Atlfast parametrisation for FCC fast simulation

Bibliography:

12/97:
"Parameterisation of the Inner Detector Performance"
E. J. Buis, R. J. Dankers, S. Haywood and A. Reichold
ATL-INDET-97-195
`http://cds.cern.ch/record/686050/files/indet-97-195.pdf`

09/98:
"Update of Inner Detector Performance Parameterisations"
E. J. Buis, R. J. Dankers, N. Labanca S. Haywood, A. Reichold and F. Tartarelli
ATL-INDET-98-215
`http://cds.cern.ch/record/683708/files/indet-98-215.pdf`

2001:
"A New Hadronic-Track Parameterisation for Fast Simulation of the ATLAS Inner Detector"
B. Epp ; V. M. Ghete ans A. Nairz
ATL-PHYS-2001-009
`http://cds.cern.ch/record/684235/files/phys-2001-009.pdf`

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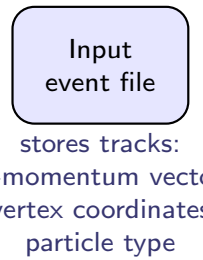
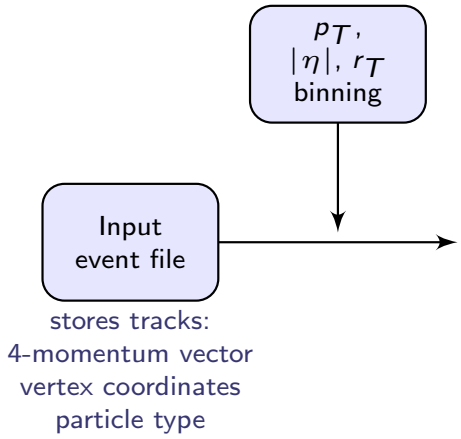
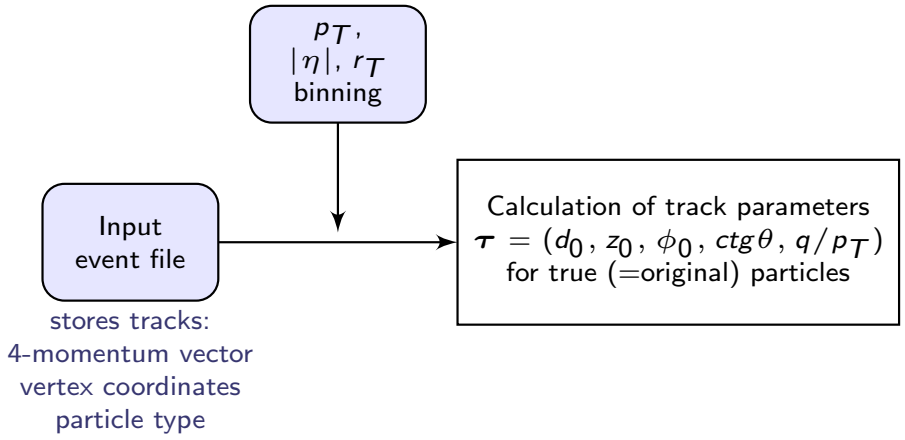
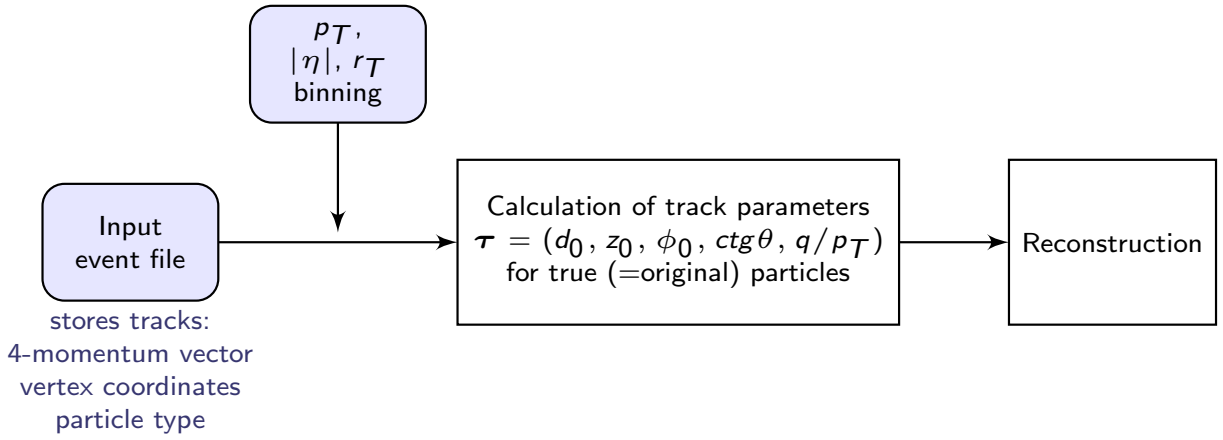
"A Parametrization for Fast Simulation of Muon Tracks in the ATLAS Inner Detector and Muon System"
A. Salzburger; D. Kuhn
CERN-THESIS-2004-051
`http://cds.cern.ch/record/813003/files/thesis-2004-051.pdf`

How to extract parametrisation


Input
event file
stores tracks:
4-momentum vector
vertex coordinates
particle type


p_T,
$|\eta|$, r_T
binning
Input
event file
stores tracks:
4-momentum vector
vertex coordinates
particle type


p_T,
$|\eta|$, r_T
binning
Input
event file
Calculation of track parameters
$\tau = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
for true (=original) particles
stores tracks:
4-momentum vector
vertex coordinates
particle type


p_T,
$|\eta|$, r_T
binning
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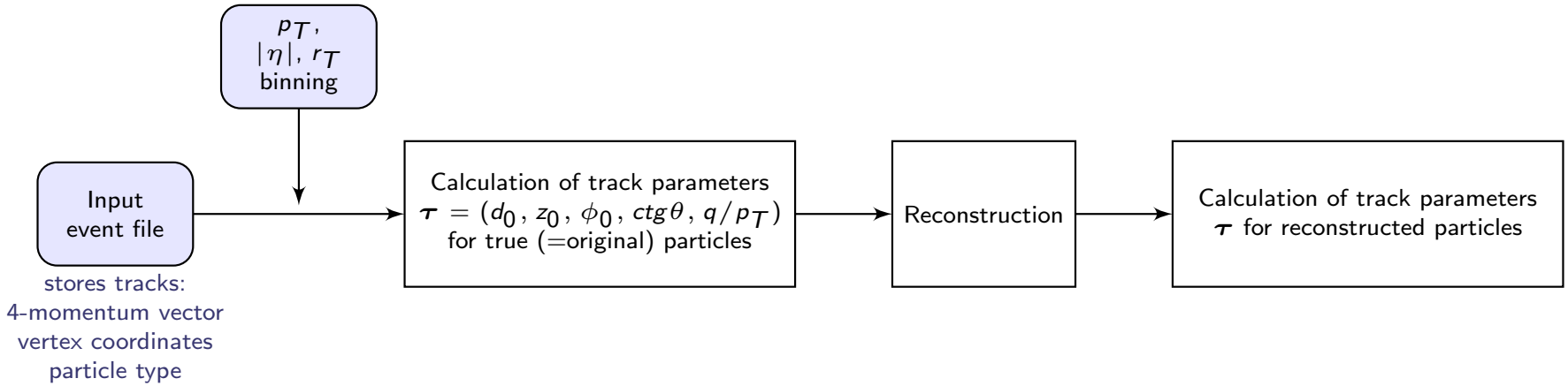
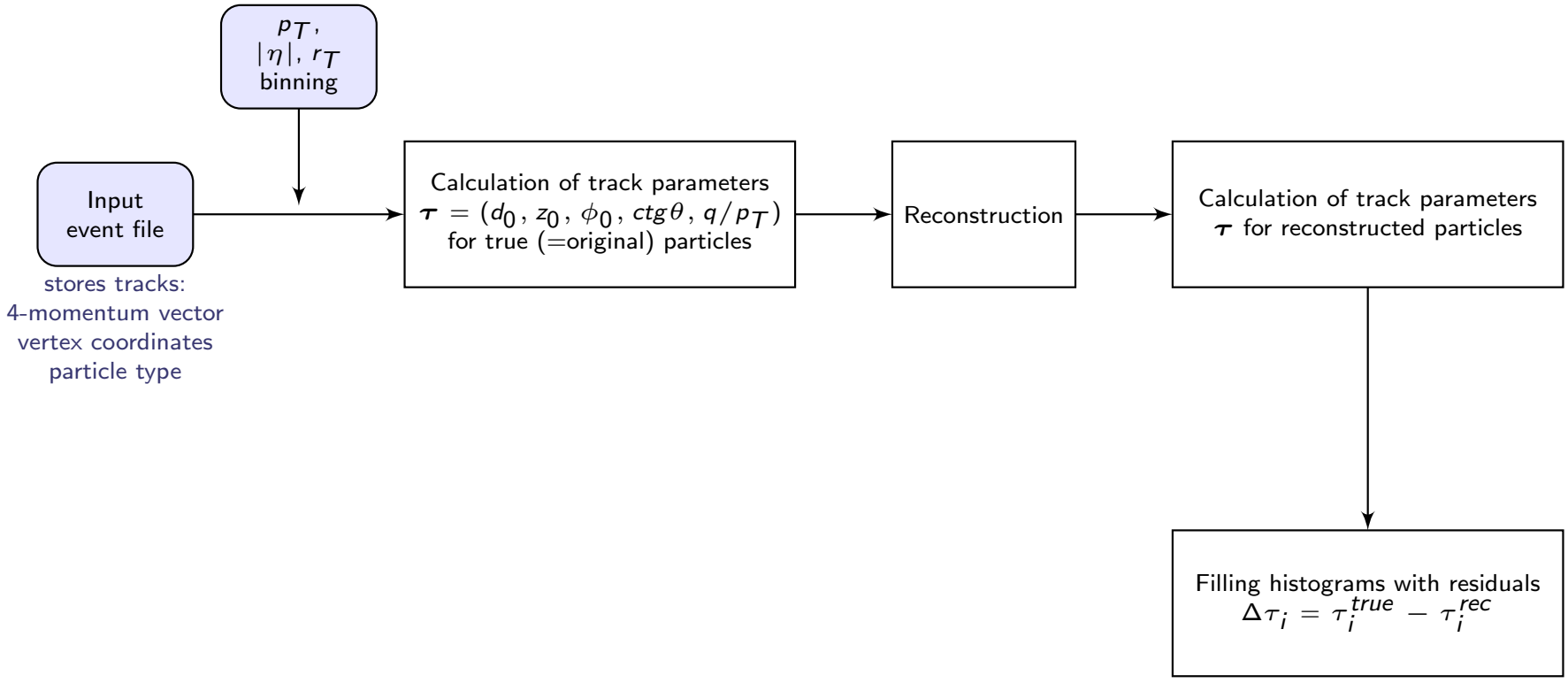
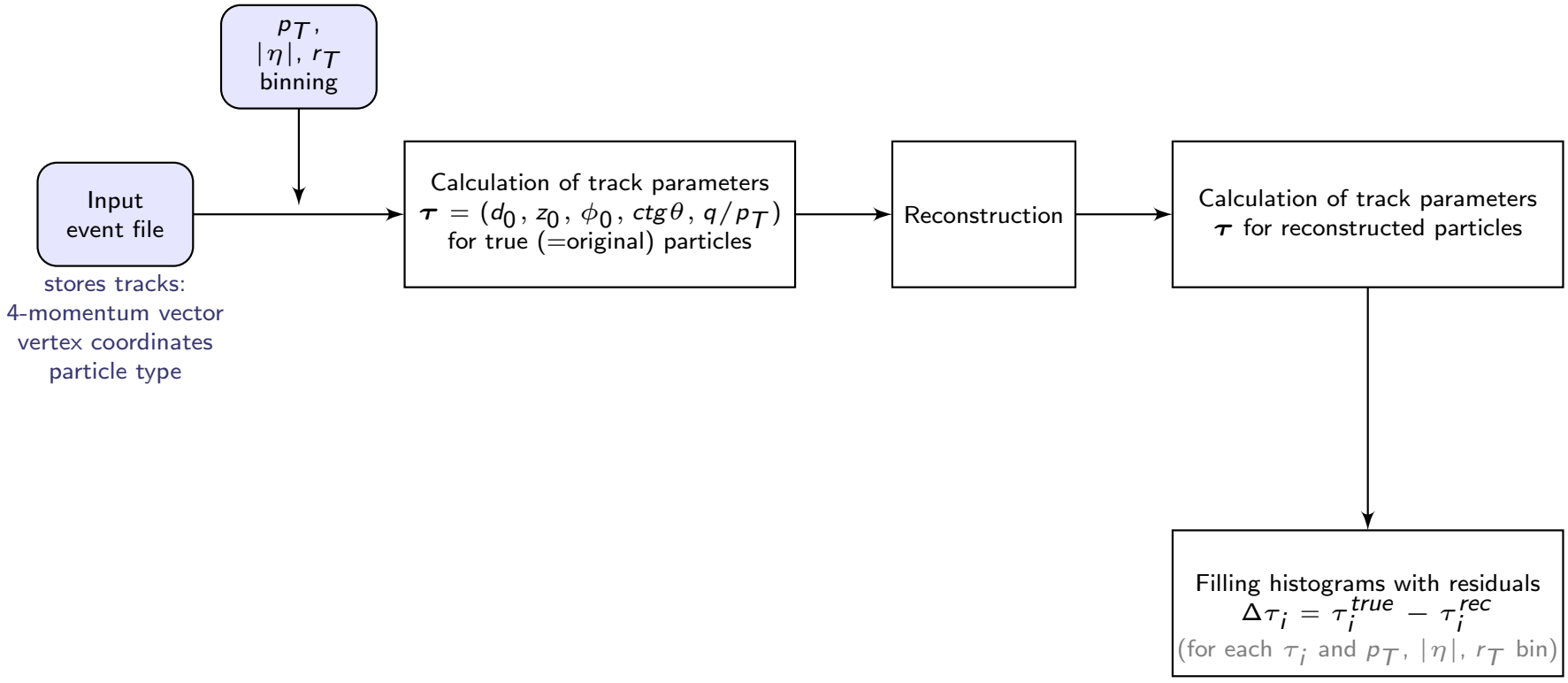
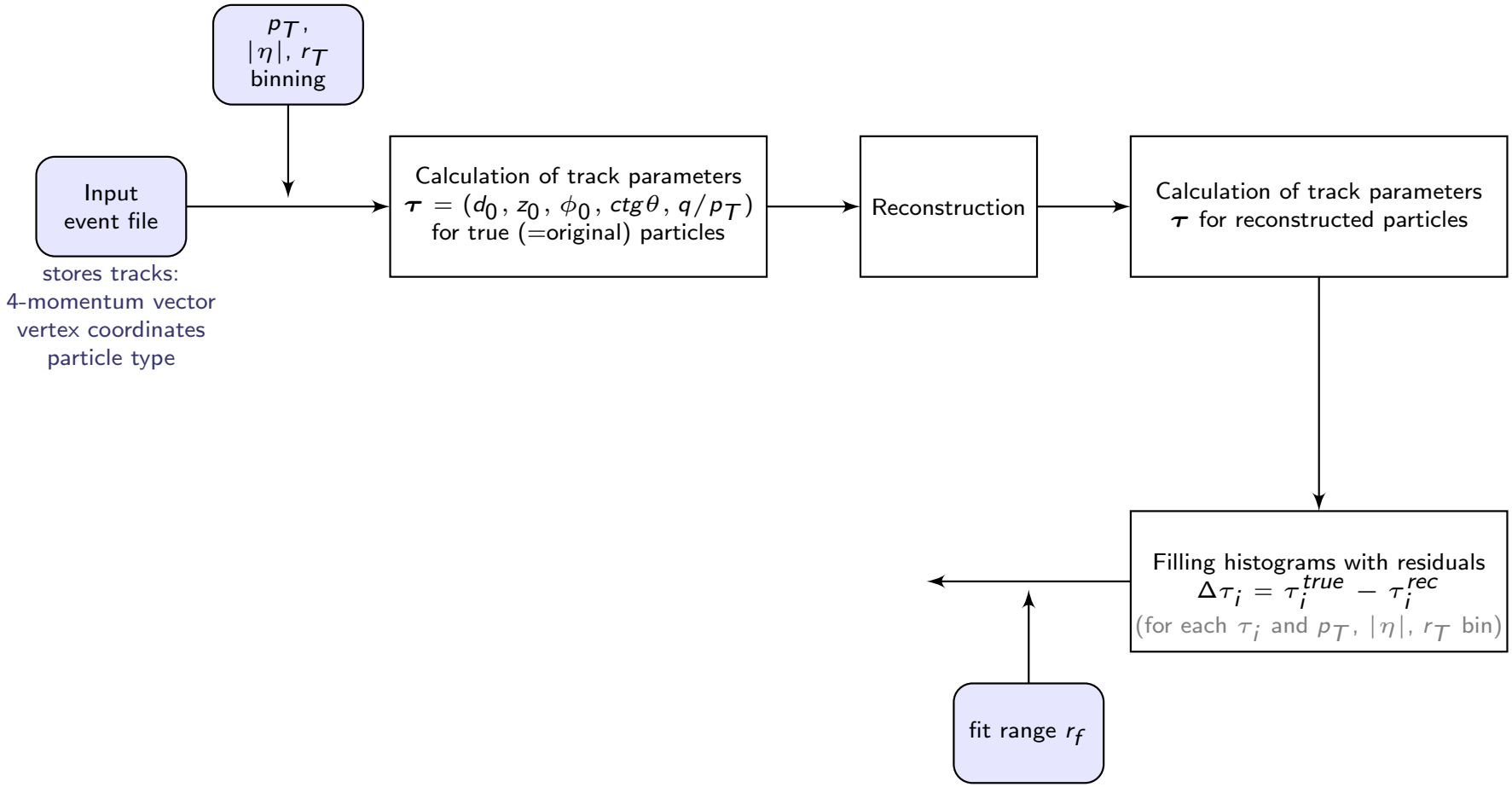
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters
$\tau = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
for true (=original) particles
Reconstruction


p_T,
$|\eta|$, r_T
binning
Input
event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters
$\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
for true (=original) particles
Reconstruction
Calculation of track parameters
$\boldsymbol{\tau}$ for reconstructed particles


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters
$\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
for true (=original) particles
Reconstruction
Calculation of track parameters
$\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals
$\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters
$\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
for true (=original) particles
Reconstruction
Calculation of track parameters
$\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals
$\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$
(for each τ_i and p_T, $|\eta|$, r_T bin)


p_T, $|\eta|$, r_T binning
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vertex coordinates
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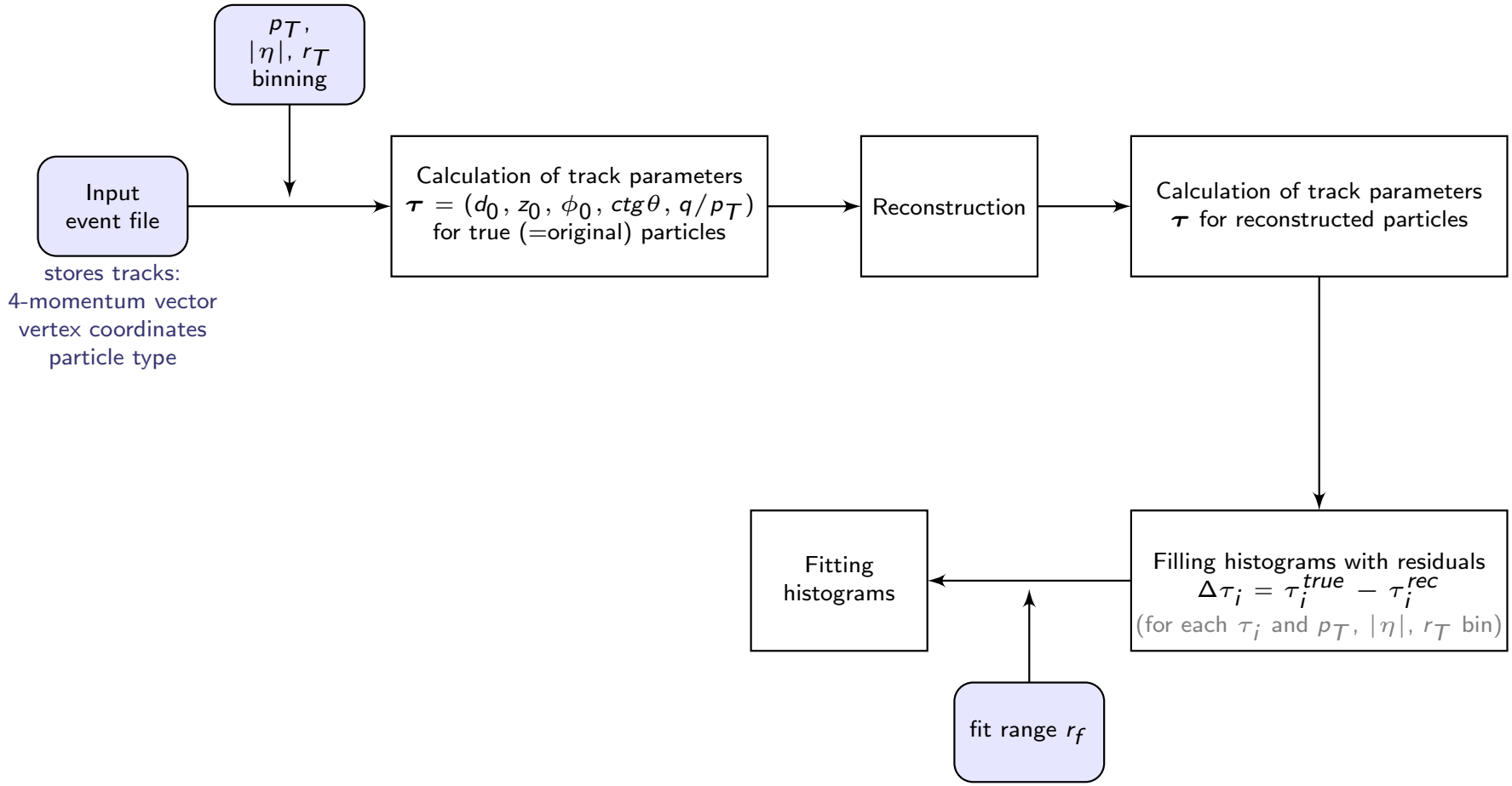
Calculation of track parameters
$\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals
$\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$
(for each τ_i and p_T, $|\eta|$, r_T bin)
fit range r_f


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
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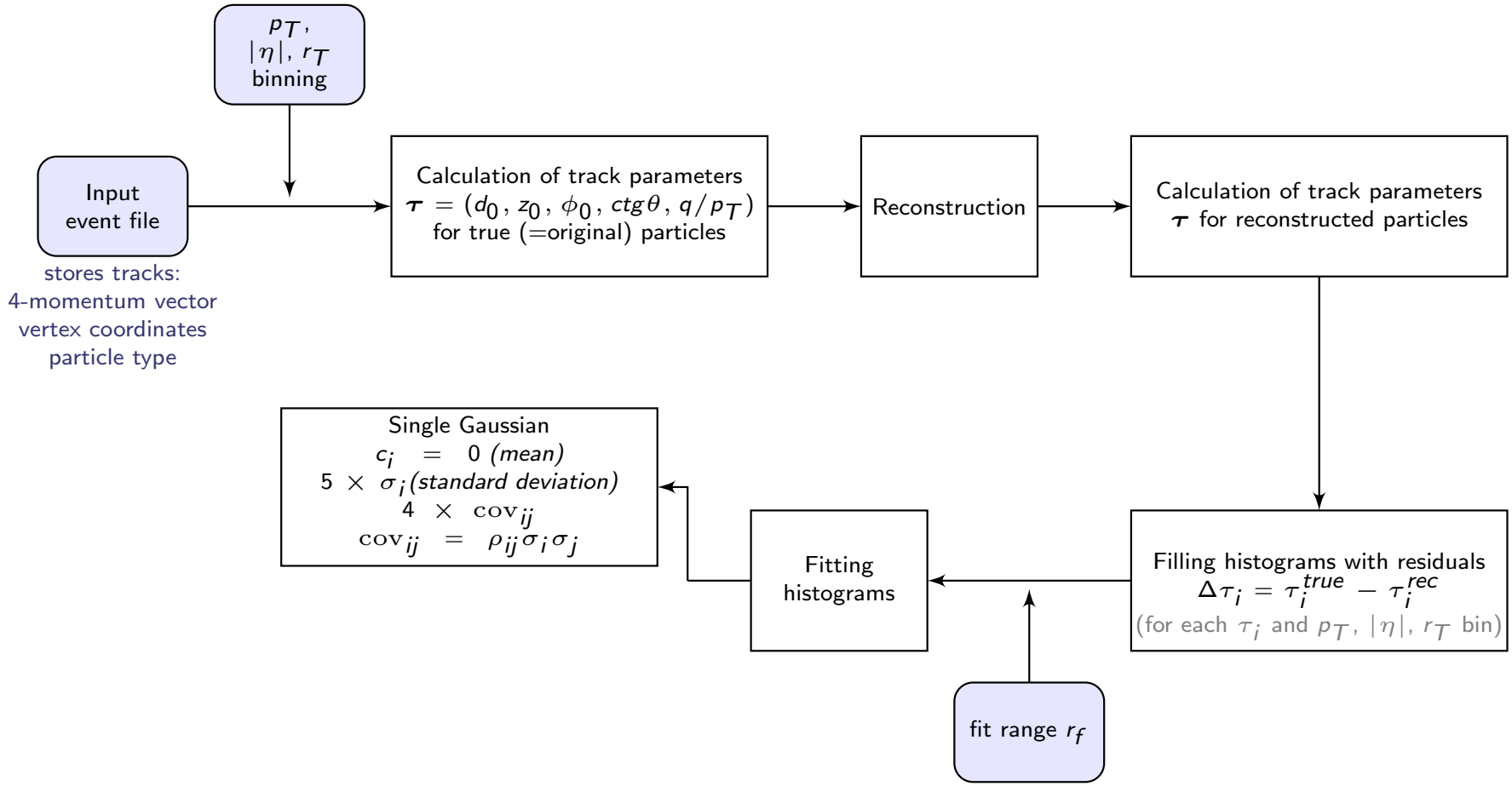
Calculation of track parameters $\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$ for true (=original) particles
Reconstruction
Calculation of track parameters $\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals $\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$
(for each τ_i and p_T, $|\eta|$, r_T bin)
Fitting histograms
fit range r_f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vertex coordinates
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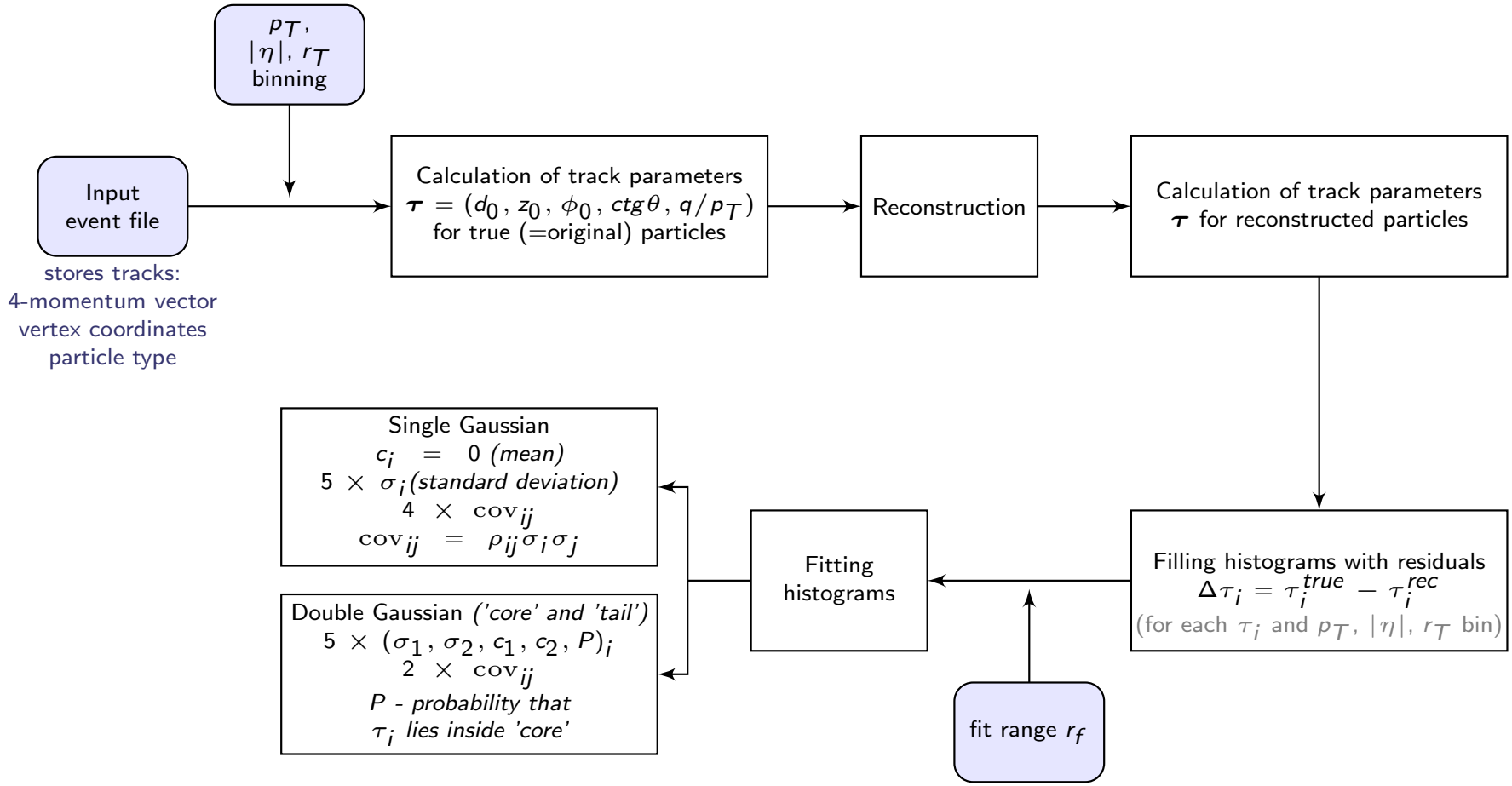
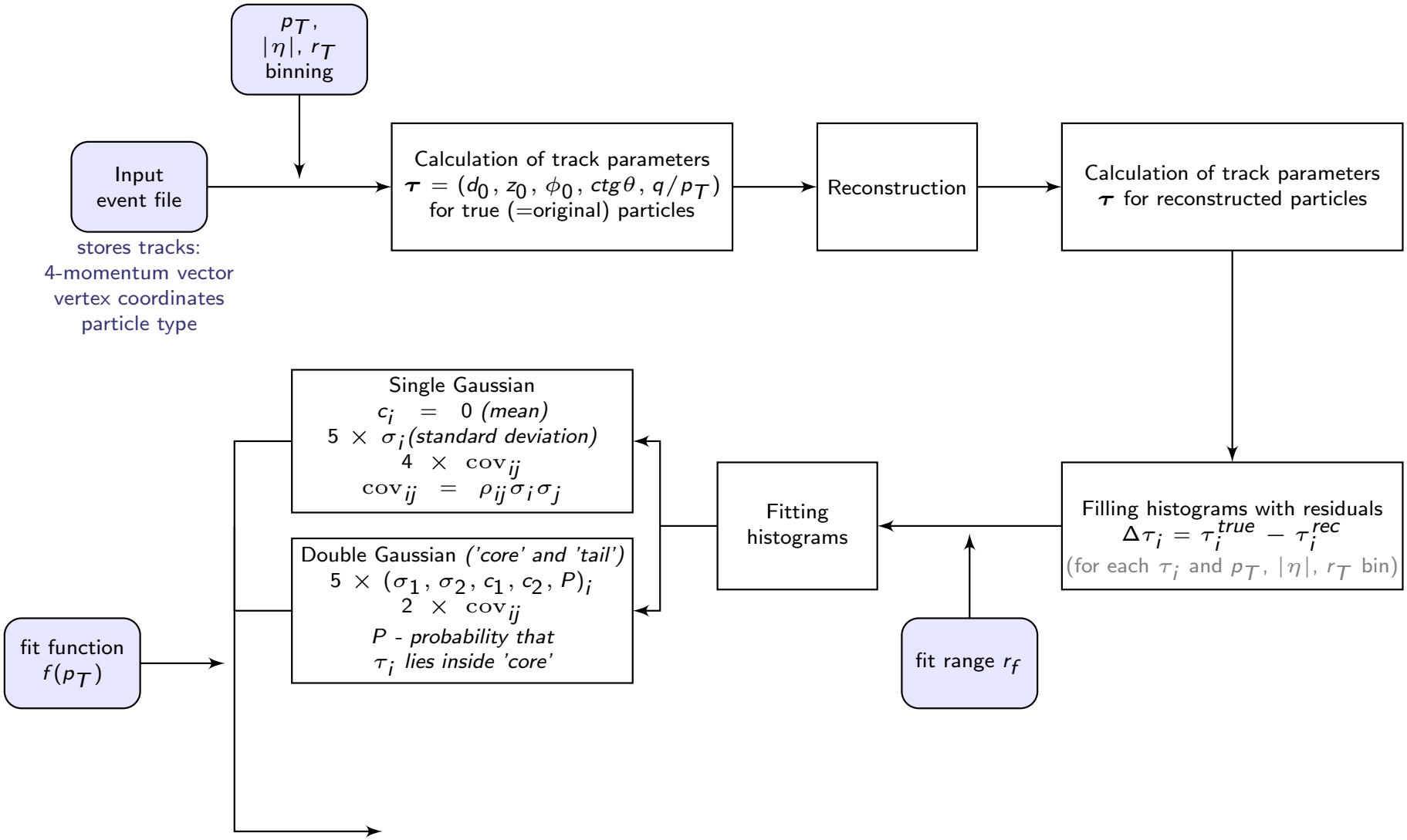
$\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals
$\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$
(for each τ_i and p_T, $|\eta|$, r_T bin)
Fitting histograms
Single Gaussian
$c_i = 0$ (mean)
$5 \times \sigma_i$ (standard deviation)
$4 \times \mathrm{cov}_{ij}$
$\mathrm{cov}_{ij} = \rho_{ij}\sigma_i\sigma_j$
fit range r_f


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters $\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$ for true (=original) particles
Reconstruction
Calculation of track parameters $\boldsymbol{\tau}$ for reconstructed particles
Filling histograms with residuals $\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$
(for each τ_i and p_T, $|\eta|$, r_T bin)
Fitting histograms
fit range r_f
Single Gaussian
$c_i = 0$ (mean)
$5 \times \sigma_i$ (standard deviation)
$4 \times \mathrm{cov}_{ij}$
$\mathrm{cov}_{ij} = \rho_{ij}\sigma_i\sigma_j$
Double Gaussian ('core' and 'tail')
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that
τ_i lies inside 'core'


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
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$\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
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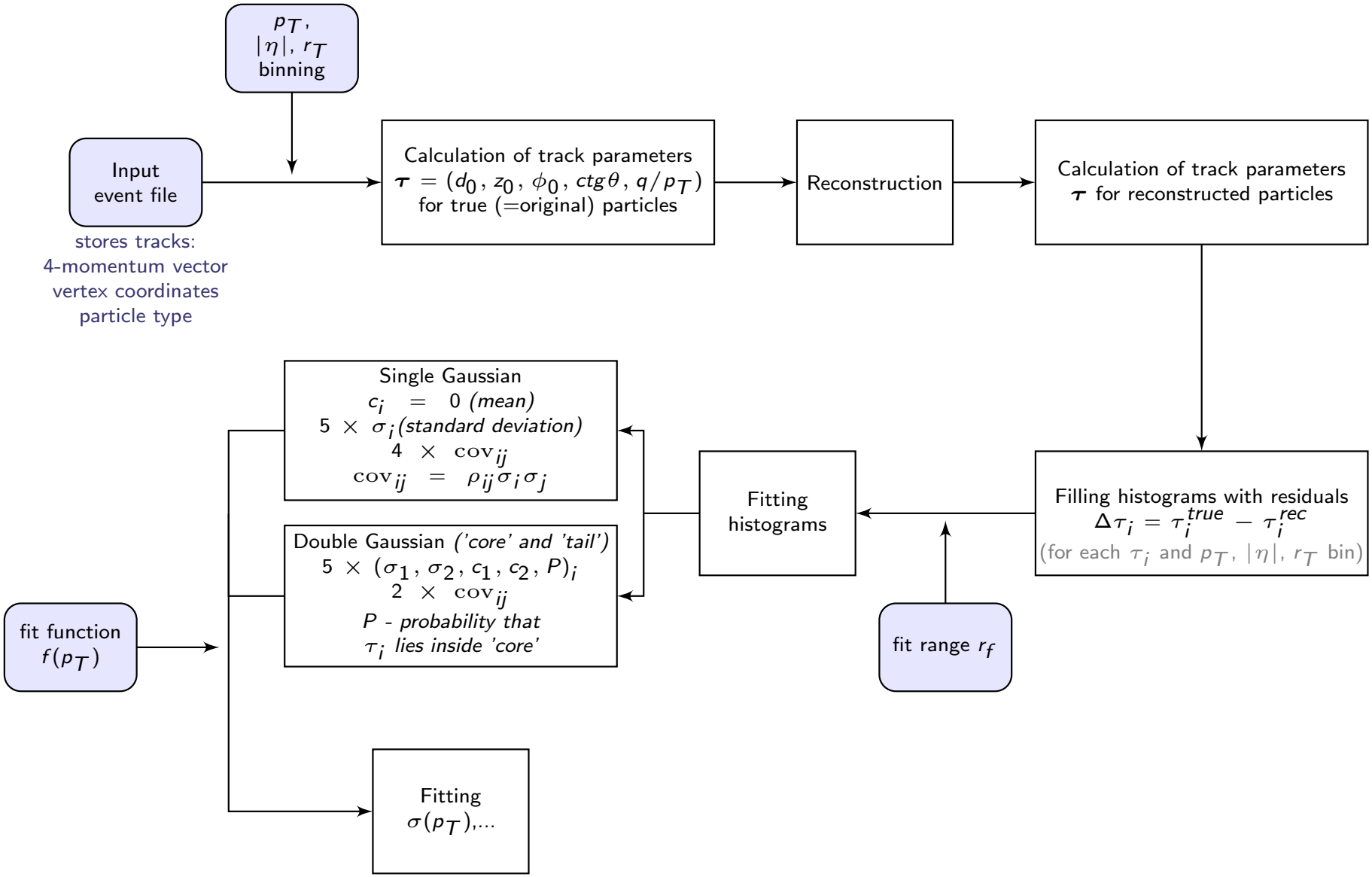
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that
τ_i lies inside 'core'
fit function $f(p_T)$
fit range r_f


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
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vertex coordinates
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$\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$
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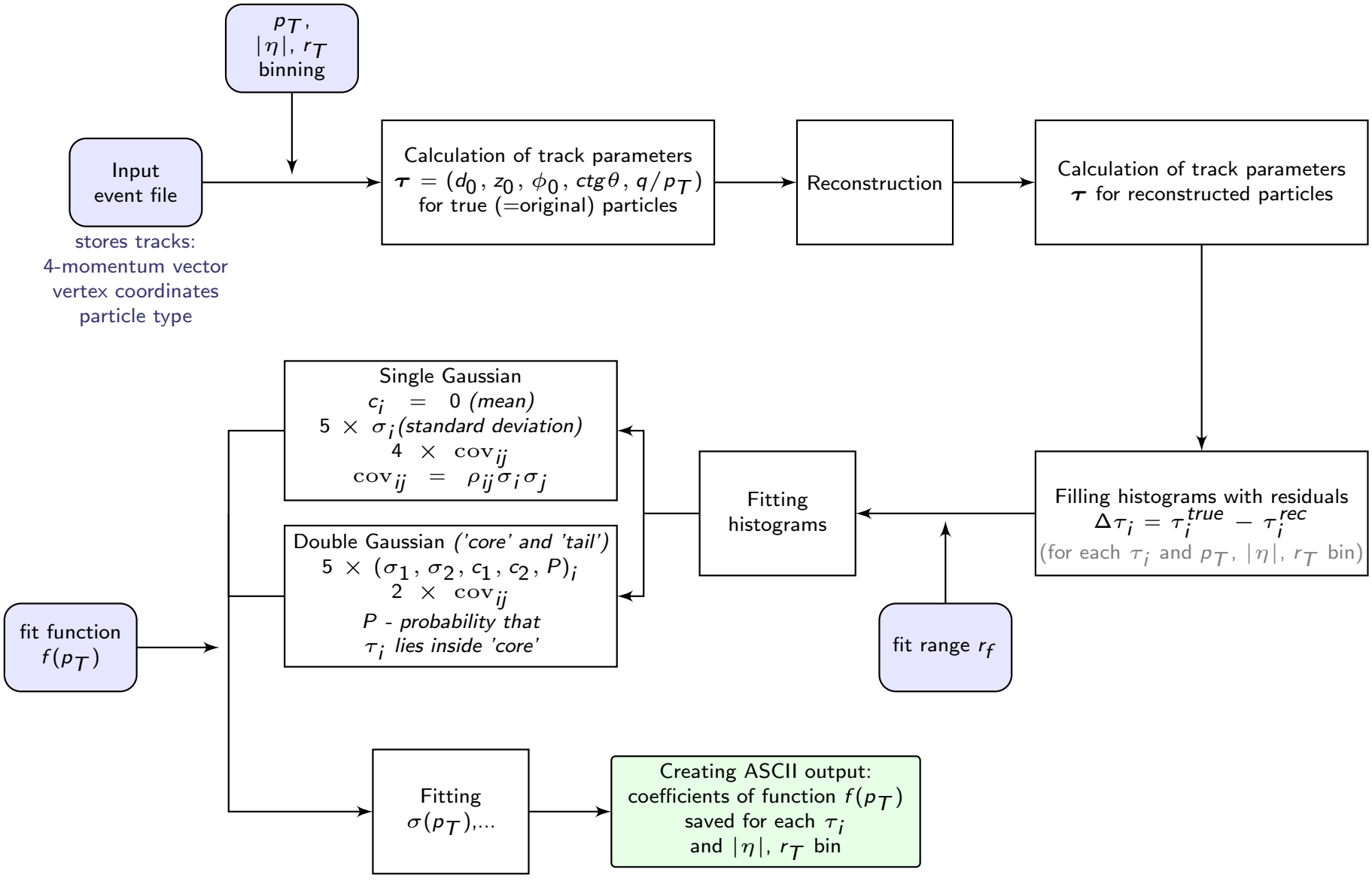
Double Gaussian ('core' and 'tail')
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that
τ_i lies inside 'core'
fit function $f(p_T)$
fit range r_f
Fitting $\sigma(p_T)$,...


p_T, $|\eta|$, r_T binning
Input event file
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Calculation of track parameters $\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$ for true (=original) particles
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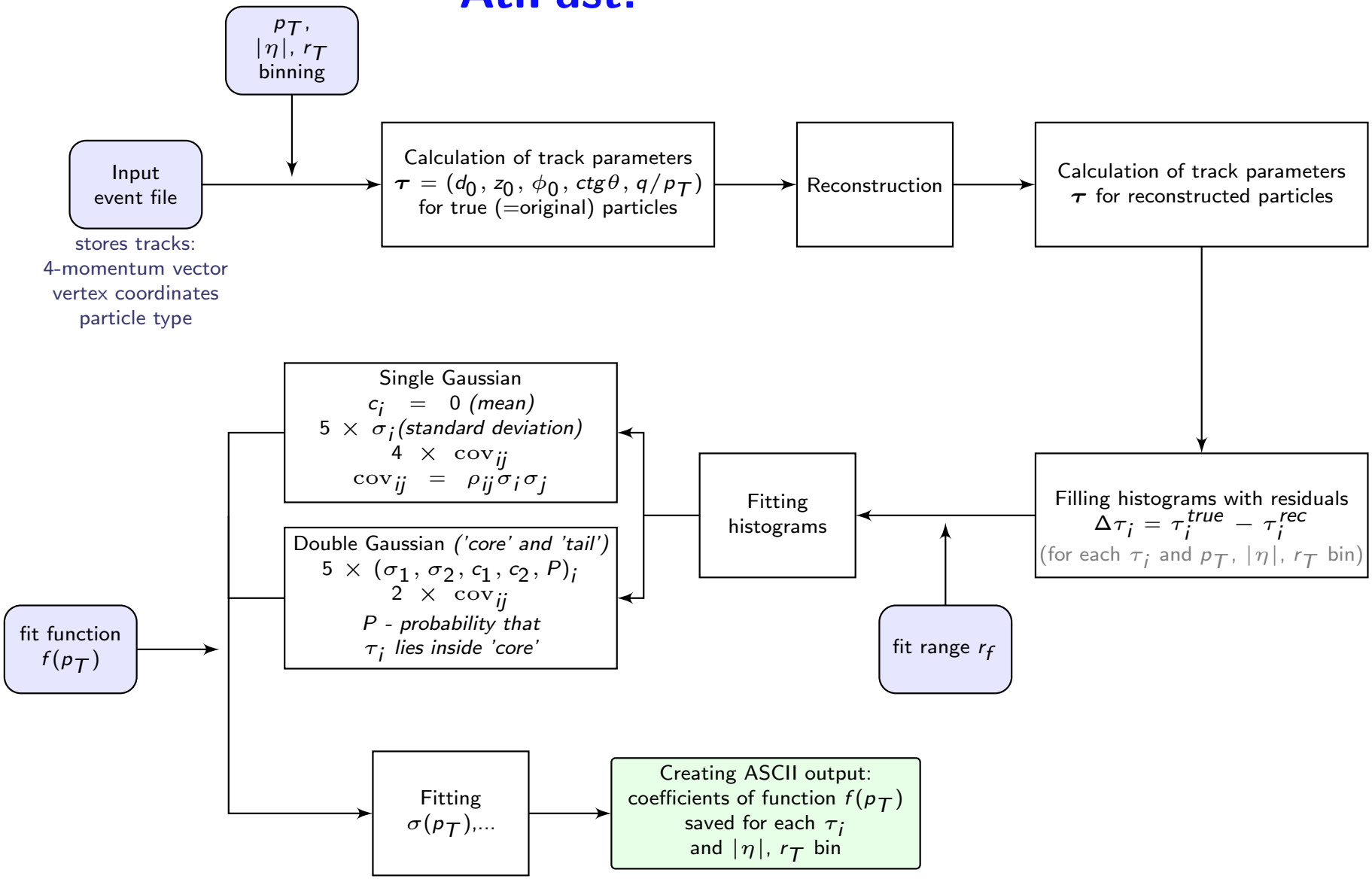
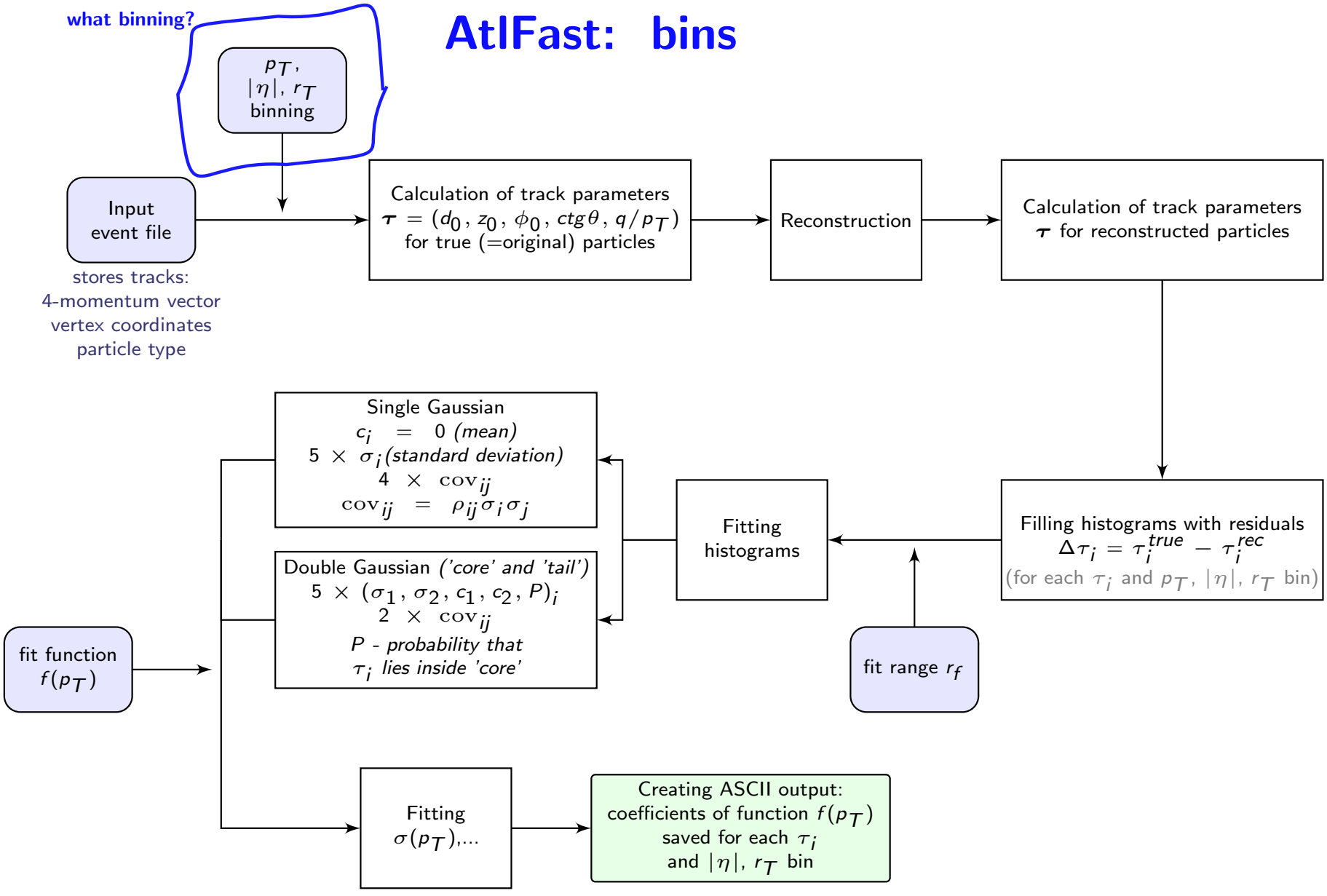
$\mathrm{cov}_{ij} = \rho_{ij}\sigma_i\sigma_j$
Double Gaussian ('core' and 'tail')
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that τ_i lies inside 'core'
fit function $f(p_T)$
fit range r_f
Fitting $\sigma(p_T)$,...
Creating ASCII output:
coefficients of function $f(p_T)$
saved for each τ_i
and $|\eta|$, r_T bin

AtlFast:


p_T, $|\eta|$, r_T binning
Input event file
stores tracks:
4-momentum vector
vertex coordinates
particle type
Calculation of track parameters $\tau = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$ for true (=original) particles
Reconstruction
Calculation of track parameters τ for reconstructed particles
Filling histograms with residuals $\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$ (for each τ_i and p_T, $|\eta|$, r_T bin)
Fitting histograms
Single Gaussian
$c_i = 0$ (mean)
$5 \times \sigma_i$ (standard deviation)
$4 \times \mathrm{cov}_{ij}$
$\mathrm{cov}_{ij} = \rho_{ij}\sigma_i\sigma_j$
Double Gaussian ('core' and 'tail')
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that τ_i lies inside 'core'
fit function $f(p_T)$
fit range r_f
Fitting $\sigma(p_T)$,...
Creating ASCII output: coefficients of function $f(p_T)$ saved for each τ_i and $|\eta|$, r_T bin

AtlFast: bins



AtlFast: bins

what binning?

10 equal bins in $|\eta| \in [0, 2.5)$

p_T, $|\eta|$, r_T binning

Input event file

stores tracks:
4-momentum vector
vertex coordinates
particle type

Calculation of track parameters $\boldsymbol{\tau} = (d_0, z_0, \phi_0, ctg\theta, q/p_T)$ for true (=original) particles

Reconstruction

Calculation of track parameters $\boldsymbol{\tau}$ for reconstructed particles

Filling histograms with residuals $\Delta\tau_i = \tau_i^{true} - \tau_i^{rec}$ (for each τ_i and p_T, $|\eta|$, r_T bin)

Fitting histograms

Single Gaussian
$c_i = 0$ *(mean)*
$5 \times \sigma_i$ *(standard deviation)*
$4 \times \mathrm{cov}_{ij}$
$\mathrm{cov}_{ij} = \rho_{ij}\sigma_i\sigma_j$

Double Gaussian *('core' and 'tail')*
$5 \times (\sigma_1, \sigma_2, c_1, c_2, P)_i$
$2 \times \mathrm{cov}_{ij}$
P - probability that τ_i lies inside 'core'

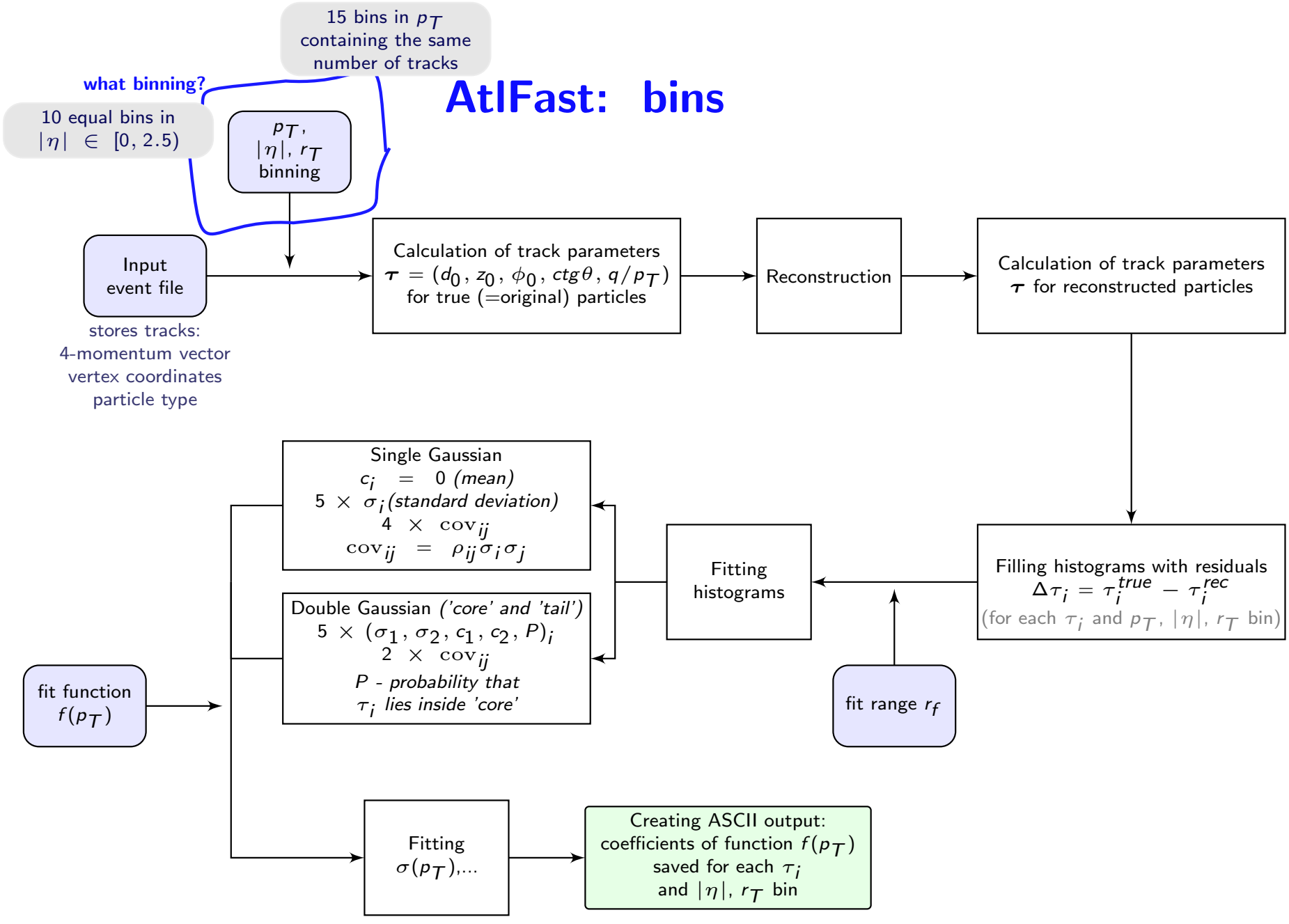
fit function $f(p_T)$

fit range r_f

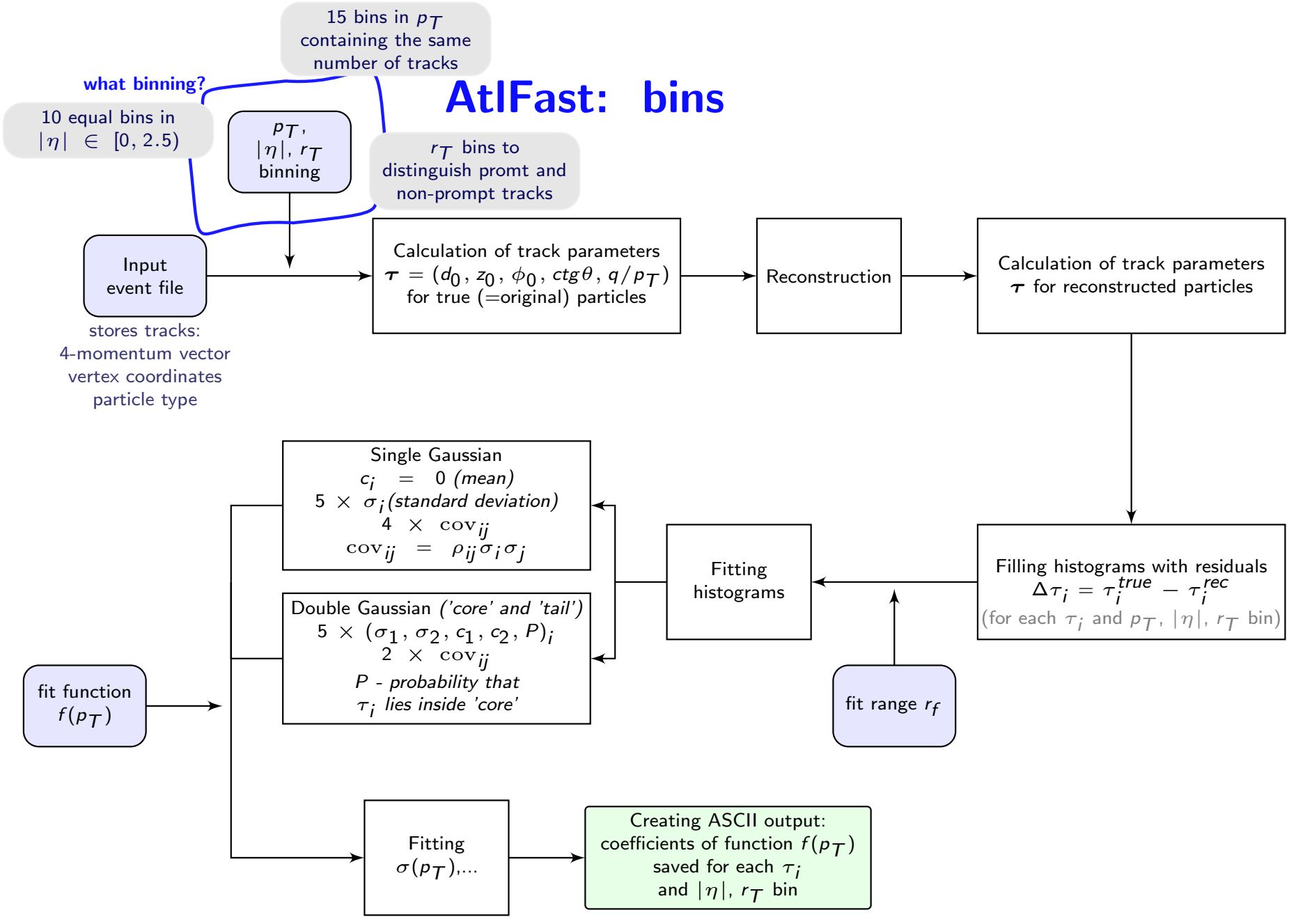
Fitting $\sigma(p_T)$,...

Creating ASCII output:
coefficients of function $f(p_T)$
saved for each τ_i
and $|\eta|$, r_T bin

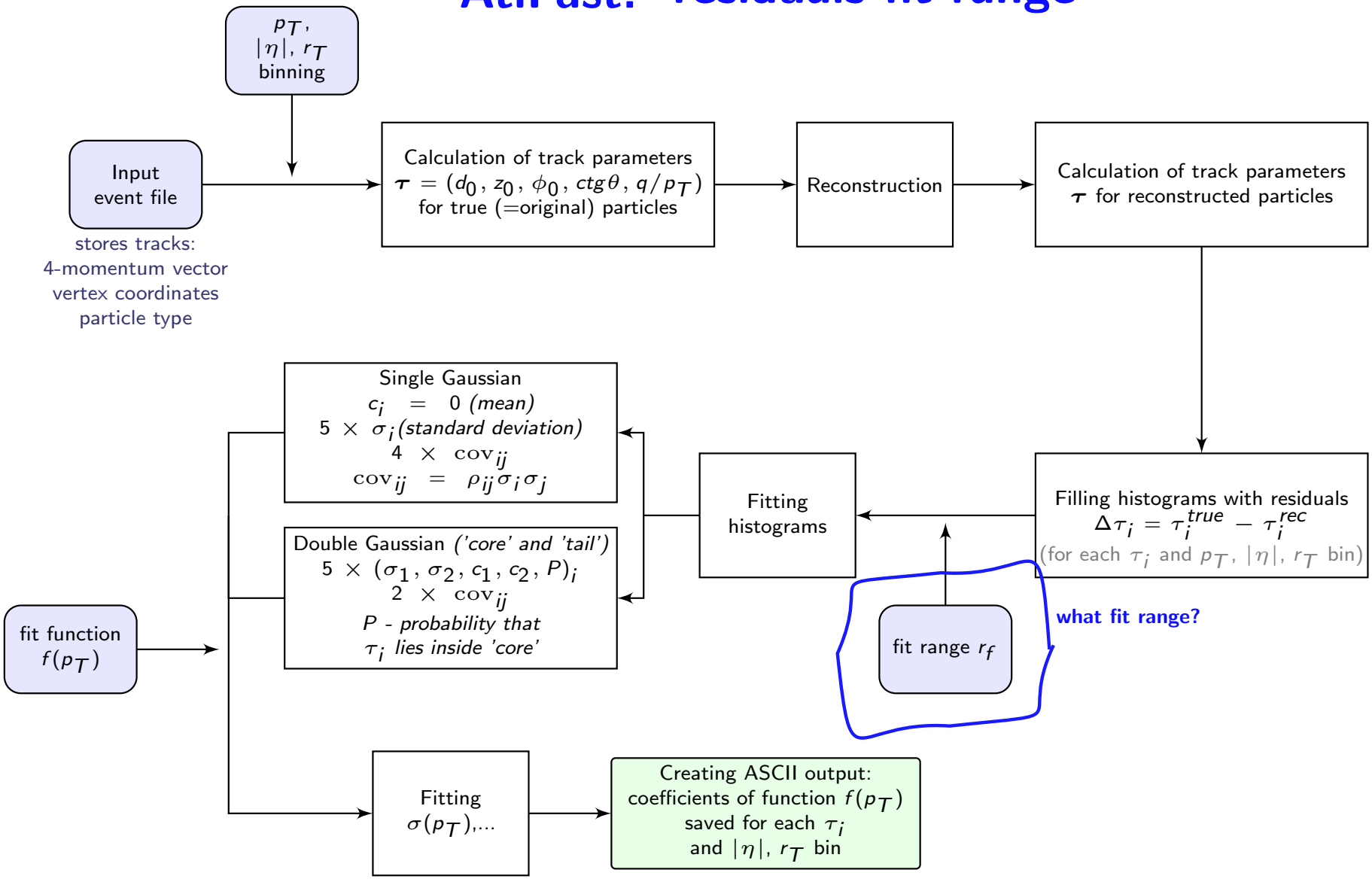
AtlFast: bins



AtlFast: bins



AtlFast: residuals fit range



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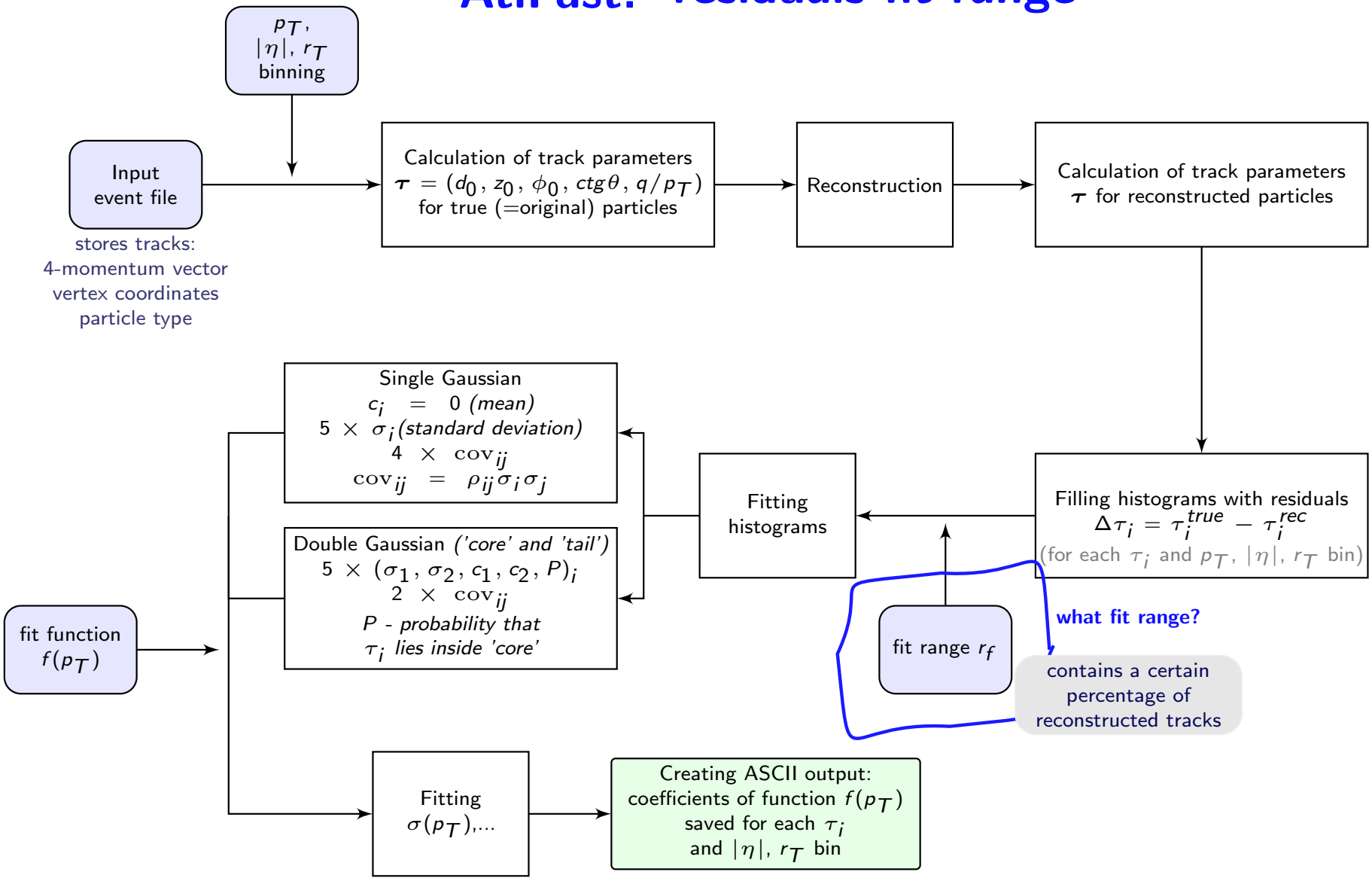
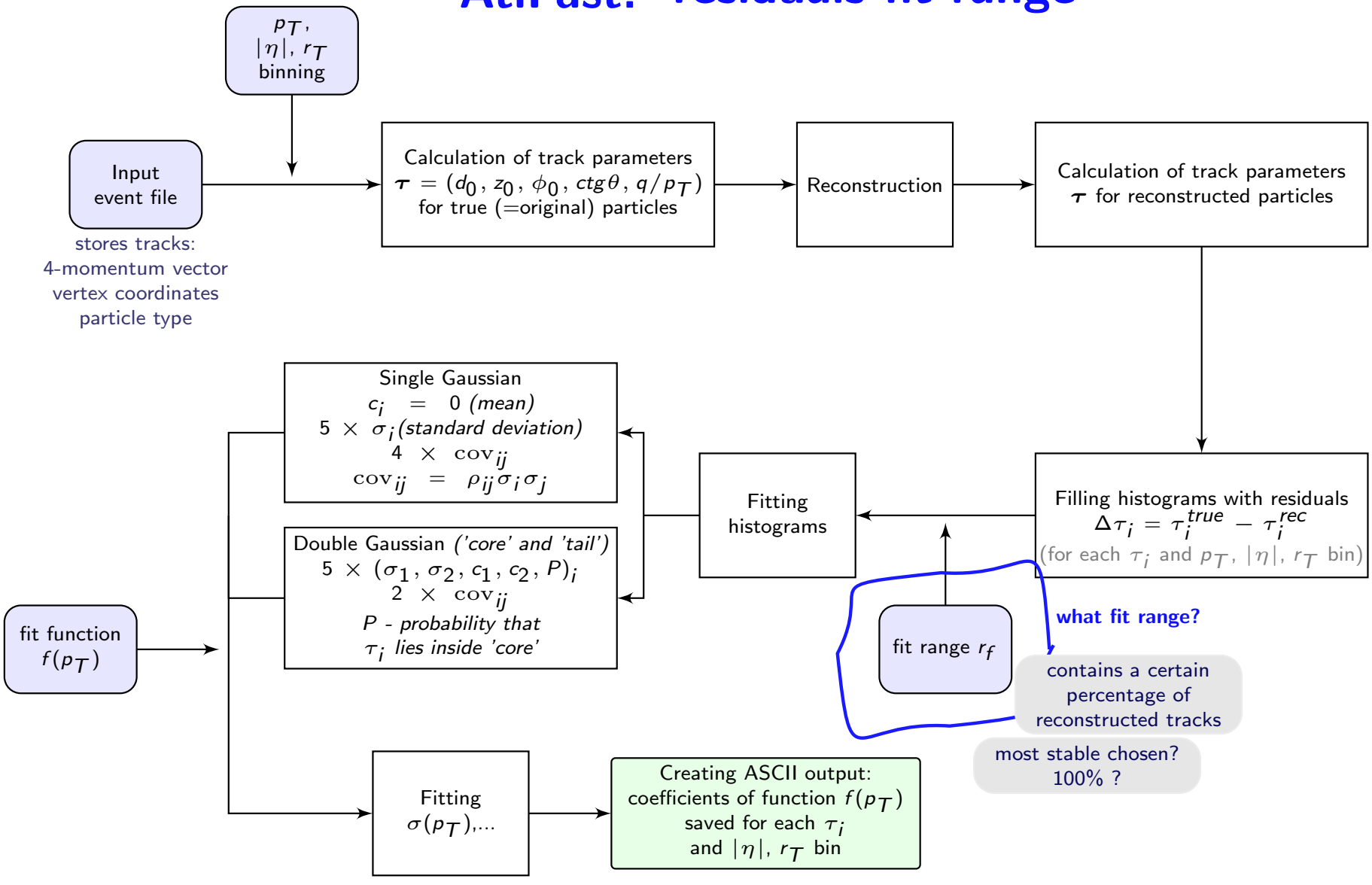
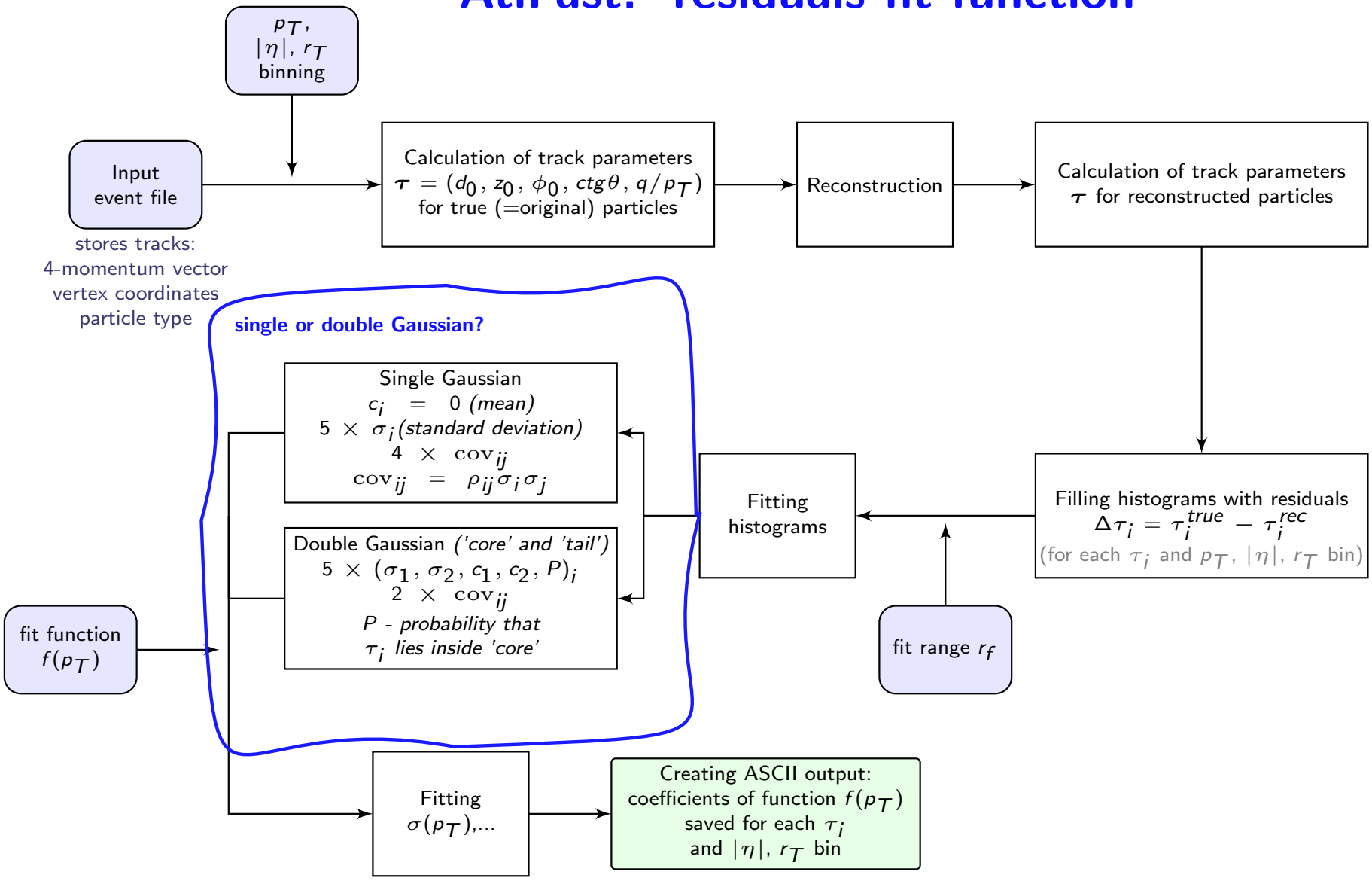


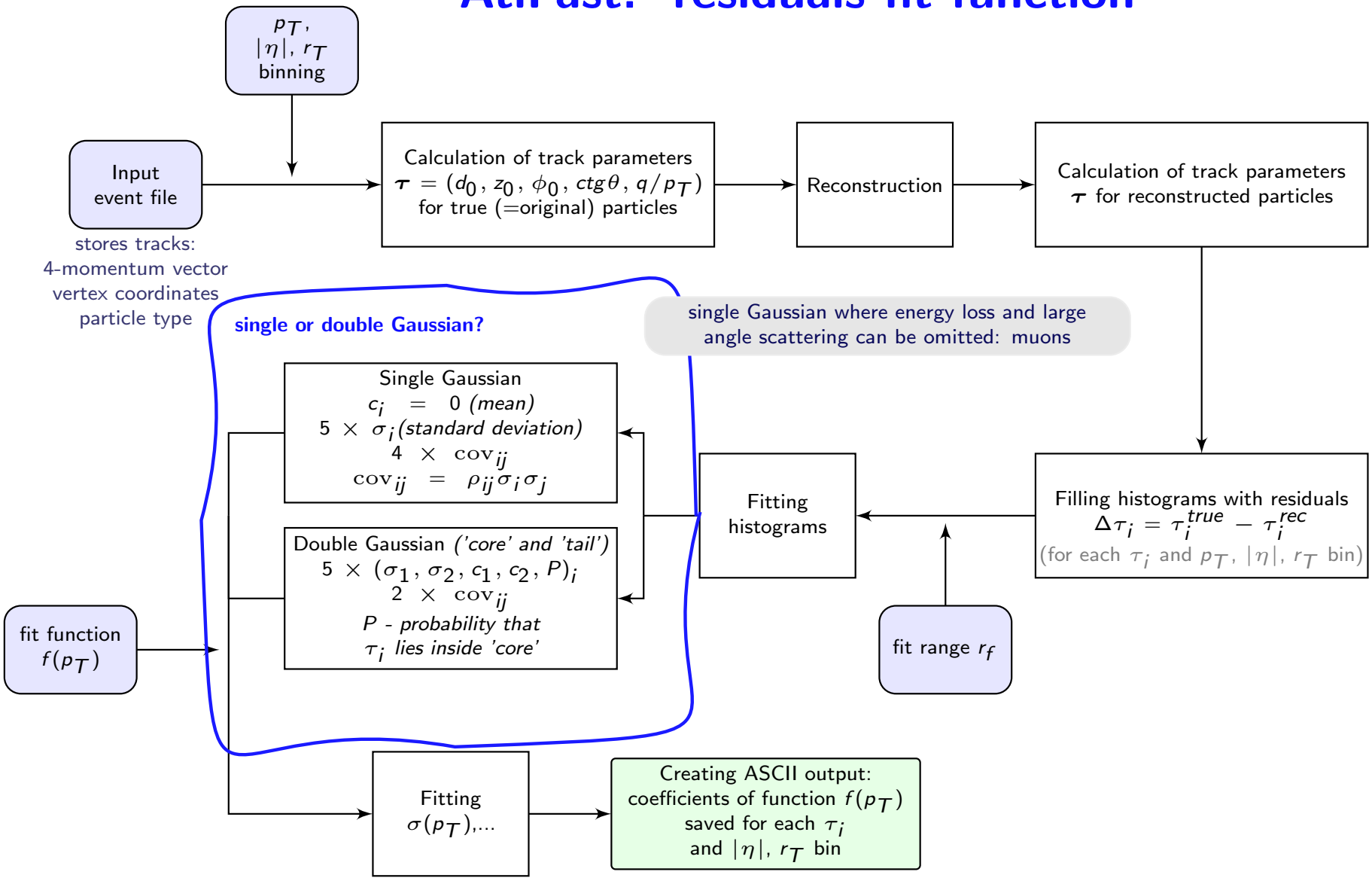
AtlFast: residuals fit range



AtlFast: residuals fit function



AtlFast: residuals fit function



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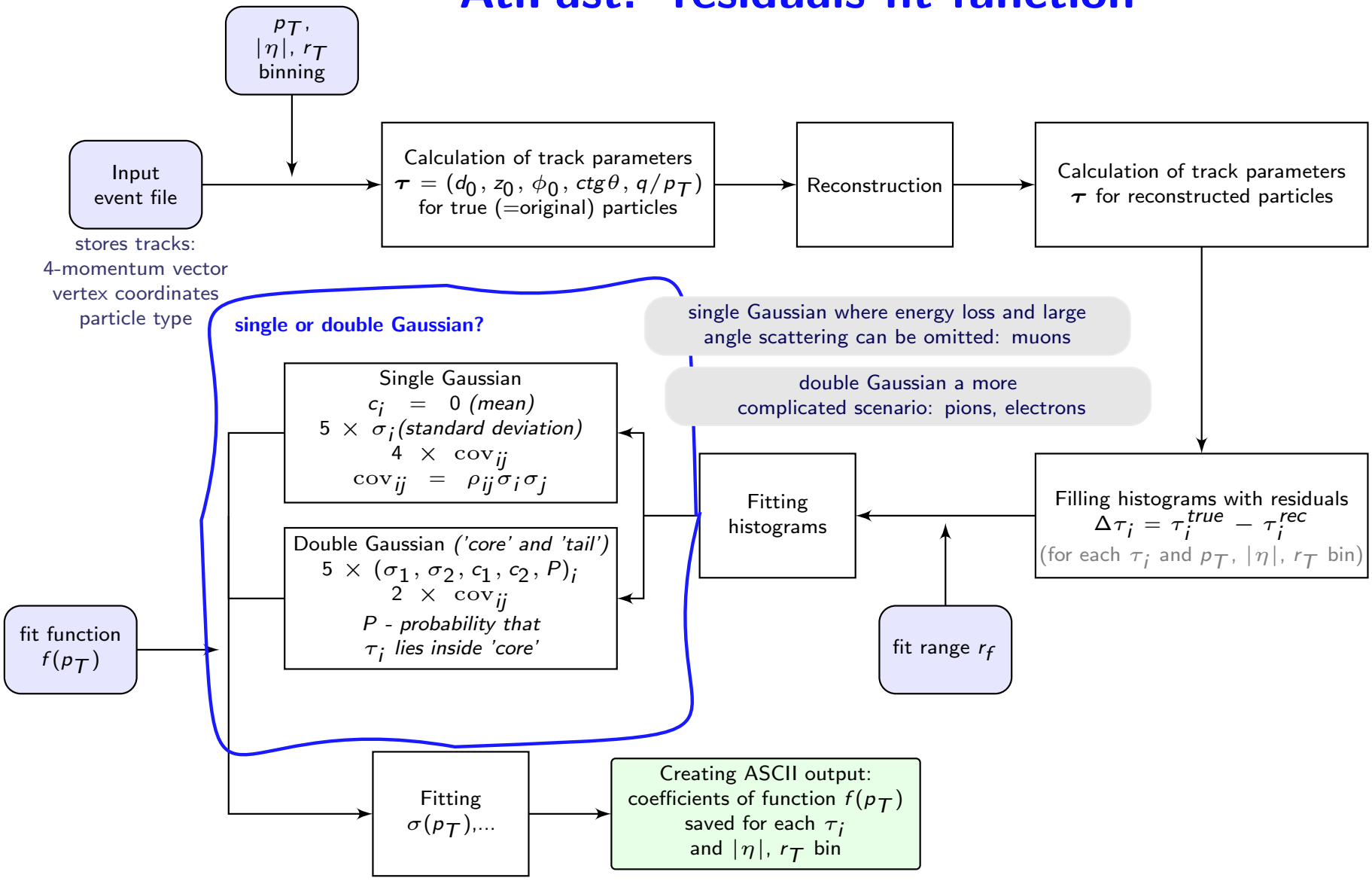

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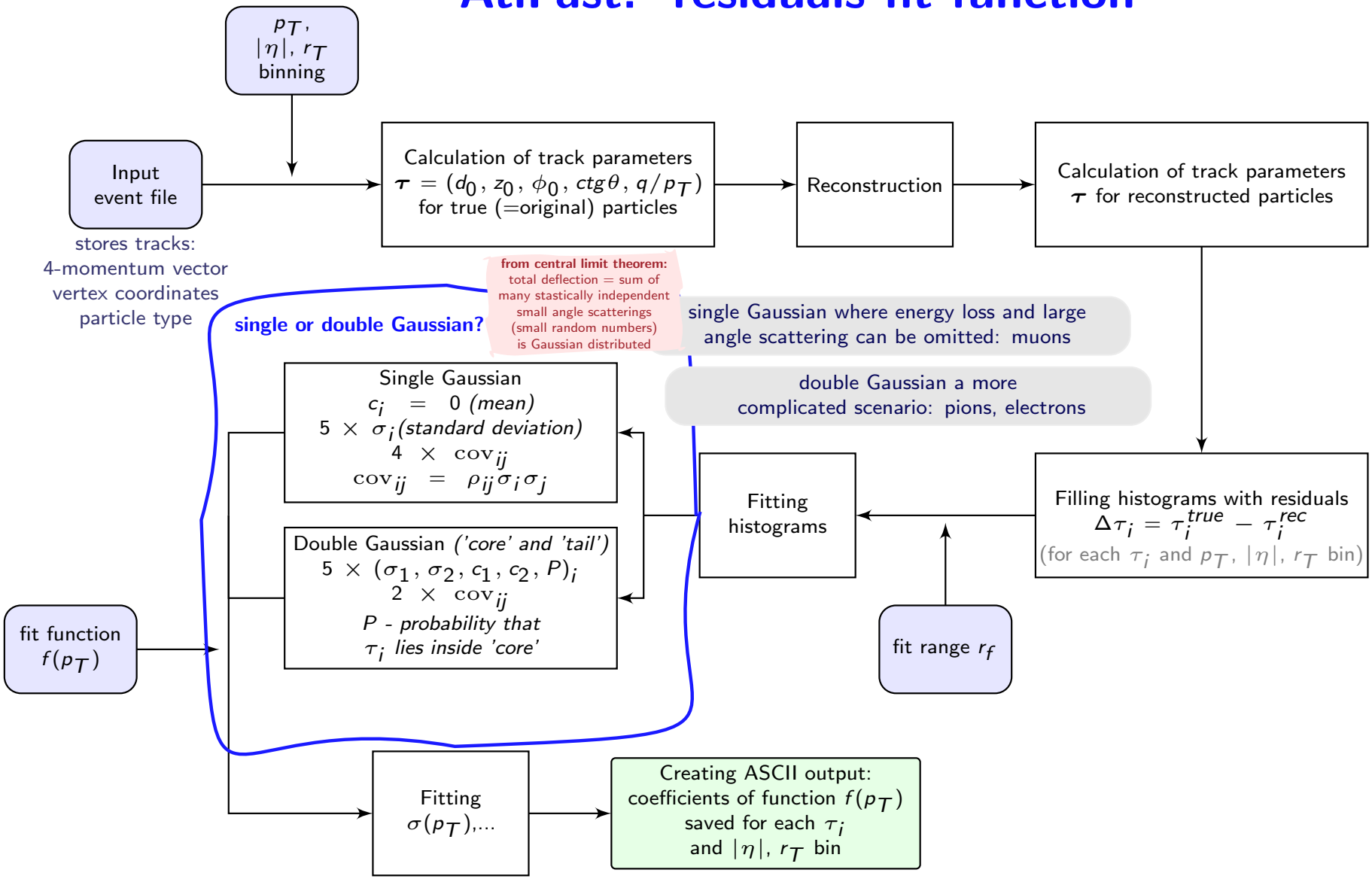
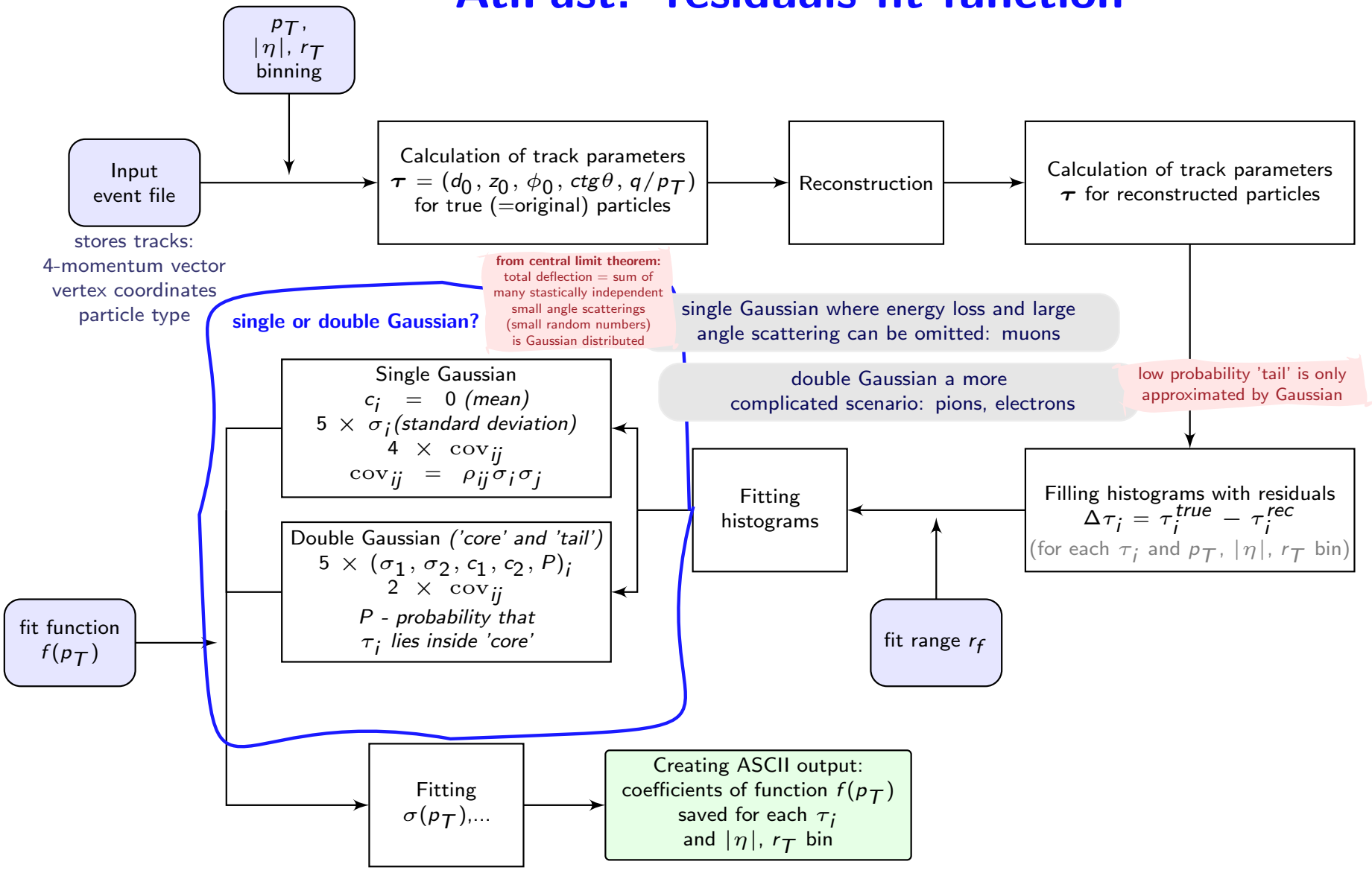
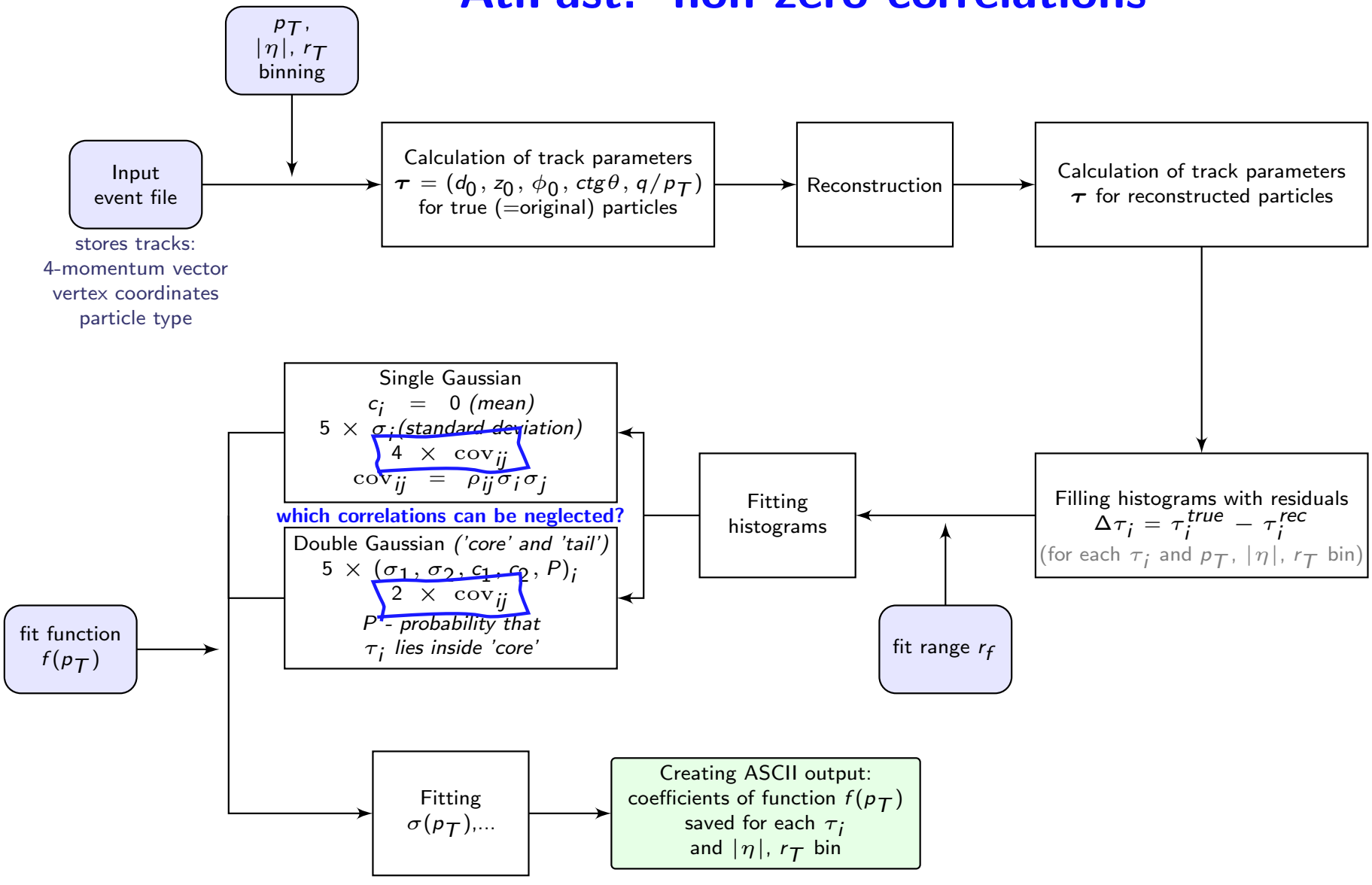


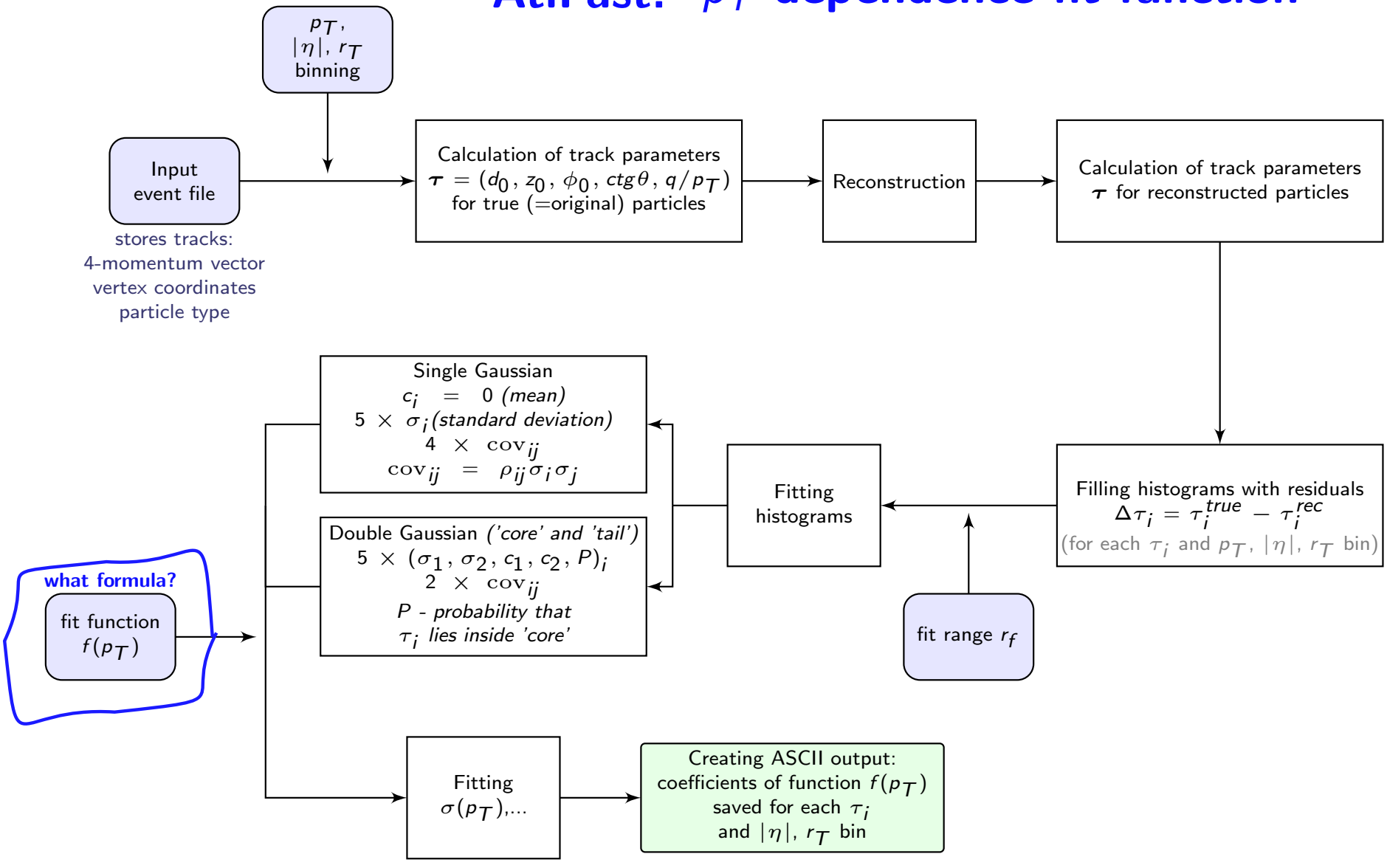
AtlFast: residuals fit function



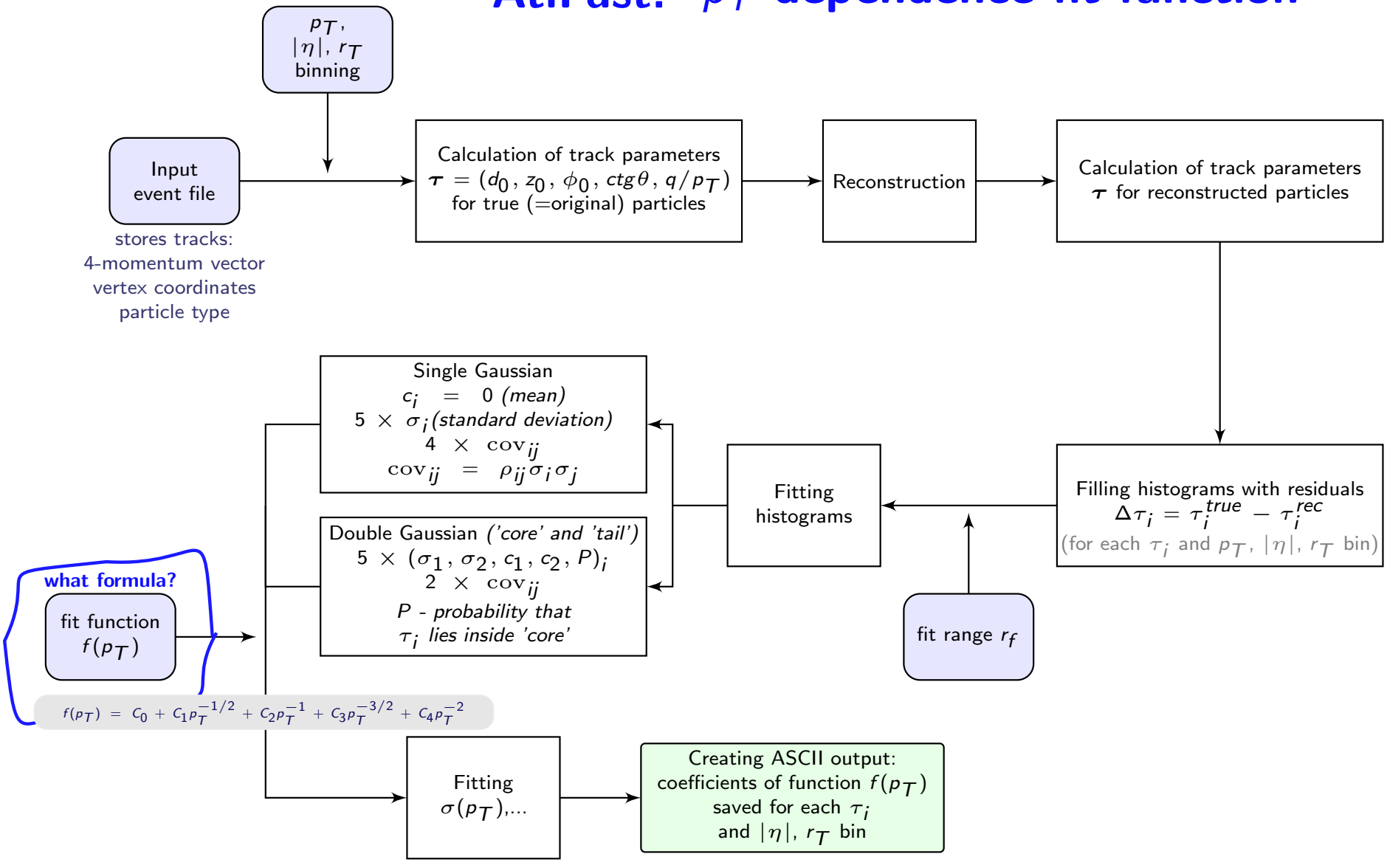
AtlFast: non-zero correlations



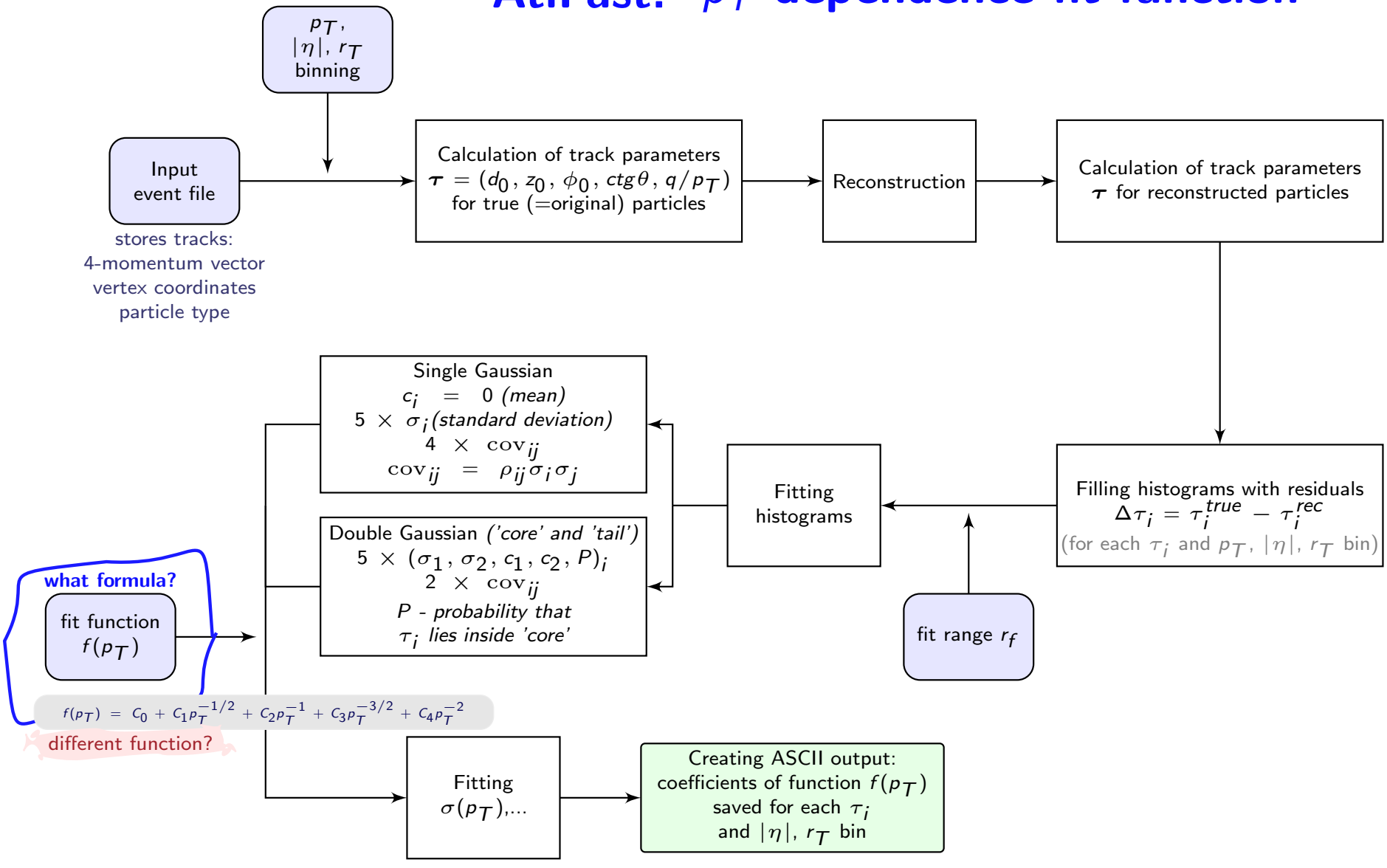
AtlFast: p_T dependence fit function



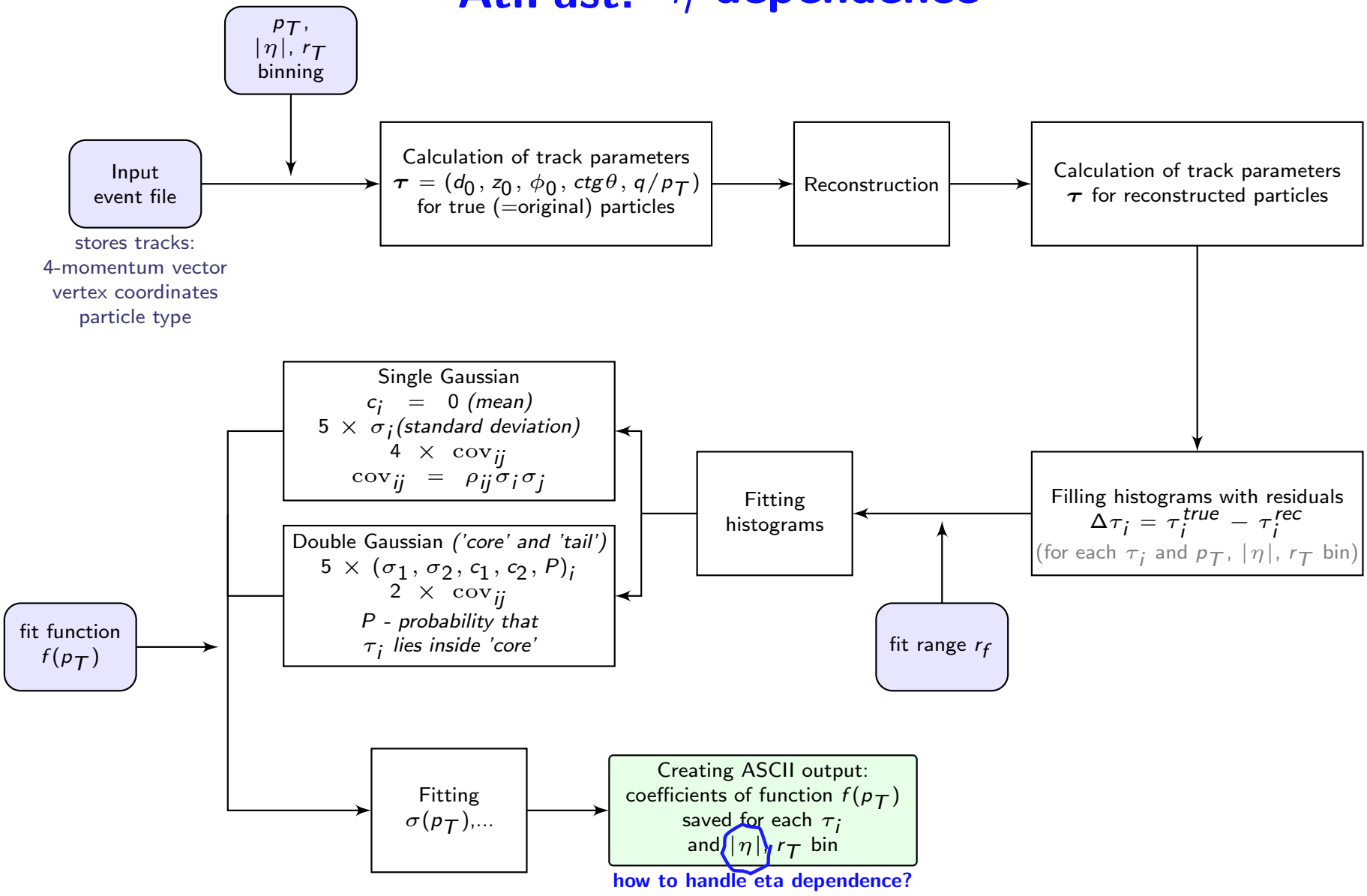
AtlFast: p_T dependence fit function



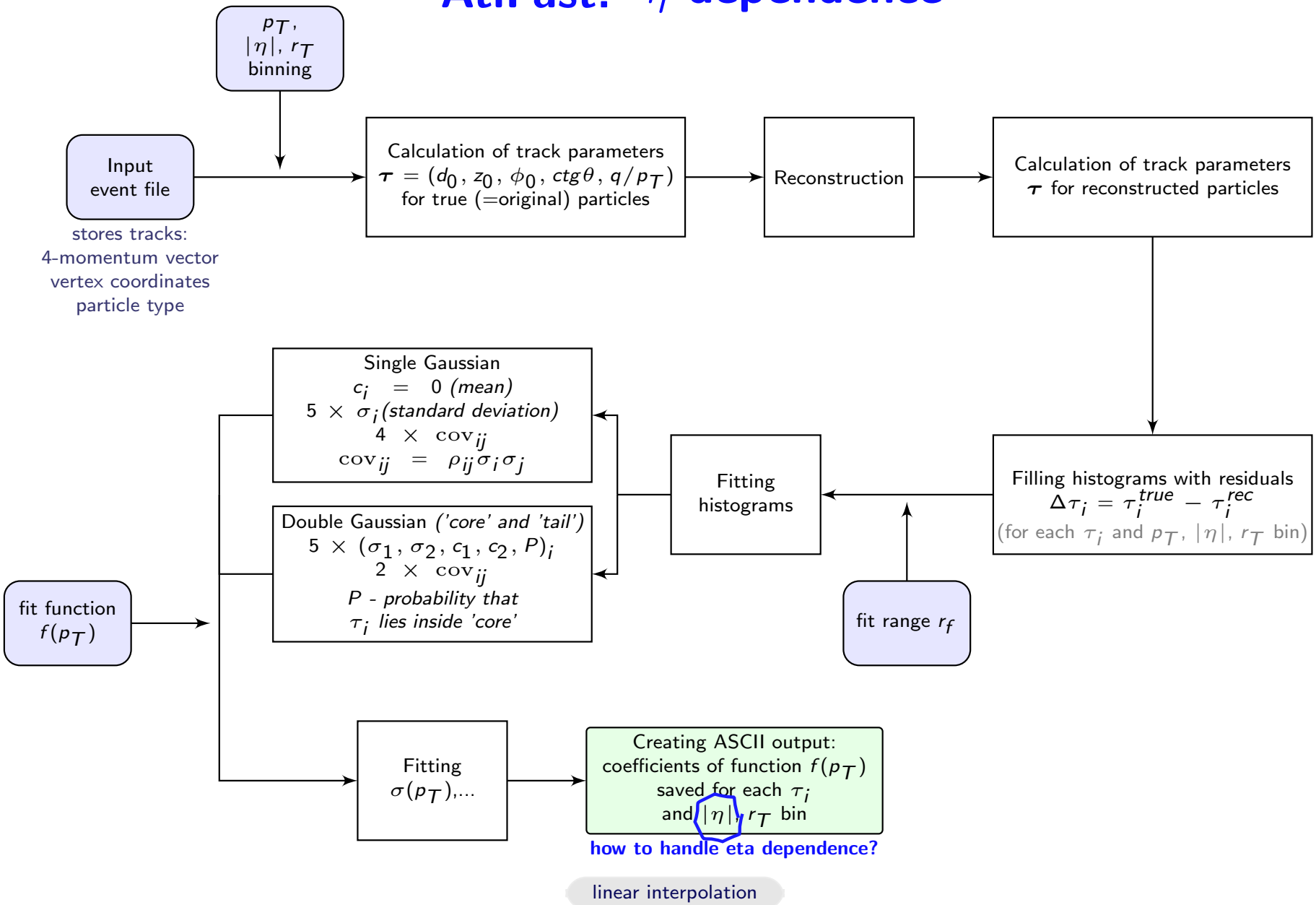
AtlFast: p_T dependence fit function



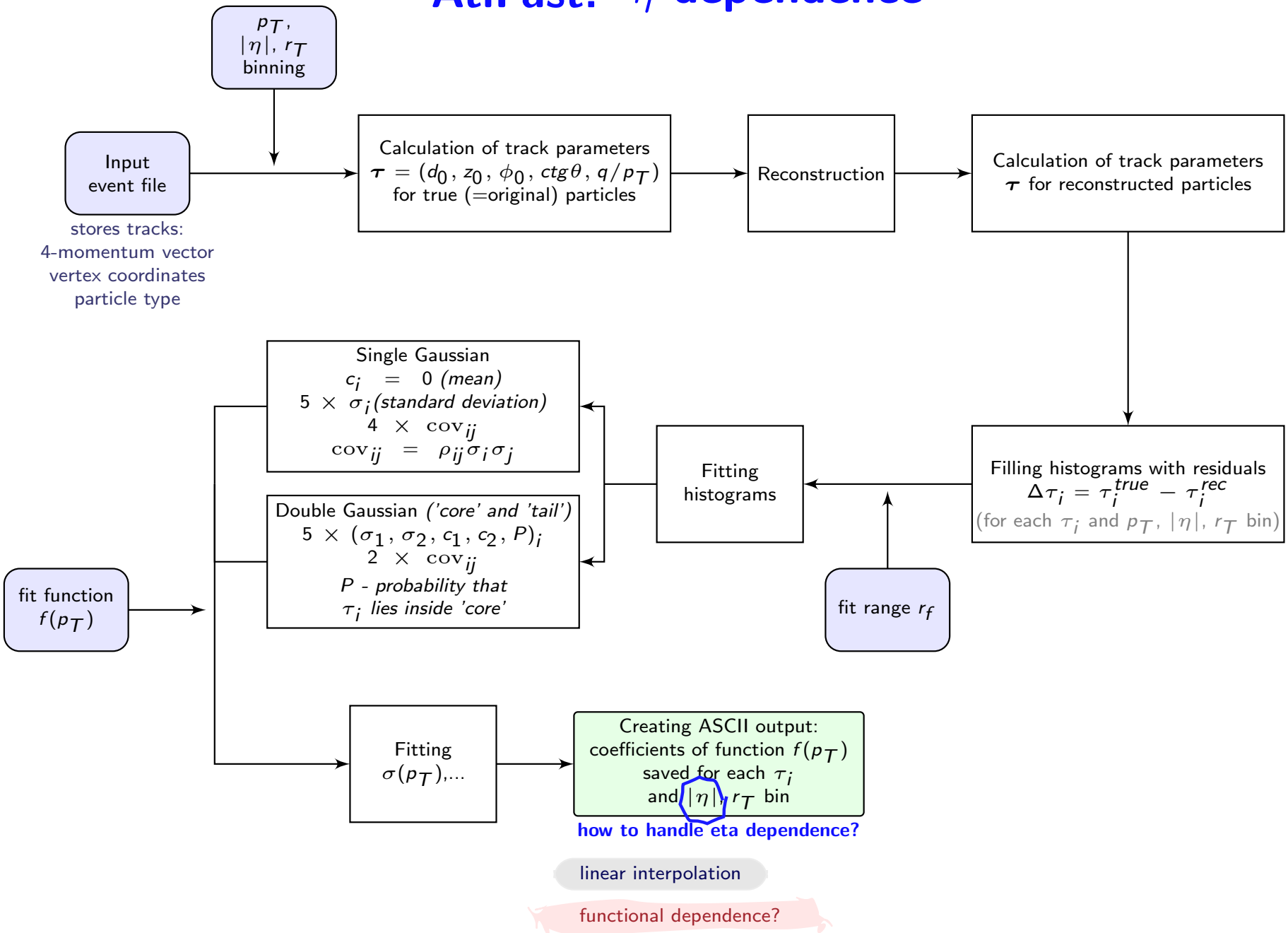
AtlFast: η dependence



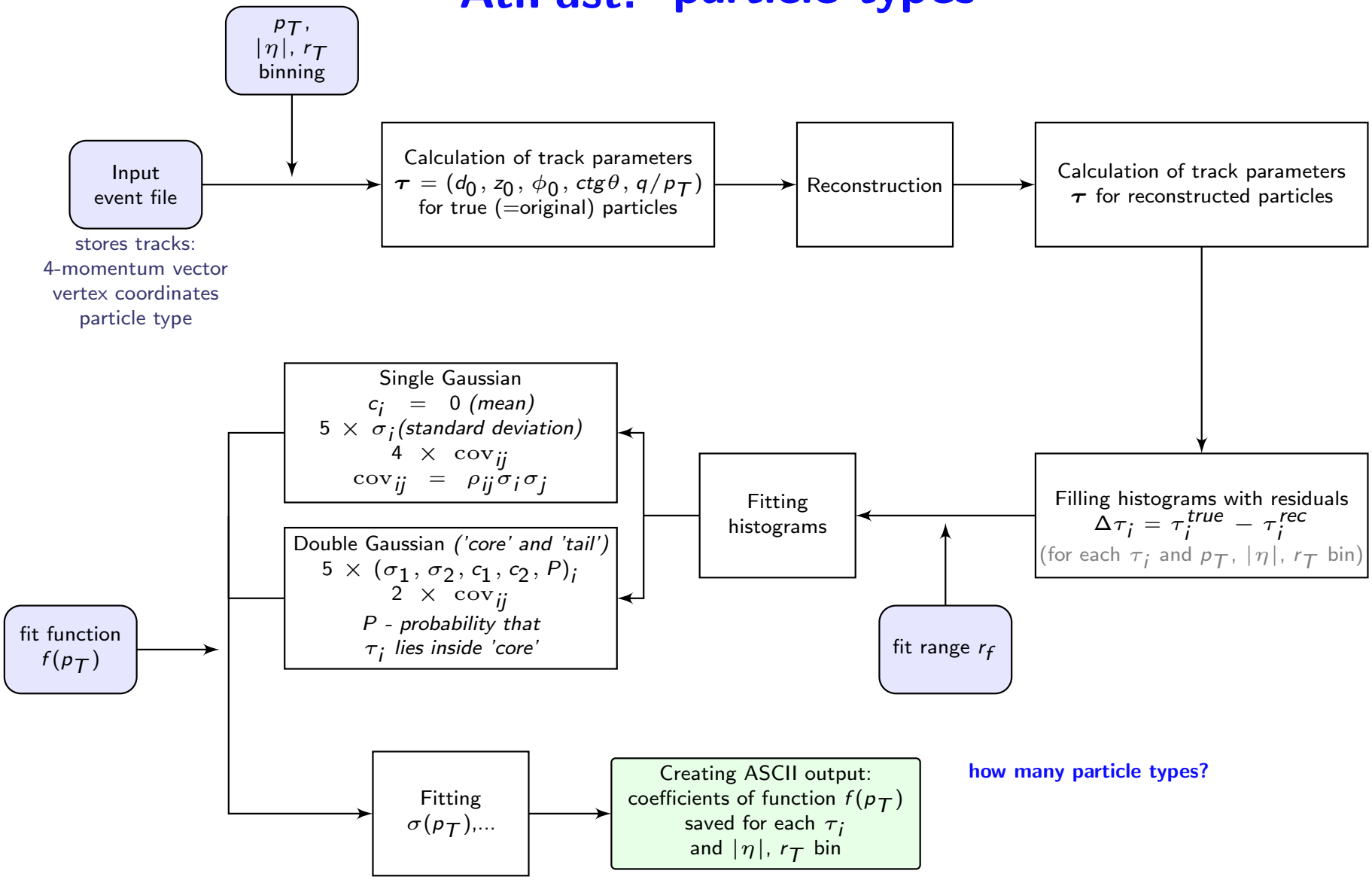
AtlFast: η dependence



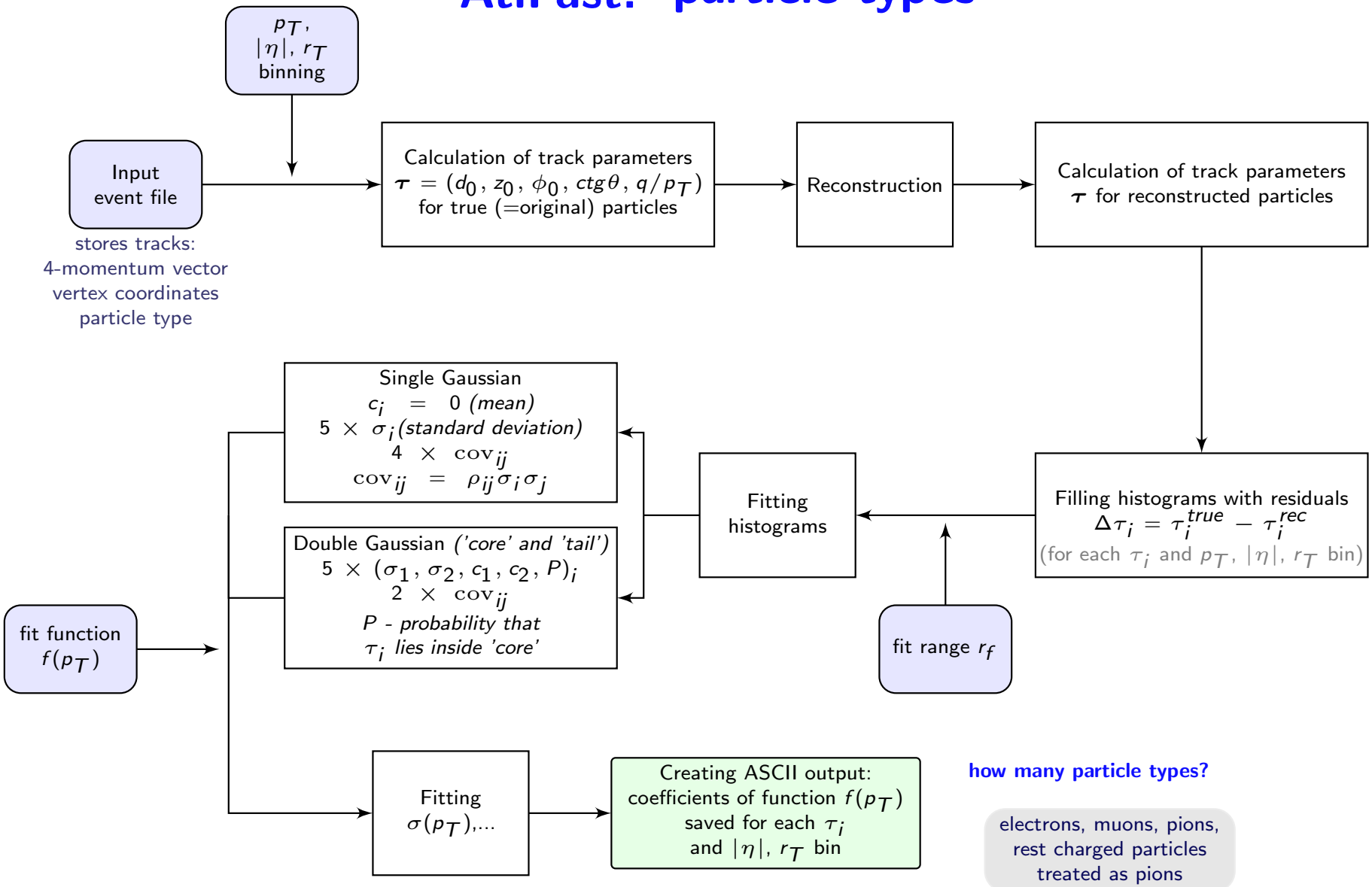
AtlFast: η dependence



AtlFast: particle types



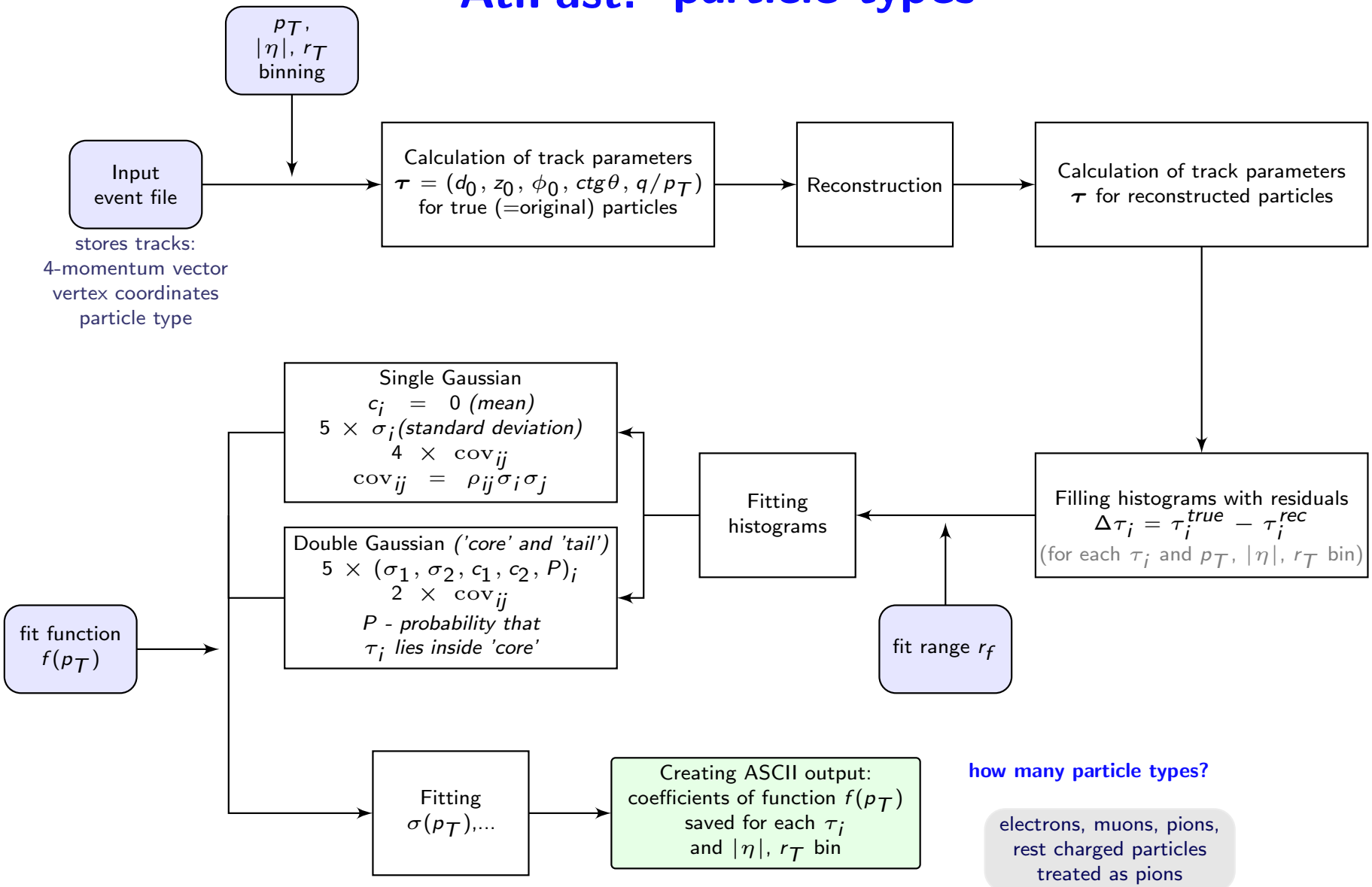
AtlFast: particle types



how many particle types?

electrons, muons, pions,
rest charged particles
treated as pions

AtlFast: particle types

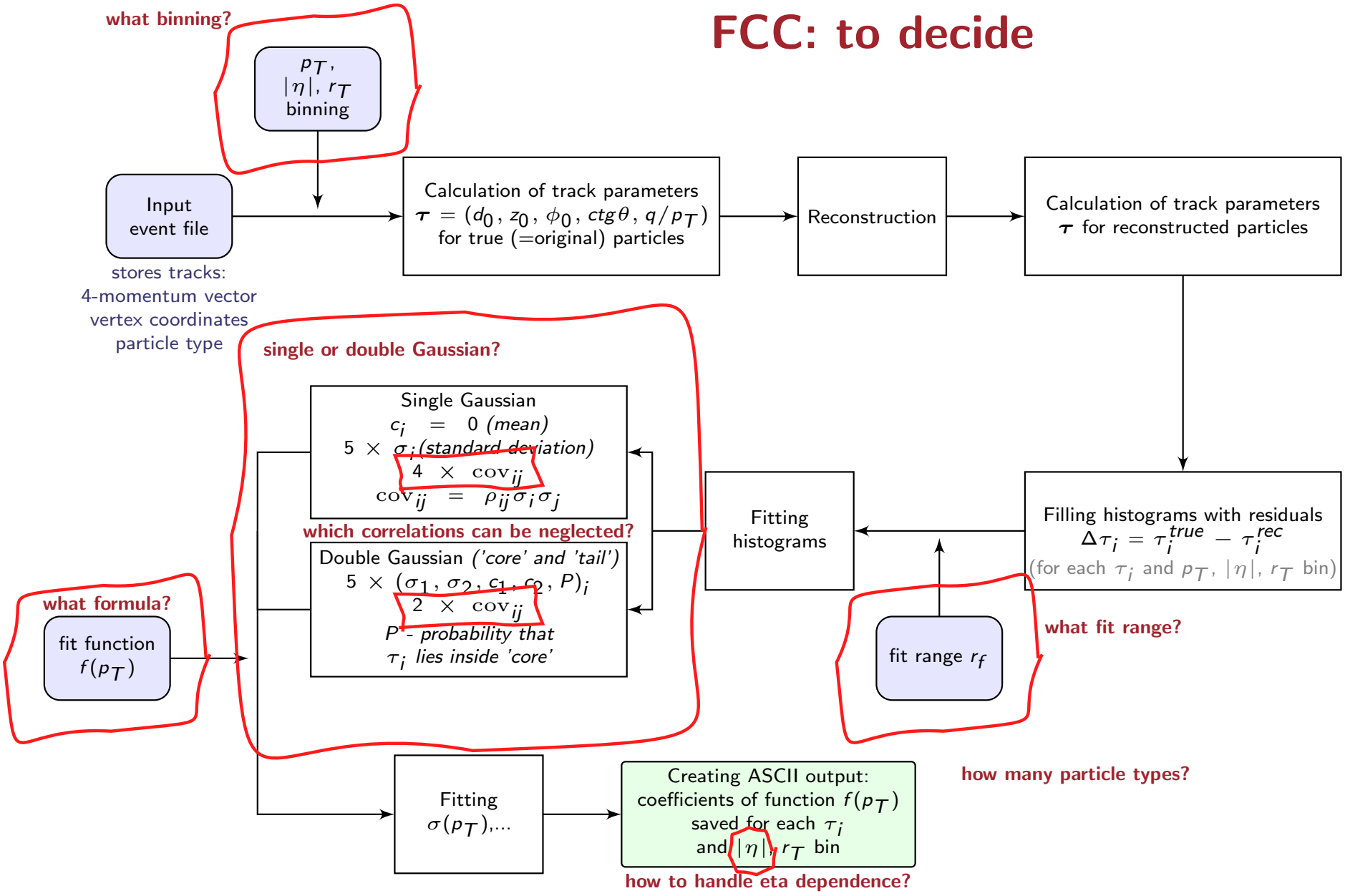


how many particle types?

electrons, muons, pions, rest charged particles treated as pions

assymetry between particles and antiparticles?

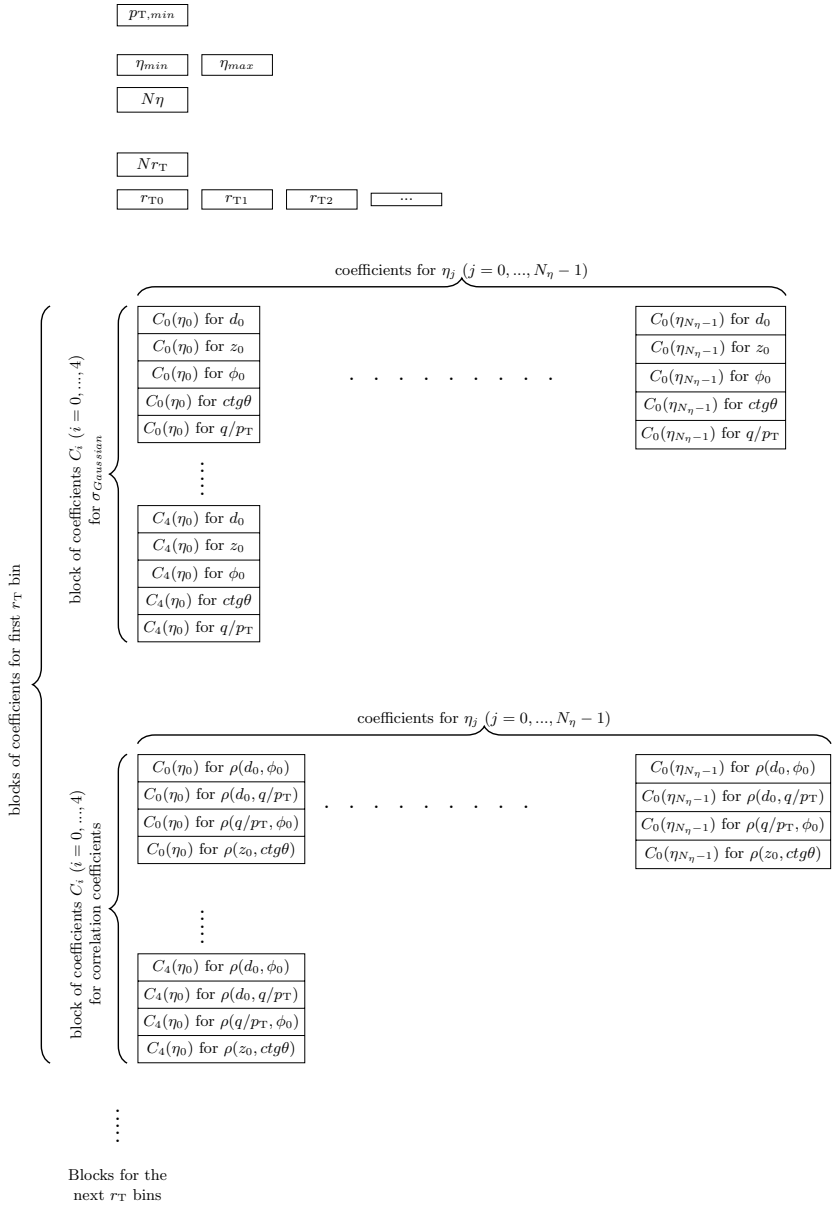
FCC: to decide



Atlfast input data file structure

example of
ASCII output

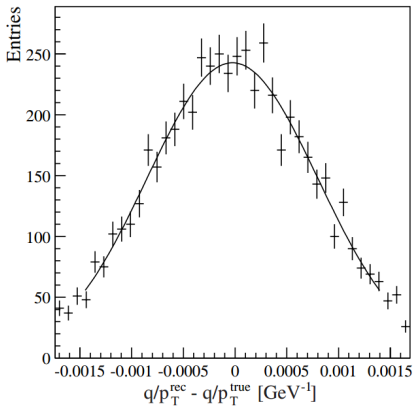
Example data file
(based on Atlfast/AtlfastAlgs/AtlfastAlgs-00-05-09/atlfastDatafiles/Atlfast_MuonResParam_CSC.dat)



More on residuals' fitting

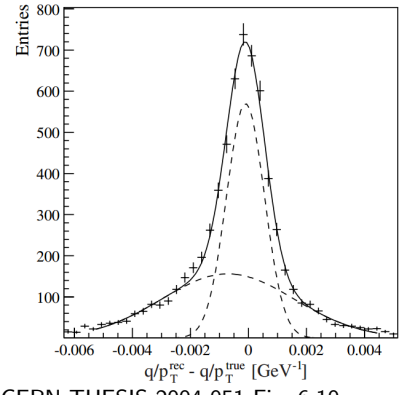
Fitting residuals : Δd_0, Δz_0, $\Delta\phi_0$, $\Delta\cot\theta$,$\Delta q/p_T$ ($\Delta\tau$)

Single Gaussian



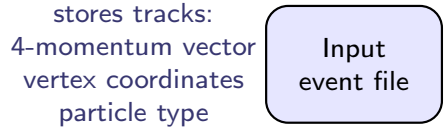
CERN-THESIS-2004-051 Fig. 6.3.

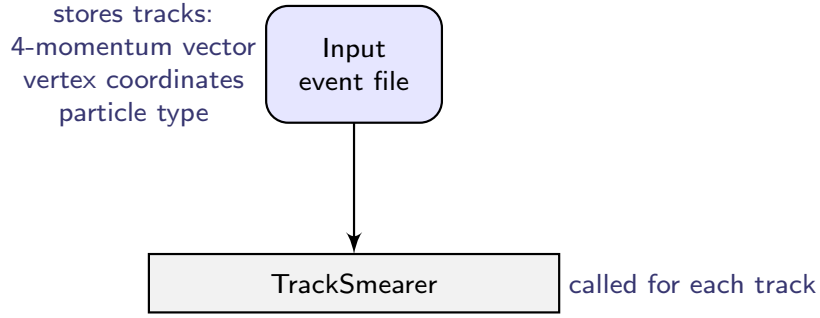
Double Gaussian

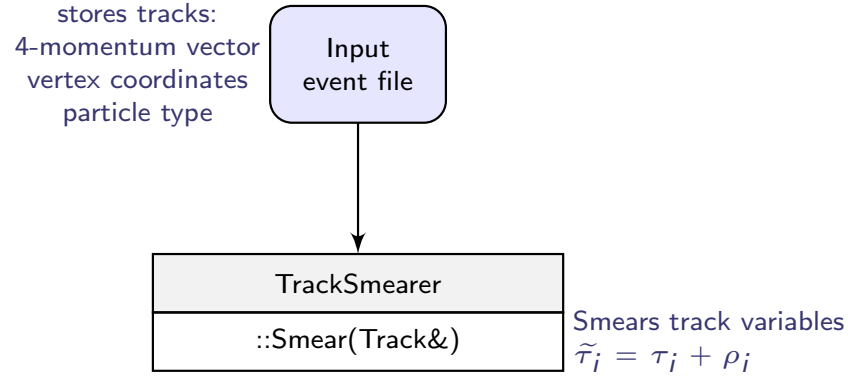


CERN-THESIS-2004-051 Fig. 6.10.

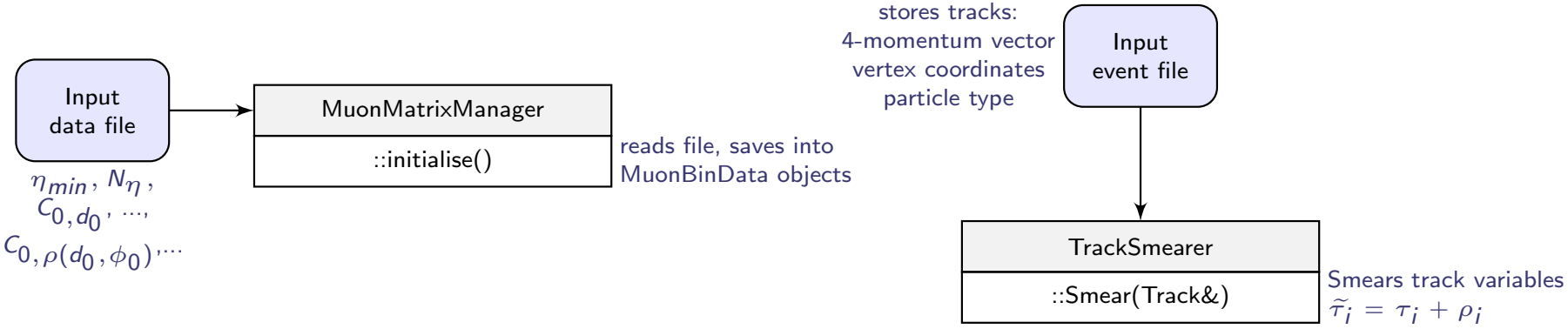
Smearing algorithm - Atlfast implementation

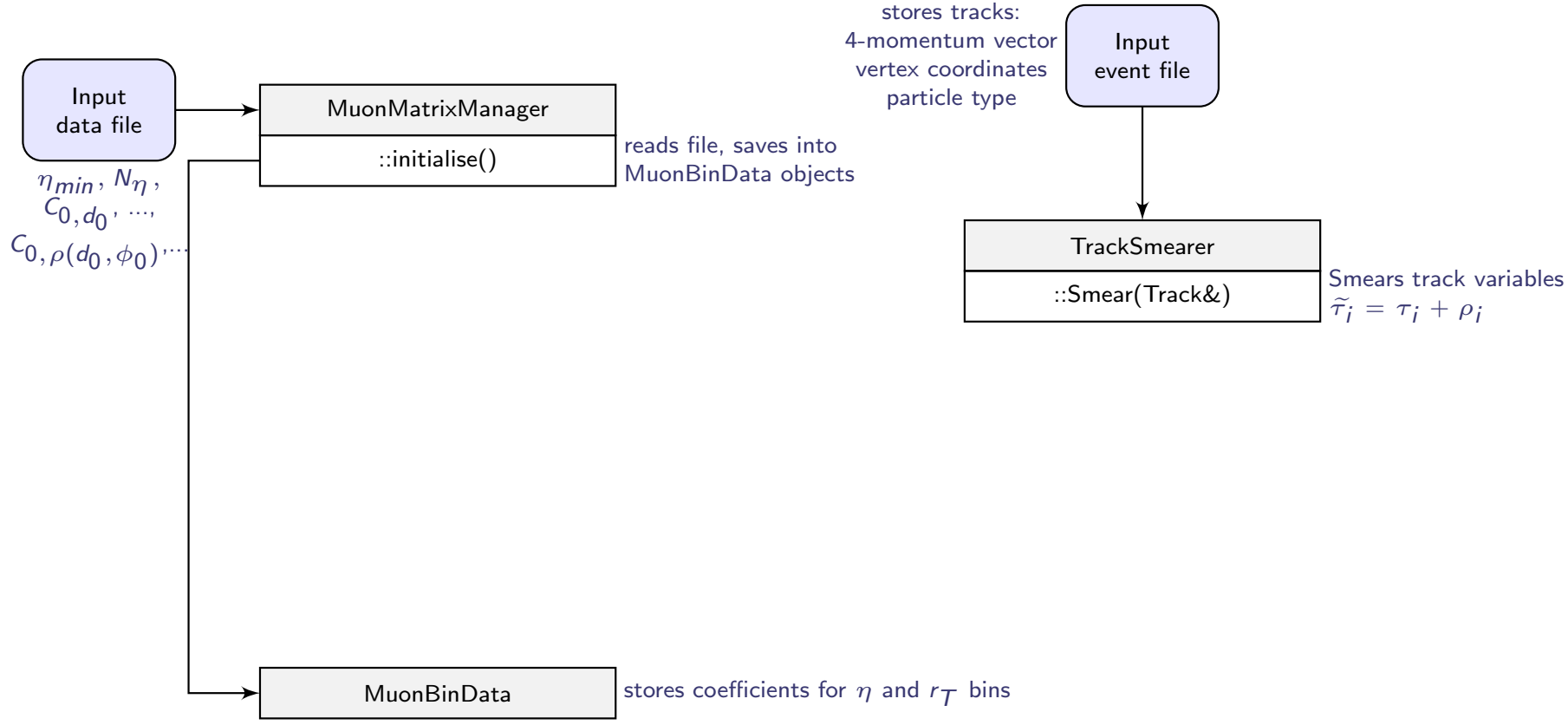

stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file

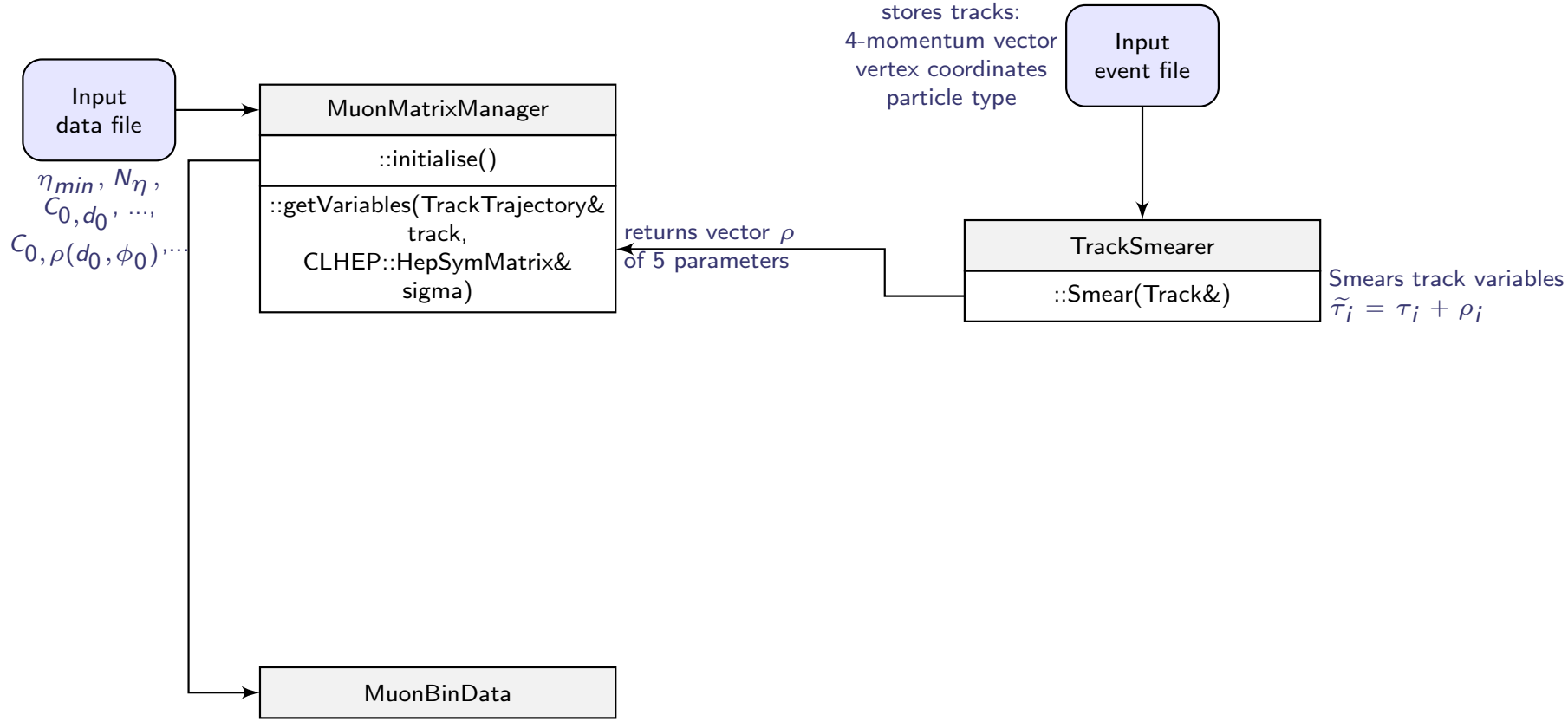

stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
called for each track

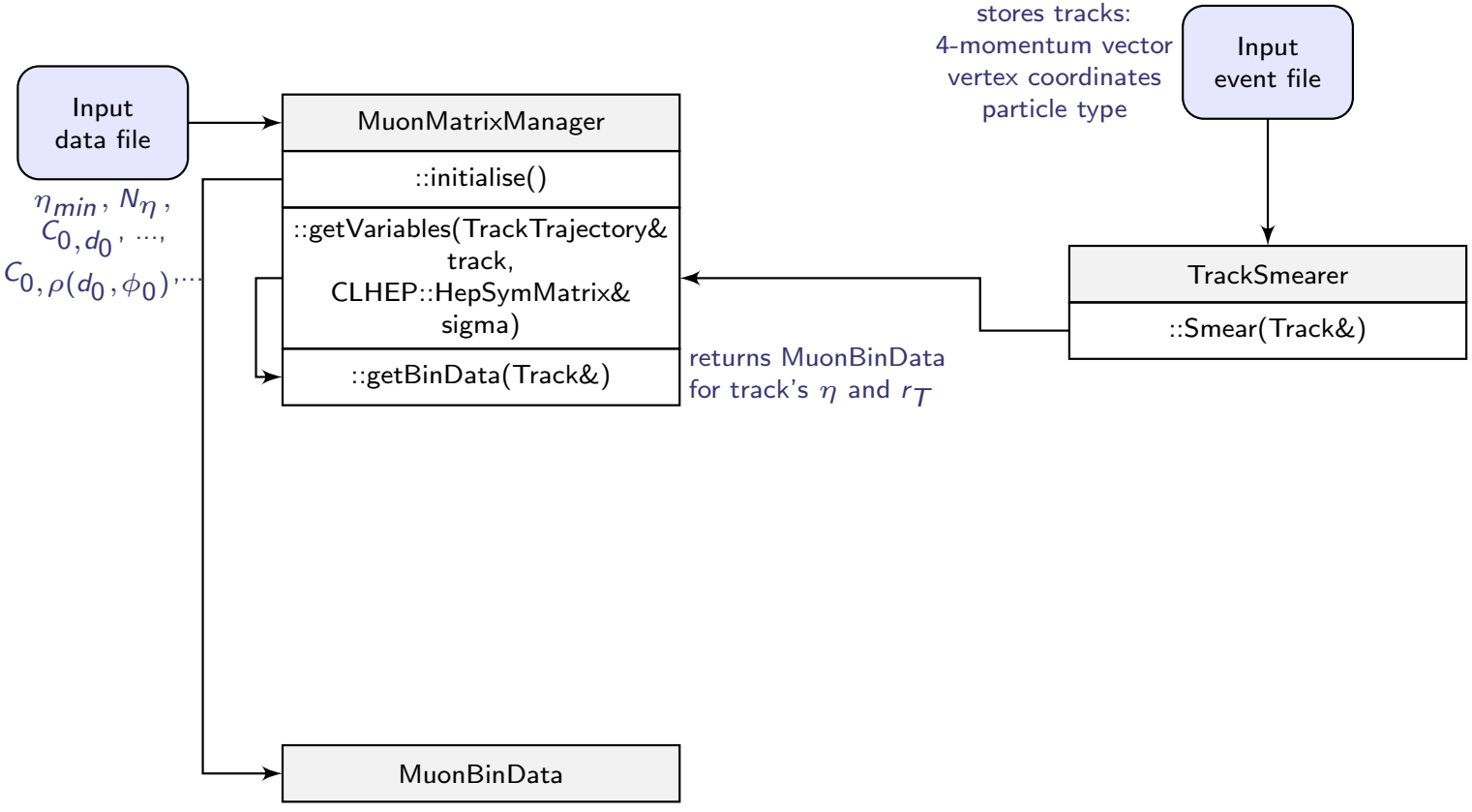

stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
Smears track variables
$\widetilde{\tau}_i = \tau_i + \rho_i$

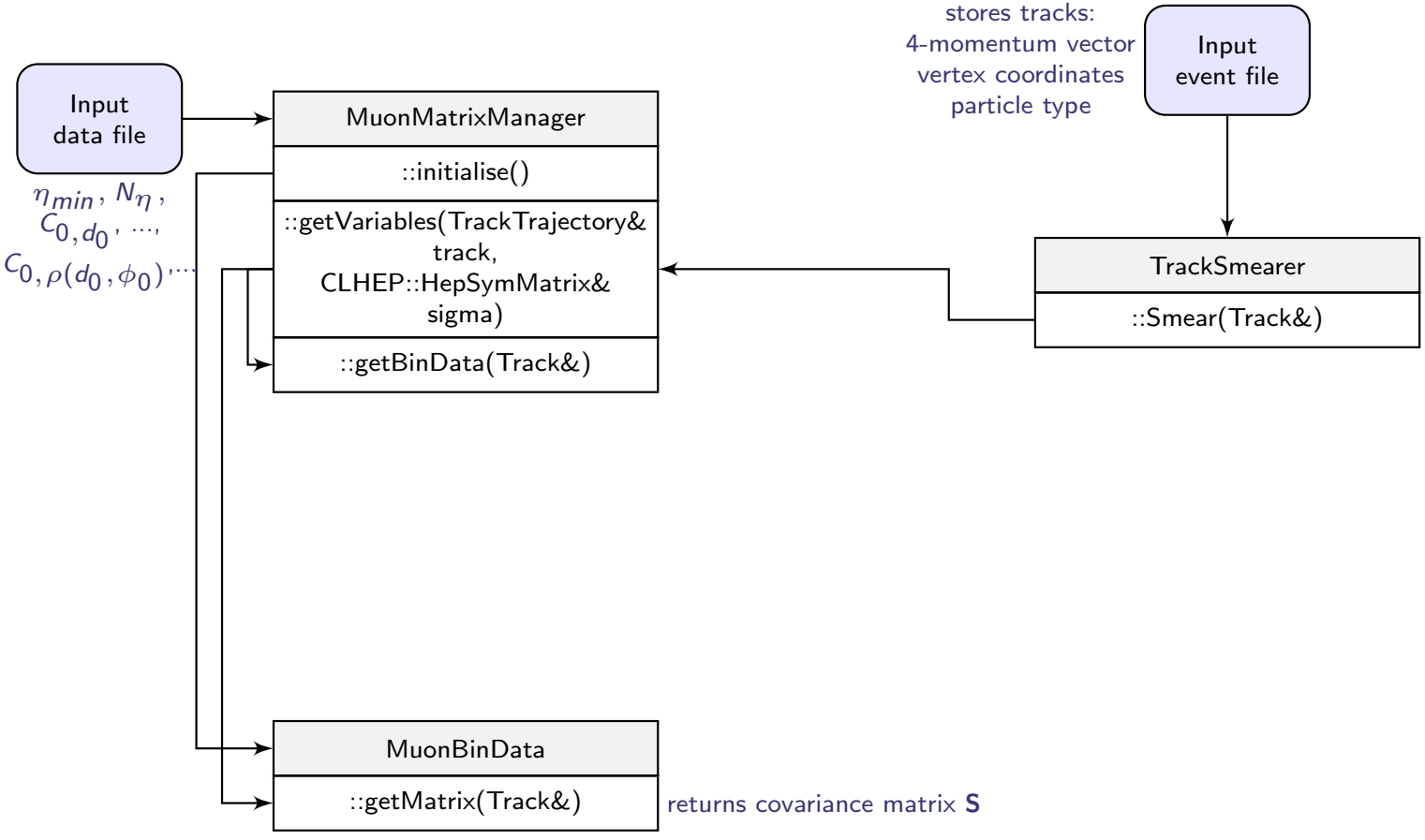

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
Smears track variables
$\widetilde{\tau}_i = \tau_i + \rho_i$

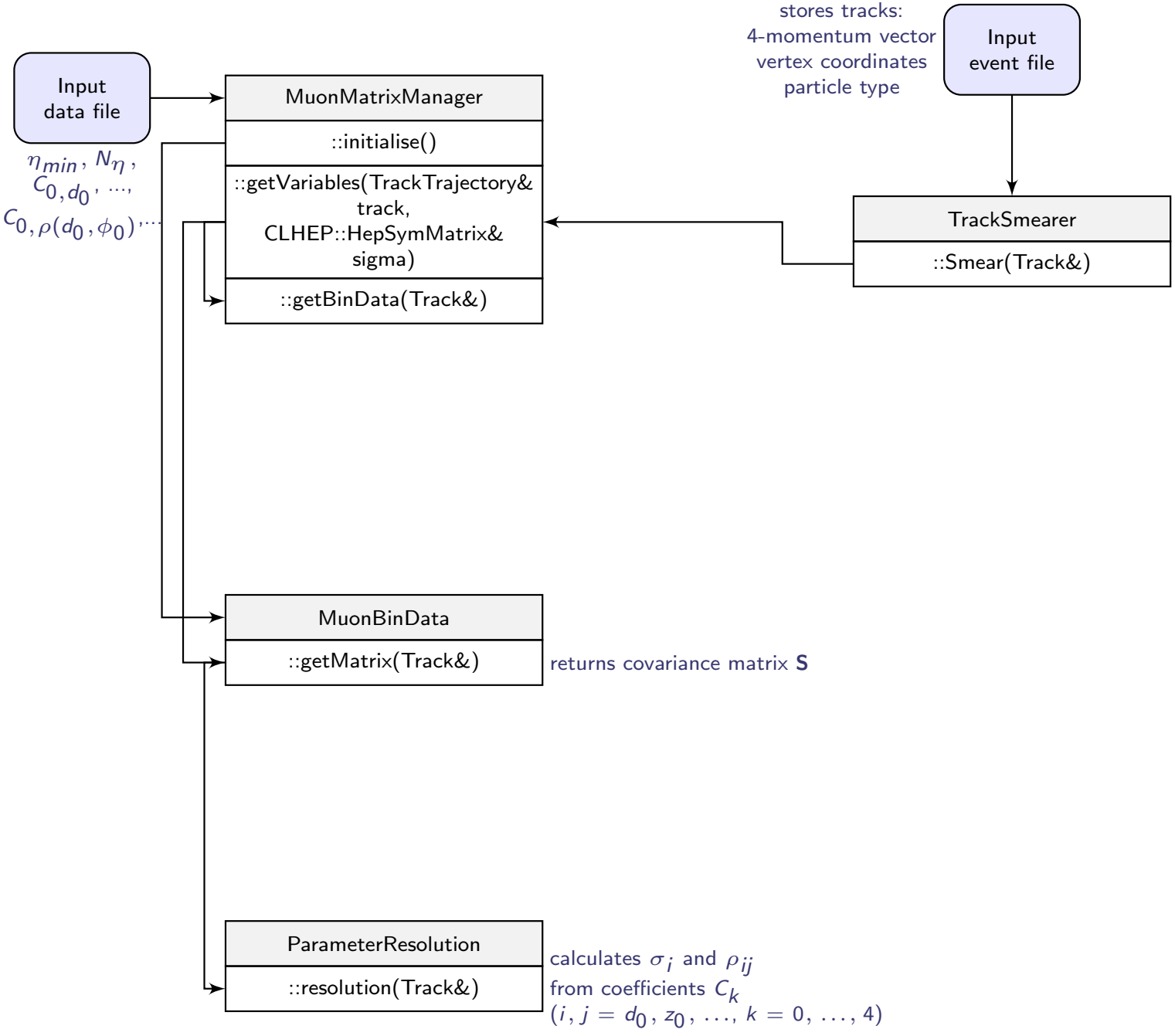

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
reads file, saves into
MuonBinData objects
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
Smears track variables
$\widetilde{\tau}_i = \tau_i + \rho_i$

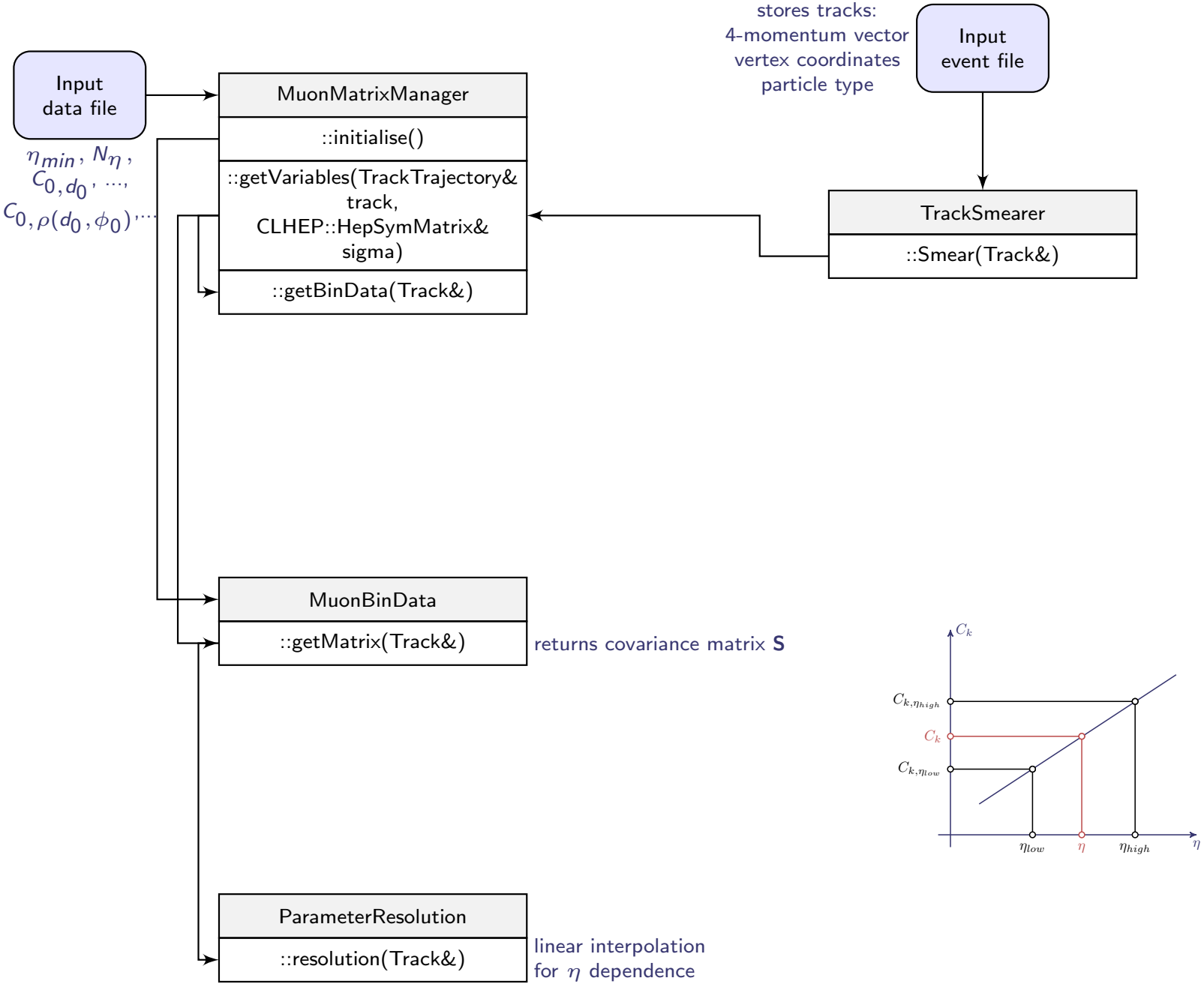

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
reads file, saves into
MuonBinData objects
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
Smears track variables
$\widetilde{\tau}_i = \tau_i + \rho_i$
MuonBinData
stores coefficients for η and r_T bins

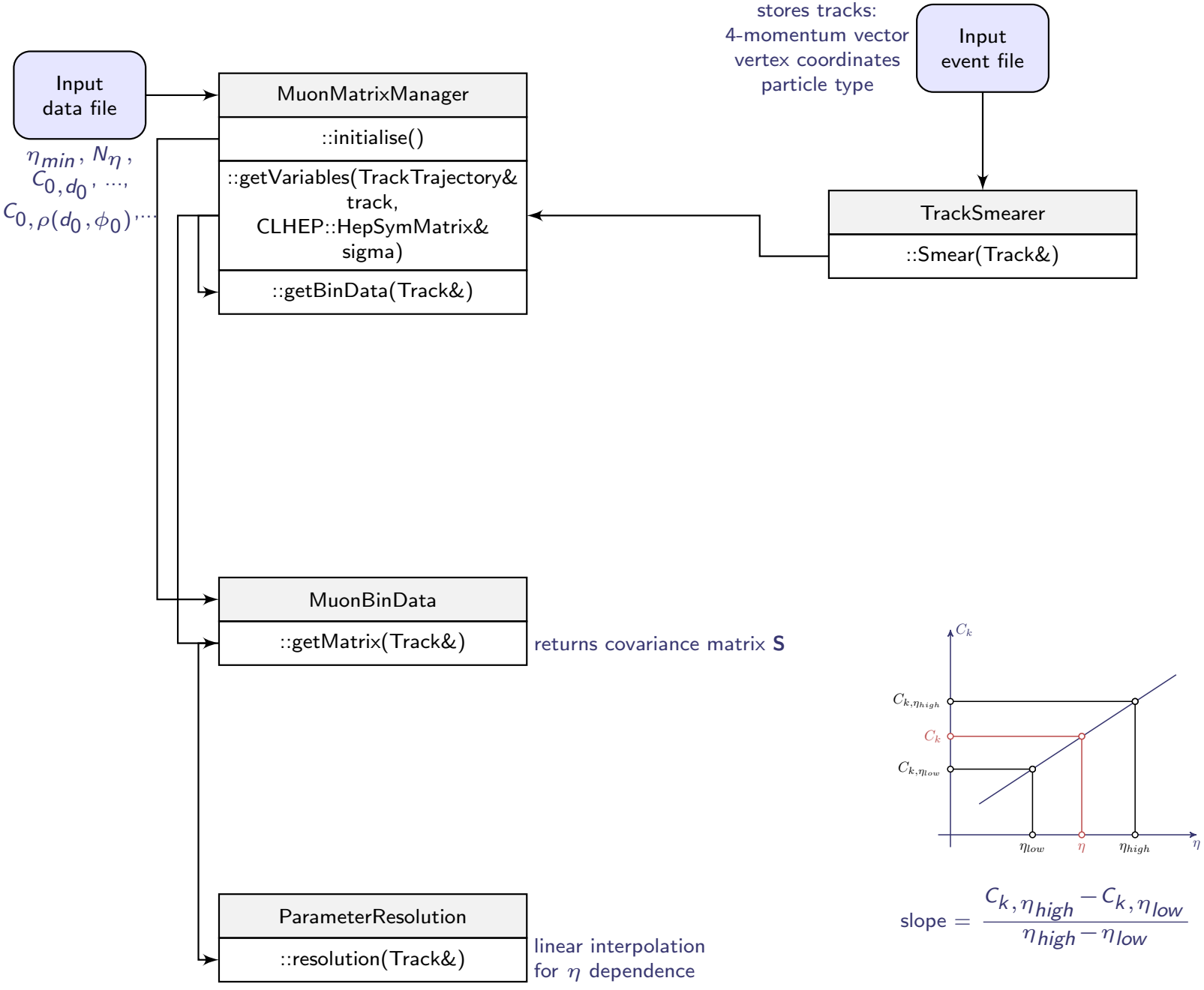

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory&
track,
CLHEP::HepSymMatrix&
sigma)
returns vector ρ
of 5 parameters
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
Smears track variables
$\widetilde{\tau}_i = \tau_i + \rho_i$
MuonBinData

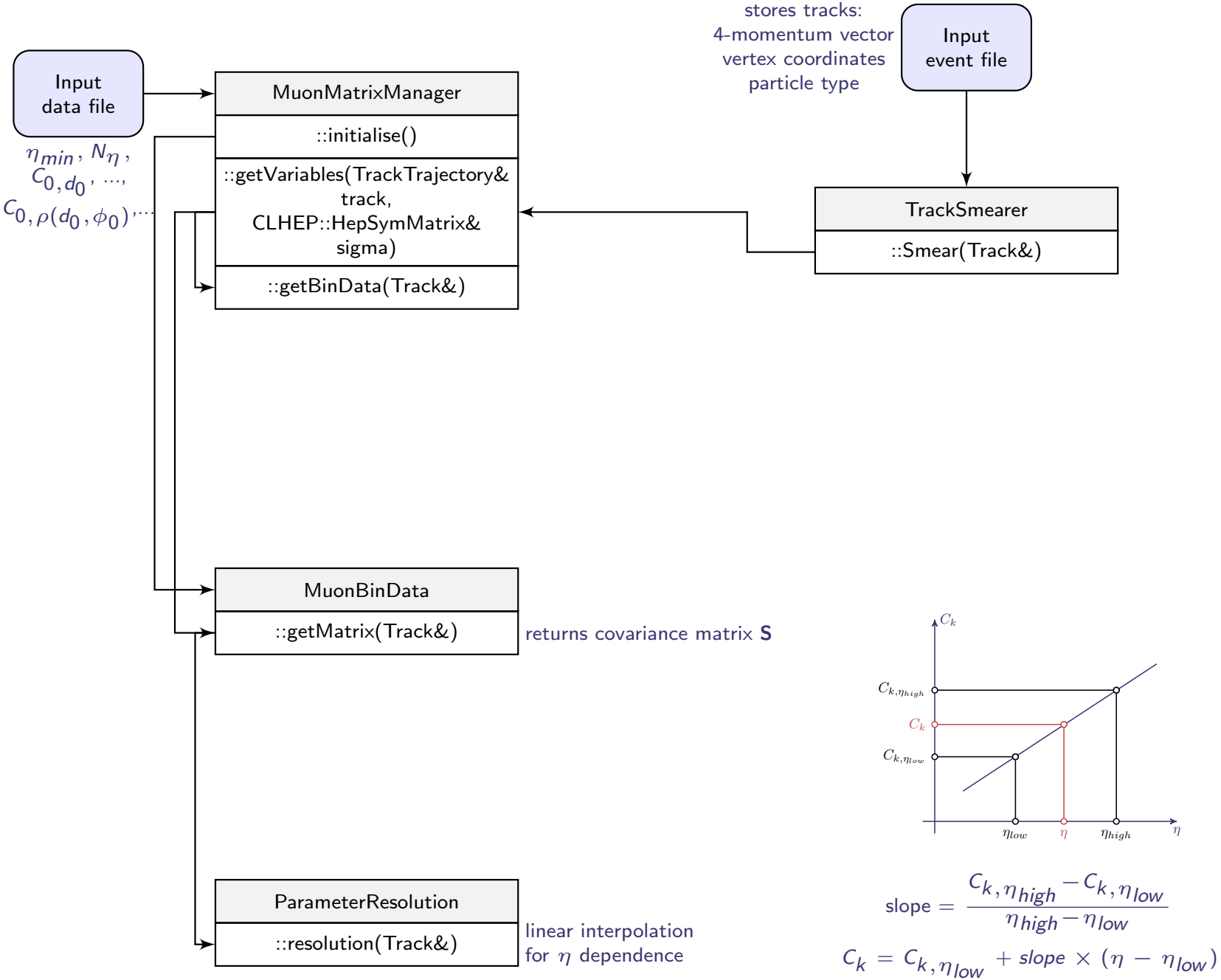

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory&
track,
CLHEP::HepSymMatrix&
sigma)
::getBinData(Track&)
returns MuonBinData
for track's η and r_T
MuonBinData
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)


Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
MuonBinData
::getMatrix(Track&)
returns covariance matrix **S**


Input
data file
η_{min}, N_η,
C_0, d_0, ...,
$C_0, \rho(d_0, \phi_0)$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory&
track,
CLHEP::HepSymMatrix&
sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
MuonBinData
::getMatrix(Track&)
returns covariance matrix **S**
ParameterResolution
::resolution(Track&)
calculates σ_i and ρ_{ij}
from coefficients C_k
$(i, j = d_0, z_0, \ldots, k = 0, \ldots, 4)$

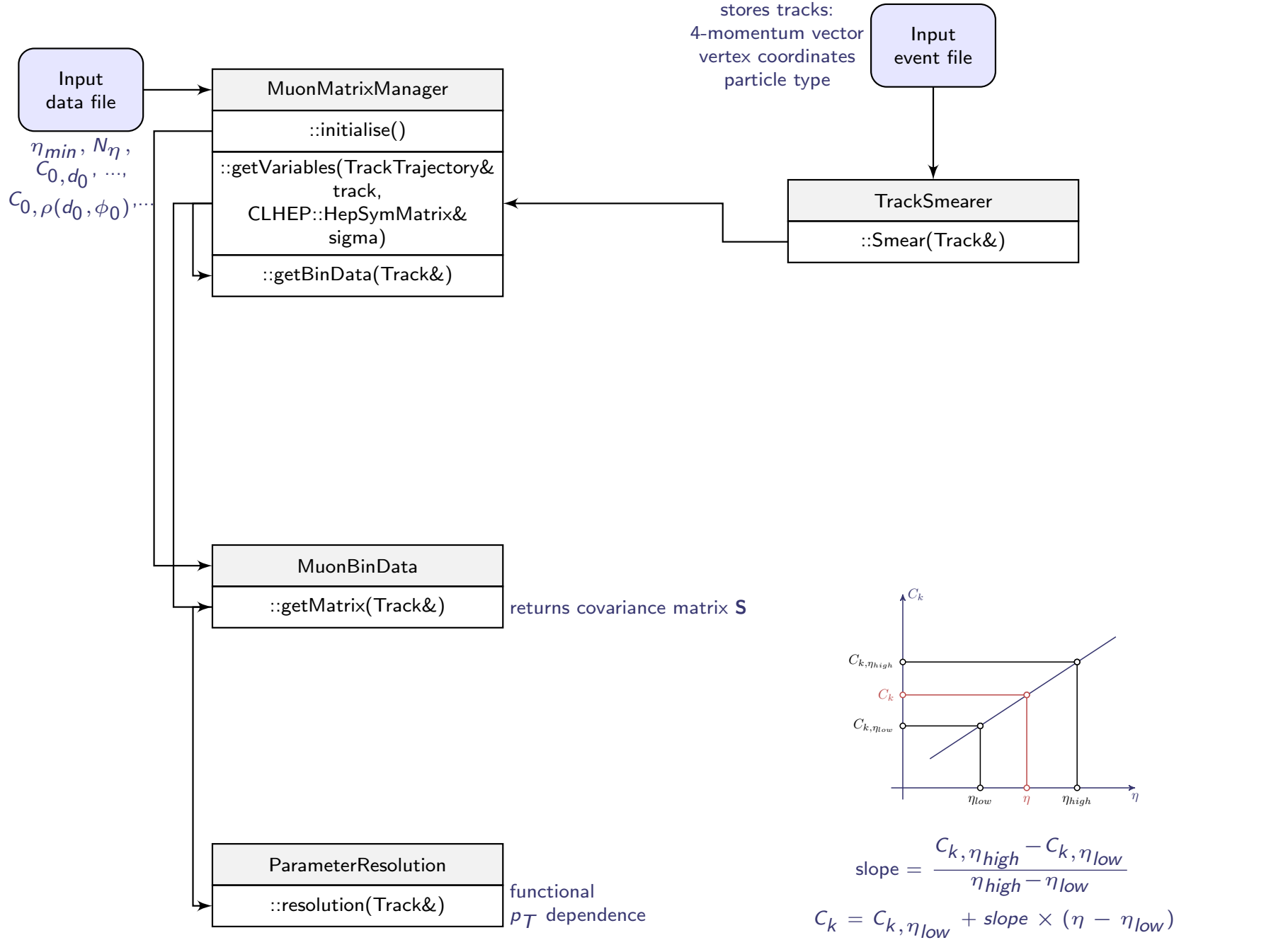

Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
MuonBinData
::getMatrix(Track&)
returns covariance matrix S
ParameterResolution
::resolution(Track&)
linear interpolation
for η dependence
C_k
$C_{k,\eta_{high}}$
C_k
$C_{k,\eta_{low}}$
η_{low}
η
η_{high}
η


Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
TrackSmearer
::Smear(Track&)
MuonBinData
::getMatrix(Track&)
returns covariance matrix **S**
ParameterResolution
::resolution(Track&)
linear interpolation
for η dependence
C_k
$C_{k,\eta_{high}}$
C_k
$C_{k,\eta_{low}}$
η_{low}
η
η_{high}
η
slope $= \frac{C_{k,\eta_{high}} - C_{k,\eta_{low}}}{\eta_{high} - \eta_{low}}$



$$\text{slope} = \frac{C_{k,\eta_{high}} - C_{k,\eta_{low}}}{\eta_{high} - \eta_{low}}$$

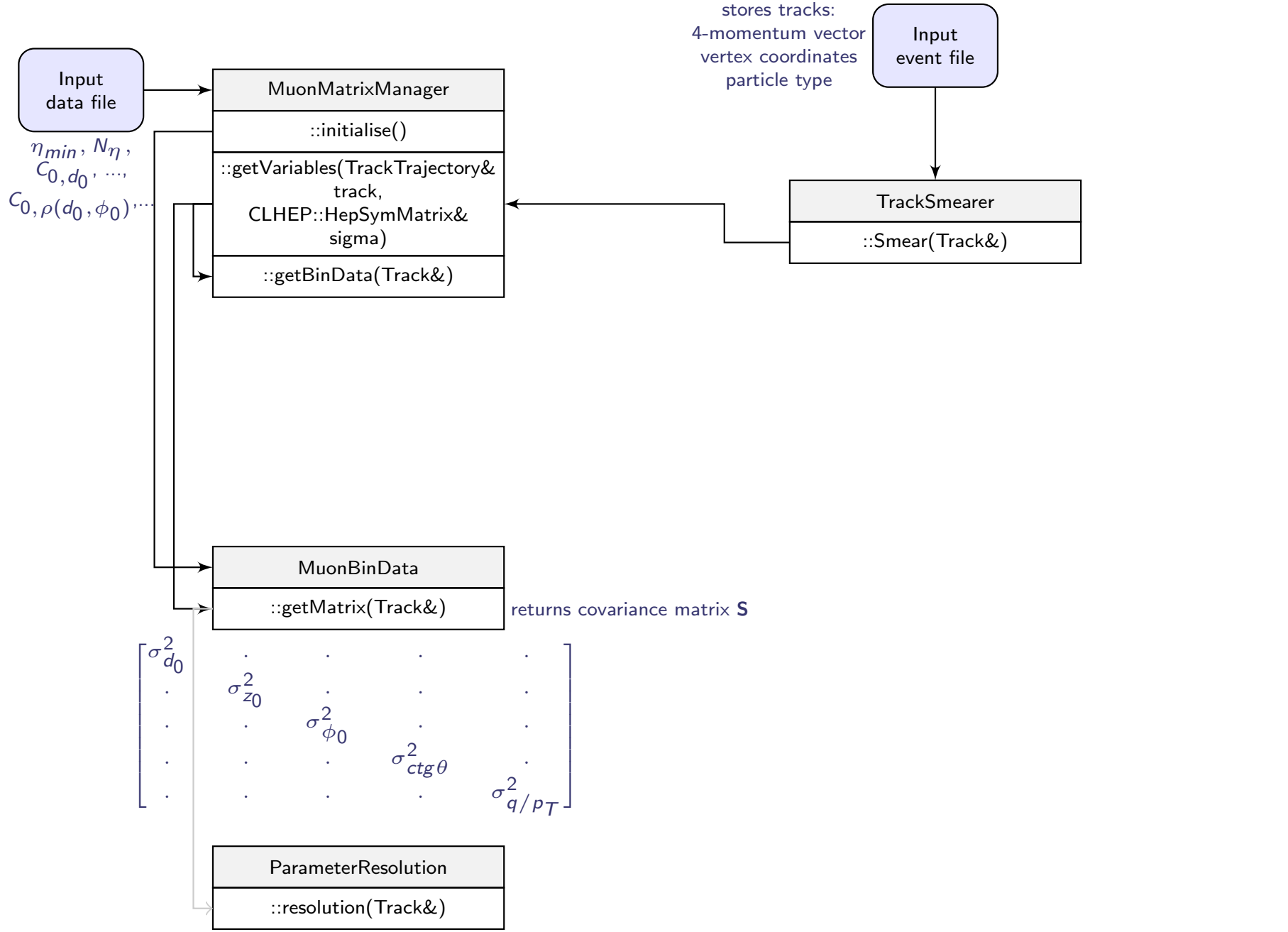
$$C_k = C_{k,\eta_{low}} + \text{slope} \times (\eta - \eta_{low})$$

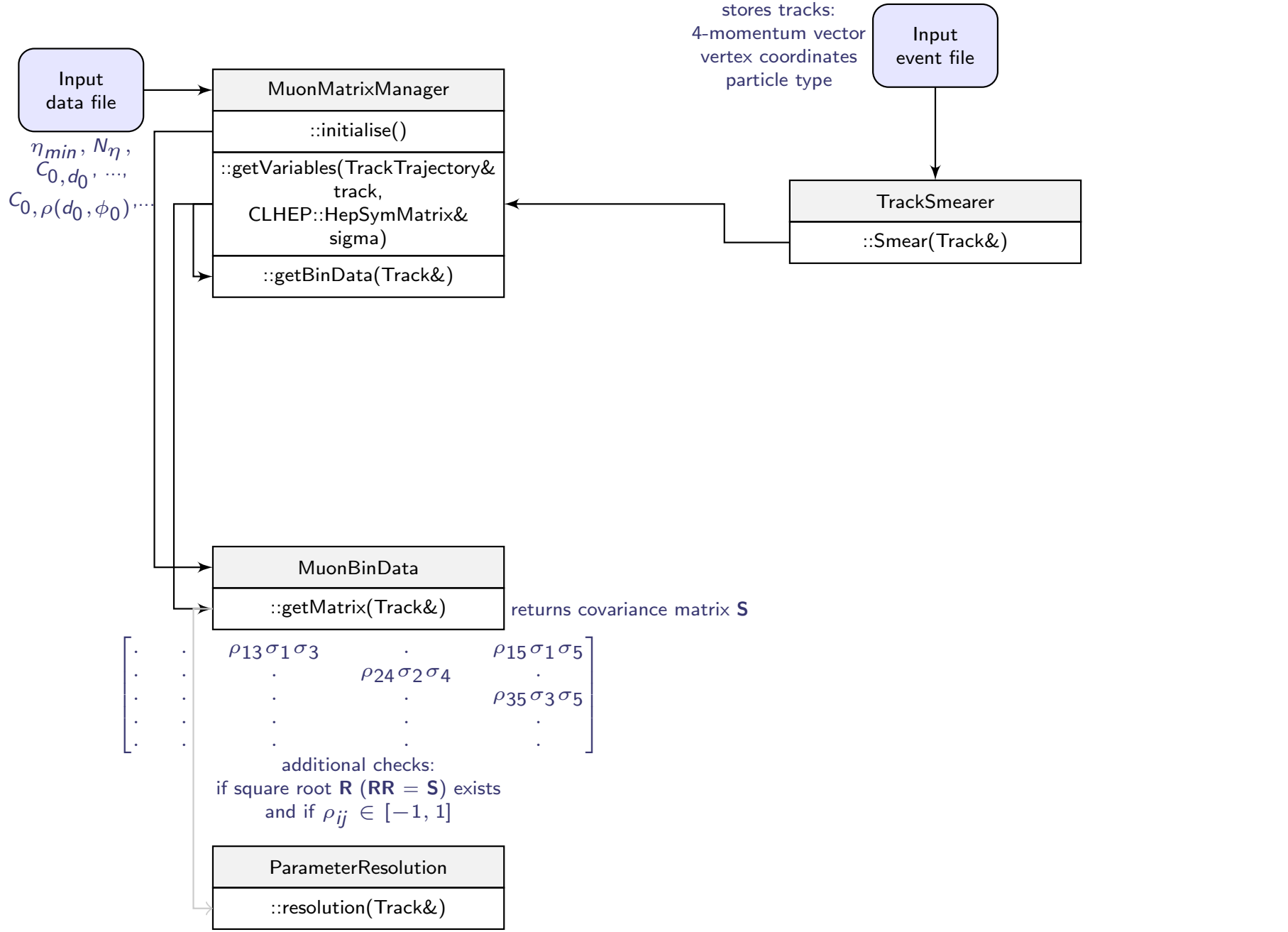


$$\text{slope} = \frac{C_{k,\eta_{high}} - C_{k,\eta_{low}}}{\eta_{high} - \eta_{low}}$$

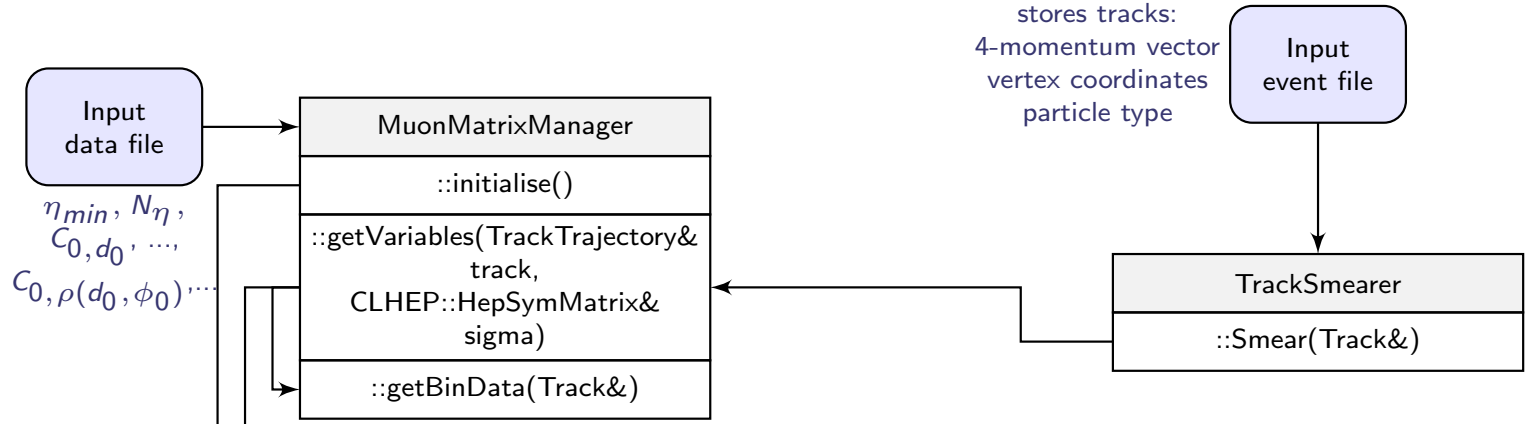
$$C_k = C_{k,\eta_{low}} + \text{slope} \times (\eta - \eta_{low})$$

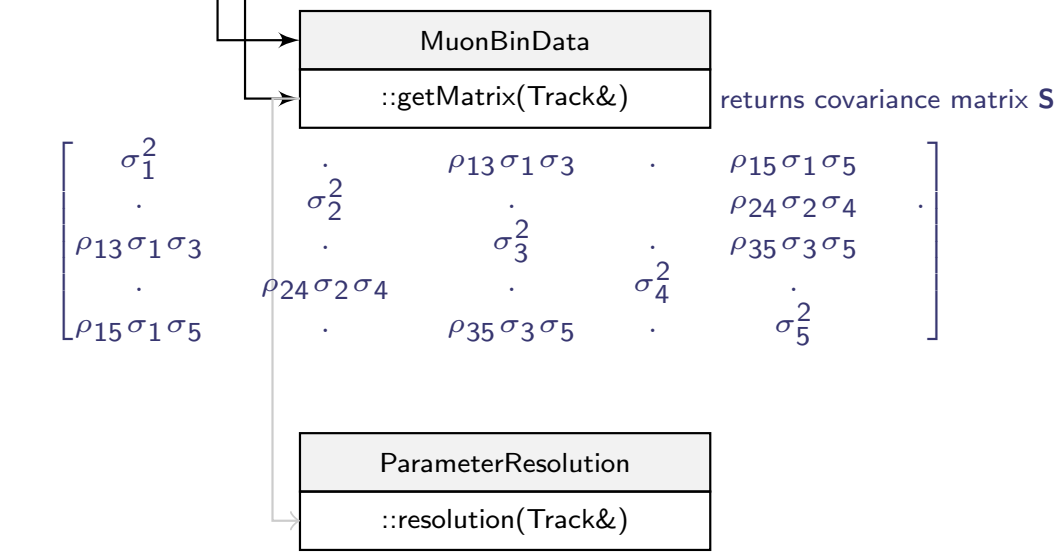
$$\sigma_i \text{ or } \rho_{ij} = C_0 + C_1 p_T^{-1/2} + C_2 p_T^{-1} + C_3 p_T^{-3/2} + C_4 p_T^{-2}$$


Input data file
η_{min}, N_η, C_0, d_0, ..., $C_0, \rho(d_0, \phi_0)$, ...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
TrackSmearer
::Smear(Track&)
MuonBinData
::getMatrix(Track&)
returns covariance matrix **S**
$\begin{bmatrix} \sigma^2_{d_0} & \cdot & \cdot & \cdot & \cdot \\ \cdot & \sigma^2_{z_0} & \cdot & \cdot & \cdot \\ \cdot & \cdot & \sigma^2_{\phi_0} & \cdot & \cdot \\ \cdot & \cdot & \cdot & \sigma^2_{ctg\,\theta} & \cdot \\ \cdot & \cdot & \cdot & \cdot & \sigma^2_{q/p_T} \end{bmatrix}$
ParameterResolution
::resolution(Track&)
σ_i or $\rho_{ij} = C_0 + C_1 p_T^{-1/2} + C_2 p_T^{-1} + C_3 p_T^{-3/2} + C_4 p_T^{-2}$

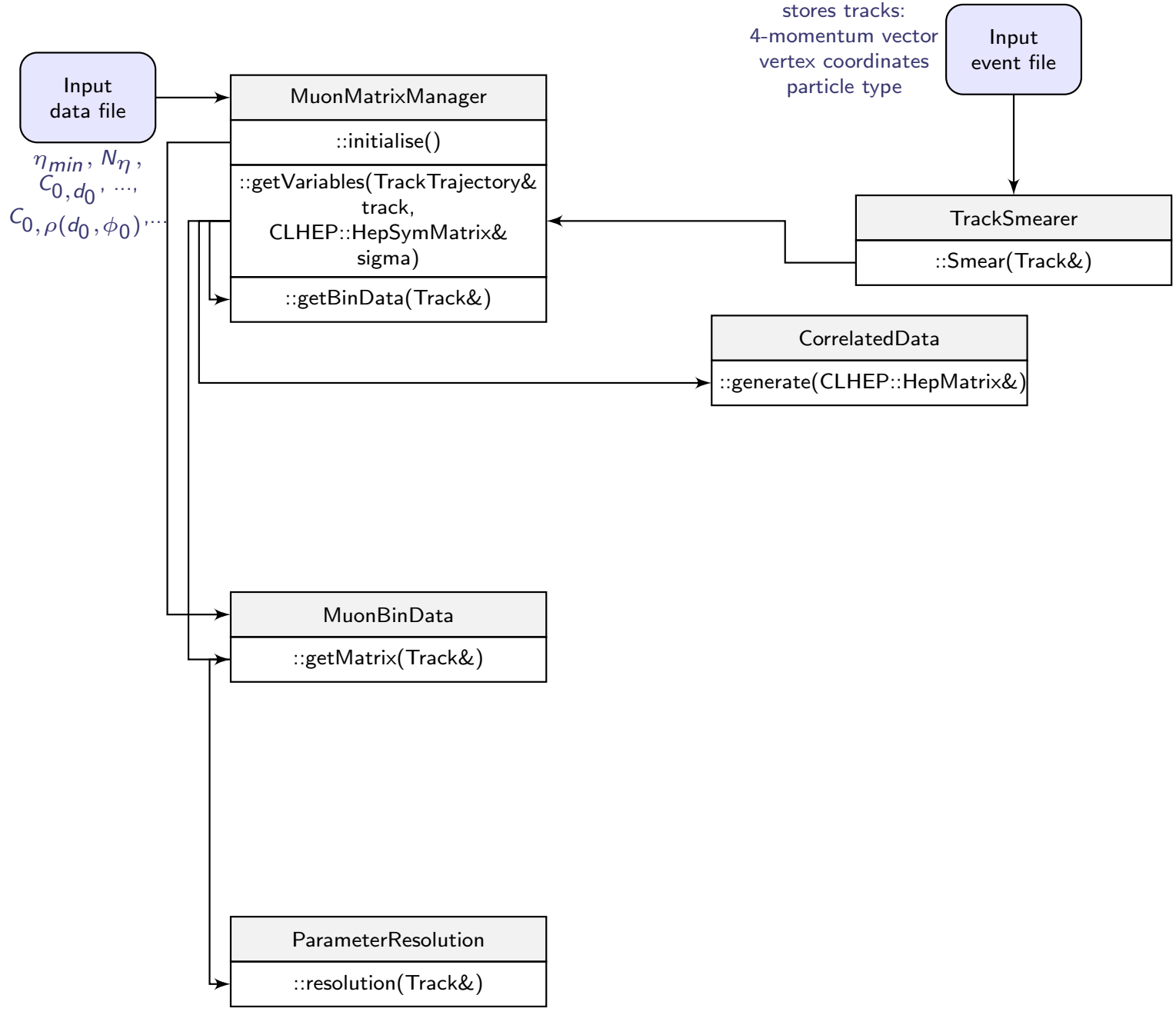


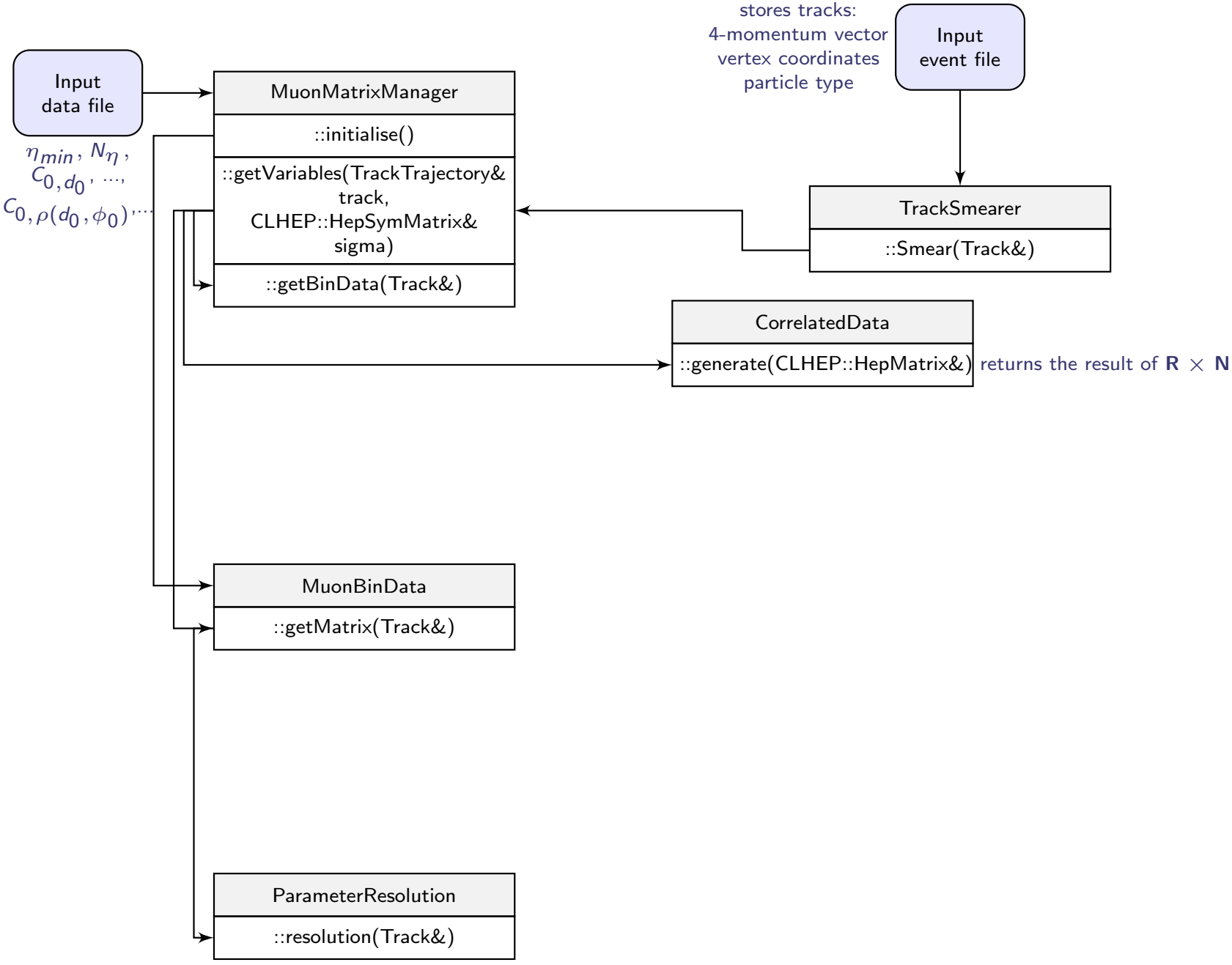
$$\sigma_i \text{ or } \rho_{ij} = C_0 + C_1 p_T^{-1/2} + C_2 p_T^{-1} + C_3 p_T^{-3/2} + C_4 p_T^{-2}$$

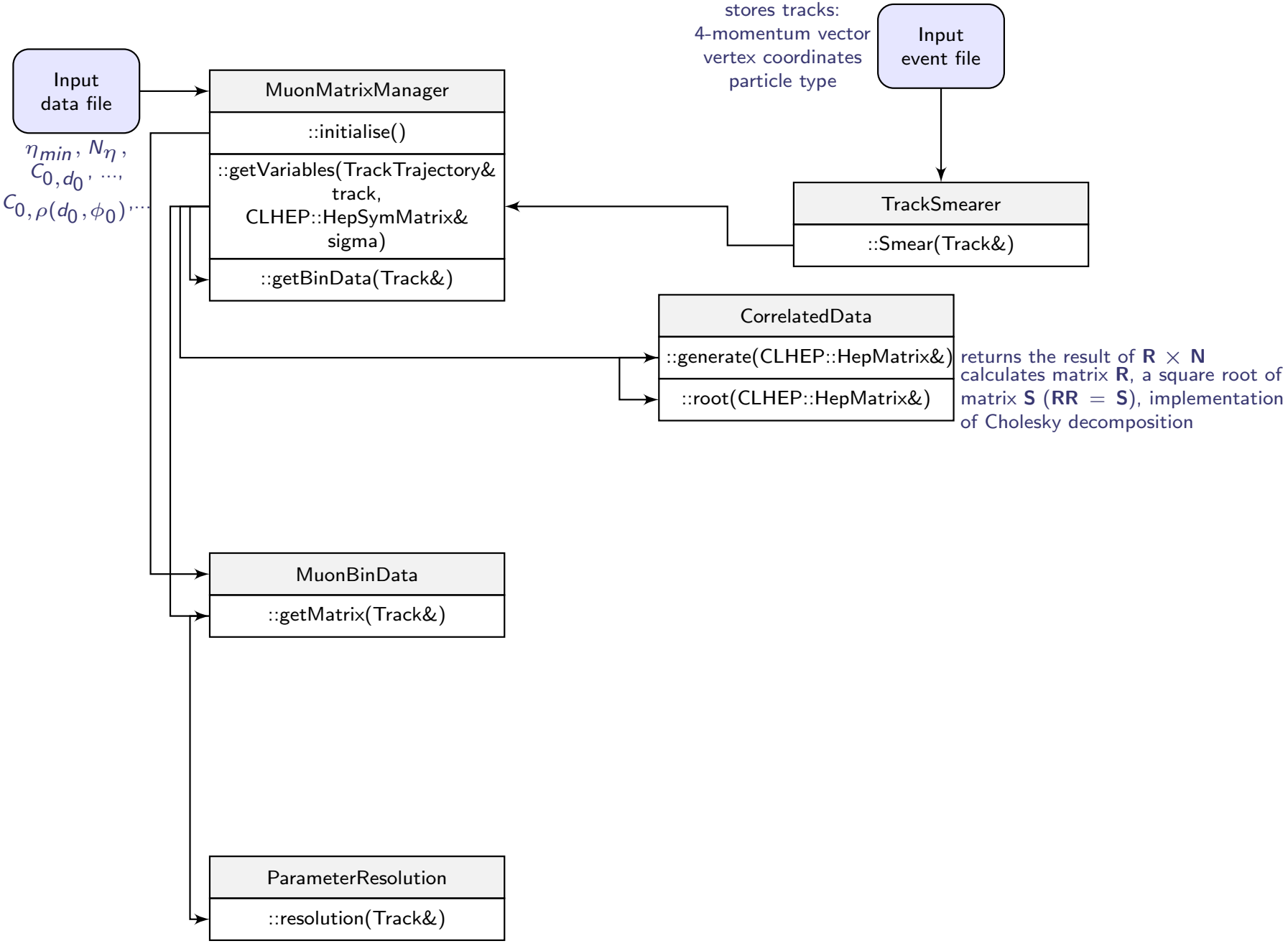


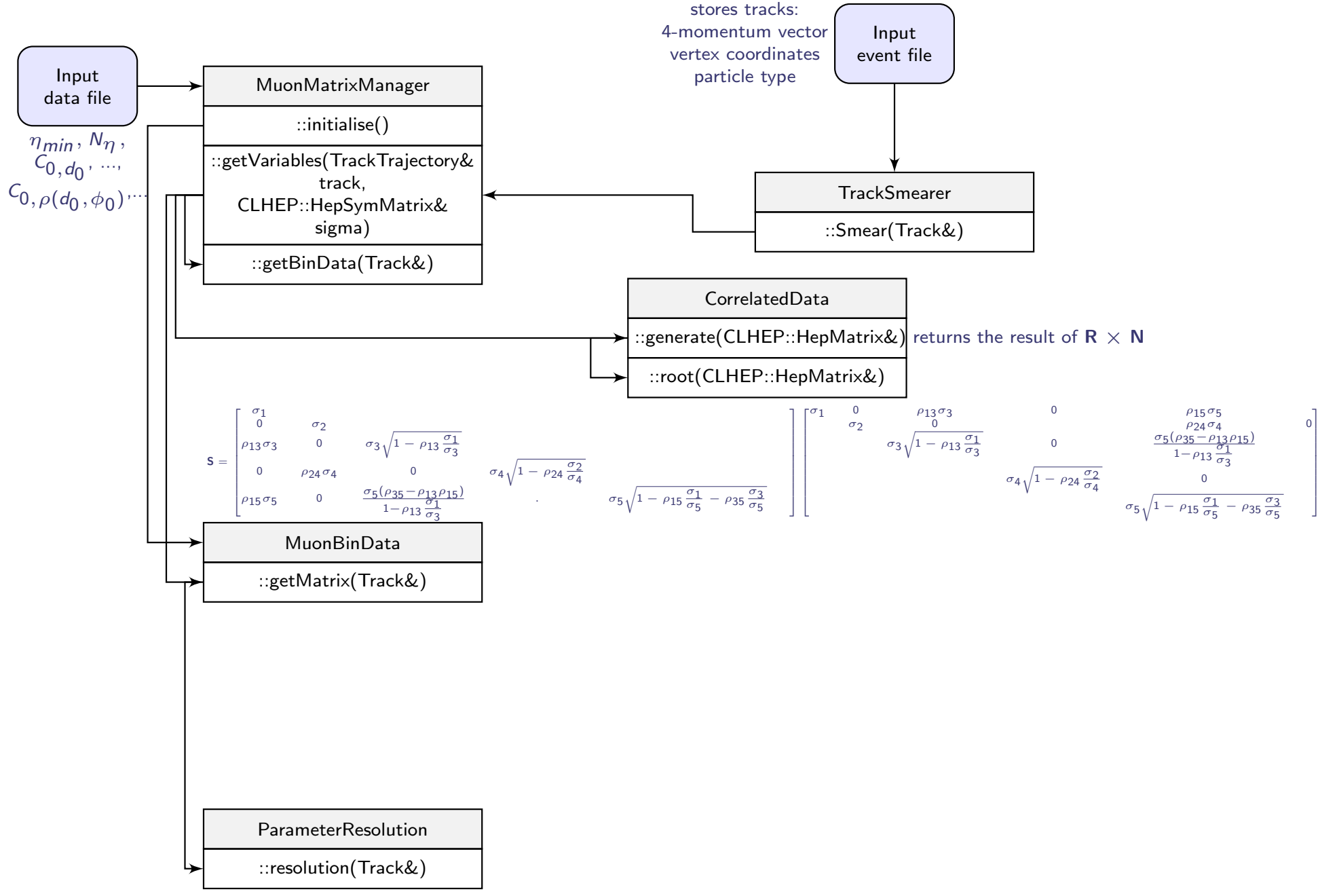


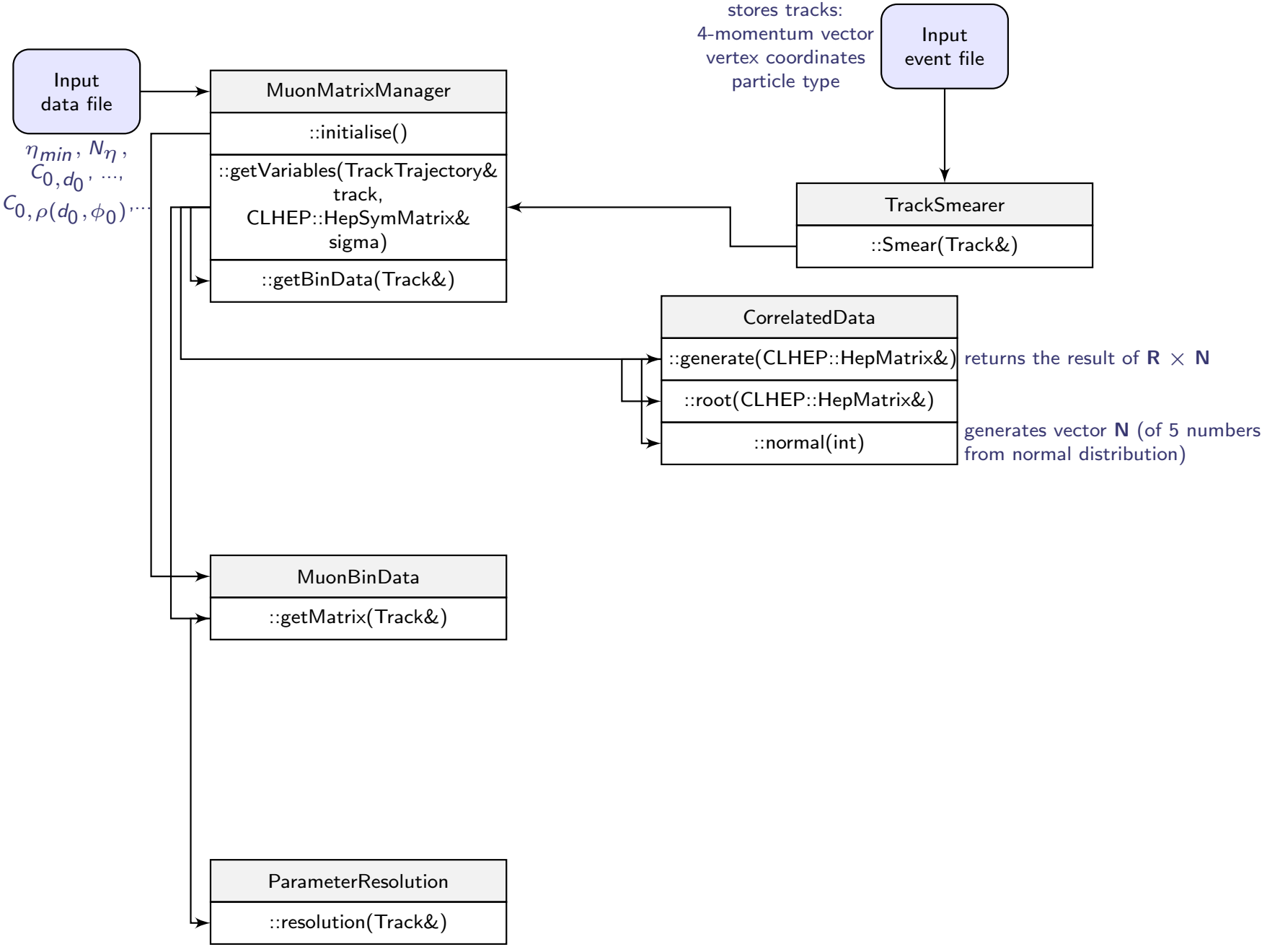
$$\sigma_i \text{ or } \rho_{ij} = C_0 + C_1 p_T^{-1/2} + C_2 p_T^{-1} + C_3 p_T^{-3/2} + C_4 p_T^{-2}$$

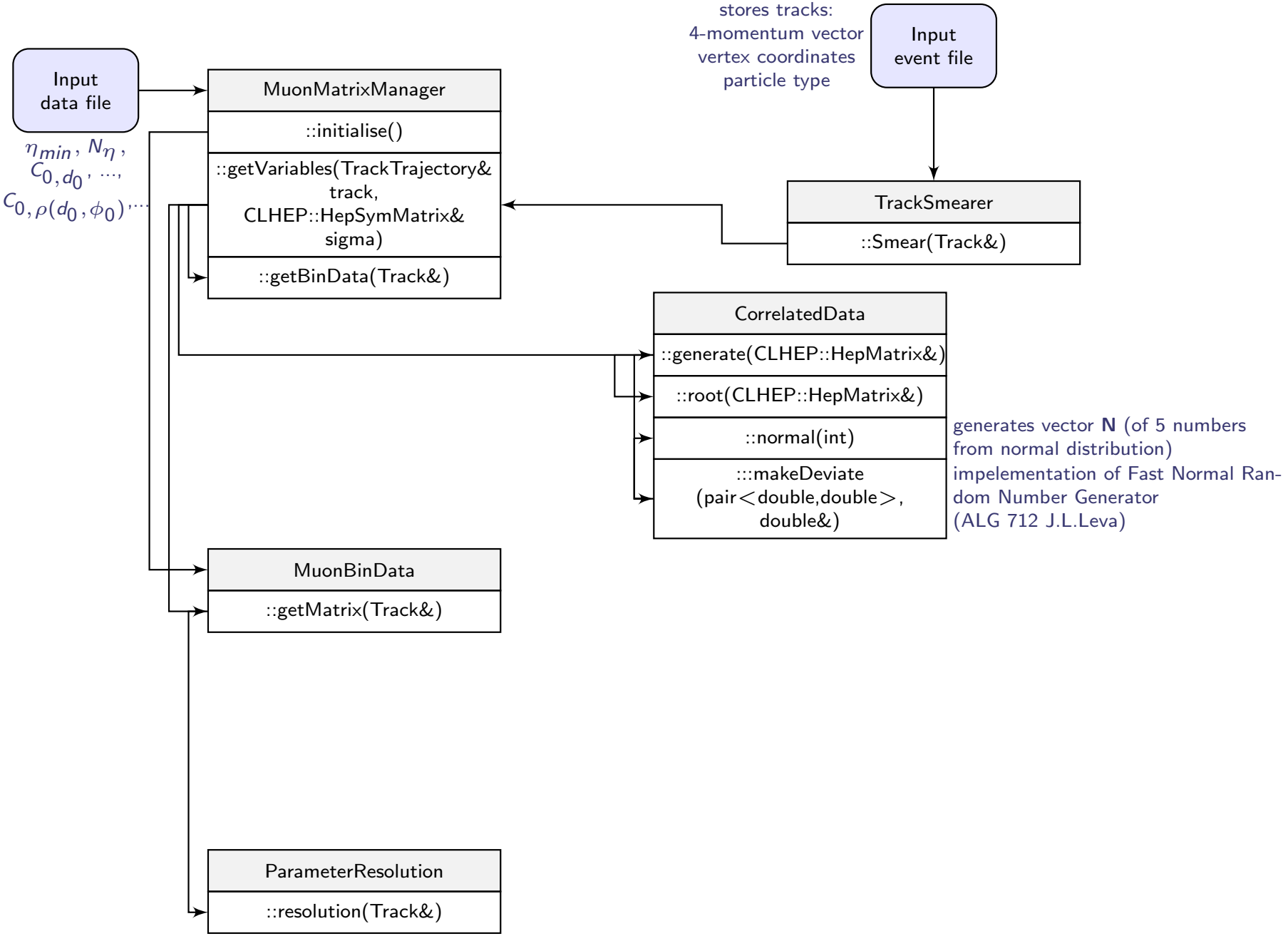

stores tracks:
4-momentum vector
vertex coordinates
particle type
Input
event file
Input
data file
η_{min}, N_η,
C_{0,d_0}, ...,
$C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory&
track,
CLHEP::HepSymMatrix&
sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)

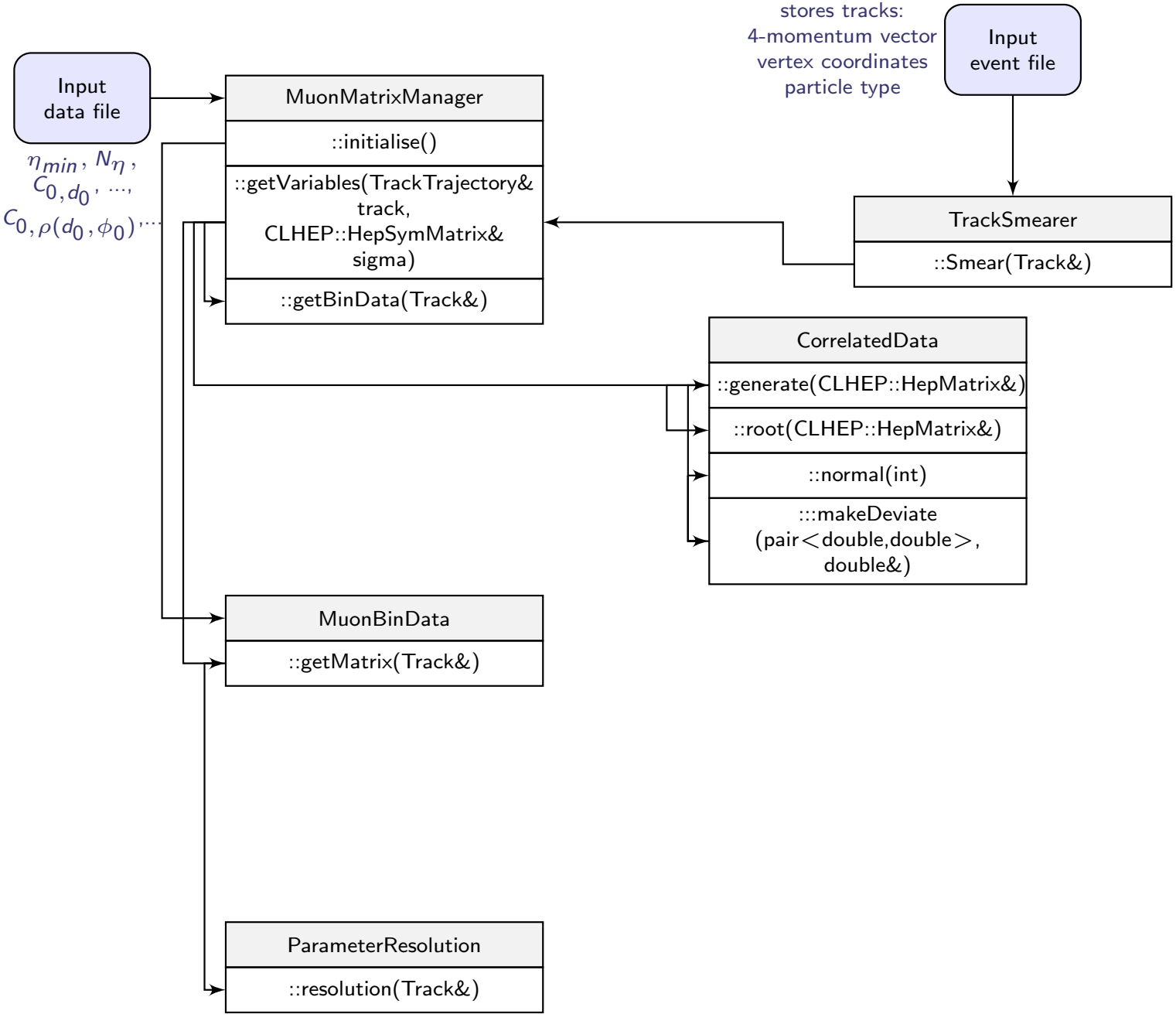

stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
returns the result of **R** × **N**
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)


stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
::root(CLHEP::HepMatrix&)
returns the result of **R** × **N**
calculates matrix **R**, a square root of matrix **S** (**RR** = **S**), implementation of Cholesky decomposition
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)


stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
::root(CLHEP::HepMatrix&)
returns the result of R × N
$S = \begin{bmatrix} \sigma_1 & 0 & \rho_{13}\sigma_3 & 0 & \rho_{15}\sigma_5 \\ 0 & \sigma_2 & 0 & \rho_{24}\sigma_4 & 0 \\ \rho_{13}\sigma_3 & 0 & \sigma_3\sqrt{1-\rho_{13}\frac{\sigma_1}{\sigma_3}} & 0 & \frac{\sigma_5(\rho_{35}-\rho_{13}\rho_{15})}{1-\rho_{13}\frac{\sigma_1}{\sigma_3}} \\ 0 & \rho_{24}\sigma_4 & 0 & \sigma_4\sqrt{1-\rho_{24}\frac{\sigma_2}{\sigma_4}} & 0 \\ \rho_{15}\sigma_5 & 0 & \frac{\sigma_5(\rho_{35}-\rho_{13}\rho_{15})}{1-\rho_{13}\frac{\sigma_1}{\sigma_3}} & . & \sigma_5\sqrt{1-\rho_{15}\frac{\sigma_1}{\sigma_5}-\rho_{35}\frac{\sigma_3}{\sigma_5}} \end{bmatrix}$
$\begin{bmatrix} \sigma_1 & 0 & \rho_{13}\sigma_3 & 0 & \rho_{15}\sigma_5 \\ & \sigma_2 & 0 & \rho_{24}\sigma_4 & 0 \\ & & \sigma_3\sqrt{1-\rho_{13}\frac{\sigma_1}{\sigma_3}} & 0 & \frac{\sigma_5(\rho_{35}-\rho_{13}\rho_{15})}{1-\rho_{13}\frac{\sigma_1}{\sigma_3}} \\ & & & \sigma_4\sqrt{1-\rho_{24}\frac{\sigma_2}{\sigma_4}} & 0 \\ & & & & \sigma_5\sqrt{1-\rho_{15}\frac{\sigma_1}{\sigma_5}-\rho_{35}\frac{\sigma_3}{\sigma_5}} \end{bmatrix}$
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)


stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$, ...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
returns the result of **R** × **N**
::root(CLHEP::HepMatrix&)
::normal(int)
generates vector **N** (of 5 numbers from normal distribution)
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)


Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
::root(CLHEP::HepMatrix&)
::normal(int)
:::makeDeviate (pair<double,double>, double&)
generates vector **N** (of 5 numbers from normal distribution)
impelementation of Fast Normal Random Number Generator (ALG 712 J.L.Leva)
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)


stores tracks:
4-momentum vector
vertex coordinates
particle type
Input event file
Input data file
η_{min}, N_η, C_{0,d_0}, ..., $C_{0,\rho(d_0,\phi_0)}$,...
MuonMatrixManager
::initialise()
::getVariables(TrackTrajectory& track, CLHEP::HepSymMatrix& sigma)
::getBinData(Track&)
TrackSmearer
::Smear(Track&)
CorrelatedData
::generate(CLHEP::HepMatrix&)
::root(CLHEP::HepMatrix&)
::normal(int)
:::makeDeviate (pair<double,double>, double&)
MuonBinData
::getMatrix(Track&)
ParameterResolution
::resolution(Track&)

Validation

Tools:

- plots of residuals: $d_0^{true} - d_0^{rec}$, $z_0^{true} - z_0^{rec}$, $\phi_0^{true} - \phi_0^{rec}$, $ctg\theta^{true} - ctg\theta^{rec}$ and $q/p_T^{true} - q/p_T^{rec}$;
- plots of correlations: $\rho^{rec}_{d_0,z_0}(\rho^{tru}_{d_0,z_0})$, etc.;
- χ^2 test:

$$\chi^2_{\tau_i} = \sum_{bins} \frac{\Delta\tau_i^{fast} - \Delta\tau_i^{full}}{\tau_i^{full}}$$

Parametrisation tests:

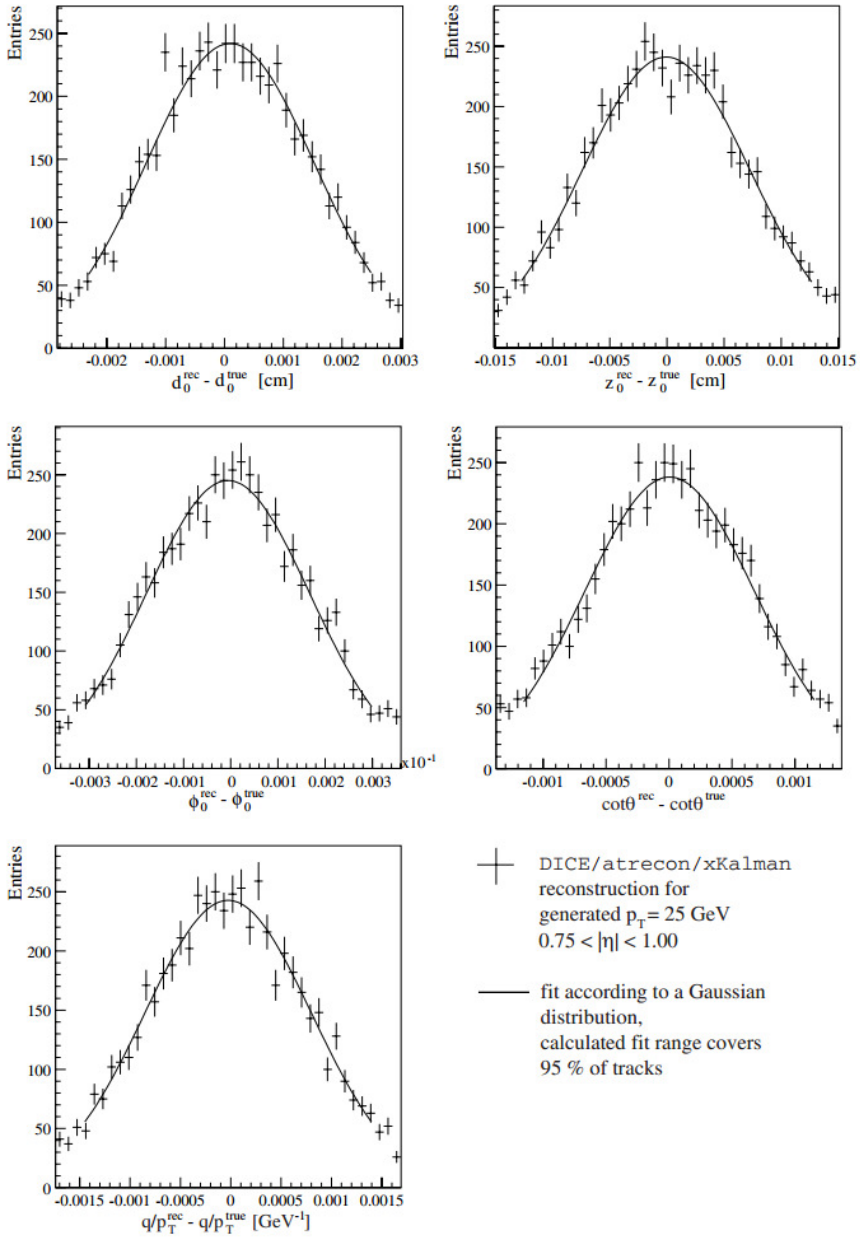
1. Binning in $|\eta|$, p_T and r_T;
2. Fit ranges on residuals' plots;
3. Fit formula to residuals' plots: single/double Gaussian;
4. Decide which correlations are significant;
5. Fit formula to describe p_T dependence;
6. Linear interpolation or functional $|\eta|$ dependence;

Validation:

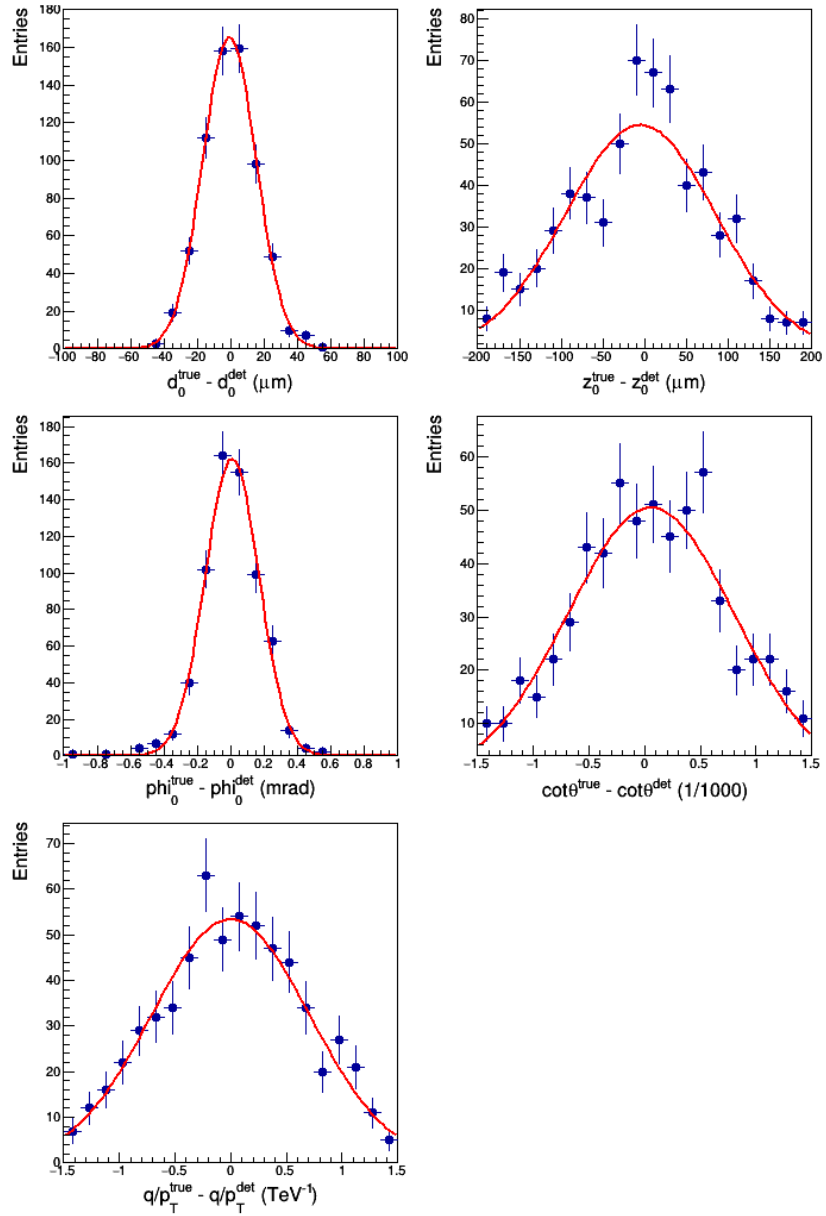
1. Cross-check against the full simulation (and fast with reconstruction) using the same event sample as for parameters' extraction;
2. Cross-check against the full simulation (and fast with reconstruction) using different event sample (H$\rightarrow$ZZ*$\rightarrow 4\mu$?);

Example

Residual of track parameters: Δd_0, Δz_0, $\Delta\phi_0$, $\Delta\cot\theta$,$\Delta q/p_T$ ($\mu^{\pm}$ $p_T = 25$ GeV)

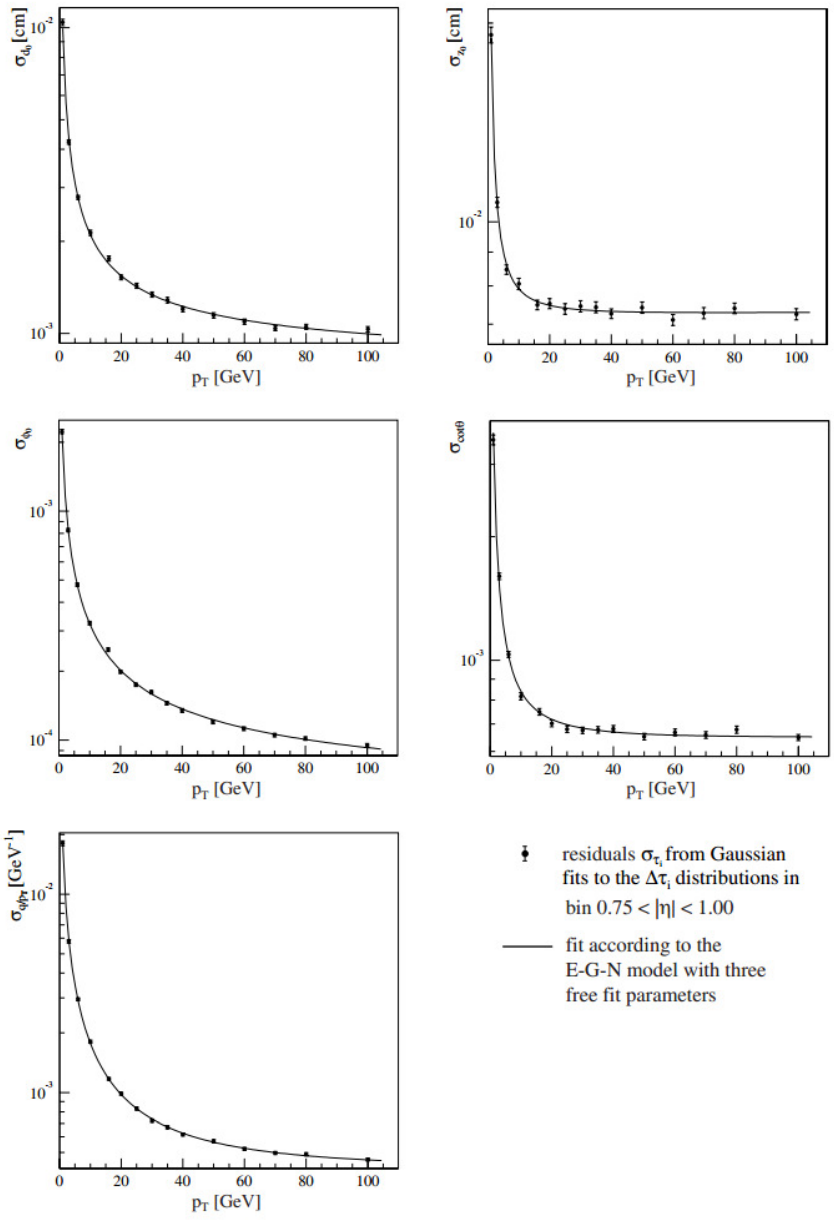


CERN-THESIS-2004-051 Fig. 6.3

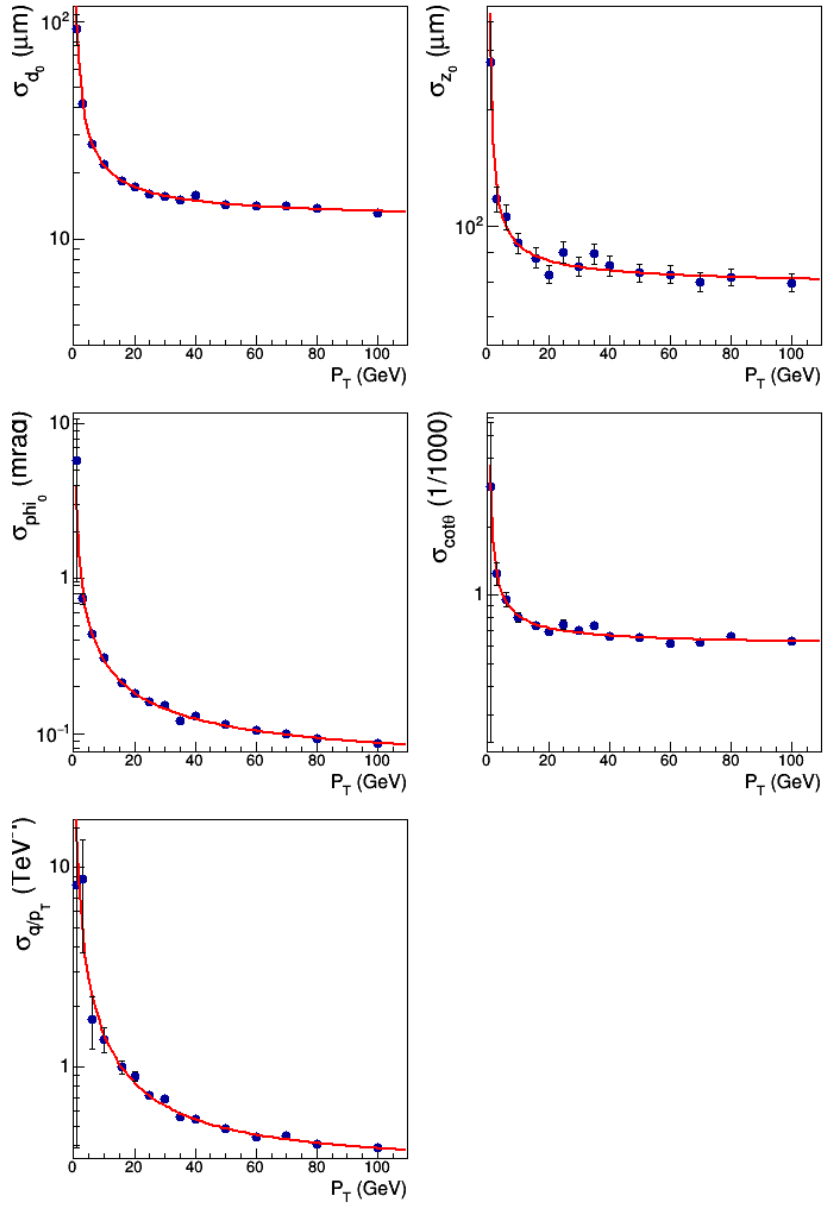


Example of smearing in a standalone G4 fast-sim, 20k muons , $|\eta| < 5.5$

Gaussian standard deviation $\sigma(p_T)$

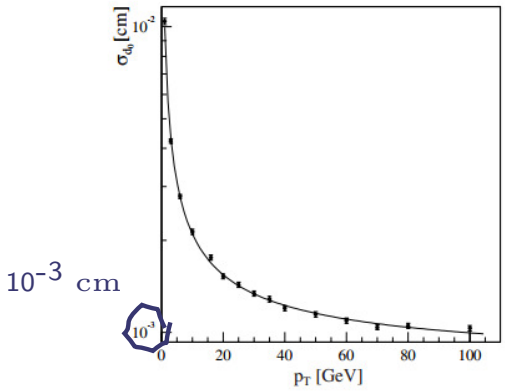


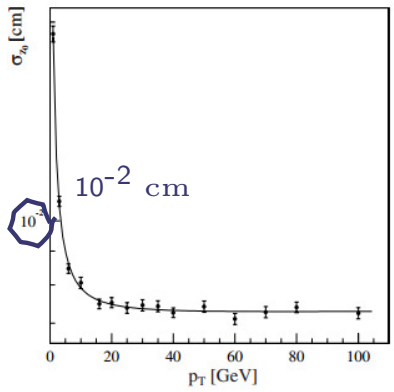
CERN-THESIS-2004-051 Fig. 6.5.

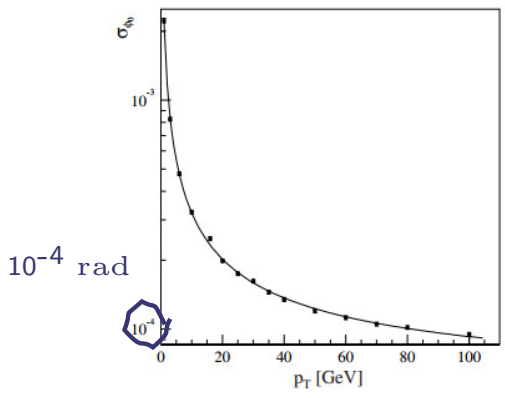


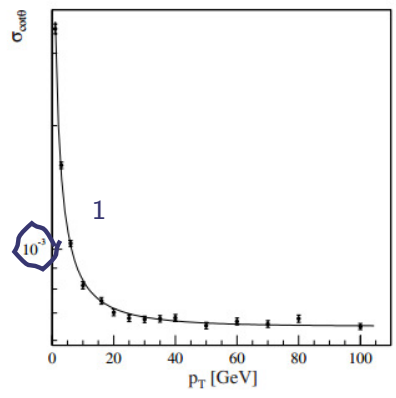
Example of smearing in a standalone G4 fast-sim, 20k muons , $|\eta| < 5.5$

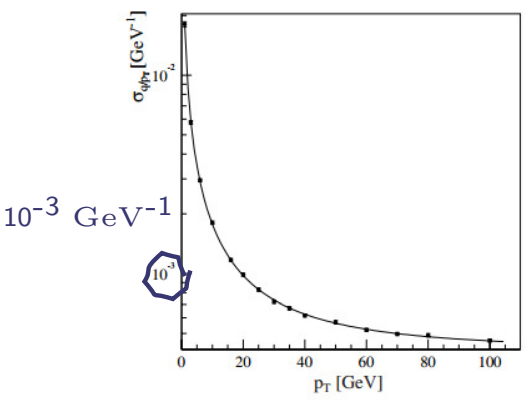
Gaussian standard deviation $\sigma(p_T)$





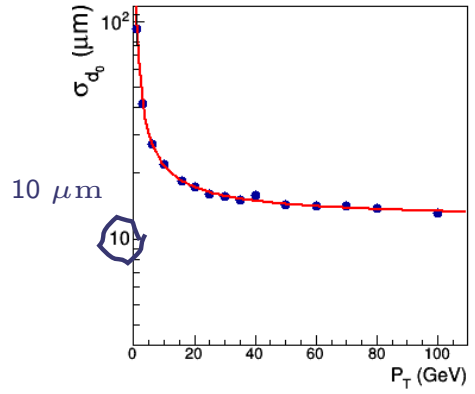


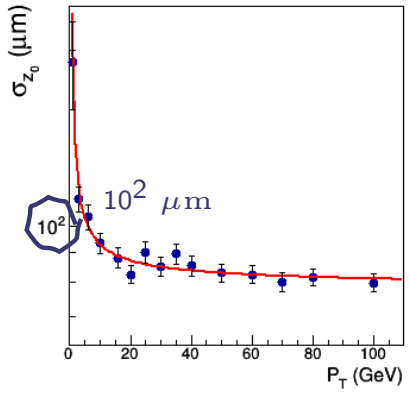


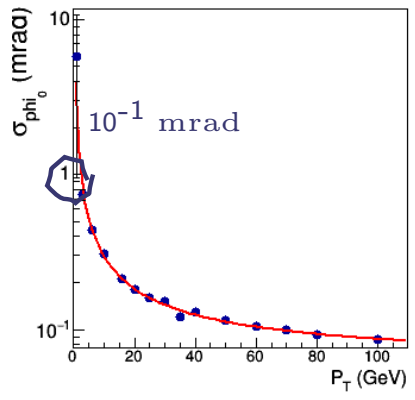


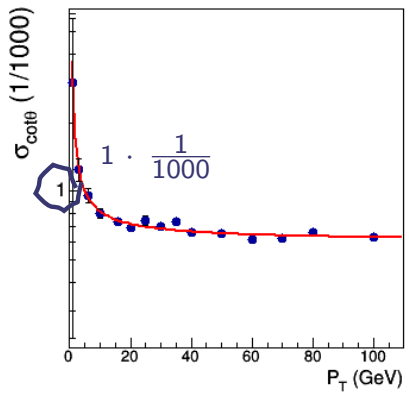
residuals σ_{τ_i} from Gaussian fits to the $\Delta\tau_i$ distributions in bin $0.75 < |\eta| < 1.00$

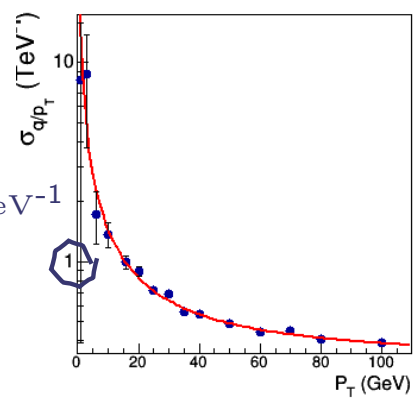
fit according to the E-G-N model with three free fit parameters











scale on axes is comparable

CERN-THESIS-2004-051 Fig. 6.5.

Example of smearing in a standalone G4 fast-sim, 20k muons , $|\eta| < 5.5$