Preliminary results for NA62 Fast MuV Prototype

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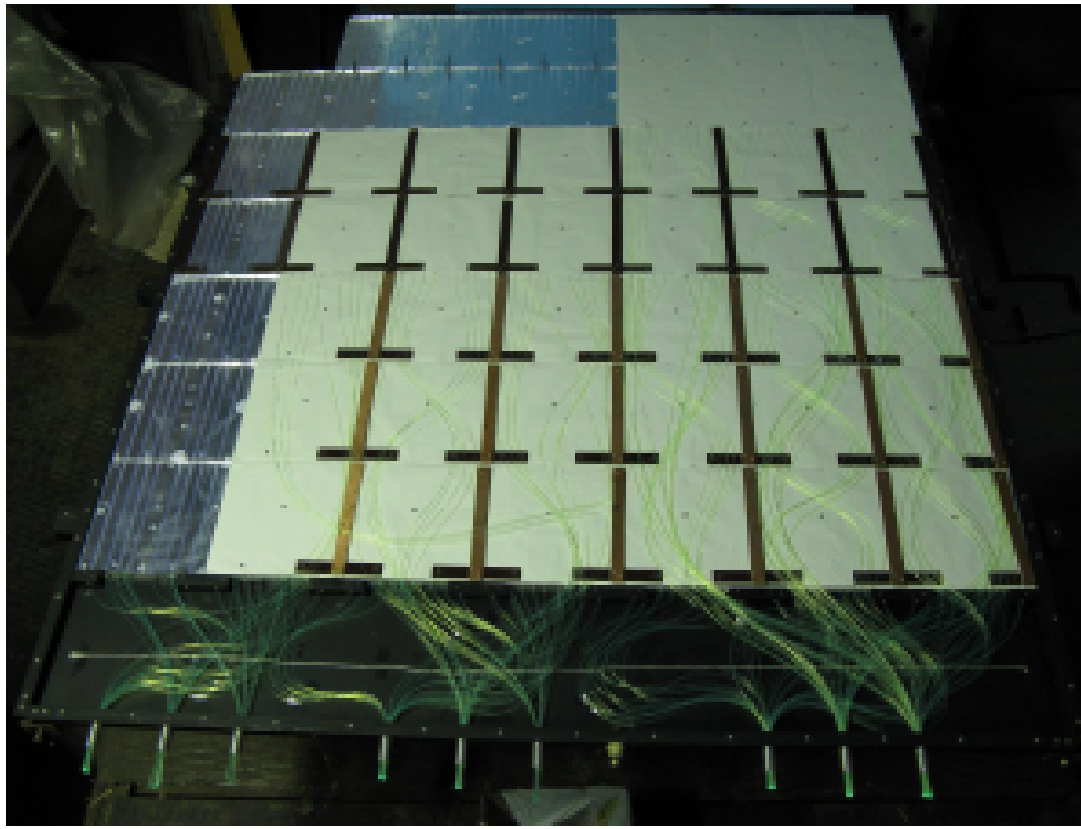
09th December 2009

MuV detector purpose

To fullfil NA62 plan to measure ultra-rare decay $K^+ \to \pi^+ \nu\overline{\nu}$, $Br \approx 10^{-10}$, the detector should suppress huge background due to Kaon decays with muon ($K^+ \to \mu^+ \nu$, $Br = 63.6\%$).
Fast **Muon veto detector** (**MuV** a.k.a. MUV3) is intended to reject extra muons in L0 trigger and help hadronic calorimeter to achieve high overall muon rejection factor. The rejection factor is assumed to be around 100.
It should be very "fast", e.g. have times resolution $\sigma \sim 1$ *ns* or better.
The more σ — the more dead time! For instance, when $\sigma = 1.2$ *ns* and muon rates $r = 9.2$ *MHz* the dead time is 5.1% (see p. 11 for details).
It should also have high efficiency: more than 99% to provide rejection factor of 100.

MuV: prototype detector description

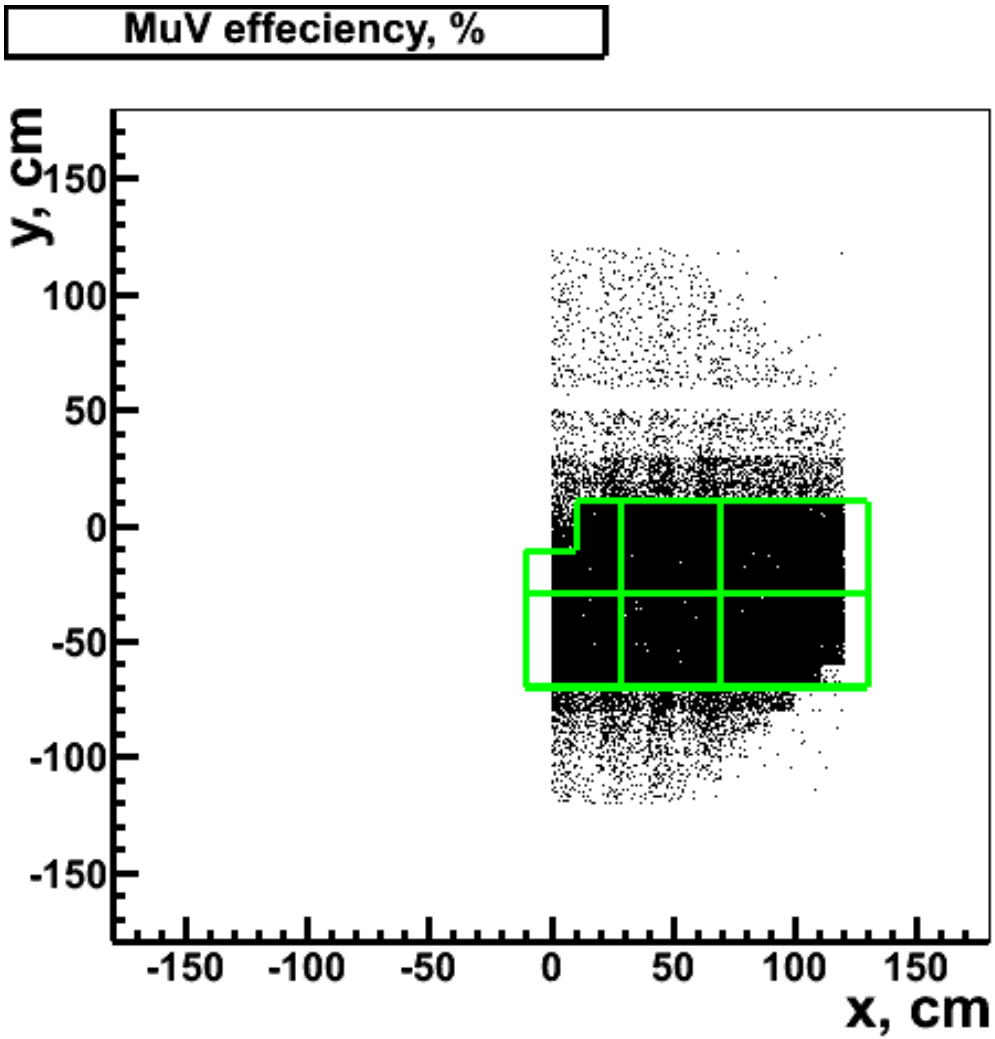
MuV prototype is scintillator hodoscope, where WLS-fibers are used for light collection. There are 2 layers of scintillator in longitudinal direction.
In transversal section hodoscope is divided into 3×3 pads of not-equal size.
Fibers of each pad go along grooves of corresponding scintillator only, beeing fully isolated from scitillators of other pads, e.g. collecting light only from one pad.



Fibers are gathered in 9 bundles read by 9 PMTs.

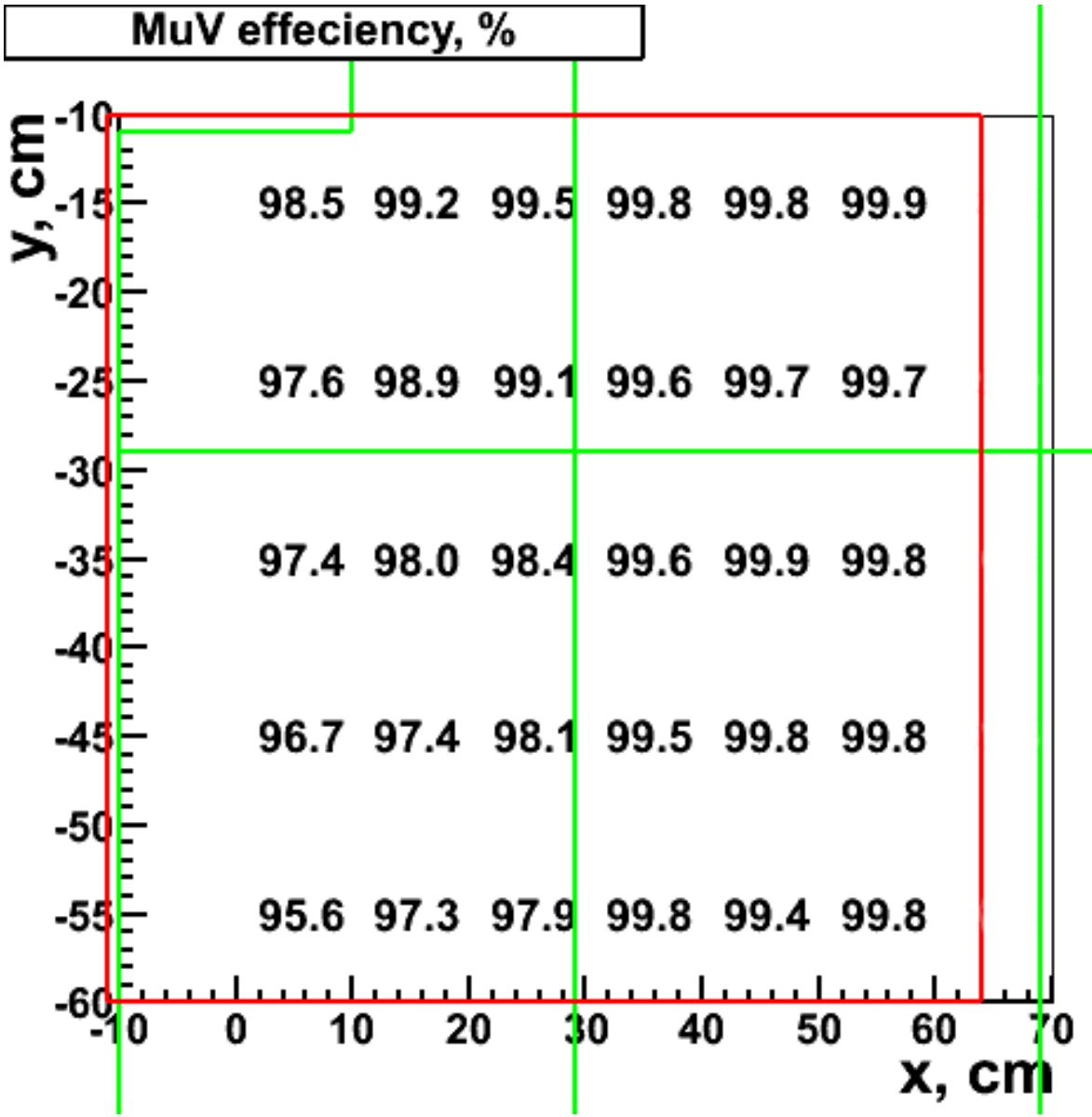
MuV test

The prototype was placed at the beam and overlapped a fourth part of muon tracks. The protype was tested during muon runs in the second half of October 2009. Six Counters of nine were turned on.



Detector efficiency

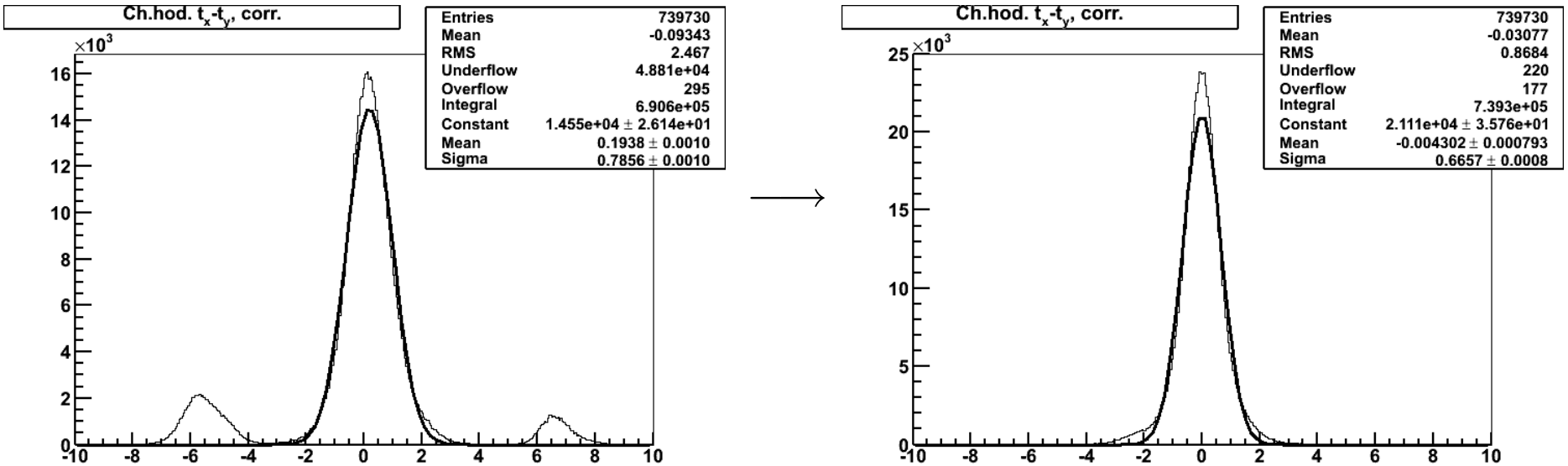
Horizontal and vertical strips of old MUV are used as trigger. Region of crossing of 2 chosen horizontal and 3 vertical strips is shown by red rectangle on the figure.
Green lines show FMUV pad bounds.
Coordinates come from charged hodoscope.



Charged hodoscope time reolution

Time drawn is the difference between times of x and y planes of charged hodoscope. Corrections t(x,y) and t(A) are applied (thanks to Ricardo). In addition, time of each strip is aligned to exclude tails in resolution (the result is shown in figure).

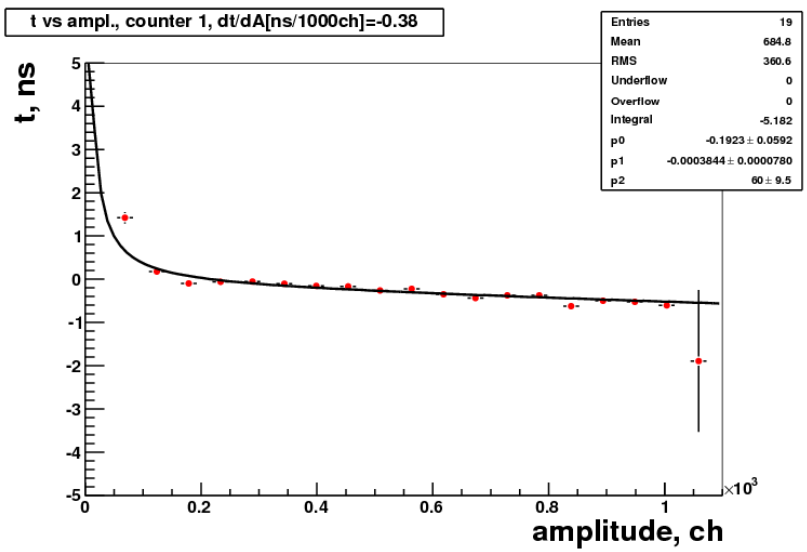
$\sigma = 0.79\ ns$ $\sigma = 0.67\ ns$

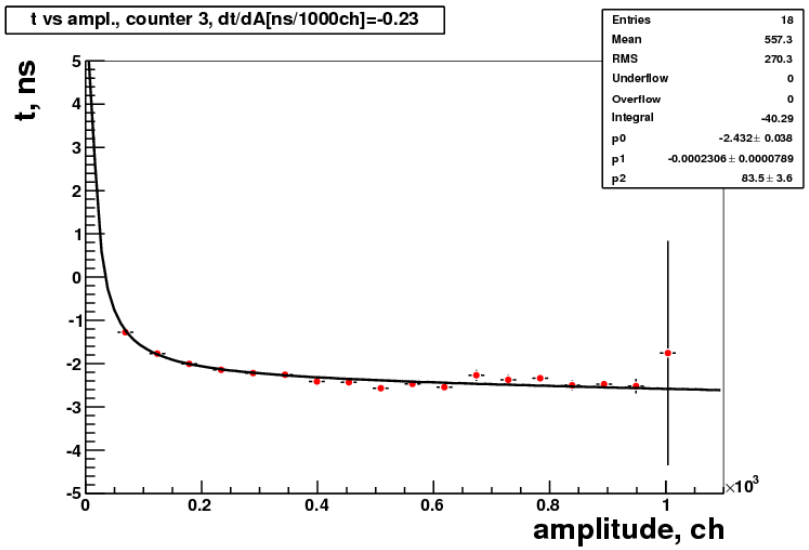


Time resolution of charged hodoscope determined by this way is 0.67 ns.

FMUV t(A) dependence

We determined accuracy of CFD, by fitting mean time dependence on amplitude by function $t(A) = p_0 + p_1 \cdot x + p_2/A$.

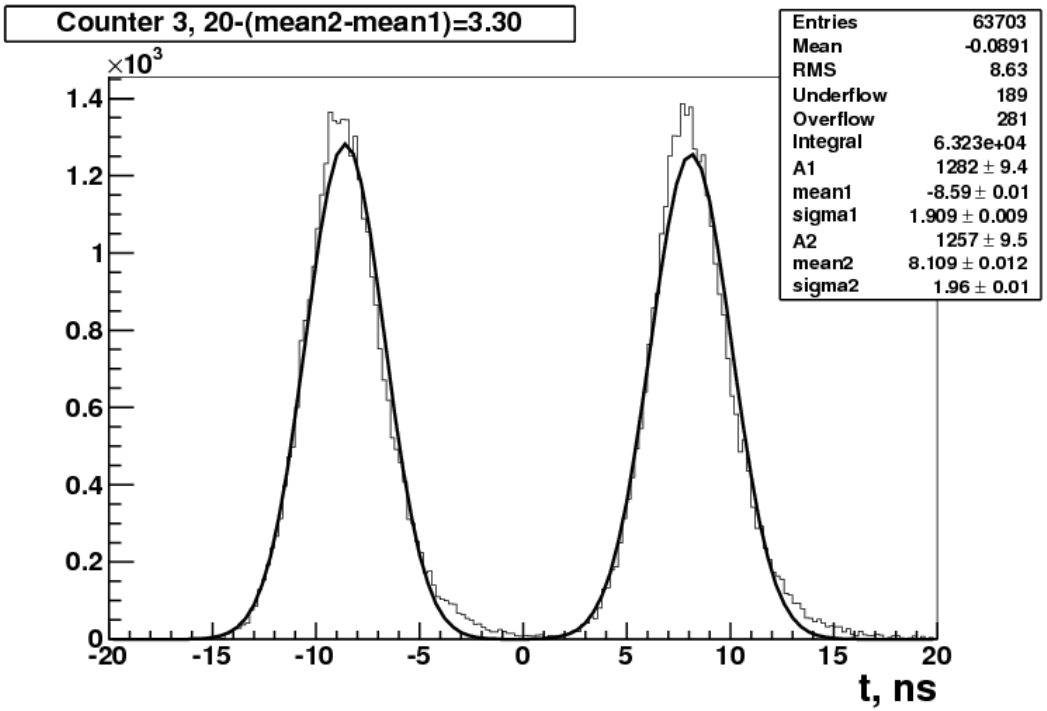




p_1 is in range $[-0.71; 0.00]$. p_2 is in range $[0; 83]$. Appropriate corrections are done (not essential for most counters).

Calibration of up/down ramp

Times for 'up' and 'down' ramp are moved apart for 20 ns interval and fitted. Difference between 20 ns and real interval is time definition error δ_t:



The error is essential only for 3rd counter: $\delta_t(3) = 3.3\ ns$. For other channels $\delta_t(i) \leq 0.3\ ns$

Improvement of current detector design

For reminding:

Following changes were introduced for FMUV in October 2009 run:

- glueing WLS fibers into grooves for better optical contact
  done for 4 pads
- in addition to FEU-85 PMT there were used Hammamatsu R7899–20 and FEU-115M;
- new reflection surface (Tyvek paper instead of aluminium foil)
  partially done

Time resolution after all corrections

Corrections: t(A), ramp, σ of charged hodoscope.

$$\sigma^2_{full} = \sigma^2_{own} + \sigma^2_{t(A)} + \sigma^2_{ramp} + \sigma^2_{Ch.Hod.}$$

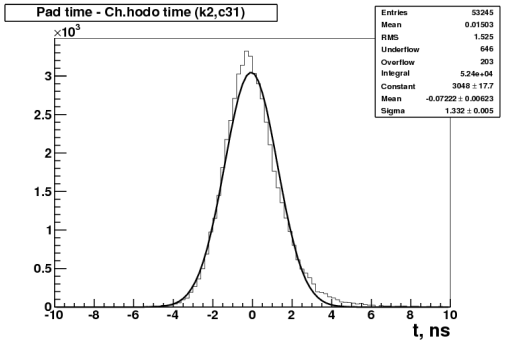


Figure: Time distribution of counter 2

Pads with glued fibers are marked by * (asterisk). Channels with Hammamatsu PMT are marked by **Green**, **Red** — FEU-115M, black — FEU-85.

year 2008 :

σ, ns	2.33	1.88	2.07	1.92	1.76	1.98
N_{pad}	1*	2*	3	4*	5*	6
run 21288: σ, ns	1.93	**1.29**	**1.71**	**1.43**	1.16	**1.76**
run 21290: σ, ns	1.81	**1.16**	**1.81**	**1.53**	**1.17**	1.74
run 21292: σ, ns	1.77	**1.24**	**1.80**	**1.99**	**1.18**	1.74
run 21298: σ, ns	1.76	1.25	**1.69**	**1.52**	**1.24**	1.73

Trigger L0 requirements for MuV time resolution

Assuming, that muon veto should suppress muon background by a factor of s=10 or s=100, we'll choose **Veto time interval** $\delta = 2 \times 1.64\,\sigma$ or $2 \times 2.58\,\sigma$ accordingly (if time resolutions is distributed as gauss). Dead time depends on muon rate: **dead time** is $1 - e^{-\delta r}$. Muon rate at MuV is usually reported to be $r = 9.2$ MHz.

Below we assume $r = 9.2\ MHz$.

σ	$\delta(s = 10)$	**dead time**(s=10)	$\delta(s = 100)$	**dead time**(s=100)
1.75	5.7 ns	5.1%	9.0 ns	8.0%
1.2	3.9 ns	**3.6**%	6.2 ns	**5.5**%
0.9	3.0 ns	2.7%	4.6 ns	4.2%

Conclusions

- "Puzzle" of low efficiency ($\approx 94 \pm 4$ %) in 2008 run resolved with the help of Old MUV muon trigger counters;
- significant improvement of time resolution is achieved by glueing fibers into pads (as expected, see report on 22nd October 2009);
- Using Hammamatsu PMT or FEU-115M does not give significant improvement as compared with FEU-85.