Towards a realistic Scintillator HCAL with SiPM read-out

Felix Sefkow

CALOR08, Pavia
May 30, 2008
From proof-of principle to reality

See talks by
Erika Garutti (test beam results)
Angela Lucaci (Calibration)
Collaborating institutes

- **Czech R.:** Prague
- **France:** LAL Orsay
- **Germany:** DESY, Hamburg, Heidelberg, MPI Munich, Wuppertal
- **Japan:** Kobe, Shinshu
- **Russia:** JINR; ITEP, LPI, MEPHI Moscow
- **UK:** Cambridge, Imperial C, UCL, RAL
- **US:** Northern Illinois
Outline

- Physics requirements and design goals
- A compact design with integrated sensors and electronics
- For the electronics itself, see subsequent talks by
  - Christophe De La Taille (front end ASICs)
  - Valeria Bartsch (DAQ)
  - Common design for ECAL, scint and gas HCAL
Calorimetry at the ILC

- $\sqrt{s} (e^+e^-) = 0.5-1$ TeV
- Multi-jet events, typically:
  - $E_{\text{jet}} \sim 50 \ldots 150$ GeV
  - $E_{\text{hadron}} \sim 1 \ldots 100$ GeV

- An imaging HCAL for particle flow reconstruction
  - Two-particle separation
  - Hadronic energy resolution

- High longitudinal and transverse granularity
  - Software compensation
Design goals

• Novel multi-pixel Geiger mode photo-diodes (SiPMs)
  - B-field proof, small, affordable
• High granularity with scintillator at reasonable cost
  - photo-sensors integrated
• Opens revolutionary design options:
  - embedded electronics and calibration system for minimal dead zones
  - thin readout gap
• Granular, compact, hermetic
Tile granularity

- Recent studies with PFLOW algorithm, full simulation and reco.
- Confirms earlier studies for test beam prototype
- 3x3 cm² nearly optimal
Geometry, optimization, integration

- Presently starting new round of detector optimization, using detailed simulations and state-of-the-art reconstruction algorithms
- Baseline: stainless steel, square tiles
  - Also considered: brass or lead
  - Scintillator striplets
- R&D and integration issues are largely independent on details of final geometry
  - Sensors and tiles
  - Ultra-low power electronics, interfaces
  - Mechanical structure

A scintillator based calorimeter with embedded sensors and electronics has not been built before

M. Thomson (Cambride)
Tile sensor systems with WLS fibre

- Present test beam system
  - 5mm thick tile with fibre, MEPHI/PULSAR SiPM, 15 pixels/MIP
- Several new options: reduce to 3 mm thick tiles
  - Hamamatsu MPPC-1600
  - MRS APDs (CPTA)

M. Danilov (ITEP)

Overvoltage, V

Green light efficiency

Light yield, pix

Gain (x106)

Cross talk, kHz

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Tile sensor direct coupling

- Possible with blue-sensitive sensors
  - Hamamatsu MPPC 1600 (400)
- Obtain about 7 (11) px/MIP from 5 mm tiles; low noise
  - ➔ increase area

- Need to restore uniformity
  - Some additional light cost

- Other proven option: strips
  - CALICE SciW ECAL

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Tile PCB coupling

- Scintillator photo-sensor system has to match electronics PCB tolerances
- Several options
  - Mega-tiles (easier assembly, but some optical cross-talk
  - New: idea “lego” tiles with alignment pins
    - 30x30x3mm³
- Other option: surface-mounted sensors on PCB
  - Different integration chain

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Integrated layer design

- Reflector Foil 100µm
- Polyimide Foil 100µm
- HBU Interface 500µm gap
- Sector wall
- Top Plate fixing
- ASIC TQFP-100 1mm high
- PCB 800µm
- Top Plate 600µm steel
- Spacer 1.7mm
- Component Area: 900µm high
- HBU height: 6.1mm (4.9mm without covers => absorber)
- Bottom Plate 600µm
- SiPM Tile 3mm
- Bolt with inner M3 thread welded to bottom plate
- Absorber Plates (steel)
- DESY

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Optical calibration system

- SiPMs, MPPCs are self-calibrating
  - Ph.e. peak distance ~ gain
- Embedded LEDs
  - Electronic signal distribution
  - Tested, no cross-talk to sensors seen
  - To be optimized: dynamic range, LED uniformity
- Alternative: central driver and optical signal distribution

I. Polak (Prague)
New ASIC on the test benches

- Auto-triggering and time measurements
- ADC and TDC integrated
- Power pulsing, low (continuous) power DAC

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Barrel HCAL architecture

1/16 of barrel half

AHCAL Slab
6 HBUs in a row

Front end ASICs embedded
Interfaces accessible

HBU
HCAL Base Unit
12 x 12 tiles

SPIROC
4 on a HBU

HEB
HCAL Endcap Board
Hosts mezzanine modules:
DIF, CALIB and POWER

P. Goettlicher (DESY)

Power:
40 $\mu$W / channel

Heat:
$T_{\text{grad.}}$ 0.3K/2m
Time constant: 6 d

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Details
Mechanical structure

- Aggressive design: 3mm walls
- No additional spacers
- FEM calculation with sector details for full barrel
  - Max displacement 2mm, stress ✓
  - Integration with cryostat and ECAL
Conclusion

- A technical design for a highly granular scintillator HCAL
  - Meets particle flow requirements
  - 1000 tiles / m², individually read out
  - Latest generation SiPMs, MPPCs

- Embedded photo-sensors, ASICs, calibration system
  - No fibres, no HV lines, no cooling pipes

- Compact mechanical design
  - Thin r/o gap, no cracks, ~99% instrumented

- Build it:
  - Electronics prototype with tiles and r/o chain in 2008
  - Layer demonstrator in 2009