Conceptual study of super-compact calorimeter design for the forward physics

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Abstract

One of the long standing puzzles in the understanding of the fundamental QCD is the production of particles in the forward direction. This kinematic region allows one to address very low Bjorken x and through this constrain the saturation scale, that determines the suppression driven by coherence effects (CGC), and greatly improve the precision of parton distributions in nuclei. The conceptual study of the super-compact ECAL in the forward region is proposed here based on the tungsten - scintillator calorimetry that provides desired acceptance and due to its compactness also possibility to include HCAL part. This design enables to measure 200GeV photons, discriminate two photons from neutral pion decay and identify direct photons in large energy range. Moreover, jet quenching measurements and jet calorimetry will be possible.

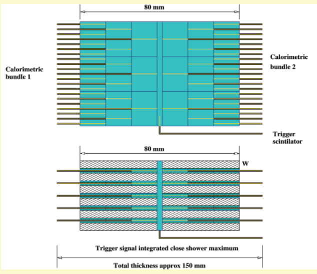
Motivation

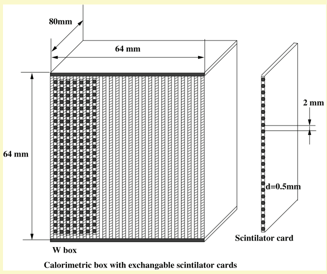
Forward rapidity region of high energy particle collisions offers opportunity for studying more details of physics at small Bjorken-x. Particles produced to this region originate dominantly from gluon interactions providing possibility to scan low x gluon densities. Furthermore, saturation effects can be studied by constraining suppression of particles produced in nuclear collisions. Basic measurements to study the physics aspects are forward π^0 and jets production, prompt photon production, quarkonia and leptons from heavy quarks, ...

The aim of our project is therefore to develop new super-compact ECAL for the forward region based on the tungsten-scintillator calorimetry for wide pseudorapidity range for photon energies up to E ≈ 200GeV able to operate in high particle fluxes.

Mechanical design

Sandwich of tungsten plates and thin scintillator cards oriented longitudinally to the beam. Scintillator cards consist of variable granularity pads with optical readout.

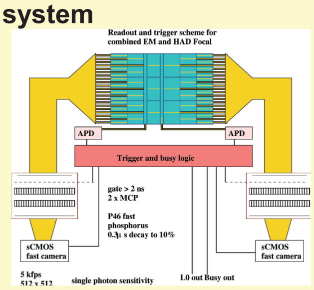




- 0.5 mm radiation hard inorganic scintillators (YAG, 3HF,…) – high quantum efficiency
- Variable granularity pad size – best resolution on the first and last layer, possible track reconstruction, integrate at the shower max
- Trigger at shower max using APD coincidence (independent fibers from trigger scintillator) to avoid random triggers
- Tungsten plates (d=1.5mm) manufactured from 97% W and 3% Cu and Ni
- Thin support needed – almost no dead zones

Readout system

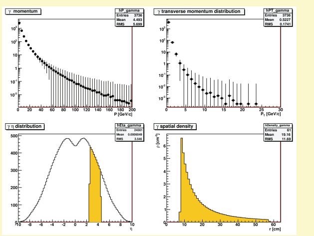
- Radiation hard optical fibers from scintillator to an image intensifier, than readout with a high speed camera
- Camera properties:
  - 200 μs / full frame
  - shutter gate > 2 ns
  - single photon sensitive
  - 12bit ADC
  - 60 kevent memory in camera
  - trigger rate: up to 5kHz
- Fast trigger ability

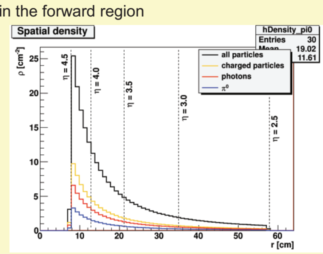


Example – HiCAM 5000:
Lambert Instruments (NL)
- 5kfps@ 512x512, gate > 2ns, up to single photon sensitivity
- Plan - first beam test with slower camera
- Using the OEM camera module we will be able to apply zero suppression for data reduction

Simulations

Particle densities in the forward region

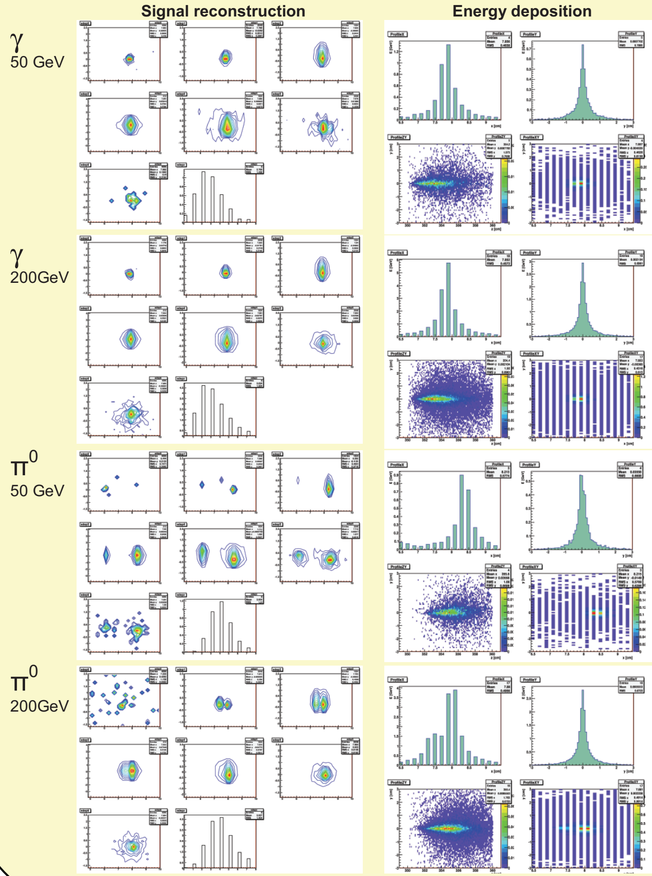




Responses to particles up to rapidity 4.5
- Threshold 2-3 MeV/pad
- Angle between layers and primary particle 1.27 degrees
- Simulated in Hijing and Geant 3

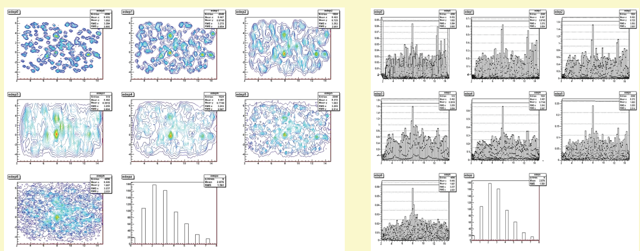
Simulations

Response of the detector (energy deposition) to particles at various energies



Simulations

Response of the detector in high multiplicity environment – high momentum γ (200 GeV) embedded in environment of 2 γ (30 GeV) / cm^2 - clearly visible in deeper layers



Summary and Conclusions

- Concept of super-compact ECAL for forward rapidity region has been examined
- γ and π^0 identification up to energy 200 GeV with full energy reconstruction
- Two γ separation ~ 5mm
- Operation in high multiplicity environment and strong radiation environment(LHC, ELI…)
- Optical readout at > 5kHz trigger rate, system is able to generate fast trigger at shower max.
- There is no need cooling and power the detector
- Prototyping: we are building the EM beam-test prototype

This work was supported by grant MSMT LC07048