# REPTile: A Miniaturized Detector for a Cubesat Mission to Measure Relativistic Particles in Near-Earth Space

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August 11, 2010

# The Radiation Belts

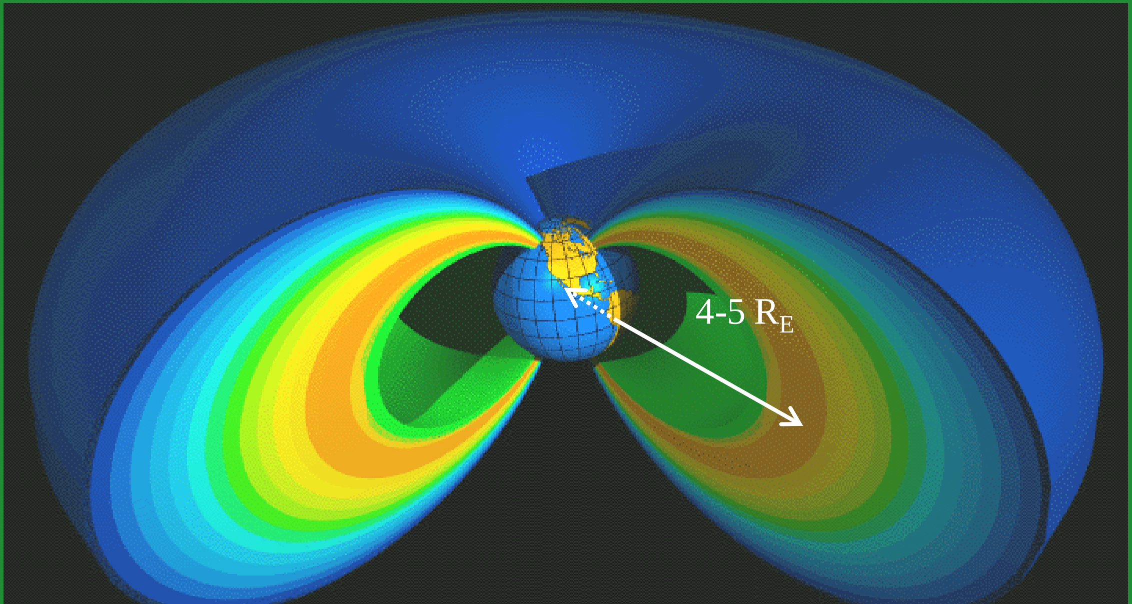


Figure borrowed from NASA's ISTP site

Dynamic system - potentially fatal to spacecraft and astronauts

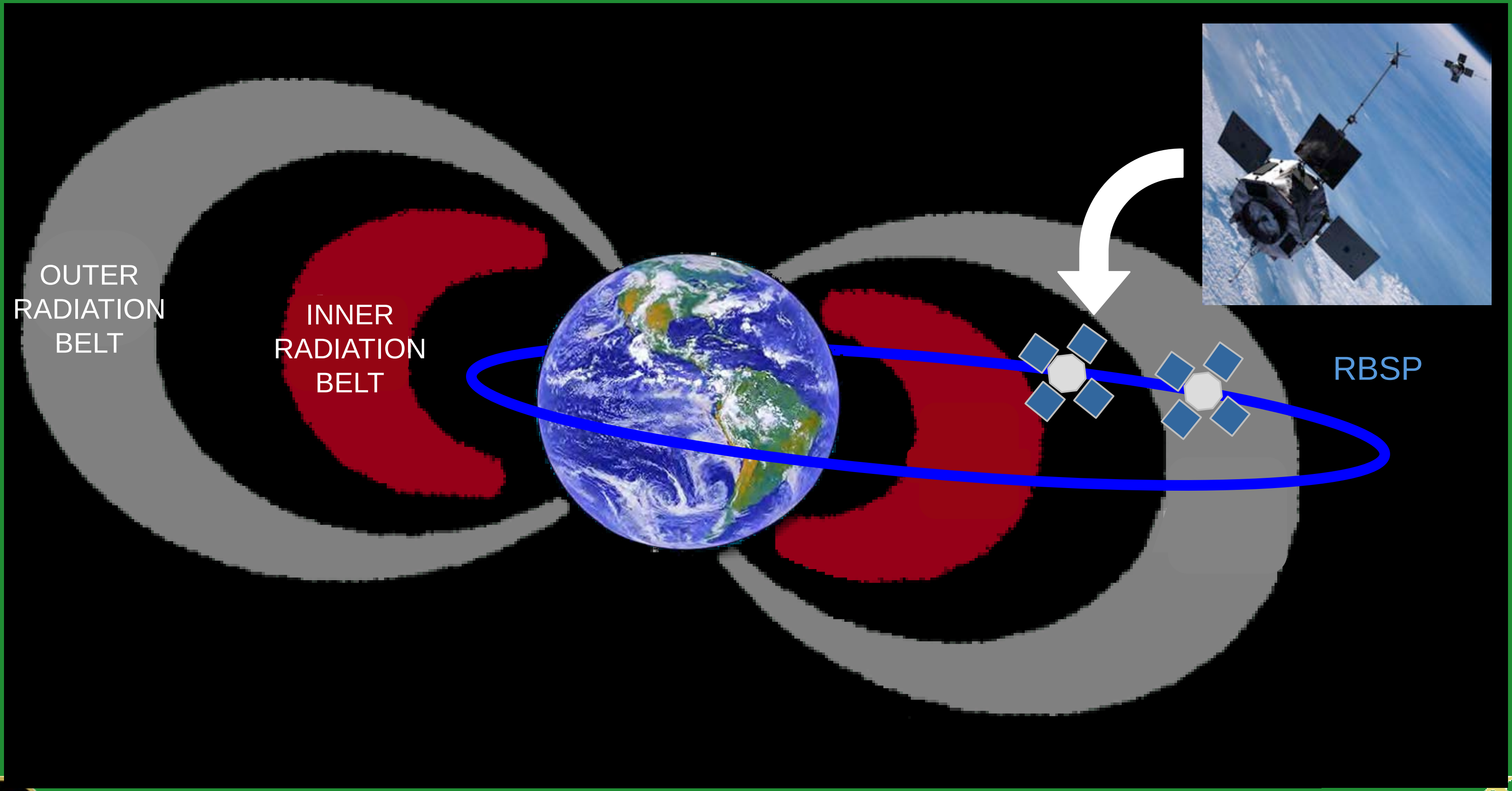
April 5, 2010 - Intelsat Galaxy 15 "ZombieSat" fails due to unexpected particle flux increase ~$300M loss

Unanswered Questions: Source, Loss, Transport Mechanisms

# Conjunctive Science

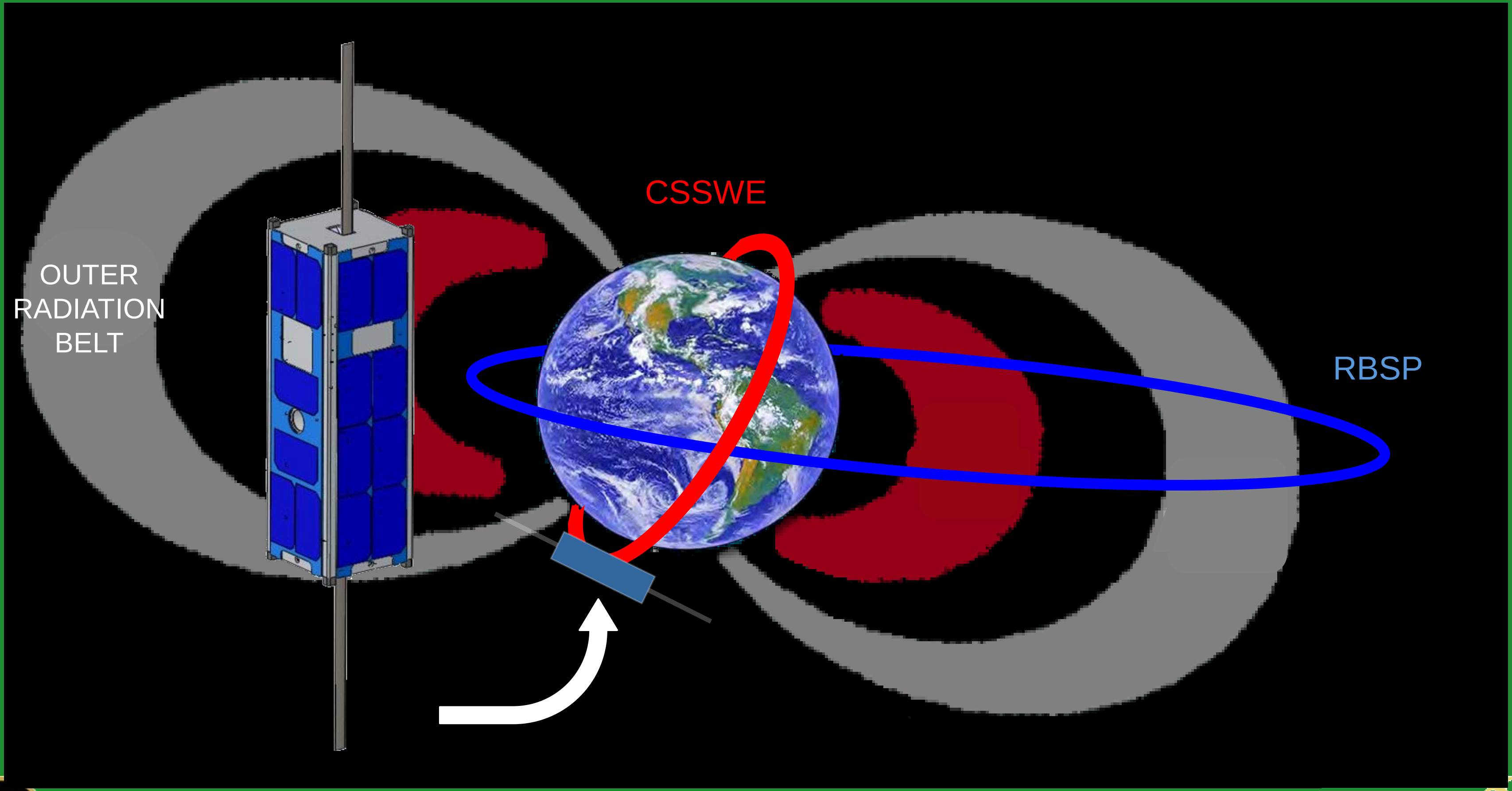
In-situ measurements: Radiation Belt Storm Probes (RBSP)

via the Relativistic Electron and Proton Telescope (REPT)



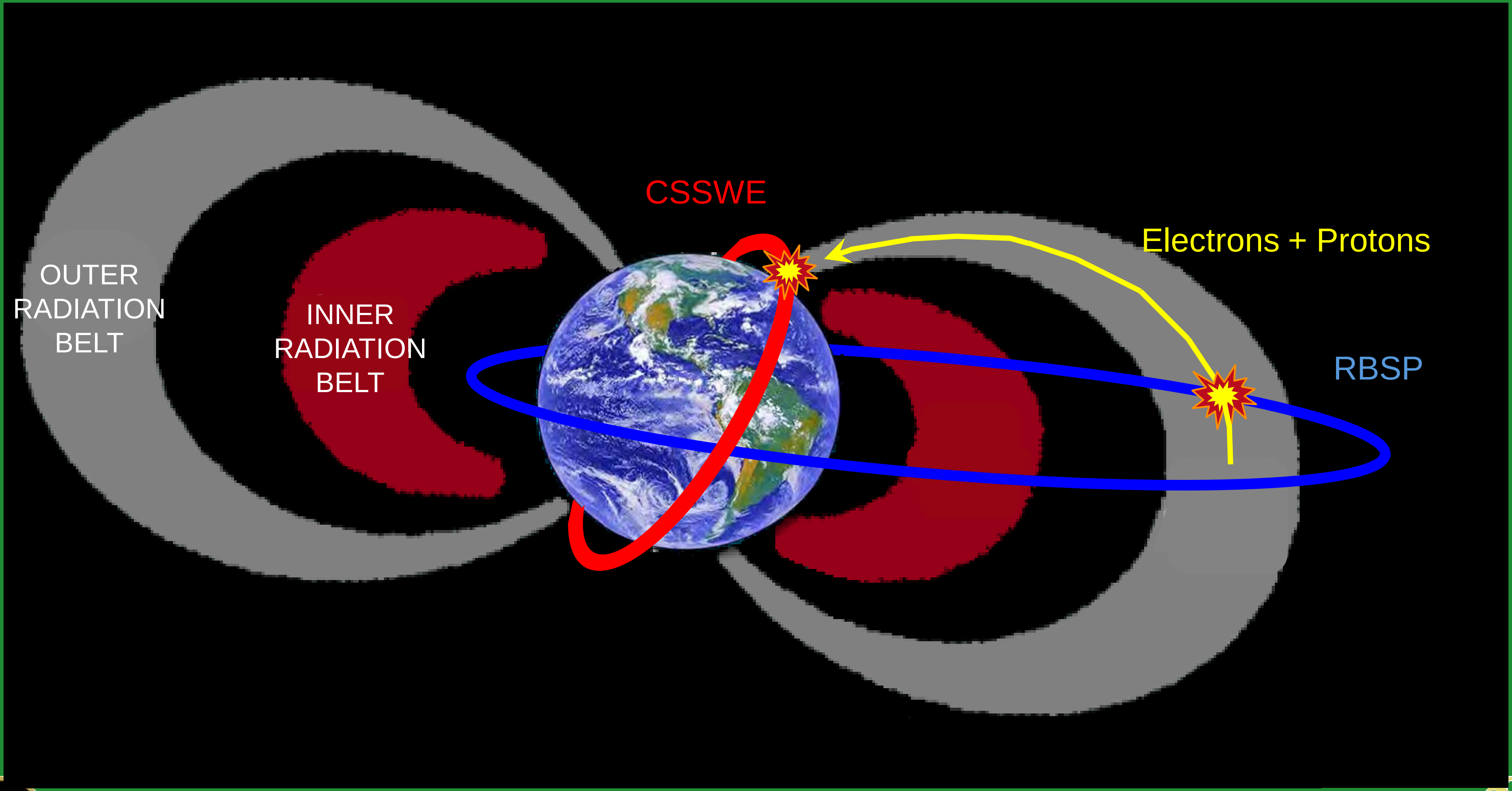
# Conjunctive Science

Colorado Student Space Weather Experiment (CSSWE)



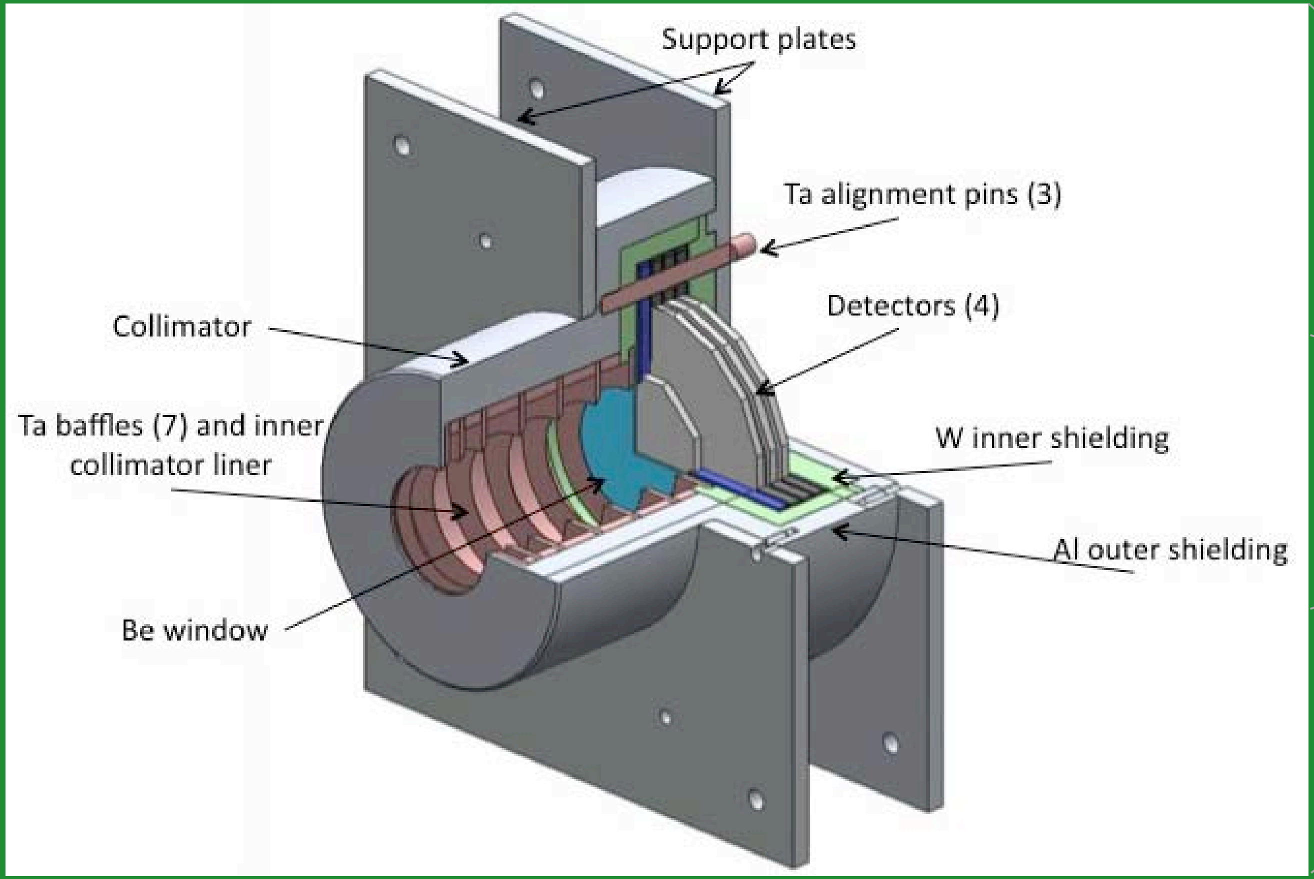
# Conjunctive Science

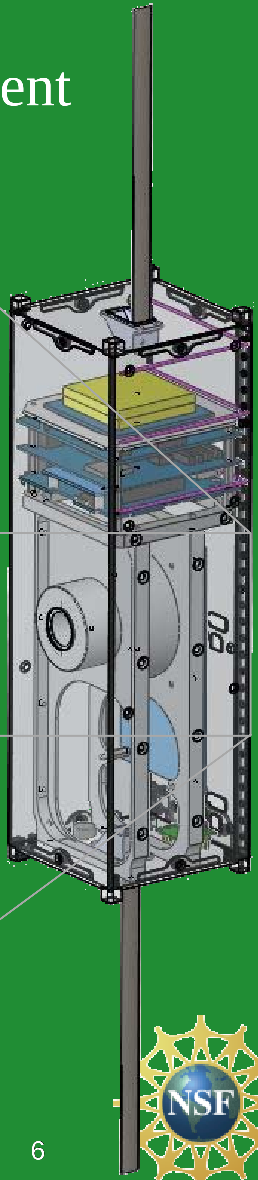
Concurrent particle measurements



# REPTile

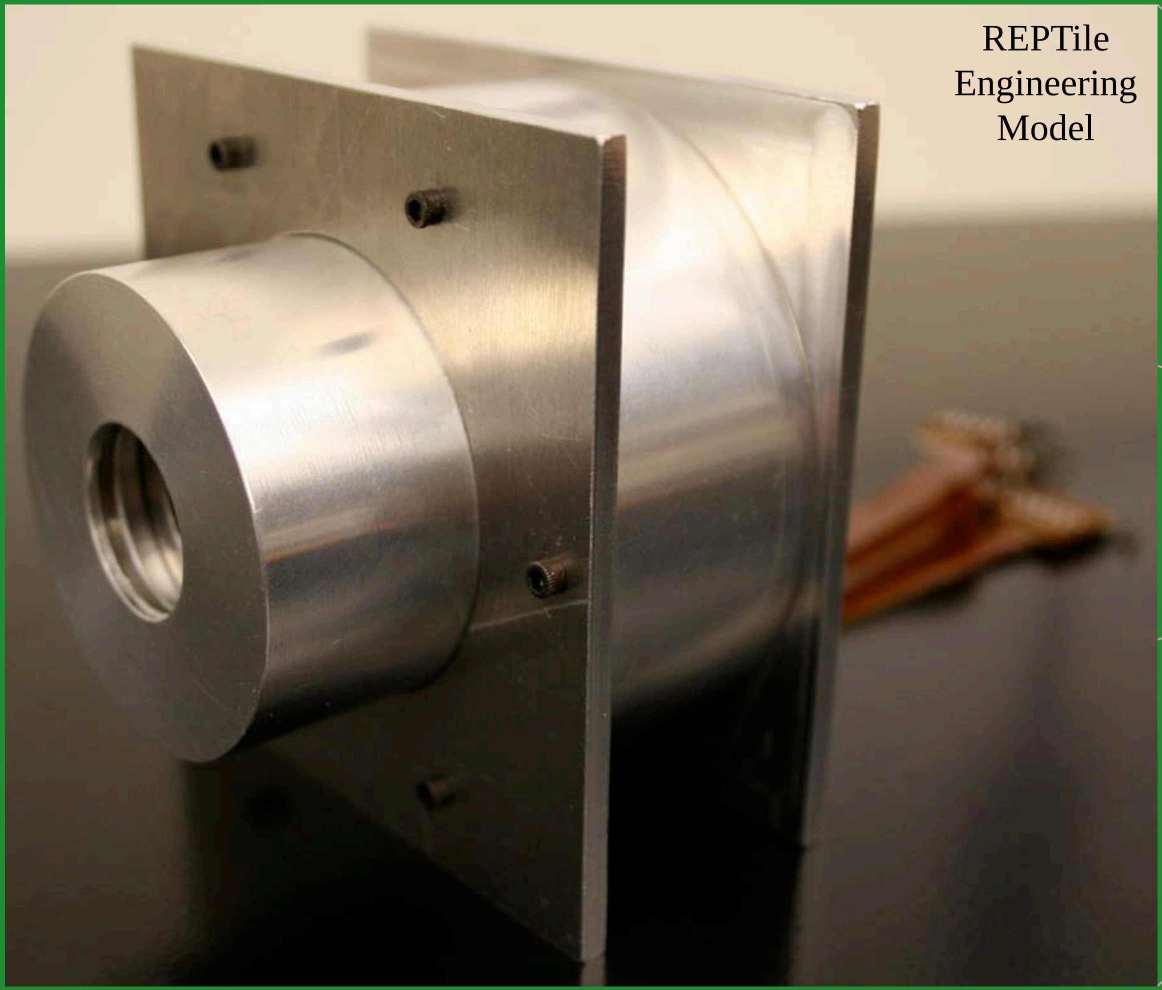
***R***elativistic ***E***lectron and ***P***roton ***T***elescope ***i***ntegrated ***l***ittle ***e***xperiment

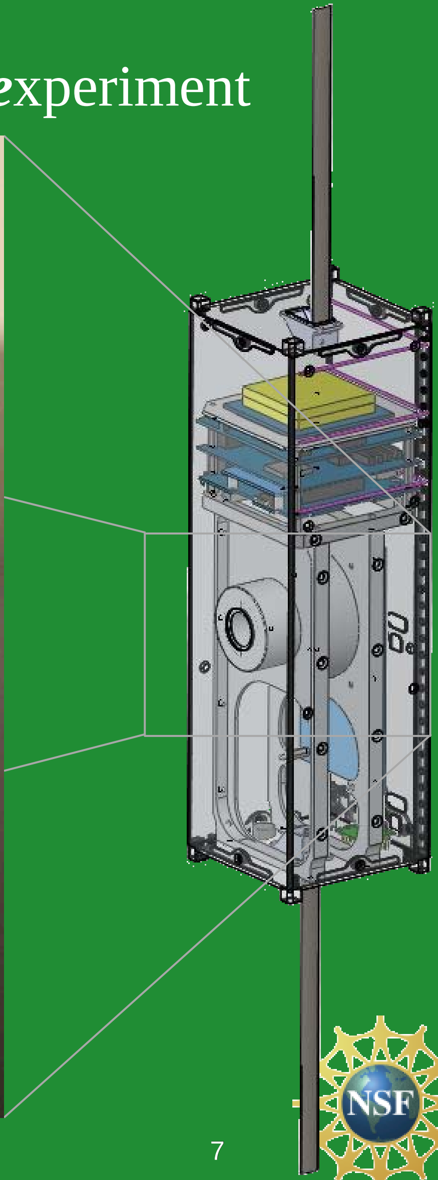


# REPTile

*R*elativistic *E*lectron and *P*roton *T*elescope *i*ntegrated *l*ittle *e*xperiment



# C●nnecting the D●ts

Noise 4 ●

● 3 Signal

● 1 Cost

●
2
Mass

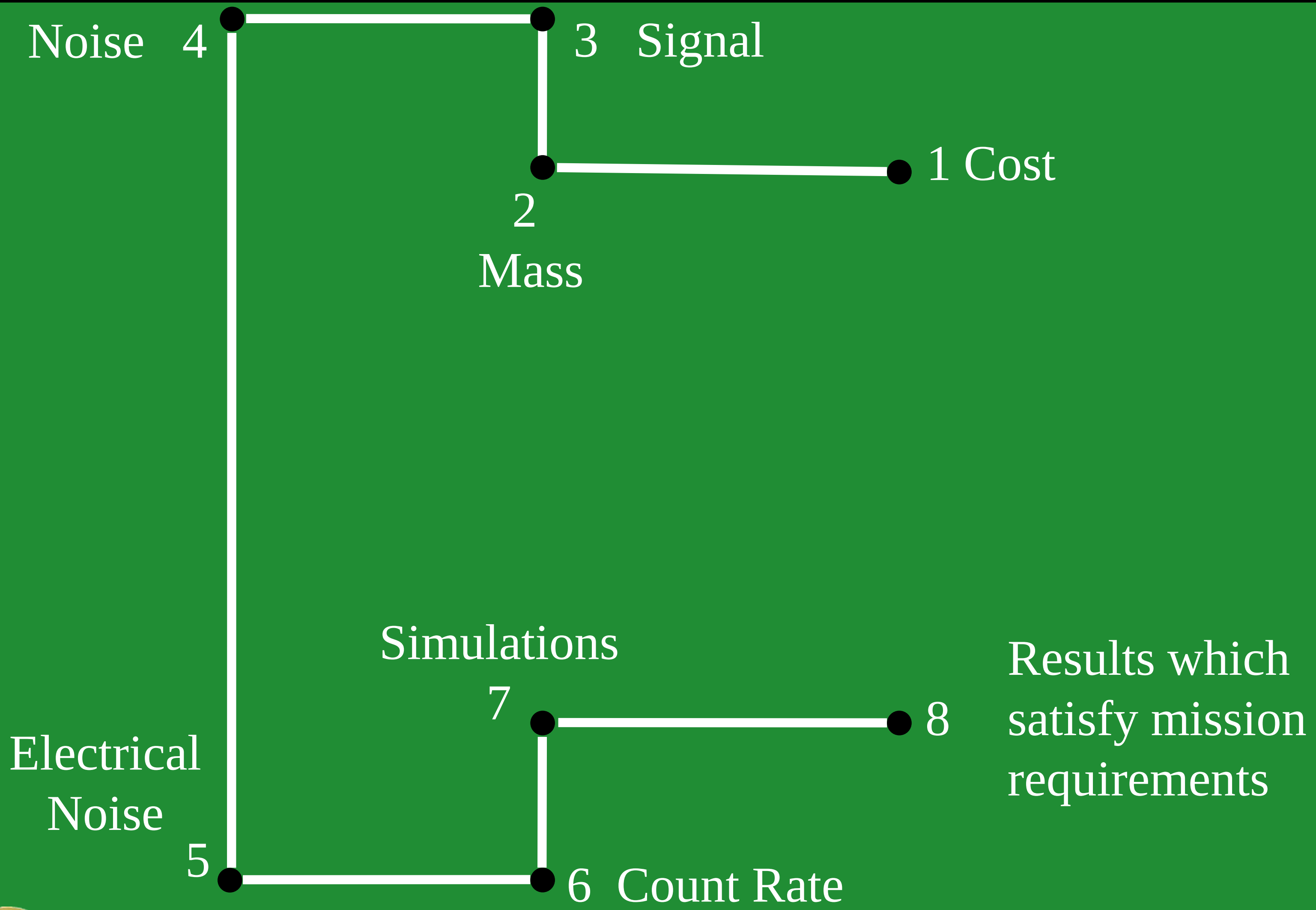
Simulations
7 ●

● 8 Results which satisfy mission requirements

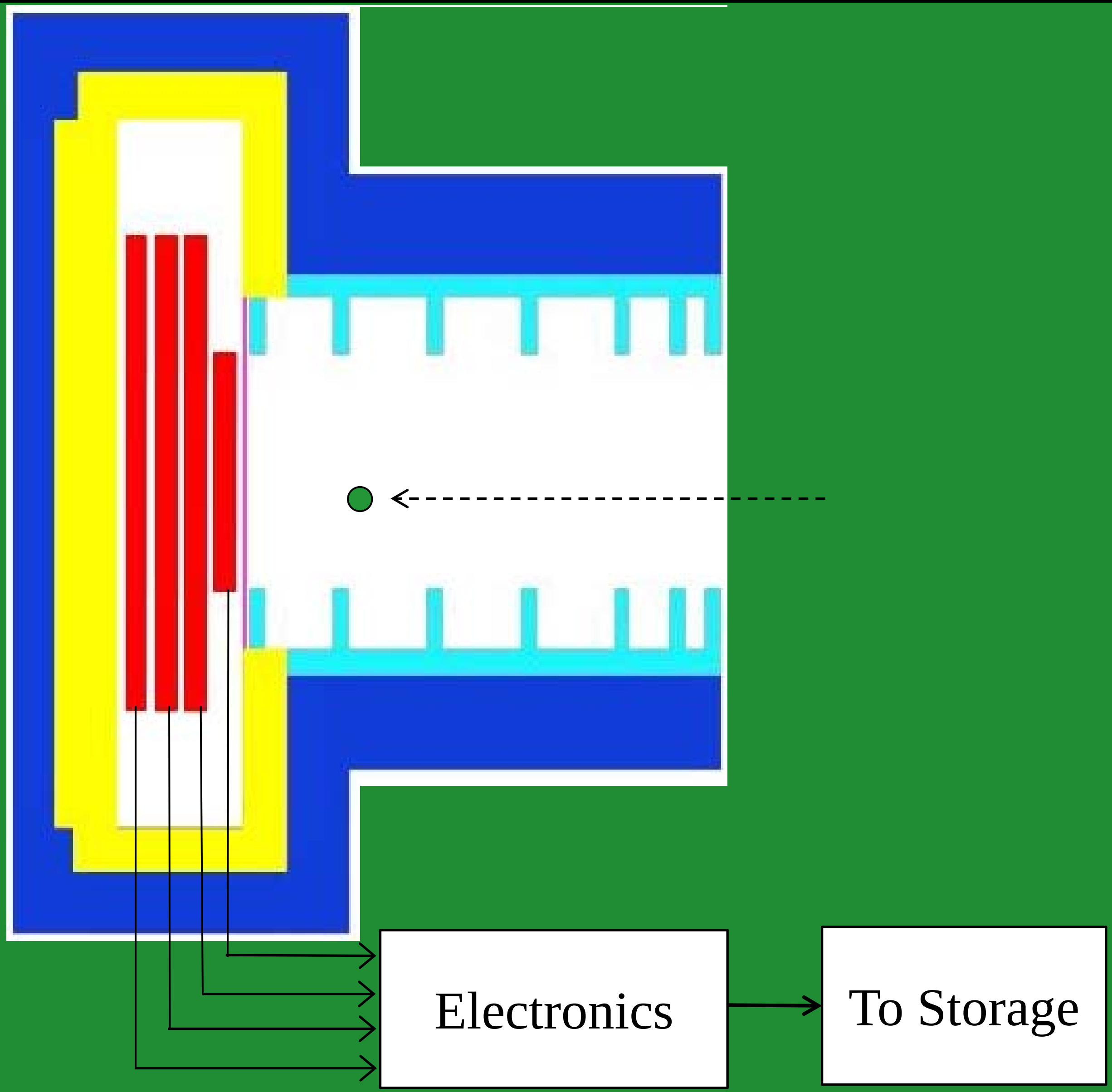
Electrical
Noise
5 ●

● 6 Count Rate

# C●nnecting the D●ts



# Simulating Science Environment



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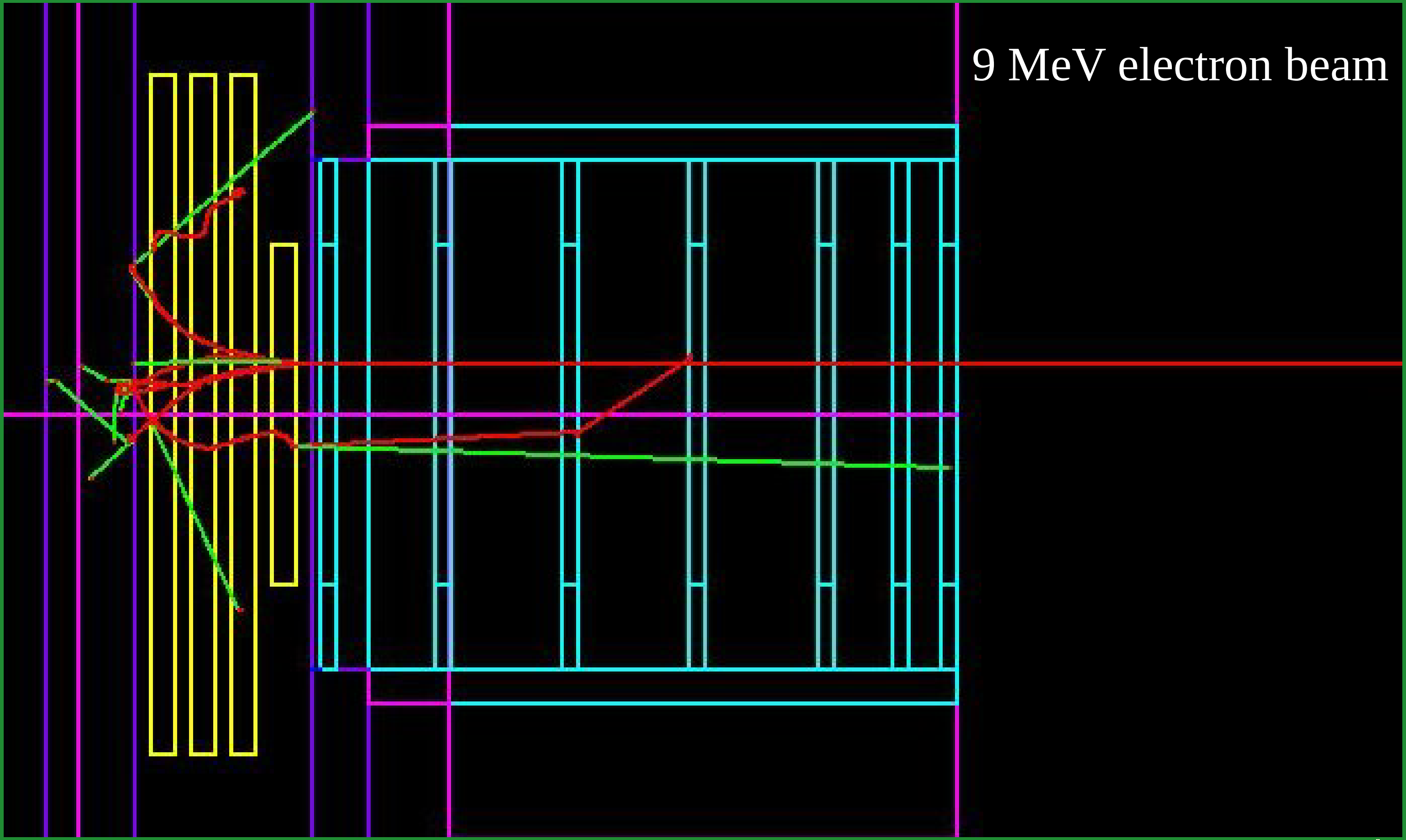
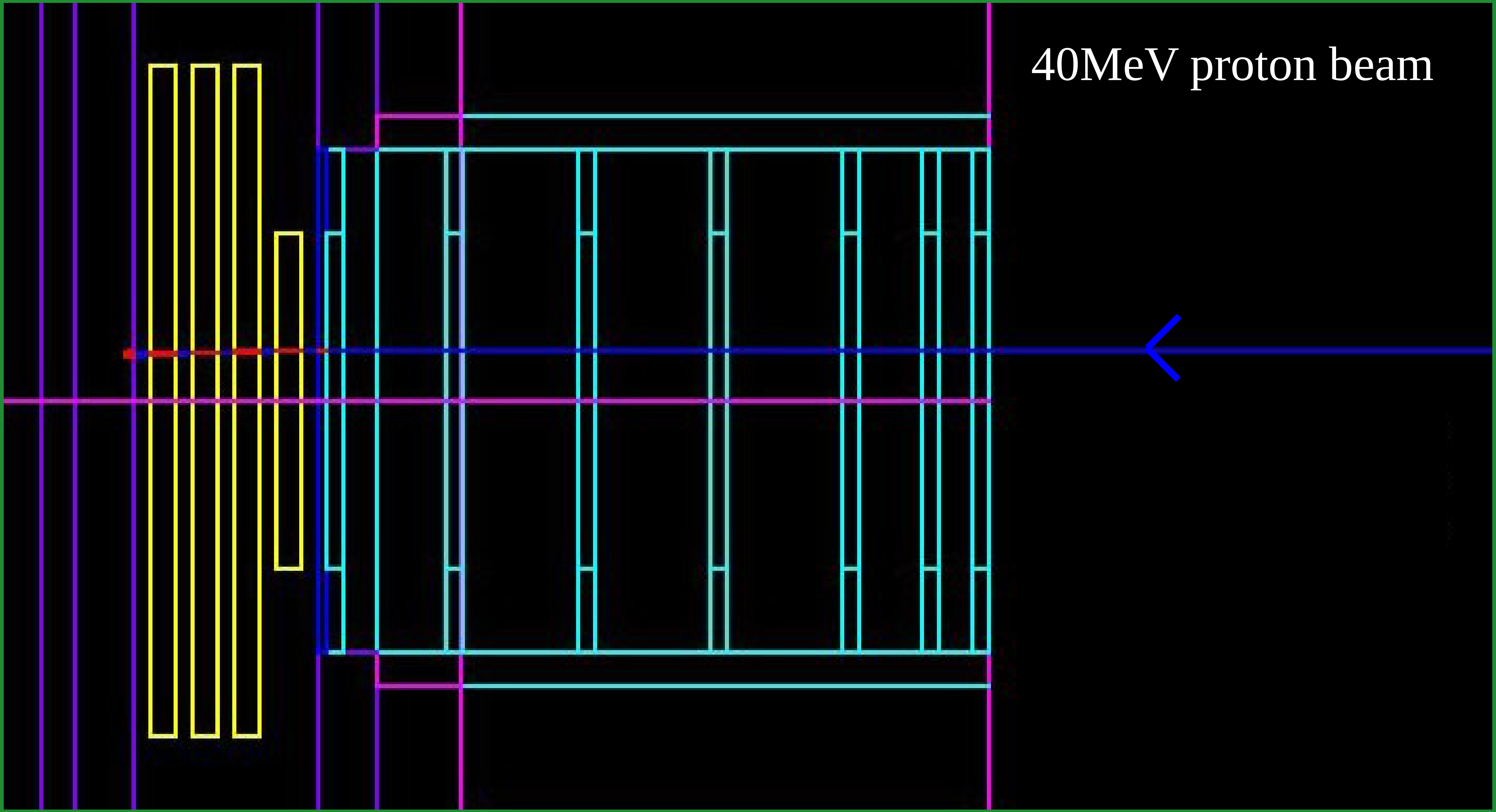
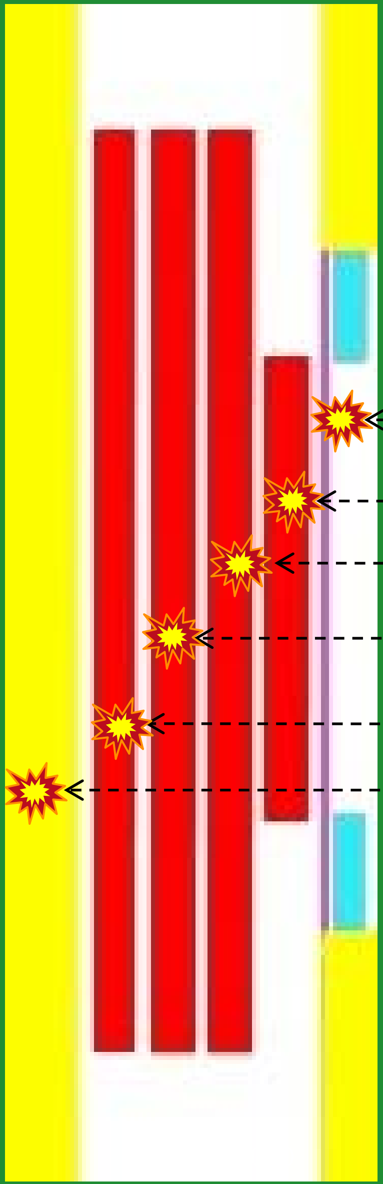
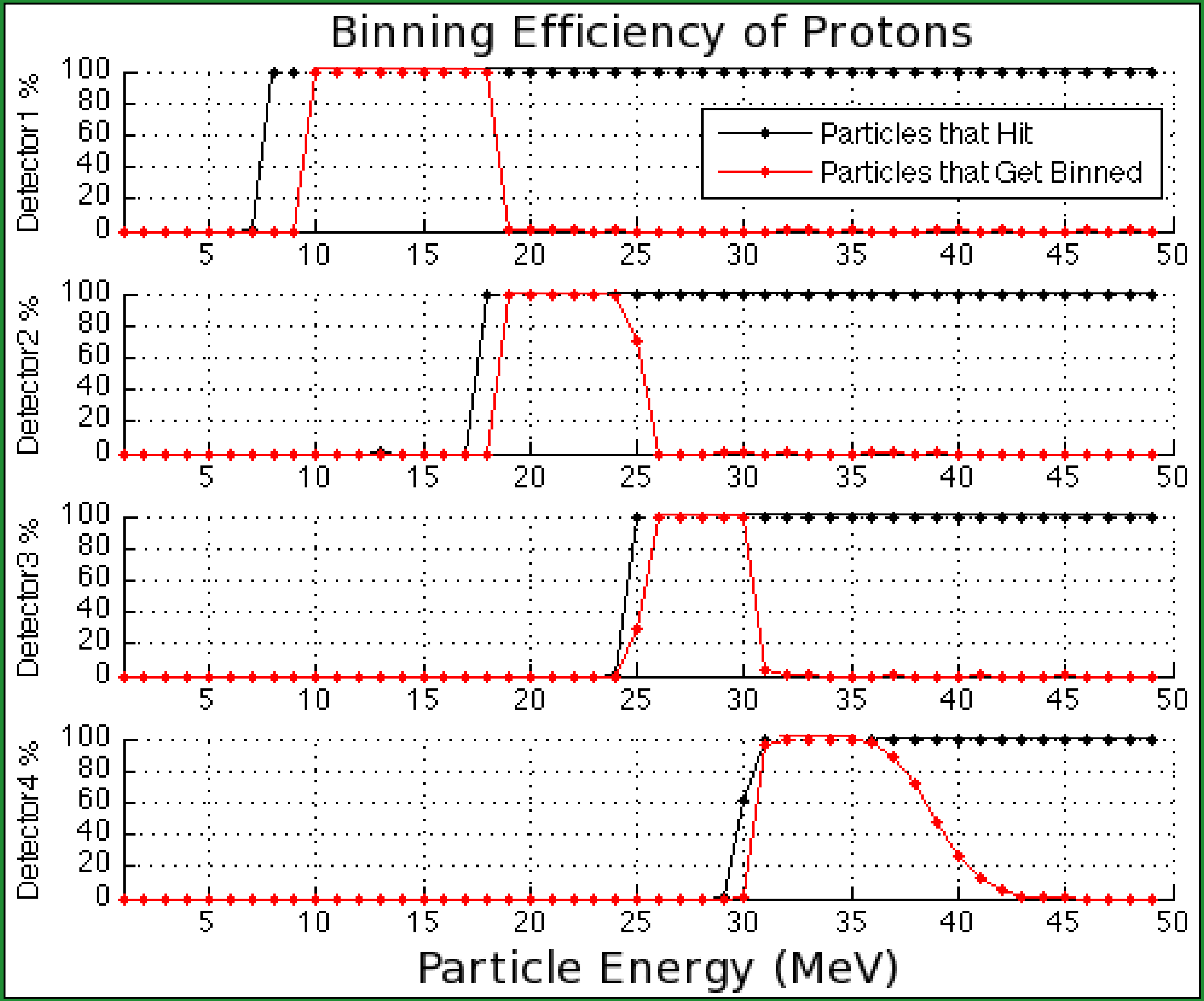


# Simulating Science Environment



# Simulating Signal





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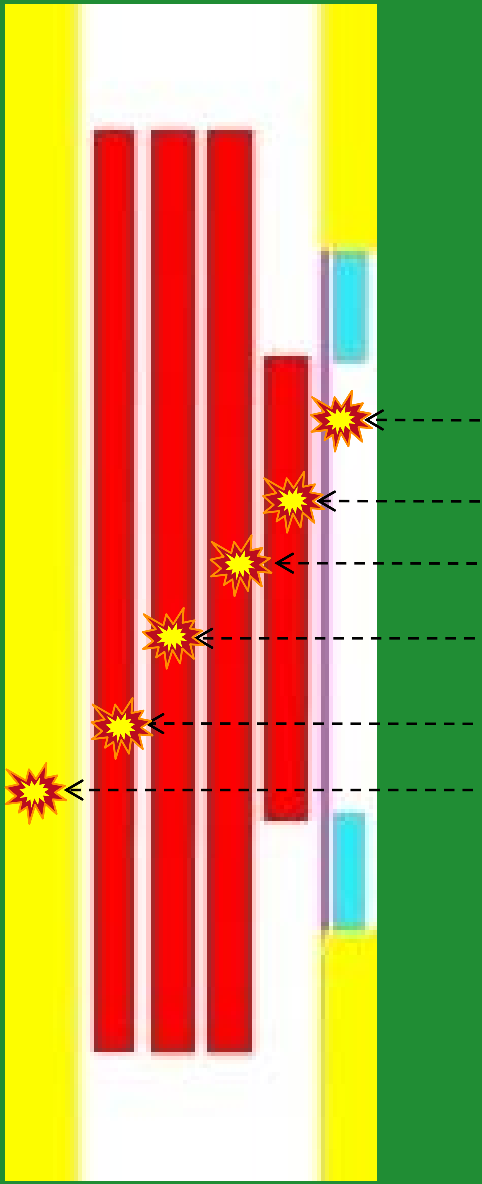
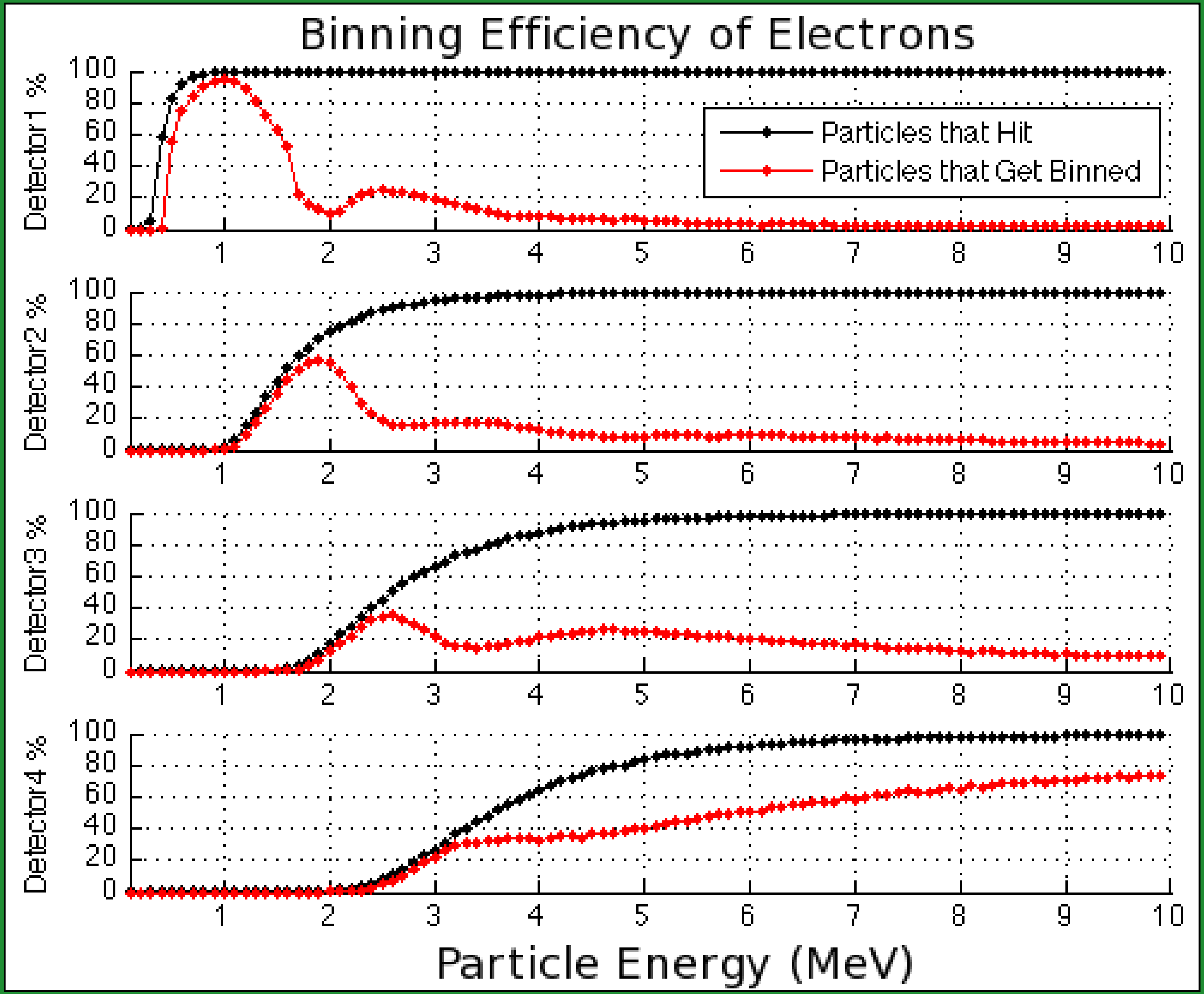
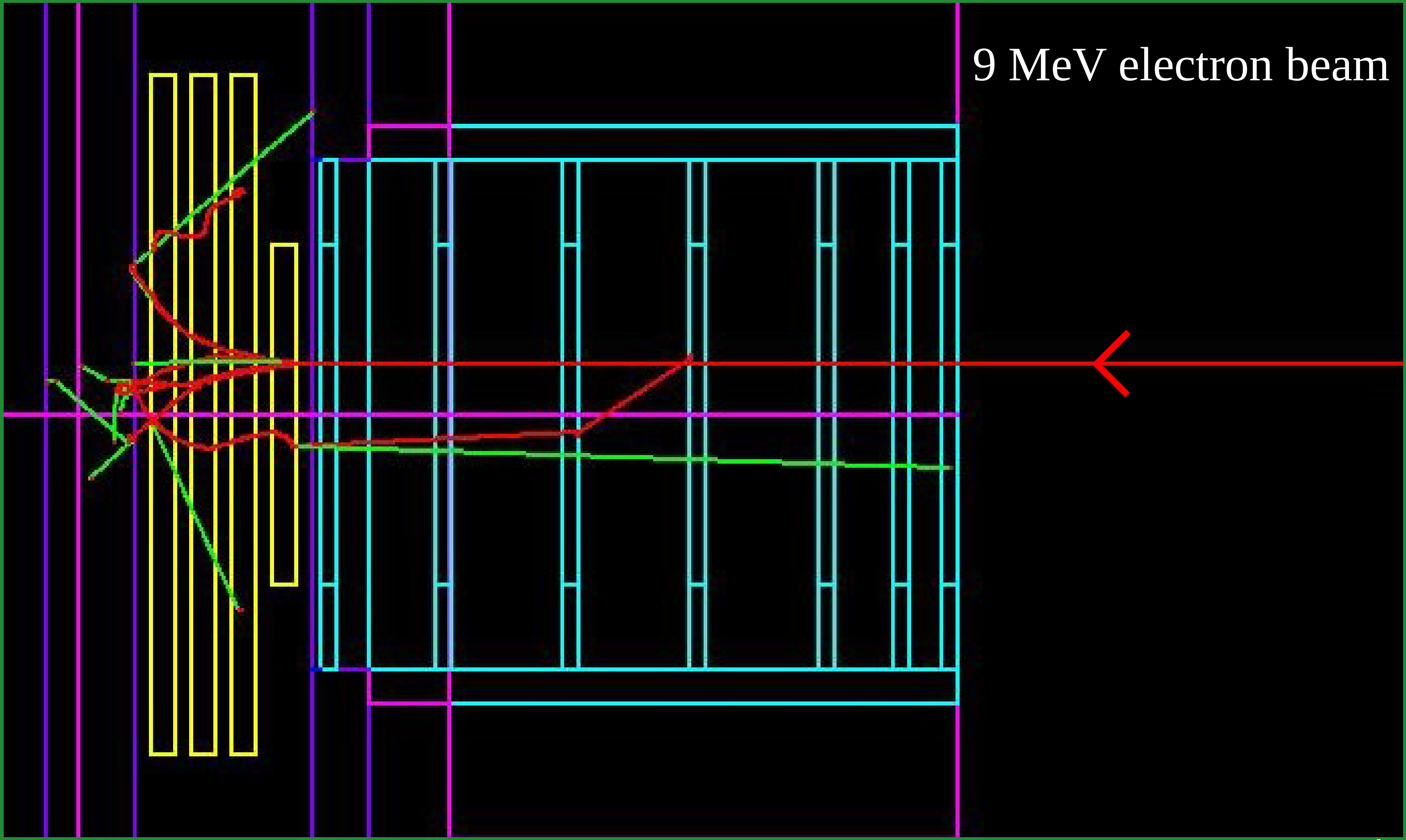
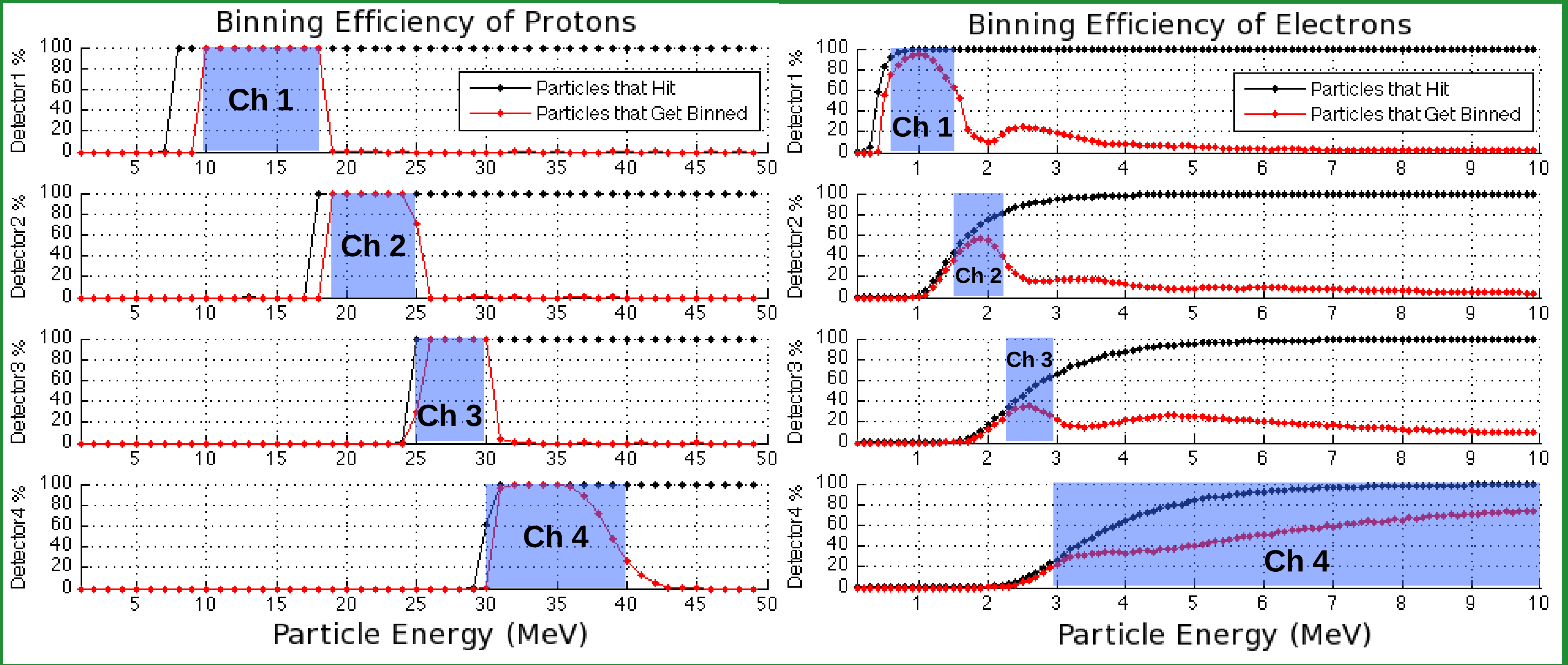




# Simulating Science Environment

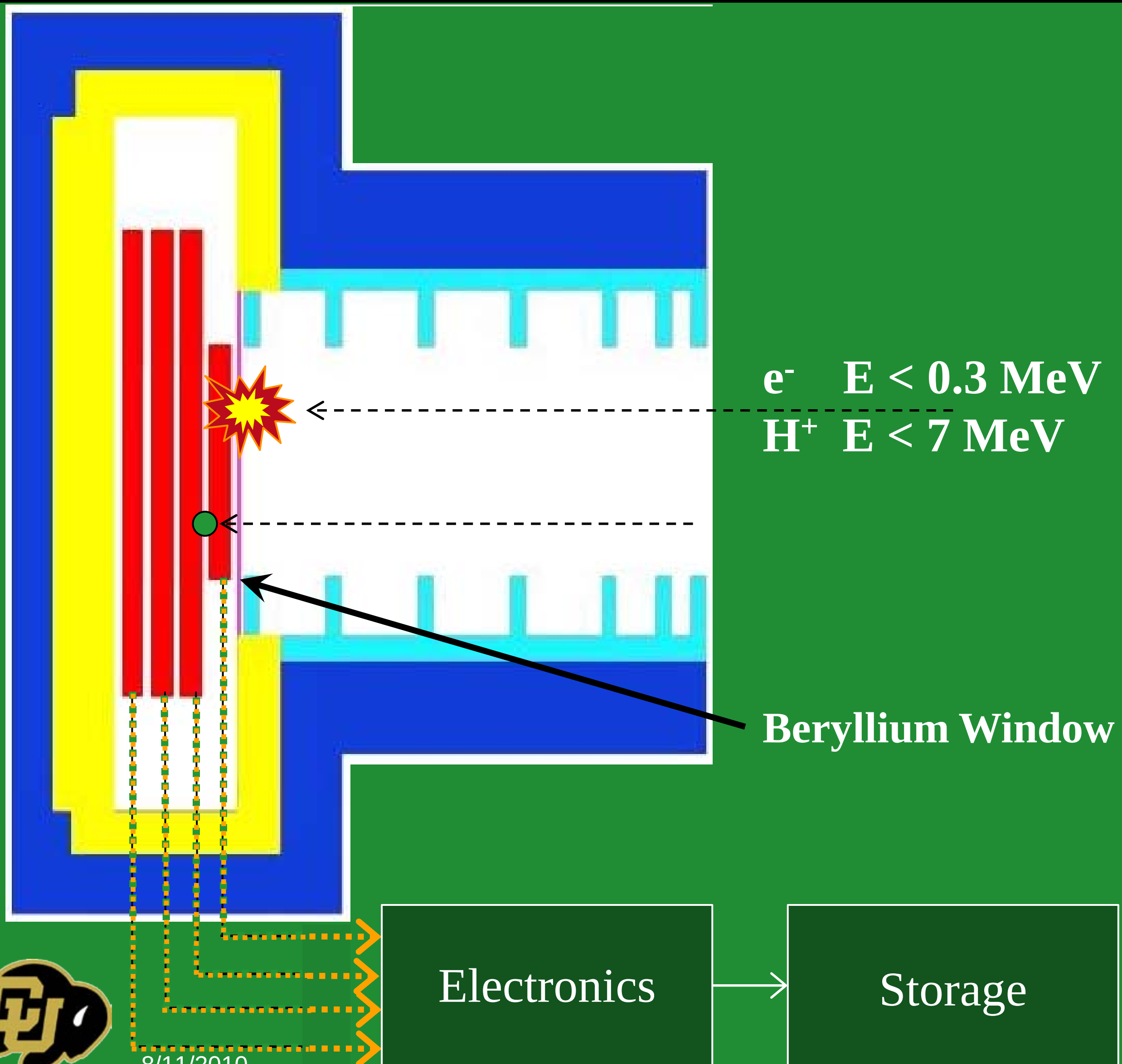


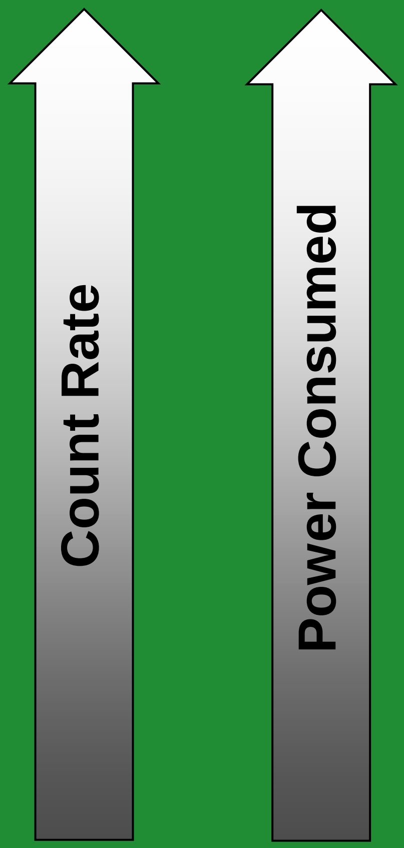
# Instrument Performance



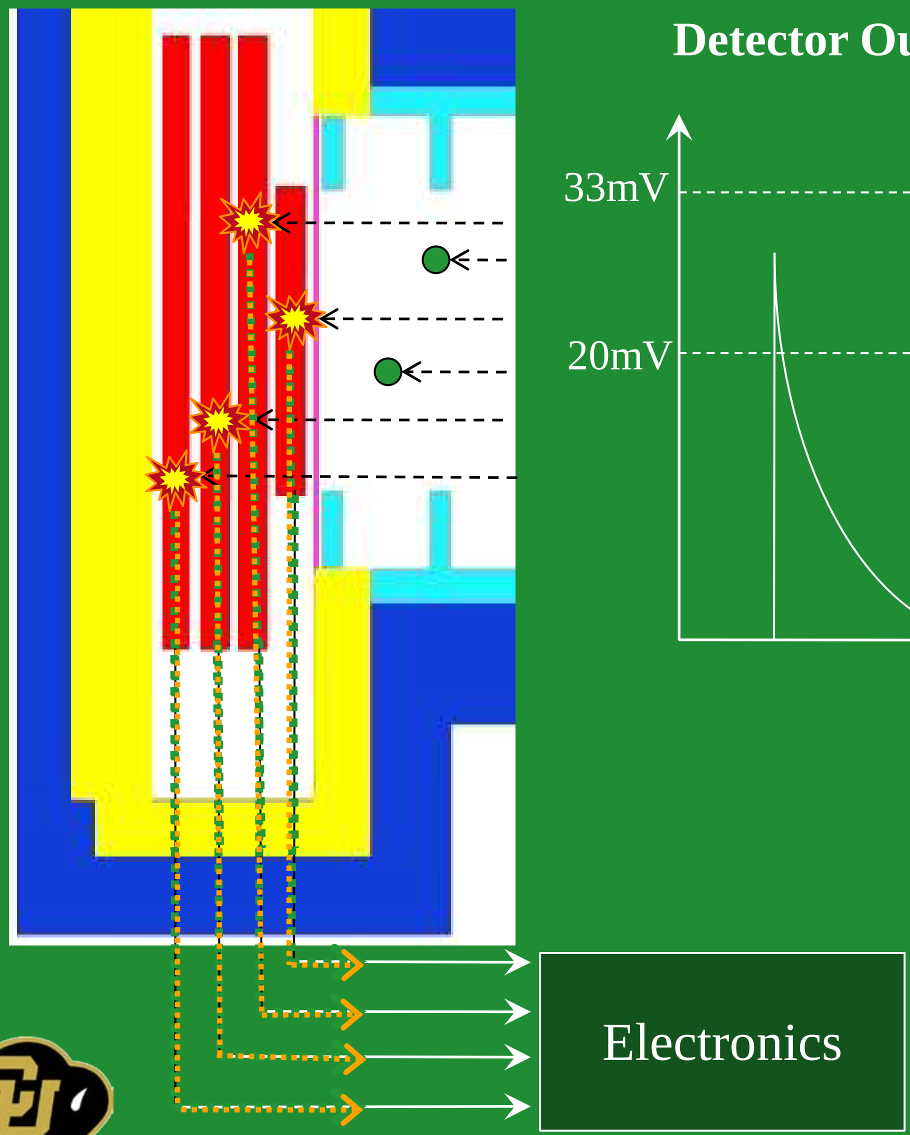

| CSSWE Science Objectives | | | | |
|---|---|---|---|---|
| | **Detector 1** | **Detector 2** | **Detector 3** | **Detector 4** |
| **Electrons** | **0.5-1.5 MeV** | **1.5-2.2 MeV** | **2.2-2.9 MeV** | **>2.9 MeV** |
| **Protons** | **10-18 MeV** | **18-25 MeV** | **25-30 MeV** | **30-40 MeV** |

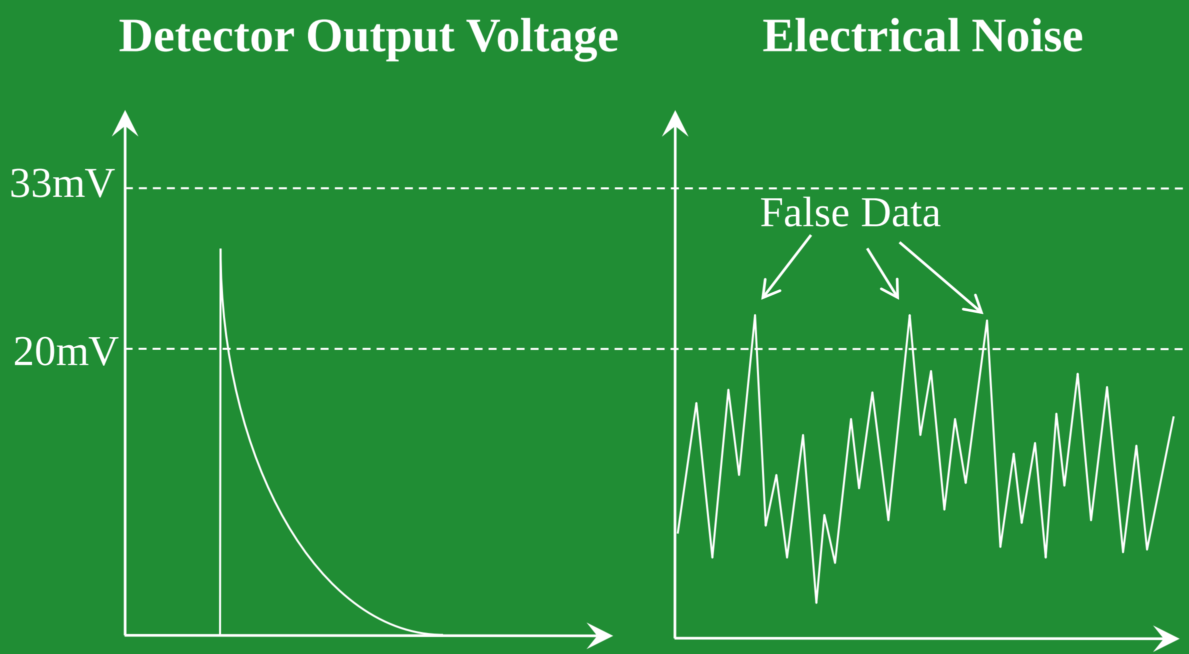
# Electronics Saturation



# Electronics Noise



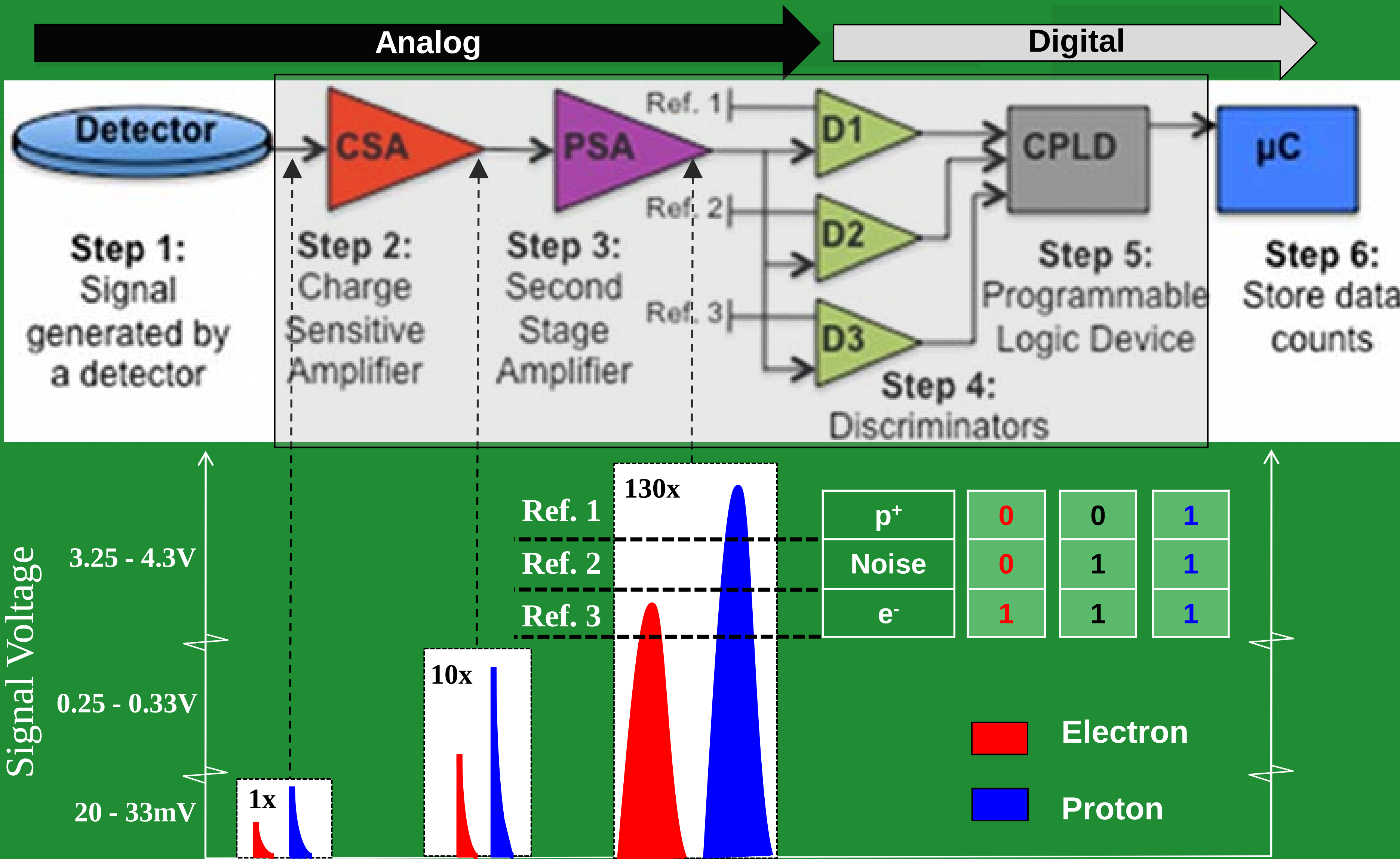




**Effects of Noise**

False data

Saturation of electronics

# Signal Chain




| | | | |
|---|---|---|---|
| $p^+$ | 0 | 0 | 1 |
| Noise | 0 | 1 | 1 |
| $e^-$ | 1 | 1 | 1 |

# Conclusions

| Challenges | Solutions |
|---|---|
| Mass and Volume Constraints | Rigorous Design Analysis |
| Particle Behavior | Detailed Performance Simulations |
| Low Amplitude Signal | Novel Electronics Board Design |
| Operational Speed | Detailed Count Rate Analyses |

**Acknowledgements**

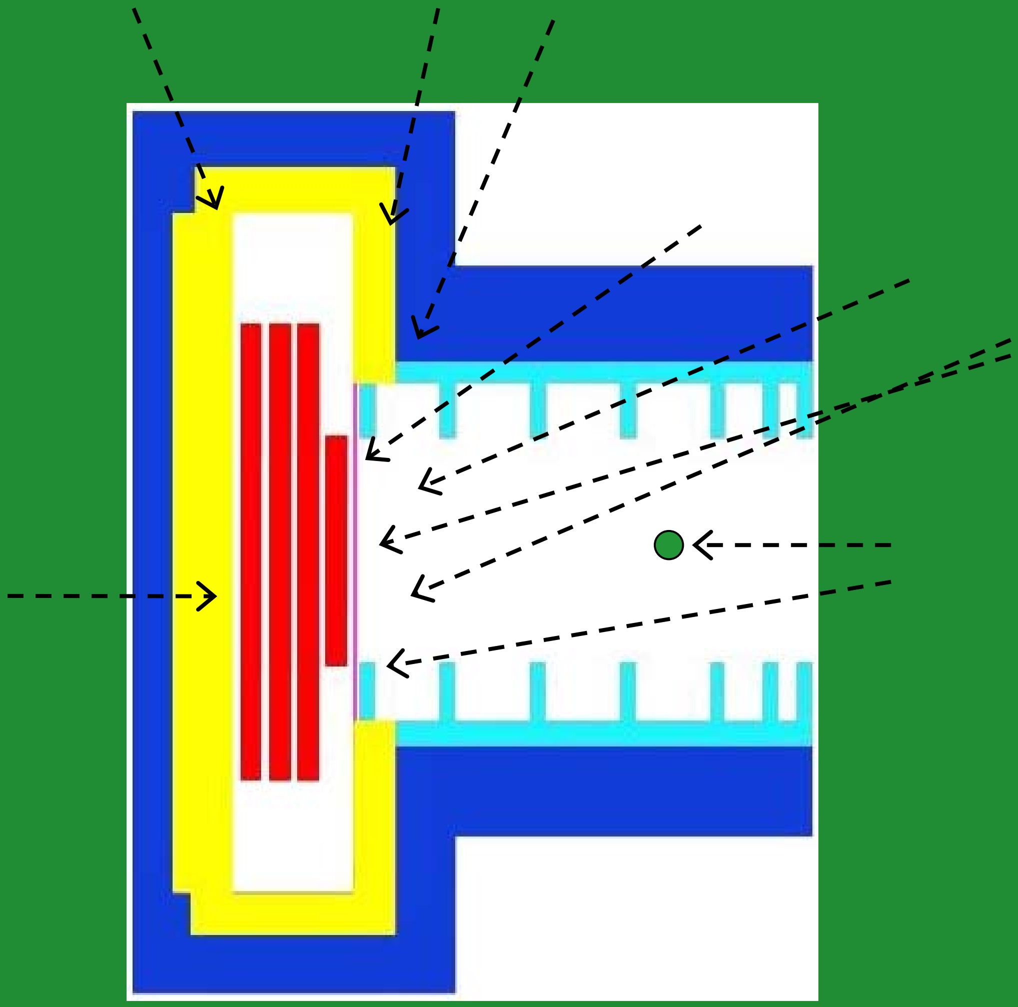
Past and present CSSWE team

LASP engineers

quintin.schiller@colorado.edu
mahendra@colorado.edu

# Backups

# Simulating Noise



**Balance Shielding and Noise**

Minimize Mass

- Maximize Signal
- Maintain Signal/Noise > 2

**Light Outer Shielding**

- Aluminum

**Heavy Inner Shielding**

- Tungsten

# Balance b/w Mass and Signal

**Light Shielding**
High Noise
Low Mass
Low Cost

**REPTile**
Cubesat Mass ≤4.0kg
REPTile Mass ~1.2 kg
CSSWE Cost <$1M

| Signal to Noise Ratio | | | | |
|---|---|---|---|---|
| | Det. 1 | Det. 2 | Det. 3 | Det. 4 |
| $e^-$ | 87.9 | 42.2 | 28.9 | 23.8 |
| $H^+$ | 13.6 | 8.5 | 6.4 | 2.2 |

REPT

**Heavy Shielding**
Low Noise
High Mass
High Cost

# Binning Logic

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| bin1: | 1 | 0 | 0 | 0 |
| bin2: | 1 | 1 | 0 | 0 |
| bin3: | 1 | 1 | 1 | 0 |
| bin4: | 1 | 1 | 1 | 1 |

**Example: bin3 particle**

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| bin3: | 1 | 1 | 1 | 0 |

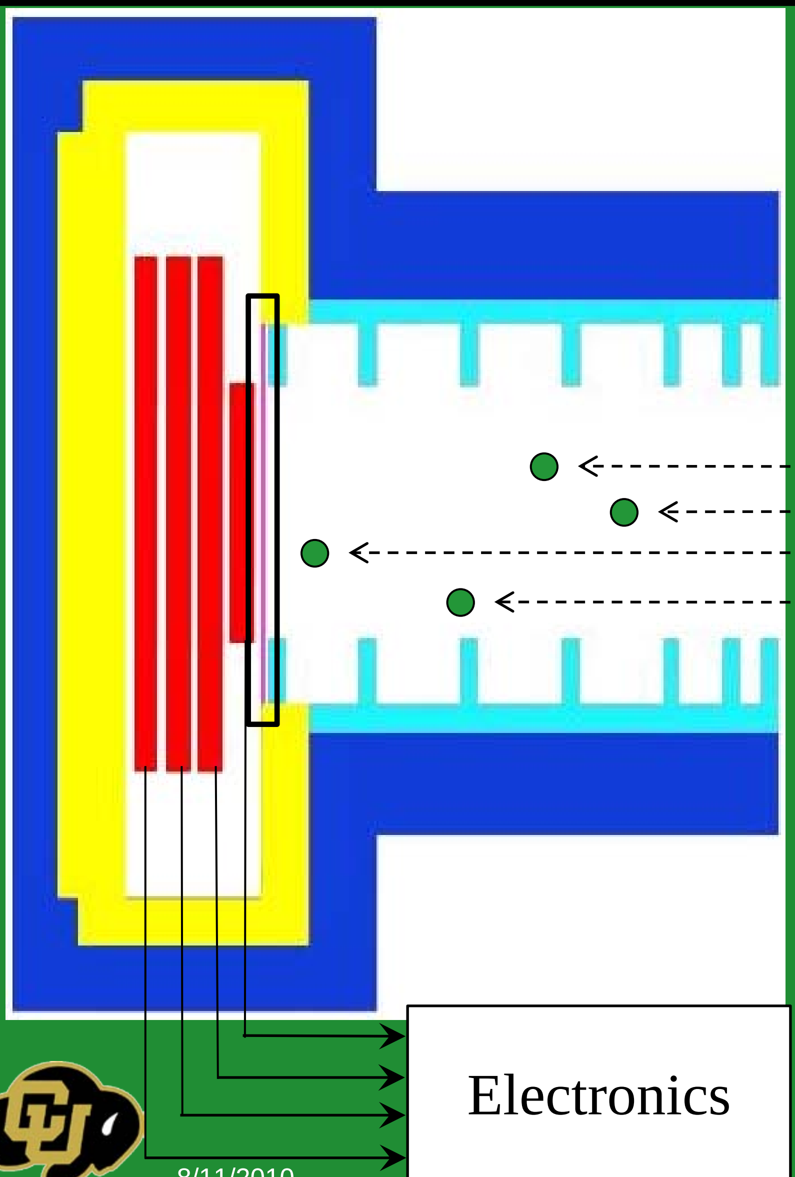
**Example: bin3 electron**

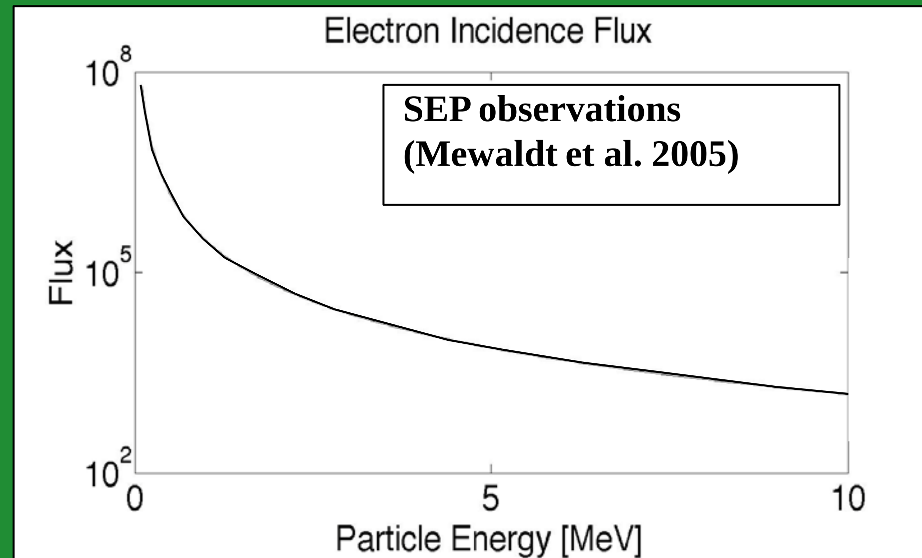
| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| bin3: | 100 | 100 | 100 | 000 |

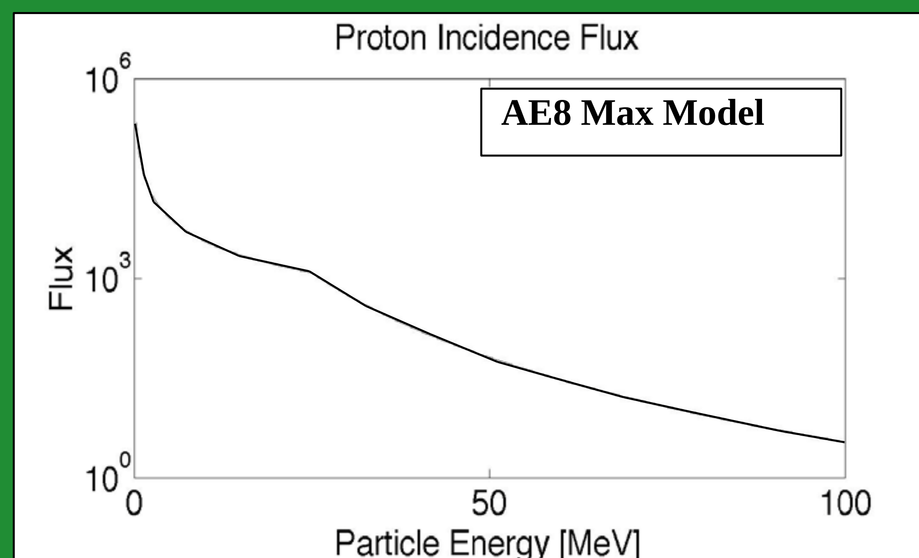
**Example: bin3 proton**

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| bin3: | 111 | 111 | 111 | 000 |

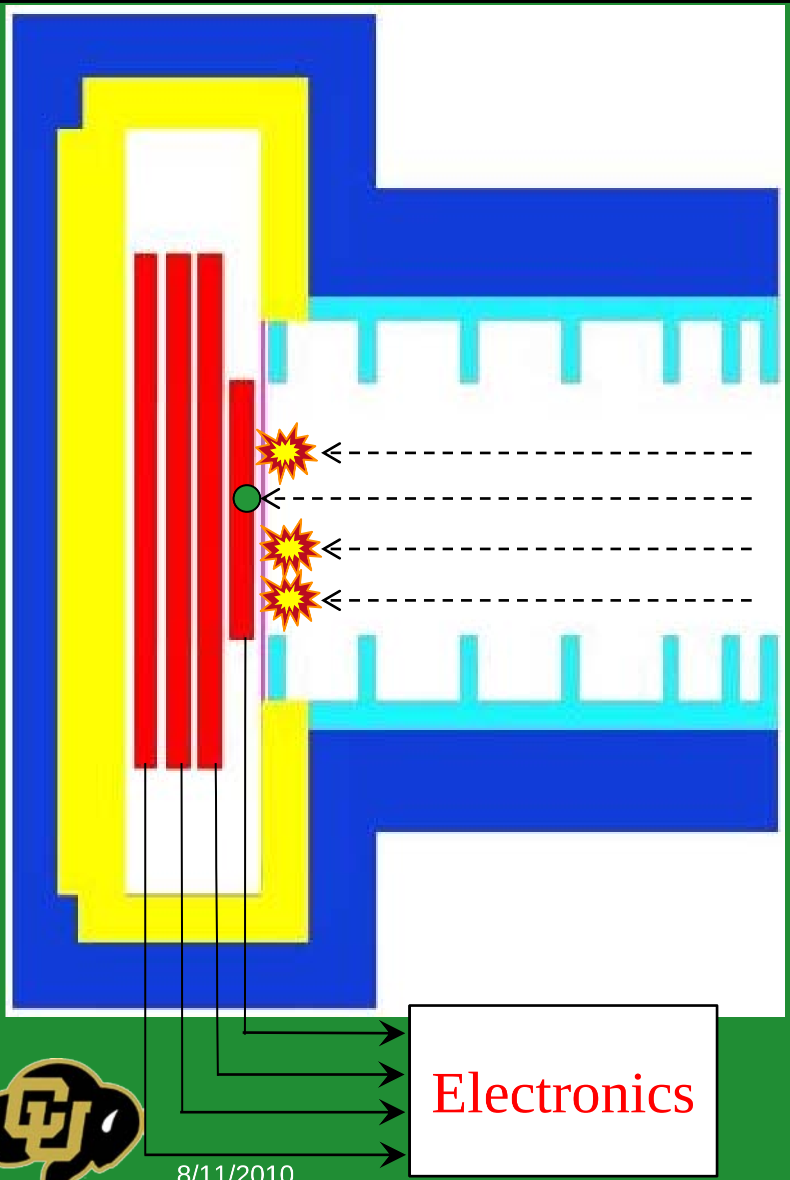
# Simulating Science Environment



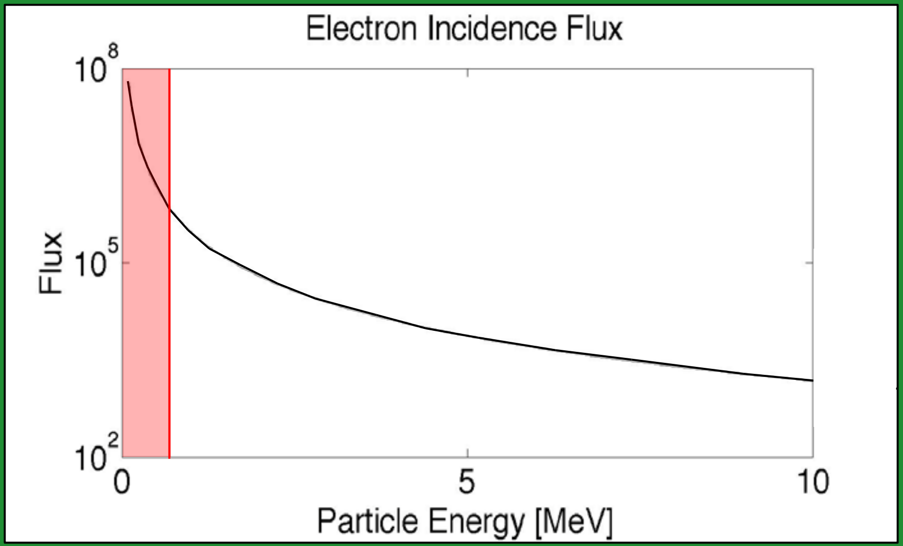



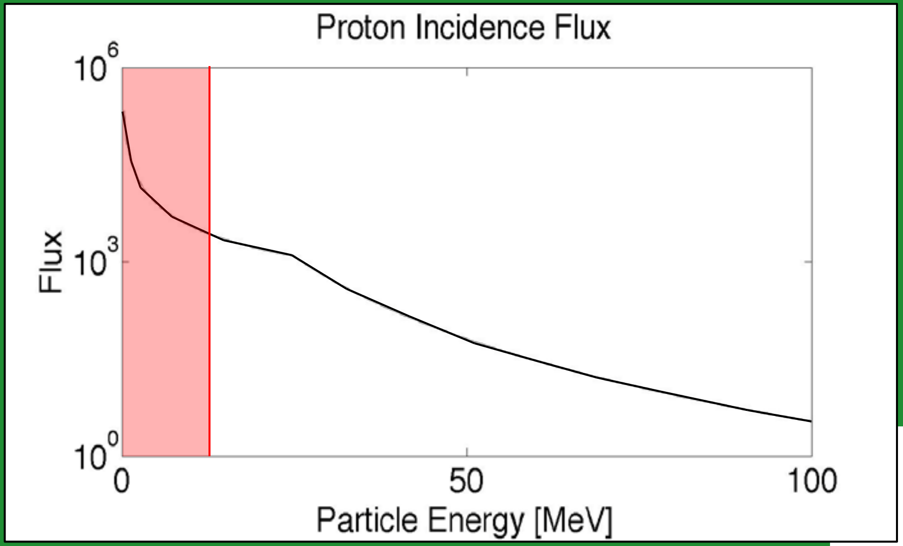
# Saturation



Electronics

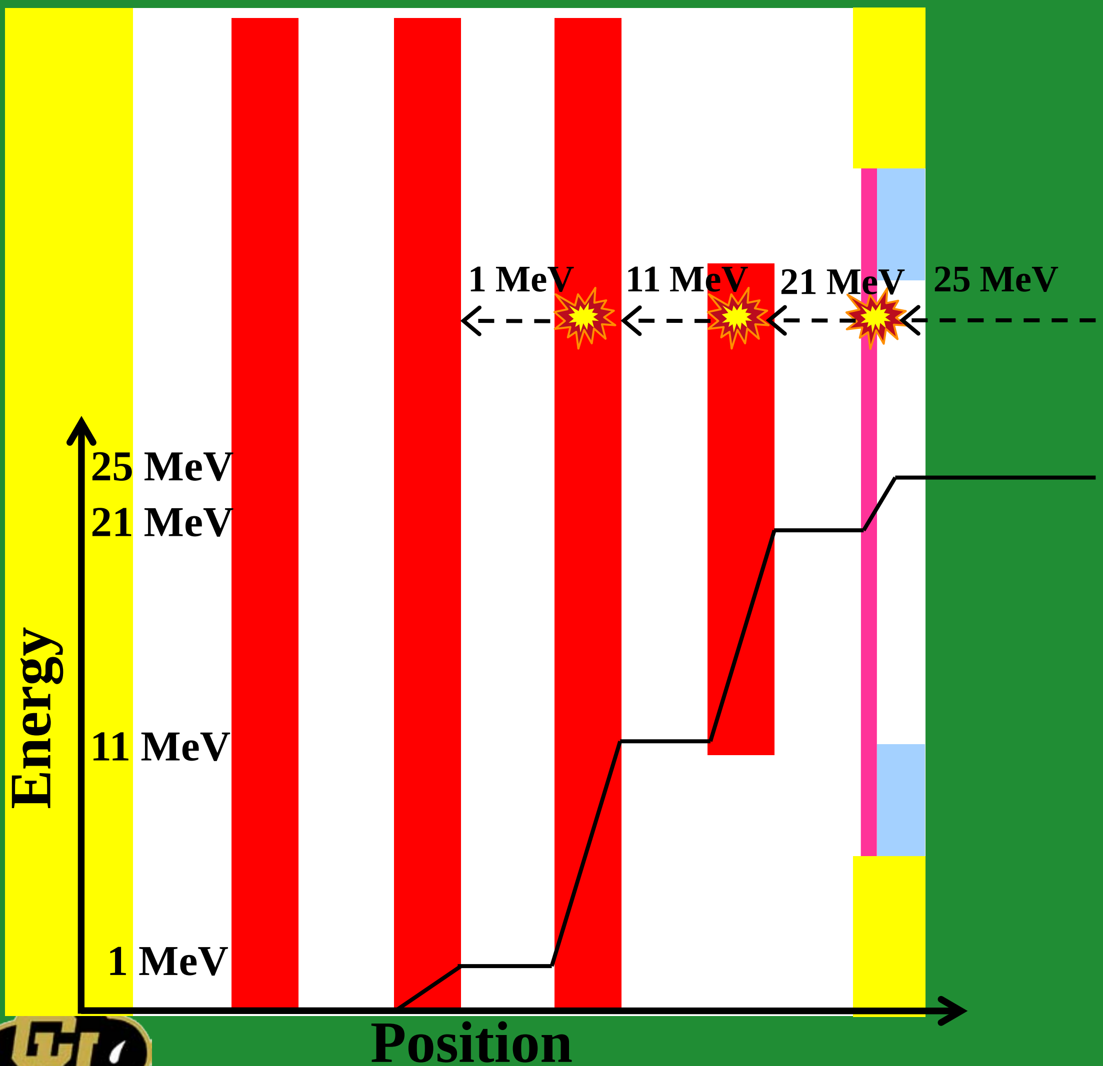



Electron Incidence Flux
Flux
$10^8$
$10^5$
$10^2$
0
5
10
Particle Energy [MeV]

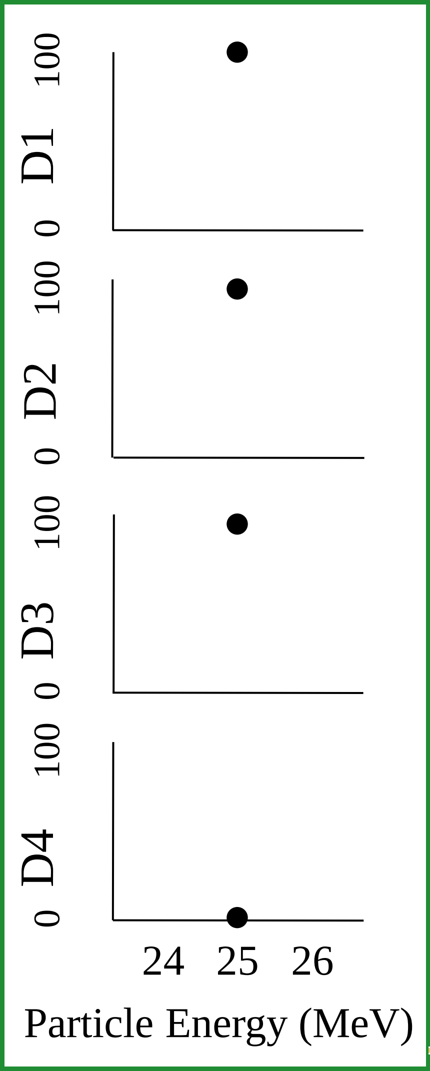



Proton Incidence Flux
Flux
$10^6$
$10^3$
$10^0$
0
50
100
Particle Energy [MeV]

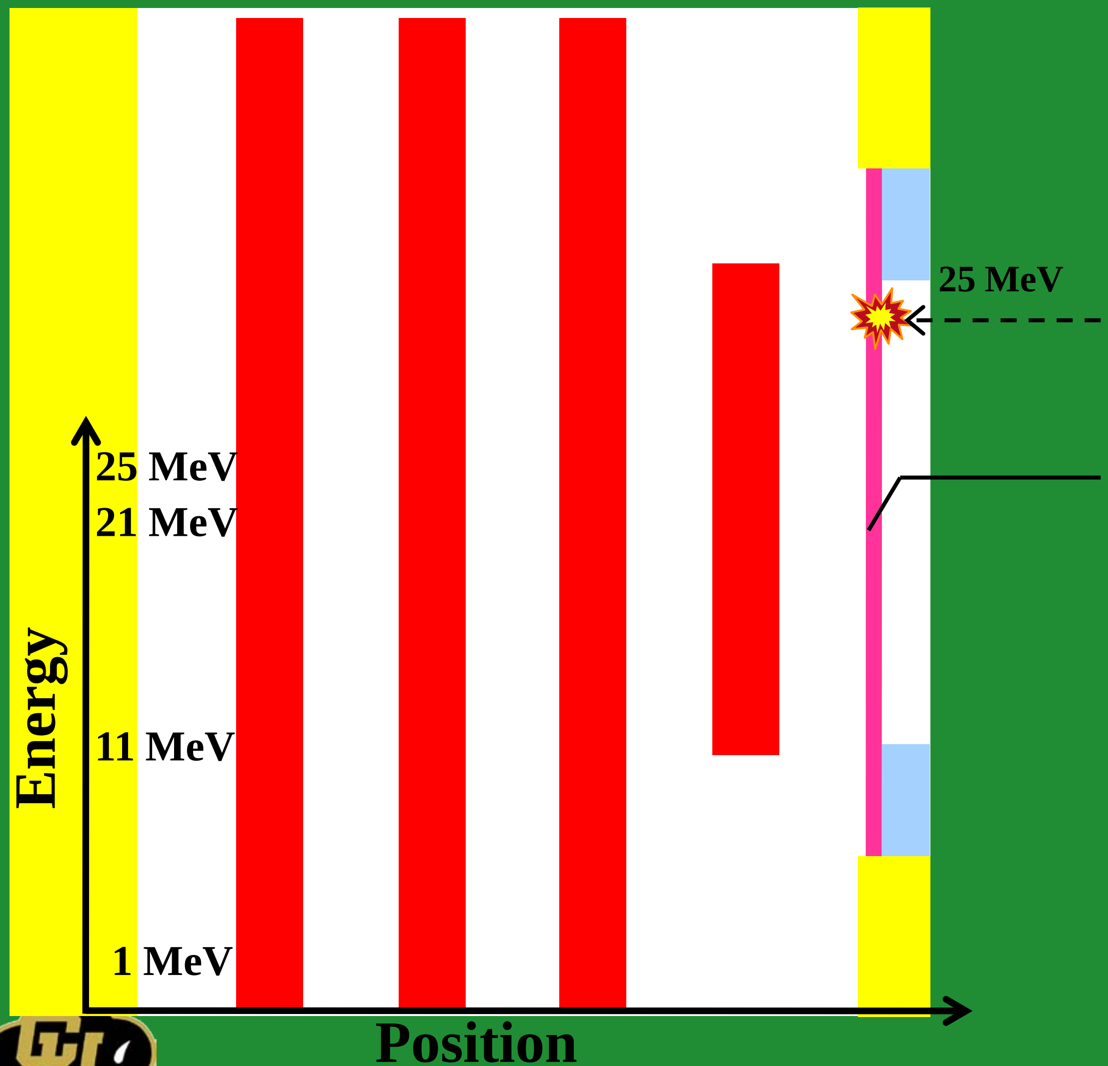
# 25 MeV Proton Beam



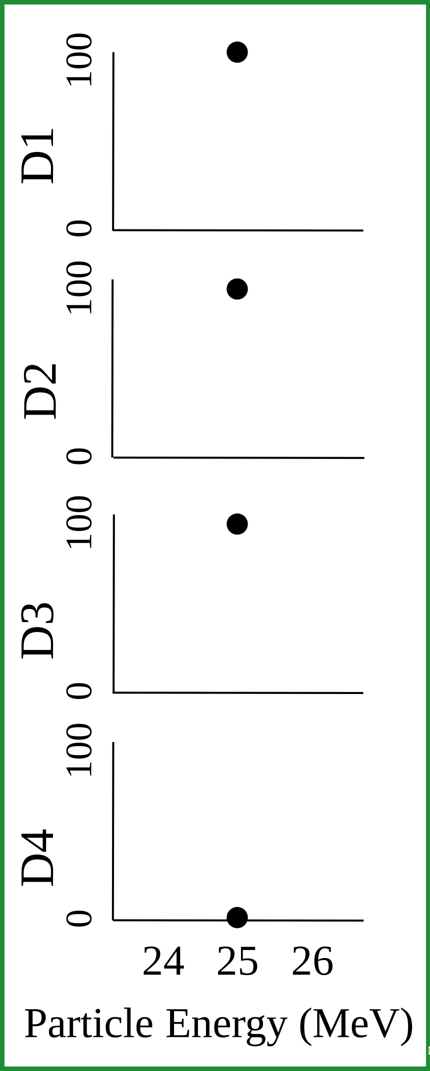

% Particle Impacts



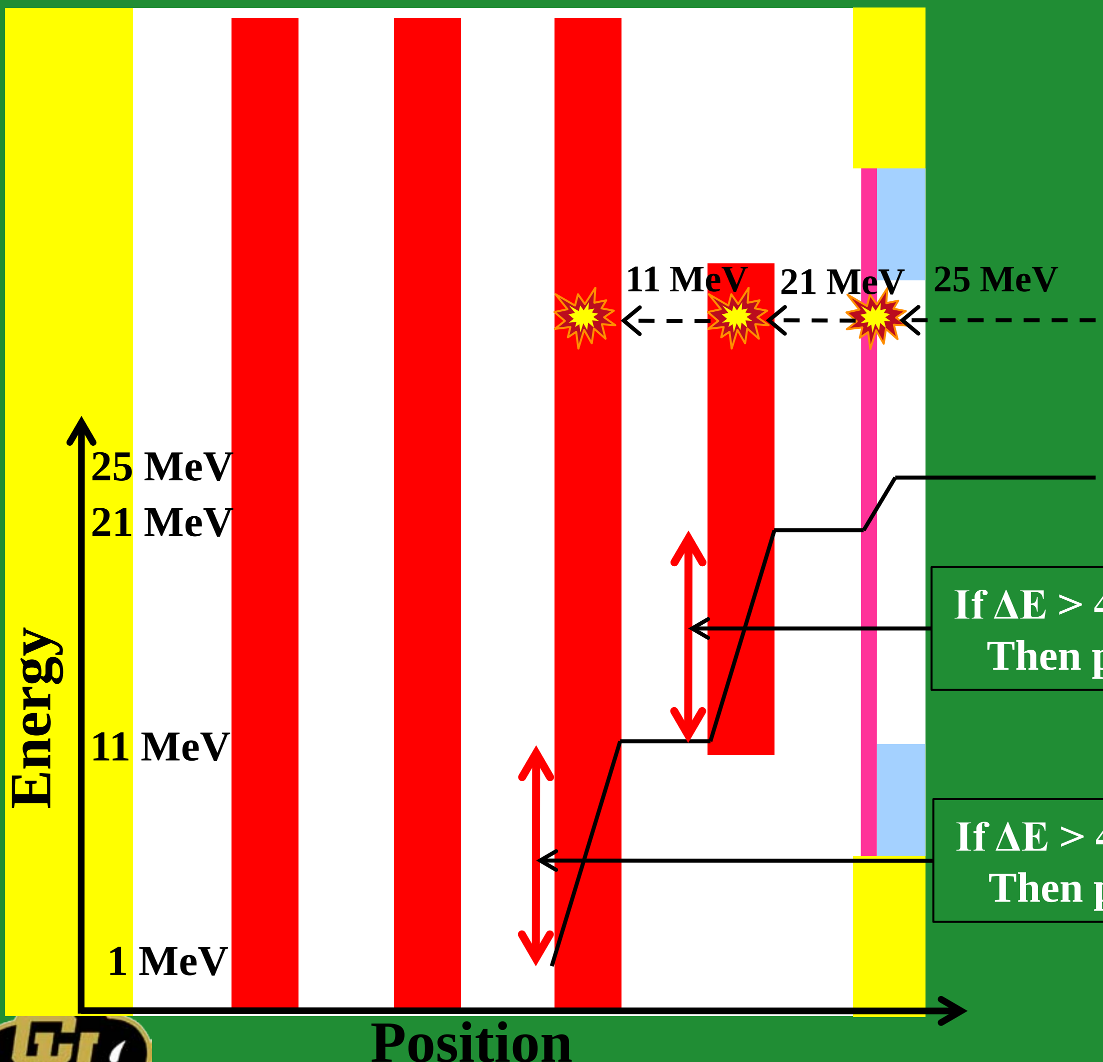
# 25 MeV Proton Beam



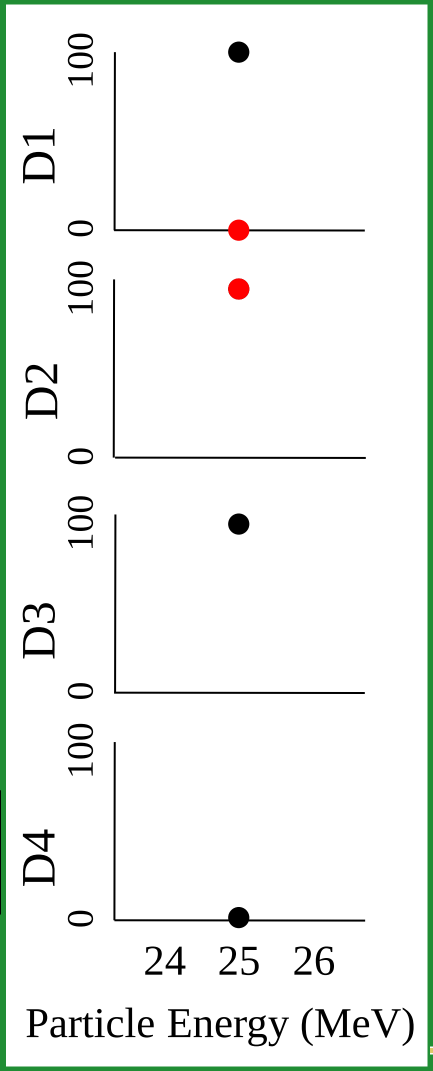

% Particle Impacts



# 25 MeV Proton Beam




% Particle Impacts



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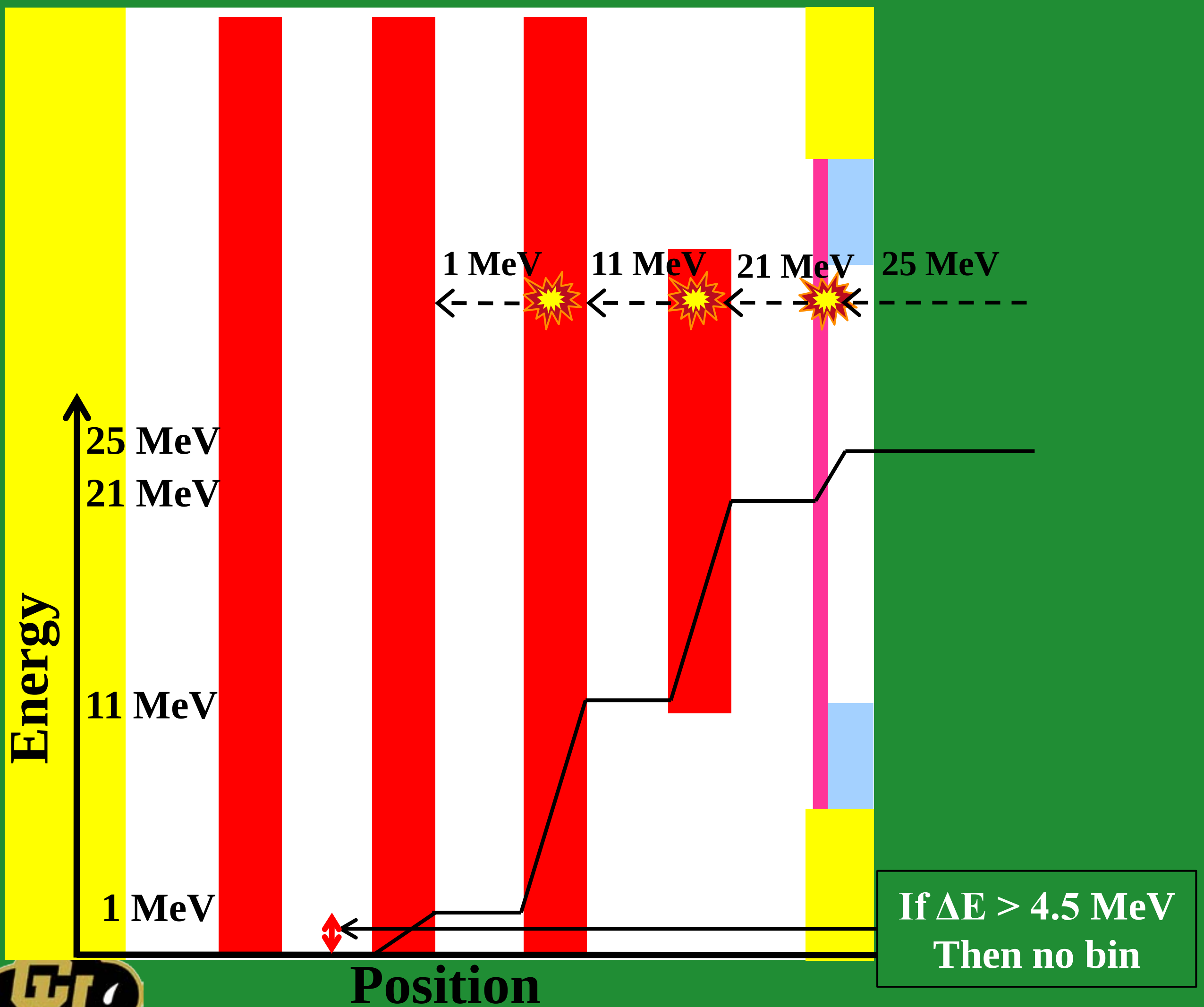
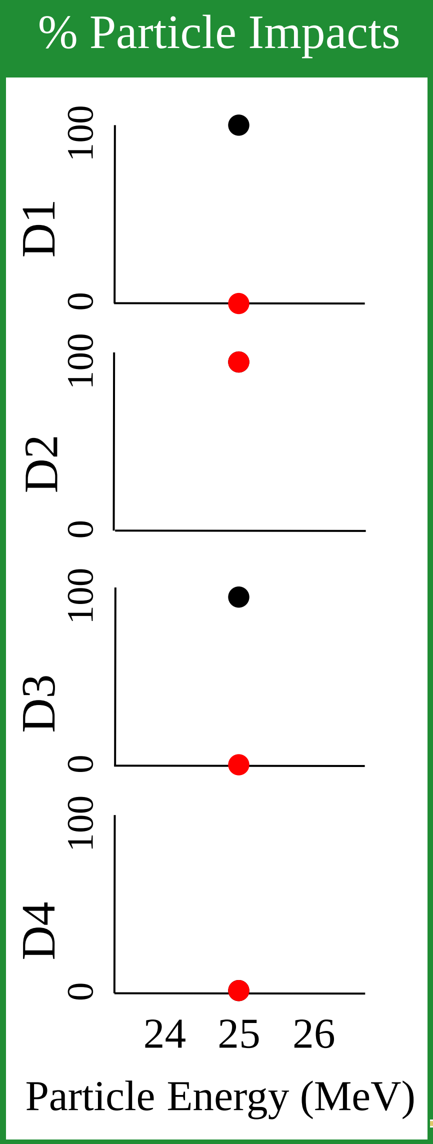
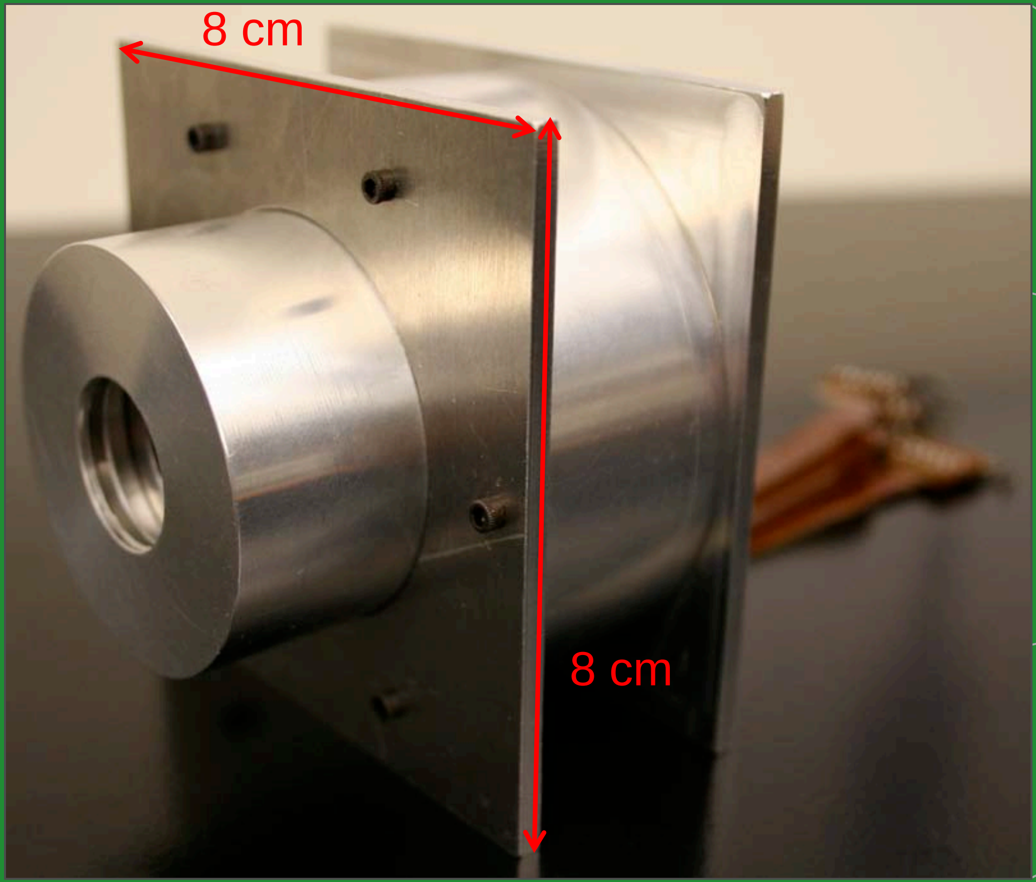
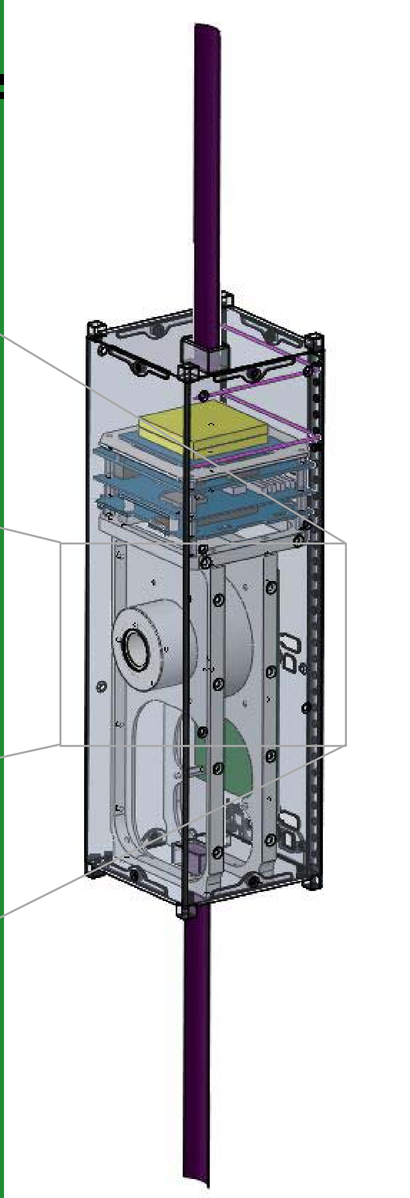


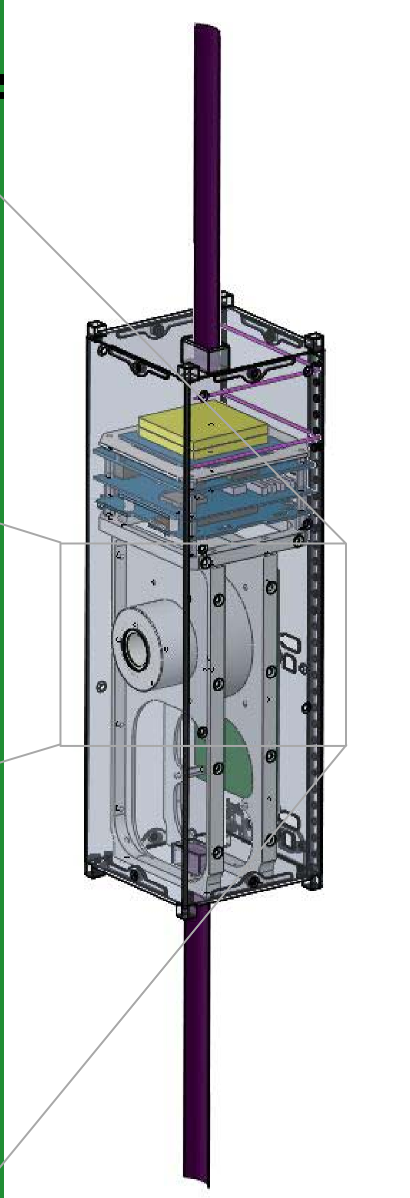



# REPTile

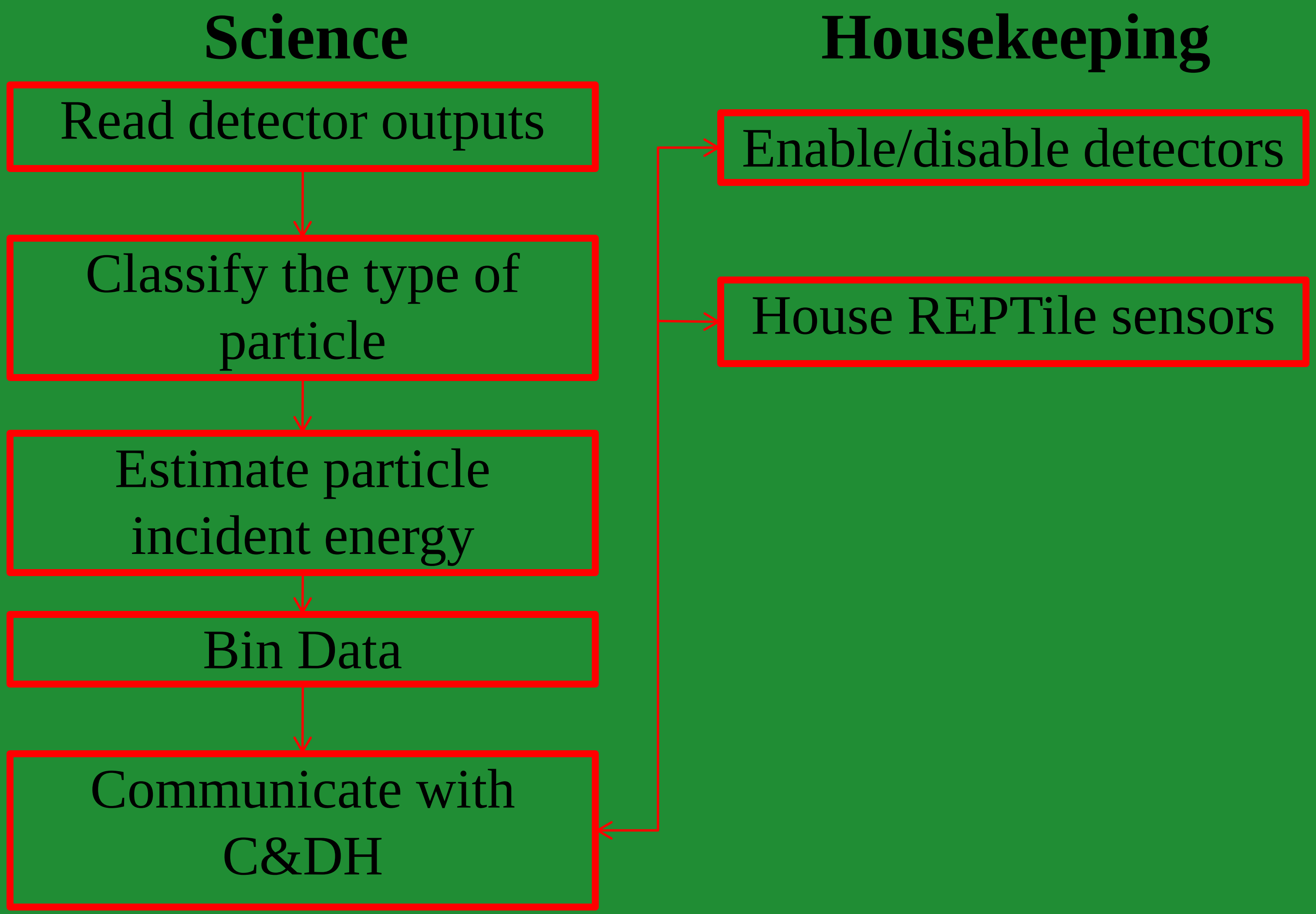


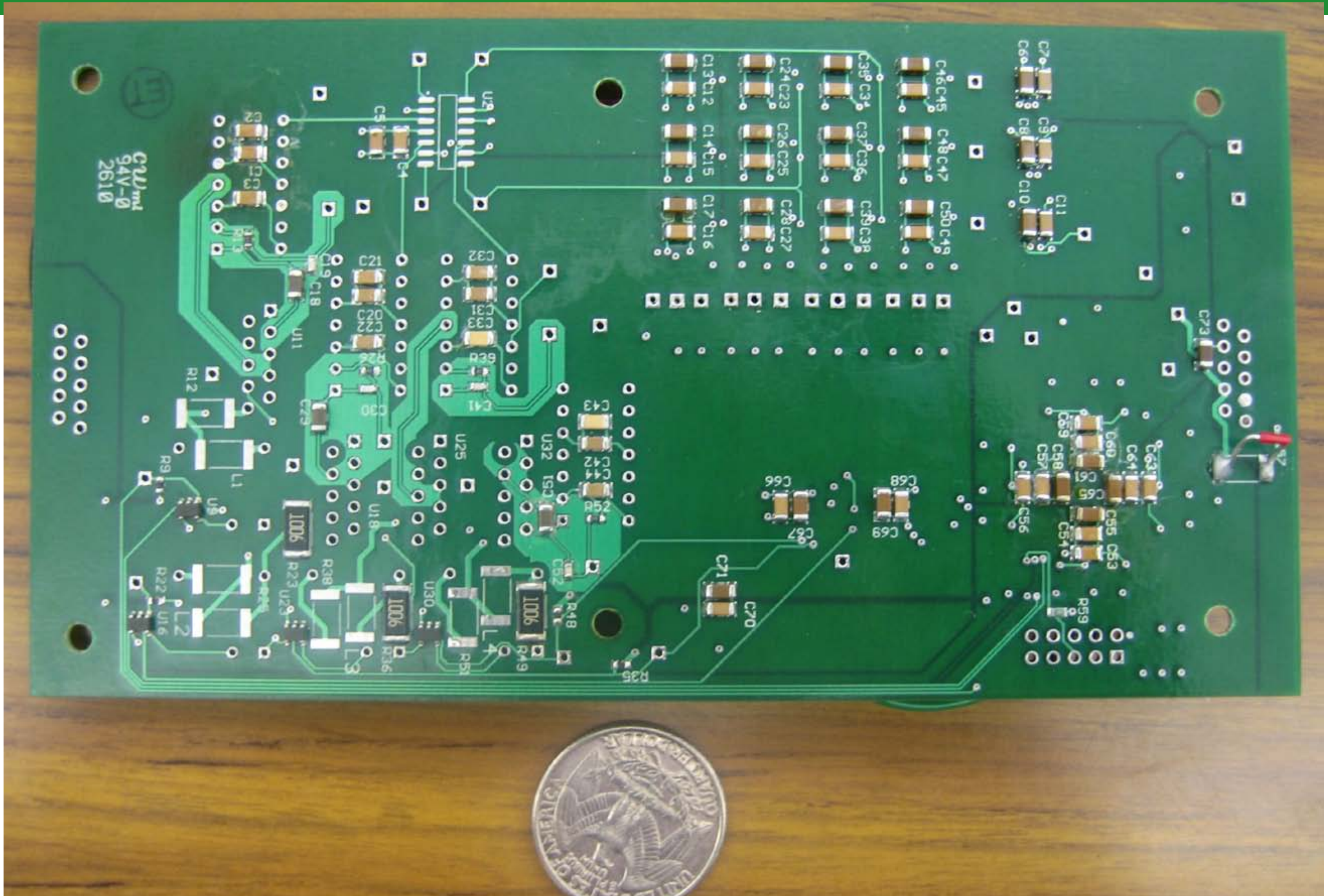
# REPTile Assembly



# Electronics Top-level Requirements



# Electronics



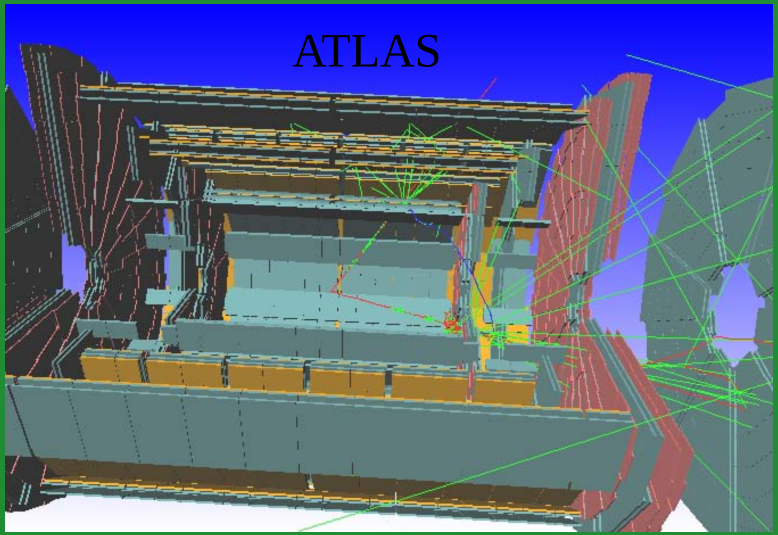
# Simulating Count Rates

## GEANT4 – A Statistical Toolkit

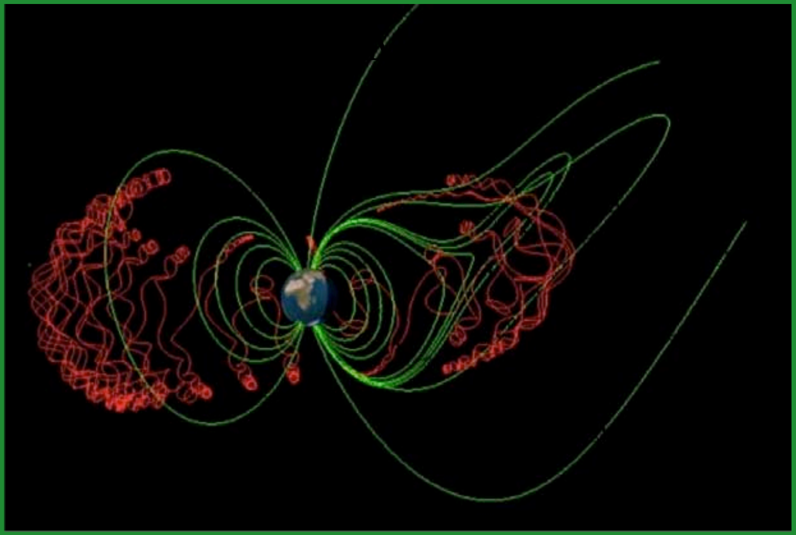
Worldwide collaboration spearheaded by physicists at CERN

All aspects of particle simulation included

Applications include any field where particles interact with matter; high energy physics, space science, radiation physics, nuclear medicine[1]




LHC experiments such as ATLAS



The Space Energetic Particle Transport and Interaction Modeling for ESA Science Studies (SEPTIMESS) project

[1]geant4.web.cern.ch

# Simulating Count Rates

C = Count Rate [#/s]

I = Environmental Particle Flux

γ = Geometric Factor

α= Detector Efficiency → Geant4

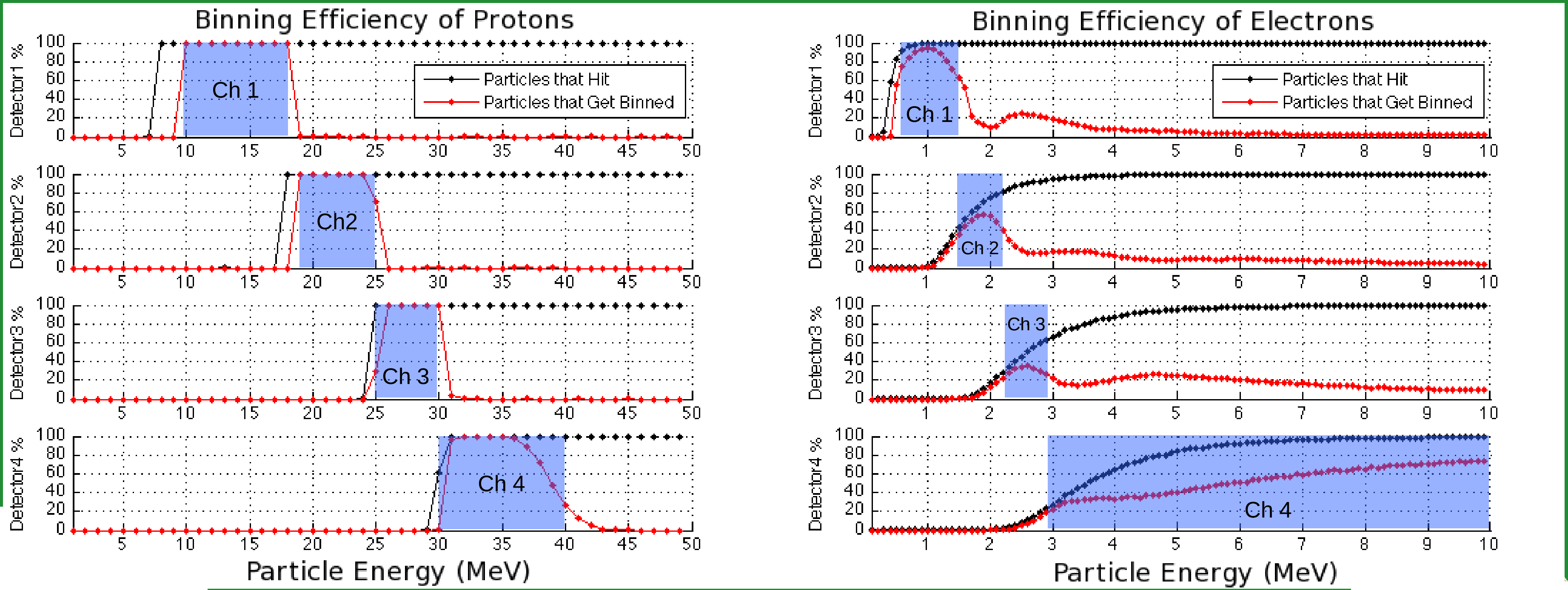
E = Incident Particle Energy

i = Detector Index

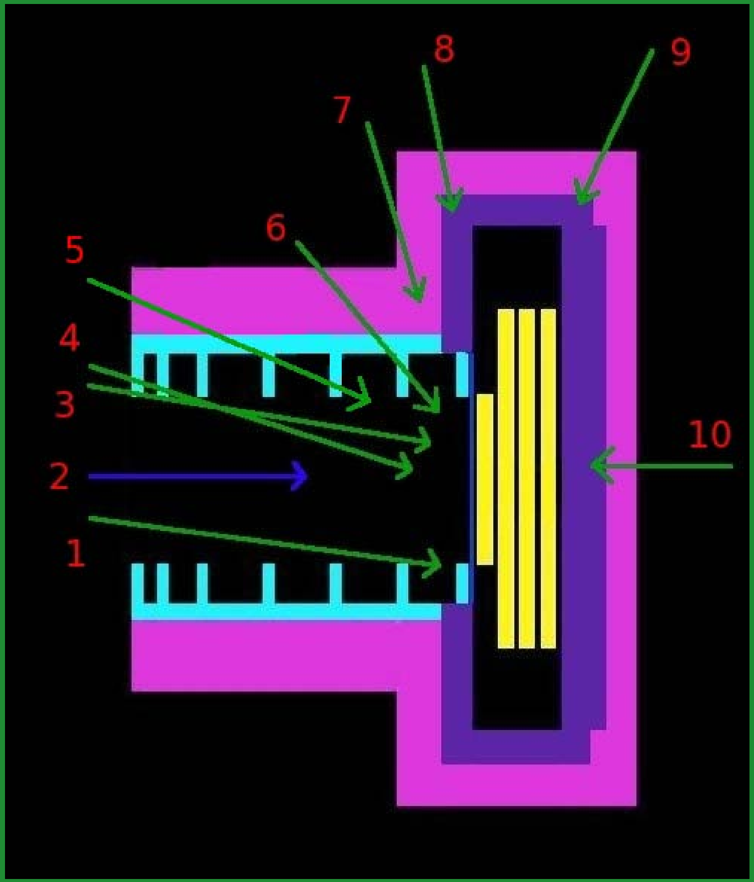
# Simulating Count Rates

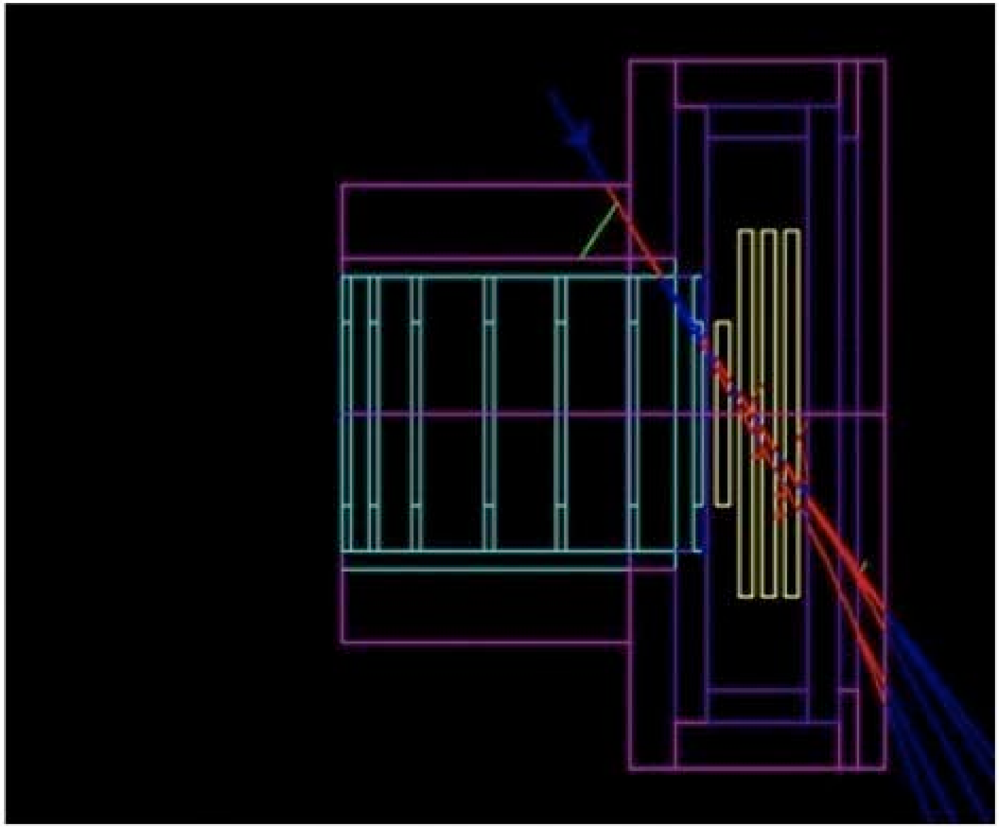
E = Incident Particle Energy
I = Environmental Particle Flux
γ = Geometric Factor
**α = Detector Efficiency**

## Detector Efficiency



# Signal vs. Noise



b) Shield penetrating protons

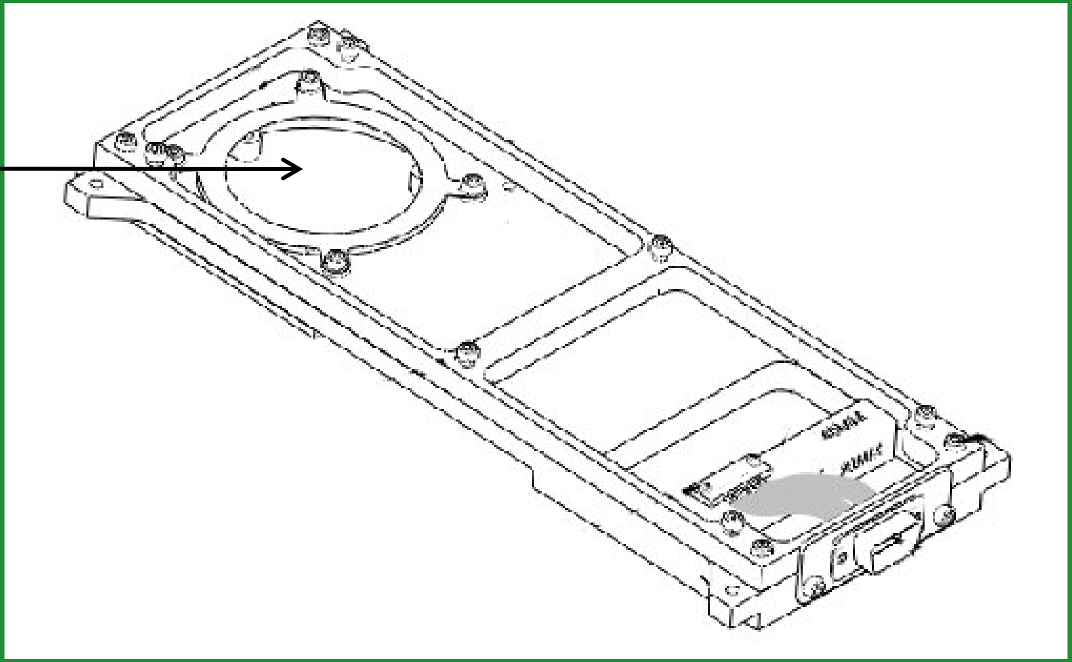
| Signal to noise ratio | | | | |
|---|---|---|---|---|
| | Det. 1 | Det. 2 | Det. 3 | Det. 4 |
| Electrons | 87.9 | 42.2 | 28.9 | 23.8 |
| Protons | 13.6 | 8.5 | 6.4 | 2.2 |

# Testing Plan:
## Detectors

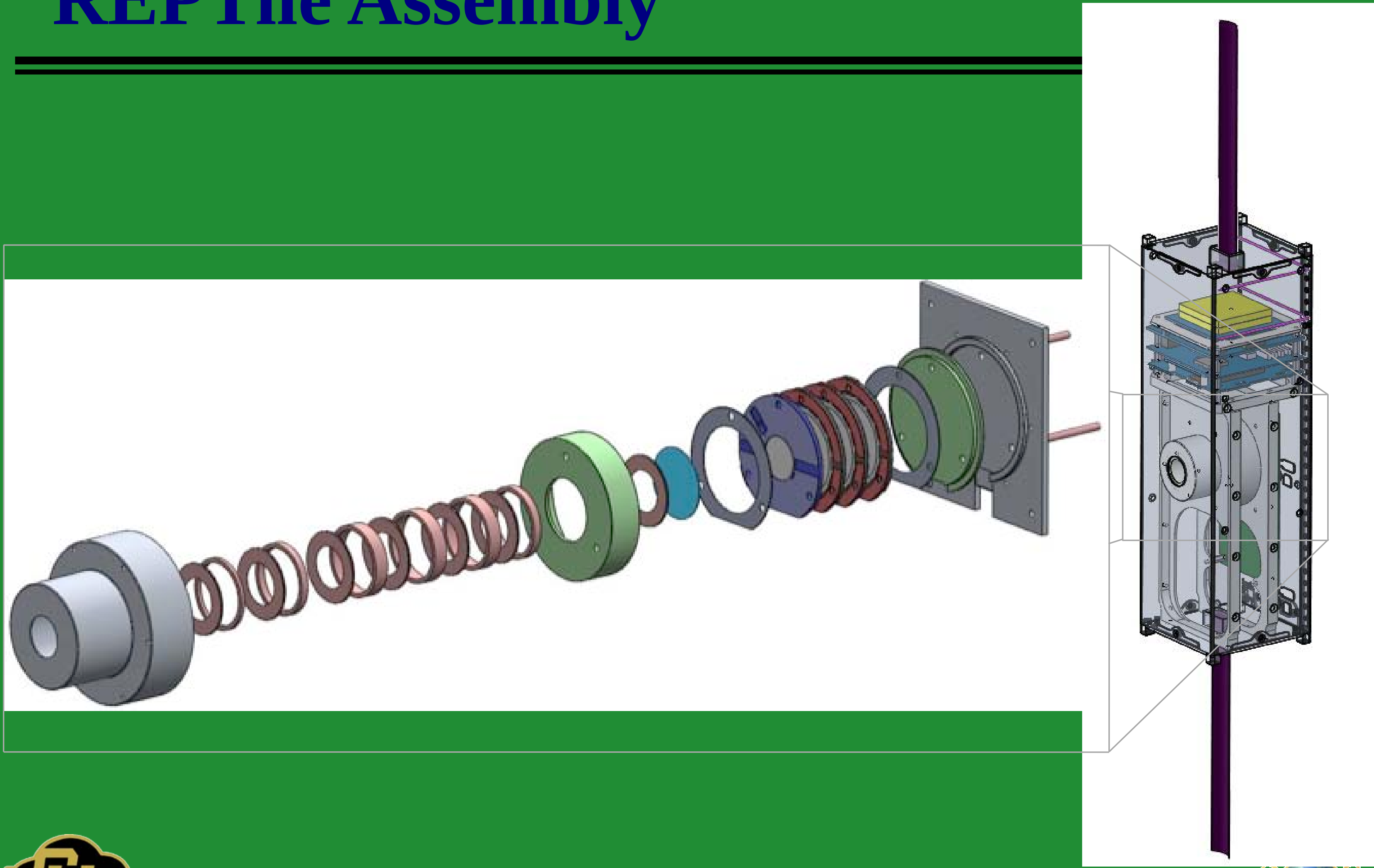
# Testing Detectors

Detector tray needed for storage and testing

- Radioactive electron sources
- Radioactive alpha sources
- Cosmic rays
- Vacuum tests
- Thermal tests



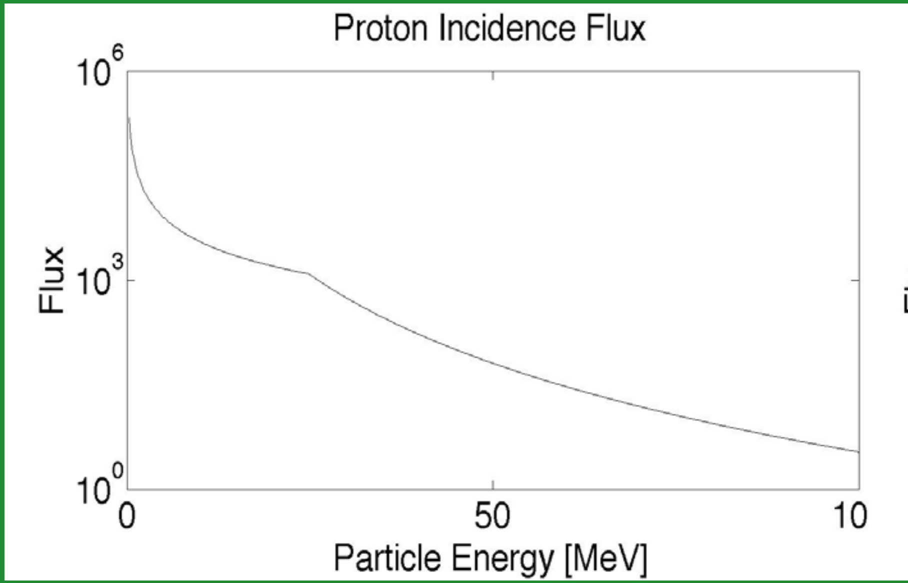
# REPTile Assembly



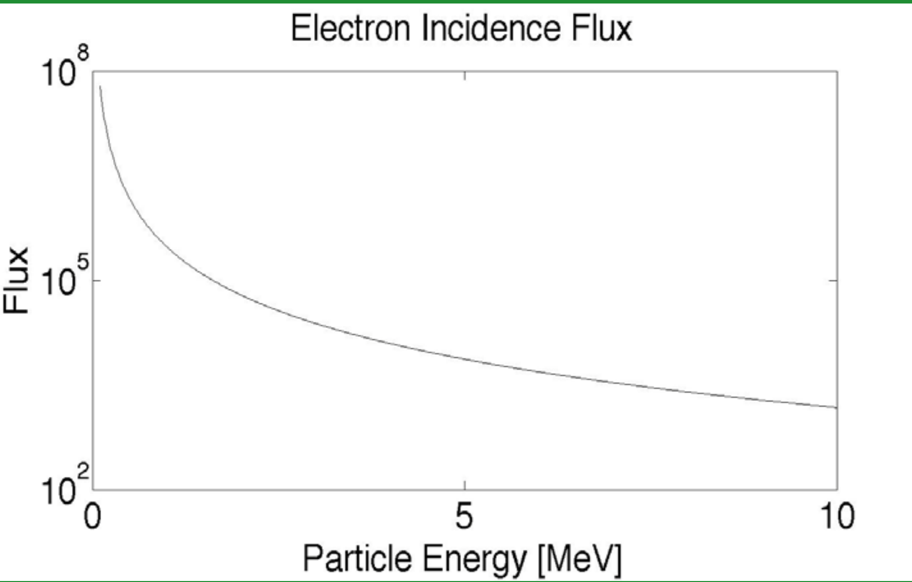
# Simulating Count Rates

E = Incident Particle Energy
**I = Environmental Particle Flux**
γ = Geometric Factor
α = Detector Efficiency

## Environmental Flux




**SEP observations (Mewaldt et al. 2005)**



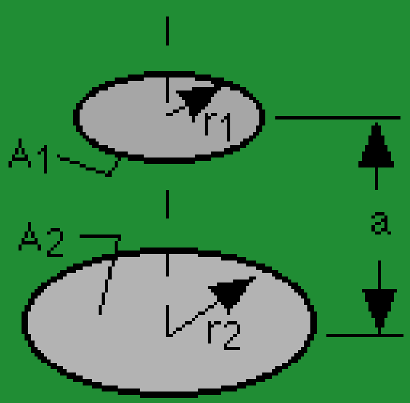

**AE8 Max**

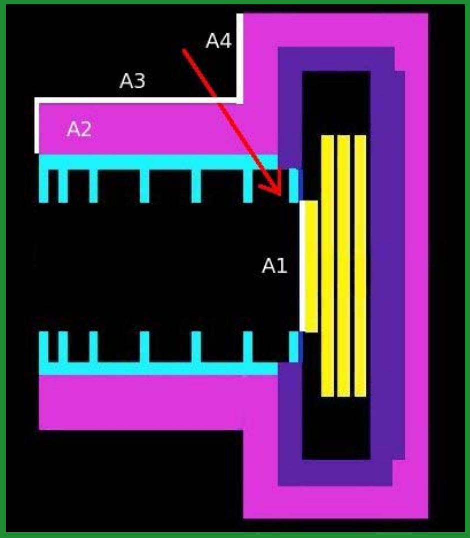
# Simulating Count Rates

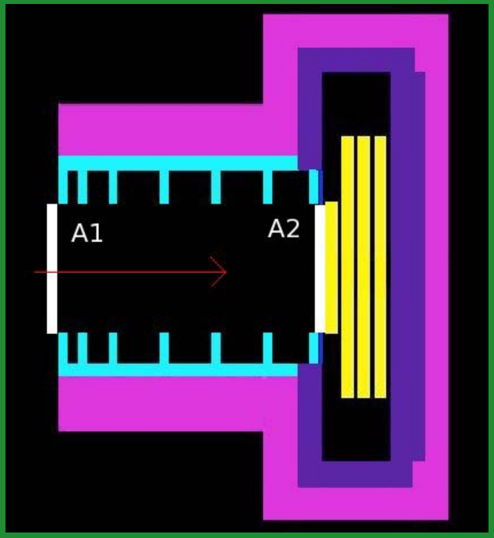
E = Incident Particle Energy
I = Environmental Particle Flux
**γ = Geometric Factor**
α = Detector Efficiency

## Geometric Factor

Derived from the Howell's Radiation Transfer Configuration Factors

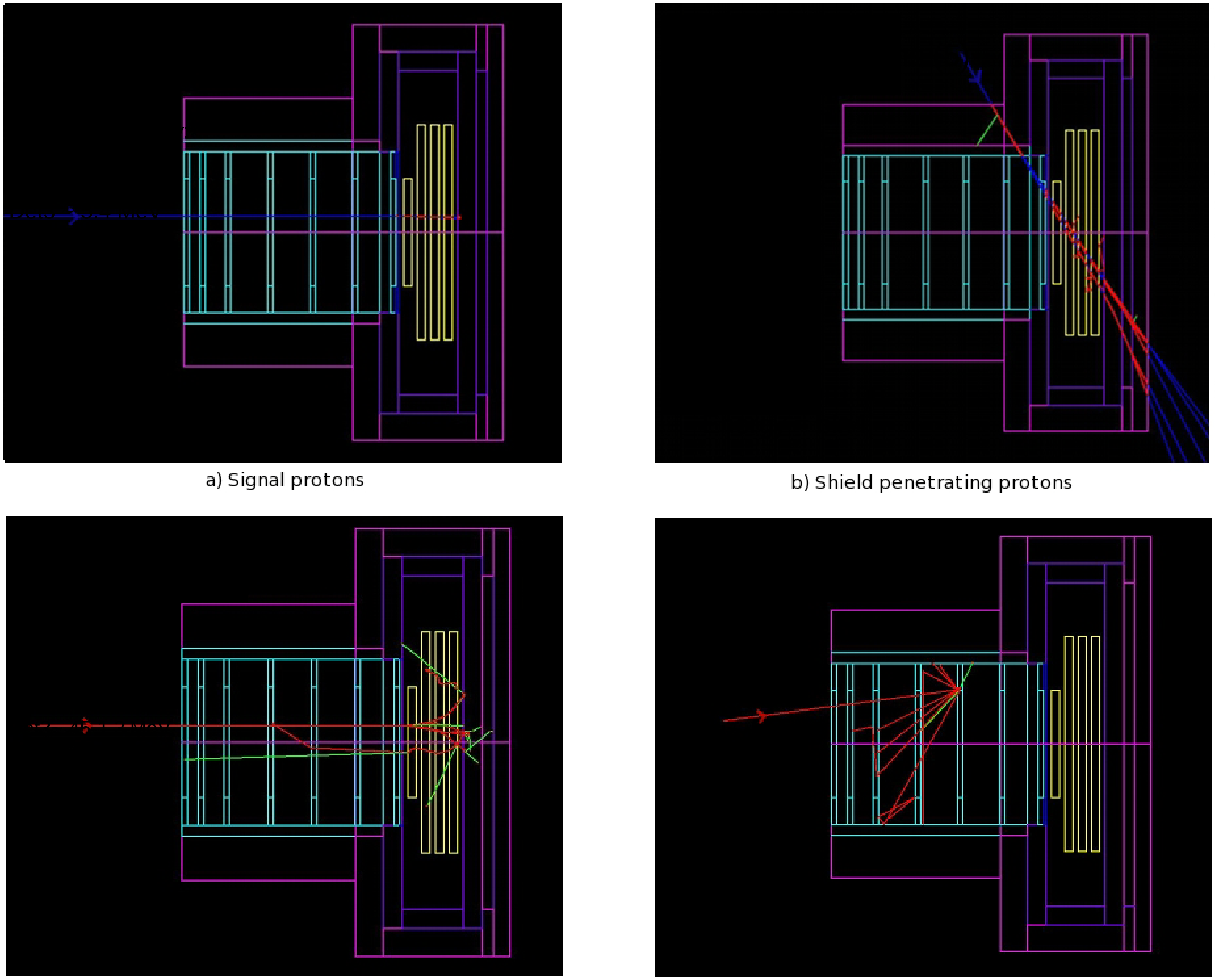



**www.me.utexas.edu/~howell/index.html**

# Signal vs. Noise



a) Signal protons

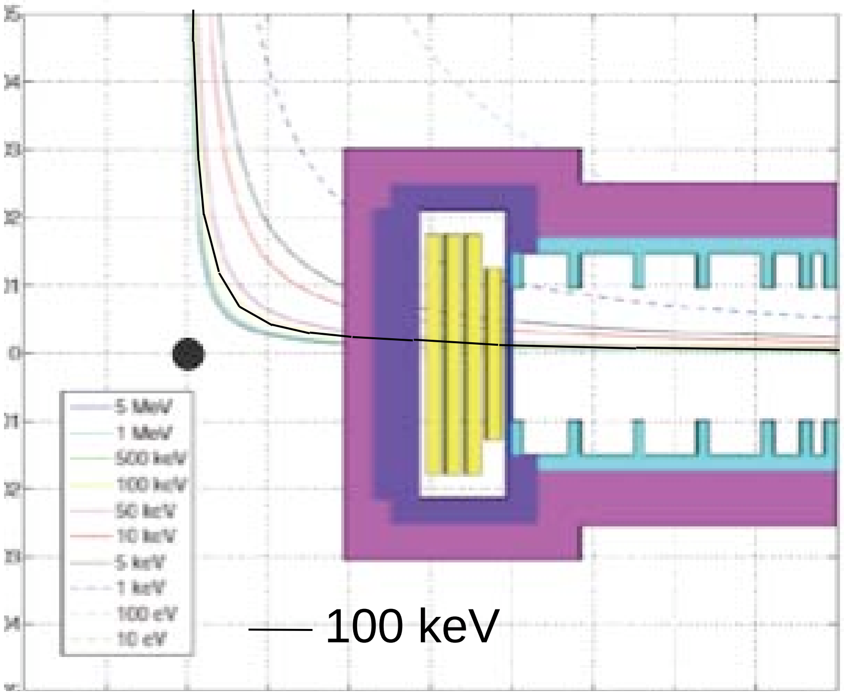
b) Shield penetrating protons

c) Signal electrons

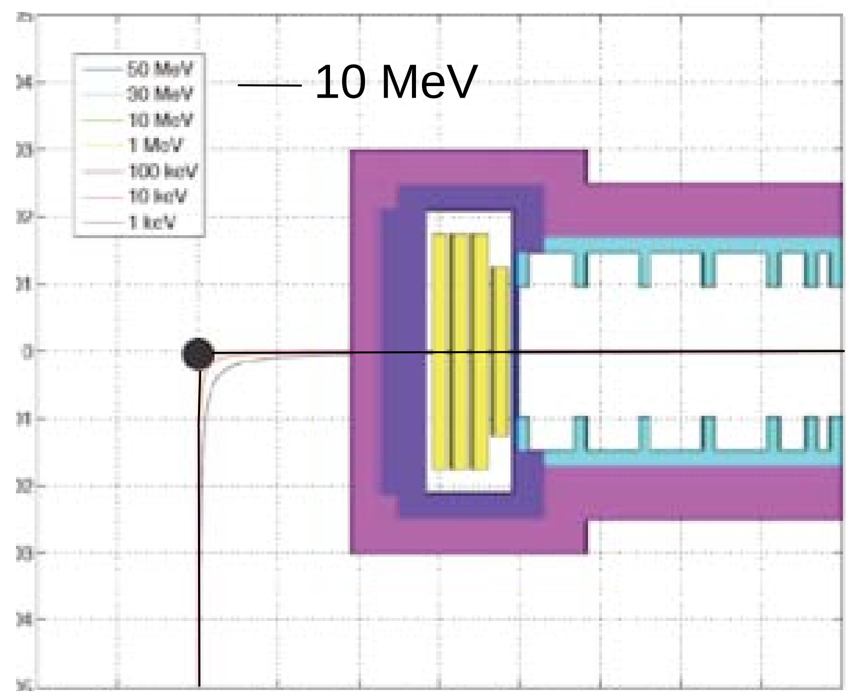
d) Collimator demonstration

# ACS Analysis

Electron Trajectories

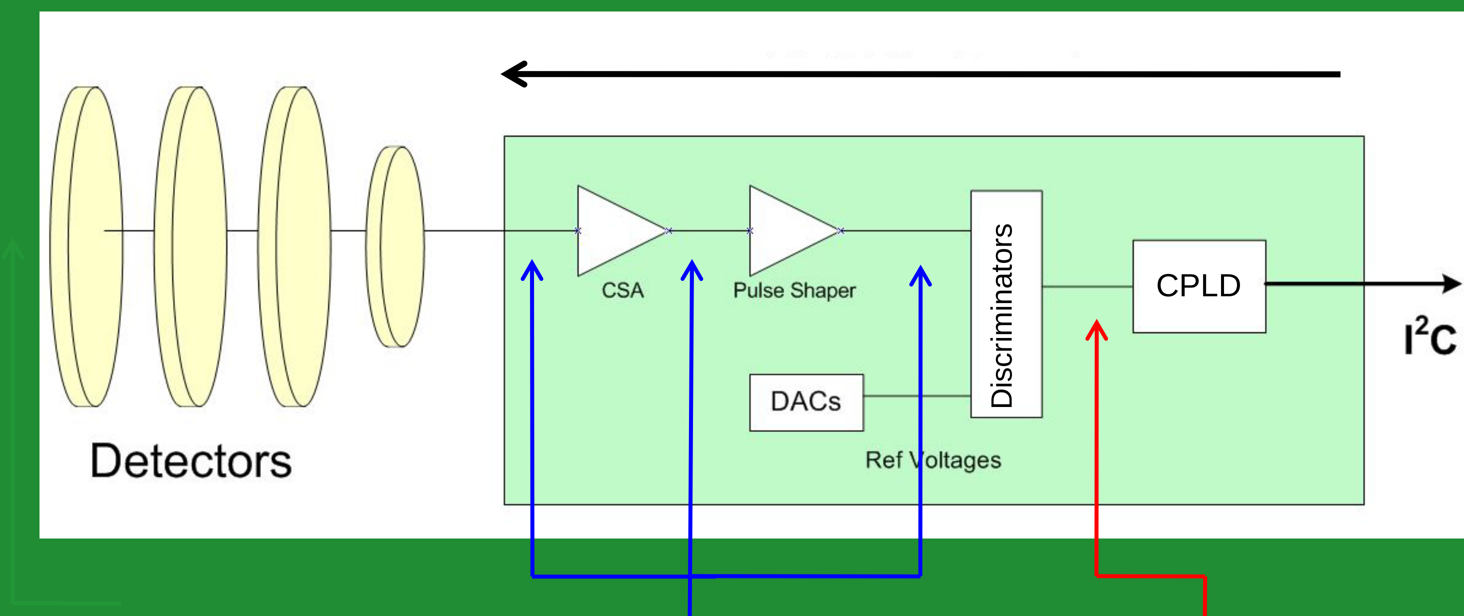



Proton Trajectories



# Testing Electronics

Test electronics module by module
Test interface between modules
Progress from digital end towards analog end
Interface the electronics with the detector




Integrated Tests

Analog Tests

Digital Tests