SAMURAI Neutron Detector (NEBULA)

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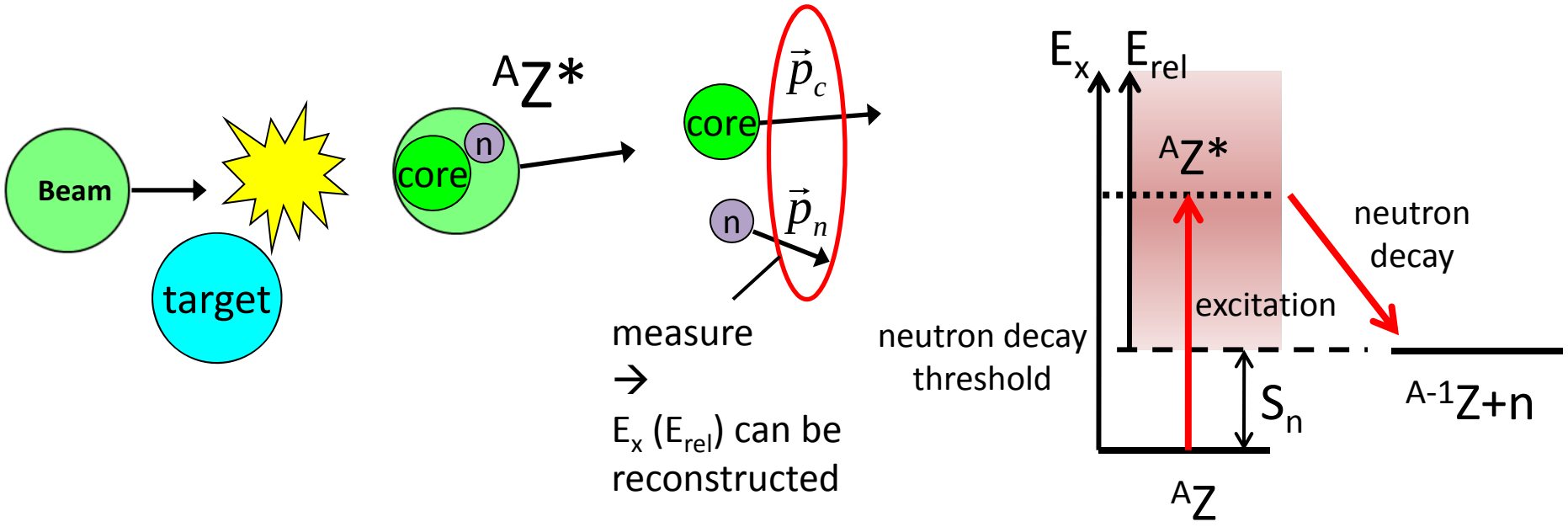
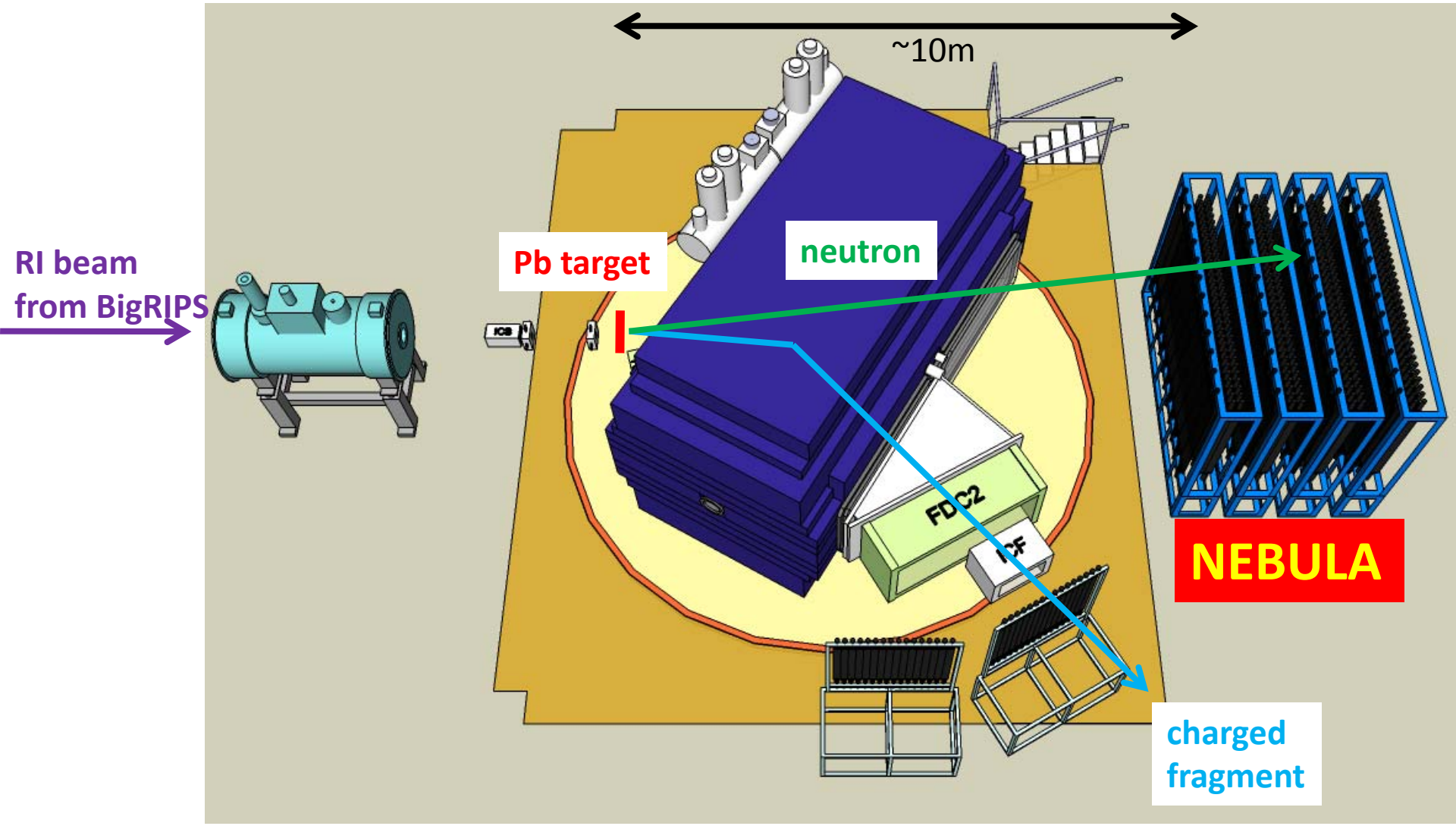
Invariant-mass spectroscopy of neutron-rich nuclei



$$E_{rel} = \sqrt{\left(\sum E_i\right)^2 - \left(\sum \vec{p}_i\right)^2} - \sum M_i$$

Typical setup (Coulomb breakup)



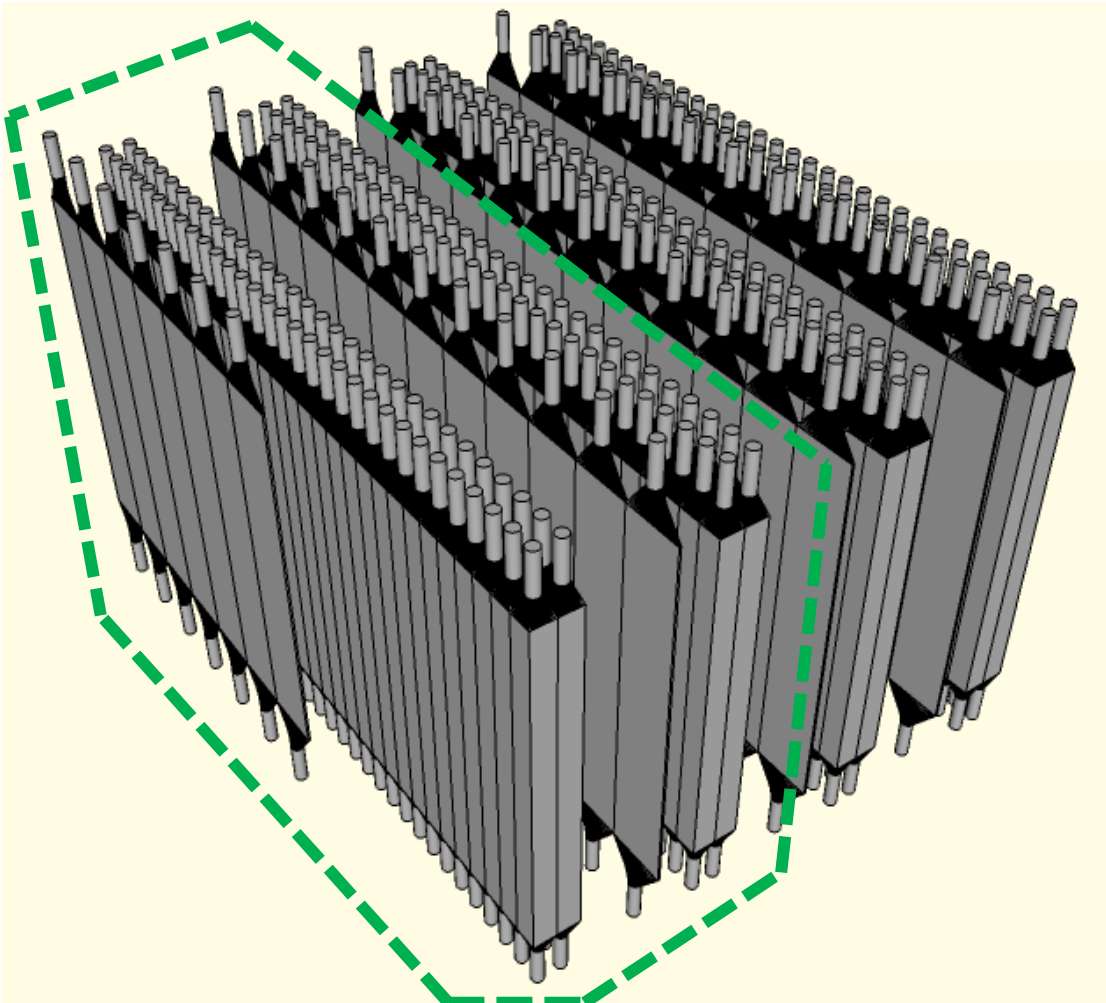
NEBULA
(Neutron-detection system for Breakup of Unstable-Nuclei with Large Acceptance)

- **Requirements**
  1. Measure momentum vector of high energy neutrons
     - E_n=100-300MeV
  2. Large Acceptance
     - 50% at E_{rel}=8MeV
  3. High intrinsic detection efficiency
     - 60% for 1n, 20% for 2n
  4. Good energy resolution
     - ΔE_{rel}~0.3-0.4MeV@1MeV, ΔE_{rel}~1MeV@8MeV
  5. Multi-neutron detection
     - Goal: detect 4n in coincidence

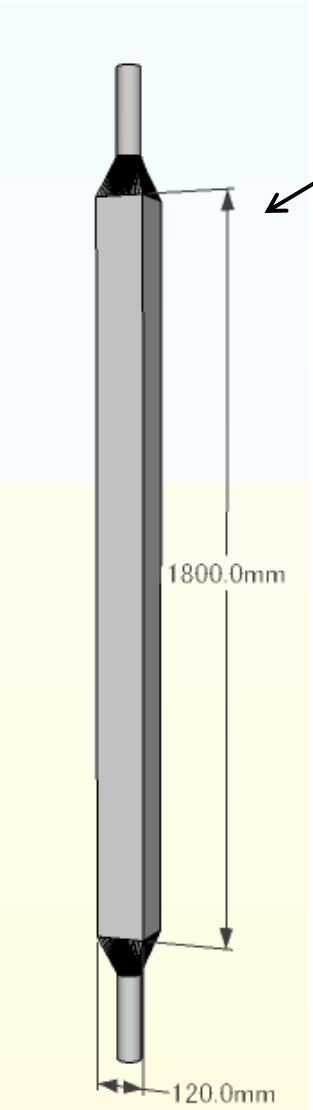
NEBULA
(Neutron-detection system for Breakup of Unstable-Nuclei with Large Acceptance)

- Design
  - 240 Neutron counters
  - 48 VETO counters
  - arranged into 4 stacks
  - each stack
    - 60 neutron counters
    - 12 VETO counters

- Funded (Current version)
  - 120 Neutron counters (half)
  - 48 VETO counters

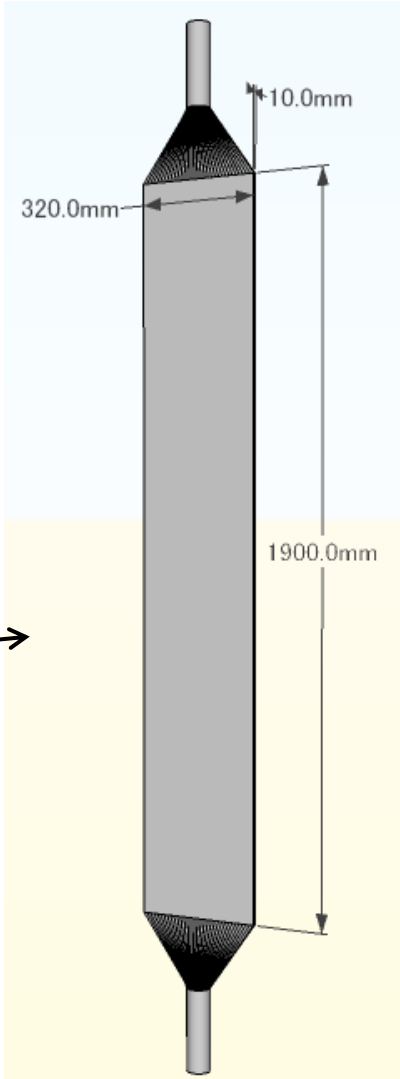


Specification



- Neutron counter
  - plastic scintillator
    - Saint-Gobain BC-408
    - 12cm x 12cm x 180cm
  - PMT
    - Hamamatsu R7724ASSY (both ends)

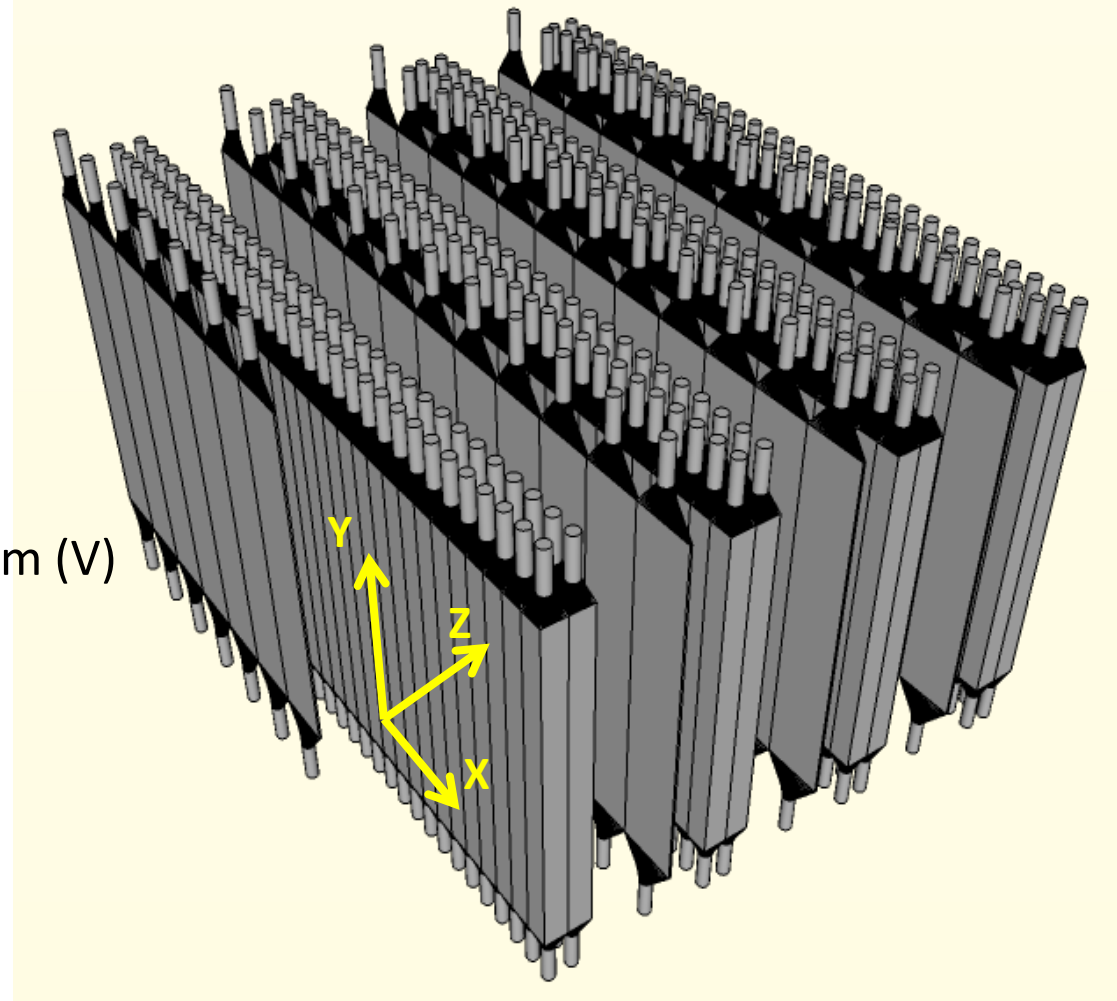
- VETO counter
  - thin plastic scintillator (BC-408)
    - 1cm x 32cm x 190cm
  - used to identify the charged particles



Specification

- $\vec{P}_n$ is derived from Position & TOF
  - TOF = $(T_u+T_d)/2 - T_{trig}$
  - X,Z from detector ID
  - Y from time diff. of two PMTs
- Detection efficiency
  - ~40% for 1n (Current version)
- Large acceptance
  - effective area : 3.6m (H) x 1.8m (V)

  →$-10^o<\theta_H<10^o$, $-5^o<\theta_V<5^o$
- Multi-neutron detection
  - crosstalk cut analysis

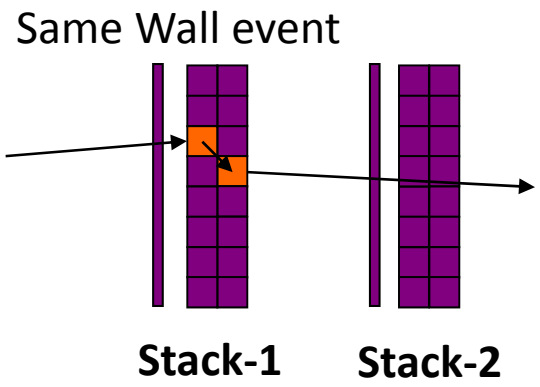


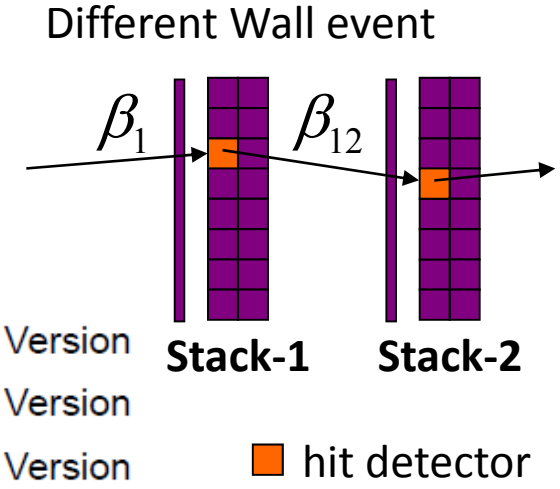
Multi-neutron detection (example:2n case)

- Crosstalk … multi hits caused by 1n
  - should be eliminated

  →kinematical condition is used

  - Same wall event → position information
    - 2 hits are regarded as 1hit if positions are close
    - lose efficiency for small E_{rel}
  - Different wall event → velocity information
    - the event is true if $\beta_{12} > \beta_1$
      - because crosstalk neutron must be slow
    - can measure up to E_{rel}~0





	Eff_1n(%)	Eff_2n(%)	Eff_4n(%)
24cm x 2Layer	41.0	12.6	
12cm x 4Layer	41.0	10.5	0.011
24cm x 4Layer	64.6	26.6	0.056

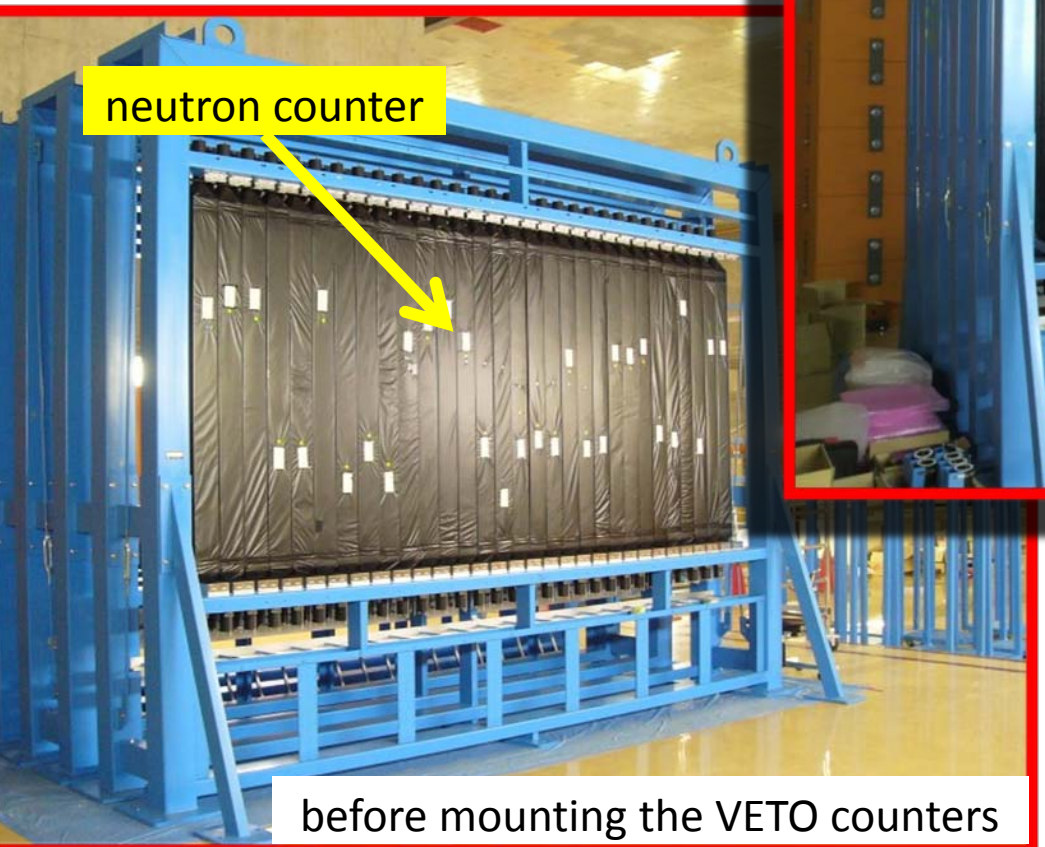
Half Version

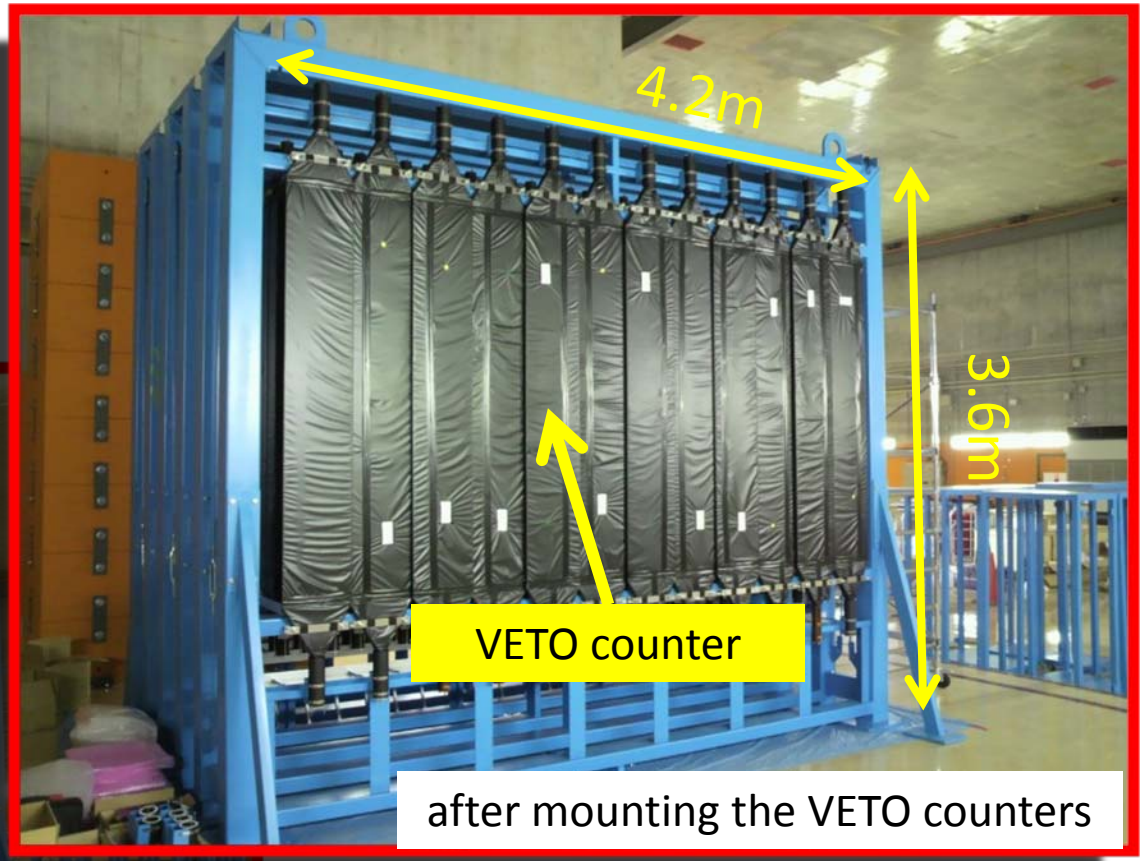
Half Version

Full Version

Full setup → 4n efficiency much improves!

Photo





Whole of a detector frame (1 stack) can be moved by using crane without dismounting detectors, cables, and electronics

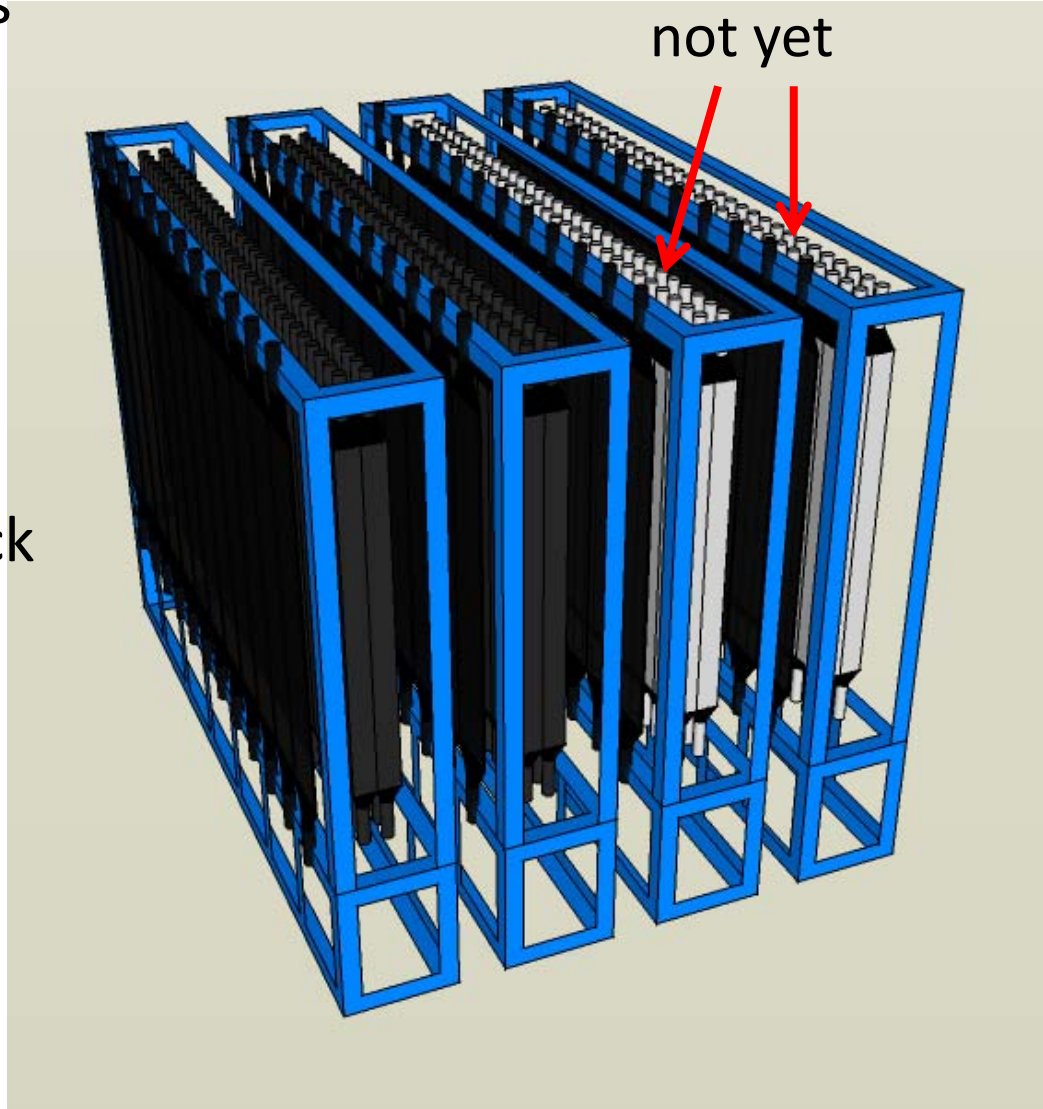
Status

- Most of the funded detectors have been fabricated
  - 117 neutron counters
    - (3 counters are now being fabricated)
  - 48 VETO counters
- Mounted on two detector frames
- Connected cables for 1st stack
- Half of 1 stack is tested
  - Cosmic ray (muon)
  - Am+Be source

    4.4MeV γ ray

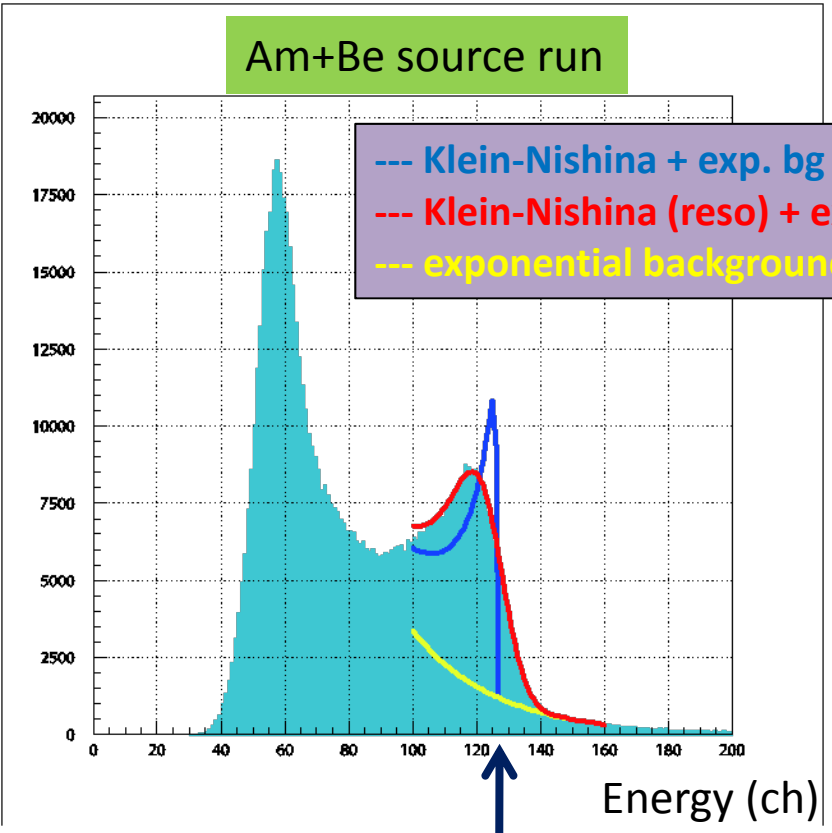
  →Evaluate resolution

  & Establish calibration method



Calibration of analog signal

Am+Be source run



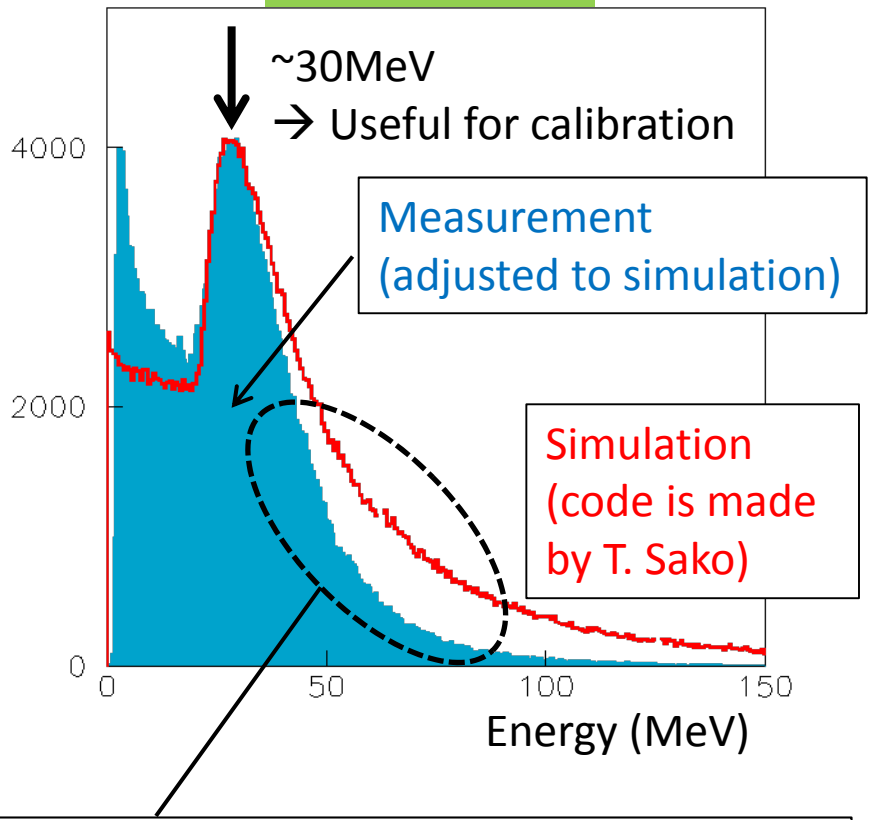
Corresponds to 4.2MeV
(Compton Edge of 4.4MeV γ ray)

$$\alpha + {}^{9}\mathrm{Be} \rightarrow {}^{12}\mathrm{C}^{*} + \mathrm{n}$$

$${}^{12}\mathrm{C}^{*} \rightarrow {}^{12}\mathrm{C} + 4.43\mathrm{MeV}$$

Analyzed
by Y. Kawada

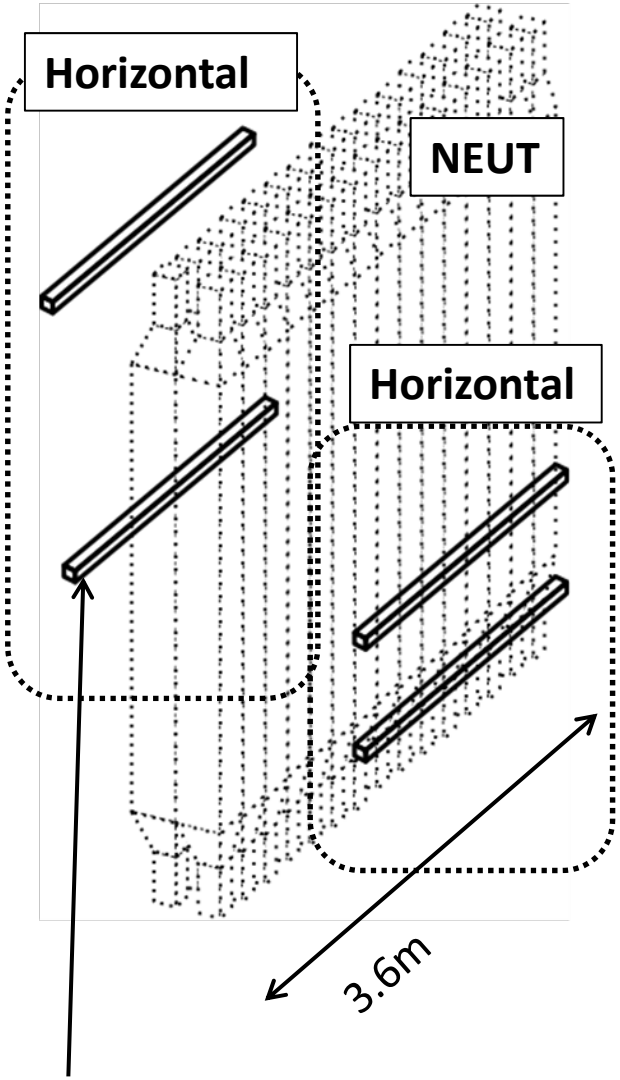
Cosmic ray run



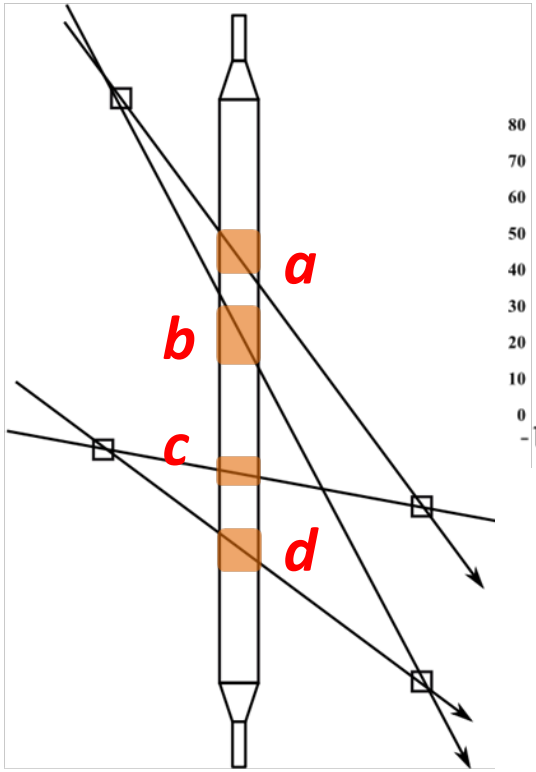
effect of RIBF building? (Pulse height ←→angle)
→angle can be determined from tracking analysis

Analyzed by Y. Kawada

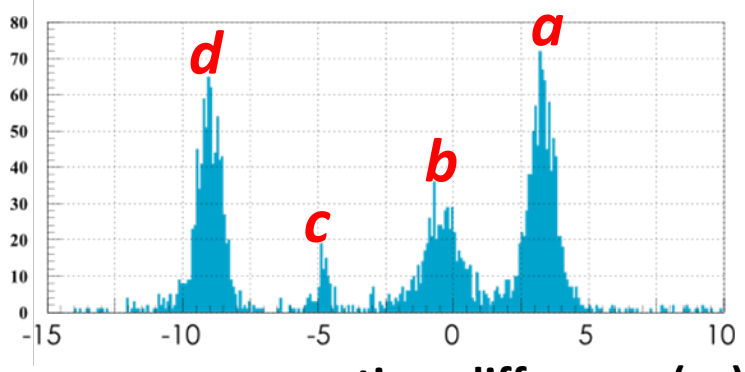
Calibration of Y Position



Plastic scintillator
(6cm x 6cm x 1m)



side view

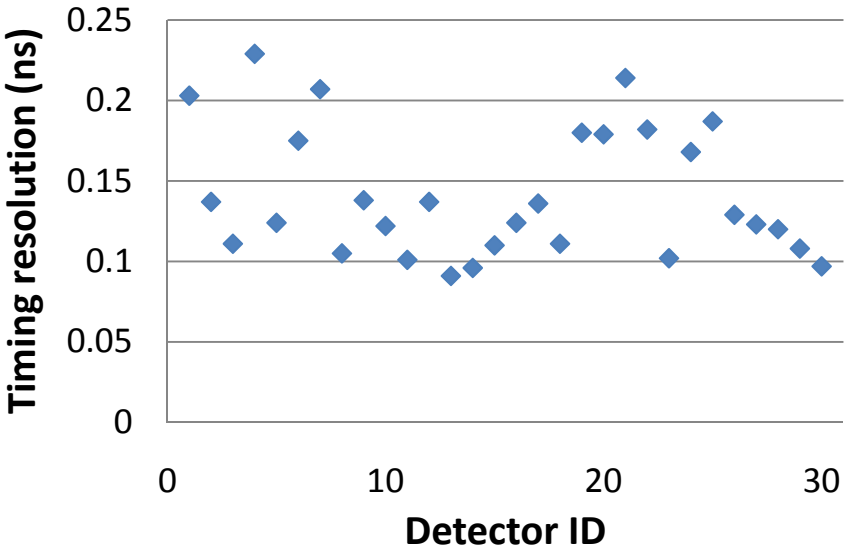


~40hours
measurement

Horizontal proportional counters (HPC)
(4m length, 50mmϕ)
Prototype is tested (Tohoku Gr.) → good

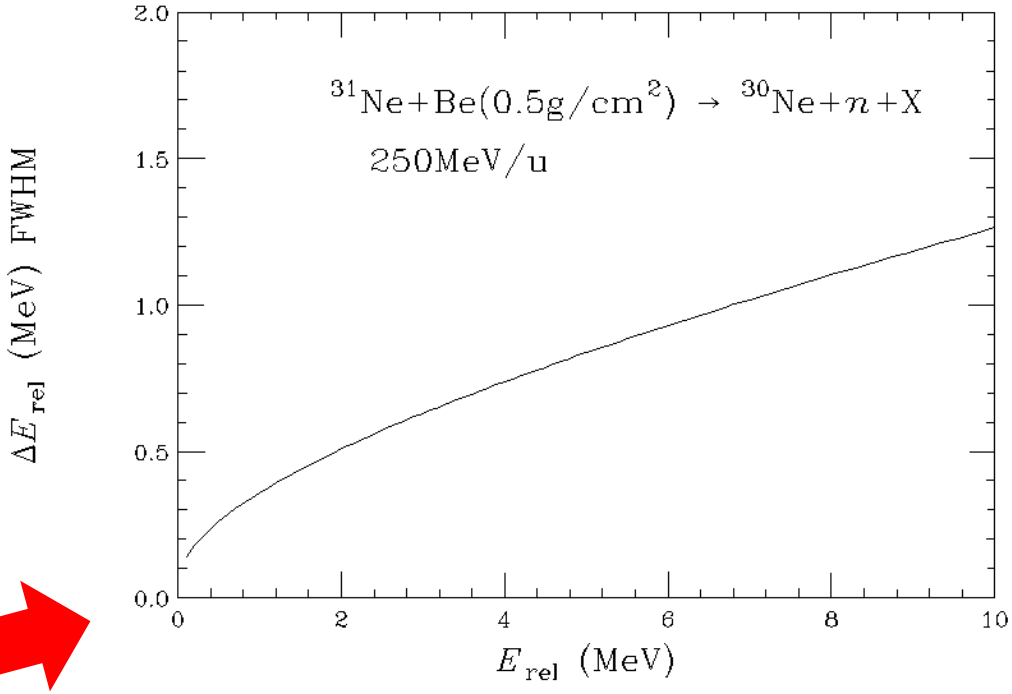
Analyzed by Y. Kawada

Resolution



- Timing resolution
  of <T>=(T_u+T_d)/2
  - average 0.16ns
- Y Position resolution
  - average 2.6cm

Relative energy resolution



Requirement

ΔE_{rel}=0.3-0.4MeV @ E_{rel}=1MeV

ΔE_{rel}=1MeV @ E_{rel}=8MeV

Remaining issues and Schedule

- Connecting cables of 2nd stack
- Detector check by cosmic ray & Am+Be source
- Response to a high energy neutron
  →test exp. using ~230MeV neutron @ HIMAC (2011 May)
  – Evaluation of timing resolution & intrinsic efficiency
  – Establish TOF calibration method
    - high energy γ ray from π^0 produced by HI collision

- Beginning of 2012
  – First experiment of SAMURAI

Summary

- NEBULA is designed for neutron measurements in SAMURAI project
  - Half of full setup is now available
  - 1/4 of available detectors are tested using cosmic ray and Am+Be source
- Schedule
  - 2011 May: Detector test by high energy neutron (~230MeV) @ HIMAC
  - ~2011 Sep: Test of all the detectors using cosmic ray and Am+Be source
  - Beginning of 2012: First experiment of SAMURAI

NEBULA collaboration (preliminary)

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