DEVELOPMENT OF CRYOGENIC DETECTORS FOR THE LEMING* EXPERIMENT

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*LEptons in Muonium
INteracting with Gravity

0 Motivation

1) Test

Weak Equivalence Principle [1]

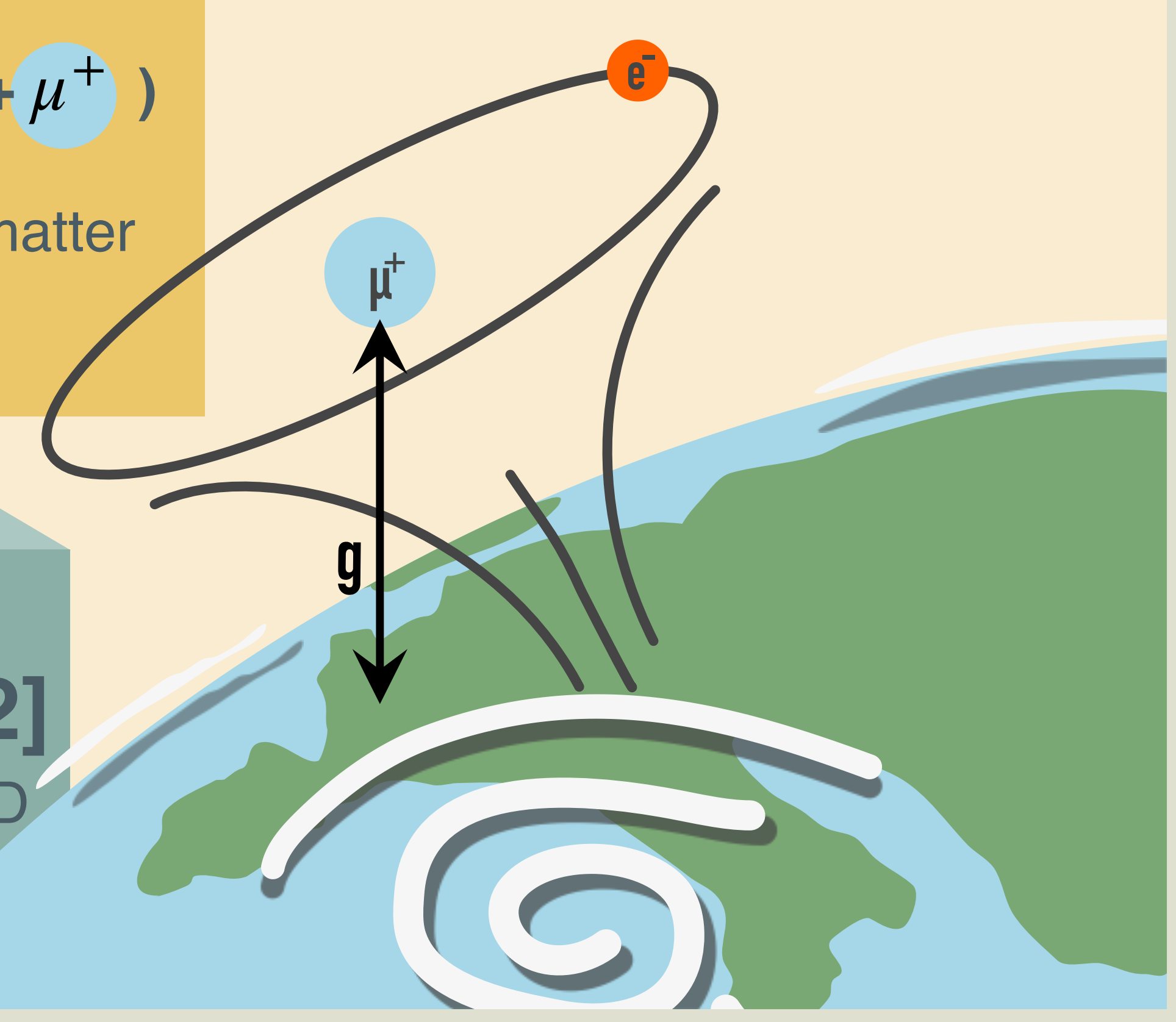
With Muonium (M = e^- + μ^+) with **purely leptonic** and **second generation** antimatter

- Do (anti)leptons fall like hadronic matter?

2) Do

Precision Spectroscopy [2]

- Test of bound-state QED
- Measure fundamental constants



1 The LEMING Experiment

3 Ingredients for LEMING

1) M Beam

- Well-defined velocity
- For novel M source using superfluid helium

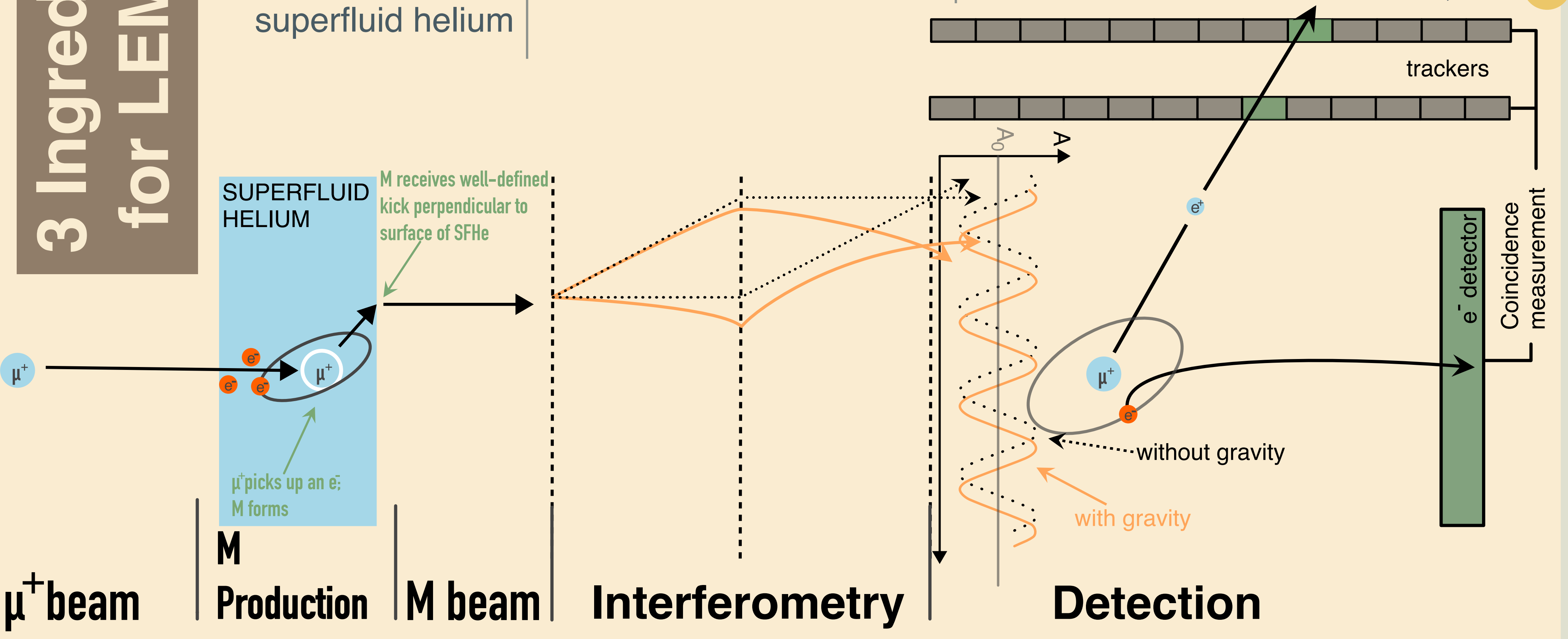
2) Interferometry

- Interference pattern shifted by gravity

➡ Requires precise control and alignment

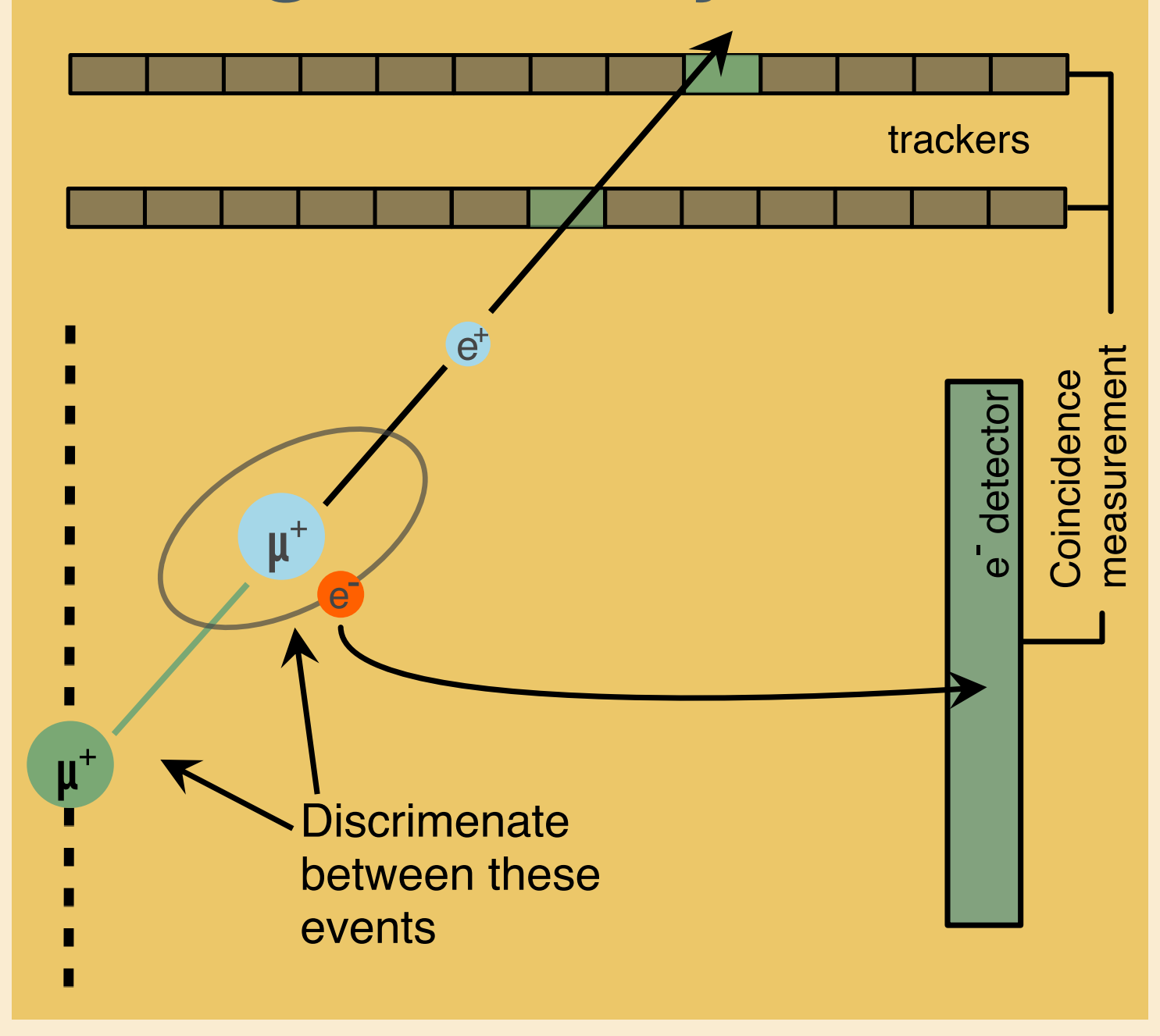
3) Detection

- **Coincidence measurement** of e^- and e^+
- Tracker for e^+
- Low-threshold detector for e^-, see 2



2 Atomic Electron Detector

Motivation: Background rejection



- Atomic electron detector (e^- - detector) used for coincidence measurement of e^- and e^+
- Efficiency of e^- - detector directly determines amount of data

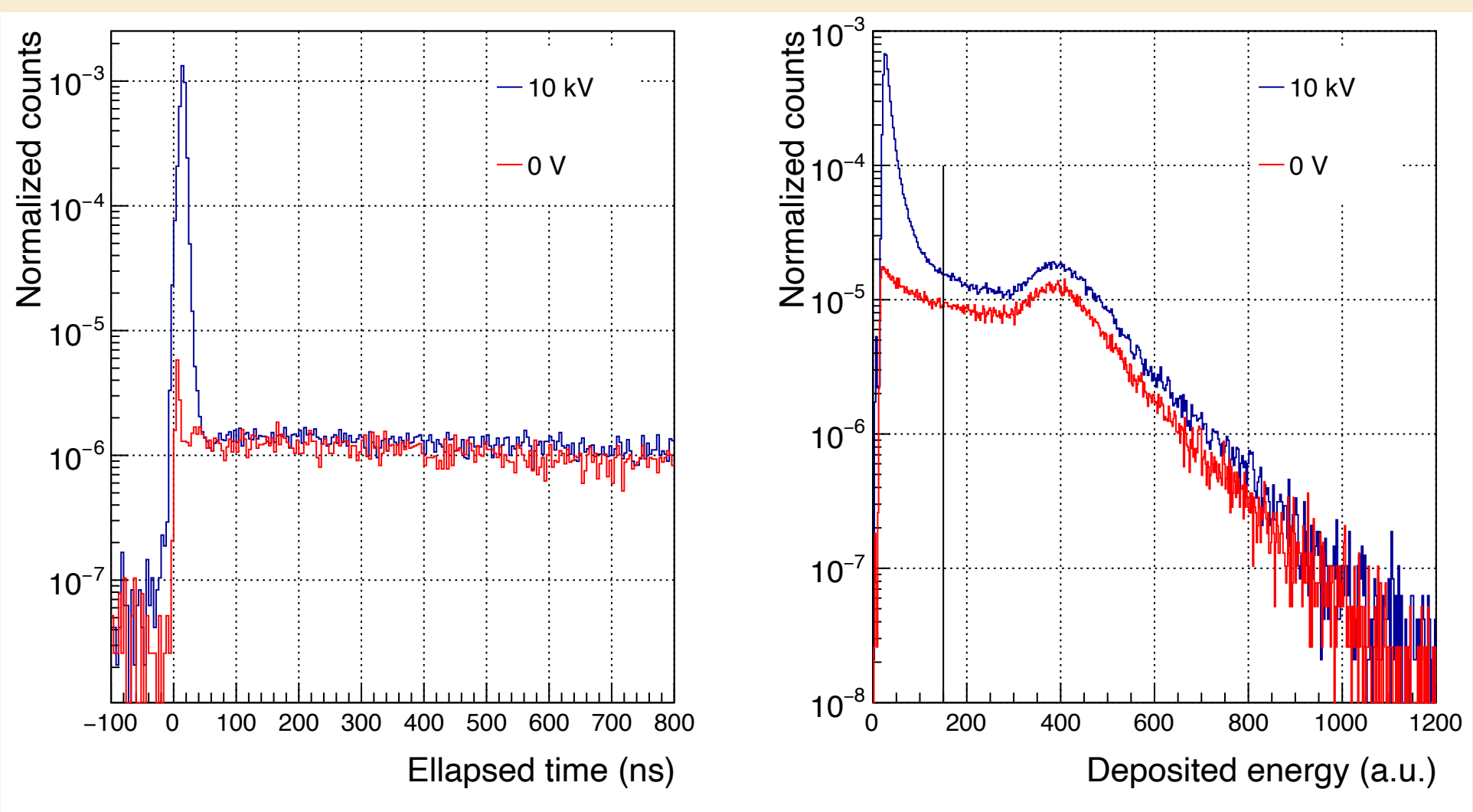
Requirements

- Operational at cryogenic temperatures and in SFHe
- Near-unity detection efficiency
- Sensitive to low energies $\mathcal{O}(\mathrm{keV})$, due to high voltage limitations, see 2A
- Up to MHz counting rate

2A Single Photon Detection with SiPMs at 0.2 K

Results

- SiPM operational at 0.2 K [5]
- Detected electrons with 10 keV at 0.2 K

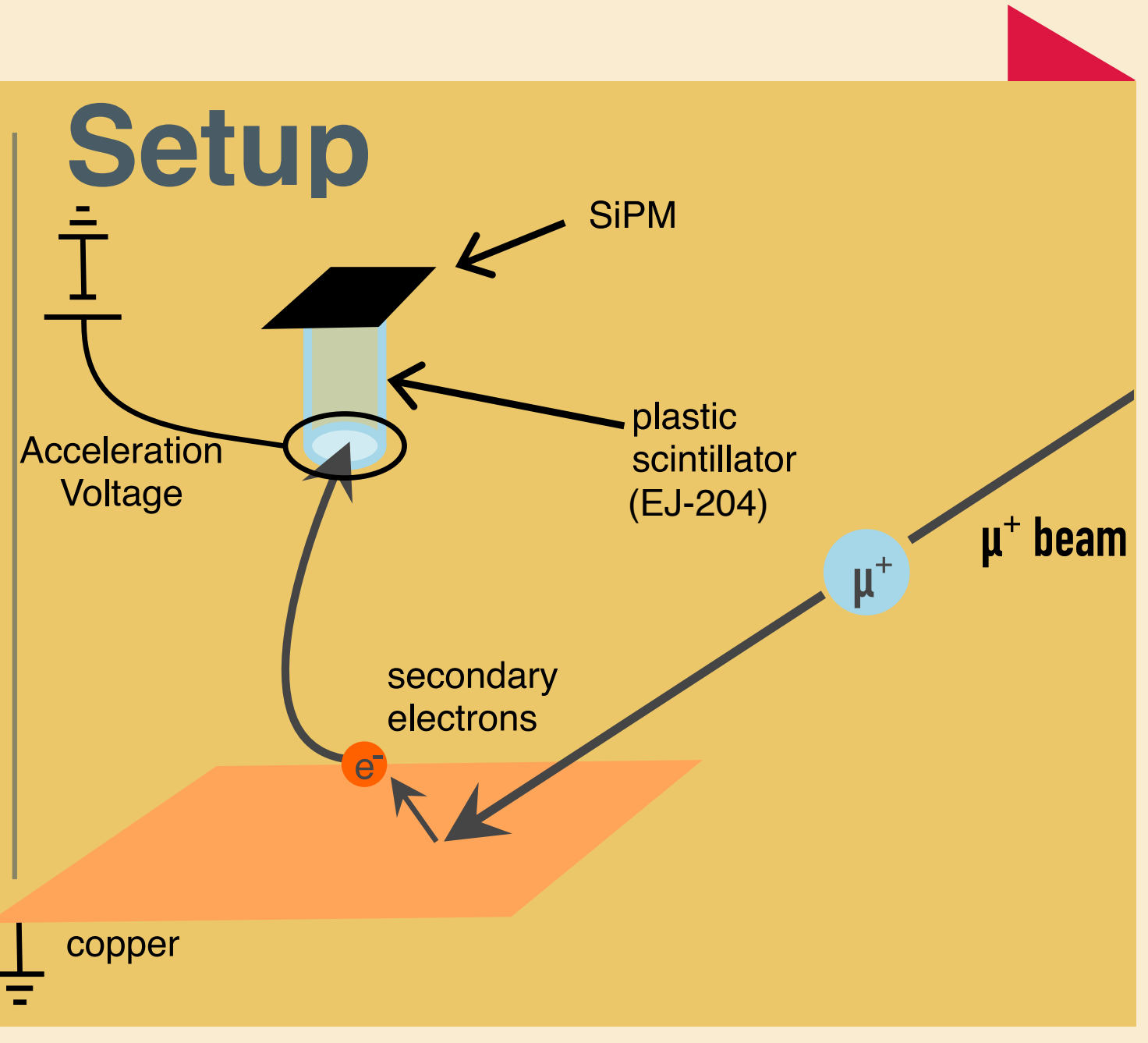


DISCHARGES IN SFHe

The Challenge

- Plastic Scintillator (EJ-204) coupled to a Silicon Photomultiplier (**SiPM**)
- Electrode ring to focus/accelerate secondary e^- kicked out by μ^+ beam

Setup

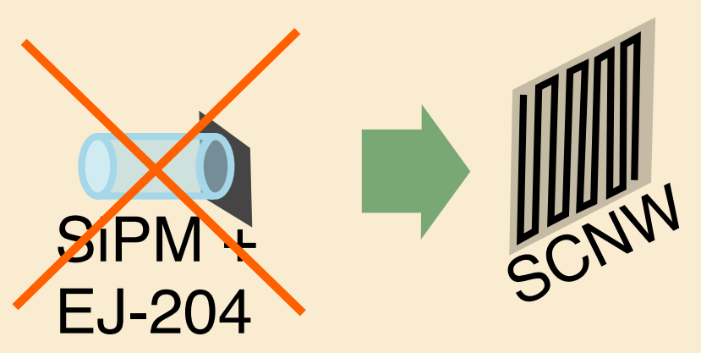


- With SFHe in the setup 10 keV e^- detection no longer possible
- SFHe limits applicable acceleration voltage

➡ **Need more efficient detector design**, see 2B and 2C

2B Superconducting Nanowires *(SCNW)*

SCNW as atomic e^- detector



- Able to detect single electrons $\mathcal{O}(10\,\mathrm{keV})$ with near-unity efficiencies [4]
- Limited size $\mathcal{O}((0.1\,\mathrm{mm})^2)$

➡ Requires focusing system

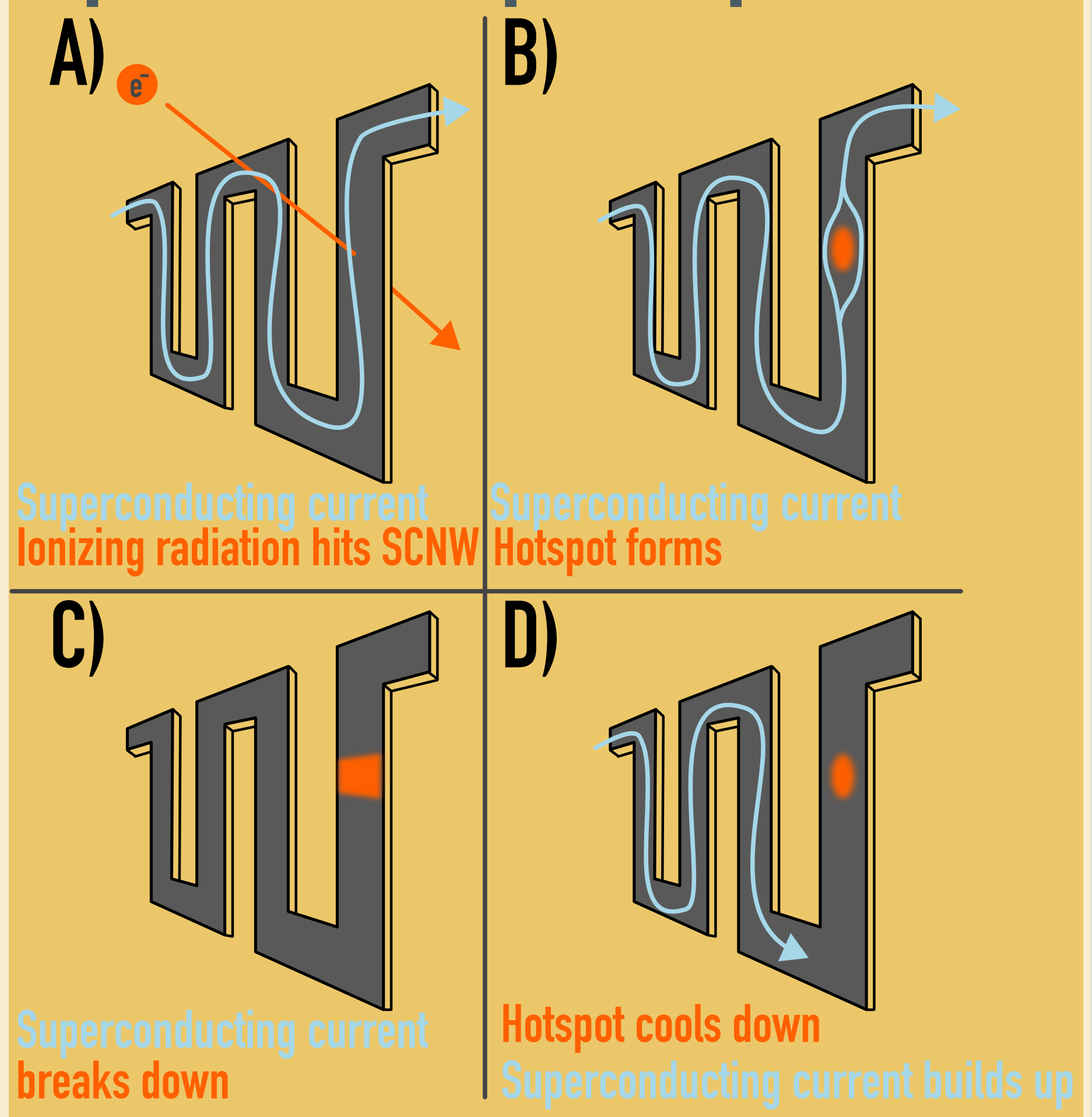
Future plans

- Test SCNW by Quantum Opus

➡ Has aluminum coating to prevent charge pile-up

- Develop and test e^- focusing system

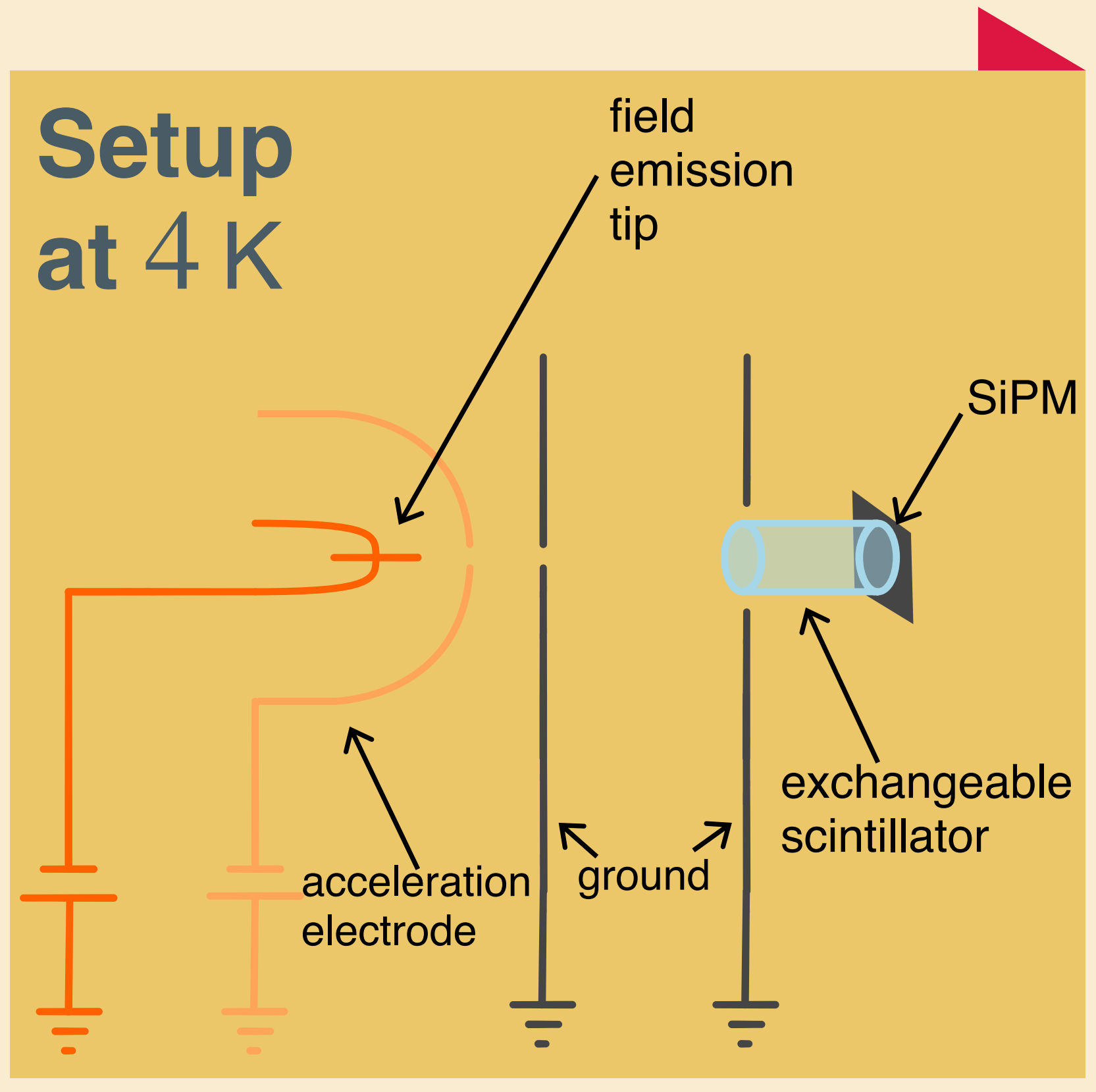
Operational principle



A) SCNW has supercurrent close to threshold; Ionizing radiation hits SCNW
B) Locally Cooper-Pairs are broken; a non-superconducting hotspot forms
C) The hotspot expands until cross section of SCNW is non-superconducting; a voltage drop is measurable
D) Parallel shunt resistance allows hotspot to cool down; supercurrent builds up

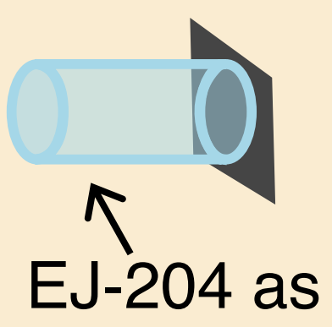
2C Perovskite scintillators

Setup at 4 K

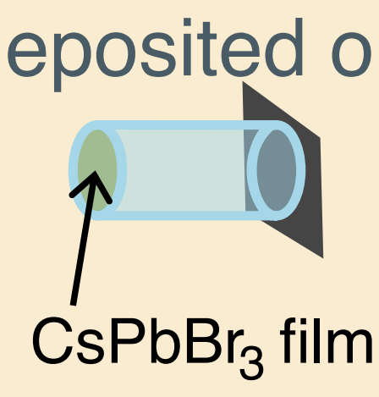


- e^- from field emission tip accelerated onto scintillator
- Setup cooled down to 4 K
- Tested 2 scintillators

➡ EJ-204 plastic scintillator


EJ-204 as in 2A

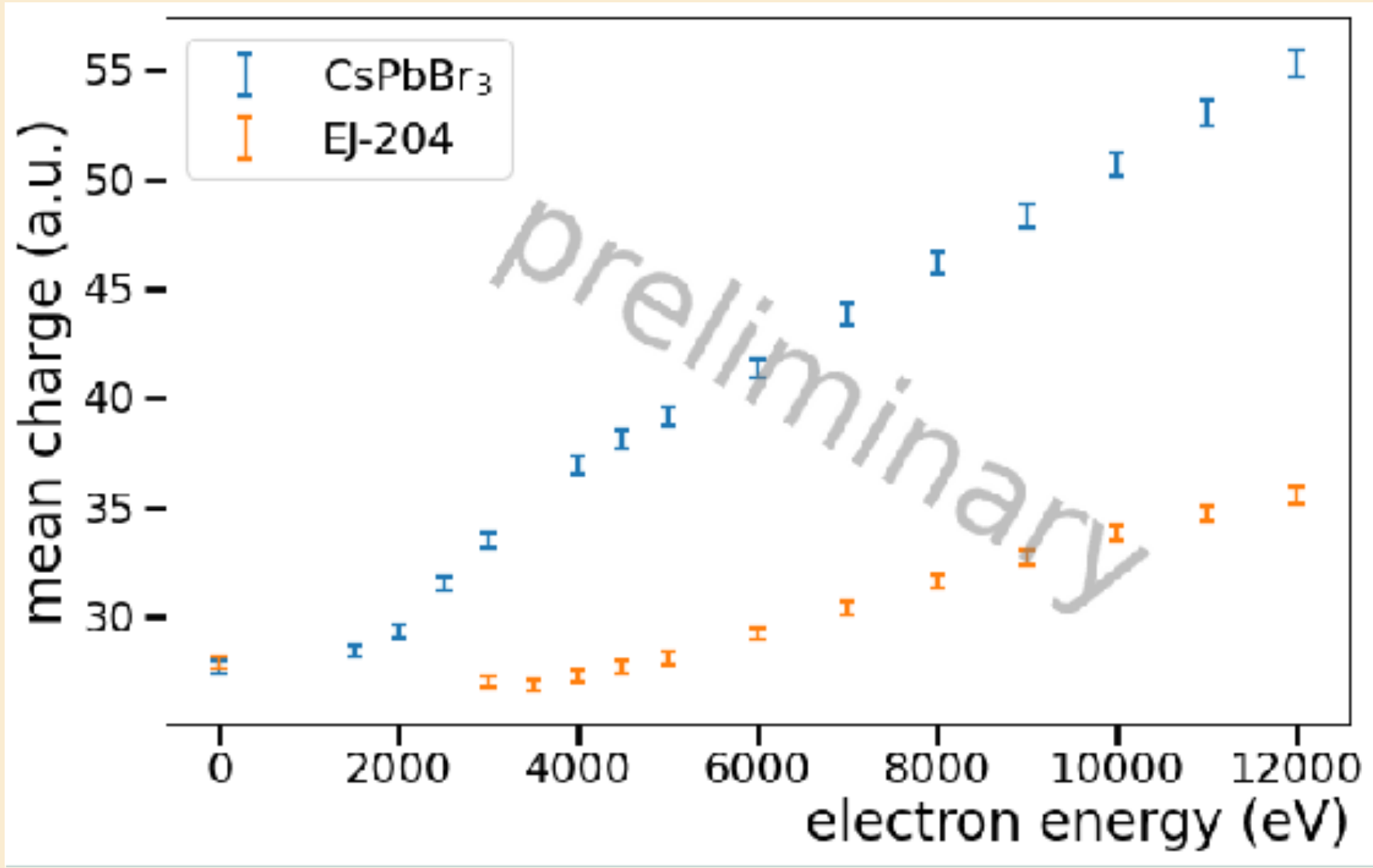
➡ $CsPbBr_3$ nanocrystals deposited on EJ-204


$CsPbBr_3$ film

Perovskite as high efficiency scintillator in the cold?

- Nanocrystals/quantum dots of $CsPbBr_3$ show remarkable scintillation properties in the cold [3]

➡ Fast decay time
➡ High light yield



Results

- Recorded charge spectrum of SiPM for different electron energies
- Further validation needed

Further Ideas

- Deposit nanocrystals directly onto SiPM as in [6]
- Use different scintillator
  - GAGG:Ce as scintillator
  - LYSO:Ce as scintillator

Bibliographie / sources

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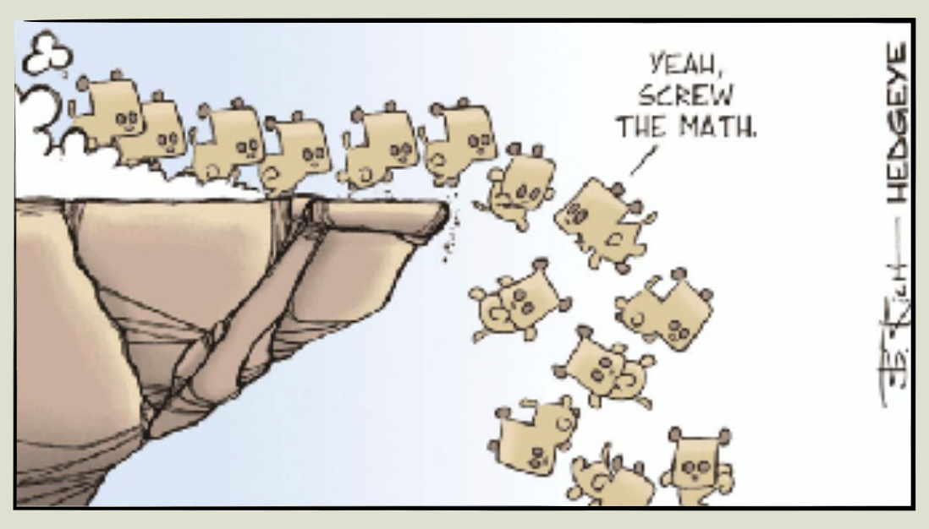

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