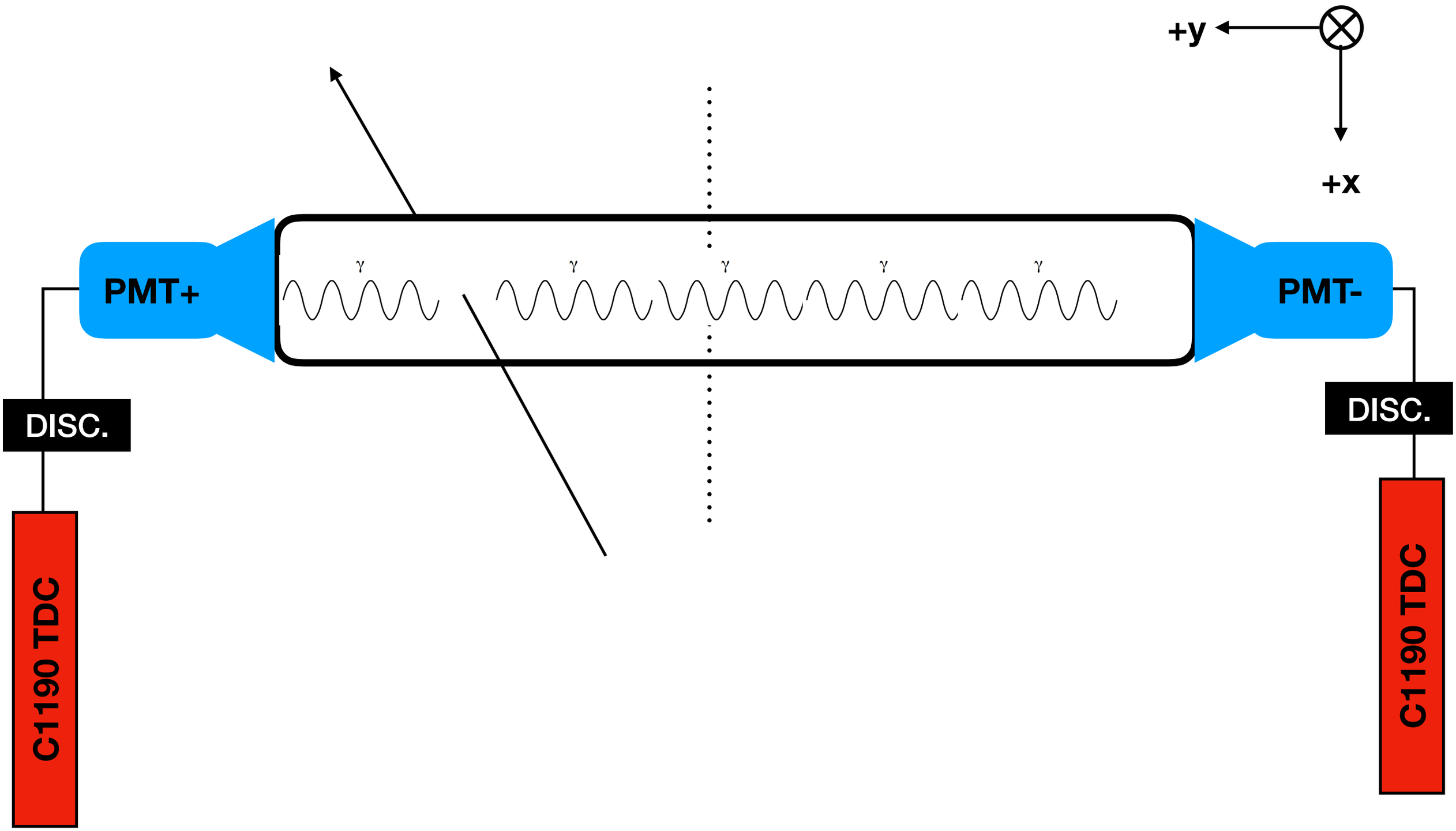
Hodoscope Calibration Procedure

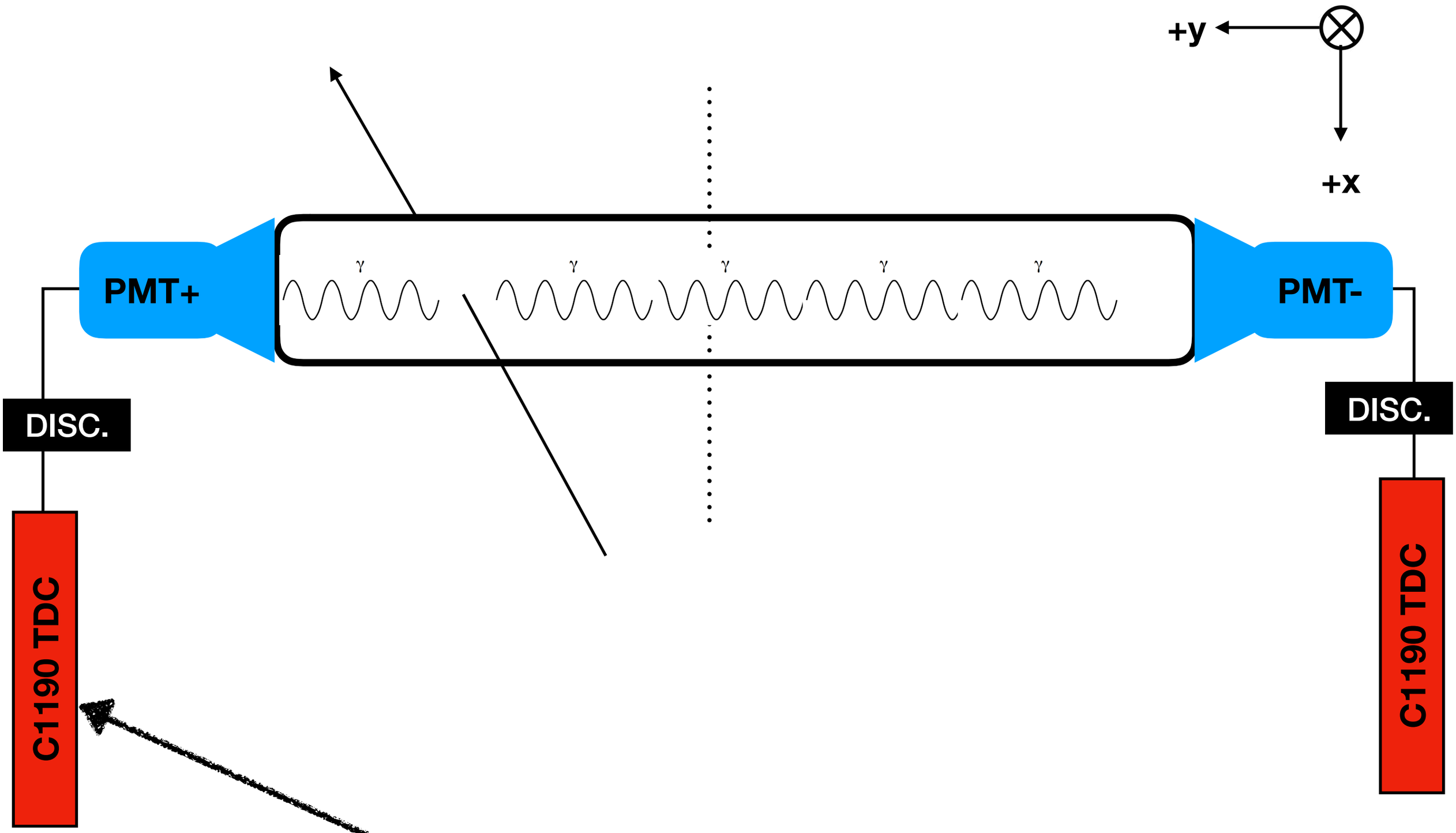
Hall C Analysis Workshop, 2018

Carlos Yero

June 26, 2018

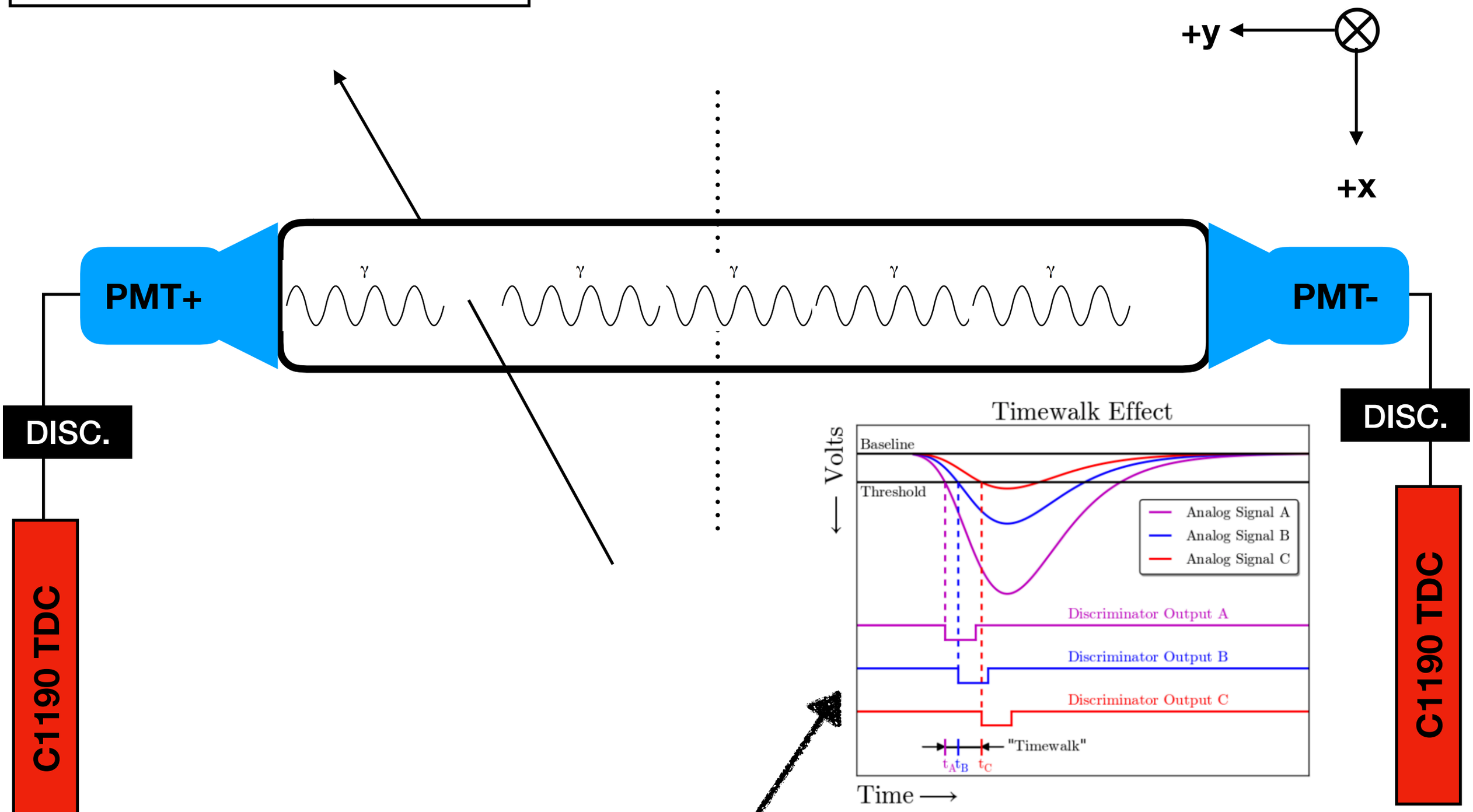


$$t^{\pm}_{Corr.} = t^{\pm}_{UnCorr.} - t^{\pm}_{TW} - t^{\pm}_{cable} - t^{\pm}_{prop.} - t^{\pm}_{\lambda}$$



$$t^{\pm}_{Corr.} = t^{\pm}_{UnCorr.} - t^{\pm}_{TW} - t^{\pm}_{cable} - t^{\pm}_{prop.} - t^{\pm}_{\lambda}$$

Image Source: E. Pooser



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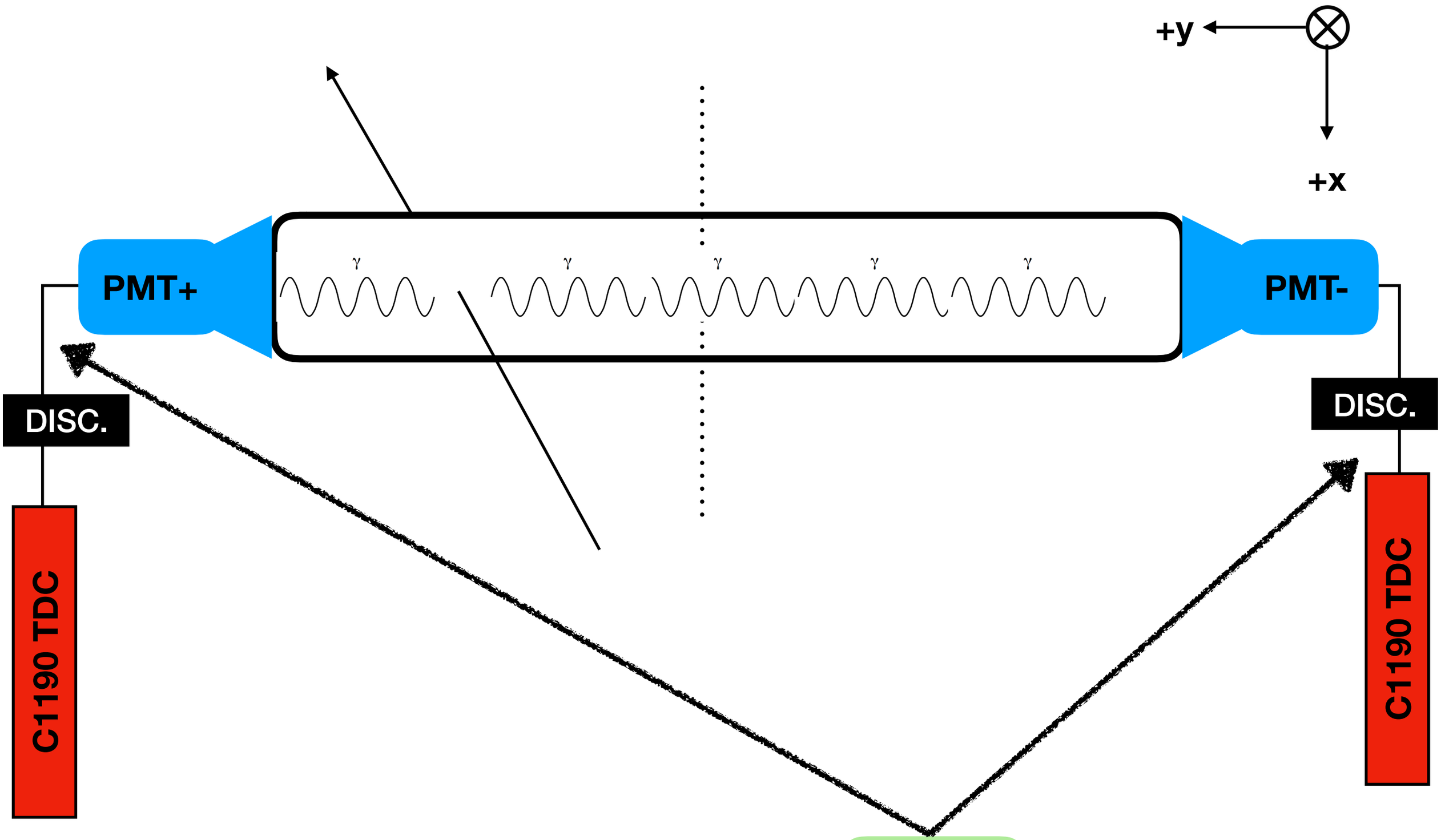

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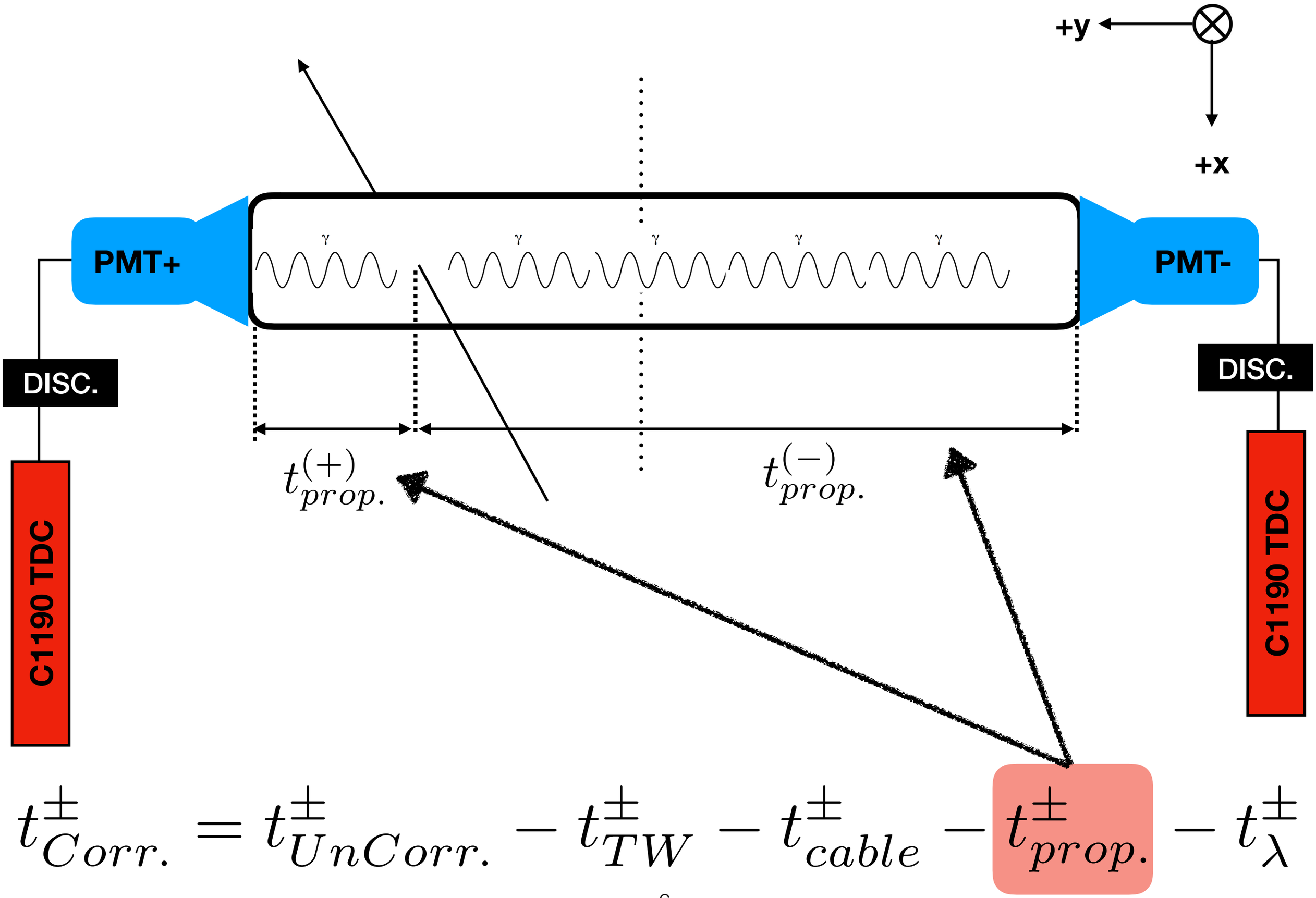

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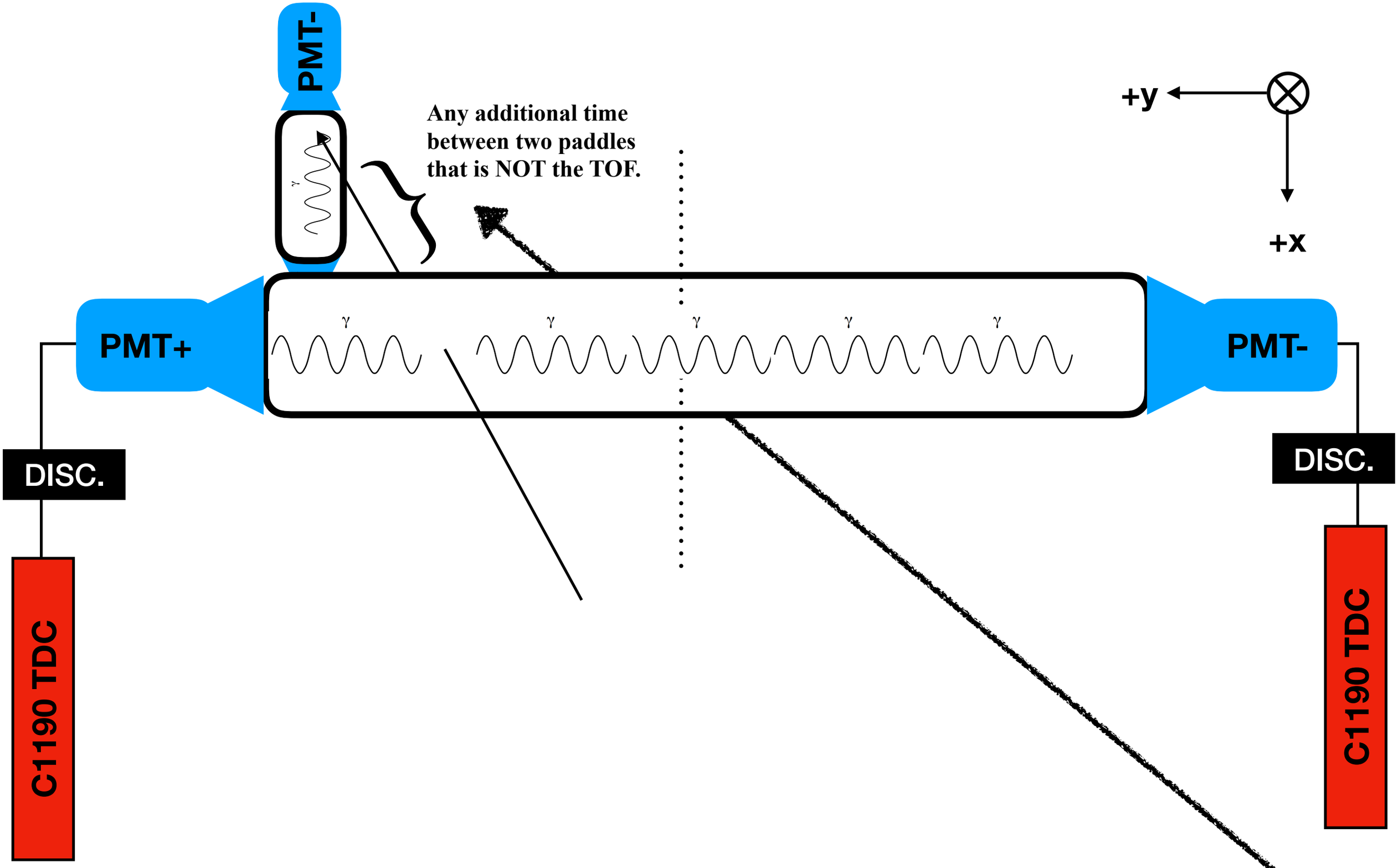


$$t^{\pm}_{Corr.} = t^{\pm}_{UnCorr.} - t^{\pm}_{TW} - t^{\pm}_{cable} - t^{\pm}_{prop.} - t^{\pm}_{\lambda}$$

Hodoscope Calibration

Procedure

STEP 1:

Set this flag to zero: `(p)htofusinginvadc = 0`

Found on directory :

`hallc_replay/PARAM/(S)HMS/HODO/`

HINT: Use the command: `grep -i (p)htofusinginvadc ./*` once in the directory above, to find the flag quickly.

STEP 2:

Replay the raw data file, typically 1-2 million events is required for a good fit.

Make sure to include the blocks of variables necessary for this calibration.
These are found on:

`/hallc_replay/DEF-files/(S)HMS/PRODUCTION/BLOCK/(p)hblock_vars.def`

hblock_vars.def

```
#*************************
# Block Definitions *
#*************************

block T.hms.*
block H.cer.*
block H.hod.*
block H.cal.e*
```

pblock_vars.def

```
#*************************
# Block Definitions *
#*************************

block T.shms.*
block P.ngcer.*
block P.hod.*
block P.cal.e*
```

STEP 3:

In the directory:

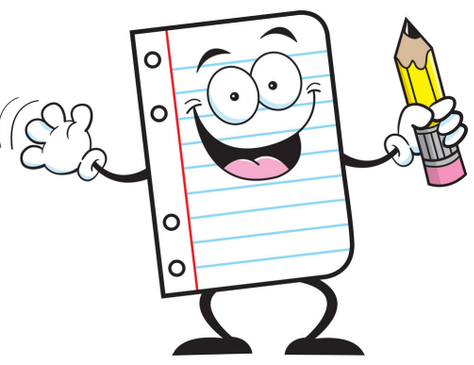
`/hallc_replay/CALIBRATION/(s)hms_hodo_calib/`

Run the following code:

```
root -l "timeWalkHistos.C(<run_num>)"
```

Code Description:

This script takes as input the ROOTfile replayed and creates another ROOTfile containing histogram objects that are used to perform the Time-Walk Correction.



NOTE: The user sets the run number interactively, however, the ROOTfile that is loaded must be changed manually in the code. Open the code and make sure the correct ROOTfile is being read.

STEP 4:

To do the time-walk corrections, run the following code:

```
root -l "timeWalkCalib.C(<run_num>)"
```

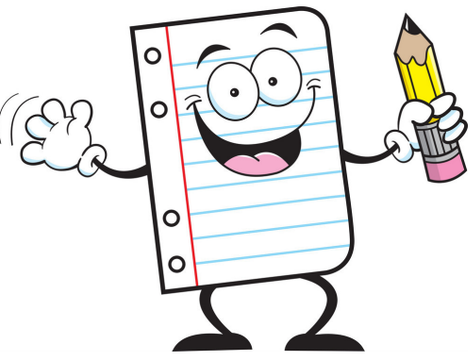
Code Description:

This script takes as input the ROOTfile containing histogram objects generated by the 'timeWalkHistos.C' script.

A parameter file containing the time-walk parameters is produced at:

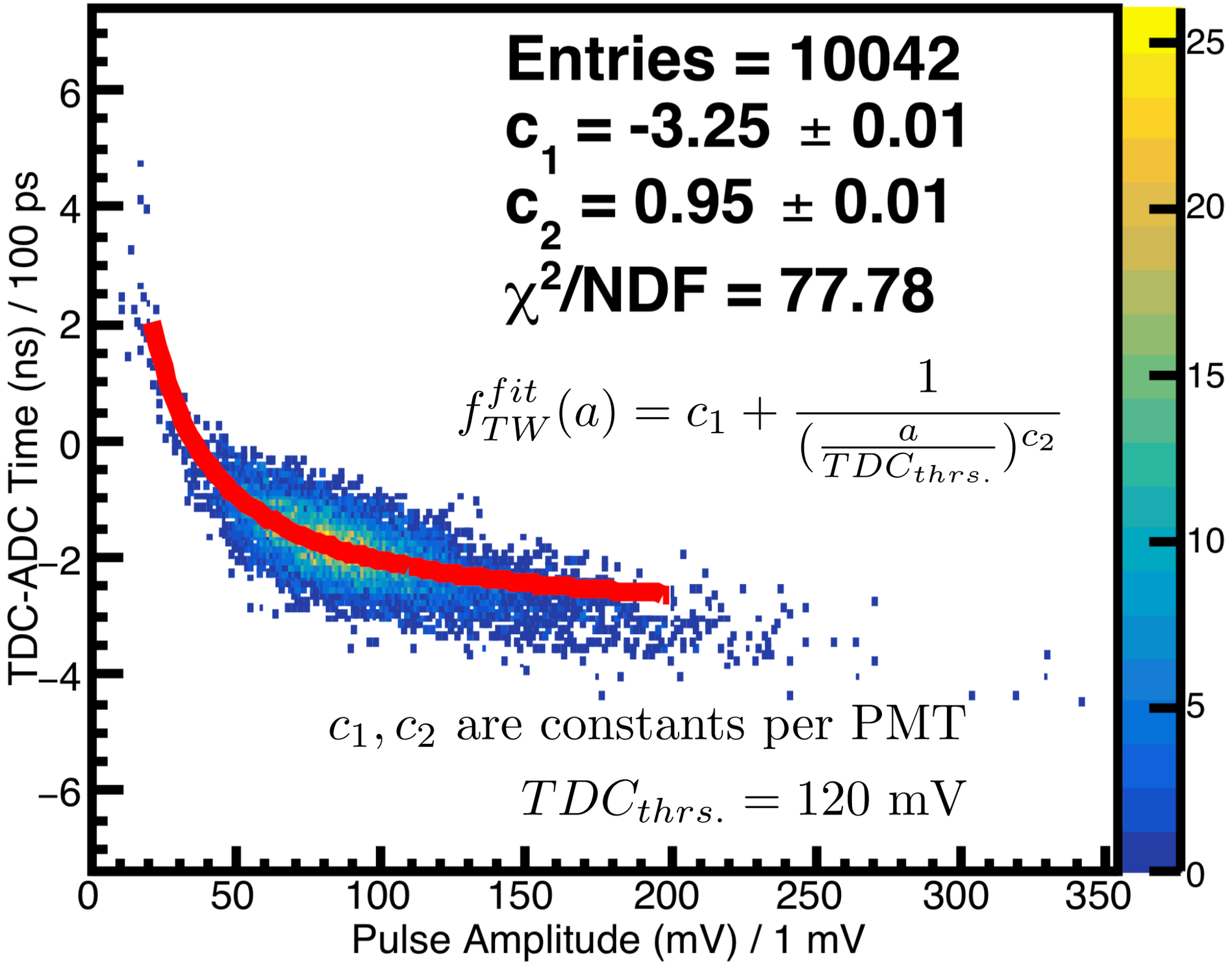
```
hallc_replay/PARAM/(S)HMS/HODO/(p)hhodo_TWcalib_runNUM.param
```

Change the parameter file name to: `(p)hhodo_TWcalib.param`
Since this is the generic file name read by hcana.



NOTE: The user sets the run number interactively, however, the ROOTfile that is loaded must be changed manually in the code. Open the code and make sure the correct ROOTfile is being read.

Time-Walk Corrections

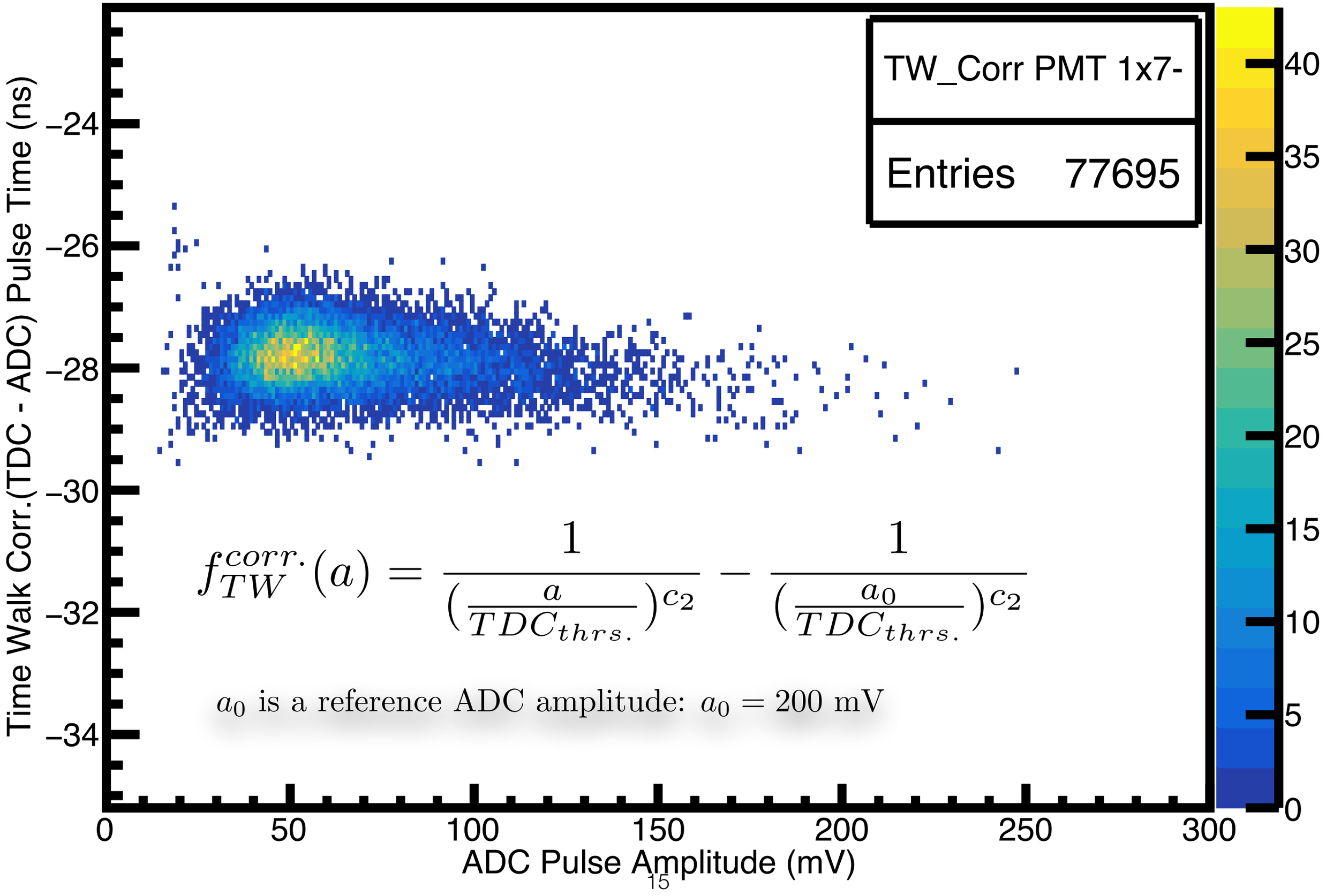


STEP 5:

Replay the raw data file a second time.

Typically, 1-2 million events, with the updated time-walk parameters, as the next code to run will need good statistics.

PMT 1x7-: Corr. (TDC - ADC) Pulse Time vs. ADC Pulse Amplitude



STEP 6:

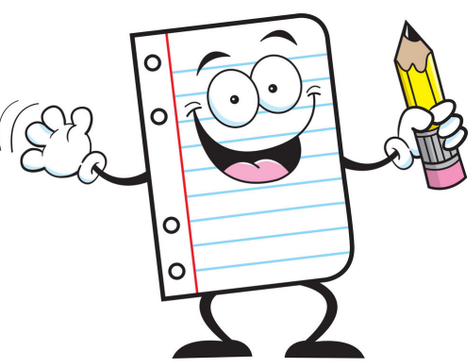
To do the cable time, propagation velocity, and paddle time difference corrections, run the following code at : `/hallc_replay/CALIBRATION/(s)hms_hodo_calib/`

```
root -l fitHodoCalib.C
```

Code Description:

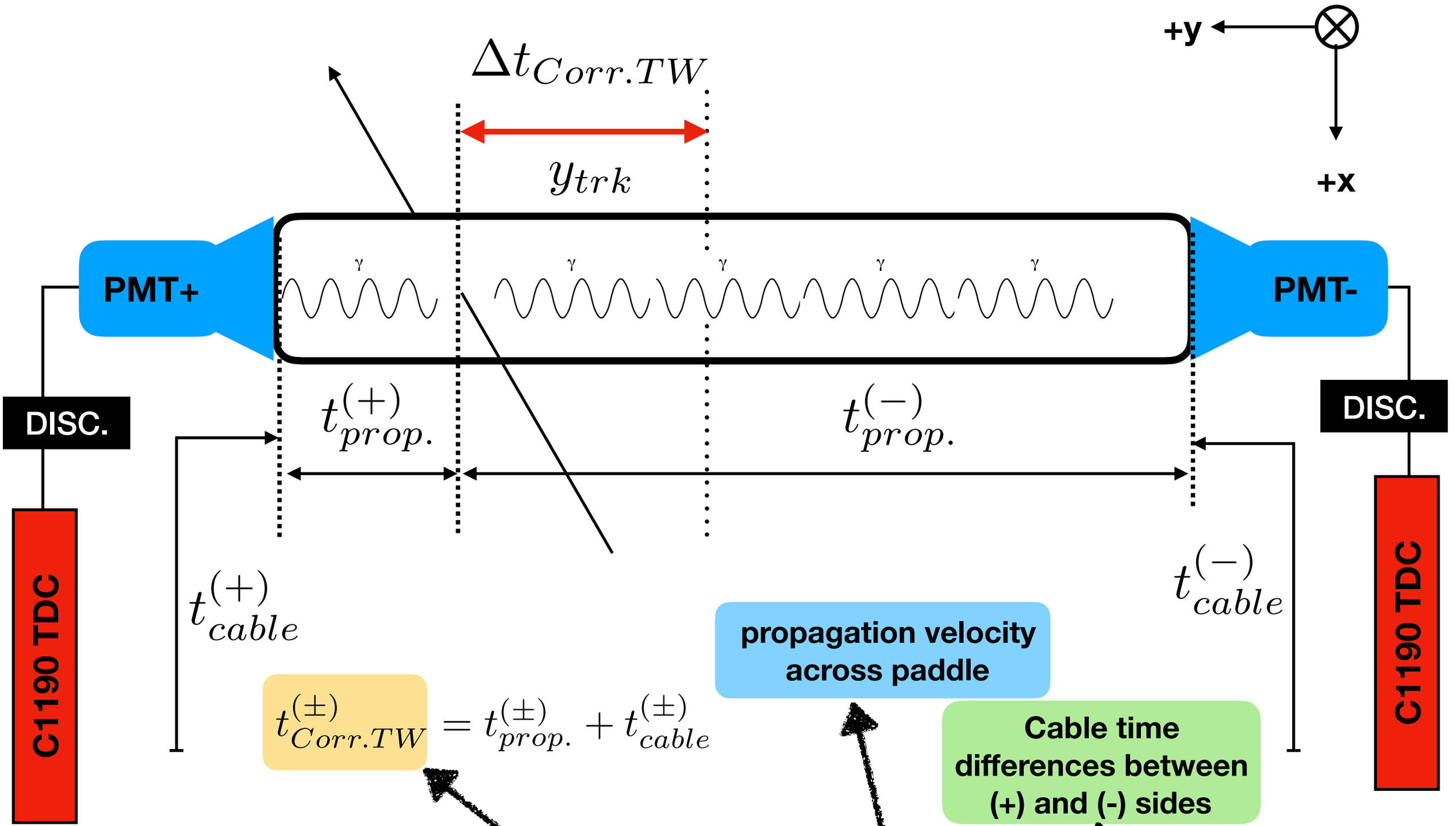
This script takes as input the ROOTfile replayed in the last step, which has been time-walk corrected.

- **The first part of this script performs a linear fit on the time-walk corrected time vs. hodoscope track to determine the propagation velocity and the cable time difference across each paddle.**
- **The second part of this code solves a matrix equation for the λ parameters mentioned in later slides.**
- **A parameter file containing the propagation velocity, cable time offsets, and lambda coefficient parameters will be produced at**
  `hallc replay/PARAM/(S)HMS/HODO/(p)hhodo_Vpcalib_runNUM.param`



NOTE: This parameter file name has to be manually changed to exclude the run number, since hcana reads in the parameter file as `(p)hhodo_Vpcalib.param`

Propagation Velocity / Cable Length Corrections



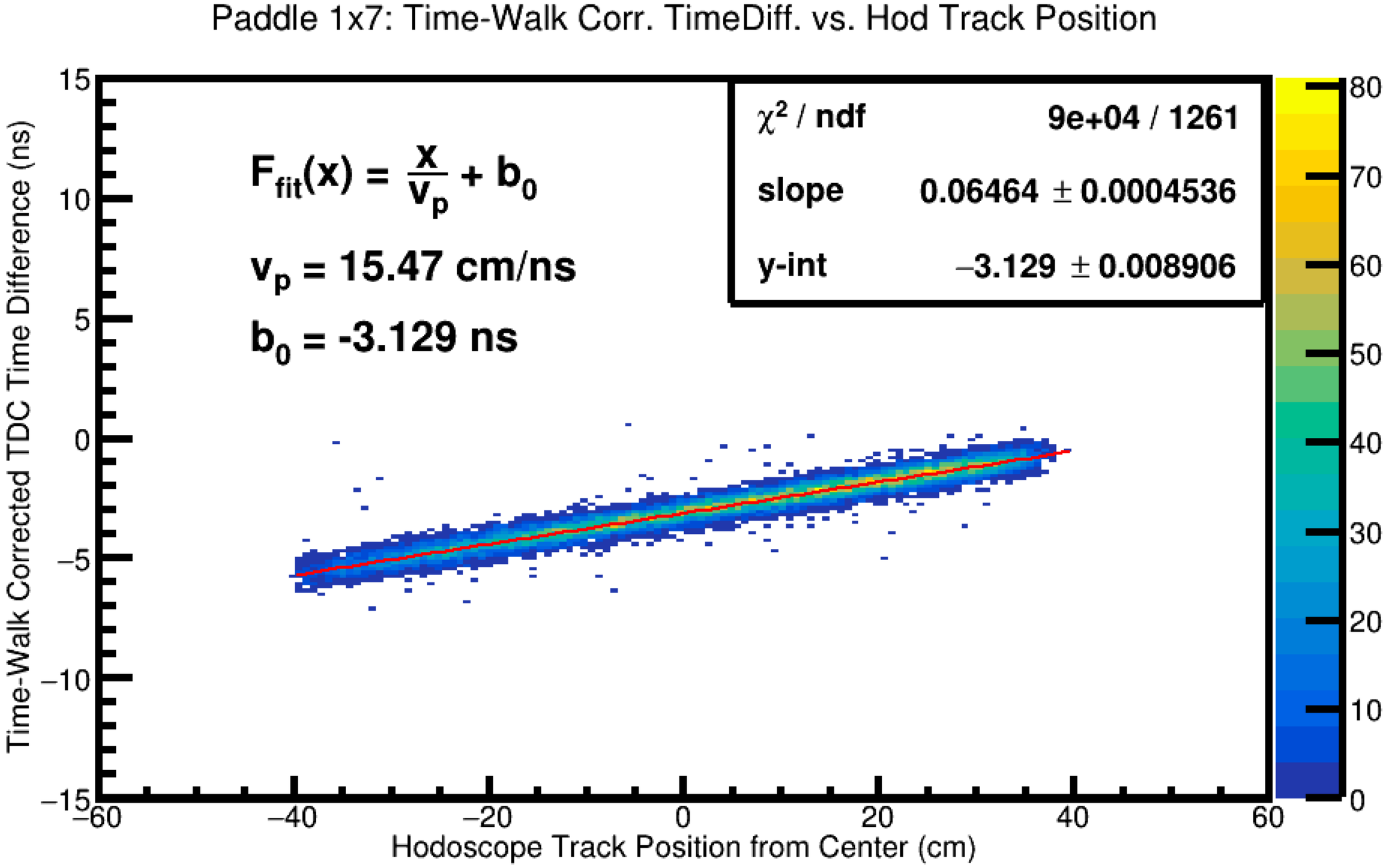
$$t^{(\pm)}_{Corr.TW} = t^{(\pm)}_{prop.} + t^{(\pm)}_{cable}$$

propagation velocity across paddle

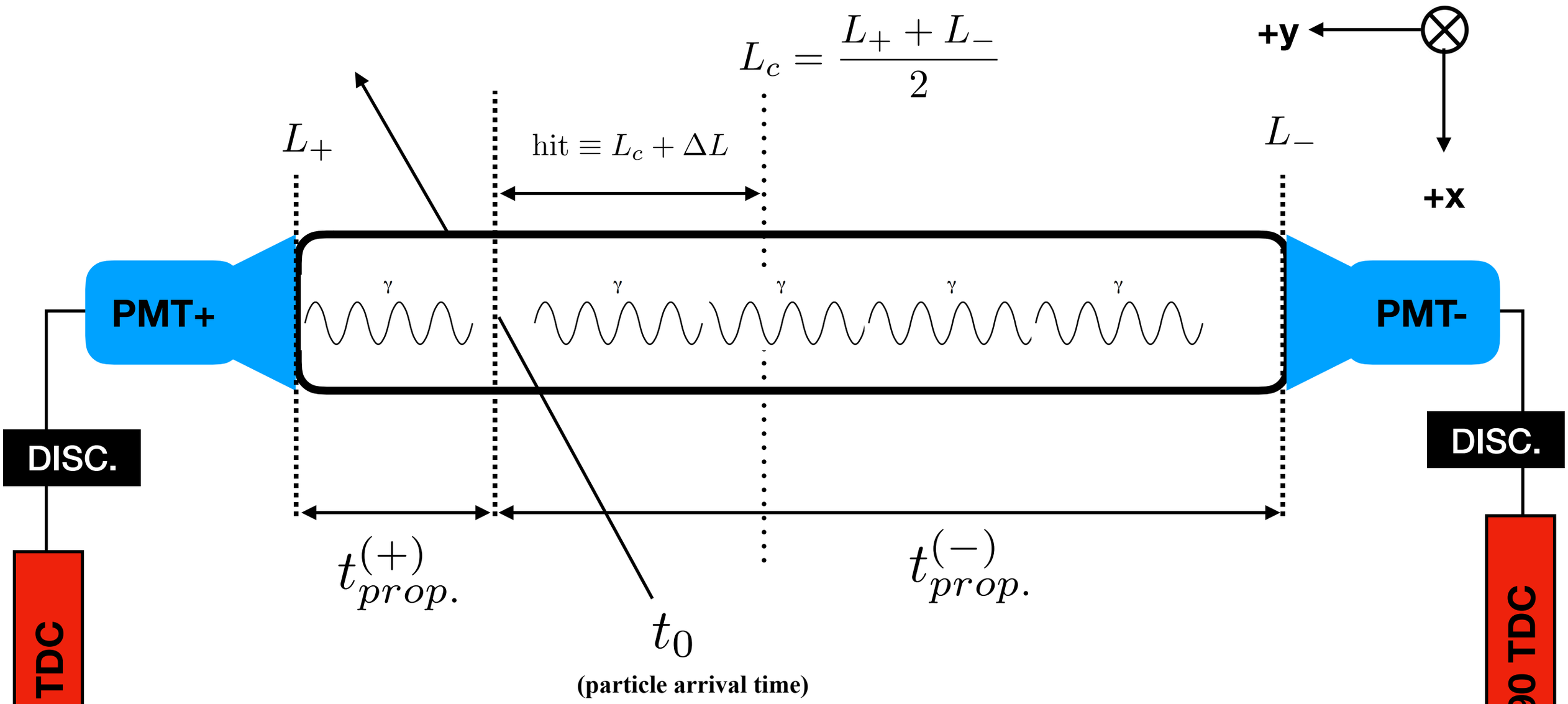
Cable time differences between (+) and (-) sides

$$\Delta t_{Corr.TW}(y_{trk}) \equiv \frac{1}{2}(t^{(-)}_{Corr.TW} - t^{(+)}_{Corr.TW}) = \frac{1}{v_p} y_{trk} + b_0$$

Propagation Velocity / Cable Length Corrections



Propagation Time Corrections



$t^{(\pm)}_{Corr.} = t_0 + t^{(\pm)}_{prop.}$ (time-walk/cable corrected)

$$\Delta L = \frac{1}{2}\left(t^{(-)}_{Corr.} - t^{(+)}_{Corr.}\right) v_p$$

$$= \boxed{\frac{1}{2}\left(t^{(-)}_{prop.} - t^{(+)}_{prop.}\right) v_p}$$

Propagation Time Corrections

$$t^{(+)}_{Corr.} = t^{(+)}_{Corr.} - (L_+ - \text{hit})\frac{1}{v_p}, \text{ where } t^{(+)}_{prop.} \equiv (L_+ - \text{hit})\frac{1}{v_p}$$

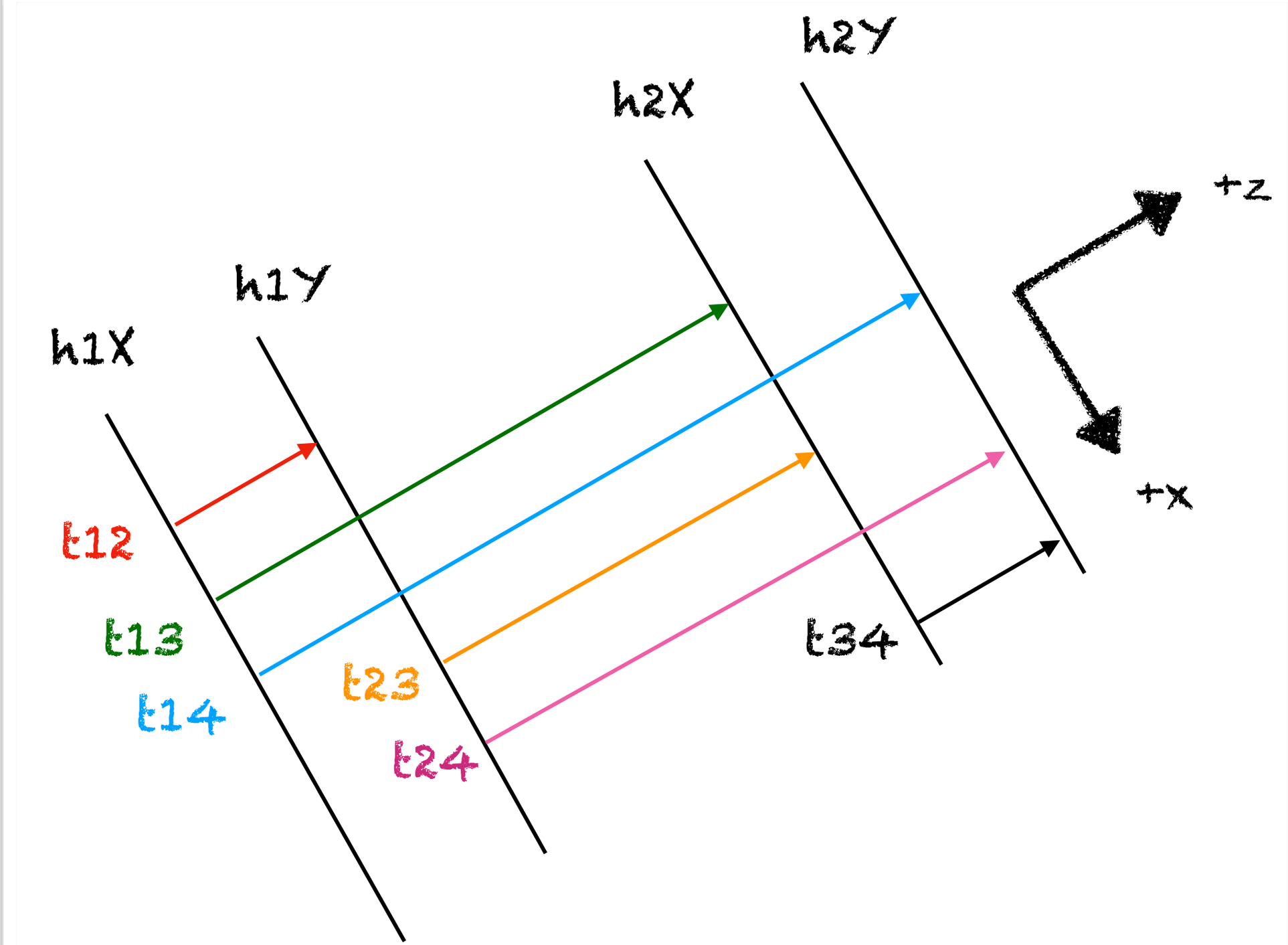
$$t^{(-)}_{Corr.} = t^{(-)}_{Corr.} - (\text{hit} - L_-)\frac{1}{v_p}, \text{ where } t^{(-)}_{prop.} \equiv (\text{hit} - L_-)\frac{1}{v_p}$$

The propagation time is subtracted from the time that has already been corrected for time-walk/cable length, to obtain the final corrected time, which is independent of the propagation time. This final time, is the true arrival time of the particle at the paddle, and an average of the two sides must be taken.

$$t_{avgCorr.} = \frac{1}{2}(t^{(+)}_{Corr.} + t^{(-)}_{Corr.}) = \frac{1}{2}(t^{(+)}_{TW_{Corr.}} + t^{(-)}_{TW_{Corr.}})$$

The time-walk corrected time is the corrected time is the right hand side of the top equations. So it turns out that the average final corrected time is the average of the time-walk corrected time, after doing some algebra.

Time Correction between Hodoscope Planes



$$t^{\pm}_{Corr.} = t^{\pm}_{UnCorr.} - t^{\pm}_{TW} - t^{\pm}_{cable} - t^{\pm}_{prop.} - t^{\pm}_{\lambda}$$

Time Correction between Hodoscope Planes

$$t_i = \frac{T_{TW}^{(+)} + T_{TW}^{(-)} - 2t_{Cable}}{2}$$

Average Corrected Paddle Time in the ith plane

Small time perturbation

Distance between (i,j) plane

$$(t_i + \lambda_i) - (t_j + \lambda_j) = \frac{D_{ij}}{v_c}$$

Time Difference between (i,j) planes

$$\lambda_i - \lambda_j = \frac{D_{ij}}{v_c} - (t_i - t_j) \equiv b_{ij}$$

Perturbative time difference between (i,j) planes

Time Correction between Hodoscope Planes

For a single event, there are 6 linear equations . . .

Linear Combination of Paddles →

6 possible combinations Between planes ↓

$$
\begin{aligned}
c_{1,1}\lambda_1 + c_{1,2}\lambda_2 + \ldots + c_{1,j}\lambda_j + \ldots + c_{1,52}\lambda_{52} &= b_{12} \\
c_{2,1}\lambda_1 + c_{2,2}\lambda_2 + \ldots + c_{2,j}\lambda_j + \ldots + c_{2,52}\lambda_{52} &= b_{13} \\
c_{3,1}\lambda_1 + c_{3,2}\lambda_2 + \ldots + c_{3,j}\lambda_j + \ldots + c_{3,52}\lambda_{52} &= b_{14} \\
c_{4,1}\lambda_1 + c_{4,2}\lambda_2 + \ldots + c_{4,j}\lambda_j + \ldots + c_{4,52}\lambda_{52} &= b_{23} \\
c_{5,1}\lambda_1 + c_{5,2}\lambda_2 + \ldots + c_{5,j}\lambda_j + \ldots + c_{5,52}\lambda_{52} &= b_{24} \\
c_{6,1}\lambda_1 + c_{6,2}\lambda_2 + \ldots + c_{6,j}\lambda_j + \ldots + c_{6,52}\lambda_{52} &= b_{34}
\end{aligned}
$$

In matrix form,

$$
\mathbf{C}^{[\lambda]}\lambda = \begin{bmatrix}
c_{1,1} & c_{1,2} & \cdots & c_{1,j} & \cdots & c_{1,52} \\
c_{2,1} & c_{2,2} & \cdots & c_{2,j} & \cdots & \vdots \\
\vdots & \vdots & \ddots & \cdots & \cdots & \vdots \\
c_{i,1} & \vdots & c_{i,j} & \ddots & \cdots & \vdots \\
\vdots & \vdots & \cdots & \cdots & \ddots & c_{5,52} \\
c_{6,1} & c_{6,2} & \cdots & \cdots & \cdots & c_{6,52}
\end{bmatrix}
\begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \vdots \\ \lambda_j \\ \vdots \\ \lambda_{52} \end{bmatrix}
= \begin{bmatrix} b_{12} \\ b_{13} \\ b_{14} \\ b_{23} \\ b_{24} \\ b_{34} \end{bmatrix}
$$

Time Correction between Hodoscope Planes

Assume, for a single event, that paddles
7 (h1X), 5 (h1Y), 8 (h2X) and 6 (h2Y)

$$\text{Plane h1X} : \text{Paddles } 1-16, \lambda_j \rightarrow j : 1-16$$
$$\text{Plane h1Y} : \text{Paddles } 1-10, \lambda_j \rightarrow j : 17-26$$
$$\text{Plane h2X} : \text{Paddles } 1-16, \lambda_j \rightarrow j : 27-42$$
$$\text{Plane h2Y} : \text{Paddles } 1-10, \lambda_j \rightarrow j : 43-52$$

Non-zero coefficients representing the paddles that fired

$$c_{1,7} = 1, c_{1,21} = -1$$
$$c_{2,7} = 1, c_{2,34} = -1$$
$$c_{3,7} = 1, c_{3,48} = -1$$
$$c_{4,21} = 1, c_{4,34} = -1$$
$$c_{5,21} = 1, c_{5,48} = -1$$
$$c_{6,34} = 1, c_{6,48} = -1$$

$$\mathbf{C}^{[\lambda]} = \begin{bmatrix} \dots & 1 & \dots & -1 & \dots & \dots \\ \dots & 1 & \dots & \dots & -1 & \dots \\ \dots & 1 & \dots & \dots & \dots & -1 \\ \dots & \dots & 1 & \dots & -1 & \dots \\ \dots & \dots & 1 & \dots & \dots & -1 \\ \dots & \dots & \dots & 1 & \dots & -1 \end{bmatrix}$$

Time Correction between Hodoscope Planes

- A single event is NOT sufficient to solve since most coefficients are zero

- Sum over many events to accumulate statistics for each coefficient, and be able to solve for each of the 51 lambda parameters. One of the parameters is set to zero (reference paddle 7) , so all time differences are measured relative to This paddle.

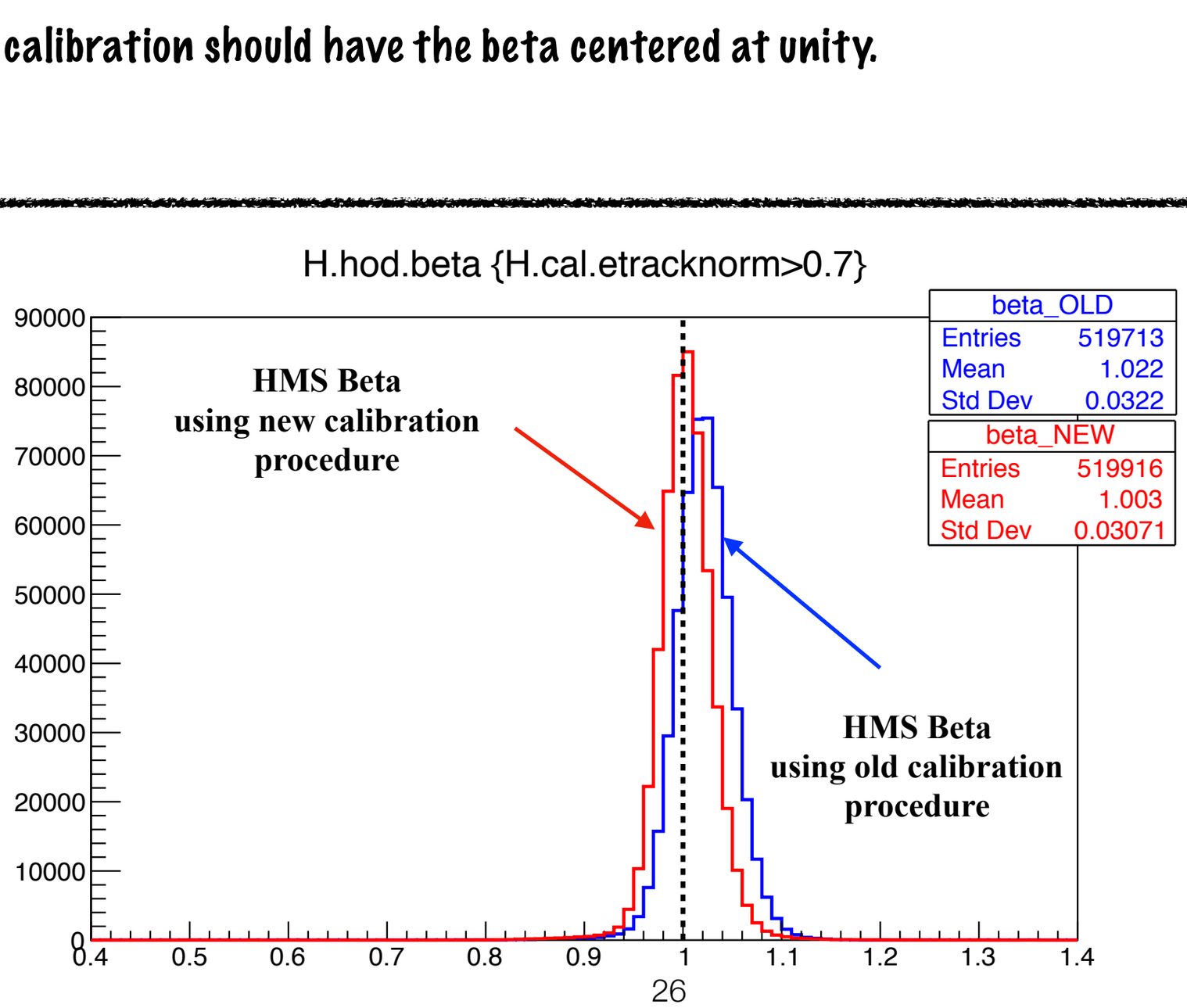
$$\mathbf{C}^{[\lambda]}\lambda = \begin{bmatrix} \sum_k c_{1,1} & \sum_k c_{1,2} & \cdots & \sum_k c_{1,j} & \cdots & \sum_k c_{1,52} \\ \sum_k c_{2,1} & \sum_k c_{2,2} & \cdots & \sum_k c_{2,j} & \cdots & \vdots \\ \vdots & \vdots & \ddots & \cdots & \cdots & \vdots \\ \sum_k c_{i,1} & \vdots & \sum_k c_{i,j} & \ddots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \ddots & \sum_k c_{5,52} \\ \sum_k c_{6,1} & \sum_k c_{6,2} & \cdots & \cdots & \cdots & \sum_k c_{6,52} \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \vdots \\ \lambda_j \\ \vdots \\ \lambda_{52} \end{bmatrix} = \begin{bmatrix} \sum_k b_{12} \\ \sum_k b_{13} \\ \sum_k b_{14} \\ \sum_k b_{23} \\ \sum_k b_{24} \\ \sum_k b_{34} \end{bmatrix}$$

STEP 7:

Replay the raw data one last time, and check the hodoscope beta distribution.

You may have to apply a calorimeter cut (e.g. `(P)H.cal.etracknorm>0.7`)

A good calibration should have the beta centered at unity.



For more information on the Hall C Hodoscopes Calibration,
See the documentation at:

https://hallcweb.jlab.org/DocDB/0009/000970/001/hodo_calib.pdf

Thank YOU!

Questions?