Novel MAPD with super high pixel density and their applications

Casablanca
22-24 September 2010

Igor Tiapkin
JINR

→ **At present photodiodes are finding many applications, and can make concurence to the PMT in some fields.**

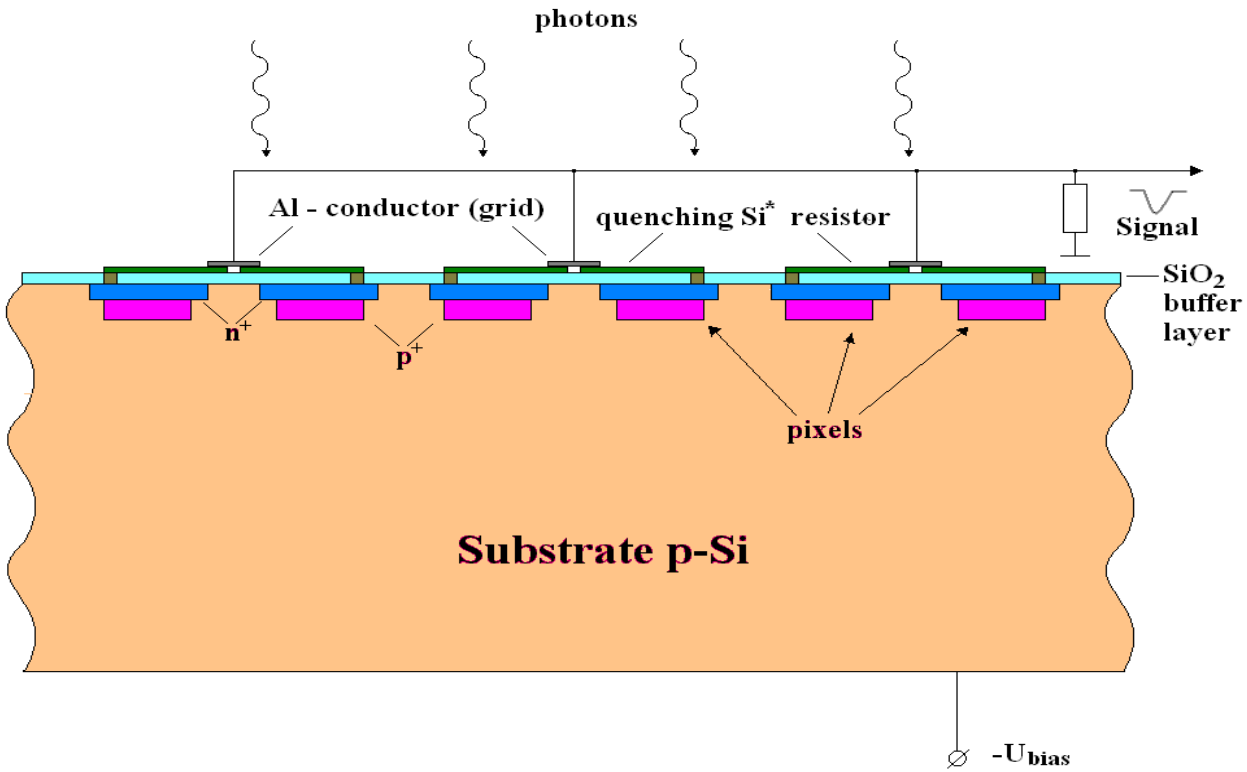
For example - in strong magnetic fields that are often present in the -

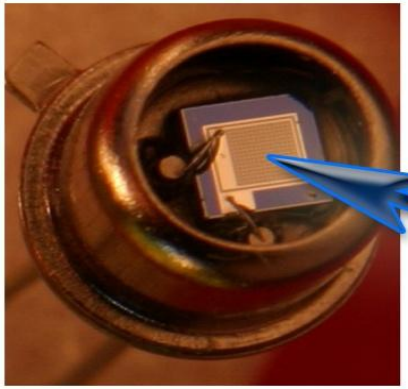
- **calorimeters operating near magnets,**
- **combined PET and MRT**

→ **!!! The main disadvantage – limited dynamic range** (corresponds to a total number of pixels).

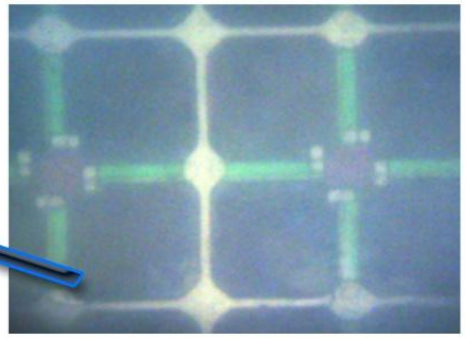
The novel deep microwell MAPD with high pixel density produced by the Zecotek Company avoids this promlem.

The results refer to MAPD laboratory study and applications: beam test results (CERN and DESY) of two different "Shashlyk" EM calorimeters for COMPASS (CERN) and NICA-MPD (JINR) with the MAPD readout and a possibility of using the MAPD in PET



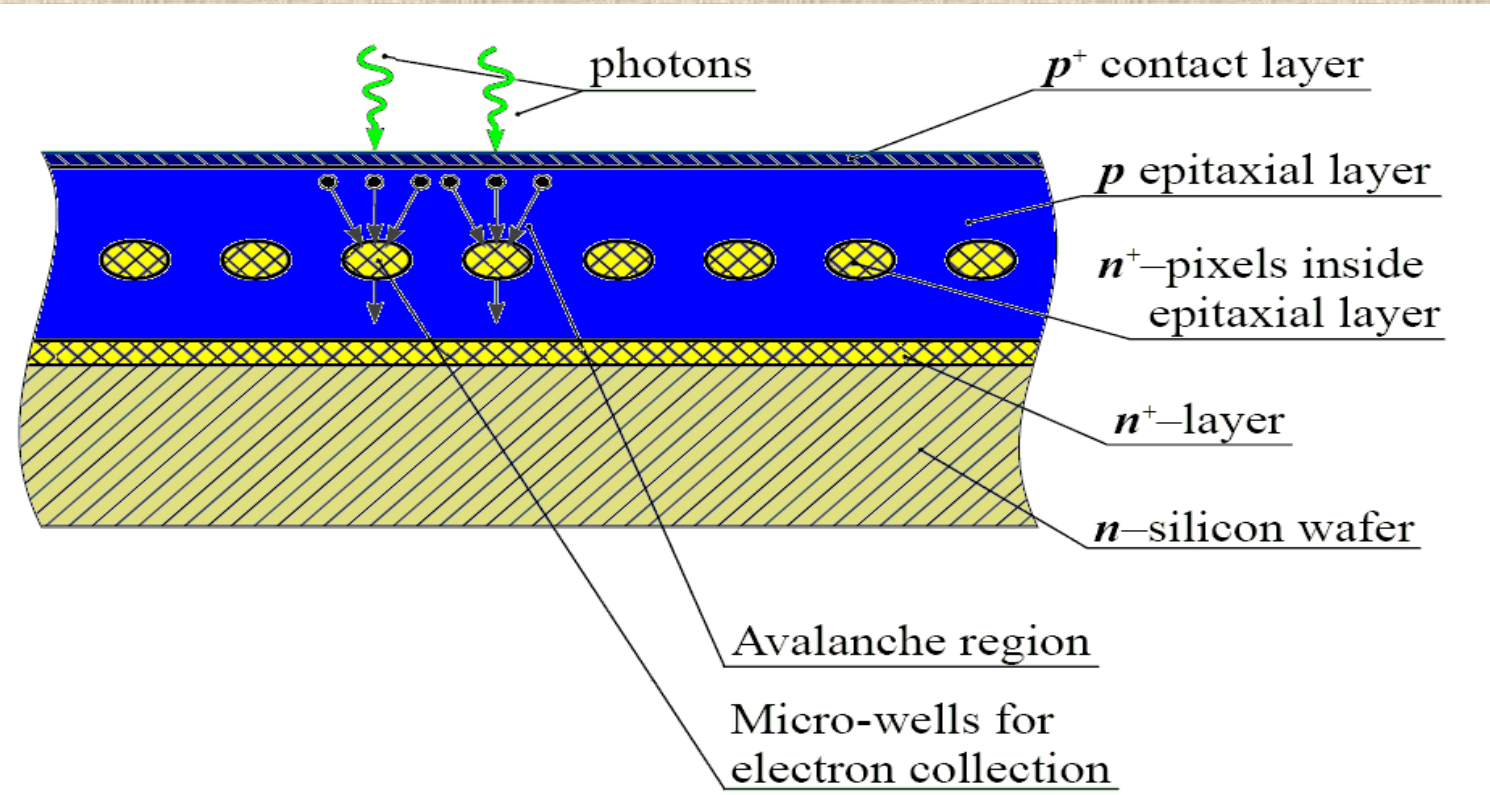


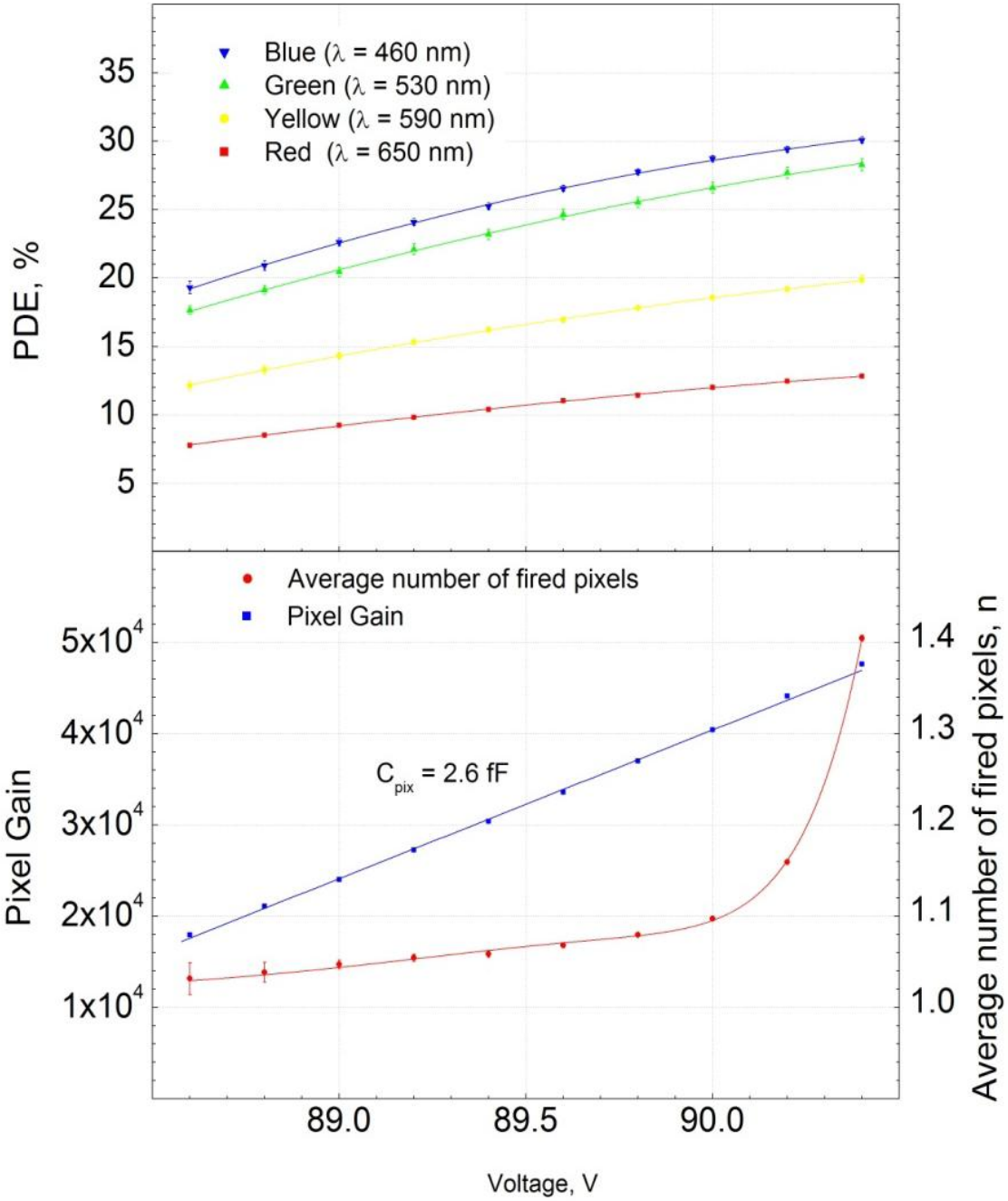
Общий вид МЛФД на корпусе КТ-1



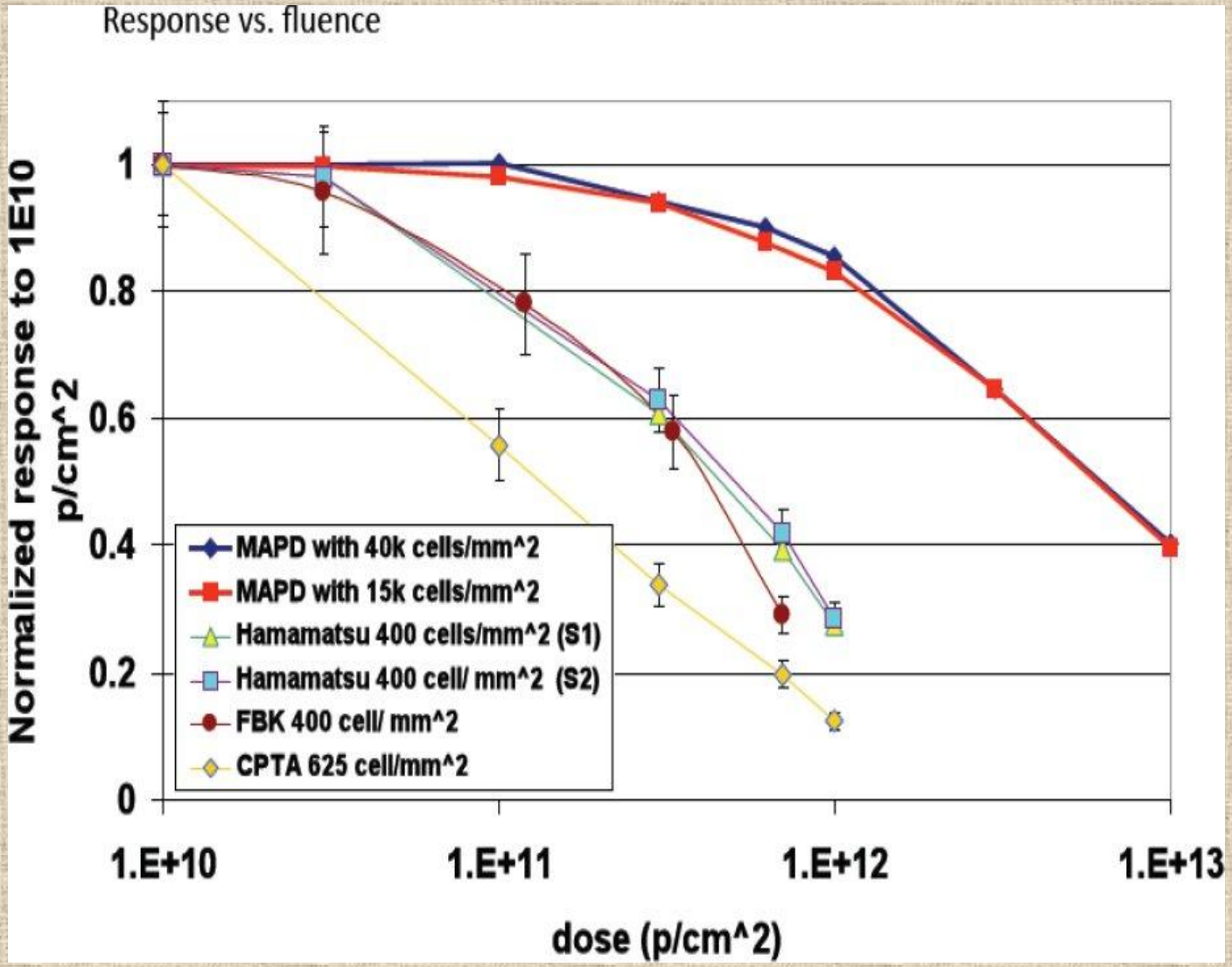
Микрофотография фрагмента матрицы МЛФД

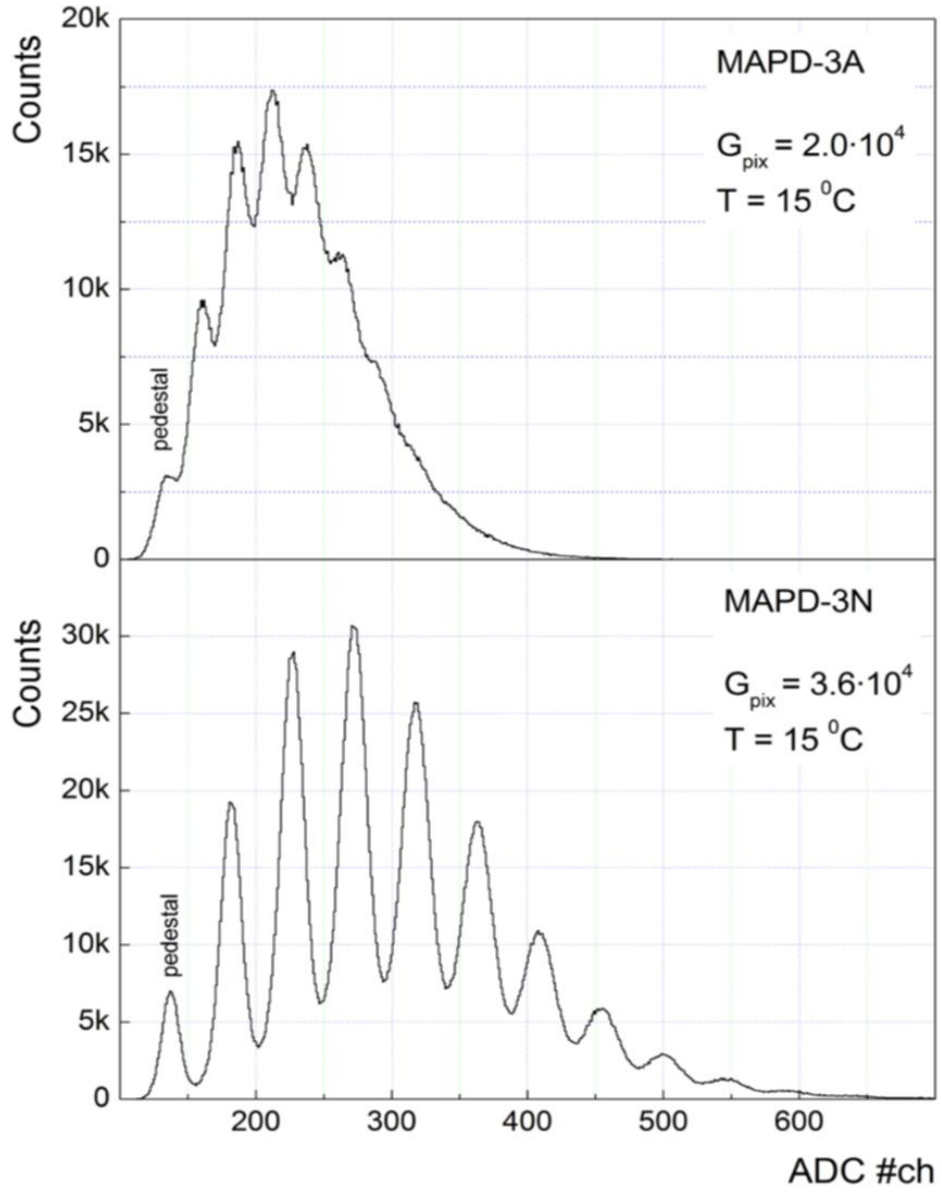
The deep microwell MAPD devices have a common p junction on the n-type silicon substrate and a clear sensitive surface as a standard APD.
Here both the matrix of the avalanche regions and the individual passive quenching elements are placed inside the silicon substrate.




Blue (λ = 460 nm)
Green (λ = 530 nm)
Yellow (λ = 590 nm)
Red (λ = 650 nm)
PDE, %
35
30
25
20
15
10
5
Average number of fired pixels
Pixel Gain
C_{pix} = 2.6 fF
Pixel Gain
$5x10^4$
$4x10^4$
$3x10^4$
$2x10^4$
$1x10^4$
1.4
1.3
1.2
1.1
1.0
Average number of fired pixels, n
89.0
89.5
90.0
Voltage, V

Radiation hardness measured by Yu. Musienko (CERN)
Irradiation by neutrons




MAPD-3A
$G_{pix} = 2.0 \cdot 10^4$
T = 15 ^{0}C
Counts
20k
15k
10k
5k
0
pedestal
MAPD-3N
$G_{pix} = 3.6 \cdot 10^4$
T = 15 ^{0}C
Counts
30k
25k
20k
15k
10k
5k
0
pedestal
200
300
400
500
600
ADC #ch

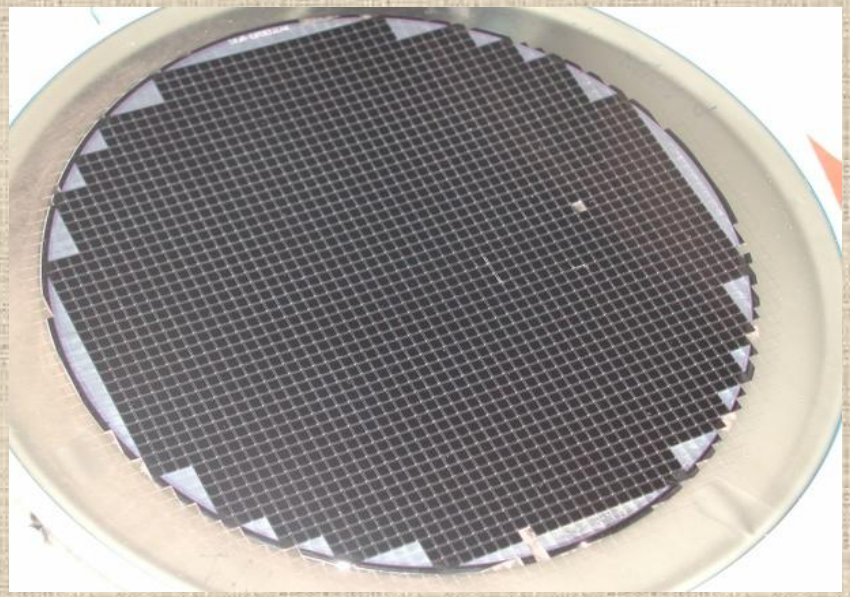
Advantages:

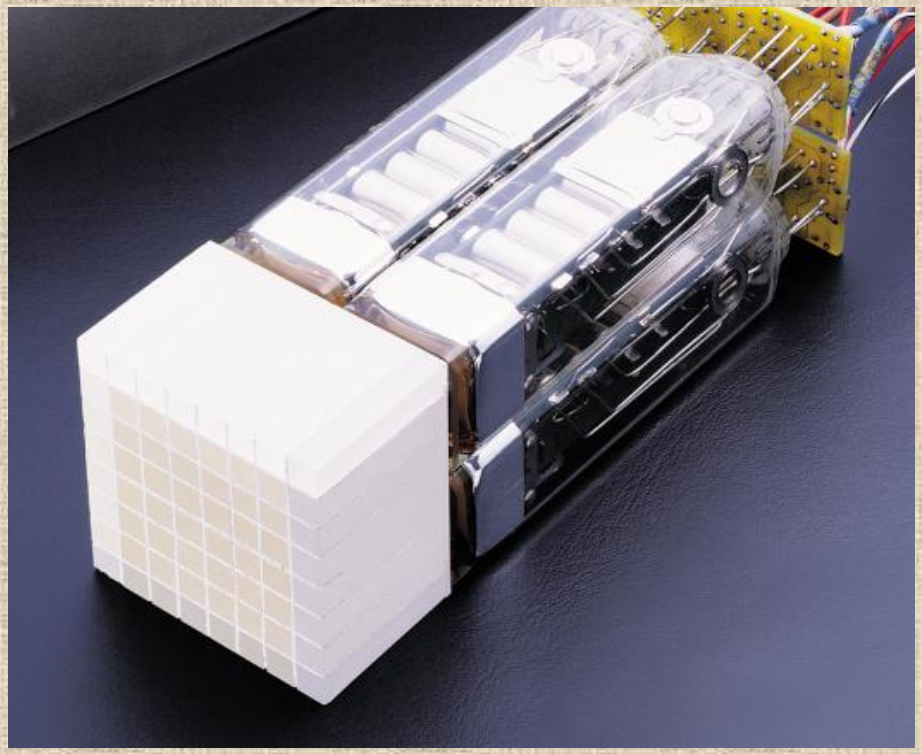
- High Dynamic Range (pixel densities of up to 40000 mm^{-2})
- Photon Detection Efficiency up to 30 %
- Better radiation hardness (up to 10^{13} protons)
- Gain up to 10^5
- Insensitivity to magnetic field.
- Compact and rigid
- Low voltage supply (< 100 V)

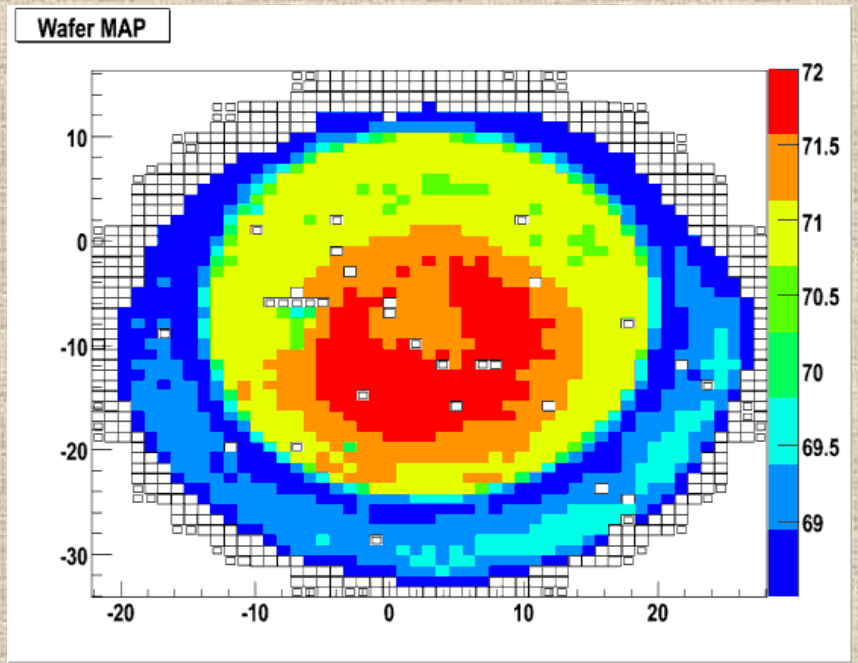
Disadvantages:

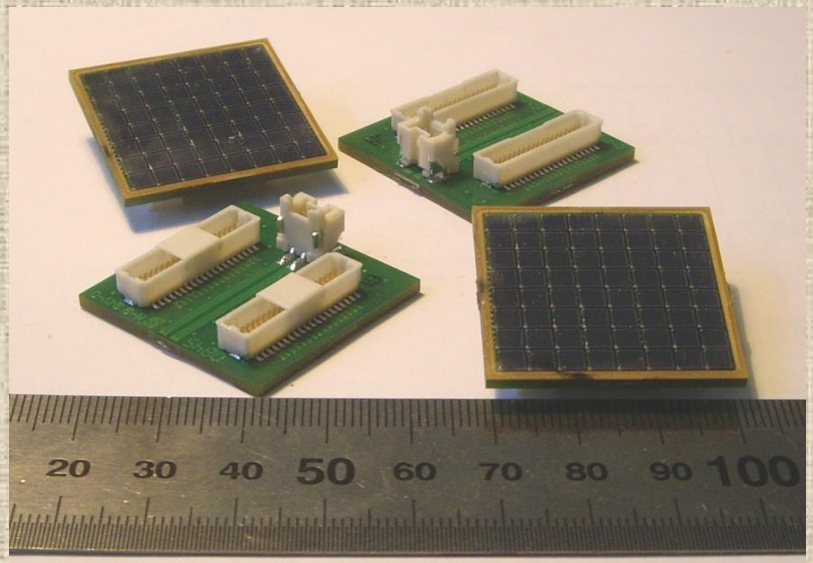
- Temperature dependence (a few %%/oC)
- High dark rate (about 0.5 MHz/mm2)
- Large Recovery time.

Positron Emission Tomography applications

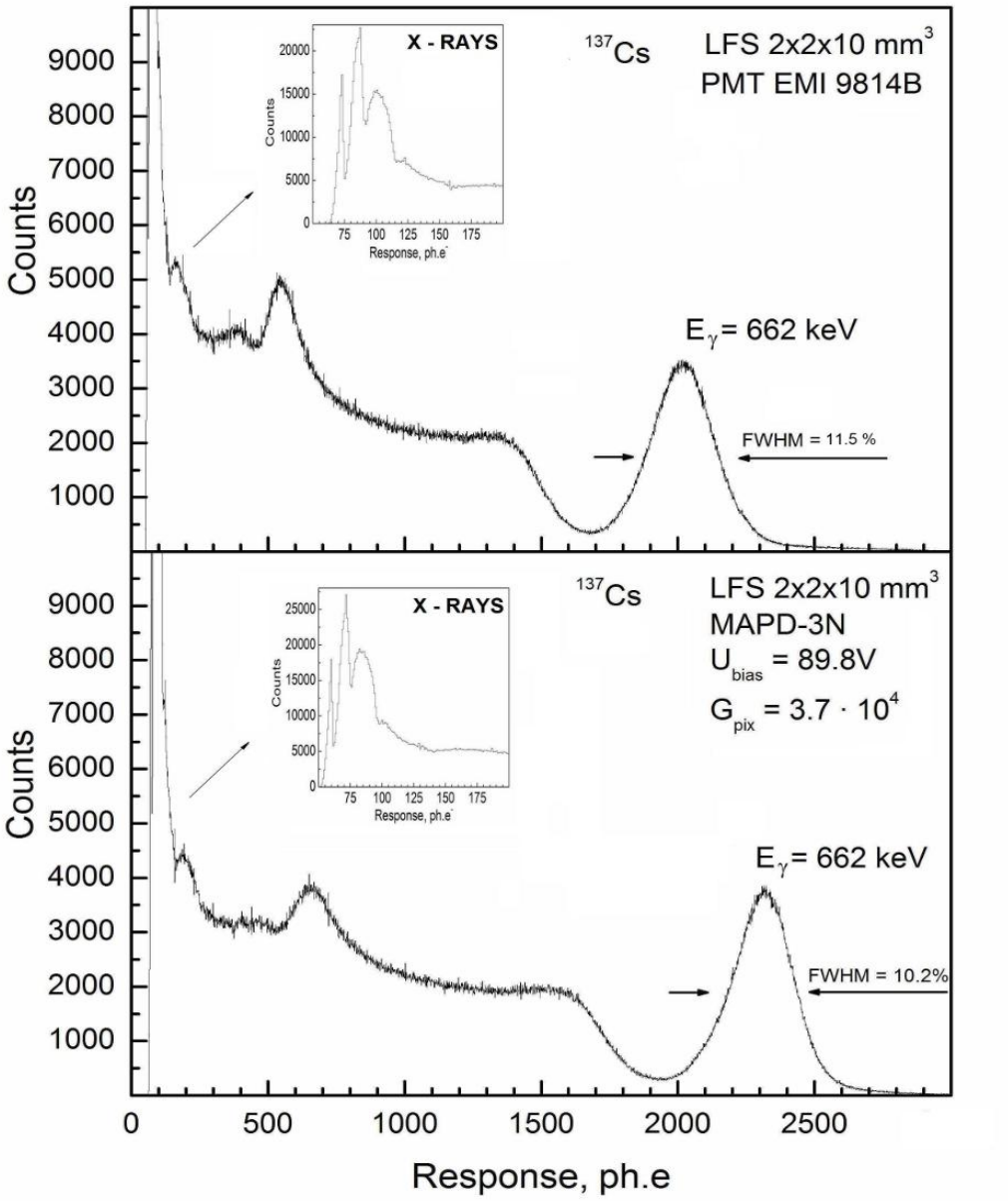




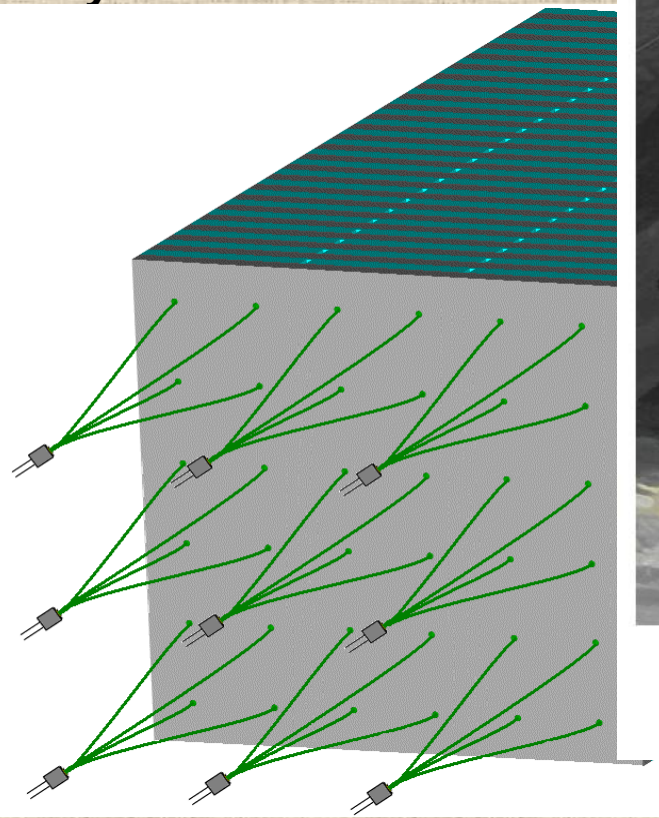




Positron Emission Tomography applications



High energy physics applications calorimetry



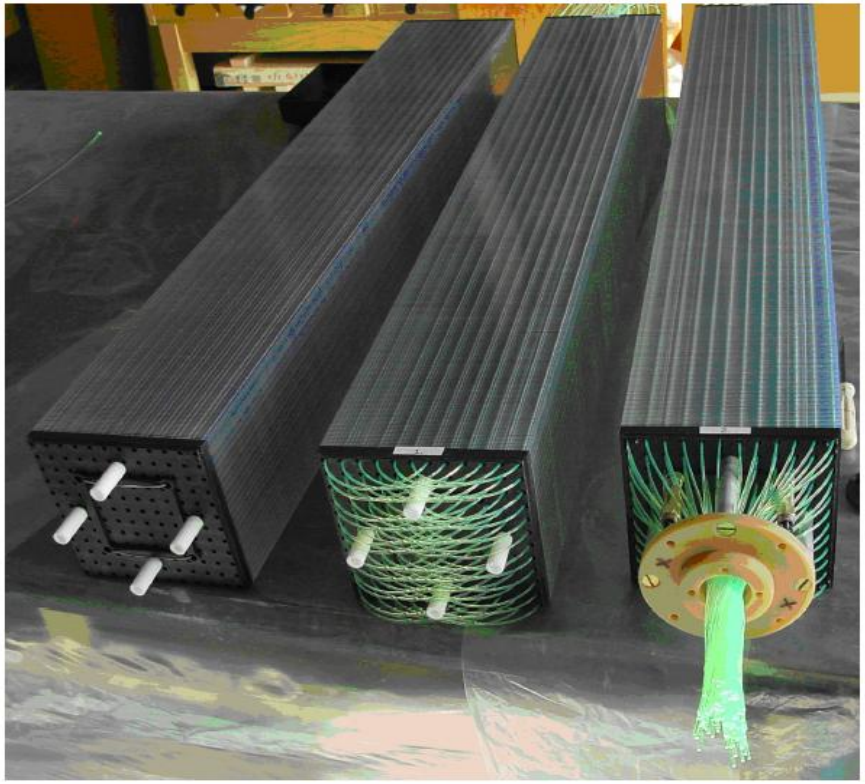
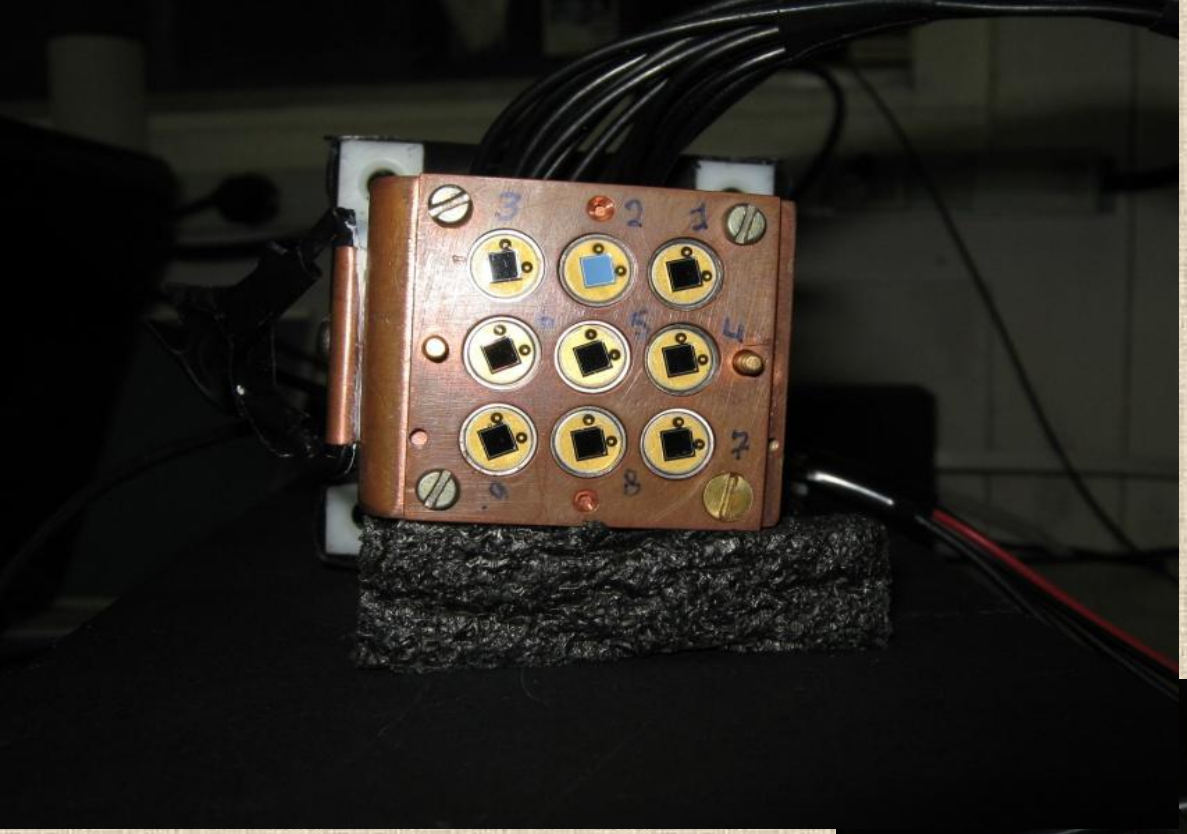


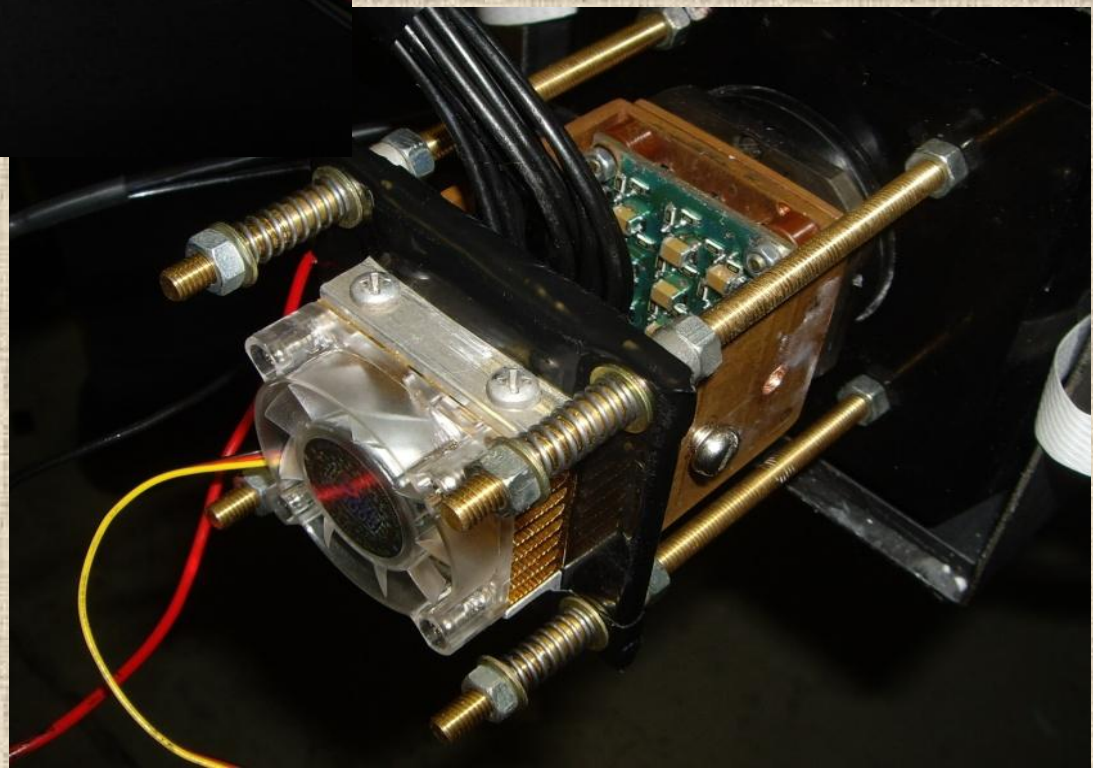
Fig. 1. The Shashlyk modules at different stages of assembly

NICA – 9 bundles
Scintillator - 1.5 mm
Lead - 0.275 mm
Distance between scintillators – 0.35 mm
Number of pair – 300 pcs.
Size of plates - 109.74109.7 mm2
Radiation length, X0 – 34.9 mm

Total length – 555 mm (15.9 X0)
Moliere radius – 59. 8 mm
Number of fibers – 144 pcs
Number of bundles – 9 pcs
Diameter of fibers – 1 mm
Bundle diameter – 6 mm

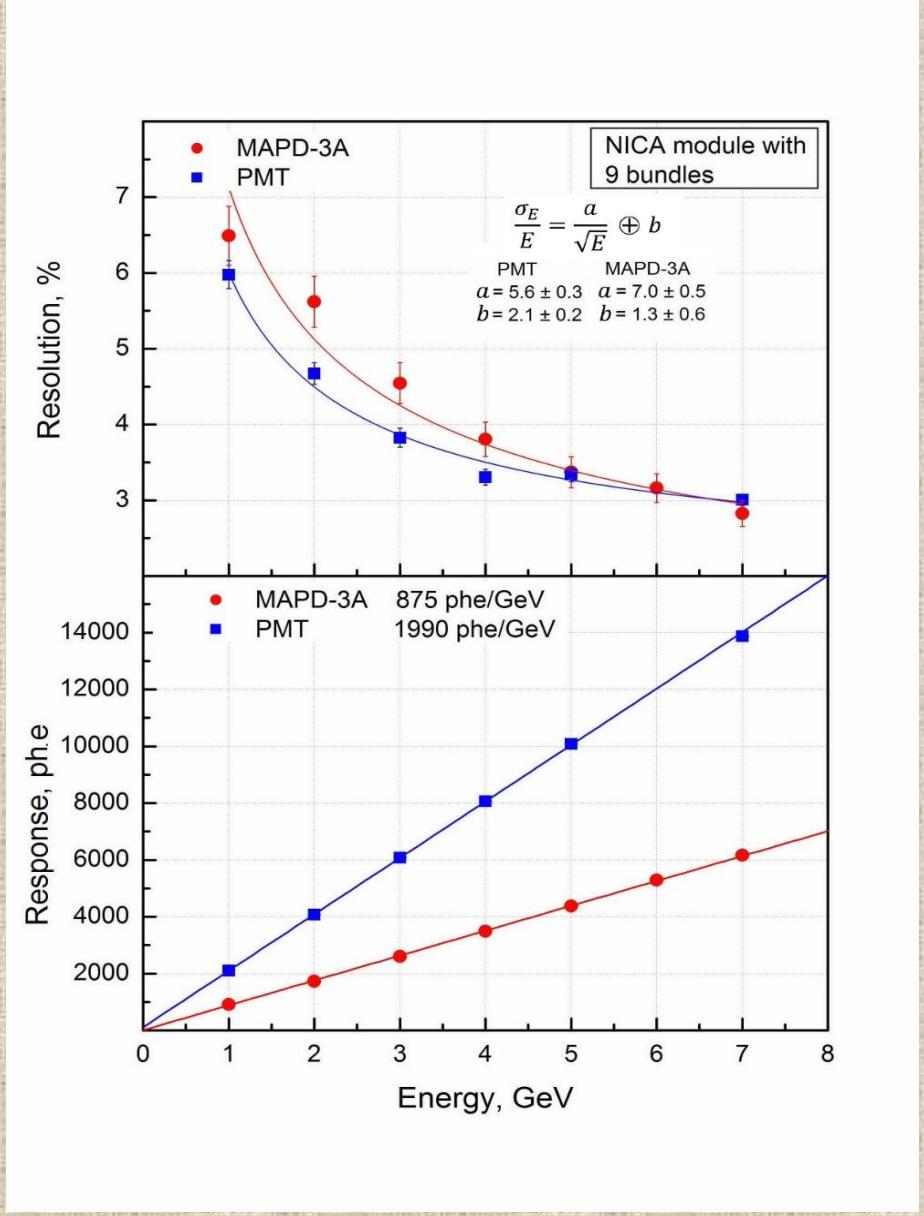


High energy physics applications: EM-calorimetry

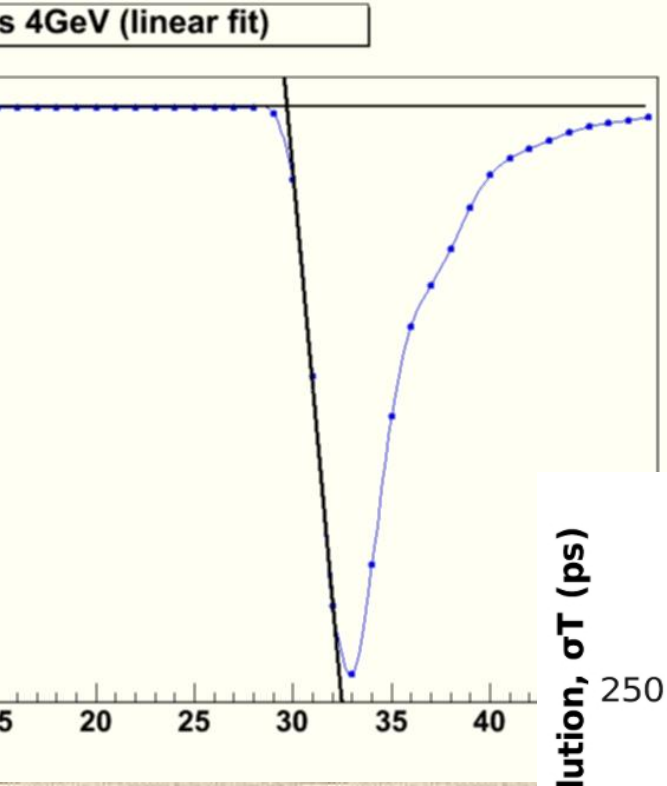


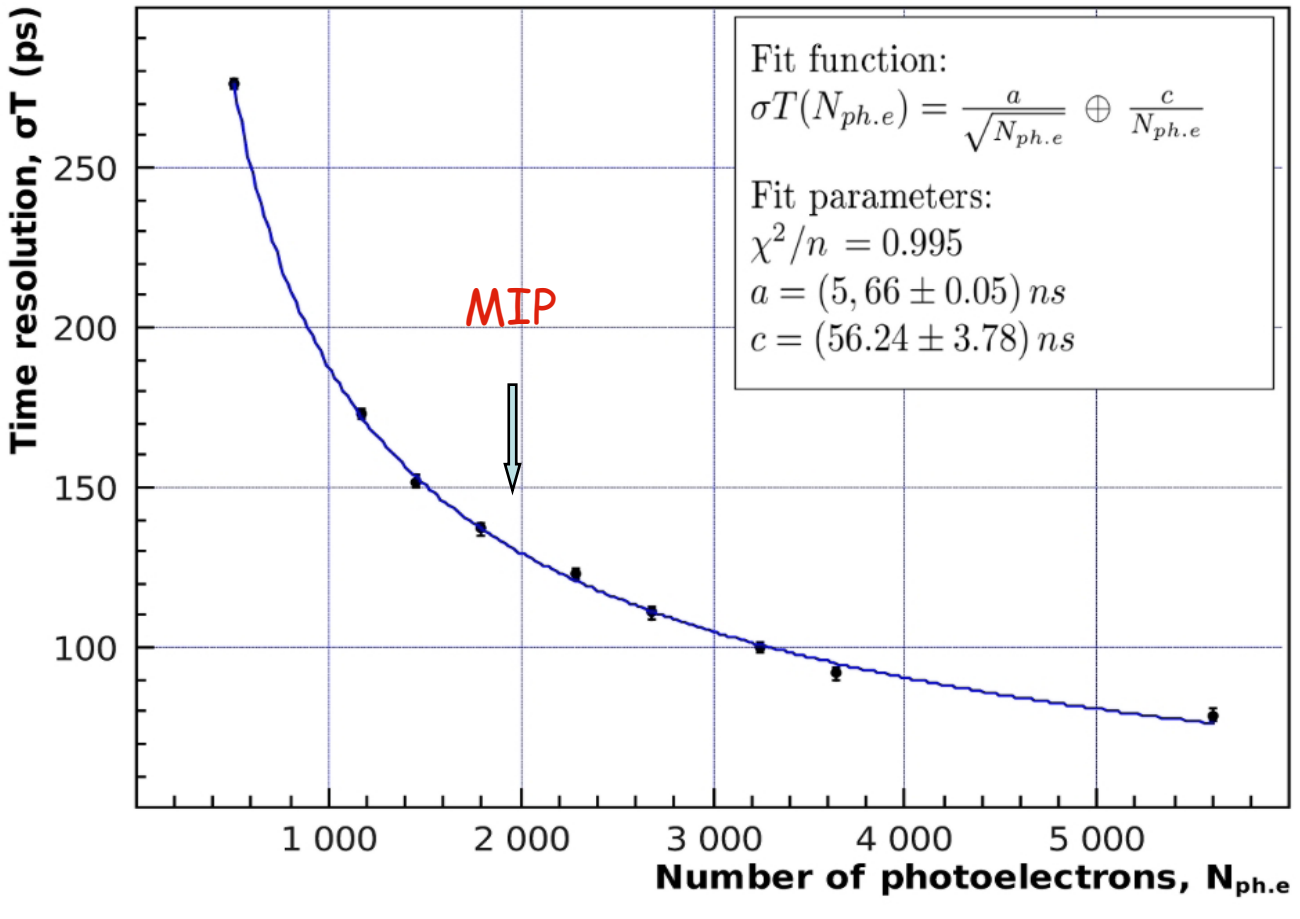
High energy physics applications: EM-calorimetry

Energy resolutions for NICA module MAPD in comparision with PMT

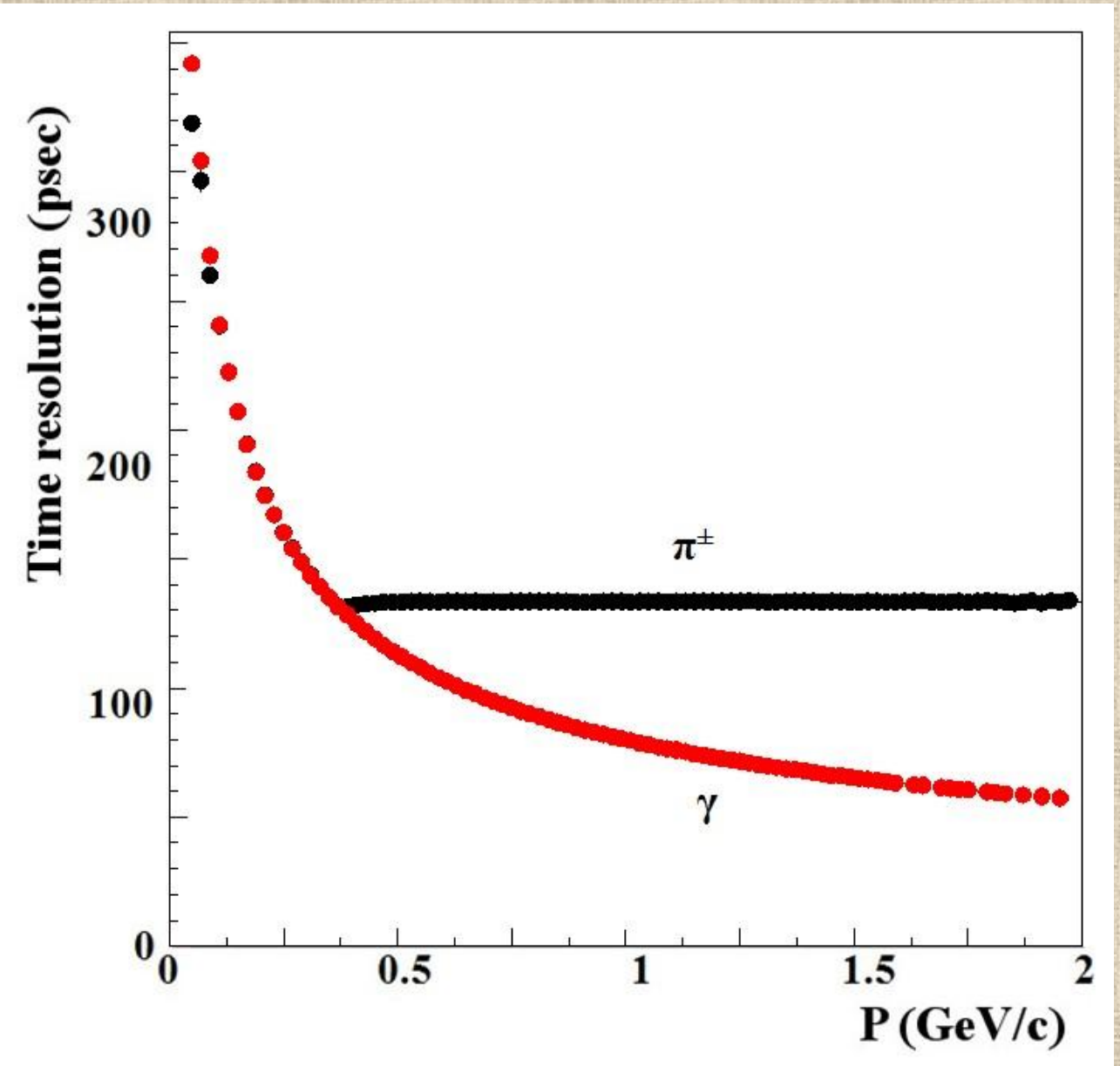


High energy physics applications: EM-calorimetry

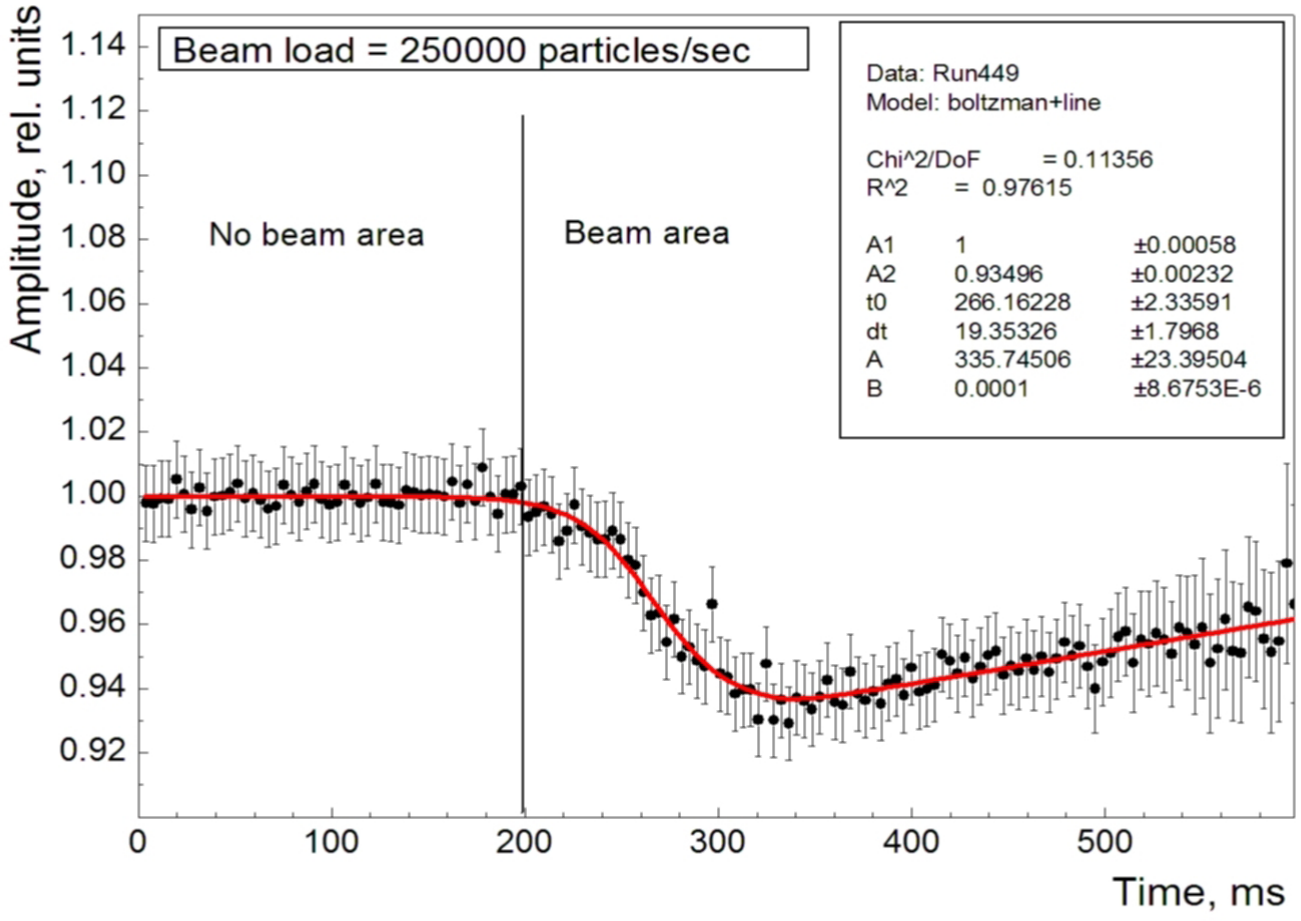




High energy physics applications: EM-calorimetry



Effect of beam load (MAPD-3A)



Conclusions:

1. The novel deep microwell MAPD with high pixel density designed at JINR and produced by the Zecotek Company (Canada/Singapore)
2. Pixel density up to 40000 mm^{-2} has been reached
3. Detectors with sensitive area up to 4x4 mm^2 produced

4. Detectors has been tested in real devices (EM calorimeters, PET)
5. Time resolution better than 100 psec was reached with the new MAPD