Use of Electron Guns for Detector Characterization

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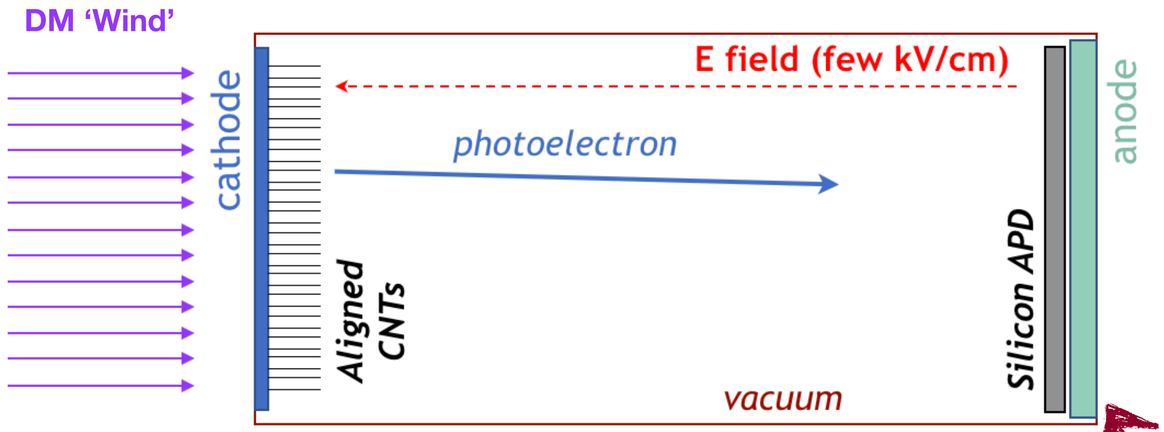
ANDROMEDA

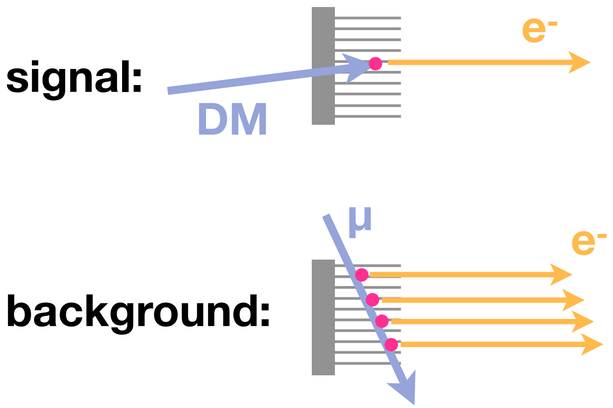
Aligned Nanotube Detector for Research On MeV Darkmatter

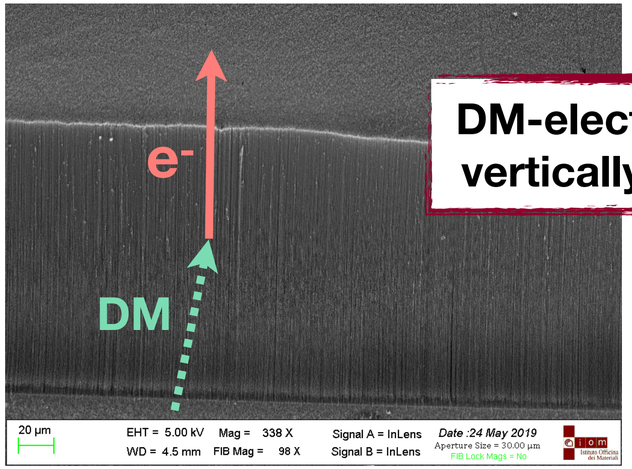
PTOLEMY Collaboration Meeting, Zandvoort, 7.10.22

Dark Matter with Aligned Carbon Nanotubes

The 'Dark-PMT'







DM-electron scattering in a target of vertically-aligned carbon nanotubes

Detection of keV electrons

Electron energy = ΔV(anode-cathode)

Would like to keep ΔV < 10 kV

Key parameter: high efficiency

Secondary parameter: energy resolution

(need to distinguish 1e$^-$ vs 2e$^-$)

The ANDROMeDa Project

- Awarded PRIN2020 grant (1M€)
  - 3-year project, started in May 2022
  - 3 units: INFN (FP, P.I.), Sapienza (G. Cavoto) Roma Tre (A. Ruocco)
- **Objective**: development of Dark-PMT prototype
- Three workpackages:
  1. Superior synthesis of **carbon nanotubes** — **Ilaria's talk**
  2. High-efficiency keV **electron reconstruction**
  3. **Dark-PMT prototype** design and construction

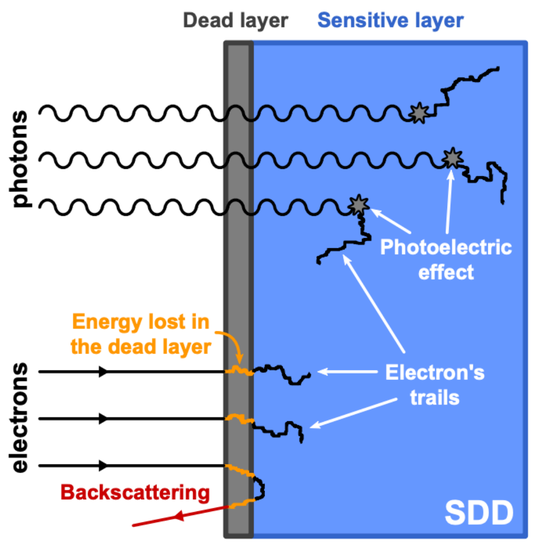
this talk and Alessandro's talk

ANDROMeDa

Aligned Nanotube Detector for Research On MeV Darkmatter

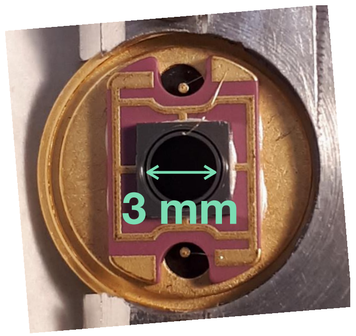
Detecting keV Electrons with Silicon Detectors

Born as photon detectors
'Windowless' versions for electrons
Silicon oxidation → dead layer

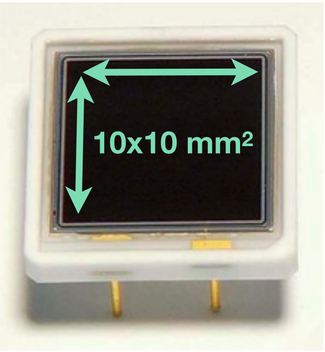


Benchmark technology: Avalanche Photodiode (APD)

HPK S11625-30N

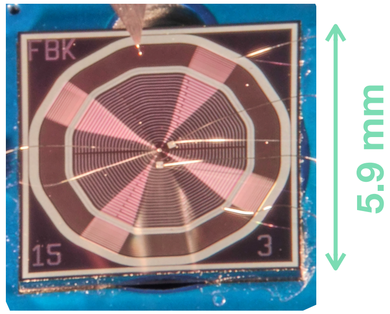


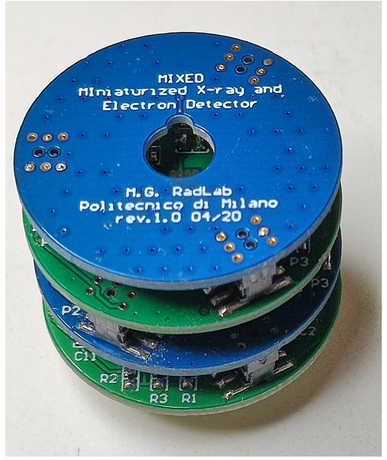
HPK S8664-1010N



- Produced by Hamamatsu
- Simple, cost-effective

Backup technology: Silicon Drift Detector (SDD)



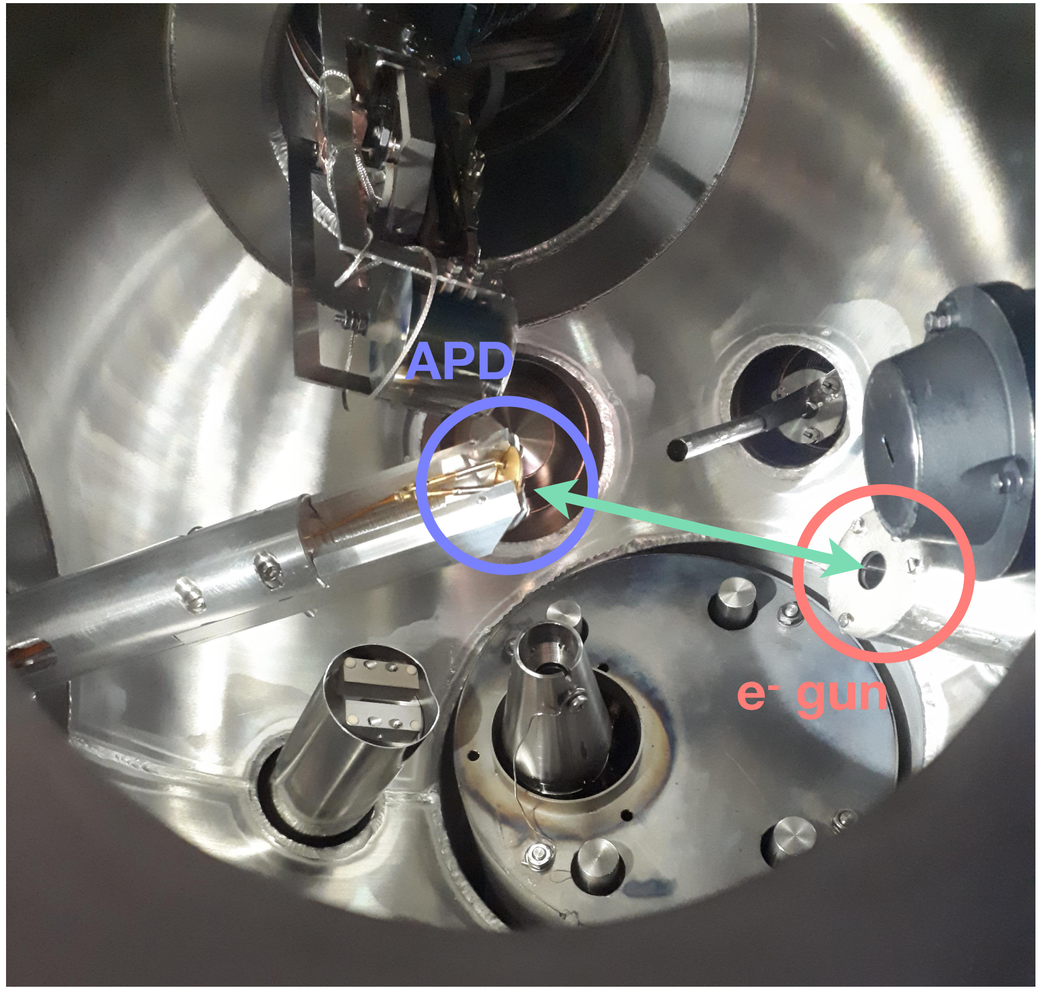


- Produced by FBK + electronics by PoliMi
- Ultimate energy resolution

Electron Gun Facility @ LASEC Labs (Roma Tre)

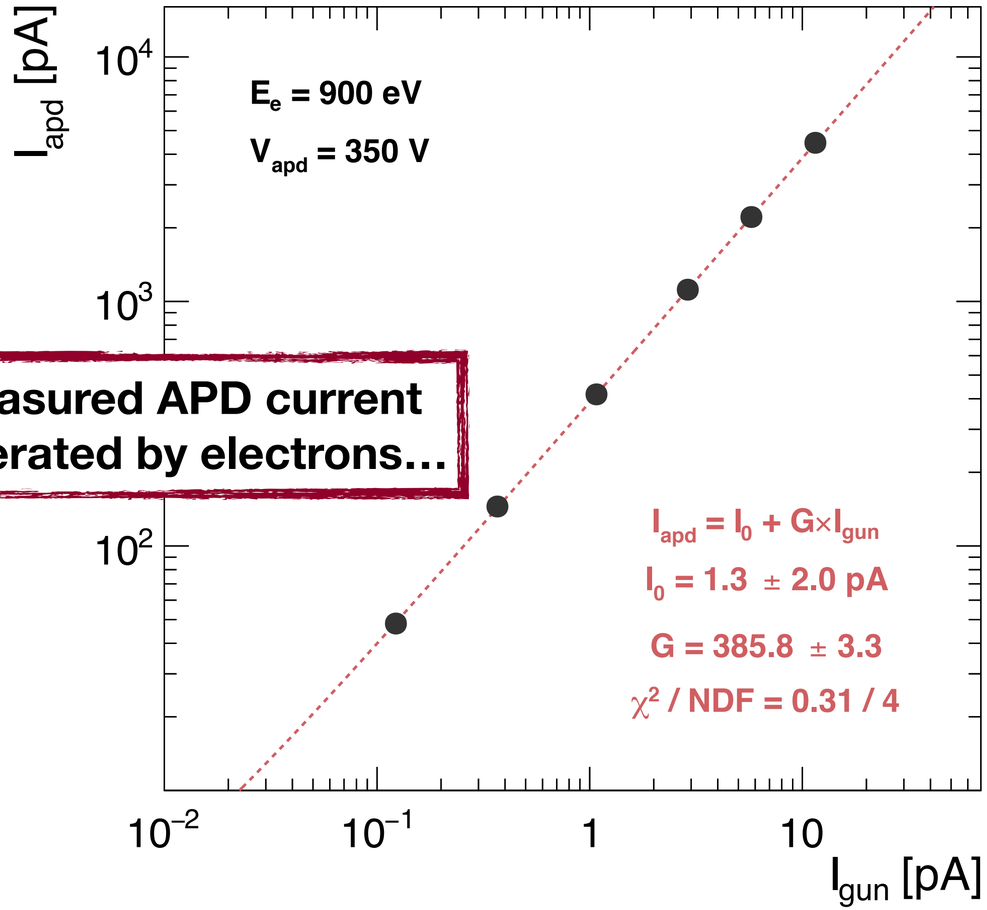
- Hot tungsten filament + electrostatic lenses
  - Electron **energy**: 30 < E < 1000 eV
  - Energy spread: 45 meV
  - Beam spot: 0.5 mm
  - Beam **current** as low as a few fA

i.e. electrons at ~10 kHz (not bunched)
→ Can probe single-electron regime



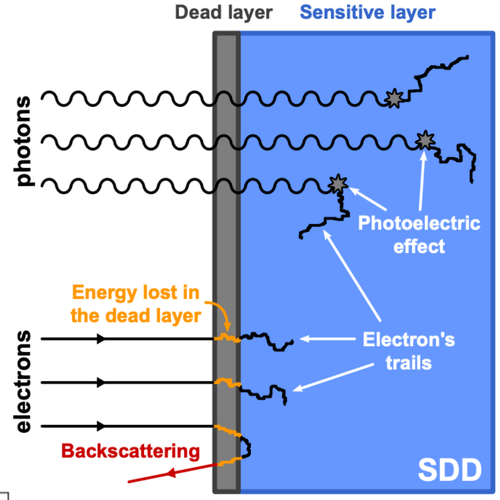
Hunting for Single-Electron Signals with APDs

A. Apponi et al 2020 JINST **15** P11015

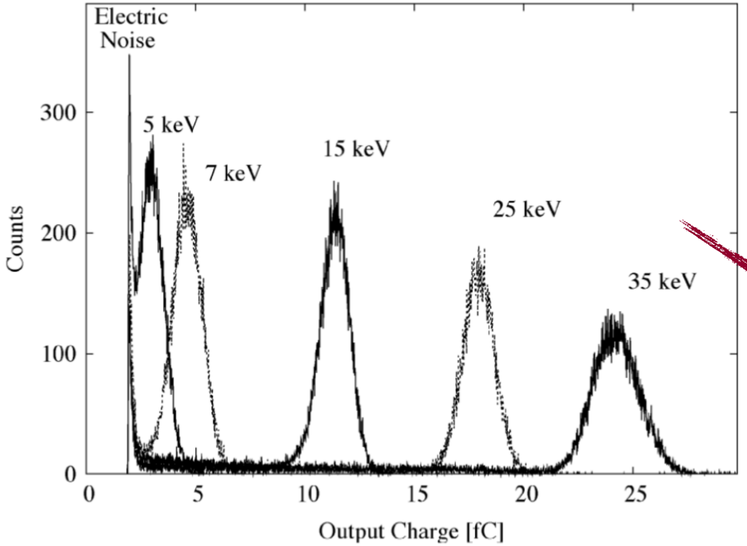


Measured APD current generated by electrons…

… but didn't see single-electron pulses



S. Kasahara, et al.,
IEEE Trans. Nucl. Sci. **57** (2010) 1549

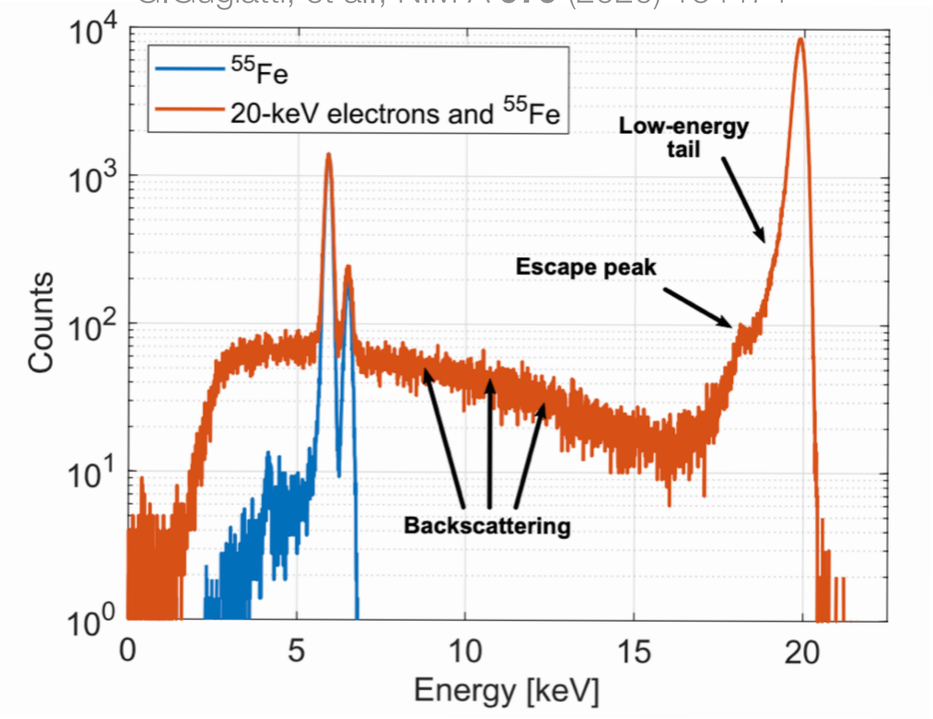


Literature: need E ≥ 5 keV to see single-electron signals with APDs

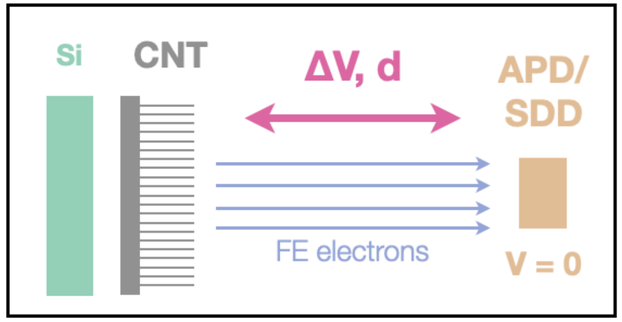
SDDs Capable of Measuring keV Electrons

Electron gun: excellent resolution for 5 < E < 20 keV

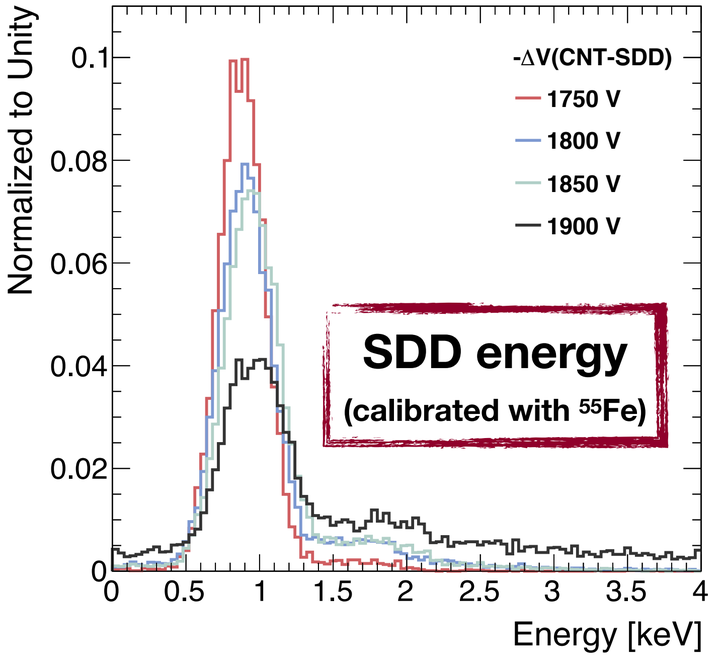
G.Gugiatti, et al., NIM A **979** (2020) 164474

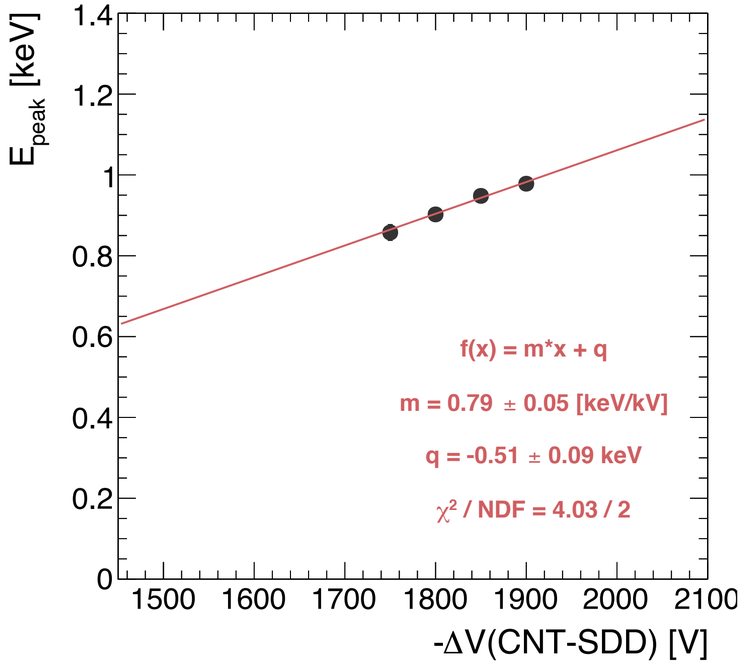


In our prototype: detecting ~2 keV electrons from CNT field emission



Hyperion Prototype





Planned: Tests @ Milano Bicocca Electron Gun

- Custom gun (photoelectric effect)
  - Electron **energy** 0 < E < 30 keV
  - Energy **spread** ~ 2 eV
  - Beam **spot** ~ 1 mm
  - Beam **current** as low as a few fA

- Planned **campaign** (Oct/Nov 2022)

- Physics program:
  - **Observe** keV electrons with APD and SDD
  - Measure energy **resolution**
  - Study response as a function of **angle** and **sensor surface** position
  - Measure single-e^- detection **efficiency** (for this need stable current)

Conclusions

- ANDROMeDa aims to develop novel **dark matter** detector
  - Target made of **carbon nanotubes**
- Key challenge: high-efficiency detection of **keV electrons**
  - With silicon APDs or SDDs
- Two (single-)electron gun facilities (I ~ few fA)
  - **LASEC@RomaTre:** 0 < E < 1 keV
  - **Milano Bicocca:** 5 < E < 20 keV

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We're opening two 24-month post-doc positions in Rome!