Digital Hadron Calorimetry for Future HEP Experiments

DoE Site Visit, UTA
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- Introduction
- Physics Motivation
- Energy Flow Technique & Need for DHC
- Issues to Cover in R&D
- R&D Plans
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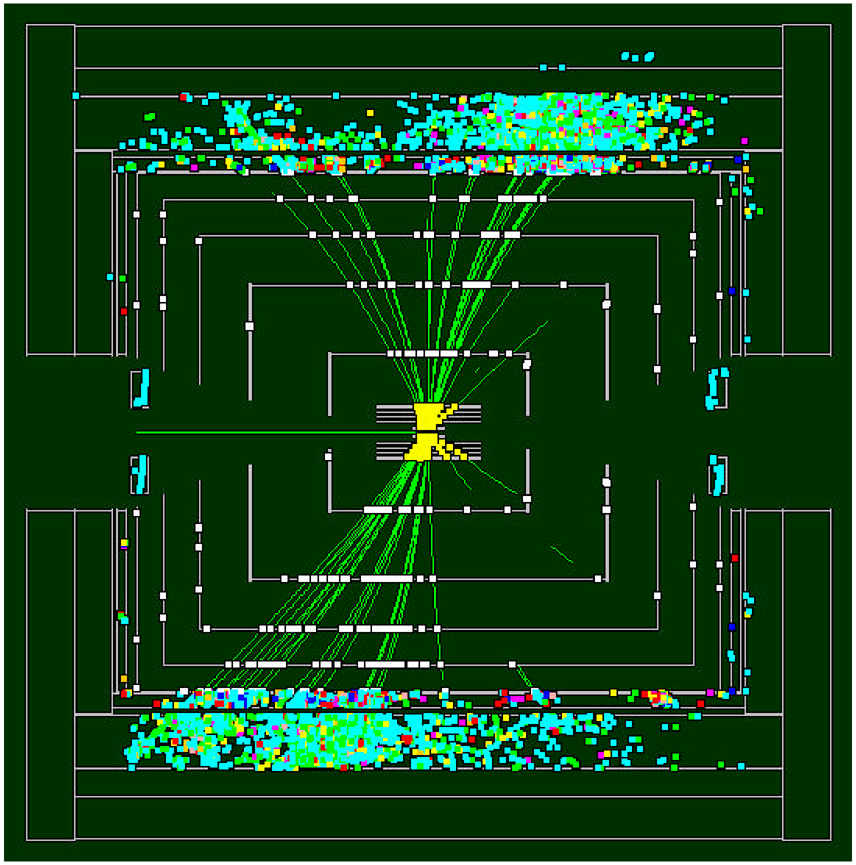
Introduction

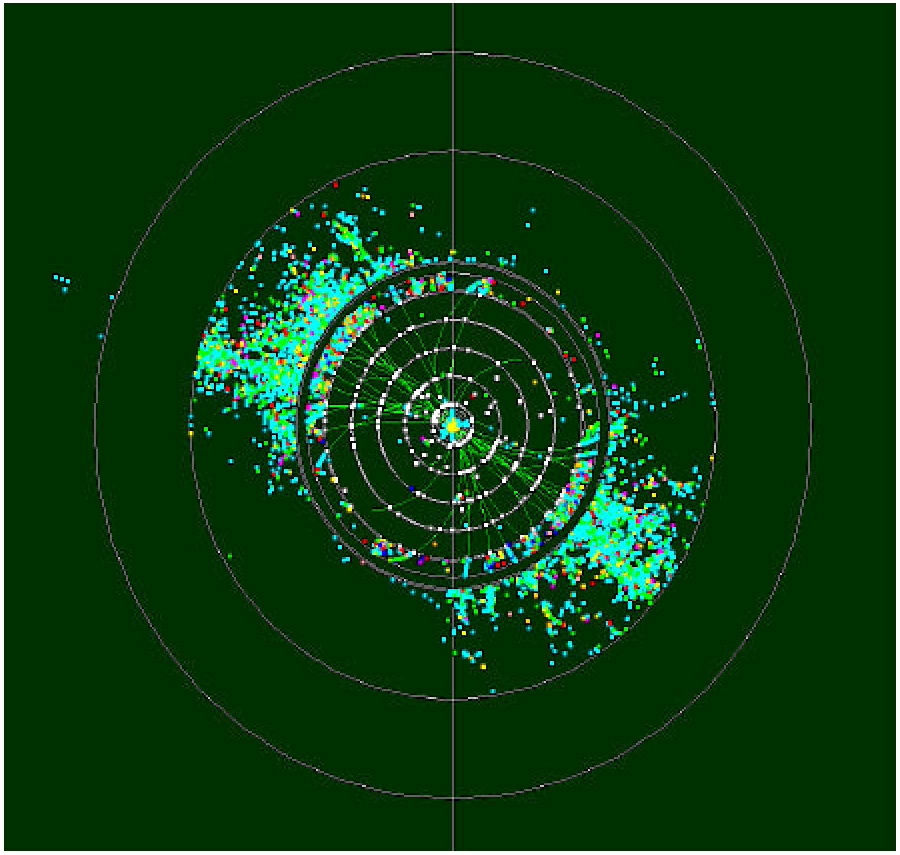
- New techniques are needed to achieve physics goals at future accelerators, such as LC
- Traditional sampling hadron calorimetery has limitations at the jet energy resolution improvements due to statistical fluctuation of shower particle sampling
- Energy Flow Technique minimizes the effect of this fluctuation by using precisely measured tracking information
- Requires large number of readout channels ➔ maybe prohibitively expensive with the conventional readout
- Digital calorimeter is a solution to alleviate this issue

Physics Motivation at an LC

- Precise measurement of Higgs characteristics (masses and natural widths)
  - To determine their types (SM or SUSY)?
  - To understand coupling to W/Z and to themselves for understanding SB mechanism
- To perform precise measurements of various SUSY parameters, if they are found
- Most these events includes jets and missing E_T in the final states
- Require better than $40\%/\sqrt{E}$ for meaningful Higgs self-coupling measurement

$e^{+}e^{-} \rightarrow hZ \rightarrow bbjj$ Event





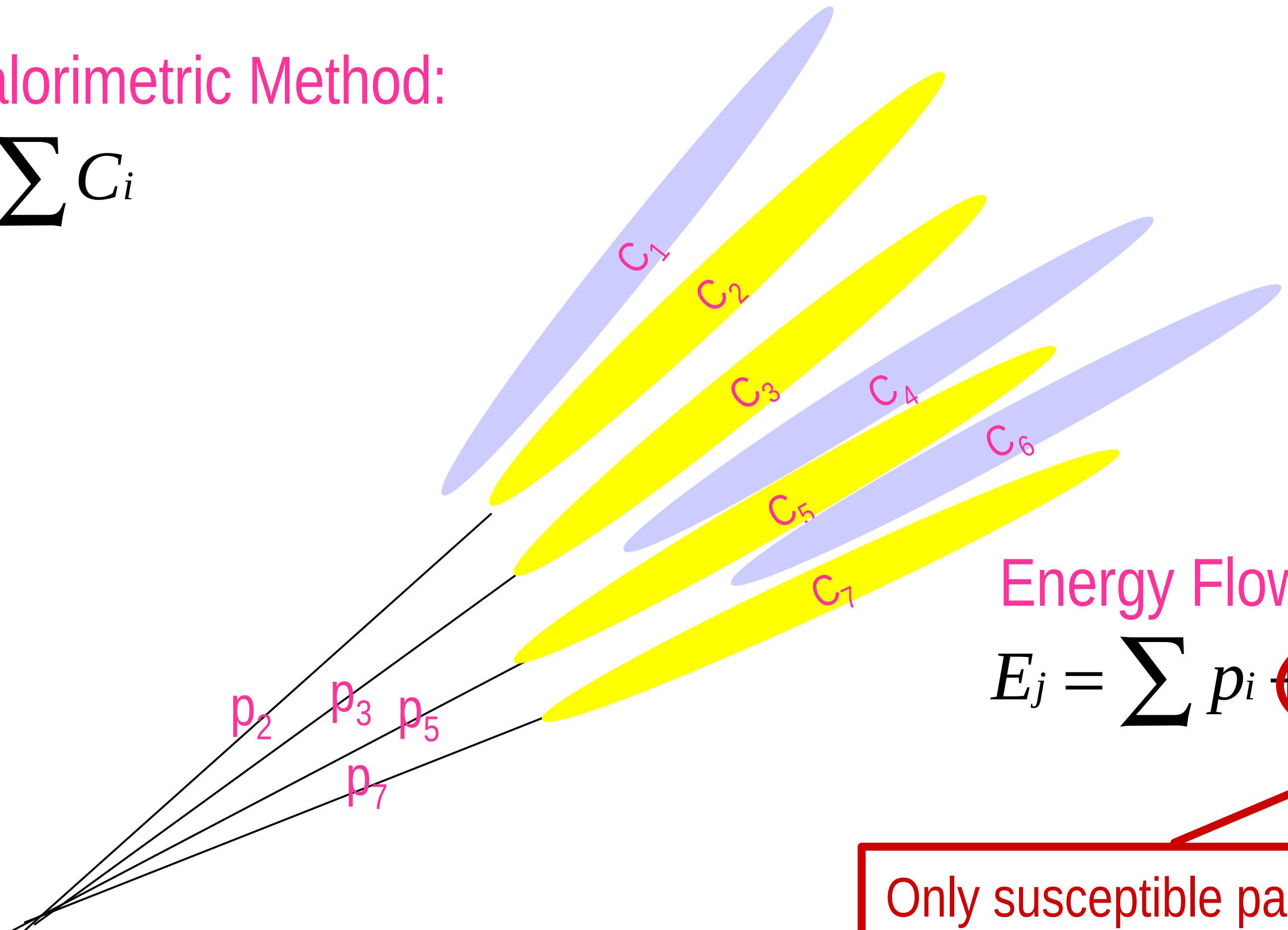
Energy Flow Technique

- Developed by ALEPH
- Hadronic jets consists of EM, charged hadrons, and neutral hadrons
  - EM particles relatively well behaved and measured
  - Charged hadrons' energy can be measured using precise tracking system
  - Replace and remove the clusters corresponds to charged hadrons
- ALEPH could have achieved up to $30\%/\sqrt{E}$ had they finer calorimeter segmentation
- To use this technique at higher energy accelerator, requires higher channel counts to provide finer segmentation ➔ Could be too expensive to readout pulse height with full 11-15 bit ADCs
- Just counting the number of shower particles might work as long as the calorimeter segmentation can be finer ➔ Digital calorimeter

EF Technique

Normal Calorimetric Method:

$$E_j = \sum C_i$$

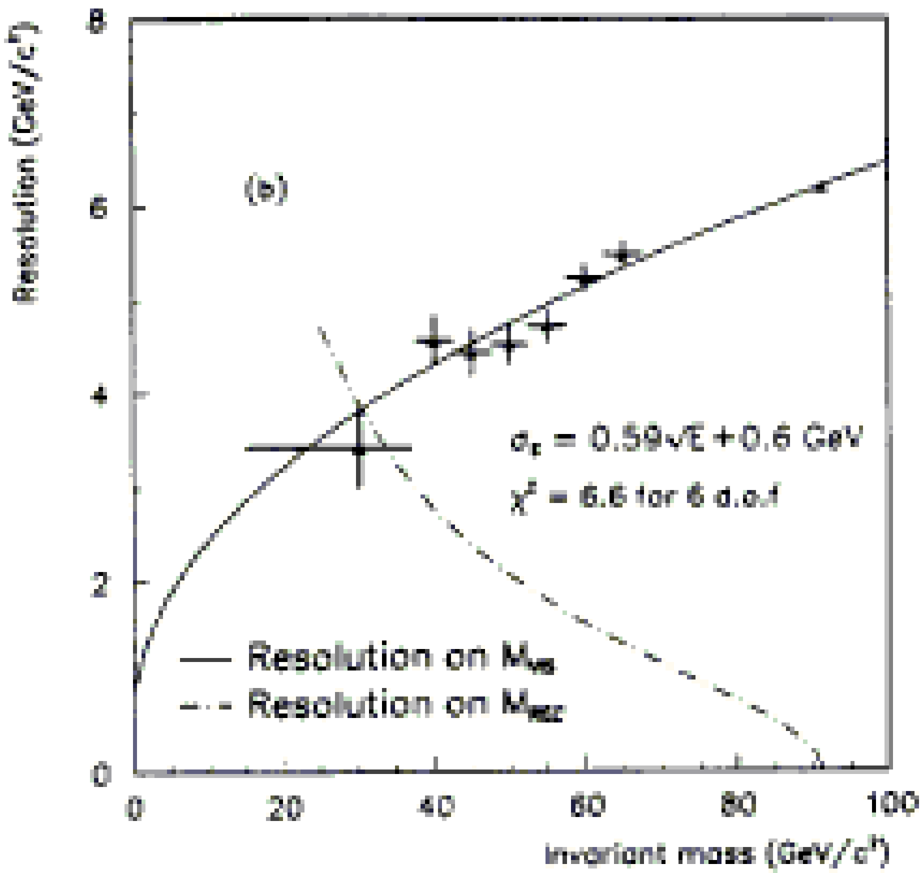


Energy Flow Method:

$$E_j = \sum p_i + \sum C_n$$

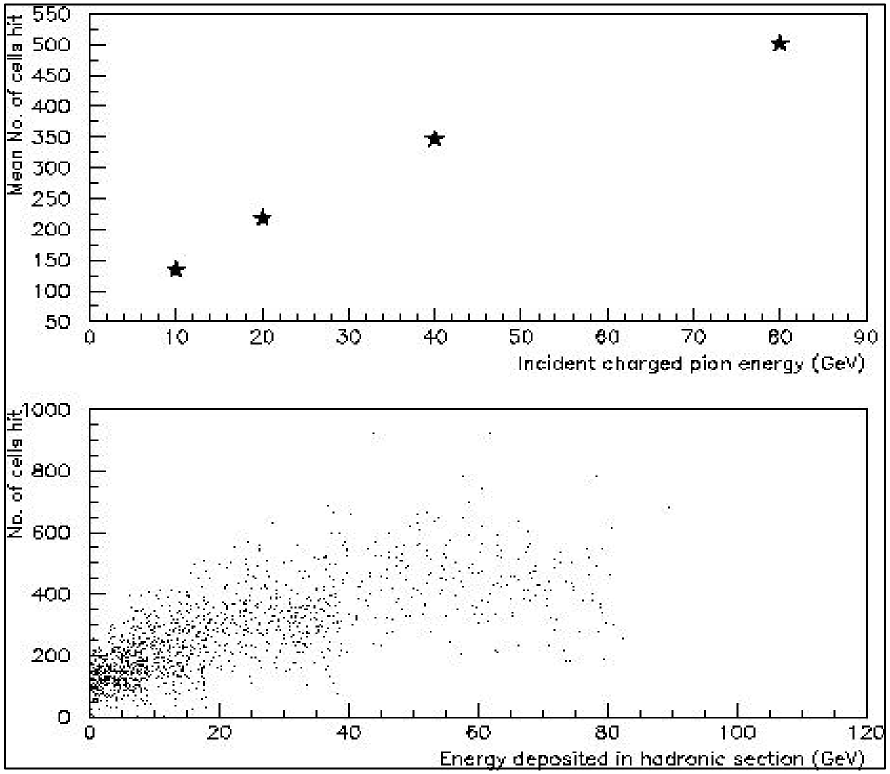
Only susceptible part to Shower statistical fluctuation

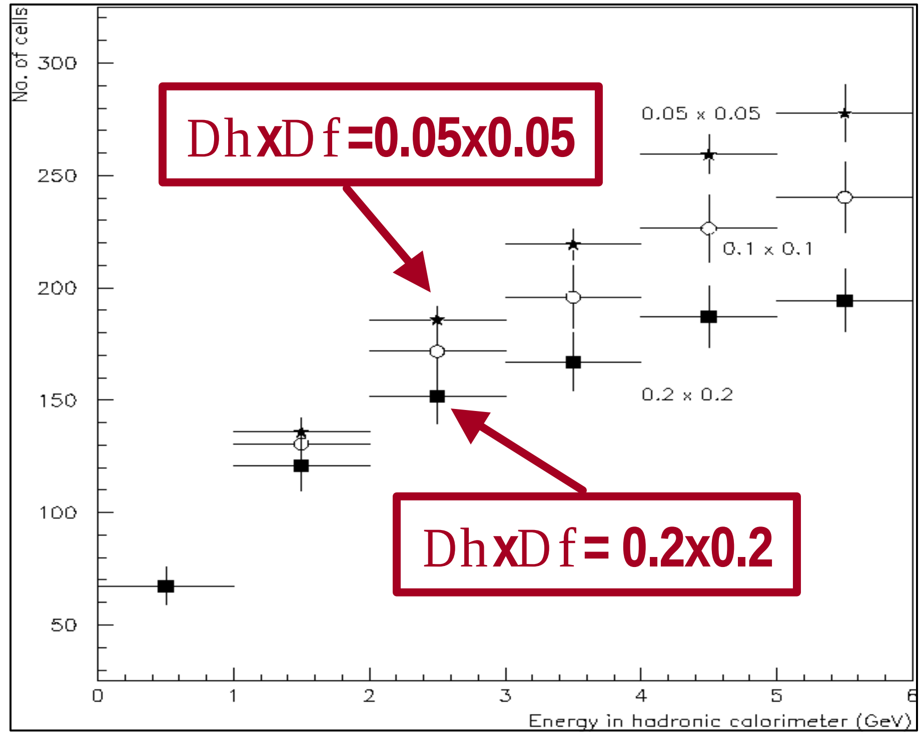
ALEPH Resolution Improvement



- Jet mass resolution at ALEPH using hard γ radiation events
- Hadron calorimeter single particle resolution ~ $80\%/\sqrt{E}$
- Usually expect ~$100\%/\sqrt{E}$
- Remarkable improvement, using EF method: ~$59\%/\sqrt{E}$

Proof of Principle MC

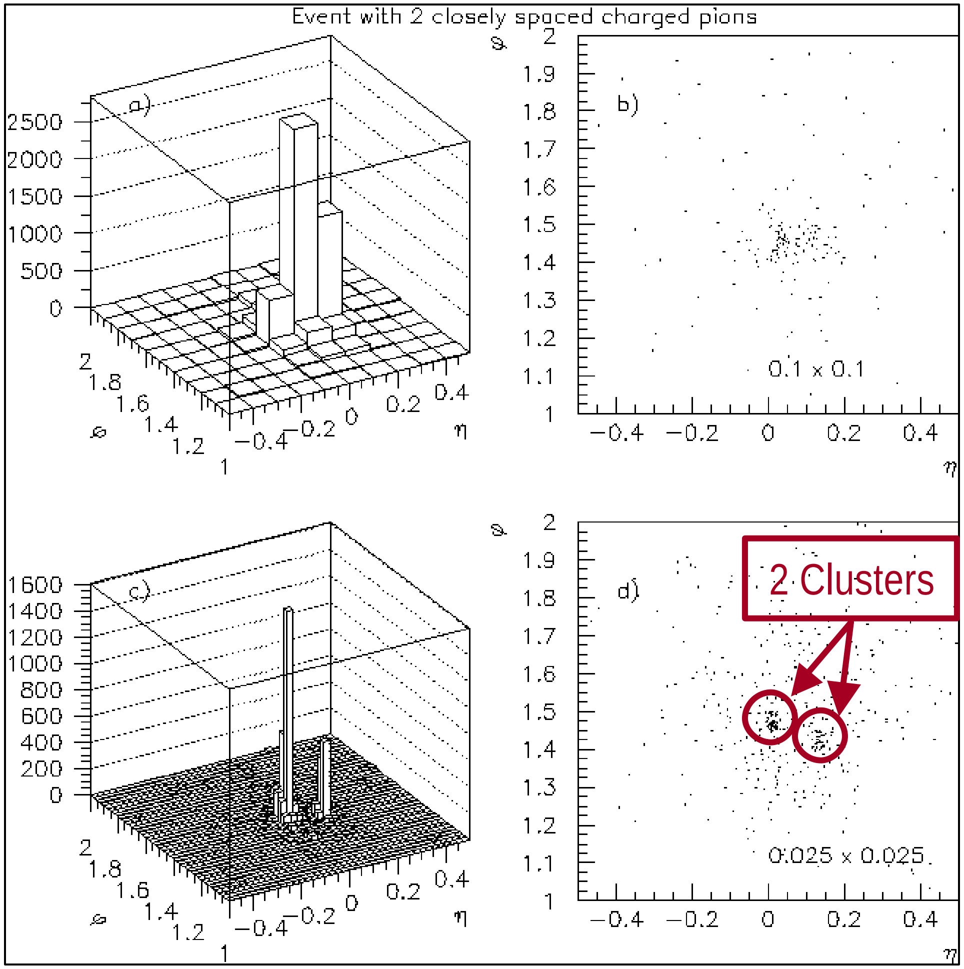




Number of cells above the threshold ("hit") is proportional to the energy deposit

- Linearity is crucial to good jet energy resolution
- Finer Segmentation provides better linearity

Resolving Power



- Essential to resolve and associate clusters with charge particles for effective removal and replacement of the clusters energies
- Finer segmentation provides higher resolving power
- Tracking for muons
- Look for late decays

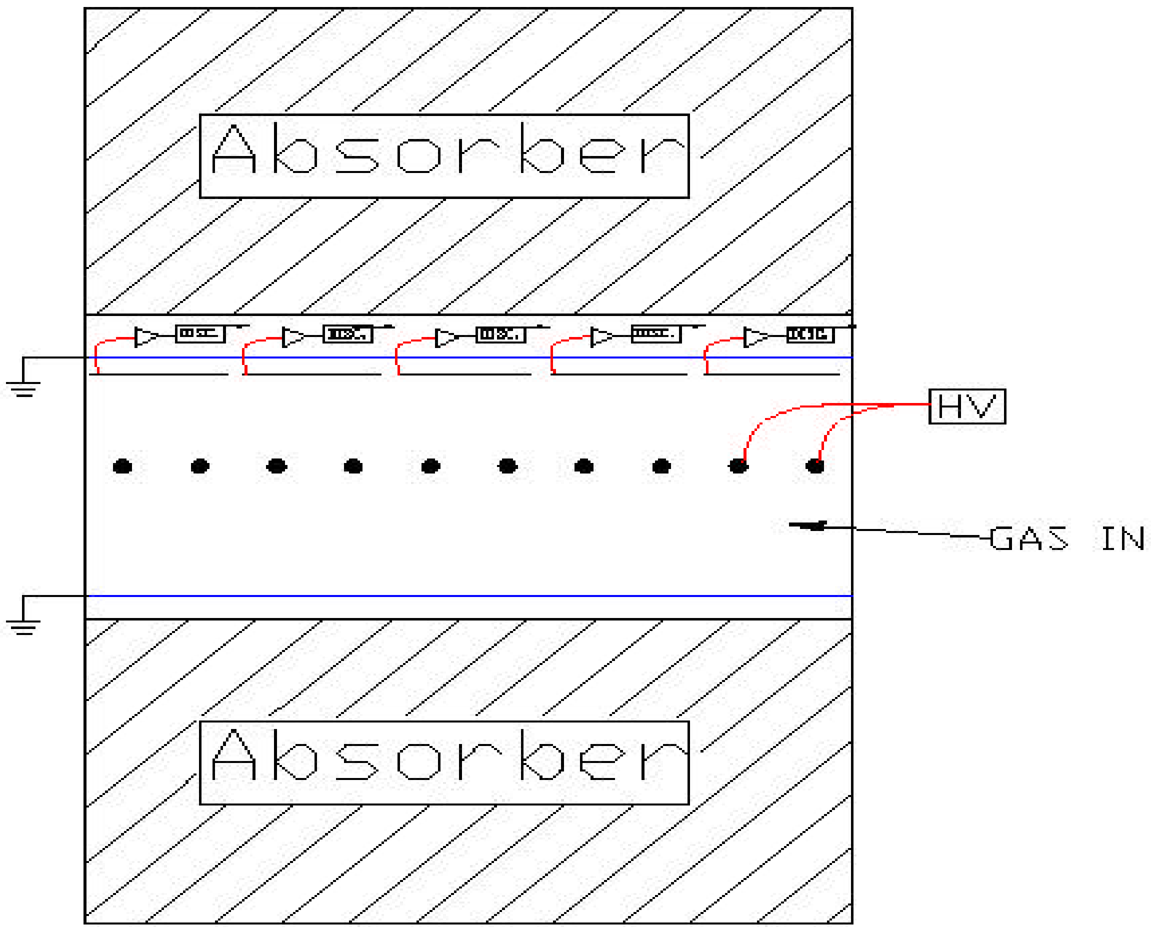
Issues for R&D

- Adequate Technology
  - Charge collection devices - High precision tracking
  - Light collection devices - Scintillator based
- Optimal Cell Sizes/Segmentation
  - Response linearity
  - Resolving power
- Optimal sampling weights (absorber thickness)
  - To minimize shower overlap
- Reduction of dead materials
  - Mechanical support structure
  - Readout routing scheme
  - HV and LV feed
- Optimal threshold
  - Reduce noisy "hits", yet Retain MIP recognition
- Algorithms for calorimeter tracking

R&D Plans

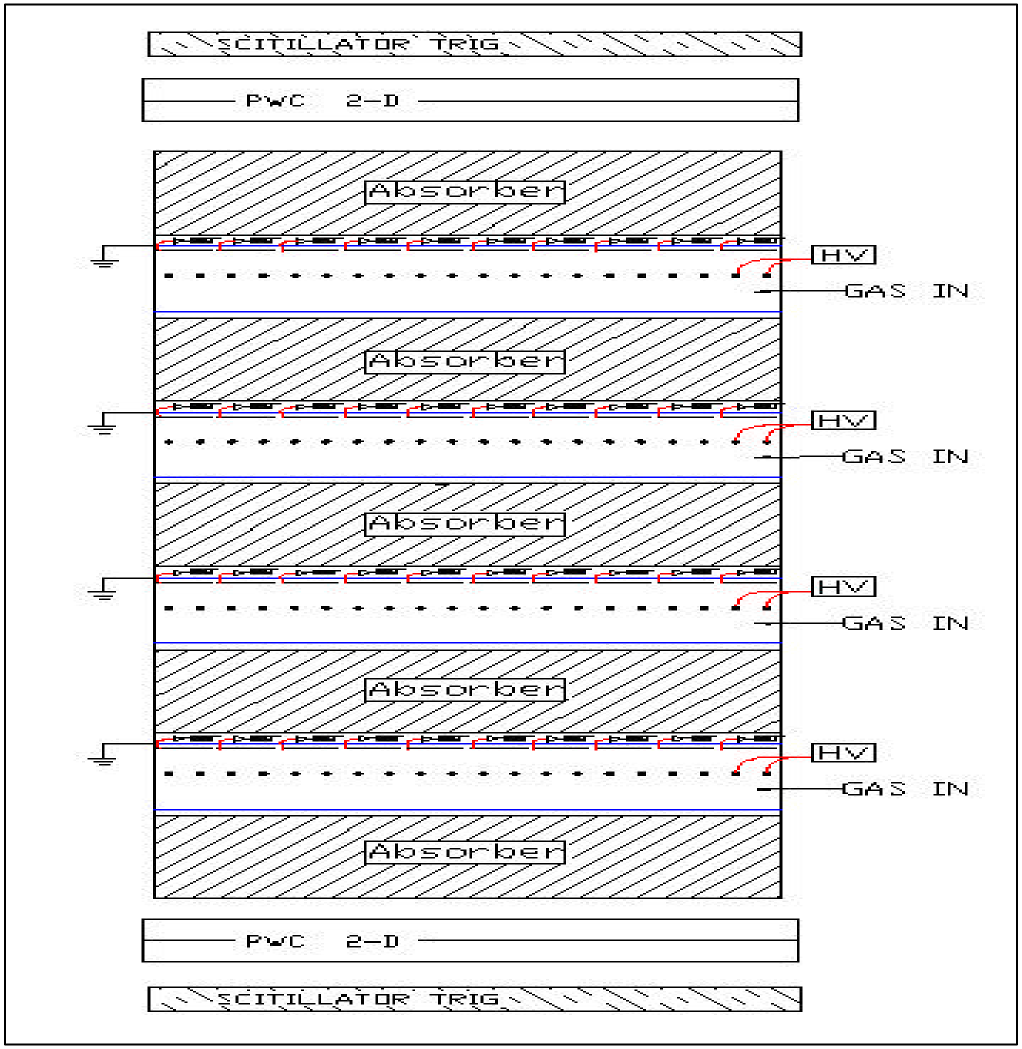
- Collaborating with NICADD/ NIU team
- Set up Geant level Simulation package
- UTA investigates viable charge collection devices:
  - Muti-wire chamber (MWC) in the Proportional region
  - MWC over the proportional region
  - Resistive plate chambers (RPC's)
  - Microstrip gas chambers (MSGC's)
  - Etc
- Develop calorimeter tracking algorithm
- Build mechanical prototypes
  - To investigate minimization of dead material
  - For HV, LV, and Readout routing

Single Layer Operating Protypes



- Choose one or more viable options
- Gas mixture
- HV operation
- Signal characteristics
- Cross-talk
- Hit efficiencies
- MiP recognition and threshold

Multi-layer Prototype



- Choose one good technology
- Use scintillation counters for trigger
- Use old PWC's to provide control tracking
- Exercise DAQ system and readout
- Accumulate and use the data for tracking algorithm development

ADR Funding Year Schedule

Tasks	Duration	Dates
Set up Simulation Software	1-2 months	May, 2002, - July, 2002
Simulation Data Production	4-6 months	July, 2002 – Jan., 2003
Understanding Energy Resolution		
Development of analysis tools and of Calorimeter Tracking Algorithm	9–18 months	July, 2002 – Dec., 2003
Investigation of Relative Merits of Charge Collection Technologies	6 months	July, 2002 – Jan., 2003
Construction of a Unit Layer Mechanical Prototype and Understand Various Design Considerations	3 - 6 months	Sep. 2002 – Jan, 2003
Construction of a Working Unit Layer Prototype and Understand HV, LV, Gas, Signal Readout, and Other Design issues	6 months	Nov., 2002 – May, 2003
Construction, testing, and evaluation of a Multiple Layer prototype	6-18 months	May, 2003 on

UTA Resources & Funding Request

- Large scale MC computing farm
- Departmental machine-shop personnel and time
- HEP Machine-shop
- Manpower for design and computing
- Need 0.5 RA to take a full responsibility on
  - Leading the effort
  - Developing testing and evaluation mechanism
  - Developing software tools and algorithms
- Requested a total funding of ~$65k for the first year

Conclusions

- Future physics goals demands higher jet energy resolution calorimetry
- Energy Flow method supplemented with digital calorimetry is a viable solution
- A good project for strategic preparation of the future of the group
- The software (MC and tracking algorithm) will be beneficial to other future projects
- This first year will provide a firm foundation for further studies to develop the DHC technology
- LC calorimeter group is very supportive on this initiative
- We believe this study will be fruitful for the future