Plans for RPC – DHCAL Prototype

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Outline

• Collaborators
• Goals
• Motivation
• Mechanical Structure
• Chamber Description
• R&D still needed
• HV Supply
• Electronics Design
• Cost Estimates
• Conclusions

See also talk by L Xia
Collaborators

- Argonne National Laboratory
- Boston University
- University of Chicago
- Fermilab

- UTA
  Developing GEMs for DHCAL

- NIU
  Developing scintillator version of DHCAL

- IHEP Protvino
- (KEK Japan)
Grand Plan:
1 m$^3$ RPC DHCAL

- 1 m$^3$ needed to contain most of Hadronic Shower
  - 40 layers of 1 m$^2$ RPCs
  - 1 cm x 1 cm pads $\rightarrow$ 400,000 readout channels
  - Steel Absorber (20 mm)

- Readout Electronics : The Real Challenge

- To be tested in a particle beam
Motivations

Physics
  No one has ever looked at Hadronic showers in such detail

Calorimetry
  Vastly better jet energy resolution if Energy Flow works

Check Simulations
Check Energy Flow Algorithms
Develop Cheap Technology for HCAL

Not just useful for LC - but for understanding of Calorimetry in General
Simulation of 1 m$^3$ Prototype

Conclusions presented at Cornell

EM and HAD showers appear **narrower** in a DHCAL with RPCs compared to a DHCAL with Scintillator.

This effect is due to **larger and wider cloud** of deposits from electrons (and protons in HAD showers) in Scintillator compared to RPCs.

Radius and E resolution of EM showers decreases. Radius of HAD shower remains large (due to protons).
Digital readout - Shower radius

- Electrons
- Pions

Showers significantly narrower in RPCs

Confirms previous studies by Videau, Sokolov
Distinct advantage for EFAs
Shower radius – $E_0$ dependence

50 GeV HAD showers

Vary $E_0$ in Scintillator

Resolution worsens with increasing $E_0$

Radius always larger than in RPCs!

Why is that?
**Shower radius – Individual components**

**EM showers in Scintillator**

Radius of $e^+$ and $e^-$ decreases with increasing $E_0$

Major effect from $e^-$

**HAD showers in Scintillator**

Radius of $e^\pm$, $\pi^\pm$ decrease with $E_0$

Radius of $p$ remains large!!!

Large radius due to protons
Mechanical structure

Work within the CALICE collaboration

Conceptual design by K Gadow (DESY)

Agreements (so far)

One mechanical structure for AHCAL and DHCALs
Absorber plates 16 mm of (regular) steel
4 mm steel plates as support of active medium
Option to increase gap for active medium to up to 10 mm
Possibility to change height, lateral position, angles

Open questions

Tolerances on absorber plate
Exact size of absorber plates
Location and size of holes to attach active medium
Funding (~$40k)
Chamber construction

Argonne built 4 chambers during 2003
   ( see talk by Lei Xia )
   - extensive tests with single pads
   - extensive tests with multi-pads
   - multi-gap
   - single-gap

U of C tested Uniformity
   - using drift chambers

During 2004 – focus on
   - larger chambers
   - more digital readout
   - engineering / technique for 1 m²
Mechanical Design of Prototype Chambers

**Glass** available as 30 x 90 cm²
- need 120 chambers

**Two versions** considered
- 2 gas gaps of 0.64 mm each
- 1 gas gap of 1.28 mm

**Spacers**
- Every 5 cm
- No offset from layer to layer in 2-gap

**Layer-by-layer**
- Offset

Many details still to be worked out…
R&D Still Needed

• Decide # gaps
• Design of Gas Flow
• Prototype Tests:
  Efficiency
  Cross-talk
  Noise
  Prototype Electronics
  Threshold vs Gas Vs Voltage vs Cross-talk
Existing Larger Test Stand for 1 m x .3 m RPC

- Cosmic Ray trigger
- Covers 1.1m x .7 m
- Hardened spectrum
- 288 ADC channels of 1 fC / tic
- Only crude tracking (4 cm res.)
Design of HV Supply System

• CCW HV Supply being developed with FNAL
• + and – with respect to gnd., (+-4.5 kV)
• Resonant control chip being developed
• ANL has built and tested a version without this chip in order to study reducing pedestal noise
We need 2 or 3 stages of RC filter to get acceptable pedestal width.

One stage behaves just as calculated.

Beyond that, geometry and physical placement of the filter determine effectiveness.
Very Narrow (~10 fC) Pedestal Width Achieved with Argonne CCW HV
- General concept for readout -

I  RPC ASIC
   located on the chambers

II Data concentrators
   funnels data from several FE chips

III VME data collector
   funnels data from several data concentrators

IV External timing and trigger system
Conceptual design of readout pad

Attempt to minimize **cross-talk**

Overall **thickness** 2 - 3 mm

One ASIC for **64 channels**

Will need **6250 ASICs** for 1 m³ prototype

**First version** of boards being laid out

ASIC: Analog signal processing

Each channel has a **preamplifier**

Needed for avalanche mode
Can be bypassed (in streamer mode)
Provides pulse shaping
Provides polarity inversion
Design of ASIC: Digital Processing Functions

Modes of operation

I  Trigger-less operation

- Timestamp counter running inside chip (with external reset)
- Store timestamp and channel number when hit

II Triggered operation

- Provide pipeline for temporary data storage
- Provide trigger input to capture data of interest (Provide trigger output: 1 bit)
- Timestamp to identify event

Attempt to implement features possibly useful for other detectors (Scintillator, GEMs)

Significant overlap with what is needed for NUMI Off-axis detector

Design is to start soon (FNAL)

G Drake, ANL
Cost estimate

Resistive Plate Chambers

- **Overview**
  120 chambers à 33 x 100 cm²
  Most likely with single gap

- **Cost (M&S)**
  - Glass: $3,000
  - Resistive ink: $1,000
  - Channels: $1,000
  - Mylar covers: $1,000
  - Steel support plates: $1,500
  - Bending and screws: $500
  - Tubes, glue, RTV, fishing line…: $2,000

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  **Grand Total**: $10,000 + 50% contingency
Electronic Readout System

● Overview

Total of 400,000 channels
64 channels readout by custom front-end ASIC
12 ASICs readout by 1 data concentrator
VME based back-end

● Cost (M&S)

FE ASIC (FNAL agrees to cover engineering) $100,000
FE readout board (pads and ASIC; 360 boards) $90,000
Data concentrator boards (need 120; each with 4 FPGAs) $45,000
VME readout (40 cards) $140,000
Power supplies, optical fibers, HV… $60,000

Total electronics $435,000 + 50% contingency

Grand total (M&S only)

Mechanical Structure $40,000
Resistive Plate Chambers $10,000
Electronic Readout $435,000

Grand Total $485,000 + 50% contingency
Conclusions

• RPC design is well advanced - not considered a problem

• No indication of ageing with glass as resistive plates
  See RPC 2003
  http://clrwww.in2p3.fr/RPC2003

• Collaboration on electronics is progressing

• Time scales: FY 2004: complete all R&D
  FY 2005: construct 1 m³ prototype section
  FY 2006: test in particle beams

• The challenge is funding the electronics