Large Acceptance Multi-Purpose Spectrometer (LAMPS) at RISP

Young Jin Kim
RISP/IBS

Behalf of the LAMPS Collaboration

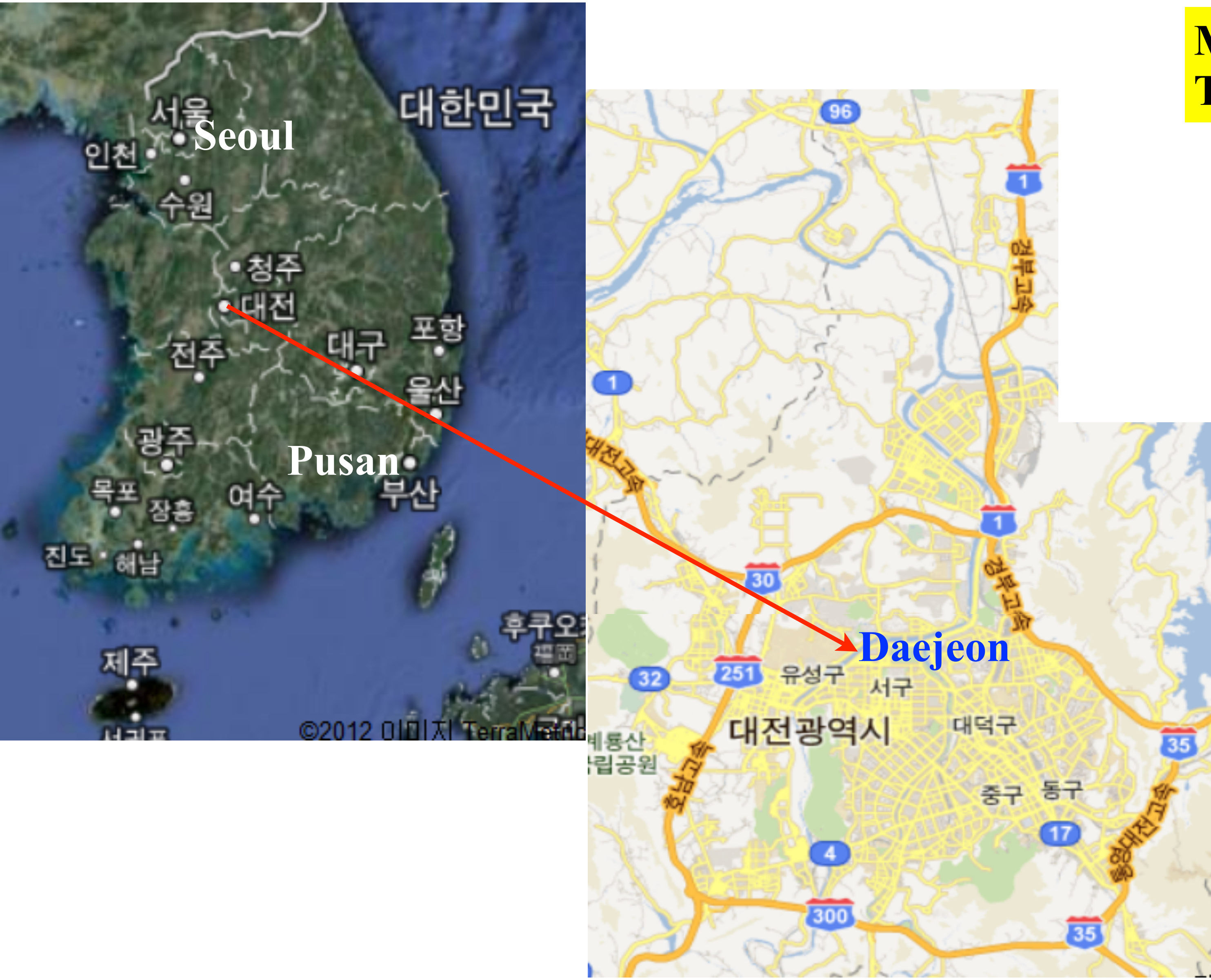
RISP and RAON

- RISP = Rare Isotope Science Project
  - Plan & build Rare Isotope accelerator and experimental facilities in Korea
- RAON = Name of Rare Isotope accelerator complex (라온)
  - Pure Korean word: meaning "delight", "joyful", "happy"

- Brief History
  - International Science-Business Belt (ISBB) plan (Jan. 2009)
  - Preliminary Design Report (Mar. 2009 - Feb. 2010)
  - Conceptual Design Report (Mar. 2010 - Feb. 2011)
  - International Advisory Committee (Jul. 2011)
  - Institute for Basic Science (IBS) established (Nov. 2011)
  - Rare Isotope Science Project (RISP) launched (Dec. 2011)
    - ✓Rare Isotope accelerator complex is the representative facility of IBS
  - Technical Advisory Committee (May 2012)
  - Baseline Design Summary (Jun. 2012)
  - International Advisory Committee (Jul. 2012)
  - Technical Design Report (Present)

More details
Talk by S. K. Kim tomorrow

Location



More details
Talk by S. K. Kim tomorrow

Location

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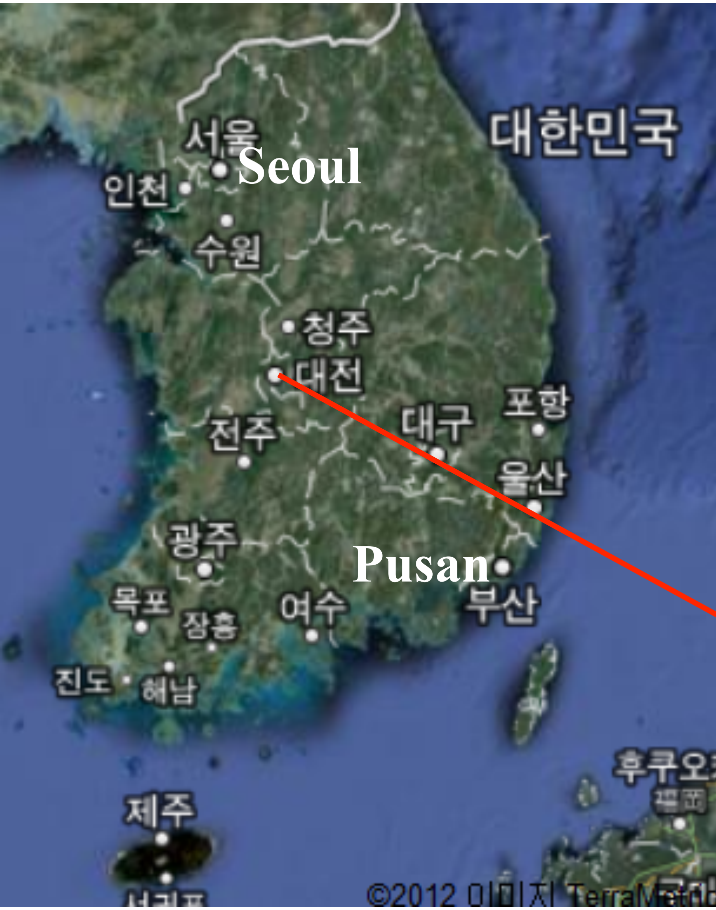
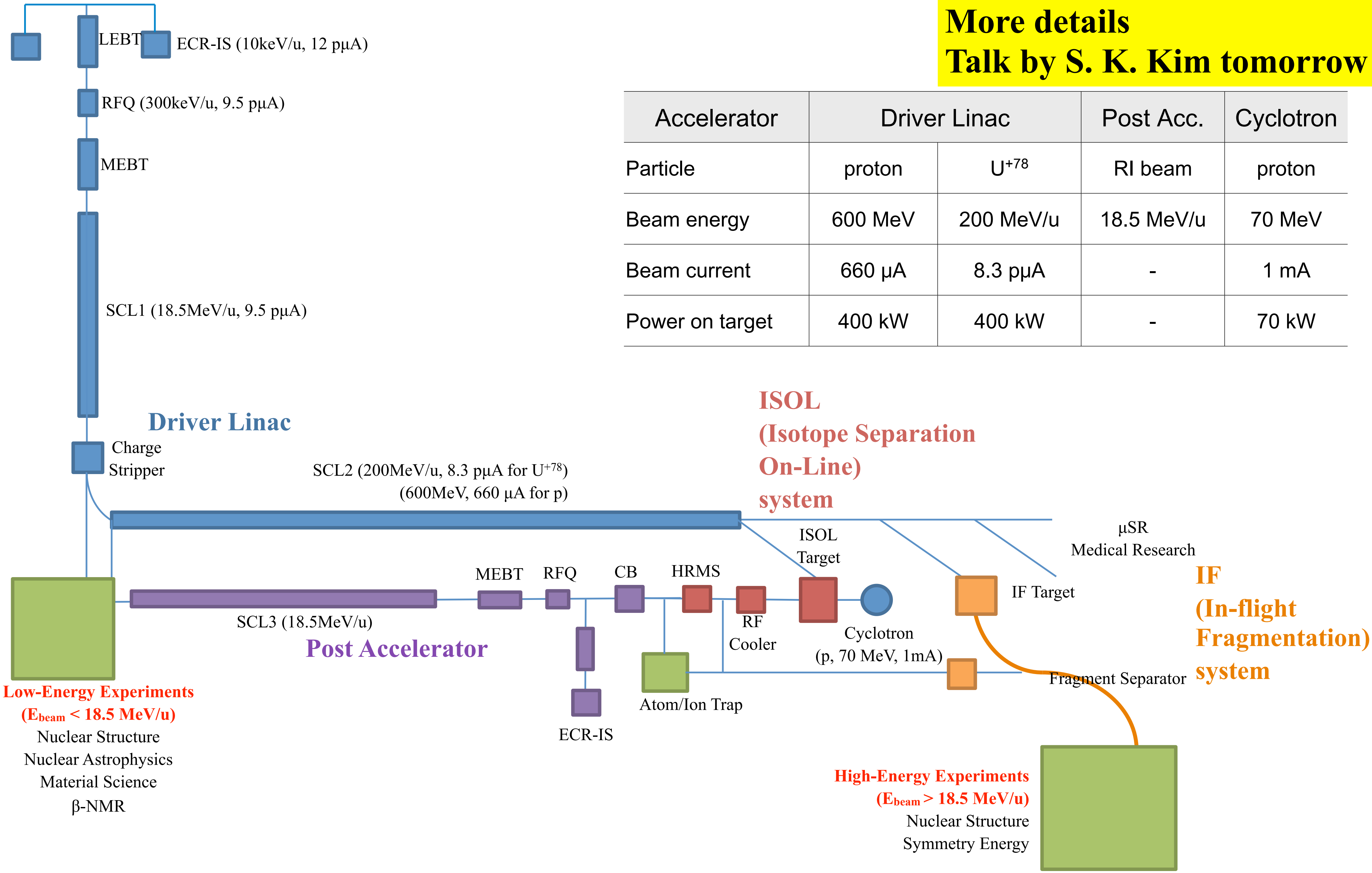


RAON/RISP Site

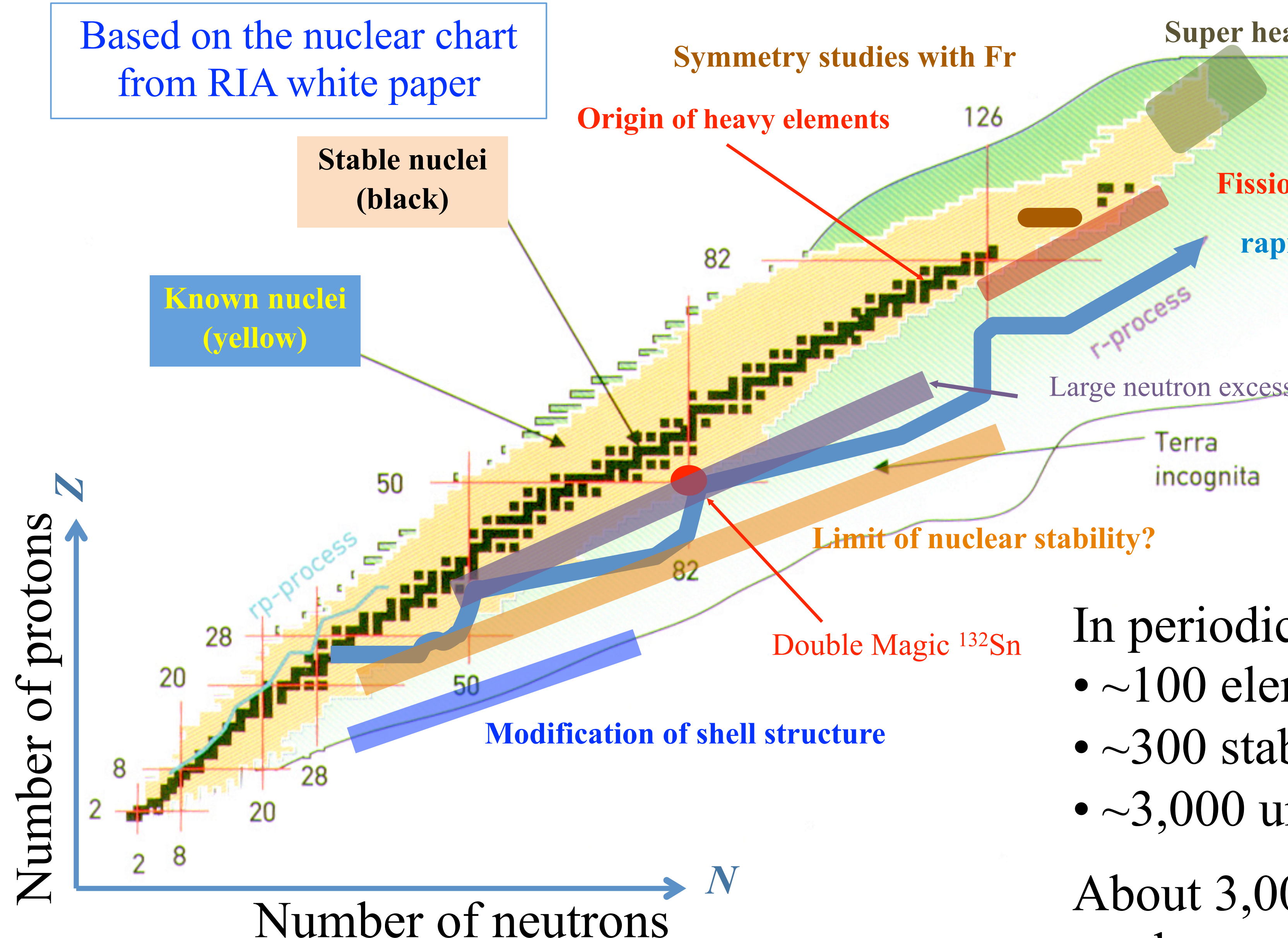
RAON Layout

More details
Talk by S. K. Kim tomorrow

Accelerator	Driver Linac		Post Acc.	Cyclotron
Particle	proton	U^{+78}	RI beam	proton
Beam energy	600 MeV	200 MeV/u	18.5 MeV/u	70 MeV
Beam current	660 μA	8.3 pμA	-	1 mA
Power on target	400 kW	400 kW	-	70 kW



Why Rare Isotope Beam?



In periodic table

- ~100 elements
- ~300 stable isotopes
- ~3,000 unstable isotopes

About 3,000 ~ 6,000 unknown isotopes yet to be discovered

Experiments at RAON

More details
Talk by S. K. Kim tomorrow

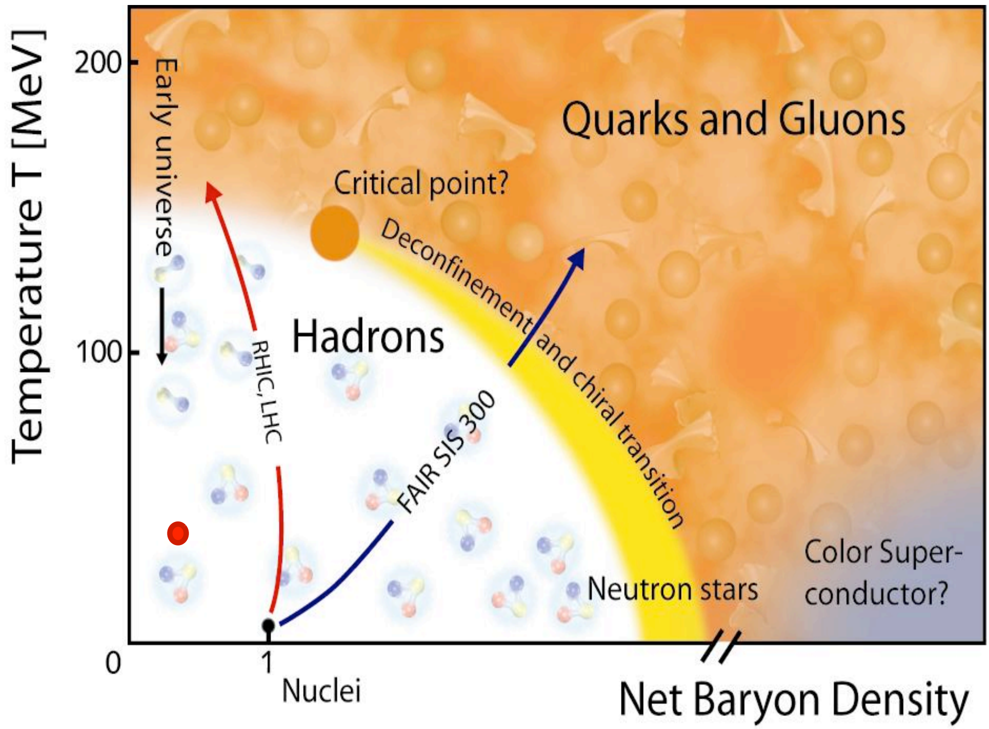
- RISP.3 Experimental Systems
  - RISP.3.3 Nuclear Science Facilities
    - RISP.3.3.1 High Resolution and ZeroDegree Spectrometers
    - RISP.3.3.2 Large Acceptance Spectrometer
    - RISP.3.3.3 Recoil Spectrometer
  - RISP.3.4 Applied Science Facilities
    - RISP.3.4.1 β–NMR System
    - RISP.3.4.2 μSR System
    - RISP.3.4.3 High Prectsion Mass Measurement System
    - RISP.3.4.4 High Prectsion Laser Spectrometer
    - RISP.3.4.5 Bio-medical Research Facilities
    - RISP.3.4.6 Neutron Science Facilities

Heavy Ion Experiment

Study of Nuclear Matter

1.Exploring the phase diagram of strongly interacting matter

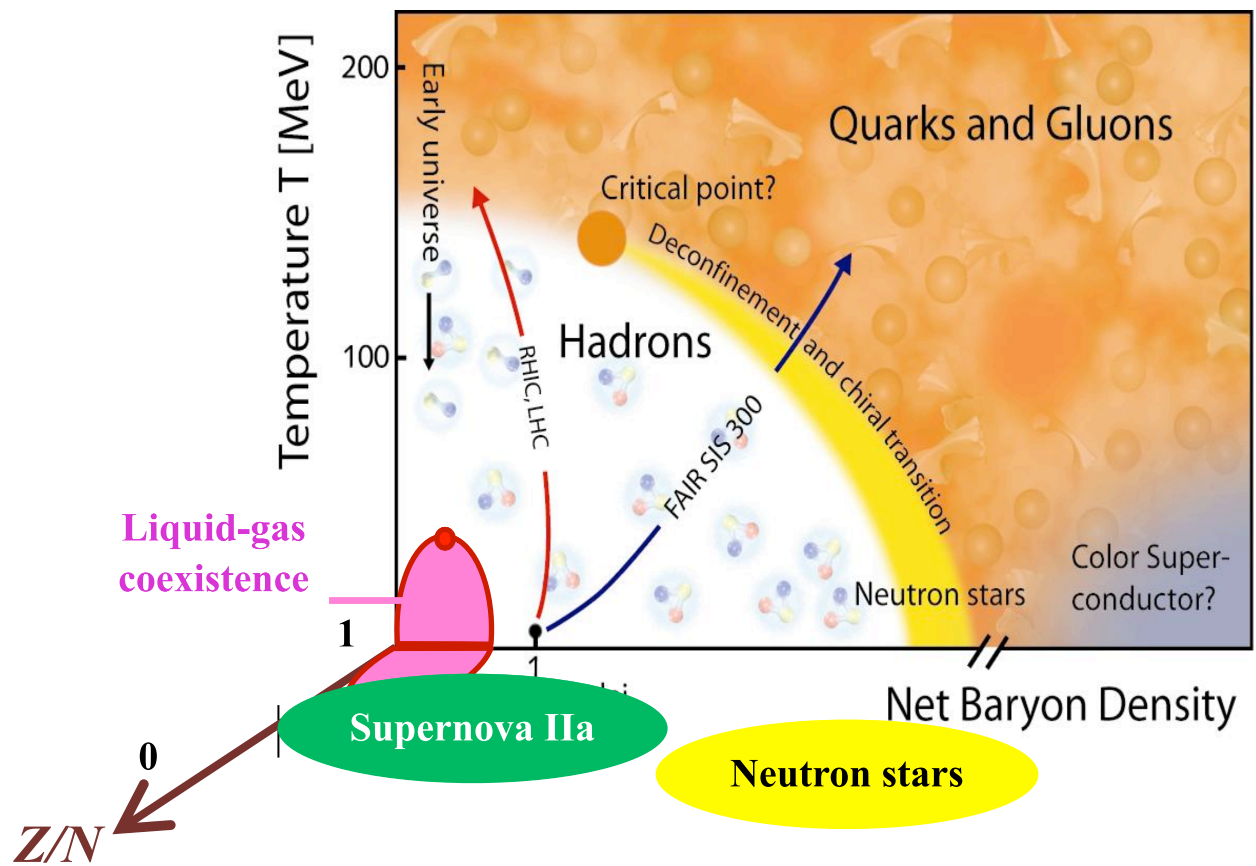
–Phase transitions (liquid ↔ gas, hadron ↔ QGP)



Heavy Ion Experiment

Study of Nuclear Matter

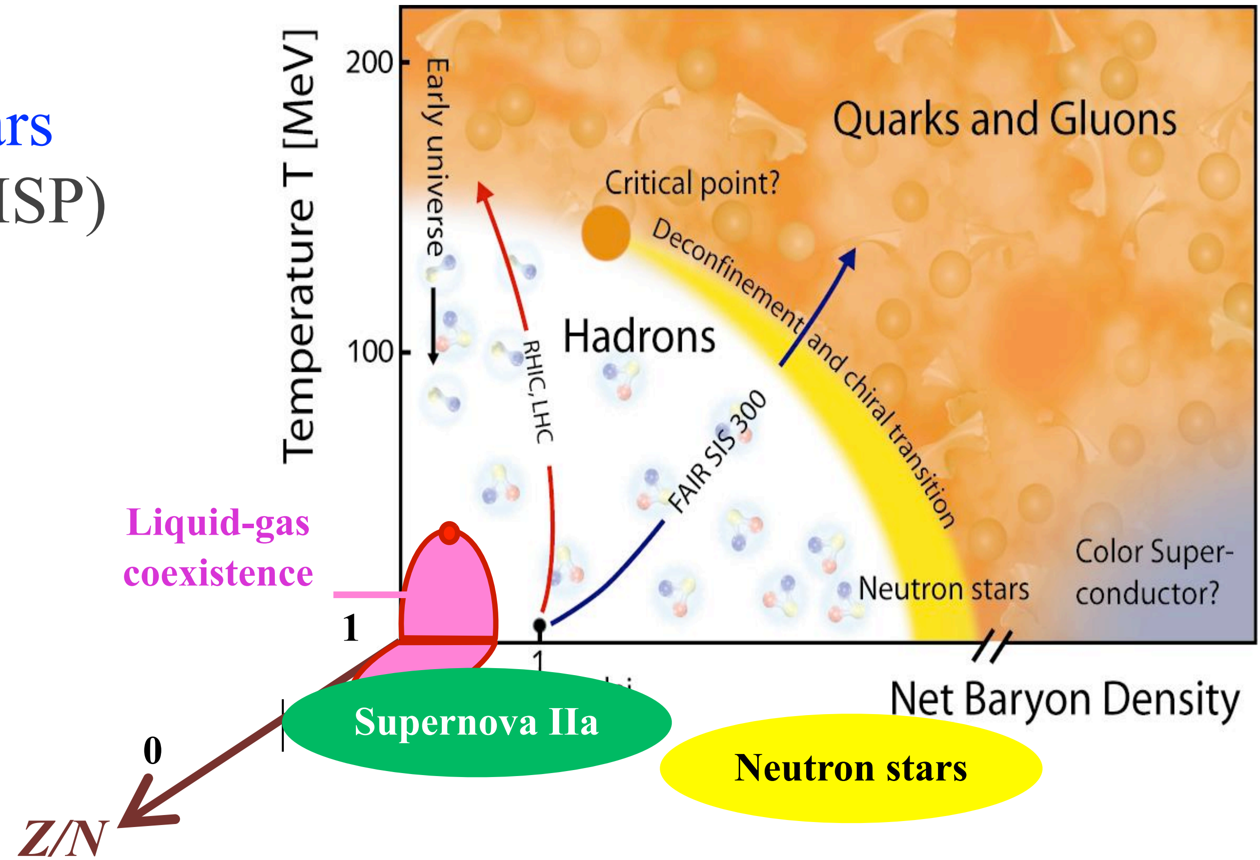
1. Exploring the phase diagram of strongly interacting matter
   - Phase transitions (liquid ↔ gas, hadron ↔ QGP)
2. Determining Equation of State (EOS) of the strongly interacting medium below and above the saturation density
   - Isospin dependence



Heavy Ion Experiment

Study of Nuclear Matter

1. Exploring the phase diagram of strongly interacting matter
   - Phase transitions (liquid ↔ gas, hadron ↔ QGP)
2. Determining Equation of State (EOS) of the strongly interacting medium below and above the saturation density
   - Isospin dependence
3. Modification of hadronic properties in dense medium
4. Importance for astrophysics
   - Supernovae and neutron stars
   - QGP at colliders (not for RISP)



Nuclear Equation of State

Bethe-Weizsäcker formula

$$B(A,Z)/A = a_V - a_s A^{-1/3} - a_c Z(Z-1)A^{-\frac{4}{3}} - a_s \frac{(N-Z)^2}{A^2} + \delta_{pair}$$

(Ref.) C. F. von Weizsäcker, Z. Physik 96, 431 (1935)
N. Bohr, Nature 137, 344 (1936)

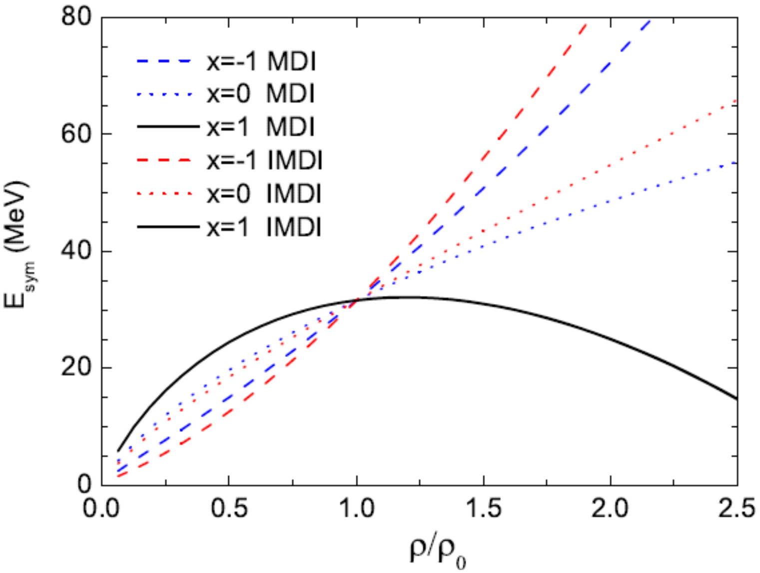
Symmetry energy
Difference between neutron and symmetric matter **(rather unknown)**

Energy of nuclear matter

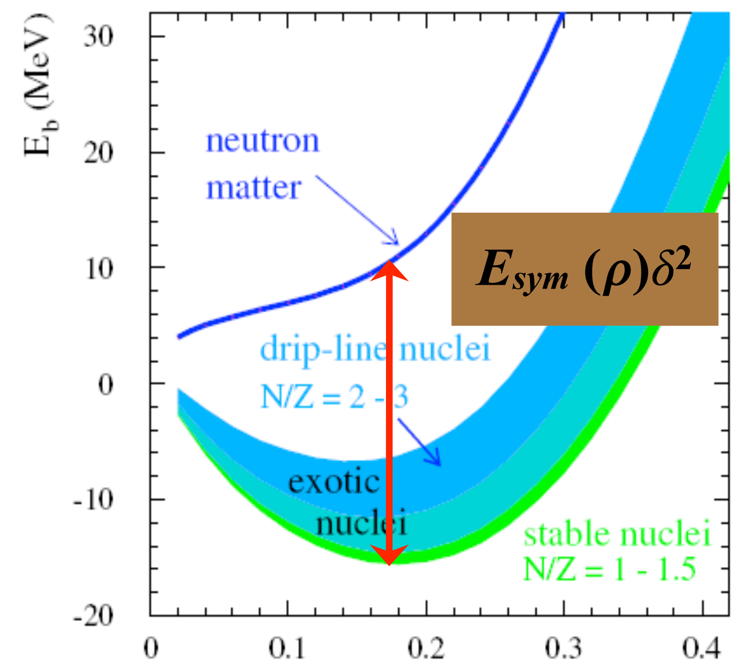
(density and isospin asymmetry dependence)

$$E(\rho,\delta)/A = E(\rho,\delta=0) + E_{sym}(\rho)\delta^2 + \mathcal{O}(\delta^4) + \cdots$$

where $\rho = \rho_n + \rho_p$, $\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$, $a_s \approx E_{sym}(0.6\rho_0)$



C. Xu and B. A. Li, PRC 81, 044603(2010)



CDR, FAIR (2001)

Physics Observables

Important to measure system size (Ca, Ni, Ru, Zr, Sn, Xe, Au, U), energy (lowest to top energies), centrality, rapidity & transverse momentum dependence

1. Pygmy and Giant dipole resonances
   - Energy spectra of gammas
   - Related to the radius of n-skin for unstable nuclei
2. Particle spectrum, yield, and ratio
   - n/p, $^{3}H/^{3}He$, $^{7}Li/^{7}Be$, π^{-}/π^{+}, etc.
3. Collective flow
   - v_1 & v_2 of n, p, and heavier clusters
   - Azimuthal angle dependence of n/p ratio w.r.t the reaction plane
4. Various isospin dependent phenomena
   - Isospin fractionation and isoscaling in nuclear multi fragmentation
   - Isospin diffusion (transport)

Design of Detector System

- We need to accommodate
  - Large acceptance
  - Precise measurement of momentum (or energy) for variety of particle species, including $\pi^{+/-}$ and neutrons, with high efficiency
  - Gamma detection for Pygmy and Giant dipole resonances
  - Keep flexibility for other physics topic
- Two setups
  - Low-energy (E < 18.5 MeV/u) setup for the day-1 experiment
  - High-energy (E > 18.5 MeV/u) setup
- Beam
  - State beam: ^{238}U up to 200 MeV/u
  - Unstable beam: ^{132}Sn up to 250 MeV/u

Heavy Ion Experiment at RAON

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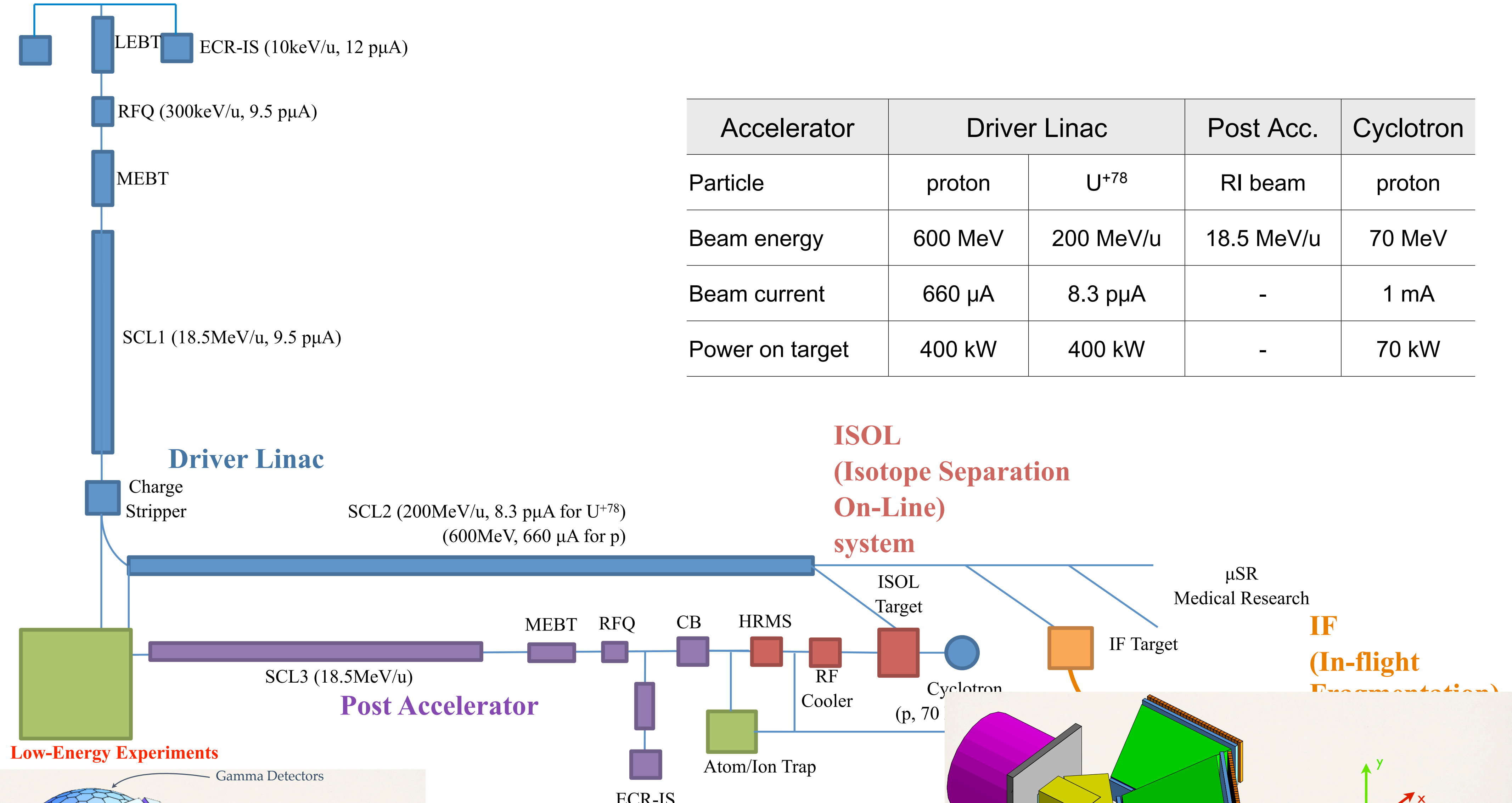
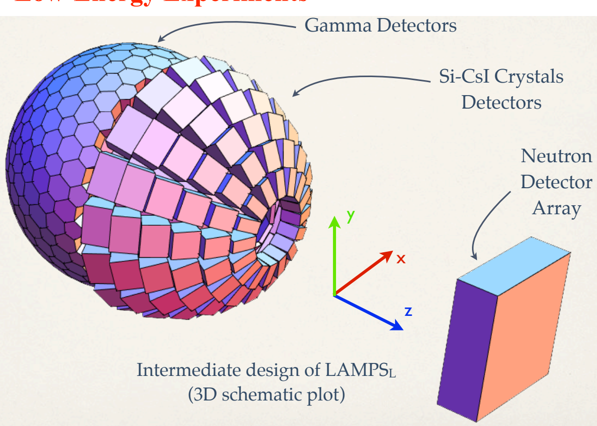
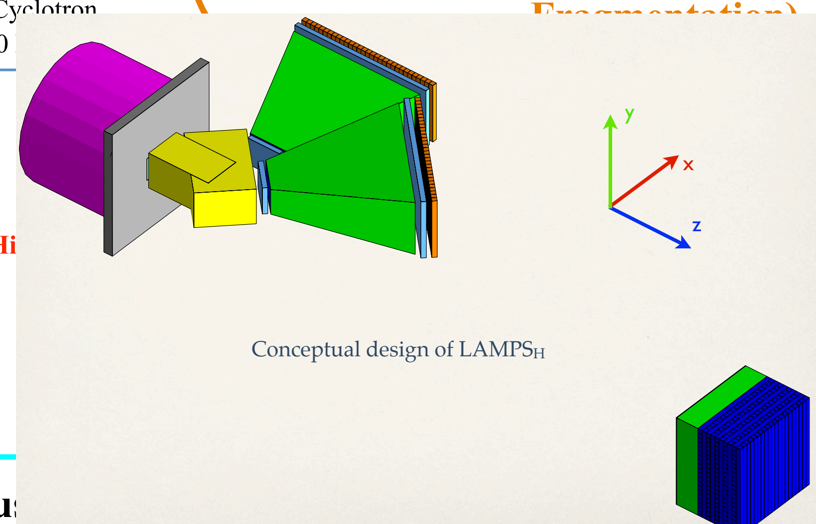


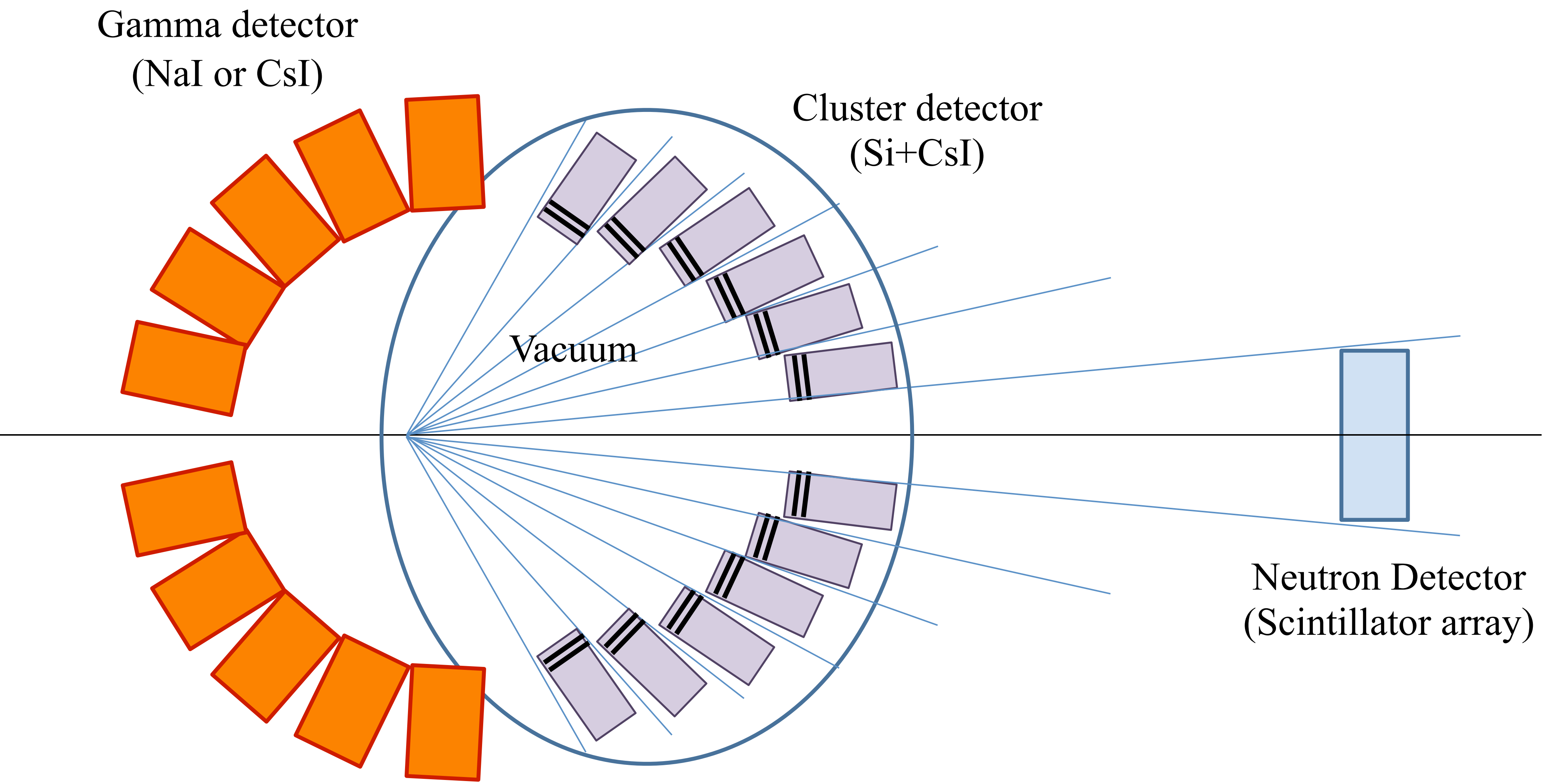


Intermediate design of $LAMPS_L$
(3D schematic plot)



Conceptual design of $LAMPS_H$

Low Energy LAMPS Experimental Setup



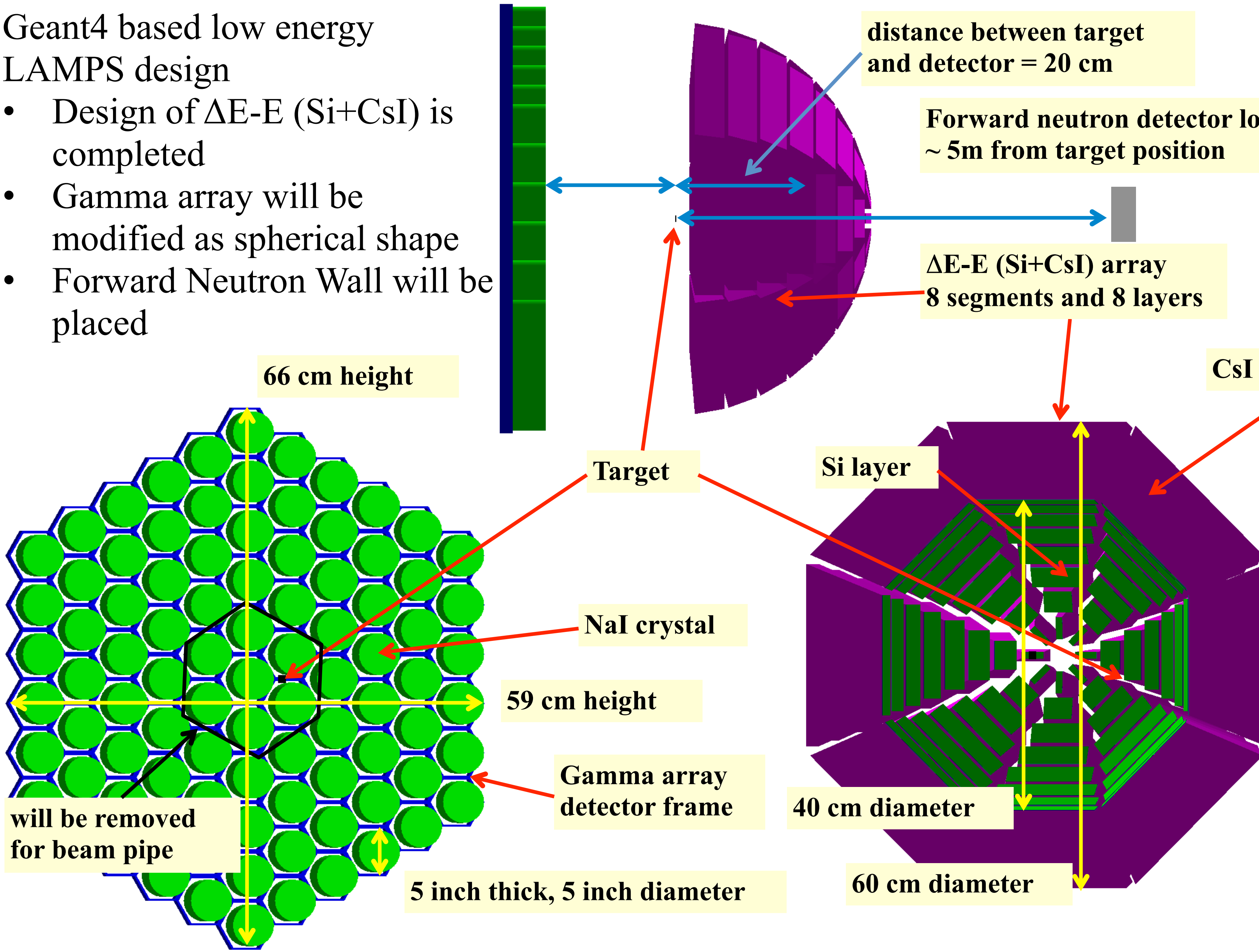
Geant4 simulation framework is under development

- Feasibility study
- Need to get all detector parameters for TDR

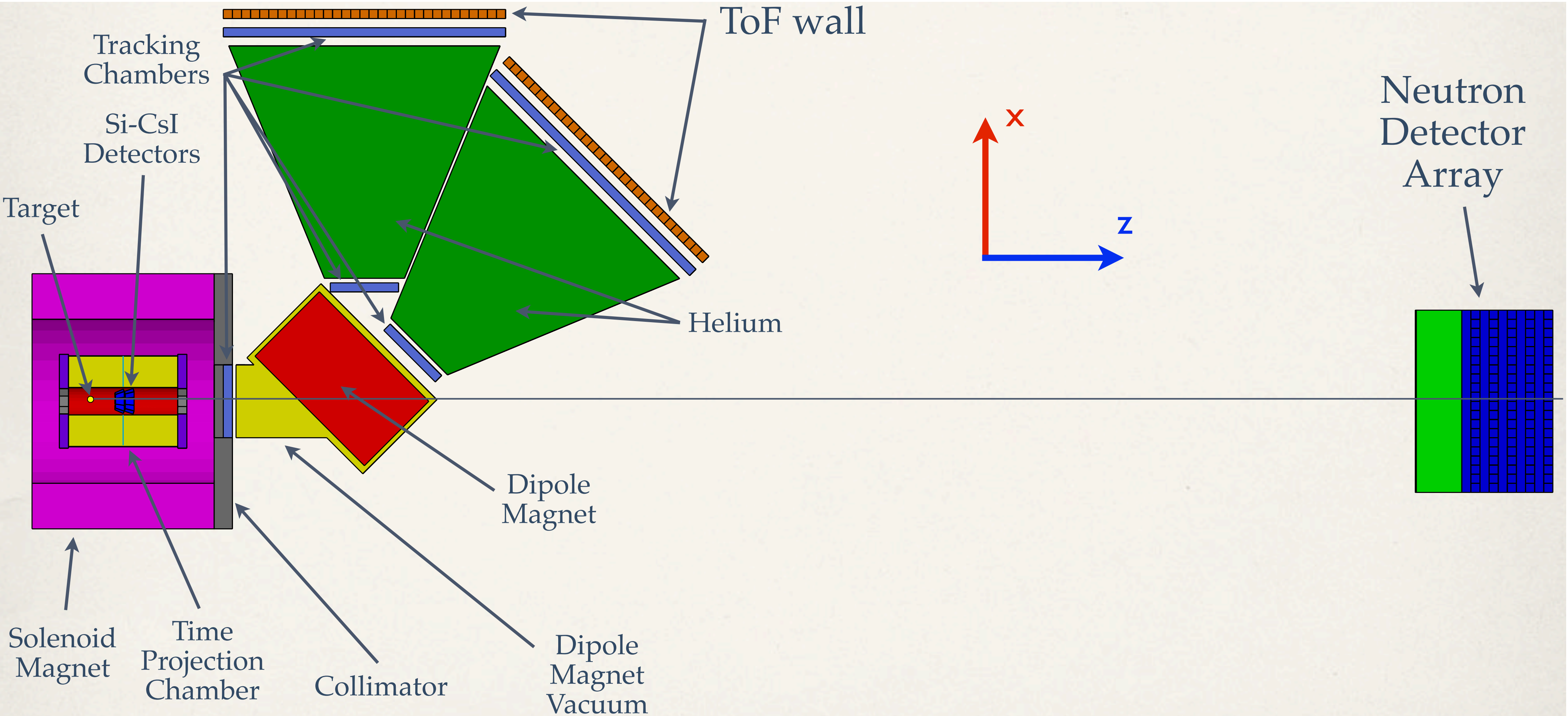
Low Energy LAMPS Experimental Setup

Geant4 based low energy LAMPS design

- Design of ΔE-E (Si+CsI) is completed
- Gamma array will be modified as spherical shape
- Forward Neutron Wall will be placed



High Energy LAMPS Experimental Setup



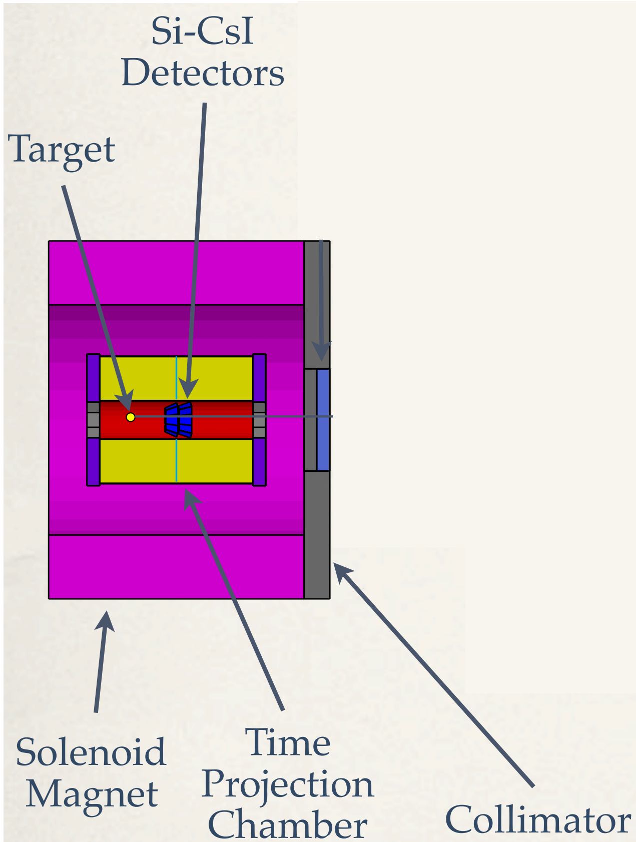
Geant4 simulation is ongoing

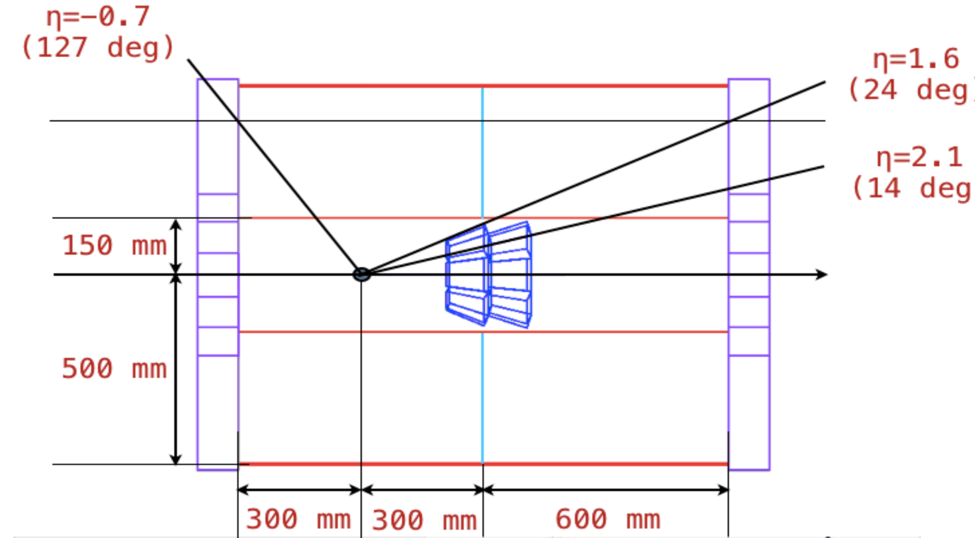
- Each detector parts (to get detector parameters)
- Full simulation for feasibility study

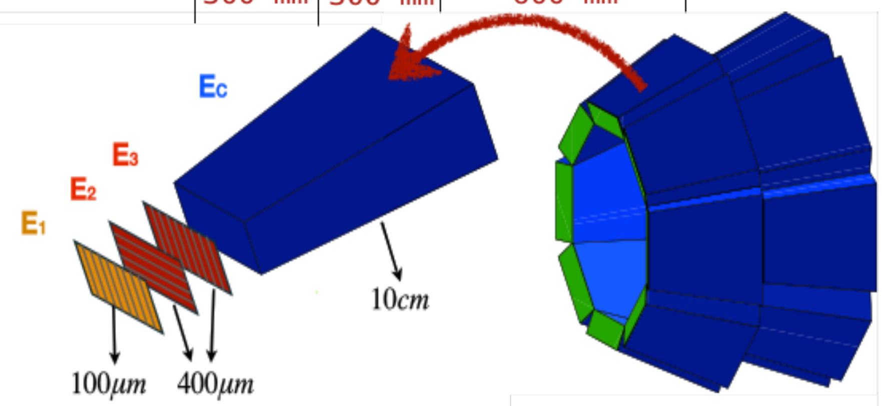
Prototype testing is in progress

More details
Next talk by G. Jhang

Solenoid Spectrometer



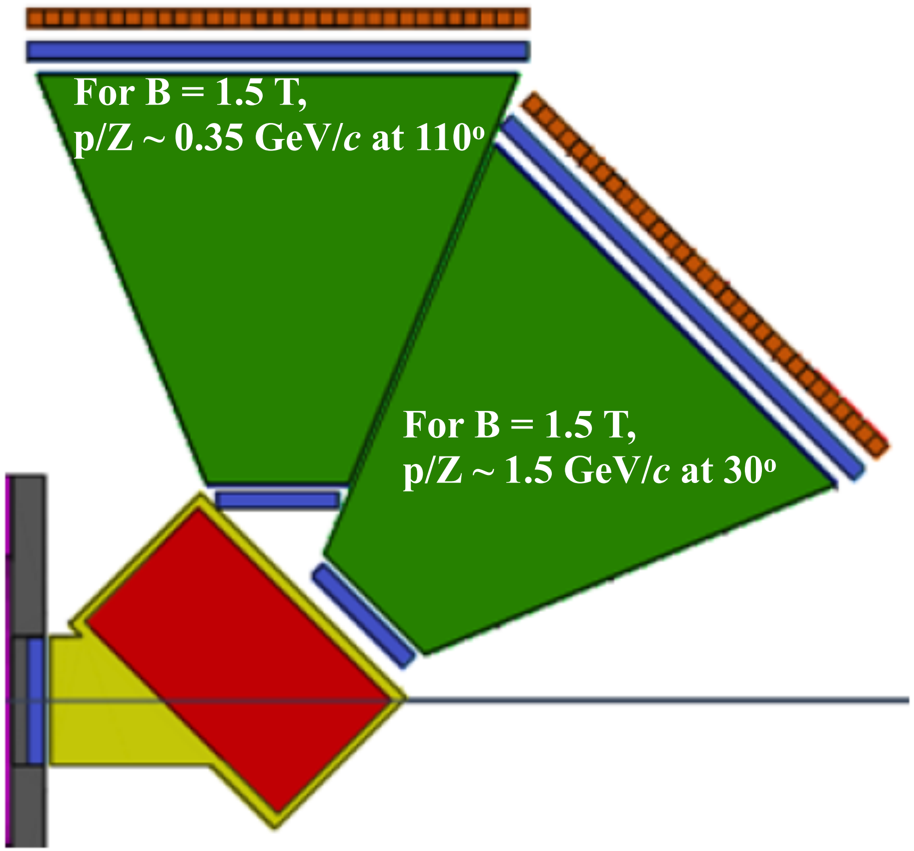


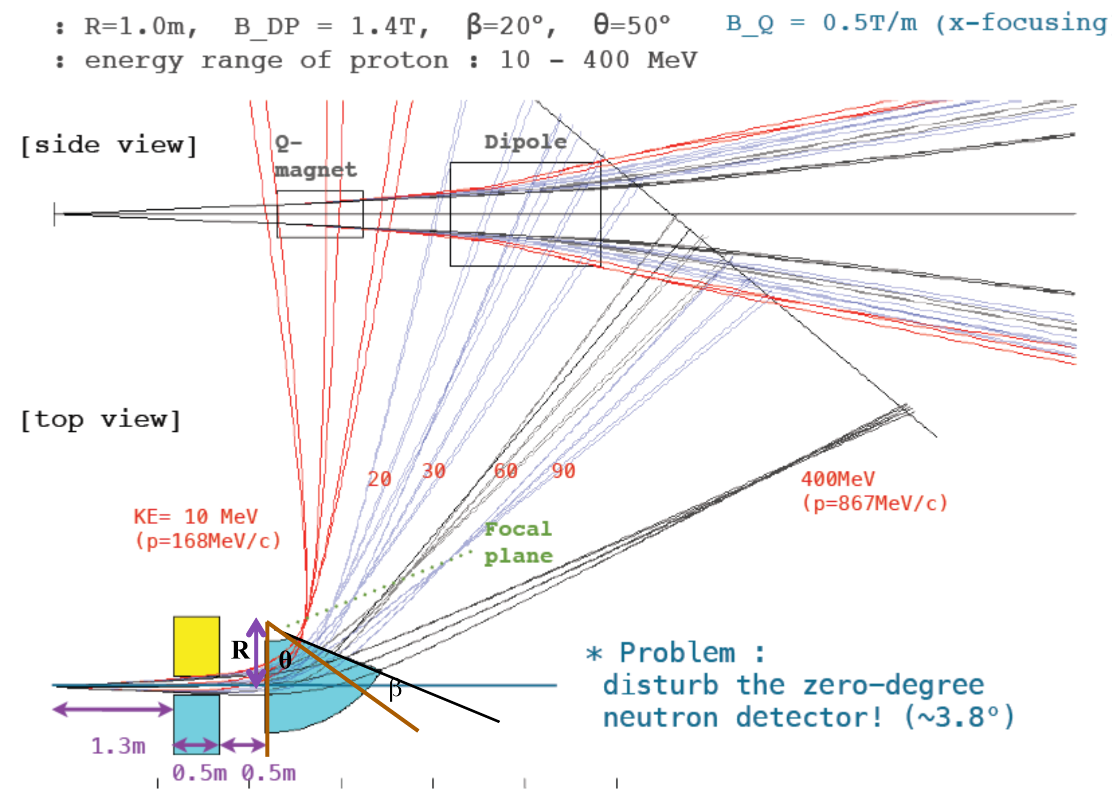


- **Time Projection Chamber (TPC)**
  - **-GEM based & pad readout in end-caps (~100 k readout channels)**
  - **-1 x 1.2 m^2 cylindrical shape**
  - **-Large acceptance (~ 3π Sr)**
- **Si+CsI**
  - **-Si layers for ΔE & CsI for E**
  - **-14^o – 19^o & 19^o – 24^o (350 mSr each)**
- **Solenoid magnet**
  - **-More detailed optics and field mapping calculations are on going**

More details
Next talk by G. Jhang

Dipole Spectrometer





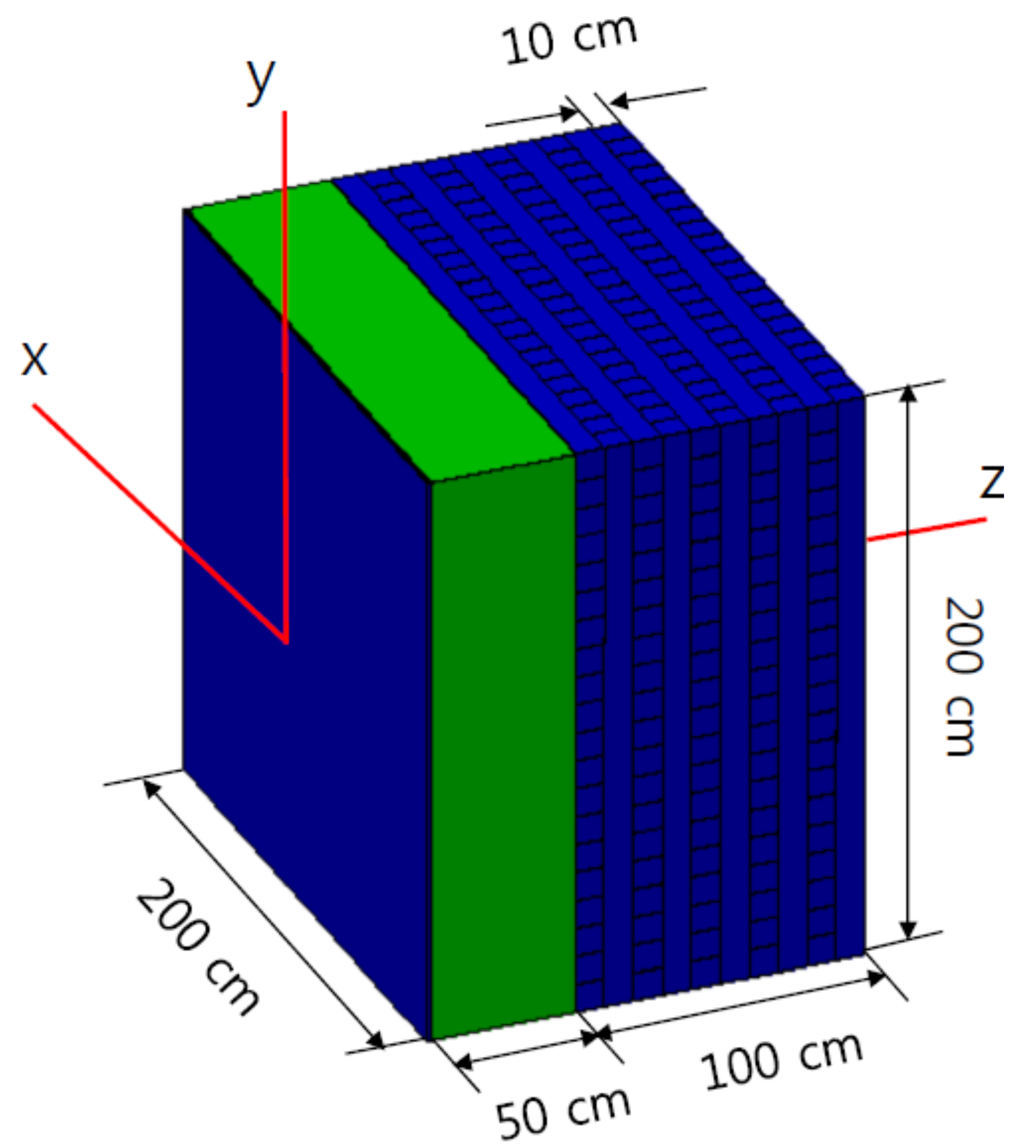
Dipole acceptance ≥ 50 mSr
Dipole length = 1 m
Rotatable+high resolution mode

- **Multi particle tracking capability of isotopes for p, He, and heavier fragments**
  - **Focal Plane detector for low momentum particles**
- **More than 3 tracking chamber stations (MWDC) for each arm**
- **Plastic scintillator ToF**
  - **σ_t < 100 ps (essential for $\Delta p/p < 10^{-3}$ @ $\beta = 0.5$)**

Forward Neutron Detector Array

Large charged particle veto detector
+ neutron detector
(composed of scintillator bars)

- Scintillator = 10 (W) x 10 (H) x 200 (L) cm^3
- 10 layers (20 scintillators/layer)
- Covering wide neutron energy range is important
- Capable for neutron tracking
- Geant simulation and detail R&D with prototype is in progress



More details
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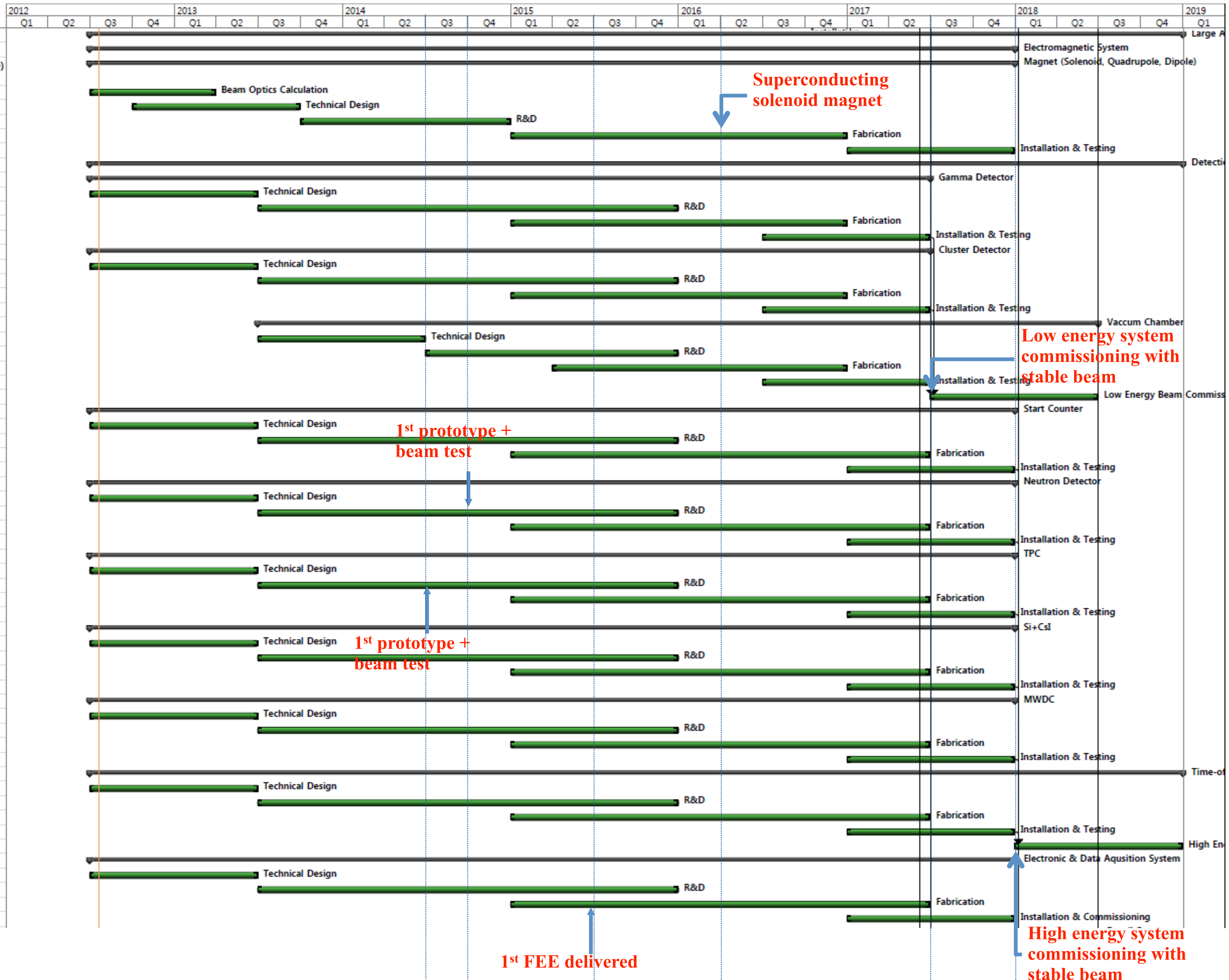
Schedule & Milestone

ID	Task Name
335	Large Acceptance Spectrometer
336	Electromagnetic System
337	Magnet (Solenoid, Quadrupole, Dipole)
338	Beam Optics Calculation
339	Technical Design
340	R&D
341	Fabrication
342	Installation & Testing
343	Detection System
344	Gamma Detector
345	Technical Design
346	R&D
347	Fabrication
348	Installation & Testing
349	Cluster Detector
350	Technical Design
351	R&D
352	Fabrication
353	Installation & Testing
354	Vaccum Chamber
355	Technical Design
356	R&D
357	Fabrication
358	Installation & Testing
359	Low Energy Beam Commissioning
360	Start Counter
361	Technical Design
362	R&D
363	Fabrication
364	Installation & Testing
365	Neutron Detector
366	Technical Design
367	R&D
368	Fabrication
369	Installation & Testing
370	TPC
371	Technical Design
372	R&D
373	Fabrication
374	Installation & Testing
375	Si+CsI
376	Technical Design
377	R&D
378	Fabrication
379	Installation & Testing
380	MWDC
381	Technical Design
382	R&D
383	Fabrication
384	Installation & Testing
385	Time-of-Flight Detector
386	Technical Design
387	R&D
388	Fabrication
389	Installation & Testing
390	High Energy Beam Commissioning
391	Electronic & Data Aqusition System
392	Technical Design
393	R&D
394	Fabrication
395	Installation & Commissioning



Summary

- RAON is RI beam accelerator in Korea
  - RAON will provide high purity, high intensity various RI beams (e.g. 10^8 pps ^{132}Sn at 250 Mev/u)
- RISP is on going for establishment of RAON accelerator and experimental facilities
  - ➡For more details, talk by S. K. Kim tomorrow

- Large Acceptance Multi-Purpose Spectrometer (LAMPS) at RAON
  - Study of nuclear symmetry energy with RI and stable beam
  - Two detector setup for low and high energy
    - ▸Low energy: gamma detector + Si+CsI detector + neutron detector
    - ▸High energy: TPC + Si+CsI detector + neutron detector + MWDC + ToF + Solenoid magnet + Dipole magnet
    - ✓To cover entire energy range of RAON with complete event reconstruction within large acceptance
  - Detail detector simulation and prototyping are in progress for TDR
    - ➡For more details, following talk by G. Jhang
  - Schedule, plan, and budget are established
  - Getting more collaborators from both domestic and oversea
    - ▸Forming International collaboration