Total Measurement
Calorimetry

S. Inayoshi & T. Takeshita
Shinshu University
HE collisions

- physics output ~ identify W/Z, top/b, H...
- emerge as multi-JET final states
- tracker: separate JETs
- precise Pt measurement
- calorimeter: measure energy of a JET
- energy resolution dominated by HCAL performance
- how to improve HCAL
HE Hadron interaction

- HCAL: hadronic interactions as cascade
- Hadronic fragments consist of mostly $\pi^+$ and $\pi^0$
- Energy measurement: $E_{\pi^0} >> E_{\pi^+}$
- Fluctuate event by event
- Due to prod. $\pi^0 = 1$ MIP

3 events of 4GeV pions in 30 superlayers (Lead 8mm/scint.2mm)x4

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a hadron event
in fine longitudinal segmentation

**Diagram:**
- **Axes:**
  - y-axis: Number of photons
  - x-axis: Layer number

- **Particles:**
  - $\pi^-$
  - $\pi^+$
  - $\pi^0$

- **Additional Text:**
  - **Abs.:**
  - **$\pi^0$ generation**
a hadron event
in fine longitudinal segmentation

5GeV pi-zeta event
at 20th layer
Total Measurement

- Heavy & transparent absorber for $\pi^0$ detection
- Precise EM energy measurement:
  - Identify EM shower
  - Longitudinally fine segmented
  - Coarse segmented in lateral
  - Combined ECAL & HCAL
  - Homogeneous detector

Cherenkov abs.

Scintillator plate

Hadron

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Response of TMC

simulation with hadrons & electrons

Number of Photons

π- 5GeV GEANT4.9 LHEP

# of Cherenkov photons

# of scintillation photons

electrons 5GeV

# of Cherenkov photons

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EM shower measurement

- 2 Lead Glasses and 2 scintillators
- Tested by 3GeV electrons

\[
\begin{array}{c}
\text{LG} \\
\text{C1} \\
\text{C2} \\
\text{S1} \\
\text{S2}
\end{array}
\]
MIP detection in absorber

- number of Cherenkov light is small with shorter wave length
- need to collect photons from as much as surfaces area
- transparent absorber: high density & large diffraction index > total reflection

emit.  
abs.

400nm
WLS Y11

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Lead Glass SF6

$n \sim 1.81$, $\rho \sim 5.2$ g/cm$^3$, $X_0 \sim 1.7$ cm

71% of weight PbO

12 cm for CR passing

PMT 2’ direct

sufficient Cherenkov photons

ADC dist. ~12 p.e.
PbF$_2$ – I

$n \sim 1.82$, $\rho \sim 7.8 \text{ g/cm}^3$, $X_0 \sim 0.9 \text{ cm}$

2 cm for CR passing

PMT 2’ direct

barely number of Cherenkov photons

ADC dist. $\sim 2\text{ p.e.}$
PbF$_2$ –II

Wave Length Shifting Fibre read out

utilize short wave length of Cherenkov

ADC dist. (PMT-F)

~7p.e.

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\(\text{PbF}_2 \text{ --III} \)

*read out by 20 wave length shifting fibers at bottom*

*by a PMT*

*~ 2.p.e Cherenkov photons*

*can detect MIPs*

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\[ \text{ADC(0.25pC/ch)} \]

- Entries: 729
- Mean: 96.12
- RMS: 4.526
- \(\chi^2 / \text{ndf} \): 8.18 / 2
- Constant: 91.88 ± 6.88
- Mean: 96.45 ± 0.15
- Sigma: 1.882 ± 0.217

~2p.e.
PbF$_2$ – IV

- one side surface is covered by 20 wavelength shifting fibers
- by a PMT
- ~ 2.p.e. Cherenkov photons
- ~ bottom read out
- can detect MIPs

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future plan

- 1 m³ detector
- with LG/PbF2 blocks
- scintillators: MPPC read out enables us to read every layers
- fine longitudinal segmentation is the key issue

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summary & outlook

- Neutral pion detection in hadronic shower is relevant for good JET energy resolution.

- EM shower detection in the longitudinal segmentation actively.

- Total Measurement Cal. TMC utilize Cherenkov light from the absorber material.

- How to collect the Cherenkov light.

- Development using the PPDs.
WaveLength Shifting plate

- Lead Glass 4cm
- cosmic Ray muons
- cosmic conversion ar
- WLSP works well
- light collection is

![Graph showing log(count) vs energy with ADC and PMT labels.]

ADC
PbF2 test by Zhao

- a straight groove on a surface of PbF2
- 2.4 p.e. detected
- we did measured ~ 0.1 p.e.