Investigation of hadronic shower time evolution

Marco Ramilli

CALICE Meeting 17/09/2012

Overview

•AHCAL test beam at CERN in November:

- Preparation of the physics case
- Timing evolution of hadronic showers
- Investigation of energy decomposition

•Conclusions and outlook

AHCAL Test-beam at CERN

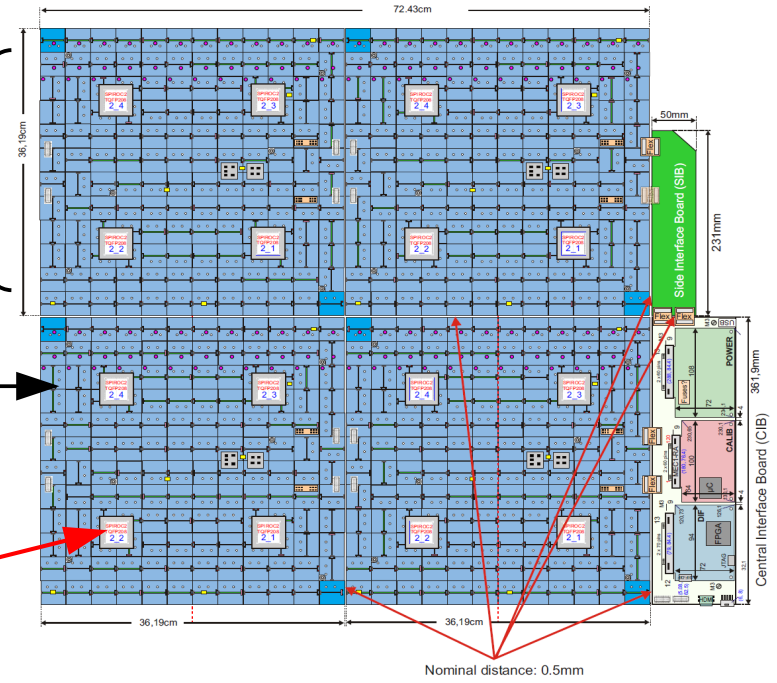
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

In November a layer of AHCAL technological prototype will go in test-beam:

- SPS facility at CERN: 10 GeV – 180 GeV pions
- Downstream the Tungsten Digital HCAL (W- DHCAL) **~ 4λ_I** (interaction lengths)

One AHCAL layer is made 4 HBUs (HCAL Base Unit)

One HBU is composed by:
12 x 12 plastic scintillator tiles with SiPMs
4 readout chips (SPIROC 2b)



One plastic tile has a 3 cm border

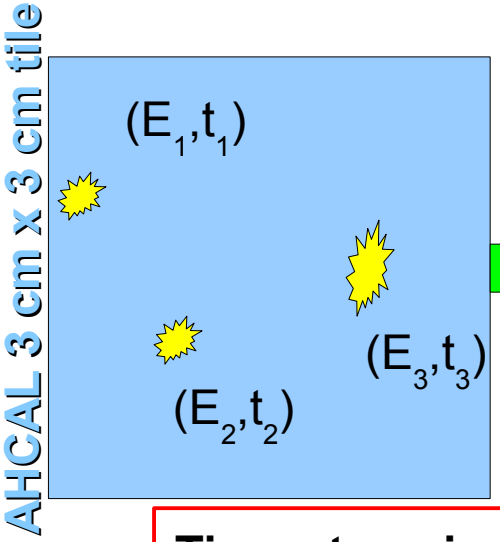
One SPIROC 2b:
•36 channels readout
•time resolution of 1 – 1.5 ns (test-beam mode)

More details in B. Hermberg talk

Time-stamping

The ROC will work in **self-triggering** mode:

Signal from multiple *energy depositions* in Cell



Cell output/Event:

1)E_{hit} =integrated charge of all energy depositions

2)t_{hit} = time of signal passing threshold

Time-stamping information
Main physics motivation: to study time evolution of hadronic showers

Montecarlo study to prepare the physics case:

- 39 layers of the AHCAL simulated with tungsten absorber (~ $4\lambda_I$)
- Shower from π- at 50 GeV and 100 GeV, QGSP_BERT and QGSP_BERT_HP
- 50000 events each
- No noise
- Processor to simulate the ROC time-stamping

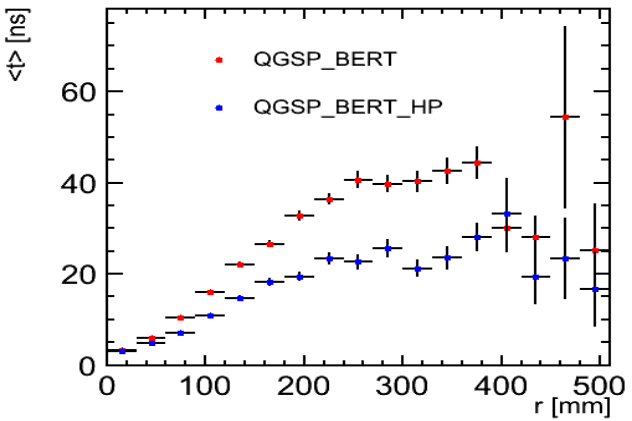
Radial Hit Time Dependency

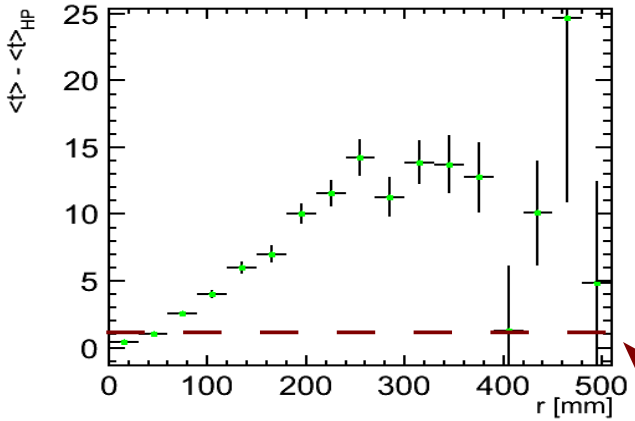
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Radial distribution of mean hit time in AHCAL position (> 4 λ_I)

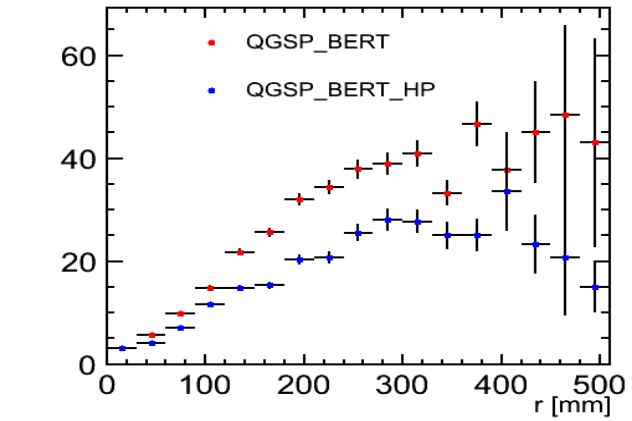
- An increase of the mean hit time with radius is observed
- Statistical errors allow to **distinguish between physics lists for 100 mm < r < 350 mm**

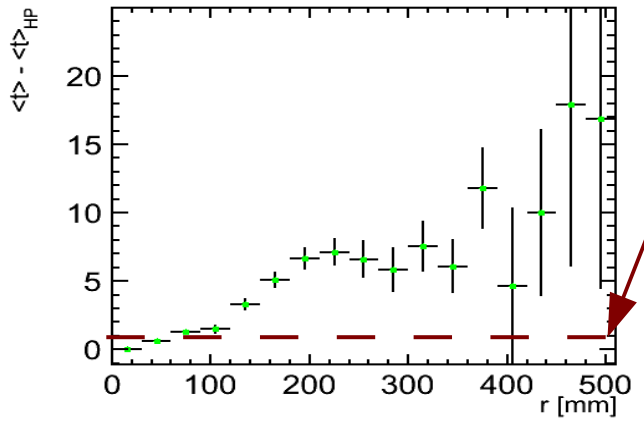
50 GeV π-





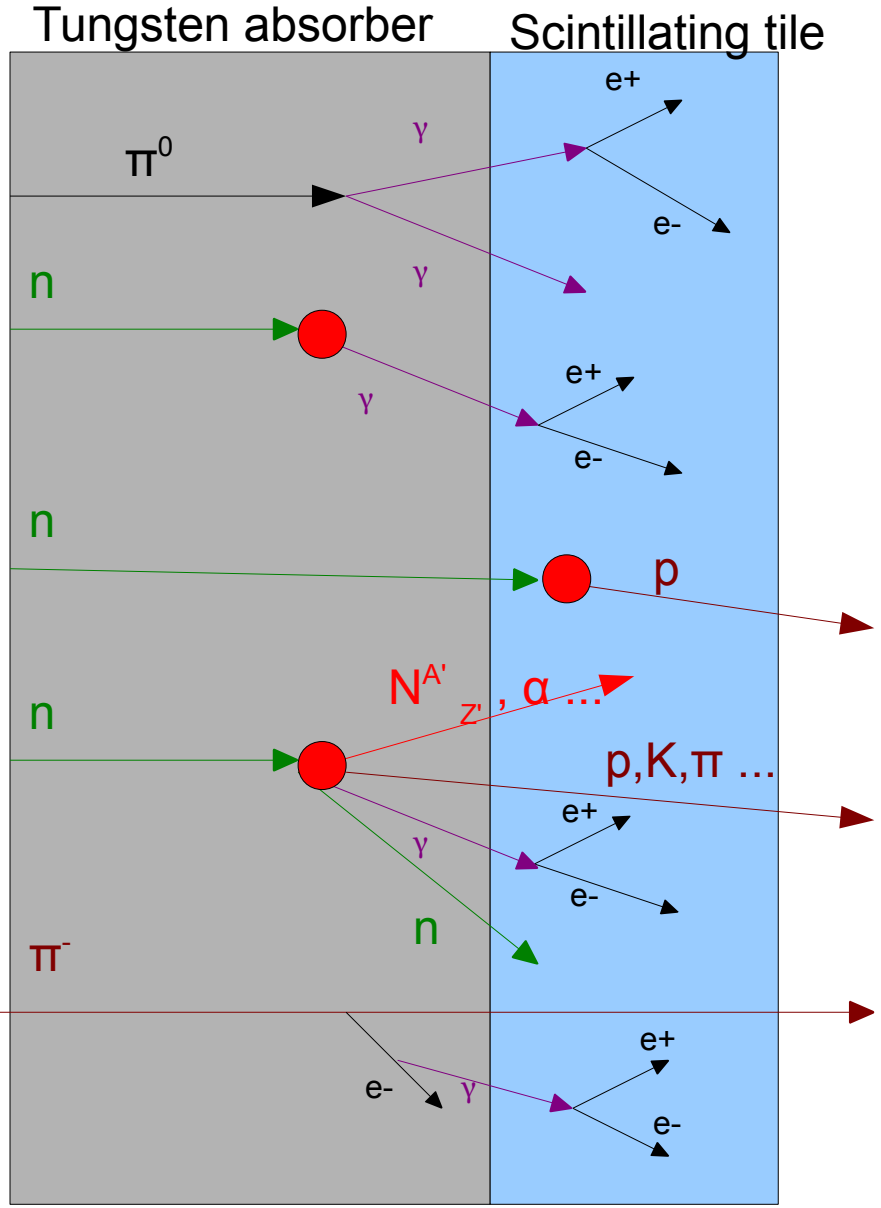
100 GeV π-





ROC time resolution

Hadronic Shower Decomposition



We want to tag energy deposition according to:

1)Electromagnetic Fraction:
Neutral meson decay in two gammas and pair production

2)Neutron capture:
nuclear de-excitation
gamma emission and pair production (also background to f_{EM})

3)Neutron elastic scattering with H nucleus
proton emission

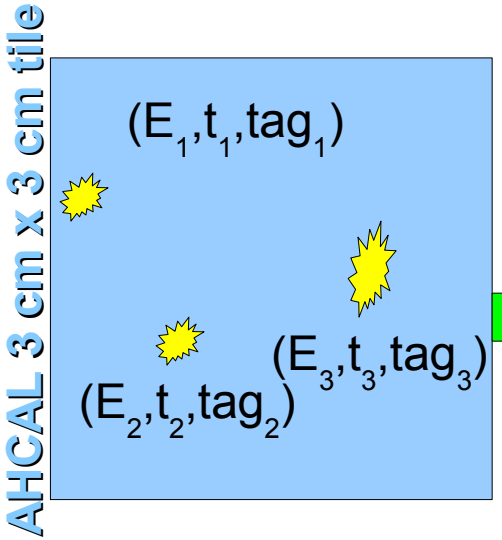
4)Neutron inelastic scattering with a nucleus
nuclear fragments, alpha particles ...
more gamma emission and delta electrons
protons, kaons, pions ...
more neutrons

5)None of the above – mainly energy deposited by charged hadrons with no neutron in history

Process Timing

More detail on this Mokka Plugin
in Shaojun Lu and Clemens Günter talks

Output of Mokka simulation:



Cell output/ Event (*modified processor)*:

1)E_{hit} = integrated charge of all energy depositions

2)t_{hit} = time of signal passing threshold

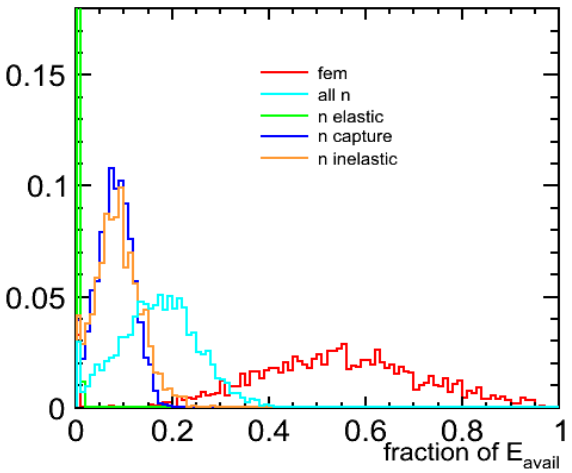
3)tag_{hit}= tag from the energy deposition $E_i > E_{thr}$

Provide MC prediction of each processes timing
To be compared with test-beam data

Energy Fractions

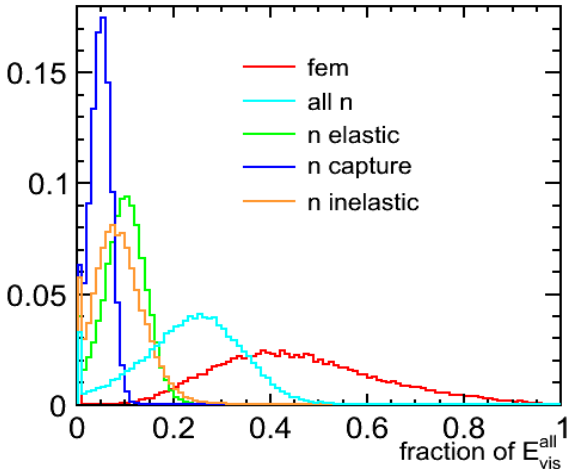
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

whole AHCAL



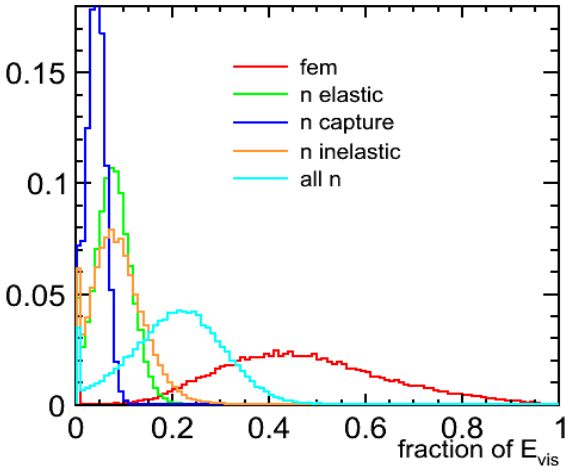
	Mean	RMS
C. Hadron	0.278	0.121
FEM	0.533	0.189
All N.	0.172	0.082
Elastic	0.002	0.002
Capture	0.081	0.038
Inelastic	0.09	0.048

Sensitive Detector



	Mean	RMS
C. Hadron	0.302	0.118
FEM	0.447	0.183
All N.	0.235	0.104
Elastic	0.098	0.044
Capture	0.048	0.023
Inelastic	0.089	0.052

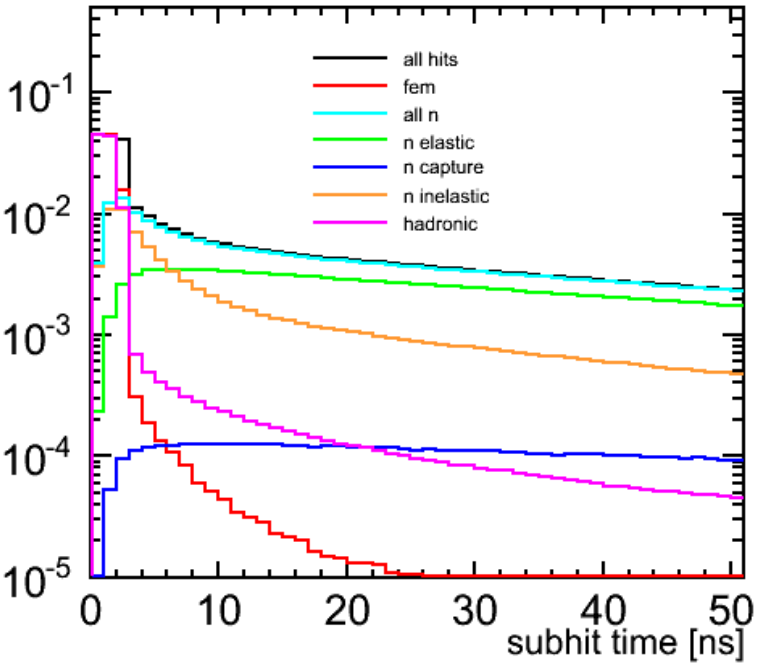
S. D. w/ Threshold



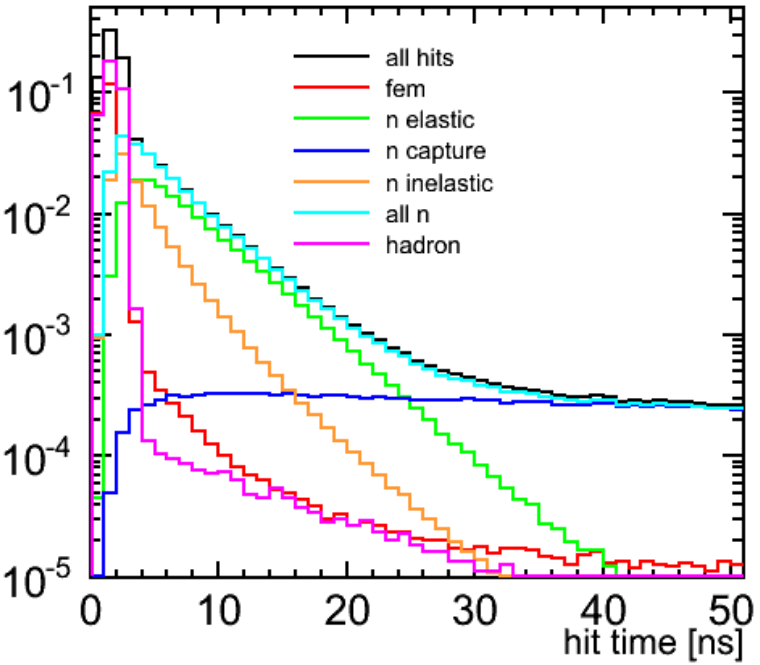
	Mean	RMS
C. Hadron	0.312	0.118
FEM	0.462	0.184
All N.	0.208	0.097
Elastic	0.077	0.038
Capture	0.042	0.02
Inelastic	0.086	0.053

Hit Time

50 GeV π- QGSP_BERT_HP
No Threshold



50 GeV π- QGSP_BERT_HP
0.5 MIP Threshold

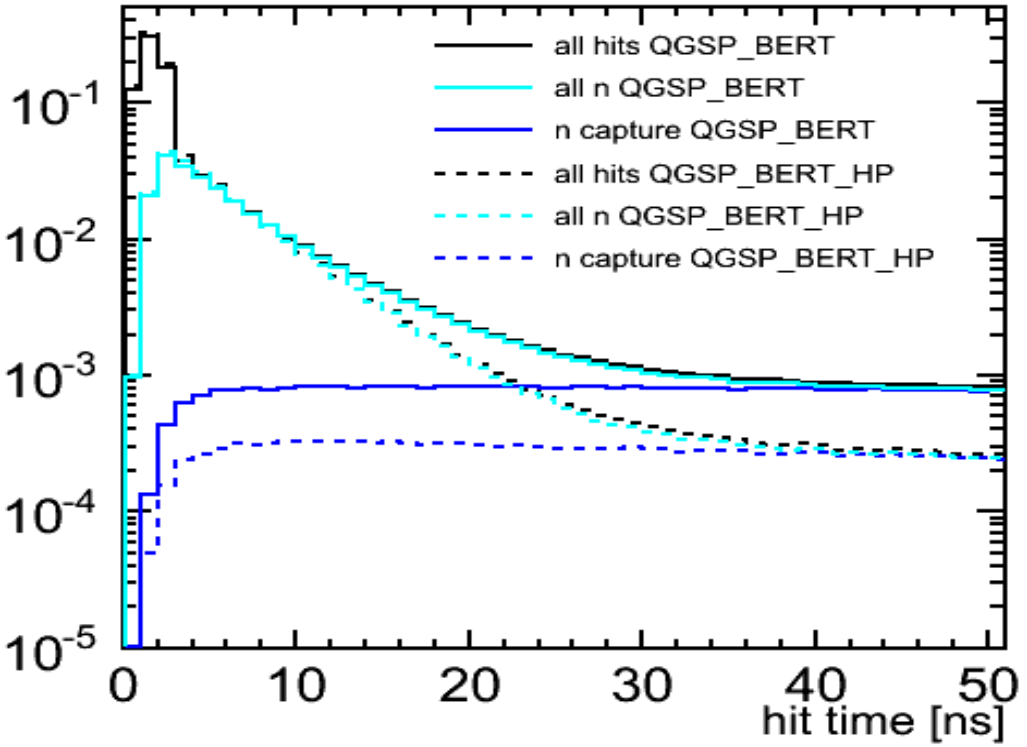


- Many late events are cut by the threshold
- FEM and Charged hadron dominant for t < 5 ns
- Neutrons dominant for t > 5 ns
- Neutron Capture dominant for t > 20 ns

Hit Time Comparison

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Comparison between 50 GeV π- QGSP_BERT and QGSP_BERT_HP:



Difference between neutron capture
With and without HP

- Time difference in tail
- Tail dominated by neutron component:
- HP predicts less late neutrons above threshold
- For t_{hit} > 20 ns neutron component dominated by neutron capture

Conclusions & Outlook

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

- One full AHCAL layer in test-beam in November 2012
  - In these days will go at DESY test-beam
- Physics goal: study time development of hadronic shower
- MC simulations to prepare the physics case:
  - At least 50000 **GOOD** events are needed distinguish between possible physics models
  - Developed Mokka plugin to tag neutron processes
- Neutron Capture is main responsible for late shower component
  - HP package predicts less neutron capture processes above 0.5 MIP cut

Backup Slides

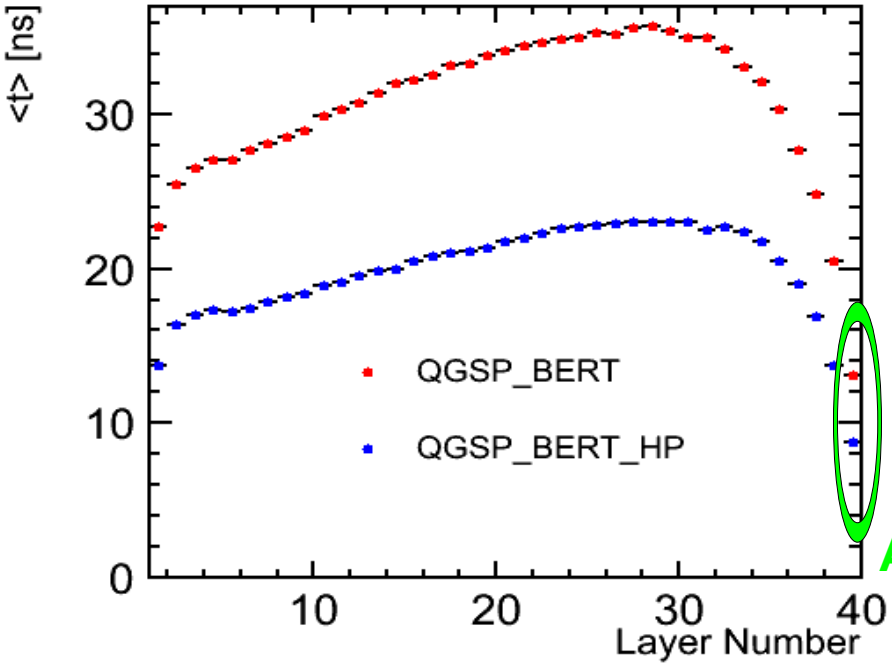
Mean Hit Time per Layer

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Physics motivation:
Study development of hadronic shower (time development, data/Montecarlo comparison)

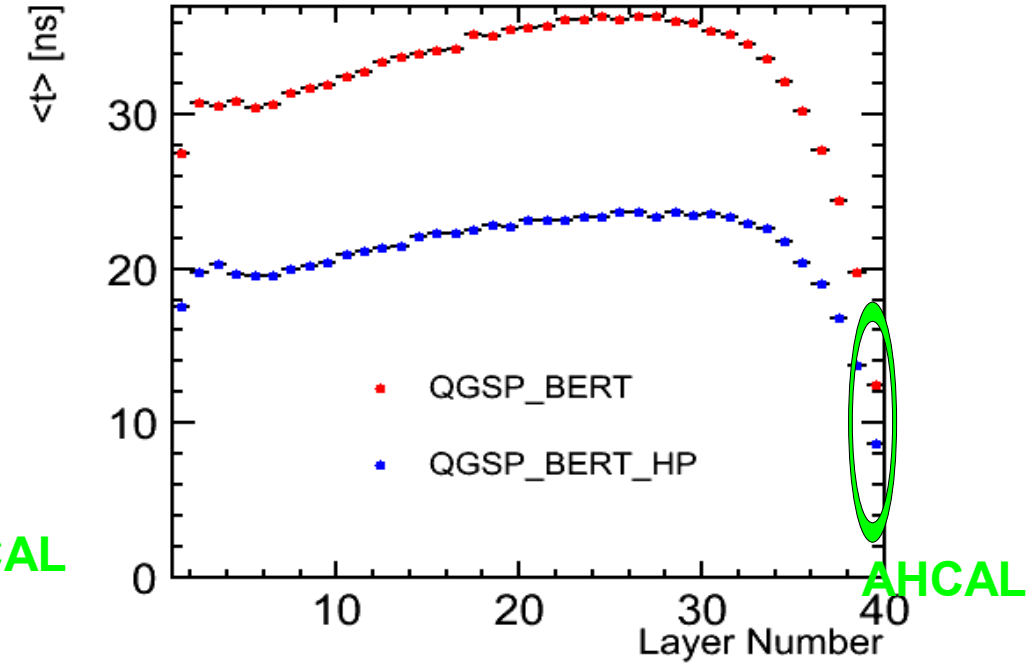
39 layers of AHCAL technological prototype with tungsten absorber had been simulated

50 GeV π^-, 50000 good events



layer	separation	sep./σ_{stat}	events
20	12 ns	70	50000
39	4 ns	20	50000

100 GeV π^-, 50000 good events



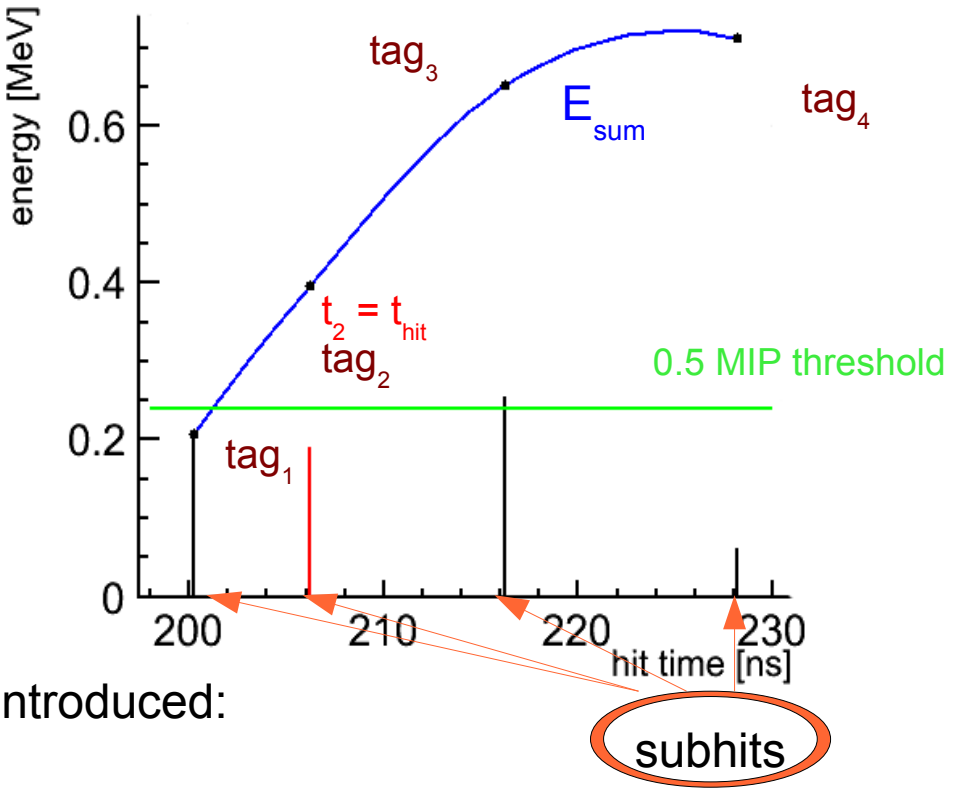
layer	separation	sep./σ_{stat}	events
20	13 ns	70	50000
39	4 ns	20	50000

ASIC simulation

To simulate ASIC behavior, for each Cell:

1a) subhits are temporally ordered
1b) subhit energy is added until $t_i = t_1 + 15$ ns
1c) $t_{hit} = t_i$ first subhit passing threshold

2) E_{sum} = sum of E_i until $t < t_{hit} + t_{hold}$ $t_{hold} \sim 50$ ns



For each hit, contribution fraction [0,1] is now introduced:

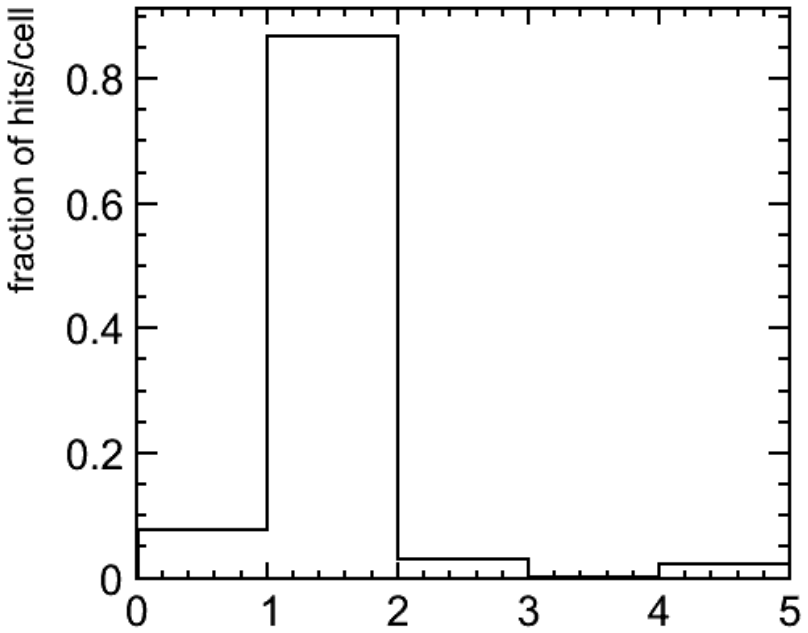
$fracNelastic = E_{elastic}/E_{sum}$

$E_{elastic} = \Sigma_i E_{i,elastic}$

Flag ambiguity

For each Hit all the subhit flags contributing to the Hit are counted:

$flag_{hit}$ = FEM

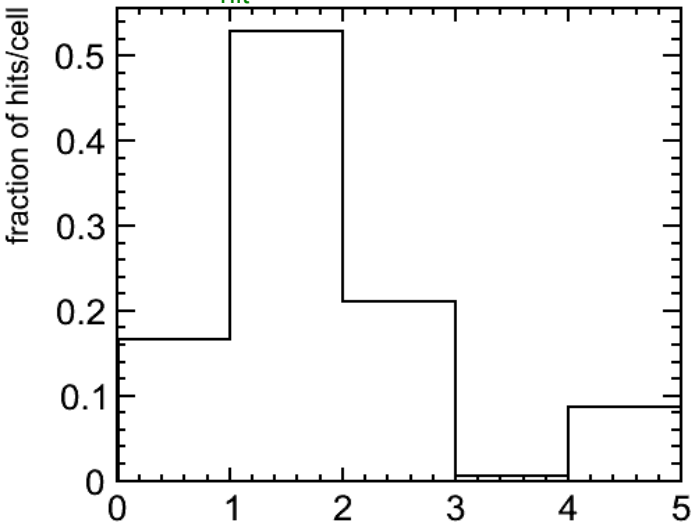


An integer has been used to label processes:
0 = Other process
1 = FEM
2 = Neutron Elastic
3 = Neutron Capture
4 = Neutron Inelastic

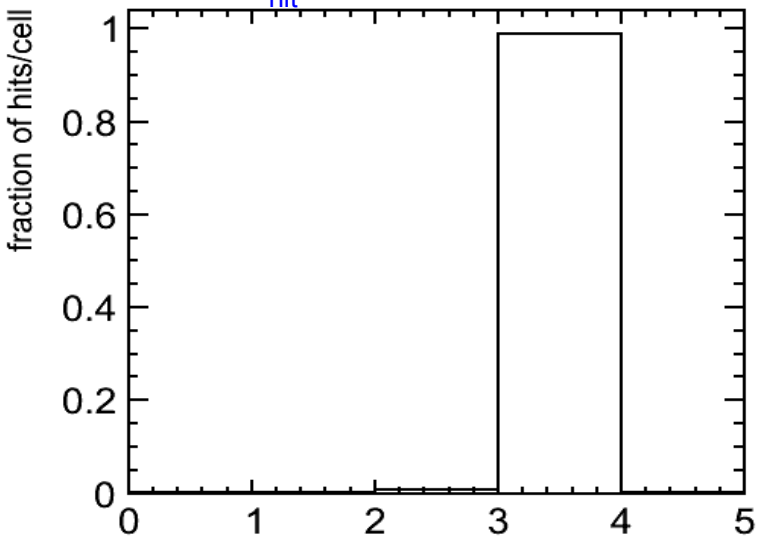
If the Hit is flagged as FEM:
•85% of other subhits are FEM too
•Less than 10% are of other processes
•Remaining divided between the three neutronic processes

Flag ambiguity

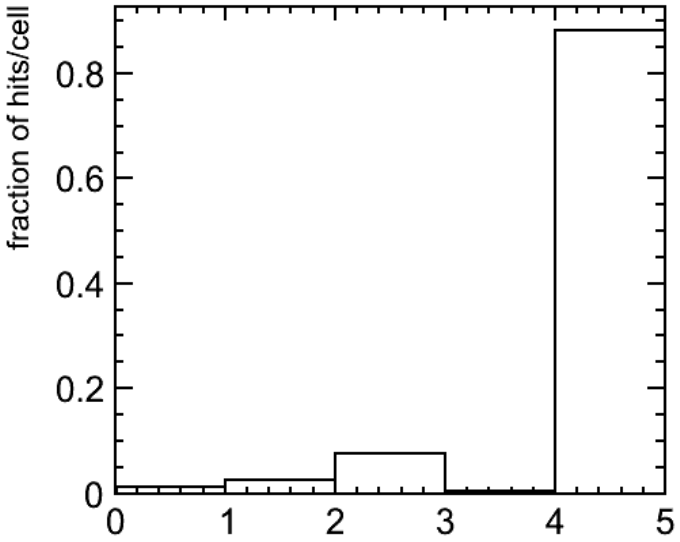
$flag_{hit}$ = Neutron Elastic



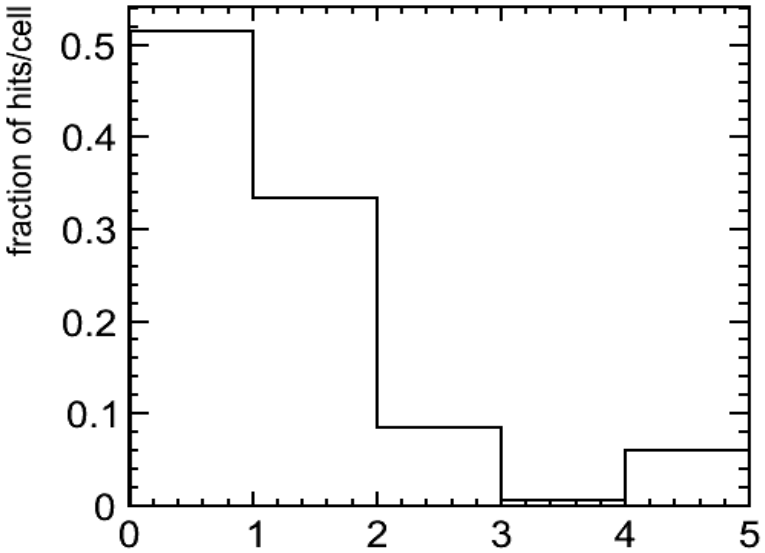
$flag_{hit}$ = Neutron Capture



$flag_{hit}$ = Neutron Inelastic



$flag_{hit}$ = Other process

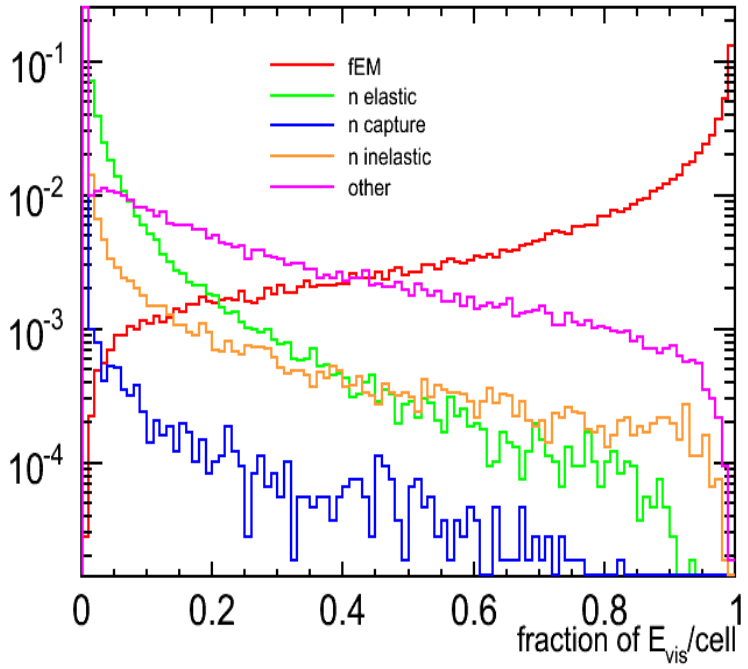


0 = Other process
1 = FEM
2 = Neutron Elastic
3 = Neutron Capture
4 = Neutron Inelastic

Flag ambiguity: Energy Fraction

For each Hit all the subhit fractions contributing to the Hit are counted:

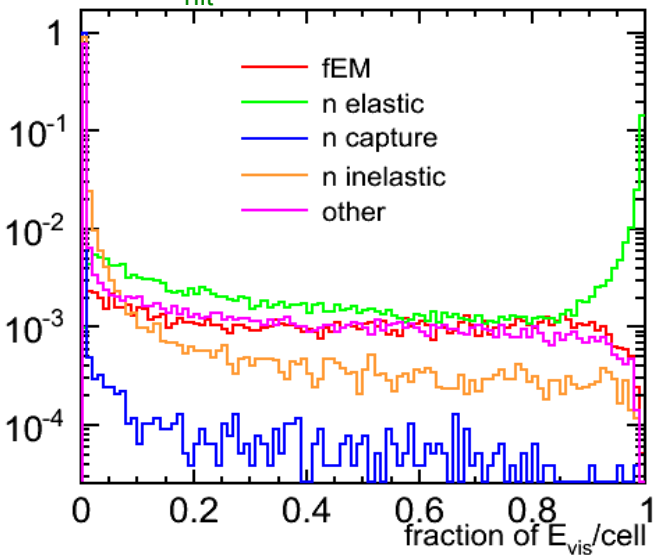
$flag_{hit}$ = FEM



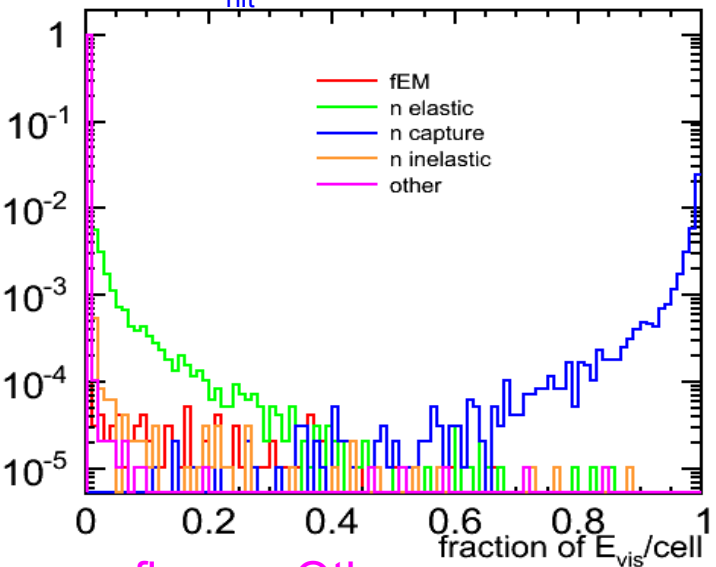
If the Hit is flagged as FEM:
- Majority of Hit Energy is FEM
- Small fraction of other processes
- Remaining divided between the three neutronic processes

Flag ambiguity

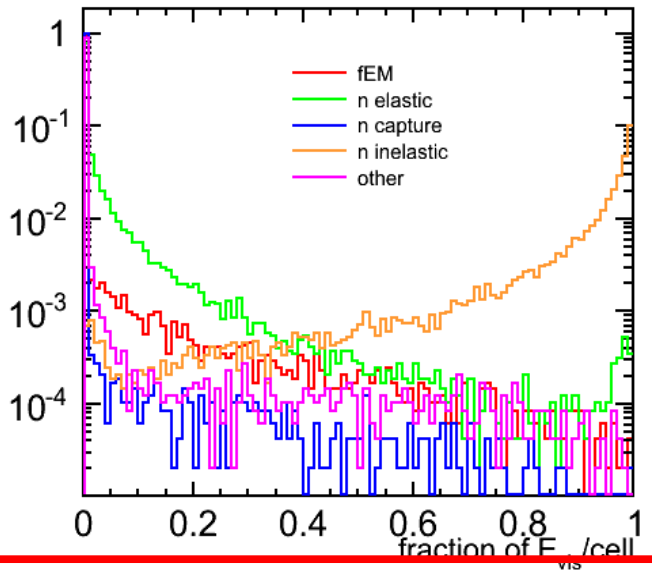
flag$_{hit}$ = Neutron Elastic



flag$_{hit}$ = Neutron Capture



flag$_{hit}$ = Neutron Inelastic



flag$_{hit}$ = Other process