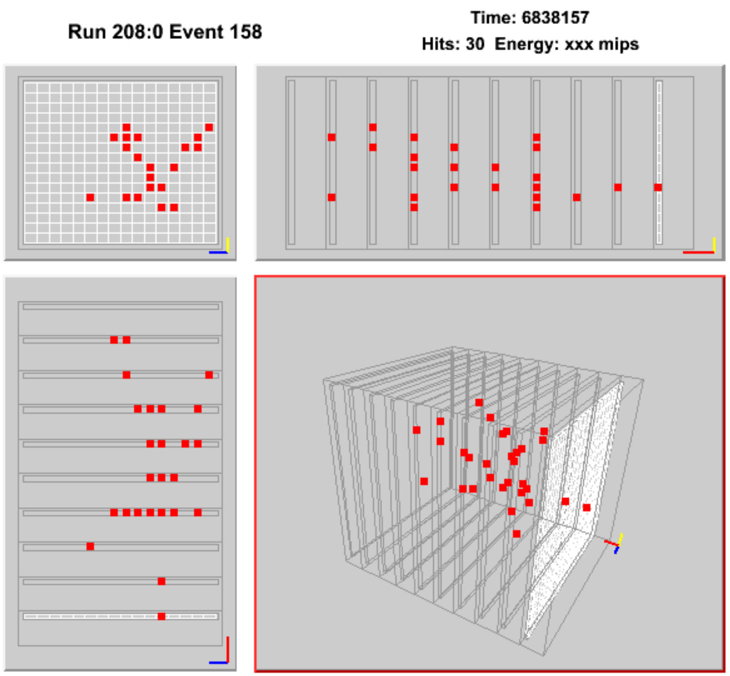
Analysis of DHCAL Data



José Repond
Argonne National Laboratory

CALICE Meeting, September 16 – 18, 2009
Université Claude Bernard Lyon I, France

Overview

I Resistive Plate Chambers for Hadron Calorimetry: Tests with analog Readout

G. Drake et al., Nucl. Instr. Meth. A578: 88 2007

(A new Readout System for "Digital Hadron Calorimetry" for the ILC)

J.Butler et al., Proceedings of the 2007 IEEE Nuclear Science Symposium, Honolulu, Hawaii

II Calibration of a Digital Hadron Calorimeter with Muons

B.Bilki et al., JINST 3:P05001, 2008

III Measurement of Postron Showers with a Digital Hadron Calorimeter

B.Bilki et al., JINST 4:P04006, 2009

IV Measurement of the Rate Capability of Resistive Plate Chambers

B.Bilki et al., JINST 4:P06003, 2009

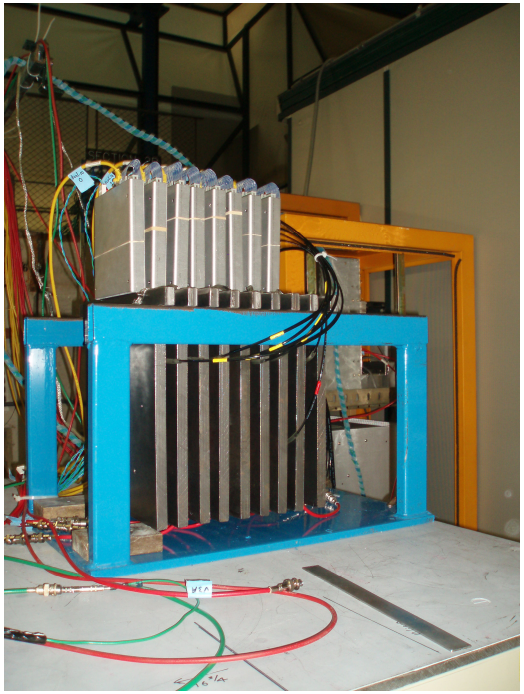
V Hadron Showers in a Digital Hadron Calorimeter

B.Bilki et al., submitted to JINST on August 28, 2009, ArXiv:0908.4236

VI Environmental Dependence of the Performance of Resistive Plate Chambers

Paper draft exists…

Reminder: Vertical Slice Test



Test of whole system with

Up to 10 RPCs, each 20 x 20 cm^2
(Up to 2560 channels)

RPCs

Up to 9 2-glass designs
1 1-glass design
Only use RPC0 – RPC5 in analysis of e^+, π^+
Only use RPC0 – RPC3 for rate dependence

Absorber

For cosmic rays, muon, pions, electrons: Steel (16 mm) + Copper (4 mm)
Rate capability measurement (120 GeV protons): 16 mm PVC with whole cut out in center

Test beam

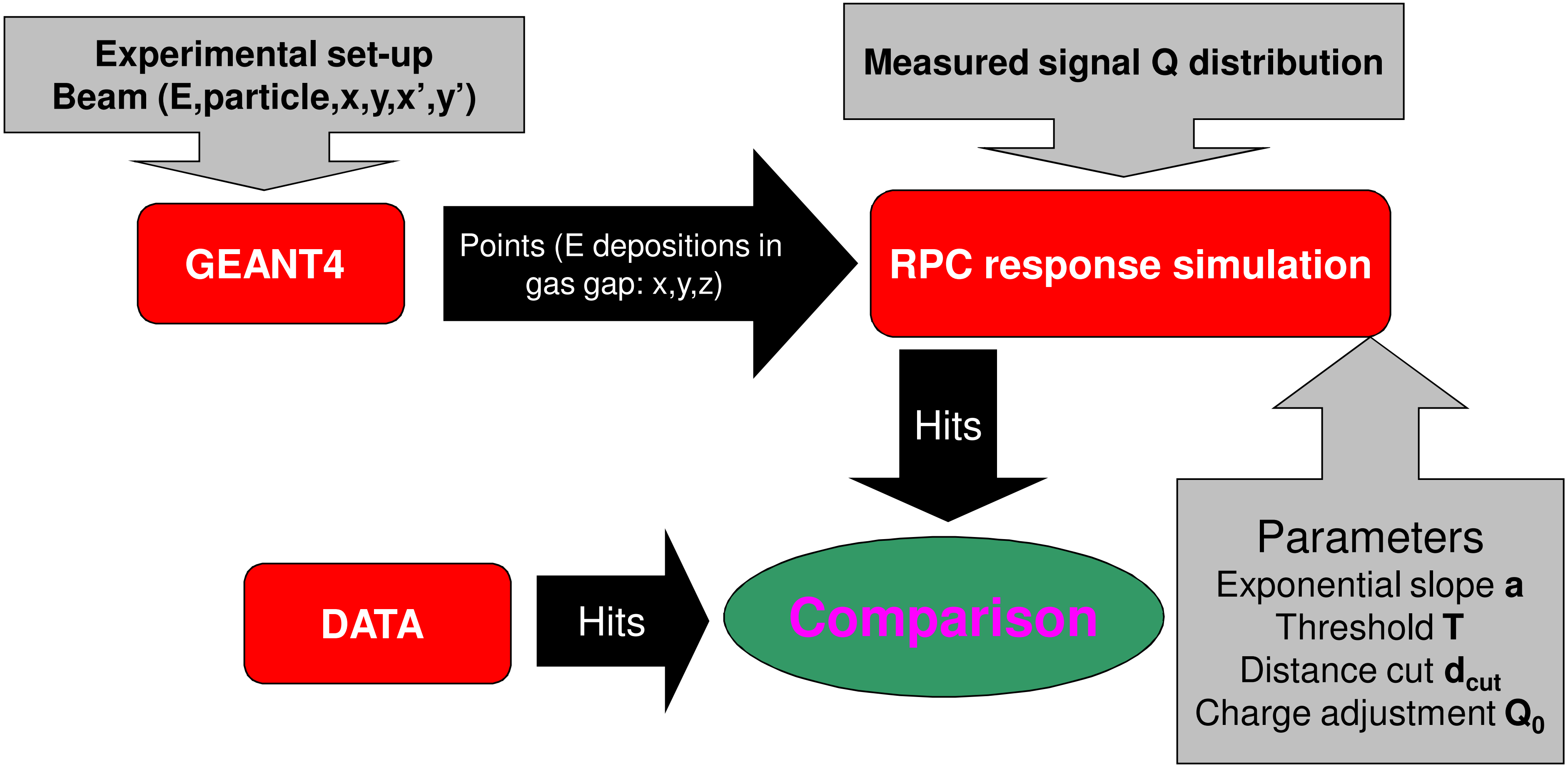
Collected data in Fermilab's MT6 beam line
Used
- Primary beam (120 GeV protons) with beam blocker for muons
- Primary beam without beam blocker for rate measurements
- Secondary beam for positrons and pions at 1,2,4,8, and 16 GeV/c

Cosmic Rays

Collected data for ~18 months

CALICE Calorimeter for ILC

Reminder: Simulation Strategy



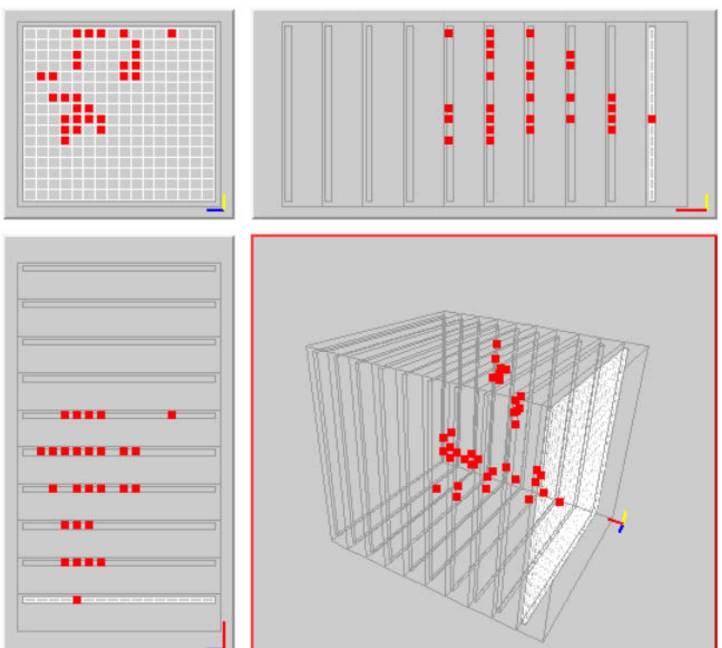
With muons – tune **a**, **T**, ($\mathbf{d_{cut}}$), and $\mathbf{Q_0}$
With positrons – tune $\mathbf{d_{cut}}$
<u>Pions – no additional tuning</u> ← **Absolute prediction**

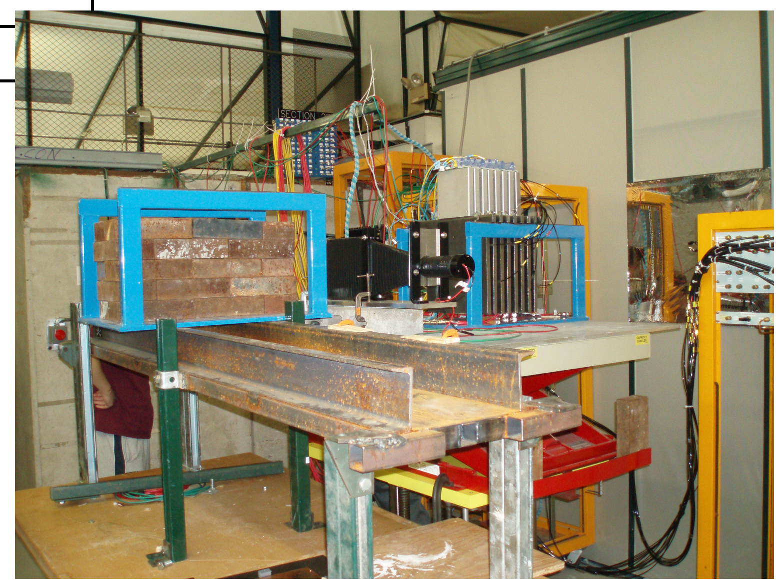
Hadron Showers in a Digital Hadron Calorimeter

Momentum [GeV/c]	**Stack of iron bricks**	**Number of events**	**Beam intensity** [Hz]	**Fraction of events without veto from the Čerenkov counters[%]**
1	No	1378	547	6.0
2	No	5642	273	5.9
	Yes	1068	80	57.3
4	No	5941	294	15.5
8	No	30657	230	24.6
16	No	29889	262	28.0

Trigger =

Coincidence of 2 scintillator paddels + veto from either Čerenkov counter





Event Selection

Requirement		Effect
At least 3 layers with hits		Rejects spurious triggers
Exactly 1 cluster in the first layer		Removed upstream showers, multiple particles
No more than 4 hits in first layer		Removed upstream showers
Fiducial cut away from edeges of readout		Better lateral containment
Second layer	At most 4 hits	**MIP selection**
	At least 5 hits	**Shower selection**

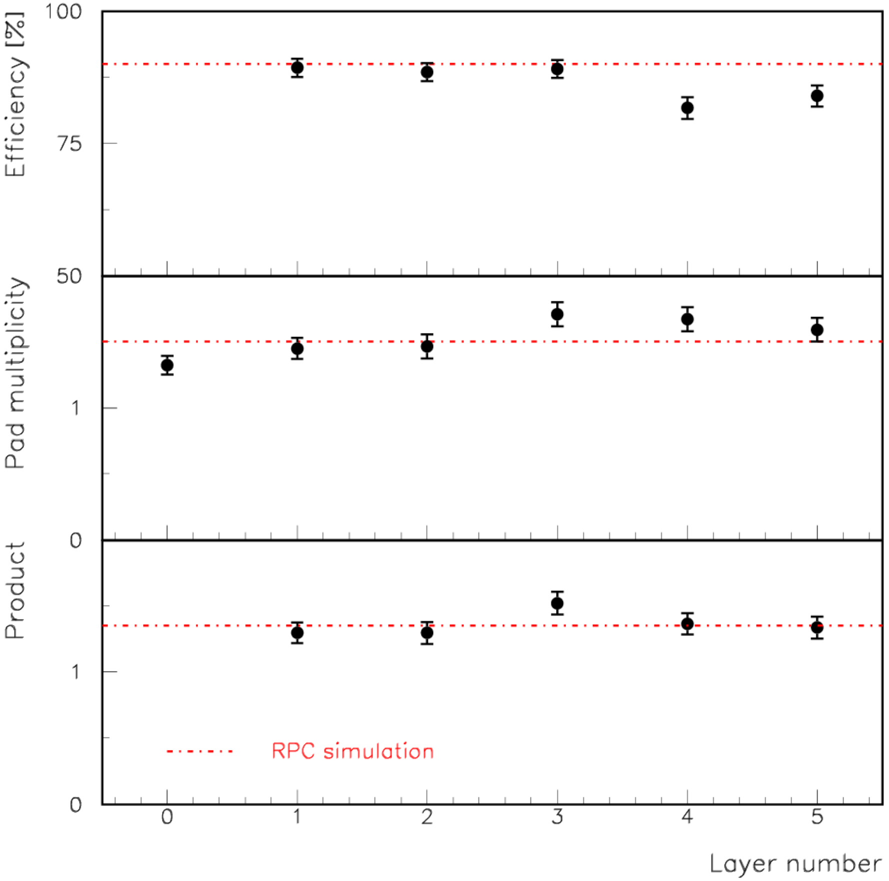
Brick data

Calibration close to expected values
→ no corrections applied

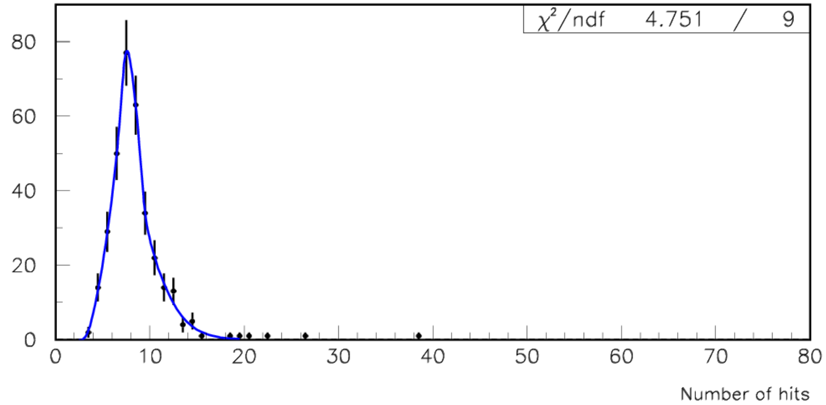
Secondary beam with +2 GeV/c selection

Fe blocks in front of RPCs

~ 50 cm deep corresponding to 3 λ_I
→ 97% of π interact
→ ΔE_μ ~ 600 MeV



Sum of hits in the DHCAL

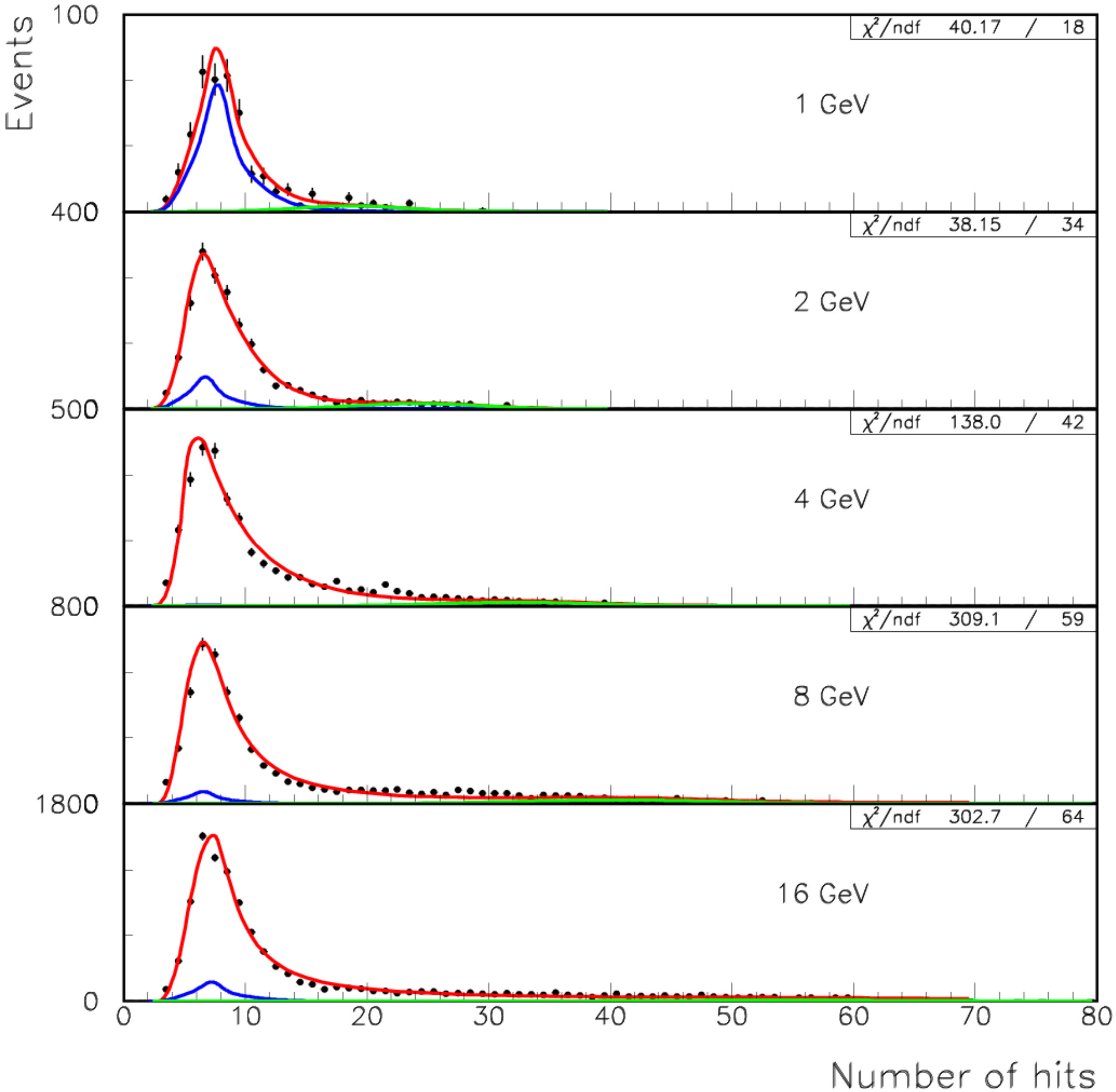


→ Emperically fit to

$$\mathbf{y} = \alpha \mathbf{e}^{-\frac{1}{2}(\frac{\mathbf{x}-\beta}{\gamma})^2} + \delta(\mathbf{x}-\mathbf{x_0})^{\epsilon}\mathbf{e}^{\phi(\mathbf{x_0}-\mathbf{x})}$$

In the following this will be our μ signal shape

MIP Selection



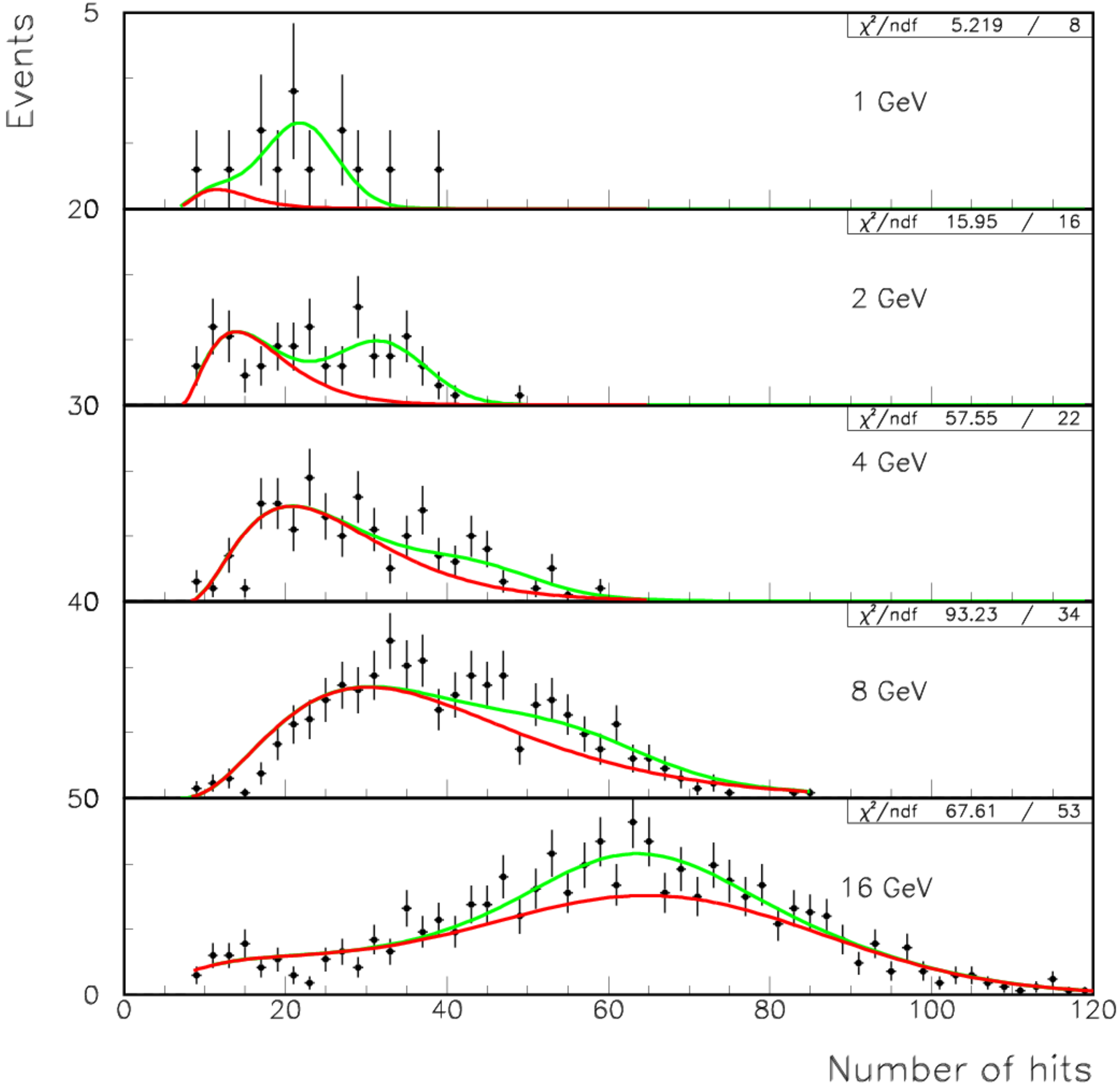
Fit to 3 components

- **Muons** (from brick data)
- **Pions** (from MC)
- **Positrons** (from MC)

(red line sum of 3 components)

MC curves = absolute predictions, apart from general scaling due to efficiency problems (rate)

Shower Selection



Fit to 2 components

- Pions (from MC)
- Positrons (from MC)

MC curves = absolute predictions, apart from general scaling due to efficiency problems (rate) at 16 GeV (-9%)

Reasonable description by simulation

Positron contamination at low energies

Not many pions at low energies

Rate problem

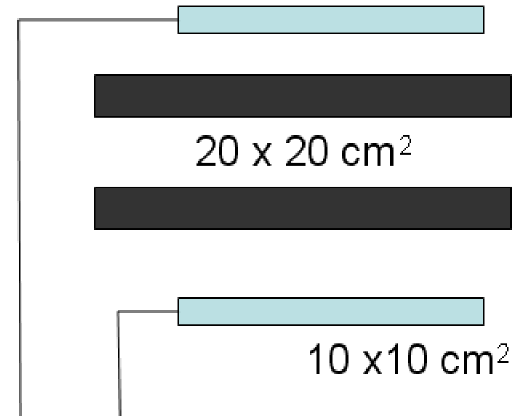
Beam intensity measured with scintillator paddles

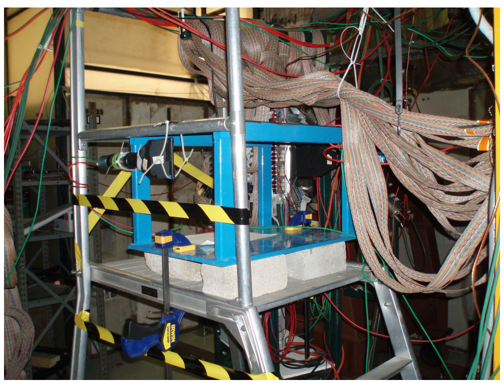
Given measured intensity did not expect a loss of efficiency

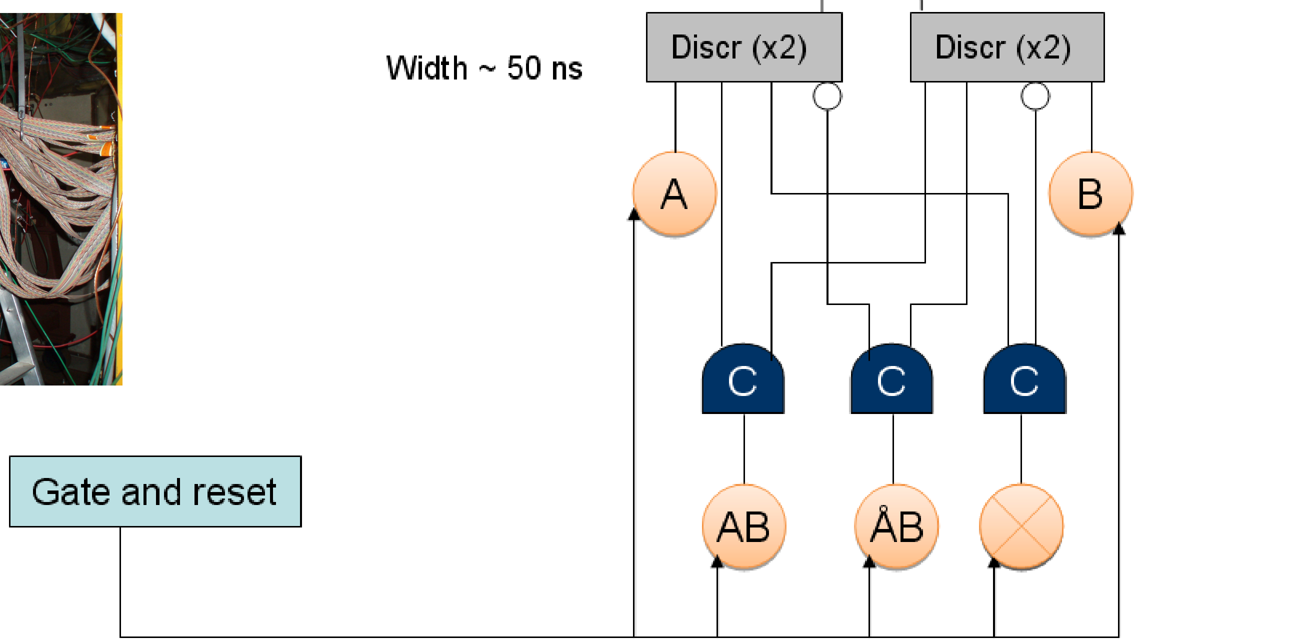
Suspect significant flux of (asynchronous) photons in beam line

Photons do not count in scintillation counters, but affect the RPCs

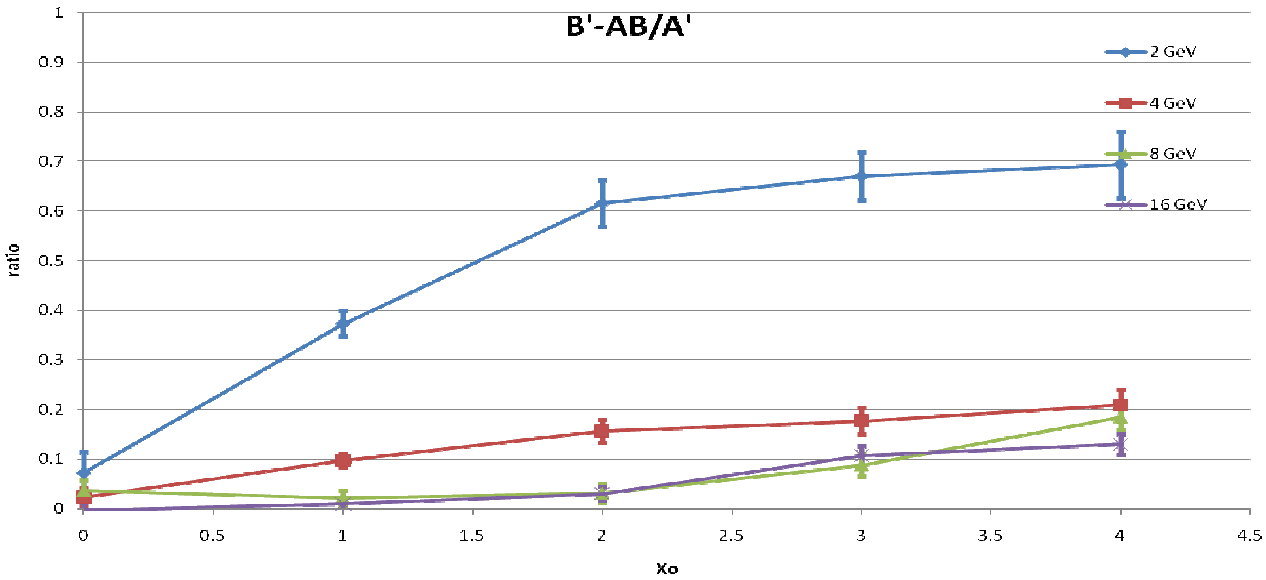
Returned to MTBF with scintillation counters and absorber plates







Evidence for Photons

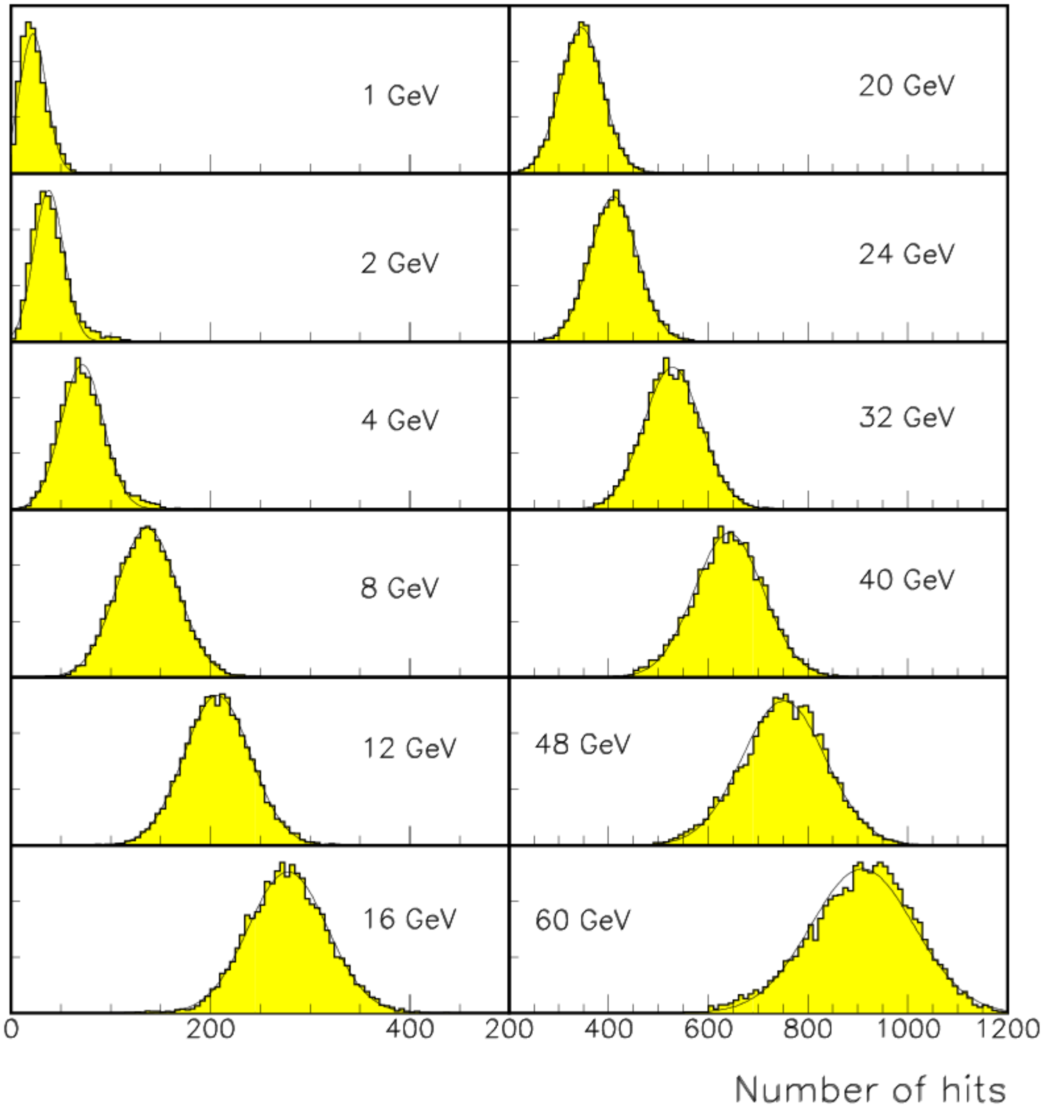


Convincing evidence for photons at 2 and 4 GeV

Will return to MTBF to measure more quantitatively

Will explore ways to reduce photon content

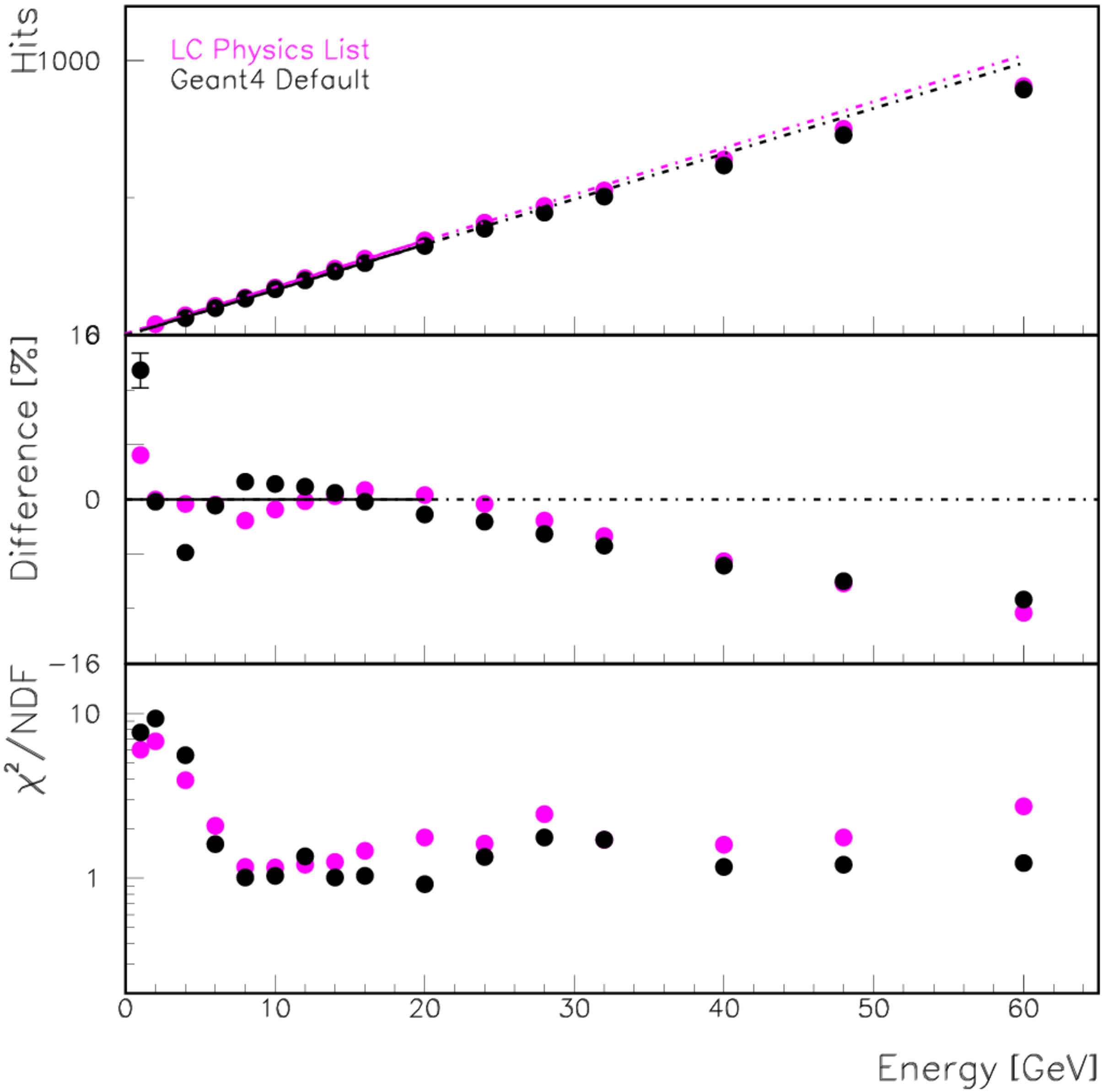
Studies of an extended RPC-based calorimeter



107 layers (minimal leakage)
Each 1.5 x 1.5 m^2

RPC performance as
for Vertical Slice Test

Response of an extended RPC-based calorimeter



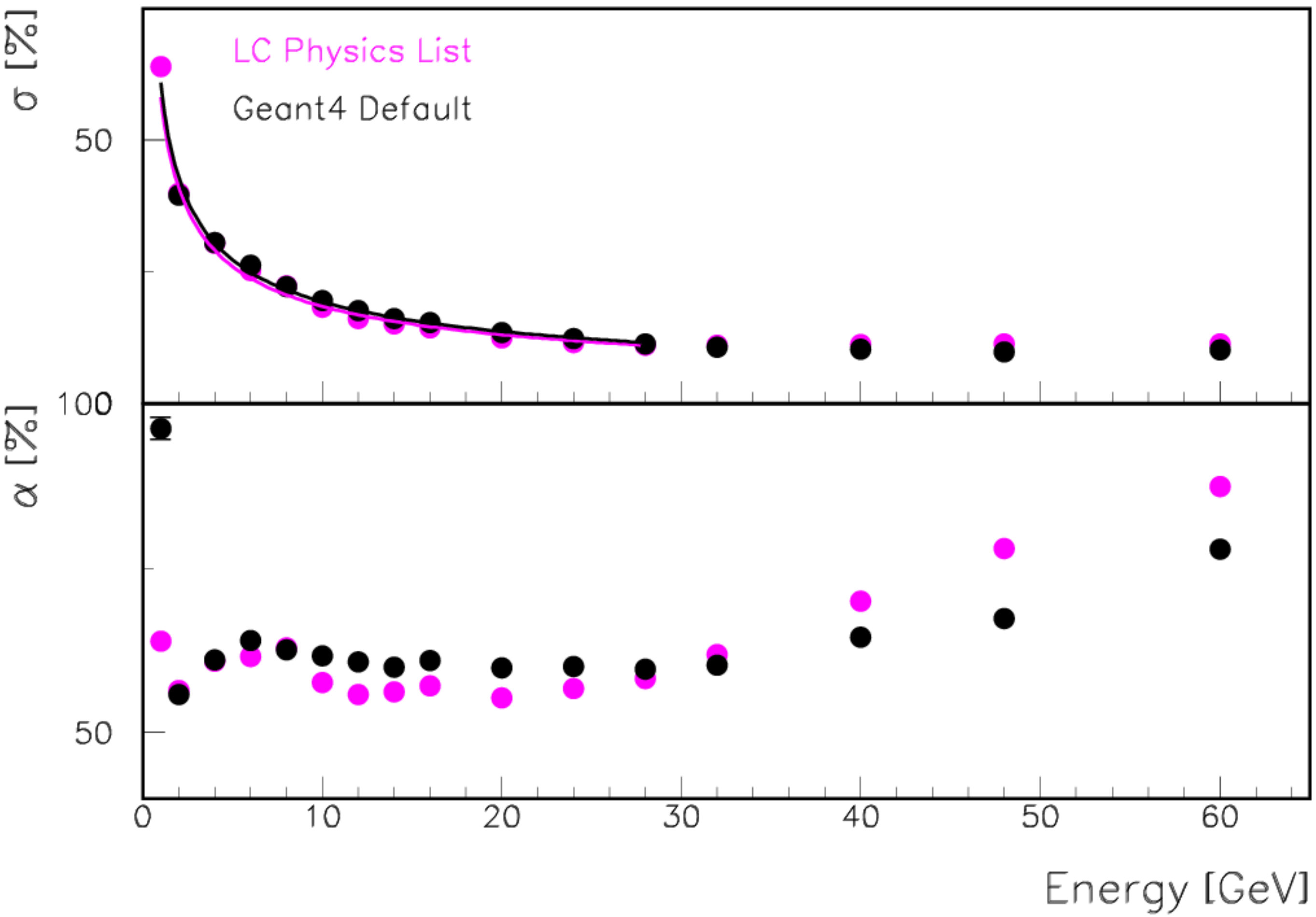
Surprisingly linear
Only -10% at 60 GeV

Distributions below 8 GeV
not really Gaussian

Discontinuity ~8 GeV for
LC physics list

Discontinuity ~4 GeV for
Fast and simple physics list

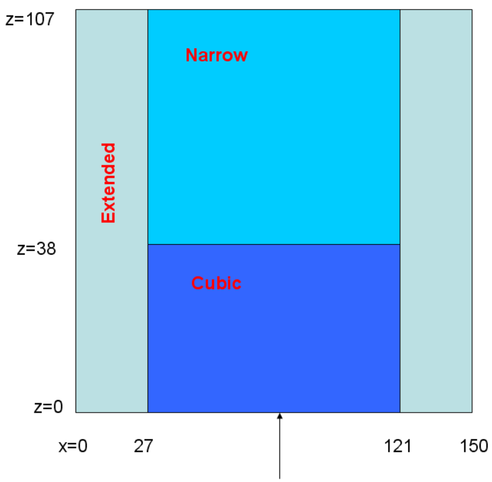
Resolution of an extended RPC-based calorimeter



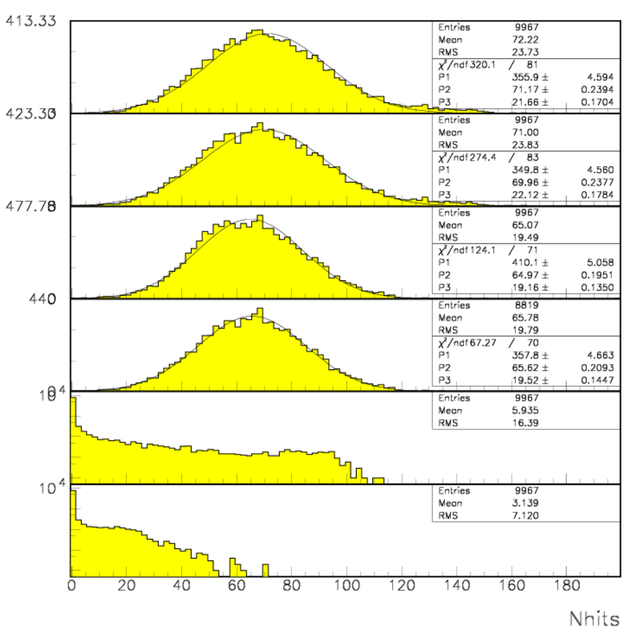
Resolution around 58%/√E up to 28 GeV

Overlap-effects degrade resolution above 28 GeV

Studies of an RPC-based calorimeter



4 GeV



Extended

Narrow

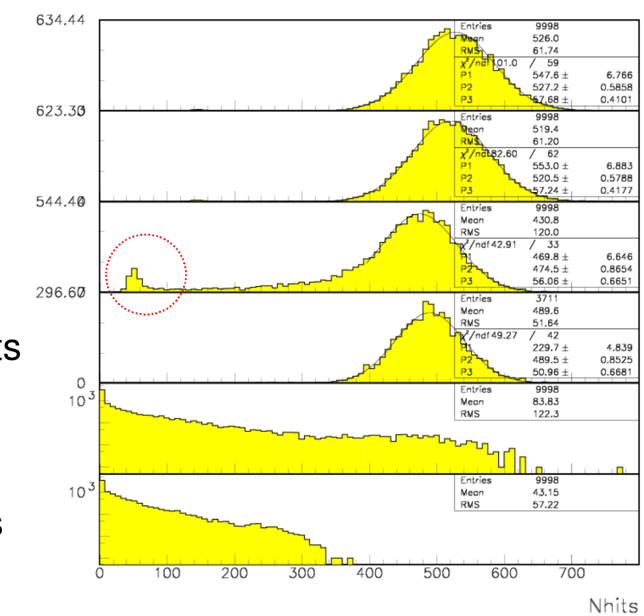
1 m^3

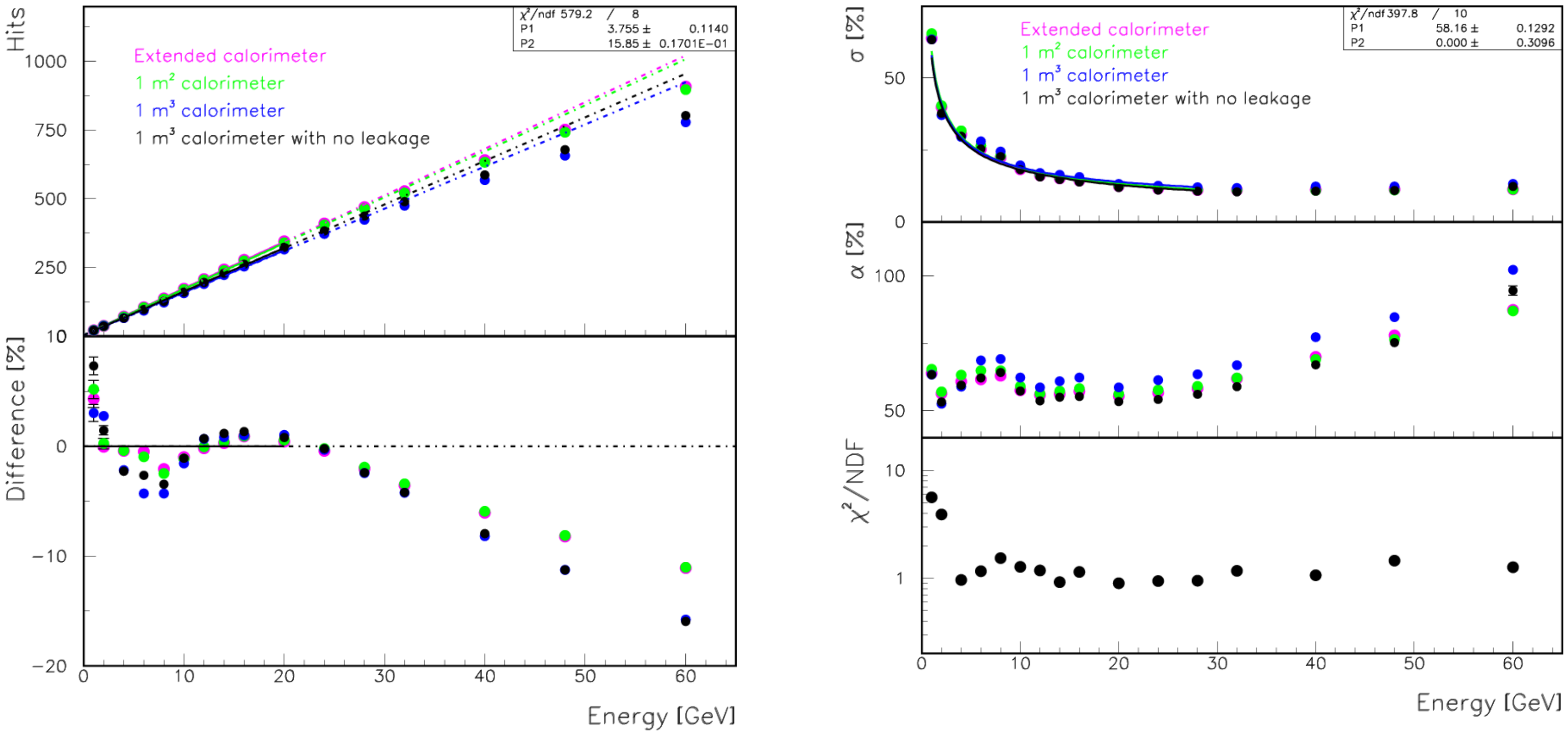
1 m^3 , TCMT <10 hits

Narrow - 1 m^3

TCMT with RPCs

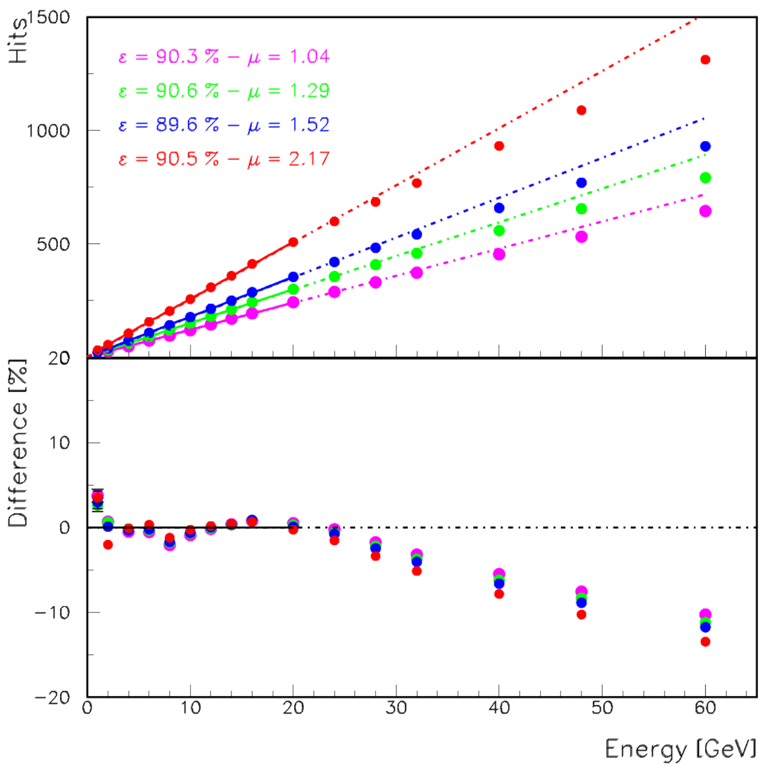
32 GeV

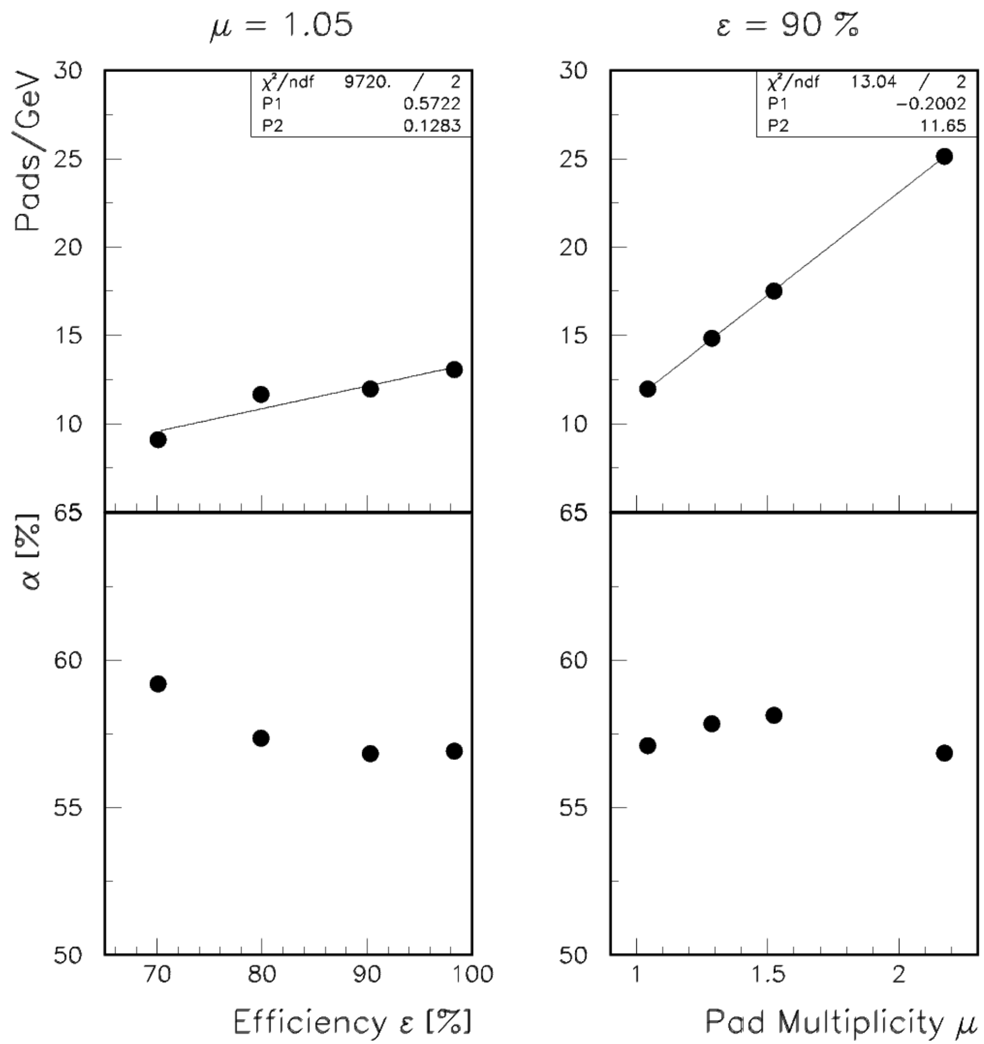




Performance of 1 m³ with leakage cuts somewhat better than extended calorimeter

Study of different extended RPC-based calorimeters





Efficiency and pad multiplicity have only minor effect on resolution

However values need to be known

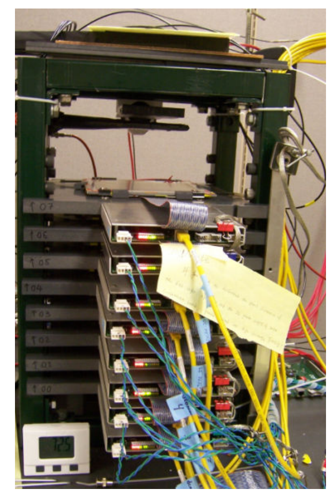
Linear corrections for ε,μ will work ($P_1 \sim 0$)

Environmental Dependence of the Performance of RPCs

Ambient temperature
Air pressure
Air humidity

↔

Noise rate
MIP detection efficiency
Pad multiplicity



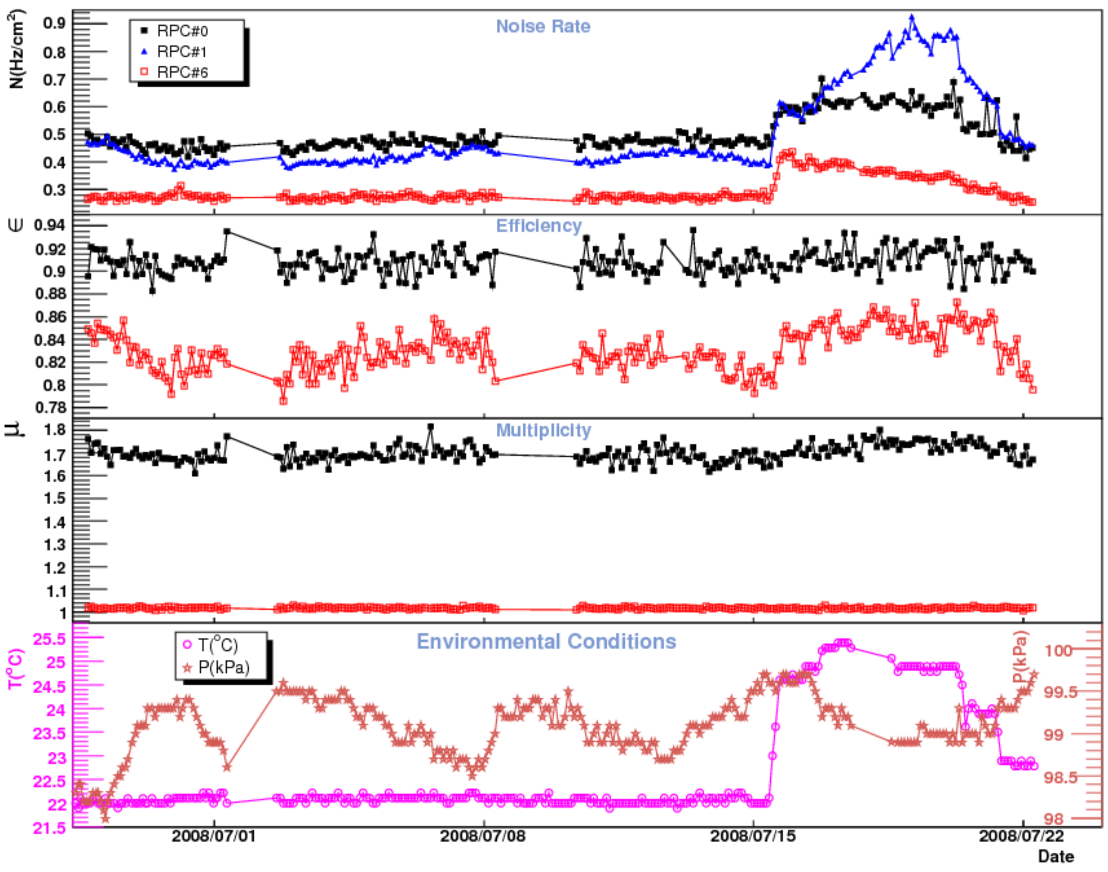
Understanding of noise/role of gas

Why do we need to flush the gas?
What goes wrong in old gas?

Understanding of the stability/calibration of the system

Corrections for environmental conditions?

Sample of the data collected over ~ 1 month

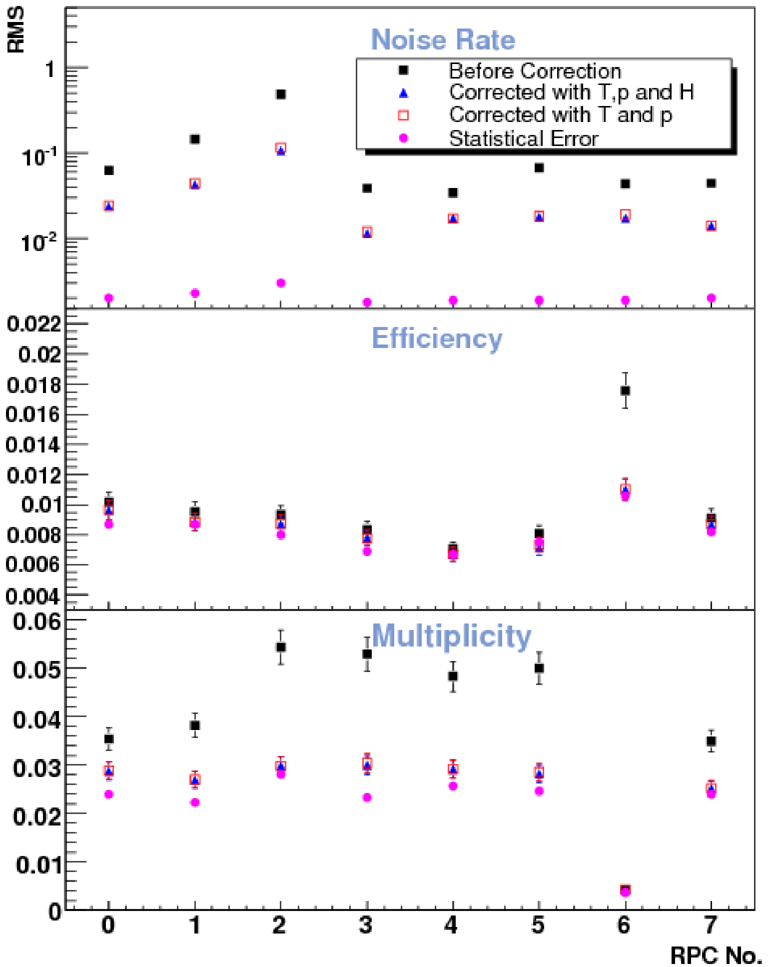


2-glass RPC
2-glass RPC
1-glass RPC

Fluctuations in the performance as well as in the environmental conditions

Linear correction for the environment

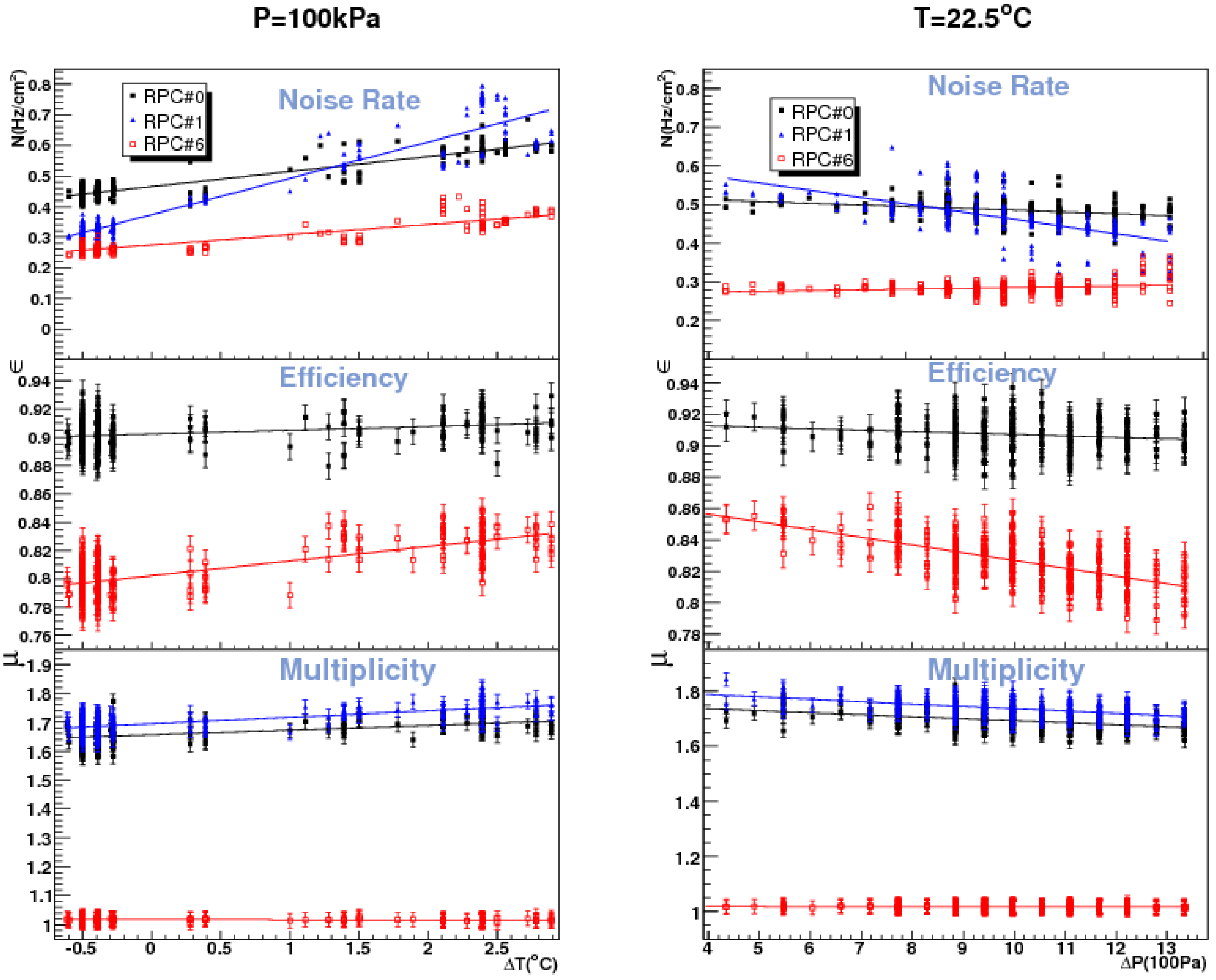
$$F_i(T,p,H) = F_{i,0} + b_{T,i}\Delta T + b_{P,i}\Delta p + b_{H,i}\Delta H \qquad \text{with } i = N, \varepsilon, \mu$$



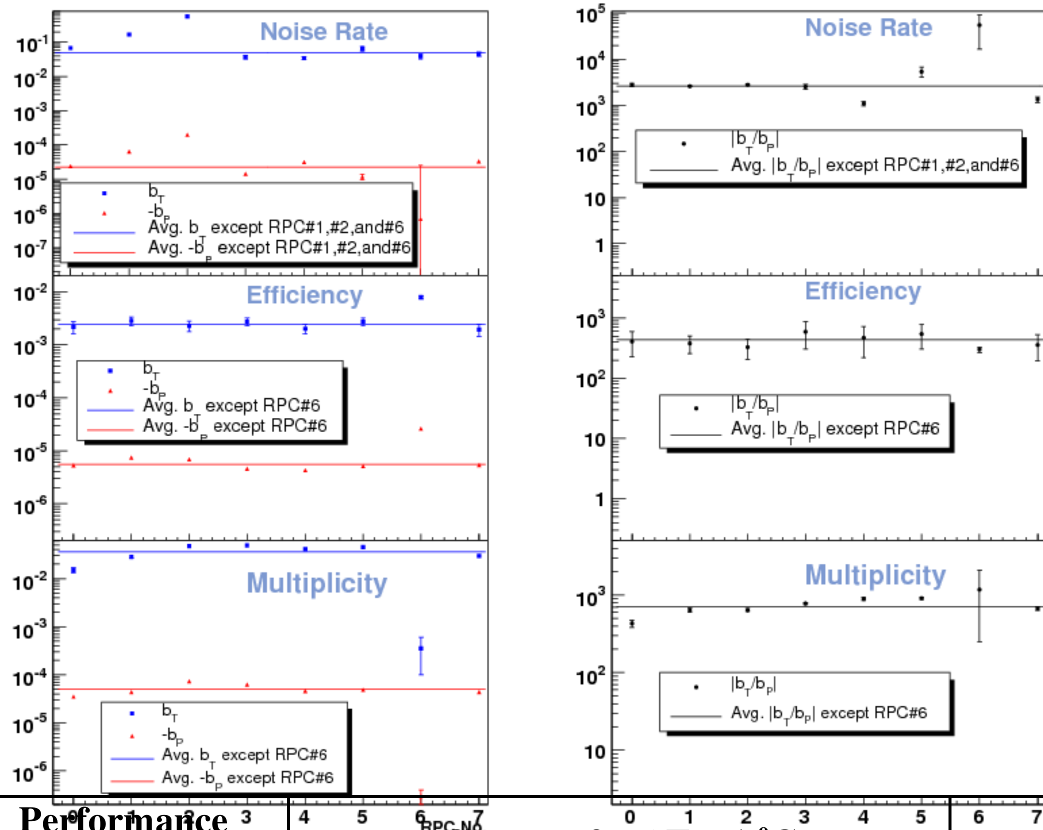
Corrections work well for ε,μ

Width of noise rate still above statistical error

Sample of slopes of environmental dependence



Slopes of environmental dependence



More or less consitent slopes for different chambers

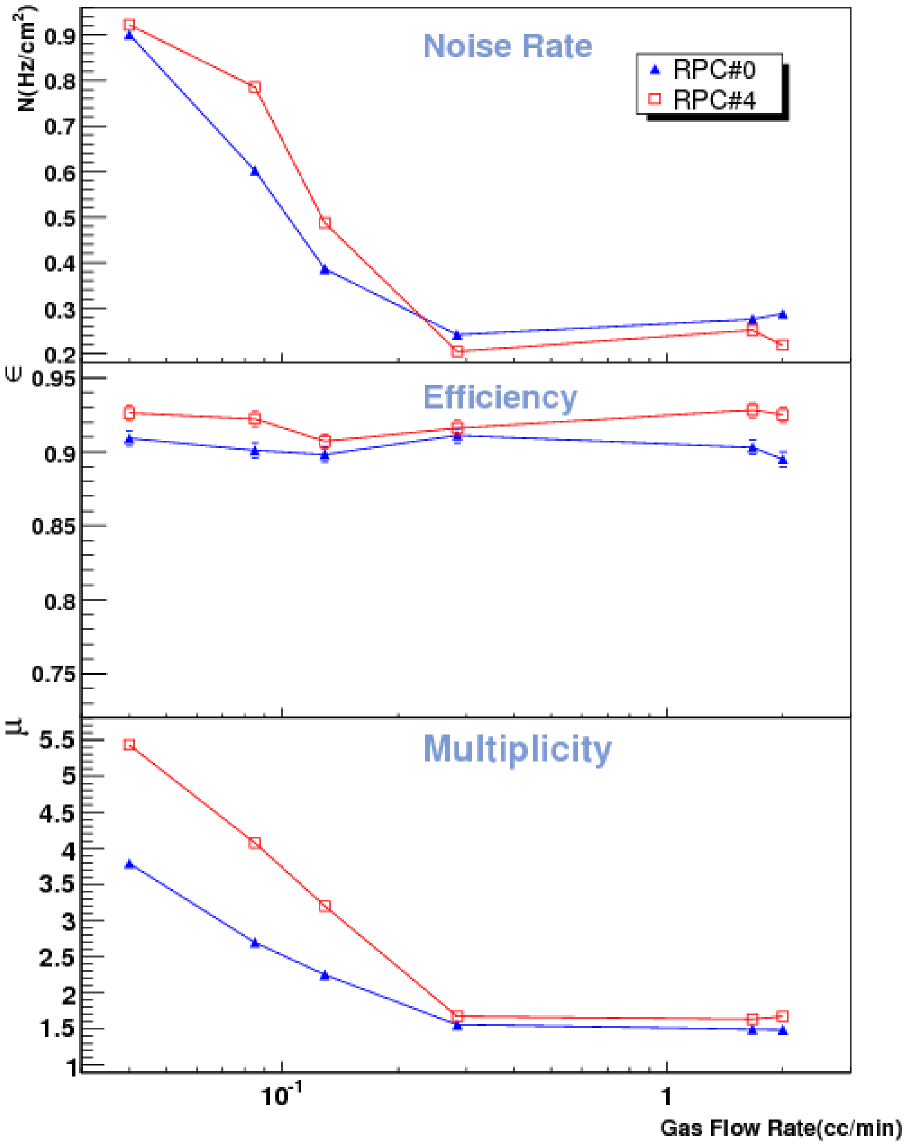
If effects entirely due to changes in mean free path in gas

→ b_T/b_p ~ 338 Pa/^{0}K

Roughly correct for ε,μ
Much larger for N
(other factors contribute to noise rate)

Performance variable	Changes for ΔT = 1 ^{0}C			Changes for Δp= 100 Pa		
RPC design	2-glass Good(%)	2-glass Damaged(%)	1-glass (Good)(%)	2-glass Good(%)	2-glass Damaged(%)	1-glass (Good) (%)
Noise rate	14±1.6	42±1.2	13±1.8	0.70±0.037	1.73±0.028	0.02±0.69
Efficiency	0.26±0.051	0.28±0.0559	0.98±0.078	0.06±0.001	0.08±0.001	0.32±0.001
Pad multiplicity	2.0±0.09	2.0±0.09	0.035±0.0250	0.30±0.002	0.26±0.002	0.003±0.001

Dependence on gas flow



Noise rate and pad multiplicity rise dramatically for flow rates below 0.3 cc/min

This data is for 20 x 20 cm^2 chambers and no beam activity

Extrapolation to larger chambers not trivial

(better understanding of the underlying mechanism for accidental noise hits would be very useful)

Conclusions

Hadron shower paper

Submitted to JINST

Photons in MTBF

Suspicion substantiated
These photons need to be removed
Will return to MTBF for further studies

1 m^3 simulation

Essentially completed

Environmental paper

Plots ~ final
Further studies of noise rate/multiplicity ongoing
→ understanding of underlying mechanism