Alexey Aparin[1], Olga Kutinova[1], Maria Patsyuk[1], Diana Seitova[2]
1 - Joint Institute for Nuclear Research, Dubna
2 – Institute of Nuclear Physics, Kazakhstan

This research has been funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21881941)

JOINT INSTITUTE FOR NUCLEAR RESEARCH
JINR

What is the EIC facility

What is the EIC:

A high luminosity ($10^{33} – 10^{34}$ $cm^{-2}s^{-1}$) polarized electron proton / ion collider with $\sqrt{s_{ep}}$ = 28 – 140 GeV

What is special:

EIC is the ONLY new collider in foreseeable future. Allows to remain at frontier of Accelerator S&T.

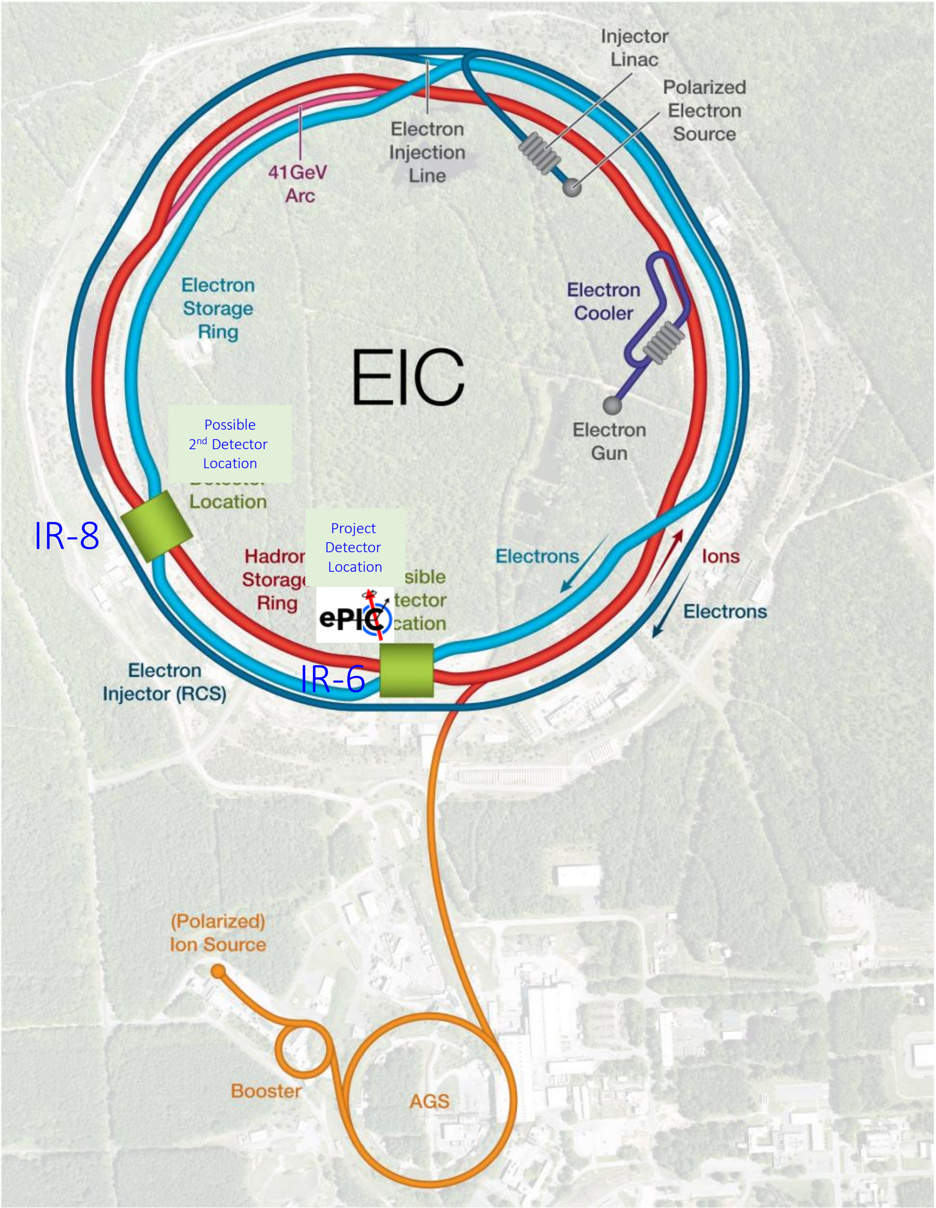
factor 100 to 1000 higher luminosity as HERA
both electrons and protons / light nuclei polarized, nuclear beams: d to U

Fixed Target Facilities i.e.:
at minimum > 2 decades increase in kinematic coverage in x and Q^2

Science Program:

"An EIC can uniquely address three profound questions About nucleons—neutrons and protons—and how they are assembled to form the nuclei of atoms:
- How does the mass of the nucleon arise?
- How does the spin of the nucleon arise?
- What are the emergent properties of dense systems of gluons?"

State of the art general purpose collider detector

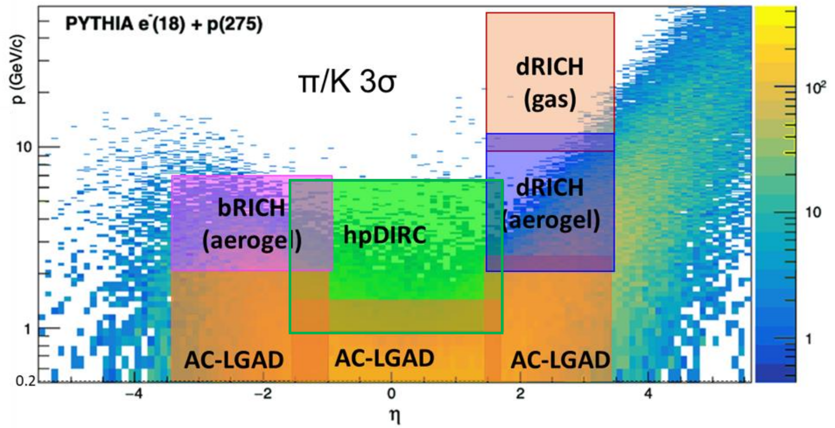


hpDIRC

hpDIRC is the baseline hadronic barrel PID system for ePIC

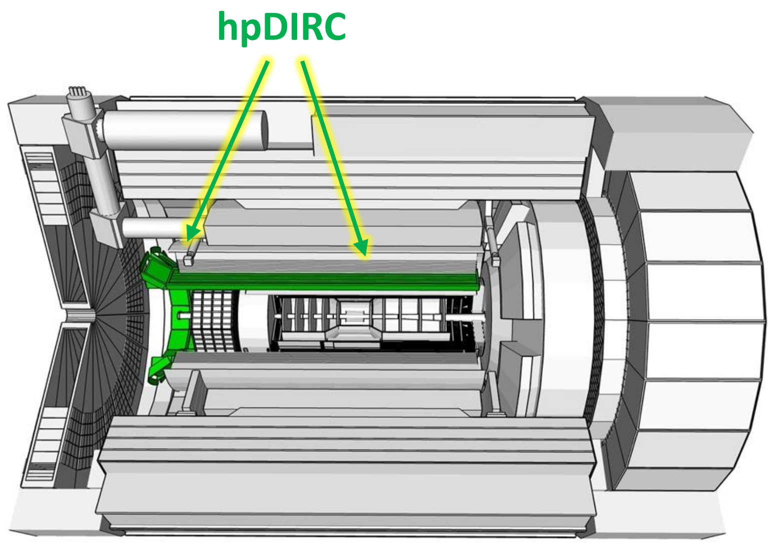
- Concept developed as part of previous Generic R&D program
- Finalizing design, validating components as part of Project R&D
- Future innovate optical DIRC configurations in new Generic R&D program

Summary of π/K PID requirements in ePIC



hpDIRC Concept:

- Fast focusing DIRC, utilizing high-resolution 3D (x,y,t) reconstruction
- Design based on BaBar DIRC, R&D for SuperB FDIRC, PANDA Barrel DIRC
- Radiator/light guide: narrow fused silica bars (radius/length flexible)
- Innovative 3-layer spherical lenses
- Compact fused silica prisms as expansion volumes
- Fast photon detection: small-pixel MCP-PMTs and high-density readout electronics
- Detailed Geant4 simulation: ≥ 3 s.d. π/K separation at 6 GeV/c,
  ≥ 3 s.d. e/π separation at 1.2 GeV/c

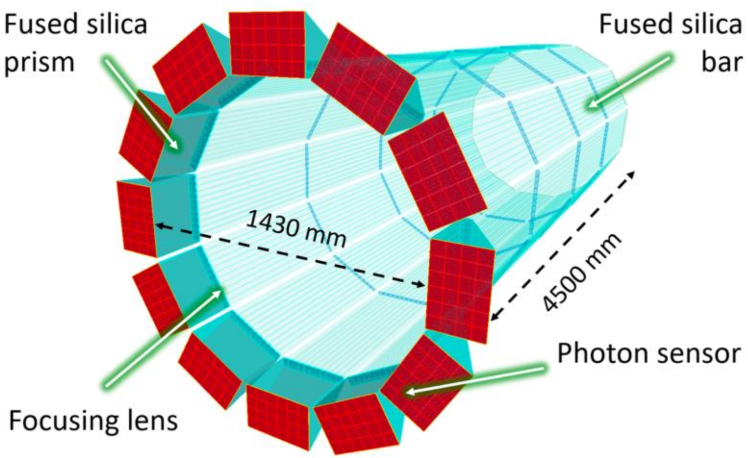


3D model of ePIC central detector

hpDIRC

hpDIRC is the baseline hadronic barrel PID system for ePIC

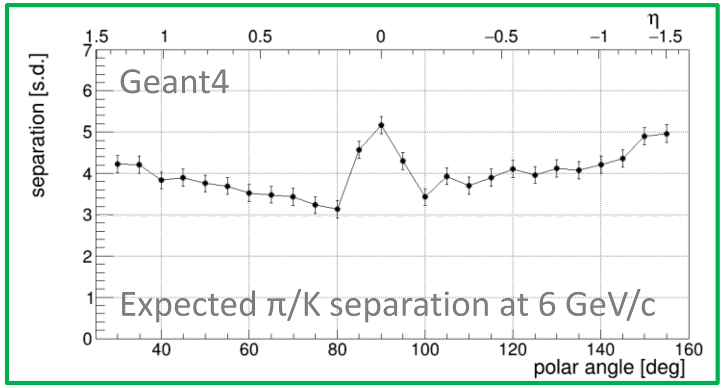
- Concept developed as part of previous Generic R&D program
- Finalizing design, validating components as part of Project R&D
- Future innovate optical DIRC configurations in new Generic R&D program

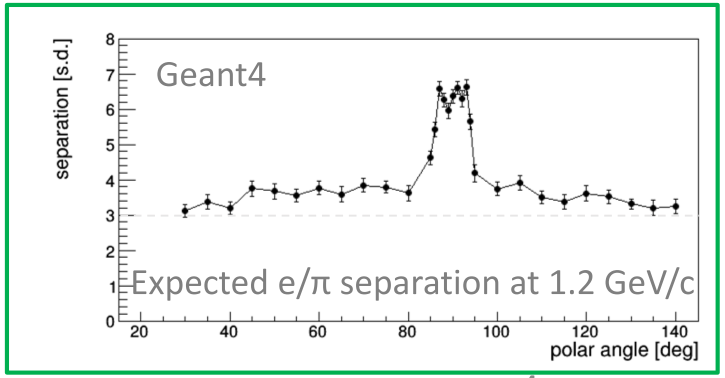


hpDIRC Concept:

- Fast focusing DIRC, utilizing high-resolution 3D (x,y,t) reconstruction
- Design based on BaBar DIRC, R&D for SuperB FDIRC, PANDA Barrel DIRC
- Radiator/light guide: narrow fused silica bars (radius/length flexible)
- Innovative 3-layer spherical lenses
- Compact fused silica prisms as expansion volumes
- Fast photon detection: small-pixel MCP-PMTs and high-density readout electronics
- Detailed Geant4 simulation: ≥ 3 s.d. π/K separation at 6 GeV/c,

  ≥ 3 s.d. e/π separation at 1.2 GeV/c





hpDIRC Preliminary Baseline Design

Radiator bars:

- Barrel radius: 720 mm, 12 sectors
- 10 long bars per sector, 4880 mm x 35 mm x 17 mm (L x W x T)
- Long bar: 4 bars, glued end-to-end,
- Short bars made from highly polished synthetic fused silica
- Flat mirror on far end

Focusing optics:

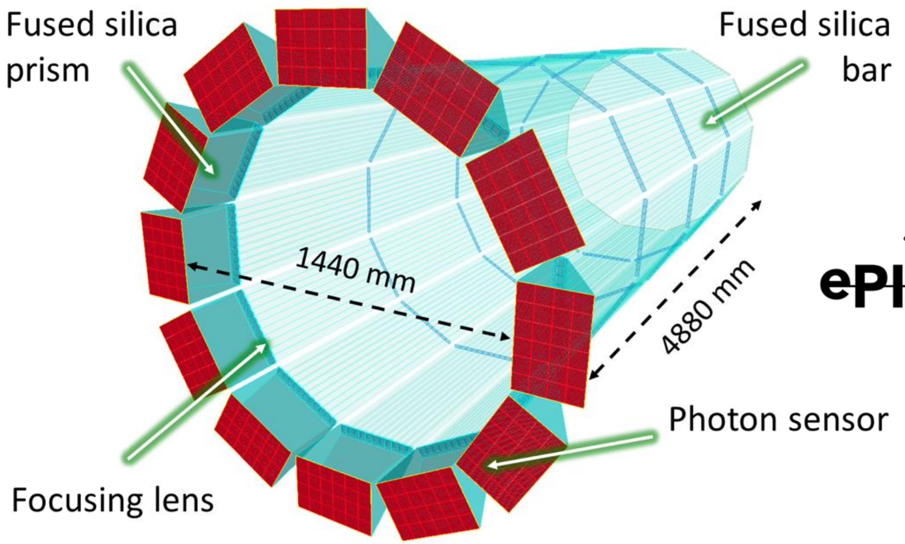
- Radiation-hard 3-layer spherical lens (sapphire or PbF_2)

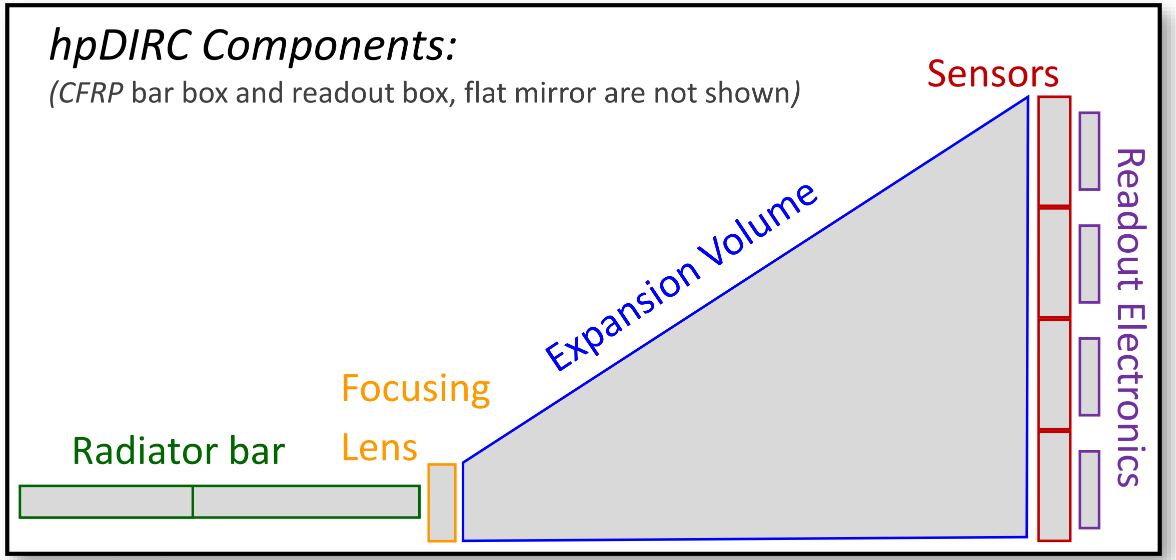
Expansion volume:

- Solid fused silica prism: 24 x 36 x 30 cm^3 (H x W x L)

Readout system:

- MCP-PMT Sensors (e.g. Photek/Photonis/Incom)
- ASIC-based Electronics (e.g EICROC)





Focusing Optics

Barrel DIRC counters (PANDA, EIC) require focusing for wide range of photon angles

Conventional plano-convex lens with air gap limits DIRC performance

- Significant photon yield loss for particle polar angles around 90°, gap in DIRC PID
- Distortion of image plane, PID performance deterioration

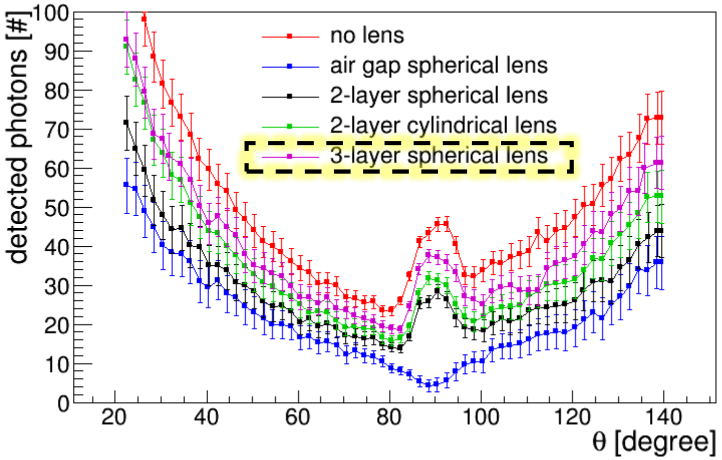
Innovative solution:

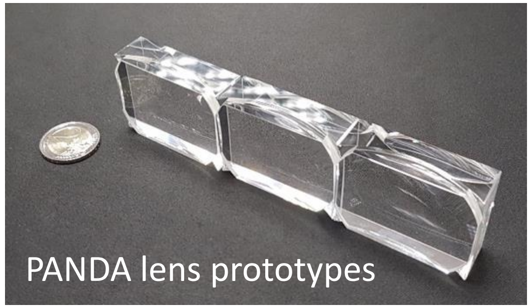
- 3-layer compound lens (without air gap):

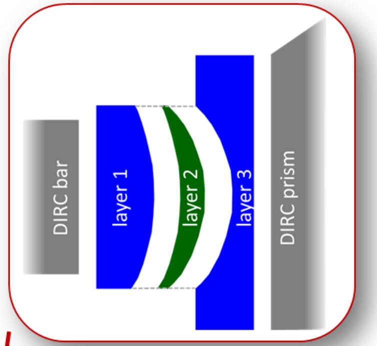
layer of high-refractive index material (focusing/defocusing)
sandwiched between two layers of fused silica

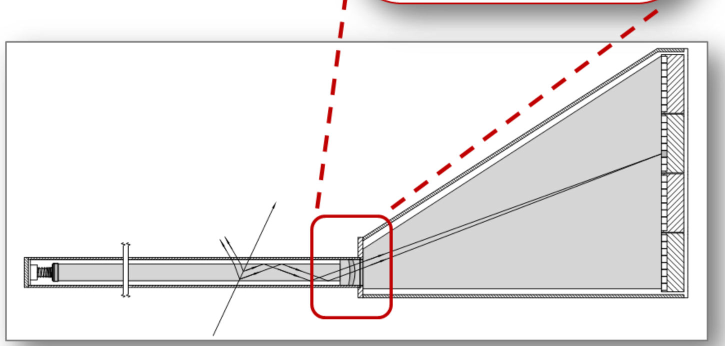
- Creates flat focal plane – matched to fused silica prism shape
- Avoids photon loss and barrel PID gap
- Detailed radiation-hardness studies performed with ^{60}Co source, neutron irradiation next
- Lanthanum crown glass (LaK33B) for PANDA, rad-hard sapphire or PbF_2 for EIC
- Industrial fabrication of lenses demonstrated
- Performance of spherical 3-layer lenses validated with PANDA Barrel DIRC prototype

Geant4 simulation: photon yield



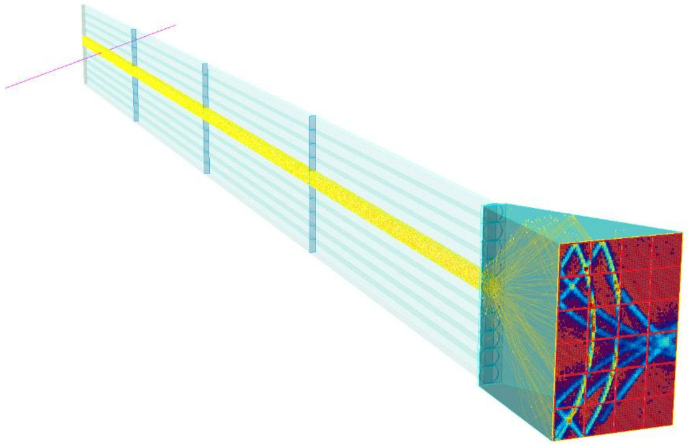




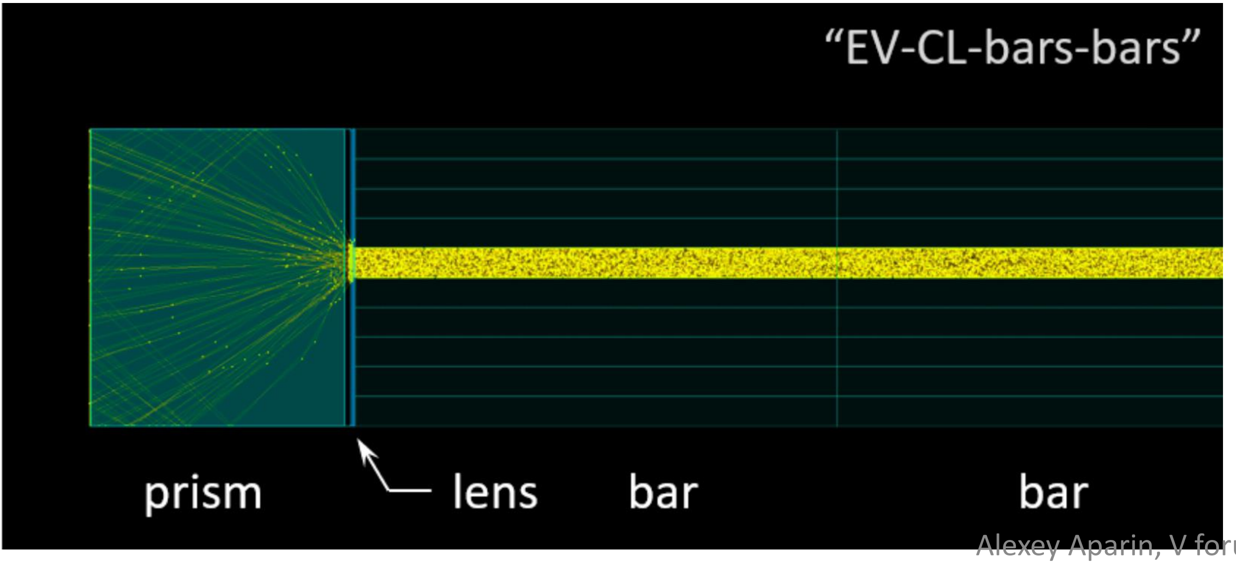


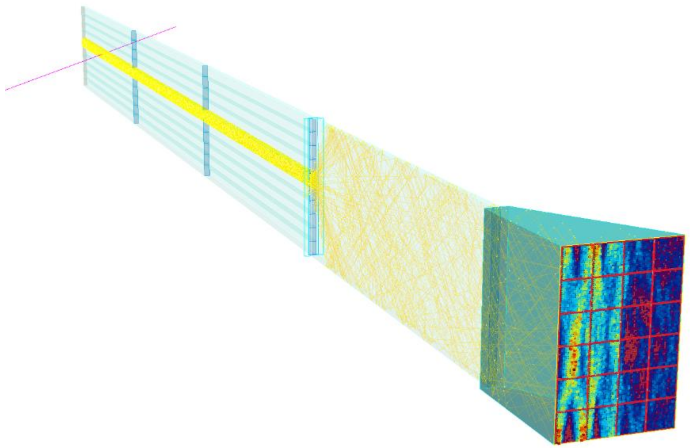
Alternative Design

- ePIC detector barrel length requires additional “light guide” section to connect BaBar DIRC bars to prism
- Alternative to baseline (narrow bars) is one single short wide plate

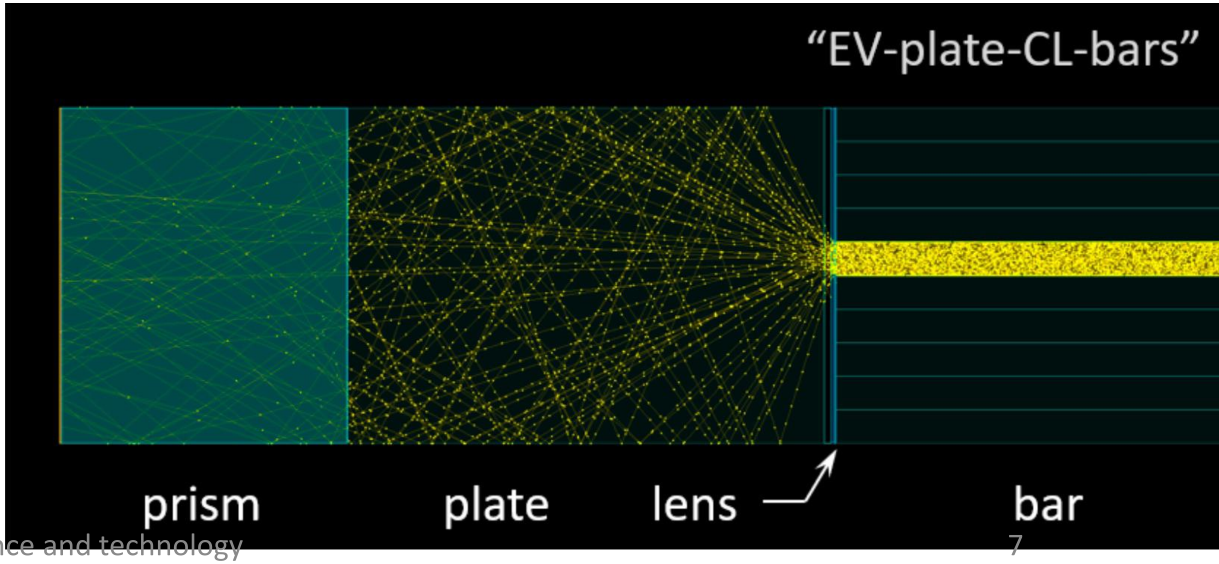


Only narrow bars in each sector

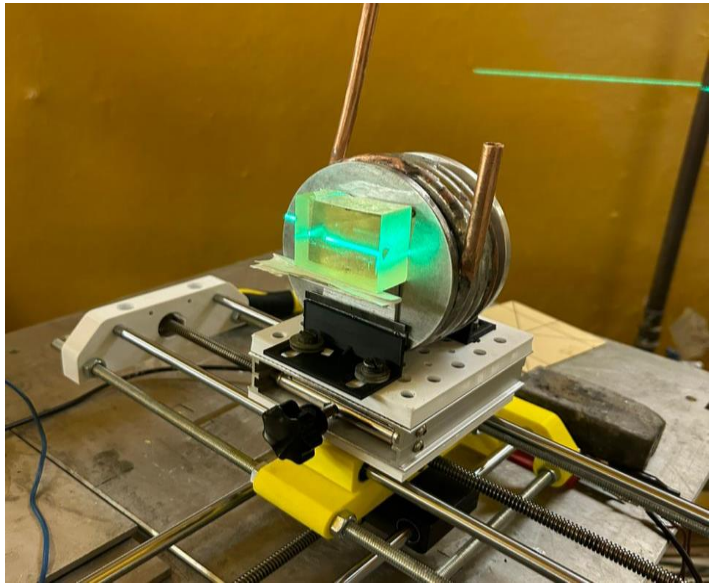




Hybrid of bars and plate in each sector



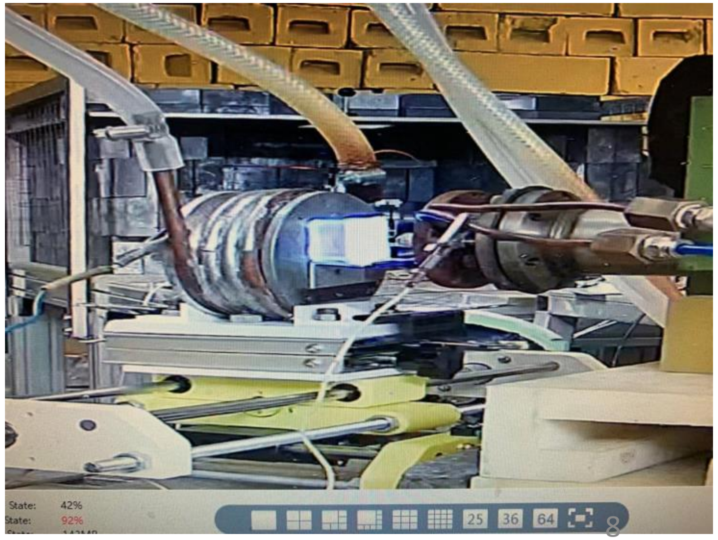
IRRADIATION SETUP



Irradiation tests were done at JINR Flerov laboratory on the Microtron MT-25 cyclotrone with the electron beams.

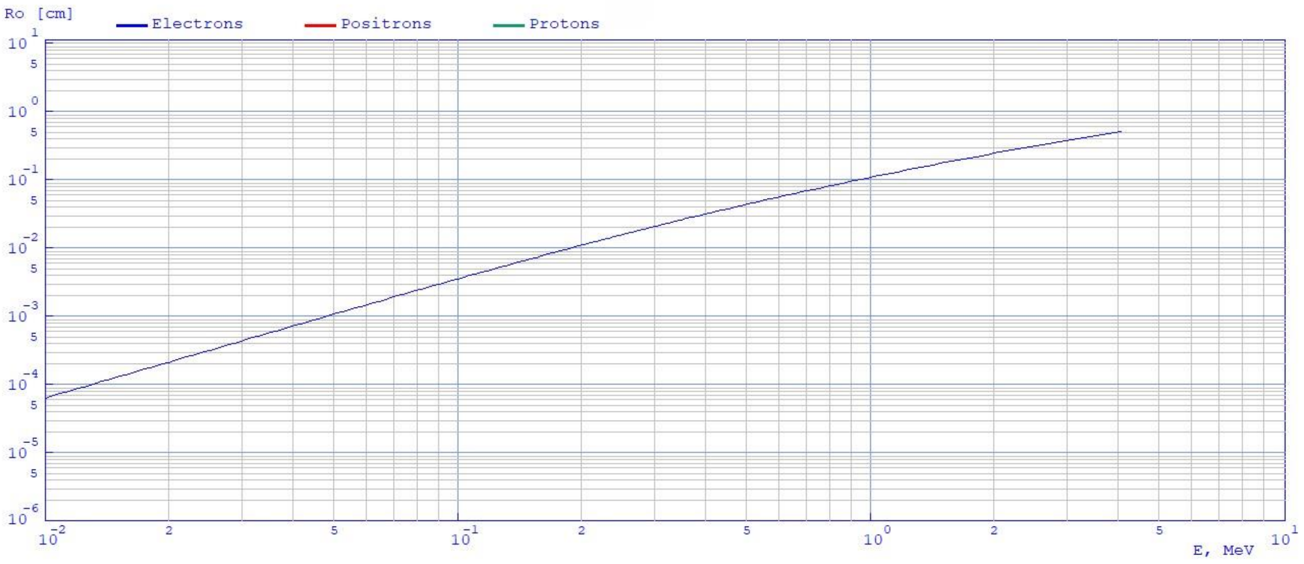
Samples of fused silica, optical sapphire, BaF2 and special optical glass TF-10 were irradiated by electron beam

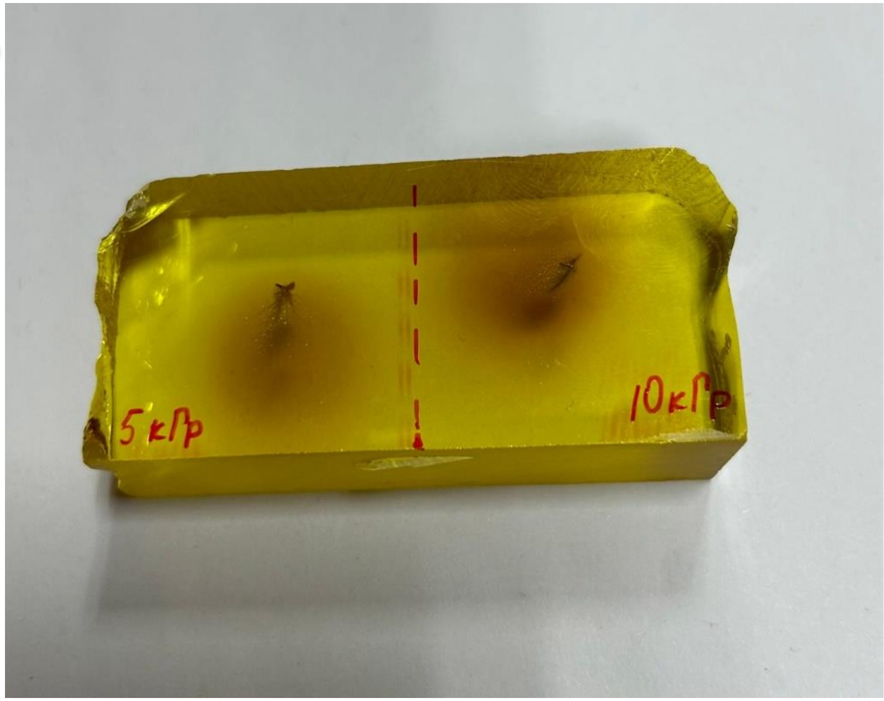
Beam energy for the samples were
5 MeV for TF-10
10 MeV for Sapphire and BaF2



IRRADIATION RESULTS

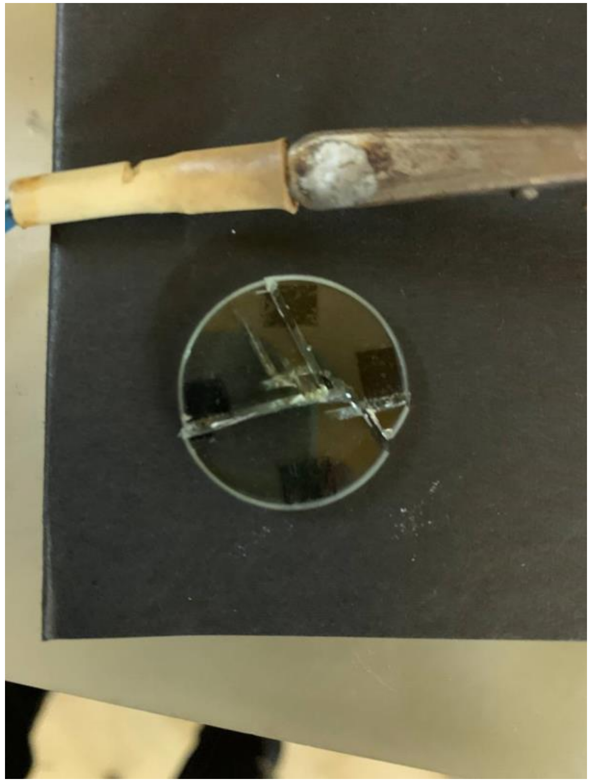
Optical glass TF-10 was damaged by the consumed electrons from the beam
Attenuation length for 5 MeV electrons was ~ 5 mm

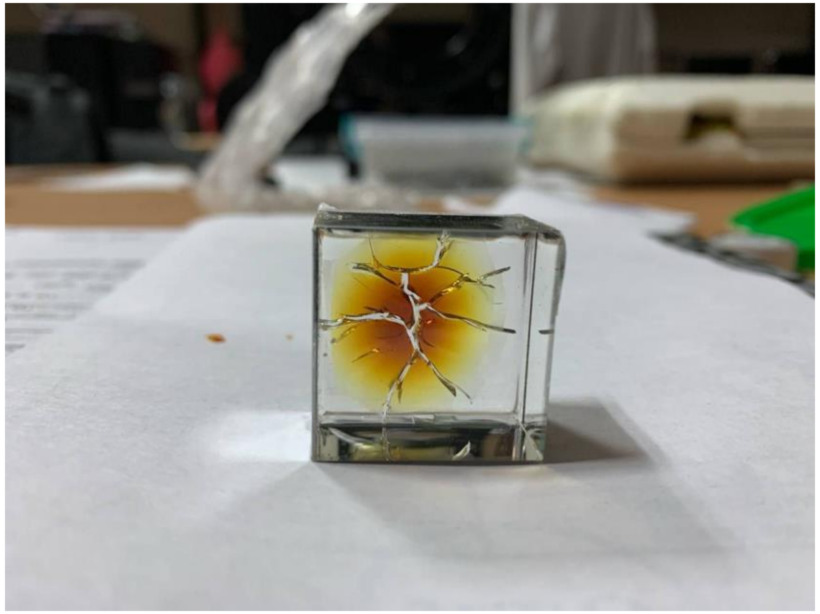




IRRADIATION RESULTS

Local thermal effect can be very harmful for some materials
It can be limiting factor for multilayer lens from those materials
Thermal effect also affect optical glue which is used to glue the radiator bars together

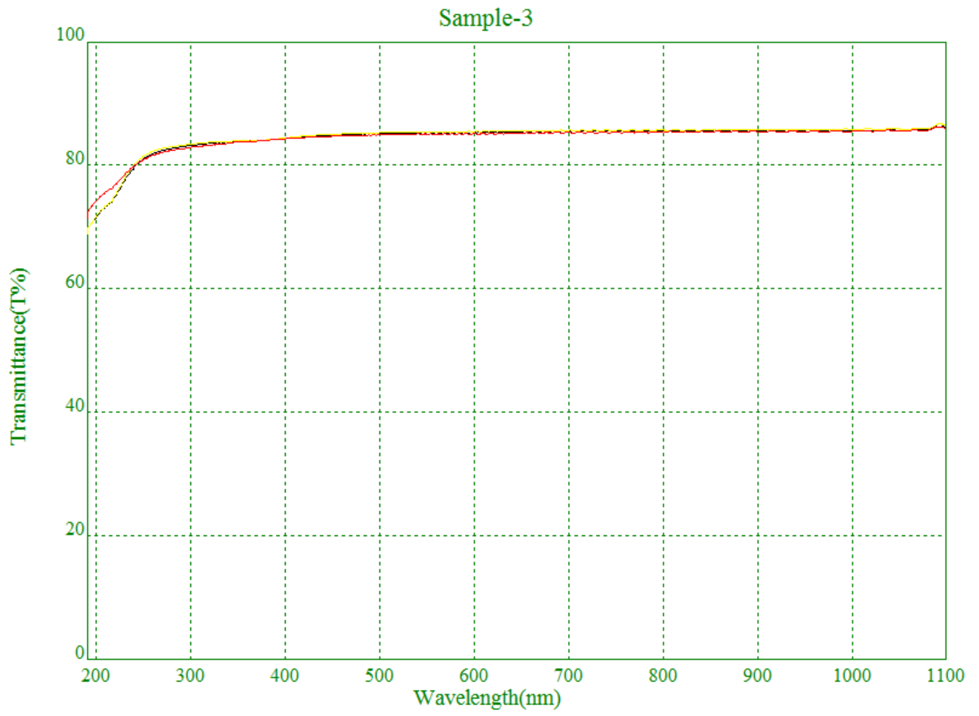


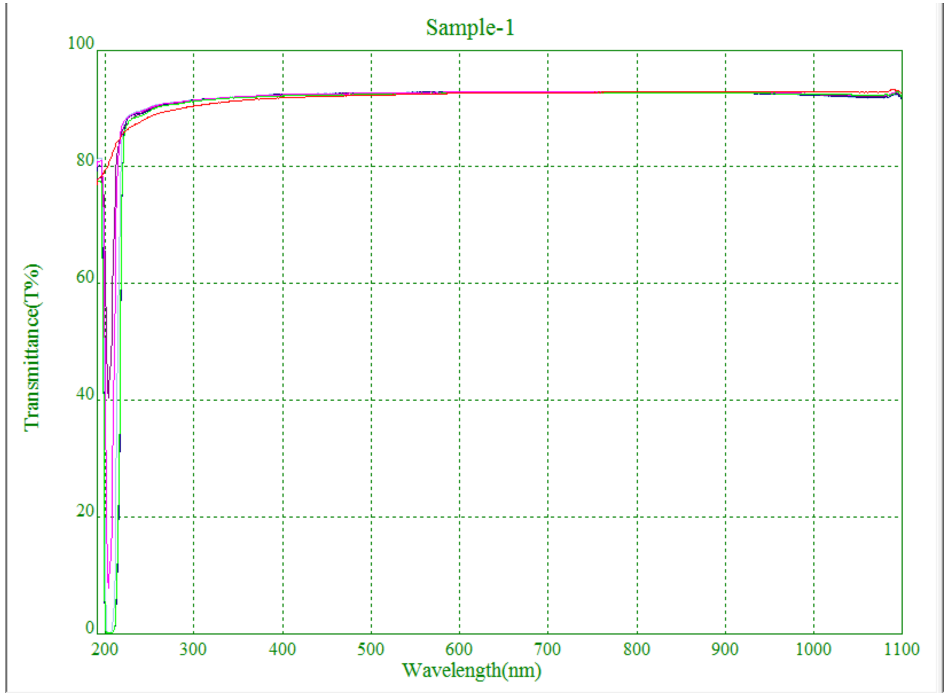


OPTICAL PROPERTIES BEFORE IRRADIATION

Sapphire

BaF2





Both samples can perform at UV wavelengths, although BaF2 had some unexpected absorption near 200 nm

SUMMARY

- ✓ Detectors based on the DIRC technology is a good opportunity for the next generation collider experiments
- ✓ DIRC detector is very sensitive to the radiator material and its optical properties
- ✓ Need to take into account material performance at high radiation load better detector capabilities
- ✓ More tests are needed with particle beams of tens and hundreds of MeV scale

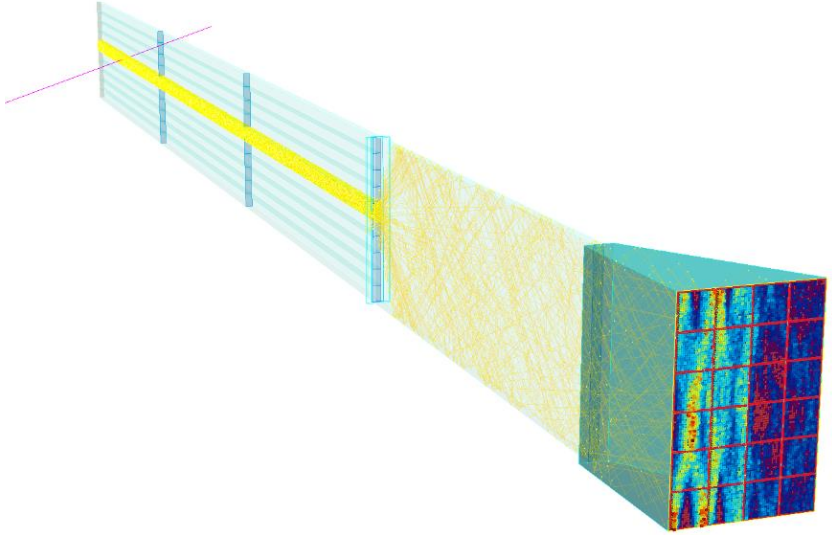
This research has been funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21881941)

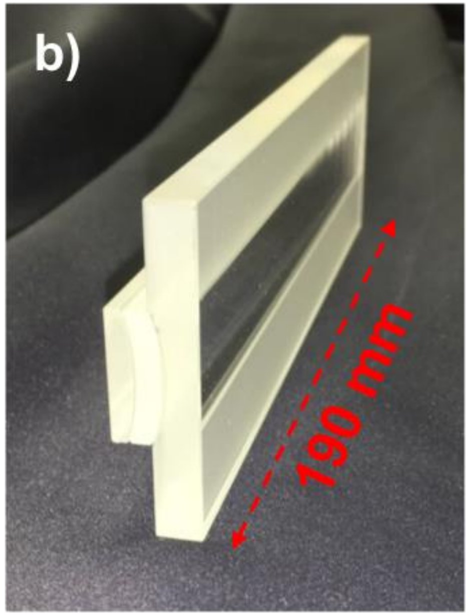
Thank you for the attention!

Спасибо за внимание!

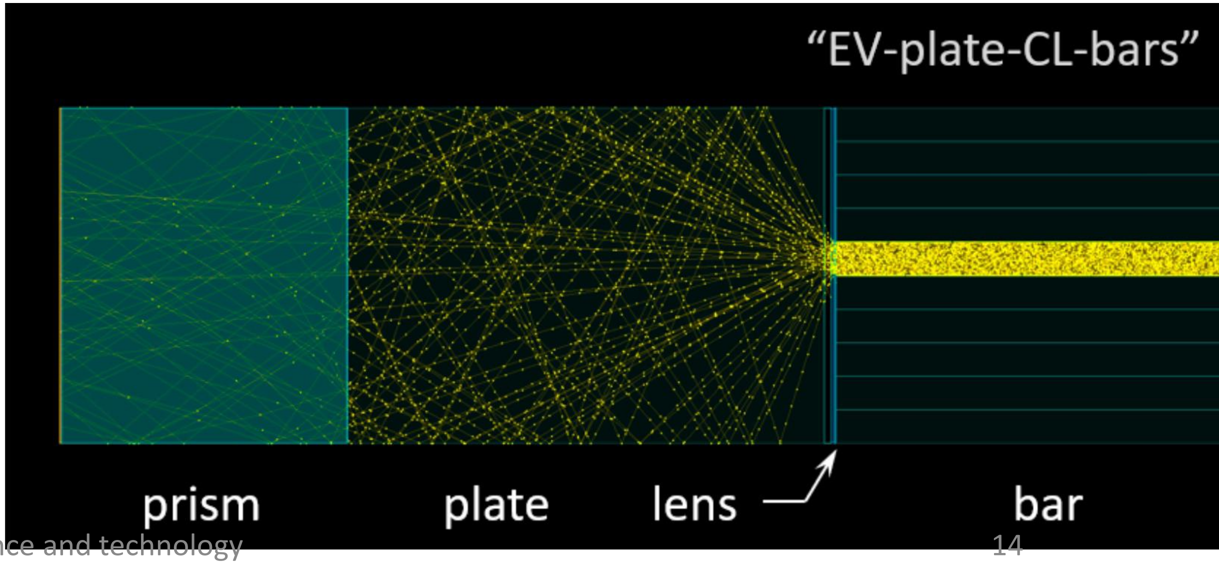
ALTERNATIVE DESIGN

- ePIC detector barrel length requires additional “light guide” section to connect BaBar DIRC bars to prism
- Alternative to baseline (narrow bars) is one single short wide plate
- Hybrid optics (narrow bars in active area, wide plates as light guides) could mitigate focusing errors and reduce cost
- Expansion volume effectively starts at end of narrow bar, improving angular resolution, possible use of cylindrical lens



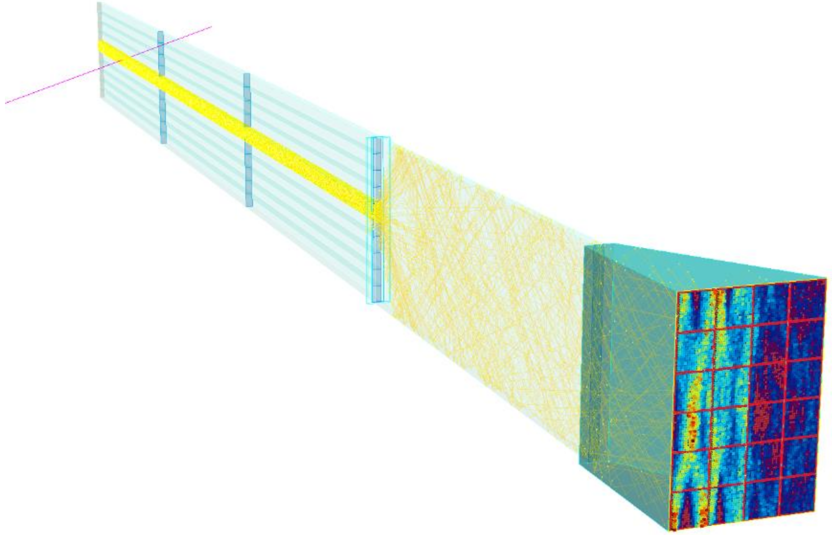


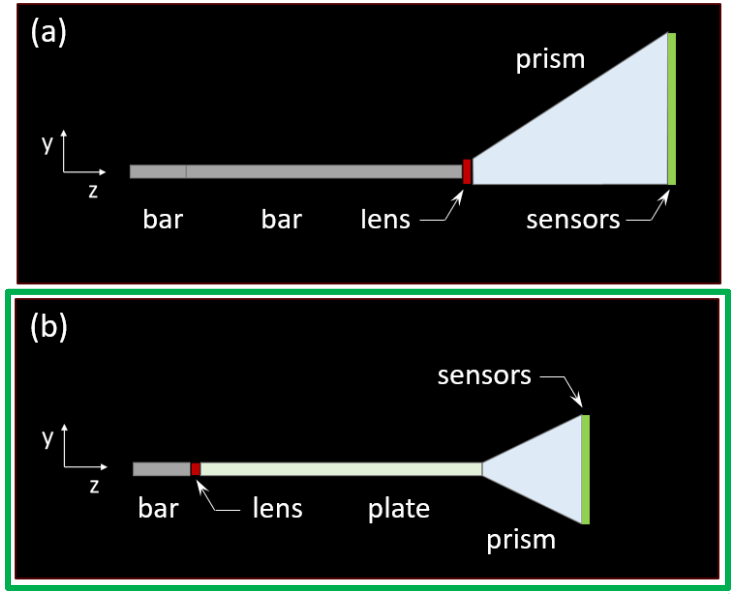
Hybrid of bars and plate in each sector



Alternative Design

- ePIC detector barrel length requires additional "light guide" section to connect BaBar DIRC bars to prism
- Alternative to baseline (narrow bars) is one single short wide plate
- Hybrid optics (narrow bars in active area, wide plates as light guides) could mitigate focusing errors and reduce cost
- Expansion volume effectively starts at end of narrow bar, improving angular resolution, possible use of cylindrical lens
- Longer expansion in plate in plate could make shorter prism possible, with smaller sensor area, possibly enabling use of SiPM





Hybrid of bars and plate in each sector