Muon Detector for Students (MUDS)

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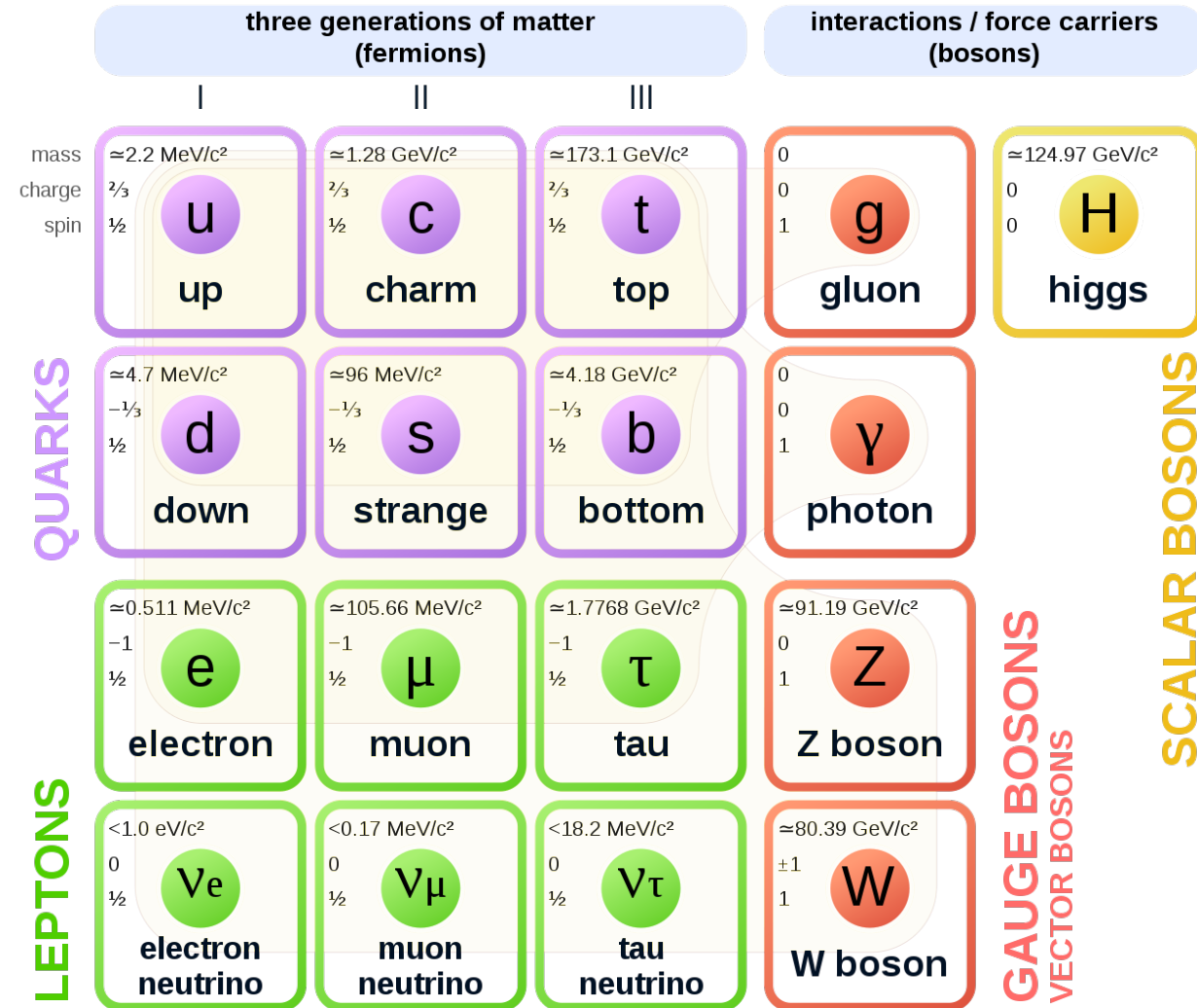
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Goals of MUDS

- Detect Muons (measure the particle rate) at Sea Level
- Circuit should be affordable and simple so that a class of high school students could potentially replicate the detector – class project?
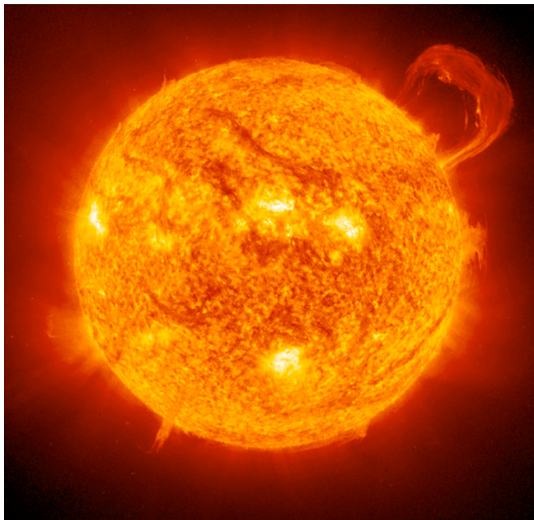
Muons?

Standard Model of Elementary Particles

What are Cosmic Rays?

- Cosmic Rays are high energy particles
  - "High Energy" = traveling near the speed of light (i.e. $\frac{v^2}{c^2}$ is not negligible)
- Cosmic Rays originate from the sun, other stars, supernovae, and other parts of the universe
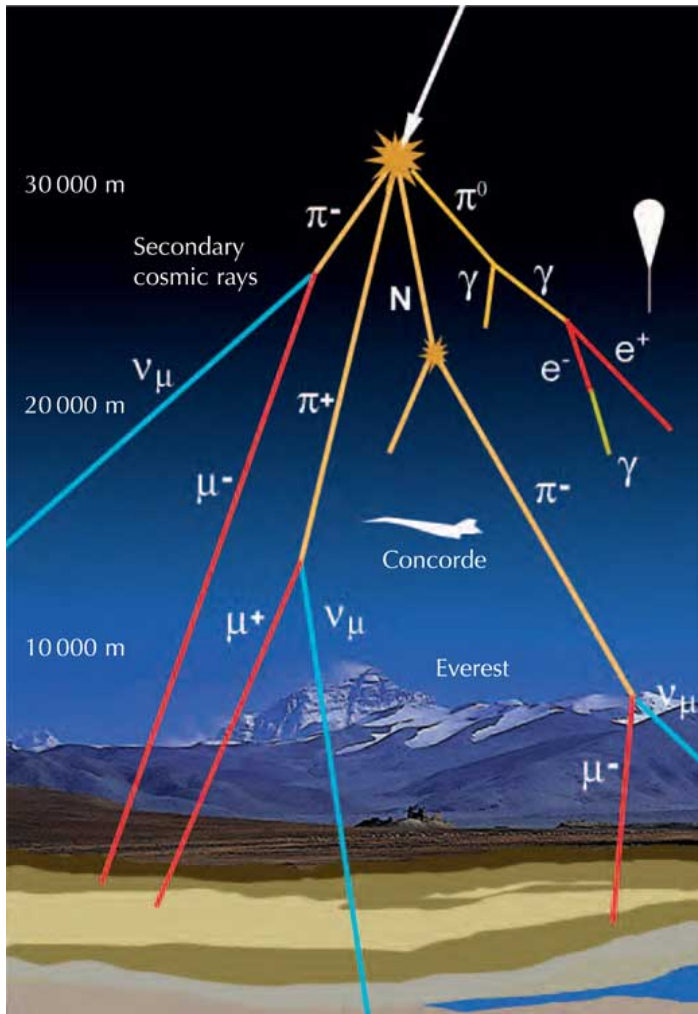

https://www.thesun.co.uk/wp-content/uploads/2019/03/NINTCHDBPICT000000417642.jpg

https://upload.wikimedia.org/wikipedia/commons/9/98/Andromeda_Galaxy_%28with_h-alpha%29.jpg

What Types of Particles are Cosmic Rays?

- 89% Protons (Hydrogen)
- 9% Alpha Particles (Helium)
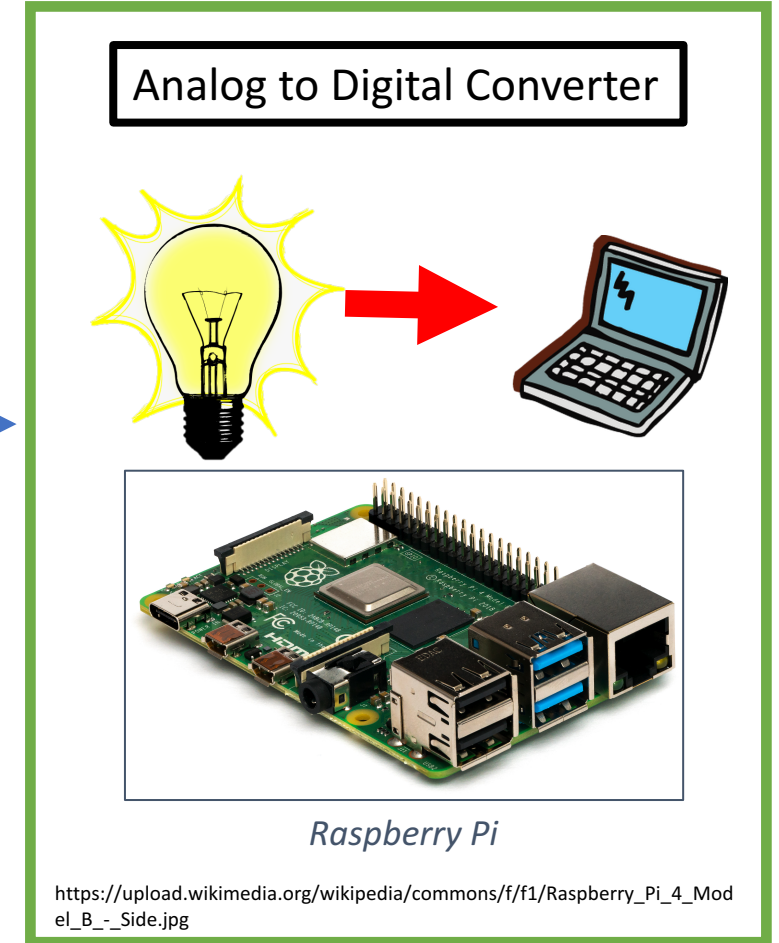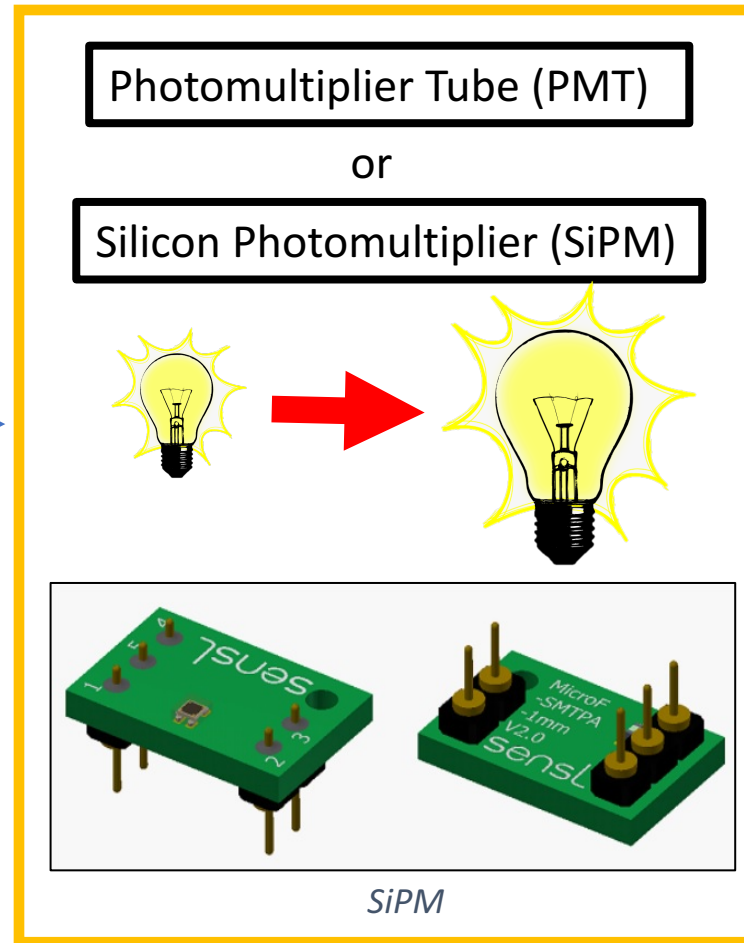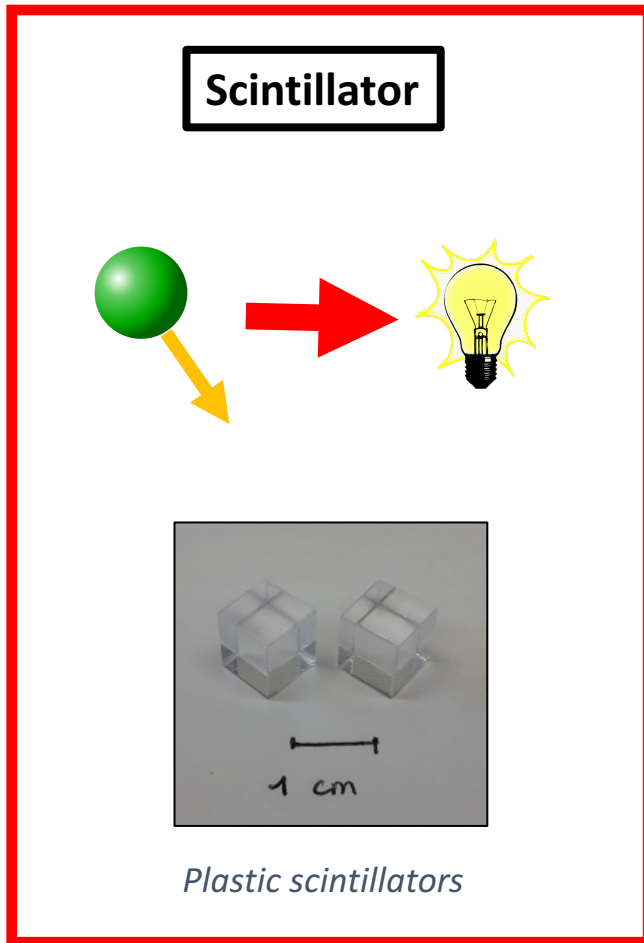- 1% Electrons
- 1% Nuclei of Other Elements
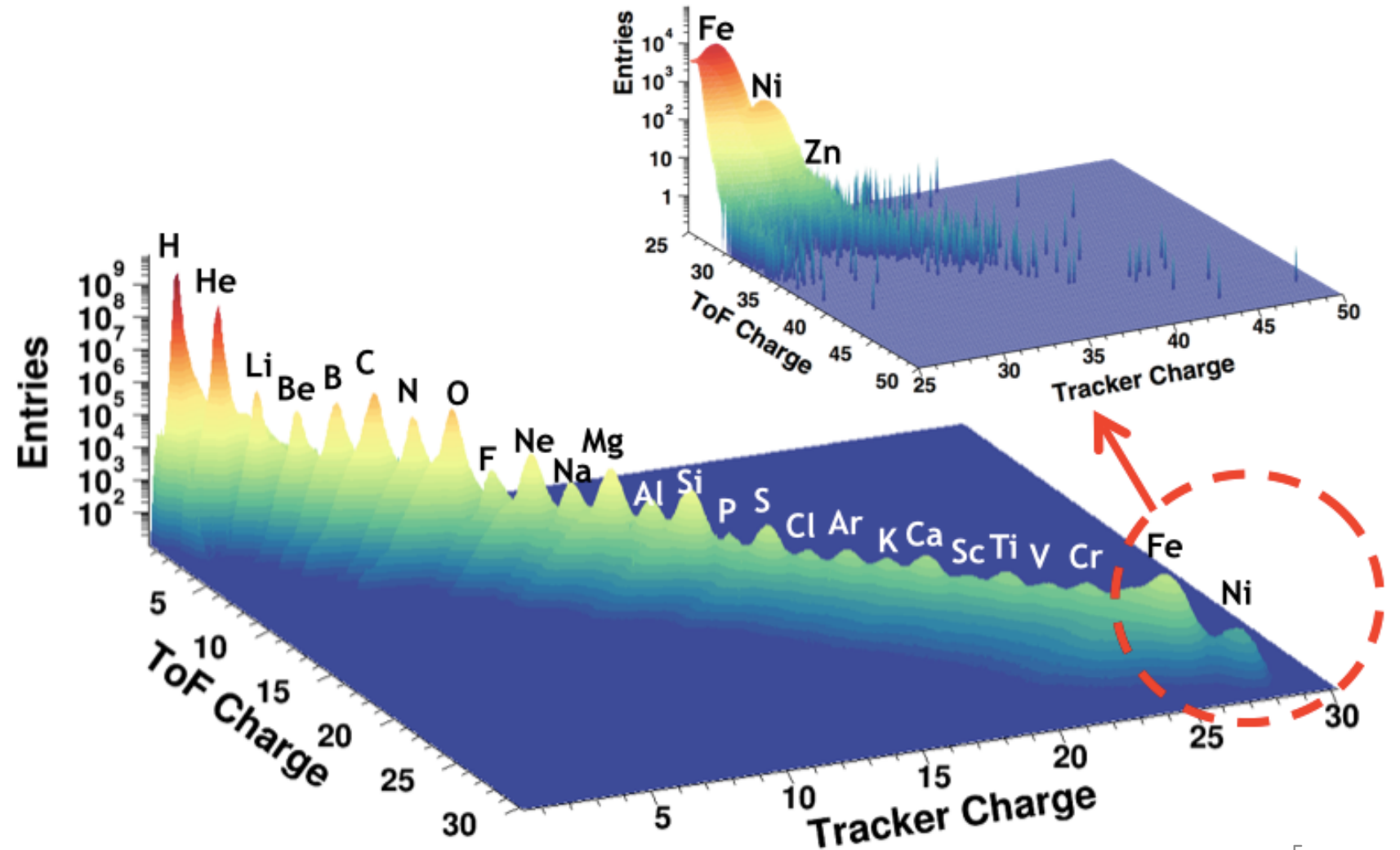
What Are the Effects of Cosmic Rays at Sea Level?

- When Cosmic Rays reach Earth, they interact with molecules in the atmosphere and create showers of new particles
- The particles created in these showers have short lifetimes and decay rapidly into other particles
- The particles which survive long enough to reach the ground are primarily Muons, Neutrinos and Gamma Rays
- At sea level every square meter receives about 100 muons per second

How to Detect Particles?
A Simplified Detector



Scintillator

Plastic scintillators

Photomultiplier Tube (PMT)

or

Silicon Photomultiplier (SiPM)

SiPM

Analog to Digital Converter

Raspberry Pi

https://upload.wikimedia.org/wikipedia/commons/f/f1/Raspberry_Pi_4_Model_B_-_Side.jpg

Requirements

Part	Considerations
Scintillator (BC-408 ?)	• Need to reduce background light so that scintillation from muon energy deposition is primary source of light
SiPM (Sensl C-Series: MicroFC-SMTPA-10035)	• Pulse Width 0.6 ns (Fast Output) • Needs Biasing circuit • Needs Transimpedance Amp to convert from Q → V (really I → V) • Additional Amp Stage?
ADC (MCP3008)	• 75-200 kilosamples/sec ($V_{DD}=V_{REF}=2.7V$ & 5V) → best possible acquisition time = 5 µs • Needs Sample and Hold

SiPM wrapped with scintillator by foil and black tape

Schematic
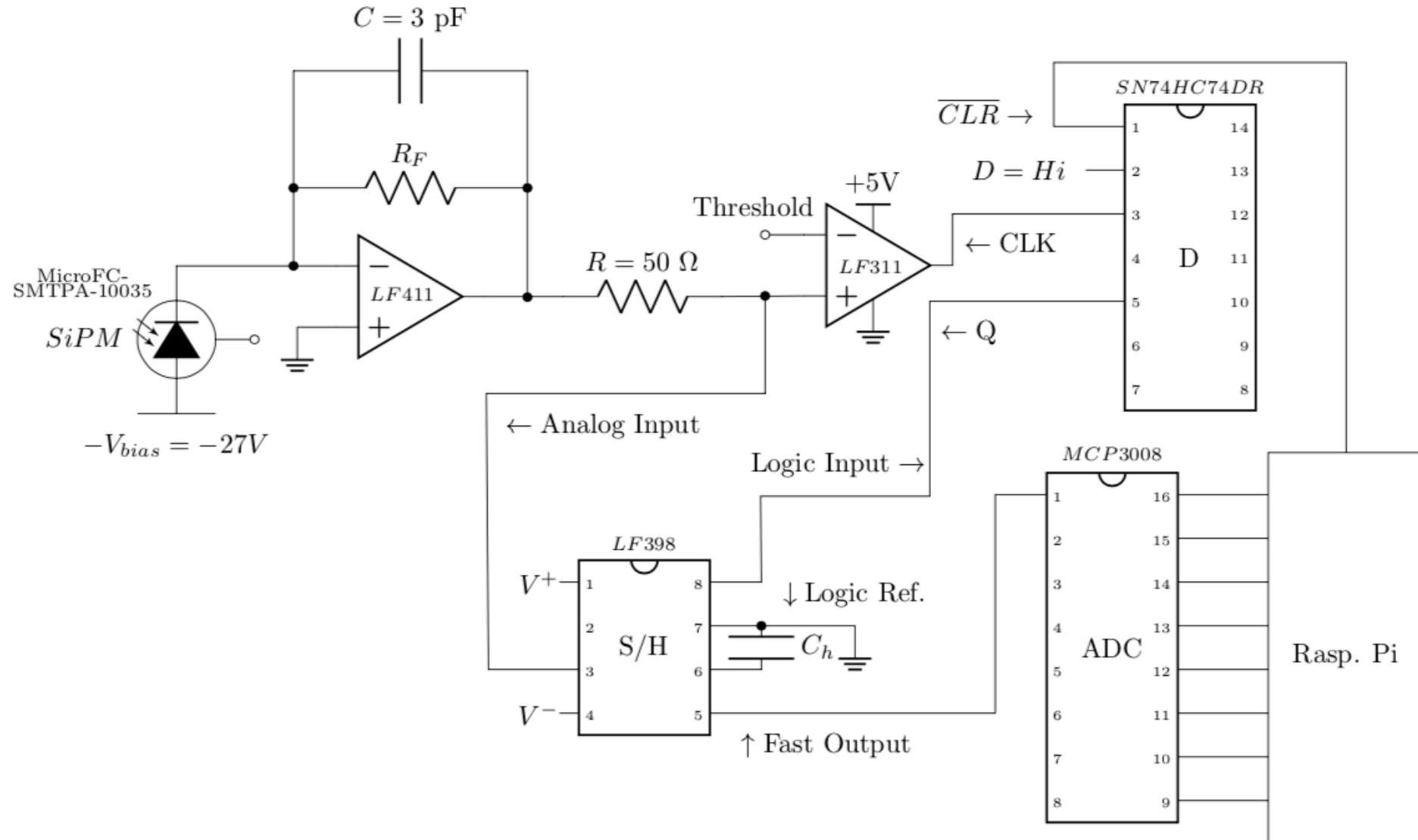
Schedule

- Build the circuit by Tuesday
- Debug/Make sure circuit works by Friday morning

Open Questions/Concerns

- Should I use the fast output or standard output of the SiPM?
- Do I need an additional amplification stage after the transimpedance amp?
- How to calculate theoretical signal? → Setting the Threshold
- Total Circuit Cost = about $200 plus cost of Rasp Pi

Questions?

Thank You For Listening!