The PANDA Barrel DIRC

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- FAIR and PANDA
- Baseline design
- Design options
- Test experiments
PANDA at FAIR

- 70 MeV p-linac
- SIS 100
- 30 GeV protons
- Ni/Cu target
- $10^7$ /s antiprotons
- ~3 GeV

Steps:
- Accumulation & Precooling
- Acceleration & Cooling
- 100 m
PANDA DIRC counters

Kaon distribution of the radiative decay $J/\psi \rightarrow K^+K^-\gamma$ (search for glue balls)
Barrel DIRC

Detection of Internally Reflected Cherenkov light

BaBar DIRC, SLAC

Magnitude of photon angles in radiator preserved

Cherenkov Photon Trajectories

± 300 nsec trigger window  →  ± 8 nsec Δt window
(~500-1300 background hits/event)  (1-2 background hits/sector/event)

Accelerator background from the water tank

Data
Baseline design: based on BABAR DIRC with key improvements

- Barrel radius ~48 cm; expansion volume depth: 30 cm.
- 80 narrow radiator bars, synthetic fused silica
  17mm (T) x 32mm (W) x 2400mm (L).

- **Focusing optics:** lens system.
- **Compact photon detector:**
  30 cm oil-filled expansion volume
  18000 channels of MCP-PMTs
  in ~1T B field.
- **Fast photon detection:**
  fast TDC plus TOT electronics,
  → 100-200 ps timing.

- **Expected performance:**
  Single photon Cherenkov angle resolution: 8-10 mrad.
  Number of detected photons for $\beta\approx1$ track: at least 15.

- **Design options:**
  Radiator plates, prism, focusing options.
Investigating several design options:

Use of one wide fused silica plate (160 mm) per sector instead of 5 narrow (32 mm) bars.

Belle II iTOP is leading the way with plate fabrication, prototyping, and software development.

Smaller number of pieces would drastically reduce the radiator fabrication cost (1.5M€+ savings possible).

Segmented optical expansion volume: “camera” (like FDIRC, iTOP)

one solid fused silica prism per sector instead of oil tank.

→ better optical and operational properties, good match to wide plates.

But: reflections in prism complicate reconstruction for narrow bars, add background.

Design also reduces the number of required MCP-PMTs.
Ongoing prototyping of optical elements

Optical elements:

- Quality assurance in optical laboratory at GSI and by producer

Radiators produced with different technologies and materials

... soon a plate from Nikon
Lens design aimed for a focal plane matching the flat photon detector plane.

\[
\text{LaK33}
\]

\[
\text{SiO}_2
\]

Radiation level ~ 10 kR

\[
\text{PbF}_2 \text{ is radiation hard, } \gamma \sim 100 \text{ kR}
\]

Other optical radiation resistant glasses?

Afternoon, Lee Allison
Optical software: Spherical lens

Dispersing + focusing lens for flat focal plane

Geant

Zemax

Dispersing + focusing lens for flat focal plane
5 x 3 Planacon MCP-PMT (XP85012/A1-Q, Photonis) 960 pixels (in total >1200 readout channels)

with pixel size 6.5 x 6.5 mm²

Work in 1T magnetic field

Survive 10 years of PANDA (ageing)
Readout chain

PADIWA3 discriminator
Keep It Small & Simple = KISS Amplifier + LVDS discriminator

TRB3 TDC board
Leading edge → timing (~10ps)
Trailing edge → TOT → walk correction

Friday morning, Michael Traxler
Experiments, CERN 2015, T9

Joint effort of groups from GSI, Uni Mainz, Uni Giessen, Uni Erlangen, JLab, and Old Dominion University.

Hadron beam with mainly pions and protons with momenta 2-10 GeV/c

Measured:
- Several bars/plates of different vendors
- High-n cylindrical/spherical lenses
- Wide range of beam-bar angles and positions
TOF counters allow to separate pions from protons up to 10 GeV/c

After walk Correction

\[ \sigma \sim 150 \text{ ps} \]
Observed Cherenkov rings are folded

$p, 3\text{ GeV/c}$
hit pattern for 3-layer lens, 7 GeV/c, 50 degree

Before hit & event selection

After hit & event selection

Event: Time cut around triggertime (scintillator in the beam)

Hit: Masking noisy pixel
    For each channel timing cuts
    - Time offset calib. with laser data

→ Noise reduction
Don't forget the lens...

hit pattern for 3-layer lens
7 GeV/c, 50 degree

no lens
Angular scans

Setup was rotated remotely by a motor, polar angle checked by a scale and a camera

Movie of many angular measurements for bar with 3-layer lens @ 7 GeV/c
Time resolution

TRB: TDC channels with **internal pulser**

- 8.5 ps
- 179 ps

Chain: PMT-PADIWA - TRB with **Picoquant-laser** (80ps)

- 179 ps, walk corrected

Largest Contribution: PADIWA Discriminator

150 ps

400 ps
Timing resolution is important for the plate.

Timing resolution determined by:
- chrom. Disp.
- PMT
- PADIWA
- TRB
Number of photons

7 GeV/c
3 component lens

Details remain to be investigated

Number of photons described by simulation on a 10% level

prelim.
Single photon angular resolution

7 GeV/c 3 component lens

SPR 30% worse than simulation
Details remain to be investigated (eg. charge sharing, beam divergence not taken into account)

10 mrad

Geometrical reconstruction

Afternoon, Roman Dzhygadlo

prelim.

Afternoon, Lee Allison

SPR [mrad]

θ_{track} [°]

beam data
simulation

Afternoon, Lee Allison
@ 3 GeV/c: PID with naked eye possible  
(125°, 3 compound lens)
Plate prototype in beam 2015

Test of wide plate with and without focusing

Simulation Data
7 GeV/c, polar angle 55°, cyl. Lens

125 cm
Probability density functions (pdf) can be generated with ~100k Monte Carlo tracks with same parameters and saved in histograms.

At 3.5 GeV/c no difference visible in x-y

PMT map, with 5 x 3 sensors, 64 pixels each

In 3 dimensions (x, y, t) hit patterns show differences between particle species

Probability density functions (pdf) can be generated with ~100k Monte Carlo tracks with same parameters and saved in histograms.

Inspired by Belle II TOP

Afternoon, Roman Dzhygadlo
In simulation this method works over the full phase space

Not yet proven on data
$P = 7$ GeV/c  (CERN, 2015)
55° polar angle

Time difference clearly visible

Reconstruction remains to be done
Summary

- **Baseline design** of the Barrel DIRC with narrow bars and high-refractive lens index meets PANDA PID goals.

- Cost optimization identified two **design alternatives** (wide plate, solid fused silica camera), to be validated with **prototype** tests.

- Prototype tests show promising results
  - Number of observed photons
  - Single photon angular resolution
  - Plate still needs reconstruction

Outlook

- Early 2016: Decision about technology (plate vs. bar / prism vs. oil tank).
- Summer 2016: TDR
- Summer 2017 component construction
- 2020 ready for beam
Time resolution

Time spectra (Leading Edge) show modulation which we ignore for \textit{walk correction}.

Understood: TOT + small high frequency noise

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Fig. 5. Simulated shape of the output signal of the system lead-glass block – PMT without (solid curve) and with addition of 300 µV noise at 40 MHz frequency (dashed curve).

\textit{NIM A791 (2015) 16, Gonella et al.}