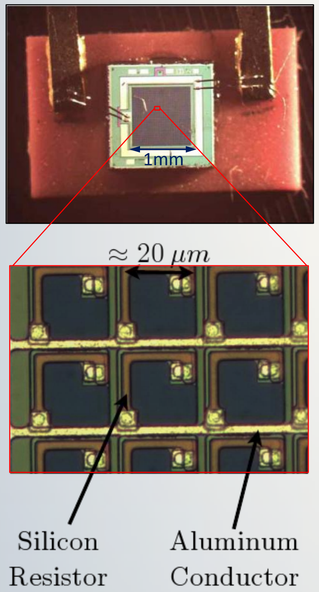
RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

Silicon Photomultipliers in High Resolution Detectors

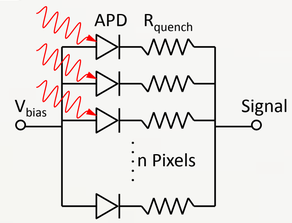
KIRCHHOFF-
INSTITUT
FÜR PHYSIK

The Silicon Photomultiplier (SiPM)

SiPM

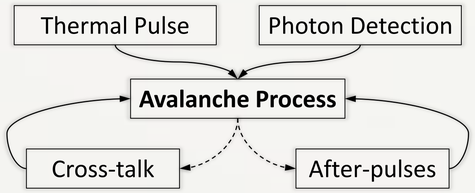


Working principle:
- Array of pixels (typ. 100 -2000 per mm^2)
- Pixel signal independent of #photons
- Pixels connected to common output
- #detected photons ↔ #fired pixels



Properties:
- High gain
- High detection efficiency
- Compact size
- Insensitive to B-fields
- Low operating voltage
- Noise:
  - Dark-rate
  - Optical cross-talk
  - After-pulses
- Non-linear response
- Temperature dependence

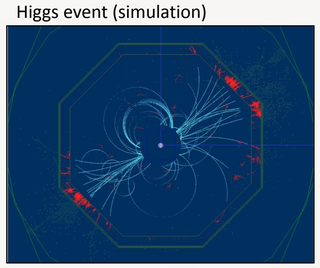
Signal Generation:



- SiPM response is complex:
  - Correlated & uncorrelated noise
  - Pixel recovery effects
  - Depends on light spot properties

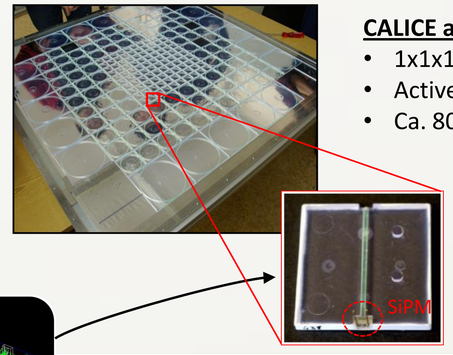
Calorimetry at the ILC

Higgs event (simulation)



ILC:
- Precision measurement of LHC physics (Higgs, BSM,...)
- Requires new generation of detectors
- Goal for calorimetry: Jet-Energy resolution $30\%/\sqrt{E}$
  ⇒ Highly granular "imaging" calorimeter

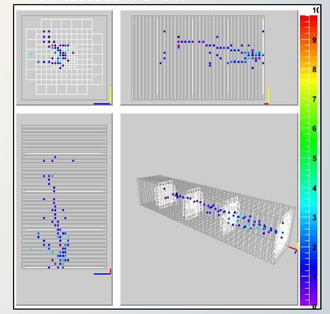
AHCAL Active layer

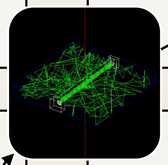


CALICE analogue hadronic calorimeter:
- 1x1x1m3 prototype
- Active layer: Scintillator tiles + *SiPM readout*
- Ca. 8000 channels

Simulation efforts:
- Timing studies
- Study saturation correction
- Optimise tile characterisation

Pion testbeam event



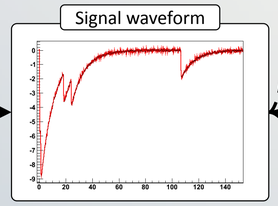


SiPM Simulation Framework

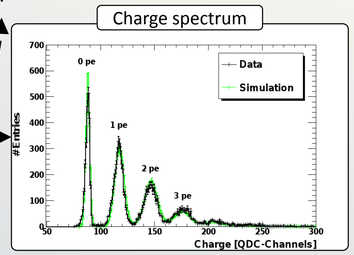
SiPM parameters

Light spot properties or Geant4

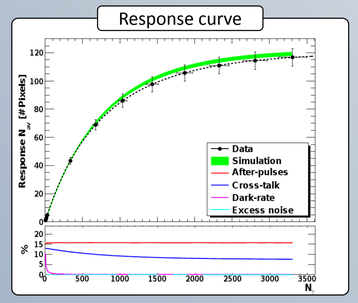
GosSiP
Generic framework for the simulation of Silicon Photomultipliers

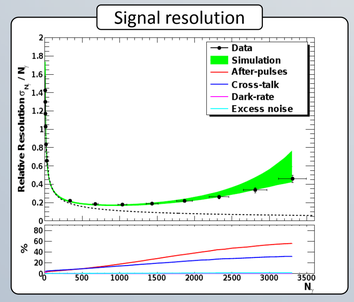


rates
timing
noise



- Detailed SiPM simulation
- Arbitrary sensors & operation conditions
- Can be combined with Geant4
- Excellent model for the whole dynamic range:



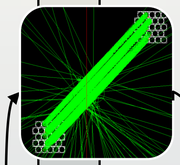


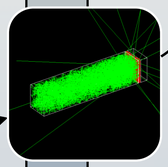
Simulation applications:
- Generic SiPM studies:
  - *Sensor properties / behaviour*
  - *Optimise operation conditions*
- Detector development:
  - *Integrate GosSiP in detector simulation*

  ⇒ *Detector optimisation*

  ⇒ *Performance studies*

  ⇒ *Etc...*



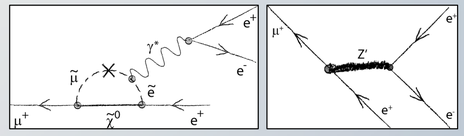


The Mu3e Experiment

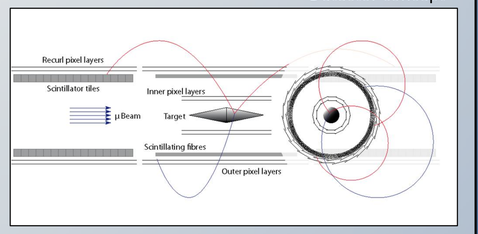
Mu3e:
- Search for lepton flavour violating decay μ→eee
- "Forbidden" in Standard Model (BR≈10^{-50})
- Observation would be clear sign for new physics!
- *Goal:* measure branching ratio with 10^{-16} sensitivity

  ⇒ 1GHz muon beam @ PSI

$$L_{LFV} = \frac{m_\mu}{(\kappa+1)\Lambda^2} A_R \bar{\mu}_R \sigma^{\mu\nu} e_L F_{\mu\nu} + \frac{\kappa}{(\kappa+1)\Lambda^2} (\bar{\mu}_L \gamma^\mu e_L)(\bar{e}_L \gamma^\mu e_L)$$



Detector concept



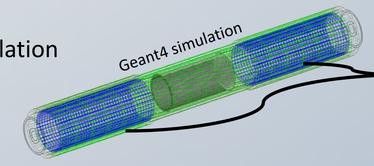
Detector concept:
- Tracking detectors (Δp<1MeV) :
  - HV-MAPS
- Timing detectors:
  - Scintillating fibres + SiPM readout (Δt<1ns)
  - Scintillating tiles + SiPM readout (Δt<100ps)
- *Challenge*: high efficiency & excellent resolution at high rates

Simulation efforts:
- Complete Geant4 + SiPM simulation

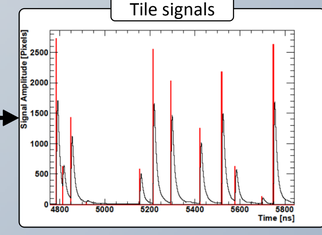
⇒ Optimize detector geometry

⇒ Optimize SiPM readout

⇒ Predict detector performance



Tile signals



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