The DHCAL
Vertical Slice Test

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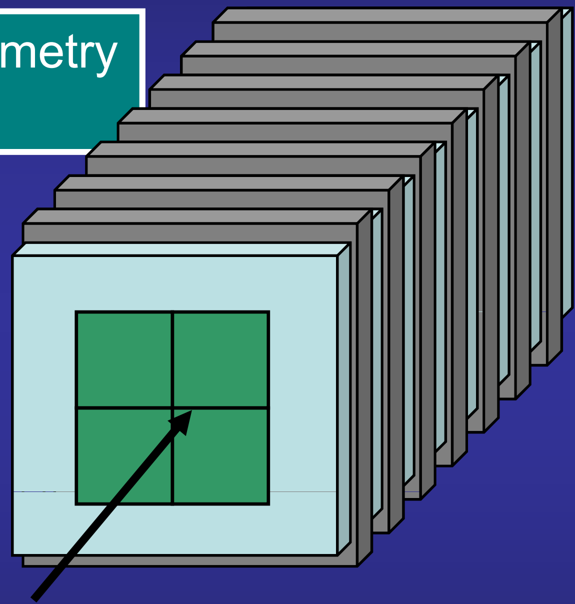
CALICE Calorimeter for ILC

SiD Meeting, by phone, October 4, 2007

Vertical Slice Test

Necessary step before beginning construction of prototype section
Where possible use identical hardware for what is needed for prototype section

Validate RPC/GEM approach to finely segmented calorimetry
Validate concept of electronic readout



Used some of the 104 front-end ASICs (DCAL)
from the 2nd prototype run

Equiped 9 chambers with 4 chips each

Chambers are 20 x 20 cm^2, rather than 30 x 100 cm^2
→ better exposure to showers in test beam
256 channels/chamber → **2300 channels total**

System designed such, that extension to 1 m^2 'natural' (but expensive)

Chambers interleaved with 20 mm steel-copper absorber plates
20 mm PVC plates with hole in middle (rate measurement)

Electronic readout system (almost) identical to the one of the prototype section

CALICE
Calorimeter for ILC

A short history

T970

MoU with FNAL – signed on July 16, 2007

Moved to FNAL – July 18th

Setup of experiment – July 19th (am)

Safety review – July 19th (pm)

Safety approval – July 20th (am)

First beam – July 20th (pm)

First events – July 21th (am)

Record Time

Shutdown – starting August 4th (pm)

Setup - configurations

Movable table

x – y motion (in 1(?)mm steps)
With remote control (from counting house)

RPC layer

(Default) Absorber

16 mm Steel + 4 mm Copper

Aborber for rate measurement

PVC with hole cut out

(Default) RPC with 2 glass plates
One (exotic) RPC with 1 glass plate only
Each layer 16 x 16 cm^2 (256 channels)

Thickness of individual layer:

Absorber	16+4 mm = 20.0 mm
RPC	3.7 mm
Pad- and FE board + ASICs	4.6 mm
Air	5.1 mm
Total	33.4 mm

Stack with 6 – 9 layers

Maximum number of channels → 2304

High Voltage

Using 1 Bertan unit for all default RPCs

HV = 6.2 – 6.5 kV

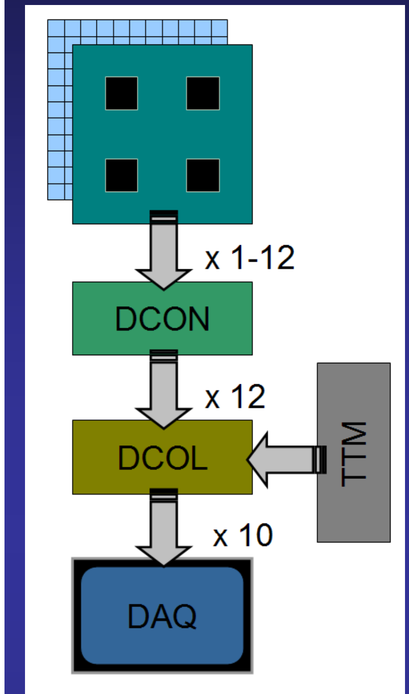
Using separate Bertan unit for exotic RPC

HV = 5.9 – 6.1 kV

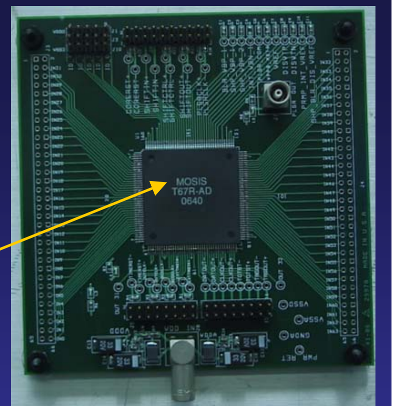
Gas system

Individual lines to each chamber
Premixed gas brought from ANL

Electronic Readout System

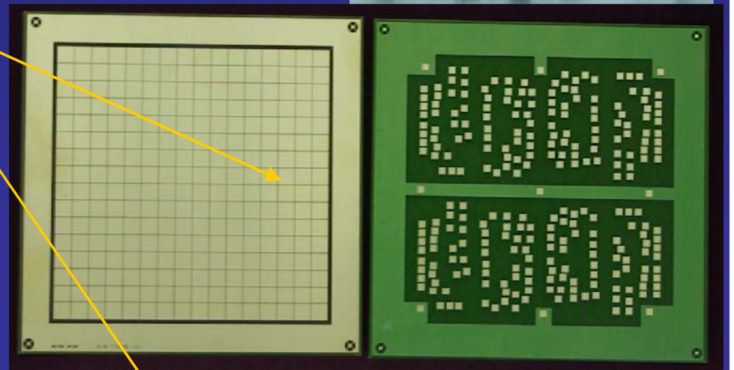


Attempt to be as similar as possible to what's needed for the PP



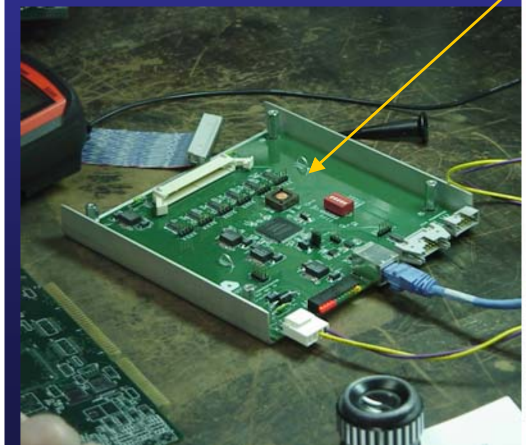
Components

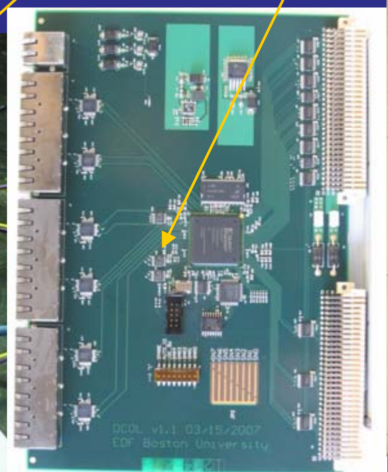
DCAL ASIC	ANL/FNAL
Pad-boards	ANL
Front-end boards	ANL
Data concentrators	ANL
Data collectors	Boston
Timing and trigger module	FNAL

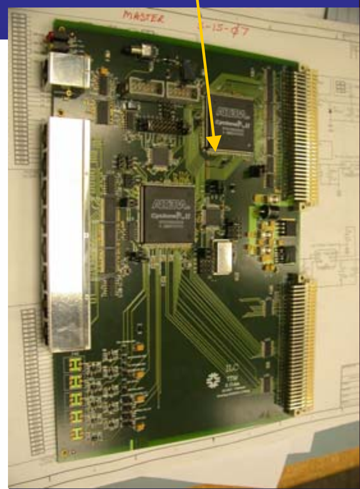


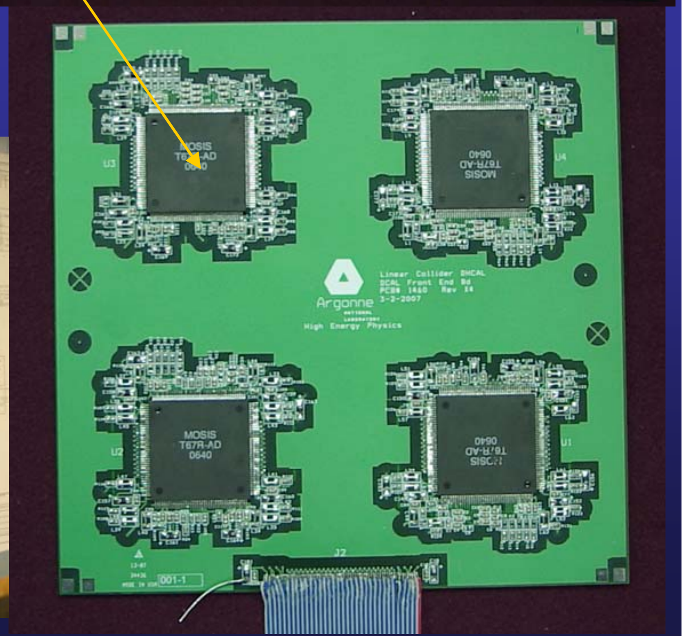
Prototyping and commissioning

Used 2nd round of DCAL prototypes
All other components: 1st prototypes
→ all worked very well









Trigger counters

Two 19 x 19 cm^2 scintillator panels
Initially used three 1 x 1 cm^2 finger counters
(imaging calorimeter makes these redundant)

Additional Fe Absorber

For muon runs at 2 GeV/c stacked additional Fe blocks in front of RPCs

~ 50 cm deep corresponding to 3 λ_I
$\rightarrow$ 97% of π interact
$\rightarrow$ ΔE_μ ~ 600 MeV

Running conditions

Beam between 6:00 – 18:00 daily
1 spill every minute with 4 sec flat top
Interruptions due to Tevatron shots/machine problems (rare…)

Rate adjusted to RPC recovery time

MTBF

Very positive experience

Machine people very cooperative!

Beams reliable and only short interruptions

Roof still leaking, but fixed in the meantime

New laser alignment system (very useful)

Nicely labeled cable panels in test area and counting house

User area greatly improved

Pictures from the past…

(Some) people


Ed Norbeck (HV, ga
Tim Cundiff (Pad-, FE-baords)
Carolyn Adams (assembly)
Dave Underwood (trigger, data taking)
Bill Haberichter (DCON)
Georg Mavromanolakis (event display)
Shouxiang Wu (DCOL)
José Repond (coordination, offline)
Eric Hazen (DCOL)
Gary Drake (electronic system)
Xia (RPC, data taking, offline)
Andrew Kreps (slow control)
Ed May (DAQ, data taking)

Problems

Scanning table

Sagging
→ solution

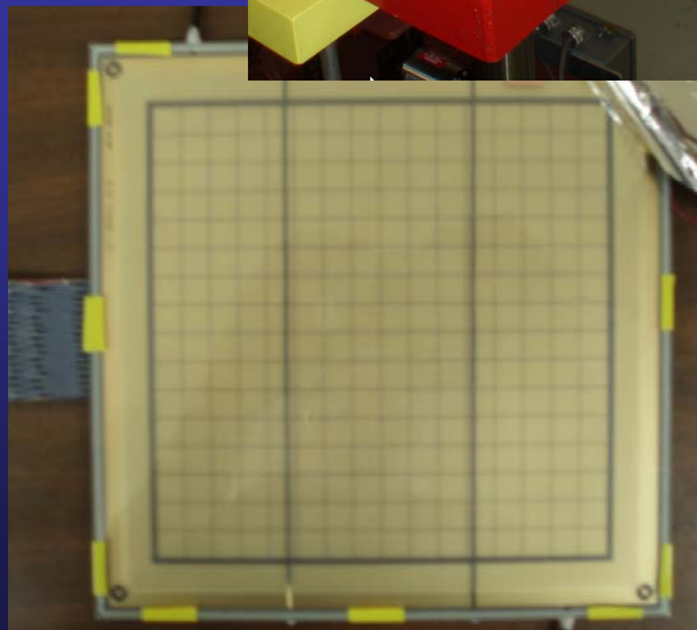
Humidity

Rain into the bulding (roof being repaired)
Very humid conditions
→ changes in the surface resistivity
→ a few HV break downs

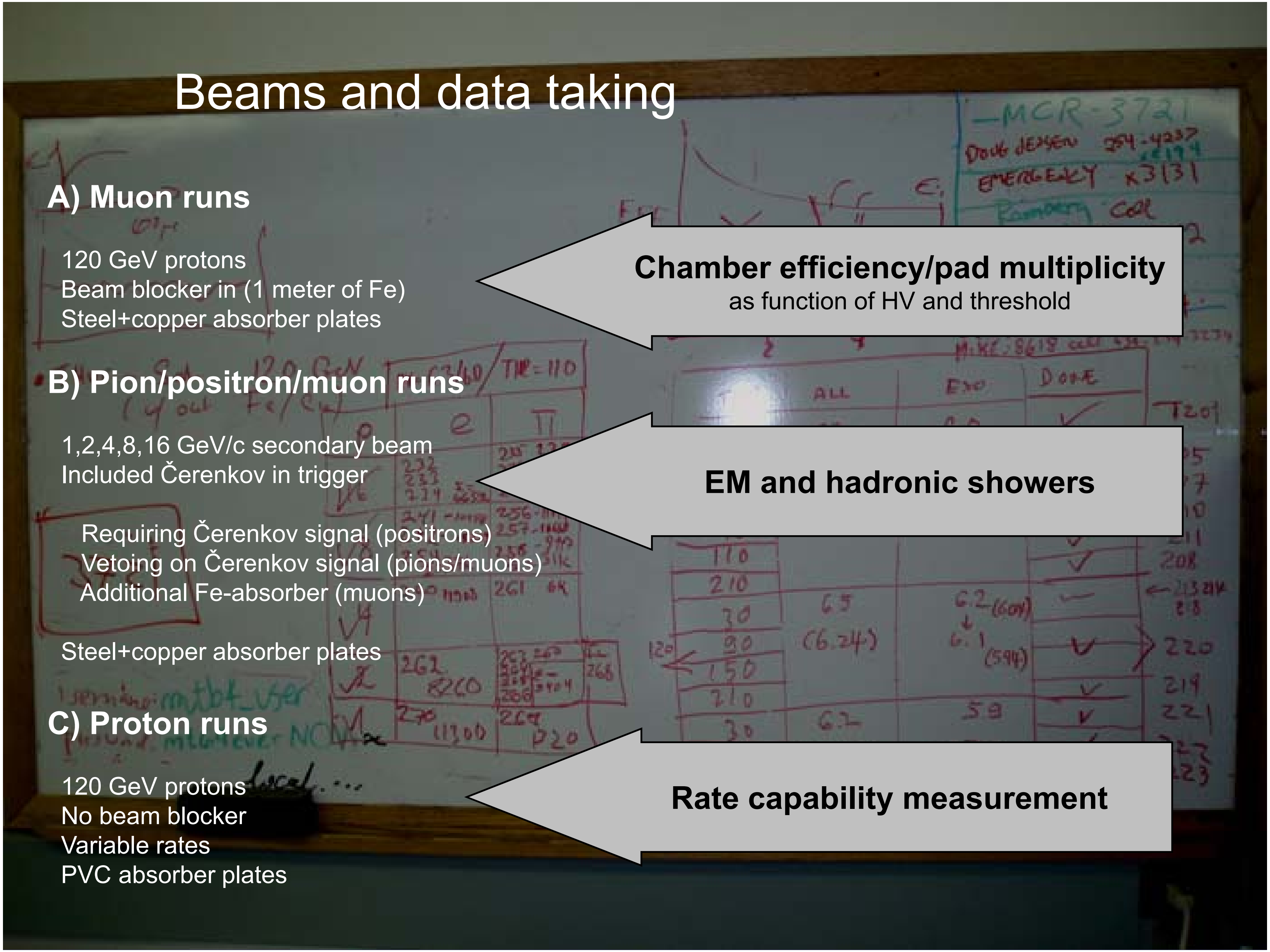
Noise

Resetting slow control constants
→ running slow control every 30 seconds
→ new grounding scheme

No show stoppers



Beams and data taking



A) Muon runs

120 GeV protons
Beam blocker in (1 meter of Fe)
Steel+copper absorber plates

→ **Chamber efficiency/pad multiplicity**
as function of HV and threshold

B) Pion/positron/muon runs

1,2,4,8,16 GeV/c secondary beam
Included Čerenkov in trigger

- Requiring Čerenkov signal (positrons)
- Vetoing on Čerenkov signal (pions/muons)
- Additional Fe-absorber (muons)

Steel+copper absorber plates

→ **EM and hadronic showers**

C) Proton runs

120 GeV protons
No beam blocker
Variable rates
PVC absorber plates

→ **Rate capability measurement**

Data Quality Monitoring

A) Online event display and monitoring

Extremely useful for quick turn around
Made shorter test runs redundant

B) Offline event display

Useful to understand beam
detect noisy layers

Available <30 seconds after EOR
Binary → ASCII (x,y,z,t) ntuple

C) Offline data analysis

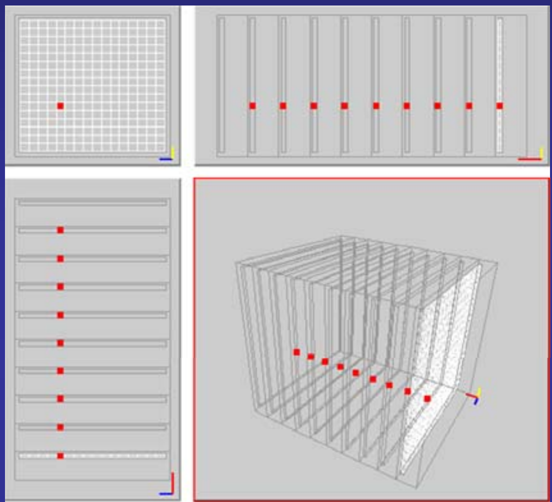
Useful to detect hardware problems
obtain quick preliminary results
decide on further runs

Plots available <60 seconds after EOR

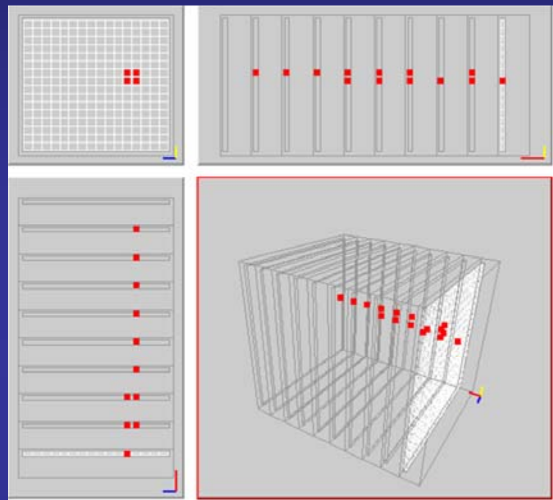
A few events… μ Calibration Runs

120 GeV protons with 1 m Fe beam block
no μ momentum selection

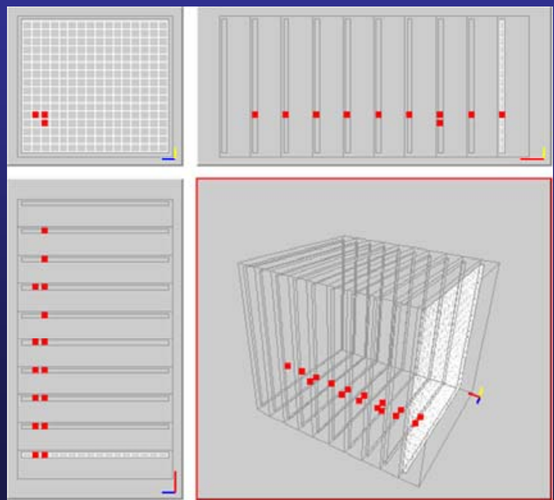
One of many perfect μ event



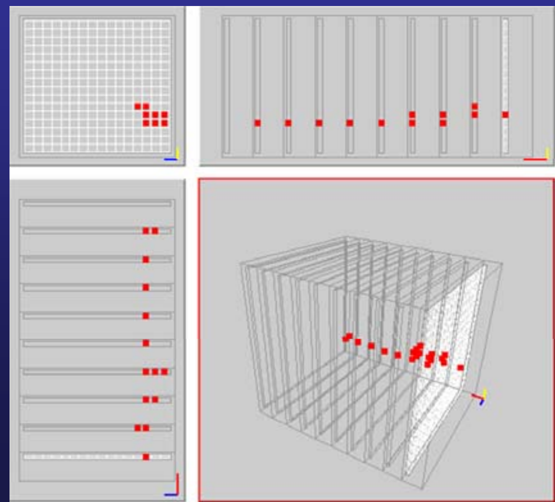
μ at an angle or multiple scattering



μ event with double hits in x



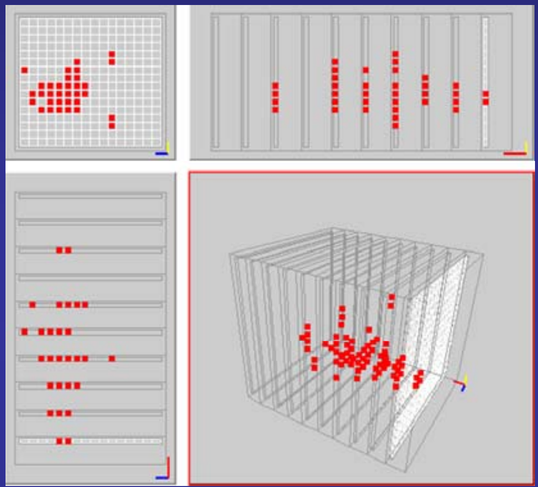
μ event with δ ray or π punch through



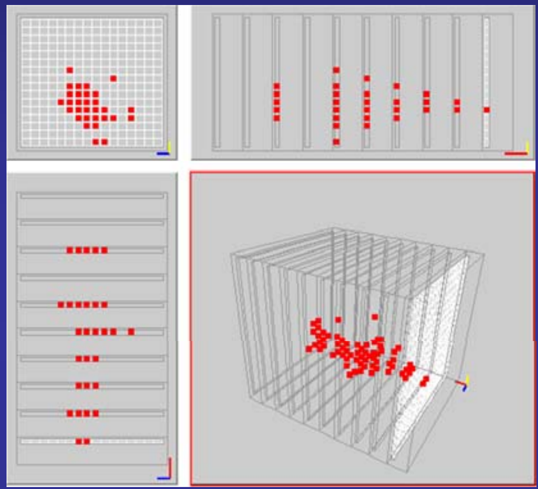
A few events…e⁺ Run

1 - 16 GeV secondary beam
Čerenkov signal required

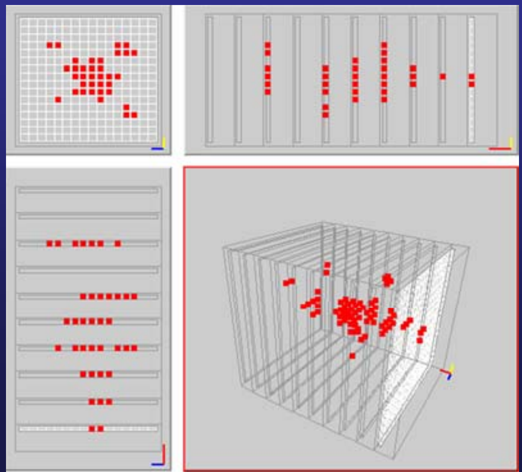
8 GeV e^+ event



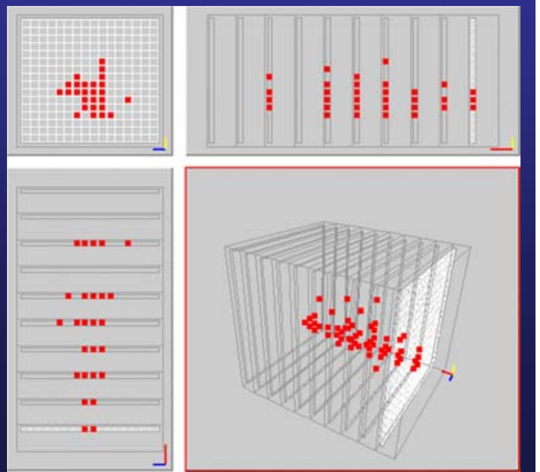
8 GeV e^+ event



8 GeV e^+ event with satellites



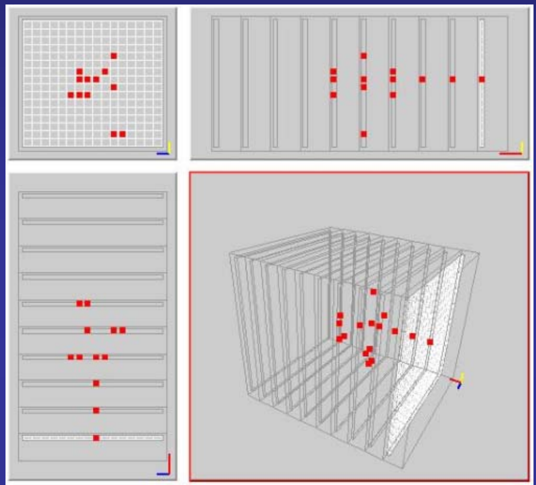
8 GeV e^+ event



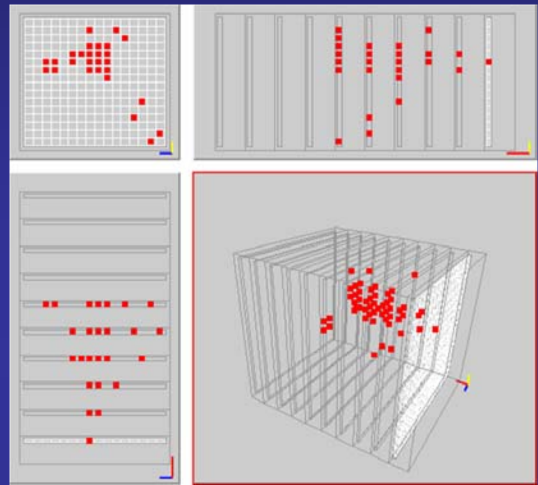
A few events… π^+ Run

1 – 16 GeV secondary beam
Veto on Čerenkov signal

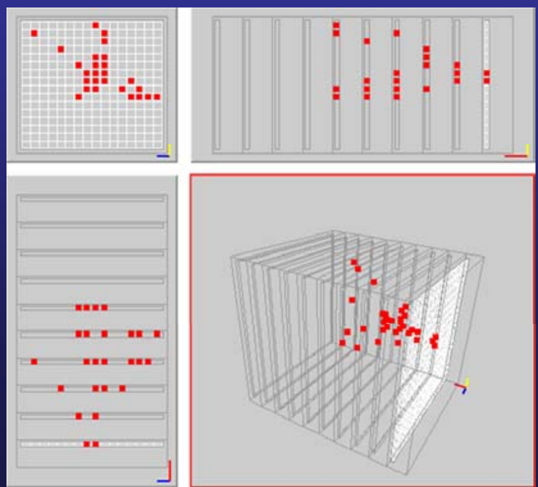
8 GeV π^+ event (typical)



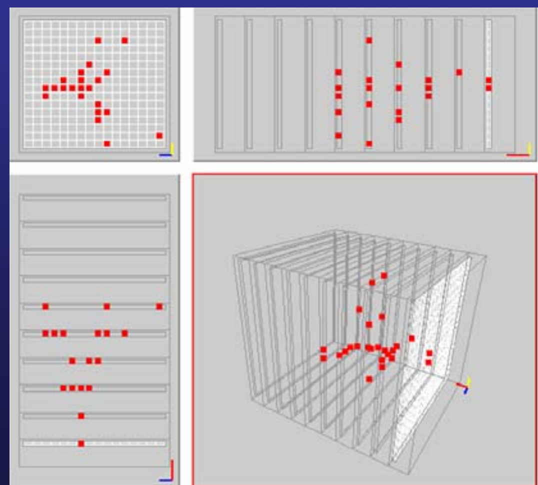
8 GeV π^+ event (early shower)



8 GeV π^+ event (early shower)



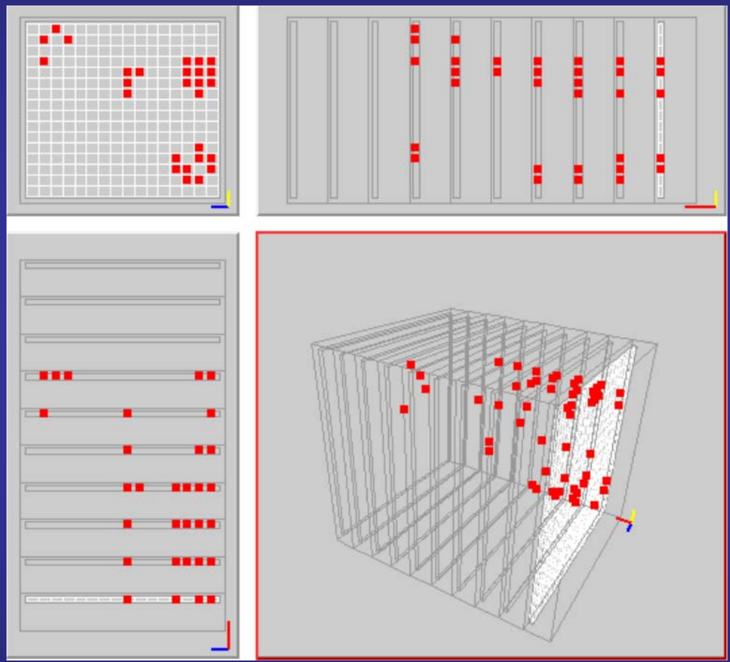
8 GeV π^+ event (early shower)



A few events…Multiple particles

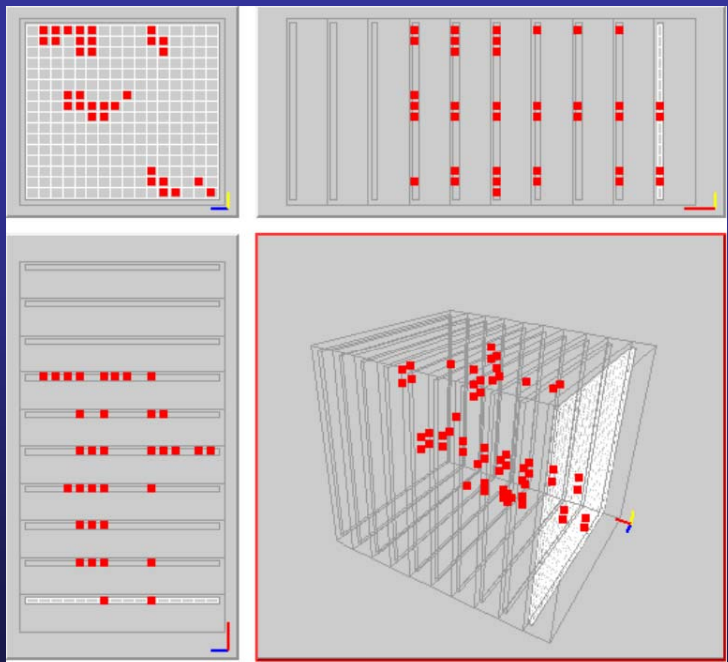
120 GeV protons without beam block

2-π event (upstream shower?)



5 cm

3-π event (upstream shower?)



Conclusion

The Vertical Slice Test was a big success

The RPCs
Electronic readout system
Data acquistion
Beam

} worked very well

Expect 4 – 5 papers

We validated the DHCAL concept and our technical approach

→ We are ready for the next step

To be completed in 2007?

i.e. prototype

Larger RPCs
Cheaper Pad- and Front-end boards
Final data concentrators

Identical to what's needed for the PP

Physics prototype

Gas and HV system ~ complete
DCAL ASIC design finalized (no more prototyping needed)
Data collector only need assembly
Timing and trigger modules are done

Test beam experience is invaluable

Much more difficult environment than lab
We were faced with many problems we did not necessarily anticipate

Noise
Humidity
Grounding
Failures

→ We are still learning about the system

(a 1% problem might be fatal when extrapolating by x200)

→ Our experience is feeding back into the final design for the PP

Physics prototype

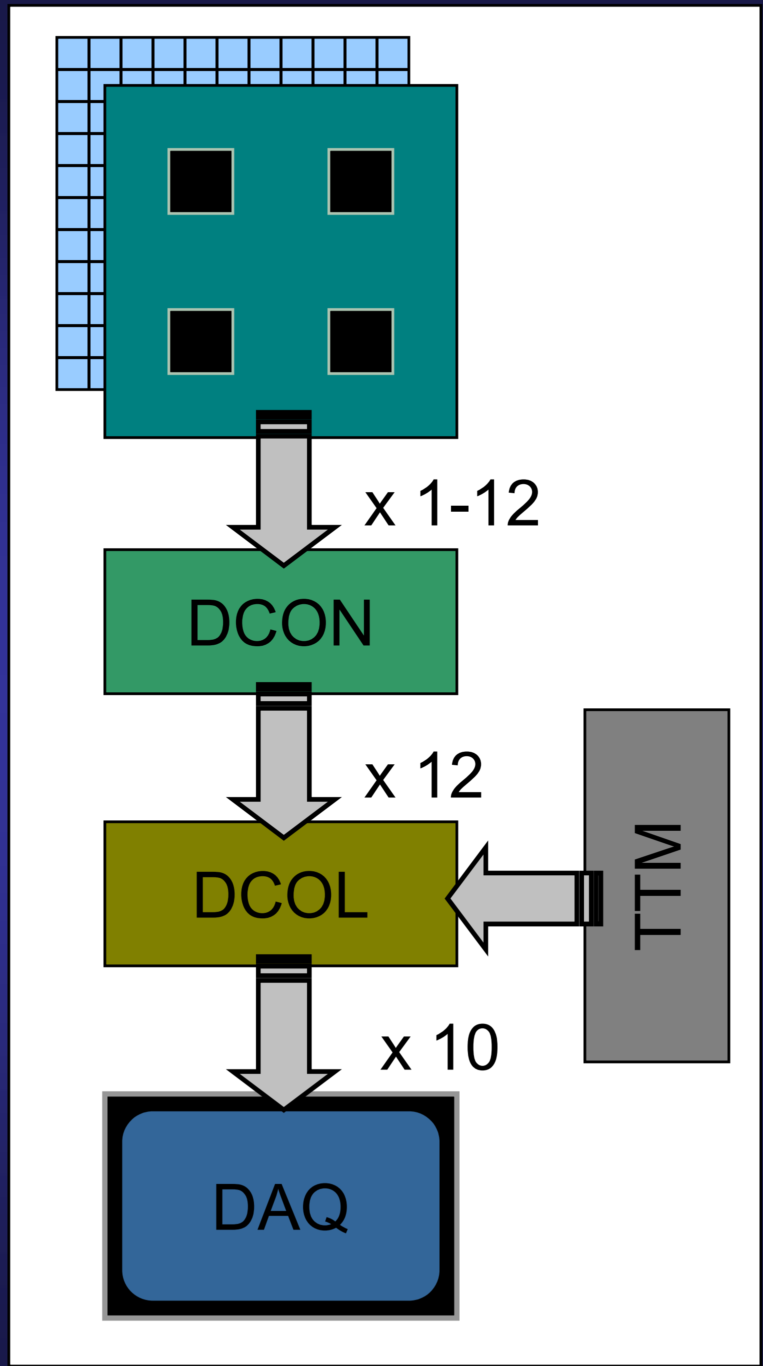
Necessary step before technical prototype (ILC wedge)
Can't solve all problems at once

Leave out: power pulsing, thickness optimization, maximum multiplexing,
integrated gas and HV/LV supplies, wedge shaped geometry…

Trying to do everything at once leads to

Slow progress, no intermediate experience with detectors, many iterations, high cost…

Backup slides


x 1-12
DCON
x 12
DCOL
TTM
x 10
DAQ