2nd CENUM Workshop
Online, July 3-4, 2020

Heavy-Ion Collision Experiments from LHC to RAON

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(Korea University)

Center for Extreme Nuclear Matters

Large Hadron Collider (LHC) @ CERN

- Physics Objectives
  - Properties of Quark-Gluon Plasma (QGP)
  - Quarkonium production (J/ψ, Y families)
  - Photon production (Reference to medium modification, nPDF)
  - UPC (Pomeron interaction, nPDF, etc.)
- CMS Experiments
  - Endcap RPC construction from 1998: Upgrade is ongoing.
  - 6 Ph.D's awarded
- Current manpower
  - (박사급) 이경세, 박재범, 한세영
  - (박사과정) 이기수, 고연주, 이수환, 김범곤 (국방의 의무 수행 후 복귀 예정)
  - 토요일 발표 참조

CMS detector

Design to cope with
$\mathcal{L}_{pp} = (1\sim2) \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Weight: 12,500 tons
Diameter: 15 m
Length: 22 m

Superconducting Coil (3.8 T)

CALORIMETERS
ECAL
76k scintillating $PbWO_4$ crystals

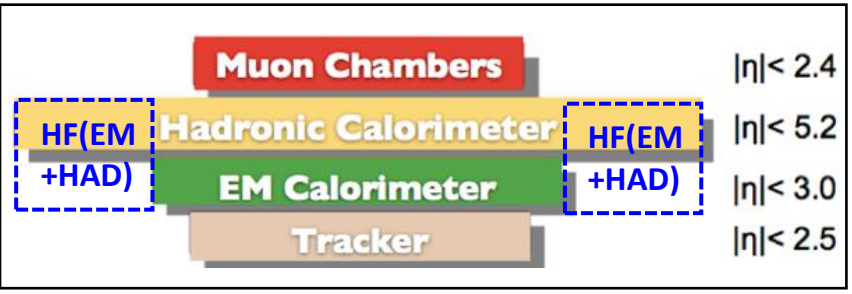
HCAL
Plastic scintillator/
Brass sandwich

Steel YOKE

BSC
MB trigger

HF
MB trigger
Centrality in HI

TRACKER
Pixels (66M Ch.)
Silicon Microstrips (9.6M Ch.)
220 m^2 of silicon sensors

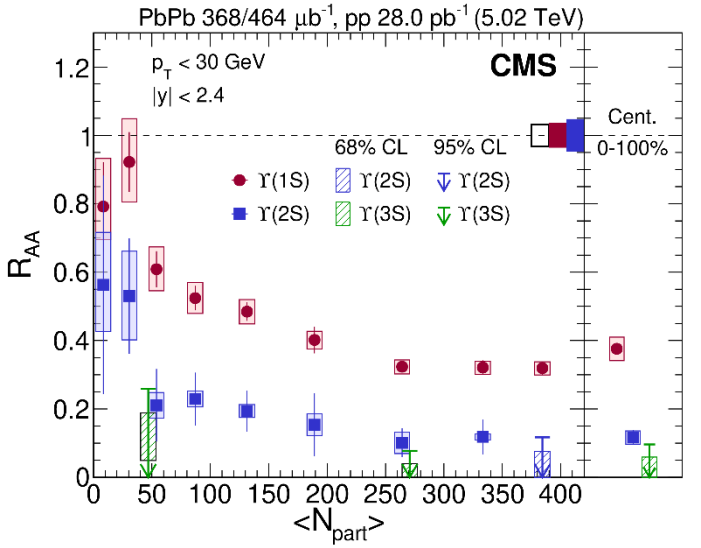


MUON ENDCAPS
Cathode Strip Chambers
Resistive Plate Chambers

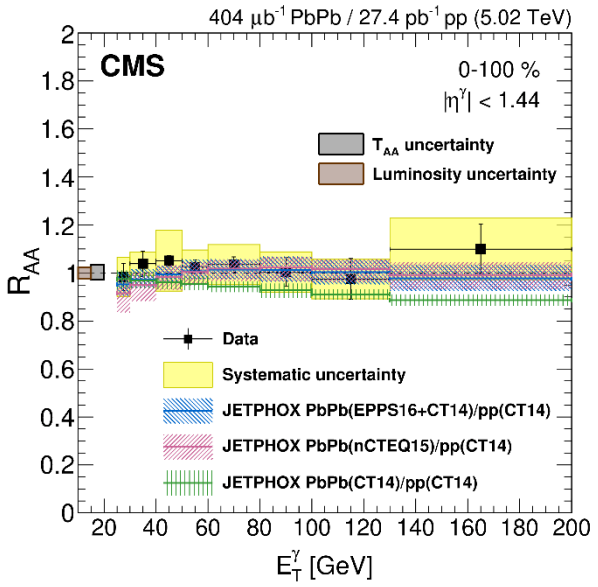
MUON BARREL
Drift Tube Chambers
Resistive Plate Chambers

Recent Analysis Highlights

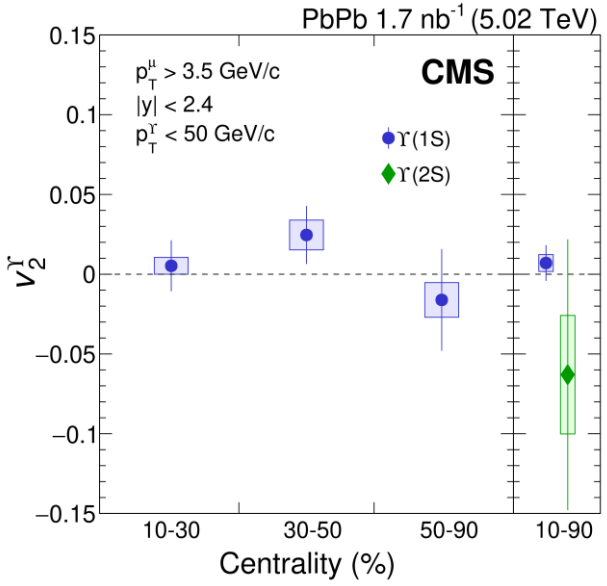
PLB 790, 270 (2019)

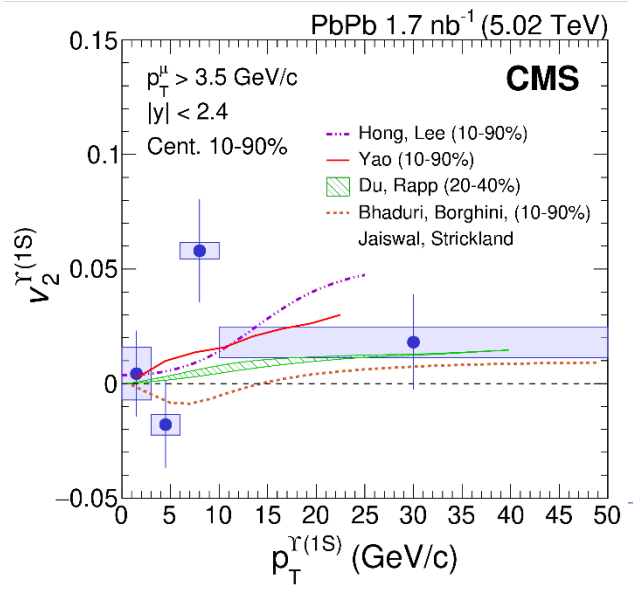


HIN-18-016 (Accepted by JHEP)



HIN-19-002 (Submitted to PLB)



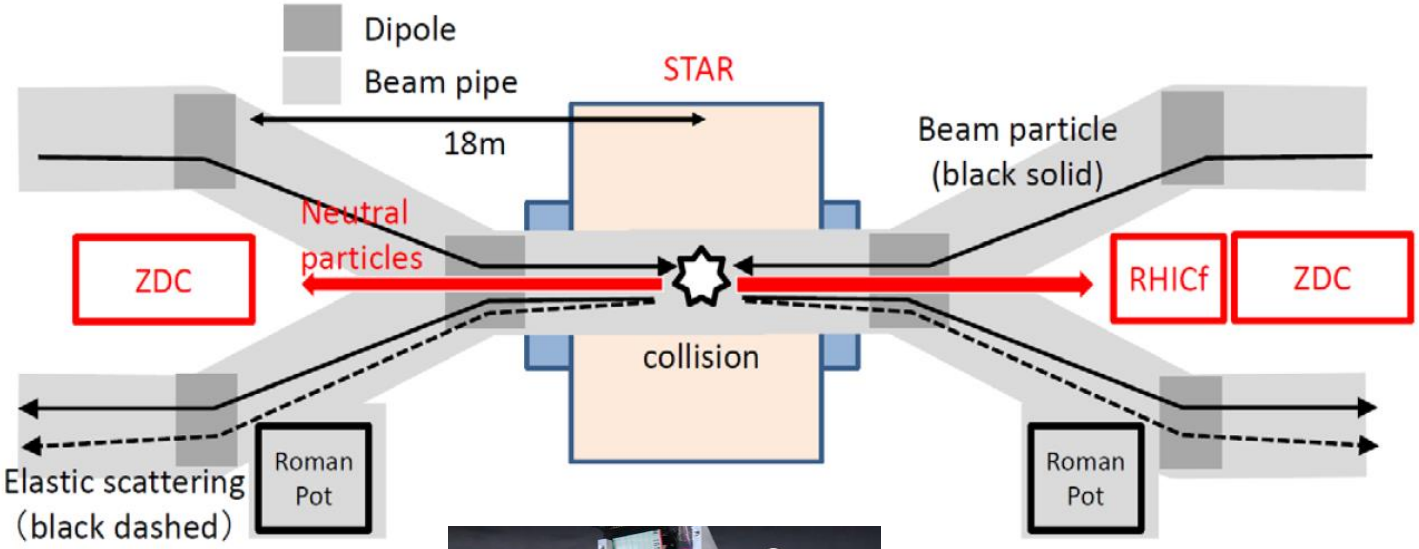


박재범 토요일 14:30
고연주 토요일 15:00

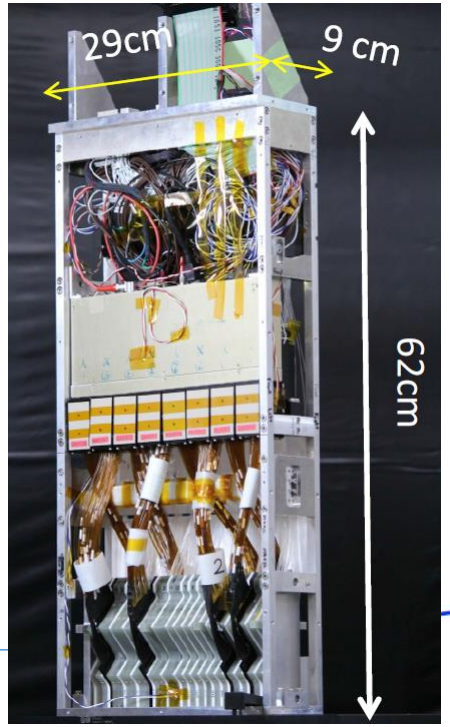
Relativistic Heavy Ion Collider (RHIC) @ BNL

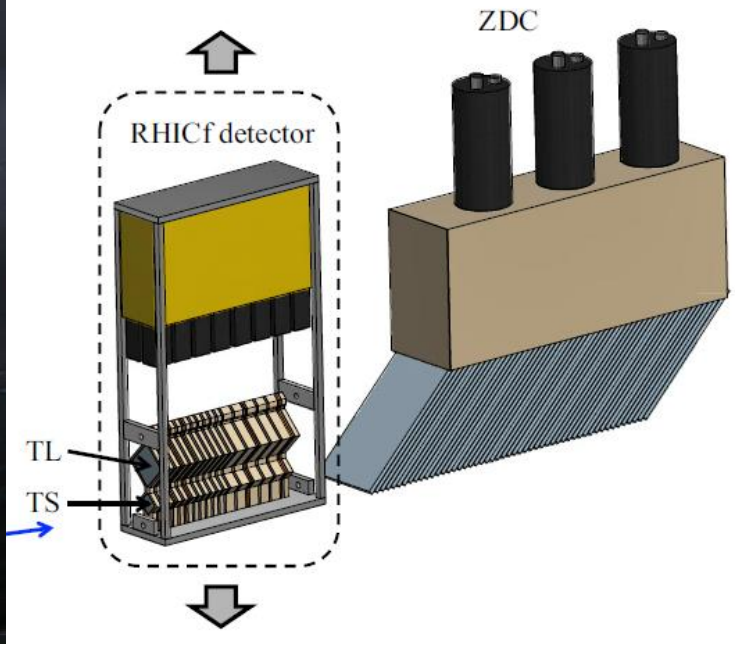
- Physics Objectives
  - Properties of Quark-Gluon Plasma (QGP)
  - Flow in small systems
  - Spin structure of the proton
  - RHICf: Spin asymmetry in very forward direction (possible diffractive process)
- PHENIX Experiments
  - Forward RPC construction in 2010
  - 5 Ph.D's awarded
- Current manpower
  - (박사) 한세영 (Flow)
  - (박사과정) 유재희, Benard Mulilo (PHENIX), 김민호 (RHICf)
  - 토요일 발표 참조

RHICf Setup



- Two position-sensitive sampling calorimeters
  - TS (small tower): 20mm x 20mm
  - TL (large tower): 40mm x 40mm
  - Tungsten absorber (44 X_0, 1.6 λ_{int})
  - 16 GSO sampling layers
  - 4 XY pairs of GSO-bar position layers (MAPMT readout)





김민호 토요일 15:45

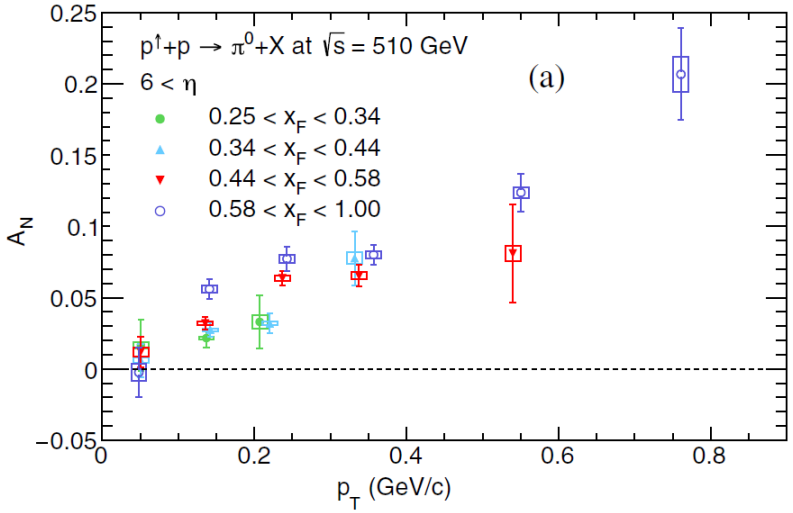
Large Spin Asymmetry in Forward Region

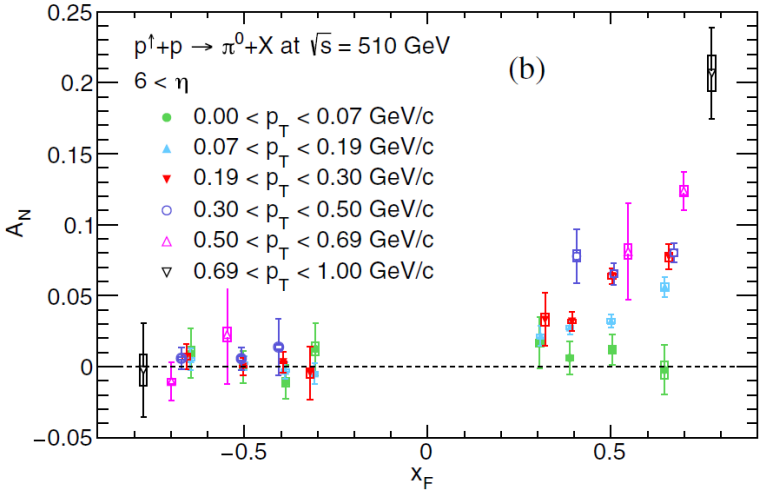
PHYSICAL REVIEW LETTERS **124,** 252501 (2020)

Transverse Single-Spin Asymmetry for Very Forward Neutral Pion Production in Polarized $p+p$ Collisions at $\sqrt{s}=510$ GeV

M. H. Kim,[1,2] O. Adriani,[3,4] E. Berti,[3,4] L. Bonechi,[4] R. D'Alessandro,[3,4] Y. Goto,[2,5] B. Hong,[1] Y. Itow,[6,7] K. Kasahara,[8] J. H. Lee,[9] T. Ljubicic,[9] Y. Makino,[6] H. Menjo,[10] I. Nakagawa,[2,5] A. Ogawa,[9] J. S. Park,[2,11] T. Sako,[12] N. Sakurai,[13] K. Sato,[6] R. Seidl,[2,5] K. Tanida,[14] S. Torii,[15] A. Tricomi,[16,17] M. Ueno,[6] and Q. D. Zhou[6,*]

(Received 8 March 2020; accepted 19 May 2020; published 22 June 2020)



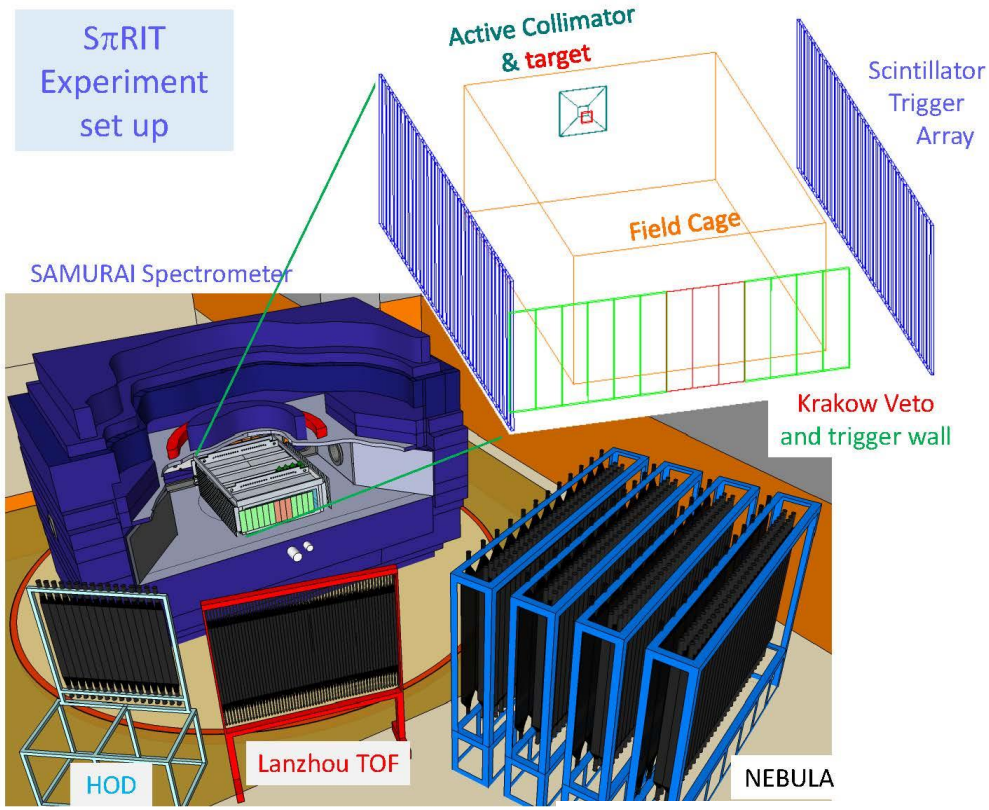


RIB: Radioactive Ion Beam Facility (RIBF) @ RIKEN
NSCL @ MSU

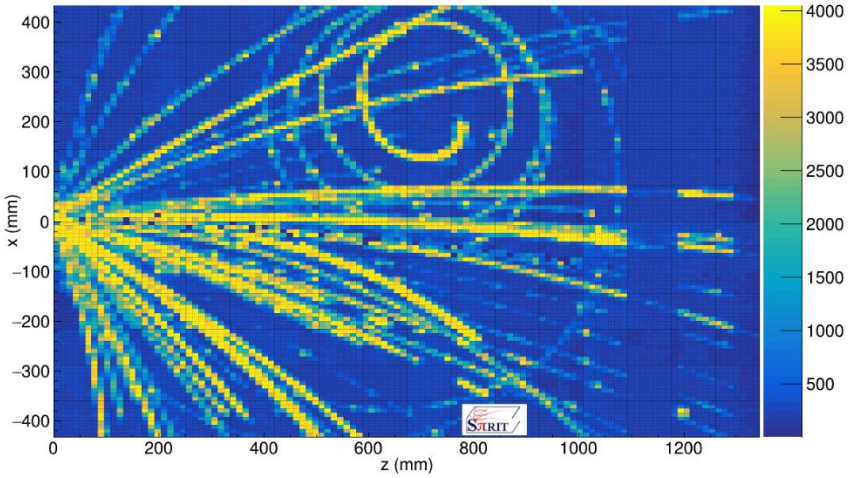
- Physics Objectives
  - Equation of State (EOS) and symmetry energy
  - Nuclear structure (in-beam gamma-ray experiments)
- SπRIT and nuclear structure Experiments
  - Tracking software for TPC
  - Production of mirror nuclei (^{3}H/^{3}He, n/p)
  - Neutron detector (LANA, Veto wall, Electronics)
  - 2 Ph.D's awarded
- Current manpower
  - (박사) 이종원
  - (박사과정) 이정우 (SπRIT), 박정혁 (NSCL), 이재환, 장영섭, 김지석 (gamma-ray detectors)
  - 금요일 발표 참조

SπRIT @ RIKEN

SπRIT Experiment set up



$^{132}Sn + ^{124}Sn$ @ 270 A MeV
(Top view)



Nuclear Inst. and Methods in Physics Research, A 965 (2020) 163840

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

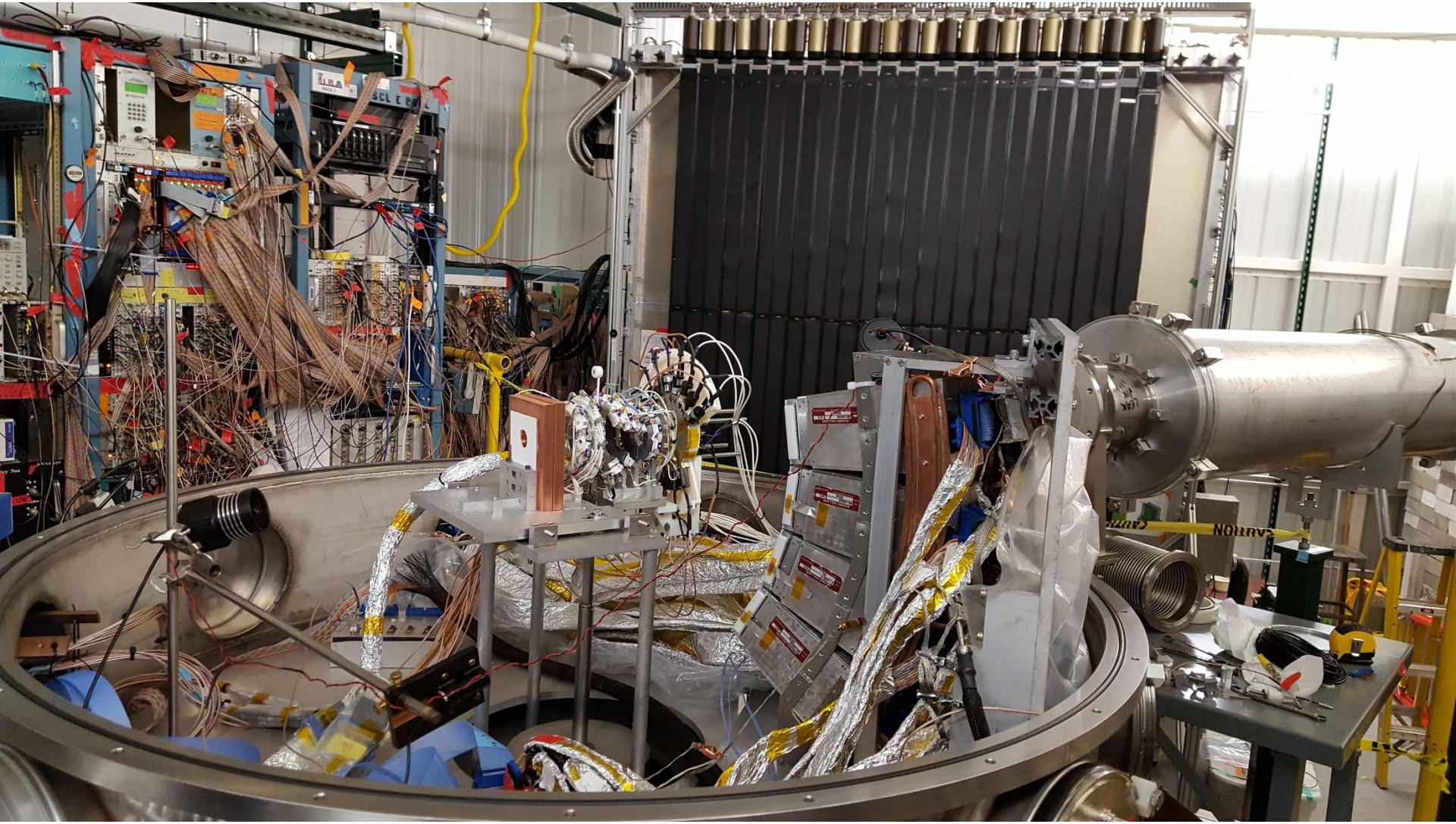
journal homepage: www.elsevier.com/locate/nima

Technical Notes

Charged particle track reconstruction with SπRIT Time Projection Chamber

J.W. Lee [a,*], G. Jhang [b,*], G. Cerizza [b], J. Barney [b,c], J. Estee [b,c], T. Isobe [d], M. Kaneko [e,d], M. Kurata-Nishimura [d], W.G. Lynch [b,c], T. Murakami [e], C.Y. Tsang [b,c], M.B. Tsang [b,c], R. Wang [b], B. Hong [a], A.B. McIntosh [f], H. Sakurai [d], C. Santamaria [b], R. Shane [b], S. Tangwancharoen [b,c], S.J. Yennello [f], Y. Zhang [g], For the SπRIT Collaboration

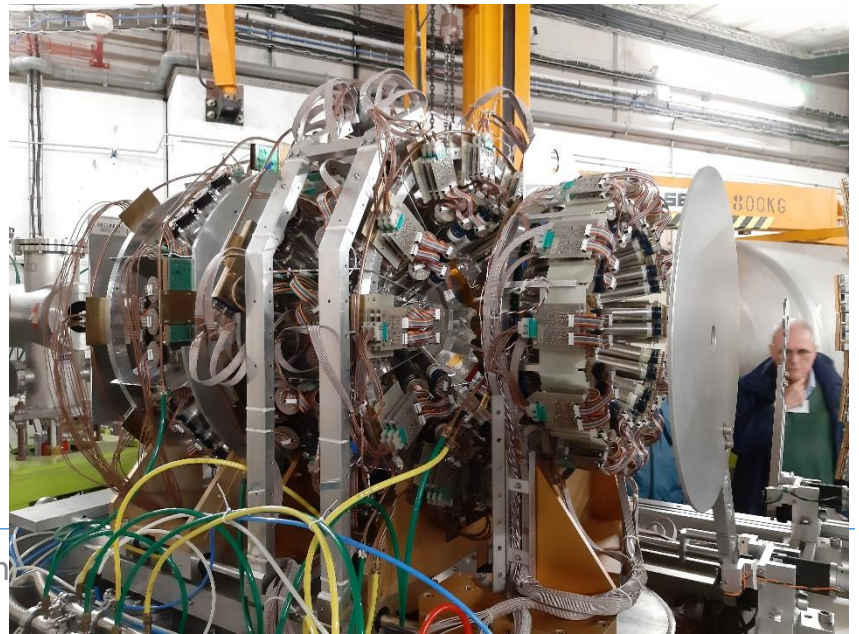
HIRA & LANA @ NSCL



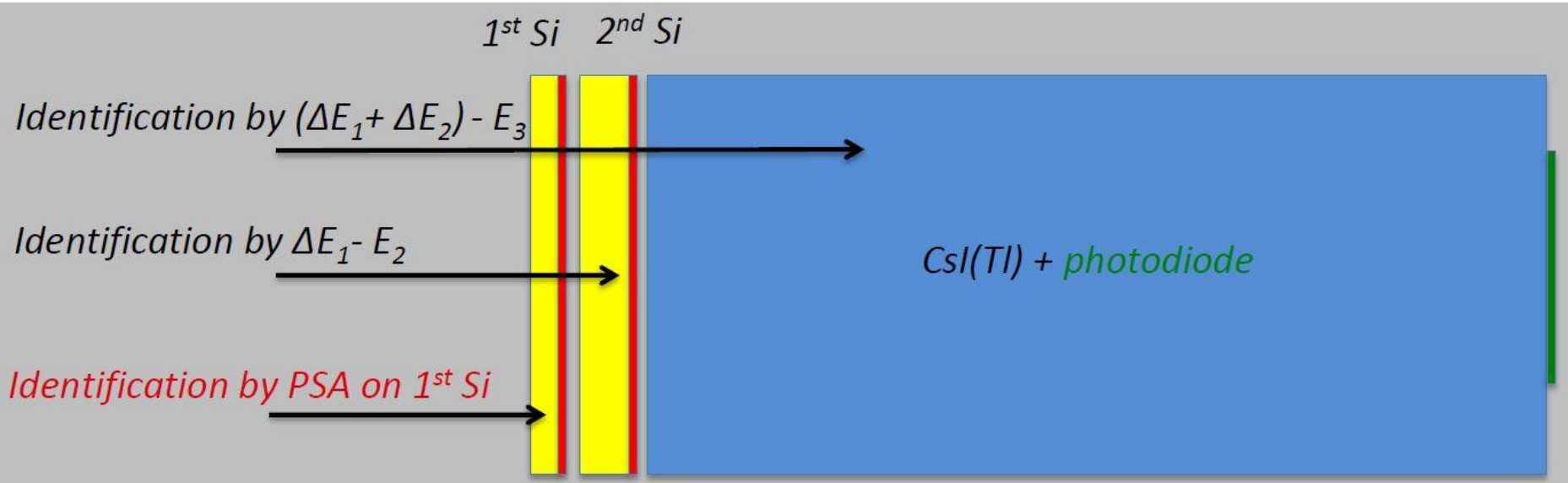
RIB: SPIRAL @ GANIL

- Physics Objectives
  - Equation of State (EOS) and symmetry energy
  - Nuclear structure
- FAZIA Experiments
  - Development of new Si sensors
  - Development of FEB
  - Joined the Collaboration in 2018
- Current manpower
  - (박사) 윤필 (다음 Workshop에서 발표 예정)
  - (박사과정) 남선호 (Flow)
  - 금요일 발표 참조

FAZIA Setup @ GANIL



FAZIA Si-CsI Telescope



1st element: reverse mount 300 µm thick, nTD Silicon of doping uniformity apt to PSA

2nd element: reverse mount 500 µm thick, nTD Silicon for redundant PSA

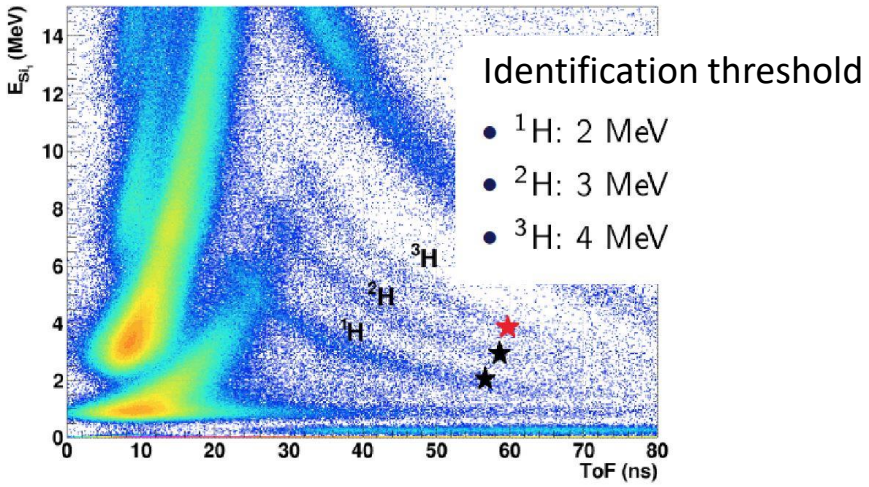
3rd element: 10 cm long CsI(Tl) crystal, coupled to Si-photodiode

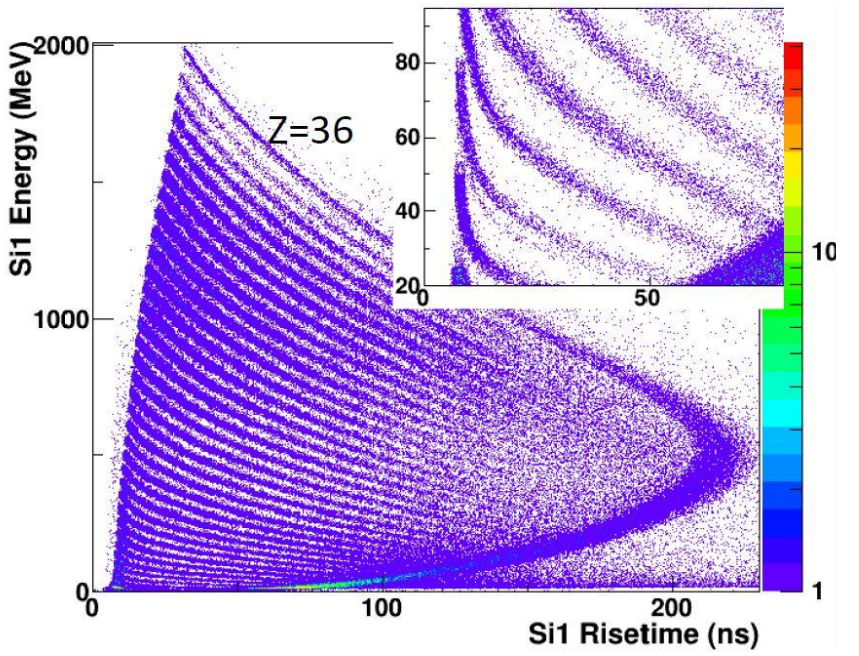
First and second Silicon detectors are cut out of a <100> crystal along a properly selected direction in order to avoid channelling.

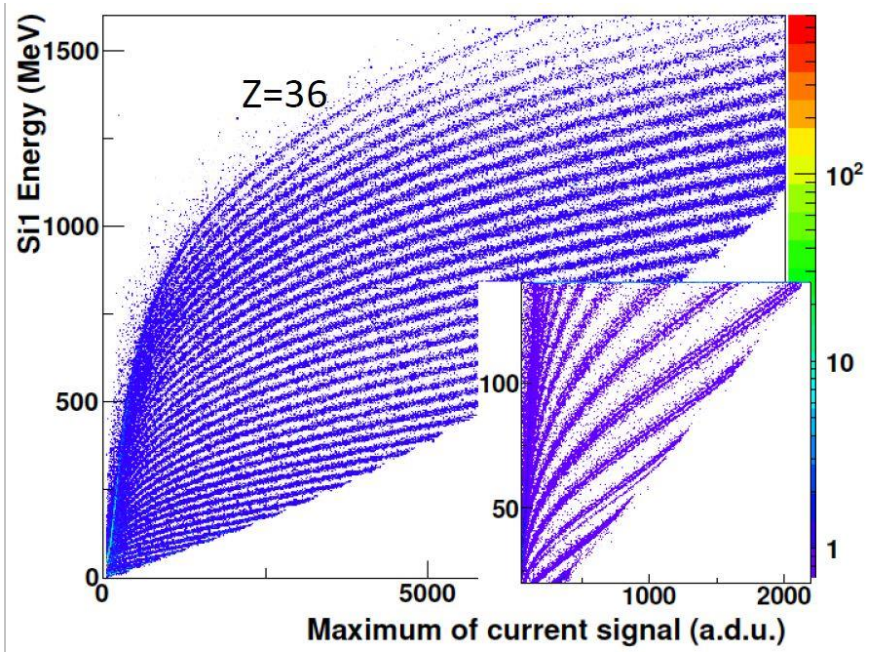
Total thickness variation of both Silicon detectors over the active area ≈ 2-3 µm

FAZIA Si-CsI Telescope

Expected performance





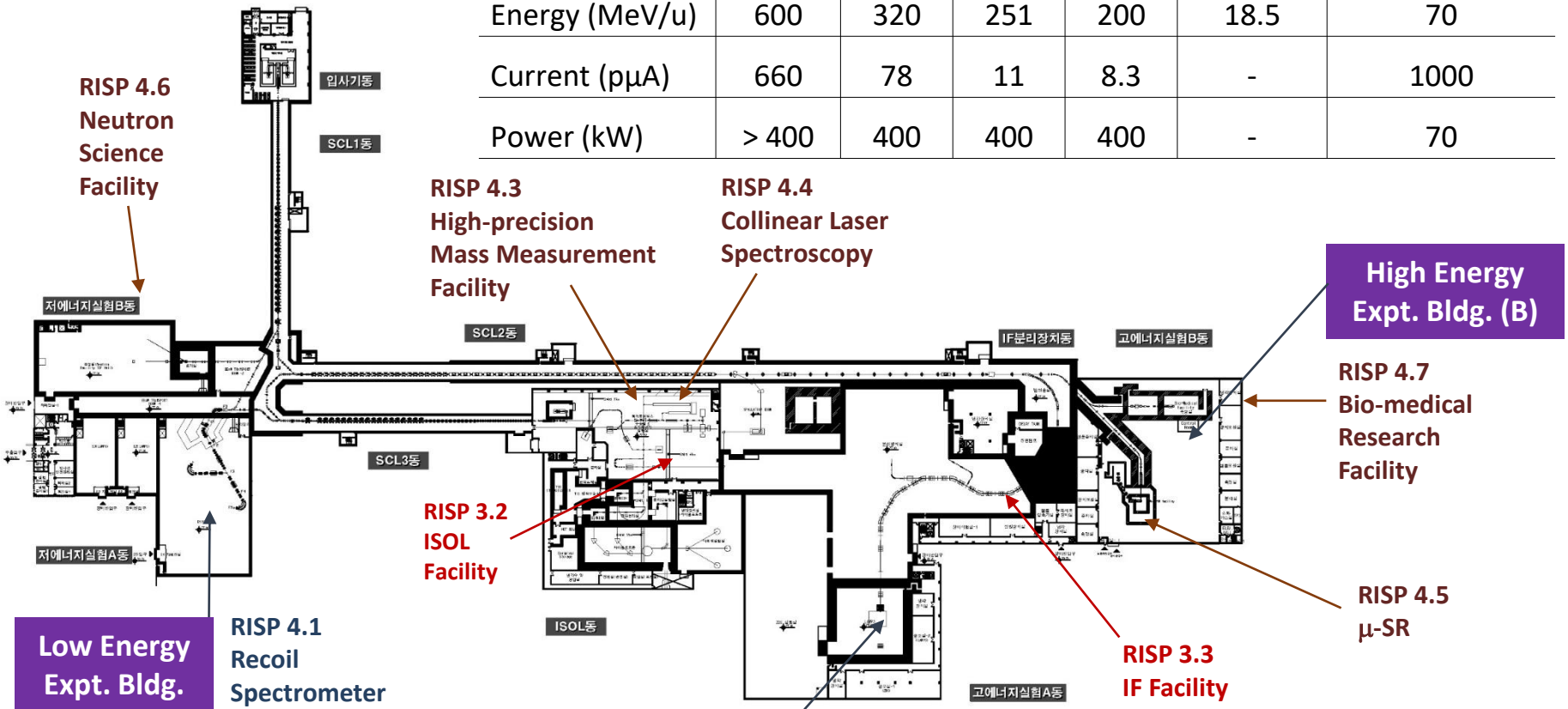


RIB: RAON @ IBS

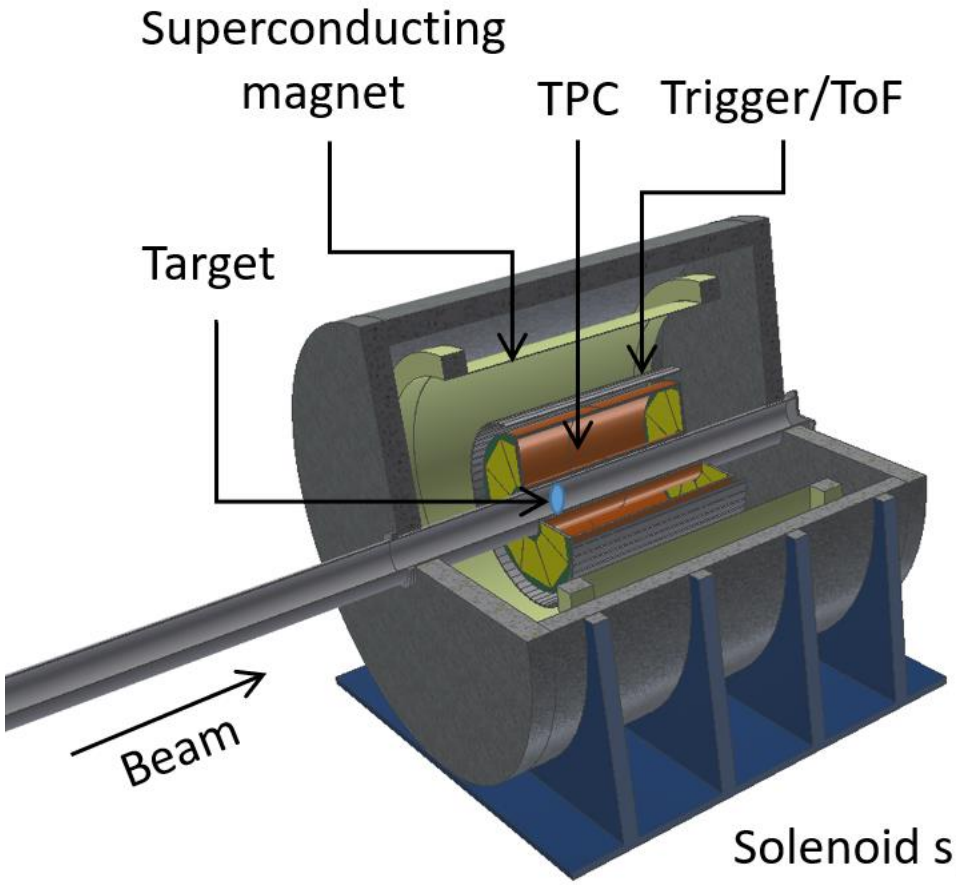
- Physics Objectives
  - Equation of State (EOS) and symmetry energy
  - Nuclear structure
- LAMPS Experiments
  - High-energy setup: Forward neutron array
  - Low-energy setup: $LaBr_3$(Ce) gamma detector
  - Si detector (FAZIA 참조)
  - AT-TPC & SC magnet in collaboration with Prof. J.K. Ahn, Y. Kim
- Current manpower
  - (박사) 이종원 (Neutron array), 윤필 (Si), 허장용 (Beam tests at KOMAC & HIMAC)
  - (박사과정)
  - 금요일 발표 참조

Layout of RAON

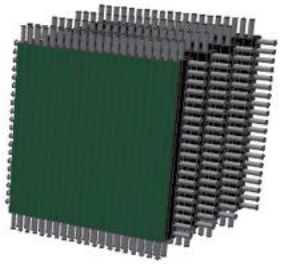
	Driver Linac				Post Acc.	Cyclotron
Particle	H^{+}	O^{+8}	Xe^{+54}	U^{+79}	RI beam	proton
Energy (MeV/u)	600	320	251	200	18.5	70
Current (pμA)	660	78	11	8.3	-	1000
Power (kW)	> 400	400	400	400	-	70



High-Energy LAMPS



Solenoid spectrometer



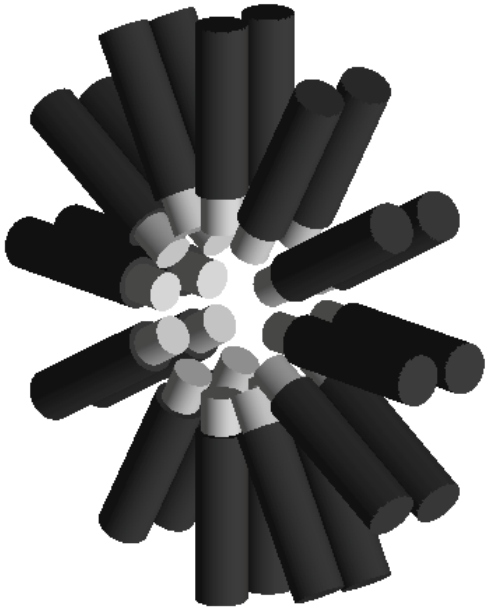
Neutron detector array

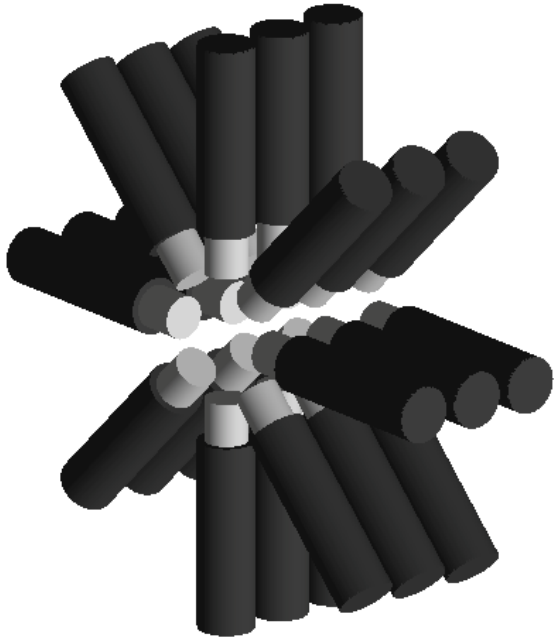
Starting version of LAMPS setup

LAMPS Neutron Array

$LaBr_3(Ce)$ gamma detector

- $LaBr_3(Ce)$ gamma detector system
  - Total 24 modules with fast timing PMTs
    (R_t< 200 ps, R_E< 3.5%, ε~6.8% at 664 keV)
  - Plan to build 12 modules by 2020





History of the Universe

http://www.particleadventure.org/history-universe.html