The PANDA MVD

Hans-Georg Zaunick
II. Physikalisches Institut, JLU Gießen
The PANDA Detector @ FAIR

- Very broad physics program:
  - Hadron spectroscopy
  - In-medium effects
  - Hypernuclear physics
  → Focus on charmed hadrons

- 4pi acceptance
- High spatial and momentum resolution
- No hardware trigger
The Micro-Vertex Detector

- 2 barrel pixel layers
- 4 pixel disks
- 2 barrel strip layers
- 2 mixed disks
- 2 optional forward wheels (@40 & 60 cm)
Benchmark Channels

open charm: e.g. $\bar{p}p \rightarrow D^+D^- \rightarrow K^+\pi^+\pi^-K^-\pi^+\pi^-$

PANDARoot Simulations with detailed detector descriptions

Reco $D^+$ mass

Reco $D^+$ decay length

$\sigma_{Reco} = 25.1$ MeV/$c^2$

$\sigma_{Vtx} = 24.5$ MeV/$c^2$

$\sigma_{4C} = 5.8$ MeV/$c^2$

$ct = 119.7 \pm 0.8 \mu m$
Benchmark Channels

open charm: e.g. $\bar{p}p \rightarrow D^0\bar{D}^0 \rightarrow K_S^0\pi^+\pi^- K^+\pi^-$

Signal events

uncorrelated background
Pixel Subdetector - Sensors

Epitaxial silicon pixel sensors

- Several thicknesses evaluated, 100 µm chosen for PANDA
- 100 x 100 µm² pixel array
- Full qualification of prototypes done
- Full size PANDA geometry

NIMA 594 (2008) p.29
Pixel Subdetector - Modules

2 chip size

Readout chip:

116 x 110 pixels

100 x 100 μm²

4 chip size

5 chip size

6 chip size

INFN Torino

Front view

Along beam axis

Barrel 1

Barrel 2

Pixel barrel layer

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Pixel Subdetector - Front-end

ToPix v2

- Torino Pixel Readout Chip, current version V3
- 2 x 128 + 2 x 32 double columns
- size 4 x 4.5 mm²
- Complete pixel cells with full column architecture, end-of-column logic and buffers
- Fully tested in lab and beam setups
- Next prototype ToPix v4 submitted, lab tests pending

ToPix v3

NIMA 596 (2008) p.96
Strip Subdetector - Setup

Barrel sensors
- Readout chip: 128 strips
- 2 × 2 chip size
- Stereo angle: 90°
- Strip pitch: \( d_{\text{pitch}} = 1.30 \, \mu\text{m} \)

Disk sensor
- Top edge: 4 chip width
- Stereo angle: 15°
- Strip pitch: \( d_{\text{pitch}} = 67.5 \, \mu\text{m} \)

Front view
- Strip barrel layer
- Strip disk
- Along beam axis
Strip Subdetector – Barrel Stave
Stave prototypes

- Ultralight carbon foam moulded in carbon fiber form sheet reinforcements
- Integrated cooling pipe in more recent prototypes
Stave prototypes

Folding of PCB around stave to connect n-side and p-side r/o

[Diagram showing folding of PCB around stave]
Sensors

1st prototyping run (CiS Erfurt) 2010
2nd prototyping run (CiS Erfurt) 2013

Silicon Strip Sensor Prototypes

- Full size PANDA geometry
- 285 µm thickness
- Strip pitches of 65 and 50 µm (barrel sensors)
- 67.5 µm pitch for trapezoidal fw sensors
- Punch-through biased and poly-Si biased

JLU Gießen

IKP Jülich
Sensor Probing and Prototype Assembly
Sensors

Many sensor characterization capabilities available

“Probecard”: fixed sensor assembly with all strips bonded to common lines (top and bottom)

Probe Station

Wafer diode test fixture
Sensors

- All relevant parameters have to be monitored for QA → full sensor characterization required
- Analysis of irradiated sensors (p/n-irradiation)
Sensors

- All relevant parameters have to be monitored for QA
  → full sensor characterization required
- Analysis of irradiated sensors (p/n-irradiation)

→ depletion, doping concentration

→ depletion, defect concentration

→ charge sharing

→ signal coupling, hf cutoff

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HIC4FAIR Detector workshop
Sensors

Irradiation with 14MeV Protons (Cyclotron Bonn)

Typical profile of hadronic lattice damage
Flex PCBs

Ver. 1: varnish 15 µm
Ver. 2: Kapton coverlay 25 µm

Laser microvias diam. 50 µm

Varnish 15 µm

Cu 12 µm
Kapton 25 µm
Cu 12 µm

duPont Pyralux Cu-Kapton-Cu laminate 49 µm
Assembly of Prototype Sensors
Prototypes

Flex-PA and squared sensor assembled on a test board and successfully tested at SPS, CERN (September 2012)
Prototypes

Laser microvias
diam. 200-650 µm

Varnish 15 µm

Cu 12 µm
Kapton 50 µm
Cu 12 µm

Thinflex A-2003AD
Cu-Kapton-Cu
laminate 74 µm

Varnish 15 µm

Bonding pads for the sensor

Pad for 1 APV readout chip

High density data connector

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Prototypes

S3 double-sided microstrip sensor

transition board

APV25 readout chip

high density data cable

Very successfully tested in testbeams @ COSY
Prototypes
Strip Frontend

- design of new selftriggered FE based on ToPIX pixel FE and TOFPET ASIC started in 2013
- modified analog stage, simplified single column buffer logic
- ToT+HiRes TDC stage for amplitude measurement

INFN Torino, JLU Giessen, IKP Jülich

Preamp. Noise:

![Preamp Noise Diagram]

unirradiated

5e13 n. eq.

![Diagram of Preamp and Buffer Circuits]

- $R_1$
- $C_1$
- $A_v \gg 1$
- $A_v = 1$
- $C_2$
- $R_2$
- $C_{fb}$
- $A_v \gg 1$
- $v_{dd}$
- $v_{ref}$
- BL Restorer
- Const. Current FB
- $e_{th}$
Module Data Concentrator

- On-module ASIC
- Multiplexes all FEs of one sensor
- Feature extraction: cluster finding, cluster correlation
- Manages slow-control + calibration of all attached FEs
- Fast GBT e-link for data out + config in

FH Südwestfalen Iserlohn
Infrastructure - Readout

Thin Al-cables
- Thin kapton carrier
- Aluminum strips, 18 diff. pairs
- For data transmission out of the MVD
- Connect FE/MDC to GBT receiver
- 320 Mbit/s serial links

GBT Project
- E-link interface to on-detector node
- Optical link to the off-detector side
Infrastructure - Powering

**DC-DC powering concept**

- Air-coil converters operate inside strong magnetic fields
- >80% efficiency
- Converter developed at CERN for LHC upgrade

AMIS5MP DC/DC converter

Strip subdetector powering
Infrastructure - Cooling

- Water cooling system in depression mode
- Operating at room temperature
- Carbon foam embedded in staves: high thermal conductivity
- Dummy staves w/ thermal loads built up and scrutinized

Customized Thermal Test Resistors
Numbers

- Number of sensors: 176 (pixel) 296 (strip)
- Number of FEs: 810 (pixel) 3112 (strip)
- Number of channels: 10.3 M (pixel) 200k (strip)
- Number of DC-DC: ~800 (pixel) 1480 (strip)
- Active area (m²): 0.106 (pixel) 0.494 (strip)
- Cables off MVD: 1584 (disks) 3592 (barrels) 614 (GBT) 5790 (total)
- Cable cross section: 21835 mm² (total)
- Power dissipation: ca. 2 kW (pixel) 800 W (strips) (~.5kW in wires)