

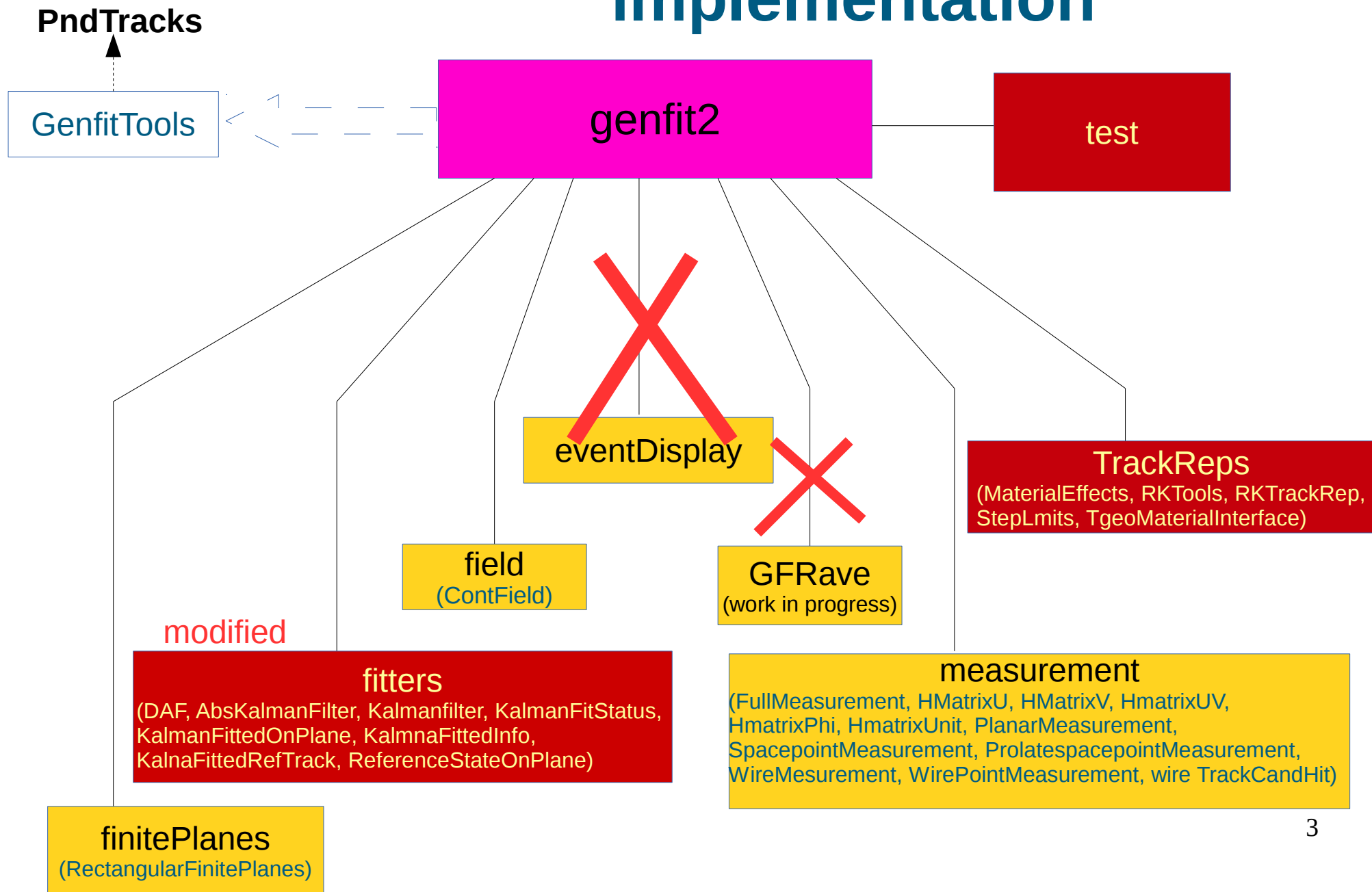
Implementation of Genfit2 in PandaRoot: update

50th PANDA Collaboration Meeting, Frascati (IT)

Elisabetta Prencipe | 8th September 2014 | Forschungszentrum Jülich

Status and perspectives

Structure of the tool – modification implementation



- Trunk rev-25545 was tested (standard revision)
- *genfit2* has been introduced also in the **rev 25545** (branch development).
- Preliminary, stable branch development:
<https://subversion.gsi.de/trac/fairroot/browser/pandaroot/development/prencipe>

Last fixes are in the branch development:

<https://subversion.gsi.de/trac/fairroot/browser/pandaroot/development/genfit2>

where Johannes Rauch (TUM) and me have committed recently the code.

- Main change: **/GenfitTools/trackrep** is NOT there any further
/genfit2/trackReps is used instead
- **State vector** is not in trackReps/RKTrackRep
- **Track follower** is part of the genfit2 tool, now
- In /development/genfit2: different genfit tool structure.
It required changes in several pandaroot packages:
/lmd/, /hyp/, /hypGe/, /stt/, /mvd/, /GenfitTools/, and few other small changes...

Tracking classes are changed in these packages: new version already provided. You can find modifications in: **/development/genfit2/**

- /gentif2/ provides the Kalman equations and the track representation
- /genfit2/ is announced to be a general tool, for every B field
- /genfit/ (rev 400) and /genfit2/ (rev 1731) are NOT compatible;
the current branch developed does not provide a switch to run both versions.
/genfit2/ is ported into /pandaroot/development as external package.
- **First tests in trunk rev 20185 w/o genfit2 were presented @last c.m.**
 - tools running, and *mainly* working: improvement shown in resolution of p , r
 - problems with the detID were found
 - problem to access the McTruth from GetMcTruth() in standard pandaroot macros.
- **Today: 2 fixes in trunk rev 25545 are presented**
 - no problems to get the correct detID
 - no problems to access true values through GetMcTruth()
 - pull distribution will be shown.

Testing the standard trunk rev-25545....

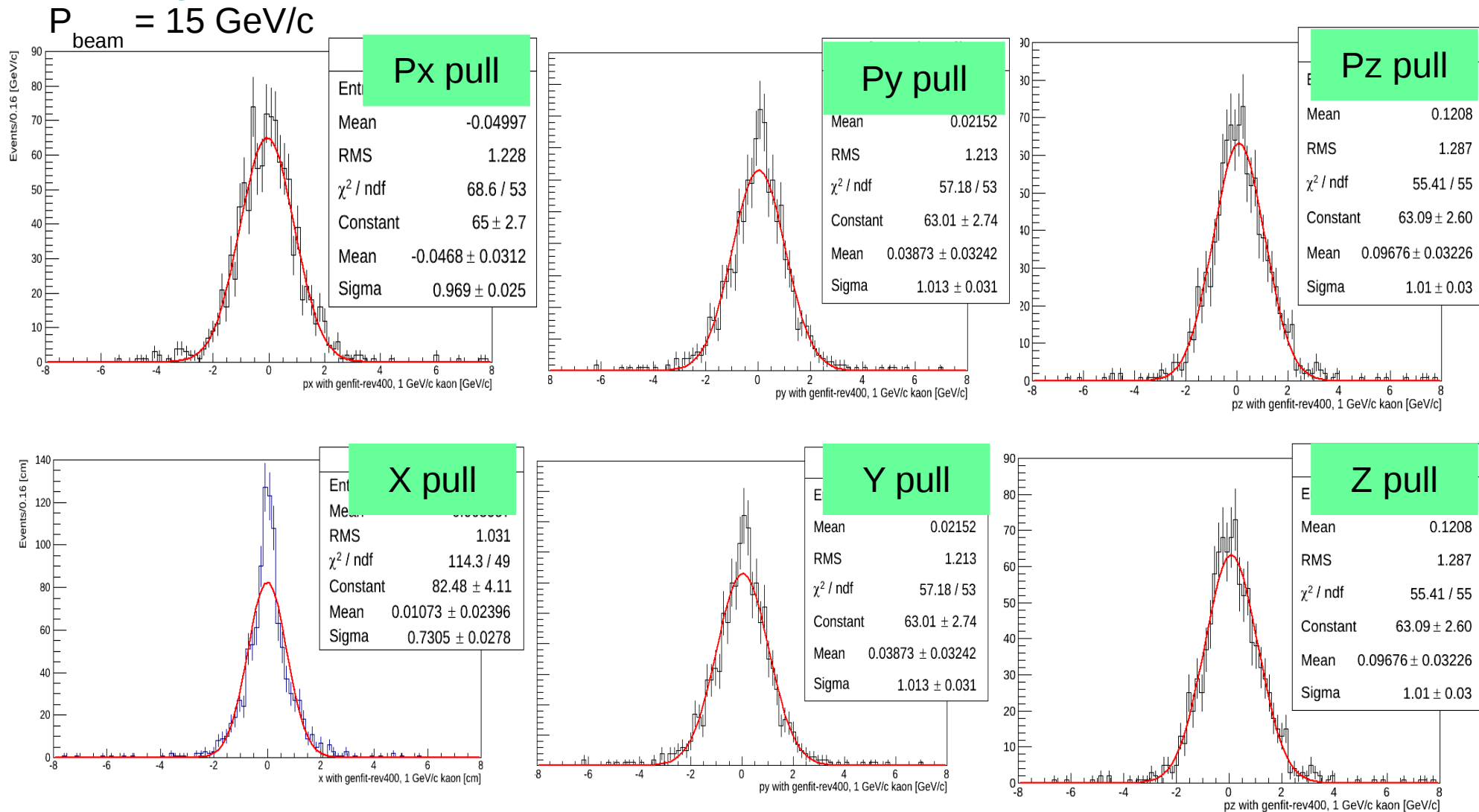
- Many informations are accessible by mean of /rho/ classes
- Basic variables to check: p_x , p_y , p_z , e , x , y , z
- Need to test:
 - ▶ reconstructed variables
 - ▶ true values
 - ▶ error distributions
- Kalman filter applies to reconstruction (central tracker)
- The equation of the motion of a charged particle (track) in a magnetic field is linear in 5 parameters:

$$z_0, d_0 = \text{Sqrt}(x^2 + y^2), \text{curvature} (\propto Q/p_t), \tan\lambda (p \cdot \cos\lambda = p_t), \phi$$

- These parameters refers to the POCA:
 - ▶ tracking parameters are built
 - ▶ error propagation: information accessible by RhoError/Cov7(i,j)
 - ▶ resolution and pull of these parameters are investigated

$$\text{Pull} = \frac{\text{var}_{\text{reco}} - \text{var}_{\text{gen}}}{\text{err}_{\text{reco}}}$$

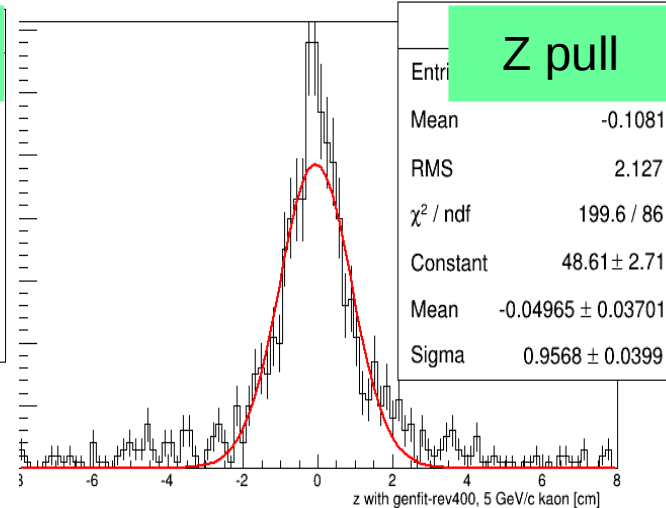
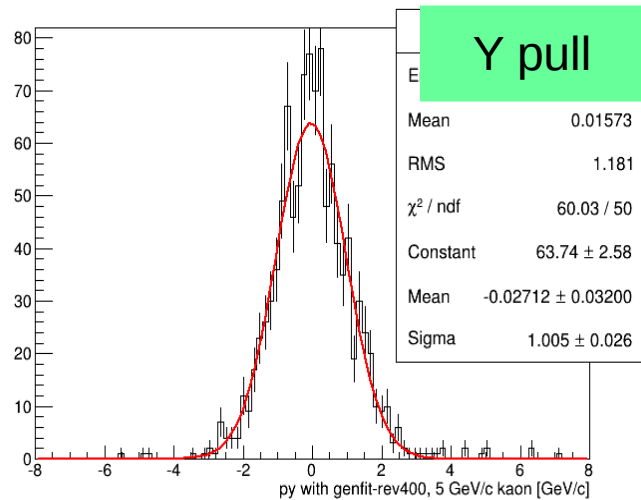
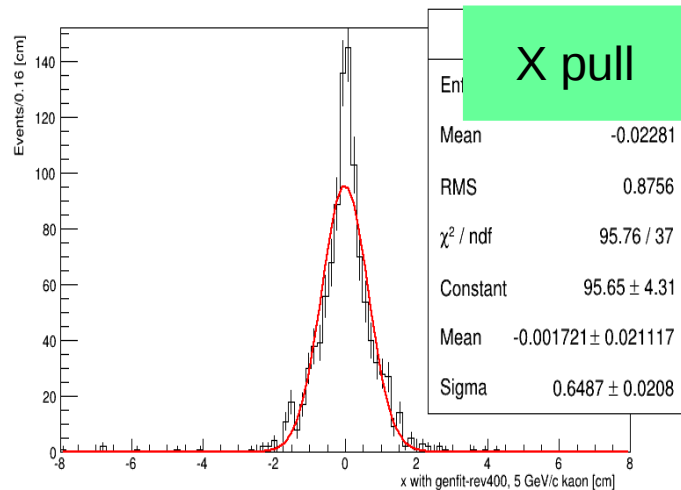
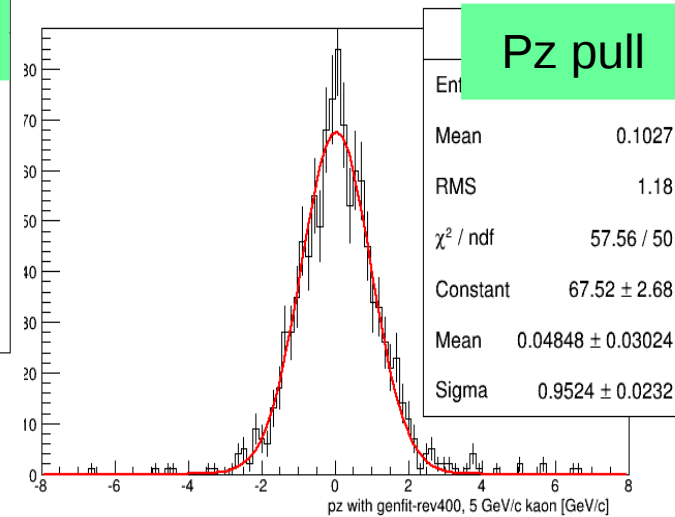
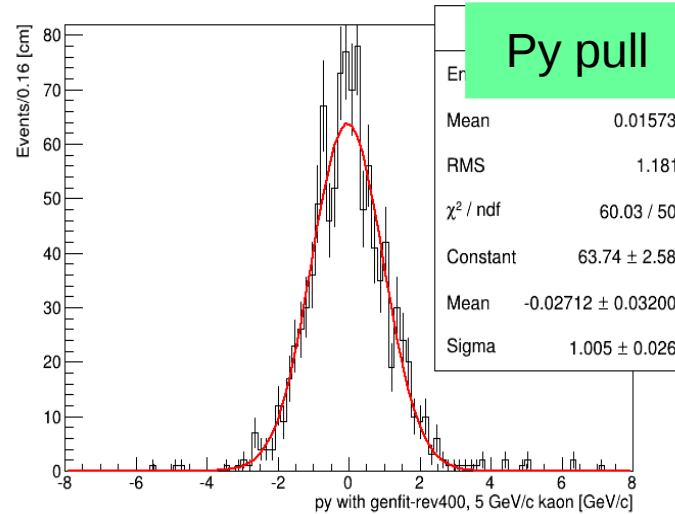
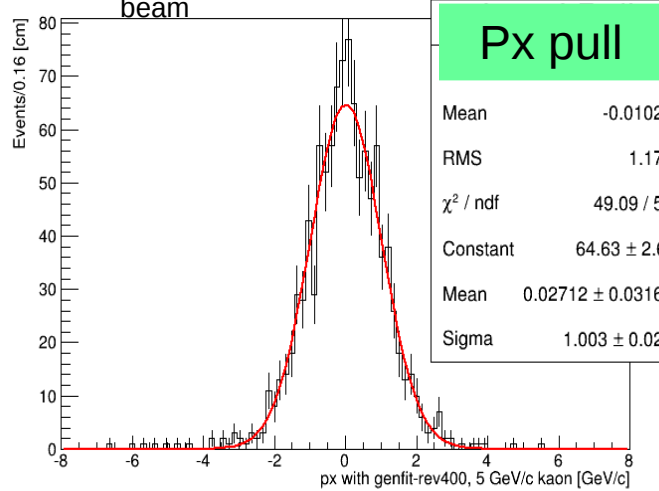
Testing the standard trunk rev-25545: pull (K^- , 1GeV/c)



- Basic test with **2500 K^-** , Box generator used, **$p = 1 \text{ GeV/c}$** : good on y, z, p_x , p_y , p_z ; not for x.
- 2101/2500 = 84% track selected and identified as **kaon** with PID = "best" ($p_K > 0.1 \text{ GeV/c}$)

Testing the standard trunk rev-25545: pull (K^- , 5 GeV/c)

$P_{\text{beam}} = 15 \text{ GeV/c}$



- Basic test with **2500 K^-** , Box generator used, **$p = 5 \text{ GeV/c}$** : good on y, z, p_x , p_y , p_z ; not for x.
- 2190/2500 = 88% track selected and identified as **kaon** with PID = "best" ($p_K > 0.1 \text{ GeV/c}$)

Debugging the standard trunk rev-25545

- 88% reconstructed tracks, with $p \geq 1$ GeV/c

starting track0
PndRecoKalmanFit::Fit
28 hits in track
SUCCESSFULL FIT!
Fitting done

- Problems frequently found:

starting track1
PndRecoKalmanFit::Fit
27 hits in track
GFException thrown with excString:
distance poca-wire > maxdistance
in line: 115 in file: /home/prencipe/panda/Rev25545/genfit/**GFWireHitPolicy.cxx**
with fatal flag 0
GFException thrown with excString:

GFException thrown with excString:
findpca failure
in line: 387 in file:
/home/prencipe/panda/Rev25545/GenfitTools/trackrep/GeaneTrackRep/**GeaneTrackRep.cxx**
with fatal flag 0
GFException thrown with excString:
findpca failure

Debugging the standard trunk rev-25545

```
starting track0  
PndRecoKalmanFit::Fit  
7 hits in track  
GException thrown with excString:  
GeaneTrackRep: PROTECT AGAINST LOW MOMENTA  
in line: 178 in file:  
/home/prencipe/panda/Rev25545/GenfitTools/trackrep/GeaneTrackRep/GeaneTrackRep.cxx  
with fatal flag 0  
SUCCESSFULL FIT!  
Fitting done
```

```
Fitting done  
PndRecoKalmanTask::Exec  
-|- PndRecoKalmanTask: contains 0 Tracks.  
Fitting done  
Found 0 tracks  
Error in ERTRAK : No prediction. Tracking stops now
```

Error in ERTRAK : No prediction. Tracking stops now ← 58/2500 ~2.3%

A window of improvement

- Tracking is the core of physics analysis
- Window of improvement in tracking to gain efficiency and better resolution
- Bugs were found in *genfit* (rev 400): need to fix → *genfit2*
- To write again “*genfit*”-equivalent code would need lot of time and manpower
- As attempt, we can start to replace *genfit2* to *genfit*, and test pandaroot
- Goal in PANDA: to track particles with different B fields;
to track low momentum particles with degraded resolution
⇒ e.g., needed for Charm Physics and QCD dynamics

Testing the modified trunk rev-25545

- Modified trunk rev-25545 —————▶ /development/genfit2
- /genfit2/ is introduced in pandaroot as external package: rev-1731
- /genfit2/ is currently used in the new Belle2 framework

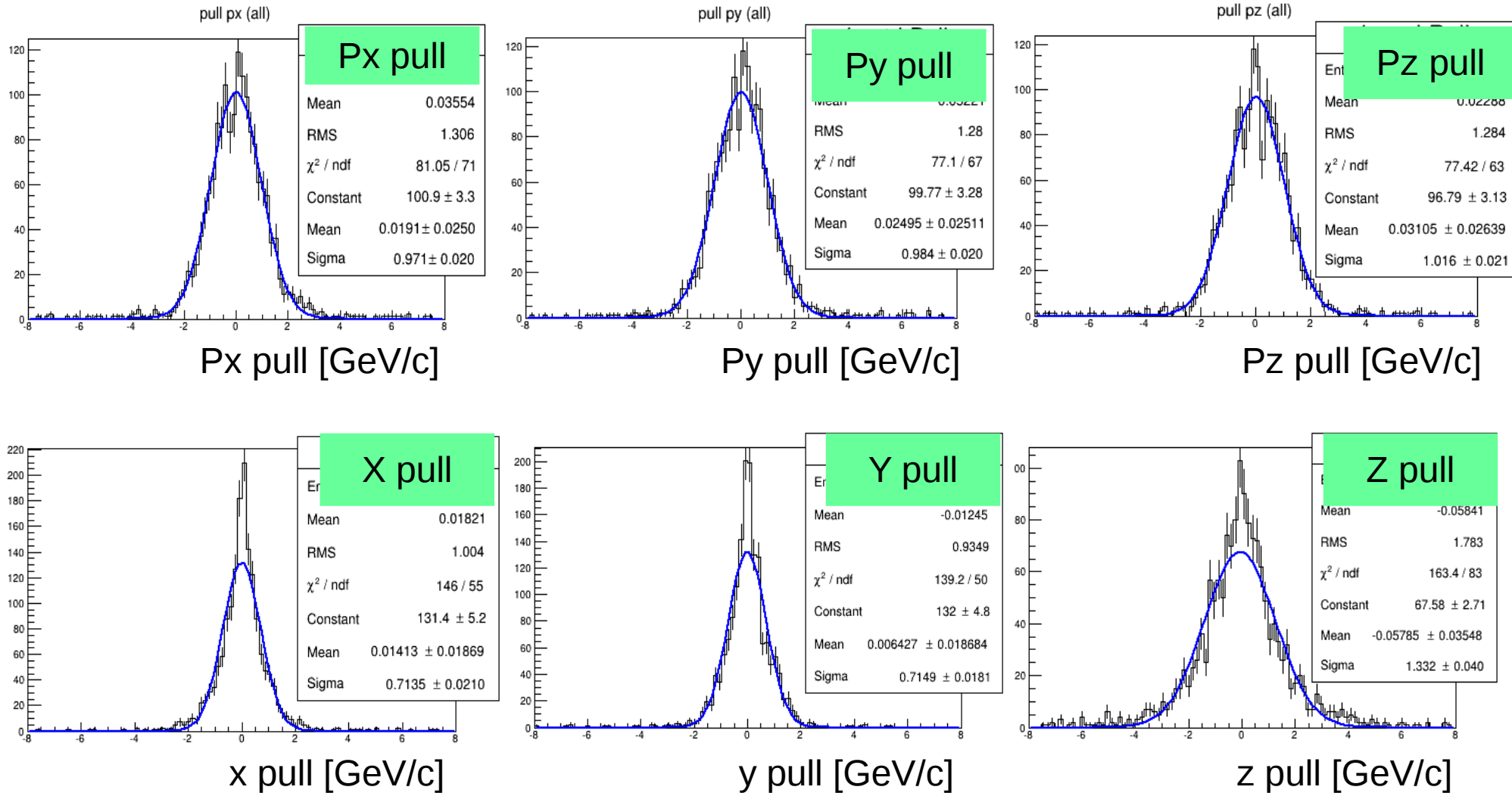
In this report:

- Track = kaon hypothesis checked, $p = [0.1; 5.0]$ GeV/c
- Positive and negative tracks are checked
- Study of resolution and pull distributions are presented
- Comparison between *genfit* and *genfit2* is shown
- All PANDA detectors are included in these full simulations

Testing the modified trunk rev-25545

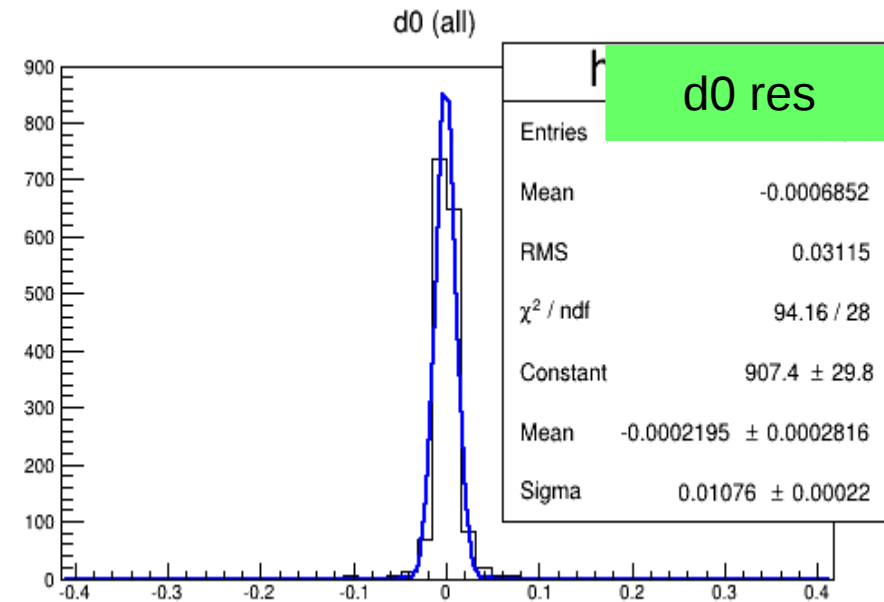
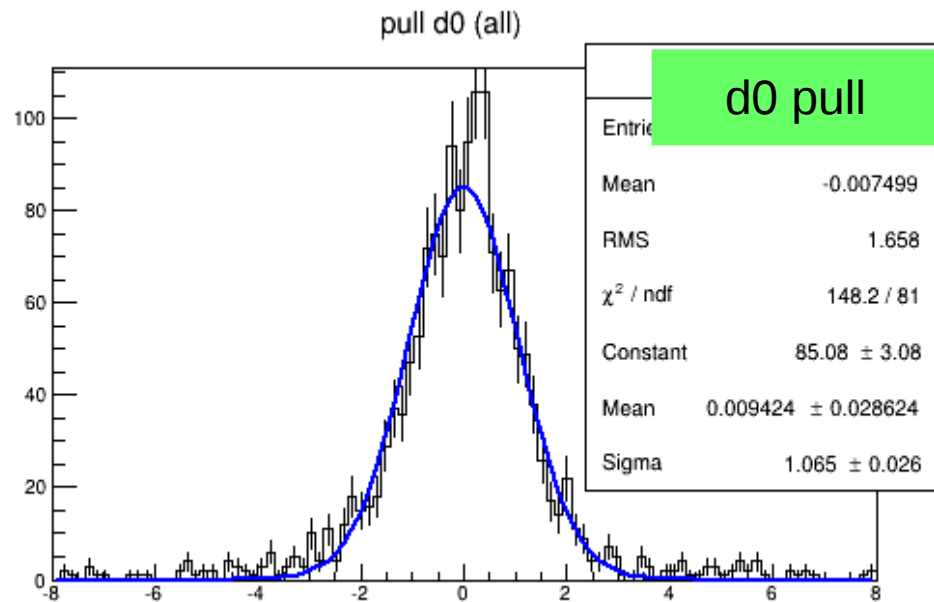
with genfit2

Hypothesis = K^- , $p = 1 \text{ GeV}/c$; $p_{\text{beam}} = 15 \text{ GeV}/c$; PID = "best"; sample: 2500 evt



Testing the modified trunk rev-25545

with genfit2



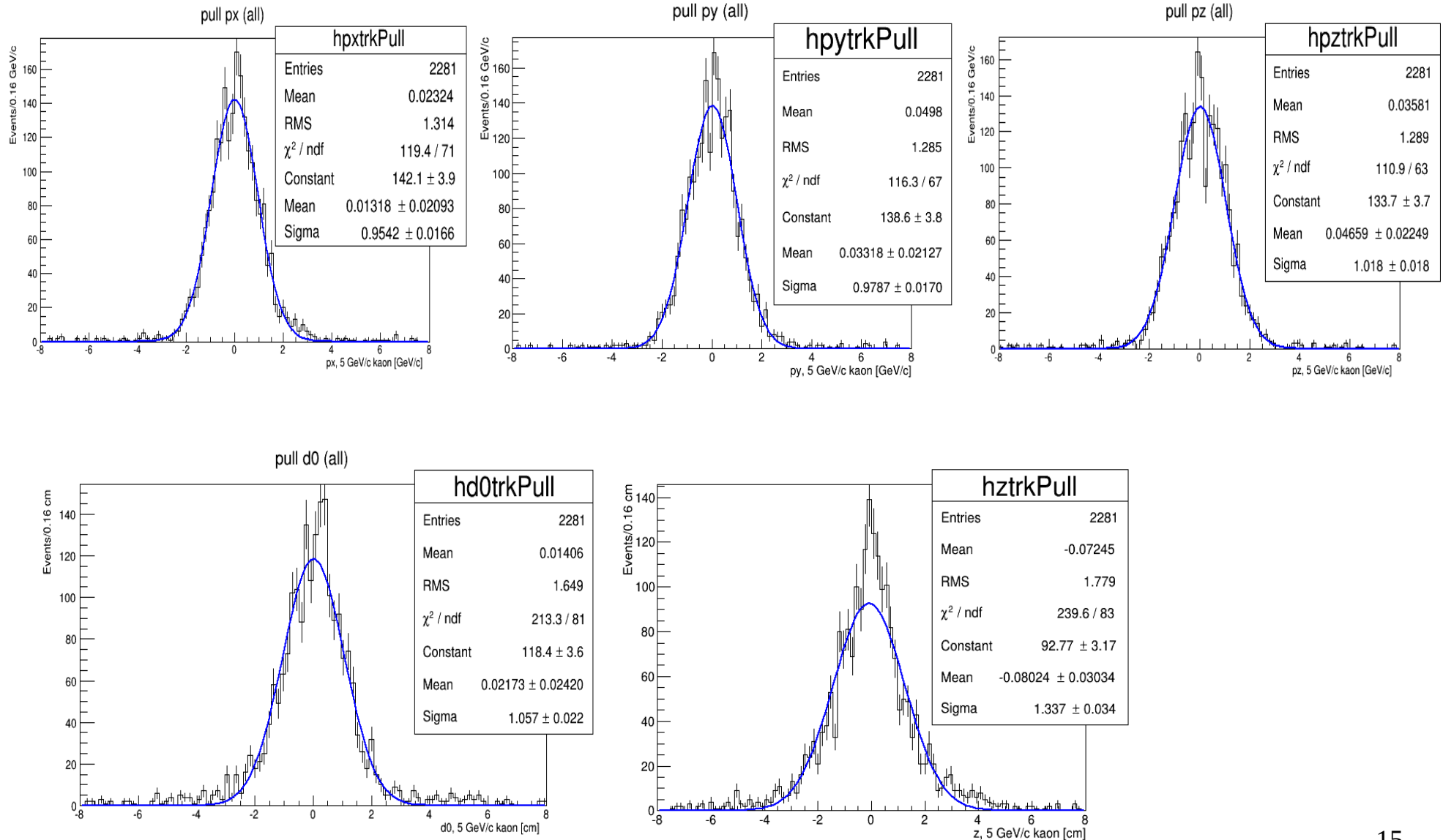
$$\text{Pull} = \frac{\text{var}_{\text{reco}} - \text{var}_{\text{gen}}}{\text{err}_{\text{reco}}}$$

$$\text{Res} = \text{var}_{\text{reco}} - \text{var}_{\text{gen}}$$

- Width of pull distributions ~ 1 even with only 2500 generated events: **GOOD!**

Testing the modified trunk rev-25545

Hypothesis = K^- , $p = 5 \text{ GeV/c}$; $p_{\text{beam}} = 15 \text{ GeV/c}$; PID = "best"; sample: 2500 evt



Debugging the modified trunk rev-25545

with genfit2

TEST 1: from Genfit to PandaRoot

===== TrackCand::print =====

TrackCandHit. DetId = 25	HitId = 2	PlaneId = 0	SortingParameter = 0
TrackCandHit. DetId = 25	HitId = 0	PlaneId = 1	SortingParameter = 1
TrackCandHit. DetId = 25	HitId = 1	PlaneId = 2	SortingParameter = 2
TrackCandHit. DetId = 27	HitId = 0	PlaneId = 3	SortingParameter = 3
		
TrackCandHit. DetId = 20	HitId = 17	PlaneId = 22	SortingParameter = 22
TrackCandHit. DetId = 20	HitId = 18	PlaneId = 23	SortingParameter = 23
TrackCandHit. DetId = 20	HitId = 19	PlaneId = 24	SortingParameter = 24
TrackCandHit. DetId = 20	HitId = 20	PlaneId = 25	SortingParameter = 25
TrackCandHit. DetId = 20	HitId = 21	PlaneId = 26	SortingParameter = 26

SUCCESSFULL FIT!

fitStatus

track has been fitted, fit has converged fully, 0 TrackPoints could not be processed, fitted charge = -1

track has been fitted with reference track, numIterations = 3, track length = 55.376, fChi2 = 48.4848, bChi2 = 48.4889, fNdf = 27, bNdf = 27, fPVal = 0.00677469, bPVal = 0.00676751

Debugging the modified trunk rev-25545

with genfit2

TEST 2: from PandaRoot to genfit

===== TrackCand::print =====

TrackCandHit. DetId = 25	HitId = 2	PlaneId = 0	SortingParameter = 0
TrackCandHit. DetId = 25	HitId = 0	PlaneId = 1	SortingParameter = 4.20163
TrackCandHit. DetId = 25	HitId = 1	PlaneId = 2	SortingParameter = 4.91853
TrackCandHit. DetId = 27	HitId = 0	PlaneId = 3	SortingParameter = 10.6507
TrackCandHit. DetId = 27	HitId = 1	PlaneId = 4	SortingParameter = 15.9073

....

Fitting done

PndRecoKalmanTask: itr=0 nhits30 -- 25 25 27 27 27 27 20 20 20 20 20 20 20
 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20

Fitting done

- This is typically what one can read when the track is successfully fitted.
- What happens when the fit fails?

1st TYPE of problems

TrackCandHit. DetId = 25	HitId = 2	PlaneId = 0	SortingParameter = 0.37393
TrackCandHit. DetId = 25	HitId = 1	PlaneId = 1	SortingParameter = 0.570593
TrackCandHit. DetId = 25	HitId = 0	PlaneId = 2	SortingParameter = 0.833432
TrackCandHit. DetId = 41	HitId = 0	PlaneId = 3	SortingParameter = 4.33151
TrackCandHit. DetId = 41	HitId = 1	PlaneId = 4	SortingParameter = 4.4159
TrackCandHit. DetId = 41	HitId = 2	PlaneId = 5	SortingParameter = 5.68304
TrackCandHit. DetId = 41	HitId = 3	PlaneId = 6	SortingParameter = 5.76742
TrackCandHit. DetId = 41	HitId = 4	PlaneId = 7	SortingParameter = 7.03426
TrackCandHit. DetId = 41	HitId = 5	PlaneId = 8	SortingParameter = 7.11861
TrackCandHit. DetId = 43	HitId = 0	PlaneId = 9	SortingParameter = 11.0491
TrackCandHit. DetId = 43	HitId = 1	PlaneId = 10	SortingParameter = 11.0956
TrackCandHit. DetId = 43	HitId = 2	PlaneId = 11	SortingParameter = 11.2173
TrackCandHit. DetId = 43	HitId = 3	PlaneId = 12	SortingParameter = 11.2559

SUCCESSFULL FIT!

fitStatus

track has NOT been fitted, track has been fitted with reference track,

*** PndGenfitAdapters EXCEPTION ***

genfit::Exception thrown with excString:

Track::getFittedState ==> no trackPoint with fitterInfo for rep

in line: 258 in file: /home/prencipe/panda/genfit2_branch/genfit/core/src/Track.cc

with fatal flag 0

- Same error as in the standard trunk:

</GenfitTools/trackrep/GeaneTrackRep/GeaneTrackRep.cxx>

with fatal flag 0

2st TYPE of problems (DetID = 41)

TrackCandHit. DetId = 41	HitId = 0	PlaneId = 28	SortingParameter = 123.278
TrackCandHit. DetId = 41	HitId = 1	PlaneId = 29	SortingParameter = 125.669
TrackCandHit. DetId = 41	HitId = 2	PlaneId = 30	SortingParameter = 161.56

genfit::Exception thrown with excString:

Tools::invertMatrix() - **cannot invert matrix, determinant = 0**

in line: 137 in file: /home/prencipe/panda/genfit2_branch/genfit/core/src/Tools.cc
with fatal flag 0

SUCCESSFULL FIT!

fitStatus

track has NOT been fitted, track has been fitted with reference track,

*** PndGenfitAdapters EXCEPTION ***

genfit::Exception thrown with excString:

KalmanFitterInfo::getFittedState: Needed updates/predictions not available in this FitterInfo.

in line: 197 in file:

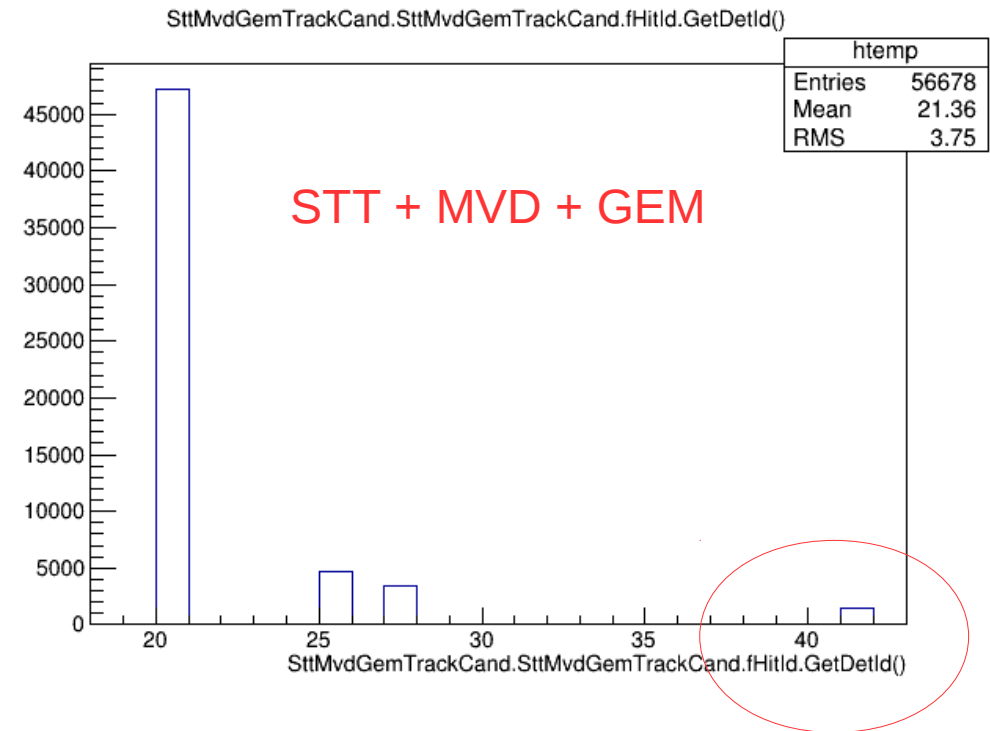
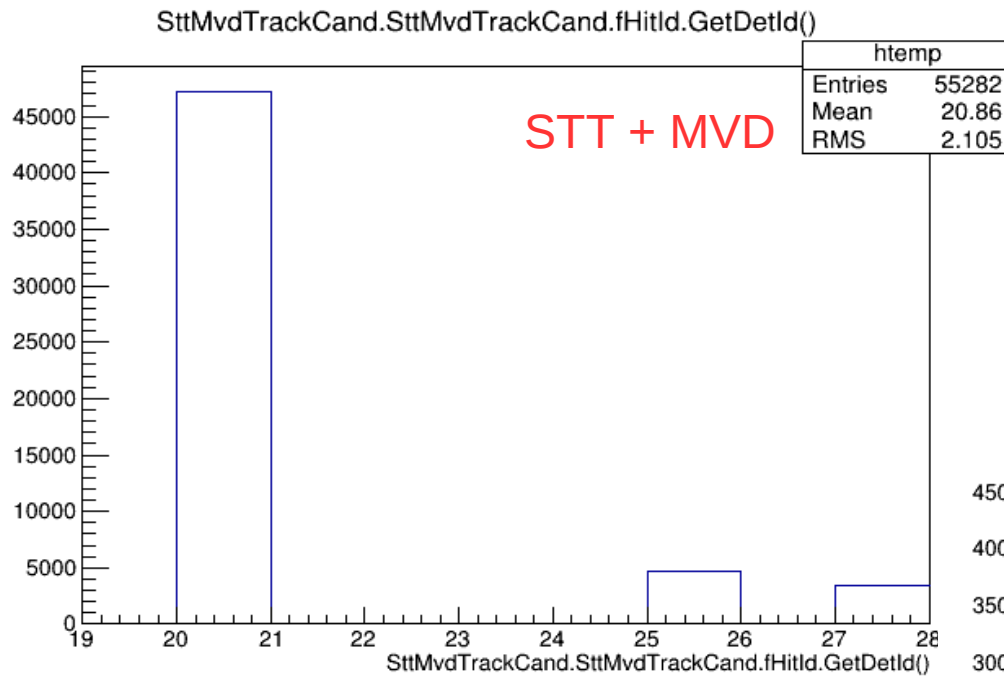
/home/prencipe/panda/genfit2_branch/genfit/fitters/src/KalmanFitterInfo.cc

with fatal flag 0

Fitting done

PndRecoKalmanTask: itr=0 nhits22 -- 25 25 25 25 20 20 20 20 20 20 20 20 20 20
20 20 20 41 41 41 41 41 41

Fitting done



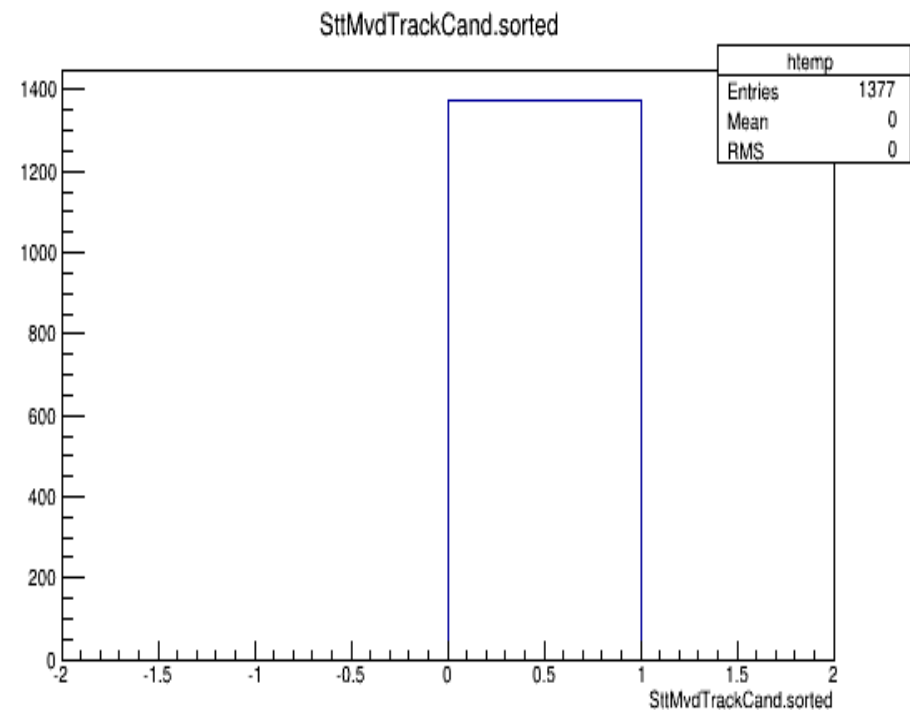
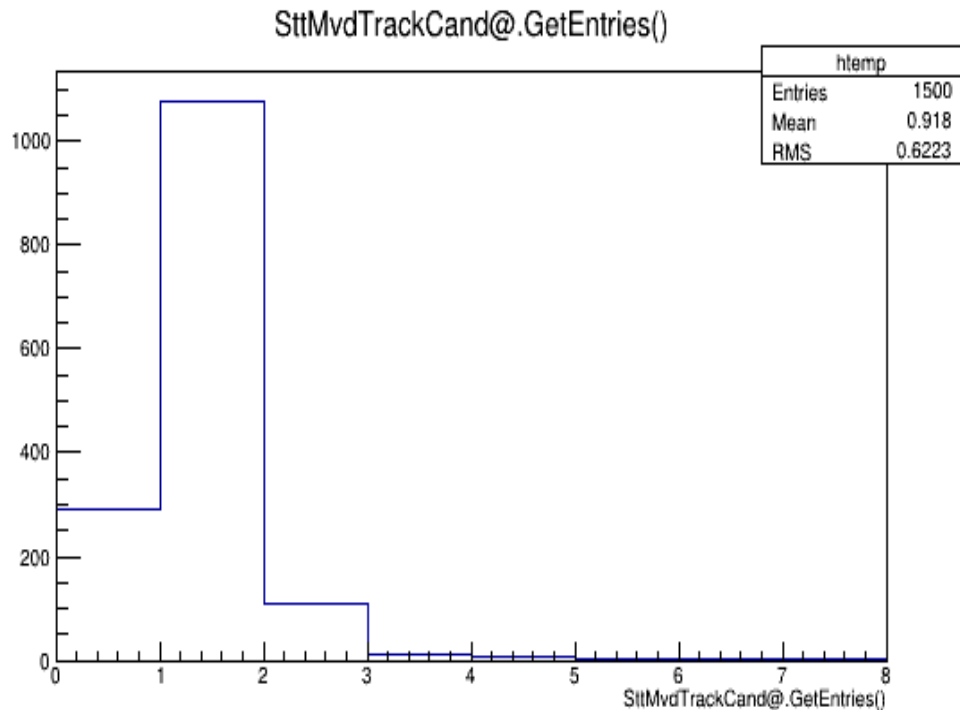
DetID 43 = FTS (ideal)

- Even higher momentum tracks, with hits in detID =41, 43 ⇒ fatal flag 0

Trying hard....

....reconstruction of low mom. tracks

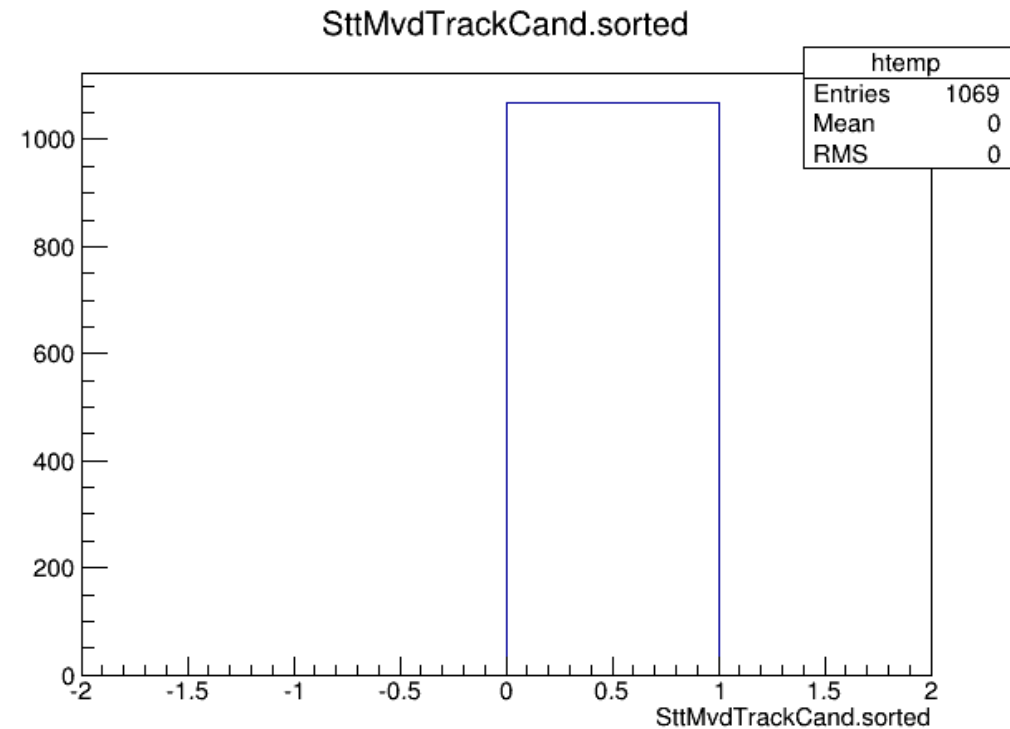
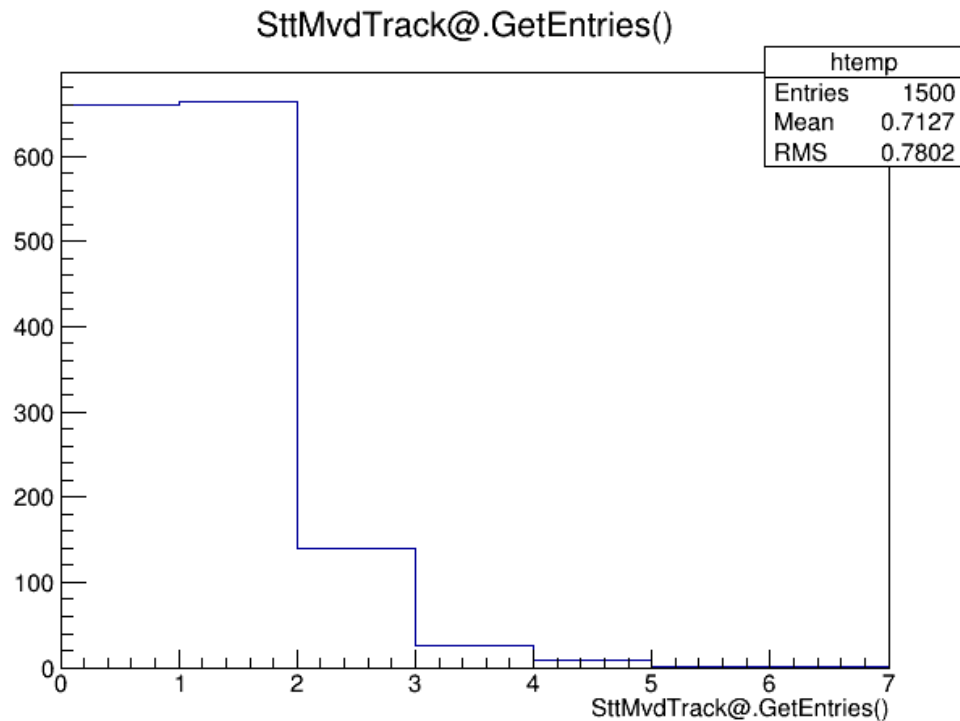
Hypothesis = K^- , $p = 0.5 \text{ GeV}/c$ \longrightarrow Reconstructed events: **92%**, no PID, STT+MVD



Trying hard....

....reconstruction of low mom. tracks

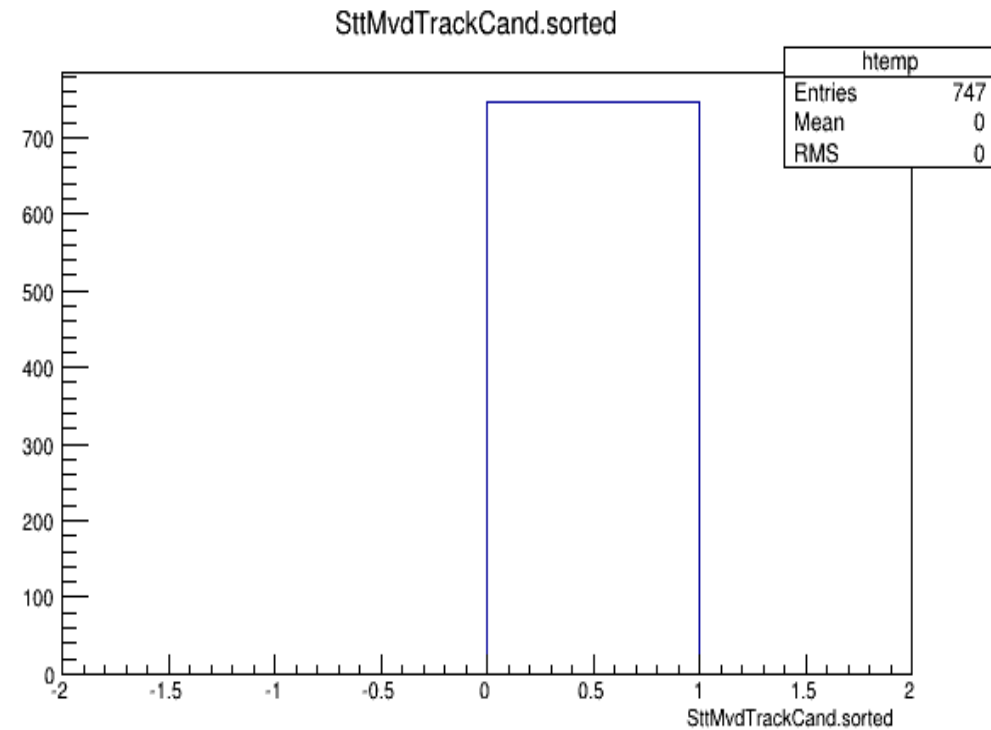
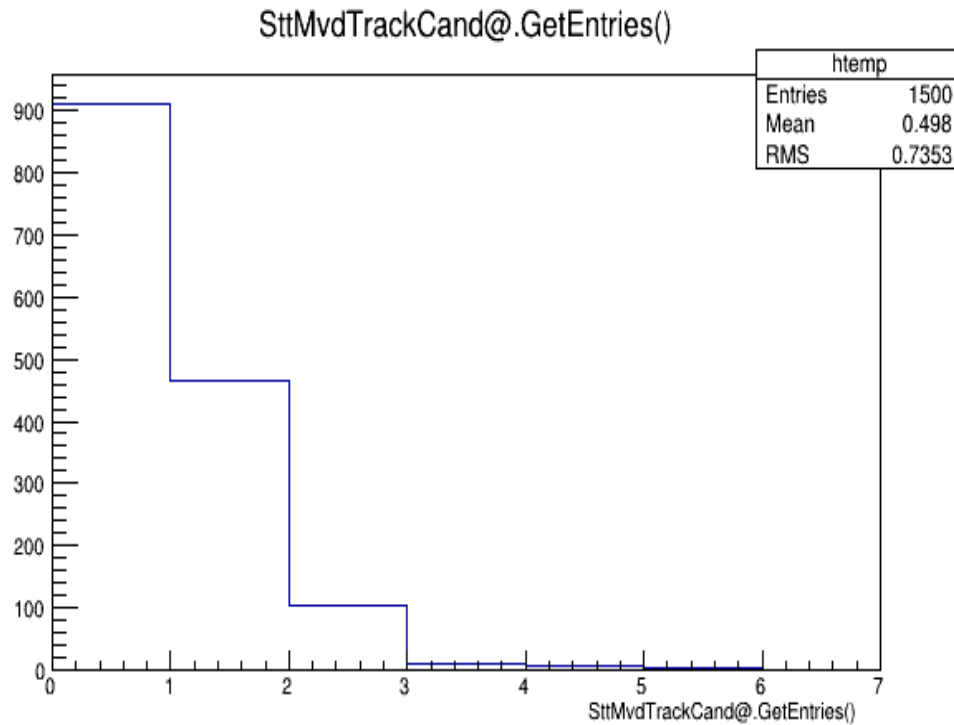
Hypothesis = K^- , $p = 0.25 \text{ GeV}/c$ → Reconstructed events: **71%**, no PID, STT+MVD



Trying hard....

....reconstruction of low mom. tracks

Hypothesis = K^- , $p = 0.10 \text{ GeV}/c$ → Reconstructed events: **50%**, no PID, STT+MVD



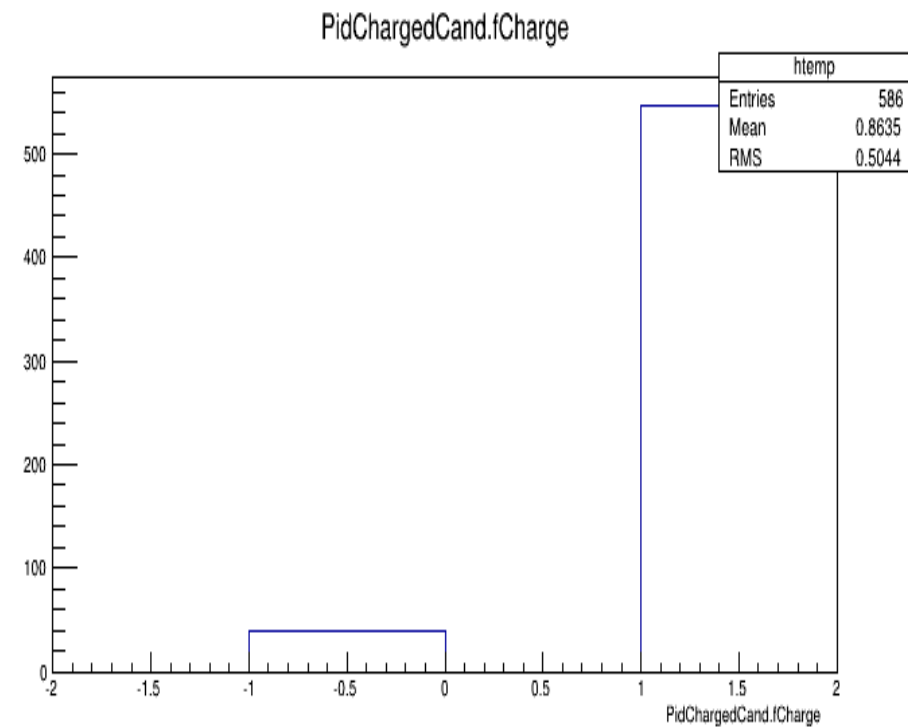
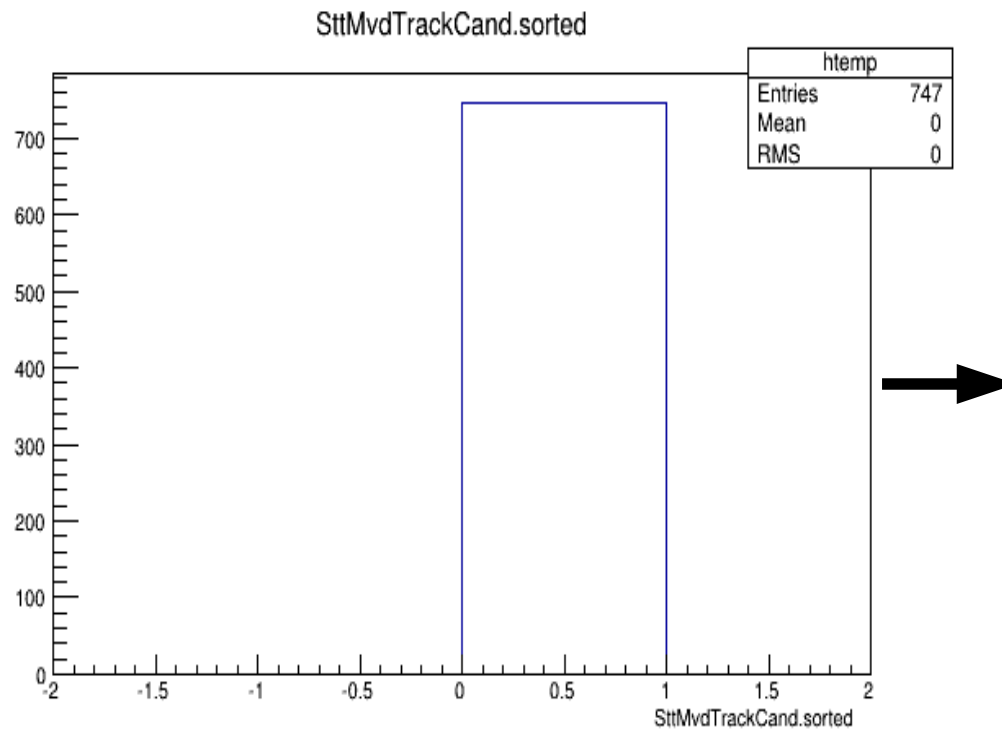
Challenge: reconstruction of very low mom tracks

$P = 100 \text{ MeV}/c, K^-$

Generated events = 1500 events (Box Generator)

Reconstructed = 747 events sorted

PID selected = 586 events sorted **~39%**



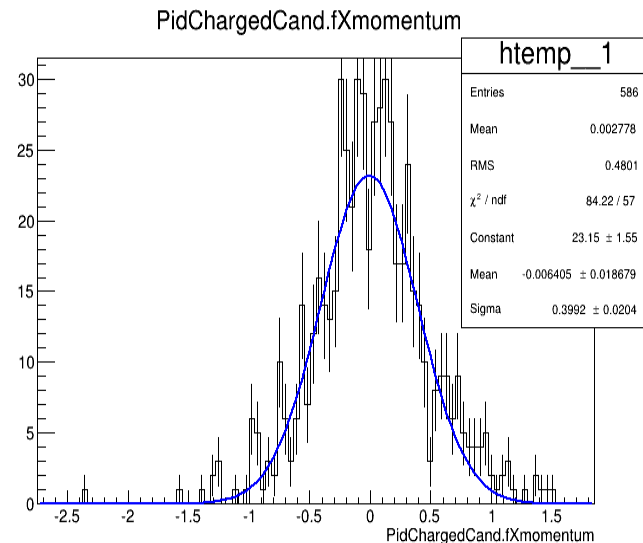
Challenge: reconstruction of very low mom tracks

$P = 100 \text{ MeV}/c, K^-$

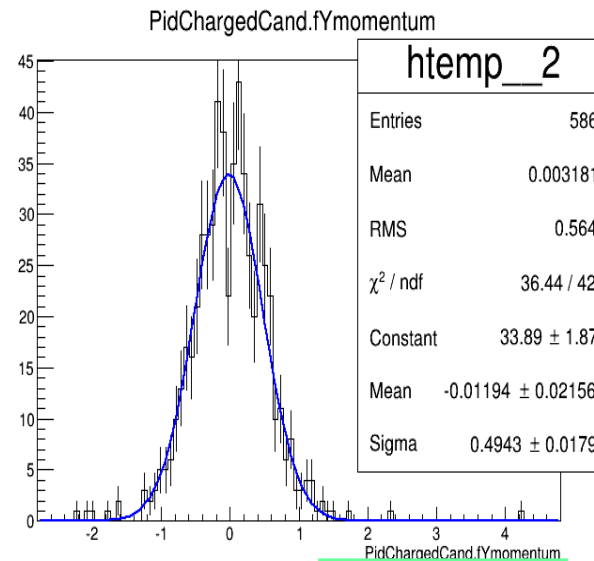
Generated events = 1500 events (Box Generator)

Reconstructed = 747 events sorted

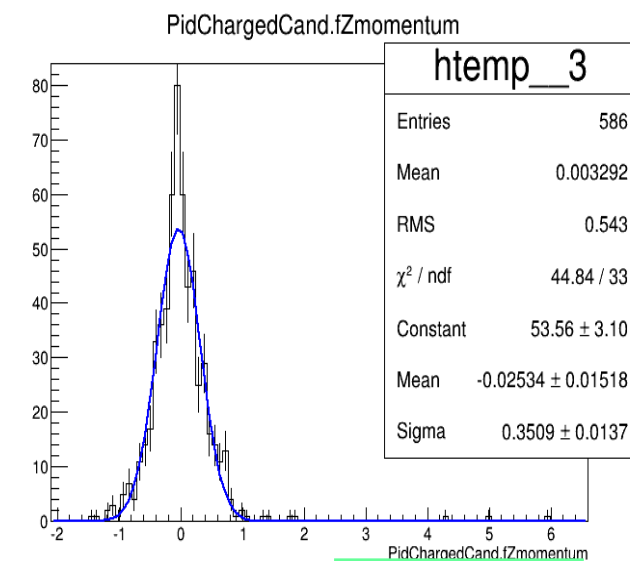
PID selected = 586 events sorted **~39%**



Px [GeV/c]



Py [GeV/c]



Pz [GeV/c]

- Resolution of tracks with $p = 100 \text{ MeV}/c$ is found 2-3 times worse than resolution of those with $p = 5 \text{ GeV}/c$. But...

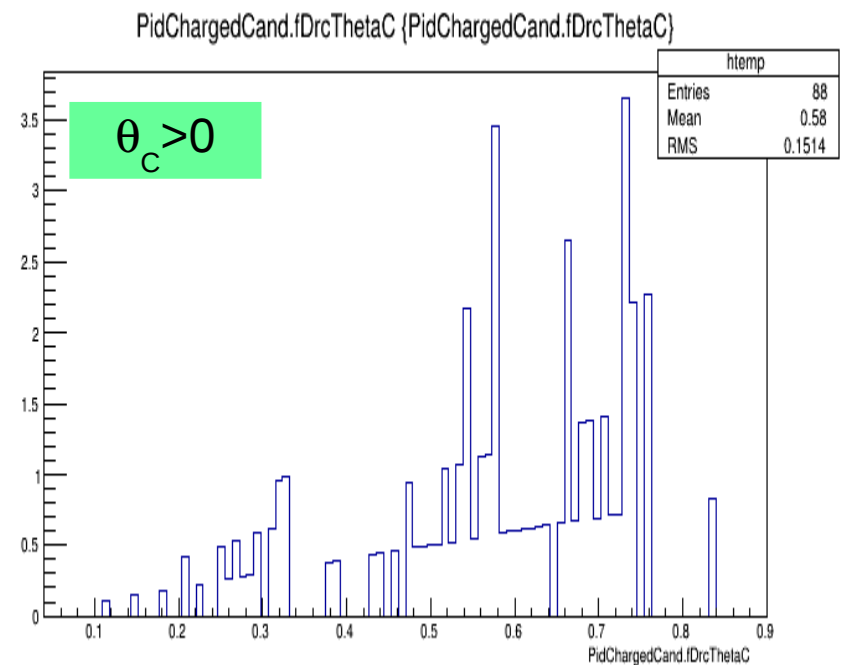
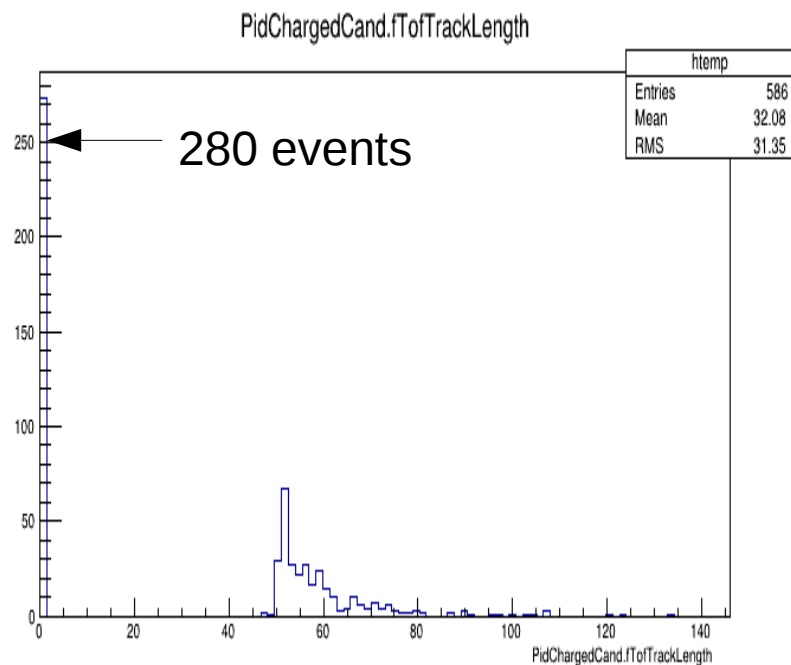
Challenge: reconstruction of very low mom tracks

$P = 100 \text{ MeV}/c, K^-$

Generated events = 1500 events (Box Generator)

Reconstructed = 747 events sorted

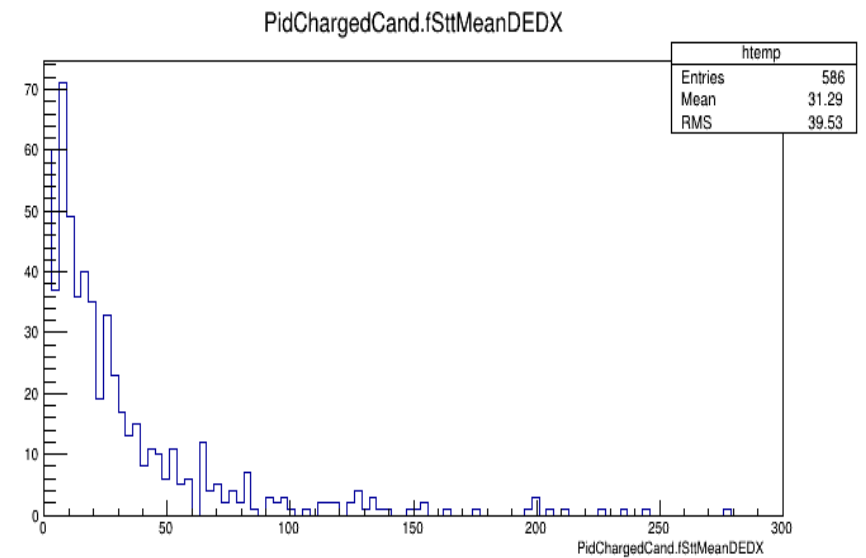
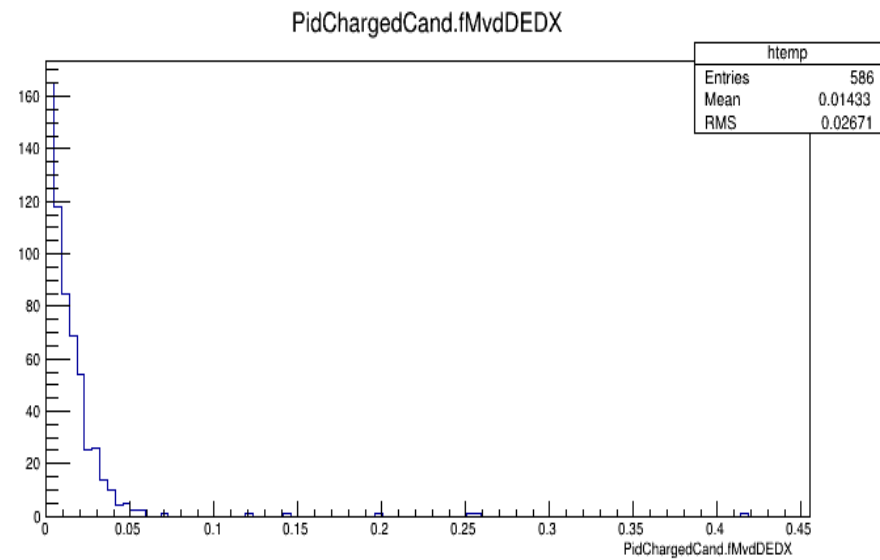
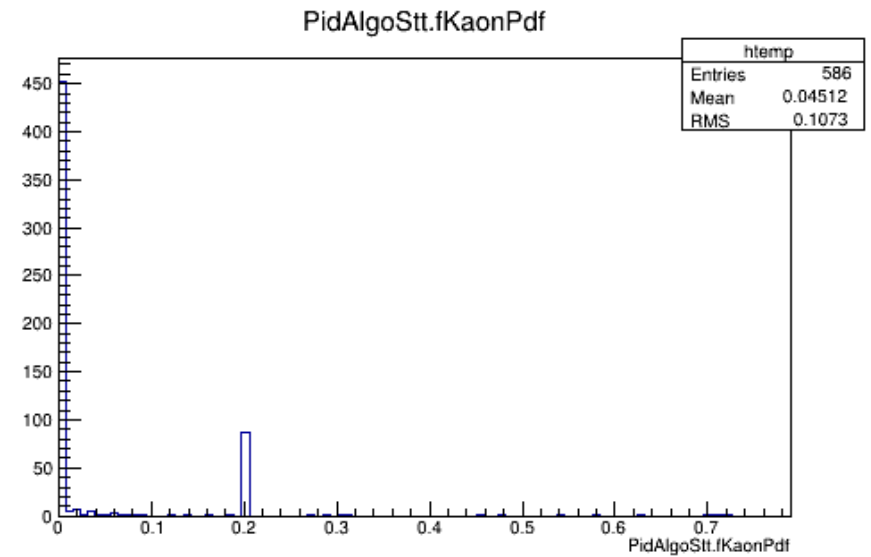
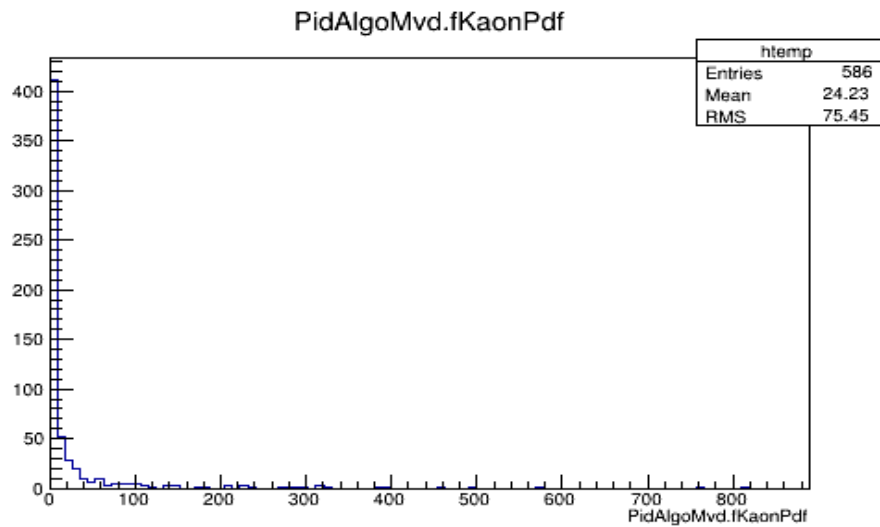
PID selected = 586 events sorted **~39%**



- Resolution of tracks with $p = 100 \text{ MeV}/c$ is found 2-3 times worse than resolution of those with $p = 5 \text{ GeV}/c$ (test must be repeated with higher statistics).
- If selection cuts on PID variables are applied to select good tracks, $\epsilon_{\text{RECO}} < 6\%$ ($p=0.1 \text{ MeV}/c$)

P = 100 MeV/c, K⁻

Generated events = 1500 events (Box Generator)



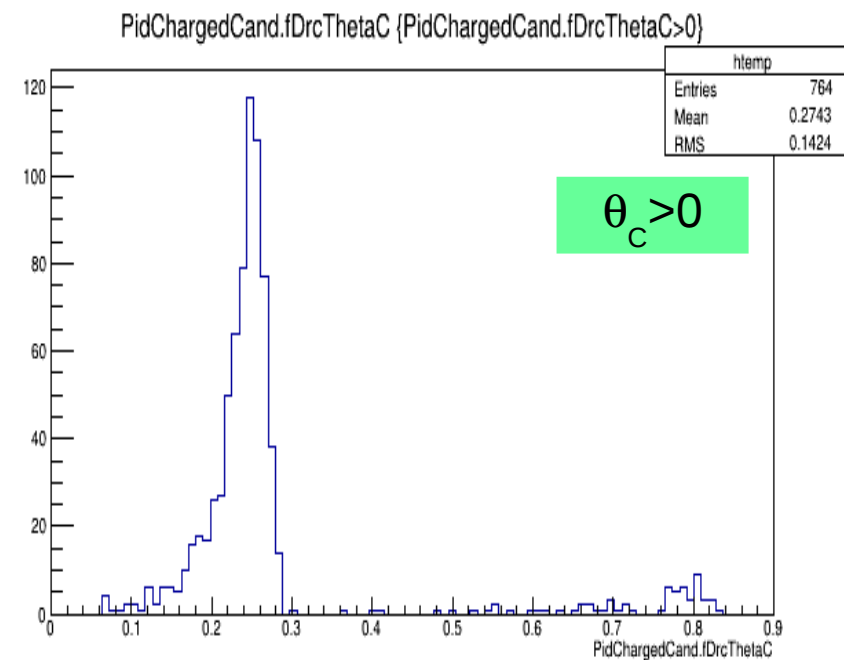
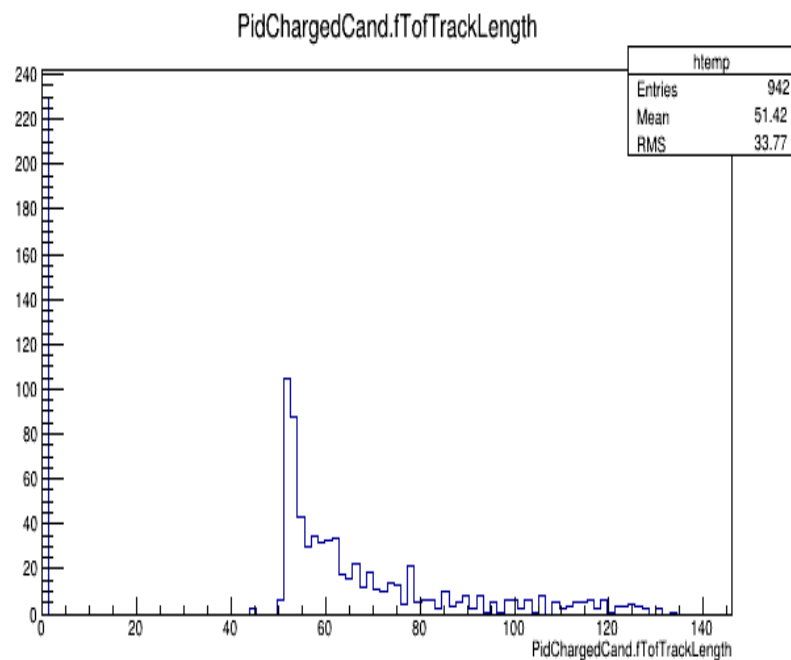
Challenge: reconstruction of very low mom tracks

$P = 500 \text{ MeV}/c, K^-$

Generated events = 1500 events (Box Generator)

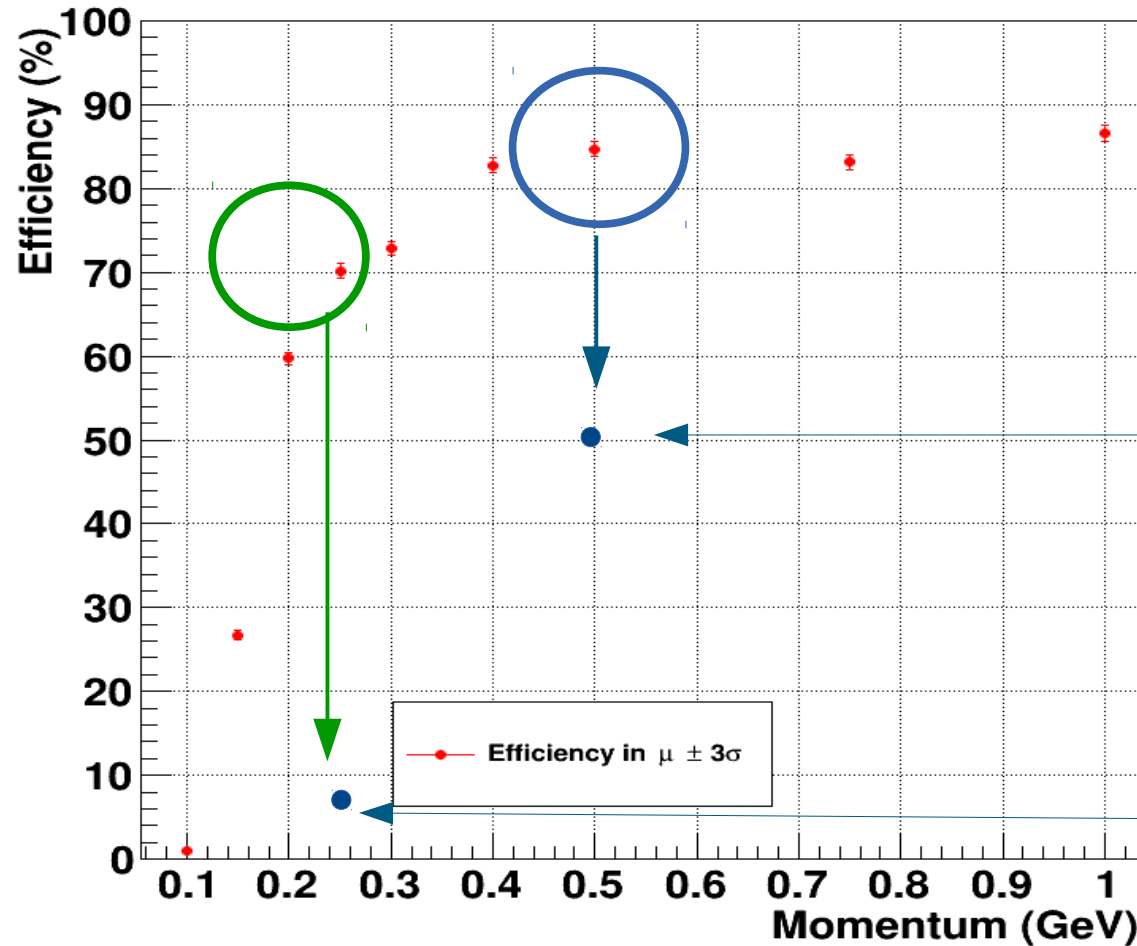
Reconstructed = 942 events sorted

PID selected = 764 events sorted **~61%**



- Resolution of tracks with $p = 100 \text{ MeV}/c$ is found 1.5 – 2 times worse than resolution of those with $p = 5 \text{ GeV}/c$ (test must be repeated with higher statistics).
- If selection cuts on PID variables are applied to select good tracks, $\epsilon_{\text{RECO}} < 51\%$ ($p=0.5 \text{ MeV}/c$)

Kalman efficiency only, for comparison....



With Full simulation,
Rev-25545, GF2,
PID: **50%**

With Full simulation,
Rev-25545, GF2,
PID: **7%**

Comparison on a small sample: 2500 generated events

PID “best” is applied

	Entries	$\epsilon, p = 5 \text{ GeV}/c$	No FTS, μ det	$\epsilon, p < 1 \text{ GeV}/c$
genfit	2101	88% ($p > 0.1 \text{ MeV}/c$)	88% ($p > 0.1 \text{ MeV}/c$)	To do
genfit2	2281	91% ($p > 0.1 \text{ MeV}/c$)	91% ($p > 0.1 \text{ MeV}/c$)	(*)

Pull fit, $p = 5 \text{ GeV}/c$	d0	z0	Px	Py	Pz
genfit	1.029±0.032	0.957±0.040	1.003±0.020	1.005±0.026	0.953±0.023
genfit2	1.057±0.022	1.337±0.034	0.954±0.017	0.979±0.017	1.018±0.018

Summary

- /genfit2/ has been ported in PandaRoot
- Additional comparison tests with old genfit version have been provided:
tests on 2500 (single track) events show improvement
- Different mass hypothesis are tested in rev-25545, at different mom. values
- PndMCTrackAssociator
- Fast simulations run smooth: no tracking (except the PndPidCorrelator)
- Please, help to check your analysis with genfit2 and report troubles, if any
- A document with all tests performed on 100 000 events will be provided
(give me some weeks to do this....)
- Do we like to introduce genfit2& related code(s) in a trunk-rev of pandaroot?

*THANK YOU for
your attention!*



*“The greatest danger for most of us lies not in
setting our aim too high and falling short;
but in setting our aim too low, and achieve our
mark.” (Michelangelo, 1475 - 1564)*