



# pGAPS: DEVELOPING A COSMIC RAY ANTI-DEUTERON DETECTOR - A Balloon-Based Search for Dark Matter -



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For the GAPS Team

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GAPS Website: <http://gamma1.astro.ucla.edu/gaps/>

## SUMMARY

The goal of the GAPS project is to develop a sensitive detector for anti-deuterons in the cosmic rays. Anti-D's can provide strong evidence for dark matter WIMP annihilations.

GAPS uses a novel, exotic-atom technique to identify anti-D's, which are detected from pions and X-rays emitted during the exotic atom decay. GAPS consists of a Si(Li) tracker, that also serves at the target, surrounded by a time-of-flight (TOF) and anti-coincidence system made of plastic-scintillators.

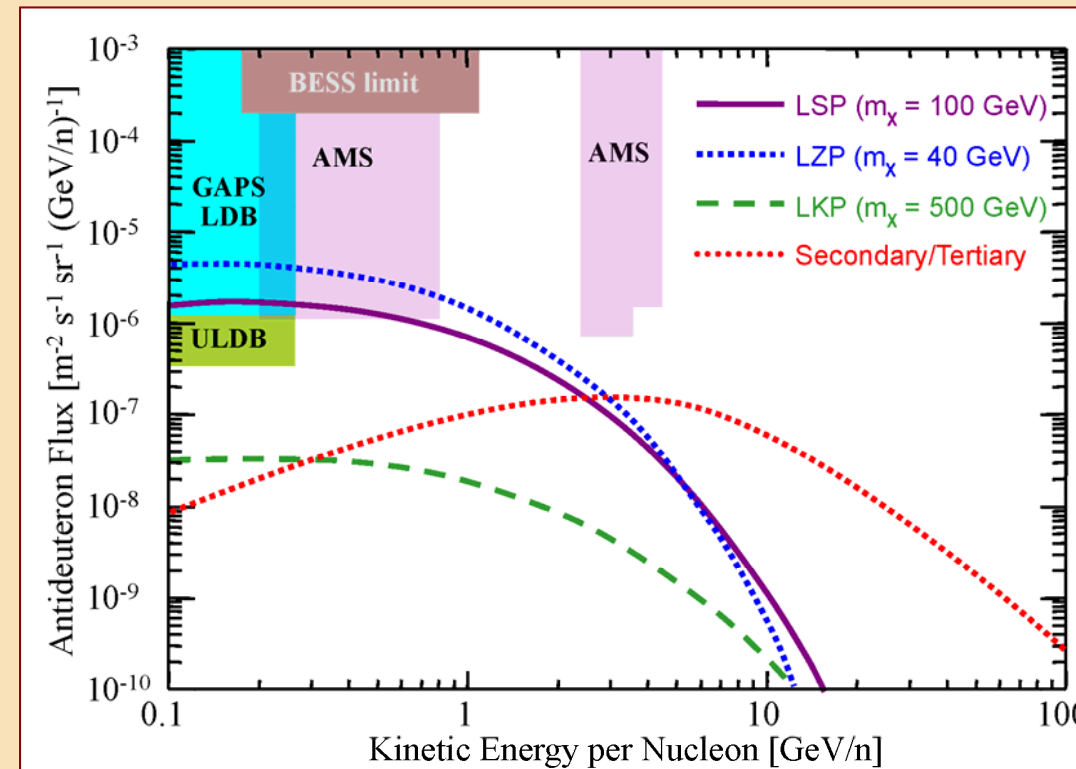
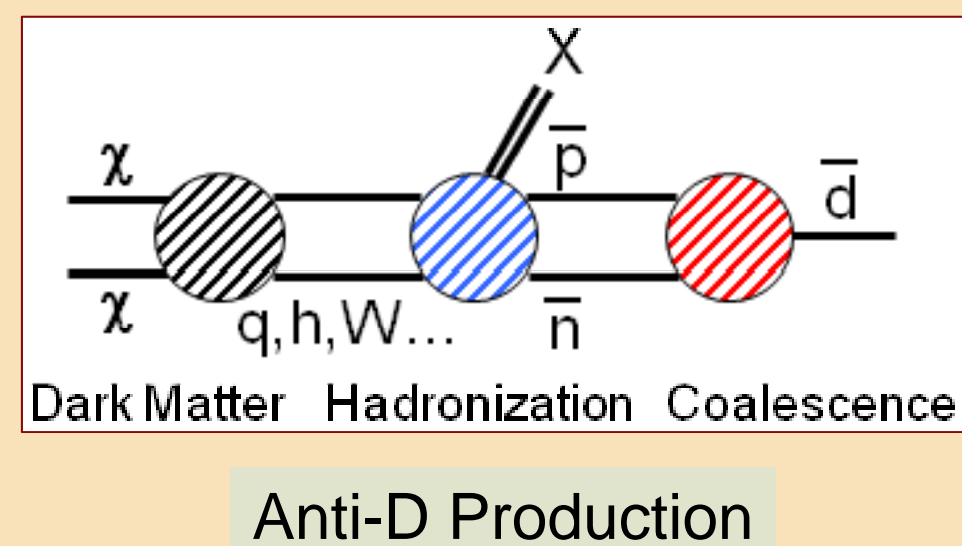
pGAPS, a prototype version of GAPS, was built for a launch from Japan in 2012. pGAPS consisted of 6 Si(Li) detectors and 3 layers (cross planes) of scintillation counters.

pGAPS had a successful balloon flight on June 3, 2012 from The Taiki Aerospace Research Field of JAXA in Hokkaido, Japan. All pGAPS systems worked well and data were taken the entire time from launch to splash down. The flight time was 6 hours with over 1 million triggers recorded.

## Why Anti-Deuterons ( $\bar{D}$ ) ?

### Dark Matter (DM):

- Comprises 85% of the mass of the Universe
- Particle candidates (WIMPs) beyond the SM:
  - SUSY, Kaluza-Klein UEDs, etc.
- DM annihilations  $\rightarrow$  cosmic ray (CR) particles



### Cosmic Ray Anti-Matter:

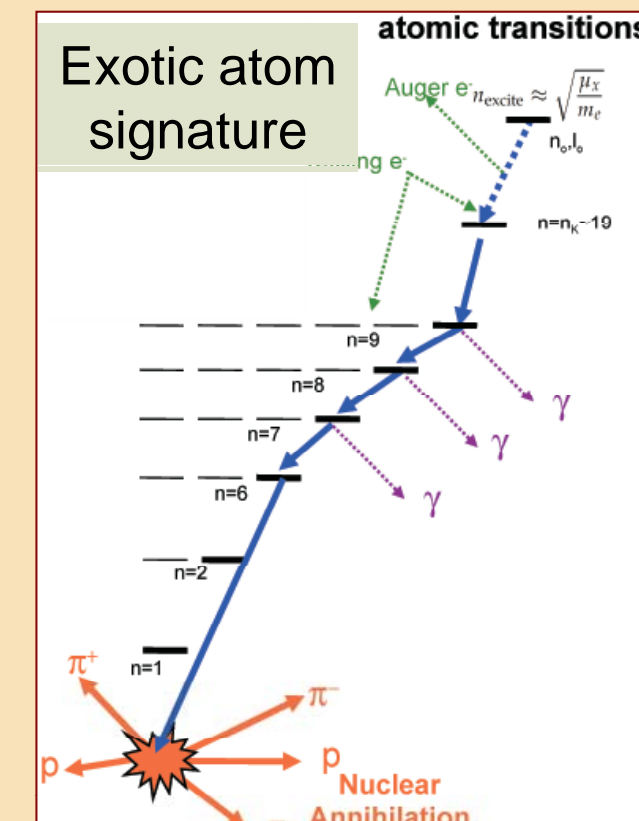
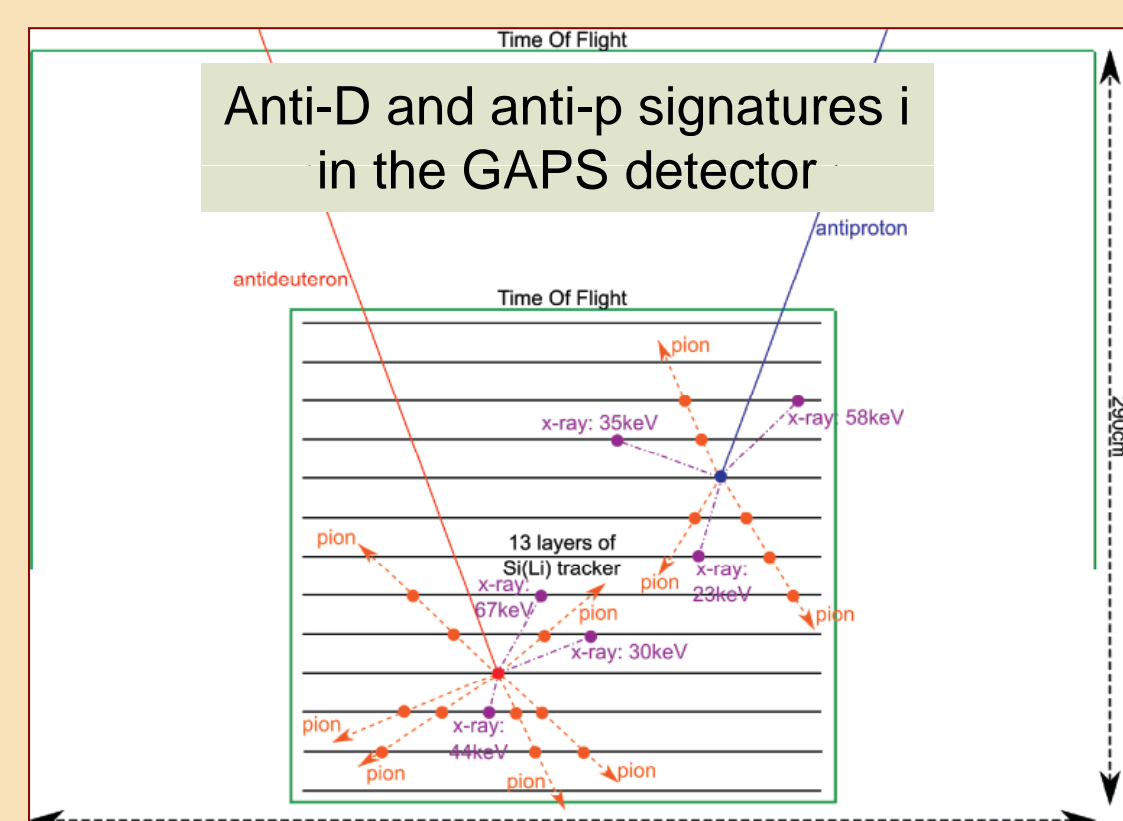
- CR  $e^+$ ,  $\bar{p}$ ,  $\bar{D}$  can be signatures for DM
  - $e^+$ 's and  $\bar{p}$ 's have large primary/secondary backgrounds
  - $\bar{D}$ 's have low expected background

$\rightarrow$   $\bar{D}$  signal from DM is background free !

## The GAPS Detector

### GAPS Detector (LDB and ULDB):

- 13 layers of Si(Li) detectors,  $\sim$ 3500 total strips  $\rightarrow$  Good X-ray resolution and particle tracking
- TOF/Anti-coincidence system of plastic scintillator
- Excellent particle-ID: velocity and dE/dx of slow moving anti-D, decay of exotic atom  $\rightarrow$  characteristic X-rays and pions from nucleus annihilation.

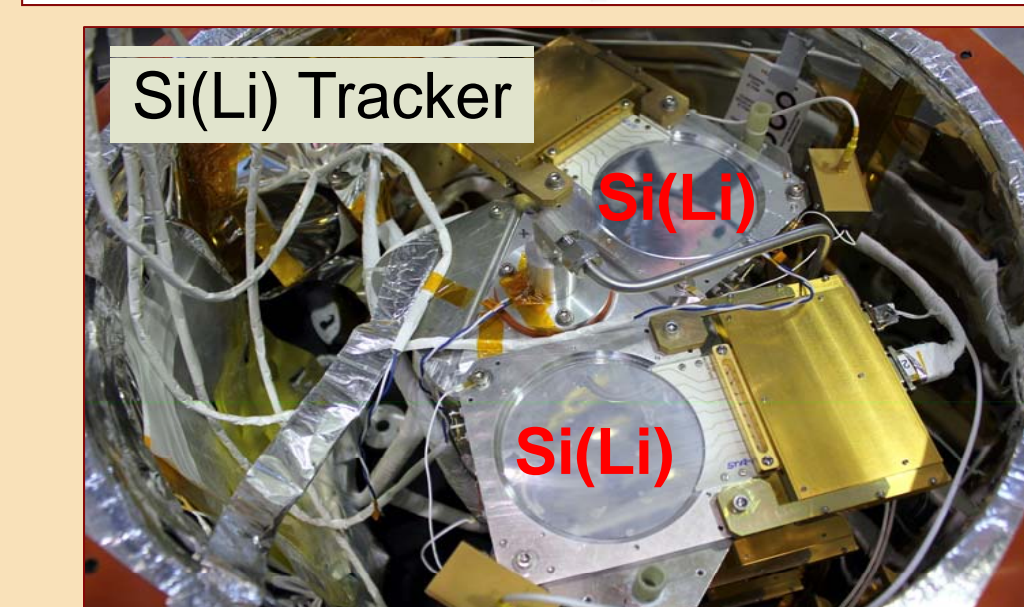
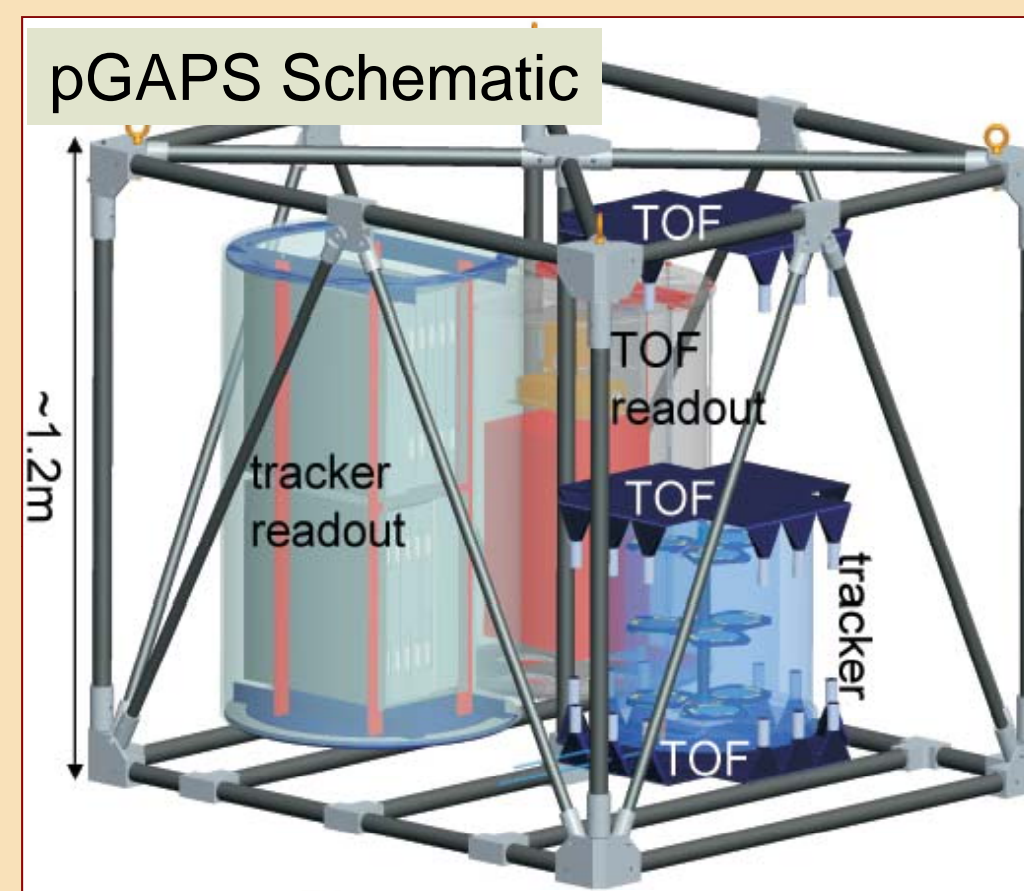


## pGAPS: Prototype Detector

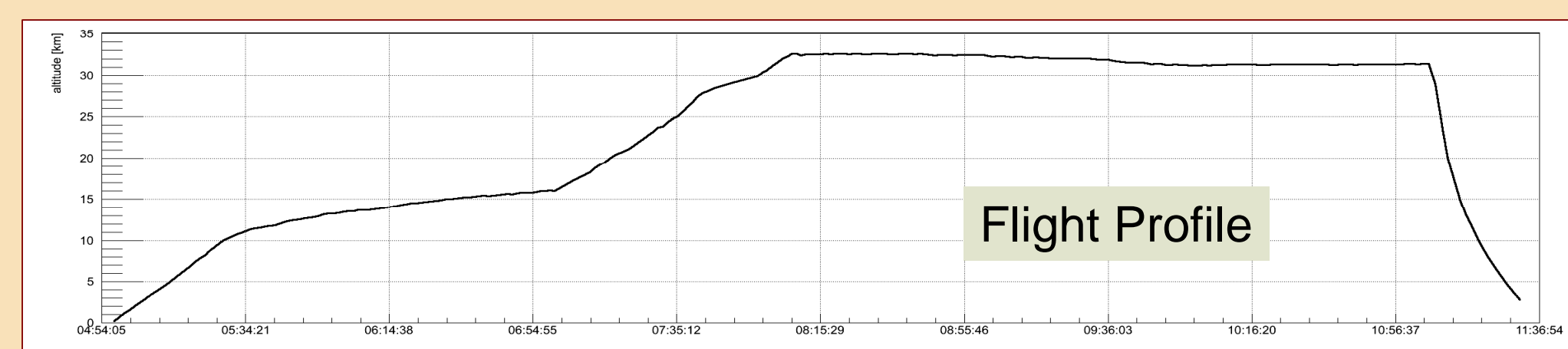
### Goals of pGAPS:

- Stable, low-noise operation of Si(Li) detectors ✓
- Functionality and operation of TOF system ✓
- Si(Li) cooling approach ✓
- Measure incoherent bkgnd in flight-like configuration ✓

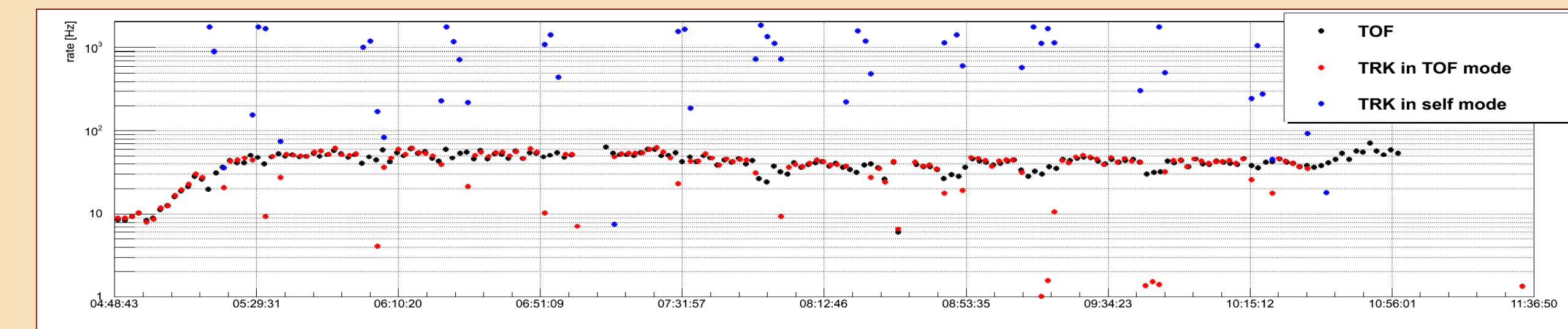
$\rightarrow$  ALL GOALS FOR PGAPS WERE MET.



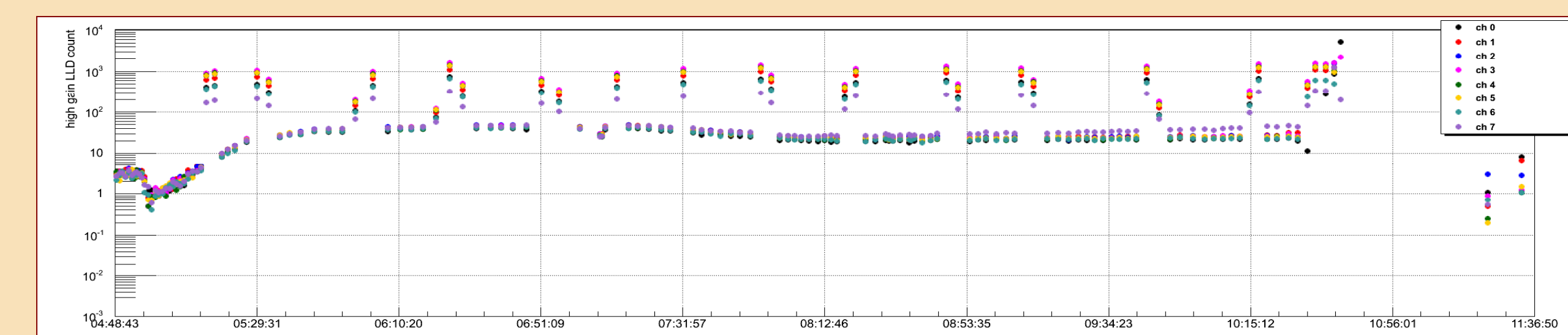
## pGAPS Flight in Japan



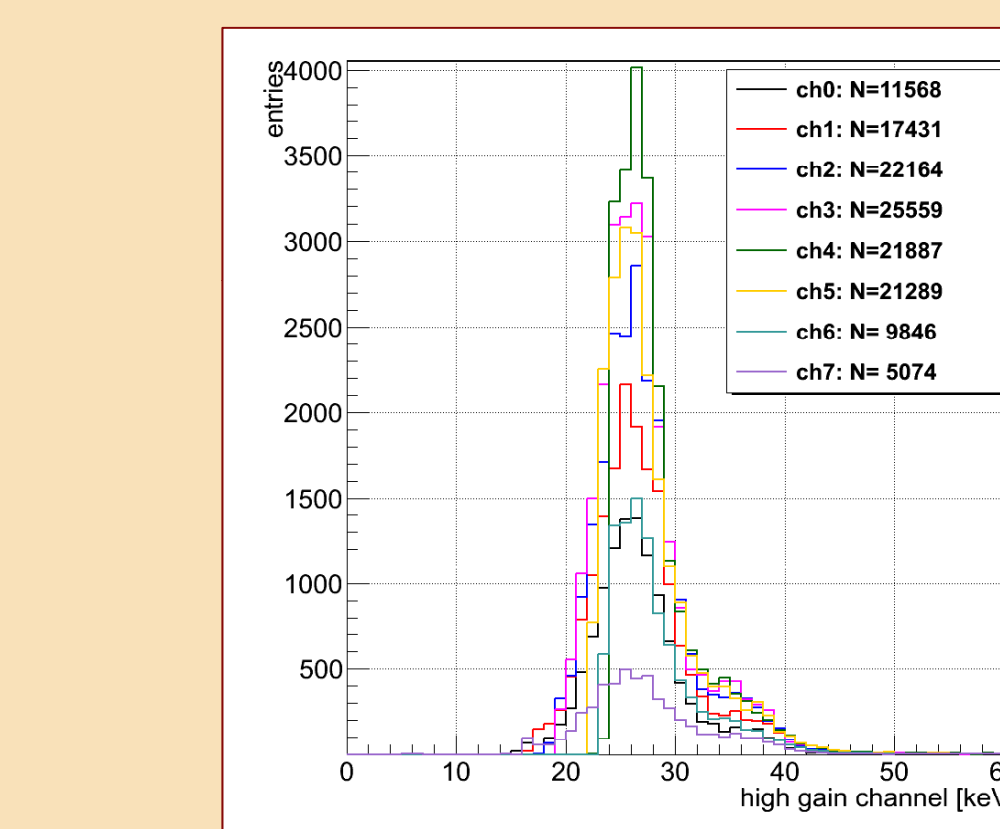
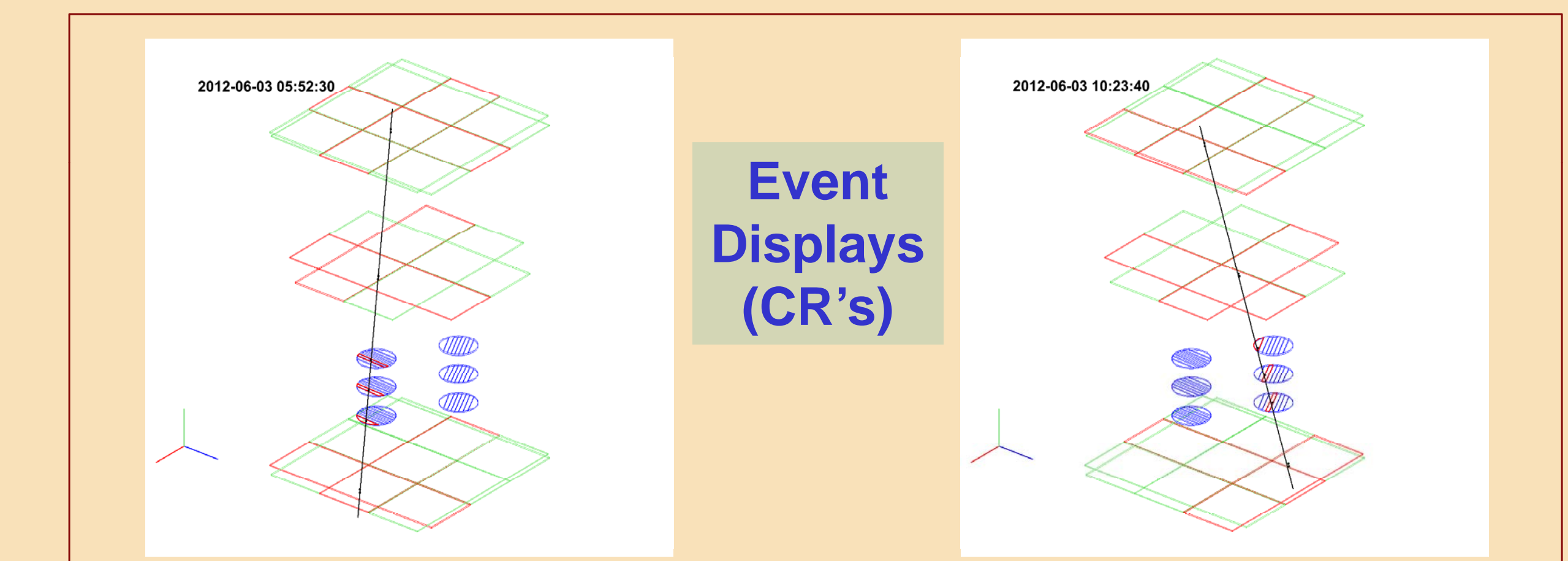
## pGAPS: Preliminary Data Analysis



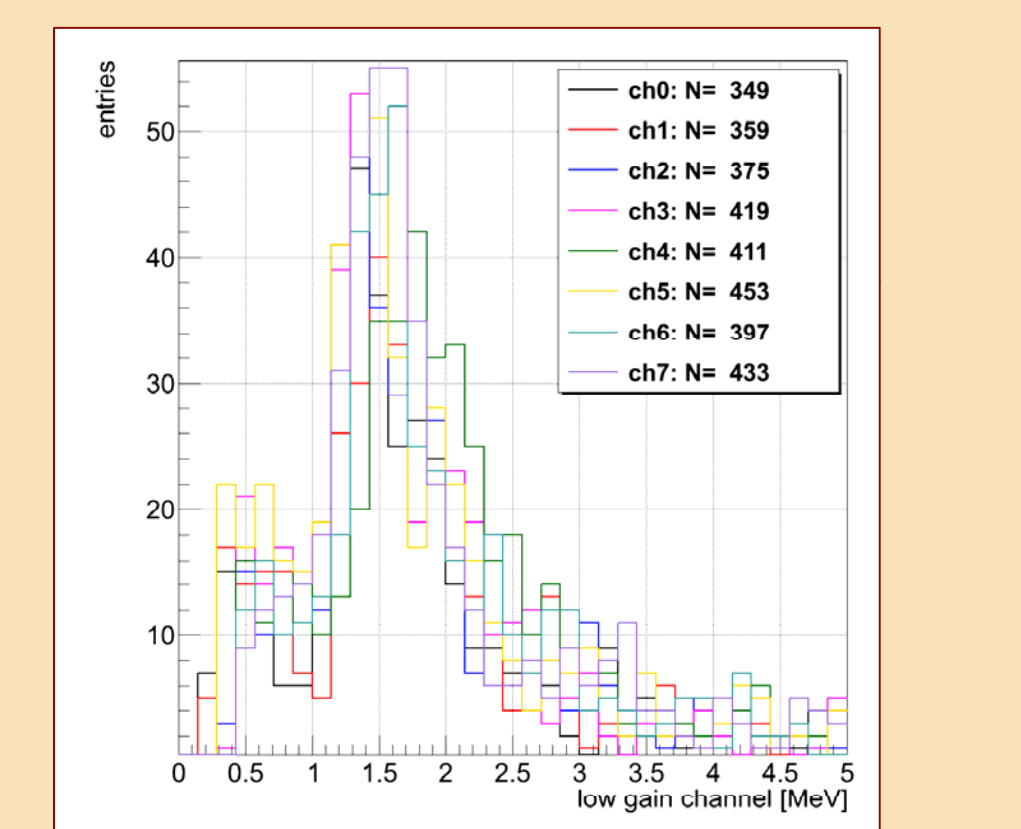
Stable Trigger Rate versus Time



Si(Li) Detector High-Gain Counts  $\rightarrow$  Stable Operations

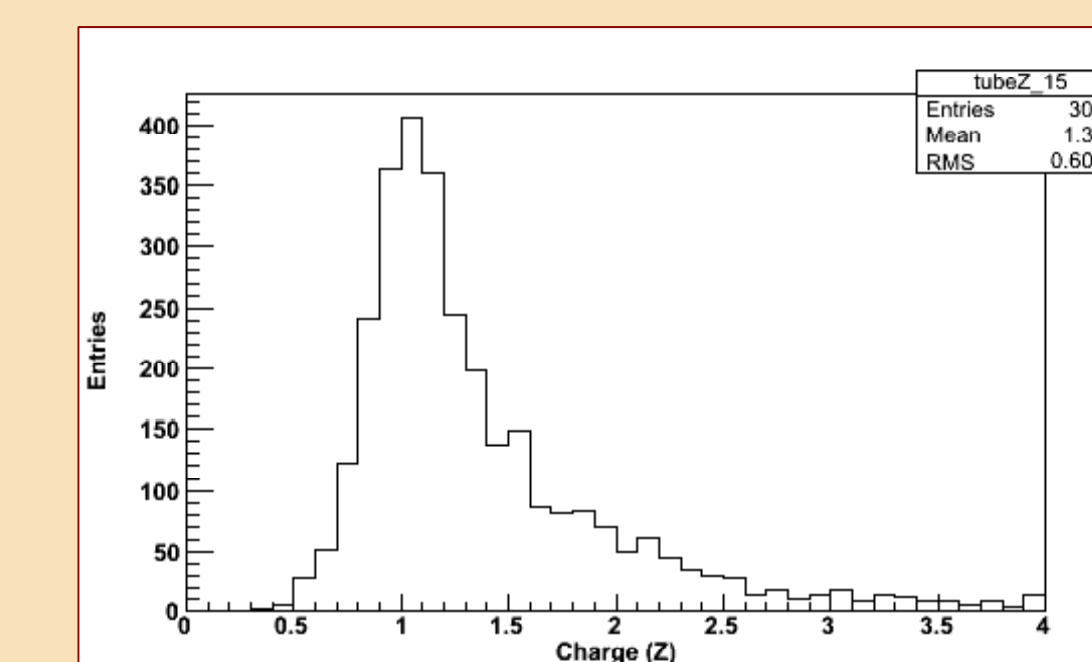
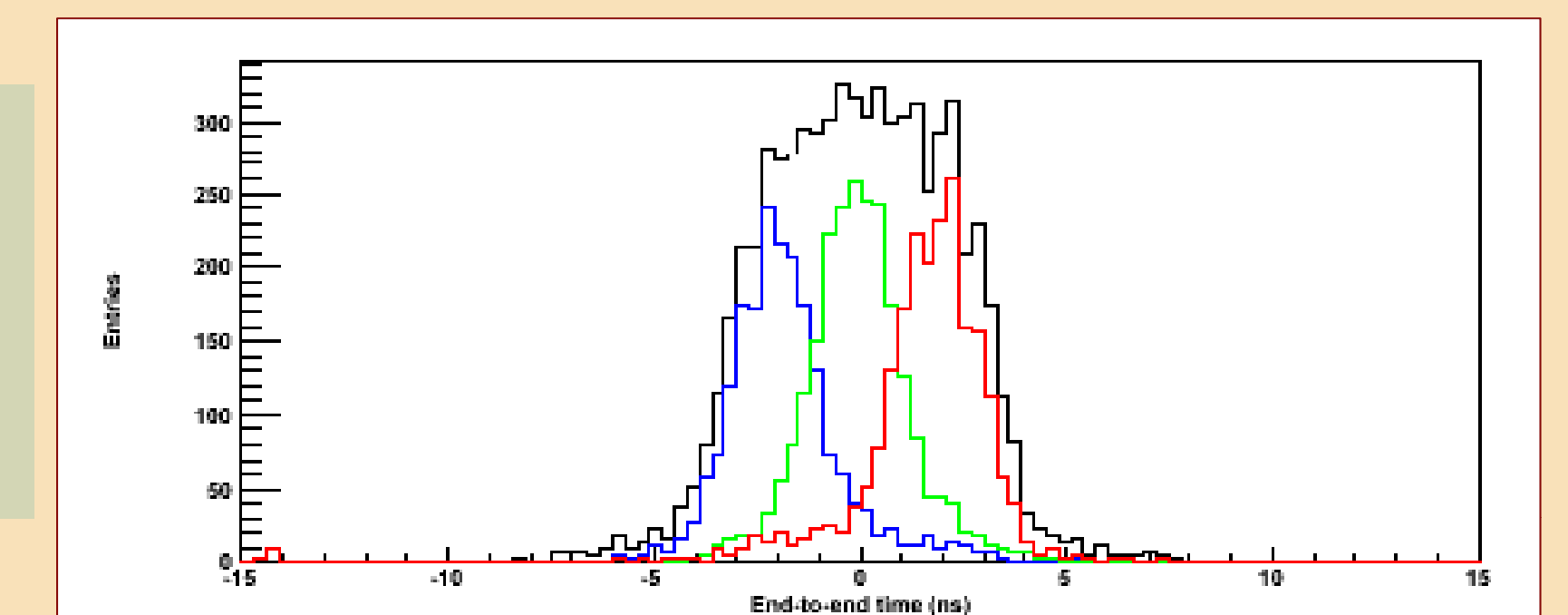


Si(Li) high-gain spectra X-ray source (in flight)

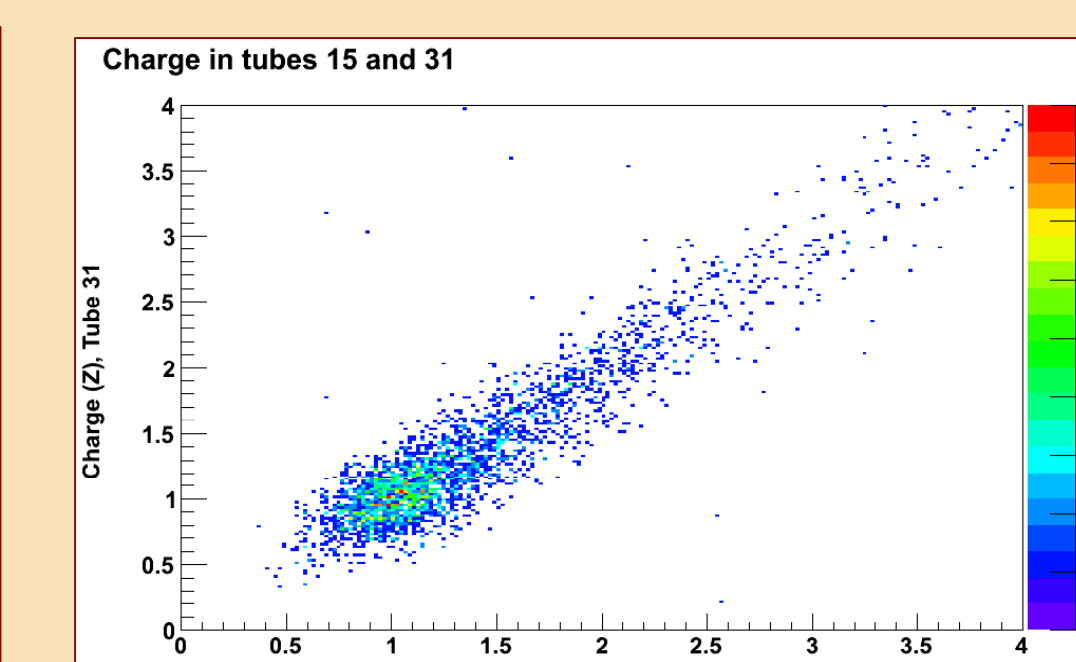


Si(Li) low-gain spectra Cosmic rays (in flight)

### TOF Data End-end Timing



TOF Charge Distribution



TOF Charge (both ends)

### Acknowledgements:

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