R&D on Electro-Magnetic Calorimetry (update since NIU)

Univ. of Kansas group:

Faculty : Graham Wilson, Dave Besson, Alice Bean, P. Baringer

Postdoc : Carsten Hensel (just hired)

Graduate Student : Darius Gallagher

Undergraduates …

Interested in collaborating : Tim Bolton, Eckhard von Toerne (Kansas State)

In contact/potential collab. : Uriel (Colorado), Paolo Checchia et al (Padova)

Can benefit/collaborate with HCAL/Sc efforts : DESY, Russia, NIU, Prague etc -
E-flow issues

• Reminder of approach
• Physics justification of E-flow ?? (also see S. Kuhlmann’s talk at Prague) :
  – nu nubar V V : is most likely NOT the compelling physics topic.
  – ZHH studies : not clear that such analyses can not be done better by other means (eg. kinematic fits, more selective b-tagging, lepton channels). Case not yet made for heavier Higgs masses
• ECAL energy resolution physics requirements
  – Z to hadrons
  – Z to tau+ tau- to hadrons …
  – Other things.
• Hybrid. Maybe there is a lot of complementarity intrinsic to a mixed Silicon/Scintillator active medium :
  – Eg. Maybe the hadronic response in scintillator could be controlled with timing information
  – Maybe the hydrogenous/non-H nature of Sc/Si can help in eliminating energy deposits essentially of hadronic origin.
  – Calibration of non-uniformities …
ECAL design considerations

• Existing Si-W calorimeters: poor sampling + not so compact active layer
  – ALEPH (12 layers) 34%/√E (at 45 GeV) 3.03 mm
  – OPAL (19 layers) 25%/√E (at 45 GeV) 3.3 mm

• Review tile/fiber projects: energy resolution, response uniformity
  – There are many: UA1 upgrade, CDF PLUG, D0MUON, OPAL TE/MIP, ATLAS etc.
  – ECAL requirements on MIP detection per layer not yet clear in hybrid Si/Sc design.
  – (Note WA69 (SPACAL) ECAL: 4000 p.e./GeV, 10%/√E BUT ⊕ 4% !)

• Looking into suitable scintillator/WLS/photo-detector possibilities with a view to source and cosmic-ray tests: see plastic slides.
  – Note that PM’s can be easily used to sum several fibers/layers, not so clear that this can be done cost effectively with VLPC’s …?
EoI in EM calorimetry design studies

• Planning work on understanding the trade-offs in the EM calorimeter design

• Si/W looks very attractive for E-flow
  – With no cost constraints – hard to beat.
  – But will need to be able to justify chosen lateral and longitudinal segmentation.

• Some weak points however:
  – **Cost** (at sufficiently large R), power dissipation, timing resolution (X-band bunch spacing of 1.4 ns tough!), intrinsic EM energy resolution.

• A hybrid-solution based on W absorber with both Si-pads and scintillator read-out could potentially address these, without over-compromising present benefits
Pros: I) Si cost is driven by layers required for E-flow PATREC II) Achievable EM energy resolution driven by number of Si + scintillator layers

Challenges: less compact ECAL (or lower light yield), engineering issues for fibre readout and co-habitation, homogeneity, granularity.

“Temporal” calorimetry desirable for forward region?
Z to hadrons

$E_{\text{g ammas}}$

$E_{\text{ne utral\_hadrons}}$

$E_{\text{ne utrino}}$

$p_{\text{charged}}$

1/9/2003

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Resolution Assumptions

- Tracker: 5 \times 10^{-5}
- ECAL: 15\% / \sqrt{E} \oplus 1.5\%
- HCAL: 35\% \sqrt{E} \oplus 3\%
\[ \sigma_E/E = 15\%/\sqrt{E} \]

- **DE\_visible**
  - entries: 10000
  - min: -8.2055
  - max: 7.6288
  - mean: -0.35398
  - rms: 1.4104

- **DE\_gammas**
  - entries: 10000
  - min: -3.4150
  - max: 3.3702
  - mean: -0.36096
  - rms: 0.35212

- **DE\_neutral\_hadrons**
  - entries: 10000
  - min: -8.1663
  - max: 8.6710
  - mean: 0.011165
  - rms: 1.1447

- **e\_char-e\_char**
  - entries: 10000
  - min: -2.8154
  - max: 3.3702
  - mean: -0.36096
  - rms: 0.35212

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Z to tau+ tau-  

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LC ought to think carefully about taus (Paige)

Tau decay drives the two-track resolution and the ECAL energy and angular resolution …

E_gammas

entries: 1000.0
min: 1.9173E-8
max: 75.257
mean: 13.646
rms: 14.489

E_neutral_hadrons

entries: 1000.0
min: 0
max: 42.517
mean: 0.19931
rms: 2.3015

E_neutrino

entries: 1000.0
min: 1.4265
max: 86.912
mean: 41.697
rms: 17.944

p_charged

entries: 1000.0
min: 3.3584
max: 88.396
mean: 35.452
rms: 16.890
Z to tau+ tau- 

All from ECAL

DE_visible

entries: 1000.0
min: -4.6318
max: 2.2946
mean: 6.0628E-3
rms: 0.60771

DE_gammas

entries: 1000.0
min: -4.6293
max: 2.2951
mean: -1.6832E-3
rms: 0.030311

DE_neutral_hadrons

entries: 1000.0
min: -0.66184
max: 2.1443
mean: 4.0276E-3
rms: 0.099950

eschar-eschar (pion hypothesis)

entries: 1000.0
min: -0.23598
max: 0.15851
mean: 3.7184E-3
rms: 0.030311

Who needs an HCAL?
E-flow basics continued ….

– Will follow up also with quark flavor dependence, gluon jets, W jets, energy dependence, including ISR

• Klong and neutron palliatives:
  – Can counting charged baryon number in the tracker help predict which events have a lot of prompt neutrons ?? (Bob Wilson all is forgiven …)
    • Not really 15%/√E improves to 14.5%/√E for the 61% of events with charged baryon number of zero.
    • Will also check how much worse for CBN of +-2.

– IF you can identify events with a lot of neutral hadronic activity, can you do better on the ones with little. For this sub-set : ECAL energy resolution becomes the driving factor.
  • Cut at 10 GeV hadronic energy. 60% of events 11.6%/√E
  • Cut at 5 GeV : 38% of events 10.5%/√E

– Is the need : achieve jet energy resolution of xxx. OR is it more KNOW event by event what your error is ….???
Conclusions

• Many solutions using (some) scintillator can work: technology pretty mature.
  – Some challenges:
    • response uniformity
    • hermeticity, integration
    • compactness if MIP detection per layer required.
  – Benefits:
    • Cost ?, EM-resolution, timing, hybrid-synergy?

• Need to work more on specifying the requirements.
Investigation and Design Optimization of a Compact Sampling EM Calorimeter with High Spatial, Timing and Energy Resolution
Immediate plans

• Review basics of energy flow concept
  – (see next slide)

• Get familiar with all levels of the software.
  – Started with generating PYTHIA u,d,s,c,b at 91 GeV. Playing with JAS on W2K. (Had trouble with linux installation)
  – Need to develop ability with the full simulation.
    • For some of the studies a more specific test-beam like geometry may be more appropriate.
  – Reconstruction software – particularly photon finders.
  – (will give feedback to developers on tutorials)
Medium-term Goals

• Investigate transverse and longitudinal segmentation dependence of the performance of the Si-W ECAL concept and the hybrid Si-W-Scintillator-W concept.
  – Energy, angular, directional, time resolution
  – Photon-pion separation

• Utility of timing resolution wrt pile-up.
Work Plan

• Repeat studies looking at tracker, ECAL, HCAL energy and angular resolution effects on energy flow.

• Explore with simulation some of the optimisation phase-space of the Si-W proposal (lateral and longitudinal segmentation) and of the hybrid idea.
  – Need an appropriate detector/physics metric
  – Will also work on developing a refined understanding of the physics requirements

• Participate in the International CALICE collaboration work on prototype development and test-beam measurements

• Choose particular aspect and work towards demonstration of the necessary performance.
Deliverables

• Understanding of the transverse and longitudinal segmentation dependence of Si-W and Si-W-Sc. performance
  – Single particle energy and angular resolution vs energy.
  – Photon-pion separation vs energy
  – Time resolution

• Contribute to the cost-performance optimisation

• Start establishing needed performance characteristics with prototypes

• Contribute to testing the E-flow concept with test-beam in framework of CALICE collaboration
Other related work and plans

• Checchia et al (INFN) – Sc. based with a few Si planes for precision position.
• DESY-based work on Sc. Tile analog HCAL
• Colorado group – planning to explore small Sc. Tiles
• Digital HCAL ideas with scintillators (NIU)
• SLAC/Oregon/Argonne/UTA studies on energy-flow
• Interest from U. Chicago, UIC, Fermilab