2024/12/02–04

Streaming Readout Workshop SRO-XII

Streaming Experience with sPHENIX INTT

Genki Nukazuka (RIKEN)
on behalf of the INTT collaboration

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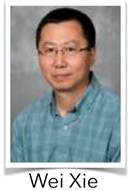
Dan Cacace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Hayato Yanagawa


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

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Wei-Che Tang


Ou-Wei Cheng


Cheng-Wei Shih


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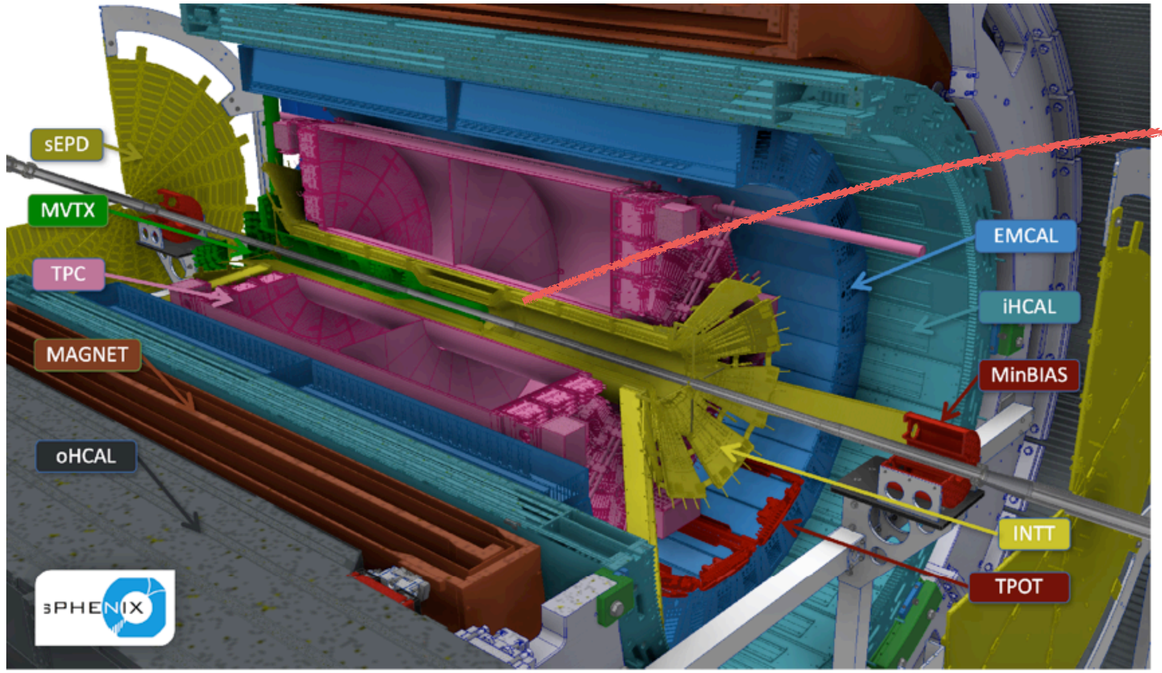
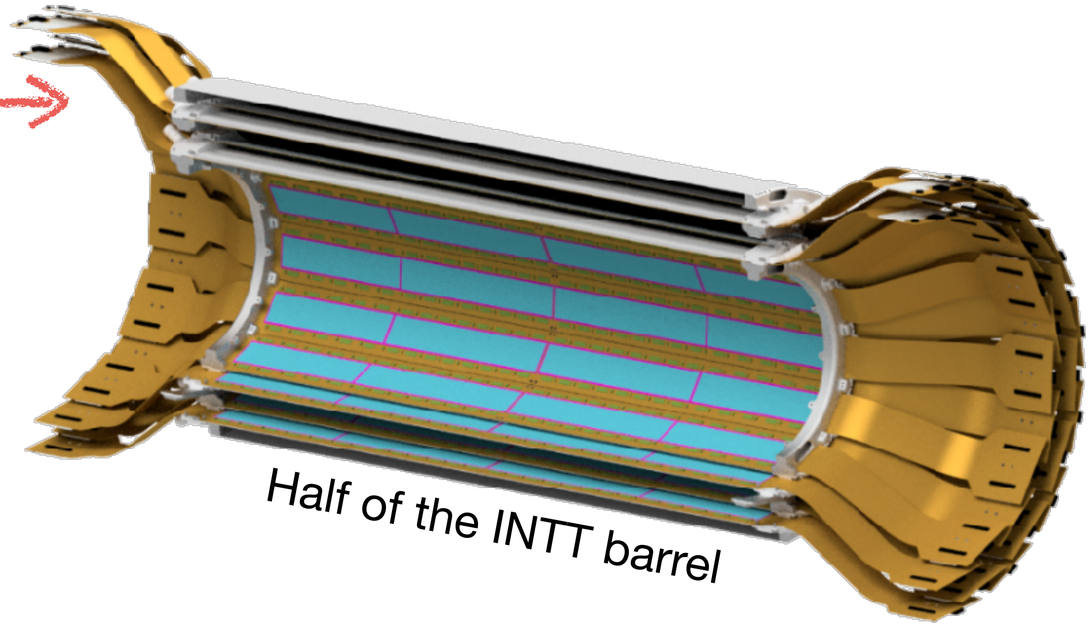
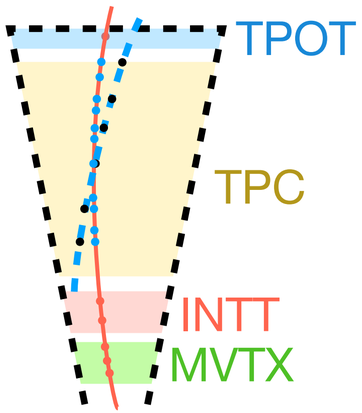
Nao Morimoto

Intermediate Silicon Tracker (INTT) at sPHENIX



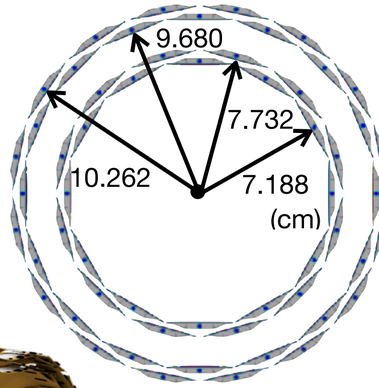




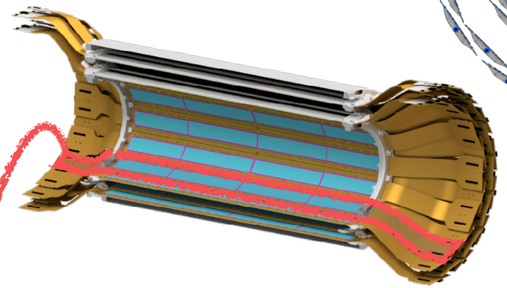
2 layers of barrel detector with silicon strip sensors

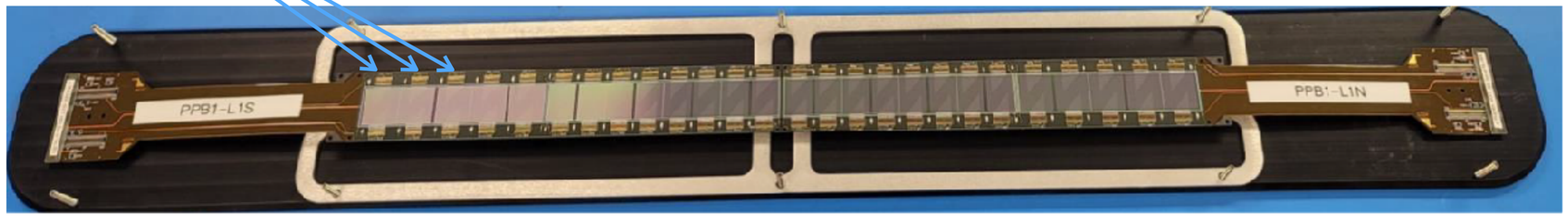
- Full azimuthal angle coverage in the midrapidity region $|\eta| < 1.1$
- 360k channels in total
  - Taking hits b/w MVTX and TPC for better tracking performance.
  - Rejection of pileup background using good timing resolution of < 1 bunch-crossing. (MVTX and TPC work at the order of μs — 10 μs)

Introduction of INTT



- INTT barrel consists of 56 ladders:
  - Inner barrel: 12 ladders × 2 layers
  - Outer barrel: 16 ladders × 2 layers
- There are 56 readout chips (FPHX chip) per ladder, which came from PHENIX FVTX detector
- An FPHX chip readouts 128 strips.





INTT ladder

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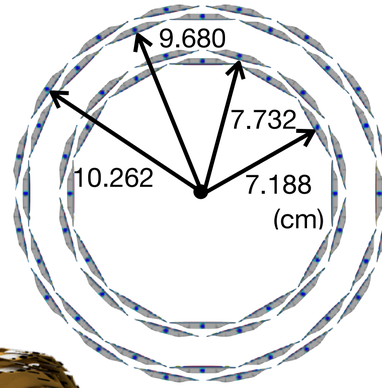

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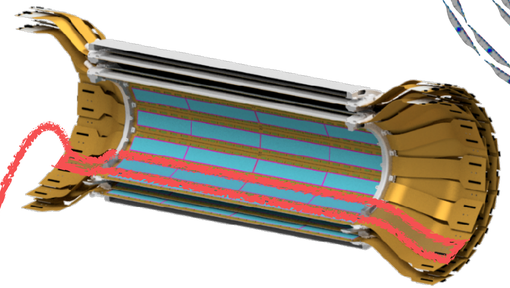

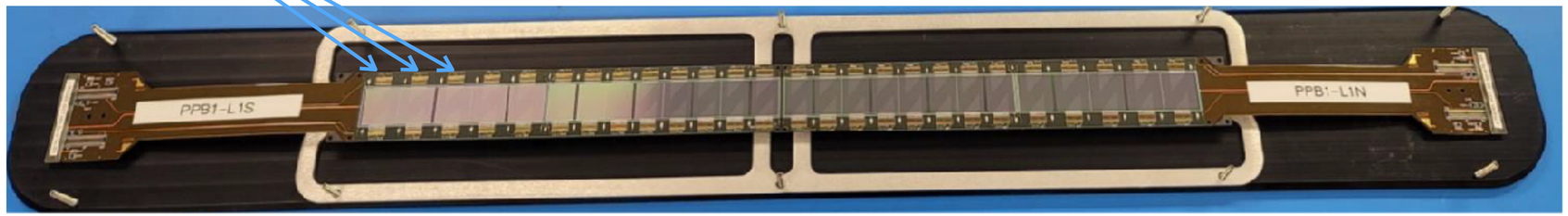

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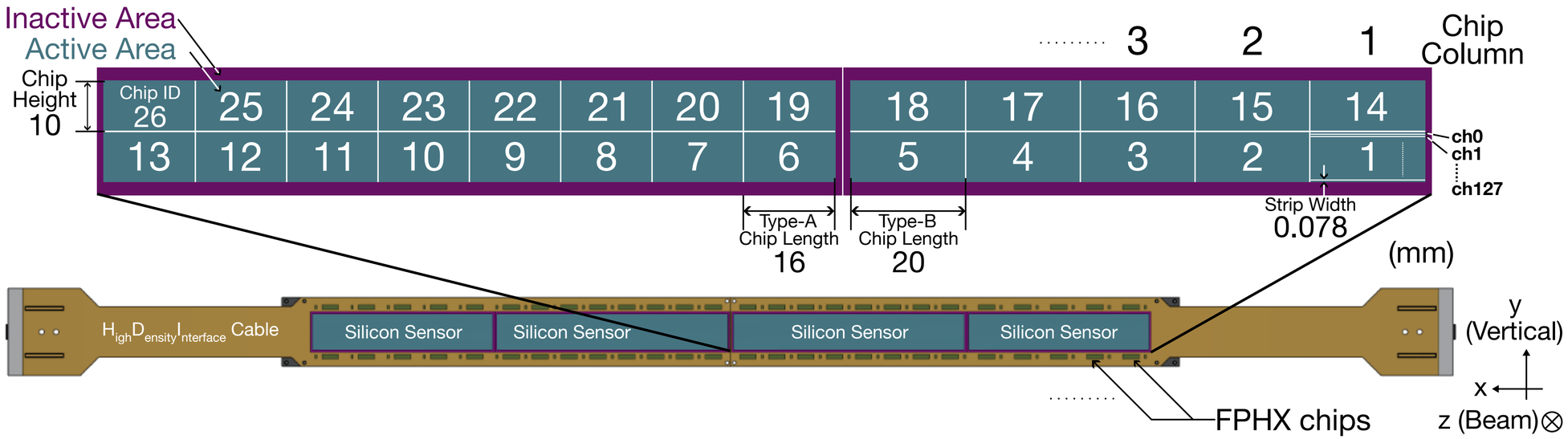
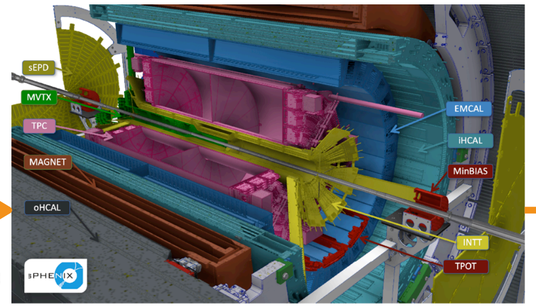


Introduction of INTT

- Global Timing Module (GTM) sends beam clock signals (BCO) synchronized with RHIC beam to the subsystems.
- Global Level-1 trigger (GL1) takes BCO and trigger signals from the subsystems.

Global Timing Module (GTM)

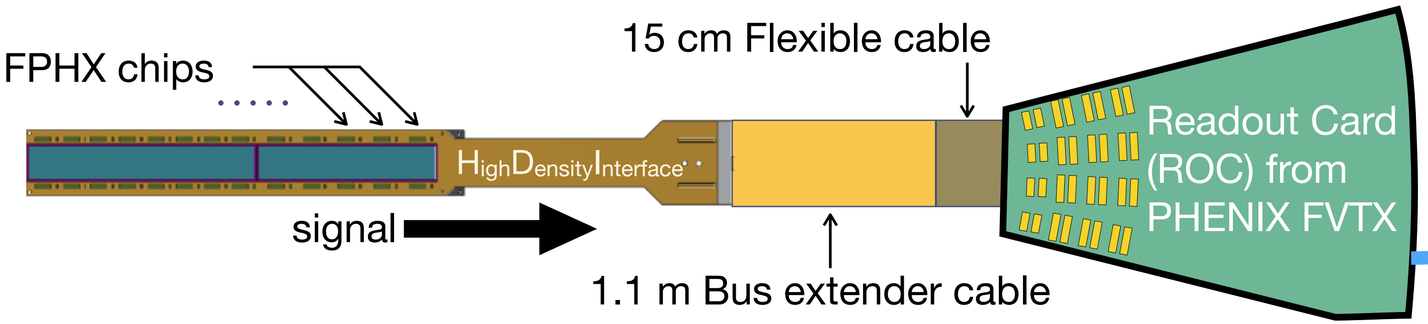
RHIC Beam clock signals (BCO)

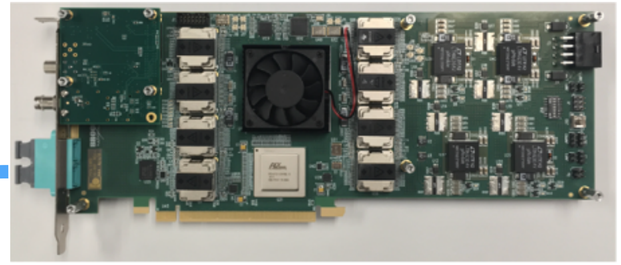


BCO
Trigger signals

Global Level1 trigger (GL1)

BCO
Trigger signals





FELIX board
originally developed for CERN ATLAS

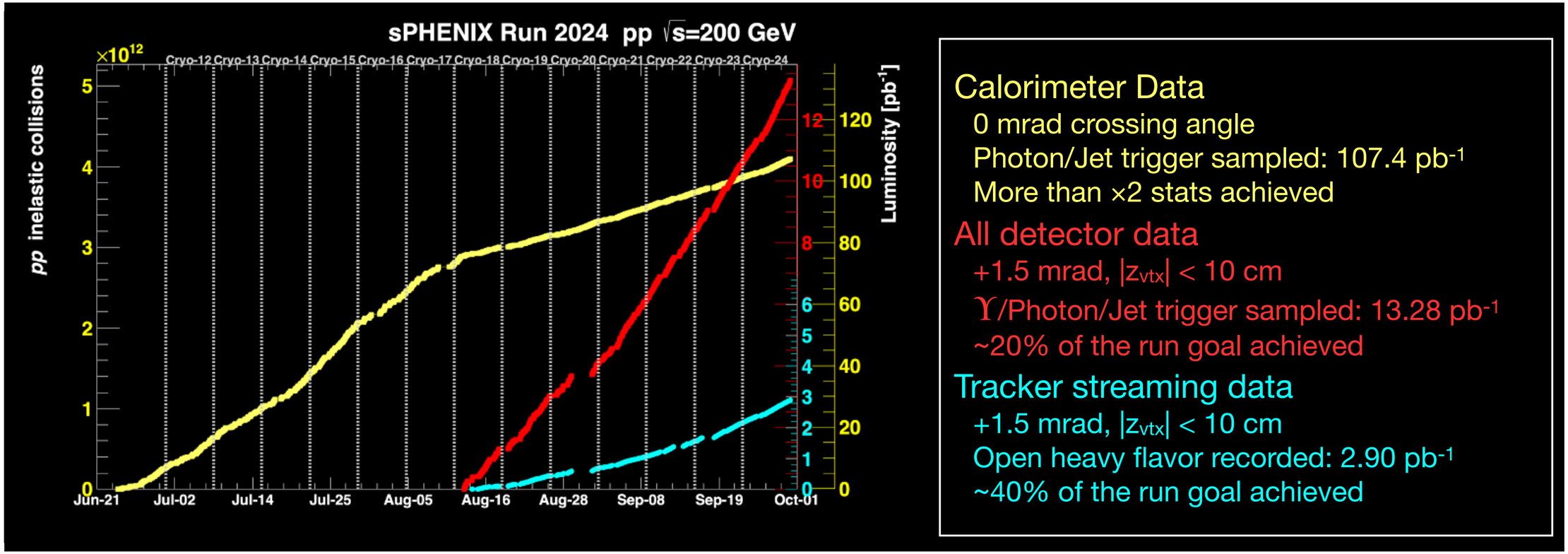
INTT FELIX server

Storage disk

- FPHX chips keep reading out and sending data to ROC.
- FELIX boards receive hit data from ROC and trigger/BCO signals from GL1. Decisions are made at this level.

Run 2024

- Transversely polarized pp @$\sqrt{s}$ = 200 GeV
  - Commissioning
  - Measurements (2024/06 — 2024/09)
- Commissioning with AuAu collision @$\sqrt{s}$ = 200 GeV



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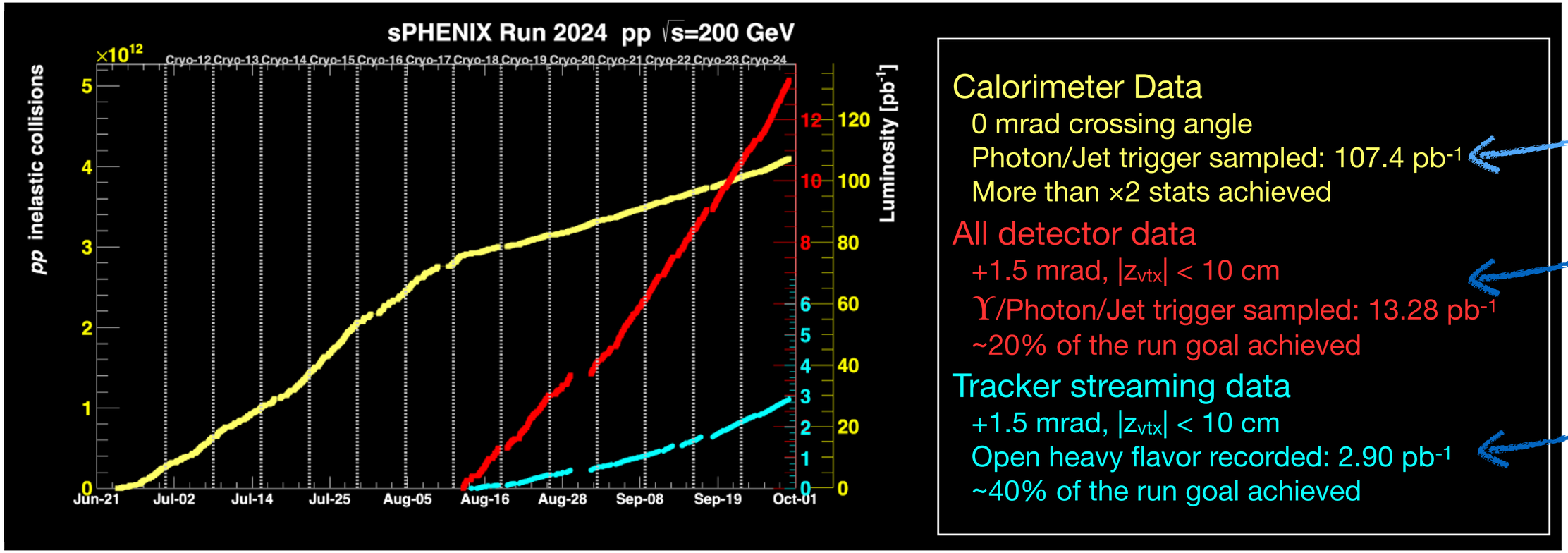
Operation of INTT

- **2023 commissioning**
  Stable operation of INTT in trigger mode had already been made.
- **2024/4**
  Commissioning with pp started
- **2024/6**
  Timing tuning ended. INTT started taking data in triggered mode stably.
- **2024/8**
  Operation mode was switched to the streaming readout, and stable operation was established.



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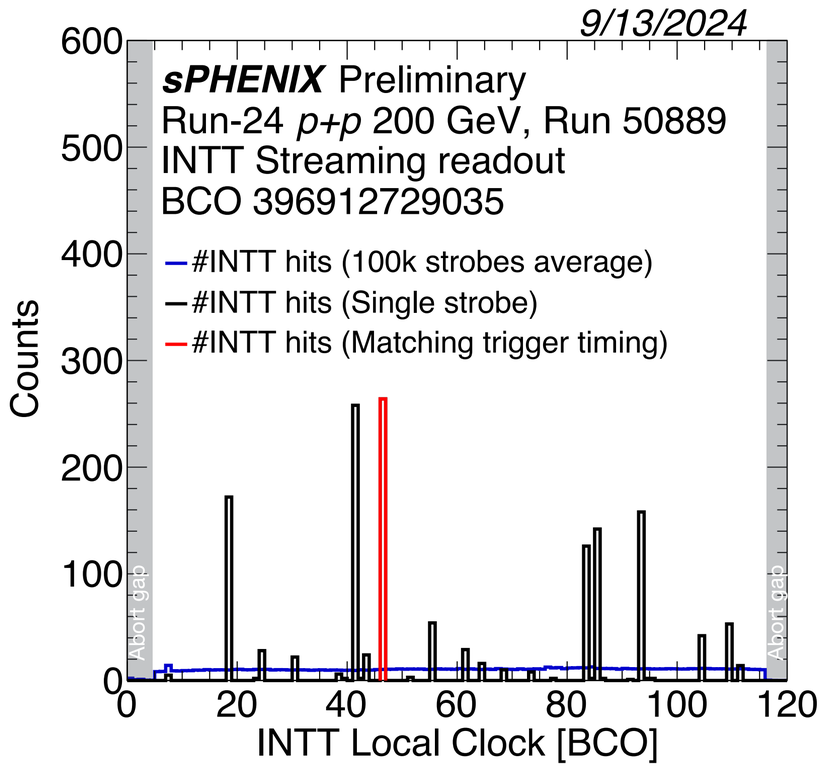
- Streaming readout mode
  - RHIC beam: 111 beam bunches + 9 empty bunches (for beam abortion)
  - Operation steps:
    1. A BCO signal is fed to INTT during no beam (abort gap), which is for 9 BCOs (~900 ns).

The number of INTT hits for each bunch crossing in a particular RHIC turn is shown.
1 bin = 1 BCO (~100 ns)



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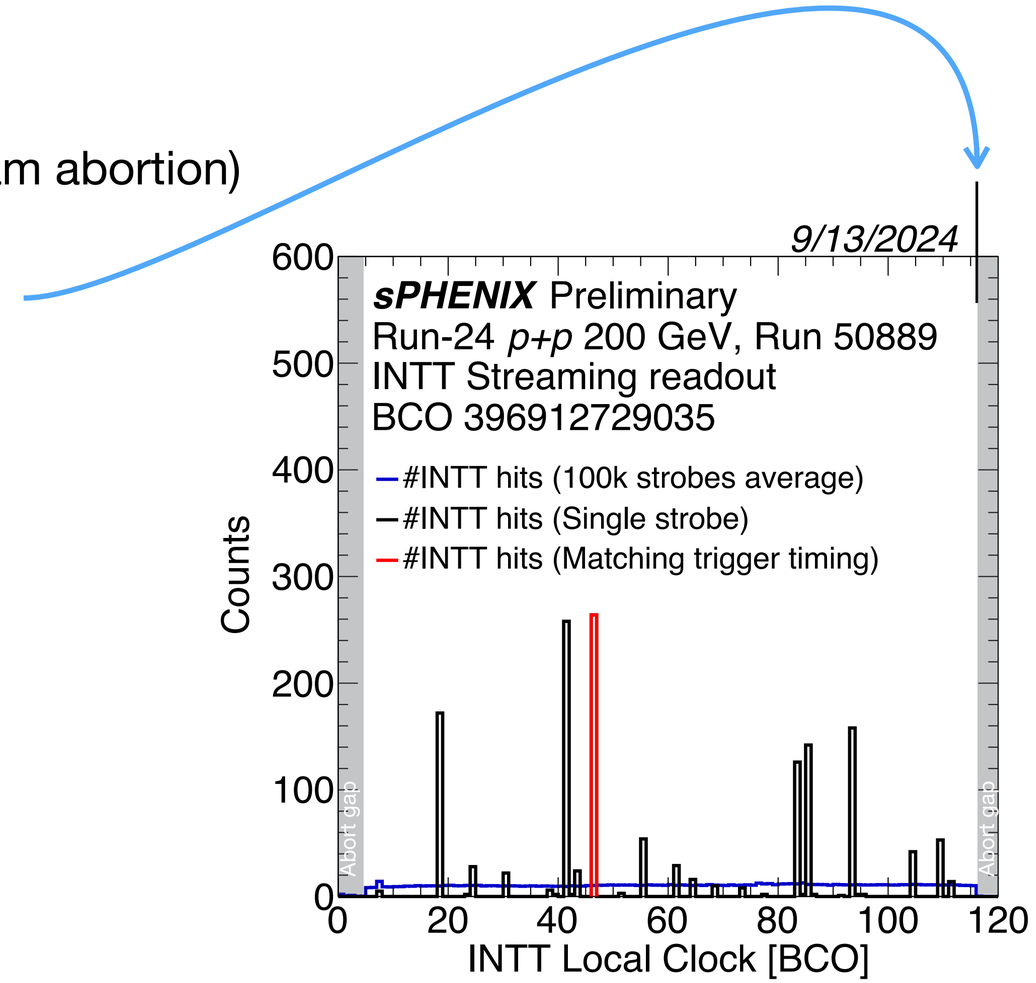

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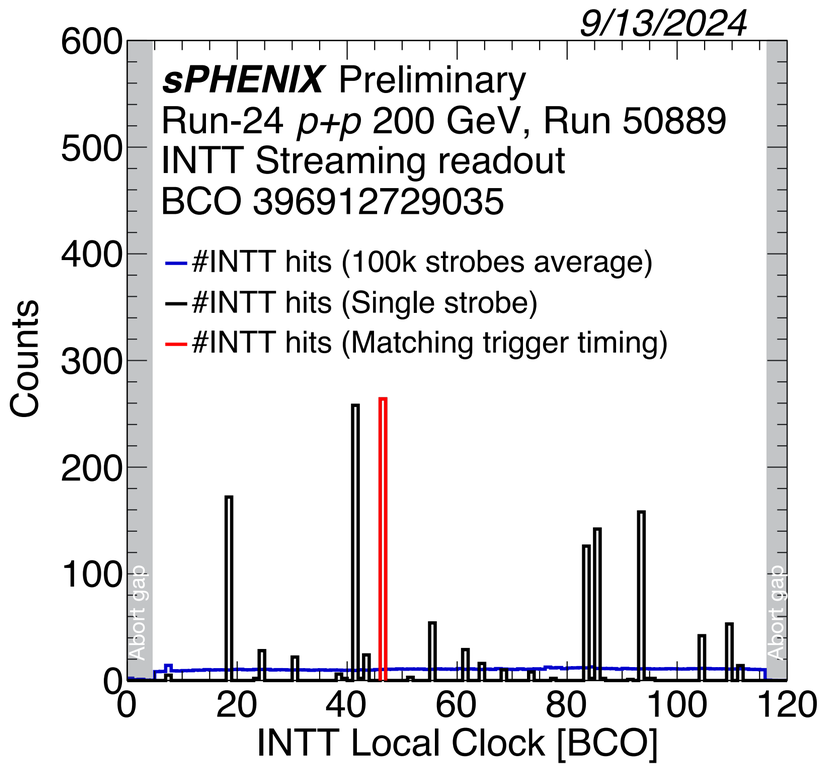

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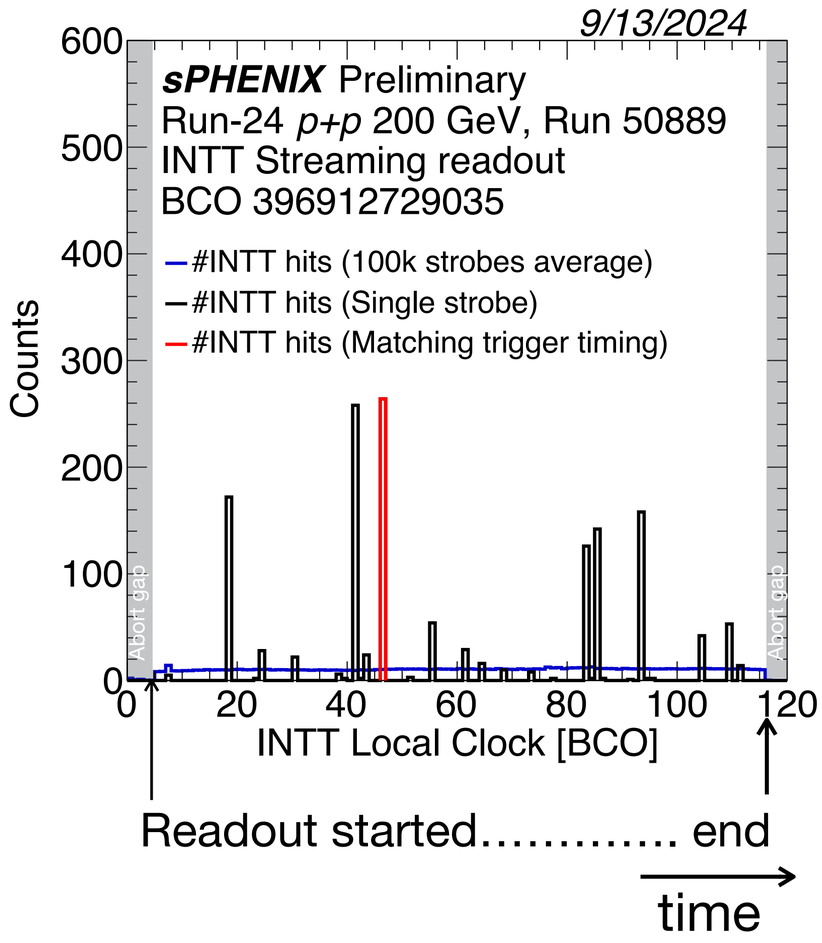

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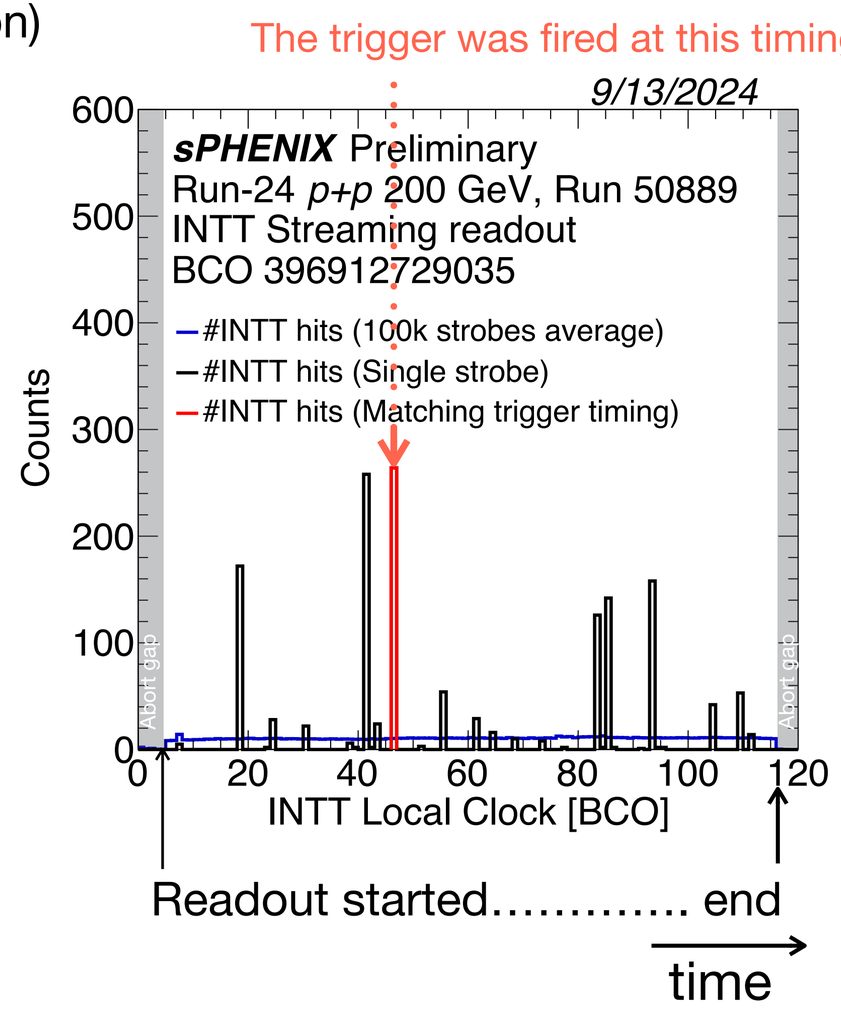

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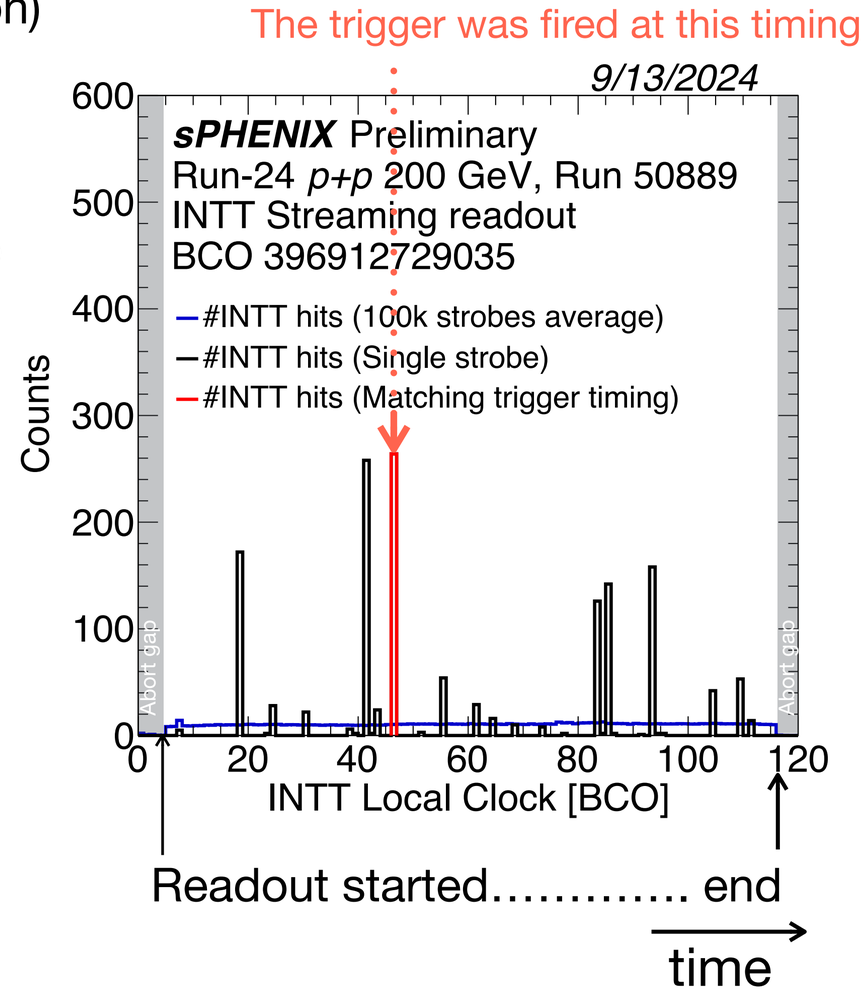
Streaming readout INTT took hits which fired the trigger. Some more hits from other collisions, which did NOT fire the trigger, were also taken.

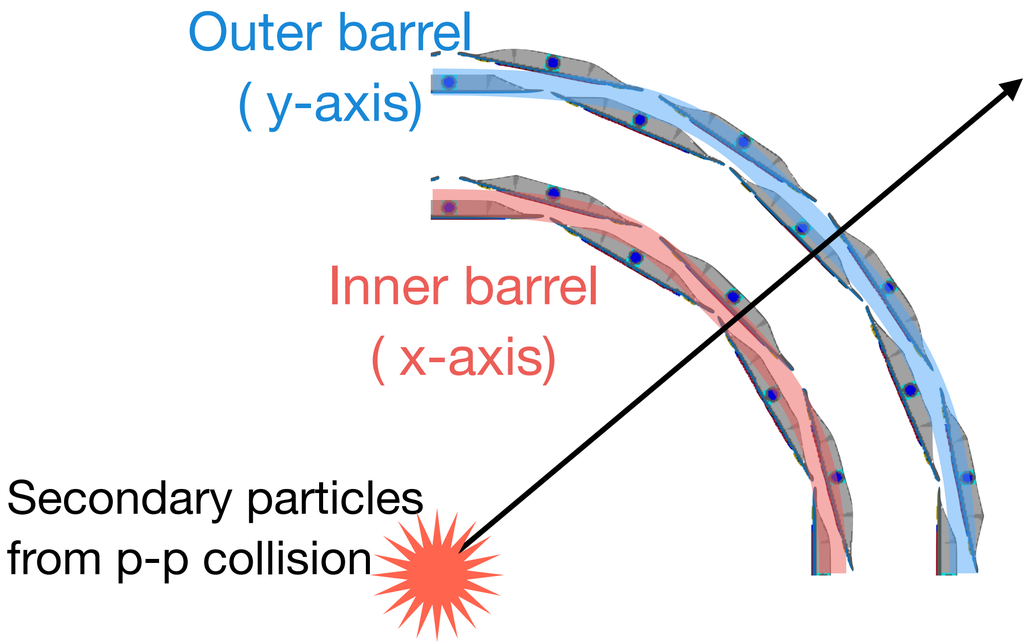


Performance: #cluster correlation b/w INTT barrels

#Hit/Cluster correlation b/w INTT barrels can confirm the simple picture: particles from collisions penetrate INTT and make hit on both INTT barrels.

Beam: p-p@$\sqrt{s} = 200$ GeV

Mode: Triggered or Streaming



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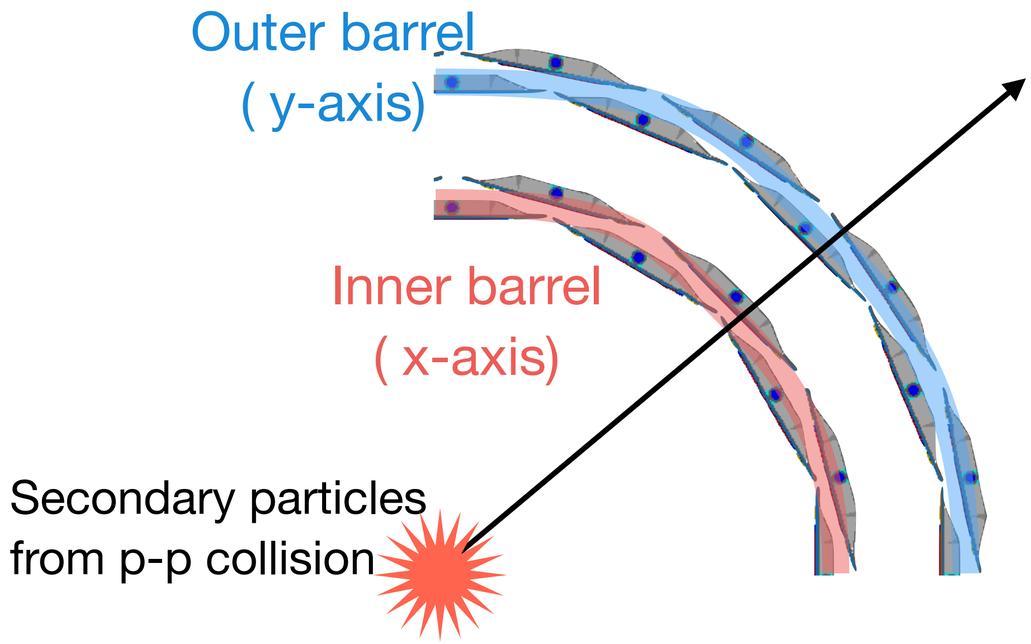
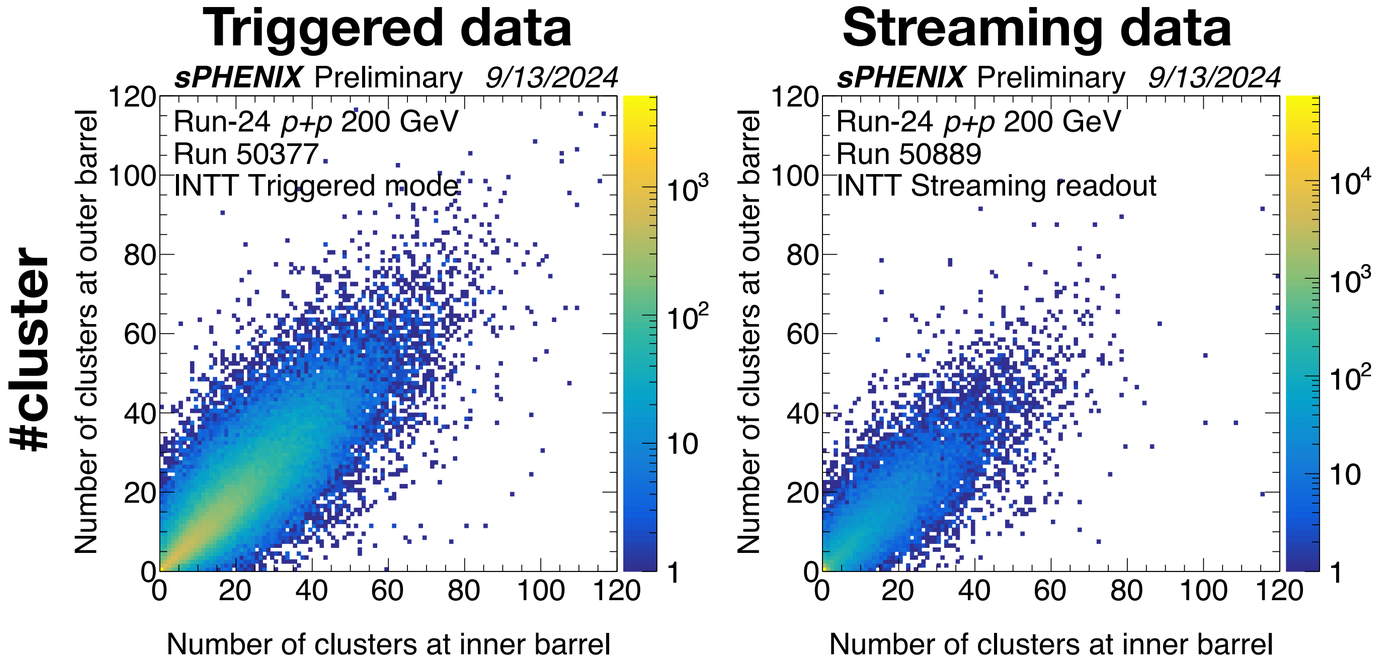


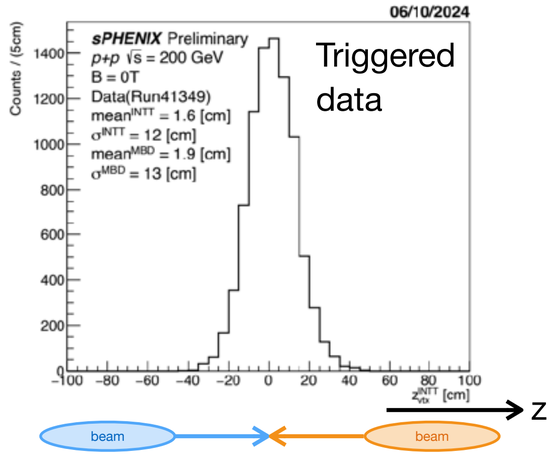


Our streaming data can see the correlations clearly

Performance: Standalone Vertexing and Tracking

- sPHENIX tracking system should give high performance on vertexing and tracking by using 3 tracking detectors.
- Standalone vertexing and tracking are nice challenges for INTT. It must be possible with pp collision at 200 GeV.
- Demonstration of them with triggered data was reported at RHIC/AGS uses' meeting in 2024 June.

Vertex reconstruction with triggered data



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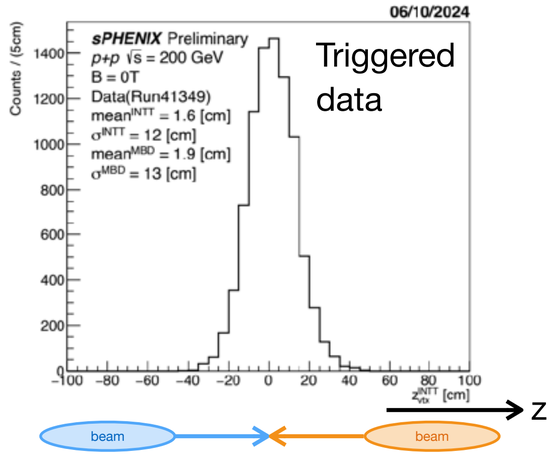
Vertex reconstruction with triggered/streaming data



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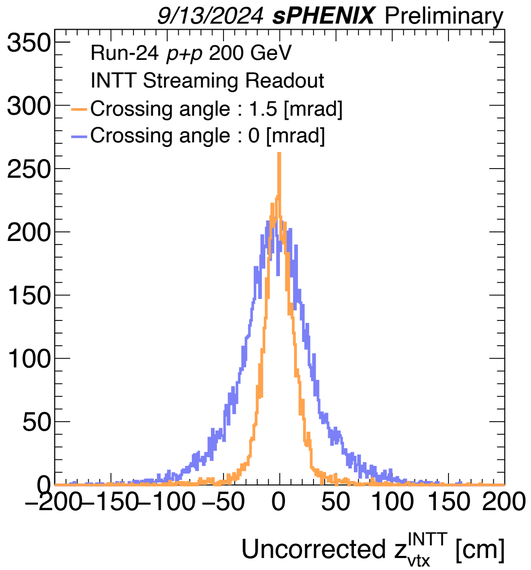
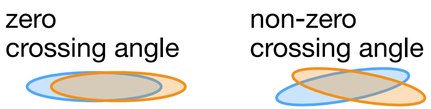


Difference by crossing angle was seen well.



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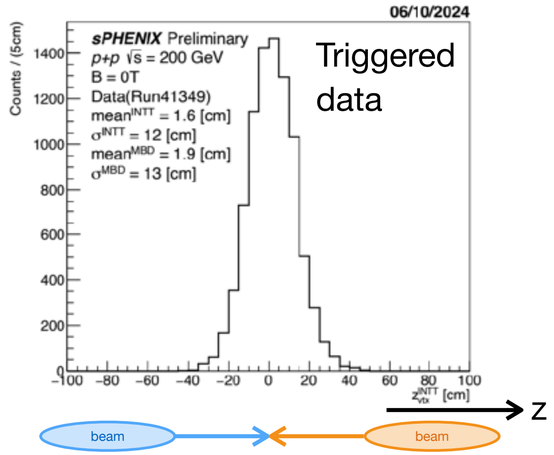

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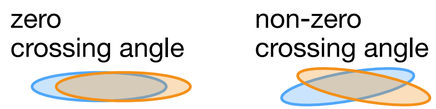

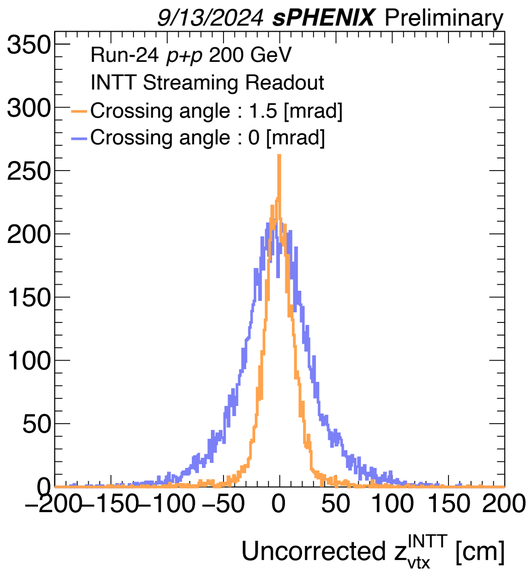

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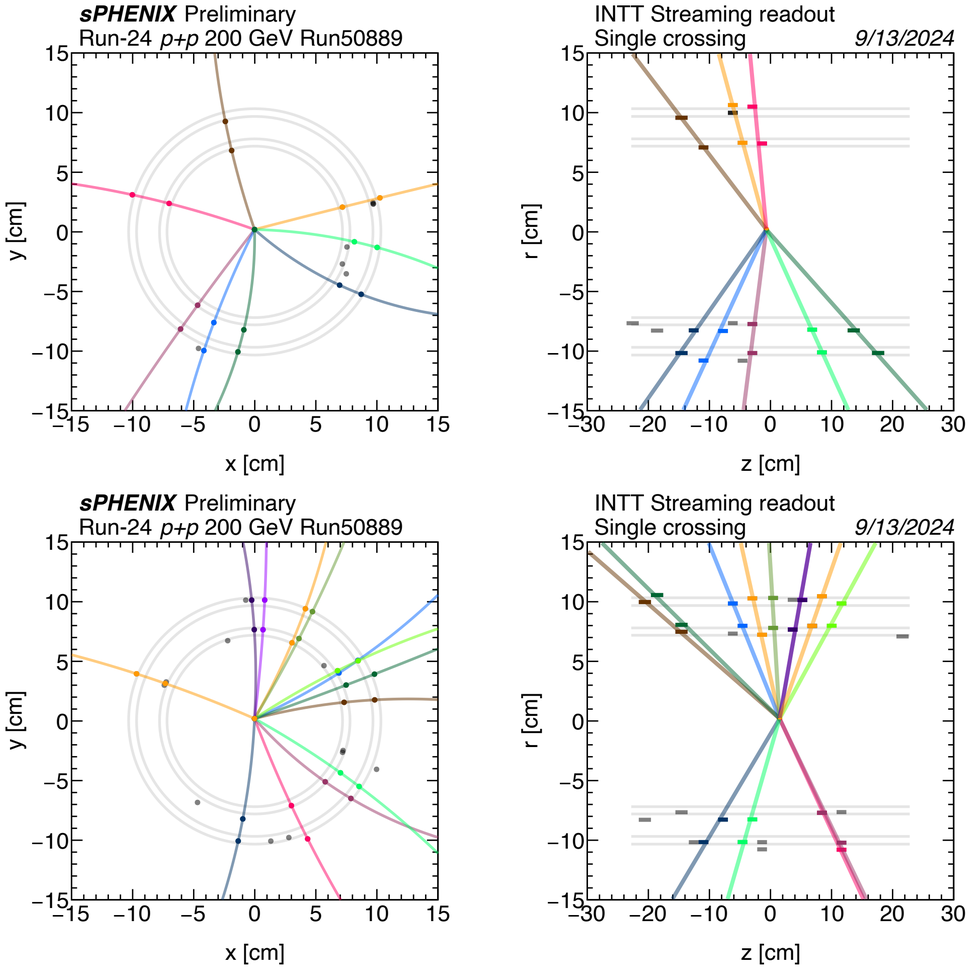
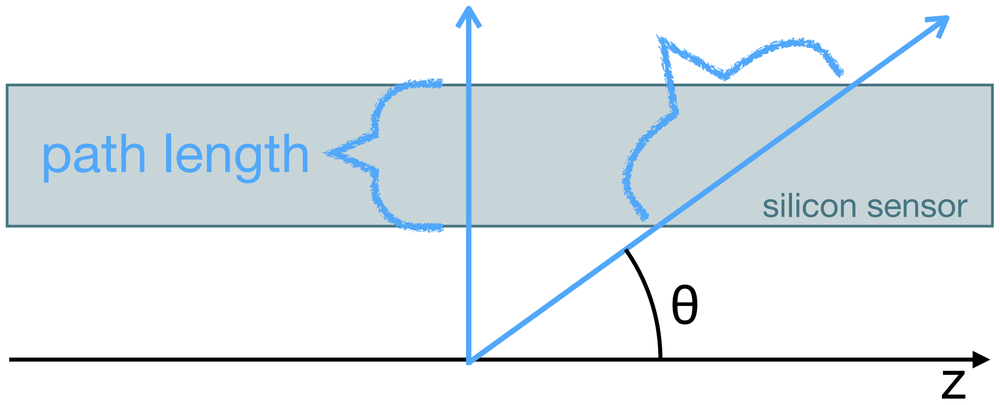
Standalone tracklet reconstruction with streaming data



Successful!

Performance: MIP peak

- FPHX chip has 3 bit ADC
- MIP peak has been measured with triggered test beam data (1 GeV e^+ beam) and triggered data in 2023 (AuAu@$\sqrt{}$200 GeV).
- The INTT standalone tracking enables us to remove noise hits and select track zenith angle.
- Energy deposit to the silicon depends on track zenith angle.



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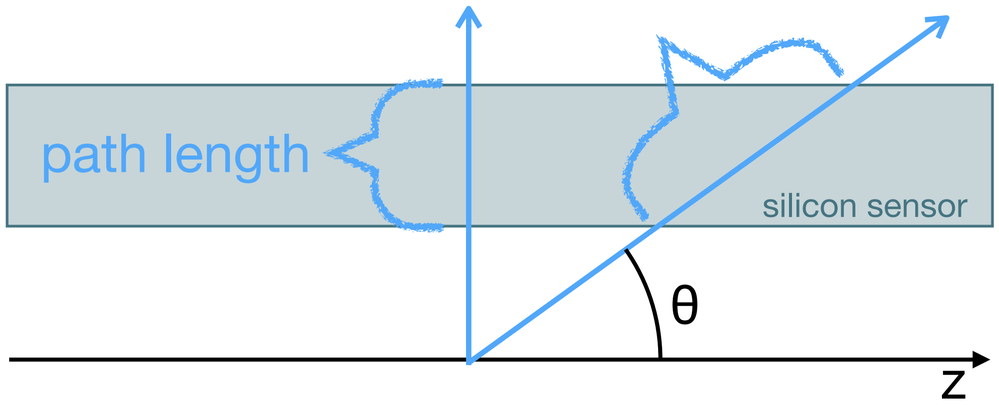

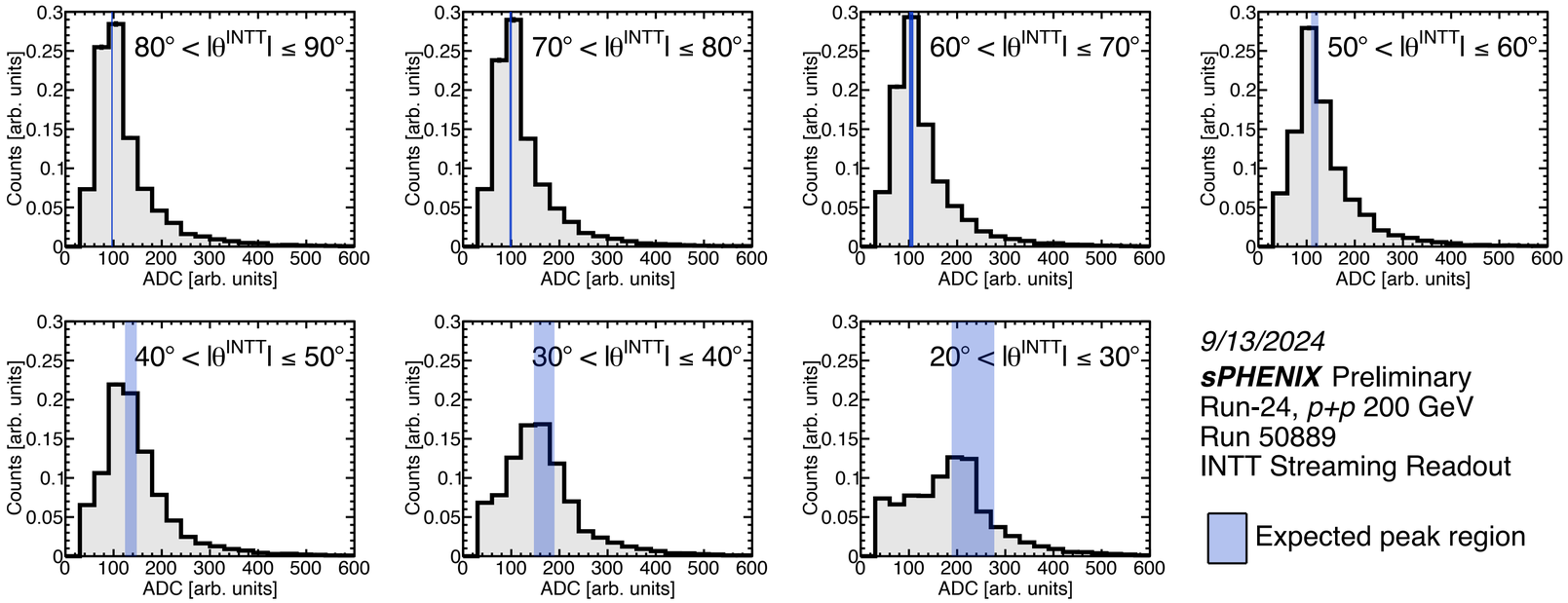

MIP peaks were successfully confirmed with streaming data.
The zenith angle dependence was seen with streaming data.

Summary

- INTT: 2 layers of barrel detector with silicon strip sensors
- Operation modes:
  - triggered: mainly for AuAu measurement
  - triggered + extended readout: stably worked in pp for 3 months
  - streaming readout: pp for the last 2 months
- Performance evaluations were conducted with the streaming data.
  - ✓ #cluster correlations b/w INTT barrels.
  - ✓ Standalone vertexing and tracking
  - ✓ MIP peak measurements
- INTT operation in 2023 and 2024 was successful for both triggered and streaming modes. Run 2025 will be successful too.
- Related poster at SRO-XII:
  “Data readout of the intermediate track detector INTT in the RHIC-sPHENIX experiment”
  by Mai Kano (NWU)