

Summary of Measurements and Simulations on NUF in the Collection of Scintillation Light

Tobias Eißner, Daniel Bremer, Valery Dormenev, Peter Drexler, Rainer Novotny, Rene Schubert for the PANDA Collaboration

II. Physikalisches Institut Gießen

PANDA Collaboration Meeting Goa, March 2013

Outline

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

Measurements

Setup I
Setup II

Impact on PANDA EMC?

GEANT 4
Simulations

Conclusion

Introduction

PANDA EMC
What is NUF?
Light Collection Simulations

Measurements

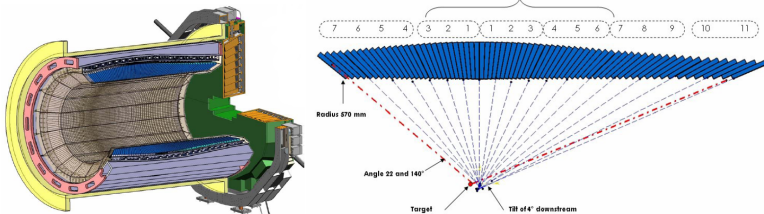
Setup I
Setup II

Impact on PANDA EMC?

GEANT 4 Simulations

Conclusion

The PANDA Electromagnetic Calorimeter



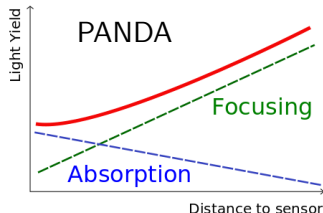
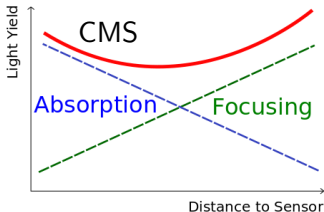
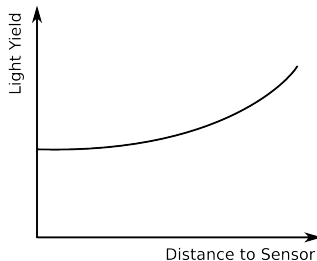
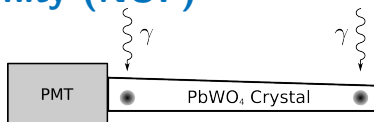
- ▶ Consisting of ~ 16000 PbWO_4 crystals
 - ▶ 13 different types, length 20 cm ($\approx 22X_0$)

Type	Location	Shape	Envisaged Readout
1 - 11	Barrel	Tapered parallelepiped	2 LAAPD
EC	Forward EC	Tapered parallelepiped	VPT / VPTT
EC-R	Backward EC	Cuboid	2 LAAPD

- ▶ Operating temperature -25°C
- ▶ Readout with 2 Large Area Avalanche Photodiodes (LAAPDs), 1 cm^2 sensitive area each

Light Yield Non-Uniformity (NUF)

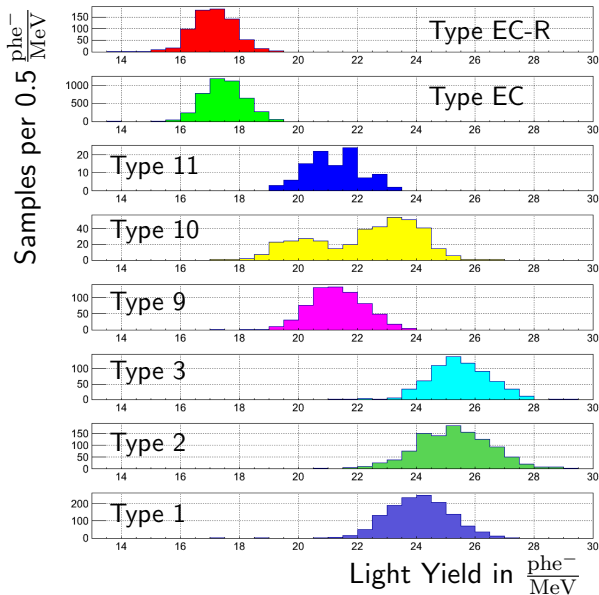
- ▶ Detected light yield depends on position of energy deposition in the crystal
- ▶ Interplay between absorption and focusing effect due to tapering



NUF Observed in Quality Control

Daniel
Bremer

- Introduction
- PANDA EMC
- What is NUF?
- Light Collection Simulations
- Measurements
- Setup I
- Setup II
- Impact on PANDA EMC?
- GEANT 4 Simulations
- Conclusion

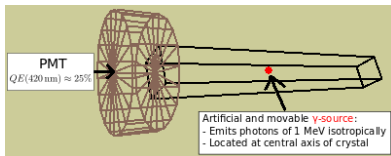
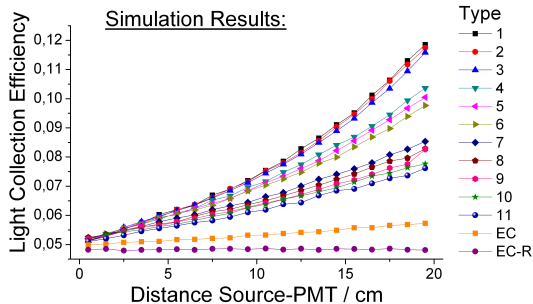


Degree of tapering →

LITRANI Simulations of NUF

Daniel
Bremer

Introduction
PANDA EMC
What is NUF?
Light Collection
Simulations
Measurements
Setup I
Setup II
Impact on
PANDA
EMC?
GEANT 4
Simulations
Conclusion



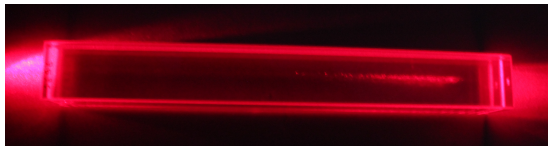
$$\text{Efficiency} = \frac{\text{Number of Collected Photons}}{\text{Number of Generated Photons}}$$

SLITRANI Simulations of NUF

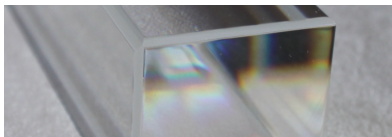
$$1.4 \approx \frac{LY(\text{top})}{LY(\text{bottom})} |_{Exp} < \frac{LY(\text{top})}{LY(\text{bottom})} |_{Sim} \approx 1,8$$

Not implemented in simulations:

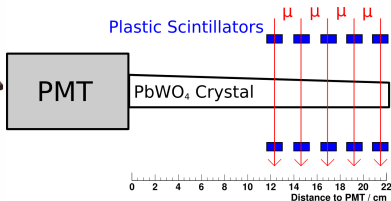
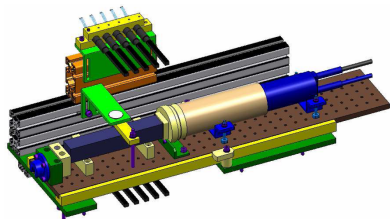
- ▶ Scattering of optical light



- ▶ Roughed crystal edges



Experimental Setup I

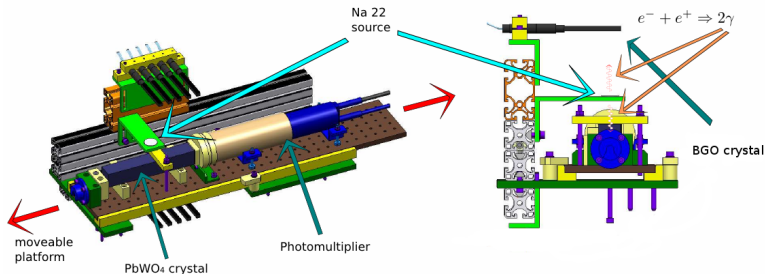


Allows measurements of cosmic muons **and** 511 keV photons

► Cosmics:

- Coincident response of upper and lower plastic scintillator defines track
- **Pro:** Path accuracy of ≈ 2 mm
- **Contra:** Extremely low event rate (< 0.1 Hz) \rightarrow four weeks of measurement per crystal
- Pathlength correction necessary

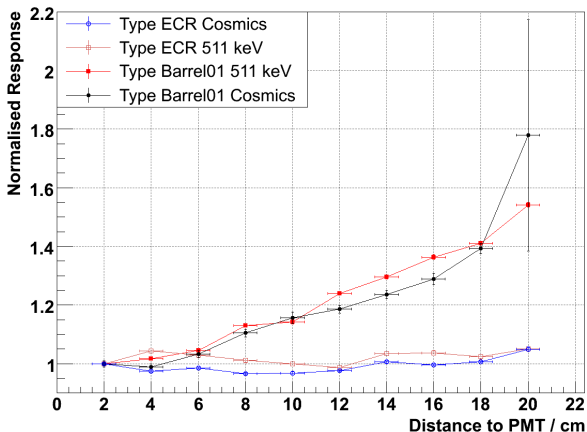
Experimental Setup I



► 511 keV photons:

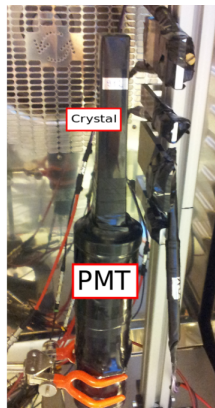
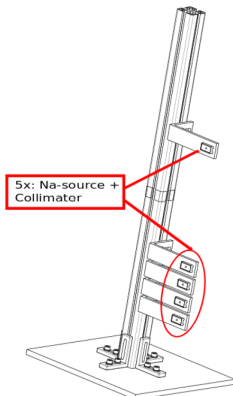
- One upper plastic scintillator replaced by $1 \times 1 \times 2.5 \text{ cm}^3$ BGO crystal
- ²²Na-source placed between PbWO₄ and BGO crystals
- Coincident detection of both annihilation photons defines impact position

Experimental Setup I - Results



- ▶ Wrapping: 8 layers teflon, 1 layer aluminium, shrinking tube
- ▶ Readout with HAMAMATSU R2059 $\varnothing 2''$ PMT at -25°C
- ⇒ **Conclusion:** Same NUF for charged particles and γ s

Experimental Setup II



- ▶ Motivation: Investigation of NUF Linearisation
- ▶ Faster, but less accurate measurement

Experimental Setup II - Different Wrappings

Daniel
Bremer

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

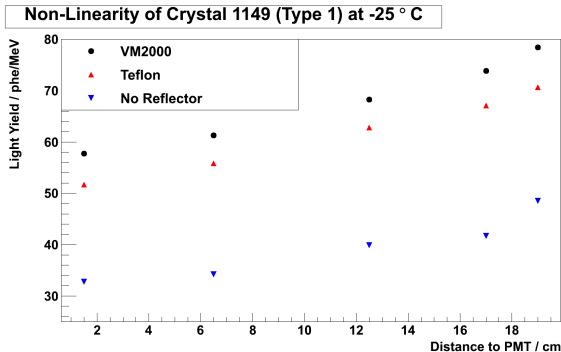
Measurements

Setup I
Setup II

Impact on
PANDA
EMC?

GEANT 4
Simulations

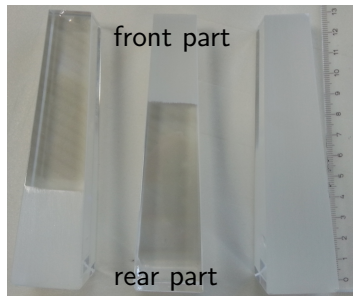
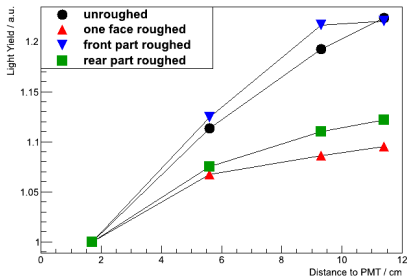
Conclusion



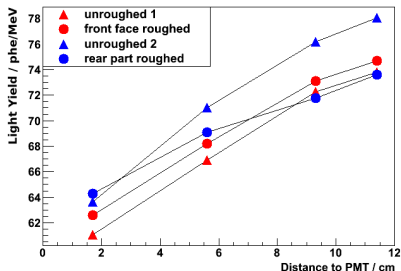
⇒ Different wrappings cause absolute LY shift
NUF unaffected

Experimental Setup II - Surface Modification

Non-Linearity of small crystal (12 cm) at -25°C



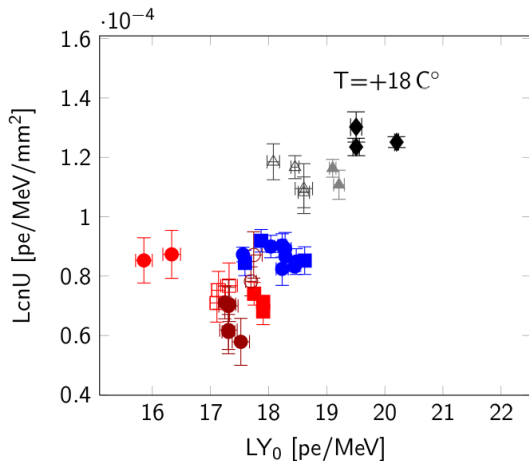
Non-Linearity of small crystal (12 cm) at -25°C



- ▶ Shorter tapered crystals from former experiment

NUF measured at Stockholm

Fit with $LY(z) = LY_0 + L_{cn}U \cdot z^2$



→ Karoly M. presentation at GSI Dec. 2012

Evaluation of NUF on PANDA Barrel EMC Performance

- ▶ GEANT4 simulation for Barrel EMC prototype (PROTO60, 6×10 type 6 geometry crystals)
- ▶ Energy deposition per event and per crystal:

$$E_{\text{Dep. Final}} = \text{Gauss} \left(\underbrace{\sum_{\text{IP}} \overbrace{E_{\text{Dep}}^*(z)}^{E_{\text{Dep}}(z) \cdot LY(z)}}^{\text{mean}}, \underbrace{\sqrt{F \cdot \text{mean}}}_{\text{sigma}} \right)$$

- ▶ Simulation includes NUF, photon statistics and APD characteristics
- ▶ No single photon tracking \Rightarrow saving time
- ▶ **Idea:** What is the effect on the energy resolution (constant term) by varying the $NUF(z)$?

Evaluation of NUF on PANDA Barrel EMC Performance

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

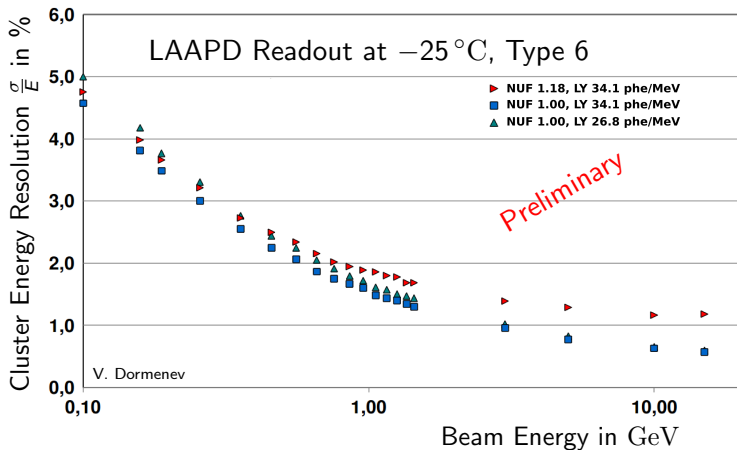
Measurements

Setup I
Setup II

Impact on
PANDA
EMC?

GEANT 4
Simulations

Conclusion



Evaluation of NUF on PANDA Barrel EMC Performance

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

Measurements

Setup I
Setup II

Impact on PANDA EMC?

GEANT 4
Simulations

Conclusion

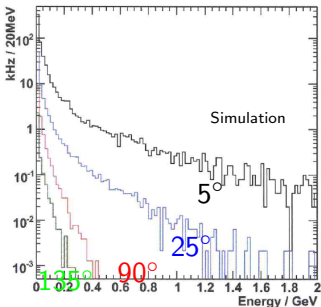


Figure 4.3: Single crystal energy differential rate spectrum for polar angles of 5° (black), 25° (blue), 90° (red) and 135° (green) using DPM at 15 GeV/c incident beam momentum.

⇒ Linearisation beneficial for energies above 400 MeV

Conclusion

- ▶ In PbWO_4 crystals with tapered geometry the LY increases with distance of energy deposition to the photo sensor
 - ▶ (S)LITRANI simulations prove that this is an effect of light collection
- ▶ **Experimental setup I**
 - ▶ Measurement with Cosmics and 511 keV photons show same behaviour
- ▶ **Experimental setup II**
 - ▶ Modification of crystal wrapping cause absolute light yield shift but NUF is unaffected
 - ▶ In contrast a surface modification and deposits affect NUF
- ▶ **Effect on PANDA EMC performance**
 - ▶ Preliminary GEANT4 Simulations for Barrel EMC prototype (PROTO60) show, that reduction of NUF is beneficial for energies $\gtrsim 400$ MeV

Daniel
Bremer

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

Measurements

Setup I
Setup II

Impact on PANDA EMC?

GEANT 4
Simulations

Conclusion

Thank you for listening!

Daniel
Bremer

Introduction

PANDA EMC
What is NUF?
Light Collection
Simulations

Measurements

Setup I
Setup II

Impact on PANDA EMC?

GEANT 4
Simulations

Conclusion

Backup Slides

Possible explanations for the discrepancy between simulation and experiment

Not implemented in simulations:

- ▶ Preliminary evaluation of roughness with SFM-measurement:
 - ▶ $R_a \approx \mathcal{O}(0.1 \mu\text{m})$

