PANDA -
a mobile reactor neutrino monitor

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Introduction

- IAEA reactor safeguard regime

  IAEA recommends investigation of near-field antineutrino monitoring capabilities.

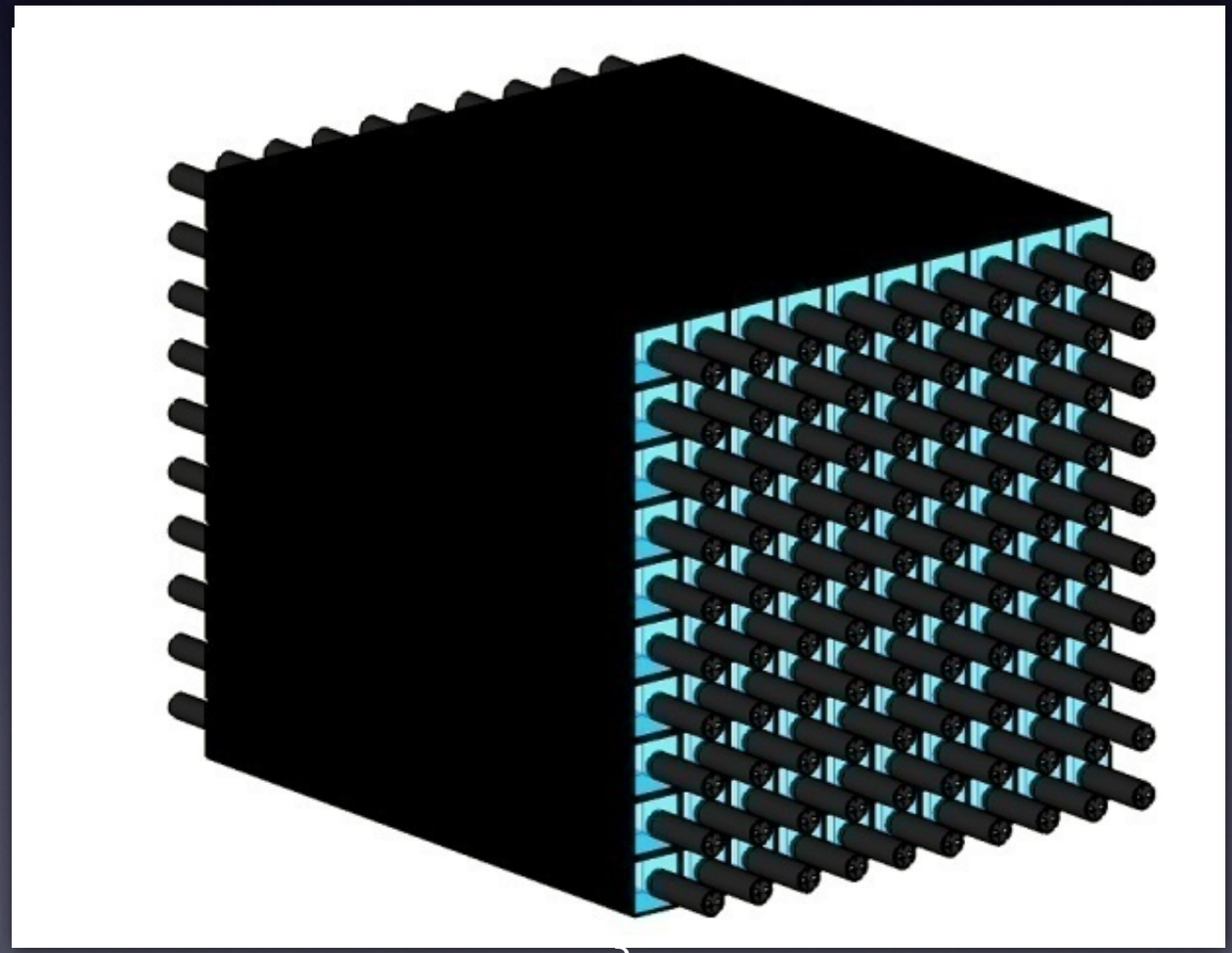
- a mobile above-ground detector

  Our detector takes advantage of non-intrusiveness of antineutrino monitoring.

PANDA Project

Plastic Anti-Neutrino Detector Array

- The detector consists of 10 x 10 modules.



PANDA Project

- PANDA Module
  - 10 cm x 10 cm x 100 cm plastic scintillator (10 kg)
  - acrylic cubic light guides
  - 2-inch PMTs
  - aluminized mylar
  - Gd doped sheet (4.9 mg/cm^2)

PANDA Project

Plastic Anti-Neutrino Detector Array

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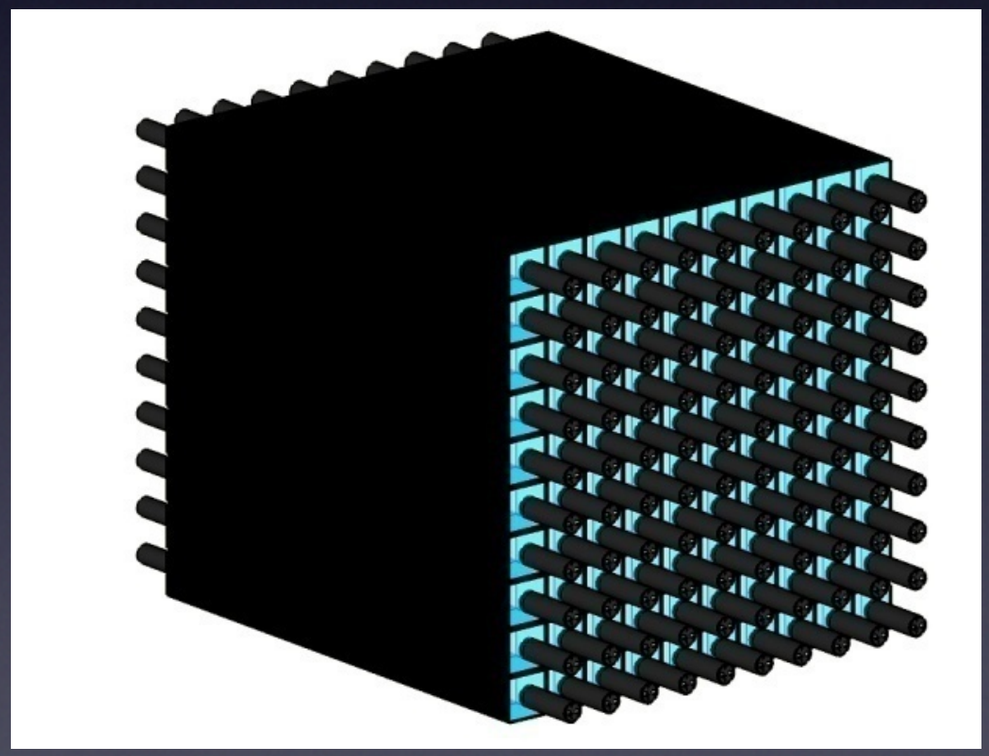
- The target mass is 1 ton.



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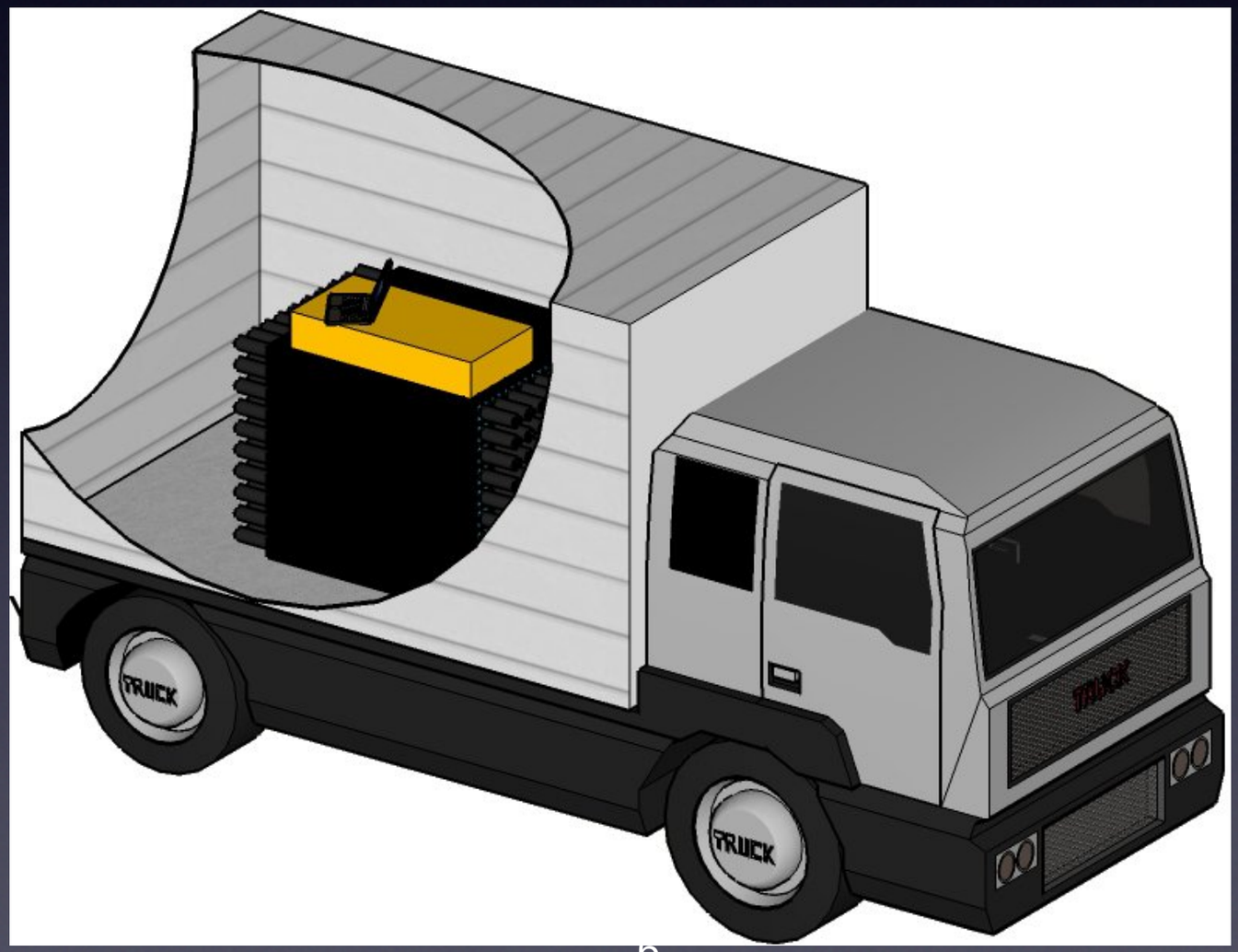

target mass:
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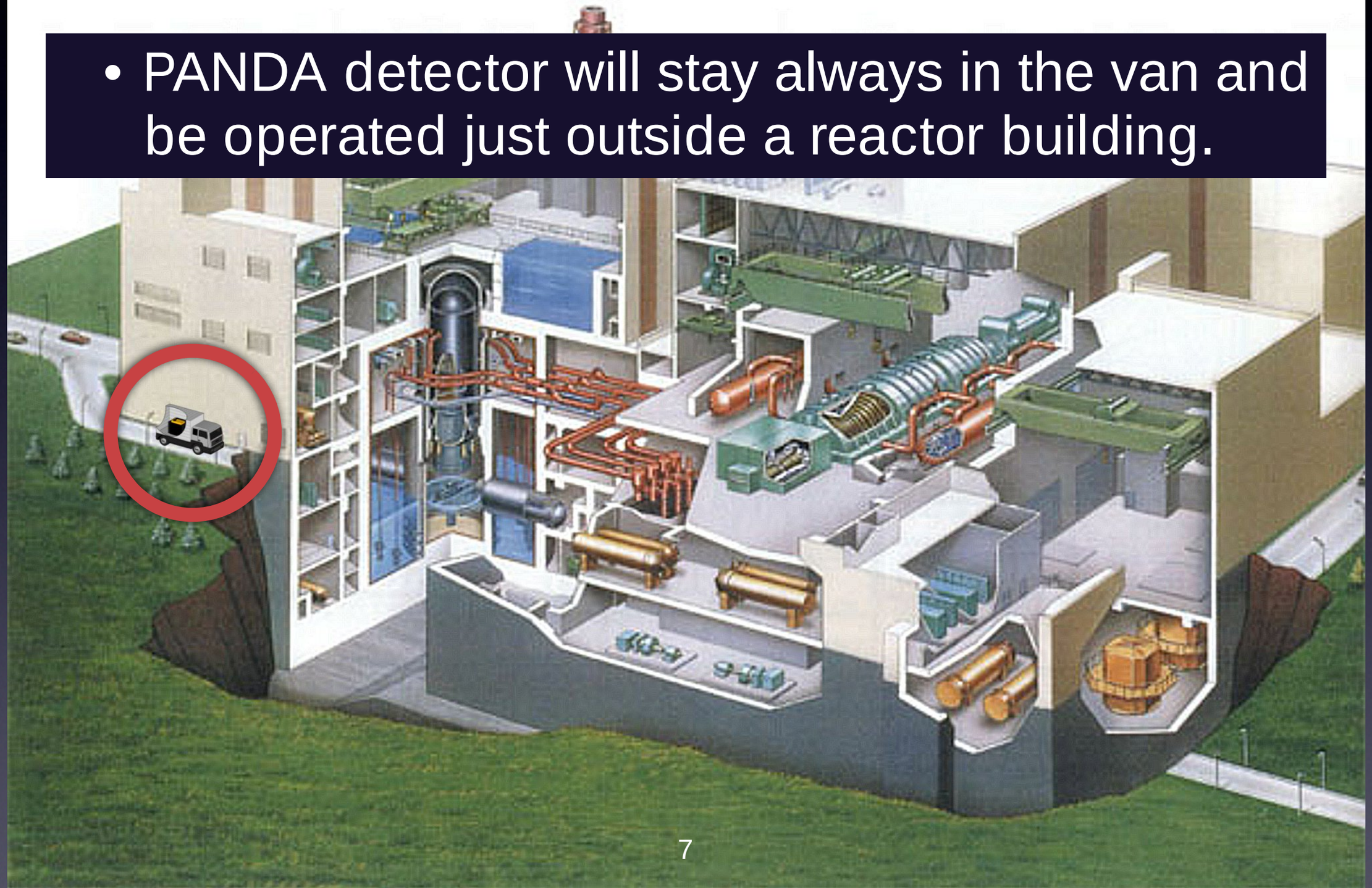


Features

- Mobility

  The target mass of PANDA detector is about 1 ton.

- Solid State

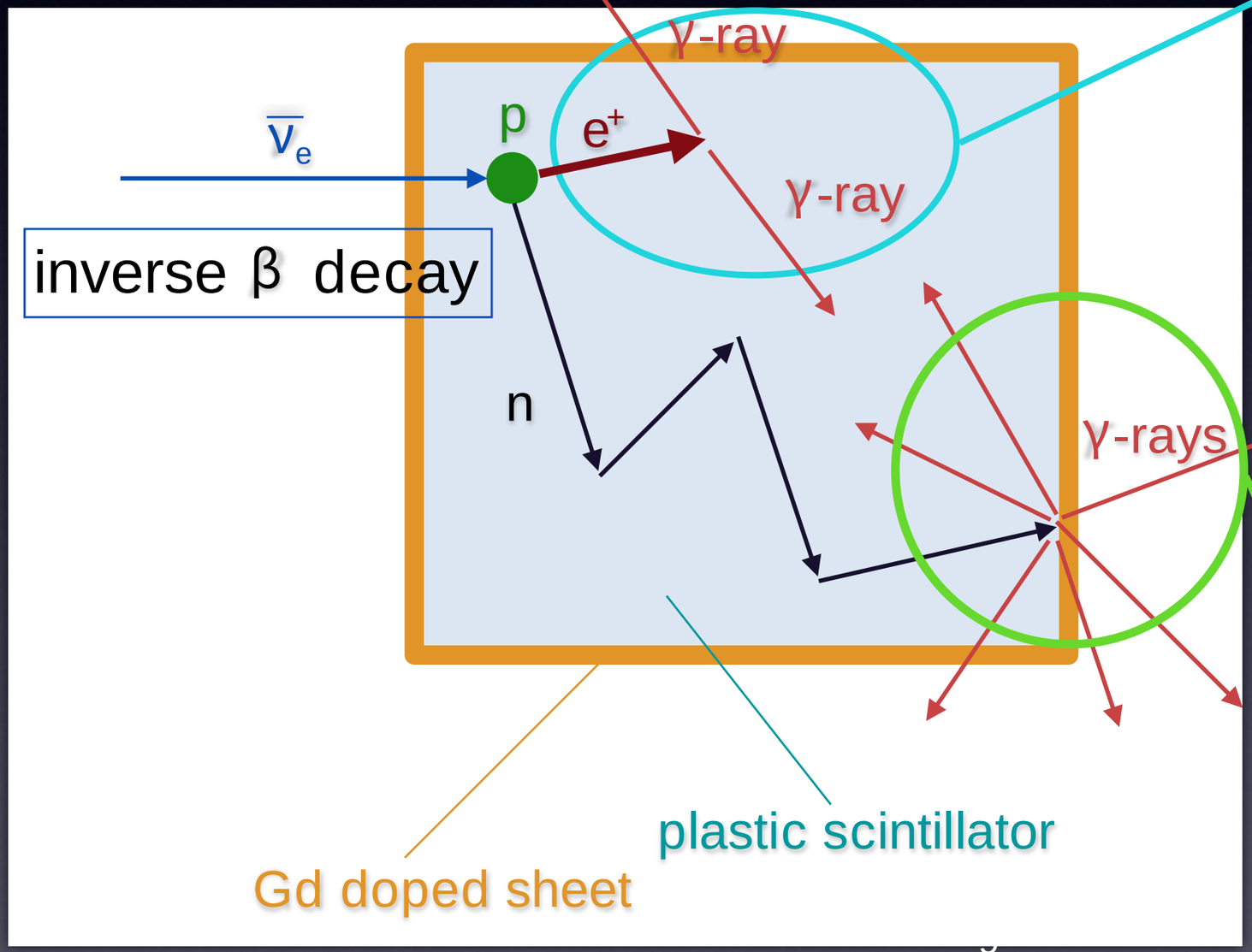
  Plastic scintillators are nonflammable and the scintillation efficiency is stable.

- Measurement at the surface

  PANDA detector will be operated just outside a reactor building at the surface. It is very nonintrusive.

Principle of Detection

- Delayed Coincidence



Prompt Event

- positron(~MeV)
- two γ rays (511 keV x 2)

60 μs

Delayed Event

- some γ rays (total 8 MeV)

Why pillar modules?

- solution in a liquid or plastic scintillator

  Neutron is captured effectively.
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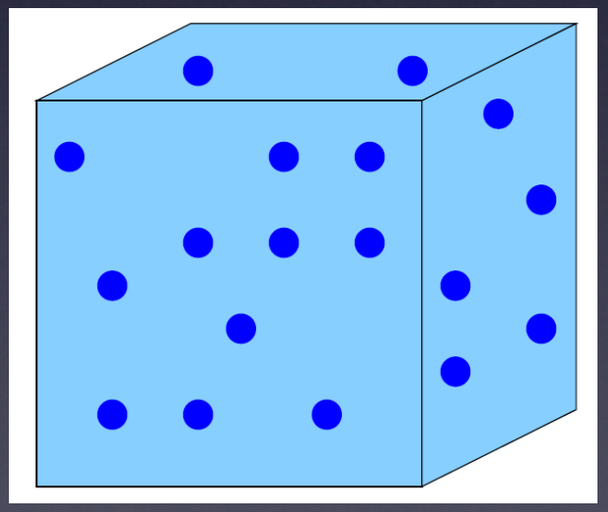
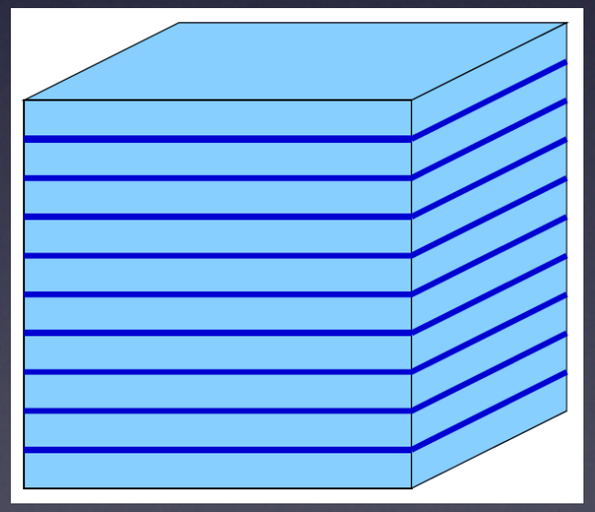
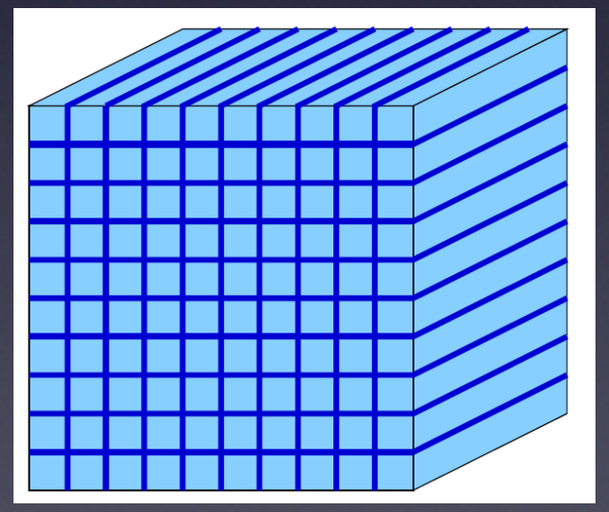


solution



sheet



pillar

Neutron Capture Efficiency

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89.4

	neutron capture efficiency	neutron capture delay time constant
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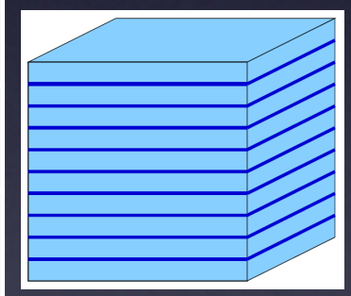
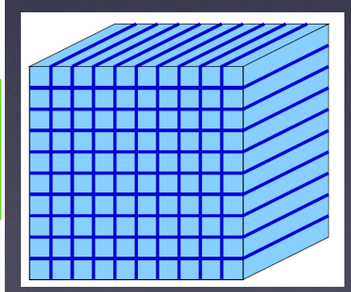
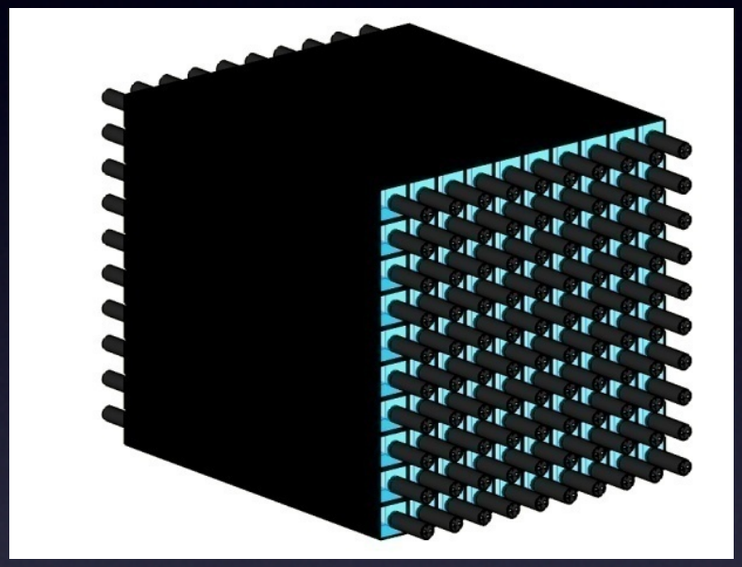


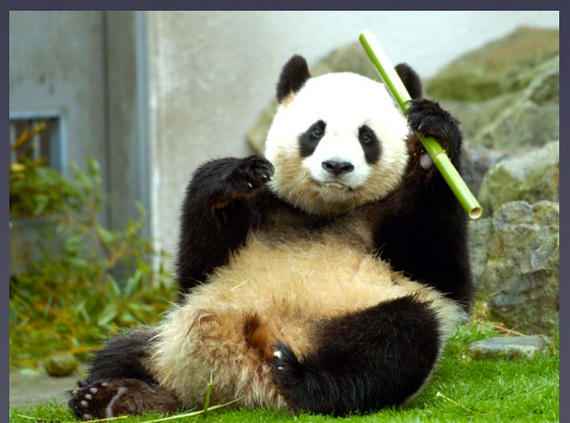


First Step of PANDA Project

PANDA Detector

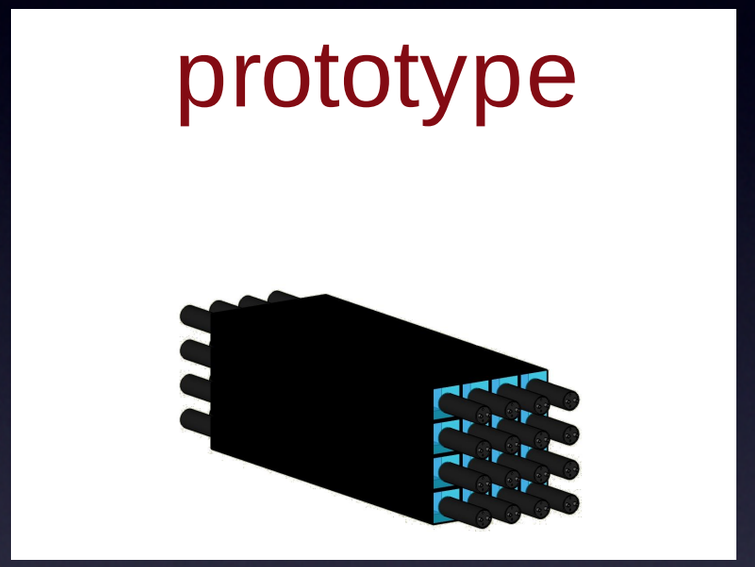


10 x 10 = 100 modules
1 ton



Lesser PANDA Detector

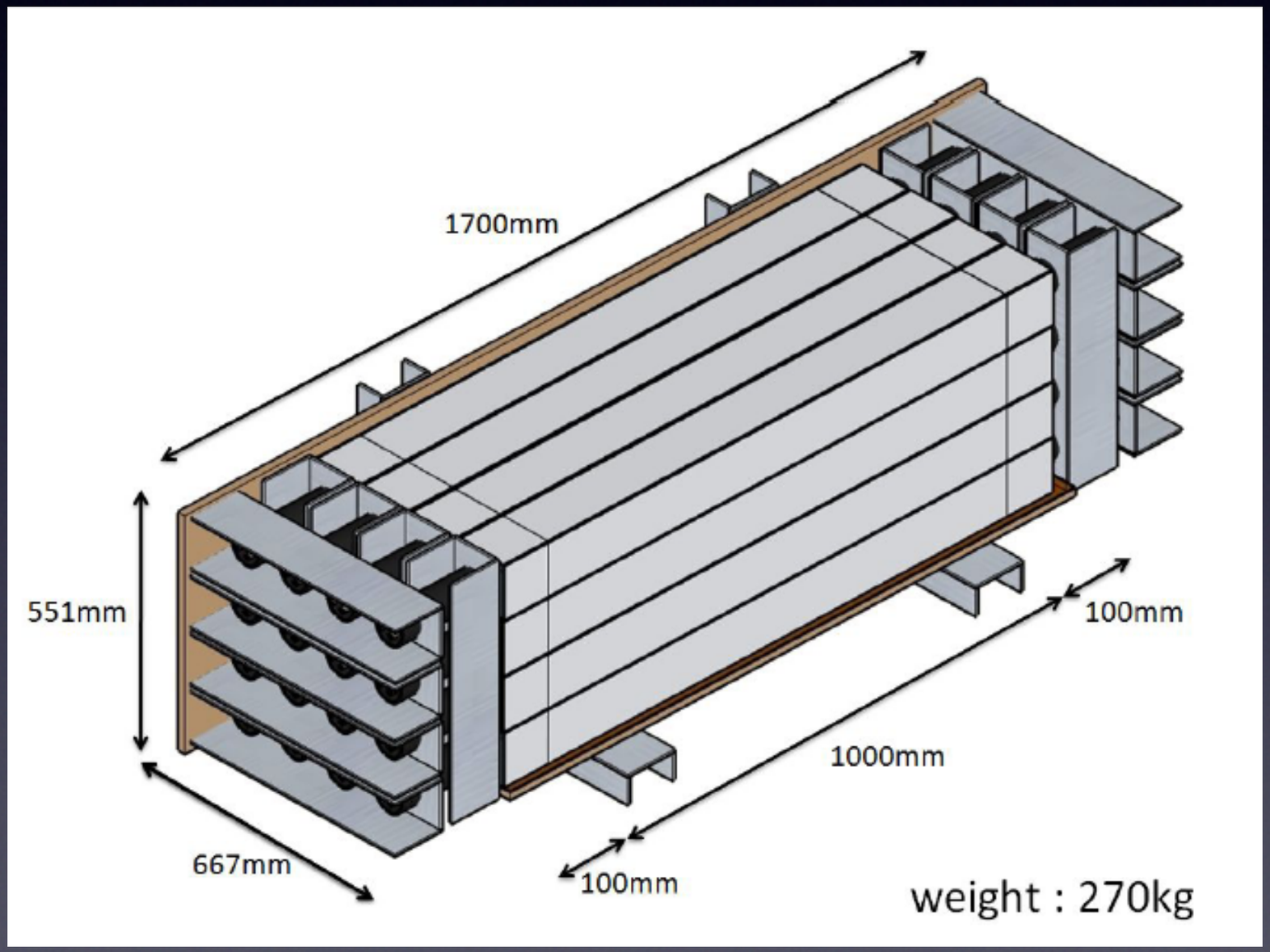
prototype



4 x 4 = 16 modules
160 kg

Lesser PANDA detector

- 1700 mm x 667 mm x 551 mm



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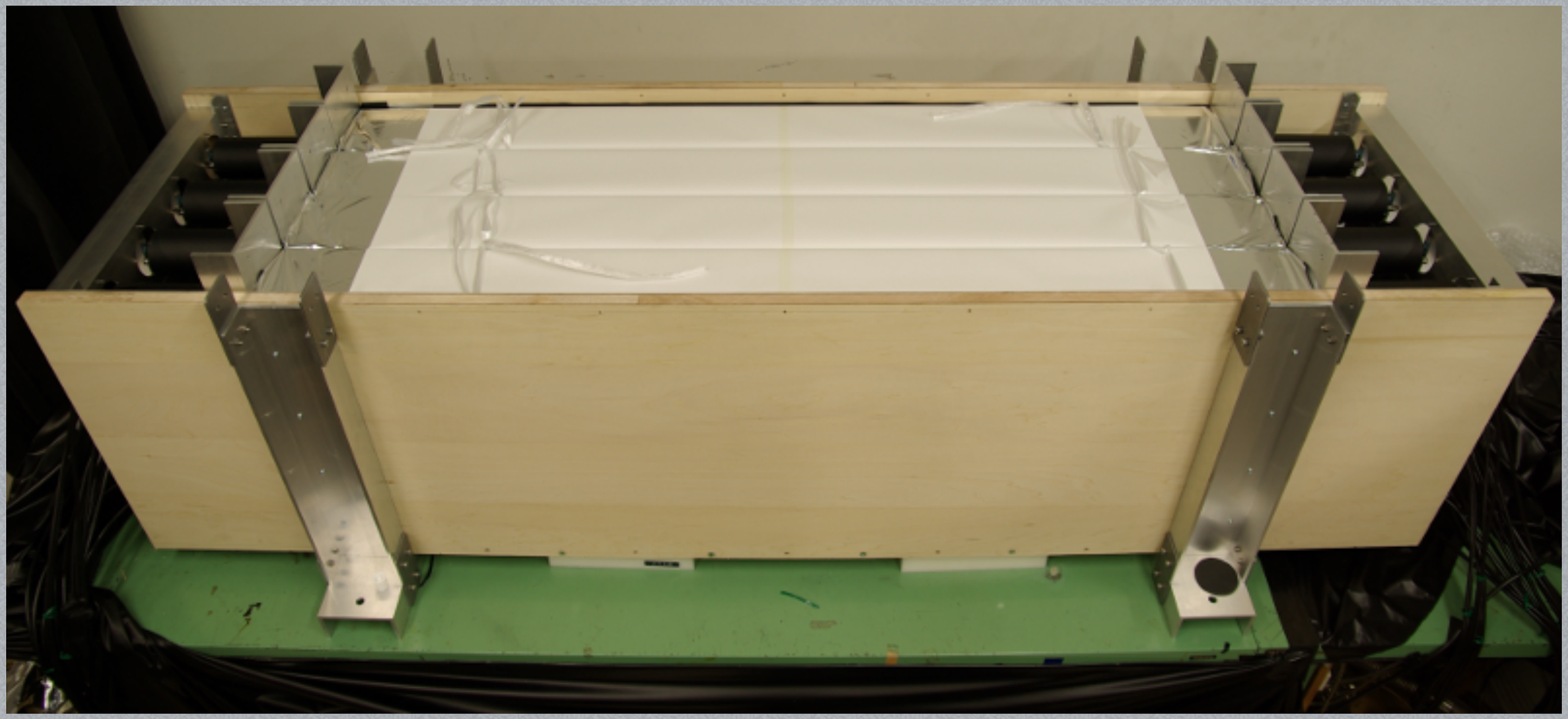

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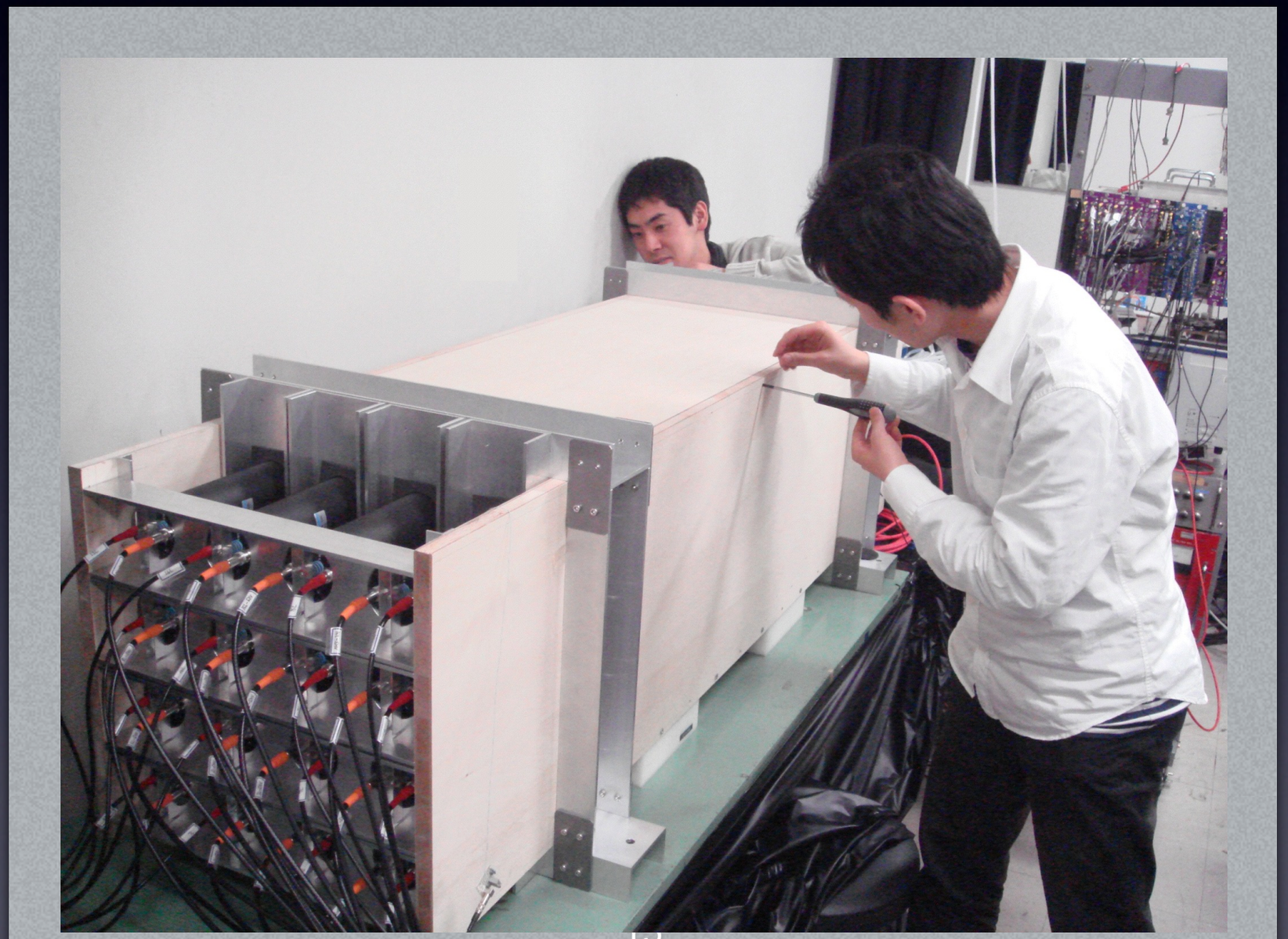
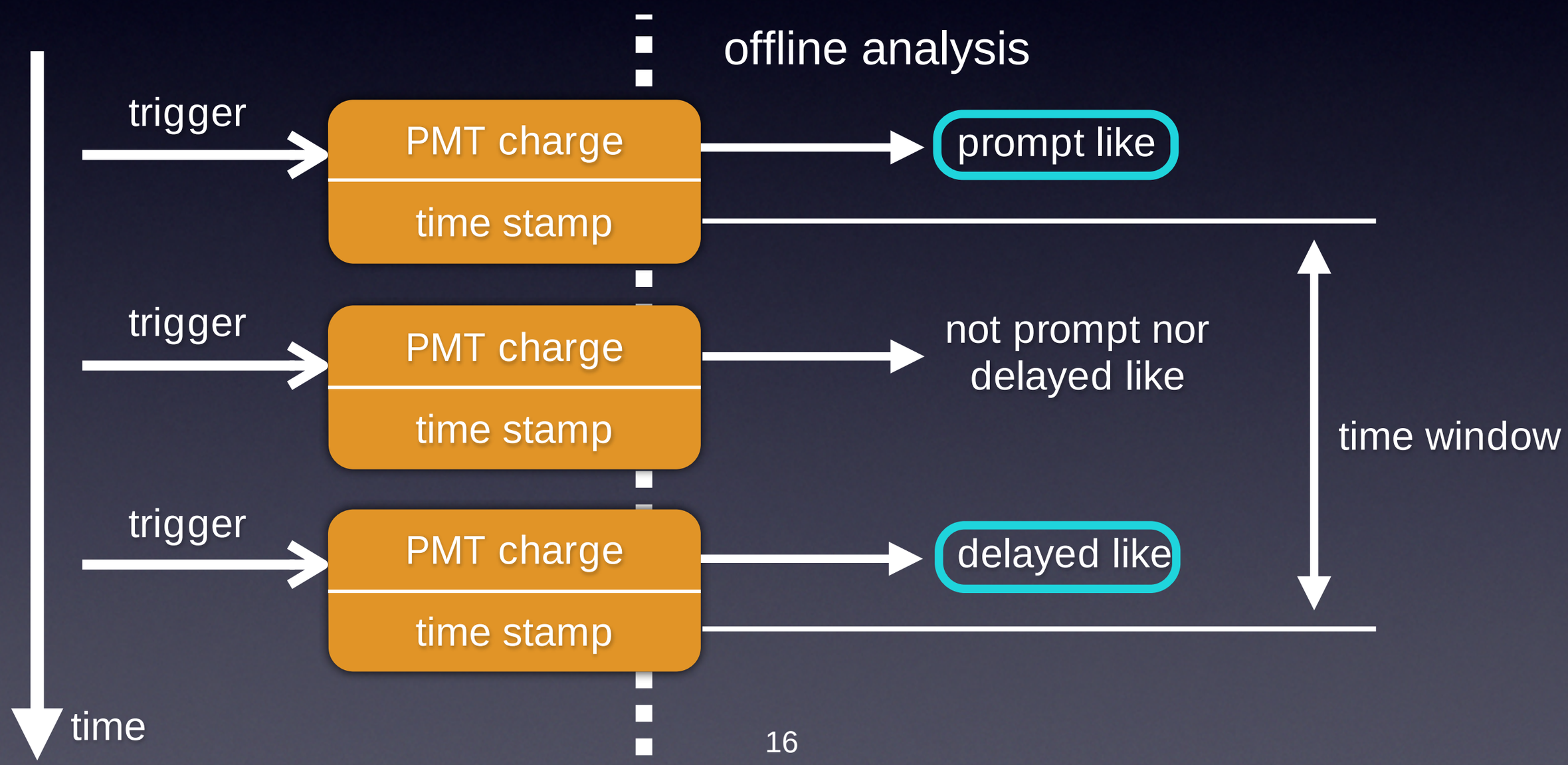
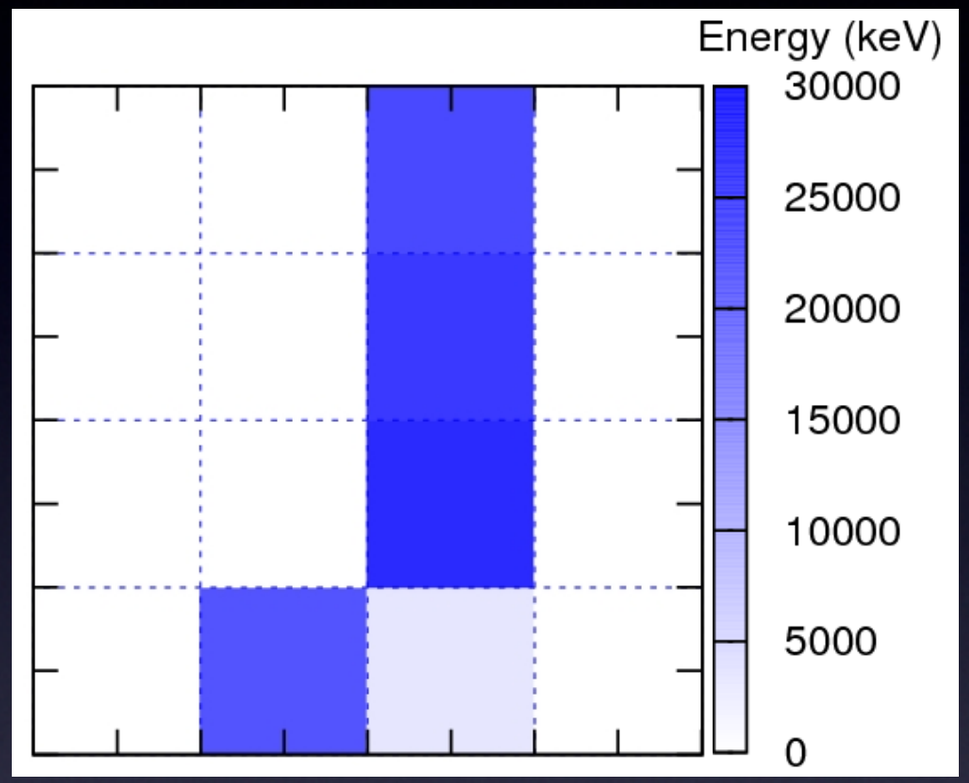


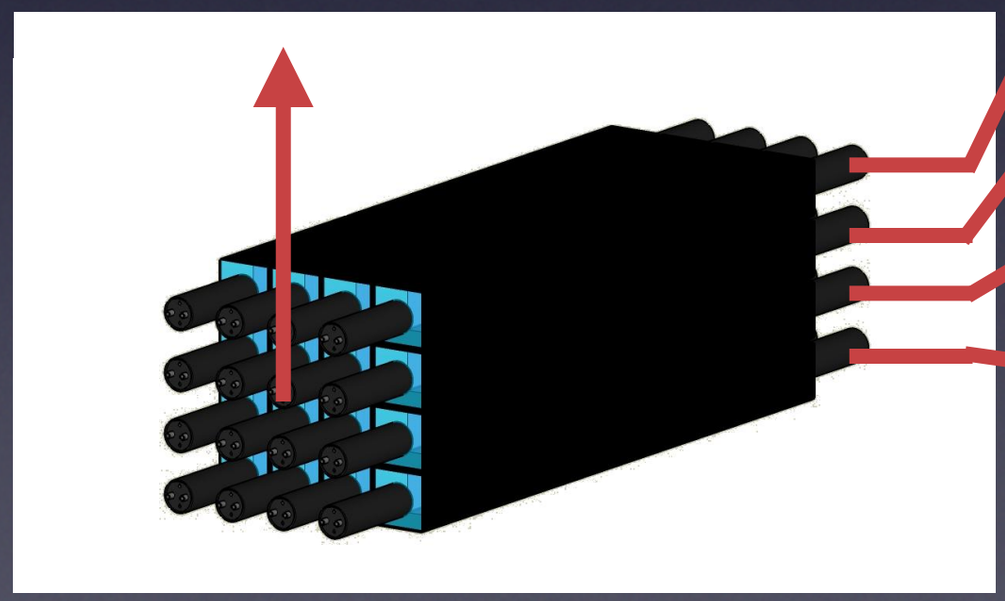
Data Acquisition

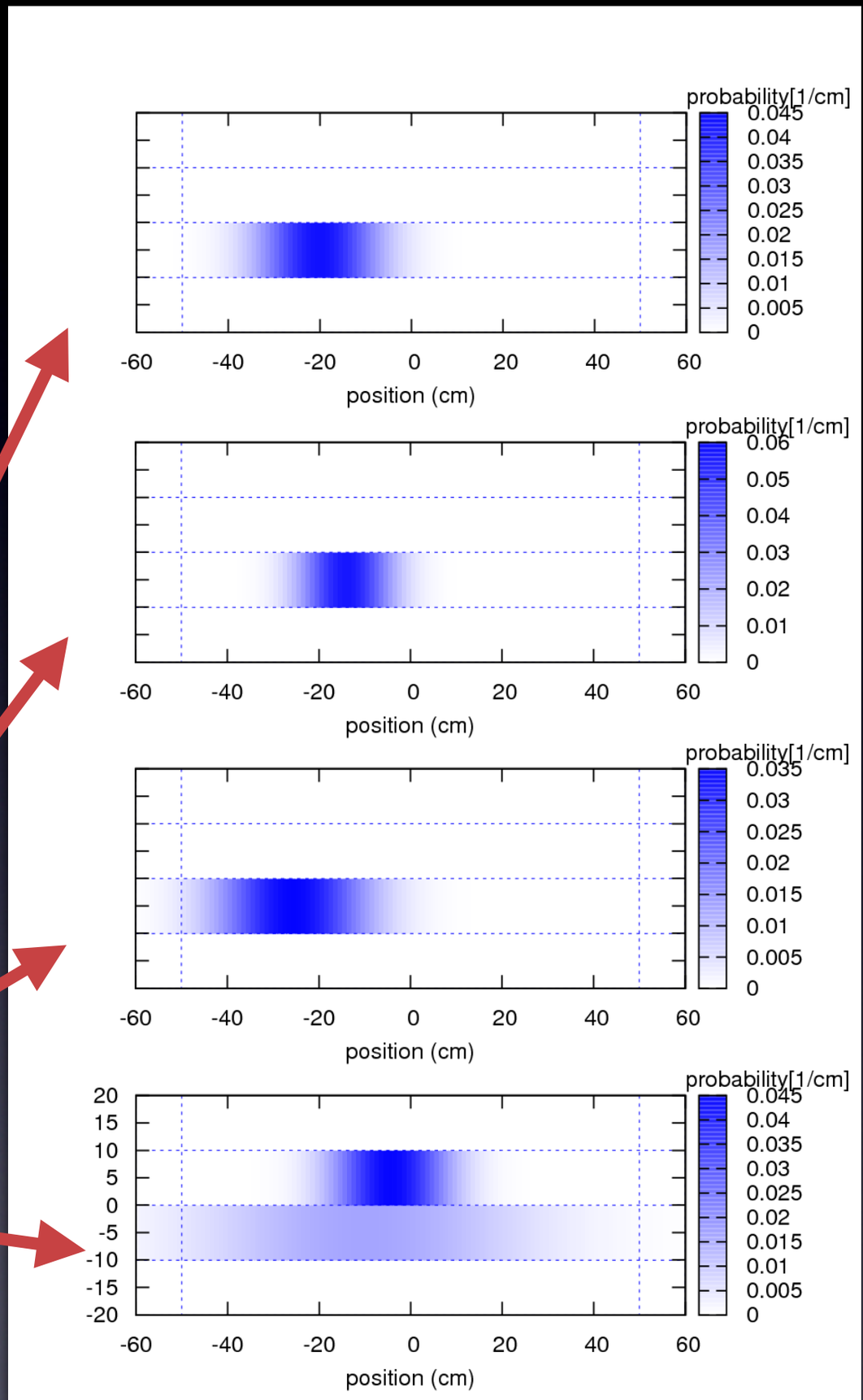
- Event data consist of 32 ch PMT charge and time stamp.



μ like event


Energy (keV)
30000
25000
20000
15000
10000
5000
0




probability[1/cm]
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-60
-40
-20
0
20
40
60
position (cm)
probability[1/cm]
0.06
0.05
0.04
0.03
0.02
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position (cm)

Selection Criteria

- Prompt Event: positron like event

  3 MeV < E_{total} < 7 MeV

  100 keV < E_{2nd} < 600 keV

- Delayed Event: neutron like event

  3 MeV < E_{total} < 8 MeV

  500 keV < E_{2nd}

coincidence time window
5-100 μs

E_{2nd}

ch.1:	41.24 keV	ch.9:	25.96 keV
ch.2:	33.67 keV	ch.10:	4650.03 keV
ch.3:	42.12 keV	ch.11:	0.00 keV
ch.4:	0.00 keV	ch.12:	16.23 keV
ch.5:	16.68 keV	ch.13:	33.43 keV
ch.6:	7.39 keV	ch.14:	31.59 keV
ch.7:	433.93 keV	ch.15:	32.41 keV
ch.8:	30.73 keV	ch.16:	9.84 keV

Total: 5405.26 keV Time: 384985060 ns

E_{total}

E_{2nd}

ch.1:	32.34 keV	ch.9:	140.31 keV
ch.2:	26.48 keV	ch.10:	940.36 keV
ch.3:	1342.92 keV	ch.11:	20.07 keV
ch.4:	30.48 keV	ch.12:	37.09 keV
ch.5:	2869.65 keV	ch.13:	51.42 keV
ch.6:	398.98 keV	ch.14:	594.59 keV
ch.7:	59.88 keV	ch.15:	32.73 keV
ch.8:	30.73 keV	ch.16:	24.07 keV

10 μs

Total: 6632.11 keV Time: 384995220 ns

E_{total}

Estimate of S/N ratio of Lesser PANDA

- neutrino event rate at 20 m from a 3 GW_{th} reactor
  (Monte Carlo simulation by Geant 4)

  detection efficiency: 5.7 % --> 45.7 events/day

- background event rate measured in our laboratory

  260 events/day --> $\sigma = \sqrt{260} \sim 16.1$ events

  Lesser PANDA can discriminate ON/OFF status of the reactor by 3 σ in one day.

Prospect for PANDA

- Lesser PANDA vs PANDA

	Lesser PANDA	PANDA
target mass	160 kg	1000 kg
detection efficiency	5.66 %	13.9 %
neutrino event rate (at 20 m from a 3 GWth reactor)	45.7 /day	679 /day
background rate	260 /day	?
σ of background	16.1	?

Summary

- PANDA detector is a mobile, stable and safe detector, because it consists of all solid state, not liquid. It will be operated at the surface.

- We built Lesser PANDA detector. The background rate was 260 events / day. We are trying to reduce the background continuously.

- We concluded that the160 kg detector can discriminate ON/OFF status of the reactor by 3 σ in one day.

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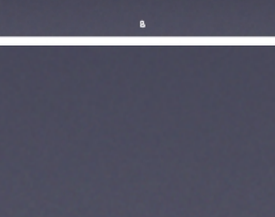

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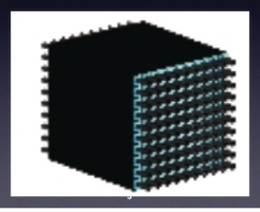

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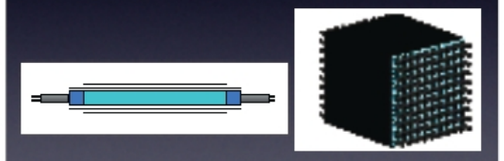

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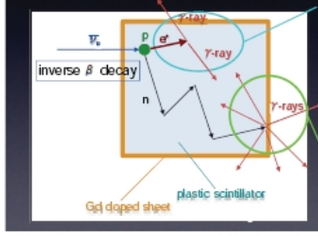

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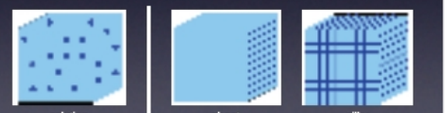

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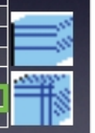

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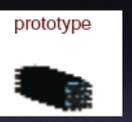
PANDA Detector

10 x 10 = 100 modules
1 ton

Lesser PANDA Detector

prototype



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12

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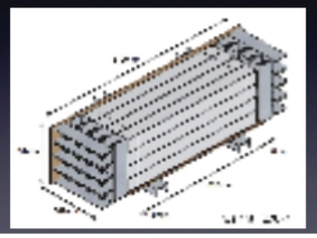

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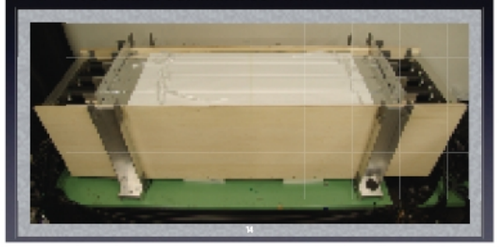

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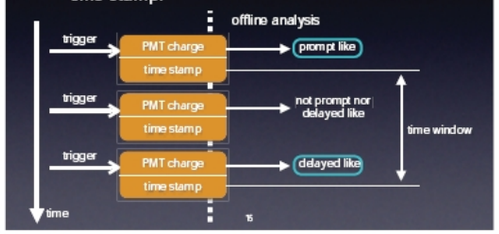

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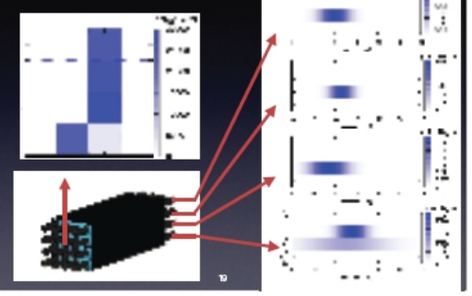
μ like event



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