Highlights of poster session 2 (Rosé) (a rather inhomogeneous session!)

Les Mûriers, Chinon rosé 2013

Christian Joram, CERN PH
23 posters, but I received only material from 12 authors (in yellow).

<table>
<thead>
<tr>
<th>Abstract ID</th>
<th>Board ID</th>
<th>Primary Author</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>34392</td>
<td>2</td>
<td>Liu Zheng</td>
<td>Quality control of the MPPC TSV arrays, and Modules (MPPC with crystal) for the External Plate of EndoTOF-PET US detector</td>
</tr>
<tr>
<td>34435</td>
<td>5</td>
<td>Vandenbussche Vincent</td>
<td>Dual ended readout by SiPMs on LYSO crystal bars: energy and spatial response</td>
</tr>
<tr>
<td>34653</td>
<td>8</td>
<td>Veloso Joao</td>
<td>easyPET: a user friendly PET system for didactic purposes</td>
</tr>
<tr>
<td>34696</td>
<td>11</td>
<td>Preziosi Enrico</td>
<td>A novel method for gamma-rays depth of interaction determination on monolithic scintillation crystals</td>
</tr>
<tr>
<td>34185</td>
<td>14</td>
<td>Kanno Ikuo</td>
<td>Effective Atomic Number Measurement with Energy-resolved X-ray Computed Tomography</td>
</tr>
<tr>
<td>34546</td>
<td>17</td>
<td>Spadola Sara</td>
<td>Development and Performance Characterization of Intraoperative Positron Probes for Tumor Surgery</td>
</tr>
<tr>
<td>34587</td>
<td>20</td>
<td>Castro Ismael</td>
<td>DRIM-PET: Dual-ended Readout Innovative Method for Positron Emission Tomography</td>
</tr>
<tr>
<td>34613</td>
<td>23</td>
<td>Moutinho Luis</td>
<td>Brachytherapy dosimeter with silicon photomultipliers</td>
</tr>
<tr>
<td>33901</td>
<td>26</td>
<td>Vladmir Morozov</td>
<td>Afterpulses of the H6780 and R7600U?200 Metal Channel Photomultiplier Tubes</td>
</tr>
<tr>
<td>34482</td>
<td>29</td>
<td>Heng Yuekun</td>
<td>The Central Detector of JUNO</td>
</tr>
<tr>
<td>34548</td>
<td>32</td>
<td>Yoshitaka Hanabata</td>
<td>Evaluation of the basic properties of the newly developed 1.5' size PMTs R-11920-100 and R-12992-100 from Hamamatsu Photonics and D569/2SA from Electron Tubes Enterprises</td>
</tr>
<tr>
<td>34929</td>
<td>38</td>
<td>Kapusta Maciej</td>
<td>ADIT 1’ photomultiplier with anode’s screening grid ? timing studies.</td>
</tr>
<tr>
<td>35306</td>
<td>41</td>
<td>Hugon Christophe</td>
<td>Step by step GEANT4 simulation for Photo Tubes</td>
</tr>
<tr>
<td>35746</td>
<td>44</td>
<td>Lubsandorzhiev Bayarto</td>
<td>Studies of vacuum photomultipliers at extremely low thresholds, photoelectron backscattering and photon detection efficiency</td>
</tr>
<tr>
<td>37494</td>
<td>47</td>
<td>Fink David</td>
<td>PMT Module Characterization Test Bench for the MAGIC IACT Telescopes</td>
</tr>
<tr>
<td>34585</td>
<td>50</td>
<td>Croci Gabriele</td>
<td>Light Response of LaBr3 and YAP Scintillators to 5-20 MeV protons for applications to thin-foil proton recoil neutron spectrometer</td>
</tr>
<tr>
<td>34612</td>
<td>53</td>
<td>Cinti Maria Nerina</td>
<td>Excellent pulse height uniformity response of a new LaBr3(Ce) scintillation crystal for gamma ray imaging</td>
</tr>
<tr>
<td>34718</td>
<td>56</td>
<td>Shunsuke Kurosawa</td>
<td>Perfomance of Ce:La-GPS scintillator with an MPPC</td>
</tr>
<tr>
<td>34722</td>
<td>59</td>
<td>Ponomarenko Sergey</td>
<td>Nanostructured organosilicon luminophores for highly efficient plastic scintillators and spectral shifters</td>
</tr>
<tr>
<td>35428</td>
<td>62</td>
<td>Liu Ben</td>
<td>FLUKA-based simulation for LYSO gamma detectors in proton therapy</td>
</tr>
<tr>
<td>35760</td>
<td>65</td>
<td>Kamada Kei</td>
<td>Development of a proto-type detector using novel Ce:GAGG scintillator arrays for high resolution radiation imaging</td>
</tr>
<tr>
<td>33307</td>
<td>68</td>
<td>Minot Michael</td>
<td>Pilot Production &amp; Commercialization of LAPPD?</td>
</tr>
<tr>
<td>34738</td>
<td>74</td>
<td>Tremsin Anton</td>
<td>Optimization of High Count Rate Photon Counting Detector with Microchannel Plates and Quad Timepix readout</td>
</tr>
</tbody>
</table>
Quality control of the MPPC TSV arrays, and Modules (MPPC with crystal) for the External Plate of EndoTOF-PET US detector.

Zheng Liu etal.
Overview

• The aim of the EndoTOFPET-US collaboration is to develop an imaging tool combining Ultrasound with Time-Of-Flight PET into an endoscopic imaging device.
• The objective of the TOF-PET scanner is to reach a CTR of 200 ps FWHM.
• The external PET detector is 256 matrices of $4 \times 4$ LYSO crystals with size of $3.5 \times 3.5 \times 15\text{mm}^3$, coupled to 256 Hamamatsu TSV-MPPC arrays (S12643-050CN).
• A full characterization of the MPPC arrays has been performed;
  • Voltage equivalent to the zero gain,
  • Current versus applied bias voltage,
  • Dark count rate (DCR) at level of 0.5 p.e.,
  • Single Photon Time Resolution (SPTR),
  • The CTR of each module (crystal glued on MPPC array),
Measurement result

U_{bd} variance in one MPPC array of all MPPCs is less than 0.5V.

Distribution of breakdown

Mean value of DCR of 4224 MPPCs is very low

Distribution of DCR.

Good SPTR (110 ps sigma)

SPTR as a function of bias voltage

For such a large number of readout units (crystals + MPPC array), such performance is very promising!

Average coincidence time resolution is 239.5 ps.
Skipped!

- ID 5
- Vandenbussche Vincent
- Dual ended readout by SiPMs on LYSO crystal bars: energy and spatial response
Comparison of simulated data with a analytical model

A novel method for gamma-rays depth of interaction determination on monolithic scintillation crystals

R. Pani¹, P. Pani², E. Preziosi³, S. Lo Meo⁴, M.N. Cinti¹, R. Pellegrini¹, A. Fabbri⁵, M. Bettiol⁶, M. Longo⁶ and R. Scafè¹

¹Department of Molecular Medicine, Sapienza University of Rome, Rome, Italy
²Nikhef, Amsterdam, The Netherlands
³Morphofunctional Science – Biophysics, Doctorate School of Biology and Molecular Medicine, Sapienza University of Rome, Rome, Italy
⁴ENEA, Bologna, Italy
⁵Department of Physics, Roma Tre University, Rome, Italy
⁶Medical Physics Post Graduate School, Sapienza University of Rome, Rome, Italy
Depth of Interaction (DoI)

Normal incidence vs. Angled incidence

As a consequence of the depth of interaction effect, the image of a tilted collimated beam is blurred along one direction.

A novel method for gamma-rays depth of interaction determination on monolithic scintillation crystals.
The $N/I$ parameter

**Scrimger and Baker function**

This function, obtained in 1967, describes the scintillation light distribution on the photodetection plane.

$$I_r = \frac{I_0}{\left[1 + \left(\frac{r}{t}\right)^2\right]^{3/2}}$$

$t$ is the depth of interaction

Integrating the function on the photodetection plane:

$$N = \int dx \int dy \frac{l}{\left[1 + \frac{x^2 + y^2}{t^2}\right]^{3/2}}$$

$\Rightarrow$ In polar coordinates $\Rightarrow$

$$N = \int d\theta \int dr \frac{l \cdot r}{\left[1 + \frac{r^2}{t^2}\right]^{3/2}} = 2\pi \int dr \frac{l \cdot r}{\left[1 + \frac{r^2}{t^2}\right]^{3/2}}$$

$$N = 2\pi \left[ -\frac{l \cdot t^2}{\sqrt{1 + \frac{r^2}{t^2}}} \right]_0^{+\infty} = 2\pi \cdot l \cdot t^2 \Rightarrow \frac{N}{I} = 2\pi \cdot t^2$$

The smaller $t$, the more peaky is the distribution

**$N/I \propto t^2 \equiv DoI^2$**

$N$ is the value of the integral of the light (charge) distribution

$I$ is the value of the maximum of the light (charge) distribution

A novel method for gamma-rays depth of interaction determination on monolithic scintillation crystals
The Figure shows the comparison between the theoretical trend and the behaviour obtained from events coming from different depth of interaction in the simulated data. The points represent the layer mean value of the N/I value of the events coming from each 0.5mm-thick layer, and the bars the standard deviation of the layer distributions.

**Results**

By choosing specific windows of the N/I parameter, it is possible to obtain different images as a function of the depth of interaction.

As showed, the parameter follows the behaviour expected from the theoretical model, and it allows to select the events as a function of their depth of interaction.
Effective Atomic Number Measurement with Energy-resolved X-ray Computed Tomography

I. Kanno, Y. Yamashita, M. Kimura, F. Inoue
Department of Nuclear Engineering, Kyoto University, Japan
Effective Atomic Number

- tissue segmentation in computed tomography (CT)
- ion range in a human body

- Can be measured with using two monochromatic X-rays, but not in hospitals
Energy-resolved X-ray CT

- Current mode detector system, transXend detector

Current measurement of X-rays

Unfolding

Energy distribution

\[
\begin{pmatrix}
I_1 \\
I_2 \\
I_3
\end{pmatrix} =
\begin{pmatrix}
R_{11} & R_{12} & R_{13} \\
R_{21} & R_{22} & R_{23} \\
R_{31} & R_{32} & R_{33}
\end{pmatrix}
\begin{pmatrix}
Y_1 \\
Y_2 \\
Y_3
\end{pmatrix}
\]
Effective Atomic Number Measurements

\[
\frac{\mu(E_1)}{\mu(E_2)} = f(Z)
\]

- \( \mu(E) \): linear attenuation coefficient at energy \( E \)

- Energy-resolved CT \( \rightarrow \) \( \mu(E_1) \), \( \mu(E_2) \) with one exposure

- \( Z_{\text{eff}} \) Al 13.1 (0.8%)
  Acrylic 6.46 (0.2%)

Applied to diluted sugar solution (soft tissue)
Skipped !
• ID 17
• Spadola Sara
• Development and Performance Characterization of Intraoperative Positron Probes for Tumor Surgery
A simple and low-cost method to measure depth of interaction (DOI):

- outer end of each LYSO crystal coupled directly to SiPM
- inner end of each group of 32 crystals coupled to a wavelength-shifting fiber, read out by 1 or 2 SiPM \( \Rightarrow \approx \text{half # of channels, simpler electronic readout} \)
1) GATE simulation of the amount of light collected by each SiPM (1 cell):

2) Experimental demonstration:
DRIM-PET: Dual-ended Readout Innovative Method for PET

1) GATE simulation of the amount of light collected by each SiPM (1 cell):

2) Experimental demonstration:
A high sensitive dosimeter was developed. The dosimeter comprises a sensitive probe with a scintillating optical fiber. SiPMs are used to read the scintillation light. This configuration allows in-vivo applications such as brachytherapy.

**Dose calibration - setup**

- capable to measure small dose variations low as 700µGy
- dosimeter response is linear with the dose increase
- for the same dose at different energies the response is not the same
  - this is due to temperature variation during the calibration
  - possible non linearity of the plastic scintillator at low energies
Afterpulses of the H6780 and R7600U-200 Metal Channel Photomultiplier Tubes
Morozov V.A., Morozova N.V.
Joint Institute for Nuclear Research, Dubna, Russia

Fig. 1. Time distributions of afterpulses in photomultipliers of various types.
Fig. 2. Dependence of the afterpulse intensity on the R7600U-200 PMT voltage.
Fig. 3. Comparative characteristics of the afterpulse intensities for the H6780, R7600U-200 and XP2020.

Fig. 4. Block diagram of the delayed-coincidence spectrometer with a double photodetector.

Fig. 4*. Half-life measurements for the 59-keV state in $^{237}$Np using the double photodetector with the R7600U-200.
• ID 29
• Heng Yuekun
• The Central Detector of JUNO

• ID 32
• Yoshitaka Hanabata
• Evaluation of the basic properties of the newly developed 1.5' size PMTs R-11920-100 and R-12992-100 from Hamamatsu Photonics and D569/2SA from Electron Tubes Enterprises

• ID 38
• Kapusta Maciej
• ADIT 1' photomultiplier with anode's screening grid ? timing studies.

• ID 41
• Hugon Christophe
• Step by step GEANT4 simulation for Photo Tubes

• ID 44
• Lubsandorzhiev Bayarto
• Studies of vacuum photomultipliers at extremely low thresholds, photoelectron backscattering and photon detection efficiency
MAGIC Camera Module Measurement - Setup Block Diagram

- Pulsed Diode Laser 355nm
- 2x Filter Wheel
- Ulbricht Sphere
- Hamamatsu R10408 6 stage PMTs with hemispherical photocathode
- Ref PMT x2
- DUT
- Optical Rcvr 7x
- DAQ 28 ch
- PC
- RS232
- FO
- Optical Rcvr 1x
- Timing
- Laser Monitor
- DAQ Trigger
- Laser Trigger
MAGIC Camera Module Measurement - Setup DAQ / Rcvr / Timing / Power
MAGIC Camera Module Measurement - Setup Enclosure

- Side access dark box w/EMI shield (courtesy Toni Engelhardt)
- Ulbricht Sphere exit port
- Monitor PMTs and control
**MAGIC Camera Module Measurement -- Setup**

- Ulbricht Sphere
- 355 nm laser
- Fixed filter and monitor fiber
- 2x filter wheels
- Similar to camera calibration source
Skipped!

- ID 50
- Croci Gabriele
- Light Response of LaBr3 and YAP Scintillators to 5-20 MeV protons for applications to thin-foil proton recoil neutron spectrometer
Excellent pulse height uniformity response of a new LaBr$_3$Ce scintillation crystal for gamma ray imaging

R. Pani$^{1,2}$, M.N. Cinti$^{1,2}$, A. Fabbri$^{4,5}$, C. Orlandi$^{1,2,3}$, R. Pellegrini$^{1,5}$, R. Scafè$^{1,2}$

(1) Department of Molecular Medicine, Sapienza University of Rome, Rome, Italy (2) INFN, Rome 1 Section, Rome, Italy (3) Medical Physics Post Graduate School, Sapienza University of Rome, Rome, Italy (4) Department of Physics, Roma Tre University, Rome, Italy (5)INFN, Rome 3 Section, Rome, Italy
New LaBr$_3$:Ce scintillation crystal

- For small field of view (FOV) detectors based on planar crystals, a reduces pulse height uniformity response is typically obtained in proximity of the crystal edges, due to the absorbent treatment used for imaging applications, with consequent energy resolution (ER) degradation.
- We propose an analysis on a new LaBr$_3$:Ce scintillation crystal (light yield 63000 photons/MeV, scintillation time 16 ns) with reflective edges that lead up to excellent ER results and pulse height uniformity response, but with dimensions proper for a small FOV gamma imager (50 mm Ø and 6 mm thickness).

The performances of the proposed LaBr$_3$:Ce are compared to ones obtained from another LaBr$_3$:Ce with absorbent edge and similar dimensions.
- Both crystals were optically coupled with a Hamamatsu R6231 (PMT) (2-inch Ø) and a Hamamatsu H10966 (52 x 52 mm2) MA-PMT used for imaging).
- Two electronic readouts were used: a single channel one for R6231, and a 64 independent channels readout for H10966.

<table>
<thead>
<tr>
<th>PMTs</th>
<th>Quantum Efficiency (@380nm)</th>
<th>Size (mm)</th>
<th>Gain (x10$^6$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R6231</td>
<td>30.0%</td>
<td>51Ø</td>
<td>0.27</td>
</tr>
<tr>
<td>PMT</td>
<td>38.7%</td>
<td>51x51</td>
<td>0.27</td>
</tr>
<tr>
<td>H10966</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA-PMT</td>
<td></td>
<td></td>
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</tbody>
</table>
ER and pulse height uniformity results

- In the spectrum shown (with R6231), the principal Co\textsuperscript{57} emission peaks (122keV and 136keV) are well discriminated.
- With H10966 MA-PMT local ER results are good on the whole area completely covered by scintillation crystal, without significant ER degradation on the edges. This behavior is due to reflective treatment of surfaces that also leads up to excellent pulse height uniformity response on the whole FOV.

Normalized pulse height uniformity response for the analyzed LaBr\textsubscript{3}:Ce scintillation crystal optically coupled with Hamamatsu MA-PMT H10966

<table>
<thead>
<tr>
<th>PMTs</th>
<th>LaBr\textsubscript{3}:Ce Reflective edges</th>
<th>LaBr\textsubscript{3}:Ce Absorbent edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>R6231</td>
<td>(6.9\pm0.3)%</td>
<td>(8.3\pm0.3)%</td>
</tr>
<tr>
<td>H10966</td>
<td>(7.1\pm0.3)%</td>
<td>(8.4\pm0.3)%</td>
</tr>
</tbody>
</table>

**ENERGY RESOLUTION @122keV (Best Values)**

**PULSE HEIGHT UNIFORMITY RESPONSE**
Imaging performances

- Traditionally, a crystal with this surfaces treatment is not expected to achieve good imaging performances, due to the compression of the FOV and to a degradation of the linearity.
- Preliminary analysis of scanning data in term of spatial resolution and linearity have shown satisfactory results, when opportune gain correction and position algorithm reconstruction are applied.

<table>
<thead>
<tr>
<th>INTRINSIC SPATIAL RESOLUTION (mm)</th>
<th>LaBr₃:Ce Reflective edges</th>
<th>LaBr₃:Ce Absorbent edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN VALUE IN CFoV</td>
<td>1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Skipped!

- ID 56
- Shunsuke Kurosawa
- Performance of Ce:La-GPS scintillator with an MPPC
Nanostructured organosilicon luminophores (NOLs) for highly efficient plastic scintillators and spectral sifters

S.A. Ponomarenko\textsuperscript{a}, N.S. Surin\textsuperscript{a}, O.V. Borshchev\textsuperscript{a}, Yu.N. Luponosov\textsuperscript{a}, E.A. Kleymyuk\textsuperscript{a}, M.S. Skorotecky\textsuperscript{a}, D.Y. Akimov\textsuperscript{b}, A.A. Burenkov\textsuperscript{b}, A.M. Muzafarov\textsuperscript{a}

\textsuperscript{a} Enikolopov Institute of Synthetic Polymer Materials, Russian Academy of Sciences, Profsoyuznaya St. 70., 117393 Moscow, Russian Federation.
\textsuperscript{b} State Scientific Centre of Russian Federation Institute for Theoretical and Experimental Physics (ITEP), Bolshaya Cheremushkinskaya st. 25, Moscow 117218, Russian Federation.
Classical plastic scintillators and “nanoscintillators”

Classical plastic scintillator

Light output is 45-65% relative to the anthracene standard.

New plastic scintillator with nanostructured organosilicon luminophores (NOLs)

Light output is 90-120% relative to the anthracene standard.

Patent RU 2380726 (2010)
Amplitude spectra, obtained under irradiation of the samples of standard PS scintillator (black) and a new scintillator containing NOLs (red) with α-particles having the energy of 5.49 MeV

Comparison of the scintillation decay times of the standard PS scintillator (blue) and the PS scintillator with NOL (black)

Our approach allows raising the scintillation light output of plastic scintillators on 50% as compared to the standard one, while their scintillation decay time improved on 40%
Plastic scintillators with NOLs having different emission range

Scintillation spectra of a few model polystyrene scintillators - standard Sc0 (black) and with NOLs (colored) having different wavelengths of the emission

Amplitude spectra, obtained under irradiation of the samples of the standard PS scintillator Sc0 (black) and PS scintillators with NOLs (colored) with the α-particles having the energy of 5.49 MeV

Our approach allows tuning the emission of plastic scintillators in a wide spectral region from 390 to 650 nm without loosing their light output, which open possibilities for their application for any type of photodetectors with different spectral sensitivity, as well as for spectral shifters.
Skipped!

- ID 62
- Liu Ben
- FLUKA-based simulation for LYSO gamma detectors in proton therapy

- ID 65
- Kamada Kei
- Development of a proto-type detector using novel Ce:GAGG scintillator arrays for high resolution radiation imaging
LAPPD™ (Large Area Picosecond Photodetector) is a microchannel plate (MCP) based photodetector, capable of imaging, and having both high spatial and temporal resolution in an UHV hermetic package with an active area of 400 square centimeters.

LAPPD™ have a uniquely simple design; a) a hermetic package comprised of top and bottom plates and square sidewall, each made with float glass.
“Next Generation” MCPs

The key breakthrough was the advent of atomic layer deposition (ALD) coating methods and materials to functionalize GCAs converting them into highly effective MCPs with electronic gain and robust performance properties. ALD is characterised by sequential precursor pulsing.

1) Precursor pulse

1) Pulse precursor into chamber, which reacts with available sites.

2) Purge

2) Purge to remove by-products. Repeat pulse/purge sequence to grow layers.

3) Precursor pulse B

3) Pulse precursor B into chamber, which reacts with available sites. Reaction is self-limiting.

4) Purge

4) Purge to remove unreacted precursors, by-products, and physisorbed species.
Advantages of the Incom Next Gen MCPs

- Larger area - 203 mm x 203 mm plates!
- Lead-free - environmentally favorable,
- High aspect ratio with no scrubbing required
- More robust and lower cost

<table>
<thead>
<tr>
<th>Key Product Feature</th>
<th>Typical</th>
<th>Incom MCP</th>
<th>Incom Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Count</td>
<td>3 cm$^{-2}$ s$^{-1}$</td>
<td>0.085 cm$^{-2}$ s$^{-1}$</td>
<td>Enhanced signal to noise</td>
</tr>
<tr>
<td>Scrubbing Time</td>
<td>200 h</td>
<td>None required</td>
<td>Lower installed cost</td>
</tr>
<tr>
<td>Secondary Electron Yield</td>
<td>3</td>
<td>7</td>
<td>Greater signal amplification</td>
</tr>
<tr>
<td>Contains Lead</td>
<td>Yes</td>
<td>No</td>
<td>Environmentally friendly, stronger and more stable</td>
</tr>
<tr>
<td>Price (8x8” MCP)</td>
<td>Not Available</td>
<td>Call</td>
<td>Lower cost New applications</td>
</tr>
</tbody>
</table>

Fully integrated sealed* ceramic LAPPD, with Incom 203mm X 203mm MCP & readout electronics (Gary Varner, U. of Hawaii).
LAPPD Target Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Demonstrated Results “Standard” LAPPD 20µ Pores &amp; Future Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MCP</strong></td>
<td>Functional area 200 mm x 200 mm x 1.2 mm, 20µ pore Φ, Pitch = 25µ, OAR=65%, Flat ±12.7µ, Resistive Layer: 10-25 megohm, Optional SEE Layer: MgO or Al2O3</td>
</tr>
<tr>
<td><strong>MCP Gain</strong></td>
<td><strong>10⁵ @ 1400 Volts, 10⁷ @ 2000 Volts.</strong></td>
</tr>
<tr>
<td><strong>MCP Gain Uniformity</strong></td>
<td><strong>&lt;20%</strong> Edge to edge variability</td>
</tr>
<tr>
<td><strong>MCP Background Rates</strong></td>
<td><strong>3000 sec background, 0.0845 events cm⁻² sec⁻¹</strong> at 7x10⁶ gain, 1025v bias on each MCP. MCP background rate is about 35kHz at the highest running gain.</td>
</tr>
<tr>
<td><strong>QE</strong></td>
<td><strong>20-25% QE</strong> @350-400nm, ±15% uniformity over 200 mmx200 mm area</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>1 mm for large signals, 5mm for single photons (application specific) (With PSEC4 or PSEC5 read-out electronics and software algorithms)</td>
</tr>
<tr>
<td><strong>Timing Resolution</strong></td>
<td><strong>64 ps Demonstrated; Target = ≤40 psec</strong> (610 nm laser, spot image of &lt;5mm, FWHM at high pulse amplitudes)</td>
</tr>
</tbody>
</table>
Optimization of High Count Rate Photon Counting Detector with Microchannel Plates and Quad Timepix readout

A.S. Tremsin, J.V. Vallerga, J.B. McPhate, O.H.W. Siegmund

Space Sciences Laboratory, University of California, Berkeley, California 94720, U.S.A.
Detector configuration and performance

- Detection of photons, ions, neutrons, alphas, high energy electrons, atoms.
- Up to ~25000 simultaneous events can be detected.
- Active area 28x28 mm\(^2\) (2x2 Timepix chips).
- Fast parallel readout (x32) allowing ~1200 frames per second with ~320 µs readout time.
- Event centroiding (~15 µm resolution, at ~5x10\(^6\) events/s) or 55 µm resolution at >5x10\(^8\) events/s.
- Time resolution can be ~20 ns at ~2.5x10\(^7\) events/s rates with 55 µm resolution.
- Timing within frames – TOF(energy) or dynamic processes can be studied. Wide energy range or most phases measured in one experiment.
Event centroiding

Each pixel measures charge accumulated in a frame (Time Over Threshold method)

Only one event per pixel is allowed in a frame
High resolution imaging through event centroiding

BOA beamline, PSI

50 µm per line

25 µm per line

Neutron radiography

Optical microscope image
UV imaging at high resolution

- “Time over threshold” - charge in each pixel instead of counts

- Charge cloud needs to be optimized for centroiding to sub-pixel accuracy

- Count rate is limited by frame readout: need to avoid event overlaps
Applications: energy resolved neutron imaging

Source, 20 - 60 Hz

Detector at 9-60 m

Sample

Stir-friction weld

28 mm

Energy-resolved transmission images.

Measured stack of images, each corresponds to $\Delta E$

Transmission spectra
Strain mapping in Ni bolt

Strain 4.16A edge

Strain 2.14A edge

Edge height

Edge Pedestal
Resonance transmission spectra

1.18 mm Ta foil: measured and theoretical transmission

Ag of various thickness

- Measured
- Calculated

Ta 1.18 mm >1 m from detector

- Ag 80 μm
- Experimental
- Calculated

- Ag 30 μm
- Experimental
- Calculated

- Ag 10 μm
- Experimental
- Calculated