

$S\pi$ RIT-TPC experiments at RIKEN 2016

SπRIT

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U.S. DEPARTMENT OF ENERGY Office of Science

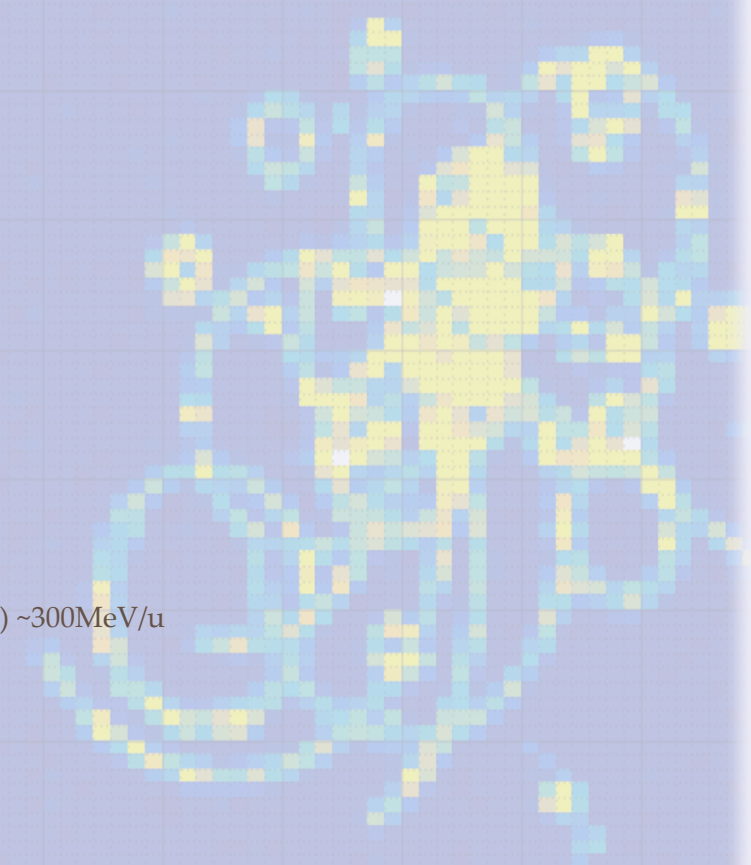
文部科学省 MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY

*Mizuki Kurata-Nishimura
For $S\pi$ RIT-TPC collaboration*

RIKEN, Nishina Center

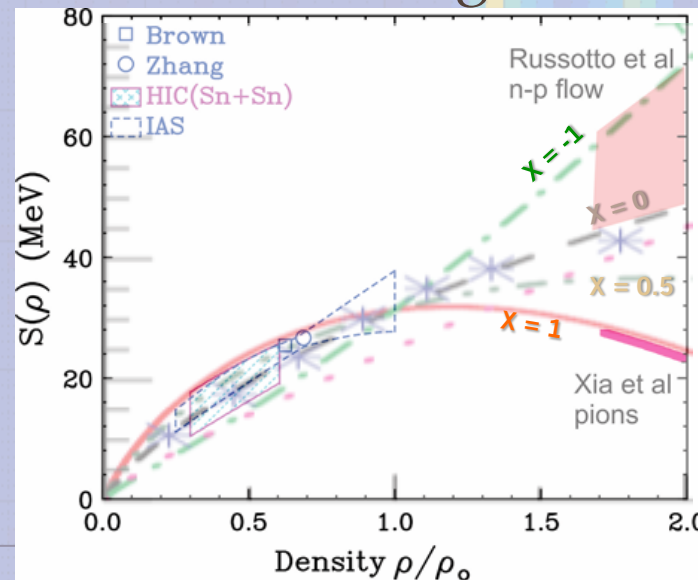
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($^{132}\text{Sn} + ^{124}\text{Sn}$), ($^{108}\text{Sn} + ^{112}\text{Sn}$), ($^{124}\text{Sn} + ^{112}\text{Sn}$), ($^{112}\text{Sn} + ^{124}\text{Sn}$) $\sim 300\text{MeV/u}$
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Physics motivation

- We constrain symmetry energy term in EOS at Supra-saturation density.
- Heavy nuclear collision with 300 MeV/u beam is expected to reach to nuclear density of two times larger than the normal nuclear density.
- Symmetry energy can be studied using radioactive beams



Russotto et al., PLB, 697, 471 (2011)
Xiao et al., PRL 102, 062502 (2009).
Adapted from Horowitz, et al.,
J. Phys. G: Nucl. Part. Phys. 41 (2014) 093001

π^-/π^+ Production Ratio

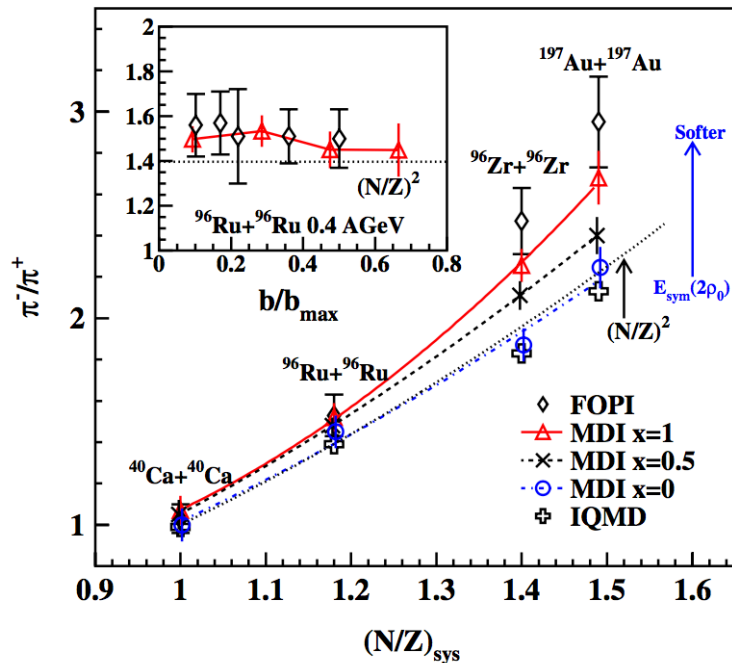
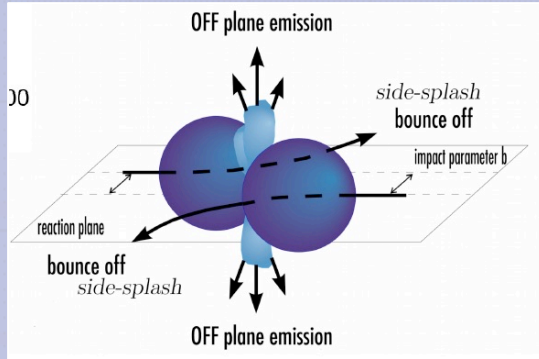


FIG. 2 (color online). The π^-/π^+ ratio as a function of the neutron/proton ratio of the reaction system at 0.4A GeV with the reduced impact parameter of $b/b_{\max} \leq 0.15$. The inset is the impact parameter dependence of the π^-/π^+ ratio for the $^{96}\text{Ru} + ^{96}\text{Ru}$ reaction at 0.4A GeV.

- FOPI data show π^-/π^+ ratio is larger than $(N/Z)^2$ ratio.
- MDI used in the IBUU04 indicates the soft EOS is preferable.
- SpiRIT experiment can directly compare with common Z and different N systems.

Directed and elliptic flow



$$F_{n-p} = \frac{1}{N(y)} \sum_{i=1}^{N(y)} P_{x_i} \tau_i \quad K_{sym} \equiv 9\rho_0^2 \left. \frac{\delta^2 S(\rho)}{\delta^2 \rho} \right|_{\rho=\rho_0}$$

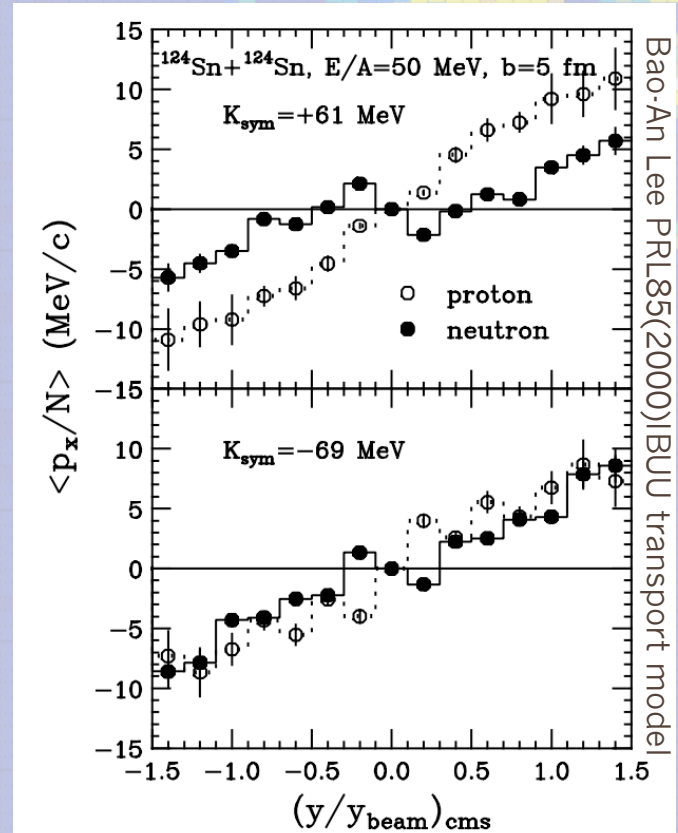
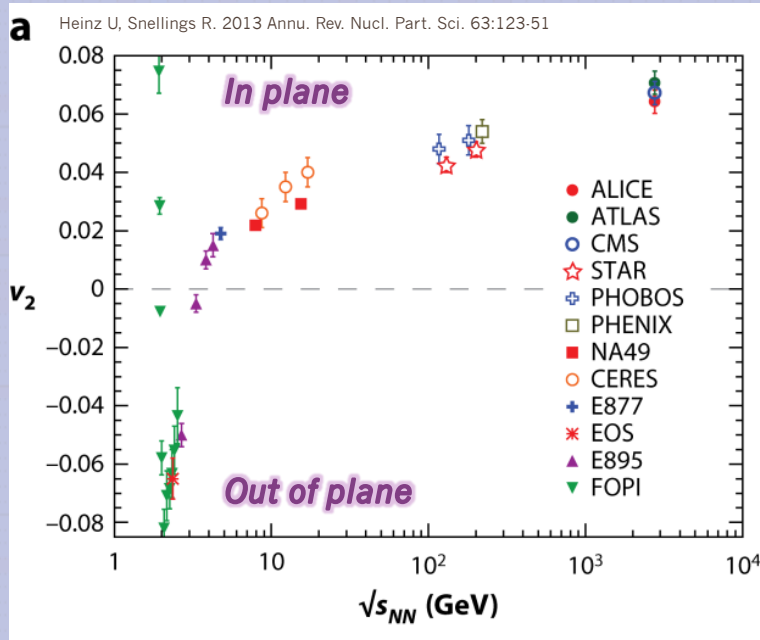


FIG. 2. The average transverse momentum per nucleon in the reaction plane for neutrons and protons as a function of reduced rapidity with the K_{sym} parameter of +61 MeV (upper window) and -69 MeV (lower window), respectively.

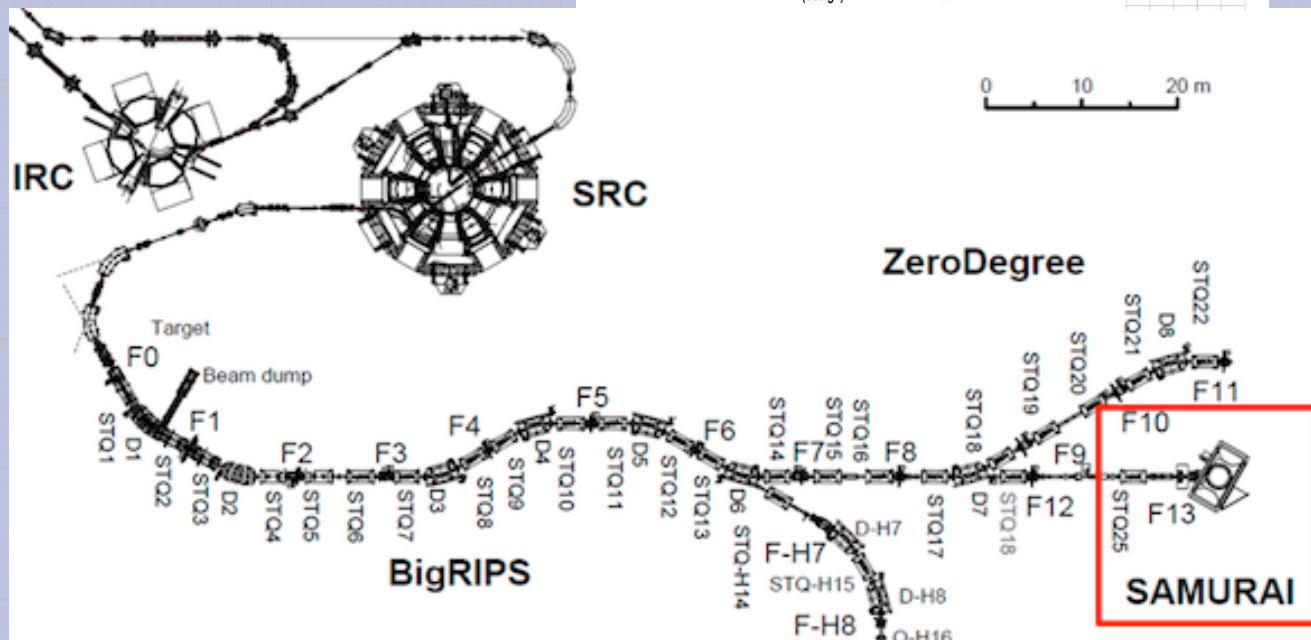
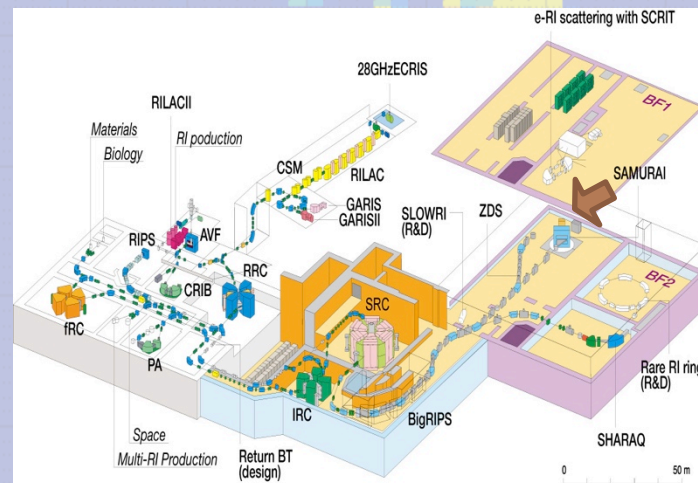
BigRIPS in RIBF-RIKEN

Unstable Sn beams provided by RIBF-BigRIPS-RIKEN.

✓ ^{132}Sn , ^{124}Sn , ^{112}Sn , ^{108}Sn

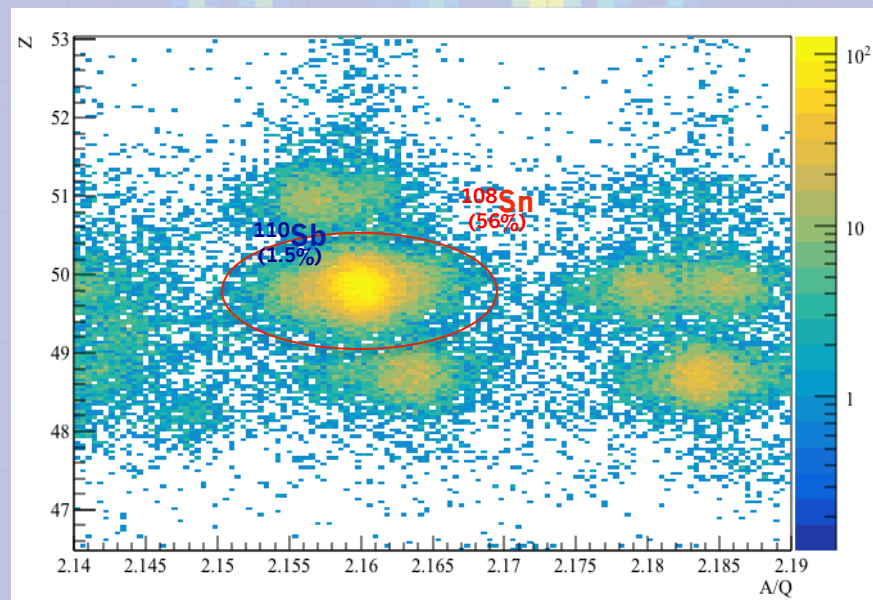
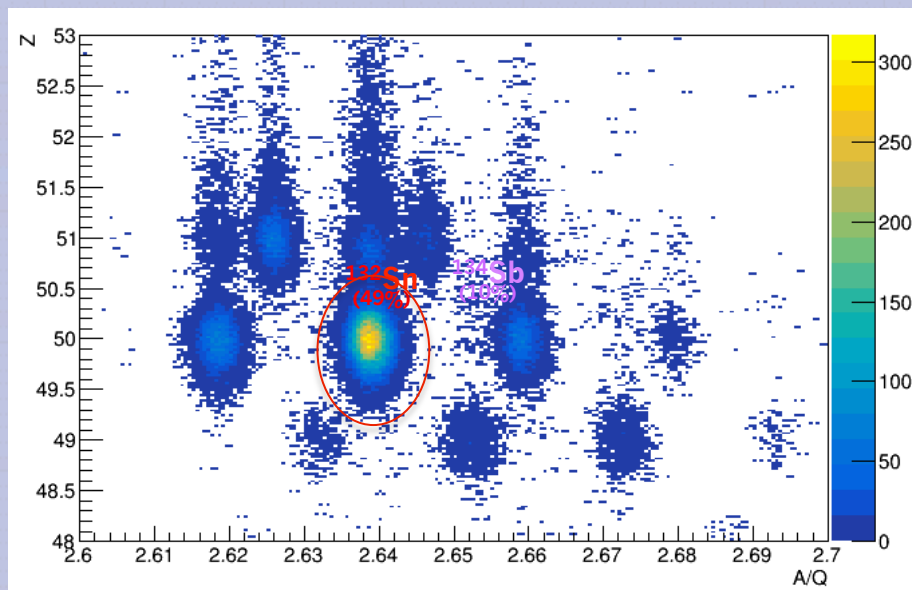
✓ ~280 MeV

Interested beams were separated through BigRIPS and transferred to SAMURAI experimental area.



Beam & Target configurations

	Beam	Purity	Energy [MeV/u]	Purpose $\delta=(N-Z)/A$	Periods
Xe	^{108}Sn	49%	268.9	neutron deficient $\delta = 0.09$	Apr. 30 - May. 4 '16
Xe	^{112}Sn	44%	270.2	reference $\delta = 0.15$	May. 4 - May. 6 '16
U	^{132}Sn	57%	268.9	neutron rich $\delta = 0.22$	May. 25 - May. 29 '16
U	^{124}Sn	10%	270.2	reference $\delta = 0.15$	May 30 - Jun. 1 '16



S π RIT-TPC

- S π RIT-TPC is designed and constructed at NSCL/MSU to be used in SAMURAI magnet chamber.

S π RIT TPC Parameters			
Pad Plane Area	1.3 m x 0.9 m	Gas Gain	2000
Number of Pads	12096 (112x108)	E-field	135 V/cm
Pad size	12 mm x 8 mm	Drift velocity	5.5 cm/ μ s
Drift Distance	50 cm	dE/dx range	Z=1-8, π , p, d, t, He, Li-O
Pressure	1 atmosphere	Two-track res.	2.5 cm
Gas composition	90% Ar + 10% CH ₄	Multiplicity limit	200



2D-motion target system

Thin-Walled Enclosure

Readout electronics

Field Cage

AsAd Boards

Rigid Top Plate

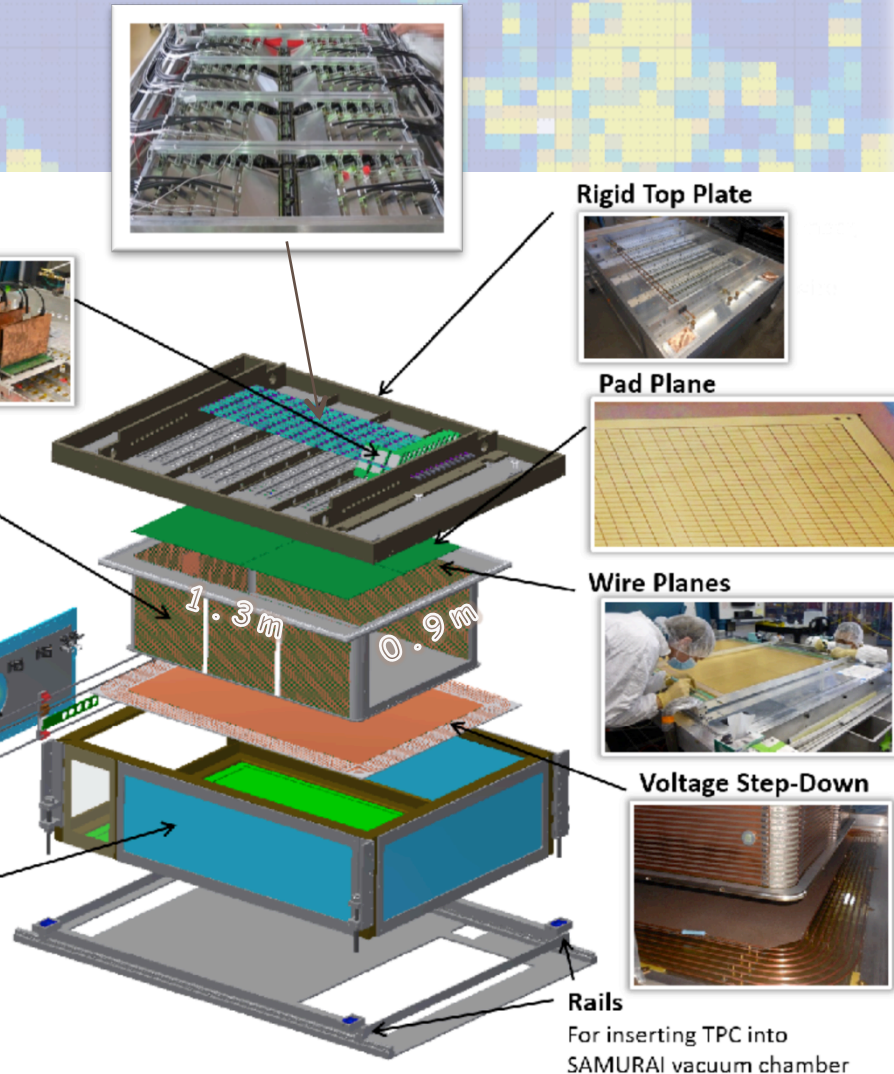
Pad Plane

Wire Planes

Voltage Step-Down

Rails

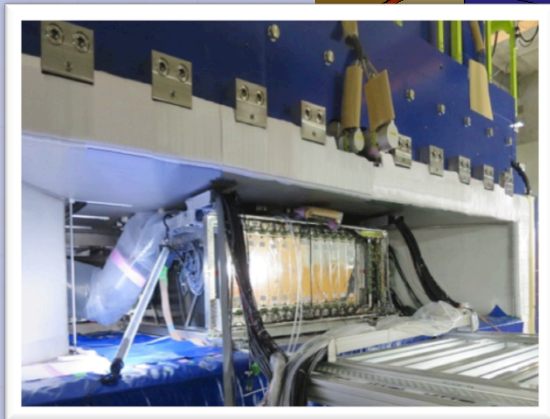
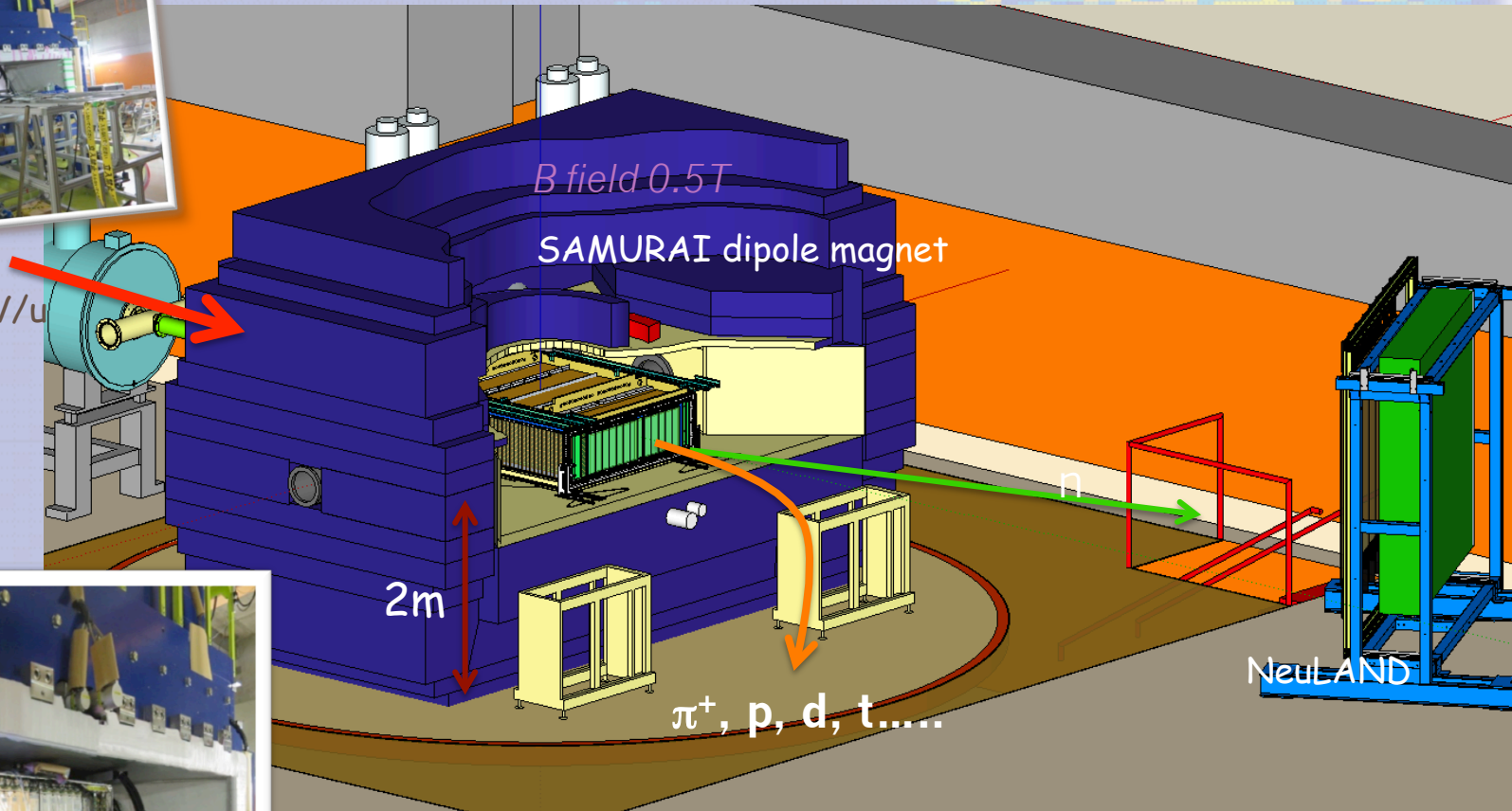
For inserting TPC into SAMURAI vacuum chamber



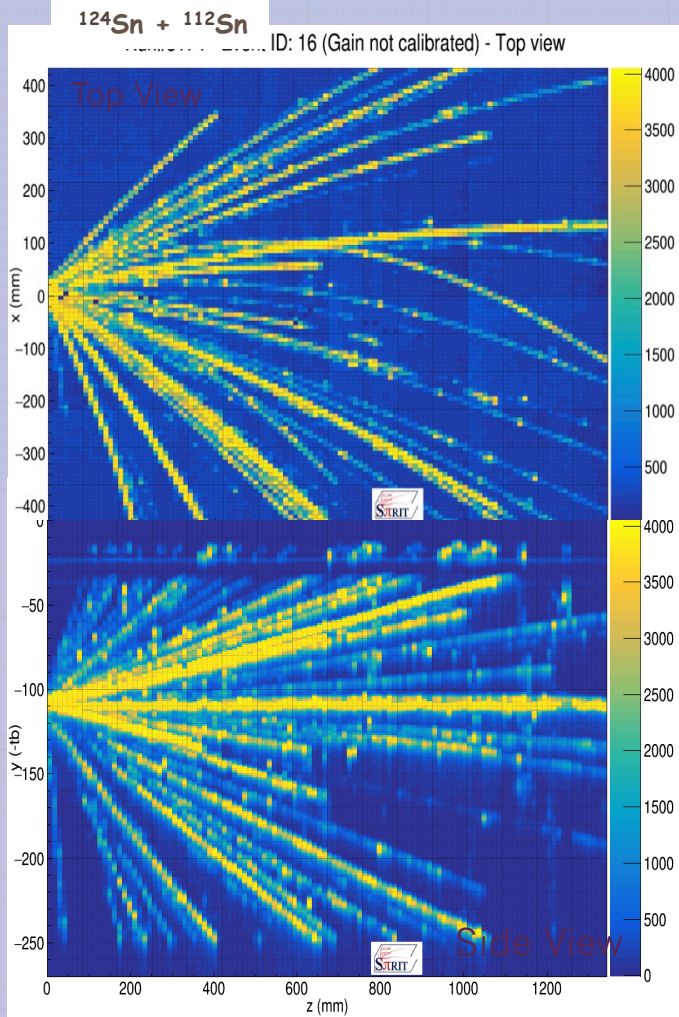
Experimental Setup at SAMURAI in RIBF-RIKEN



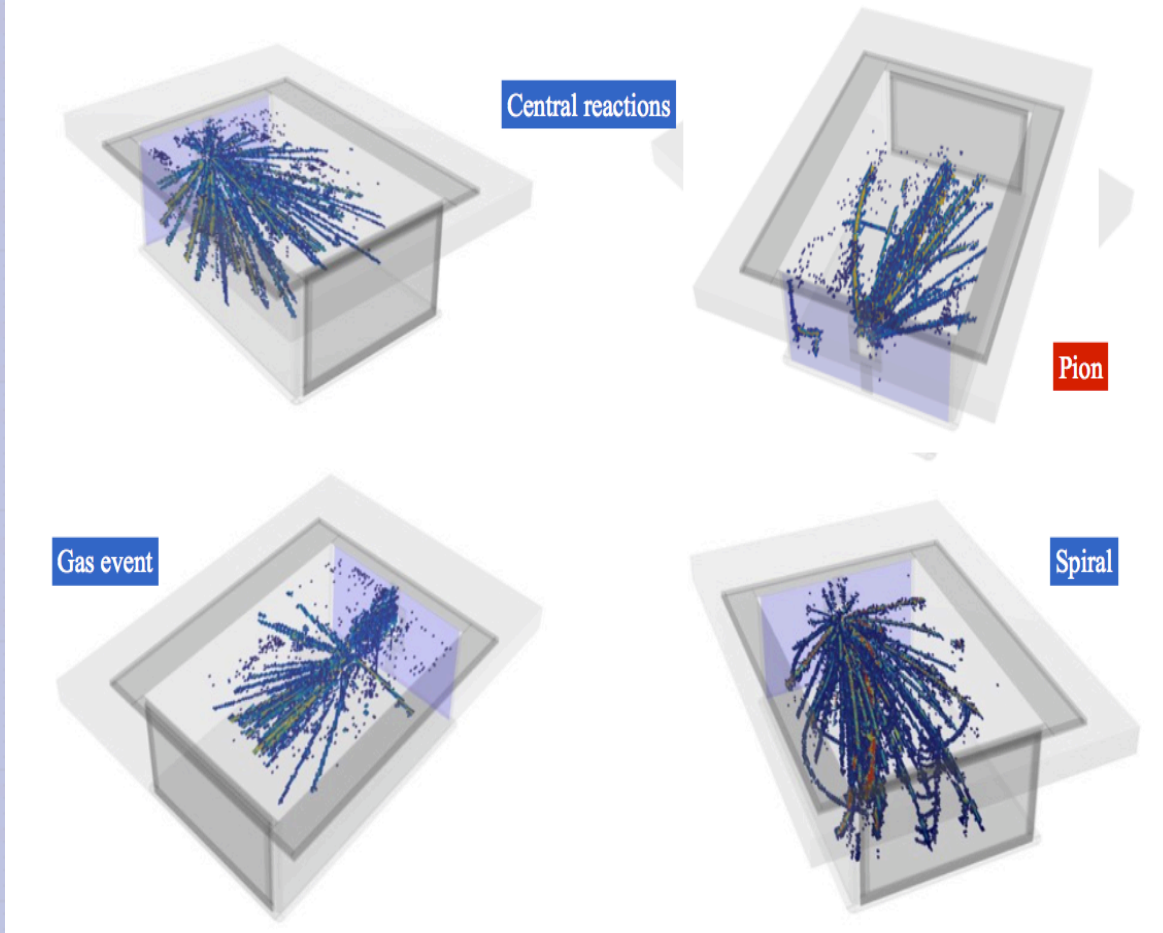
$S_n \sim 300 \text{ MeV/u}$



2D & 3D Event Display

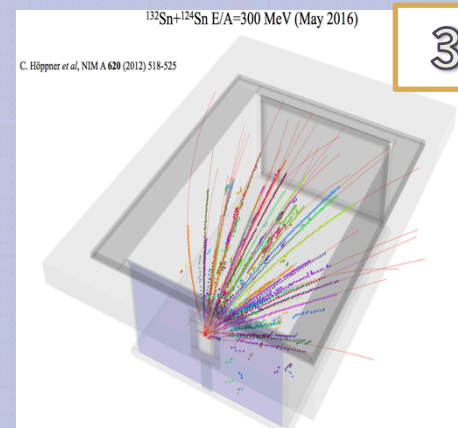
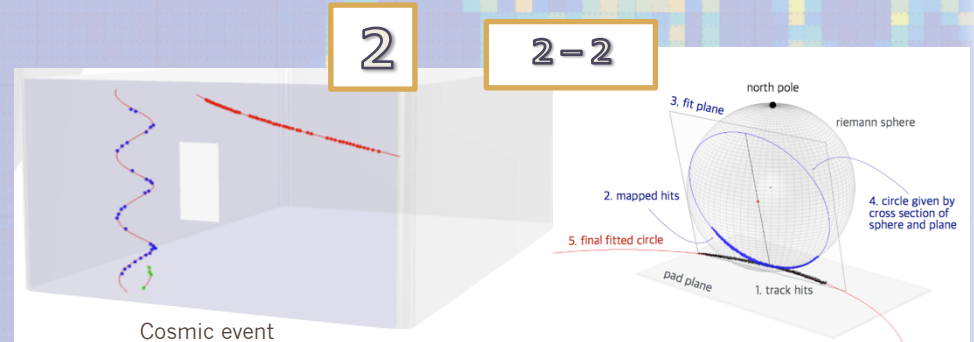
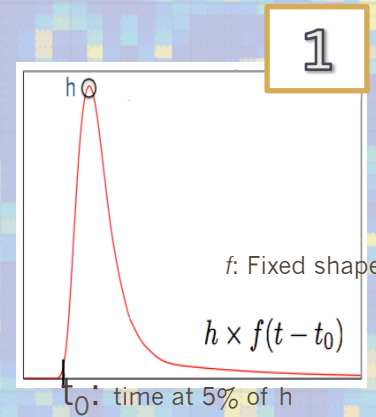


$^{132}\text{Sn} + ^{124}\text{Sn}$ E/A=300 MeV (May 2016)

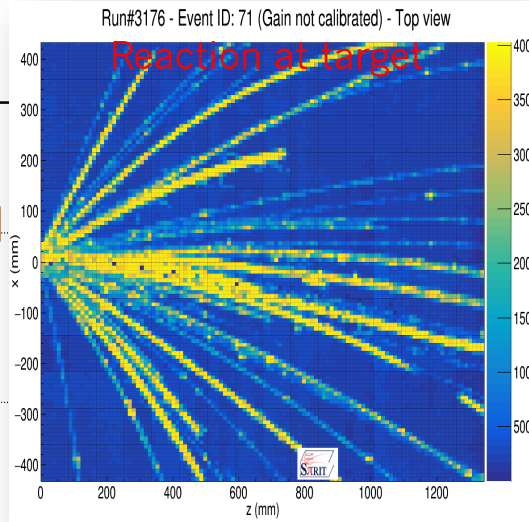
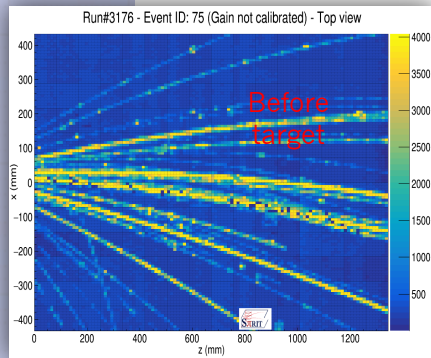


Track Reconstruction

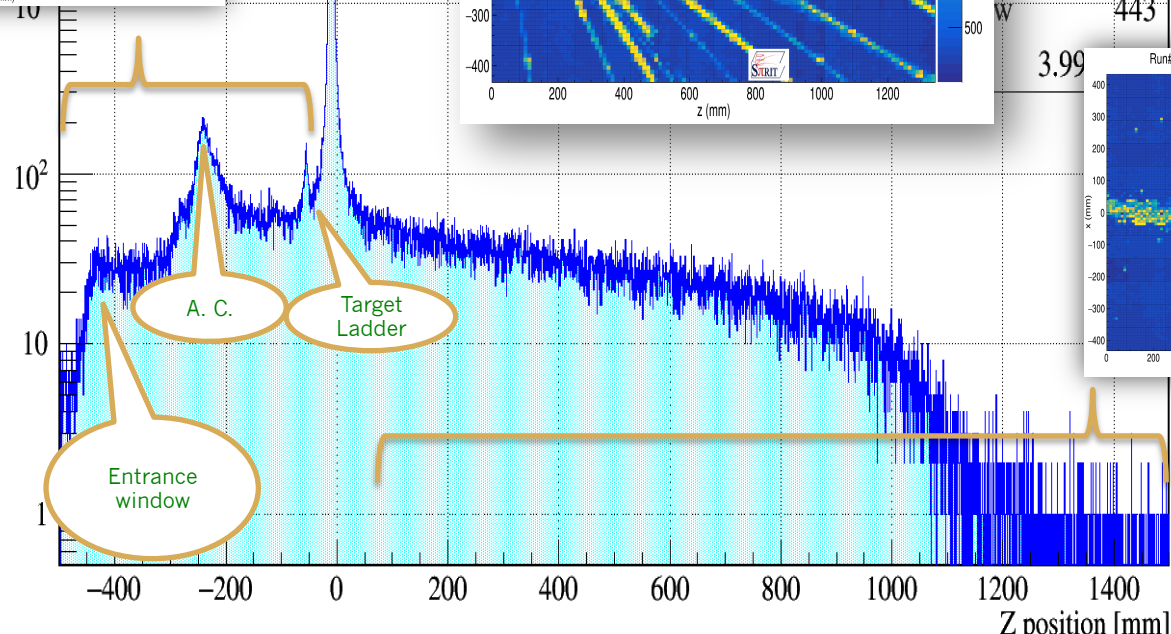
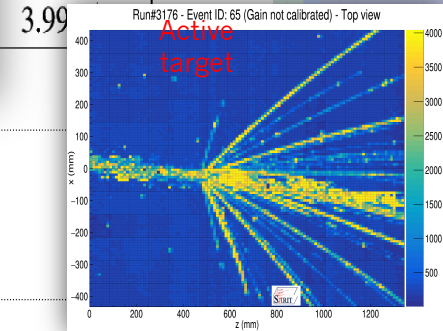
- Pulse Shape Analysis
- Helix tracking: 3D momentum
 - ✓ Track separation
 - ✓ Riemann fit: 2D
 - ✓ Helix fit: 3D
 - ✓ Clustering
 - ✓ Initialize GENFIT parameters
- GENFIT: precise fitting
(Parameterization, extrapolation)
- RAVE(Reconstruction vertices)



Vertex Reconstruction



VertexZ
407879
25.76
208.5
8382
443

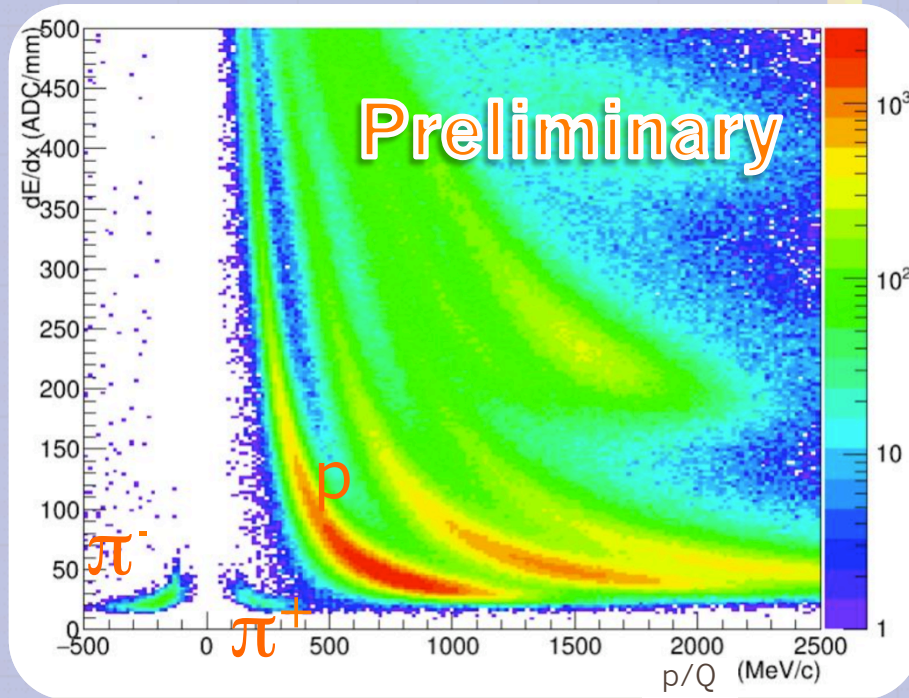


Background can be eliminated

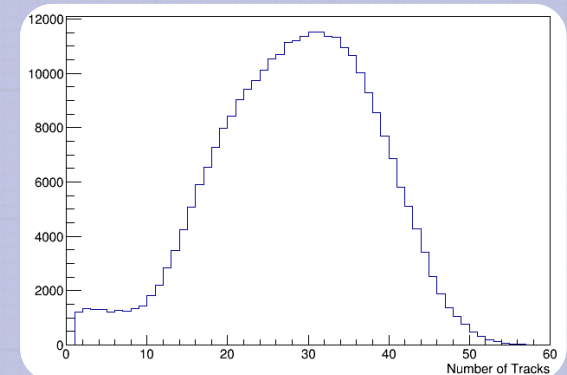
transport 2017

Particle Identification by TPC

PID by TPC ($^{132}\text{Sn} + ^{124}\text{Sn}$ @E/A=280MeV)



- π^- , π^+ can be identified.
- p , d , t , $^3,^4\text{He}$ are also visible.

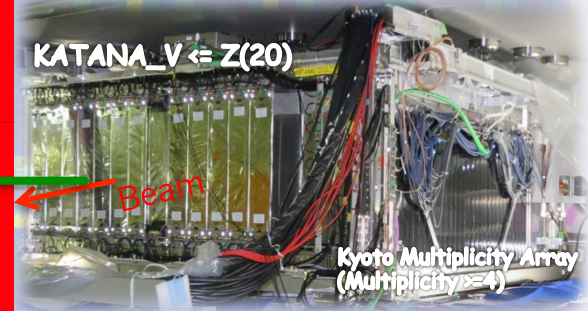
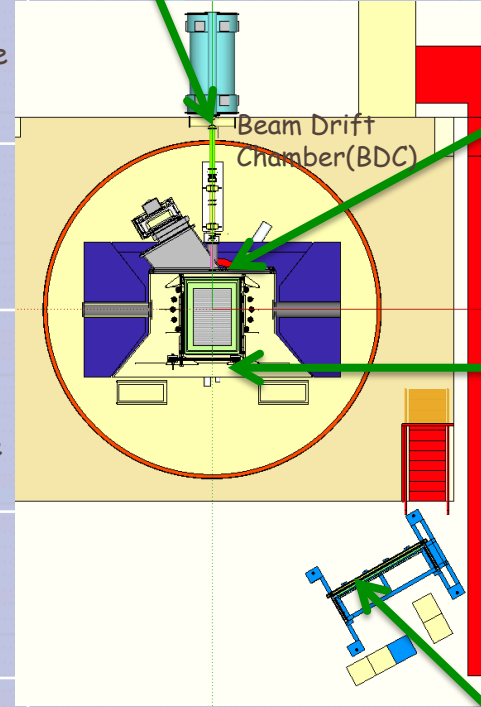
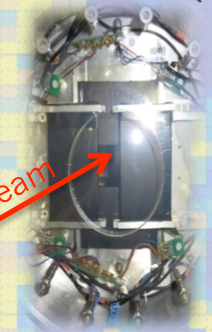


Ancillary Detectors

SBT:Start Counter (hitting)

Active Collimator (no hit)

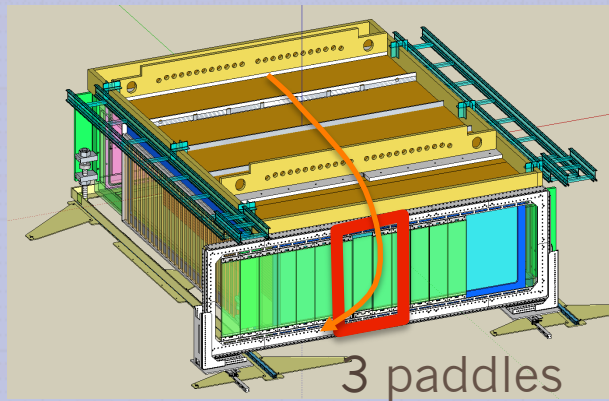
Detector	Location	trigger	Purpose
SBT: Start Counters	After STQ mag.	Hitting	Count number of beam and determine start timing
Active Collimator	In front of the target	No hit	Reject beam passing through outside of the target.
KATANA-Veto	After the exit window	Pulse Height $\leq -30\text{mV}$	Reject beam-like residues with Z greater than 20 passing through the TPC
Kyoto Multiplicity Array	Left and Right side	Multiplicity ≥ 4	Trigger central collision events
BDC: Beam Drift Chamber	In beam line after S.C.	not included	Reconstruct a beam track
NeuLAND	8.5m, 30deg	not included	Detect neutron and charged light particles



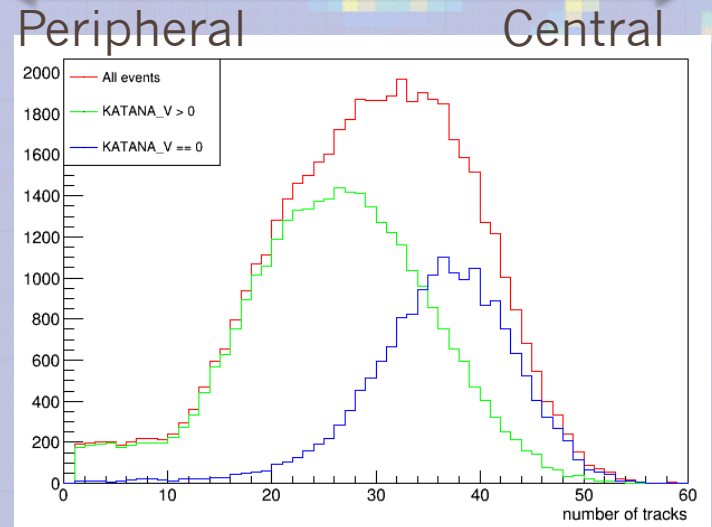
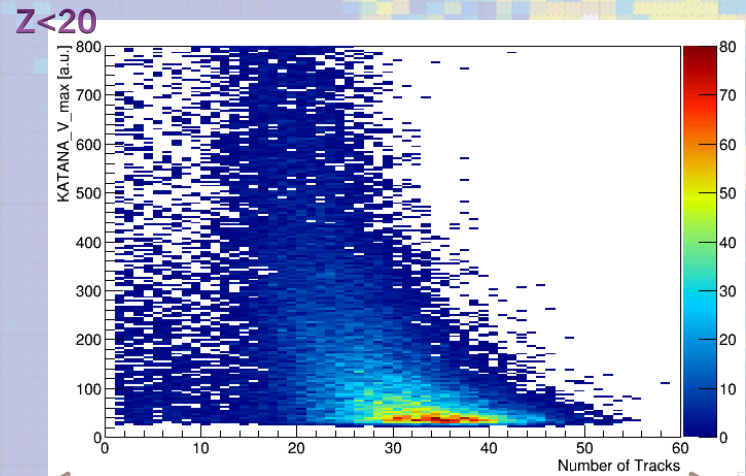
NeuLAND : Neutron detection



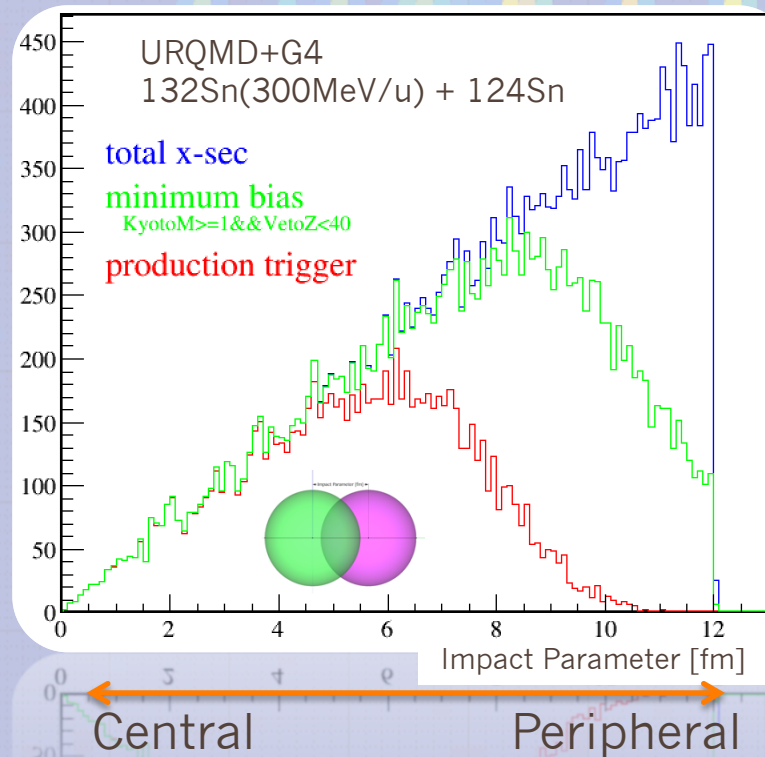
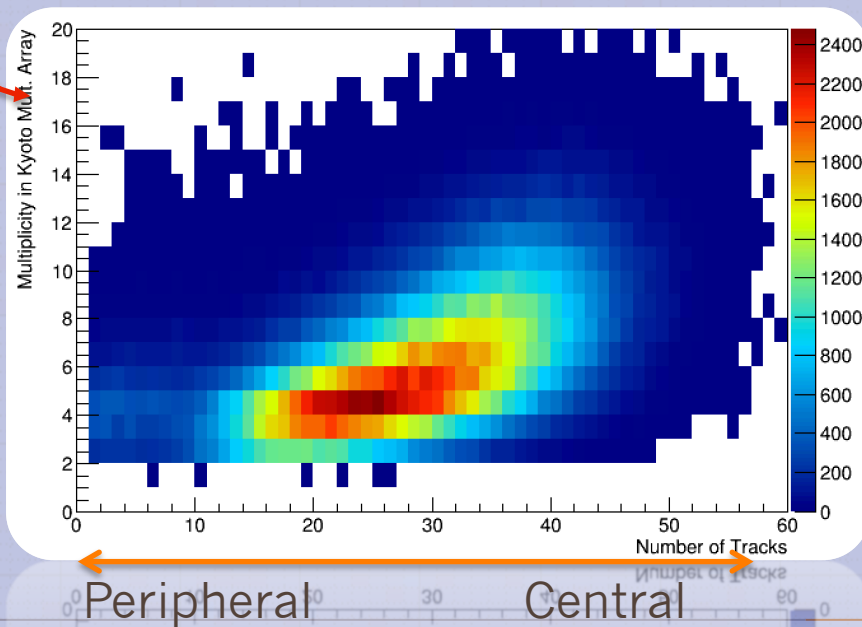
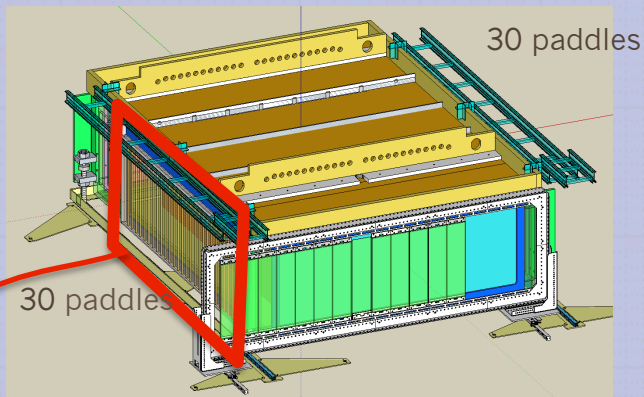
Centrality Trigger by charge of beam fragment with KATANA_V



- If beam like heavy fragment hits KATANA_V, veto trigger is generated.

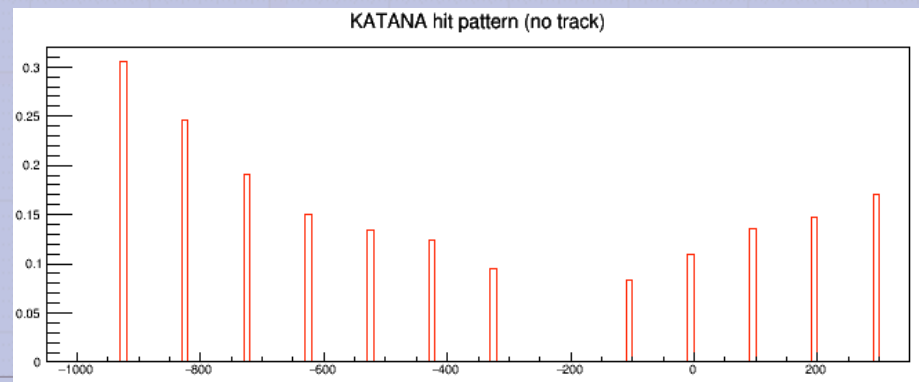
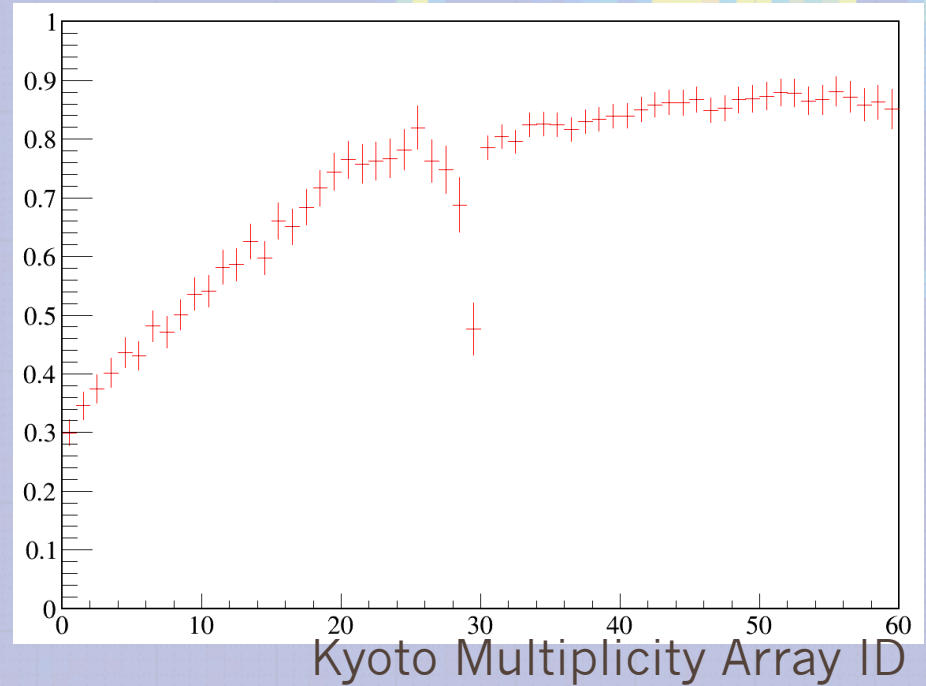
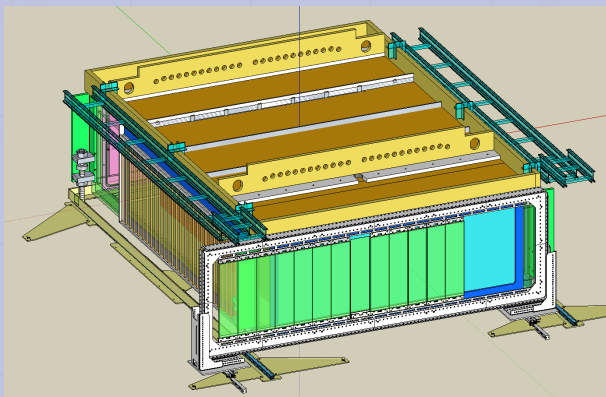


Centrality Trigger

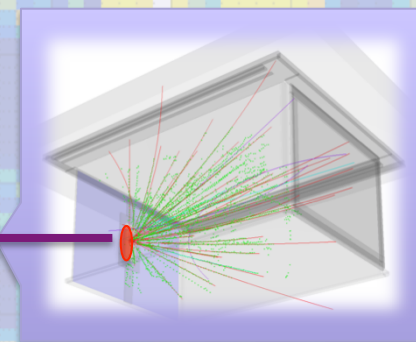
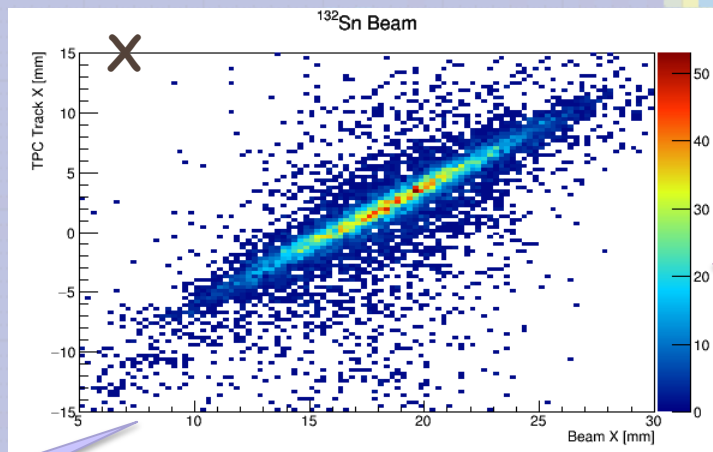


Tracking Efficiency

- Tracking efficiency can be estimated from the trigger arrays, KTANA and Kyoto Multiplicity Array.
- More than 80 % efficiency.

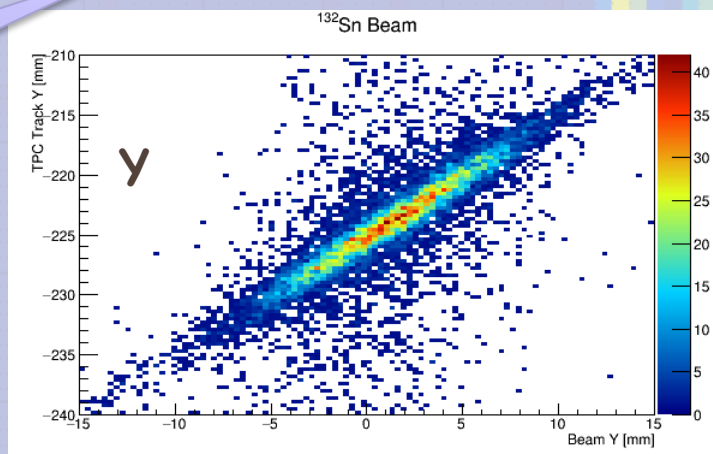
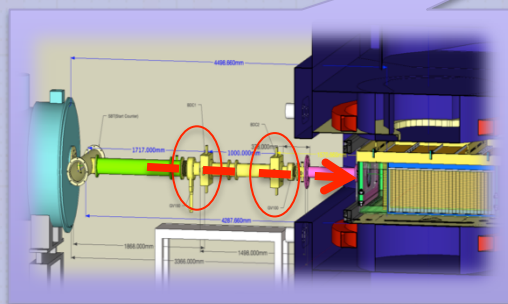


Correlation between Extrapolated track from TPC and Beam at the target.



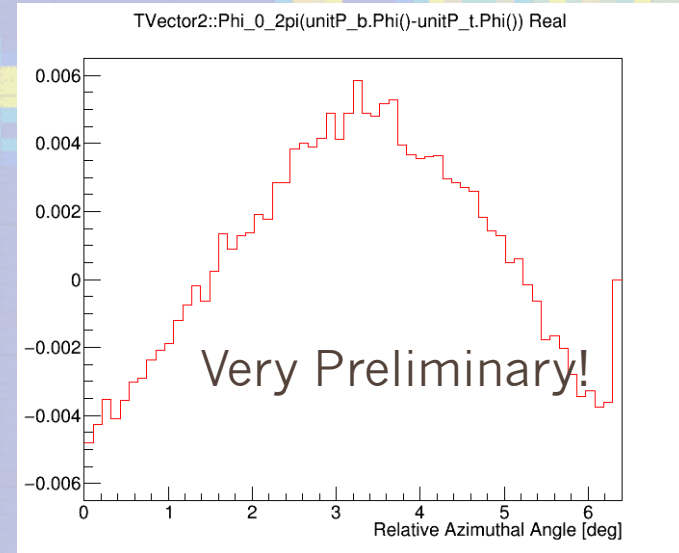
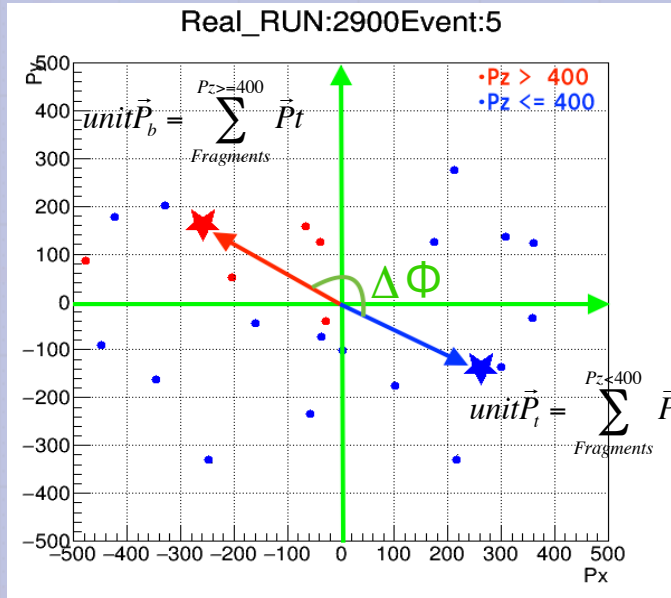
Each track extrapolated onto the target

Two drift chambers provide us beam position at the target

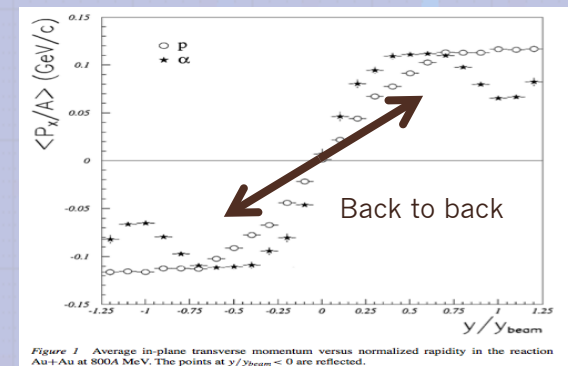


Nice correlation indicates the successful operation of DAQ synchronization and vertex reconstruction
Intrinsic spatial resolution is estimated to be $\sim 1\text{mm}$.

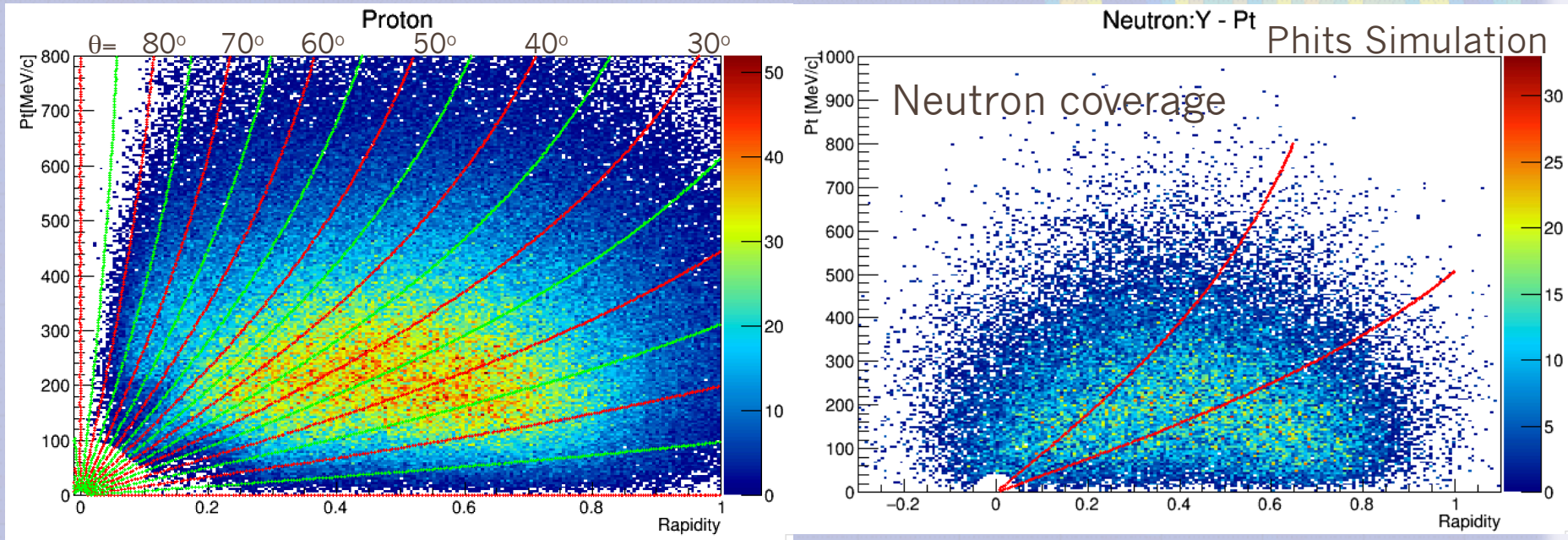
Flow Analysis



- Sub-event analysis indicates an evidence of directed flow.
- Azimuthal distribution of π^+ , n, p, d, t, ^3He , ^4He , w.r.t. the reaction plane can be studied.



Acceptance



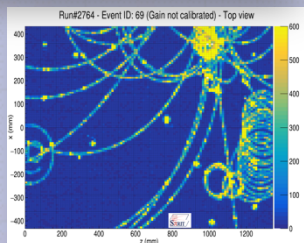
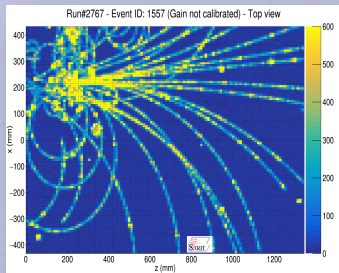
	thr.		Theta [deg]
pi+	30 ~	MeV/c	0 ~ 80
proton	100 ~	MeV/c	0 ~ 55
neutron	1 ? ~	MeV	22 ~ 43

Summary

- ❑ The first experiments were performed from April to June in 2016.
- ❑ For $(^{132}\text{Sn}+^{124}\text{Sn})$, $(^{108}\text{Sn}+^{112}\text{Sn})$ reaction, $\sim 10\text{M}$ triggers accumulated.
- ❑ π^- , π^+ , p , d , t , He were identified.
- ❑ Correlation between TPC and ancillary detectors confirmed that
 - ✓ Typical space resolution is $\sim 1\text{mm}$
 - ✓ Tracking efficiency is more than 80%
- ❑ Development of tracking reconstruction code has been on progressing
- ❑ The evidence of flow was observed.

- ❑ Perspectives
 - ✓ π^+/π^- ratio comparison among neutron rich and poor configurations.
 - ✓ Evaluate v_1 and v_2 for π^+ , π^- , n , p , d , t , ^3He , ^4He .
 - ✓ π^+/π^- , p/n ratio with respect to the reaction plane

Thank you for your attention



Other Participants: H. Baba, Chica, Ichihara, Kondo, T. Nakamura, H. Otsu, Saito, Togano
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- R. Shane (MSU)
- D. Suzuki (RIKEN)
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- Y. Zhang (Tsinghua U)

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