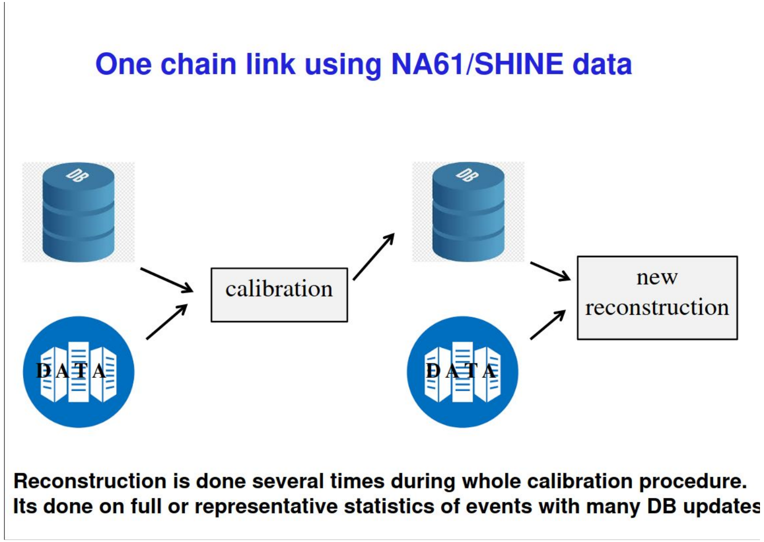
TPC calibration
v_D, T0

Evgeny Kashirin (MEPhI)

NA61/Shine Autumn School
05/11/2020

TPC calibration chain

- Stage1 - TPC phase calibration
- PRE-2 - Drift velocity “smoothing”
- Stage2 - Drift velocity scaling
- Stage3 - T0-s calibration
- Stage4 - Alignment
- BPD-TPC initial alignment
- Residuals
- dE/dx calibration



G.Stefanek, From raw to physical data Pt II.

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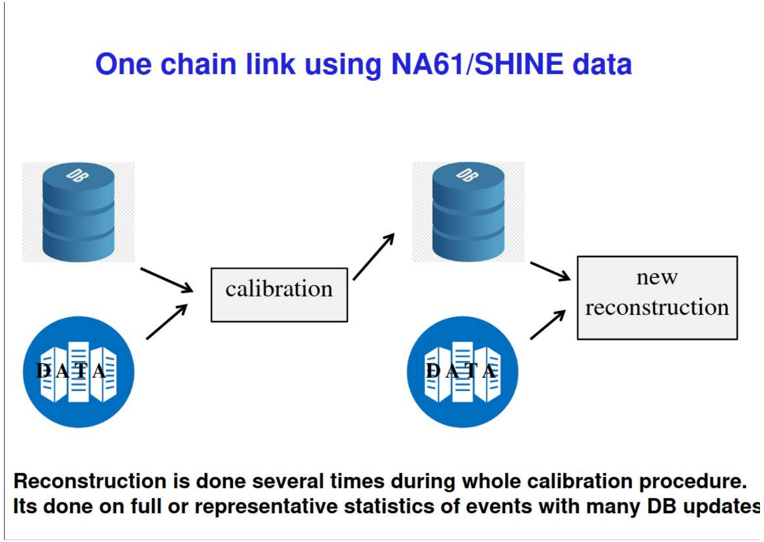


G.Stefanek, From raw to physical data Pt II.

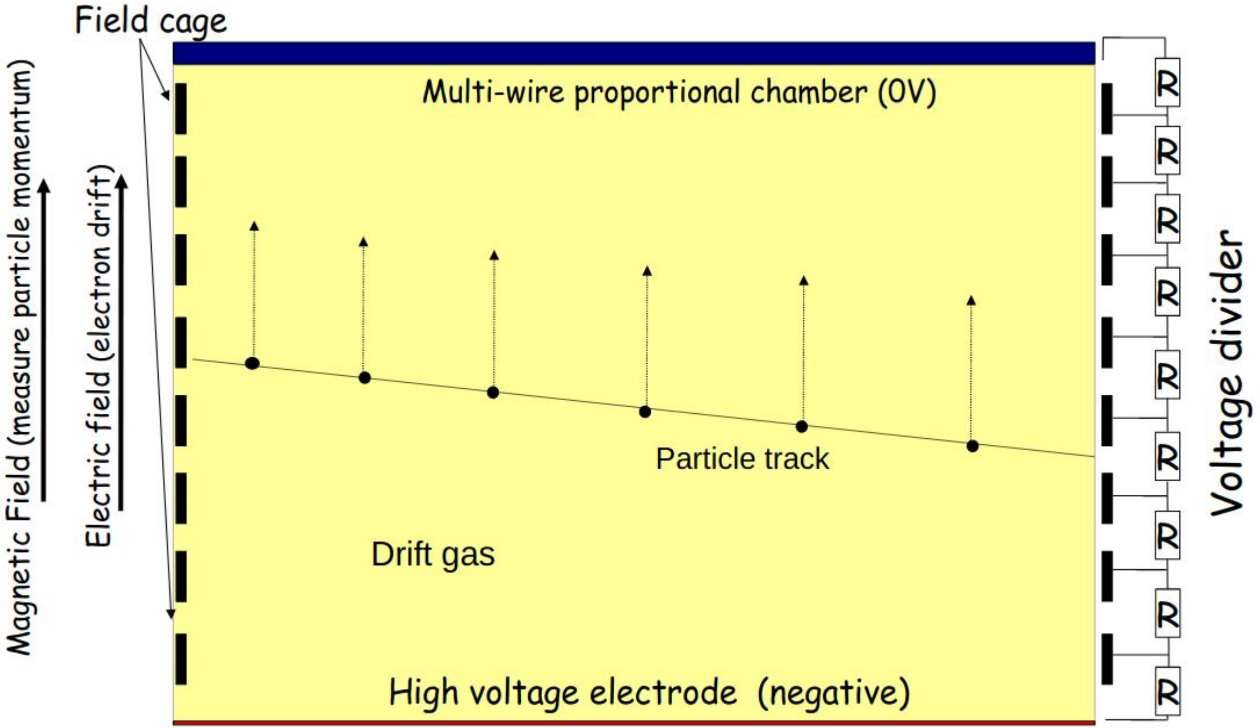
Reminder: TPC working principle

$y = y_0 - v_D\,(t_0 + t_{meas})$

Reconstruction parameters:

- v_D - drift velocity
- t_0 - readout delay (Const**)
  - electronics warm-up
  - cable lengths

  …
- y_0 (Const**)
  - vertical position of TPC
  - TPC height



[R.Renfordt, Introduction to TPCs]

** at least during datataking session

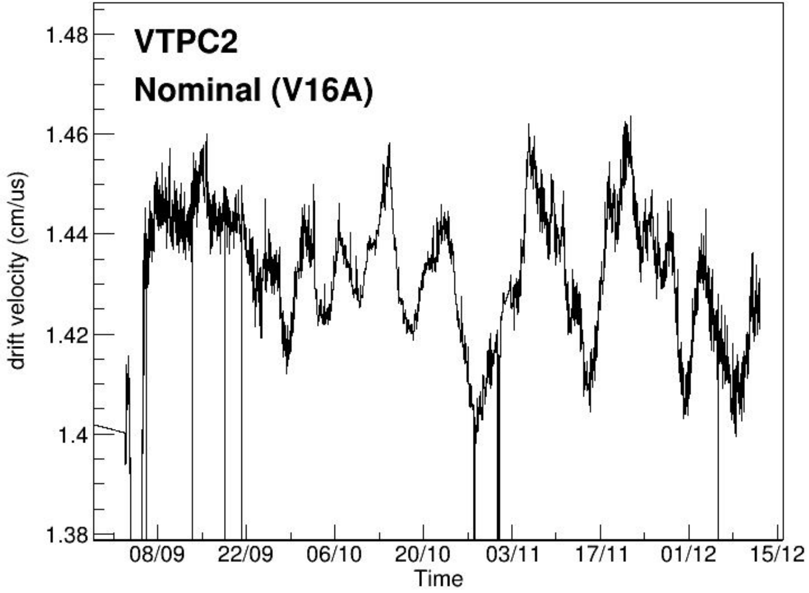
Drift velocity

Cluster vertical position: $y = y_0 - v_D (t_0 + t_{meas})$

Magnitude of the drift velocity depends on:

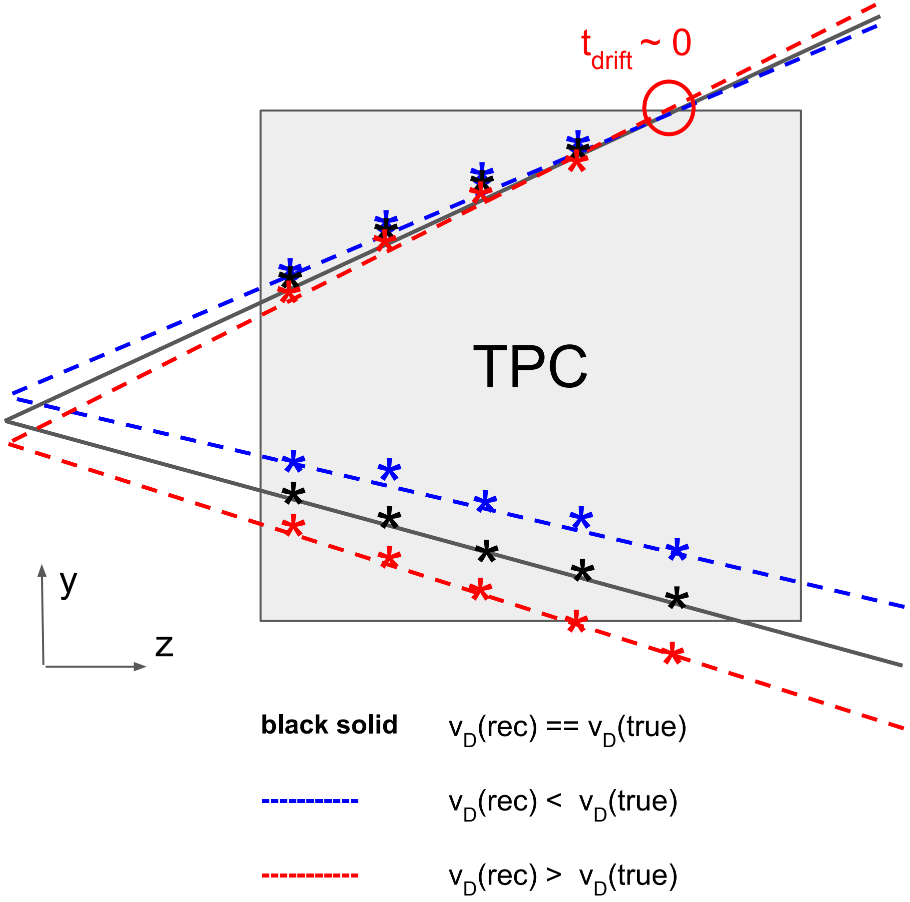
- temperature (T)
- pressure (P)
- gas composition
- electric field (E)

$T=T(t),\ P=P(t),\ E=E(t) \rightarrow v_D = v_D(t)$



Effect of v_D miscalibration

- Linear effect: tracks are straight
- Difference scales with drift time (of drift length (or -*Y*))
- Slopes are different



v_D calibration: Option 1 - matching with reference detector

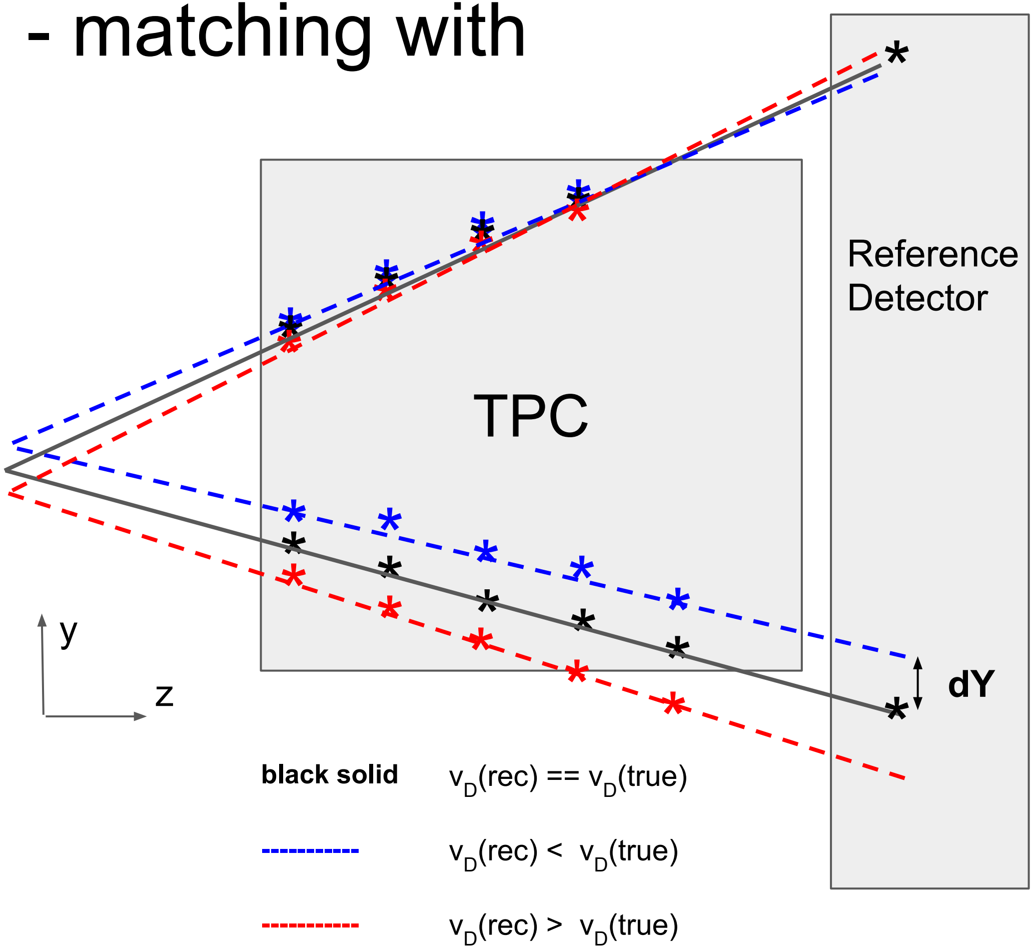
- Local TPC tracks are extrapolated to Z-plane of reference detector

- Vertical position of extrapolated track is compared with position from reference detector

$$\epsilon(v_D) = \frac{v_D(rec) - v_D(true)}{v_D(true)}$$

$$dY = y(TPC) - y(ref)$$

$$dY \sim \epsilon(v_D) Y$$



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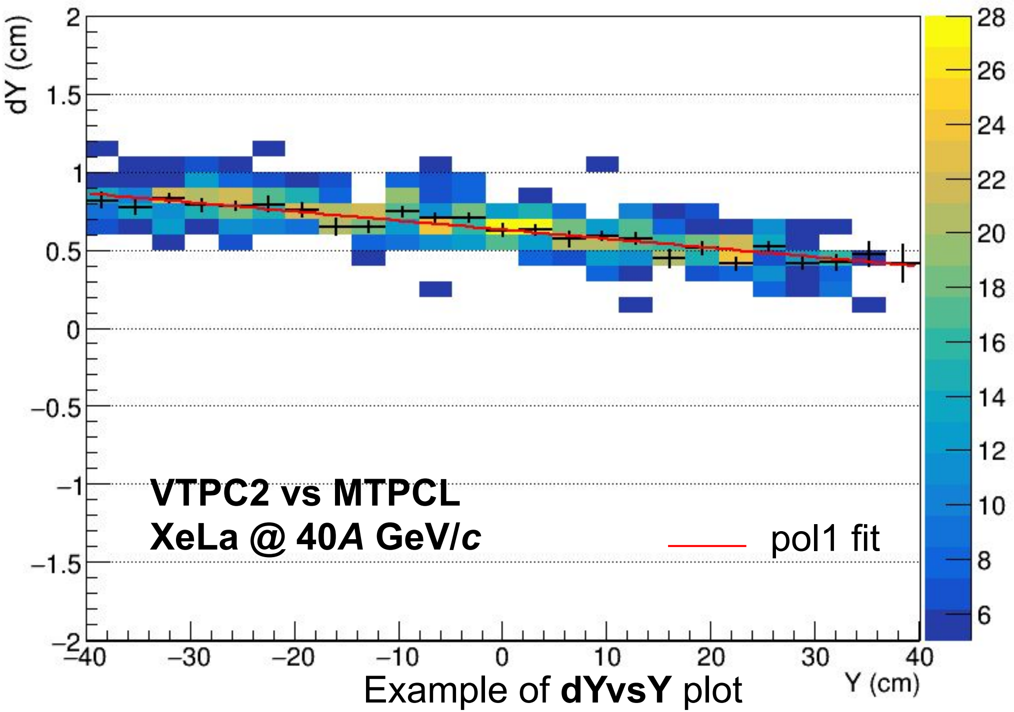
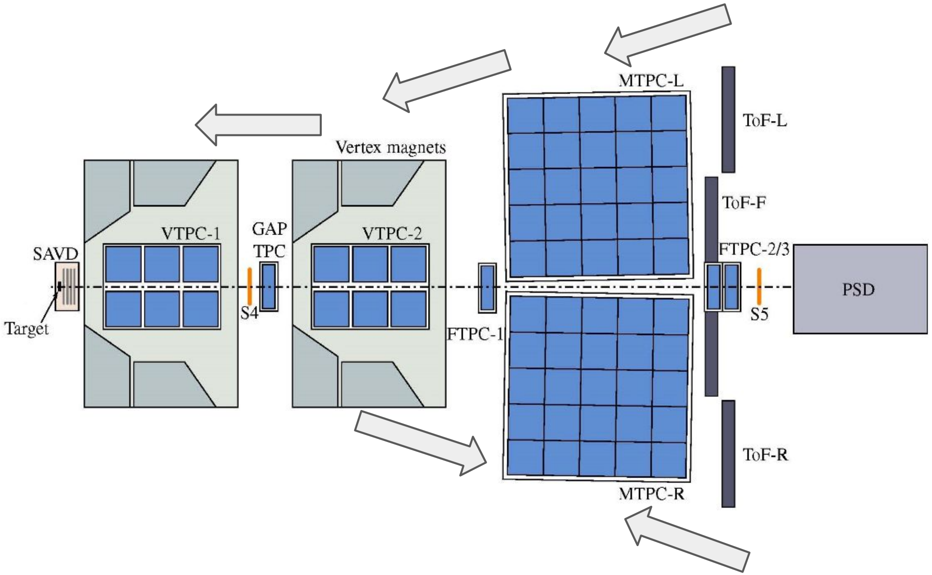


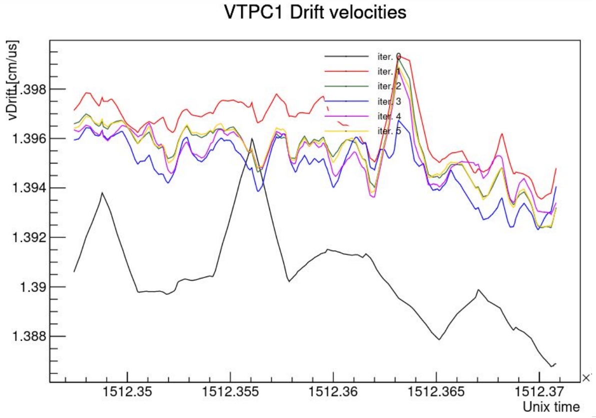
Example of **dYvsY** plot

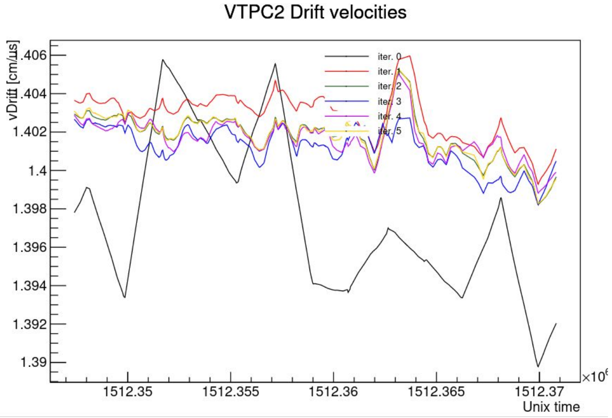
v_D calibration chain using matching with ref. detector

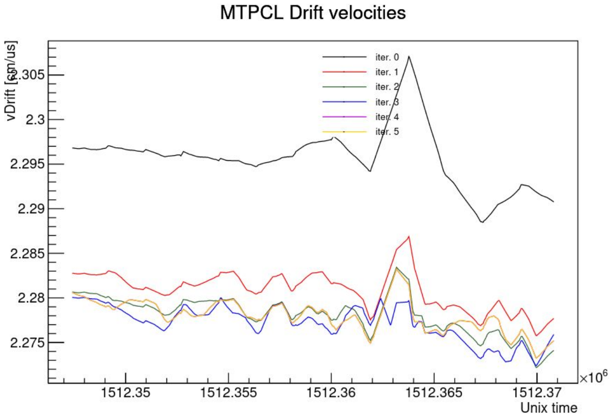


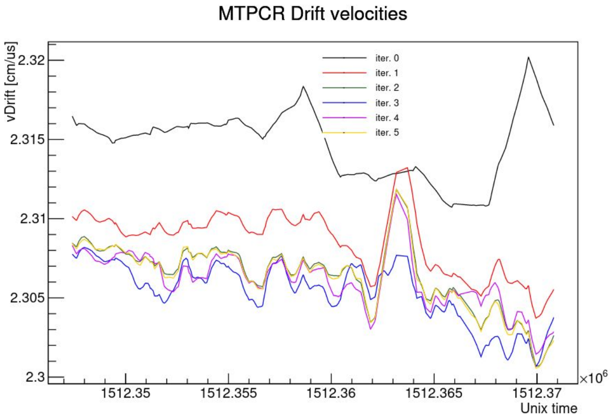
- v_D(MTPCL) is calibrated using TOFL as a reference detector
- Subsequent TPCs are calibrated in order represented by arrows. Already calibrated TPC is used a reference detector for the next one.
- For cross-check MTPCR is calibrated using VTPC2 and TOFR

Issue #1: Error accumulation



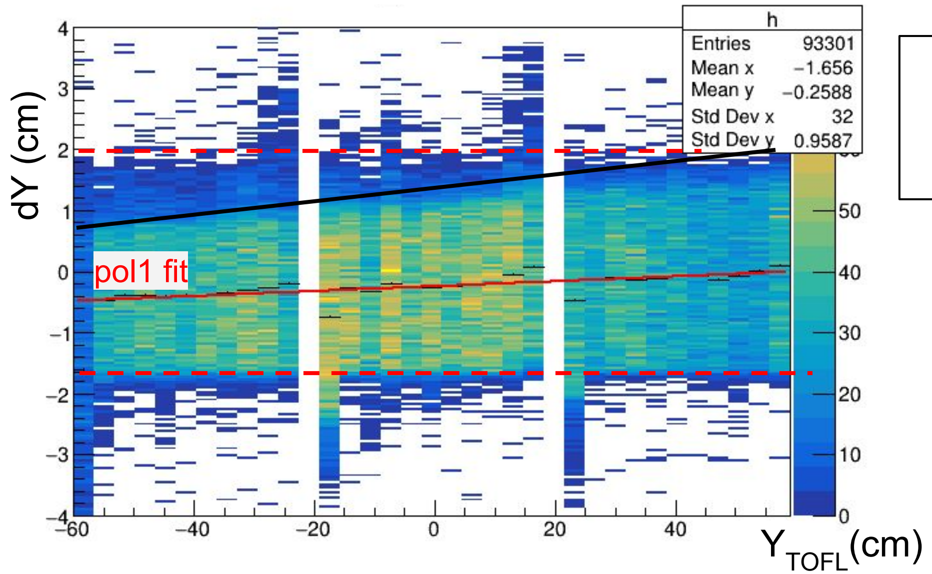






- small-scale fluctuations are propagated

Issue #2: Granularity of TOFL/R



Pb+Pb 30A GeV/c
gk 16_025
run #025450

Example of dYvsY plot for MTPCL vs TOFL $\Delta v_D / v_D = 1\%$.

Desired precision: $\Delta v_D / v_D < 0.1\%$;   dY ~ 1mm at the bottom of MTPCL

Vertical size of TOF cell is MUCH larger: 35 mm

Issue #3: No reference detector

Significant part of Xe+La @ 150*A* GeV/*c* is collected with no TOF data.

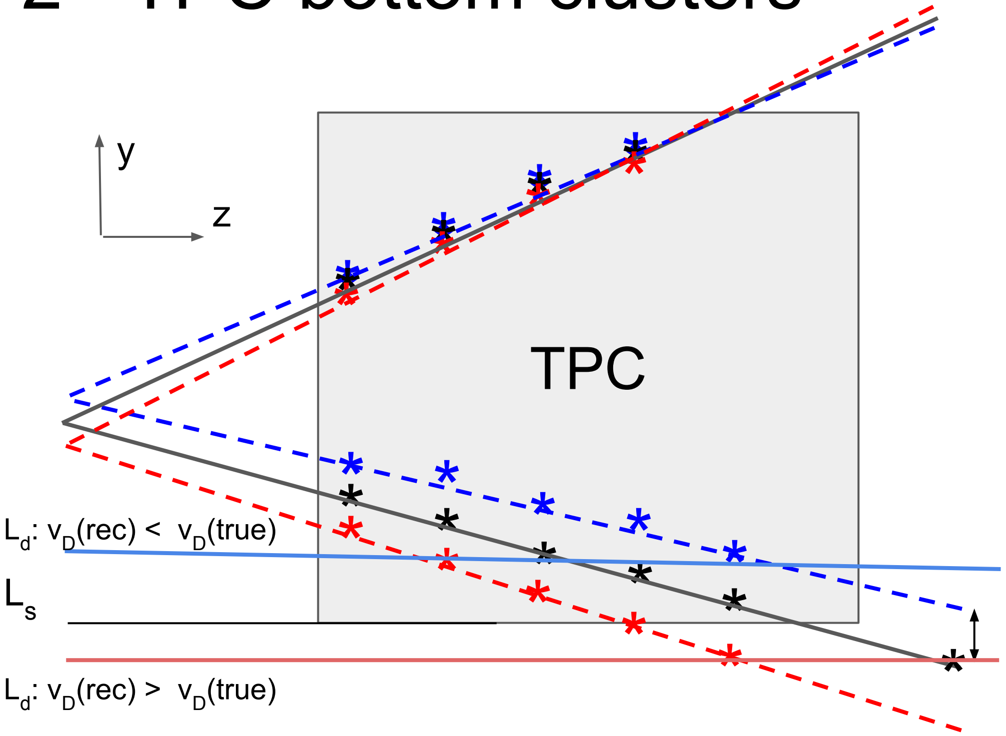
v_D calibration: Option 2 - TPC bottom clusters

- Drift length of the last cluster (L_d) of track corresponds → vertical size of the sensitive volume in TPC

$$L_d = v_D(t_0 + t_{b.c})$$

where $t_{b.c}$ is measured drift time of bottom cluster

- Height of sensitive volume (L_s) was precisely measured during geometry survey



But t_0 is not known (not yet calibrated, initial value is taken) at this stage!

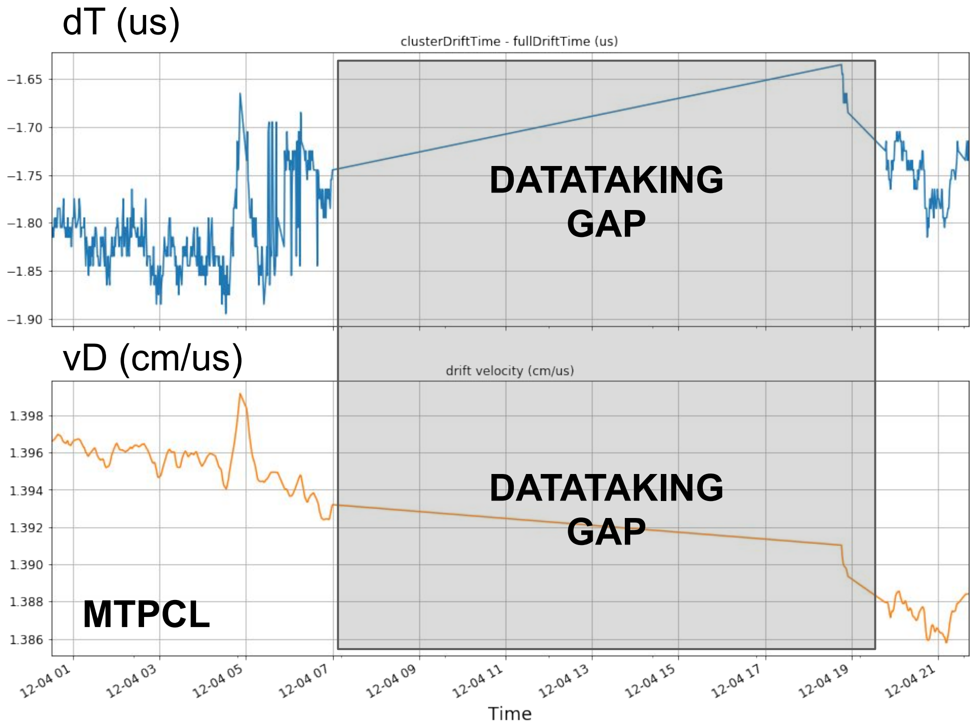
Correlated fluctuations of v_D and dT

$$t_{full\,drift} = \frac{L_S}{v_D}$$

$$dT = t_0 + t_{b.c} - t_{full\,drift}$$

dT is expected to be time-independent

In reality *dT* is *strongly* correlated to fluctuations of drift velocity



XeLa 40*A* GeV/*c* runs #35100-035130
after 3rd iteration of Stage2

Option 1 + Option 2

$$\epsilon(v_D) = \frac{v_D(rec) - v_D(true)}{v_D(true)}$$

Split $\varepsilon(v_D)$ on time-dependent and time-independent parts:

$$\epsilon(v_D)(t) = \epsilon_0 + \epsilon_1(t)$$

$$\langle \epsilon_1(t) \rangle_t = 0$$

- Correct $\varepsilon_1(t)$ using TPC bottom points (new stage - PRE-2)
- Correct ε_0 with matching (Stage2)

PRE-2 concept

$dT = t_0 + t_{b.p} - L_s/v_D(rec)$ - fluctuating with time

v_D(corr) is defined so that:

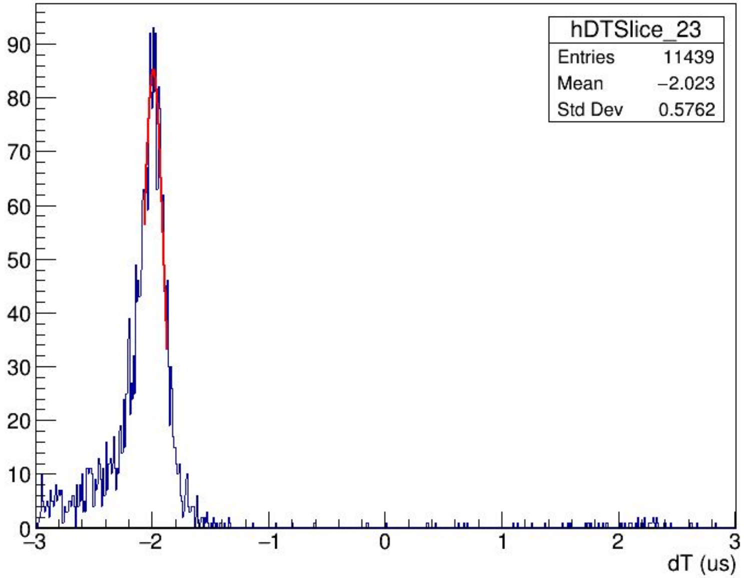
$$dT_{ref} = t_0 + t_{b.p} - L_s/v_D(corr) = Const \quad (1)$$

and $\langle v_D(rec)\rangle_{\Delta T} = \langle v_D(corr)\rangle_{\Delta T}$ (2)

From (1): $\epsilon_1(t) = \frac{dT - dT_{ref}}{T_{full\ drift}}$

From (2): $\langle \epsilon_1(t)\rangle_{\Delta T} = 0$ and

$$dT_{ref} = \langle dT\rangle_{\Delta T}$$

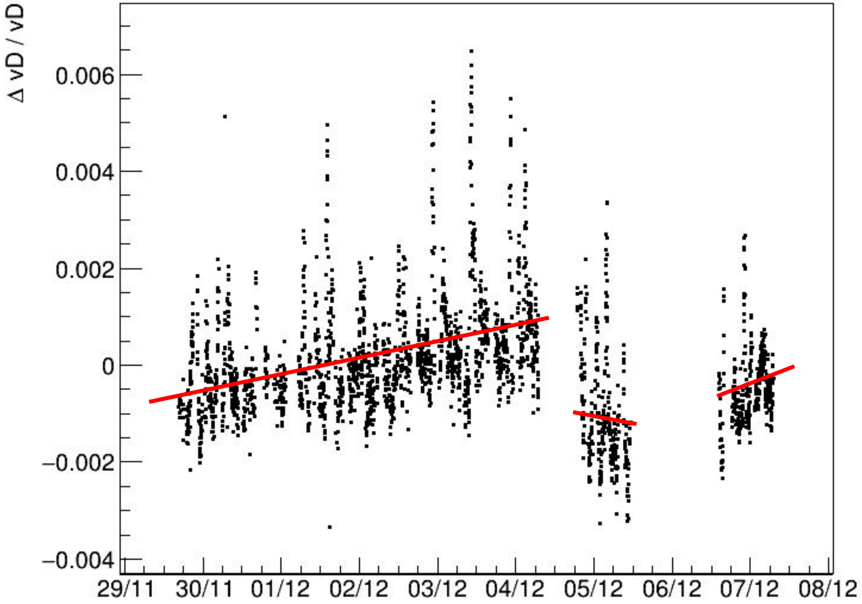


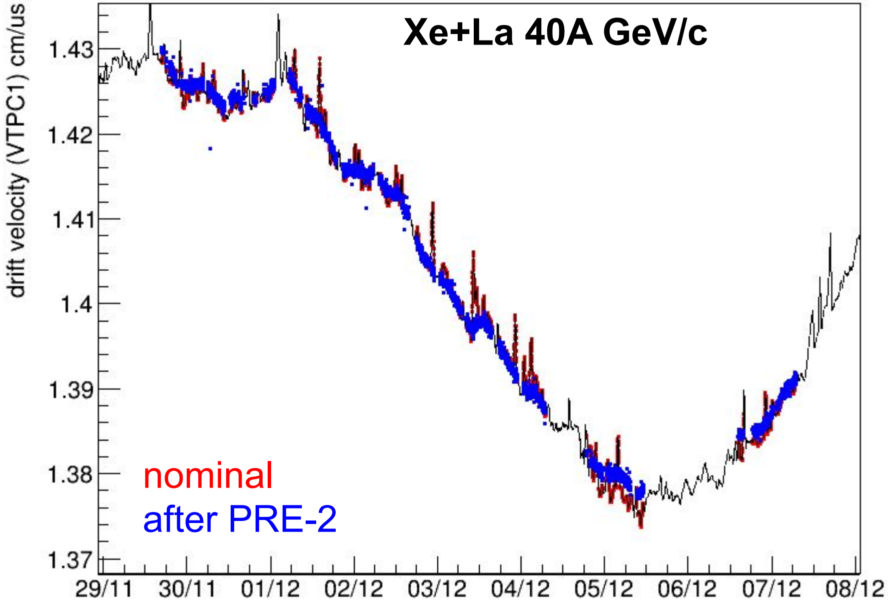
ΔT - characteristic time of drift velocity evolution

Limitations

- global T0 and chamberT0-s are assumed to be constants during datataking session
- true global & chamber T0s are not known at the moment of PRE-2 stage
  - drift velocity is calibrated up to unknown scaling factor $1+\varepsilon_0$:
    v_D (corrected) = $(1+\varepsilon_0)$ v_D (real)
  - ε_0 is the subject of Stage2
- $|\varepsilon_1(t)| << 1$
- $t_{fluc} << \Delta T$

PRE-2 performance: VTPC1

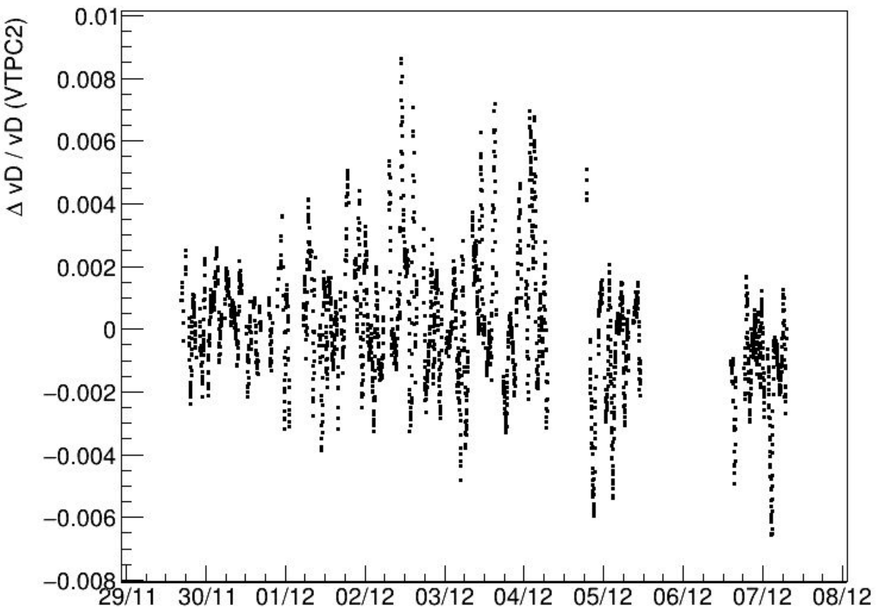


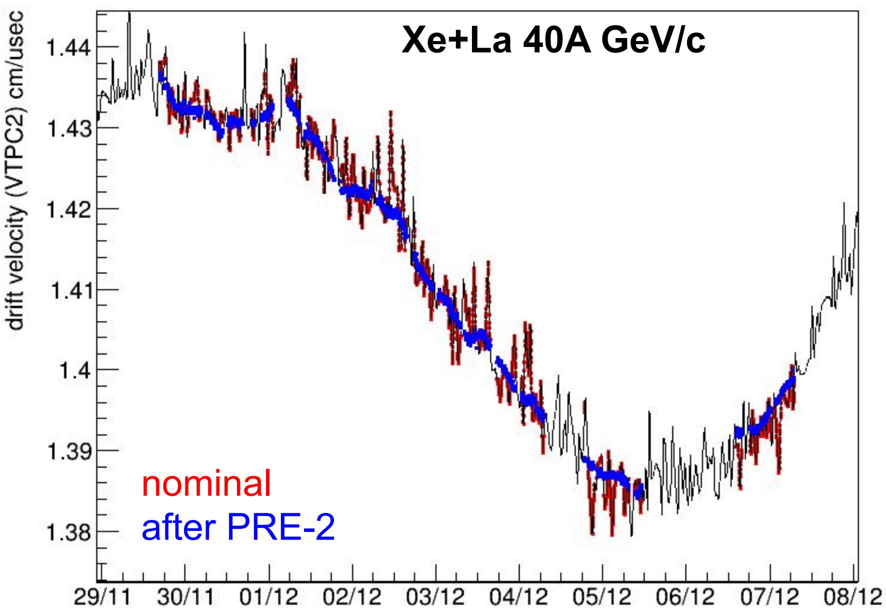


- Fluctuations of nominal v_D up to 6 ‰
- Piecewise structure of $\Delta v_D / v_D$
- Global positive trend of $\Delta v_D / v_D$

- corrected v_D is distorted
- solitary outliers are present - dT fit divergence
  - post-processing is required

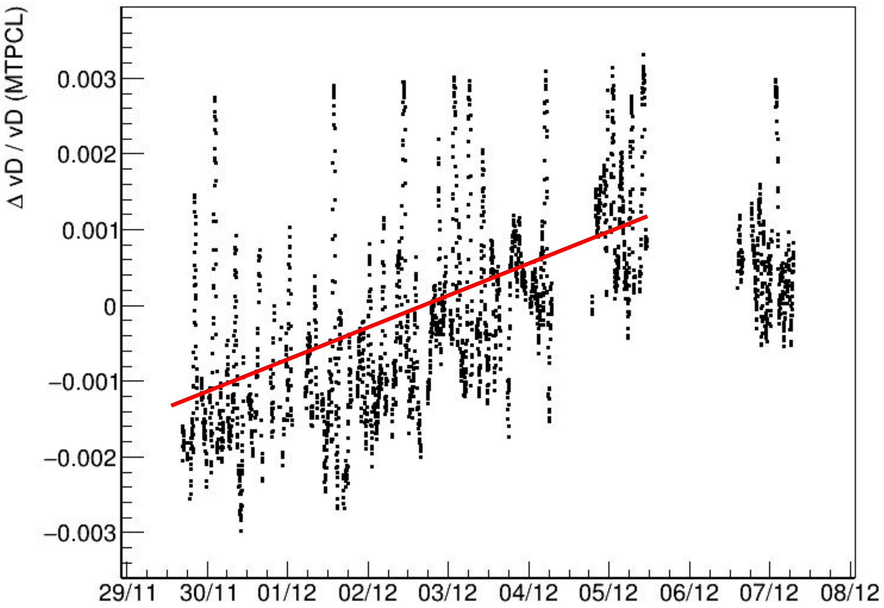
PRE-2 performance: VTPC2

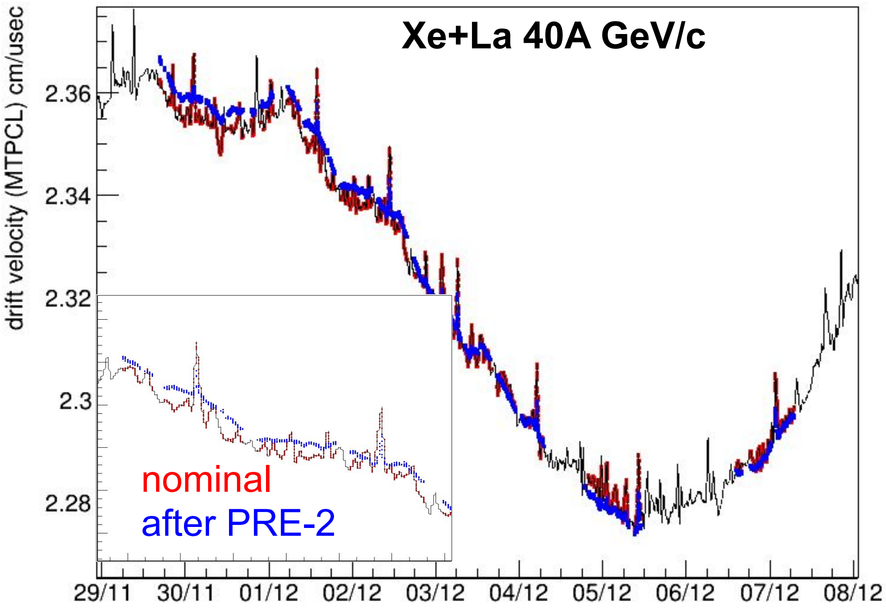




- Fluctuations of nominal v_D up to 1 %

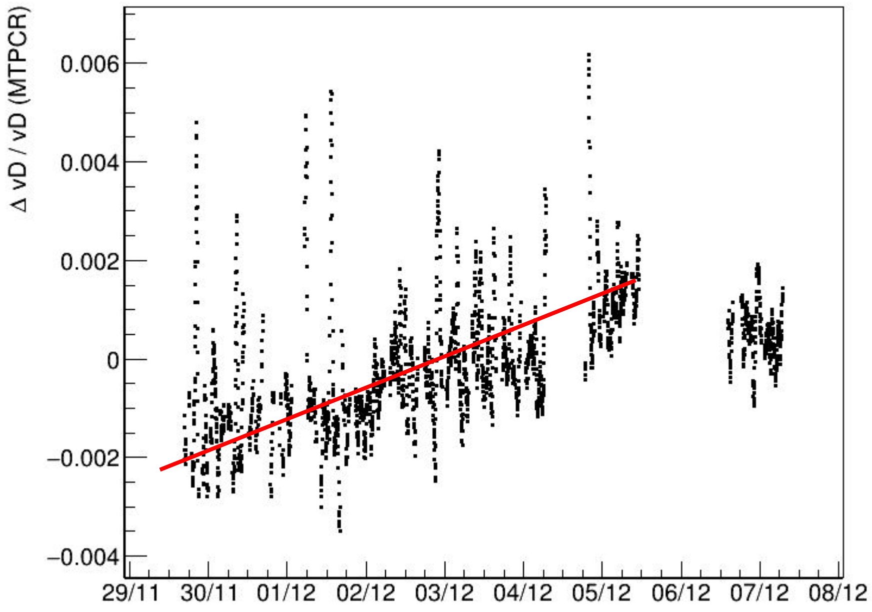
PRE-2 performance: MTPCL

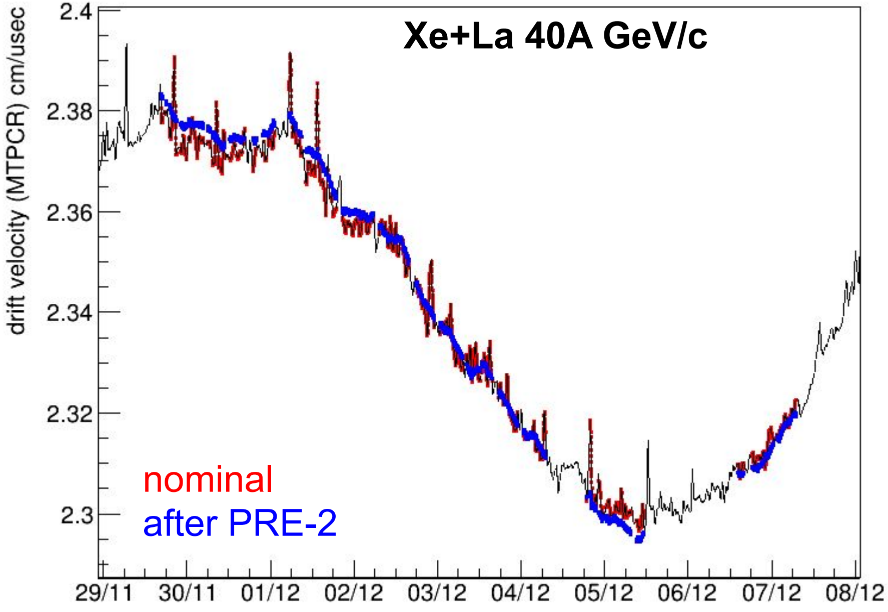




- Fluctuations of nominal v_D up to 3 ‰
- Global positive trend of $\Delta\, v_D / v_D$
- Few v_D spikes are survived correction

PRE-2 performance: MTPCR

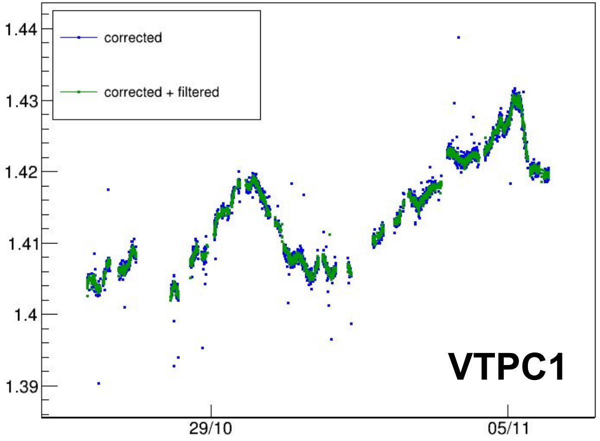


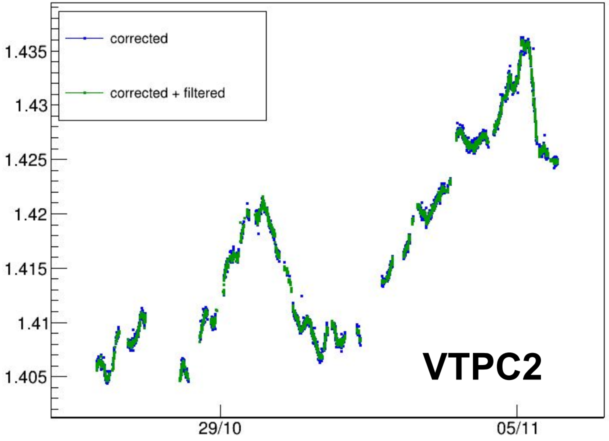


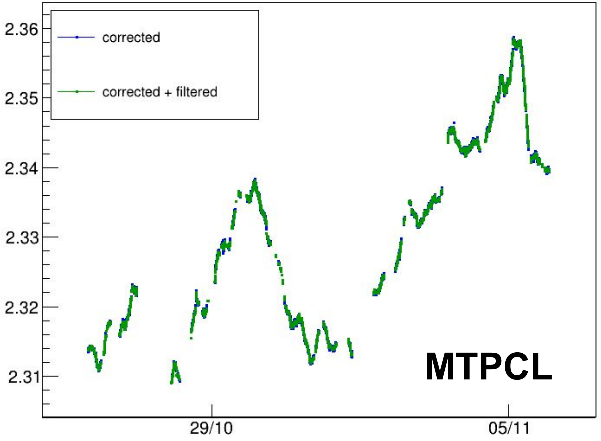
- Fluctuations of nominal v_D up to 6 ‰
- Global positive trend of $\Delta v_D / v_D$

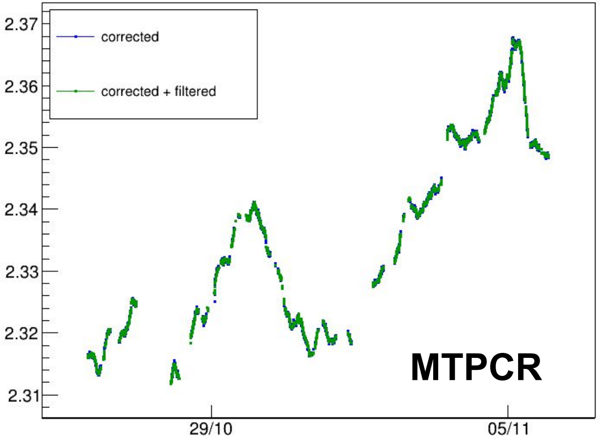
Additional v_D filtration

1. rolling (n=3) median filter
2. rolling (n=3) mean filter





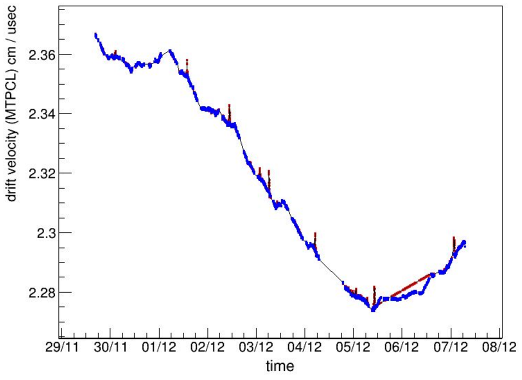




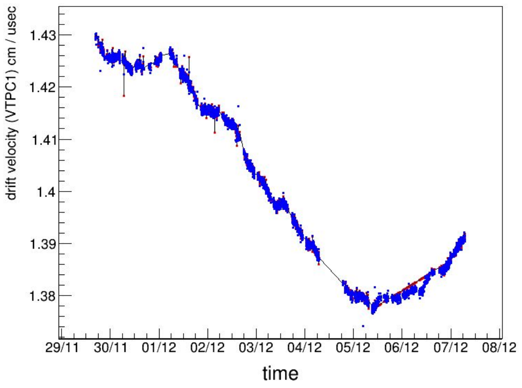
- solitary outliers in VTPCs are mostly gone
- less distorted
- vD of MTPC-s are almost unchanged

PRE-2 convergence test

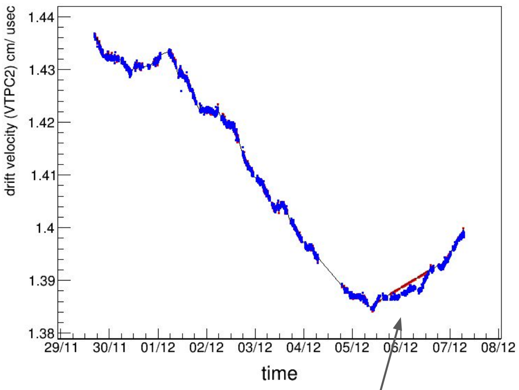
MTPCL



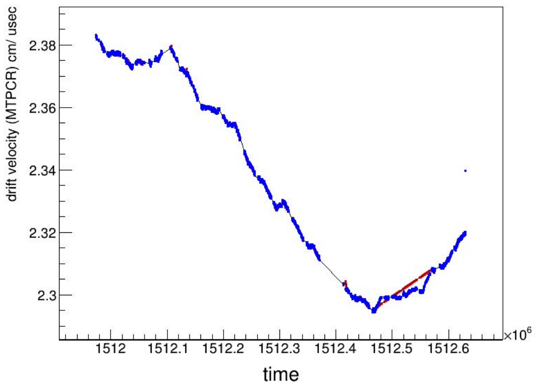
VTPC1



VTPC2



MTPCR

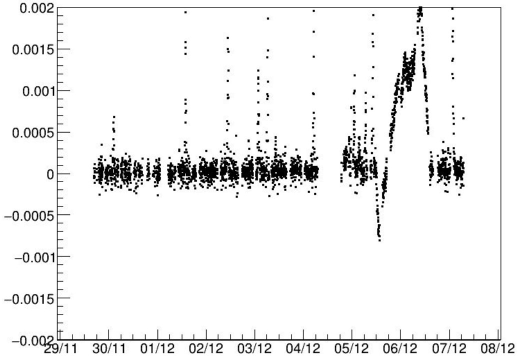


- PRE-2 stage converges after 1-st iteration

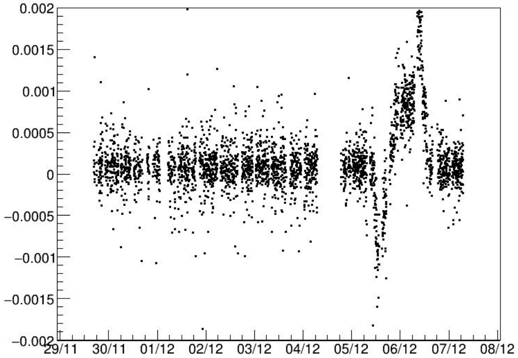
This piece was missing
at 1st iteration of PRE-2

PRE-2 - ε(t)

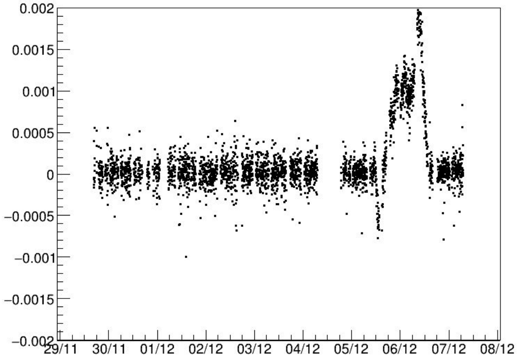
MTPCL



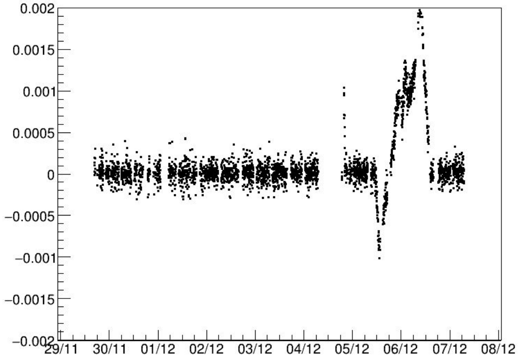
VTPC1



VTPC2

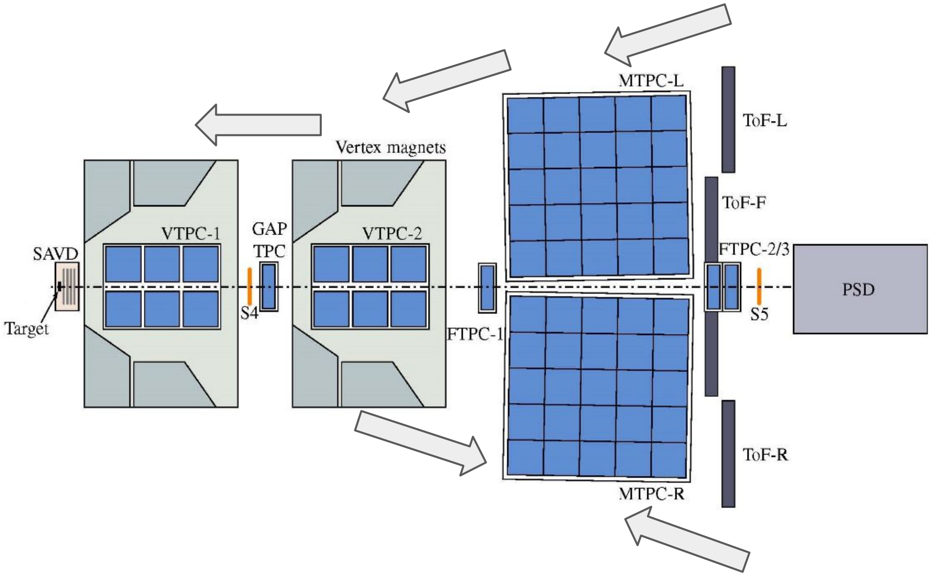


MTPCR



- TPC bottom points method precision ~7×10^{-4} for VTPCs and ~4×10^{-4} for MTPCs

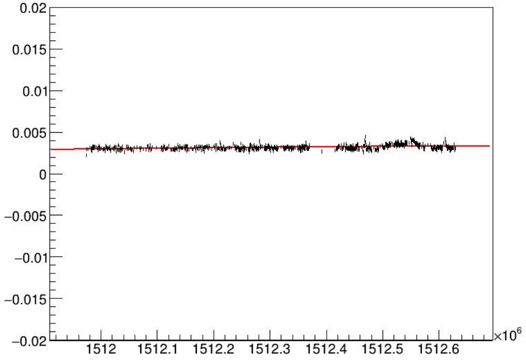
Stage2 - scaling v_D using matching with reference detector



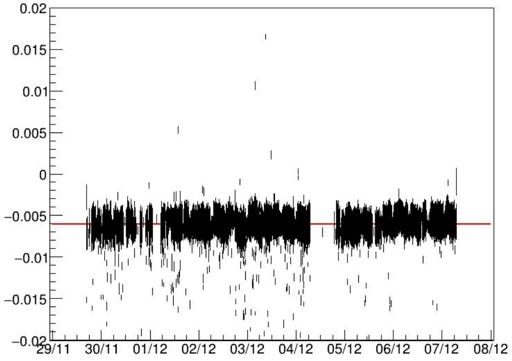
- v_D(MTPCL) is calibrated using TOFL as a reference detector
- Subsequent TPCs are calibrated in order represented by arrows. Already calibrated TPC is used a reference detector for the next one.
- For cross-check MTPCR is calibrated using VTPC2 and TOFR
- **Problem is now time-independent!**

Stage2 - dY vs Y slope (ε(t))

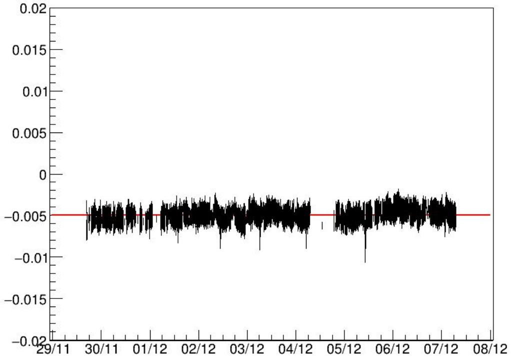
MTPCL



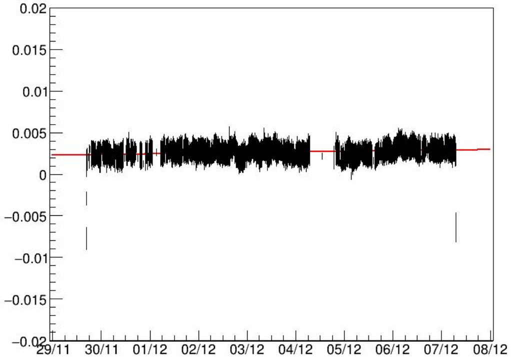
VTPC1



VTPC2



MTPCR



- v_D' (TPC)(t) = ϵ_0 v_D(TPC)(t)

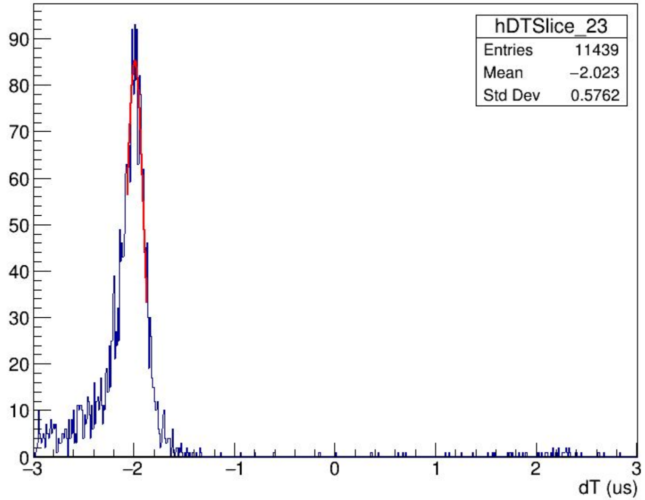
Stage3:

$$y = y_0 + v_D\,(t_0 + t_{meas})$$

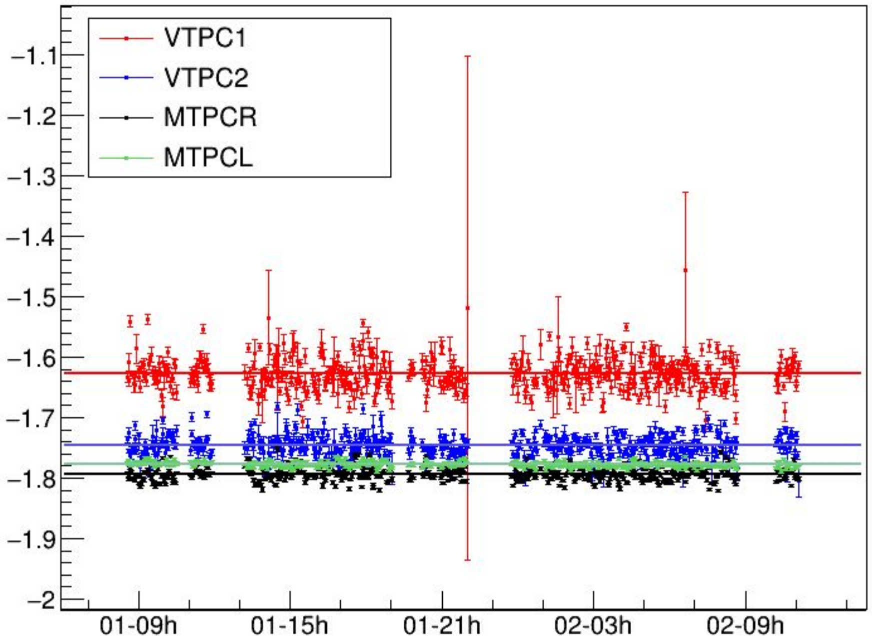
vD is calibrated
y0 is not calibrated (geometry survey)

$$dT = t_{\text{bottom point}} - L_{drift}/v_D$$

- T0(VTPC1) = -94.6 ns (by convention)
- global T0 = dT(VTPC1) - T0(VTPC1)
- T0(VTPC2) = dT(VTPC2) - globalT0
- T0(MTPCL) = dT(MTPCL) - globalT0
- T0(MTPCR) = dT(MTPCR) - globalT0



T0 vs time



- global and chamber T0-s are time-independent

Future plans

Improvement of the available documentation

- GitLab README.md: https://gitlab.cern.ch/na61-software/framework/Shine/-/tree/master/Applications/Standard/Calibration/Stage2/vD_calib_calculator
- Up to date TWiki pages - In progress

Assignee: Me

Improve user interface of Stage2

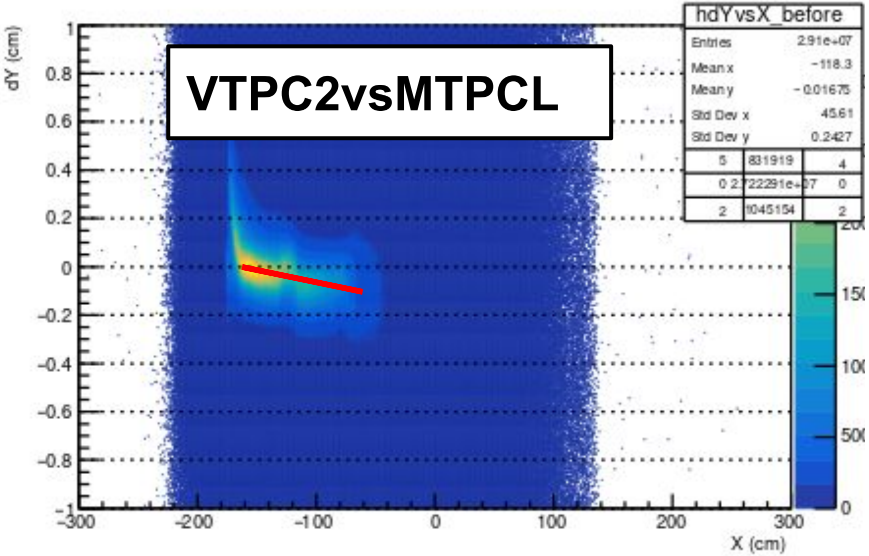
Hard-coded configuration

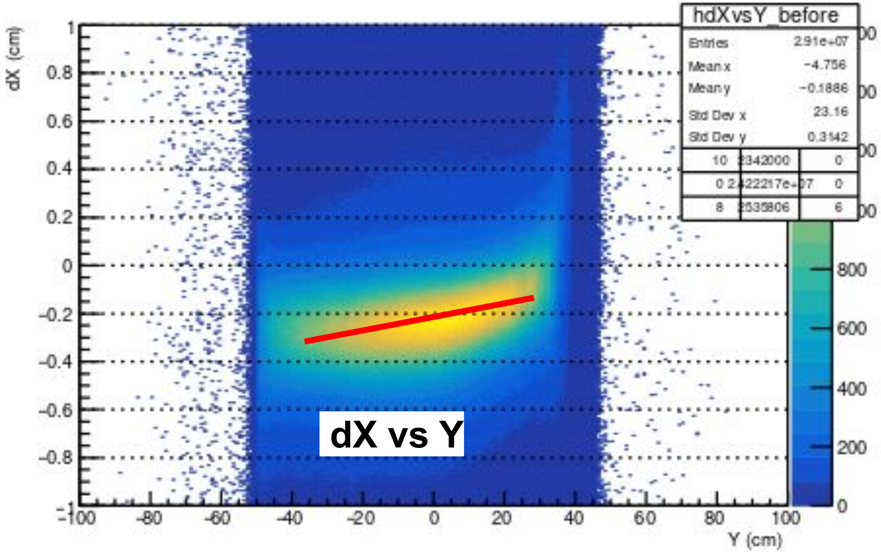
```
std::vector<CalibTask_t> calibTasks{
  CalibTask_t("MTPCL", kMTPCLvsTOFL).ne(20000).smoSpanSlope(1800)
    .bottom(-60).top(60),
//    CalibTask_t("FTPC2", kMTPCLvsFTPC2, kMTPCLvsTOFL).ne(2000).ndy(40).xLim(-100,100)
//    .bottom(-30).top(30),
//    CalibTask_t("FTPC3", kMTPCLvsFTPC3, kMTPCLvsTOFL).ne(2000).ndy(40).xLim(-100,100)
//    .bottom(-30).top(30),
    CalibTask_t("VTPC2", kVTPC2vsMTPCL, kMTPCLvsTOFL).ne(20000).ndy(160).xLim(-110, 60)
    .bottom(-55).top(55),
//    CalibTask_t("FTPC1", kVTPC2vsFTPC1, kVTPC2vsMTPCL).ne(2000).ndy(40).xLim(-100, 100)
//    .bottom(-30).top(30).swap(),
//    CalibTask_t("GTPC", kGTPCvsVTPC2, kVTPC2vsMTPCL).ne(2000).ndy(40).xLim(-60, 60)
//    .bottom(-20).top(20),
    CalibTask_t("VTPC1", kVTPC1vsVTPC2, kVTPC2vsMTPCL).ne(20000).ndy(160).xLim(-100,100)
    .bottom(-35).top(35),
    CalibTask_t("MTPCR", kVTPC2vsMTPCR, kVTPC2vsMTPCL).ndy(160).ne(20000).swap(),
    CalibTask_t("MTPCRfromTOFR", kMTPCRvsTOFR).ne(20000).smoSpanSlope(1800),
    };
```

JSON/YAML based configuration

Assignee: Me

Multidimensional fitting dY = dY (X, Y)





- Structure of dY vs X and dX vs Y suggests possible mis-rotation of TPCs or other unknown effect

Automation and QA-ing

- List of QA plots was defined during the mini-workshop after previous CM

- No automation scripts / calibration scenarios provided yet
  - Run PRE-2, Stage2 and Stage3 in one iteration
  - Merge software into single ‘framework’

TPC calibration software 2020+

1. Stage1 - TPC phase

2.a PRE-2 - v_D smoothing new!

2.b Stage2 - v_D scaling

3. Stage 3 - Global/Chamber T0

4. Stage 4 - Alignment validation

I have to focus on my PhD thesis so…

Maintainer / Calibrator wanted!

The entire procedure should be tested in 2020+ environment

Thank you!

Previously calibrated samples: Pb+Pb 13/30*A* GeV/*c* (2016)

- reconstructed with old strategy (no PRE-2) - vD fluctuations
- bad TPC-TOF matching
- old potential points module
- old BPD reconstruction module
- new dE/dx calibration is available

Decision is needed!