The PANDA
Barrel Time-of-Flight Detector

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On behalf of the Panda B-TOF group

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Outline

• PANDA at FAIR
• PID Performance
• Detector Setup
• SiPM Configuration
• Detector Performance
• Relative TOF
The PANDA Experiment

- One of the four pillar Collaborations at FAIR
- **Fixed target** experiment with cooled **anti-protons** on protons or nuclei
  - Momentum range of **1.5 to 15 GeV/c**
- Two modes of operation of the High Energy Storage Ring (HESR):
  - High resolution mode ($\Delta p/p \leq 10^{-5}$, 2 MHz)
  - High luminosity mode ($2 \cdot 10^{32}$ cm$^{-2}$s$^{-1}$, 20 MHz)
The PANDA Detector
PID in PANDA

• **Main PID** detector for PANDA in the barrel is the barrel-**DIRC** detector

• **Blind** below the Cherenkov threshold

• More detailed talk by J. Schwiening on 4\(^{th}\) Aug at 09:00
Particle Identification (PID)

- Calculated assuming knowledge of the ideal annihilation time
- Time resolution of the B-TOF assumed to be 75 ps (including safety margin)
- Result is combination of tracking and time information by multiple detectors
- Excellent separation power below the Cherenkov threshold
The Barrel TOF
The Barrel TOF

- 16 independent segments
- 120 scintillating tiles per segment in two rows
- Scintillator: EJ-232 or EJ-228 (BC-422 / BC-418)
- Scintillators read out on each short side by 4 SiPMs
- SiPM: 3x3 mm² active area
The Barrel TOF

- The 16 independent segments are made up of many separate modules
- Backbone of each segment is a large PCB housing 4 · 60 signal lines
  - 2400 x 180 mm²
  - Mechanical support for the scintillator
- FEE on backwards side of each module
  - TOF PET 2 ASIC by PETsys electronics
Scintillator Modules

- Two scintillating tiles **read out** on two sides each
  - Scintillator dimensions: \(87 \times 29.4 \times 5 \text{ mm}^3\)
- 60 modules per board → **1920 scintillators**
- Read out by 4 SiPMs in serial connection on each short side → **15360 SiPMs** in **3840 channels**
SiPM Configuration

- **Simplifies** readout for larger sensitive area
- Serial connection reduces effective capacitance 
  → shorter rise and fall times 
  → improved timing performance
- Hybrid connection needs a lower bias voltage but voltage evenly split (not ideal)
Performance Validation

- Measurements done in Erlangen
  - Using $^{90}$Sr (beta source)
- Mean time resolution of $\sim 51$ ps
- High uniformity of the time resolution along the tile
- Time resolution + lower effective speed of light allow position resolution of $\sim 1$ cm along the x-axis
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Scintillator Thickness Study

- Possibilities to improve the performance
  - Increase number of SiPMs (cost increase)
  - SiPMs with larger sensitive area (cost increase)
  - Decrease/Increase scintillator thickness (cost neutral)
- SiPM and scintillator dimensions do not match
  - Potential to save material

- Thinner scintillators produce less photons
  \[ \rightarrow \text{worse time resolution} \]
- Thicker scintillators show only a marginal performance increase to the cost of the material budget
Polished & Quenched Scintillator

- **Polishing** the scintillator does not lead to a performance decrease

<table>
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<th>NpeAve</th>
<th>Time Res [ps]</th>
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<tr>
<td>5 mm</td>
<td>81.5</td>
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<tr>
<td></td>
<td>52.3 ± 3.5</td>
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<tr>
<td>5 mm p</td>
<td>79.8</td>
</tr>
<tr>
<td></td>
<td>51.5 ± 3.0</td>
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- A **quenching** agent in the scintillator might improve the time resolution by reducing the slow emission component
  - EJ-232Q0.5
- An overall **reduction** in time resolution (~ 71 ps)
- **Worse uniformity**
Relative TOF

- No start time detector in PANDA
  - No conventional TOF measurement possible
- Method determines annihilation time and particle identity
- Utilizes information from other detectors
  - Path length
  - Momentum
- Results improve for higher particle multiplicities

- Permutes through possible mass assumptions
- Calculates most likely combination
- Simulations achieved a time resolution of $\sigma \leq 71$ ps
Summary

- **Excellent separation power** for particles below the Cherenkov Threshold
  - Ideal complement to the barrel DIRC
- **Using scintillating tiles and SiPMs** to read out the detector
- **Achieve a time resolution** of ~51 ps
  - **Position resolution** of ~1 cm in x direction
- **Utilizing a serial connection** of 4 SiPMs
- **Using relative TOF** have an annihilation time resolution of ~71 ps
Thank you for your attention
Backup
SiPM Position Effect

- Serial connection of SiPMs introduces position dependent timing
- Time difference in the order of 18 ps/cm close to the SiPMs
- No effect visible further than ~ 1 cm
Railboard

- 16 layers PCB
- 2400 · 180 mm²
- 4 · 60 lines per board
- Detector designed to be cable less
- Multiple designs are being tested

- Space efficient transmission and mechanical support
- Signal lines in coaxial structure with shielding in between lines
Railboard Crosssection

- Three structurally distinct designs with 3, 2 and 1 separate ground layers
- Tested for crosstalk levels and attenuation
Crosstalk & Attenuation

- Measured using a 1V amplitude sinusoidal signal
- Crosstalk levels measured with a spectrum analyzer
- 1 ground design shows smoother distribution with less crosstalk

- All lines terminated in 50 Ω scope input
- Attenuation measured by measuring amplitude after passing through PCB
- 1 ground design shows slightly lower attenuation
Experimental Challenges

- The PANDA detector will be operated with a free flowing data acquisition
- Data rate in the order of 200 GB/s
  - Needs to be reduced by a factor of 1000
- The barrel time of flight detector plays a vital role in this regard
- The Barrel TOF provides:
  - Interaction time
  - Particle identification
  - Event selection
all important for data reduction
Event Sorting

- PANDA will be utilizing free flowing data acquisition
- Event rates up to 20 MHz → occasional overlap of events
- Challenge is to find all events and save all interactions with minimum of doubled data
- Simple speed of light correction applied
- 99% of primaries and 75% of all arrive in 4 ns