Heavy-Ion Meeting 2012-04
APCTP, Pohang, Korea, April 13, 2012

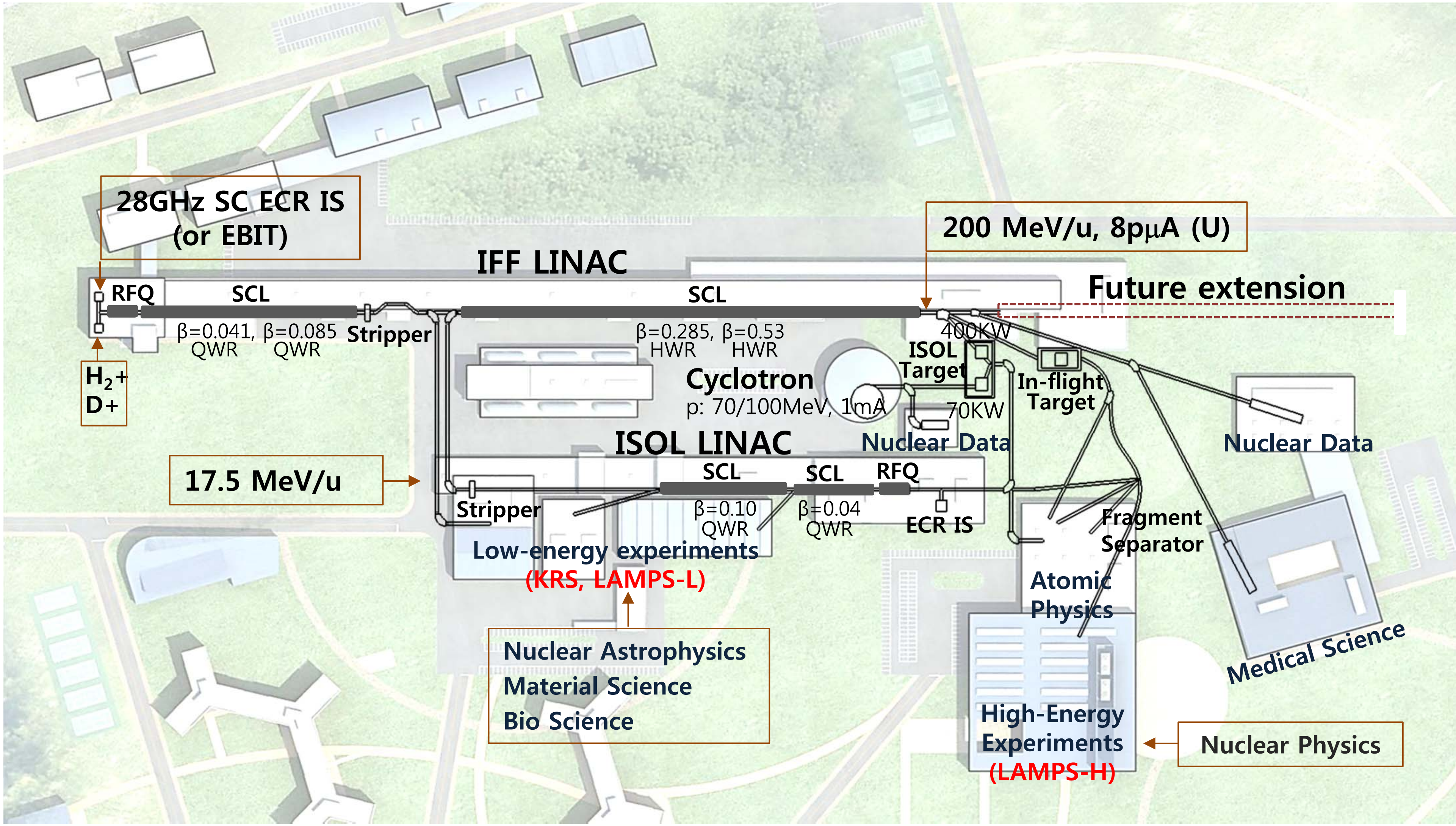
Plan for LAMPS at Korea Rare-Isotope Accelerator

Byungsik Hong (Korea University)

Outline

- Introduction to KoRIA & symmetry energy
- Two selected experimental observables
- Current design of LAMPS
- Summary

Korea Rare-Isotope Accelerator



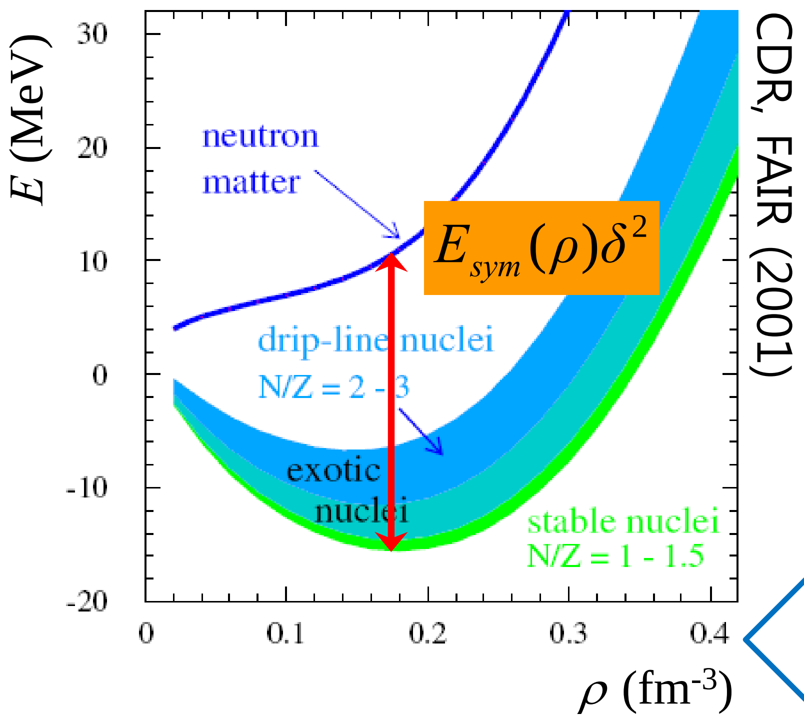
Nuclear Equation of State

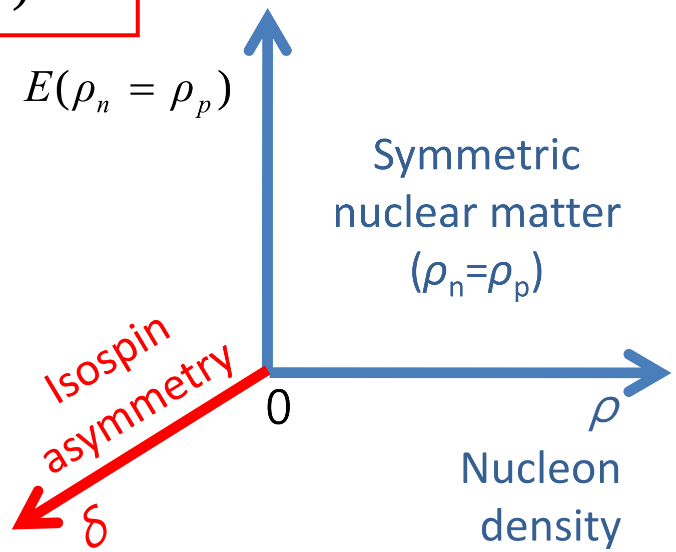
$$E(\rho_n,\rho_p) = E(\rho_n=\rho_p) + E_{sym}(\rho)\delta^2 + O(\delta^4)$$

$$E_{sym}(\rho) = \frac{1}{2}\frac{\partial^2 E}{\partial \delta^2} \approx E(\rho)_{\substack{\text{pure}\\ \text{neutron matter}}} - E(\rho)_{\substack{\text{symmetric}\\ \text{nuclear matter}}}$$

with $\rho = \rho_n + \rho_p,\ \delta = (\rho_n - \rho_p)/\rho = (N-Z)/A$

B.-A. Li, L.-W. Chen & C.M. Ko
Physics Report, **464,** 113 (2008)





F. de Jong & H. Lenske, RPC 57, 3099 (1998)
F. Hofman, C.M. Keil & H. Lenske, PRC 64, 034314 (2001)

Proposed Experimental Observables

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

➢ See the presentations by Hermann and Betty after me

Two Examples

$$E_{sym}(\delta) = E_{sym}(0) + \frac{L}{3}\delta + \frac{K_{sym}}{18}\delta^2$$

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Pygmy Dipole Resonance

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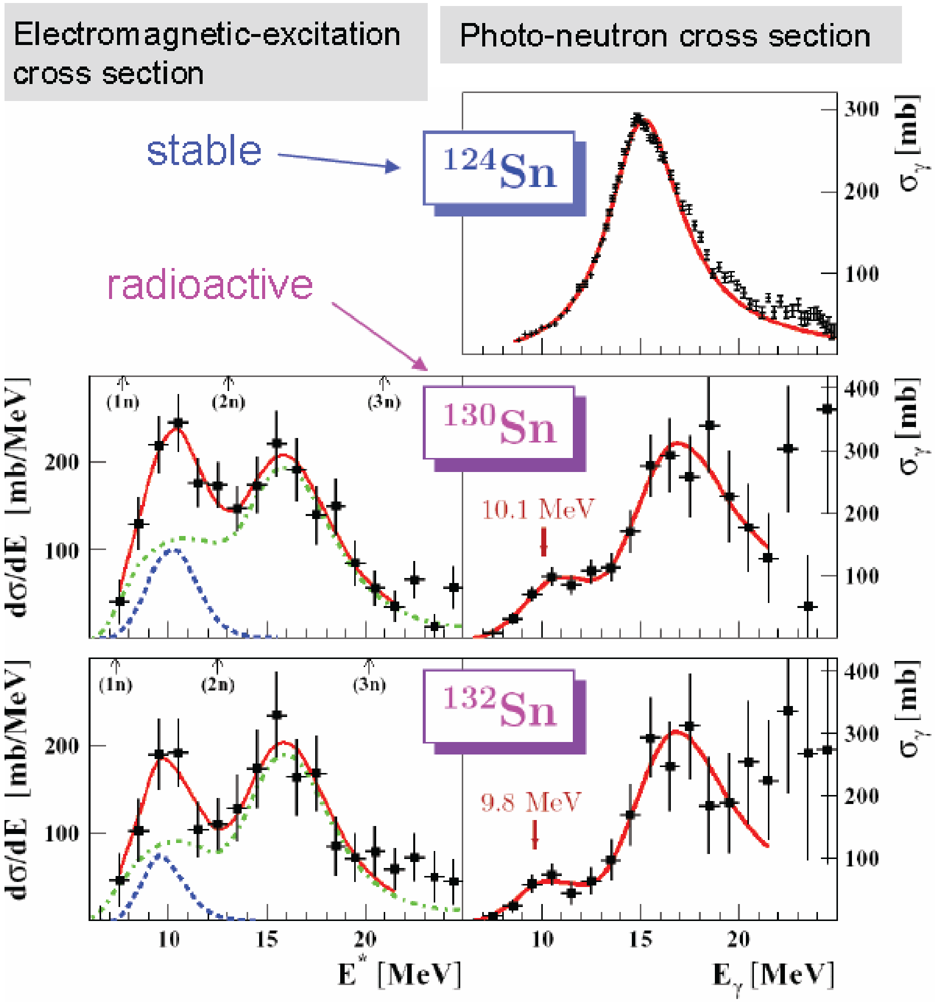
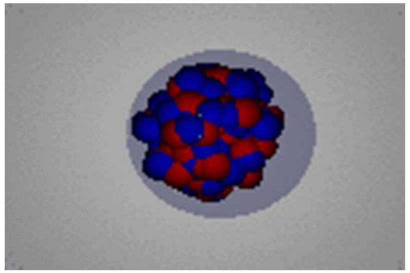
Pygmy Dipole Resonance

Collective Flow

Pygmy Dipole Resonance

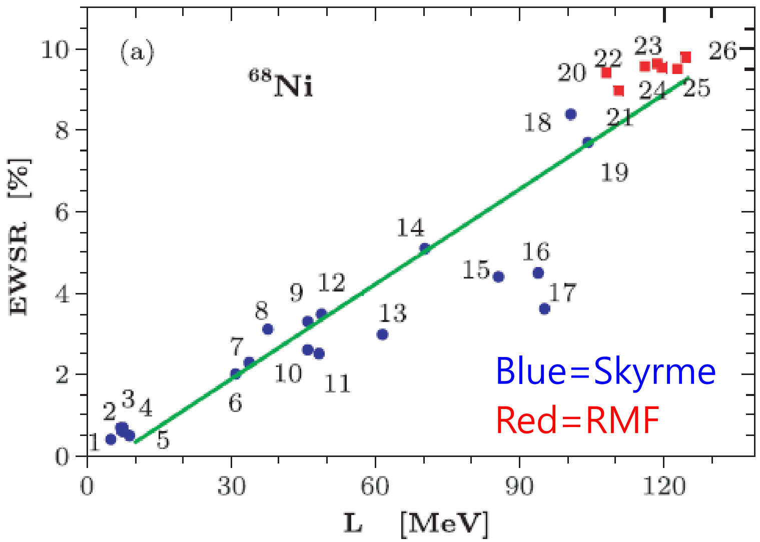
P. Adrich et al., PRL 95, 132501 (2005)

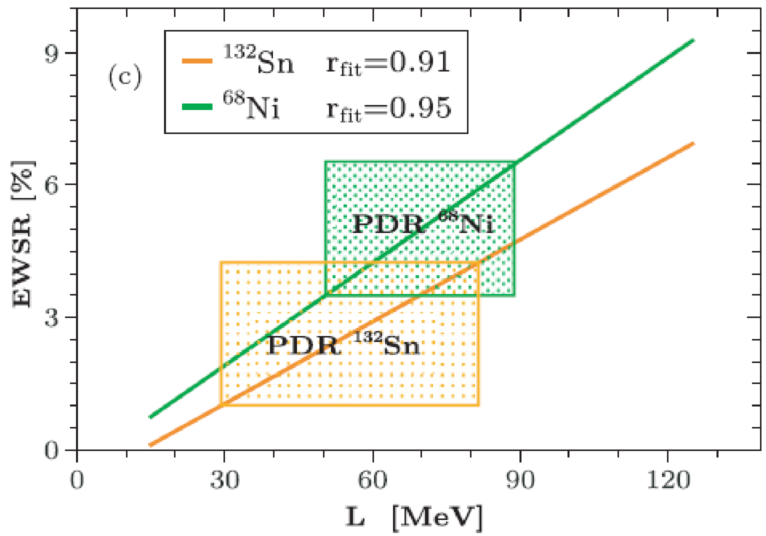


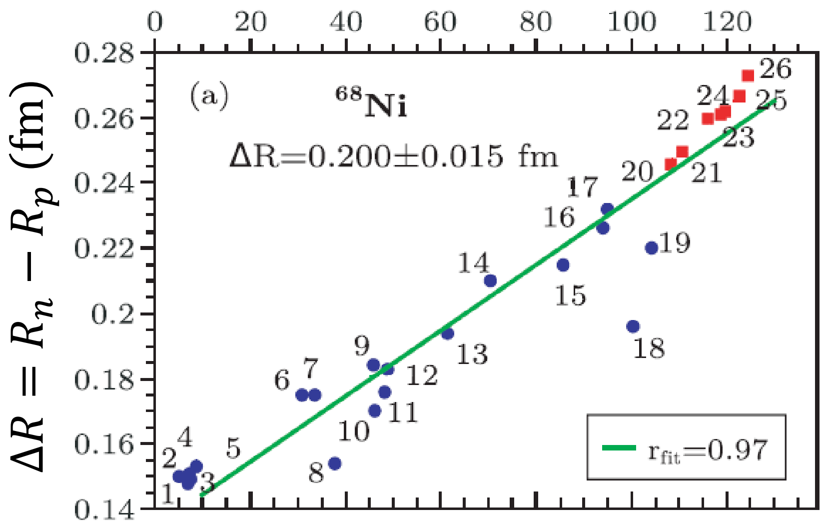


- Coulomb excitation of neutron-rich $^{130,132}Sn$ isotopes reveals a peak at ~10 MeV, which is absent for stable isotopes
- Can be interpreted as an oscillation of a neutron skin relative to the core

PDR and Symmetry Energy







$\mathrm{EWSR_{Exp}}[^{68}\mathrm{Ni}] = 5 \pm 1.5\%$

$L = 64.8 \pm 15.7$ MeV
(still large error bar)

A. Carbone et al.,
PRC 81, 041301 (2010)

Collective Flow

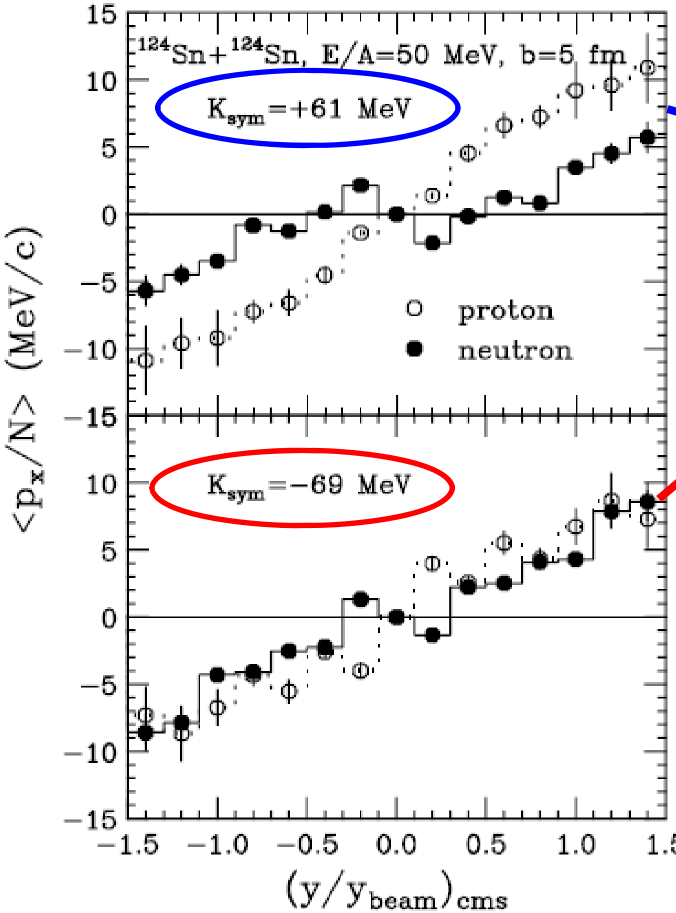
B.-A. Li, PRL 85, 4221 (2000)

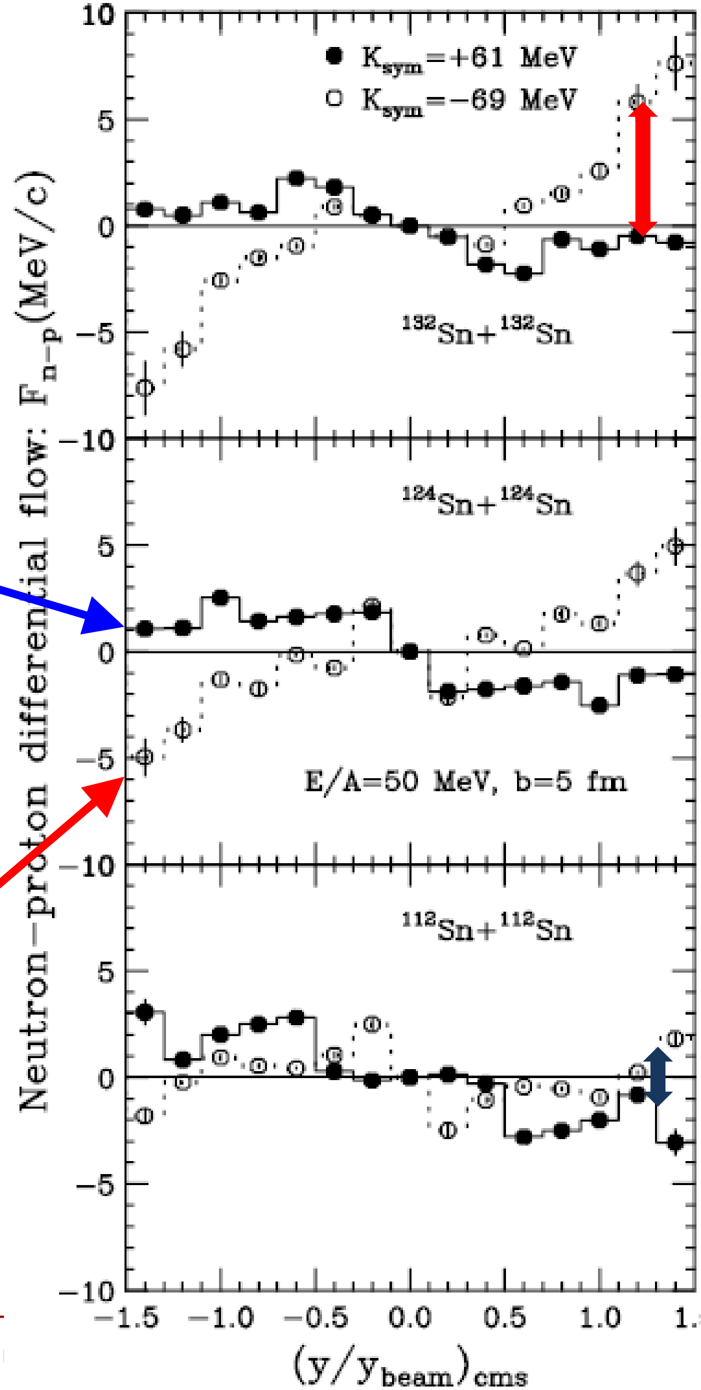
$$K_{sym} \equiv 9\rho_0^2 \left. \frac{\partial^2 E_{sym}(\rho)}{\partial \rho^2} \right|_{\rho=\rho_0}$$

Stiff

Also known as v_1

Super Soft





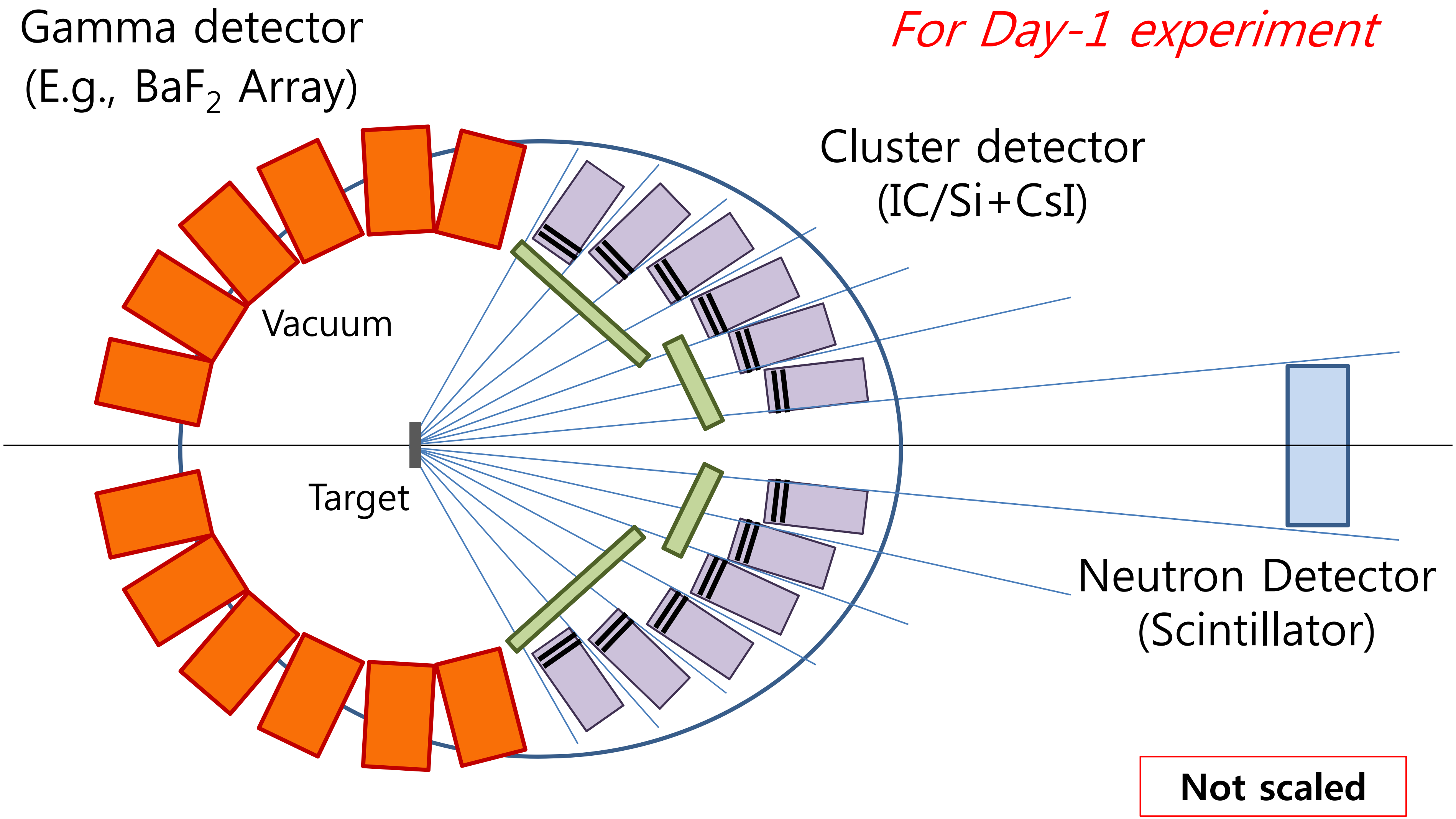
Large N/Z

Small N/Z

Design of Detector System

1. 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 PDR
   - Keep flexibility for other physics topics
2. This leads to the design of **LAMPS**
   - Large-Acceptance Multipurpose Spectrometer
3. Two setups (under discussion)
   - Low-energy setup for the day-1 experiment
   - High-energy setup: full version of LAMPS

Conceptual Design of $LAMPS_L$

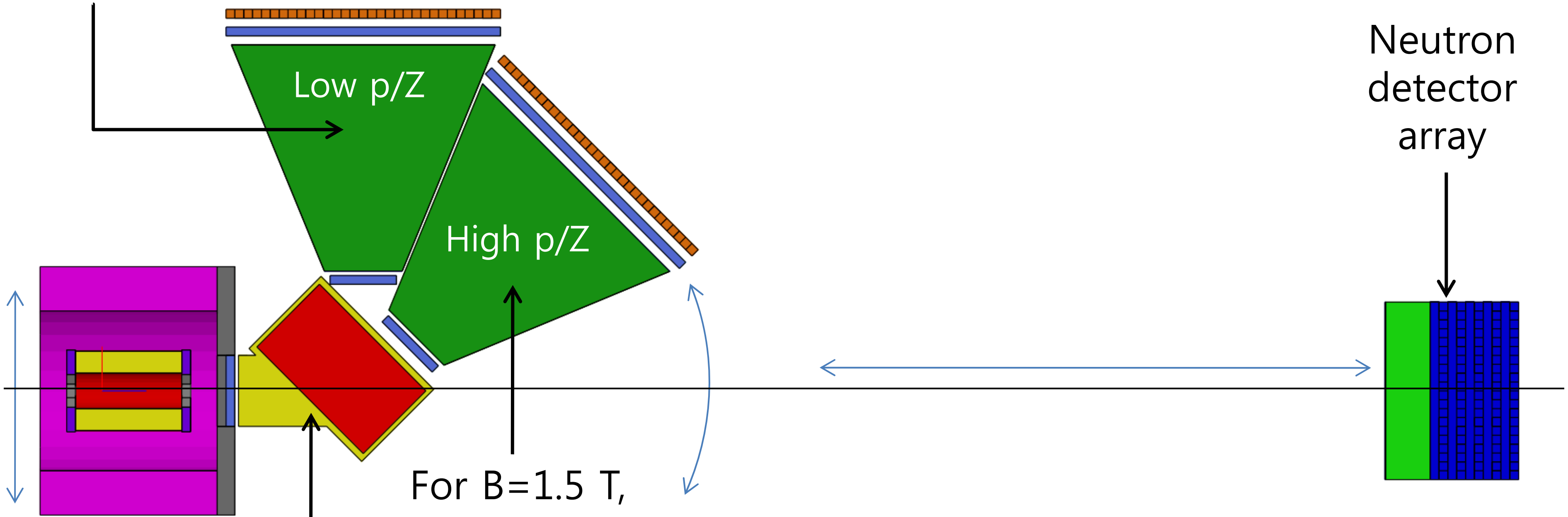


Conceptual Design of $LAMPS_H$

- Dipole acceptance ≥ 50mSr
- Dipole length =1.0 m
- TOF length ~8.0 m

For B=1.5 T,
p/Z ≈ 0.35 GeV/c
at 110°

Neutron
detector
array



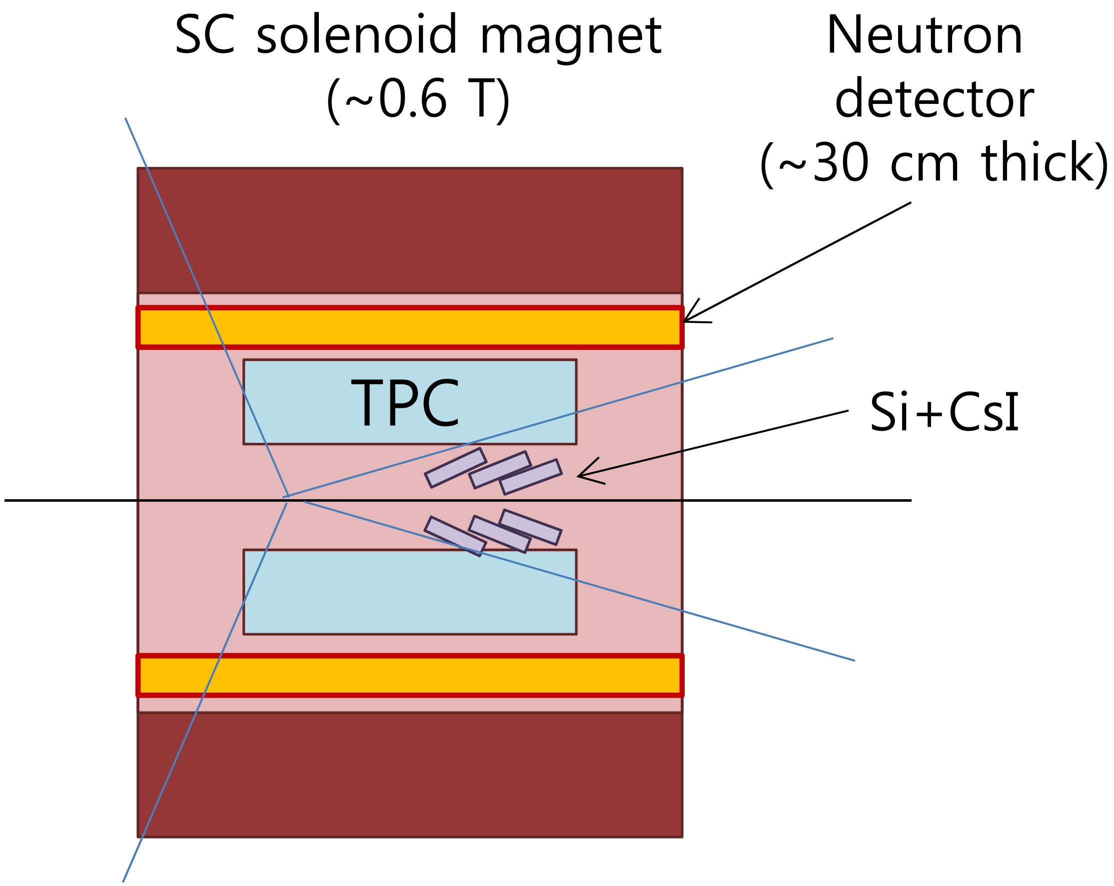
For B=1.5 T,
p/Z ≈ 1.5 GeV/c at 30°

Solenoid
magnet

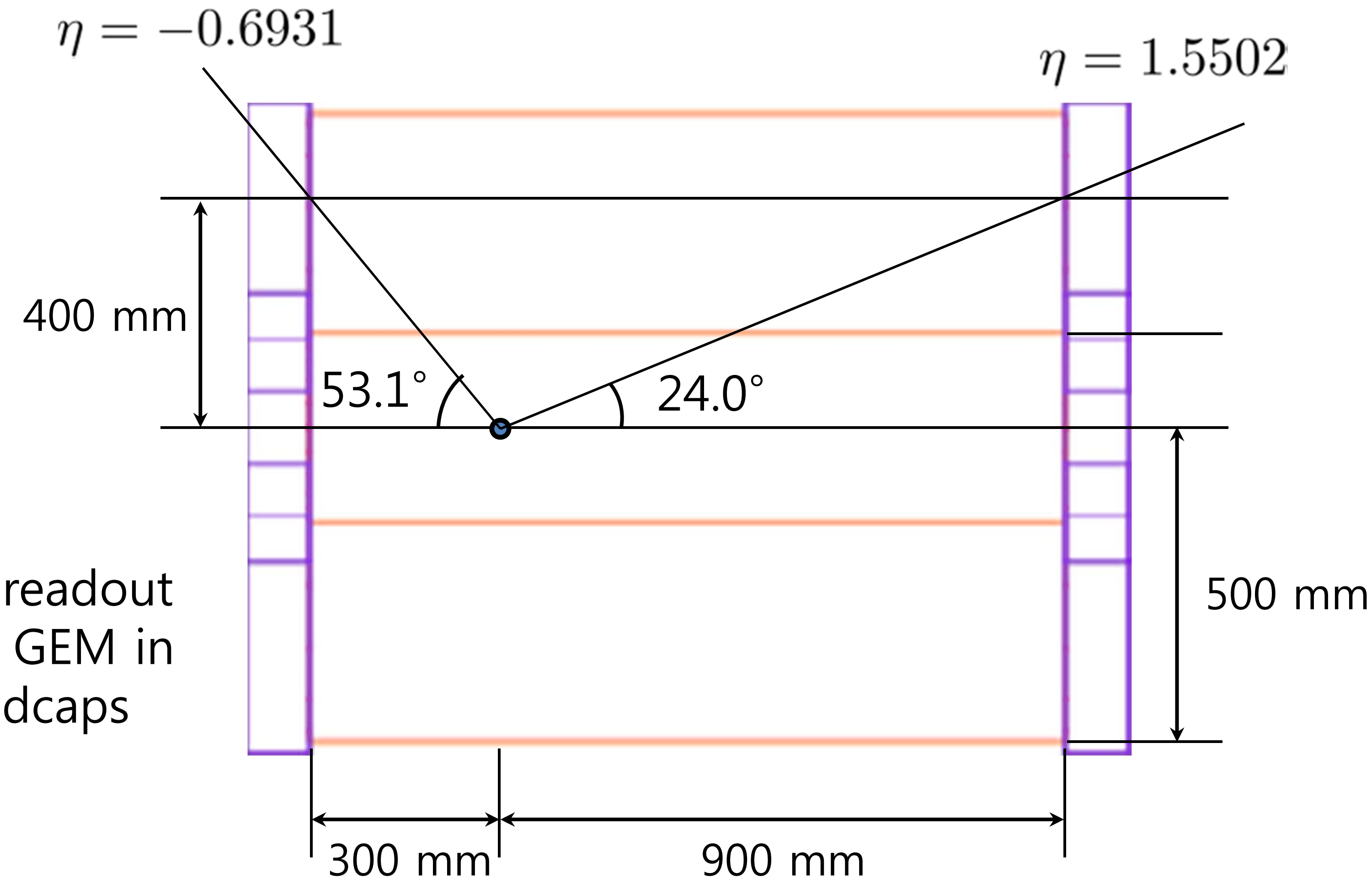
Dipole magnet: Considering the large aperture (rotational) superconducting dipole magnet (SAMURAI type).

Solenoid Spectrometer

- TPC
  - Large acceptance (~3π Sr)
  - $\pi^{+/-}$
  - Light fragments
- Si+CsI
  - Si layers for ΔE
  - CsI(Tl) for E
  - Fragments
  - Also useful for event characterization



Time Projection Chamber

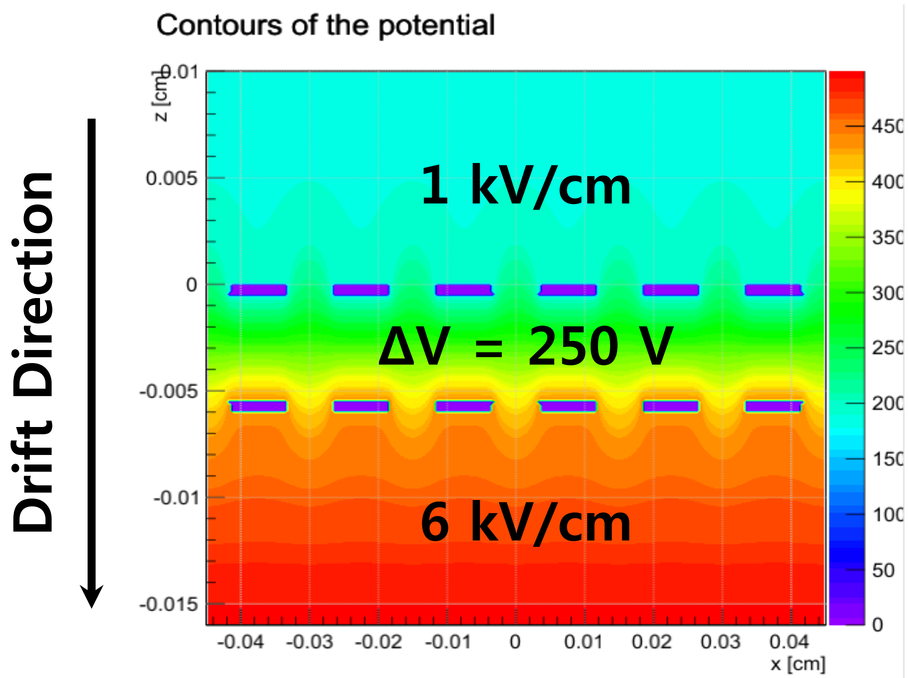


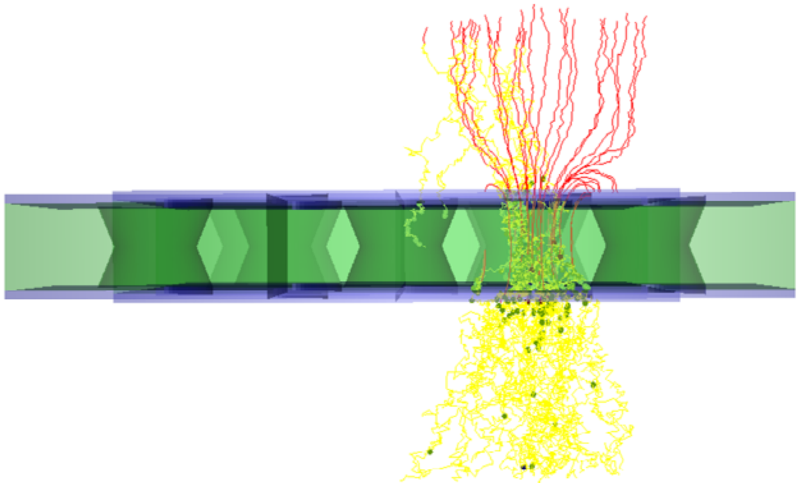
Pad readout with GEM in endcaps

Time Projection Chamber

Genie Jhang (Korea Univ.)

- Detailed GEM simulation in Garfield++
  - To determine gain and dispersion
  - Outcome will be used for the fast TPC simulation

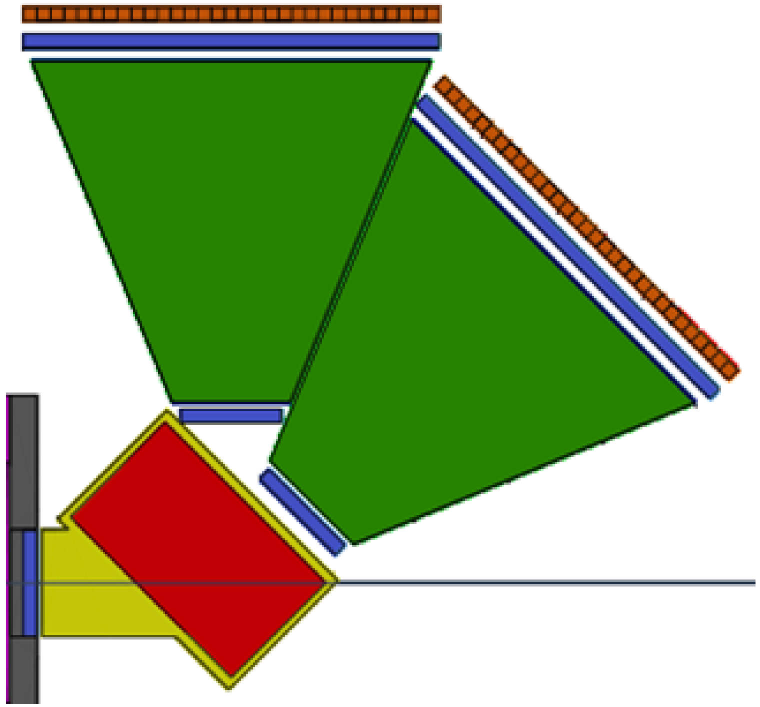




|B| = 0.6 T in z

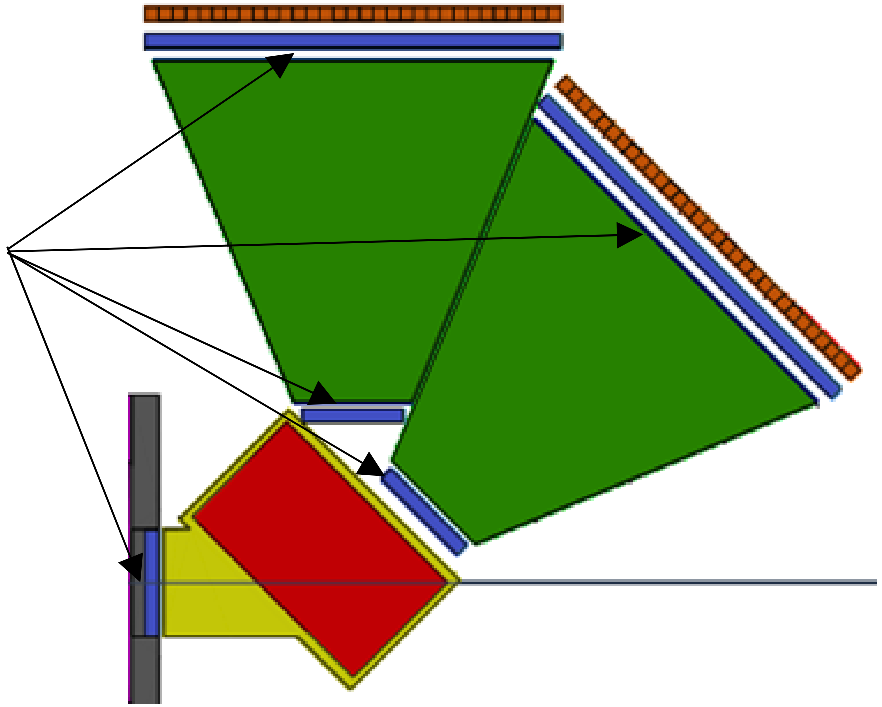
Dipole Spectrometer

- Multiparticle tracking capability of isotopes for p, He, and heavier elements.



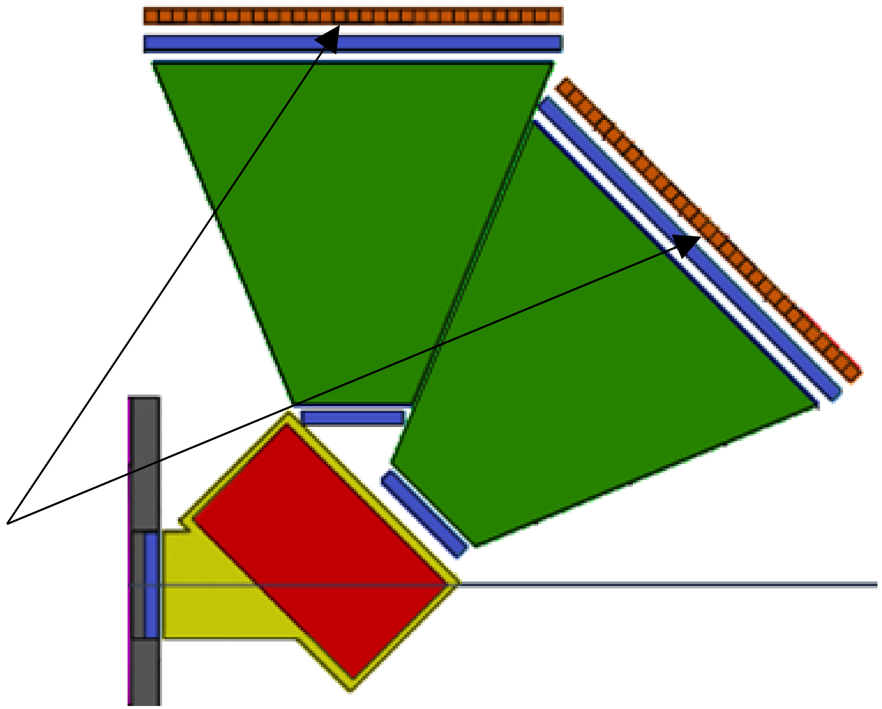
Dipole Spectrometer

- Multiparticle tracking capability of isotopes for p, He, and heavier elements.
- Tracking chambers: ≥ 3 stations of drift chambers (+pad readout possible) for each arm



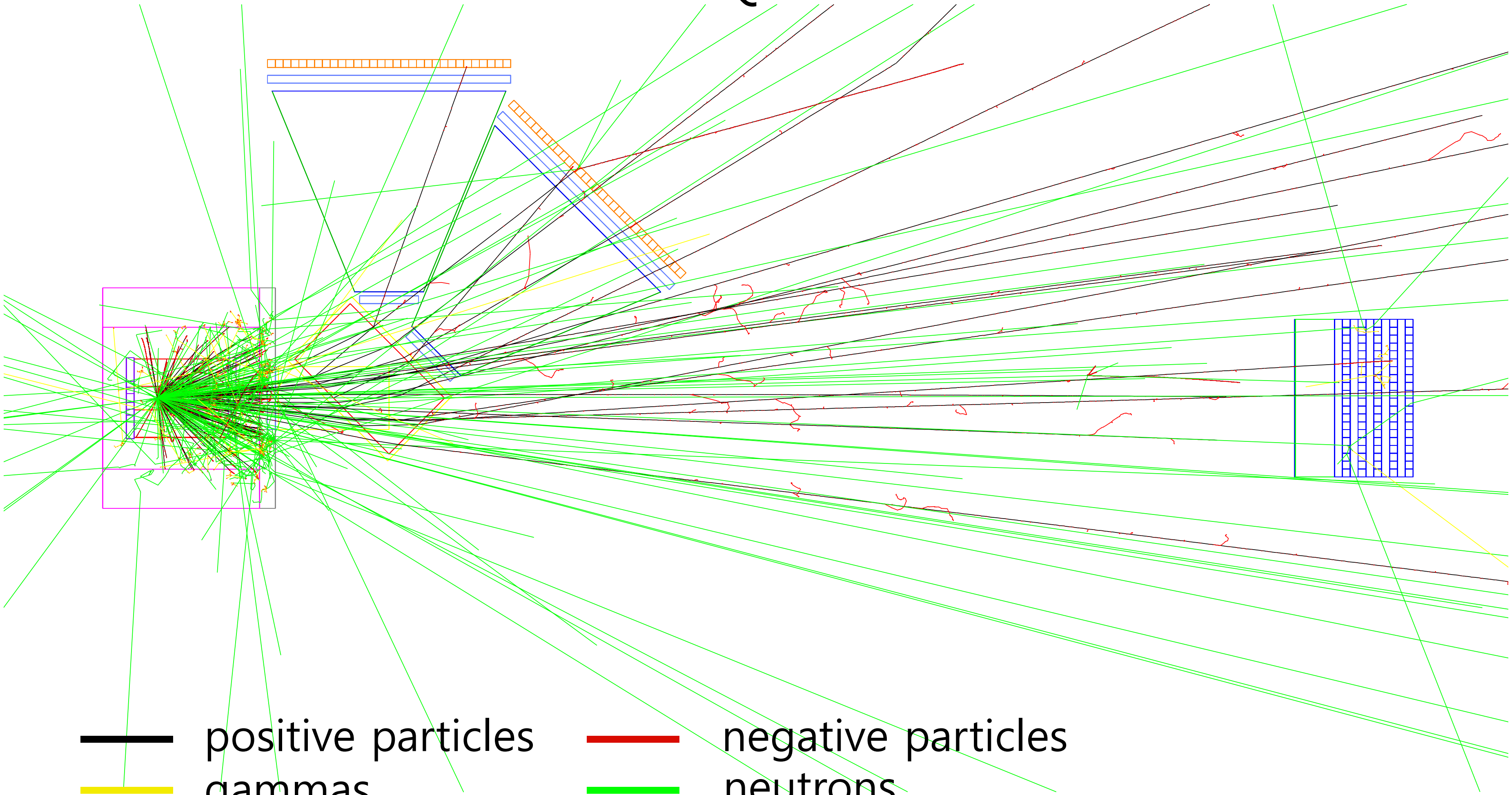
Dipole Spectrometer

- Multiparticle tracking capability of isotopes for p, He, and heavier elements.
- Tracking chambers: ≥ 3 stations of drift chambers (+pad readout possible) for each arm
- ToF: Conventional plastic scintillator detector or multigap RPC technology
  - σ_t < 100 ps, essential for $\Delta p/p < 10^{-3}$ @ $\beta=0.5$



Event Simulation

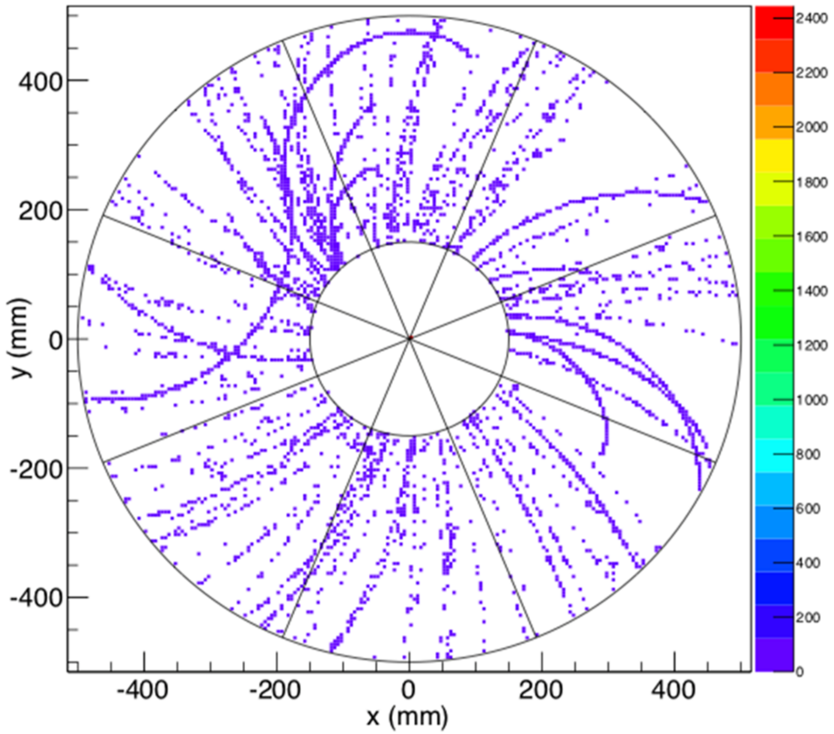
IQMD for Au+Au at 250A MeV



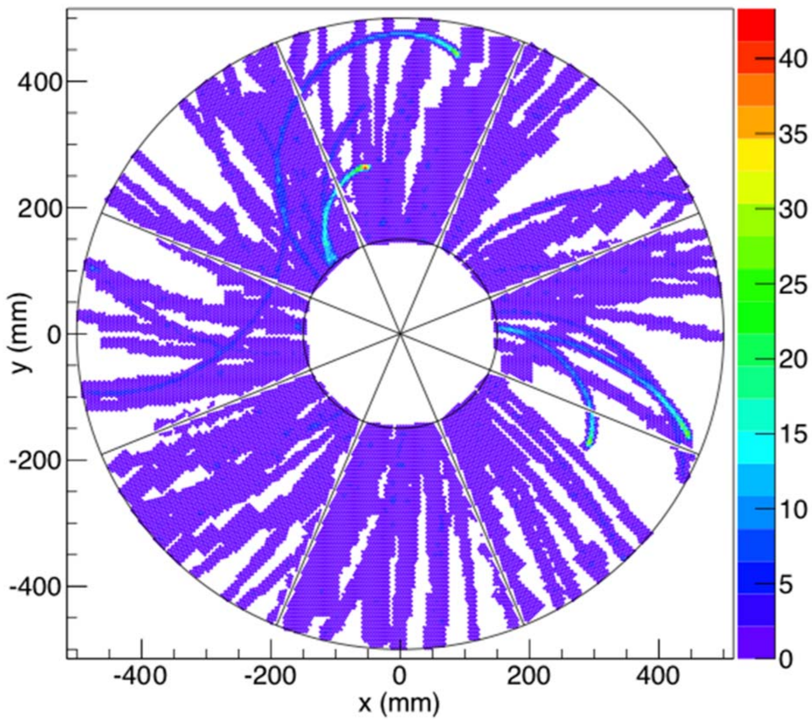
Event Simulation

Genie Jhang (Korea Univ.)

Generated hit information in TPC



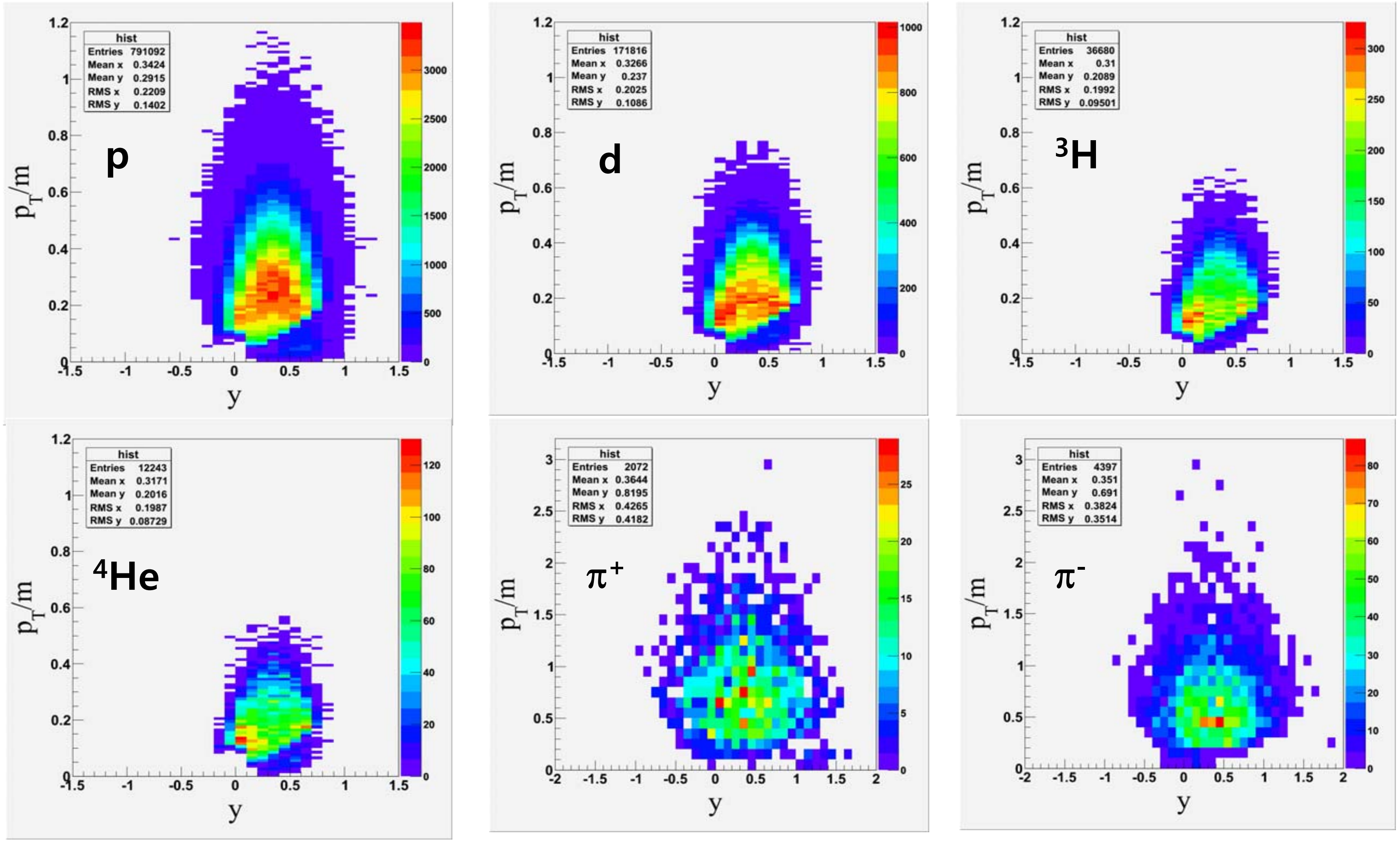
After digitization including the detailed detector response



Acceptance of $LAMPS_H$

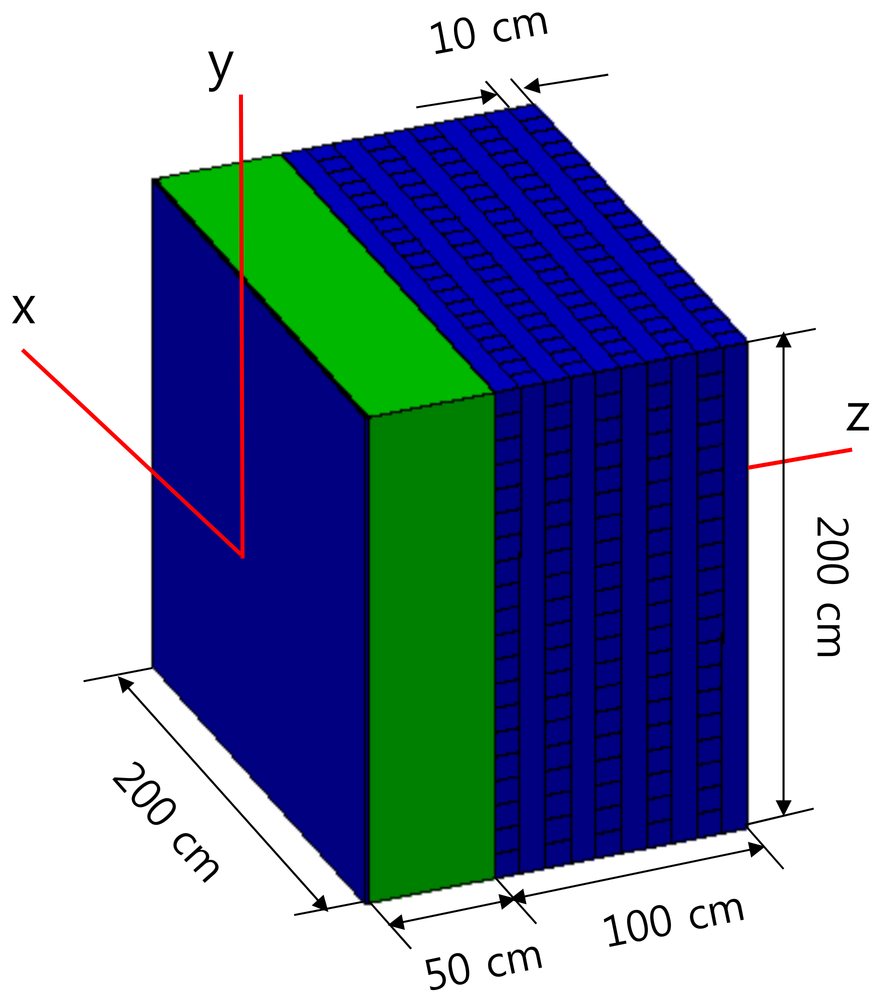
Au+Au @ 250A MeV

Genie Jhang (Korea Univ.)



Neutron-Detector Array

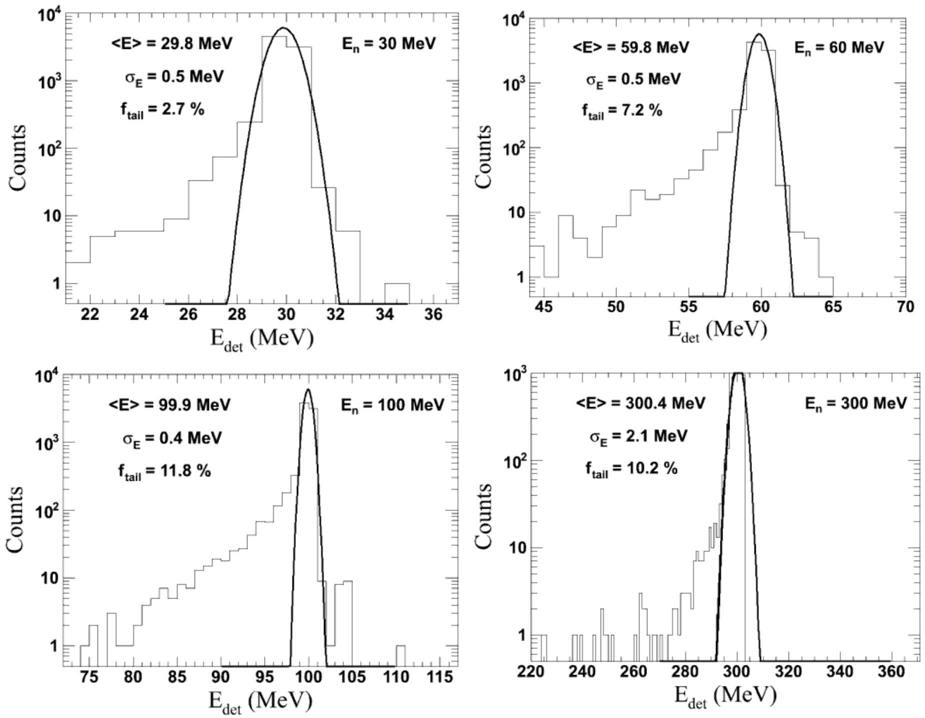
- Neutrons are important for the nuclear symmetry energy
- Covering wide neutron-energy range is also important
- Large veto and neutron detector array are composed of scintillator bars



Simulation of Neutron Detector

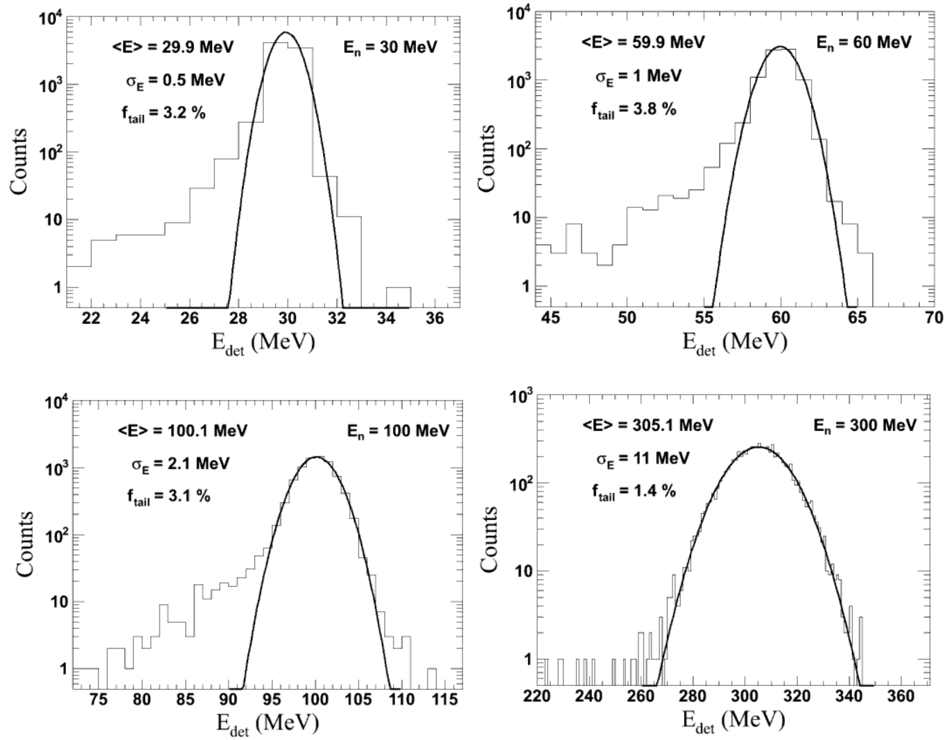
Assuming Perfect Time Resolution

Eunah Joo & Hyunha Shim (Korea Univ.)



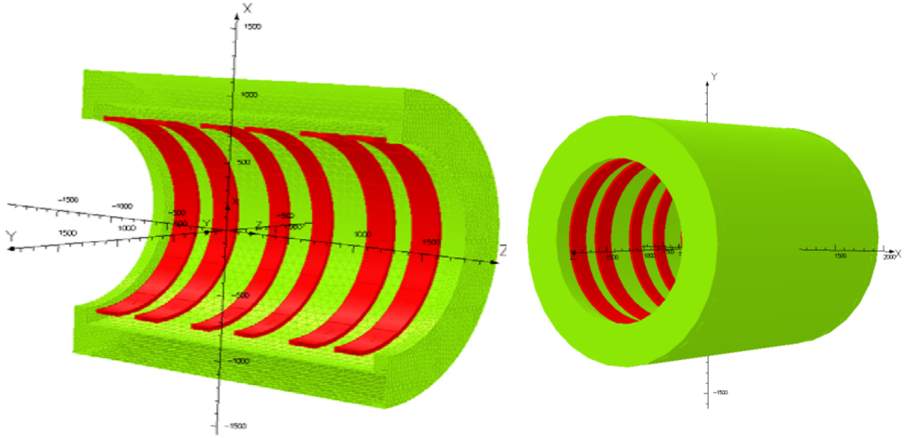
E_n estimated by ToF

Assuming σ_t = 1.0 ns

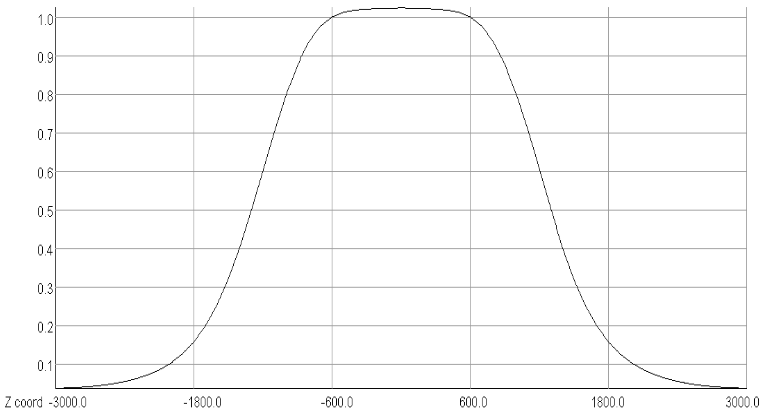


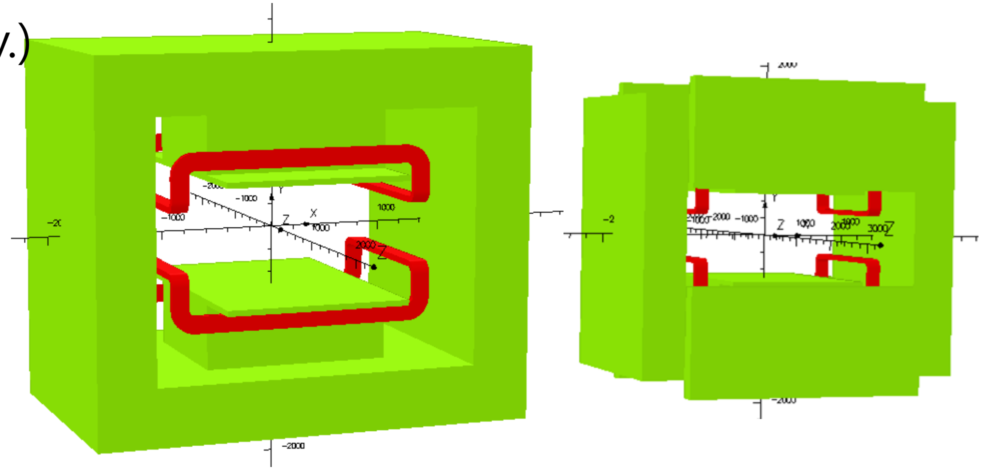
Magnets

S. Hwang & J. K. Ahn (Pusan Nat. Univ.)

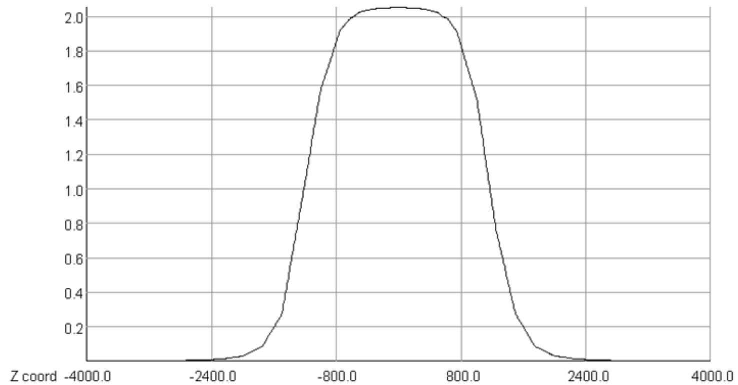


Solenoid
Size (r, z) : (50 cm, 200 cm)
Maximum B_z: about 1.0 T





H-type dipole
Pole size: (x, z)=(150 cm, 100 cm)
Maximum B_y: ~1.5 T (~4 T for SC option)
Gradient: 1.0 T·m < $\int B_y \cdot dz$ < 2.0 T·m



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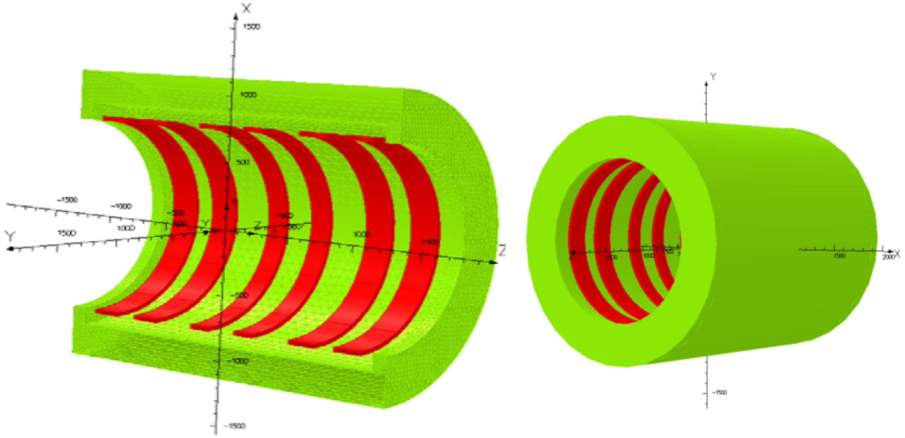

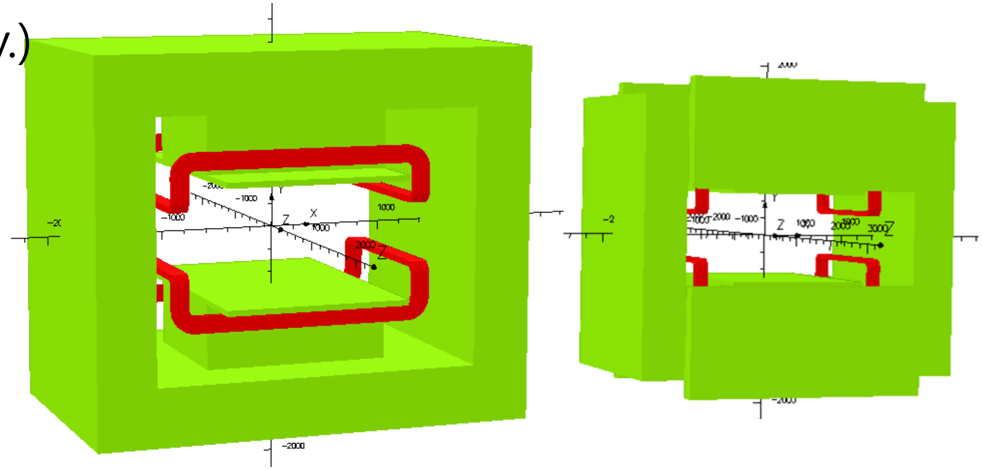

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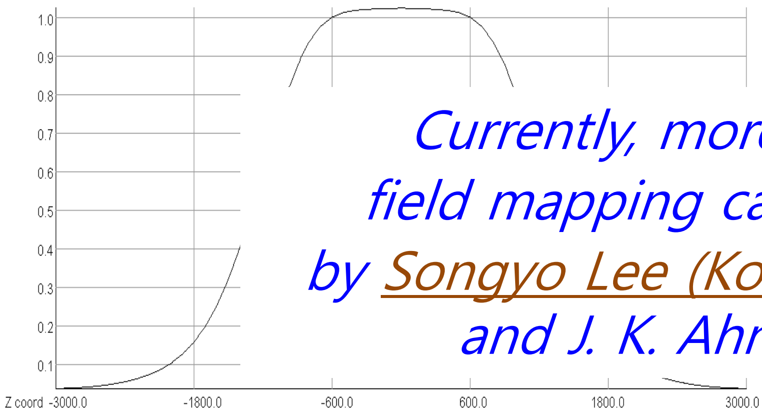

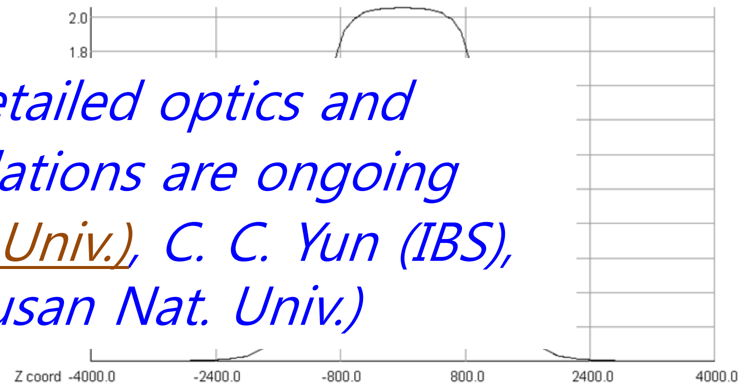

Currently, more detailed optics and field mapping calculations are ongoing by Songyo Lee (Korea Univ.), C. C. Yun (IBS), and J. K. Ahn (Pusan Nat. Univ.)

Summary

1. Korea Rare Isotope Accelerator
   - Plan to deliver more exotic high-current RI beams by combining ISOL and IFF technologies
2. Large-Acceptance Multipurpose Spectrometer (LAMPS)
   - Low energy setup for day-1 experiment
   - Full setup for high-energy experiments: combination of solenoid and dipole spectrometers
3. Symmetry Energy in EoS
   - Crucial to understand the neutron-rich matter & several astrophysical objects
   - Long-standing unsolved problem in nuclear physics
   - LAMPS would like to contribute to this effort.