# STAR Run22 Report

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The Center for Exploration of Energy and Matter (CEEM),
Indiana University

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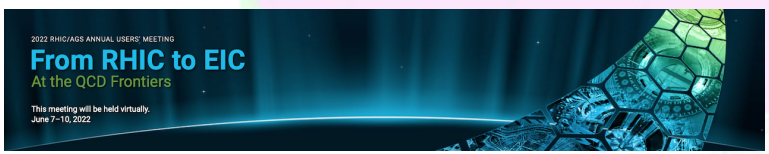


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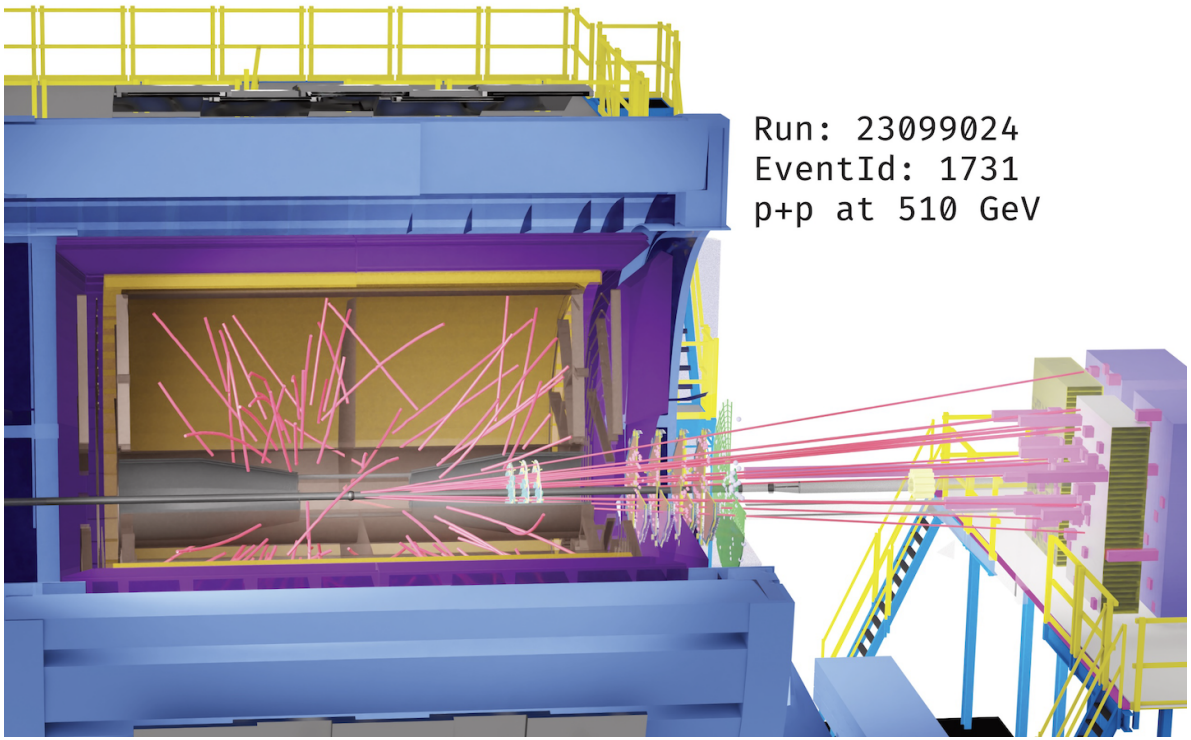
# Outline

- Physics goals
- Overview
- STAR operations
- Conclusion



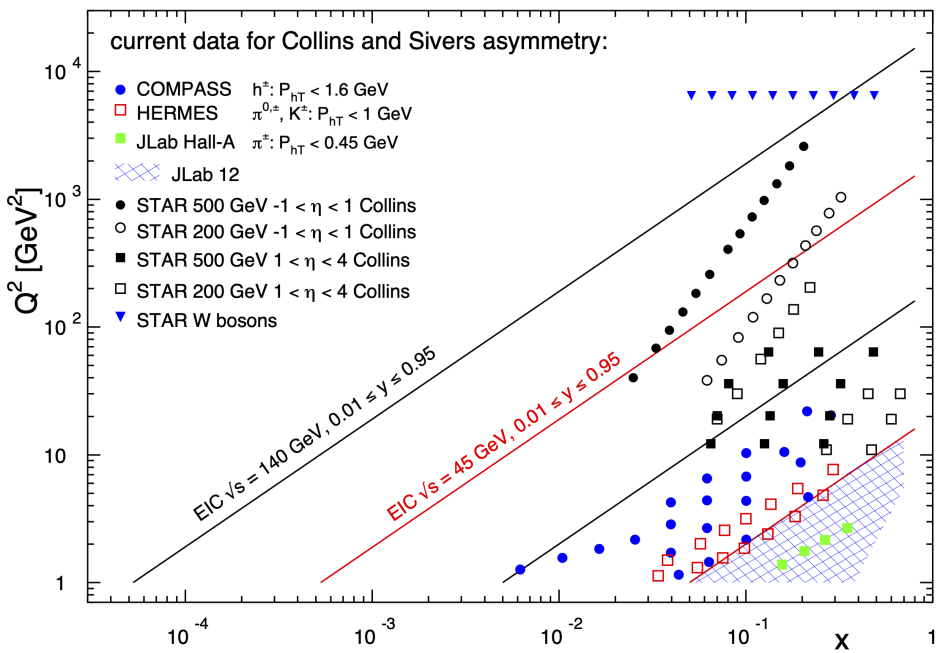
# Physics goals

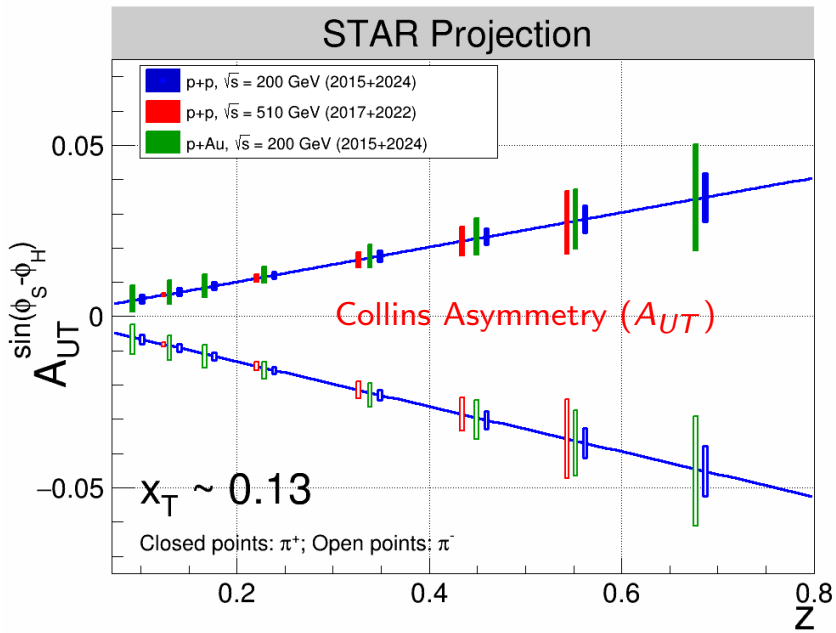
- Commissioning the new forward detector upgrade, small-strip Thin Gap Chamber (sTGC), Forward Silicon Tracker (FST), and Forward Calorimeter System (FCS), $2.5 < \eta < 4$, facing the blue beam
- Beam use request for run22

| $\sqrt{s}$ (GeV) | Species | Polarization | Run Time | Sampled Luminosity (pb$^{-1}$) | Polarization (%) |
|---|---|---|---|---|---|
| 510 | $pp$ | Transverse | 16 weeks | 400 | $\geq 55\%$ |

- Study the transverse spin structure of the proton, for example, probing high-$x$ valence quarks up to $x \sim 0.5$ through Collins and Sivers asymmetries

More from O. Eyser's talk on Wednesday



# Installation of forward detectors

- FCS: installed in 2020 and commissioned during run21

  $7m$ from IP; E-cal + H-cal

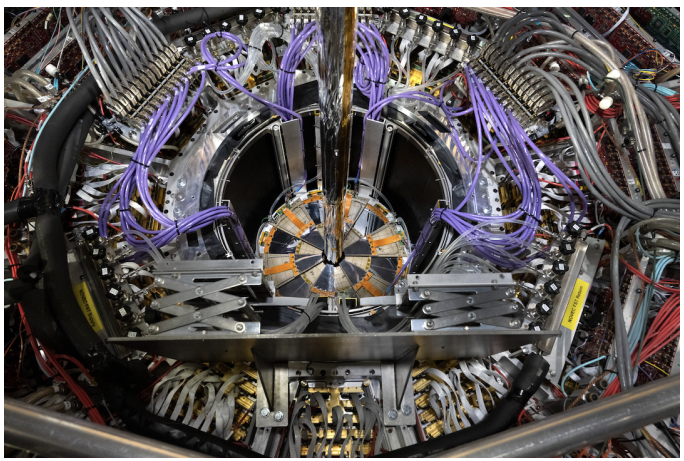
  New trigger/readout electronics (DEP boards)

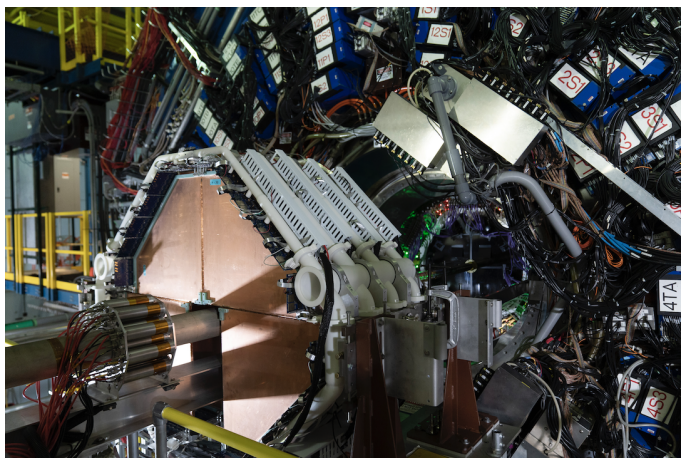
- FST and sTGC installed in 2021

  FST, 3 disks, NOVEC cooling system

  sTGC, 4 planes, $CO_2$ + n-pentane (flammable,

  and pentane is a liquid at room temperature)





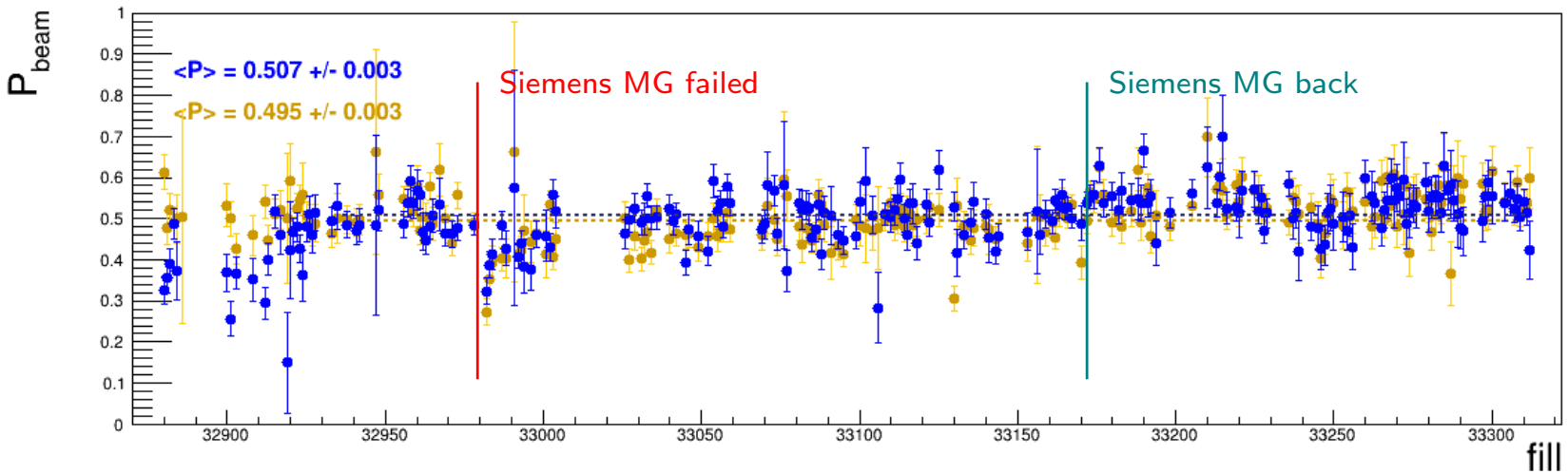
**Despite COVID and lab limited operation mode, all finished before RHIC ring cool-down!**

# Timeline

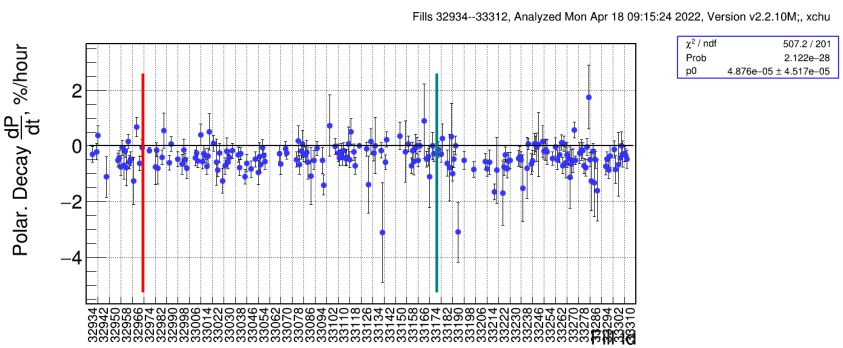
- 11/9/21, STAR two-person watch shift started
- 11/15, original cool-down start date. Blue ring cool-down started
- 11/16, STAR hybrid four-person shift started, with three persons onsite + one online
- 11/29, yellow cool down started, delayed by 13 days due to cryo-control upgrade
- 12/3, broken coils of blue snake at 9 o'clock (Bi9-2, inner helical dipole) from power outage
  - Ran partial blue snake (with Bi9-1,4) at 85% of spin rotation
- 12/15, first physics data taking (Mid-rapidity)
- 12/20, physics running declared (18 days from the first injection)
- 12/25, full physics data taking (Mid-rapidity + forward rapidity)
- 1/2, beam energy lowered from 254.87 to 254.21 GeV to maximize vertical component of the proton spin
- 1/12, AGS Siemens motor generator (MG) failed, and was switched to backup Westinghouse MG, lower beam polarization out of AGS
- 3/8, switch back to Siemens MG
- 4/4, 2-week extension
- 4/18, run ended

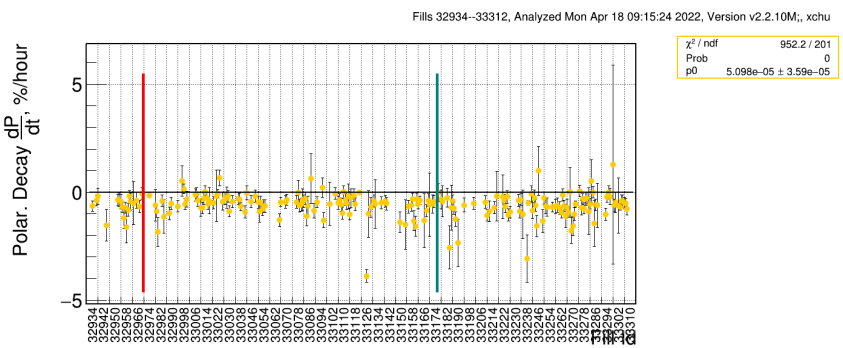
# Beam polarization and its decay

- Absolute polarizations from H-jet
- $< P_B > = 51\%$ and $< P_Y > = 50\%$, lower than requested in BUR




- Blue and yellow beam polarization decay from p$C$-CNI polarimeter

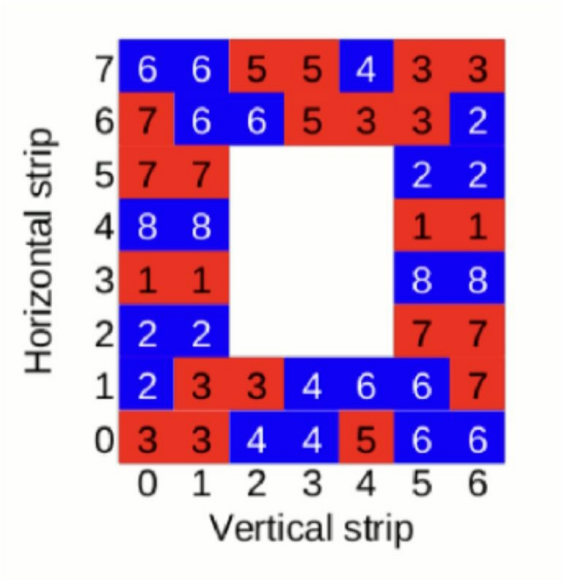



- Polarization decay $\frac{dP}{dt}$ on average $< 0.1\%$ per hour

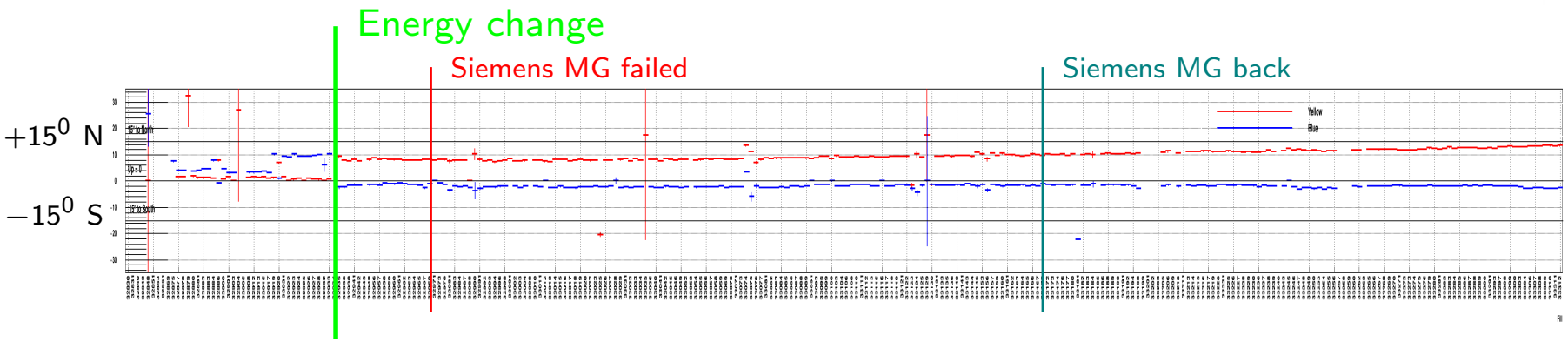
# Beam polarizations at STAR

- Monitor spin direction relative to the vertical axis and cross-check beam polarizations to make sure their angle and amplitude stable, e.g. when Siemens MG failed
- STAR Zero Degree Calorimeter (ZDC): SMD strips to determine the horizontal and vertical positions in the transverse plane




Grids $\rightarrow \phi$

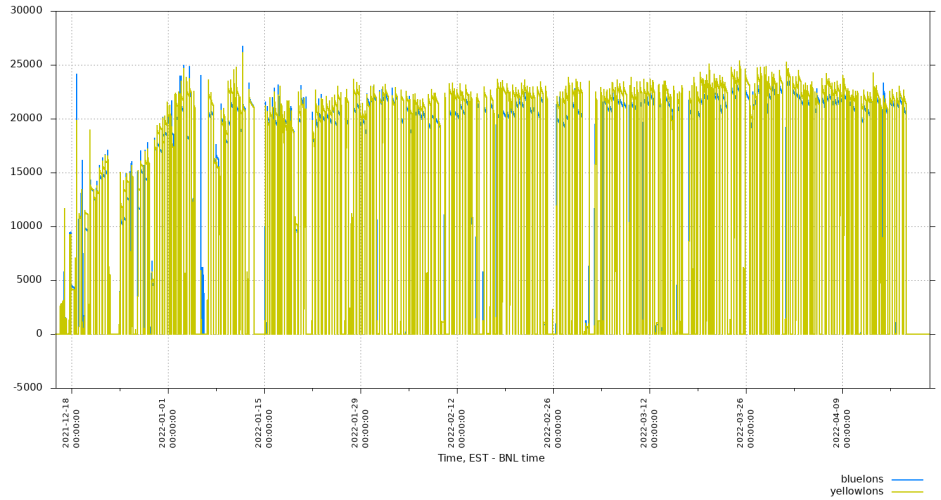
- Polarization angle:



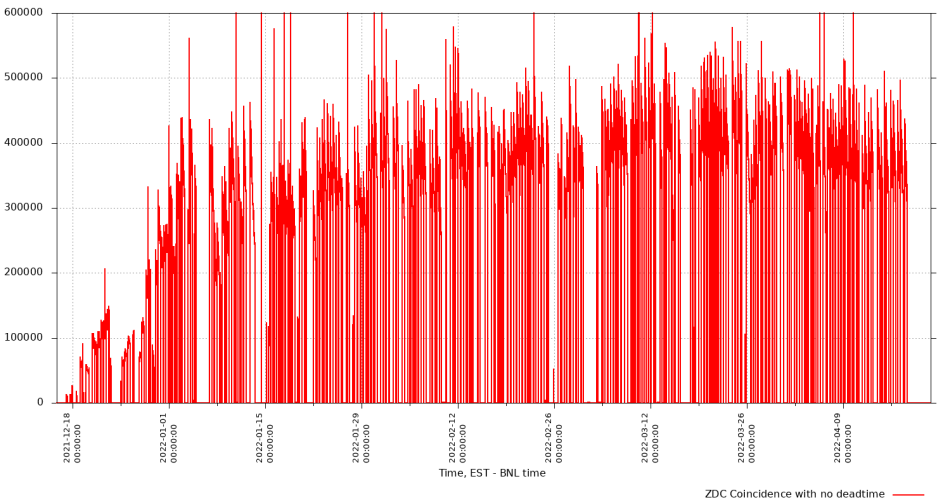

- Due to partial snake in blue beam (pointing to the forward detectors), smaller $E_{beam} = 254.21$ GeV allows the polarization direction closer to the vertical axis than $E_{beam} = 254.87$ GeV
- From rotator scans: $\sim$ 10% polarization observed in the longitudinal direction

# Beam current and collision rates

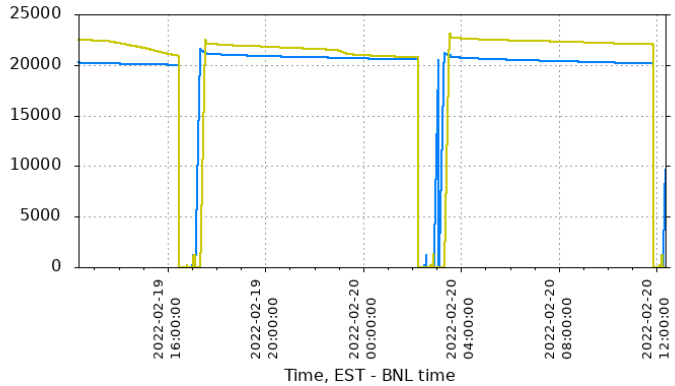
- Beam current: $\sim 2 \times 10^{13}$ (all filled bunches)



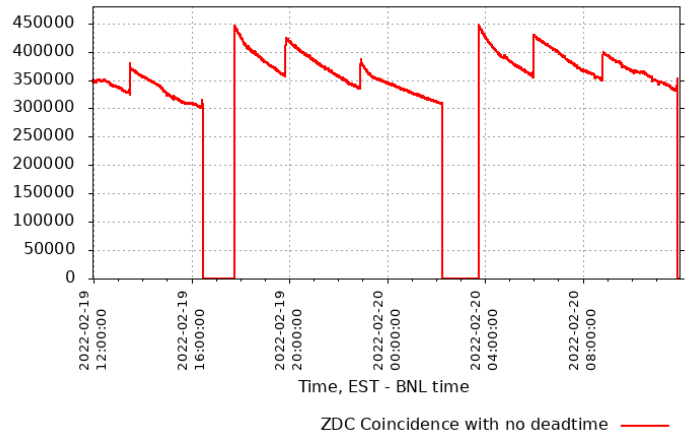

- ZDC coincidence rate: $\sim 400$ kHz




For a given fill



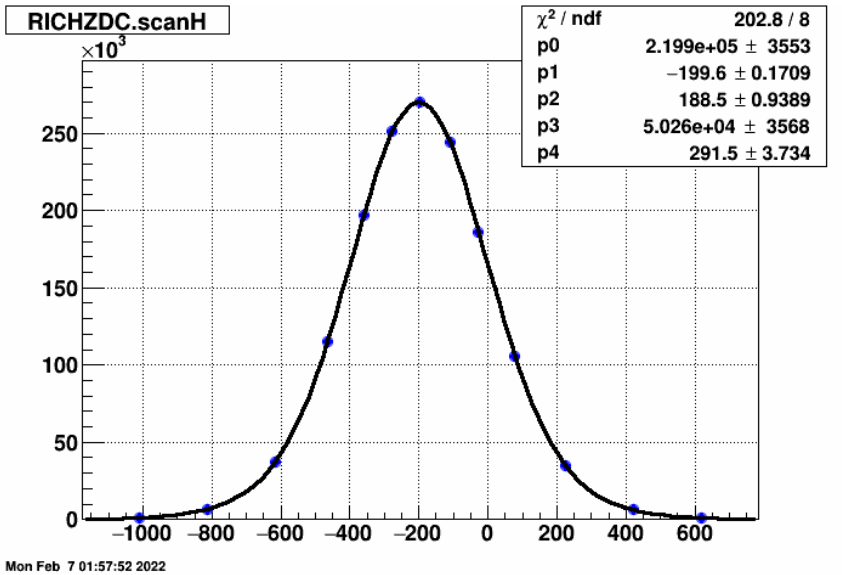

Two $\beta$ squeezes during a normal 8-hour fill to maintain luminosity

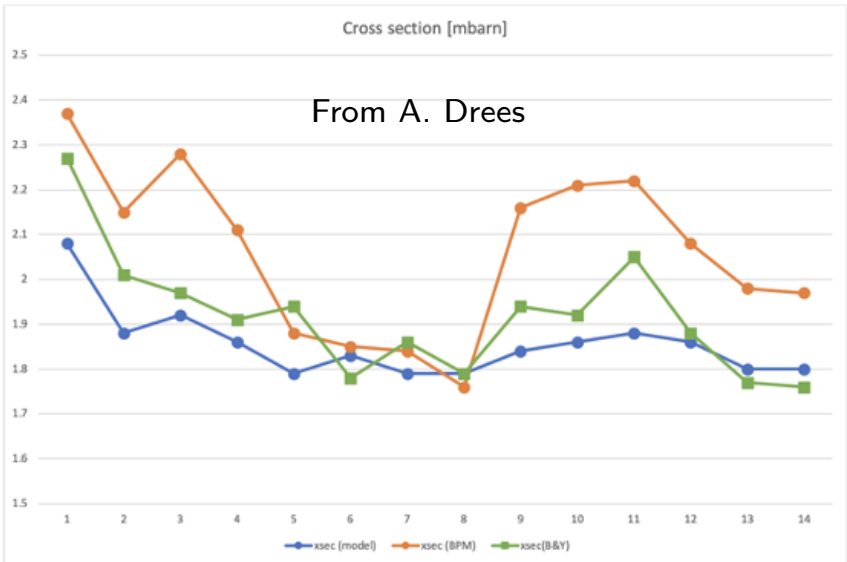



- Low luminosity runs $O(10^3)$ for forward detector alignments and precise cross-section measurements

# Luminosity monitoring

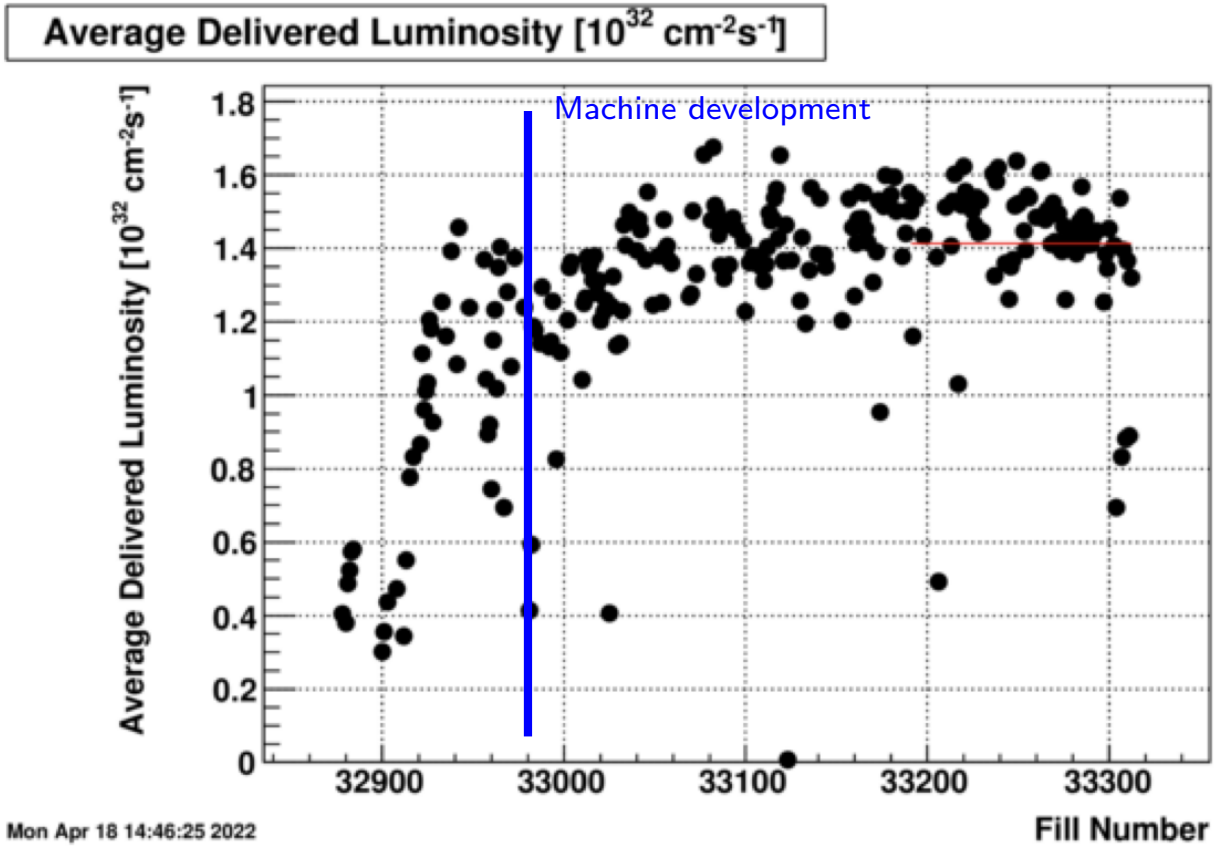
- Vernier scan, collision rates vs. relative beam movements in the horizontal and vertical plane respectively




- Measure the beam overlapping size, and derive the corresponding effective cross-section $\sigma_{eff}$
- $\sigma_{eff}$ will be used to calculate luminosities from the monitored collision rates during normal data taking
- From 16 vernier scans throughout the entire run, $\sigma_{eff} = 1.86\ mb$, (corresponding to the STAR ZDC coincidence rate after accidental and multiple corrections)

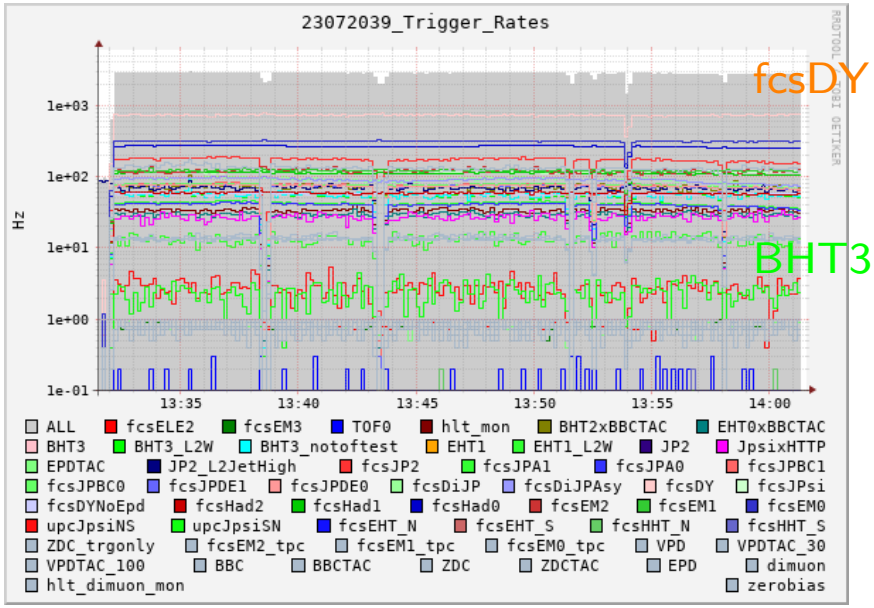
# Delivered instantaneous luminosity

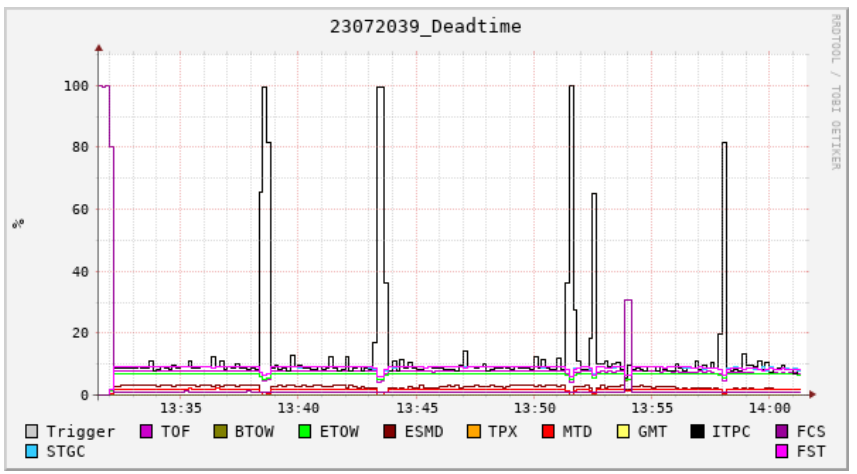



- Average delivered luminosity, $L = 1.3 \times 10^{32}\mathrm{cm}^{-2}s^{-1}$, better than the 2017 run average, $L = 1.2 \times 10^{32}\mathrm{cm}^{-2}s^{-1}$
- More stable luminosity after machine development, including reducing beam backgrounds due to high emittance, and work on tune/chromaticity, injection, and so on

# STAR physics triggers and sub-systems

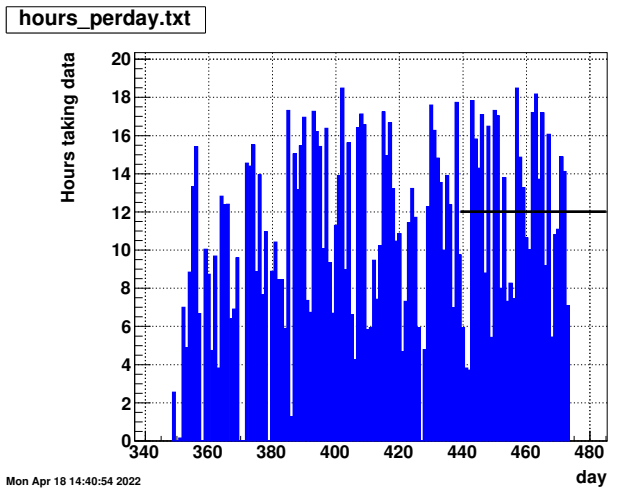
- More than 40 physics triggers
- Sub-systems ran close to their limits
- Total trigger rates $\sim$ 3 kHz
- Forward triggers:
  - $\sim$ 1 kHz for Drell-Yan events
  - $O(100)$ Hz trigger rates for other triggers such as jet patch triggers
- Mid-rapidity triggers: "Barrel EM-cal high tower 3" (BHT3) for $W$-boson events, $\sim$ 60 Hz
- Low dead-time for STAR sub-systems with auto-recoveries built: $< 10\%$

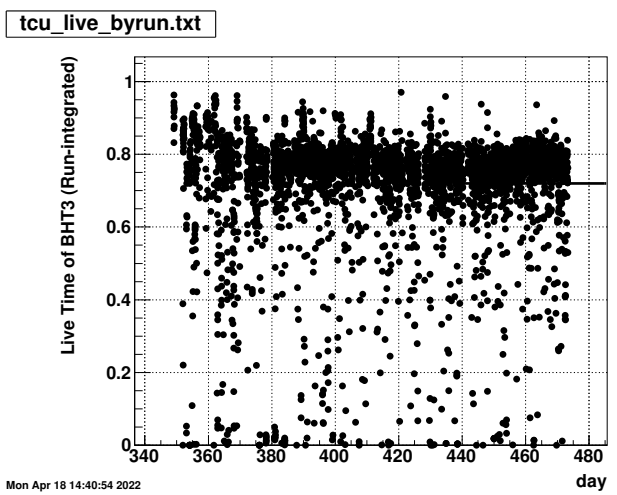


# STAR data taking performance

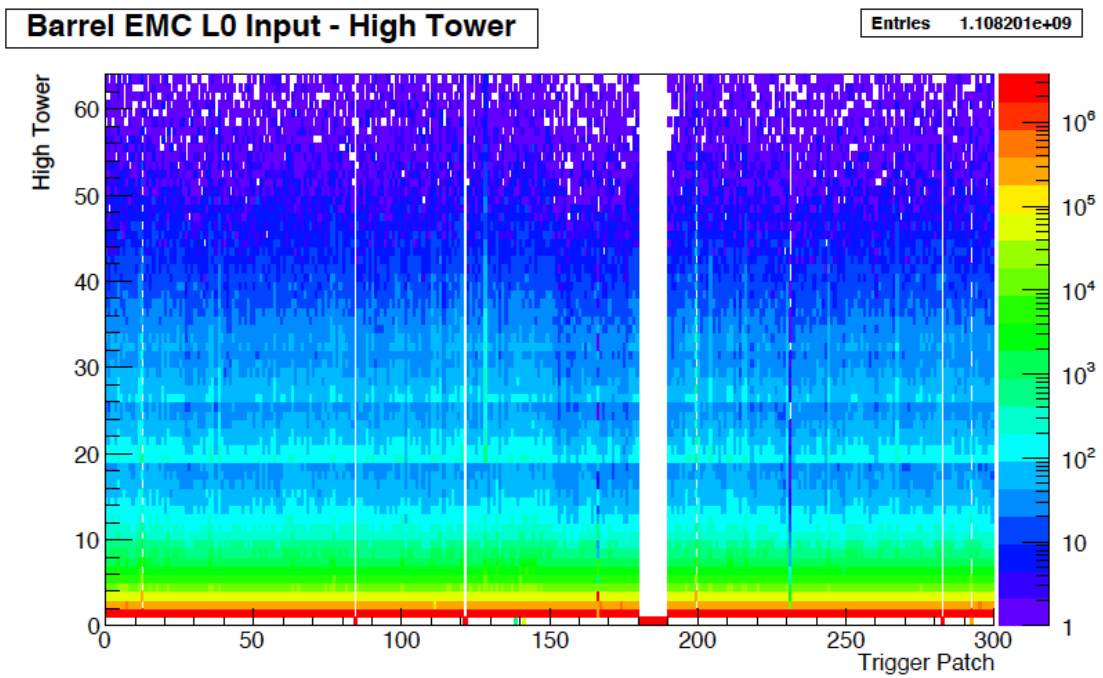
- Maximize data taking efficiency
  1. Sub-systems are ready before "Physics on"
  2. Respond promptly to events such as $\beta$ squeezes and polarization measurements
  3. Include the di-muon trigger when beam background is low
  4. Take local ZDC polarimetry data while preparing sub-systems for beam dump
  5. Daily sub-system calibration and pedestal data
- Hours of data taking per day: $\sim$ 12 hours
- TCU live time (for BHT3): $\sim$ 75%

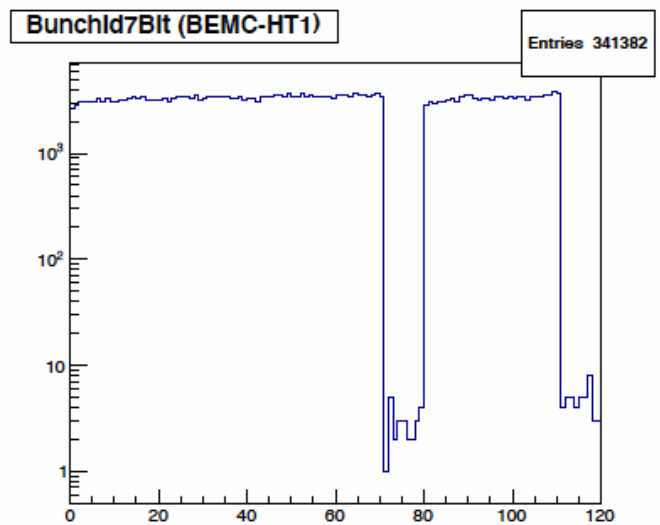


# Mid-rapidity physics: barrel EM-calorimeter HT triggers

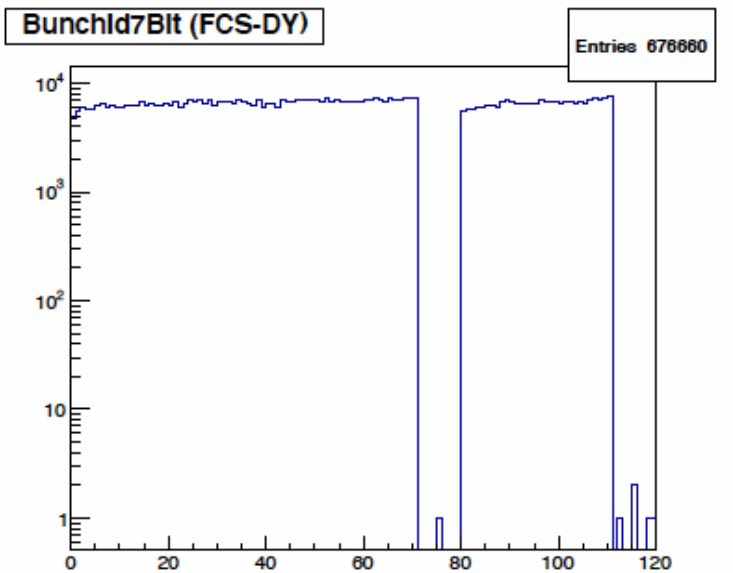
- Barrel EM-calorimeter HT ADC vs. trigger patch ID
- The number of BHT1 triggered events vs. bunch crossing ID



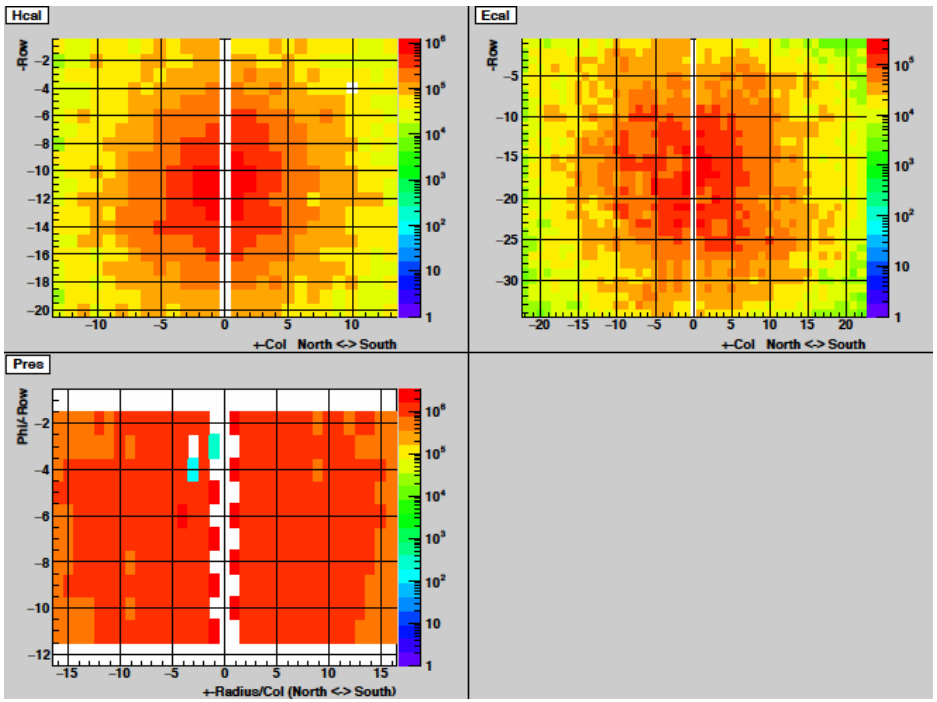



# Forward calorimeter system

- FCS real-time quality-assurance plot
- Critical detector to trigger forward Drell-Yan events, gain updated weekly
- The number of FCS Drell-Yan triggered events vs. bunch crossing ID



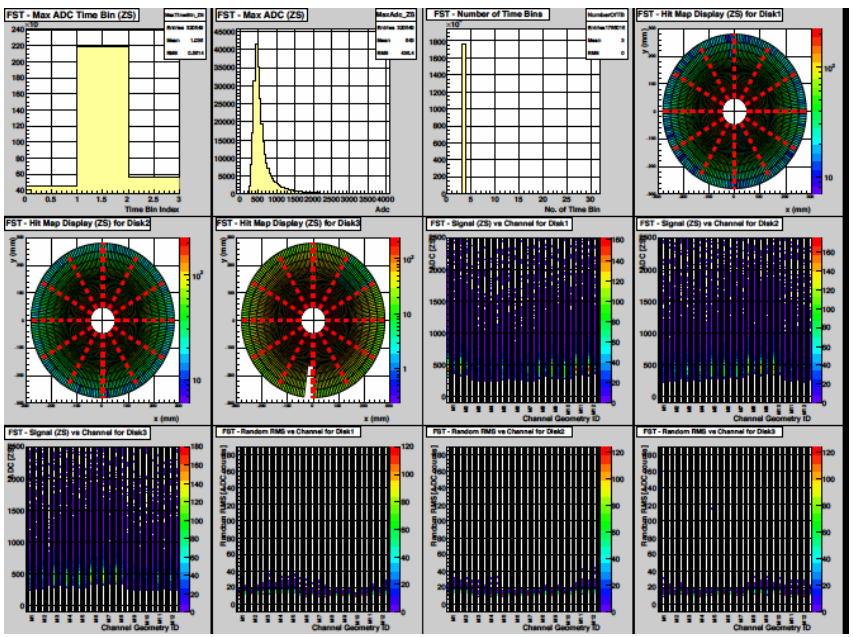

- H-cal, E-cal and Pre-shower ADC vs. channel number



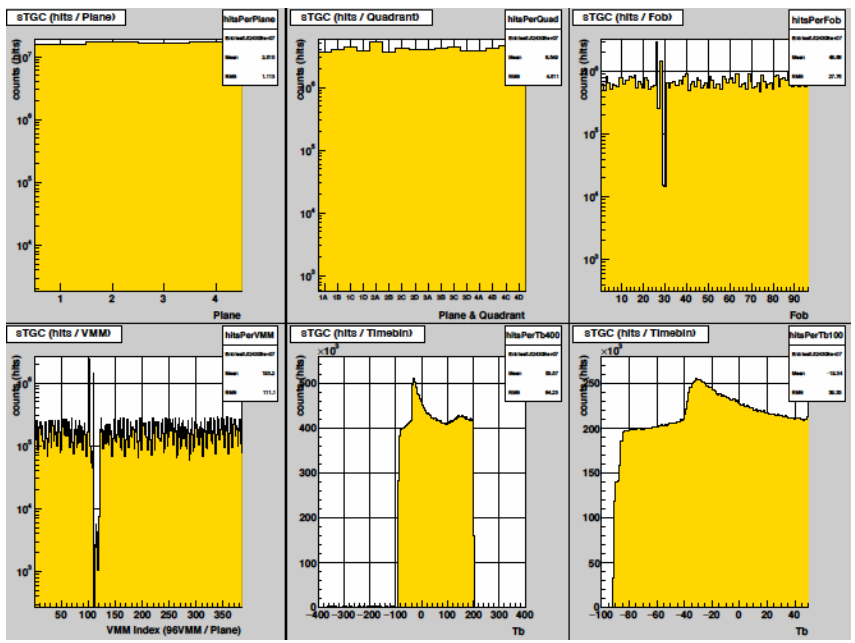
# Forward tracking detectors

- Real-time quality-assurance plots monitored by shift crew

- FST

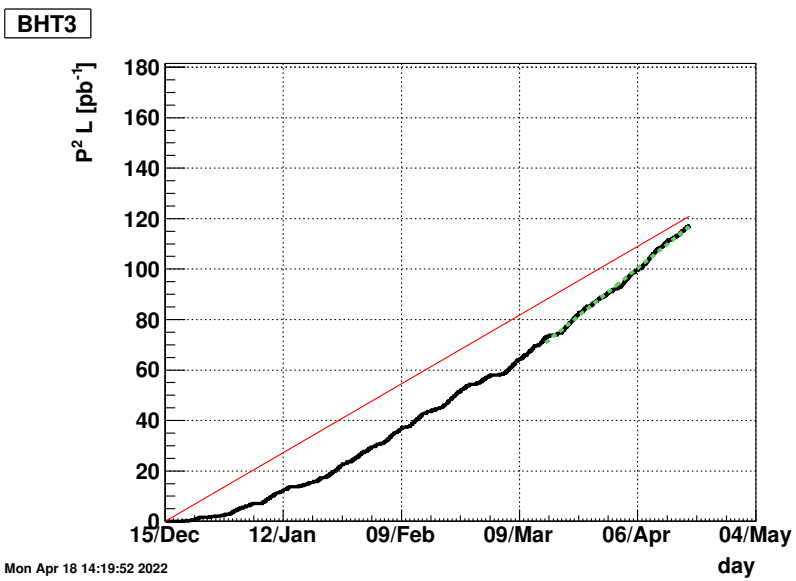


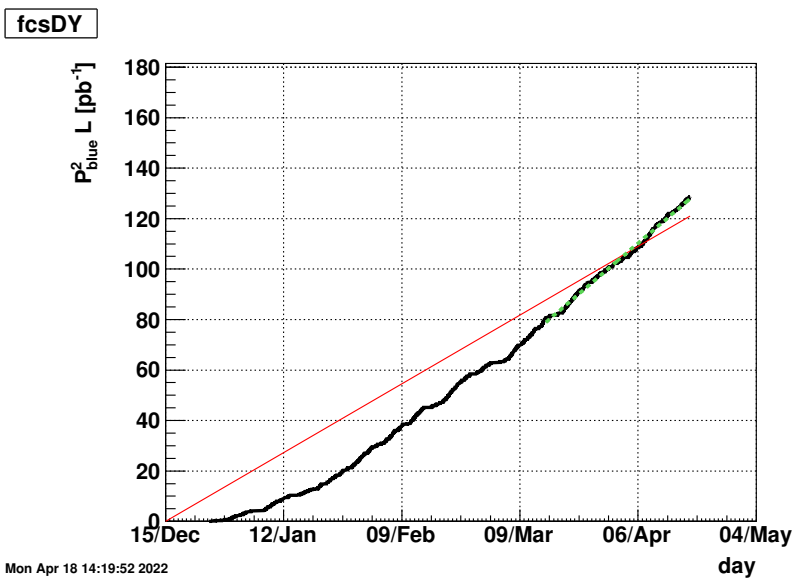

- sTGC



# Run22 final score

- Physics data taking period: 57 days ( $\sim$ 16 "physics week")
- Total sampled luminosity: $\int L = 452,\ pb^{-1}$ (113%)
- Figure of merit $Fom = \int P^2 \cdot L = 117.2\ pb^{-1}$, 98% of the goal for mid-rapidity BHT3 triggered events
- $Fom = 126\ pb^{-1}$ (106%) for forward rapidity FCS-DY triggered events



# Looking forward: Run23+

- Beam use request, assuming 28 cryo weeks (24 physics weeks) per year

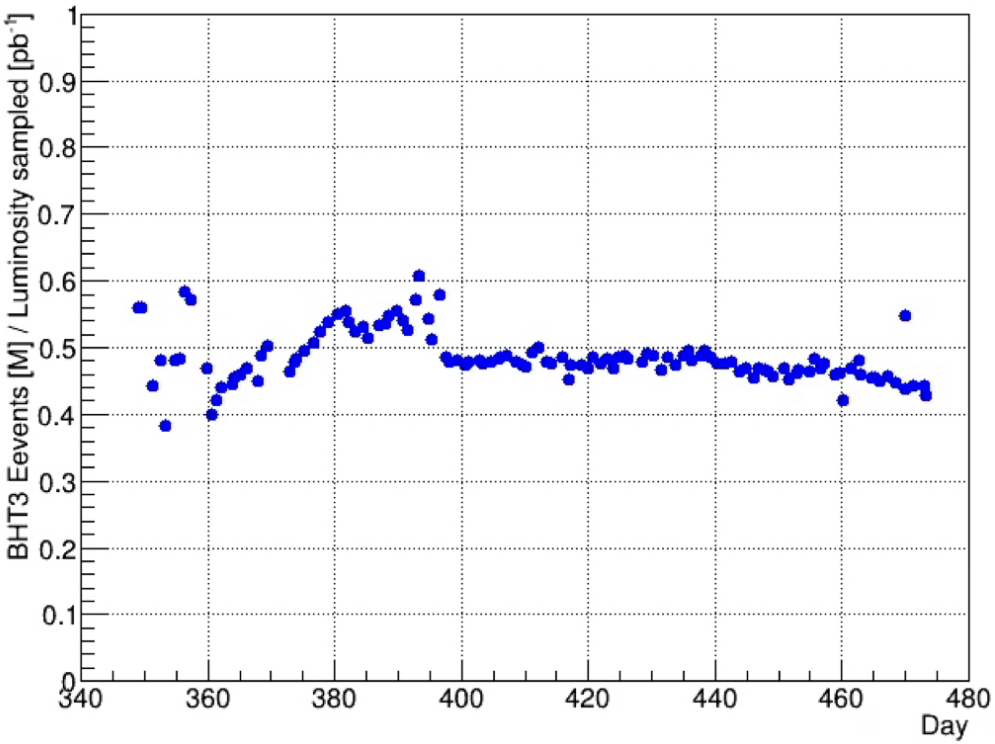
| $\sqrt{s}$ (GeV) | Species | Number of events / Sampled Luminosity | Year |
|---|---|---|---|
| 200 | $Au + Au$ | 20 B / 40 $nb^{-1}$ | 2023+2025 |
| 200 | $p + p$ | 235 $pb^{-1}$ | 2024 |
| 200 | $p + Au$ | 1.3 $pb^{-1}$ | 2024 |

- High luminosity for rare probe/high-$p_T$ physics + controlled low luminosity for minimum bias physics
  - High-$p_T$: ZDC $\sim$ 100 kHz (29 physics weeks)
  - Minimum bias: leveled ZDC rate at $\sim$ 10 kHz (19 physics weeks)
  - Mix two modes depending on beam conditions
- Forward upgrade detectors are ready

# Conclusion

- Run22: despite rough times at the beginning, we achieved our goals
- No significant issues with STAR sub-systems and recorded data
- Forward detectors are successfully commissioned and are performing well
- Hybrid shift mode worked efficiently during the COVID era
- **Thanks for all the work done by CAD to make Run22 successful**

# Comparison of BHT3 and ZDC rates at STAR




- No indication of change of effective ZDC cross section at STAR