Digital Hadron Calorimetry with glass RPC active detectors

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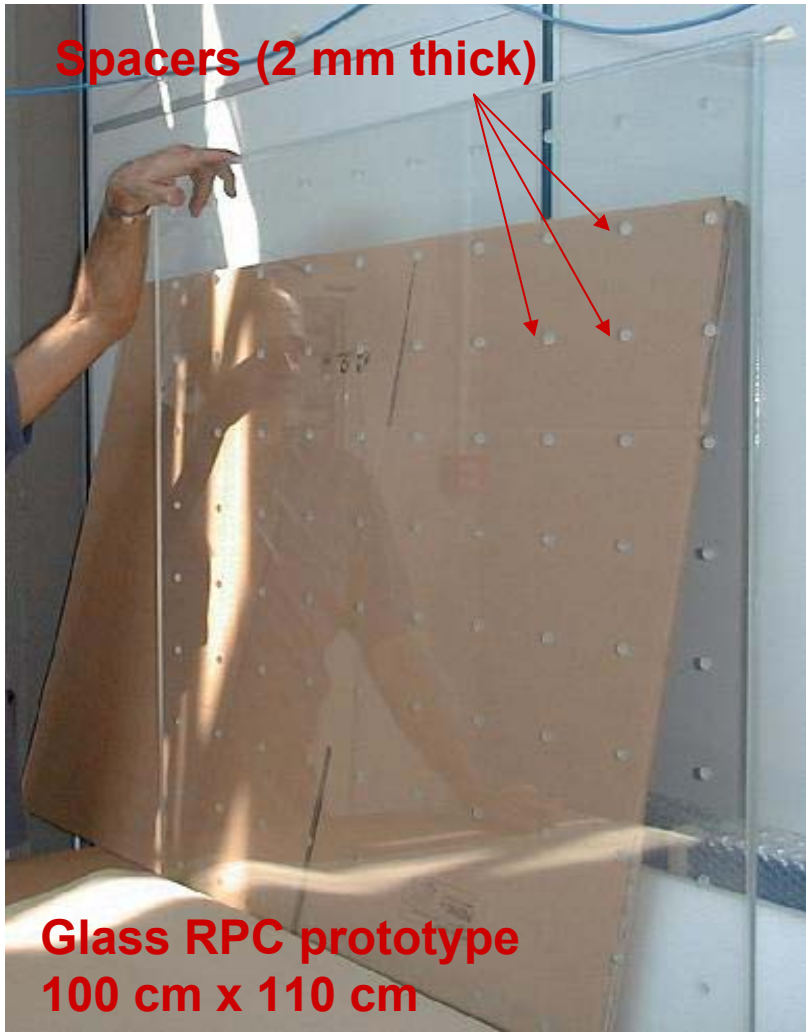
Outline:

- R&D on glass RPC detectors for the ILC
- DHCAL simulation with RPC detectors
- Outlook and Conclusions

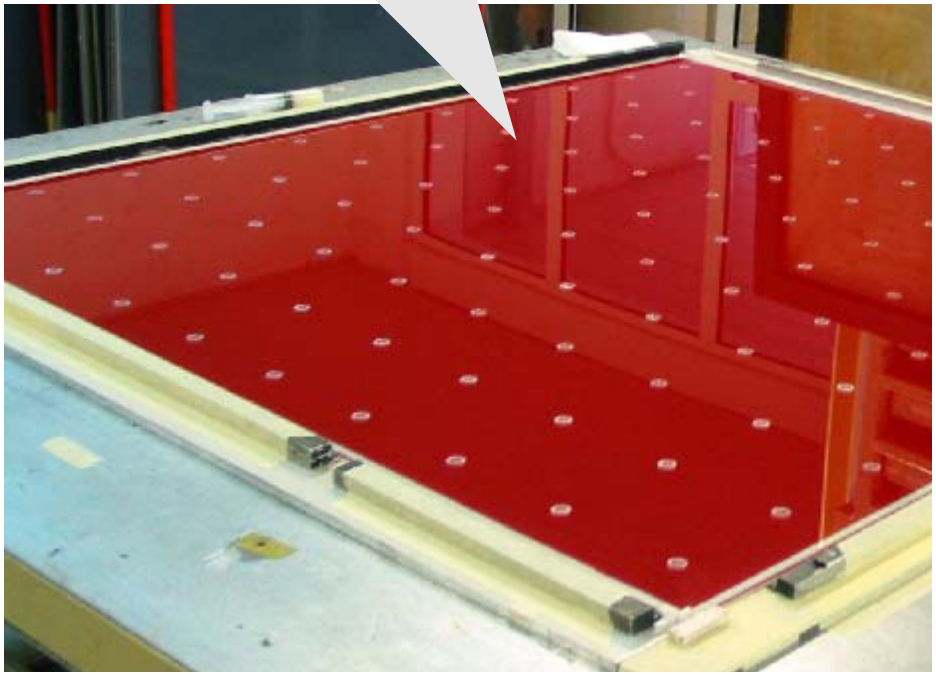
Glass RPC prototypes



- RPC prototypes [1]
  - 100 cm x 110 cm surface
  - 2 mm gap
  - 2 x 2 mm glasses
    (ρv=3-5 x 10^{12} Ωcm @ 25 ºC)
- Rate capability in streamer mode around 1 Hz/cm^2
  - Just right for barrel DHCAL
  - Avalanche mode under study to extend the rate capability (up to 10 Hz/cm^2 in the endcaps)

[1] CaPiRe Collaboration:
T.T.F's talk at LCWS04,
M.Piccolo's talk at LCWS05

Silk Screen Printing

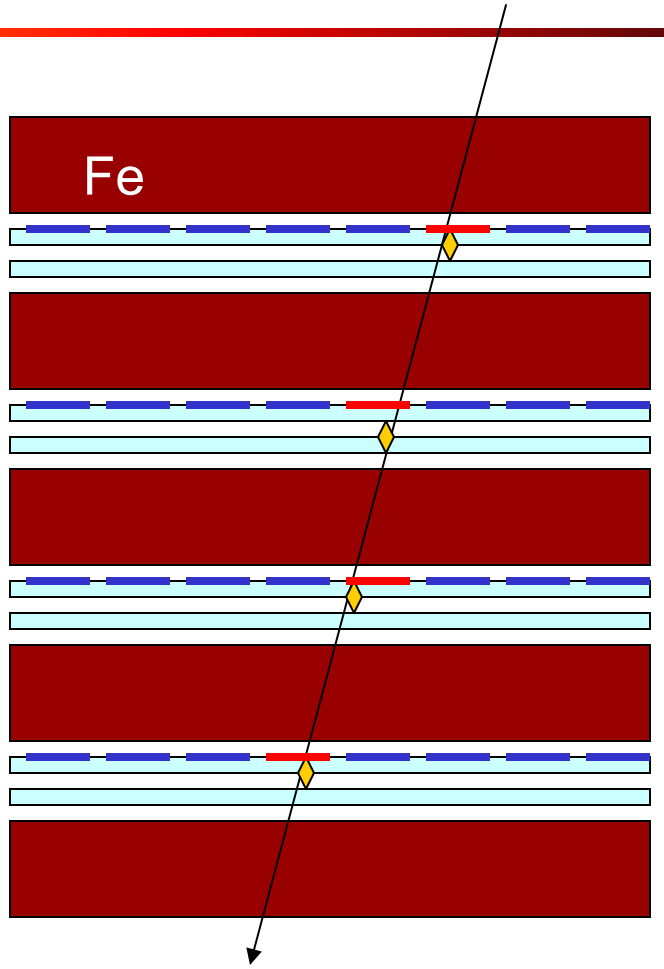


- Technique for electrical contacts deposition derived from automotive industry [2]
- Prove to be fast and reliable
  - Up to 1000 m^2 /day
  - Reproducible
- Can be exploited for readout pad deposition directly on the glass surface

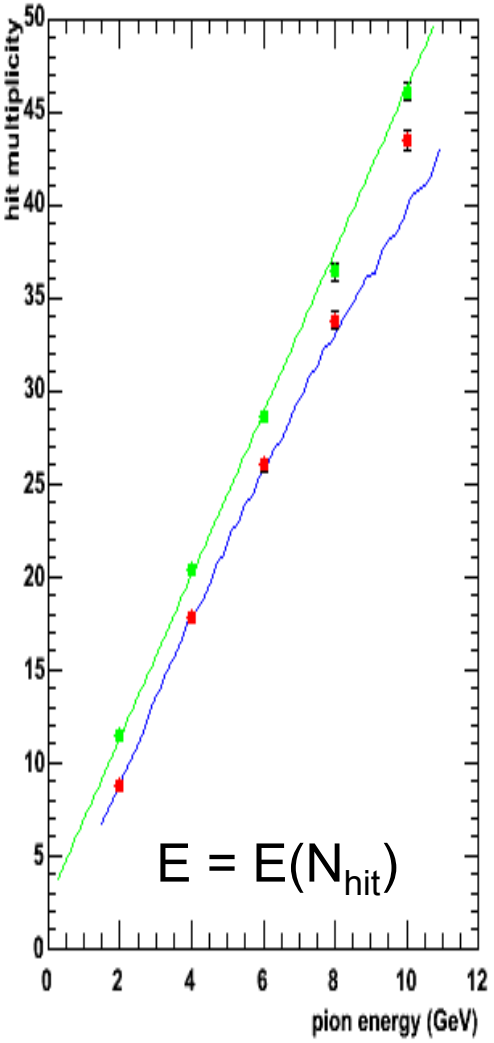
[2] G.C. Trinchero, A. Giuliano, P.Picchi, Nucl. Instr. and Meth. A 508 (2003) 102
M. Ambrosio et al. Nucl. Instr. and Meth. A 508 (2003) 98.

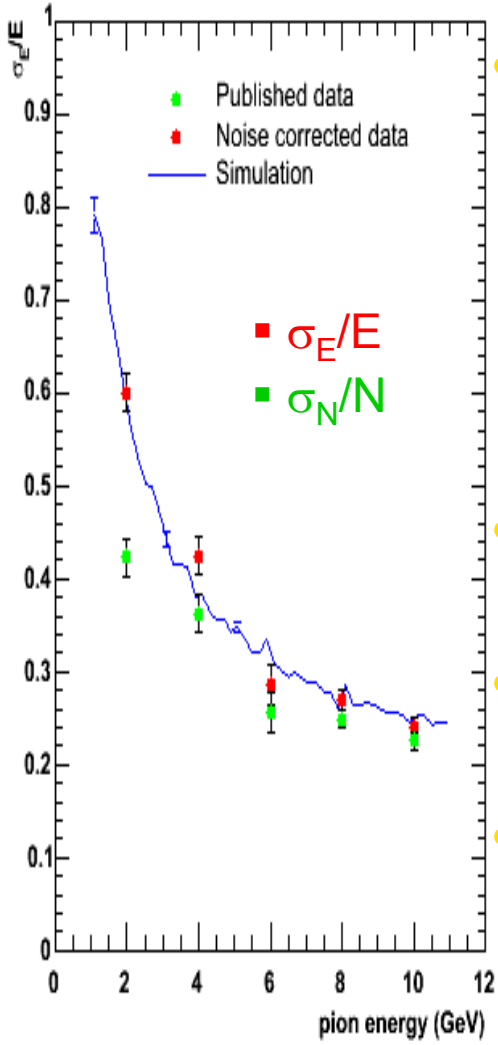
DHCAL simulation

- Geant3 based simulation
  - 38 x 2 cm iron layers
  - 1 cm gaps for RPC detectors
    - 2 x 2 mm glasses
    - 2 mm gas gap
    - 2 x 2 mm free for cabling
  - Non pointing geometry
- Elementary streamers generated on a 2x2 mm^2 grid (with 93% efficiency)
- Signals induced only on the facing pad (no induction on nearby pads)



Validation of the simulation

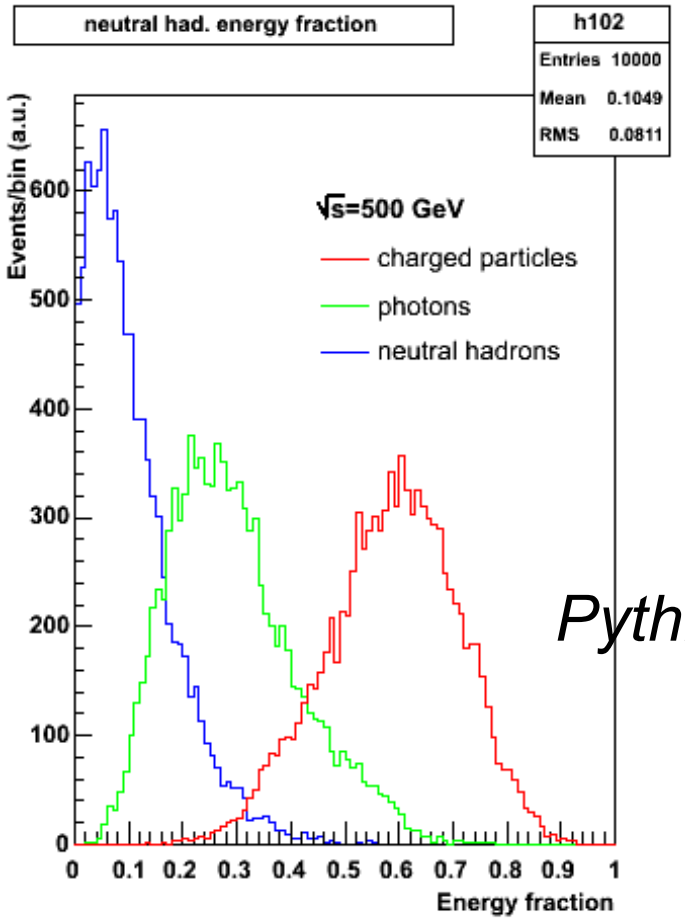


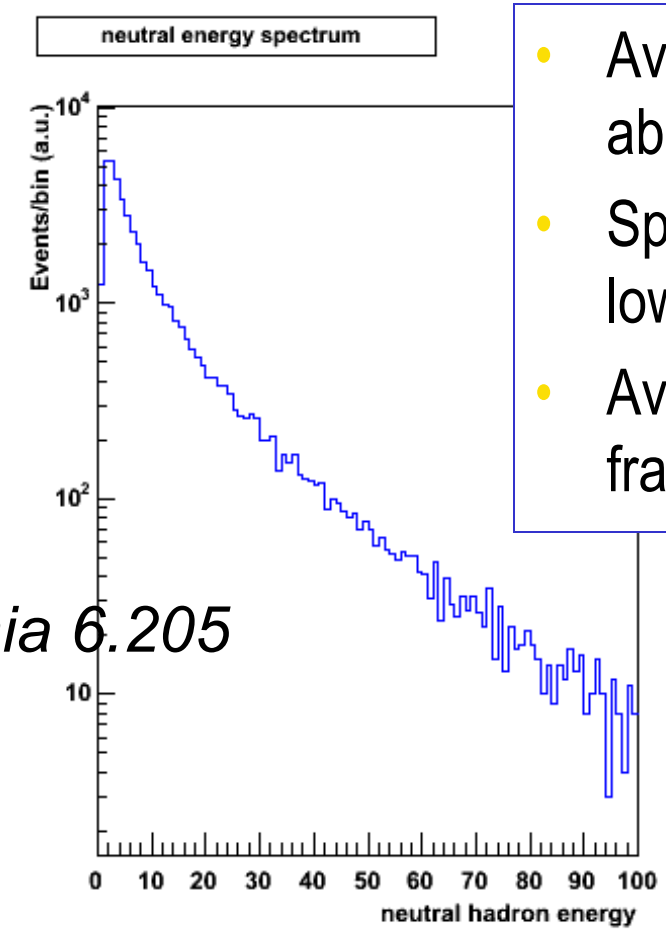


- Single pion data collected with the "Monolith prototype" [3]
  - 20 x 5 cm iron layers
  - 2 cm gaps for glass RPC
  - 1 cm pitch readout strips wide in one view
- Published data uncorrected for noise offset
- Simulation hit multiplicity calibrated on muon data
- Simulation fairly agrees with data after noise subtraction

[3] C. Gustavino et al., NIM A 456 (2000) 67

Neutral hadrons at the ILC





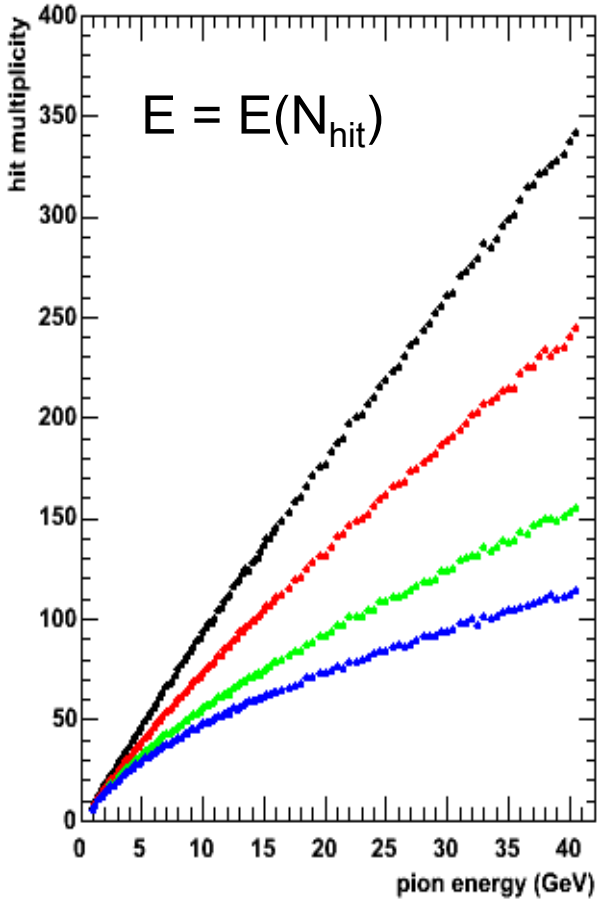
- Average energy about 11 GeV
- Spectrum peaked at low energies
- Average energy fraction about 10%

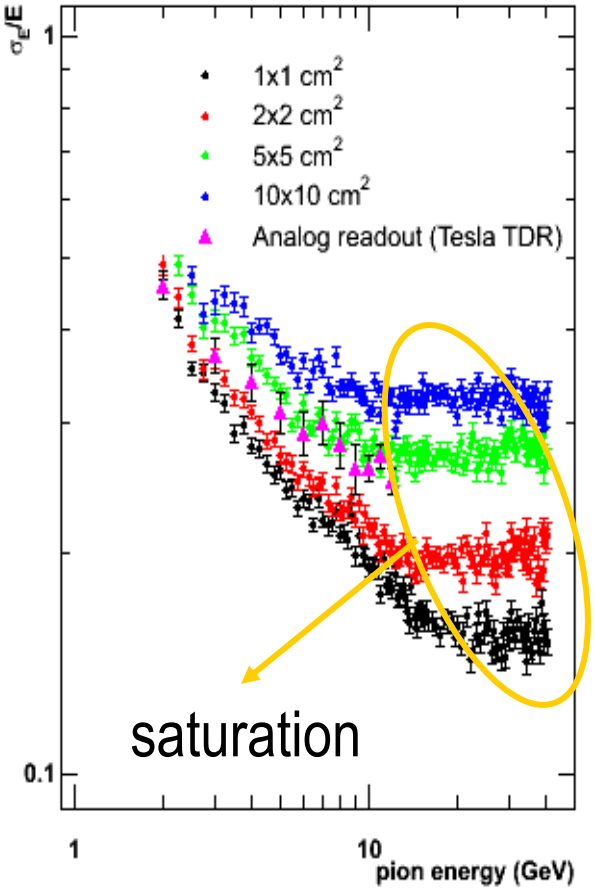
Pythia 6.205

Validation in the most relevant energy range

DHCAL with RPC detectors

Single hadrons at normal incidence



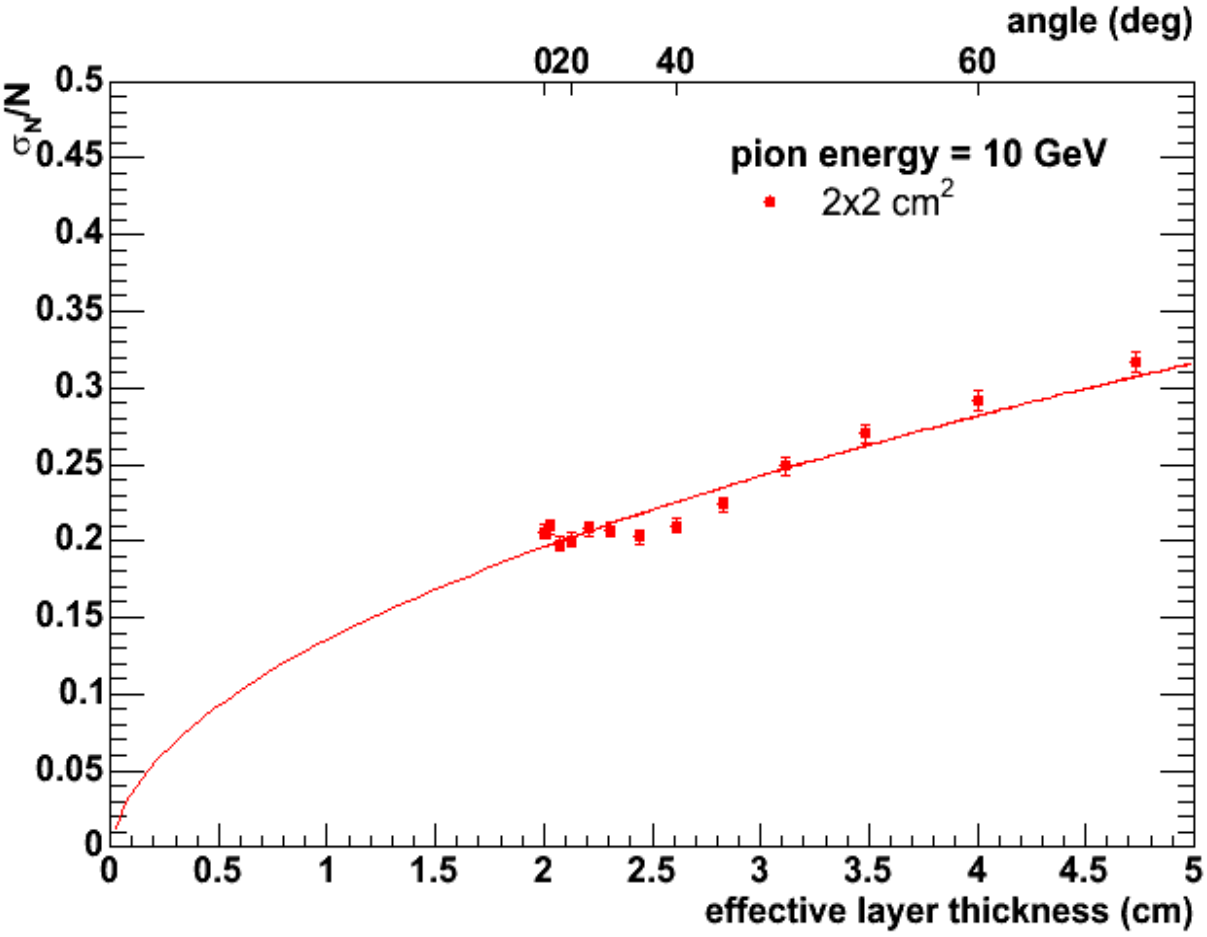


- For small pad sizes better than analog calorimetry
- Agreement with earlier works [4]

- ≈ 55%/√E ⊕ 16%
- ≈ 53%/√E ⊕ 10%

[4] V.Ammosov, NIM A 493 (2002) 355

Angular dependence



- Pions at different incidence angles
- Resolution scales with $\sqrt{d} / \cos\theta$
- Effect of the non pointing geometry (variation of the sampling fraction)

Fast simulation for jet energy resolution

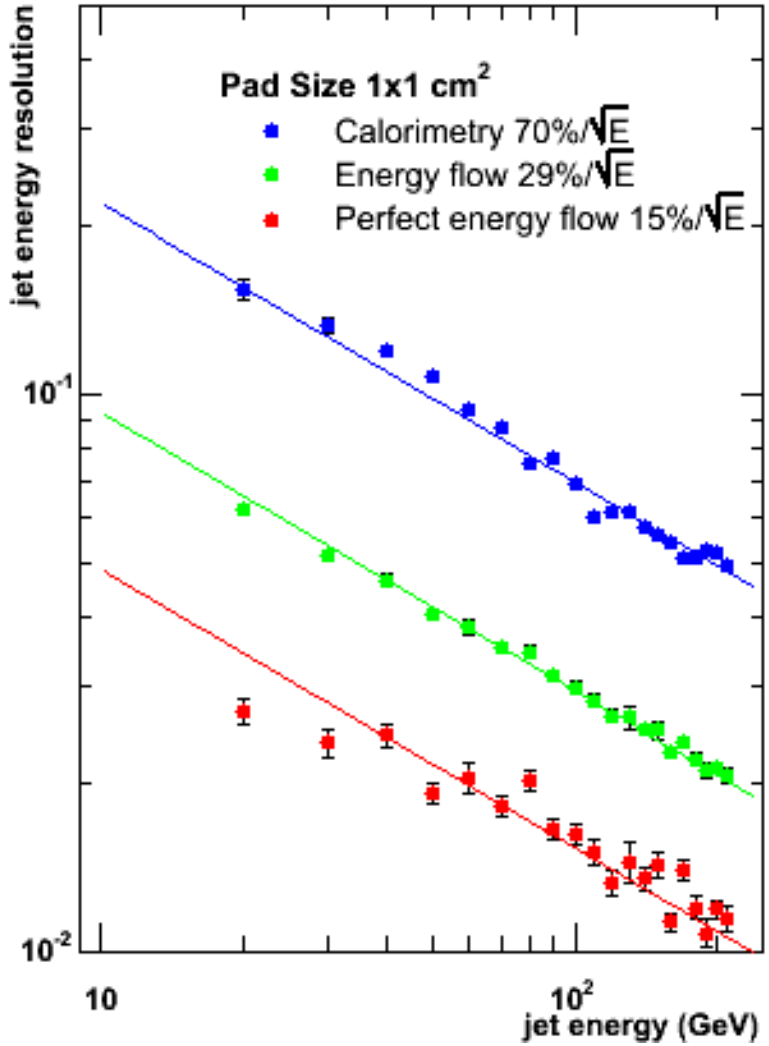
- Use ZZ and WW events from PYTHIA standalone
  - Photon energy smeared according to $\sigma_E/E = 15\%/\sqrt{E}$
  - Neutral hadron energy smeared according to the DHCAL simulation (including angular dependence)
  - For charged particles:
    - Assume perfect momentum resolution → Energy flow
    - Smear energy according to the calorimeter response → Calorimetry
- Jets clusterization with standard *LUCLUS* algorithm
- Check resolution for
  - Calorimetry
  - Perfect energy flow
  - Energy flow with $\sigma_{confusion} = 25\%/\sqrt{E}$

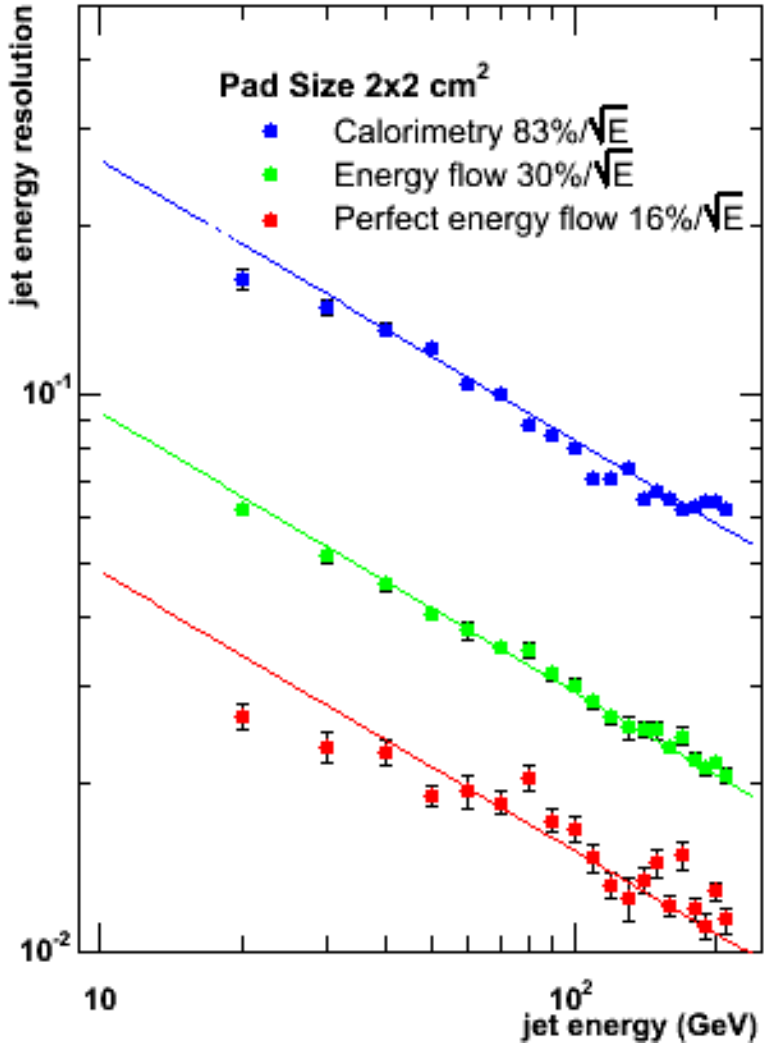
Pessimistic assumption for 1x1 cm^2 and 2x2 cm^2 pad sizes

(estimated for 5x5 cm^2 analog readout towers [5])

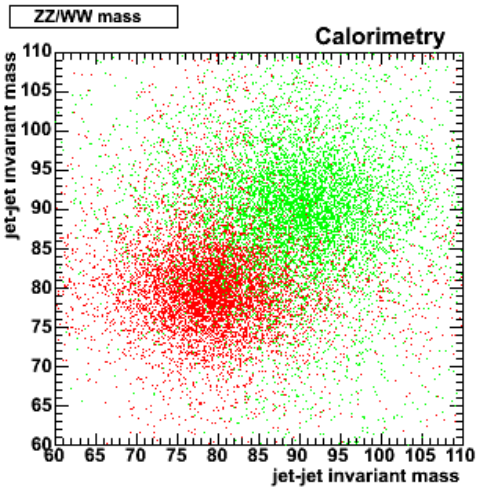
[5] D. Karlen, LCWS03, Conf. Proc.

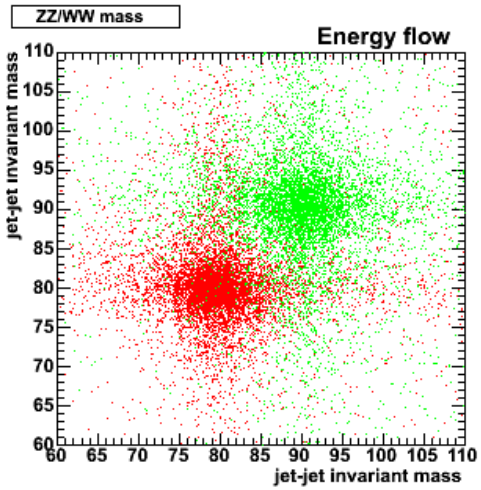
Jet energy resolution

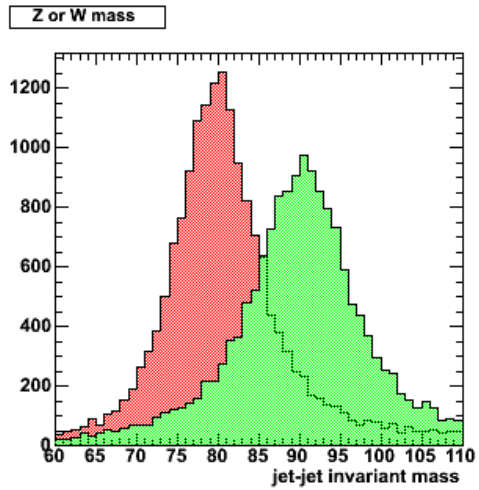


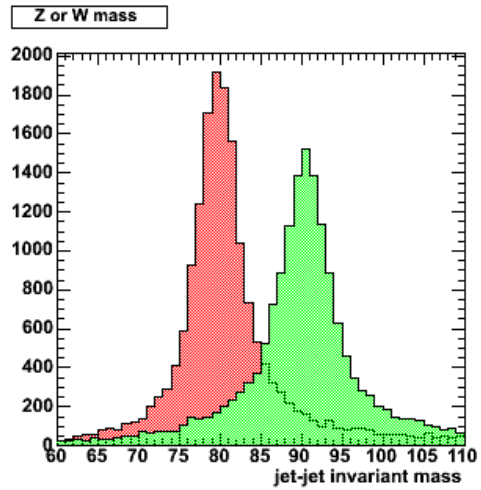


WW/ZZ separation









- Events forced to 4-jet topology
- Best pairing of jets chosen according to consistency to WW and ZZ mass hypotheses
- Jet energy and directions from the fast simulation

  (No constraints on the energy and momentum conservation in the event)

Conclusions and Outlook

- Glass RPC detectors with silk screen printed electrodes are attractive candidates as active detectors of the Digital Hadron Calorimeter at the ILC
- A standalone simulation of the DHCAL response with RPC response has been developed and validated on existing data
- A fast (parametric) simulation shows that the DHCAL with RPC detectors matches the target performance for the ILC physics
- Further studies should address
  - The full simulation within the ILC detector
  - The contribution of DHCAL to the muon identification