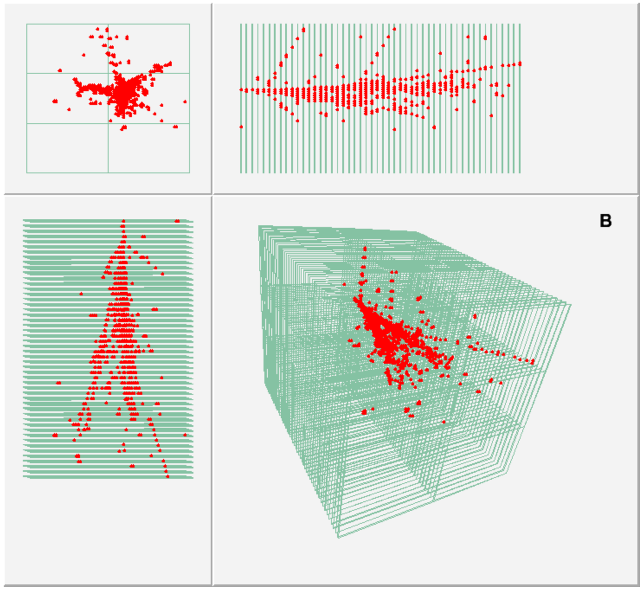
Status of the DHCAL Project



José Repond

Argonne National Laboratory

SiD Collaboration Week
January 12 – 14, 2015
SLAC

Outline

- The DHCAL project
- Recent Results
- Identified Issues
- R&D to be completed
- On a personal note

The Digital Hadron Calorimeter (DHCAL) I

Active element

Thin Resistive Plate Chambers (RPCs)

- Glass as resistive plates
- Single 1.15 mm thick gas gap

Readout

1 x 1 cm^2 pads
1-bit per pad/channel → digital readout
100-ns level time-stamping

Calorimeter

54 active layers

- 1 x 1 m^2 planes with each 9,216 readout channels
- 3 RPCs (32 x 96 cm^2) per plane

Absorber

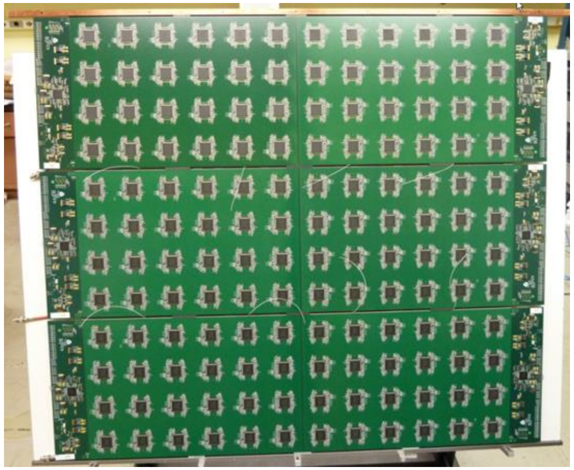
- Either Steel or Tungsten

CALICE Calorimeter for ILC

The Digital Hadron Calorimeter (DHCAL) II

DHCAL = First large scale calorimeter prototype with

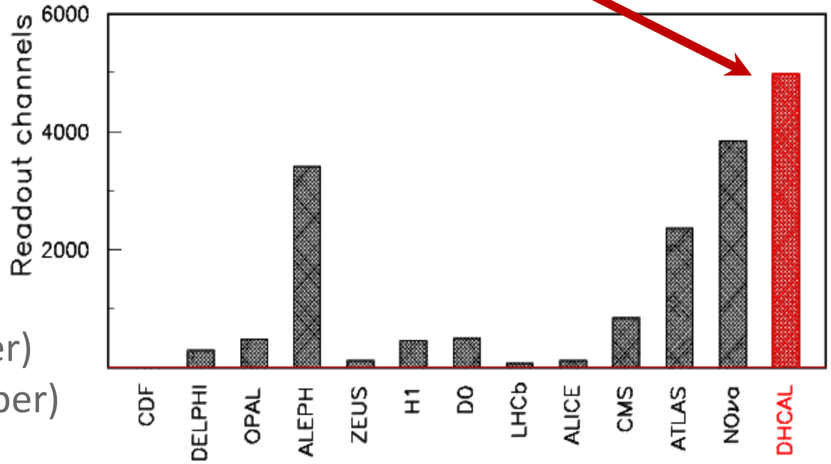
Embedded front-end electronics
Digital (= 1 – bit) readout
Pad readout of RPCs (RPCs usually read out with strips)
Extremely fine segmentation with 1 x 1 cm^2 pads



DHCAL = World record channel count for calorimetry
World record channel count for RPC-based systems

479,232 readout channels

This is only a prototype
For a colliding beam detector multiply by × 50



DHCAL construction

Started in Fall 2008
Completed in January 2011

CALICE
Calorimeter for ILC

Test beam activities

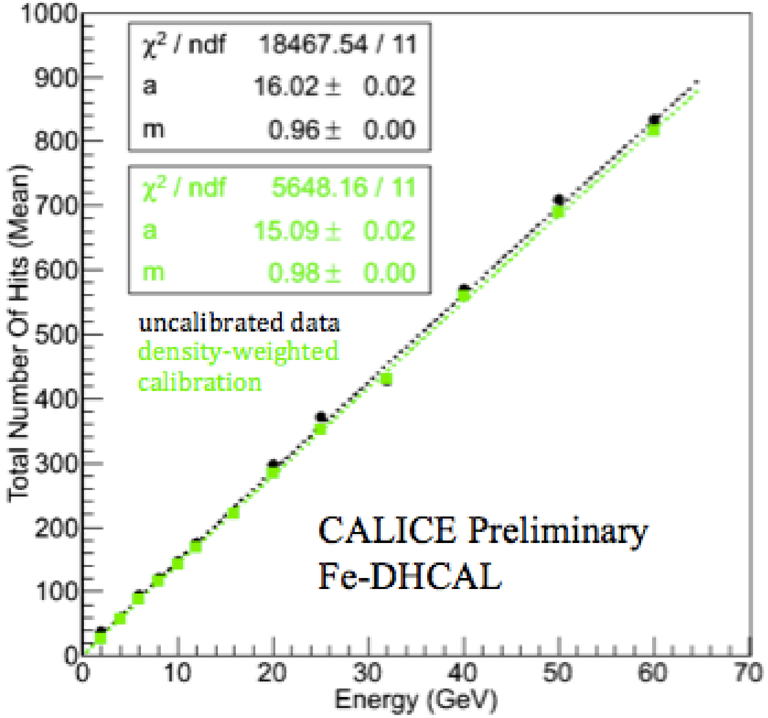
~ 5 month in the Fermilab testbeam (Steel absorber)
~ 5 weeks in the CERN testbeams (Tungsten absorber)

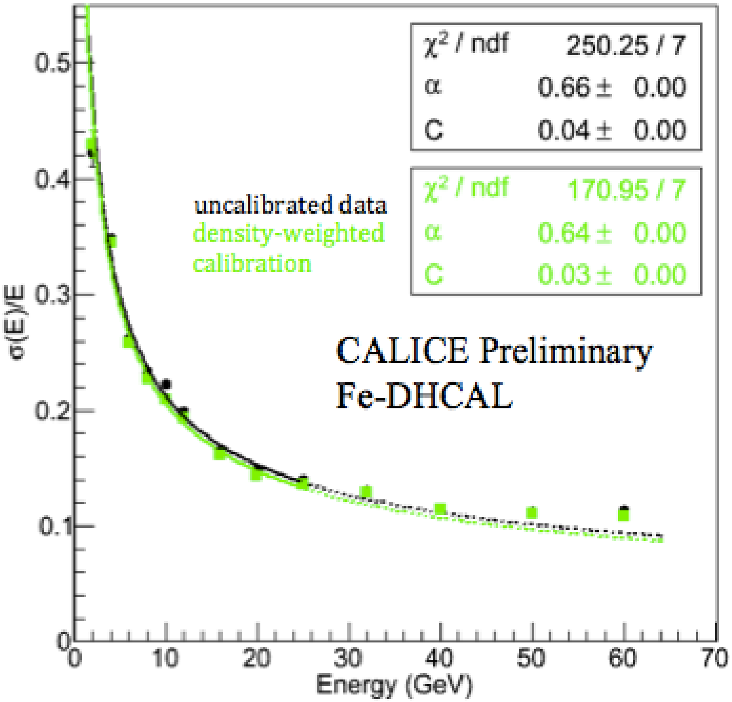
Recent Results I

Burak Bilki

Response of Fe-DHCAL to Pions

(Density-weighted) calibration improves linearity
Close to linear up to 60 GeV
Fit to power law aE^m, where m is measure of saturation





Hadronic Resolution

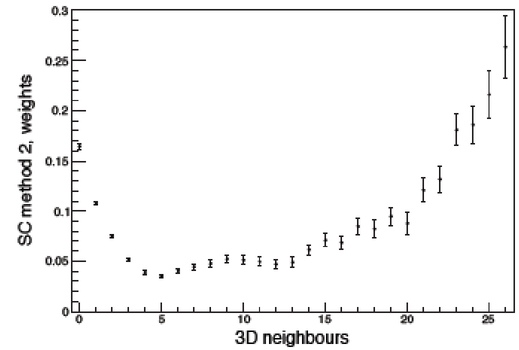
Calibration improves resolution somewhat
Saturation (=multiple hits/pad) degrades resolution > 30 GeV
Stochastic term of 64%/√E (adequate for hadron calorimetry)

Recent Results II

Coralie Neubüser

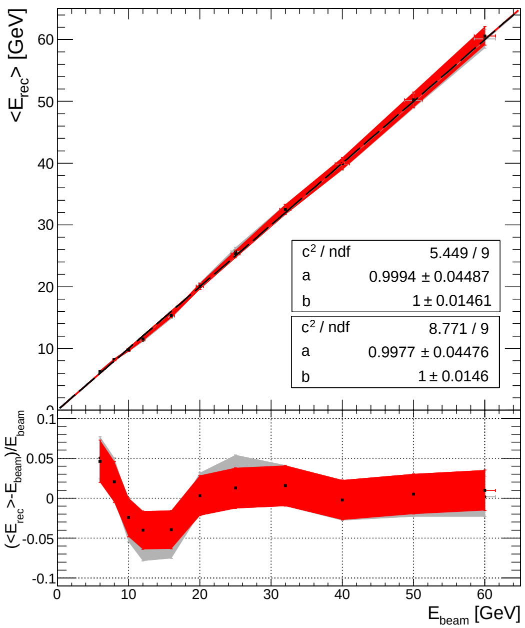
Fe-DHCAL: Software compensation

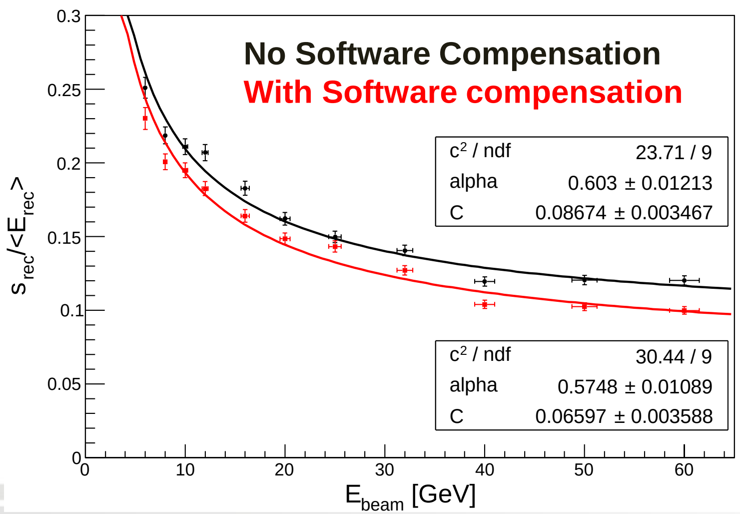
- Define hit density (= for every hit, the number of neighboring hits within 3 x 3 x 3 array)
- Define χ^2 to linearize positron or pion response (use only subsets of the data for this)
- Minimize χ^2 by adjusting weights of individual hits depending on their hit density
- Apply weights to pion data
- Linearize positron/pion response → energy reconstruction



Pion response 6 – 60 GeV

SC → significant improvement
→ 7 – 15 %





Method still being optimized

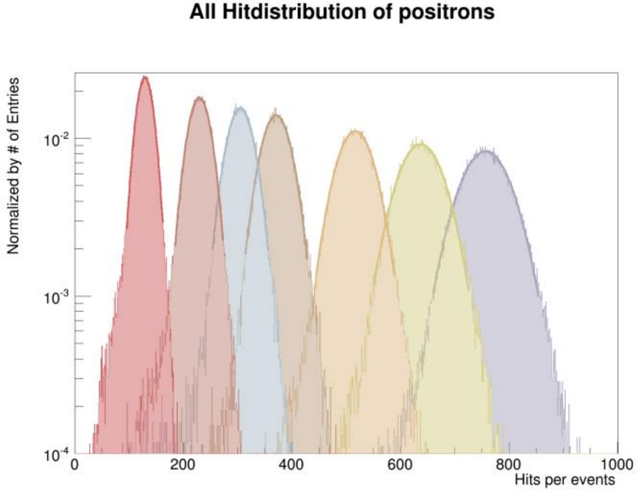
Recent Results III

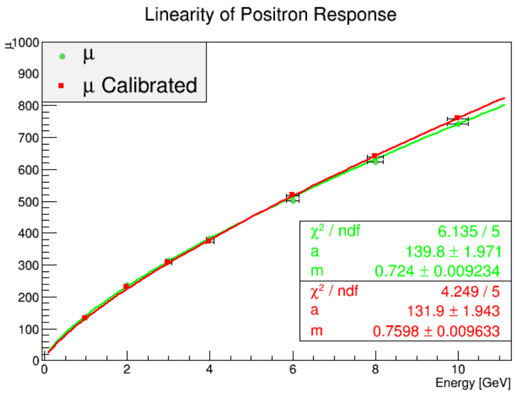
Configuration with minimal absorber structure

Removed steel absorber plates
50 layers with each 0.4 X_0 or 0.04 λ_I (detector cassette, glass, readout board)

Data set

Muons, **positrons** and pions
Momentum 1 – 10, 32 GeV



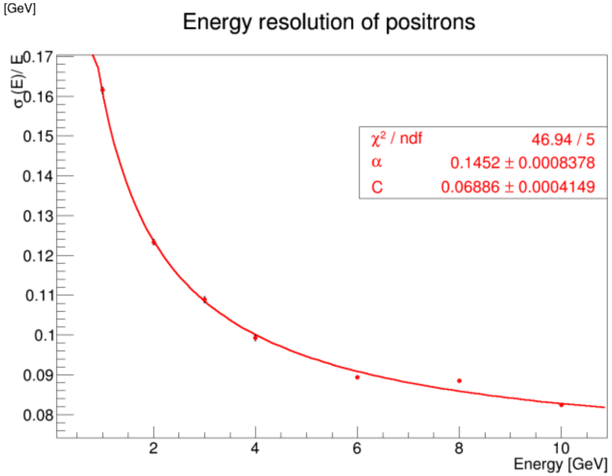


Response

Highly saturated
→ as expected

Resolution

Spectacular!
(Corrected for
non-linearity)



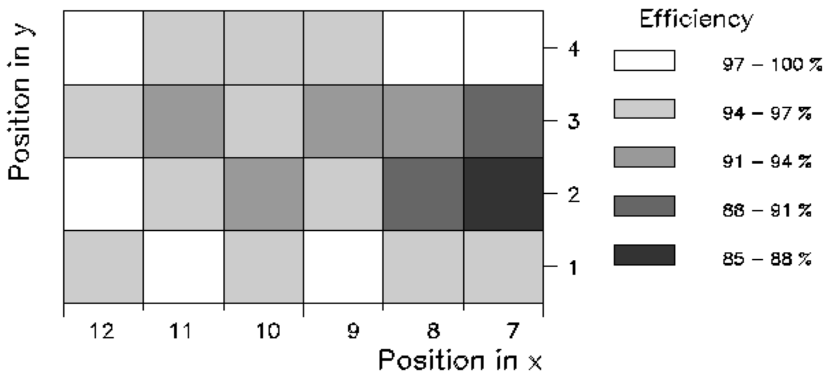
Comparison to GEANT4 simulations coming soon

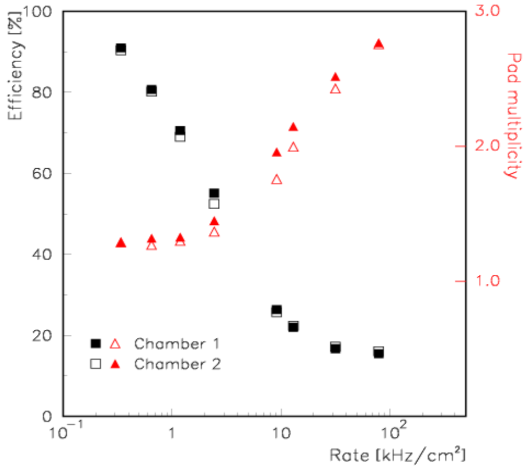
Recent Results IV

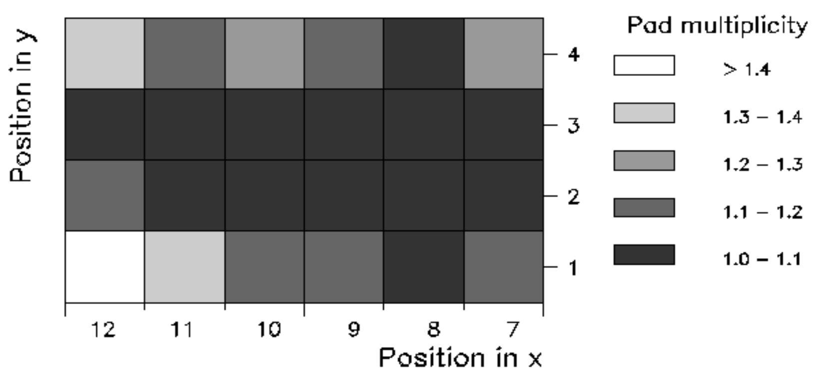
Validation of 1-glass RPC design

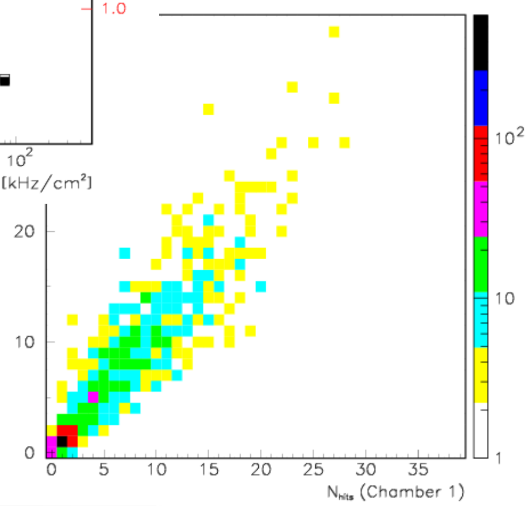
Design proposed and developed by Argonne group
Built 2 large chambers (32 x 48 cm^2)
Tested with Cosmic Rays and in Fermilab testbeam

Conclusion → Performance as expected









Identified Issues I

Loss of efficiency

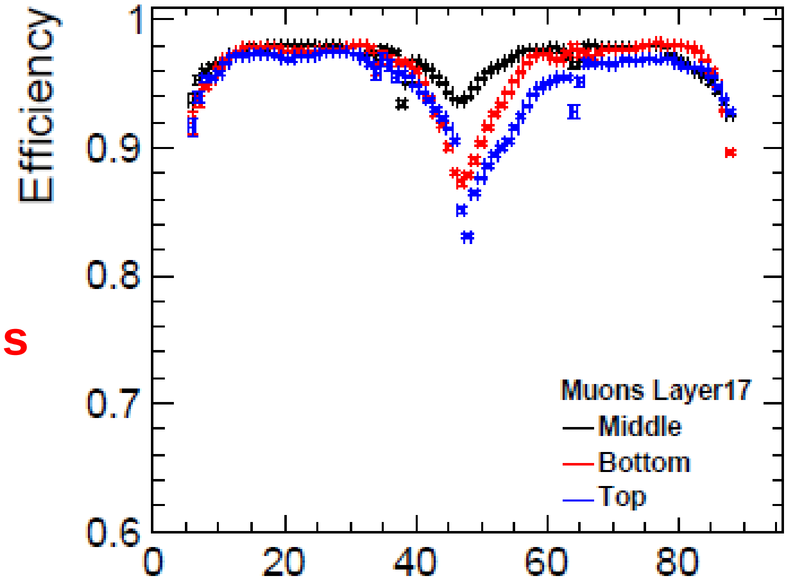
During operation of DHCAL in test beam: loss of efficiency on some chambers
Problem traced back to chemical reaction at HV lead increasing resistivity
Some chambers recovered by increasing the applied HV

Solution → use of Kapton film as resistive layer (commercially available)

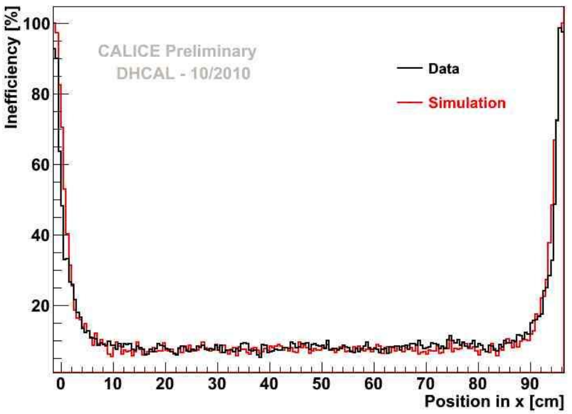
Bending of boards

Readout boards initially flat to within <1 mm
Noticed loss of efficiency in center of chambers in CERN data (2012)
Traced back to bending of boards

Solution → mechanically constrain boards within cassette (SDHCAL did that)



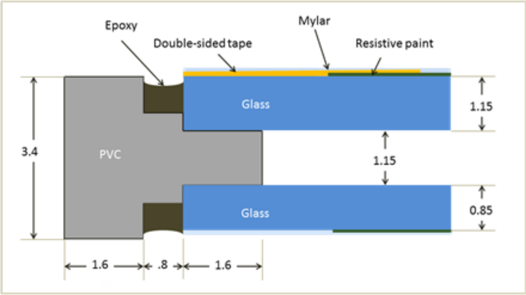
Identified Issues II



Loss of efficiency at borders

Chambers inefficient close to the physical borders
Effect larger than anticipated
Traced back to increased gap size due to misshapen channels

Solution → improved shape of channels

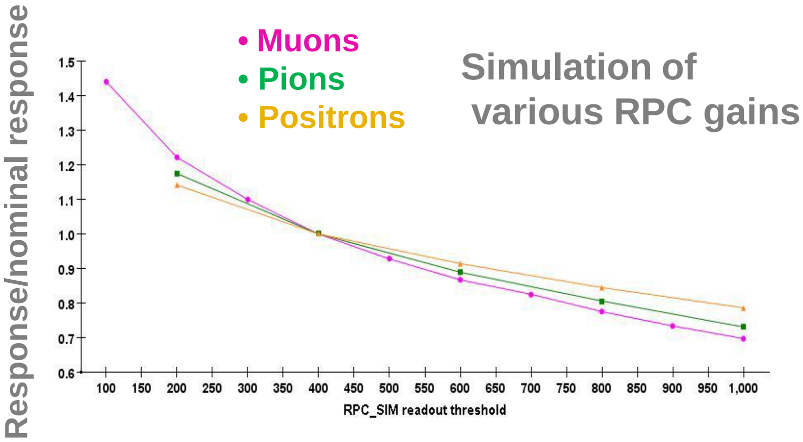


Equalization of the RPC responses

(In simulation) different dependence of the response to the RPC performance parameters for different particles

Solution → Equalization of response for each particle type individually

(unpleasant !)



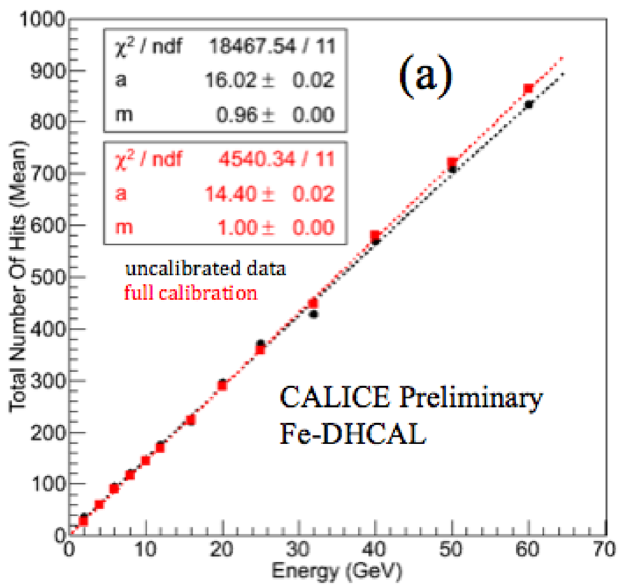
Simulation of various RPC gains

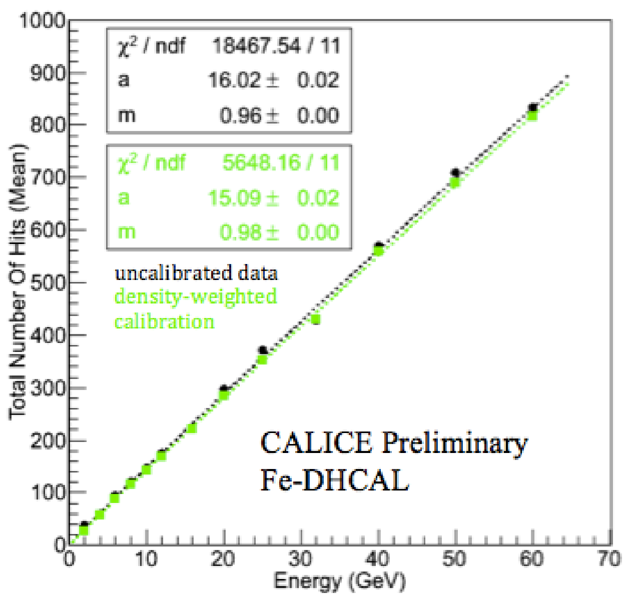
Identified Issues III

Equalization of the RPC responses

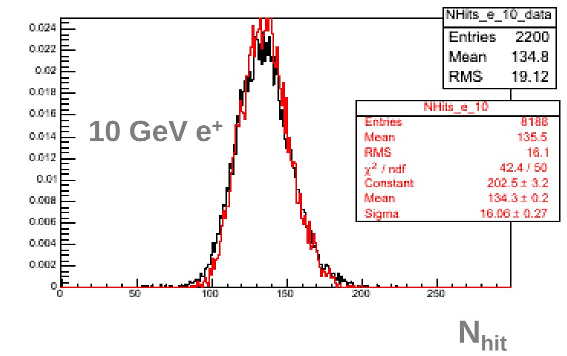
Overcorrection for multiple avalanches on single pad
Leads to improved linearity (contrary to MC predictions)

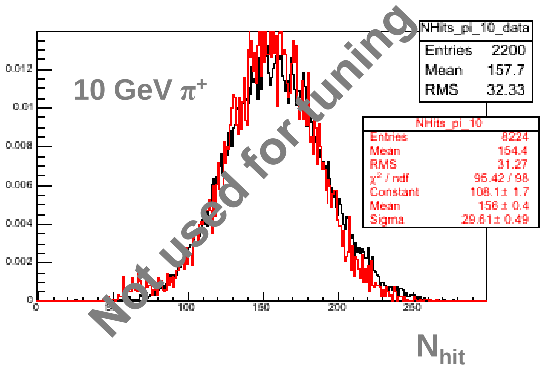
Solution → Density-weighted calibration
(work still ongoing)

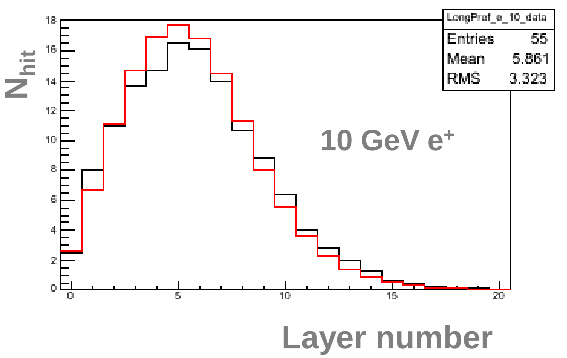


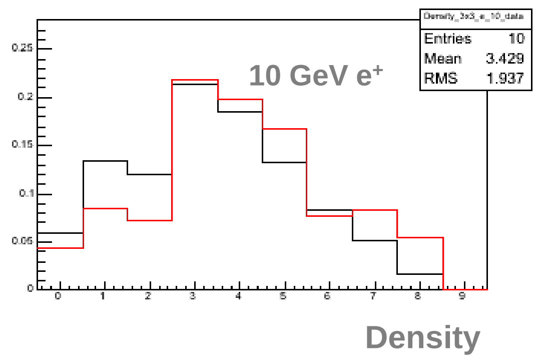


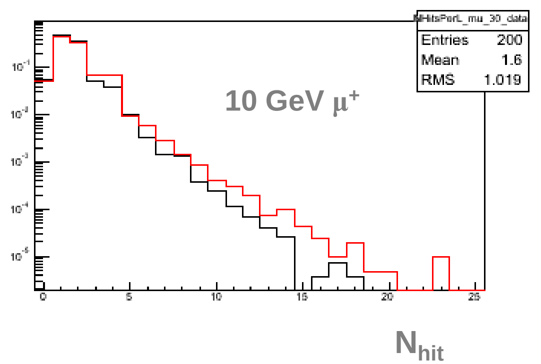
Identified Issues IV











Simulation of RPC response

Standalone program (RPC_sim)
Explored a number of different functional forms to spread charge on readout plane

Currently best version → Sum of 2 Gaussians
(still not entirely satisfactory)

Identified Issues V

No identified issues without proposed solution!

R&D still to be completed I

HV distribution system

Every of the ~6,000 layers will need to be controlled individually
University of Iowa started developing a system to distribute HV to multiple channels

Turn on/off individual channels
Monitor current and voltage
Adjust individual channels by several hundred volt

Prototype (1 channel) tested successfully

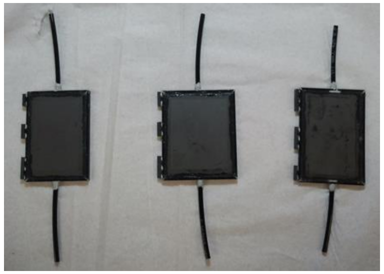
Status → activity stopped due to lack of funding

Gas recycling system

Gas needs to be exchanged to eliminate poisons
For environmental and cost reasons gas needs to be recycled
University of Iowa initiated the development of a
'Zero Pressure Containment' system
Part of a prototype system already assembled

Status → activity stopped due to lack of funding

R&D still to be completed II



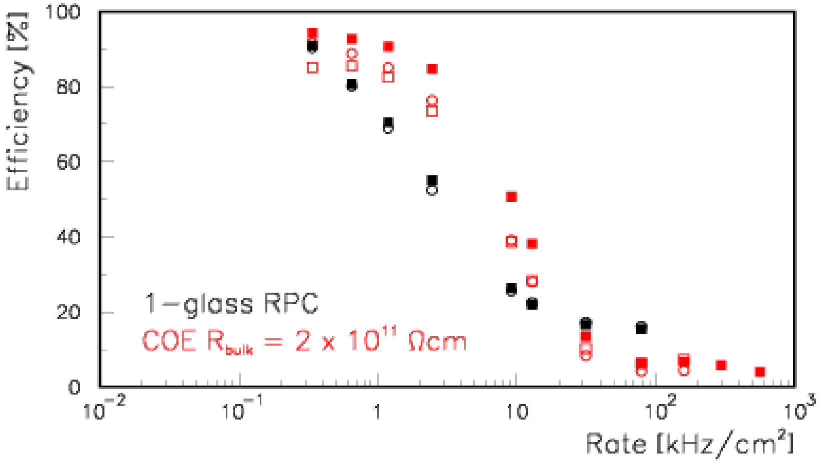
Development of high-rate RPCs

Typically glass RPCs lose efficiency for rates above 100 Hz/cm^2
Rate capability sufficient for most of ILC hadron calorimeter, but marginal for forward region
Rate capability depends on bulk resistivity of resistive plates (~ 10^{13} Ωcm)
Together with COE College (Iowa) developing semi-conductive glass
First RPCs with new glass (~10^{11} Ωcm) built and tested

Conclusion → rate capability improved

New glass with lower bulk resistivity in hand
(not yet measured)

Status → work on hold



Mechanical design of hadron calorimeter

Started development some time ago

Status → work on hold

R&D still to be completed III

Unless we complete this R&D, an RPC-based imaging hadron calorimeter can not seriously be proposed for an ILC detector

On a personal note…

For FY2015 the DOE **cut all funding** for LC related activities

→ apart from a meager amount for accelerator R&D
→ against P5 recommendations

On 10/17, **Glen Crawford** wrote a letter to the CALICE steering board informing them that I was ordered to step down as their spokesperson

As of the start of FY2015 all **DHCAL activities** lost their support at Argonne

→ leaves our collaborators (CERN, COE, Iowa, UTA, China) hanging
→ in the past 10 years we were leading the development of the DHCAL technology, which will now be pursued by others (China and France with the exclusion of the U.S.)

The **global impact** of a U.S. withdrawal from ILC/CALICE is not clear

→ But it will certainly not help getting the ILC approved by the Japanese Government
→ The U.S. will loose its leadership in the development of new calorimeter technologies
→ Argonne's future participation in the construction of the calorimeter for ILC/CLIC will face significant difficulties (loss of expertise, manpower, starting all over again….)