Visualizing the internal structure of a cryptodome with cosmic ray muon radiography

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MNR 2012

Imaging a thick target

thick→
Less muon after pasing through the otarget

Short time →
Less muon
↓
Exposure time should be longer

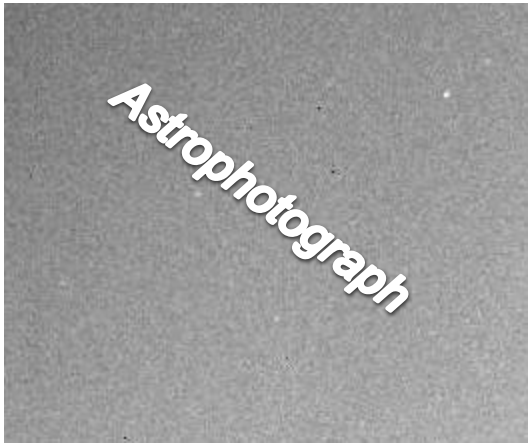
ISO3200
1 sec

Longer Exposure time

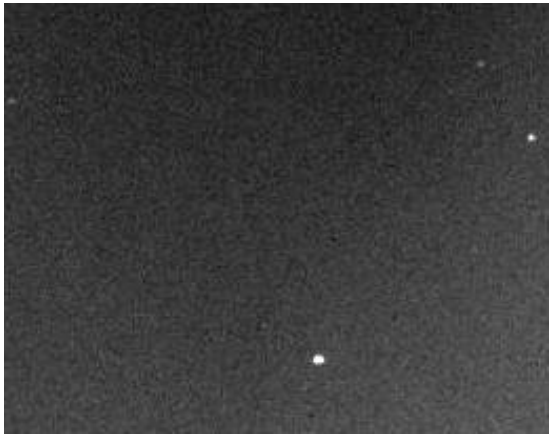
ISO3200
60 sec

If exposure time becomes longer noise become significant

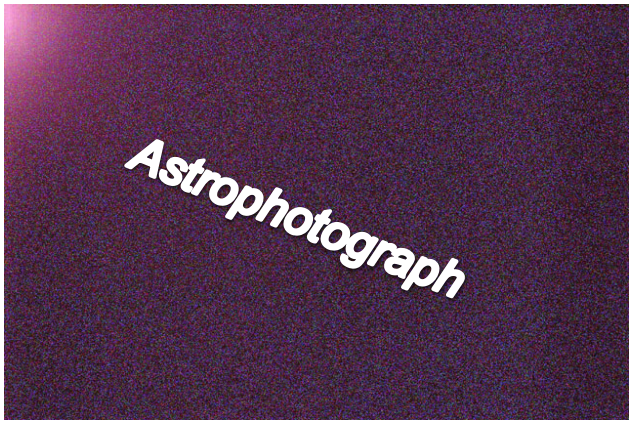
Uniform background



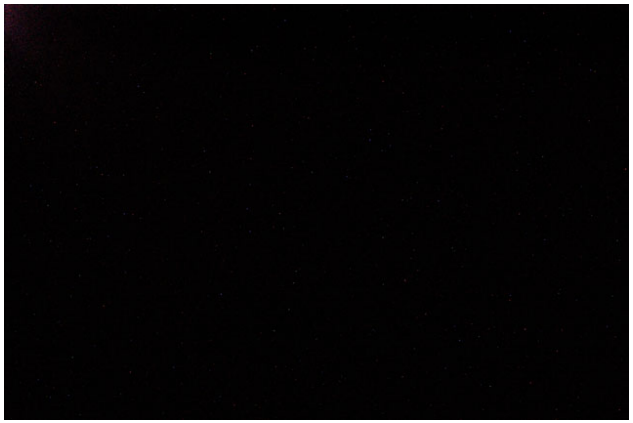
Noise reduction →



Non-uniform background



Noise reduction →



Sanyo Longtime exposure 180sec
ISO1600

Long time exposure 260 sec
ISO1600

When signal is sufficient

$N > \Delta N$

$$\sqrt{(N+\Delta N)} \sim \sqrt{N}$$

But if the target becomes thicker

$N < \Delta N$

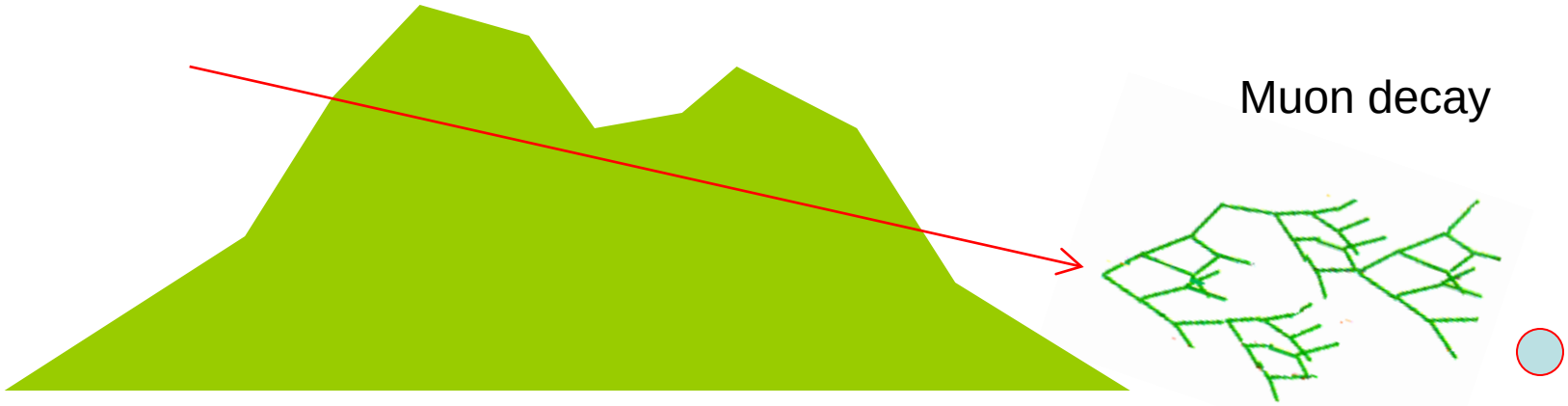
$$\sqrt{(N+\Delta N)} \sim \sqrt{\Delta N}$$

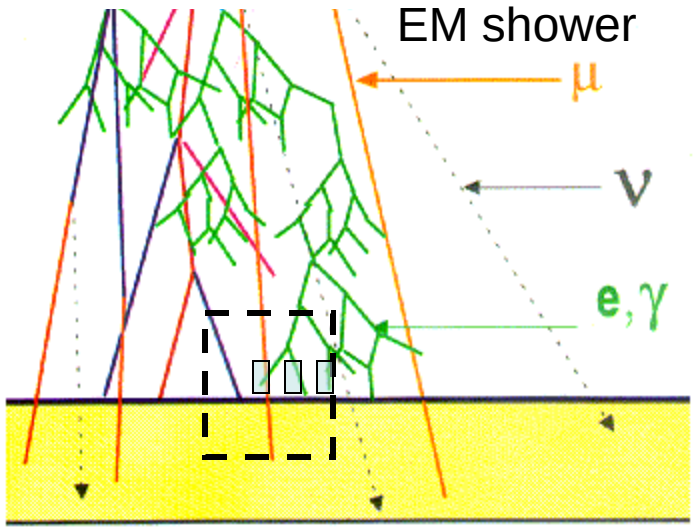
- When we reduce the noise level, weak muon can be seen

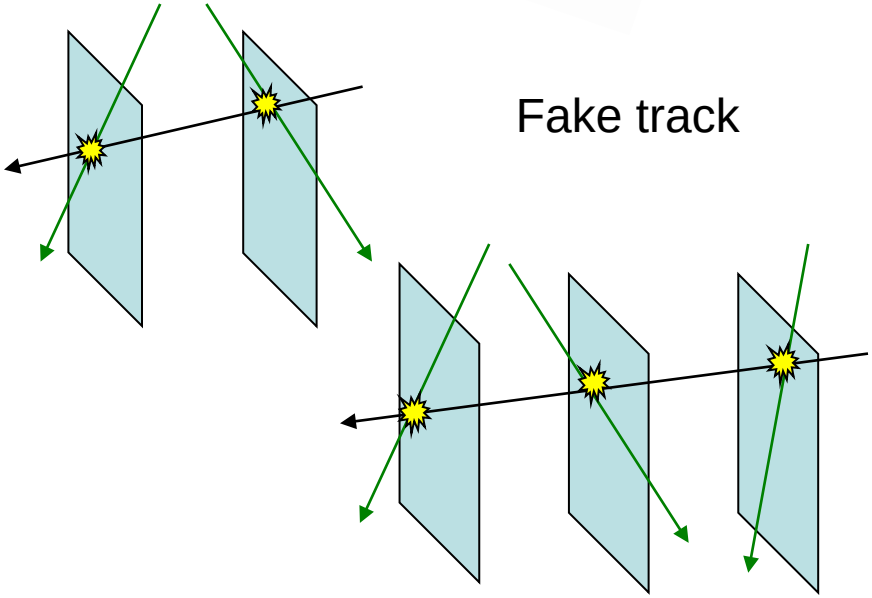
＝　We can shorten the observation time

How to reduce the noise level?

Possible background source

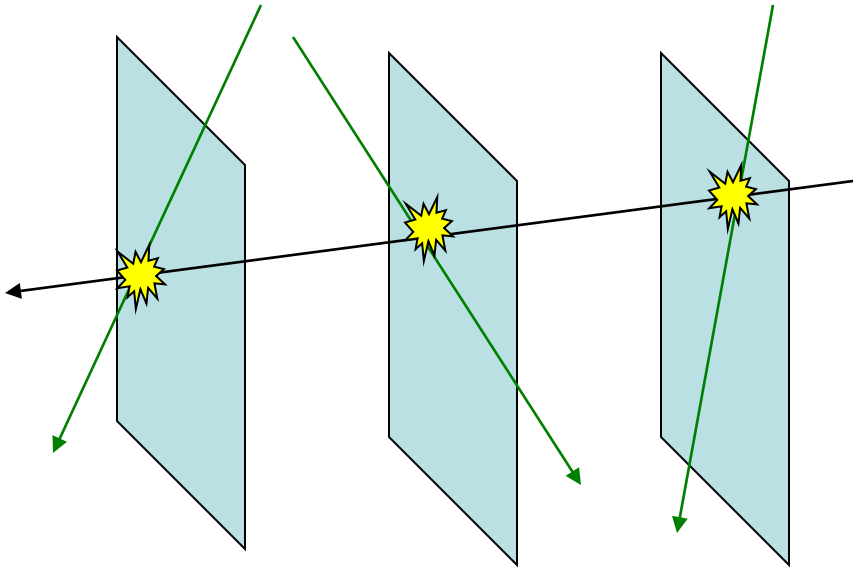






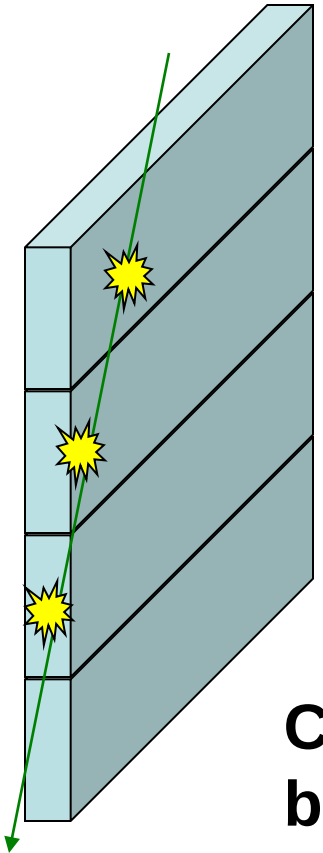
Removal of fake tracks

non-linearity cut



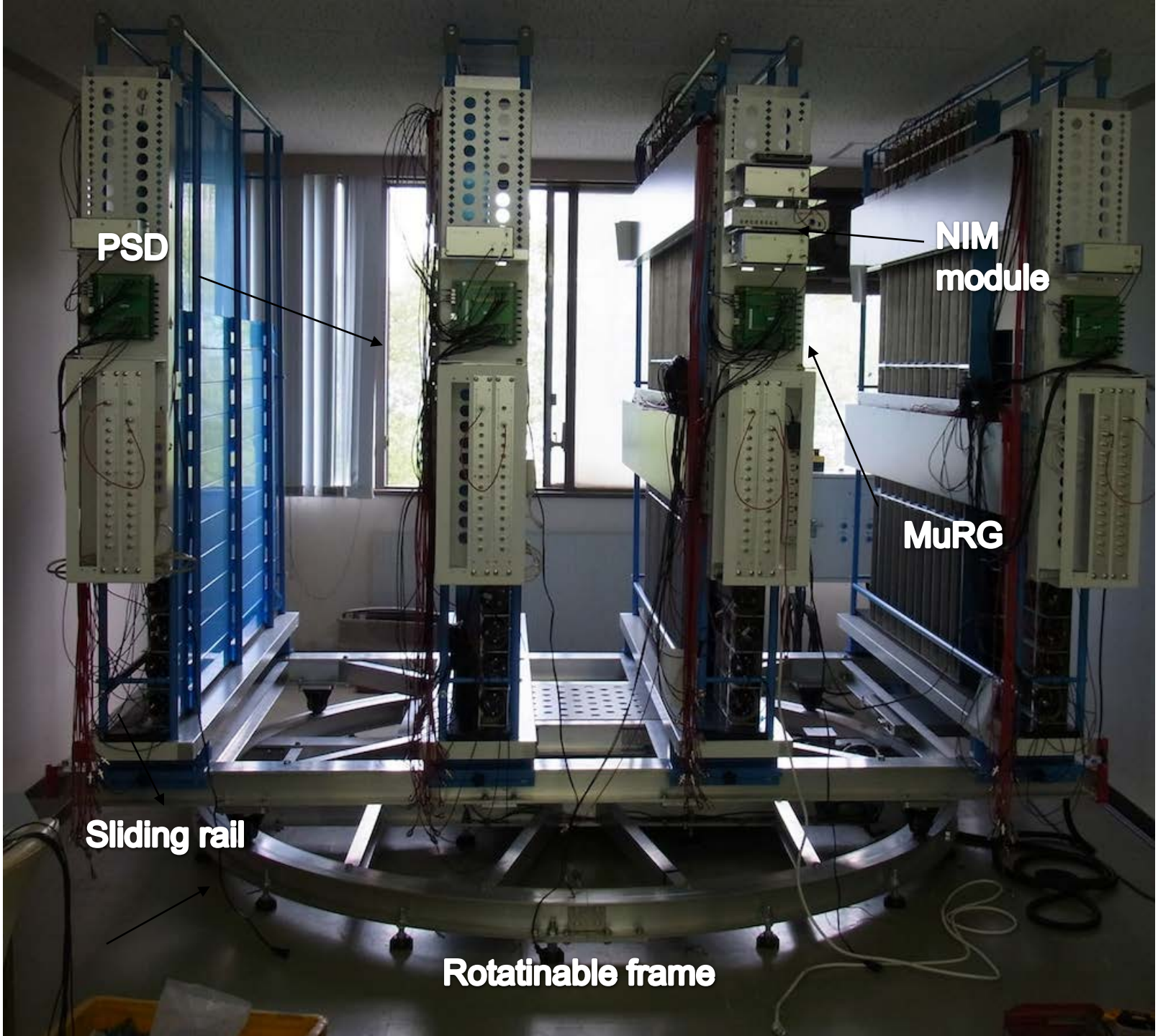
Pros：can reject events with wide range of incident angles.
Cons：cannot reject events making straight lines within the position resolution of the detector.

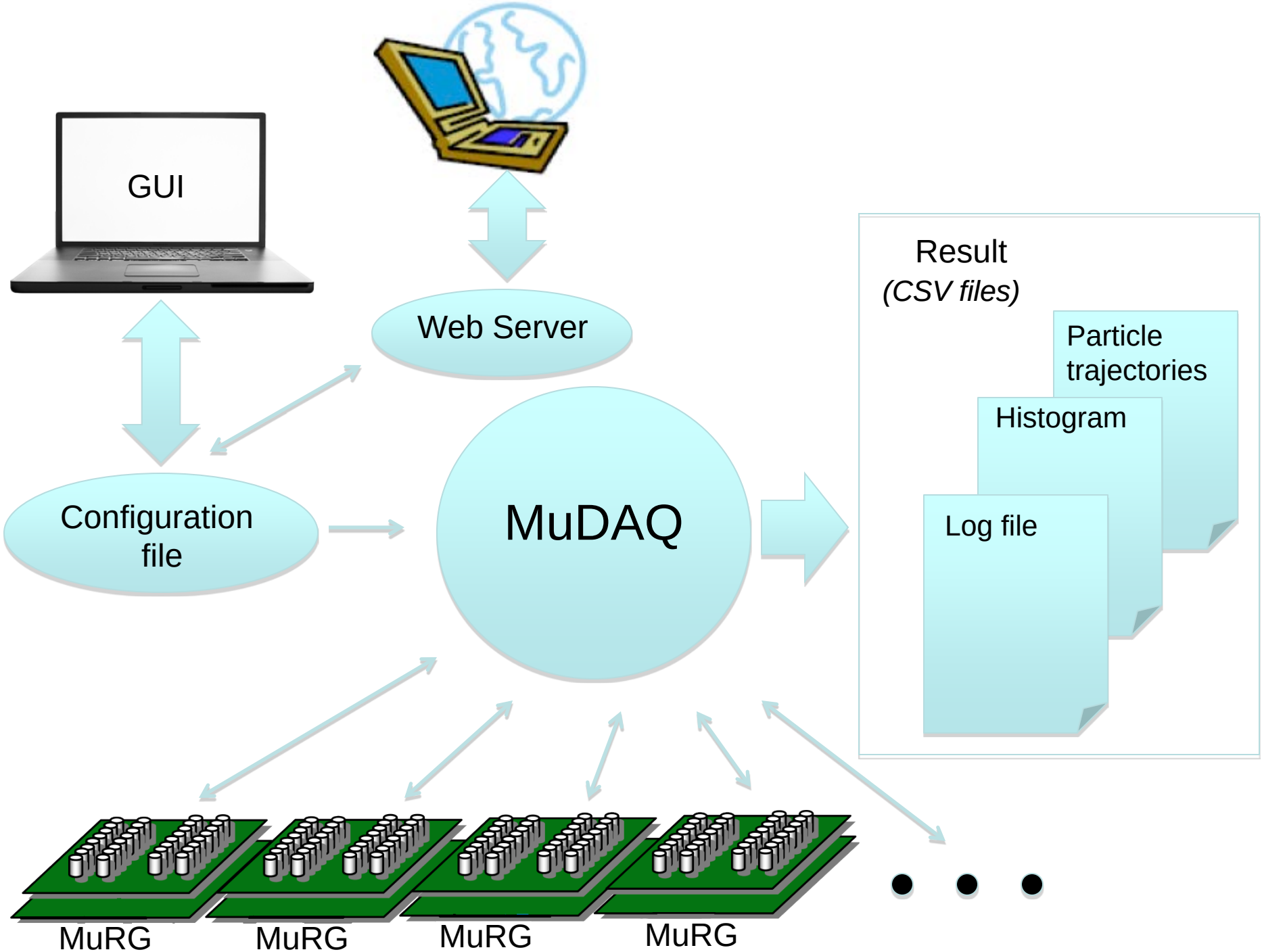
Multihit cut



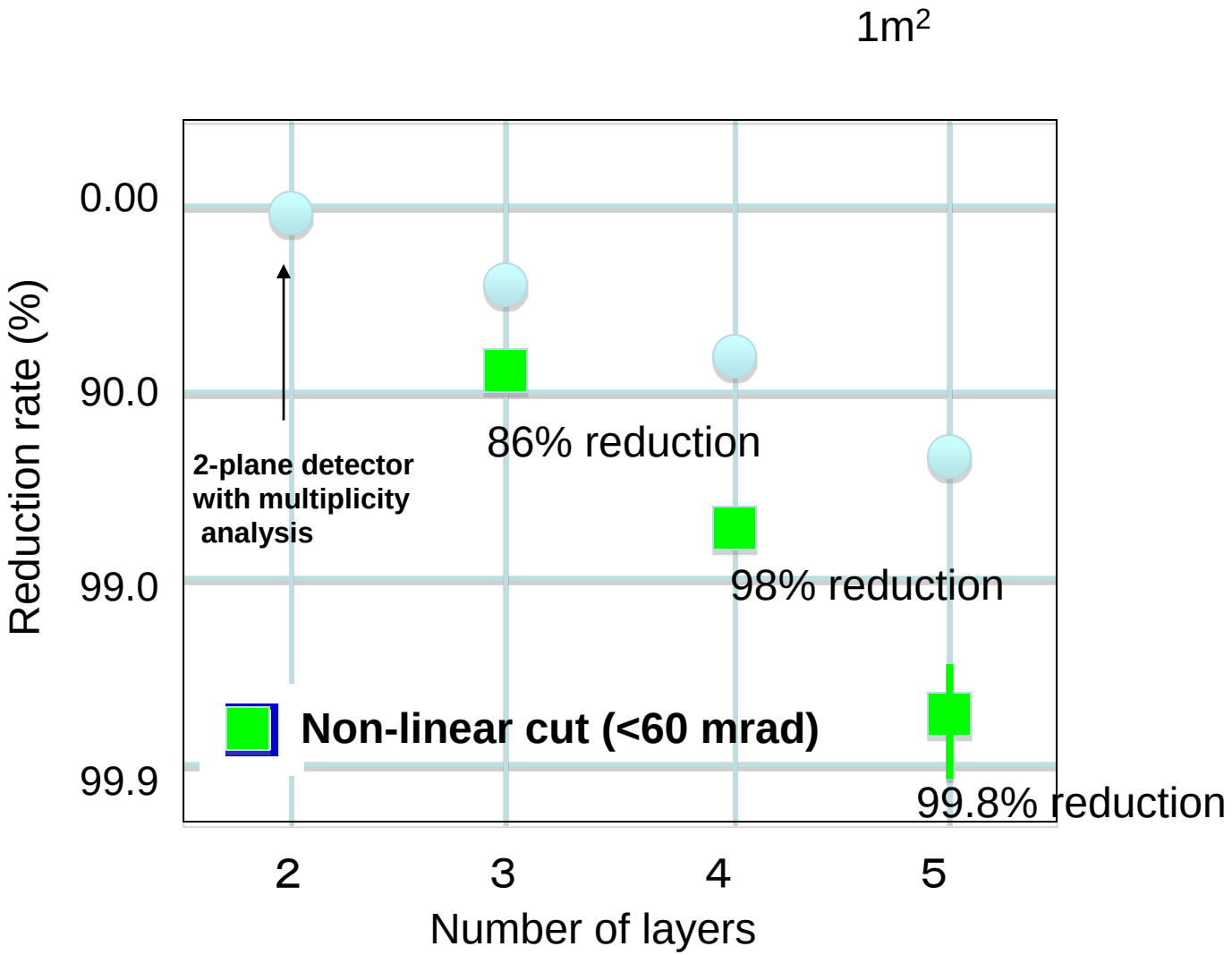
Pros： can reject all events from vertical.
Cons：cannot reject events arriving the angle: >(thickness)/(width)

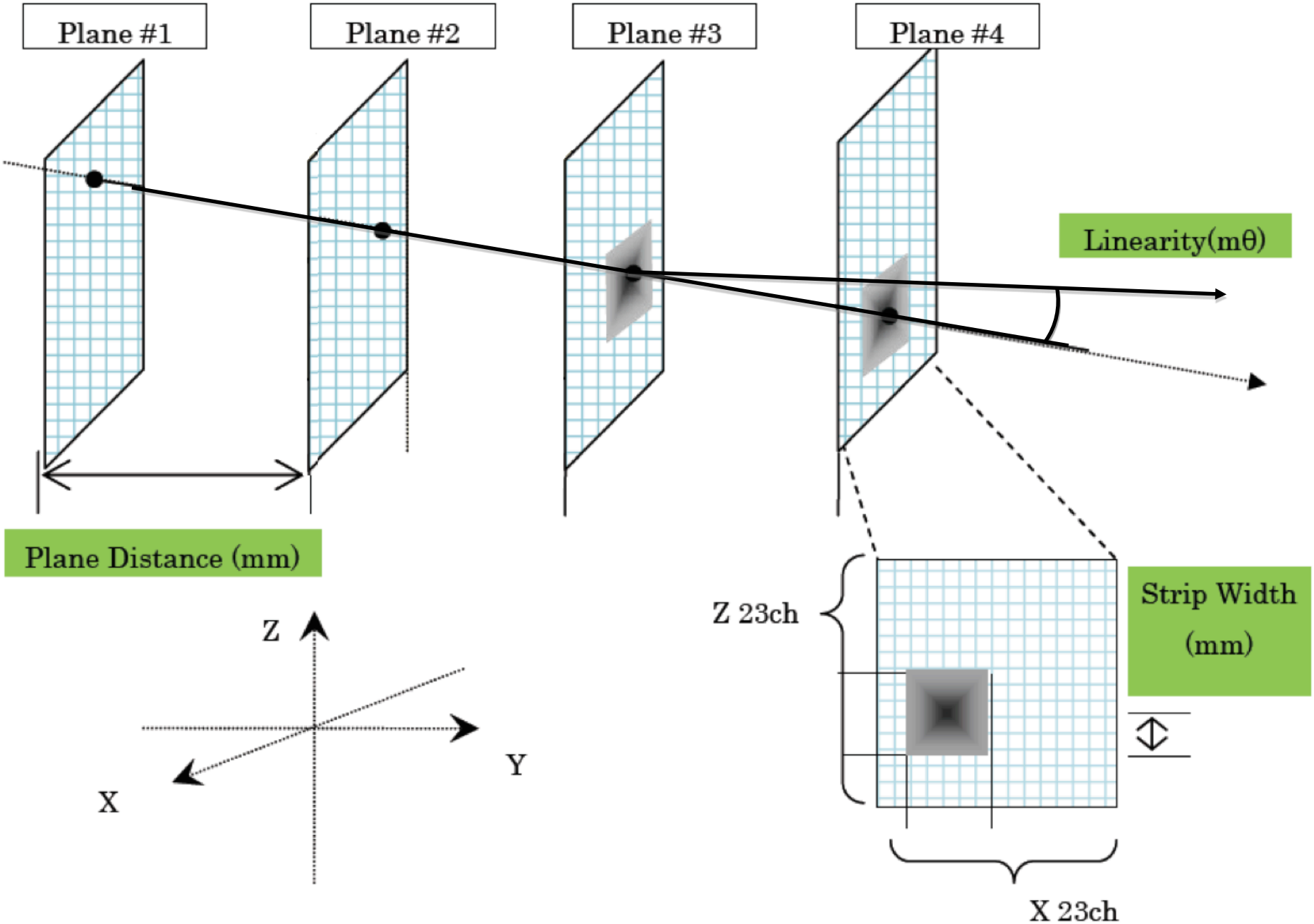
Combination of both methods


PSD
NIM
module
MuRG
Sliding rail
Rotatinable frame


GUI
Web Server
Configuration file
MuDAQ
Result
(CSV files)
Particle trajectories
Histogram
Log file
MuRG
MuRG
MuRG
MuRG

Layer number effect




Plane #1
Plane #2
Plane #3
Plane #4
Linearity(mθ)
Plane Distance (mm)
Z
Y
X
Z 23ch
Strip Width
(mm)
X 23ch

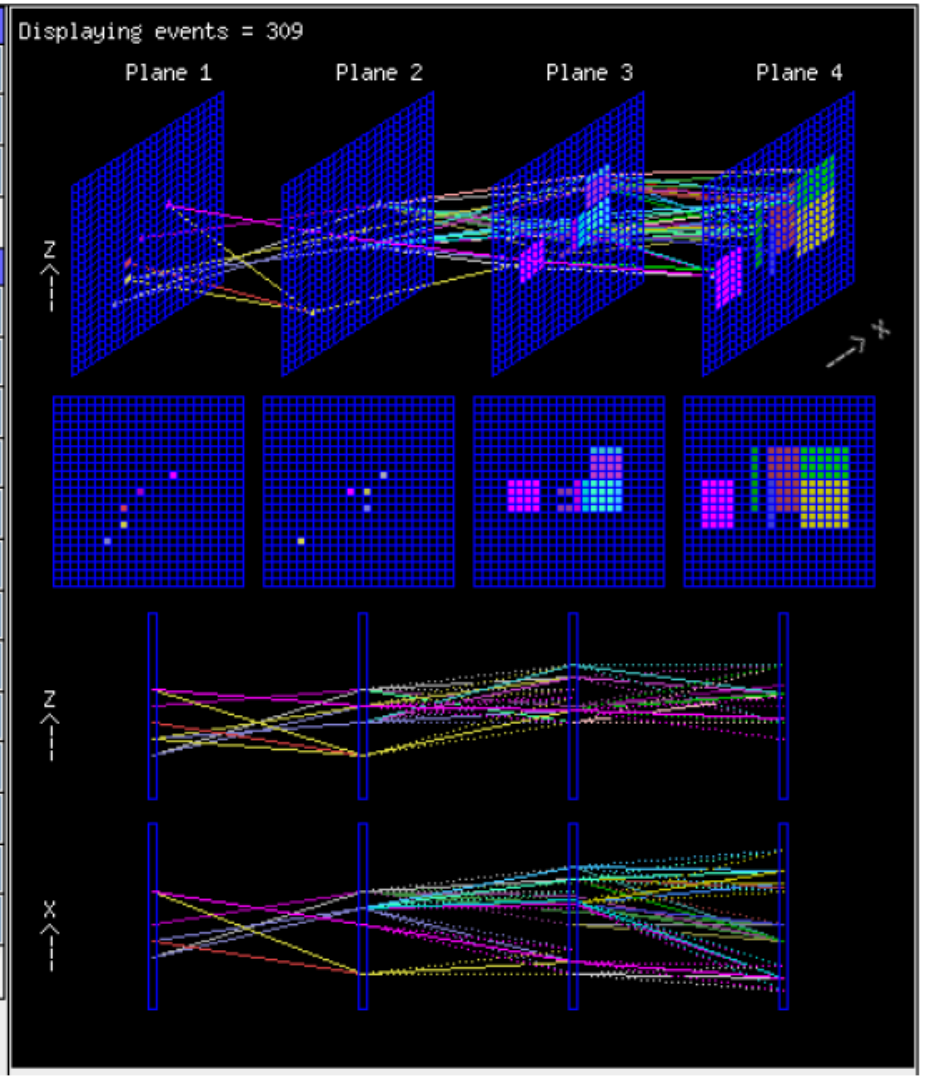
GUI Screen

Event Display for Plane 1-2-3-4

Testing Information	
Start Time	2009/10/08 16:52:48
Current Time	2009/10/08 16:56:44
Duration	0days 00:03:56
☑ update time and graphs. 10 seconds	

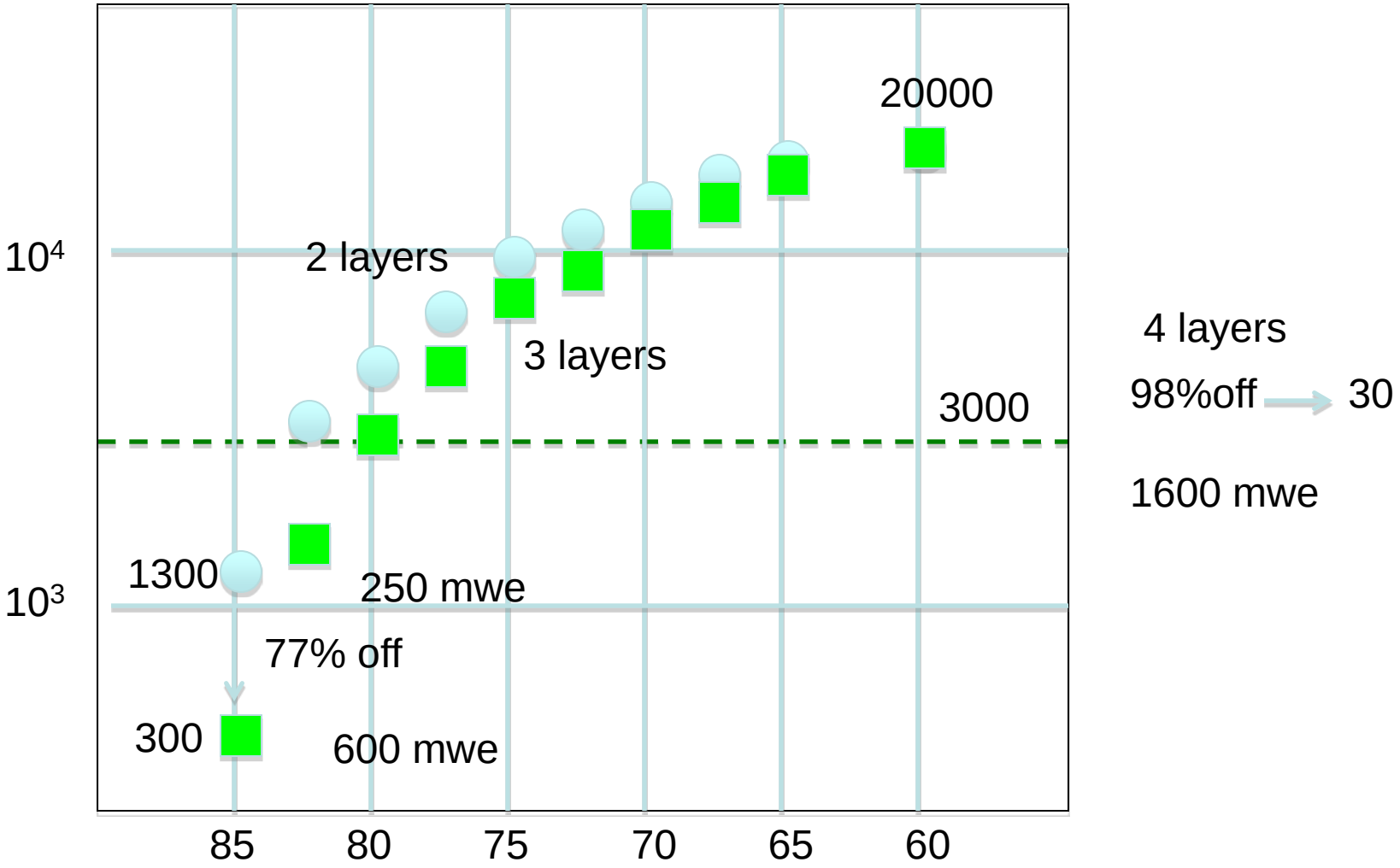
Settings	
Plane Distance 1-2 [mm]	1000
Plane Distance 2-3 [mm]	1000
Plane Distance 3-4 [mm]	1000
Strip Width [mm]	100
Linearity [mrad]	100
Linearity(Multiplicity) [mrad]	100
Multi Plane Window [nsec]	200
Plane Window [nsec]	255
Multiplicity X [0-22]	22
Multiplicity Z [0-22]	22
Data Save Interval [hours]	1
Graph Display Events[events]	3000
Data Update Interval[sec]	5

Update Settings

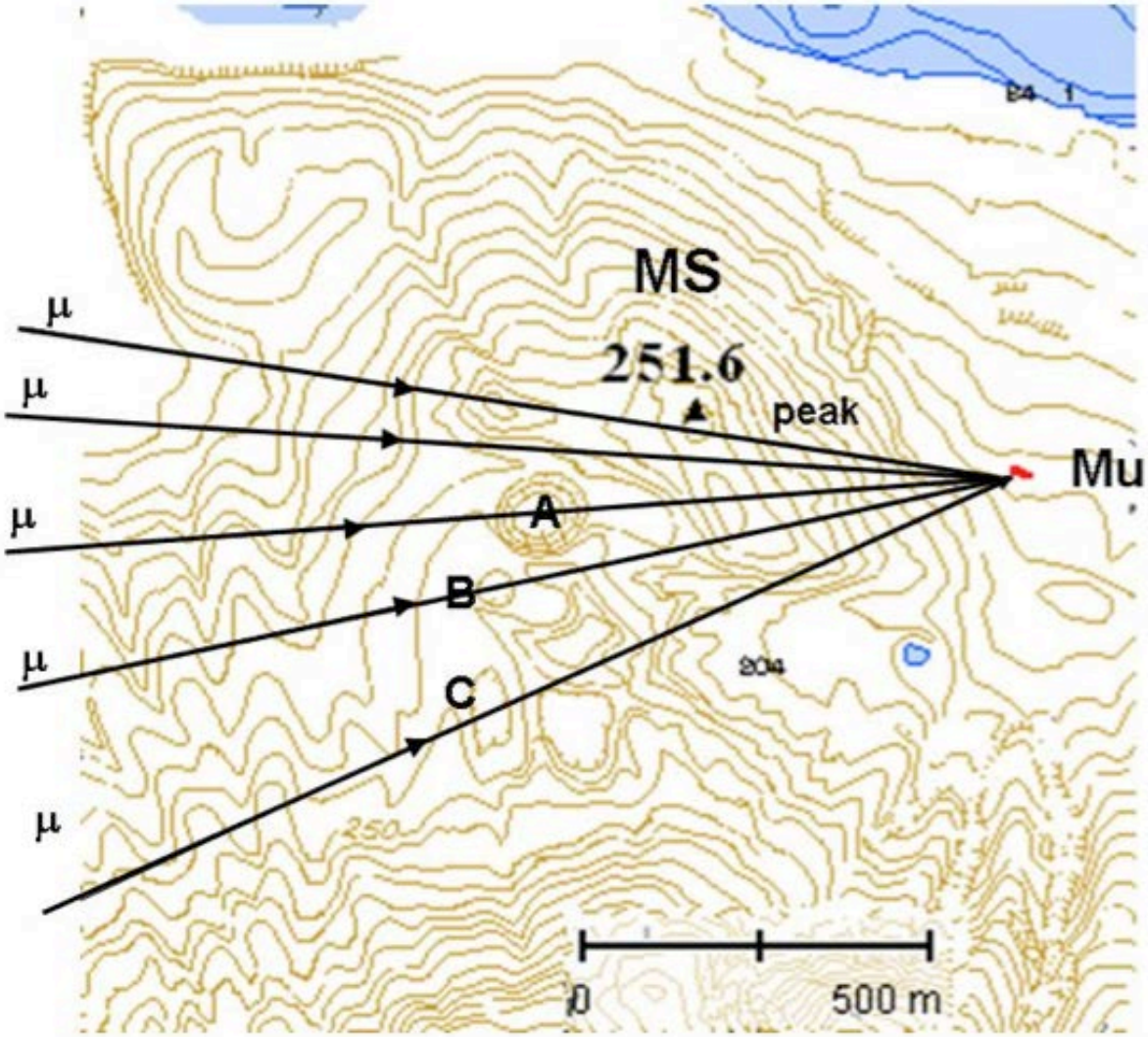


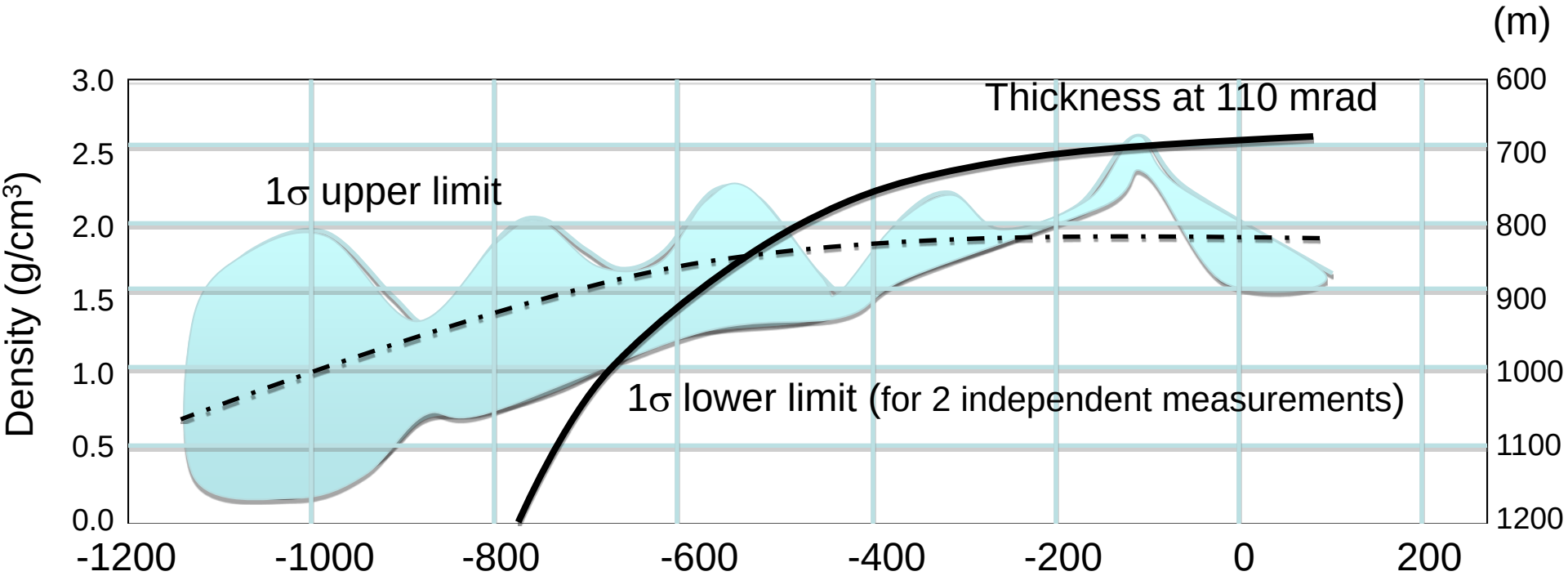
Test Experiment

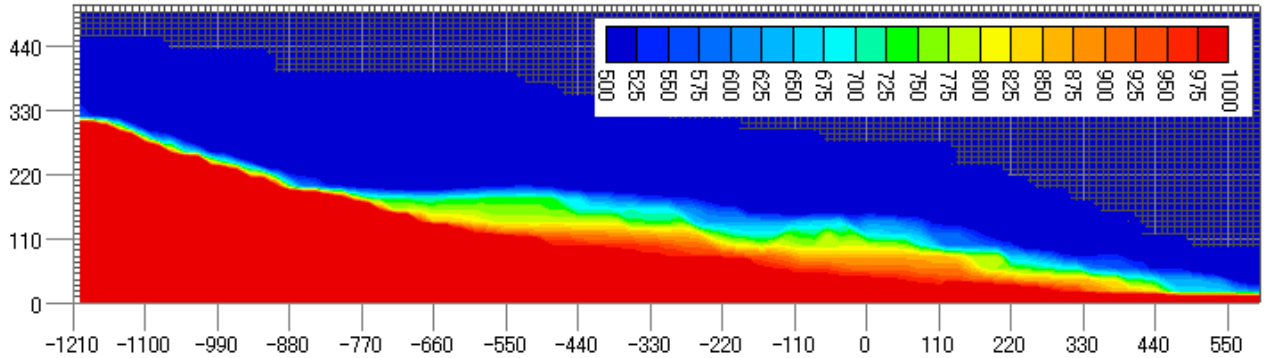
Test result


20000
10^4
2 layers
3 layers
4 layers
98%off
30
3000
1600 mwe
1300
10^3
250 mwe
77% off
300
600 mwe
85
80
75
70
65
60

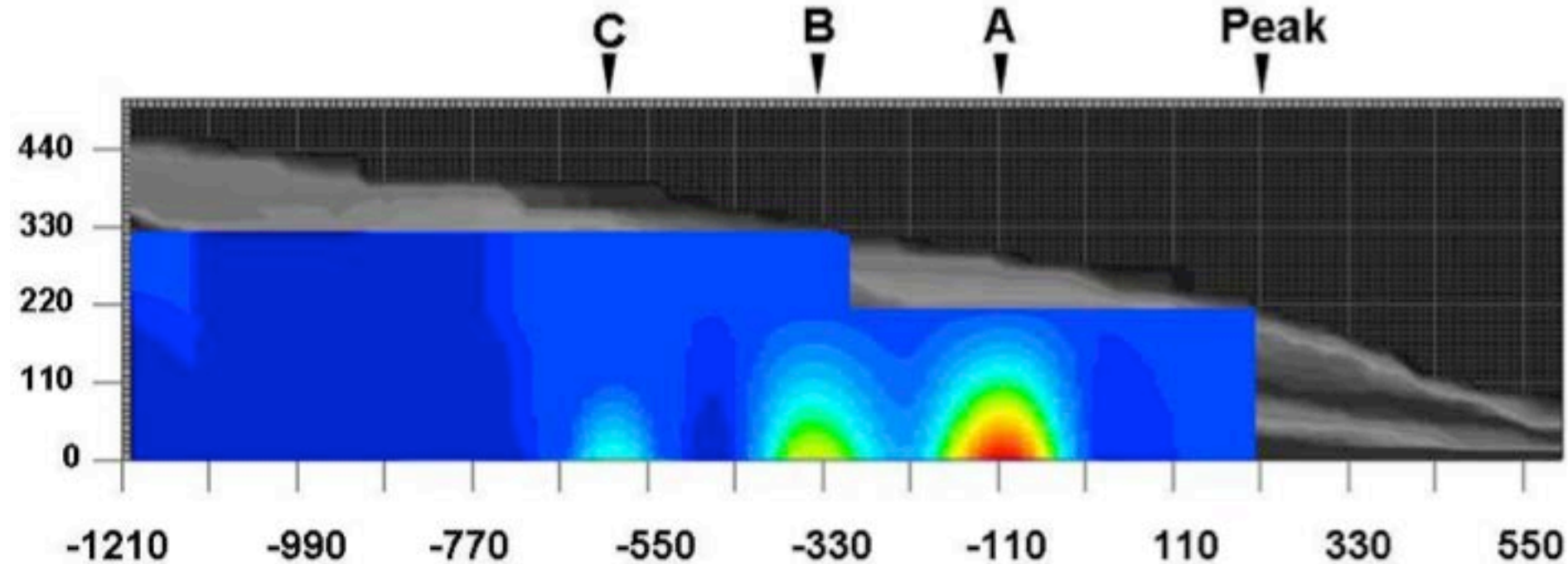
Test measurement part 2

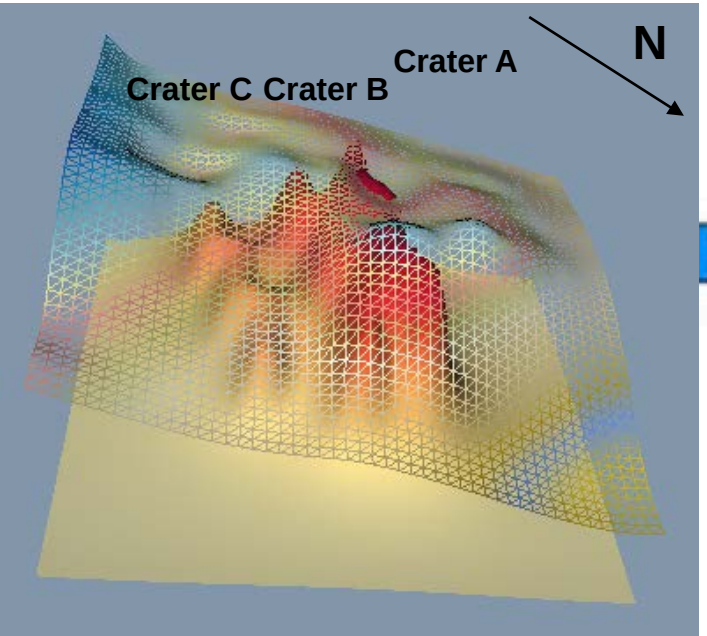


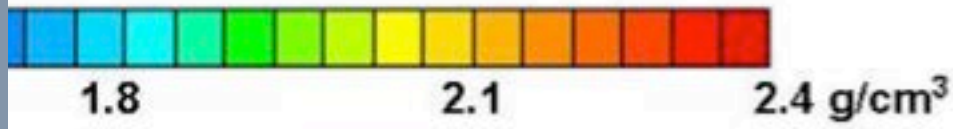

(m)
Thickness at 110 mrad
1σ upper limit
1σ lower limit (for 2 independent measurements)
Density (g/cm³)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
600
700
800
900
1000
1100
1200
-1200
-1000
-800
-600
-400
-200
0
200


440
330
220
110
0
-1210
-1100
-990
-880
-770
-660
-550
-440
-330
-220
-110
0
110
220
330
440
550
500
525
550
575
600
625
650
675
700
725
750
775
800
825
850
875
900
925
950
975
1000

10 days


C
B
A
Peak
440
330
220
110
0
-1210
-990
-770
-550
-330
-110
110
330
550
Azimuth angle (mrad)

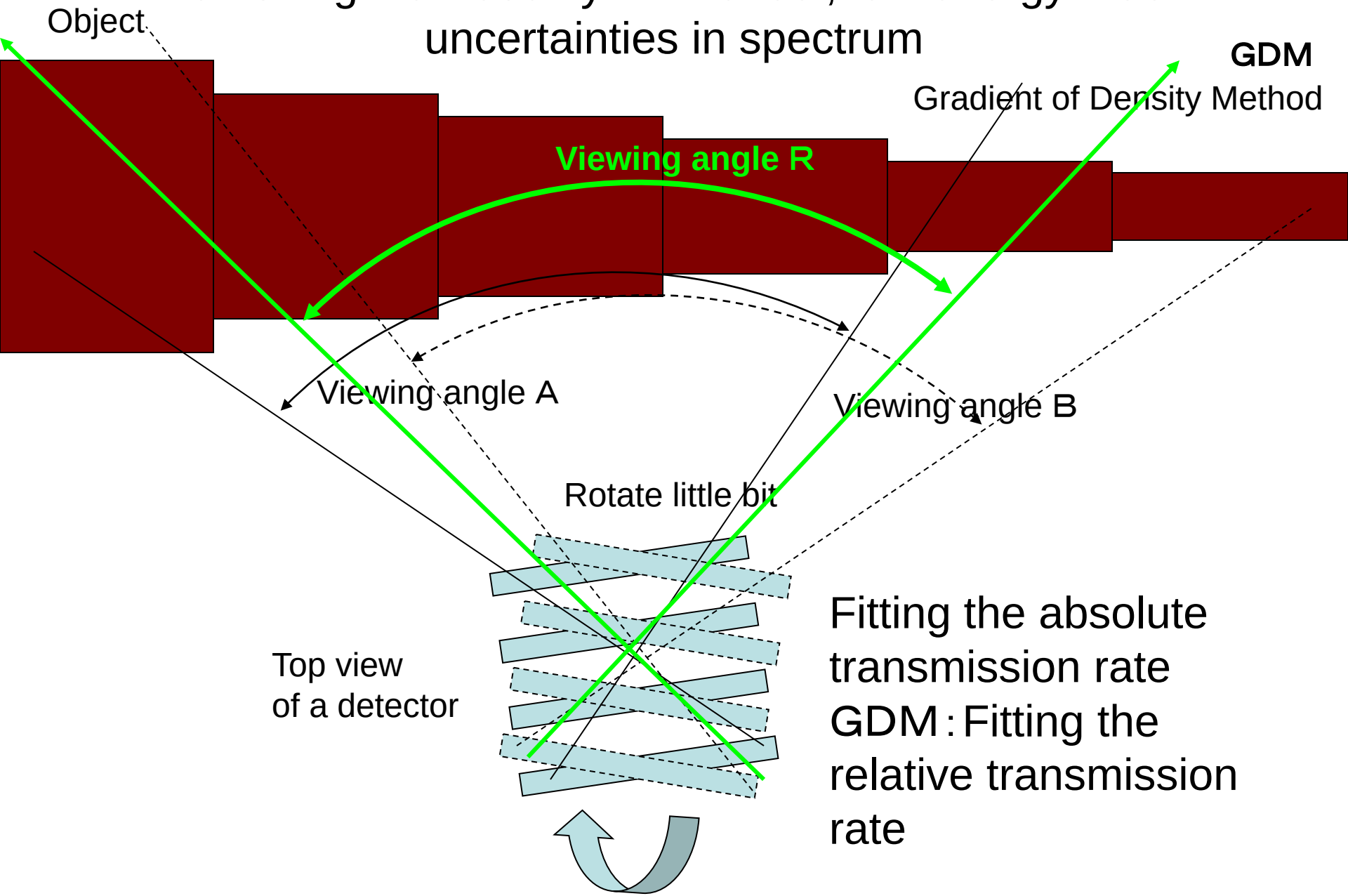

Crater A
Crater C Crater B
N


1.8
2.1
2.4 g/cm³

Conclusion

- Multi-layered PSD system worked well.
- Meij-shinzan lava dome was imaged within 10 days.
- This can be shortened to 5 with a full detector.

Removing individuality E-W effect, low energy muon uncertainties in spectrum

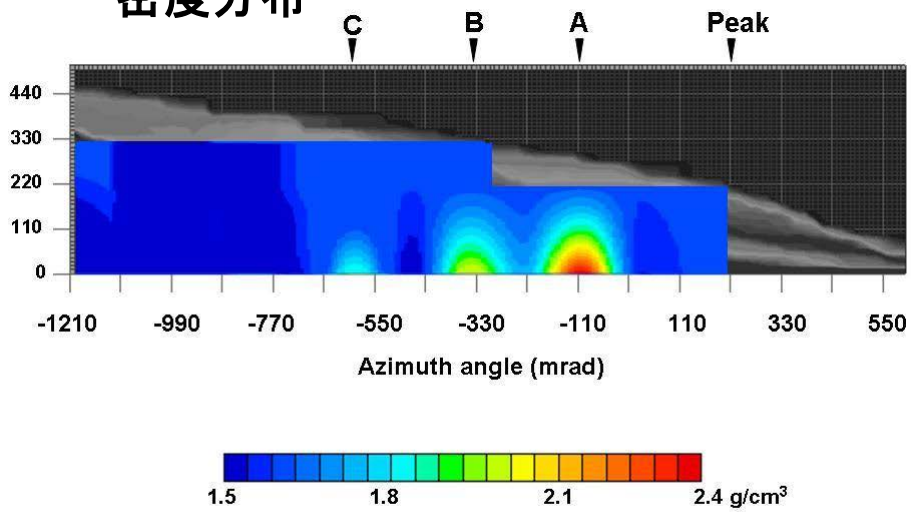


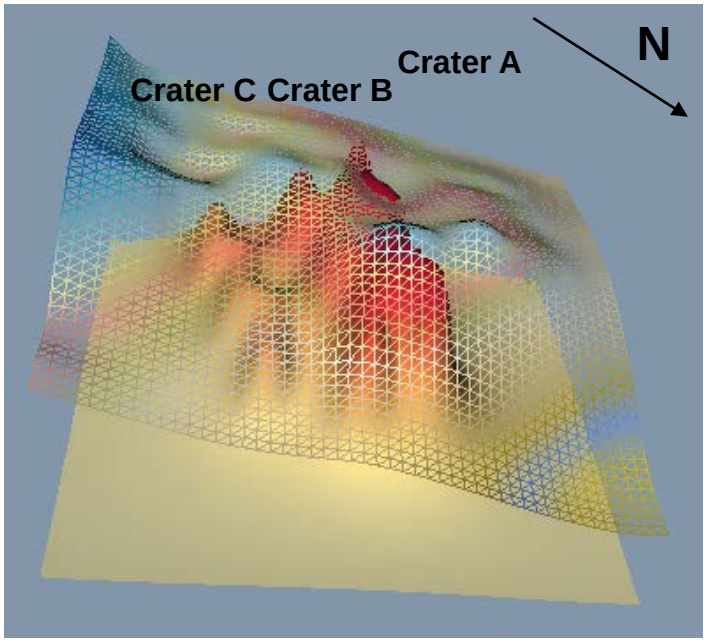
Fitting the absolute transmission rate

GDM : Fitting the relative transmission rate

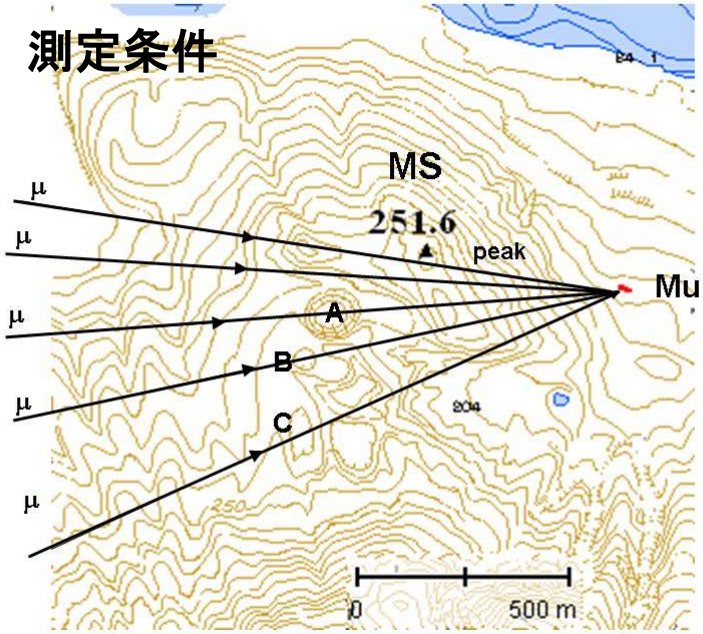
明治新山の測定結果

密度分布

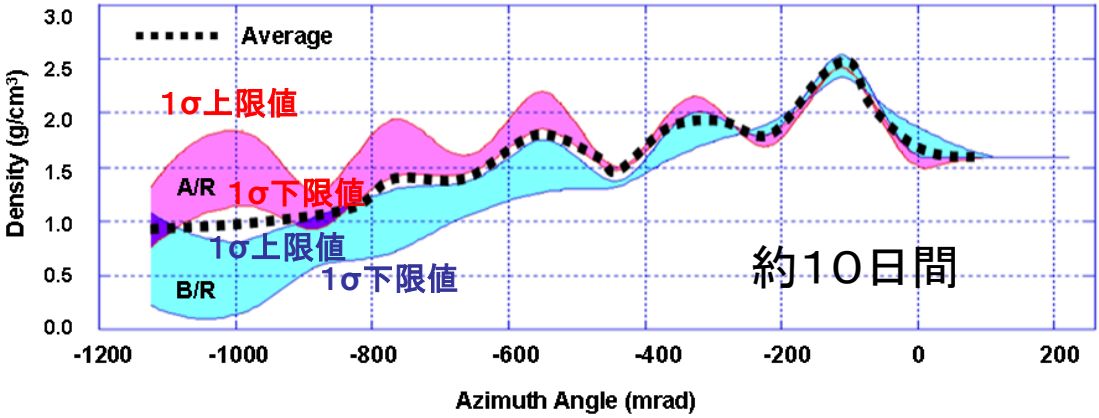




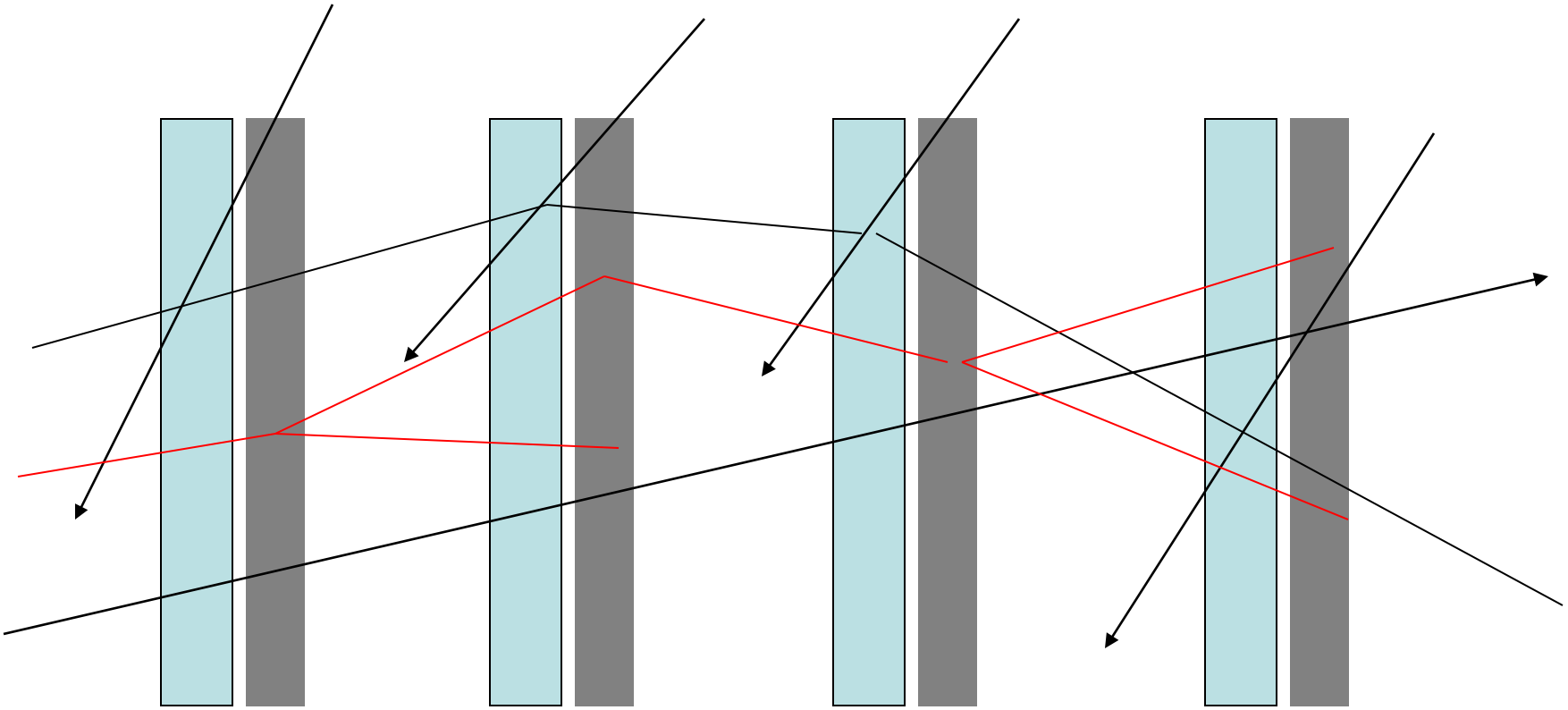
測定条件



導出密度の確証度

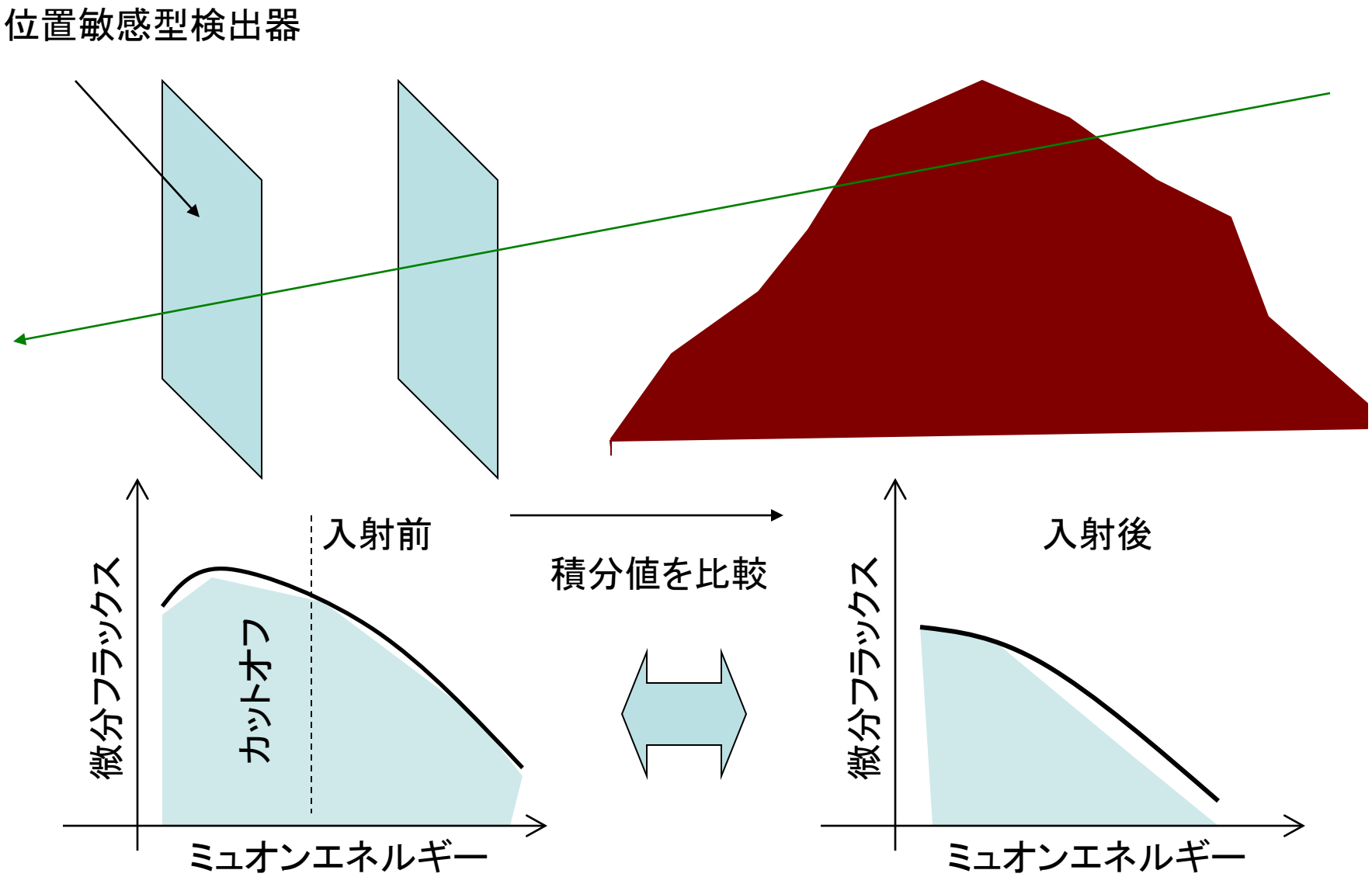


原理



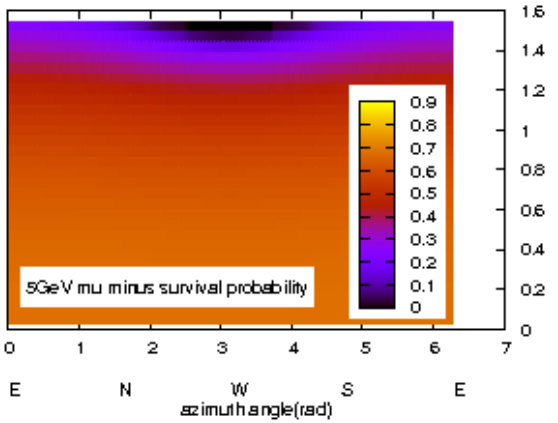
線形性の要求
十分な厚さの散乱体による吸収・散乱
多重イベント解析による除去

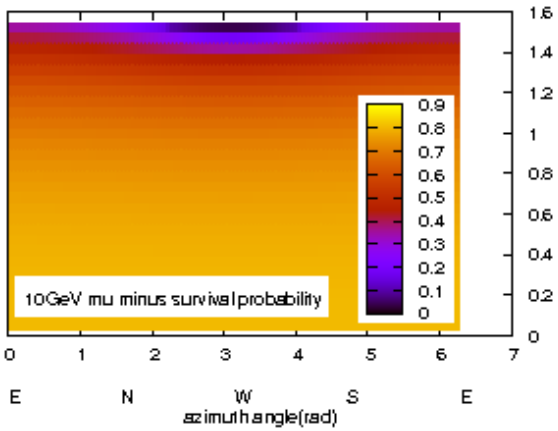
従来のミュオンラジオグラフィー
Tanaka et al. 2003

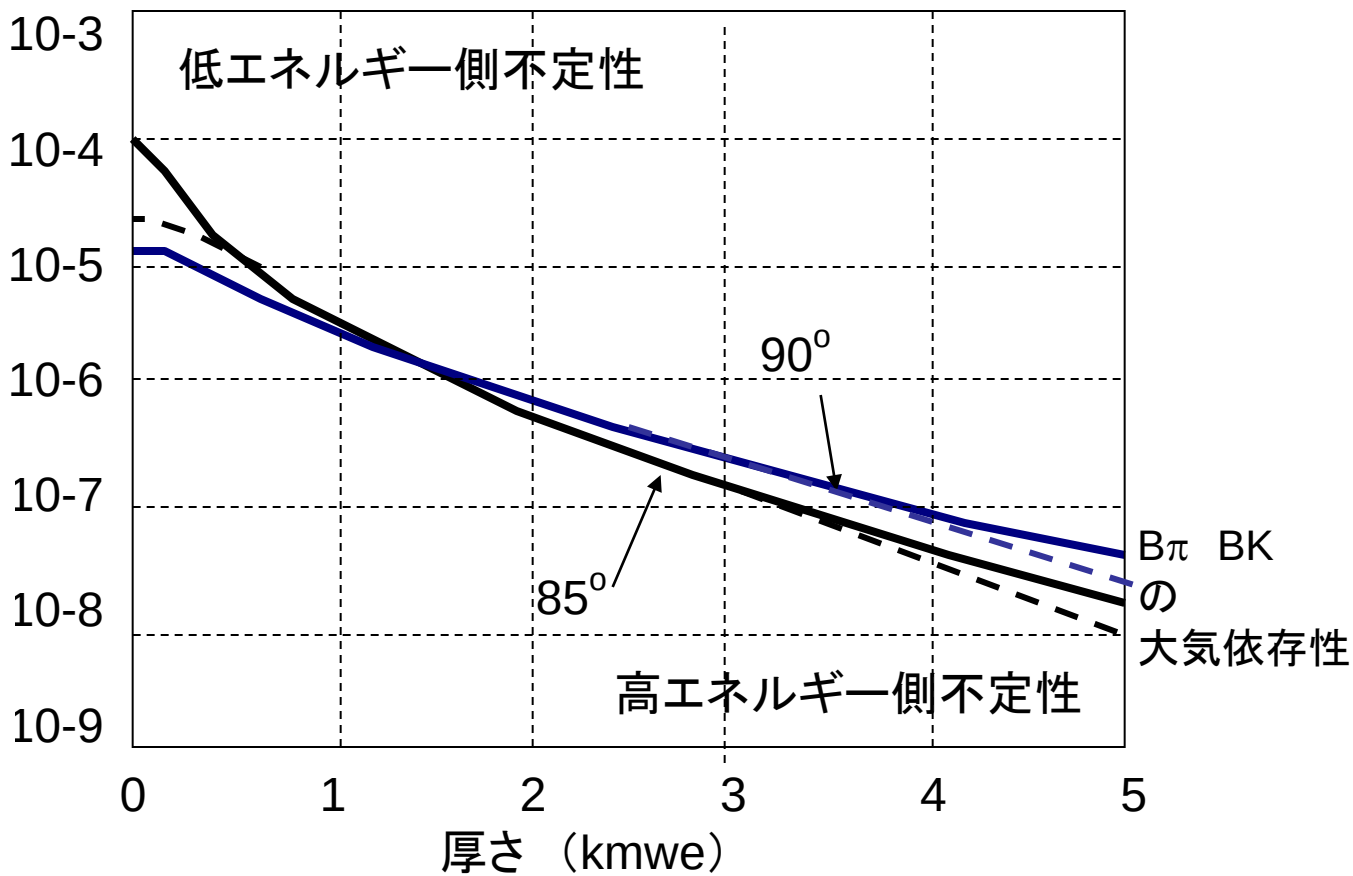


火山体のミュオンラジオグラフィーのIntrinsicな問題

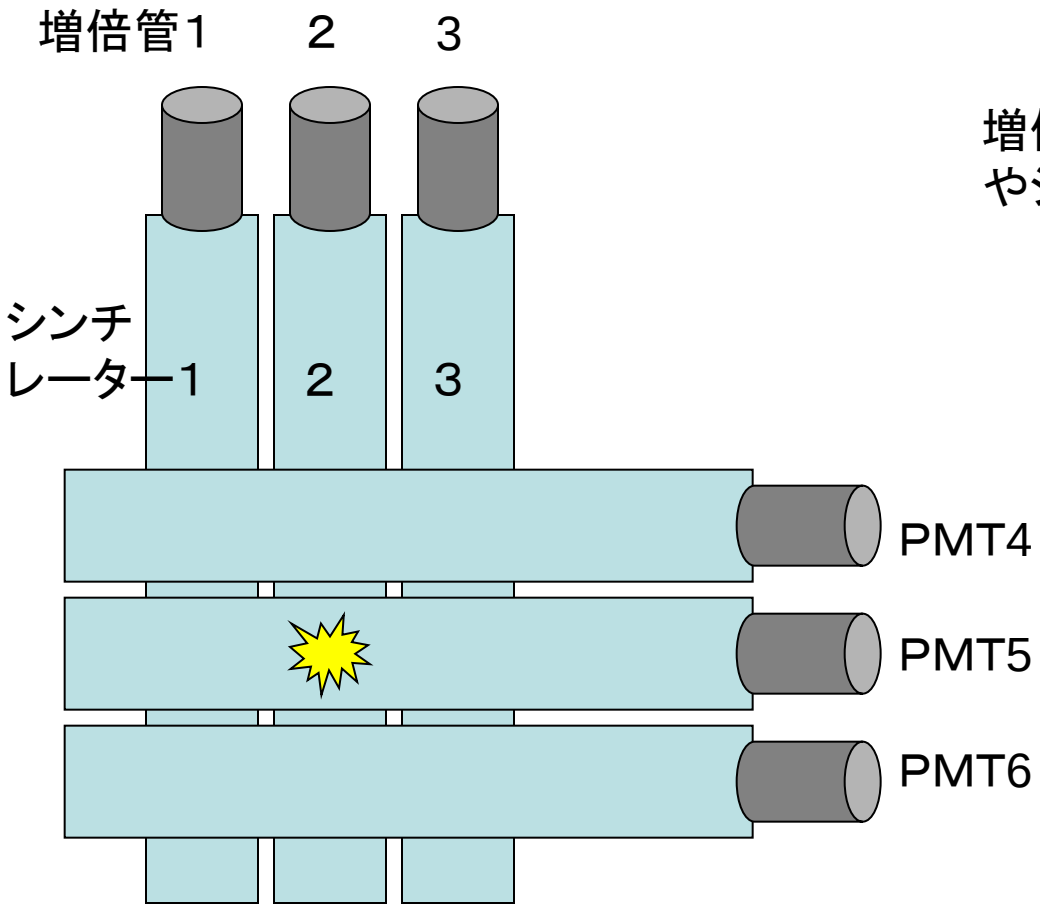
ミュオン微分フラックスのモデルに依存する。



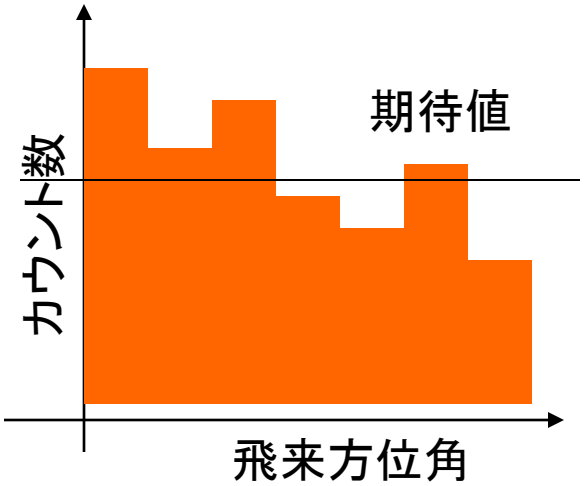




検出器の個性による非一様バックグランド （デジカメの出力アンプの熱ノイズに相当）



増倍管
やシンチレーターの個性は一つ一つ違う。



従来は違う仰角の方位角分布で
規格化＝多分不十分

今後の課題

- 厚くなるに従い導出密度が低くなる
  - 厚くなるに従いSN比が落ちる。
  - 検出器の枚数を増やす
- 現在のスペックは６０％
  - 検出器をフルスペックに
  - １０日間の測定時間が6日間に
- GDM解析アルゴリズムの自動化
  - 誰でもボタン一つで密度分布をマッピング

EM成分による一様バックグランド （デジカメのダークノイズに相当）