TRD in combined tracking

Executive summary (pp tracking)

TRD tracking commissioned using **pp data** sample one year ago

TRD tracking is ready to be used for the pp data taking. Not further code development needed.

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

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

Local performance worsening due to the TPC space charge distortion **strongly mitigated → more homogenous performance**

Executive summary (PbPb tracking)

TRD in combined tracking for PbPb - to be commissioned with additional improvements related to **high occupancy tracking**

- TOF fakes tagging (removal)
- significant degradation of performance as function of occupancy
- outliers filtering TPC+TRD O(50 %) improvement expected

Important development for RUN2

Even more important for RUN3

- **10 time higher occupancy - 50 KHz instead of the 8 kHz in Run2**

Outlook

Performance of global tracking with/without TRD

TRD acceptance and matching efficiency with the TPC

Comparison of the performance of combined tracking with and without TRD

- low IR
- consideration for high IR - distortion fluctuation
    - mitigation of local worsening of performance due distortion fluctuation
- consideration for short TPC tracks
    - tracks at the sector boundaries

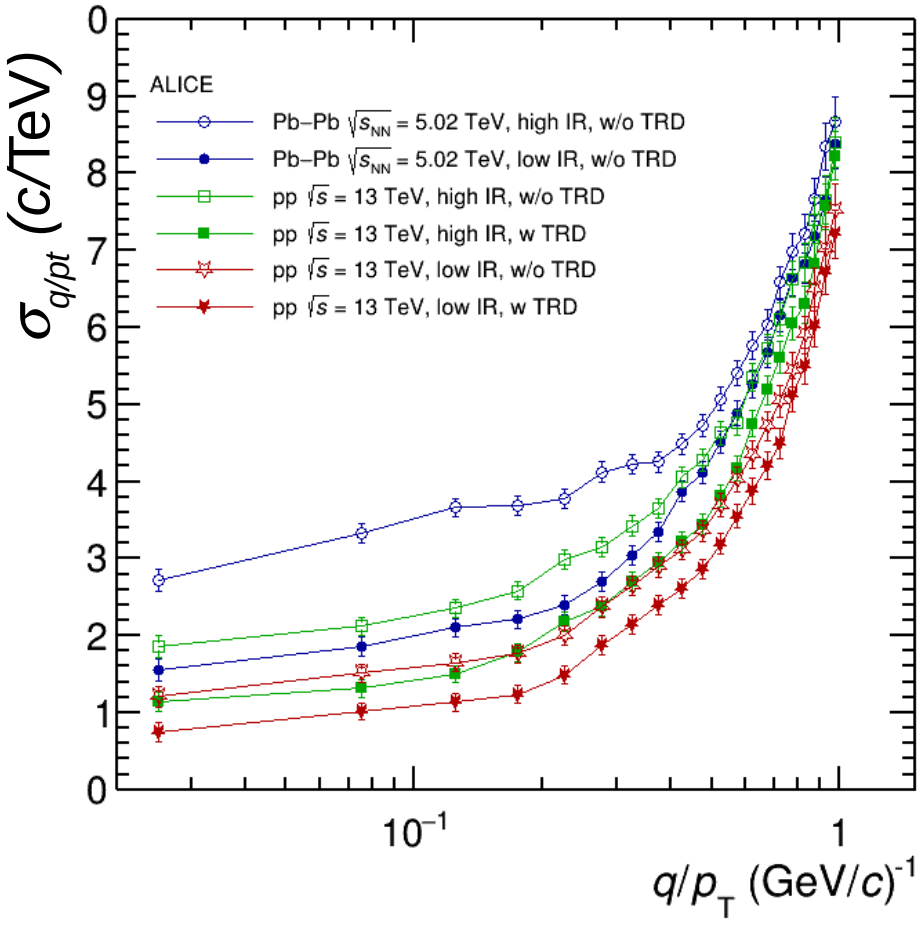
TPC+ TRD reconstruction production

Triggered raw data sample used for commissioning of the TRD in global tracking

- 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
- reconstruction done at GSI only for the pp data
- PbPb triggered raw data sample prepared but not yet
  - not available in the moment of reconstruction production
  - in following slides PbPb data from the central reconstruction production used

Full statistic of triggered data sample used in GSI production O(hours)
4 Different reconstruction settings tested

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



Only ITS and TPC track cuts used

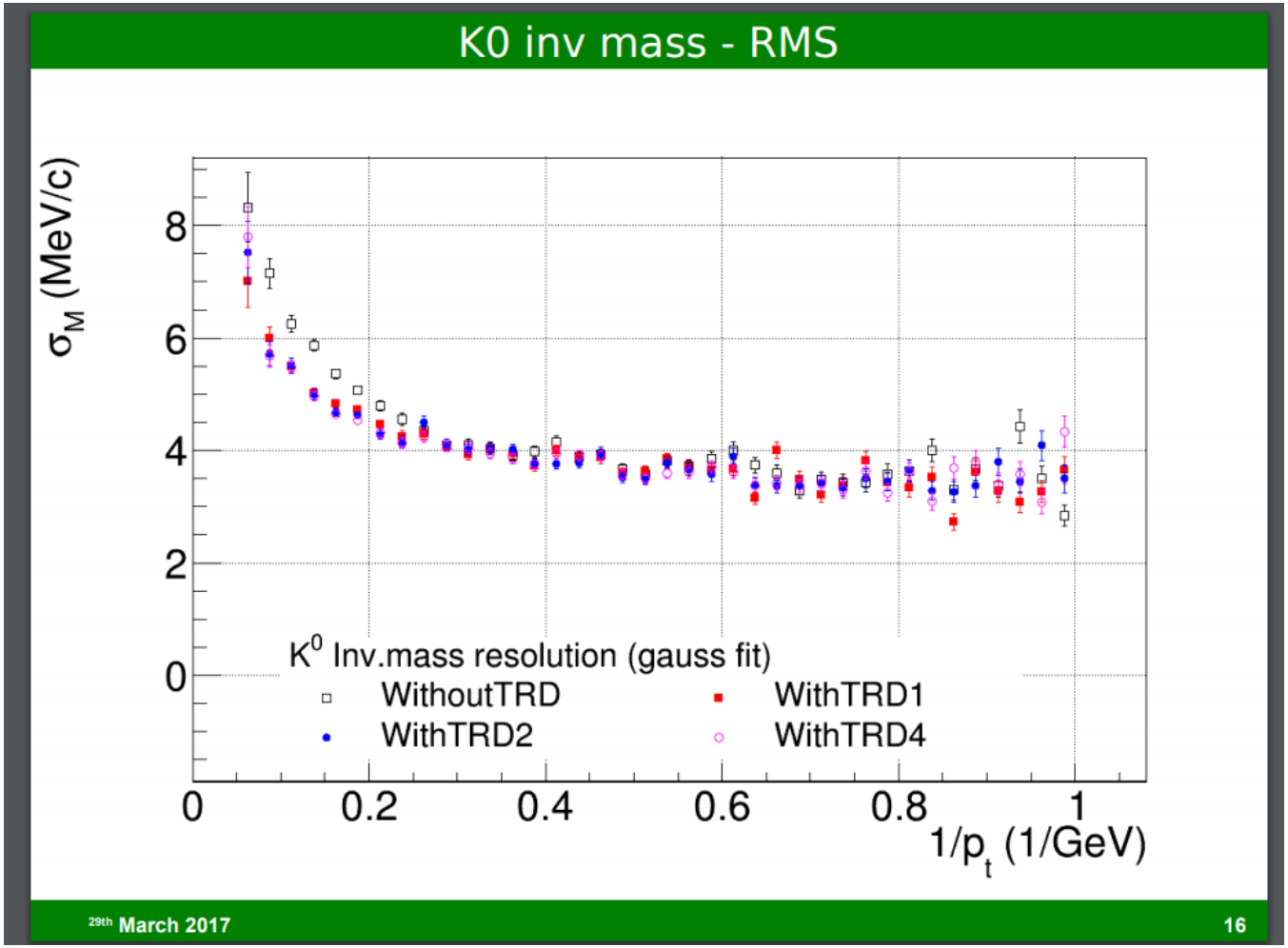
w TRD - TRD in reconstruction
w/o TRD- TRD not in reconstruction

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

K0s invariant mass



Pt reach up to 10 GeV
~ 5 GeV/c of tracks

Settings:

- **No TRD**
- **TRD, sys. error x1**
- **TRD, sys. error x2**
- **TRD, sys. error x4**

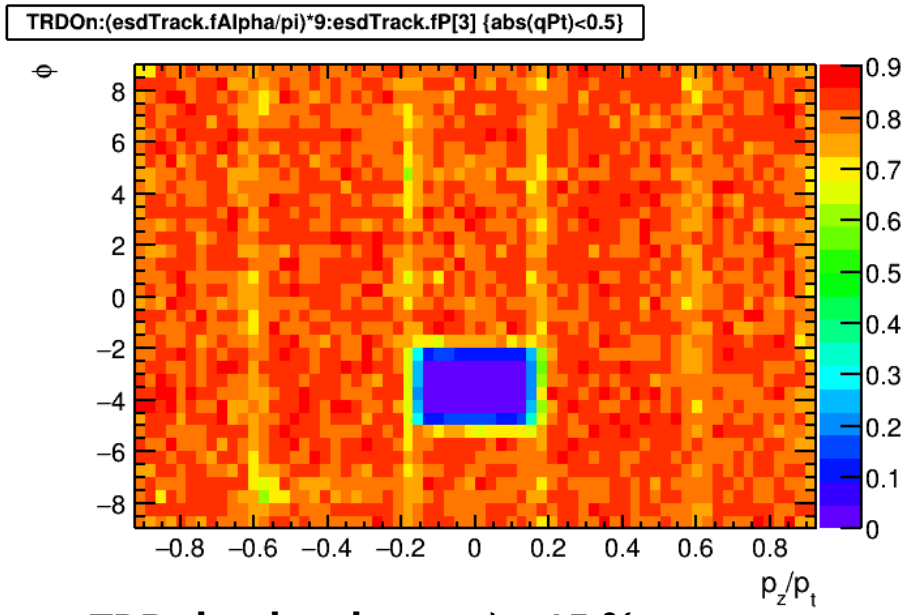
Improvement of the resolution confirmed by the K0s invariant mass analysis at low pt

Special performance/PID/calibration trigger (TRD jet) to be used to increase statistic

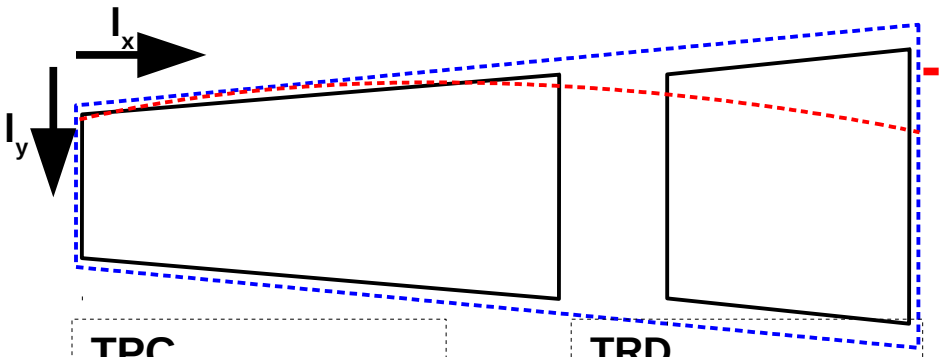
https://indico.cern.ch/event/624025/contributions/2526333/attachments/1436754/2209791/Testreconstruction29032017.pdf

TRD matching efficiency and combined TPC+TRD efficiency

TPC+TRD acceptance (0)

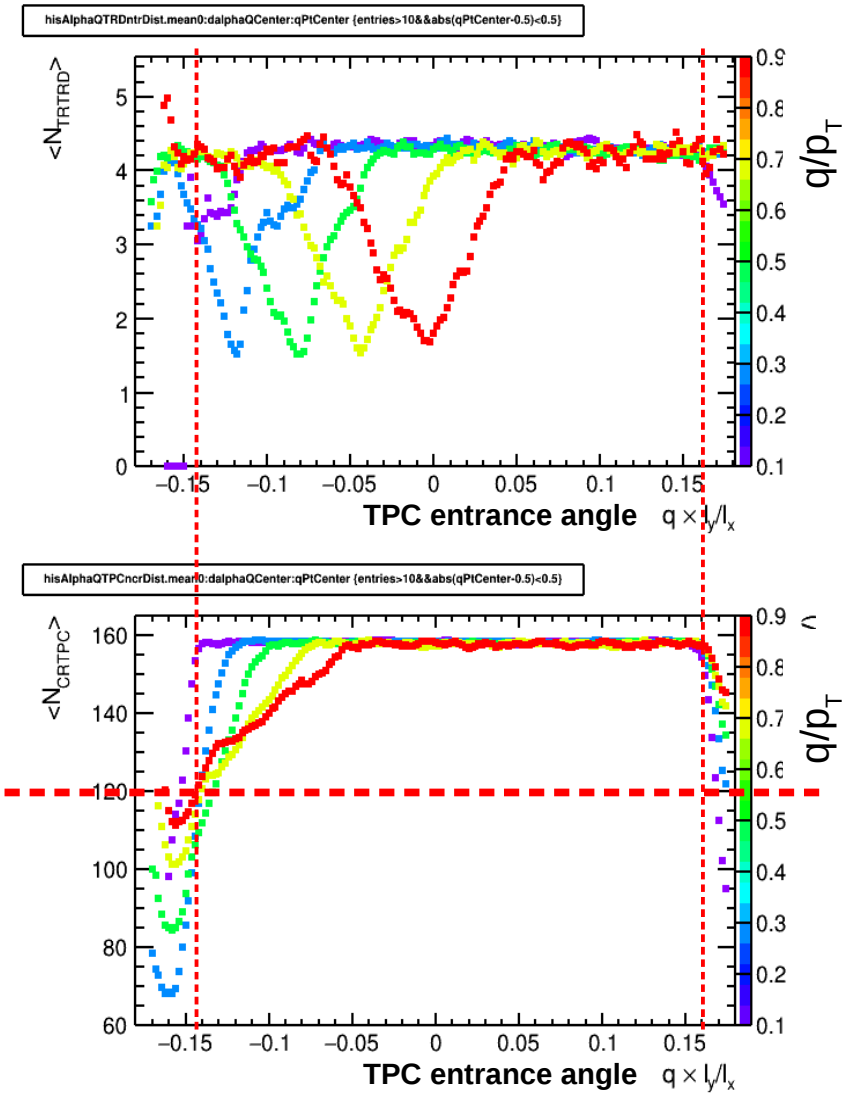


TRD dead volume rϕ~ 15 %
dead region - PHOS hole



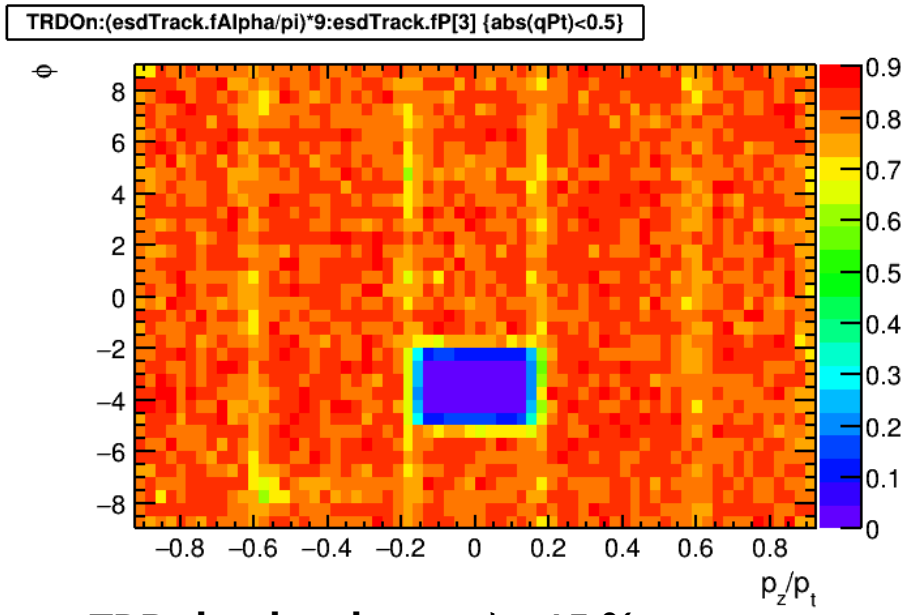
TPC
Δrϕ ~ 1.5 cm
10 % at l_x=83.6

TRD
Δrϕ ~ 7 cm
15 % at l_x 300cm



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

TPC+TRD acceptance (1)



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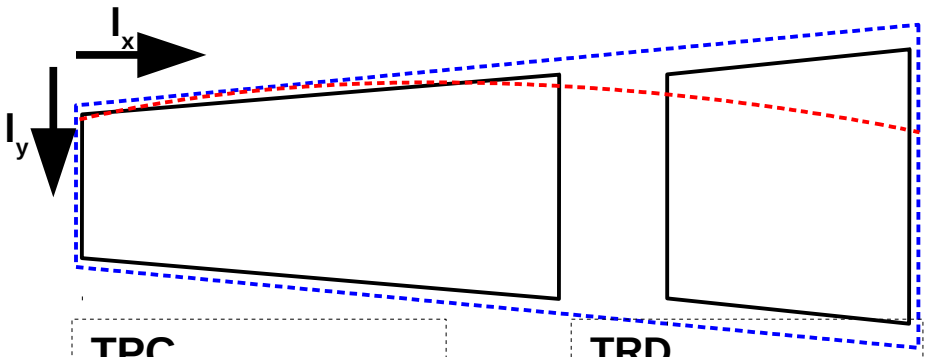

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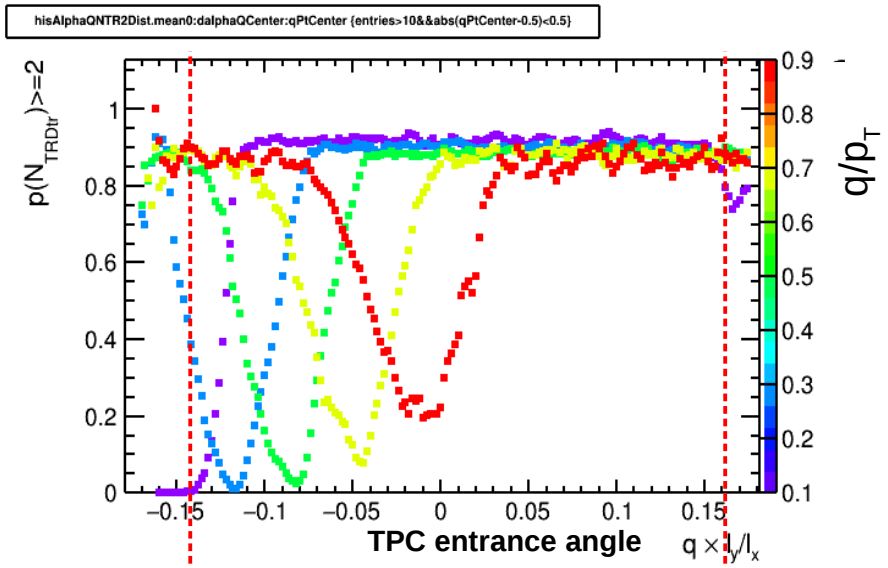
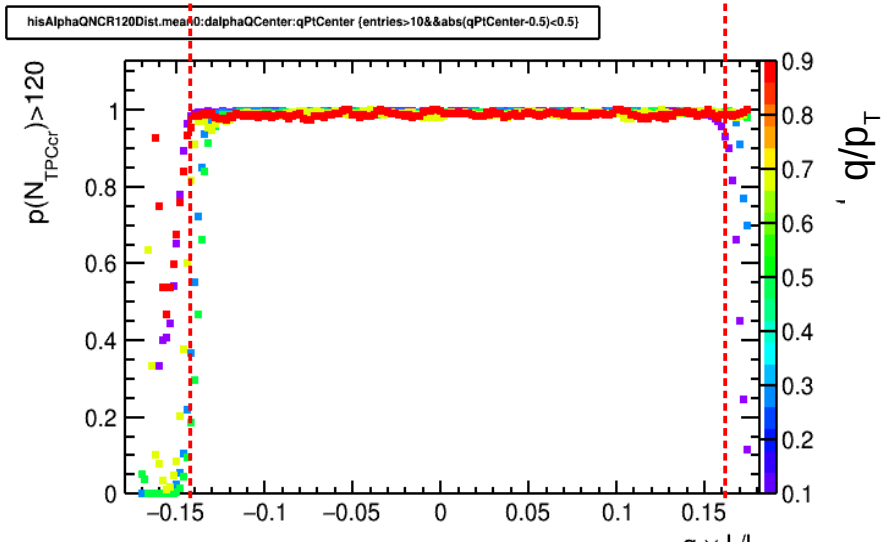
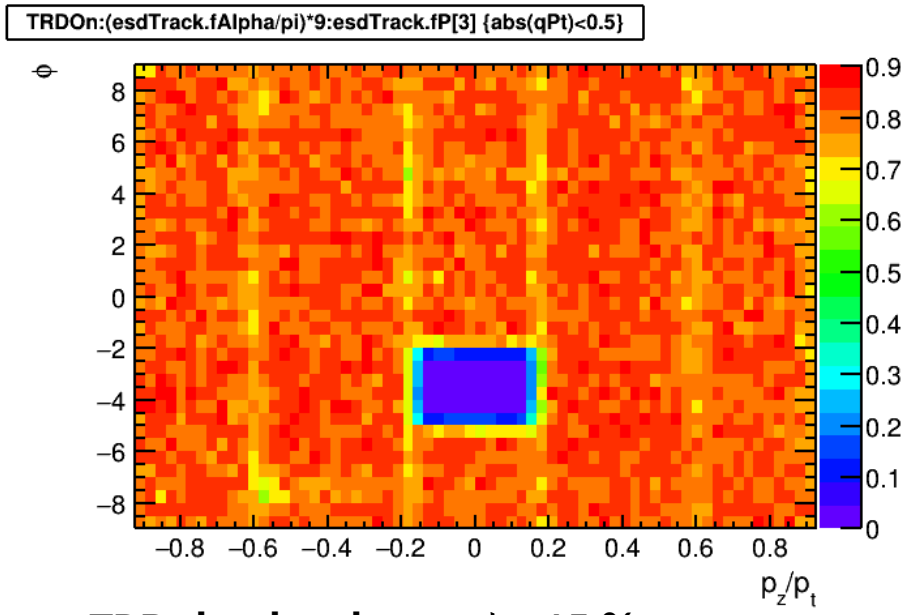


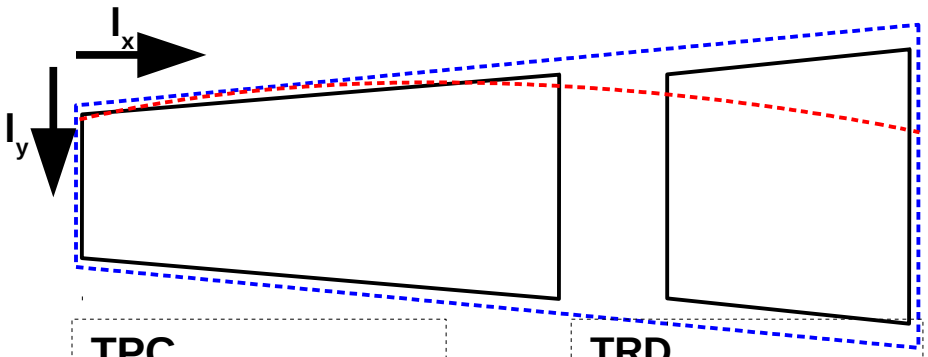


p(N_{det} >thr) vs local y position at the TPC entrance (lx=83.6 cm)

TPC+TRD acceptance (2)



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



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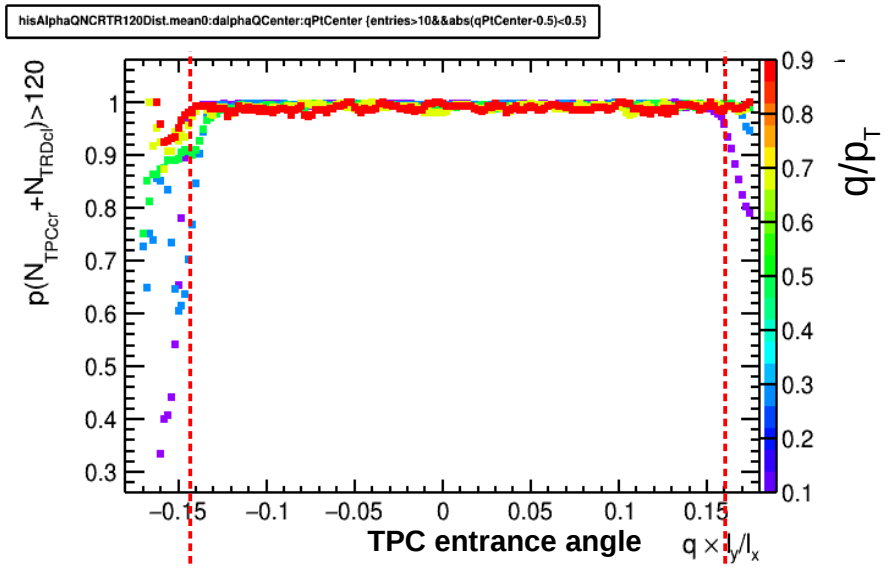
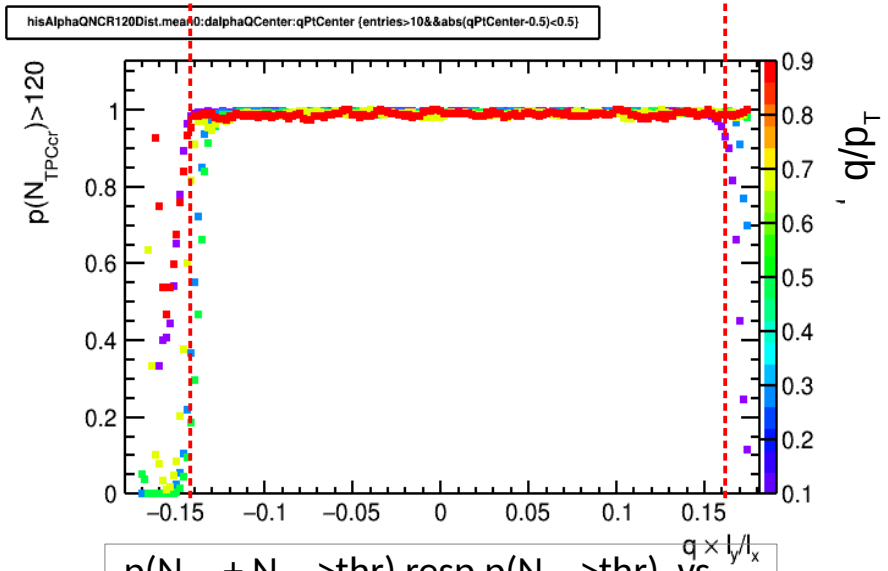
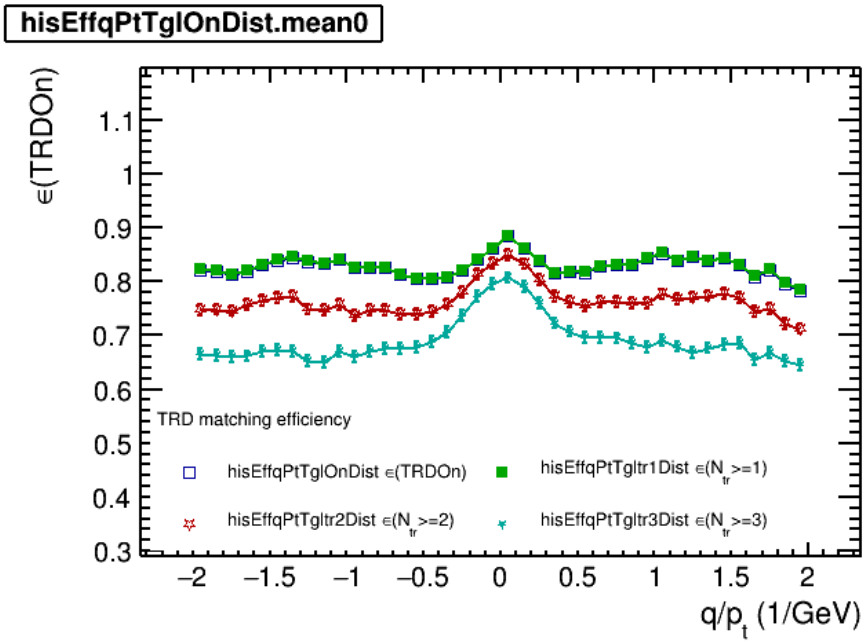
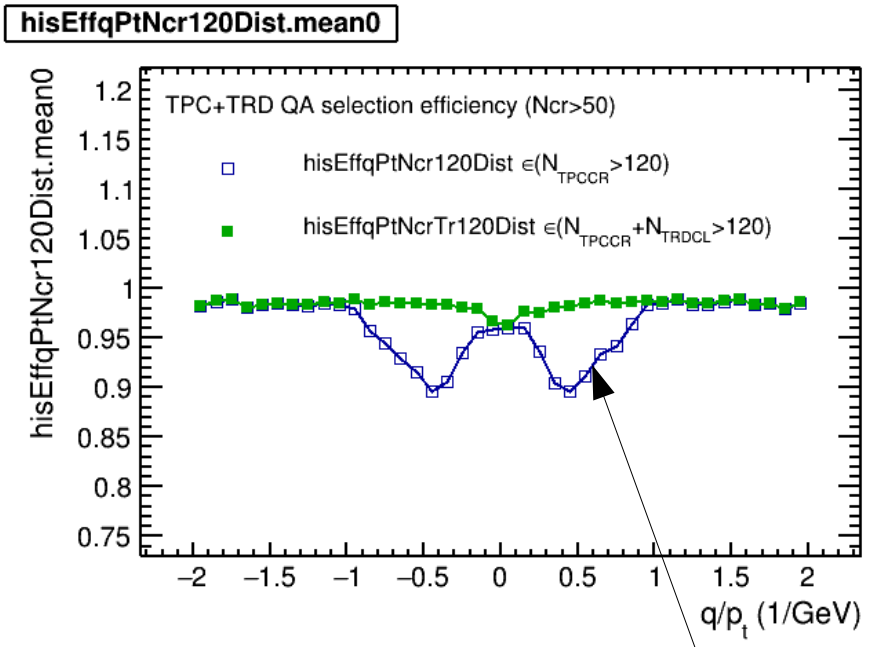




p(N_{TPC} + N_{TRD}>thr) resp p(N_{TPC}>thr) vs local y position at the TPC entrance (lx=83.6 cm)

Track cut efficiency at intermediate pt





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

- deep in the tracking efficiency at intermediate pt (1-5 Gev/c) can be recovered

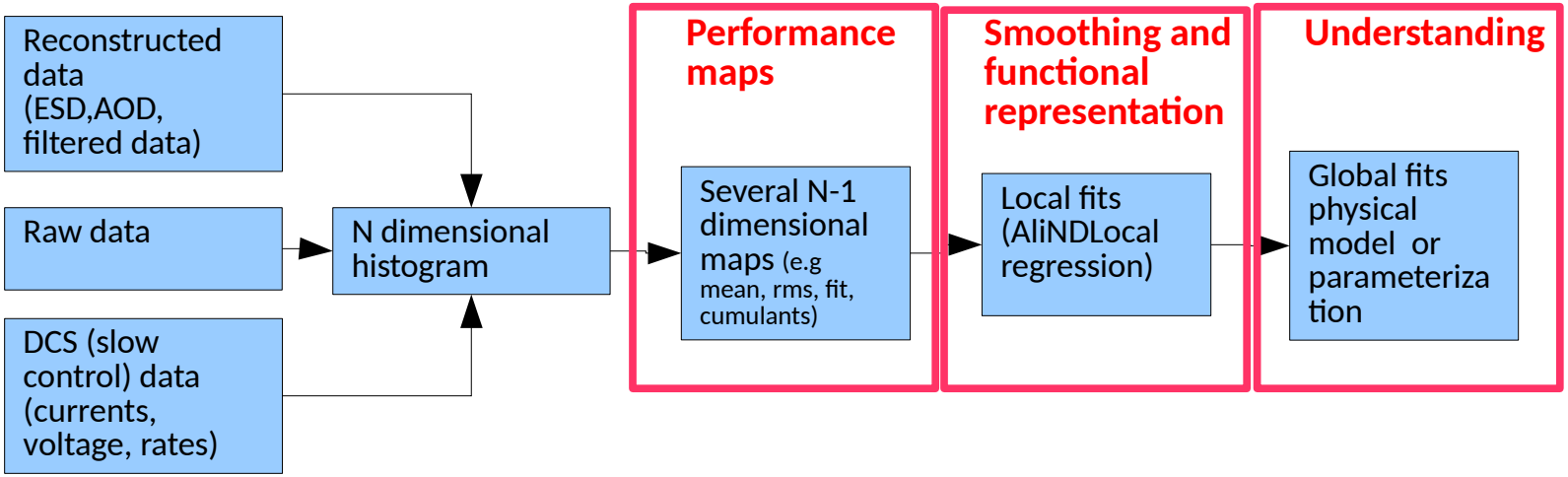
Requiring a minimal combined track length quality of the short TPC tracks will be not affected

Tracking efficiency will increase without compromising performance
Tracking efficiency flatter in space

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 - pipeline



My standard calibration, QA, performance maps done and interpreted in multidimensional space **(available for collaboration on the web)**

- dimensionality depends on the problem to study (and on resources)
- Data →Histogram → set of ND maps → set of NDlocal fits → Global fits
  - for all objects standard support of TFormula and TTreeFormula
  - combining different maps using interpreted (or compiled) functions (ration diffs fits)

Set of generic functions

Experts but also analyzers can understand detector

We can use knowledge of detector (QA, regression test, MC tune on data, ML)

Resolution,pulls and bias maps: Definition

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

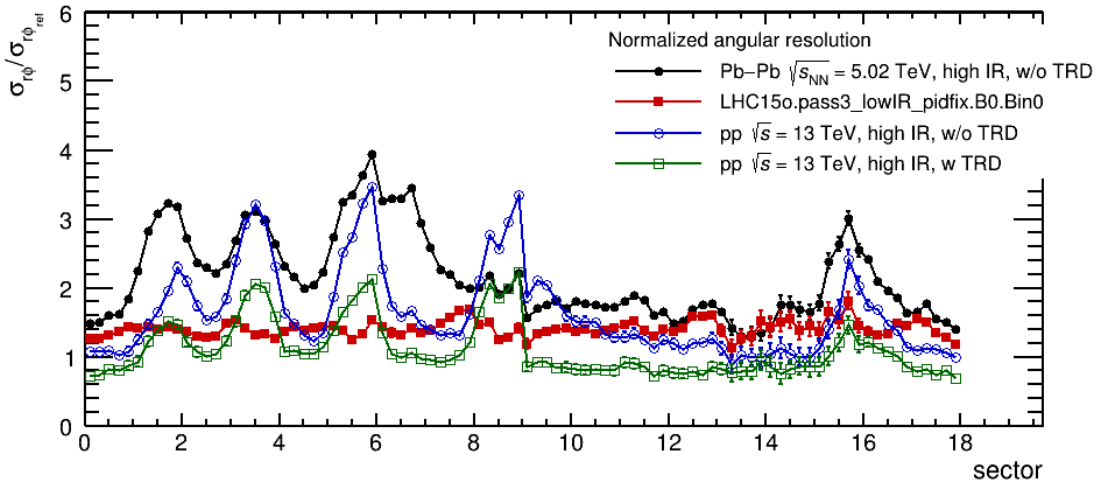
Performance maps created from distribution of Δ and pulls in many multi-dimensional histograms

- several statical information of PDF in bins extracted entries mean, rms, LTM, gauss fit

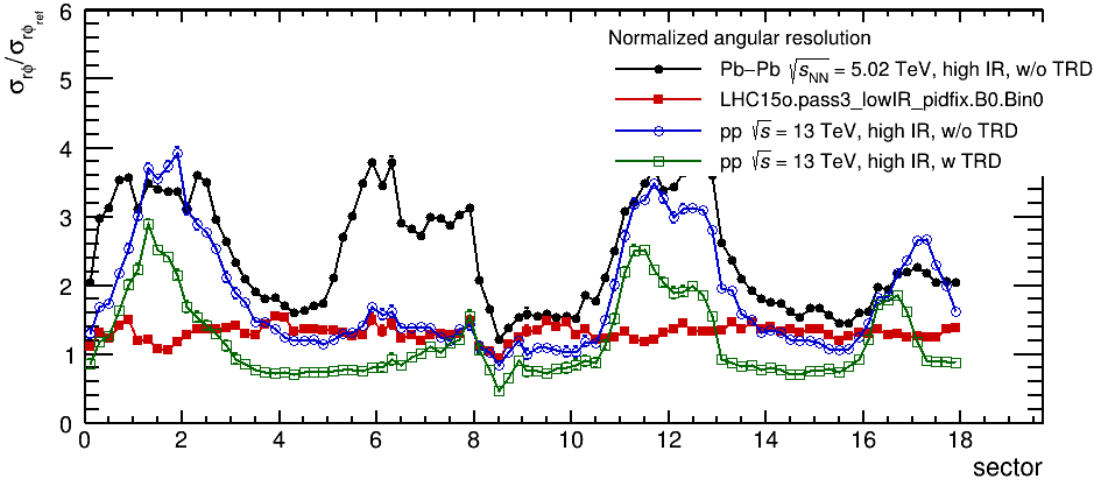
Next slides:

- DET0=TPC+(TRD)
- DET1=ITS+TPC+(TRD)
- 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

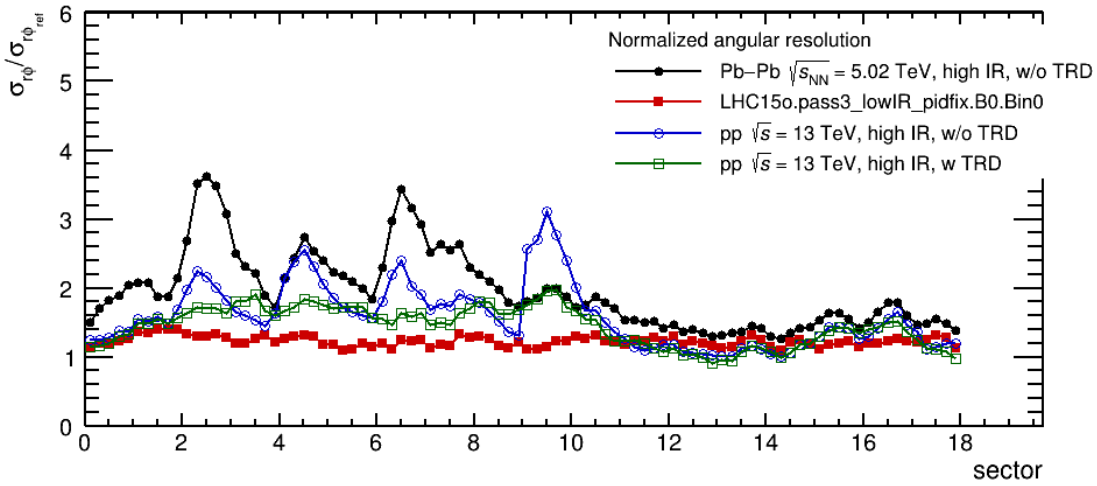
Significantly worse performance in region with **local distortion O(3-4)**

Using TRD significant improvement sector modulation reduced

More homogeneous performance

Overall performance better using TRD in refit

Constrained Angular resolution



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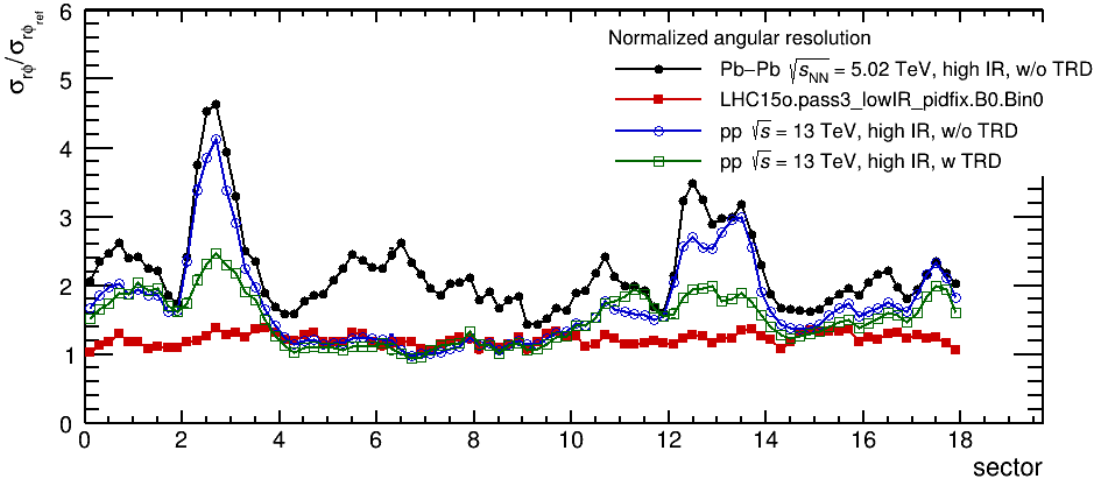

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Performance map normalized to reference performance map - pp low IR (LHC15n) w/o TRD

At high IR non flat performance map

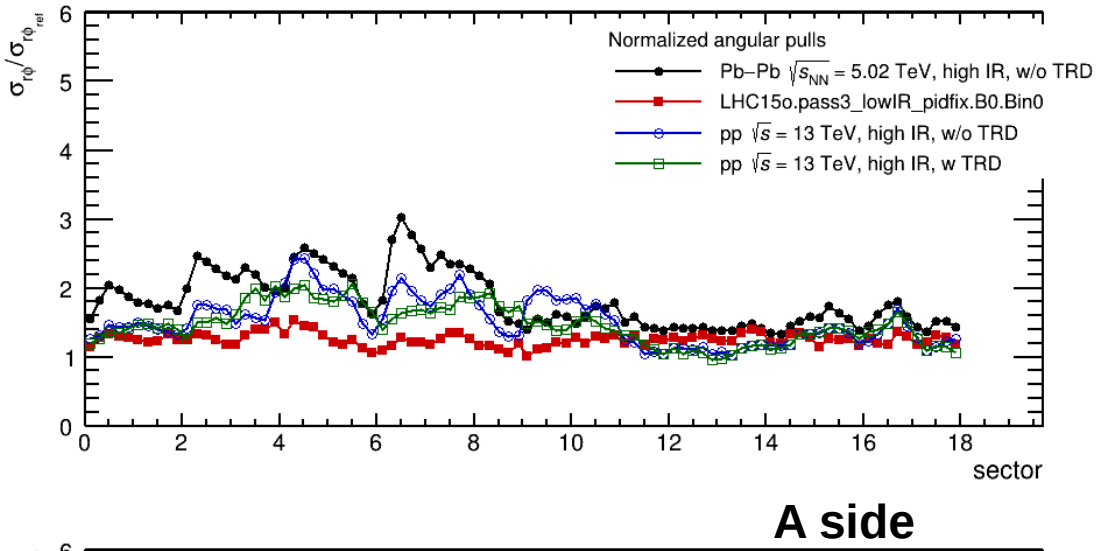
Significantly worse performance in region with local **distortion O(3-5)**

Using TRD significant improvement sector modulation reduced

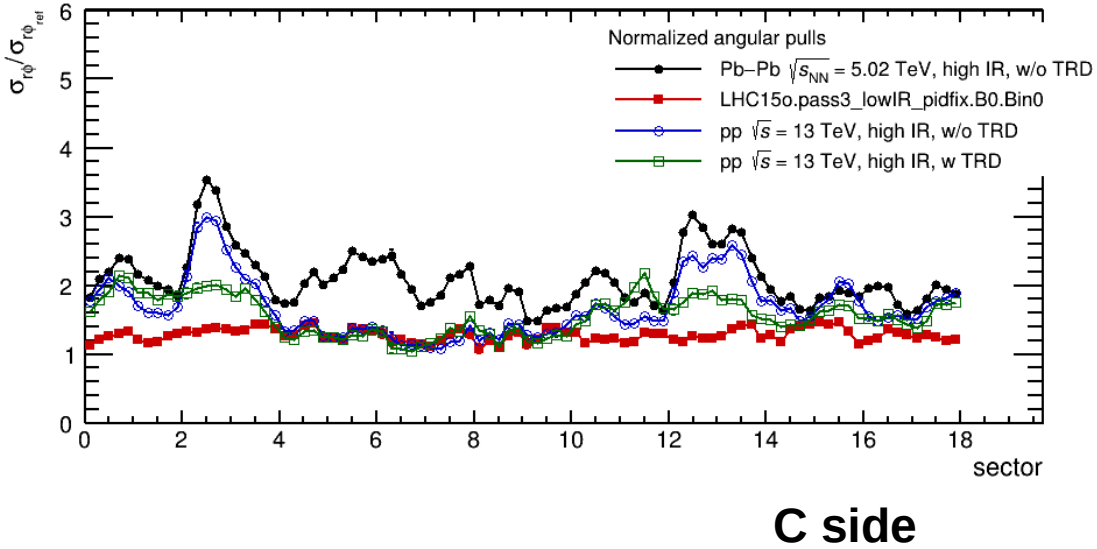
Using TRD more homogeneous performance

Overall performance better using TRD in refit

Const. Angular pulls: Comparison of the reco. productions



A side



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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)**

Using TRD significant improvement sector modulation reduced

Using TRD more homogeneous performance

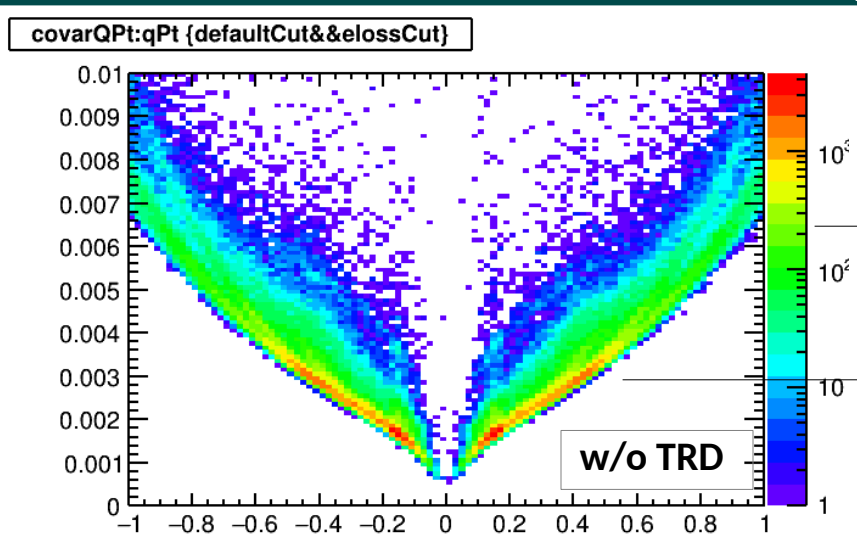
Overall performance better using TRD in refit

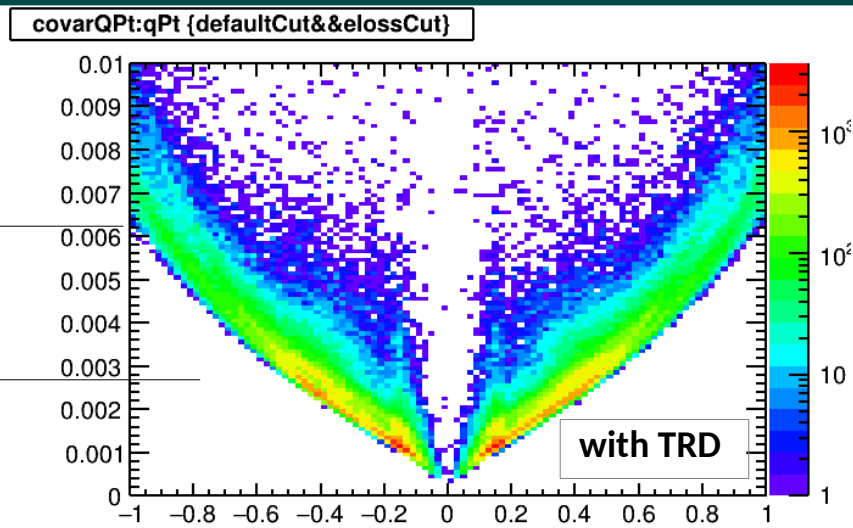
Q/Pt covariance matrix
With/Without TRD

* disclaimer. Structure at pt ~6 GeV because of trigger used
* disclaimer: Pure covariance matrix without pulls scaling. Real spread of resolution wider

* *Maybe I will finish with scaled version before the meeting*

Low IR: q/p_T covariance matrix





Q/p_T resolution as obtained from covariance matrix

- standard cuts+ additional cut on the energy loss between TPC and vertex (to be standard for high pt analysis)
- Left: reconstruction pass without TRD in refit
- Right: reconstruction pass with TRD in refit

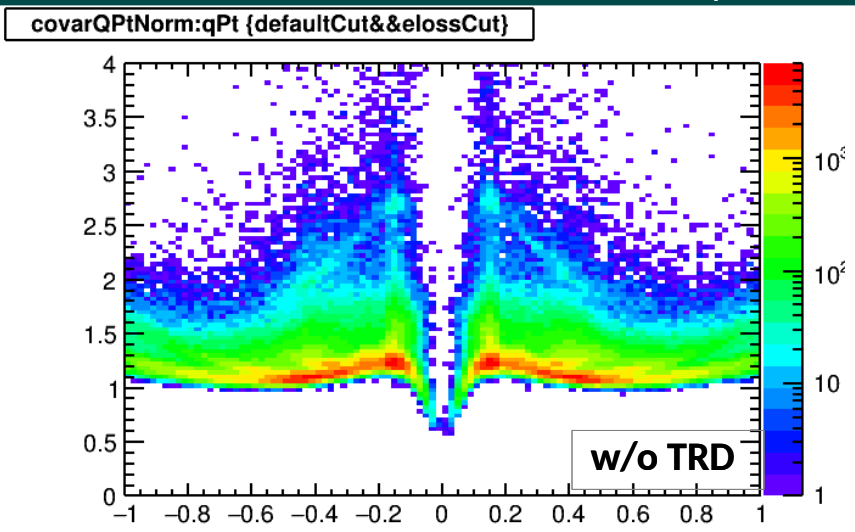
With/Without TRD comparable below 1 GeV

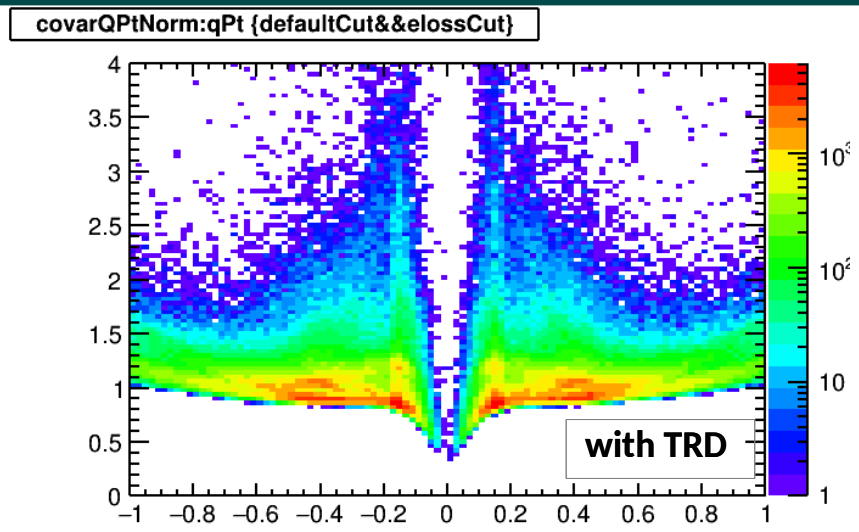
At higher pt TRD improve resolution

- 2 bands for tracks with/without TRD in refit

	w/o	with
1 GeV	~0.007	~0.0065
5 GeV	~0.0018	0.0012

Low IR: q/p_T normalized covariance matrix





Normalized Q/p_t resolution as obtained from covariance matrix

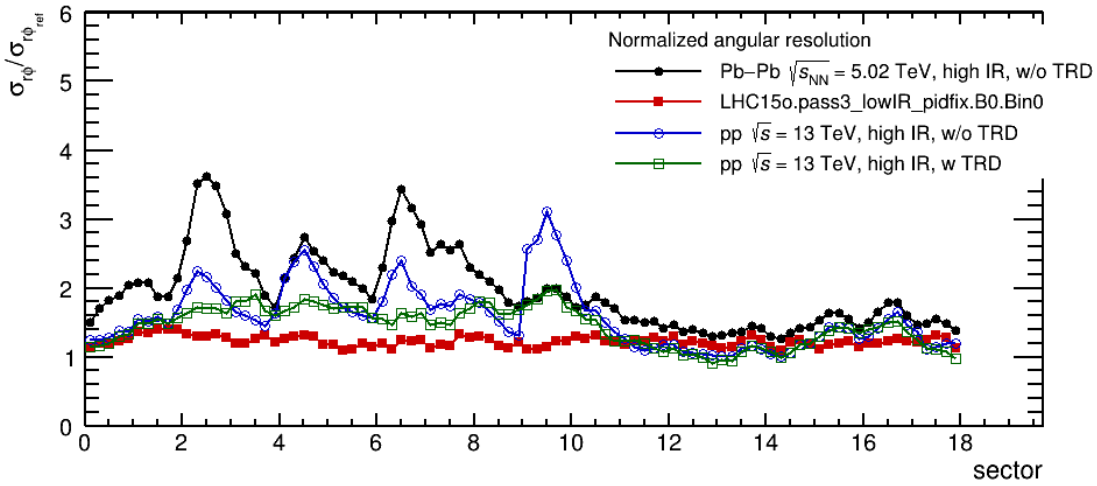
- standard cuts+ additional cut on the energy loss between TPC and vertex (to be standard for high pt analysis)
- Left: reconstruction pass without TRD in refit
- Right: reconstruction pass with TRD in refit

With/Without TRD comparable below 1 GeV

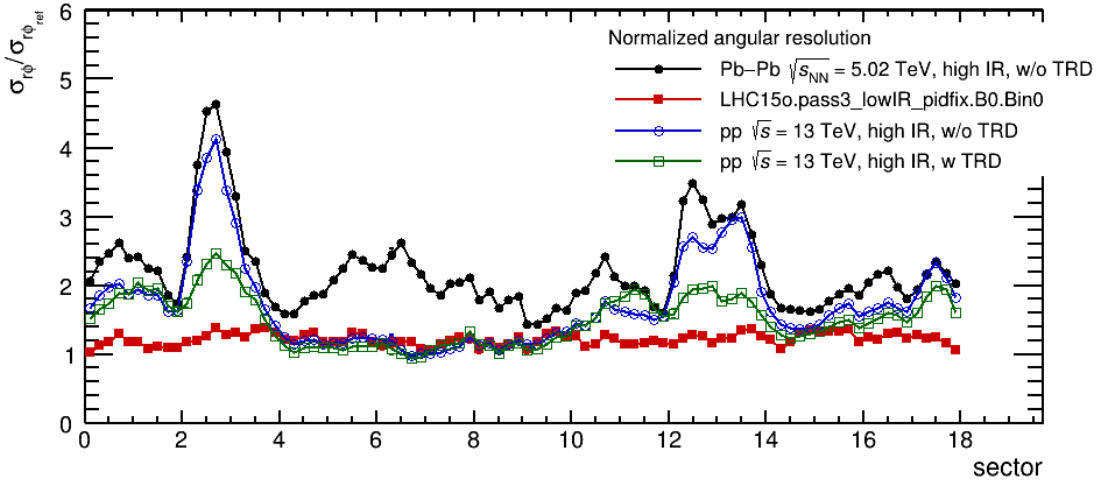
At higher pt TRD improve resolution

- 2 bands track with/without TRD

Placeholder. High IR performance modulation



A side



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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

P_T resolution unfolding

Different performance of the tracking (q/P_T resolution) always there

- different track length, theta inclination angle
- At High IR strong local variation because of local distortion fluctuation
  - resolution at distortion region significantly worse than in good region
- **Using TRD local variation of performance is strongly reduced**

In the Raa analysis histogram of the Q/p_T resolution was used for the unfolding

- **Generally recommended strategy**

Duplication of track parameters

Duplication of the track parameters **not recommended:**

- more information to be stored which we can not afford
  - all tracks above 1 GeV/c profit
- more CPU - refit 2 times
- strong modification of the tracking and analysis code
- **Not clear benefits - data samples not homogeneous anyway**
  - expected performance at 2018 (Ar, small distortion) should anyway differ
  - 2015,2016 (Ar- big distortions)
  - 2017 (Ne - smaller distortion)
  - 2018 - Ar - small distortion expected thanks to hardware modifications

Performance improvement should be confirmed by central production

- with/without TRD
- TRD 2 legs jet trigger (and calorimeter) trigger to be used

Executive summary (pp)

TRD tracking commissioned using **pp data** sample one year ago

TRD tracking is ready to be used for the pp data taking. Not further code development needed.

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

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

Local performance worsening due to the TPC space charge distortion **strongly mitigated → more homogenous performance**

TRD in the reconstruction for PbPb

PbPb reconstruction/update

Tracking performance at PbPb significantly worse than in the pp

- chi2, dca resolution,pulls …
- TOF fakes …
- Estimated about 30-50 % worsening for MB
  - ??? for PbPb central
  - 5 time higher mean occupancy - in Run3

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

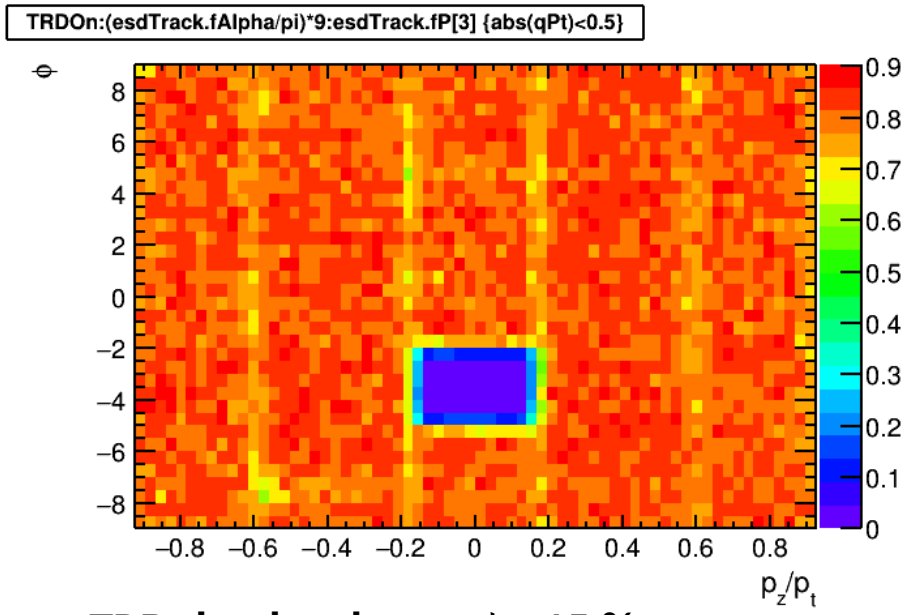
- cluster filter as in the calibration
- cluster error estimate using local properties
- prototype for the TRD tracking exist

TOF fake tagging using the TRD information

- simple ncluster counter/nfindable counter in the TPC ↔ TOF interpolation
- material budget counter in the TPC ↔ TOF interpolation
  - improved version of my old TOF tracking algorithm

Development important for high interaction rate data taking at RUN3

TOF/TRD tagging



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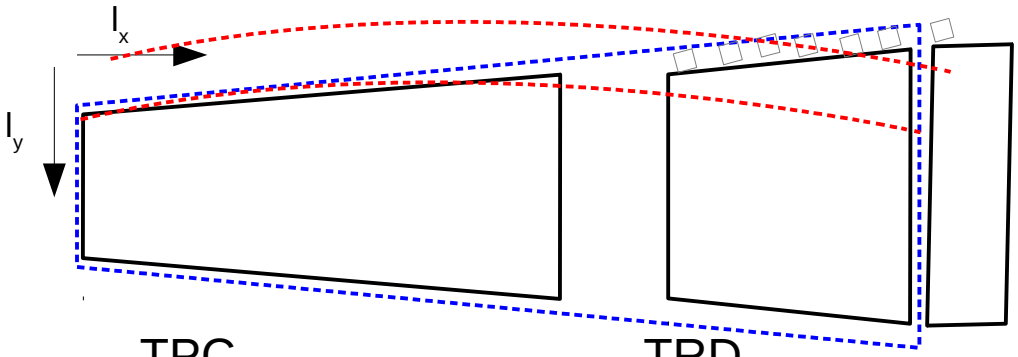

TPC
Δrϕ ~ 1.5 cm
~ 10 %

TRD
Δrϕ ~ 7 cm
~ 15 %

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

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

TRD can be used to clean the TOF background

- **tagging (probability) track exist**
- **TRD TOF as one tracking detector**

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

TOF/TRD tagging - status

Active volume selection:

- TRD dead detector map - OK
- TRD dead zone in rf query OK
- TRD boundary cross counter

Code/query to be moved to STEER part to enable interactive queries (e.g in ESD or AOD trees)

Code to be commissioned, exercised with nuclei analysis

Executive summary (PbPb)

TRD in combined tracking for PbPb - to be commissioned with additional improvements related to **high occupancy tracking**

- TOF fakes tagging (removal)
- significant degradation of performance as function of occupancy
- outliers filtering TPC+TRD O(50 %) improvement expected

Important development for RUN2

Even more important for RUN3

- **5-10 time higher occupancy - 50 KHz instead of the 8 kHz in Run2**