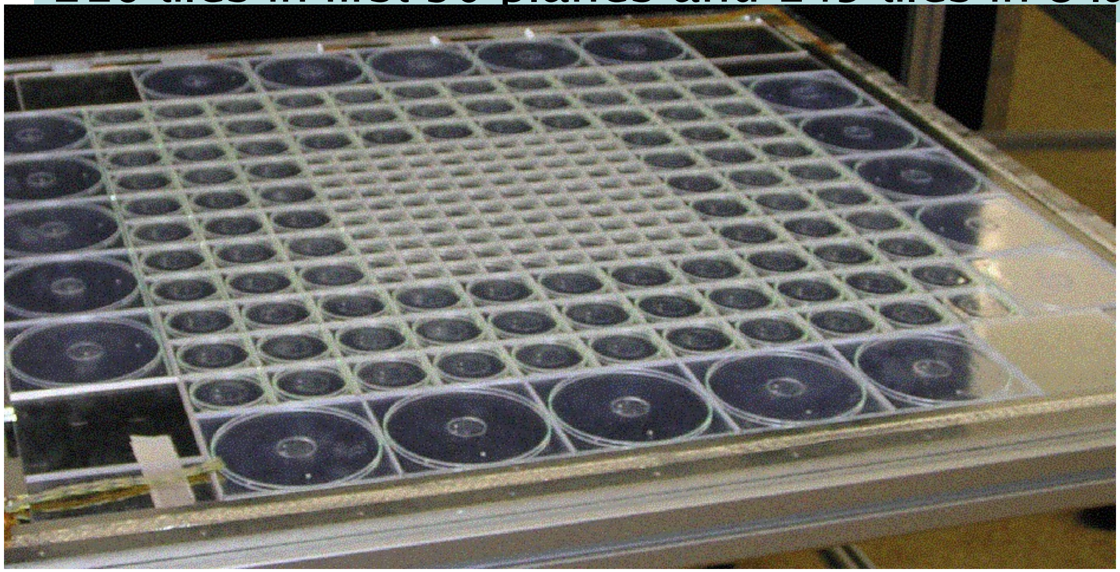
Scintillator tile and SiPM tests for AHCAL prototype at ITEP(Moscow)

(E.Tarkovsky, ITEP)

Outline

- ✓ Test of photodetectors
- ✓ Assembly of tiles
- ✓ Results of R&D (scintillating tiles and strips)

The HCAL prototype comprises 38 planes of scintillating detectors with 216 tiles in first 30 planes and 145 tiles in 8 last ones.



SiPM propertis

Sensitive area - 1x1 mm^2, Matrix of 1156 (34x34) pixels operating in Geiger mode

A fired pixel gives $\Delta Q = V \cdot C$

So net signal ~ number of detected photons

Limited dynamic range due to limited number of pixels ⇒ saturation at $N\gamma \sim N_{pixels}$

Light registration efficiency ⇒ QE(~80%) x $_{Geiger}$(~60%)x $_{geom}$(~35%) ~ 17%, with maximum for green light

Gain ~10^6 (V~3V, C~50fF)

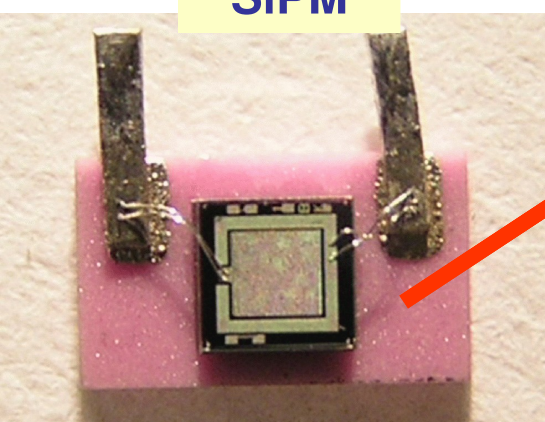
Noise ~2MHz, exponentially falls with threshold

Optical inter pixel crosstalk <~ 0.3 restricted operation voltage

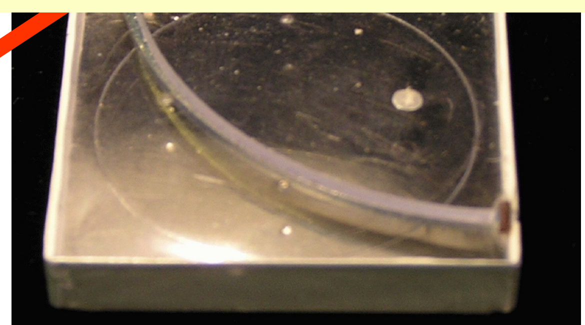
Insensitive to magnetic field (Tested up to 4 T)

Light from a tile is read out via WLS fiber and SiPM

SiPM



Tile of 3x3 cm^2 WLS fiber and SiPM



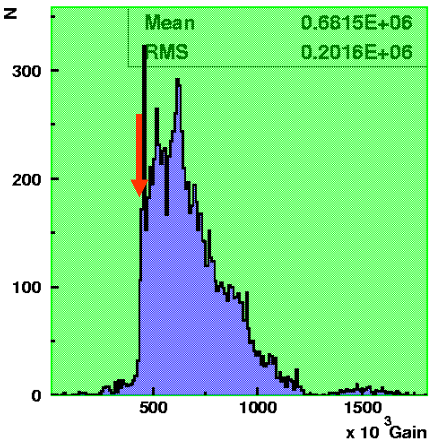
Selection criteria for SiPM's

Number of pixels for 1 MIP light	= 15
Gain	> $4.3*10^5$
Noise	< 3 MHz
Noise frequency at ½ MIP threshold	< 3 kHz
SiPM crosstalk	< 0.35
SiPM current	< 2 mA
Stability od SiPM current	< 20 nA
Number of pixels at ~200 MIP light	> 900

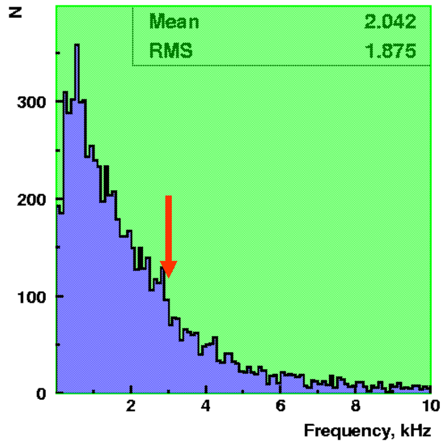
More than 10000 SiPM tested

Accepted	-	7660
Assembled in 26 modules	-	5772
Assembled in TCMT	-	360
Used for R&D purposes	-	170

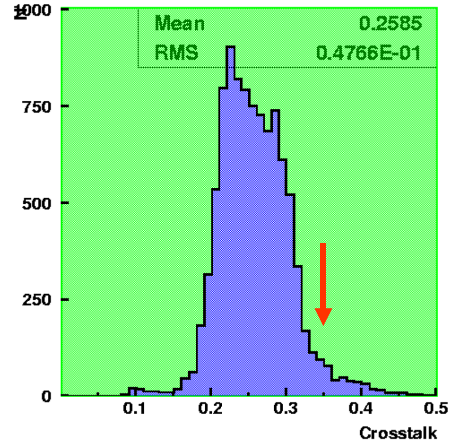
Parameters of tested SiPM's



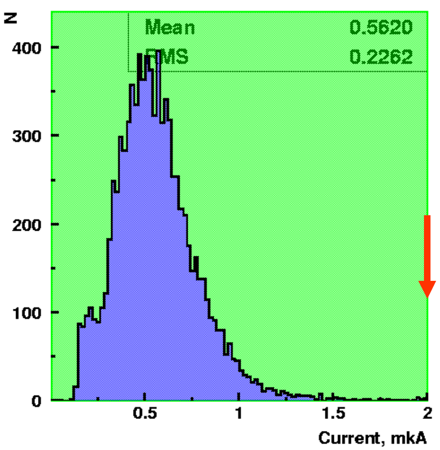
GAIN



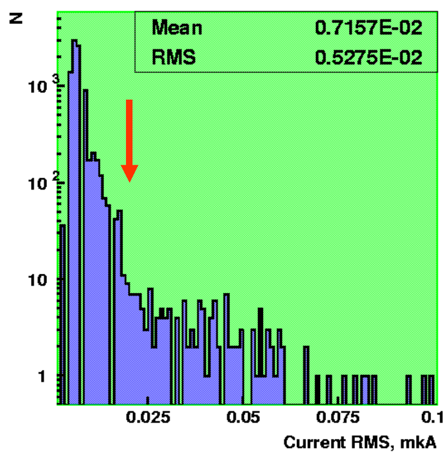
NOISE AT ½ MIP(7.5 pixels)



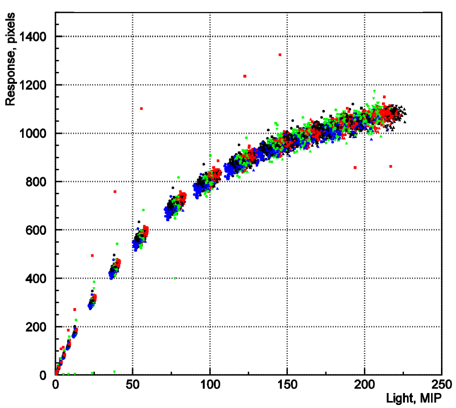
CROSS TALK



SIPM CURRENT

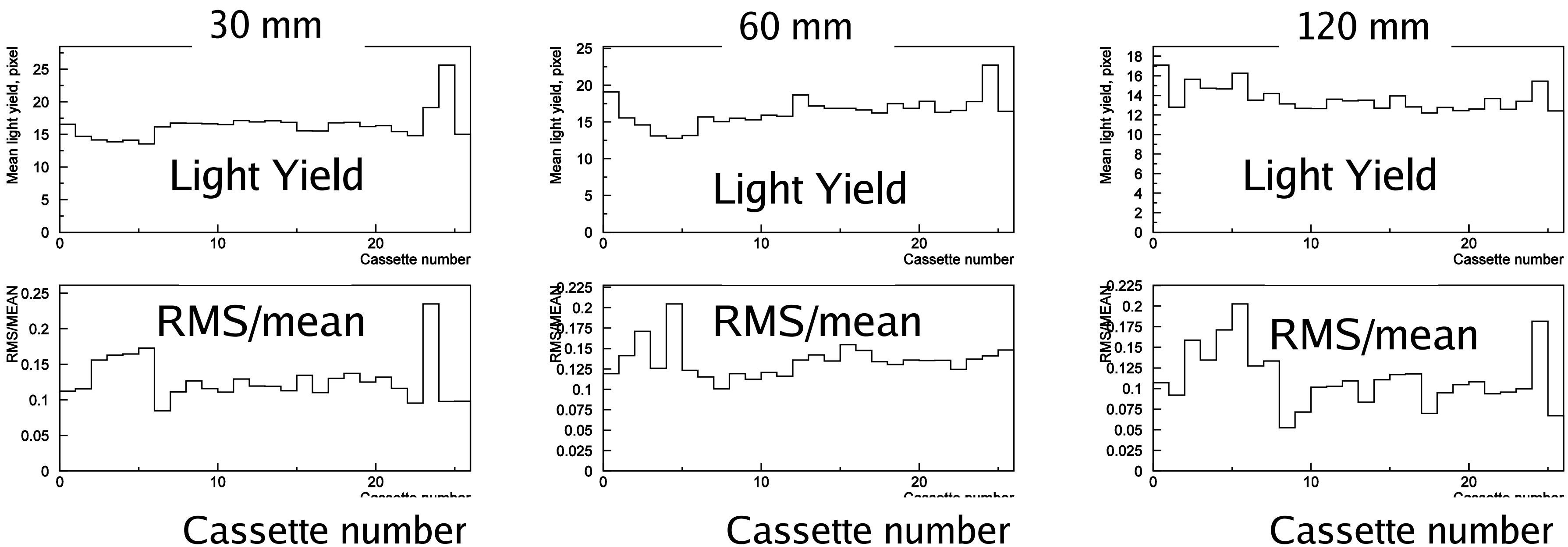


CURRENT STABILITY



SATURATION CURVE

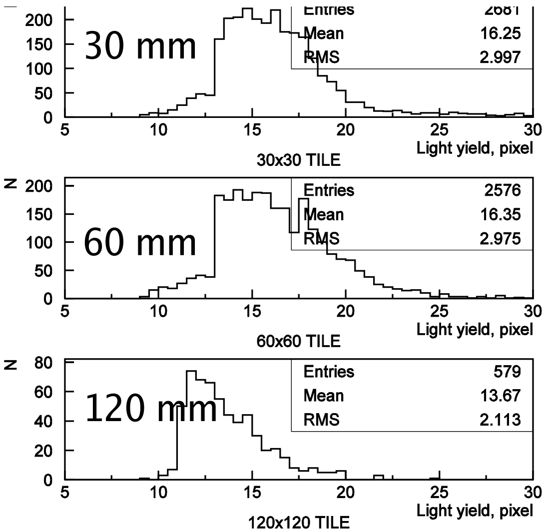
Light yield and RMS of tiles for first 26 cassettes



Tiles for module # 25 have been done with optical contact between fiber end and SiPM.

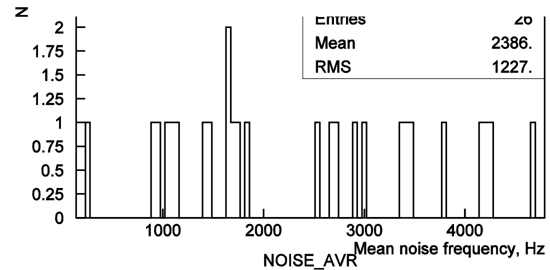
Estimation of noise at ½ MIP threshold in assembled tiles

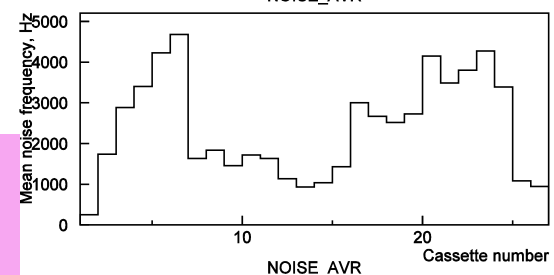
Light yield in tiles of cassettes 1-26



After tile test one may calculate noise frequency at real ½ MIP and plot distribution

Noise in assembled tiles





$N_{hit}=\langle F \rangle * 220 * 10^{-9} * 216 * 24 = \sim 3$

This is much smaller than we have at beam test

Possible reasons:

1. MIP in the beam is ~1 pixel less than “MIP” from β-source – noise variation factor =~8 per 2 pixels

2.Two very fist modules have been assembled with SiPMs selected with softer criteria and they have higher noise at ½ MIP threshold.

We expect in the nearest few months completion of SiPM’s supply. This will give us possibility to have AHCAL prototype fully equipped with tiles by April 2007.

The next step in AHCAL R&D should be construction of a prototype with final detector geometry and use of mass production technology

We tested light yield and response uniformity of 3 mm thick tiles - thinner tiles allow to reduce the total calorimeter thickness

Tiles with direct readout of scintillator light by a SiPM (no WLS fiber) have been tested – this design makes production and assembly of detectors much simplier.

Results of R&D for 30 mm scintillating tiles

All tiles had diffuse reflecting edges and were covered at top and bottom with mirror reflecting film

Test beam of ITEP synchrotron p_{proton} = 860 MeV/c (dE/dx ~1.5*dE/dxMIP)

2 time delay chambers to measure particle coordinates

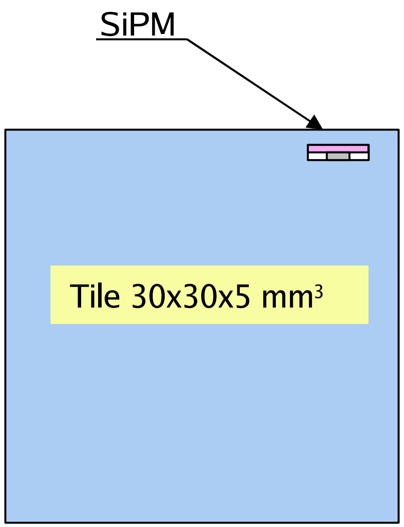
~5000 particles/burst

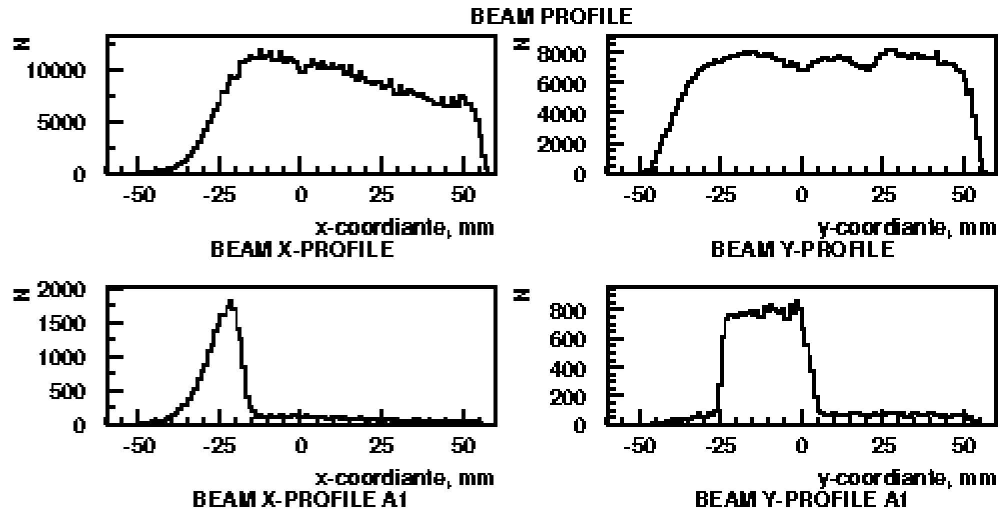
~500 ms burst duration

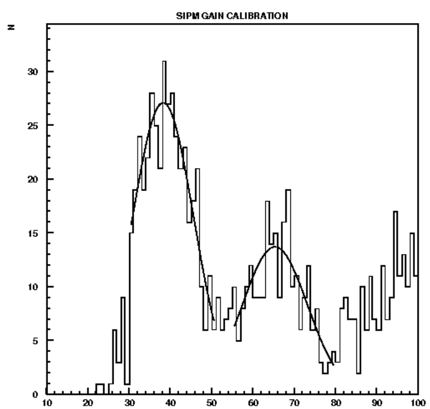
15 bursts per minute

2 trigger counters 10x10 cm^2 and 30x30 cm^2

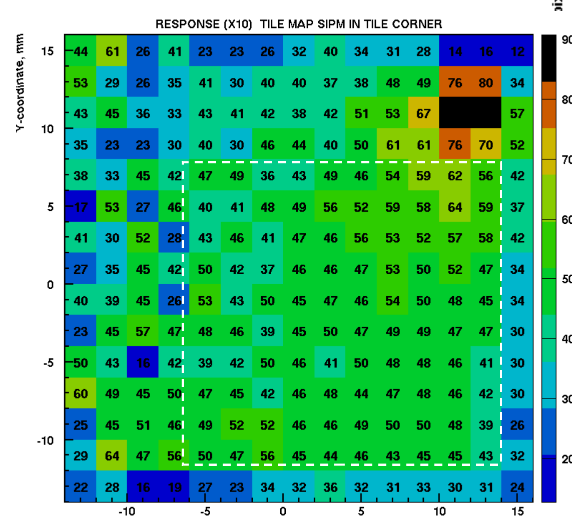
SiPM in tile corner (noWLSF)

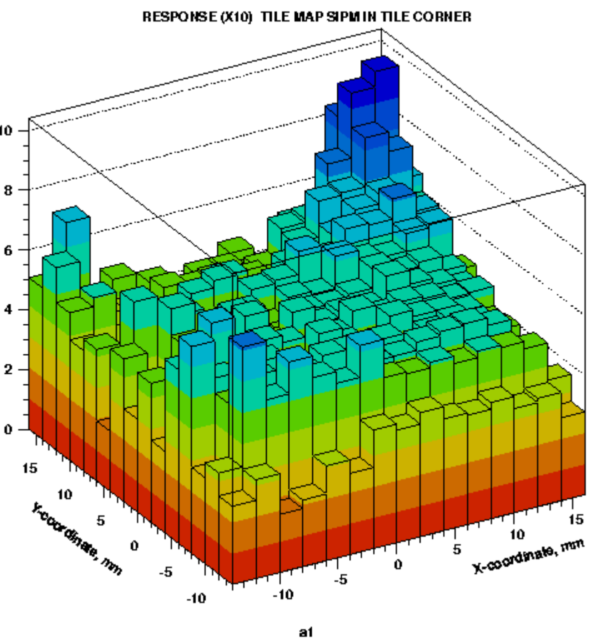






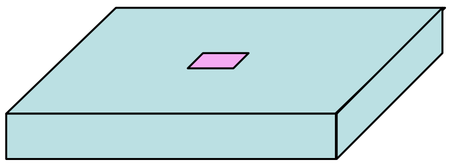
SiPM calibration

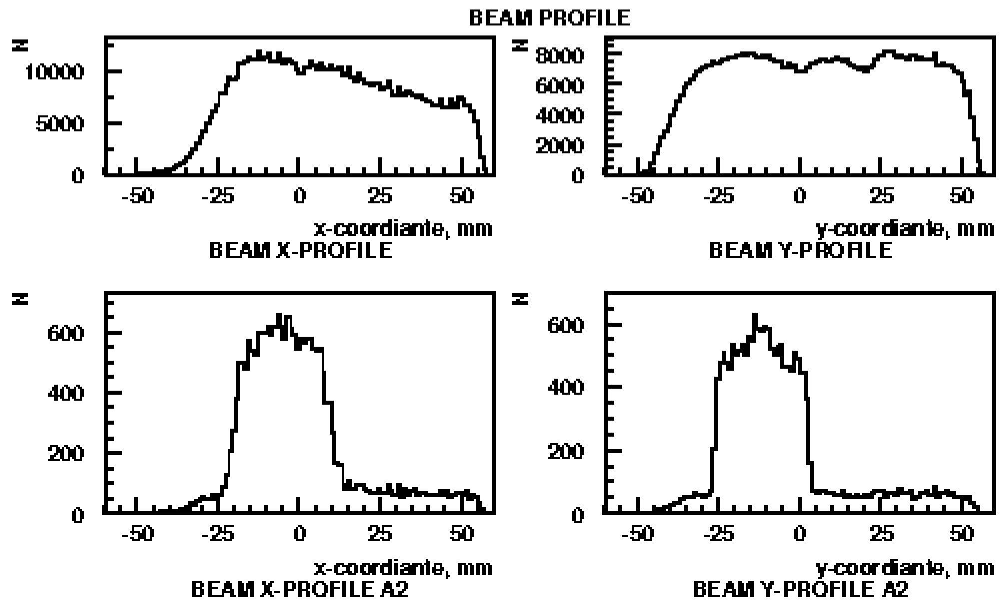


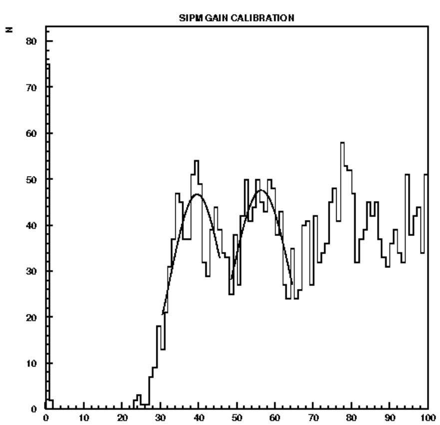


SiPM on top of a tile (no WLSF)

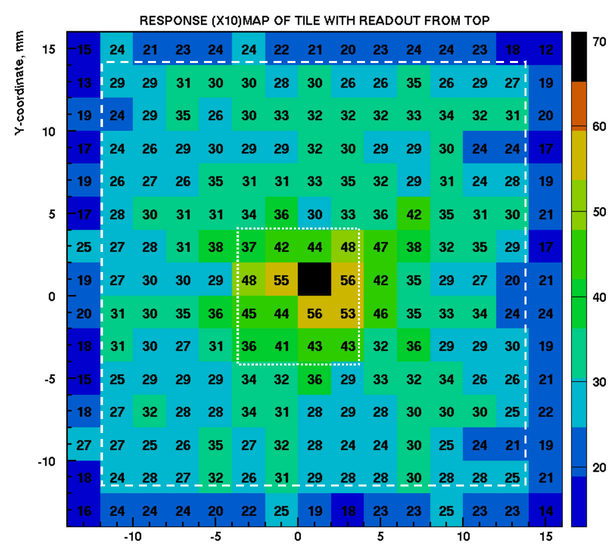
Tile 30x30x5 mm3

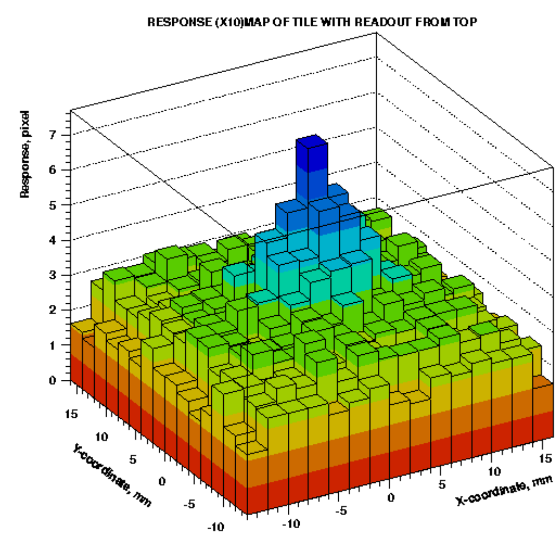






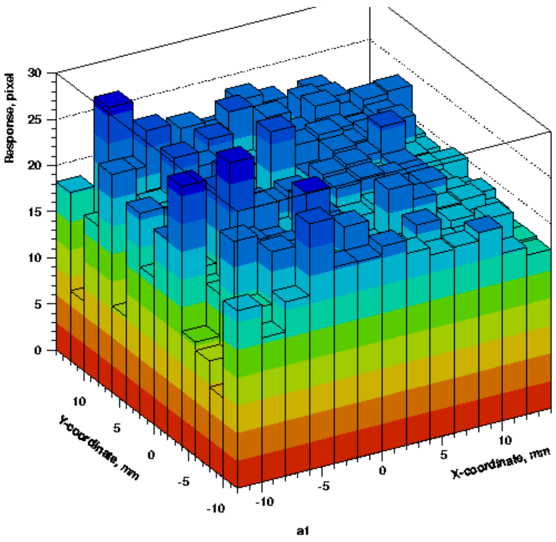
SiPM calibration



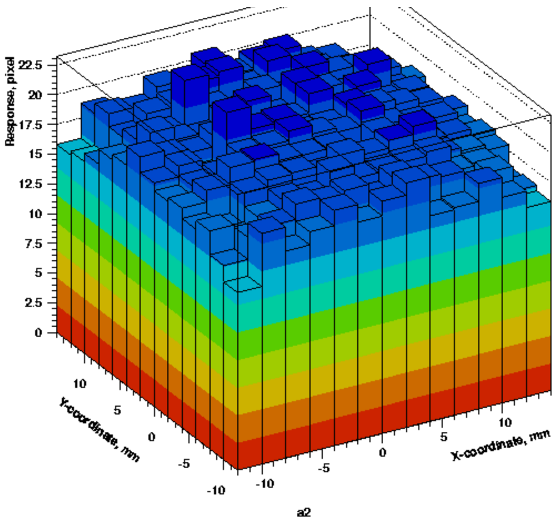


3 mm thick tiles with WLS fiber

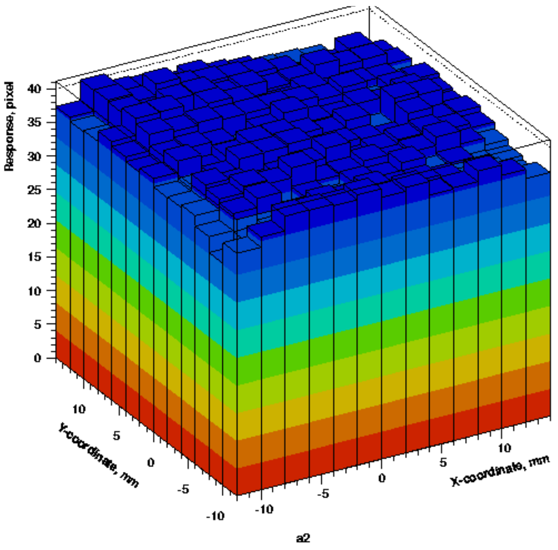
Tile with diagonal fiber



Tile with arch fiber



Standard 5 mm thick tile
with arch fiber



Tile response uniformity

Tile description	Response and RMS over 26x26 mm^2 area		Response and RMS over selected area**	
	Mean response [pixel]	RMS [%]	Mean response [pixel]	RMS [%]
No WLS fiber SiPM in tile corner	5.4	22*	5.5	11
No WLS fiber SiPM on tile top	3.5	21	3.3	15
3 mm tile diagonal fiber	21	9.5*		
3 mm tile arch fiber	19.3	8.3		
Standard tile # 1	38.2	4.2		
Standard tile # 2	27.8	5.8		
Standard tile # 3	28.3	7.4		

*) - Only ~half of tile had good statistics during beam test

**)Resuts are taken over the area out of SiPM vicinity

Remarks on results of tile test

Tiles with WLS fibers have considerably better uniformity

Beam coordinate measurements were not perfect (1 beam chamber was dead) this leads to worse RMS near tile edges

Tiles uniformity near edges will be better in dense tile packing

Possible ways to improve uniformity in tile with direct light readout
- masking of tile surface near photodetectors

In order to increase light yield SiPM's with larger sensitive area have to be used

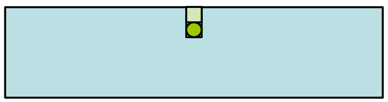
We will have more tests in the nearest future with tile dense package. SiPM's of bigger sensitive area 2x2 mm2 and 3x3 mm2 will be tested

The same technique using solid state photodetectors can be used for light readout in scintillating strips

This can be employed in construction of μ -detectors for ILC experiments

Scintillating strips with MRS APD have been studied

Test of ~150 strips with MRS APD

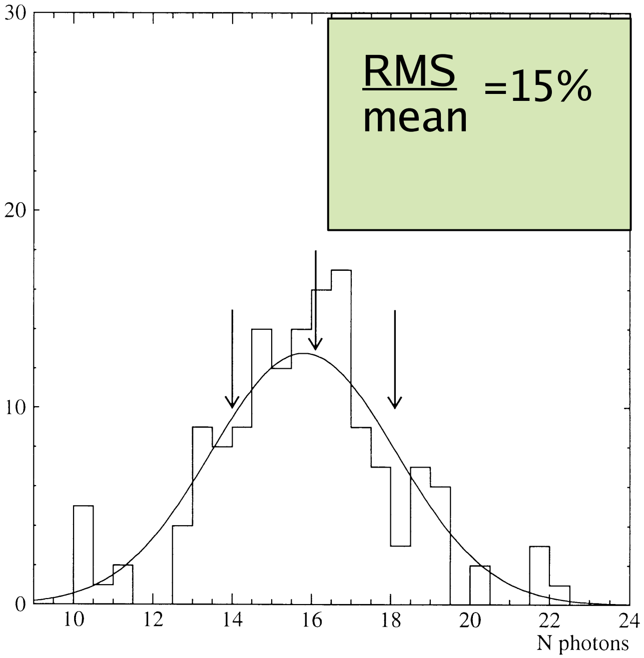


1000x40x10 mm^3

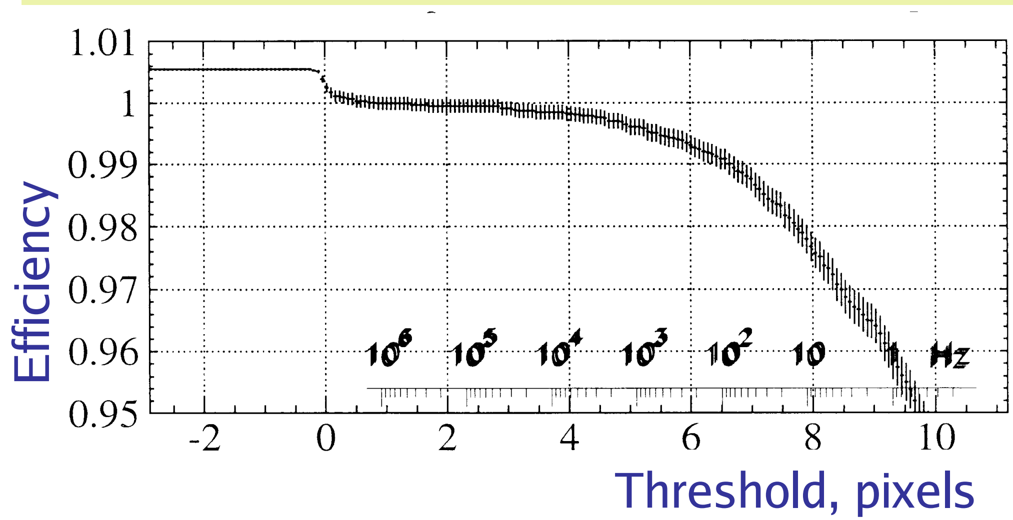
coated with TiO_2 white paint

Ø1.2 mm Kuraray Y11 WLS fiber glued into a groove

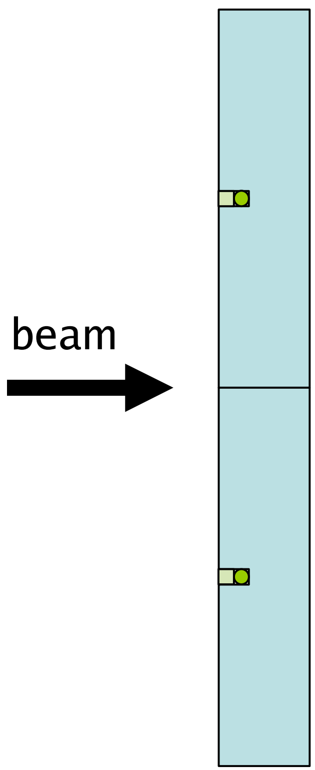
Strip to strip uniformity measured for 149 strips

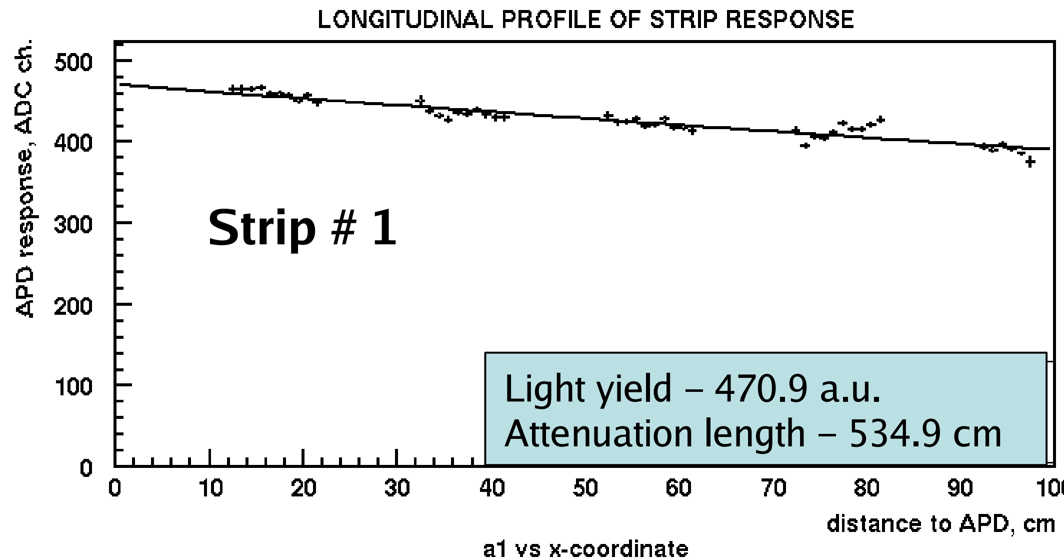


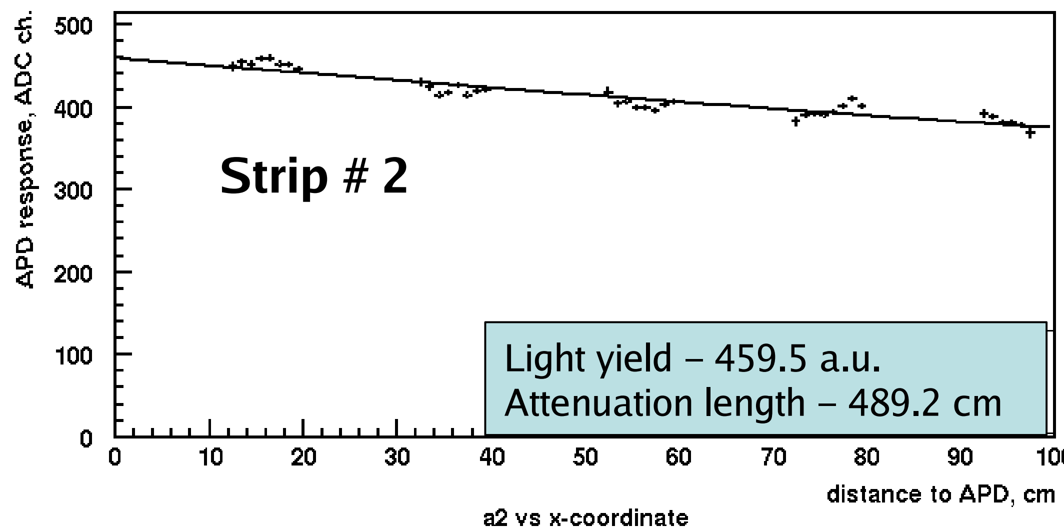
Strip efficiency and noise vs threshold



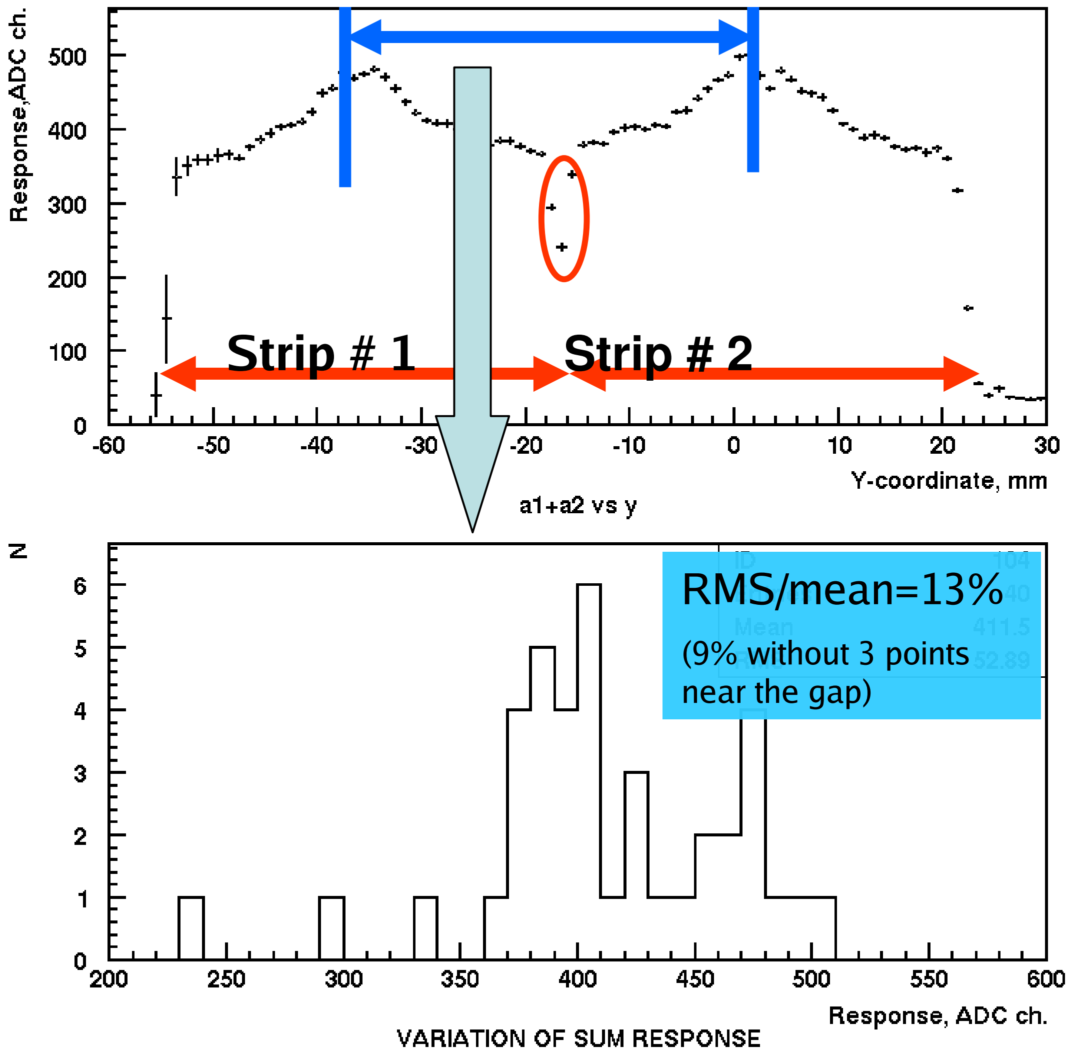
Longitudinal profile of strip response



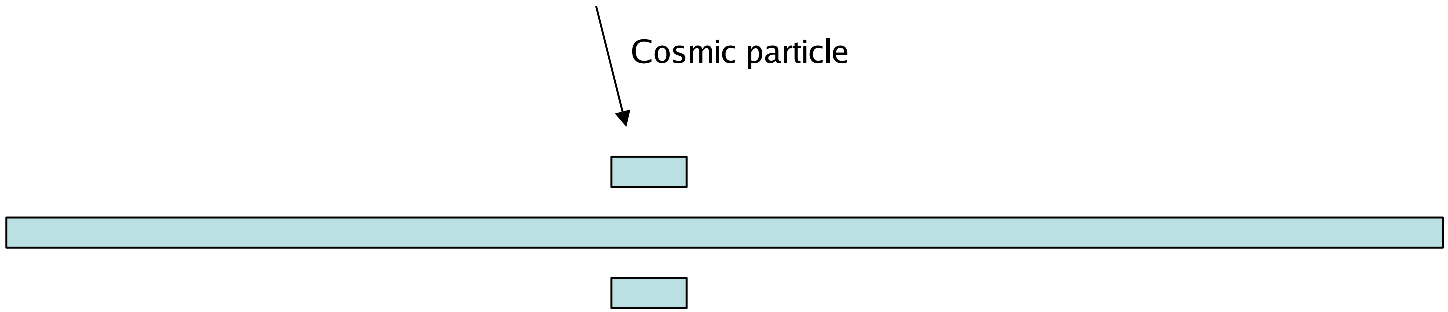


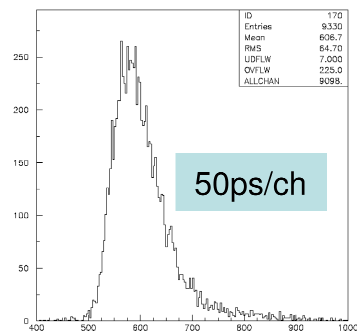


Transversal distribution of strip response

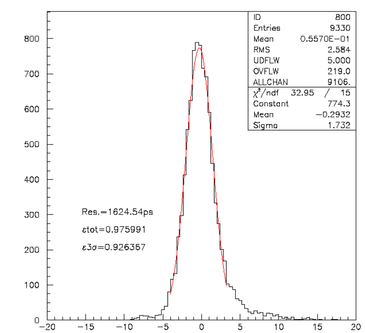


Time resolution of 1 m strips

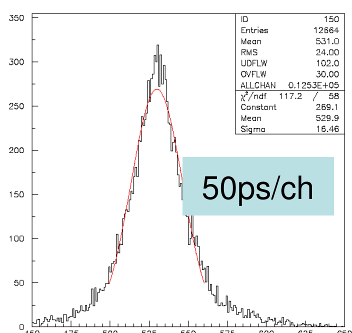




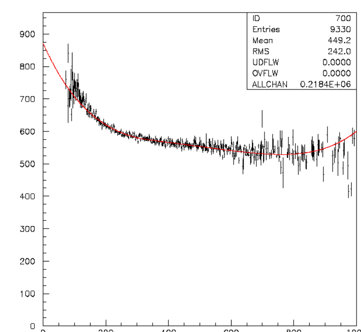
time spectrum



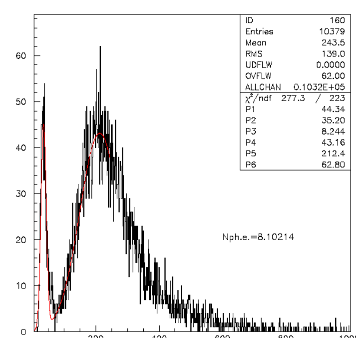
ΔT distribution



start system resolution



time-charge plot



charge spectrum

Time resolution of 1 m strips

	Strip1 SiPM Edge	Strip1 Center	Strip1 far edge	Strip2 SiPM edge
ΔT	1.9 ns	2.0 ns	1.6 ns	1.7 ns

Conclusions

- ✓Silicon photomultipliers and tiles for 26 cassettes of AHCAL prototype have been selected, assembled and tested during CERN beam test
- ✓Measurement of thinner tiles and tiles with direct light readout show the possibility for calorimeter design improvement and use of mass production technology
- ✓Tests of scintillating strips with solid state photodetectors demonstrate excellent efficiency at reasonable noise level
- ✓Time resolution of scintillating strips may be used for slow particle identification