PERSPECTIVES OF FORWARD CALORIMETRY IN ALICE

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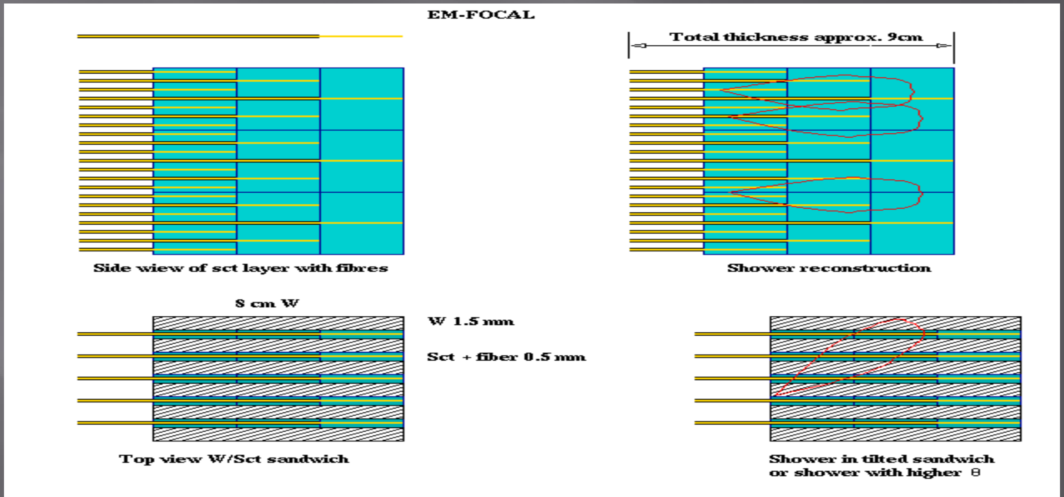
Outline

- 3-D scintillator readout – rad-hard fibres
- 3-D scint super-compact ECAL, E+HCAL
- Simulation of the worst case scenario & y=4.5
- Response to individual particles
- Response in high multiplicity environment
- Limitations of the design
- Further simulations
- Prototyping
- Summary & conclusions

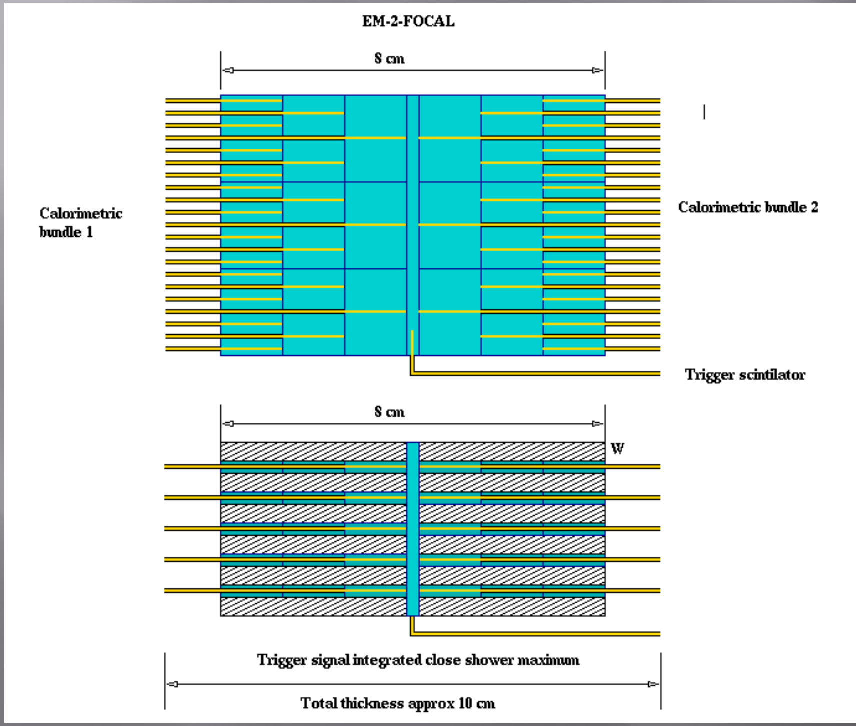
3-D scint. readout scheme

- Variable granularity scintillator pad size
- Hi position resolution in shower start
- Direct integration in shower max
- Rad-hard scint. – inorganic YAG, Kuraray…
- Quartz fibers from scintillator to the image intensifier



Super-compact ECAL

- ECAL using optical readout – 9 cm thickness
- Cheap design – exchange when rad. damaged

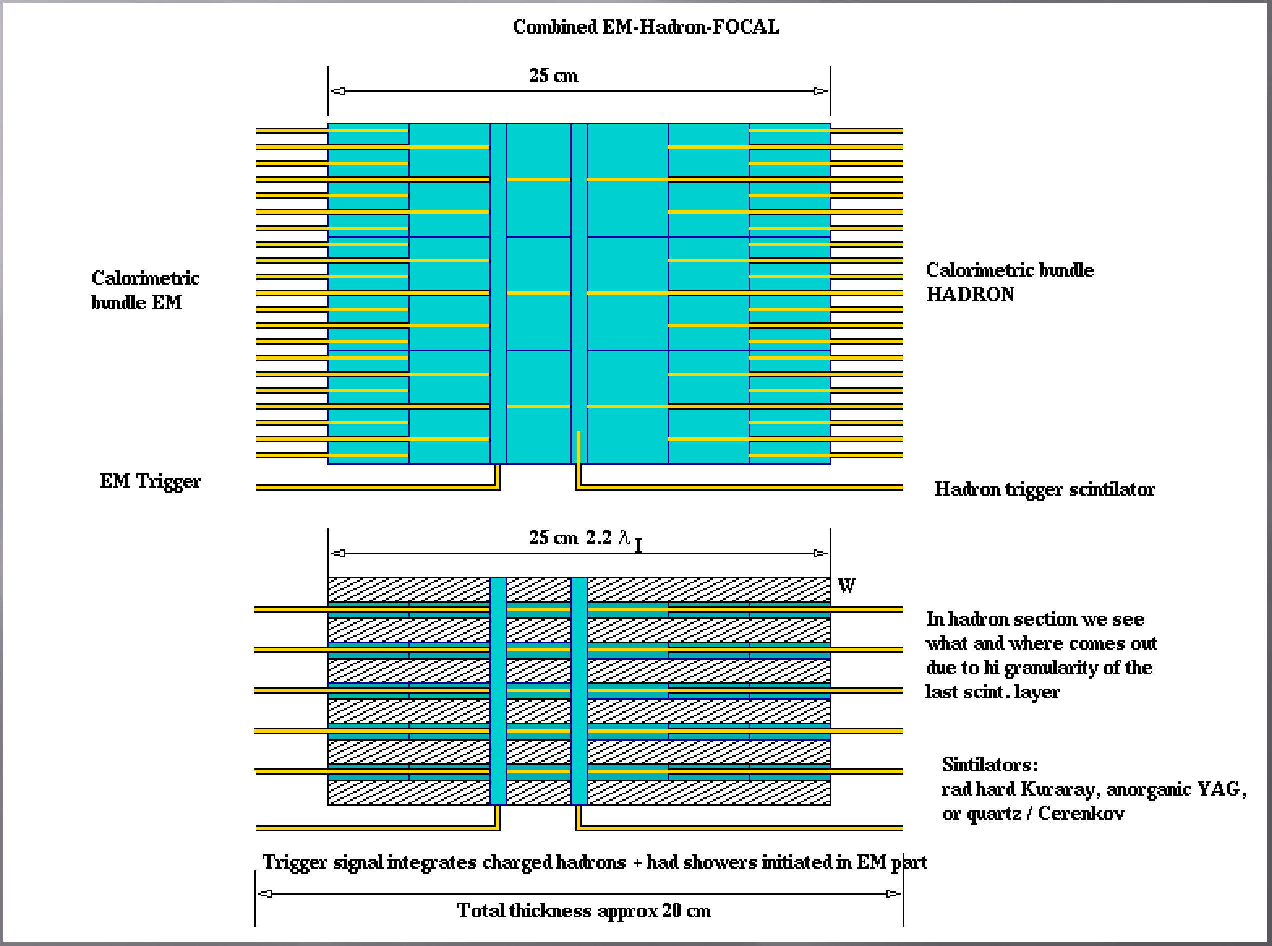


- Precise structure of shower end
- Trigger in shower max.
- Trigger using APD coincidence (indep. fibres from trig. scint) to avoid random triggers
- Readout not in strong rad. env.

BUT – we still have more space even in most limited place …….
WHAT TO PUT THERE?

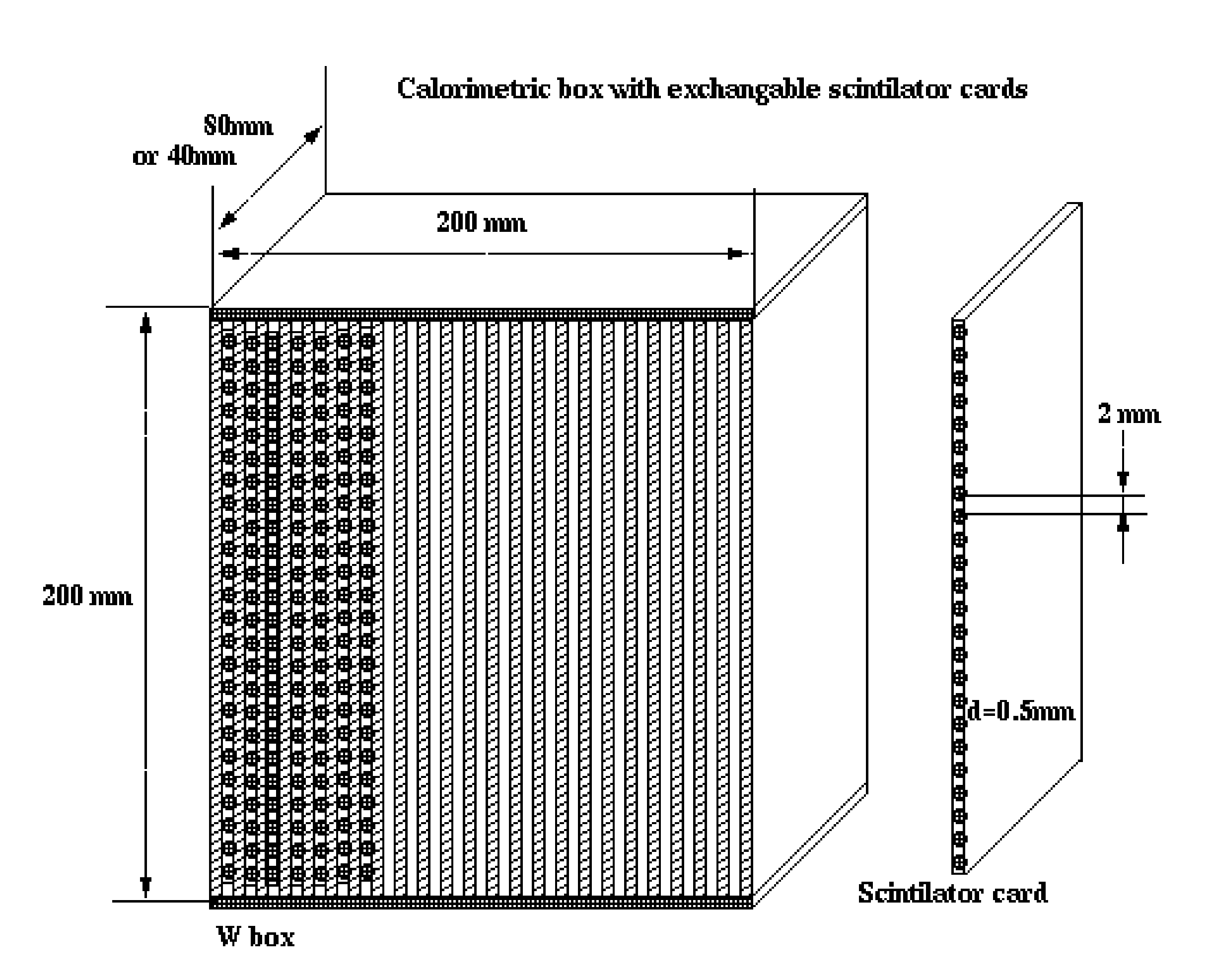
Super-compact E+HCAL

- Even the tightest space (30cm) allows for HCAL



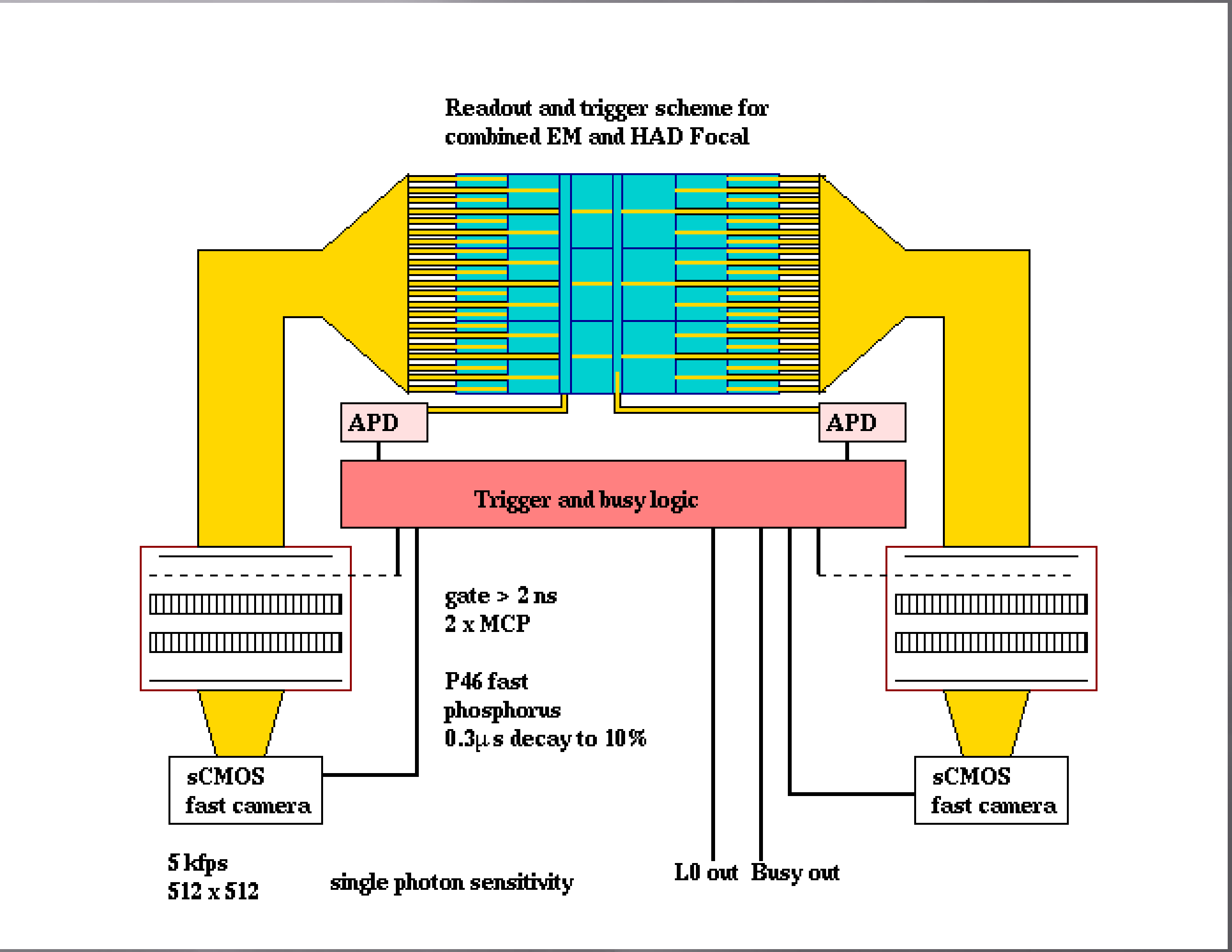
- min. 25cm W = 2.2 int. l. for pion
- separate E & H trigger scintillators
- in free regions more int. length possible (int. length (W) = 11.2 cm)
- when something is lost we know where – high granularity
-in HCAL possible comb. of scint and Si02 cerenkov fibers – dual readout – better dE/E

Scintillator exchange



Damaged scintillators can be exchanged

Readout system



For the whole E+HCAL
(750 x 750 mm quadrant)

3x3 camera blocks / quad
each block 2 cameras
= 72 cameras in total

L0 trigger ability

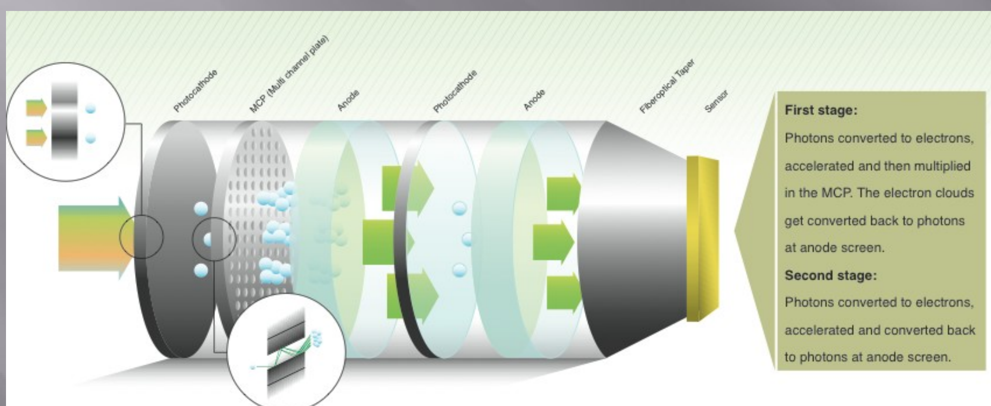
Camera readout:
200 mic.s / frame
gate > 2 ns
Single photon sensitive
12bit ADC
60 kevent memory in
camera, JPEG comp.

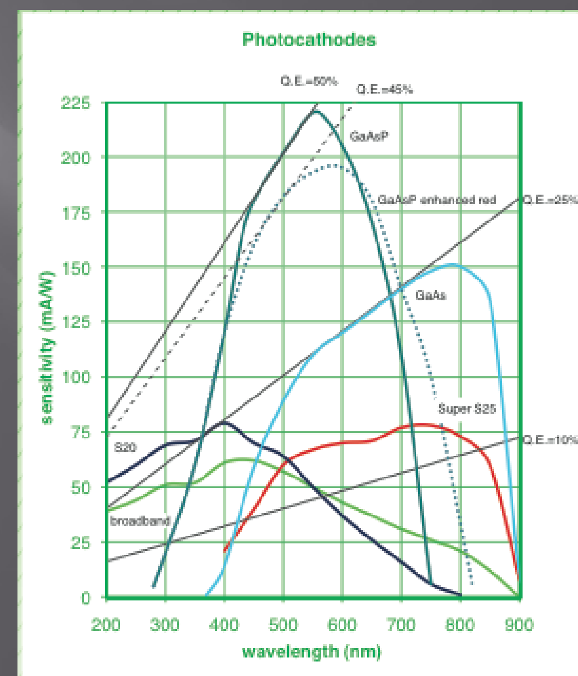
trigger rate: up to 5kHz

Camera details

Example : Lambert Instruments (NL)

5kfps (512x512), gate > 2ns, up to single photon sensitivity
We plan first beam test with slower camera
Using the OEM camera module we will be able to apply zero suppression for data reduction.



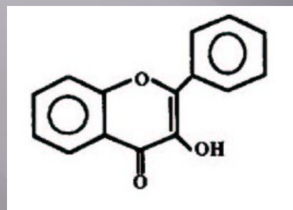


High QE ~ 50% for GaAsP photocathode & 420-520 nm

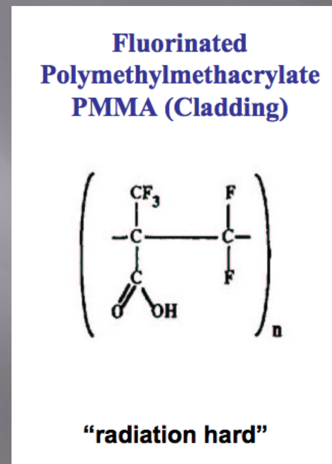
Rad-hard Kuraray 3HF fibers

- Used by LHCf, DIRAC
- • 500ppm - 3HF square fiber from Kuraray • Fluorinated PMMA cladding • High S-value (for mechanical stability)
- 3HF are not damaged up to 500 Krad measured ^{60}Co-γ, pions
- Strong annealing effects after irradiation (in certain cases attenuation length fully recovered)

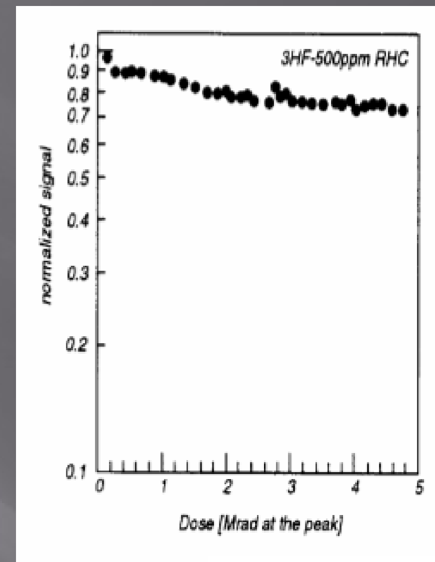
3HF fibers - properties



3-Hydroxyflavon
rad-hard dopant



Fiber cladding



CERN -RD25

Light output as function of dose

K.Hara et al. NIMA 411 1998 31

$$\lambda/\lambda_0 = 0.80 - 0.144 \cdot \log_{10}(D[Krad])$$

Attenuation length as function of dose

Max output wavelength 530 nm

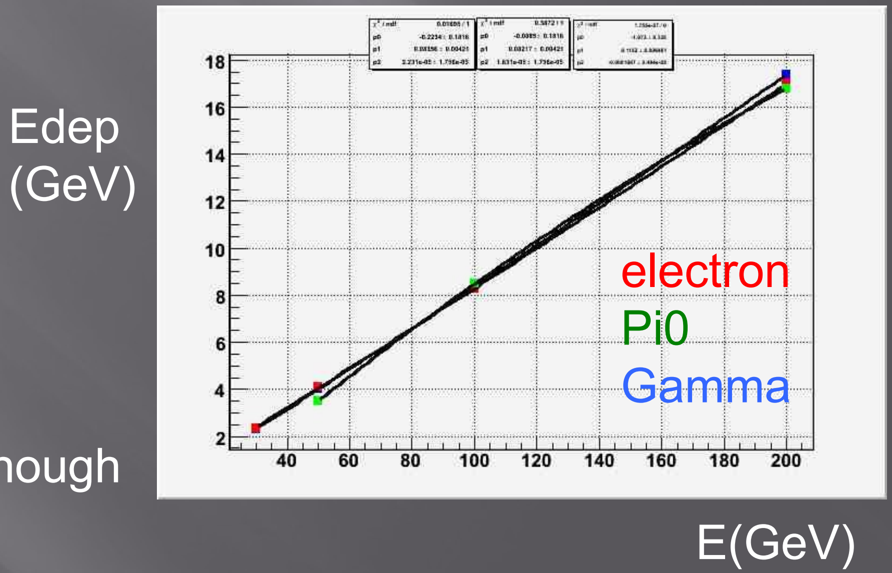
Well in sensitive range of intensifier !
QE ~ 50%

Inorganic – Hi-gain fibers

crystal type / properties	$PbWO_4$ (PWO)	LYSO	LuAG : Ce	YAP : Ce	YAG : Ce
density (g/cm^3)	8.28	7.2	6.7	5.4	4.5
radiation length X_0 (cm)	0.89	1.16	1.4	2.7	3.5
index of refraction	2.3	1.81	1.84	1.94	1.83
decay time (ns)	<20	42	50	25	100
emission wavelength (nm)	420-440	420	530	370	550
# of emitted photons / MeV at RT	125	27000	12500	10000	24000

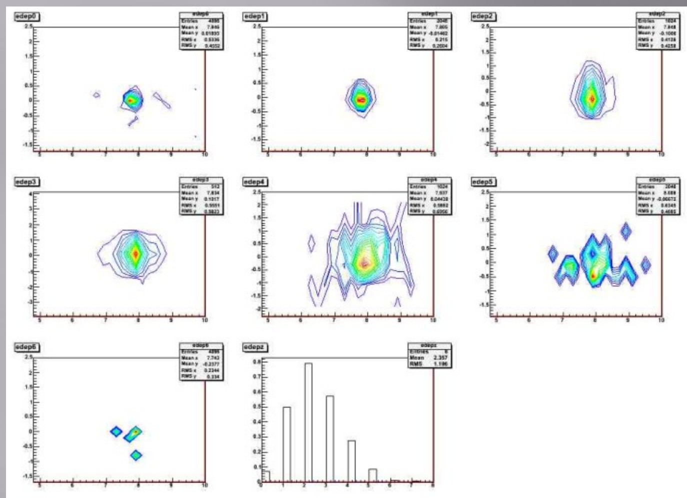
Simulation

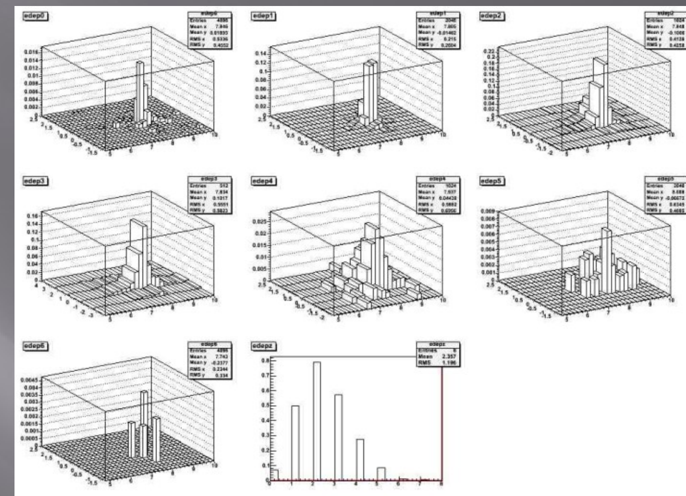
- Response to various particles and energies
- Threshold 2-3 MeV/pad + zero suppression – event size limitation
- Energy deposition in scintillator

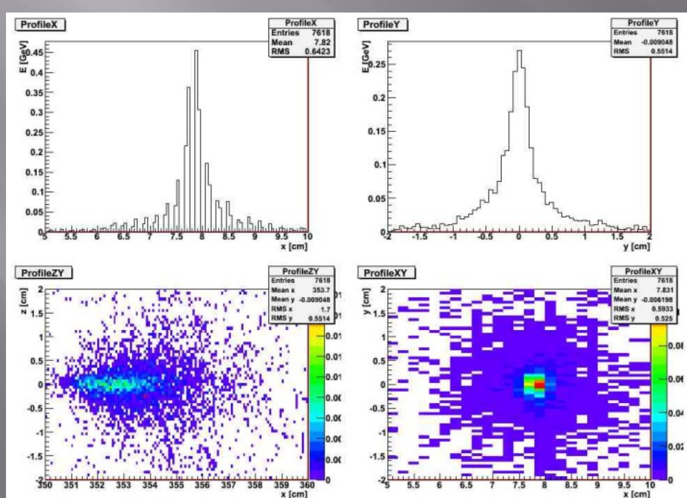


For muons and passing p
ECAL can be blind (thr. > MIP)
but sensitivity for MIP is good enough

Gamma 30 GeV

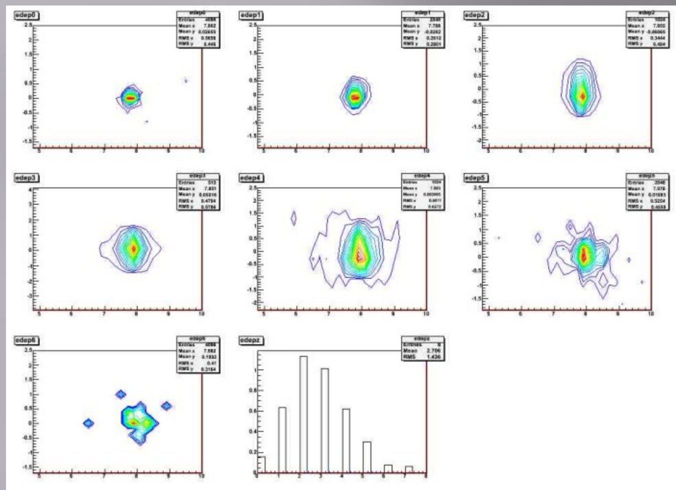


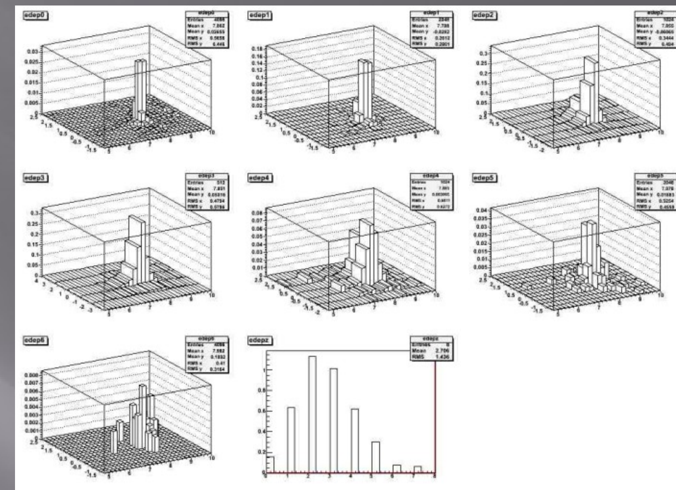


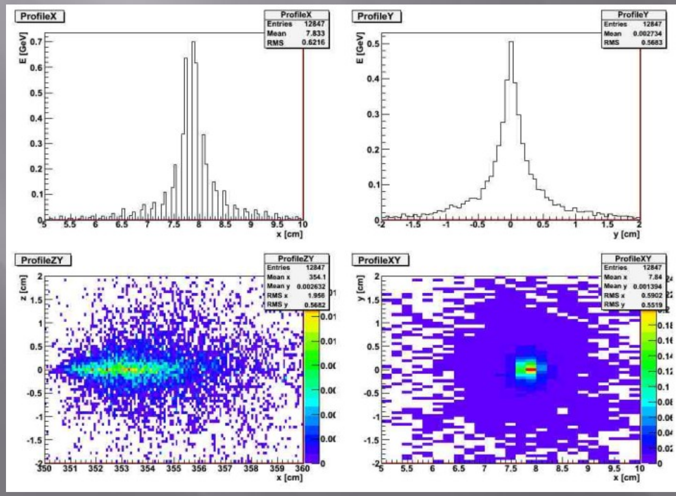


pad threshold 2 MeV all layers, y=4.5
deposited energy 2.83 GeV
reconstructed energy 2.31 GeV (81.7%)
(above threshold)

Gamma 50 GeV

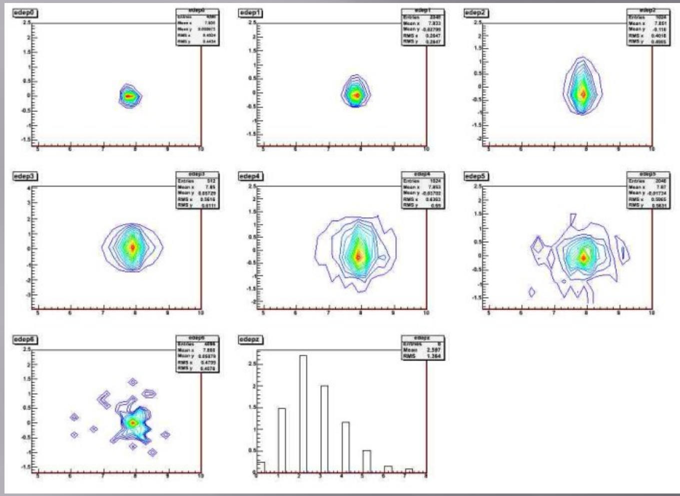


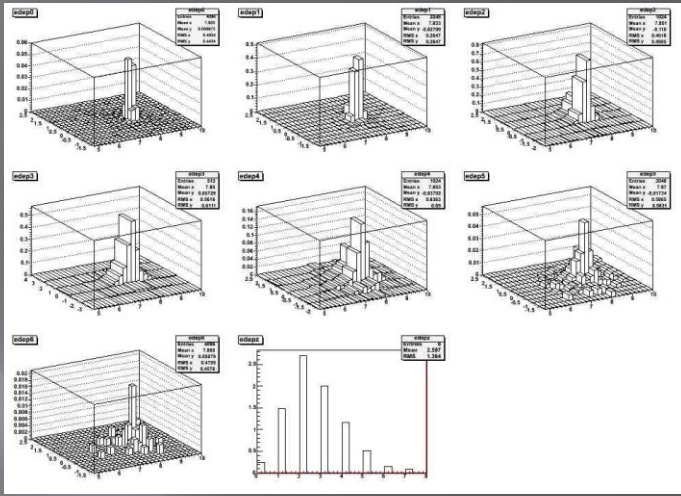


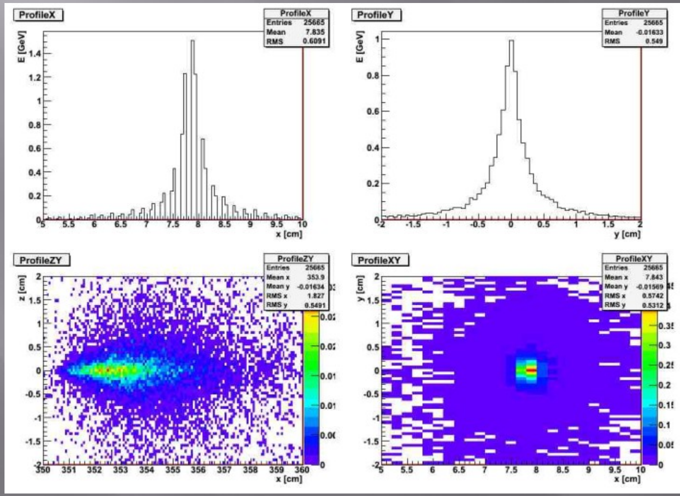


pad threshold 2 MeV all layers, y=4.5
deposited energy 4.78 GeV
reconstructed energy 4 GeV (83.7%)

Gamma 100 GeV

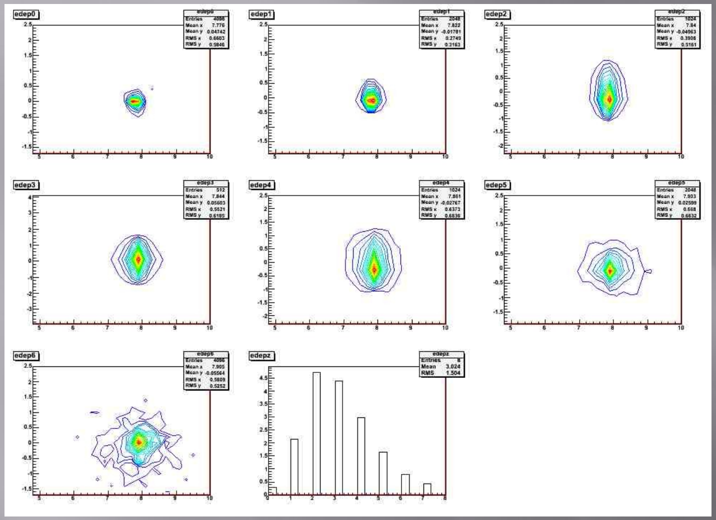


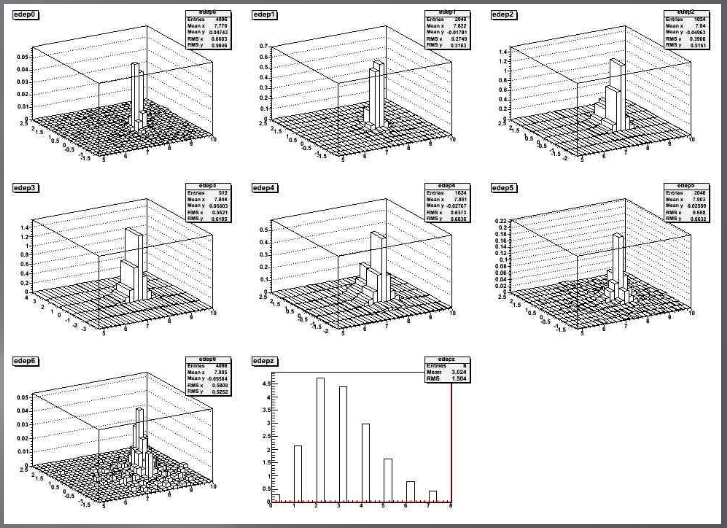


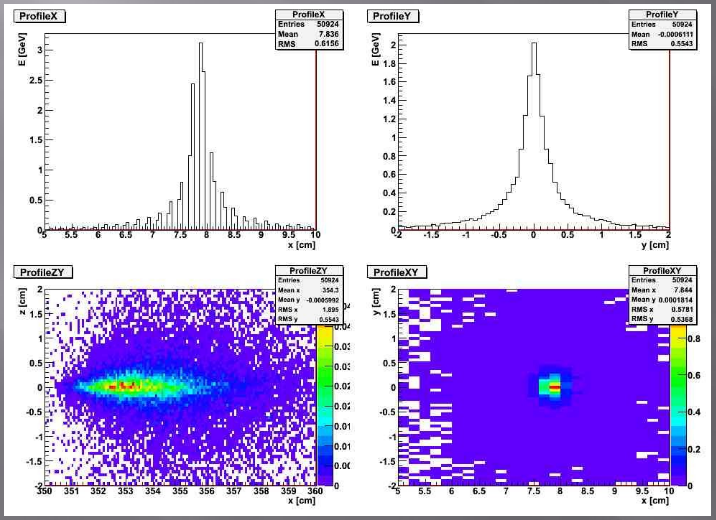


pad threshold 2 MeV all layers, y=4.5
deposited energy 9.52 GeV
reconstructed energy 8.36 GeV (87.7%)

Gamma 200 GeV

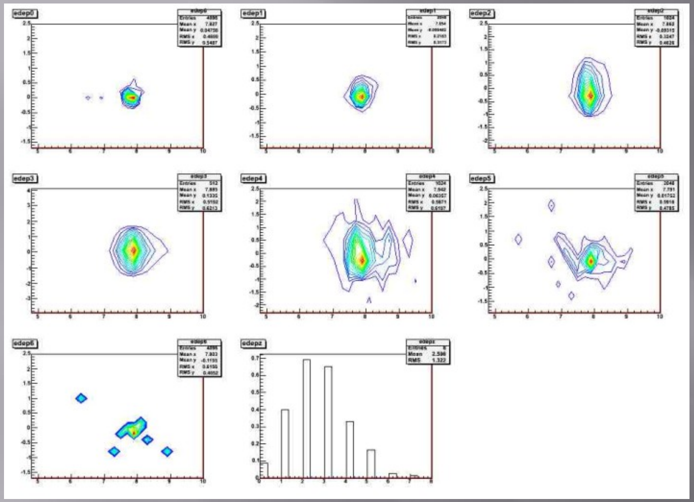


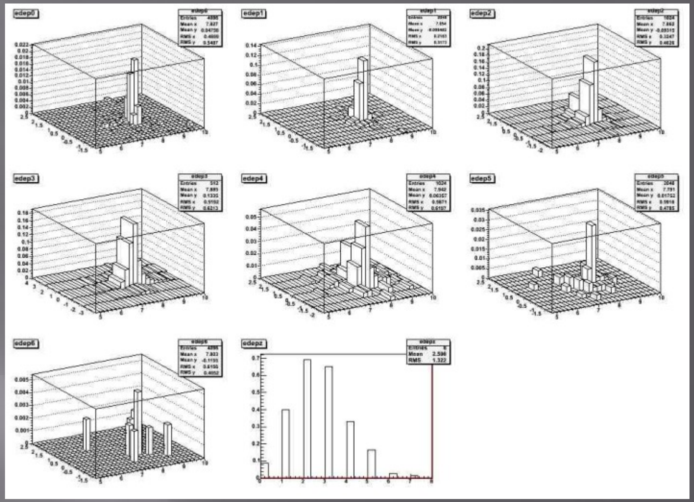


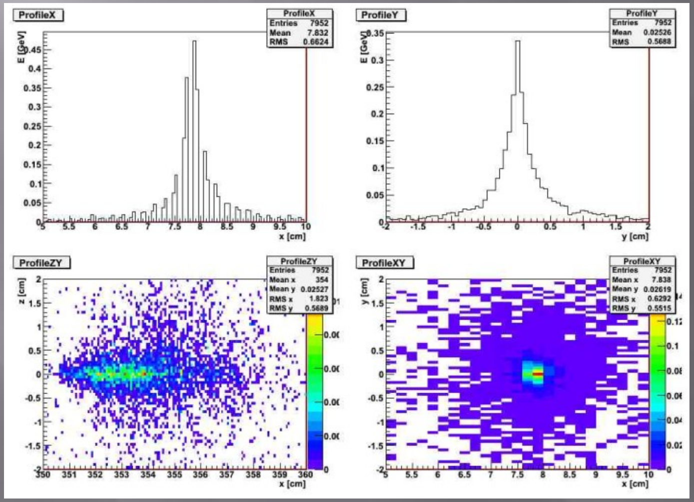


pad threshold 2 MeV all layers, y=4.5
deposited energy 18.32 GeV
reconstructed energy 17.38 GeV (91.5%)

Electron 30 GeV

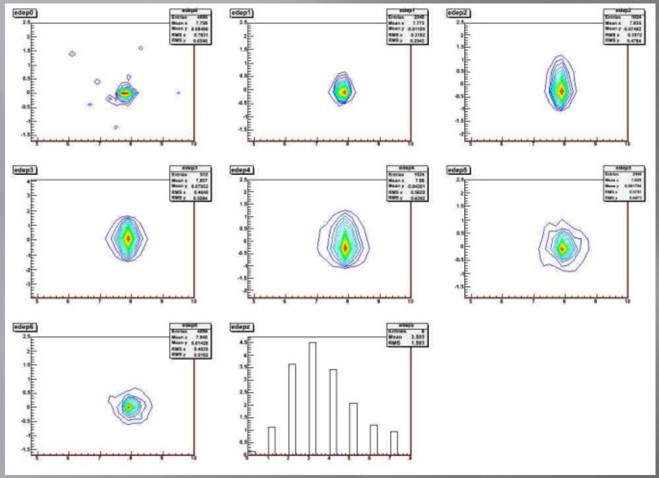


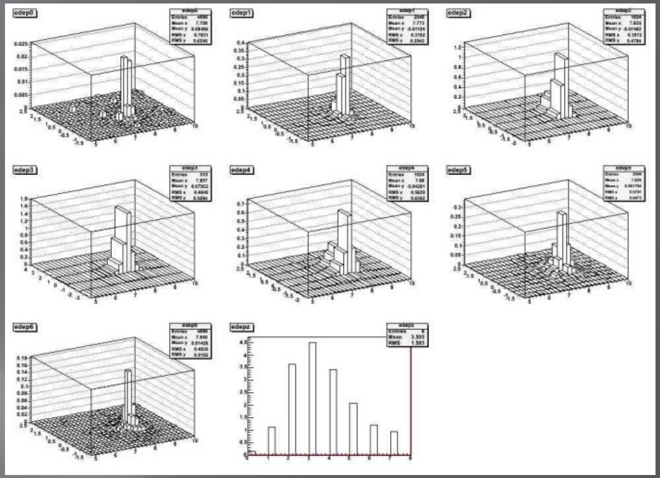


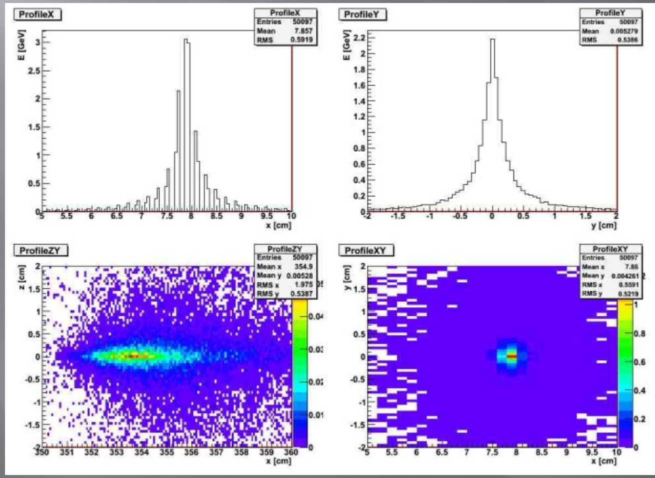


pad threshold 2 MeV all layers, y=4.5
deposited energy 2.91 GeV
reconstructed energy 2.36 GeV (81.1%)

Electron 200 GeV



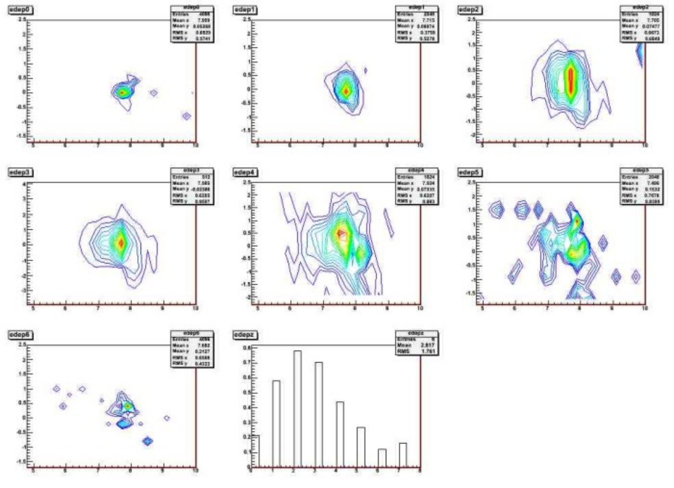


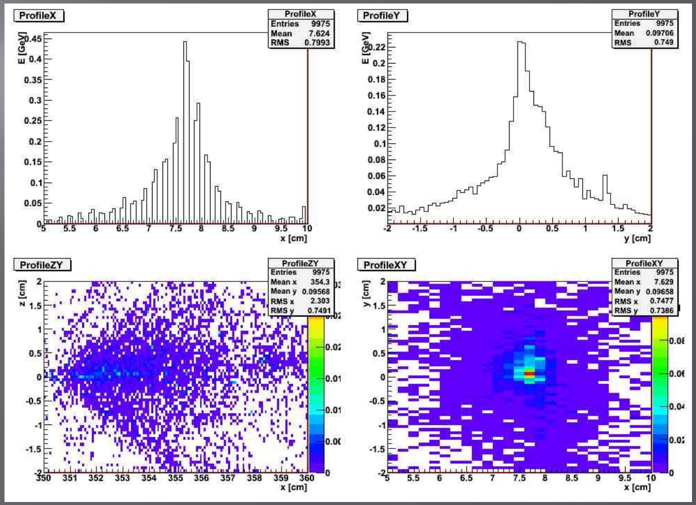


pad threshold 2 MeV all layers, y=4.5
deposited energy 18.63 GeV
reconstructed energy 17 GeV (91.4%)

Nucleons

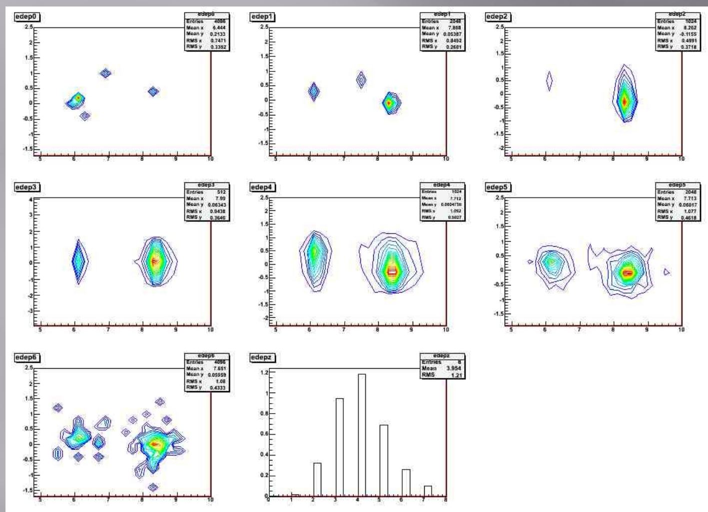
- Some n,p interact in 0.7 Int. length – different shower shape and lower Edep

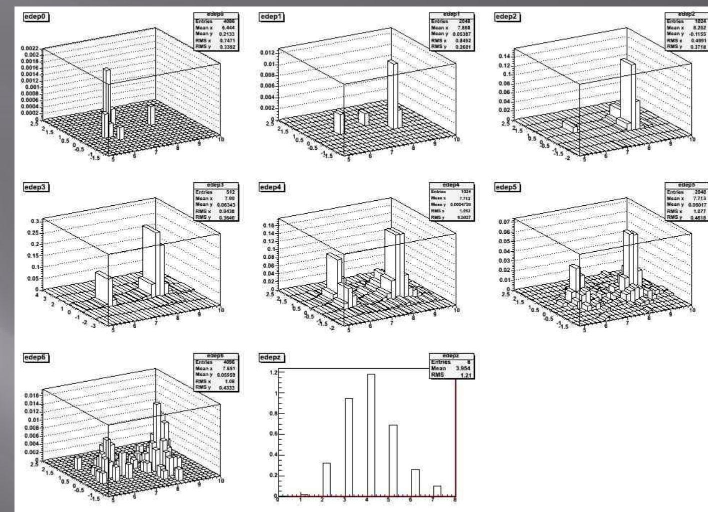


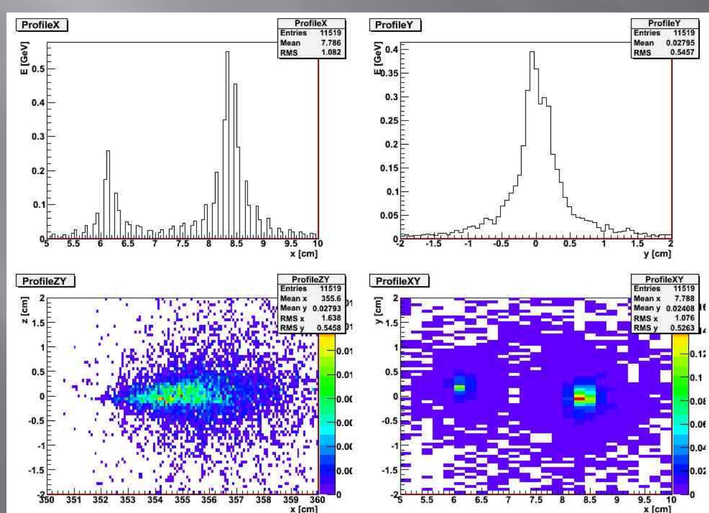


Compare with shape of 30 GeV gamma with comparable deposited energies
Deposits 40% of reconstructed energy compared to 100 GeV gamma, electron

π^0 50 GeV

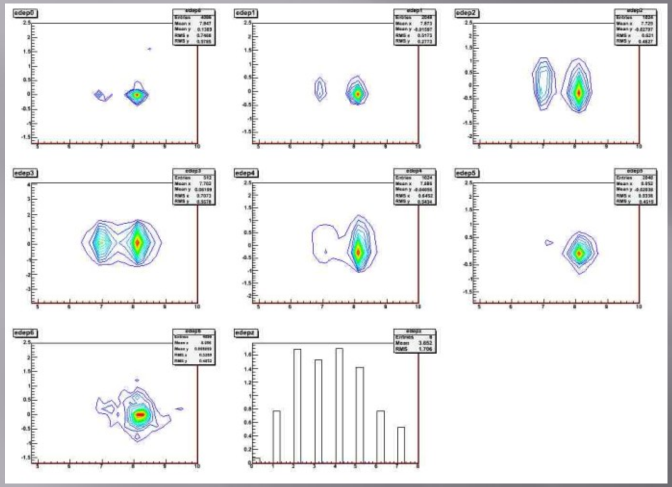


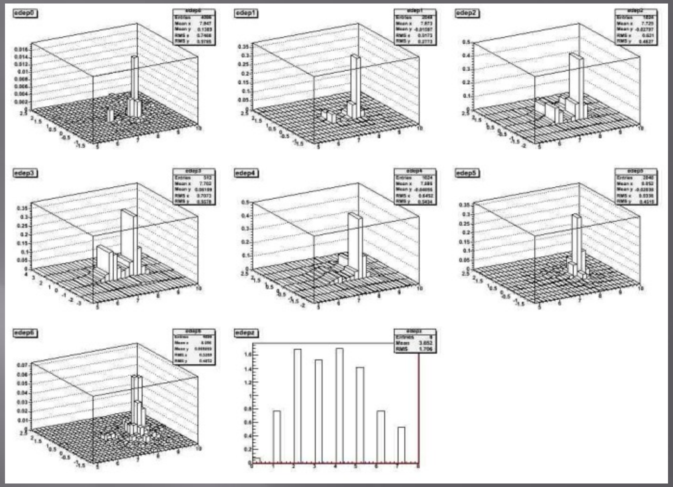


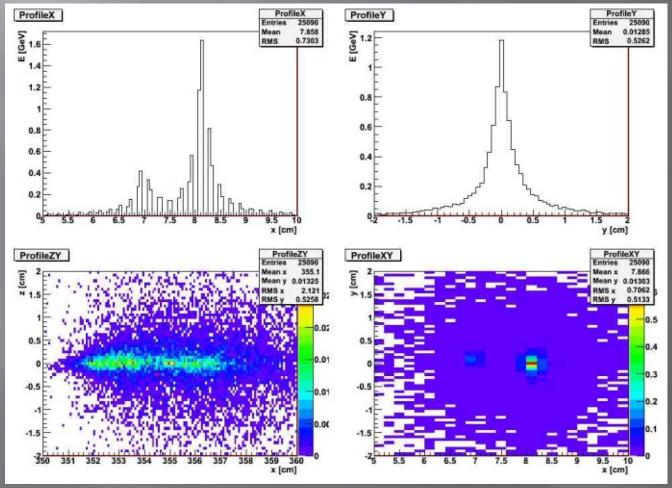


pad threshold 2 MeV all layers, y=4.5
deposited energy 4.31 GeV
reconstructed energy 3.52 GeV (81.6%)

π^0 100 GeV

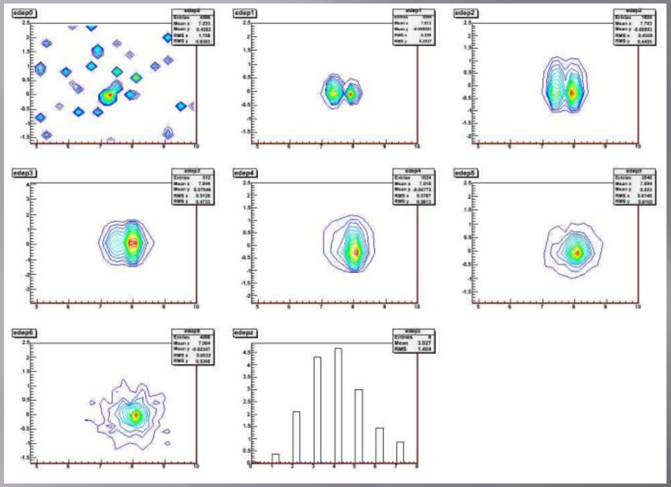


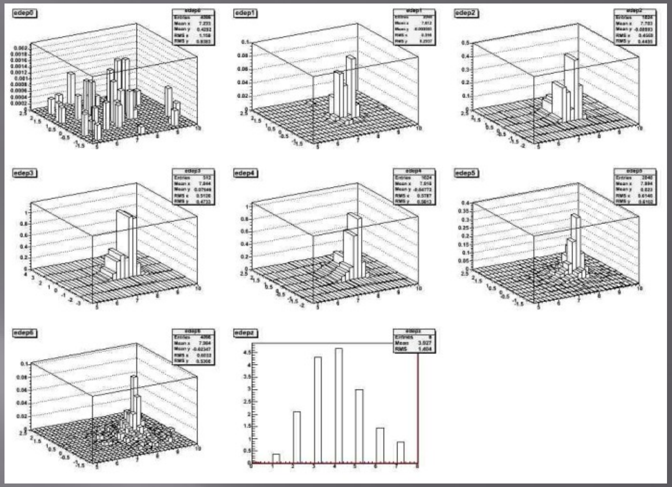


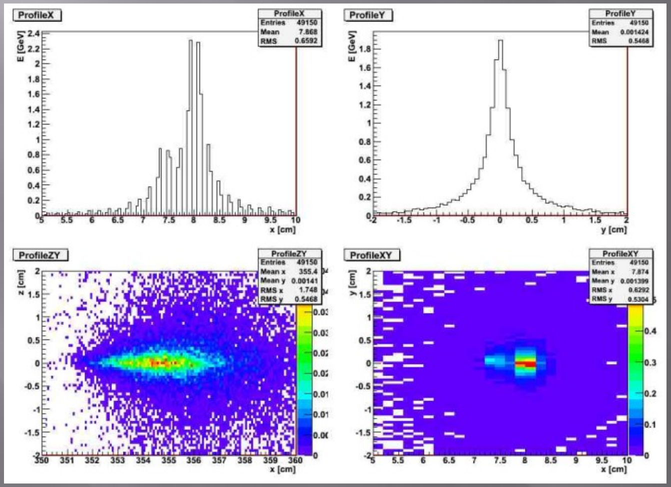


pad threshold 2 MeV all layers, y=4.5
deposited energy 9.62 GeV
reconstructed energy 8.48 GeV (88.1%)

π^0 200 GeV







pad threshold 2 MeV all layers, y=4.5
deposited energy 18.4 GeV
reconstructed energy 16.8 GeV (91.3%)

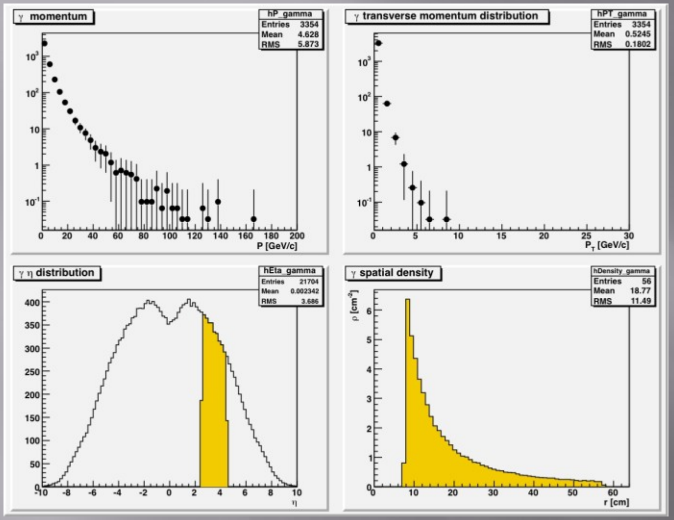
Pt limit at
y=4.5 for Pmax ~200 GeV, Pt max ~5GeV
y=4. for Pmax ~200 GeV, Pt max ~7.5GeV
y=3 for Pmax ~200 GeV, Pt max ~20GeV

High multiplicity environment

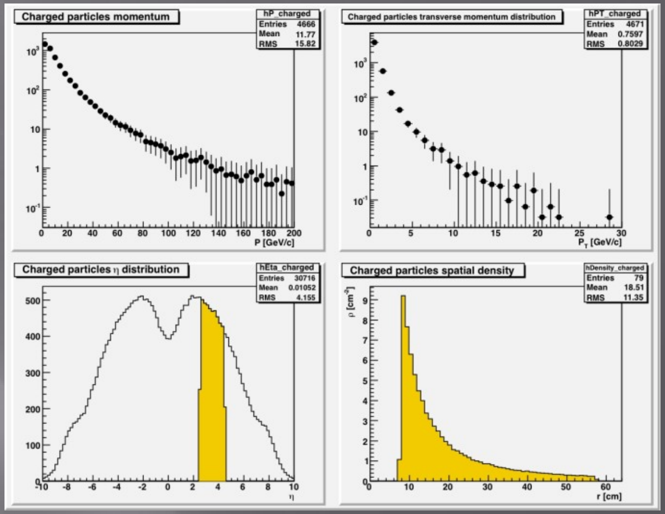
- simulation of max. allowed shower density
- gamma (30 GeV) reconstruction for <density> 1,2,3,4,5 gamma/cm^2
- examined ability to distinguish gamma

What can we expect at y=4.5

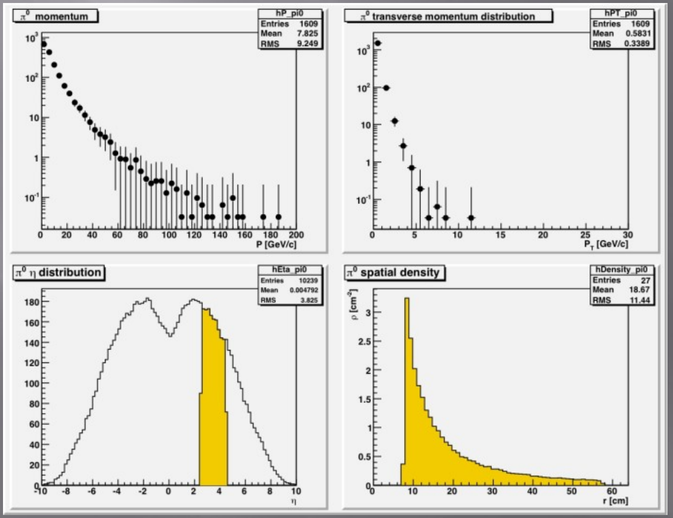
Photons



Charged hadrons

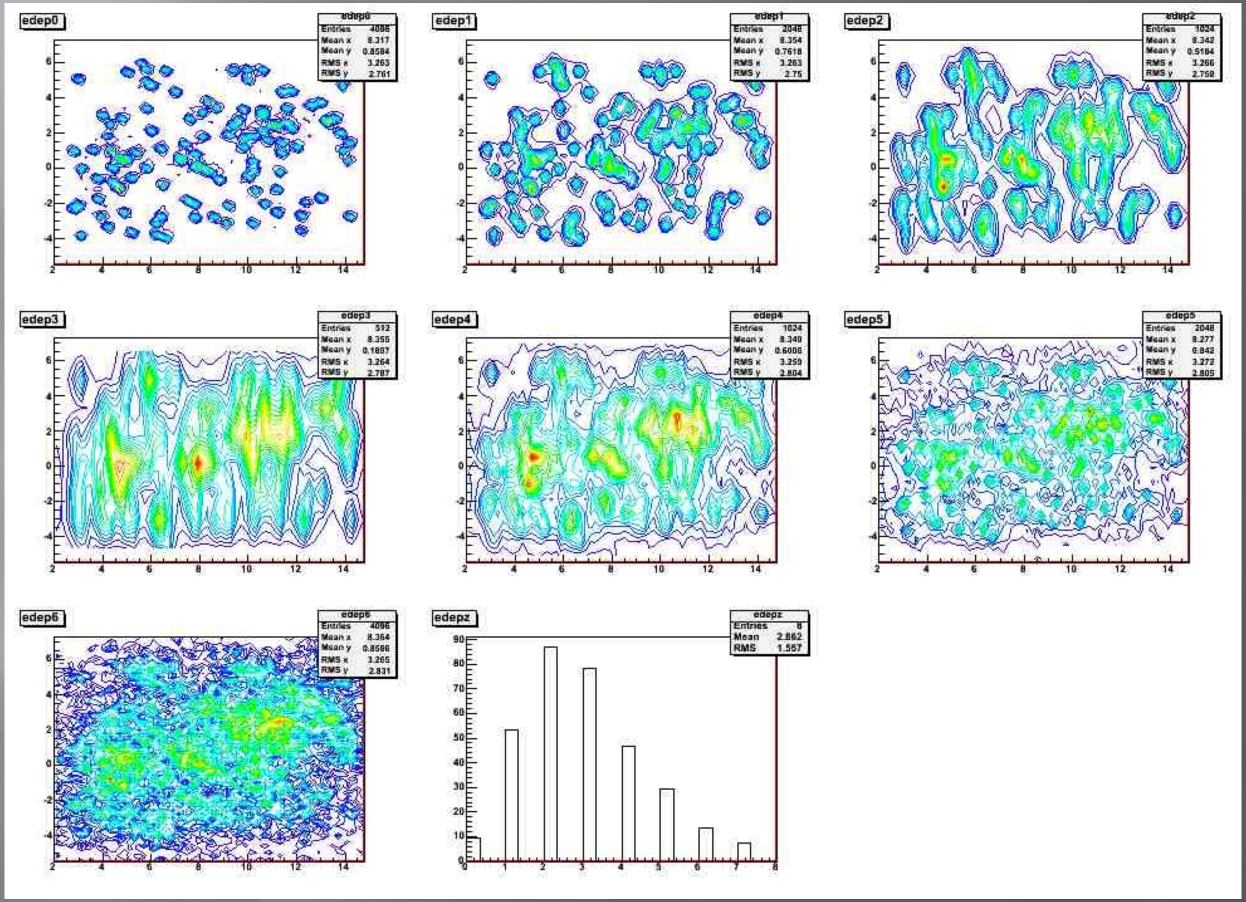


Pi0



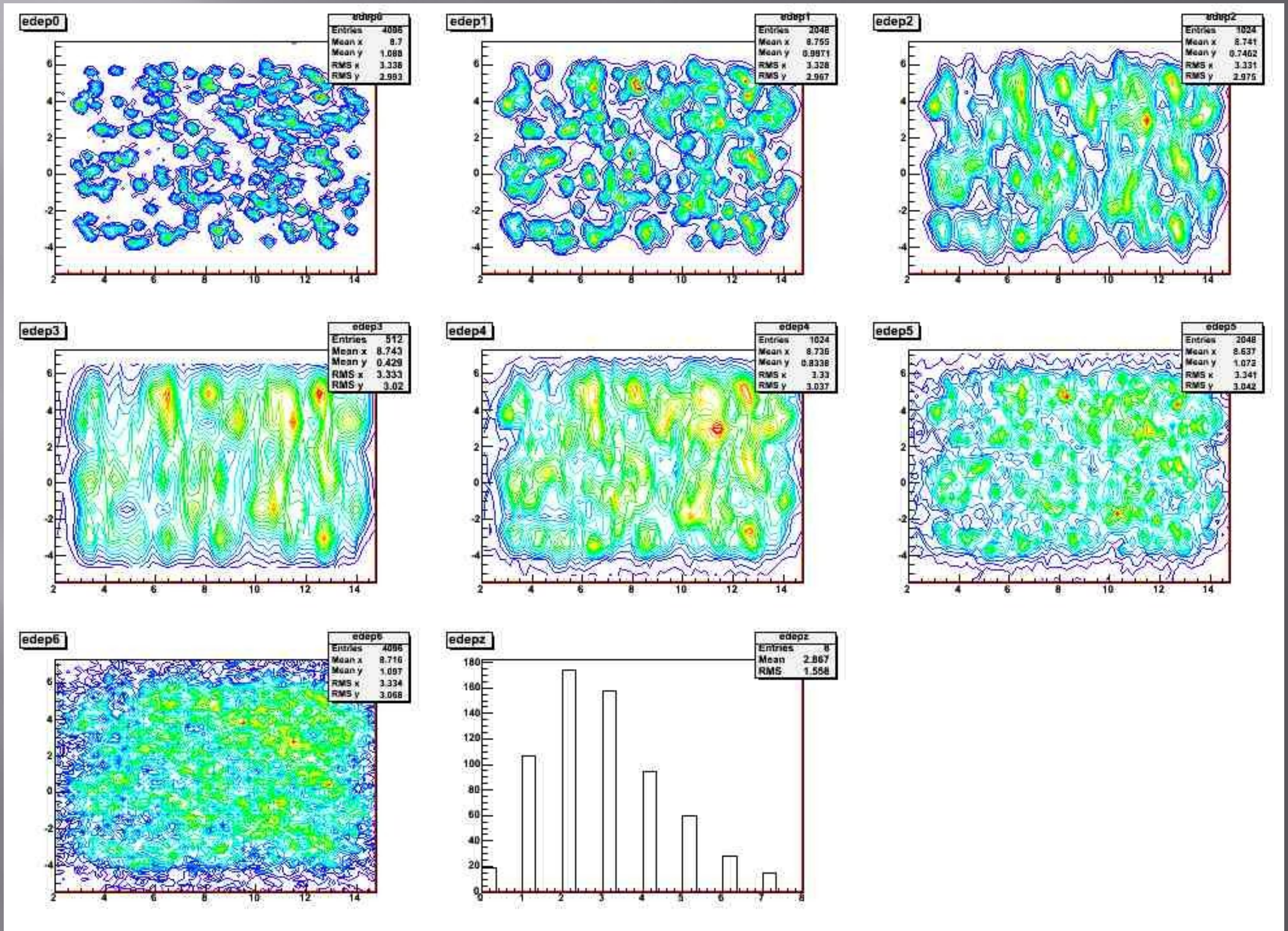
Sqrt(s) = 5.5 TeV/n-n
Pb-Pb

1 Gamma (30 GeV)/ cm^2



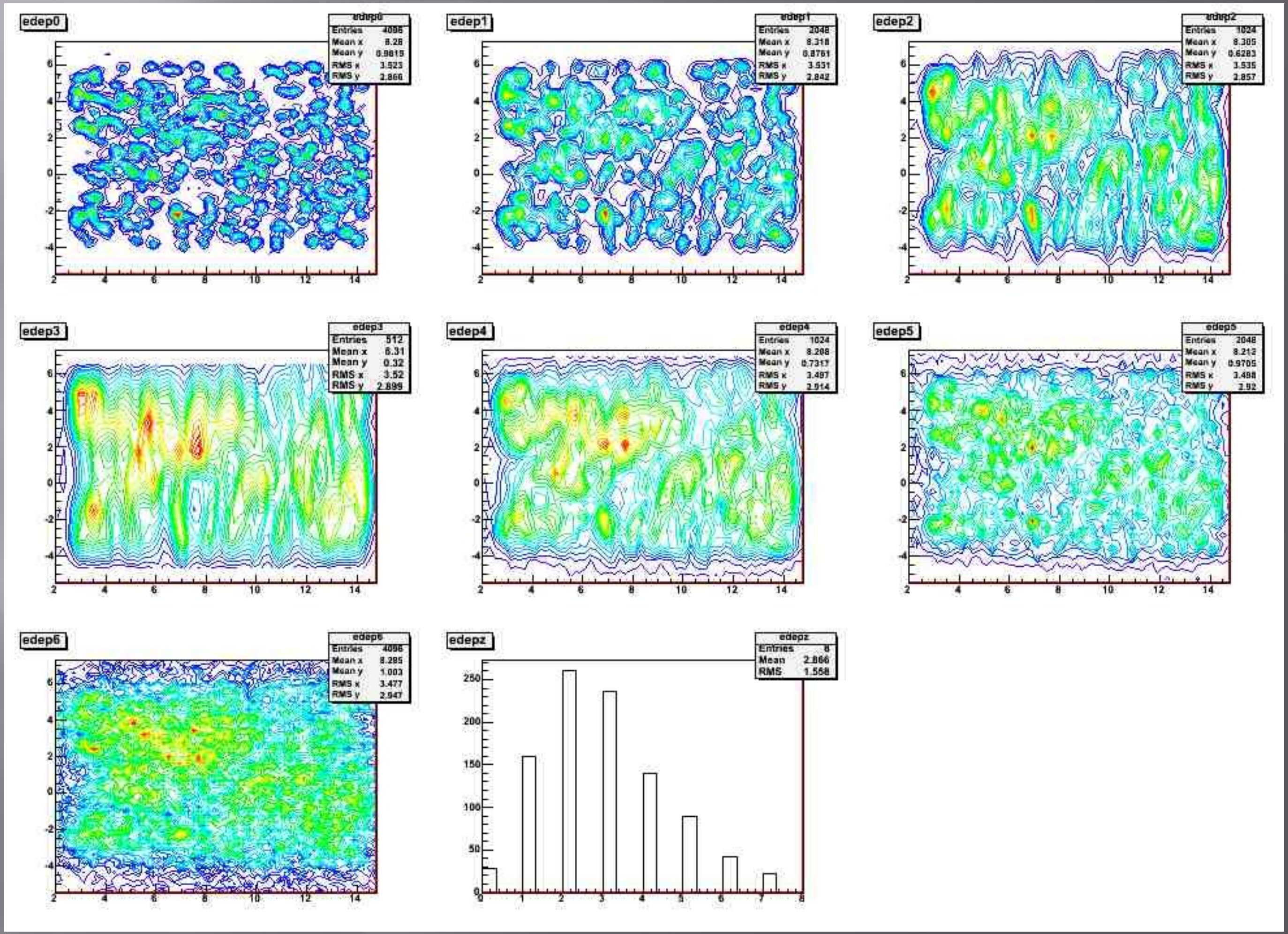
pad threshold 2 MeV all layers, y=4.5, total 115 gamma 30 GeV
total reconstructed energy (above threshold) 324.6 GeV i.e. 2.82 per particle

2 Gamma (30 GeV)/ cm^2



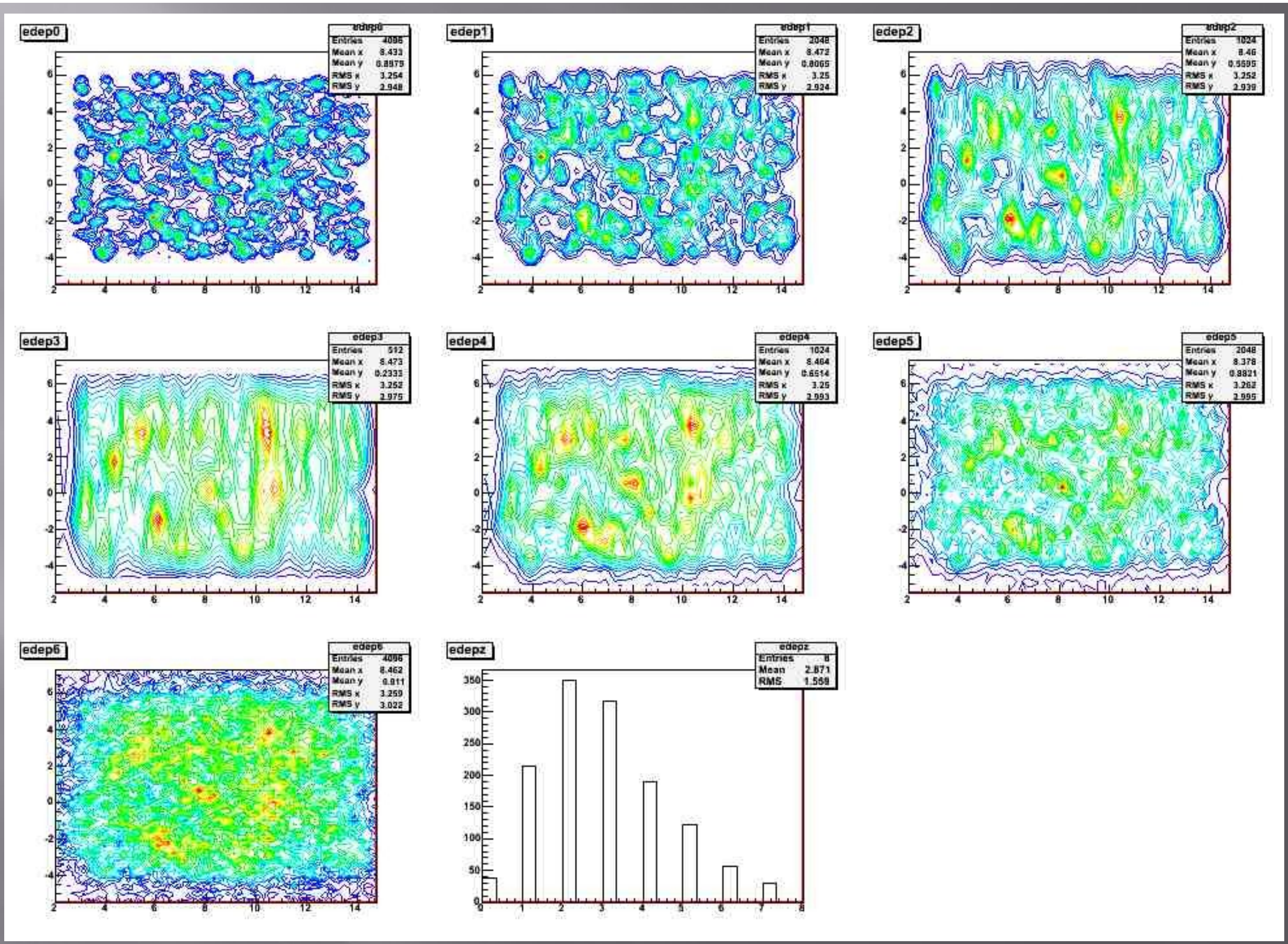
230 gamma 30 GeV, total reconstructed energ 653.6 GeV i.e. 2.84 per particle

3 Gamma (30 GeV)/ cm^2



345 gamma 30 GeV, total reconstructed energy 978 GeV i.e. 2.83 per particle

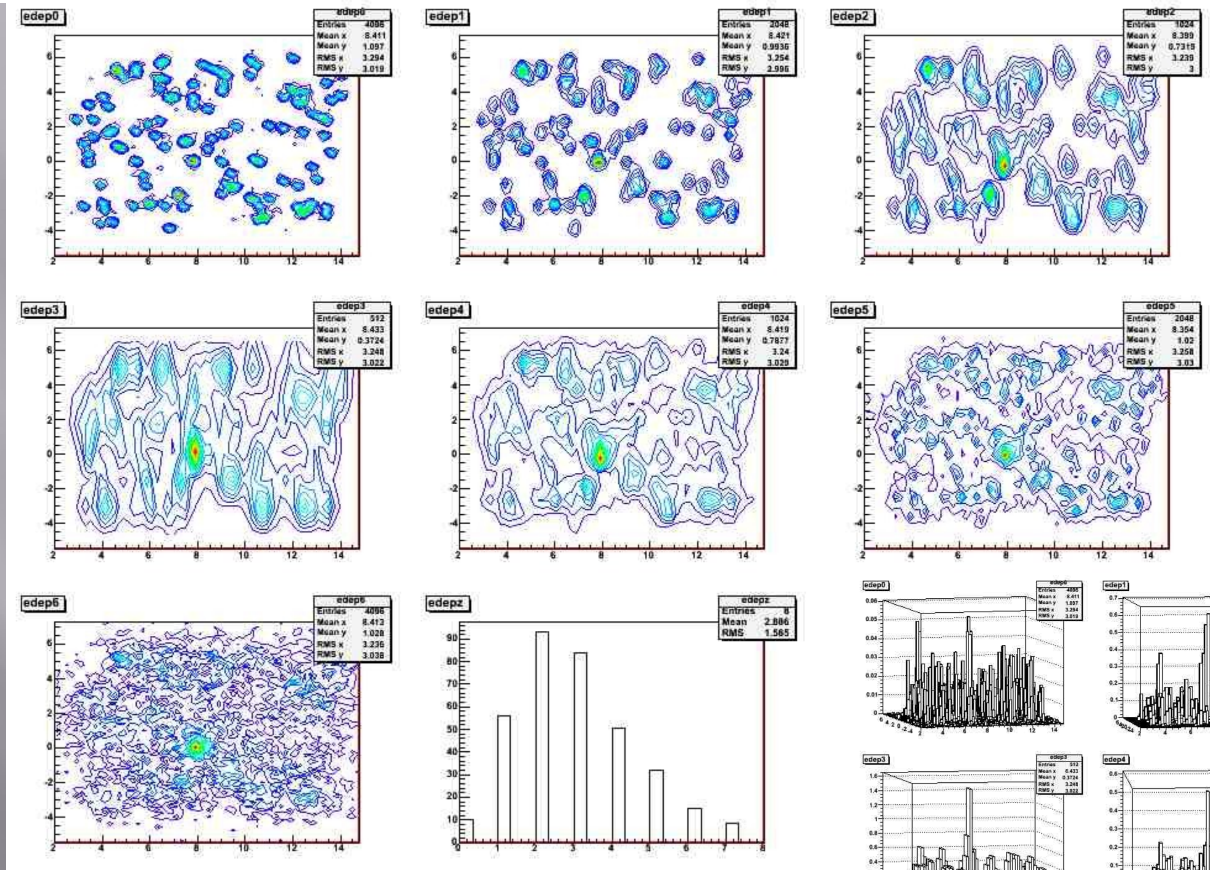
4 Gamma (30 GeV)/ cm^2

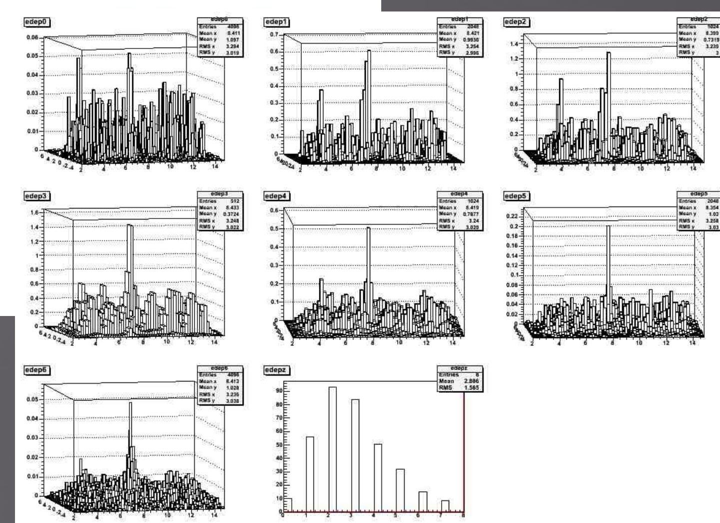


460 gamma 30 GeV, total reconstructed energy 1313 GeV i.e. 2.85 per particle

Obvious percolation in layer peak signals - close to limit of individual shower counting

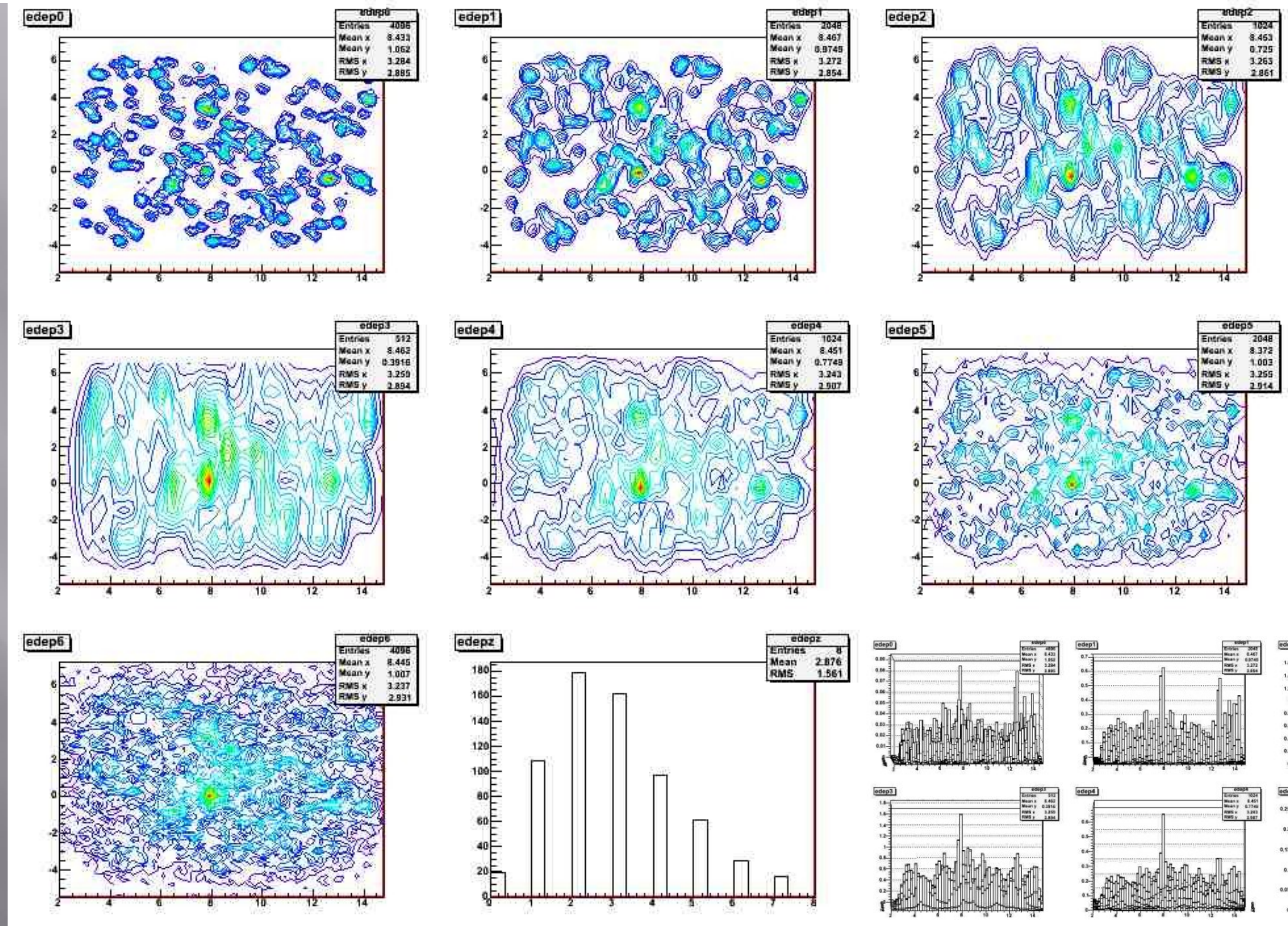
High-P Gamma embedded

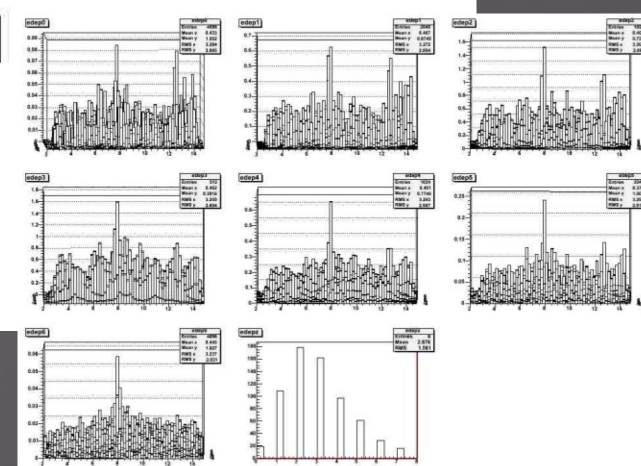




200 GeV Gamma in
<n> =1 (30 GeV) Gamma/ cm2
Signal above threshold in deep layers
could be used as HLT for detection of High P gammas

High-P Gamma embedded

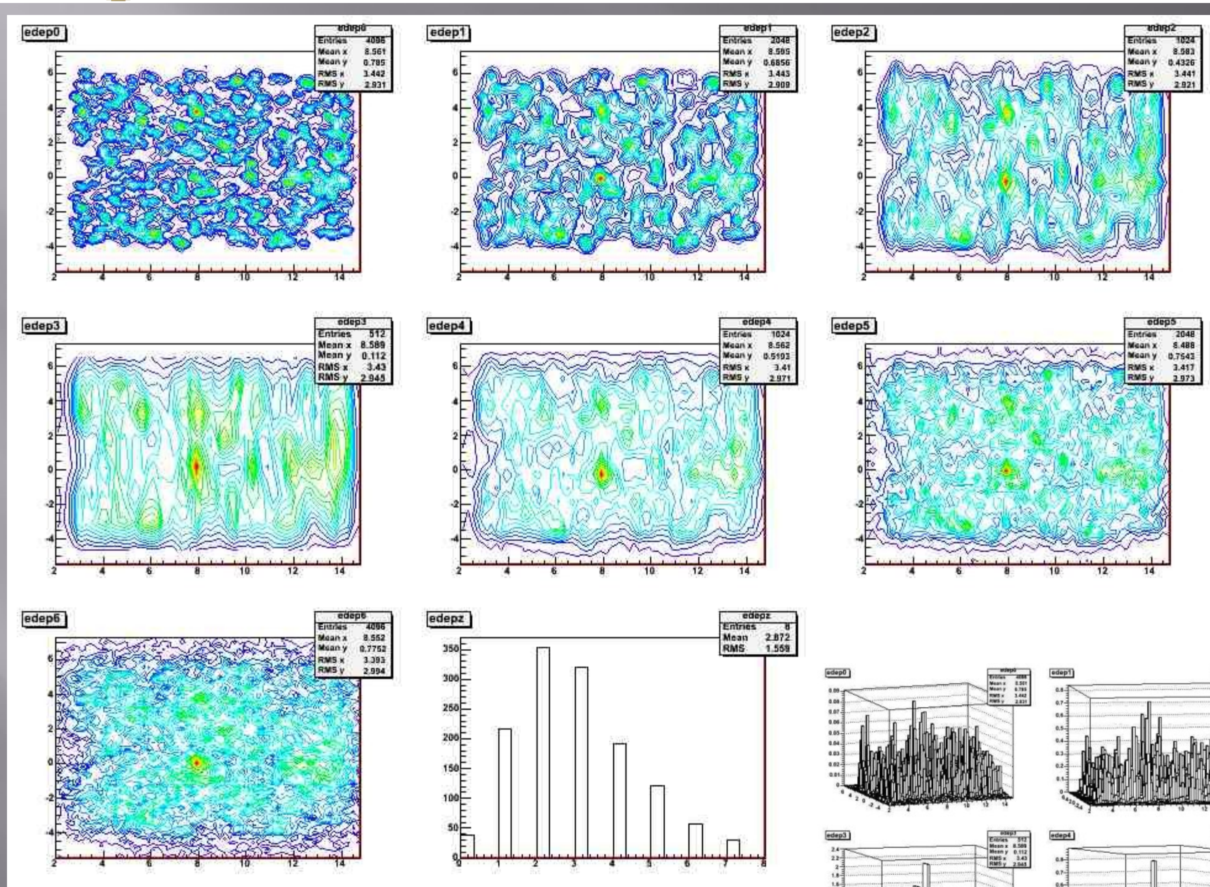


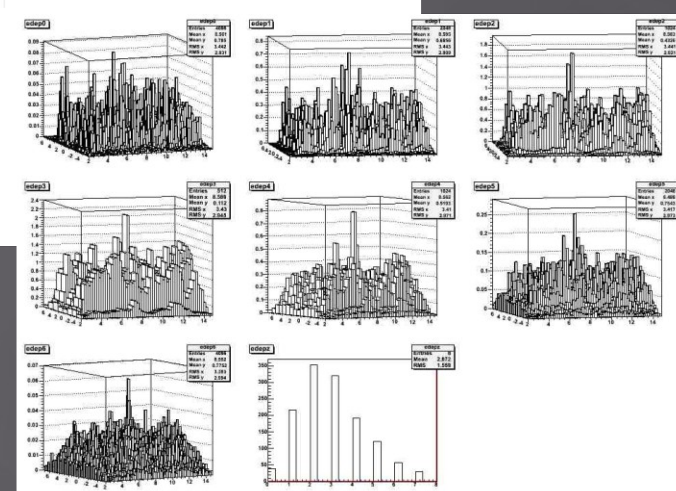


200 GeV Gamma in

<n> =2 (30 GeV) Gamma/ cm2

High-P Gamma embedded





200 GeV Gamma in
<n> =4 (30 GeV) Gamma/ cm2
It is clearly visible in deeper layers

Limitations

- Energy resolution in high multiplicity region
- But - cleaner for high P penetrating deeper in low P background
- Pi0 topology - lower P gamma in close vicinity of high P shower - sensitivity to background & noise, improved with penetration depth
- P max for Pi0 ~ 200 GeV

Next steps

- Simulation: Pi0 reconstruction SW run on realistic background
- Simulation of the hadronic stage - thin 2.5 Int. Length which fits close to beampipe
- Simulation of the thick HCAL stage for lower y (3-3.5)
- Prototyping: we are building the EM beam-test prototype first test this fall - PS

Summary & Conclusions

- Concept of super-compact ECAL in forward region has been examined
- Design allows for operation in high multiplicity environment close to y=4.5
- Thickness of the detector leaves space for thin 2.2 Int l. hadronic stage at y=4.5, thicker on lower rapidities
- Optical readout allows for 5kHz trigger rate, system is able to generate L0 trigger in EM shower max and for HCAL stage
- We can now examine options for combined EM and HAD calorimetry - thought with limited energy resolution (punch through situation in Hcal can be detected).