INTT Ladder NIM and Publication Plan

RIKEN/RBRC

Itaru Nakagawa

on behalf of INTT Group

191th sPHENIX Fortnightly Meeting

Friday Feb 7, 2025, 12:00 PM → 2:35 PM US/Eastern

1008 conference room (Universe)

Description

ZOOM connection

Join ZoomGov Meeting
https://bnl.zoomgov.com/j/1617309690?pwd=EI7Mv9sw6AwlV0JSLchfLRsdR2Ioq9.1

Meeting ID: 161 730 9690
Passcode: 041516

Recording

To be posted here

12:00 PM → 12:10 PM **INTT NIM paper** 10m
Speaker: Dr Itaru Nakagawa (RIKEN)

12:10 PM → 12:30 PM **Collaboration news** 20m
Speakers: Dr Jin Huang (Brookhaven National Lab), Megan Connors (Georgia State University)

12:30 PM → 12:50 PM **Speaker's bureau news** 20m
Speaker: Marzia Rosati (Iowa State University (mrosati@iastate.edu))

12:50 PM → 1:10 PM **Shutdown progress and Run 25 preparations** 20m
Speakers: Joel Vasquez, John Haggerty (Brookhaven National Laboratory), Ron Belmont (University of North Carolina Greensboro), Rosi Reed (Lehigh University)

1:10 PM → 1:30 PM **Computing/production news** 20m
Speakers: Chris Pinkenburg (BNL), Joe Osborn (Brookhaven National Laboratory), Sasha Lebedev (ISU)

Proposed plan for INTT Publications

Topics	Target Journal	Leading Author	Timeline	Remaining Issues
Bus Extender ✔ (Electrical)	The Japan Institute of Electronics Packaging	Takashi Kondo (TIRI)	2022/May → published Aug. 2022	To be announced from Takashi later
2021 Beam Test✔	ELPH Ann. Rprt.	Genki/Cheng-Wei	2022/Winter	ADC distribution, Resolution, Efficiency, cluster size
2021 Beam Test	NIM		2025/Summer	
Bus Extender (Mechanical)	NIM	Takashi	2025?	Final evaluation of the yield rate
INTT Ladder	**NIM**	**Itaru**	**2025/Winter**	**Ladder, BEX, CC, ROC**
INTT Barrel	NIM	Itaru/Rachid	2025/Summer	Felix, mechanical structure, cooling/power system, stream readout, etc.

Bus Extender Published Paper ✔

[Technical Paper]

Development of Long and High-Density Flexible Printed Circuits

Takashi Kondo[1]*, Kohei Fujiwara[1], Takashi Hachiya[2,3], Hikaru Imai[4], Miu Morita[2], Itaru Nakagawa[3,4], Naoyuki Sato[5], Masato Tsuruta[4], and Daisuke Yanagawa[5]

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(Received August 3, 2021; accepted July 7, 2022, published August 4, 2022)

- Only Japanese authors (Students involved in R&D ~2021)
- Focus on electrical property of the bus extender
- Mechanical property such as radiation hardness or mass production technologies are to be discussed in other NIM paper.

Abstract

The super Pioneering High-Energy Nuclear Interaction eXperiment (sPHENIX), which aims to unravel the mysteries of the creation of the universe, is scheduled to be launched in 2023 at Brookhaven National Laboratory, U.S.A, using the relativistic heavy ion collider. As a typical high-energy particle accelerator-based experiment, the collision area of sPHENIX is to be tightly occupied with various radiation detectors, requiring a minimal special budget to run cables and transmit massive signals generated by these detectors to downstream electronics for data processing located in a remote distance. Accordingly, a long, high signal line-density cable has been developed based on the flexible printed circuit (FPC) technology. FPC comprises multilayers and has extraordinarily long and thin transmission lines. Liquid crystal polymer was employed to suppress losses in transmission lines. Electrical characteristics were evaluated using S-parameters, time domain reflectometry, and eye-diagrams. Furthermore, we have developed manufacturing technology to achieve high-precision microfabrication and improved reliability, which has been demonstrated in peel strength and thermal shock tests. FPC is currently in the mass production phase.

Keywords: FPC, LCP, S-parameter, TDR, Eye-diagram, Peel Strength, Through-hole Plating, Radiation Detector Cable

1. Introduction

Scheduled to start in 2023, sPHENIX is a novel experiment set up to study a deconfined state of nuclear matter, the quark-gluon plasma (QGP) created in high-energy heavy-ion collisions at the Relativistic Heavy Ion Collider. [1] The intermediate tracker (INTT) is a novel silicon strip detector that can measure more than 1,000 particles generated in collisions. The massive raw data generated from INTT are transmitted at high-speed to downstream electronics for signal-processing through the narrow, curved cable path for longer than 1 m.

Because no commercial cable satisfies the requirement, a novel cable has been developed based on flexible printed circuits (FPC). This technology can simultaneously satisfy high-density signal lines, length, and flexibility.[2–7]

*: Corresponding author

2. Design

2.1 Requirements

Long and high-density signal lines FPCs are required a signal transmission medium for the INTT detector to newly developed for the sPHENIX. Because the transn sion lines are required to be long and thin, in the devel ment, it is severely challenging to suppress the sig attenuation and manufacture the fine lines with high ac racy. In addition, high mechanical reliability is requi owing to strictly limited access for the maintenance of isolated detector region. The region is to be designated a radiation area during the experiment; hence, detect are fully operated remotely. Furthermore, the FPC installed in a confined space of the sPHENIX detec complex, and is exposed to a high radiation environm from the collision point and external noise from other nal cables running close to each other. These constrai facilitate the structure of multilayered FPC design,

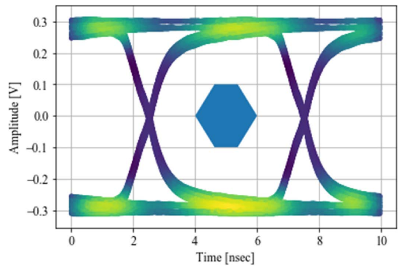

Fig. 4 Simulation results for eye-diagram

(a) Overall view

(b) Connector section

Fig. 5 FPC prototype

line was also confirmed. The gradual increase in the impedance in the time axis direction is a significant characteristic; however, it is known as the effect of the reflected signals that are gradually attenuated by long and thin transmission lines.

To verify that the square-shaped digital signal can be transmitted to a receiver with minimum distortion, the

Acknowledgement

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2021 Beam Test Results ✓

Coarse introduction of INTT→

(ELPH Experiment : #2984)

Performance evaluation of the Intermediate Tracker for sPHENIX

G. Nukazuka[1], C.W. Shih[2], Y. Sugiyama[3], Y. Akiba[1], H. En'yo[1,4], T. Hachiya[3], S. Hasegawa[5], M. Hata[3], H. Imai[4,6], M. Morita[3], I. Nakagawa[1,4], Y. Nakamura[6], G. Nakano[6], Y. Namimoto[3], R. Nouicer[7], M. Shibata[3], M. Shimomura[3], R. Takahama[3], K. Toho[8], M. Tsuruta[8], and M. Watanabe[3]

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Three leading authors: Genki, Cheng-Wei, Yuka for their major contribution to the analysis

§2. INTT

INTT is a silicon strip barrel detector consisting of two layers of silicon strip sensors surrounding the collision point seven to ten centimeters away (Figure 1). Hits detected by this detector are used not only for interpolation of tacking between MVTX and TPC but also bunch-crossing identification to suppress event-pileup background thanks to the best timing resolution of all tracking detectors in sPHENIX. 24 or 32 INTT ladders form the inner and outer layers. The INTT ladder (Figure 2) consists

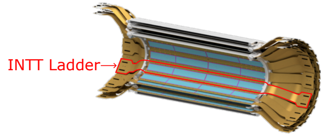


Fig.1. A half part of the INTT barrel. The inner and the outer barrels consist of 24 and 32 INTT ladders, respectively. The red box indicates an INTT ladder.

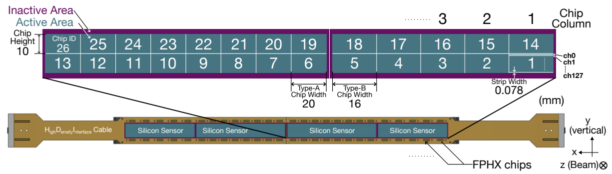


Fig.2. The INTT ladder consists of two types of silicon sensors, FPHX chips, High-Density Interconnect cable, and CFC stave. The sensors are divided into 10 or 16 cells. The silicon cells have 128 strips with 78 µm width and 320 µm thickness. The x-, y-, and z-axes in the test beam experiment are also shown.

DAC Scan→

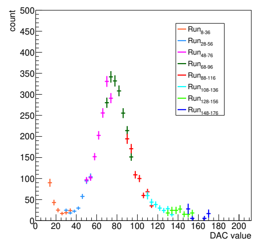


Fig.4. The ADC distribution of the eight runs after normalization. The legend indicates the scanning region of the runs.

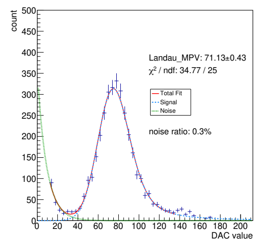


Fig.5. The energy deposit curve as a function of DAC value. Fitting to the distribution with the sum (red) of a Landau-Gaussian convolution function (dotted blue) and an exponential function (dashed green) is also shown.

position, as we expected. In the experiment, the runs with different beam-spot positions were conducted. The efficiency from the run is shown on the right-hand side of Figure 10. The detection efficiency was over 99% at the edge. Therefore, the performance of the INTT ladder was excellent over the column.

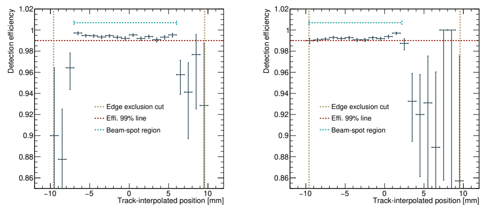
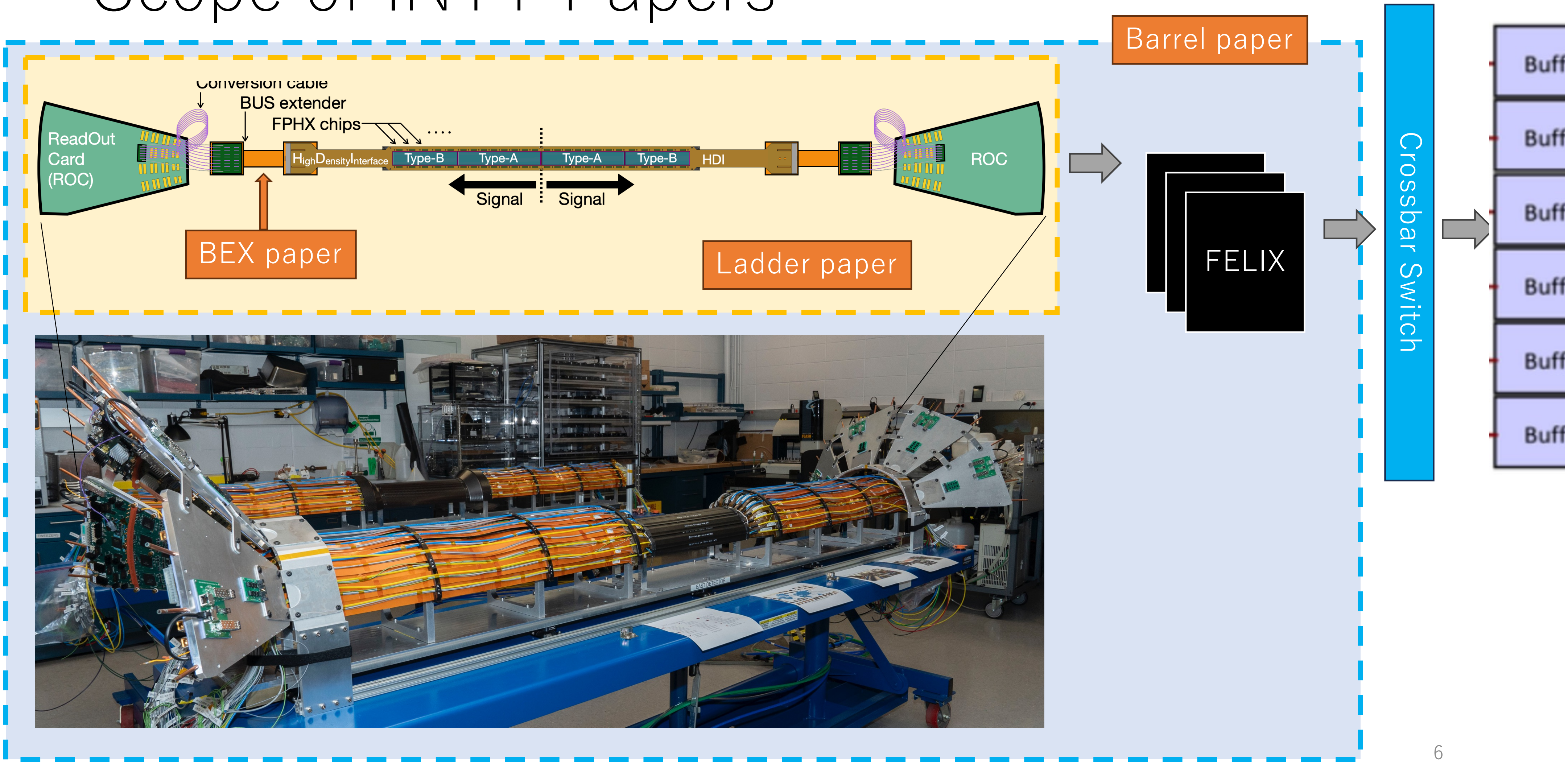


Fig.10. The detection efficiency as a function of the track position. (Left) The beam spot is in the middle. (Right) The beam spot aligns with the edge. The error bars indicate the statistic uncertainties.

→ Detection Efficiency ~ 99%

Scope of INTT Papers



INTT Ladder NIM

The Ladder and Readout Cables of Intermediate Silicon Strip Detector for sPHENIX★

Y. Akiba[a,b], H. Aso[g,a], J. T. Bertaux[i,b], D. Cacace[c], K. Y. Chen[d], K. Y. Cheng[d,b], A. Enokizono[a], H. Enyo[a,b], K. Fujiki[g,a], Y. Fujino[g,a], M. Fujiiwara[e,a], T. Hachiya[e,b], T. Harada[g,a], S. Hasegawa[f], M. Hata[e,b], B. Hong[k], J. Hwang[k,b], T. Ichino[g,a], M. Ikemoto[e,a], H. Imagawa[g,a], H. Imai[g,a,b], Y. Ishigaki[e,a], M. Isshiki[e], K. Iwatsuki[e,a], R. Kan[e], M. Kano[e,a], T. Kato[g,a], Y. Kawashima[g,a], T. Kikuchi[g,a], T. Kondo[h], C. M. Kuo[d], C. Kureha[e], T. Kumaoka[a], H. S. Li[i], R. S. Lu[j], E. Mannel[c], H. Masuda[g,a], G. Mitsuka[b], N. Morimoto[e,a], M. Morita[e,b], I. Nakagawa[a,b,*], Y. Nakamura[g,a], G. Nakano[g,a], Y. Namimoto[e,b], D. Nemoto[g,a], S. Nishimori[e], R. Nouicer[c], G. Nukazuka[a], I. Omae[e,a], R. Pisani[c], Y. Sekiguchi[a], M. Shibata[e,b], C. W. Shih[d,b], K. Shiina[g,a], M. Shimomura[e], R. Shishikura[g,a], M. Stojanovic[i,b], K. Sugino[e], Y. Sugiyama[e], A. Suzuki[e,b], R. Takahama[e,b], W. C. Tang[d,b], Y. Terasaka[e], T. Todoroki[b], H. Tsujibata[e,a], T. Tsuruta[g,a], Y. Yamaguchi[b], H. Yanagawa[g,a], M. Watanabe[e,b], R. Xiao[i] and W. Xie[i]

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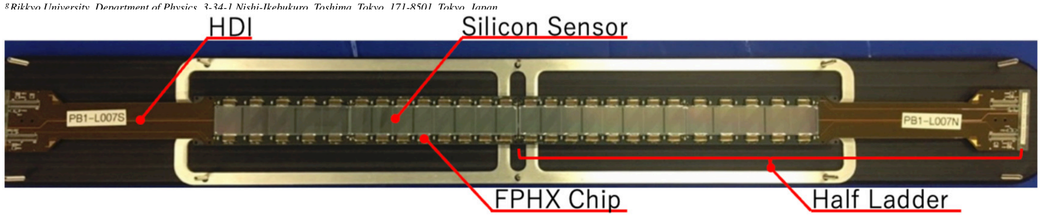
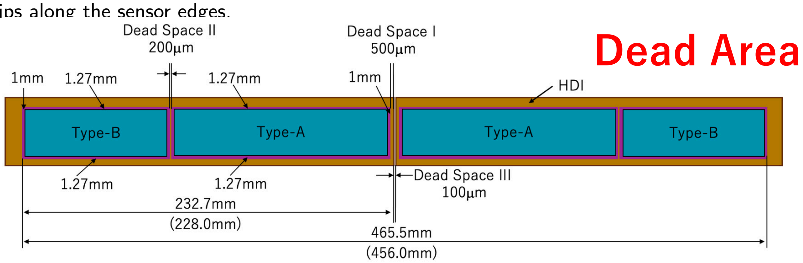
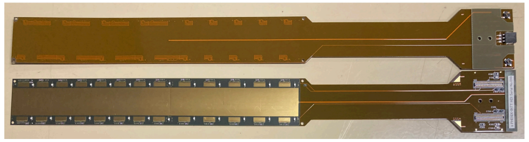


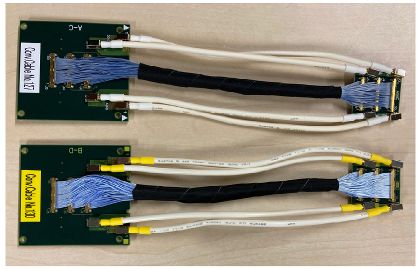
Figure 2: Photo of the INTT ladder with sensors facing up. Note the center line dividing the two halves of the sensor and the rows of FPHX chips along the sensor edges.

Dead Area



Cables





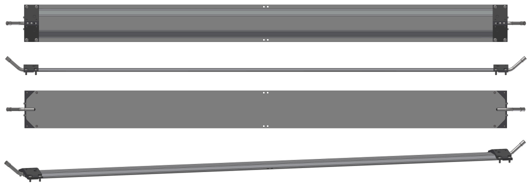


Figure 9: The INTT stave. The HDI is assembled on the bottom flat CFC plate.

Material Budget

Table 9
The material budget of the silicon ladder. The TC-2810 is the thermally conductive glue. The radiation thickness of the HDI listed in the table is for the production batch 1 and 2.

Item	Thickness mm	Radiation Length X/X_0 %
Silicon Sensor	0.32	0.34
Silver epoxy	0.01	0.02
HDI	0.42	0.43
TC-2810	0.05	0.02
Stave	3.76	0.33
Total	4.56	1.14

Radiation Hardness

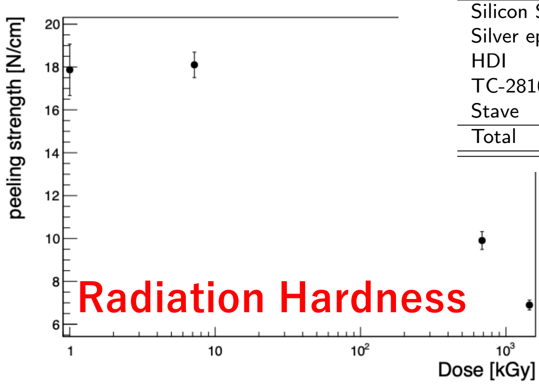


Figure 17: The peel strength measurement results of samples exposed to various radiation doses. The vertical axis is the peel strength in units of N/cm, while the horizontal axis is radiation dose in units of kGy. The measurement of the sample with no radiation exposure is plotted at 1 kGy on purpose.

Scope for the Barrel NIM

The Barrel Type Intermediate Silicon Strip Detector for sPHENIX★

Y. Akiba[a,b], H. Aso[g,a], J. T. Bertaux[i,b], D. Cacace[c], K. Y. Chen[d], K. Y. Cheng[d,b], A. Enokizono[a], H. Enyo[a,b], K. Fujiki[g,a], Y. Fujino[g,a], M. Fujiiwara[e,a], T. Hachiya[e,b], T. Harada[g,a], S. Hasegawa[f], M. Hata[e,b], B. Hong[k], J. Hwang[k,b], T. Ichino[g,a], M. Ikemoto[e,a], H. Imagawa[g,a], H. Imai[g,a,b], Y. Ishigaki[e,a], M. Isshiki[e], K. Iwatsuki[e,a], R. Kan[e], M. Kano[e,a], T. Kato[g,a], Y. Kawashima[g,a], T. Kikuchi[g,a], T. Kondo[h], C. M. Kuo[d], C. Kureha[e], T. Kumaoka[a], H. S. Li[i], R. S. Lu[j], E. Mannel[c], H. Masuda[g,a], G. Mitsuka[b], N. Morimoto[e,a], M. Morita[e,b], I. Nakagawa[a,b,*], Y. Nakamura[g,a], G. Nakano[g,a], Y. Namimoto[e,b], D. Nemoto[g,a], S. Nishimori[e], R. Nouicer[c], G. Nukazuka[a], I. Omae[e,a], R. Pisani[c], Y. Sekiguchi[a], M. Shibata[e,b], C. W. Shih[d,b], K. Shiina[g,a], M. Shimomura[e], R. Shishikura[g,a], M. Stojanovic[i,b], K. Sugino[e], Y. Sugiyama[e], A. Suzuki[e,b], R. Takahama[e,b], W. C. Tang[d,b], Y. Terasaka[e], T. Todoroki[b], H. Tsujibata[e,a], T. Tsuruta[g,a], Y. Yamaguchi[b], H. Yanagawa[g,a], M. Watanabe[e,b], R. Xiao[i] and W. Xie[i]

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ARTICLE INFO

Keywords:
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INTT
Silicon Detector
FELIX
Stream readout

ABSTRACT

A new barrel type silicon detector was constructed in the central rapidity region of sPHENIX detector complex as a part of its tracking system. The sPHENIX is the novel detector launched in 2023 and has been commissioned using proton+proton and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at the Relativistic Heavy Ion Collider in Brookhaven National Laboratory. The new silicon detector is called intermediate tracker (INTT) provides a single event timing resolution and establishes advanced tracking together with a CMOS monolithic-active-pixel-sensor (MAPS) based silicon-pixel vertex detector (MVTX), a time-projection chamber (TPC), and a micromegas-based detector. The INTT detector is two layer structure of full azimuth coverage and its inner and outer barrels comprise of 24 and 32 silicon ladders, respectively. Each silicon ladder consisted of four silicon strip sensors to cover the rapidity range of $-1.1<\eta<1.1$ at the radial distance of 7 to 10.3 cm from a beam axis. The silicon sensor is 78 μ pitch, 320 μm thick, and its length is either 16 or 20 mm. The INTT detector was fully integrated into the daq system of the sPHENIX and its signals were processed by eight Felix servers as a part of the data acquisition.

Hardware

- INTT Barrel
- Mechanical structure
- LV/Bias power system
- Cooling System and Performance
- Felix

Performance

- Timing resolution
- MIP distribution by DAC scan
- Signal to noise ratio for high rate env.
- Detection efficiency
- Stream readout performance
- # of live channels
- Clustering
- Tracklet
- Vertex reconstruction performance
- Acceptance
- etc

dN/dη paper

Schedule

INTT internal release → English Review → sPHENIX collaboration Review → Submission

Jan.3rd　　Jan.21st　　Feb.7th　　Feb.21st　　End of Feb. ～Early March

Schedule

INTT internal release → English Review → sPHENIX collaboration Review → Submission

Jan.3rd

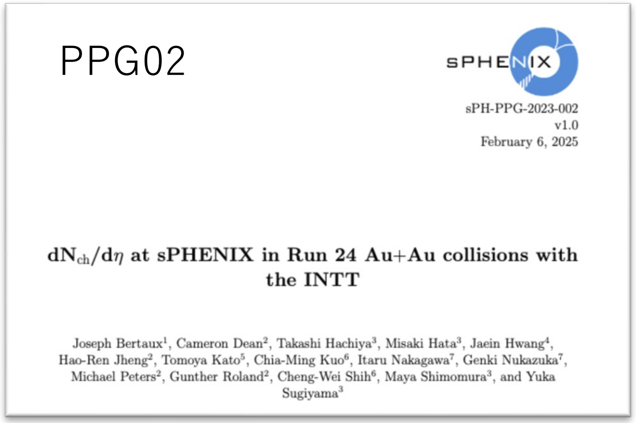
Jan.21st

Feb.7th

Feb.21st

End of Feb. ～Early March

IRC Formation on Feb.10th


PPG02

sPHENIX

sPH-PPG-2023-002
v1.0
February 6, 2025

$dN_{ch}/d\eta$ at sPHENIX in Run 24 Au+Au collisions with the INTT

Joseph Bertaux[1], Cameron Dean[2], Takashi Hachiya[3], Misaki Hata[3], Jaein Hwang[4], Hao-Ren Jheng[2], Tomoya Kato[5], Chia-Ming Kuo[6], Itaru Nakagawa[7], Genki Nukazuka[7], Michael Peters[2], Gunther Roland[2], Cheng-Wei Shih[6], Maya Shimomura[3], and Yuka Sugiyama[3]

INTT Ladder NIM is to be cited

Summary

- INTT Ladder NIM draft will be released for the sPHENIX collaboration review on Feb. 7th.
- The ladder NIM suppose to be cited from PPG02 dN/dη paper.
- The INTT team is planning to publish other NIMs
  - 2021 Beam test
  - Bus extender cable production
  - INTT Barrel + Felix (Stream readout)

Your feedback is more than welcome!