

# TPC Calibration Review Report

Zhangbu Xu

Bill Christie, Carl Gagliardi, Frank Geurts, [Marian Ivanov](#), Ivan Kisel, Tonko Ljubicic , Maria Stefaniak, Jim Thomas, Qinghua Xu, Xin Dong (ex officio), Rongrong Ma (ex officio)

Committee Formed on January 26, 2021

[Star-tpccalrev-l@lists.bnl.gov](mailto:Star-tpccalrev-l@lists.bnl.gov)

We took a very different approach from the traditional review committee, we had one-day presentations from TPC calibration team, but continue to work with them on daily basis more as a steering committee, This only works if the team is willing to work diligently with the committee. I would like to thank the team for that!

# Charges:

**From:** Starmail-l <starmail-l-bounces@lists.bnl.gov> on behalf of "Ruan, Lijuan via Starmail-l" <STARMAIL-L@lists.bnl.gov>

**Reply-To:** Lijuan Ruan <ruan@bnl.gov>

**Date:** Tuesday, January 26, 2021 at 4:41 PM

**To:** STARMAIL-L <STARMAIL-L@lists.bnl.gov>

**Subject:** [Starmail-l] Formation of the STAR TPC calibration review committee

Dear All,

We just formed the STAR TPC calibration review committee. It is timely and critical to look at the offline calibration tasks and issues.

The committee is charged to evaluate the readiness of the **TPC calibration for the BES-II** data production and provide answers to the following questions by **the end of March 2021**:

1. What is the **status** of the tracking and production calibration?
2. Where is the **bottleneck** of the TPC calibration procedure?
3. Are there enough collaboration **manpower and resources** for the tasks?
4. How are the online/operation/fast-offline/PWGs **efforts coordinated** to accomplish the goals?
5. Is there **a clear document of procedures** in calibration and what are the unexpected and expected issues in BES-II datasets? What are the steps in calibration, and how are the current responsibilities assigned?
6. What is the **timeline and path toward** completion of whole BES-II calibration for production?
7. **Any lesson learned** toward future runs?

Lijuan, Helen, and Xin for the management team

# Presentations from experts

<https://indico.bnl.gov/event/10740/>

Full-day 02/16/2021  
from 9AM – 5PM

Thank all the experts and presenters  
for their preparation and patience with  
Q&A

## STAR TPC calibration review committee

Tuesday Feb 16, 2021, 9:00 AM → 2:00 PM US/Eastern  
Maria Stefaniak (WUT/Subatech) , Zhangbu Xu (BNL)

[FXT T0 Work | The ...](#) [ppbarM2-TPC-calib...](#) [STAR\\_Run20\\_TPC...](#) [STAR\\_TPC\\_Intro.pdf](#) [TPC\\_Calibrations.pdf](#)  
[TPC survey.pdf](#)

Registration [Participants](#) [Regis](#)

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**9:00 AM** → 9:20 AM **The calibration of the TPC is done by members of the TPC group, resource/management organization.** ⌚ 20m  
Speaker: Gene Van Buren (BNL)  
[TPC\\_CalibrationOrg...](#)

**9:20 AM** → 9:40 AM **Surveys used/applied** ⌚ 20m  
Speaker: flemming videbaek (BNL)  
[Presentation1Videb...](#) [STAR iTPC - PadPla...](#)

**9:40 AM** → 10:50 AM **Geometry/B-Field & alignment** ⌚ 1h 10m  
Speaker: Yuri Fisyak  
[STAR TPC Calibrati...](#) [TpcCSTransformati...](#)

**11:00 AM** → 11:40 AM **Space Charge and Grid Leak Distortion Corrections** ⌚ 40m  
Speaker: Gene Van Buren (BNL)  
[Run19\\_SCGL\\_calibr...](#) [TPCDistortions.pdf](#)

**11:40 AM** → 12:20 PM **T0 Calibration** ⌚ 40m  
Speaker: Irakli Chakaberia (Brookhaven National Laboratory)  
[2021-02-16 - START...](#) [2021-02-16 - START...](#)

**12:20 PM** → 12:40 PM **Resources for HLT and express production** ⌚ 20m  
Speaker: Hongwei Ke (BNL)  
[TPCCalibrationRevi...](#)

**12:40 PM** → 1:00 PM **QA, QC (BES-II)** ⌚ 20m  
Speaker: Daniel Cebra (University of California, Davis)  
[TPC\\_Calibratons\\_Re...](#)

**1:00 PM** → 2:00 PM **ALICE material and discussions** ⌚ 1h  
Speaker: Marian ivanov  
[ALICE TPC calibrati...](#) [ATO-490-DataDriven...](#) [ATO-534\\_ALICEforS...](#) [NDimensionalPipeli...](#) [Reconstruction pas...](#)

# Major categories of TPC Calibration

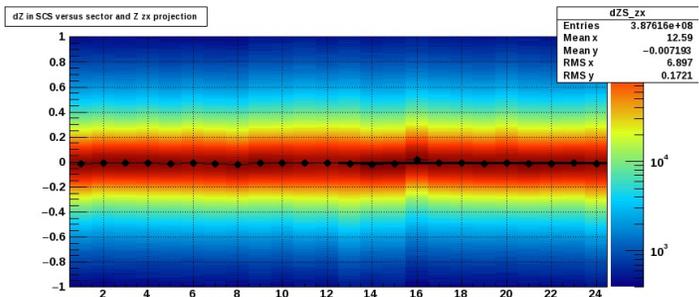
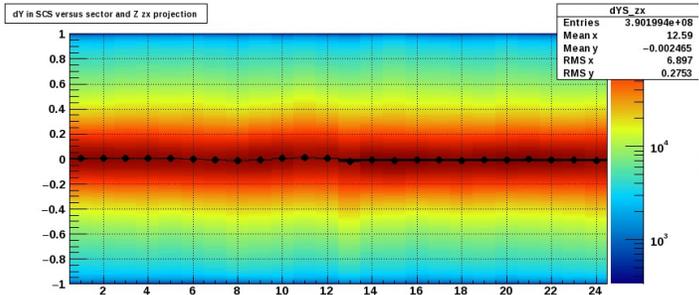
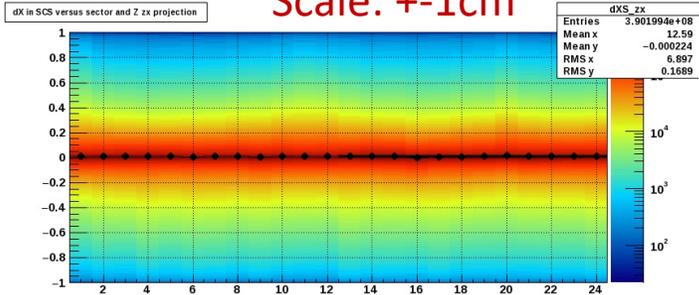
- Geometry  
(where the TPC sectors are physically located in the global and local coordinates)
- T0  
(signal starting point relative to the true collision time)
- Drift Velocity  
( $\sim 5.5\text{cm}/\mu\text{s}$ , one RHIC bunch crossing time 100ns, 5.5mm drift)
- Static Distortion
- Dynamic Distortion (Space Charge)
- $dE/dx$



# The issues holding up the production

Step 1: Yuri

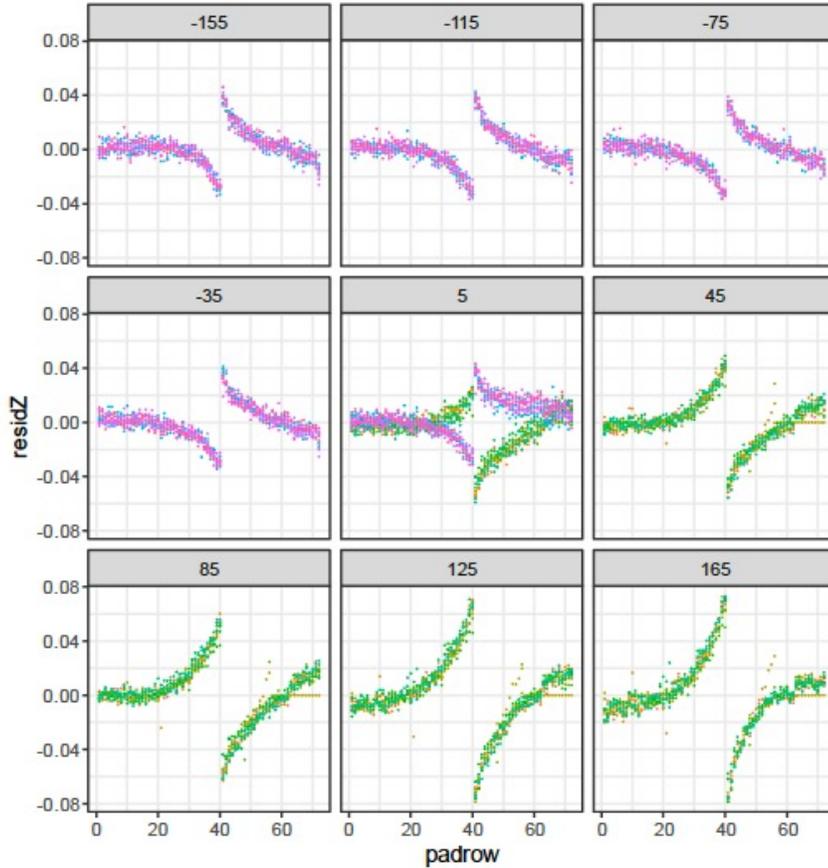
Scale:  $\pm 1\text{cm}$



Step 2: Irakli

$\pm 800\mu\text{m}$

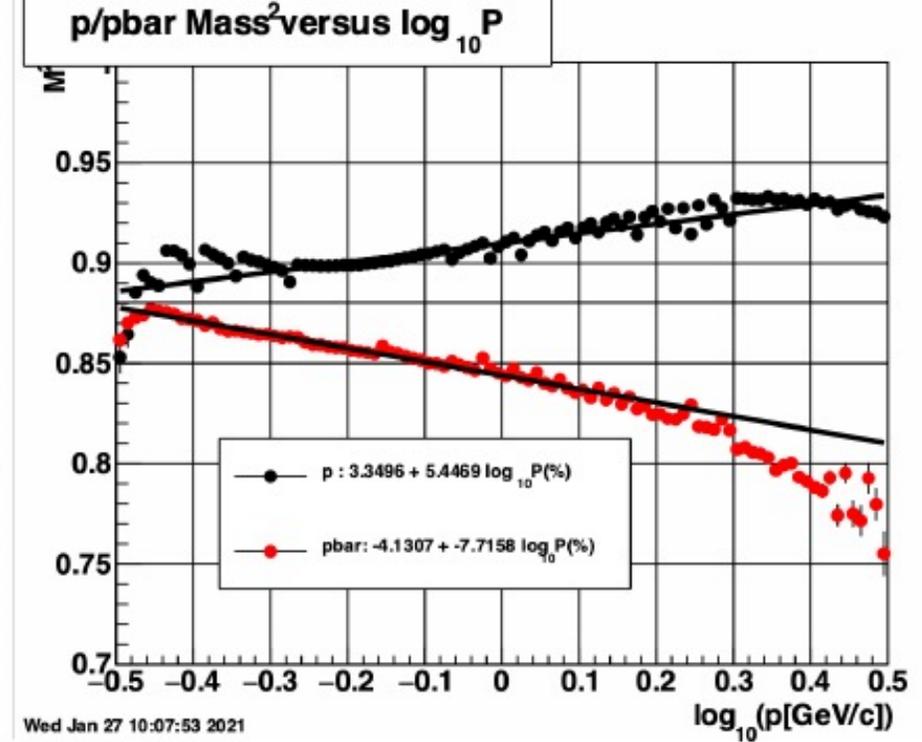
Residuals Along Z in Z slices of 40cm



Step 3: TOF

$0.7-1\text{GeV}^2$

• P20ic (06/25/20, 9.6 M events)



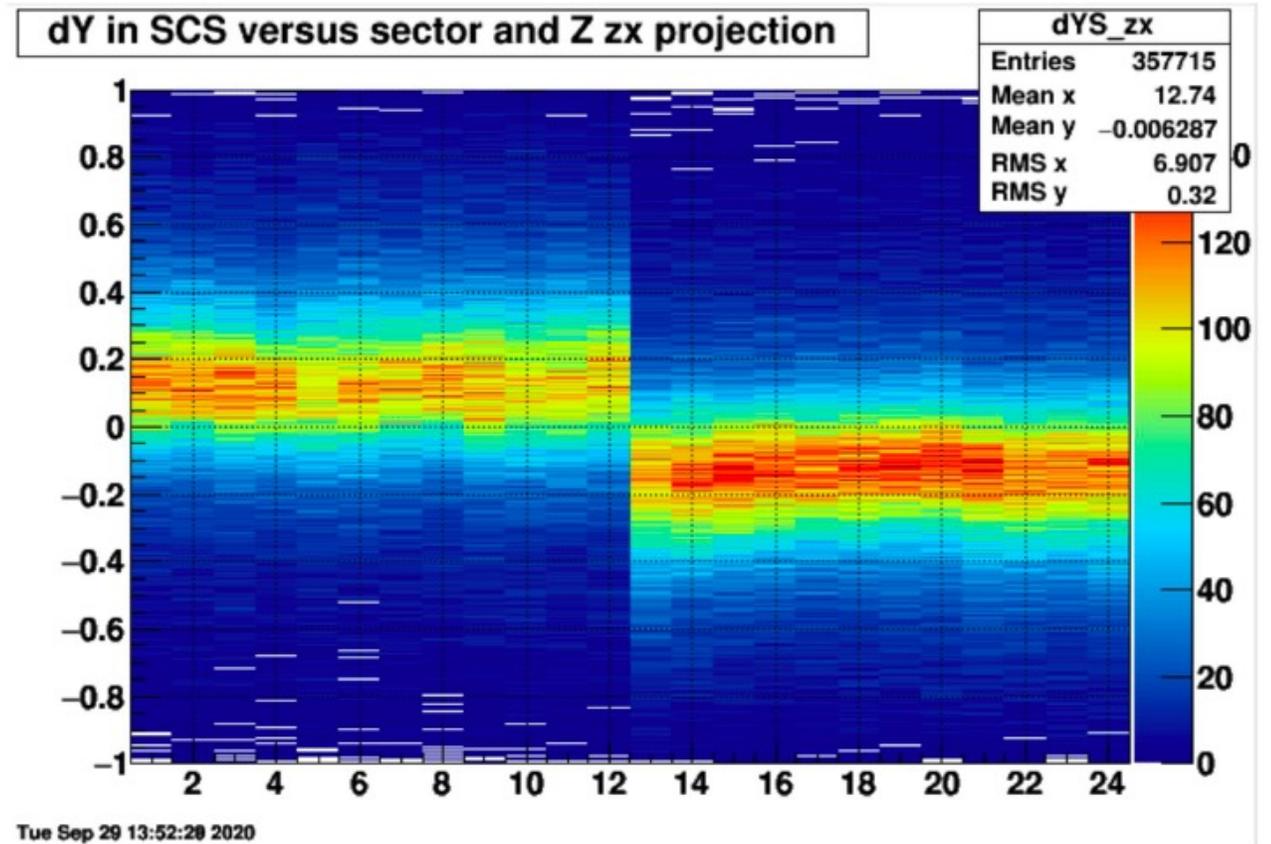
First step calibration looks OK, second step showed split and need to move TPC, results in 3<sup>rd</sup> step mass split  
I am simplifying the storyline (maybe to the extent of misleading, but one gets the point)

# Slide from Irakli at the 02/16 review presentation

- In order to complete the picture, the supersector alignment was also revisited and it was found that there is substantial split in the primary vertex DCA from the vertex reconstructed from each sector (as shown on the plot)
- Alignment was re-done but the new parametrization caused a split in the reconstructed  $m^2$
- A lot of efforts were made to understand the problem since but the problem is not quite understood/agreed upon at the moment

Full story on my blog:

<https://drupal.star.bnl.gov/STAR/blog/iraklic/run19-cosmics-and-supersector-alignment>



Many efforts and checks for one and half years before the TPC Calibration Committee and after

# Major categories of TPC Calibration

- Geometry  
Survey says that the geometry should be better than  $100\mu\text{m}$   
Cannot be moved by 4mm
- T0  
(signal starting point relative to the true collision time)  
The only thing can be wrong is the T0;  
That is where the committee and experts focused on for 2 months
- Drift Velocity  
( $\sim 5.5\text{cm}/\mu\text{s}$ , one RHIC bunch crossing time 100ns, 5.5mm drift)
- Static Distortion
- Dynamic Distortion (Space Charge)
- $dE/dx$

# What is T0?

We went through details of the timeOffset (T0), Thank Yuri and Tonko who spent a few hours with me today (02/19/2021).

there are quite a few of them:

- t1: timeOffset in padrow from pulser; There is still a missing step of equalization of timing offset between rows.
- t2: tpcSectorT0OffsetC from prompt hits;
- t3: tpcRDOT0offsetC; (RDO deviation from prompt hits)
- t4: triggerTimeOffsetC set at 2.372249us in April 2019 but was a different value before that. This is likely due to the change in iTPC electronics; (that may be where the earlier confusion is)
- t5: tpcElectronicsC->tZero() set at -0.119 us;
- **t6: effectiveGeometry** (another sets of timing) due to the drift between GG and anode, and also different drift timing between outer and inner sectors and prompt hits and regular hits.
- t7:  $t0zoffset = -3 * \tau * \text{Diftvelocity}$  ( $\tau=55\text{ns}$  for signal shaping time)

# Status (1): Issue has been identified in a single DB entry

- The EffectiveGeometry database entries are parameters used to correct for the drift between GG and anode, due to the wire location difference between inner and outer (0.8 and 1cm). The result difference in the drift by Garfield is about **1.2 and 1.7cm**. Those are in the runs before run19. It is not really a geometry but a drift timing converted to distance.
- In run19,20,21, different approach is used to determine the tpcSectorT0offset, currently use prompt hits, however, the prompt hit correction time is different between inner and outer (0.32 vs 0.53cm). This results in the new database entries in the EffectiveGeometry of **0.93 and 1.1cm**
- Because of this change, the triggerT0TimeOffset has to be changed as well because part of the time offset has been absorbed by the tpcSectorT0Offset from the prompt hit timing.
- TrgT0TimeOffset+tpcSectorT0Offset+EffectiveGeometry have to be updated correctly and coherently
- These crucial database tables were updated by Yuri in his calibration but the EffectiveGeometry database table was not updated in the version used by Irakli or subsequent production
- With the fix, everything seems to fall into places.

Remaining issue: why is effectiveGeometry different between run 18 and run19?

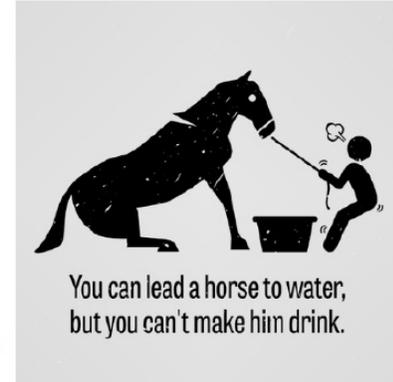
# Bottleneck (2) of the calibration procedure

1. there are not enough monitoring tools and plots which are consistent and agreed upon among the experts at different calibration steps.
2. there is not checklist (similar to travellers during the detector construction phase) to confirm and clearly document changes, updates and database entries from one step to the other.
3. major concern is the breakdown in some of the communication channels and coordination.

## 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).



Yuri

**I would agree with the general spirit,  
But there has to be discipline and engineer control tools  
If we are to arrive at any place we would like to be.  
That horse will die very soon without water.**

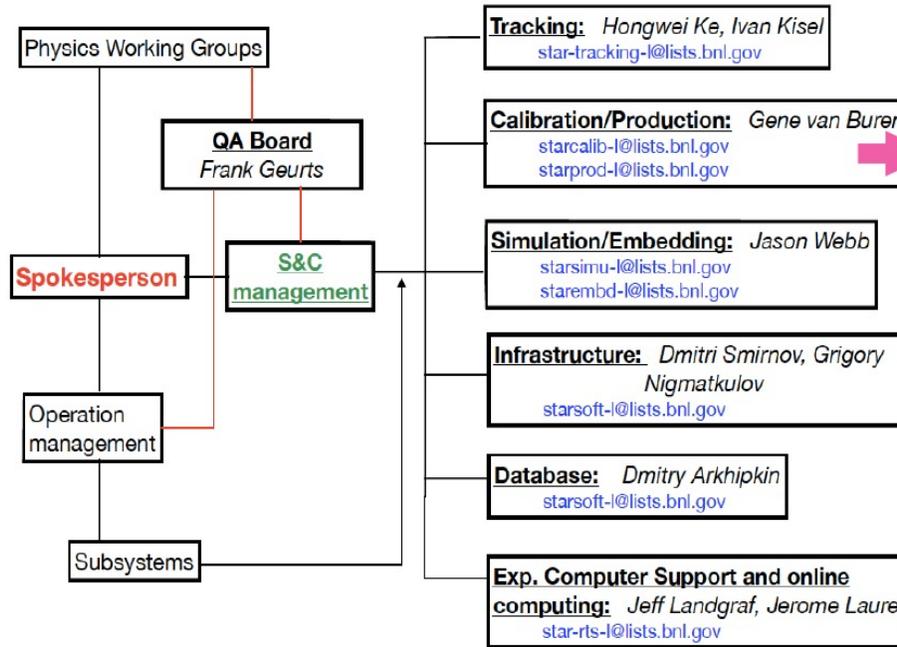
# 3. Are there enough collaboration manpower and resources for the tasks?

## S&C Organization

It is a relatively easy question to answer;  
but this is a very difficult issue to address

Very few experts, collaboration helpers are hard to retain or gain knowledge necessary for in-depth involvement

S&C Organization Chart - 2020.11



The Software Sub-system coordinators (+) in each specialized area are as follows :

Detector sub-systems:

- TPC Software – Yuri Fisyak (BNL)
- GMT Software – [vacant]
- DAQ Software – Jeff Landgraf (BNL)
- EMC2 Software – (co-lead / historically in two groups)
  - Raghav Kunnawalkam Elayavalli (WSU)
  - Nicholas Lukow (Temple)
- FMS/FPS Software – Oleg Eysler (BNL)
- bTOF/VPD Software – Frank Geurts -> Zaochen Ye (Rice)
- eTOF Software – Florian Seck (Darmstadt)
- MTD Software – Rongrong Ma (BNL)
- Trigger Detectors (BBC, FPD, CTB, ZDC, MWC, ...) – Akio Ogawa (BNL)
- HFT Software – Xin Dong (LBNL)
- HLT Software – Hongwei Ke (BNL)
- PP2PP/RP Software – Yip Kin (BNL)
- EPD – Prashant Shanmuganathan (Lehigh)
- Forward Upgrade – Daniel Brandenburg (BNL). Forward Upgrade includes FCS, s
  - FCS – Akio Ogawa (BNL)
  - sTGC – Daniel Brandenburg (BNL)
  - FST – Shenghui Zhang/Zhenyu Ye (UIC)

G. Van Buren - STAR TPC Calibrations Review

My personal experience and suggestion:  
need to find a way to simplify the procedure and demystify the calibration.  
Most of the collaborators treat TPC calibration as a blackbox.  
The very example of issues here (DB entry) does not need an expert to figure out.  
Everyone knows to check the nHitsFits, but no one would check the T0 variation (why?)

The biggest challenge is that every run, there is something new expert needs to deal with

## 4. How are the online/operation/fast-offline/PWGs efforts coordinated to accomplish the goals?

- This is related to the lessons learned. In every step, the knowledge from the limited expert manpower is relatively self-contained and does not propagate well to the next step. This includes the information about trigger/T0/pulser from operation at first step, timing,  $dE/dx$  calibration at second step, distortion and geometry at third step and physics quantity QA at last step. Both experts and committee feel the need to improve communication and coordination. If the communication and work format stay as it is, we have to establish documentation, checklists and QA tools consistently throughout the steps from operation to PWG analyses.
- My concern:  
the efforts from the Tracking Task Force and Online express process were designed to support/strengthen the offline production and eventually work as a cohesive unit. It is perceived that the express and offline are further apart from that goal as time goes by instead of closer at reaching that goal.

# 5. Is there a clear document of procedures in calibration and what are the unexpected and expected issues in BES-II datasets? What are the steps in calibration, and how are the current responsibilities assigned?

- Documentations in blogs are available to the experts and collaboration. A centerized documentation was available before 2014. Every year, there is something new and unexpected which consumes all the experts' effort. See slide#10 in Gene's presentation: [https://indico.bnl.gov/event/10740/contributions/45615/attachments/32765/52338/TPC\\_CalibrationOrganization.pdf](https://indico.bnl.gov/event/10740/contributions/45615/attachments/32765/52338/TPC_CalibrationOrganization.pdf)
- Specific to BESII, iTPC is effectively a new detector in run19. This new detector with new electronics requires new calibration in T0. That is what the committee focuses on to figure out potential issues. Refers to item#1 for the details of issues and solutions.
- All agree that this needs to be revisited

## Documentation

- There is a central Drupal page for TPC Calibration links which I kept somewhat current up until ~2014
  - Some "how-to" instructions
  - Mostly results for various datasets' calibrations
  - A few broken links
- Much work is dispersed in individuals' blogs
- Clearly needs revisited!

1. TPC survey instructions	• Should be done each time the TPC was to be moved (up, down, or back into the hall) or done in general	
2. TPC Field Notes	• Necessary for online cluster finding and pile-up suppression	
3. TPC Field Review Plans & Status	• Necessary for online cluster finding and pile-up suppression	
4. TPC Dual Read	• Monitor continuously during run	
5. Data Velocity	• Monitor continuously during run	
6. TPC Axioms	• These should be recorded to avoid during reconstruction	
7. You do not have access to view this page	• Dependence of reconstructed line on pulse height: see only in Run 9 so far (run-shaped pulses)	
8. TPC TOF	• Potentially global, sector, and/or	
9. TPC TOF	• Potentially global, sector, and/or	
10. You do not have access to view this page	• New users need determination of location and upgrade, and may require low luminosity data	
11. TPC Sector Alignment	• Residuals from (Other Alignment, and for per-sector Alignment)	
12. TPC Clocking / Synchronization of the TPC system	• Calibration believed to be approximately needed once per year	
13. TPC TOF	• Calibration believed to be approximately needed once per year	
14. TPC TOF	• Calibration believed to be approximately needed once per year	
15. TPC TOF	• Calibration believed to be approximately needed once per year	
16. TPC TOF	• Calibration believed to be approximately needed once per year	
17. TPC TOF	• Calibration believed to be approximately needed once per year	
18. TPC TOF	• Calibration believed to be approximately needed once per year	

Is the documentation to explain more clearly to the collaborators for more involvement or as an administrative/engineer control tools to reduce mistakes?

- My opinion: the first step is to use documentation as tools to reduce mistakes

## 6. What is the timeline and path toward completion of whole BES-II calibration for production?

We believe that there is a path forward and the calibration is close to final in weeks

- a. Test production of 19.6GeV is done, will also process 14.6GeV, and 11.5GeV and 9.2GeV for comparison and consistent checks of issues and calibration of T0 (separate time bucket vs cable delay)
- b. Known issues need to be worked on and updated from the test production TOF calibration; dE/dx calibration; dynamic distortion; event-by-event T0
- c. Known issues without a good understanding or solutions:
  - I. known issues with inner sector time offset (distance) measured by charge step increase from 0 to 600um from inner most padrow to outer radius, but such feature now seen in outer sector.
  - II. variation of charge step (measured in distance from prompt hits) shows sin-wave variation and similar in east and west (can not due to central membrane because both east and west show same pattern), TPC drift velocity from laser are measured to be quite consistent within different sectors. Gene brought up an issue with inner sector cluster deconvolution having discrete charge distribution. This certainty is more severe in the inner vs outer radius. Does this distort the charge step distribution?
- d. We discussed about monitoring QA. ALICE has a suit of automatic QA plots with different distortion/displacement monitoring.  
<https://lists.bnl.gov/mailman/private/star-tpccalrev-l/2021-March/000137.html>  
STAR has slightly different approach, Fast offline monitoring the large scale data quality. Offline calibrations are divided into several steps. each step has experts monitoring on specific observables. Last monitoring is PWGs, which is quite productive in the fast offline phase. For the test production, similar QA is in the work.

## 7. Any lesson learned toward future runs?

1. there should establish a checklist of changes and QA plots which are same at each step. Some of them may not be filled at early steps but should be available with same quantities to be able to compare at each step the improvement or deterioration. Although there are significant QA at each step, it is often impossible to judge what changes because the quantities used are quite different.
2. There are different sets of calibration tools and data. It should be made clear what information is used for which specific calibration, and what data is used for QA. The precision and requirements should be clearly identified.
3. in every step, the knowledge from the limited expert manpower is relatively self-contained and does not propagate well to the next step. This includes the information about trigger/T0 from operation (first step), timing, dE/dx calibration at second step, distortion and geometry at third step and physics quantity QA at last step. Both experts and committee feel the need to improve communication and coordination.
4. documentation and categorization of different parts of the calibrations could make it easier for non-experts to understand and participate in a meaningful way of helping.