TRD tracking in the HLT
- update -

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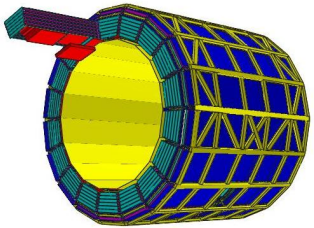
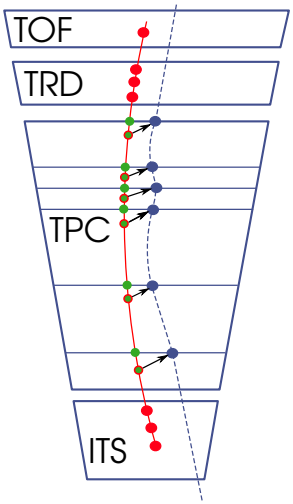
Outline

- plans for TRD tracking in the HLT
- prerequisites and implementation status
- tracking performance



Introduction

- idea in 2016: port TPC space point calibration from offline to HLT
  $\rightsquigarrow$ required online TRD tracking, also necessary for Run 3!
- offline TRD tracking is based on clusters
  $\rightsquigarrow$ data volume too high for HLT / Run 3
- online tracking based on TRD tracklets calculated in FEE
  - originally designed for trigger decision
  - need to be adapted for low-p_{T} tracks



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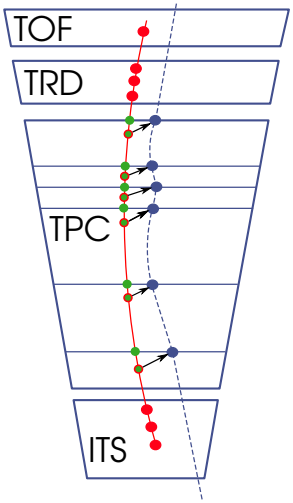
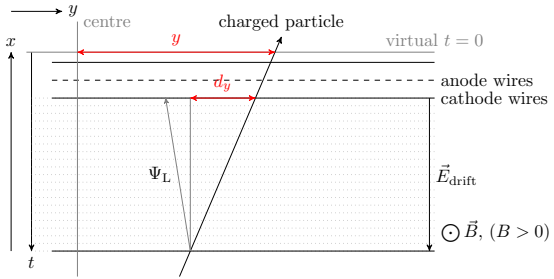
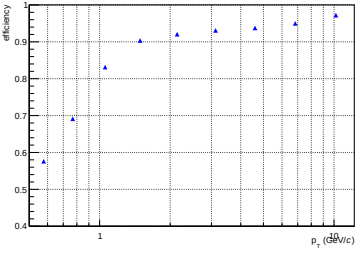


$\Rightarrow$ **due to timing constraints this development is aimed towards Run 3**

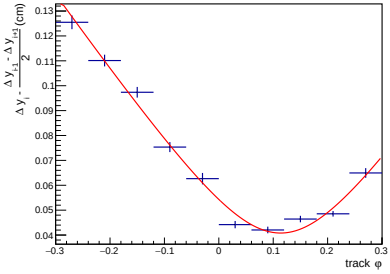
TRD online tracklets



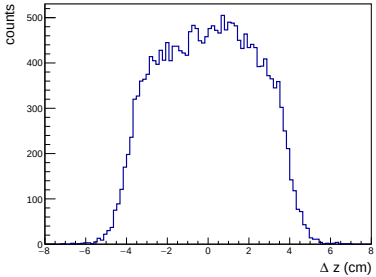


- online tracklets consist of 32 bits:
  y-position (13 bits), deflection d_y (7 bits), pad row (4 bits), PID (8 bits)
- optimized for high–p_{T} tracks (trigger)
  - tracklets are allowed to spread over 2 pads only $\rightsquigarrow$ implicit p_{T} cut

Position resolution



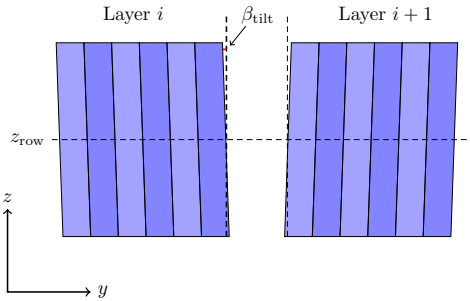
y resolution



z resolution

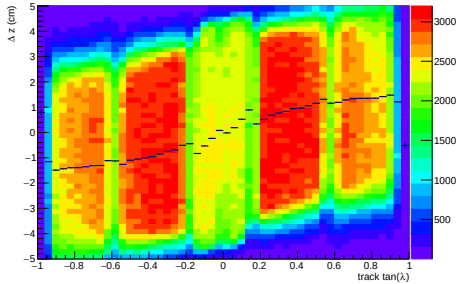
- tracklet y resolution depends strongly on track angle φ
  - below 400 µm for 'ideal' tracks ($\varphi = \varphi_L$)
- resolution in z determined by pad length (7.5 cm to 9 cm)

Tracklet position correction (y)

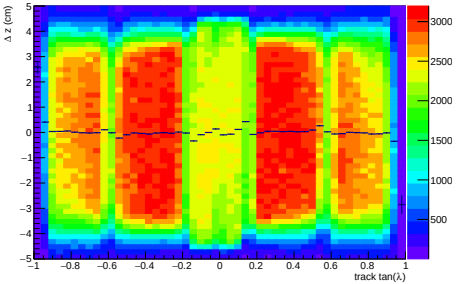


- readout pads are tilted by $\beta_{\text{tilt}} = 2^\circ$ to improve z-resolution:
  $y_{\text{corr}}^{\text{trklt}} = y^{\text{trklt}} + (-1)^{\text{iLy}} \cdot \tan(\beta_{tilt}) \cdot (z^{\text{pad}} - z^{\text{trk}})$
- this introduces correlation between y and z measurement
  $\rightsquigarrow$ taken into account in tracklet covariance matrix

Tracklet position correction (z)

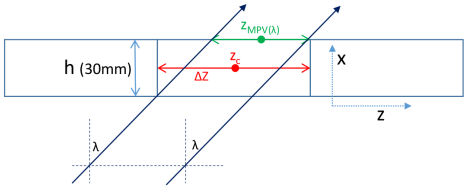


before correction



after correction

- most probable z position of tracklet depends on the track dip angle
- correction via:
  $z_{corr} = z_{center} + f_{zCorr} \cdot \tan(\lambda)$



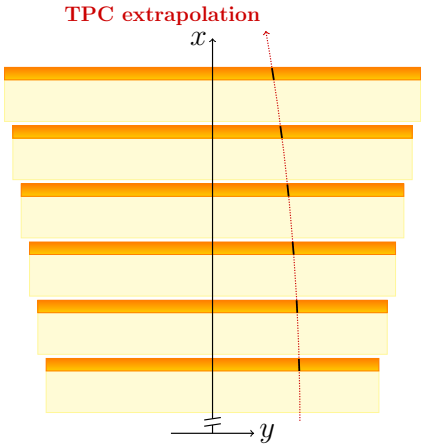
[R.Shahoyan]

Tracking algorithm

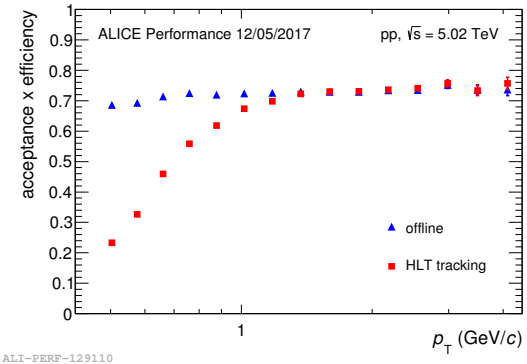
- given are reconstructed TPC (+ITS) tracks and TRD online tracklets
- for the development process the following algorithm is used

  1) propagate track to radius of TRD layer
  2) search for closest tracklet within search window:
     $\Delta y \leq 7 \cdot \sqrt{\sigma^2_{y,\mathrm{track}} + \sigma^2_{y,\mathrm{tracklet}}} + 2\,\mathrm{cm}$
     $\Delta z \leq 7 \cdot \sqrt{\sigma^2_{z,\mathrm{track}} + l^2_{\mathrm{pad}}/12}$
  3) update track with closest tracklet, if present
  4) continue in next layer

- currently tracks with $p_{\mathrm{T}} < 0.6\,\mathrm{GeV}/c$ are ignored

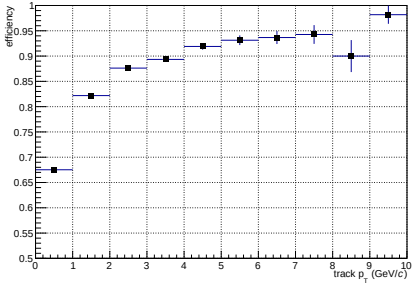


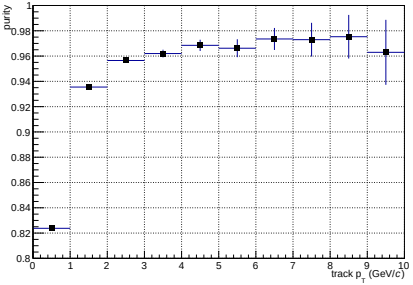
Efficiency & purity (pp)



- shown is the probability for a track to have at least two tracklets attached
- efficiency in HLT drops for low-p_{T} due to implicit p_{T} cut for online tracklets
- fake rate for pp is on the per mille level

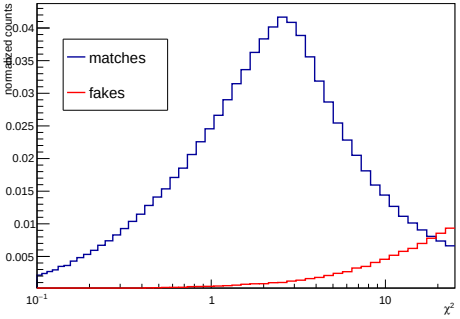
Efficiency & purity (PbPb)





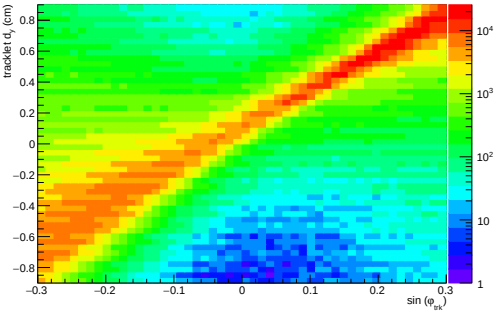
- tracks are required to be in the geometrical acceptance of the TRD in at least one layer
- left plot shows the fraction of these tracks with at least two TRD tracklets attached
- right plot shows the fraction of the tracks with at least two tracklets without any fake tracklets
- fakes / matches are defined by MC label

χ^2 threshold

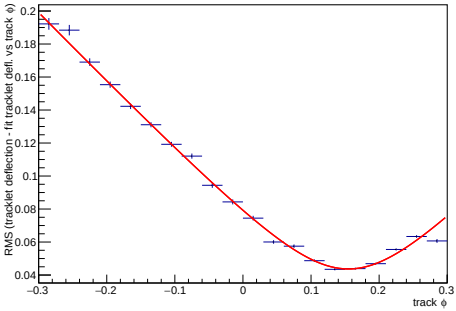


- for a correct update $< \chi^2 > \sim 2.5$
- from $\chi^2 \sim 18$ on more fakes are attached than matching tracklets

Angular resolution



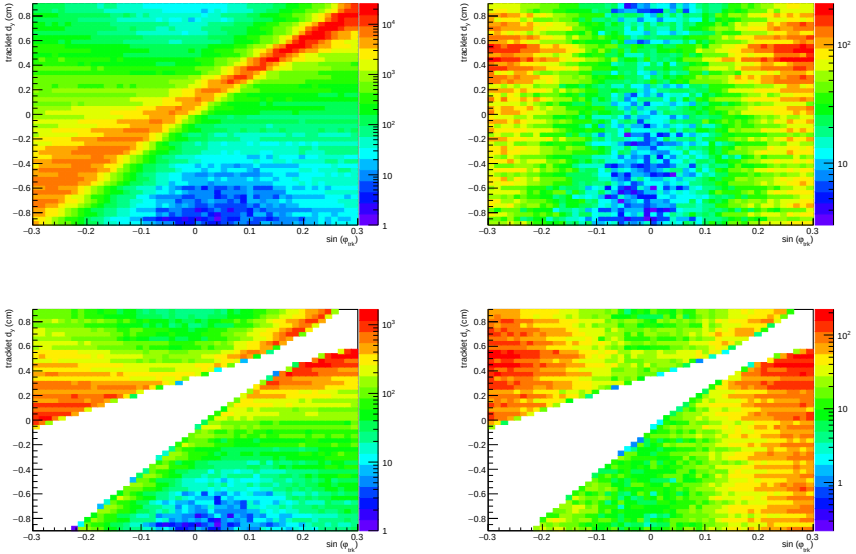
track φ vs. tracklet d_y



angular resolution w.r.t. fit

- left plot is fitted with pol2
- right plot shows deviation of tracklet d_y w.r.t. fit
- best performance for tracks close to Lorentz angle

Using tracklet d_y to reduce fakes?

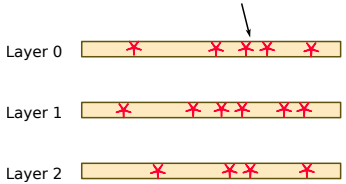


matches fakes

$\Rightarrow$ **not really sure how to tune the cut, most fakes at large angles (no cut used at the moment)**

Multiple candidate tracking

- **idea:** keep multiple hypothesis in each layer (including no update)
  - keep N candidates per layer
  - choose best candidate depending on $\chi^2_{\mathrm{glb}}/ndf$
- so far only marginal improvement visible



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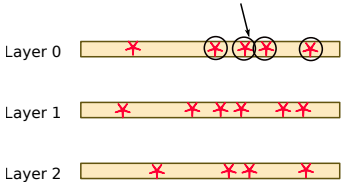

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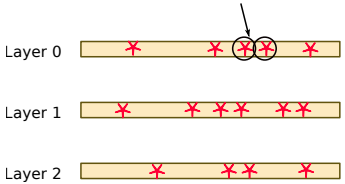

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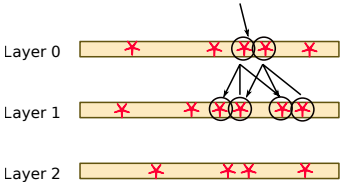

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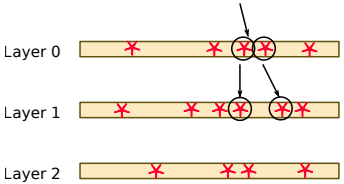


$\Rightarrow$ **parameter optimization ongoing**

Summary:

- space charge distortions in the TPC motivate online TRD tracking in Run 2
  - needed for Run 3 anyway
- TRD tracking relies on online tracklets instead of clusters
- good performance for high-p_{T} tracks in pp
- PbPb a bit more complicated but performance looks promising
  - ideal tracker parameter settings under study

Outlook:

- tested on HLT with PbPb events @ 350 Hz input rate on Wednesday $\rightsquigarrow$ worked
- TOF should be added ("7th TRD layer")
- code needs to be ported to O2 and possibly adapted for GPUs

Appendix

Current implementation

- tracklet position corrected for pad tilting, if $\Delta z = z_{trklt} - z_{trk} < l_{pad}$ and $\sigma_{z,trk} < l_{pad}/\sqrt{12}$
  $y_{corr} = y + (-1)^{layer} \tan(\beta_{tilt})\Delta z$
- z-position corrected (most probable position depends on track λ) via:
  $z_{corr} = z_{center} + f_{zCorr} \cdot \tan(\lambda), \qquad f_zCorr = 1.4$
- tracklet covariance matrix is recalculated for each track and each layer depending on the azimuthal angle φ:

$$C = \begin{pmatrix} c & s \\ -s & c \end{pmatrix} \cdot \begin{pmatrix} \sigma_y^2 & 0 \\ 0 & \sigma_z^2 \end{pmatrix} \cdot \begin{pmatrix} c & -s \\ s & c \end{pmatrix}$$

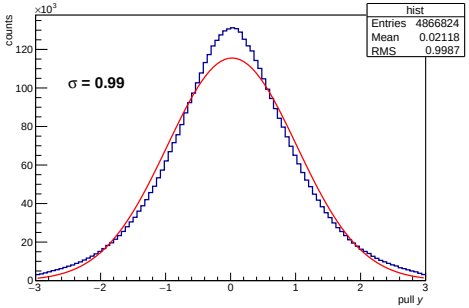
$$= c^2 \begin{pmatrix} \sigma_y^2 + t^2\sigma_z^2 & t(\sigma_z^2 - \sigma_y^2) \\ t(\sigma_z^2 - \sigma_y^2) & \sigma_z^2 + t^2\sigma_y^2 \end{pmatrix}$$

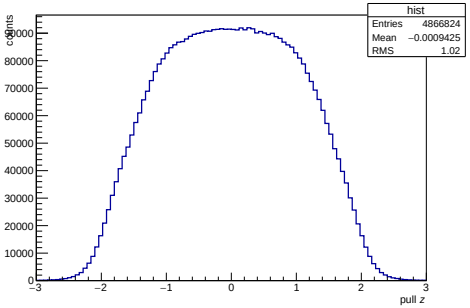
with $c = \cos(\beta_{tilt}), \quad s = \sin(\beta_{tilt}), \quad t = \tan(\beta_{tilt})$ and $\beta_{tilt} = 2^\circ$

$$\sigma_y = \sigma_y(\sin\varphi_{trk}) = \sqrt{(400\,\mu\text{m})^2 + (3.3\,\text{mm})^2 \cdot (\sin(\varphi_{trk}) - \sin(\varphi_L))^2}$$

$$\sigma_z = l_{pad}/\sqrt{12}$$

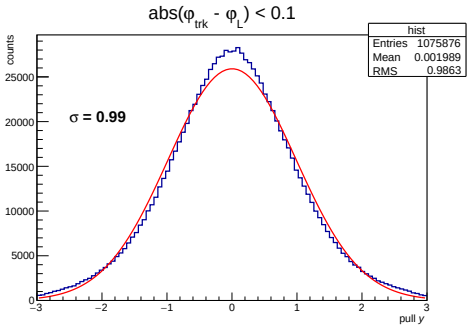
Pulls in y and z for matching tracklets





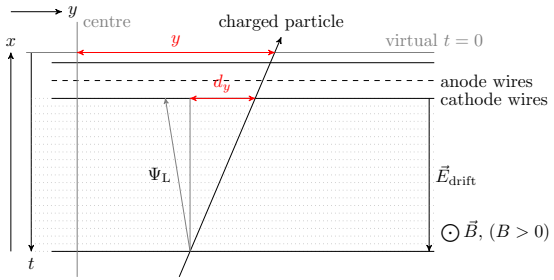
- pulls integrated over all track azimuthal angles
- I checked the same for tracks with an angle around the Lorentz angle (see next slide)

Pulls in y with angular cut



- maybe tails less pronounced? change hardly visible

TRD online tracklets

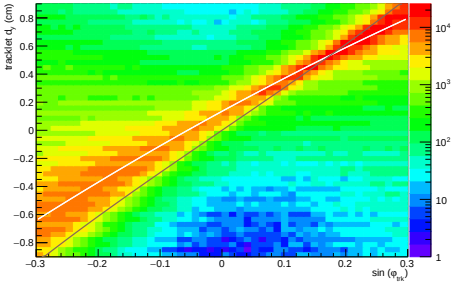


- $d_y = \tan(\varphi_{trk}) \cdot x_{drift}$ with $x_{drift} \approx 3\,\text{cm}$

  $\rightsquigarrow \sin(\varphi_{trk}) = \frac{d_y / x_{drift}}{\sqrt{1+(d_y/x_{drift})^2}}$

- the Lorentz angle and the pad tilting is corrected in the detector electronics

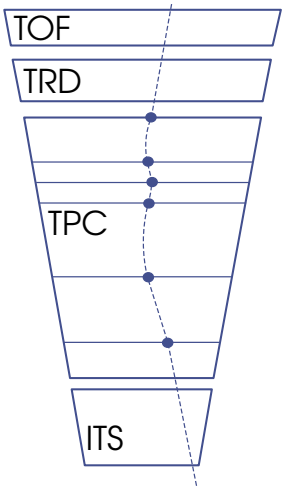
Tracklet deflection



- white: fit pol2: $d_y = 0.13\,\text{cm} + 2.4\,\text{cm} \cdot \sin(\varphi) - 0.64\,\text{cm} \cdot \sin^2(\varphi)$
- brown: conversion: $d_y = \frac{3\,\text{cm} \cdot \sin(\varphi)}{\sqrt{1-\sin^2(\varphi)}}$

Space charge distortion calibration

Method



- reconstruct track from distorted clusters in the TPC with relaxed tolerances

Space charge distortion calibration

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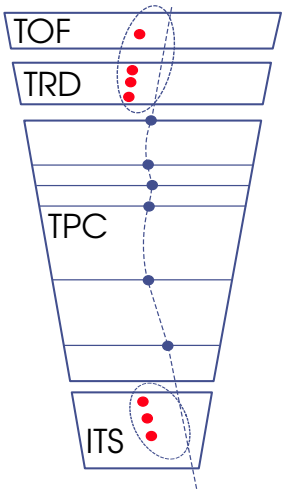

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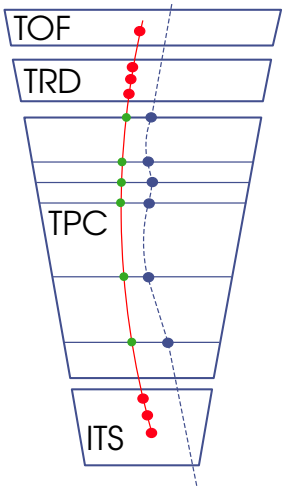

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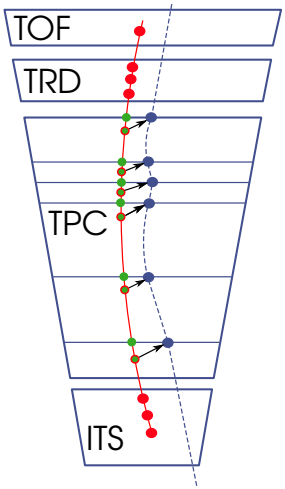

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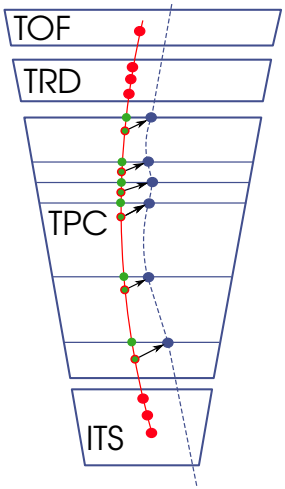

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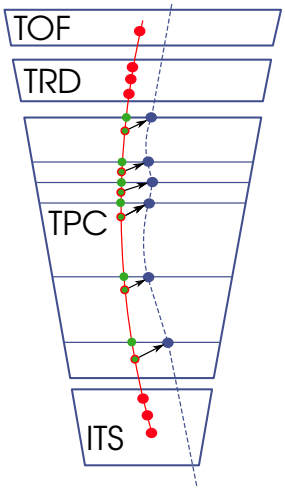

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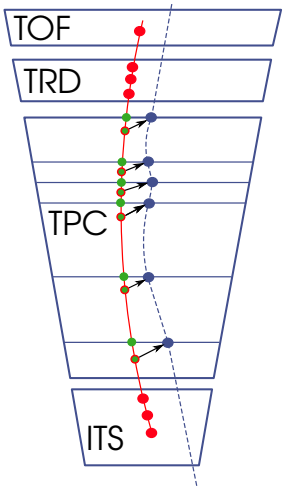

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