Two-phase Cryogenic Avalanche Detectors in Ar with THGEM/GAPD-matrix optical readout

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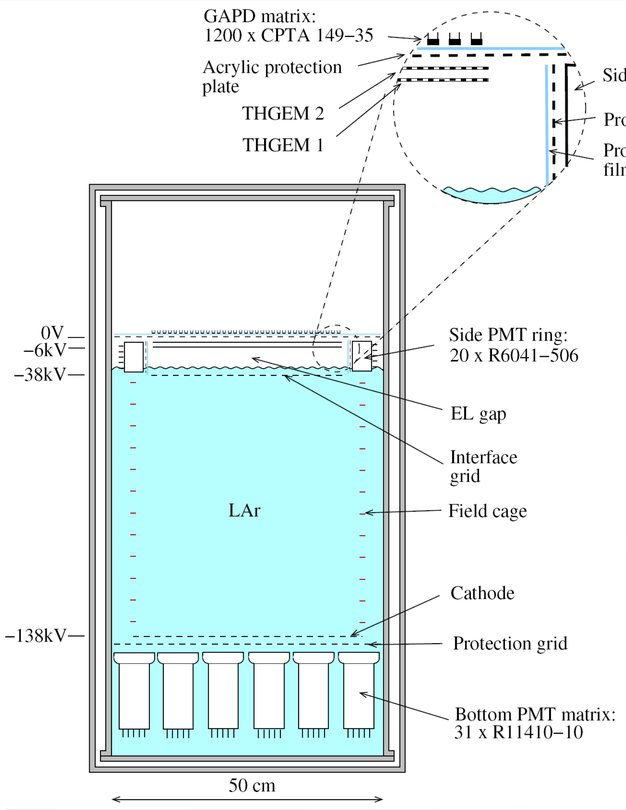
Cryogenic Avalanche Detector (CRAD) for rare-event experiments: concept

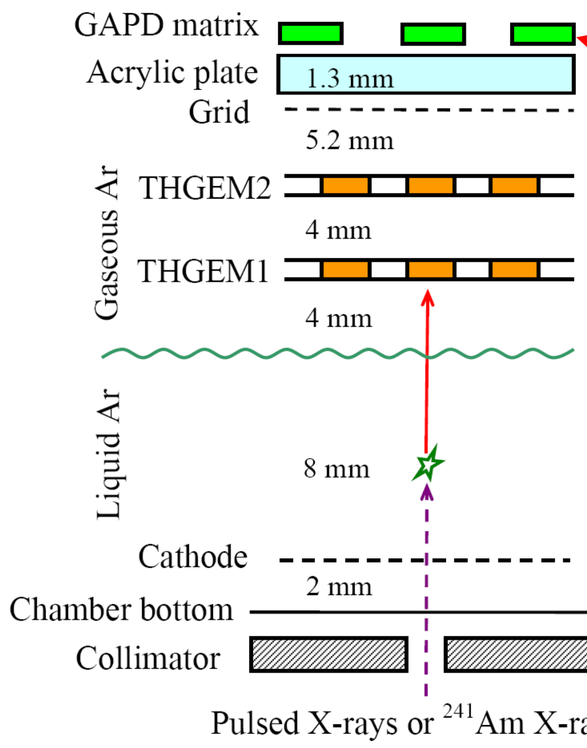


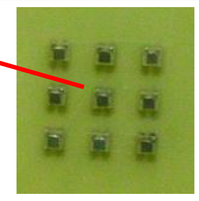
Two-phase Ar CRAD with combined THGEM/GAPD-matrix optical readout in the NIR for Dark Matter Search and Coherent Neutrino-Nucleus Scattering experiments [1,2].

- Detector fiducial volume – 50 L;
- Number of photomultipliers – 51;
- Number of GAPDs – 1200;

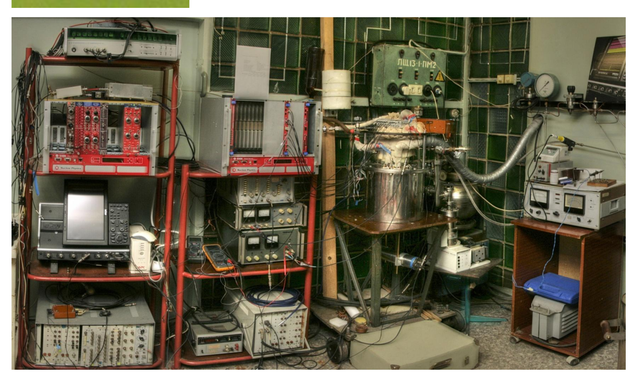
1. A. Buzulutskov, JINST 7 (2012) C02025
2. A. Bondar et al., JINST 7 (2012) P06014

Two-phase Ar CRAD prototype: experimental setup



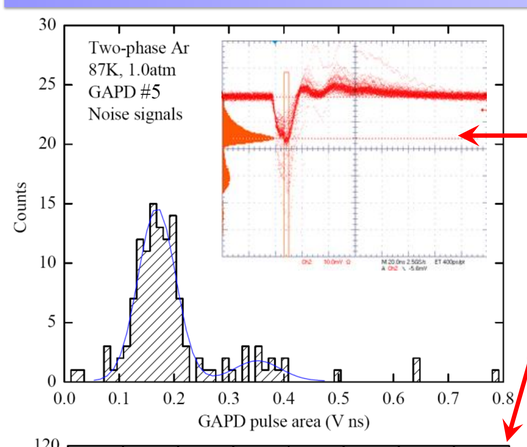


3x3 GAPD matrix:
2.1x2.1 mm^2 active area each,
1 cm spacing



- 9 liters cryogenic chamber
- ~1 liter of liquid Ar
- THGEM/GAPD assembly inside
- DAQ using flash ADC CAEN V1720: 8 ch., 250 MHz

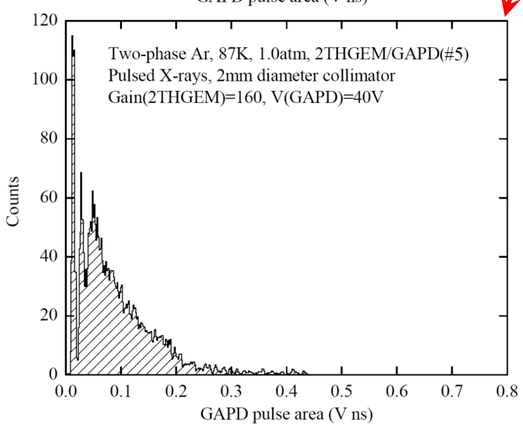
GAPD rate dependence problem

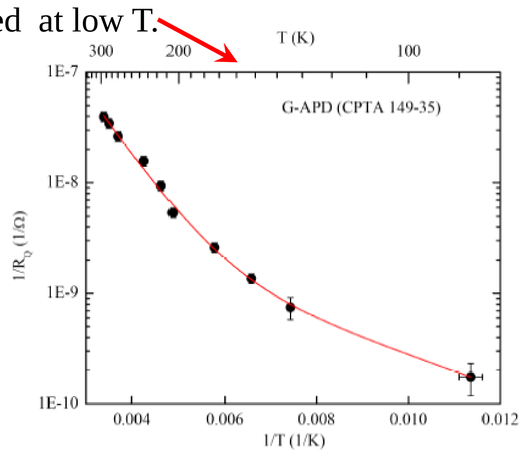


The infrequent nose signals had a nominal GAPD pulse-area distribution: well defined single-pixel peak is accompanied with secondary (cross-talk) peaks.

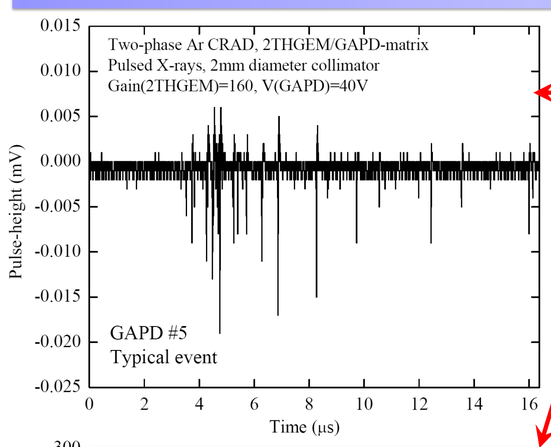
However, at higher rates (240Hz) and intense photon flux the single pixel pulse-area spectrum was degraded.

This is presumably due to considerable increase of the pixel quenching resistor observed at low T.





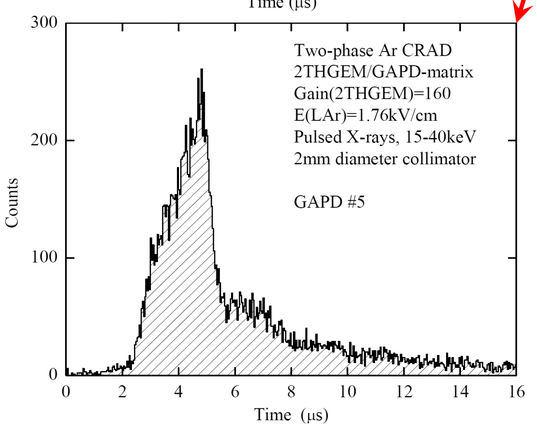
GAPD signal example and time properties

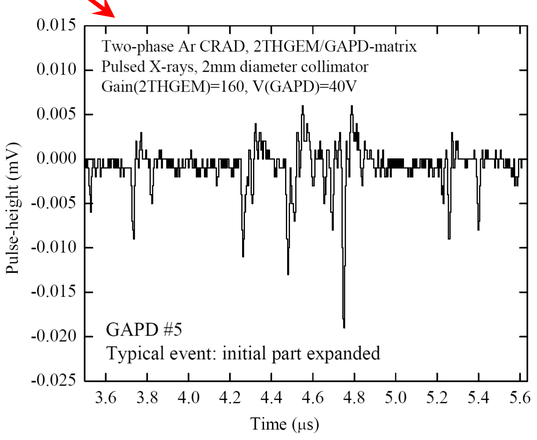


Typical GAPD signal: ~20 pe per 20 keV X-ray.

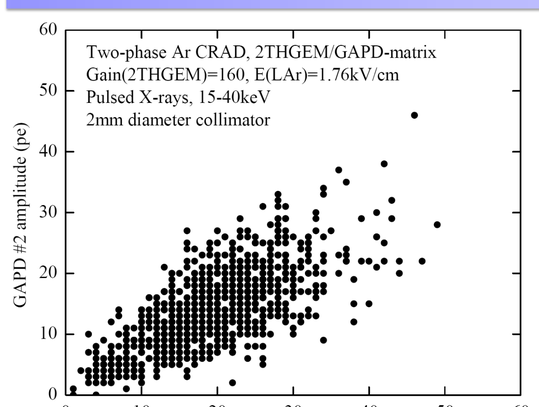
Long (>16 μs) signal due to slow electron emission component presented in two-phase Ar systems (see signal time spectrum).

Measuring GAPD amplitude: counting the number of peaks using dedicated peak-finder algorithm.

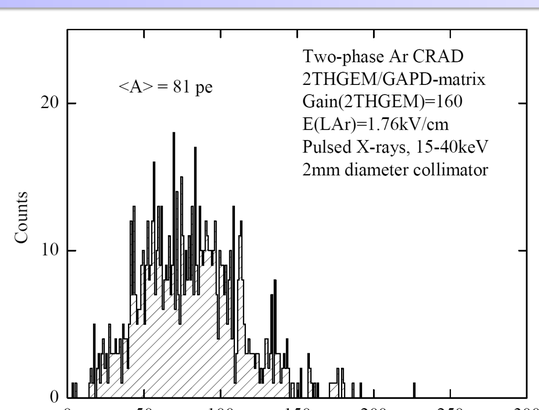




Combined THGEM/GAPD multiplier yield



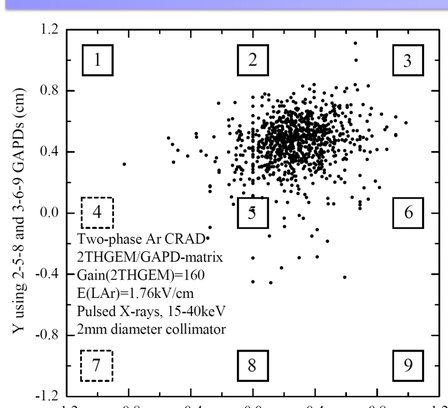
Correlation between GAPD channel amplitudes.



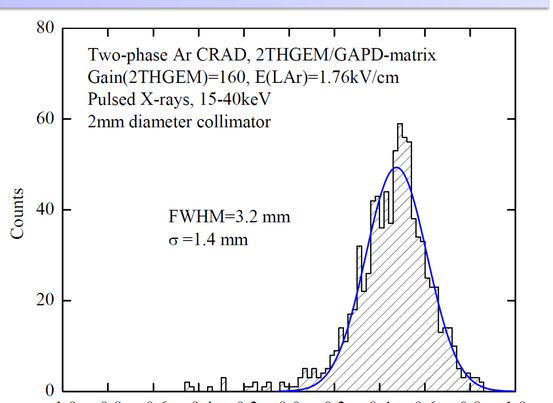
Total multiplier (7 active channels) amplitude: 80 pe per 20 keV X-ray, at charge gain of 160.

That means that we may still have reasonable GAPD matrix yield for low energy deposition: >10 pe per 1 keV at charge gain of 600. Higher yield is expected when the GAPD rate problem will be solved.

Spatial resolution



Reconstructed image of X-ray conversion region (defined by 2 mm collimator) from GAPD-matrix amplitudes.



Using center-of-gravity algorithm gives FWHM=3 mm.

Spatial resolution of THGEM/GAPD-matrix readout is far superior compared to that of PMT-matrix: of the order of 1 mm, for deposited energy of 20 keV at charge gain of 160.

Conclusions

1. The two-phase CRAD in Ar with THGEM/GAPD-matrix multiplier optical readout in the NIR showed excellent performance, namely high sensitivity (>100 pe per 20 keV at charge gain of ~100) and superior spatial resolution (~1 mm).
2. Such kinds of CRADs may come to be in great demand in rare-event experiments, such as those of Coherent Neutrino-Nucleus Scattering and Dark Matter Search.

This work is supported by the Grant of the Government of Russian Federation (11.G34.31.0047).