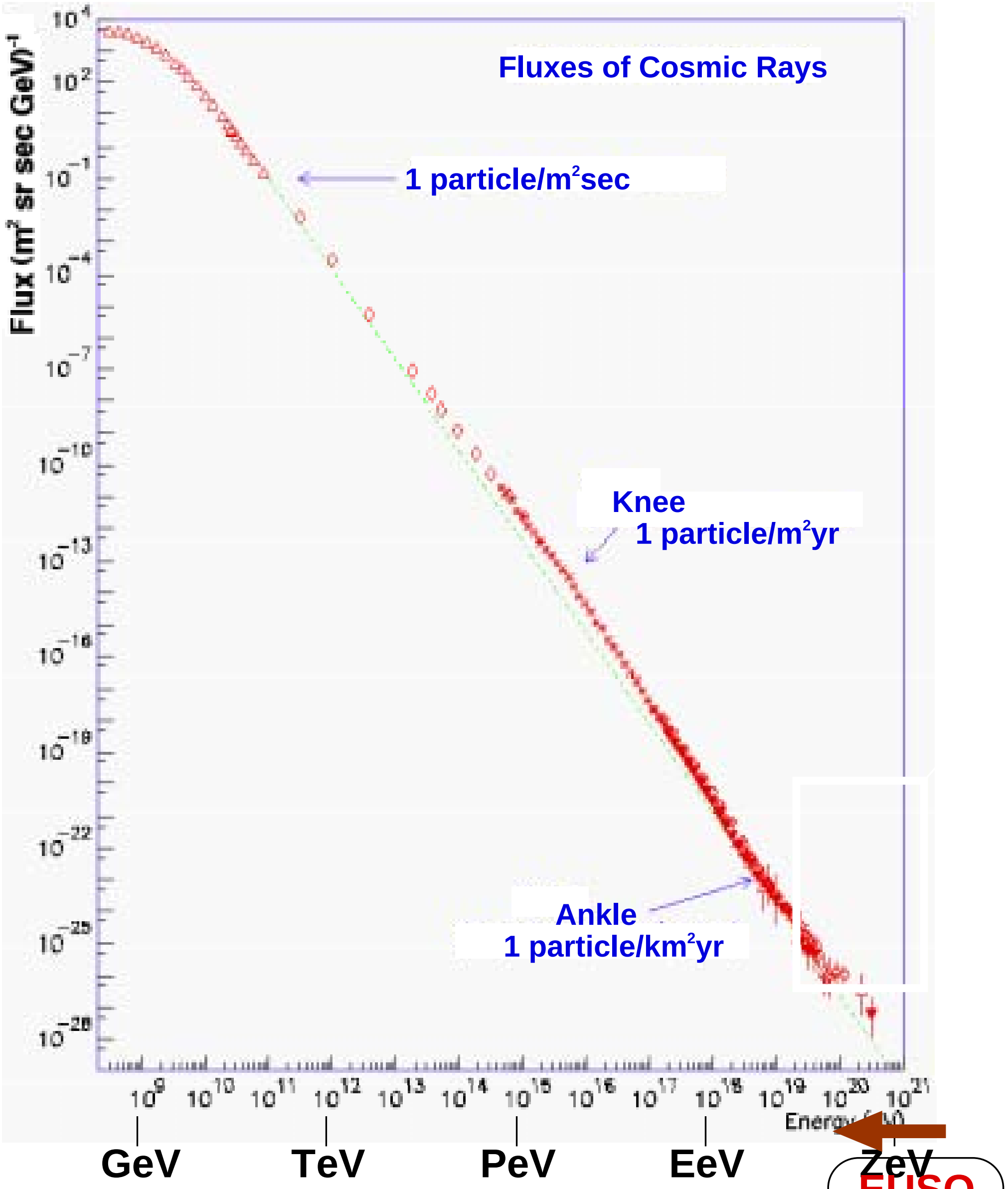
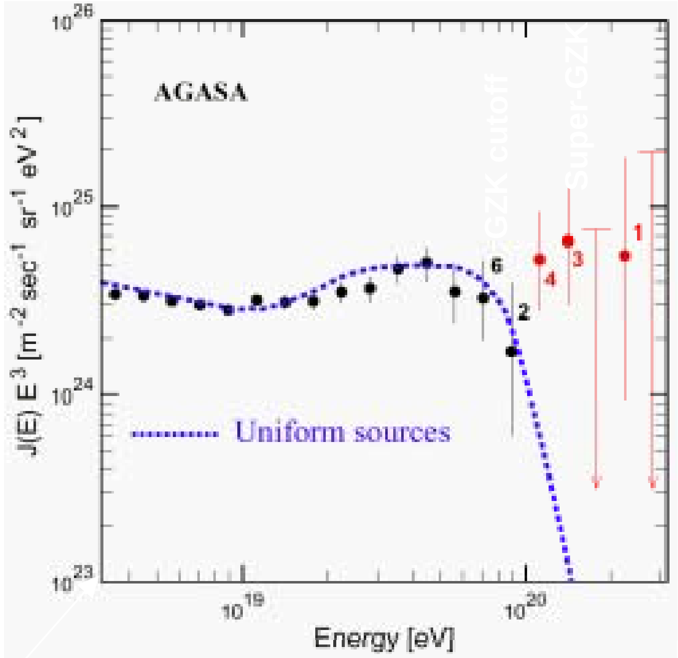
EUSO:
現状報告及び全体計画

戒崎俊一
(理化学研究所)
EUSO-Japan

Cosmic Ray Spectrum





Super-GZK宇宙線の起源

- トップダウンシナリオ
  - 極めて重い素粒子の崩壊
    - 大統一理論のX粒子；宇宙位相欠陥
- ボトムアップシナリオ
  - ガンマ線バースト
  - 活動的銀河核
  - 銀河団・超銀河団

Super-GZK宇宙線の伝播

- 線源が近傍にある (<50Mpc)
  - 低降着率ブラックホール
  - 宇宙論的衝撃波
- GZK効果による損失が起こらない
  - ニュートリノ？
  - 極めて重い未知の粒子？
  - 相対論のローレンツ不変性の破れ？

Super-GZK宇宙線の空間分布

- Super-GZK宇宙線は数度しか曲がらない
  - 起源モデルに制限を与える
- 空間分布
  - 今の統計では超銀河団程度に広がった線源を棄却できない。
- 空間クラスタが存在
  - 独立な点源がたくさんあることを示唆

統計精度の向上が先決

AGASA

4σ excess beyond the GZK cutoff

1 event/year × 10 year = 10 events

EUSO

700event/year × 3 year = 2100 events

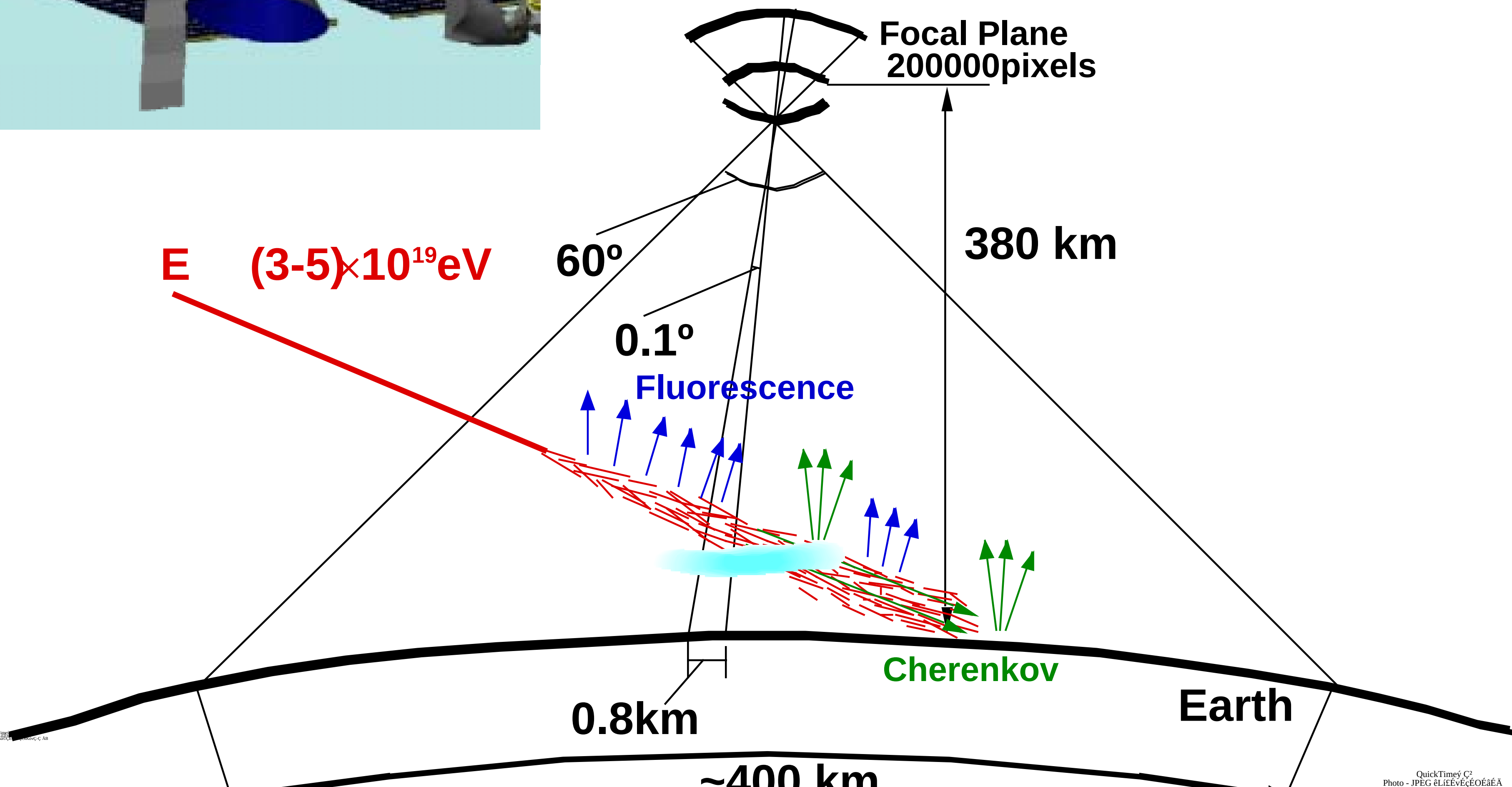
空間分布・時間分布

↓

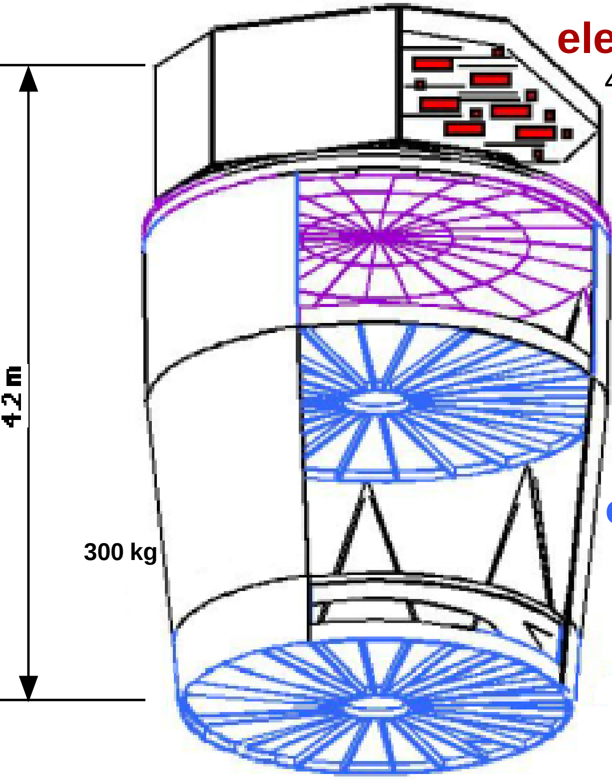
宇宙線天文学

Extreme Universe Space Observatory on the International Space Station

Extreme Energy Cosmic Rays
Neutrino-induced Air Showers
Atmospheric Phenomena
Night glows, Elves, Aurora, Meteoroids, …



EUSO Telescope



electronics

400 kg / 450W / 300 Mbits

detector

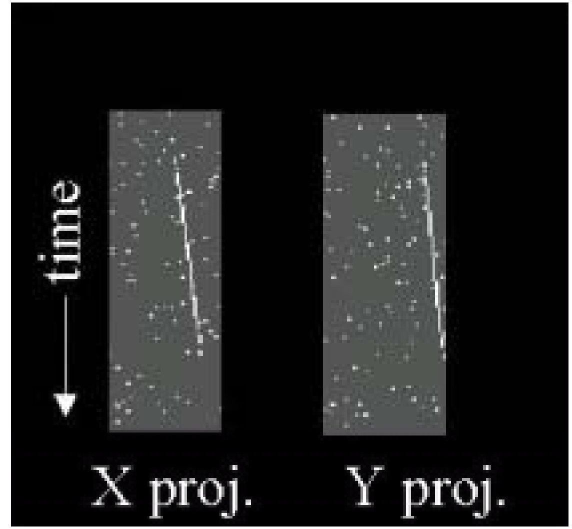
R7600-M64

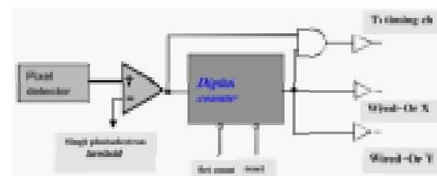
250 kg / 250W

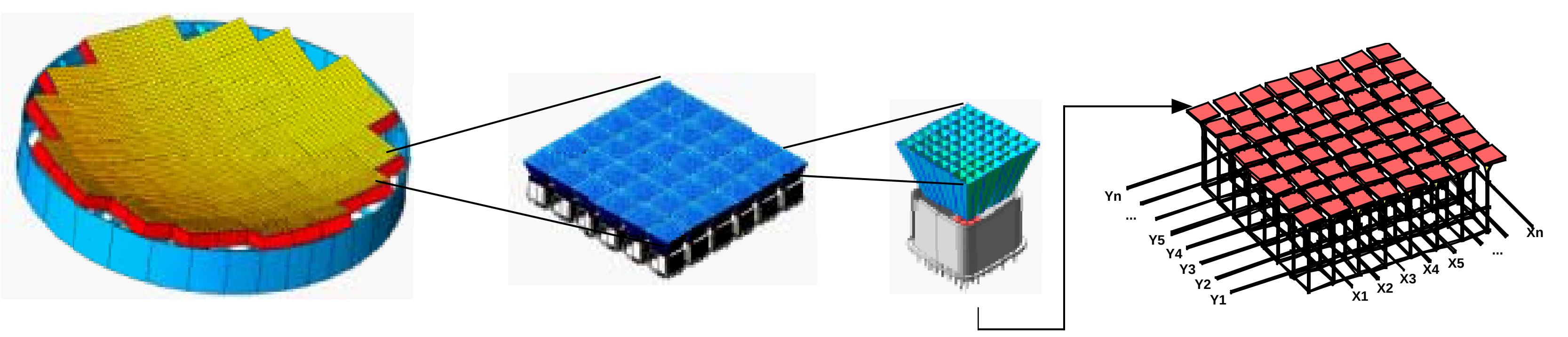
optics

f/# = 1.15

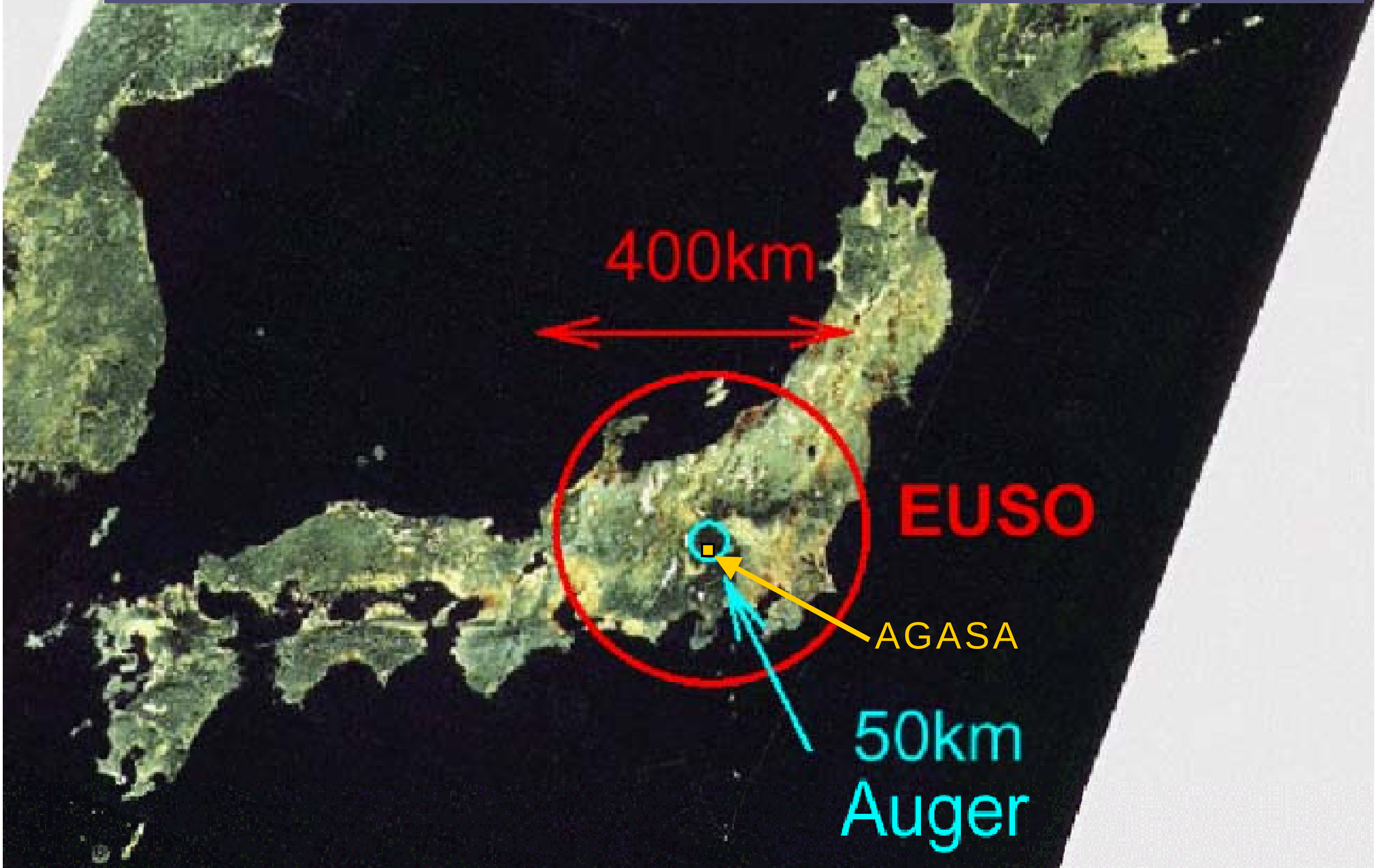
100-200 kg

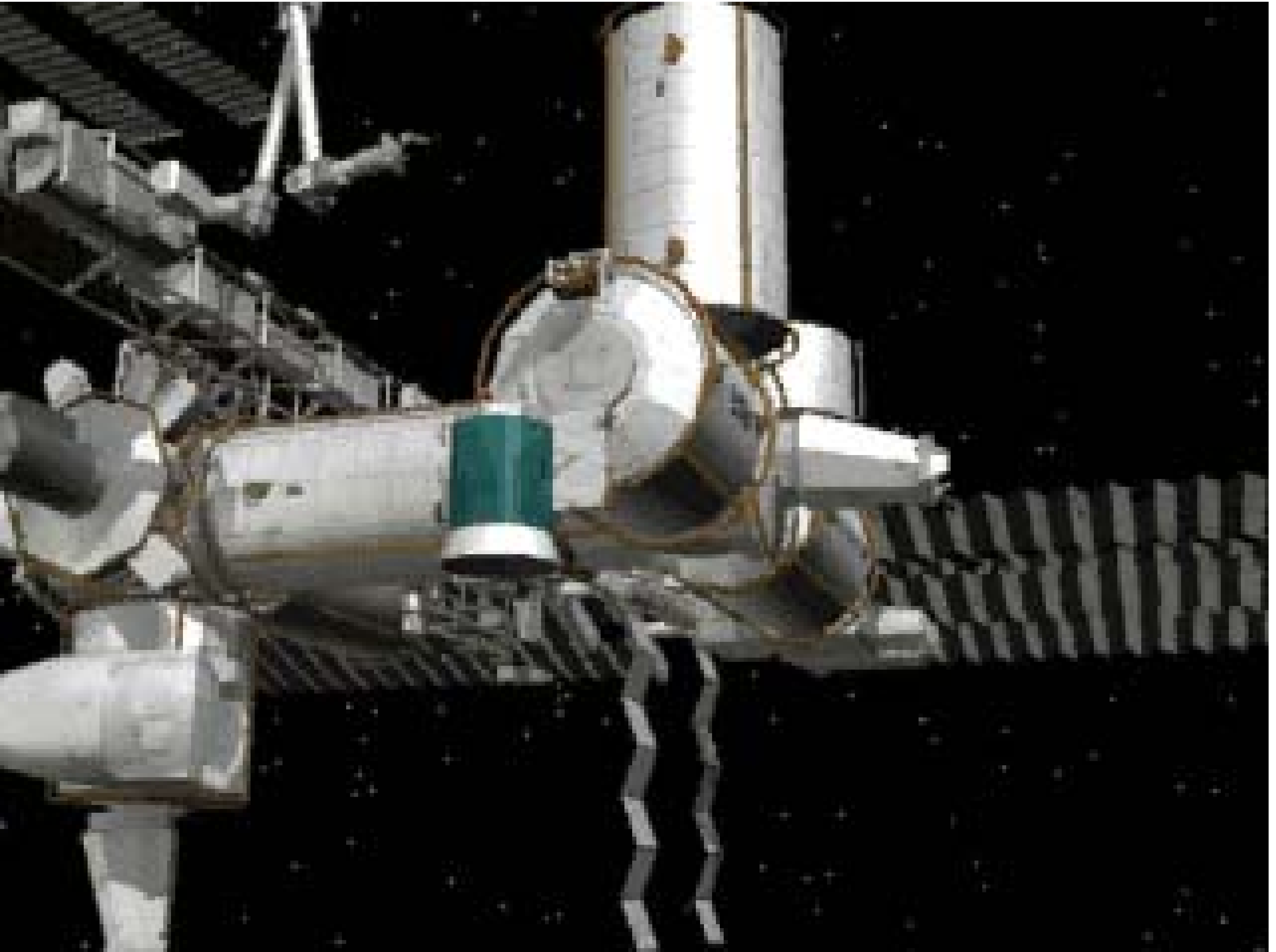






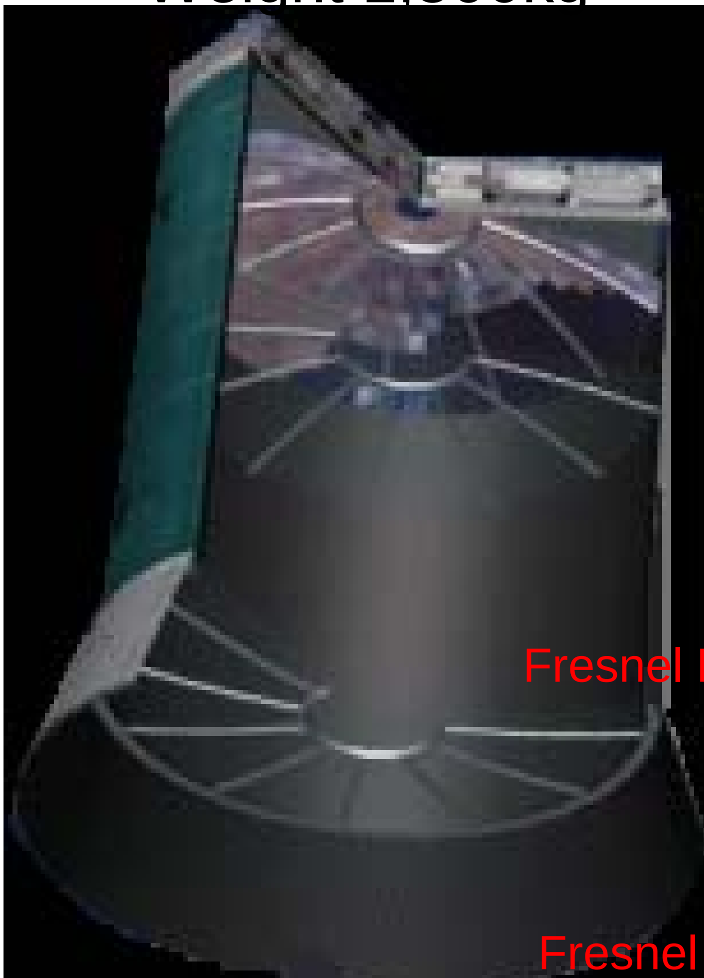
EUSO ~ 300 x AGASA ~ 10 x Auger
EUSO (Instantaneous) ~3000 x AGASA ~ 100 x Auger

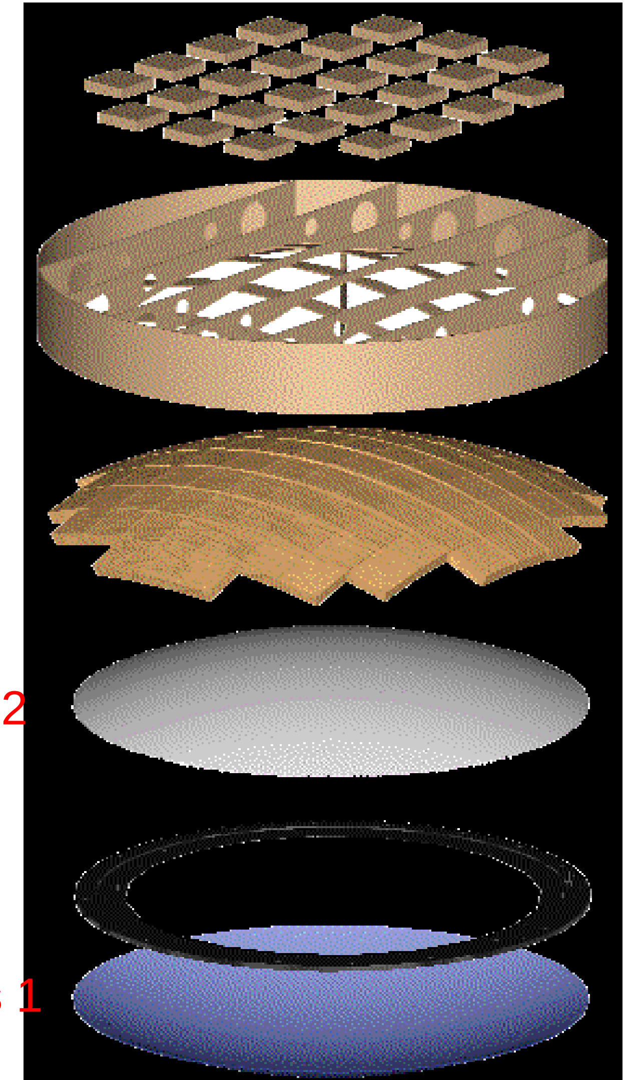




Detector Element

Weight 1,500kg





Electronics

Focal Surface
Support Structu

Focal Surfac

Entrance
pupil

役割分担

- 光学系　アメリカ
- 焦点面検出器　日本
- アナログ回路系　フランス
- デジタル回路系　イタリア
- トリガー回路系　イタリア
- システム構築　業者
  - PhaseAはイタリアのAlenia
- データセンター　ポルトガル
- シミュレーション　イタリア (代表)
- データ解析・outreach　イタリア (代表)

EUSO Consortium

Participant Nations and Institutions

France
- APC (Paris)
- LAPP (Annecy)
- ISN (Grenoble)
- ODP (Paris)
- CESR (Toulouse)
- LPTHE (Paris)
- IAP (Paris)
- LAPTH (Annecy)
- DASE
- SA

Italy
- IASF CNR
- ISAO CNR
- INFN Genova
- INFN Catania
- INFN Trieste
- INFN Torino
- INFN Firenze
- University of Genoa
- University of Palermo
- University of Roma
- University of Torino
- University of Firenze
- University of Trieste
- Osservatorio Arcetri
- Osservatorio Catania
- CARSO
- INOA

Japan
- Riken
- ICRR
- Konan University
- ISAS
- Rikkyo
- NASDA
- KEK
- NAO
- University of Tokyo
- Saytama
- Aoyama
- Kinki
- Seikei
- Kanazawa

Portugal
- LIP

USA
- NASA MSFC, NSSTC
- University of Alabama Huntsville
- UCLA
- Vanderbilt
- University of California Berkeley
- University of Texas, Austin

UK
- University Of Leeds

Germany
- MPIFR Bonn

各国の状況

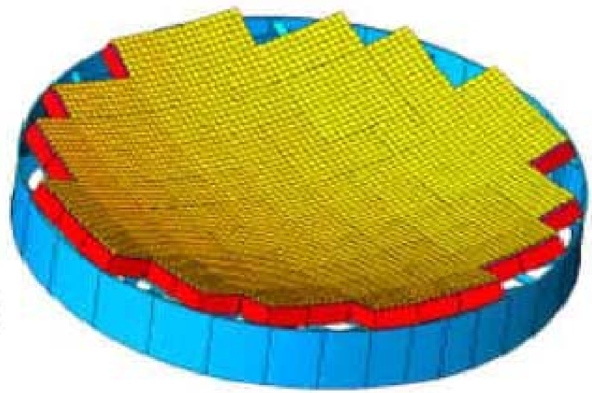
- ESA：Phase-A Study
  - 2002.3~2003.6
- NASA:MIDEX Mission for Opotunities
  - 採択：42件中唯一つ
- NASDA/JSF：地上公募研究
  - 採択：重点研究として
  - 日本におけるPhase-A研究として定義

Focal Surface Detector
Baseline design

THE FOCAL SURFACE DETECTOR
HIERARCHICAL VIEW

Focal surface detector

(89 macrocells = 205056 pixels)



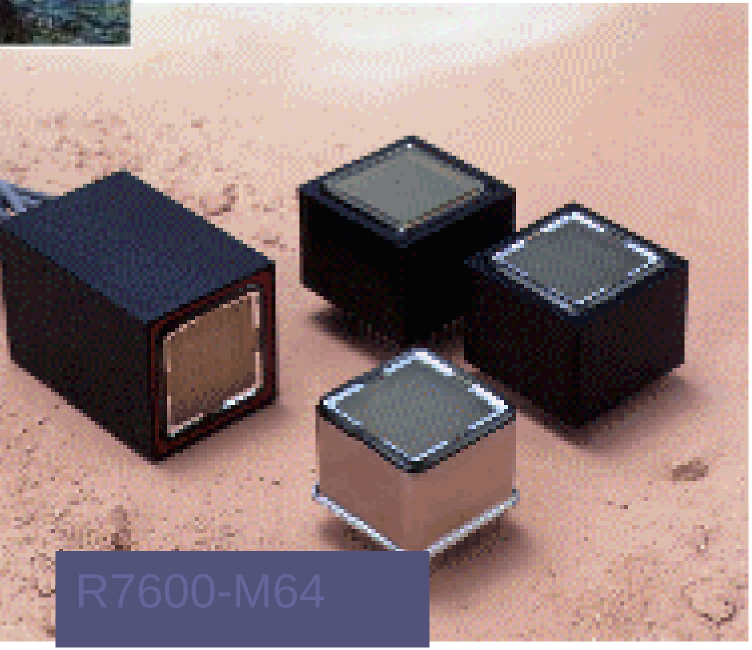
Macrocell

(6x6 basic units = 2304 pixels)

Basic unit

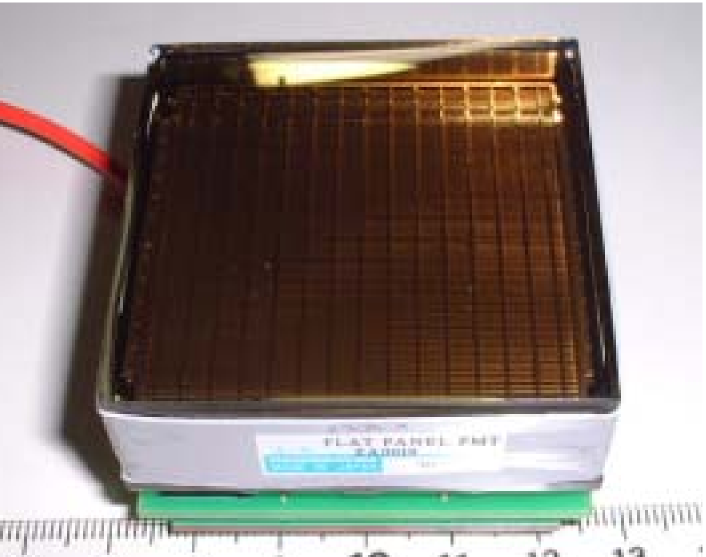
(8x8 pixels)

Multianode Photomultipliers



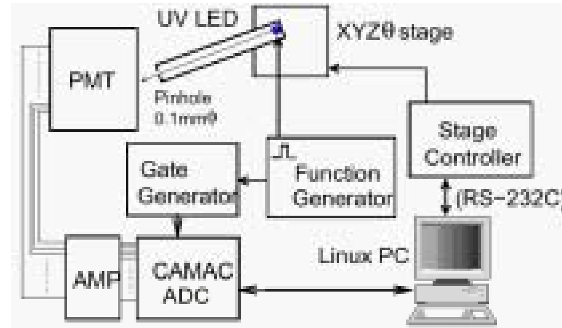
R7600-M64

New Development by RIKEN Group
Higher Photon Collection efficiency
R8900-M16/M25/M36 (45% → 85%)

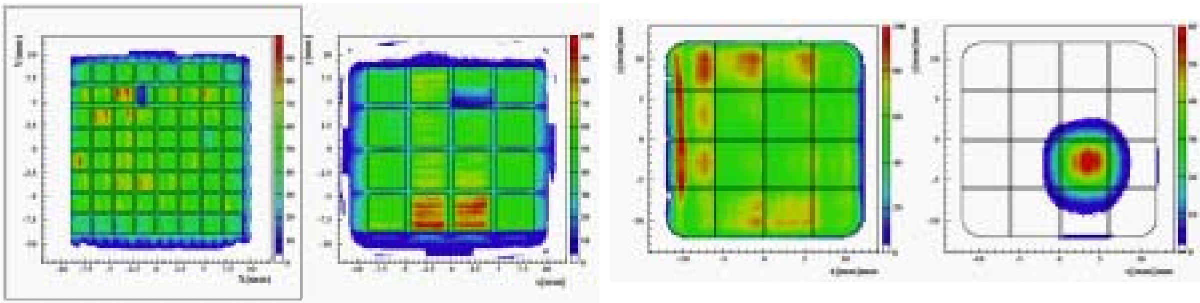


Flat Panel MAPMT
R8400-M64 (89%)

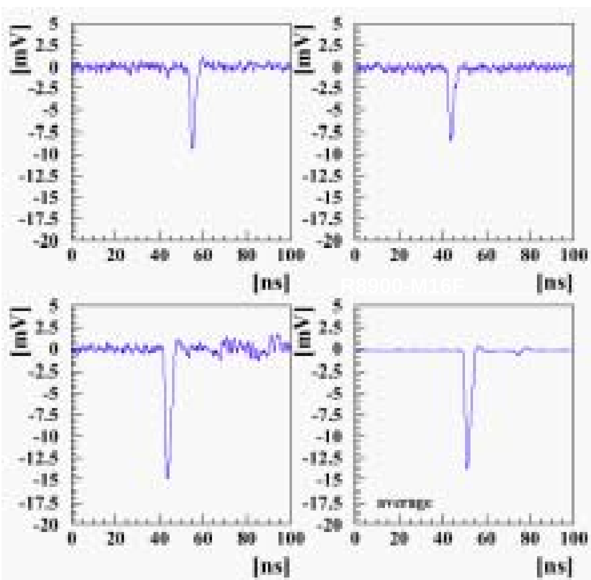
R8900-M16



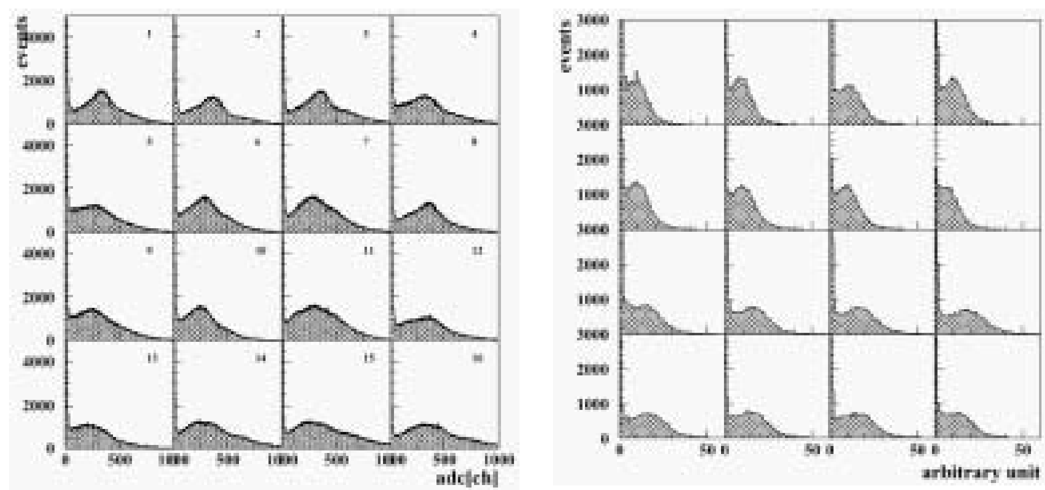
Gain Map



Pulse Shape

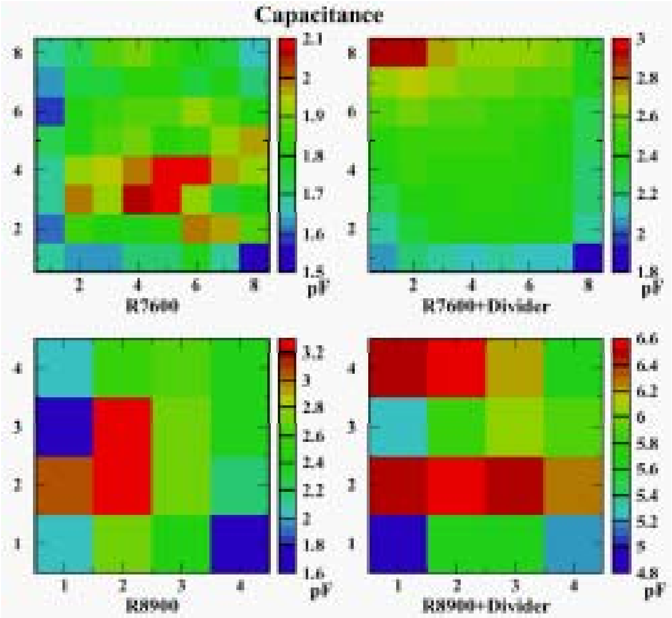


Pulse Height Distribution - Single Photoelectron Peak Separation



R8900-M16

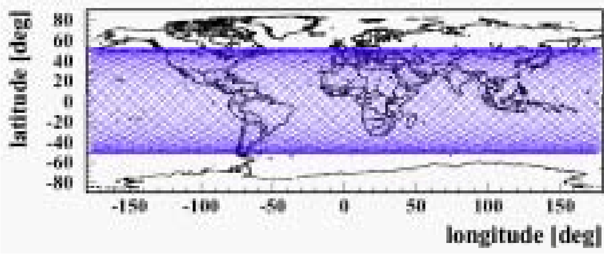
Capacitance (between Anode Pins and the Package)



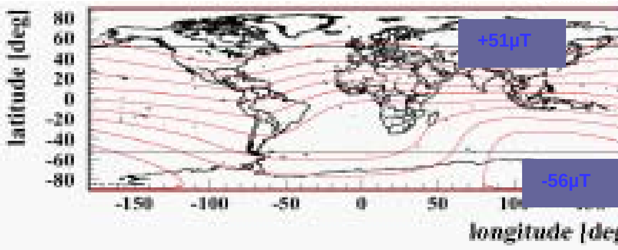
R5900-M64
1.82pF (σ=0.13pF)

R8900-M16F
2.50pF (σ=0.46pF)

ISS orbit (2002/04/01-2002/04/05)

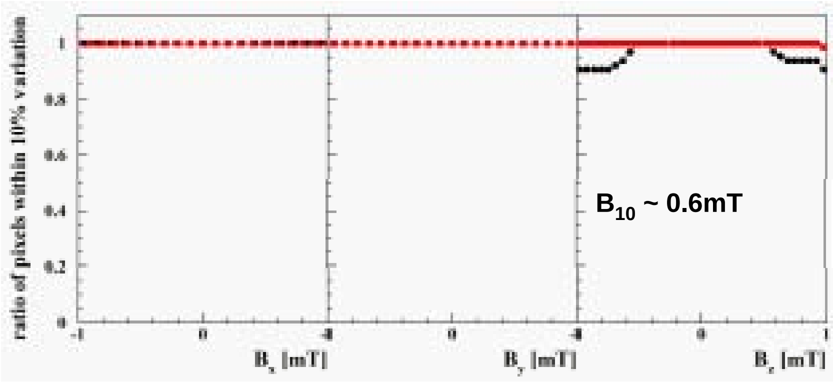


Vertical Component of Geomagnetic Field

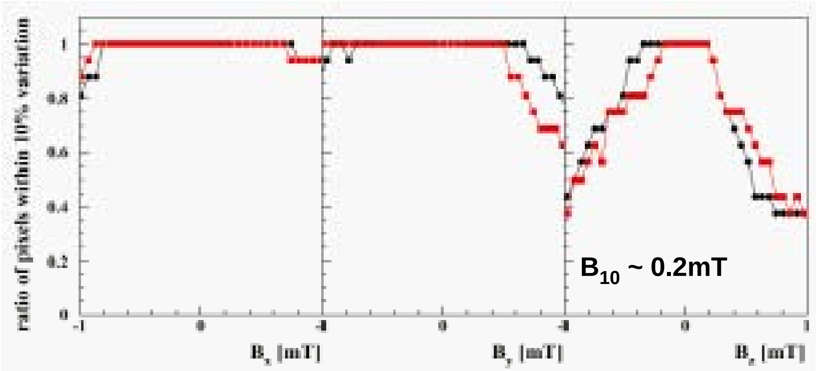


Influence of External Magnetic Field

R5900-M64 (2 samples)



R8900-M16F (2 samples)

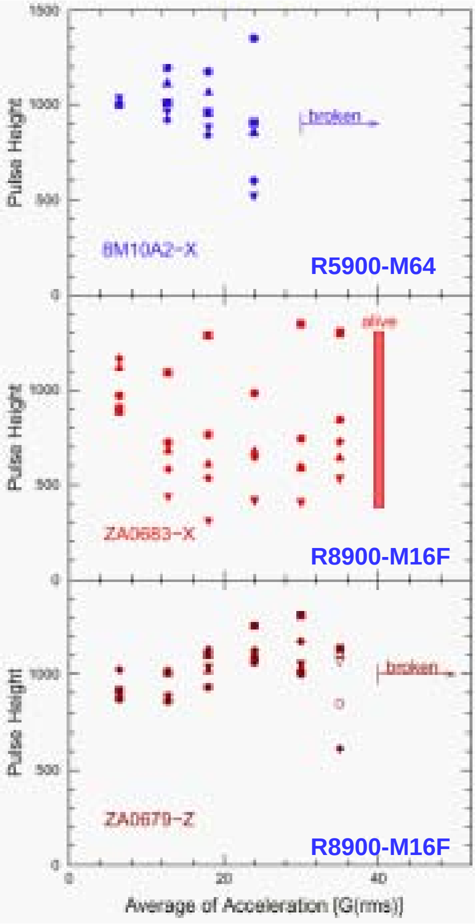


B_{10} : maximum field in which the gain of all pixels stays within 10% variation

Environmentals (system engineering) (R8900-M16)

Robustness against Mechanical Shock and Vibration

2min.



Temperature Range

R5900, R7600, R8520, R8900 series Multianode Photomultipliers

Best S/N-ratio at 0°C
((25±3)°C usually recommended on ground)
(ΔQ.E./Q.E.)/(ΔT) ~ - 0.4%/°C
Operating Temperature
min = - 30°C max = + 50°C
Non-operating Temperature
min = - 80°C max = + 50°C

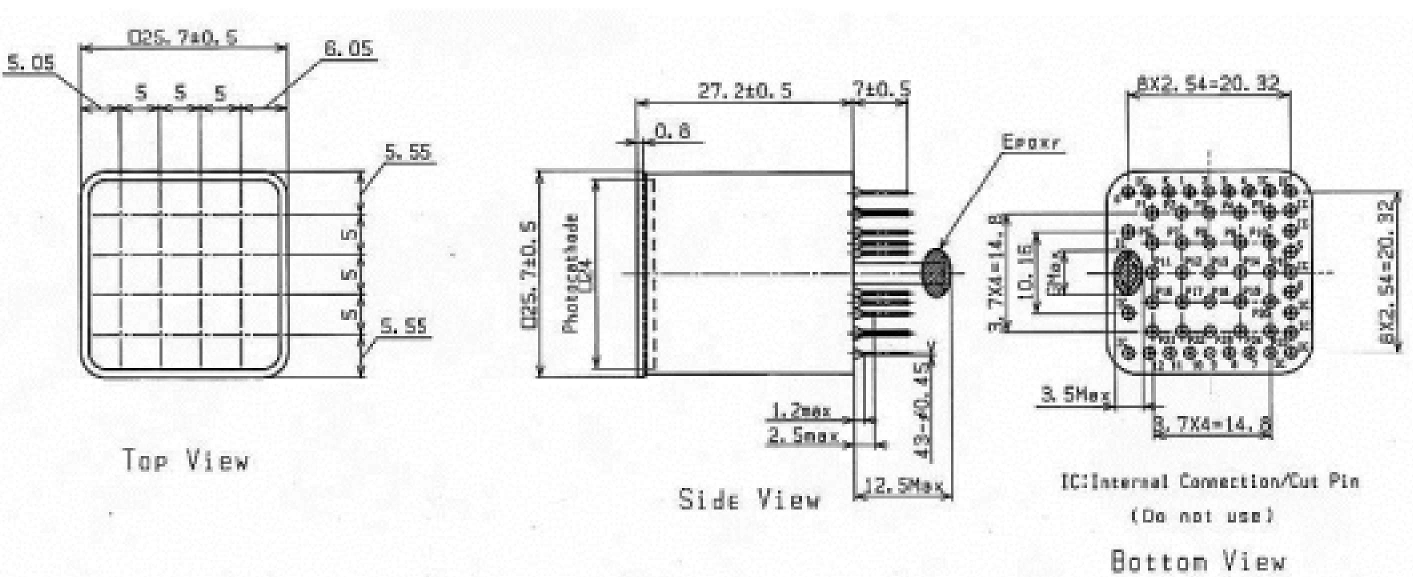
(0±10)°C during observation

Radiator + Heat Pipes

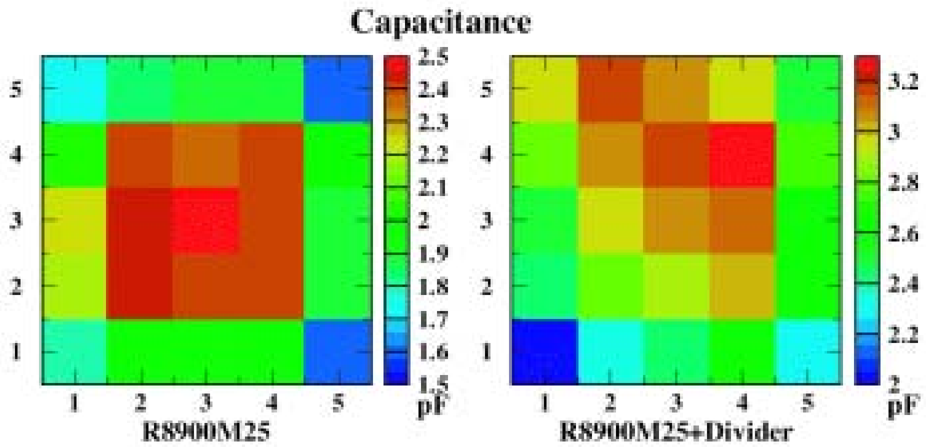
Damage from Radiation and Chamical Environment

Ageing

R8900-M25



Capacitance



Ref. EUSO-J Doc. #11
http://euso.riken.go.jp/protect/report/2002/eusoj011.pdf

R8900-M25

Gain Map

Individual Anodes

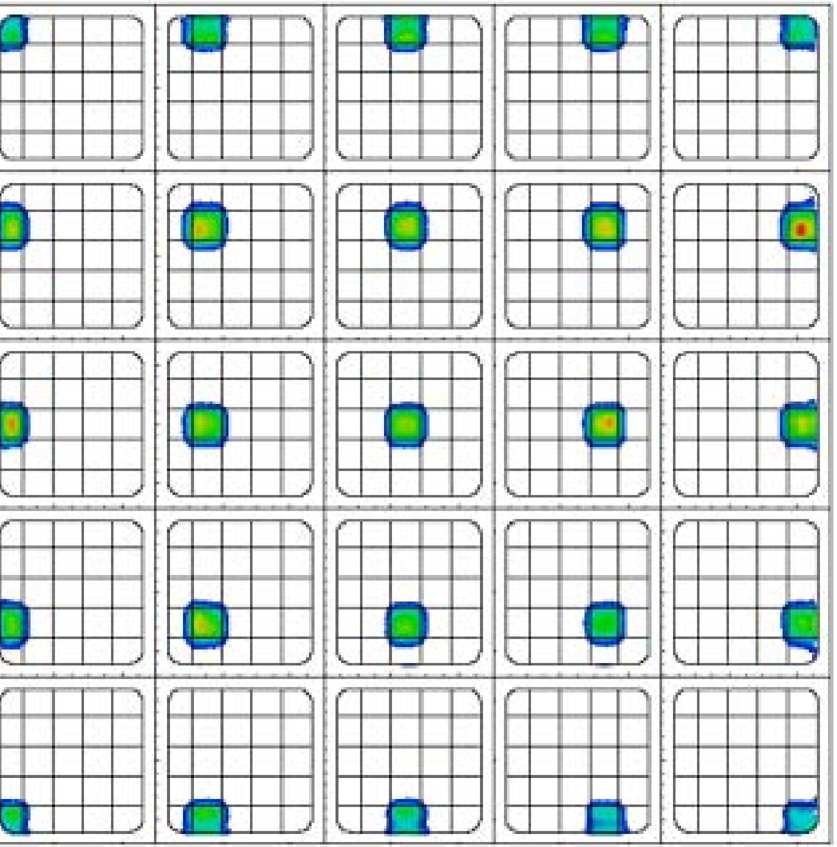
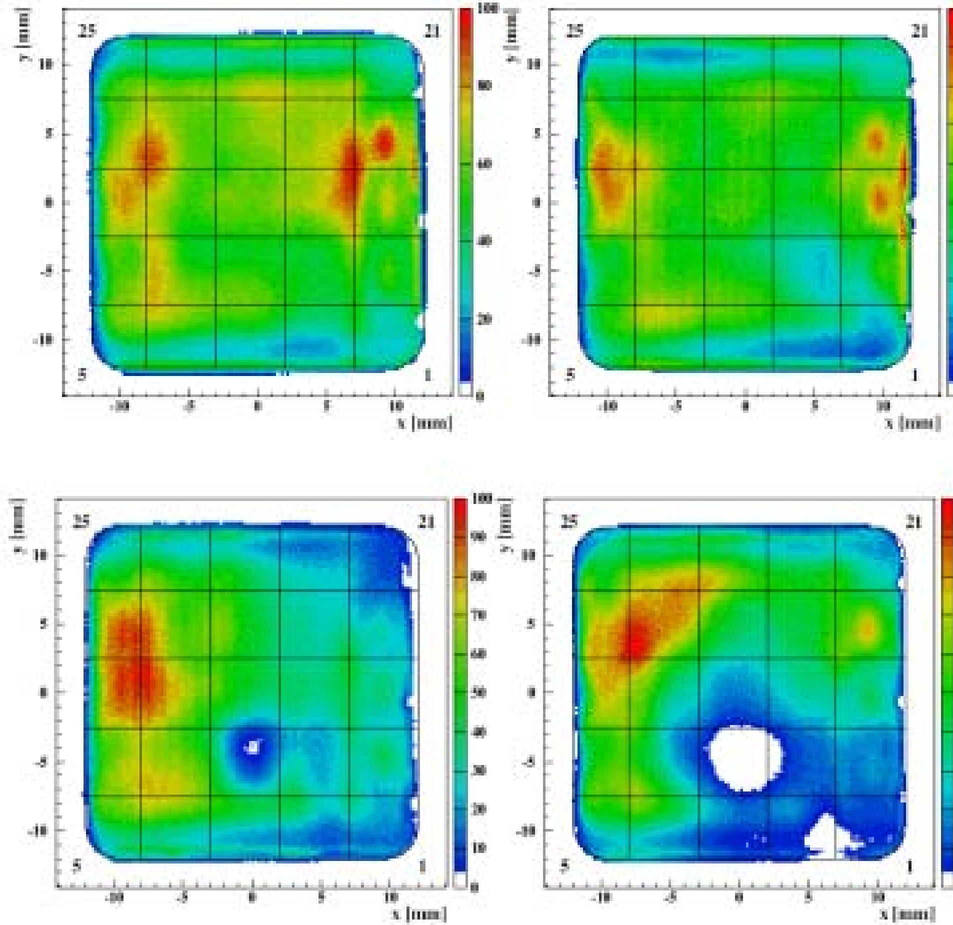


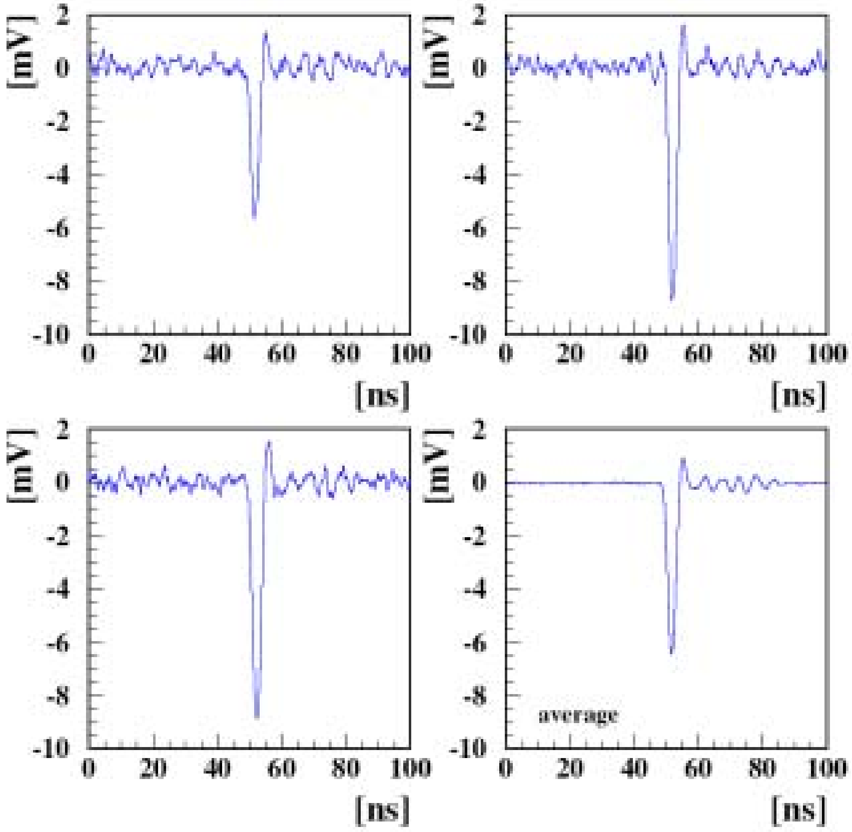
Fig. 3. Sensitivity map of each pixel. The PMT is the upper left one in Fig. 2 (ZA0901).

Sum



R8900-M25

Pulse Shape



pulse height	~6.4mV
rise time (10% → 90%)	~2ns
fall time (90% → 10%)	~2ns
width (FWHM)	~3ns

R8900-M25

Vibration Test

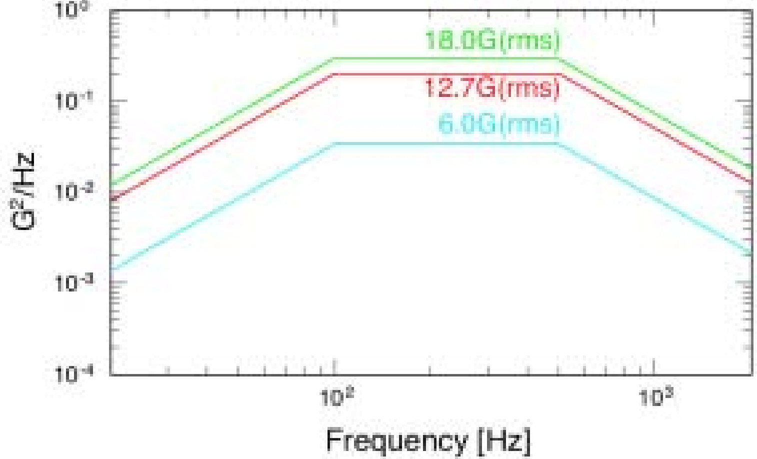
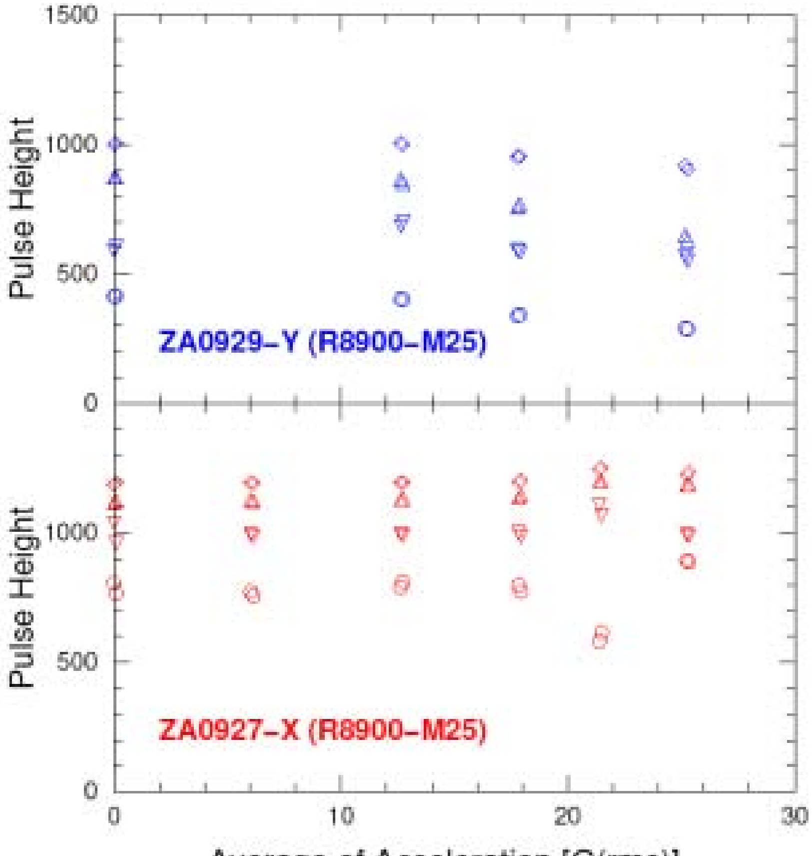
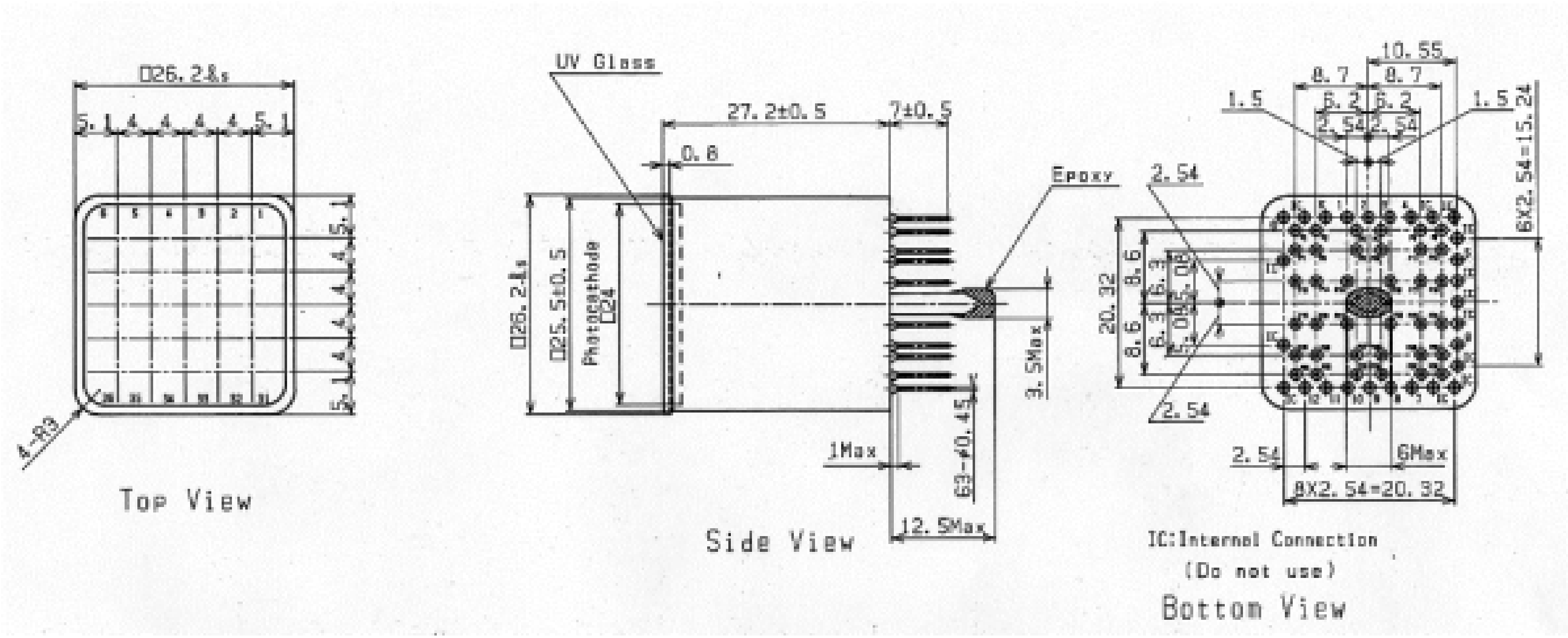


Fig. 9. MAPMT R8900-M25 attached to the vibration generat



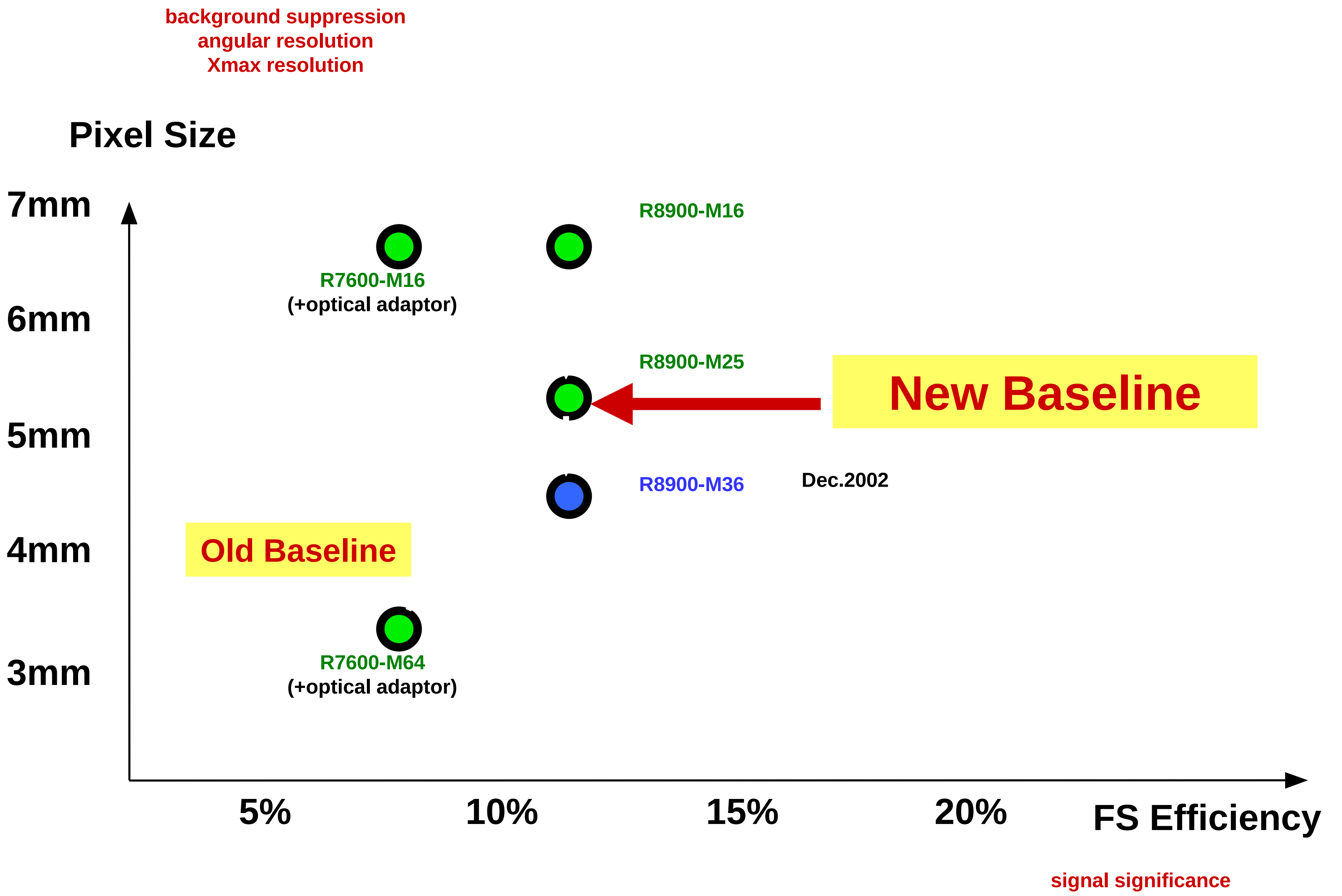
OK
up to 25 g

R8900-M36



coming up in Dec. 2002

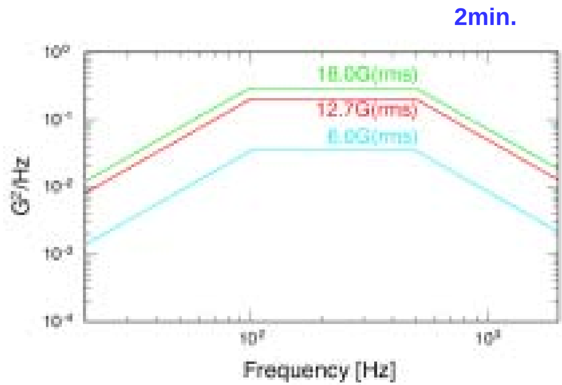
Multianode Photomultipliers for EUSO



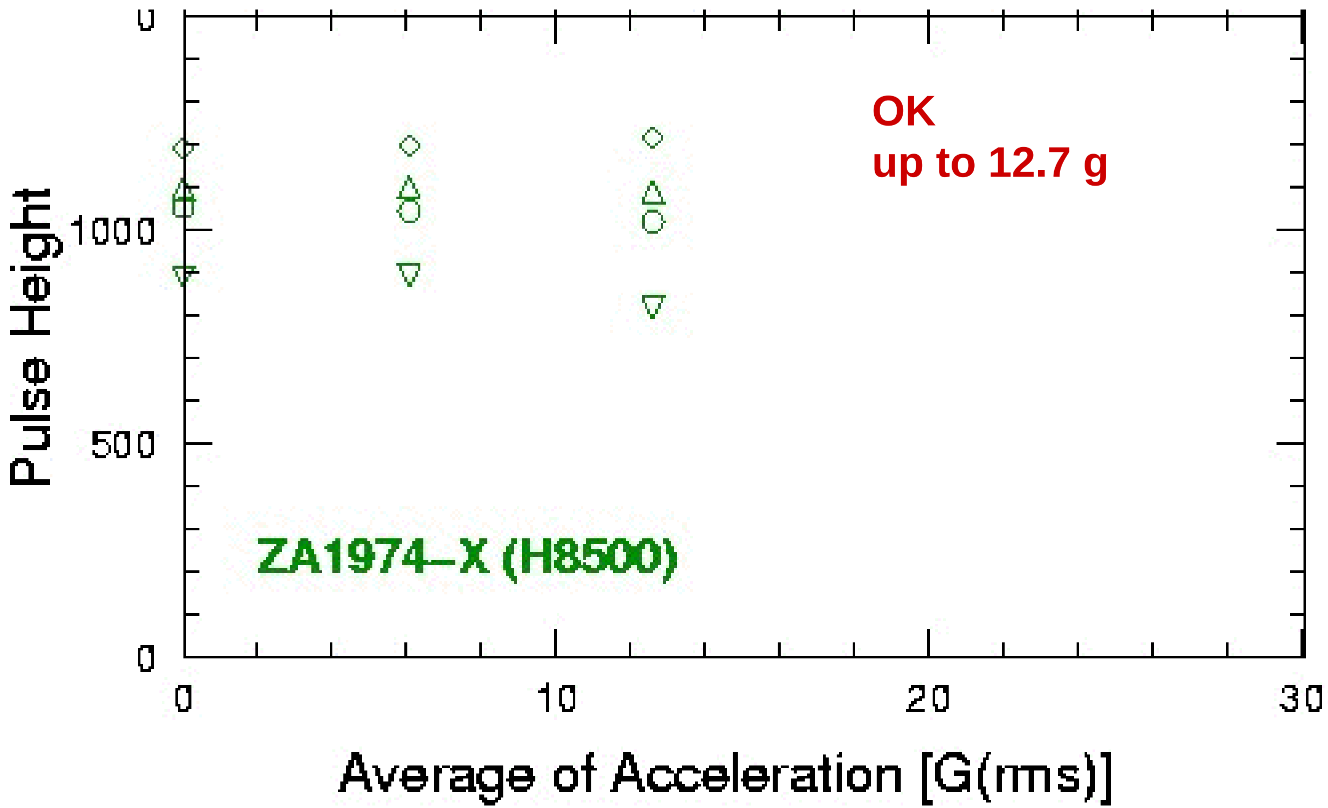
R8400-M64

(evaluation pieces / non-vibration robust)

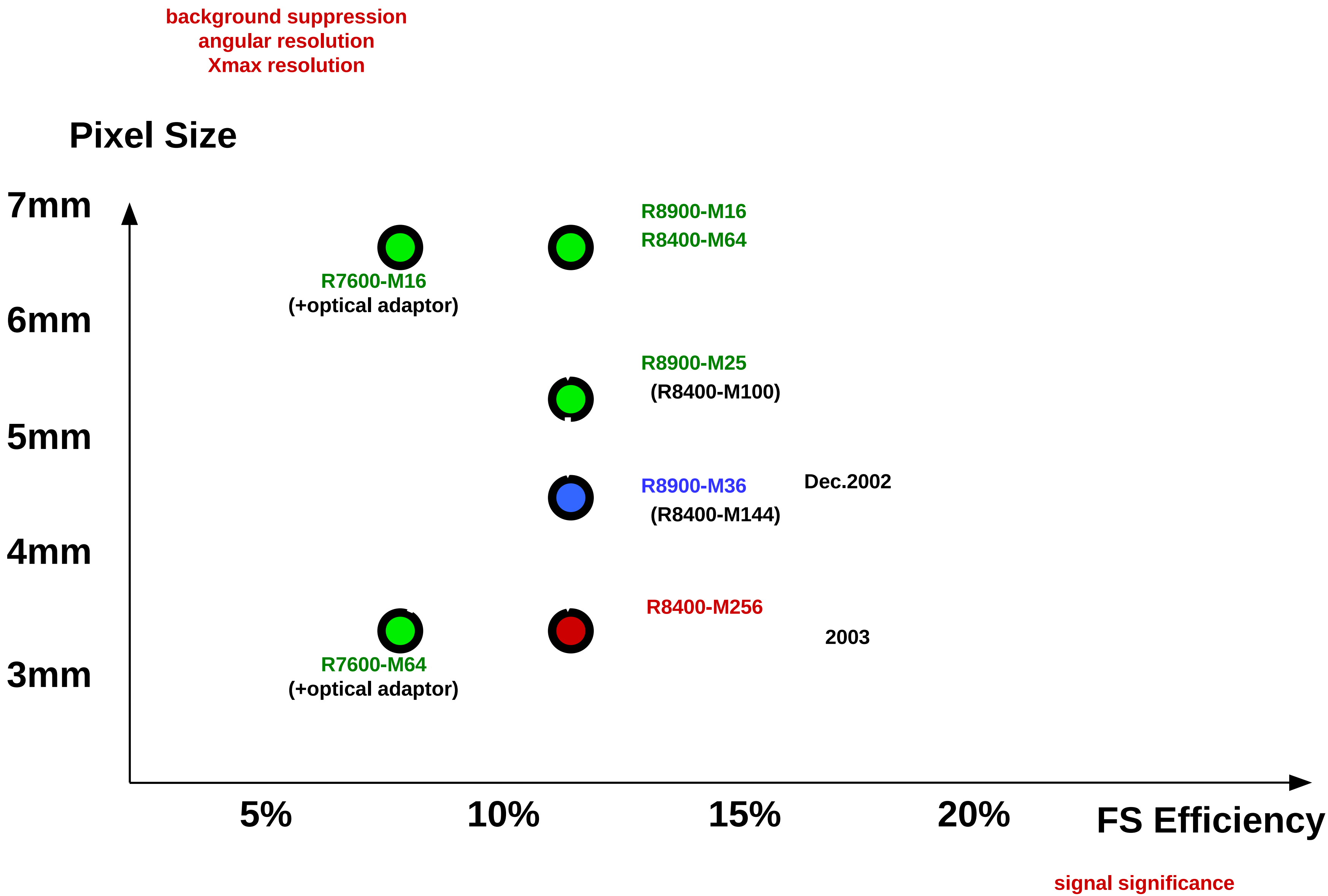
Vibration Test



Assembled Set of R8400 = H8500



Multianode Photomultipliers for EUSO



EUSO Japan

21 Institutes, 48 scientists

Riken: T.Ebisuzaki, K.Kawai, Y.Kawasaki, W.Lin, M.Miysaka, S.Morita, Y. Moriyasu, H.Ohmori, C.Otani, N.Sakaki, H.M.Shimizu, M.Takeda, T.Suzuki, Y.Takizawa, Y.Uehara, Y.Ueno

ICRR U.Tokyo: M.Teshima, N.Hayashida, K.Shinozaki, K. Mase

KEK: J.Fujimoto, T.Ishikawa, T.Kaneko, Y.Kurihara, Y. Shimizu

NAO: T.Kajino, Y.Mizumoto

Fukui-Tech: M. Nagano, Y. Miyazaki

Saitama Univ.: N.Inoue, Y. Fukushima

Ehime: H. Yoshii, S. Mizobuchi

Chiba Univ.: S.Yoshida

Shinshu Univ.: T.Kifune

Rikkyo Univ.: S.Kitamoto

Kinki: M.Chikawa

Konan: H.Sato

Yamanashi: H.Sato

Osaka City: S. Kawasaki

Kanazawa: T.Murakami

Nara-Sangyo: A.Masaike

Aoyama: T.Shibata,A.Yoshida

Seikei T.Kon

JAERI-Kansai: T.Tajima

Mushashi-Tech.: K. Kadota

NIRS: Y. Uchihori

予算

- 科学研究費補助金･一般基盤研究(B)(2)
  - 衛星軌道からの最高エネルギー宇宙線観測のための焦点面検出器の基礎研究
    - 平成14年度　　13,600千円
    - 平成15年度　　1,500千円
- 日本宇宙フォーラム･地上研究の公募
  - 重点研究　EUSOの焦点面検出器の開発
    - 平成14年度　　7,518千円
    - 平成15年度　　7,959千円

予算とスケジュール

- 日本担当分予算：30億円弱
  - 焦点面検出器製作：　　　20億円
  - 衛星構造体／3：　　　　10億円
- スケジュール
  - デリバー：　2007年
  - 打ち上げ：　2009年以降
    - FIRST READY, FIRST GO

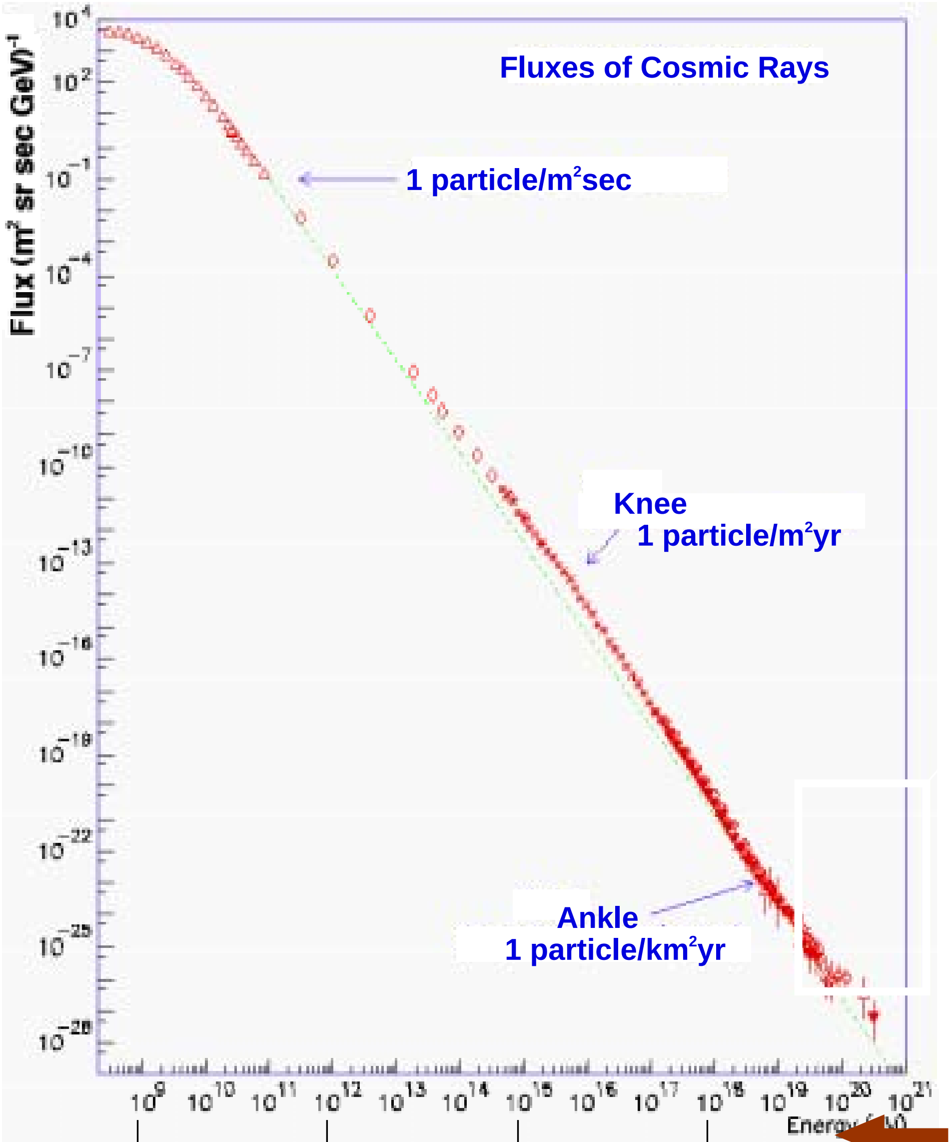
まとめ

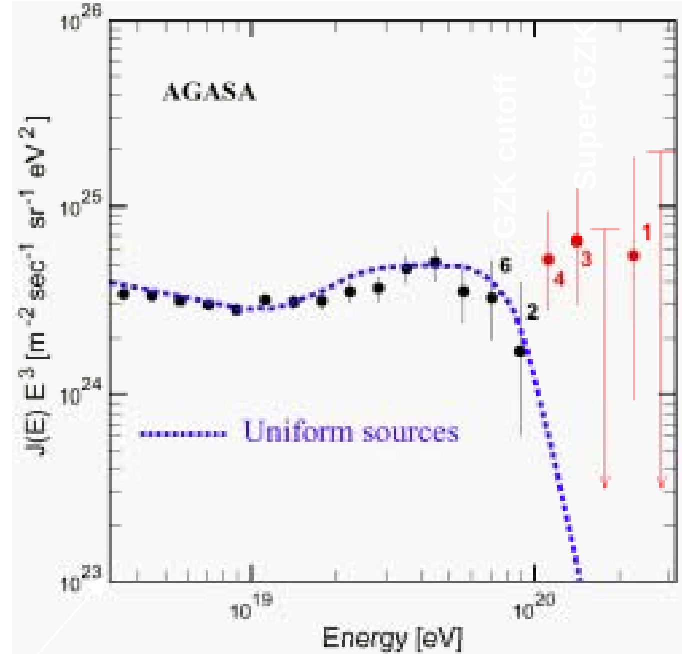
- 各国順調にPhase-A研究を実施中
- これまでに、大きな困難は発見されていない
- 日本において正式にPhase-A研究開始
  - JSF/NASDAの地上公募研究に採択
  - 検出器の開発は順調
- 国際ワークショップを開催
  - 2002年11月5日･6日
  - ProceedingsはUAPから出版予定
- 科研費特別推進研究に応募

提案

- 最高エネルギー宇宙線観測
  - ＧＺＫ-cutのあるなしに関わらず「豊穣な物理」
    - まだまだ続く
  - ＡＵＧＥＲ/新ＴＡの次は宇宙からのＥＵＳＯ方式
  - 日本としても一口噛んでおく必要（少なくとも）
  - ＡＧＡＳＡの実績を無駄にしない
- 地上から宇宙への一貫したシナリオ
  - 協力し、一緒に、楽しく物理を楽しみたい

Cosmic Ray Spectrum

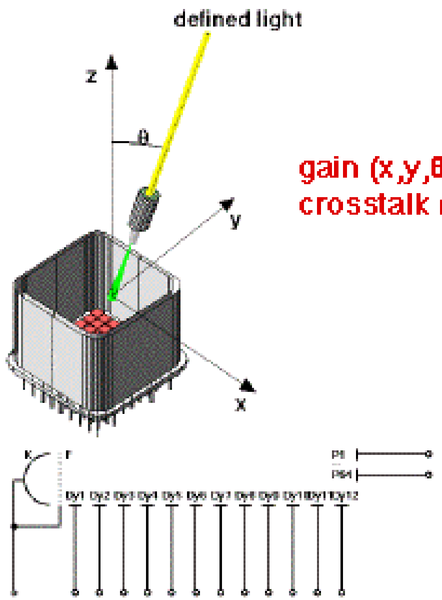




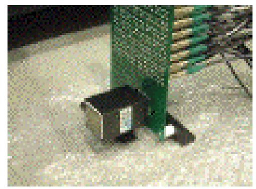
GeV TeV PeV EeV ZeV

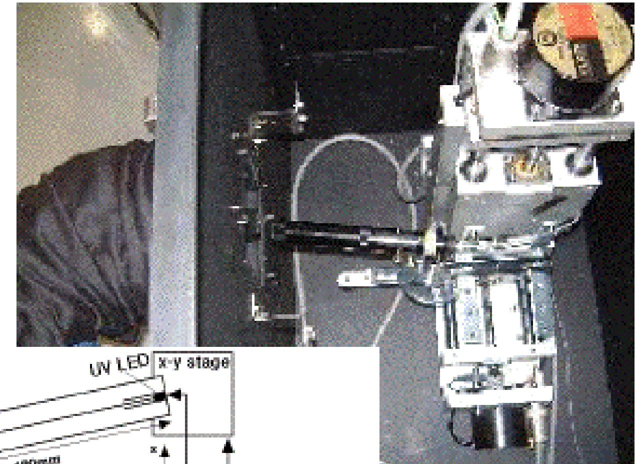
EUSO

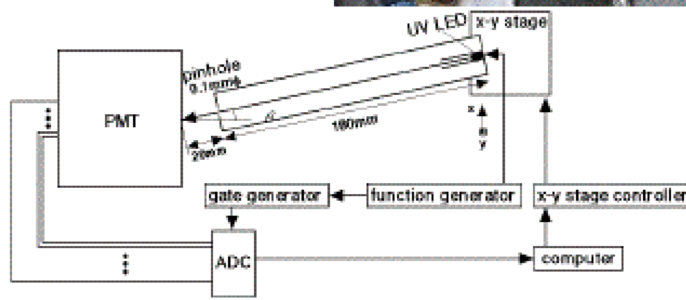
Photomultiplier Characterization

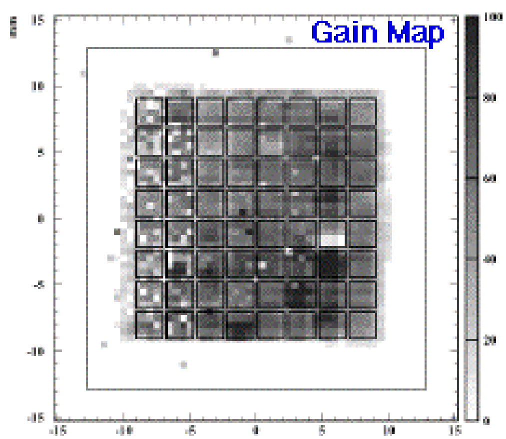


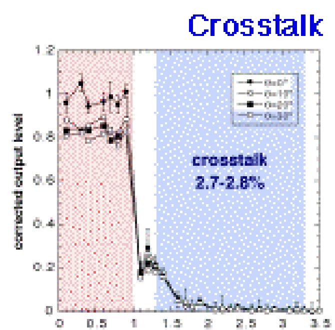
gain (x,y,θ,HV)
crosstalk (x,y,θ,HV)

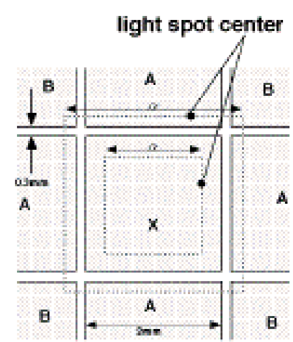






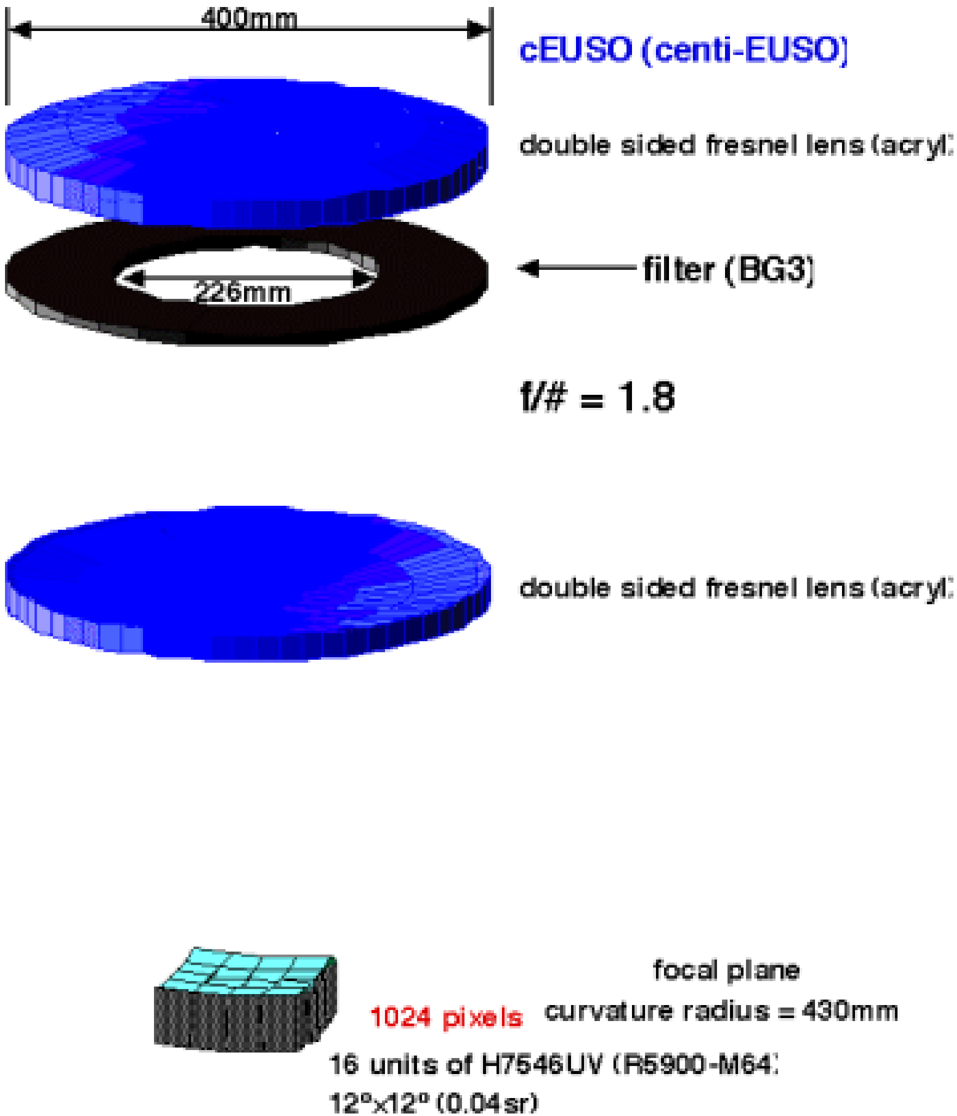




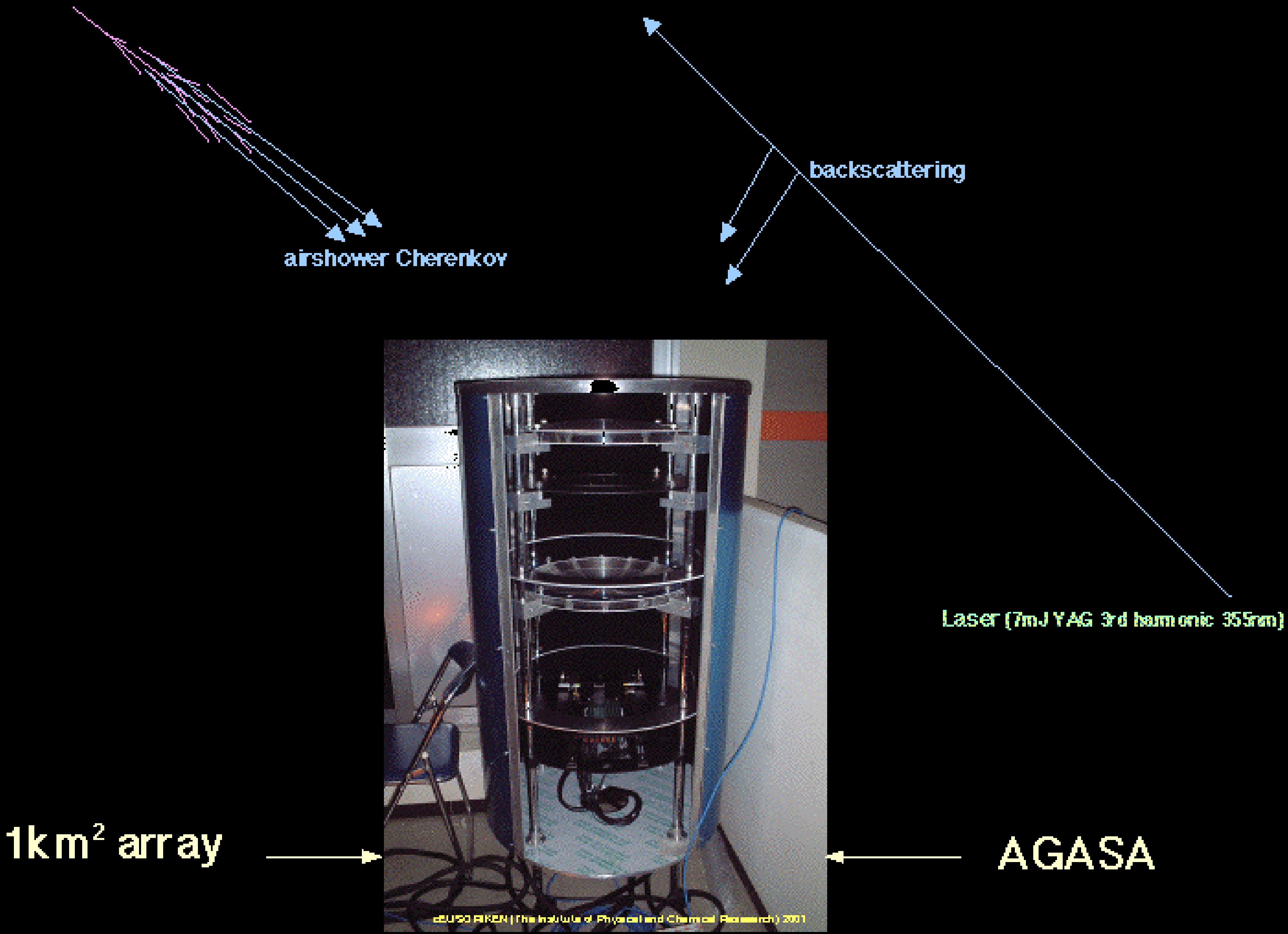


4.2-4.8% 1.2-1.5%

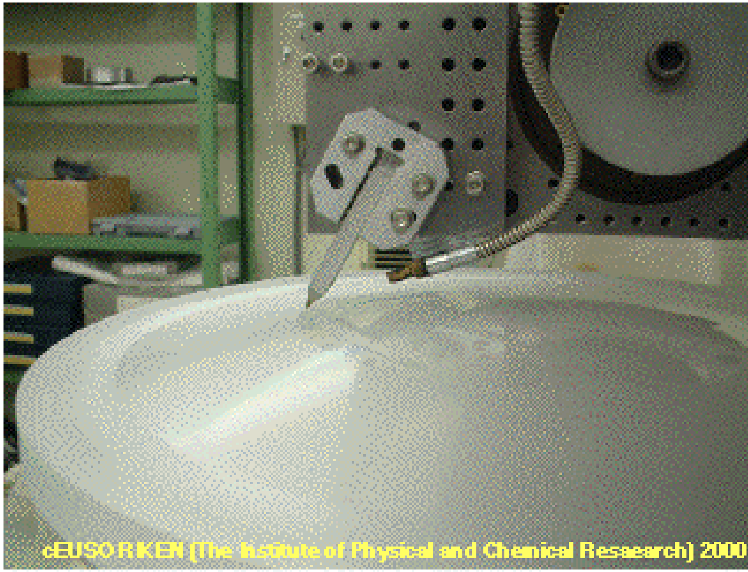
The First Small-scale Prototype for Characterization of Focal Plane Detector

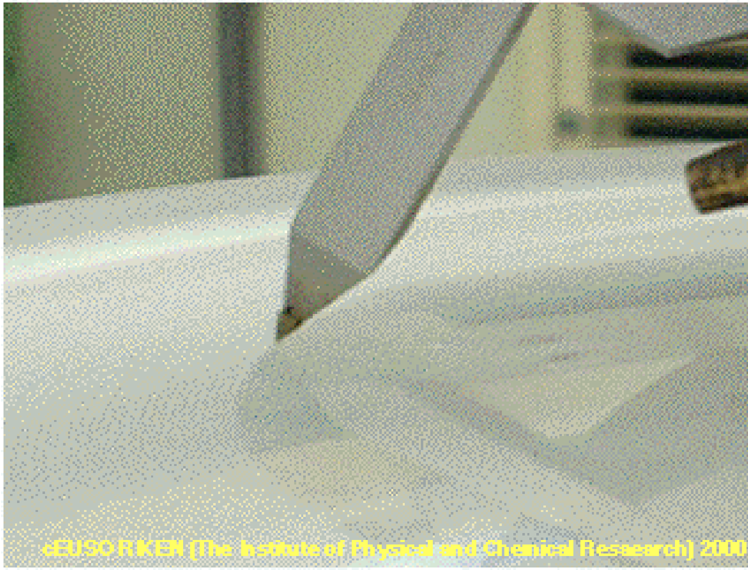


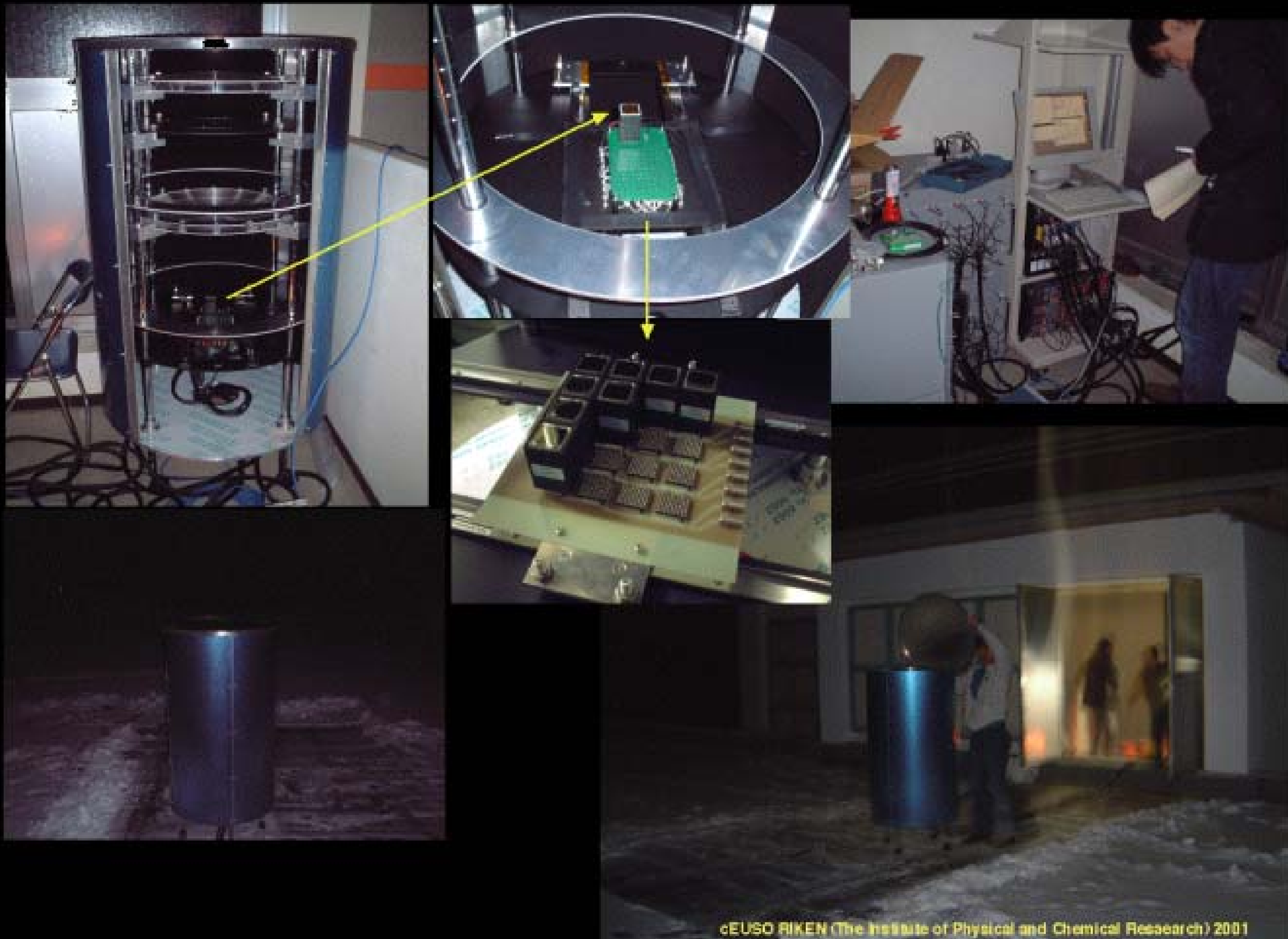
cEUSO at Akeno Cosmic Ray Observatory



cEUSO Lens Fabrication acryl



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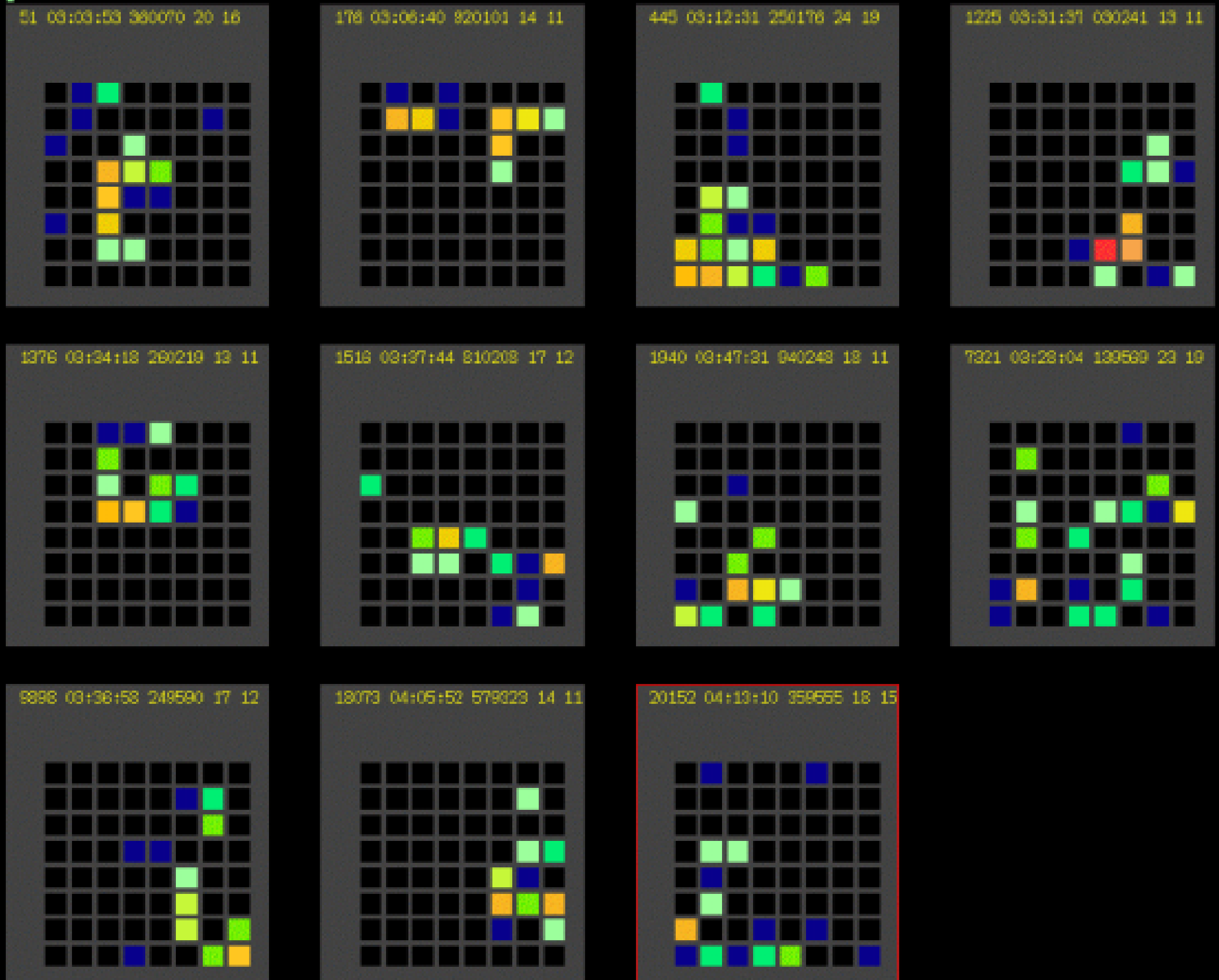
Sample Events obtained with cEUSO



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