6th Korea-Japan PHENIX/sPHENIX/RHICf/EIC Collaboration Meeting

sPHENIX-INTT Silicon Tracker

G. Nukazuka (RIKEN BNL Research Center)
on behalf of the sPHENIX INTT group

Brookhaven National Laboratory

sPHENIX

RIKEN

INTT Group

3 countries,
9 institutes,
34 staff and students











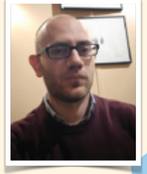

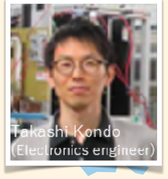









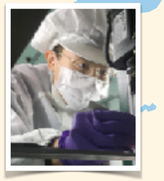






TIRI
Takashi Kondo

BNL
Rachid Nouicer, Dan Cacace,
Connor Miraval, Robert Pisani,
Steven Andrade, Donald Pinelli,
Antonio Vederosa, Sioan Zohar

Rikkyo Univ.
Hikaru Imai,
Genta Nakano,
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Shoichi Hasegawa

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Wei Xie,
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RIKEN, RBRC
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Lian-Sheng Tsai, Ou-Wei Cheng

National Central Univ.
Chia-Ming Kuo, Kai-Yu Cheng,
Cheng-Wei Shih, Wei-Che Tang

Nara Women's Univ.
Takashi Hachiya,
Maya Shimomura, Miu Morita,
Mika Shibata, Runa Takahama,
Yumika Namimoto, Yuka Sugiyama

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  - INTT ladder : silicon sensor, stave
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- **Barrel construction**

Flowing talks for sPHENIX INTT:

14:00 → 14:25 (25 min)
"INTT Silicon Ladder Performance",
Yumika Namimoto (Nara Women's Univ.)

14:25 → 14:45 (20 min)
"Development of Long and High Density Flexible Cable (Bus Extender) for INTT"
Takashi Hachiya (Radiation Laboratory, RIKEN and Nara Women's Univ.)

14:45 → 15:15 (30 min)
"INTT Bus Extender Performance",
Miu Morita (Nara Women's Univ.)

RHIC sPHENIX

- sPHENIX, a successor of PHENIX, will start data taking from 2023 to study quark-gluon plasma (QGP) and cold QCD physics at RHIC
- Main physics channels:
  - QGP: γ jet, b-quark tagged jet, Υ (1S, 2S, 3S), …
  - Cold QCD: transverse SSA (direct photon, D^0, and inclusive jet in the mid-rapidity), Collins FF, $p^{\uparrow}$+A…
- The detector complex covers full azimuthal angle 2π in $|\eta| < 1.1$ and $|z_{vtx}| < 10$ cm

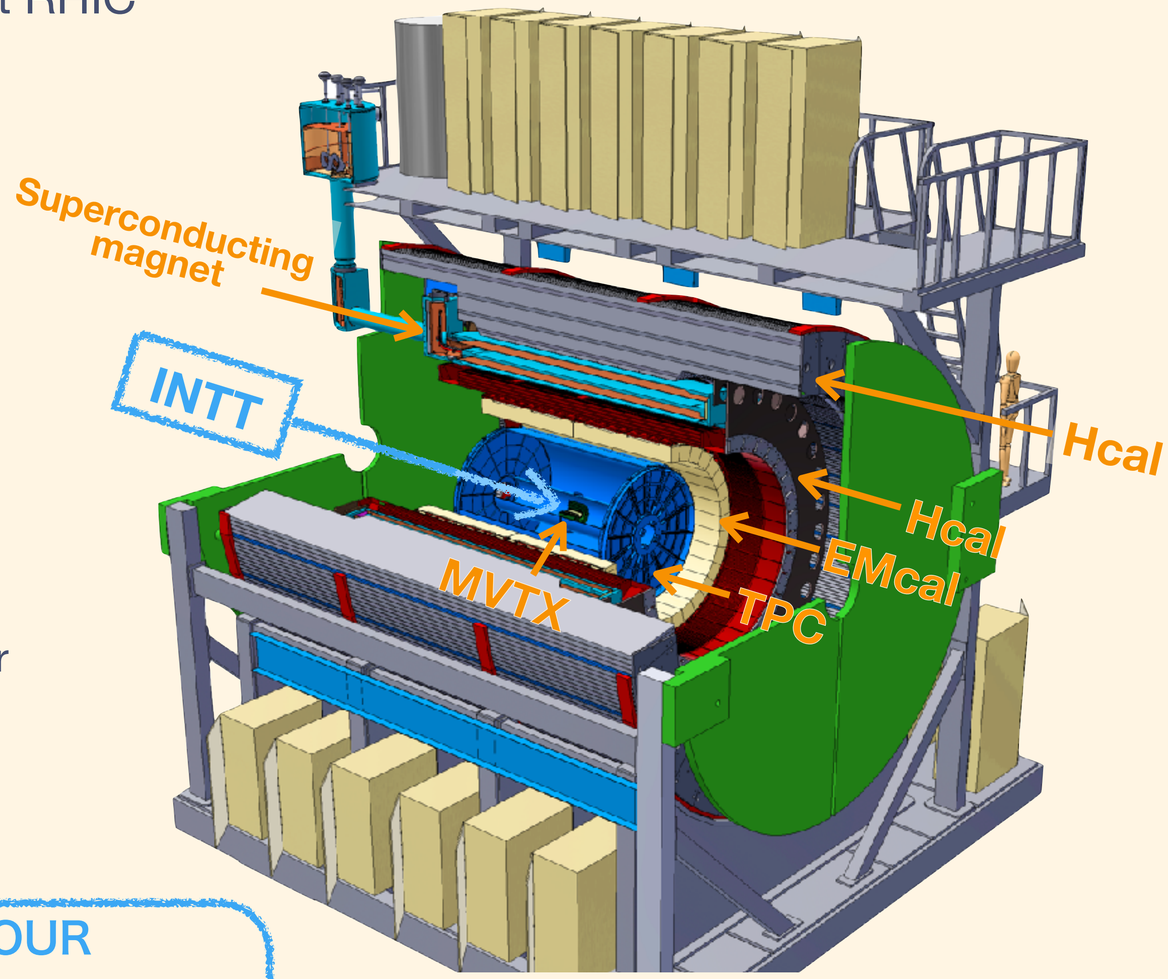
Magnet
Superconducting solenoid magnet from Babar at SLAC provides 1.5 T

Hadronic Calorimeter
(divided into inside and outside the magnet parts)
Inside part: non-magnetic metal and scintillator
Outside part: Ion and scintillator
Measurements can be done before multiple scattering of hadron shower by the cryostat for the magnet

ElectroMagnetic Calorimeter
consists of tungsten and scintillation fiber
compact, small segmentation ($\eta \times \phi = 0.024 \times 0.024$)

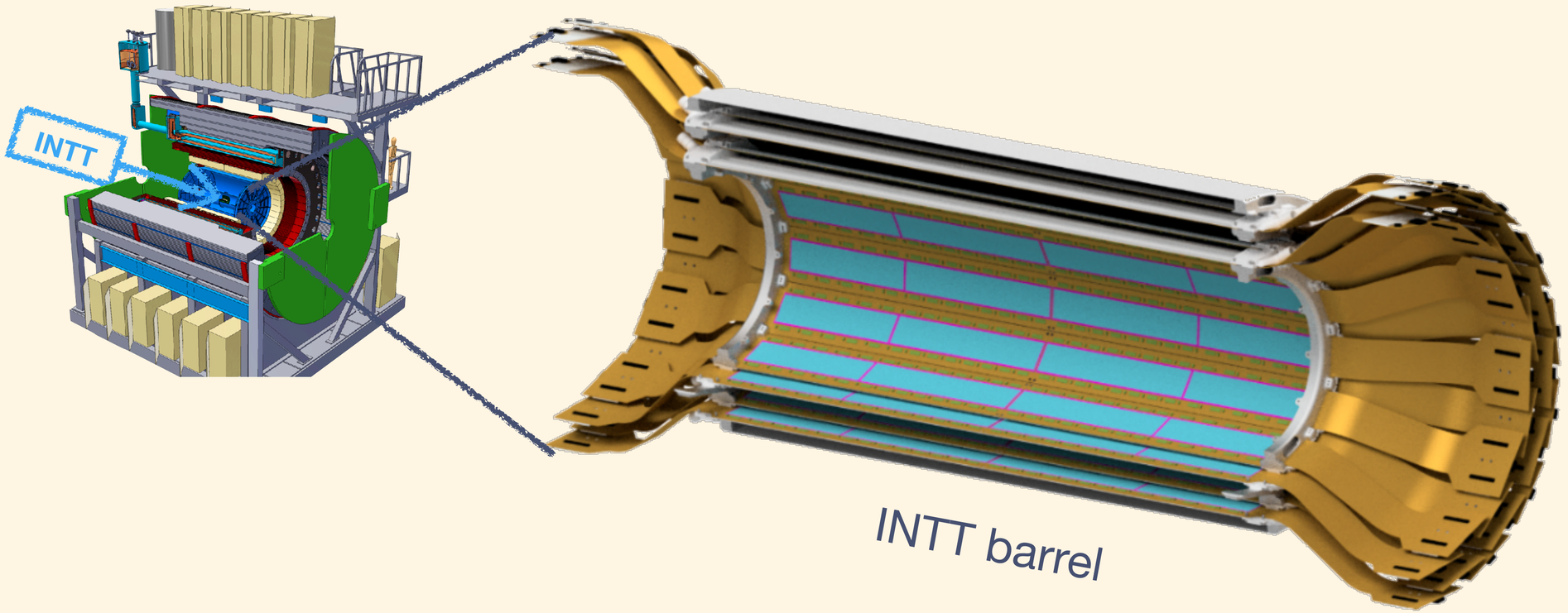
Charged Particle Tracking detectors
TPC: r < 80 cm, contributes good momentum resolution
INTT: r < 10 cm, (see the next page)
MVTX: r < 4 cm, Monolithic active pixel detector for vertex determination

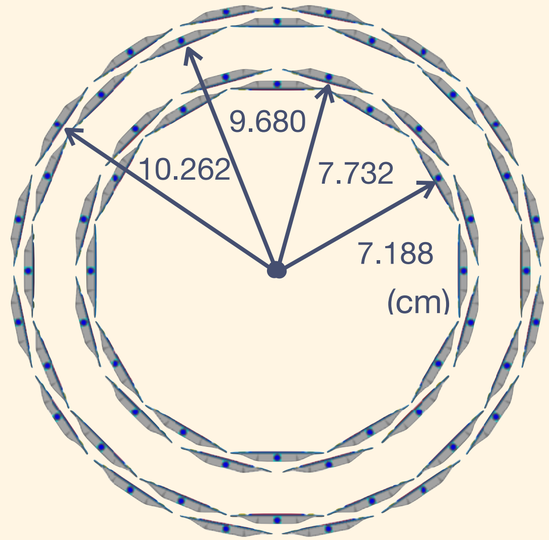
OUR RESPONSIBILITY



sPHENIX detector complex

Overview of Intermediate Silicon Tracker (INTT)



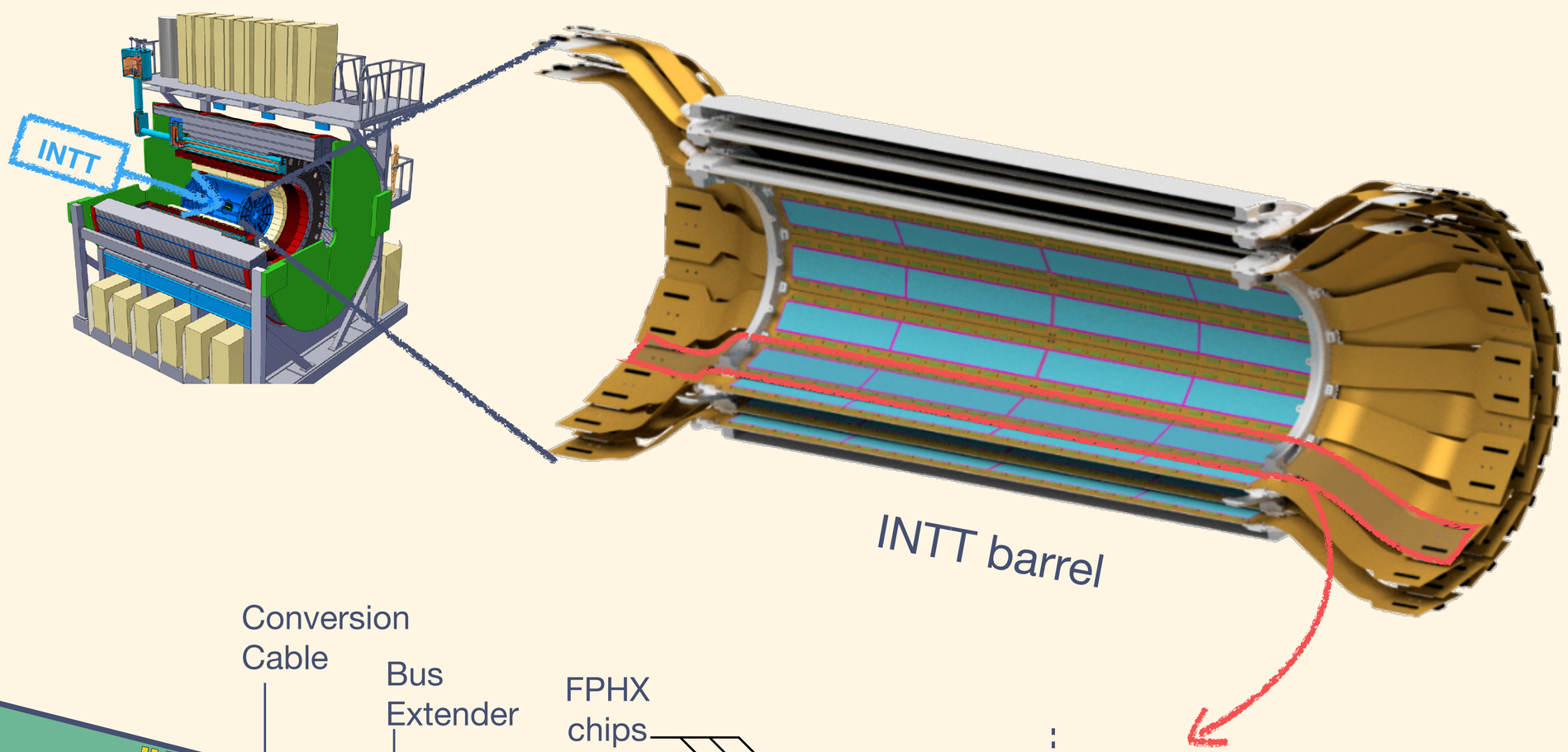


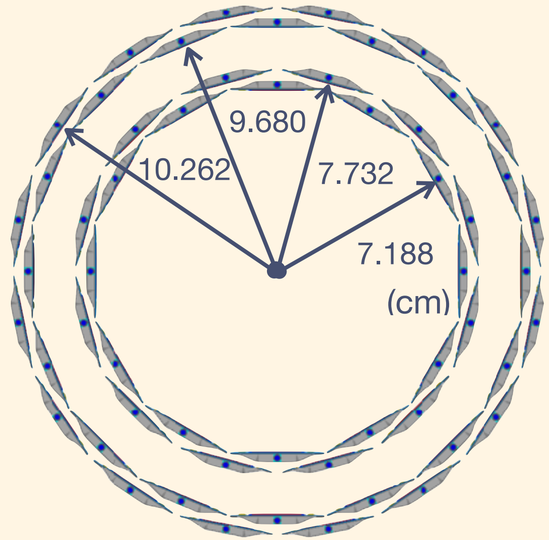
Cross-section of the INTT barrel

2 layers of barrel with silicon semiconductor strip detectors.

- Hits on INTT are used for track interpolation between TPC and MVTX.
- Operation at the bunch-crossing 106 ns (MVTX and TPC works at the order of μs - 10 μs)
- Full azimuthal angle coverage in the central rapidity region $|\eta| < 1.1$
- Low radiation length about $X/X_0 < 1.1\%$ / ladder
- 360k channels in total

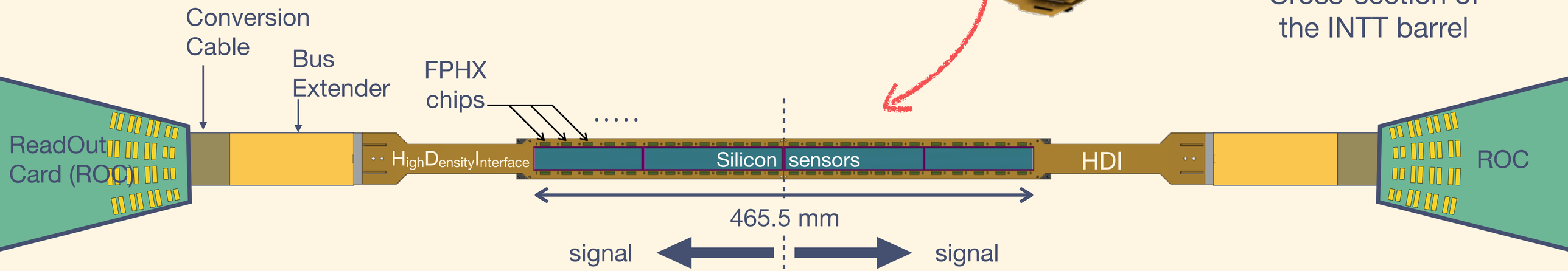
Overview of Intermediate Silicon Tracker (INTT)



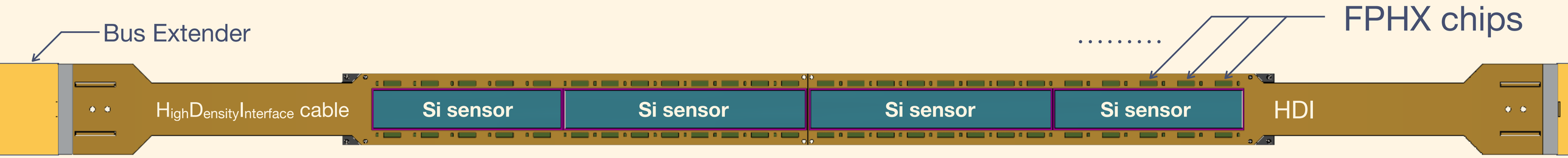


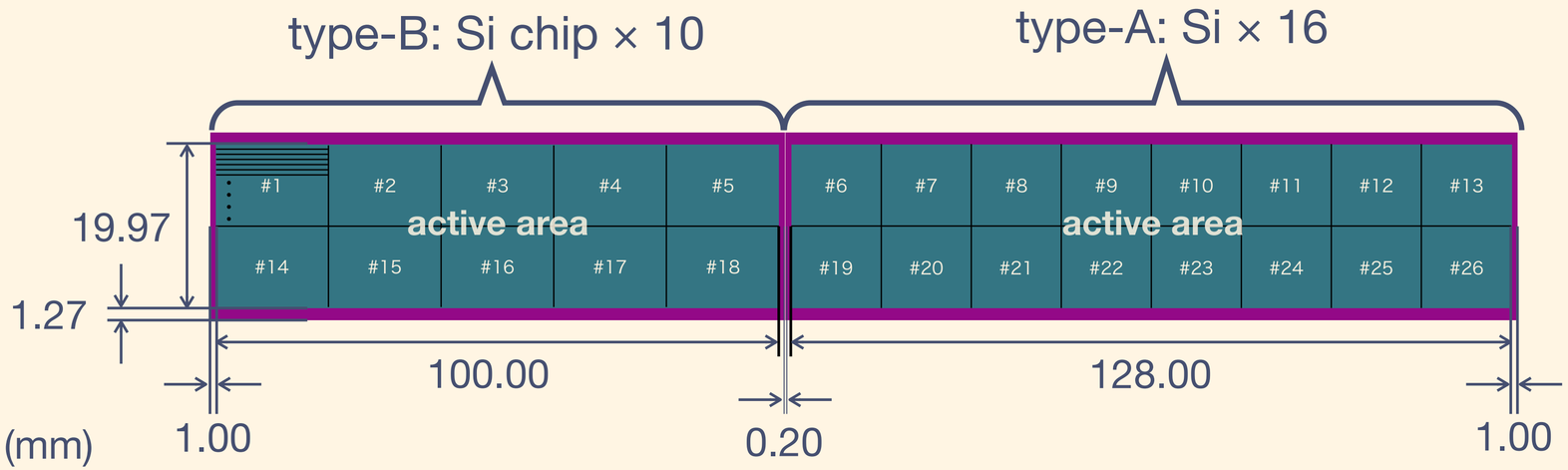
Inner ladders: 12 × 2
Outer ladders: 16 × 2
Total: 56

Cross-section of the INTT barrel



Intermediate tracker (INTT), ladder, silicon sensor

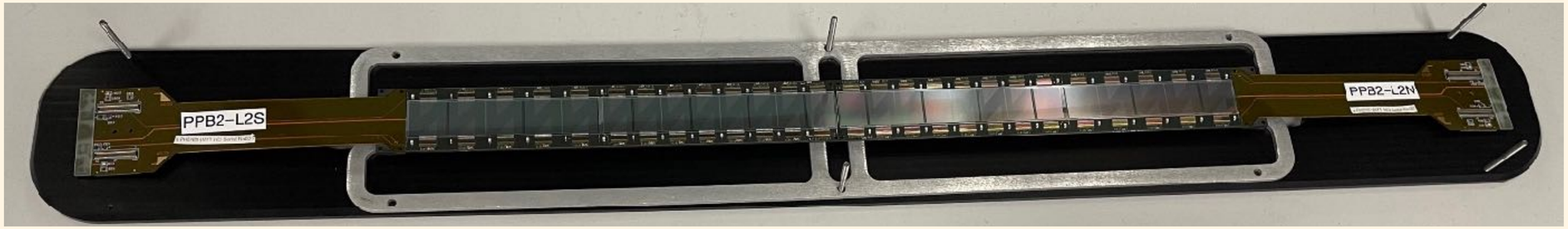




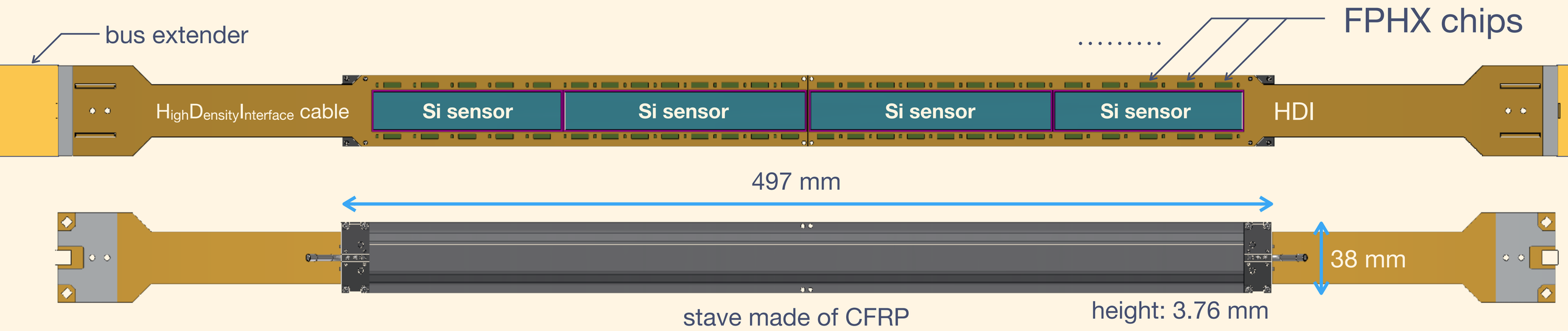
2 types of silicon module with thickness of 320 μm
（Hamamatsu, 78 μm × 16 mm or 20 mm）

#ch / ladder:
128 [ch/chip]
× (16+10) [chip / half ladder]
× 2 [half ladder / ladder]
= 6656 ch

AD conversion of signals created in a silicon chip is done by a chip implemented for PHENIX FVTX detector (FPHX chip)

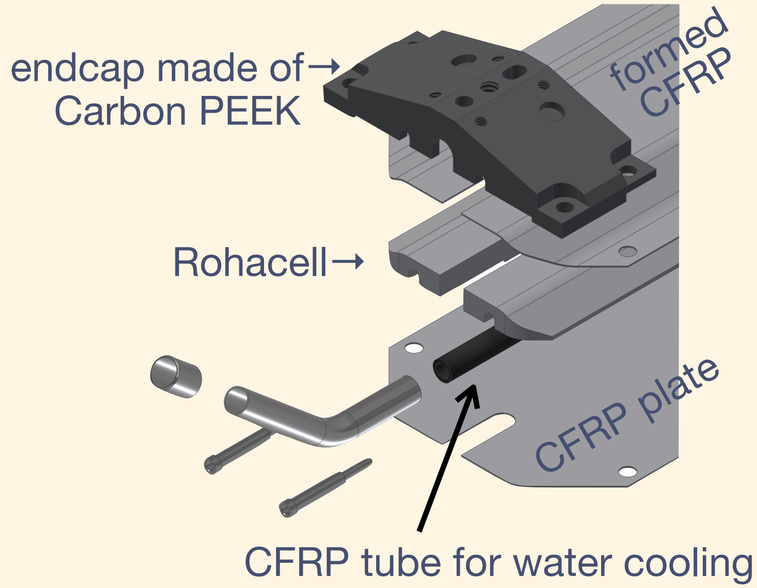


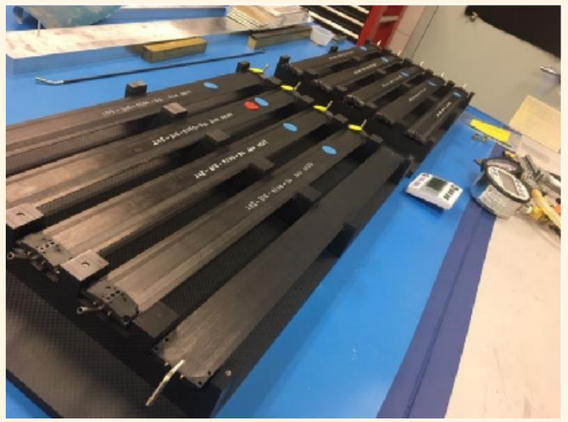
Intermediate tracker (INTT), ladder, outer side



Stave

- Flat CFRP stave
  carbon fiber with very high thermal conductivity 500 W/m K
  flatness: 100 μm
- Formed CFRP plate
- CFRP tube for water cooling
- Rohacell
- Endcap made of Carbon PEEK
- Components are glued with epoxy adhesive





Mass production of most of components (silicon sensor, FPHX chips, HDIs, conversion cables) were already finished.

Production

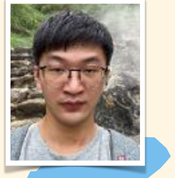

























BNL

- Mass production of ladders
  ~50 ladders already produced
- Construction of the INTT barrel
- Tests for produced ladders

some ladders for tests
ROCs for upgrade

Taiwan

- Mass production of ladders
  30 half ladders and
  2 ladders already produced
- Tests for produced ladders

a lot of ladders

some ladders for tests

Japanese group

- ☑ Production of silicon sensors, HDIs
- ☑ Production of carbon stave
- ☑ R&D for bus extenders
- ☐ Production of bus extenders

NWU/RIKEN testbenches

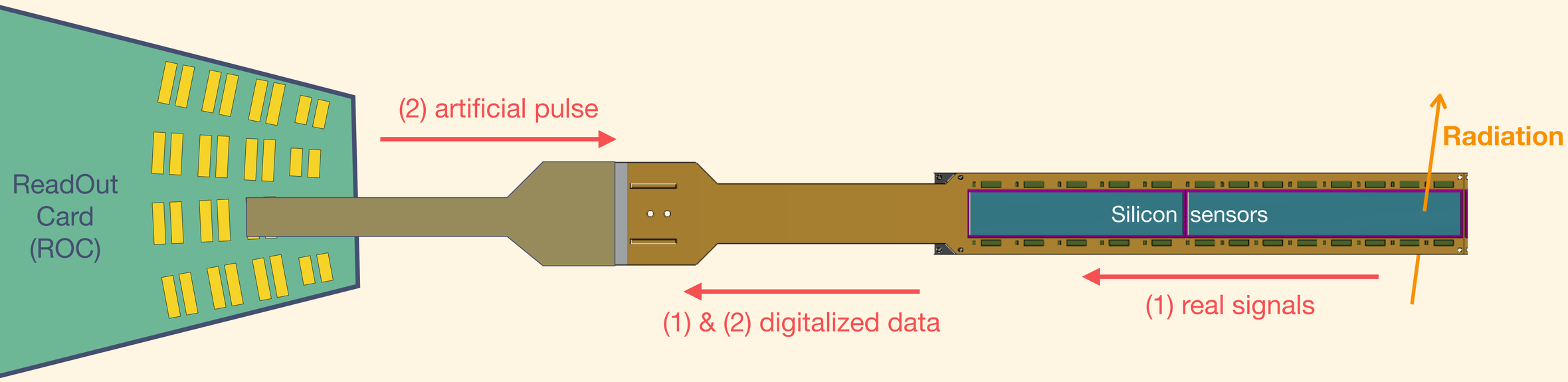
- Tests for produced ladders
- Performance evaluation
- ROCs upgrading and tests
- Debugging
- etc.

Operation of testbench

Our testbenches can be operated in 2 modes:

(1) Radiation: Measurement of the real signal generated in the silicon sensor

(2) Calibration: Measurement of artificial pulse from ROC



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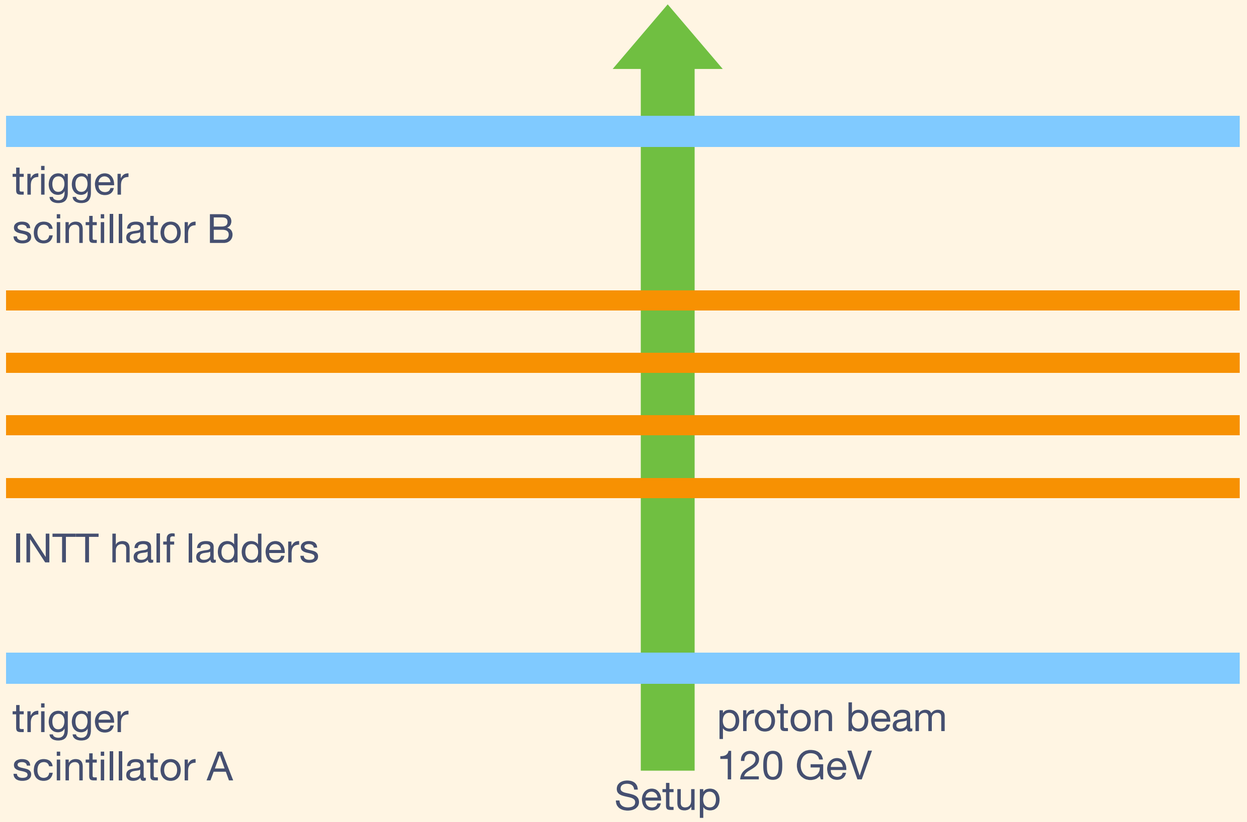
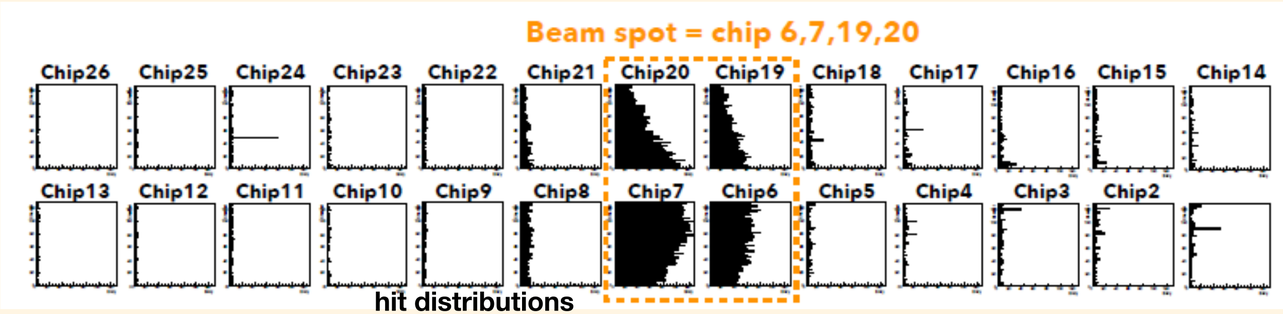
Test beam experiments

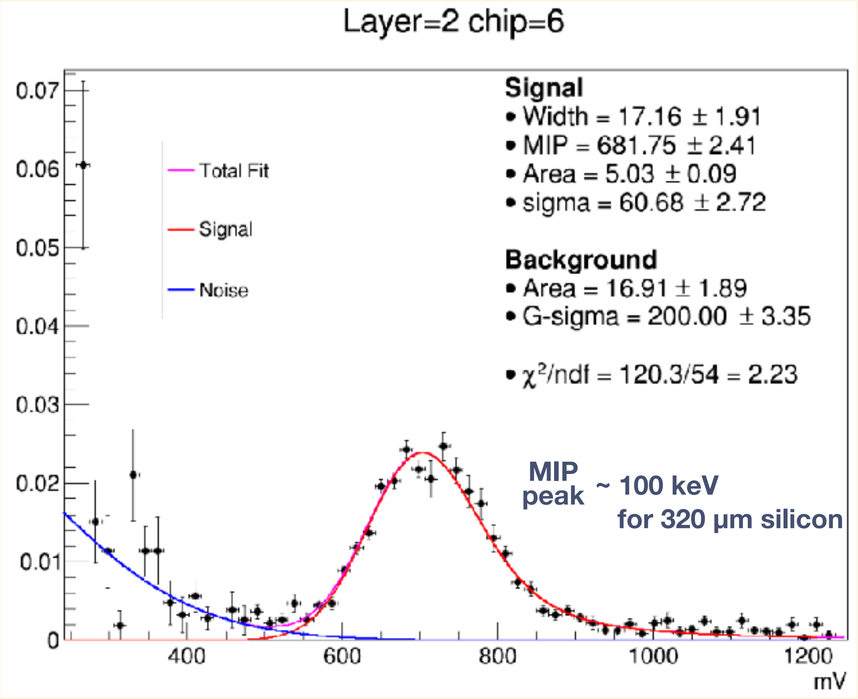




S. Suzuki, Master thesis, Nara Women's University, 2020

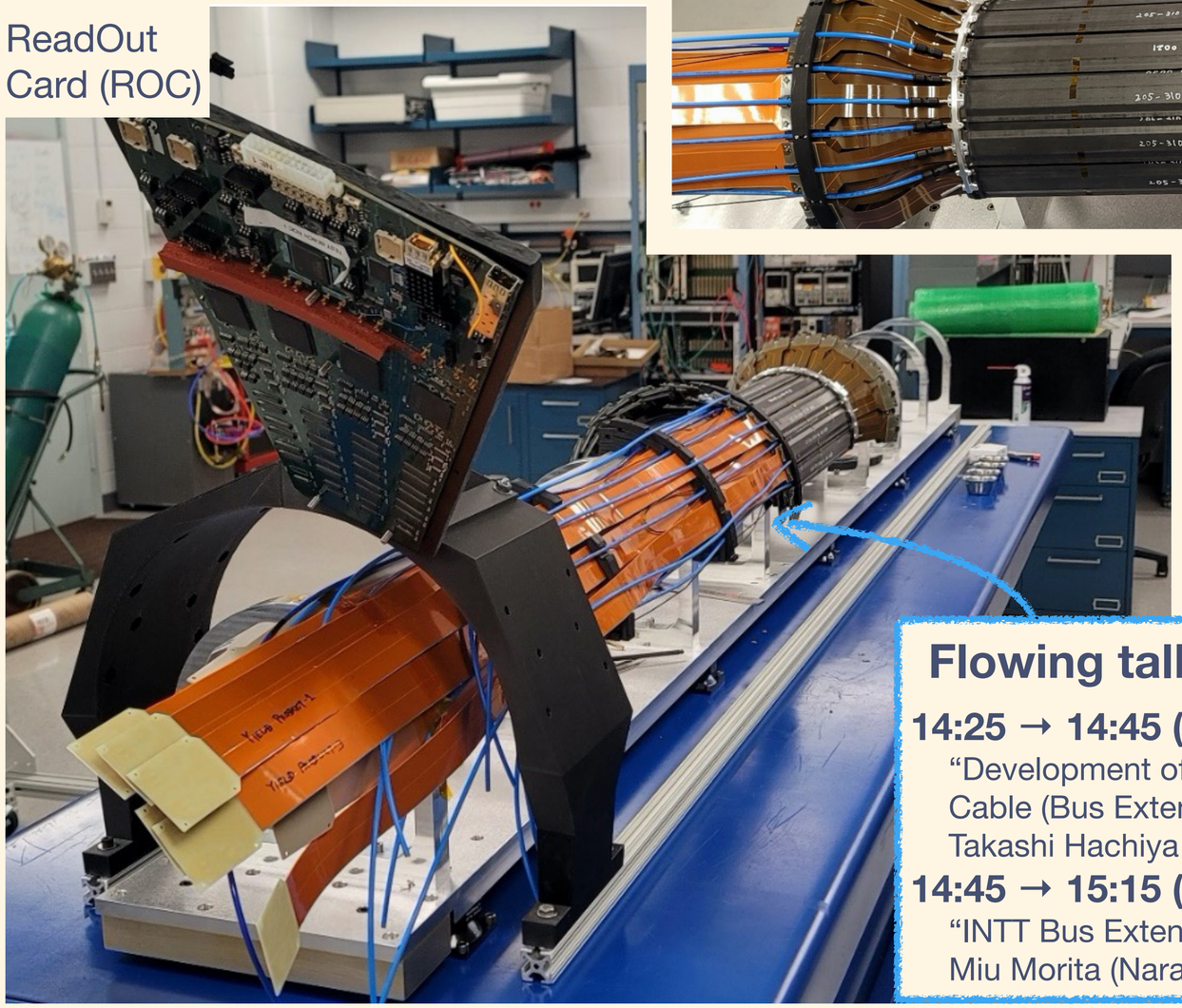
- Performance evaluations with beam were performed twice. In the recent experiment with 120 GeV proton beam at FNAL in 2019,
  - beam position distribution
  - MIP peak (20000 e)
  - signal/Noise ~ 20
  - detection efficiency: 96.0 ± 0.6%

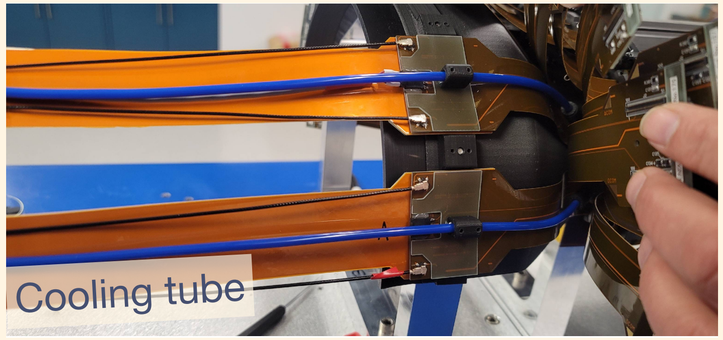
  were measured. We plan the next experiment with the latest ladders, bus extenders, etc.



INTT Barrel Assembly at BNL: Mockup

ReadOut
Card (ROC)





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Summary

RHIC sPHENIX Collaboration

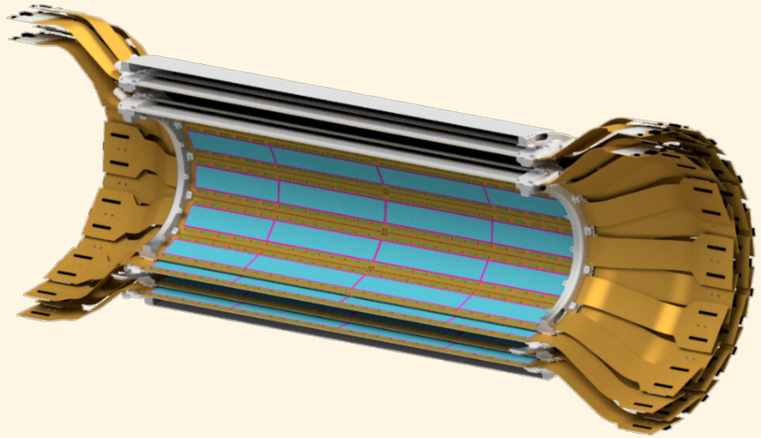
- sPHENIX will start data taking from 2023 to study QGP and cold QCD physics. γ-jets, b-quark tagging, and Y(1S, 2S, 3S) measurements are main channels for QGP while TSSA of direct photon, and inclusive jet, Collins FF, etc. for cold QCD physics.

The Intermediate silicon tracker (INTT)

- consists of 2 layers of barrel silicon semiconductor strip detectors.
- covers full azimuthal angle in $|\eta| < 1.1$, $|z_{vtx}| < 10$ cm.
- 56 ladders forms 2 layers of the barrel.
  - consists of silicon modules (78 μm strip, 320 μm thickness, 128 ch × 26 chips × 2), FPHX chips, HDI, CFRP stave.

Status of mass production, test beam experiments, construction

- Most of components are ready.
- Mass production of ladders are ongoing at BNL and Taiwan.
- Test beam experiments were done twice with prototype components.
- Mockup of the INTT barrel is under construction.



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