Development of very low threshold detection system for low-background experiments

International Workshop on New Photon-detectors 2012

Presented by Ivan Alexandrov

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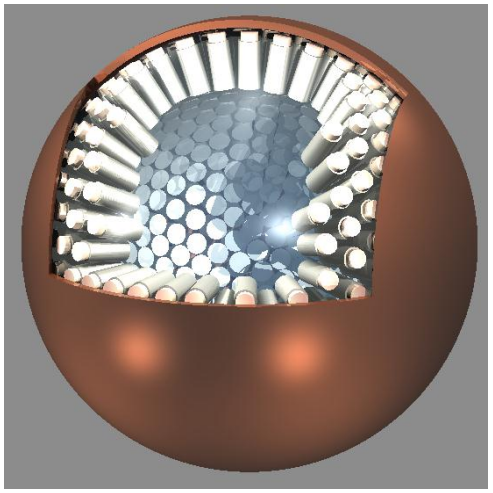
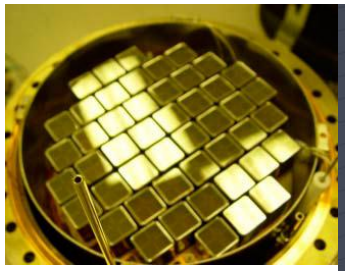
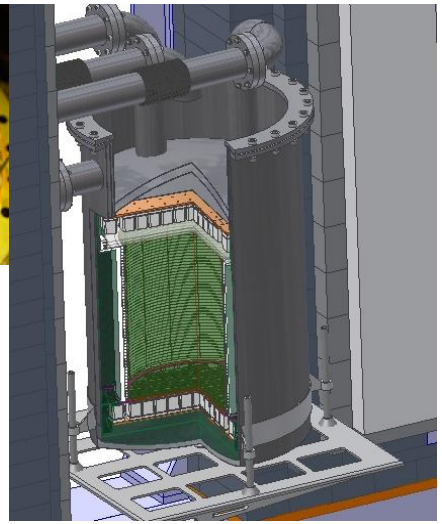
3National Research Nuclear University "Moscow Engineering Physics Institute»

Xe detectors for "Dark Matter" experiments

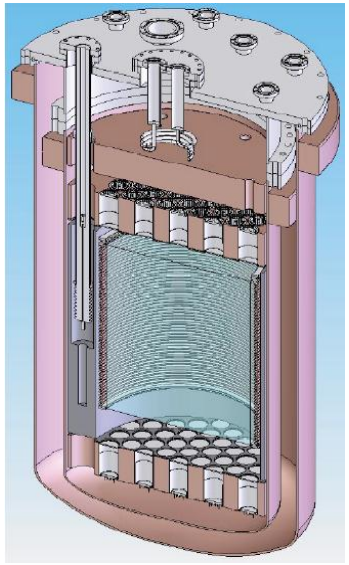


XMASS at Kamioka

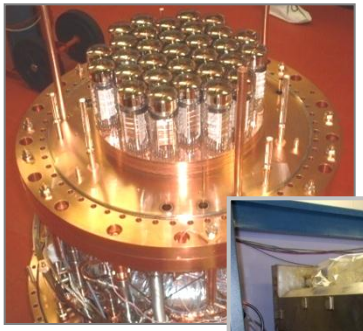




Xenon10,100
at Gran Sasso



LUX at DUSEL



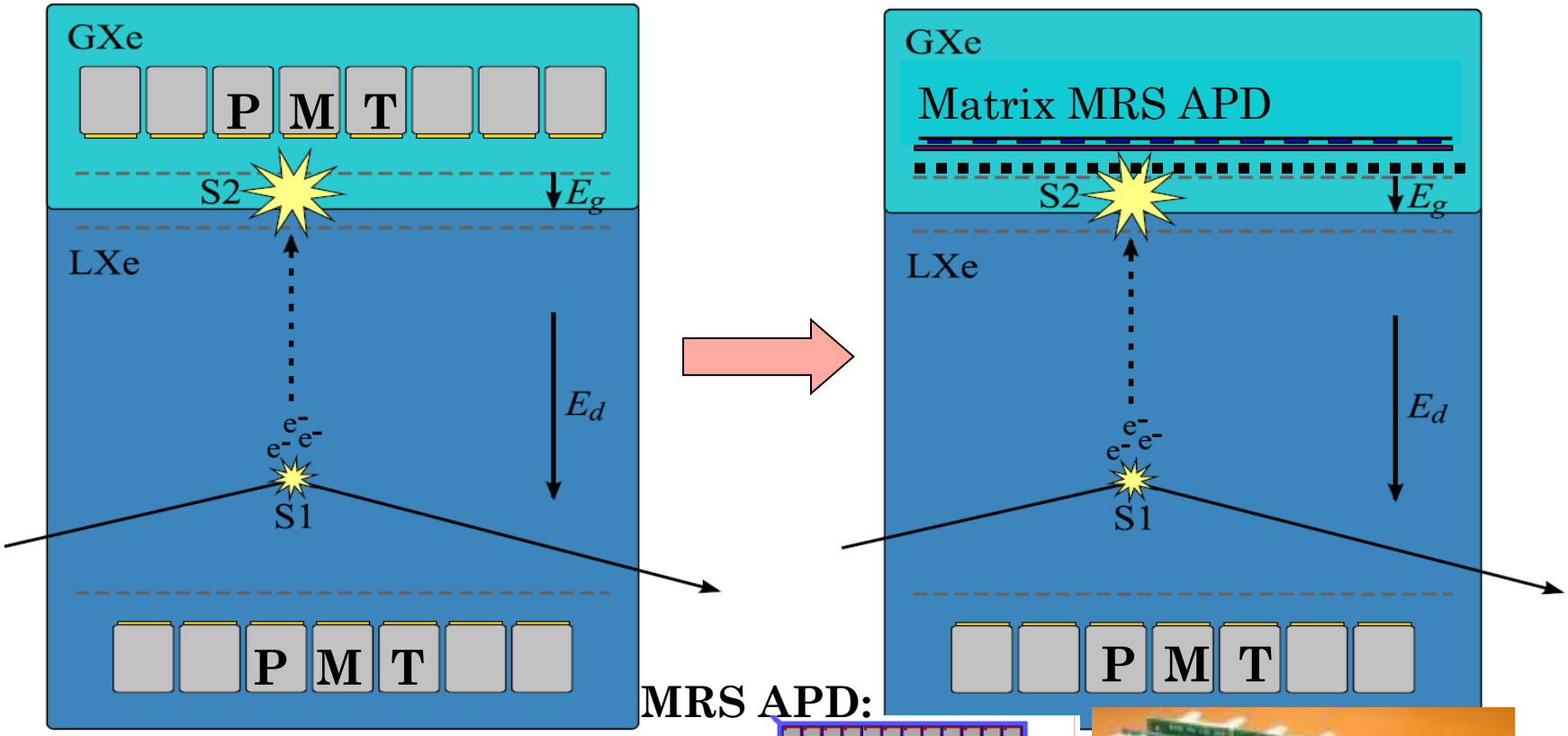
ZEPLIN III at
Boulby mine

All detectors utilizes PMTs for detection of the LXe VUV light.

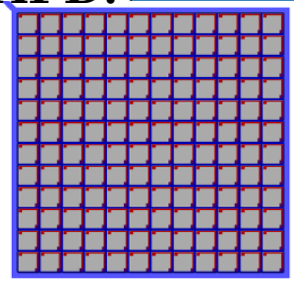
At present, PMTs (even low-background) are the most radioactive elements of detector.

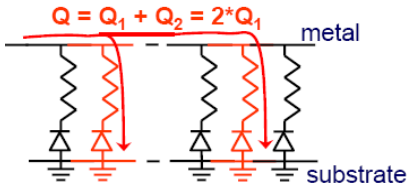
Search for a replacement of PMTs for the future detectors is actual.

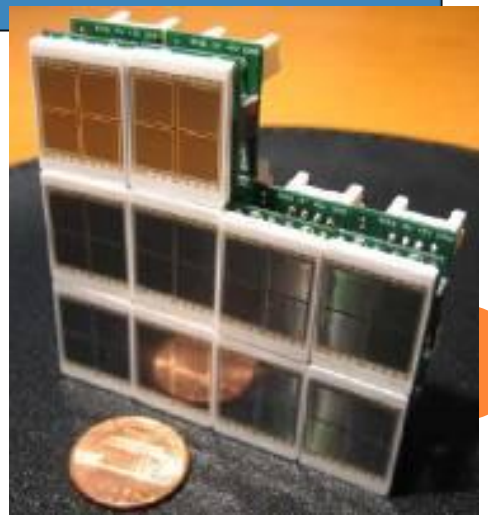
PMT ➡ MRS APD + WLS+THGEM



MRS APD:



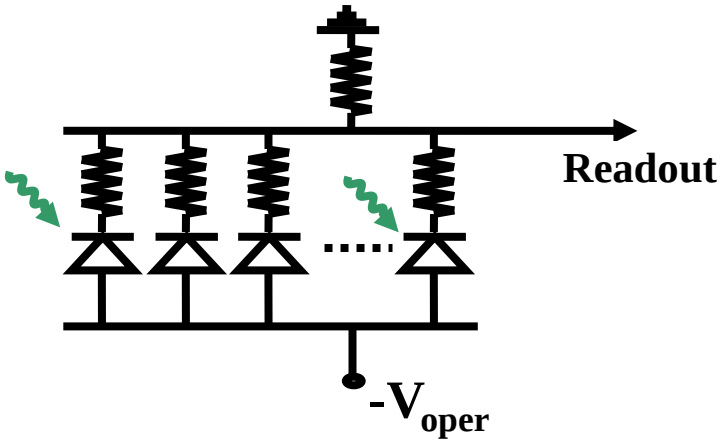




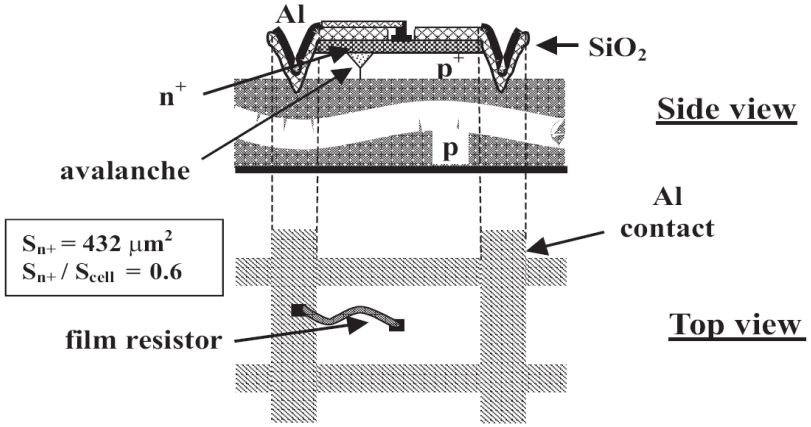
Some advantages of MRS APD:

- Small size
- Made from clean materials
- no high voltage

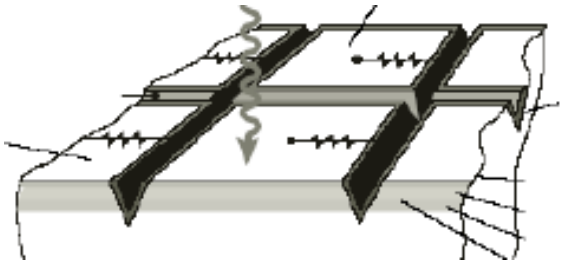
Multipixel avalanche Geiger photodiode



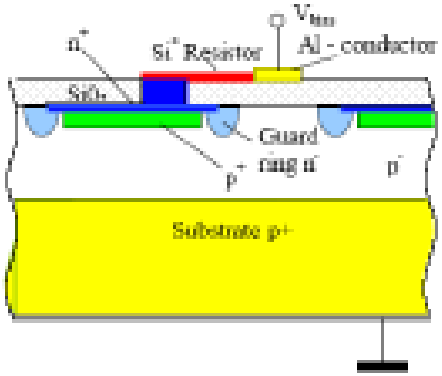
Scheme of MRS APD



Structure of 1 cell

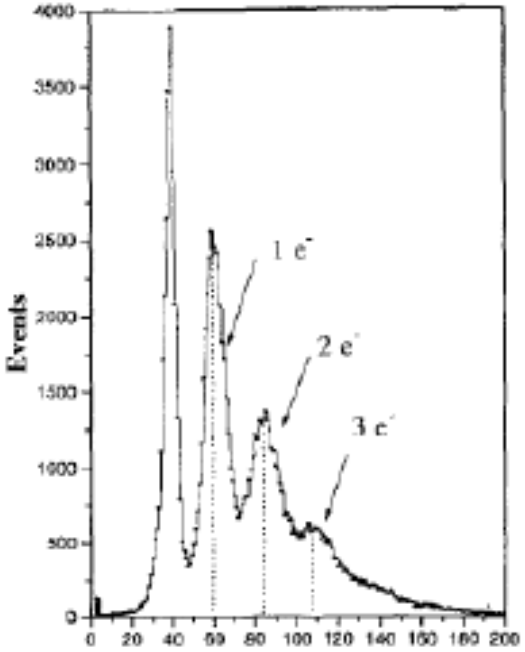


View of matrix cells



Multipixel avalanche Geiger photodiode

LED pulse spectrum
(A. Akindinov et al., NIM387 (1997) 231)

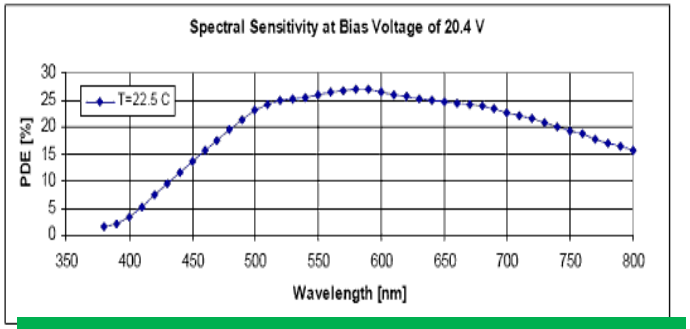


Multiplication: $M = C*(U - U_{br})$

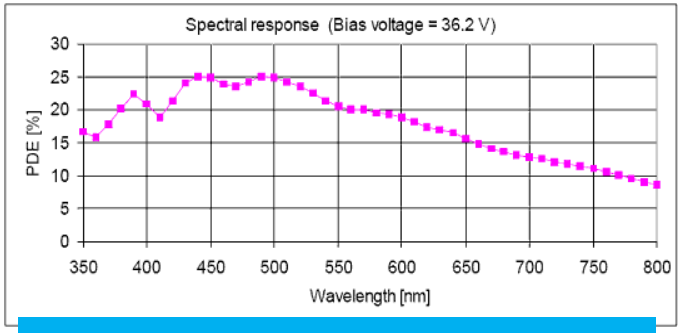
Charge: $Q = e*N_{cell}*C*(U - U_{br})$

Photon Detection Efficiency:
$PDE = Q.E.*R_G*\varepsilon_{geom}$

Typical PDE for CPTA 2x2 mm²

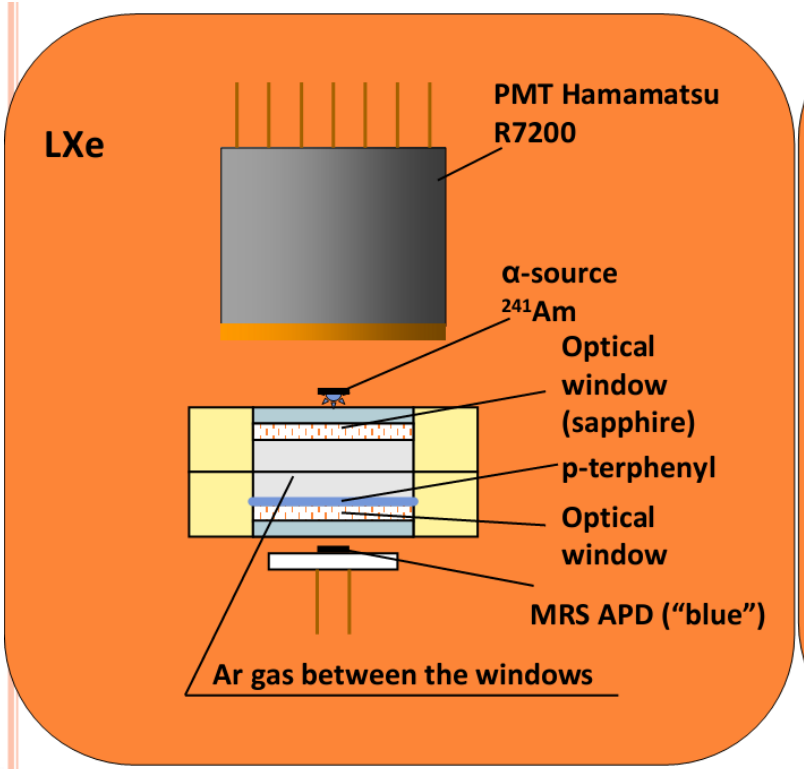


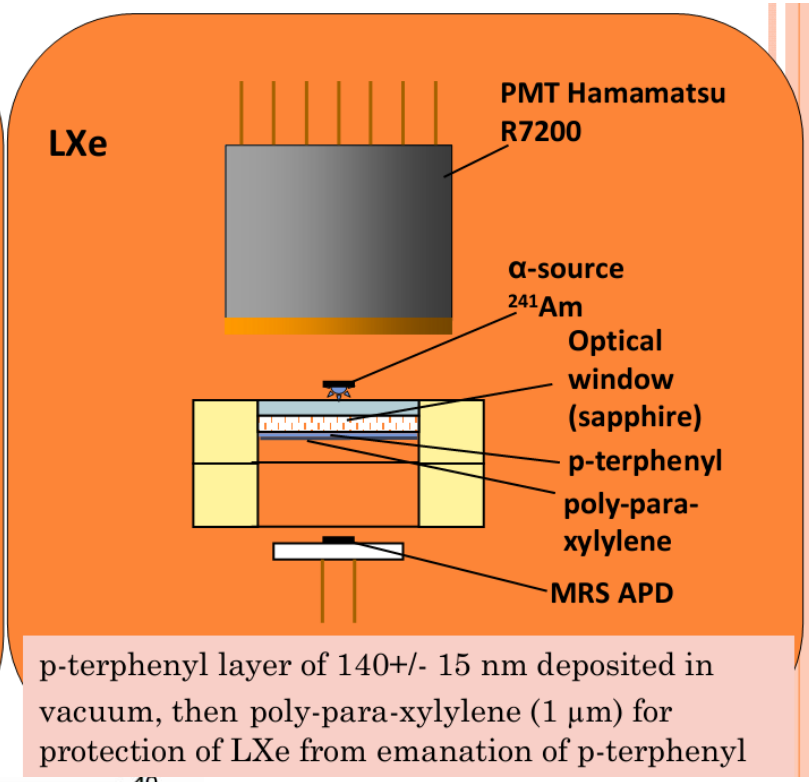
CPTA "green" – blue, **green**, IR



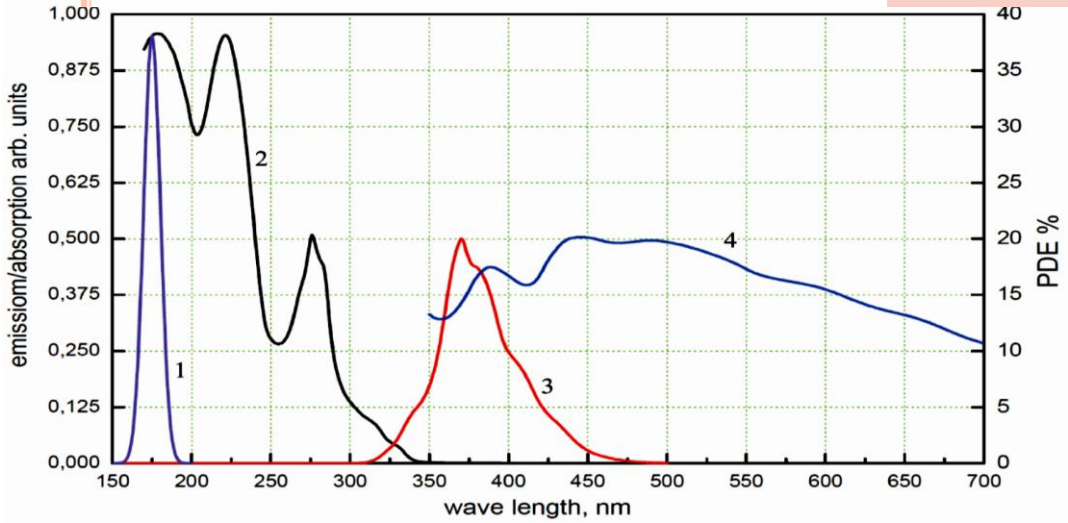
CPTA "blue" – **blue**, green, IR

Wave Length Shifter in liquid xenon





p-terphenyl layer of 140+/- 15 nm deposited in vacuum, then poly-para-xylylene (1 μm) for protection of LXe from emanation of p-terphenyl



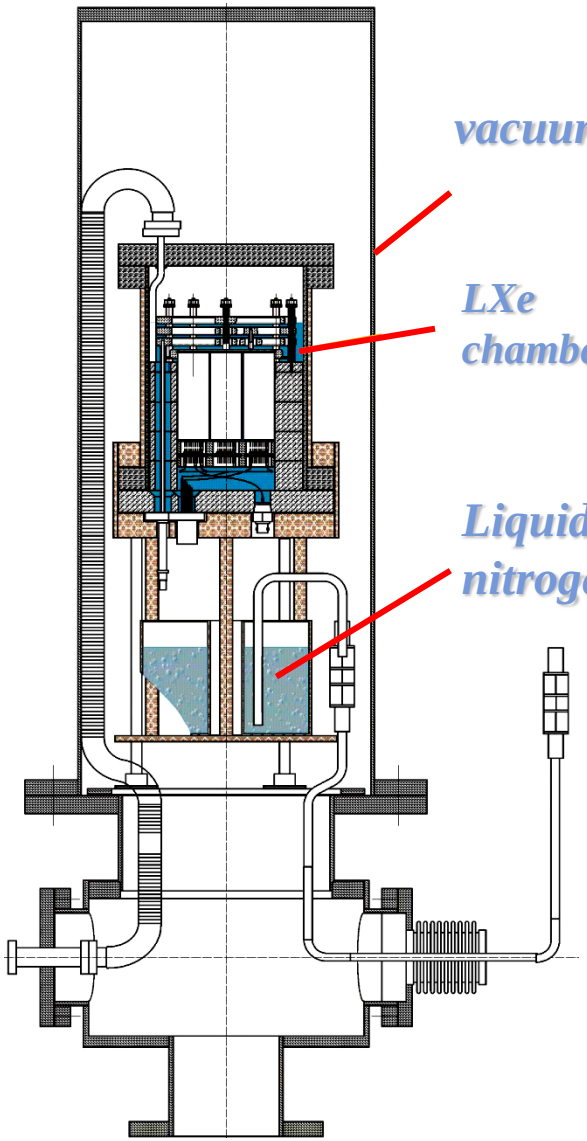
1- emission of LXe,
2 – absorption p-terphenil,
3 – emission of p-terphenyl,
4 – range of sensitive MRS APD

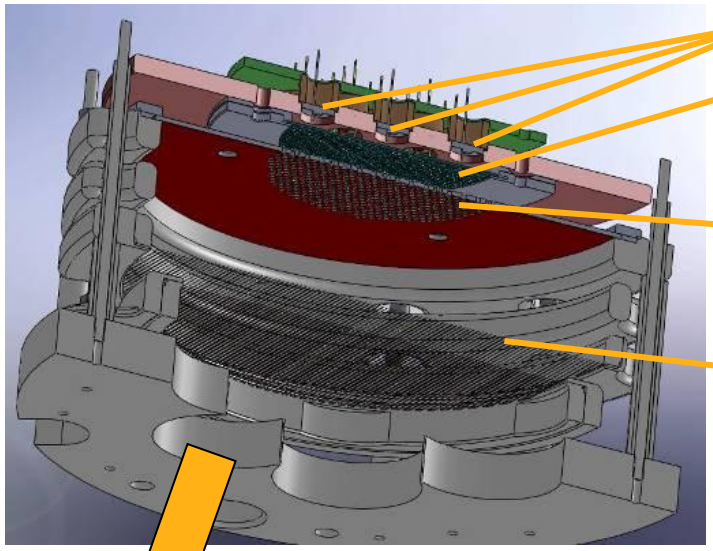
First tests. Results

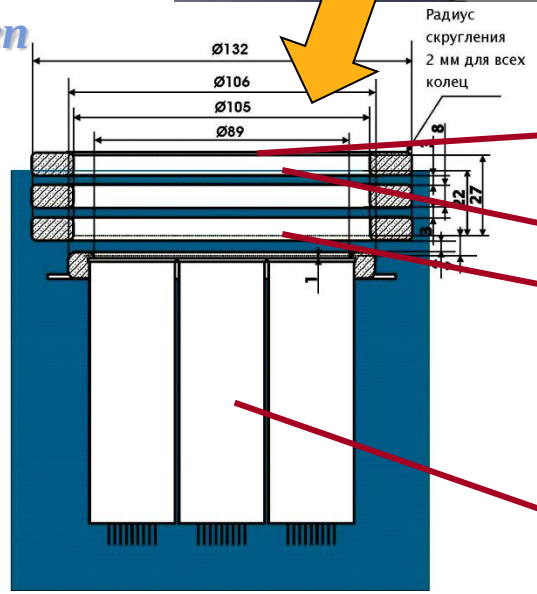
Construction of WLS	N_{cells}	PDE ,%
P-terphenyl encapsulated by saphfire window	24±0.5	9.7±1.2
P-terphenyl cowered by poly-para-xylynen film	72±1.5	8.4±1.1

P. Benetti, et al., *Nucl. Instr. Meth.* **A505**, 89 (2003).
For a blue sensitive PMT (QE ≈20%) with WLS: ~ 10%

Single THGEM Experimental setup



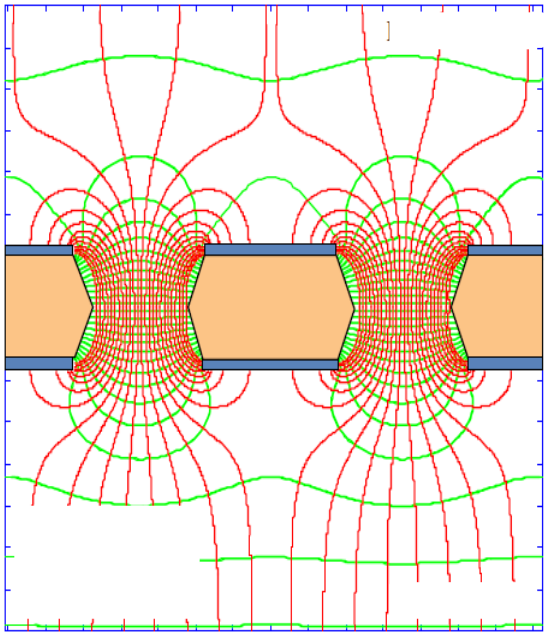


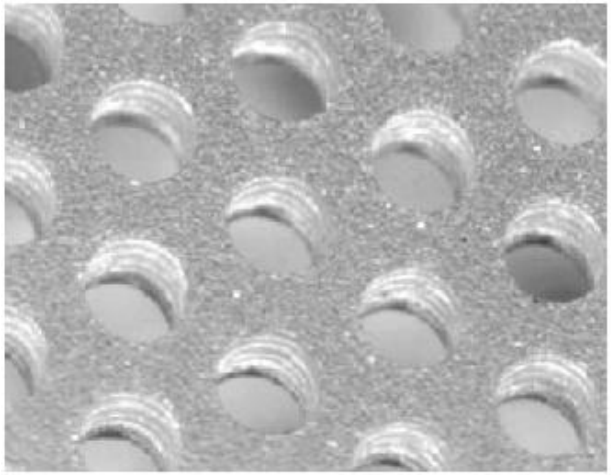


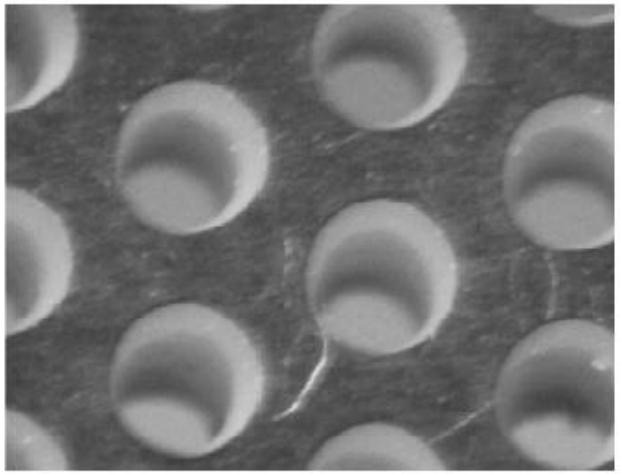
Diameter THGEM (50 mm) less than diameter LXe chamber (106 mm)

THGEM principle of operation

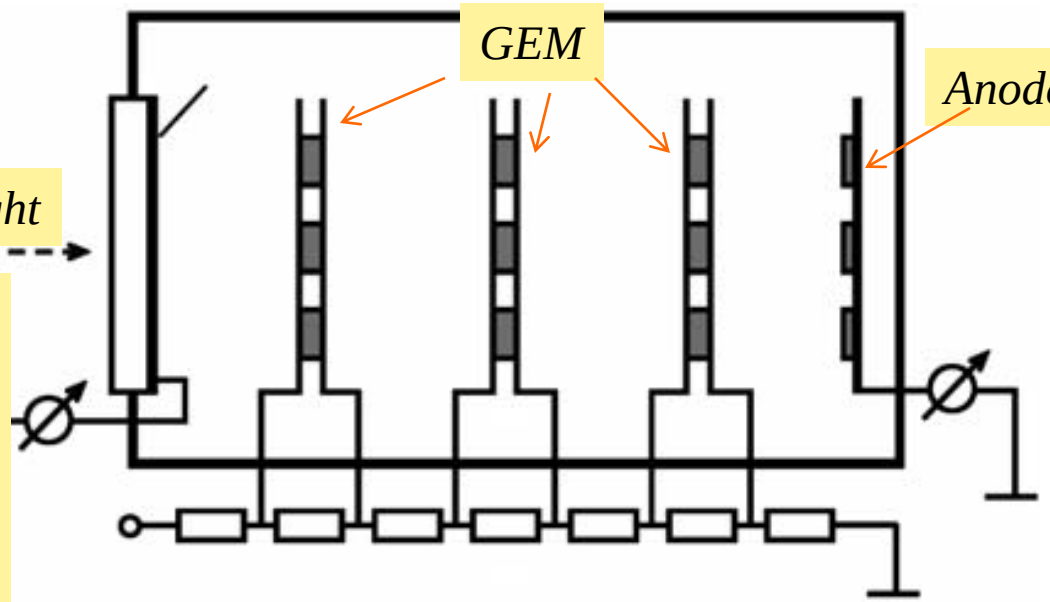
Electric field in GEM







Photos of GEM

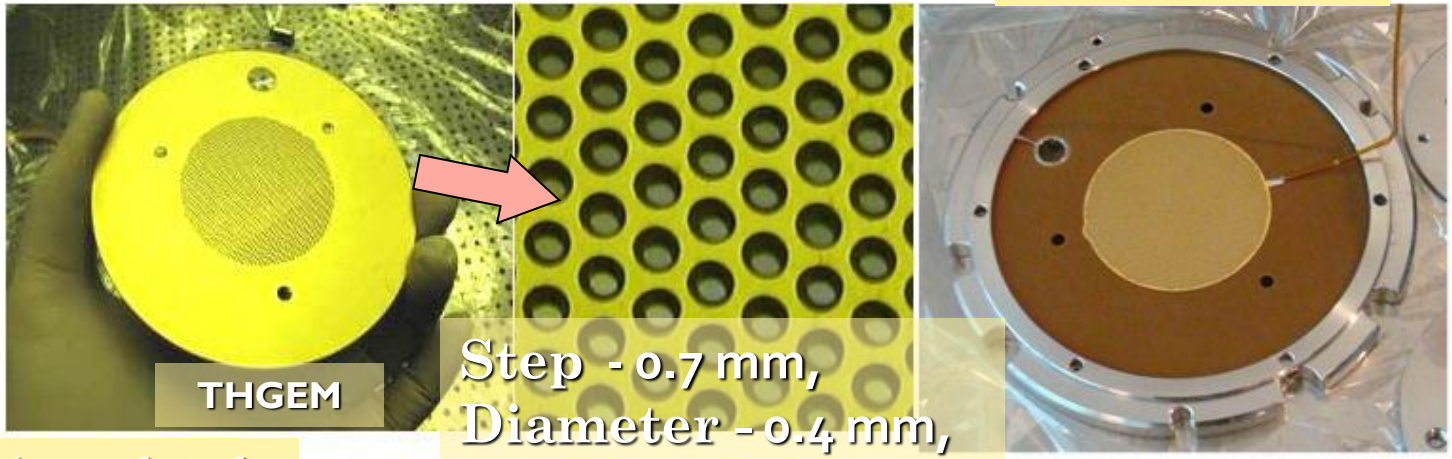


A unique property of GEMs, as compared to other micro-pattern detectors, is their capability to operate in cascade

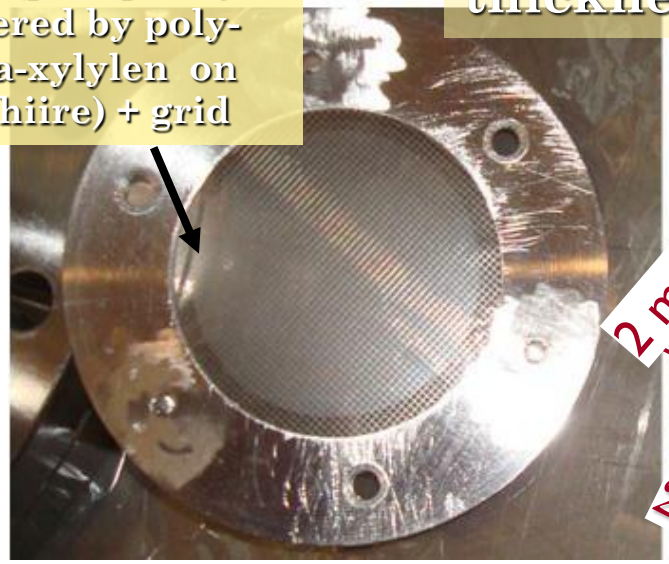
Scheme of photo detector based on GEM

Experimental setup

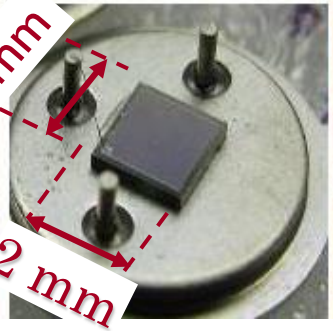
Matrix MRS APD



WLS (p-terphenyl covered by poly-para-xylylen on saphiire) + grid

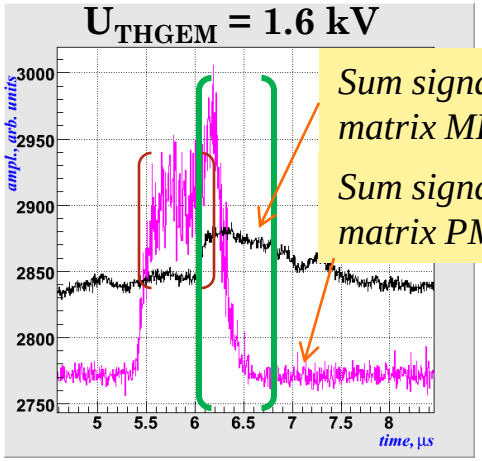


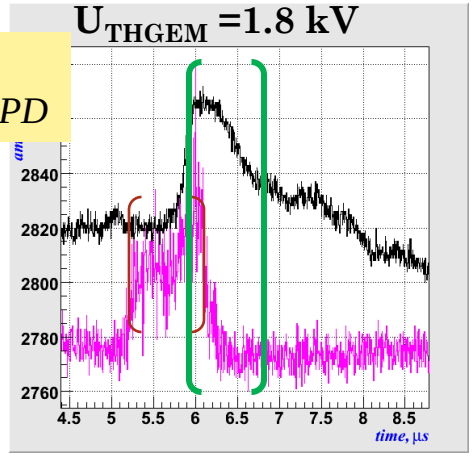
MRS APD (CPTA)

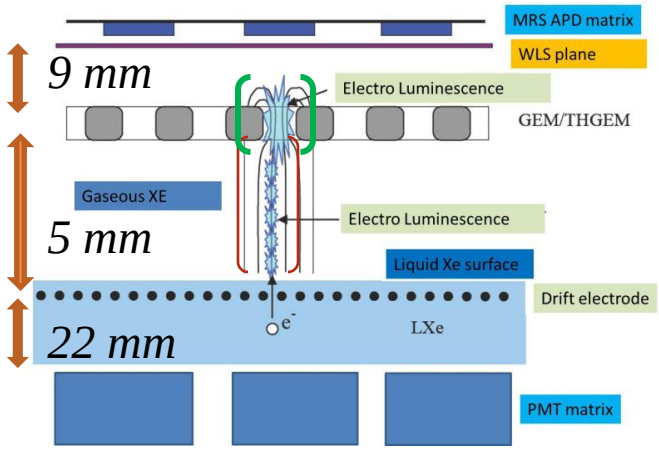


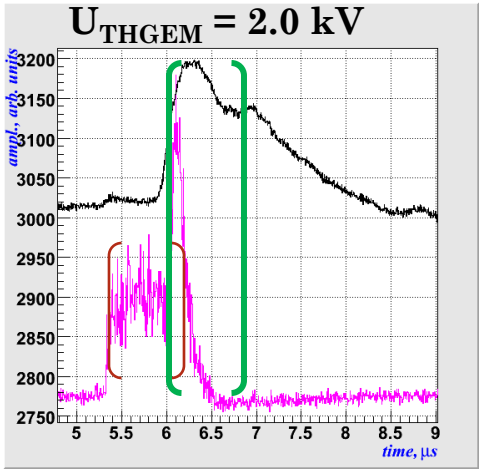
Matrix MRS APD + WLS

FIRST RESULT

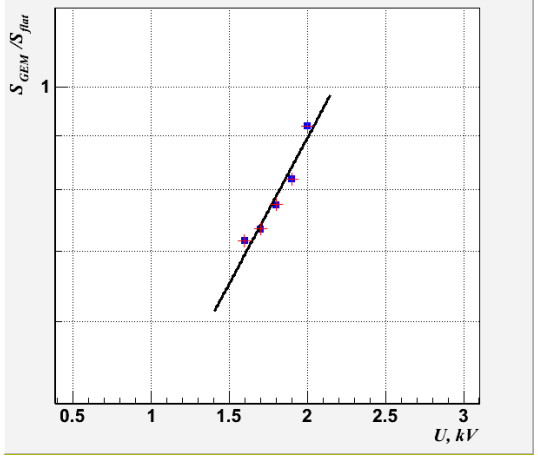


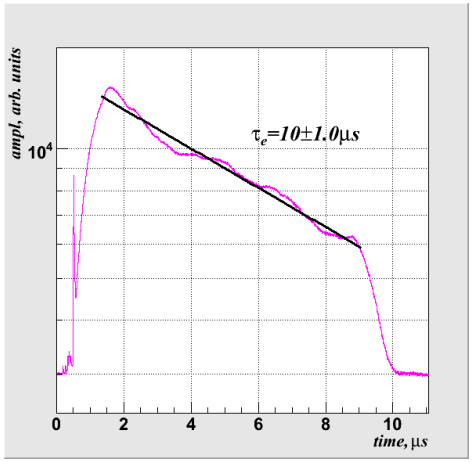




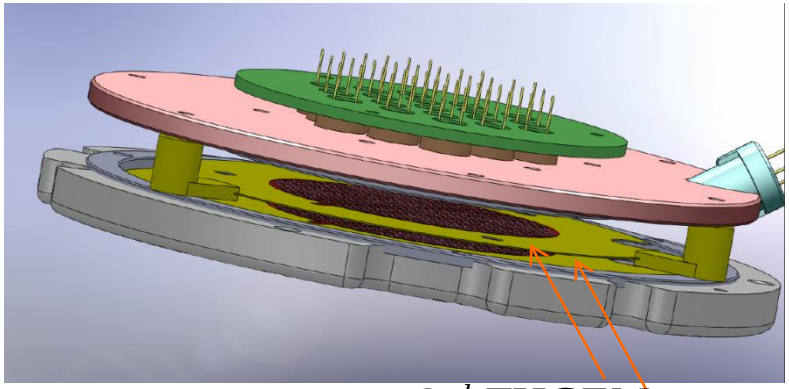


Dependence electroluminescence in THGEM on Δ U



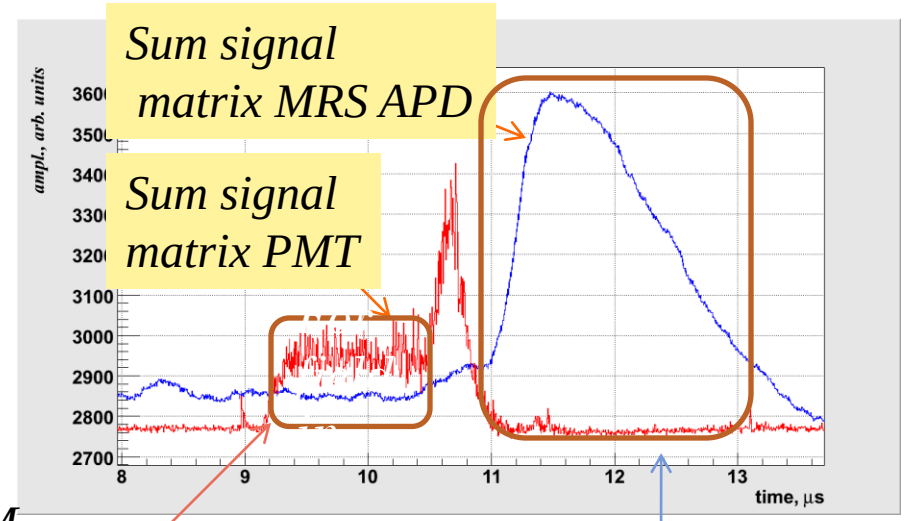


SECOND TEST RUN (DOUBLE GEM)



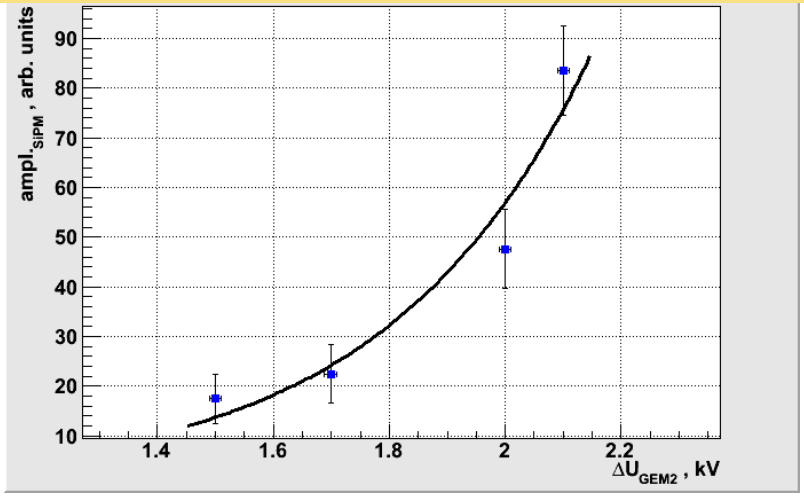
2nd THGEM

1st THGEM



For field in liquid 2.5 kV/cm and in gas 4.90 kV/cm
Area corresponds to 5950 ph.e. and 850 e (7 ph.e./e.)

Electroluminescence from 2nd THGEM dependence on Δ U



~ 10 cells/e
Can be achieved.

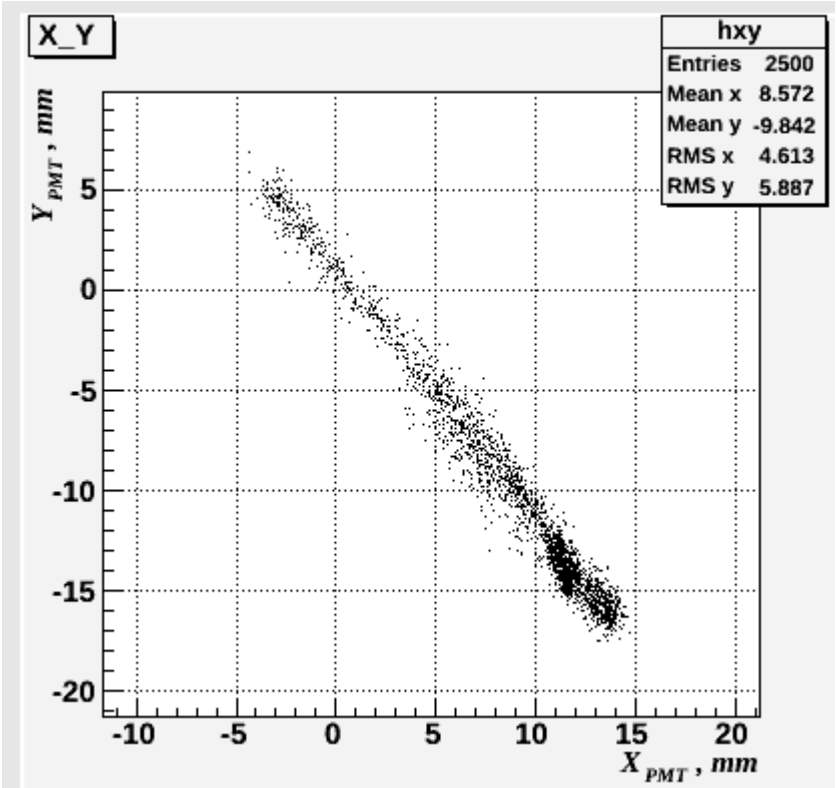
For THGEM2 U=1.6 kV
MRS APD array signal ~150 cells

~300 for THGEM2 U=2.1 kV
For 1V overvoltage ->3% PDE (MRS APD +WLS)
Fill factor for array ~6% -> 50%
So, it can be increased by a factor of 60, i.e. ~9000 cells

SECOND TEST RUN (DOUBLE GEM)

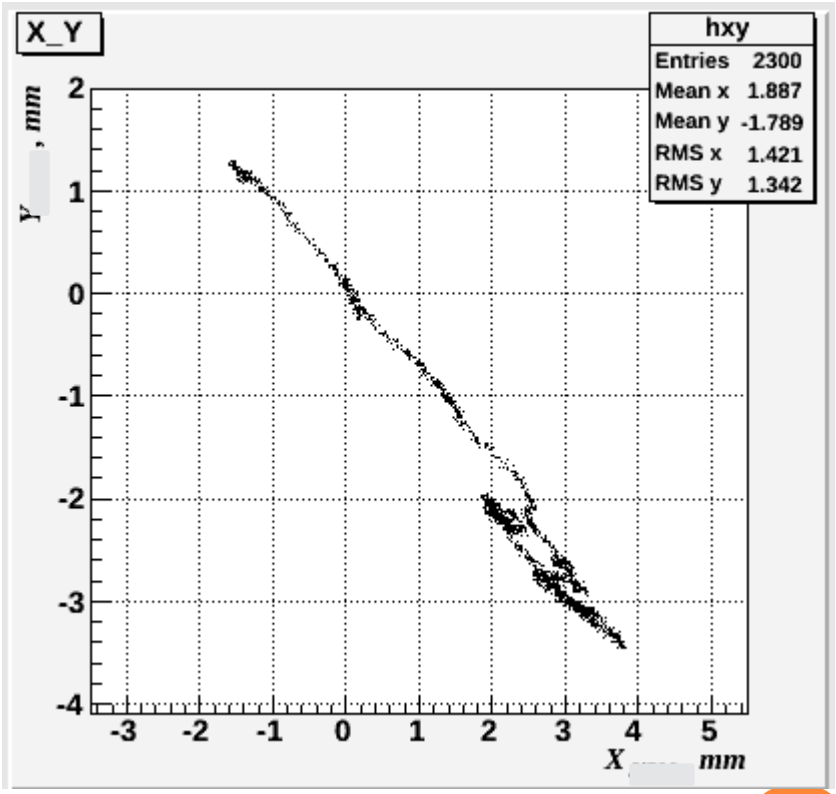
Reconstruction of muon track by

PMT Matrix



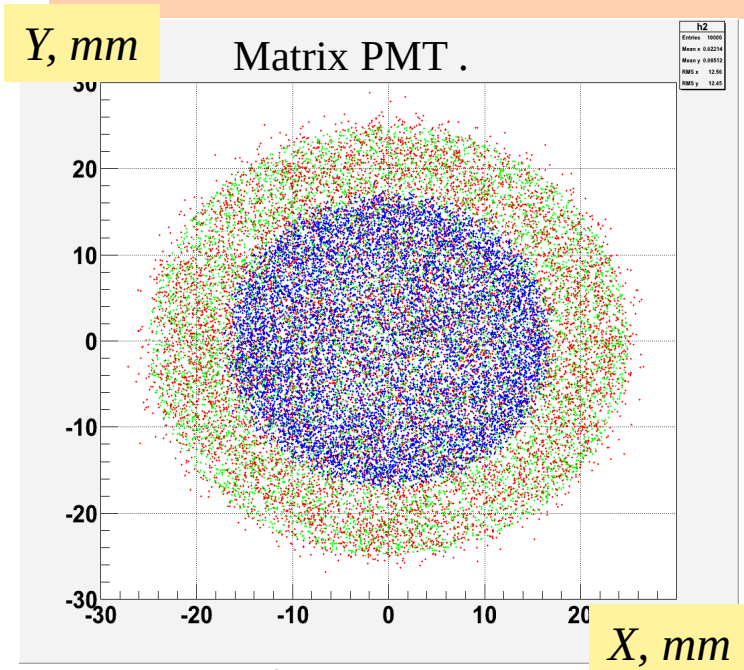
0.19 mm

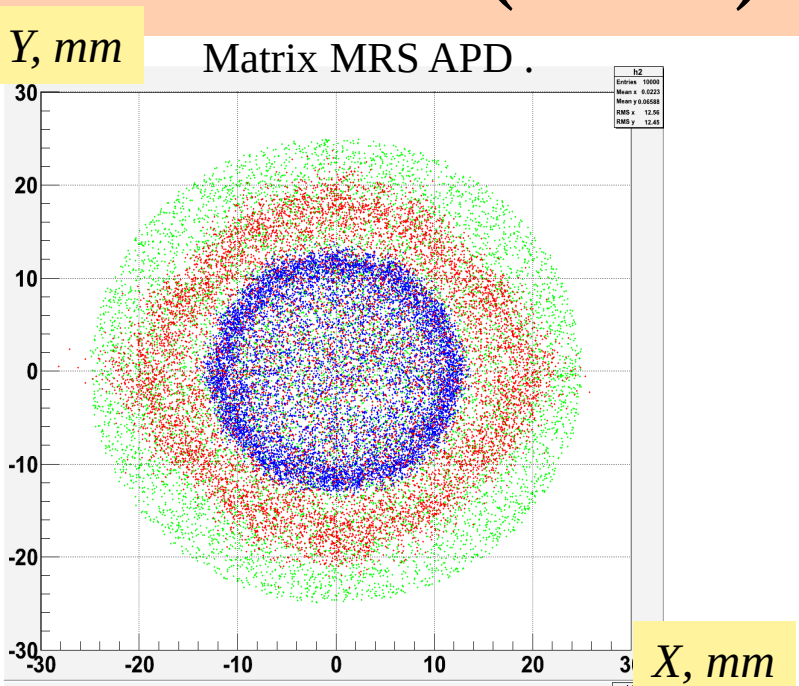
MRS APD Matrix

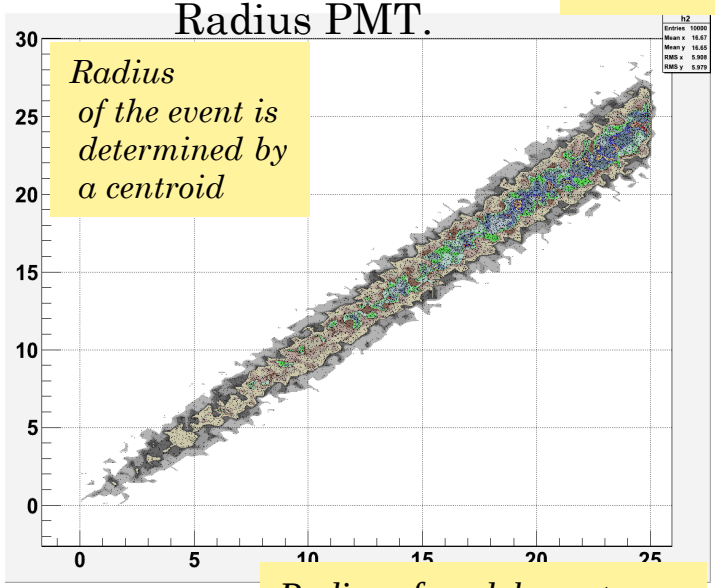


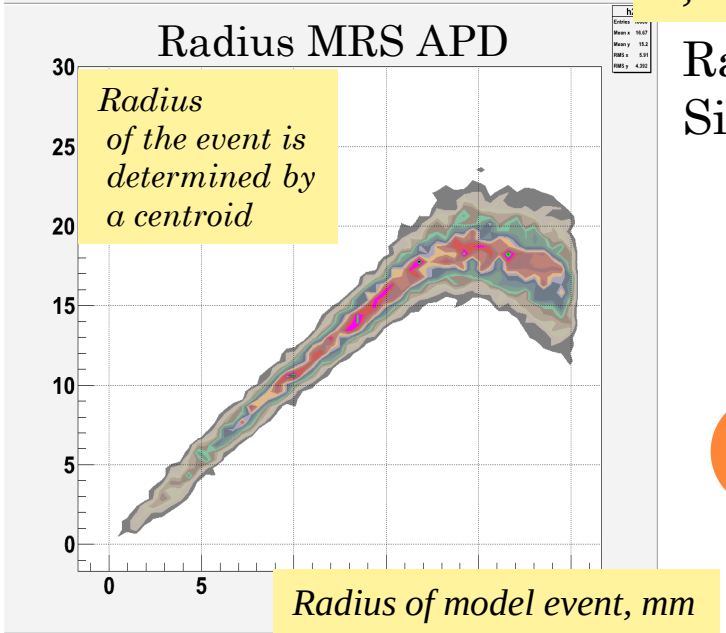
0.036 mm

MONTE CARLO SIMULATION (GEM)









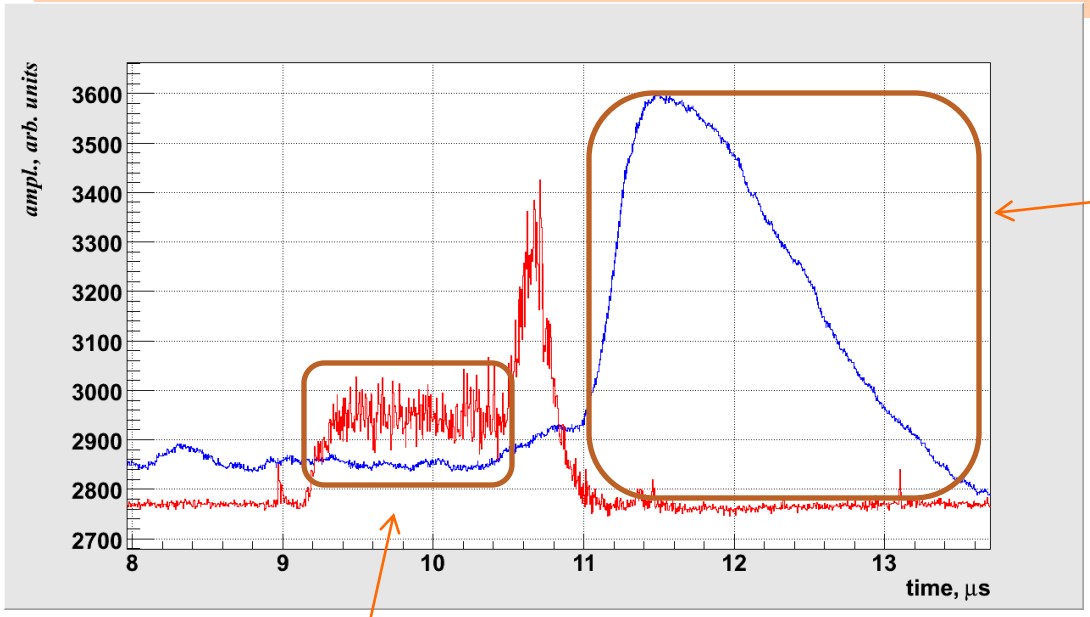
Radius SiPM.

Conclusion

- Large-size WLS plate with protection layer was tested successfully in Xe (electron life time seems O'k)
- THGEMS were tested in pure Xe
- The estimated single electron signal is ~10 cells for 50 % fill of array and full PDE

Backup

ESTIMATION OF FIRED CELL NUMBER PER SINGLE IONIZATION ELECTRON EXTRACTED FROM LIQUID



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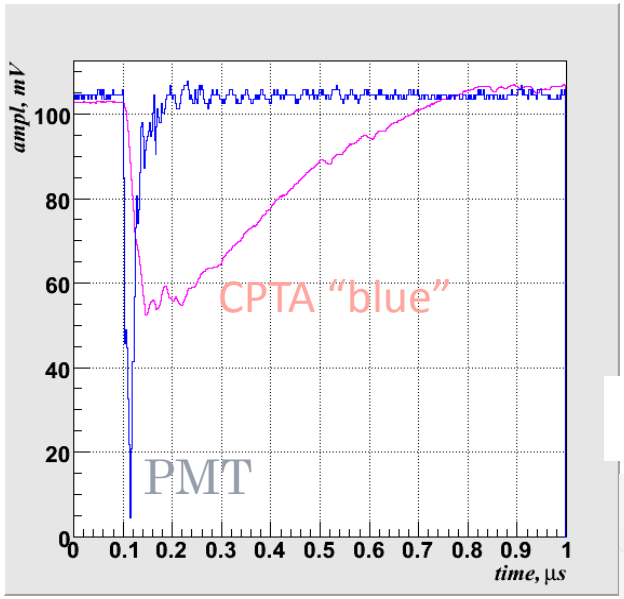
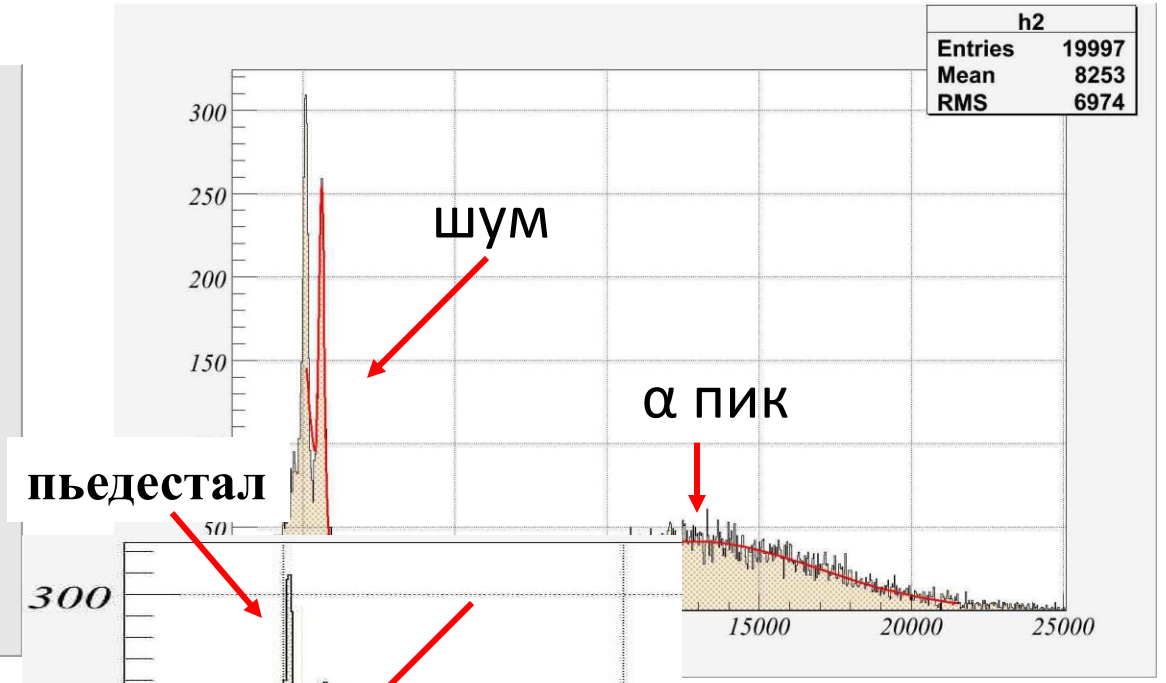
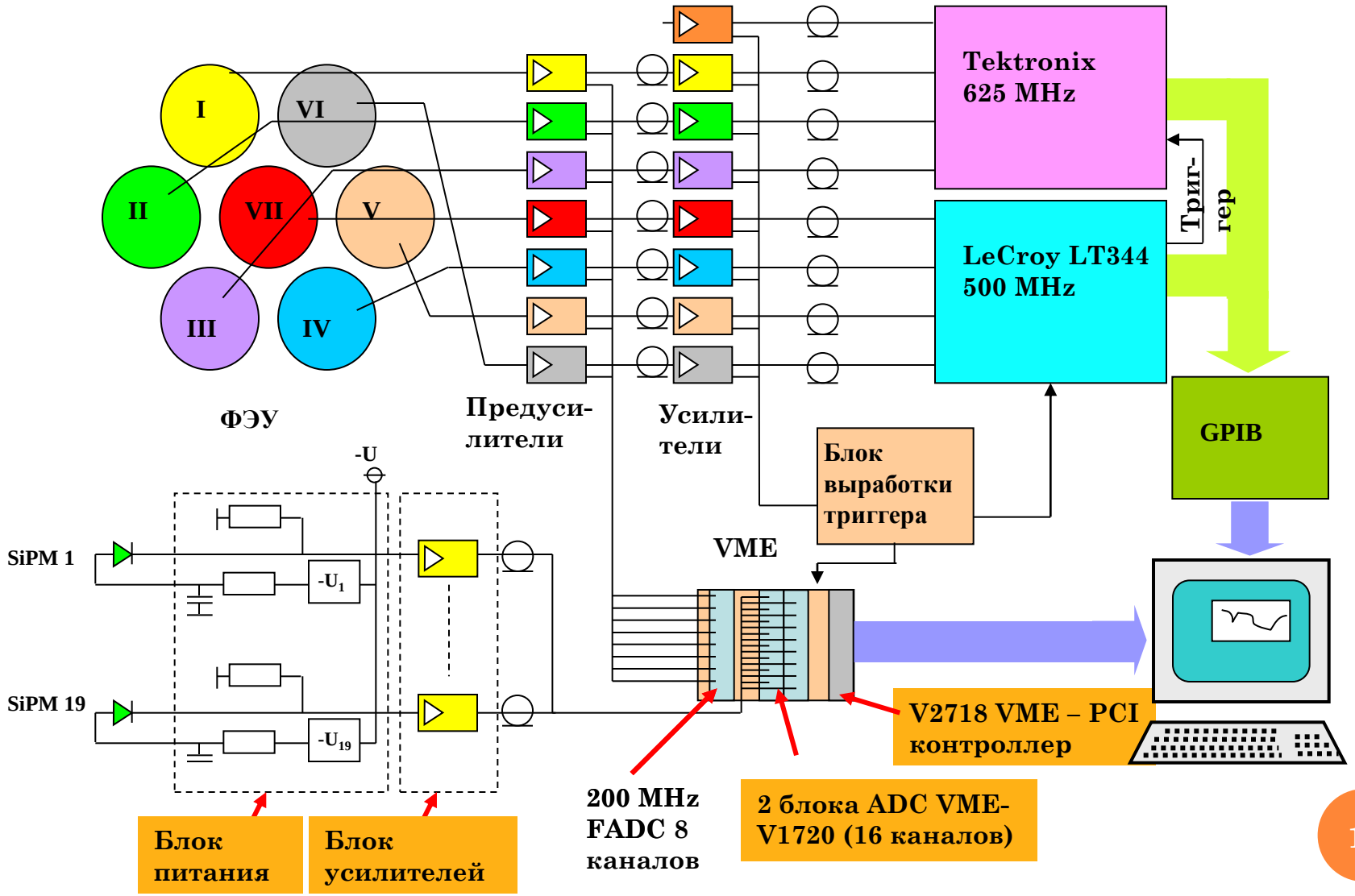
SPECTRUMS



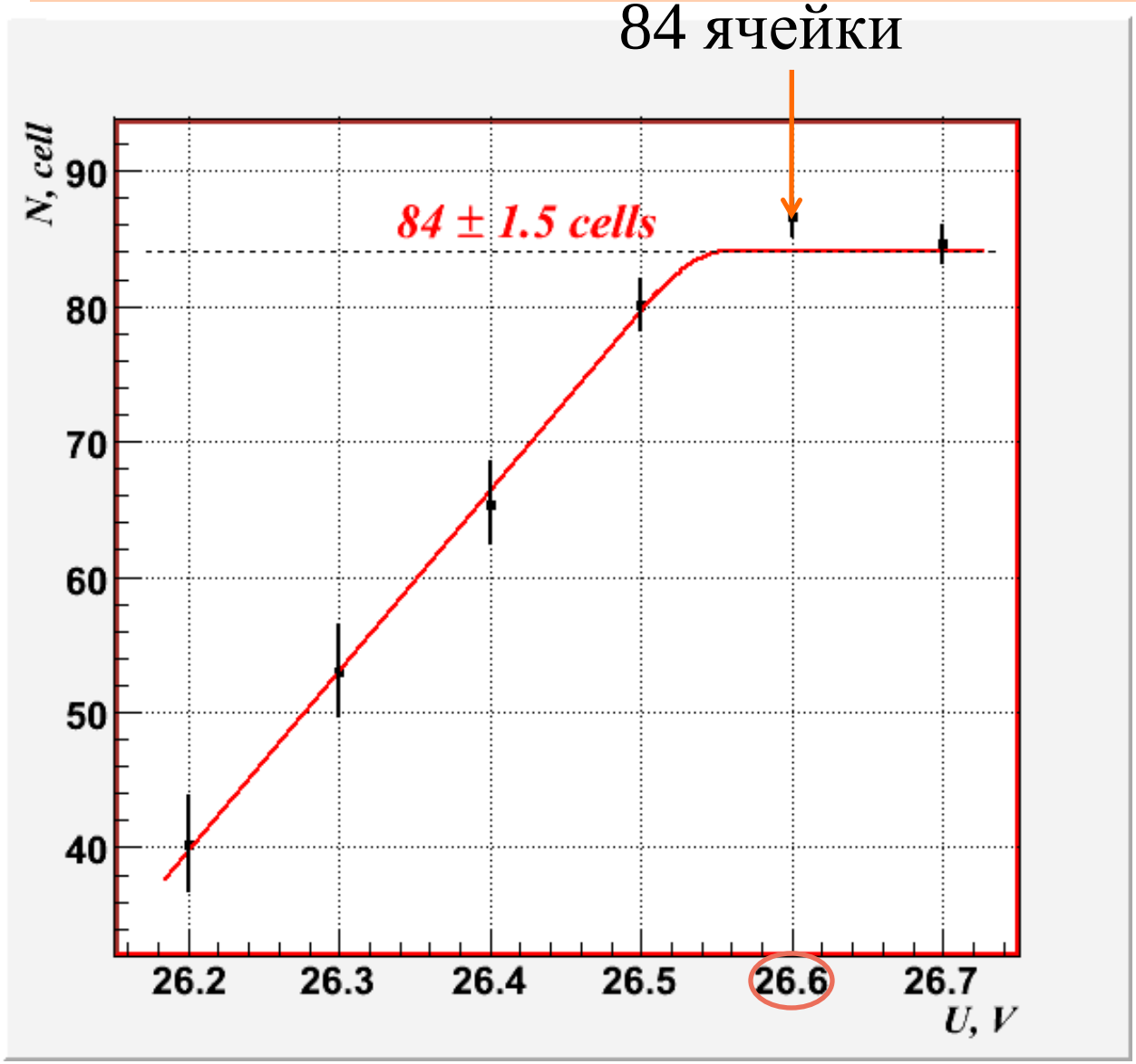


Положения а пика
1 вариант 27 ячеек
2 вариант 84 ячейки

Схема электроники



Результаты & вычисление эффективности



SECOND TEST RUN (DOUBLE GEM)