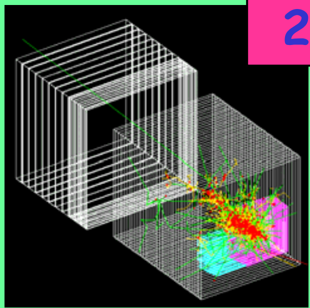
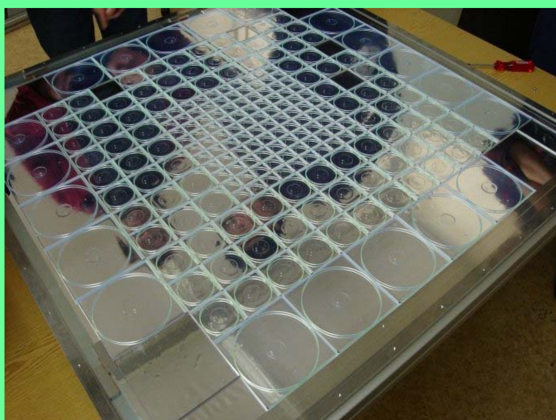
Future for the Tile HCAL ??

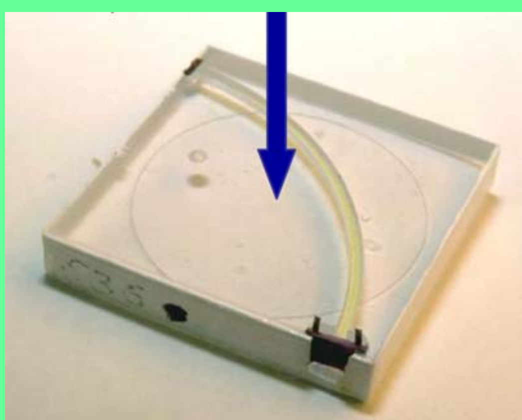


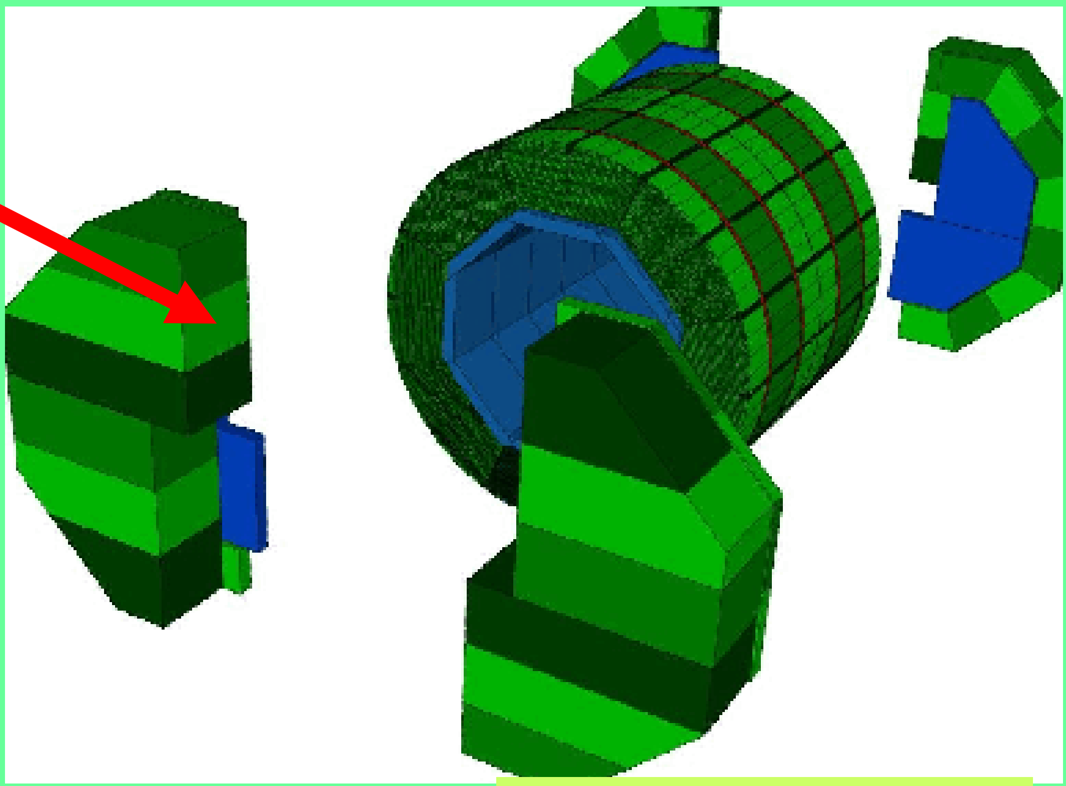
25 GeV,p

8000 active cells

1000 times more cells

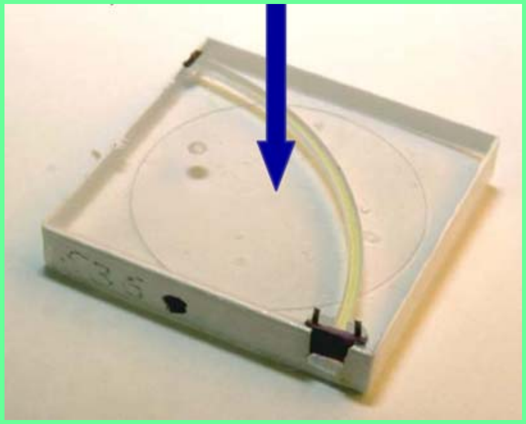


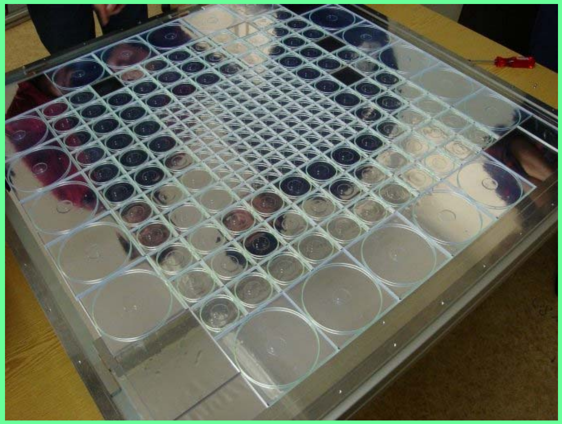




New era for scintillator-based detectors:
High granularity** at relatively **low cost

Our vision in Year 2000 …….>>>> 2008?



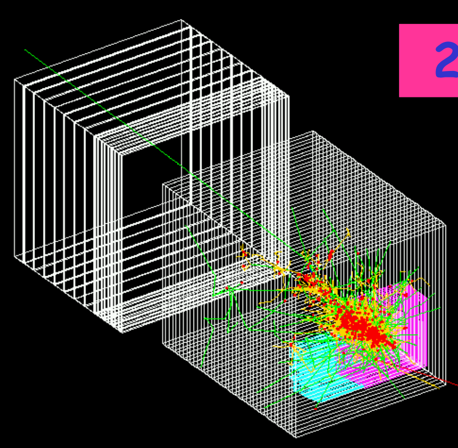


Scintillator tiles

Scintillator

- optimize pad lateral size (!!!!)
- thinner tiles (e.g. 3mm), (!!!) ?
- Other material for absorber ??
- cheaper scintillator material (!!!!)
- extrusion, no further treatment any more
- No WLS-fibre, try for direct light RO?
- Mega tiles (!!!), ~ m2 size?, Pad separation ?
- Single tiles (??!!)
- Combination of both (???)

- Or large grids made from reflector material, to be filled with tiles, get rid of tolerances
- Need blue sensitive larger area photodetectors
- Need cheap direct optical coupling



25 GeV,p

Future: Photodetectors

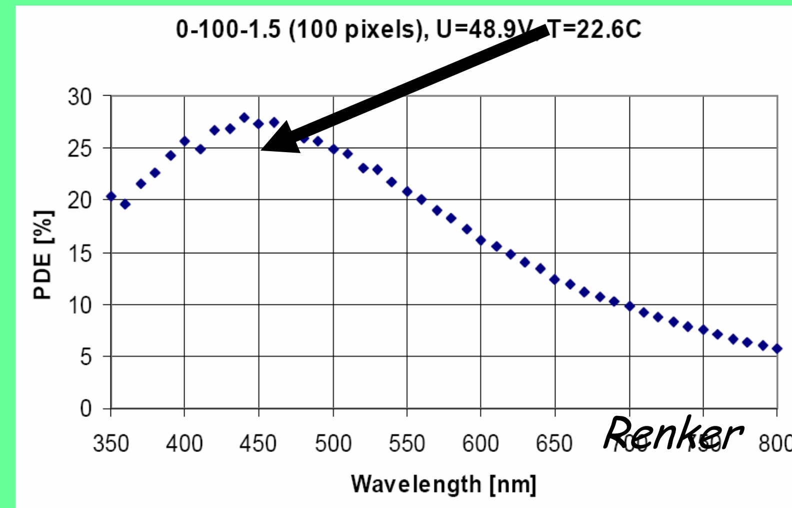
SiPM Applications increasing:

PET, night vision, Astronomy, Space technologies, Safety Monitoring,…

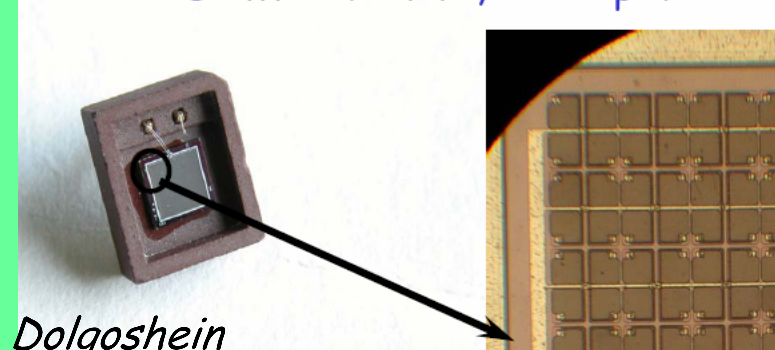
--Boris Dolgosheim: "Progress report on SiPM development its applications"
www-flc.desy.de/flc/science/hcal/index.html
CALICE Main Meeting, October 12.-14. 2005
--D. Renker, ETH Zuerich
at Beaune Conf. on Photodetectors, June 2005

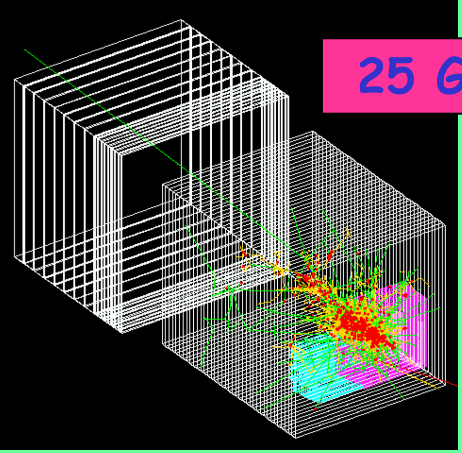
Development now at:

- **MEPHI/Pulsar (Moscow)**
- **CPTA, Obninsk, (GUS)**
- **JINR, DUBNA (GUS)**
- **SensL, Ireland, EU R&D-funding, GlueX-BCAL**
- **MPI- Muenchen**
- **Hamamatsu (Japan)**



SiPM 3x3 mm^2, 5625 pixels





Future: SiPMs, 2

Ongoing Si-PM R&D:

<u>to reduce:</u>

- noise rate, self triggering
- X-talk, resolution
- Operation bias voltage spread, cost/power
- Bias voltage ?? Power

<u>to increase:</u>

- geometrical efficiency,
- optical efficiency, in range of scintillation light,
- larger gain would need less preamp power

More robust,
larger pixel size from 20 to 100μm ?
larger detector size, from 1x1 to 2x2 mm^2 ?
Optimize the dynamical range needed for your experiment
Increase stability, reduce/manage T and V dependence ?

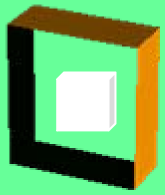
>>Can we read the scintillation light directly, without WLS?
(this requires larger PD area)

>>Reduce costs to the a few Euro level for large quantities

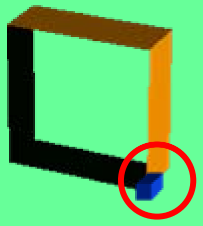
Direct coupling of SiPM and scintillator

2 examples, others could be poosible

Study on the 3cm x 3cm x 0.5cm tile

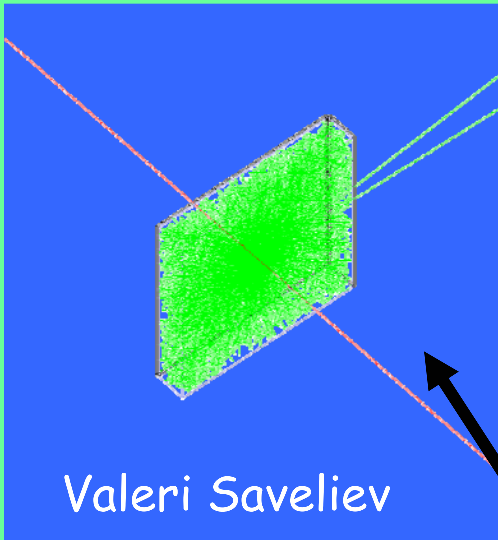


Where? Distribution of the emitted light from the scintillator: HOMOGENEITY



How? Technological improvement of the SiPM: EFFICIENCY

Light distribution studies

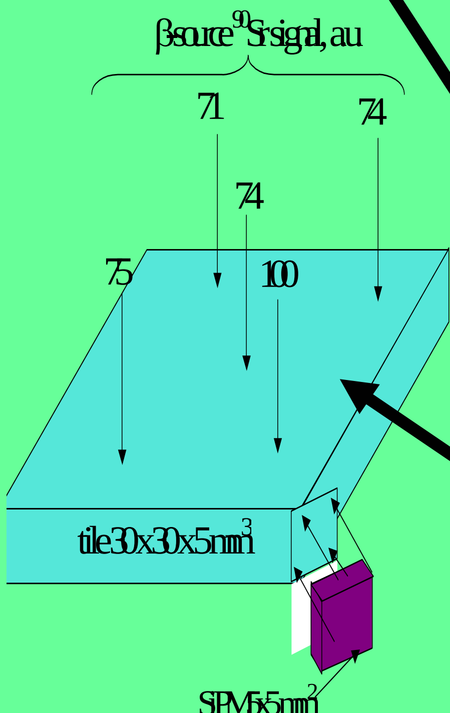


Geant 4 full simulation of the light propagation in the scintillation tile/photosensor module

6 GeV muons cross the tile

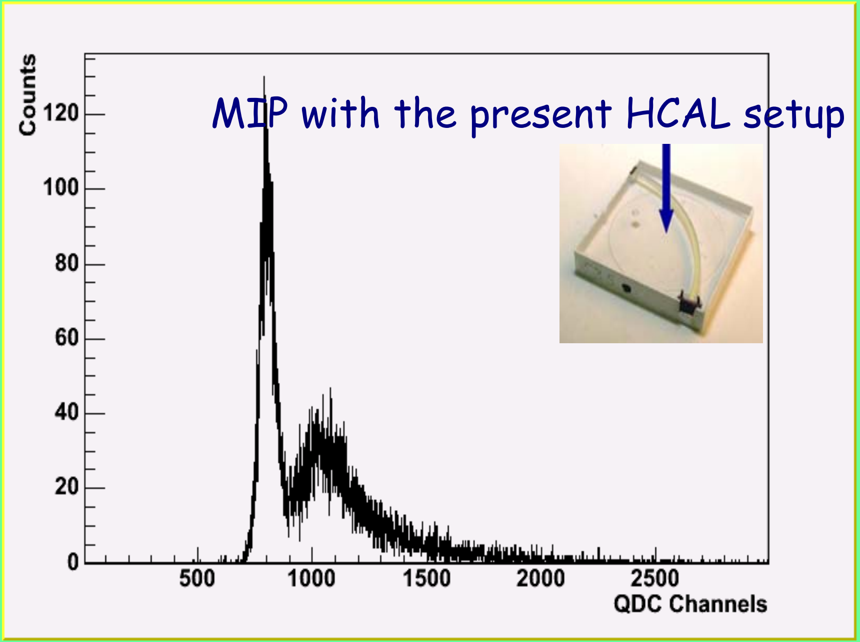
The light emitted on the surface is a factor 3 less than the one emitted on the edge

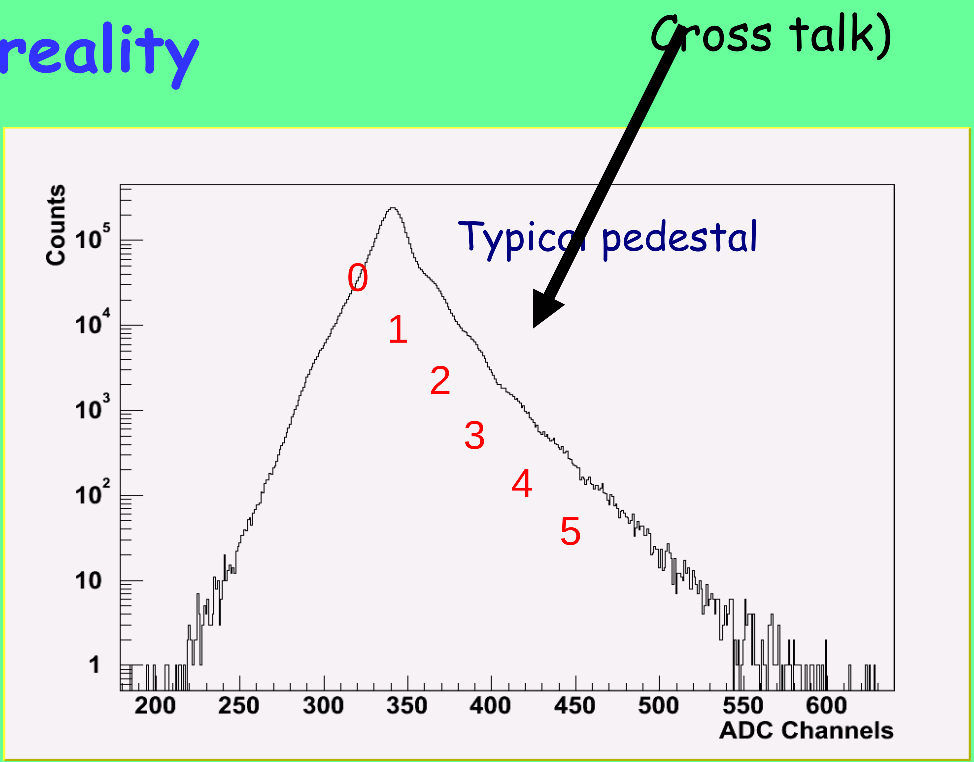
Setup for experimental verification of the MC studies in preparation



get rid of the local response non-uniformities

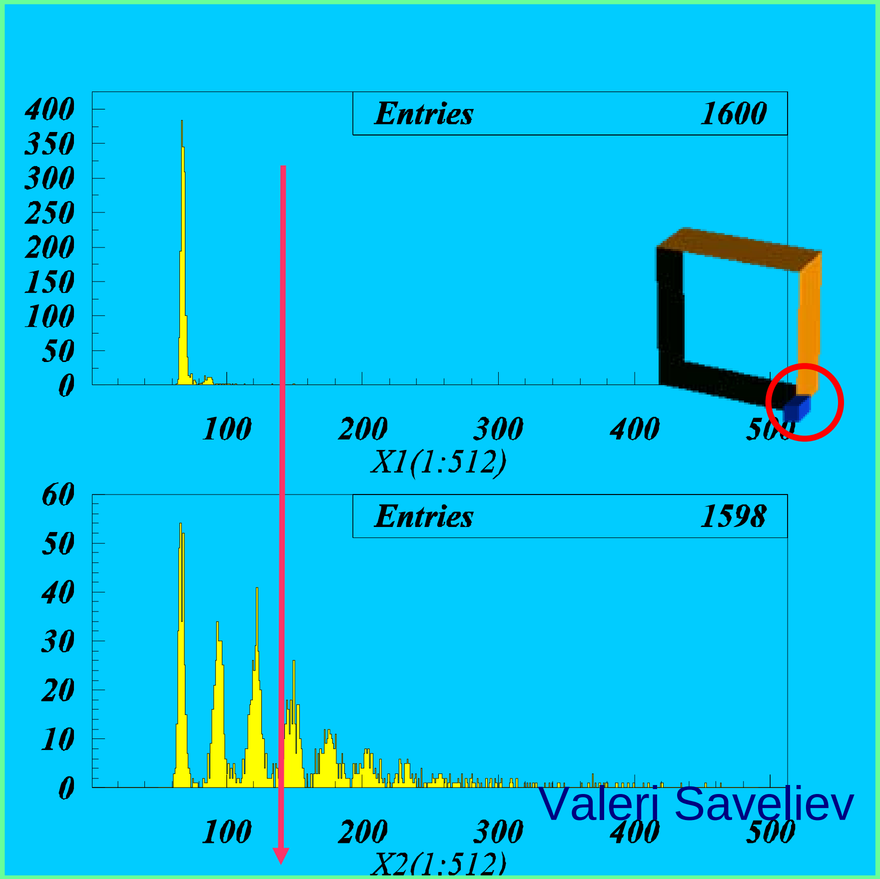
The reality





Minimization of the influence of the background noise
(caused by dark rate and cross talk)
Pure Poisson statistics, with no cross-talk:
95% efficiency with mean 5 p.e./MIP and a threshold cut at 1.5 p.e.
WANTED: In practice > 5 p.e./MIP

Increase of the area of the SIPM



Direct readout of blue emitting scintillation tile (3x3 cm, 5mm) with Teflon reflectors by "green sensitive" SiPM size 1x1 mm ~1100 microcells

(CPTA Moscow)

Cosmic Muons

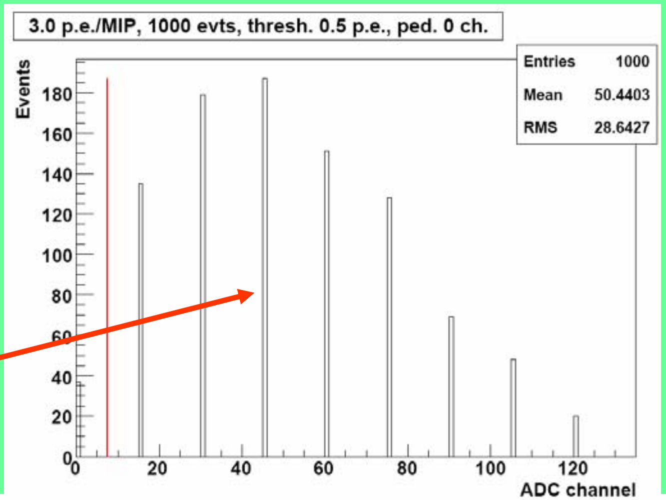
Mean value is 1.8 photoelectrons/mip (from Poisson Distribution)

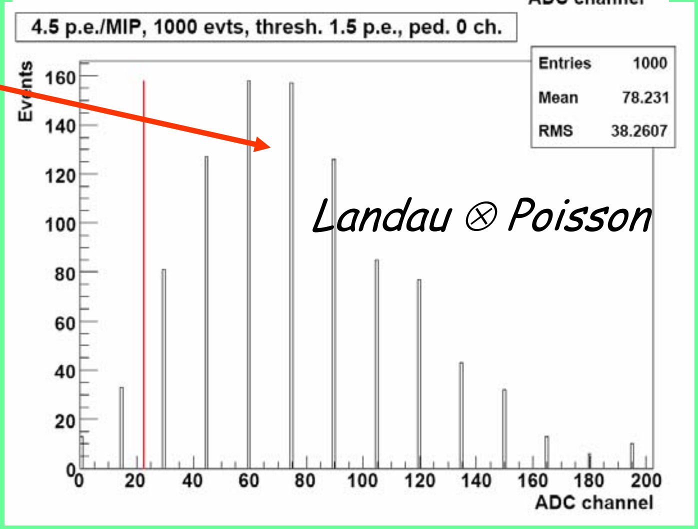
3 x more light connection needed (AREA)

Light yield limits

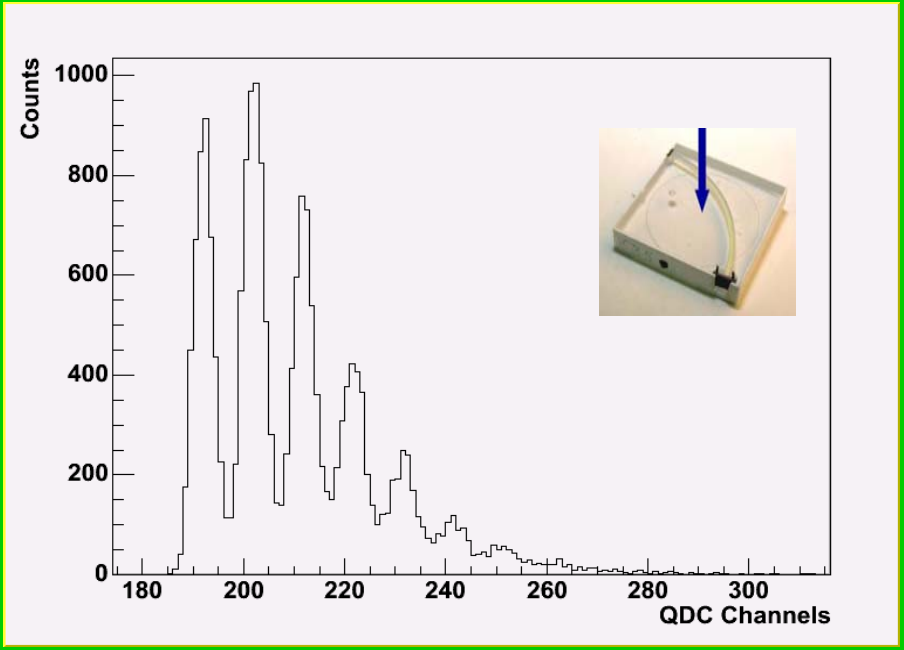
- Even with the best SiPM need minimum light yield
- Need 95% MIP efficiency with Poisson statistics
- No dark rate, no cross talk
  - Cut at 0.5 ph.e., need 3 ph.e / MIP
- Dark rate, but no cross talk
  - Cut at 1.5 ph.e, need 4.5 ph.e / MIP

- In practice
  - Finite peak width
  - Safety margin for robust fit
- **Will need ~ 7-8 ph.e. / MIP**





New Hamamatsu SiPMs :
after few production iterations, General features



400 pixels, larger, 1 x 1 mm2

Standard wavelength shifter green fiber coupling (HCAL)

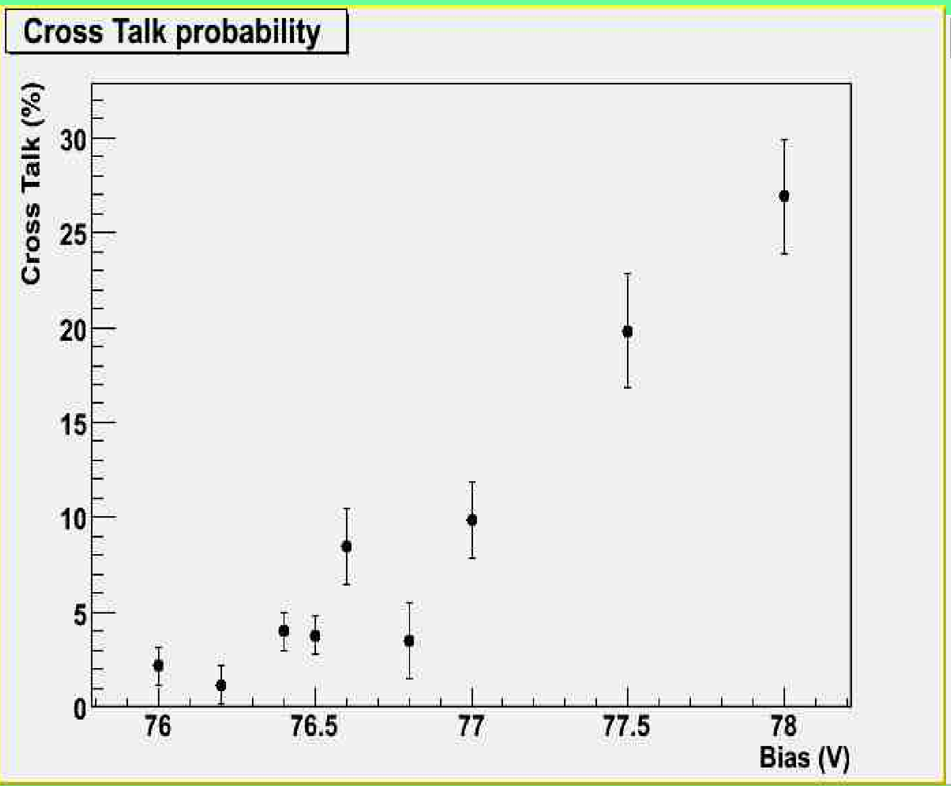
Higher efficiency in the green: Due to change in the technology

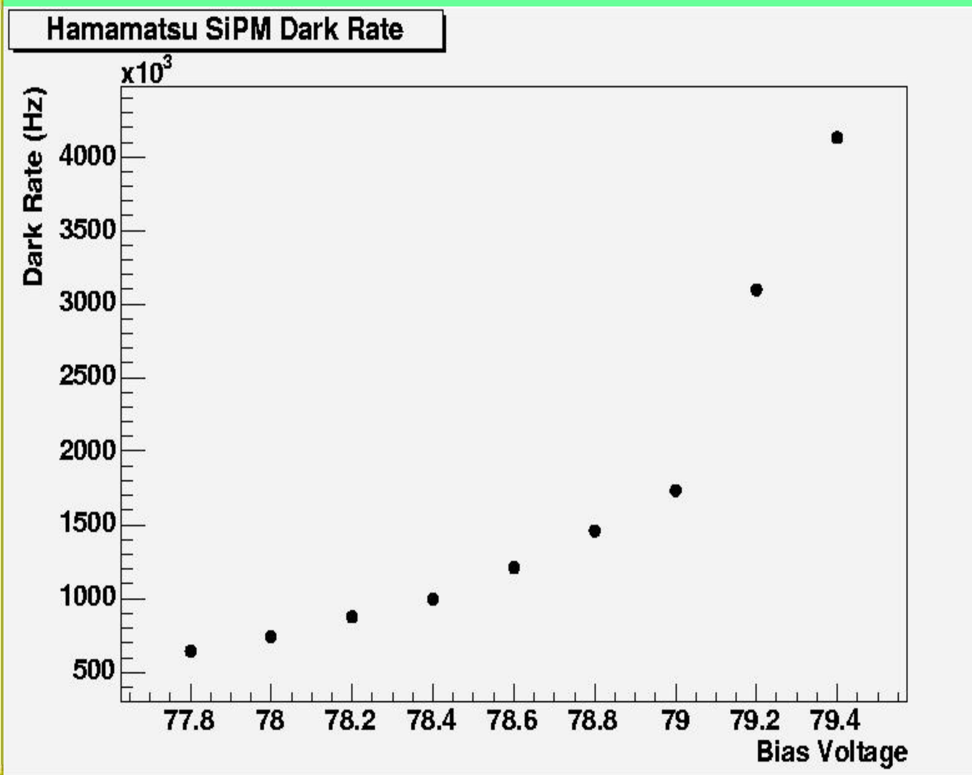
The results from the last Batch

	311-32A-003-DESY-2 (69V)	320-32A-007-DESY-1 (78V)	320-32A-007-DESY-2 (78V)
MIP response (px/MIP)	23.2(1)	36.6(3)	32.7(2)
Gain (ADC ch./px)	14.1(3)	21.5(3)	21.2(4)
dG/dU/G (%/V)	75(2)	47(1)	46(1)

MEPHI Type was about 16 pixels/MIP

Further studies on Hamamatsu SiPMs

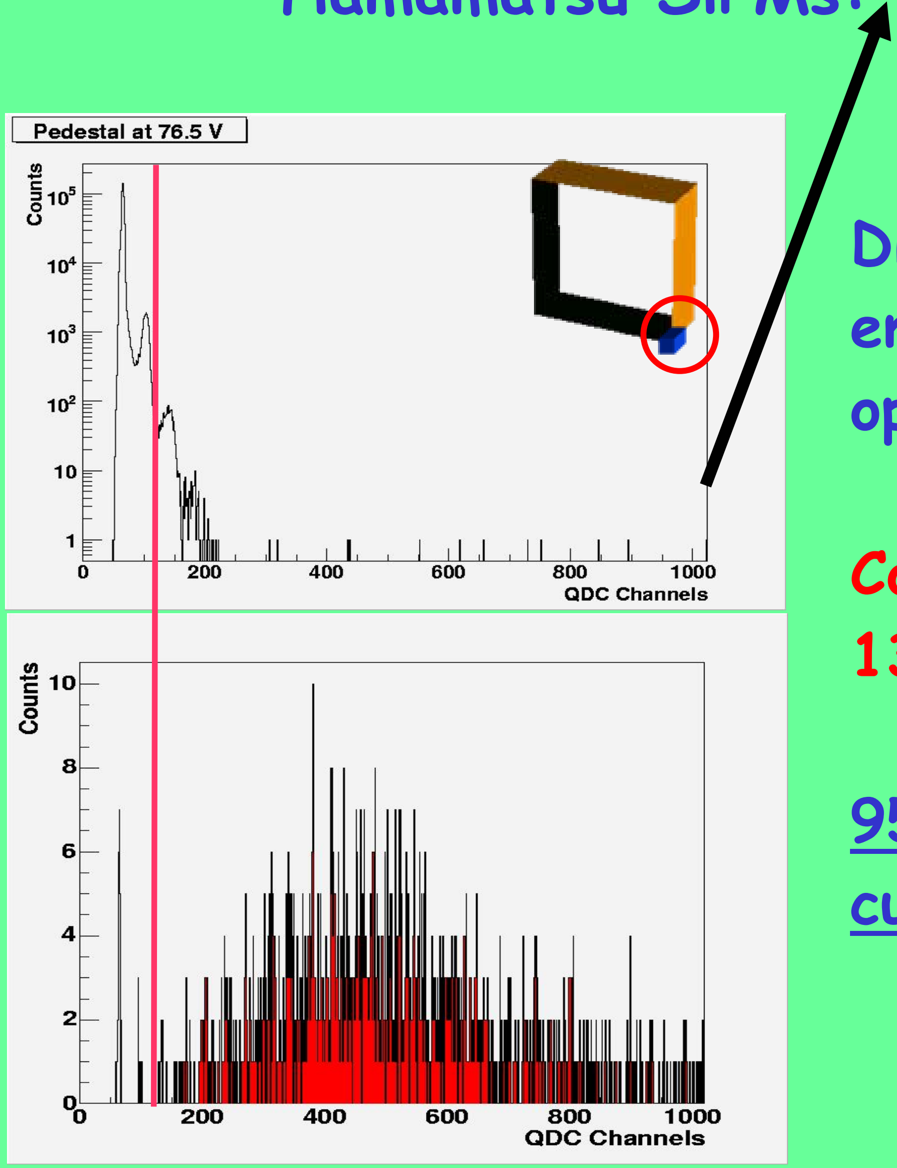




The cross talk probability is the deviation from the Poisson distribution, decreases your resolution

Cross Talk <10%, Dark Rate <500 KHz, Gain up to 6 10^5@ <77V

Hamamatsu SiPMs: blue sensitivity!

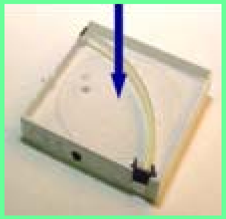


Direct coupling with a blue emission scintillator. No optical medium between.

Cosmic muons setup gives: 13.38(+-0.09) Pixels/MIP

95% MIP efficiency, with a cut @1.5 pixels.

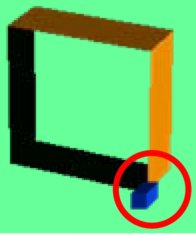
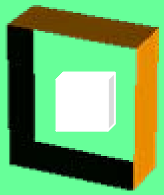
To conclude... direct coupling: where and how?

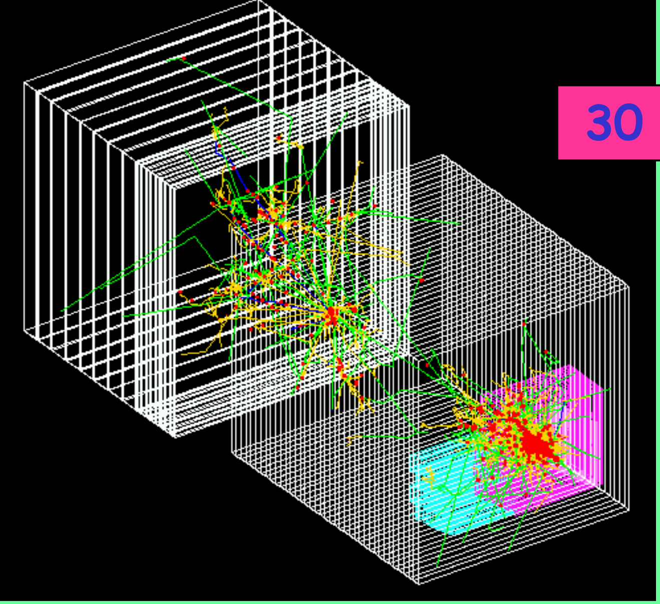


At the moment: green SiPM coupled with green fiber

15 pixels/MIP, ~1100 pixels -> ~80 MIP range

(NOISE !!!)

		
Green sens. ~1100 pixels (CPTA)	~1.8 pixels/MIP factor 3 area needed ~200 MIP range (TOO MUCH!)	0.6 pixels/MIP (simulation) factor 9 area needed ~200 MIP range (TOO MUCH!)
Blue sens. ~400 pixels (HPK)	~13 pixels/MIP ~29 MIP range (TOO FEW!)	~5 pixels/MIP (simulation) ~80 MIP range AT THE LIMIT (~ x2 needed)



30 GeV,p

Future, Calibration

Calibration and monitoring

Do we need the LED/PIN system
with light injection by fibres?
What is the precision in energy resolution we get
if we use MIPs only ??

MIPs from:

a) Halo
b) Cosmic
c) Branches in real events shower trees.

Simulation studies available, test beam results valuable!

How many MIPs or muons do we need for calibration?

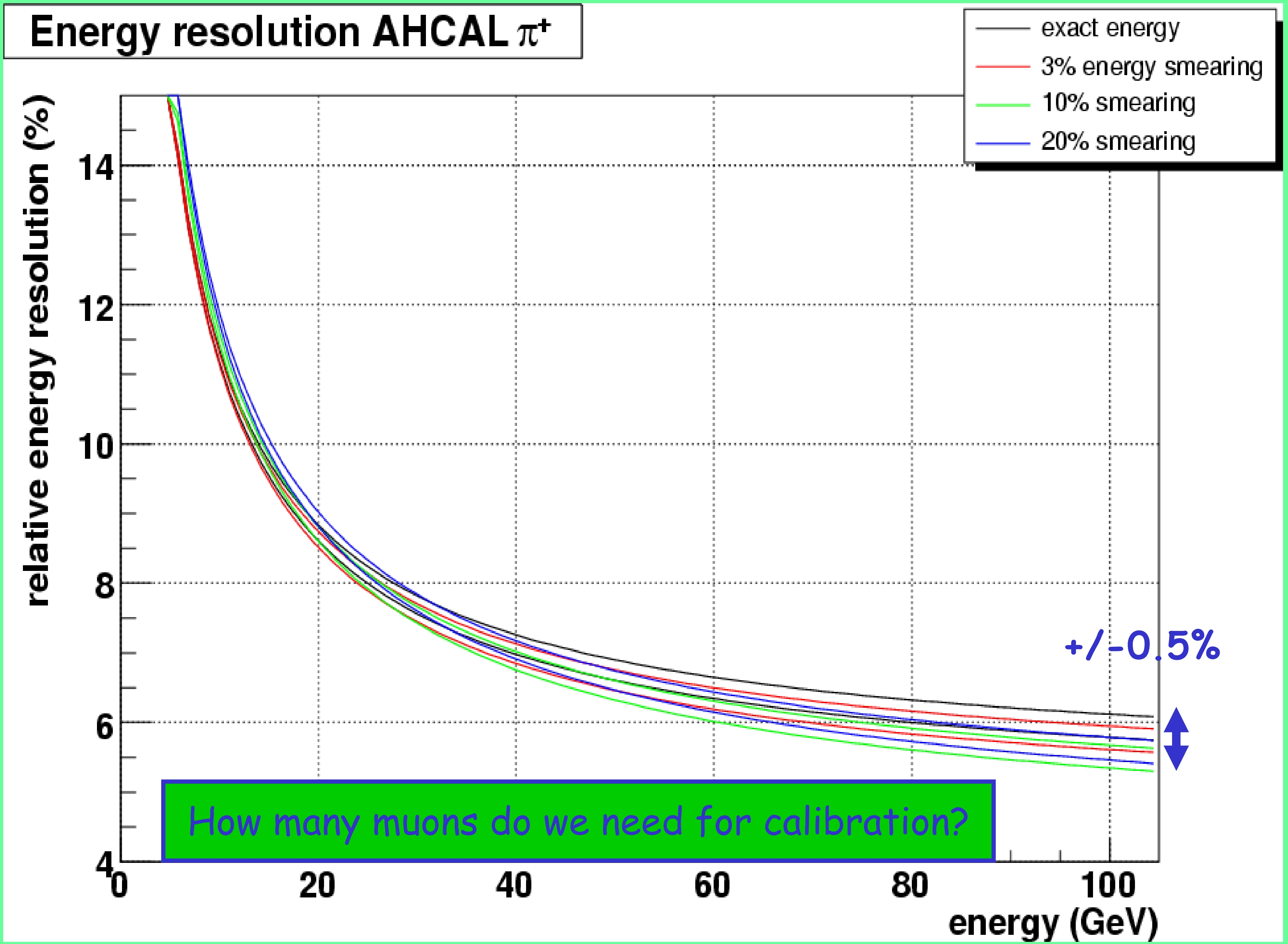
threshold: 3 p.e. repeats: 10000

$N_{p.e.}$ / MIP	Nevt	MIP efficiency (%)	MIP resolution (%)
15	100	100.000 ± 0.000	2.65 ± 0.21
	500	99.988 ± 0.000	1.77 ± 0.29
	1000	99.989 ± 0.000	1.24 ± 0.14
	5000	99.988 ± 0.000	0.55 ± 0.03
10	100	99.354 ± 0.008	3.59 ± 0.52
	500	99.361 ± 0.004	2.22 ± 0.35
	1000	99.365 ± 0.003	1.56 ± 0.17
	5000	99.359 ± 0.001	0.67 ± 0.03
8	100	97.285 ± 0.016	5.06 ± 1.36
	500	97.244 ± 0.007	2.2 ± 0.24
	1000	97.256 ± 0.005	1.8 ± 0.2
	5000	97.252 ± 0.002	0.78 ± 0.04
6	100	no fit possible because of threshold	
	500	89.547 ± 0.014	4.35 ± 1.56
	1000	89.537 ± 0.010	2.94 ± 0.67
	5000	89.534 ± 0.004	1.24 ± 0.12

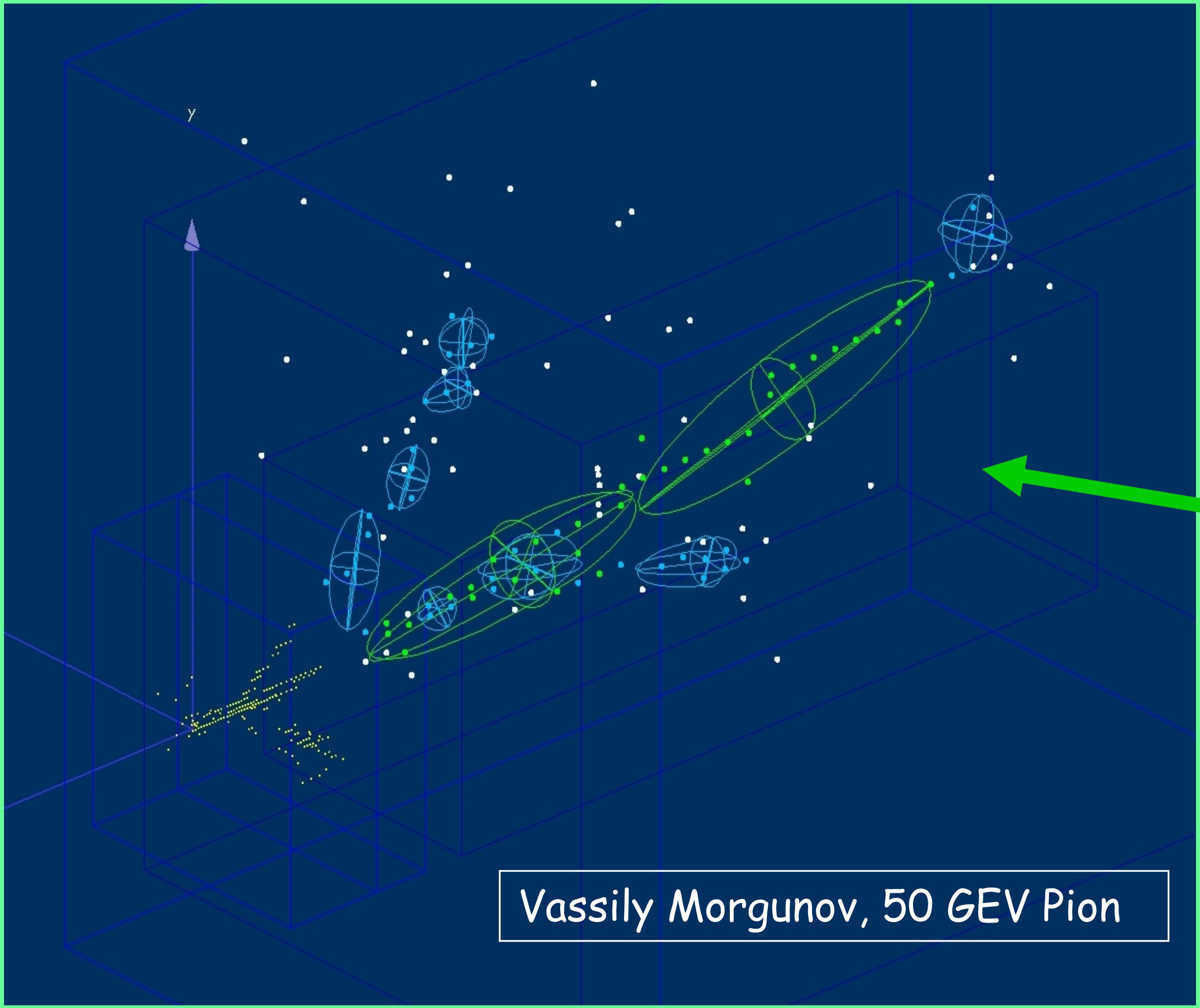
Many cells contribute to each single event

>> calibration precision statistically reduced

Need MIPs for best Calibration, thus Efficiency should be high

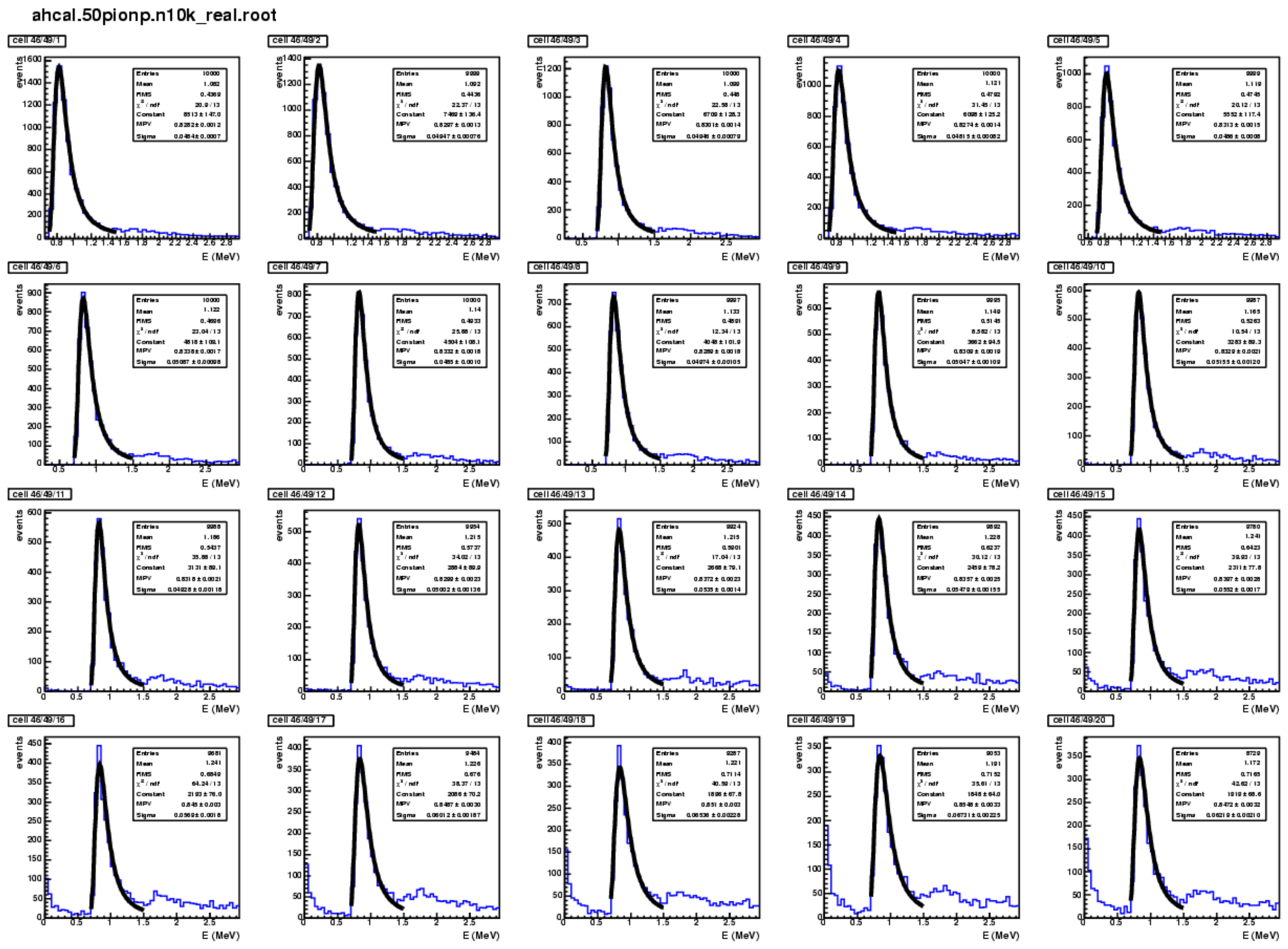

Energy resolution AHCAL π+
exact energy
3% energy smearing
10% smearing
20% smearing
relative energy resolution (%)
energy (GeV)
14
12
10
8
6
4
0
20
40
60
80
100
+/-0.5%
How many muons do we need for calibration?

Calibration with MIPs



MIPs

Calibration with MIPs

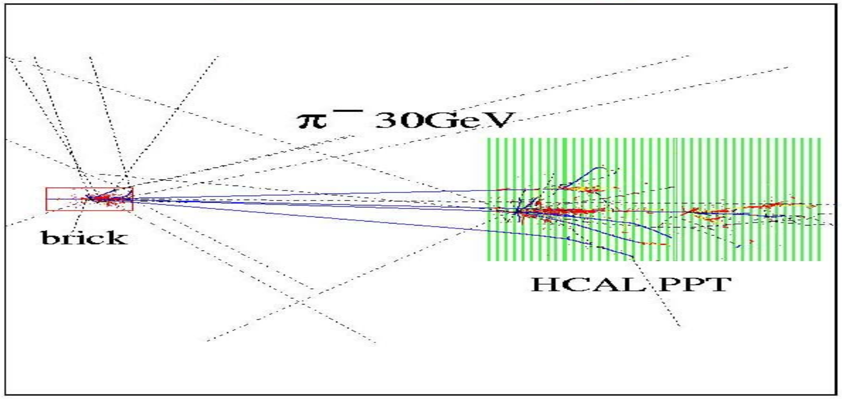


50 GeV pions,

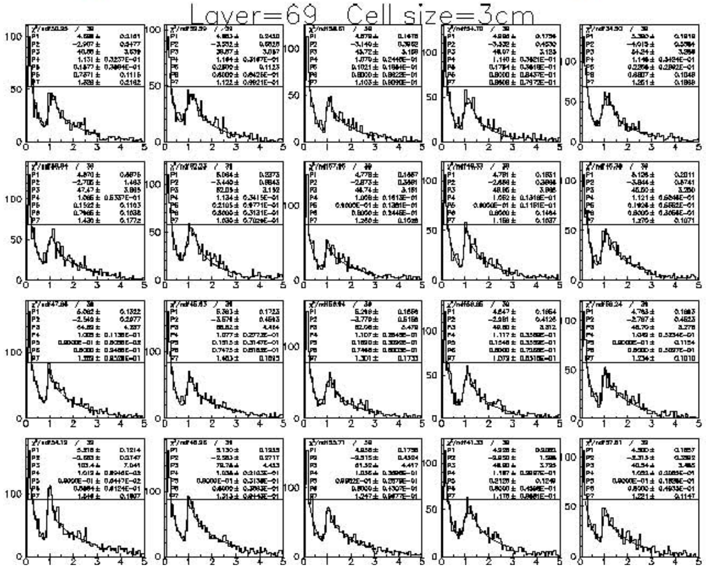
1 hit/plane

Cell Calibration with MIPs

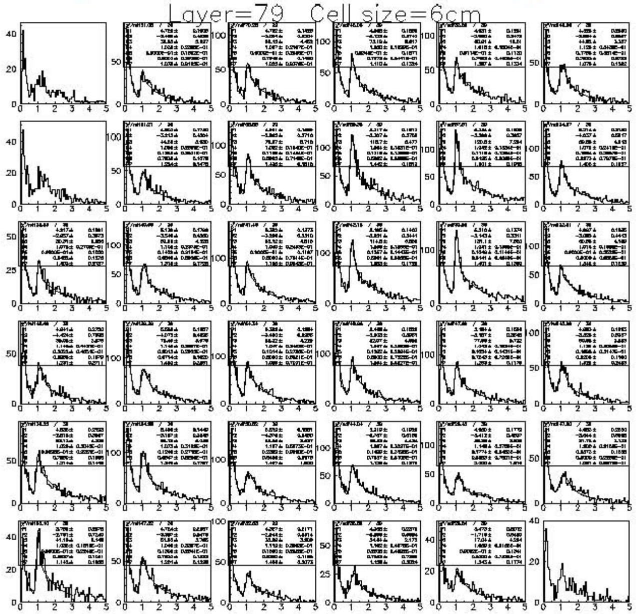
Proposed Experimental Setup (Illustration)



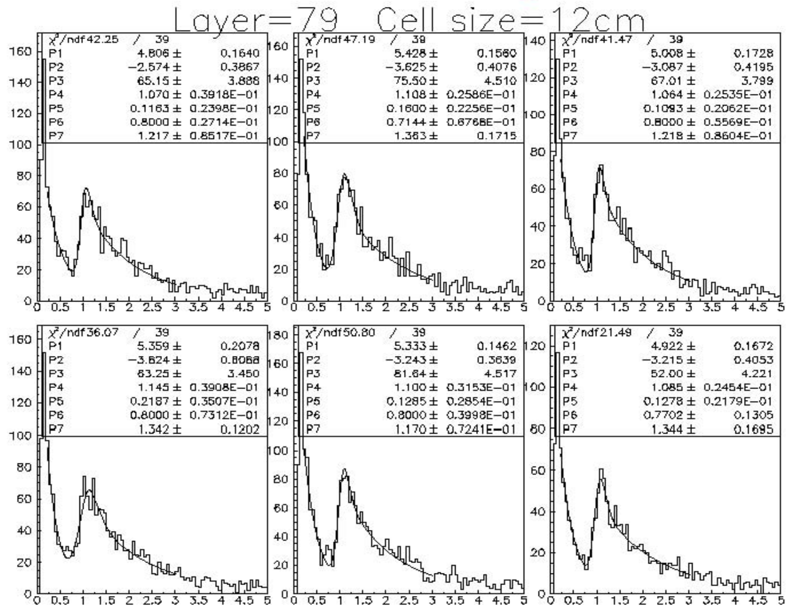
Hit spectra 3x3 cm² cells of one quadrant



Hit spectra 6x6 cm² cells of one quadrant



12x12 cm² cells of one quadrant

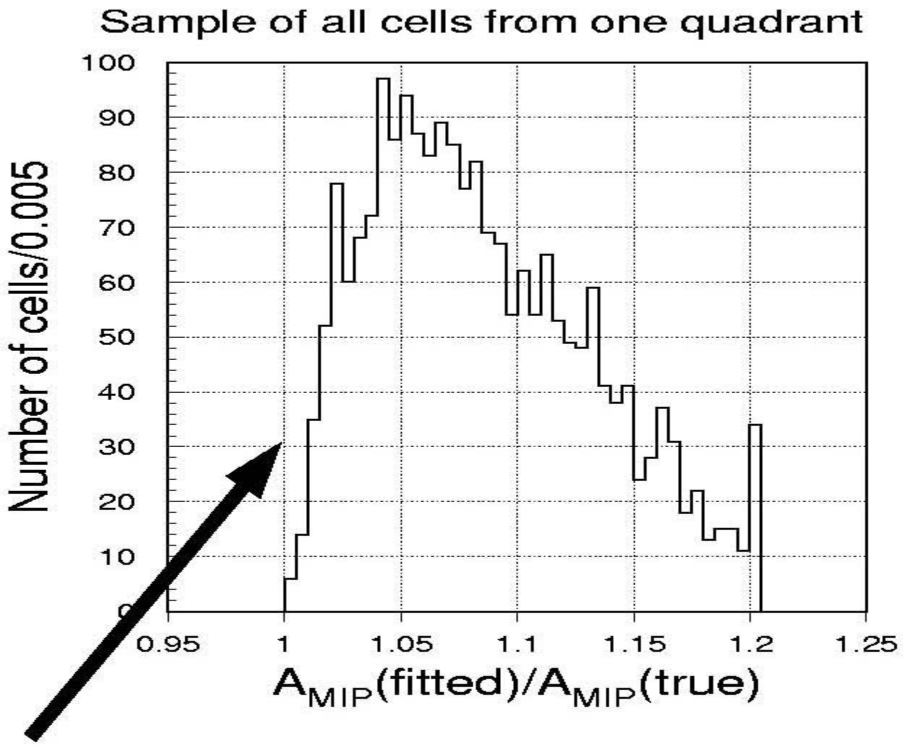


Cell Calibration with MIPs

Spectrum of fitted MIP peaks

MIP peak extracted by fitting hit spectrum is defined in units of true MIP

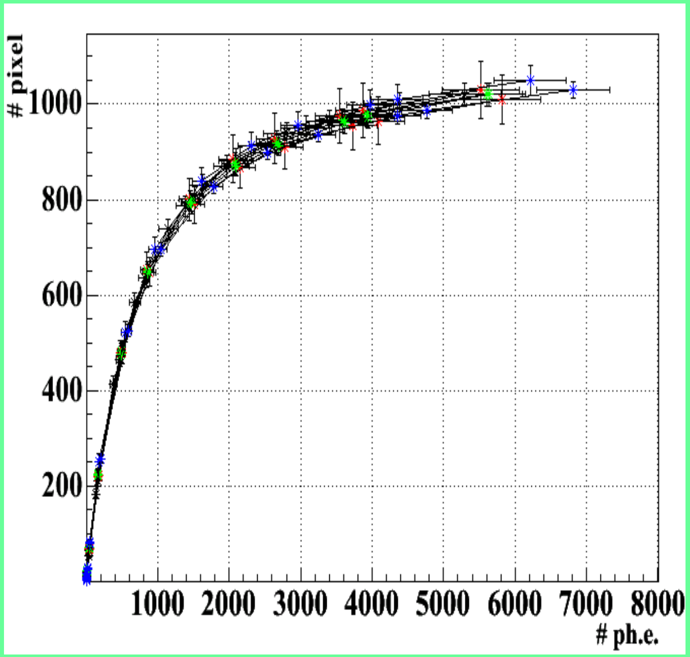
True MIP – peak in the distribution produced by MIP particle penetrating cell @ angle 90°

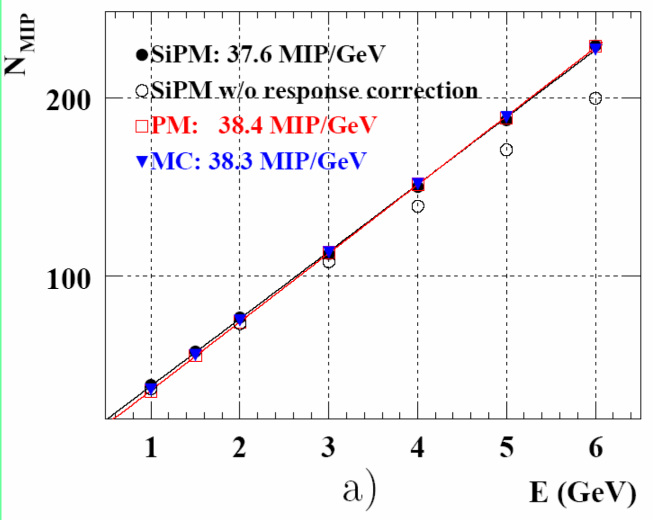


Shift in peak value w.r.t. true MIP position due to arbitrary angles (≠ 90°) at which MIP particles penetrate cells → source of systematics?

Dynamic range, non-linearity

- Required dynamic range is ~ 50 – 100 MIP
- Required calibration accuracy
  - ~ 20% for purely statistical variations
  - < 5% for systematic shifts
- Non-linearity < 5% (< 10% of pixels fired) translates into ~10'000 pixels (for LY = 15 px / MIP)
- We correct for non-linearity
  - Using uniform response function px=f_{resp}(ph.e)
  - Individual light yield of tile in px / MIP
- Successfully exercised with minical prototype

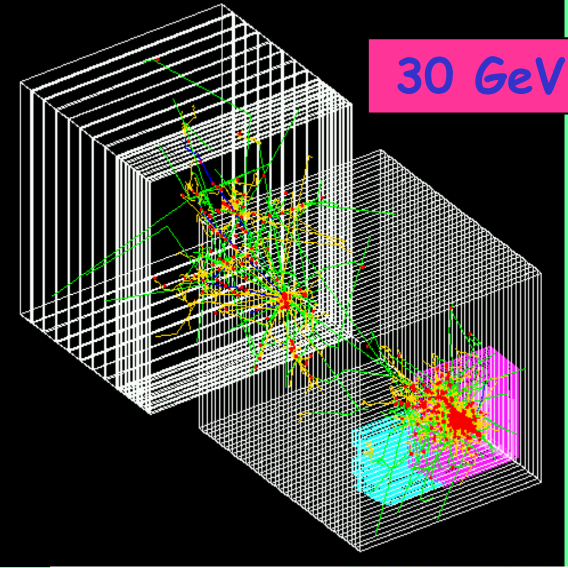




The new SiPMs from Hamamatsu

Based on our now many years of experience with the first SIPMs Hamamatsu encourage us to do more detailed systematic measurements

- **Bias voltage spread**
- **Increase of blue sensitivity**
- **noise (dark rate) reduction, we plan for o self-triggering detector**
- **Minimized inter-pixel cross-talk**
- **Gain vs preamp gain**
- **light yield (the response to a minimum ionizing particle (MIP) traversing the tile, measured in units of fired pixels), which provides a relative measure of photon detection efficiency**
- **Saturation, dynamic range**
- **Temperature dependence**
- **Radiation hardness, gammas (DESY, LINAC) and neutrons (Geesthacht??)**
- **Field test with a complete 216 channel calorimeter cassette**
- **Due to our very heavy duty in the 1m3 PT test, we invite collaborators to help us.**
- **All equipment is available for performance comparison**



30 GeV,p

Future, Time measurement??

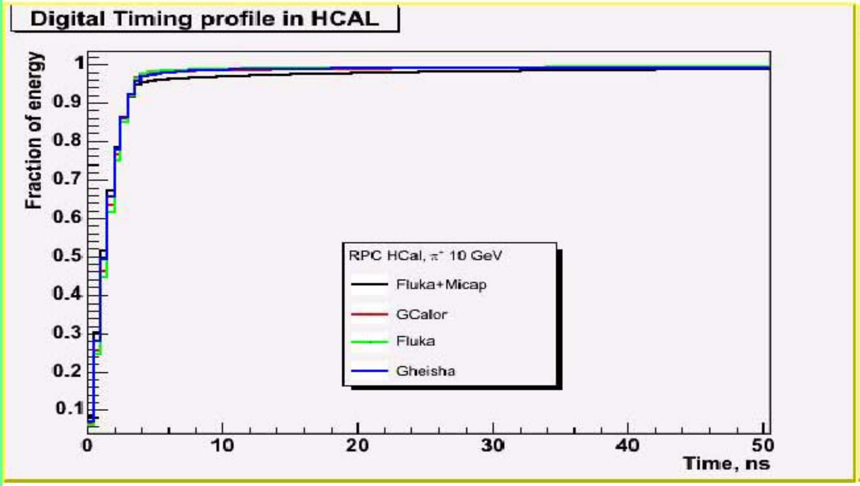
Time measurement in cells ?

--SiPM have excellent timing performance, few psec level.

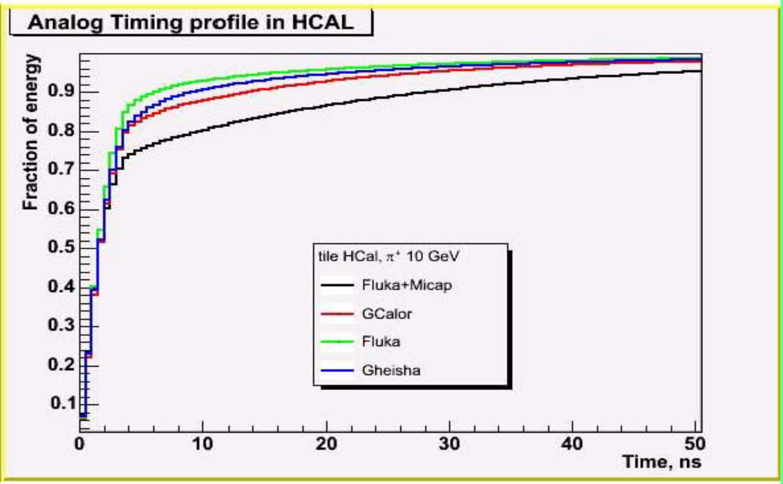
--Scintillator- has larger shower radius than Gas-Calo.

--Due to slow neutron component which fires single cells, time measurement to exclude such hits.

RPC HCAL



Tile HCAL

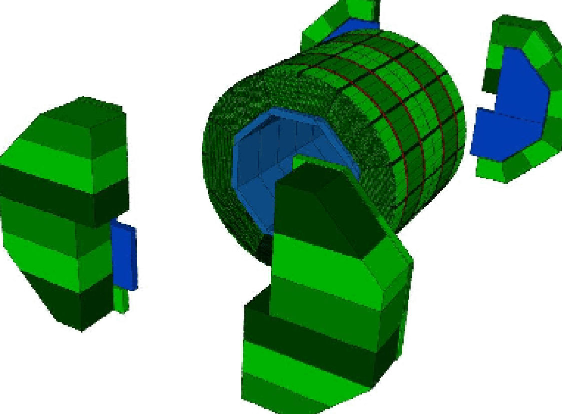


Timing profile has fast component ~5ns and tail

Fraction of visible deposited energy in the tail :

2% for RPC HCAL and 10-25% for tile HCAL

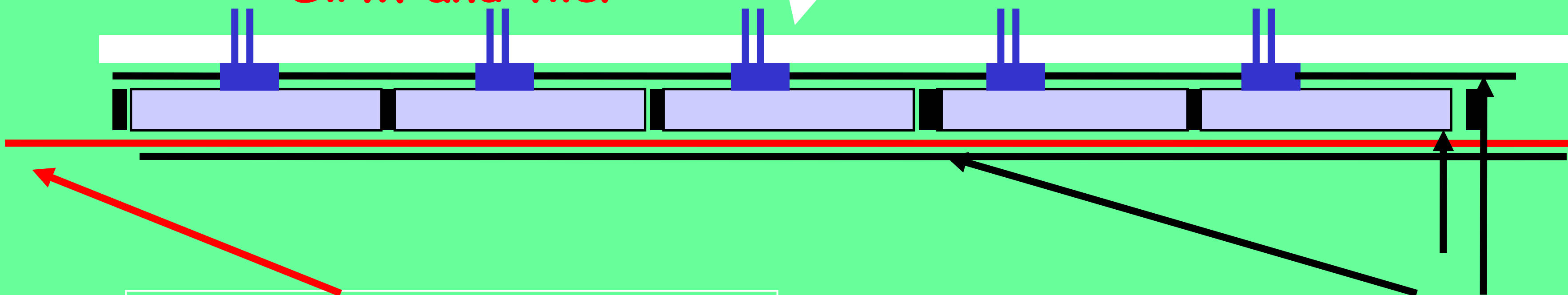
Reason : lower sensitivity of RPC gas to slow neutrons



A ROB concept to be studied

ROB, housing:
SiPM
Bias voltage
Preamps, shaper and S&H memory
18 fold?
Clock for time measurement?

Problem!
Light contact between
SiPM and tile!



1mm thick quartz fibre,
Type party fibre,
Injects light in 1 row of tiles

3M Super reflector,
Glued on a grid,
To house the tiles,
Gets rid of the tile tolerances

Advantage: ROB can be fully equipped on a test bench,
housing a reference tile array and reference quartz fibres