



# Summary of research activities and achievements at LAMPS

Lee Jongwon

Center of extreme nuclear matter, Korea Univ.

**KOREA**  
UNIVERSITY



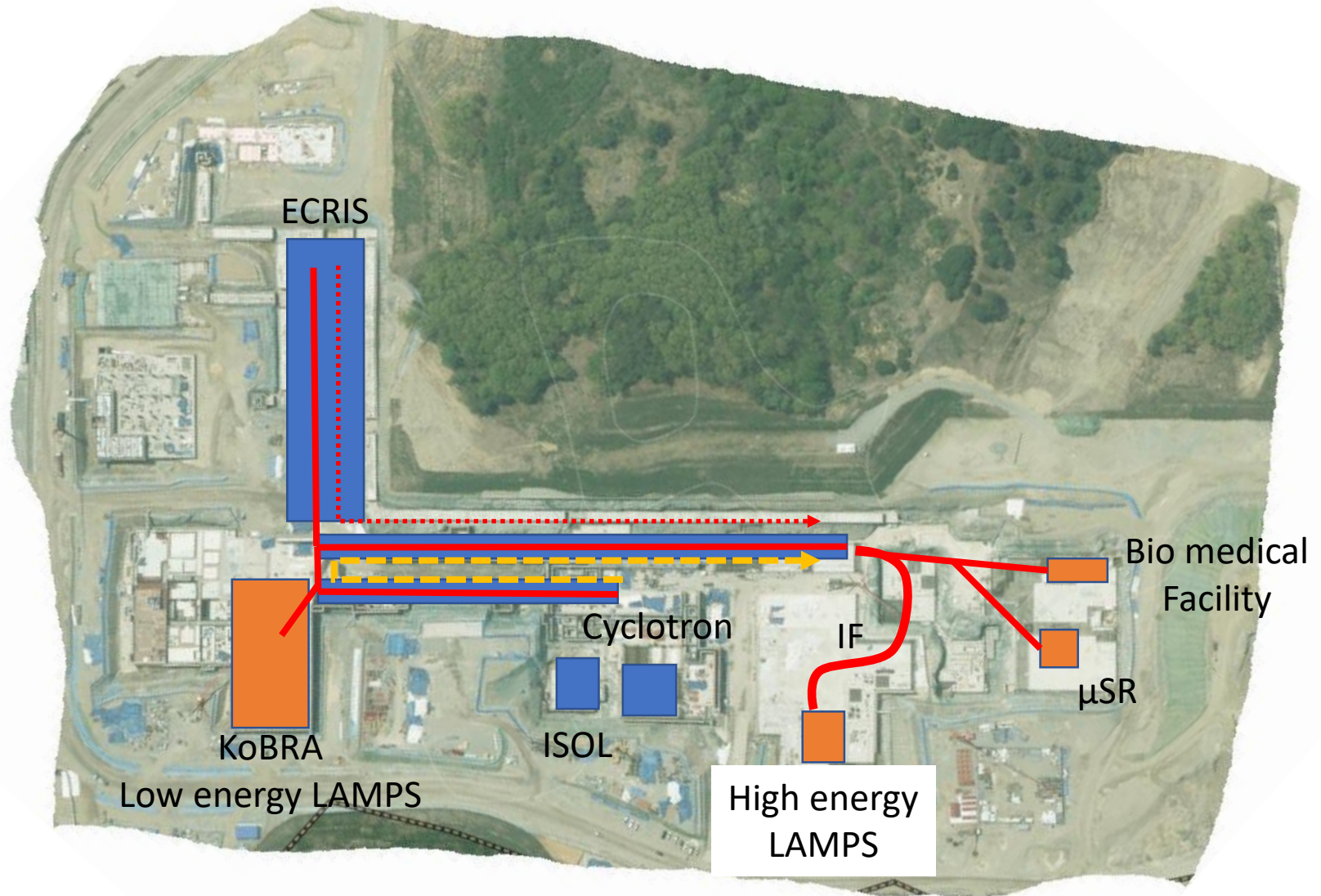
**CENUM**

# RAON

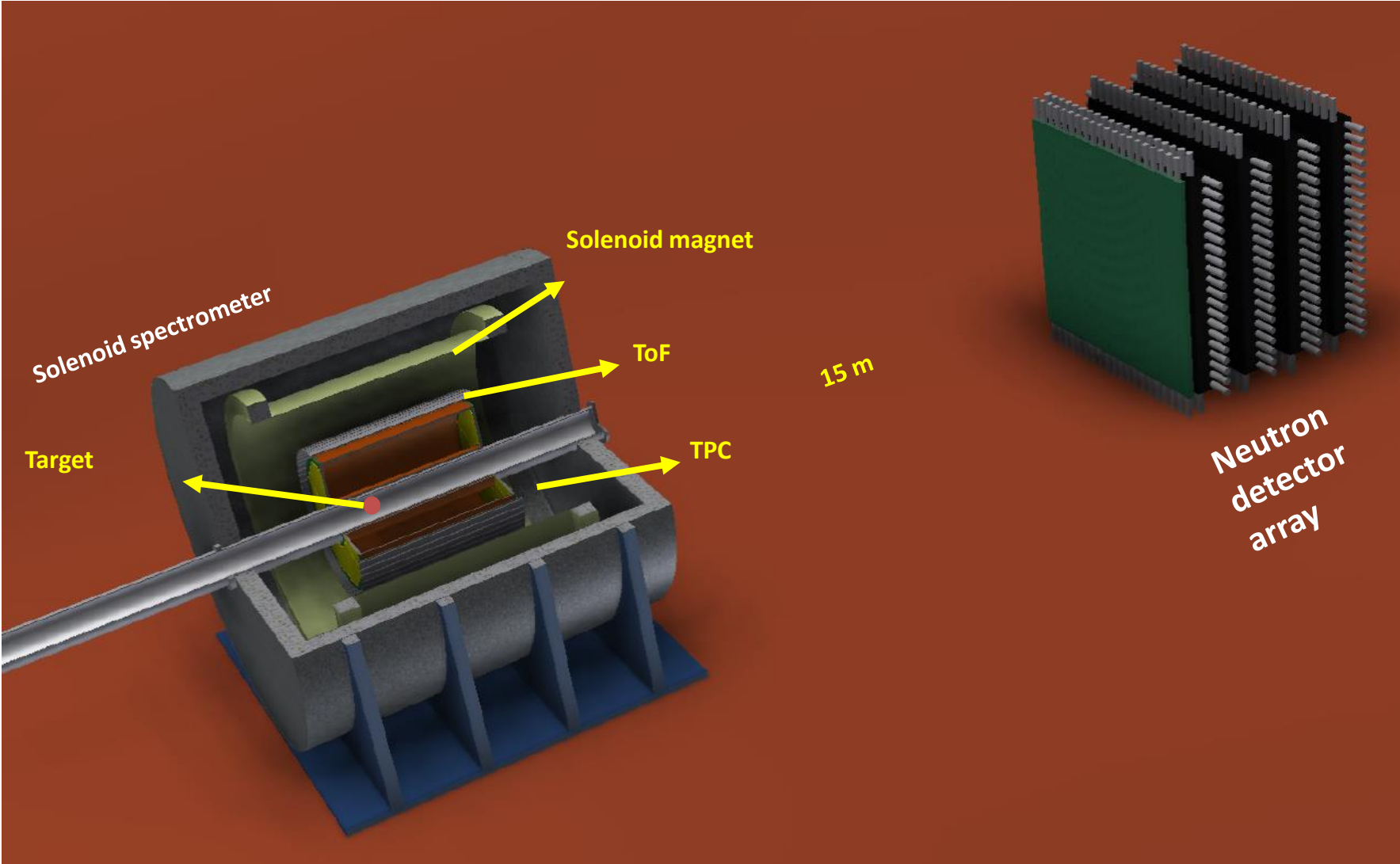




# RAON

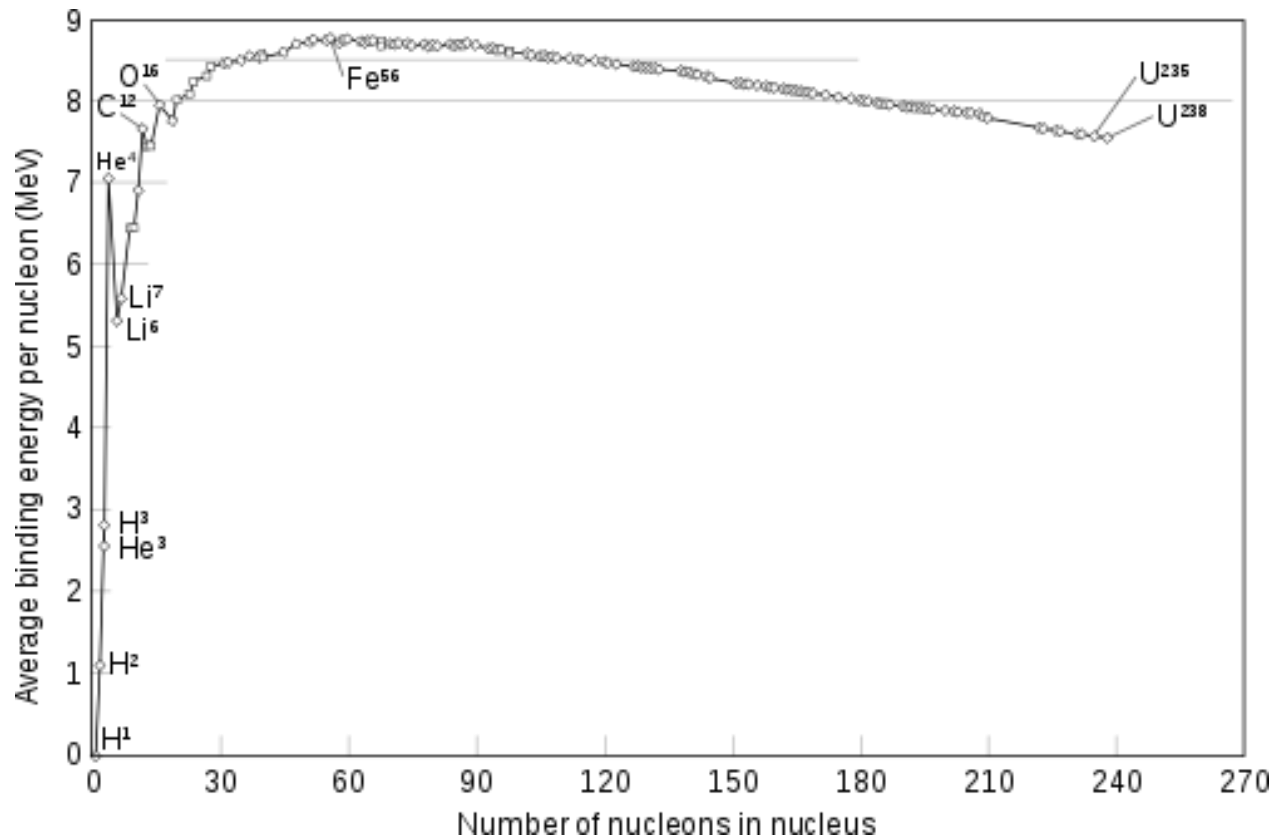


# LAMPS experiment



# Symmetry energy - Nuclear binding energy

$$B(A, Z) = a_{vol}A - a_{sur}A^{2/3} - a_{Coul} \frac{Z(Z-1)}{A^{1/3}} - a_{sym} \frac{(N-Z)^2}{A} \pm \delta_{pair}$$



# Symmetry energy

- Energy of nuclei and nuclear matter

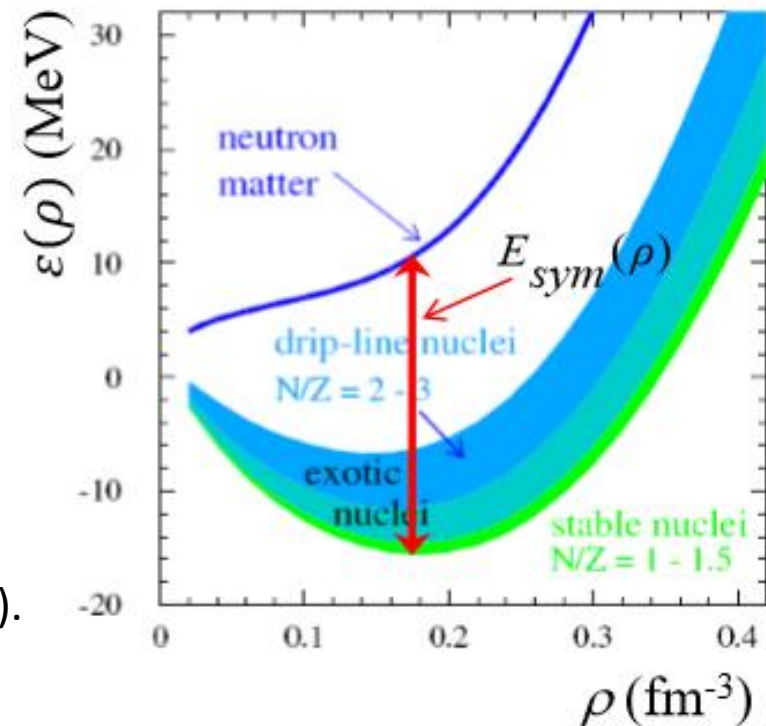
$$\varepsilon(\rho, \delta)A = Zm_p + Nm_n - B(A, Z)$$

$$\varepsilon(\rho, \delta) = \varepsilon(\rho, \delta = 0) + E_{sym}(\rho)\delta^2 + \mathcal{O}(\delta^4) + \dots$$

$$\text{where } a_{sym} \approx E_{sym}(0.6\rho_0)$$

**Symmetry energy** : Energy difference between the neutron matter and isospin symmetric ( $N = Z$ ) matter

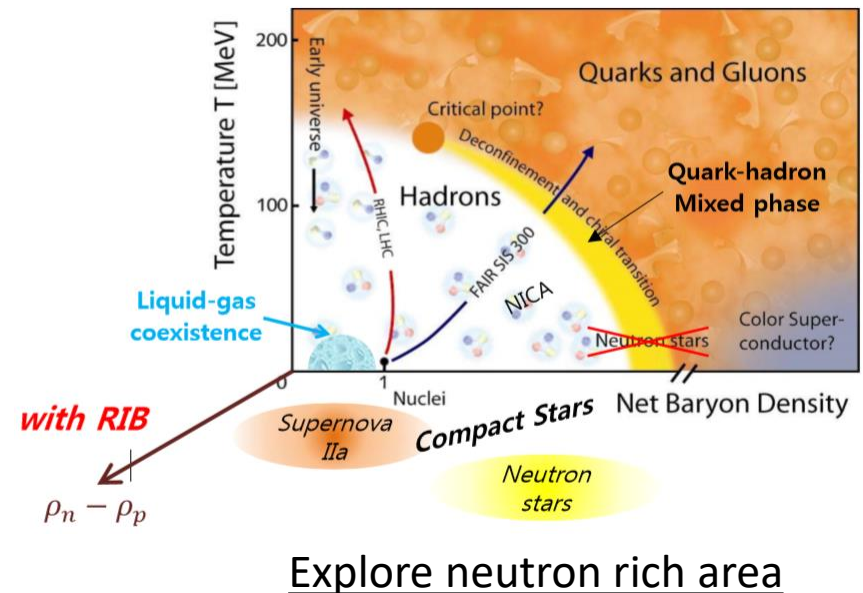
Know about symmetry energy leads to know about neutron matter(=neutron star).



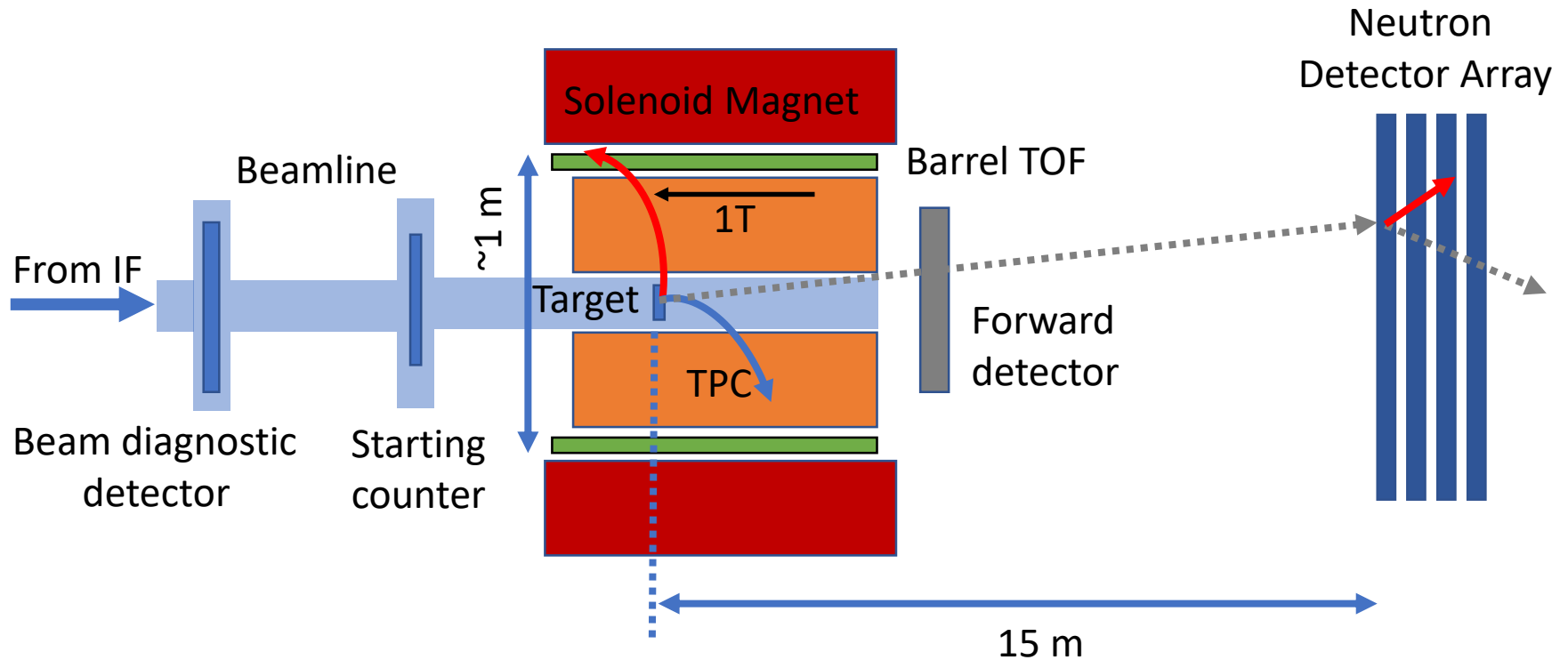
# Physics of LAMPS experiment

LAMPS = **L**arge **A**cceptance **M**ulti-**P**urpose **S**pectrometer

- Nuclear symmetry energy at supra-saturation density via heavy-ion collision
  - Using rare isotope beam
  - Various beam energy
  - Various collision system
  - $50,54\text{Ca} + 40\text{Ca}$ ,  $68,70,72\text{Ni} + 58\text{Ni}$ ,  
 $106,112,124,130,132\text{Sn} + 112,118,124\text{Sn}$   
...
- Measurable Parameters
  - Particle ratios :  $n/p$ ,  ${}^3\text{H}/{}^3\text{He}$ ,  $\pi^-/\pi^+$ ,  $N/Z$ ...



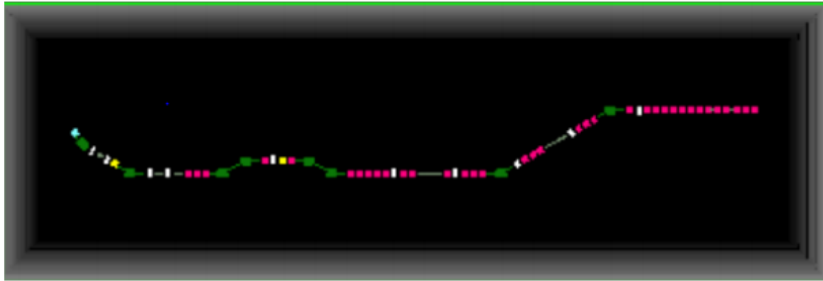
# LAMPS detector



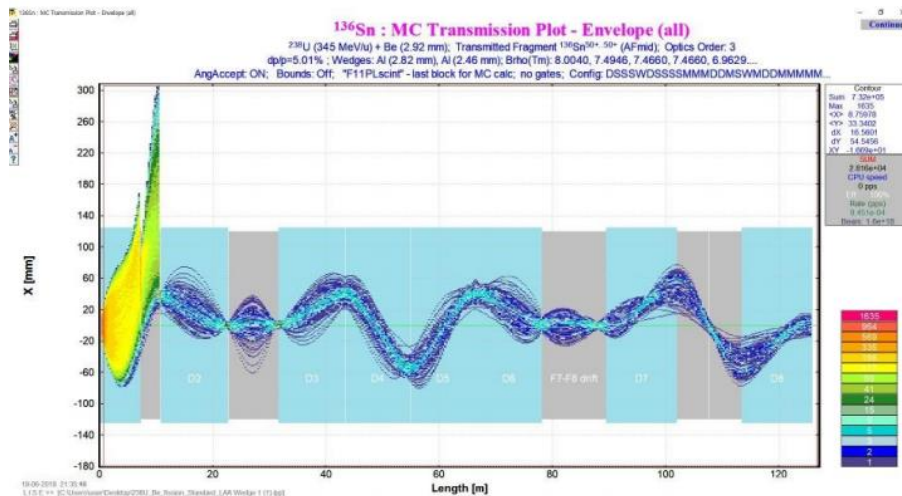


# Beamline simulation

## Beamline simulation test



Schematic view of BigRIPS in LISE++



Beam process for only <sup>136</sup>Sn

- Beamline simulation with LISE++
- Design extraction beamline and estimate beam profile / flux.
- Train student with BigRIPS (RIKEN) beamline layout.
- Test with IF beamline soon.

# Beam diagnostic detector

## Samurai Beam profile monitor

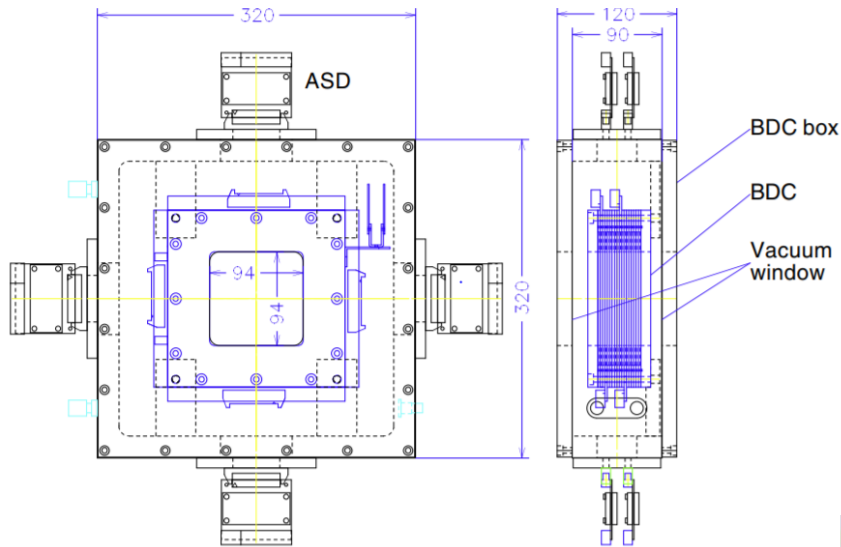
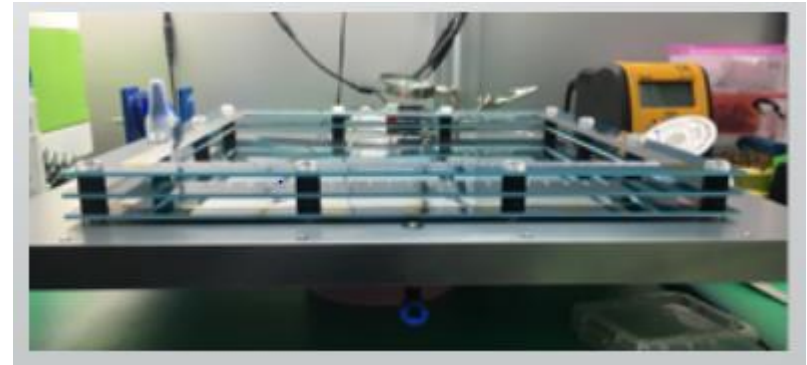
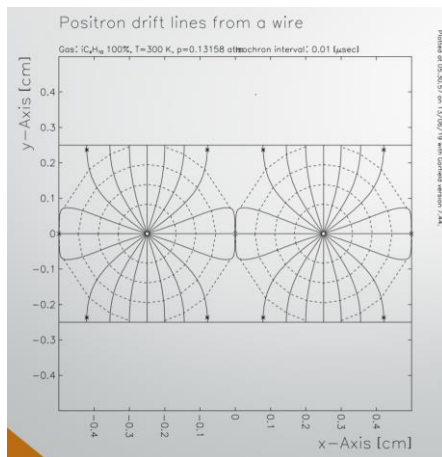


Fig. 9. Schematic view of the BDC and the BDC box.

- Measure beam profile.
- Low material density -> Gas chamber
- Adopt Samurai BDC Design & Prototype production

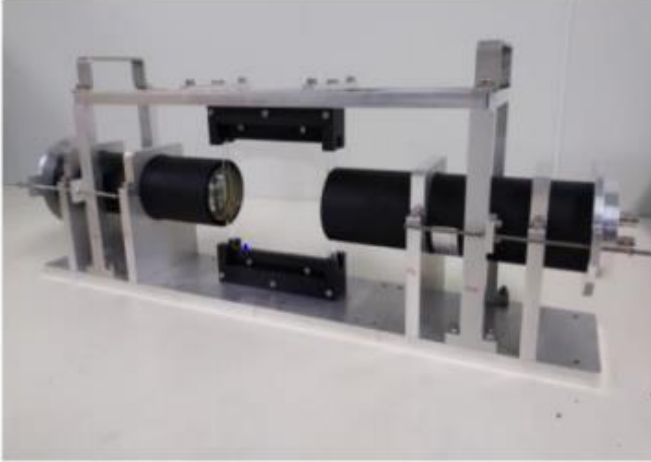
## Garfield simulation



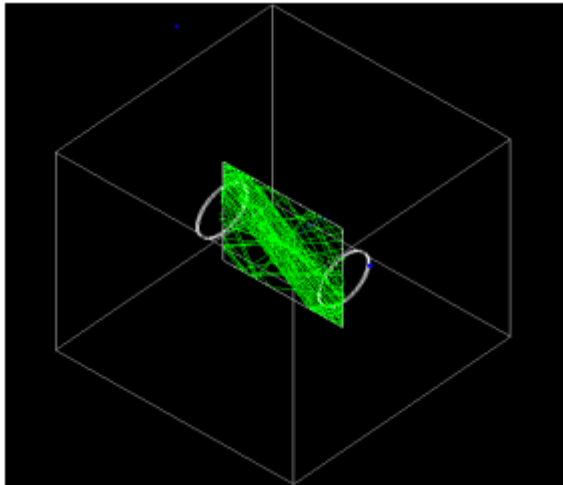
**KRISS**

# Starting counter

KoBRA Start counter



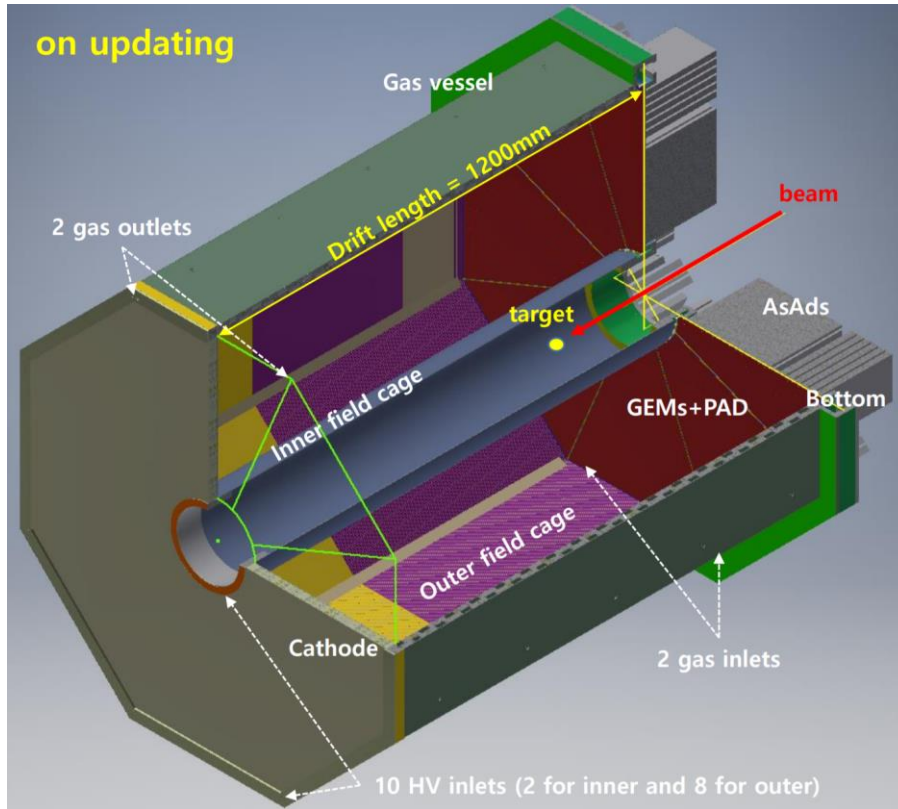
Geant4 Simulation



- Measure event timing with good timing resolution (  $\sim 50$  ps ).
- 100 mm x 100 mm sensitive area
- Test with KoBRA Start counter design
  - 100 mm x 100 mm x 100~200  $\mu$ m Scintillator
  - Two H2431-50 PMT
- Simulate with Geant4 and Purchase materials

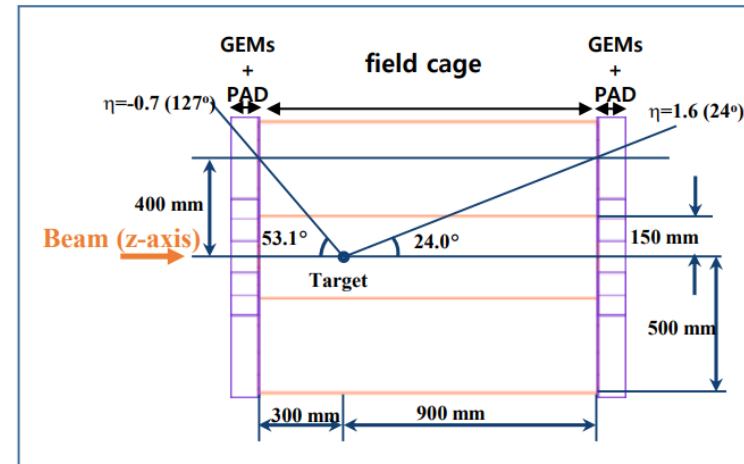
# Time Projection Chamber (TPC)

LAMPS TPC



- Main charged particle tracker
- TPC using GEM
- Octagonal prism shape with beam hole
- Drift length : 1200 mm
- DAQ : GET system + NARVAL DAQ
- Large acceptance  $> 3 \pi$

Cross-sectional view of LAMPS TPC

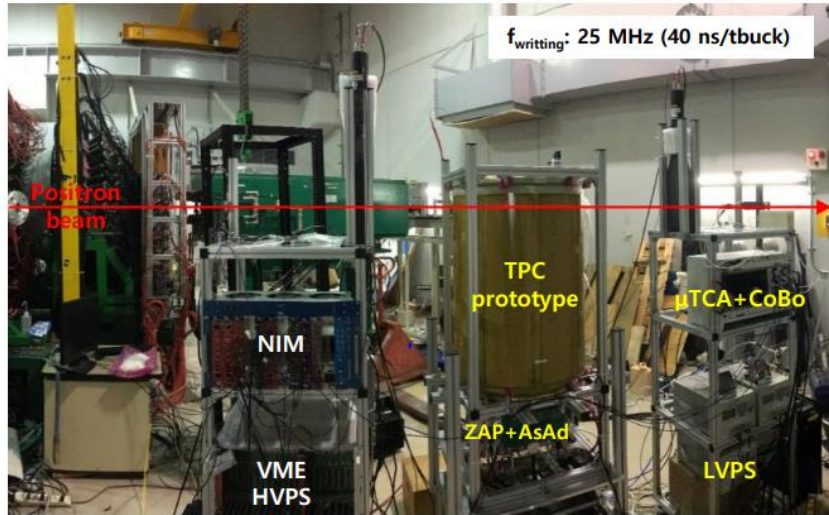




# TPC status

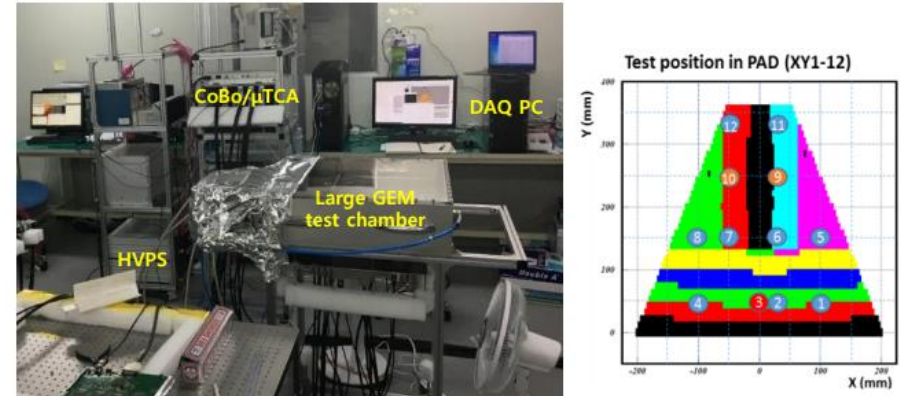
## Beam test with prototype (2016)

Test setup of TPC prototype at ELPH (Nov. 1-2 in 2016)



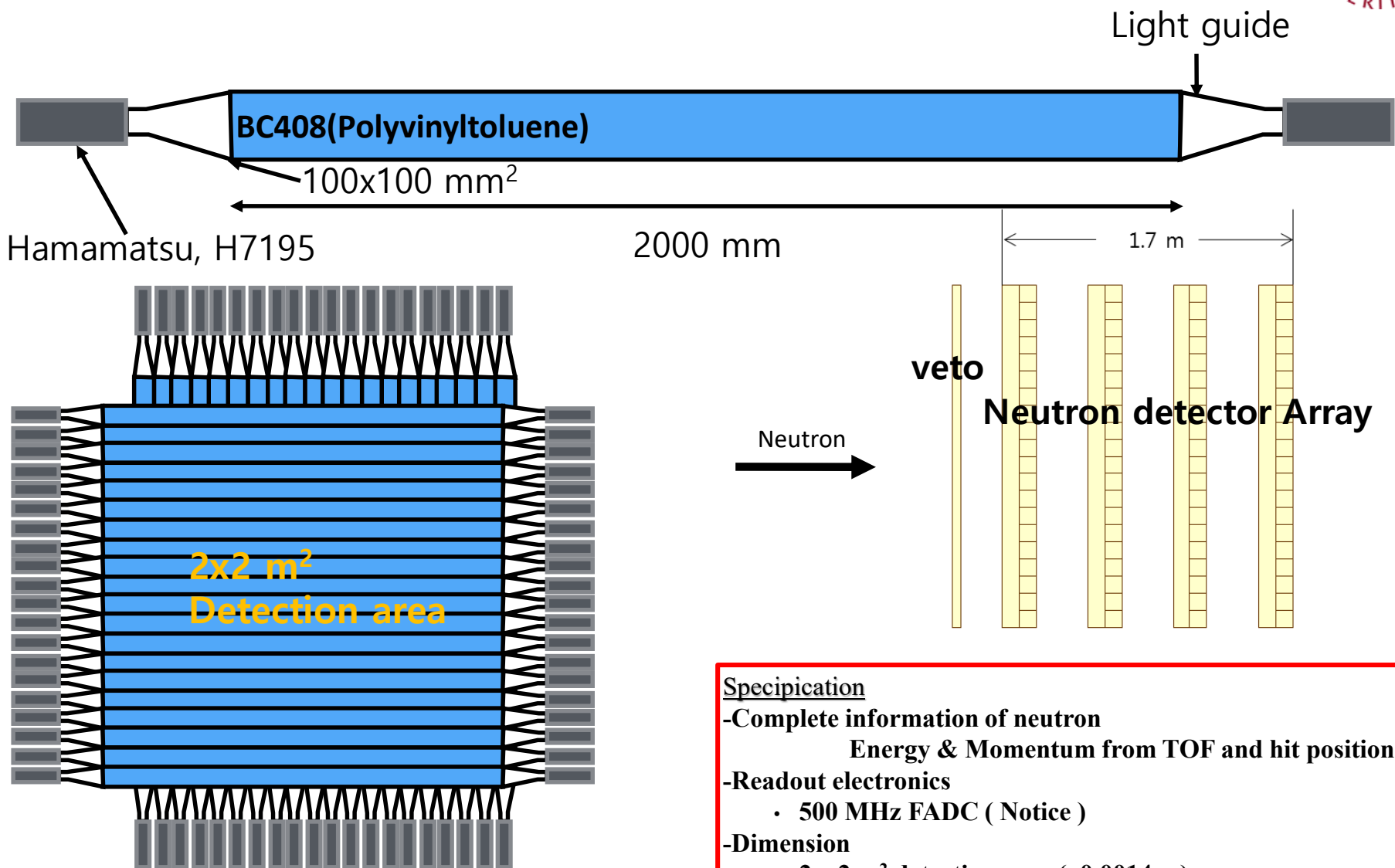
- Tested with 1/8 size prototype
- Max drift velocity : 6.7 cm/ $\mu$ s
- Position resolution : 228  $\mu$ m
- Transverse diffusion < 500  $\mu$ m/cm
- Max gain :  $8 \cdot 10^3$

## Real size GEM test



- Design of gas vessel and field cage.
- GEM sample test and final design
- Operational system preparation
  - HV supply system
  - Gas supply system
  - Laser calibration system

# Neutron Detector array (NDA)



- Specipication
- Complete information of neutron
    - Energy & Momentum from TOF and hit position
  - Readout electronics
    - 500 MHz FADC ( Notice )
  - Dimension
    - 2 x 2 m<sup>2</sup> detection area (~0.0014 sr)
    - Thickness : 20 cm / stage, 4 stages in total
    - 180 modules / 360 channels

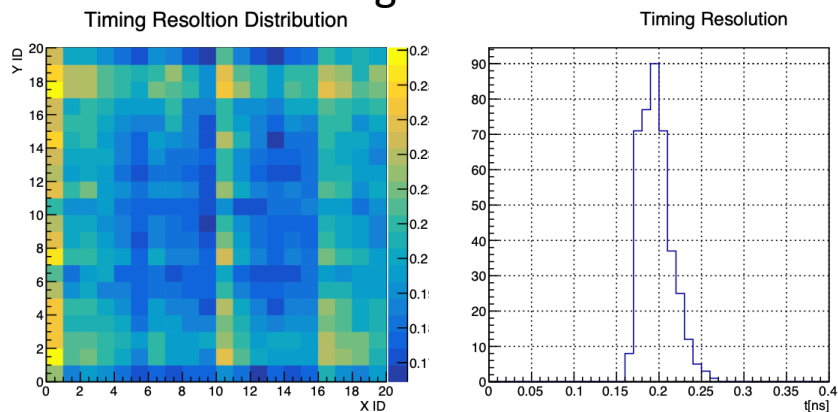
# NDA status



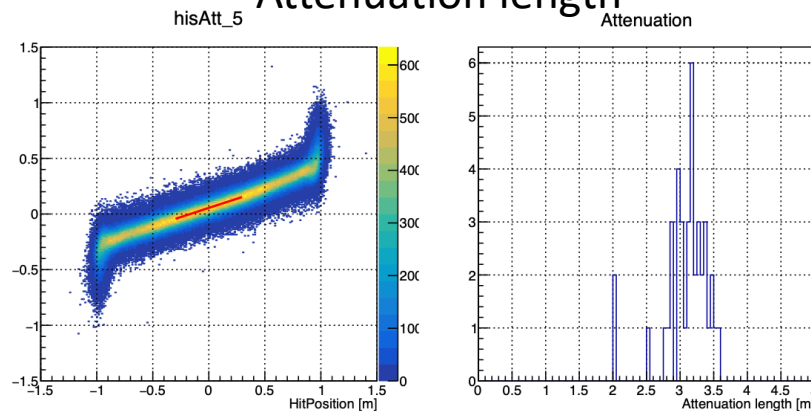
Current status of NDA

- All detectors and DAQs were installed.
- Commissioning with cosmic ray

## Timing resolution



## Attenuation length



	Prev ( 1 module )	Current ( 40 module )
t res.	139 ps	140 ps ( 197 ps )
pos res.	23 mm	-
Attenuation length	3.3 m	3.1 m

# Summary

- Symmetry energy in neutron-rich nuclei gives us information about neutron star.
- All of detectors in LAMPS experiment are under development toward RAON.

Detector	Status	Detector	Status
Beamline	Simulation	Time projection chamber	Design & Production
Beam diagnostic detector	Simulation & Prototype production	Barrel TOF	Design
Starting counter	Simulation & Prototype production	Neutron detector array	Constructed & Commissioning