Characterization of VUV-sensitive SiPMs for nEXO

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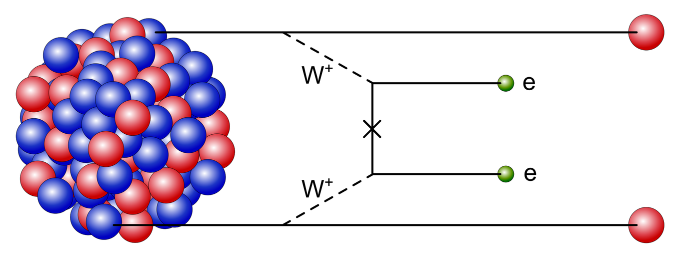
Physics beyond Standard Model?

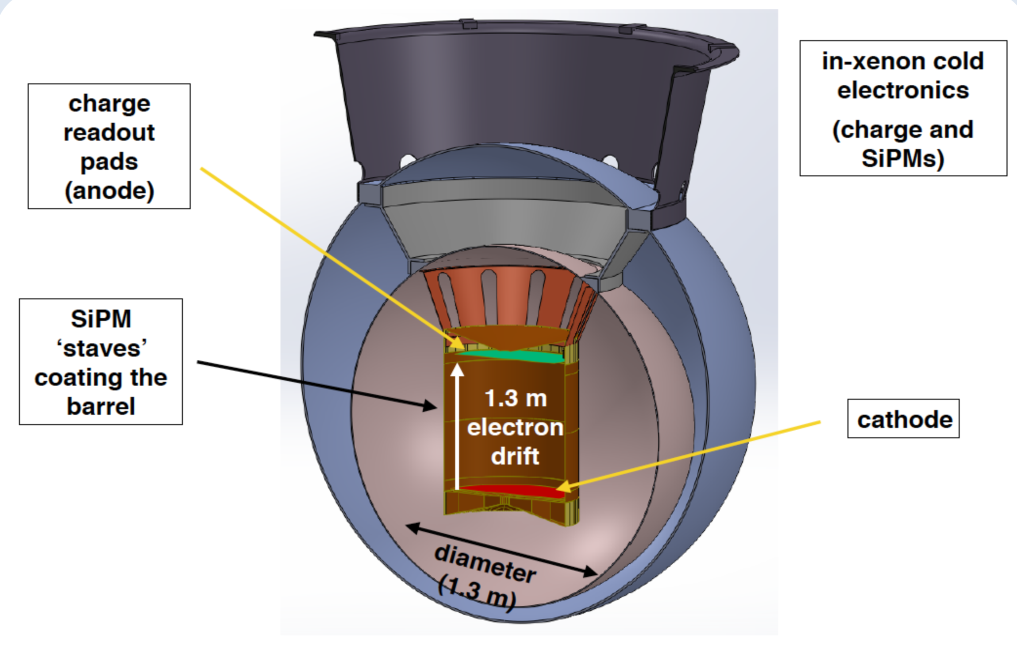
- The neutrinoless double beta decay opens window to physics beyond SM
- Are neutrinos Majorana particles?



- Current 0νββ searches are sensitive to a half-life of about 10^{26} years [1, 2]
- nEXO plans to increase sensitivity [3]

The nEXO detector [3, 4]

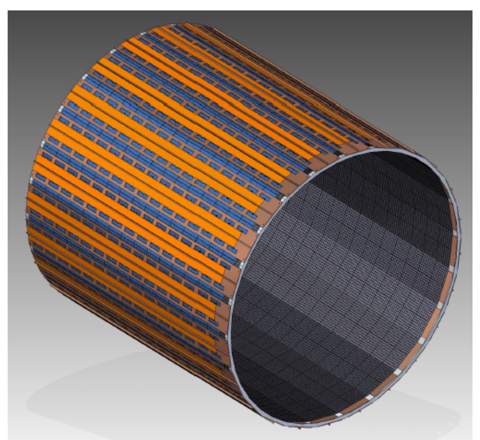
- Time-projection-chamber (TPC) filled with ~ 5 tons of liquid Xenon (LXe) – enriched to 90 % in ^{136}Xe
- Cylindric barrel with a diameter and height of 1.3 m
- Detector set up in underground lab to shield from cosmic rays (likely SNOLAB, 6000 mwe.)
- Signal detection via charge readout tiles (end cap) and VUV-sensitive SiPMs (inner cylinder surface)
- Cathode set to -50 kV to produce axial drift field
- Extensive radiopurity screening to constrain BG
- Homogeneous detector & multi-parameter analysis



[1] Agostini et. al., 1705.02996
[2] EXO-200-Coll., arXiv:1707.08707
[3]: nEXO-Coll., arXiv:1710.05075
[2]: nEXO-Coll., arXiv:1805.11142

Light detection

- nEXO sensitivity depends on photon transport efficiency and photon detection efficiency
- Inside wall covered with 4 m^2 of VUV-sensitive SiPMs
- Detection of 178 nm scintillation light in LXe
- Goal: 1 % energy resolution at Q-value (2458 keV)
- Strong requirements on SiPM parameters



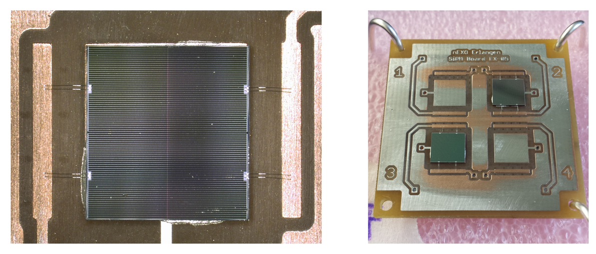
Parameters	Value
Photo detection efficiency at 175-178 nm (without AR coating measured in gas/vacuum)	>15%
Radiopurity: Contribution of photo-detectors to the overall background	<1%
Dark noise rate	<50 Hz/mm²
Probability for correlated avalanches per parent avalance	<20%
Active area per single photo-detector	>1cm²
Capacitance	<50pF/mm²
Pulse width (after electronics shaping)	<100 ns

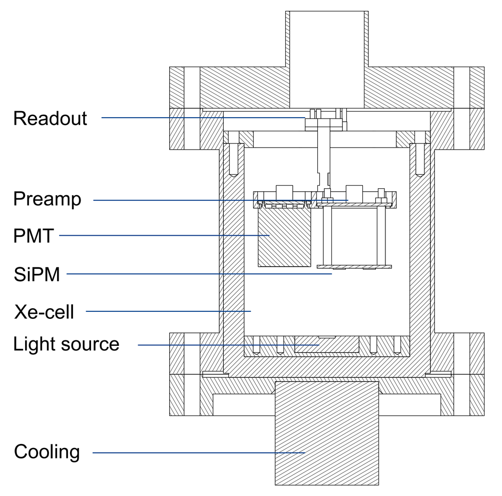
SiPM characterization test setups

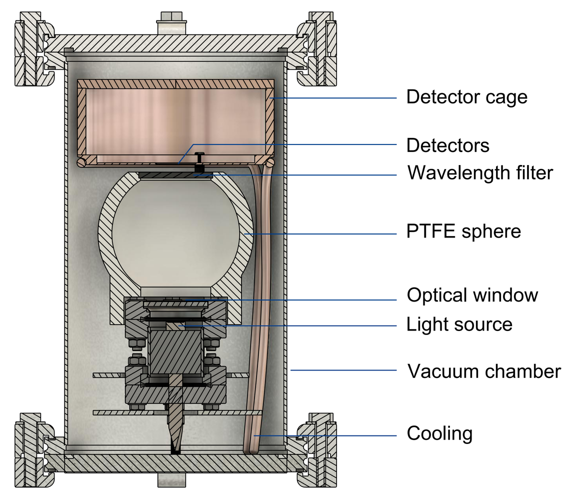
- ECAP, Erlangen (Dark noise, PDE, VUV reflectance)
- IHEP, Beijing (HV behaviour, VUV reflectance)
- TRIUMF, Vancouver (Dark noise, PDE)
- UA, Alabama (VUV reflectance)
- Stanford (PDE, SiPM tiles)
- UMass (PDE, LXe)

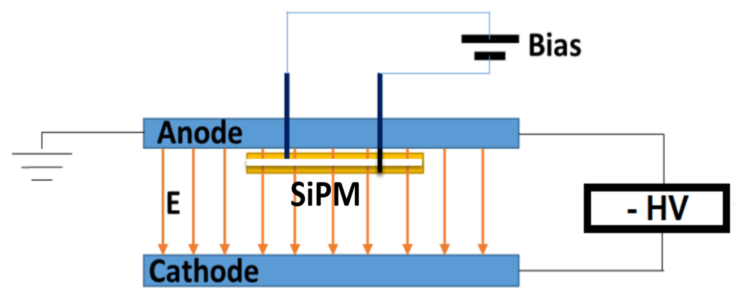
Various SiPMs

- Hamamatsu VUV3, VUV4
- FBK NUV 2016 LF & STD





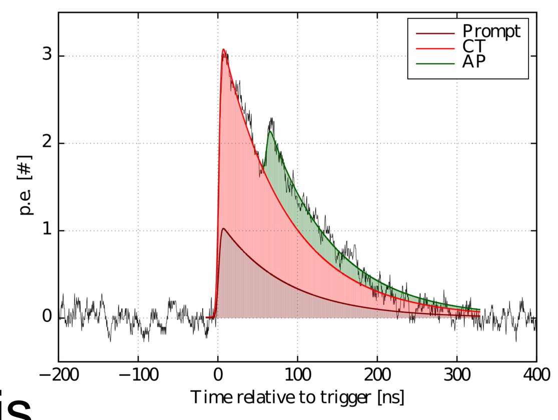


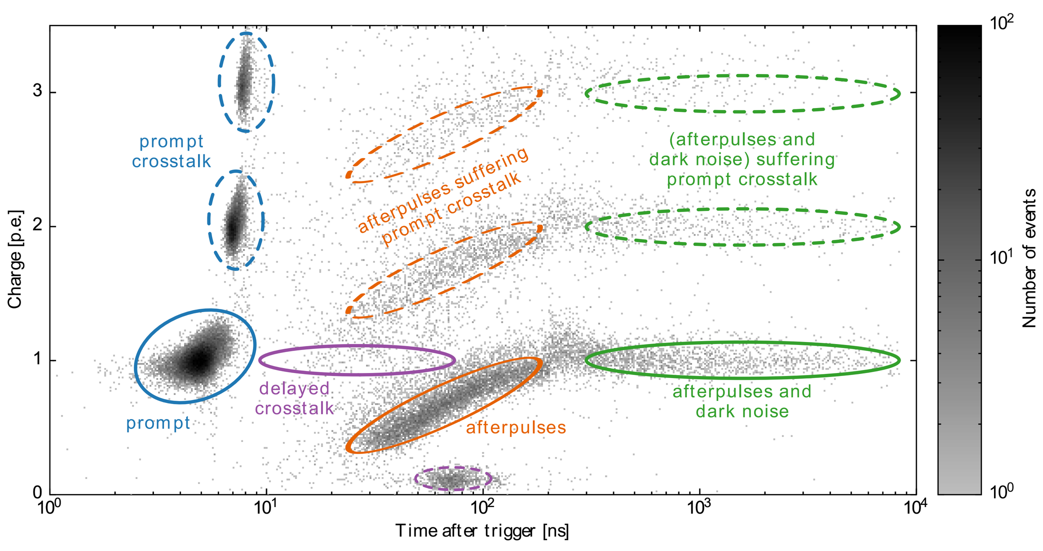


From left to right:
Test setup at ECAP, test setup at Stanford, HV setup at IHEP

Measuring procedure @ ECAP

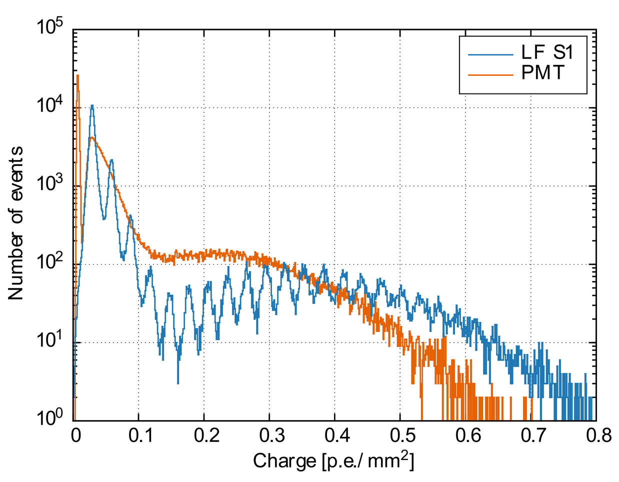
- Record SiPM dark pulses at -100°C
- Fit pulse template to waveforms
- Use amplitude, timestamp, rise & fall time for analysis





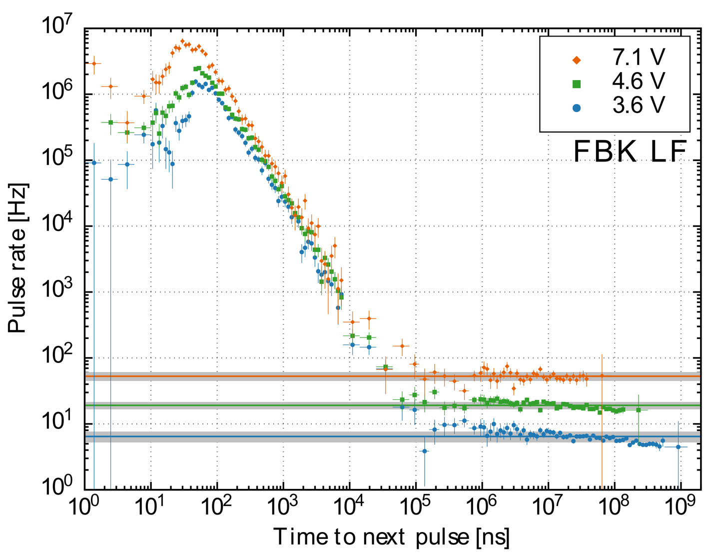
Measuring procedure @ Stanford

- Record PMT and SiPM pulses from ^{252}Cf
- Calibration of single photon responses
- Extract charge ratio of the decay spectrum peaks
- Translate into absolute PDE using the PMT reference QE
- Account for correlated noise



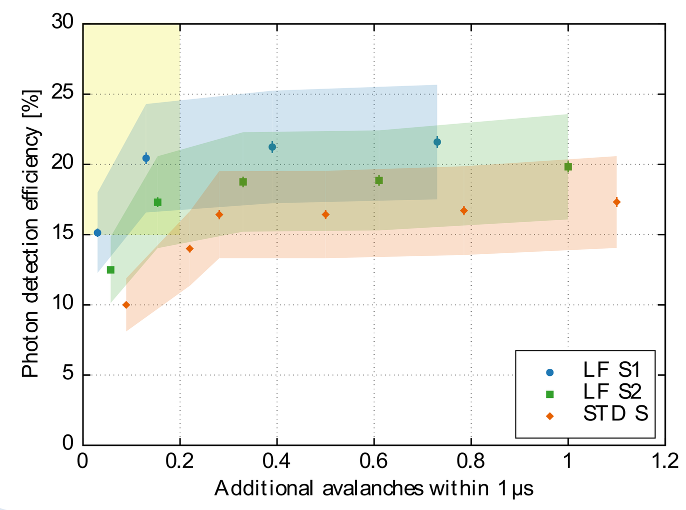
Afterpulsing

- Delayed avalanches correlated to the primary pulse
- Important nuisance charge contribution



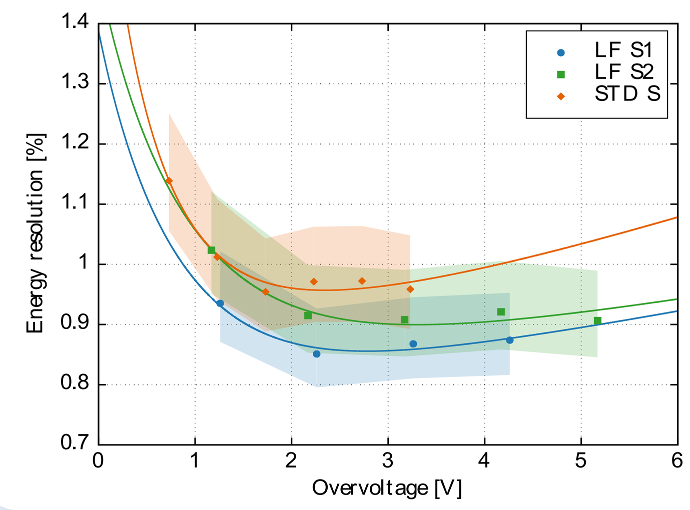
PDE

- Efficiency to detect single photons
- Angle-, wavelength- and bias voltage-dependent
- nEXO requirements met



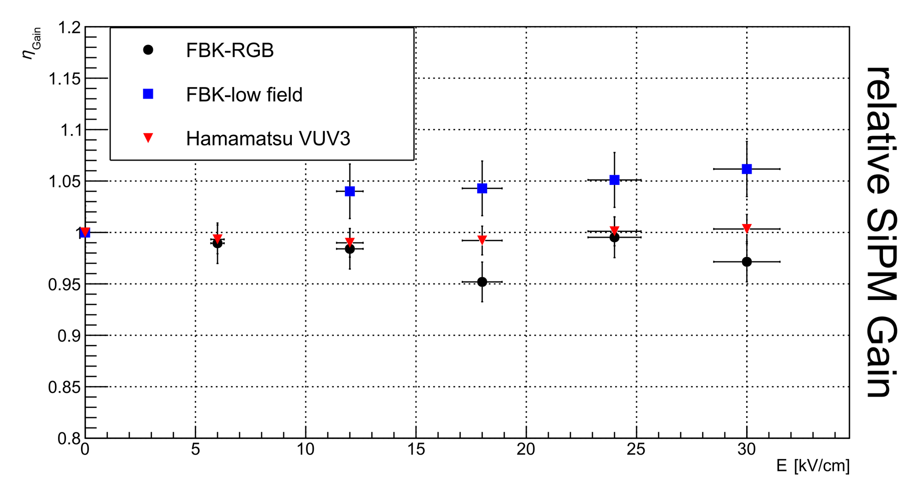
nEXO energy resolution

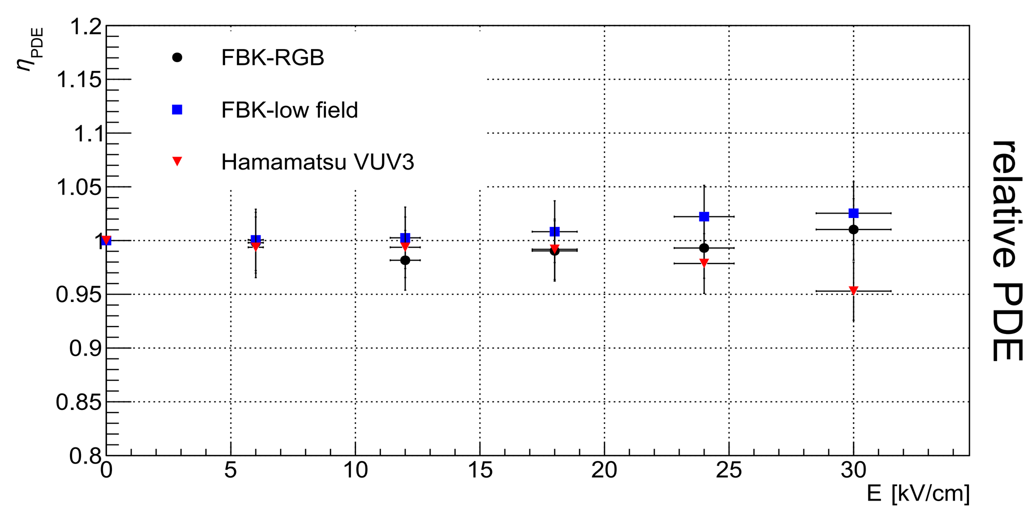
- Depends on PDE & photon transport efficiency (PTE)
- Plot shows case of PTE = 0.2 (electronic noise neglected)
- Resolution goal achievable

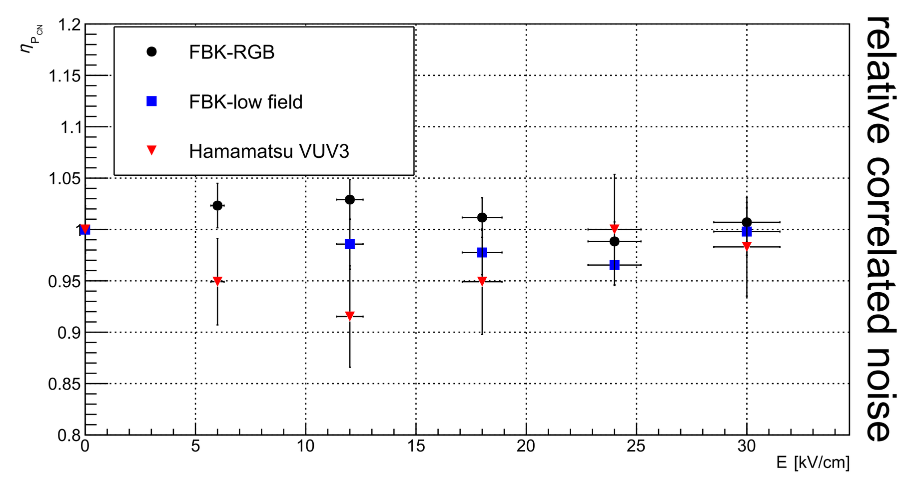


SiPM HV robustness

- SiPMs will be exposed to external electric fields up to 20 kV/cm in nEXO according to COMSOL simulations
- Detectors found to be operational in high electric fields at cryogenic temperatures
- Basic parameters unaffected; No discharge
- No damage - even on a microscopic level







nEXO

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SEE ALSO:
Study of Photon transport and SiPM in external electrical field in nEXO
Dr. Pin LVi, id: #405

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS