Young Investigator Group: Supersymmetry at the Terascale

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"Helmholtz-Hochschul-Nachwuchsgruppe" at DESY
in Co-operation with the Hamburg University (5 years)

Goals of the Young Investigator Group

Search for Supersymmetry at CMS:

- Optimisation of search strategies and data analysis
  - SUSY found?
    - comparison of different models
  - SUSY not found?
    - Setting of exclusion limits
    - Search for other physics beyond the Standard Model

Studies for future experiments:

- LHC-Upgrade (hadron calorimeter)
- Detector optimisation for the International Linear Collider

Roadmap

Data analysis:

- High energetic jets
- Missing energy
- Leptons (esp. muons)
- Search for a very small signal below high QCD background

Co-operation with the Hamburg University

CMS contribution:

- Development of offline data quality monitoring (DQM) tools based on SUSY analysis (use of the "express line" reconstruction)
- Studies for the upgrade of the HCAL
- Shifts at DESY (CMS Center) and CERN

Group structure:

- Group leader (I.M.-P.), 2 Postdocs, 3 PhD students (up to now only one PhD student employed – still 2 vacant positions)

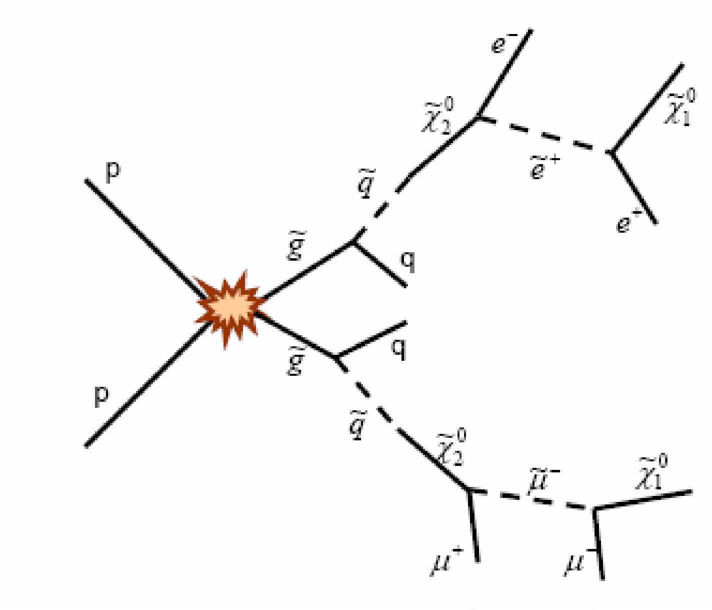
Planned SUSY Analyses

Jets + E_T^{miss} + 2 (same-sign) muons

- Trigger quite simple
- Small QCD background

Jets + E_T^{miss} + 1 muon

- Relativ clean signature due to muon
- Trigger must be understood (probably difficult in the beginning)
- Background: top quark production, QCD events with jets, elektroweak boson production



Jets + E_T^{miss} + 2 (odd-sign) muons

- Characteristic invariant mass distribution of the two muons

Same sign dimuons

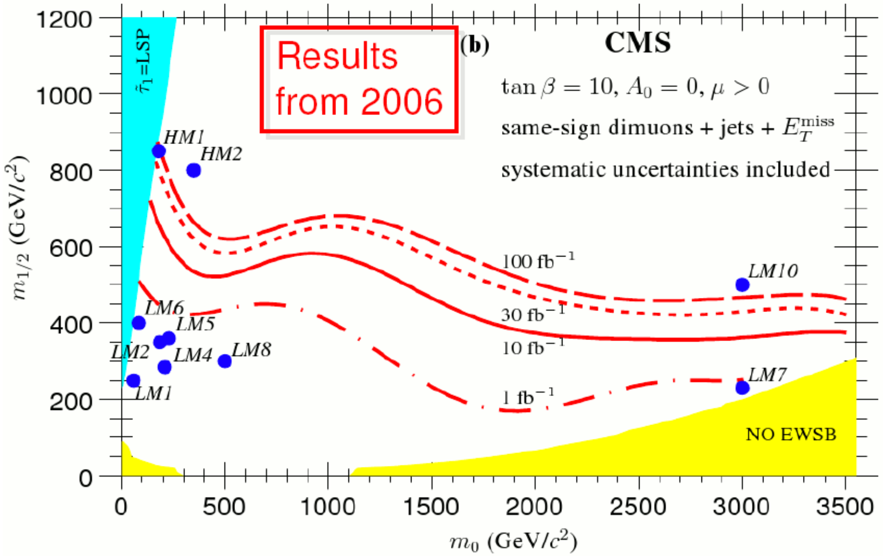
Already much work done by other groups, e.g.

D.Acosta, P.Avery, D.Dobur, Alexey Drozdetskiy, A.Korytov, K.Matchev, G.Mitselmakher, Yu. Pakhotin, R.Remington, J.Yelton
With many thanks to B.Kim and the UF T2 and HPC
(University of Florida, Gainesville)

(see talks in leptonic SUSY meeting 26/02/2009 and 26/03/2009)

Our plan:

- Establish and reproduce "standard" analysis
- Concentrate on MET measurements
- Implement SUSY variables in DQM



$\not{E}_T$ Collection InputTag	Data Type	CMSSW Version	Input to MET Algorithms
*** met	CaloMET	All Versions	SchemeB CaloTowers w/ HF, w/o HO
metNoHF	CaloMET	$\geq$ 2.0.0	SchemeB CaloTowers w/o HO,HF
metHO	CaloMET	$\geq$ 2.1.8	SchemeB CaloTowers w/ HO,HF
metNoHFHO	CaloMET	$\geq$ 2.1.8	SchemeB CaloTowers w/ HO, w/o HF
metOpt	CaloMET	$\geq$ 2.0.0	Optimized CaloTowers w/ HF, w/o HO
metOptNoHF	CaloMET	$\geq$ 2.0.0	Optimized CaloTowers w/o HO,HF
metOptHO	CaloMET	$\geq$ 2.1.8	Optimized CaloTowers w/ HO,HF
metOptNoHFHO	CaloMET	$\geq$ 2.1.8	Optimized CaloTowers w/ HO, w/o HF
pfMet	PFMET	$\geq$ 2.2.0	PFCandidates
tcMet	MET	$\geq$ 3.0.0	met, tracks, muons, pixelMatchGsfElectrons
htMetIC5	MET	$\geq$ 2.0.0	iterativeCone5CaloJets
htMetKT4	MET	$\geq$ 2.0.0	kt4CaloJets
htMetKT6	MET	$\geq$ 2.0.0	kt6CaloJets
htMetSC5	MET	$\geq$ 2.0.0	sisCone5CaloJets
htMetSC7	MET	$\geq$ 2.0.0	sisCone7Calojets
genMet	GenMET	$\leq$ 3.0.0	GenParticles excluding BSM's, ν's, and μ's
genMetNoNuBSM	GenMET	$\leq$ 3.0.0	GenParticles excluding prompt ν's and μ's
genMetFromIC5GenJets	GenMET	$\geq$ 2.0.0	iterativeCone5GenJets
genMetCalo	GenMET	$\geq$ 3.0.0	same as for genMet
genMetCaloAndNonPrompt	GenMET	$\geq$ 3.0.0	same as for genMetNoNuBSM
genMetTrue	GenMET	$\geq$ 3.0.0	GenParticles excluding BSM's and neutrinos

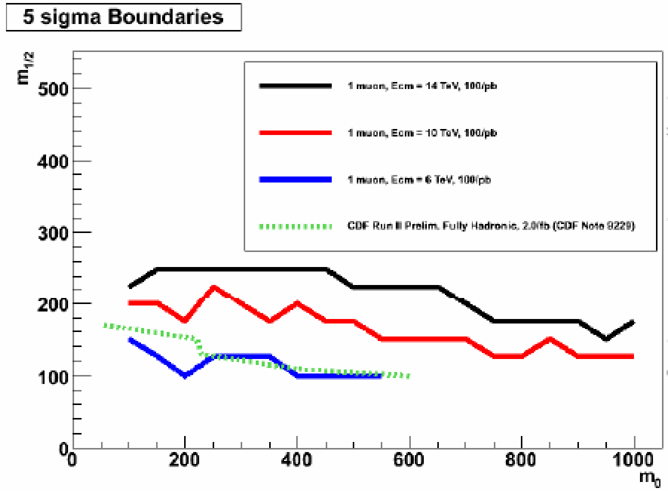
One muons + jets + MET

Other groups involved: Aachen,

Chris Justus, Finn Rebassoo, Jeffrey Richman, David Stuart
UCSB

Estimated 5 σ Discovery Reach: LHC v. Tevatron cont.

(see talks in leptonic SUSY meeting 12/02/2009 and 12/03/2009)



- Reproduced analysis with same parameters as CDF.
- 100 pb^{-1} at 6 TeV has same reach as 2 fb^{-1} at Tevatron
- 100 pb^{-1} at 10 TeV will exceed Tevatron limits

3/12/2009 Chris Justus 27

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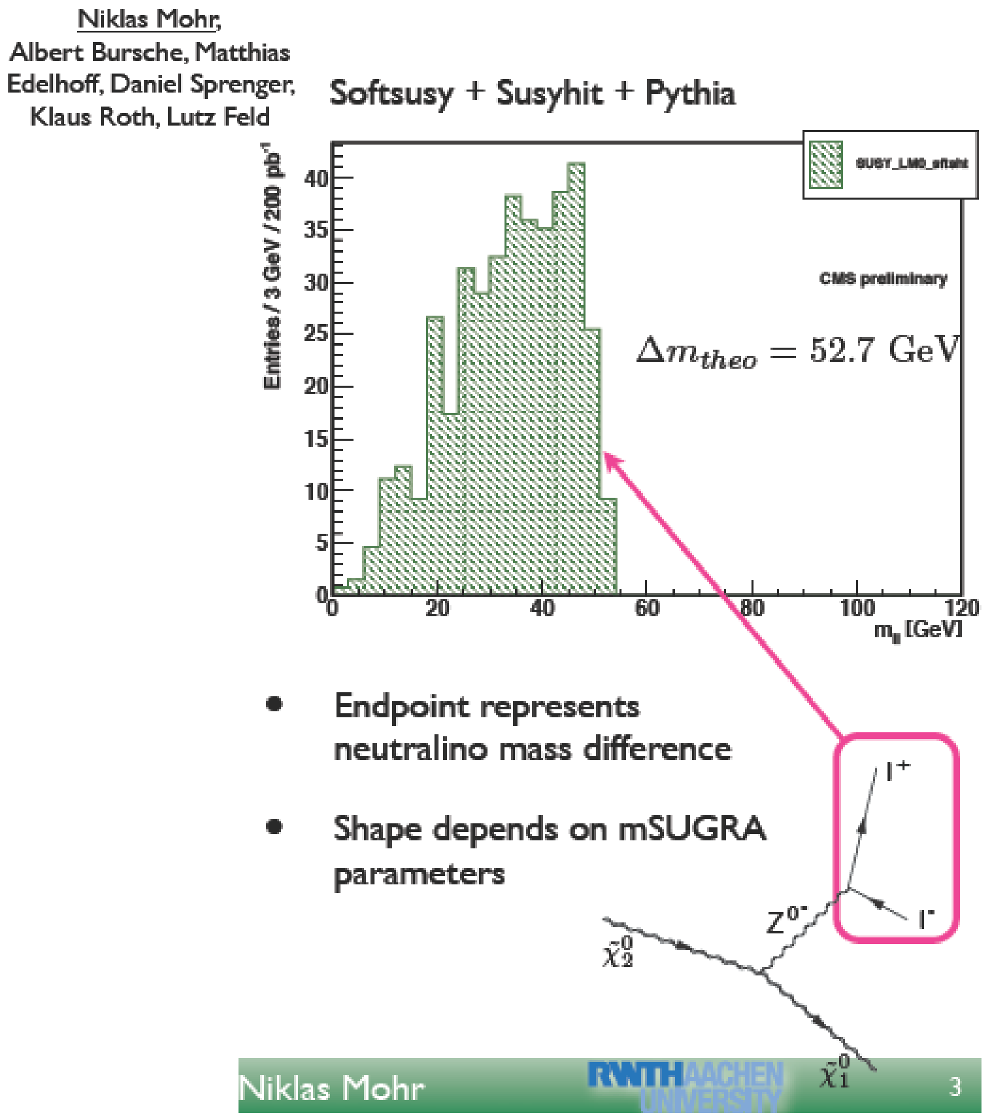
Odd-sign dimuons

Far developed analysis: Aachen
see SUSY meeting 07/04/2009

Most interesting about
this analysis:
mass edge describing the
neutralino mass difference



Technical work: DQM and CMS Center

Data Quality Monitoring (DQM):

- All SUSY analyses shall contribute to the DQM based on SUSY specific variables
- One postdoc will spend about 1/3 of his/her time on DQM work, the second postdoc about 20%
- All group members will contribute substantially to DQM shifts (from the CMS Center)

CMS Center:

- One postdoc will spend about 10% of his/her time supporting Günter Eckerlin

HCAL Upgrade:

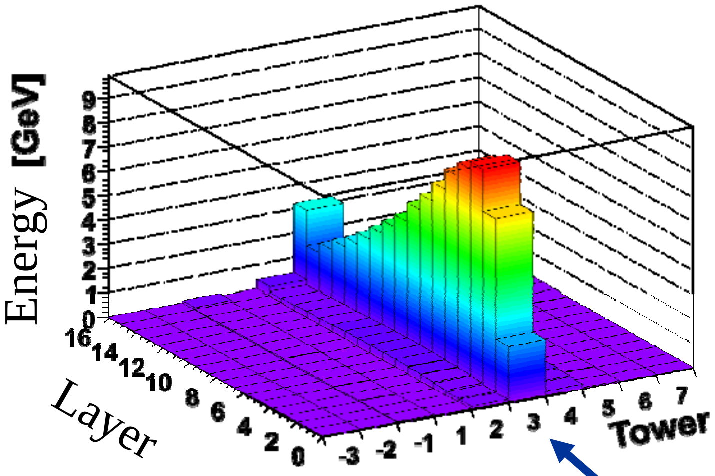
- One postdoc will spend about 20% of his/her time on HCAL upgrade simulations
- Already work started from one PhD student (MS) in January

HCAL upgrade studies

Main question for the studies (=simulations):

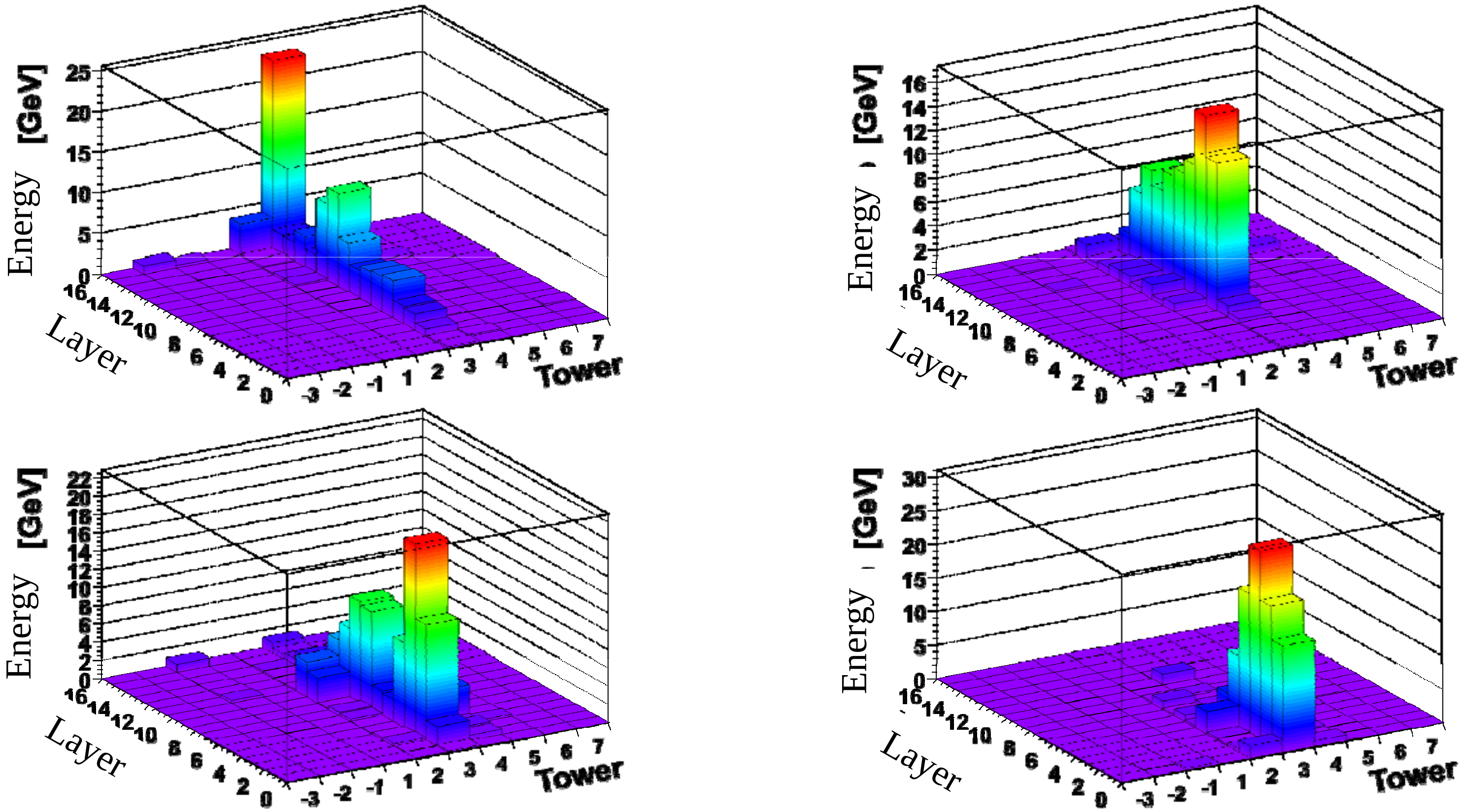
Can a longitudinal segmentation of the HCAL improve its resolution? How?

Energy distribution for 15000 events



100 GeV π
15000 events

Energy distribution for single events



Use longitudinal resolution to distinguish between em (high energy density) and hadronic part of the shower (use of different weights possible)

Why Weighting?

Efficiency is usually different for hadronic and em component :

$\mathbf{S_h = \varepsilon_h E_h + \varepsilon_e E_e}$ ε_h= hadr. efficiency, ε_e= em efficiency

$\mathbf{\frac{E_h}{E} = 1 - f_{\pi^0} = 1 - k \cdot \ln E \text{ (GeV)}}$ $\mathbf{k \approx 0.1}$ em component dependent on energy

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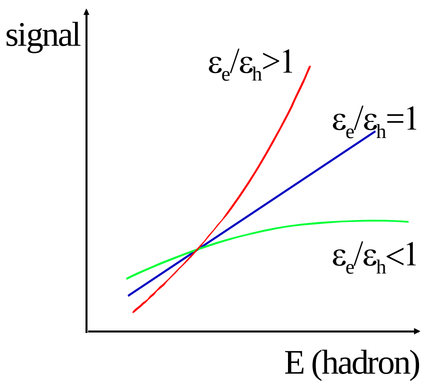
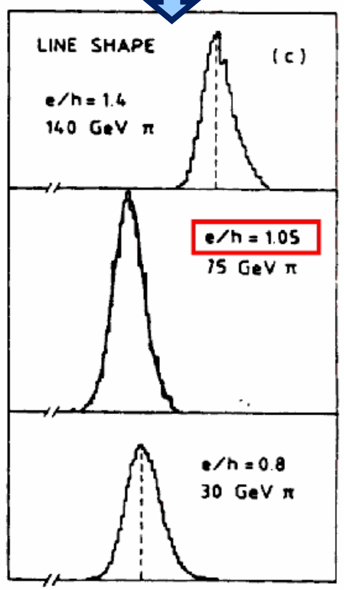
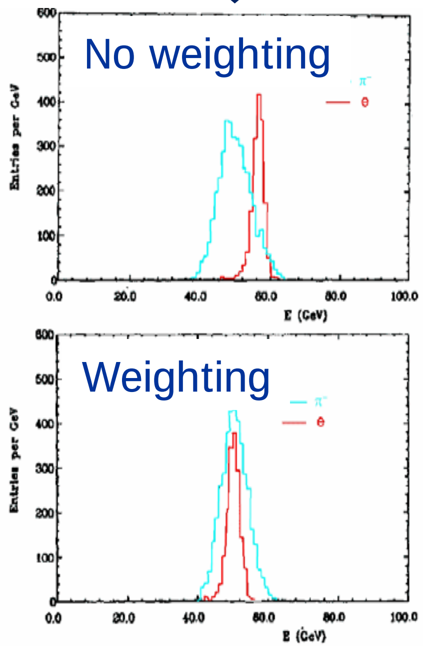
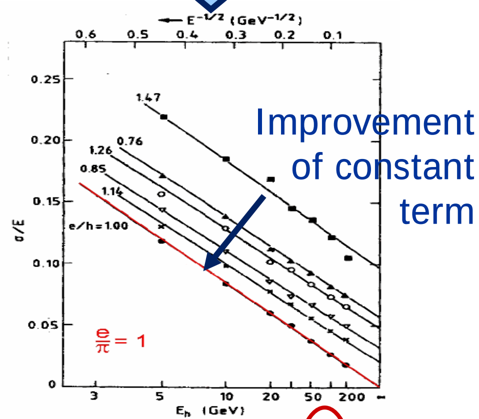
⇨ **Signals not linear** | **Signals not Gaussian** | **Signal(h)≠Signal(e)** | **Resolution worse**









$$\mathbf{\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} + b\left|\frac{\varepsilon_e}{\varepsilon_h} - 1\right|}$$

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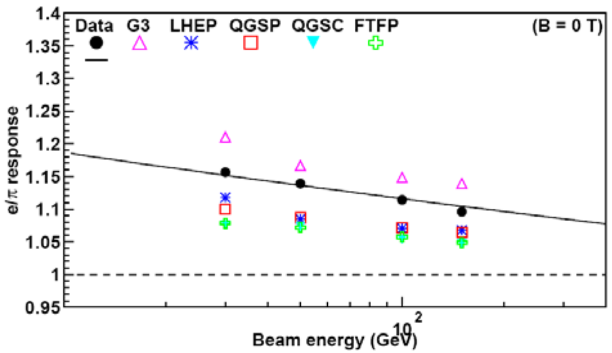
$$\mathbf{\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} + b \cdot \left| \frac{\varepsilon_e}{\varepsilon_h} - 1 \right|}$$

e/π response from CMS NOTE-2004/032
"Validation of Geant4 Physics Using 1996 CMS HCAL Test Beam Data"



Resolution for CMS HCAL: from CMS NOTE-2004/020
"Measurement of the Pion Energy Response and Resolution in the Hadronic Barrel Calorimeter using CMS HCAL Test Beam 2002 Experiment"

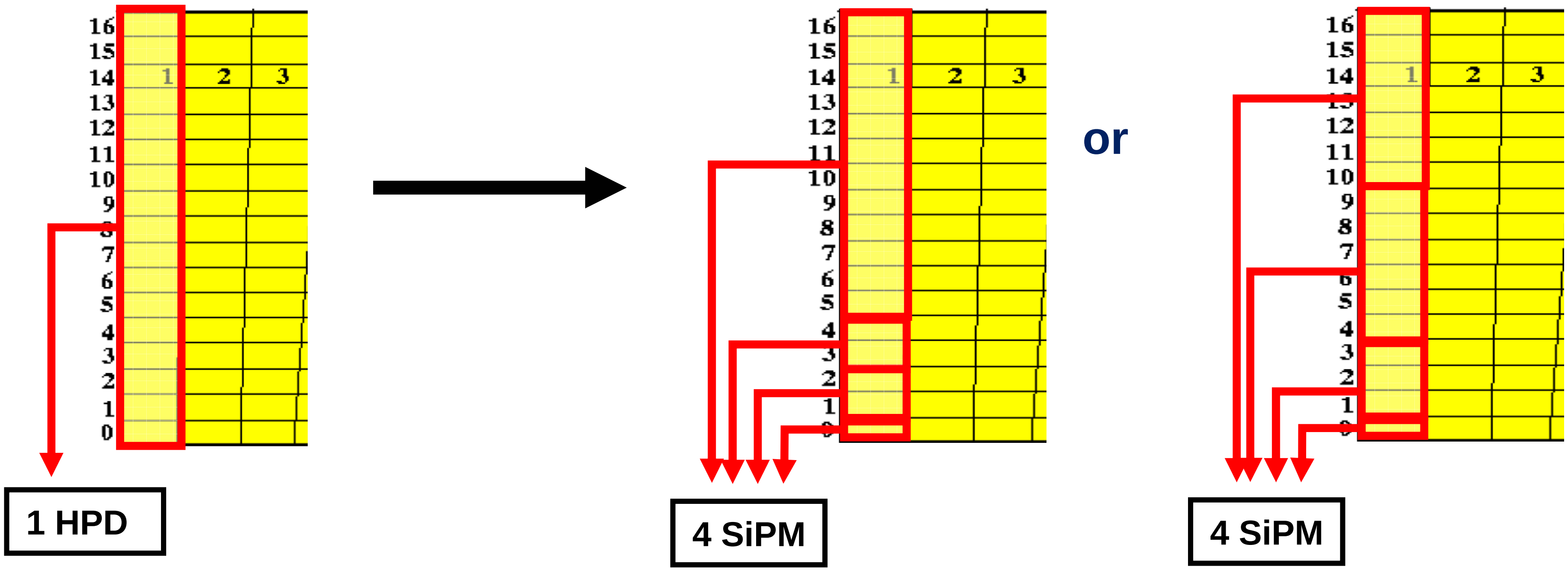
$$\left(\frac{\sigma(E)}{E}\right)^2 = \frac{115^2}{E} + 5.5^2$$

Compensation:

enlarge ε_h, lower ε_e → Offline-Weighting → Improve constant term

Example scheme

Weighting is only possible with longitudinal resolution
(the more layers the better ☺ - one discussed possible option: 4 layers)



- Different **weighting methods possible** (H1 method (iterative), tabulated weights (both methods need MC input from energy deposited in absorber),...)

Status

Started to work with a standalone (Geant3) simulation (faster, all information available (absorber energy, invisible energy etc.))

Why Geant3? – Simply because we have an expert ("Thanks to Vladimir Andreev!!") who managed to write the first version within one week.

- Calculate and apply the weighting factors (for different π energies)

$$w^i(E_{meas}, \rho^i) = \frac{\langle E_{true} \rangle}{\langle E_{meas} \rangle}$$

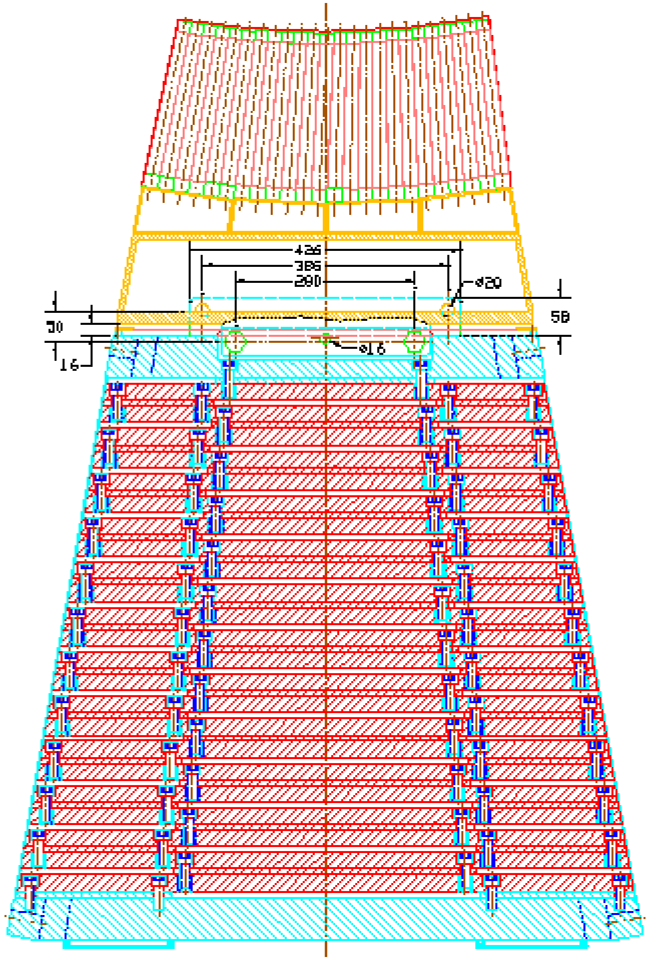
i : index
ρ: energy density (energy/volume)
E_{meas}: measured energy
E_{true}: true energy (= absorber + scint. energy)

- Compare the energy spectra before/after weighting
- Determine energy resolution before/after weighting
- Try different schemes

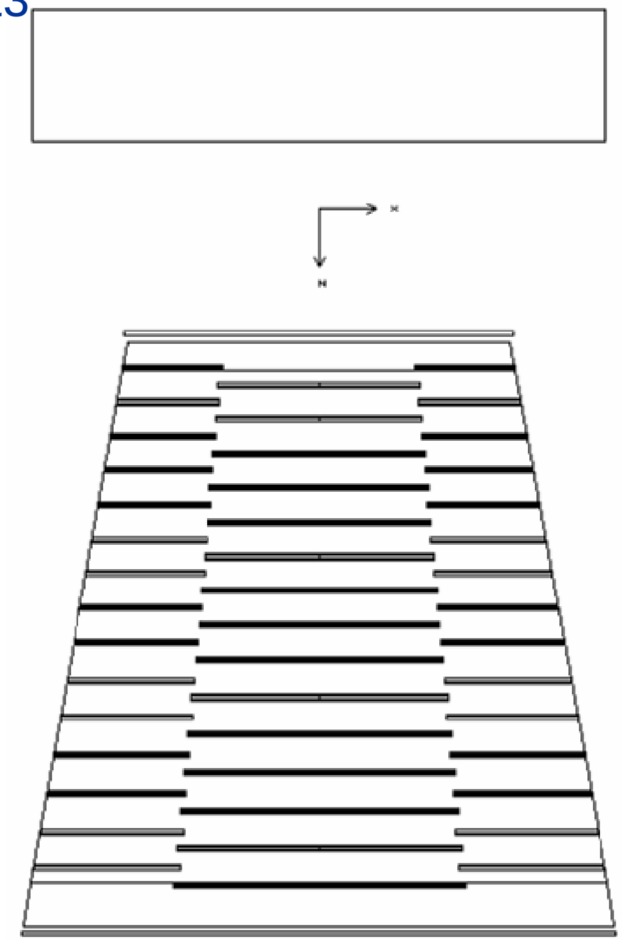
- Try different weighting procedures

HCAL in Geant 3 standalone

Complex Detector in CMSSW

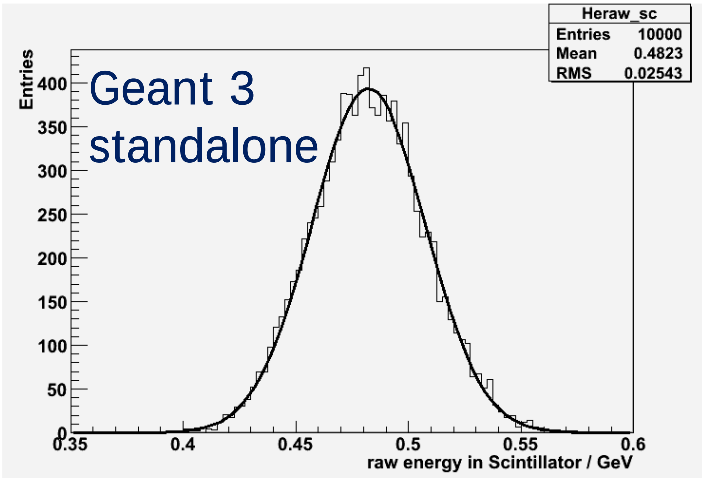


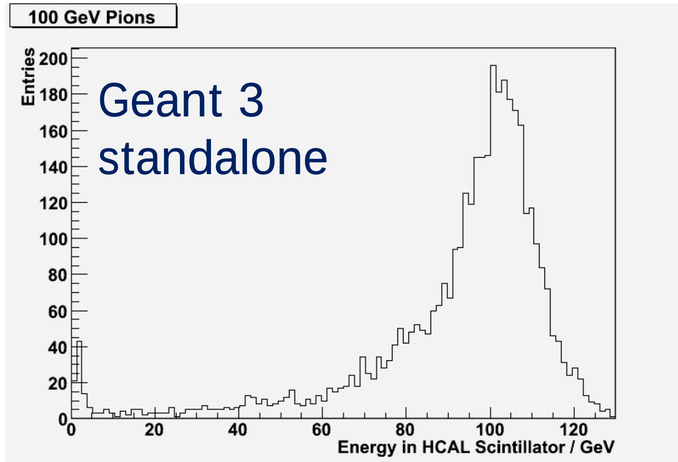
Simple HCAL standalone simulation (with single block of ECAL in front) in Geant3



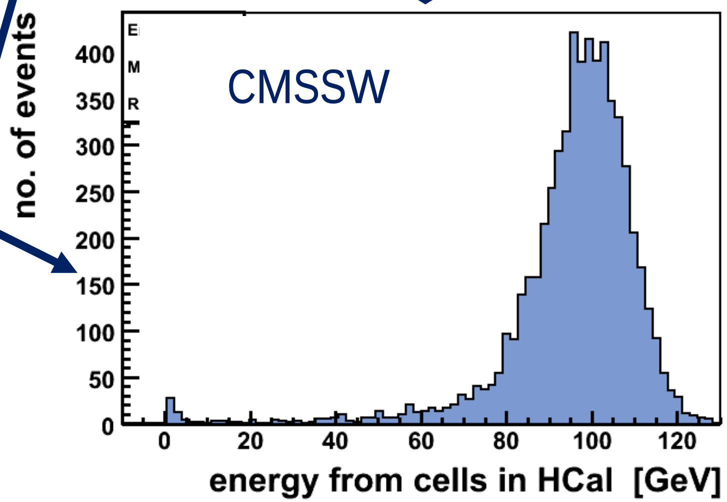
Comparison Geant3 - CMSSW

“Calibration” with 50 GeV e-





Don’t expect perfect agreement, but comparison looks similar for total energy → check energy distribution in single layers (see next page)

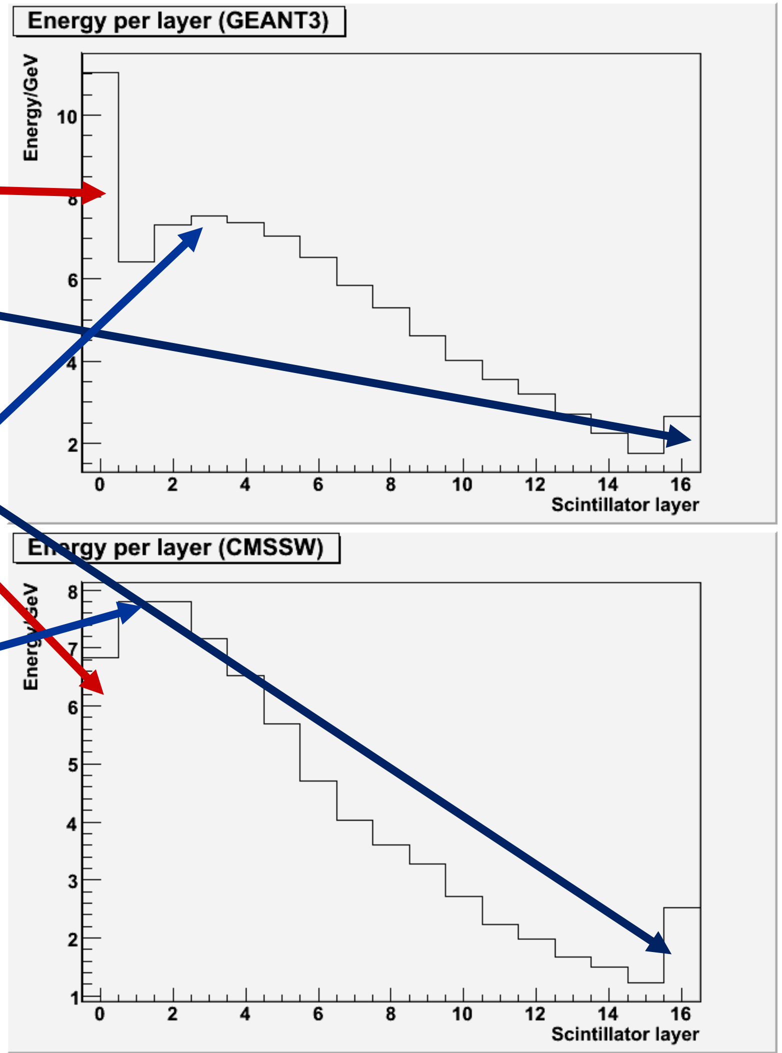


Comparison CMSSW - Geant3

Layer 0 and 16 thicker

Layer 0 has in addition an attenuator which reduces light output by ½ (not included in Geant 3)

Maximum is shifted



Conclusion and Outlook

Manpower:

- Official start of the group: May
- Postdocs will join the group within the next months
- One PhD student so far – looking for two more...

A lot to do:

- Work on simulation for HCAL upgrade started
- SUSY analyses to start soon
- DQM and work in CMS center will start with the postdocs

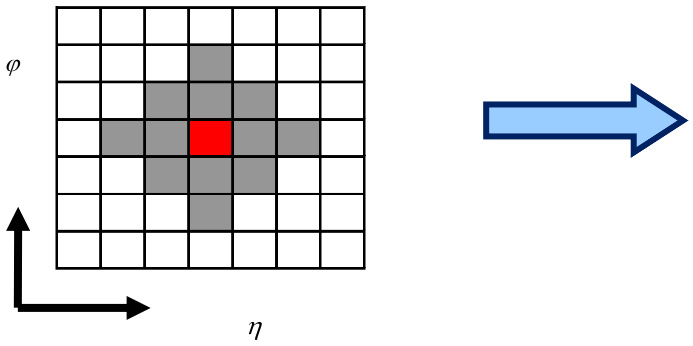
BACKUP

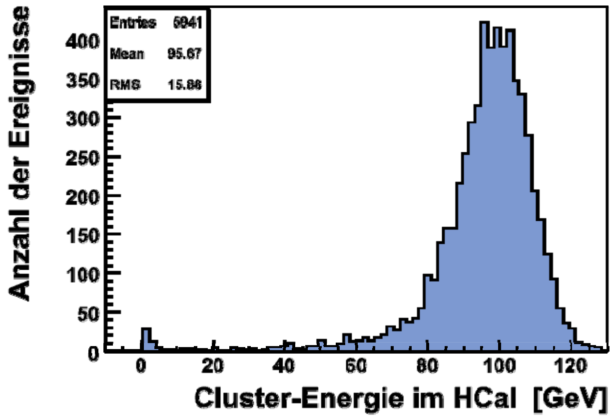
Geant 3 parameters

```
LIST
  TRIGGERS  1000
  DEBUG     1   1    0
  SWIT      1   0
  HADR 4
  TIME 0.  7. 1
  CUTS  0.0001  0.0001  0.0001  0.0001  0.0001
  ANNI 1
  BREM 1
  COMP 1
  DRAY 1
  LOSS 1
  MULS 2
  MUNU 1
  PAIR 1
  PFIS 0
  PHOT 1
  RAYL 0
  STRA 0
  KINE 2=8. 0.50  0.00 -110.0  0.0  0.0  100.00
END
```

Work from Matthias Stein

- 15.000 π (100 GeV) shot in the middle of tower 3
- Use only events with < 1 GeV in ECAL
- Simple reconstruction using clustering algorithm shown below:





- Define sensitive variable: **energy density** ρ_E (energy/scintillator layer)
- Plot energy density for each (longitudinal) channel vs cluster energy
- ↳ energy density has different meaning for the different longitudinal channels (because of different number of layers (1-2-2-12)
- Calculate weights from mean energy densities

$$w^i(E_{meas}, \rho^i) = \frac{\langle E_{true} \rangle}{\langle E_{meas} \rangle}$$

i : index
ρ: energy density (energy/volume)
E_{meas}: measured energy
E_{true}: true energy (= absorber + scint. energy)