7th International Symposium on Nuclear Symmetry Energy (NuSYM2017)
GANIL, Caen, France, September 4-7, 2017

Status of RAON and LAMPS in Korea

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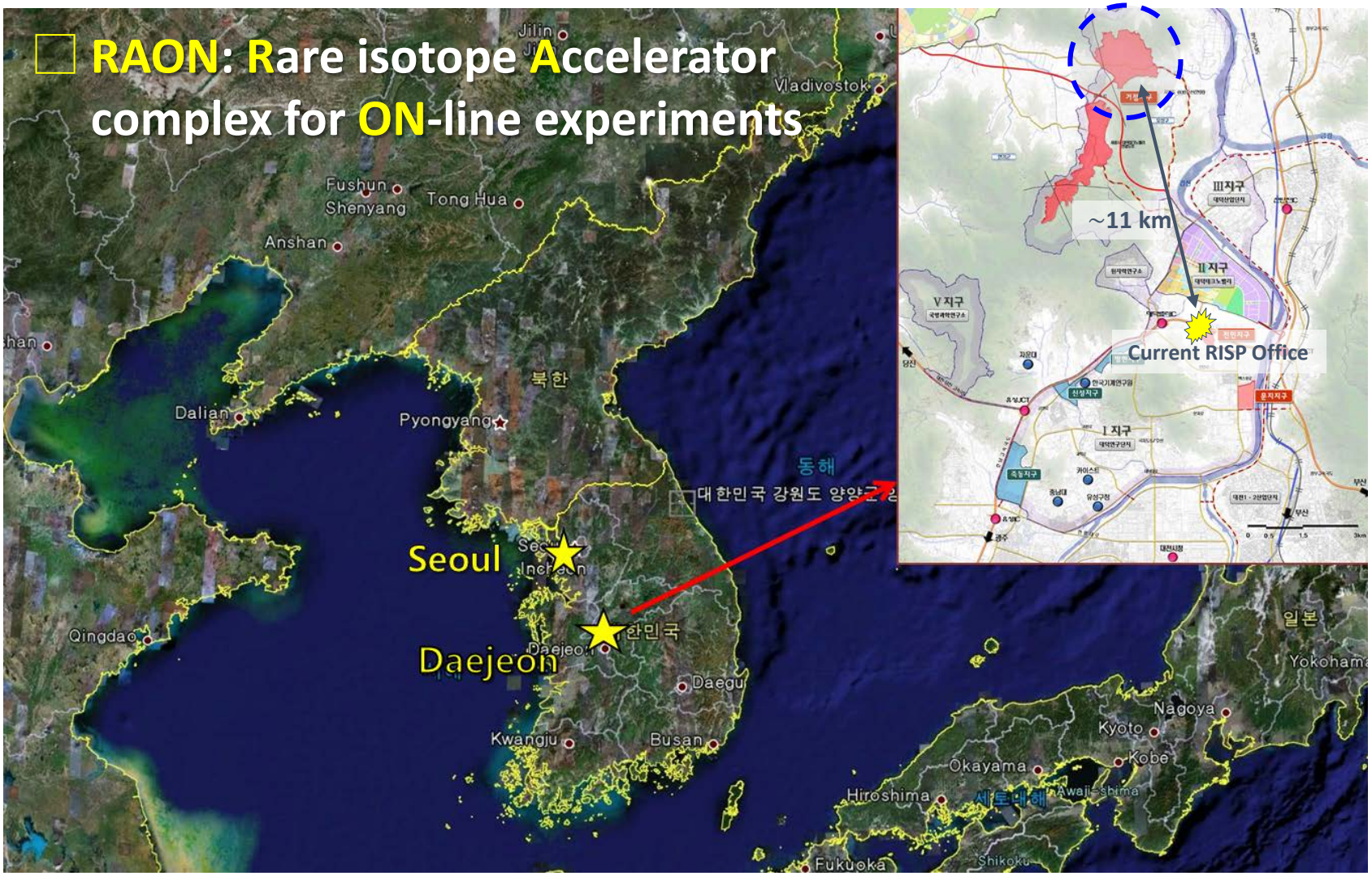
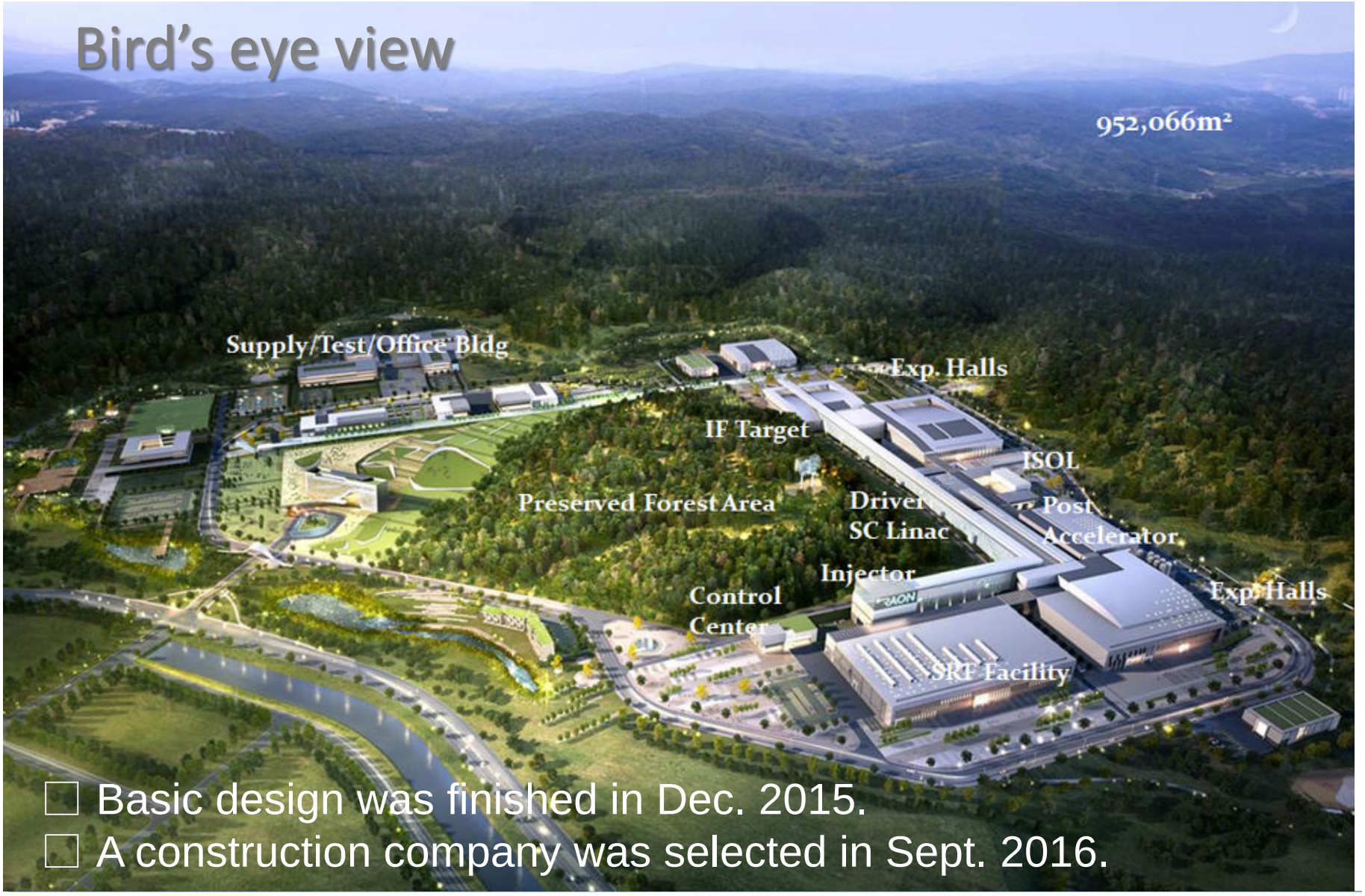
(Korea University)

Location of RAON Complex



Site Plan

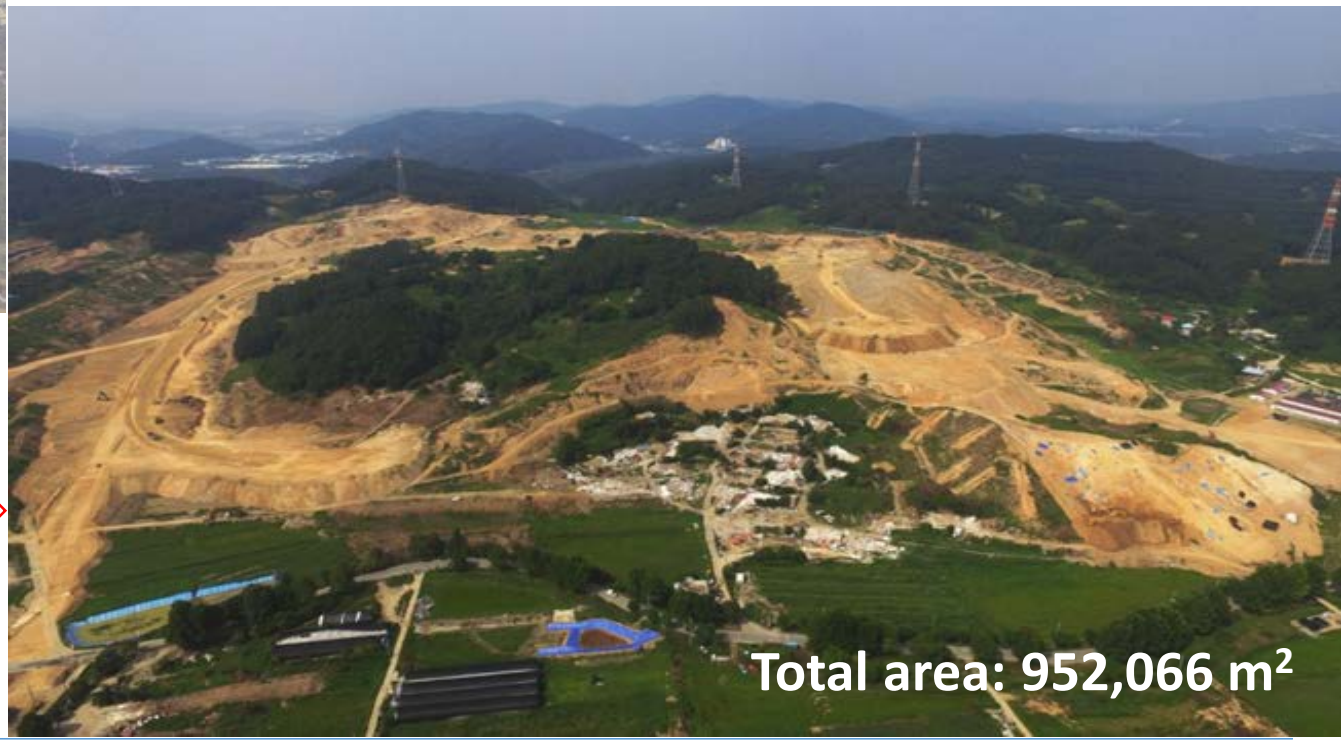
Bird's eye view



- Basic design was finished in Dec. 2015.
- A construction company was selected in Sept. 2016.

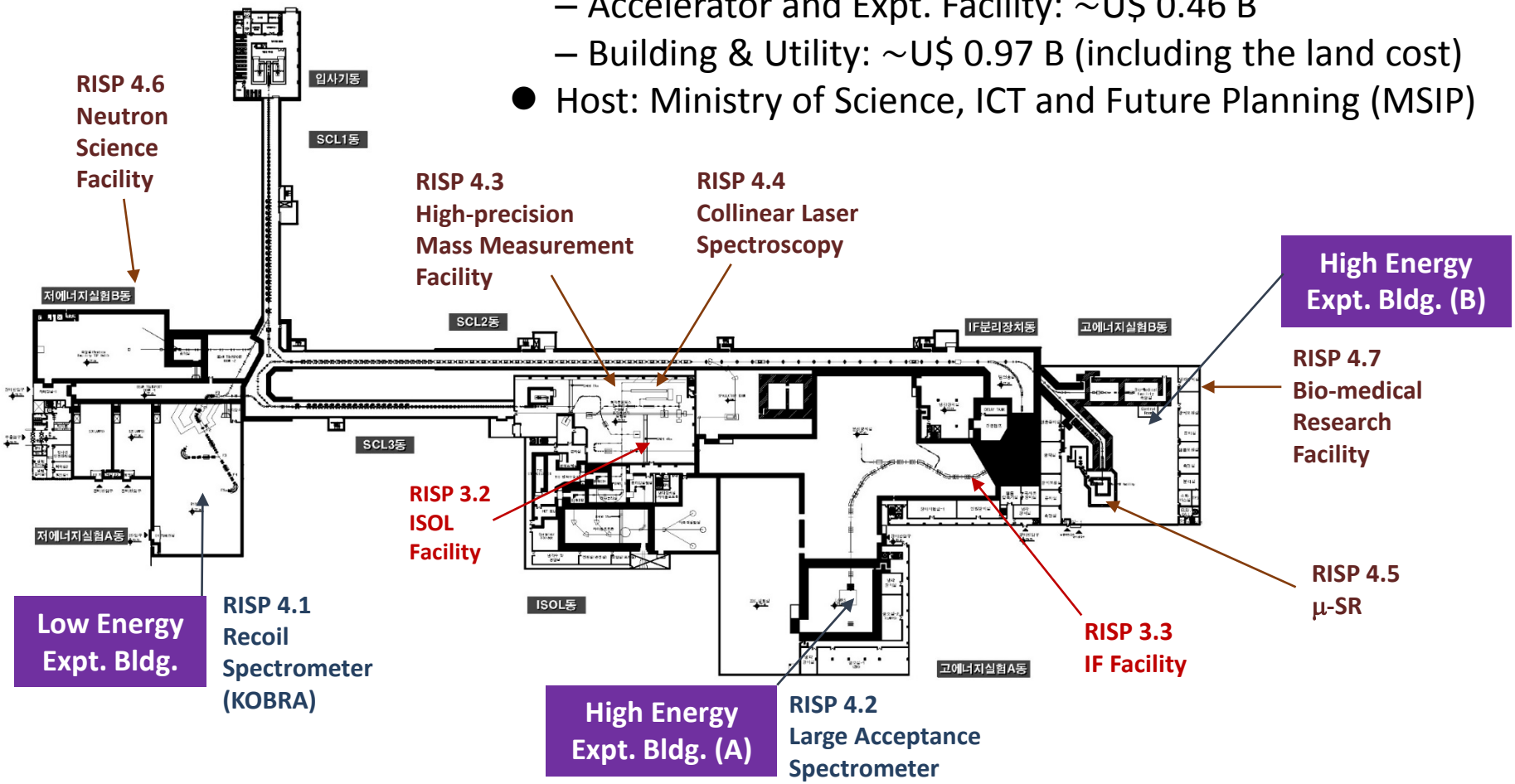
Site Preparation

- Construction and civil engineering for RAON has begun.
- The ground breaking for accelerators and experimental buildings was done on Feb. 13th this year.



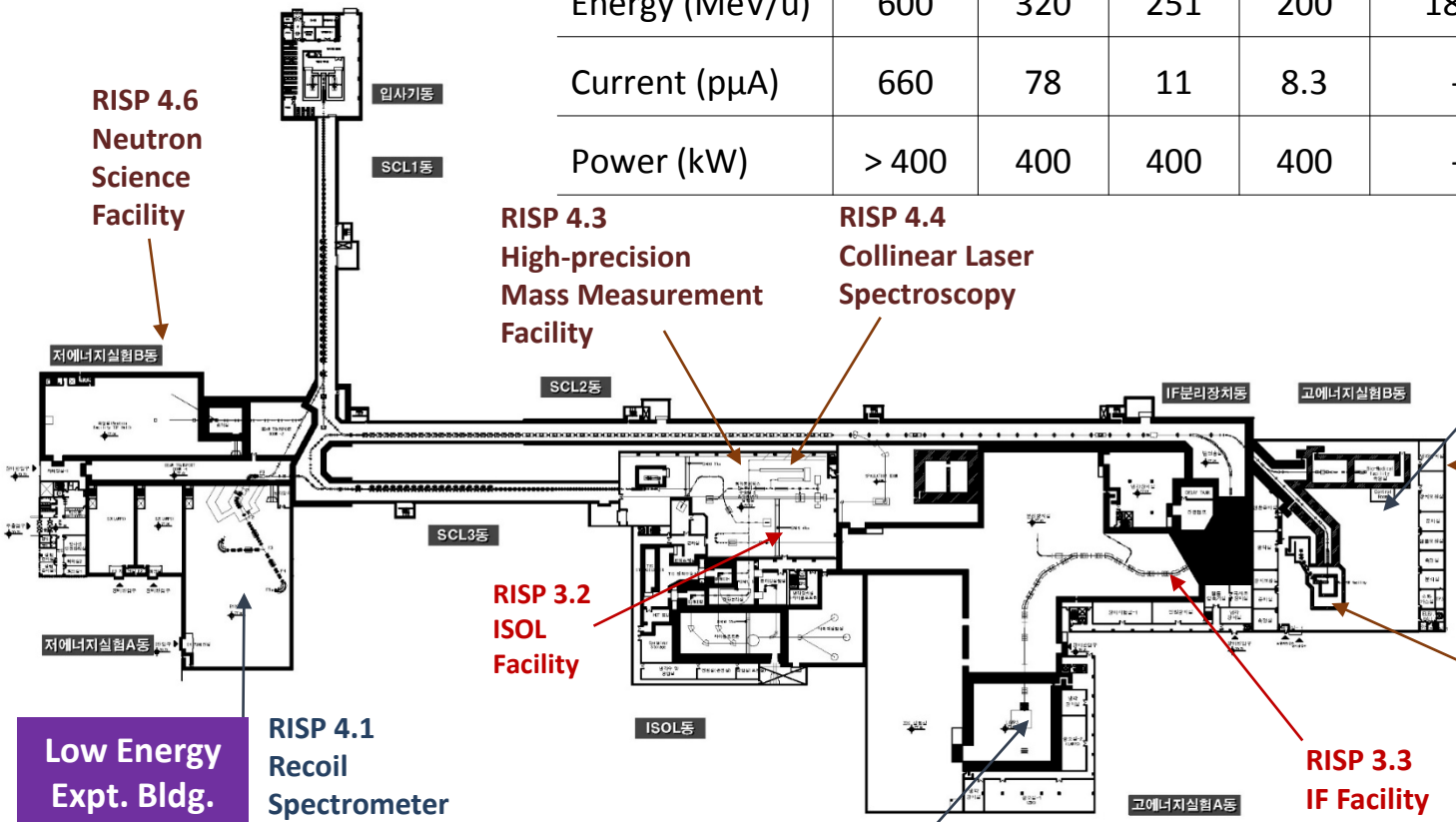
Layout of RAON

- Project period: Dec. 2011 ~ Dec. 2021
- Scope: Accelerator Facility, Buildings & Utilities
- Budget: Total ~U$ 1.43 B
  - Accelerator and Expt. Facility: ~U$ 0.46 B
  - Building & Utility: ~U$ 0.97 B (including the land cost)
- Host: Ministry of Science, ICT and Future Planning (MSIP)

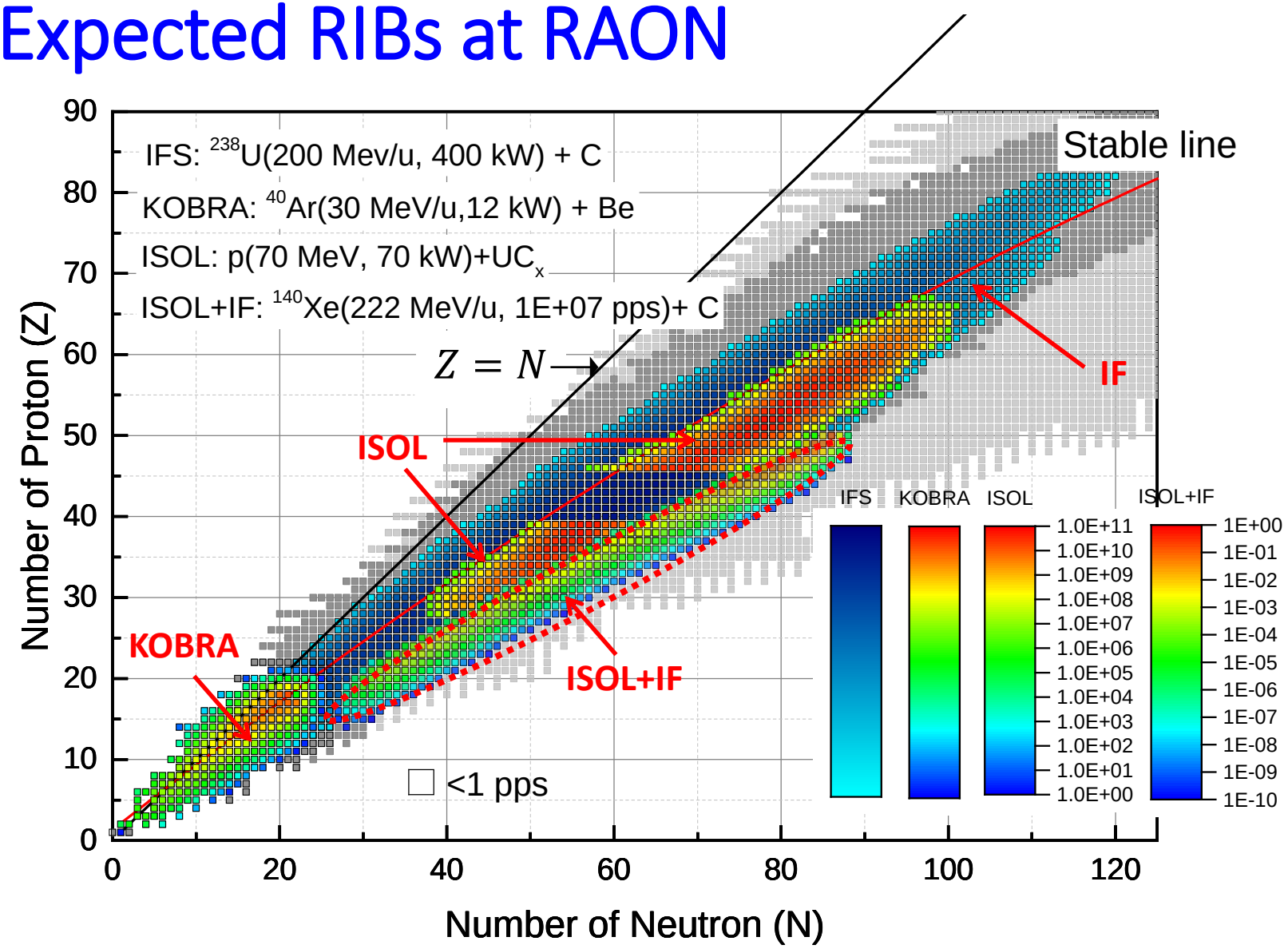


Layout of RAON

	Driver Linac				Post Acc.	Cyclotron
Particle	H^{+}	O^{+8}	Xe^{+54}	U^{+79}	RI beam	proton
Energy (MeV/u)	600	320	251	200	18.5	70
Current (pμA)	660	78	11	8.3	-	1000
Power (kW)	> 400	400	400	400	-	70

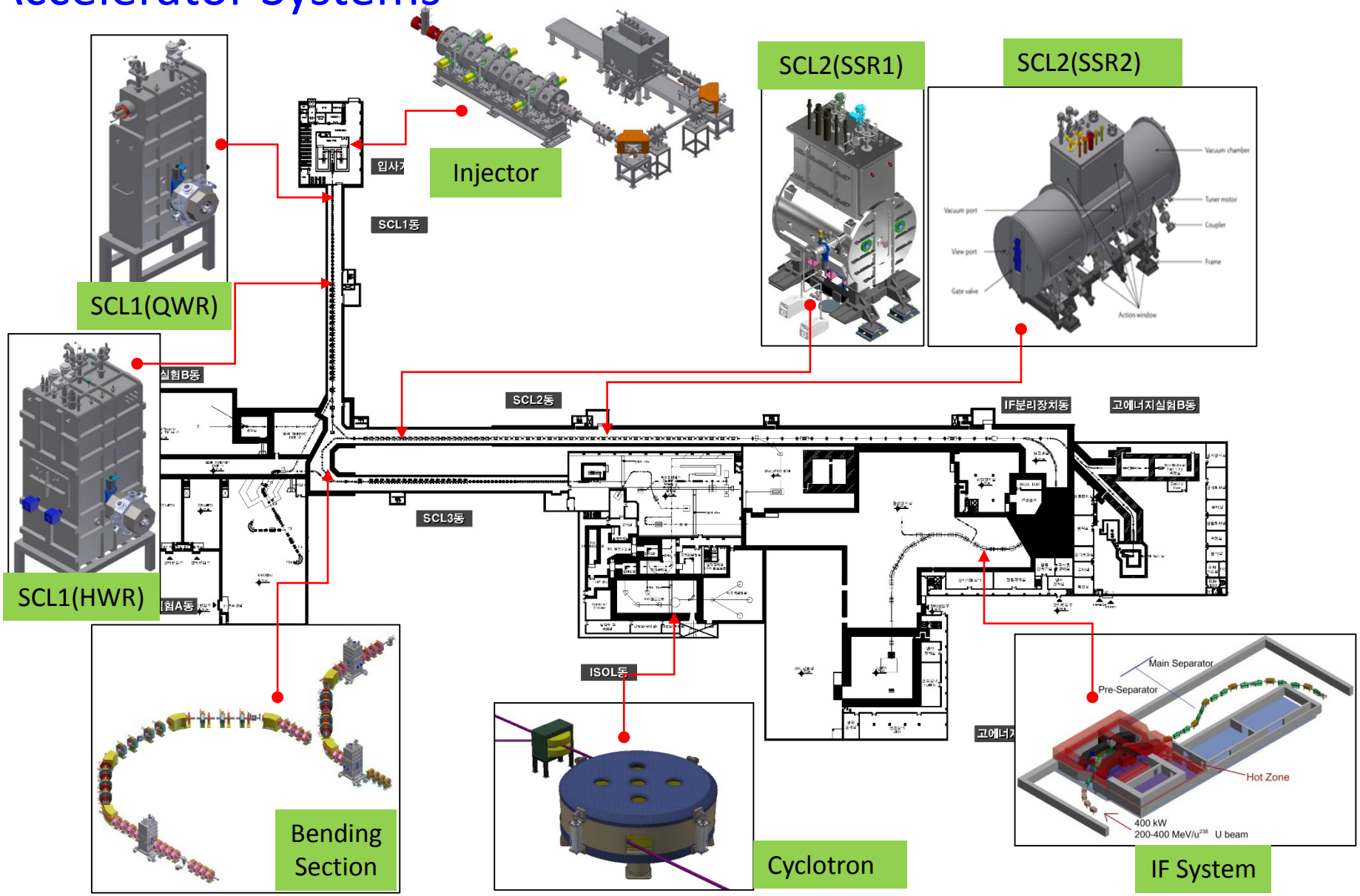


Expected RIBs at RAON



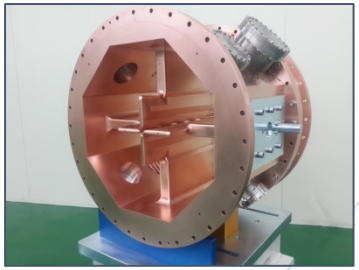
RAON aims to provide an access to unexplored regions of nuclear chart.

Accelerator Systems

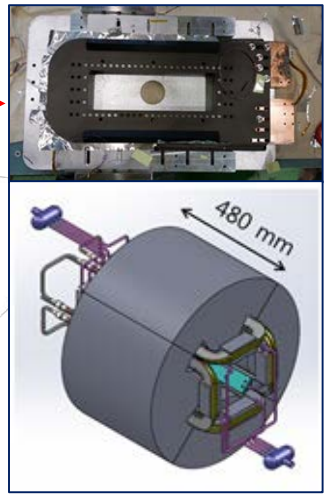


Prototypes of Accelerator Components

28 GHz ECR Ion Source



RFQ



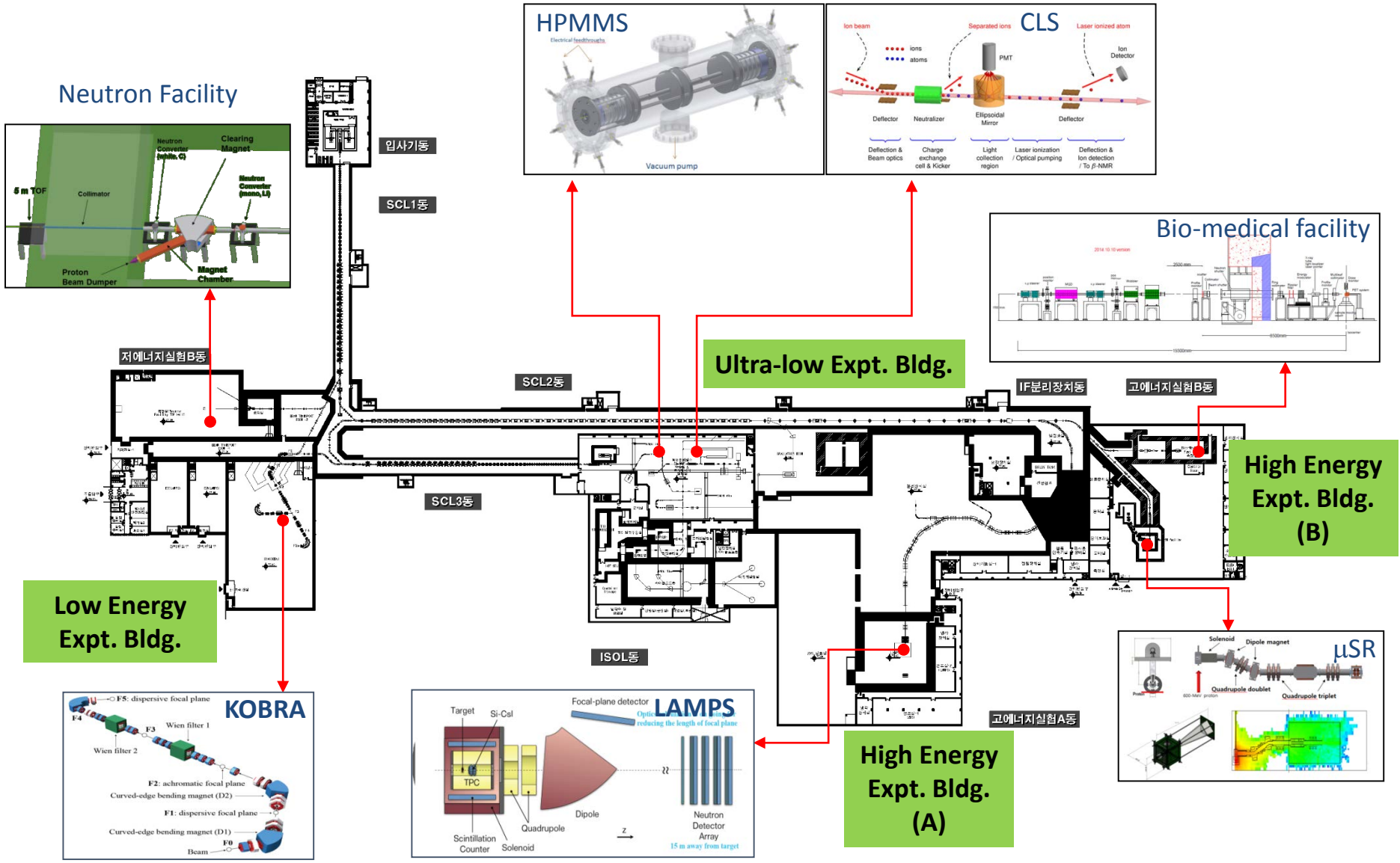
HTS Q-magnet

QWR SC Cavity & its Cryomodule

HWR SC Cavity & its Cryomodule

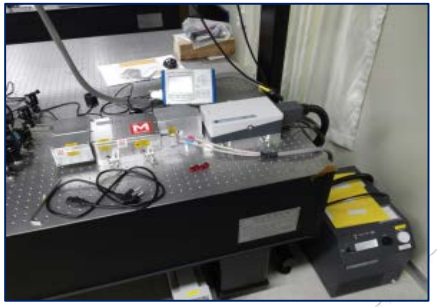
SSR SC Cavity and its Cryomodule

Experimental Systems

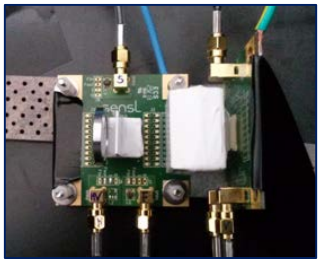


Prototypes of Experimental Systems

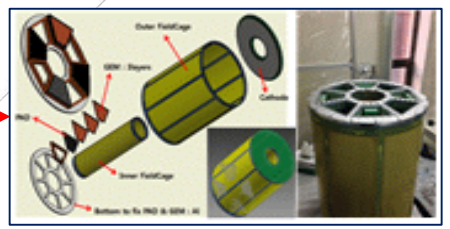
Gamma array



LASER for collinear laser spectroscopy

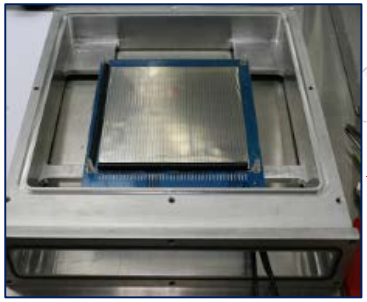


β-detection system for μSR

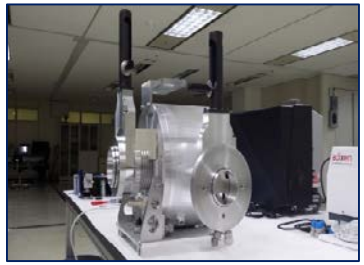


Time Projection Chamber

ISOL beam diagnostics

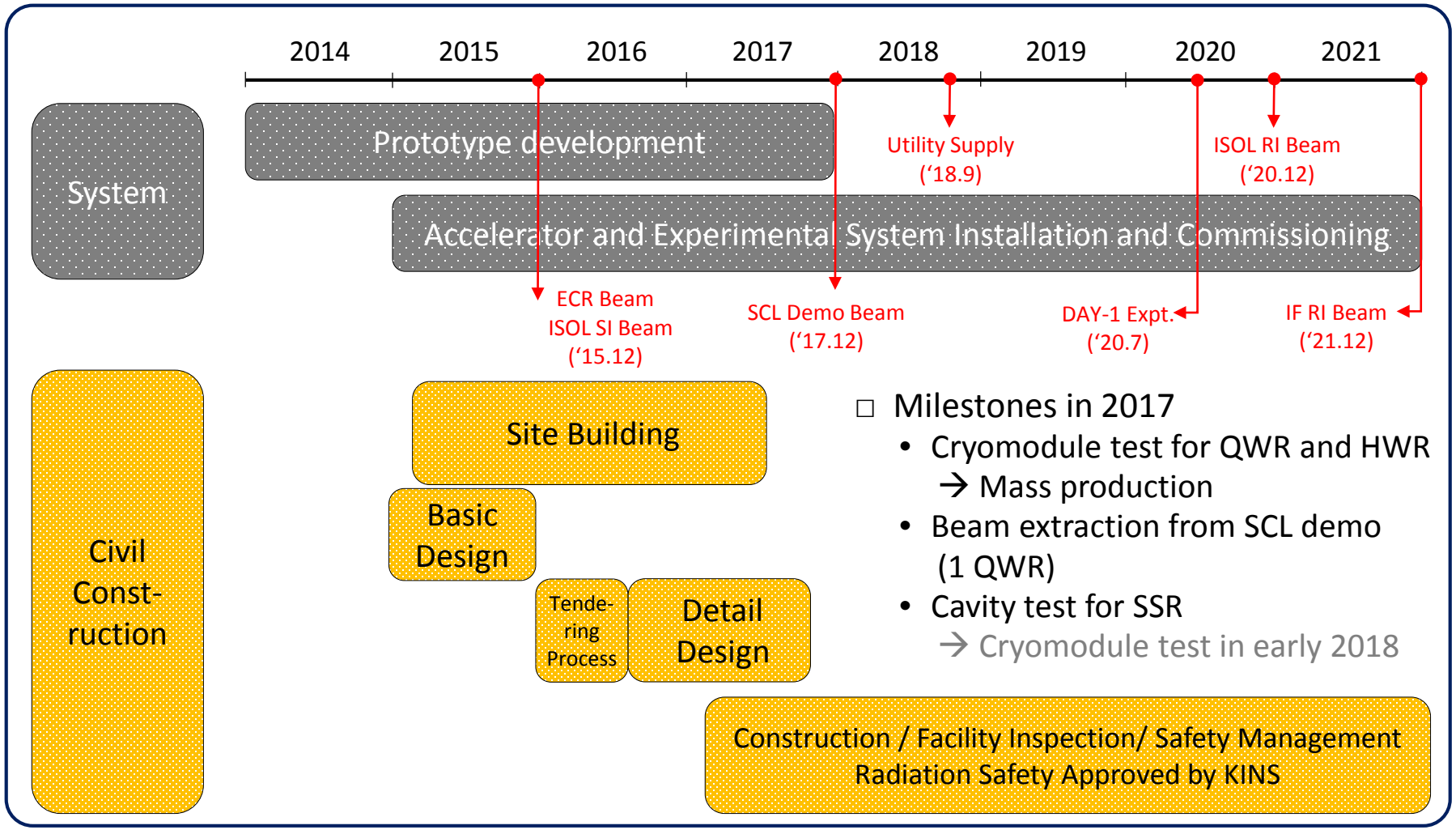


Beam-tracking detector (PPAC)



ISOL target

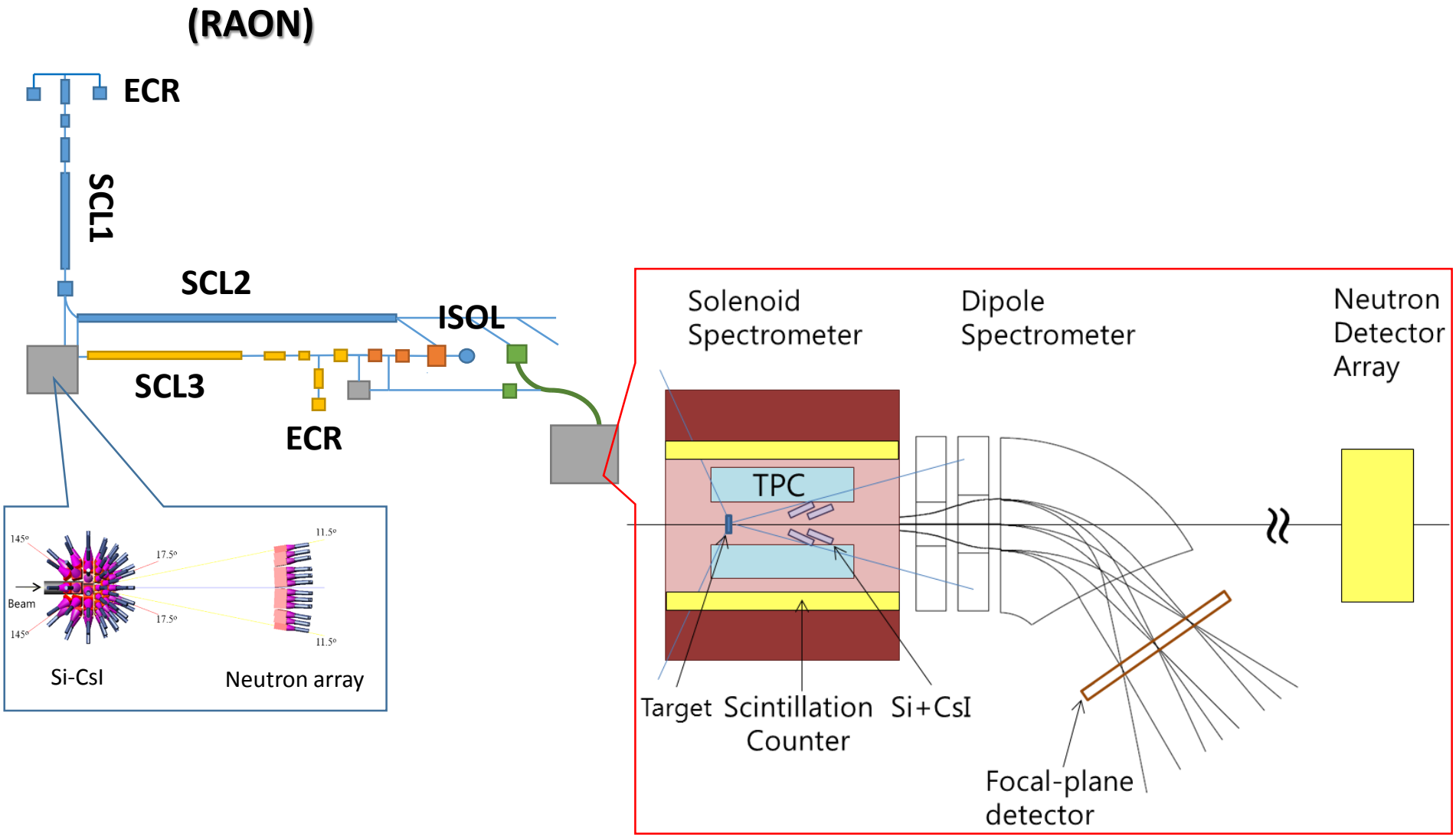
Major Milestones



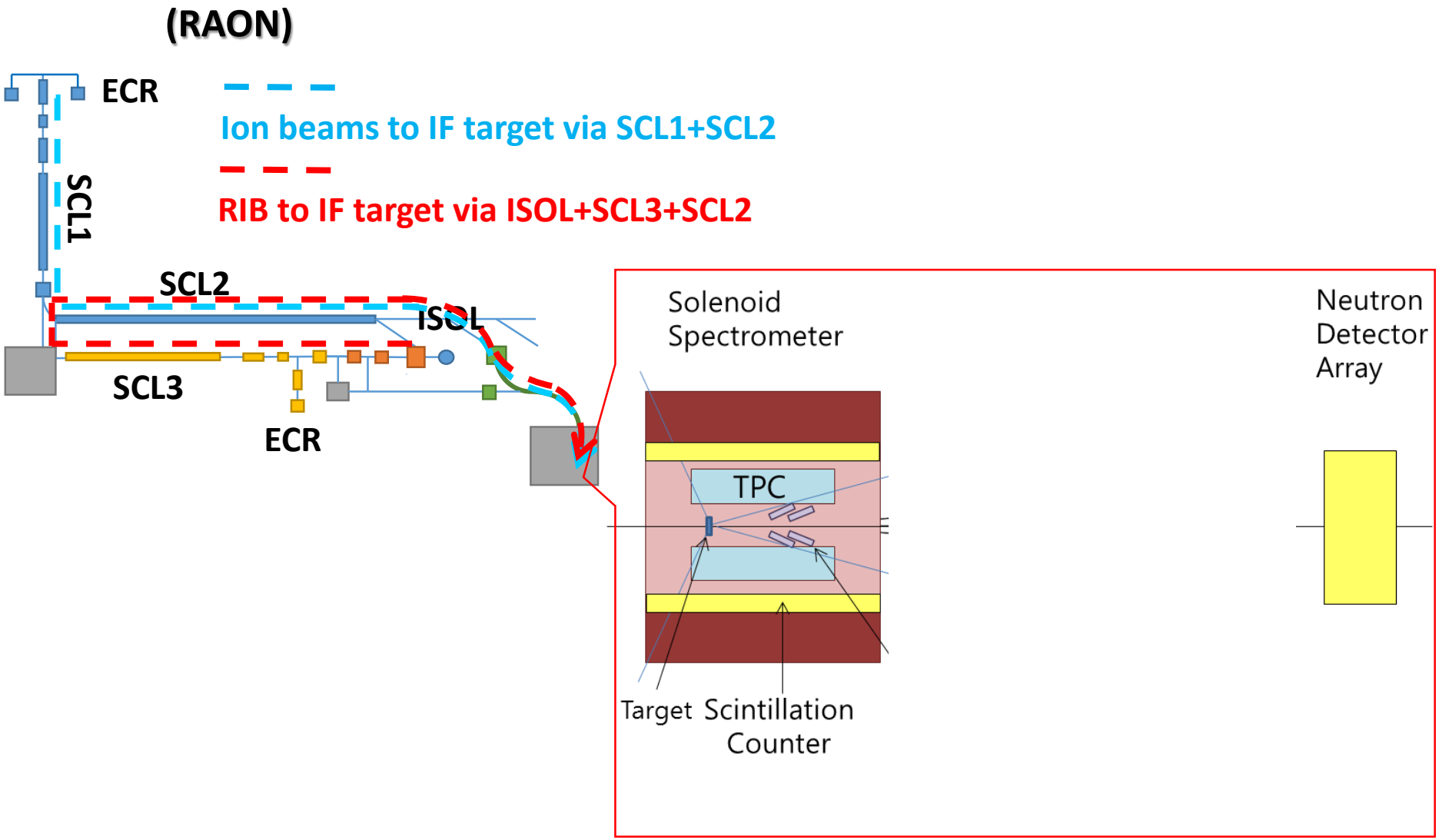
- Milestones in 2017
  - Cryomodule test for QWR and HWR
    → Mass production
  - Beam extraction from SCL demo (1 QWR)
  - Cavity test for SSR
    → Cryomodule test in early 2018

LAMPS:
Large-Acceptnce
MultiPurpose
Spectrometer

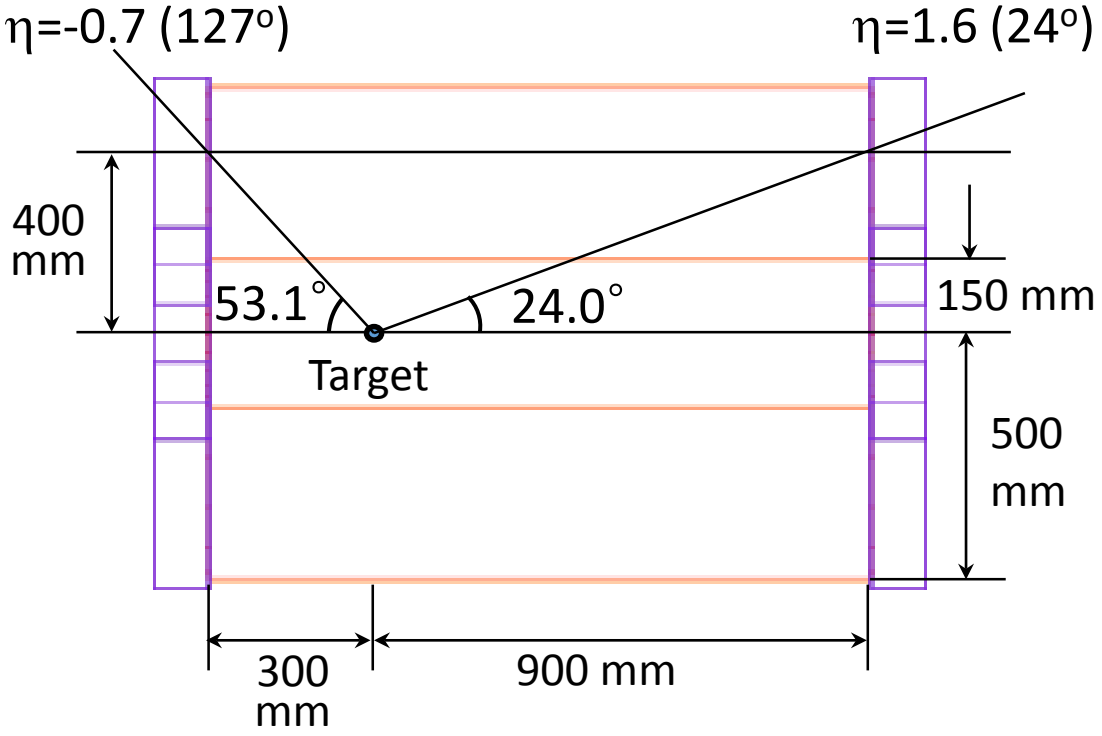
Location of LAMPS

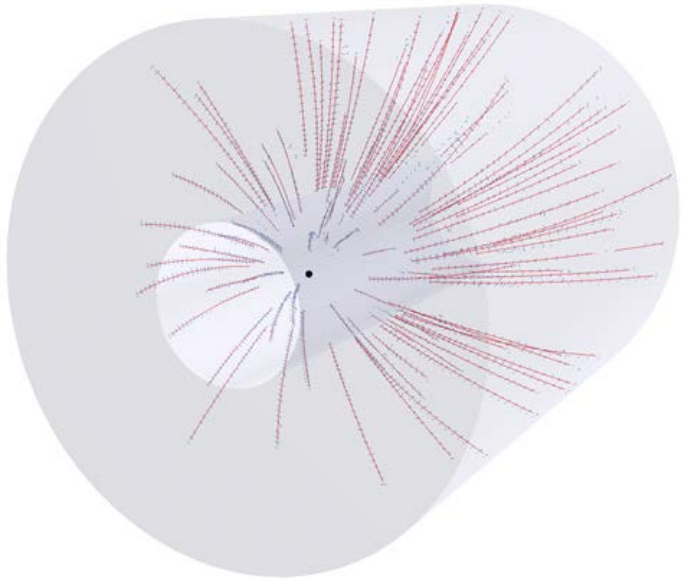


Location of LAMPS

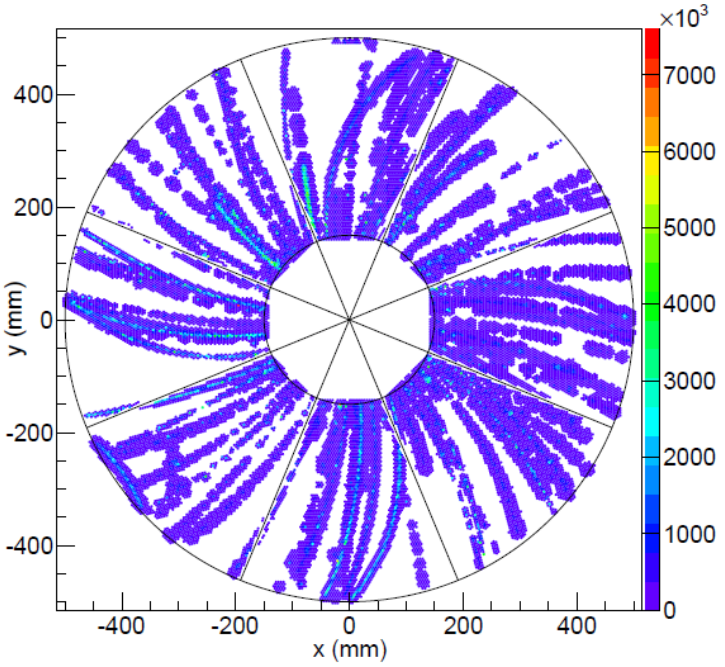


Time Projection Chamber

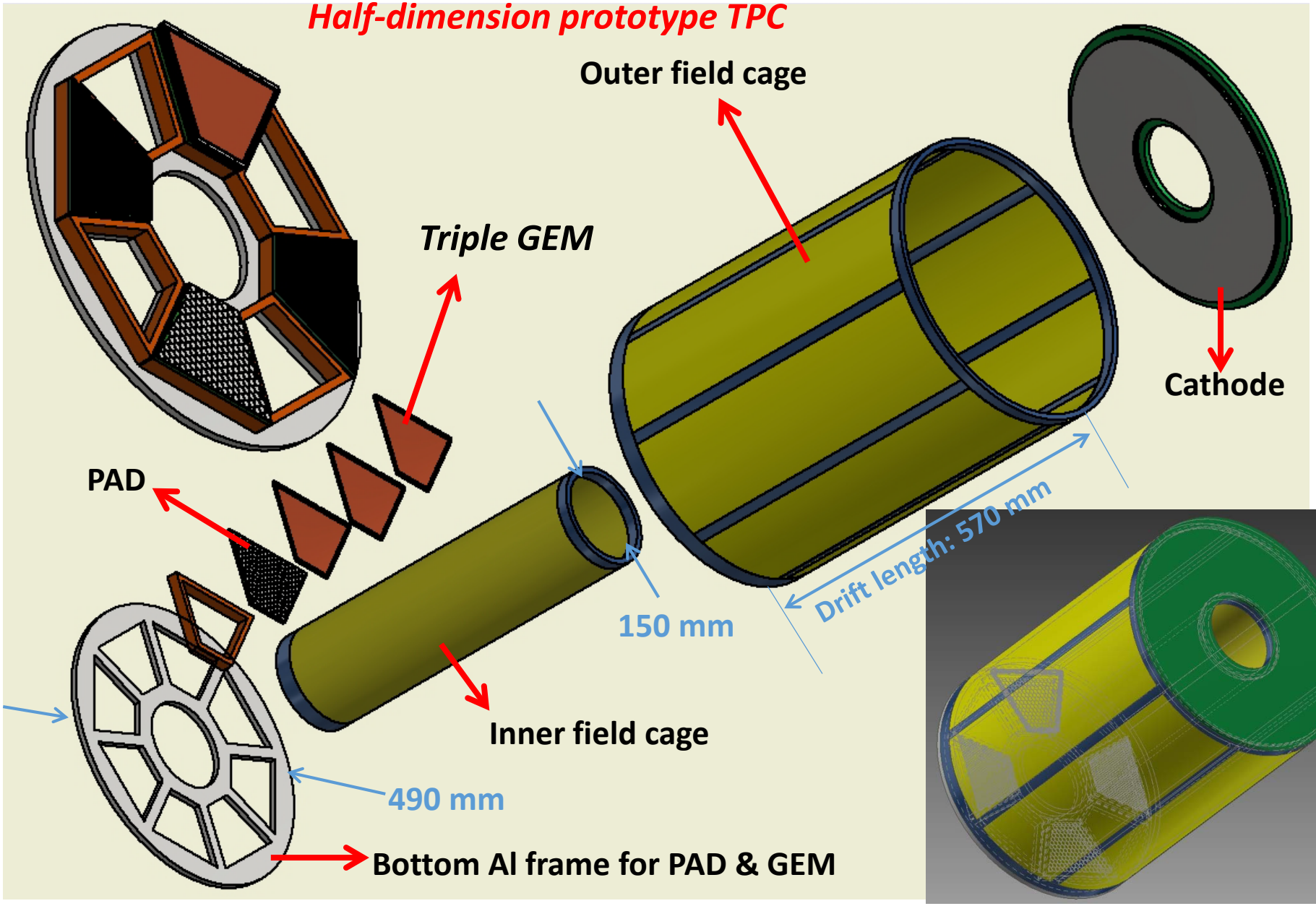




One central Au+Au event at 250 AMeV (IQMD)

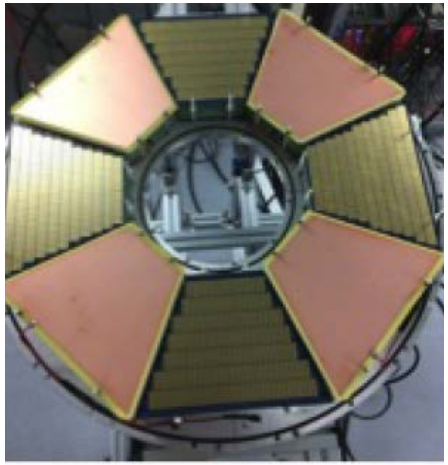


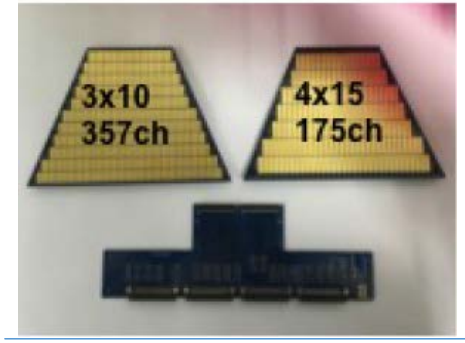
Prototype TPC: Design



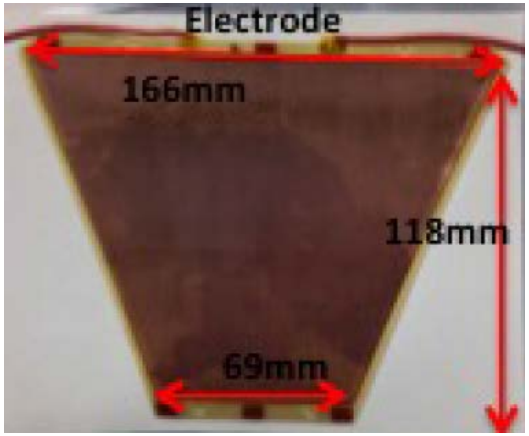
Prototype TPC: Components

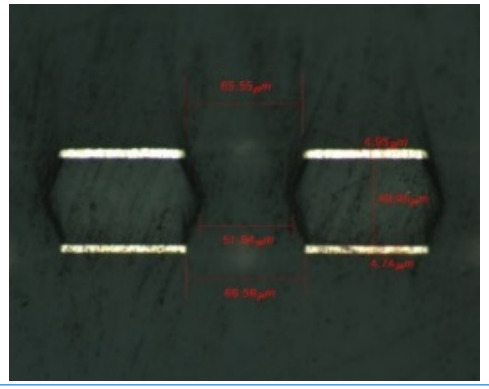
[Readout Pads]
Tested pads with the two different dimensions
3×10 mm^2: 357 Ch./Oct.
4×15 mm^2: 175 Ch./Oct.
Multi-layer PCB board



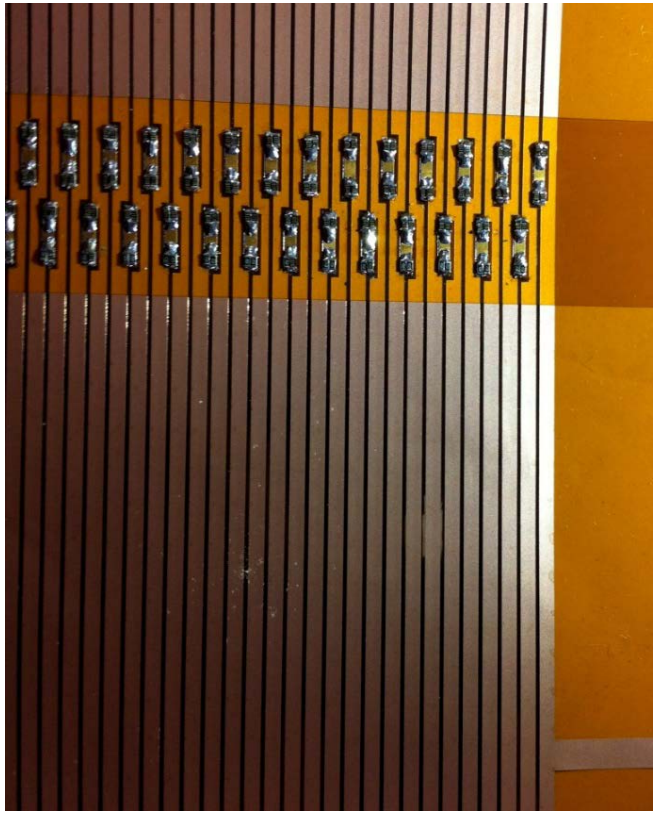


[GEM Foil]
Trapezoidal shape
Thickness: 75 μm
Area: 166×118 mm^2
Triple layers for each plane



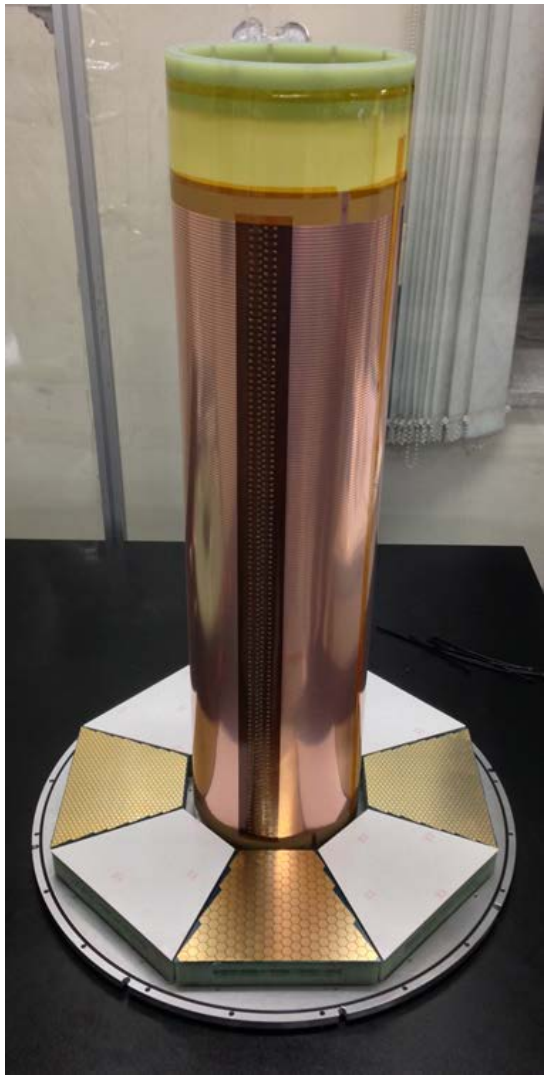


[Field Cage]
35 μm thick and 2 mm wide Cu strips
500 μm gap between adjacent strips
Mirror strips on the back
1 MΩ resistors with 0.1% var.
TPC body: G10 + Aramid honeycomb

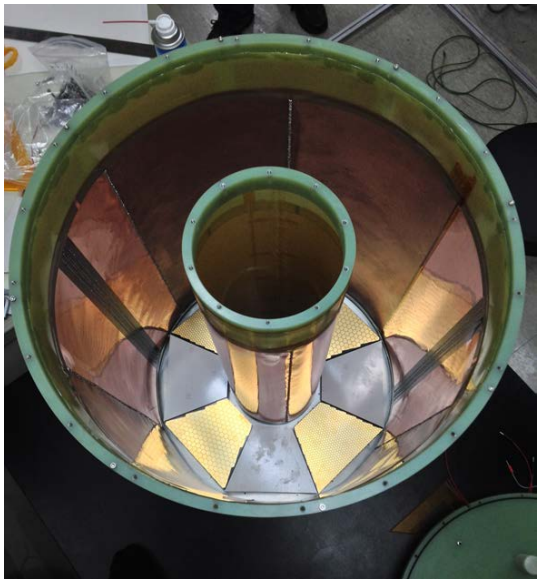


Prototype TPC: Assembly

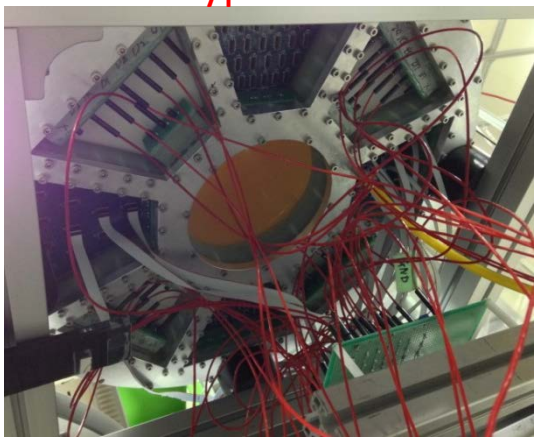
Inner Field Cage installed



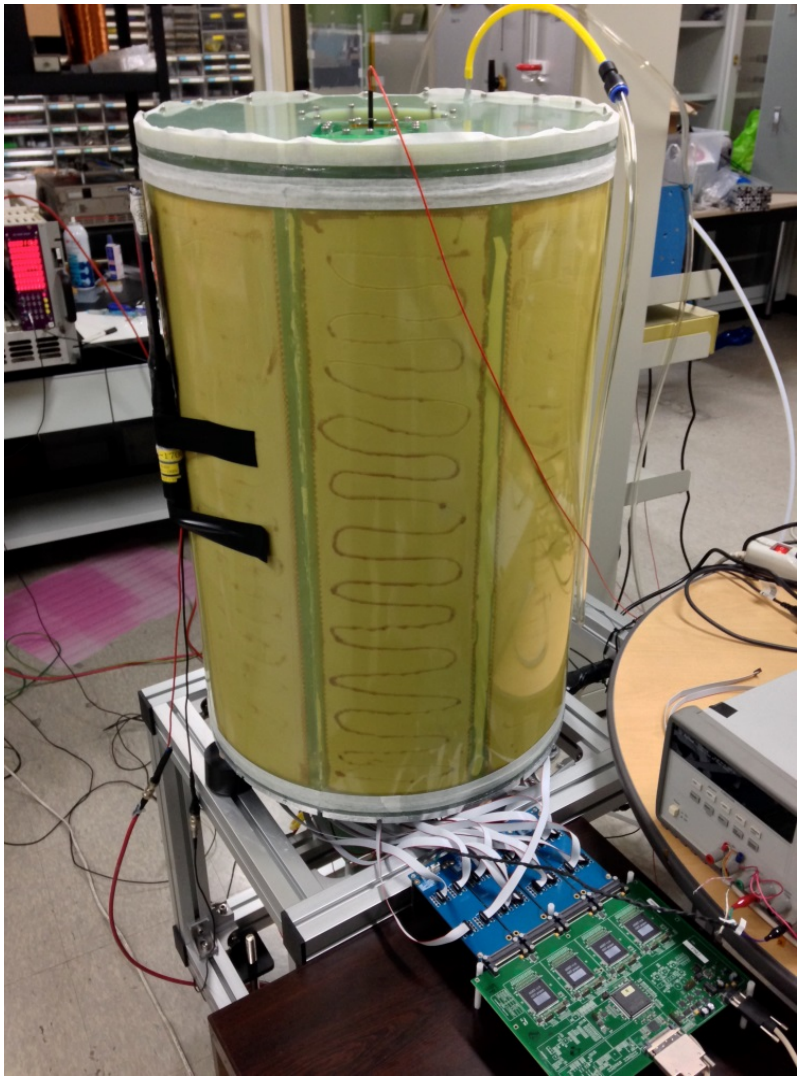
Outer Field Cage installed



Prototype TPC: back

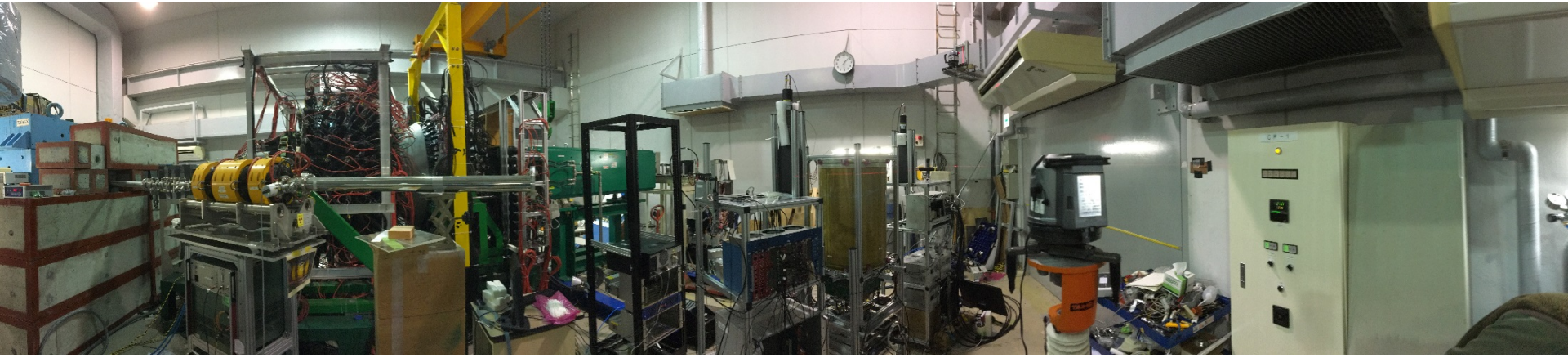


Prototype TPC assembled

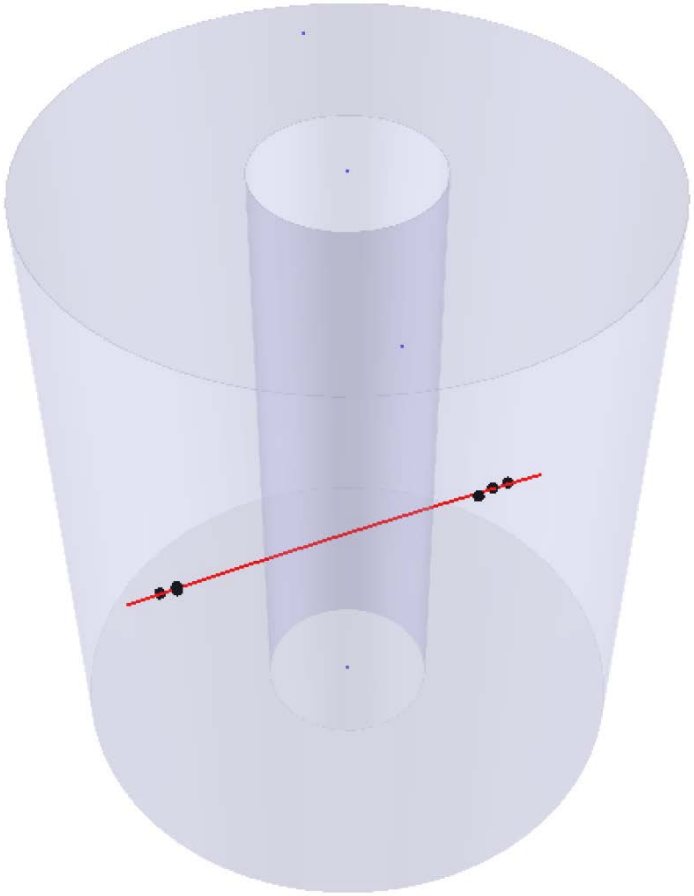


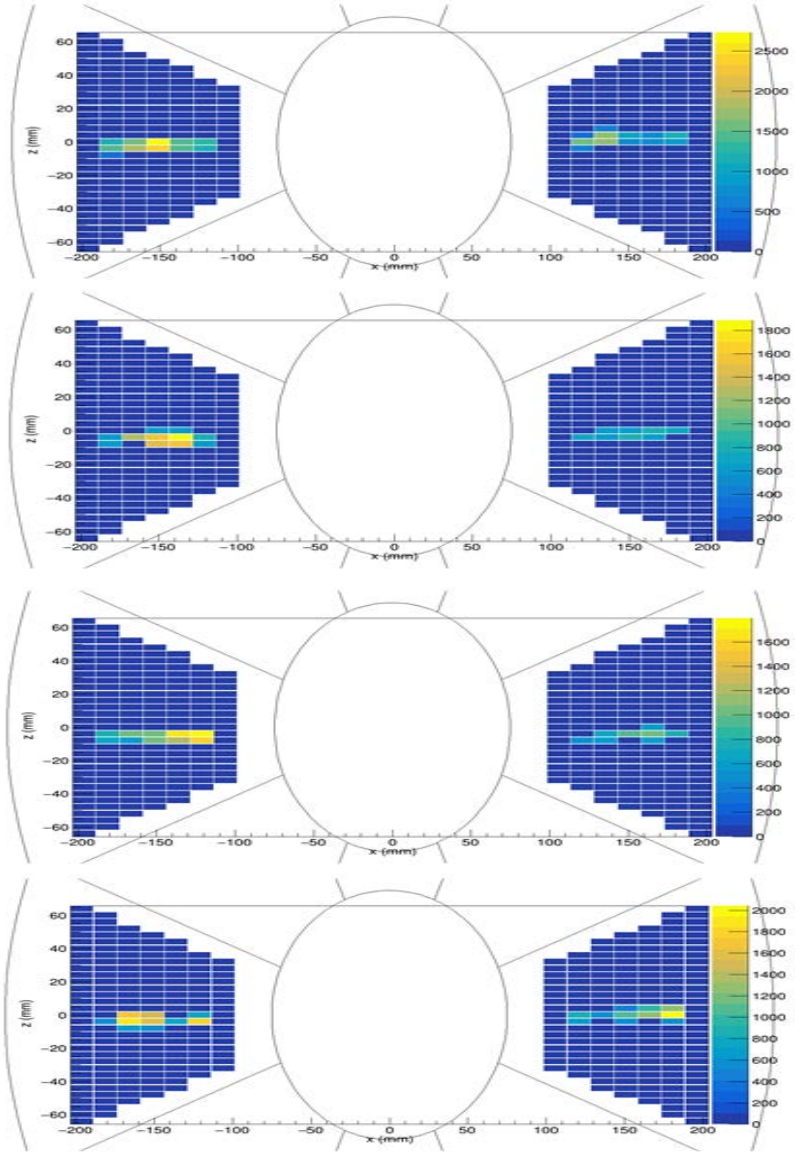
Prototype TPC: Test at ELPH

- ELPH: Research Center for Electron Photon Science at Tohoku University, Japan
- Dates: November 1-2, 2016
- Beams: e^+ beams at 500 MeV
- Gas: Ar(90%)+CH_4(10%) (P10)
  Ar(90%)+CO_2(10%) ($ArCO_2$)
- Purpose: To study the detailed characteristics, such as v_{drift}, diffusion and σ_x, of LAMPS TPC

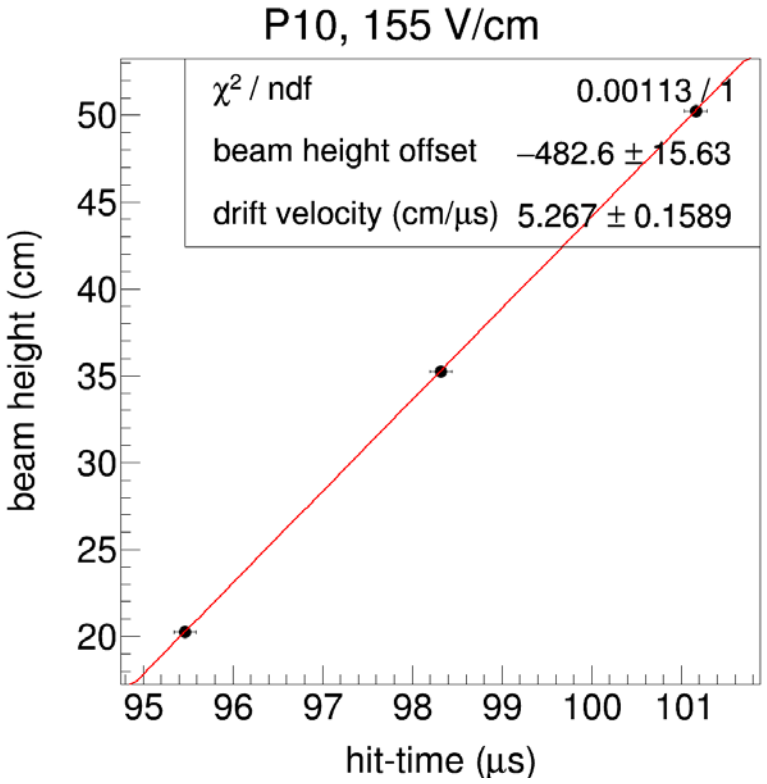


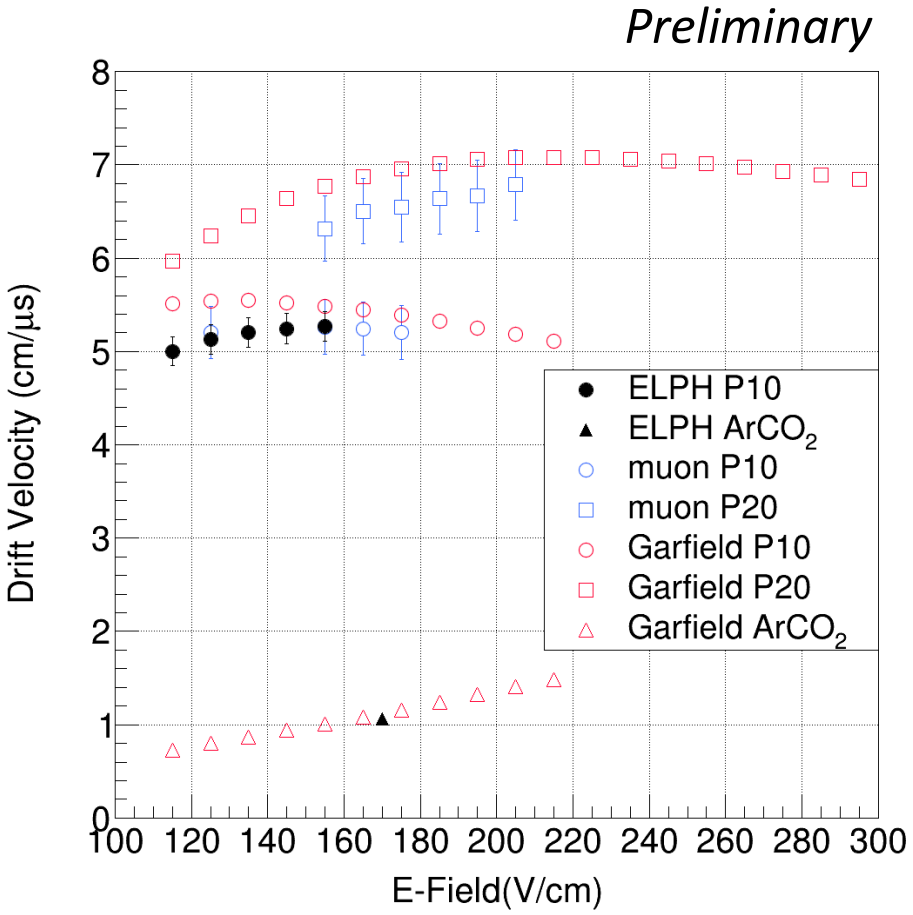
Prototype TPC: Event Displays





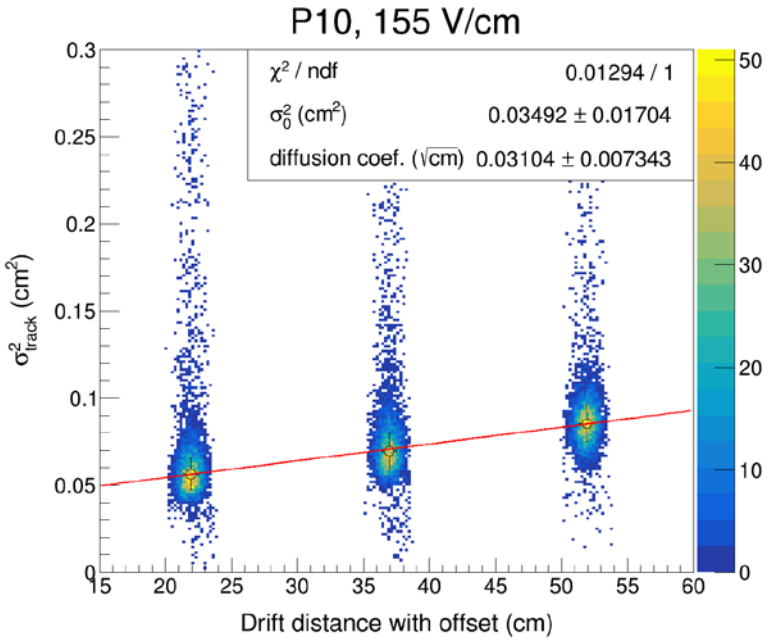
Prototype TPC: Drift Velocity



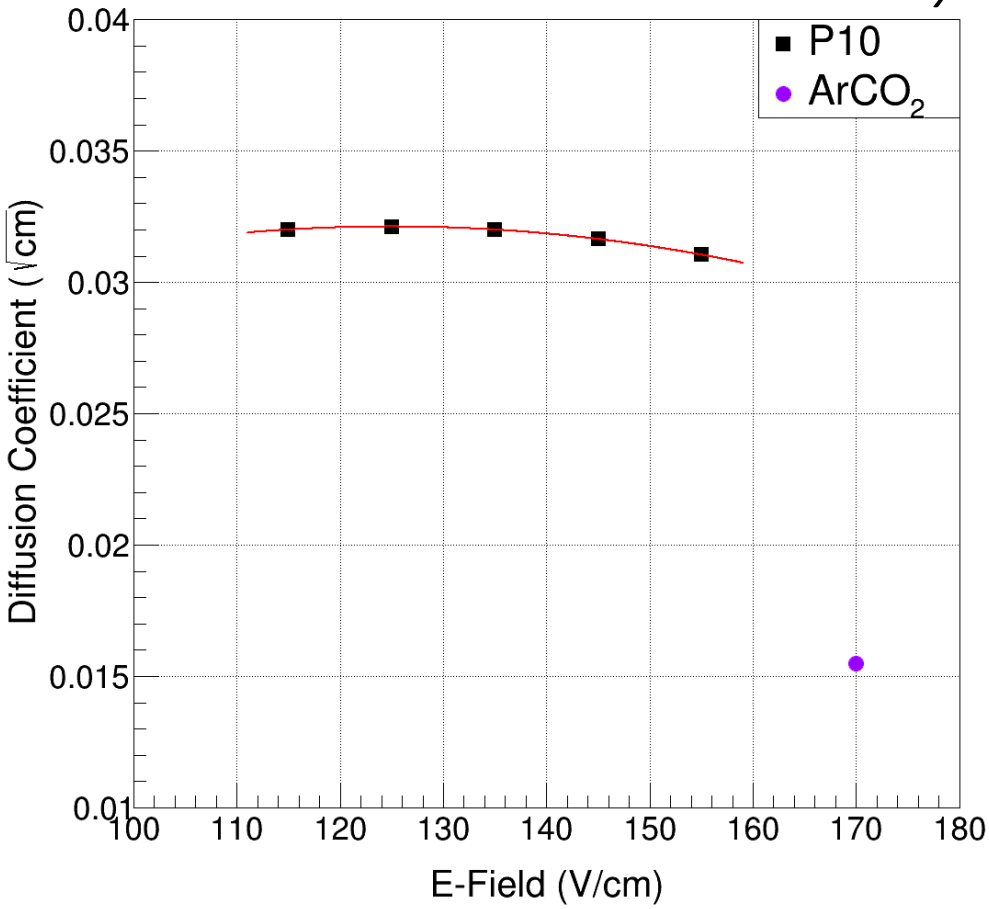


- $v_{drift} \lesssim 5.3\ \mathrm{cm}/\mu s$ for P10:
  Maximum distance: $512\ \text{timing bins} \times 0.04\ \mu s/\text{bin} \times 5\ \mathrm{cm}/\mu s \cong 100\ \mathrm{cm}$
- Tested P20 with cosmic muons: $v_{drift} > 6\ \mathrm{cm}/\mu s$ that will be suitable for LAMPS TPC if read out from only one endcap side.

Prototype TPC: Diffusion



Preliminary



$$\sigma_{track}^2 = D^2 z + \sigma_0^2$$

where

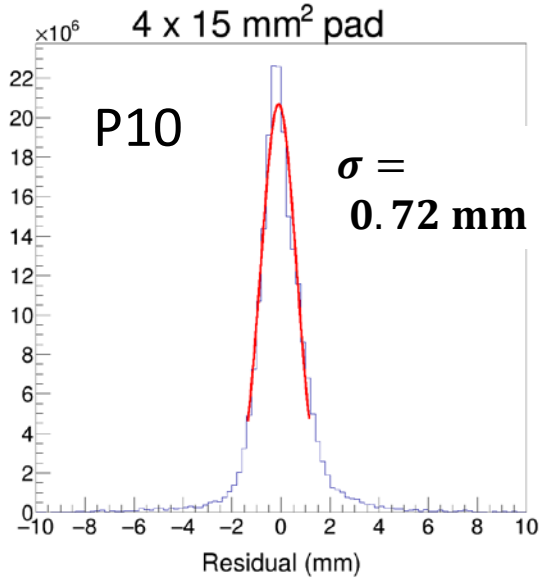
z: drift length

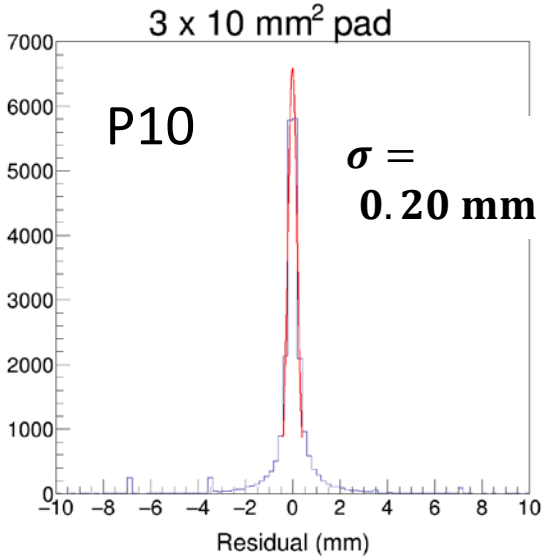
σ_{track}: width of hit distributions w.r.t. the fitted track

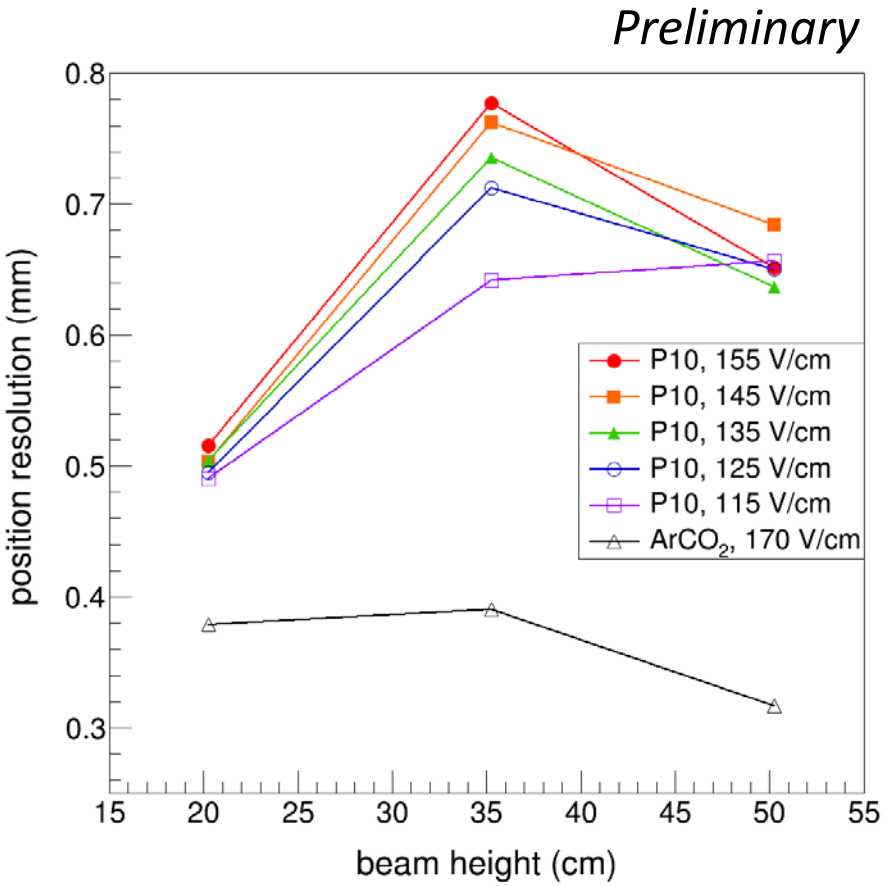
D: diffusion coefficient

σ_0: coefficient depending on the amplification system

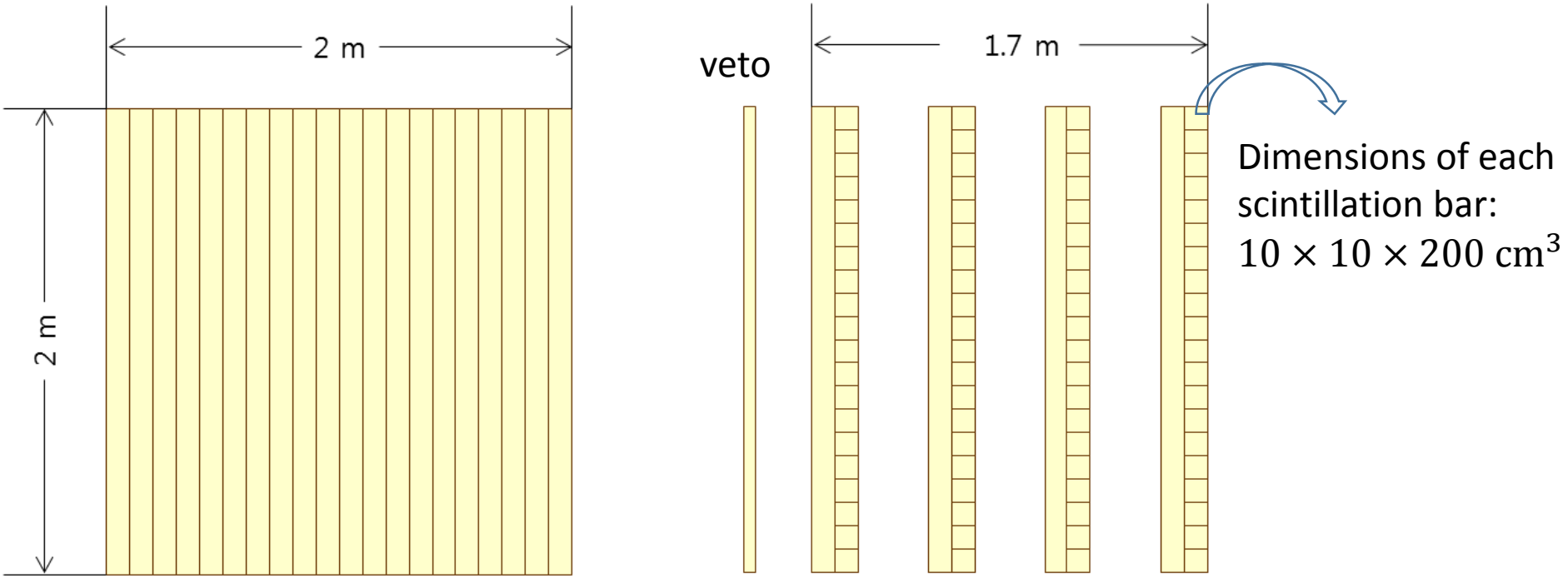
Prototype TPC: Position Resolution





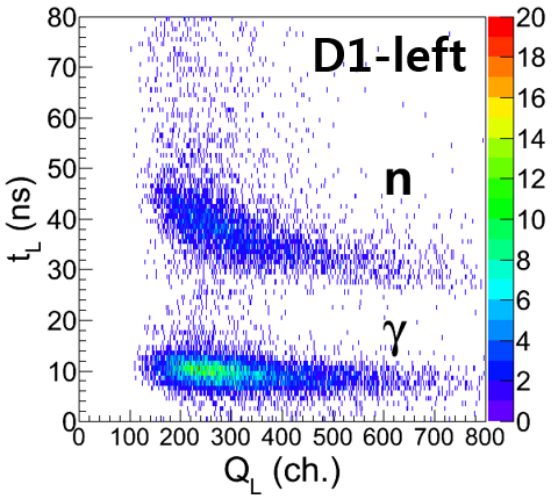


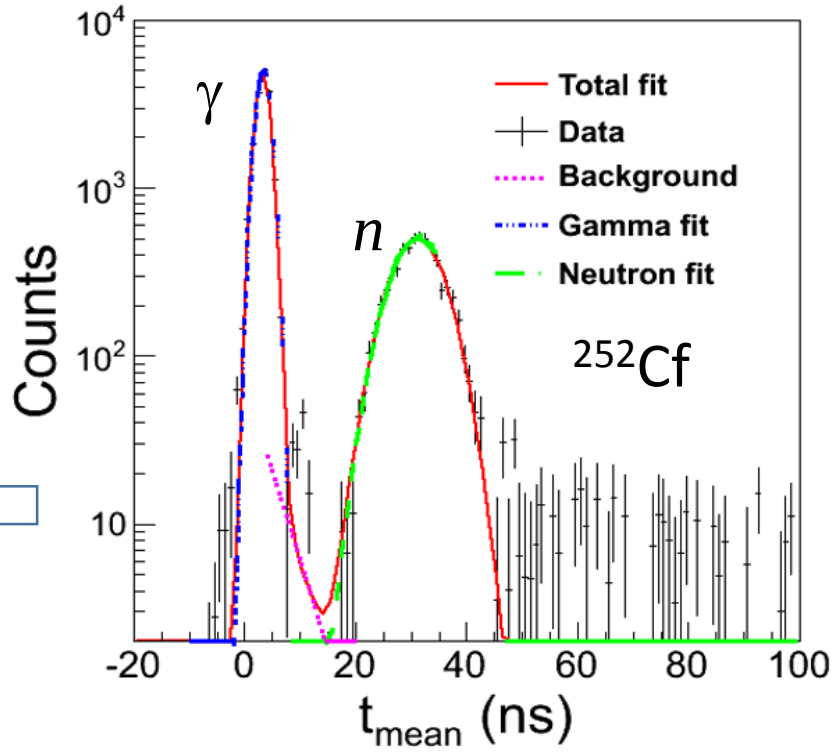
Neutron Detector Array

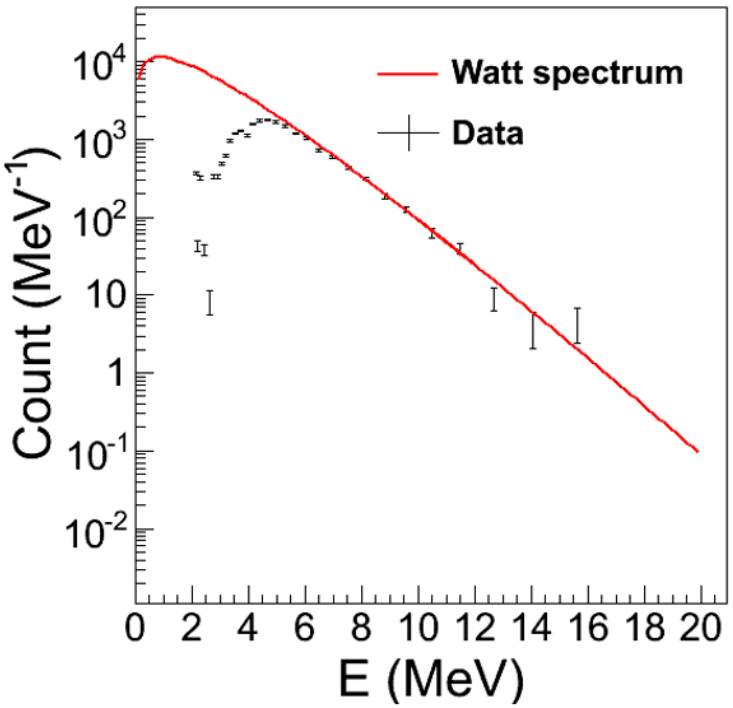


- Construction of the real-size prototype detectors and test of their performances using
  - Radiation-source test: ^{60}Co and ^{252}Cf
  - Neutron-beam test at RCNP, Japan

NDA: Results from Source Test





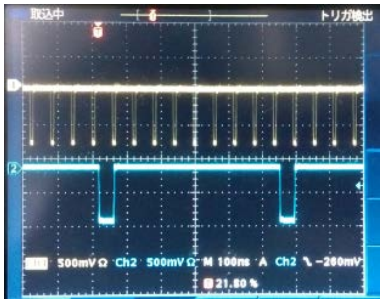


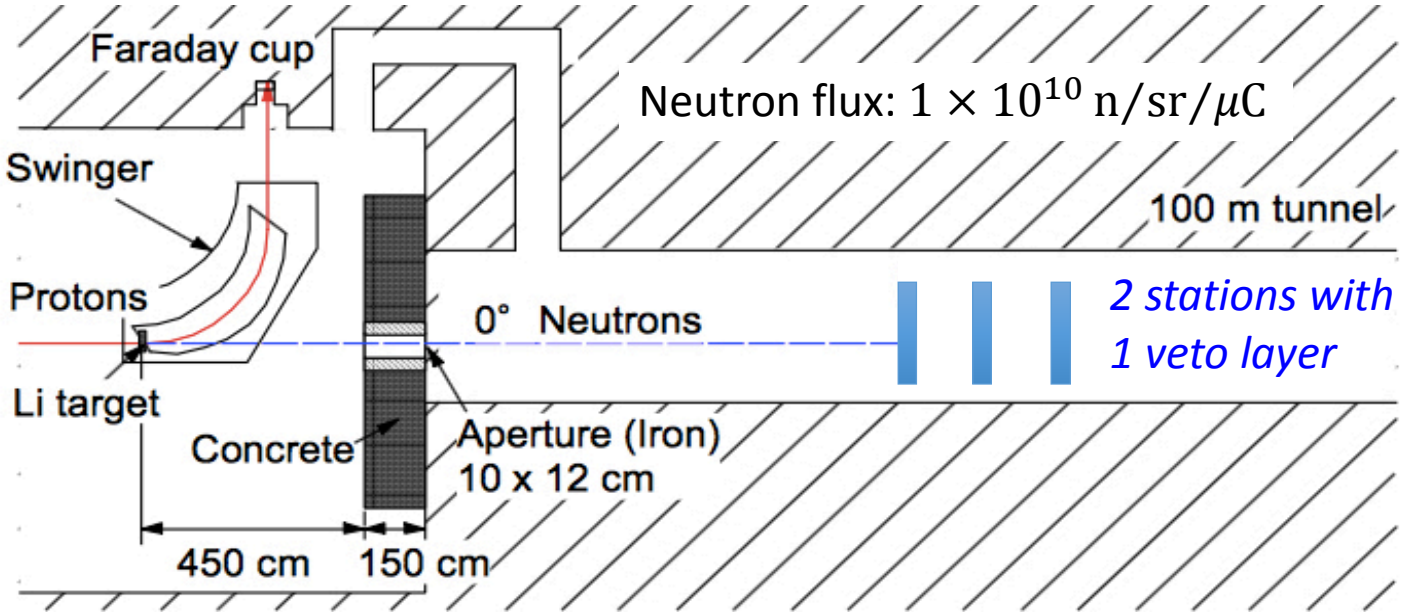
- Watt spectrum: $dN/dE \propto e^{-aE} \sinh\sqrt{bE}$
  - a=0.88 MeV^{-1} and b=2.0 MeV^{-1}
  - B. Watt, Physical Review 87, 1037 (1952)

NDA: Beam Test at RCNP

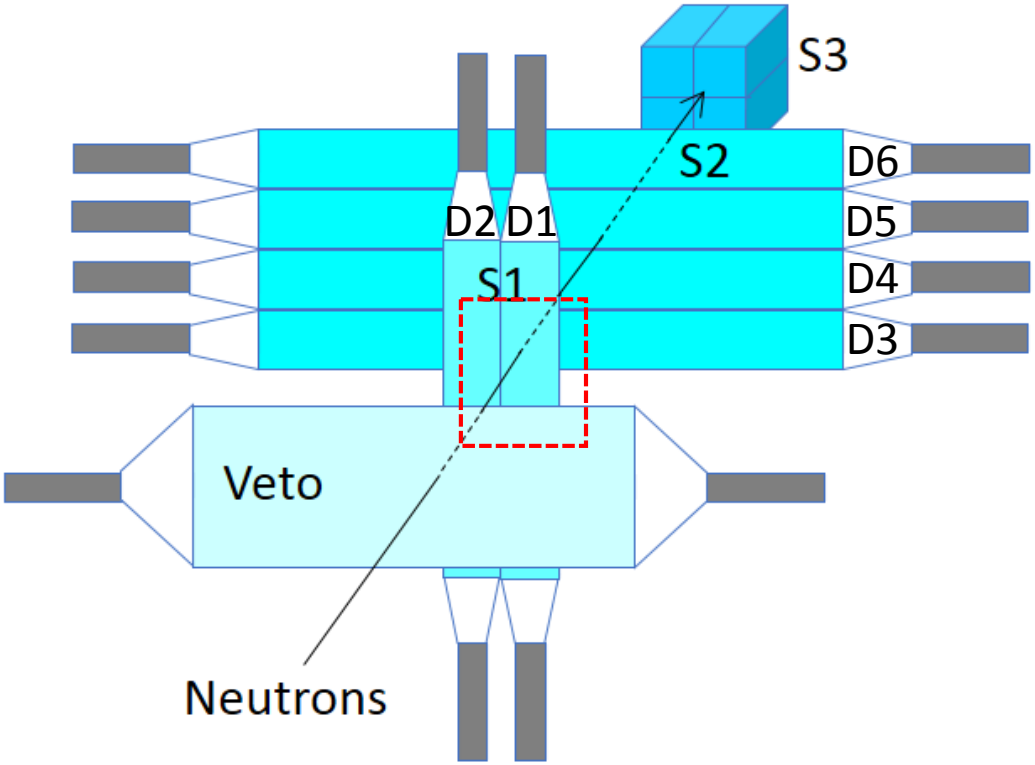
- E479 approved in B-PAC in March 2016
- Date: May 29, 2016 (Visited RCNP for May 22 – June 2)
- Beam specifications
  - Protons on Li production target (p+^{7}Li → n + ^{7}Be)
  - Neutron energies: 65 and 392 MeV in N0 beamline
  - 10 nA flux × 1/9 chopping
  - Background neutron above 3MeV is less than1% [NIMA629, 43 (2011)]

Chopping signals





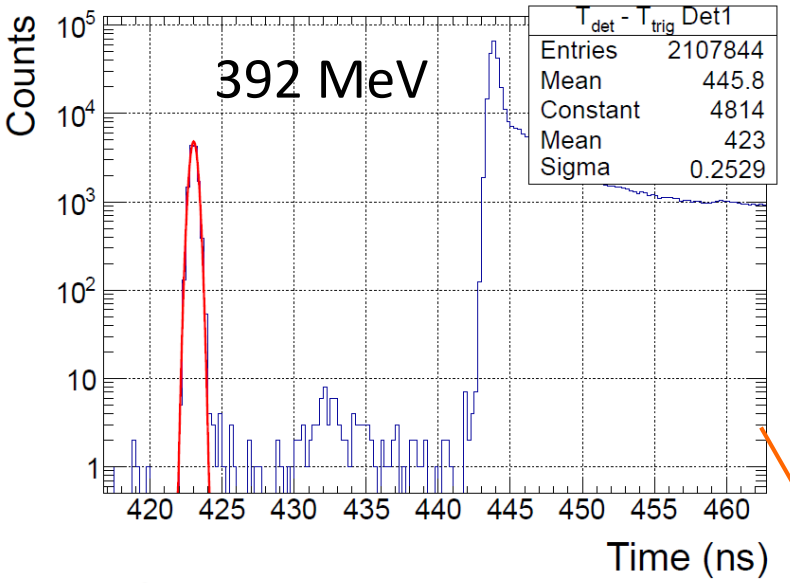
NDA: RCNP-E479

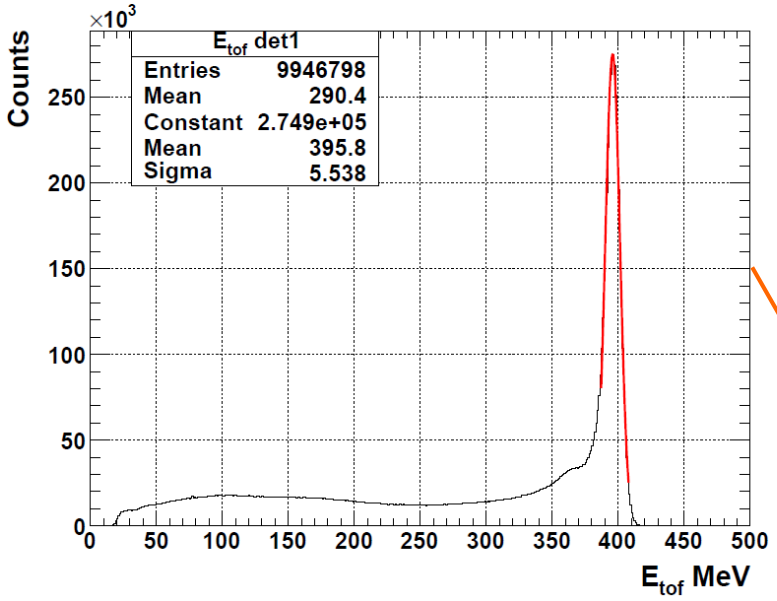


- Distance from target to the detector: 15 m
- Gap between stations: 60 cm
- Dim. of each S1 detector: $10 \times 10 \times 100$ cm^3
- Dim. of each S2 detector: $10 \times 10 \times 200$ cm^3
- Beam size at S1: 25×30 cm^2

NDA: Energy Resolution for Neutrons

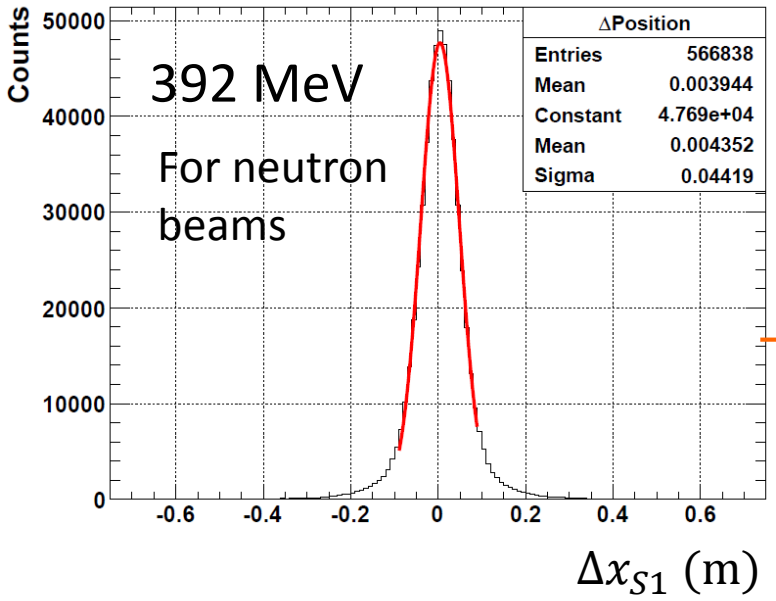
Preliminary

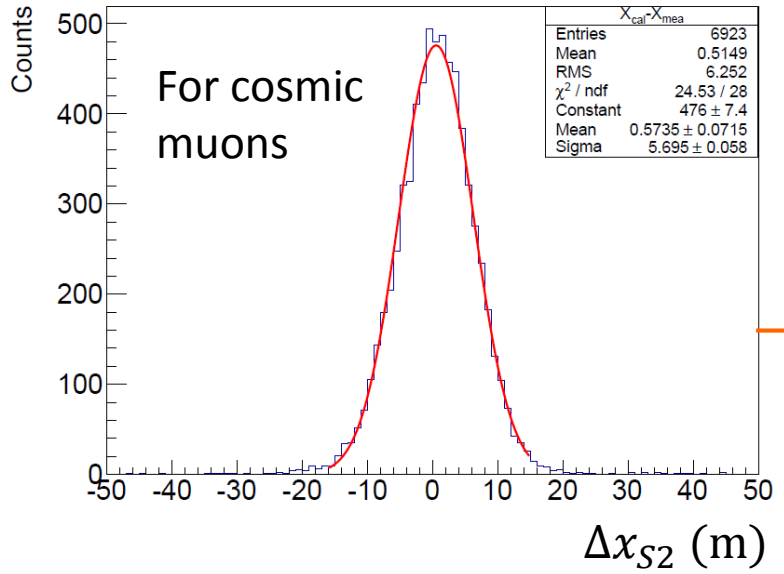




- Time resolution:
  $\Delta t = \sqrt{(\Delta\tau)^2 + (\Delta x/v)^2} = 0.66$ ns
  where
  $\Delta\tau$ = FWHM of γ peak = 0.60 ns
  Δx = effective thickness of the detector
  = (Total thinness of Li target, veto, and neutron detector)/2 = 6.0 cm
  v = neutron velocity = 21.3 cm/ns
- Neutron energy resolution:
  $\frac{\Delta E}{E} = \gamma(\gamma+1)\frac{\Delta t}{t} = 3.2\%$
  where
  Lorentz $\gamma = 1 + E/mc^2 = 1.42$
  $t = 70.4$ ns
- Energy resolution (FWHM/E)= 3.3 %

NDA: Position Resolution for Neutrons & Cosmics





Preliminary

- Hit position difference between $D1$ and $D2$ for neutrons:

$$\Delta x_{S1} \equiv x_{D1} - x_{D2}$$

for 10 MeV threshold and $\delta t < 3$ ns

- Relative position resolution for neutrons for one bar:

$$\sigma_n = \frac{\sigma(\Delta x_{S1})}{\sqrt{2}} = 3.1 \text{ cm}$$

- Position difference between the projected hit position and the hit position for $D3$ for cosmic muons:

$$\Delta x_{S2} \equiv x_{D3,proj} - x_{D3,hit}$$

- Relative position resolution for cosmic muons for one bar:

$$\sigma_\mu = \frac{\sigma(\Delta x_{S2})}{1.87} = 3.1 \text{ cm}$$

Summary

- Rare Isotope Science Project (RISP) at IBS, Korea is moving forward.
- The construction and civil engineering for RAON has begun: The ground breaking for accelerators and experimental buildings was done on Feb. 13th this year.
- LAMPS is a dedicated spectrometer for nuclear symmetry energy at RAON.
- Performance tests of the prototype TPC and the neutron-detector-array modules with accelerator beams were done, and we are analyzing the data.