DHCAL Prototype Construction

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Digital Hadron Calorimeter

Fact Particle Flow Algorithms improve energy resolution compared to calorimeter measurement alone

Assumption Confusion term is the dominant contribution to jet energy resolution

Particles in jets	Fraction of energy	Measured with	Resolution [σ^2]
Charged	65 %	Tracker	Negligible
Photons	25 %	ECAL with 15%/√E	$0.07^2\ E_{jet}$
Neutral Hadrons	10 %	ECAL + HCAL with 50%/√E	$0.16^2\ E_{jet}$
Confusion	Required for 30%/√E		**$\leq 0.24^2\ E_{jet}$**

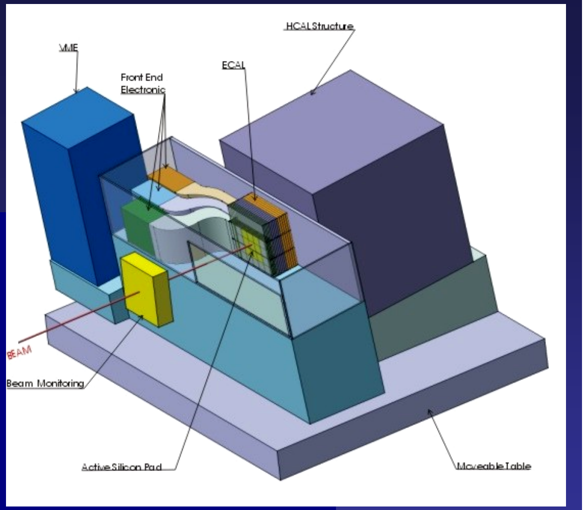
18%/√E

Minimize confusion term Maximize segmentation of calorimeter readout

High segmentation 1 – bit resolution on readout preserves energy resolution for hadrons

Technical implementation Resistive Plate Chambers (RPCs)
Gas Electron Multipliers (GEMs)

DHCAL R&D Goal



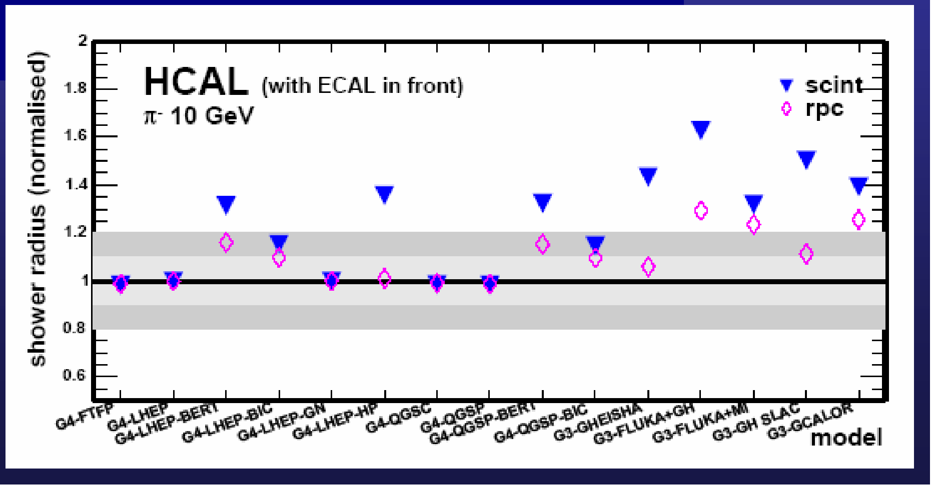
Prototype section

- 1 m^3 (to contain most of hadronic showers)
- 40 layers with 20 mm steel plates as absorber
- Lateral readout segmentation: 1 cm^2
- Longitudinal readout segmentation: layer-by-layer
- Gas Electron Multipliers (GEMs) and Resistive Plate Chambers (RPCs) evaluated

Motivation for construction and beam tests

- Validate RPC approach (technique and physics)
- Validate concept of the electronic readout
- Measure hadronic showers with unprecedented resolution
- Validate MC simulation of hadronic showers
- Compare with results from Analog HCAL

Comparison of hadron shower simulation codes by G Mavromanolakis



Why different active media?

	Scintillator	GEMs	RPCs
Technology	Proven (SiPM?)	Relatively new	Relatively old
Electronic readout	Analog (multi-bit) or Semi-digital (few-bit)	Digital (single -bit)	Digital (single -bit)
Thickness (total)	~ 8mm	~8 mm	~ 8 mm
Segmentation	3 x 3 cm^2	1 x 1 cm^2	1 x 1 cm^2
Pad multiplicity for MIPs	Small cross talk	Measured at 1.27	Measured at 1.6
Sensitivity to neutrons (low energy)	Yes	Negligible	Negligible
Recharging time	Fast	Fast?	Slow (20 ms/cm^2)
Reliability	Proven	Sensitive	Proven (glass)
Calibration	Challenge	Depends on efficiency	Not a concern (high efficiency)
Assembly	Labor intensive	Relatively straight forward	Simple
Cost	Not cheap (SiPM?)	Expensive foils	Cheap

Status of DHCAL Active Detectors

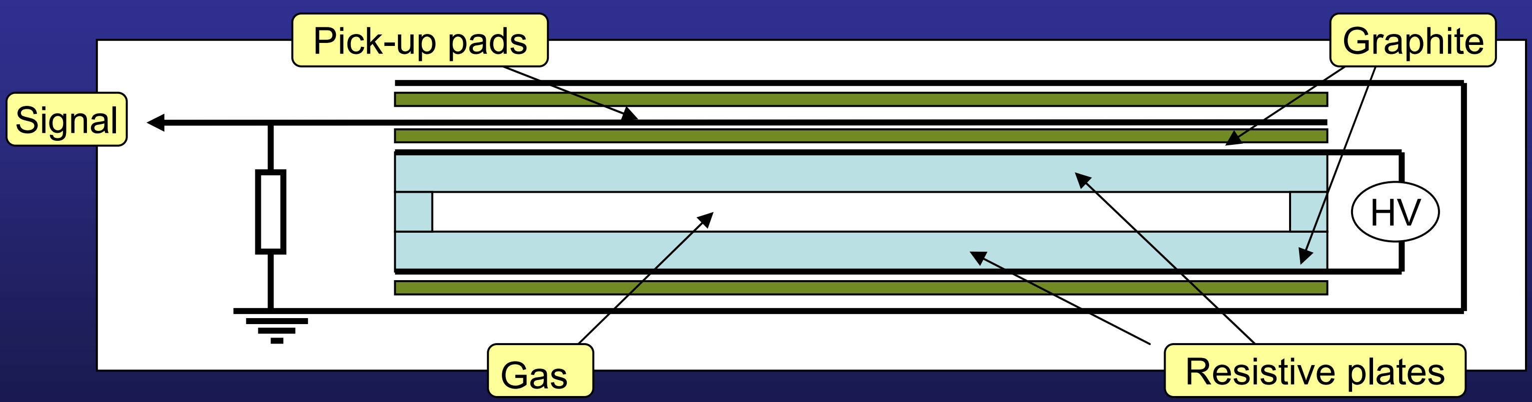
Measurement	RPC Russia	RPC US	GEM
Signal characterization	yes	yes	yes
HV dependence	yes	yes	ongoing
Single pad efficiencies	yes	yes	ongoing
Geometrical efficiency	yes	yes	no
Tests with different gases	yes	yes	yes
Mechanical properties	?	yes	no
Multipad efficiencies	yes	yes	ongoing
Hit multiplicities	yes	yes	ongoing
Noise rates	yes	yes	no
Rate capability	yes	yes	no
Tests in 5 T field	yes	no	no
Tests in particle beams	yes	no	no
Long term tests	ongoing	ongoing	ongoing
Design of larger chamber	yes	ongoing	ongoing

Virtually all R&D completed

Catching up

Default RPC chamber designs

Layer	Russia	US
Resistive layer anode	Anode readout pads	1÷50 MΩ/□
Glass thickness in [mm]	0.55	1.1
Gas gap in [mm]	1.2	1.2
Glass thickness in [mm]	0.85	1.1
Resistive layer cathode	~1 MΩ/□	1÷50 MΩ/□



Electronic Readout System for Prototype Section

400,000 readout channels

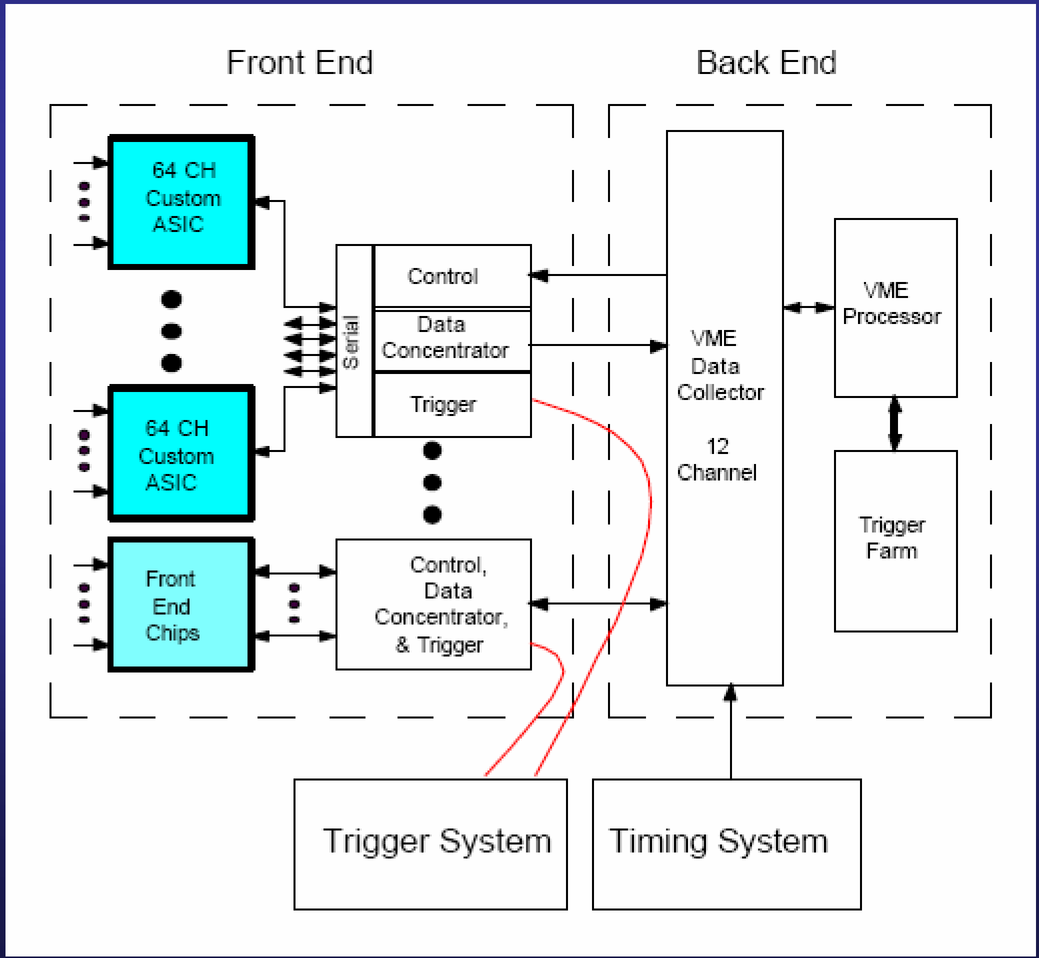
Conceptual design of system

I Front-end ASIC

II Data concentrator and Superconcentrator

III VME data collection

IV Trigger and timing system



Common development for RPC and GEM based Digital Hadron Calorimeter

Parameter	RPCs	GEMS
Type	Avalanche	(Gas)
Geometry	1cm x 1 cm Pads	1 cm x 1 cm Pads
Capacitance	10-100 pF	10-100 pF
Smallest Signal	~100 fC	~5 fC
Pulse Width	~5 nS	~3 nS
Rise Time	~2 nS	?
Largest Signal	~10 pC	~100 fC
Noise Rates	~0.1 Hz	?
Env. Noise Susceptibility	Low	Low

Front-end ASIC…

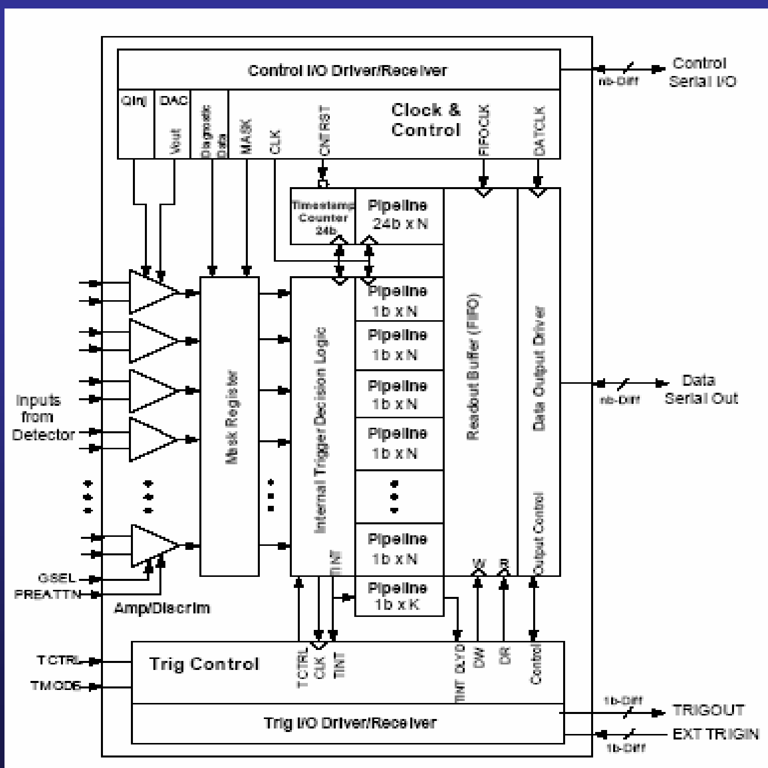
64 inputs with choice of input gains

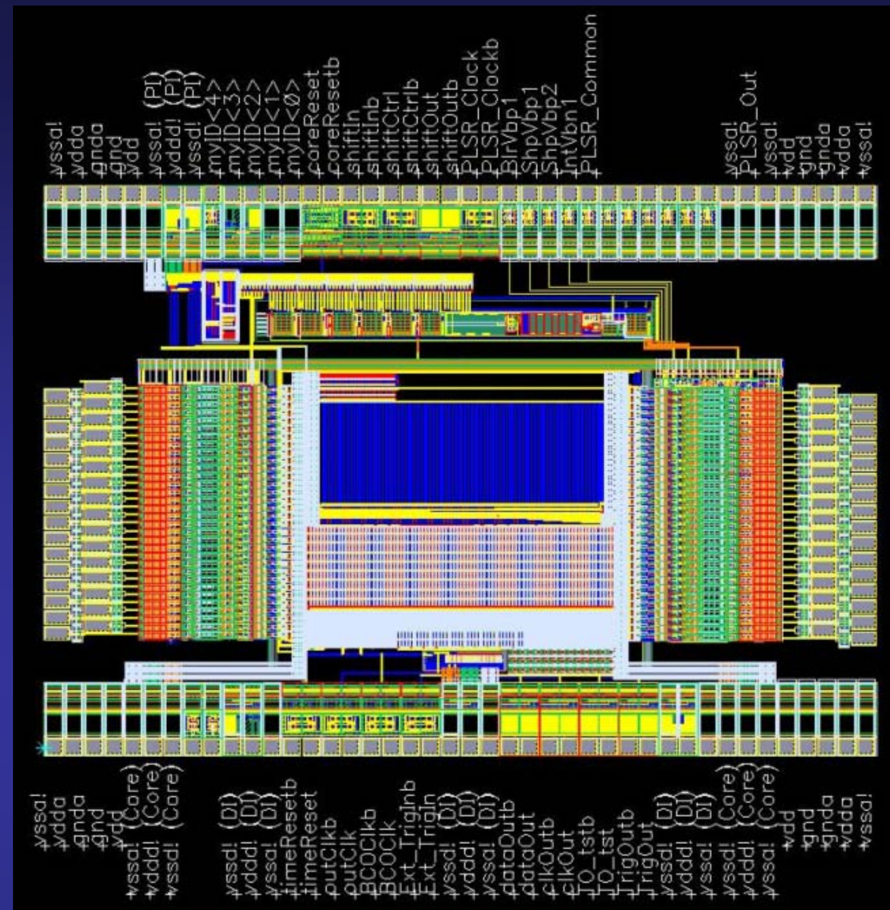
RPCs (streamer and avalanche), GEMs…

Triggerless or triggered operation

100 ns clock cycle

Output: hit pattern and time stamp





Abderrezak Mekkaoui
James Hoff
Ray Yarema

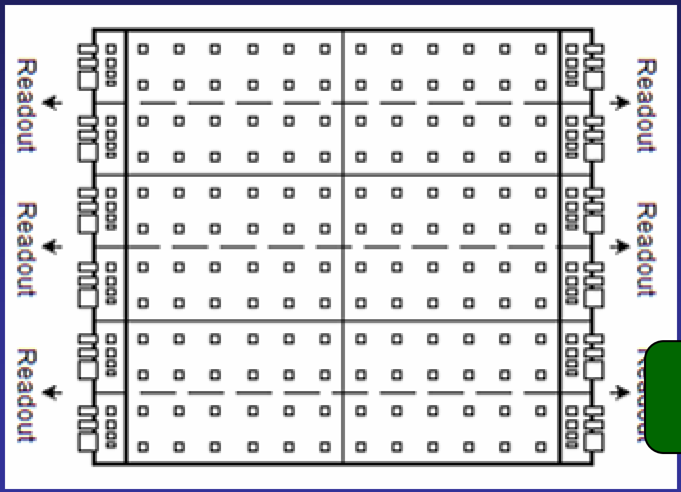
Design work at FNAL

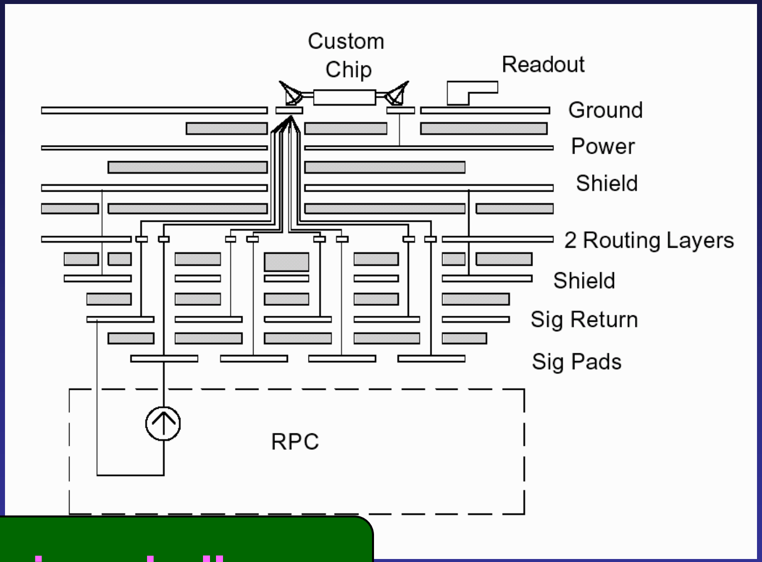
Design work started in June, 2004

Digital completed

First version submitted on March 18th 2005

Front-end boards…

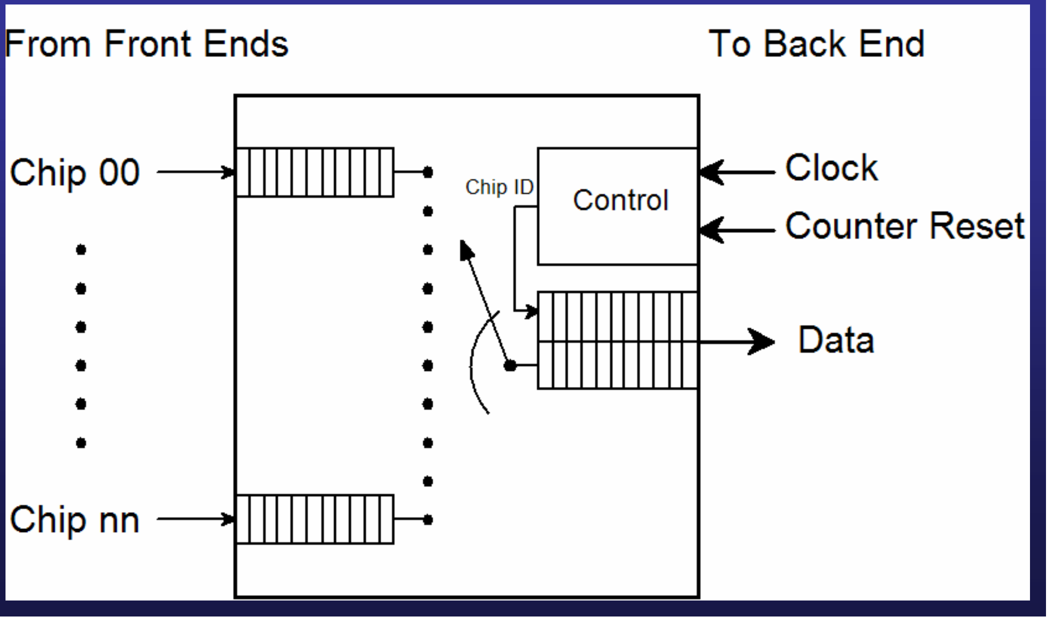




Design challenge

8 layer boards
Each housing 24 ASICs
Overall thickness < 3 mm
Contains both analog and digital signals

Data concentrators…



Readout 12 ASICs
Located on sides of section
Can buffer events
Distribution of trigger and timing
Essentially FPGAs
All transmissions in LVDS

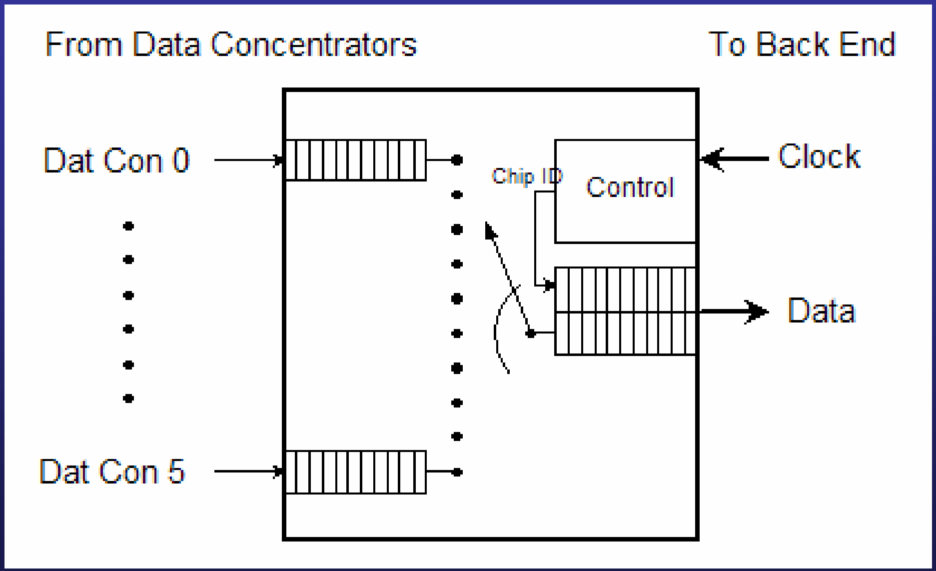
Super concentrators…

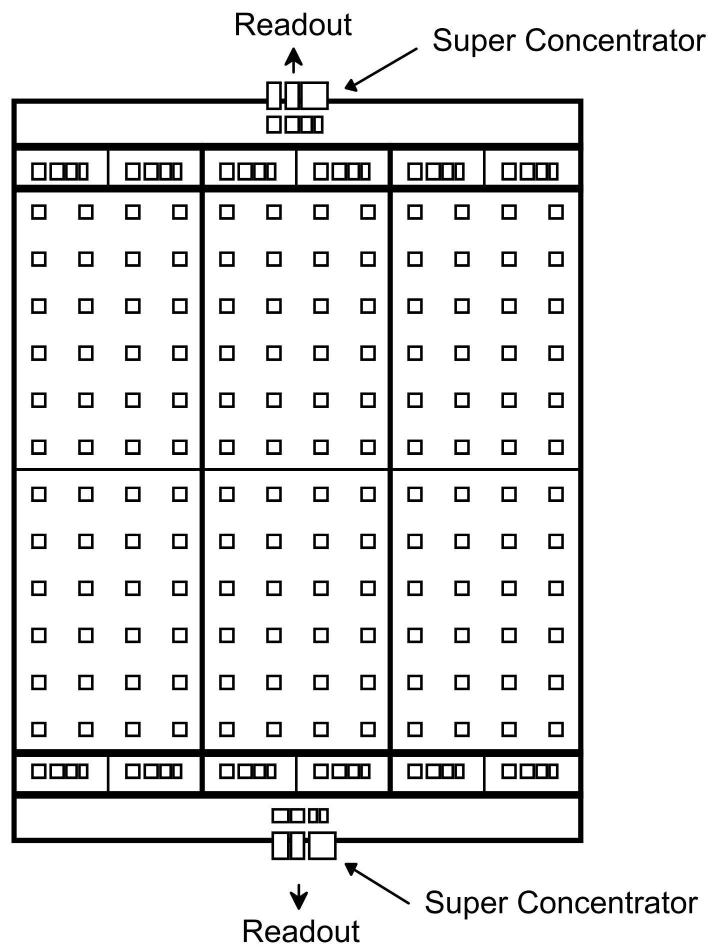
Driven by urge to reduce cost (VME)

Reads out 6 data concentrators

Located on side of module

Similar design to data concentrator



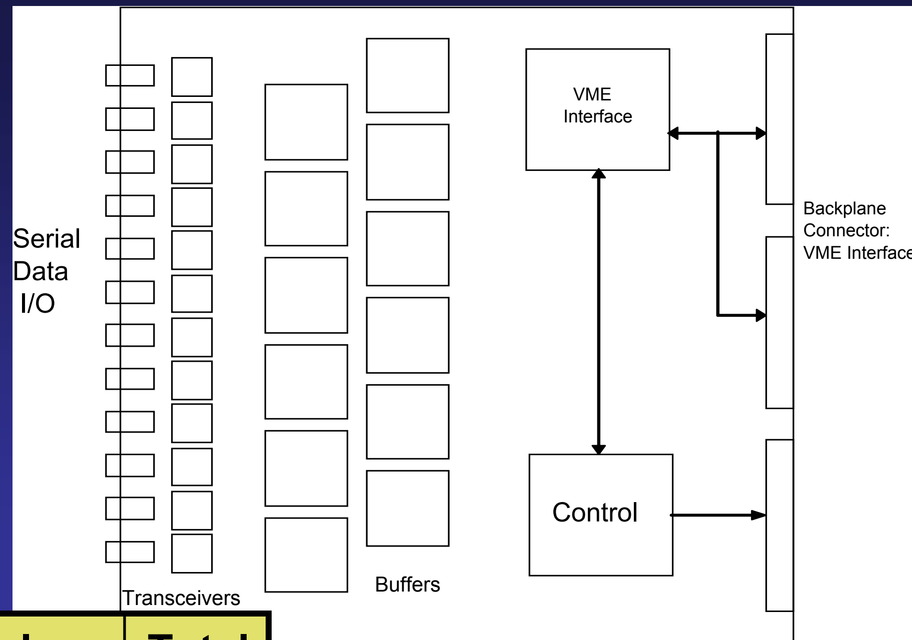


View of Plane

Data collector…

Initiated design effort
Pursuing two possibilities

a) PCI links with switch
b) VME-based system



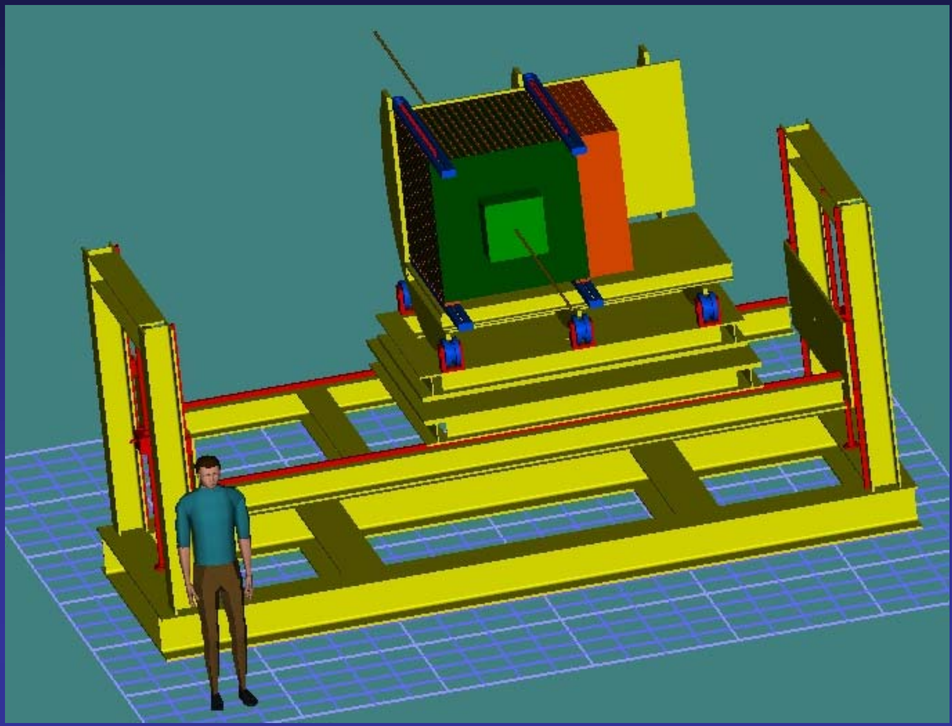
Summary…

Component	#/chamber	#/plane	Total
Planes	-	1	40
Chambers	1	3	120
DCAL ASIC	48	144	5760
Front-end boards	2	6	240
Data concentrators	4	12	480
Super concentrators	-	2	80
Data collectors	-	-	7
VME crates	-	-	1

List of subtasks

1	Overall engineering and design	**ANL**
2	ASIC engineering and design	**FNAL**
3	ASIC testing Test board design Test board production Measurements	ANL **FNAL**
4	Front-end PC board engineering and design prototyping and testing	**ANL** **FNAL**
5	Data concentrator engineering and design prototyping and testing	ANL Chicago
6	Data collector engineering and design prototyping and testing	ANL Boston
7	DAQ system: VME processor and programming	**Washington**
8	Timing and trigger system engineering and design prototyping and testing	**UTA**
9	High voltage system	**Iowa**
10	Gas mixing and distribution system	**Iowa**

Mechanical Structure



CALICE builds versatile structure

Absorber 20 mm **Steel** → 1 X_0 sampling
40 layers → 4 λ_I at 90^0

Recent studies might indicate that Tungsten with

Thickness of 0.7 cm → 2 X_0 sampling
58 layers → 4 λ_I at 90^0

might result in better PFA performance (see talk by S Magill)

Questions

a) Do we need to test a Tungsten prototype
b) If yes, can we re-use the CALICE structure
c) What is the optimum sampling depth for W

Cost estimate (M&S only)…

Item	Cost
Resistive Plate Chambers	$20,000
Front-End ASIC	$225,000
Front-end Readout Boards	$50,000
Data Concentrator Boards	$85,000
Data Collector System	$60,000
Power Supplies, Optical Fibers, HV…	$60,000
Grand total	

$200,500

$500,000 + 50% contingency

Not yet updated to reflect latest developments

Item	Cost
GEMs	$200,000
Front-End ASIC	$125,000
Front-end Readout Boards	$50,000
Remaining systems from RPCs	$0
Additional for GEMs	

$375,000 + 50% contingency

Recent Proposals to Funding Agencies…

Agency	Institutes	Request	Award
LDRD (ANL directorate) **used for manpower mostly**	ANL	300,000	181,500
LCRD (DOE)	ANL, Boston, Chicago, Iowa	105,000	
LCRD (DOE)	UTA, Washington	105,170	
U of C Collaborative Grants	ANL, Chicago	To be submitted	
US-Japan	ANL (LBNL. Oregon, SLAC…)	50,000	0
MRI **3 calorimeter prototypes**	ANL, Oregon, UTA	964,000	

Time scales

2005	Russia	Equip 1 m^2 with Minsk-based readout (32 x32 channels)
	US	Develop and test design of larger chambers
	GEMs	Cosmic ray studies with stacks of GEMs
	GEMs	Initiate long foil production and testing
	US	Prototype ASICs: submission March 31st
	US	Specify remainder of readout system by CALICE meeting
	US	Design and prototype other subsystems
2006		Produce chambers
		Produce ASICs
		Produce other subsystems
2007		Move to test beam
		Take data
2008		Take data
		Design LC hadron calorimeter

Tune Hadron Simulation