SPiRIT project for the study of density dependent symmetry energy of high dense matter with Heavy RI collisions at RIBF

Tadaaki Isobe (RIKEN)
for the SPiRIT collaboration

SPiRIT Collaboration (2009~)

SAMURAI Pion Reconstruction and Ion-Tracker

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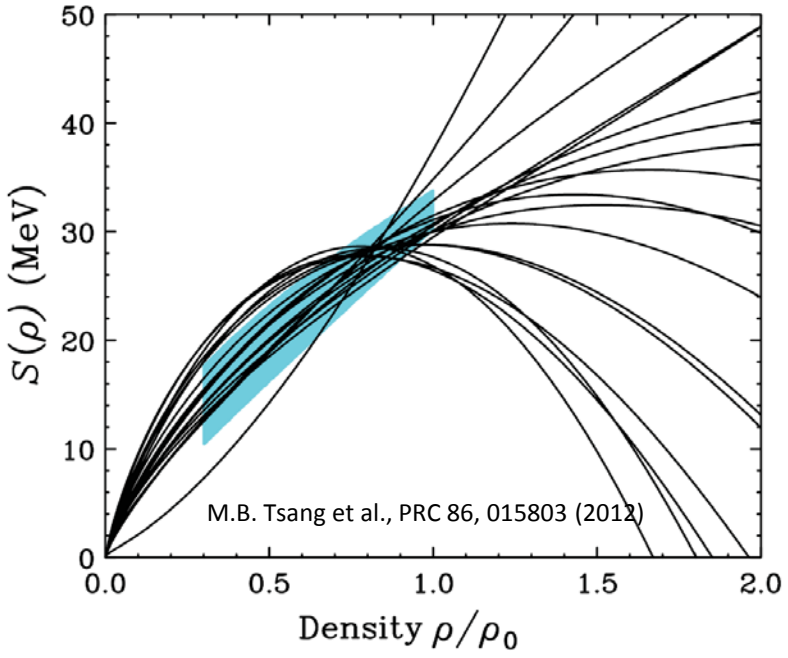
GSI: T. Aumann

Contents

- Physics motivation
- Setup and readiness
  - Simulation study on n/p measurement
- RI beam production at RIBF

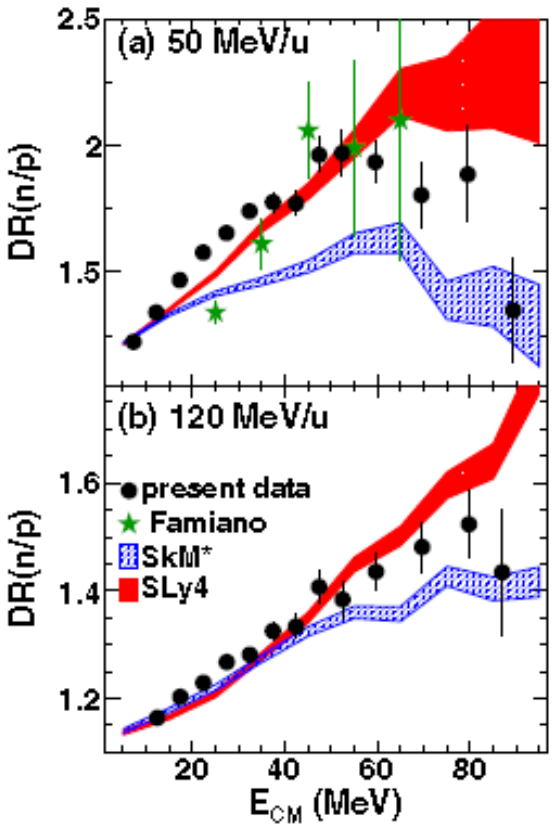
Physics motivation:
Constrain the density dependent symmetry energy

- Well studied for $\rho \sim \rho_0$ region and below.
  - Based on the study of nuclear structure.
- Towards high dense region.
  - Essential to understand the extreme matter such as NS.
  - Up to $\rho \sim 2\rho_0$ with HI collision at RIBF energy (E/A=300MeV).
- Study with asymmetric dense matter realized with heavy RI collision.
  - Same-Z, different-N.
  - Useful to control coulomb effect.



What we are going to measure.

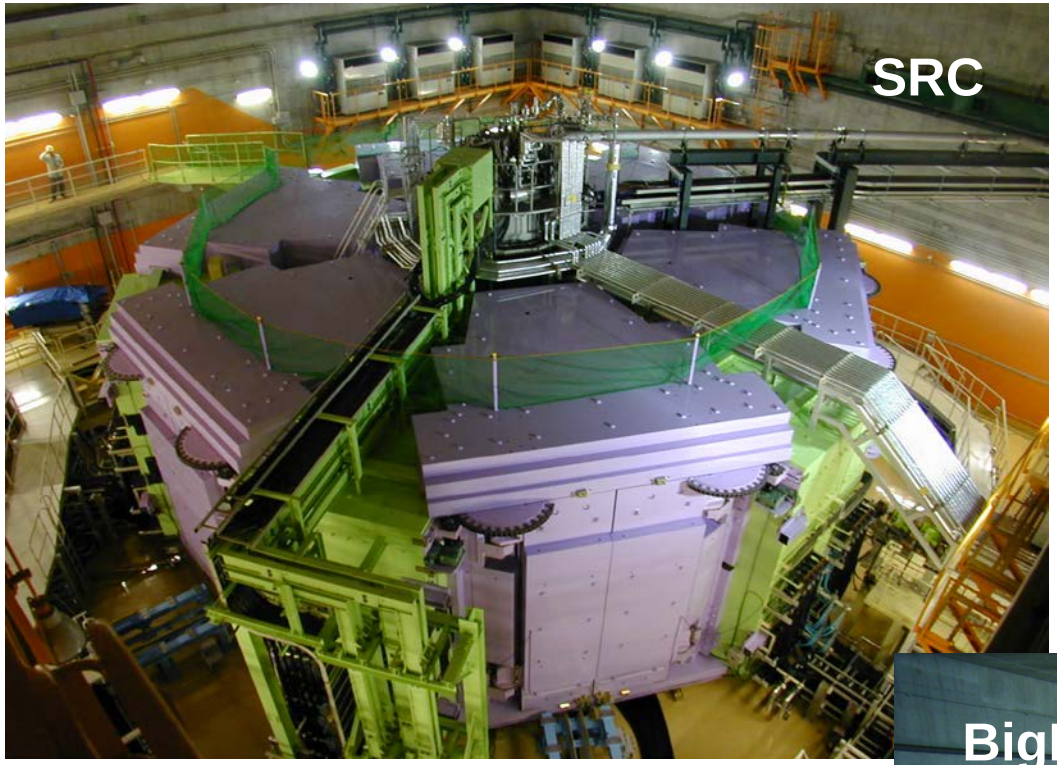
- To study the symmetry energy of high dense region with HIC, we need to understand the HIC dynamics
- Need multiple observables to constrain theoretical inputs to the transport theoretical calculation.



- Charged particles
  - Charged pions, protons, and light ions.
  - Identified with dE/dX – track rigidity.
  - Momentum can be reconstructed.
- Neutrons
- Event characterization
  - Impact parameter, reaction plane →flow

- Charged pion ratio, p/n ratio, ^{3}He/t ratio
- Symmetry energy
- Both the **momentum** and **density** dependencies of the isovector potentials ← p/n ratio, different energy.

RI=Radioactive Isotope B=Beam F=Factory
Mass production of radioactive isotopes as secondary beams



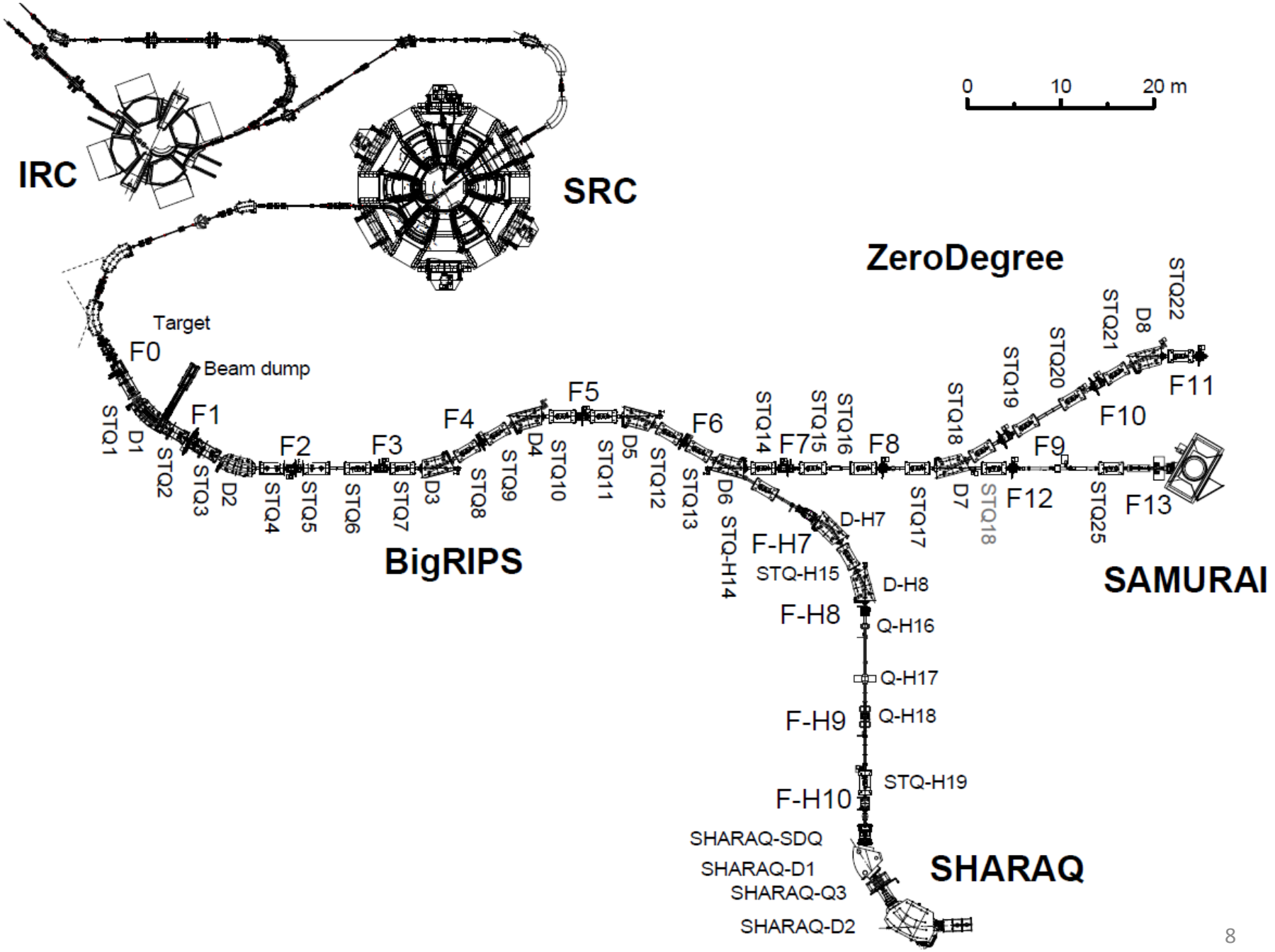
World's First and Strongest
K2600MeV
Superconducting Ring Cyclotron

400 MeV/u Light-ion beam
345 MeV/u Uranium beam

Available primary beam:
^{18}O, ^{48}Ca, ^{70}Zn, ^{124}Xe and ^{238}U

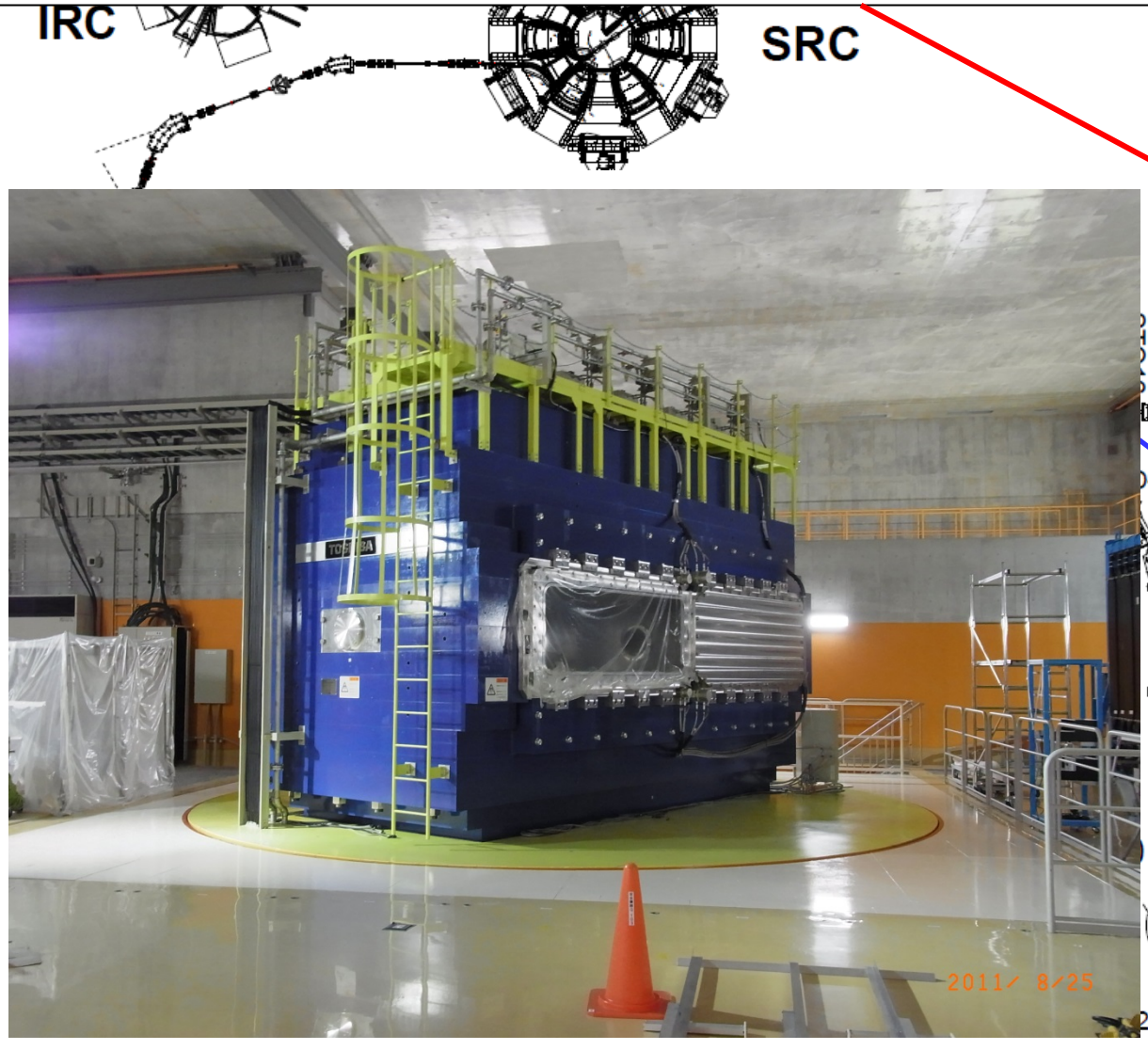
World's Largest Acceptance
9 Tm
Superconducting RI beam Separator

~250-300 MeV/nucleon RIB


IRC
SRC
0
10
20 m
ZeroDegree
Target
F0
Beam dump
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12
F13
STQ1
D1
STQ2
STQ3
D2
STQ4
STQ5
STQ6
STQ7
D3
STQ8
STQ9
D4
STQ10
STQ11
D5
STQ12
STQ13
D6
STQ-H14
STQ14
STQ15
STQ16
STQ17
D7
STQ18
STQ19
STQ20
STQ21
D8
STQ22
STQ25
BigRIPS
SAMURAI
D-H7
F-H7
STQ-H15
D-H8
F-H8
Q-H16
Q-H17
F-H9
Q-H18
STQ-H19
F-H10
SHARAQ-SDQ
SHARAQ-D1
SHARAQ-Q3
SHARAQ-D2
SHARAQ

SAMURAI Spectrometer

Superconducting Analyzer for Multi particles from Radio Isotope Beams



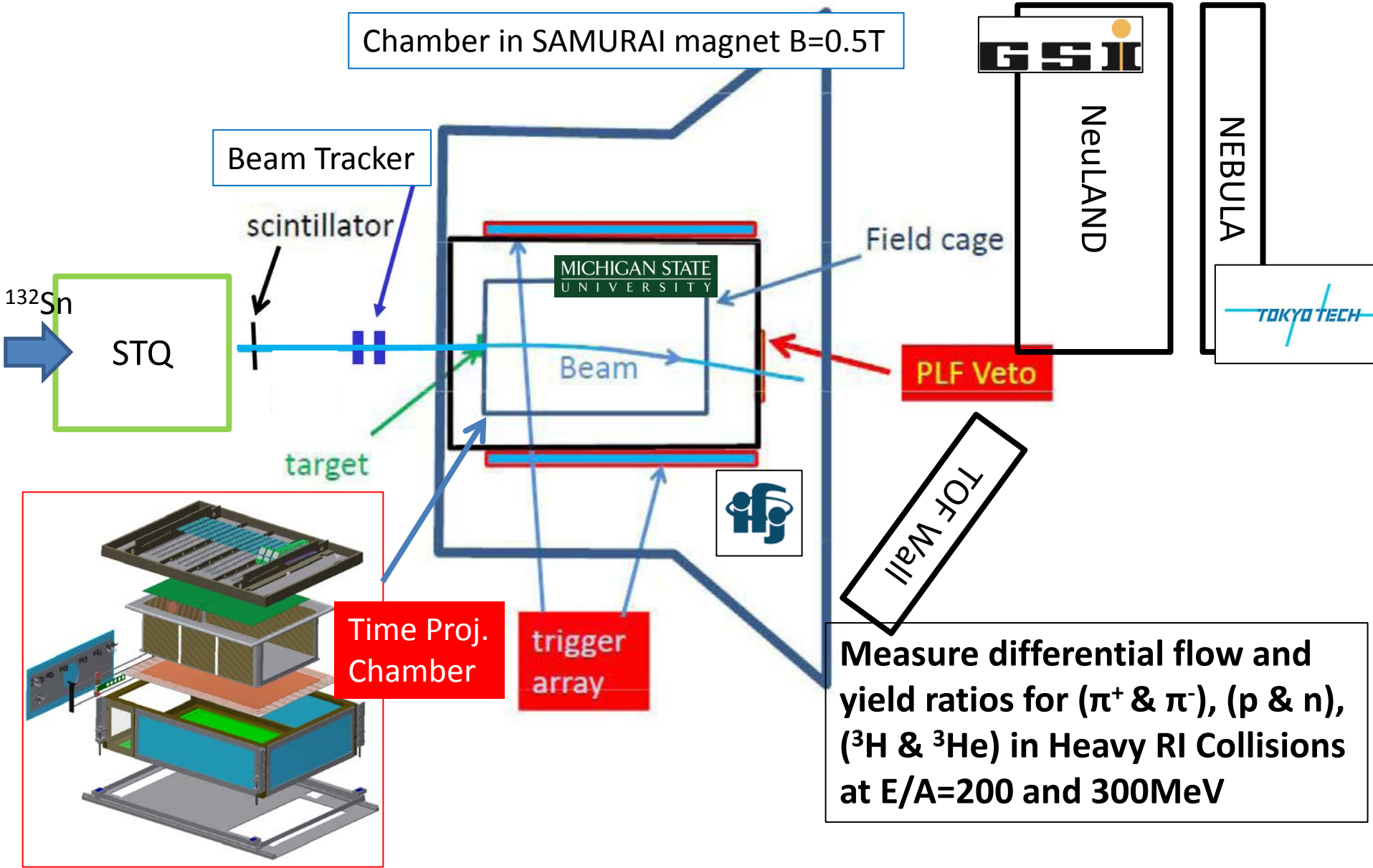
Field integral =7Tm

High-resolution beam line

SHARAQ by U. of Tokyo

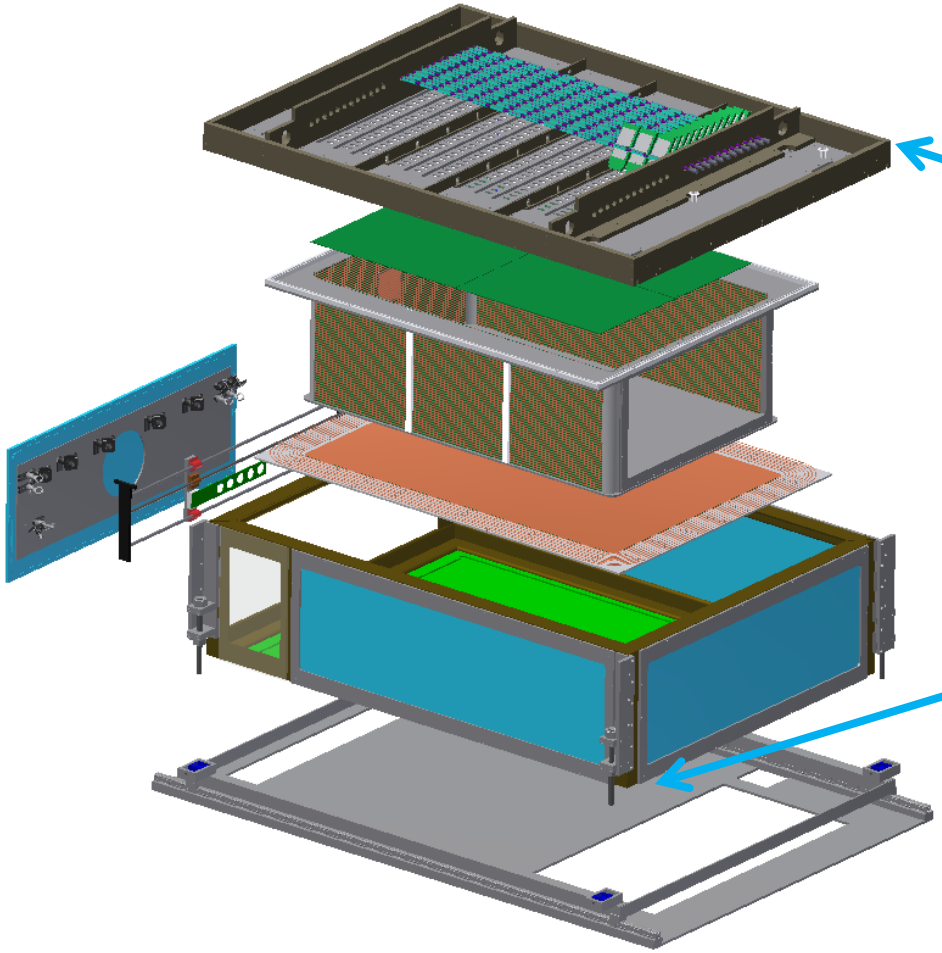
Max. rigidity =6.8Tm max.

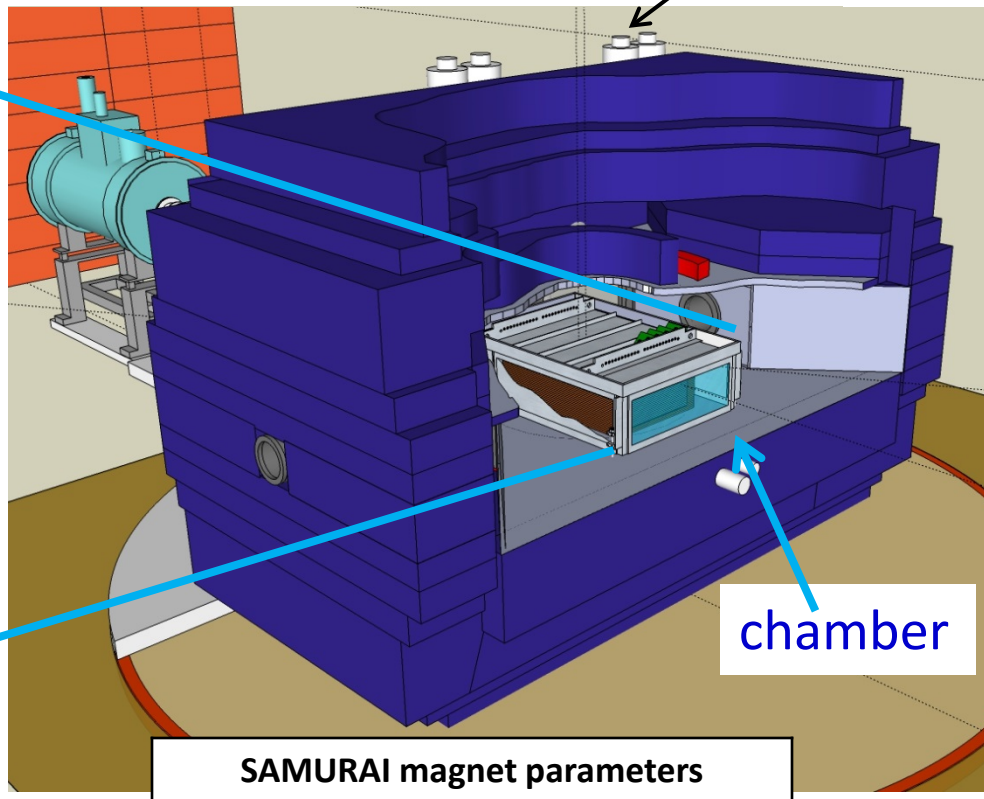
Experimental setup (Dayone)



Measure differential flow and yield ratios for (π^+ & π^-), (p & n), (^{3}H & ^{3}He) in Heavy RI Collisions at E/A=200 and 300MeV

MSU-TAMU-RIKEN-Kyoto initiative: Time Projection Chamber installed in the SAMURAI magnet to detect pions, charged particles at $\rho \sim 2\rho_0$





SAMURAI magnet parameters	
B_{typ}, B_{max}	0.5T, 3T
R, pole face	1 m
Gap	80 cm
Usable gap	75 cm

Supported by USA DoE funding ($1.2M), and Japanese Grant-in-Aid for Scientific Research on innovative areas ($1.3M).

Basic design of chamber

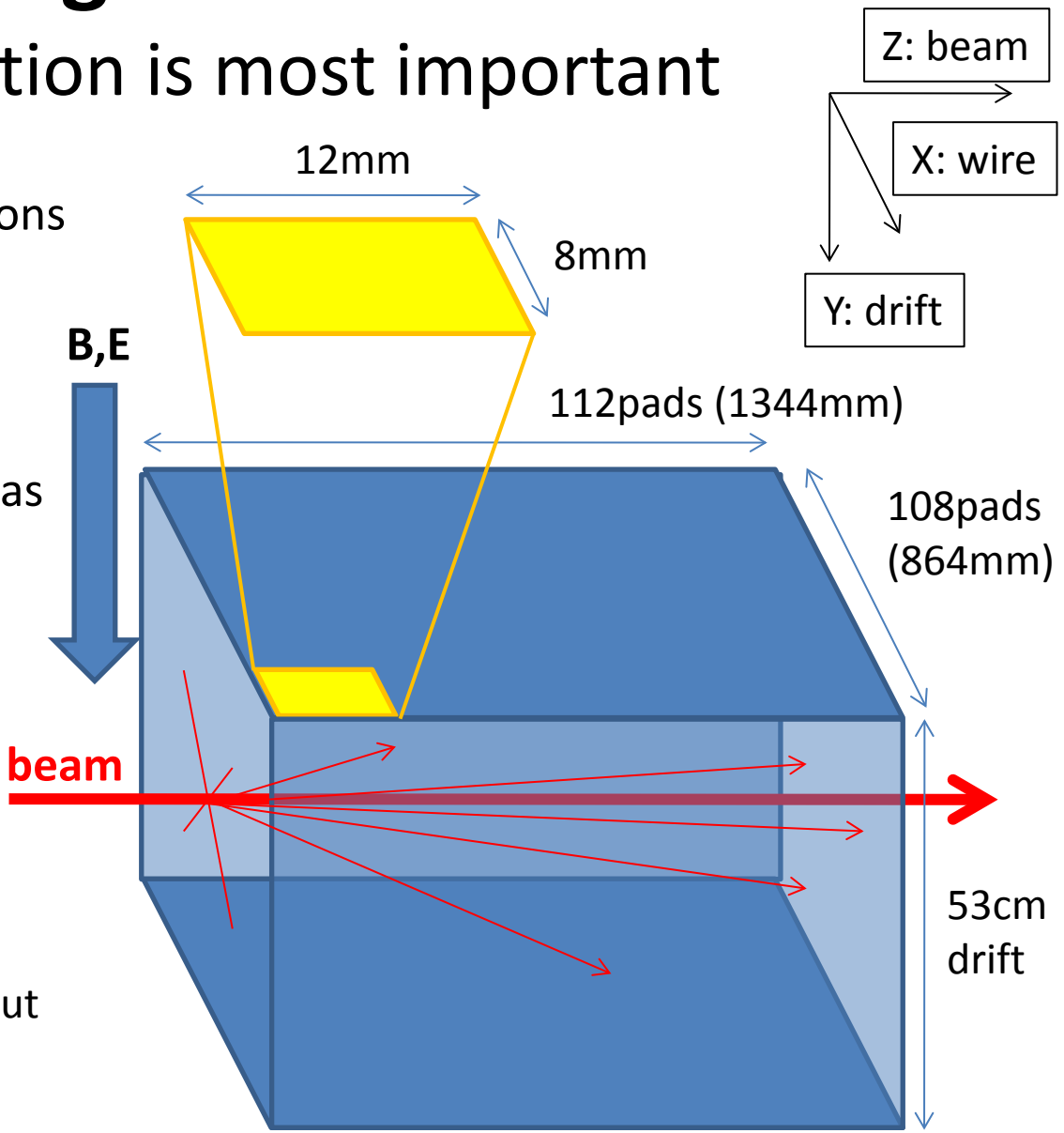
stable operation is most important

- For the measurement of light charged particles: pions, protons and light ions. Beam passes through chamber as well.

- Based on Bevalac EOS TPC.
- Wire amplification with P10 gas (1atm).
- Target at the entrance of chamber.
- Readout with ~12000 pads.
- 2 track separation: 2.5cm
- Multiplicity: 10~100

- Readout with GET system
  - 12bit high throughput readout

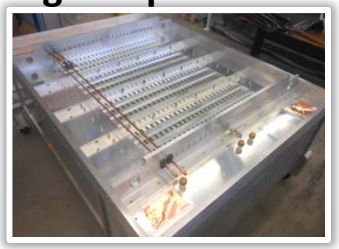
→ Next talk by W. Powell



SAMURAI TPC: Exploded View

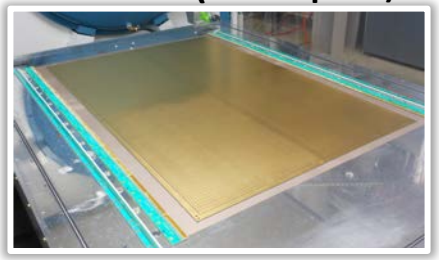
Front End Electronics

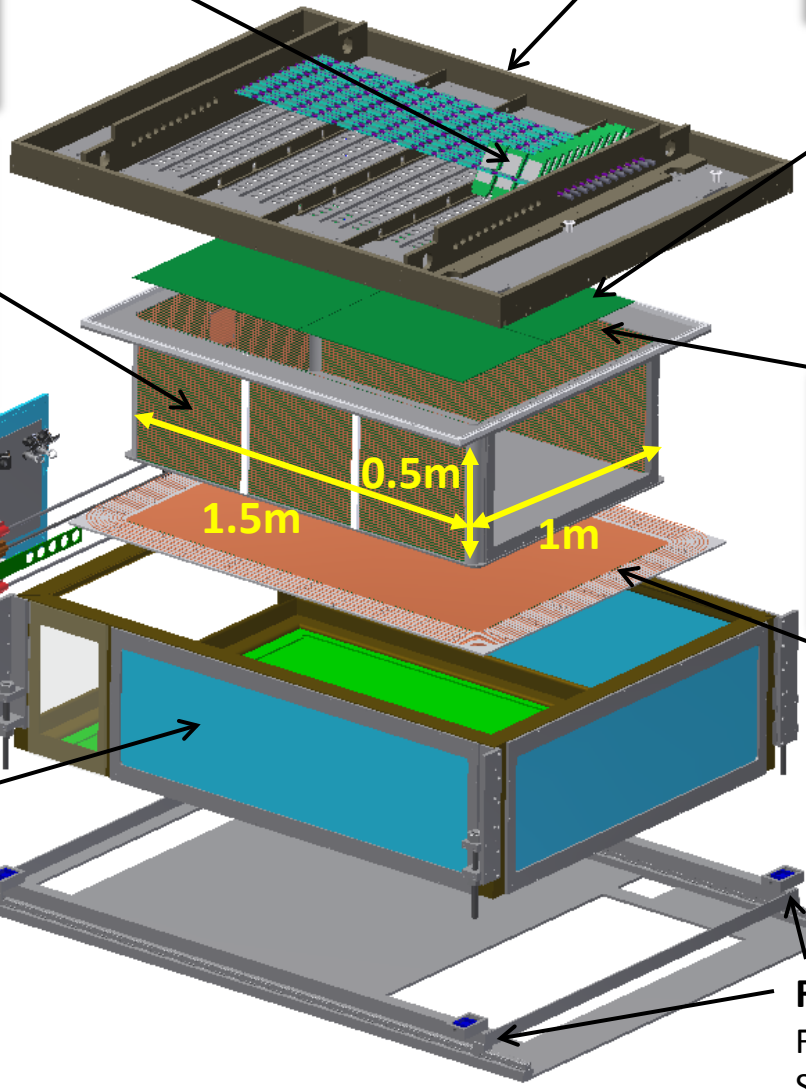
Rigid Top Plate



Field Cage

Pad Plane (12096 pads)



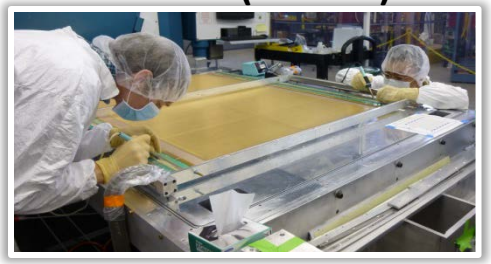


Beam

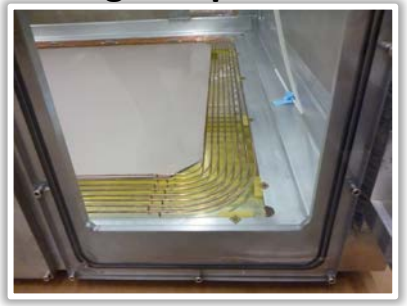
Calibration
Laser Optics

Target Mechanism

Wire Planes (e- mult)



Voltage Step-Down



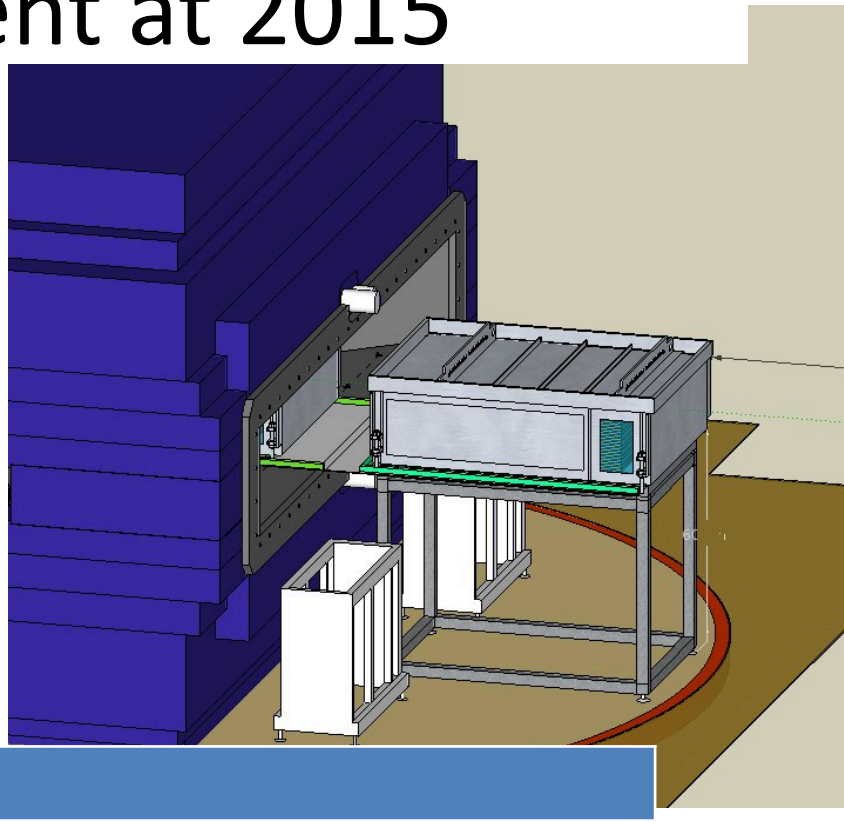
Thin-Walled Enclosure

Rails

For inserting TPC into
SAMURAI vacuum chamber

came to RIKEN at February 2014

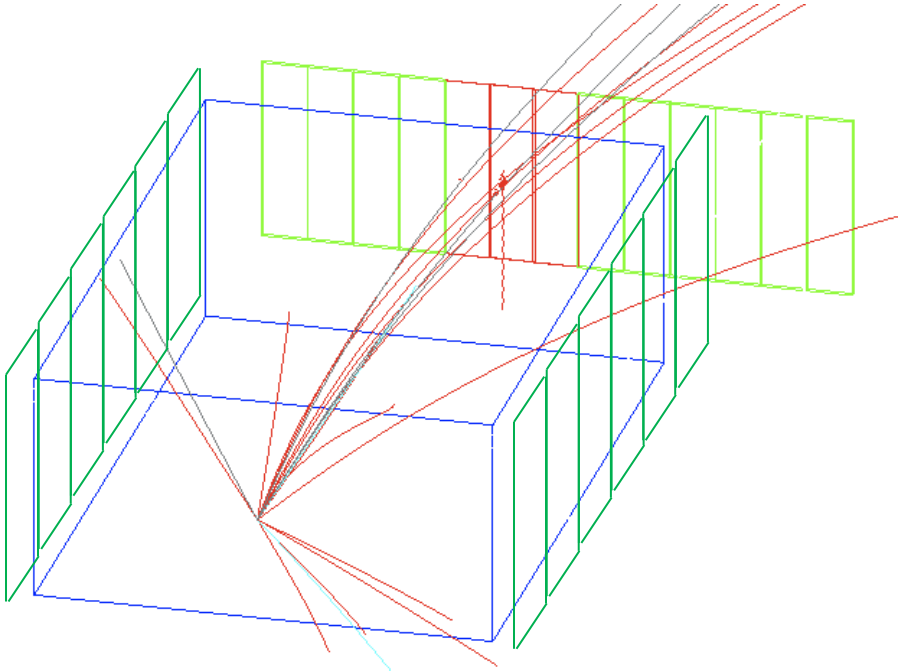
Under preparation at RIKEN towards first experiment at 2015



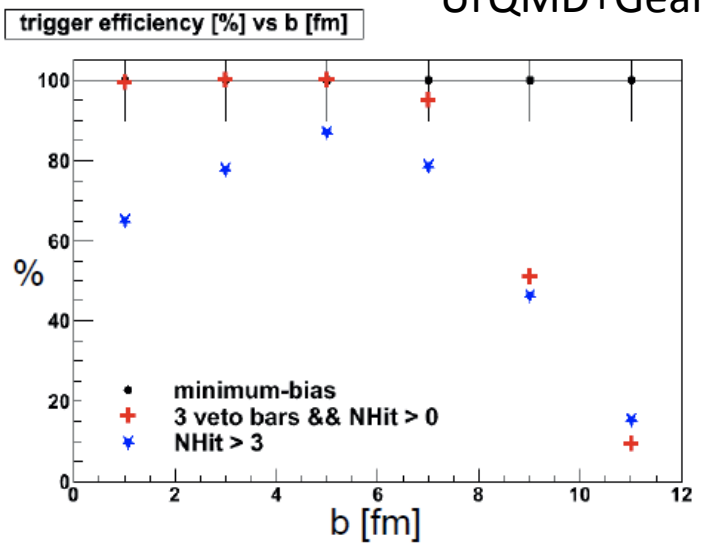
Date	Item
2014-Jul.	TPC installation test into SAMURAI chamber Test under 0.5T magnetic field
2014-Sep.	Mount all of electronics on TPC Readout of cosmic events with GET
2014-Nov.	Electronics and Trigger beam test at HIMAC
2014-Dec./Jan.	Start the preparation of day one experiment

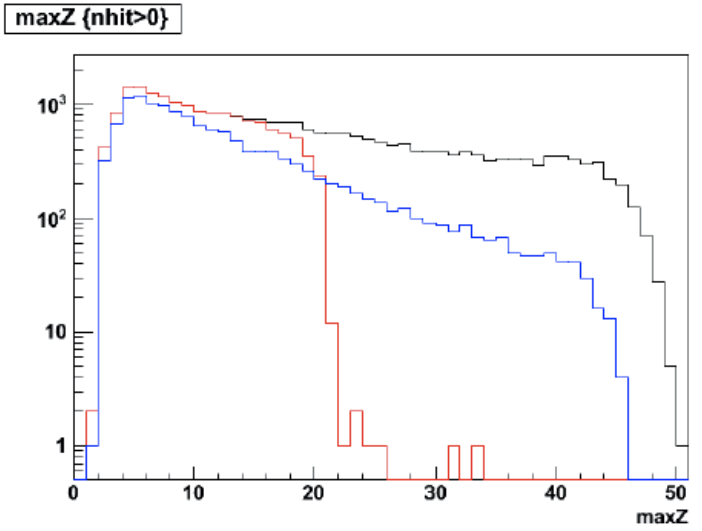
Trigger array

- Need to trigger the central collision events.
  - TPC needs 1st level trigger to open the gate for the detection of signal.
  - High level trigger with TPC information is possible.
- >95% efficiency for b<5fm.
- Plastic + MPPC readout to be able to operate under magnetic field.



UrQMD+Geant4





Neutron detector: NeuLAND+NEBULA

NEBULA

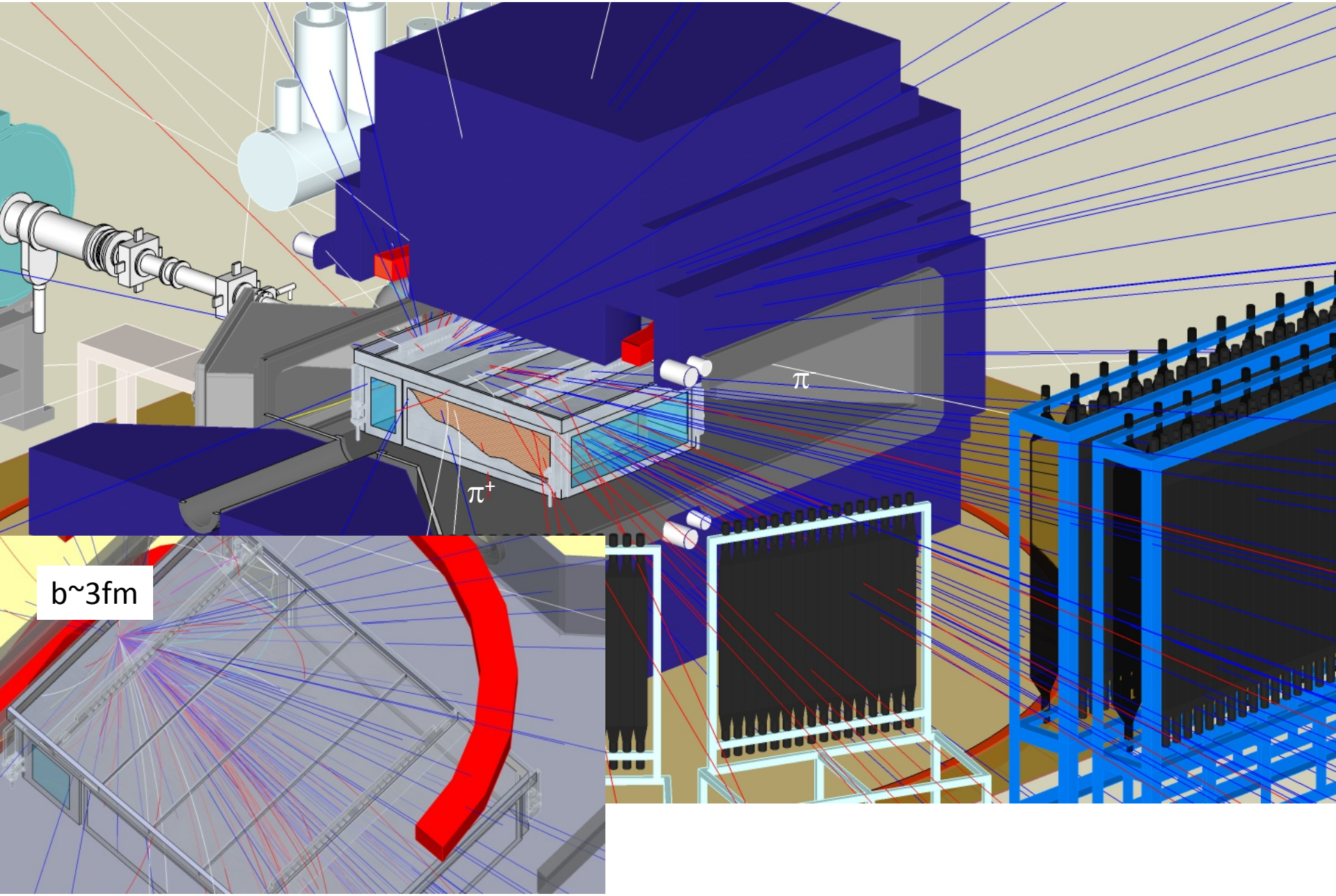
- 1scintilator: 180cm x 10cm x 10cm
- 4layer w/ 120 Neutron counters
- 12 VETO counters for every 2 layers
- Detection efficiency~40% for 1n
- Front acceptance: 3.6m (H) x 1.8m (V)

NeuLAND

Come to RIKEN at the end of 2014

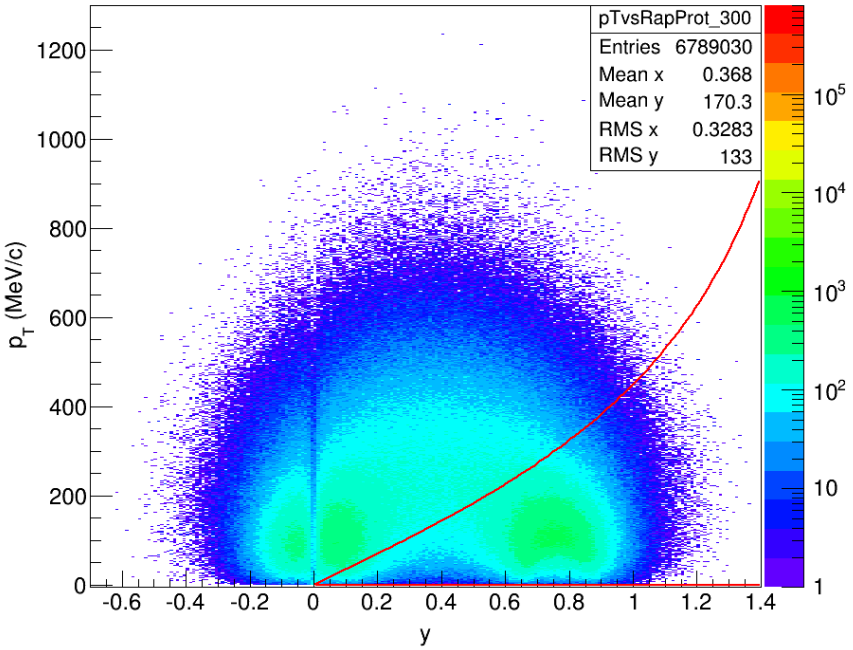
- Tracking type neutron detector
- 1scintilator: 250cm x 5cm x 5cm
- Front acceptance 250cm x 250cm w/ 50 bars
- Depth: 3m with 60 layers

Simulation study: $^{132}Sn+^{124}Sn$ E/A=300MeV

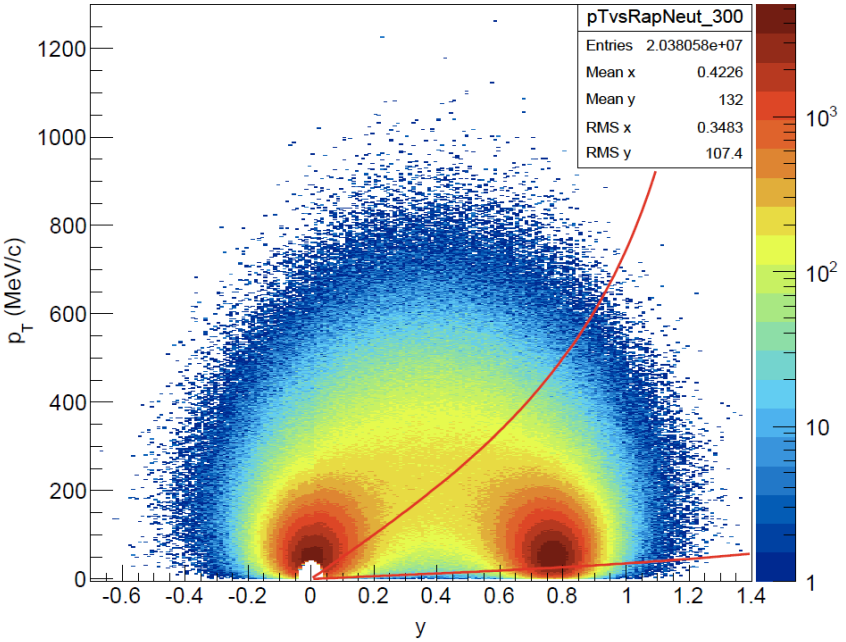


Acceptance of SPiRIT
$^{132}Sn+^{124}Sn$ E/A=300MeV

proton

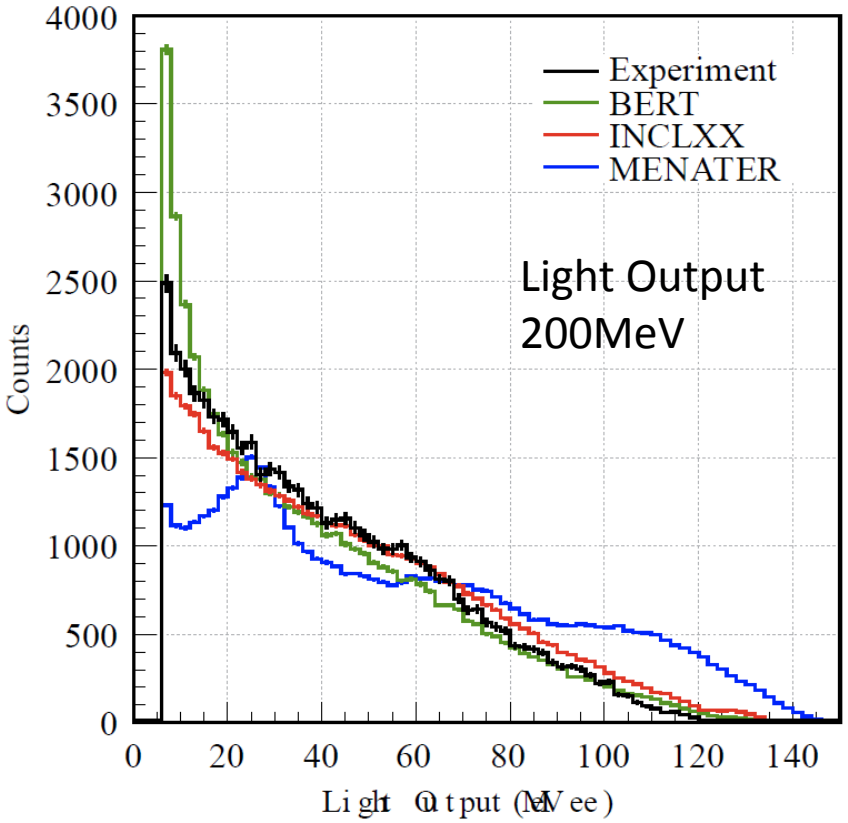


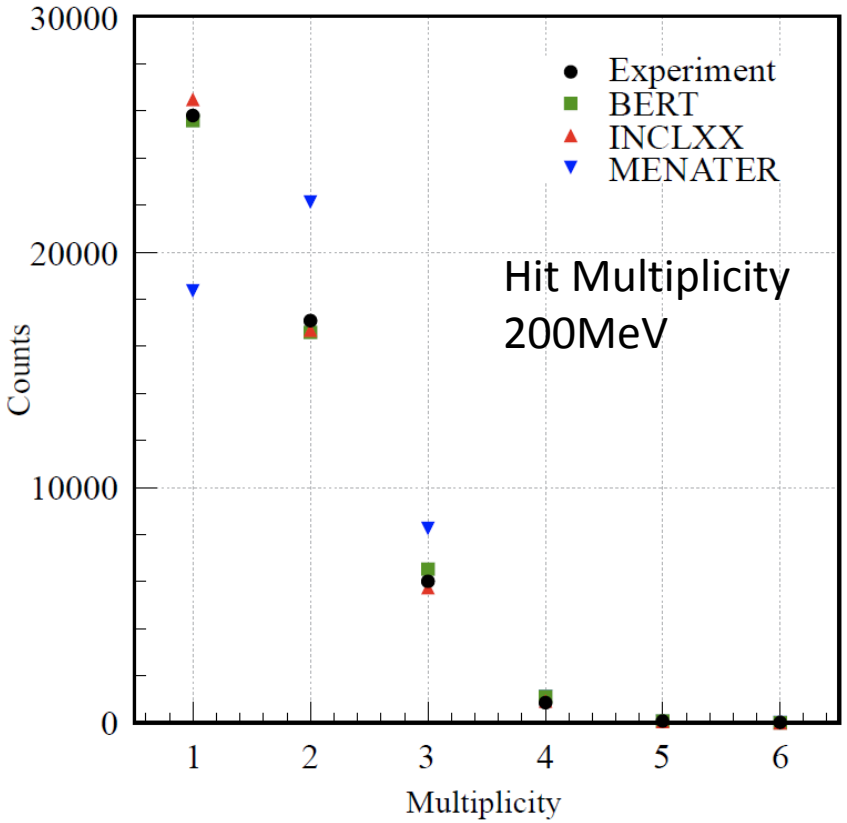
neutron



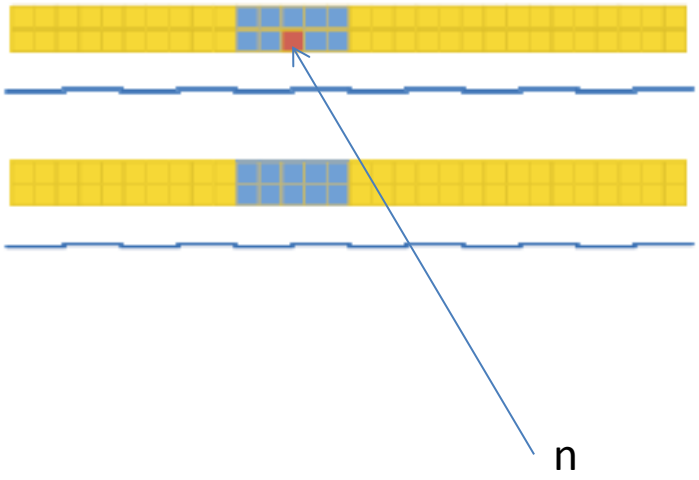
Neutron simulation w/ GEANT4

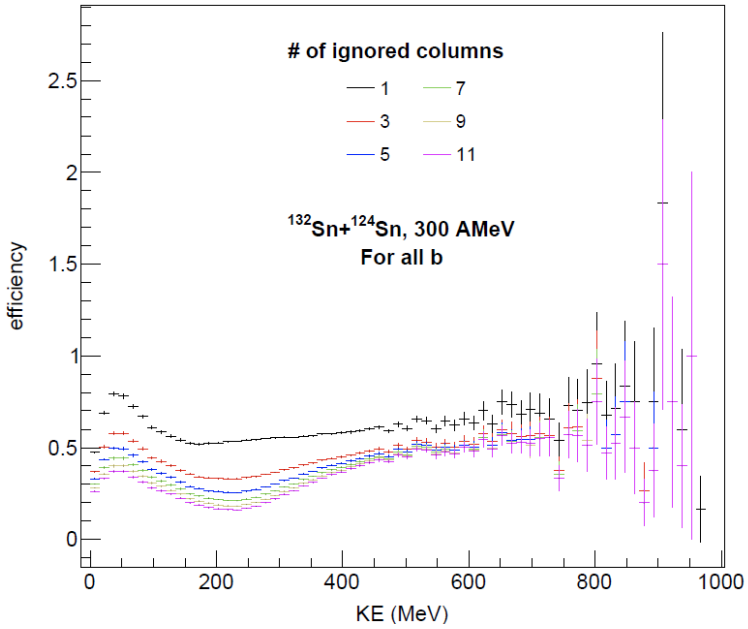
- $^{7}Li(p,n)^{7}Be$ reaction to evaluate the NEBULA performance.
  - E=200MeV, 250MeV
- INCLXX seems best to reproduce the neutron response.



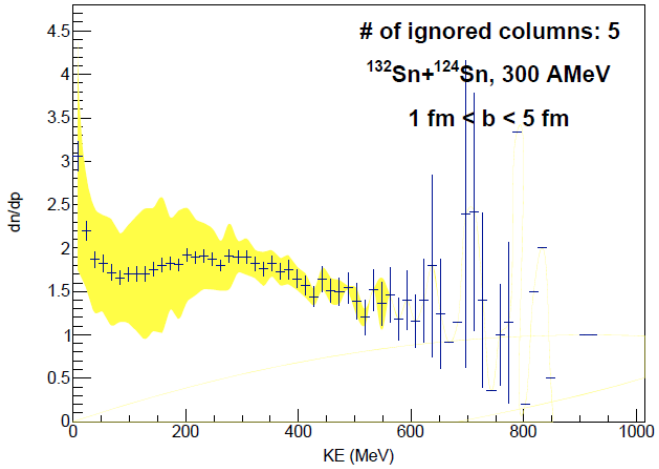


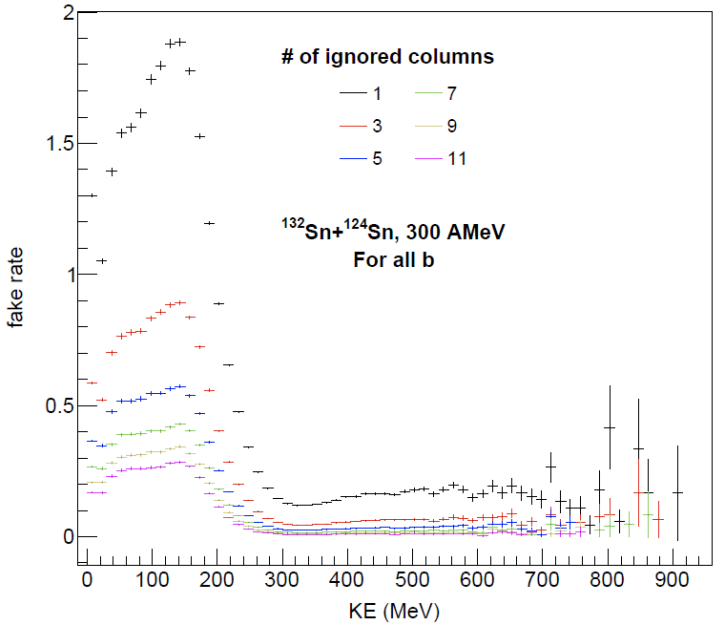
Expected performance on p/n measurement





- ^{132}Sn+^{124}Sn E/A=300MeV
- Large fake rate with loose cut.
- 15~30% error for energetic neutron.

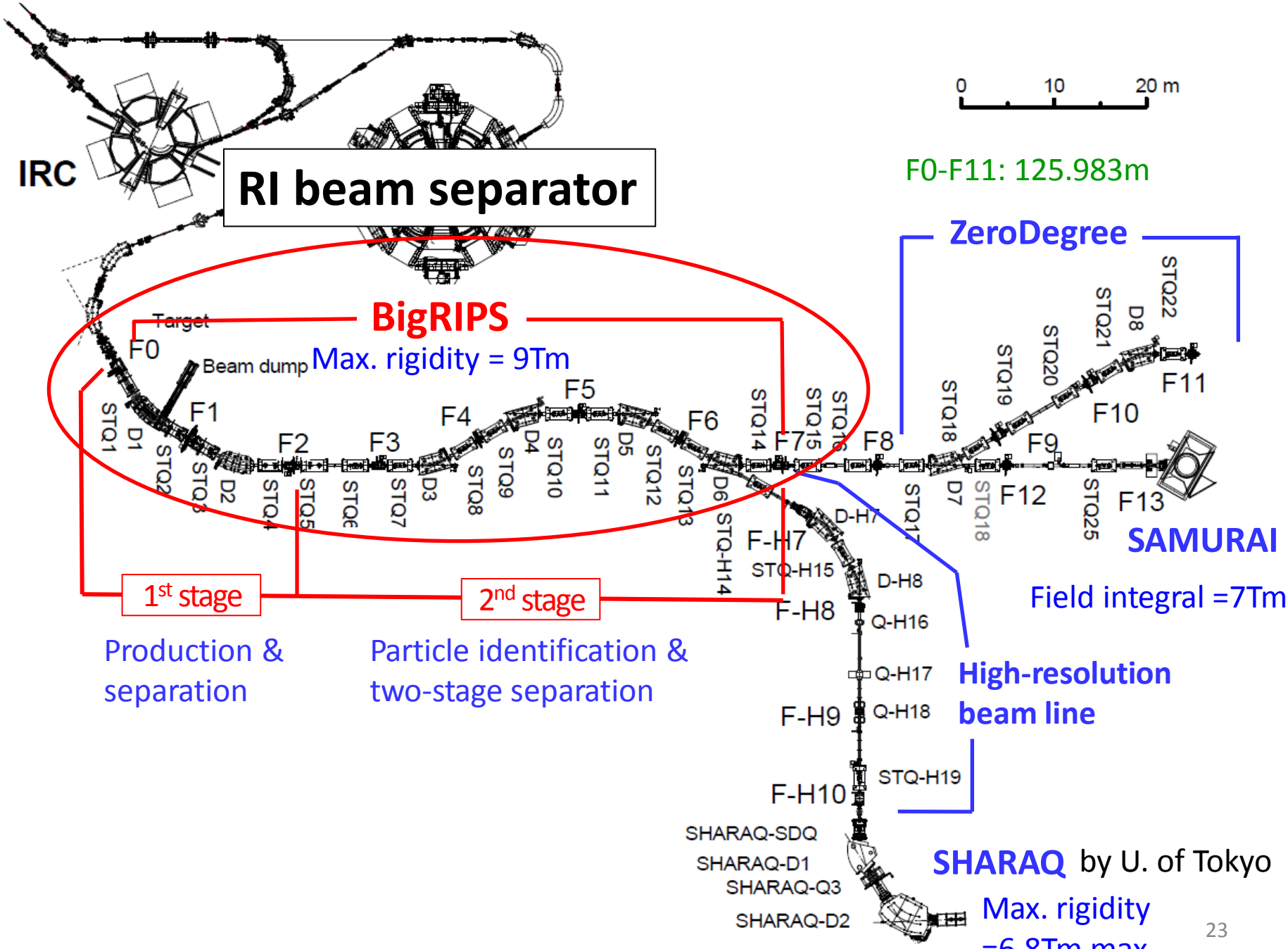




RI beam production at RIBF

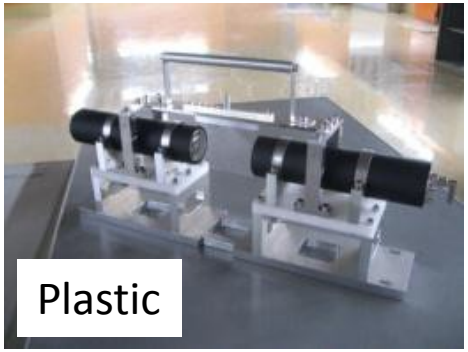
- Approved beam time at RIBF
  - NP1306-SAMURAI15, NP1312-SAMURAI22

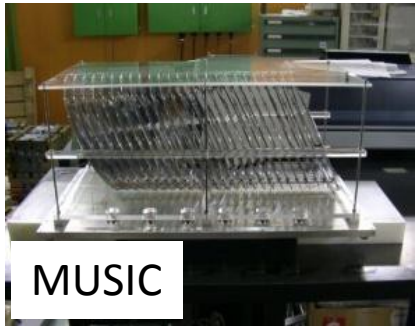
Primary	Beam	Target	E_{beam}/A	δ_{sys}	Goal	Days
^{238}U	^{132}Sn	^{124}Sn	300	0.22	Probe maximum δ	3
	^{124}Sn	^{112}Sn	300	0.15	Probe intermed. δ, σ_{nn}, σ_{np}	3
^{124}Xe	^{108}Sn	^{112}Sn	300	0.09	Probe minimum δ	3
	^{108}Sn	^{124}Sn	300	0.15	Probe intermed. δ, σ_{nn}, σ_{np}	3

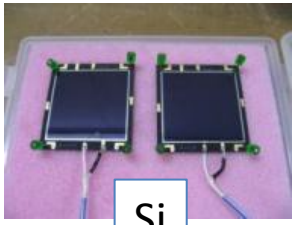

IRC
RI beam separator
0
10
20 m
F0-F11: 125.983m
ZeroDegree
BigRIPS
Max. rigidity = 9Tm
Target
F0
Beam dump
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12
F13
STQ1
D1
STQ2
STQ3
D2
STQ4
STQ5
STQ6
STQ7
D3
STQ8
STQ9
D4
STQ10
STQ11
D5
STQ12
STQ13
D6
STQ14
STQ15
STQ16
STQ17
D7
STQ18
STQ19
STQ20
STQ21
D8
STQ22
STQ25
D-H7
F-H7
STQ-H14
STQ-H15
D-H8
F-H8
Q-H16
Q-H17
F-H9
Q-H18
STQ-H19
F-H10
SHARAQ-SDQ
SHARAQ-D1
SHARAQ-Q3
SHARAQ-D2
1st stage
2nd stage
Production & separation
Particle identification & two-stage separation
SAMURAI
Field integral =7Tm
High-resolution beam line
SHARAQ by U. of Tokyo
Max. rigidity =6.8Tm max.

Particle identification (PID) detectors at BigRIPS

TOF-$B\rho$-ΔE method with track reconstruction → Beam by Beam PID







ΔE: MUSIC, Si

Isomer γ-ray: Ge

$B\rho$ with track reconstruction

Target

β_{35}, $B\rho_{35}$

β_{57}, $B\rho_{57}$

PPAC x2

PPAC x2

PPAC x2

Wedge

F2 F3 F4 F5 F6 F7

STQ5 STQ6 STQ7 D3 STQ8 STQ9 D4 STQ10 STQ11 D5 STQ12 STQ13 D6 STQ14 STQ15

1st stage

2nd stage

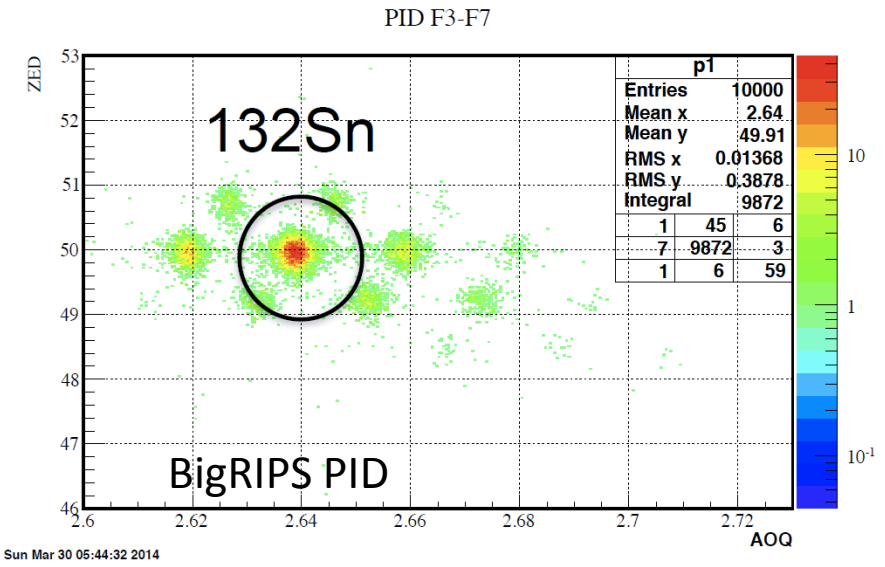
TOF: β

Plastic scinti.

PID without measuring TKE

^{132}Sn beam production as of 2014 spring

- Stable <u>15pnA</u> U primary beam was delivered at 2014 spring RIBF experimental campaign.
- Other experiment using ^{132}Sn at SAMURAI:
  - E/A = 285MeV
  - ^{132}Sn Purity = 50%
  - Total rate: 20kcps



Summary

- SPiRIT project has been formed for the study of density dependent symmetry energy by using asymmetric heavy RI collision.
  - $\rho \sim 2\rho_0$
- Systematic measurement of:
  - Pion measurement
  - Proton/Neutron measurement
  - Light ions

  at different energy and different system is possible.
- Dayone experiment next year.
  - First report at next NuSYM!