CC coherent π

Hide TANAKA
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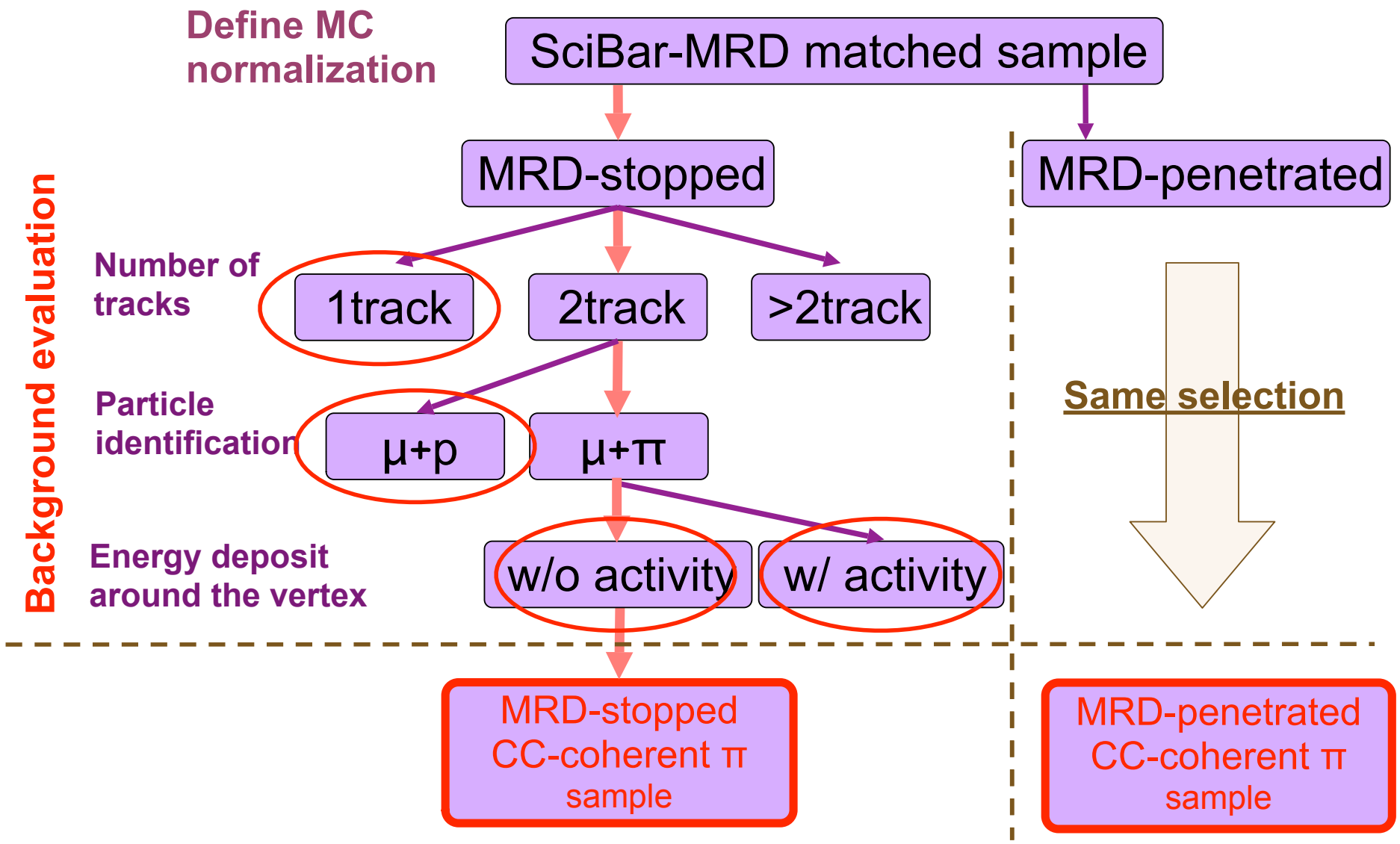
SciBooNE Collab Mtg 2010/05/25

Contents

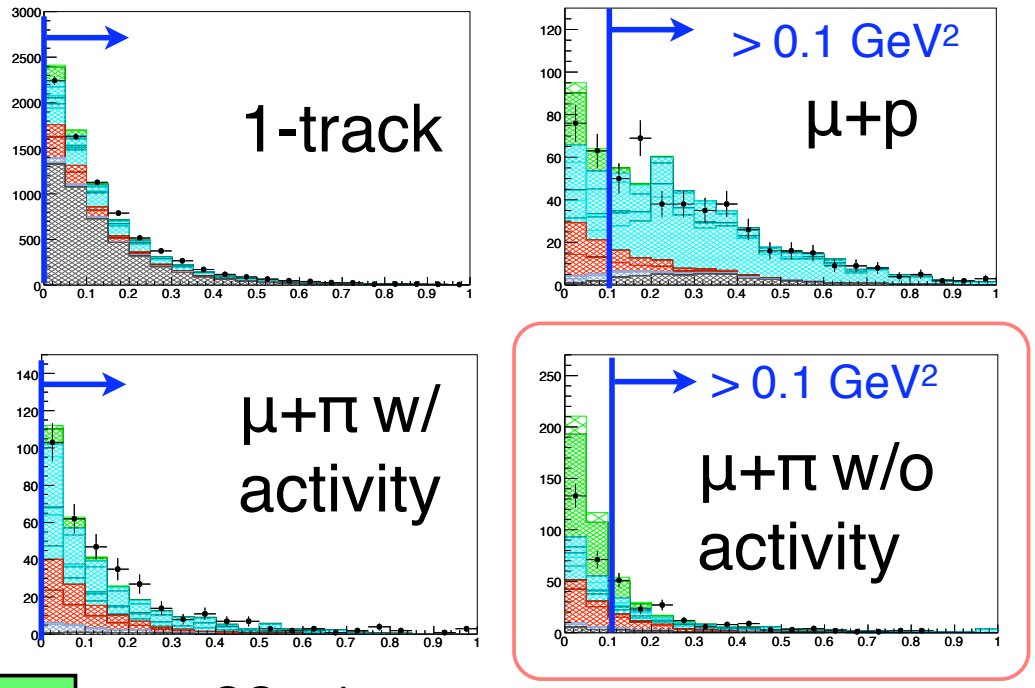
- Background evaluation (Q^2-fit) in $\bar{\nu}$ mode

Event selection



Background evaluation

- Tune MC by fitting four Q^2 distributions with systematic parameters (fit parameters)
- Use the same χ2 definition as in coh-π paper



Signal sample

: ν̄+ν CC coherent π
: ν̄ CC resonant
: ν̄ Other (DIS, EC/MRD, NC)
: ν̄ CC QE
: Wrong-Sign

χ2 definition:

$$\chi^2 = \chi^2_{dist} + \chi^2_{sys}$$

$$\chi^2_{dist} = 2\sum_{i,j}\left(N^{\rm exp}_{ij} - N^{\rm obs}_{ij} \times \ln\frac{N^{\rm obs}_{ij}}{N^{\rm exp}_{ij}}\right)$$

(use Poison likelihood)

i: runs over four samples
j: runs over Q^2-bins
N^{obs}: Observed #events
N^{exp}: Expected #events (next page)

$$\chi^2_{\rm sys} = (\boldsymbol{P_{sys}} - \boldsymbol{P_0})\boldsymbol{V}^{-1}(\boldsymbol{P_{sys}} - \boldsymbol{P_0})$$

V: covariance matrix
P_0: initial value
P_{sys}: fit parameters (next page)

Fit parameters

$$N^{\rm exp}_{i,\ 1{\rm trk}} = R_{\rm norm} \cdot \left[n^{\rm QE}_{i,1{\rm trk}} + R_{\rm res} n^{\rm res}_{i,1{\rm trk}} + R_{\rm other} n^{\rm other}_{i,1{\rm trk}} \right]$$

$$N^{\rm exp}_{i,\ \mu\pi{\rm H}} = R_{\rm norm} \cdot R_{2{\rm trk}/1{\rm trk}} \cdot \left[n^{\rm QE}_{i,\mu\pi{\rm H}} + R_{\rm res} n^{\rm res}_{i,\mu\pi{\rm H}} + R_{\rm other} n^{\rm other}_{i,\mu\pi{\rm H}} \right]$$

$$N^{\rm exp}_{i,\ \mu p} = R_{\rm norm} \cdot R_{2{\rm trk}/1{\rm trk}} \cdot R_{p/\pi} \cdot \left[n^{\rm QE}_{i,\mu p} + R_{\rm res} n^{\rm res}_{i,\mu p} + R_{\rm other} n^{\rm other}_{i,\mu p} \right]$$

$$N^{\rm exp}_{i,\ \mu\pi{\rm L}} = R_{\rm norm} \cdot R_{2{\rm trk}/1{\rm trk}} \cdot R_{\rm act} \cdot \left[n^{\rm QE}_{i,\mu\pi{\rm L}} + R_{\rm res} n^{\rm res}_{i,\mu\pi{\rm L}} + R_{\rm other} n^{\rm other}_{i,\mu\pi{\rm L}} \right]$$

new

$$n^{\rm mode}_{i,{\rm sample}} \equiv \left(n^{\bar{\nu}-{\rm mode}}_{i,{\rm sample}} + R_{\rm WS} \cdot n^{\nu-{\rm mode}}_{i,{\rm sample}} \right)$$

new

- **R_{WS}**: scaling factor for Wrong-Sign (WS) events -- no constrained
- **$R_{2tr/1trk}$**: migration parameter between [1trk]-[2trk] samples
- **$R_{p/\pi}$**: migration param. between [μ+p]-[μ+π] samples
- **R_{act}**: migration param. between [with activity]-[w/o activity]
  - no constrained
- **R_{res}**: scale factor for resonant-π
- **R_{other}**: scale factor for "other" (≡ multi-π, DIS, EC/MRD)
  - no constrained
- **R_{pscale}**: momentum scale
- **R_{norm}**: overall normalization -- no constrained
- **kappa**: only for QE -- no constrained

Systematics: physics related

for covariance matrix

- Pion FSI
  - absorption, charge exchange, inelastic (variation: ±30%)
- Nucleon FSI
  - re-scattering (variation: ±10%)
- DIS cross section
  - (variation: ±30%)
- non-QE/QE ratio
  - (variation: ±20%)

Re-weighting method

for example:

$$w_{fsi} = \frac{P_{tot} - \mathcal{F}_{scale} \cdot P_{fsi}}{P_{tot} - P_{fsi}}$$

w_{fsi} : re-weighting factor

P_{tot} : probability of events w/ p/π emission

$\mathcal{F}_{scale}$: scaling (e.g. 1.3 for +30% vary)

P_{fsi} : probability of p/π FSI

Systematic errors on fit-params

~Physics related~

Source	Variation (+, -)	$\delta R_{2trk/1trk}$		$\delta R_{p/\pi}$		cov ($\times 10^{-4}$)
		+	-	+	-	
Fermi mom.	--, 212 MeV	--	TBA	--	TBA	TBA
M_A	--, 1.11 GeV	--	TBA	--	TBA	TBA
π abs.	±30%	-3.4%	+3.3%	+3.8%	-3.6%	-12.6
π charge ex.	±30%	-0.5%	+0.4%	+0.7%	-0.7%	-0.3
π inelastic	±30%	-1.3%	+1.1%	+1.1%	-0.9%	-1.2
Nucl. rescat.	±10%	-0.9%	+0.9%	+0.5%	-0.6%	+1.8
DIS x-sec	±30%	+0.5%	-0.5%	-0.2%	+0.2%	-0.1
nQE/QE	±20%	+5.5%	-5.9%	-2.8%	+3.5%	-17.9
Detector π-int	±10%	TBA	TBA	TBA	TBA	TBA

- Dominant systematic error on $R_{2/1trk}$ and $R_{p/\pi}$
  - pion absorption
  - non-QE/QE cross section ratio

Systematics: detector related

for covariance matrix

- Use identical NEUT vector
- Vary syst. parameters in detector simulation:
  - PMT 1 p.e. resolution (30%, 70%)
  - Scintillator quenching (0.0185, 0.0231)
  - PMT cross talk (2.75%, 3.55%)
  - Hit threshold (1.6 p.e., 2.4 p.e.) -- not done yet

Systematic errors on fit-params
~Detector response~

Source	Variation (+, -)	$\delta R_{2trk/1trk}$		$\delta R_{p/\pi}$		cov ($\times 10^{-4}$)
		+	-	+	-	
1pe resolution	70%, 30%	-0.3%	+0.3%	-1.6%	-0.3%	-0.2
Scint. quench	0.0231, 0.0185	-1.9%	+1.4%	-1.2%	-0.5%	-4.4
Hit threshold	2.4pe, 1.6pe	TBA	TBA	TBA	TBA	TBA
X-talk	3.55%, 2.75%	-1.2%	+0.7%	-6.1%	-3.2%	-2.4

- Dominant systematic error on $R_{2/1trk}$ and $R_{p/\pi}$
  - PMT cross-talk (?)
  - Scintillator quenching

In addition to these, μ-momentum scale error 2% is taken into account.

Covariance matrix

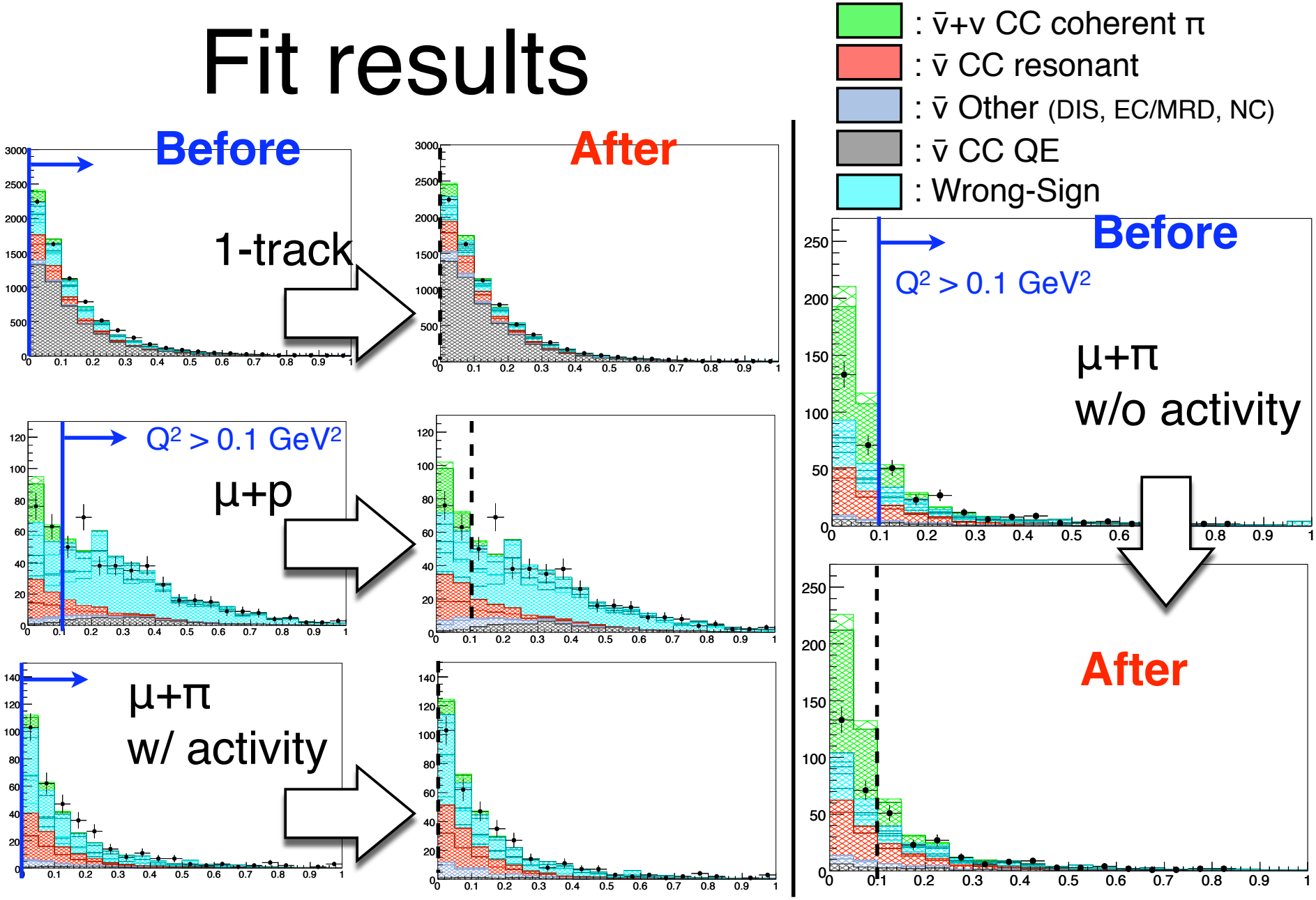
- Obtained covariance matrix:

$$
V = \begin{array}{c} \\ \\ \\ \\ \end{array}
\begin{array}{cc}
\begin{array}{cccc} R_{2/1\text{-trk}} & R_{p/\pi} & R_{res} & R_{pscale} \end{array} & \\
\begin{bmatrix}
(0.071)^2 & -(0.062)^2 & (0.097)^2 & 0.0 \\
-(0.062)^2 & (0.079)^2 & -(0.072)^2 & 0.0 \\
(0.097)^2 & -(0.072)^2 & (0.157)^2 & 0.0 \\
0.0 & 0.0 & 0.0 & (0.02)^2
\end{bmatrix} &
\begin{array}{c} R_{2/1\text{-trk}} \\ R_{p/\pi} \\ R_{res} \\ R_{pscale} \end{array}
\end{array}
$$

$$\chi^2_{\text{sys}} = (\boldsymbol{P_{sys}} - \boldsymbol{P_0})\boldsymbol{V}^{-1}(\boldsymbol{P_{sys}} - \boldsymbol{P_0})$$

$$P_{\text{sys}} = \begin{pmatrix} R_{2/1\text{trk}} \\ R_{p/\pi} \\ R_{\text{res}} \\ R_{\text{pscl}} \end{pmatrix} \qquad P_0 = \begin{pmatrix} 1.0 \\ 1.0 \\ 1.0 \\ 1.0 \end{pmatrix}$$

Fit results



- χ2/ndf: 162/75=2.16 ➜ 77/66=1.17

Fit results

Antineutrino mode

Note: not full sys err yet

Param	Value	Error
R_{norm}	1.107	0.031
$R_{2trk/1trk}$	1.034	0.047
$R_{p\pi}$	0.984	0.063
R_{act}	0.996	0.076
R_{pscale}	1.029	0.002
R_{res}	1.070	0.104
R_{other}	1.82	0.449
Kappa	1.056	0.014
R_{WS}	0.71	0.099

- Before: χ^2/ndf = 162/75=2.16
- After: χ^2/ndf = 77/66=1.17

cf. Neutrino mode

Param	Value	Error
R_{norm}	1.025	0.028
$R_{2trk/1trk}$	0.905	0.037
$R_{p\pi}$	0.985	0.046
R_{act}	1.032	0.061
R_{pscale}	1.032	0.002
R_{res}	1.195	0.101
R_{other}	1.58	0.144
Kappa	1.020	0.005

- Before: χ^2/ndf = 423/75=5.64
- After: χ^2/ndf = 152/67=2.27

Error matrix

	R_{norm}	$R_{2/1trk}$	$R_{p\pi}$	R_{res}	R_{pscale}	Kappa	R_{act}	R_{other}	R_{ws}
R_{norm}	1.000	0.086	0.084	-0.064	-0.026	0.360	0.411	-0.467	-0.326
$R_{2/1trk}$	0.086	1.000	-0.584	0.669	-0.047	0.012	-0.413	-0.437	-0.164
$R_{p\pi}$	0.084	-0.584	1.000	-0.180	0.226	-0.000	0.451	0.378	-0.442
R_{res}	-0.064	0.669	-0.180	1.000	0.027	0.007	-0.302	-0.425	-0.286
R_{pscale}	-0.026	-0.047	0.226	0.027	1.000	-0.036	0.051	0.354	-0.413
Kappa	0.360	0.012	-0.000	0.007	-0.036	1.000	0.051	-0.058	-0.076
R_{act}	0.411	-0.413	0.451	-0.302	0.051	0.051	1.000	-0.040	-0.238
R_{other}	-0.467	-0.437	0.378	-0.425	0.354	-0.058	-0.040	1.000	-0.309
R_{ws}	-0.326	-0.164	-0.442	-0.286	-0.413	-0.076	-0.238	-0.309	1.000

Large correlations in:

$R_{res} \rightleftarrows R_{2/1trk}$, $R_{p/\pi} \rightleftarrows R_{2/1trk}$

$R_{other} \rightleftarrows [R_{norm}, R_{2/1trk}, R_{p/\pi}, R_{res}]$

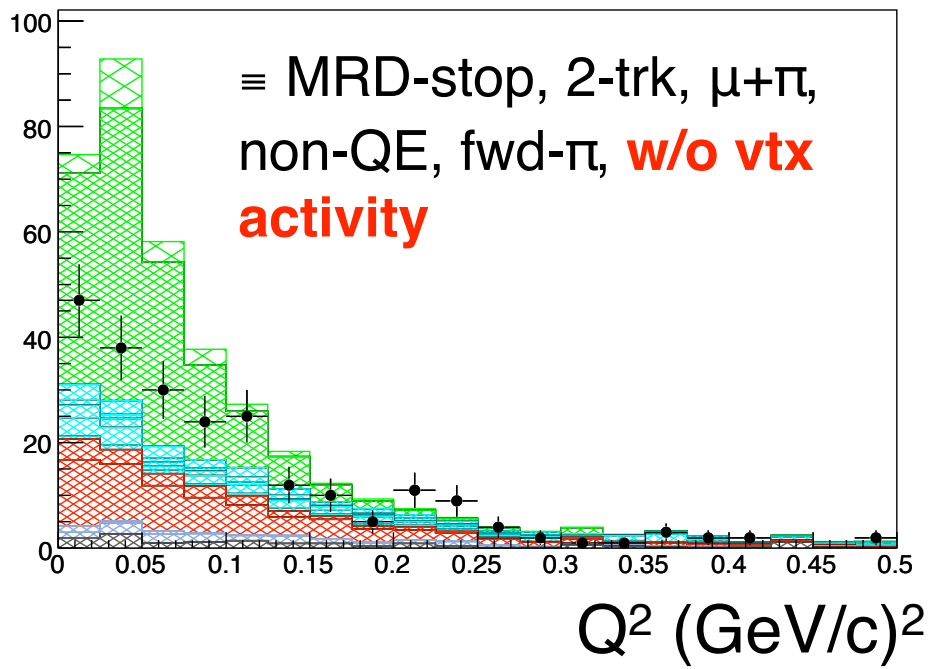
$R_{act} \rightleftarrows [R_{norm}, R_{2/1trk}, R_{p/\pi}, R_{res}]$

$R_{WS} \rightleftarrows [R_{norm}, R_{p/\pi}, R_{res}, R_{other}]$ -- all negative corr

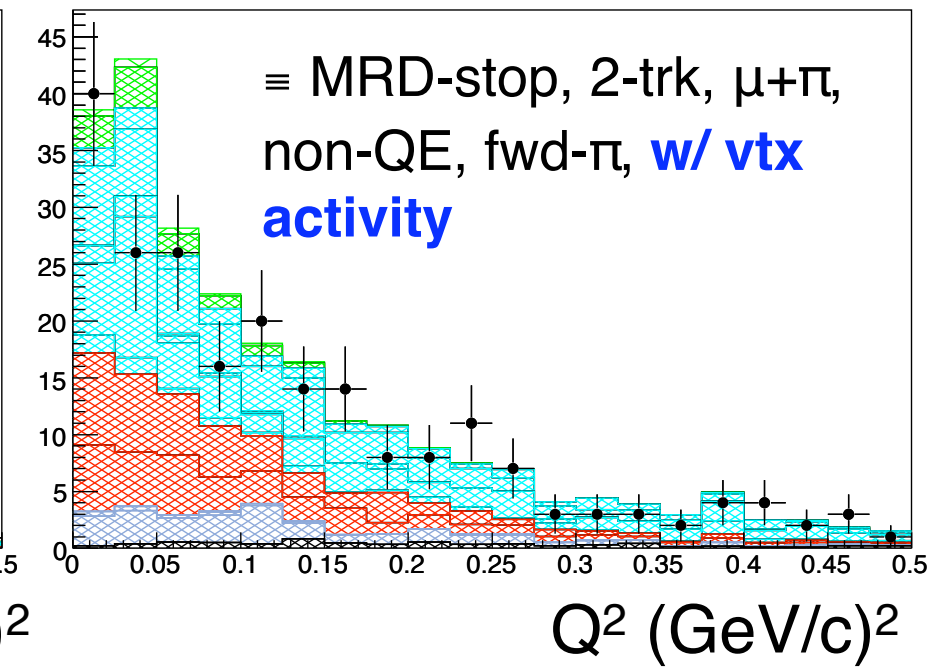
Reconstructed Q^2 dist

After fit

Coherent-π sample



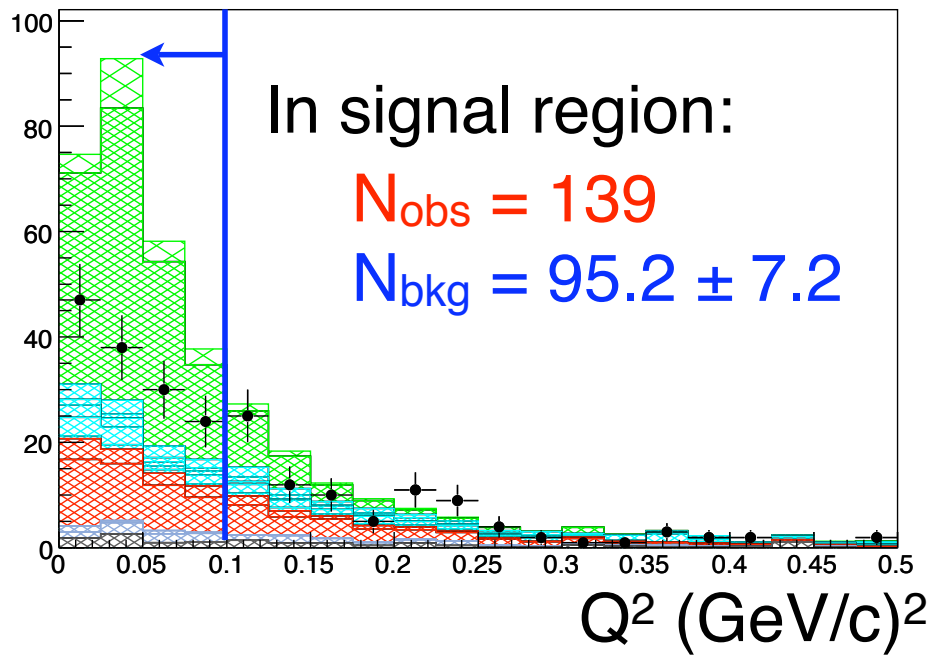
Coherent-π counter-sample



: $\bar{\nu}$+ν CC coherent π
: $\bar{\nu}$ CC resonant
: $\bar{\nu}$ Other (DIS, EC/MRD, NC)
: $\bar{\nu}$ CC QE
: Wrong-Sign

Number of events
in coherent-π sample

Signal region ≡ $Q^2 < 0.1$ $(GeV/c)^2$



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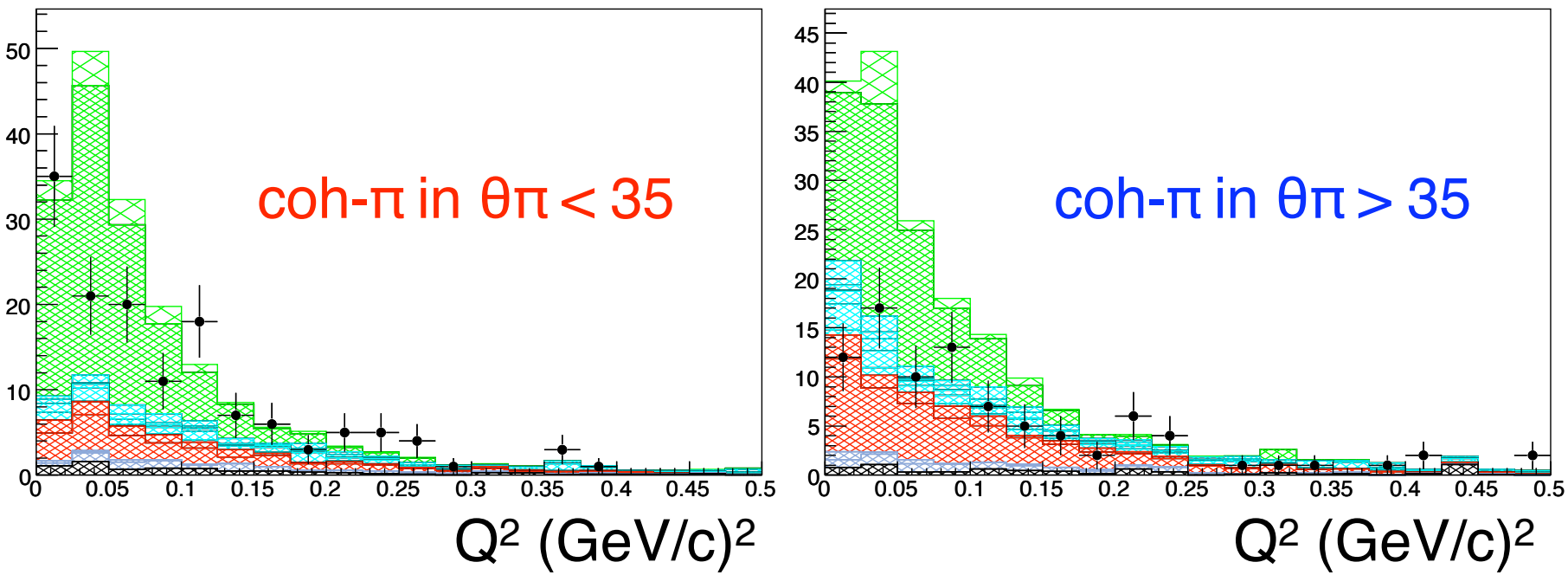
Quick look...

- Divide coh-π sample (after fit) into two subsamples: [θπ < 35] and [θπ > 35]



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Summary

- Need to do...
  - $\bar{\nu}$ mode analysis:
    - Add remaining syst. errors to Q^2-fit:
      - Fermi mom, M_A, Detector pion abs, Hit threshold
    - Reliability test of Q^2-fit (background evaluation)
    - Cross section ratio
      - MC processing are underway
    - Look at distributions (other than Q^2)

  - ν & $\bar{\nu}$ systematic errors

  - Packing, packing, packing, packing, ...