CALICE
Calorimeter for ILC

Calorimeter R&D for Future Calorimeters

Characterisation of Silicon Based Photomultipliers

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Development and Application of Intelligent Detectors

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Forschungsgemeinschaft
DFG

Outline

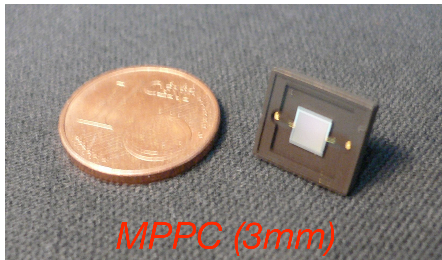
- Photodetectors & the Silicon Photomultiplier
- Two Applications:
  - Calorimetry
  - Positron Emission Tomography
- Characterisation of Silicon Photomultipliers

Photodetectors

- **Photomultipliers:**
  - High Gain *(G = 10^6)*
  - High operation voltage *(few KV)*
  - Bulky, sensitive to magnetic fields
- **Photodiodes, Avalanche Photodiodes (APDs)**
  - Low Gain
  - Compact & insensitive to magnetic fields
- **Silicon Photomultiplier**
  - High Gain *(G = 10^5-10^6)*
  - Low operation voltage *(HV<100V)*
  - Compact & insensitive to magnetic fields

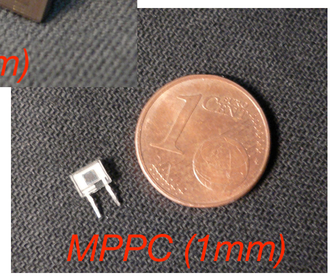
→ **Many application fields**

Photomultipliers



MPPC (3mm)

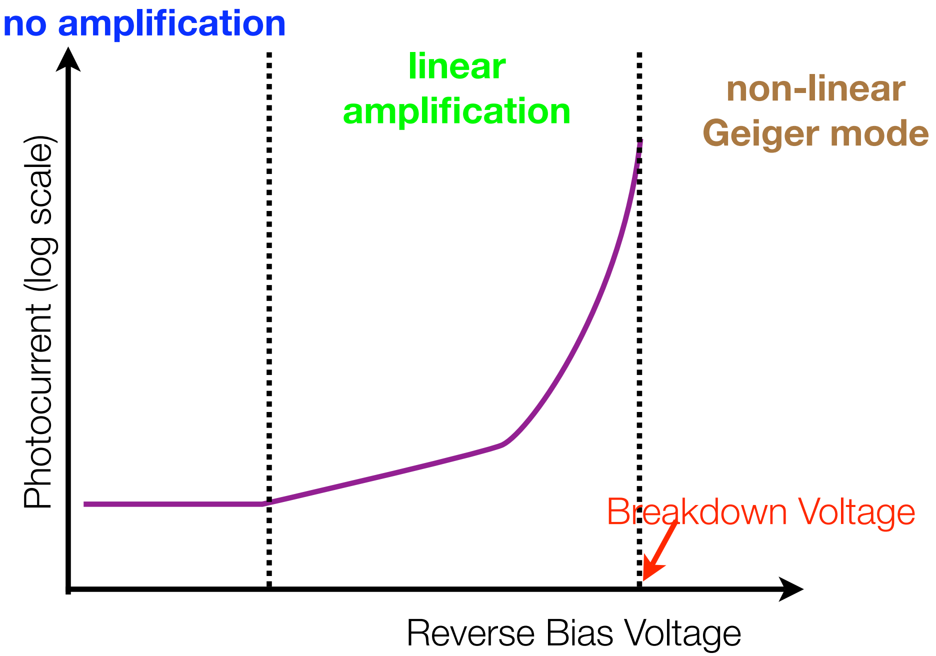
SPM

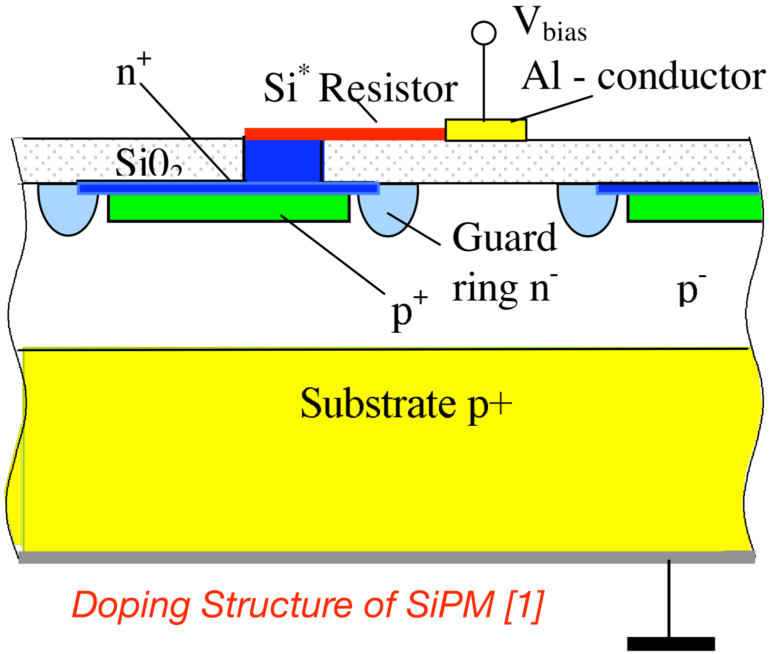


MPPC (1mm)

Silicon Photomultiplier: Geiger Mode

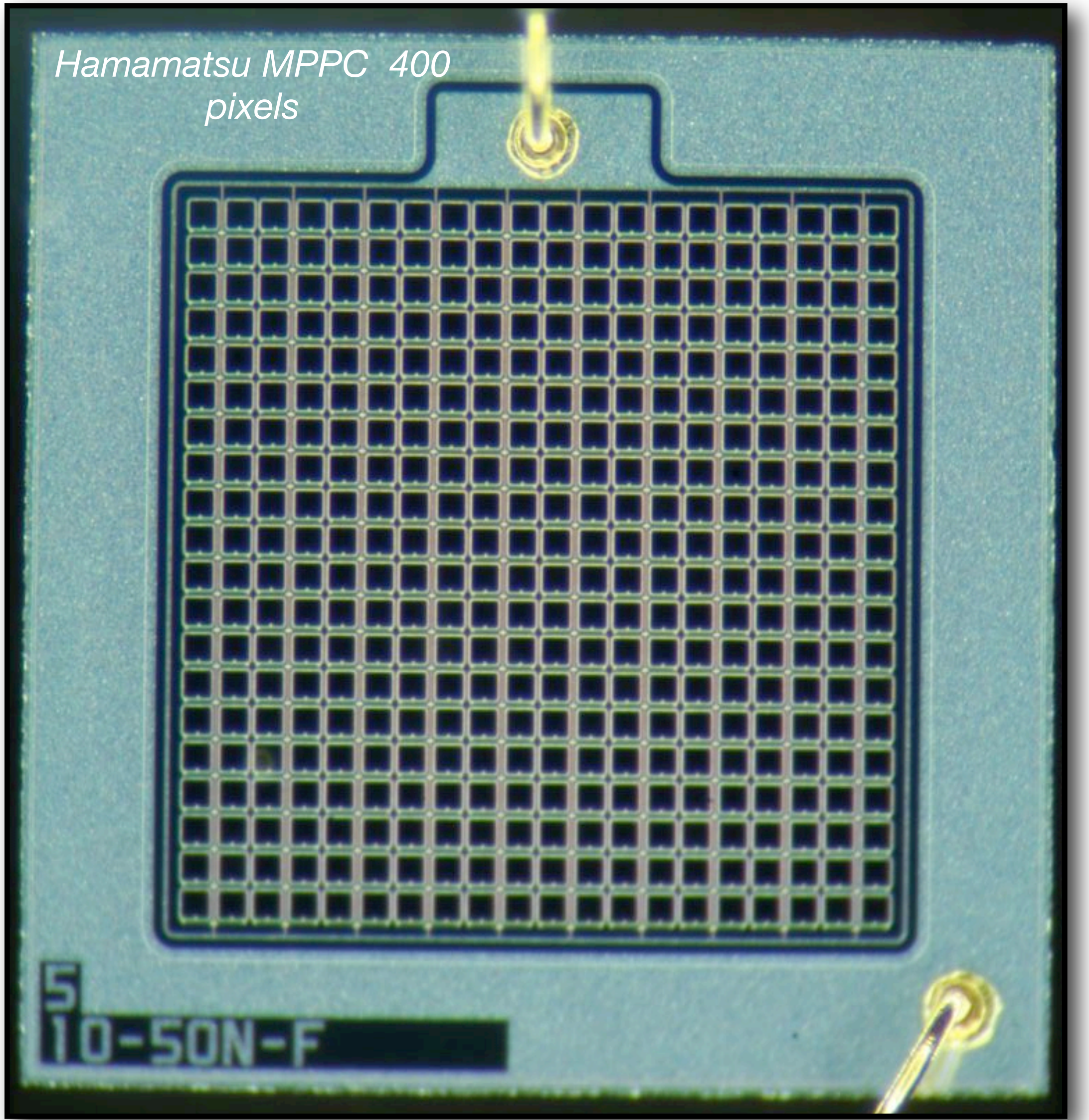
- **Pixels operated in Geiger mode** *(non-linear response)*





Doping Structure of SiPM [1]

Silicon Photomultiplier: Linearity

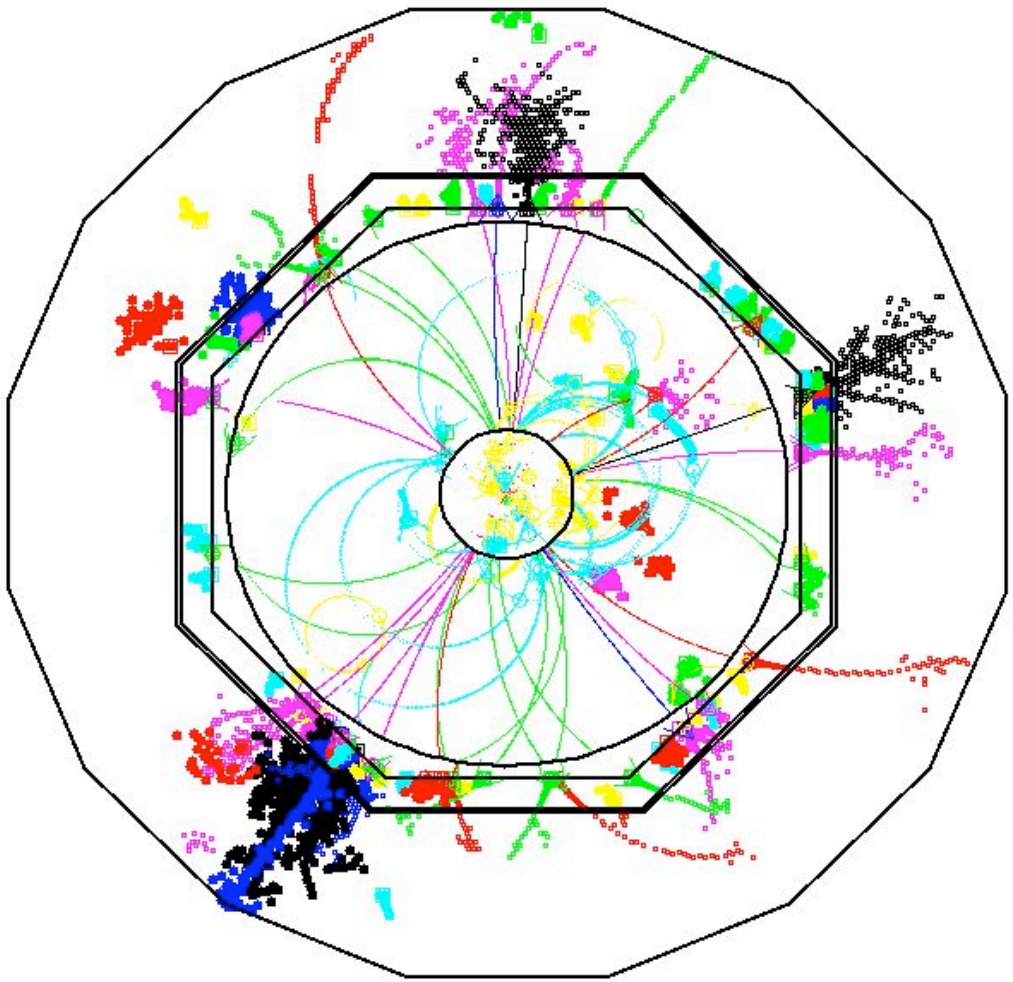


- **Signal:** $S = \sum s_{pixel}$
- **Linear response for $N_{ph} << N_{pix}$**
  (typical: N_{pix}=1000/mm^2)

Application: Two Examples

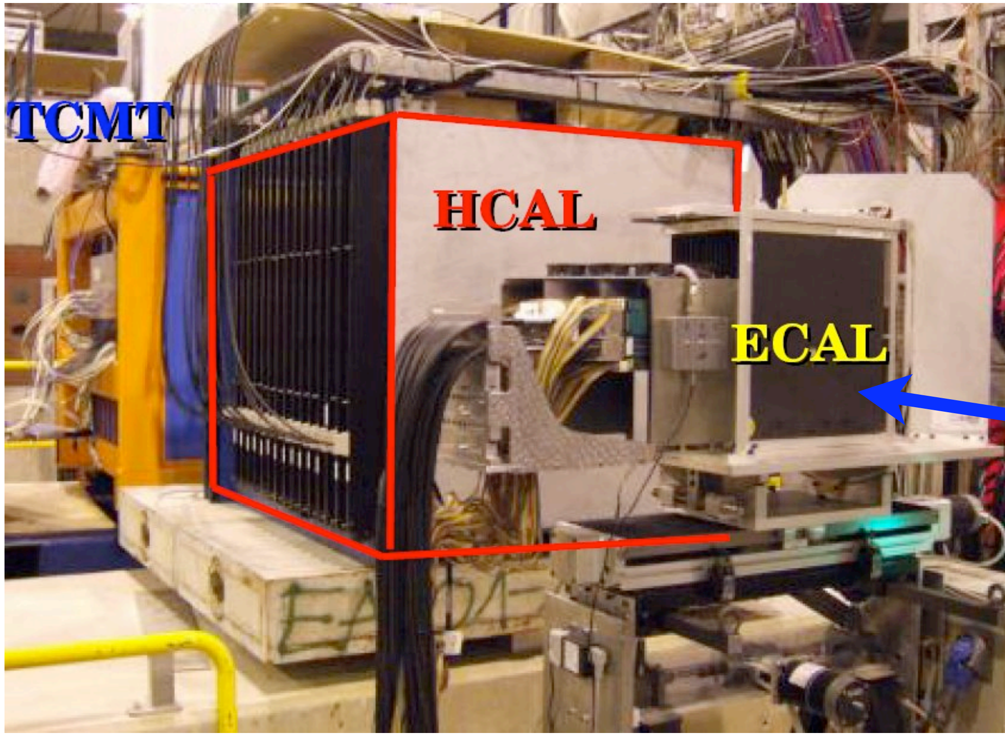
Imaging Calorimeter

- Jet energy resolution improvement
- Isolate neutral from charged components ➔ High granularity!
- Insensitivity to magnetic fields ➔ SiPM
- Not just a concept! ➔ Prototype



Particle detector profile
ILC LDC concept

Analogue Hadronic Calorimeter Prototype (CALICE)

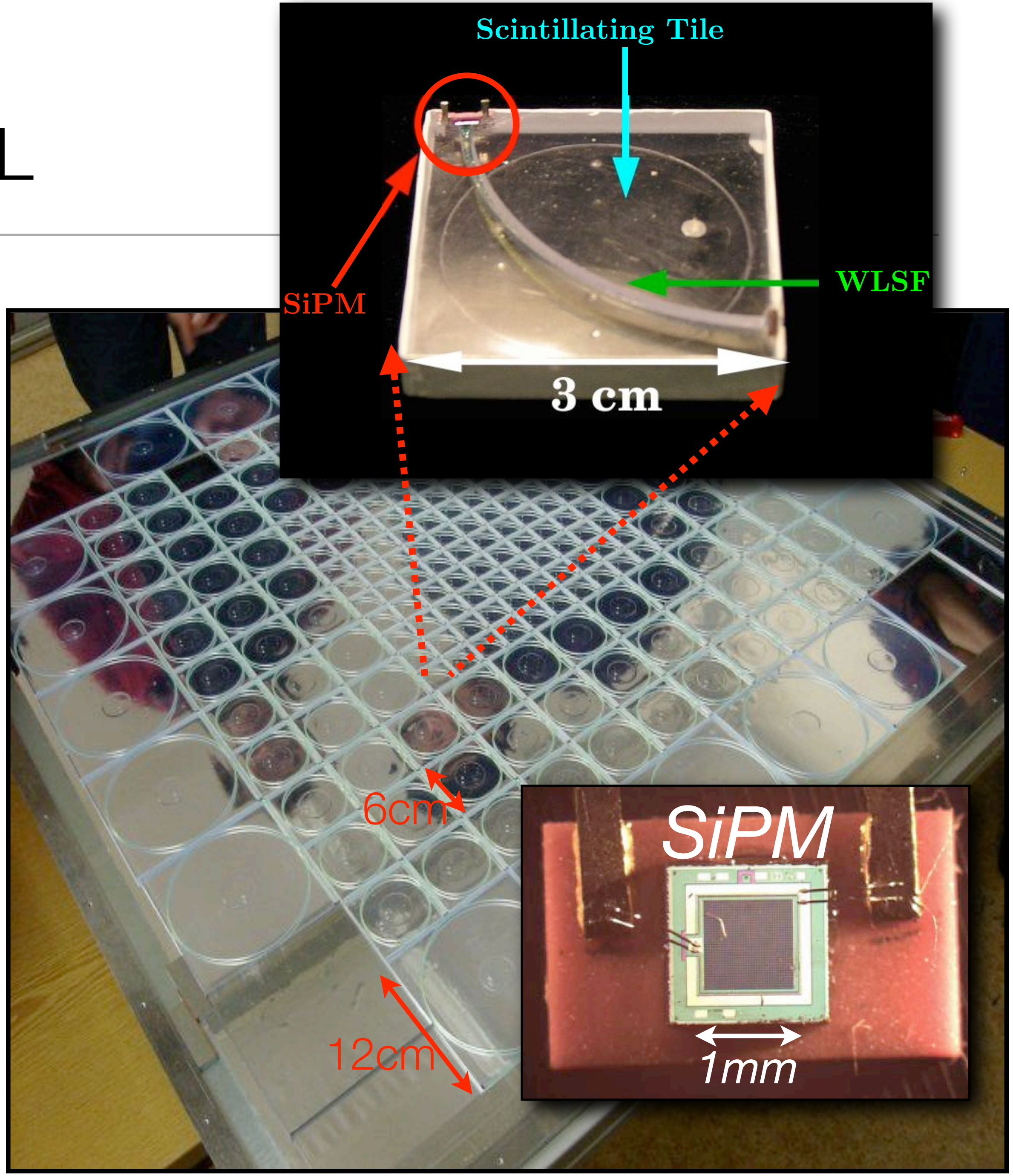


Beam Direction

- 1m^3 physics prototype
  (steel-scintillator sandwich, 2cm steel, 0.5cm scint.)
- Test beam at CERN and FNAL
- HD: Test-beam activities, SiPM calibration, readout electronics

One Layer of the HCAL

- High granularity
  centre: 3x3x0.5 cm^3
- Organic scintillator
  (blue emission)
- SiPM readout
  Green sensitive →
  wavelength shifting fibre (wlsf)
- Possible: MPPCs
  Blue sensitive →
  direct readout without wlsf



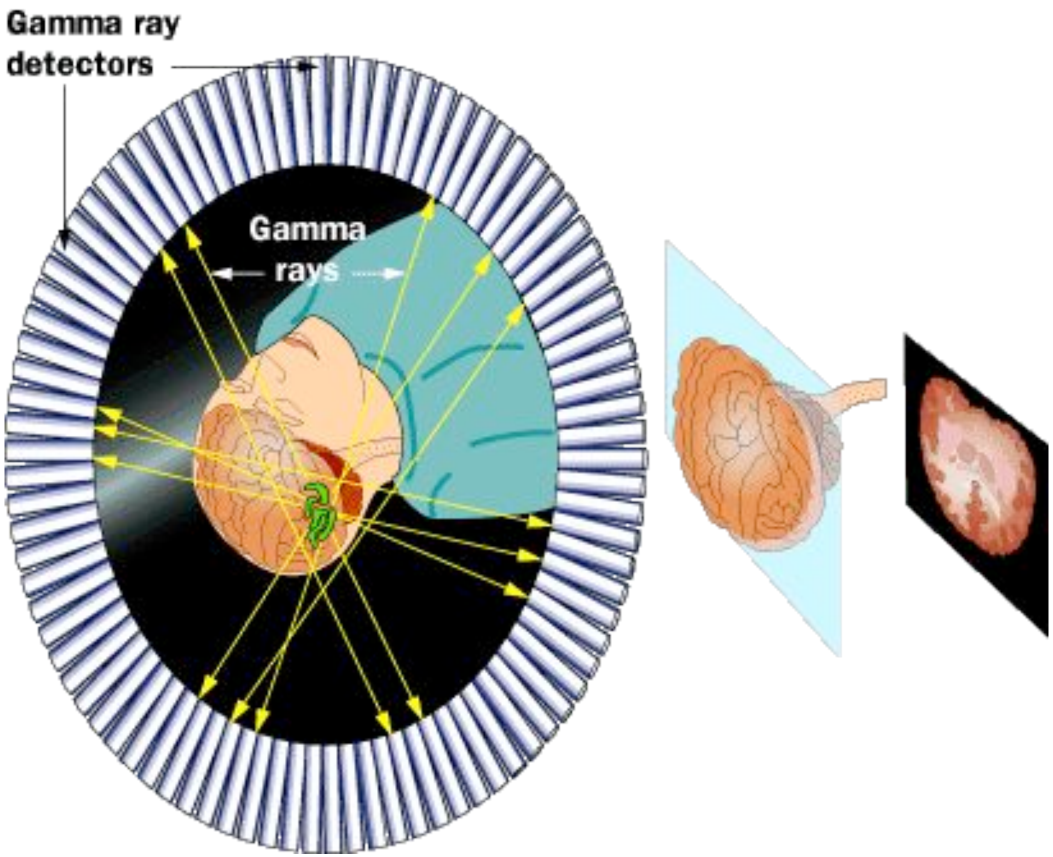
Positron Emission Tomography

- Positron Emitting Nuclei
  (^{11}C, ^{13}N, ^{15}O, ^{18}F)

- Coincidence events
  ➜ Line of Response

- Background Reduction
  - Energy Resolution
  - Timing Resolution

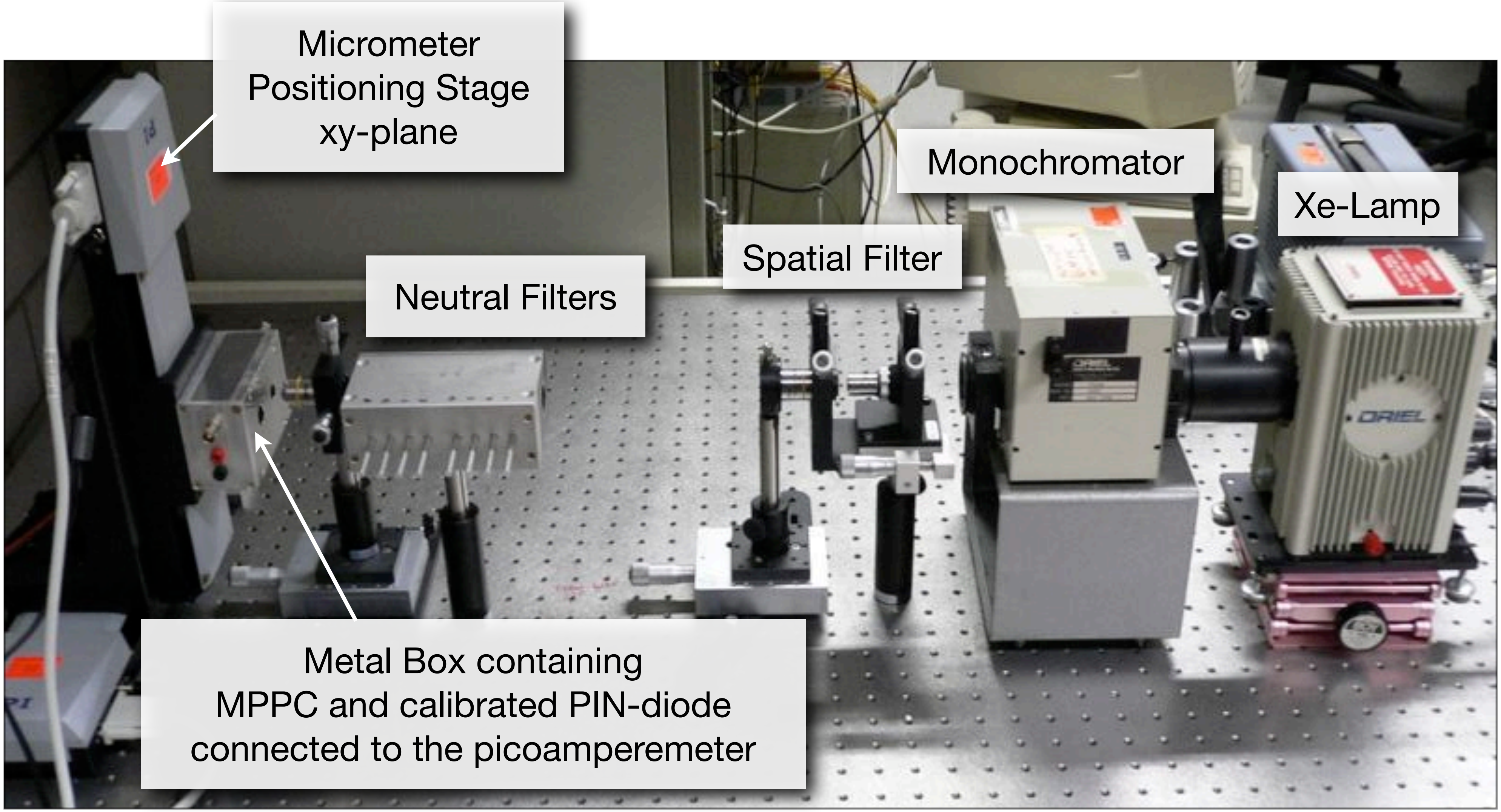
- Use MPPCs:
  - Blue sensitiveness ➜ LSO
  - Compactness (spatial resolution)
  - Insensitivity magnetic field (PET+MRI)



Characterisation of SiPMs

- Test stand for SiPM measurements
  - Gain
  - Dark-rate
  - Photon Detection Efficiency
  - Uniformity tests
- PET Application
  - Energy & Timing

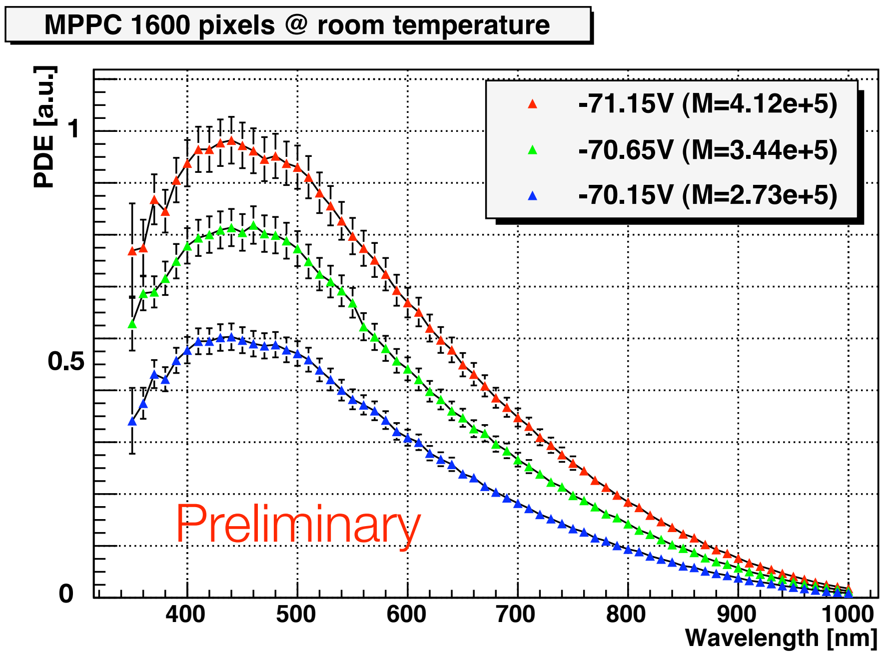
Photon Detection Efficiency Measurements

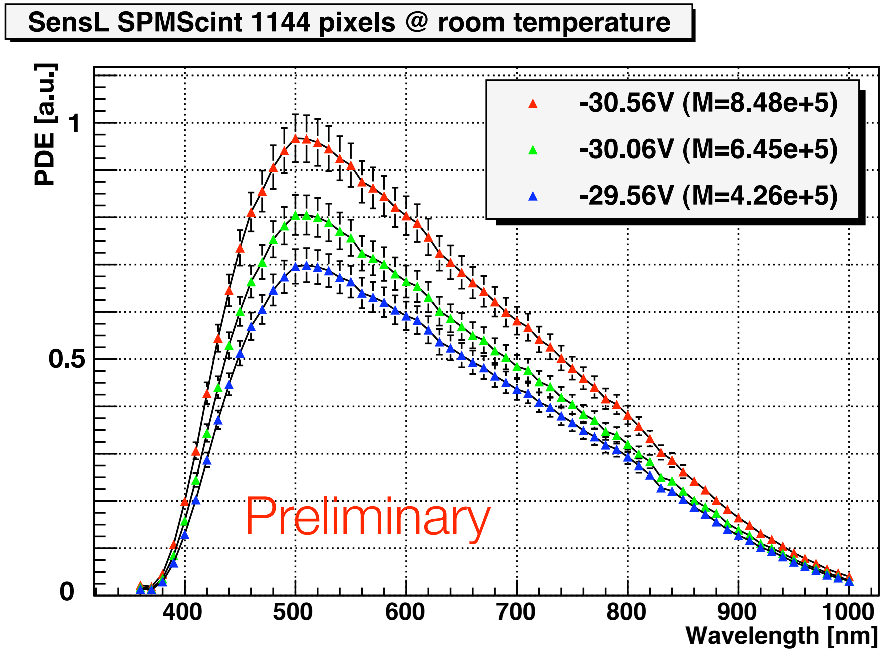


$$\boxed{PDE = f(I_{SiPM}, I_{PIN}, Gain, f_{calib})}$$

PDE Measurement Results

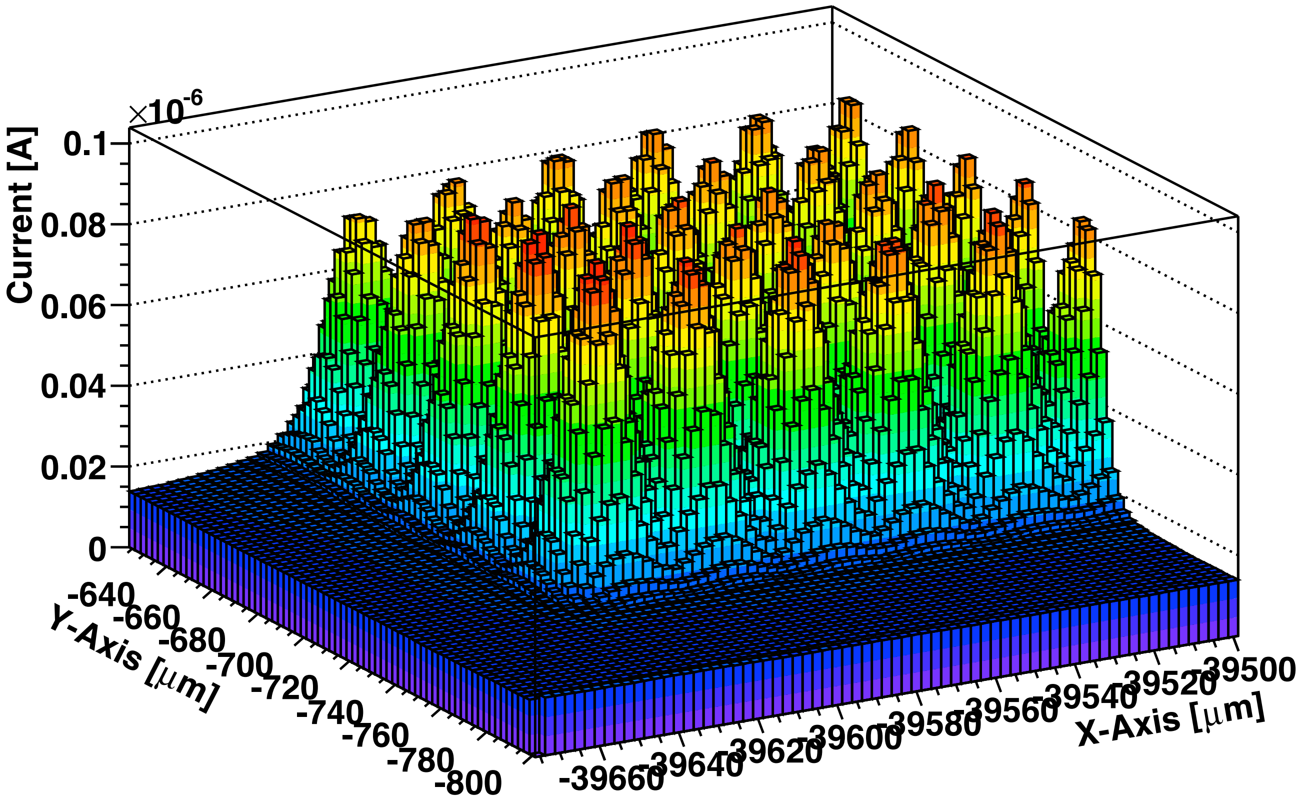
- MPPC: blue sensitive
- SensL SPMScint: green sensitive
- Further investigation necessary
  (crosstalk, after-pulses, dc light source, systematic errors)





Uniformity Tests

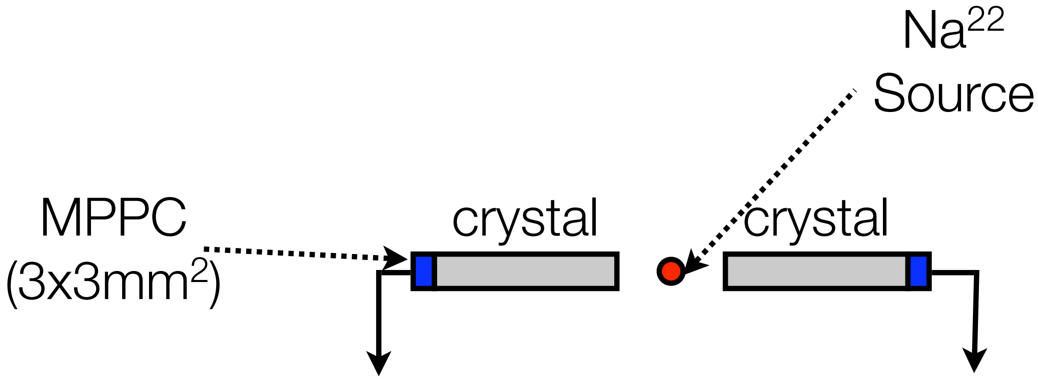
- Automated surface scar with small light spot
- Single pixels can be resolved
- Tool for uniformity tests
- Future: Single pixel characterisation



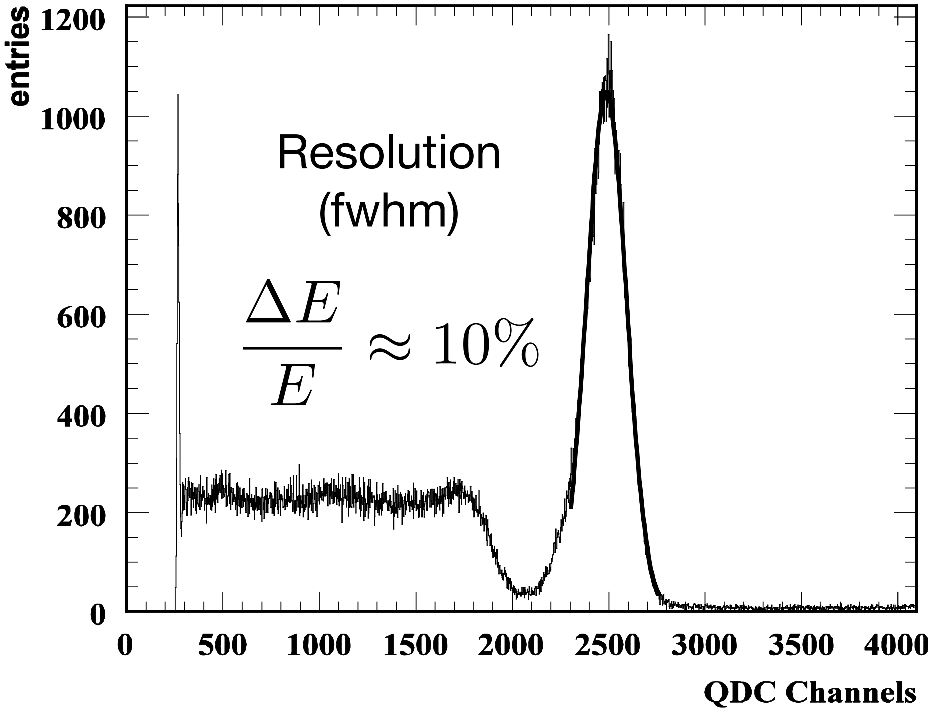
Hamamatsu MPPC 1600 pixels 25μm pitch

PET: Energy & Timing

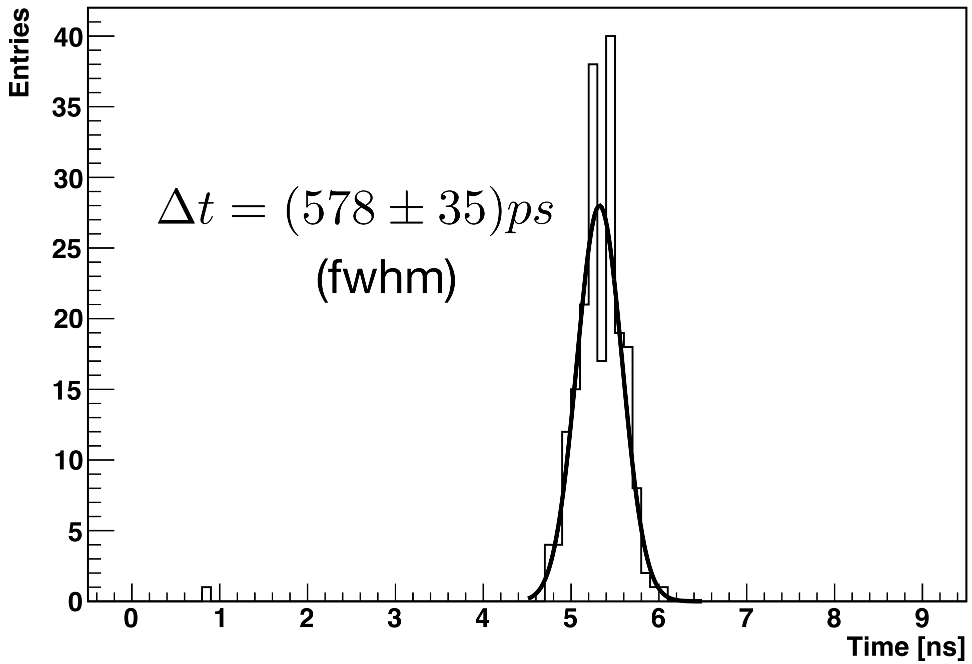
Co-operation with DESY



Energy Spectrum LSO



Timing Resolution



- Energy Resolution competitive to PMT readout (LSO: 10%, LFS : 11%)

- Timing resolution of 578ps

Conclusion

- **R&D for SiPM use in future detectors:**
    - Characterisation setup ready for testing
      Gain, dark-rate and PDE measurements (350 - 1000nm)
    - Accurate positioning → single pixel measurements
      recovery time, crosstalk, PDE without geometrical effects
- **Future Plans:**
    - Development of infrastructure allowing large scale quality assurance tests
    - PET-prototype in co-operation with DESY