Global tracks with TRD information

Marian Ivanov for BTG/DPG

Summary

TRD tracking commissioned using **pp triggered raw data** sample at series of production at GSI (2017)

Improvement confirmed in central AliEn productions (LHC17o MC/Data)

- TRD tracking enabled in ongoing central production for period LHC18m

At **high p_T strong improvement of performance** - according expectation

Performance worsening due to the TPC space charge distortion **strongly mitigated → more homogeneous performance**

- Distortion fluctuations even more important in **RUN3**

At **intermediate p_T (1-5 GeV/c)** tracking efficiency can strongly increase and **dead region in acceptance eliminated**

Ongoing activities to commission TRD in track refit for PbPb data

- tracking improvement + TOF PID improvement "fake" tagging using TRD tracklet information

GSI commissioning - triggered raw data sample (Argon) in 2017

- High pt event trigger (track>6 GeV/c, V0s>4 GeV/c) full statistic
- Different reconstruction setting (trust in covariance matrix)
- The same input data sample, all setting the same except usage of TRD in refit
- **Several reconstruction passes - with limited GSI resources**
    - similar approach to be used **in RUN3**

Central alien production to confirm performance improvements (Neon) -test in 2018:

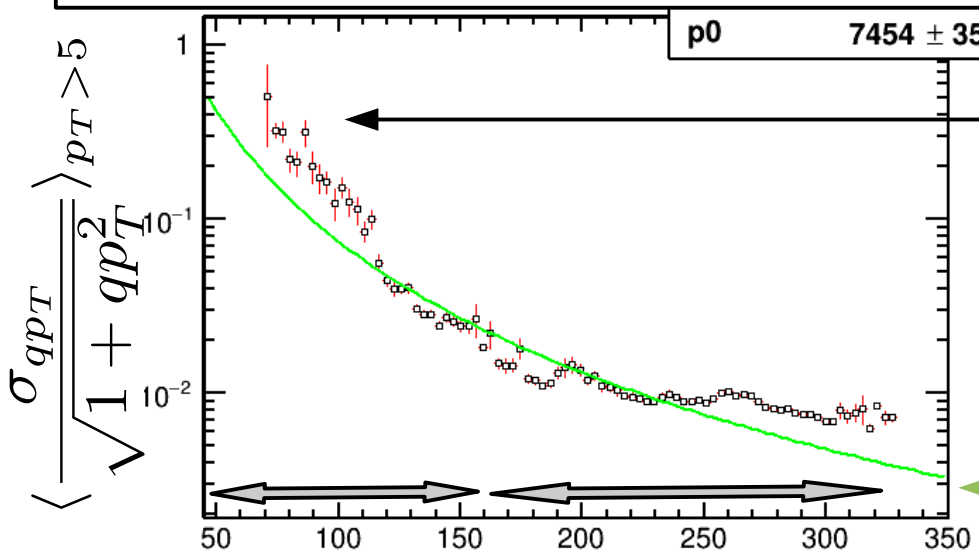
- Central production LHC17o
- Anchored MC production LHC18g2

Comparison:

- Momentum resolution improvement
- Distortion fluctuation mitigation
- Efficiency recovery at the edges
- V0 resolution confirming p_T resolution estimate

Momentum resolution expectation

Mean expected p_T resolution from covariance matrix (pT>5GeV)



Short track - worse resolution
Edge cluster → higher error assigned
deviation from scaling

raw scaling $N^{-2.5}$

$$\sigma_{qp_{\mathrm{T}}} \approx \frac{\sigma_{\mathrm{cl}}}{\sqrt{N_{\mathrm{cl}}}L^2} \oplus \sigma_{qP_{\mathrm{T}\,MS}} \qquad N_{\mathrm{CRTPC}} + N_{\mathrm{ClTRD}}$$

$$\frac{\sigma_{p_{\mathrm{T}}}}{p_{\mathrm{T}}} = \sigma_{qp_{\mathrm{T}}} p_{\mathrm{T}}$$

Simplified analytical expectraction for homogeneously spaced points with uniform resolution

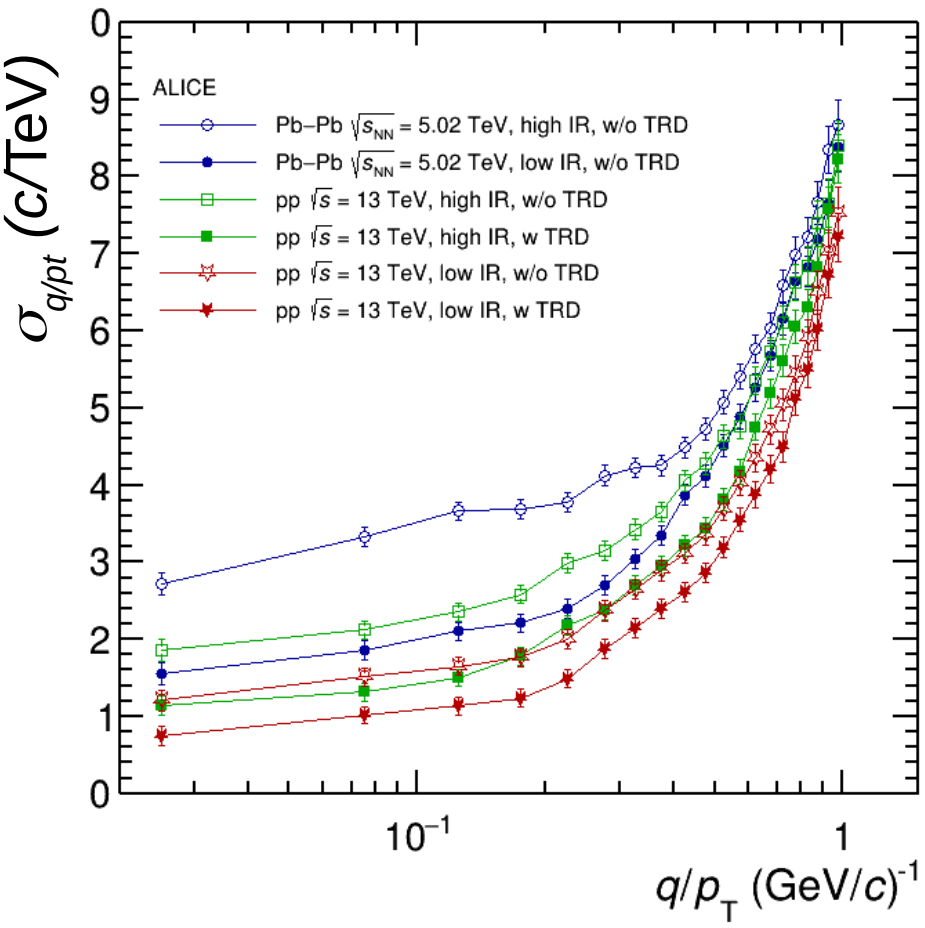
For short tracks (<130 N TPC crossed rows + TRD N_{cl}) steep worsening of Pt resolution

At 70 CR p_T resolution 10 time worse than for long tracks >130 CR

Significant improvement of resolution using TRD N>150 (already after 2-3 tracklets)

P_T resolution (Argon mixture)

$$\sigma_{p_{\mathrm{T}}}/p_{\mathrm{T}} = \sigma_{q/p_{\mathrm{T}}} \times p_{\mathrm{T}}$$



Only ITS and TPC track
RAA analysis cuts used (tracks without TRD included in sample)

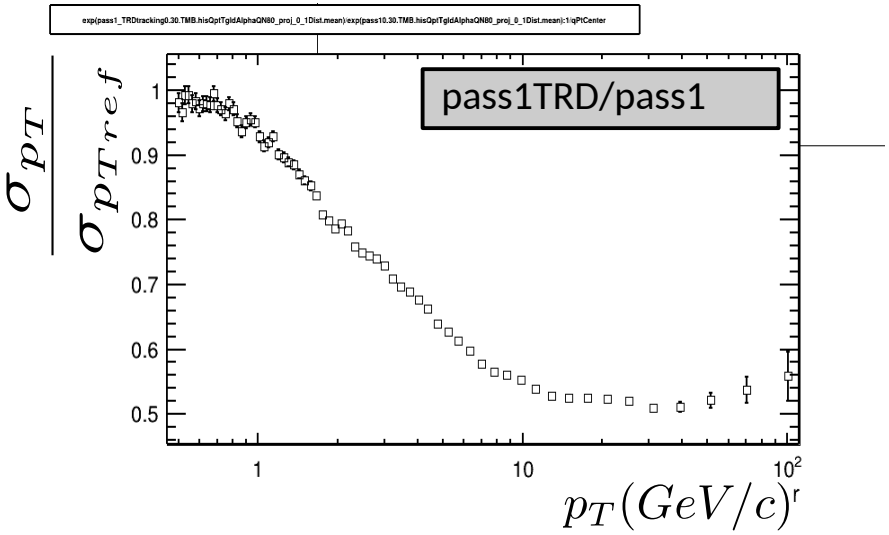
w TRD - TRD in reconstruction
w/o TRD- TRD not in reconstruction

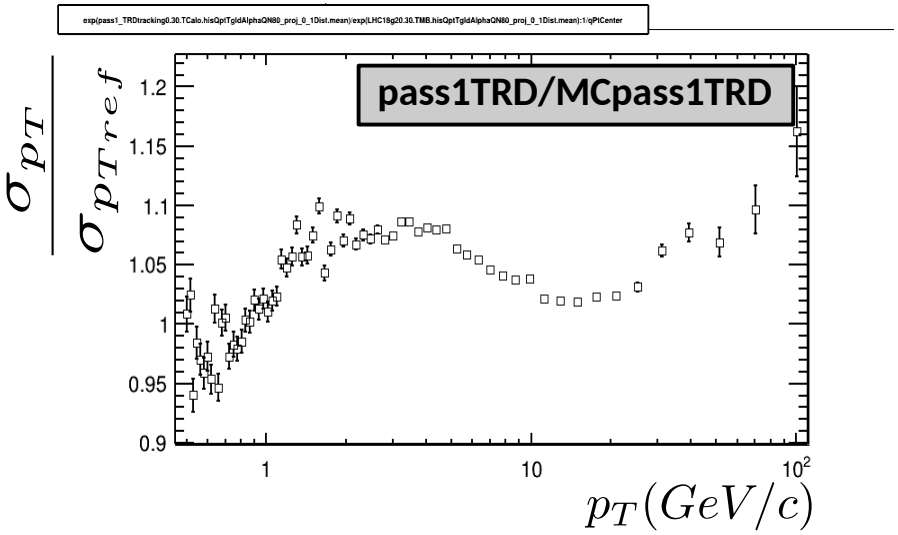
q/P_T resolution from the **covariance matrix** multiplied by constrained **angular pulls** (*see next slides)

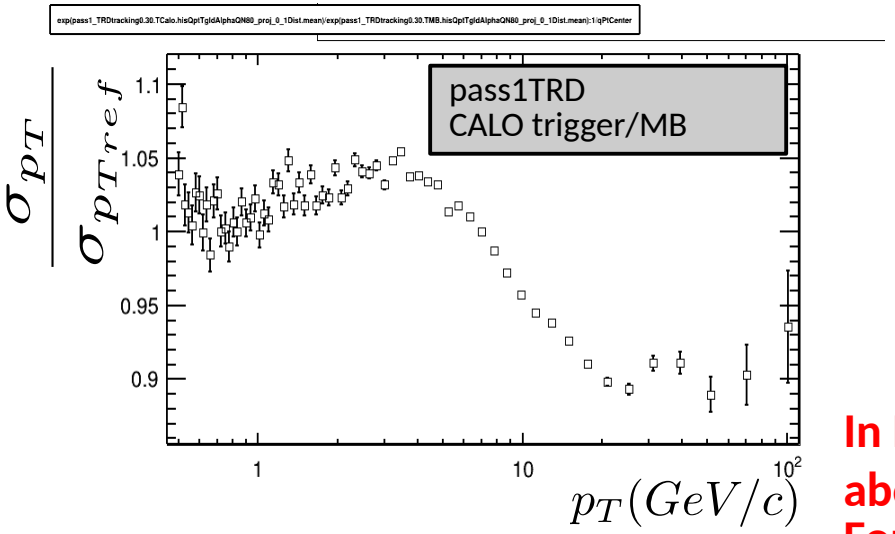
	Low IR	High IR
	σ_{1pt}(1/Gev)	σ_{1pt}(1/Gev)
pp w/o TRD	**0.0012**	**0.0018**
pp with TRD	**0.0007**	**0.0012**
PbPb w/o TRD	**0.0016**	**0.0028**

Using TRD in the track refit - improvement of performance in term of p_T resolution
Performance at high IR significantly worse than in low IR
Performance in PbPb (Minimum bias) significantly worse than in pp

P_T resolution ratio - LHC17o - (Neon mixture)







P_T resolution ratio (covariance matrix)

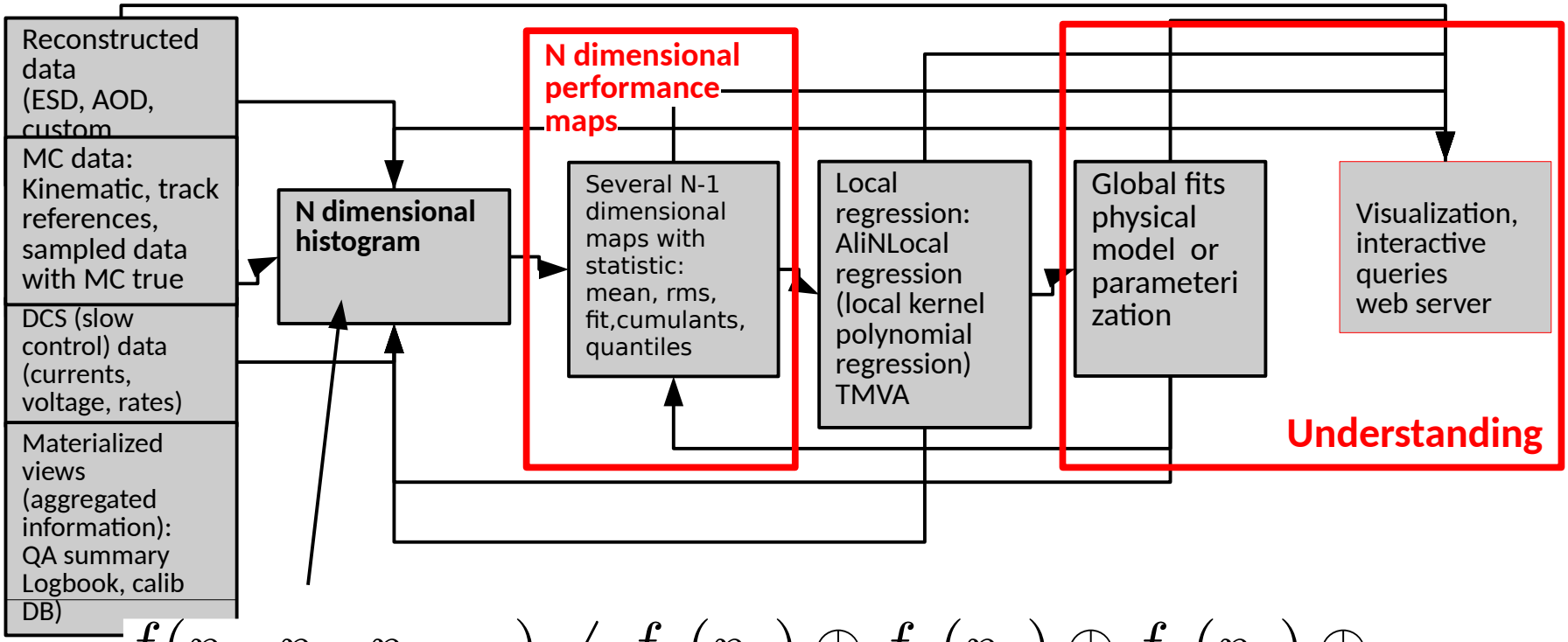
- **Left:** 50% improvement using TRD at pt >10 GeV/c
- **Right:** at low pt MC (jet) describes the data within ~5 %
- for Calorimeter high pt triggers mean covariance matrix is smaller than for MB
  - **smaller** "leak" from lower p_T

In Neon - 50 % improvement of p_T resolution above 10 GeV
For short tracks Improvement also at low pt (see slides>13)

Distortion fluctuation mitigation

* disclaimer: PbPb data sample and pp data sample with opposite B field
* to be taken into account interpreting results PbPb/pp

Performance maps - standard ND pipeline (0)



$$f(p_0, p_1, p_2, \ldots) \neq f_0(p_0) \oplus f_1(p_1) \oplus f_2(p_2) \oplus \ldots.$$

Standard calibration/performance maps interpreted in multidimensional space

- dimensionality depends on the problem to study (and on available resources)
- Data →Histogram → set of ND maps → set of NDlocal regression/TMVA → Global fits → **Interactive visualization on web server** **(Jupyter notebooks prototype for THn and TTree browsing almost ready)**

Resolution,pulls and bias maps: Definition

$$\vec{P}_{\mathrm{DET}} = l_y, l_z, sin(\phi), tan(\theta), q/p_T$$
$$\Delta_P = \vec{P}_{\mathrm{DET0}} - \vec{P}_{\mathrm{DET1}}$$
$$pull_{Pi} = \frac{P_{iDet0} - P_{iDet1}}{\sqrt{\sigma^2_{P_{iDet0}} + \sigma^2_{P_{iDet1}}}} \quad (1)$$

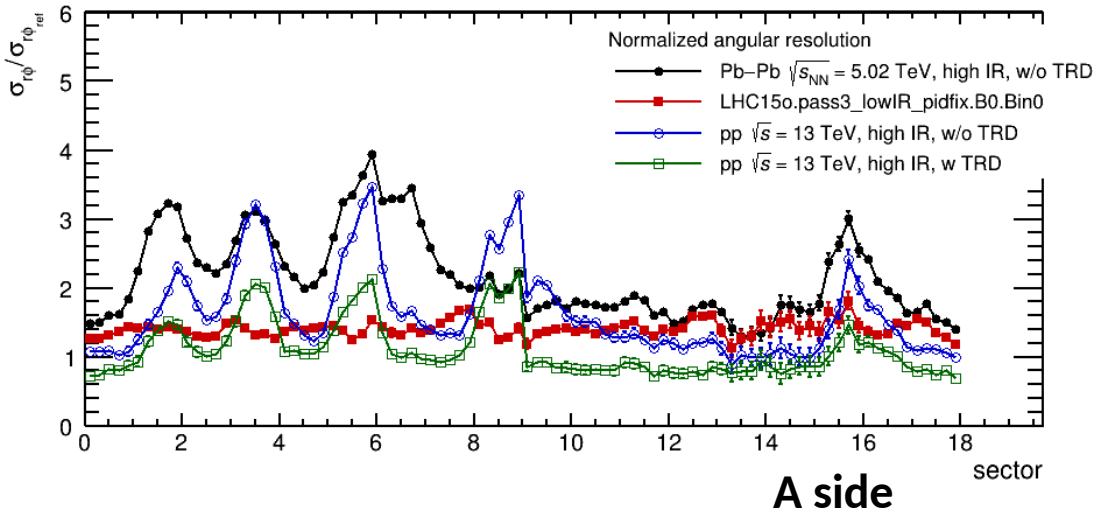
Performance maps created from distribution of track matching Δ and pulls in many multi-dimensional histograms

- several statical information of PDF in bins extracted entries mean, rms, LTM, gauss fit
- **Track matching delta and pulls more sensitive to tracking imperfection** than chi2 (mostly dominated by point error)
- Track matching pulls to estimate imperfection of covariance matrix infromation

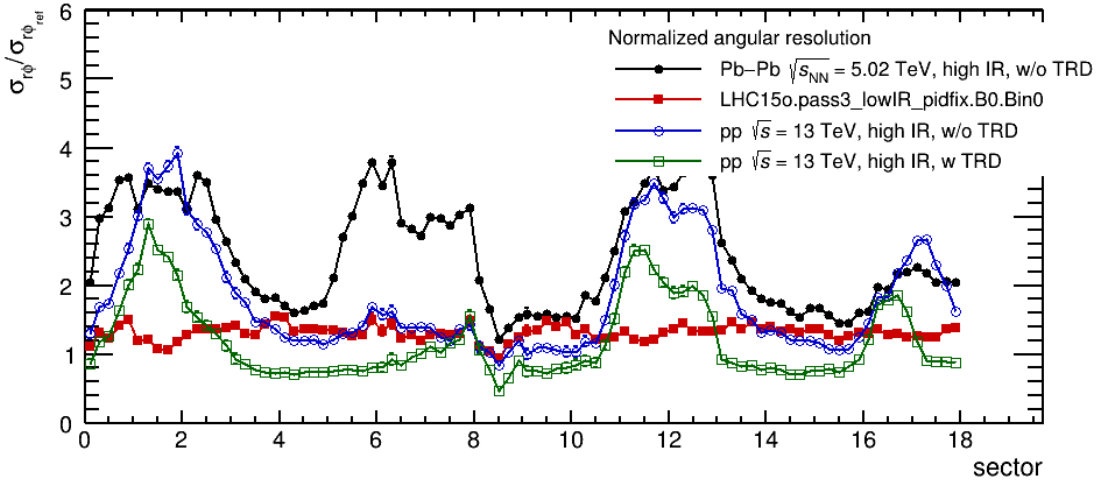
Next slides:

- DET0=TPC+(TRD) track
- DET1=ITS+TPC+(TRD) track
- Shown statistics: rms of gaussian fits
- Explicitly indicating if the track constrained to vertex or not

Angular resolution



A side



C side

PbPb high rate w/o TRD
PbPb low rate w/o TRD
pp high rate w/o TRD
pp high rate with TRD in tracking

Performance map normalized to reference performance map - pp low IR (LHC15n) w/o TRD

At high IR non flat performance map

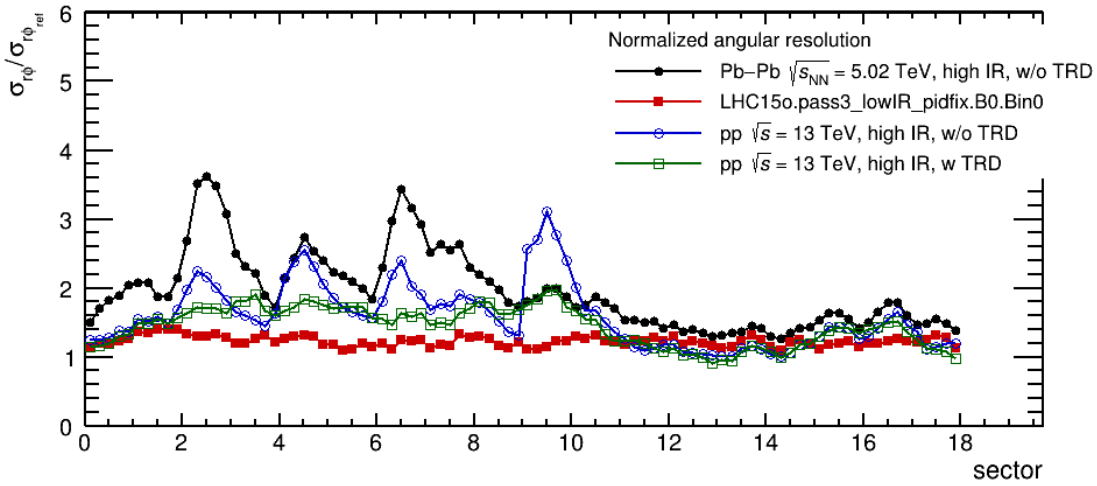
Significantly worse performance in region with **local distortion O(3-4)**

Significant improvement- sector modulation reduced

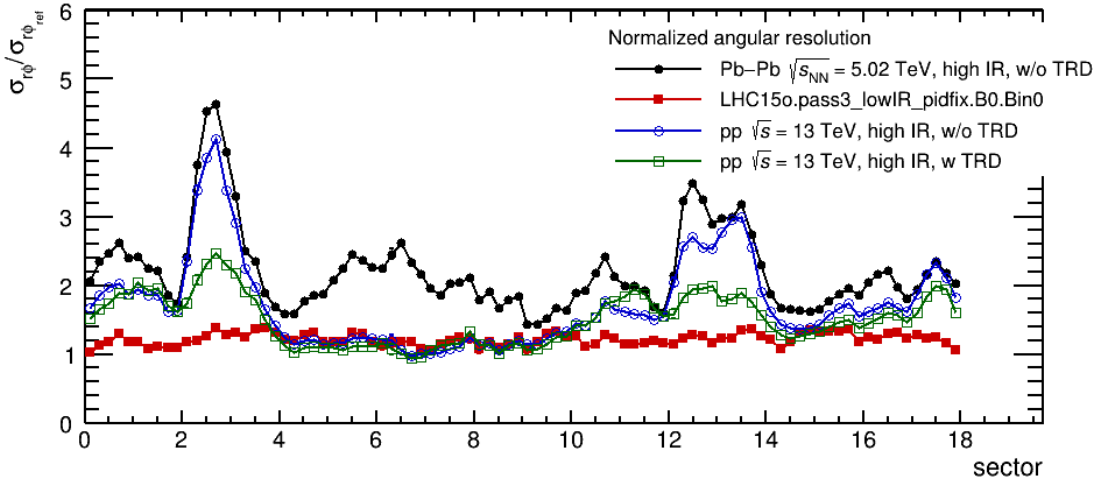
More homogeneous performance

Overall performance better using TRD in refit

Constrained Angular resolution



A side



C side

PbPb high rate w/o TRD
PbPb low rate w/o TRD
pp high rate w/o TRD
pp high rate with TRD in tracking

Performance map normalized to reference performance map -
pp low IR (LHC15n) w/o TRD

At high IR non flat performance map

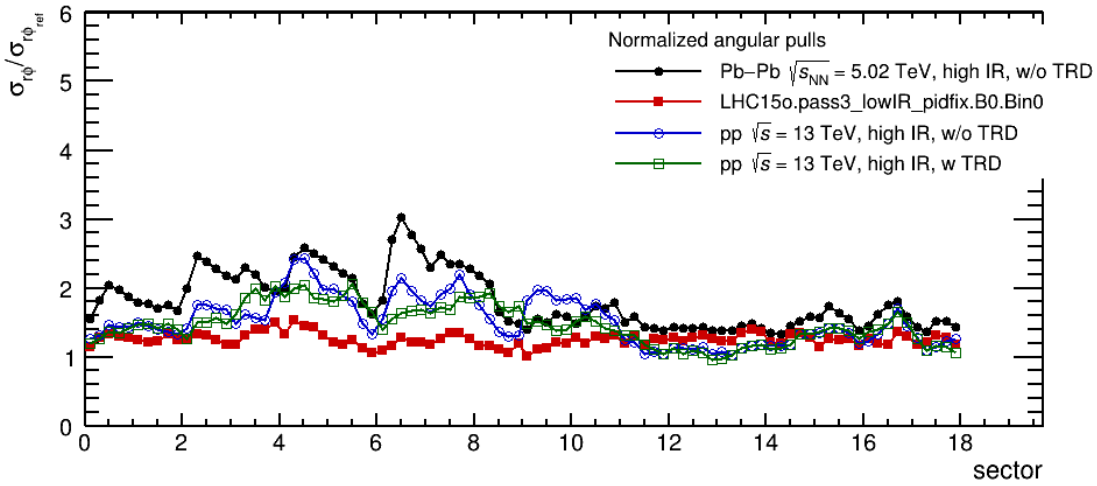
Significantly worse performance in region with local **distortion O(3-5)**

Using TRD significant improvement sector modulation reduced

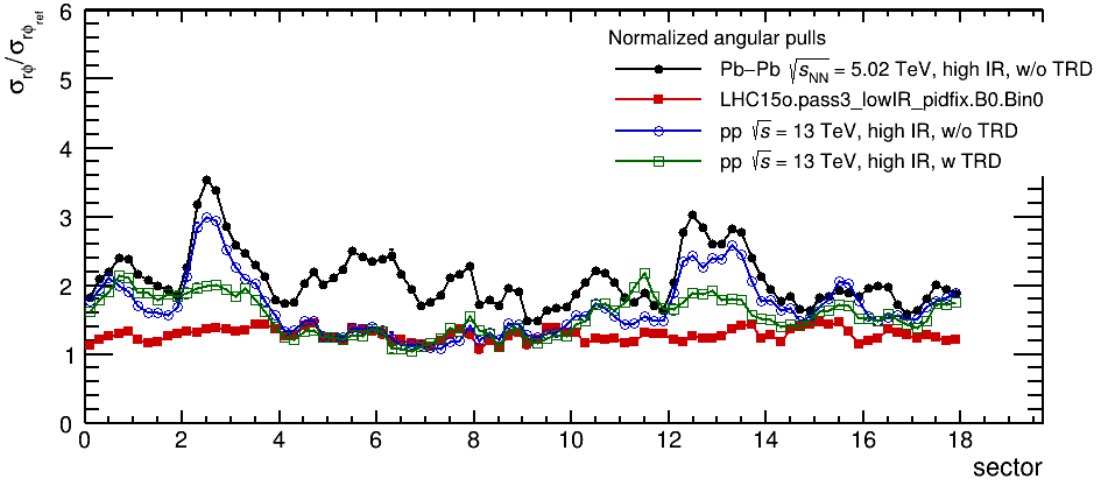
Using TRD more homogeneous performance

Overall performance better using TRD in refit

Const. Angular pulls: Comparison of the reco. productions



A side



C side

PbPb high rate w/o TRD
PbPb low rate w/o TRD
pp high rate w/o TRD
pp high rate with TRD in tracking

Performance map normalized to reference performance map - pp low IR (LHC15n) w/o TRD

At high IR non flat performance map

Significantly worse performance in region with local distortion
Covariance matrix describes local worsening only **partially O(2-3)**

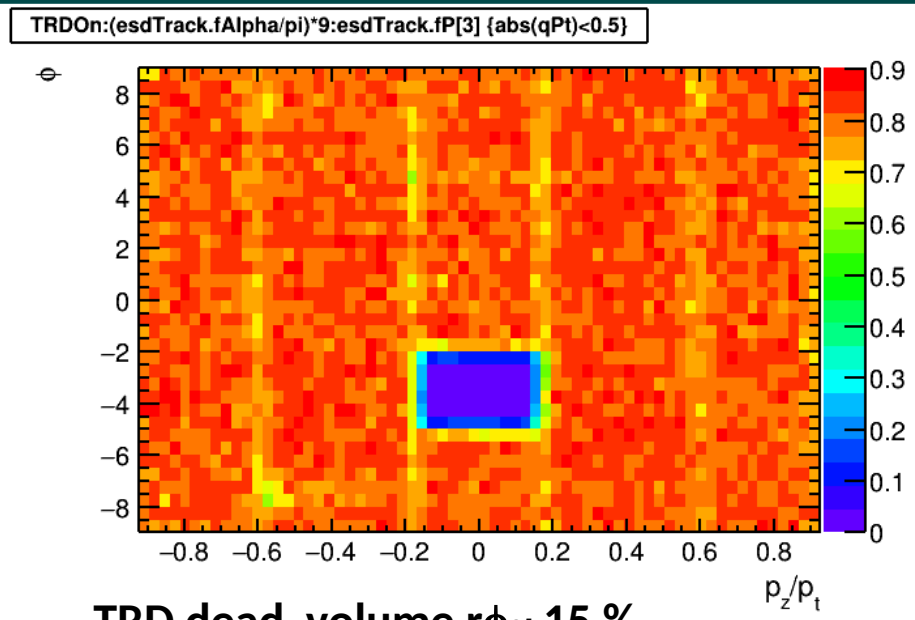
Significant improvement- sector modulation reduced

More homogeneous performance

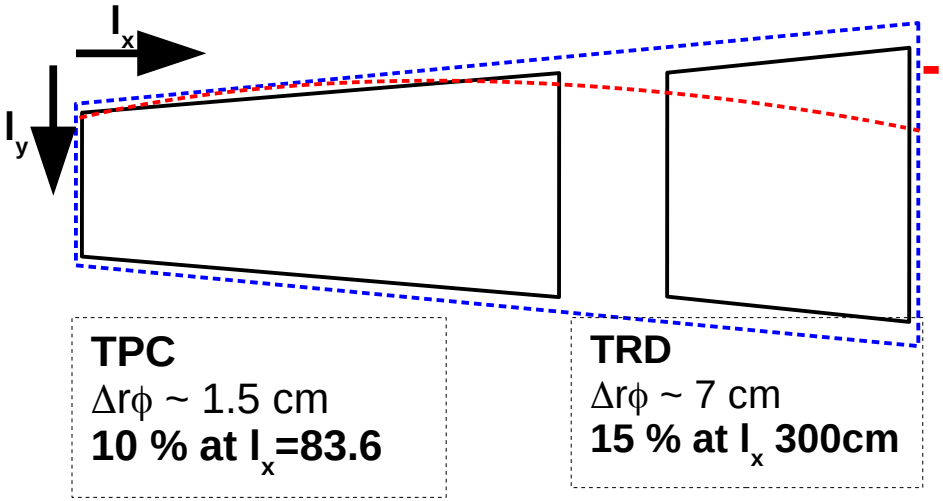
Overall performance better using TRD in refit

Short tracks - edge effect
MC/Data comparison

TPC+TRD acceptance

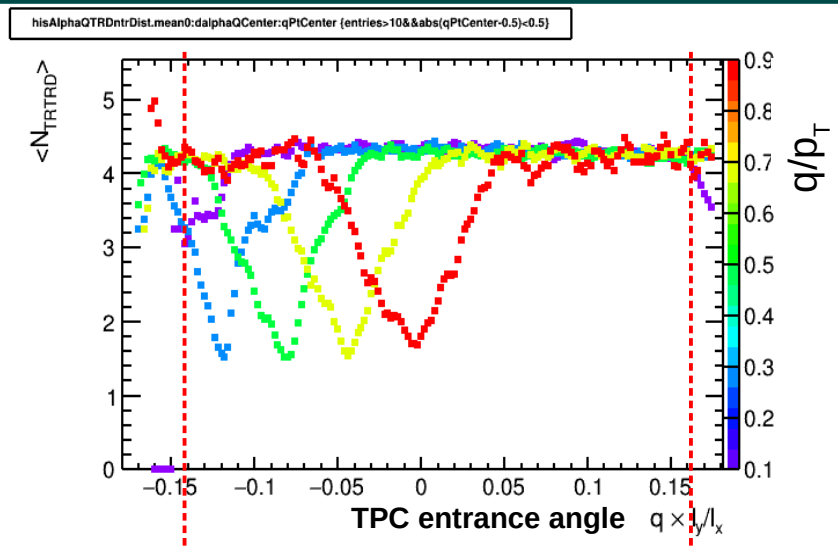


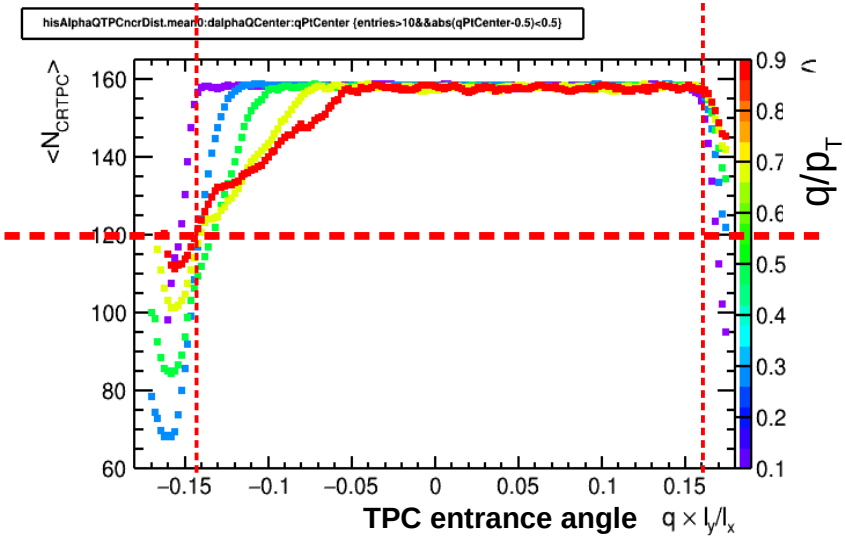
TRD dead volume rϕ~ 15 %
dead region - PHOS hole



TPC
Δrϕ ~ 1.5 cm
10 % at l_x=83.6

TRD
Δrϕ ~ 7 cm
15 % at l_x 300cm

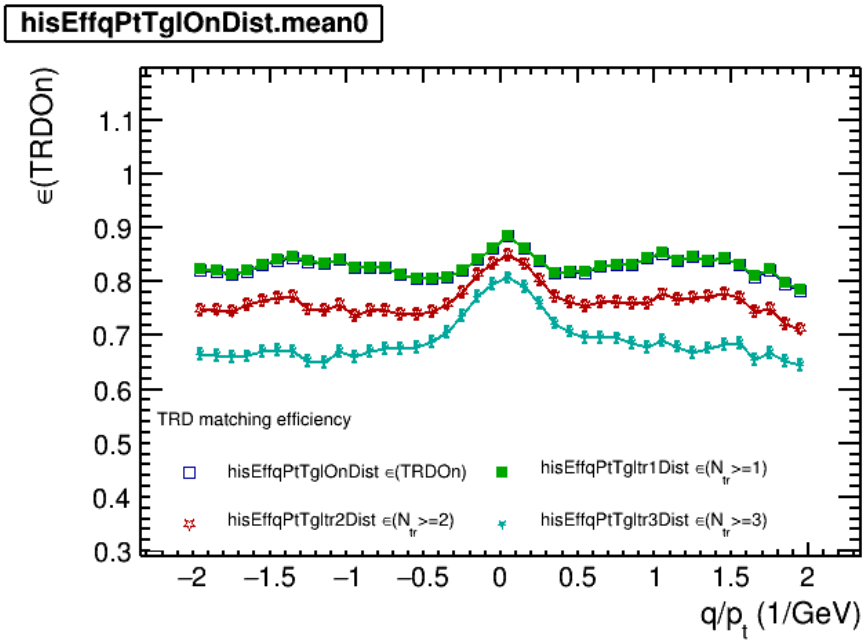


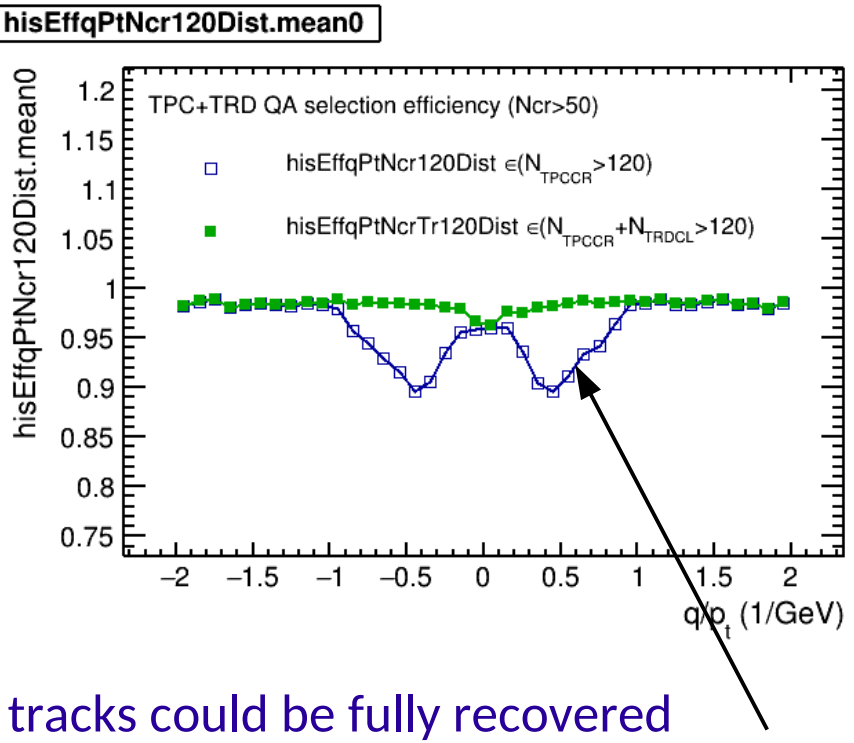


N_{det} vs local y position at the TPC entrance (l_x=83.6 cm)

Tracks in TPC dead zone - in active zone of TRD

Track cut efficiency at intermediate p_T





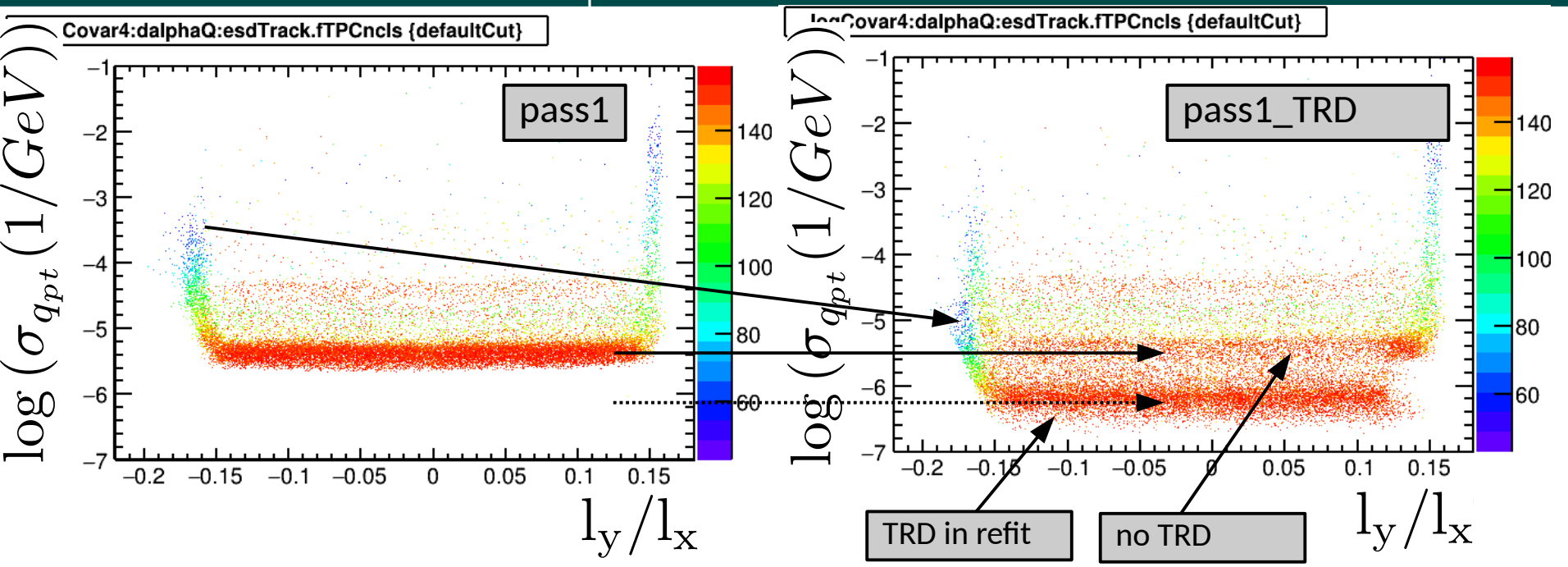
Including TRD in the track refit TPC short tracks could be fully recovered

- dip in the tracking efficiency at intermediate pt (1-5 Gev/c) disappeared

Requiring a minimal combined track length quality of the short TPC tracks will be not affected

Tracking efficiency increase without compromising performance
Tracking efficiency flatter in space

Expected p_T resolution. With/Without TRD

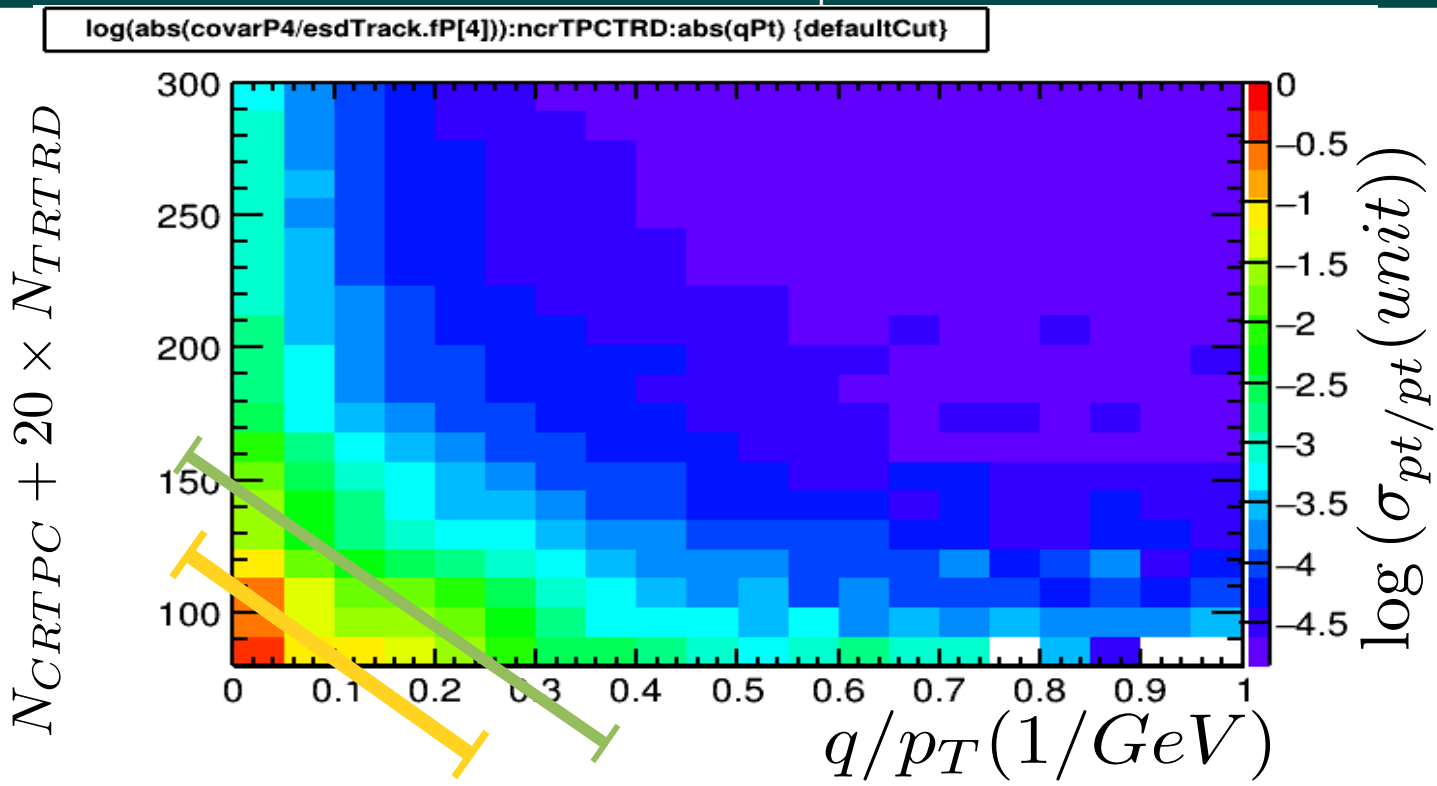


Log of $\sigma_{q/pt}$ as function of relative sector position at the TPC entrance for **tracks above 5 GeV** (N_{CR} TPC as a color code)

- Long track region - 2 times better resolution for pass1_TRD
- Short tracks bending into TRD recovered (left edge - q l_y/l_x< -0.15)
- Short tracks (right edge - q l_y/l_x > 0.15) dead TRD area
  - for lower moment tracks (not shown bot sides recovered)

Including TRD - significant improved resolution in bulk and recovery at the edges

Expected relative p_T resolution

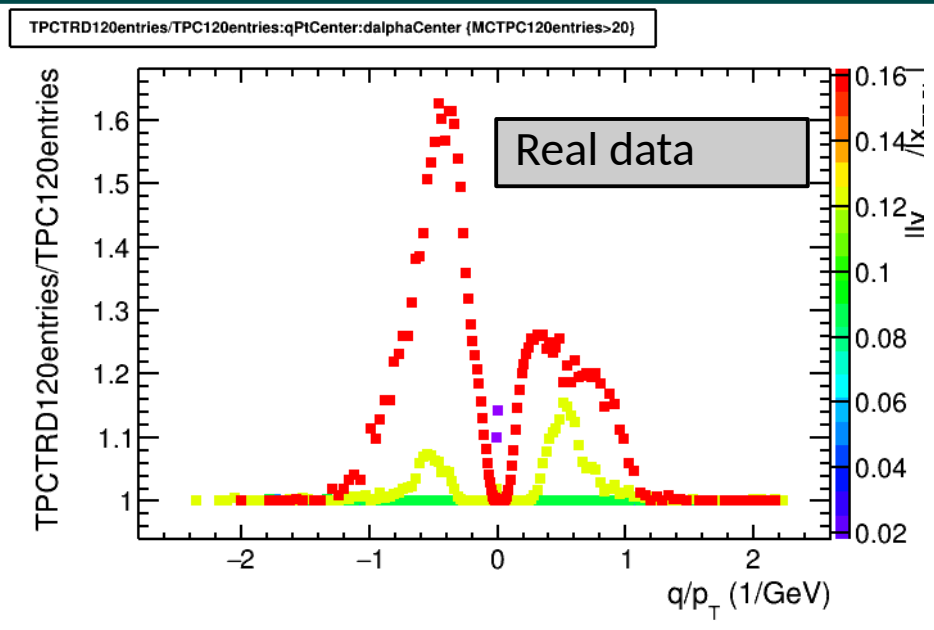


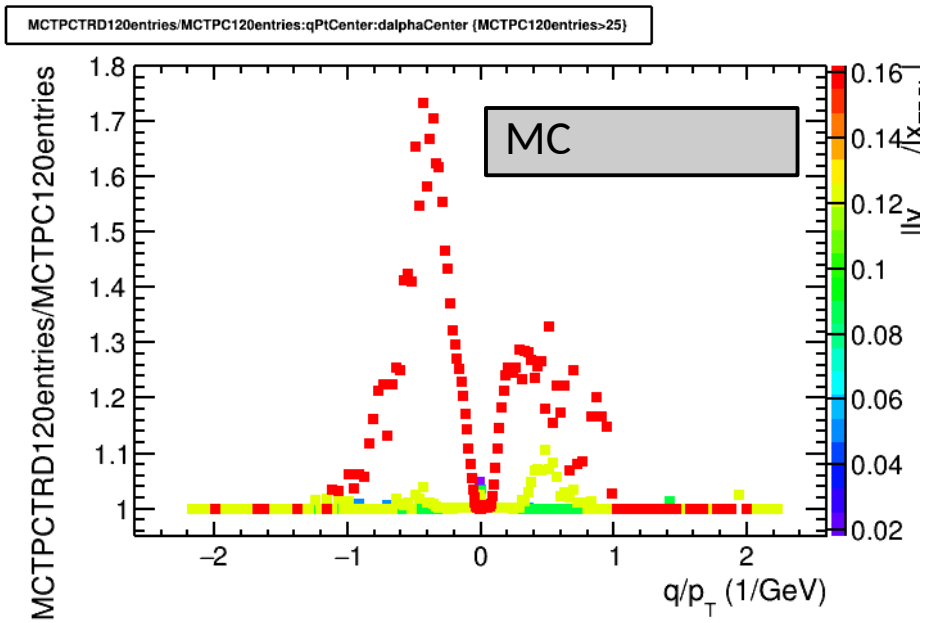
Mean logarithm of relative pt resolution (**nominal p_T resolution ~ 1%~-4.6**)

- p_T dependent selection on track length to guarantee acceptable resolution
- **e.g should be σ<5 % (log<-3), or σ<30 % log<-1.2**
  - systematic error of covariance matrix+-20 % can lead to big systematic error in unfolding

Short tracks and very high pt - non reliable p_T measurement - to be removed from sample. Covariance or pt dependent N_{CR} selection

Ratio of number of long tracks (TPC vs TPC+TRD). Cut 120





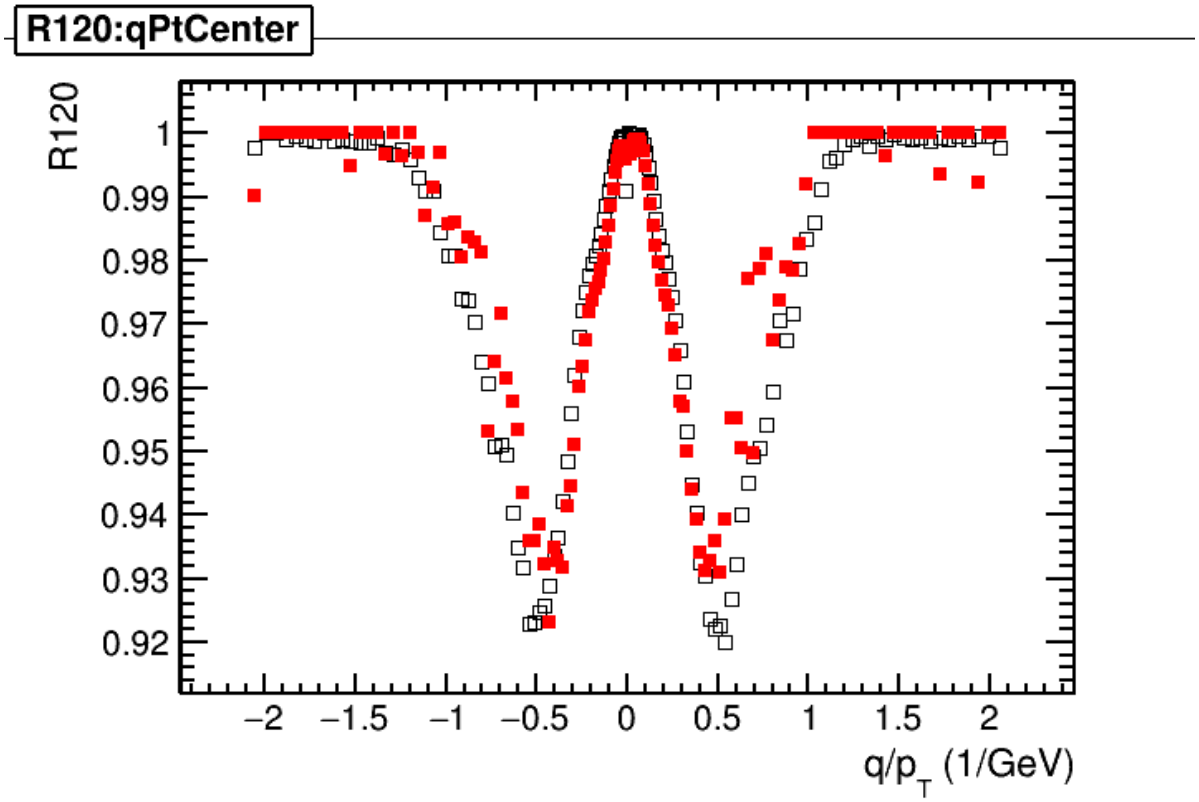
$$\mathrm{cut_{NCR}} = (\mathrm{N_{CRTPC}} + \mathrm{N_{TRD}} * 20 + 10/\mathrm{pt}) > \mathbf{Ncr}$$

Pt dependent cut on the number of crossed rows

Significant part of the short tracks at the **TPC edges** (**ly/lx~0.12**, **ly/lx~0.15**) recovered

Data described by MC

Number of long tracks (TPC vs TPC+TRD). Cut recovery 120



$$\mathrm{cut_{NCR}} = (\mathrm{N_{CRTPC}} + < \mathrm{N_{TRD}} * 20 > -10/\mathrm{pt}) > \mathbf{Ncr}$$

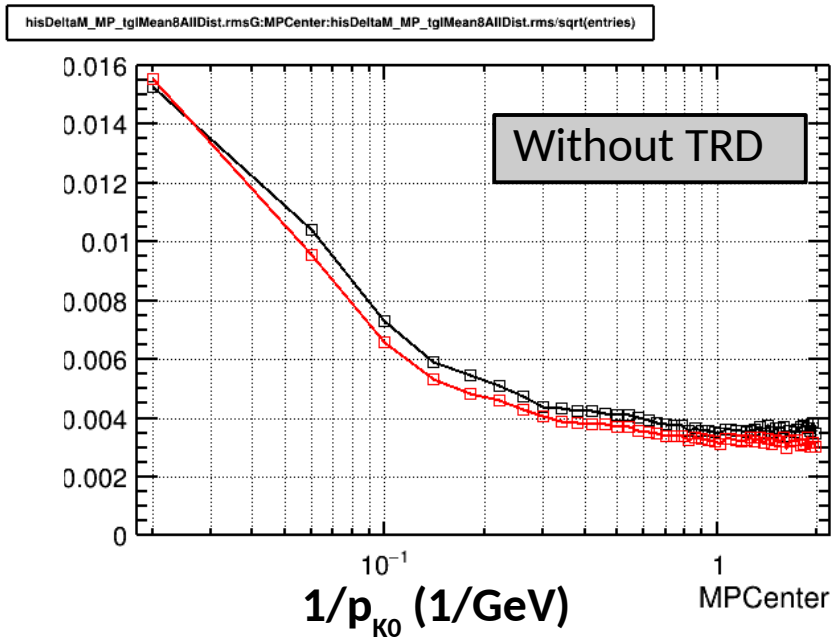
Significant fraction of the TPC short tracks at the sector boundary recovered using TRD

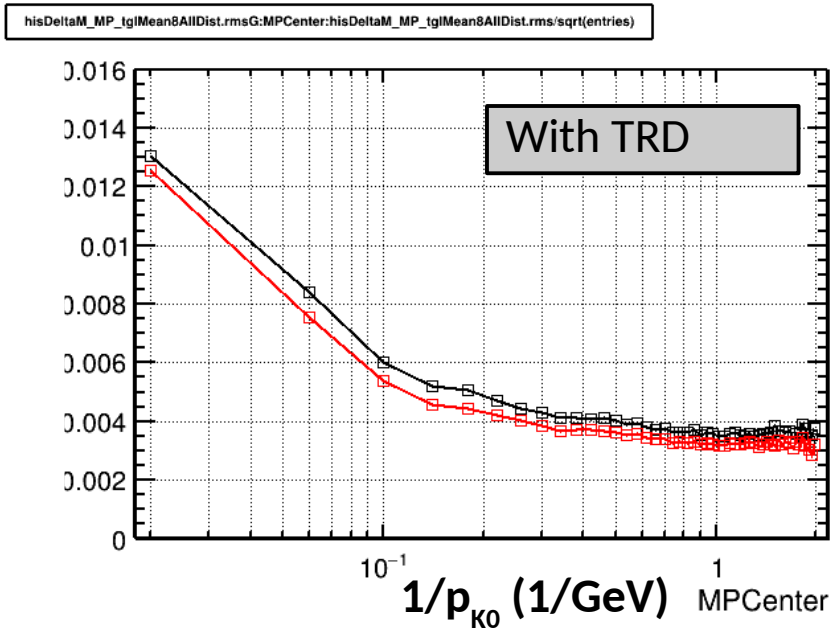
- **MC recovery fraction** agree **with real data** recovery fraction within ~ 1%
- Actual track length cut to be analysis dependent

V0 invariant mass studies

K_{0s} and Lambda

K0s mass resolution



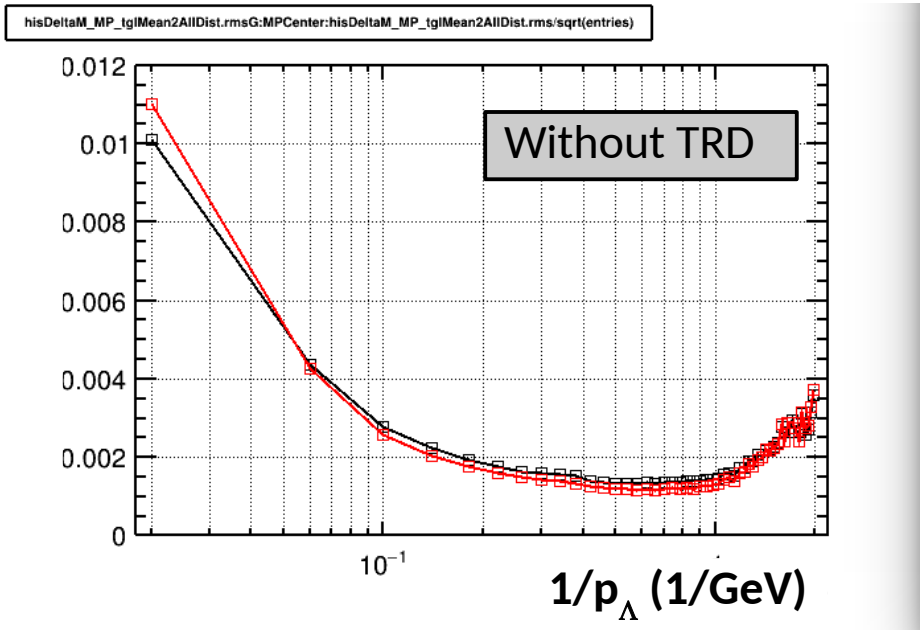


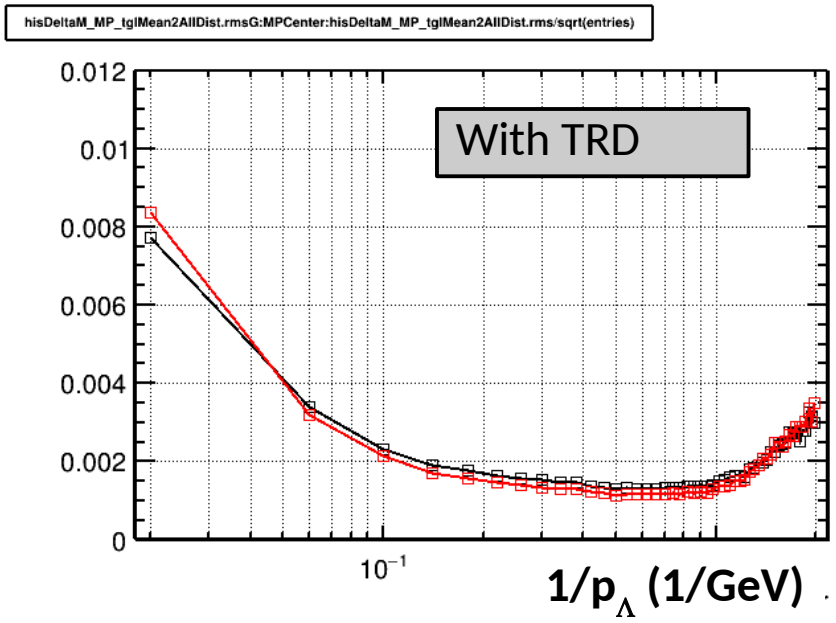
K0 invariant mass width (gaussian sigma) resolution

- Left - without TRD in refit
- Right - with TRD in refit
- **Black** - standard Inv mass
- **Red** - Invariant mass using AliKF fit (without primary vertex constraint)

Significant improvement in expected p_T resolution at high p_T → confirmed by the invariant mass peak width

Lambda mass resolution





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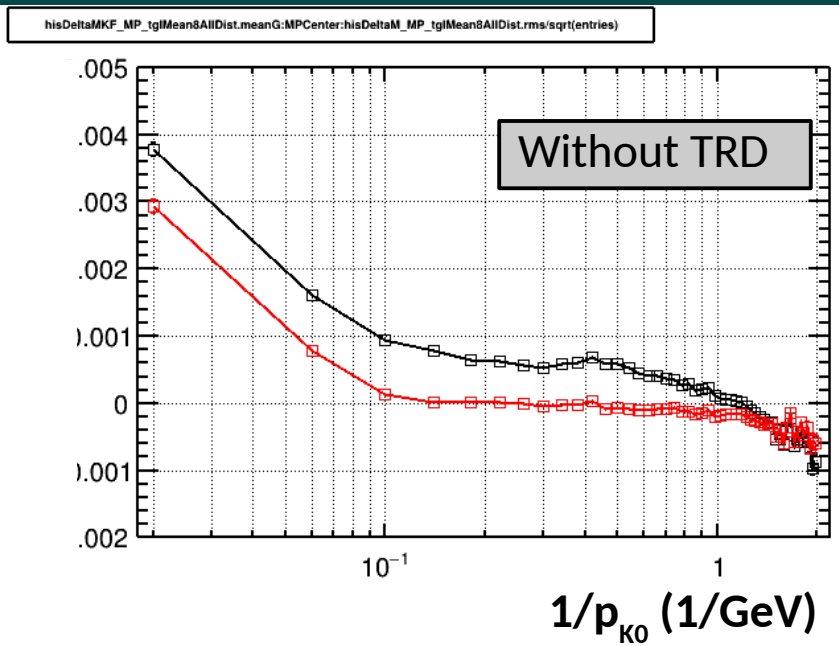
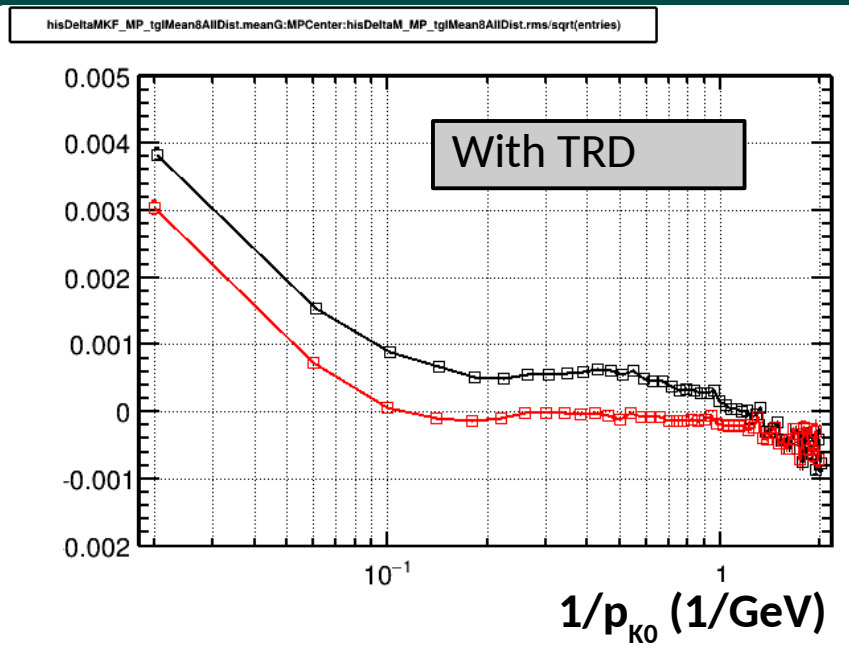
Significant improvement in expected p_T resolution at high p_T → confirmed by the invariant mass peak width

K0s mass bias



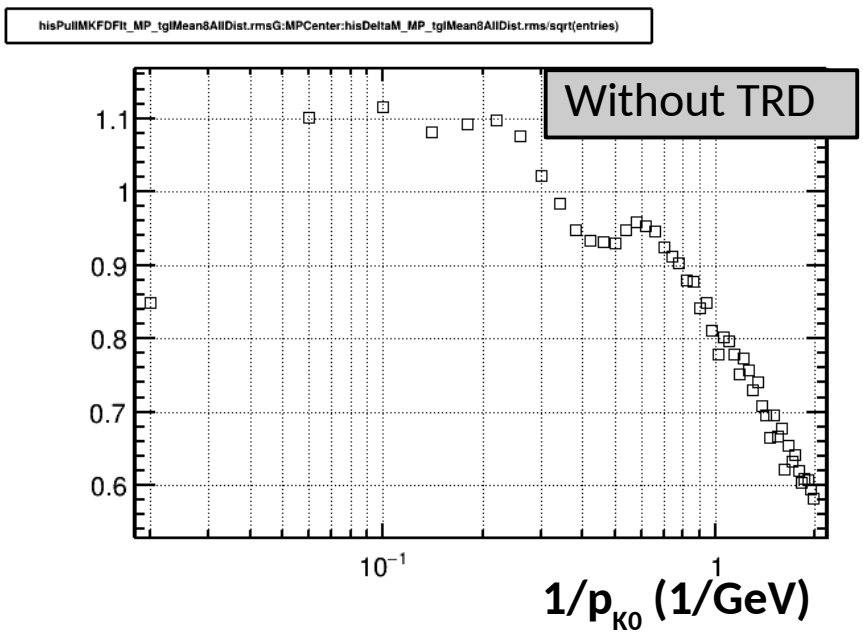


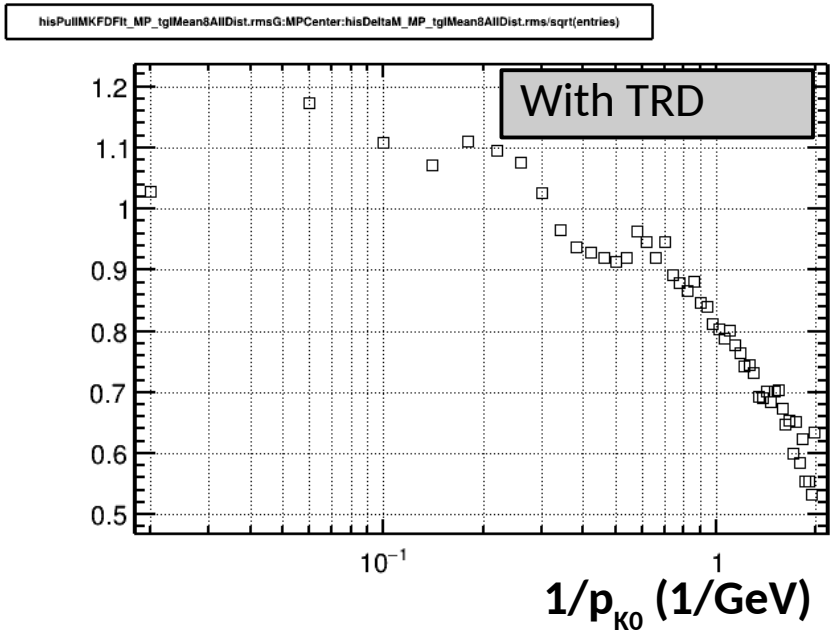
K0 invariant mass bias (gaussian mean) resolution using TRD

- Left - without TRD in refit
- Right - with TRD in refit
- **Black** - standard Inv mass
- **Red** - data corrected for q/pt shift, scaling and energy loss
  - global fit using K0, Lambda, ALambda

Small correctable pt bias seen in both setups with and without TRD mostly due energy loss correction imperfection

K0s mass pull





K0 invariant mass pull width/expected err (gaussian sigma) resolution using TRD

- Left - without TRD in refit
- Right - with TRD in refit
- **at high p covariance matrix describe the data**
  - at low p MS error overestimated

Significant improvement in expected p_T resolution at high p_T → confirmed by the invariant mass peak width. Pulls at high p_T close to 1

PbPb reconstruction/update

Tracking performance at PbPb significantly worse than in the pp

- chi2, dca resolution,pulls …
- TOF fakes …
- Estimated performance about 20 % worsening for MB and ~ 60% for PbPb central
  - **Effect even more important at RUN3**

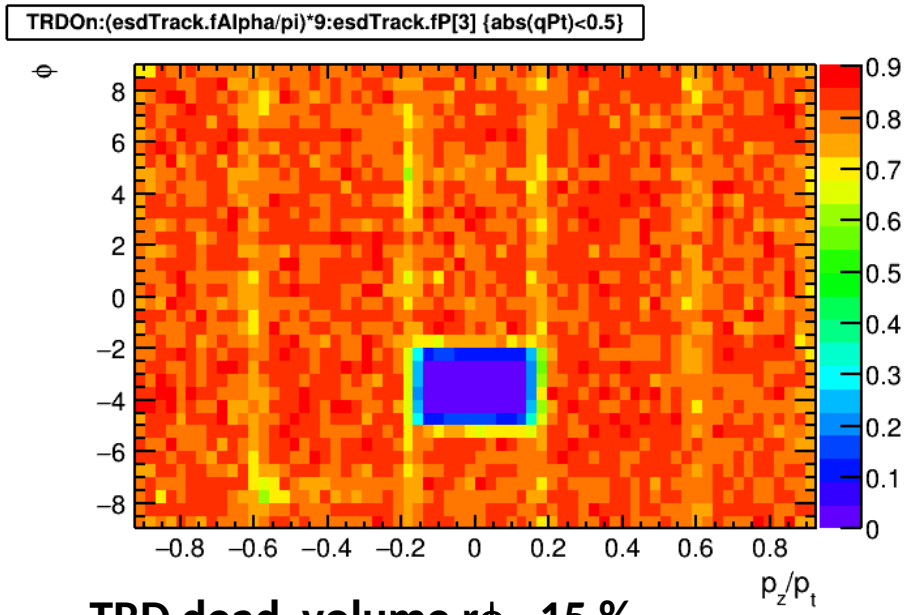
Worsening of the performance can be strongly reduced (In TRD I expect almost recover):

- TPC - cluster filter as in the space charge distortion calibration
- TRD - cluster error estimate using local properties (tracklet angle)
  - prototype for the TRD tracking exist

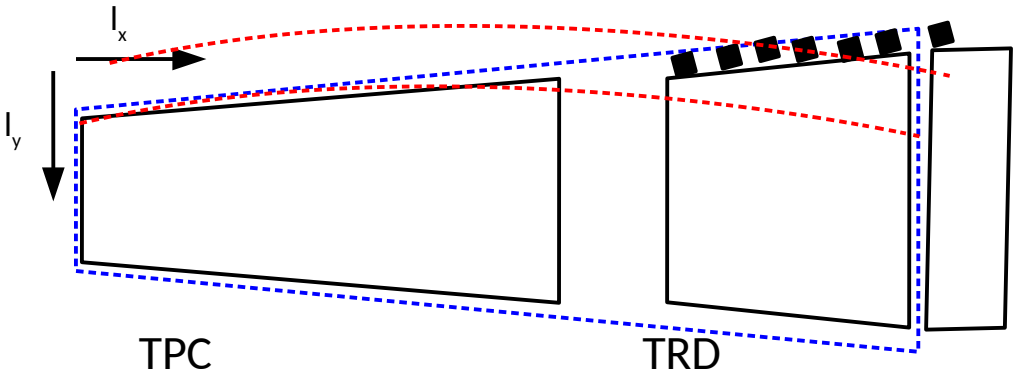
TOF fake tagging using the TRD information

- almost background free TOF PID using causality information
- simple cluster counter $N_{cl}/N_{clfindable}$ in TRD along TPC ↔ TOF interpolation
- material budget counter in the TPC ↔ TOF interpolation
  - improved version of my old TOF tracking algorithm

TOF/TRD tagging



TRD dead volume rϕ~ 15 %
dead region - PHOS hole



TPC
Δrϕ ~ 1.5 cm ~ 10 %

TRD
Δrϕ ~ 7 cm ~ 15 %

Significant fraction of tracks crossing frame absorbed (in rϕ and z)

- at low P almost all
- at high p_T if not absorbed - significantly deflected
- in active region absorption cross section smaller than in the frame but should be also considered

TRD tagging can be used to clean the TOF background

- tagging (probability) track exist

In analysis (suboptimal):

- number of found/findable tracklets after boundary cross
- cross section
- → likelihood track still exist
- correction for wrong mass hypothesis during tracking
- Problem - TRD efficiency not 100 %

TOF tagging in reconstruction

- **in standard reconstruction** tracks lost in the TRD because of chi2 selection
- in updated reconstruction - TRD cluster counting - association along TPC-TOF interpolation
- following all TOF hypothesis

Summary

TRD tracking commissioned using **pp triggered raw data** sample at series of production at GSI (2017)

Improvement confirmed in central AliEn productions (LHC17o MC/Data)

- TRD tracking enabled in ongoing central production for period LHC18m

At **high p_T strong improvement of performance** - according expectation

Performance worsening due to the TPC space charge distortion **strongly mitigated → more homogeneous performance**

- Distortion fluctuations even more important in **RUN3**

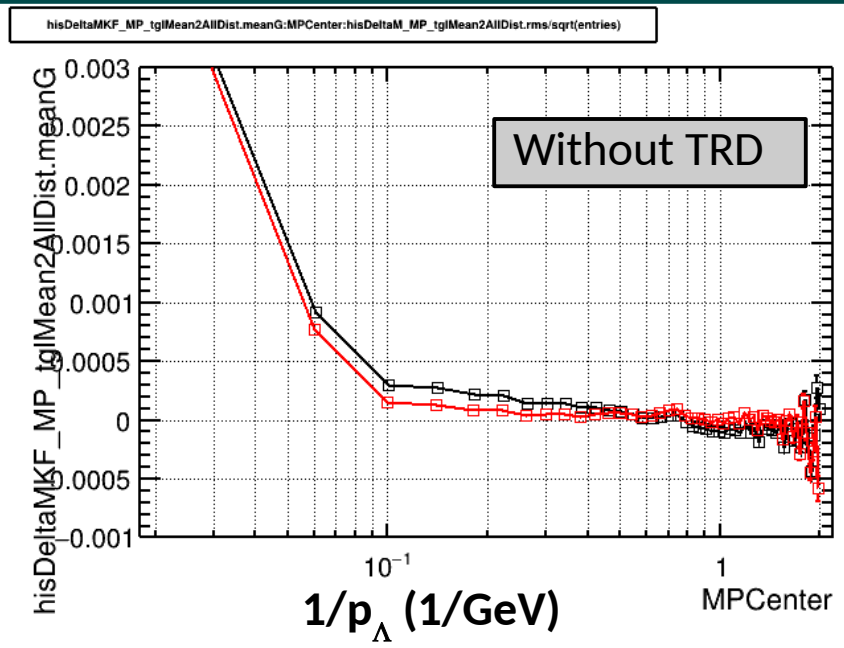
At **intermediate p_T (1-5 GeV/c)** tracking efficiency can strongly increase and **dead region in acceptance eliminated**

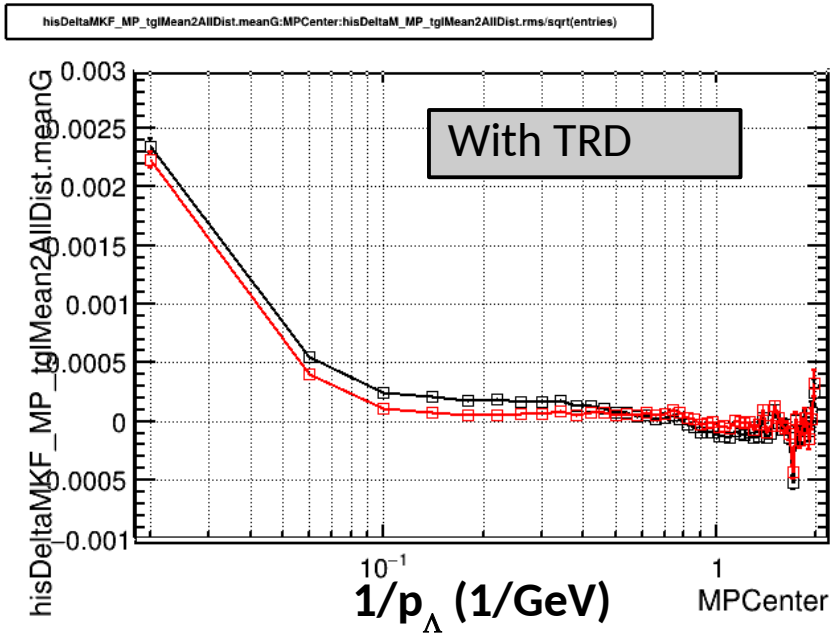
Ongoing activities to commission TRD in track refit for PbPb data

- tracking improvement + TOF PID improvement "fake" tagging using TRD tracklet information

Backup

Lambda mass bias



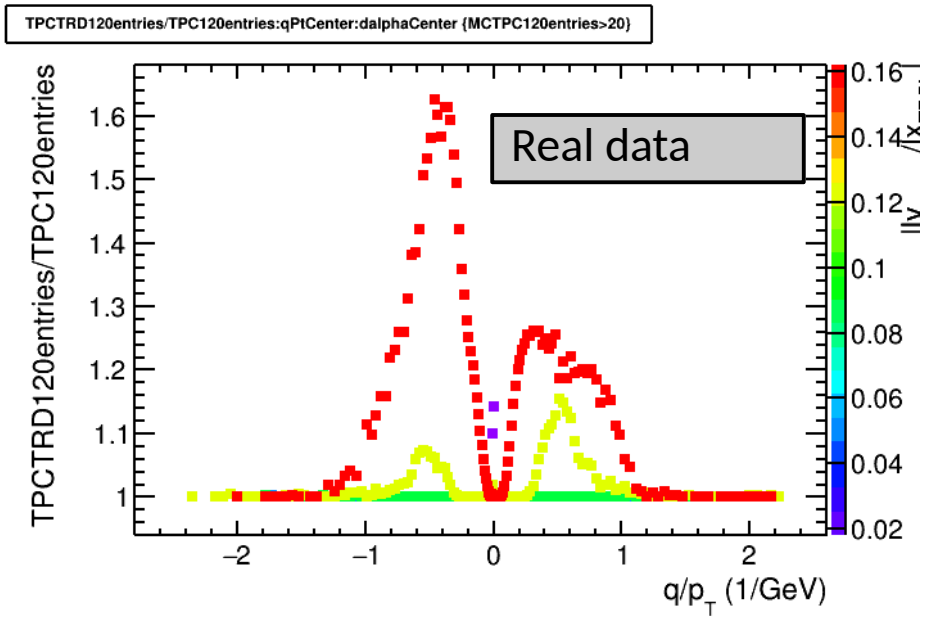


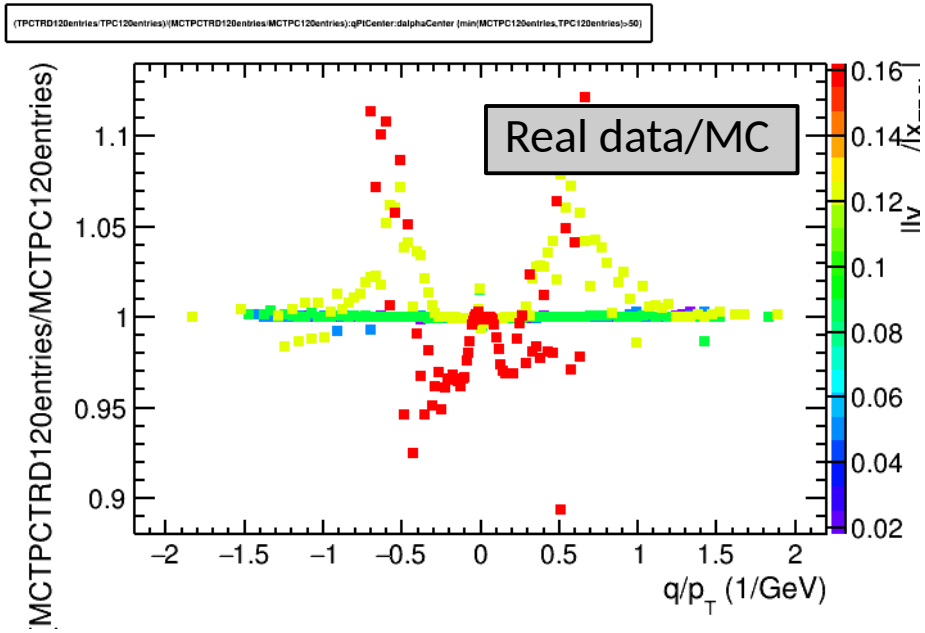
Lambda invariant mass width (gaussian sigma) resolution using TRD

- Left - without TRD in refit
- Right - with TRD in refit
- **Black** - standard Inv mass
- **Red** - data corrected for q/pt shift, scaling and ellos
  - global fit using K0, Lambda, ALambda

Significant improvement in expected pt resolution at high pt → confirmed by the invariant mass peak width

Number of long tracks (TPC vs TPC+TRD). Cut 120





$$\mathrm{cut_{NCR}} = (\mathrm{N_{CRTPC}} + < \mathrm{N_{TRD}} * 20 > -10/\mathrm{pt}) > \mathbf{Ncr}$$

Pt dependent cut on the number of crossed rows

Significant part of the short tracks at the TPC edges (ly/lx~0.12, **ly/lx~0.15**) recovered

Right MC double ratio - relative agreement ~ 5 %

Pt spectra

Cut variation:

- ITS pixel required
- Number of crossed rows
  - 70,100,130 crossed rows TPC
  - 70,100,130 crossed rows TPC+TRD
- Normalized covariance matrix cut
  - 0.05,0.15,0.3

Trigger:

- Minimum bias
- Calo
- EJ1 (neutral energy 19 GeV) with/without TRD
- EJ2 (neutral energy 14 GeV) with/without TRD

Phi region

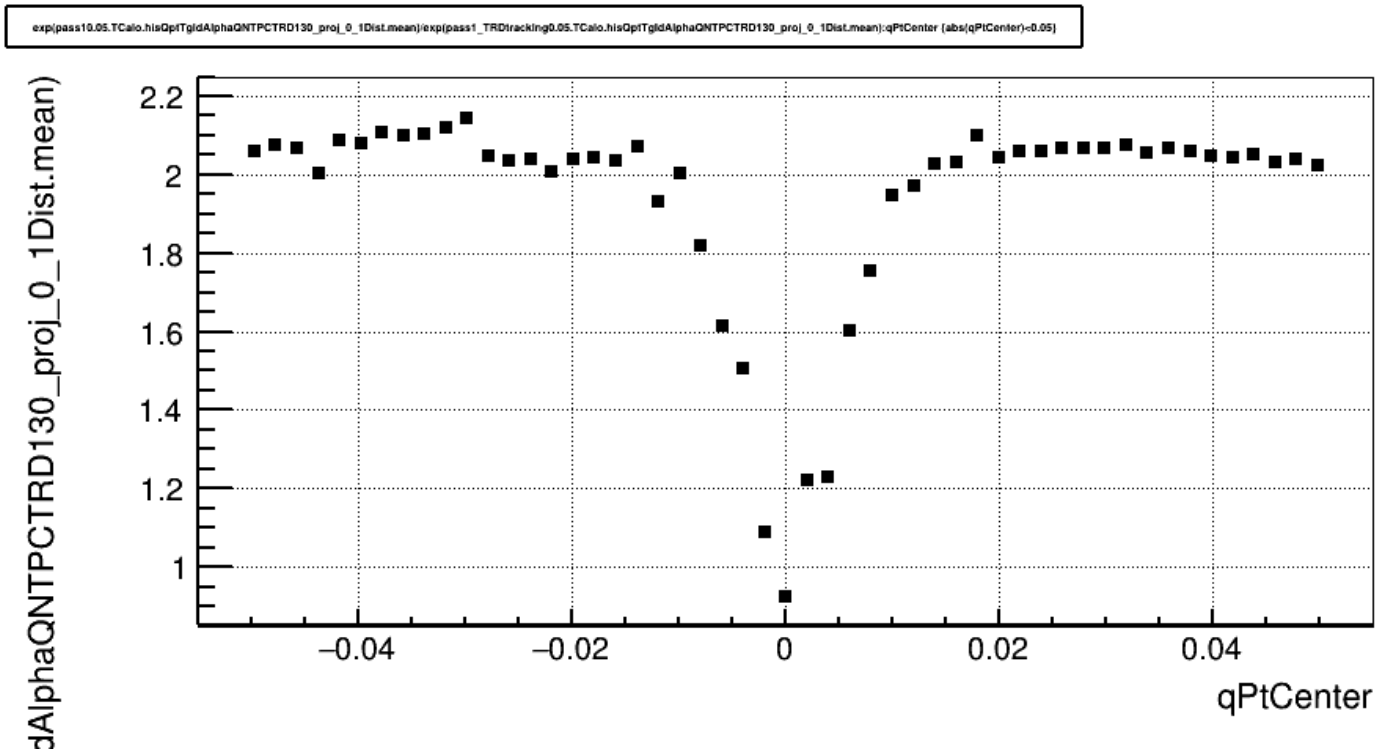
- 5 region

Reconstruction:

- Not TRD in refit (pass1)
- TRD in refit (pass1_TRDTracking)

Expected resolution ratio (pass1/pass1TRD_Tracking)

```
tree0->Draw("exp(pass10.05.TCalo.hisQptTgldAlphaQNTPCTRD130_proj_0_1Dist.mean)/exp(pass1_TRDtracking0.05.TCalo.hisQptTgldAlphaQNTPCTRD130_proj_0_1Dist.mean):qPtCenter","abs(qPtCenter)<0.05","")
```

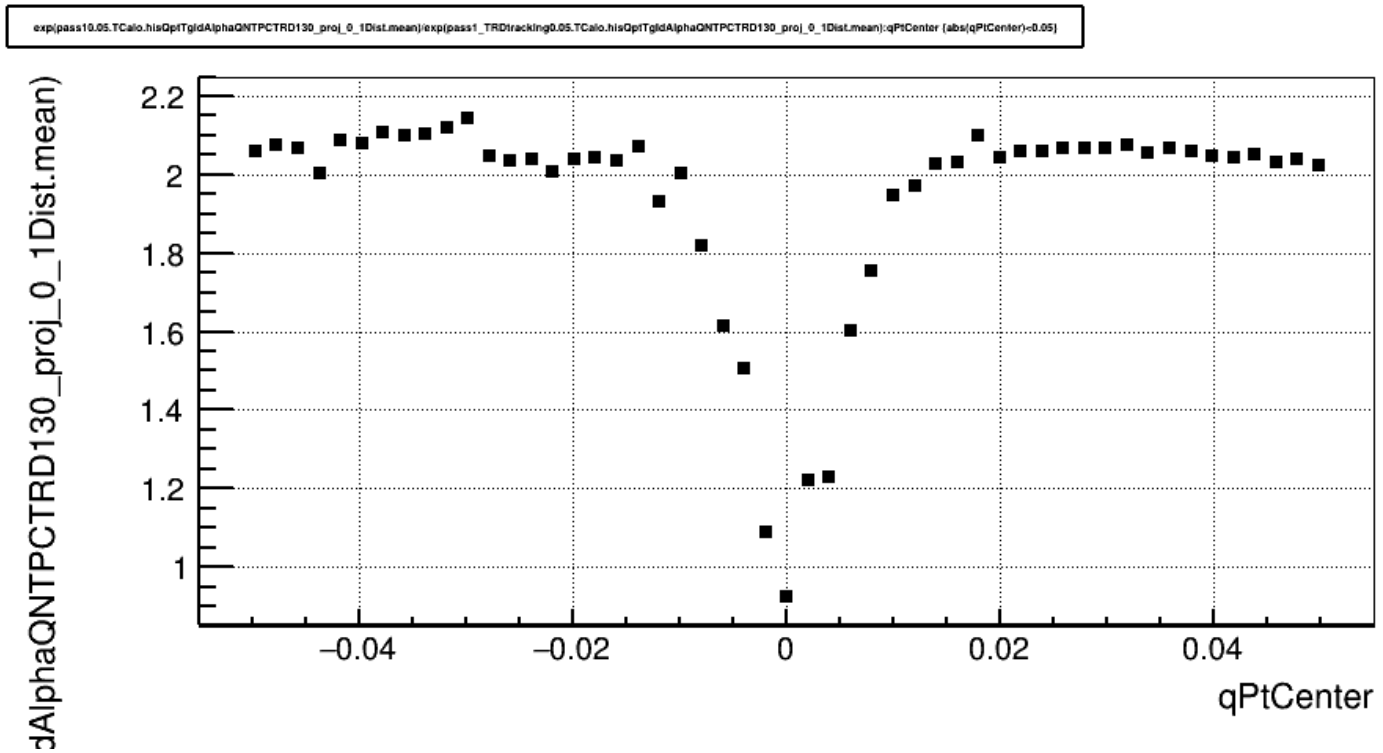


At high pt - expected resolution in setting with TRD in refit ~ 2 times better

- at region above 100 GeV smaller improvement
- to check TRD refit efficiency (not yet in default histograms)

Expected resolution ratio (pass1/pass1TRD_Tracking)

```
tree0->Draw("exp(pass10.05.TCalo.hisQptTgldAlphaQNTPCTRD130_proj_0_1Dist.mean)/exp(pass1_TRDtracking0.05.TCalo.hisQptTgldAlphaQNTPCTRD130_proj_0_1Dist.mean):qPtCenter","abs(qPtCenter)<0.05","")
```

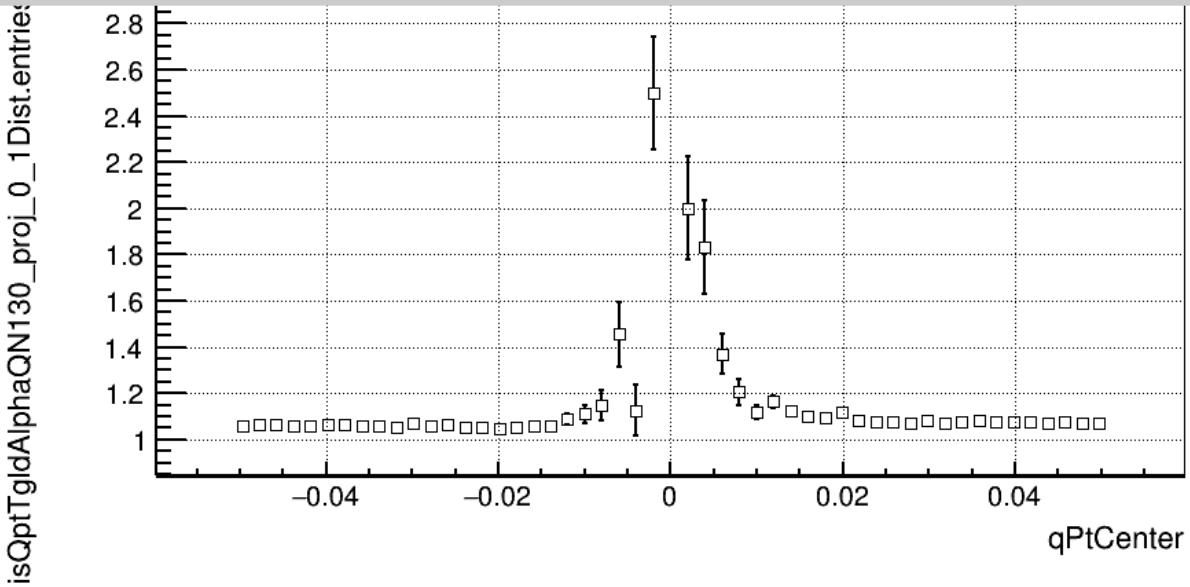


At high pt - expected resolution in setting with TRD in refit ~ 2 times better

- at region above 100 GeV smaller improvement
- to check TRD refit efficiency (not yet in default histograms)

Raw Pt spectra ratio -MB

```
TStatToolkit::MakeGraphErrors(tree0,"pass1_TRDtracking0.30.TMB.hisQptTgldAlphaQN70_proj_0_1Dist.entries/pass1_TRDtracking0.05.TMB.hisQptTgldAlphaQN1
0_proj_0_1Dist.entries:qPtCenter:sqrt((pass1_TRDtracking0.30.TMB.hisQptTgldAlphaQN70_proj_0_1Dist.entries-
pass1_TRDtracking0.05.TMB.hisQptTgldAlphaQN130_proj_0_1Dist.entries))/pass1_TRDtracking0.30.TMB.hisQptTgldAlphaQN70_proj_0_1Dist.entries","abs(qPtCe
ter)<0.05&&qPtBin!=101",25,1,1)->Draw("ap");
```



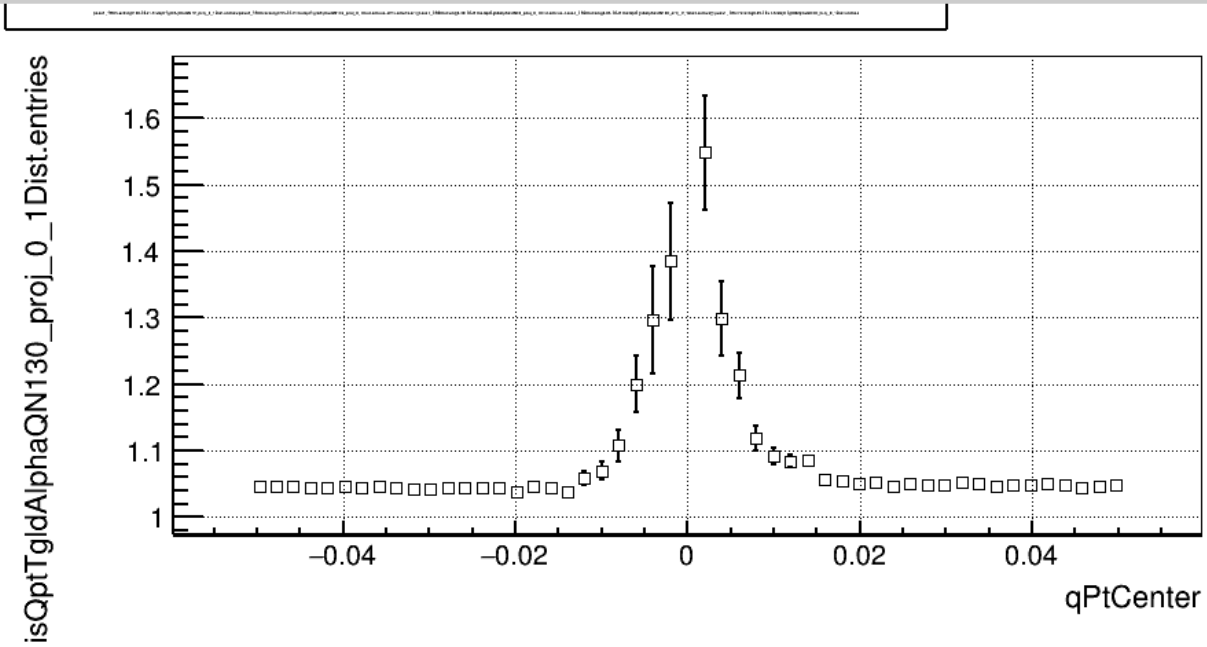
Selection

- Minimum bias
- Cluster cut: 70 clusters/130 cluster
- Covar cut: 0.30/0.05
- Minimum bias

Breakdown 1/pt ~ 0.015 1/GeV

Raw Pt spectra ratio -EJ1

```
TStatToolkit::MakeGraphErrors(tree0,"pass1_TRDtracking0.30.TEJ1.hisQptTgldAlphaQN70_proj_0_1Dist.entries/pass1_TRDtracking0.05.TEJ1.hisQptTgldAlphaQN
130_proj_0_1Dist.entries:qPtCenter:sqrt((pass1_TRDtracking0.30.TEJ1.hisQptTgldAlphaQN70_proj_0_1Dist.entries-
pass1_TRDtracking0.05.TEJ1.hisQptTgldAlphaQN130_proj_0_1Dist.entries))/pass1_TRDtracking0.30.TEJ1.hisQptTgldAlphaQN70_proj_0_1Dist.entries","abs(qPtC
enter)<0.05&&qPtBin!=101",25,1,1)->Draw("ap");
```



Selection

- Minimum bias
- Cluster cut: 70 clusters/130 cluster
- Covar cut: 0.30/0.05
- EJ1 trigger

Breakdown at 1/pt ~ 0.01-0.005 1/GeV, at pt>100-200 GeV/c