TPC calibration

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STAR TPC calibration review, 02/16/2021

Outline

- **Geometry & alignment**
  - TPC Survey
  - STAR magnetic field
  - Laser drift velocities
  - Alignment, Cosmic & collider data
    - Prompt hits
    - Inner to Outer sector alignment
    - Super Sector alignment
    - West and East halves of TPC alignment : STAR global T0
- **dE/dx calibration**
- **Tracking Focus Group (TFG). TFG software releases.**
- **Express production, task, results.**
- **Express calibration.**
- **Validation procedures and QA**
- **Bottle neck in timely calibrations**

TPC surveys results has been presented in Flemming talk

References:

- Survey data is located at https://www.star.bnl.gov/~fisyak/star/Tpc/Survey/, codes are in (TFG) $STAR/macros/TpcSurvey.C and TpcSurvey.doc
- The survey results have been presented in https://drupal.star.bnl.gov/STAR/system/files/TpcSurvey.pdf and https://drupal.star.bnl.gov/STAR/system/files/Static%20TPC%20distorions.pdf (02/19/2014) and the table below is used as TPC position in Magnet and TPC halves positions in TPC

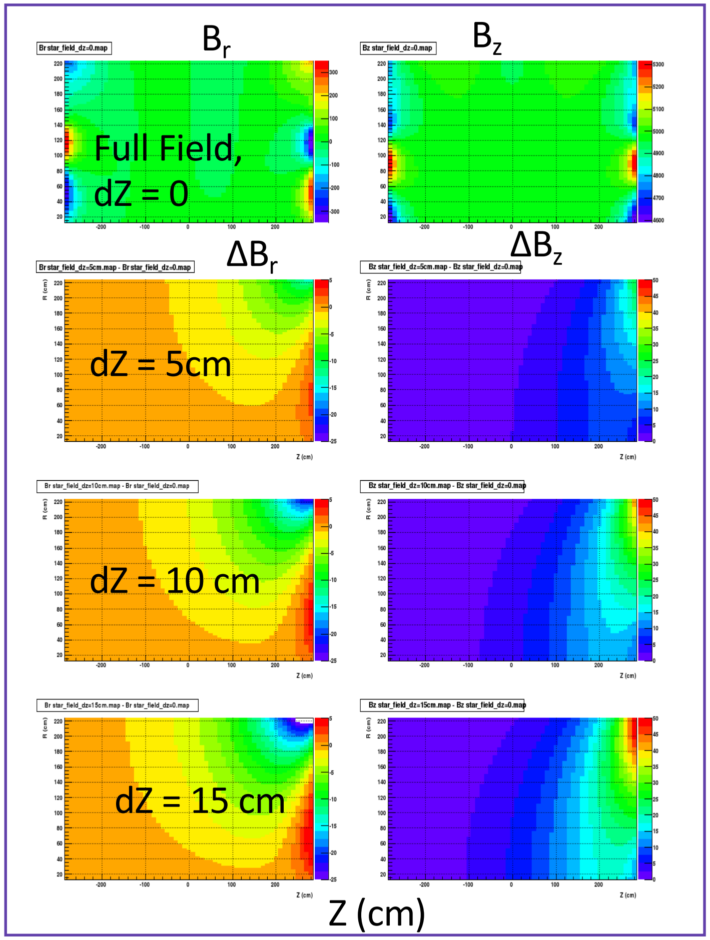
	x(cm)	y(cm)	z(cm)	α(mrad)	β(mrad)	γ(mrad)
TPC in STAR magnet	-0.2383	-0.1732	-0.1957	0.10	-0.48	0.36
West Wheel in TPC	0.0193	-0.0133	-0.0156	0.16	0.11	-0.39
East Wheel in TPC	0	0	0	0	0	0.03

Summarizing the results :

- We have measured the whole TPC position with respect to magnet and the West and East endcap wheels with respect to TPC:
- TPC is shifted ~2 mm with respect to the center of magnet.
- TPC is rotated around vertical axis (Y) with β = -0.48 mrad and around Z axis by γ = 0.36 mrad.
- The rotation around Y is essential contributor in static ExB distortions.
- TPC West wheels are shifted with respect to TPC by ~200 μm and rotated around Z axis by γ = -0.39 mrad.
- The comparison of 2013 survey (full ToF, ~1T) with previous ones showed a difference within ~200 μm and ~0.1 mrad.

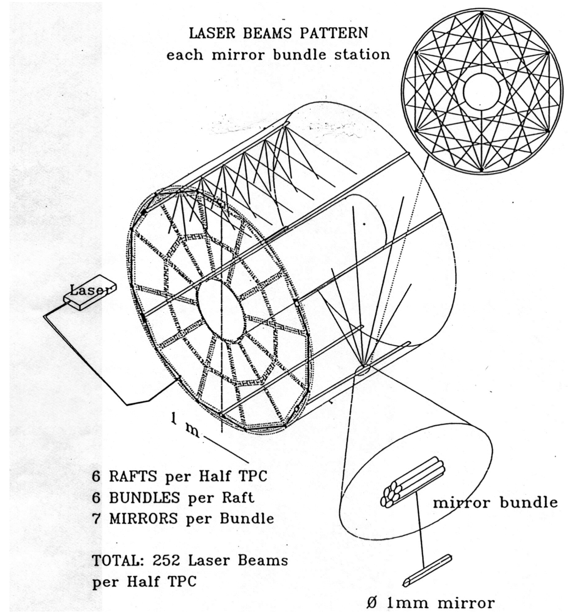
STAR magnetic field.

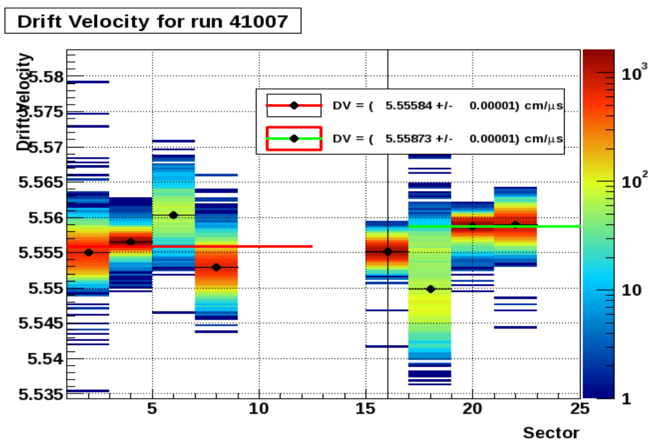
- The STAR magnetic field has been **measured and tabulated** by Kenneth Foley, William A. Love, and Stephen Trentalange in October 1998 for 4 field setting (1,0.5,-0.5,-1.0). The table of the magnetic field is used since.
- In 2003 STAR detector has been **upgraded** with Endcap Electromagnetic Calorimeter (EEMC). This colorimeter has stainless steel cover and supporting plate with minimum impact on the magnetic field. But the calorimeter's PMTs are covered with magnetic field shielding which is equivalent of a iron plate with thickness of a few centimeters. Jim Sowinski (STAR Note 426) has showed that the influence of **can be controlled**. But till 2015 nobody did it.
- Wuzheng Meng (CAD) made calculation of the influence of the iron plate on the back of West pole tip with different thickness (dZ = 5, 10, and 15 cm). The influence of EEMC is ~0.2%. The problem is that we don't know the effective length (dZ) of this "iron" plate.
- G.Nigmatkulov (https://drupal.star.bnl.gov/STAR/blog/gnigmat/2013/aug/22/measurement-magnetic-field, StRoot/StEandBDirMaker and EandB.C) has tried to estimated this length using an average direction of low energy electrons (~20 MeV) reconstructed in TPC in order to reconstruct the magnetic field direction (B_r/B_z). His estimation gave us value **dZ = 7.5 cm**. This value for Wuzheng Meng's correction has been used for the STAR magnetic field since.
- The point which I want to make that **this study** has to **be revisited**. The reason for that will be shown later in QA plots.
- The main magnet coil current has jumped from 4500 A to 4505 A in y2005, and it is slightly increasing since. Now this measurement is about 4510 A, i.e. ~0.2% higher than set value 4500 A. There are some doubts (William B. Christie, private communication) that the measurement device is still using the same Ampere units as before 2005.
- We do need an **independent magnetic field measurement**.



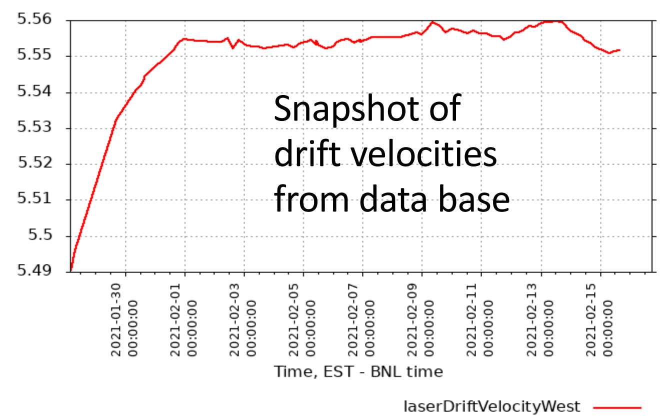
Laser drift velocities

- TPC drift velocity is measured using the laser system.
- The laser runs each 4 hours with 10 Hz rate collecting ~4k events per run.
- Daq files from the laser stream are transported to HLT farm and processed by the standard reconstruction chain as a cron job with StRoot/StLaserAnalysisMaker in it ("lana" option).
- StLaserAnalysisMaker for reconstructed global tracks with p>10 GeV/c,
  - matches them with a bundle using Z position of the farthest from the beam line track hit,
  - matches with a mirror in the bundle using the track and the measured laser beam directions,
  - for each event and for each raft slope of difference (Z_P - Z_M) versus Z_M is fitted, where Z_M is the mirror Z position in TPC coordinated system, and Z_P is the predicted track interception (Z_P) with line (X_M,Y_M) defined by the mirror.
  - The slope is the scale factor to the "current" drift velocity in order to obtain new one.
  - Each matched track mirror combination is saved in a "laser" TTree.
  - Using all laser files from the given run (LanaTrees.C) the averaged scale factor over all rafts and events defines the new drift velocity and put it in the data base by a cron job. Overall precision of the drift velocity measurement is ~0.01%.





If we do have enough active laser beams, then the drift velocity is well under control.



Alignment using tracks (requirements)

- The first pass of TPC alignment with tracks (J. Danlop, et al.) has been done using 2001 zero field data. It was used primary tracks at almost zero dip angle from the primary interaction near the end of TPC (Z ~ ± 200 cm).
- In 2004 with upgrade from DAQ10 to DAQ100 we observed a dynamical distortions (a few mm) which was called as “Grid Leak”.
- With STAR TPC electronics upgrade from DAQ100 to DAQ1000 (2008) data acquisition rates increased by an order of magnitude.
- RHIC II (https://aip.scitation.org/doi/abs/10.1063/1.3293915) upgrade gave us another order of magnitude in statistics.
- As the results of these upgrades, we got practically new detector with new requirements on precision, data model, …
- Another set of requirements came from STAR Heavy Flavor Tracker (HFT) program.
- In this sense we had to **revisit** the TPC calibration procedures (https://drupal.star.bnl.gov/STAR/system/files/Static%20TPC%20distorions.pdf), and TPC response simulator.

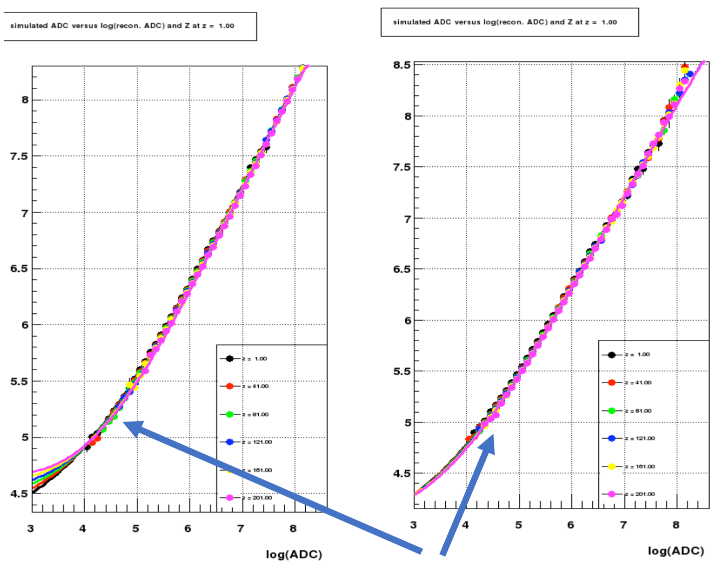
TPC Response Simulator: TpcRS

We had to developed new TPC Response simulator https://drupal.star.bnl.gov/STAR/system/files/TpcRS_0.pdf with goals:

1. To reduce systematic errors in the track reconstruction efficiencies from ~5% to 1÷2%,
2. To estimate **nonlinearity** conversion of cluster ADC to deposited energy due to thresholds in a cluster finder, $Log(ADC_{MC}) = F(Log(ADC),Z)$ parameterization.
3. To estimate systematic **slewing** of the estimated cluster Z position versus cluster size, $time_{MC}$ = time + F(No. of time buckets in cluster)

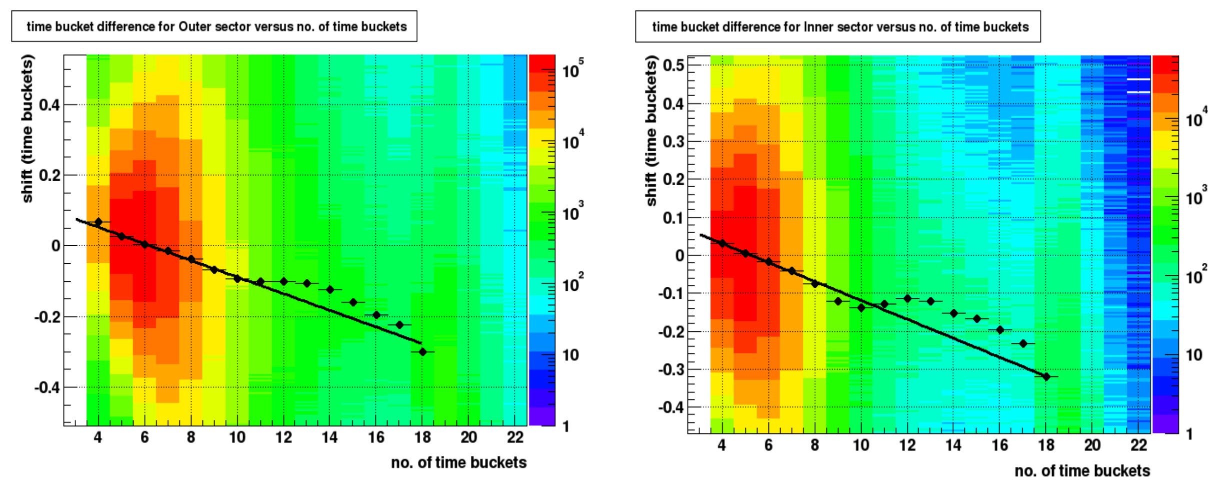
The last two points are used in the calibration procedure as a priori corrections.

TpcAdcCorrectionB, via
StRoot/StTpcMcAnalysisMaker, TpcT.C, AdcTpcT.C



Effects of threshold in the cluster finder

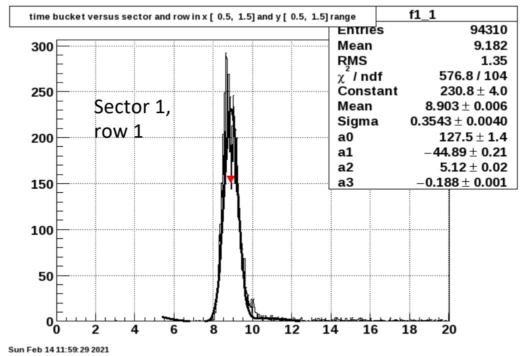
tpcTimeBucketCor, linear versus no. of time backets in cluster

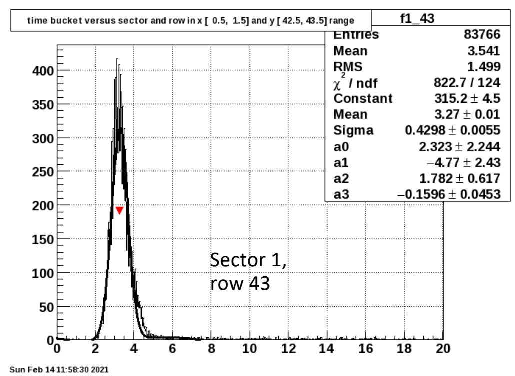


Alignment with tracks, sub sector time offsets using prompt hits

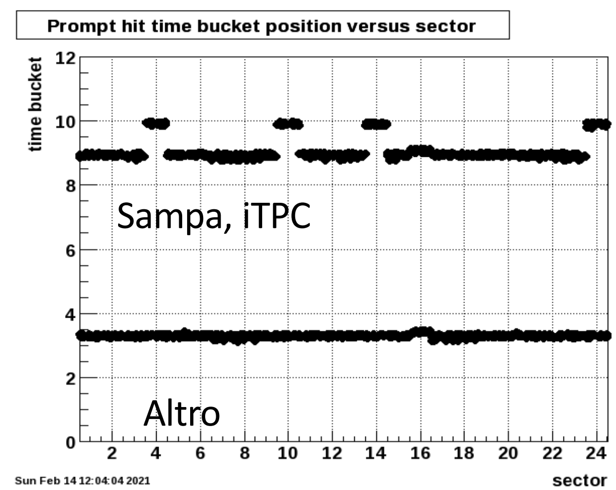
Time and gain equalization on pad level is done using pulser runs for each sub sector. Altro/Sampa microcircuit allows to detect signals coming before trigger. Thus, we are detecting hit coming directly from MWPC.

Examples prompt hit position fits





This allows us to measure time offsets for each sub sector (TpcPrompt.C, **tpcSectorT0offset**).



Sector alignment.

The coordinate transformation from measurement in local sub sector coordinate (**L**) to the STAR global coordinate system (**G**) is expressed a product of 4x4 matrices (ROOT::TGeoHMatrix)

$$\mathbf{G} = \mathbf{R}_{TPC} \times (\mathbf{T}_{wheel} \times \mathbf{R}_{wheel}) \times (\mathbf{R}_{sector} \times \Delta\mathbf{R}_{sector}) \times \mathbf{R}_{flip} \times \Delta\mathbf{R}_{inner,outer} \times \mathbf{L},$$

$\mathbf{R}_{TPC}$ is the surveyed position of TPC in STAR magnet (StTpcPosition),

$\mathbf{T}_{wheel}$ is translation of in Z direction by $\pm Z_{GG}$ for the West and East halves of TPC, respectively, where Z_{GG} = 208.707 cm is the Gating Grid position.

$\mathbf{R}_{wheel}$ is the surveyed position of West and East wheel in TPC,

$\mathbf{R}_{sector}$ is the ideal sector position in TPC half,

$\Delta\mathbf{R}_{sector}$ is the super sector misalignment,

$\mathbf{R}_{flip}$ is conversion (x,y,z) ⇒ (y,x,-z) from local sector coordinate system to sector one,

$\Delta\mathbf{R}_{inner,outer}$ is inner / outer sector misalignment,

L is the local sector coordinate as result of transformation of (pad, row, time backet) ⇒ (x, y, z ≡ drift distance).

The alignment procedure is a way to find $\Delta\mathbf{R}_{sector}$ and $\Delta\mathbf{R}_{inner,outer}$.

Before **iTPC** era we assumed that $\Delta\mathbf{R}_{inner} = \mathbf{I}$, i.e. we did only alignment of $\Delta\mathbf{R}_{outer}$.

After **iTPC** was install we froze the previous $\Delta\mathbf{R}_{outer}$, and did alignment of $\Delta\mathbf{R}_{inner}$.

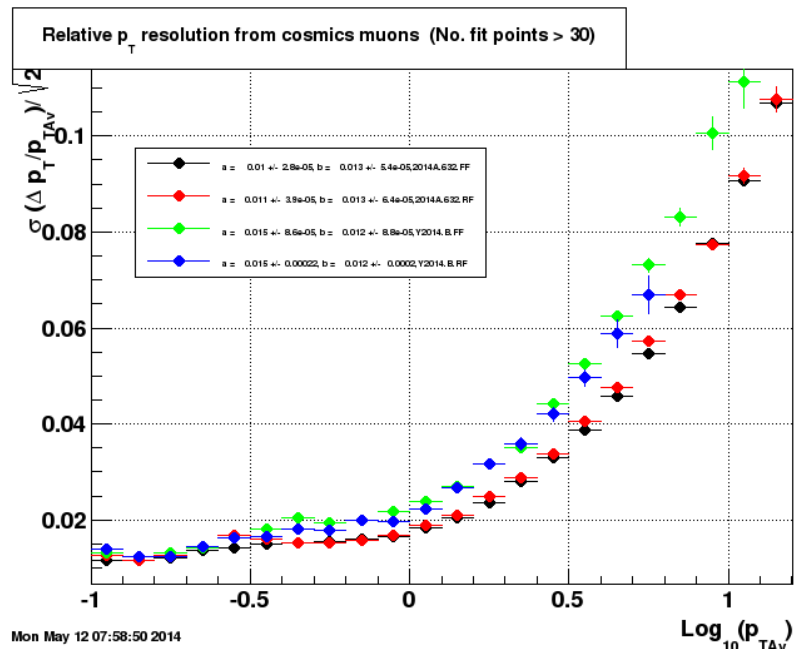
ΔR is defined as product on translation (δx, δy, δz) and rotations (α around X, β around Y, γ around Z).

Inner to Outer Sector alignment.

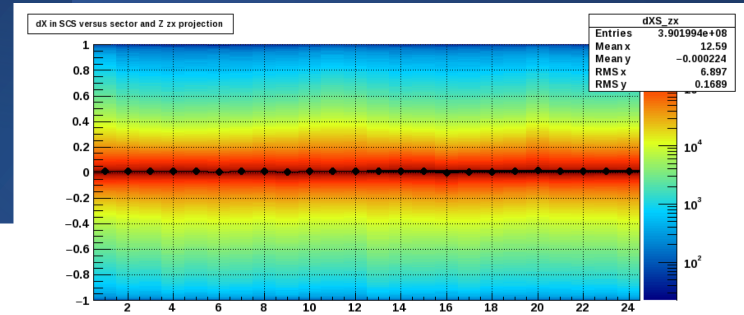
To align outer (**TpcOuterSectorPositionB**) with respect to inner sector (for iTPC we aligned inner with respect to outer, **TpcInnerSectorPositionB**) we used cosmics (StRoot/StTpcAlignerMaker, TpcAligner.C, TpcAlignerDraw.C).

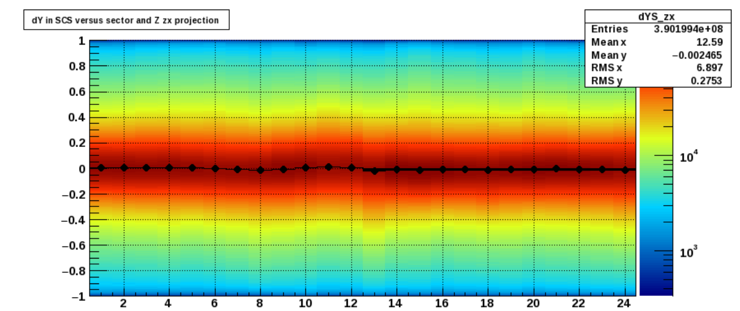
During the alignment we are using only static distortions, the **dynamic** distortions are assumed to be **negligible**.

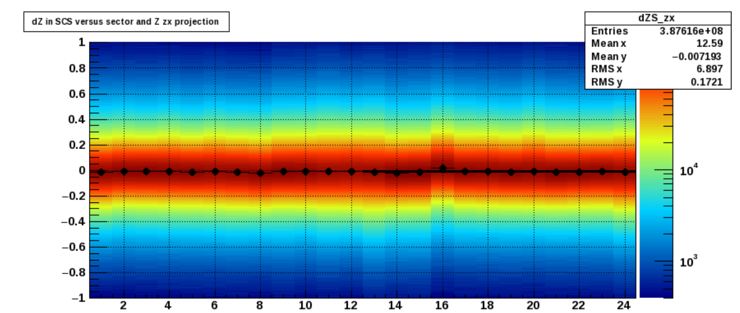
- The tracks were reconstructed in each sub sector of TPC,
- The track were matched at Y = 122 cm, between Inner and Outer sectors
- direction and coordinate deviations for these tracks are been calculated,
- The deviations has plotted as function of deviation derivatives with respect to parameters (δx, δy, δz, α, β, γ), and
- A linear fit gives estimation of these parameters at the derivative equals to zero. (This is a variant of least squares fitting.)
- The procedure is iterative. It is rather stable. The convergence is considered as achieved when δ ~ 100 µm and rotation angles ~ 0.1 mrad
- Using the same cosmic particle reconstructed with both track we can estimate moment resolution. This "new" TPC alignment procedure gives **~15% improvement** in momentum resolution (black and red, for Full Field and Reverse Full Field, respectively) with respect to old one (green and blue). https://drupal.star.bnl.gov/STAR/blog/fisyak/momentum-resolution-cosmics-after-magnetic-field-dependent-outer-inner-sector-alignment)



Super sector alignment.







- Super sector alignment (**TpcSuperSectorPositionB**) is based on tracks reconstructed in a sector only i.e. track merging from different sectors is forbidden.
- The track reconstructed in different sectors are matched at the border of the sector.
- The deviations the matched tracks the parameter predictions are expressed as function of derivatives with respect super sector alignment variables. The alignment variables are founded as a result the linear fit.
- This procedure has **instabilities**. To freeze super sector alignment parameters, it is very useful to have **external measurement**. In 2014 it was used HFT.
- As another source for the super sector alignment, we use the reconstructed **primary vertex** (KFParticle, MuTpcG.C) and calculate DCA for track in a given local sector coordinate system.
- An example of these DCA from the Run XXI express calibration based on the first 3 weeks of running is shown the plots on right.
- The calculation difference in the Z positions of the primary vertices reconstructed using only West and only East TPC tracks allow us to measure the STAR trigger time offset (**trgTimeOffsetB**).
- The plots show distribution of X,Y,Z components of DCA versus sector number for RunXXI. The plots corresponds to well aligned super sectors situation.

dE/dx calibration.

The main goal of the calibration is to reduce systematic in dE/dx measurement to level below 1%.

- Calibration parameters are grouped in 3 categories:
  1. **fixed or out of offline control**,
  2. **calibrated offline, mainly depend on gas state**, **and**
  3. **used to account specific conditions for the given run.**
- The list of parameters (DB tables) includes:
  1. "tpcGain" correction **(tpcPadGainT0, itpcPadGainT0),**
  2. ADC/Clustering nonlinearity correction **(TpcAdcCorrectionB),**
  3. Cuts of sectors borders, and positions near TPC membrane and gating grid. Dependence of the Gain on distance from Chamber edges (**TpcEdge**),
  4. Gas gain correction for sector/row (**TpcSecRowB**),
  5. Gas gain dependence on drift distance (**TpcZCorrectionB),**
  6. Correction for Electron Attachment due to O_2 (**TpcDriftDistOxygen**),
  7. Dependence of the Gain on the Anode Voltage (**tpcGainCorrection** based on **TpcAvgPowerSupply)**,
  8. Dependence of the Gain on Gas Density due to Pressure (**tpcPressureB**),
  9. Dependence of the Gain due to its variation cluster position on sector (**TpcLengthCorrectionB**, **TpcPadCorrectionMDF**),
  10. Global track multiplicity dependence (**TpcMultiplicity**),
  11. Dependence of the Gain on total charge accumulated so far (**TpcRowQ**, **TpcAccumulatedQ**),
  12. dX correction (**TpcdXCorrectionB**),
  13. Dependence of the Gain on interception angle (**TpcTanL**),
  14. Variation of truncated mean, fitted dE/dx and dN/dx for track and its relative error versus its length in TPC and average sampling <dX> (**TpcLengthCorrectionB**, **TpcLengthCorrectionMDF**).
  15. …

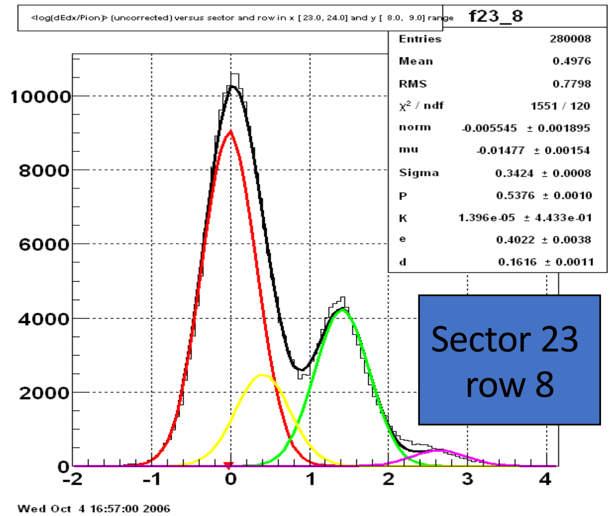
  The usual calibration sequence is : **TpcSecRowB ➜ TpcZCorrectionB ➜ TpcSecRowB ➜ TpcPadCorrectionMDF ➜TpcSecRowB ➜ tpcPressureB ➜TpcSecRowB ➜ TpcLengthCorrectionMDF**

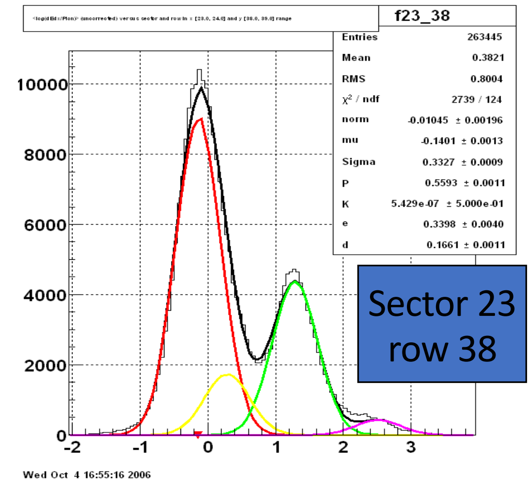
Calibration procedure

- Calibration sample is
  - good clusters : used in track fit, with no overlaps ;
  - good global tracks with Track length in TPC > 20[or 40] cm;
  - tracks with $0.4 < p < 0.5$ GeV/c (~MIP for pions: $\beta\gamma = p/m = 4$), i.e.
    - calibration point is MIP for π, and
    - βγ dependence is completely defined by Bichsel model,
    - For **BESII** calibration we are using only **negative** tracks due to significant contamination of protons in the positive track sample.
- For each cluster create histograms of

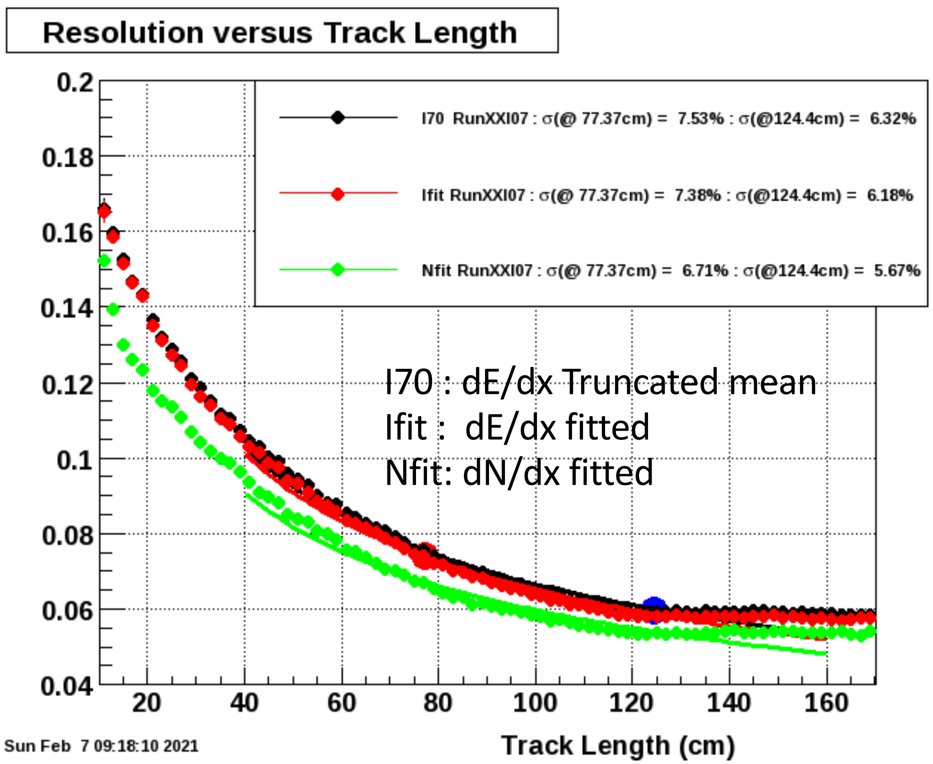
  Z = log {(dE/dx) measured / (dE/dx) predicted for π},

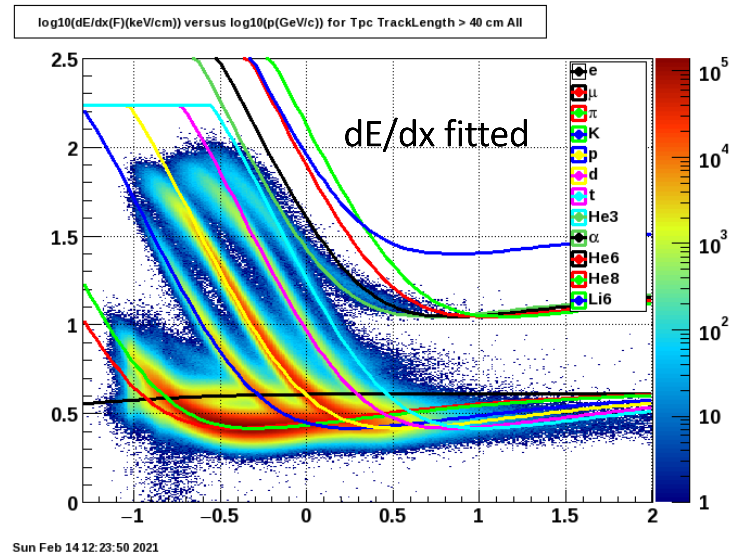
  where prediction is taken from Bichsel model.
- Fit this histogram by 5 Gaussians with respect to position (μ) and σ of π, with fixed relative positions of K- π, P-π, e-π, d-π. The position (μ) of π defines the calibration correction.
- Define calibration parameters which provide condition μ = 0, and
- Parameterized them versus appropriate variables (pressure, Track Length and <dX>, sector, row, …).

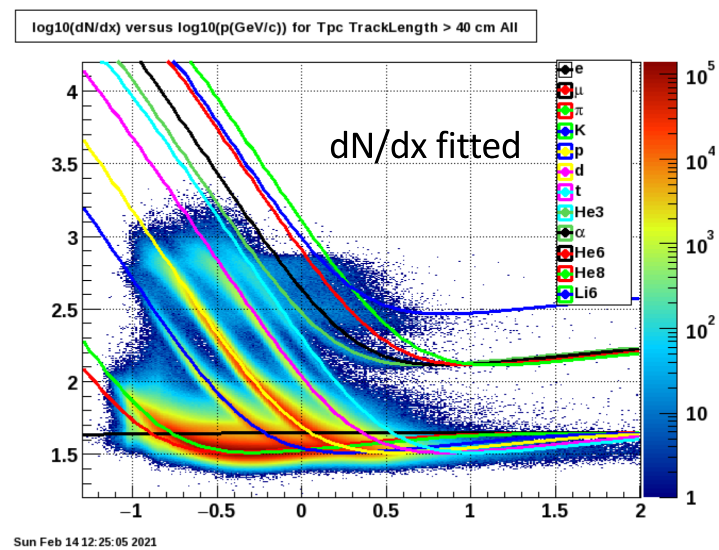




Run XXI 7p7GeV data sample, express calibration.







Tracking Focus Group (TFG)

- TFG has been created on STAR Collaboration Meeting, Jun. 1-6, 2015, Stony Brook University (https://drupal.star.bnl.gov/STAR/meetings/star-collaboration-meeting-june-1-6-2015)
- The main tasks (https://drupal.star.bnl.gov/STAR/meetings/star-collaboration-meeting-june-1-6-2015/tracking-focus-group/charge-spokesman) were set :
  - To restart StiCA project which has been blocked by S&C management after the StiCA successful STAR collaboration review (https://drupal.star.bnl.gov/STAR/system/files/TrackingReview_Nov2011_v1.ppt) **"… CA should be deployed for Run12, …"**
  - To prepare tracker/tracking for iTPC era,
  - To continue the development of tracking Algorithm in forward region,
  - To study and recommend on how to take advantage of current tools in physics analyses with Kalman Filter [KFP, KFV]
  - …
- Some of the tasks has been **completed** (StiCA, iTPC, VMC, …). Some of them are still under development.
- After STAR S&C reorganization in May 2020 **TFG** became STAR **Tracking group.**

Express Chain, the task:

A slide from Aihong Tang talk at STAR Collab. Mtg, Aug. 19, 2016
(https://drupal.star.bnl.gov/STAR/system/files/TFG_HLT_STARCollabMtgAug2016.pdf)

Speed up offline code and run on HLT farm

Impression from the Town Hall discussion on Wednesday : we want to speed up the analysis cycle, in particular for BES-II.
What about having a preliminary copy of pico dst ready when the run finishes !

- It was in our plan to offer the collaboration an option of fast data production (BFC) with HLT farm during BES-II --- Challenging but we'd like to try.
- Solving the optimization problem (identified by TFG, clean solution implemented by offline team) have already given us a factor from 1.5 to 2 in CPU performance …
- Another speed up by ~12% can be obtained from switch from 32 bits to 64 bits. TFG shows ways how to do this for reconstruction codes. The simulation requires additional work.
- Tracking with full CA instead of only using CA as seeder (a reduction factor of ~3)
- Run tracking on both cpu and phi coprocessors.

From PAC :

> The STAR collaboration has expressed concern about continuation of their limited computing resources and disk storage, which the PAC considers to be a very serious issue. In order to enable the timely reconstruction and release of STAR data, BNL management is urged to find ways to improve on the current constrained resources and to seriously consider the following recommendations:

Collective efforts in addressing PAC's concern

TFG git repository

In order to provide **reproducibility** of results with version control we had to create **TFG git repository,** which is accessible by STAR community, and the library **releases** are exported from HLT via cvmfs (/cvmfs/star.sdcc.bnl.gov/TFG/)

- -TFG16a Production of 50 M events 2014 AuAu200 and 32 M 2013 pp510W 2016-02-12 13:06:04 -0500 (tag: v02-11-16, TFG16a)
- …
- TFG19e HLT express production 2019 2019-05-30 20:23:14 -0400 (HEAD -> master, tag: TFG19e_4)
- TFG19g old CA, add to StarMCSimplePrimaryGenerator real PV position 2019-07-26 10:26:59 -0400 (HEAD -> master, tag: TFG19g_4)
- …
- TFG19e HLT express production 2019 2019-05-30 20:23:14 -0400 (HEAD -> master, tag: TFG19e_4)
- TFG19m Prepare xProduction of Run XX 2019-12-24 12:00:04 -0500 (HEAD -> master, tag: TFG19m)
- TFG20a Prepare xProduction of Run XX Fixed Target 2020-01-28 16:53:27 -0500 (HEAD -> master, tag: TFG20a_1)
- …
- TFG21c express production release for Run XXI, add fix TpcHitMaker 2021-02-13 19:02:40 -0500 (HEAD -> master, tag: TFG21c_5)
- .DEV2 head of TFG git repository

Releases tagged as TFG16a_1, TFG19e_4, TFG19m, TFG20a_1, and TFG21c_5 has been and are used for express production.

Express production (2019)

In 2019 we have made a **first try** of the express production.

The main **goal** was to achieve the event production rate **~300 Hz**. To do this we:

- Use only HLT good event, a factor of from 3 to 5 reduction of input event rate.
- Switch to 64b version of reconstruction (+25% with respect default reconstruction)
- Switch from default gcc 4.8.5 to gcc 6.3.1 (+10%)
- Replace Sti track finder and fitter to Stx track fitter using tracks found by CA only and GenFit2 for final track fitting (+75%).
- As result we speed up reconstruction by a **factor ~2.4**
- Thus, we have achieved HLT farm event production rate ~5 M/day => **60 Hz of HLT good events** and we could **handle all** BES-II collider data.

Express production, 2019. Goals for 2020-2021.

Ivan Kisel based on 2019 data production experience has reformulated express production goals for 2020 – 2021 and presented them during Cracow STAR collaboration meeting (https://drupal.star.bnl.gov/STAR/system/files/Kisel%20STAR%20Coll%20Meeting%2022.08.2019.pdf) :

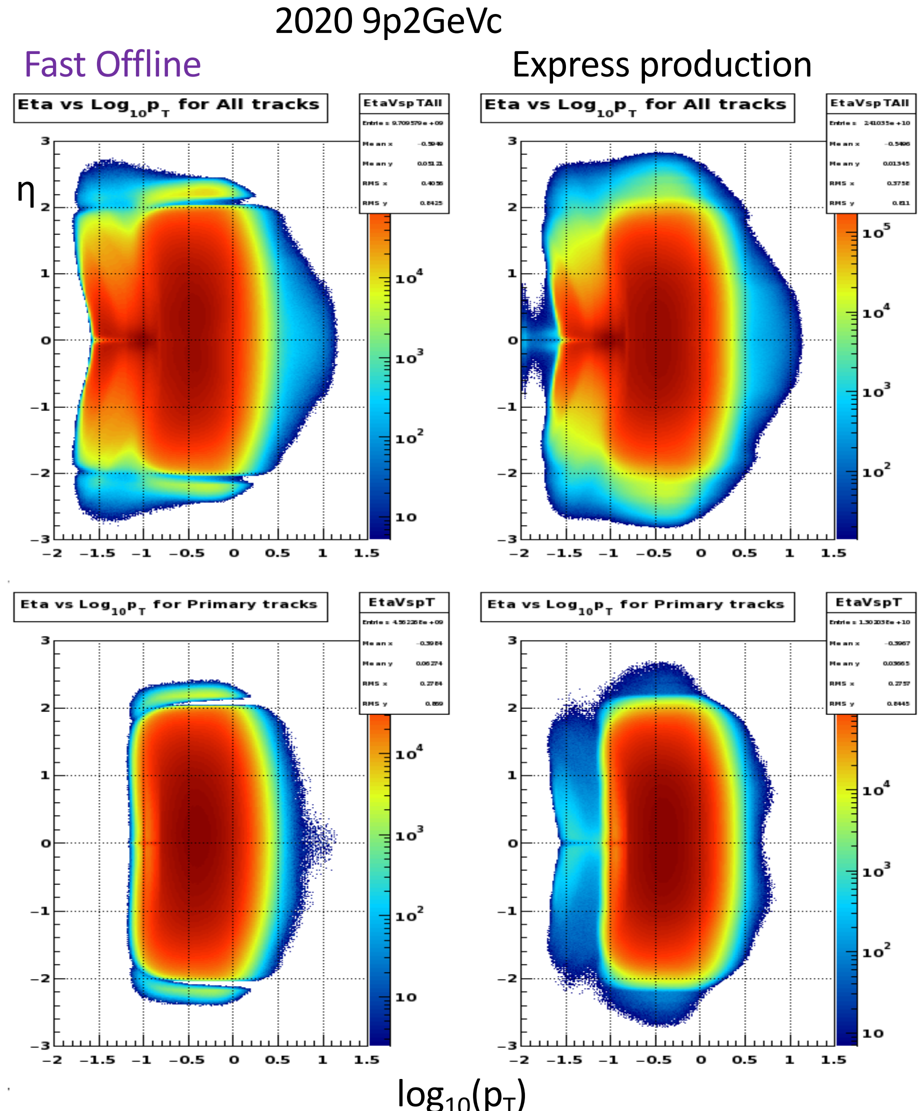
- “The standard calibration, production and analysis remain unchanged.
- Start the **calibration procedure as soon as** data become available.
- Make possible **physics analysis** of the data **as soon as the calibration** is reasonable.
- Unify approaches in extended (x)HLT and online (o)RCF to speed up the express workflow.
- Combine high competence of xHLT and oRCF experts involved in online operation.
- Provide **PWGs with instant and uncomplicated access to the da**ta, like picoDST etc.”
- Because we understood that the CPU performance is not an issue and due to some quality track reconstruction degradation with **GenFit2** we decided to step back to upgraded **StiCA** for track reconstruction.

2019 data sample express production Ivan Kisel' summary on Cracow STAR collaboration meeting https://drupal.star.bnl.gov/STAR/system/files/Kisel%20STAR%20Coll%20Meeting%2022.08.2019.pdf

- We are clearly seen Hyperons at all BES-II energies: 3, 3.2, 3.9, 7.7, 9.1, 14.5, 19.6, 27 GeV. Hyper Nuclear $^{3}_{\Lambda}H$ and $^{4}_{\Lambda}H$ are observed with high significance.
- We have built a short way from data acquisition to physics, including **calibration**, processing and physics analysis of the data.
- The express calibration has included analysis of cosmics data for iTPC alignment and 19 GeV dE/dx calibration which was frozen and put in database and released as TFG19e.
- The results of this calibration has been presented during the final DoE iTPC project review.
- Express production provides high quality of the dE/dx measurement for particles up to ^{7}Li with BToF and allows us to get clean spectra with high significance.
- The online chain is implemented right on the HLT farm and allows us to perform the physics analysis of the data during the process of data taking, which makes it possible, for example, to observe unexpected effects and/or modify the run program if required.
- The express chain provides an access to the data processed within 1 day, which is necessary for the production and copying of picoDST files from HLT to RCF but allows you to do the physics analysis of the experimental data in the regular environment.
- We have already processed all the currently collected energies of BES-II, which allows us to study wide range of physics including hyperons and hypernucleus in one go using the KF Particle Finder package.
- Our perspective on the future, if (we all want?) to do the full analysis of the BES-II data in 2020:
  - Expansion of the computer and disk resources for online processing and express data analysis.
  - Better synergy of all groups involved in data taking and online/fast offline data processing.
  - Involvement of key physics working groups in the express analysis of the newly collected data.

Express production, 2020.

- As I mentioned above, we understood from 2019 express production that we don't have CPU performance issue with processing collider BES-II data.
- We replace Stx (GenFit2 based) by Sti i.e. new express chain contains now **new CA** and Sti. Thus, we have traded some CPU for efficiency.
- In **new CA** we allow reconstruction of loopers in order to **increase acceptance** for high η and low p_T (W. Christie has proposed this on one of the iTPC reviews).
- The effect of **new CA** can be seen from the distributions reconstructed global and primary tracks versus $\log_{10}(p_T)$ and η for fast offline and express production of 2020 9p2GeVc data. There is a **clean increase of acceptance** with new CA in both p_T and η with respect to "official version" (Fast Offline).
- We have achieved production rate of collider data on the level of ~2M/day, which is mainly limited by **DAQ rate**.
- For fixed target data with DAQ rate ~2 kHz we were limited mainly by HLT disk capacity. With new disk we could handle whole band width with production rate ~5M events/day.



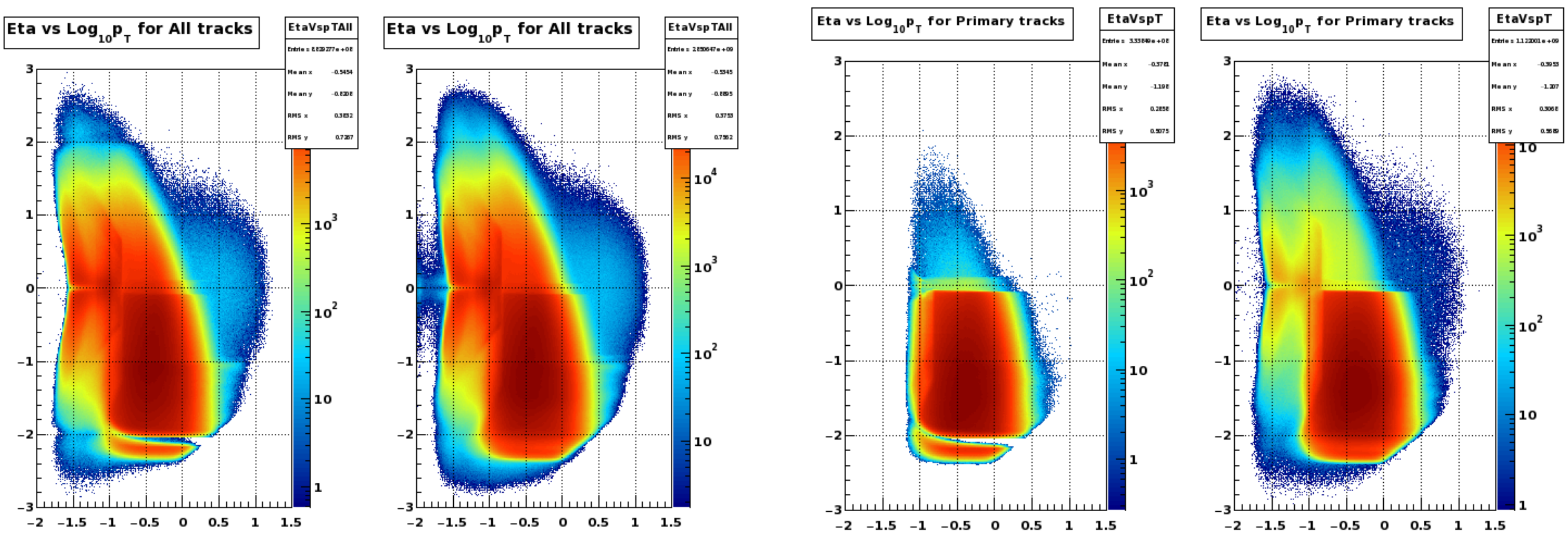
The same η – p_T plots for 9p8GeV_**fixedTarget** 2020,
we do see significant increase of acceptance with **new CA** (express production)
with respect to “official” version (fast offline).

Global tracks

Primary tracks

Fast Offline | Express production | Fast Offline | Express production

η



$\log_{10}(p_T)$

2020 data

sample express production
Ivan Kisel' summary on Berkeley STAR collaboration meeting
https://drupal.star.bnl.gov/STAR/system/files/Kisel%20STAR%20Collaboration%20Meeting%2021.09.2020.pdf

- Based on CBM FLES package an **express data production chain has been created** that extends the functionality of HLT including alignment, calibration, processing and physics analysis of data in real time.
- The express chain provides **access to the data within 1day**, which is necessary for the production and copying of picoDST files from HLT to RCF but allows to make physics analysis of the experimental data in the regular environment.
- We have already processed all the currently collected energies of BES-II, which allows us to study wide range of physics including hyperons and hyper nuclei in one go using the KF Particle Finder package.
- Excellent results of Runs 19 and 20 data analysis validate the high quality of the express stage of data analysis.
- A common online/offline software package is highly beneficial to significantly shorten the time to the final physics result.
- For 2021 using **expanded disk storage** on HLT we plan to increase percentage of reconstructed **FXT data from 15% to 90%** running on HLT and RCF.
- For **2022–2025** runs we would like to revisit **alignment and calibration procedure** in high occupancy environment.

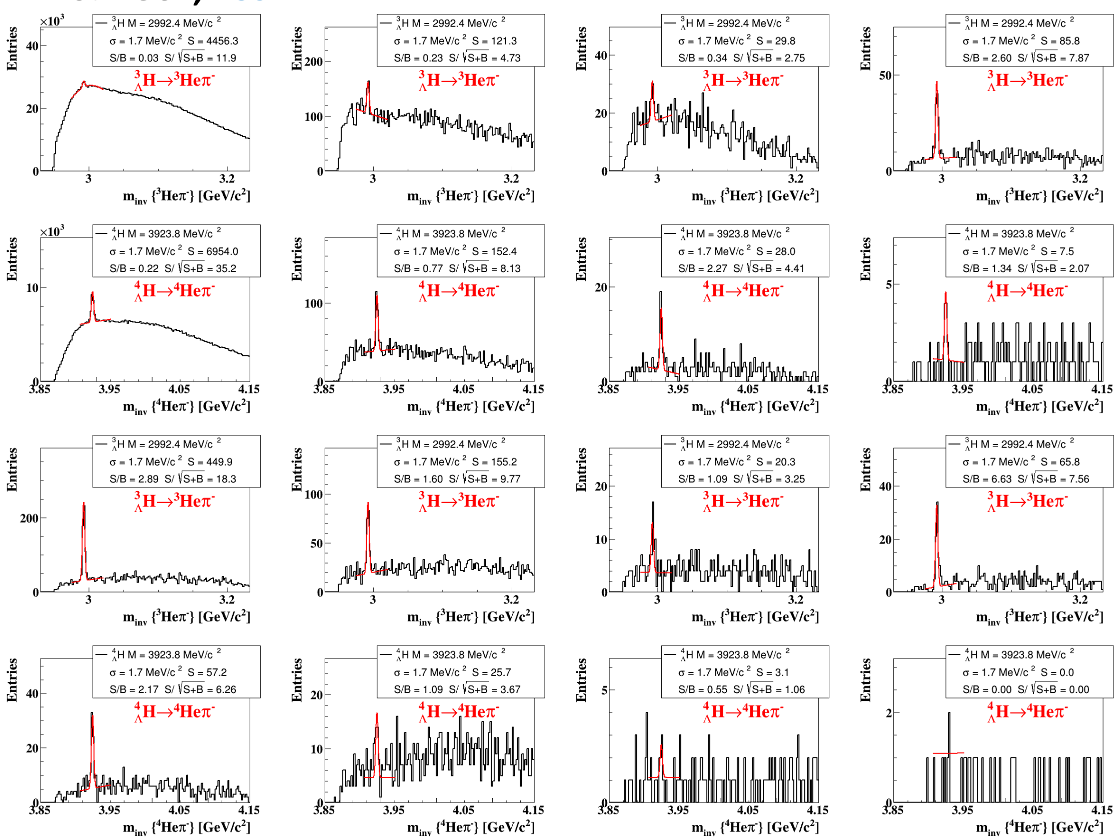
Helen Caines - STAR - PAC Meeting - May 2020

(https://indico.bnl.gov/event/7882/contributions/37810/attachments/28407/43767/BESII-Update-PAC.pdf)

BES-II: Online hypernuclei

3.4 GeV, 285 M

9.2 GeV, 23M



11.5 GeV, 216M

27 GeV, 300M

Run-18-20:

At FXT energies
- yields of fragmentation nuclei rising.

Significant increase of observed hypernuclei

After corrections can merge dataset to get precision lifetime measurements.

Can use lifetime can extract yields vs √sNN

Unique studies possible

Summary of Express Production for BES-II 2019-2021 data samples (picoDst):

- We have processed
  - ~90% of collider data, and
  - ~15% of fixed Target data mainly due to disk space limitation. 26p5GeV collected after July 2020 (new disk) have been process on 90% level.
- The data is located
  - Only on RCF /gpfs01/star/pwg_tasks/tfg02 (30TB)
  - Only on HLT /hlt/cephfs/Pico/
  - And on both RCF and HLT
  - We cannot provide full samples on RCF due to disk limitation.
  - The request to provide 100 TB storage for express production picoDST to PWGC has the following (https://drupal.star.bnl.gov/STAR/system/files/Production_Priorities_18Dec2020.pdf):
    - **Conclusions:** it was agreed upon that 10% of each dataset and 100% of a few selected dataset will be kept on RCF. For the latter, a list of such datasets will be proposed by interested PWGs.
    - Total retained data set size limited to 30T.

Beam Energy (GeVn)	$\sqrt{S}$ (GeV)	No. Events requested (recorded) (M events)	Date Collected	HLT good events (M events)	TFG processed and kept on HLT or/and RCF farms (M events)	Ratio	KF Particle (M events)
13.5	27	(560)	Run-18	555.7	DDS?		300
9.8	19.6	400 (582)	Run-19	581.6	70.3(RCF)	12%	37.2
7.3	14.6	300 (324)	Run-19	324.6	209.8(RCF)	68%	181.6
5.75	11.5	230 (235)	Run-20	332.6	164.4(RCF), 281.4(HLT)	84%	216
4.59	9.2		Run-19	1.1	0.05(RCF)	4%	
4.59	9.2	160 (162)	Run-20	10.8	10.1(HLT)	93%	8.9
4.59	9.2		Run-20b	67.9	62.2(HLT)	92%	53.9
4.59	9.2		Run-20c	178.9	161.7(HLT)	90%	146.5
26.5	7.2 (FXT)		Run-18	146.5	DDS?		
26.5	7.2 (FXT)		Run-20	315	72(RCF,HLT)	23%	60.3
31.2	7.7 (FXT)	100(50)	Run-19	50.5	9.9(RCF)		9.8
31.2	7.7 (FXT)	100 (112)	Run-20	112.5	9.9(RCF),16.4(HLT)	14%	15.7
19.5	6.2 (FXT)	100 (118)	Run-20	118.5	15.2(RCF,HLT)	13%	14.6
13.5	5.2 (FXT)	100 (103)	Run-20	97.9	15.6(RCF)	16%	14.1
9.8	4.5 (FXT)	(100) (108)	Run-20	142.2	13.2(HLT)	9%	11.9
7.3	3.9 (FXT)	(100) (117)	Run-20	117.4	17.0(HLT)	14%	
5.75	3.5 (FXT)	100 (116)	Run-20	115.6	19.4(HLT)	16%	12.1
4.59	3.2 (FXT)	100 (200)	Run-19	200.6	152.5(RCF)	76%	47.4
3.85	3.0 (FXT)	100 (259)	Run-18	257.1	3.4(RCF) DDS		284.8
3.85	7.7		Run-19	2.9	2.8(RCF)	96%	
3.85	7.7	100	Run-20	4.8	4.3(HLT)	90%	3.8
3.85	7.7	100	Run-21	+12.9	+11.7(HLT)	90%	+10.1

Two comments to the decision:

- Total STAR gpfs storage is 2.5 PB (+ 12 PB on distributed disks) thus the request is ~4% of STAR gpfs disk budget (~$30k), and
- we cannot provide “PWGs with instant and uncomplicated access to the whole data sample”.

Express calibrations

In order to do express production, we do need an express calibration.

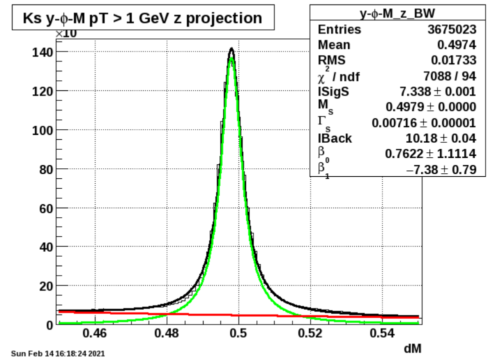
The greatest advantage of the express calibration is that we can access the fresh data directly from the event builder machines avoiding using HPSS.

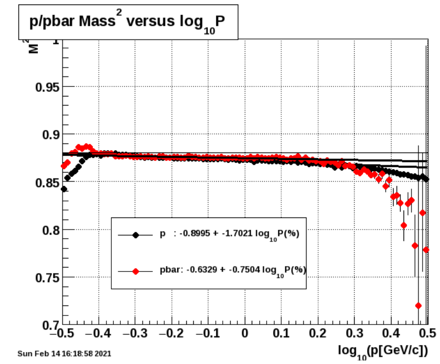
- 2019
  - This year we the first time used full iTPC,
  - To do alignment it was used ~100 M event with Cosmic trigger
  - The alignment was completed in April of 2020
  - dE/dx calibration has been done using 19p5GeV collider data
  - The alignment and calibration constants have been obtained and put in the STAR Database on 2019-04-16.
  - The whole express production for Run XIX has been done with these frozen constants.
  - The results based on the express production has been presented to ”the STAR iTPC Project Closeout/Transition to Operations Review” on May 2, 2019. The conclusion of the review (https://drupal.star.bnl.gov/STAR/system/files/STAR%20iTPC%20Closeout%20Review%20Coverletter_FINAL.pdf) contains a statement “… The findings of the review indicate that deliverables have been met with all key performance parameters met or exceeded. …”
- 2020
  - We have started with Cosmics data end of November 2019 and continue with 11p5GeV collider data begin of December 2019.
  - We observed that it is needed to do realignment of TPC.
  - The alignment and calibration has been done, frozen and released as TFG20a on 11 January 2020. This release has been used for the express production whole data sample for 2020 and 2020b.
- 2021
  - Using limited statics of cosmics events we have checked 2020 version of TPC alignment and did not find any essential problems.
  - Using 7p7GeV collider data we have checked global timing and super sector alignment and done dE/dx calibration.
  - The 2020 alignment and 2020 and 2021 dE/dx calibration has been put in the database on 2011-02-11 and the express production with release TFG21c has been started.
  - Essential change in 2021 is that we have on HLT farm 100 TB of disk storage which allows to keep 2% of data (event.root files) and to work continuously on calibration during data taking period with a goal to have **final calibration by the end of the data taking**.

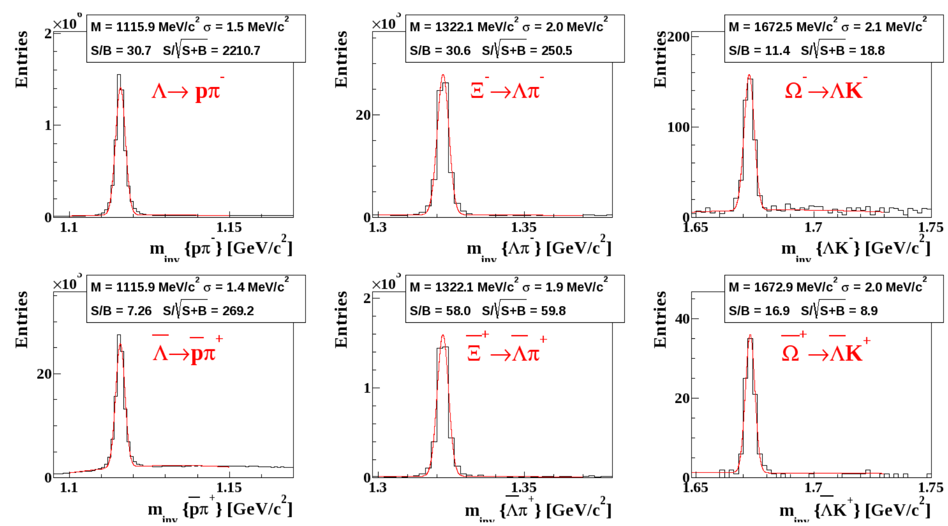
Validation procedures and QA

- Essential part validation of data is included in the calibration procedures.
- The typical validation of express production is done using KFParticleFinder. Examples of the plots are shown here:
    - K_S^0 mass spectrum for particles with $p_T > 1$ GeV/c, check :
        - signal to background ratio, significance
        - Mass position
        - Width
    - ToF M^2 for proton and anti protons selected by dE/dx versus momentum
    - Hyperon's signals.
- The same procedure (kfQA.C) has been applied to data on run-by-run basis in order to check stability of these and many other parameters.
- For Run XIX it was done by FIAS (Artemiy Belousov).
- For Run XX it was done by KENT group (Eddie Duckworth, https://drupal.star.bnl.gov/STAR/system/files/Eddie-KFParticle-HLT-QA.pdf).
- For Run XXI it is still responsibility of KENT and FIAS, but the names of responsible people have not defined yet.

9.1 M 2021 7p7GeV sample



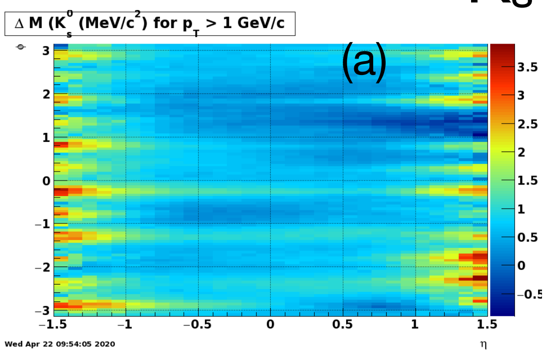


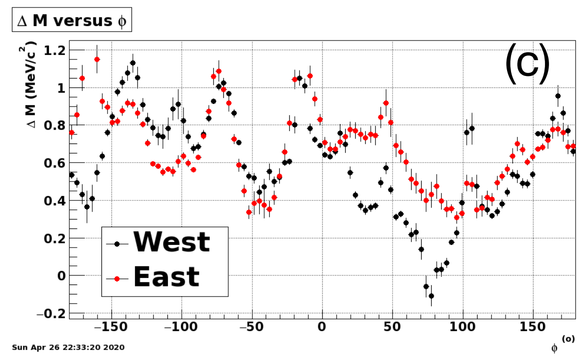


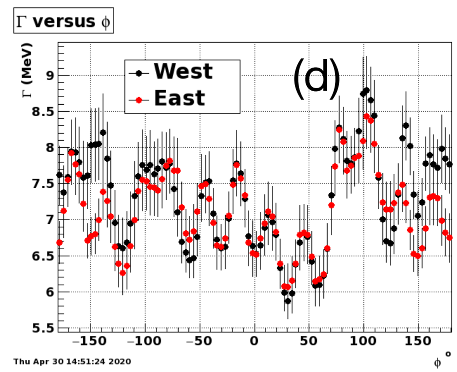
K_S^0 mass from 2020 AuAu 11.5 GeV sample (~250M) (https://drupal.star.bnl.gov/STAR/system/files/Ks_0.pdf)

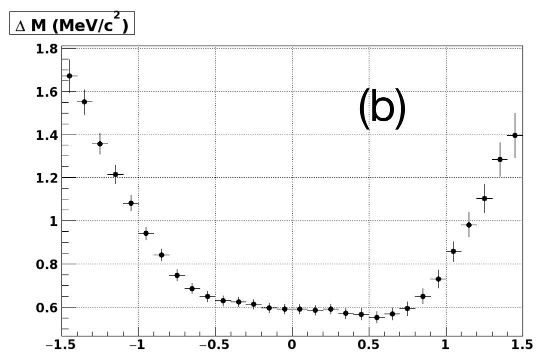
K_S^0 mass versus ϕ and η

|η|<1









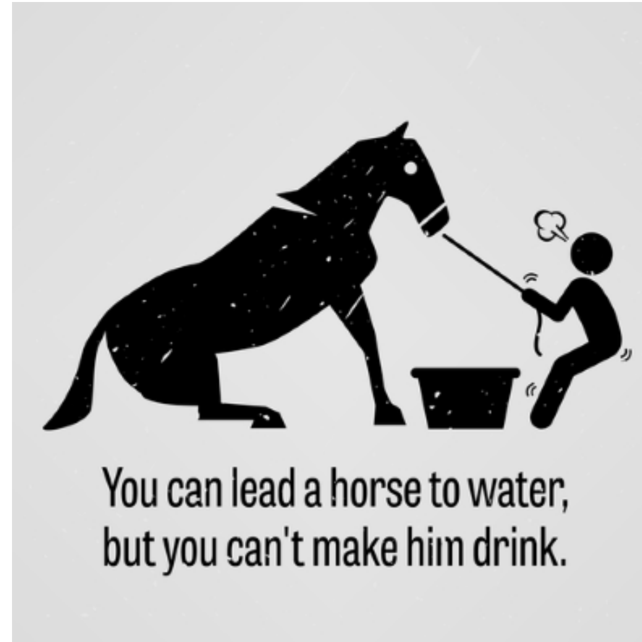
The variation of mass associated with sector borders give us an indication that we still have problems with super sector alignment. This can explain a reason why our Upsilon signal is significantly wider than we expected.

Using the 11.5 GeV AuAu sample difference between reconstructed with Breit-Wigner fit K_s^0 mass and its PDG value has been plotted versus |η| and ϕ (**a**) for K_s^0 with $p_T > 1$ GeV/c. I would like to make the following points:

- There is asymmetry in η (**b**) which I attribute to distortion to magnetic field map due to the STAR endc ap calorimeter which is not completely accounted. (Overall shift by 0.6 MeV/c2 is due to miscounting beam pipe entry loss).
- In ϕ (**c**) there is a structure associated with the TPC super sectors edges (15° with 30° steps). The same structure is observed in K_s^0 width (Γ,**d**).
- My guess is that we see differences between K_s^0 reconstructed in the same sector and in two adjusted sectors. These differences can be attributed to TPC super sector alignment.

Specifics for run19

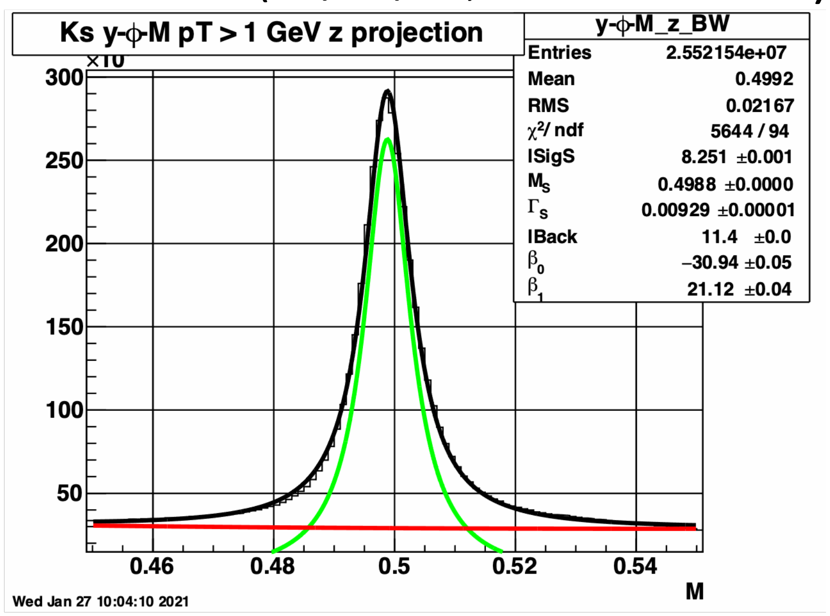
I would like to repeat a statement from a famous Russian historian (Владимир Мельников в фильме “Покровские ворота”): “It is impossible to make people happy against their will”. The translation the statement into English looks like this horse` cartoon.



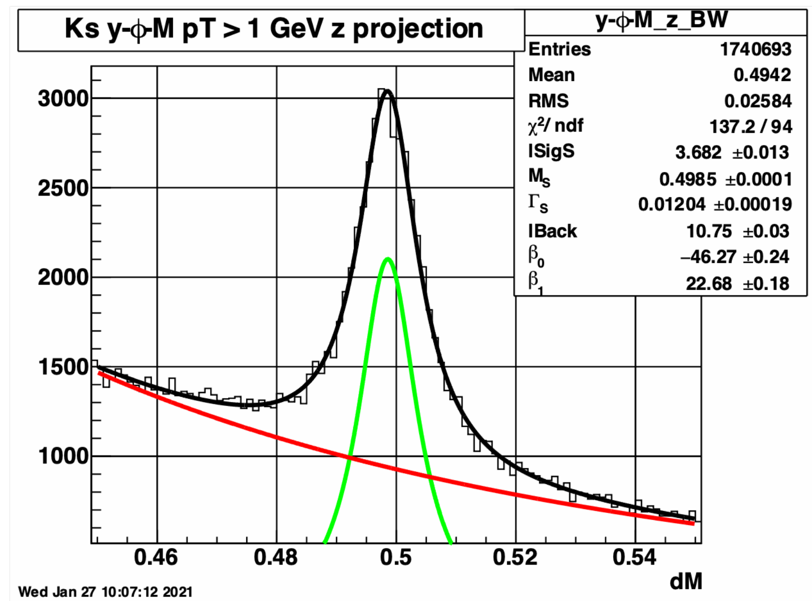
- On October 2019 Database spaceChargeCorR2 and tpcGridLeak tables have been changed and whole TPC alignment procedure has been repeated by S&C team using a “official” S&C software.
-
- In July 2020 the “official” calibration production (P20ic) with new alignment has been done.
- The results of the “official” production don’t look very promising.
- Below I show comparison of some plots obtained in the express production (TFG19e) and the “official” calibration production (P20ic).

K_S^0 mass for $p_T > 1$ GeV/c

- TFG19e (07/11/19, 15.4 M events)



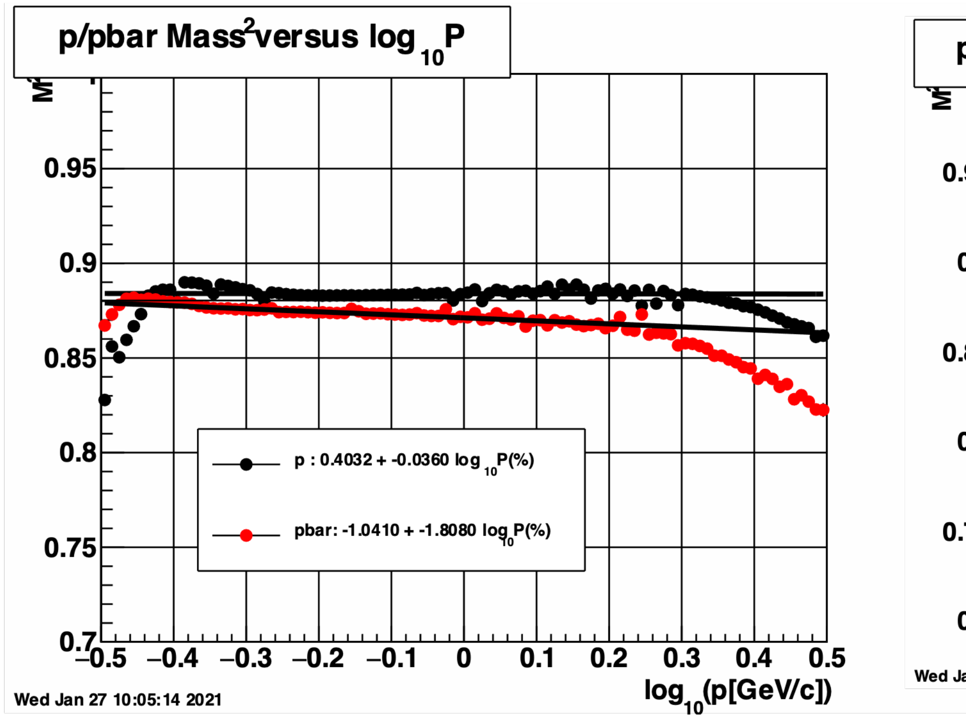
- P20ic (06/25/20, 9.6 M events)



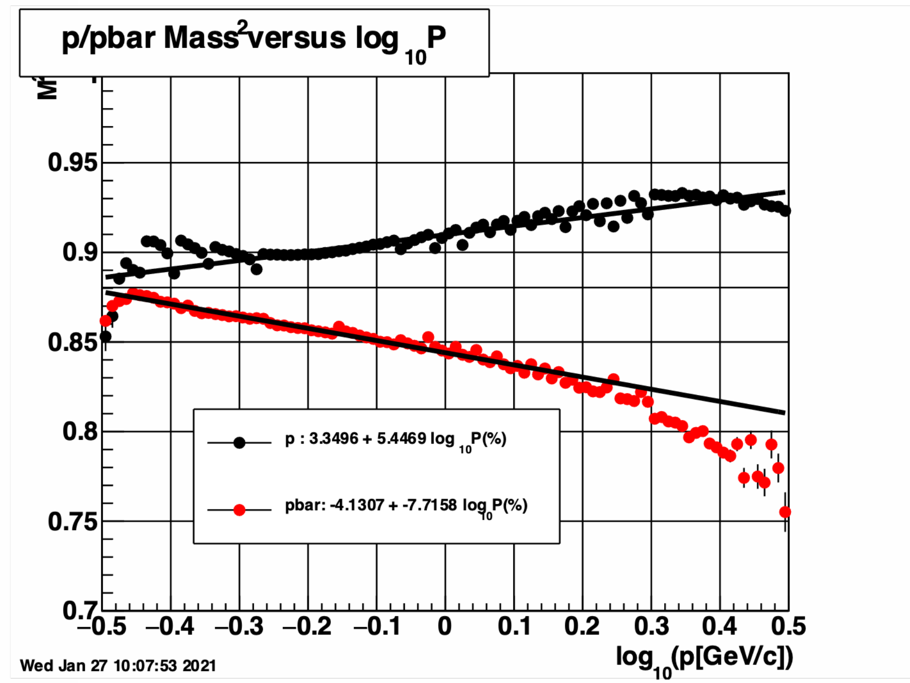
K_s^0 width degraded from 9.2 MeV/c^2 to 12 MeV/c^2 with huge background increase

M^2 for p pbar

- TFG19e (07/11/19, 15.4 M events)



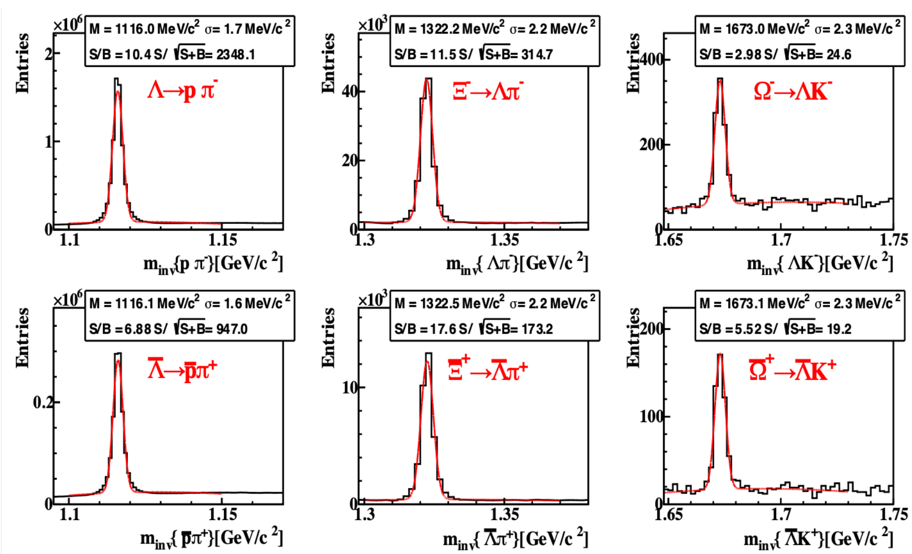
- P20ic (06/25/20, 9.6 M events)



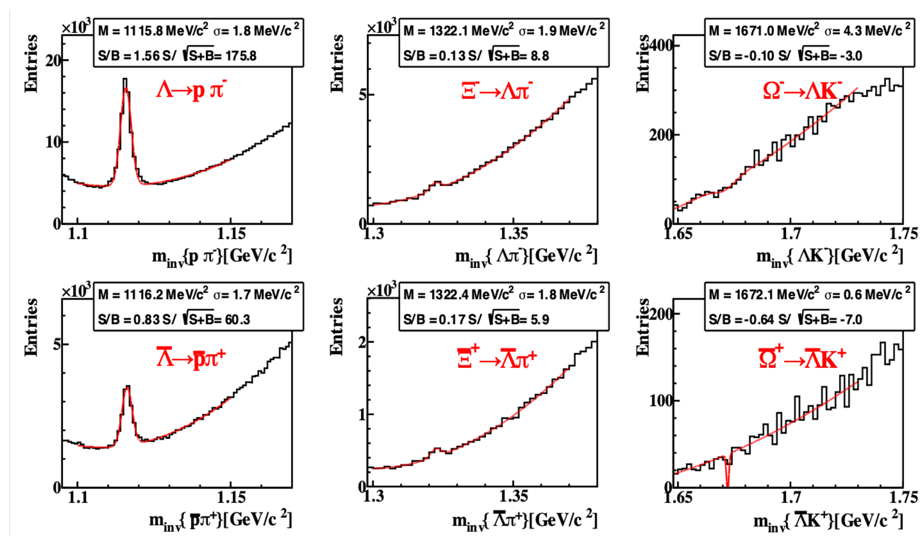
Significant degradation of p/pbar M^2 measured by BToF in "official" production.

Hyperons

- TFG19e (07/11/19, 15.4 M events)



- P20ic (06/25/20, 9.6 M events)



In the "official" (P20ic) production

- Λ signal to background ratio drops by a factor of 6,
- Ξ signal to background ratio drops by a factor of 100, and
- Ω signal is disappeared

Concluding specifics for run19 statement:

The observed differences are not related to difference in software between TFG and “official” S&C, but

The differences are due to changes in the database

- Calibrations/tpc,
- Geometry/tpc,
- Calibrations/rich

entered after 07/11/19

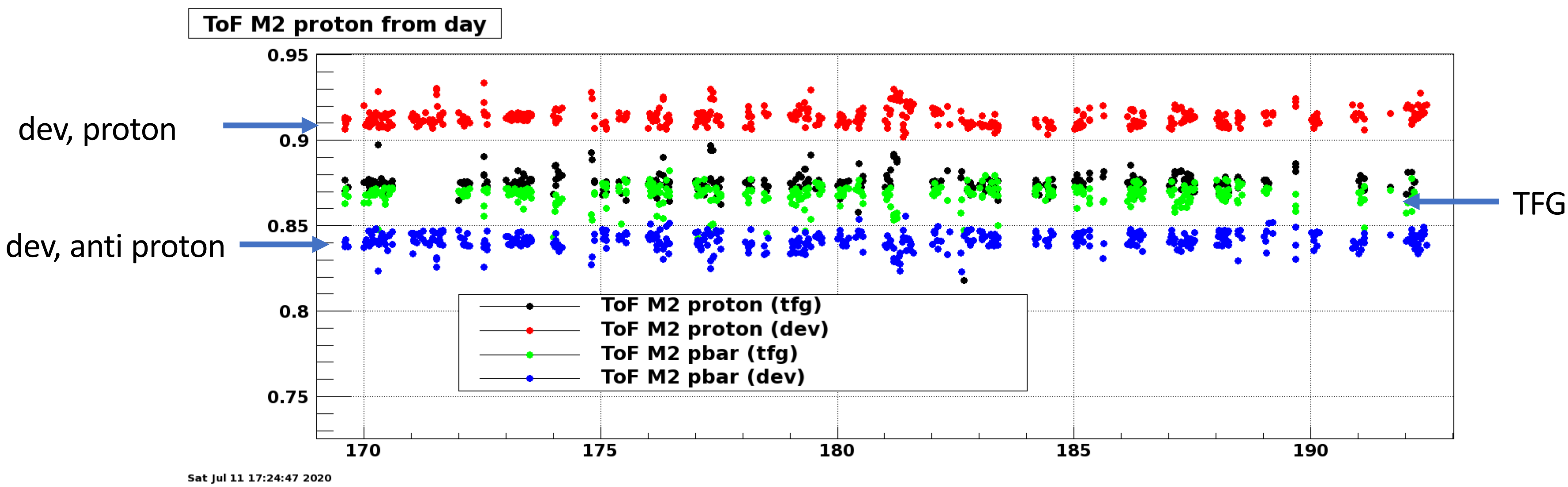
Bottle neck in timely calibrations

- In sense of the express production on HLT withing TFG we don't have any essential problems
  - An example with the Run XXI express calibration just shows that. We have now ~12 M events been processed with physics quality.
  - With available disk resources on HLT we intend to have (let's say almost) final calibration by the end of data taking.
  - Just avoid unexpected inventions with data base tables.
- On RCF the main problem is disk space.
  - For example, to redo Run XIX alignment and calibration it is needed ~10 TB.
- But the most essential thing is to have a will to be happy !

Thank for your attention and I am waiting for your questions.

Backups

ToF proton and pbar mass^2 (2020)

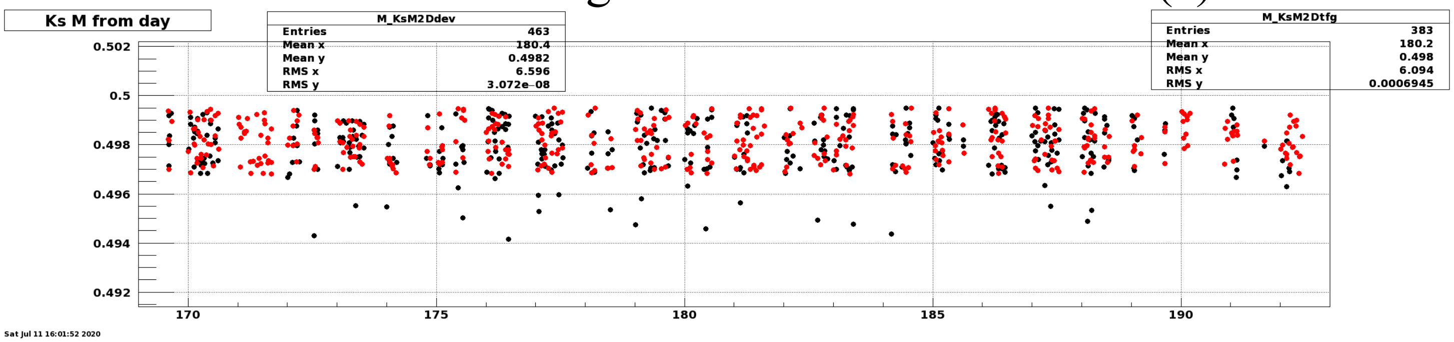


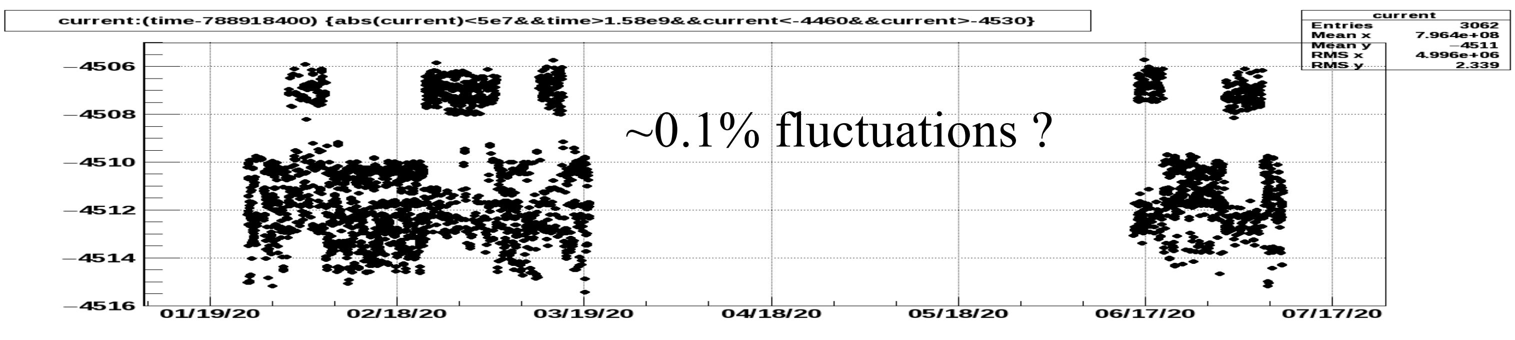
In the fast offline there is a significant difference between M^2 for p and pbar which is much less in the express production.

K_s^0 mass (2020)

Color: tfg dev

Mass variation (~0.1%) versus time could be due to fluctuations in the Main STAR magnet current measurements (?).





Lessons and procedures learned from iTPC prototype commissioning (2018)

- Coordination
- … 15 Mar 2018 17:31:30