Future R&D of the RPC based Digital Hadron Calorimeter (DHCAL)

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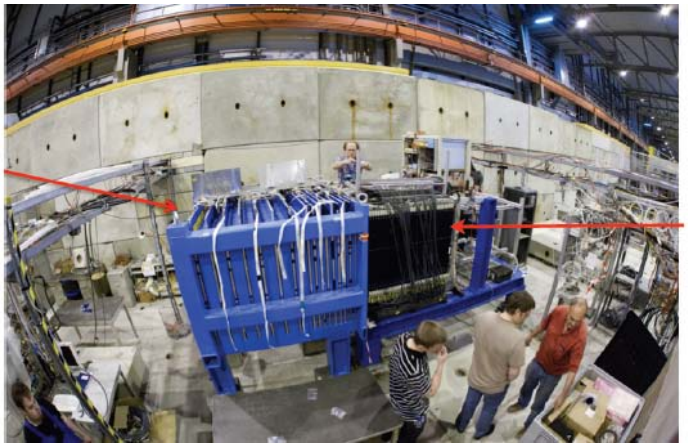
Outline

- Test beam at CERN with W absorber
- Possible new mechanical design for DHCAL module
- RPC issues found in the last 5 test beam campaigns
  - Gas gap uniformity
  - Gas tightness
  - HV paint
  - Noisy regions
  - Coherent noise
- Future RPC/DHCAL R&D
  - 1-glass RPC
  - High rate RPC
  - Nano-second timing DHCAL
  - Gas recirculation

Test beam with W absorber

- Tungsten (W) absorber is a natural choice for a deeper HCAL with thickness constrains
- CERN CLIC detector R&D group already tested CALICE AHCAL layers with a set of W absorbers at CERN test beam
- The CERN group and the RPC DHCAL group will have a combined test beam of RPC layers with W absorber in 2012
  - Test beam will be at CERN, due to limited availability of Fermilab test beam in 2012
  - Expect 2 run periods, first one could be as early as April 2012
  - Argonne group visited CERN test beam after Granada workshop
  - CERN group joined DHCAL test beam run at Fermilab in Nov. 2011
  - Discussion on details of DHCAL shipping is on-going

tail catcher:
installed for higher
energy program

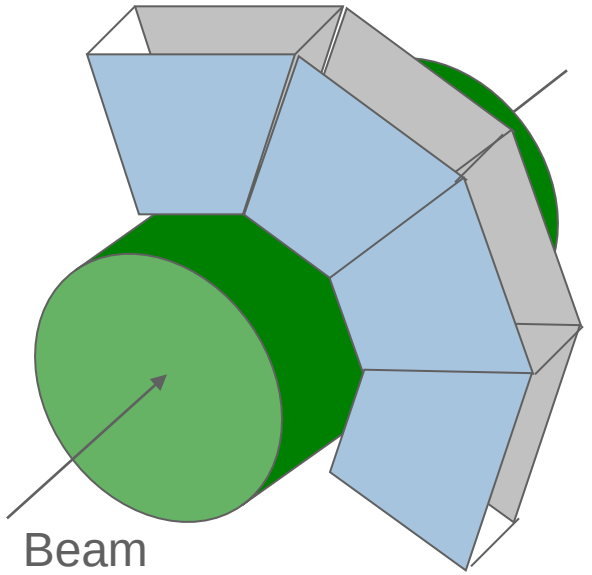


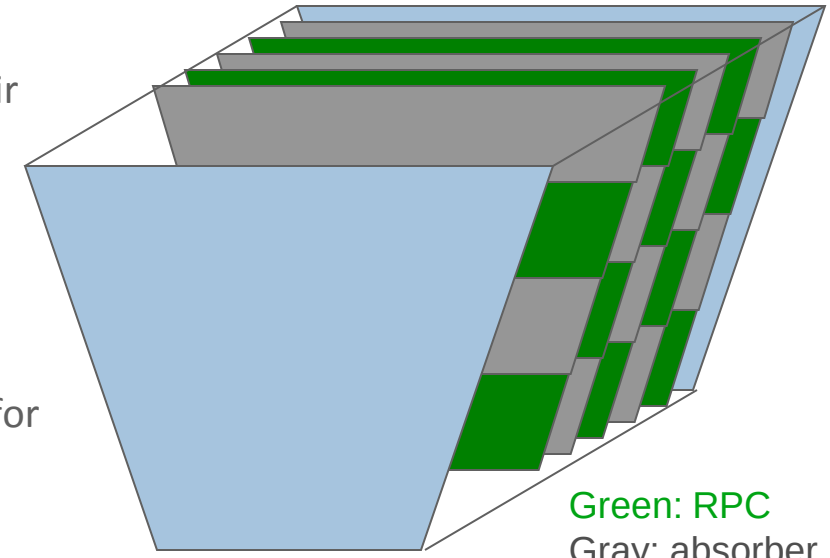
AHCAL + W test beam

Possible new DHCAL module design

- Our mechanical engineer (Victor Guarino) came up with this ‘ATLAS Tile Cal’ like design
- Many advantages compare to atraditional wedge design
  - RPC’s are much smaller
  - RPC’s have only a few different shapes
  - RPC’s are all vertical (same orientation)
  - FEB will also have only a few different shapes
  - Services (HV, LV, gas, data link) can be naturally vertical as well
- Disadvantage
  - Don’t know any at the moment
  - Our ATLAS colleagues didn’t complain about their HCAL configuration…
- Physics performance
  - Hadron response: setting up Geant4 to do simulation study
  - PFA performance: need study
  - If needed, might be able to re-configure DHCAL for test beam study

DHCAL modules



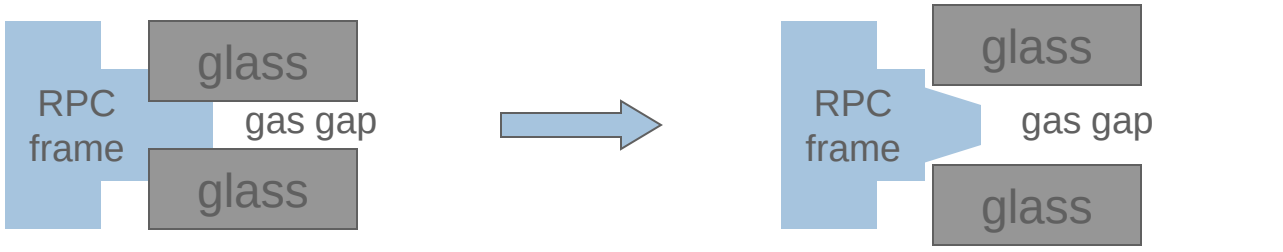


Green: RPC
Gray: absorber

1 DHCAL Module

Issues found in DHCAL test beam

- We had 5 x (4 weeks) very successful test beam of the DHCAL ($1m^3$) physics prototype in the last 14 months
- Both RPC's and the readout system performed really well
- Nevertheless, found some issues that worth attention:
  - ~3 RPC's (out of 180+) went totally dead
    - Due to resistive paint losing its conductivity → no HV can be applied to gas gap
    - Don't know the reason for paint to go bad
    - Will do more study on current resistive paint solution
    - Will also try new solutions (currently waiting for samples)
  - ~10 RPC's saw inefficiency regions around corner and rim
    - Mostly only affect regions ~ a few cm off corner or rim (worst case ~ 10 cm around corner)
    - Due to larger than normal gap size in these regions
    - Need to improve side profile of the extruded RPC frame
    - Also need to improve/simplify assembly procedure



RPC frame in design

RPC frame out of extrusion

Issues found in DHCAL test beam

- Issues need attention (continue…)
  - ~20 RPC's developed some leakage (all RPC's passed leakage tests when produced)
    - This was not a significant issue until the test beam run last month (11/2011)
    - Had to replace ~10 leaky RPC's and take care a few more RPC's with small leakage
    - Not 100% sure about the reason, but have 3-4 'theories'
    - Will study the leakage and fix the leaky ones
    - Will also develop preventive measures (implemented a few on repaired layers based on guessing)
  - ~1/3 RPC's in the DHCAL developed at least 1 noisy spot
    - We believe that we understood the problem, but need more tests
    - Noisy region = inadequate cleaning on glass inner surface + high running temperature
    - Will develop ways to prevent the problem, and will try to see if it is possible the 'fix' the noisy spots
  - Observed very low level coherent noise in both noise runs and beam runs
    - It is not a problem for the $1m^3$ prototype, but don't know how it will scale to larger detector
    - Source not well understood, knew it was grounding related
    - Noise analysis is on-going and we will do more tests to figure things out
- Side remark
  - We did need a large enough device, and long enough play time with it to see all these issues

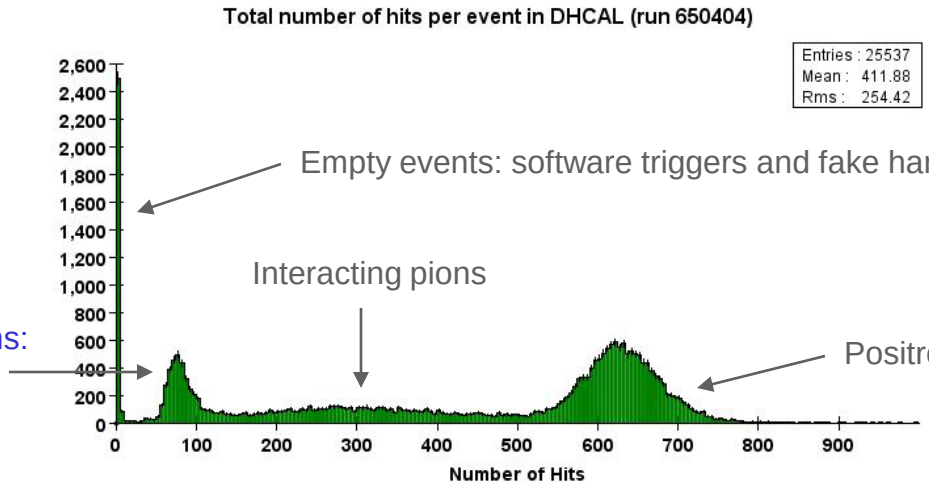
Future RPC/DHCAL R&D

- 1-glass RPC development
  - A lot of advantages compare to traditional 2-glass ones
  - Built/tested 3 small RPC's like this in the past → very successful
  - Have ideas on how to build larger 1-glass RPC's, will try in early 2012

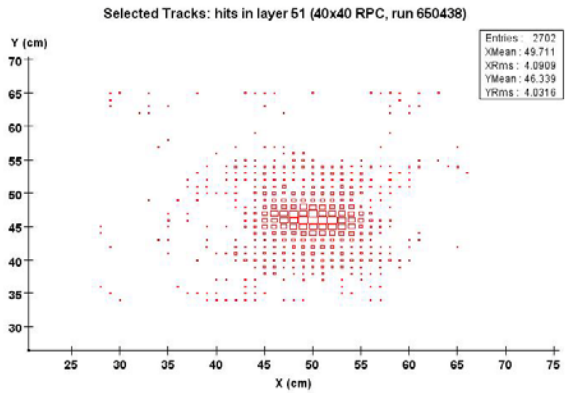
- High rate RPC development
  - Collaborating with COE college to develop low resistivity glass for high rate glass RPC's
    - First sample will be available soon
  - Collaborating with the University of Michigan on developing low resistivity Bakelite RPC's for ATLAS 'small wheel' (end cap muon trigger) upgrade
    - Using new Bakelite plates with very low resistivity → much higher rate capability (> ~10kHz/cm^2)
    - Using same/similar RPC design as the DHCAL RPC's → potential future application for DHCAL
    - First prototype RPC's were constructed and tested in lab
    - Combined beam test of 2 prototype RPC's at Fermilab test beam during last DHCAL test period
      - Installed behind the entire DHCAL, tested with secondary beam at 1, 8, 10 GeV
      - Using DHCAL readout, data joined DHCAL data flow
      - First results are encouraging

Combined RPC test beam with U. Michigan

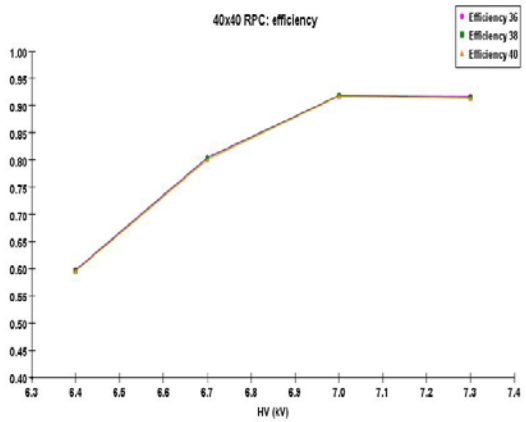
- Useful beam components are the muons and non-interacting pions
- Using last 10 layers of DHCAL for tracking to measure Bakelite RPC properties



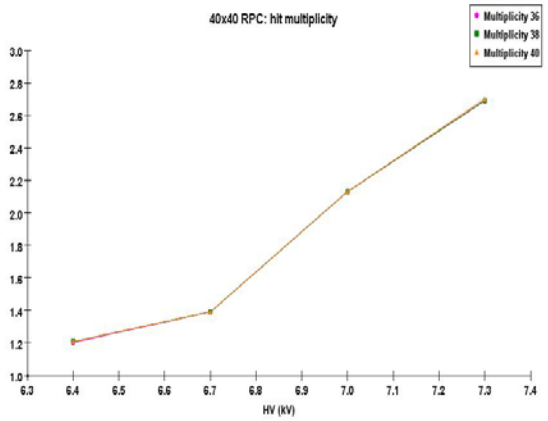
Beam particles at 8 GeV



Beam profile on Bakelite RPC



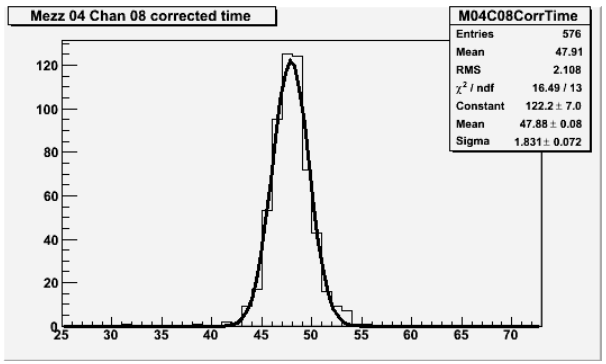
HV scan: efficiency



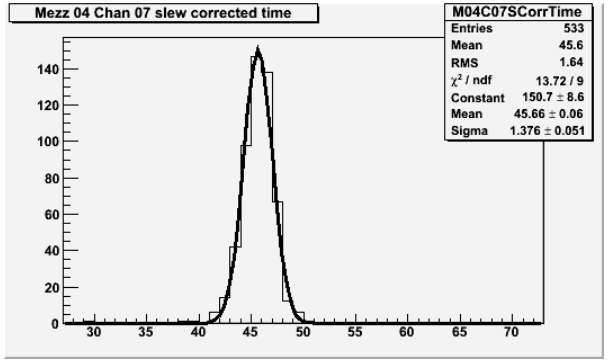
HV scan: hit multiplicity

Future RPC/DHCAL R&D

- Nano-second timing DHCAL
  - CLIC requires nano-second level timing resolution for calorimeter
  - It might also help PFA in some way (not sure…)
  - CALICE is moving towards this direction already
    - Detailed shower timing measurement with scintillator + W absorber (T3B)
    - New generation readout chips included timing capability
  - RPC is great at fast timing → we are interested in developing a nano-second timing DHCAL
    - U. Michigan measured our DHCAL RPC with their MDT readout at CERN test beam and confirmed the timing capability of our RPC: ~1.2ns (no correction) / ~0.77ns (with slew correction)



1.4ns rms: no correction, including readout resolution
~1.2ns, no correction, excluding readout



1.1ns rms: slew correction, including readout resolution
~0.77ns, slew correction, excluding readout

- Need major upgrade / redesign of DCAL chip: started serious thinking
  - Time stamp or no time stamp
  - Pipe line or circular buffer
  - Power consumption will be a major consideration

Future RPC/DHCAL R&D

- Gas recirculation system
  - Jose has talked about it many times
  - It is needed for any large RPC system (environment/cost)
  - Will collaborate with other big RPC users on this development

Summary

- We've had 5 successful test beam runs, and have one more to go
- A major part of our time will be devoted to data analysis
- At the same time, there are exciting new opportunities for RPC/DHCAL R&D
  - New type of RPC's
  - High rate RPC, low resistivity electrode material
  - Nano-second timing DHCAL
  - Gas recirculation
  - …