The electromagnetic calorimeter of the PANDA detector at FAIR/GSI

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Overview

- PANDA @ FAIR/GSI
- Overview of the PANDA EMC
  - EMC components
- PWO scintillator studies
- EMC barrel readout
  - APDs and low noise preamplifier
- Ongoing test measurements with prototype Proto 60
- Summary & Outlook
AntiProton ANnihilations at DArmstadt
The PANDA detector

EMC barrel

Target spectrometer

Forward spectrometer

EMC endcaps
The EMC of PANDA

EMC barrel
- approx. 11,000 crystals
- envisaged readout: APDs

EMC endcaps
- approx. 5,000 crystals
- envisaged readout in forward endcap: VPTs
Requirements for the EMC

- Nearly $4\pi$ solid angle (PWA)
  - Target- and Forward Spectrometer
- High rate capability: $2 \times 10^7$ interactions/s
  - fast scintillator material
- High resolution & low threshold (10 MeV)
  - scintillator with high efficiency (LY)
- Compact design: EMC inside solenoid
  - scintillator with small radiation length
- Operation in magnetic field of ~ 2T
  - readout with field-insensitive photosensor
Requirements lead to **PbWO$_4$ (PWO):**

<table>
<thead>
<tr>
<th>Property</th>
<th>PbWO$_4$ (PWO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refraction index</td>
<td>2.16</td>
</tr>
<tr>
<td>Density [g/cm$^3$]</td>
<td>8.28</td>
</tr>
<tr>
<td>Radiation length [cm]</td>
<td>0.89</td>
</tr>
<tr>
<td>Molière rad [cm]</td>
<td>2.19</td>
</tr>
<tr>
<td>dE/dx [MeV/cm]</td>
<td>13.0</td>
</tr>
<tr>
<td>Decay time [ns]</td>
<td>5-15</td>
</tr>
<tr>
<td>Max. emission [nm]</td>
<td>420-440</td>
</tr>
<tr>
<td>Rel. light yield (NaI(Tl))</td>
<td>0.01</td>
</tr>
</tbody>
</table>
**PWO LY studies**

Low light yield (LY) of the crystals:
- Cooling of the whole calorimeter down to $T = -25^\circ C$

Influence of cooling on LY:

\[
\text{dLY/dT} = (-2.49 \pm 0.05) \% / ^\circ C
\]
(measured with protons)

LY-gain by cooling to $T = -17^\circ C$:
- factor 3!
(measured with photons)

04.06.2007 Andrea Wilms – GSI Darmstadt – SCINT 2007, Wake Forest University
Radiation hardness of crystals at $T = -25^\circ C$

Radiation setup at IF in Protvino

Cooling

$\gamma$-source: $^{137}\text{Cs}$

Crystal-Box with PMT-readout
Dose rate 2 rad/h

- The signal losses are significantly bigger @ T = -20°C than @ T = +20°C

- Even after 80h of irradiation no equilibrium reached @ T = -20°C

Defects frozen @ T = -20°C?
PWO-II under irradiation

Measured with γ-source $^{137}$Cs at IHEP, Protvino with PMT readout

- $+20^\circ$C
- $-25^\circ$C
PWO-II recovery

Recovery measured at two different temperatures

Recovery @ T = +20°C

Recovery @ T = -25°C

More details: talk OF2 (by R. Novotny)
**PWO-II testbeam results**

Beamtime with tagged photons (MAMI, Mainz)

- 3x3 PWO-II crystal matrix (20x20x200)mm³ crystal size
- LAAPD readout
- Preamplifier: SP883b
- Temperature: $T = 0^\circ C$

- Lowest photon energy ever tested
- Excellent energy resolution

Comparable with PMT readout

\[
\frac{\sigma}{E} = \frac{1.21}{\sqrt{E/\text{GeV}}} \pm 2.22 \cdot \ln(E/\text{GeV}) \pm 2.14
\]

\[
\frac{\sigma}{E} = 2.46\% \text{ at } E = 1\text{ GeV}
\]
PANDA EMC forward endcap design

- Insulation
- Crystal + VPT
- Interface block
- Mounting plate (with cables in grooves just below the downstream insulation plate)

- PANDA interface block: only 50 mm thick
- Cables to be guided outside along the 8 spokes which hold the mounting plate

Downstream view

Dimensions:
- $(1440 - 1066) \text{ mm} = 374 \text{ mm}$
PANDA EMC endcap design

CMS Super Crystal mounting
One alveole unit: 25 crystals

@ PANDA: all crystals closely packed → off point smeared by ca. 4%
LAAPD studies

Following APD properties have to be measured (@ room temperature and @ T = -25°C):

- Gain - bias voltage ($V_R$) dependence
- Dark current – $V_R$ dependence
- Capacitance
- Quantum efficiency
- Uniformity measurement
- Noise measurement
- Search for surface defects (e.g. resin wounds) with direct-light microscope

(Nearly) All measurements done: depending on bias voltage!

Measurements have to be ‘re-done’ after irradiation!
LAAPDs for the PANDA-EMC

First measurements of LAAPD properties at CERN

QE @ $\lambda = 420$ nm: $>70\%$
Typical LAAPD properties

LAAPDs for PANDA-EMC barrel readout

- Active area: 
  \((10 \times 10) \text{ mm}^2\)
- \(\text{QE} @ \lambda = 420 \text{ nm}:\)
  \(70\% < \text{QE} < 72\%\)
- Typ. dark current @ \(M = 50:\)
  \(10 \text{ nA} < I_d < 50 \text{ nA}\)
- Typ. capacitance @ \(M = 50:\)
  \(270 \text{ pF} < C < 320 \text{ pF}\)
- Typ. value of \(V_B-V_R\) (\(M = 50\)):
  \(46 \text{ V} < V_B-V_R < 48 \text{ V}\)

See also: poster session today
(poster by B. Lewandowski)
Requirements for first prototype:

- Large dynamic range: 1 MeV – 5 GeV
- Low noise
- Low consumption device @ T = -25°C

ENC measured with pulser @ different temperatures:

Test-PCB of ASIC group

first chip prototype

Detector Capacitance [pF]

- C ∼ 270 pF
EMC barrel prototype: Proto 60

- 60 PWO-crystals in alveoles
- Mechanical holding
- Cooling
- Aluminium plate on rear side with feedthroughs for light guides
- Preamplifier with 4 APDs
- PCBs for HV & Signals
Proto 60 status

Status and planned activities 2007

- Proto 60 assembly completed
- Test of cooling and electronics in preparation (Orsay)
- Planned testrun with cosmics (Orsay)
- Summer 2007: beamtime with tagged photons (Mainz)
Summary & Outlook

- Realization of a fast and compact PWO-EMC for PANDA at an operation temperature of $T = -25^\circ C$ possible
  - Open question: radiation hardness

- Excellent energy resolution at $T = 0^\circ C$ measured:
  \[
  \frac{\sigma}{E} = 2.46\% @ 1\text{GeV}
  \]

- Radiation hard Large Area APDs (LAAPDs) available
  - together with developed low noise preamp: excellent EMC barrel readout

- First EMC barrel prototype Proto 60 assembled and ready for testing

To do list:

- Radiation hardness studies continue
- Testruns with cosmics and photons for Proto 60