Kinematic Tagging of Muons in STT

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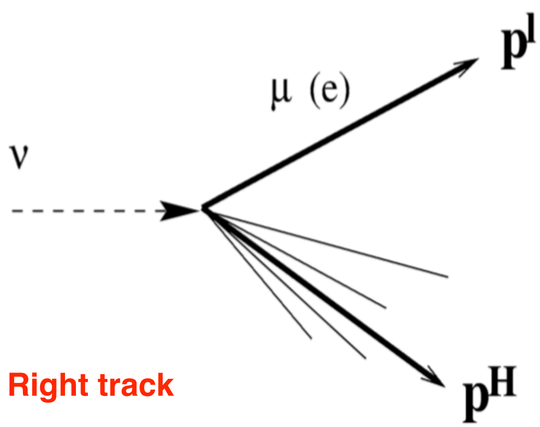
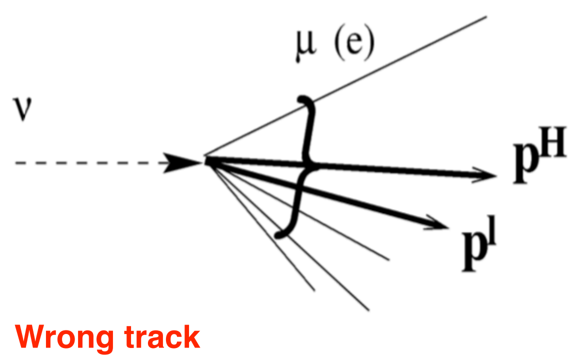
KINEMATIC VARIABLES

✦ *Kinematic tagging must discriminate between the true $\mu^{\pm}$ track and wrong $h^{\pm}$ track inside the SAME CC event: total visible momentum is constant (3 constraints).*

✦ *Consider 4 kinematic variables for muon tagging:*

- p_T^l: *transverse momentum of the track candidate;*
- $\theta_{\nu l}$: *angle of the track candidate with respect to beam direction;*
- y_{Bj}: *ratio between the energy of the "hadron system" (visible energy minus track energy) and the total visible energy;*
- R_{Q_T}: *ratio between the transverse size of the of the "hadron system" $\langle Q_T^2 \rangle_H$ and that of the full event $\langle Q_T^2 \rangle$, where Q_T component of the track momentum perpendicular to the total visible momentum.*





KINEMATIC TAGGING OF μ^- AND μ^+

- *From reconstructed momentum vector determine if the track will reach outer yoke: (i) sample reaching outer yoke; (ii) sample NOT reaching outer yoke.*

- *Veto tracks interacting within STT volume (both μ^- and μ^+ tagging).*

- *Veto protons for μ^+ tagging using NN for proton ID.*

- *For events with ≥ 2 candidate tracks calculate a NN value for each candidate track using two separate NN trainings for the two samples:*
  - *Tracks reaching outer yoke: use training with all events with ≥ 2 candidate tracks, NN_1;*
  - *Tracks NOT reaching outer yoke: use training with events with ≥ 2 candidate tracks & $\mu^\mp$ NOT reaching outer yoke (NN_2), multiply NN_2 values by optimized constant $c = 15.0$.*

- *Select the single negative/positive track in the event with the highest NN output:*

Event sample	*Selected track*	*Tagging efficiency*
FHC ν_μ CC	μ^-	**99.1%**
RHC $\bar{\nu}_\mu$ CC	μ^+	**99.3%**

REJECTION OF NC BACKGROUND

- *Focus on tagged tracks NOT reaching outer yoke* (~ 30% of μ^-, 14% of μ^+):
  - *NC background from tagged tracks reaching outer yoke* $\sim 0.1\%$;
  - *For tracks reaching outer yoke external muon identifier provides additional rejection.*

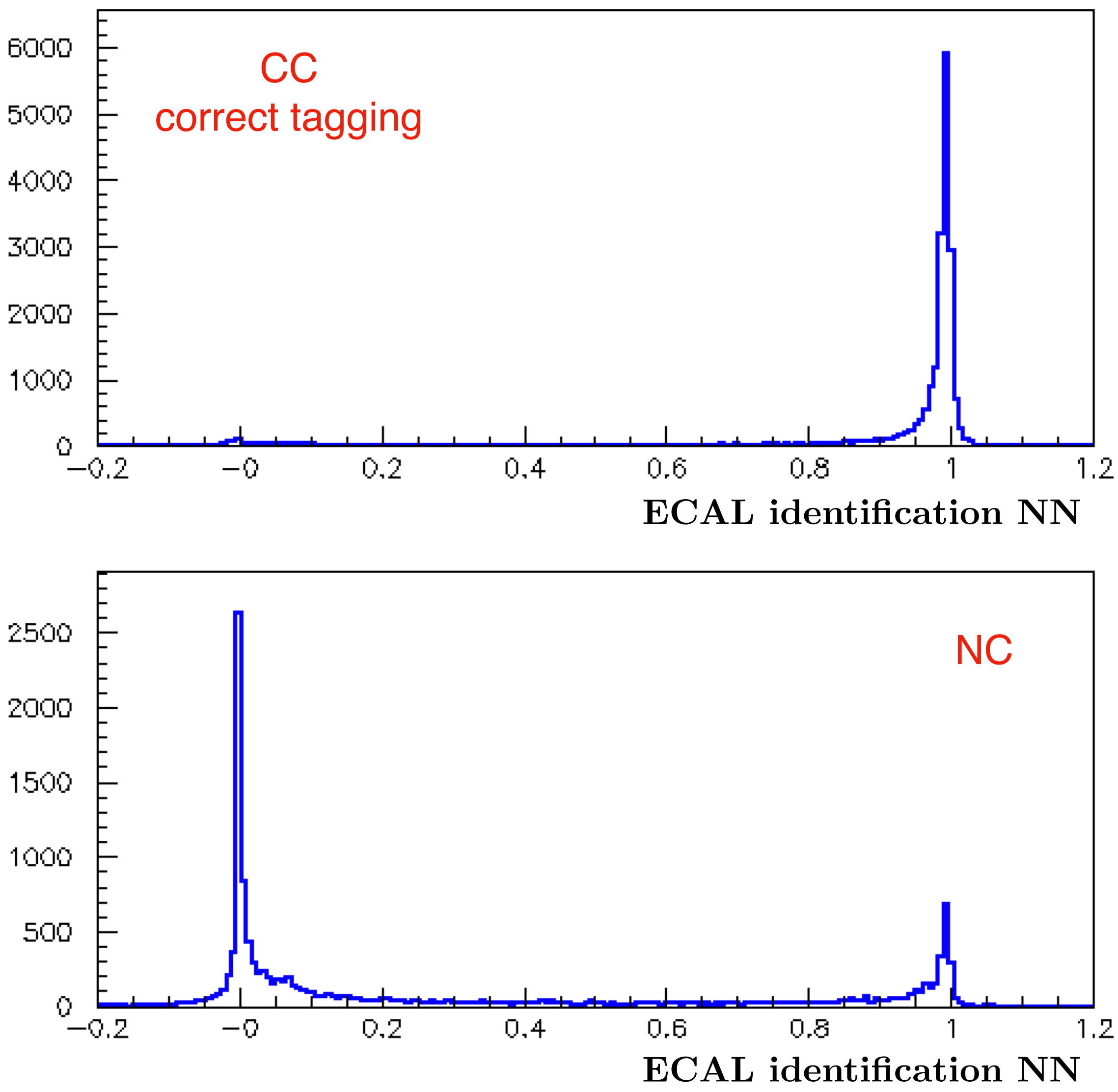
- *Three rejection criteria available*:
  - *Energy deposition and topology (interactions) in ECAL;*
  - *Track variables related to the kinematic tagging;*
  - *Event kinematics based on isolation & transverse plane kinematics.*

  $\Longrightarrow$ *Specific cuts applied will depend on the particular physics analysis*

- *For the selection of CC interactions on hydrogen only $\mu^\pm$ tagging needed: kinematic selection of H reduces NC backgrounds to $< 10^{-3}$.*

- *Initial optimization of $\mu^\pm$ identification without global event kinematics.*

  $\Longrightarrow$ *Apply initial loose ECAL identification with NN>0.36 (to be optimized)*



Tagged tracks reaching barrel ECAL and NOT reaching outer yoke

REJECTION OF WRONG SIGN BACKGROUND

✦ *For each event apply BOTH μ^- and μ^+ tagging*

⟹ *Select single μ^- and single μ^+ candidate within same event*

✦ *If wrong sign candidate exists:*

- *Reject events with wrong sign candidate reaching outer yoke;*
- *Reject events with wrong sign candidate identified in ECAL if right sign one NOT reaching outer yoke.*

⟹ *Efficient tagging allows use of magnet yoke to filter out wrong sign background*

Event selection	Efficiency	Purity ν_μ CC + $\bar{\nu}_\mu$ CC + NC	Wrong sign contamination
RHC μ^+ selection	98.7 %	93.6 %	0.7 %
RHC μ^- selection	95.6 %	90.7 %	1.4 %

Event selection	*Efficiency*	*Purity* ν_μ *CC* + $\bar{\nu}_\mu$ *CC* + *NC*	*Wrong sign contamination*
RHC μ^+ *selection*	*98.5 %*	*93.8 %*	*0.7 %*
RHC μ^- *selection*	*94.6 %*	*91.0 %*	*1.4 %*

Selection assuming 100% ID efficiency for tracks reaching outer yoke (external identifier)

Backup slides