HADRON CALORIMETERS WITH MICROPIXEL APD READOUT FOR HEAVY ION EXPERIMENTS

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(Troitsk)

- **Role of the PSD in the studies of nucleus collisions**
- **Conception and main features of the PSD**
- **Results of the PSD supermodule beam test at CERN (Sep-07)**

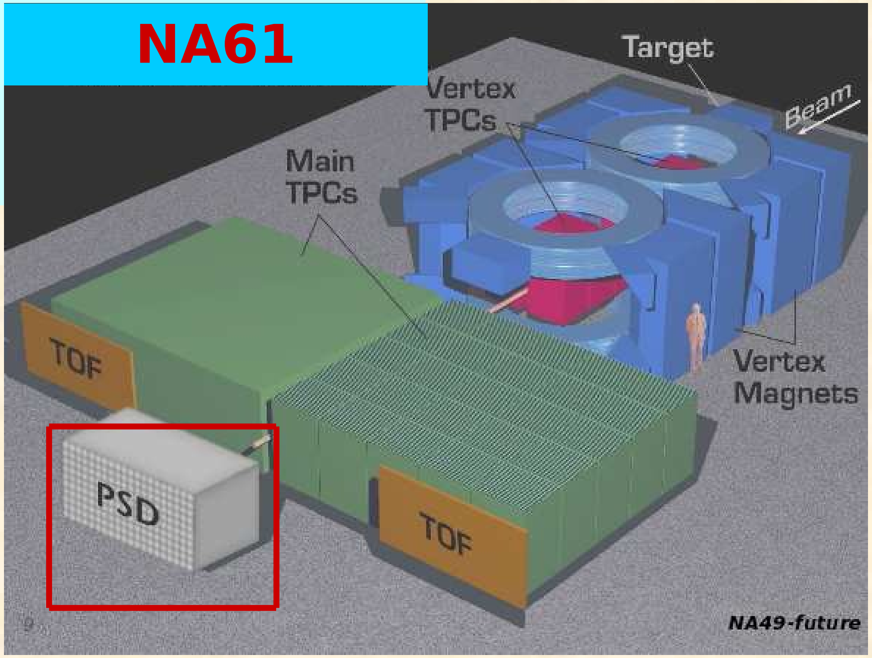
Projectile Spectator Detector (PSD) for heavy ion experiments (NA61, CBM, NICA)

- Measurement of centrality: *$b = f(A - N_{spect})$*
  (selection of centrality at trigger level)

- Measurement of event-by-event fluctuations
  (to exclude the fluctuation of participants)

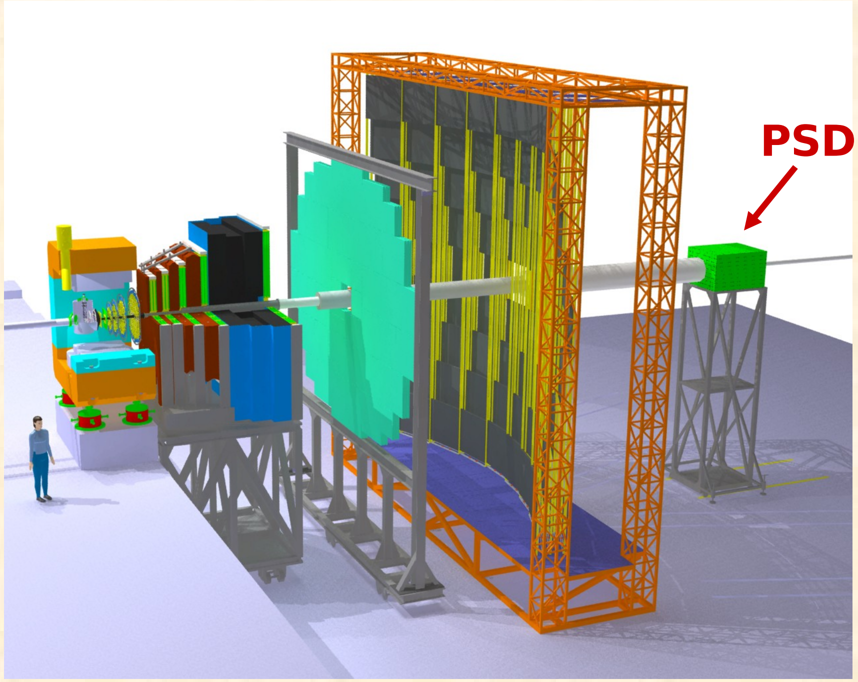
- Reconstruction of the reaction plane

- Beam intensity monitoring

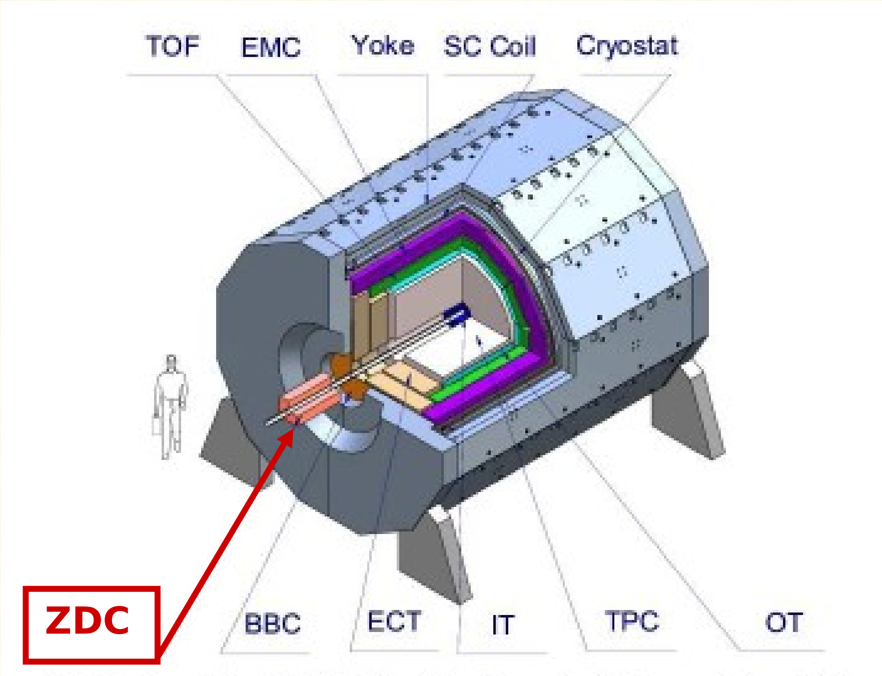


The PSD in the CBM and NICA

CBM (FAIR)



NICA (JINR)



Conception of PSD

I. <u>Compensation</u>:

$\varepsilon_e / \varepsilon_h = 1$ **-- compensated calorimeter.**

$\sigma(E)/E = a/\sqrt{E} + b\cdot|1 - \varepsilon_e/\varepsilon_h|$ -- constant term equals to zero.

II. <u>Lead/Scintillator sandwich</u>: Compensation at Pb:Scint=4:1.

For thickness δ_{Pb}=16 mm and δ_{Scint}=4 mm $\sigma_E/E \sim 50\%/\sqrt{E}$.

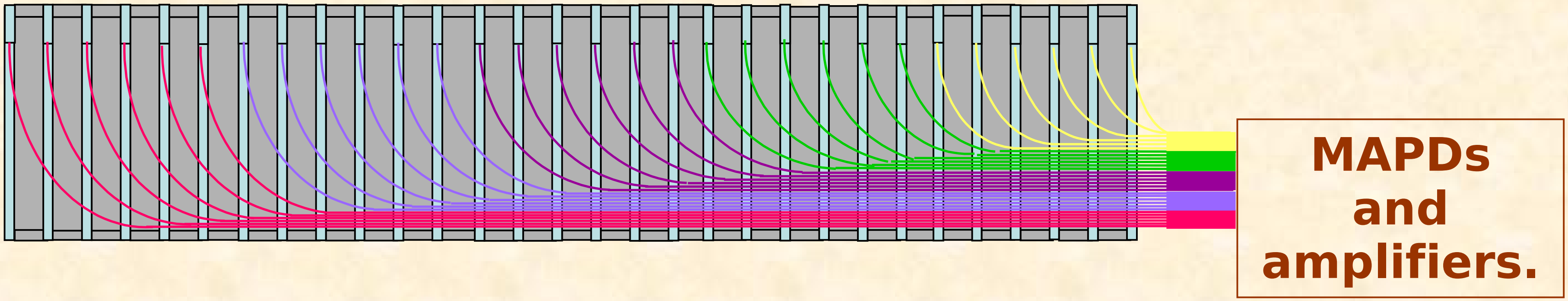
III. <u>Light readout</u> – WLS-fibers to avoid the Cherenkov radiation.

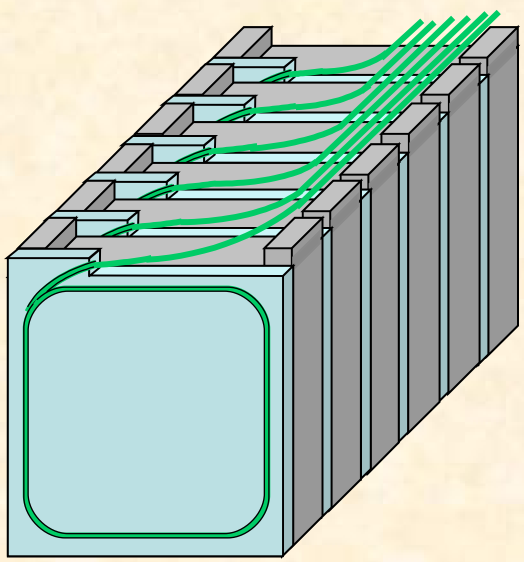
IV. <u>Signal readout</u> – Micropixel APD (MAPD) to avoid nuclear counter effect, detection of a few photons signal, compactness, low cost, new technology.

V. <u>Longitudinal segmentation</u> – for permanent calibration of scintillators in radiation hard conditions, uniformity of light collection from WLS-fibers.

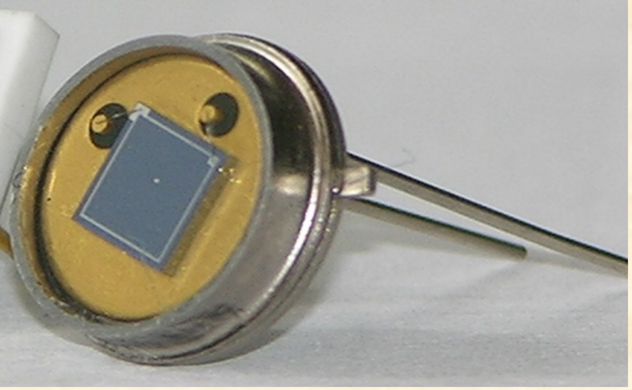
VI. <u>Modular design</u> – transverse uniformity of resolution, flexible geometry, simplicity.

Structure of PSD module





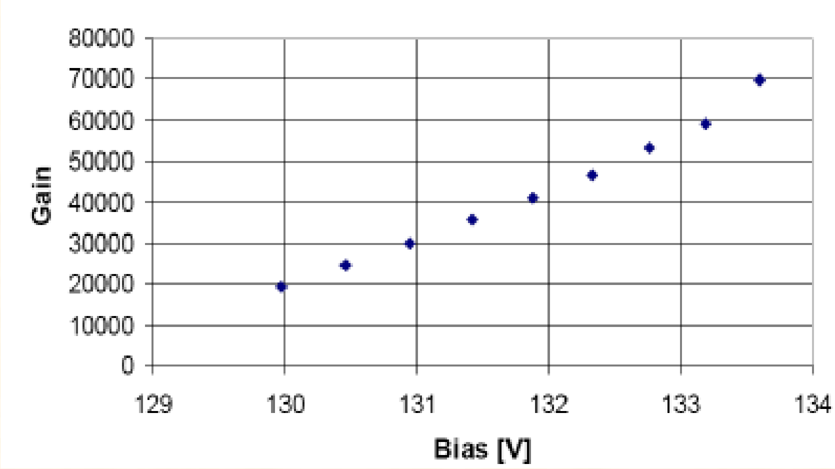
- 60 lead/scintillator sandwiches
- 10 longitudinal sections
- 6 WLS-fiber/MAPD
- 10 MAPDs/module
- 10 Amplifiers with gain~40



Properties of MAPDs

Production: Dubna-Mikron Co. (Z.Sadygov)

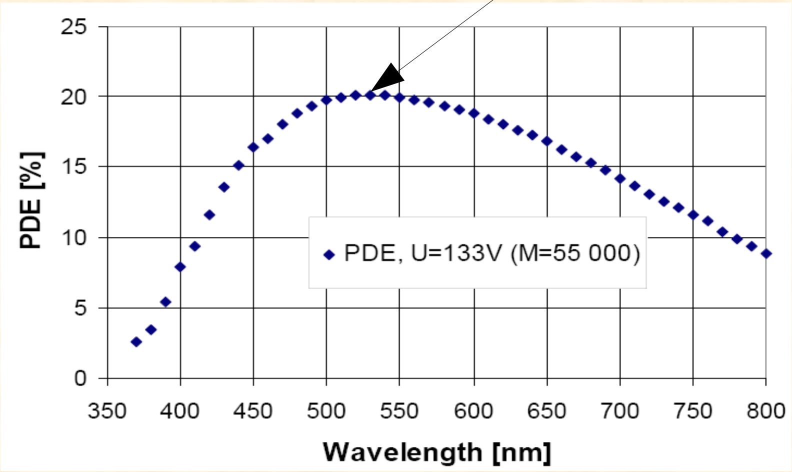
- Active area: 3x3 mm^2
- Number of pixels: 10^4/mm^2
- Photon detection efficiency:~20%
- Gain: 5-6 x 10^4
- Working voltage: 130-140V
- Dark current: ~1 mA



New generation of micropixel APD produced in Singapore by Zecotek

- Active area: up to 5x5 mm^2
- Number of pixel: up to 4x10^4/mm^2
- High stability
- Gain ~ few x 10^4
- Voltage ~65 V
- Dark current ~50 nA

from WLS



Dynamical range of MAPD.

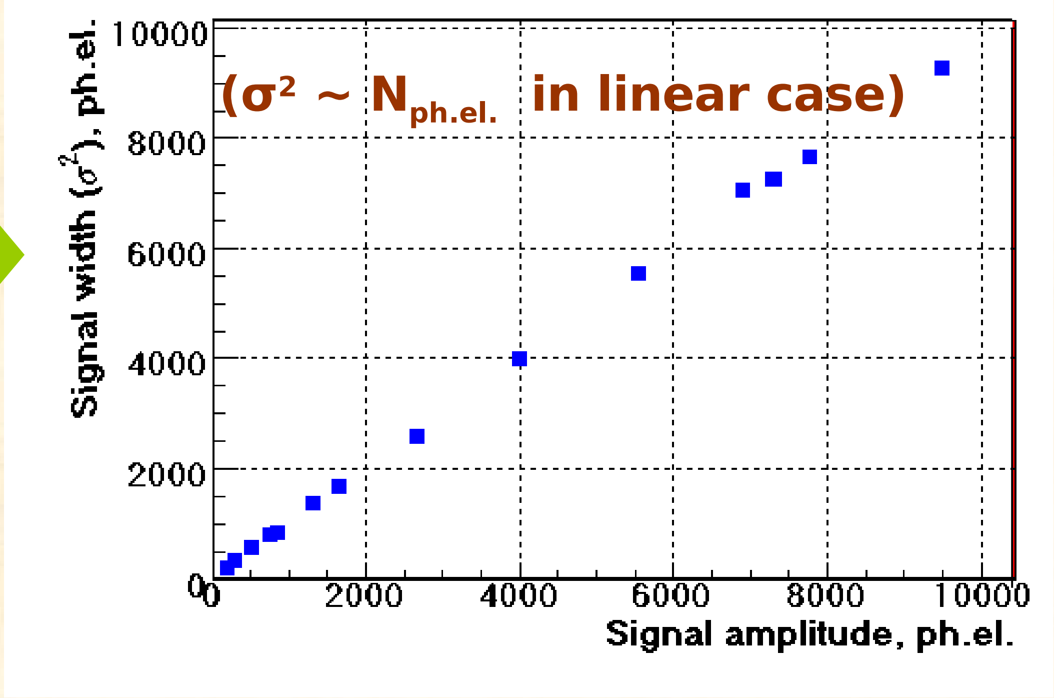
Linearity of response depends on total number of pixels (analytical formula)

$$N_{fired} = N_{total}\left(1 - \exp\left(\frac{-N_{photons} \cdot PDE}{N_{total}}\right)\right)$$

pixels

3x3 mm² MAPD with pixel density >10⁴/mm² has a linear response.

Very fine for calorimetry !



Dependence of signal width (σ^2) on signal amplitude $N_{ph.el.}$ in photoelectrons.

Milestones in the PSD development

August 2006 – beam test of first prototype module

- study of MAPDs signal readout from Scint.plates w. WLS fibers
- possibility of energy calibration of module with muon beam

September 2007 – beam test of supermodule (3x3 array)

- study of supermodule energy resolution
- study of MAPDs long term stability

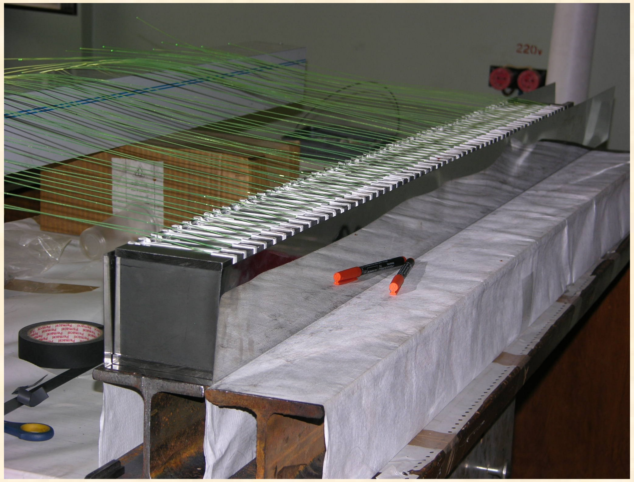
August 2008 – tests of new MAPDs&FEE&DAQ

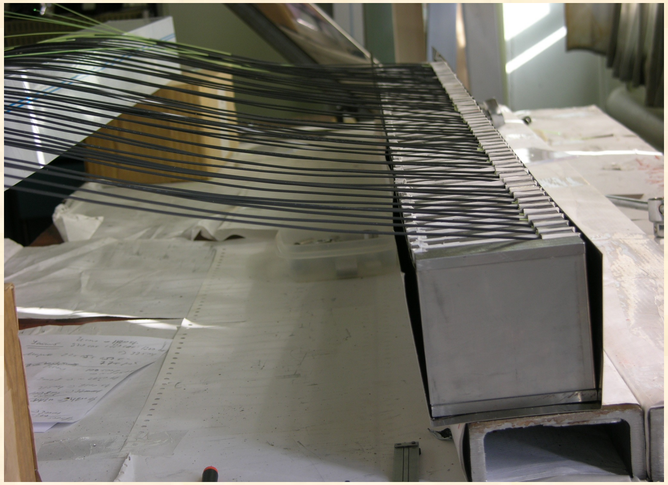
- tests of new FEE and standalone DAQ based on commercial PCI card

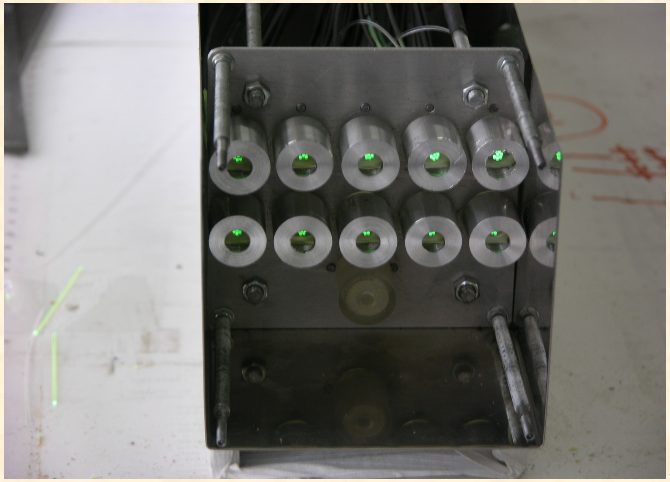
August 2009 – test of hypermodule (5x5 array)

- study of energy resolution
- transverse uniformity of the energy resolution

Modules production and assembling at INR







PSD supermodule beam test at NA61 beam line
(Sept. 27 – October 1, 2007)

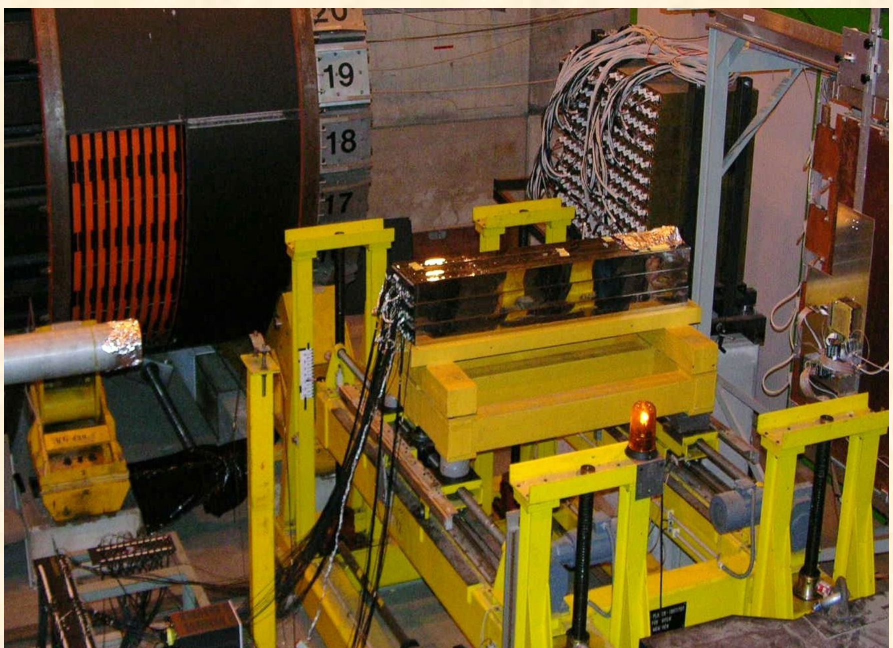
Program of measurements:

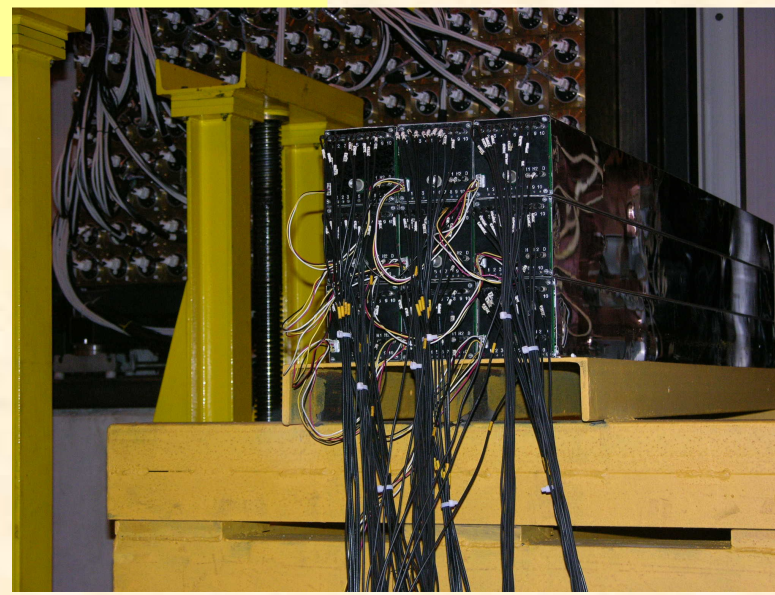
-modules calibration with muon beam;

-study of the response and energy resolution of the PSD on hadron beams 20, 30, 40, 80, 158 GeV/c;

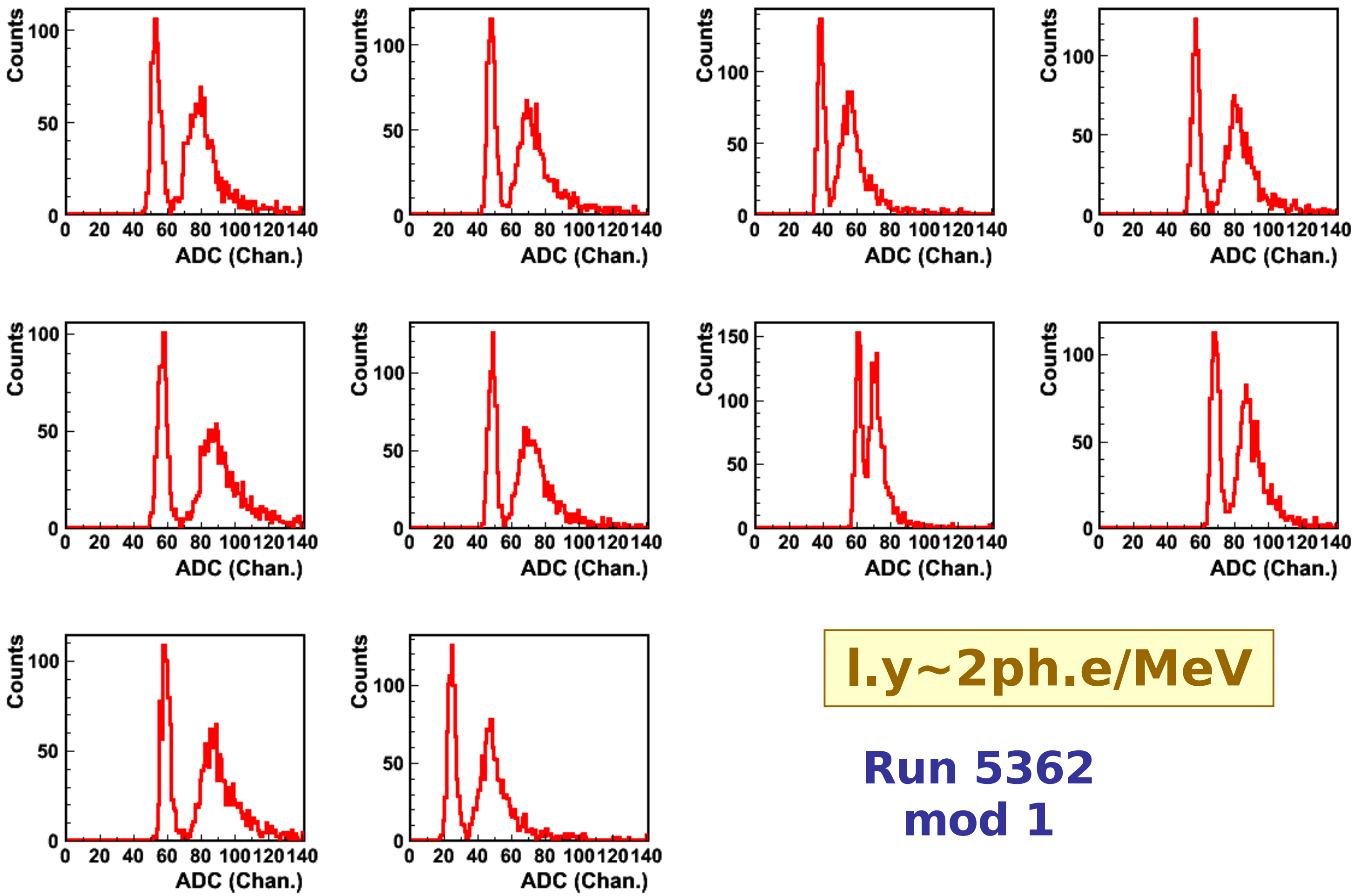
-study of the PSD compensation;

-study of APDs long term stability





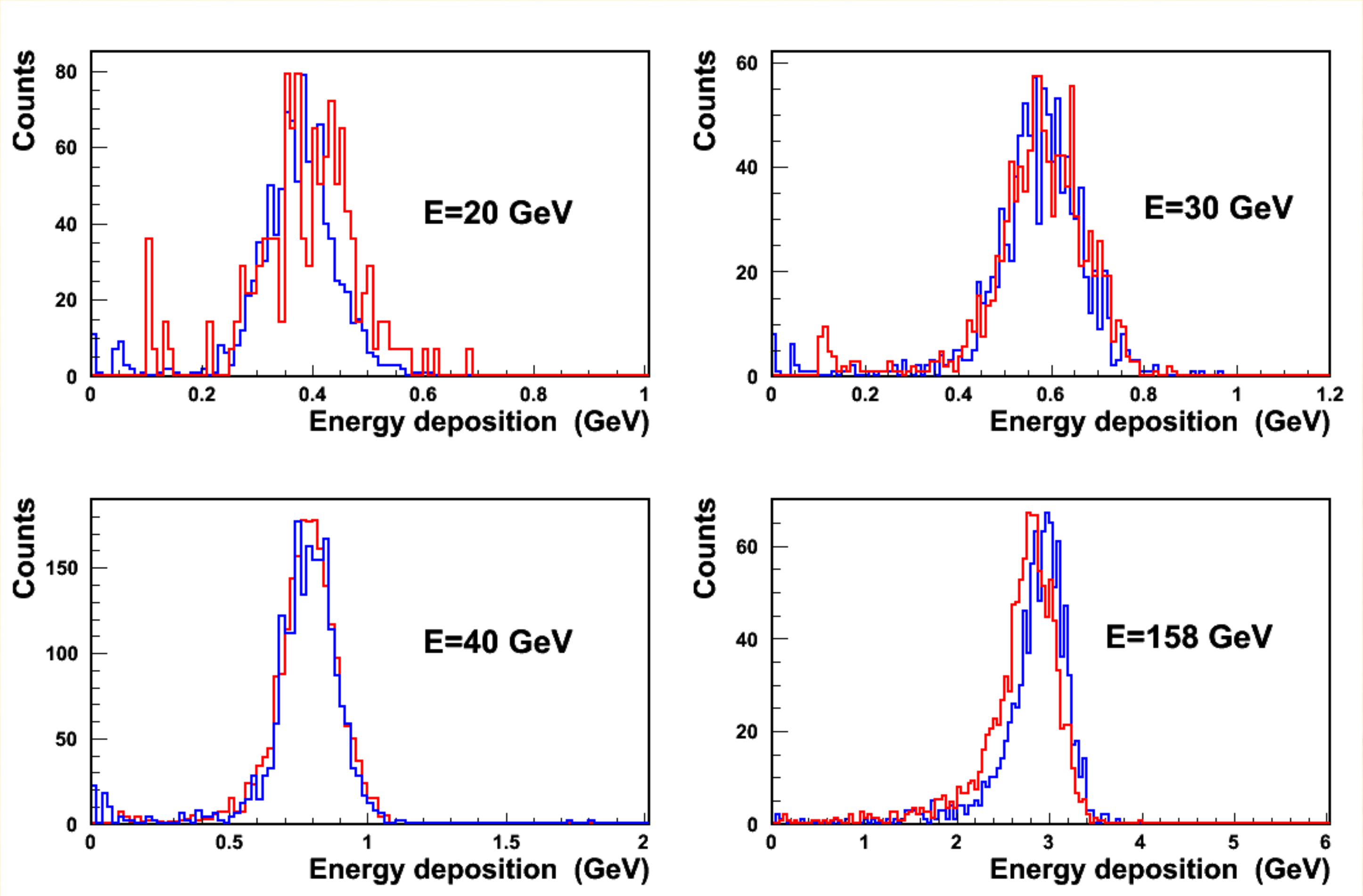
Calibration of modules by 75 GeV muon beam
(response of each section in module)



l.y~2ph.e/MeV

Run 5362
mod 1

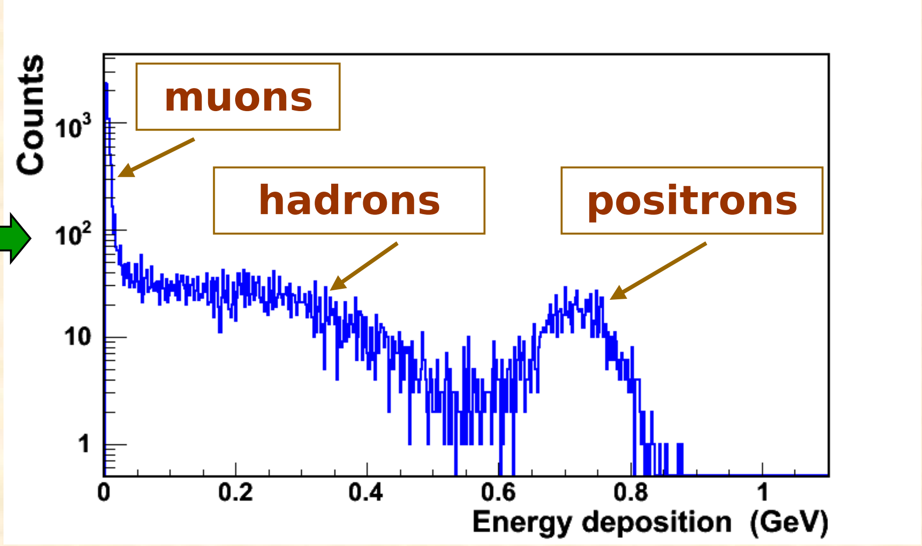
Deposited energy in 9 modules: simulation and experiment



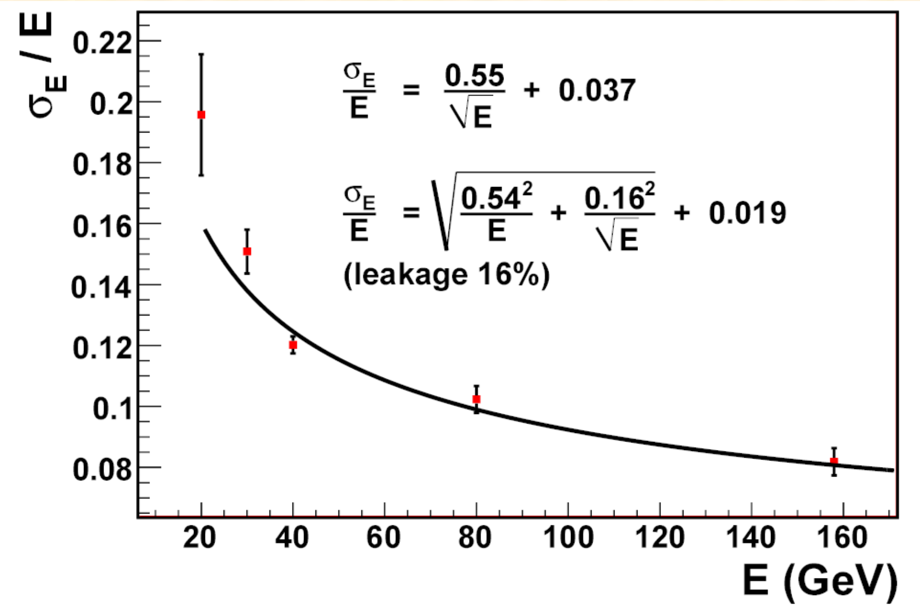
Performance of calorimeter

Energy spectrum in first section of module for mixed 30 GeV beam of pions, positrons and muons.

PID and rejection of secondary particles are possible.



Energy resolution of 3x3 prototype:
stochastic term ~ 55%
constant term ~ 3.7%



Lateral shower leakage 16% is introduced in parameterization*:
stochastic term ~ 54%
constant term ~ 1.9%

*NIM A308(1991)481-508

Results of the supermodule beam test 2007

- **At first time the performance of modular longitudinally segmented PSD calorimeter (supermodule) with micropixel APDs working in Geiger mode was studied.**

- **The possibility of PSD calibration with muons was demonstrated.**

- **Energy resolution was measured for 5 beam energies (54% -stochastic term with constant term ~ 1.9%)**

- **Our analysis demonstrated that constant term in energy resolution is essential only for energy measurement of single particle. It is not important in case of measurement of total energy from many nucleons with the same energy, according to formula:**

$$\frac{\sigma(E)_N}{E_N} = \frac{\sqrt{\Sigma_i \sigma(E)_i^2}}{E_N} = \frac{\sqrt{N}\,\sigma(E)_1}{NE_1} = \frac{1}{\sqrt{N}} \cdot \frac{\sigma(E)_1}{E_1}$$

Thank you for your attention !