Tungsten H-CAL Test Beam at CERN

A. Münnich

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Outline

Motivation

- Why is a tungsten HCAL needed?
- What have we learned from simulation?

W HCAL Prototype

- Hardware
- Test-beam Setup
- First Results

Additional Technologies

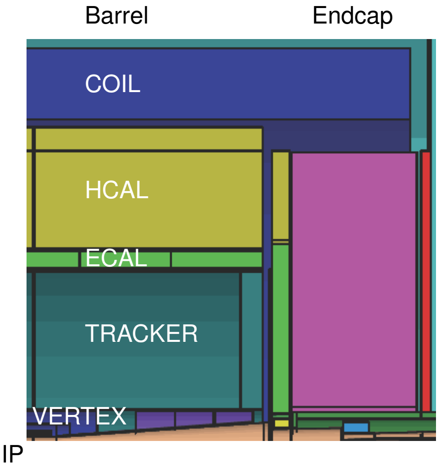
- T3B
- Micromegas

Calorimetric resolution is driven by intrinsic resolution and by leakage.

- Reduce leakage
  = more interaction lengths
    - Deeper calorimeter or
    - Denser calorimeter

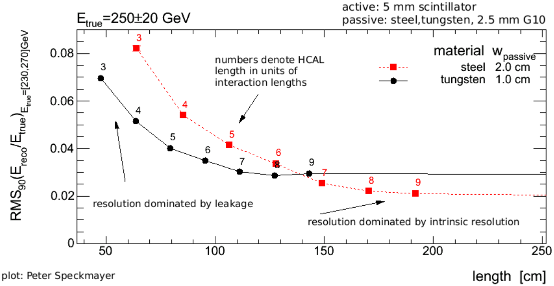
Depth limited by:

- Feasible coil size:
  $\longrightarrow$ larger coil with smaller B
  $\longrightarrow$ larger B with smaller coil
- Tracker size:
  $\longrightarrow$ larger tracker
  $\longrightarrow$ better momentum resolution

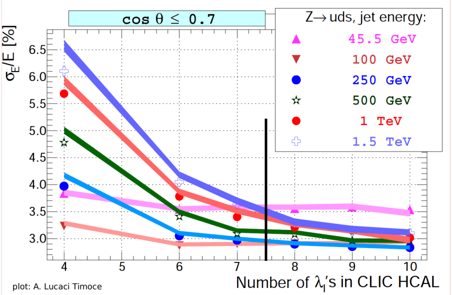


Simulation

- Shorter HCAL
  $\rightarrow$ more leakage
  $\rightarrow$ worse resolution
- Flat region reached earlier in tungsten
  $\rightarrow$ shorter HCAL possible



- E_{jet} = 45.5 GeV: res.constant, dominated by calorimeter res.
- $E_{jet} > 100$ GeV: dominated by leakage and confusion



Final decision on HCAL depth:

7.5 λ (+1 λ ECAL)

Tungsten

Benefits

- More contained showers $\rightarrow$ less leakage with same depth
- Smaller shower diameter $\rightarrow$ better separation of showers

But: Experimental verification needed because

- So far: Tungsten used in ECALs typically 1 λ deep
- No experience with tungsten HCALs 4-9 λ
- Simulation of hadronic showers in tungsten not validated
  - No MC/data comparisons
  - No validation for high granularity
  - Low energy neutrons $\rightarrow$ effect time structure of shower
    $\rightarrow$ requirements for time stamping

Final Goal:

Good energy resolution with Particle Flow using the whole detector

Absorber Material

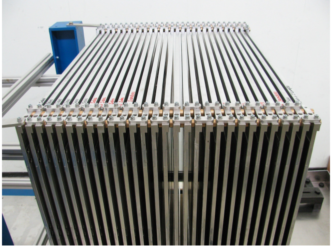
30 plates of 1 cm thick tungsten:
λ_{int} (W) = 10 cm , X_0(W) = 0.35 cm

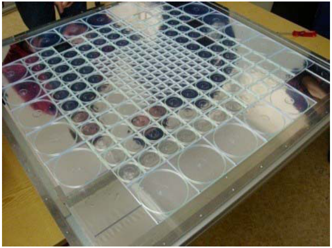
Compared to steel:

- Less visible energy (ionization)
- More neutrons (spallation, slow)

Active Material

- Scintillator tiles: 3x3 cm^2, 6x6 cm^2
- Light collection via WLS fibres readout using multi-pixel SiPMs

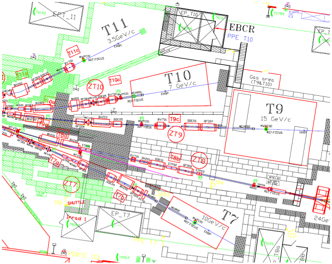




Beam at CERN/PS (T9) and Data Sets

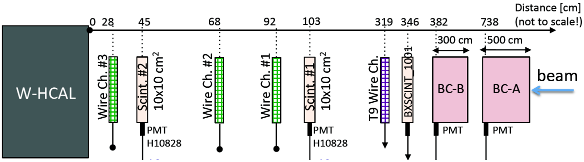
19 days of data taking

- Typical working mode: 2-3 spills per 45 seconds, 24-33 Hz DAQ rate
- 20 million events with energies between 2 and 10 GeV at 1 GeV intervals, positive and negative polarity

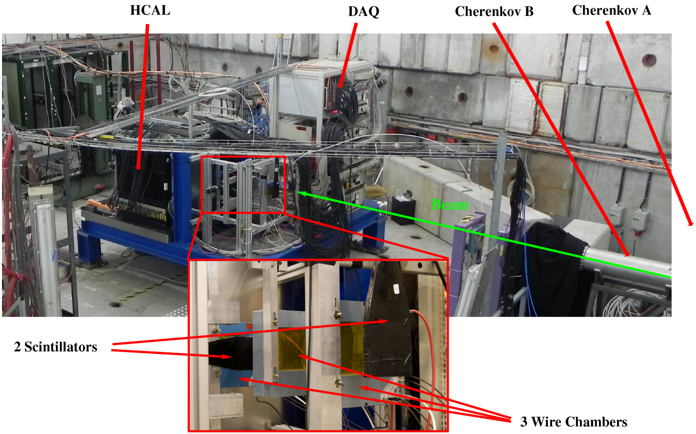


Particle Mix in T9			
p(GeV/c)	e^+ [%]	π^+ [%]	p [%]
2	55	30	15
3	30	50	20
4	15	60	25
5	10	60	30
6	5	55	40
7	5	50	45
8	0	45	55
9	0	40	60
10	0	40	60

Test Beam Setup



Trigger= coincidence of Scinti #1 and #2



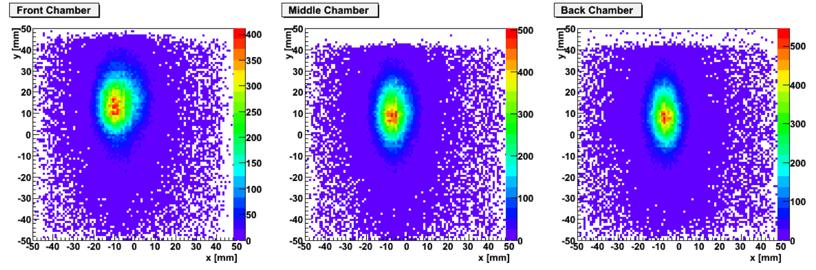
Beam Instrumentation

Particle ID

- 2 Cherenkov counters for particle ID to be used offline to select between electrons, pions and protons
- Gas: CO_2, Cherenkov A: 3m long, Cherenkov B: 5m long

Tracking

3 wire chambers to measure the beam profile and provide extrapolation to HCAL

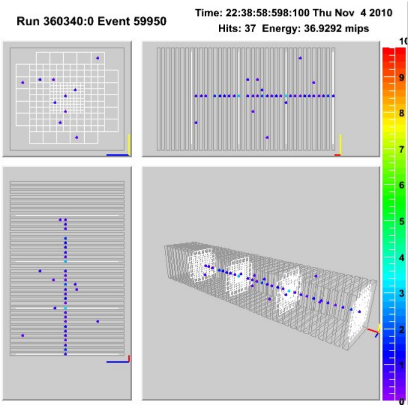


First Results: Event Display

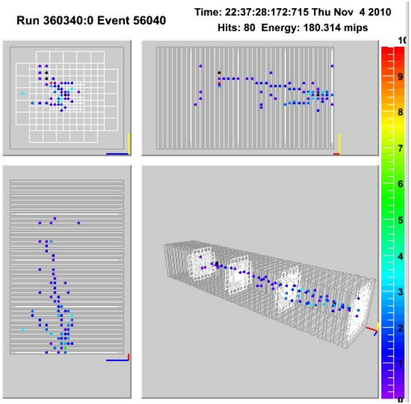
- Data analysis has started.
- Obtain a good calibration first (ongoing work).
- Then reconstruct data.

Calibration

mip = energy deposited by 1 muon in 1 tile

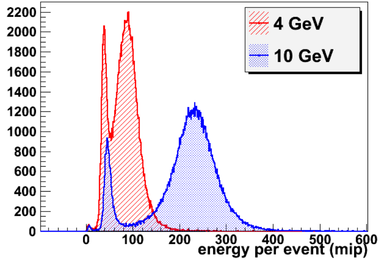


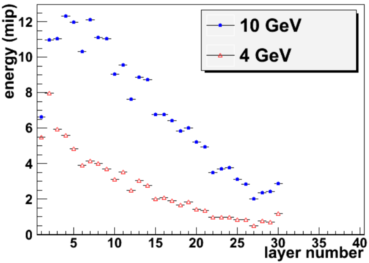
μ

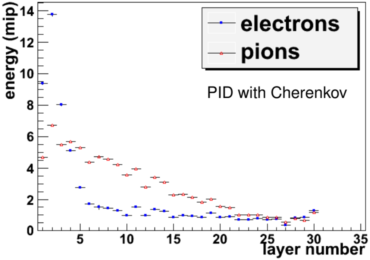


π

ALL PLOTS VERY PRELIMINARY

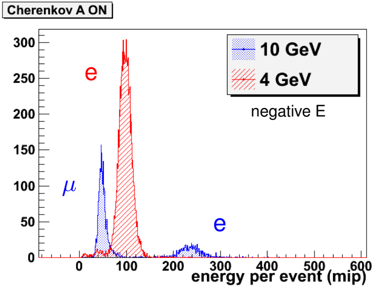




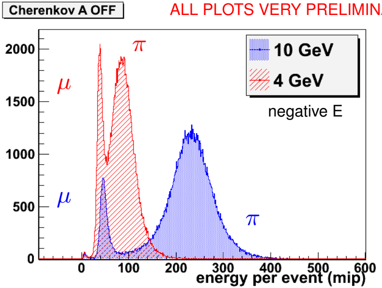


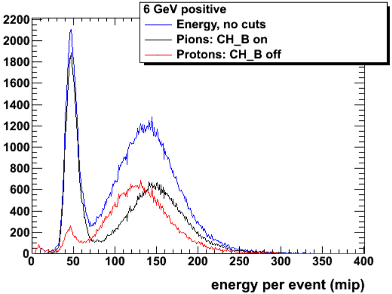
- Used old energy calibration from 2007
- Shower profile as expected
- Separation of particles based on shower profile possible
- μ contribution visible in most samples

First Results: Particle ID



ALL PLOTS VERY PRELIMINARY

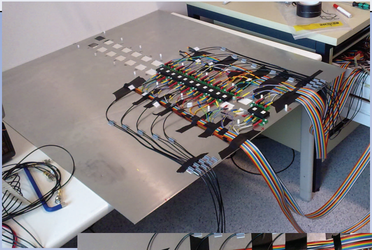


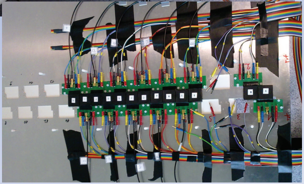


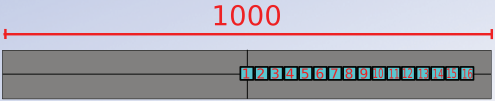
- Ch. A at low pressure (0.2 bar) to ID electrons
- Ch. B at higher pressure (3 bar) to distinguish between pions and protons
- Separation better at higher energy, also efficiency of Cherenkovs better

The Test Beam Setup of T3B

- One layer = row of 15 scintillator tiles
- Tile size: 3 x 3 x 0.5 cm^3
- SiPM: Hamamatsu MPPC-50C
- Readout: 4 x PicoScope 6403
  - Fast Digitizer (1.25GSa/s on 4CH)
  - Deep memory (1GSa)
  - Fast data capturing (up to 1MHz)





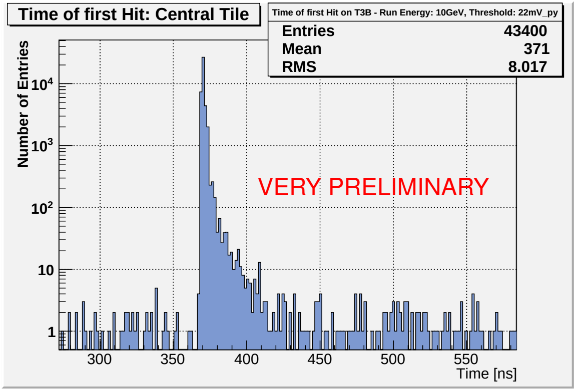


Munich, 30.11.2010 Weuste/Soldner 2

T3B: Very Preliminary Results

First timing plot:

- No Correction for: - photon travel time in scintillator
  - exponential drop of signal
- No double particle rejection

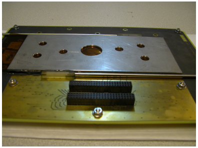


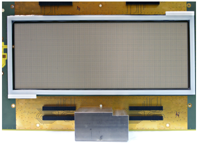
plot: L.Weuste, C.Soldner

Micromegas: Digital HCAL

source: M. Chefdeville

First prototypes : 6x16 and 12x32 cm^2 with 1 cm^2 pads (2008-2009)



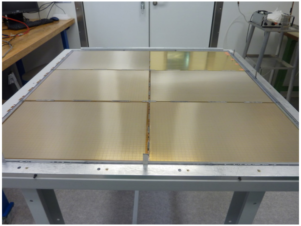


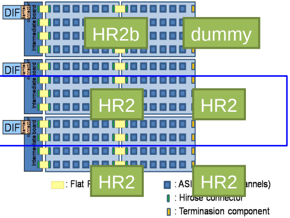
Typical MIP signal 20 fC (gas gain of 10^4)
Gassiplex electronics, mezzanine boards

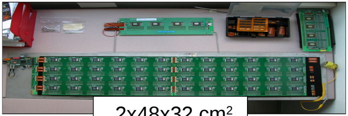
At 1.5 fC threshold:
- Efficiency 97 % with variations below 1 %
- Multiplicity below 1.1

First prototype of 1 m2 made of 6 boards of 32x38 cm^2

Boards with 24 ASICs (HARDROC2)
Embedded on the back side of the Bulk PCB







2x48x32 cm^2

Micromegas: First Results

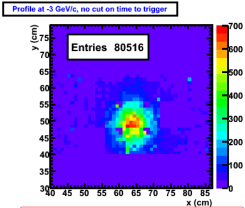
source: M. Chefdeville

TB in W structure, oct-nov 2010, PS/T7-T9
Micromegas prototype acts as layer 31^{st}

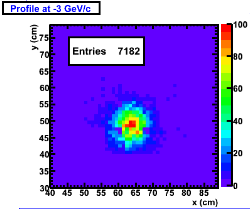
Motivation : measure tails of hadronic showers
Use shower start information from AHCAL
→ common offline event reconstruction
→ synchronization of AHCAL/Micromegas DAQ

4000 particles/spill
Self-triggered ASIC with 200 ns clock
→ sensitive to all beam particles

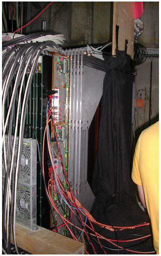
Trigger from AHCAL ~ 600/spill
→ ~ 10 % of hits remain at the time of trigger



All hits (beam + noise)



Hits at time of trigger (beam only)



Long time to bring the synchro to work → 3 days of data taking
→ About 2.10^6 triggers recorded at 3, 5, 9 and 10 GeV

Summary & Outlook

What we have learned:

- Working with tungsten mechanically
- CALICE DAQ and software
- Test beam procedures and preparation

What is next:

- Data analysis has started
- Next test beam at SPS in 2011
  - 10 additional tungsten plates
  - Energies up to 400 GeV
  - Possible operation with tail catcher from CALICE
  - RPC, Micromegas or other technologies also planned to be included again
- After 2011: Use next generation scintillator prototype to measure the time structure of hadron showers (DESY, Heidelberg, Munich, Wuppertal, CERN)