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(NuSYM14)
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Prospects of the Nuclear Symmetry Energy Research in Korea

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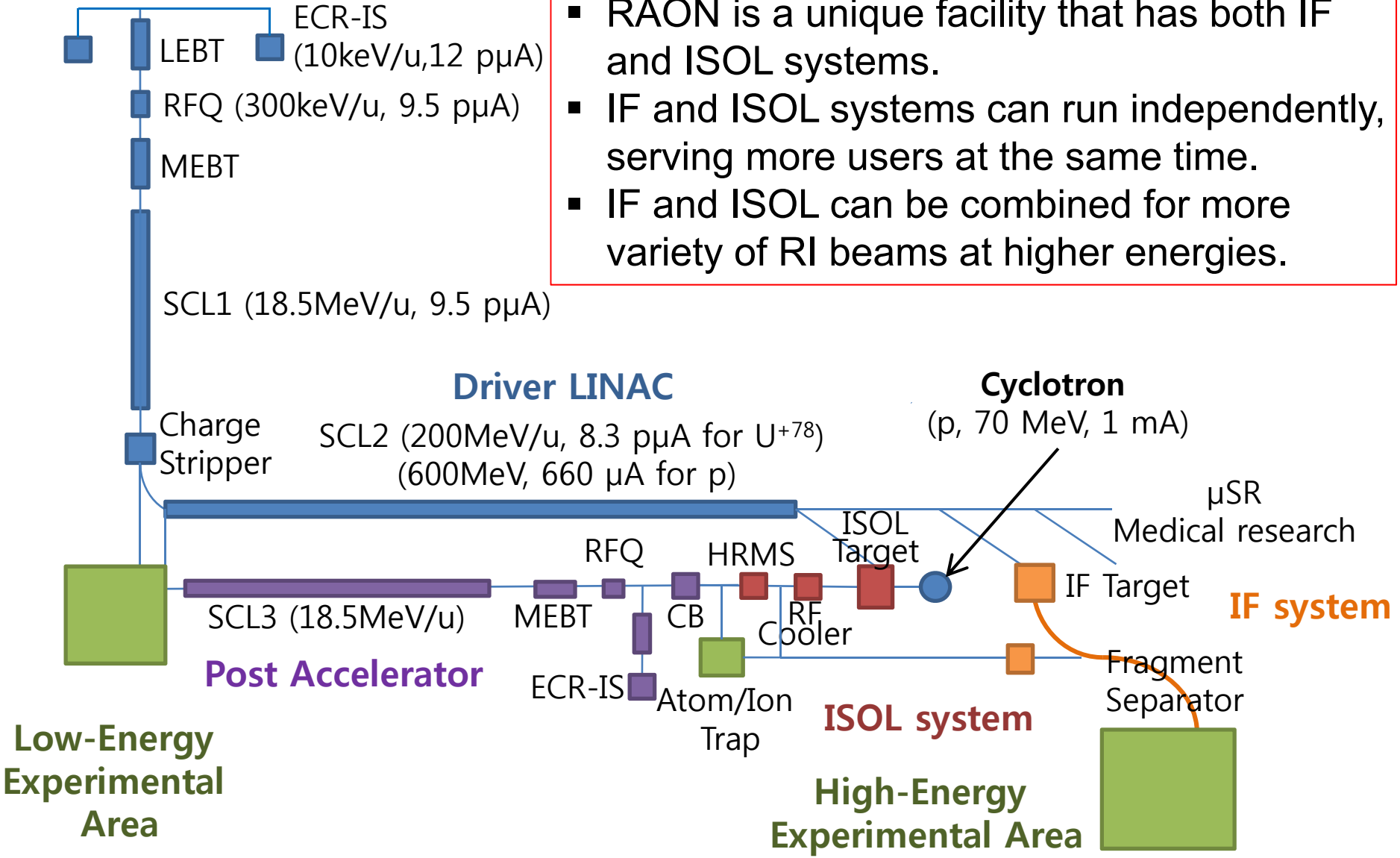
Outline

- **Plan for RAON and LAMPS in Korea**
- **Current R&D activities**
- **Summary**

RAON

- RAON is a unique facility that has both IF and ISOL systems.
- IF and ISOL systems can run independently, serving more users at the same time.
- IF and ISOL can be combined for more variety of RI beams at higher energies.



Beam Parameters of RAON

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

Some Examples of Expected RIBs

Assuming

✓ ISOL (10 kW power @ 1st stage, 70 MeV proton beams on UCx target)

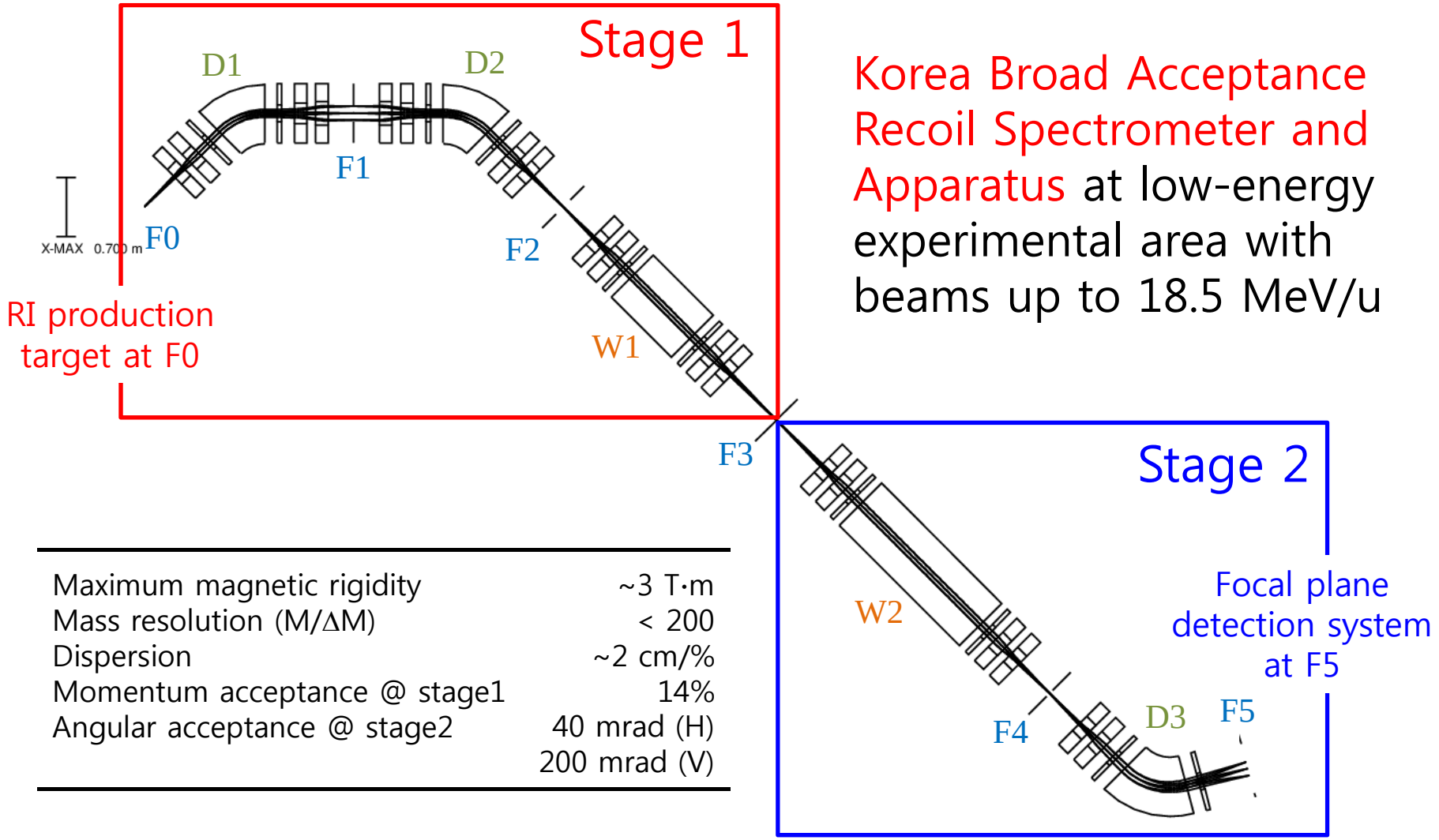
✓ IF (400 kW SC LINAC and C target)

RIB Species	Beam Energy (AMeV)	Beam Intensity (pps)	Beam Intensity at Expt. (pps)	Prod. Method (Primary Beam)
^{106}Sn	10-250	10^9	10^9	IF (^{124}Xe)
^{132}Sn	5-250	$>10^7$	10^7	High-purity: ISOL (p) High-energy: IF (^{238}U)
^{140}Xe	10-250	10^8	10^8	ISOL (p)
^{142}Xe	10-250	10^7	10^7	ISOL (p)
^{144}Xe	5-20	10^5	10^5	ISOL (p)

Physics Topics/Observables to be Covered by LAMPS

- Low-energy LAMPS @ KOBRA in LE Expt. area
  - Fusion reaction cross section
  - Dipole emission
    - Yield & the polar angle dependence
  - Intermediate-Mass Fragments
    - Charge equilibration/Isospin mixing/Neck fragmentation
- High-energy LAMPS @ HE Expt. area
  - Ratio of mirror nuclei
  - Isospin diffusion parameter
  - Collective flow
  - π^-/π^+ ratio
  - Dipole emission
    - For example, peak position of GDR and yield of PDR

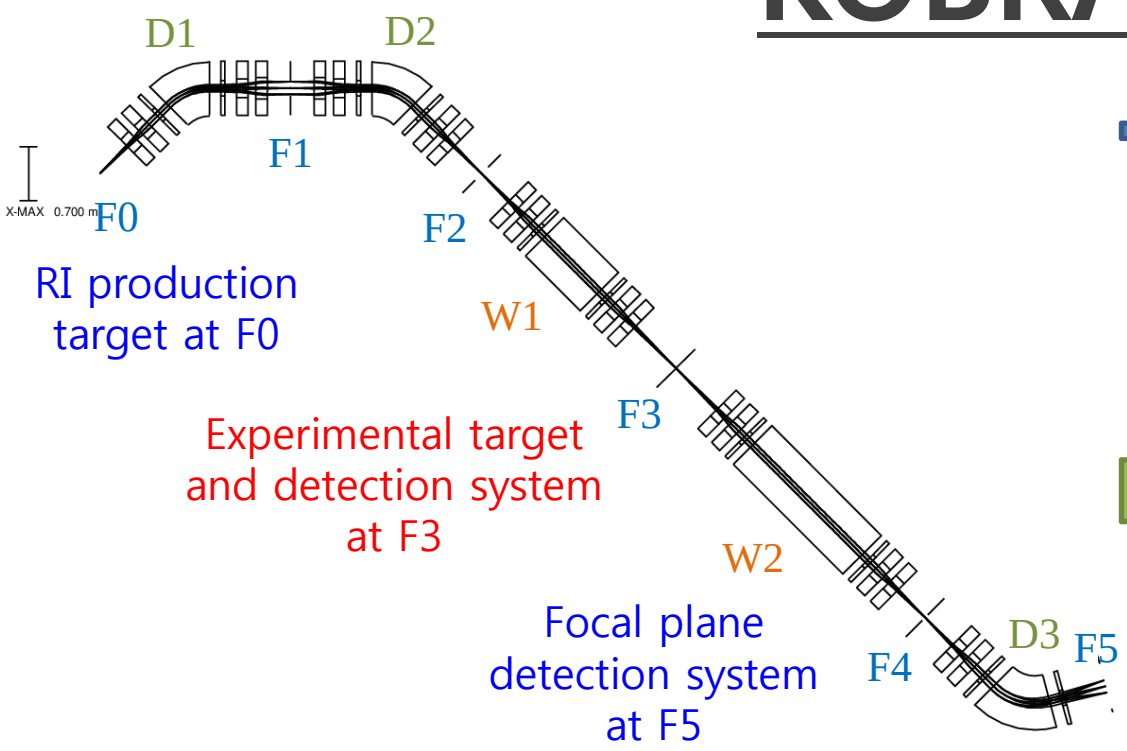
KOBRA

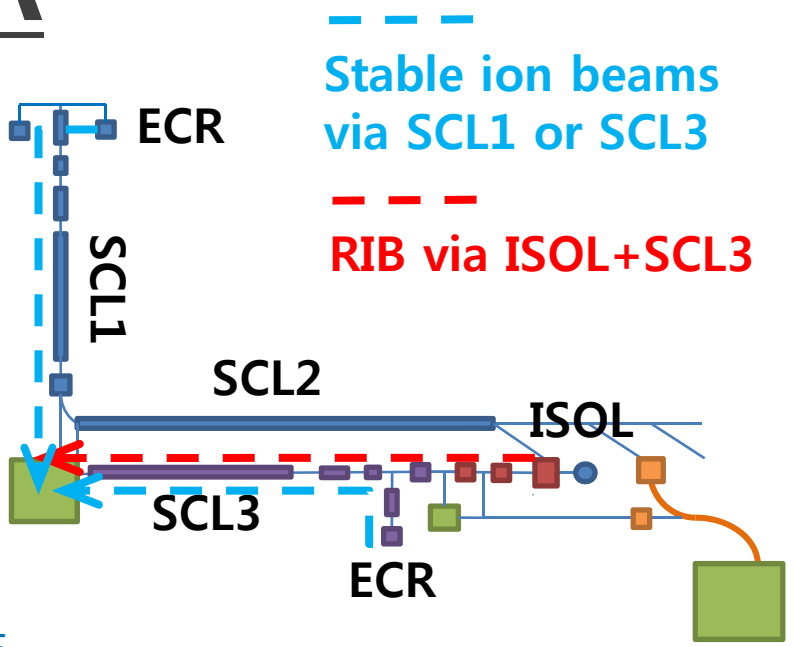


Korea Broad Acceptance Recoil Spectrometer and Apparatus at low-energy experimental area with beams up to 18.5 MeV/u

Maximum magnetic rigidity	~3 T·m
Mass resolution (M/ΔM)	< 200
Dispersion	~2 cm/%
Momentum acceptance @ stage1	14%
Angular acceptance @ stage2	40 mrad (H) 200 mrad (V)

KOBRA

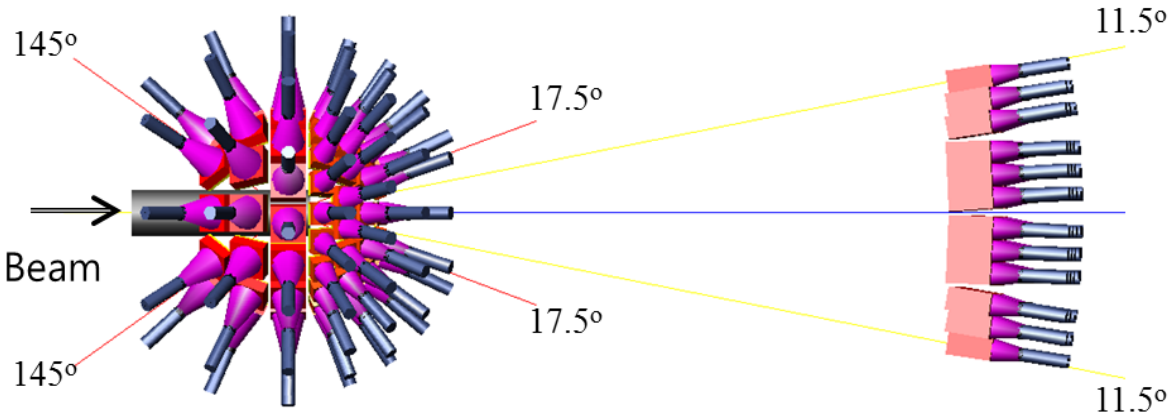




- Stage 1 (F0~F3): Production and separation of RIBs by in-flight method with high-intensity stable ion beams from ECRs
- Experimental target at F3 (available space of 2~3 m): In-beam γ-ray spectroscopy, Symmetry energy & charged particle spectroscopy, etc.
- Stage 2 (F3~F5): Big-bite spectrometer with Wien filter

Low-Energy LAMPS (LAMPS-L)

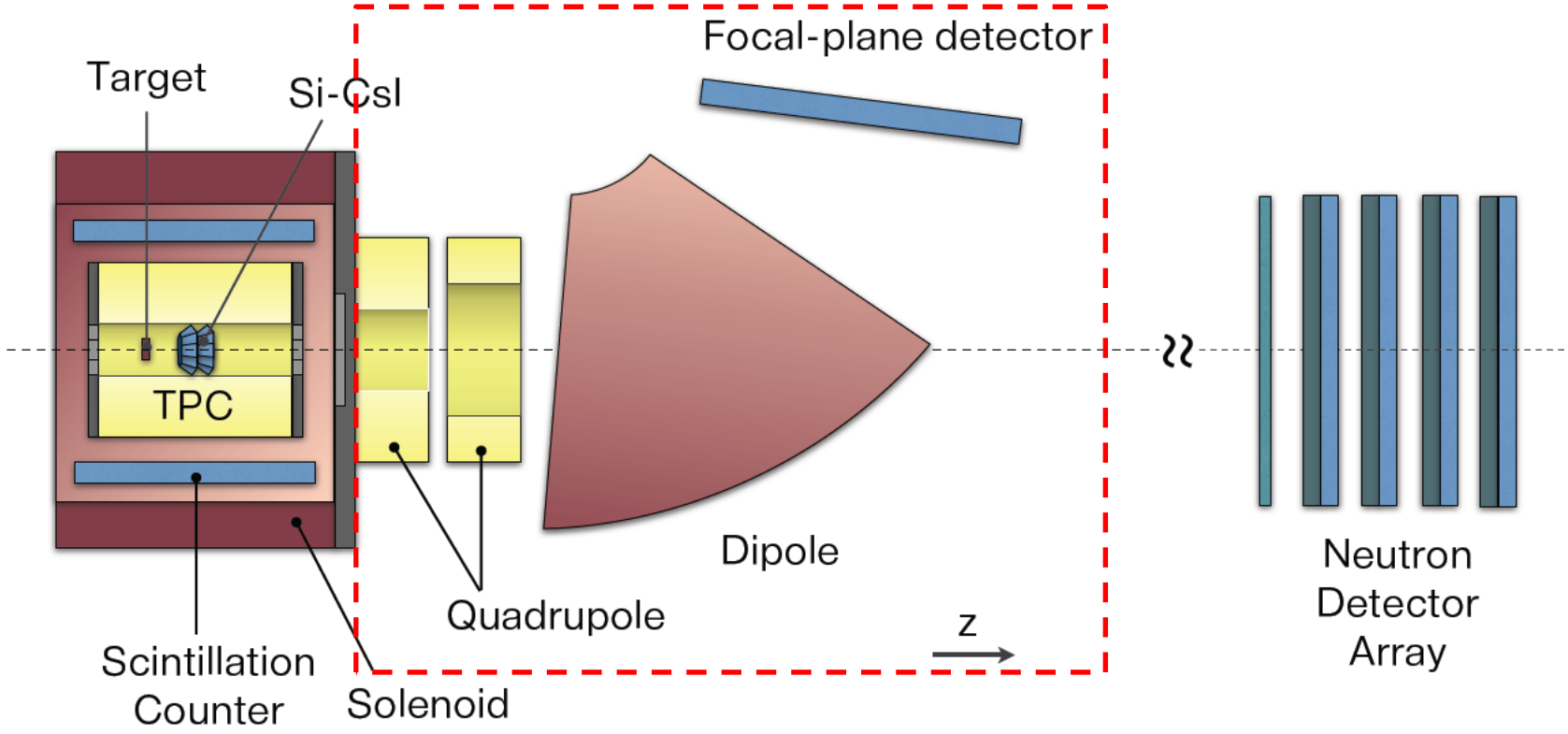
- Si-CsI Array
  - ✓ Charged particles & γ's
  - ✓ $\Delta E/E$ ~10^{-2}
  - ✓ Particle ID
- Scintillator Array
  - ✓ Neutrons
  - ✓ Acceptance=100~300 mSr
  - ✓ $\Delta E/E$ ~5.0X10^{-2} via TOF



Si-CsI Scintillator array

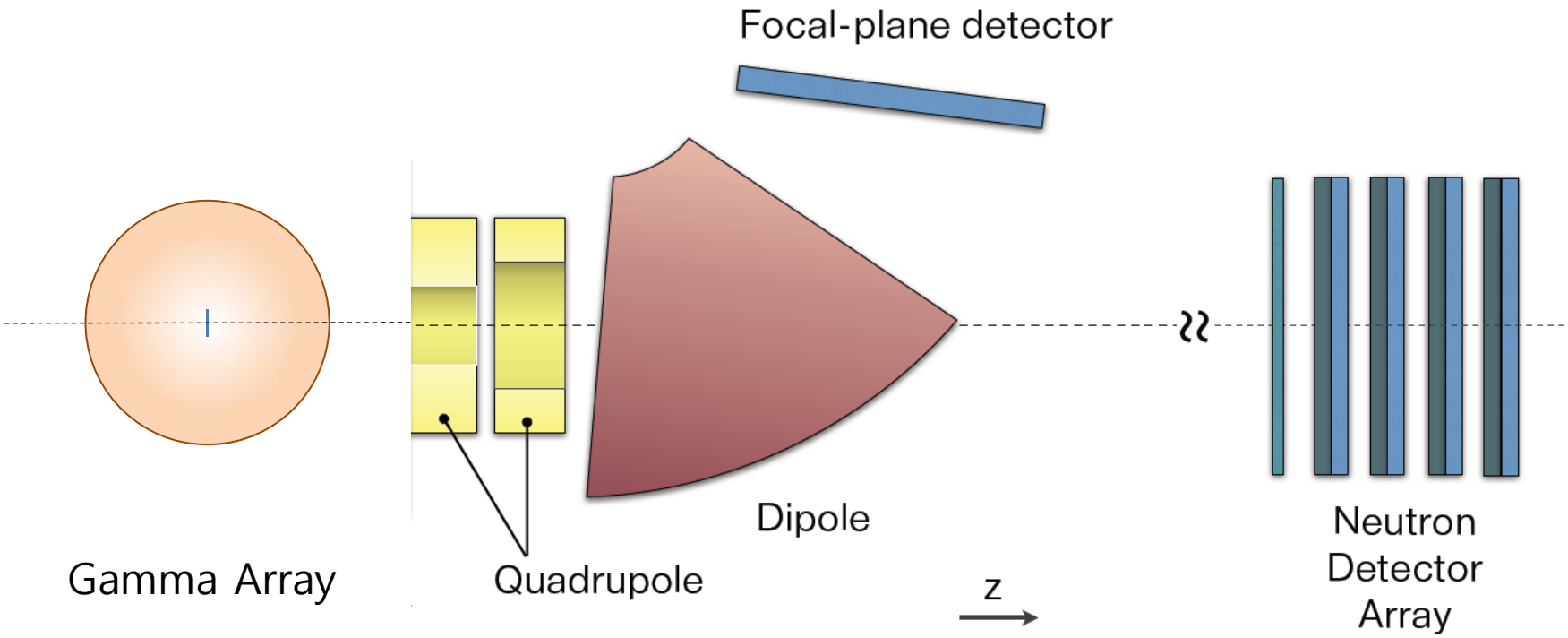
High-Energy LAMPS (LAMPS-H)

- Solenoid Spectrometer + Dipole Spectrometer + Neutron Detector Array

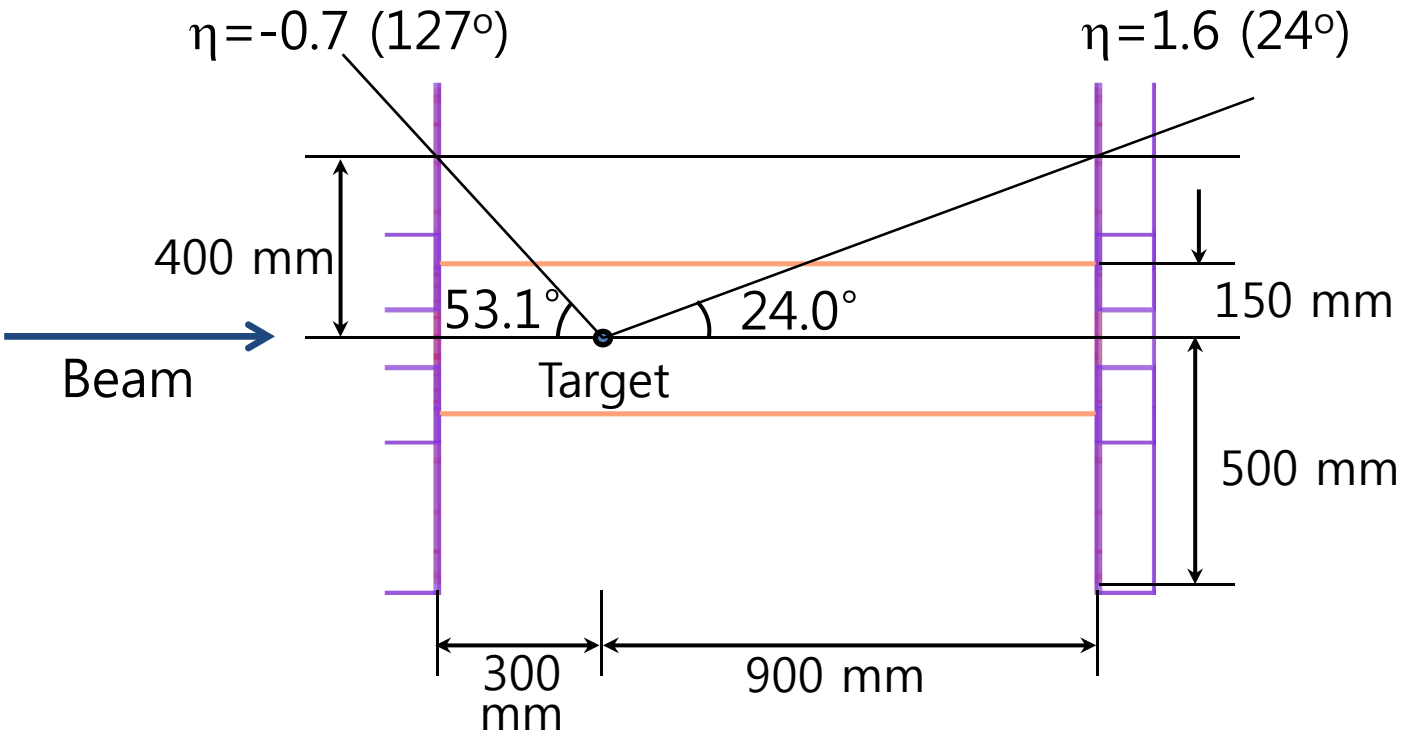


High-Energy LAMPS (LAMPS-H)

- For the various Coulomb breakup experiments



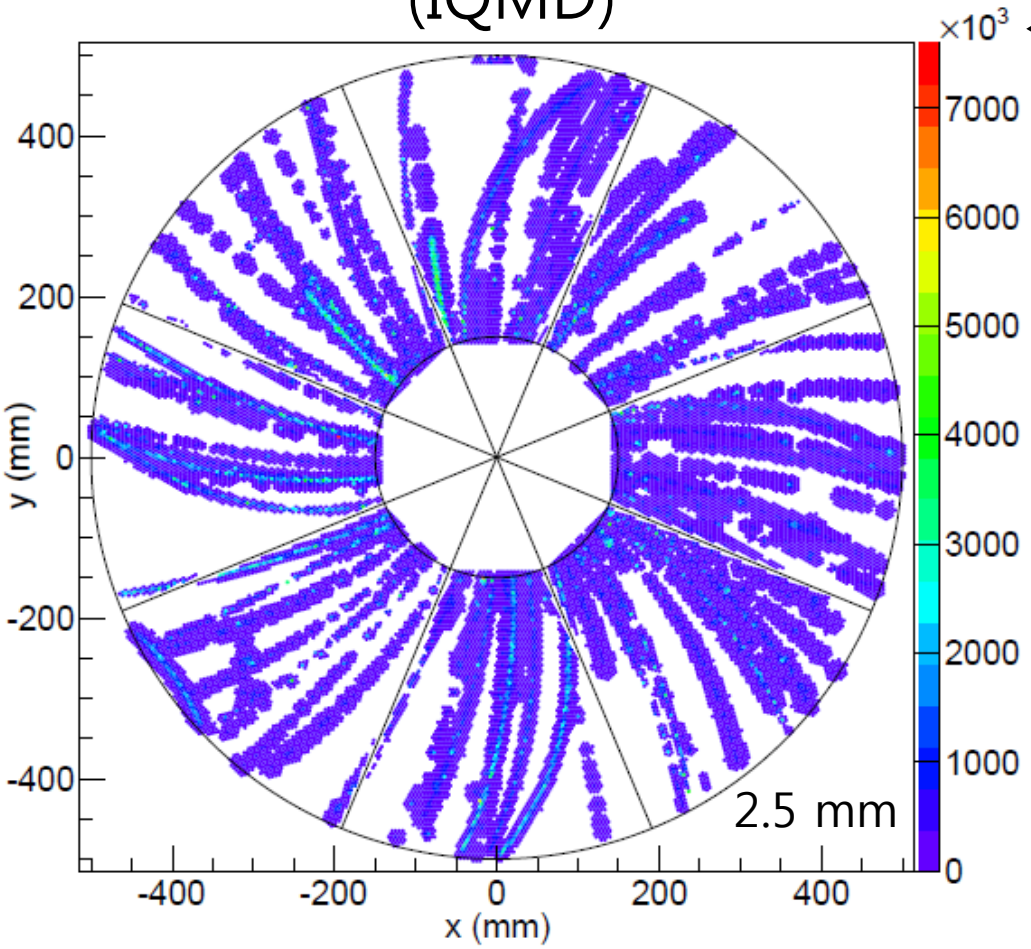
Time Projection Chamber



- Simulation with triple GEM readout using Garfield++
  - Gas mixture: Ar 90%+CO_2 10%, Voltage for each foil: 450 V
  - <Gain>~1.4X10^6, <Drift velocity>~50 mm/μs
  - <Dispersion> after 60 cm (maximum drift distance) < 3 mm

Time Projection Chamber

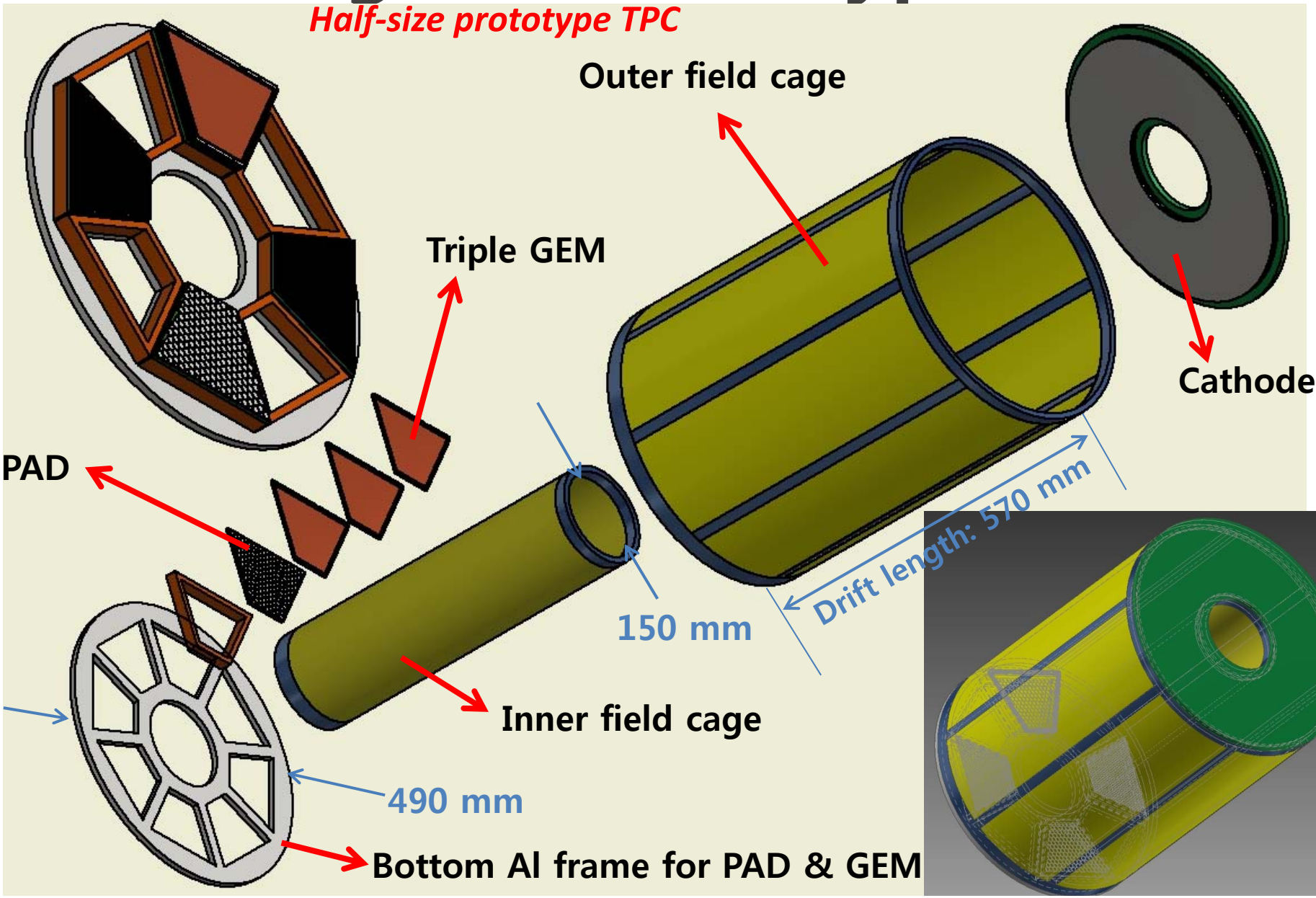
Central Au+Au at 250 AMeV
(IQMD)



Color scale: the number of electrons in each pad

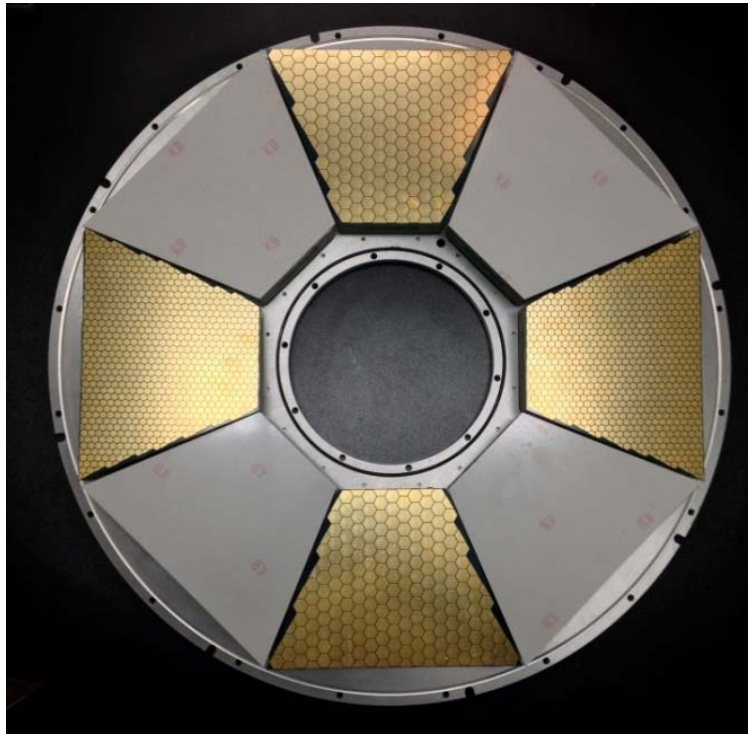
- Pad
  - Shape: hexagon
  - Total number of pads >20,000 for 5 mm
- Signal processing
  - GET: General Electronics for TPC

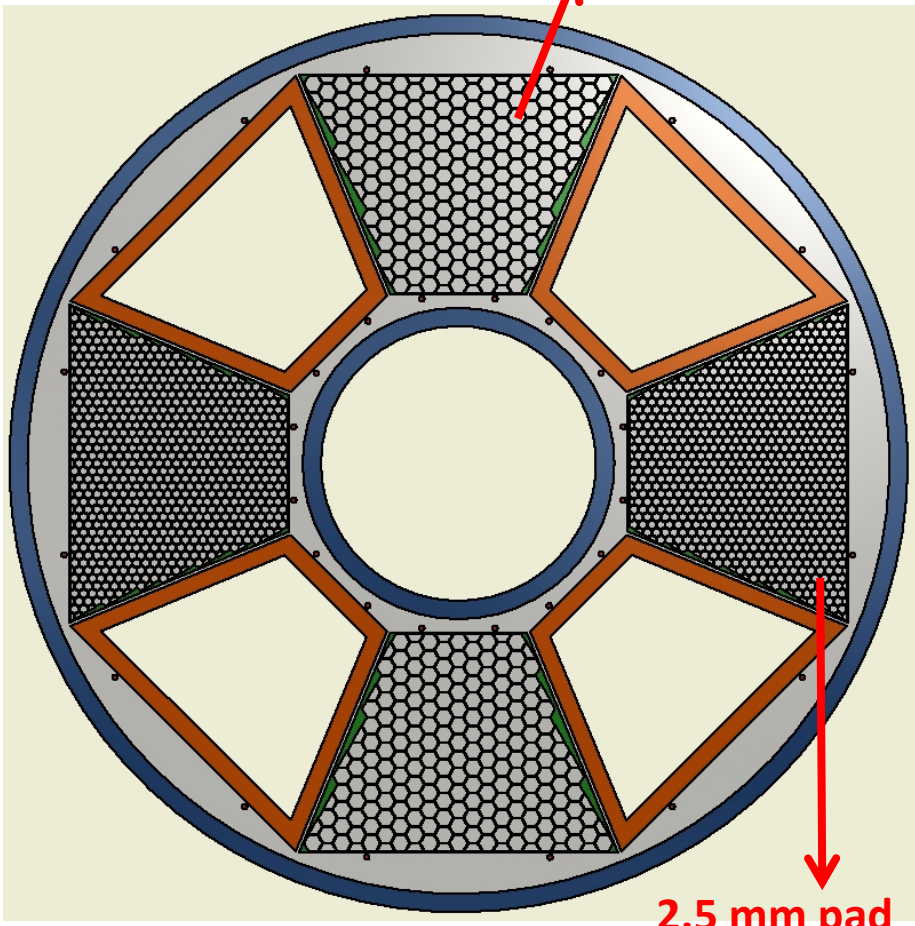
Design of Prototype TPC



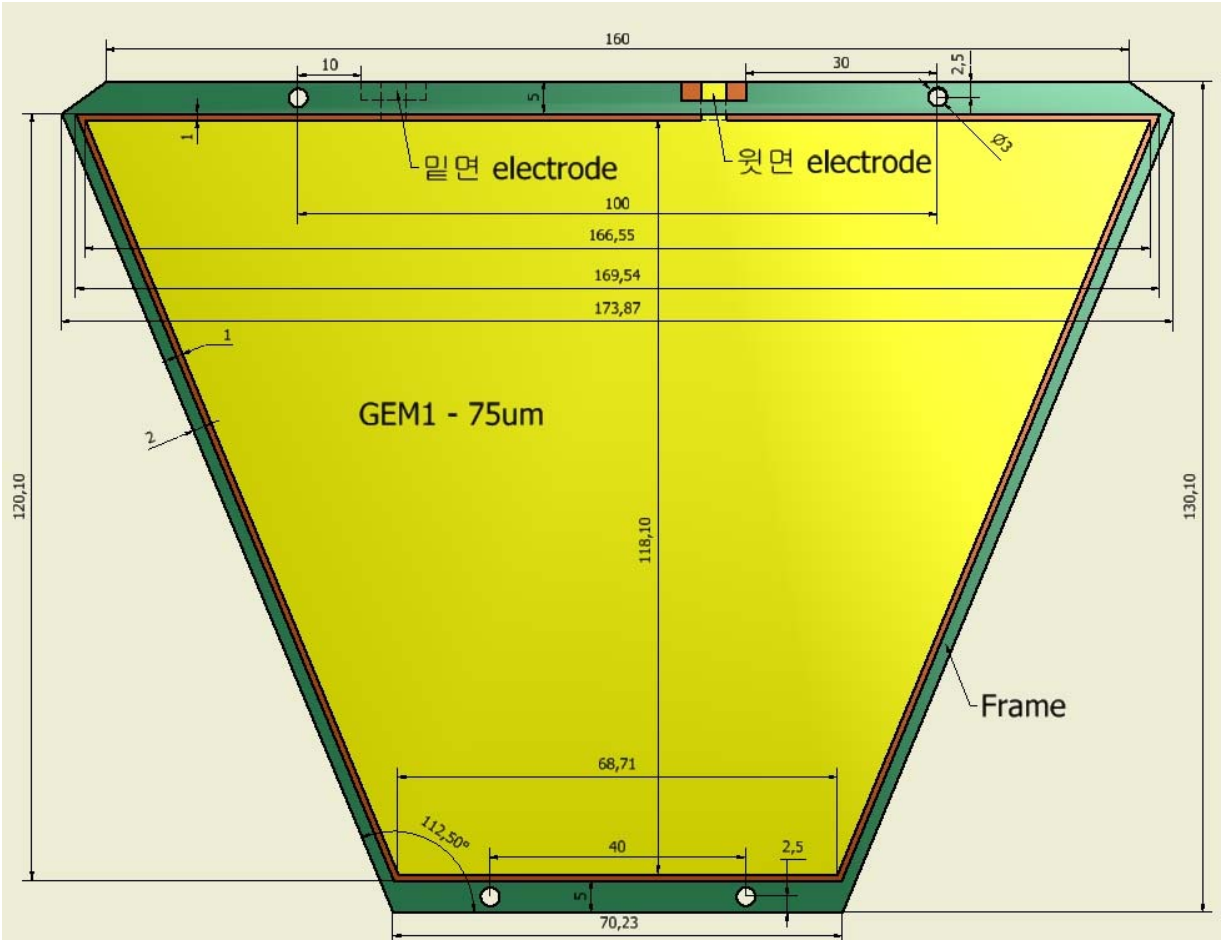
Prototype TPC-Pad Plane

- Hexagonal shape: 5 & 2.5 mm
- 500 μm gap between two pads
- Multi-layer PCB board
- 16 pin SMD type connectors

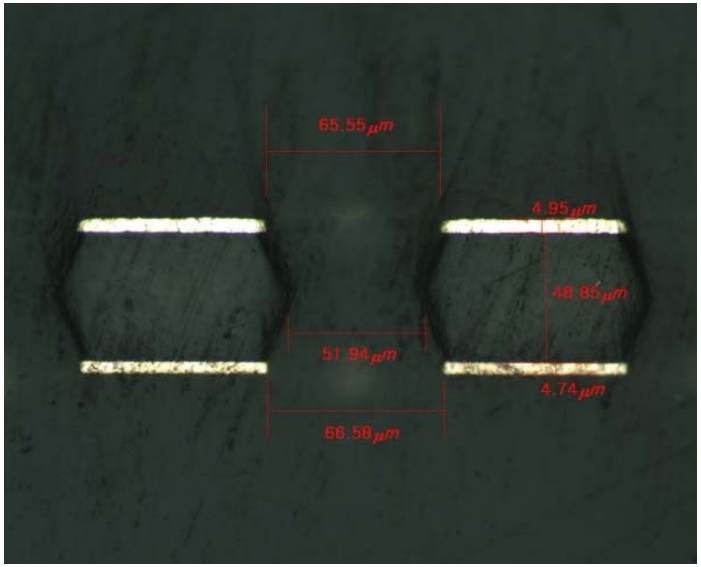




Prototype TPC-GEM

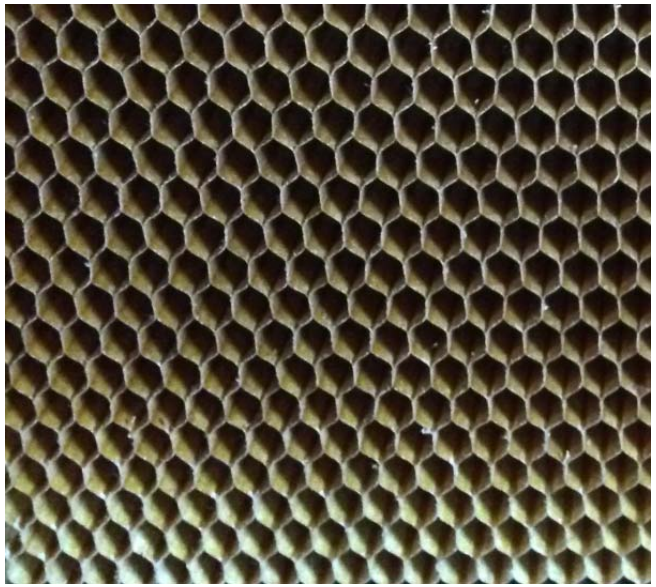


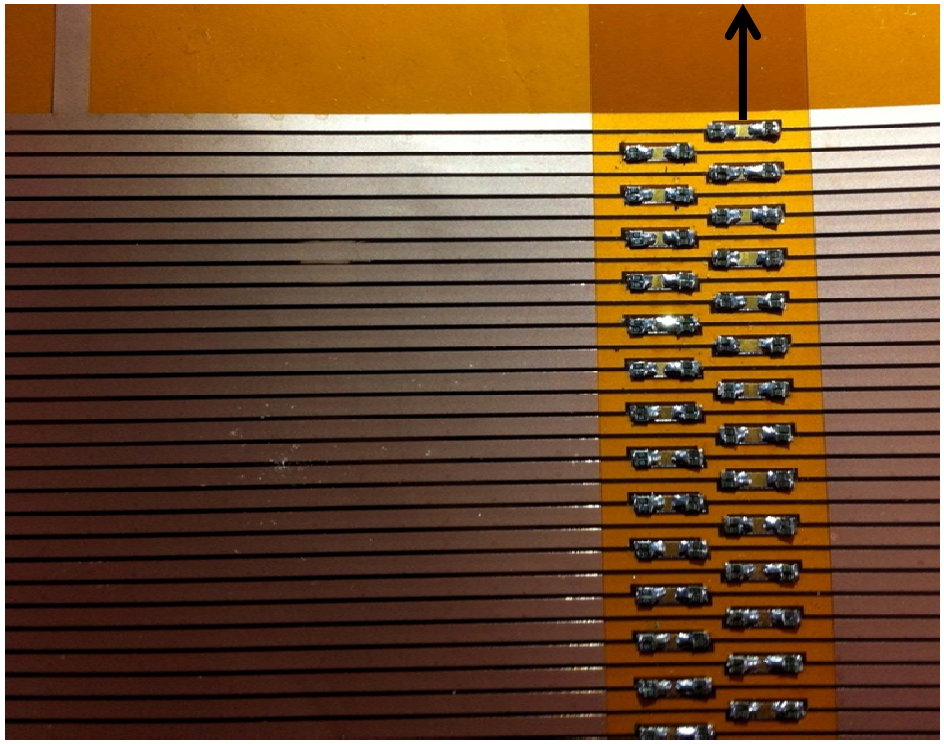
- Trapezoidal shape
- Thickness: 75 μm
- Area: 160X120 mm^2
- Triple layers for each pad

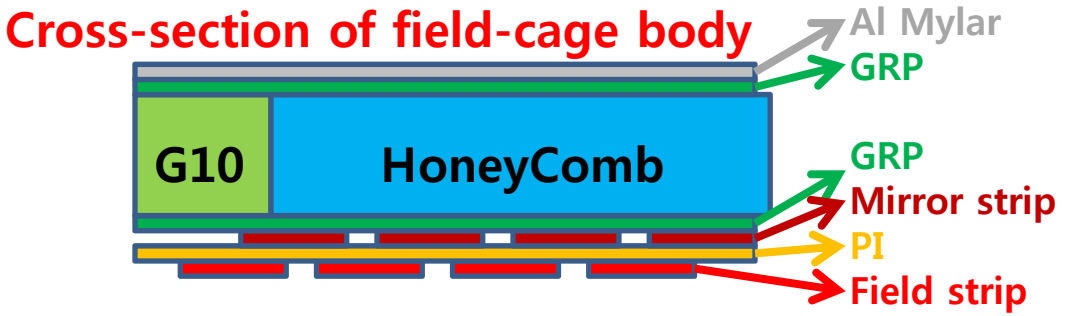


Prototype TPC-Field Cage

- 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

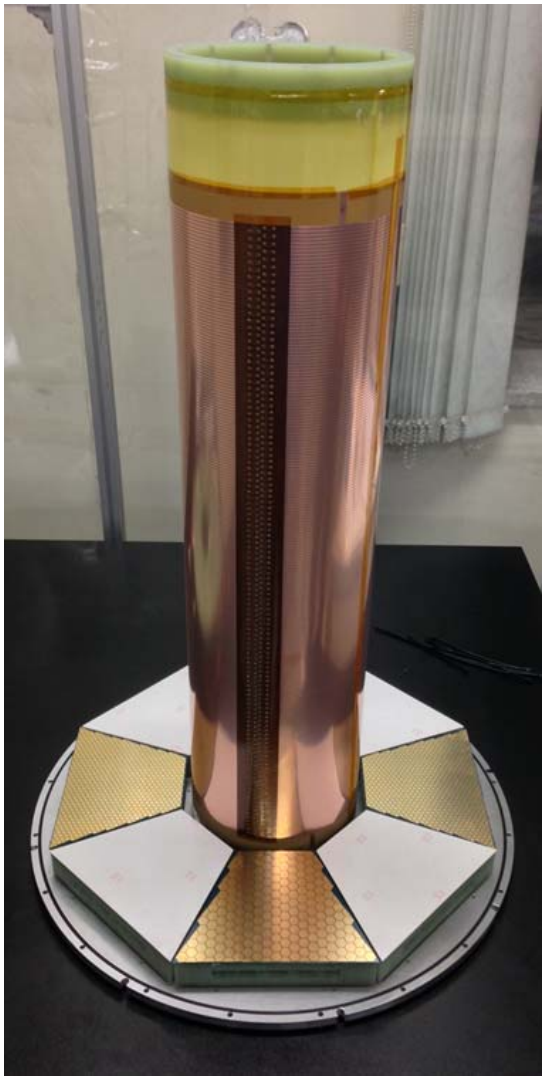




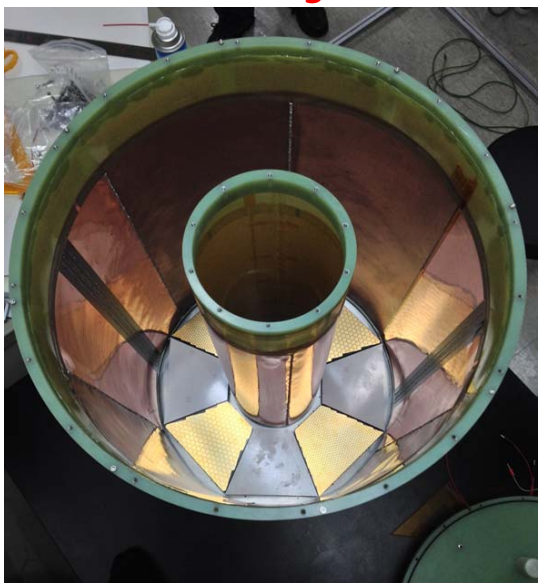


Prototype TPC-Assembly

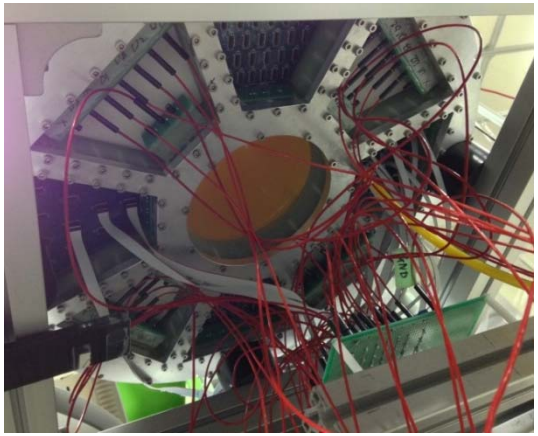
Inner Field Cage installed



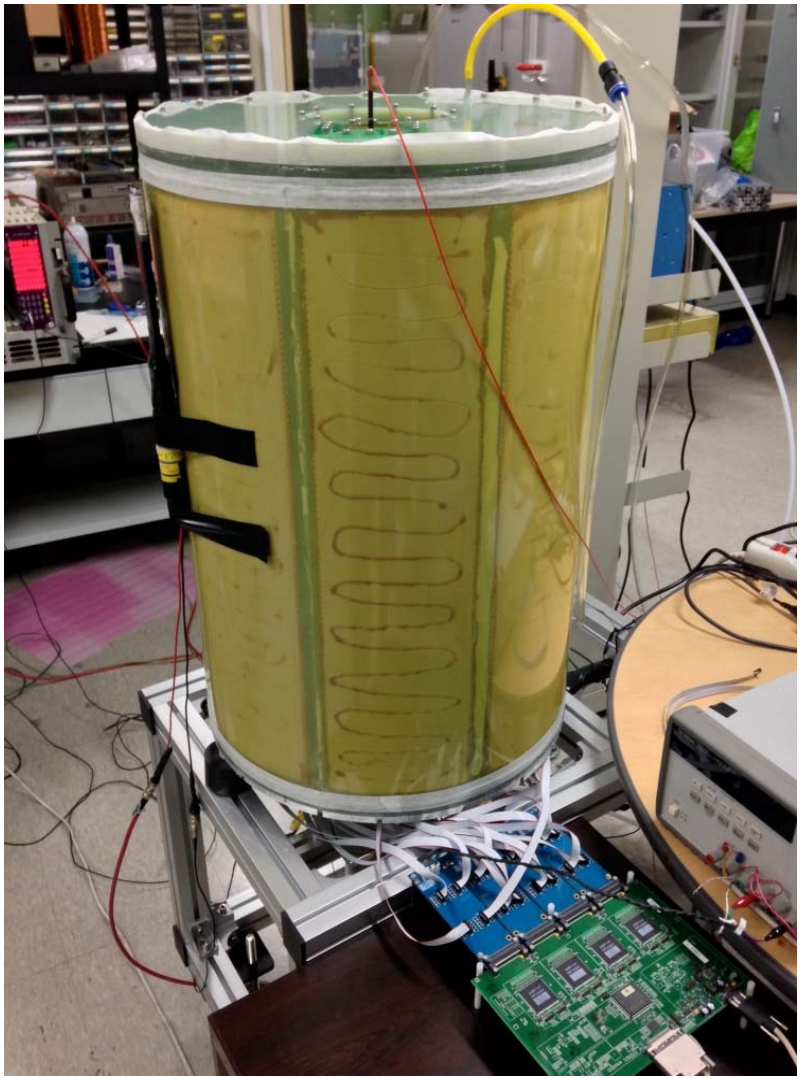
Outer Field Cage installed



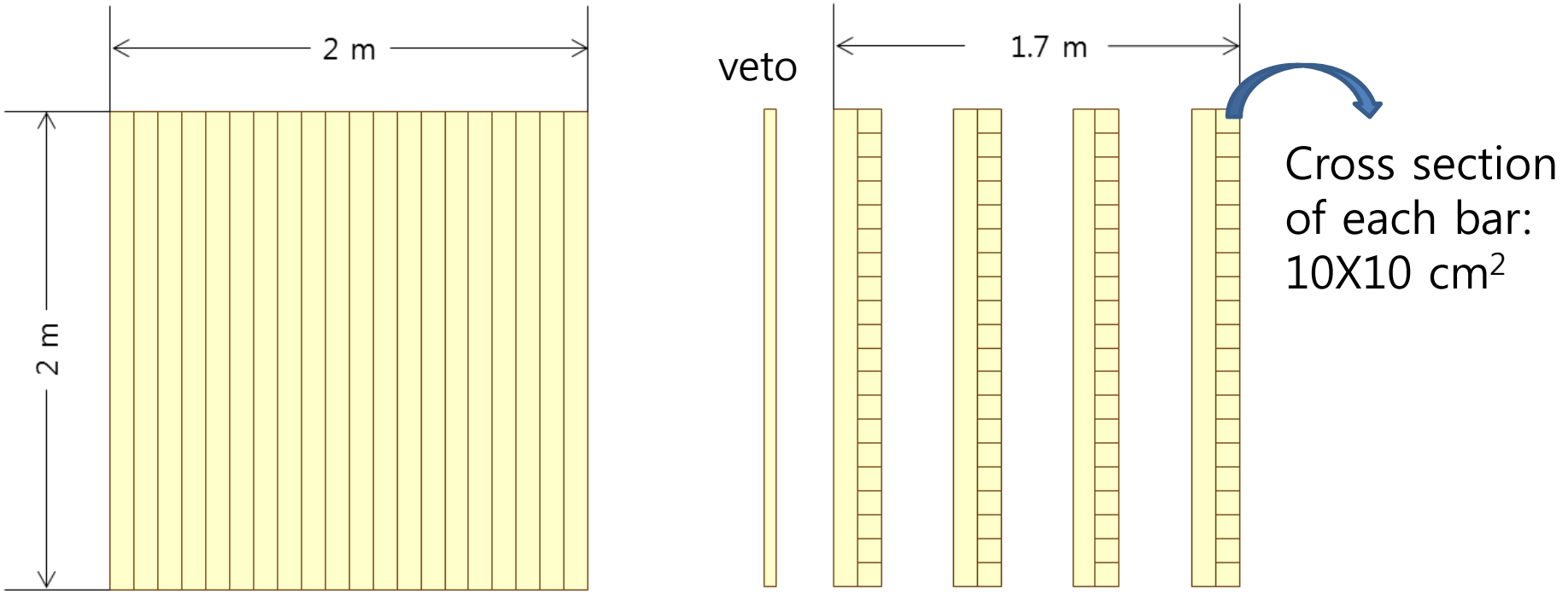
Prototype TPC : back



Prototype TPC assembled



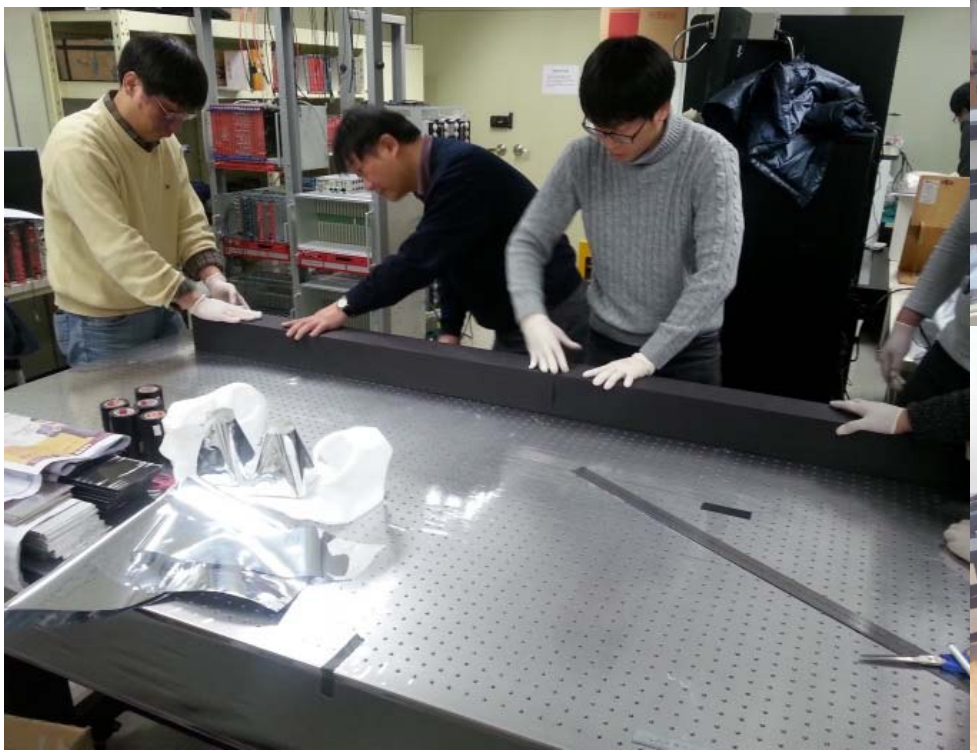
Neutron Detector Array

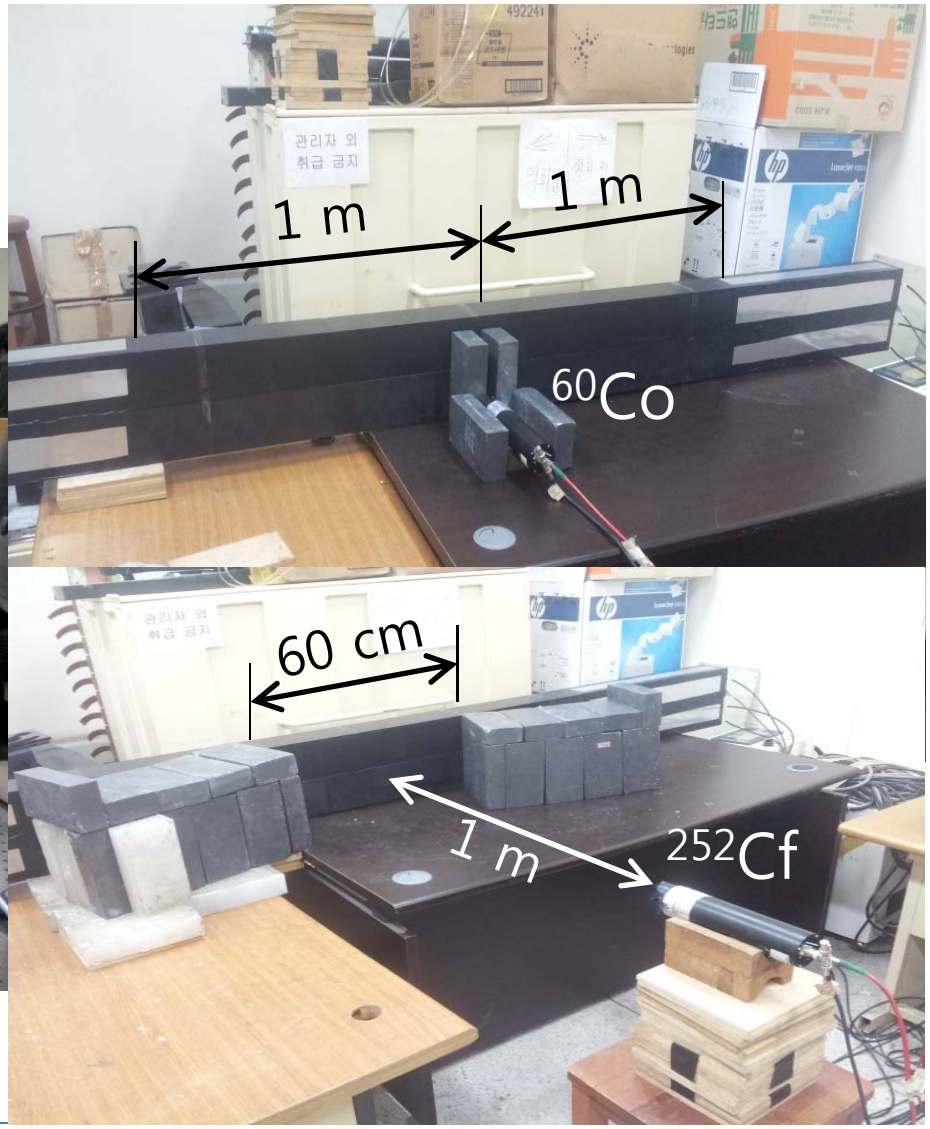


- Construction of the real-size prototype detector and test with radiation sources
  - Dimension: 0.1X0.1X2.0 m^3
  - Sources: ^{60}Co and ^{252}Cf

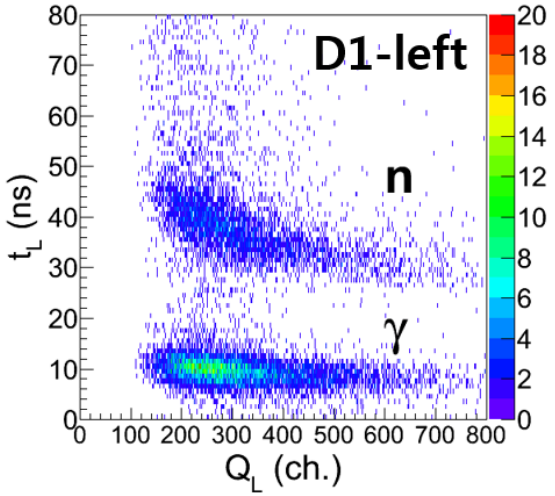
LAMPS-H Neutron Array

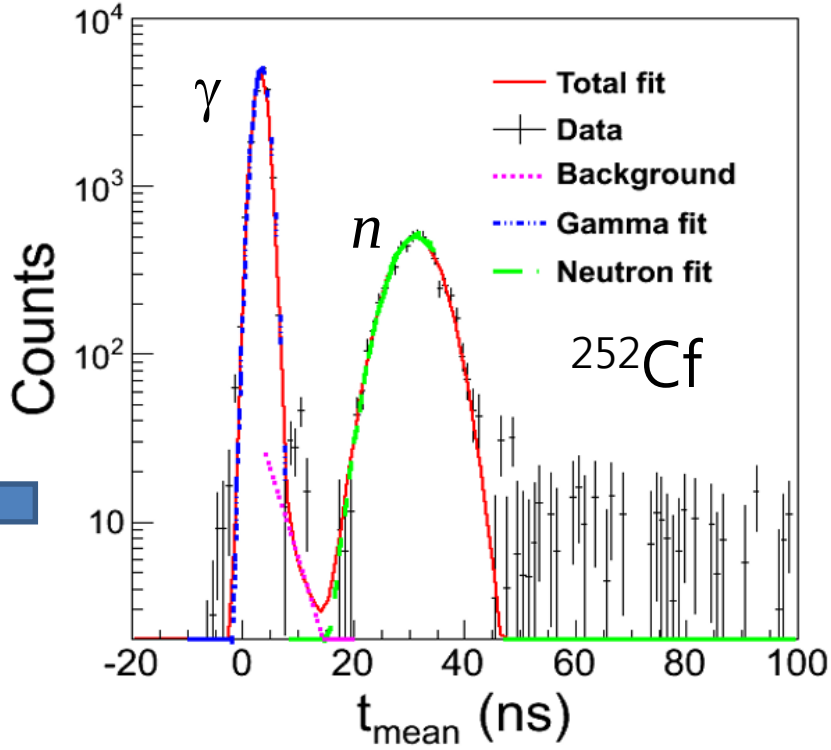
Assembly of the real-size prototypes (2 m long)

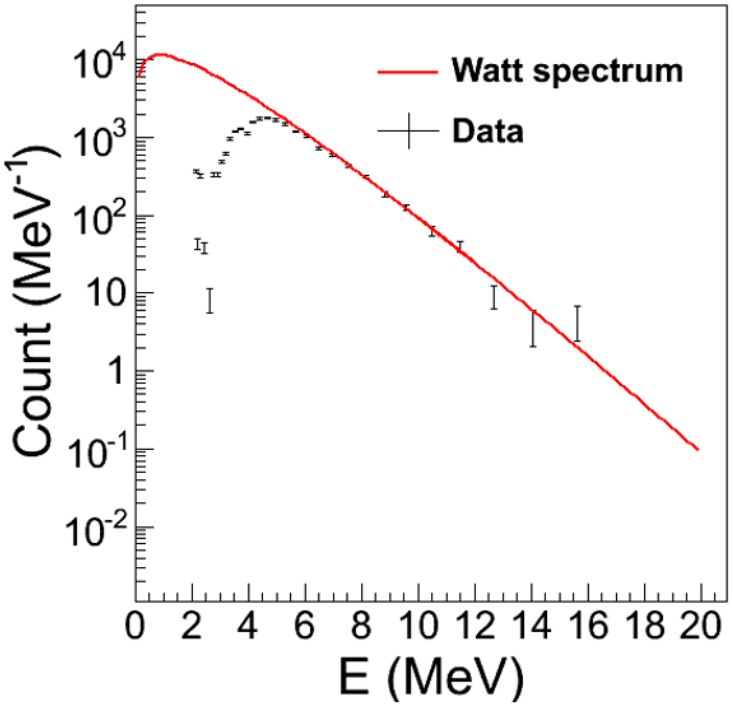




LAMPS-H Neutron Array







- 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)

Summary

1. RAON project
   - New opportunity will be available in Korea for heavy-ion reactions with radioactive-ion beams.
   - First beam on target: LAMPS-L in 2019 and LAMPS-H in 2021
2. LAMPS
   - The low- and high-energy LAMPS setups will be constructed.
   - The major physics objective is to study the nuclear symmetry energy below and above ρ_0.
   - Presently, we are working on the simulations, optimizations, and testing the prototype detectors.
   - There will be a call for EOI (Expression of Interest) to the international user community.