Peripheral projects with Nuclear Emulsion

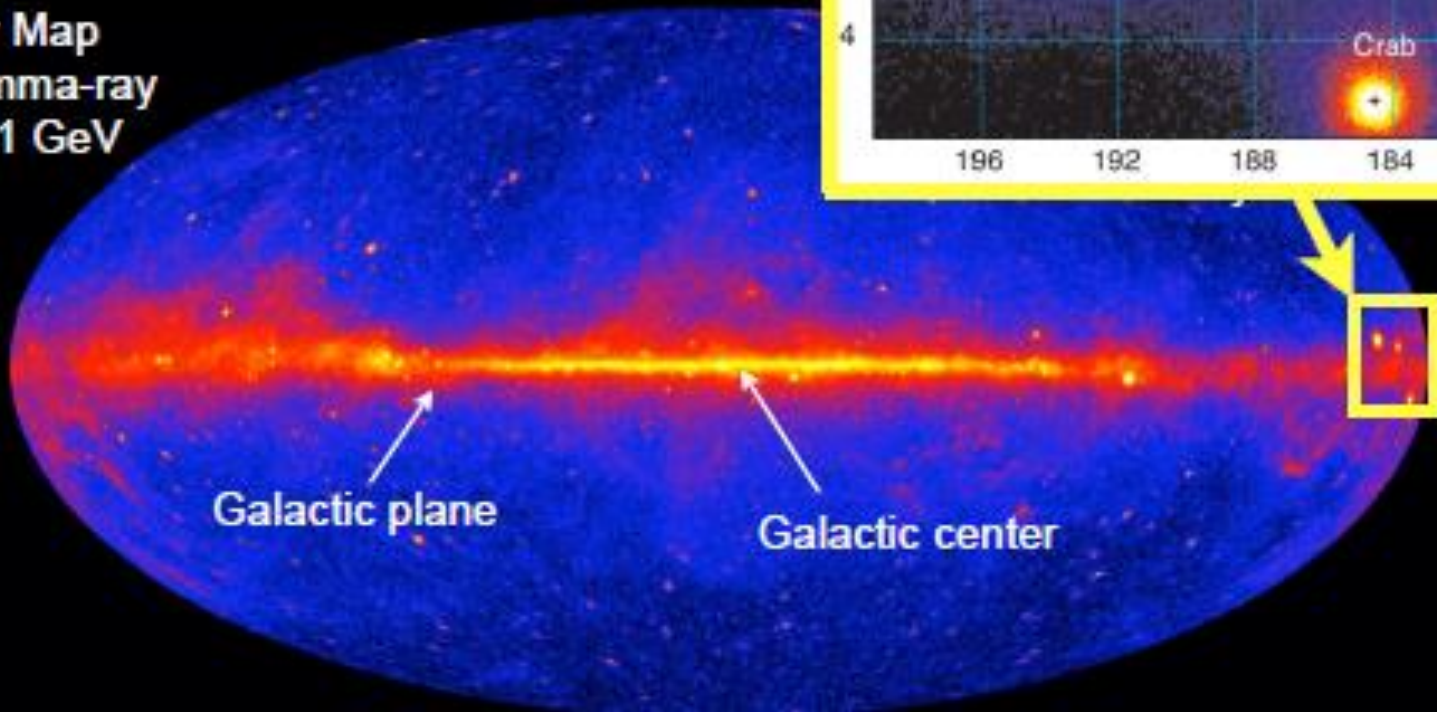
O.Sato Nagoya Univ
B02 group

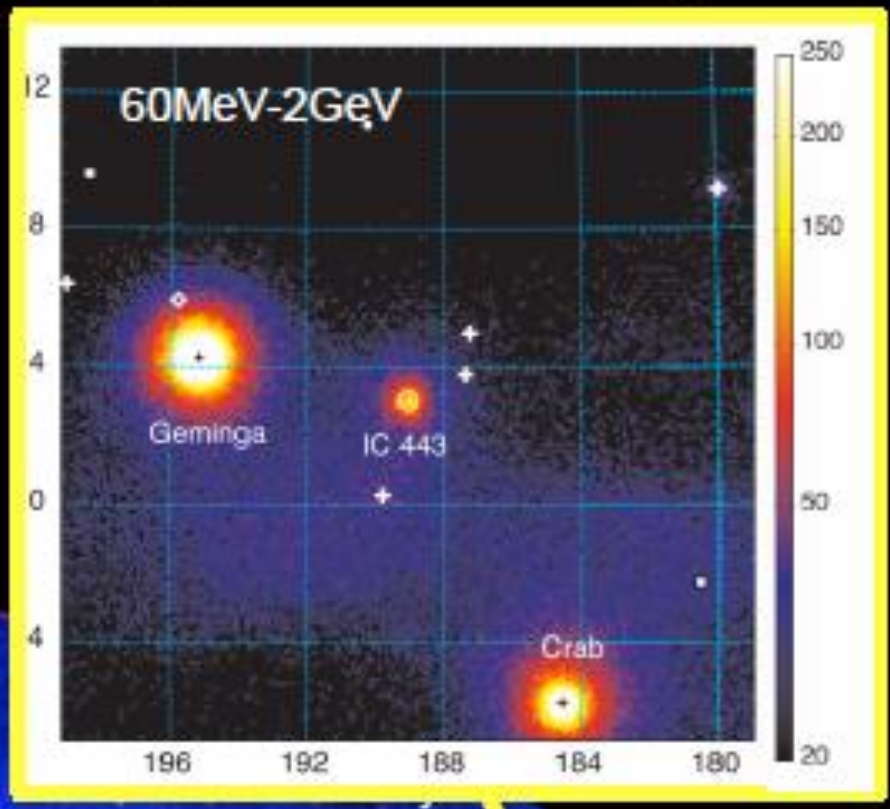
「ニュートリノで拓く素粒子と宇宙」
領域研究会2019

Gamma-ray Observation (GeV/sub-GeV region)

	Telescope	Detected sources
1990-2001	EGRET spark chamber	271
2008-	Fermi-LAT SSD tracker	>3000

All-Sky Map via gamma-ray above 1 GeV

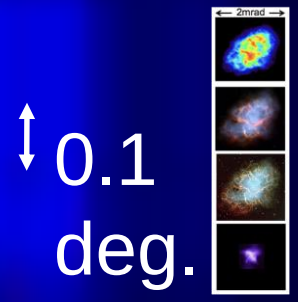




Resolution by gamma ray

gamma
1GeV
NEWEST DATA)

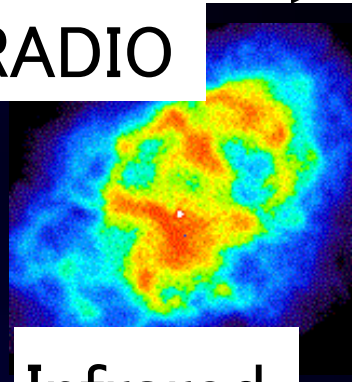
かに星雲
(M1:SN1054)



0.1
deg.

Similar size with moon

RADIO



Infrared

Visible ligh

X ray

Nuclear Emulsion

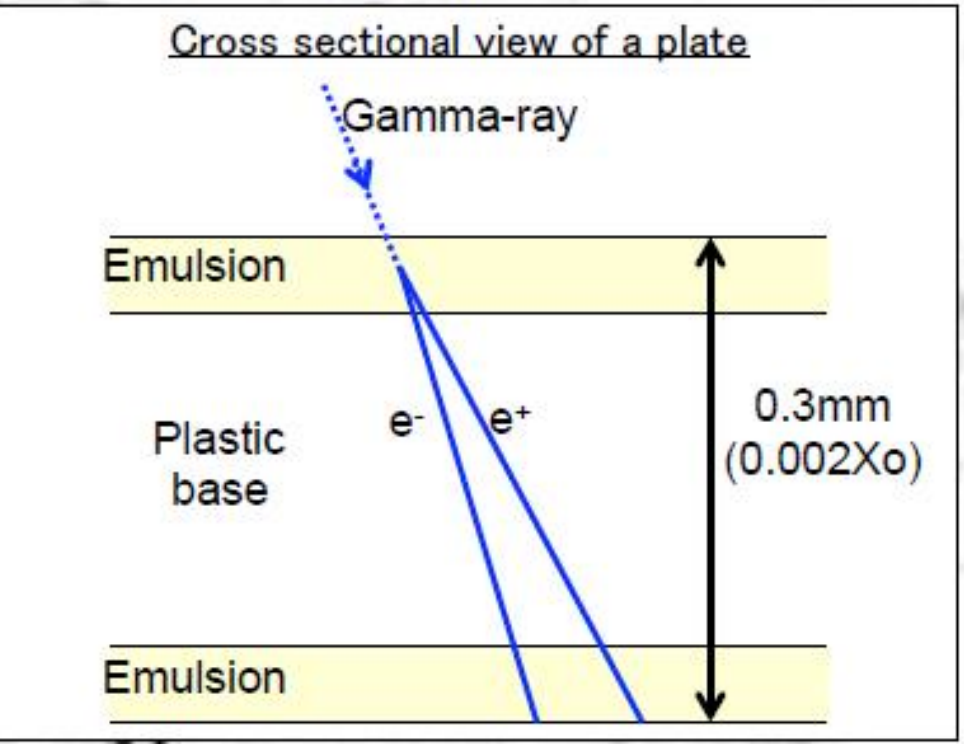
Microscopic view
10micron

Gamma-ray

$e^{+/-}$

$e^{-/+}$

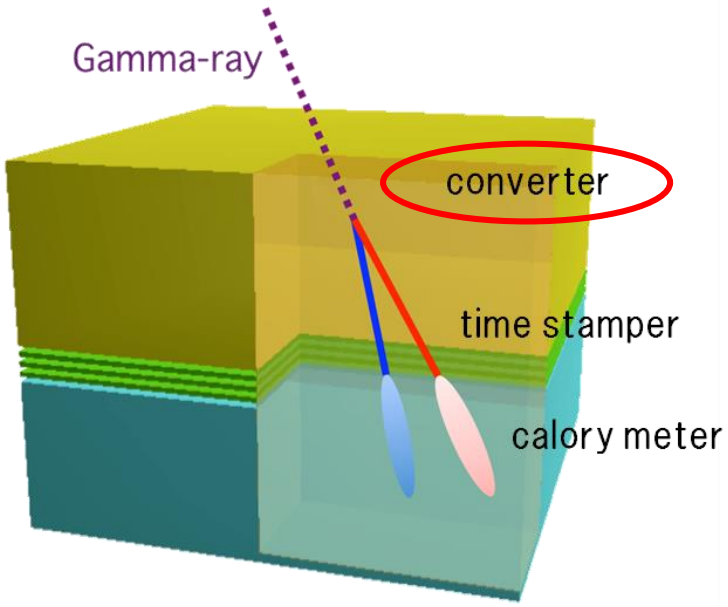
Cross sectional view of a plate



GRAINE Gamma-Ray Astro-Imager with Nuclear Emulsion

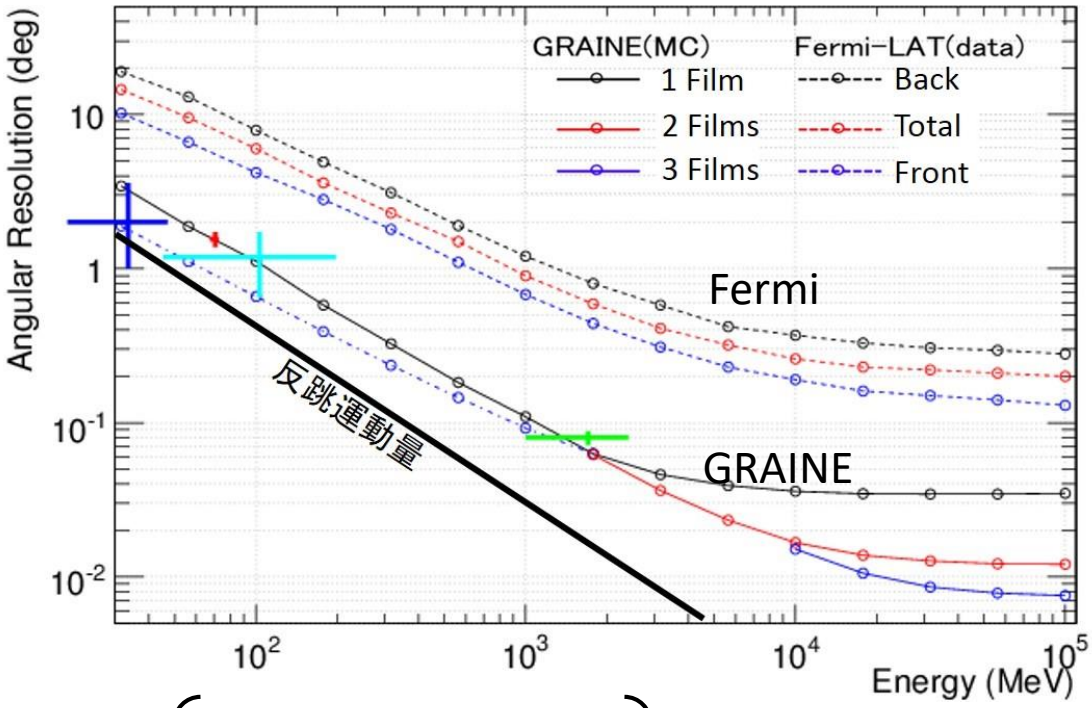
Target : 10MeV—100GeV γ-ray Balloon exp.

Emulsion γ ray telescope



The incident direction of the Converted electron pairs by Emulsion

Angular Resolution of Emulsion telescope

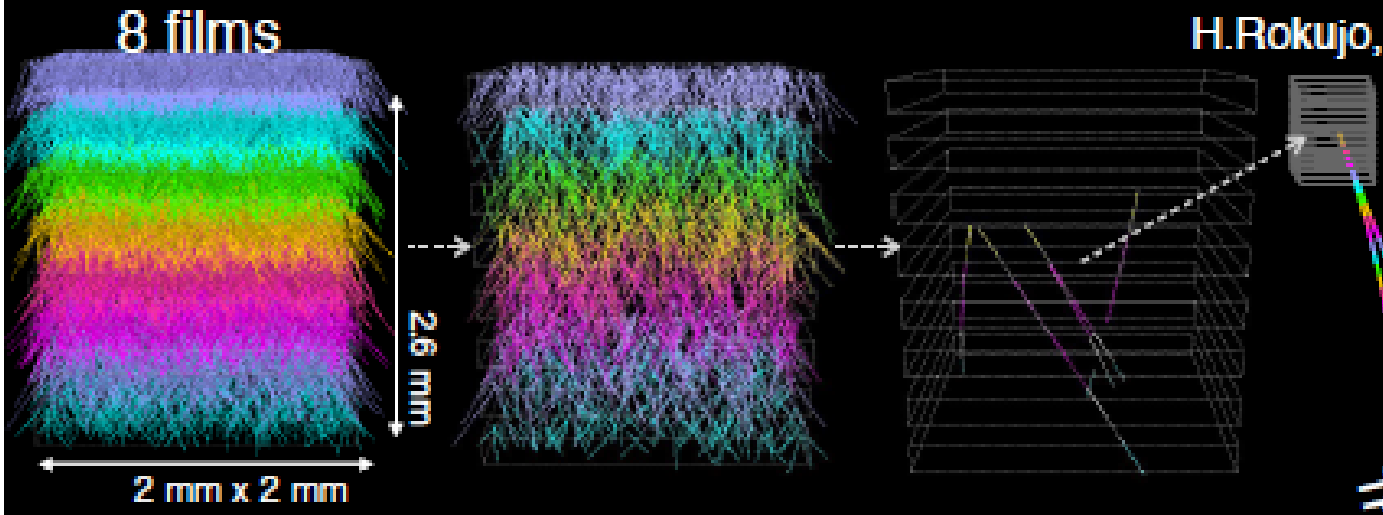


10 mrad @ 100 MeV
1.5 mrad @ 1 GeV

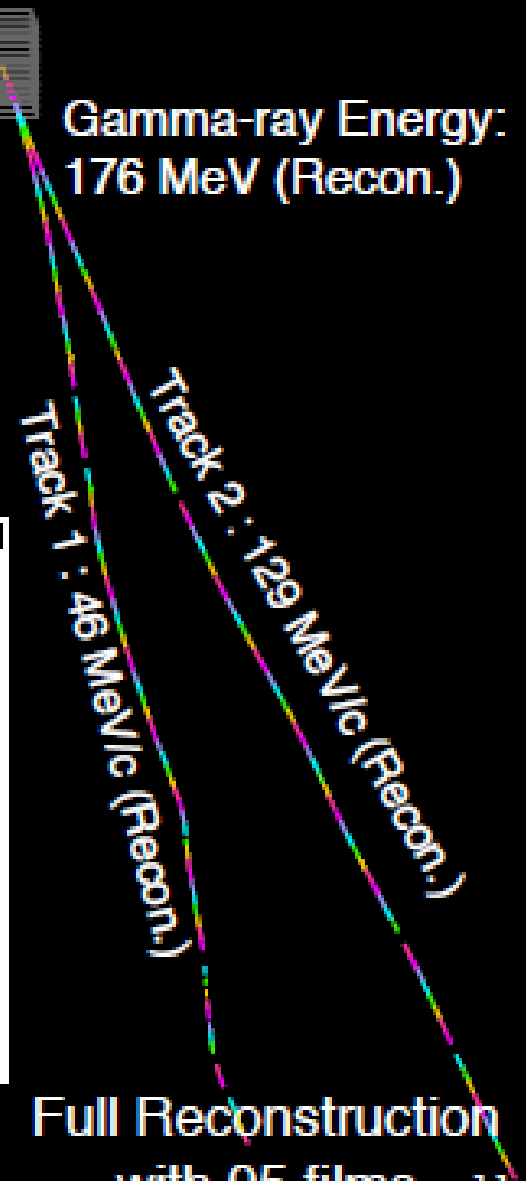
GRAINE2015

Automatic Event Selection

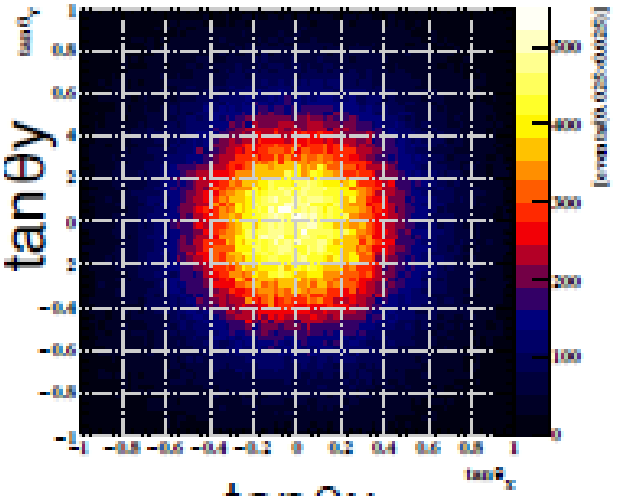
H.Rokujo, et al. PTEP(accepted).



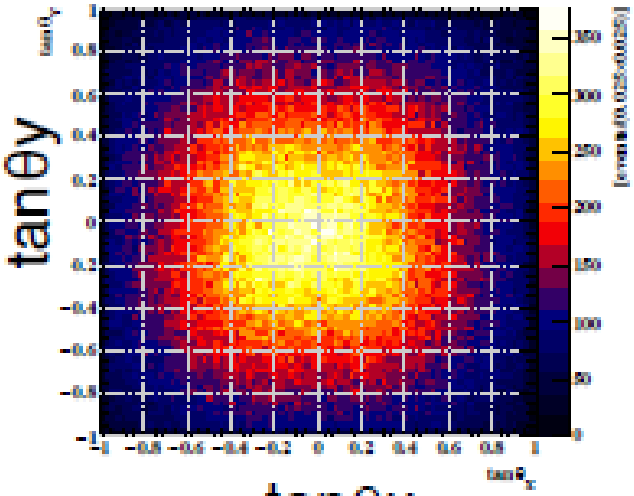
Gamma-ray Energy:
176 MeV (Recon.)



Events before flight



Events during flight

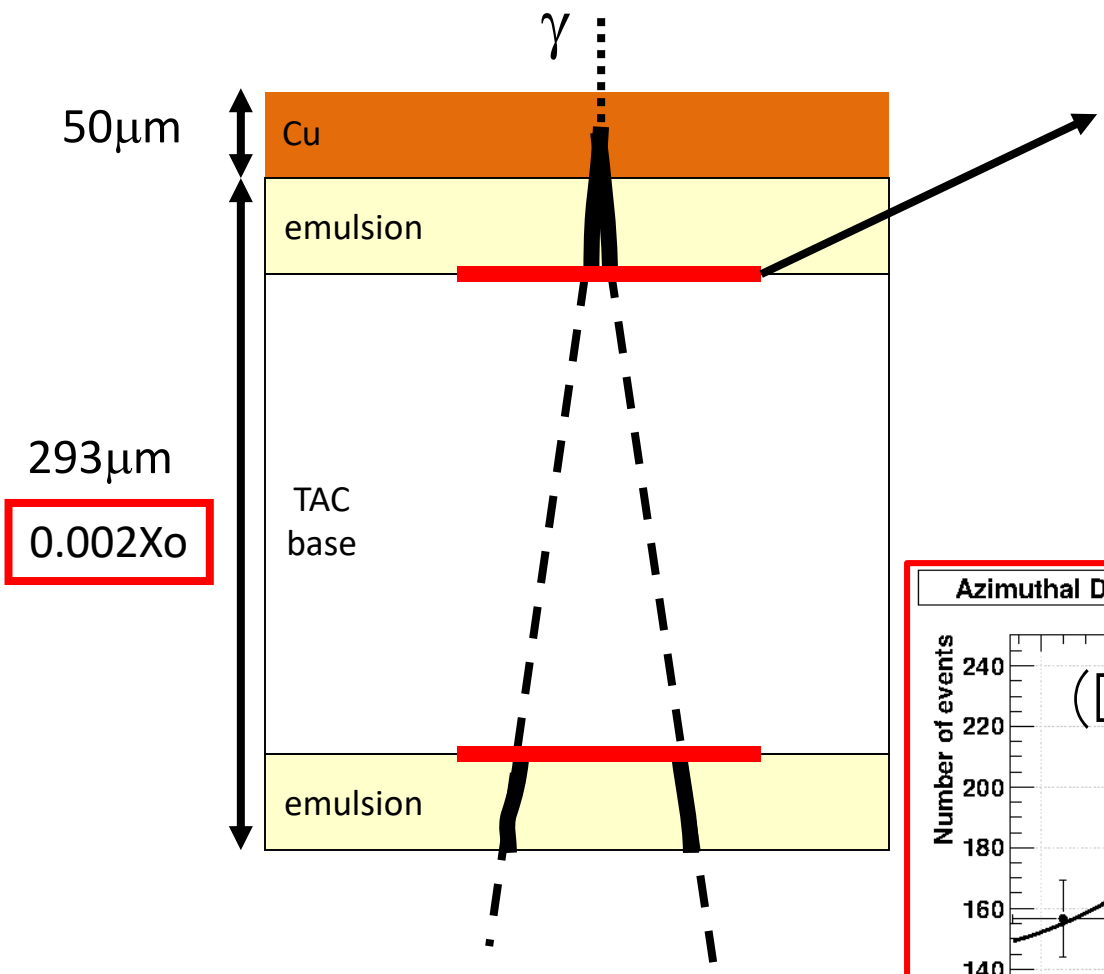


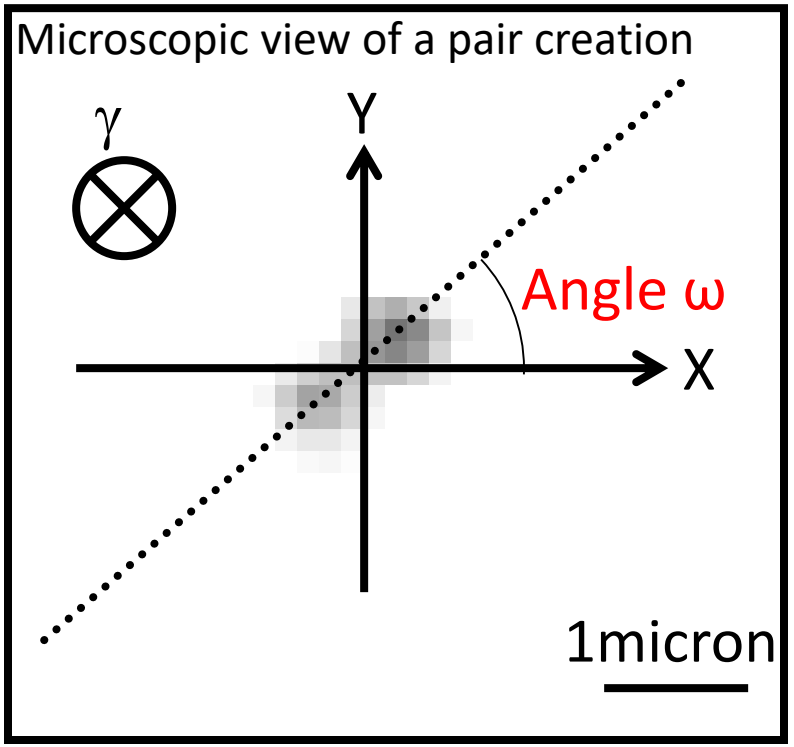
~10^6 events (GRAINE2011 x10^4)

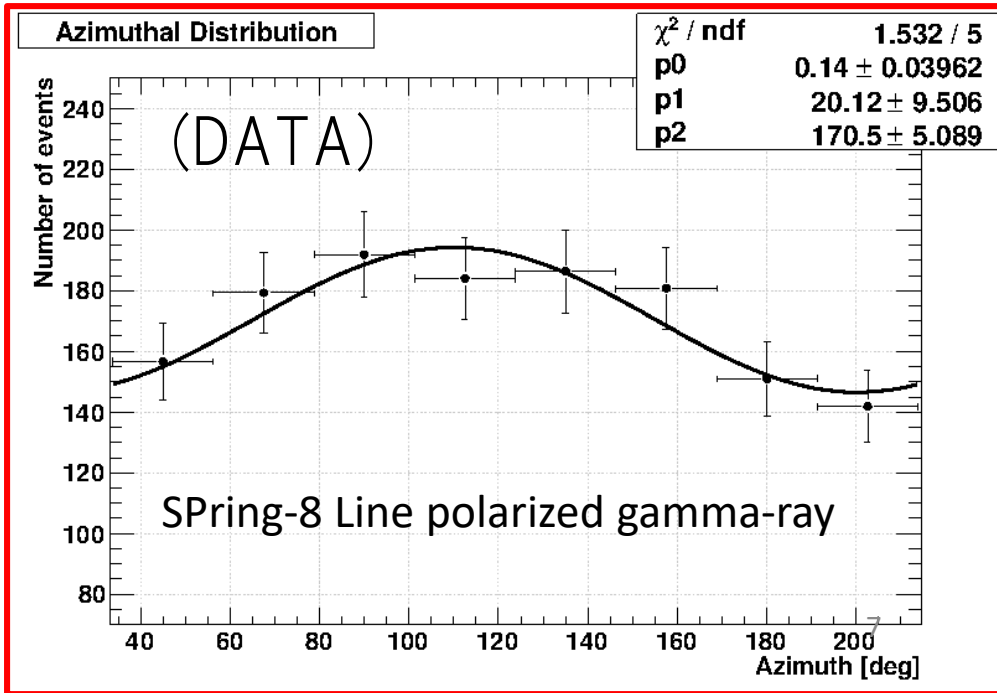
reliability 95%, almost full analysis (~75%)

Full Reconstruction
with 95 films

Polarity Measurement

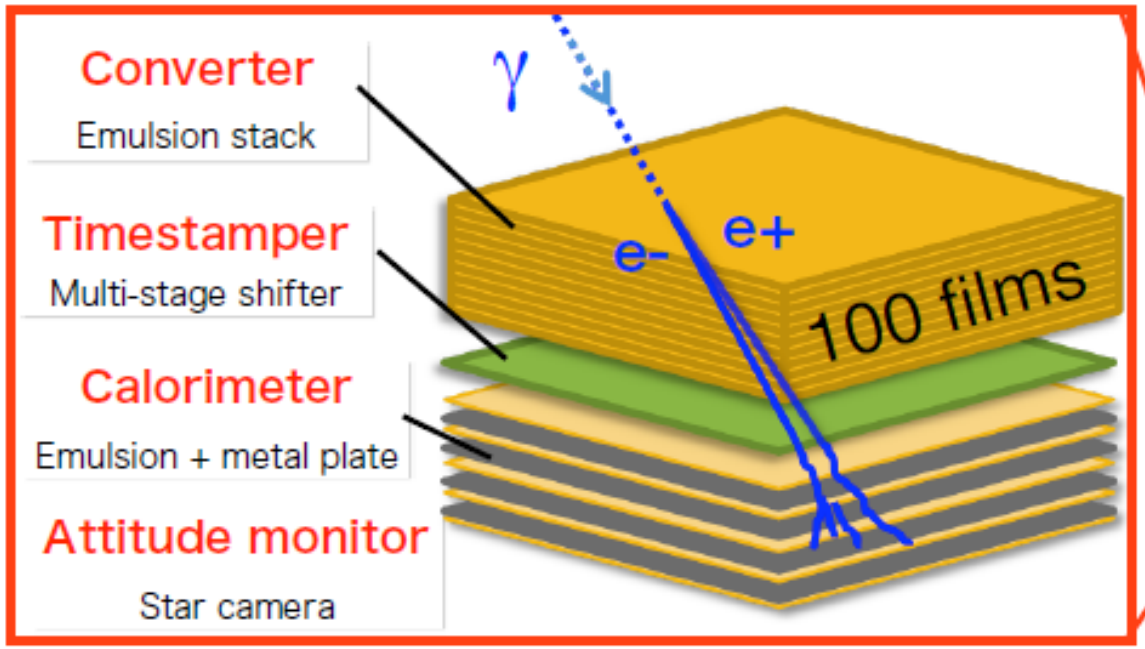




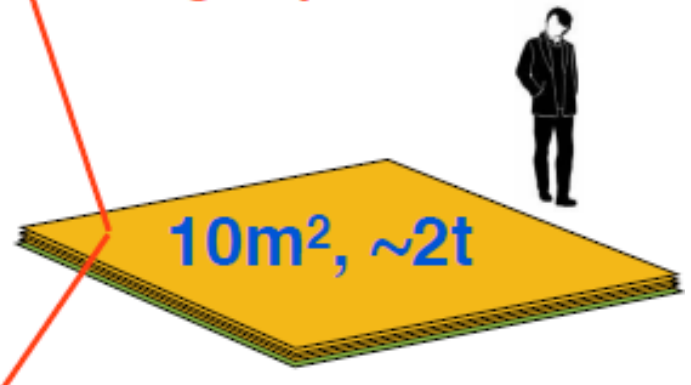


GRAINE can measure the Polarity
(Proven by 3.5σ)
Fermi : impossible

Emulsion Gamma-ray Telescope



- Higher Angular Resol.
- Polarization Sensitive
- Large Aperture Area



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

Flow of experiment

Detector development /preparation ← Analysis ← Scanning (2nd data taking)

↓

Observation(balloon flight) several days - 1 week → Recovery of detector

GRAINE project

2004– Development on ground

S.Takahashi et al. NIMA 620, 192 (2010)
K.Ozaki et al. NIMA 833, 165 (2016)

2011(Jun.) 1st Balloon-Exp.

- Checking Feasibility

H.Rokujo et al. NIMA 701, 127 (2013).
S.Takahashi et al. PTEP 2015 043H01

2015(May.) 2nd Balloon-Exp.

- establishment of experimental flow
- imaging demonstration

K.Ozaki et al., JINST 10, P12018 (2015)
S.Takahashi et al. PTEP 2016, 073F01
H,Rokujo et al., PTEP 2018 (accepted)

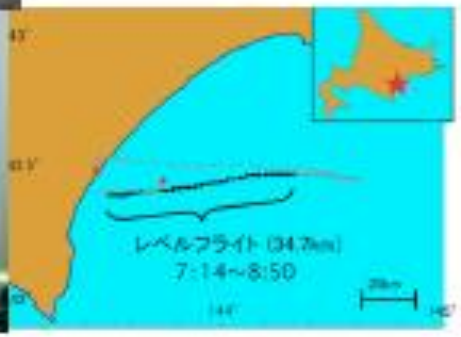
2018(26th Apr.)3rd Balloon-Exp.

- Celestial source detection

Demonstration phase w/ 0.4m²

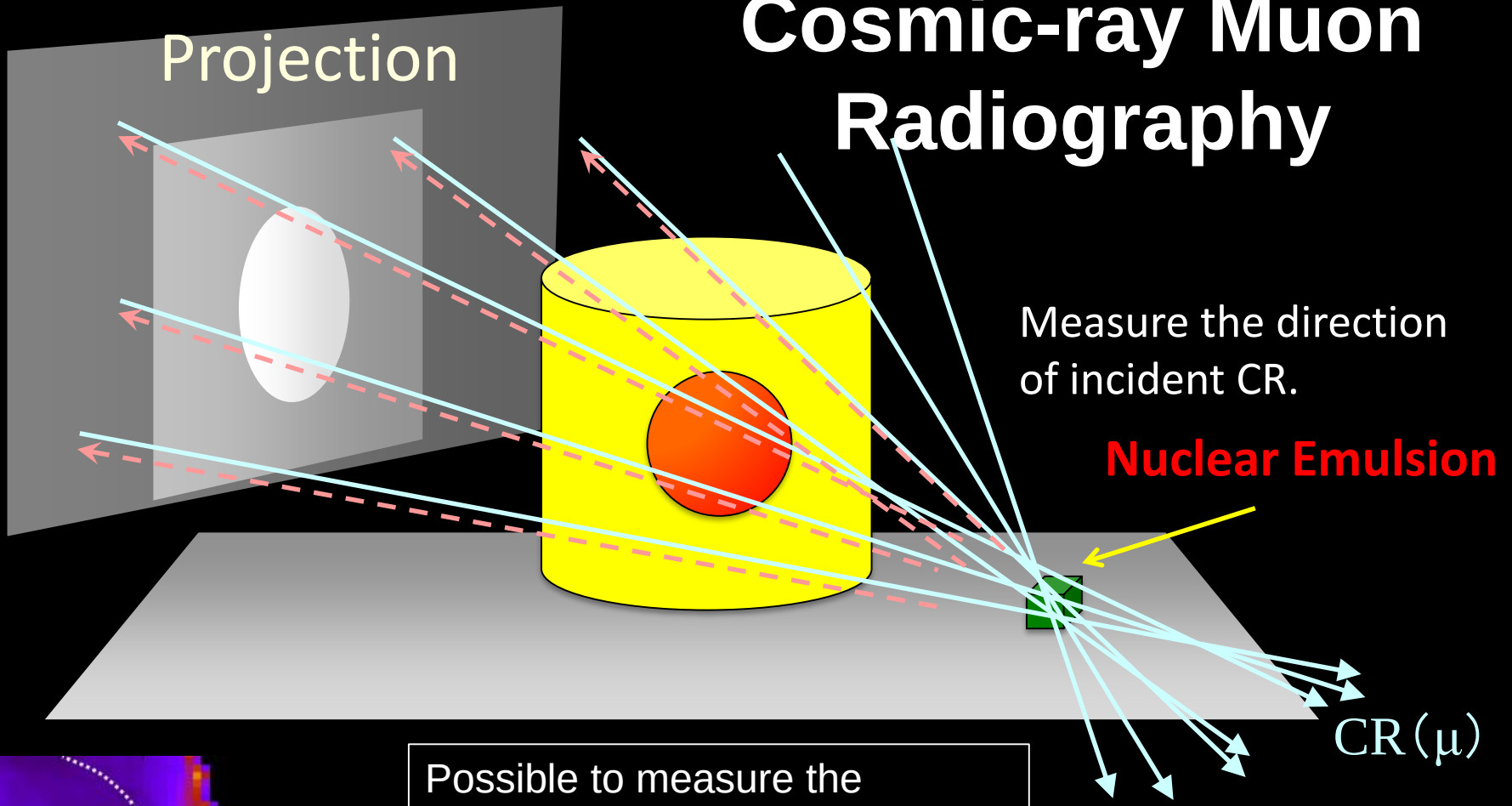
2021- Start scientific observation w/10m²

GRAINE 2011
Aperture : 0.013m²
1.6 h@35km

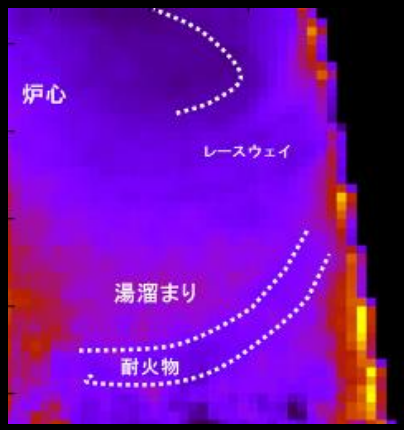


GRAINE 2015
Aperture : 0.38m²
11.5 h@36-37km

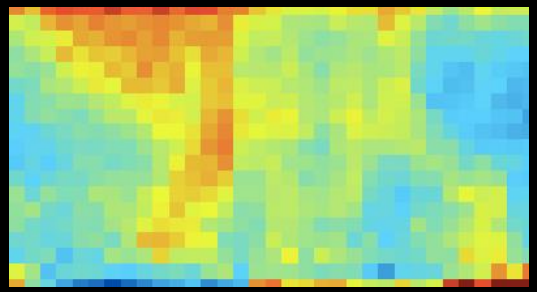
Cosmic-ray Muon Radiography



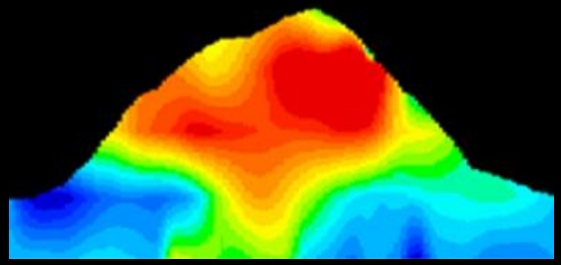
Possible to measure the material distribution of the object



Iron Furnace



Atomic Power Plant(F1)



Volcano (SHOWA SHINZAN)

Scan Pyramids (2015-)

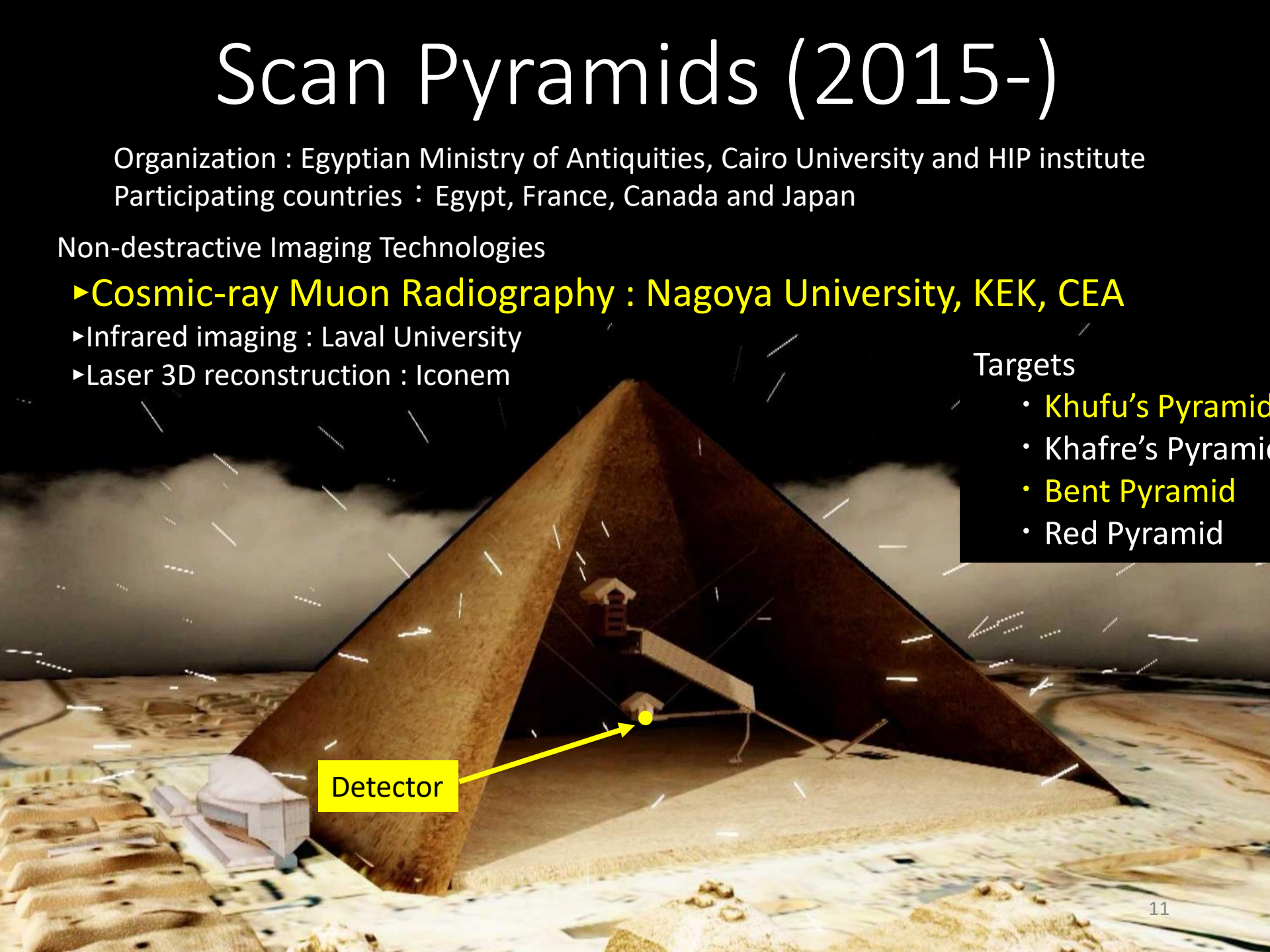
Organization : Egyptian Ministry of Antiquities, Cairo University and HIP institute
Participating countries：Egypt, France, Canada and Japan

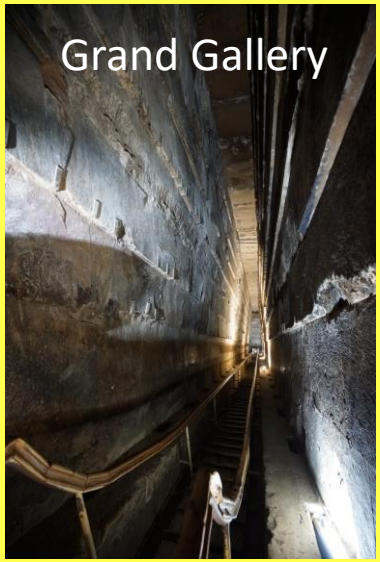
Non-destractive Imaging Technologies

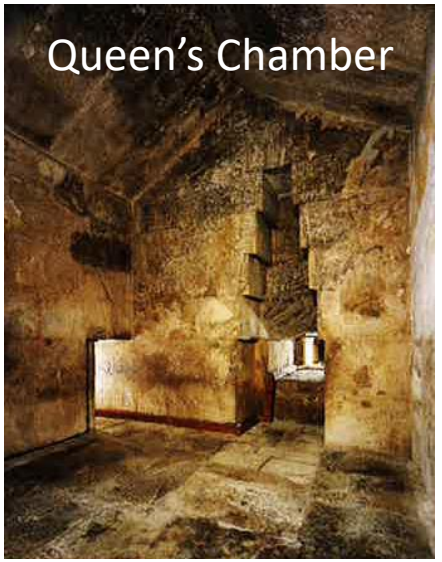
- ▸Cosmic-ray Muon Radiography : Nagoya University, KEK, CEA
- ▸Infrared imaging : Laval University
- ▸Laser 3D reconstruction : Iconem

Targets

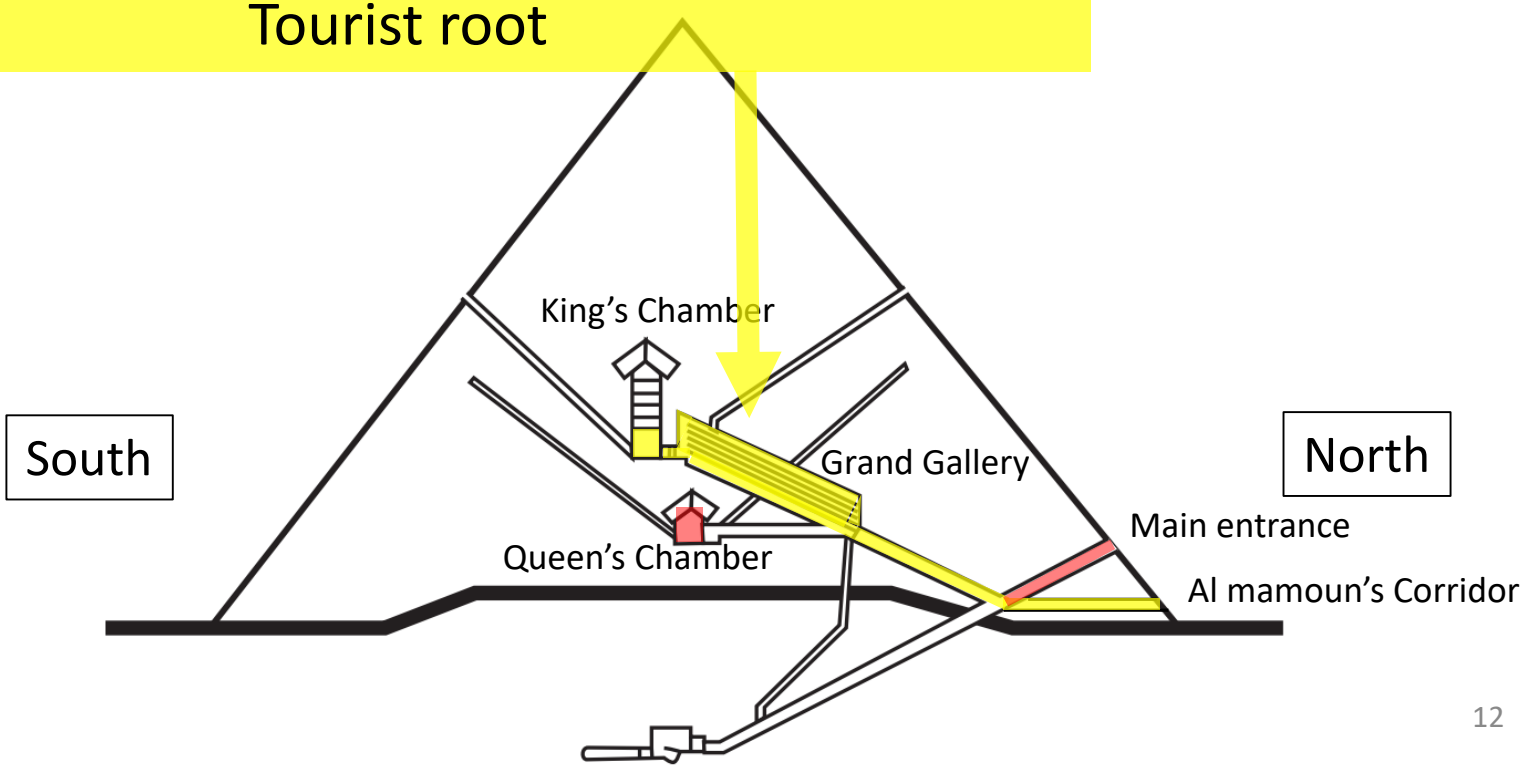
- Khufu's Pyramid
- Khafre's Pyramid
- Bent Pyramid
- Red Pyramid

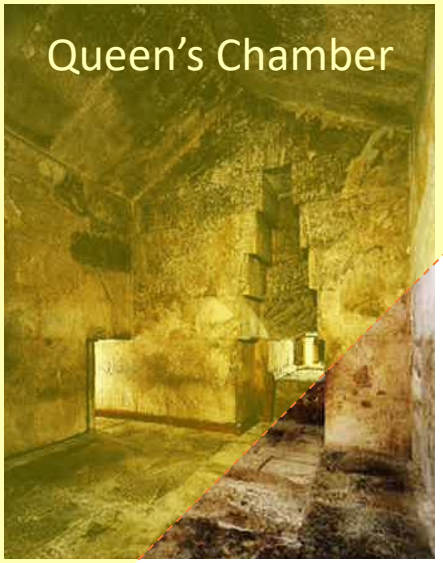




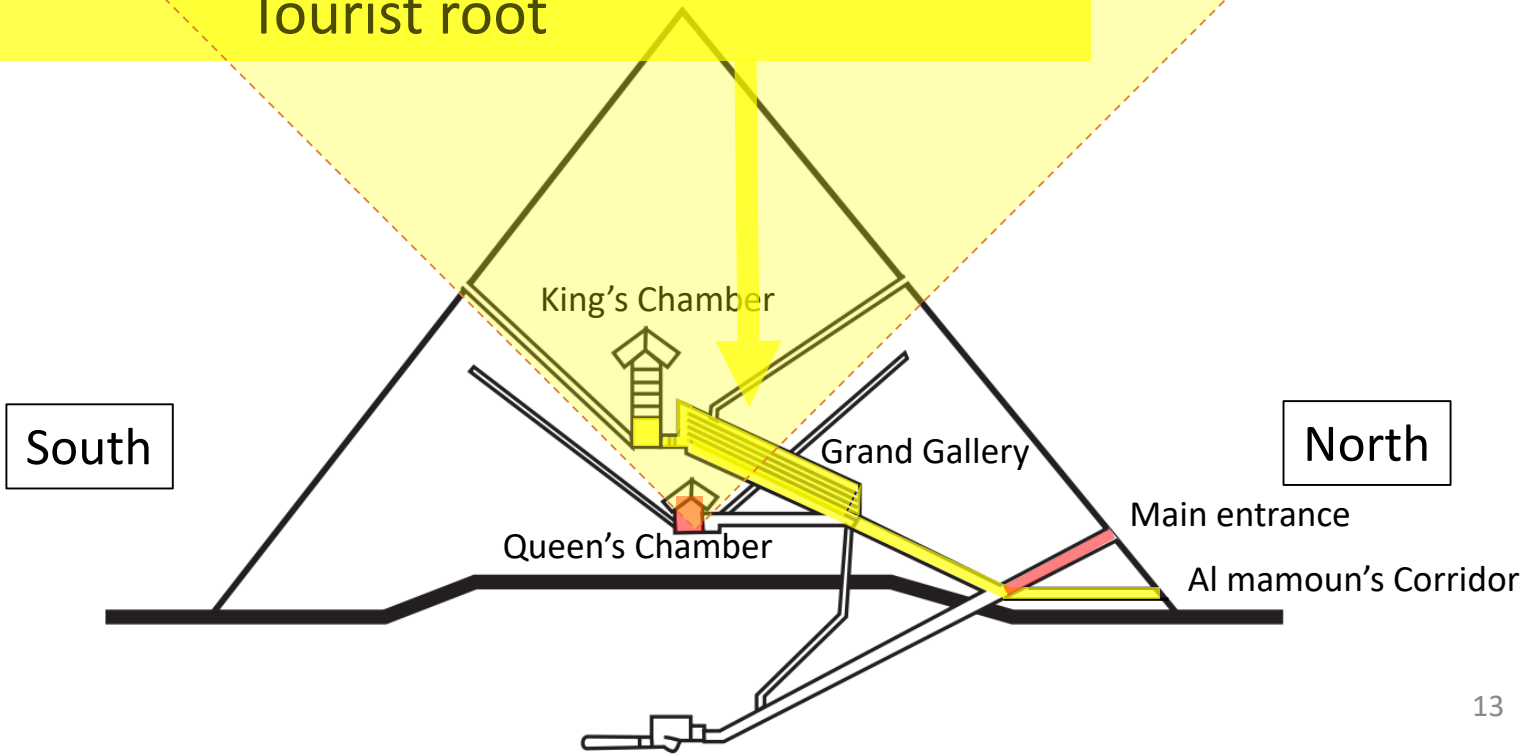


Tourist root

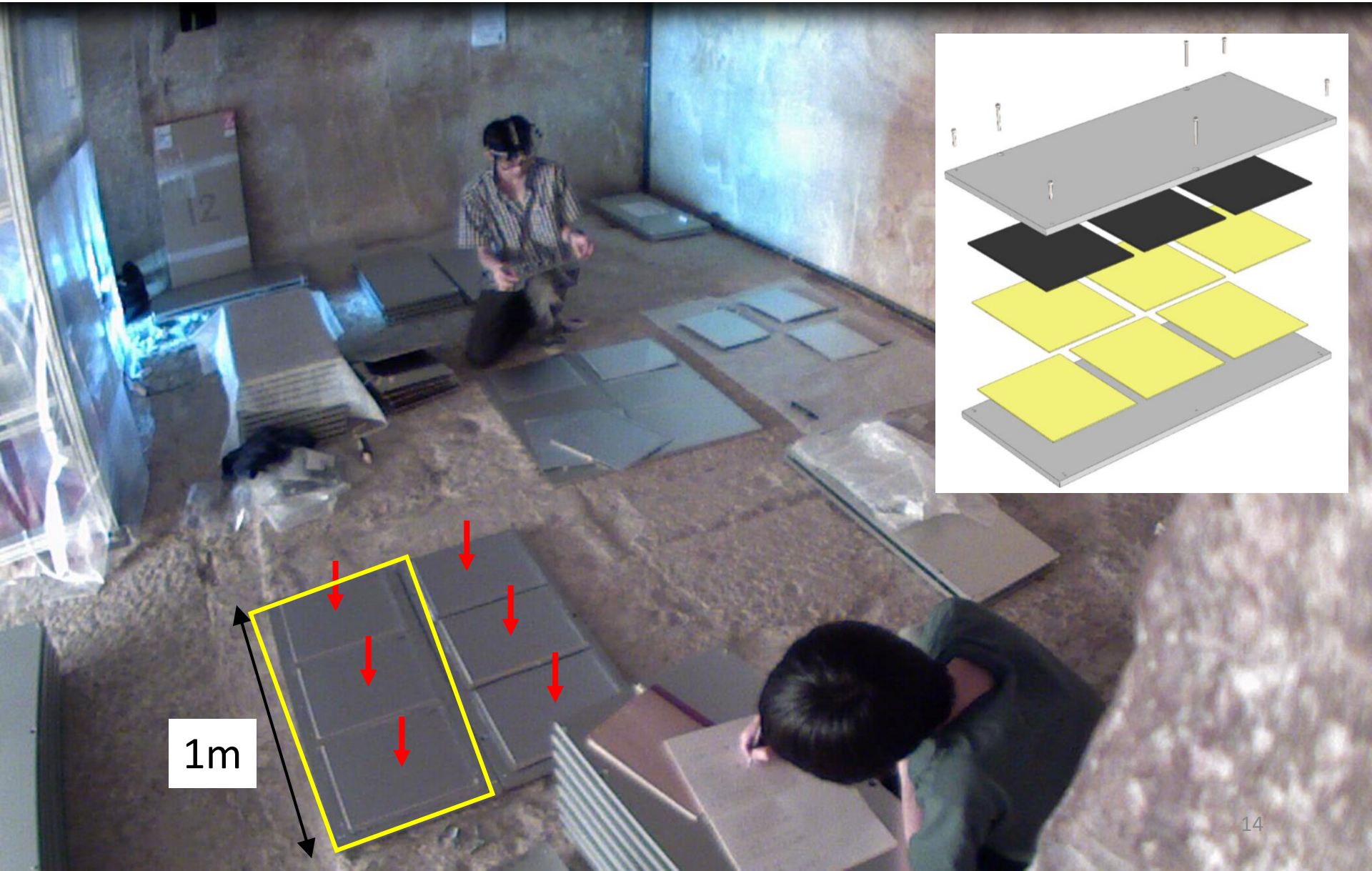




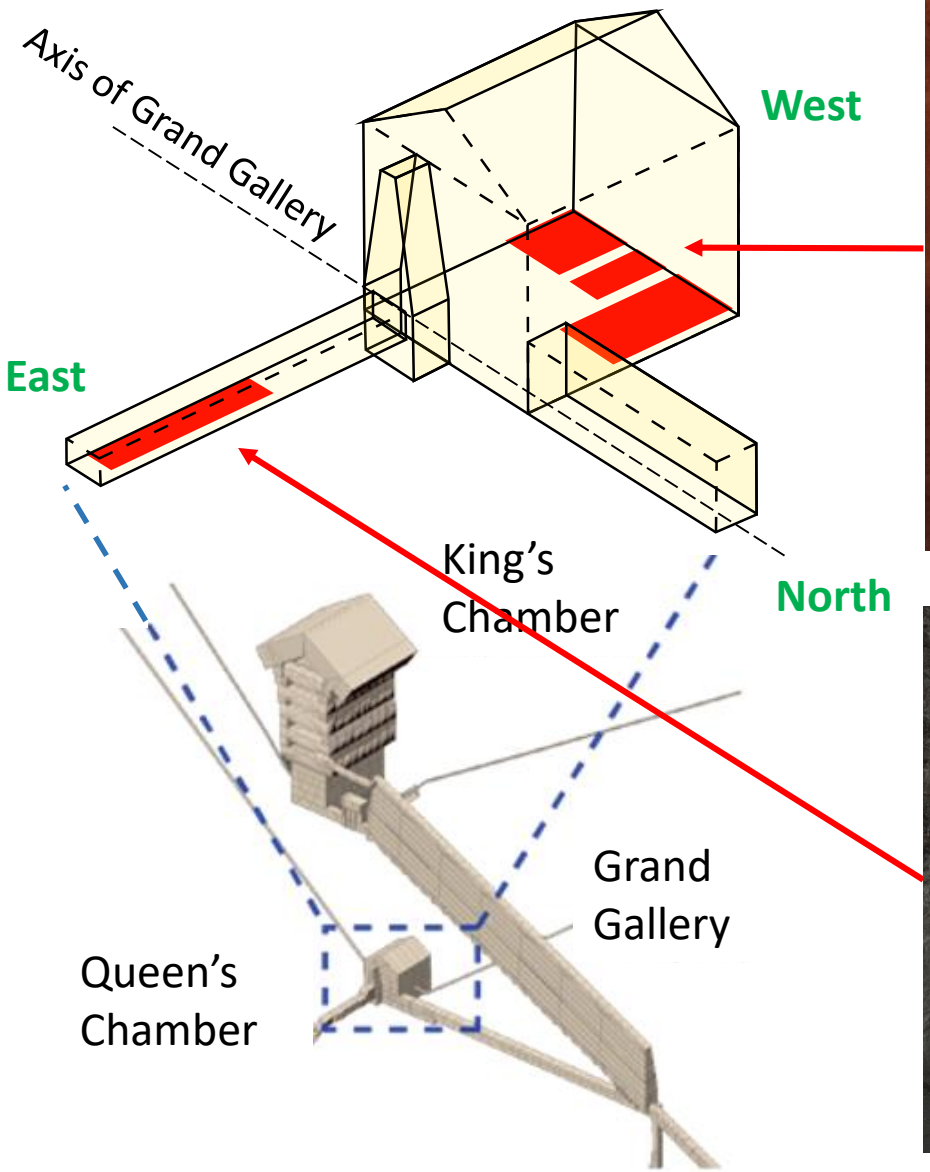
Tourist root

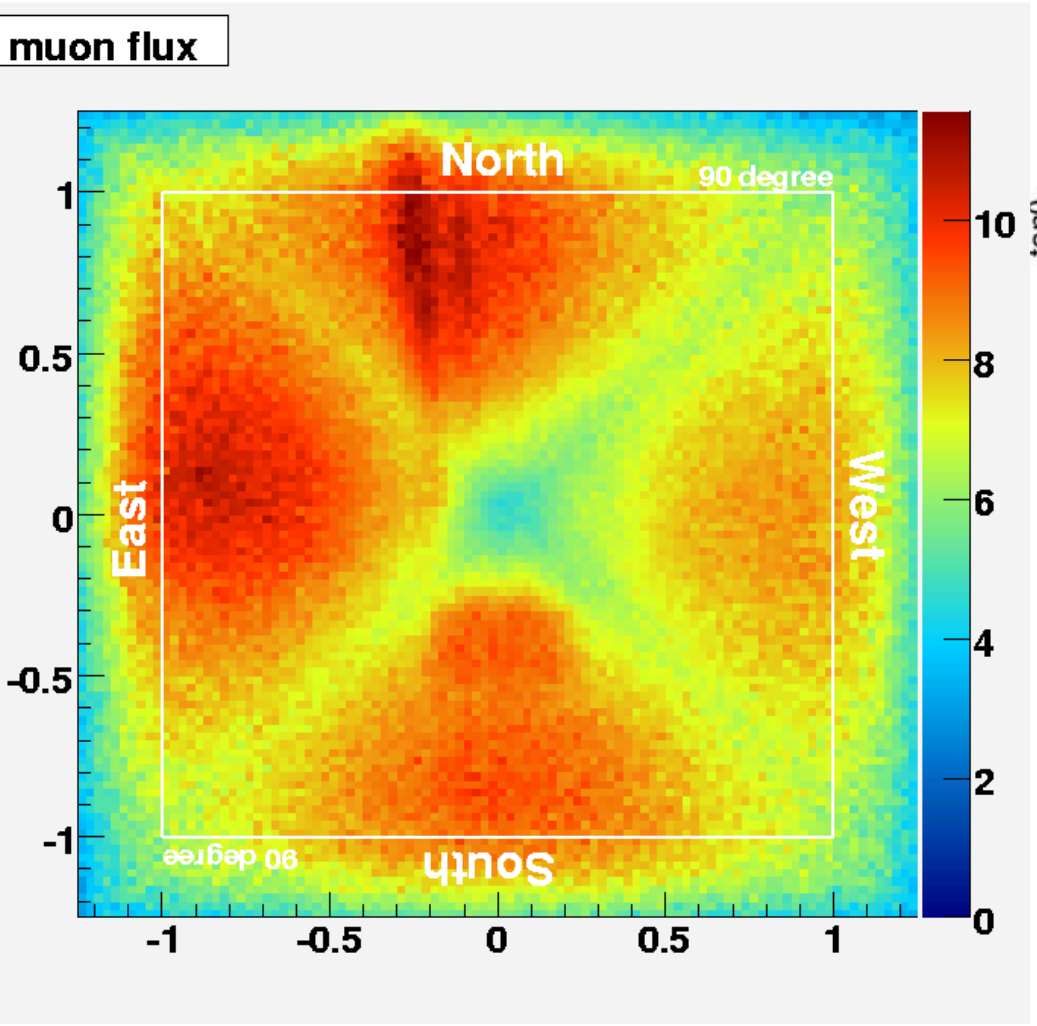


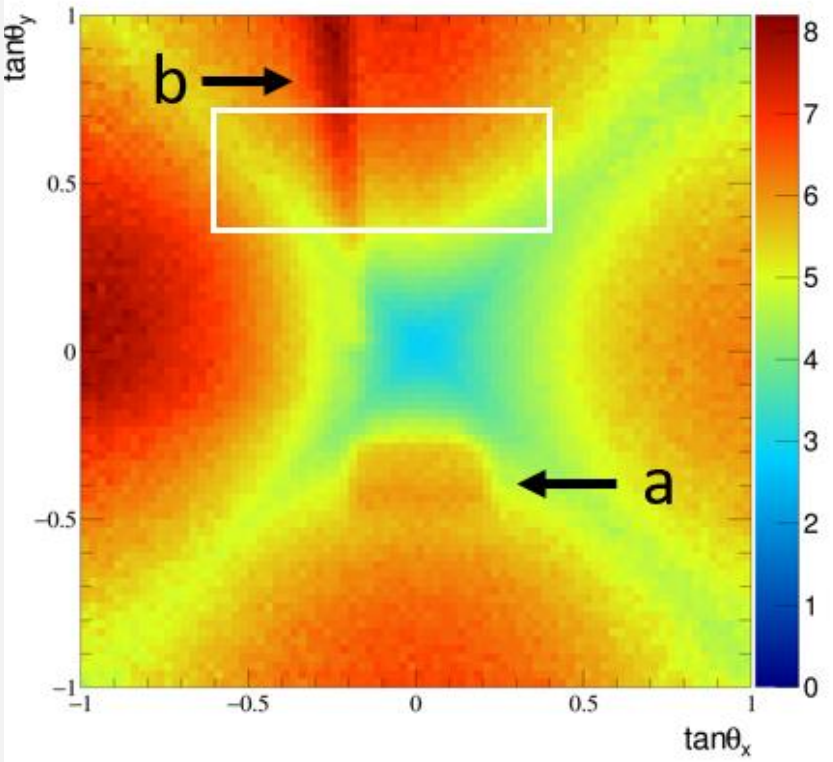
Installation in the Queen's Chamber

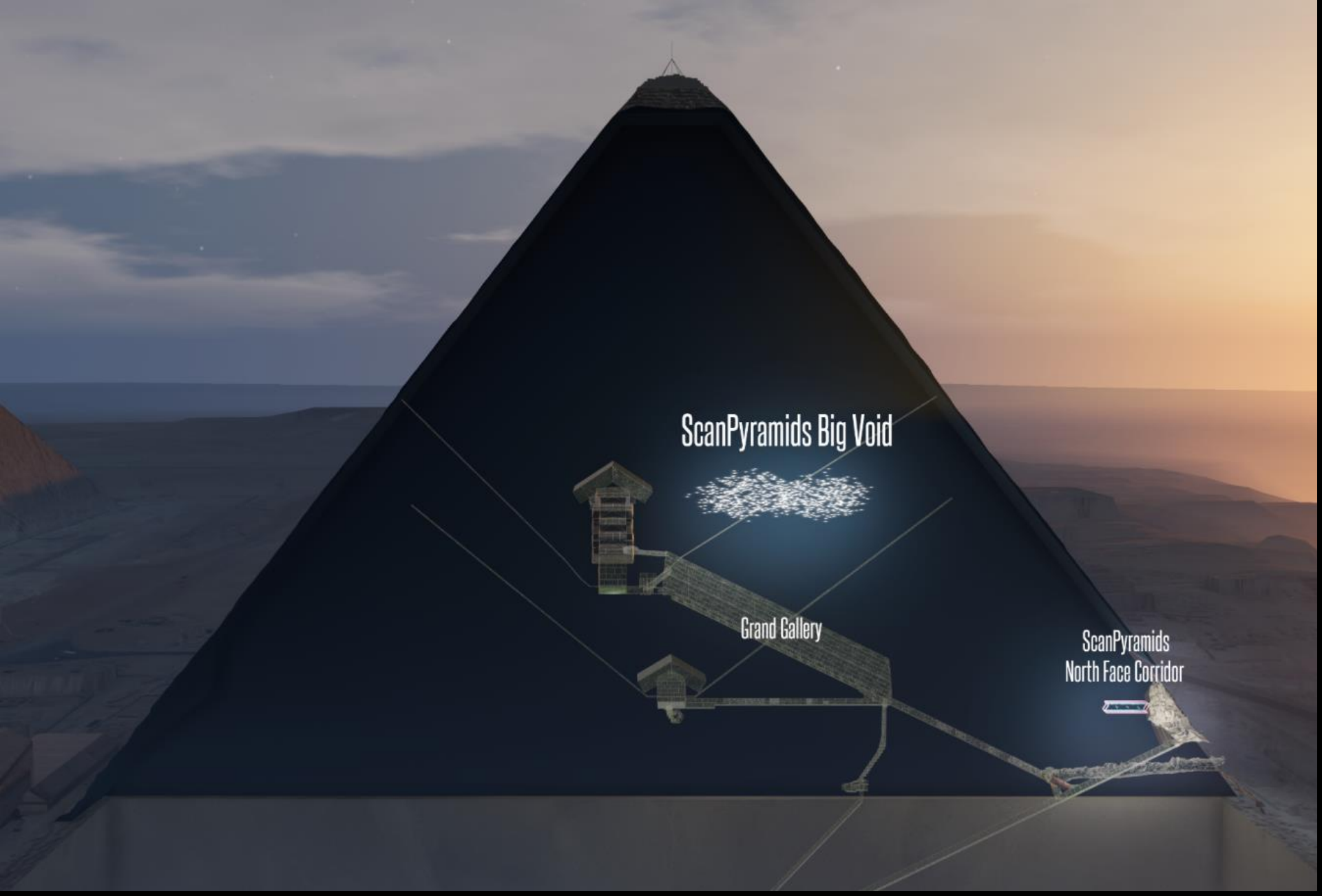


Observation from the Queen's Chamber



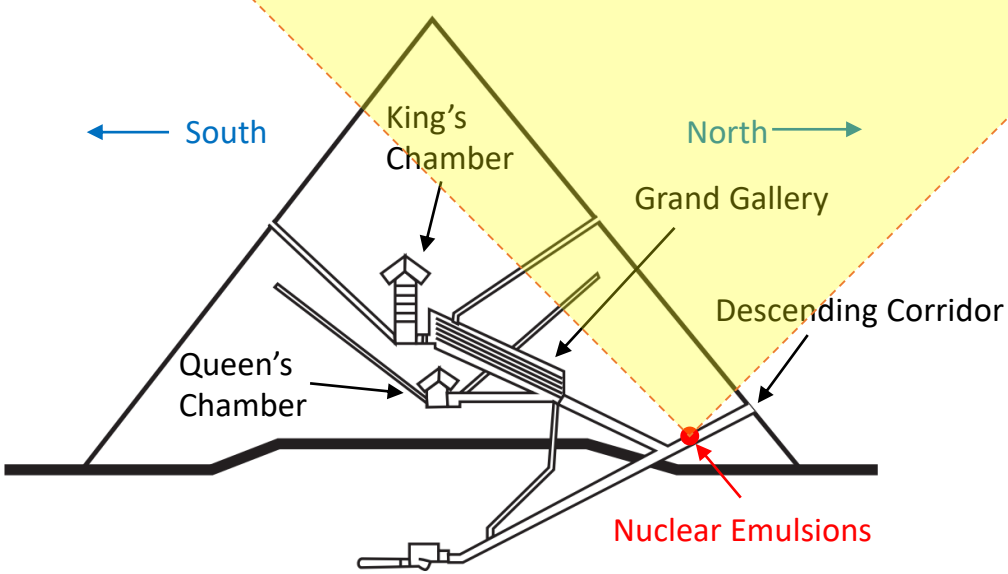

muon flux
North
90 degree
East
West
South
90 degree
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
10
8
6
4
2
0

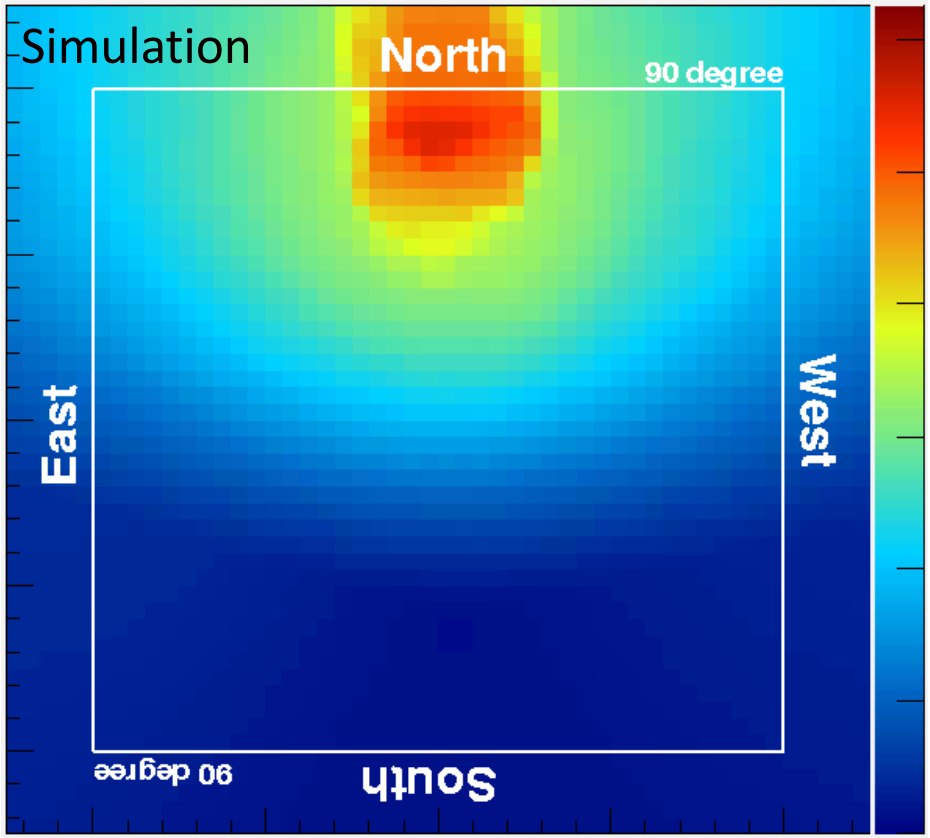

b
a
tanθy
tanθx
1
0.5
0
−0.5
−1
−1
−0.5
0
0.5
1
8
7
6
5
4
3
2
1
0

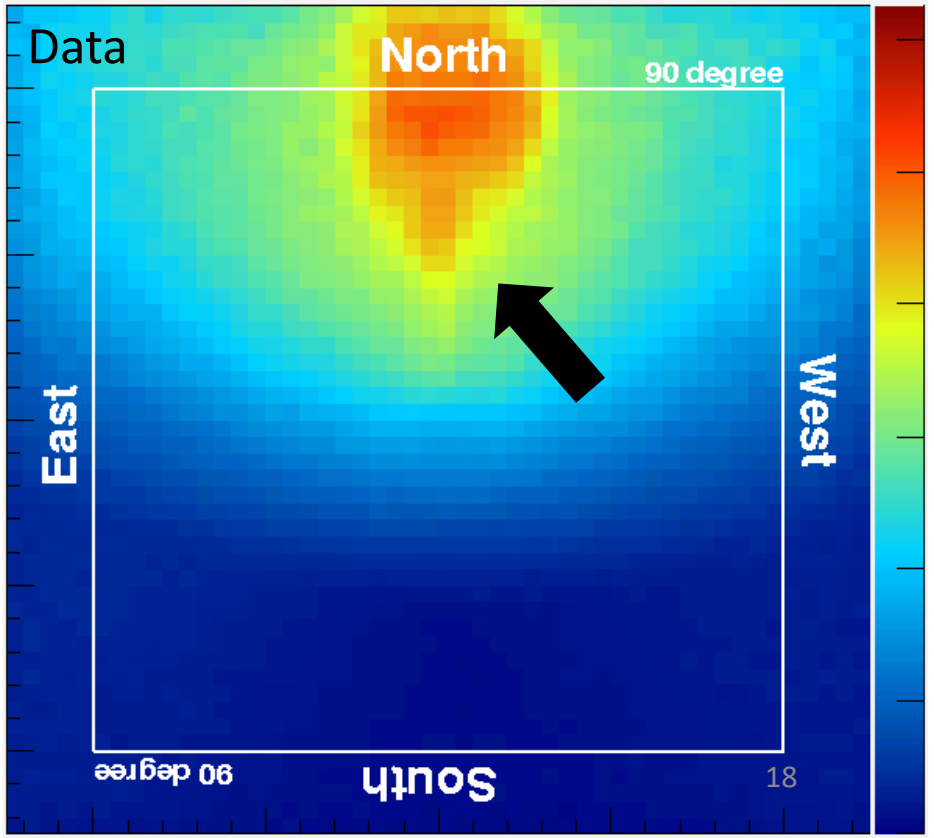


Nature (2017)24647, doi:10.1038/nature24647, Kunihiro Morishima et al.,
Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons

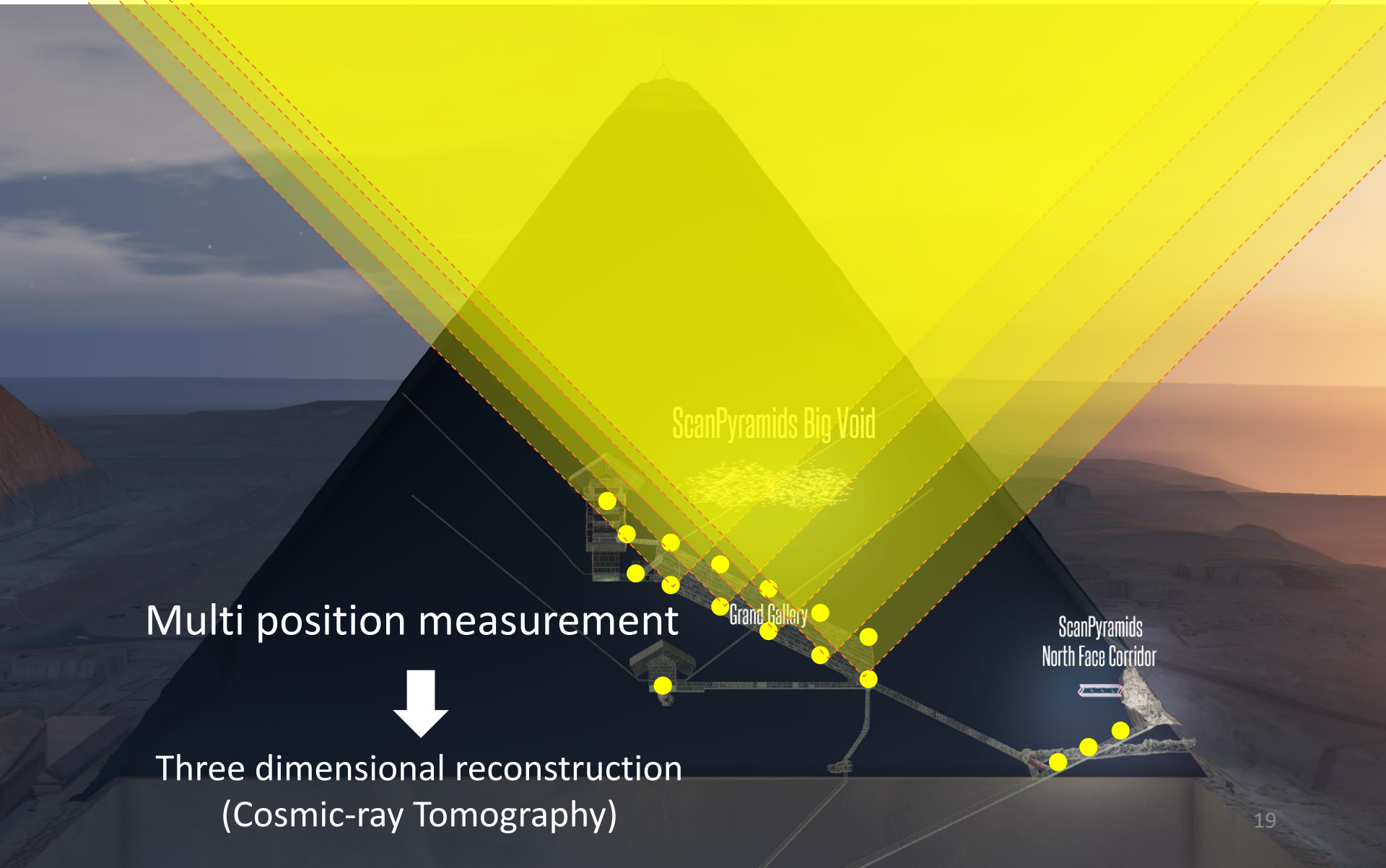
Observation from the Descending Corridor







Future prospect of Khufu's Pyramid



Multi position measurement

Three dimensional reconstruction
(Cosmic-ray Tomography)

summary

- Nuclear Emulsion itself do not need electronic power ,
  it just stay there and accumulate the track information in it !
- Very handy device to accumulate events .

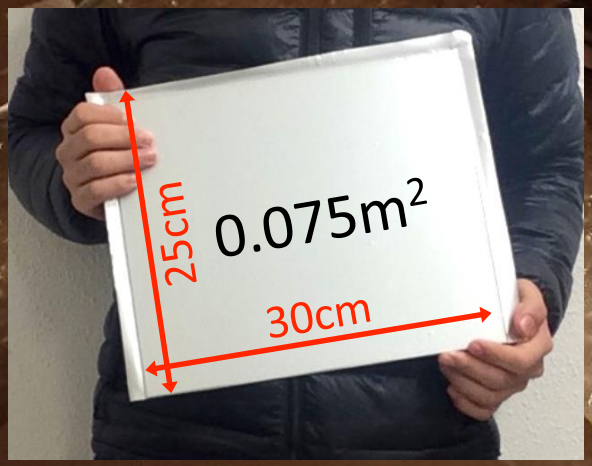
- So Nuclear Emulsion applications is not only neutrino experiments but also astro-physics , geo-physics.

- Very fine position resolution gives good angular resolution and then good for gamma ray telescope. Polarization of gamma also can be measured.

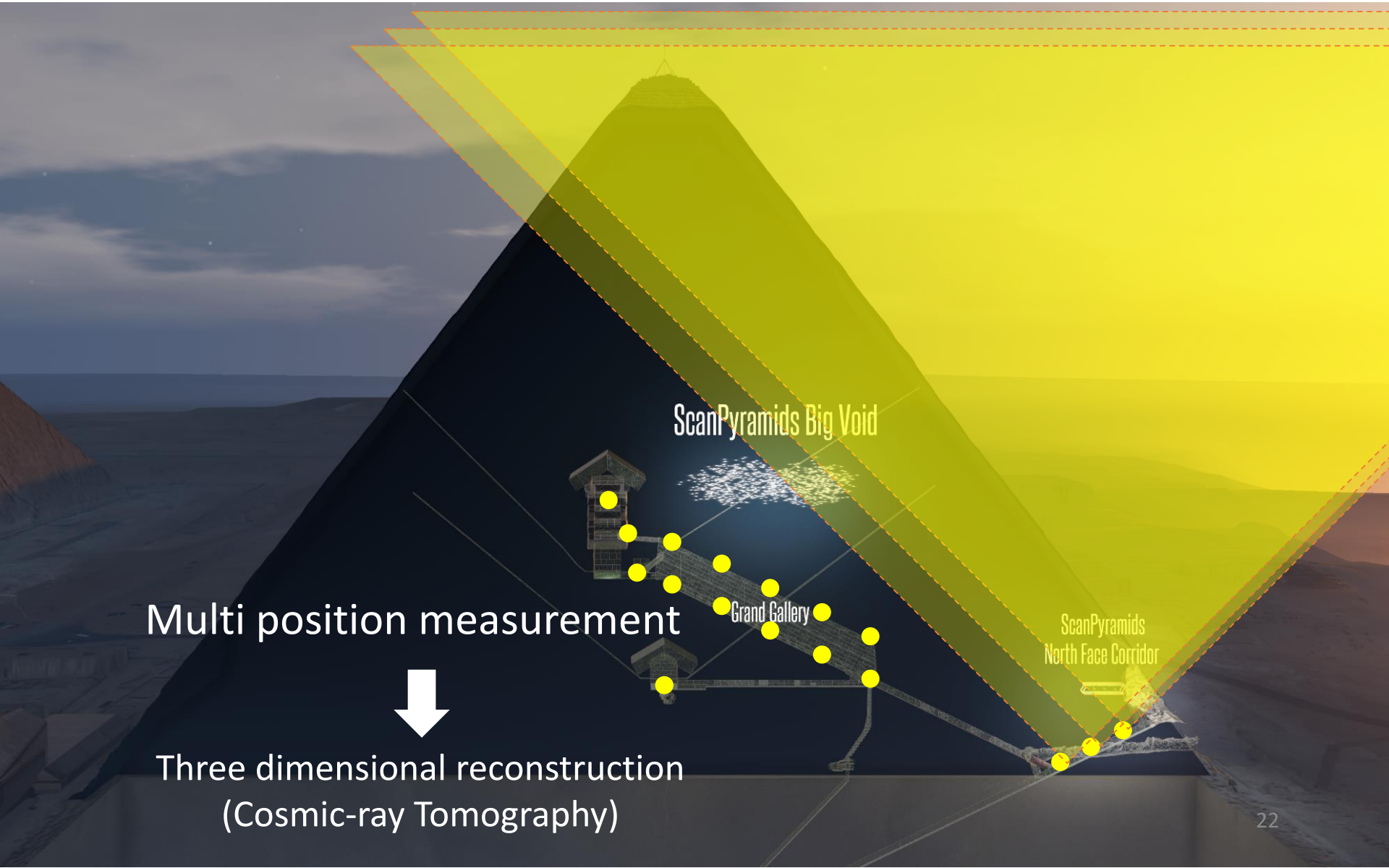
- Nuclear emulsion properties can be tuned to experiment, for example a fine grained emulsion used for Dark Matter search or
  neutron detector or
  High dE/ dX particle such like mono-pole search.

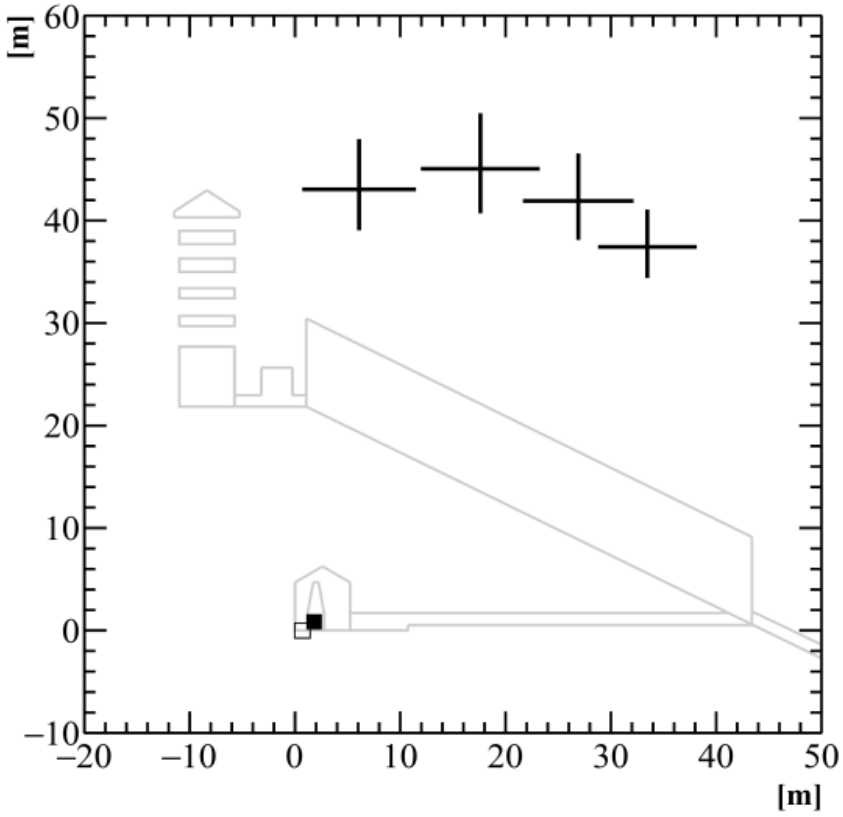
- We will prepare large –scale Nuclear Emulsion production machine and investigate all interesting things what Nuclear Emulsion can detect.

Nuclear Emulsion Detectors

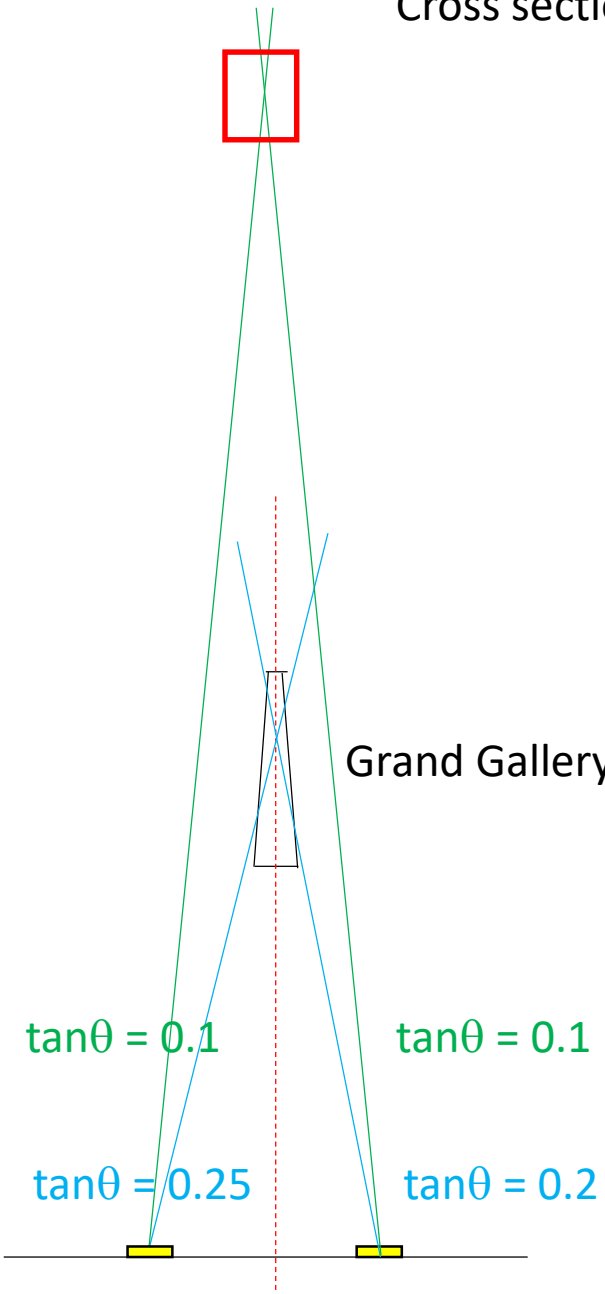


Future prospect of Khufu's Pyramid





Cross section in tanθy=0.5



→ 40~50 m

17.8m

なぜ原子核乾板 for ニュートリノ

- チャーム寿命・生成率測定
- タウニュートリノ反応断面積測定
  寿命が短い。→高位置分解能。

- 陽子などの短い飛跡
  高サンプリングに耐える。 陽子同定能。

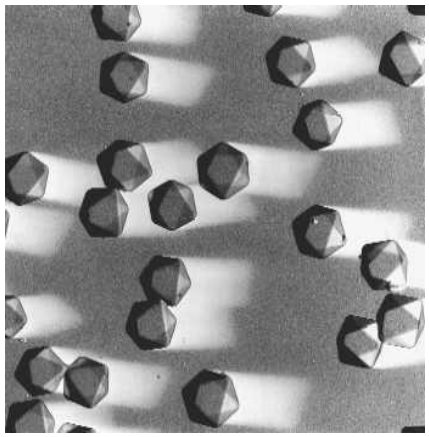
- 電子ニュートリノ
  π0→ 2γのバックグランドが問題。
  → 高サンプリング＆高位置分解能。

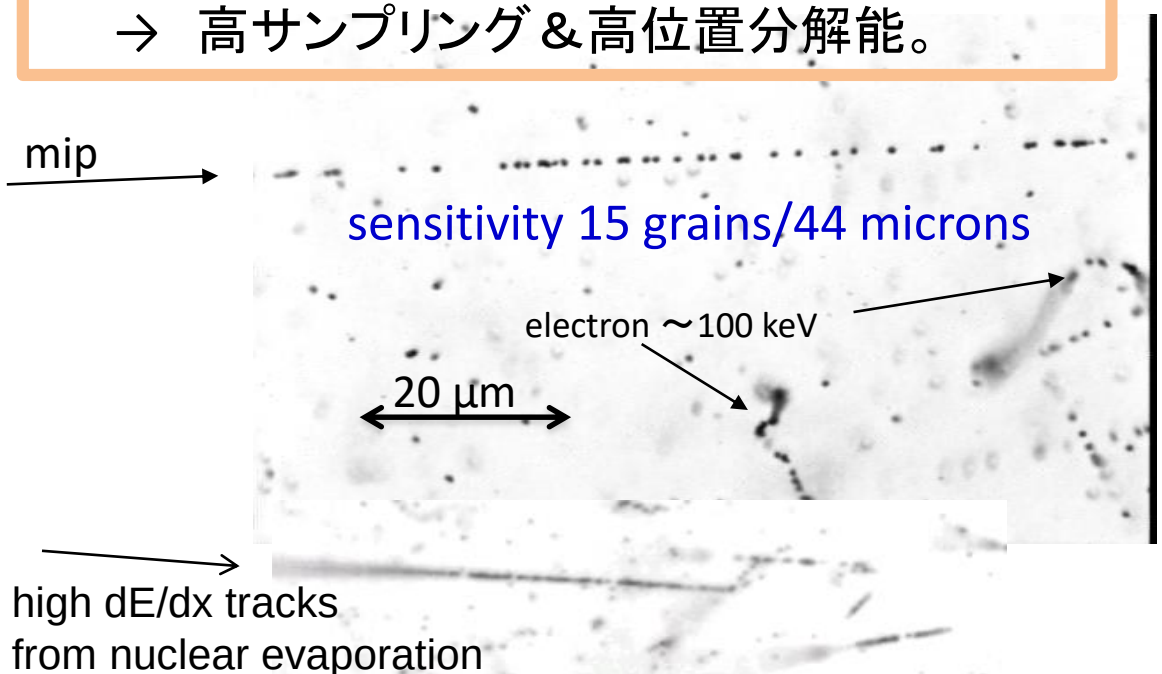
basic detector: AgBr crystal,

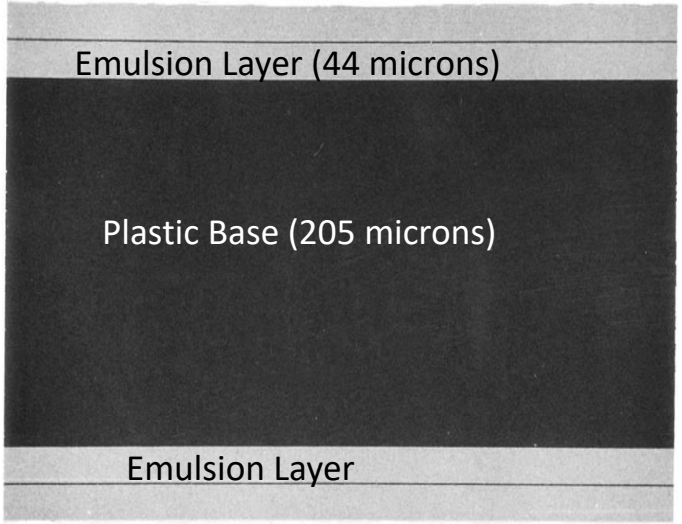
size = 0.2 micron

detection eff.= 0.16/crystal

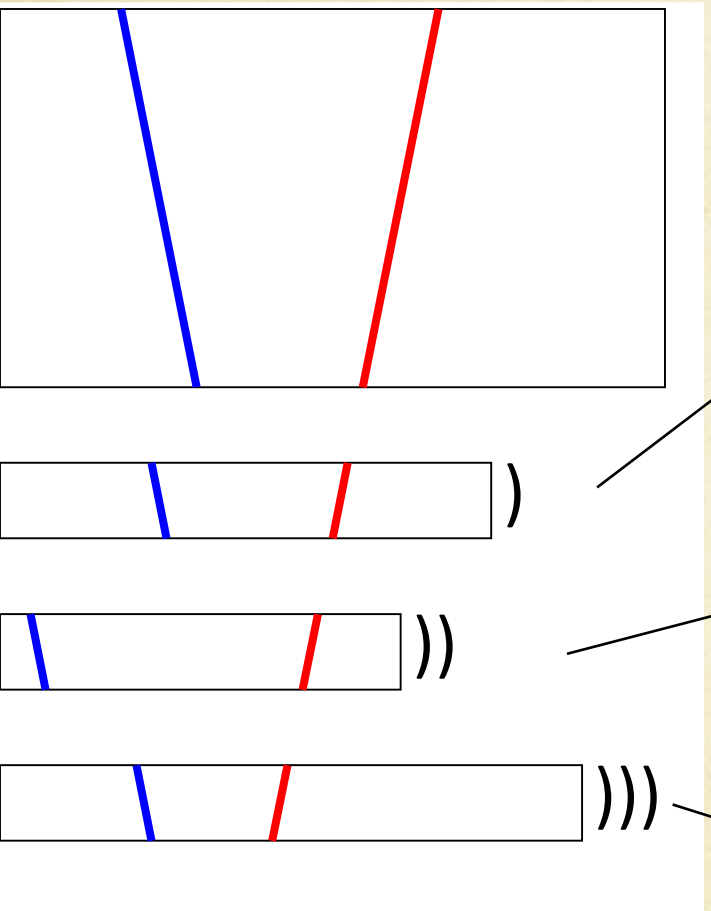
10^{13} "detectors" per film

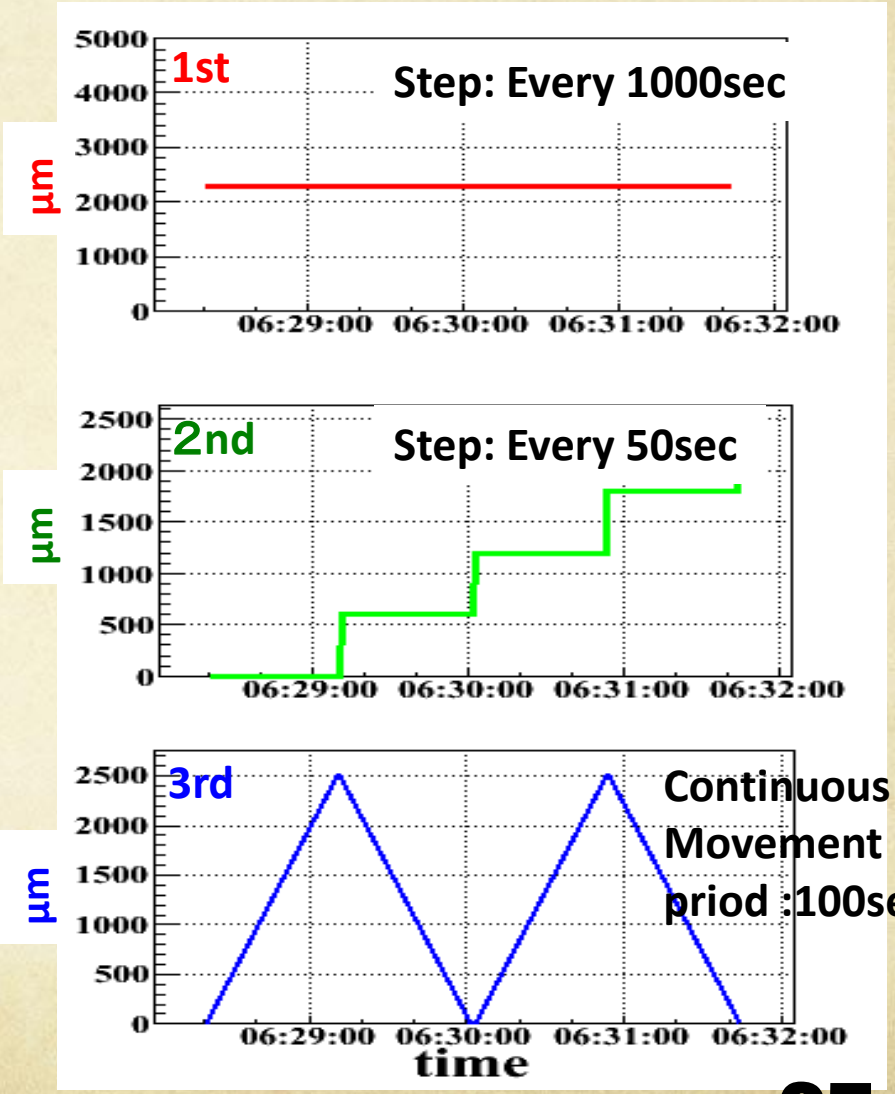






Time Stamp System = Shifter





Aim to resolve 10msec

Directional WIMP detection by Nuclear Emulsion

NEWSdm @LNGS

Japan Group SP: NAKA T.

Japan – Italy- Russia- Turkey –Korea Collaboration

Dark Matter Wind

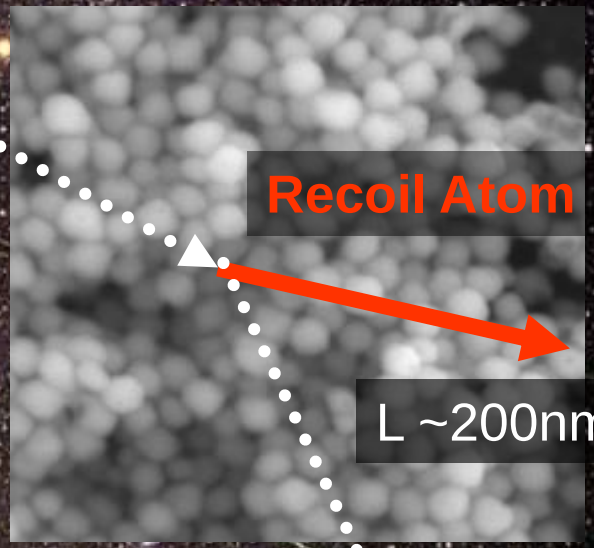
WIMPS

Earth

太陽

230km/sec

Nano Imaging Tracker



$V_{recoil} = 2 (V_{sun} + V_{WIMP})$

$= 100 \sim 1000 km/sec$

- Detect the direction of recoil atoms

  → Dark Matter Telescope
- Easy to realize Ton scale detector

チャーム粒子（X particle）は原子核乾板によって発見！

Sakata and His Group

Cosmic Ray Events

1971 Niu et al.

Evidence for the 4th element?

Some Japanese groups began to investigate the four-quark model

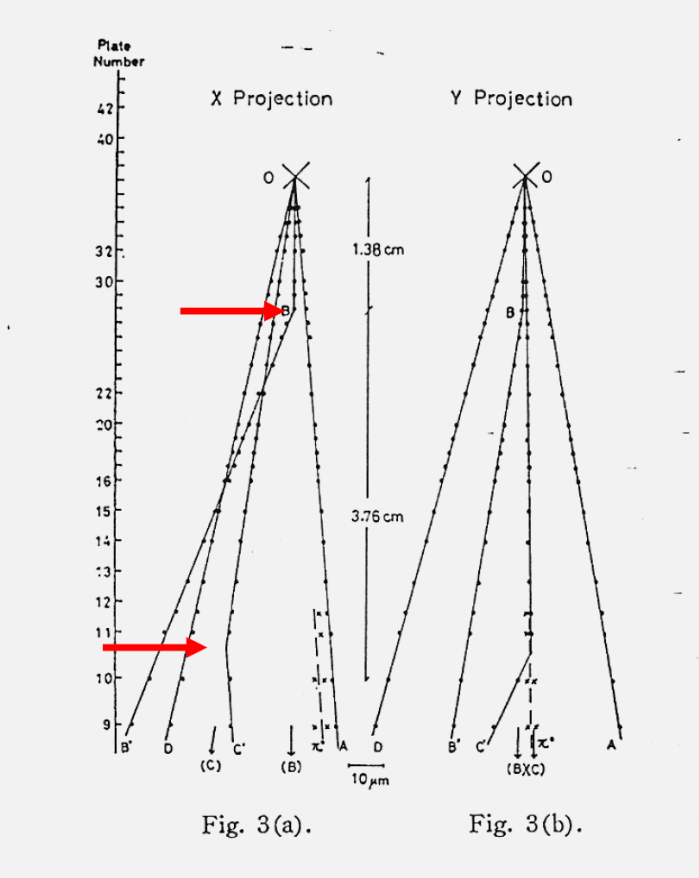


Fig. 3(a). Fig. 3(b).

Emulsion Technique
- Applied to accelerator exp.
- Life time measurement of the new flavors

KOBAYASHI Makoto: Nobel Prize Lecture

Emulsion Cloud Chamber (ECC)

with “cheap” double coated thin emulsion layer film

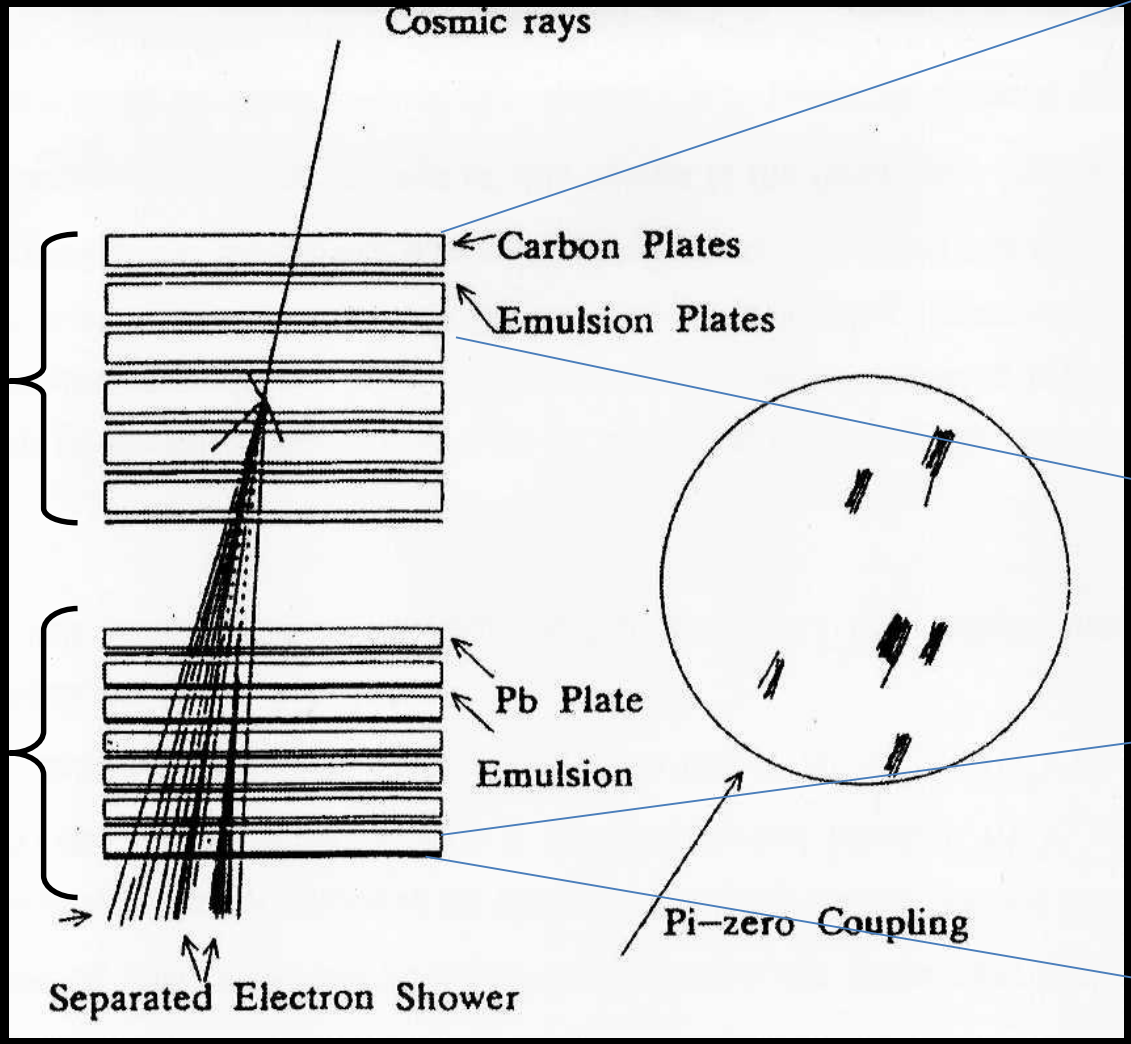
1950’s Nuclear Emulsion R&D by Fuji photographic film.

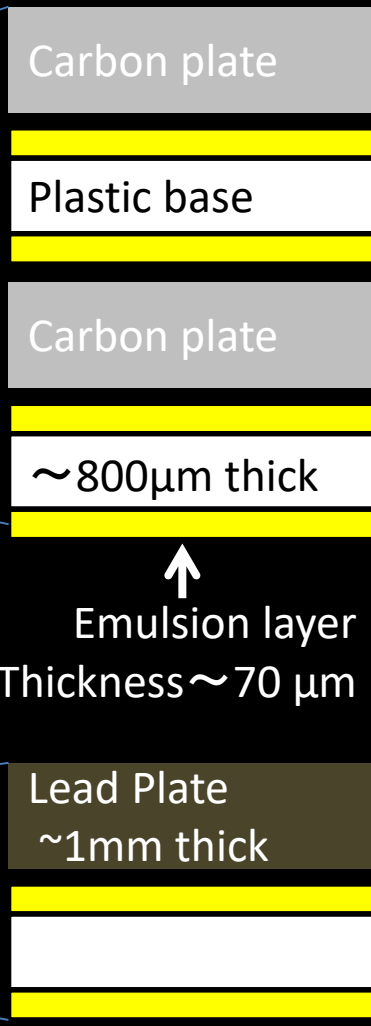
Interaction Vertex Detection

Separator

Shower Det. E-Cal & P Meas. by MCS

Multiple Coulomb Scattering





Expose to Cosmic-ray at high altitude

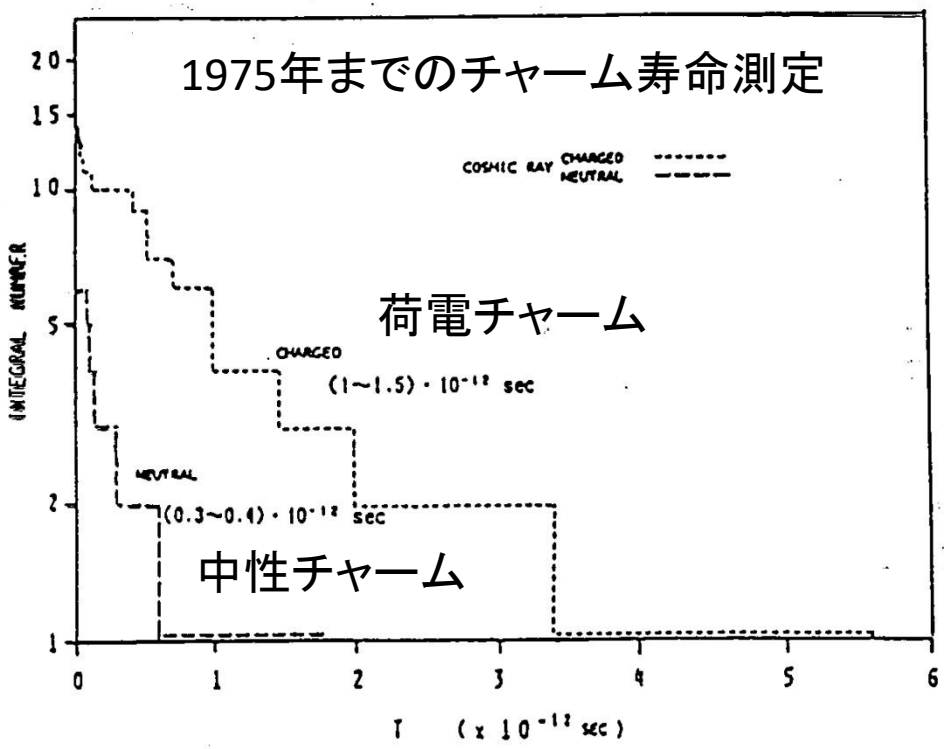
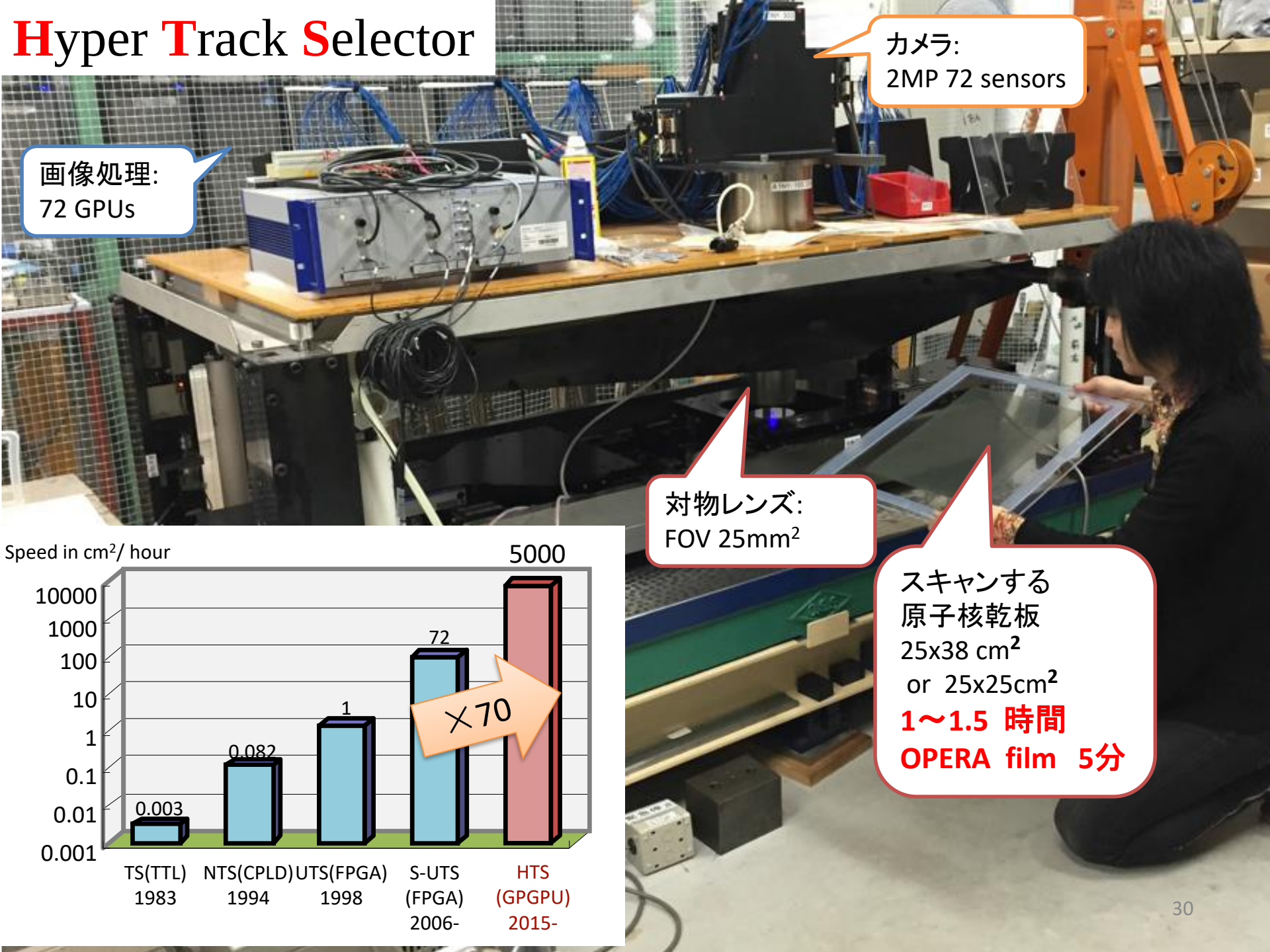


Fig.11 Life-time difference between charged and neutral charm particles observed in cosmic ray experiment (up to 1975)

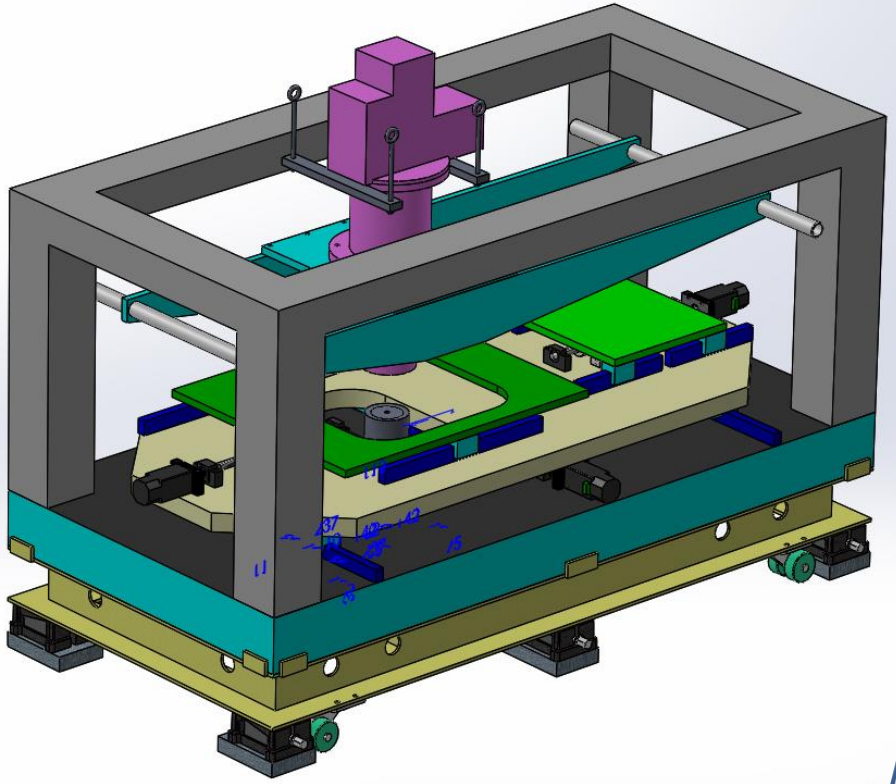
Hyper Track Selector



HTS Ⅰ ×5倍 ！2019

HTS Ⅱ

under construction



HTS Ⅰ

STEP Movement（a=5G)

～ 5000cm²/h

～ 1000㎡/Year

（1Y～8h/day×250days）

Continuous Movement

1）Slant Optics

→ reject Z dive

2）Flash Laser light source

Aiming Speck

2.5㎡/h

～5000㎡/Y