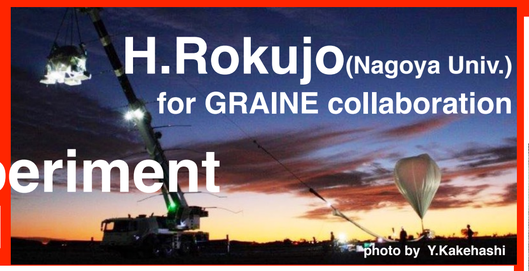
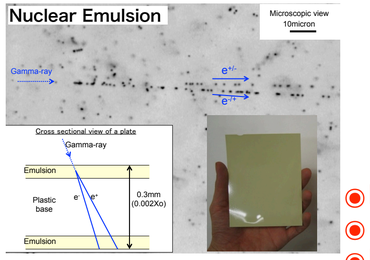
Observation of sub-GeV Atmospheric γ rays on GRAINE 2018 Balloon Experiment & Comparison with HKKM

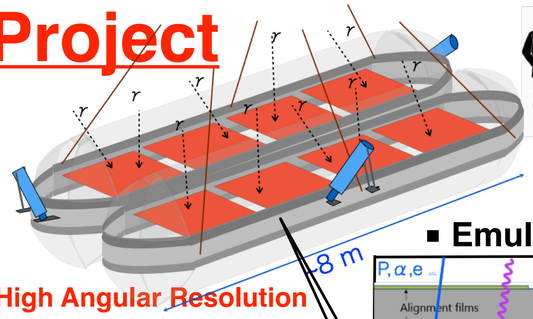
H.Rokujo (Nagoya Univ.)
for GRAINE collaboration



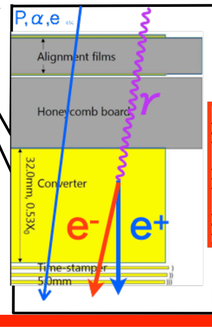
I. GRAINE Project

- High-Res. Observation of Galactic Center
- Polarization Measurement
- High-sensitive Burst Event Search





▪ Emulsion γ-ray Telescope



Flat Films
Emulsion +honeycomb borad

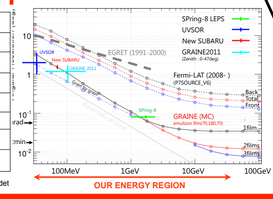
Converter Emulsion stack
Vertical Profiles
100 films(Total: 33 mm)
0.52 X_0 , $\varepsilon_{conv.}$ = 33%
Plastic base (PS)180μm
Emulsion layers 75μm
(coated both sides)

Timestamper
Multi-stage shifter

- ◉High Angular Resolution
- ◉Polarization Sensitive
- ◉Large Aperture Area

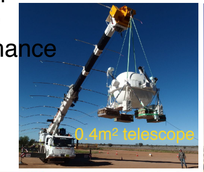
	Fermi LAT		GRAINE
Angular res.@100 MeV	6.0° (105 mrad)	x1/6 →	1.0° (17 mrad)
@1 GeV	0.90° (16 mrad)	x1/9 →	0.1° (1.7 mrad)
Energy range	20 MeV–300 GeV		10 MeV–100 GeV
Polarization sensitivity	No		Yes
Effective area @100 MeV	0.25 m²	x8 →	2.1 m² *
@1 GeV	0.88 m²	x3 →	2.8 m² *
Dead time	26.5 μsec (readout time)		Dead time free

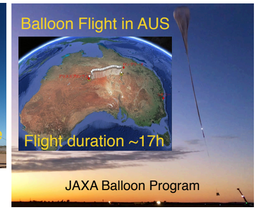
* $10m^2 * \varepsilon_{trans} * \varepsilon_{conv} * \varepsilon_{det}$

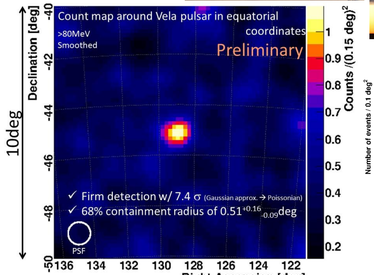


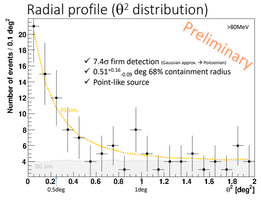
II. Balloon Exp. in 2018

To detect Vela pulsar & demonstrate overall-performance of emulsion telescope





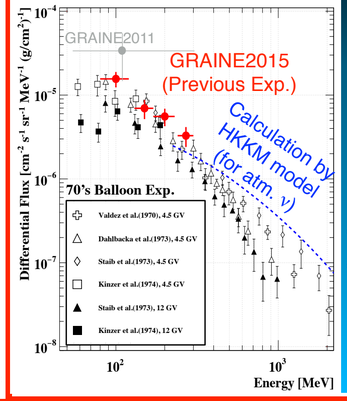


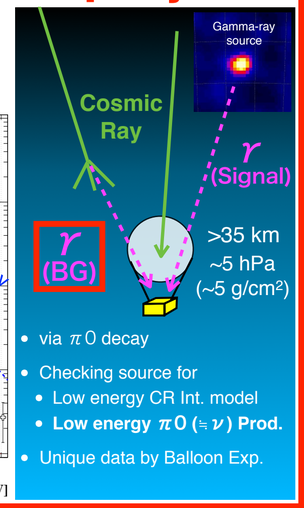


✓ Detection of Vela pulsar (7.4σ)

✓ World's Highest imaging
0.51deg 68%radius (>80MeV)

III. Atmospheric γ rays Observation

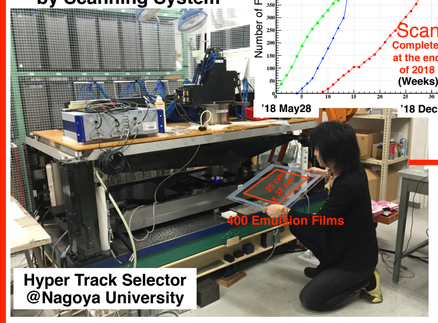




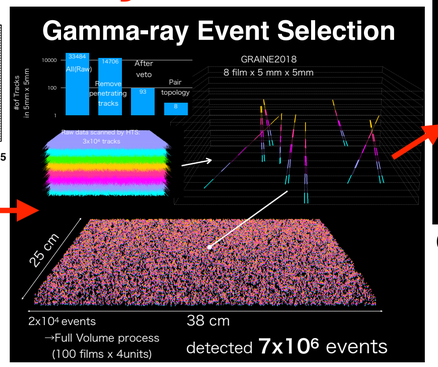
- via π0 decay
- Checking source for
  - Low energy CR Int. model
  - **Low energy π0 (≒ν) Prod.**
- Unique data by Balloon Exp.

IV. Flight Data Aanalysis

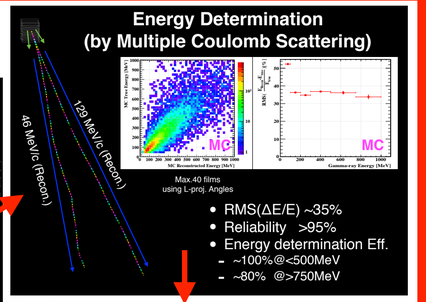
Emulsion Data Acquisition by Scanning System



Gamma-ray Event Selection

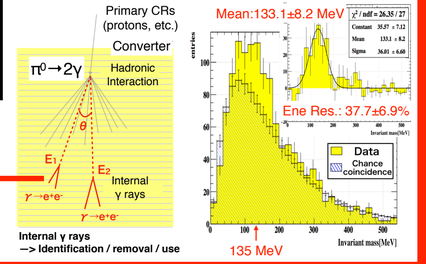


Energy Determination (by Multiple Coulomb Scattering)



- RMS(ΔE/E) ~35%
- Reliability >95%
- Energy determination Eff.
  - ~100%@<500MeV
  - ~80% @>750MeV

Calibration using Internal γ rays



Internal γ rays
—> Identification / removal / use

Checking kinematical distributions between data and MC.
—>Estimation of Detector response

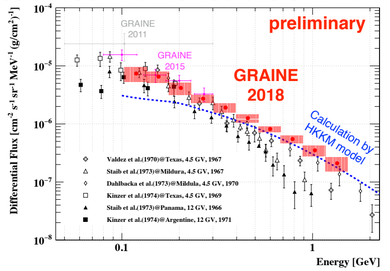
Gamma-ray Flux calculation

$$F(E) = \frac{N_{SIG}}{S\,\Omega\,T\,\Delta E\,\varepsilon_{detect}\,\varepsilon_{\gamma\to e+e-}\,P_{air}}$$

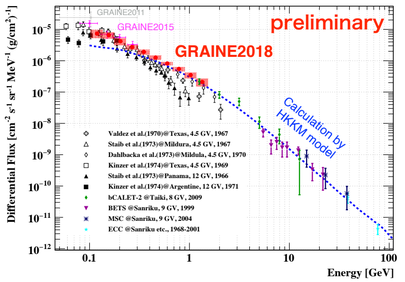
$[cm^{-2}\,s^{-1}\,sr^{-1}\,MeV^{-1}\,(g/cm^2)^{-1}]$

V. Results

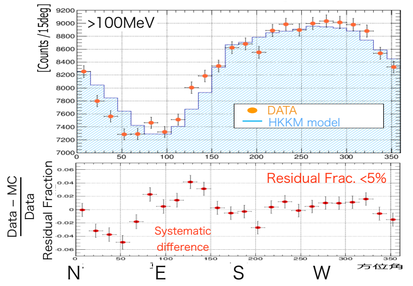
Measured Flux of sub-GeV Atm.



Comparison with Multi-GeV Measurements



Azimuth Distribution of Atm. γ-ray (EW-effect)



Atmospheric γ-ray spectrum (0.1-1 GeV) on GRAINE 2018

~ 1 GeV: Smooth connection with Multi-GeV measurements

~ 0.1 GeV: Unexpected deviation of latest HKKM model (under investigation)

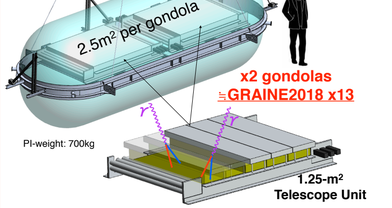
First observation of E-W effect of atmospheric γ rays at balloon altitude

Matches HKKM model with less than 5%

Systematic difference has been observed.

VI. Outlook

GRAINE-Next in 2023 (approved)



- Commissioning towards scientific observation
- The world's largest aperture GeV gamma-ray telescope
- High-resolution imaging of Vela in GeV region
- Observation of Gal. center region (diffuse, point sources)
- Survey for transient sources (~2 events/flight is expected)

Developments