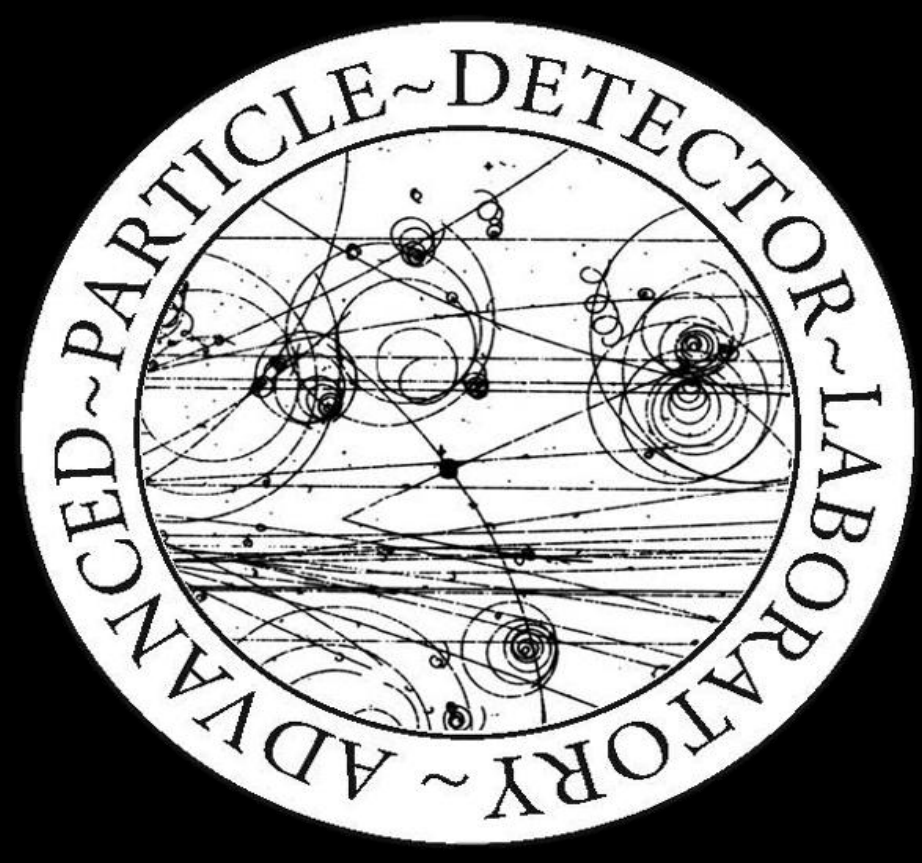




Measurement of Muon Ionization Loss in the High Granularity Dual-Readout Calorimeter

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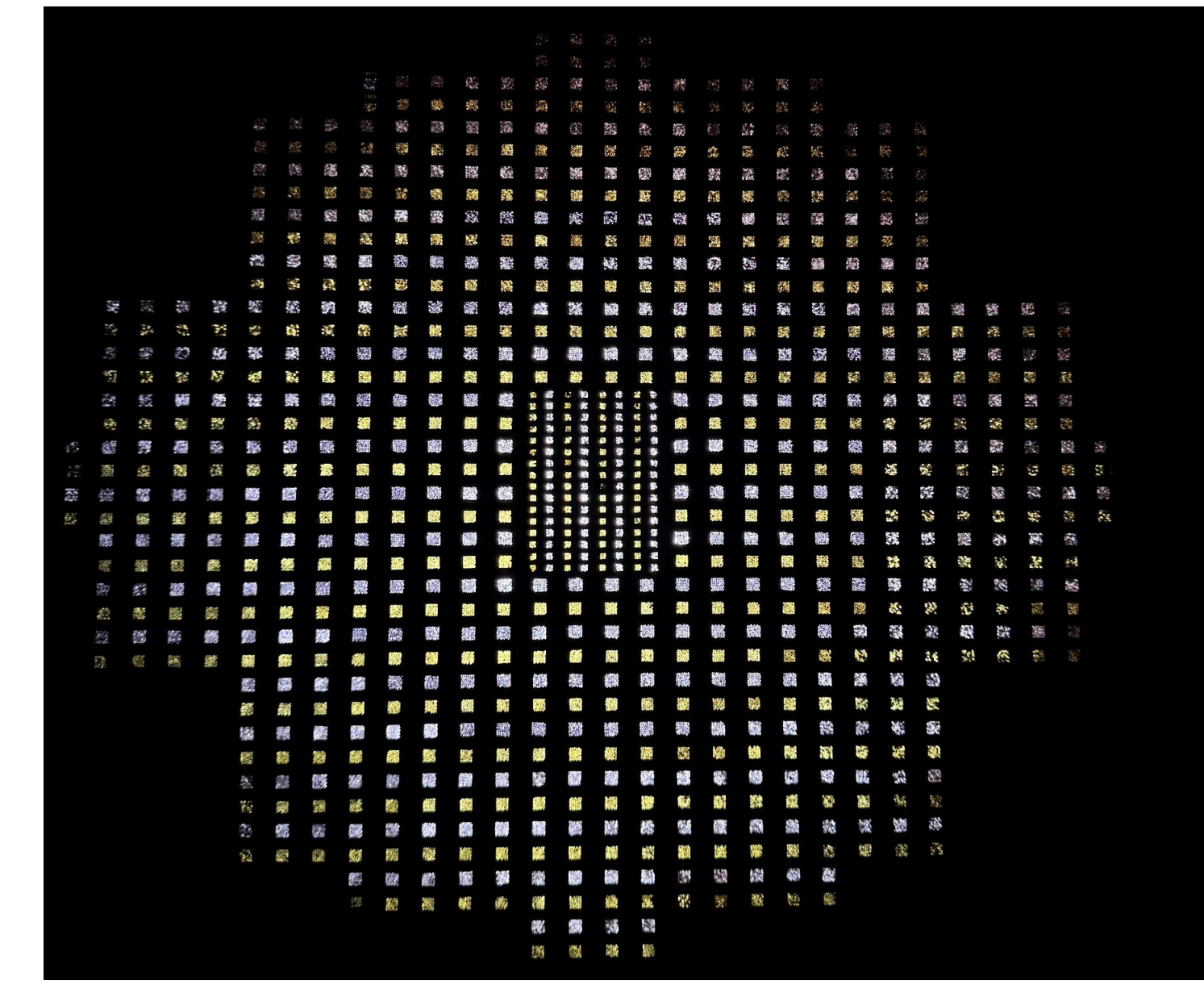
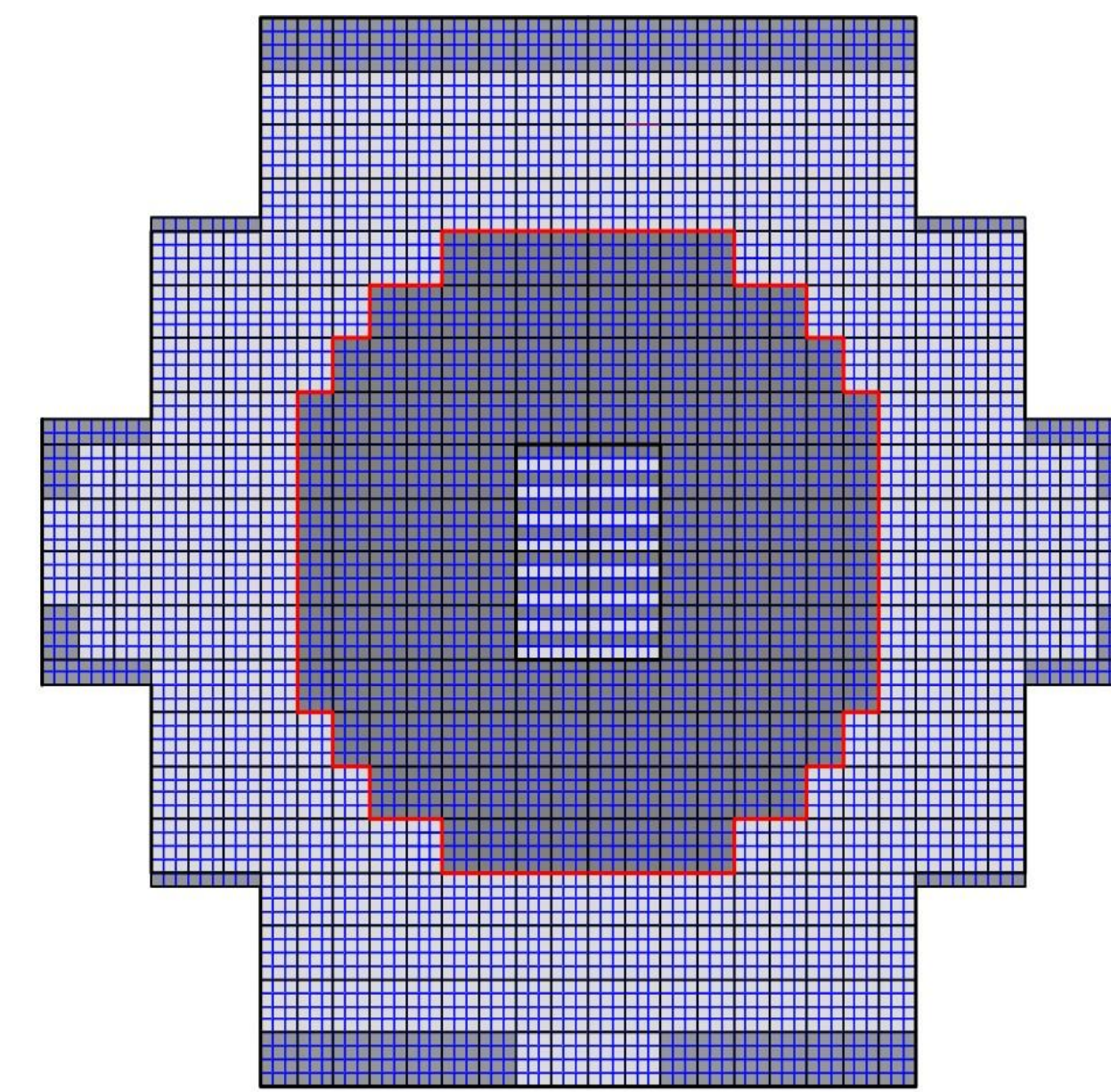


High Granularity Dual-Readout Module (HG-DREAM)

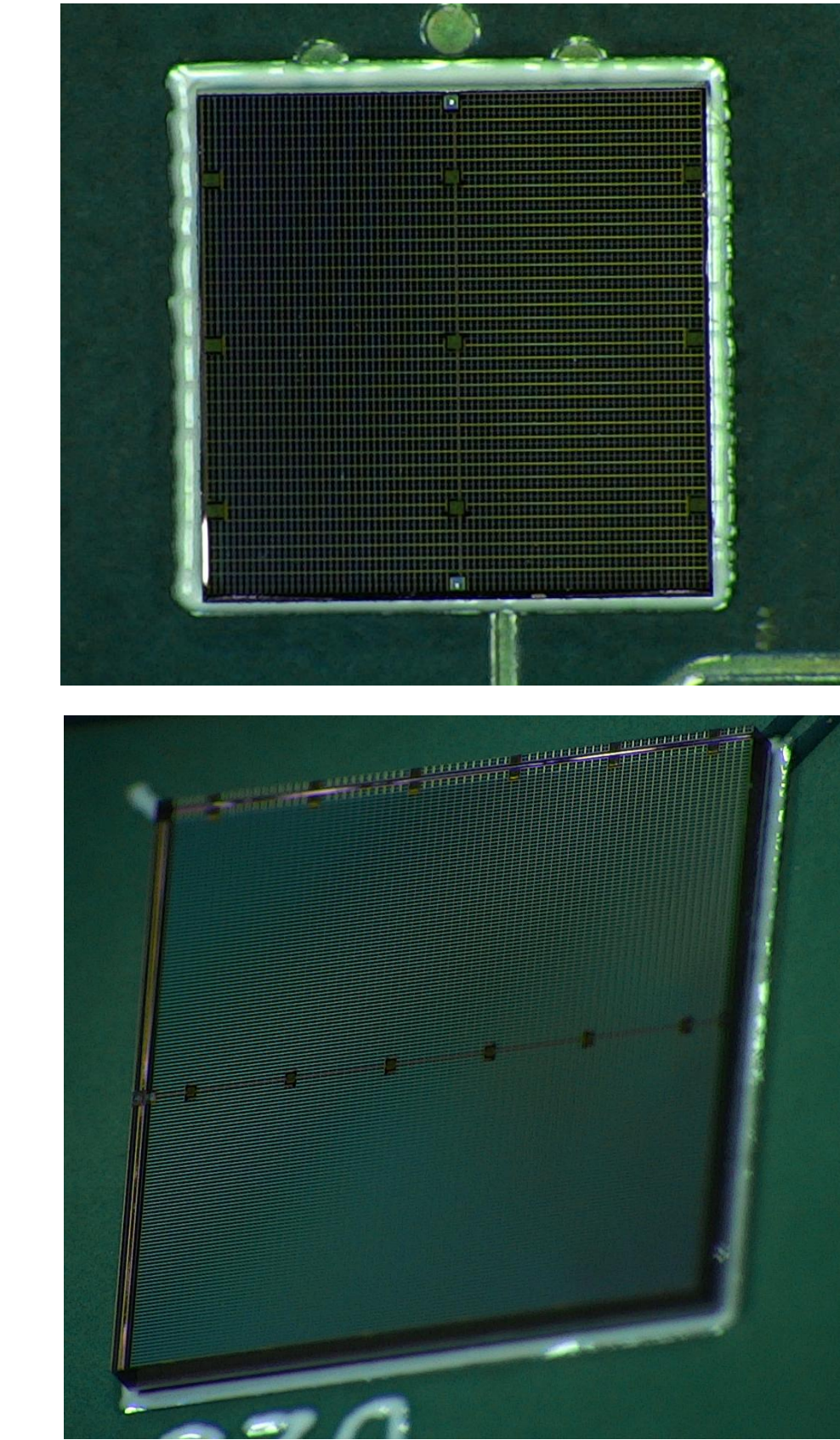
- Copper as absorber
- Used two fiber media: Cherenkov and Scintillating (Dual Readout)
- Photons within the critical angle, θ_c , will undergo total internal reflection (TIR) and get trapped in the fiber until the readout
- Readout by Silicon Photomultipliers (SiPM's)



HG-DREAM active area

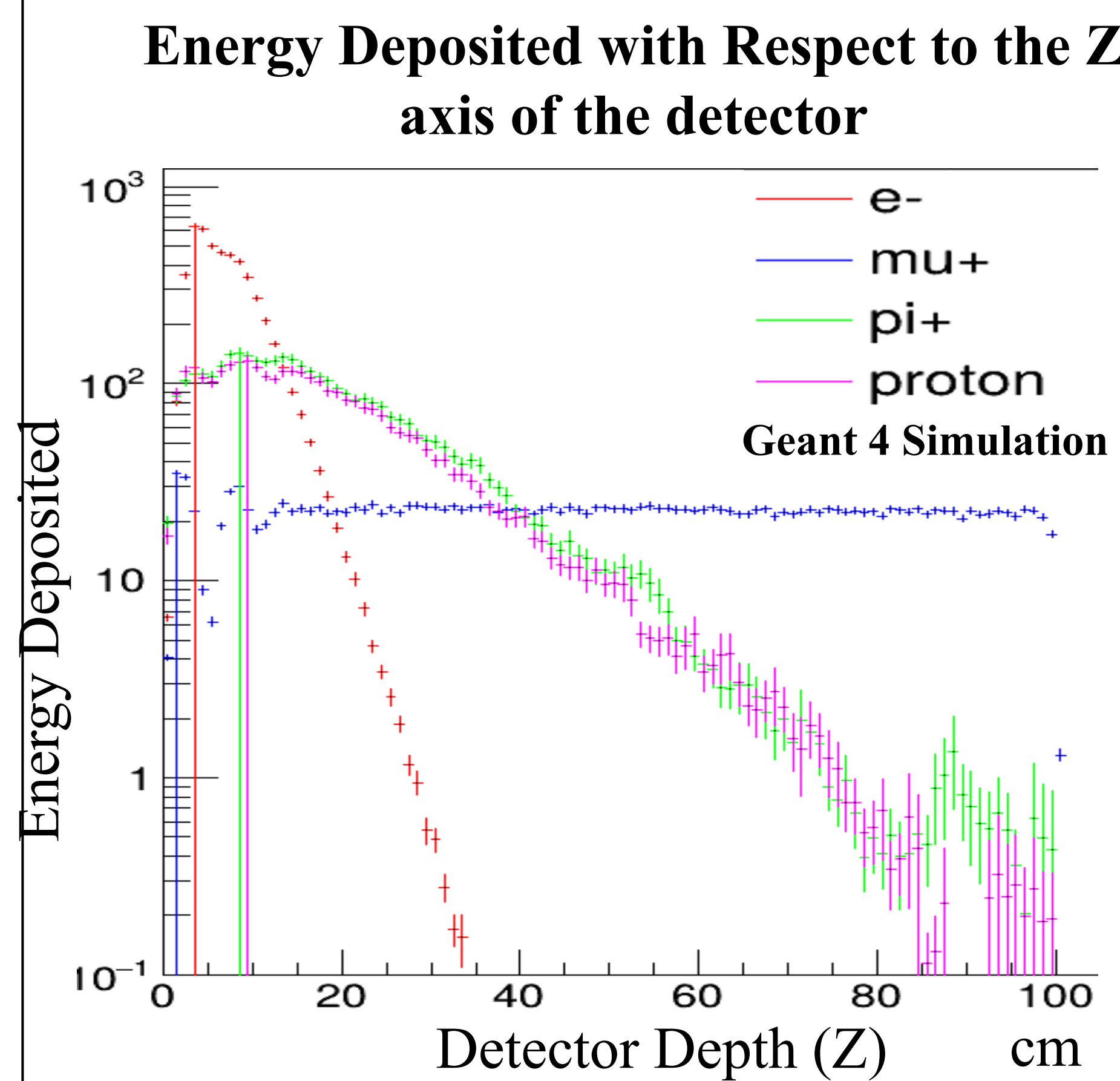


- 448 Cherenkov Channels
- 448 Scintillating channels



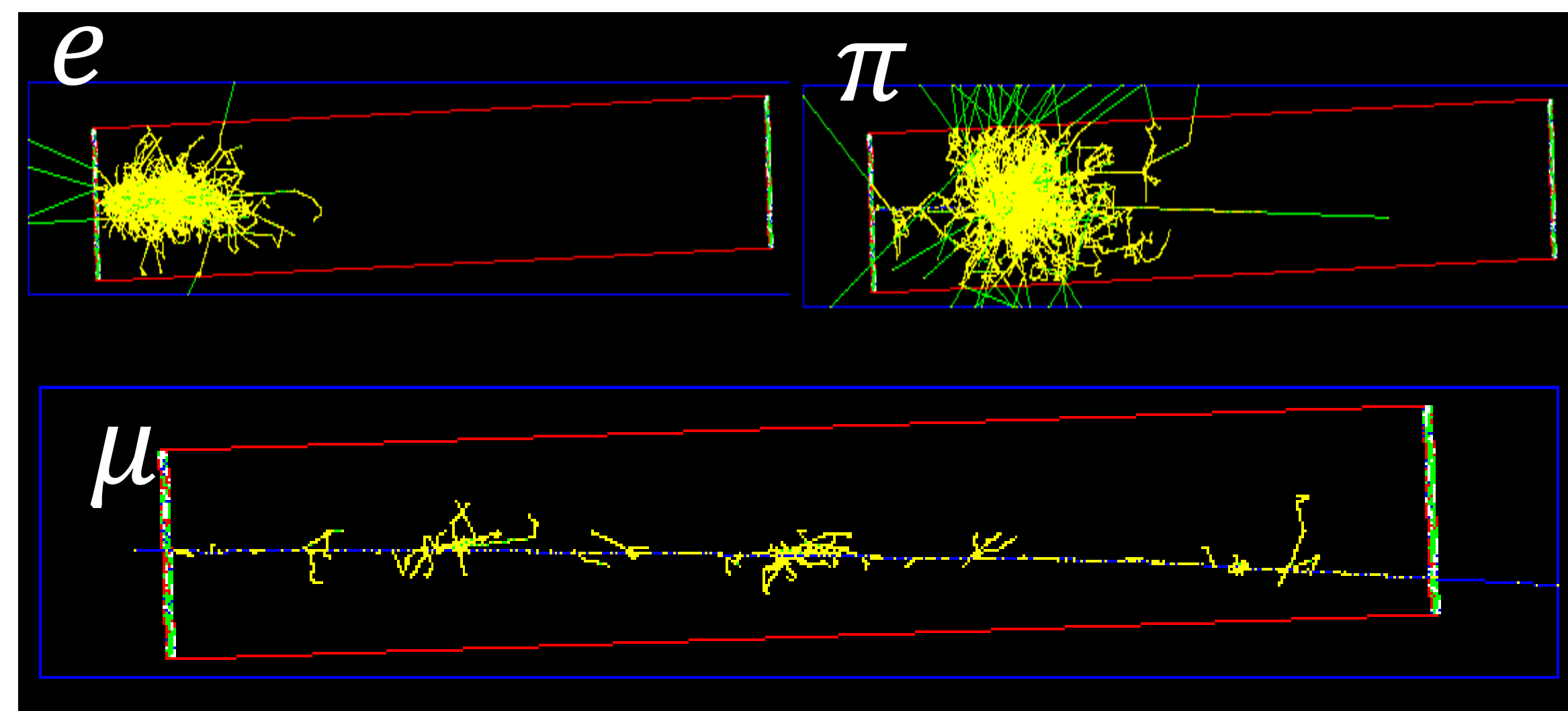
- All channels readout by J-Series SiPMs
- SiPMs allow for increased spatial segmentation and ≈ 100 ps timing resolution resulting in 4D measurements

Simulating Muons in HG-DREAM

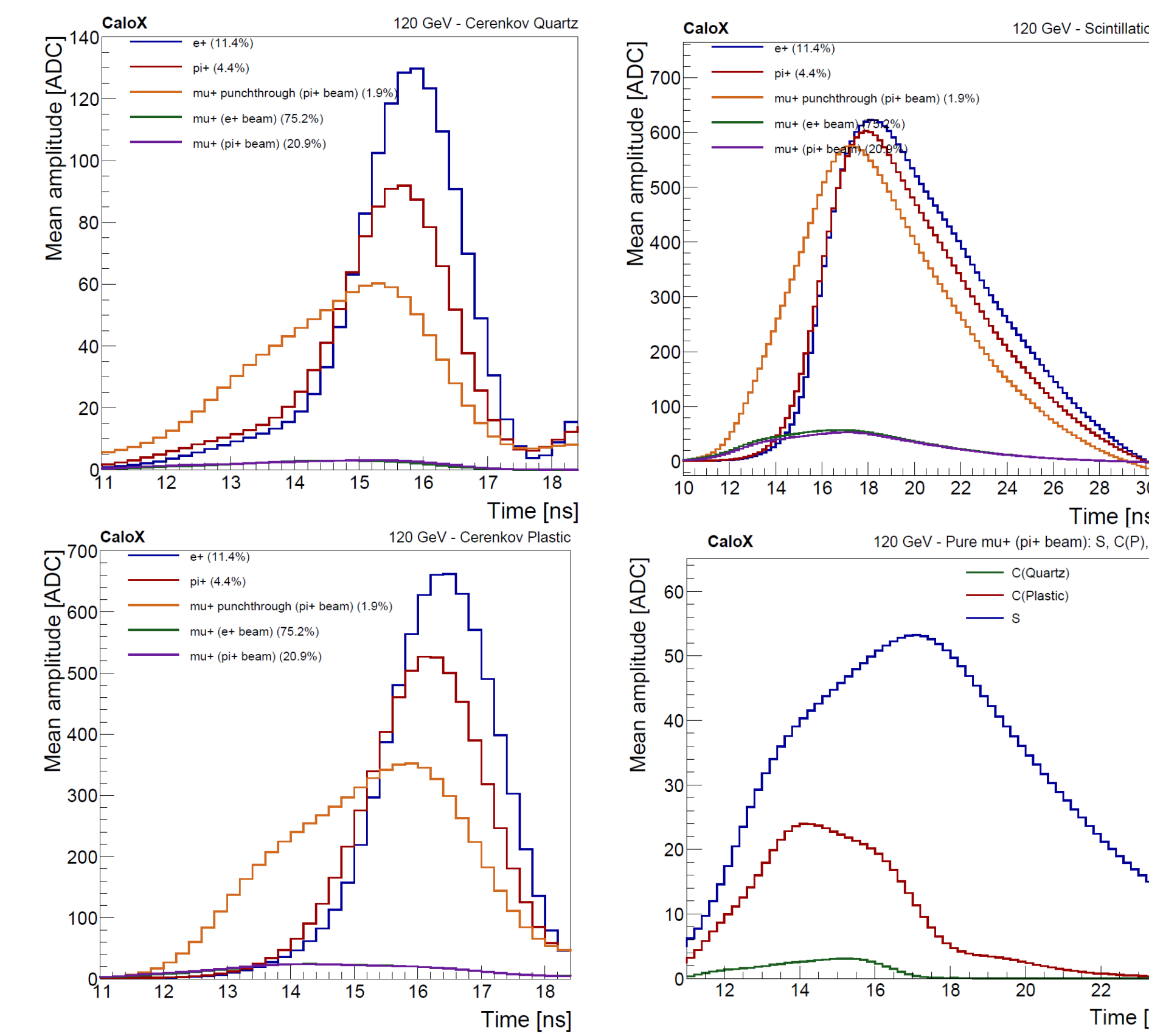


Particle's energy deposition vs the Z axis, also showing shower max (top) and shower profiles for different particles (bottom)

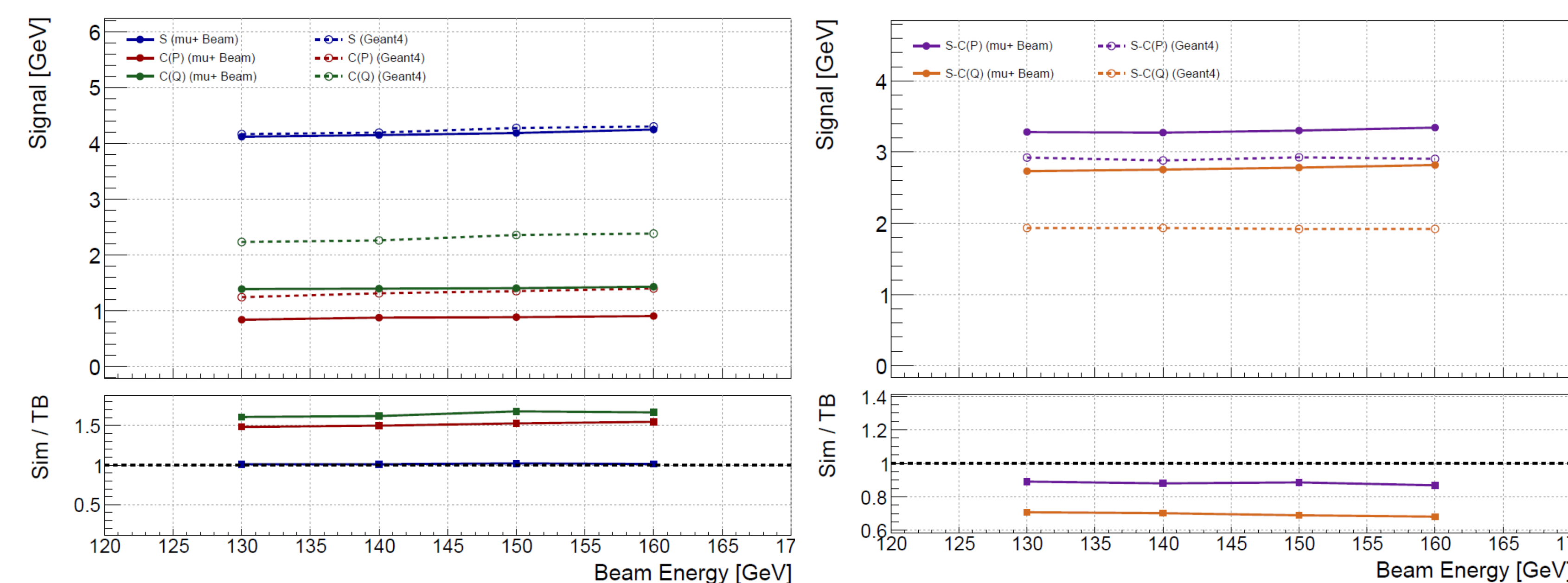
- Muons deposit a constant dE/dx (ionization)
- Energy lost due to bremsstrahlung and other radiative processes scale with $\frac{1}{m^2}$



Measurement of Muon Ionization

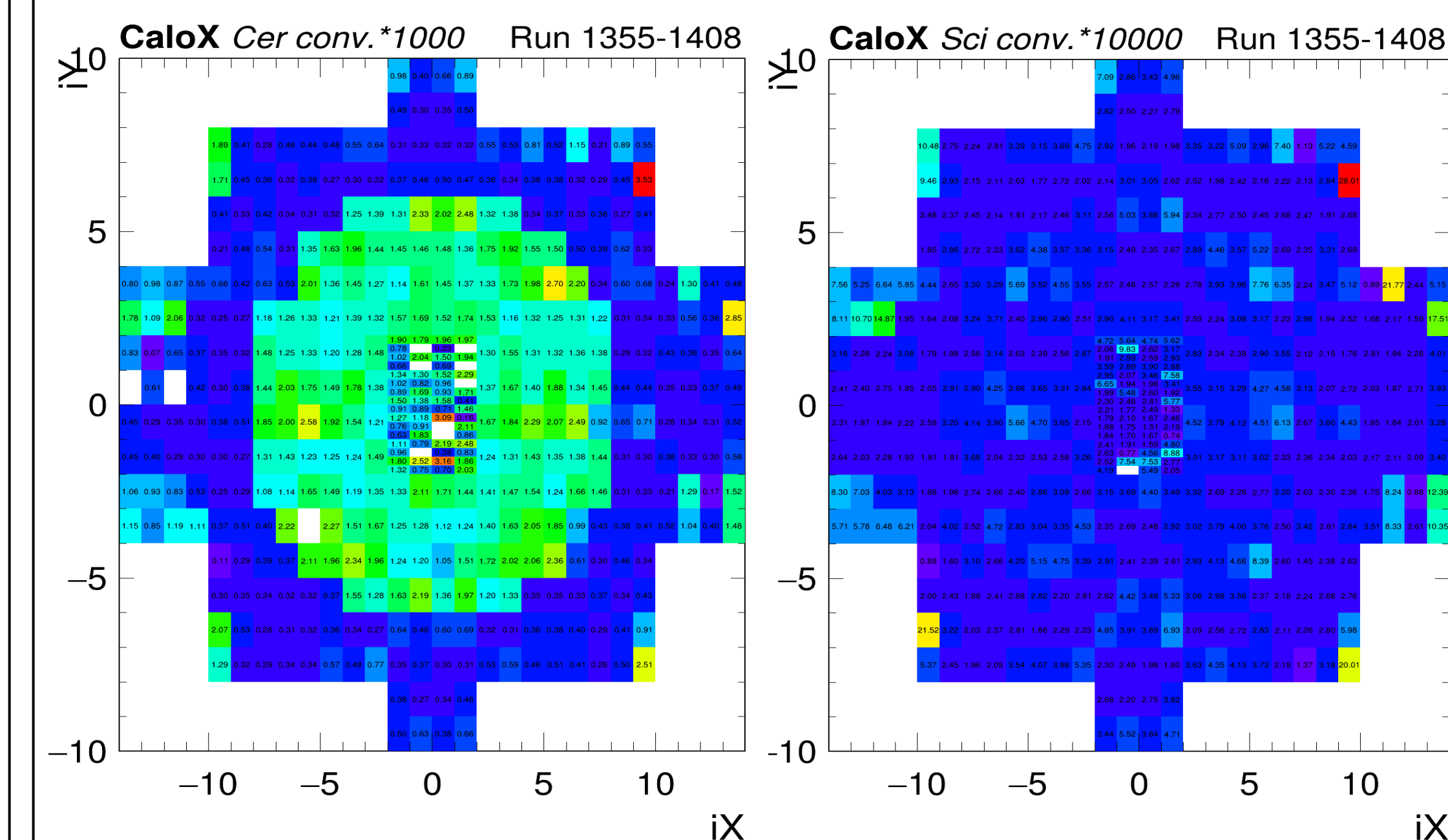


- Since the beam/shower particles are traveling $> \frac{c}{n}$ the light captured deeper in the calorimeter will arrive first
- We can successfully see the effects of punch through muons and pure muons
- Punch through muons are muons that were produced in the pion shower development and triggered the muon counter at the end of the beamline
- Muons will typically not shower, and the calorimeter will have a relatively low response to them
- The calorimeter was calibrated using electrons, so the scintillation (S) and Cherenkov (C) active media respond the same to EM showers
- When responding to muons, the scintillation fibers will see both the ionization and radiative components, while the Cherenkov fibers will only see the radiative component, since the photons produced via ionization fall outside the fiber's numerical aperture
- Subtracting the two responses, S-C, will give just the ionization deposited by the muon, on the EM scale, which is only possible in a dual readout calorimeter such as this one



Calibration Using Positrons

- Using 40 GeV positrons, we scanned the entirety of the detector to calibrate each SiPM's response. Since we are using positrons, the Cherenkov and Scintillation response will be the same
- The calibration method is as follows
 - The pedestal of each SiPM is found and subtracted using the mean value from a fitted gaussian
 - High Gain and Low Gain values are cross-calibrated via a linear fit to account for any saturation in the High Gain
 - After this pre-processing, the output of each channel is fed into the linear regression model.



- Value map of the calibration constants for each Cherenkov (left) and scintillation (right)
- The ring-like structure observed in the Cherenkov channel map arises from the refractive index difference between the fused-silica and plastic fibers without any prior input into the model