The DarkMESA Detector System

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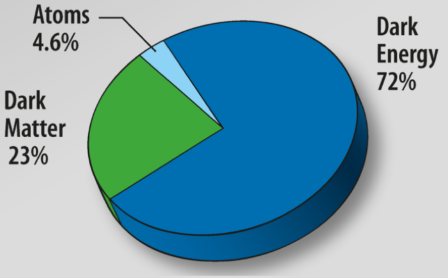
Outline

- Introduction to DarkMESA
- Material Studies at MAMI
- Prototype Calorimeter
- Prototype Veto Detector
- Summary and Outlook

DarkMESA

Motivation and basics of the experiment



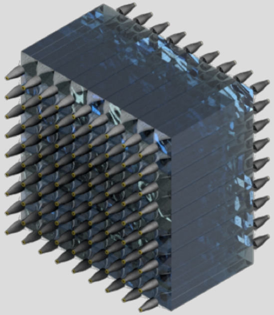
Possible model: SM matter interacts with DM through a massive Dark Photon

Parameters: coupling constants ε, a_D and DM masses $m_\gamma > 2m_\chi$

DarkMESA

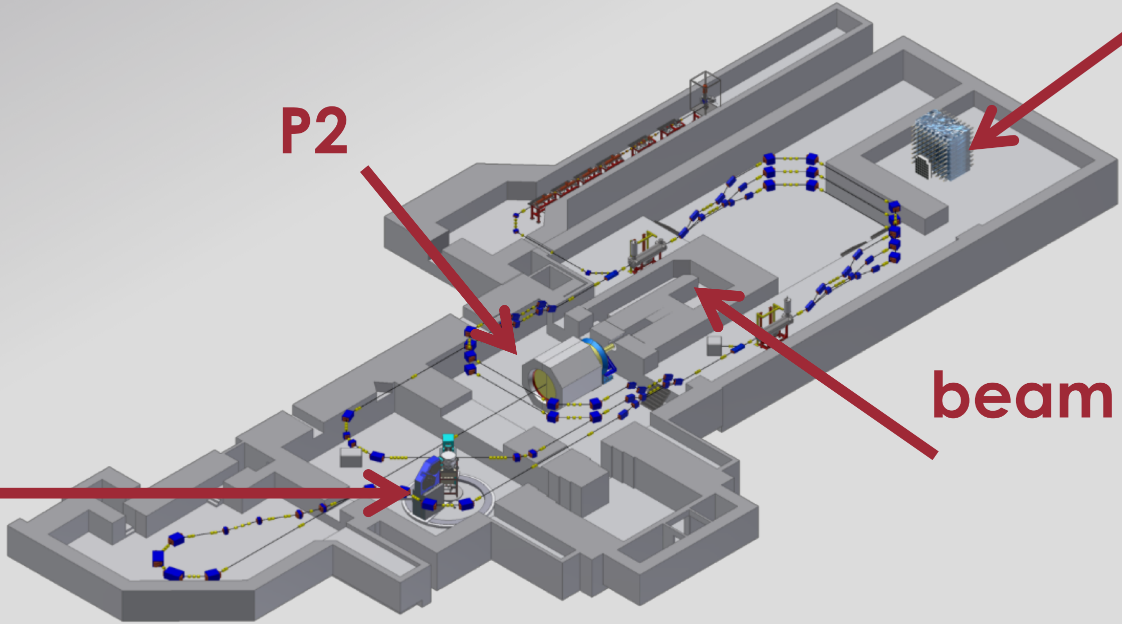
Motivation and basics of the experiment

DarkMESA



P2

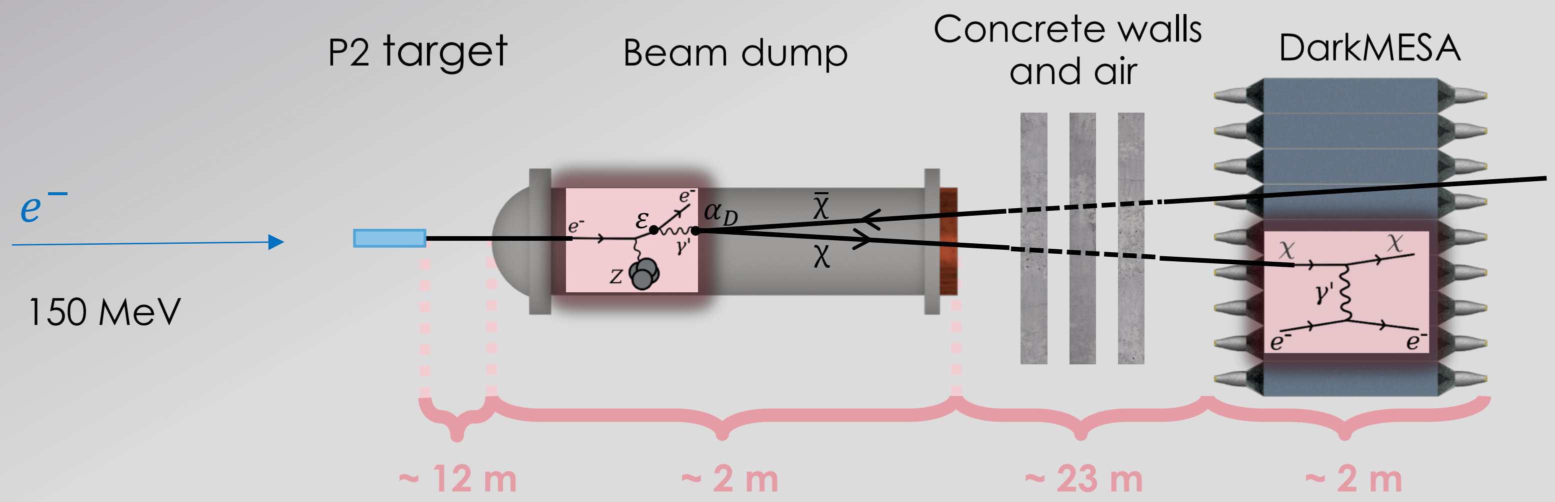
MAGIX



beam dump

DarkMESA

Motivation and basics of the experiment



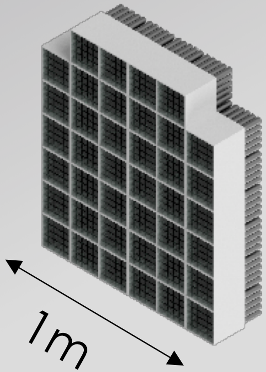
Calorimeter for Beam Dump Experiment (DarkMESA)

→ Detector needs to be able to detect low-energy recoil electrons

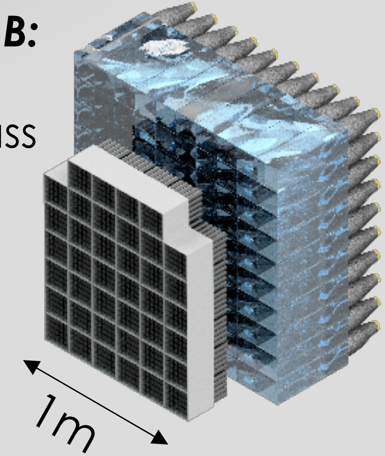
DarkMESA – Staged Approach

Motivation and basics of the experiment

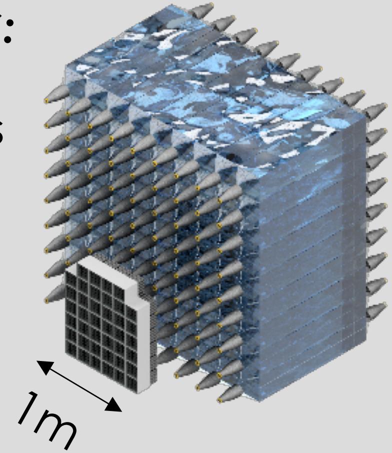
Stage A:
0.13 m^3
PbF_2



Stage B:
+ 1 m^3
Pb glass



Stage C:
+ 10 m^3
Pb glass



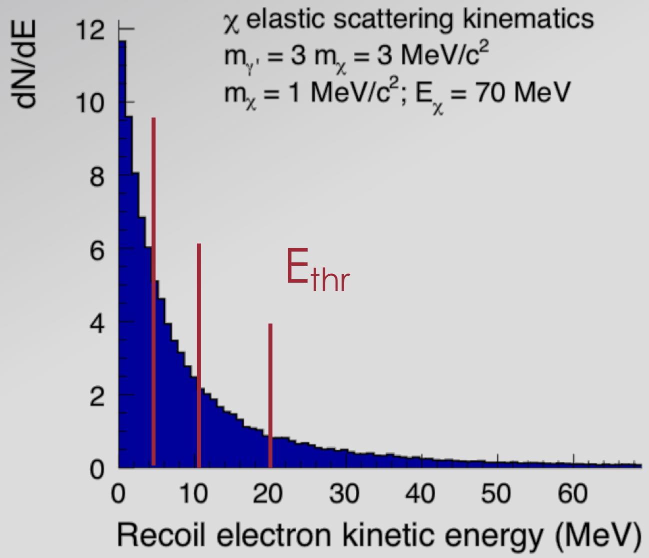
~1000 crystals from
former A4 experiment

Expansion of the active volume

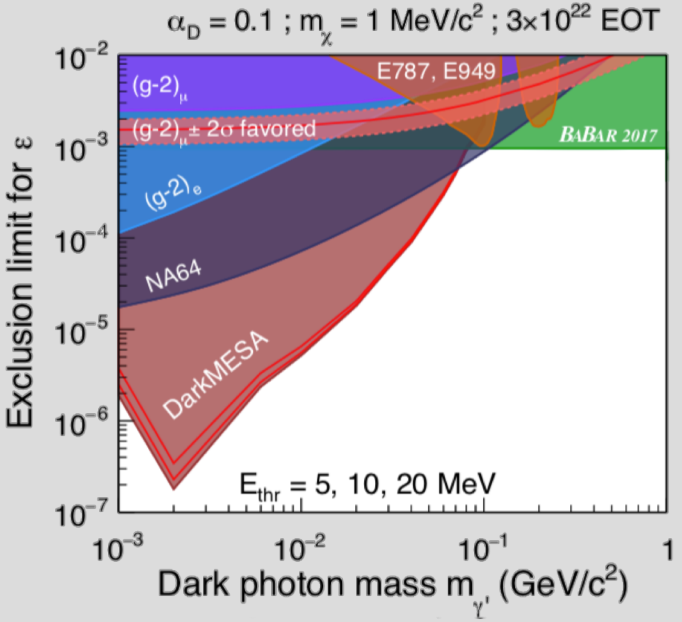
DarkMESA

Motivation and basics of the experiment

What kind of recoil electrons are expected?



Experiment sensitivity



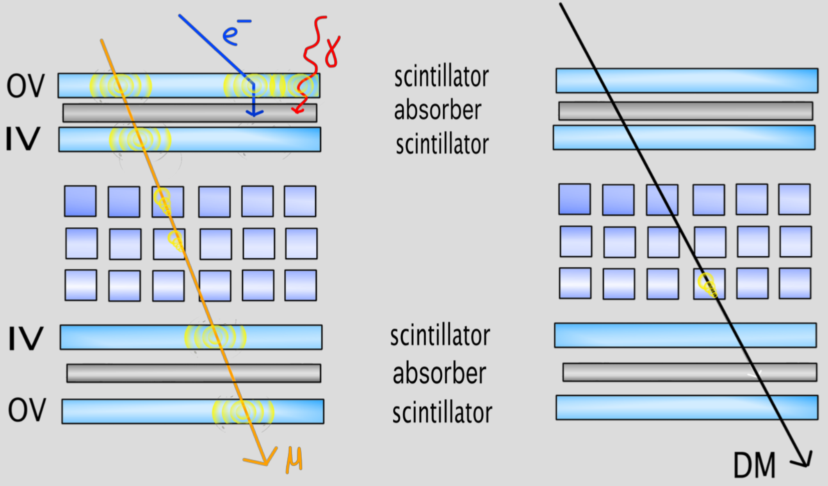
DarkMESA

Overview of experiment

What to measure?
→ Signals produced by DM in calorimeter crystals

What about background radiation?
→ Development of Veto Detector System with scintillator

OV = Outer Veto
IV = Inner Veto



Material Studies for the DarkMESA Calorimeter

MAMI beam time (Jul & Dec 2018)

Material Studies for the DarkMESA Calorimeter

Considered Material:

- PbF_2
- SF5
- SF6
- SF57HTUltra

Cherenkov Radiators

- CsI (Tl)
- BGO

Scintillator

Material Studies for the DarkMESA Calorimeter

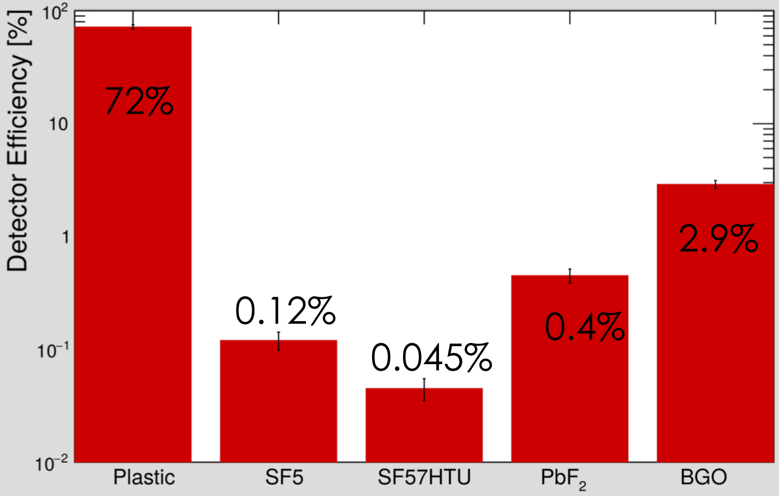
Material comparison:

Cherenkov

- lower sensitivity to background neutrons
- lower light yield
- fast
- directionalty

Scintillator

- higher light yield
- higher costs

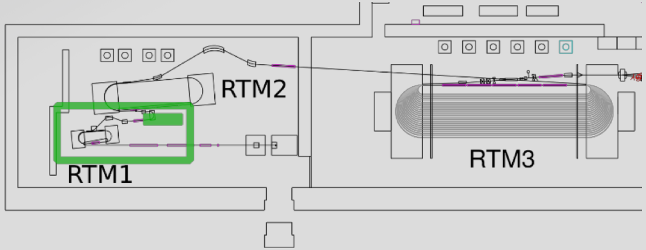


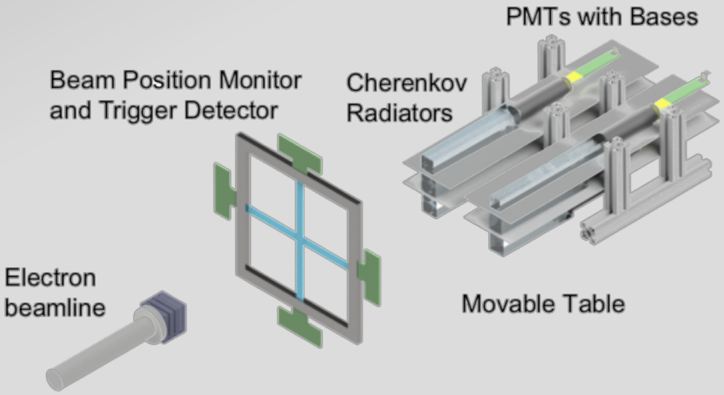
→ The neutron efficiency 10^{-3} compared to plastic

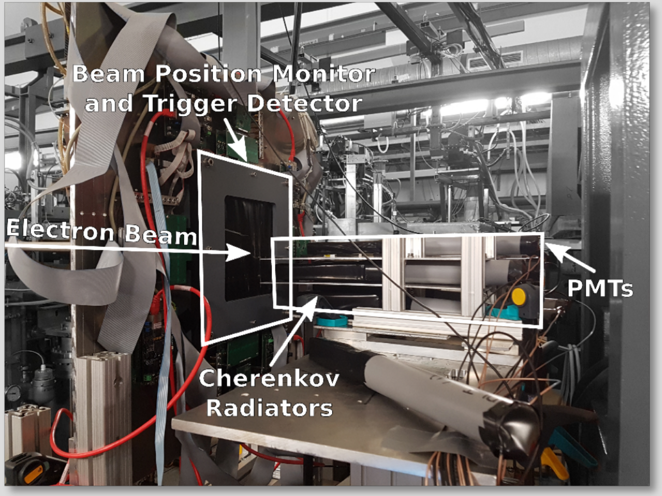
Material Studies for the DarkMESA Calorimeter

<u>Experimental setup:</u>

- 6 - 14 MeV electron beam at MAMI
- Fiber detector as trigger system
- calorimeter prototypes tested
- Energy spectra using *CAEN* QDC

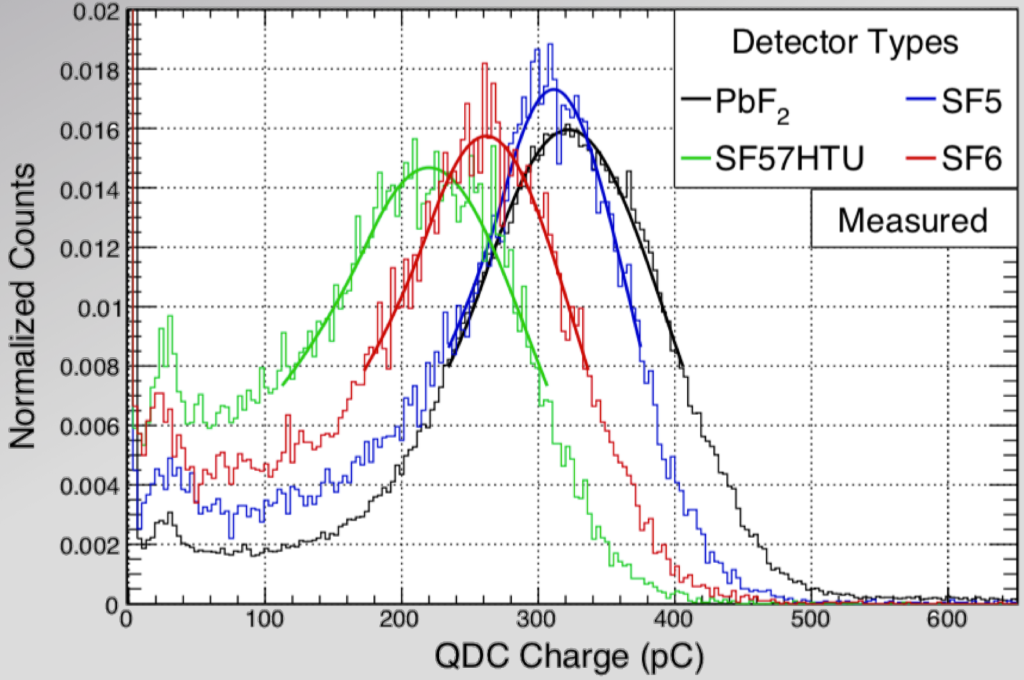






Material Studies for the DarkMESA Calorimeter

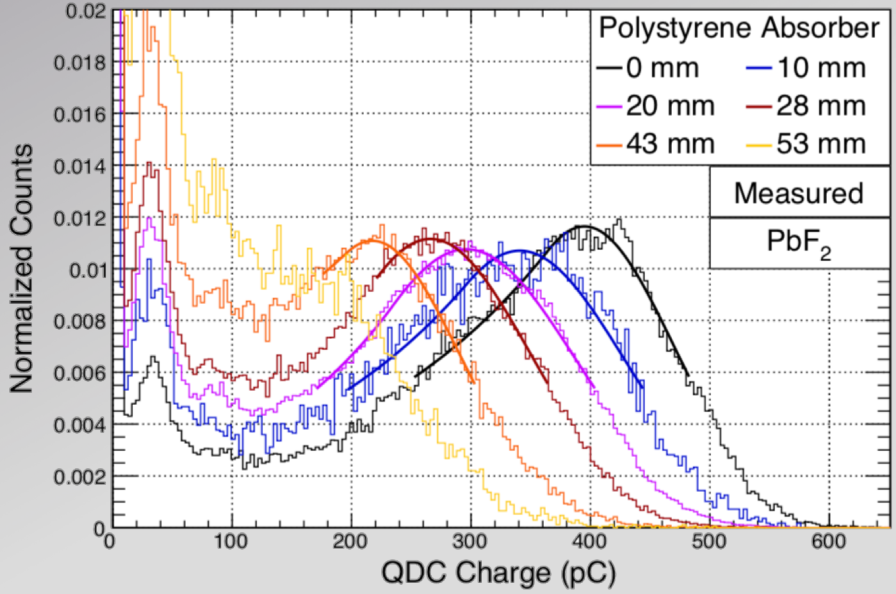
Different detector types



- PbF_2 has the highest light yield
- Out of the lead glasses SF5 performs best

Material Studies for the DarkMESA Calorimeter

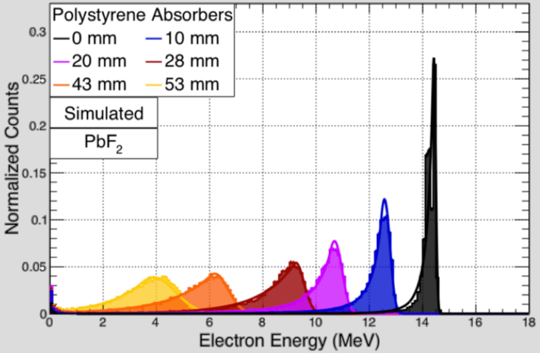
Different beam energies



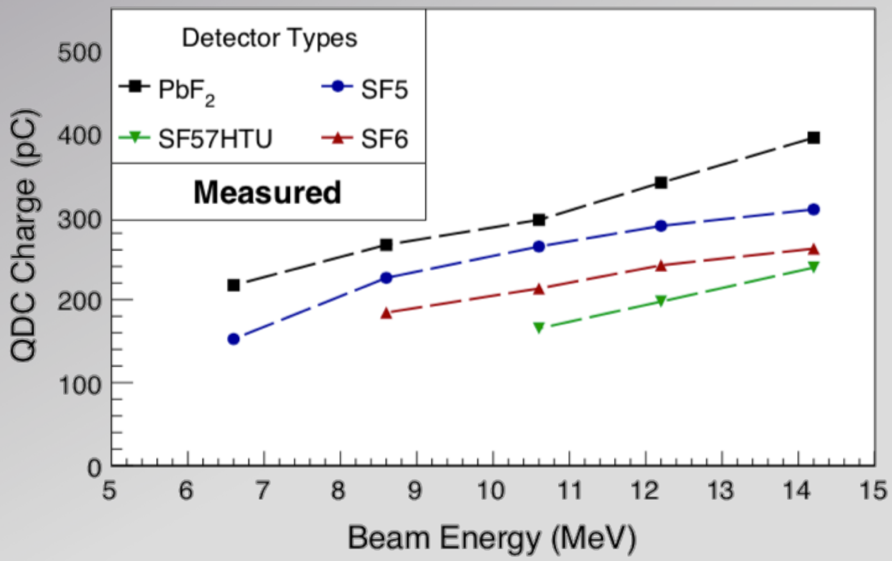
Varying absorber thicknesses

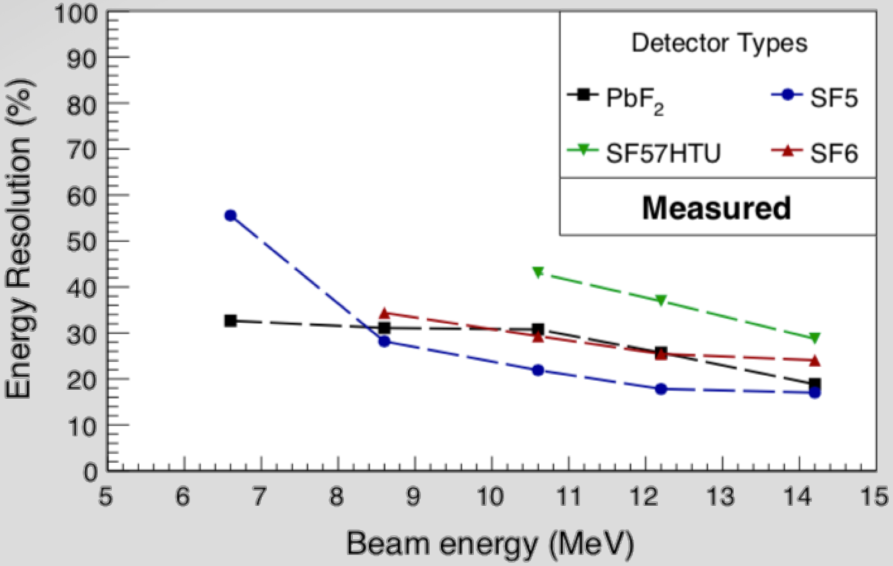
- signal well separated from noise
- signals can be resolved even for electrons below 10 MeV

Simulation



Material Studies for the DarkMESA Calorimeter





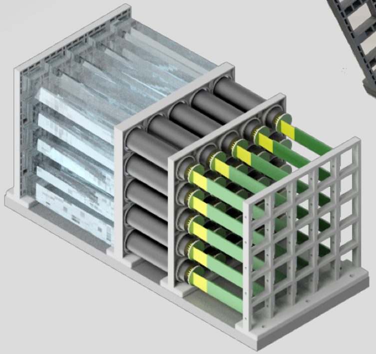
→ PbF_2 and SF5 offer the highest light yield and best energy resolution for electrons with 14MeV and below

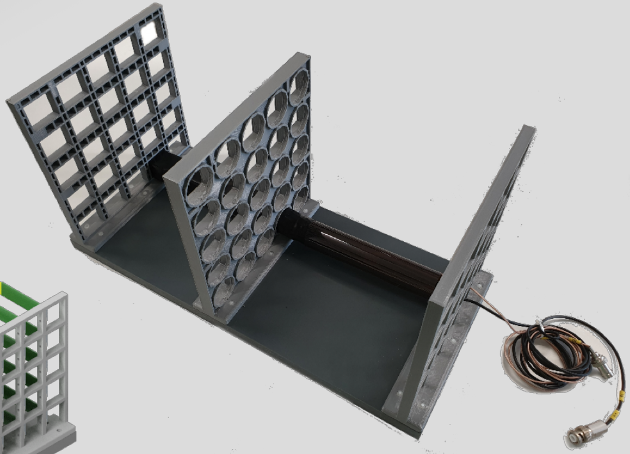
Prototype Calorimeter with Veto Detector

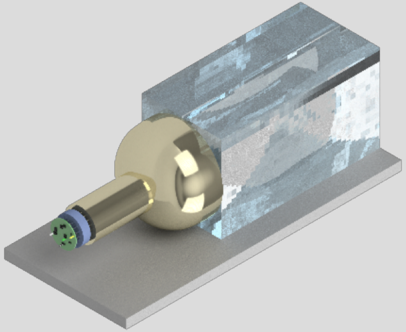
Construction & background studies

Calorimeter Prototype
Construction

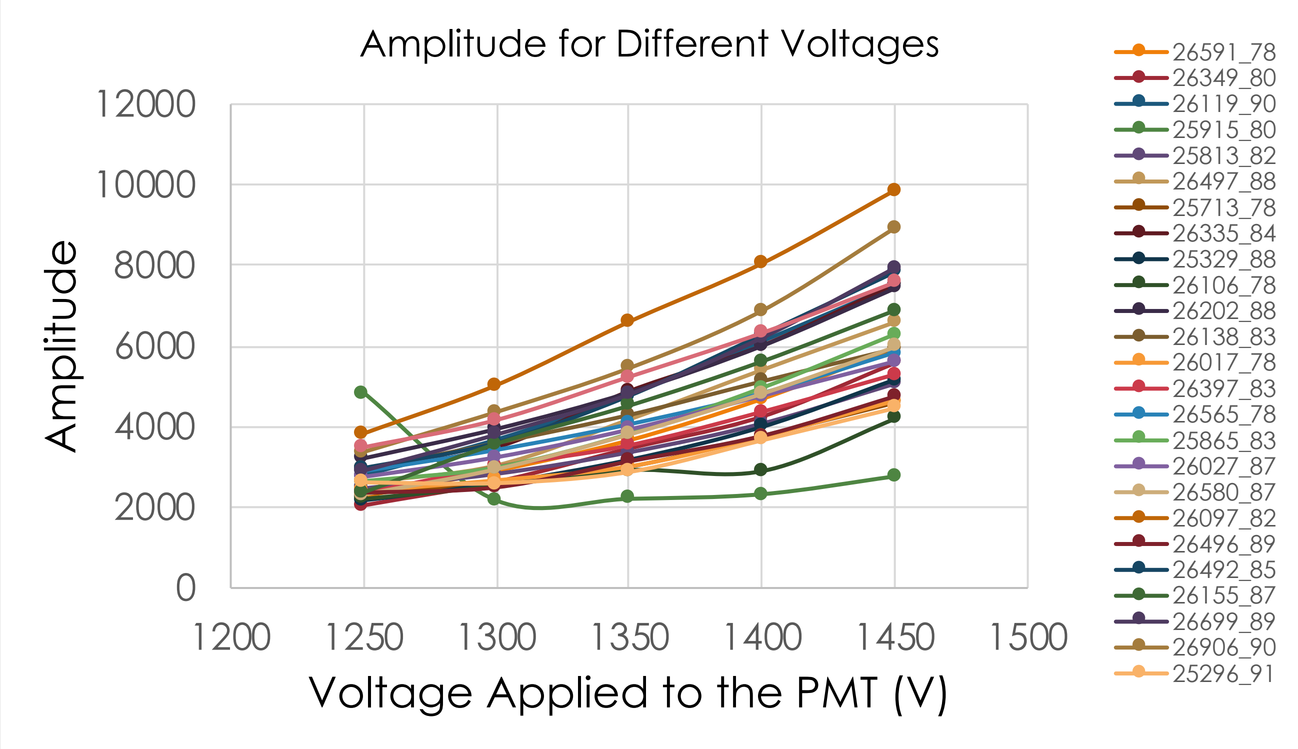
- 3d-printed construction for holding
- 25 lead fluoride crystals and the PMTs



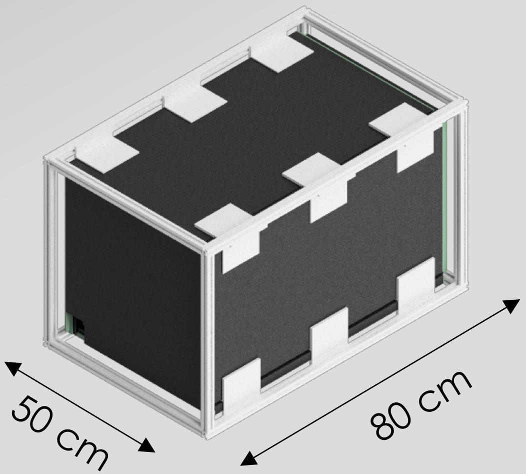




Calorimeter Prototype
Gain measurements

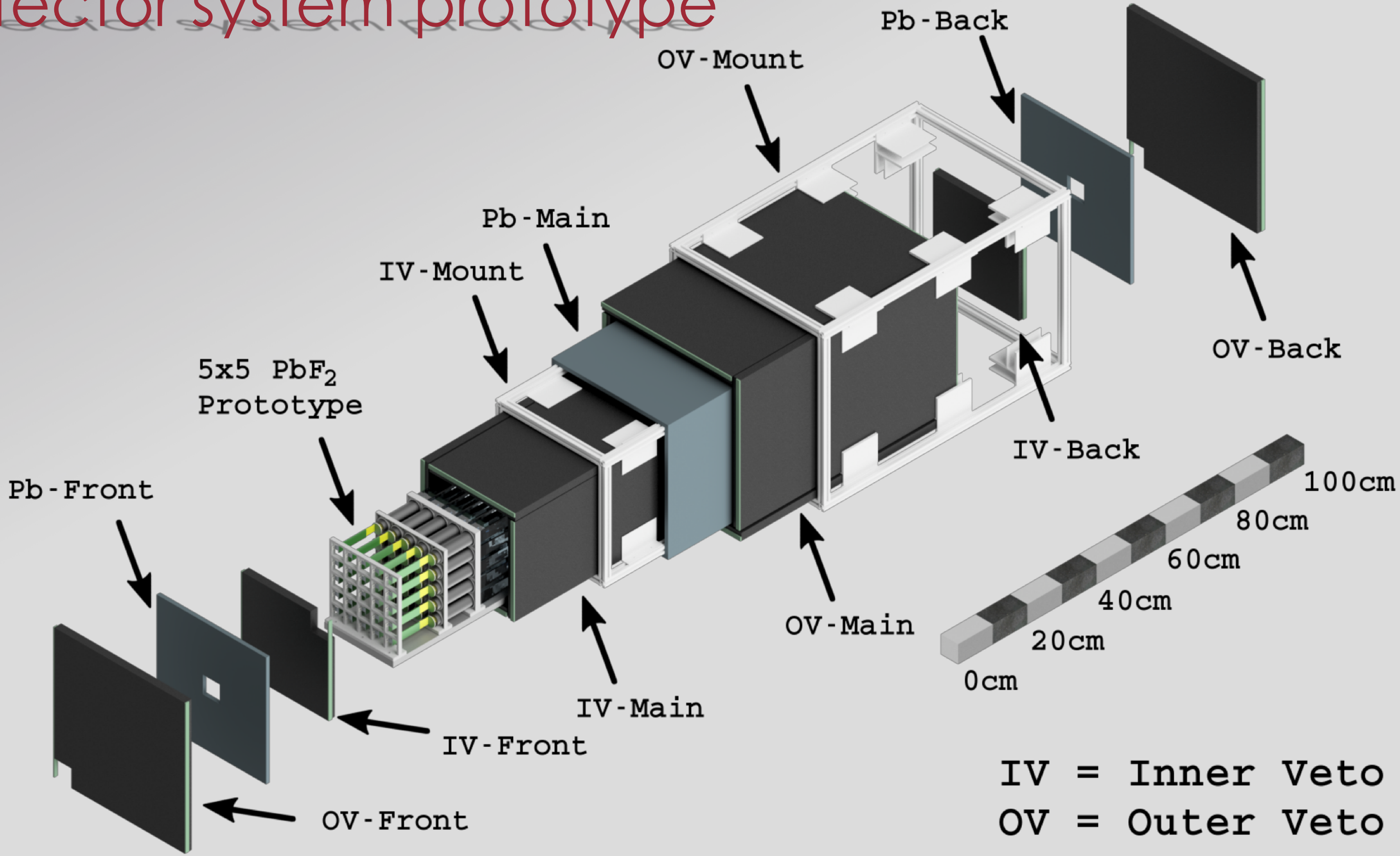


DarkMESA
Detector system prototype



Calorimeter has to distinguish events from background events
→ Scintillator as Veto Detector

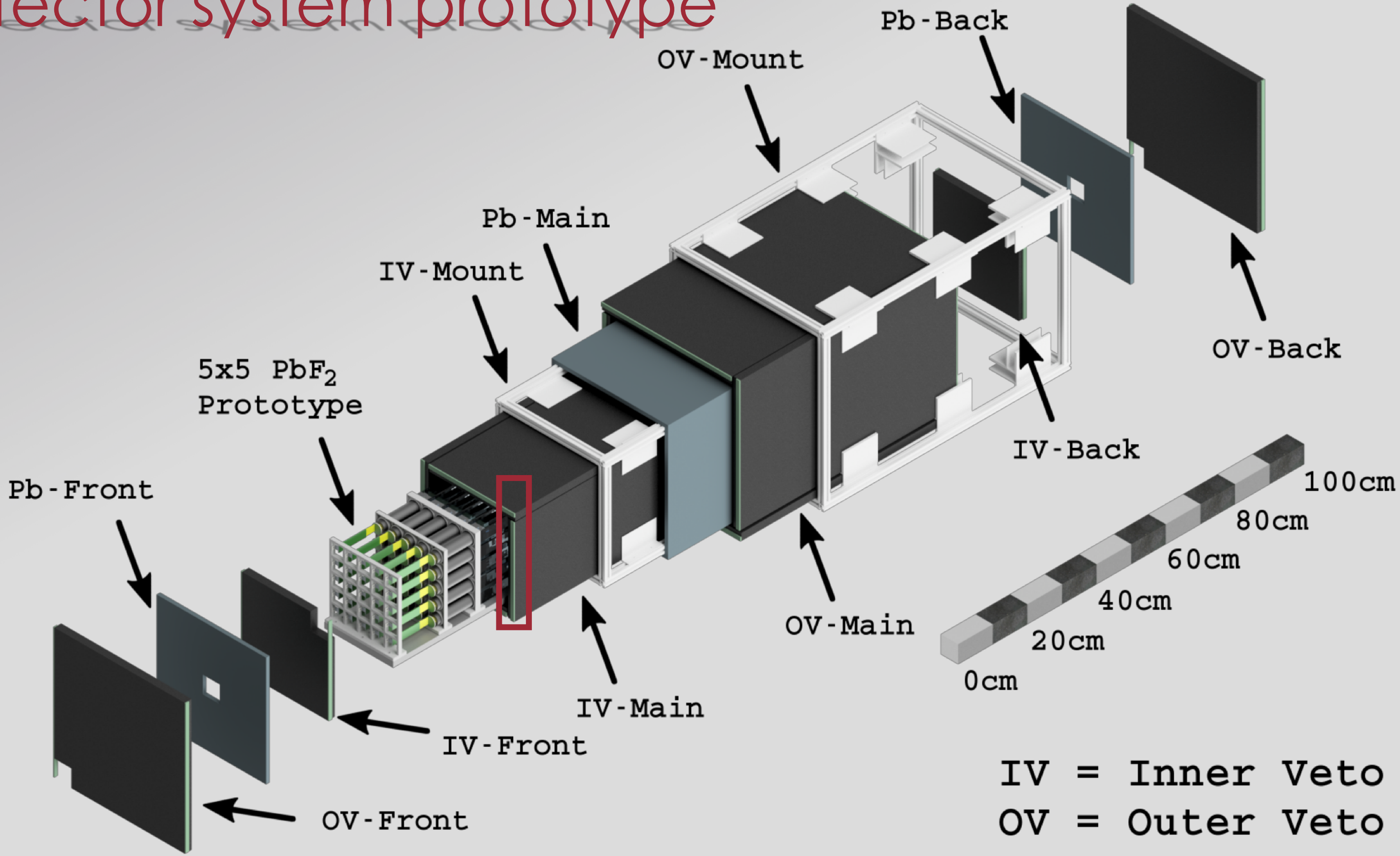
DarkMESA
Detector system prototype



IV = Inner Veto
OV = Outer Veto

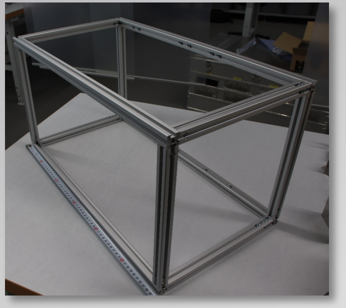
DarkMESA

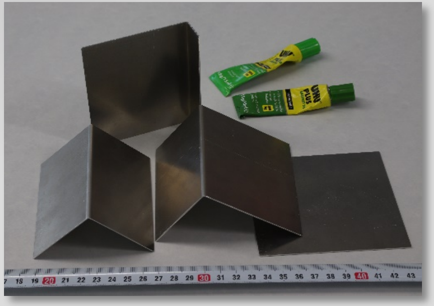
Detector system prototype

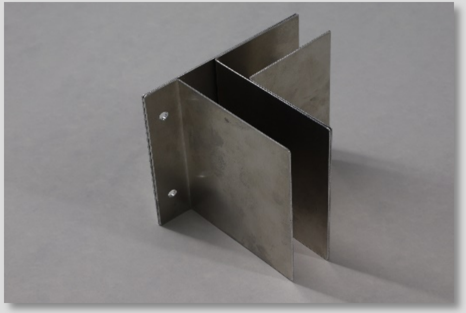


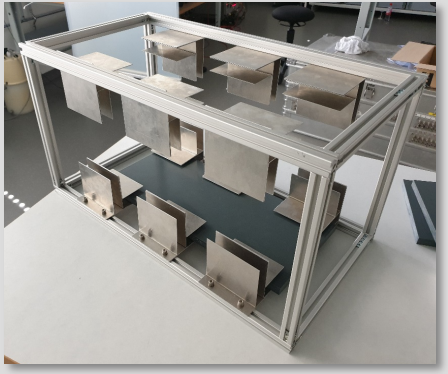
IV = Inner Veto
OV = Outer Veto

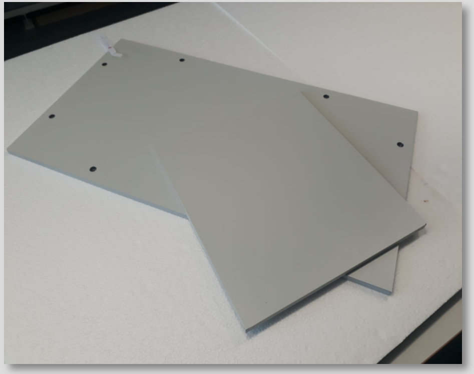
Veto Detector Prototype
Construction





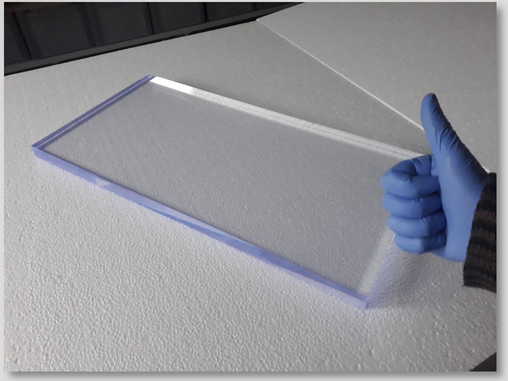






Veto Prototype
Plastic scintillator and SiPMs

EJ-200 properties
Scintillation Efficiency:
10000 photons/MeV
Wavelength of Maximum
Emission: 425 nm

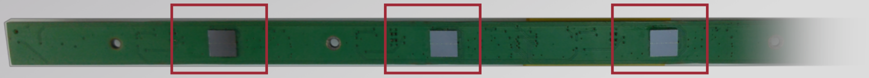


Properties of SiPM (SensL)

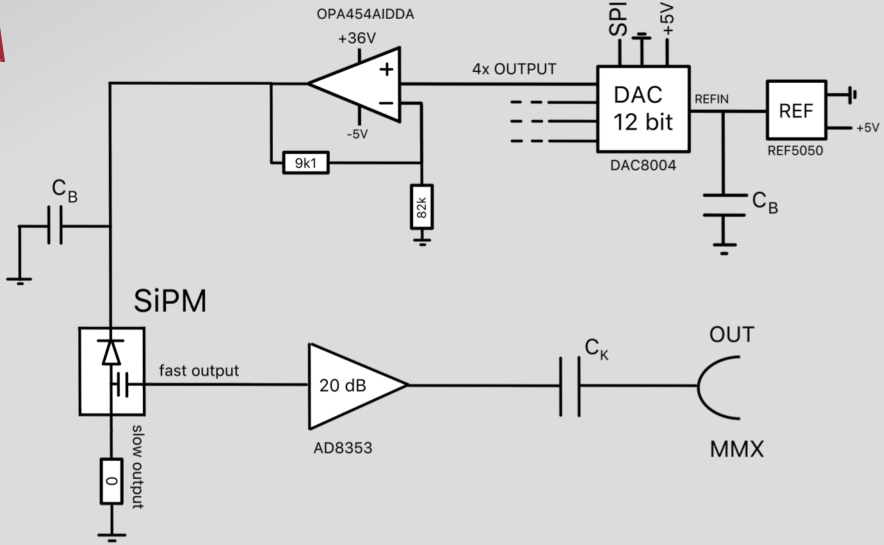
Size:	6mm x 6mm
Operating voltage:	25V – 30V
Peak Wavelength:	420 nm
Gain:	1x 10^6 - 1.9 x 10^6

Veto Prototype
Readout system with SiPM

Frontside



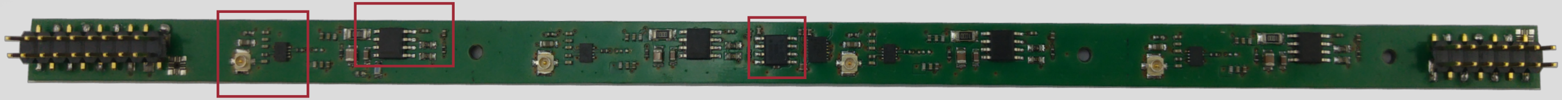
4 SiPMs



Backside

OP Amplifier

DAC



Amplifier
Analog Output

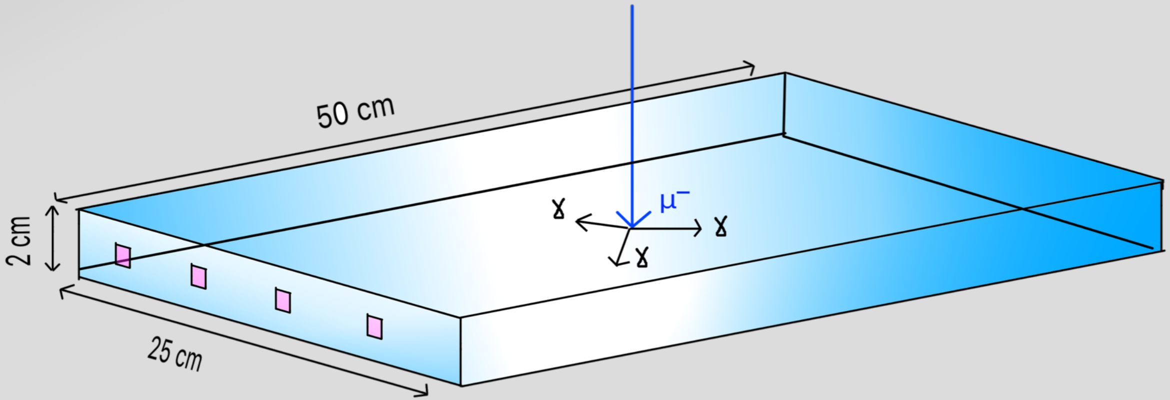
Veto Prototype
Readout system with SiPM

Light collection:

~ 40000 emitted photons in 2 cm scintillator

→ about 10 photons/SiPM

→ increase light yield with wavelength-shifting fibers



Veto Prototype
Readout system with SiPM

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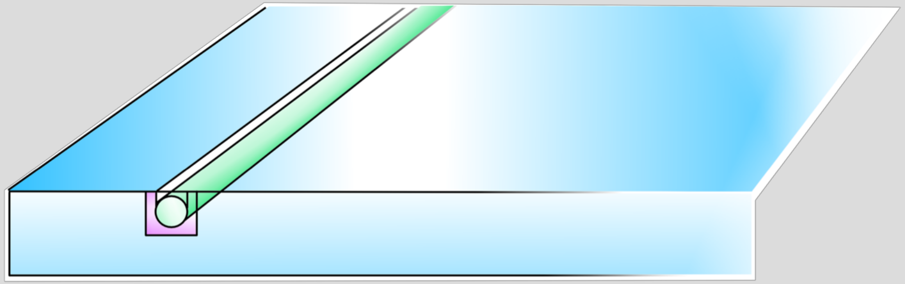
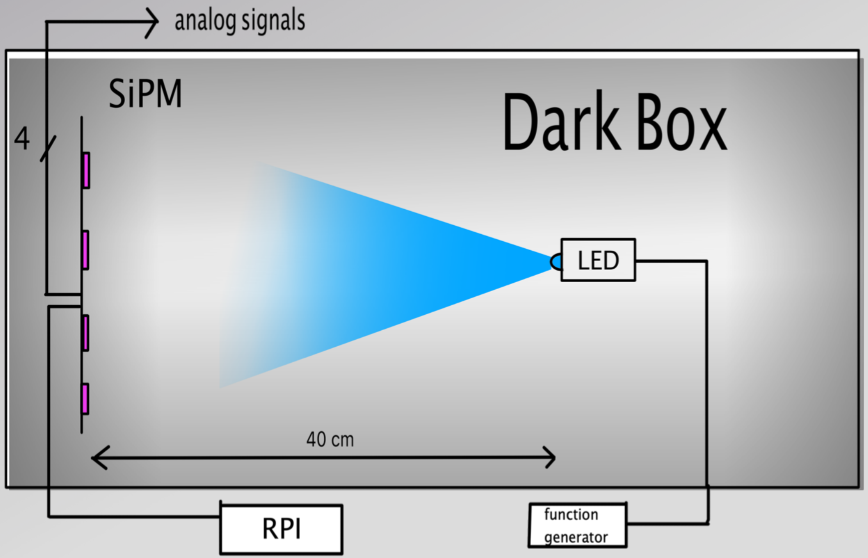
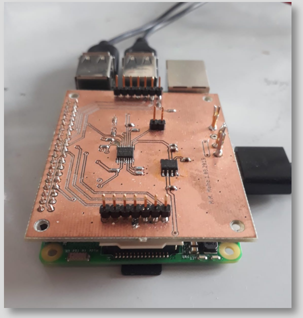
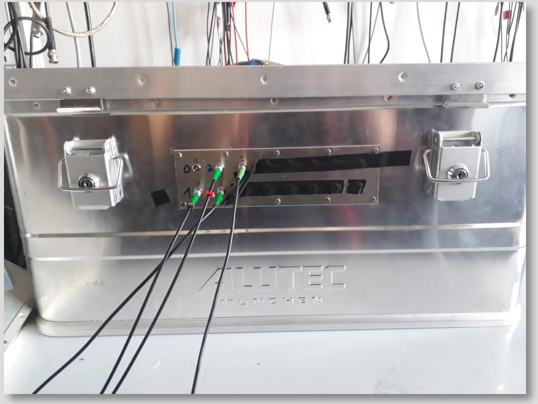


Veto Prototype Characterisation

Light response



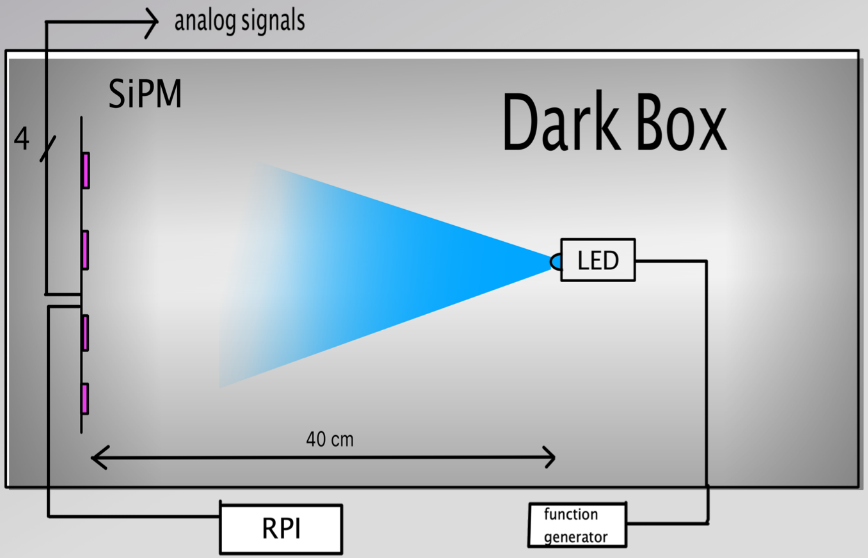


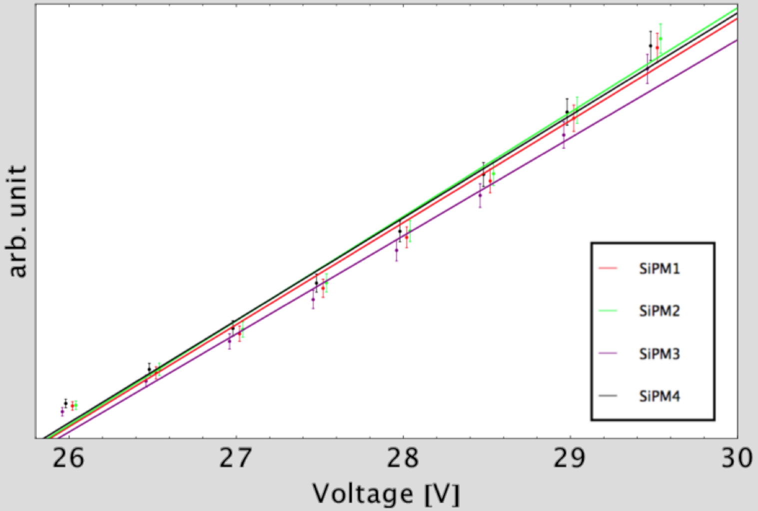


→ Measuring QDC spectra
→ Compare gains of SiPM

Veto Prototype Characterisation

Light response





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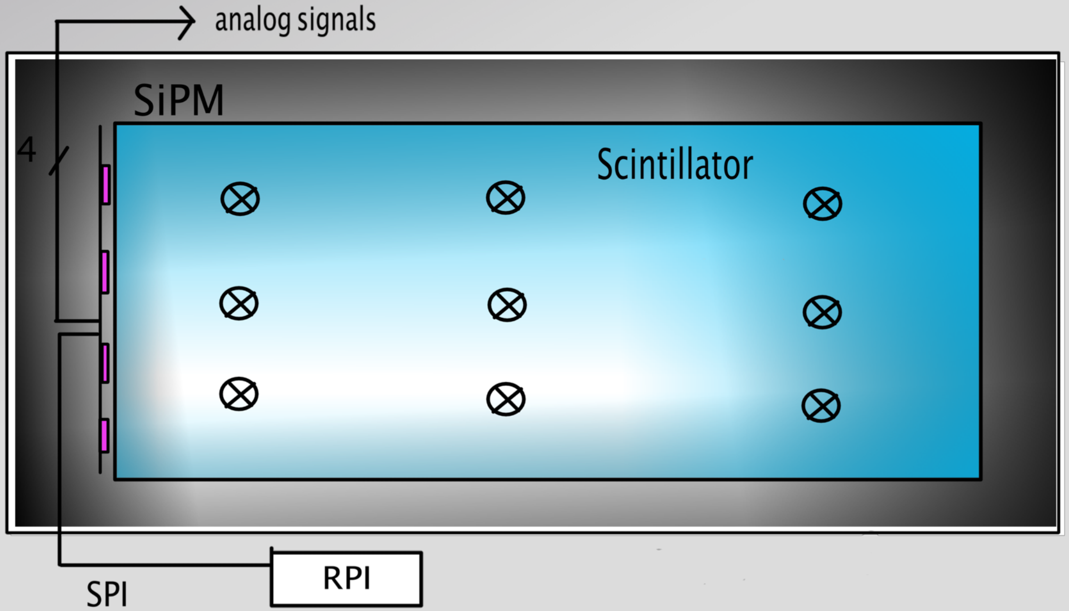
→ Compare gains of SiPM

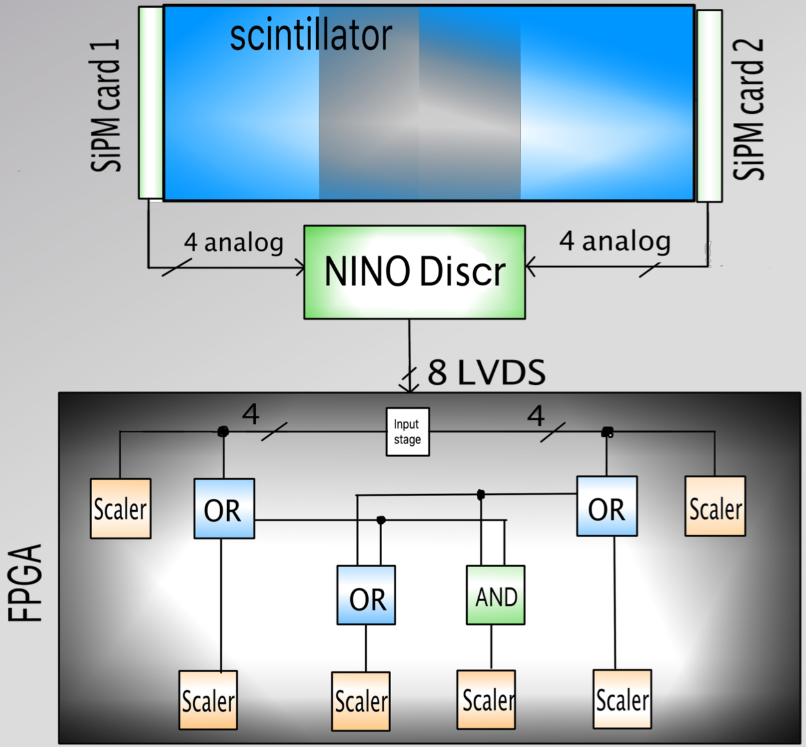
Veto Prototype Characterisation
Light response

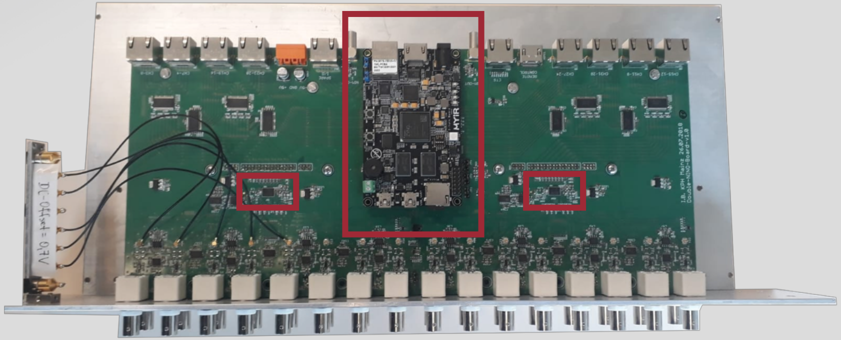


→ Measuring QDC spectra with different sources (Alpha, Sr90, muons)
→ Determine light yield depending on entry point of particle

Veto Prototype Characterisation

Readout electronics

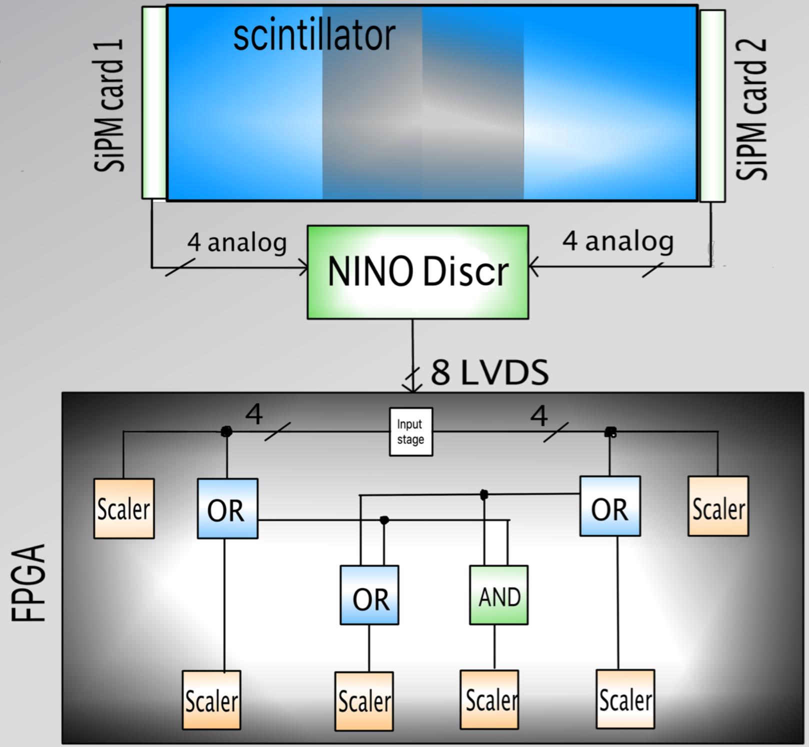


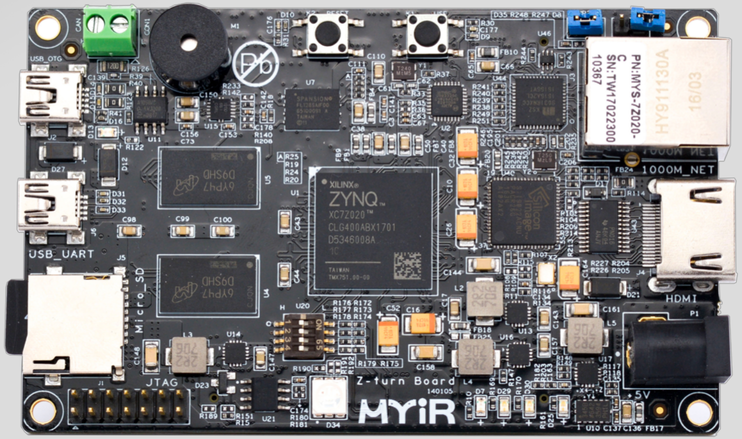


→ Measure single rates and coincidence rates with an FPGA

Veto Prototype Characterisation

Readout electronics





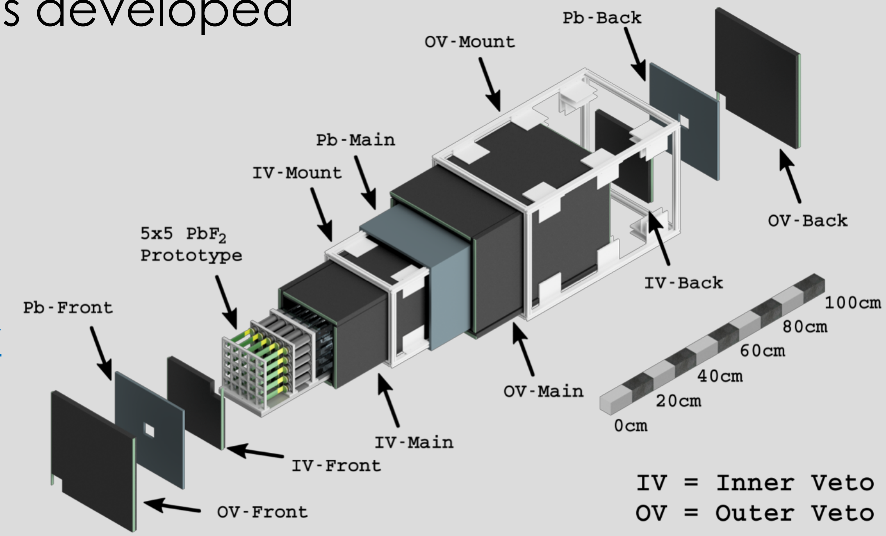
→ Measure single rates and coincidence rates with an FPGA

Summary and Outlook

- DarkMESA Detector system prototypes studied
- DarkMESA readout electronics developed
- Publications in preparation
- Heraeus-Seminar 2020

  Light Dark Matter Searches

https://www.we-heraeus-stiftung.de/veranstaltungen/seminare/2020/light-dark-matter-searches/



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