TPC Rate increase for Run 23 and on

Flemming Videbæk
on behalf
TPC DAQ upgrade task force

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Charge from management

We would like to form the STAR TPC DAQ improvement task force. With the firmware changes on the TPC electronics, it is possible for us to double the TPC electronics readout rate with a minimal cost. This will greatly enhance STAR physics capability. Our past Beam Use Request has taken the planned upgrade into account. The long shut down anticipated after Run 22 provides us an opportunity to do the firmware change and evaluate the impact for physics data analysis. The task force is charged to evaluate the readiness of the TPC DAQ improvement for Run 23 and beyond:

- What are the resources required to realize DAQ improvement?
- Where is the bottleneck for this upgrade? What are the risks?
- What software changes (online and offline) are required to accommodate the upgrade?
- What hardware and network changes are required to handle this upgrade?
- Evaluate the impact of proposed changes on physics capabilities.
- What is the timeline and path toward completion of this upgrade?
- Report to management regularly and provide input to beam use request for Run 23 and beyond.

We believe that

- Our first input to the BUR is to make clear what the constraints on data running conditions (rates, data volume, deadtimes). This is the main point of the discussion today, and is based on the first estimates presented earlier by Tonko

Task Force

The members are:

- Richard Witt (co-Chair), Flemming Videbaek (co-Chair),
- Zhenyu Chen, Xin Dong, Yuri Fisyak, Carl Gagliardi, Jeff Landgraf, Tonko Ljubicic, Chun Yuen (Tommy) Tsang, Gene Van Buren

- The group has had 2 meetings
  - Feb 17 and March 24.
  - There is a drupal page* with presentations, minutes

    https://drupal.star.bnl.gov/STAR/subsys/tpc/TPC-speed-upgrade-2022

*Also on BUR page

Last years BUR

- Assumed 3.5kHz
- Envision data taking with lower and high luminosity

Reality checks:

- The overall beam conditions i.e. #bunches, ion intensities is set by sPHENIX requirements
- High, low lumi conditions will have to be set be local IR beam conditions at STAR
  - beta*, crossing angles

Table 2: Proposed Run-23 - Run-25 assuming 28 cryo-weeks of running every year, and 6 weeks set-up time to switch species in 2024. Sampled luminosities assume a "take all" triggers.

$\sqrt{s_{NN}}$ (GeV)	Species	Number Events/ Sampled Luminosity	Year
200	Au+Au	10B / 31 nb^{-1}	2023
200	pp	235 pb^{-1}	2024
200	p+Au	1.3 pb^{-1}	2024
200	Au+Au	10B / 31 nb^{-1}	2025

year	minimum bias [$\times 10^9$ events]	high-p_T int. luminosity [nb^{-1}] all vz	$\|vz\|<70$cm	$\|vz\|<30$cm
2014 2016	2	27	19	16
2023 2025	20	63	56	38

Table 9: STAR minimum bias event statistics and high-p_T luminosity projections for the 2023 and 2025 Au+Au runs. For comparison the 2014/2016 event statistics and luminosities are listed as well.

Conditions that may be reached if all goes well (goal for task force)

- High lumi running (w. additional central and other high multiplicity,forward detectors similar to run 16)
  - 3kHz 20% dead time
- Low lumi running (plain min bias e.g. 10kHz ZDC rate*)
  - 5kHz TPC rate 30% dead time.
- The BUR should be based on these assumptions, and must take into account other bottlenecks that are imposed by other detectors, electronics, network, storage resources (to be discussed)
- STAR needs to discuss with C-AD how in particular the low lumi running mode can be achieved.

*Higher ZDC rate will result in pile-up and much lower rate

Plan and Status

- The details were outlines at the coll meeting talk.
  - Modify FPGA firmware for iTPC (Fee's and RDO) for TPX (Fees, RDO(2))
  - DAQ PC software (reorganize , cluster finder upgrades)
  - DAQ PC hardware (memory upgrades), network upgrades,
  - EVB upgrades, HPSS transfer rates identified.
- First round of iTPC FPGA done, will setup development for full sector TPX,TPC after end of run. Will test performance with simulated data (taken from real data runs in 16 and 19). Look plausible
- Request has been made by STAR for SDCC resource needs (HPSS, tape storage, computing capacity for *2 data volume.
- Details on status from Mar24 meeting

Other constraints

- Forward suite
  - FST current max rate is 4.5 kHz; may have issues with CPU power for zero suppression; significant data volume
  - Like not be useful for more central events ->
  - But in central to mid-central events, the sTGC will also likely (a) be black and (b) contribute a large data volume. Thus, there might be a significant advantage separating the large event count triggers into “central” and “peripheral” versions, with the bare minimum of overlap necessary to make sure they can be stitched together for those analyses that don’t require the sTGC and FST.
- If old QT boards are to be used for some detectors ; can only run up to ~ 3kHz.
- *plan in place to replace QTB (please confirm what detectors uses te old QT) DSM2 should also be implemented.

Summary

- The BUR must pay attention to the optimal running conditions,;
- Cannot put together a program that break the constraints imposed by limitations of readout system.
  - High lumi running (w. additional central and other high multiplicity,forward detectors similar to run 16)
    - 3kHz 20% dead time
  - Low lumi running (plain min bias e.g. 10kHz ZDC rate)
    - 5kHz TPC rate 30% dead time.

- What can the rates be for pp 200 and pA? (Matt)
- Daniel (- brief write-up of TPC daq readout for run 23-25

Beam Projections

- beam ions+bunches will be determined by sPHENIX request.
- STAR can adjust crossing angle and beta*
- We can also employ luminosity levelling to get uniform conditions for the Min Bias

Table 4: Demonstrated and projected luminosities for 100 GeV/nucleon Au+Au runs.

Parameter	Unit	FY2016	2022E	2023E	2024E	2025E	2026E	2027E
No of bunches k_b	…	111	111	111	111	111	111	111
Ions/bunch, initial N_b	10^9	2.0	2.15	2.2	2.40	2.75	2.75	2.75
Average beam current/ring I_{avg}	mA	224	236	242	264	302	302	302
Stored beam energy	MJ	0.71	0.75	0.77	0.84	0.96	0.96	0.96
Envelope function at IP β^*	m	0.70	0.70	0.65	0.63	0.60	0.60	0.60
Beam-beam parameter ξ/IP	10^{-3}	-3.9	-4.1	-4.2	-4.6	-5.3	-5.3	-5.3
Initial luminosity L_{init}	**10^{26} cm^{-2}s^{-1}**	**155**	**171**	**193**	**237**	**313**	**313**	**313**
Events per bunch-bunch crossing μ	…	0.40	0.44	0.50	0.61	0.80	0.80	0.80
Average/initial luminosity	%	56	60	65	64	64	64	64
Average store luminosity L_{avg}	**10^{26} cm^{-2}s^{-1}**	**87**	**103**	**126**	**152**	**200**	**200**	**200**
Time in store	%	65	62	62	62	62	62	62
Max. luminosity/week	μb^{-1}	3000	3860	4710	5700	7520	7520	7520
Min. luminosity/week	μb^{-1}		3000	3000	3000	3000	3000	3000
L within $\|z\|$<70 cm, θ = 0 mrad, r_0*	%	72	72	90	90	90	90	90
L within $\|z\|$<30 cm, θ = 0 mrad, r_0*	%	59	59	74	74	74	74	74
L within $\|z\|$<10 cm, θ = 0 mrad, r_0/r_θ*	%	19/19	19/19	33/33	33/33	33/33	33/33	33/33
L within $\|z\|$<10 cm, θ = 1 mrad, r_0/r_θ*	%			31/57	31/57	31/57	31/57	31/57
L within $\|z\|$<10 cm, θ = 2 mrad, r_0/r_θ*	%			26/82	26/82	26/82	26/82	26/82

* Luminosity $L(z,\theta)$ within vertex cut $|z|$ for full crossing angle θ. The values r_0/r_θ are $r_0 = L(z,\theta)/L(10\text{ m},0)$ and $r_\theta = L(z,\theta)/L(10\text{ m},\theta)$.