CERN-BINP Workshop for young scientists in e^+e^- colliders

Gas Electron Multiplier based detectors in the experiments at e^+e^- colliders in Budker Institute of Nuclear Physics

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Outline

GEM detectors at BINP:

- Tagging System of KEDR experiment
- DEUTRON facility
- Upgrade of CMD-3 detector
- Project of Super Charm-Tau factory

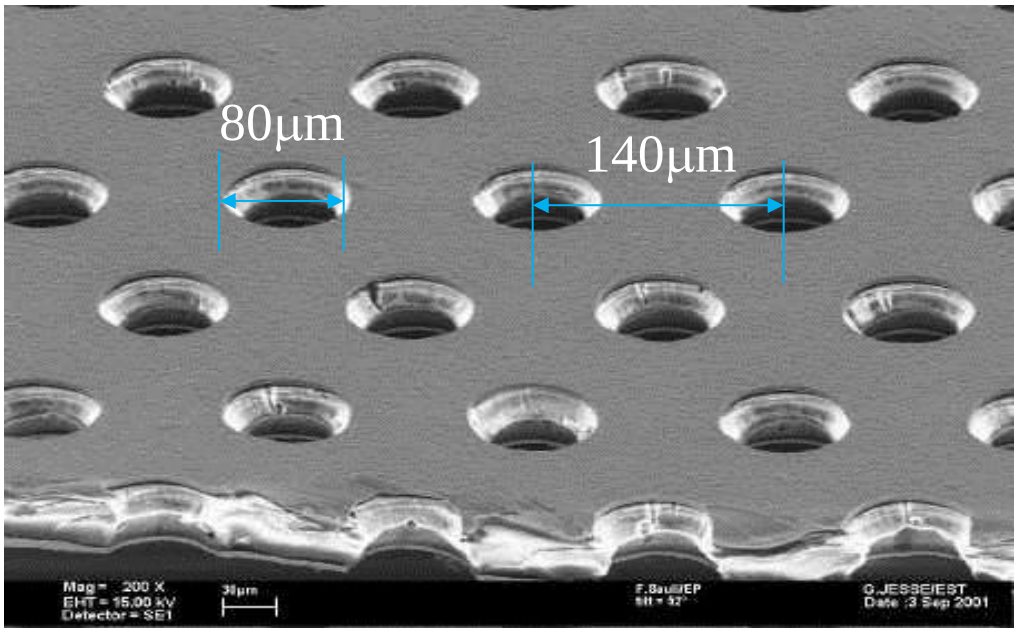
CERN

August 2016

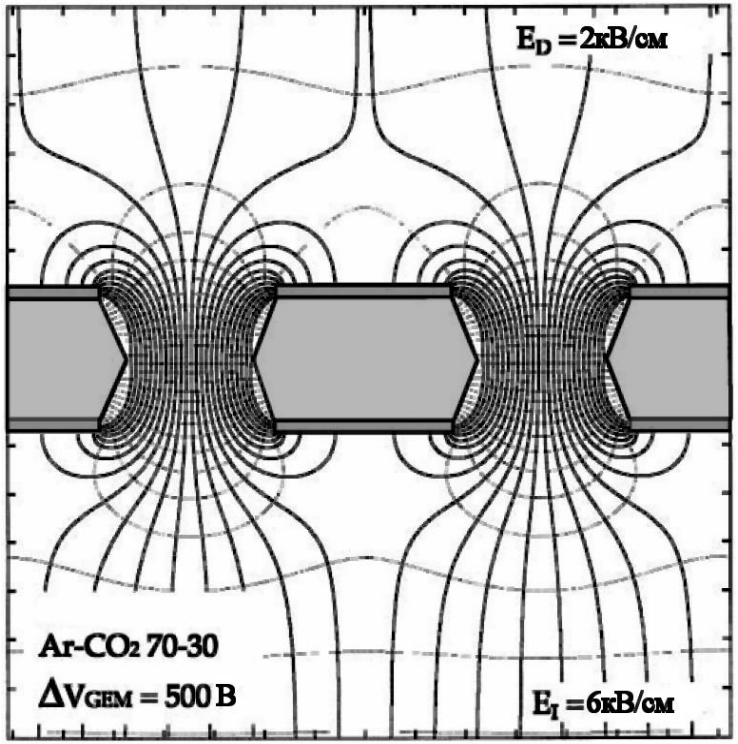
GEM detectors in general

General characteristics:

- Spatial resolution 35 – 75 μm
- Rate capability – up to 10^7 cm^{-2} s^{-1}
- Uniform gas converter
- Low cost (if to compare with semiconductor detectors)
- Radiation hardness
- Cascade structure for high gain

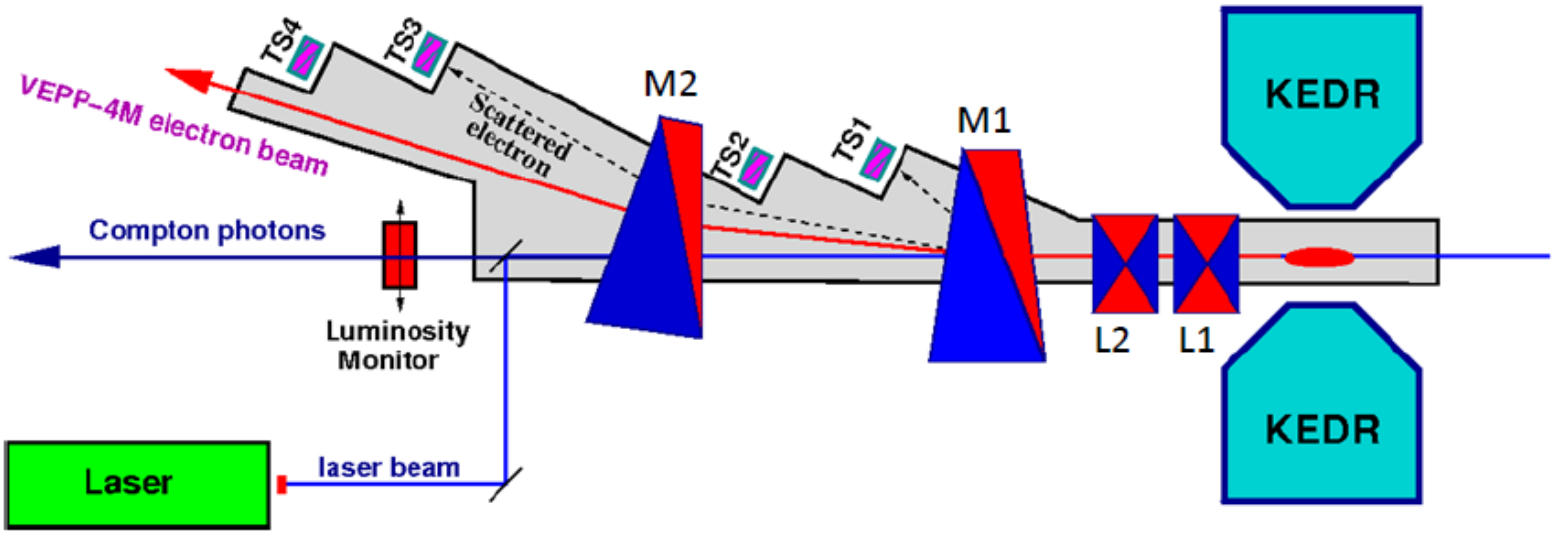


Fabio Sauli,
Nuclear Instruments and Methods. A 386 (1997) 531.



Bachmann S., Bressan A., Ropelewski L. et al. Charge amplification and transfer processes in the gas electron multiplier // Nucl. Instrum. and Methods. 1999. Vol. A438.

GEM detectors for the Tagging System of the KEDR experiment

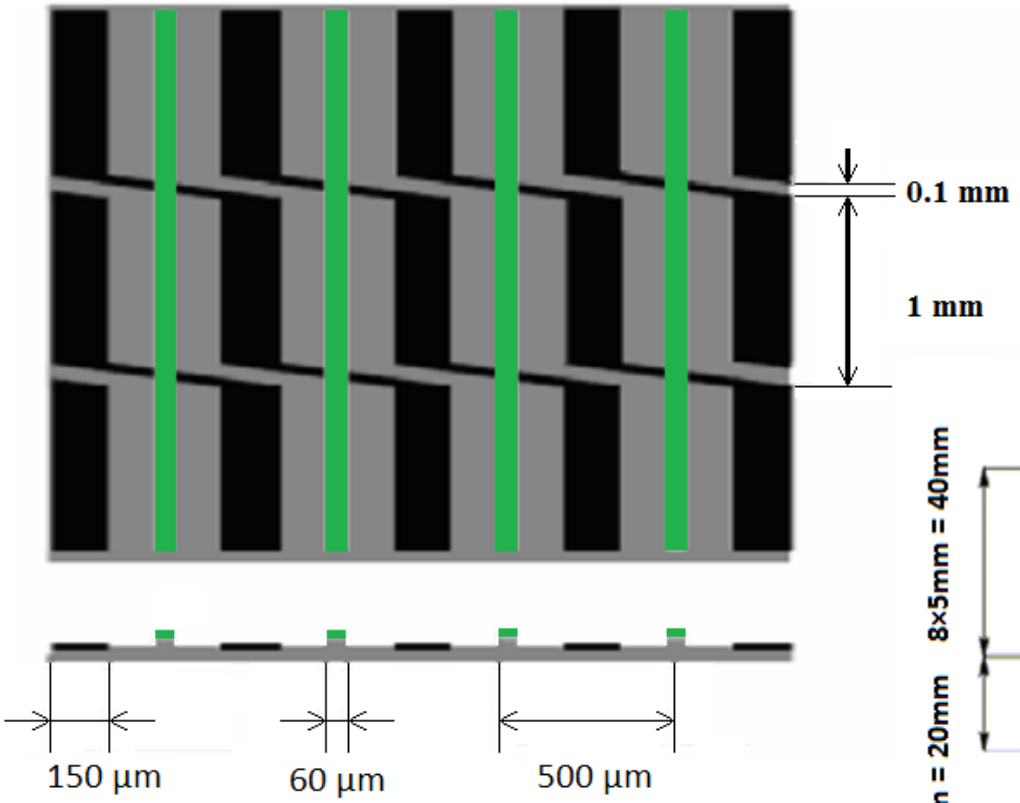


Tagging System of the **KEDR** experiment at the **VEPP-4M** collider

Physical program:

- Measurement of total cross-section $\gamma^*\gamma^* \rightarrow$ hadrons at small Q^2, where Q is a momentum transfer
- Study of C-even resonances (mainly π-mesons)
- Search for exotic states

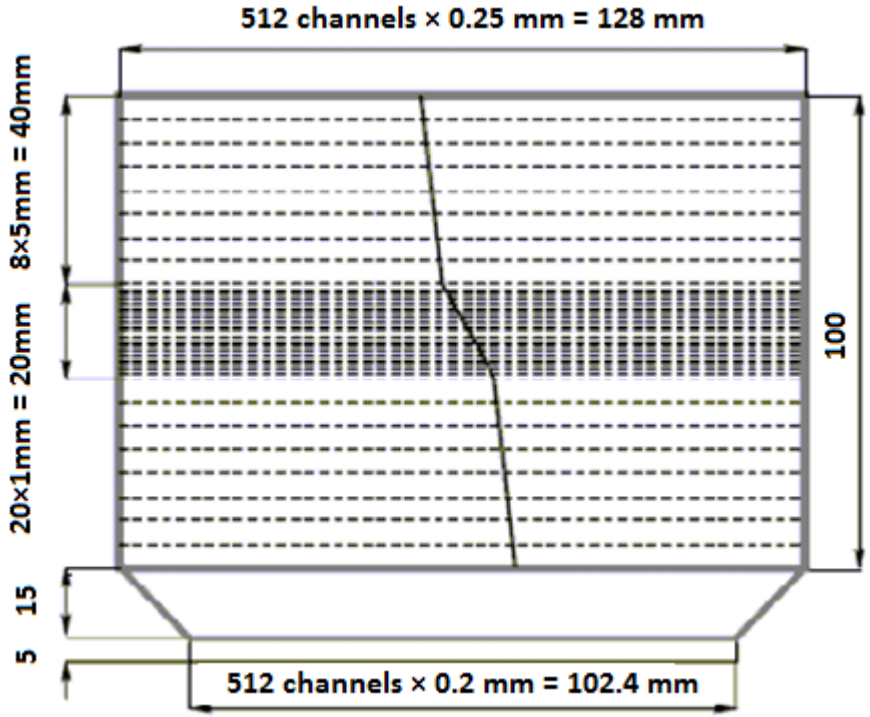
GEM detectors for the Tagging System of the KEDR experiment



Readout structure with small-angle stereo strips

Detectors dimensions:
9 detectors – 128mm × 100mm
3 detectors – 256mm × 100mm

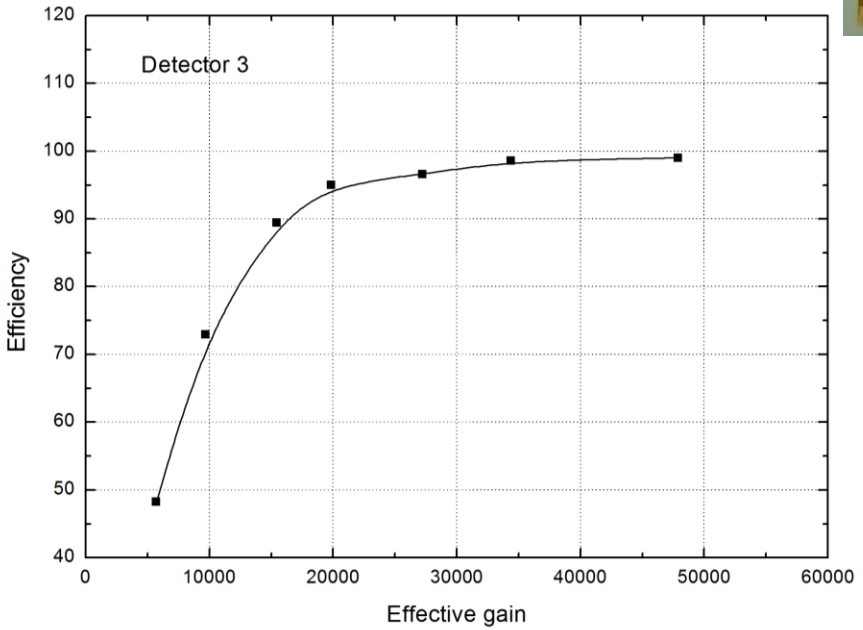
Triple-GEM detectors
X/X_0 = 0.58% (calculation)



Arrangement of channels and strips on the readout board

GEM detectors for the Tagging System of the KEDR experiment

Segmented GEM, effective pitch of the gaps – 5 mm



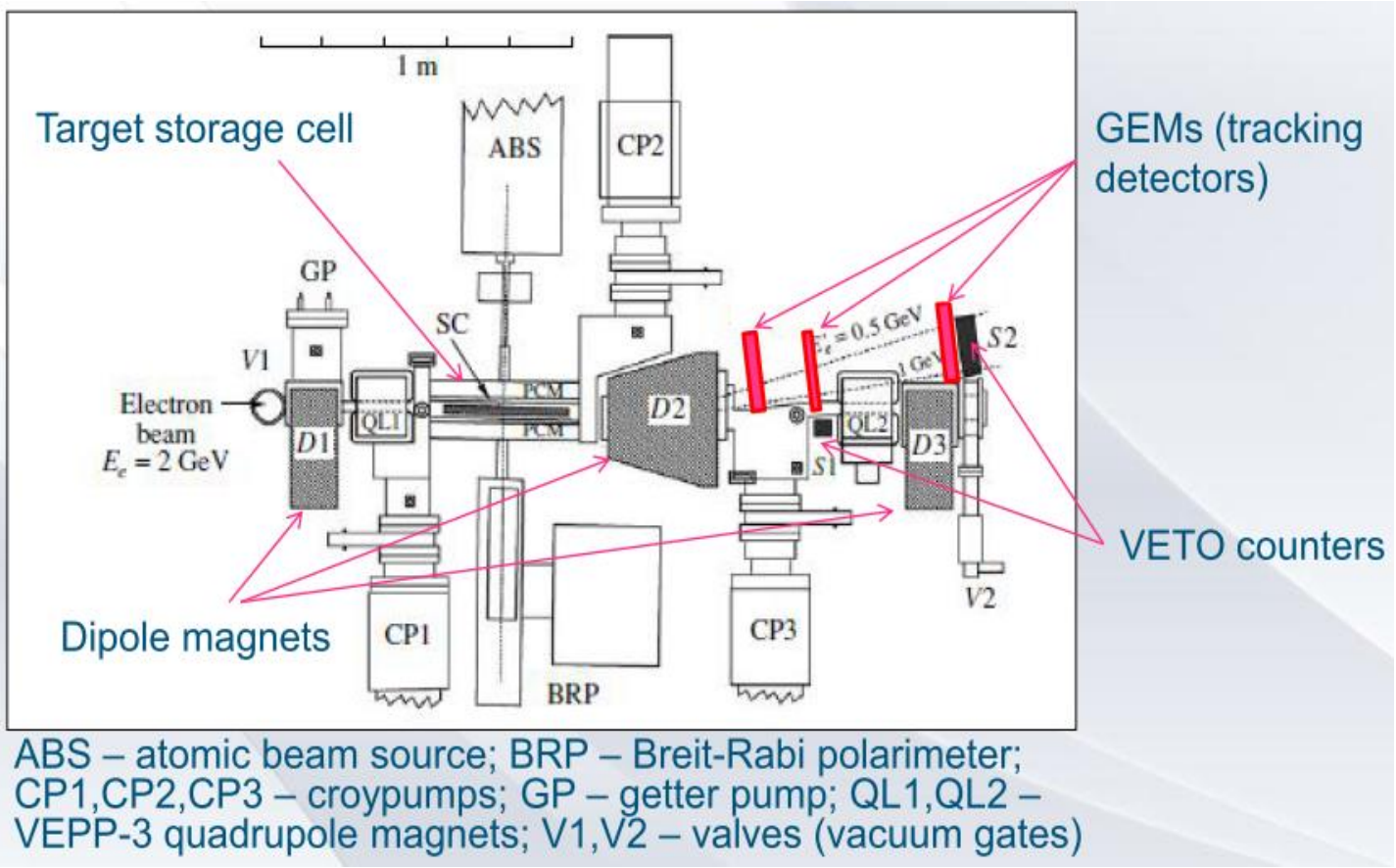
Trigger efficiency as a function of effective gain

Measurements at the extracted beam facility (2012)

Spatial resolution for orthogonal tracks

$$\sigma_{det} = 65 \pm 3\ \mu m$$

GEM detectors at the DEUTRON facility



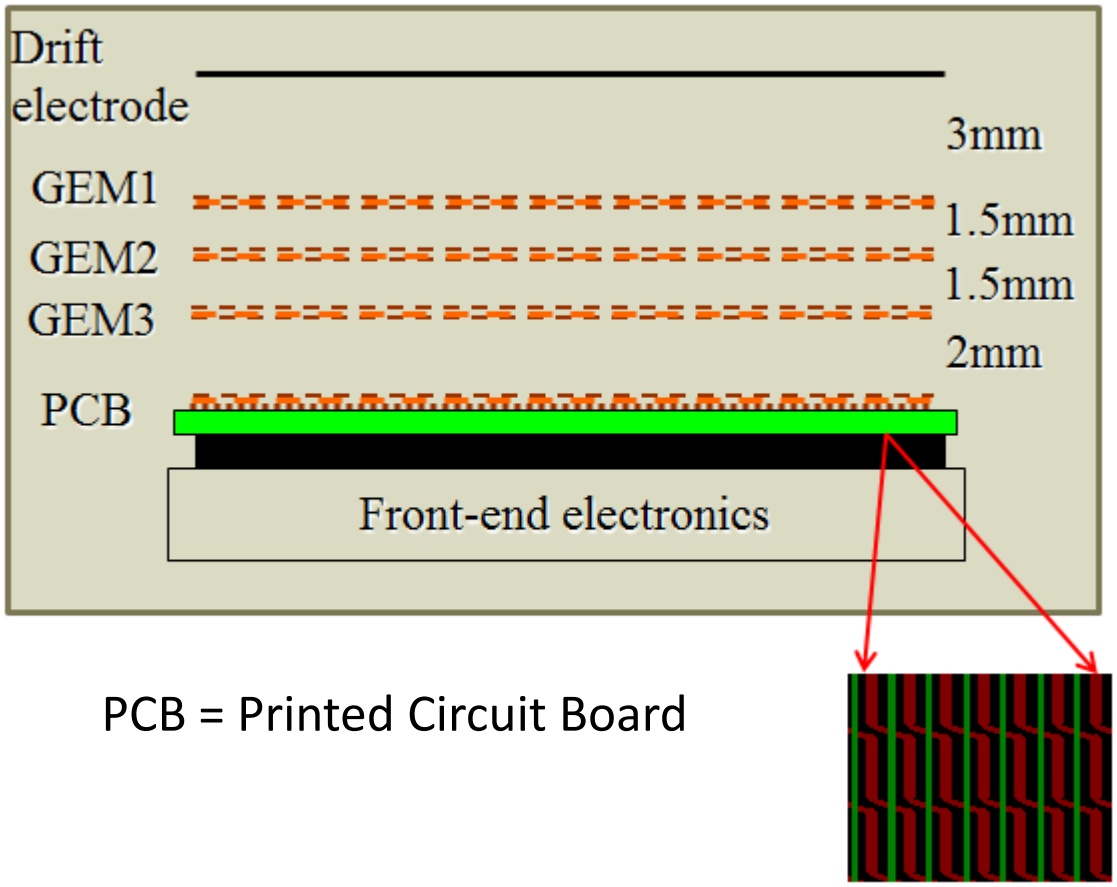
The DEUTERON internal target facility at the VEPP-3 storage ring in BINP

Physical program:

- Measurements of tensor asymmetries in fundamental nuclear reactions
- Measurements of the polarized observables in photo-nuclear reactions with photon energies up to 1.5 GeV

GEM detectors at the DEUTRON facility

Triple-GEM with low material budget



PCB = Printed Circuit Board

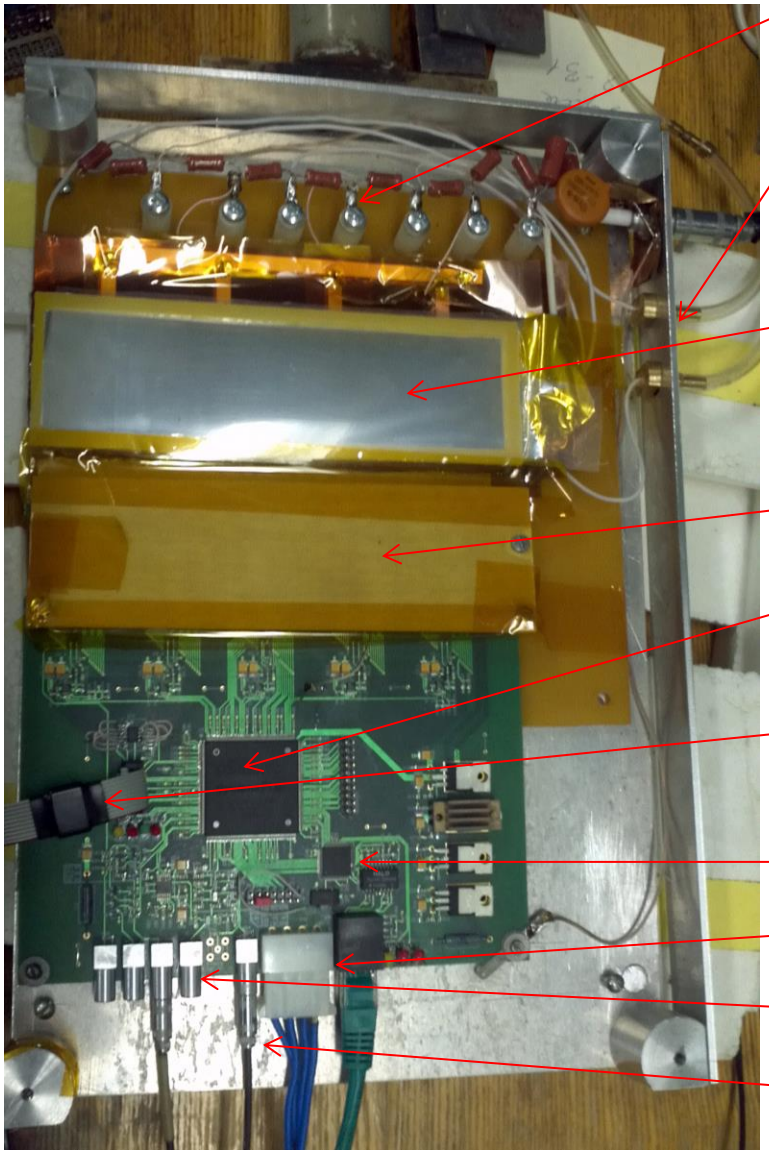
Detector element (material)	Rad.length, cm	x/X0
Si 300um	9.4	$3.2*10^{-3}$
Copper 5μm	1.44	$3.5*10^{-4}$
Kapton 50 μm	28.57	$1.8*10^{-4}$
Argon 1cm	11762	$0.85*10^{-4}$
Triple-GEM detector (5 layers of kapton 50 μm, 7 layers of copper 5 μm, 7mm of Ar)		$3.4*10^{-3}$
Light Triple-GEM detector (5 layers of kapton 50 μm, 7 layers of copper 1 μm, 7mm of Ar)		$1.5*10^{-3}$

Calculation of the radiation length according to anticipated thickness of materials

Measurements at VEPP-4M extracted beam in 2015

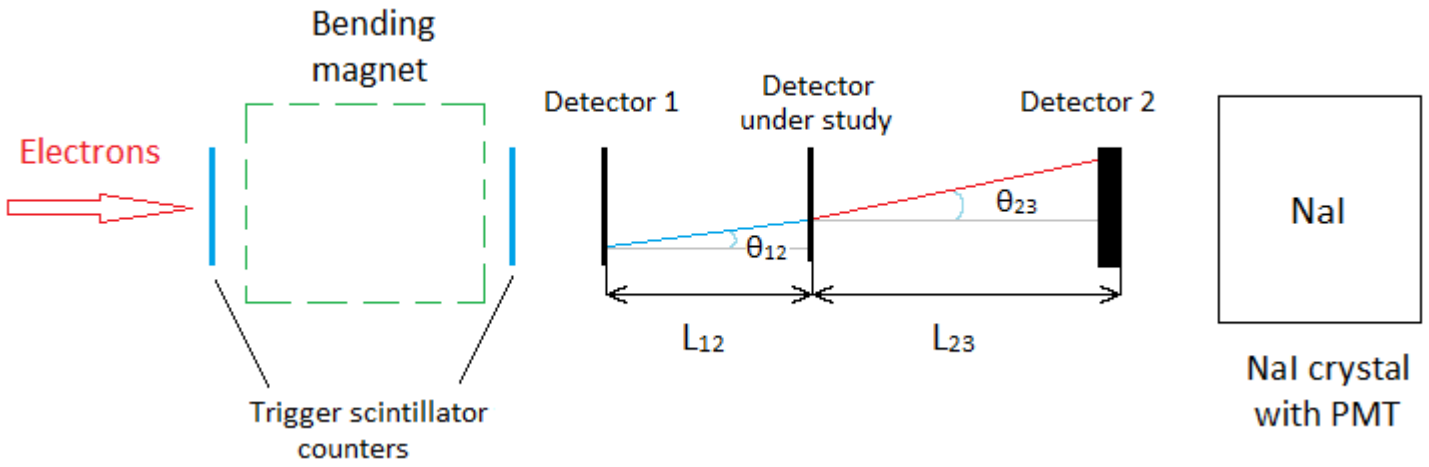
- $X/X_0 = 0.24\% \pm 0.05\%$
- Spatial resolution is less than 50 μm for orthogonal tracks

GEM detectors at the DEUTRON facility

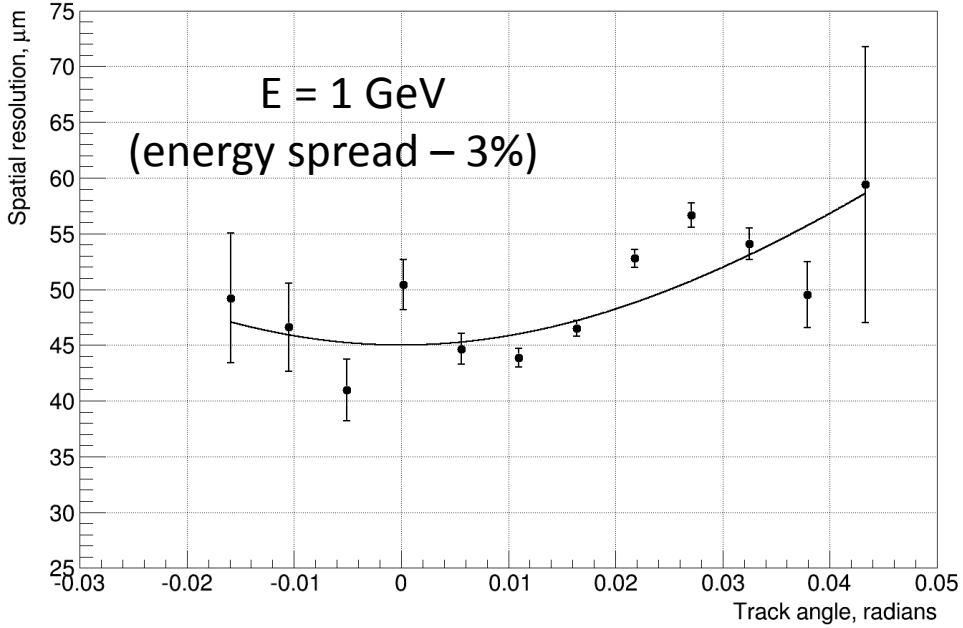


Structure of the GEM detector for the DEUTRON facility

GEM detectors at the DEUTRON facility



Principle scheme of material budget and spatial resolution **measurements** at the extracted beam facility at VEPP-4M accelerator complex



Measured dependence of **spatial resolution on track angle** (2016)

GEMs for the upgrade of CMD-3 detector

CMD-3 at the VEPP-2000 collider in BINP
Energy range of VEPP-2000: 0.3 GeV – 2 GeV

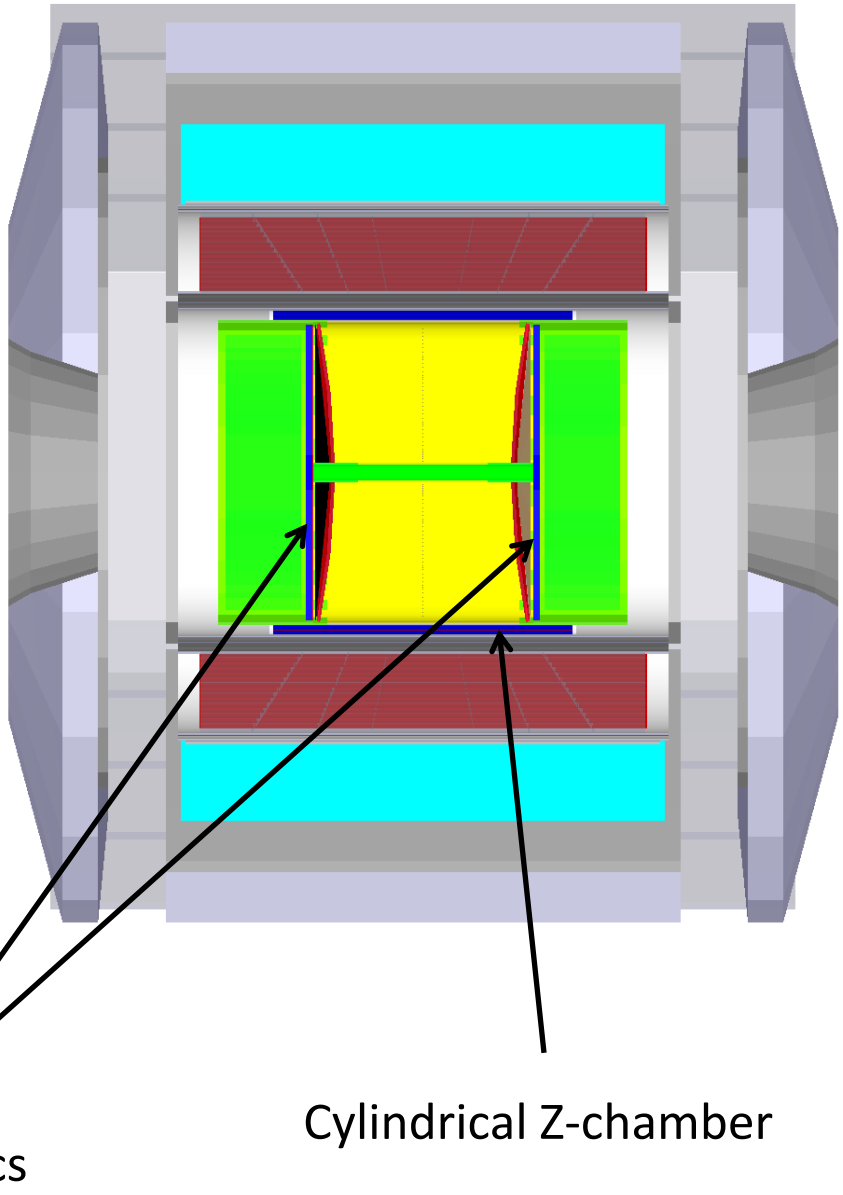
Physical program:

- Measurements of σ(e^+e^- → hadrons)
- Study of vector mesons
- Study of $n\bar{n}$ and $p\bar{p}$ production cross sections near threshold of the reactions
- Search for exotic hadrons

Large cylindrical triple-GEM detectors (CGEM) and flat triple-GEM end-cap discs are proposed for the upgrade of the CMD-3 detector

Advantages of upgraded Drift Chamber:

- Better spatial resolution
- Higher rate capability



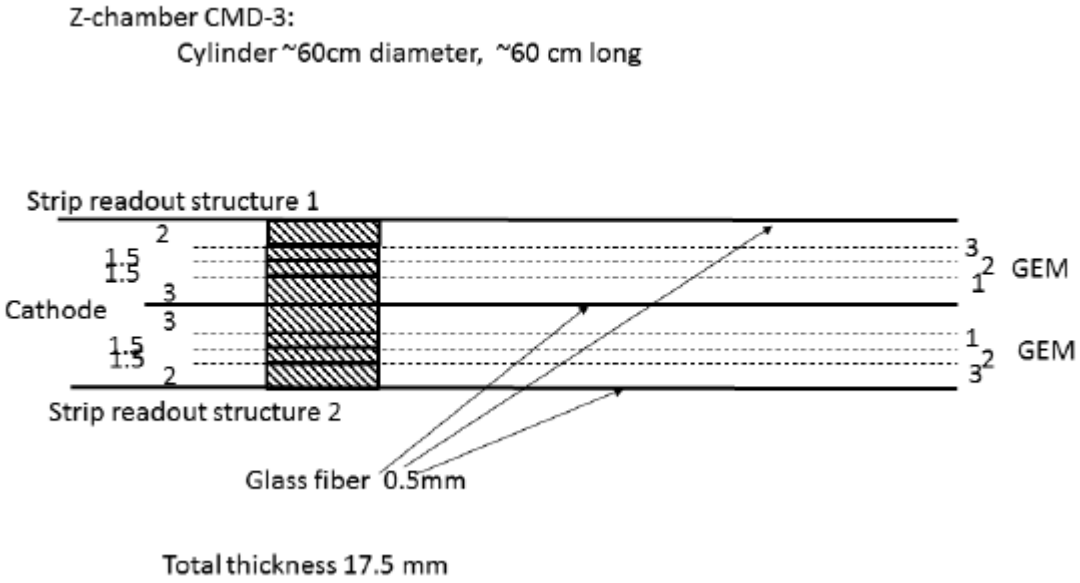
GEMs for the upgrade of CMD-3 detector

Existing Z-chamber (ZC) with MWPC needs upgrade

Cylindrical GEM (CGEM) technology (experience of KLOE-II)

CGEM with a digital read-out

Front-end electronics will be situated at the ends of the chamber

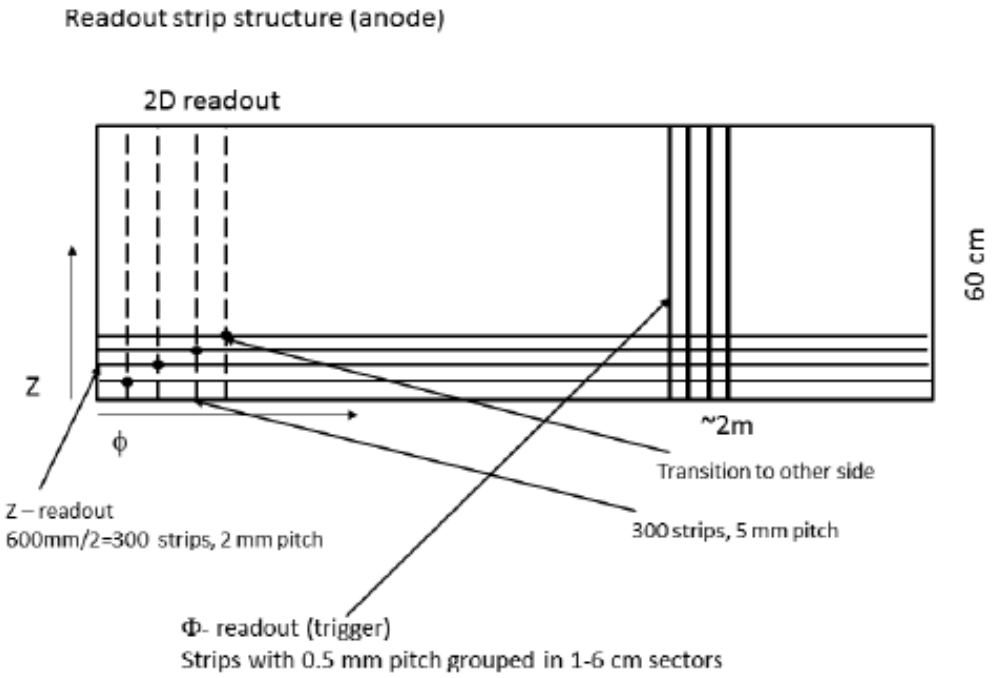


Cross section of the proposed structure of the CGEM ZC

Advantages of CGEM:

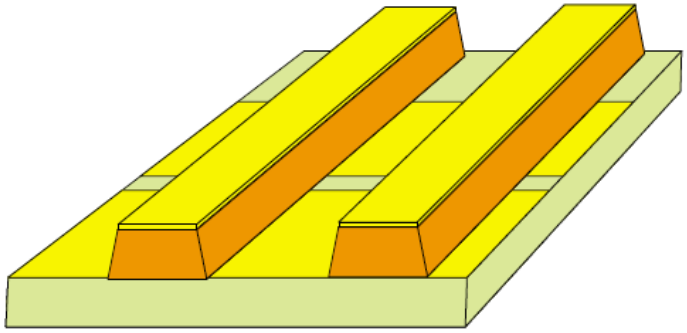
- Absence of wires (mechanical stability)
- Counting rate capability at least two orders of magnitude higher with respect to the wire chambers
- Segmentation prevents damage in the case of short circuit after a breakdown

GEMs for the upgrade of CMD-3 detector



Schematic structure of the readout board of the CGEM ZC

PCB – two layers with perpendicular strips, like in the triple-GEM detectors for COMPASS experiment at CERN



Bottom layer is segmented in 1.9 mm wide strips with a pitch of 2mm that provide measurement of Z-coordinate (along the beam).

The top layer of the readout board provides trigger signals. It is segmented in strips parallel to the cylinder axis (Z-direction) that are 100 – 150 µm wide and have pitch of 0.5 mm

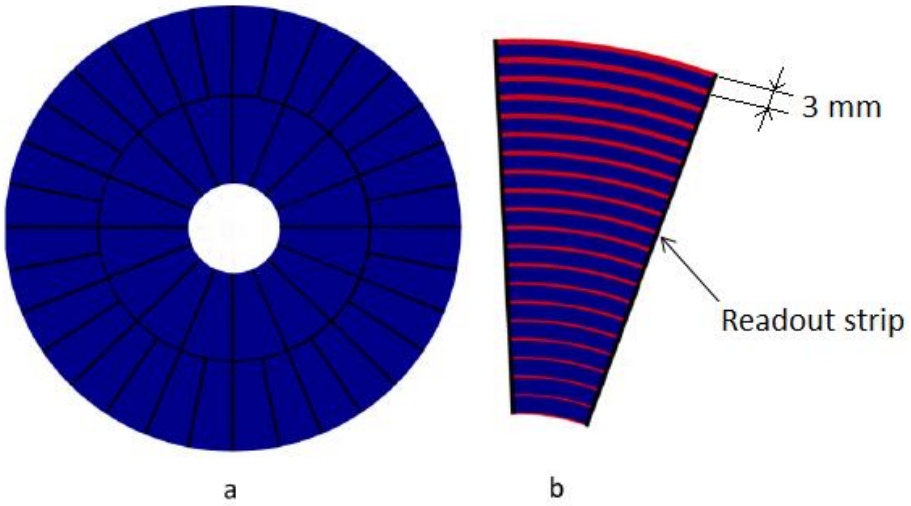
GEMs for the upgrade of CMD-3 detector

GEM end-cap tracker

Precise measurements of pion form factor in the wide energy range using ISR (initial state radiation)

Precise measurements of charge asymmetry for the process $e^+e^- \rightarrow \mu^+\mu^-$ (maximum of the cross-section at small polar angles)

Discs are similar to TOTEM experiment at CERN



Parameters

- Outer diameter – 500 mm
- Inner diameter – 100 mm
- 48 pads per disc
- About 1600 strips per disc
- Thickness 13.5 mm
- Electronics on the outer edges form trigger signal from each segment

Layout of the readout board of the end-cap discs: a) layout of the trigger pads; b) layout of the coordinate strips inside a trigger pad

Super c-τ factory

Physical program:

- Study of rare decays of D mesons, τ-lepton
- Study of $D^0\overline{D^0}$ oscillations
- Search for yet unobserved lepton-flavor-violating decays of τ-lepton

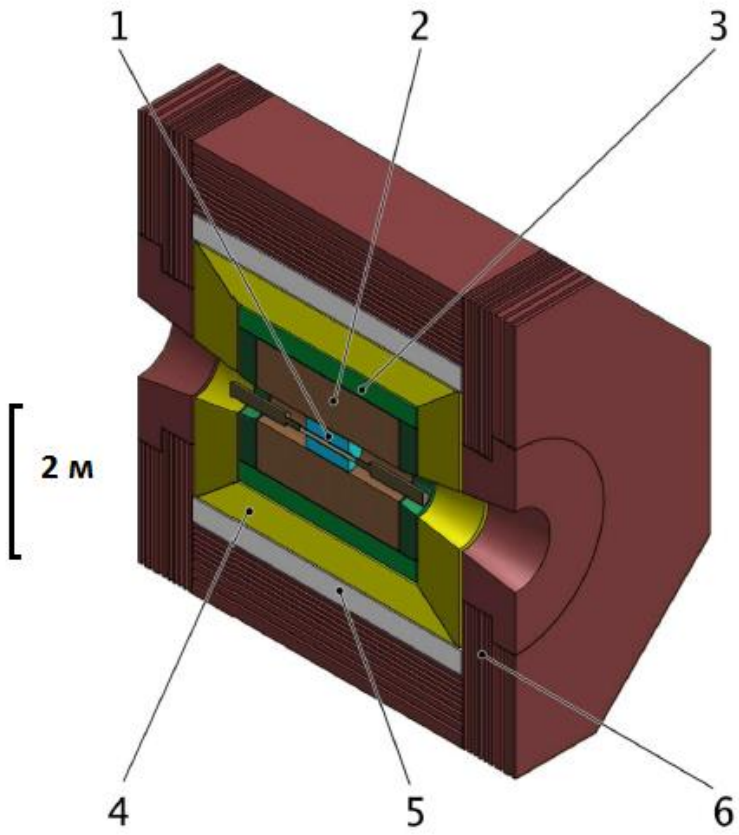
Peak luminosity 10^{35} $cm^{-2}s^{-1}$

2E = 2 ÷ 5 GeV

Time Projection Chamber (TPC) is proposed for the Vertex Detector

Universal magnetic detector for Super c-τ factory:

1 – vertex detector;
2 – drift chamber;
3 – identification system based on FARICH;
4 – calorimeter;
5 – superconducting coil;
6 – yoke with a muon system.



GEM detectors at Super Charm-Tau factory (project)

TPC is proposed for the Vertex Detector

Disadvantages of TPC based on Multiwire proportional chamber (MWPC):

- Essential backflow of ions
- Space charge accumulation and electric field distortion
- Spatial resolution is deteriorated
- Special protection mesh is needed
- Large dead time
- Detector can not work in the continuous mode

Solution: TPC with GEM and Micromegas

Advantages of TPC with GEM and Micromegas:

- Reduction of the backflow of ions by more than three orders of magnitude
- Detector can work in the continuous mode

Experience of

- PANDA Collaboration - continuous readout using GEMs
- LC TPC Collaboration at International Linear Collider - GEM + Micromegas

Conclusions

Essential experience in development and application of GEM detectors exists by the moment at BINP, which is largely due to international collaboration with CERN

The development of GEM based detectors at BINP is in active phase

GEM based detectors operates in BINP at:

- Tagging System of the KEDR experiment
- DEUTRON facility

- Extracted beam facility of VEPP-4M collider
- Laser polarimeter at VEPP-4M collider
- Detector for Dark Matter search

Have not been discussed in the presentation

GEM based detectors are proposed for:

- Upgrade of CMD-3 detector at VEPP-2000 collider
- Vertex Detector of Super Charm-Tau Factory

Thank you for your attention