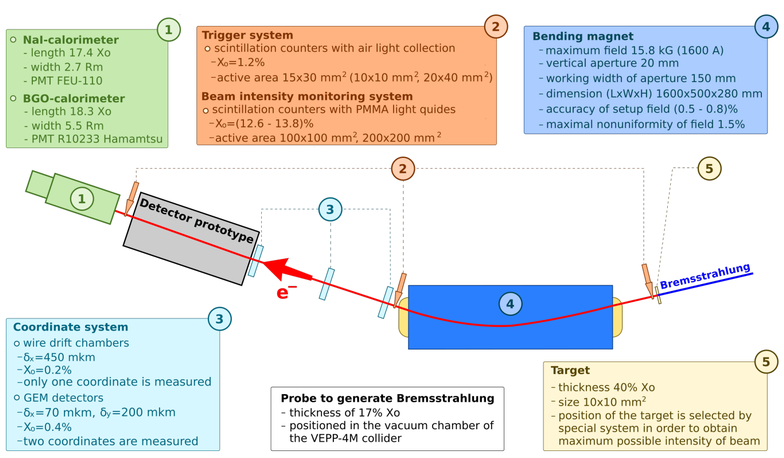
Principle of the beam production



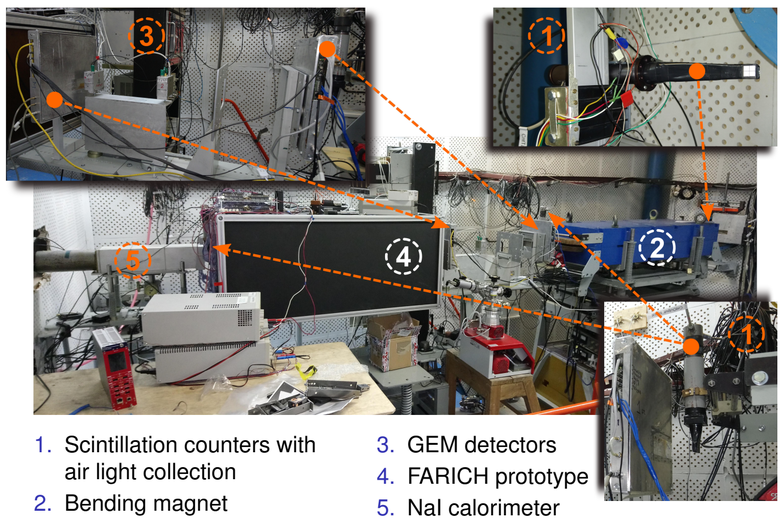
1. A special probe is moved into the halo of a primary electron beam of the VEPP–4M collider for generation of Bremsstrahlung.
2. These gammas are converted to electron – positron pairs on a lead target at the entrance to the experimental hall.
3. Electrons with a certain momentum are selected using a bending magnet.

The beam parameters	
Energy range	0.1 ÷ 3.5 GeV
Intensity	50 ÷ 100 Hz
Energy spread	7.8% for 0.1 GeV and 2.6% for 3.0 GeV

Test electron beam: Infrastructure



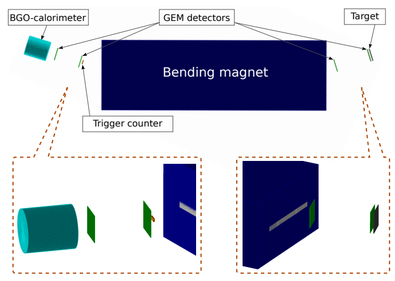
Example disposition of equipment in experimental hall (15/03/2018)

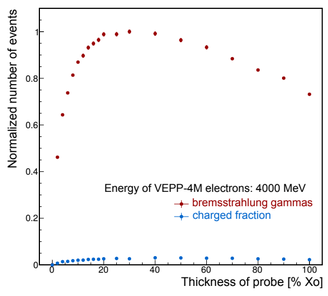


1. Scintillation counters with air light collection
2. Bending magnet
3. GEM detectors
4. FARICH prototype
5. NaI calorimeter

Test electron beam: MC simulation

- For the simulation GEANT4 toolkit was used.
- The simulation includes:
  - A complete description of geometry of the equipment in the experimental hall: the GEM detectors, the target, the bending magnet, the trigger counters and the calorimeter. Spatial resolution of the GEM detectors and magnetic field maps in the bending magnet are taken from experimental data.
  - Beam channels and the vacuum chamber of the VEPP–4M collider are described in details.
- The simulation is used for: evaluation of the optimal background conditions in the place where the prototype detector is located, to determine the optimum thickness and position of the probe and the target, and for other tasks.
- Example geometry description (left) and results of calculations for optimal thickness of the probe (right).



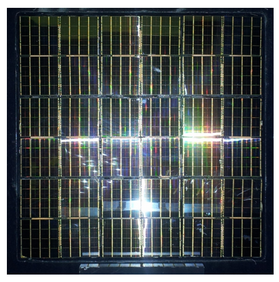


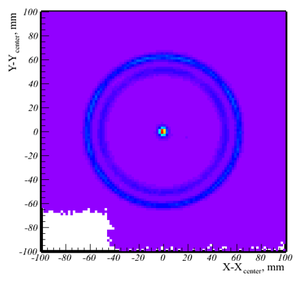
Test electron beam: Experiments

- Since 2011 the installation has been used successfully for the following experiments (more than 150 shifts):
  - Development of FARICH detector prototypes (FARICH – Focusing Aerogel RICH). FARICH is a promising detector for particle identification in future experiments, for example, Super Charm-Tau Factory at Novosibirsk.
  - Calibration of coordinate detectors based on GEM. These detectors are now used actively in several BINP experiments.
  - Detectors based on microchannel plates (MCPs) can be used for measurement of the time resolution and detection efficiency of charged particle. This is a new development mode for the upgrade of the endcap electromagnetic calorimeter of the CMS detector at the LHC (high luminosity).

Focusing Aerogel RICH

- Four FARICH prototypes were tested from 2011 to 2018.
- Prototype the PDPC FARICH detector – season 2013 (left) and cherenkov ring (right).

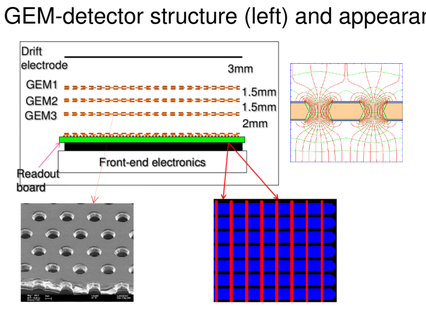


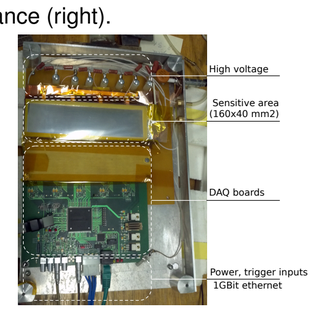


- Several single layer and focusing aerogel samples were tested at the beam.
- Focusing effect has been observed:
  - four layers aerogel (thickness 30 mm) $\Rightarrow \sigma_r = 1.1$ mm
  - single layer aerogel (thickness 20 mm) $\Rightarrow \sigma_r = 2.1$ mm

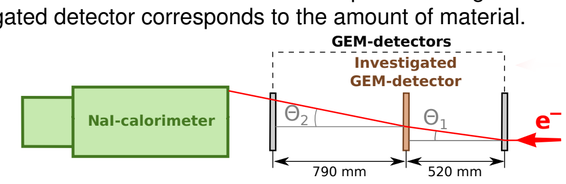
GEM based detectors

- GEM-detector structure (left) and appearance (right).





- Amount of material and spatial resolution for the GEM detectors were measured.
- The amount of material was measured, using 100 MeV electrons. The angular distribution of the tracks after multiple scattering in the investigated detector corresponds to the amount of material.

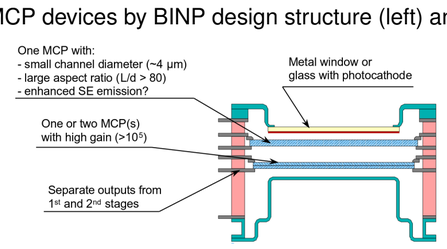


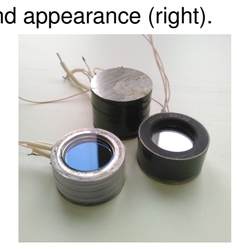
For example, for GEM-detector intended for DEUTERON facility at VEPP–3 the result was obtained: $0.203 \pm 0.003\%\ X_0$ ($\Leftrightarrow$ estimation 0.15% X_0).

- The spatial resolution ($1500 - 3000$ MeV electrons were used) varies within about $35 - 65$ μm.

MCP based devices

- MCP devices by BINP design structure (left) and appearance (right).

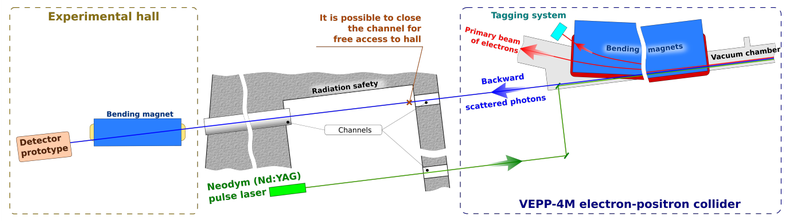




- For trigger and time reference two MCP PMT based Cherenkov counters are used.
- MCP based devices working in ionization mode could provide MIP detection efficiency up to 90% with time resolution better than 50 ps.

Tagged photon beam

Principle of the beam production



1. A pulsed laser is used to form the photon beam. The special setup of mirrors transported the laser photons to the interaction point of VEPP–4M.
2. After interaction a photon gets part of the primary electron energy and moves along the electron beam direction mainly within a cone with an angle of $1/\gamma$.
3. To determinate the photon energy the scattered electron energy is measured by the unique tagging system. This device has the energy resolution of $\sigma_E/E \sim 10^{-3}$.

The beam parameters	
Energy range	$(0.39 \div 0.97) \times$ E
Intensity	~ 1000 Hz

✓ The photon beam was used in 1998 last time for testing BELLE CsI calorimeter prototype. So, it takes some time (about 2-3 months) for its come back.

Compton and Bremsstrahlung spectra (photon beam)

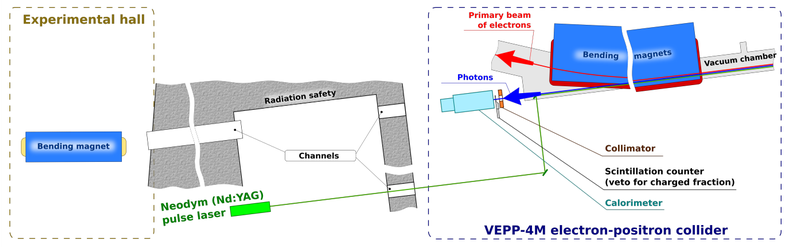
- Energy spread of the primary electron beam in the VEPP–4M is $\sigma_E/E = 3 \times 10^{-4}$.
- The energy scale and resolution of the NaI and BGO calorimeters were calibrated using the edges of the Compton (by laser) and Bremsstrahlung (by residual gas) spectra.
- The edge (maximum energy) of the Compton spectra is defined as:

$$w_{max} = E\frac{x}{1+x},$$ where: E – energy of the primary electron beam in the VEPP–4M, $x = 4\omega_0 E/m_e^2c^4$, ω_0 is the laser photon energy (1.165 eV and 2.33 eV for I and II harmonics, respectively)

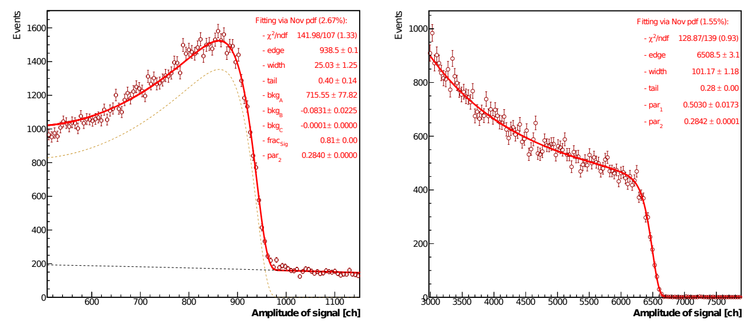
- List of possible calibration points at VEPP–4M collider

VEPP–4M energy [MeV]	Bremsstrahlung edge [MeV]	Compton edge I harmonic [MeV]	Compton edge II harmonic [MeV]
1850	1850	59	115
3000	3000	152	290
4000	4000	267	500

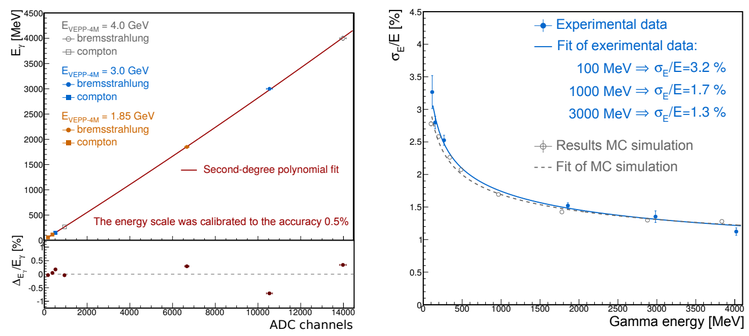
- Calorimeters were located next to the output window of the vacuum chamber of the VEPP–4M.



- Examples of fit of Compton spectrum near edge (left) and of Bremsstrahlung spectrum near edge (right).



- The calibration results of energy scale (left) and energy resolution (middle) for the BGO calorimeter.



Summary

- The test electron beam facility is fully operational since 2011.
- The parameters of the test electron beam:
  - energy range: $100 - 3500$ MeV
  - energy spread: 7.8% (100 MeV) – 2.6% (3000 MeV)
  - itensity: 50÷100 Hz
- A series of experiments with FARICH prototype detectors, MCP-based devices and GEM detectors were successfully performed on the electron beam.
- The tagged photon beam was used in 1998 last time for testing BELLE CsI calorimeter prototype. It takes some time (about 2-3 months) for its come back, if we will have tasks for it.
- Calibration energy resolution of calorimeters can be performed using the edges of the Compton and Bremsstrahlung spectra of the VEPP–4M collider.

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