

# Extending pandaroot to run Kalman Filter with all Hypotheses

Walter Ikegami Andersson

Uppsala University  
on behalf of the  $\bar{\text{P}}\text{ANDA}$  collaboration

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GSI



## Kalman filter current design

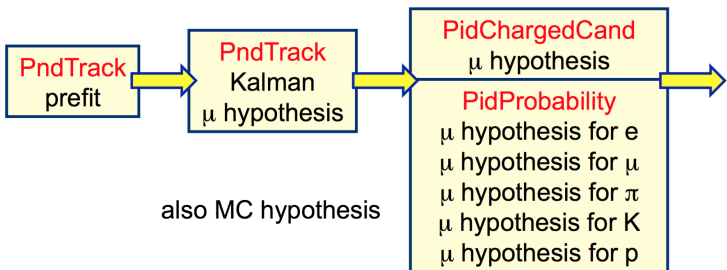


Figure from PANDA Computing Workshop 2017

## Kalman filter current design

Following tasks are run during the reco- and PID stages:

- RecoKalmanTask: Perform track fitting (Kalman Filter)  
with  $\mu$  hypothesis
- PidCorrelator: Extrapolate tracks to EMC  
with  $\pi$  hypothesis to distinguish neutrals  
Cut is made on EMCquality variable  
(done by user at analysis level instead?)
- PidAlgo: Run all PID algorithms from each subdetector
- McCloner: Filter out MC tracks that are not related to (for 500  $\bar{\Lambda}\Lambda$ ,  
20.000  $\rightarrow$  2000 tracks)

## Pull Distributions (Stretch Functions)

The pull distribution  $z$  for an observation  $i$ , also known as stretch function, is defined as (calling it MC pull distribution)

$$z_i = \frac{y_{MC,i} - \eta_i}{\sigma(\eta_i)}$$

- Pull distribution used to study performance of kinematic fits
- MC pull used to see performance of Kalman filter

All tests in this presentation on  $\bar{p}p \rightarrow \bar{\Lambda}\Lambda \rightarrow \bar{p}p\pi^+\pi^-$  @ 1.642 GeV/c

# Performance of Kalman Filter

In an ideal fit:

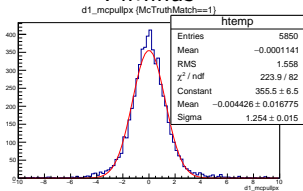
- Pull distributions should be normal distributed

There are issues with the fit if:

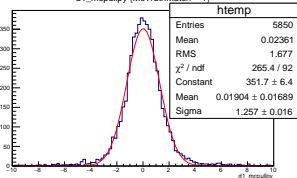
- Skews in pull distributions  $\implies$  bias in measurements
- Narrower (broader) normal distributions  $\implies$  errors over(under)estimated
- Background contamination can also alter pull distributions  $\implies$  remove with MC truth info

# MC pull distribution, (no Ideal Hypothesis)

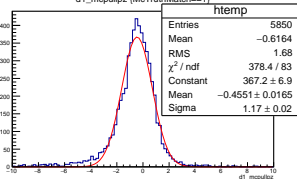
## PiMinus



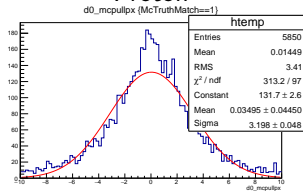
d1\_mcpulpy (McTruthMatch==1)



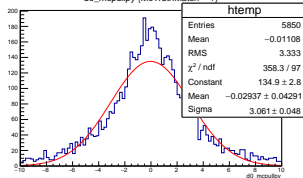
d1\_mcpulpz (McTruthMatch==1)



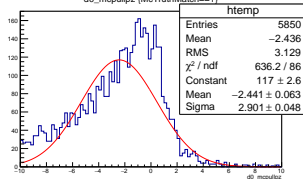
## Proton



d0\_mcpulpy (McTruthMatch==1)

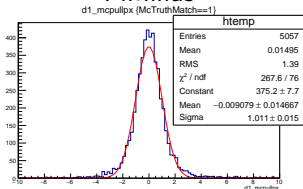


d0\_mcpulpz (McTruthMatch==1)

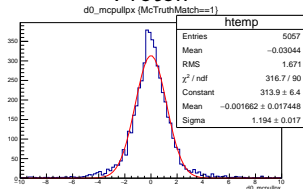


# MC pull distribution (with Ideal Hypothesis)

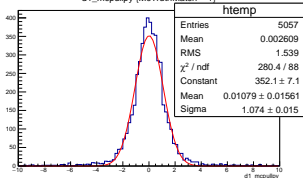
## PiMinus



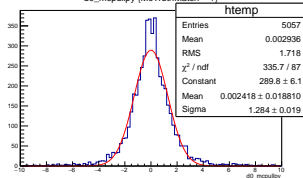
## Proton



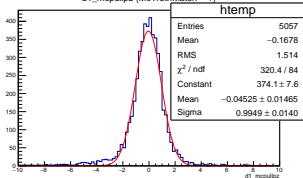
d1\_mcpulpy (McTruthMatch==1)



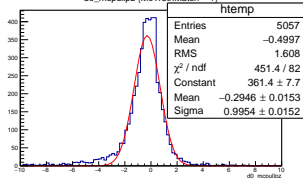
d0\_mcpulpy (McTruthMatch==1)



d1\_mcpulpz (McTruthMatch==1)



d0\_mcpulpz (McTruthMatch==1)



# Kalman filter new design

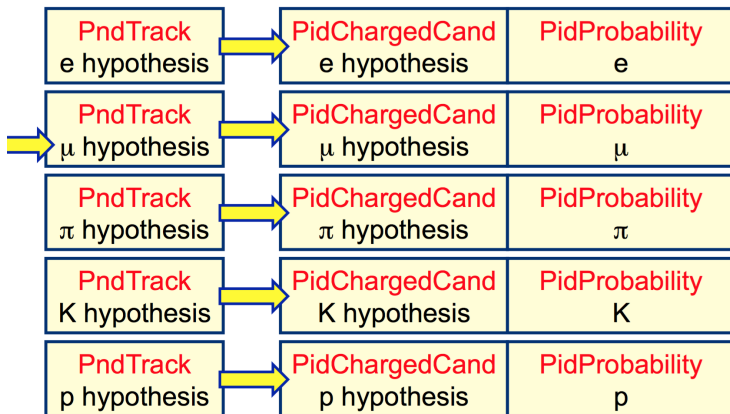


Figure from PANDA Computing Workshop 2017



## Reconstruction Stage

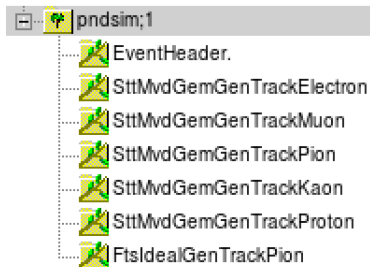
- In reco macro, pass option "multikalman", and Kalman filter will run 5 times with all hypotheses
- If e.g. only pions and protons are interesting, pass them in option string

```
// ----- Initial Settings -----  
PndMasterRunAna *fRun= new PndMasterRunAna();  
fRun->SetInput(input);  
fRun->SetOutput(output);  
fRun->SetFriend1(friend1);  
fRun->SetFriend2(friend2);  
fRun->SetFriend3(friend3);  
fRun->SetFriend4(friend4);  
fRun->SetParamAsciiFile(parAsciiFile);  
fRun->Setup(prefix);  
  
// ----- Add tasks -----  
// fRun->SetOptions("multikalman;pion;proton");  
fRun->SetOptions("multikalman");  
fRun->AddRecoTasks();
```

# Reconstruction Stage

PndMultiKalmanTask properties:

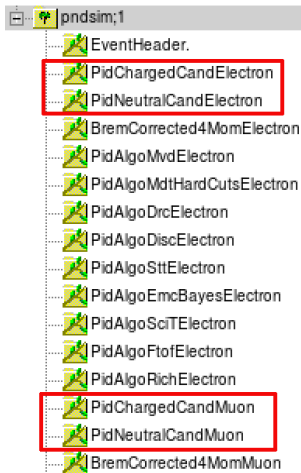
- Possible to run with standard pattern recognition as well as ideal PR
- If no hypotheses are specified in the options, all five hypotheses are used
- Currently, PndMultiKalmanTask does not run with FTS PR output...  
⇒ only running pion hypothesis for now



# PID Stage: PndCorrelator

PndCorrelator - first task PID stage

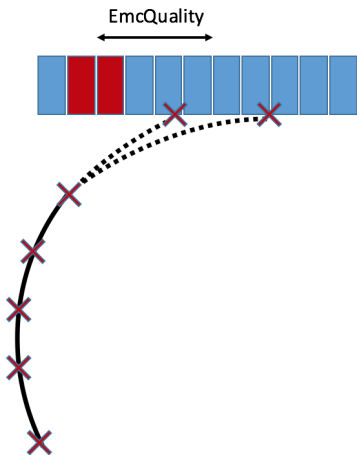
- Produces PndPidCandidates for
  - Track candidates
  - charged
  - EMC bumps
  - neutral
- PndCorrelator run for each track fit hypothesis



## PID Stage: PndCorrelator

Why 5 sets of neutral  
PndPidCandidates?

- A given track can have successful fit with one hypothesis but failed with another
- Neutrals produced if EmcBump distance to track larger than EmcQuality
- Extrapolating track to EMC dependent on particle hypothesis
- Five sets of neutrals produced by extrapolating with different hypothesis



## PID Stage: PndPidAlgos, PndMcCloner

Significant changes:

- PndAlgos and PndBremCorrector running for each hypothesis
- New PndMcCloner2 class:
  - Checks if a MC track is related to a track that was successfully fitted with any hypothesis (Again, Kalman fit can converge for e.g. pion hypothesis but fail for proton hypothesis).
  - Save MCtrack if that is the case.
- Everything handled in new PndMasterMultiPidTask class
- If no hypotheses specified in options, all five hypotheses are used

```
// ----- Add tasks -----  
fRun->SetOptions("multikalman;pion;proton");  
// fRun->SetOptions("multikalman");  
fRun->AddPidTasks();
```

## Analysis Stage

PndAnalysis - main analysis object taking care of file read/write

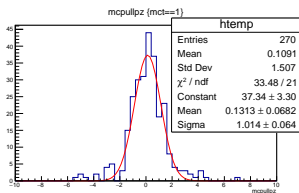
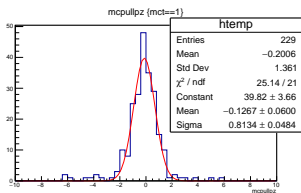
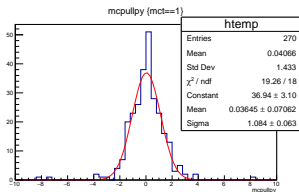
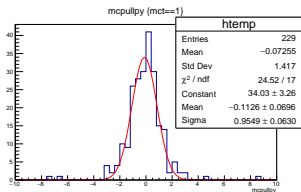
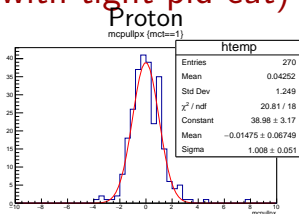
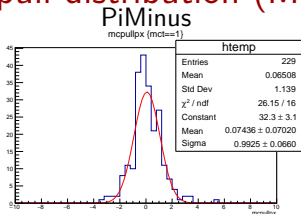
- Now reads up to five sets of TClonesArrays, one set for each hypothesis
- When filling RhoCandLists, following is specified
  - Particle hypothesis + PID criteria + Charge
  - Name of branch containing subdetector PID info
- Usage same as before

```
// theAnalysis->FillList(piplus, "PionAllPlus");
// theAnalysis->FillList(piminus, "PionAllMinus");
// theAnalysis->FillList(protonplus, "ProtonAllPlus");
// theAnalysis->FillList(protonminus, "ProtonAllMinus");

theAnalysis->FillList(piplus, "PionAllPlus", "PidAlgoIdealCharged");
theAnalysis->FillList(piminus, "PionAllMinus", "PidAlgoIdealCharged");
theAnalysis->FillList(protonplus, "ProtonAllPlus", "PidAlgoIdealCharged");
theAnalysis->FillList(protonminus, "ProtonAllMinus", "PidAlgoIdealCharged");

// theAnalysis->FillList(piplus, "PionTightPlus", "PidAlgoStt;PidAlgoMvd;PidAlgoEmc");
// theAnalysis->FillList(piminus, "PionTightMinus", "PidAlgoStt;PidAlgoMvd;PidAlgoEmc");
// theAnalysis->FillList(protonplus, "ProtonTightPlus", "PidAlgoStt;PidAlgoMvd;PidAlgoEmc");
// theAnalysis->FillList(protonminus, "ProtonTightMinus", "PidAlgoStt;PidAlgoMvd;PidAlgoEmc");
```

# MC pull distribution (Multikalman, with tight pid cut)



# Summary

- Pandaroot simulation and analysis chain modified to run MultiKalman filter
- Preliminary tests shows significant improvements for protons in  $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$  @ 1.642 GeV/c
- Feature will be pushed to dev branch soon...
- Issues: Ideal FTS pattern recognition not working with all hypotheses...



# Outlook

- New implementation runs all tasks 5 times, regardless of physical motivation
  - Running Bremstrahlung corrector for all hypotheses - useful for systematic error studies or useless?
- Belle 2 experiment runs  $\pi$  hypothesis for  $e, \mu, \pi$ , compromise between accuracy and computing resources (see talk by S. Spataro at CHEP)
- Should cut on EmcQuality variable be available to analysts (instead of a fix cut hidden from the user?)
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Thank you for your attention!

# Backup