The xpDIRC Concept for the Next-Generation DIRC Detector

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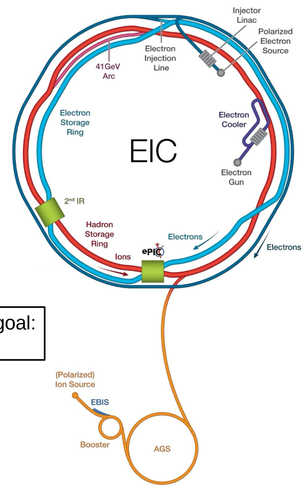
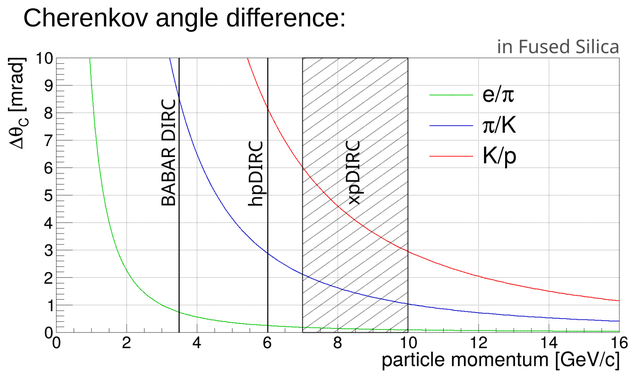
on behalf of the EIC DIRC group

DIRC PID

- DIRCs offer compact and robust solution for charged particle PID
- xpDIRC explores ways to extend performance limits of DIRC technology
- active R&D (eRD14, eRD103, EICGENRandD22)
- potential application - 2nd IR Detector at EIC



Cherenkov angle difference:



Cherenkov resolution per particle:

$$\sigma_{\theta_C}(\text{particle}) \approx \sqrt{\left(\frac{\sigma_{\theta_C}(\text{photon})}{\sqrt{N_\gamma}}\right)^2 + \sigma^2_{\text{correlated}}}$$

xpDIRC goal: < 1 mrad

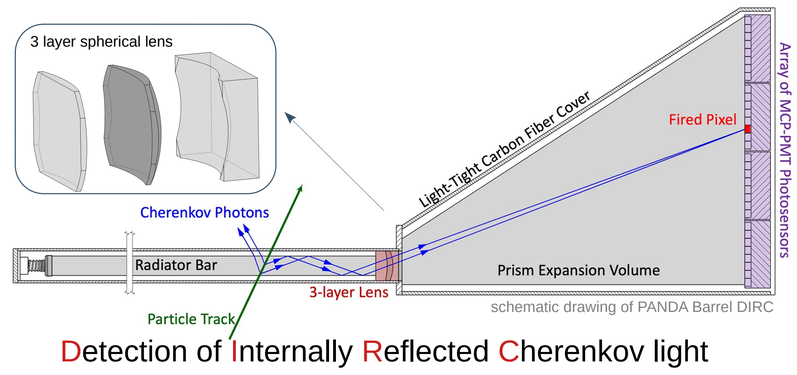
strategy:
use better tracking system, mitigate multiple scattering
use photon detectors with better PDE
improve Cherenkov angle resolution per photon

$$\sigma_{\theta_C}(\text{photon}) \approx \sqrt{\sigma^2_{\text{bar}} + \sigma^2_{\text{pix}} + \sigma^2_{\text{chrom}}}$$

BABAR DIRC		Improve for future DIRCs via:	
size of bar image	~4.1 mrad	focusing optics	SuperB, Belle II
size of PMT pixel	~5.5 mrad	smaller pixel size	PANDA, EIC (hpDIRC, xpDIRC)
chromaticity (n(λ))	~5.4 mard	better time precision	
total	9.6 mrad	5-6 mrad per photon	~1 mrad per particle for hpDIRC <1 mrad per particle for xpDIRC

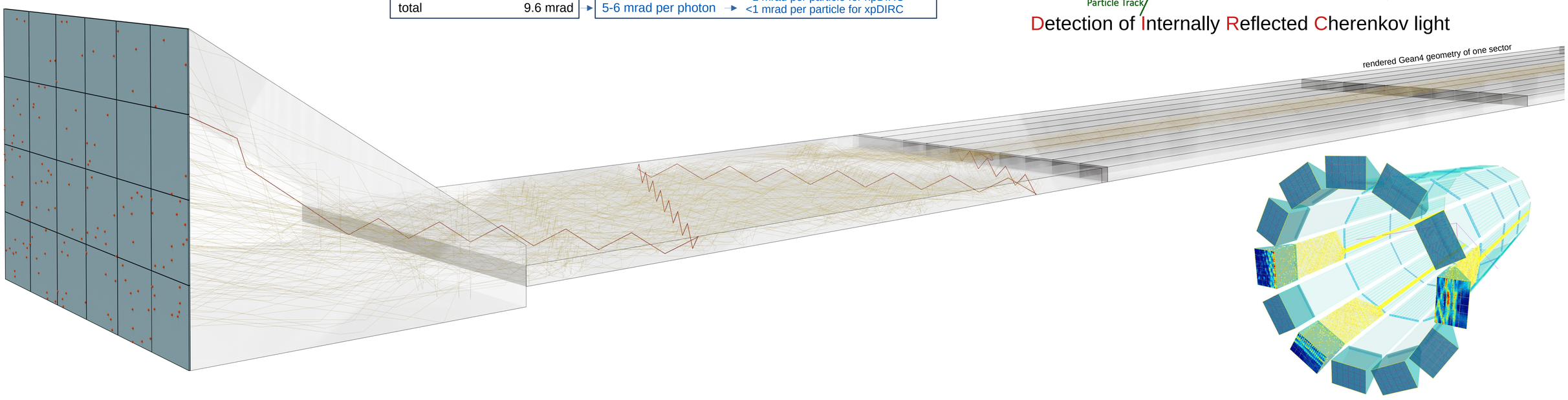
DIRC / hpDIRC Concept

- 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
- innovative 3-layer spherical lenses (SL)
- compact fused silica prisms as expansion volumes
- fast photon detection



schematic drawing of PANDA Barrel DIRC

Detection of Internally Reflected Cherenkov light



Geant4 display of 3 pions hitting bars together with accumulated hit pattern from 1k tracks

Factors Limiting Performance

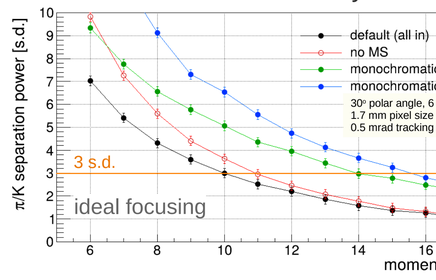
- multiple scattering (MS) inside the bar (dominates at lower momenta)
- chromatic dispersion of angle and time
- aberrations of focusing system
- time precision
- photo-sensor's pixel dimensions
- photo-sensor's dark count rate (DCR) (for SiPMs)

Studies performed with Geant4 DIRC simulation software

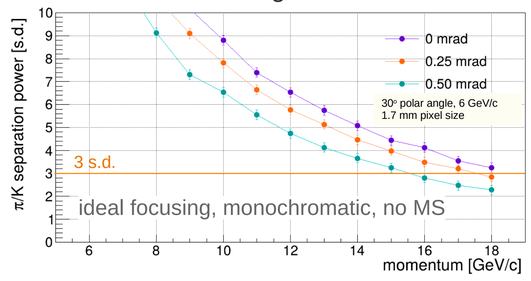
Simulations includes:
- realistic material
- wavelength dependent refraction and absorption
- mirror reflectivity
- photon transport efficiency
- wavelength dependent photon detection efficiency
- detection time precision (100 ps)
- tracking resolution

Reconstruction:
- geometrical
- time imaging

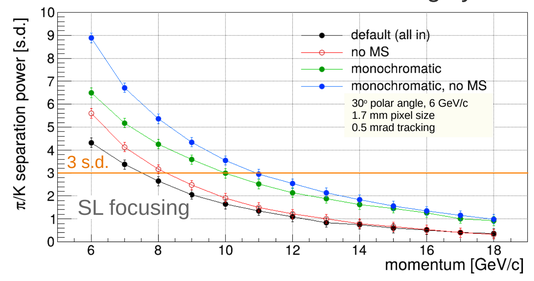
contribution of chromaticity and MS



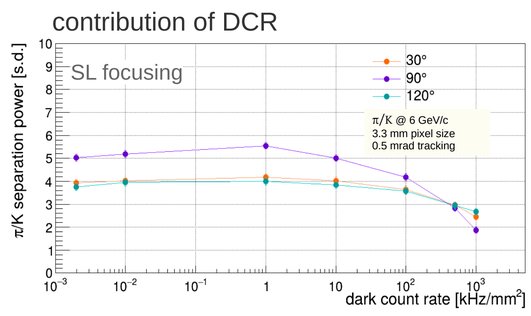
contribution of tracking resolution



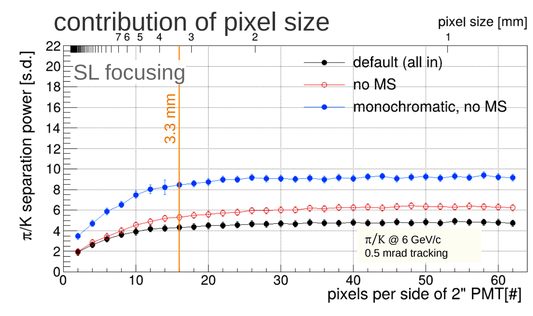
contribution of aberrations in focusing system



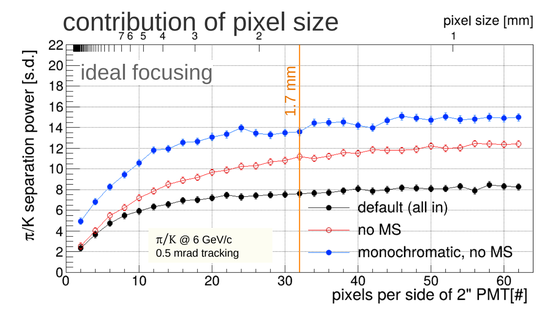
contribution of DCR



contribution of pixel size

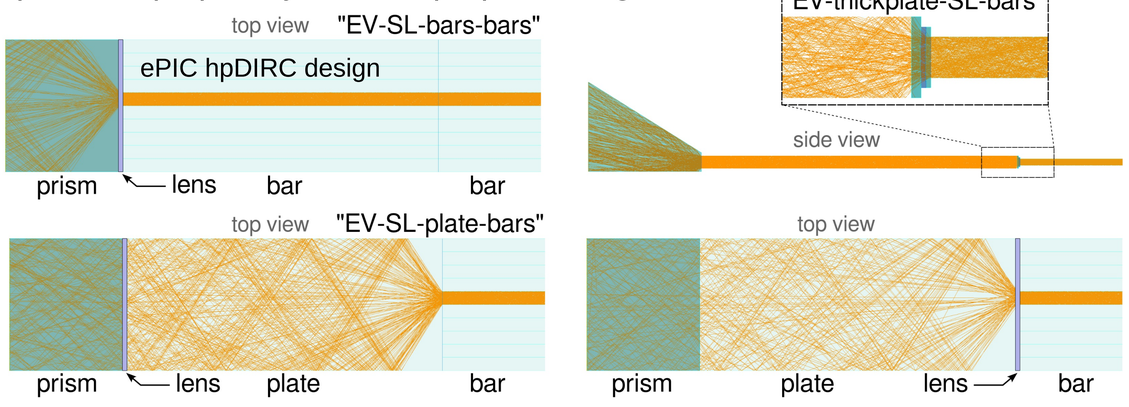


contribution of pixel size

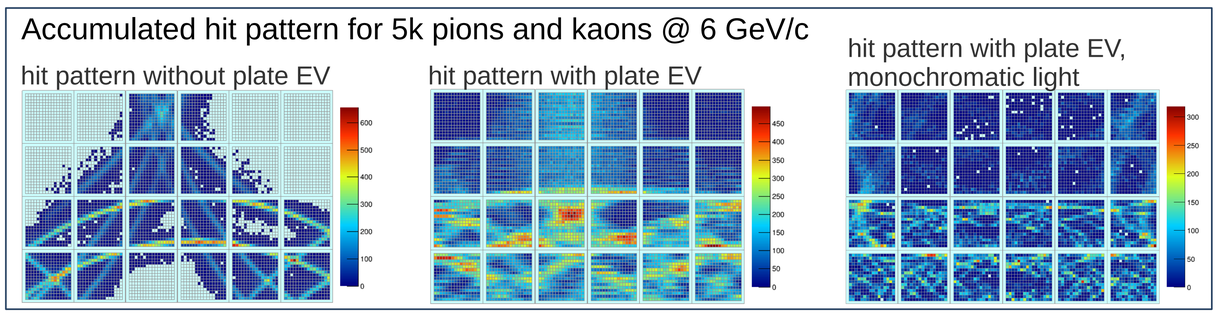


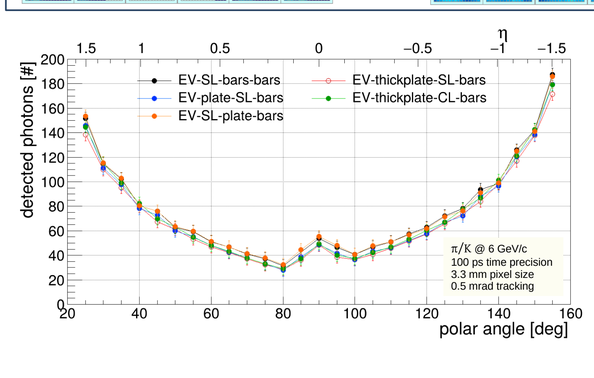
xpDIRC Hybrid Designs

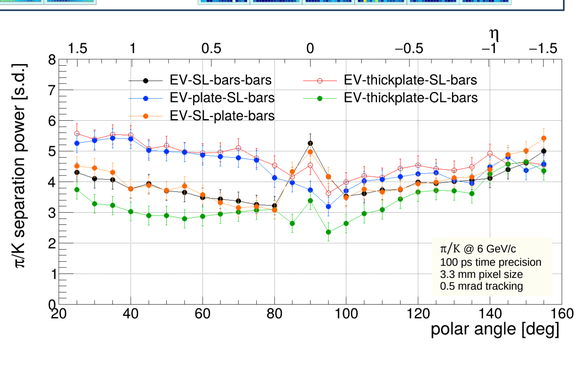
- based on hpDIRC design
- narrow bars in "active area" ensure robust performance in multi-track events
- plate as a part of the expansion volume (EV) provides better angular resolution
- spherical (SL) vs cylindrical (CL) focusing



Accumulated hit pattern for 5k pions and kaons @ 6 GeV/c

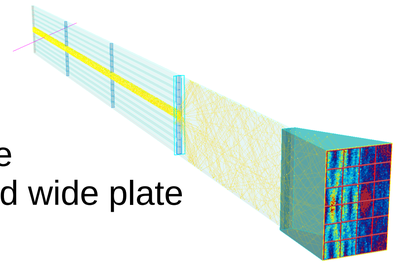






Summary

- xpDIRC pushes state of the art of DIRC-based PID
- multiple design options are under consideration
- best performance achieved for hybrid design with the spherical lenses placed between the narrow bars and wide plate



Outlook

- mitigate multiple scattering (MS) inside radiator
- mitigate chromatic dispersion
- improve focusing system to reduce aberrations
- ML reconstruction
- potential performance validation with cosmic muons