CALICE Scintillator ECAL beam test @ DESY

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for the CALICE collaboration

ECFA2008 @ Warsaw

Introduction

Scintillator ECAL module

Beam test @ DESY

Detector calibration

Detector response to EM showers

Future plans

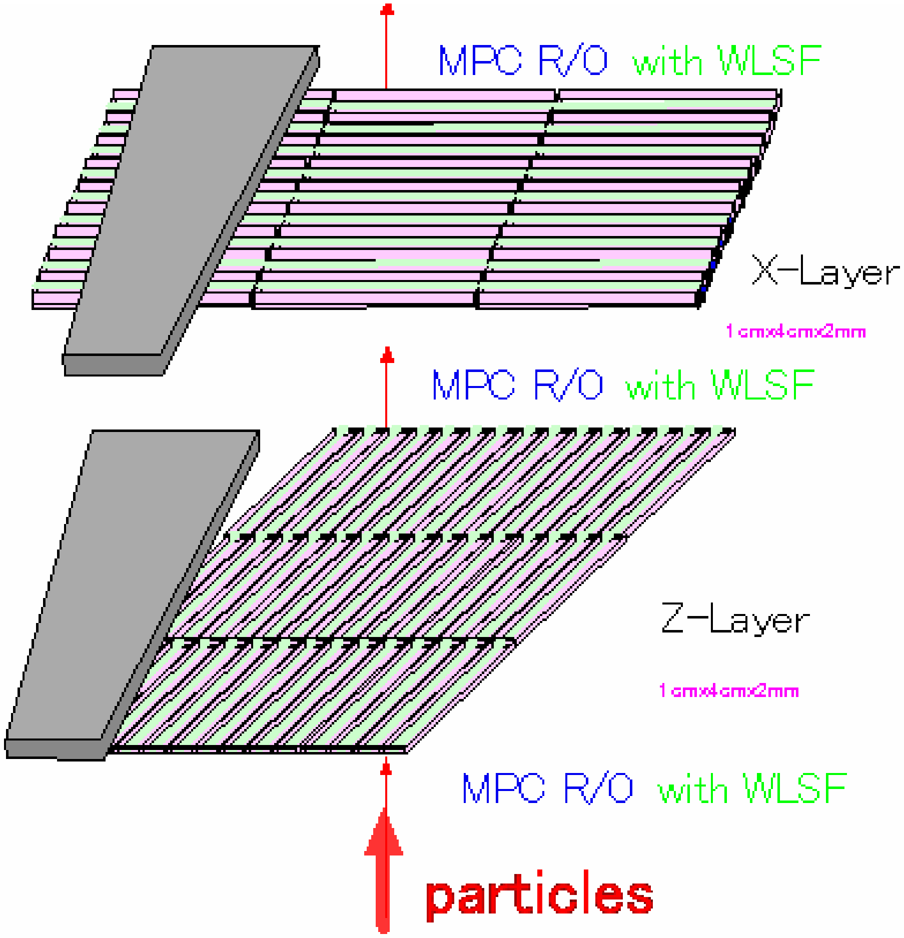
strip scintillator calorimeter for an ILC detector

sampling calorimeter
- active material: scintillator
- absorber: Tungsten

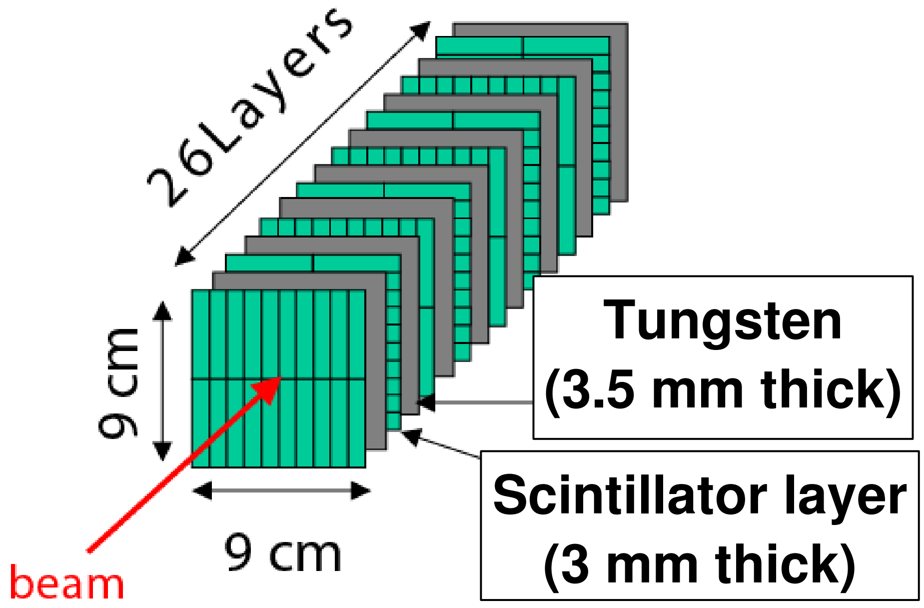
designed for PFA: fine segmentation
- scintillator strips ~1x4 cm^2
- orthogonal layers

each strip read out by MPPC
- photon counting device from Hamamatsu Photonics

built and tested small prototype
- first test of scintillator + MPPC calorimeter
- check suitability for ILC ECAL

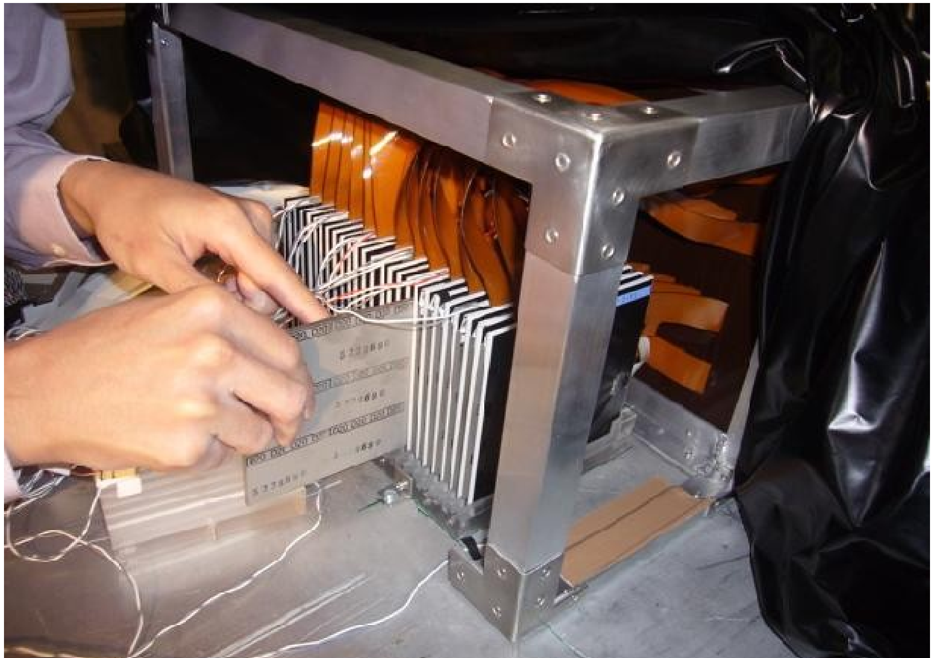


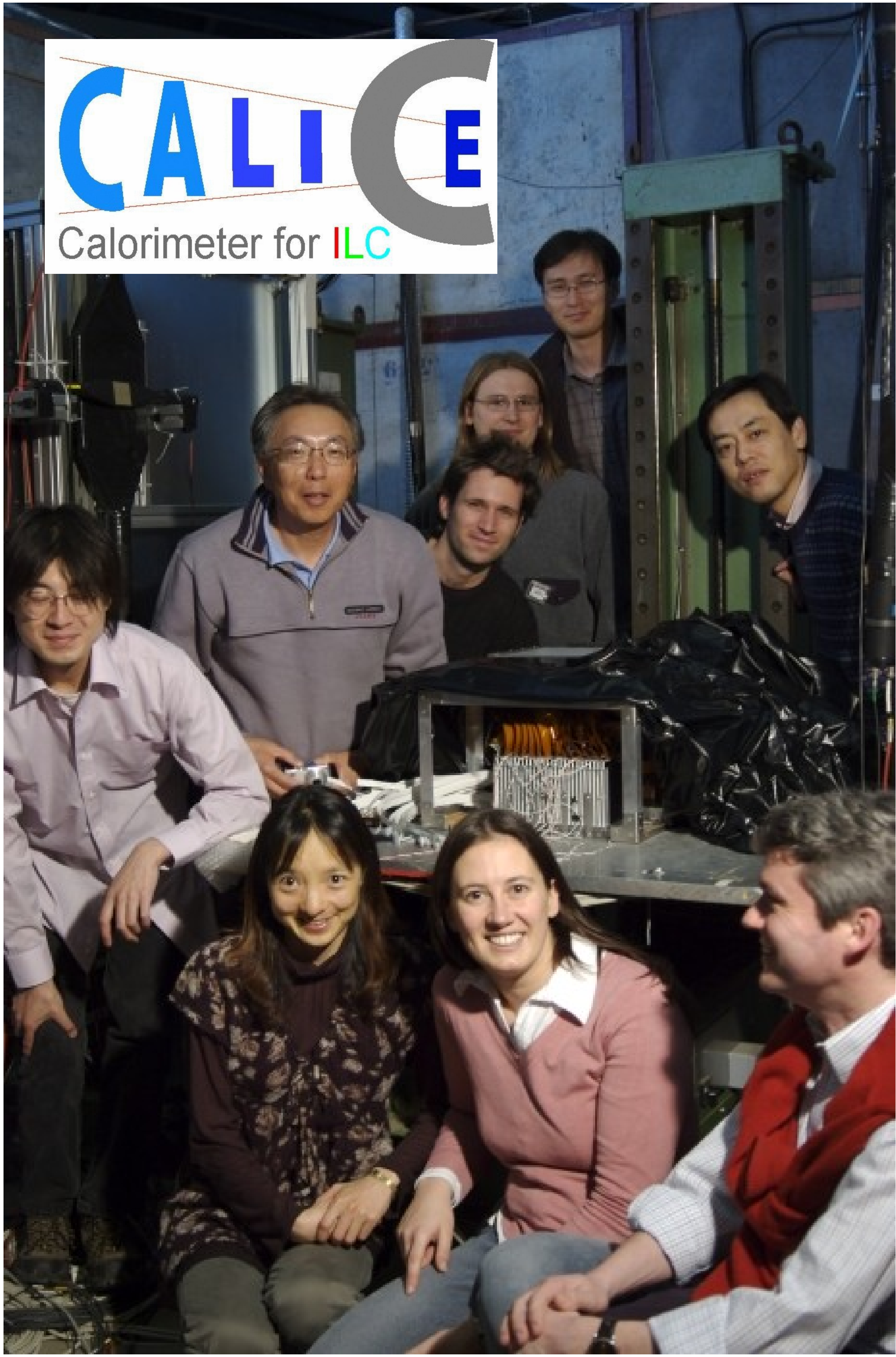
exposed to 1-6 GeV e+ beam at DESY 03/07



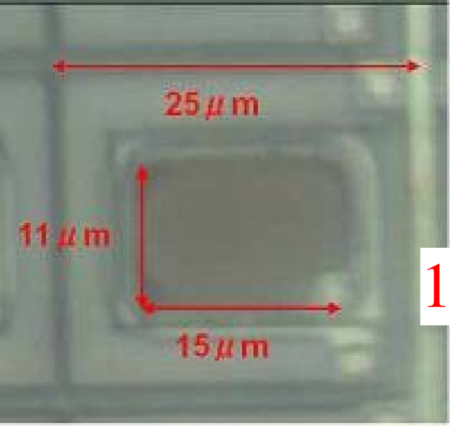
Tungsten (3.5 mm thick)

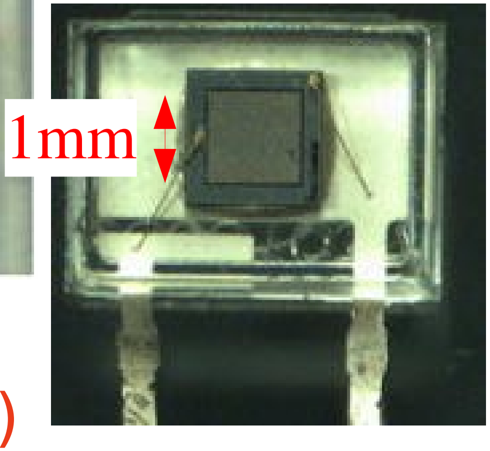
Scintillator layer (3 mm thick)

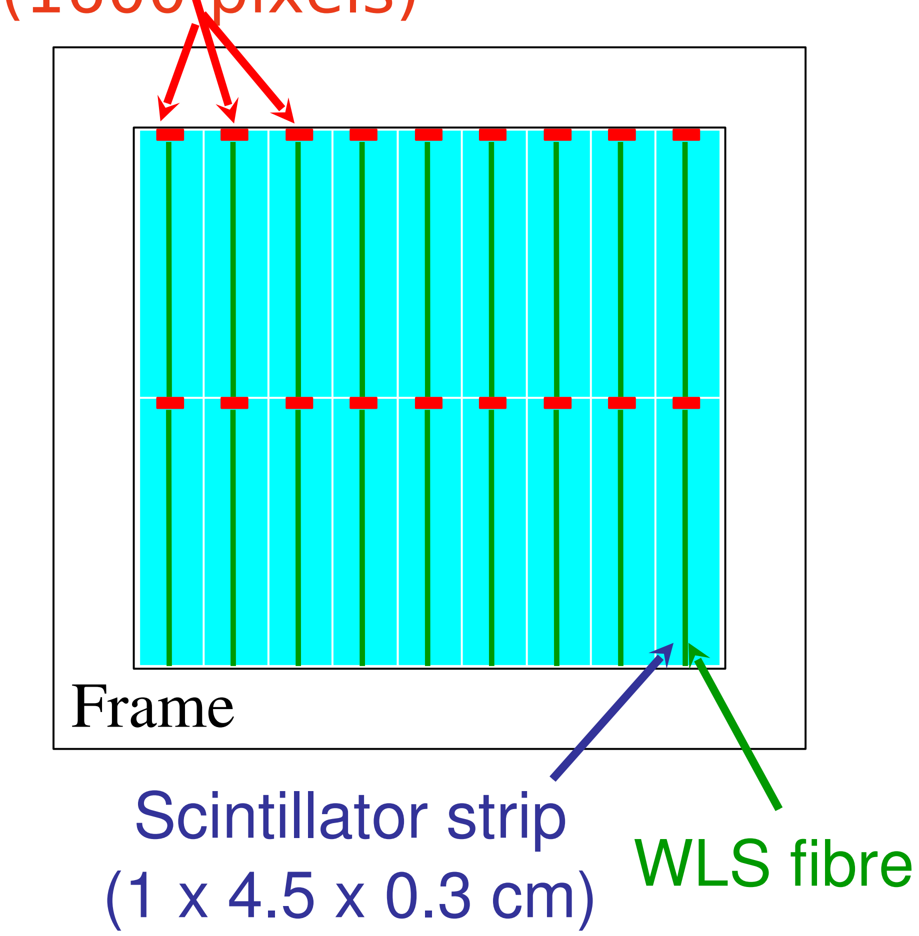




Detector setup, scintillator types







MPPC: good photon detection efficiency, compact size, reasonable price

3 types of scintillator strips:
Kuraray (Megastrip)
- WLSF readout
- direct readout (simpler)

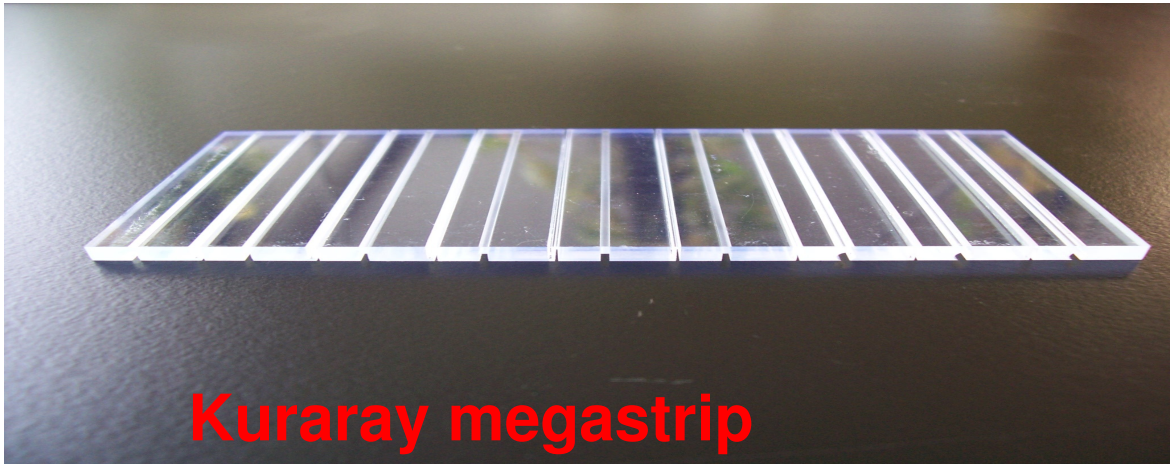
Misung Chemical Company (Korea) & Kyungpook National University
- individual extruded strips (inexpensive)
- co-extruded TiO_2 covering
- WLSF readout

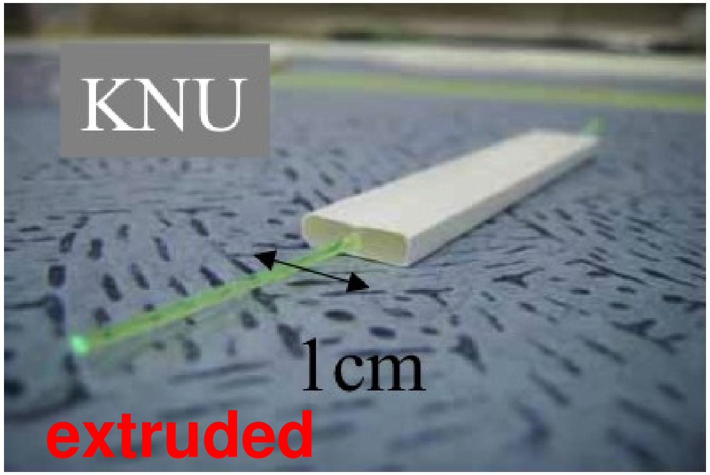
~12 p.e. per MIP

CALICE readout electronics and DAQ
(from LAL-Orsay, DESY, UK groups)
same as used by CALICE Analogue-HCAL group

produced 3 half-modules (13 layers each)
with different scintillator types

tested 3 configurations
- Kuraray (fibre) + Kuraray (direct)
- Kuraray (direct) + Kuraray (fibre)
- Extruded (fibre) + Kuraray (fibre)

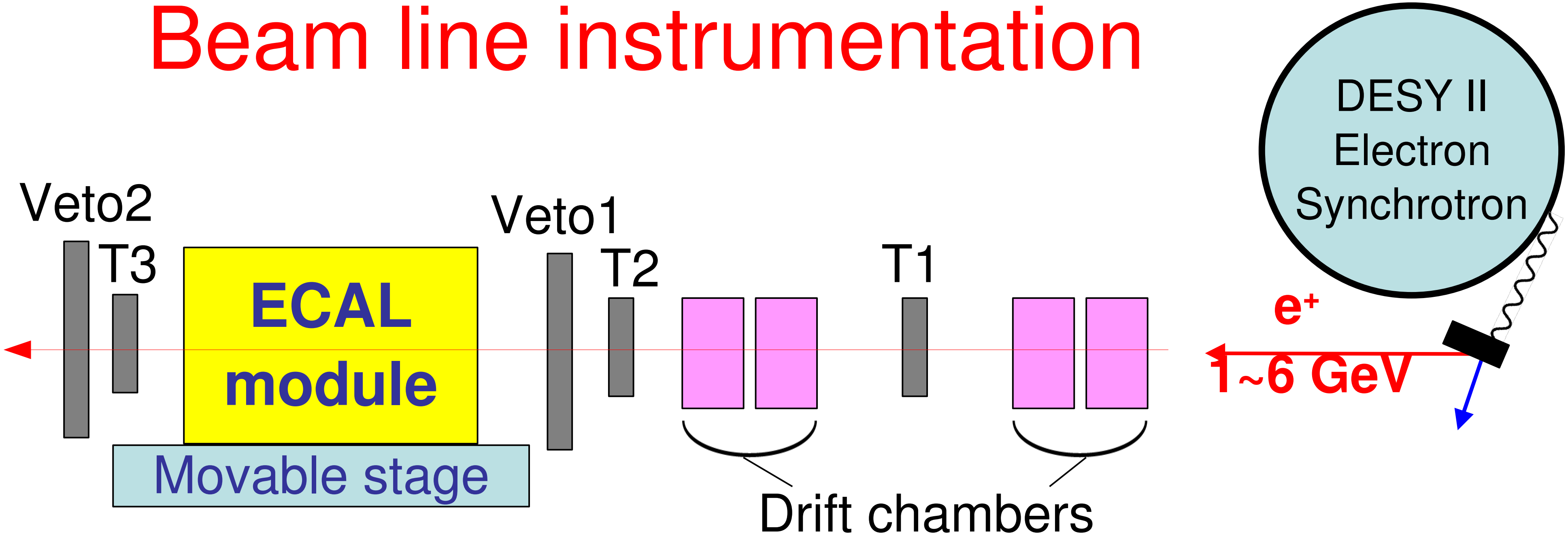

Kuraray megastrip

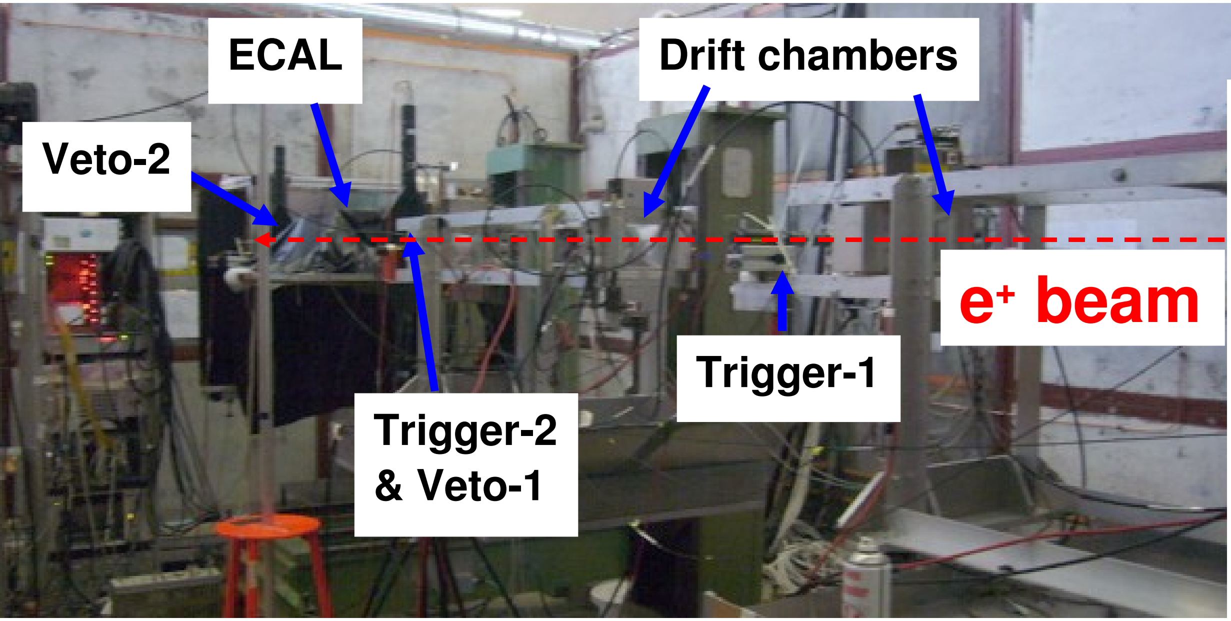


extruded

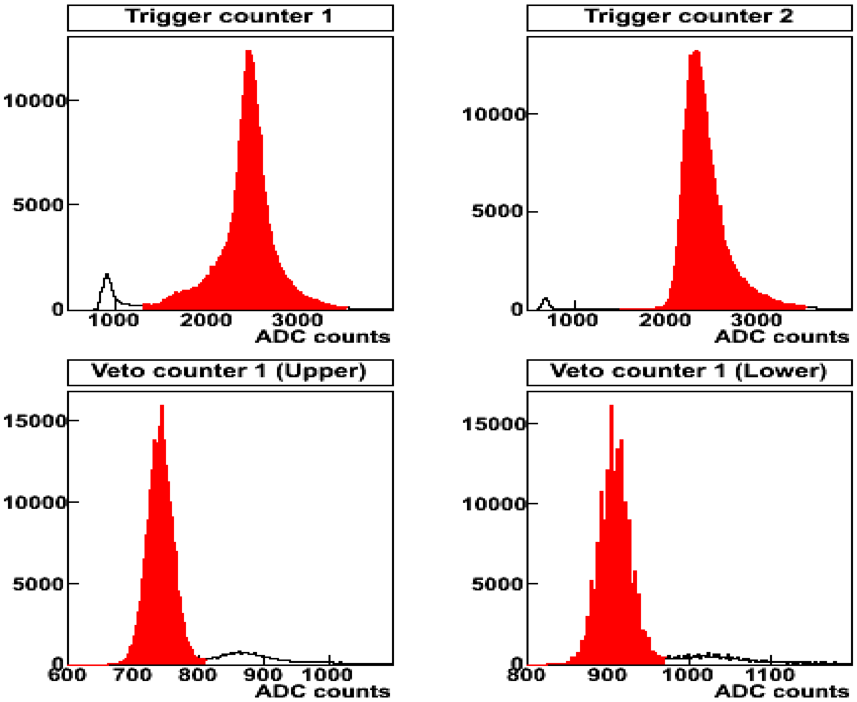
compare performance of configurations

Beam line instrumentation





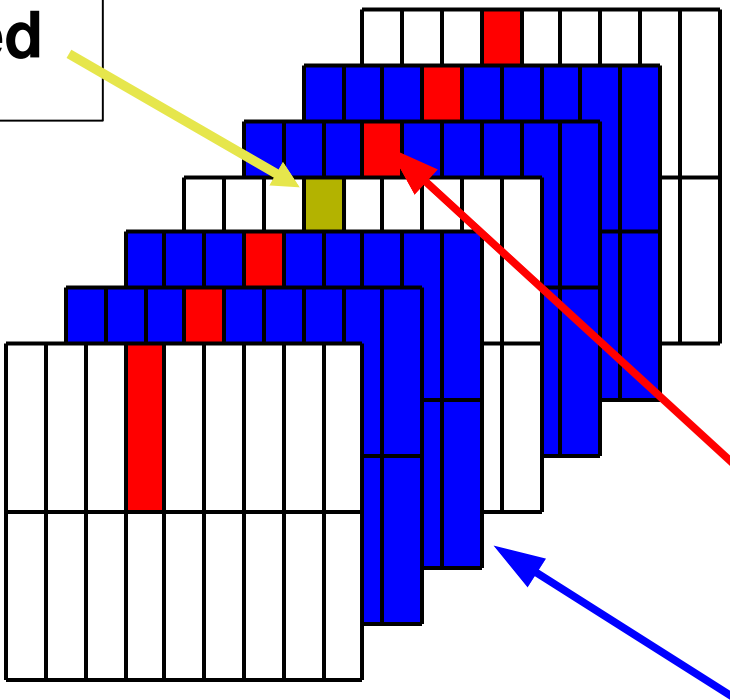
Trigger & veto

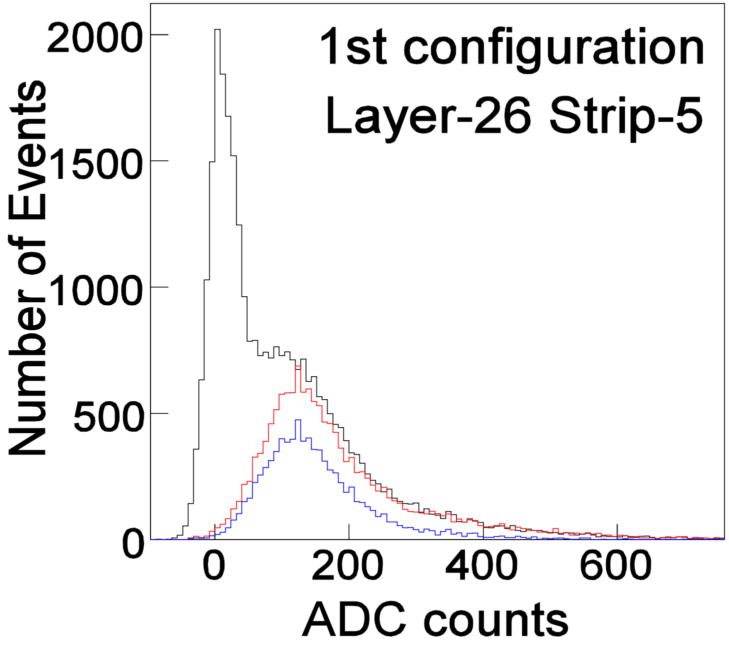


detector calibration

e+ beam, no W plates

Strip being calibrated

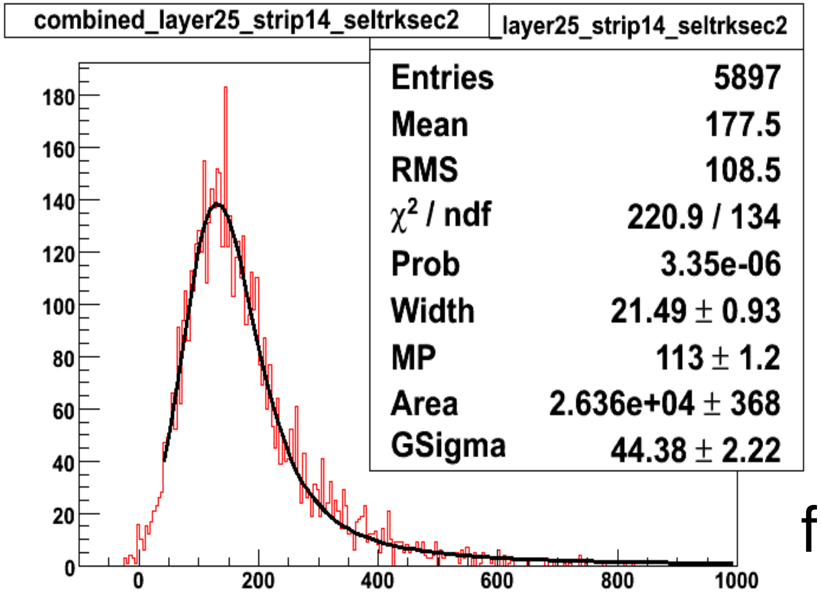




Trigger only

Red strips have non-pedestal signal

Blue strips have only pedestal signal



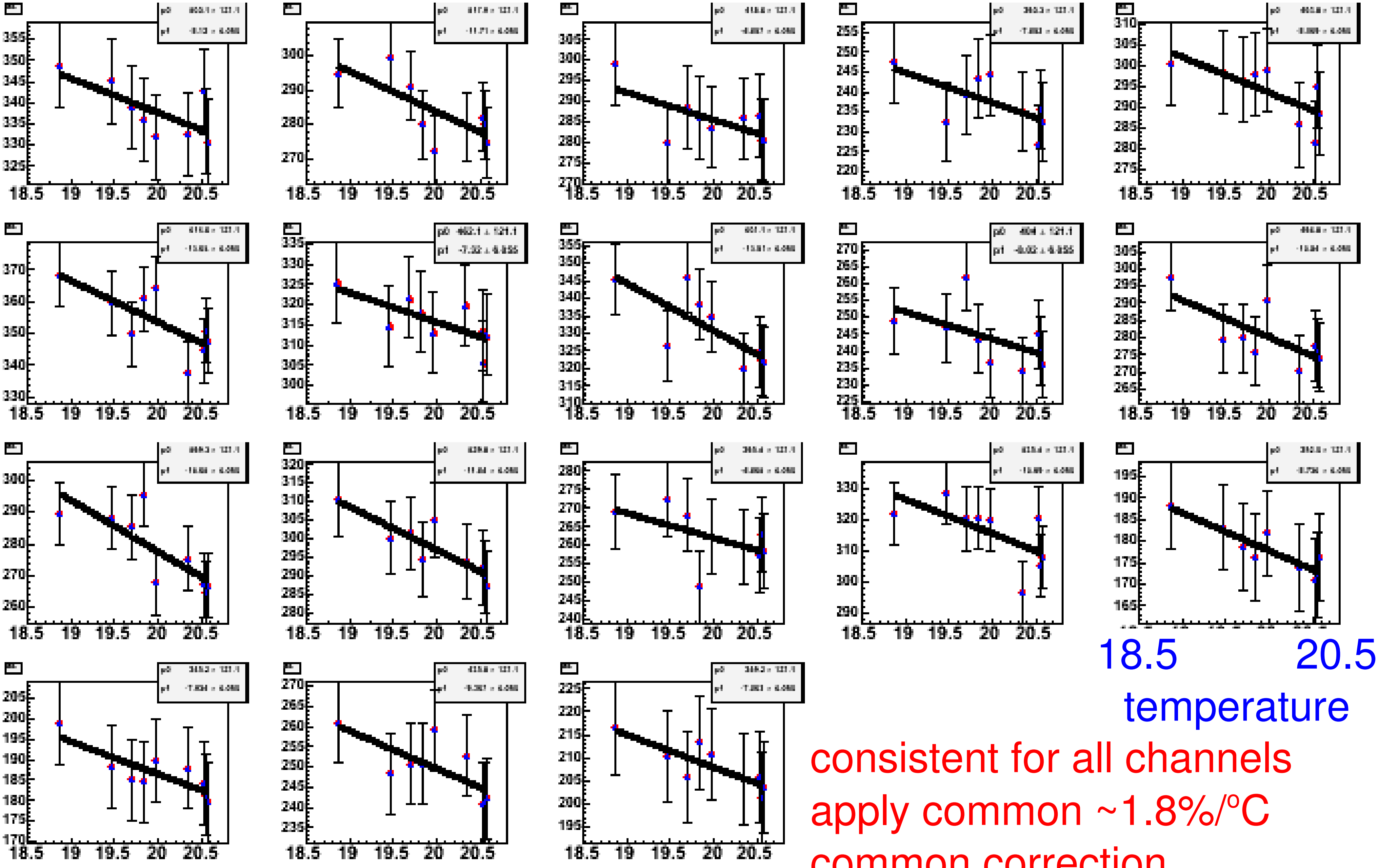
Entries	5897
Mean	177.5
RMS	108.5
χ^2 / ndf	220.9 / 134
Prob	3.35e-06
Width	21.49 ± 0.93
MP	113 ± 1.2
Area	2.636e+04 ± 368
GSigma	44.38 ± 2.22

fit to Gaussian-convoluted Landau

MIP response temperature dependence

MPPC properties change with temperature

example: 18 strips in one layer



consistent for all channels

apply common ~1.8%/°C

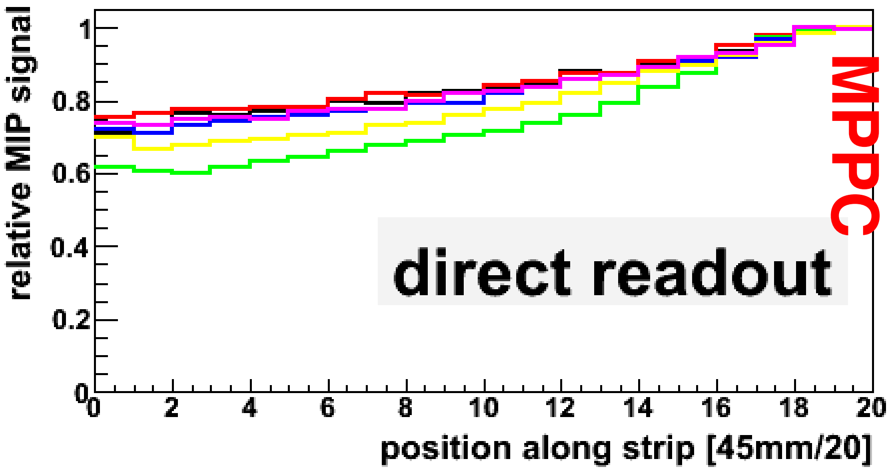
common correction

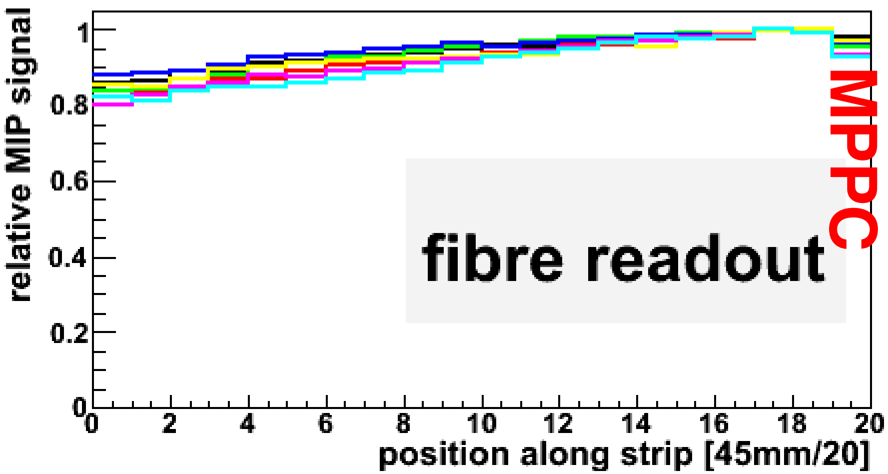
MIP response uniformity

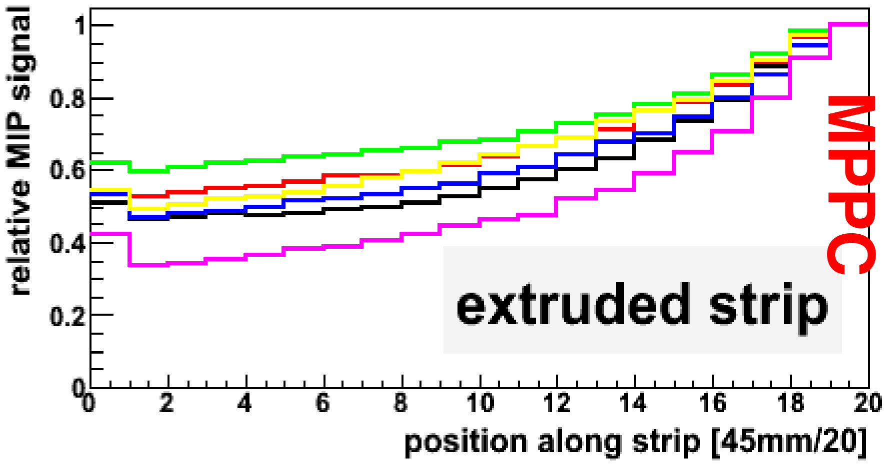
extruded strips show significant
non-uniformity

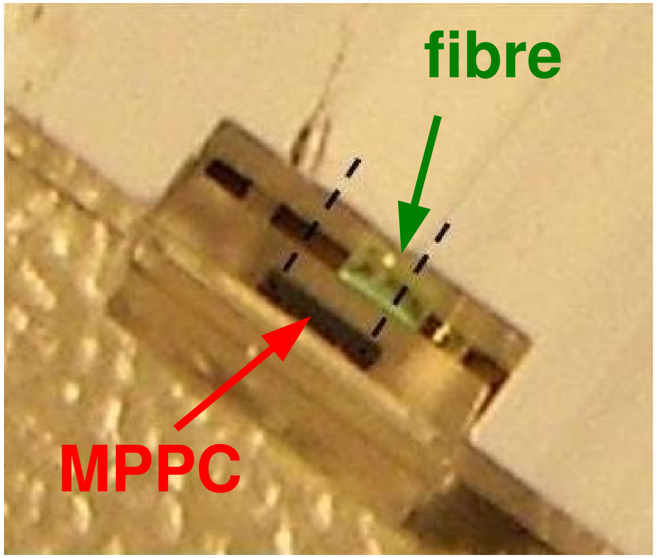
fibre-MPPC matching found
to be bad in some extruded strips
mixture of fibre & direct light

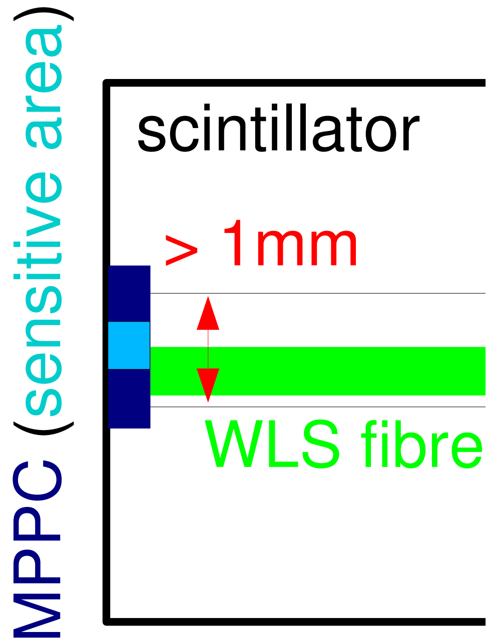
checked in dedicated beamtest @ KEK
improved extruded scintillator
now in production



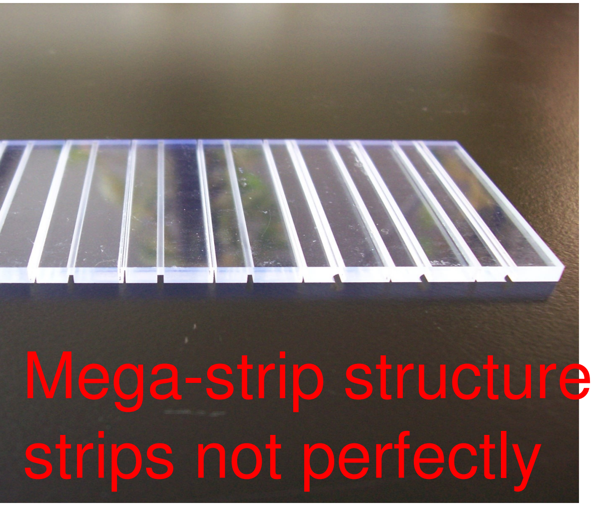




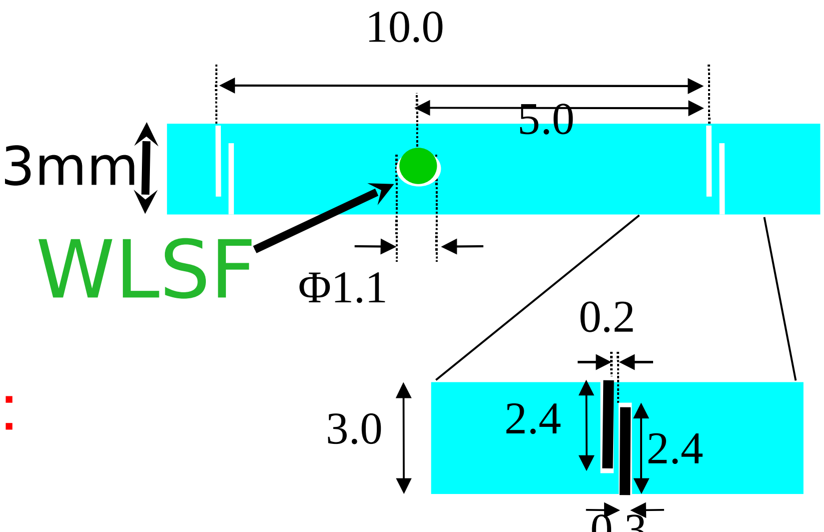


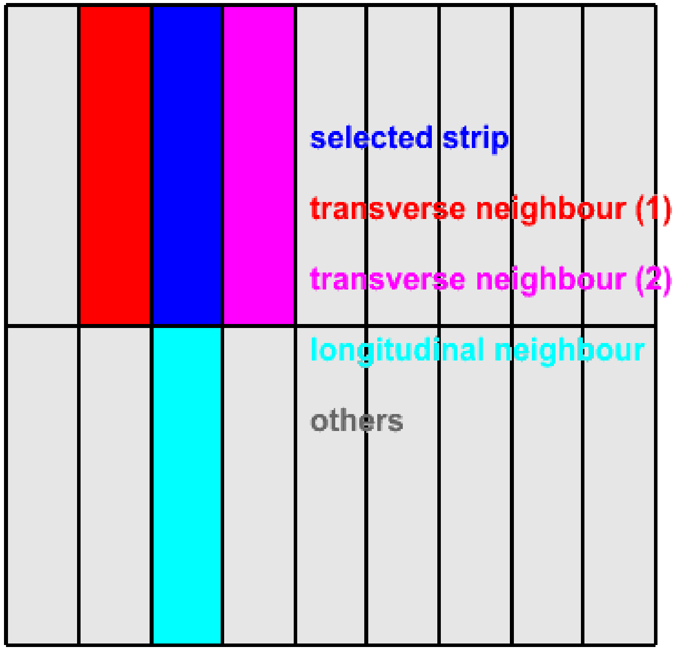


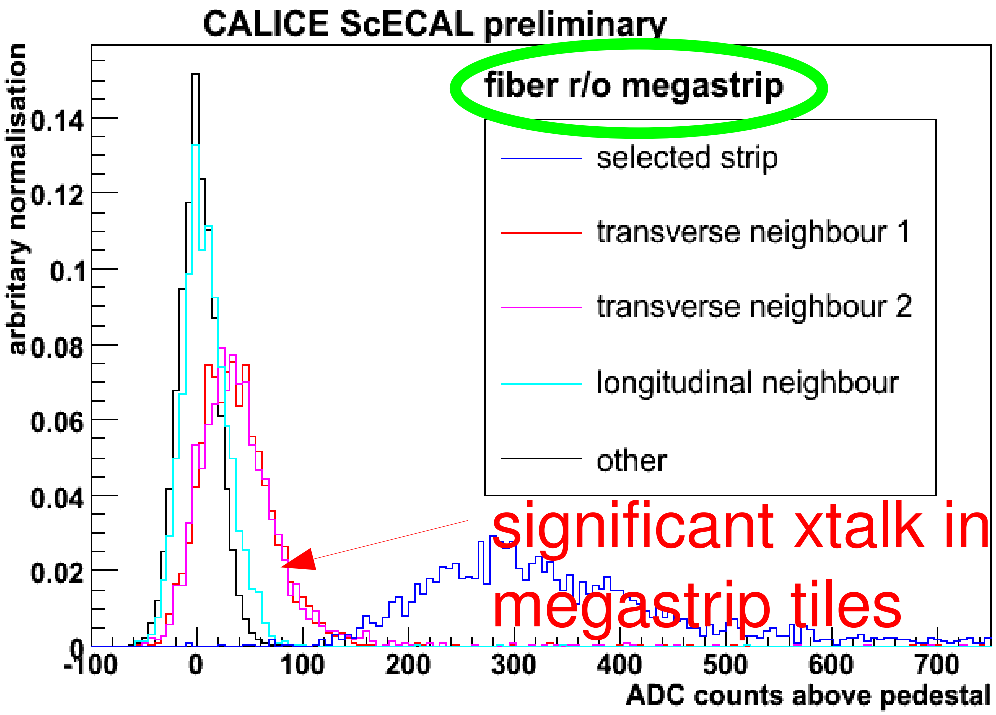
light cross-talk between adjacent strips



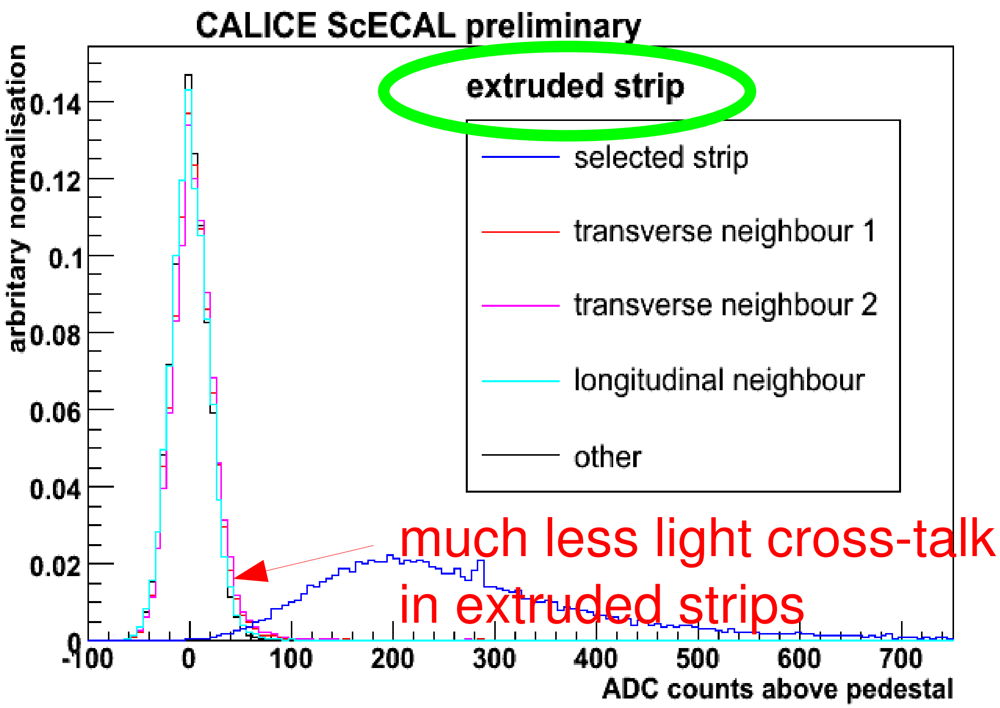
Mega-strip structure: strips not perfectly optically isolated







significant xtalk in megastrip tiles



much less light cross-talk in extruded strips

MPPC response saturation

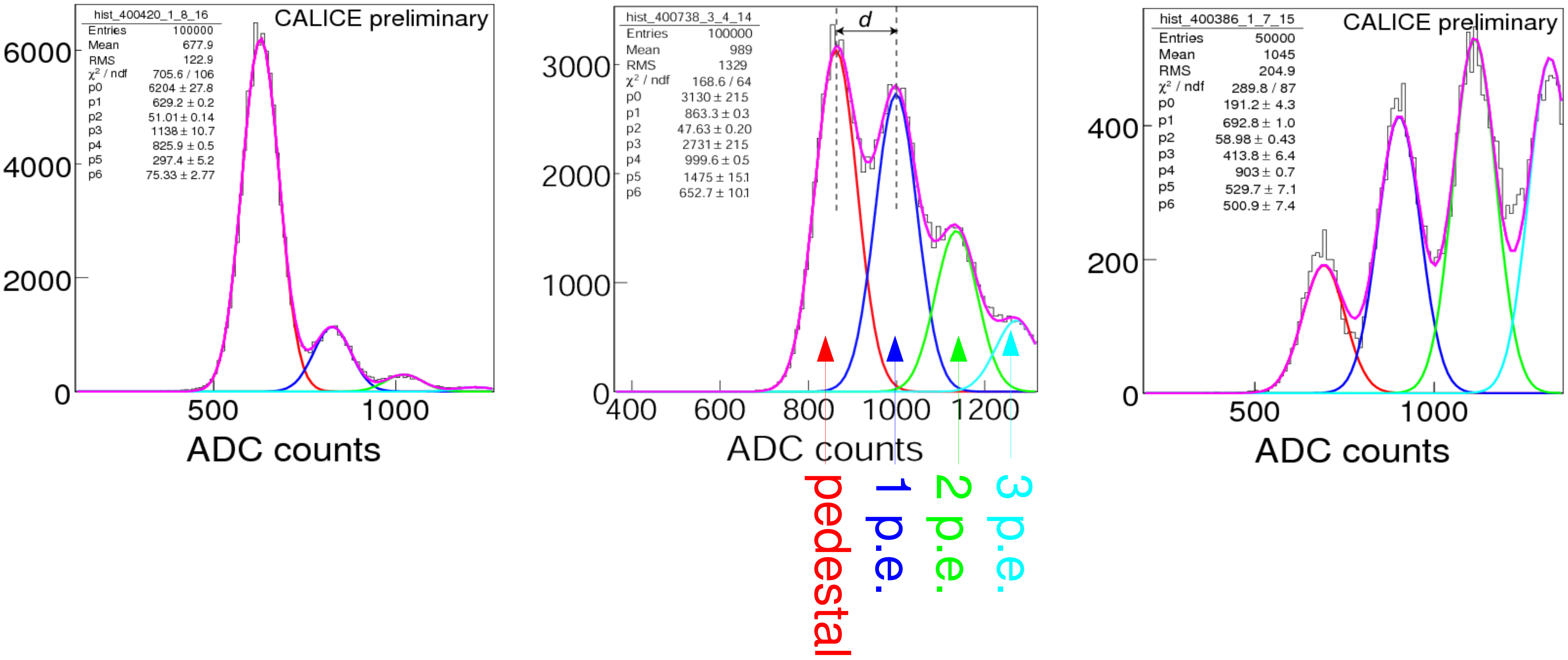
MPPC has 1600 pixels, each can be fired by single photon

pixel recovery ~4 ns – double firing possible

depends on # pixels -> need to convert MPPC signal to # fired pixels

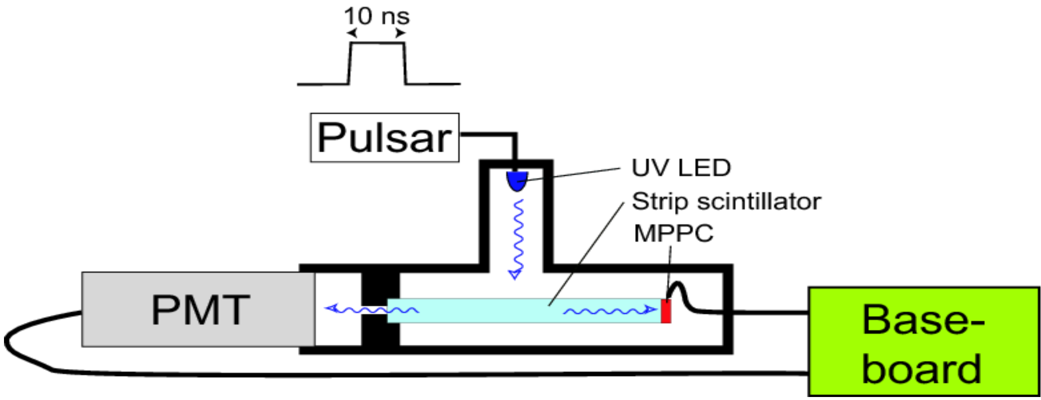
expose MPPC to low intensity light & measure signal per fired pixel

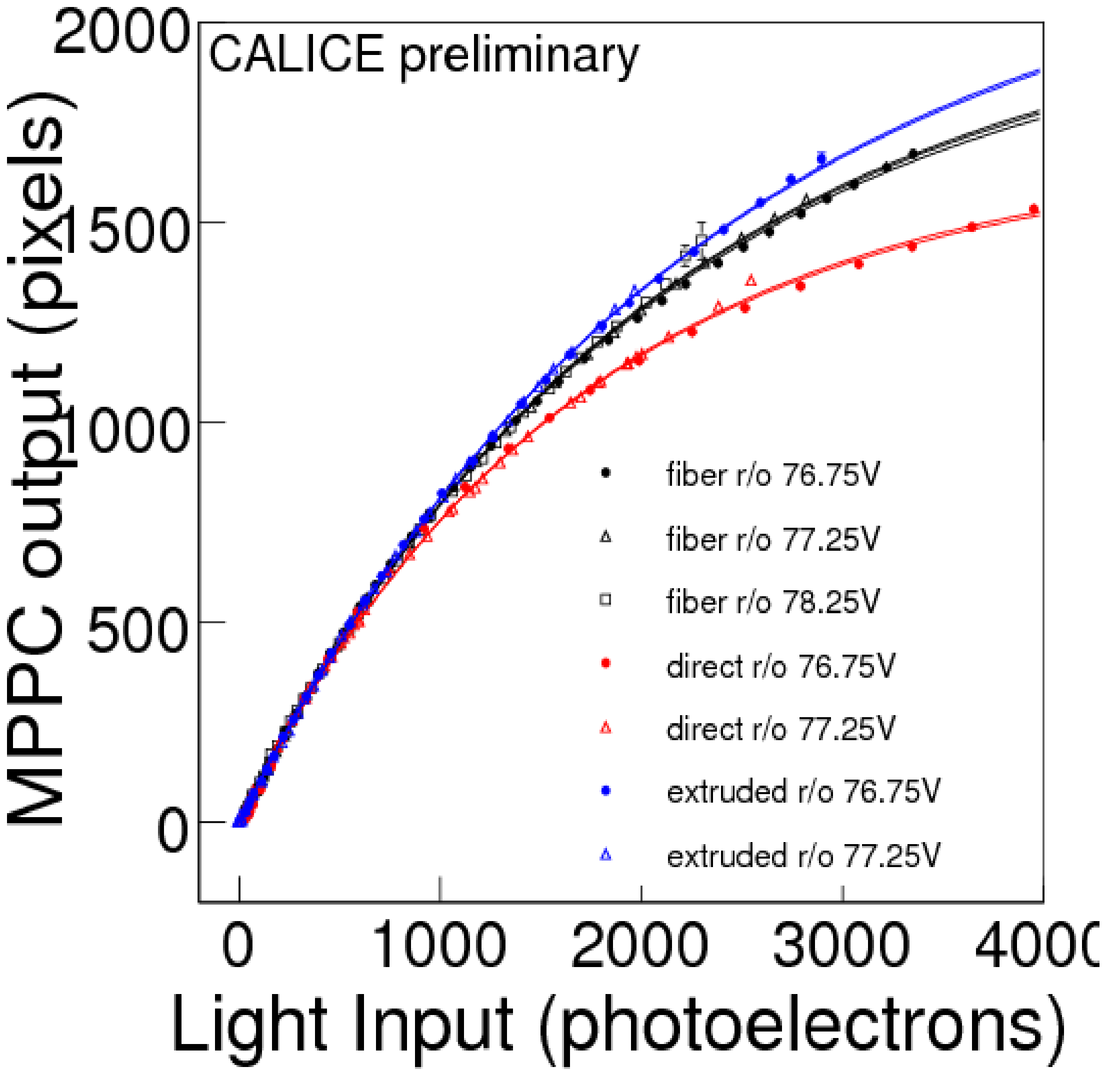
3 representative measurements



MPPC saturation (II)

compare MPPC & PMT signals over wide range of light intensities





Test different scintillator types & MPPC bias voltages

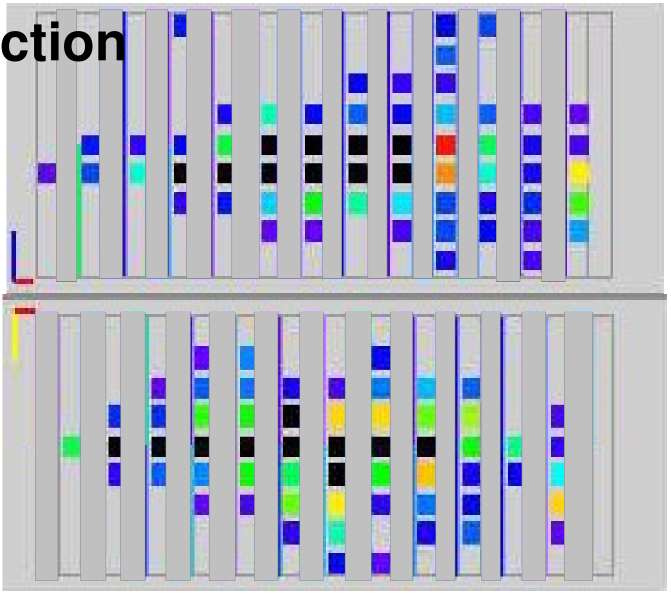
saturation level depends on scintillator strip type: different time structure of light pulse -> more or less pixel recovery

saturation level independent of MPPC bias voltage
(~pixel efficiency)

use curves to convert
pixels to # photoelectrons

runs with tungsten plates

6 GeV e+, center injection

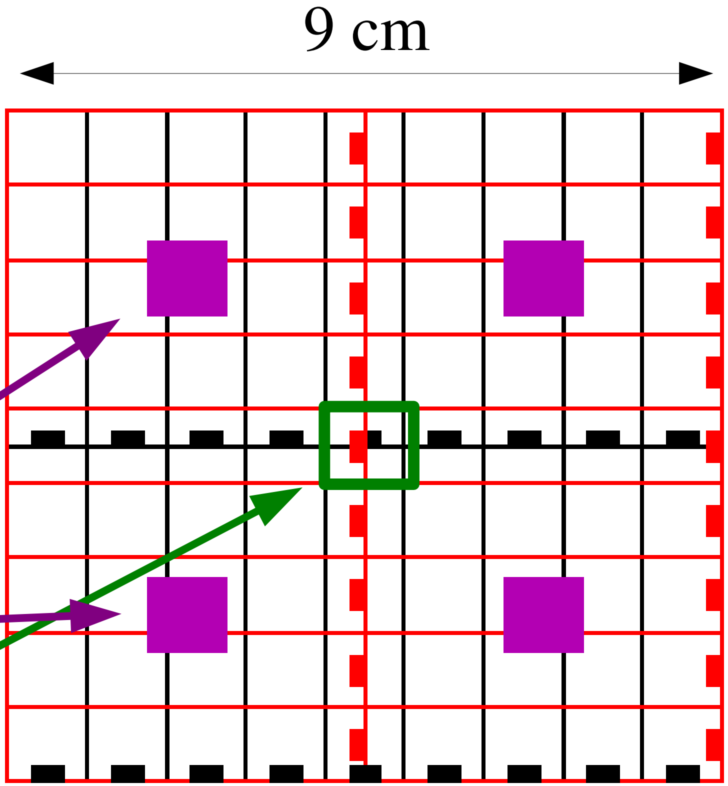


range of e+ beam momentum: 1->6 GeV/c

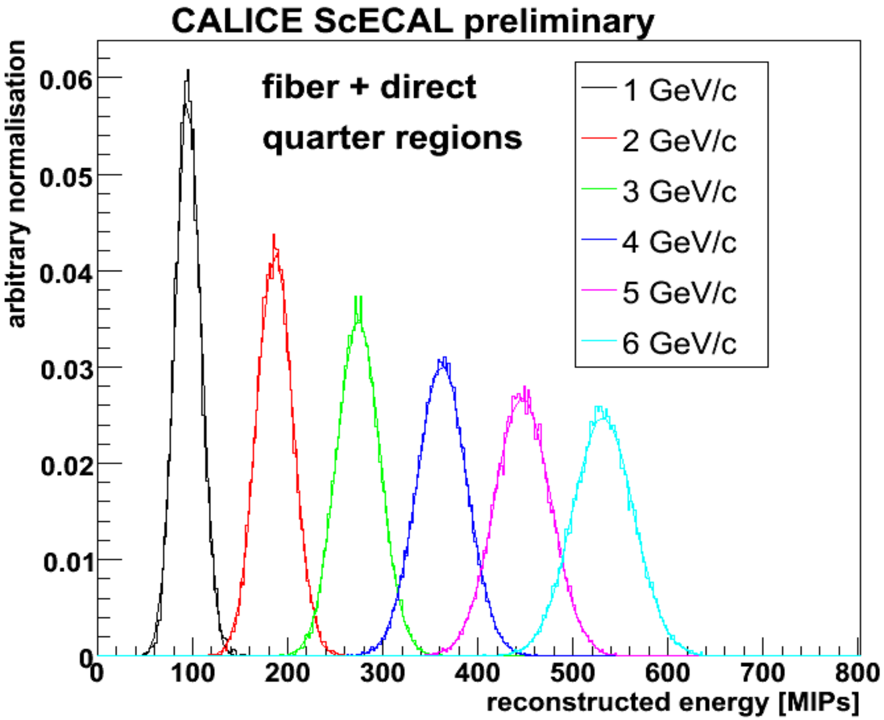
scanned front face of detector

apply calibration constants
    temperature correction
    cross-talk correction

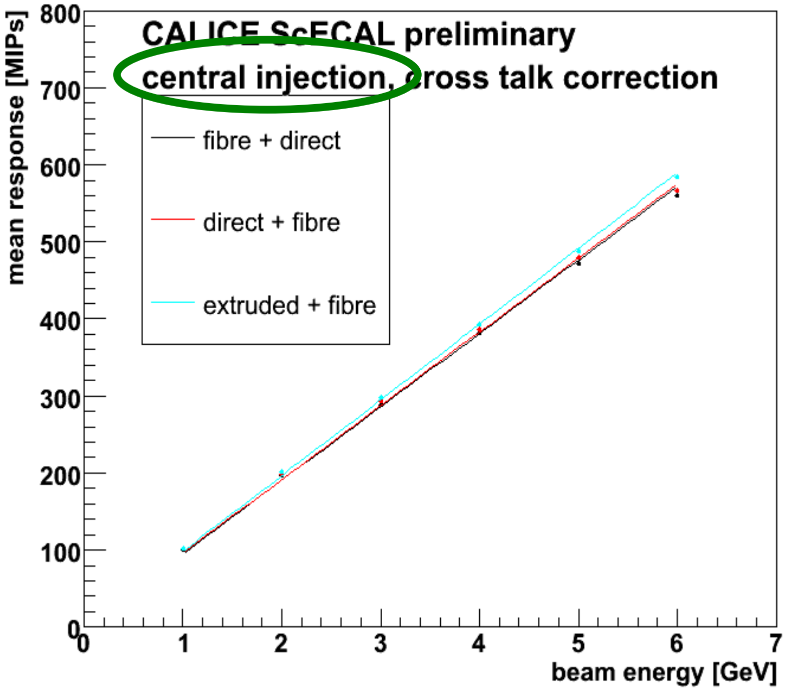
look at different detector regions
    quarter regions – most uniform
    central region – least uniform, least leakage

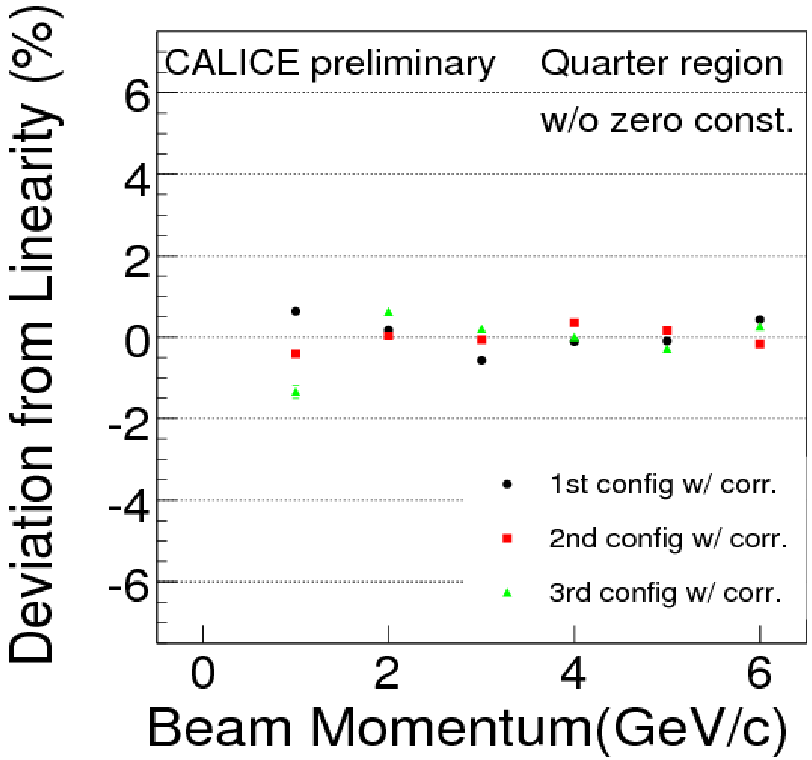


reconstruct total energy deposited in calorimeter



energy response





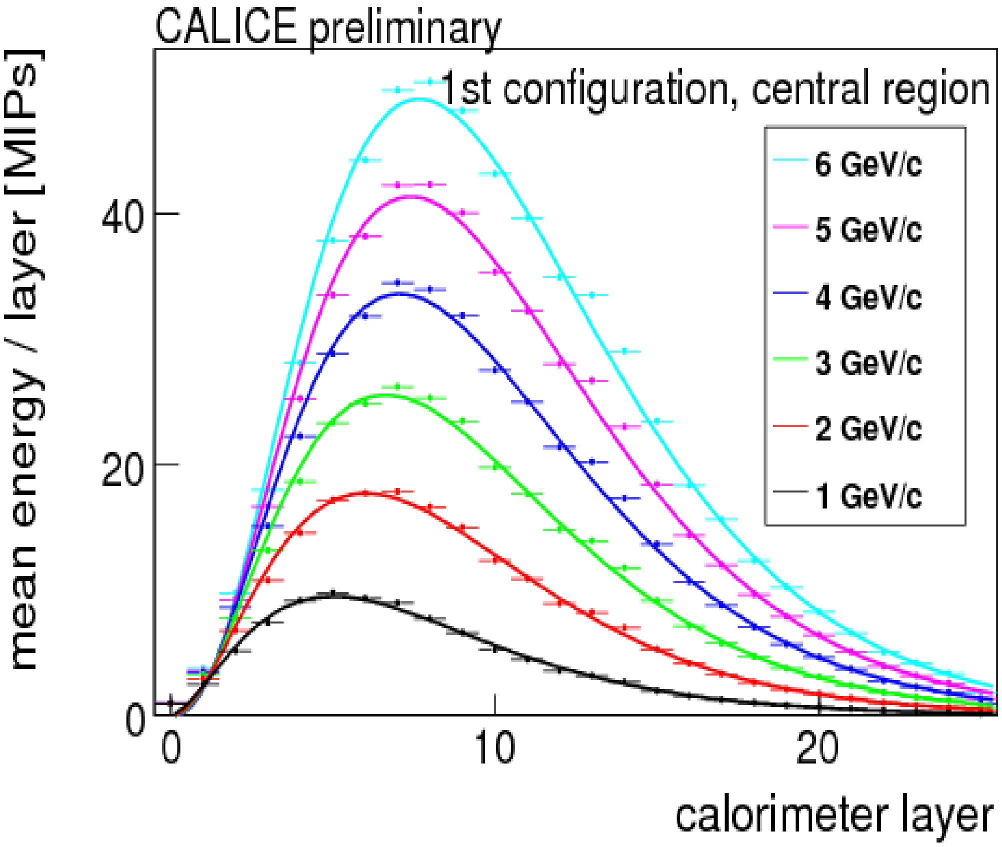
linear response within
~ 1% in range 1-6 GeV

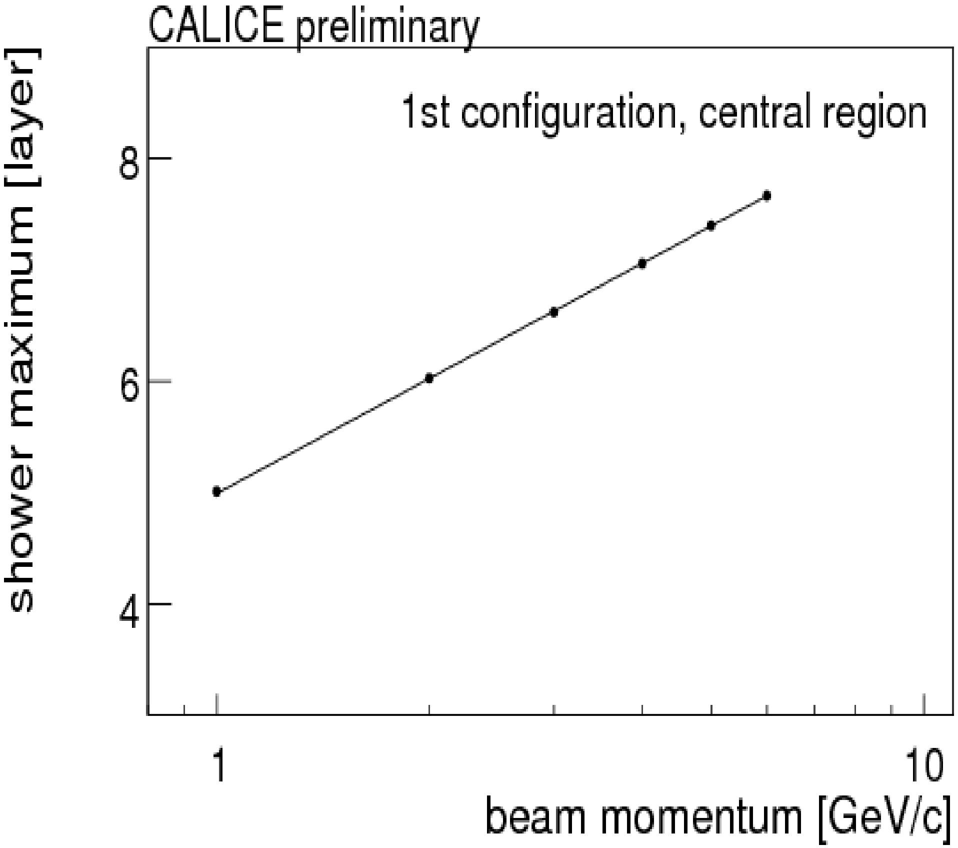
correction of MPPC
saturation works

longitudinal shower profiles

well fitted by energy = $A\,t^{B}\,e^{-Ct}$ (t = calorimeter layer)

shower maximum position shows expected logarithmic dependence on energy

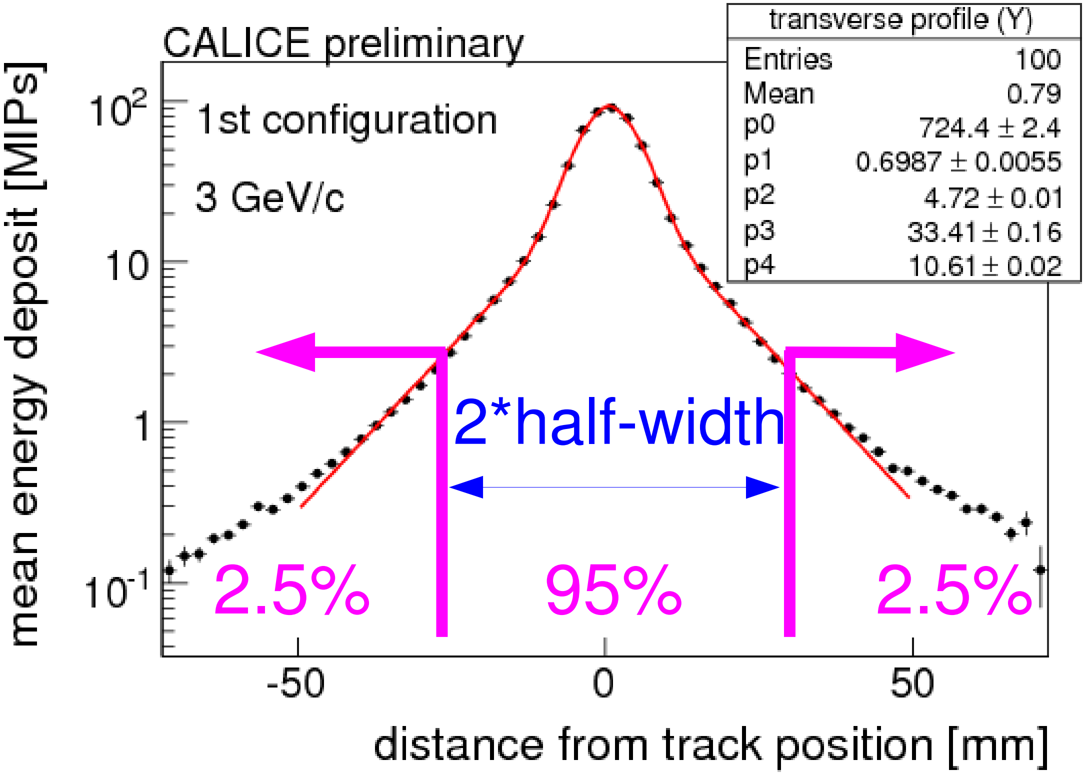


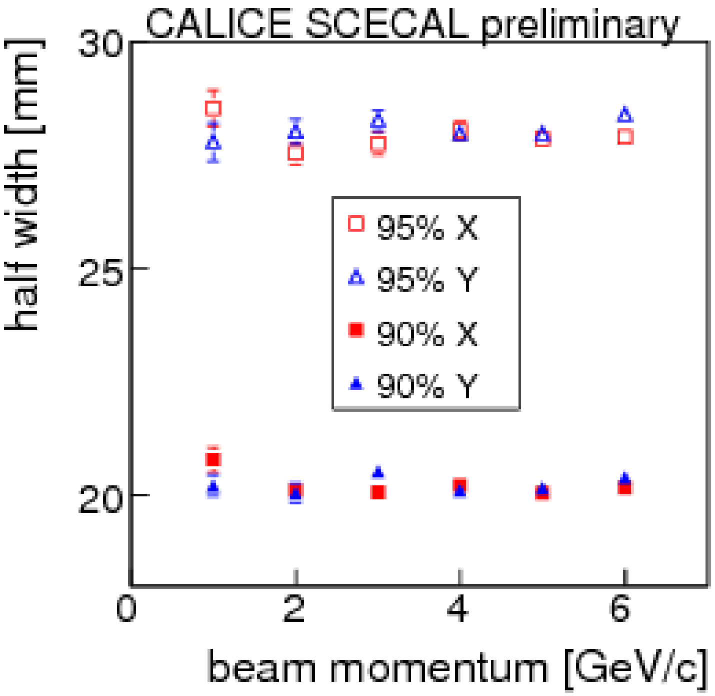


Transverse shower profiles

because of strip geometry, cannot directly measure Moliere radius

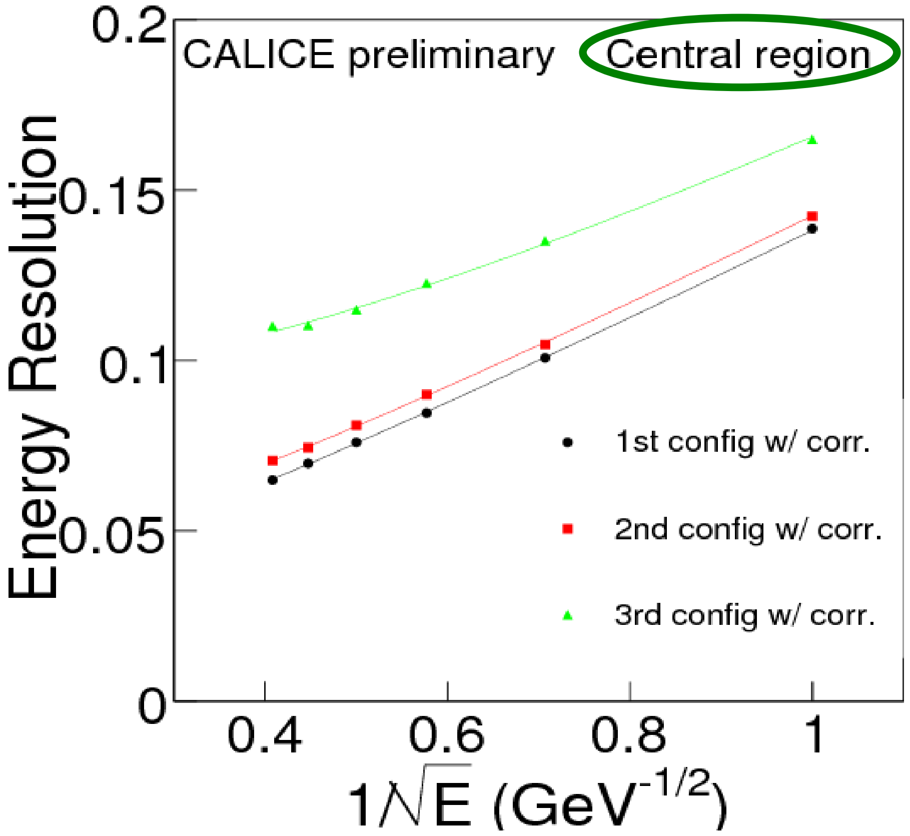
define Moliere radius-like quantity,
    considering shower projection onto x, y directions

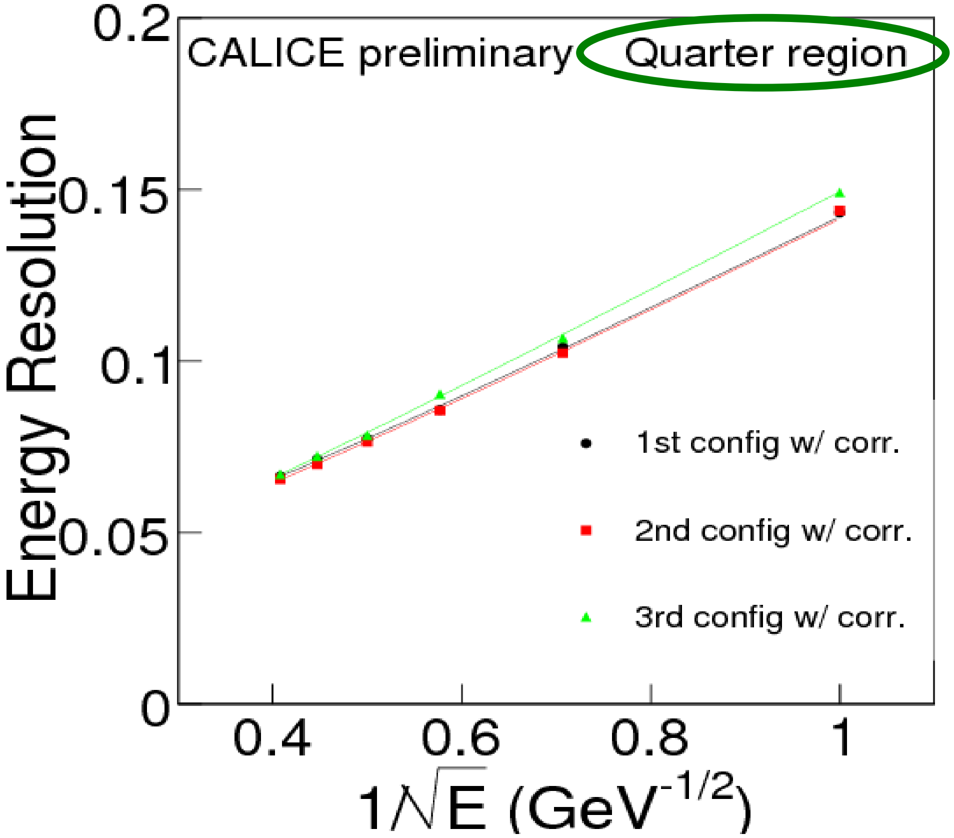




Independent of beam momentum

Energy resolution of 3 configurations





resolution of configurations similar in quarter regions

at centre of detector, extruded+fibre (3rd config.) has large constant term:

effects of strip uniformity enhanced in this region

Measured energy resolution

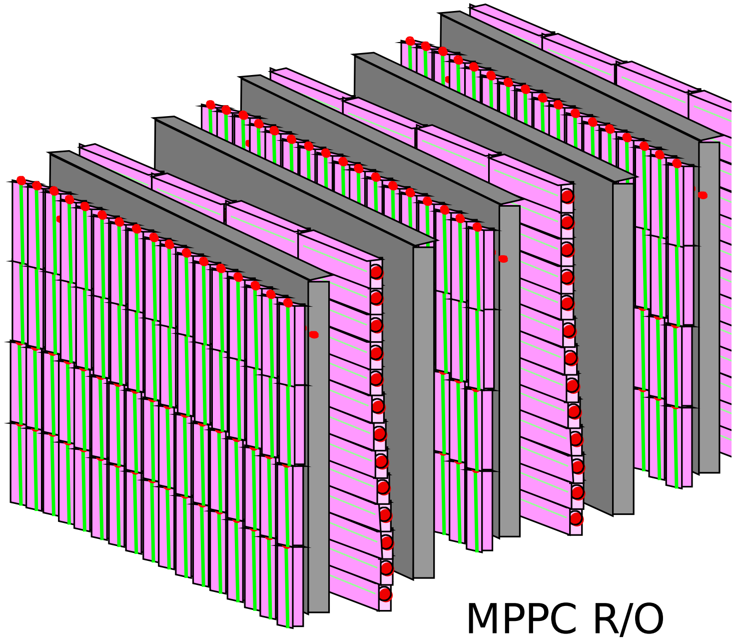
	quarter regions		central region	
	stoch. term(%)	const term(%)	stoch. term(%)	const term(%)
fiber+direct	13.76±0.07	3.52±0.07	13.24±0.05	3.65±0.05
direct+fiber	13.73±0.08	3.35±0.07	13.43±0.06	4.45±0.04
extruded+fiber	14.62±0.08	3.01±0.10	13.84±0.10	9.02±0.04

Shower leakage gives significant contribution to constant term

Non-uniformity gives increased constant term in central region

Constant term somewhat larger than expected investigating using detailed simulation

future plans



now constructing ~4x larger detector
- improved extruded scintillator strips
  - -> more uniform response
- 30 layers, 18x18 cm^2
  - -> less energy leakage

CALICE beamtest at FNAL – September '08
- run together with Scintillator+SiPM HCAL

test with different particles, wider energy range
- hadrons, muons, $\pi^0 \rightarrow \gamma\gamma$

Conclusions

Analysis of DESY testbeam data in good shape

In uniform regions, detector works well

- sufficient energy resolution for ILC ECAL
  - $(\sigma/E \sim 14\%/\sqrt{E} \oplus 3\%)$

Non-uniformity of extruded strips significantly degrades performance

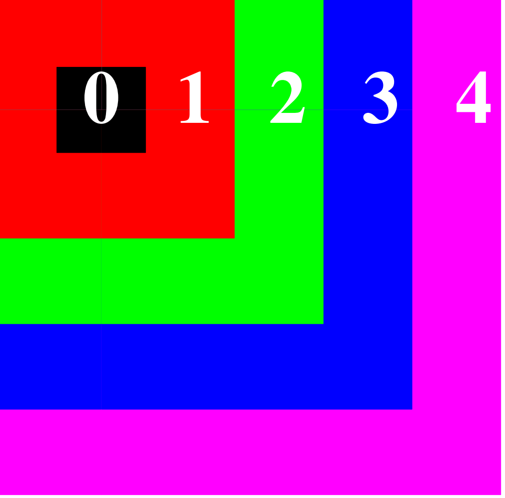
- improved samples have since been tested

In progress...

Detailed detector simulation

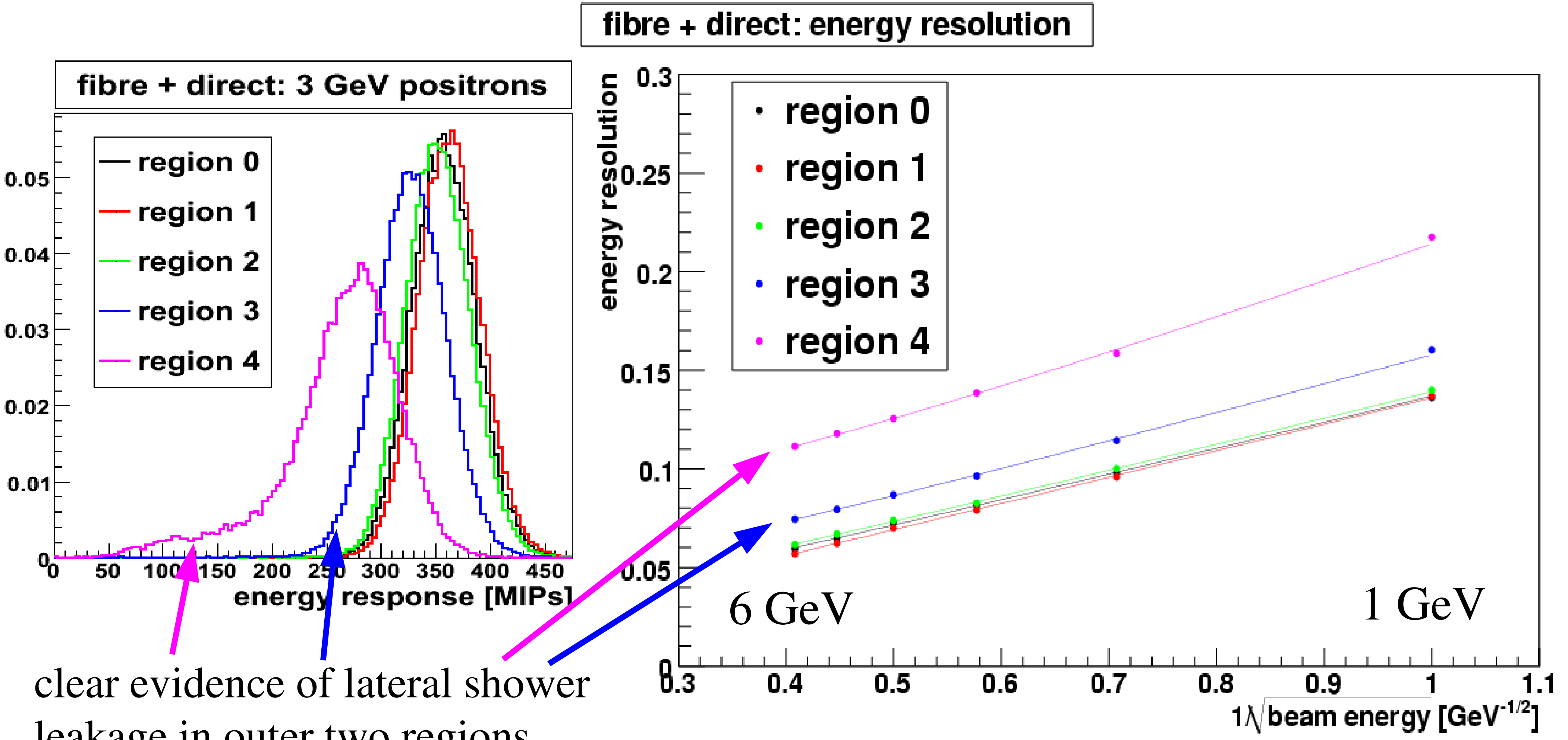
Preparations for next beam test

Backups



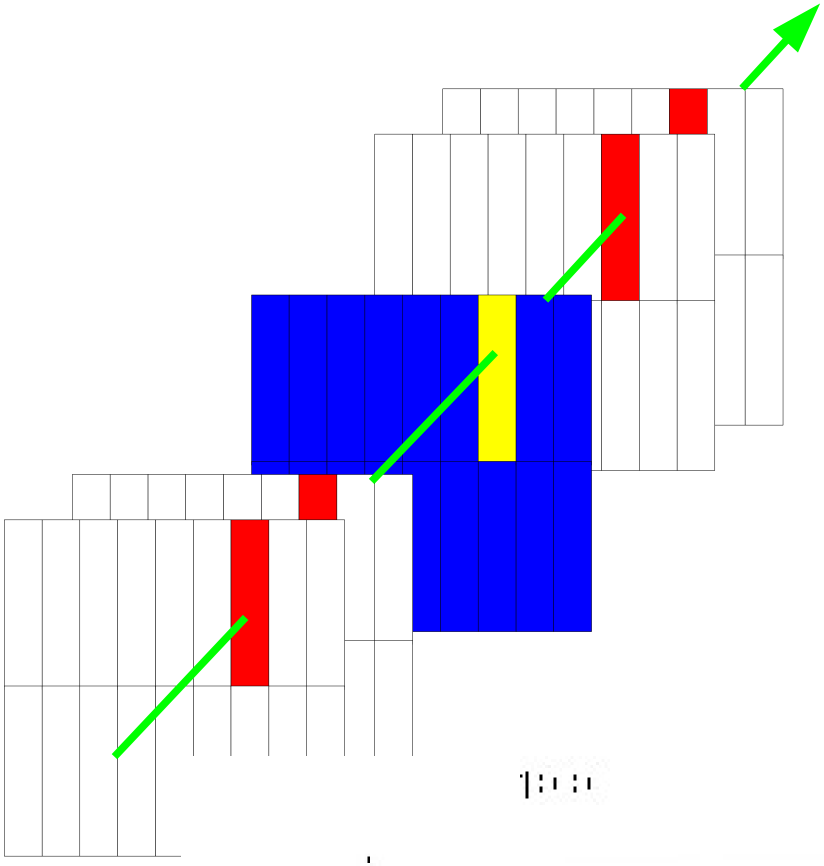
Energy resolution in different detector regions

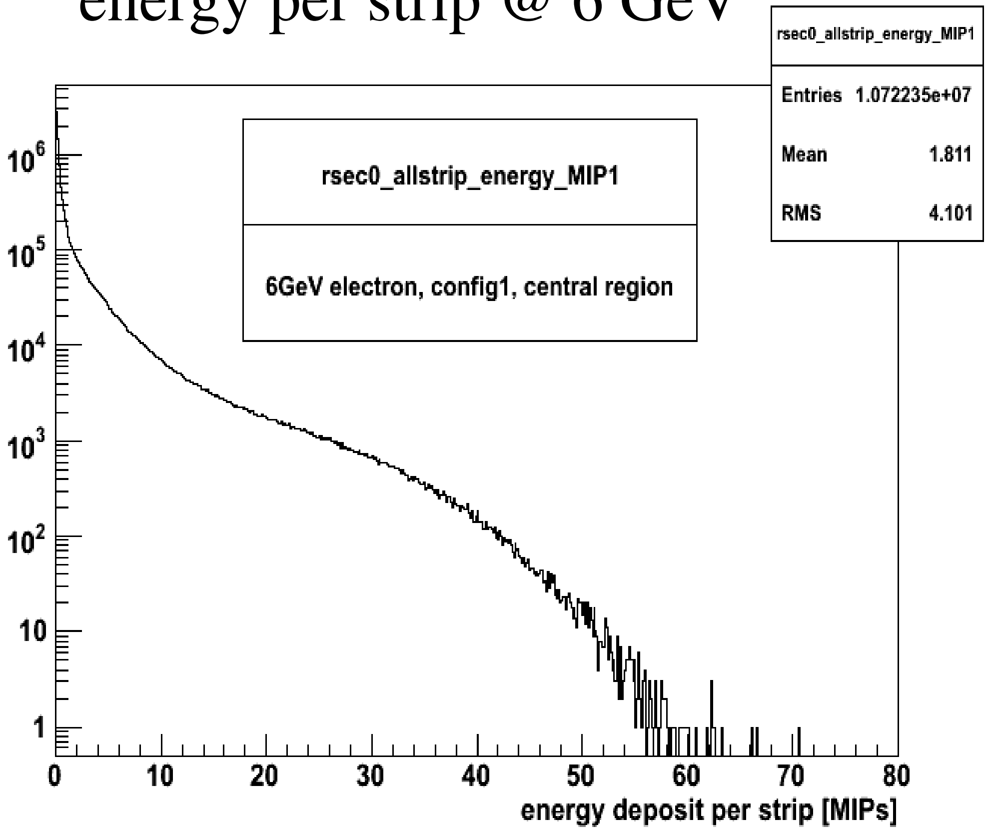
(fibre+direct, with absorber)

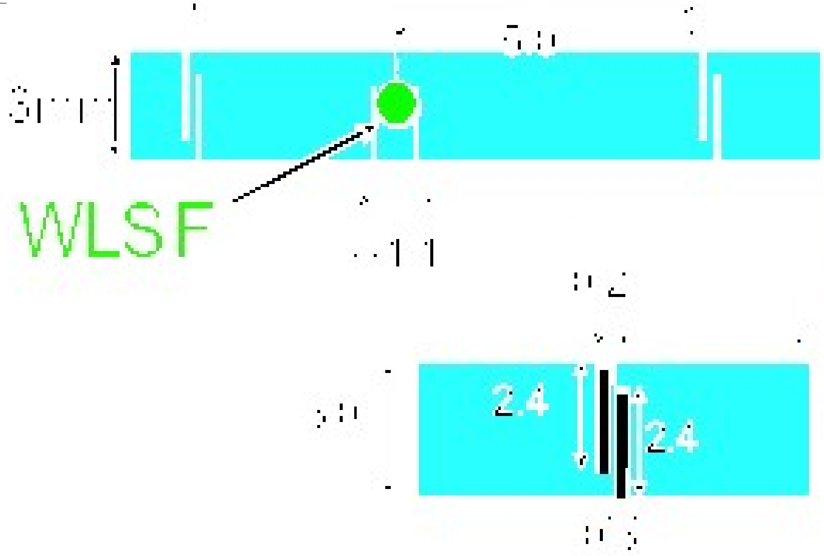


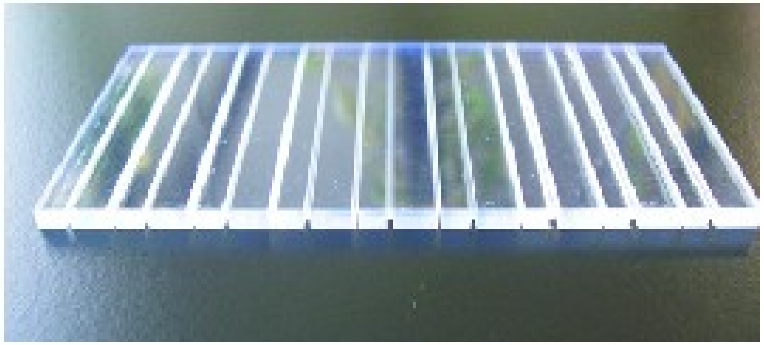
clear evidence of lateral shower leakage in outer two regions

energy per strip @ 6 GeV









Tracking detector alignment

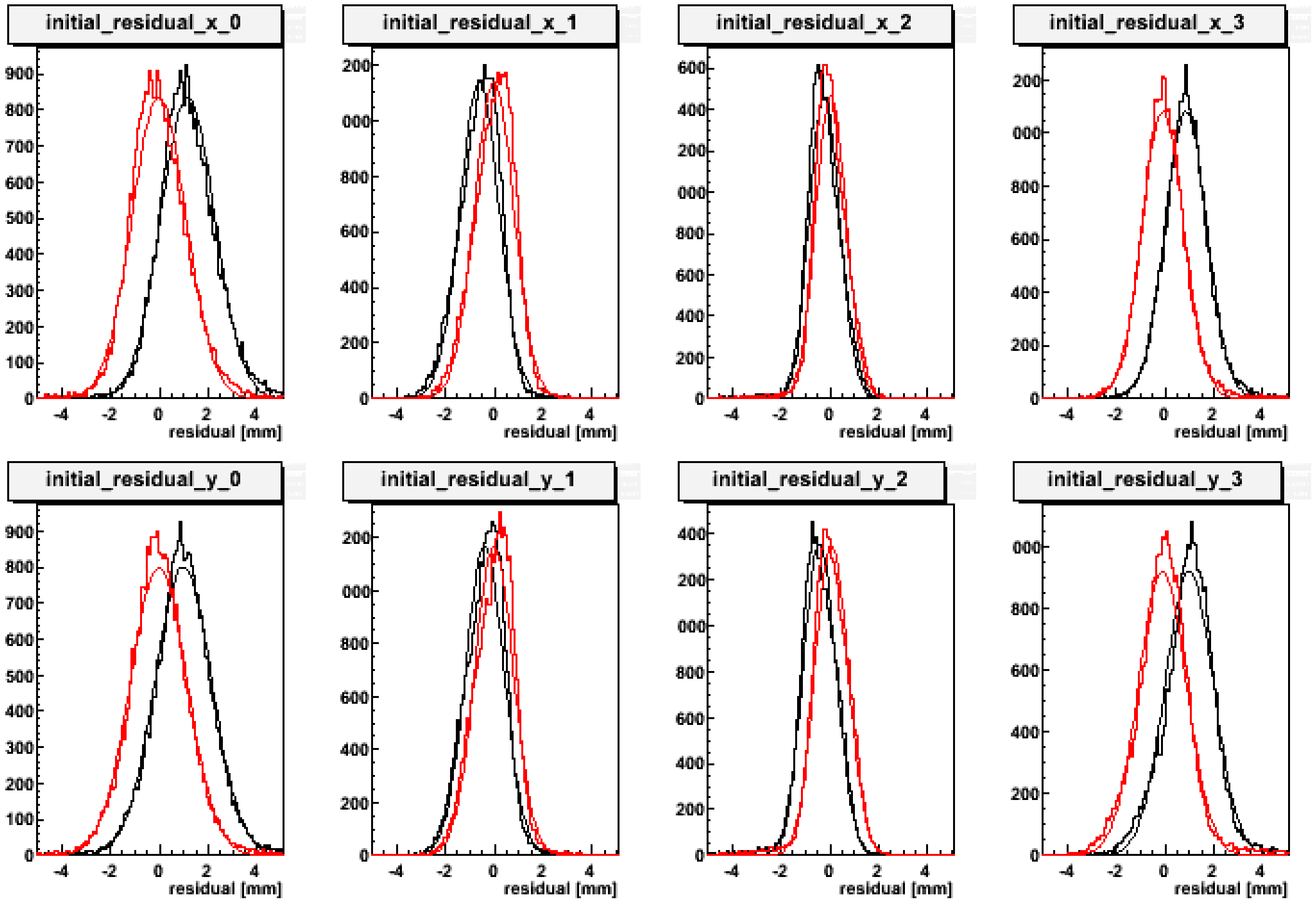
determine drift velocity and relative positions of 4 drift chambers

each chamber measures x,y position

chamber 0 1 2 3

x

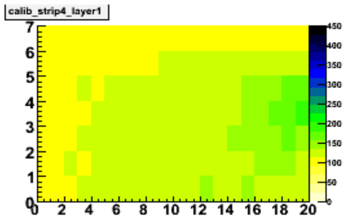
y

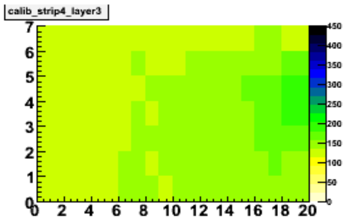


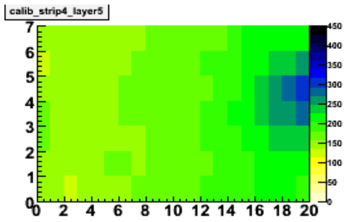
before
(after)
alignment

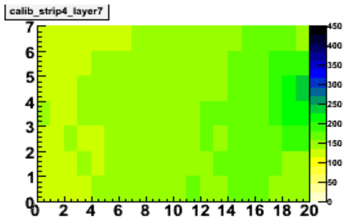
hit residual/mm

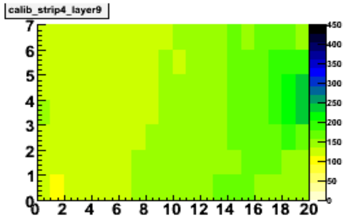
MIP response uniformity: detailed scan across single strip

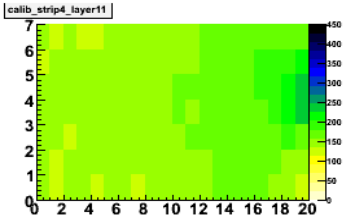


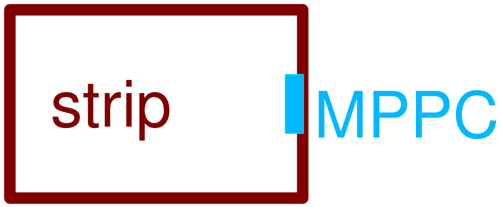




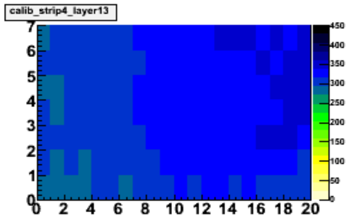


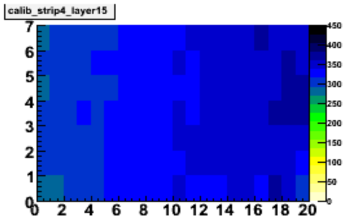


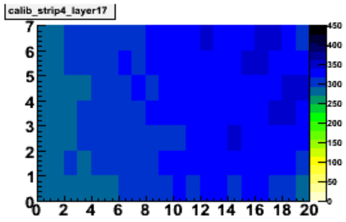


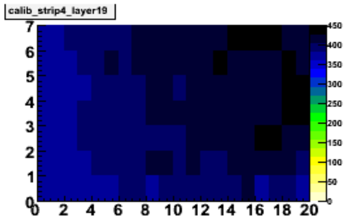


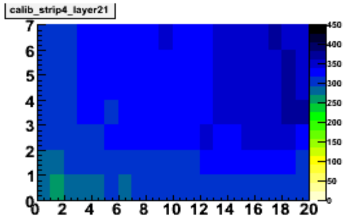
Kuraray
direct readout

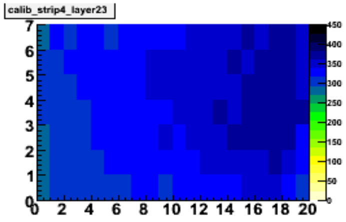


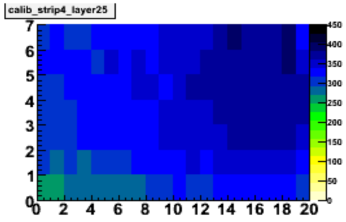




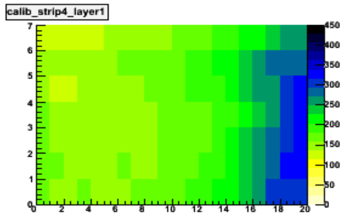


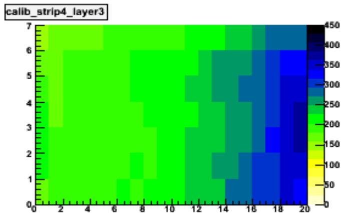


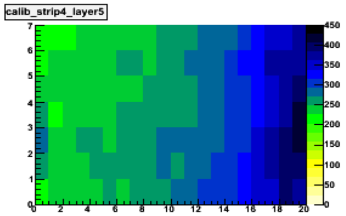


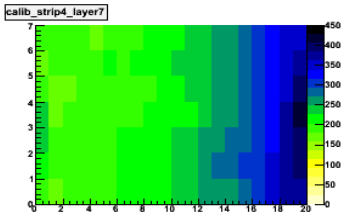


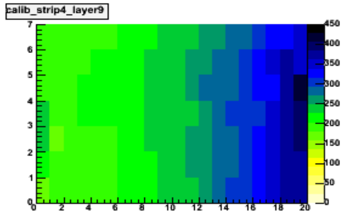
Kuraray
fibre readout

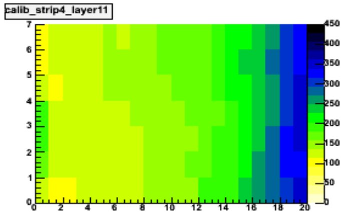






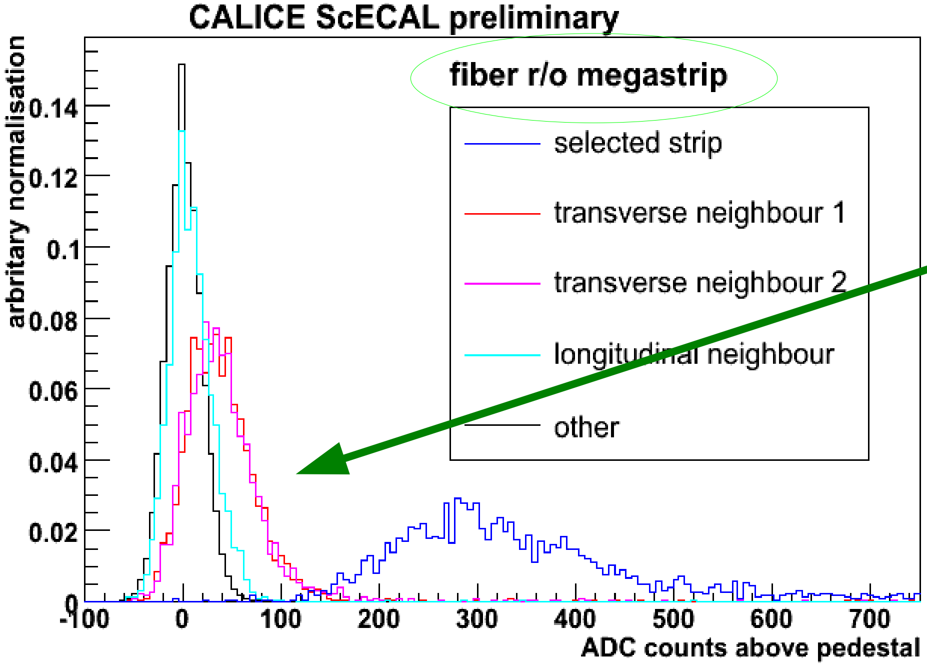




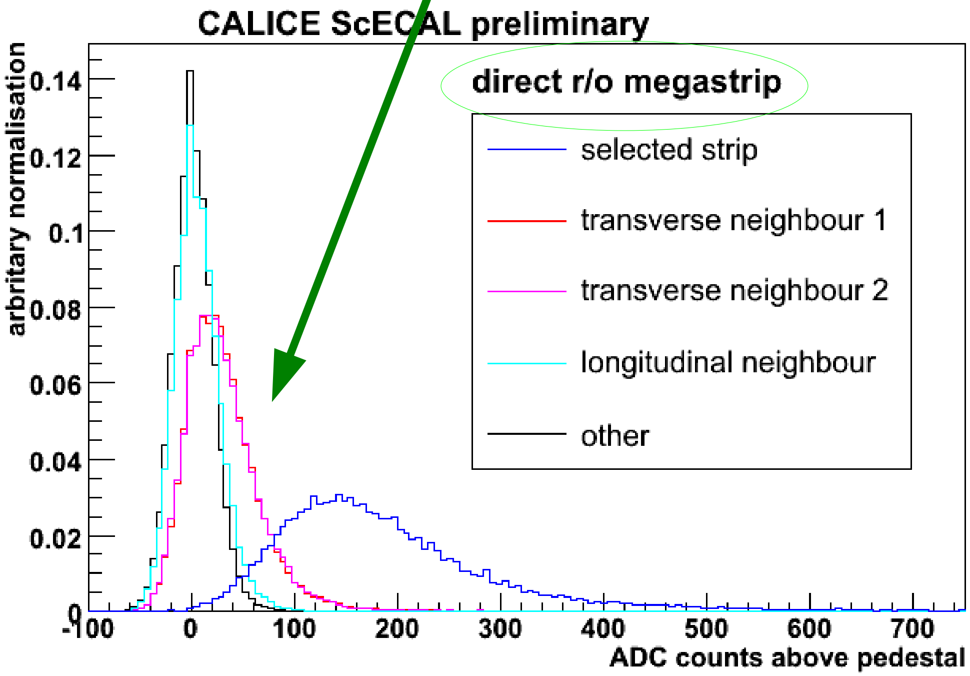


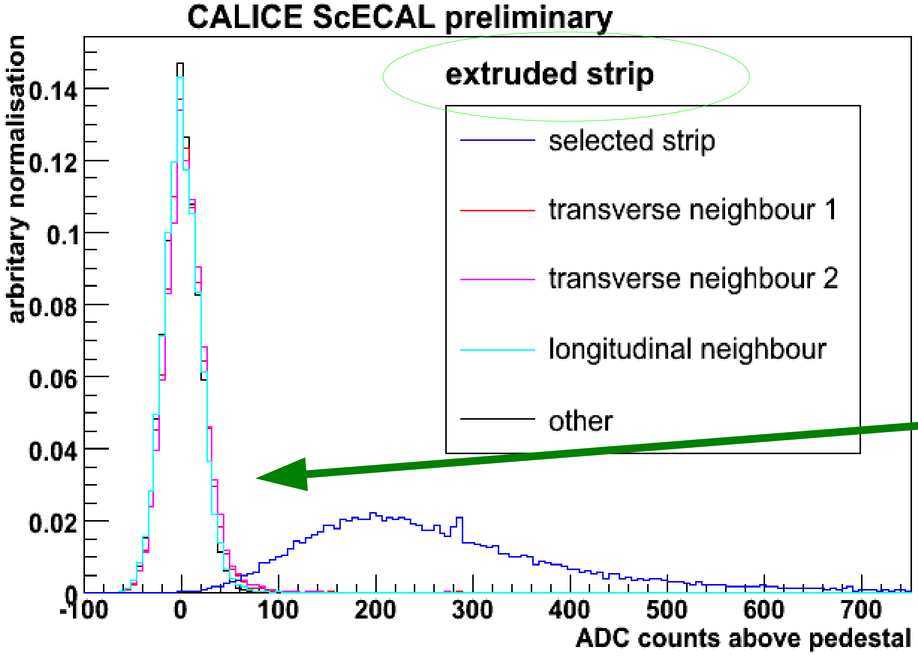
KNU extruded
fibre readout

light xtalk in different scintillators



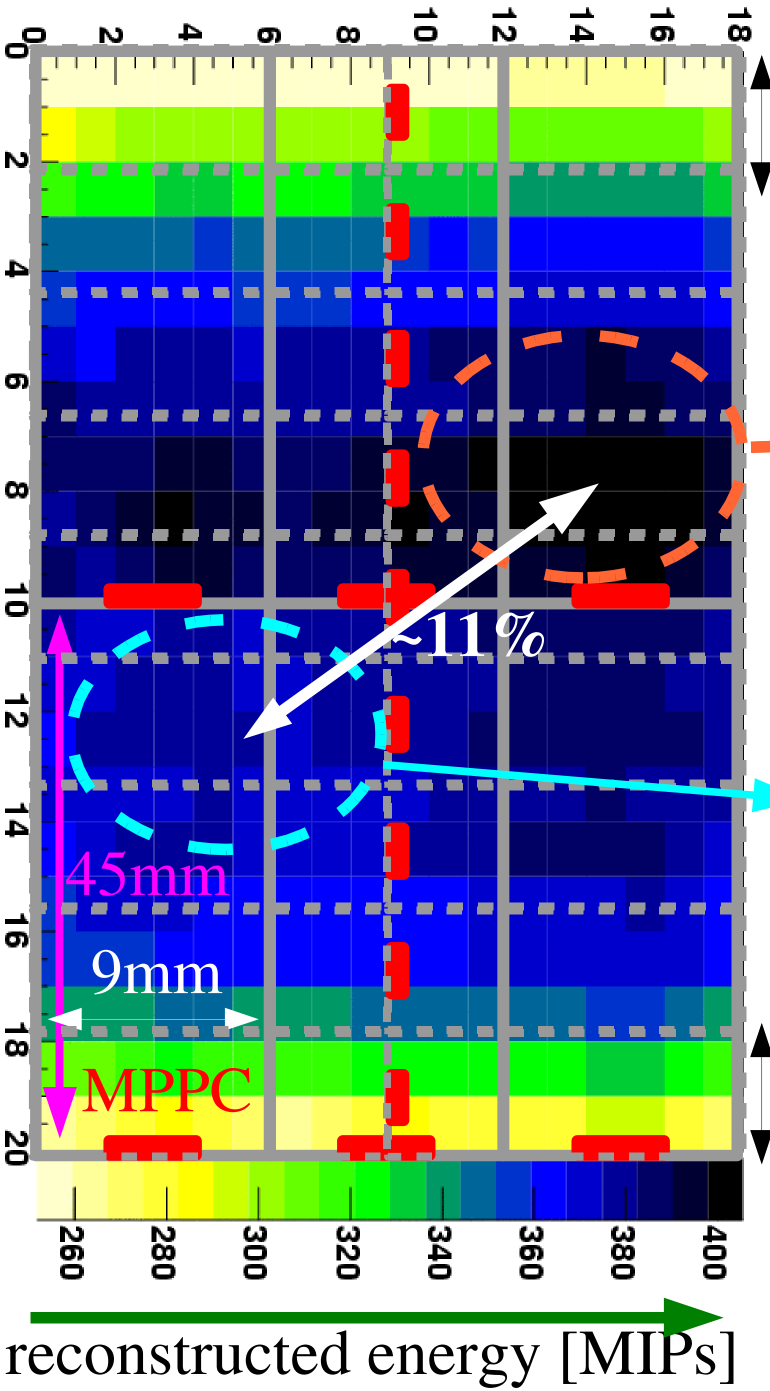
significant xtalk in megastrip tiles





much less light cross-talk in extruded strips

Energy response uniformity, direct+fibre, 3 GeV

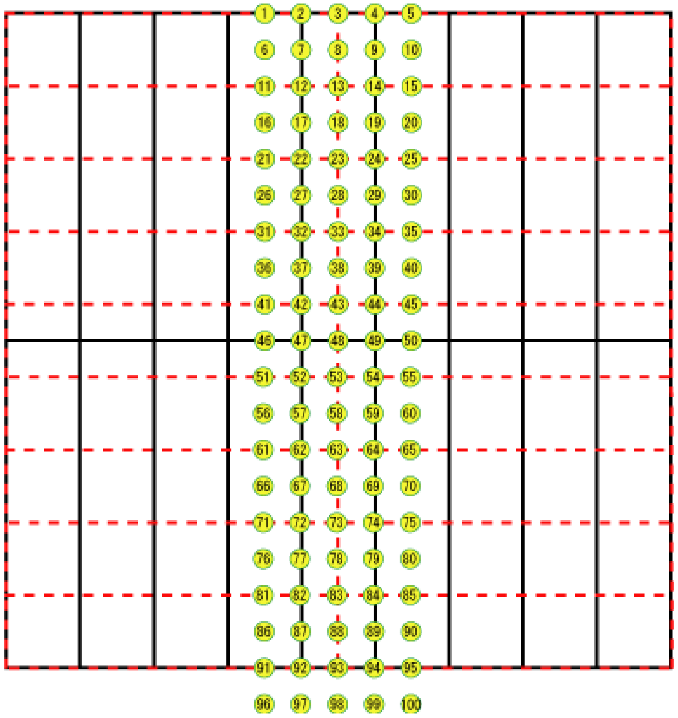


lateral shower leakage

high response near MPPCs

low response far from MPPCs

lateral shower leakage

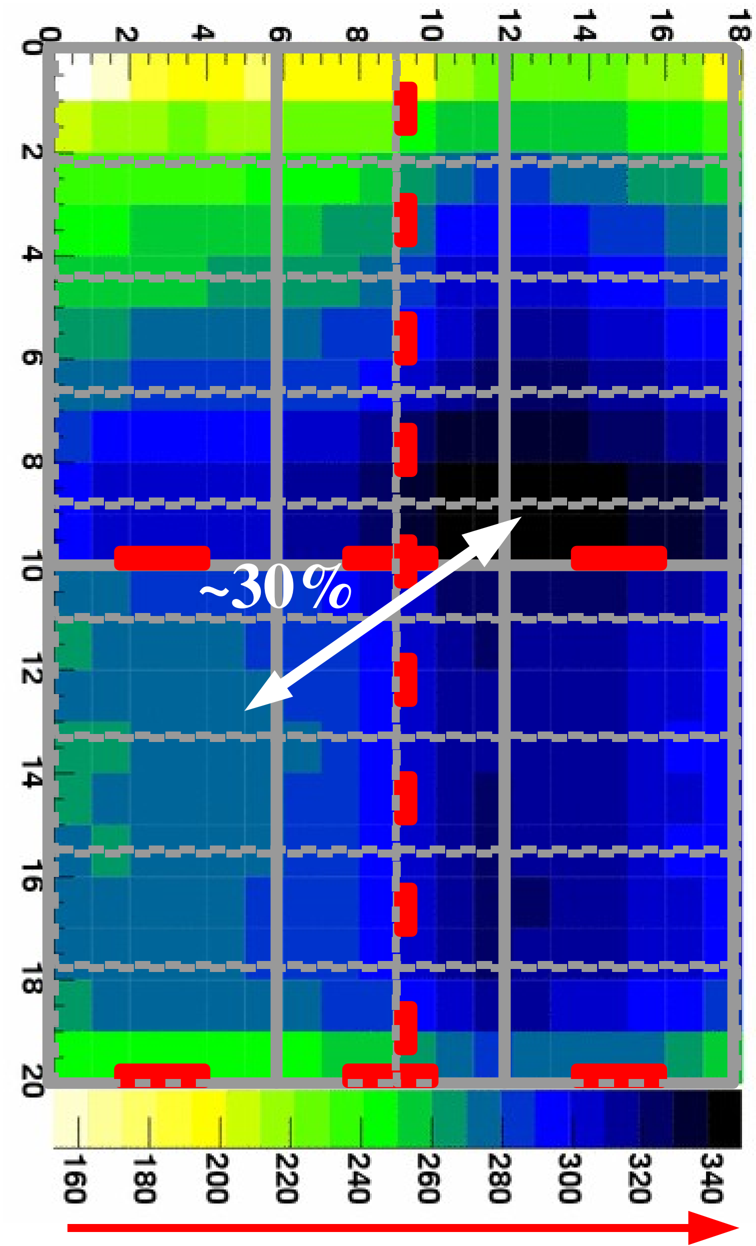


scanned 1/3 detector

can alternate orientation to minimise this effect

extruded+fibre @ 3 GeV: energy response vs. position

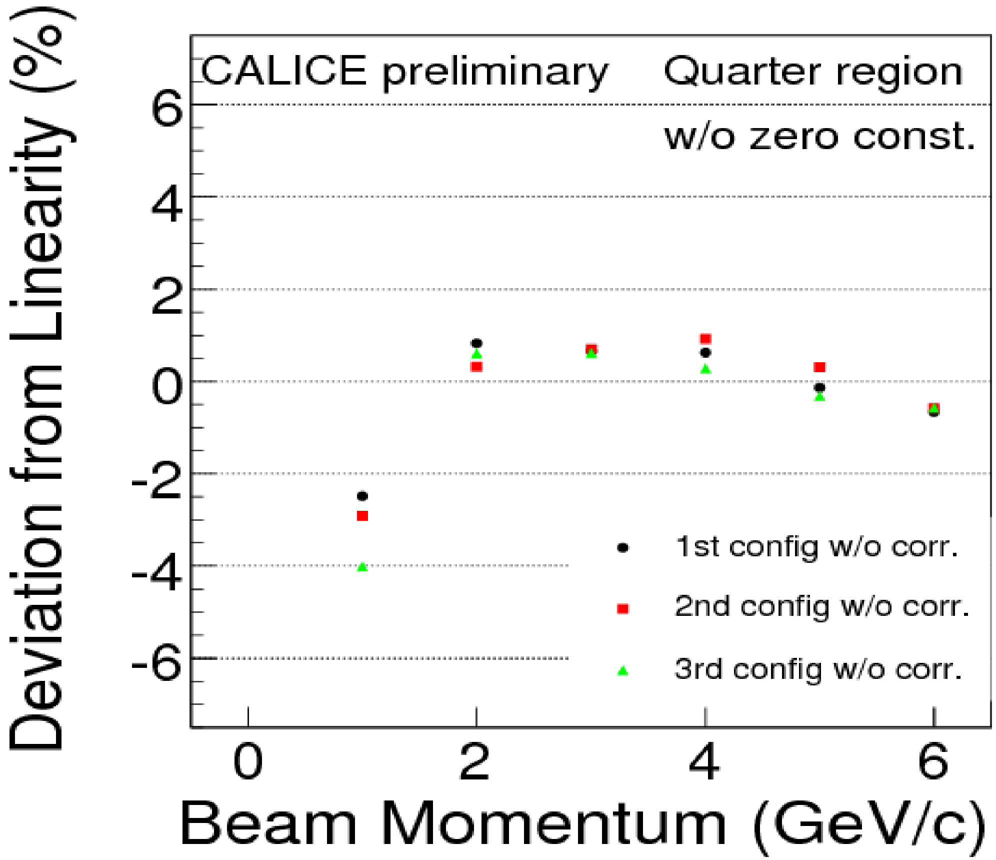
energy response



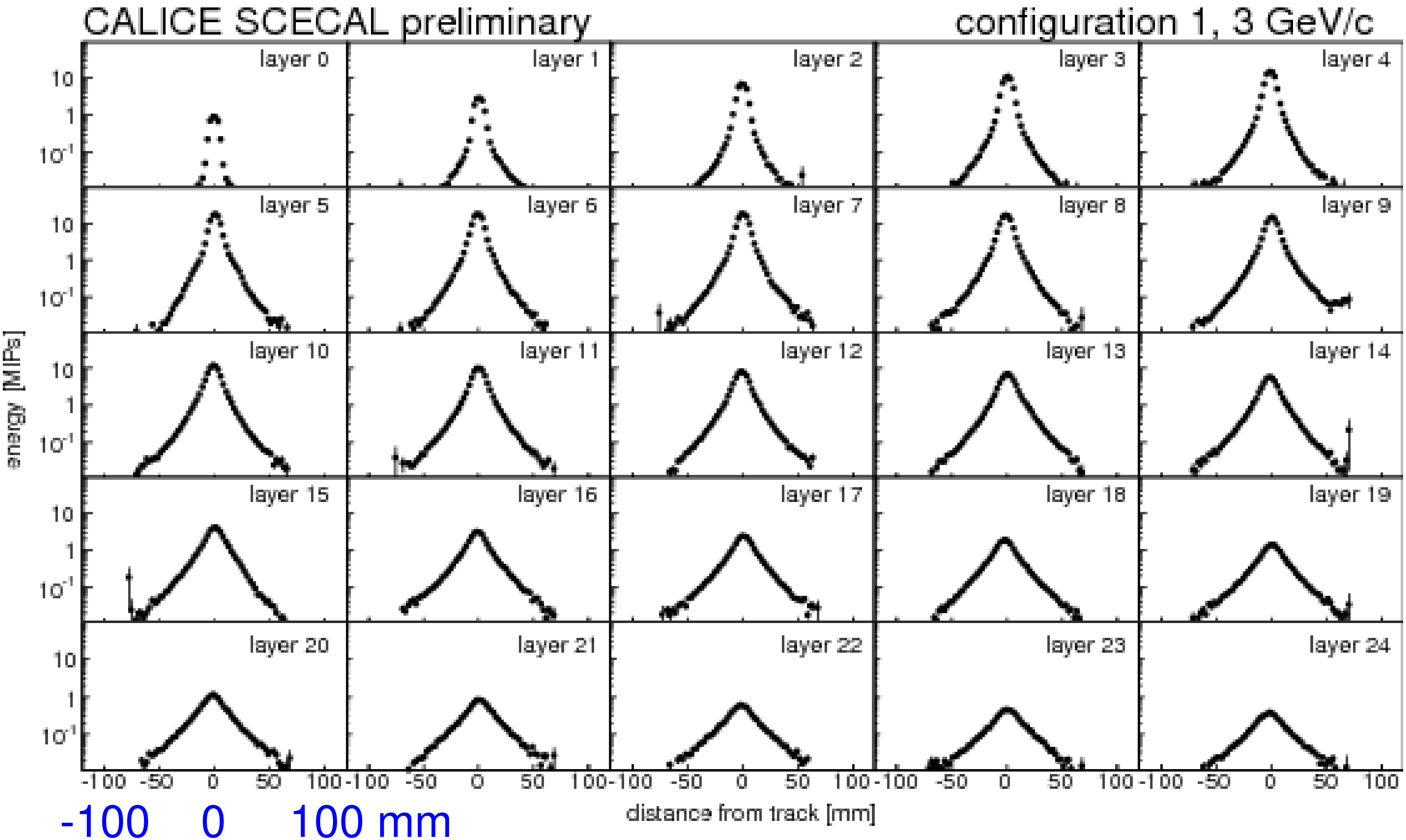
energy response [MIPs]

2-3 times more variation that direct+fibre configuration

extruded strips are less uniform


CALICE preliminary
Quarter region
w/o zero const.
Deviation from Linearity (%)
6
4
2
0
-2
-4
-6
0
2
4
6
Beam Momentum (GeV/c)
● 1st config w/o corr.
■ 2nd config w/o corr.
▲ 3rd config w/o corr.

Transverse shower profile vs. calorimeter layer



-100 0 100 mm

Measured energy resolution (no saturation correction)

	quarter regions		central region	
	stoch. term(%)	const term(%)	stoch. term(%)	const term(%)
fibre+direct:	13.98 ± 0.07	1.96 ± 0.12	13.39 ± 0.05	2.57 ± 0.07
direct+fibre:	13.83 ± 0.07	2.58 ± 0.09	13.70 ± 0.06	3.39 ± 0.05
extruded+fibre:	14.61 ± 0.08	2.35 ± 0.12	14.52 ± 0.09	7.26 ± 0.05

Shower leakage gives significant contribution to constant term

Non-uniformity gives large constant term in central region