Update on $\nu\bar{\nu}\mathrm{H}, \mathrm{H} \to \mu\mu$

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Update on $\mathrm{H} \rightarrow \mu\mu$ with improved analysis methods

- Started to work on $\mathrm{H} \rightarrow \mu\mu$ update.

Plan

1. Final selection with TMVA.
2. Weigth on $\sigma(\mathrm{M}(\mu^{+}, \mu^{-}))$ event by event (Mikael suggestion).

Weight on $\sigma(\mathrm{M}(\mu^+, \mu^-))$

Mikael Suggestion

- Dimuon mass given by muon momentum measurement.
  - Variance on $\mathrm{M}(\mu^+, \mu^-)$ $\longrightarrow$ error propagation from momentum uncertainty.
- Well measured signal events have small $\mathrm{M}(\mu^+, \mu^-)$ errors.
- Badly measured background events lying around signal window would have larger $\mathrm{M}(\mu^+, \mu^-)$ errors.

$\longrightarrow$ Variable $1/\sigma(\mathrm{M}(\mu^+, \mu^-))$ could improve S/B.

($\mathrm{M}(\mu^+, \mu^-)$ depends simetrically on both muons)

$$\sigma^2(\mathrm{M}(\mu^+, \mu^-)) = \frac{1}{\mathrm{M}(\mu^+, \mu^-)^2}[\mathrm{P}_1^{\mathrm{T}}\,\Sigma_2\,\mathrm{P}_1 + \mathrm{P}_2^{\mathrm{T}}\,\Sigma_1\,\mathrm{P}_2]$$

(*) P_i column vector $x^i = (E, px, py, pz)$, P_i^T, row vector $x_i = g_{ij}x^j = (E, -px, -py, -pz)$

(g_{ij} metric in the Minkowski space: [+1 -1 -1 -1]), Σ_i covariance matrix of muon i.

Weight on $\sigma(\mathrm{M}(\mu^+, \mu^-))$

$$\sigma^2(\mathrm{M}(\mu^+, \mu^-)) = \frac{1}{\mathrm{M}(\mu^+, \mu^-)^2}[\mathrm{P}_1^{\mathrm{T}}\, \Sigma_2\, \mathrm{P}_1 + \mathrm{P}_2^{\mathrm{T}}\, \Sigma_1\, \mathrm{P}_2]$$

(*) P_i column vector $x^i = (E, px, py, pz)$, P_i^T, row vector $x_i = g_{ij}x^j = (E, -px, -py, -pz)$
(g_{ij} metric in the Minkowski space: [+1 -1 -1 -1]), Σ_i covariance matrix of muon i.

- I assumed $Var(m_i) = 0$ (m_i, muon mass).
- Even without mass constraint, at 1 TeV, i would expect lim $\frac{Var(m)}{Var(p)} \approx 0$

ReconstructedParticle.getCovMatrix() returns null

- This covariance matrix is not filled (why not?).

$\longrightarrow$ Need to perform additional algebra.

  - Covariance matrix from associated track is available.
  - In helix parameterization basis: $d_0, z_0, \Omega, \phi, tan\lambda$
  - If $\mathfrak{J}$ is the Jacobian matrix from helix parameters to (px,py,pz,E)

$\longrightarrow$ $\Sigma_i' = \mathfrak{J}\, \Sigma_i\, \mathfrak{J}^T$, covariance matrix in momenta space.

Jacobian helix parameters to momenta space

- After some derivative exercises ...

$$\mathfrak{J} = \begin{bmatrix} \frac{\partial P_x}{\partial tan\lambda} & \frac{\partial P_y}{\partial tan\lambda} & \frac{\partial P_z}{\partial tan\lambda} & \frac{\partial E}{\partial tan\lambda} \\ \frac{\partial P_x}{\partial \Omega} & \frac{\partial P_y}{\partial \Omega} & \frac{\partial P_z}{\partial \Omega} & \frac{\partial E}{\partial \Omega} \\ \frac{\partial P_x}{\partial d_0} & \frac{\partial P_y}{\partial d_0} & \frac{\partial P_z}{\partial d_0} & \frac{\partial E}{\partial d_0} \\ \frac{\partial P_x}{\partial z_0} & \frac{\partial P_y}{\partial z_0} & \frac{\partial P_z}{\partial z_0} & \frac{\partial E}{\partial z_0} \\ \frac{\partial P_x}{\partial \phi} & \frac{\partial P_y}{\partial \phi} & \frac{\partial P_z}{\partial \phi} & \frac{\partial E}{\partial \phi} \end{bmatrix} = \frac{-1}{\Omega} \begin{bmatrix} 0 & 0 & -\Omega P_T & -\frac{P_z^2\,\Omega}{E\ tan\lambda} \\ P_x & P_y & P_z & \frac{P^2}{E} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ P_y\,\Omega & -P_x\,\Omega & 0 & 0 \end{bmatrix}$$

$\longrightarrow$ $\Sigma_i' = \mathfrak{J}\,\Sigma_i\,\mathfrak{J}^T$, covariance matrix in momenta space.

- Could be useful storing this covariance matrix for charged particles.
- so that, we could retrieve it by calling ReconstructedParticle.getCovMatrix(). (Currently returning null matrix)

Status / Plan

Comeback to $\mathrm{H} \rightarrow \mu\mu$

- Plan to update analysis with accumulated experience.
  - Final selection TMVA-based.
  - Check if $\sigma(\mathrm{M}(\mu^+, \mu^-))$ variable could improve S/N.
    - Found that covariance matrix in ReconstructedParticle not stored.
    - Getting it from propagation uncertainty from track cov. matrix.

Plan

- Short term
  - Finish with the cov. matrix evaluation algorithm in momenta space.
  - Compare new variable $\sigma(\mathrm{M}(\mu^+, \mu^-))$ for signal/background around signal window.
- Longer term
  - Keep working in updated analysis implementing new ideas/tools.