Some considerations on the sensitivity calculation

- A coherent matrix formalism is adopted to treat correlation between different detectors and different neutrino flavors
- Inclusion of different systematic uncertainties contributions is straightforward (at the moment only the flux systematic is properly treated)
- Some results on the sensitivity for the νe appearance from anomalous $\nu\mu$ oscillations

General assumptions

- Up to now only the νe appearance channel has been considered
- Up to now only two detectors have been considered in the computations:
  - Lar1-ND detector @100 m
  - ICARUS (T600 / T1200) detector @600 m
- Only the measured νe have been considered in the sensitivity to retain only the genuine appearance signal (i.e. no direct measurement of the $\nu\mu$ component enters in the sensitivity computation)
- Three years and 6.6e20 pot have been assumed for both detectors

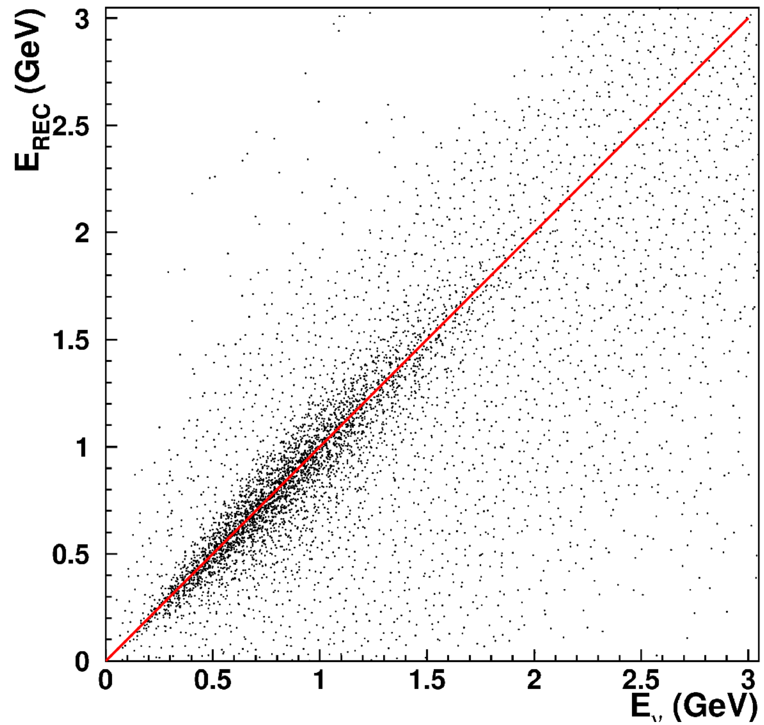
Global flow of the computation

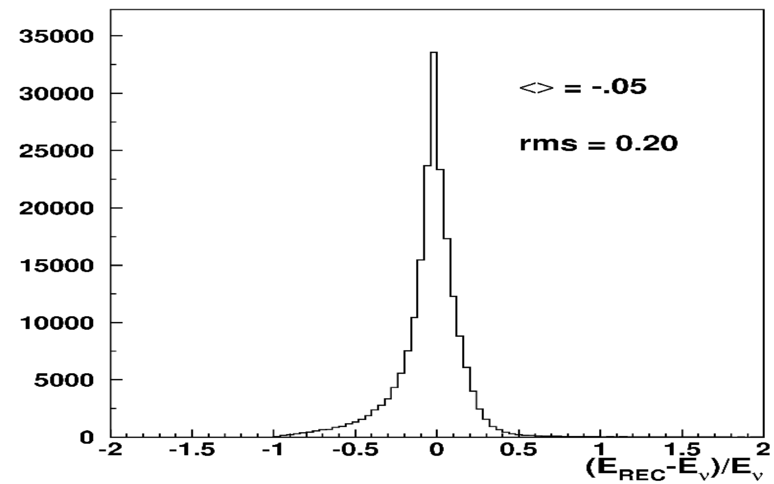
- Unoscillated spectra at the different detector locations (true ν energy E_ν)
- Beam systematic uncertainty on the E_ν spectra (including correlations between different flavors/detector positions)
- Cross section systematic
- Simulation of the experimental reconstruction of the signal (reconstructed ν energy E_{REC})
- Contributions from misidentified ν interactions
- Detector/reconstruction dependent systematic uncertainties
- Estimated sensitivity
- Coherent matrix formalism to treat all systematic uncertainties and the detector response

The νe signal: event energy reconstruction 1

- The energy reconstruction has been obtained by MC simulation of the intrinsic νe events inside the detector, separately correcting the visible hadronic and leptonic energy to account for the average undetected and or non contained energy as a fuction of the vertex position (thanks to Paola).

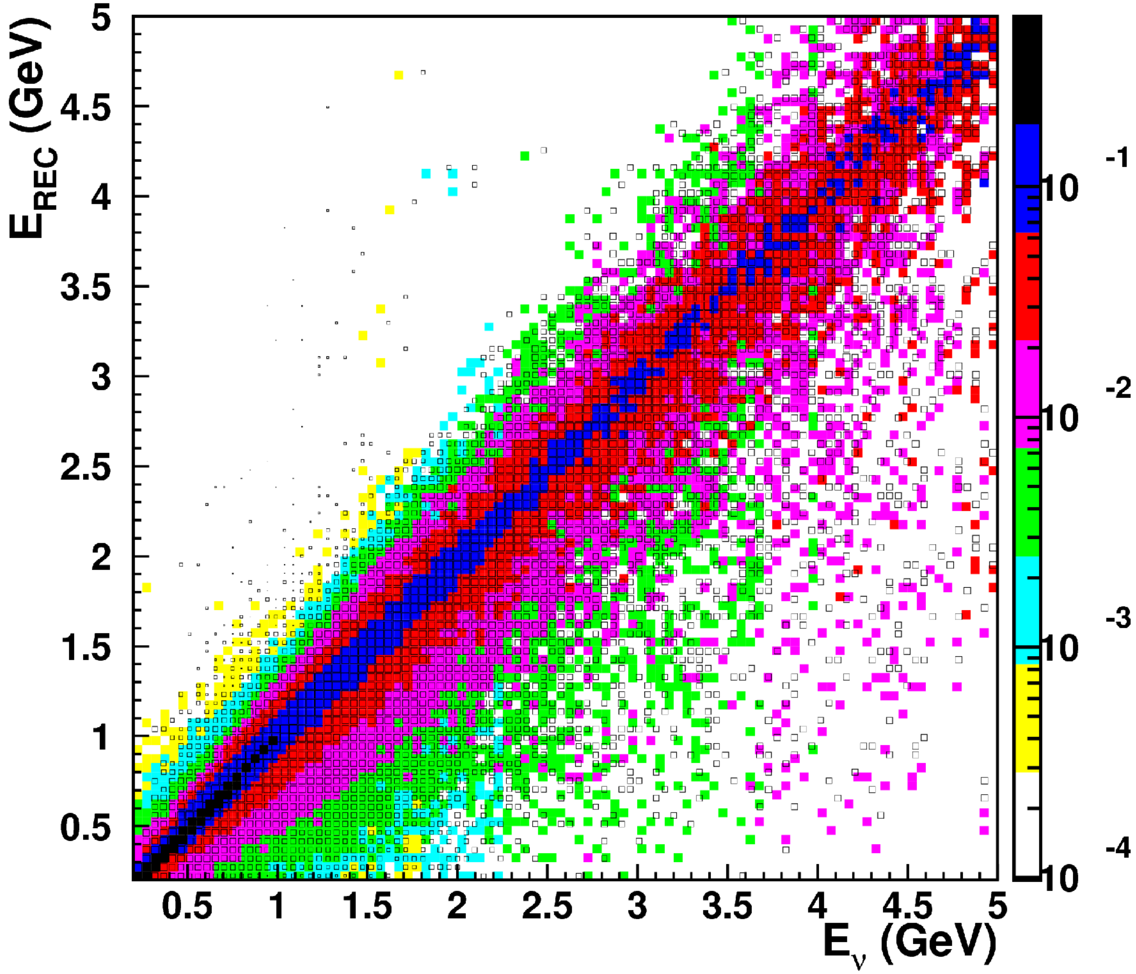
- The average reconstructed energy is close to the true neutrino energy with a smearing of ≈ 20%





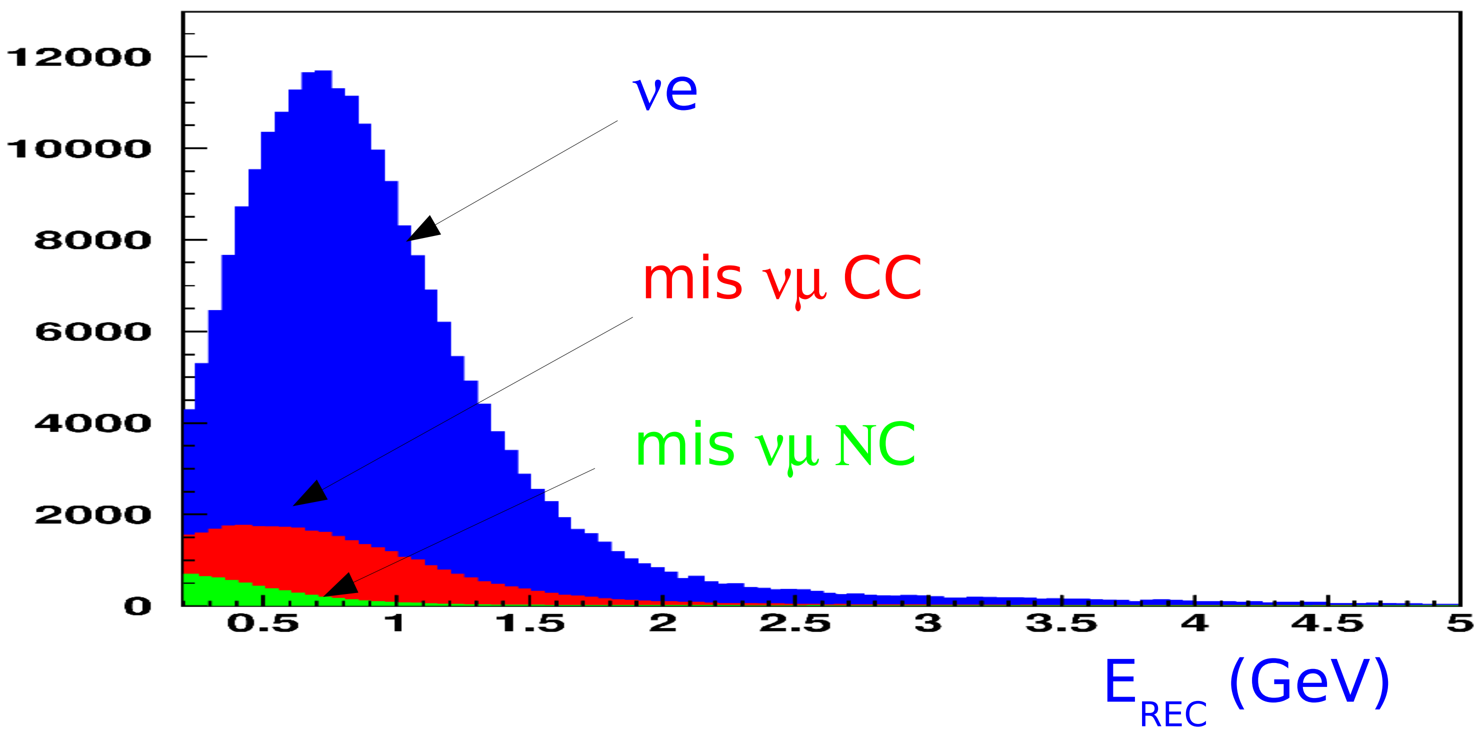
The νe signal: event energy reconstruction 2

- The detector response is simulated with a smearing matrix $S_{ee}(j_\nu, i_{REC})$ transforming E_ν to E_{REC}



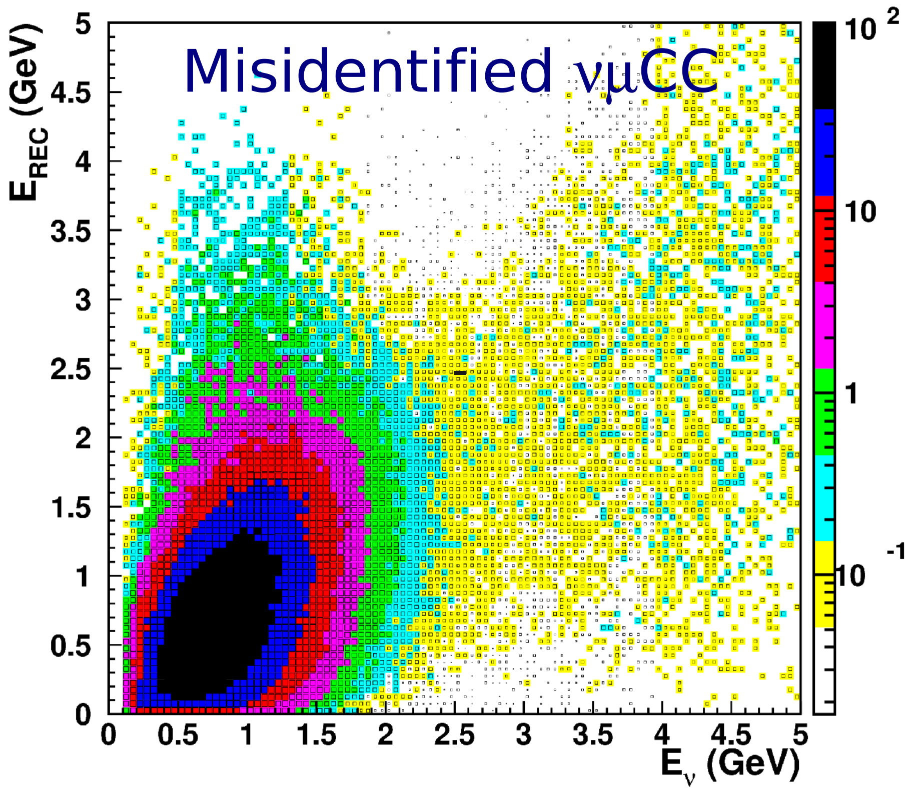
Background from misidentified NC and CC

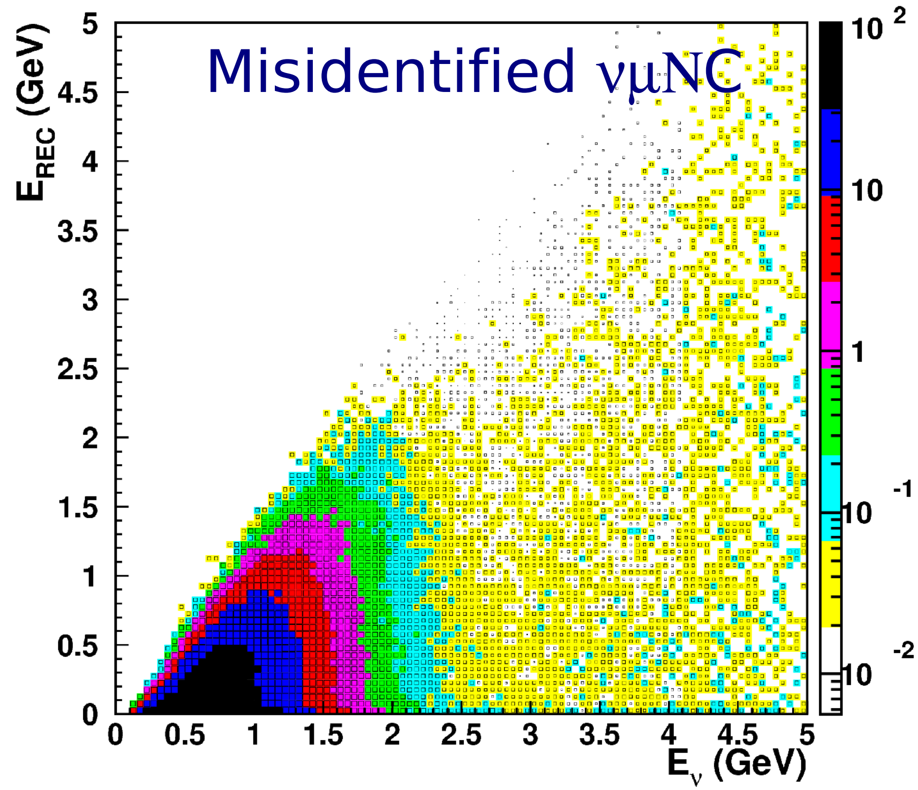
- A rough estimate of the misidentified NC and CC is adopted
- The reconstructed energy for these components is computed with a scheme similar to the one adopted for the true νe events



The reconstructed energy for the $\nu\mu$ misidentified as νe is computed with matrices $B_{\mu e}^{NC,CC}(j_{\nu\mu}, i_{REC})$ transforming E_ν to E_{REC} and properly accounting for the relative normalization

$$n_{i_{REC}}^{NC,CC} = \sum_{j_{\nu\mu}} B_{\mu e}^{NC,CC}(j_{\nu\mu}, i_{REC}) \; n_{j_{\nu\mu}}$$





The expected νe spectra

- At each detector the reconstructed unoscillated νe spectrum is factorized as

$$n_{e0} = S_{ee}\ \ \nu_e CC_0\ + \left(B^{NC}_{\mu e} + B^{CC}_{\mu e}\right)\ \nu\mu CC_0$$

No oscillation

Using the previously defined reconstruction matrices S_{ee} for νe and $B_{\mu e} = \left(B^{NC}_{\mu e} + B^{CC}_{\mu e}\right)$ for the misidentified νμCC and νμNC and the unoscillated neutrino spectra $\nu_e CC_0$ and $\nu\mu CC_0$

- in case of oscillation the reconstructed νe spectrum at each detector

$$n_{e\ Osc} = S_{ee}\ \ \nu_e CC_{Osc}\ + \left(B^{NC}_{\mu e} + B^{CC}_{\mu e}\right)\ \nu\mu CC_{Osc}$$

With oscillation

is expected to be generated by the oscillated neutrino spectra

$\nu_e CC_{Osc}$ and $\nu\mu CC_{Osc}$

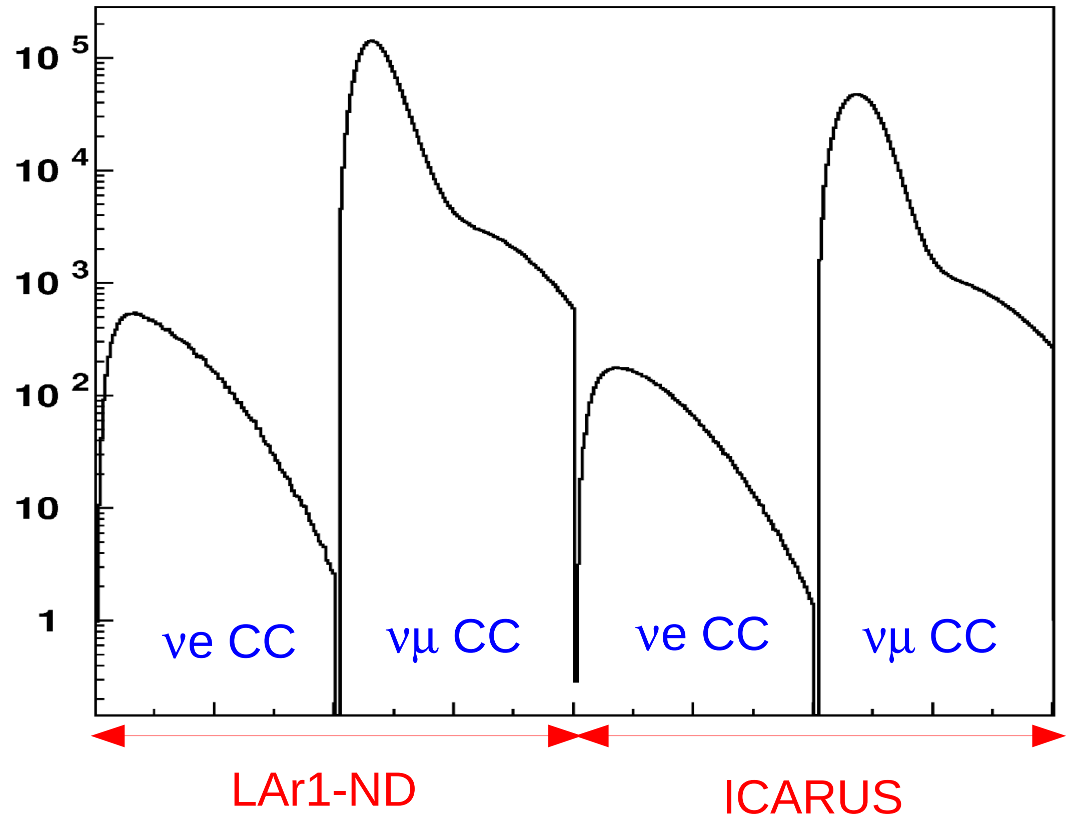
The full neutrino spectra

- The νe and νμ at the different sites (Lar1-ND @100m +ICARUS @ 600m) are packed together into a 4-fold vector νCC

νCC =

νe CC (100m)
νμ CC (100m)
νe CC (600m)
νμ CC (100m)

graphically



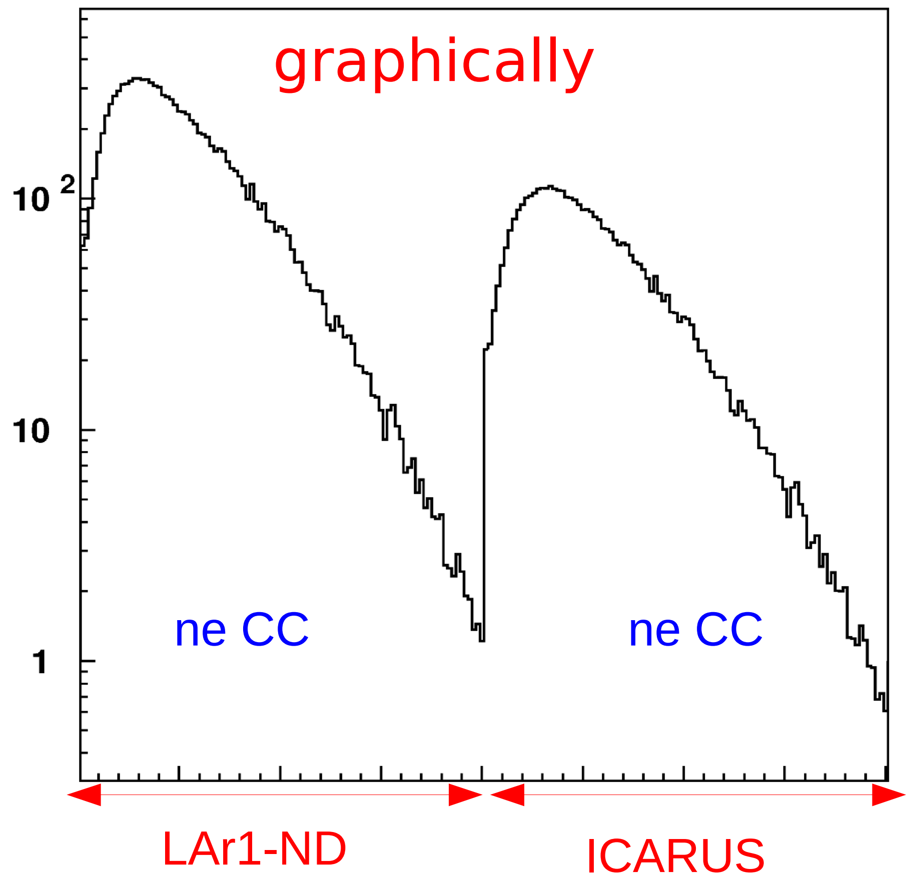
- With such a choice both the correlations between different flavors and between different detectors can be fully exploited in the analysis

The reconstructed νe spectra

- The reconstructed electron neutrino events at the two sites are packed together into a two-fold vector n_e

n_e =

ne (100m)
ne (600m)



- The correlations between the two detectors can be fully exploited in the analysis

From true νCC to reconstructed electron spectra n_e (1)

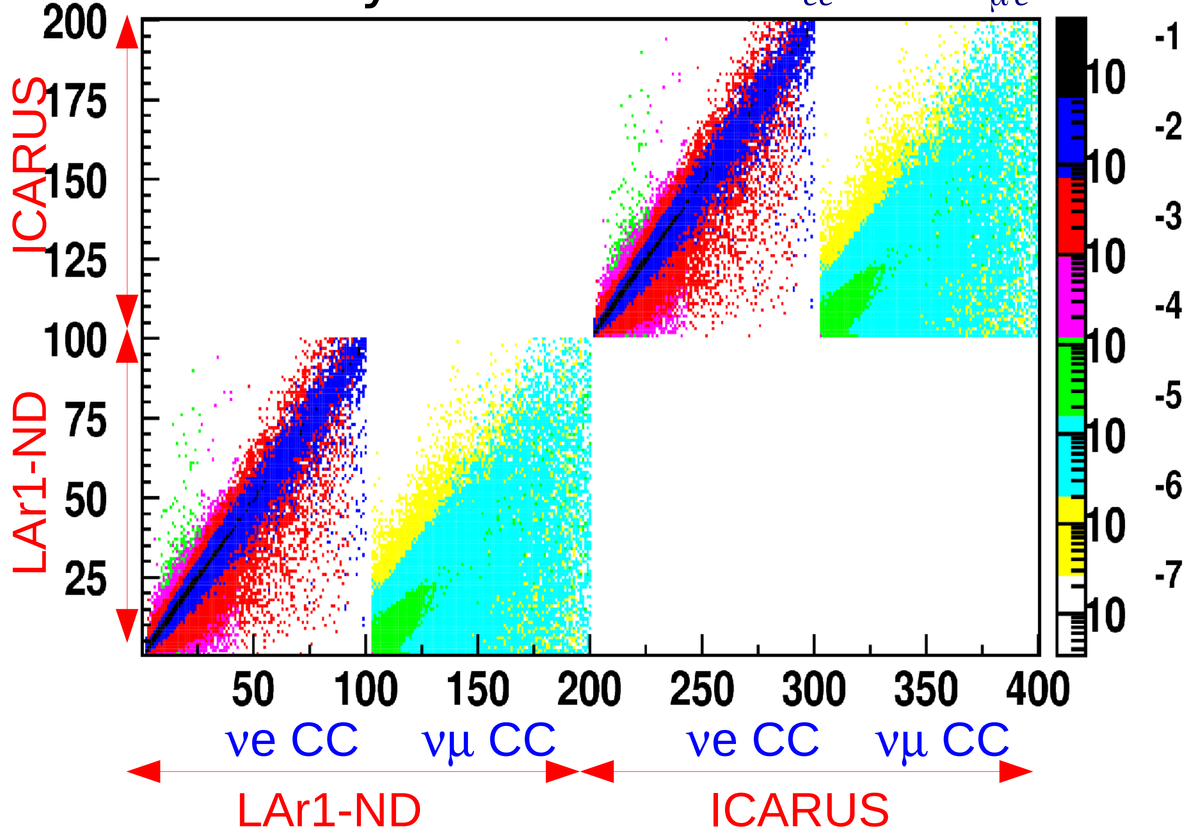
- The measurement of the neutrino spectra by the detectors corresponds to a linear transformation mapping the 4-fold vector νCC to the two-fold vector n_e with a 2x4 -fold matrix T:

$$n_e = T \; \nu CC$$

T is a proper combination of the already introduced S_{ee} and $B_{\mu e}$

T =

S_{ee}	$B_{\mu e}$		
		S_{ee}	$B_{\mu e}$



From true νCC to reconstructed electron spectra n_e (2)

- The linear dependence of n_e on νCC

$$n_e = T \ \nu CC$$

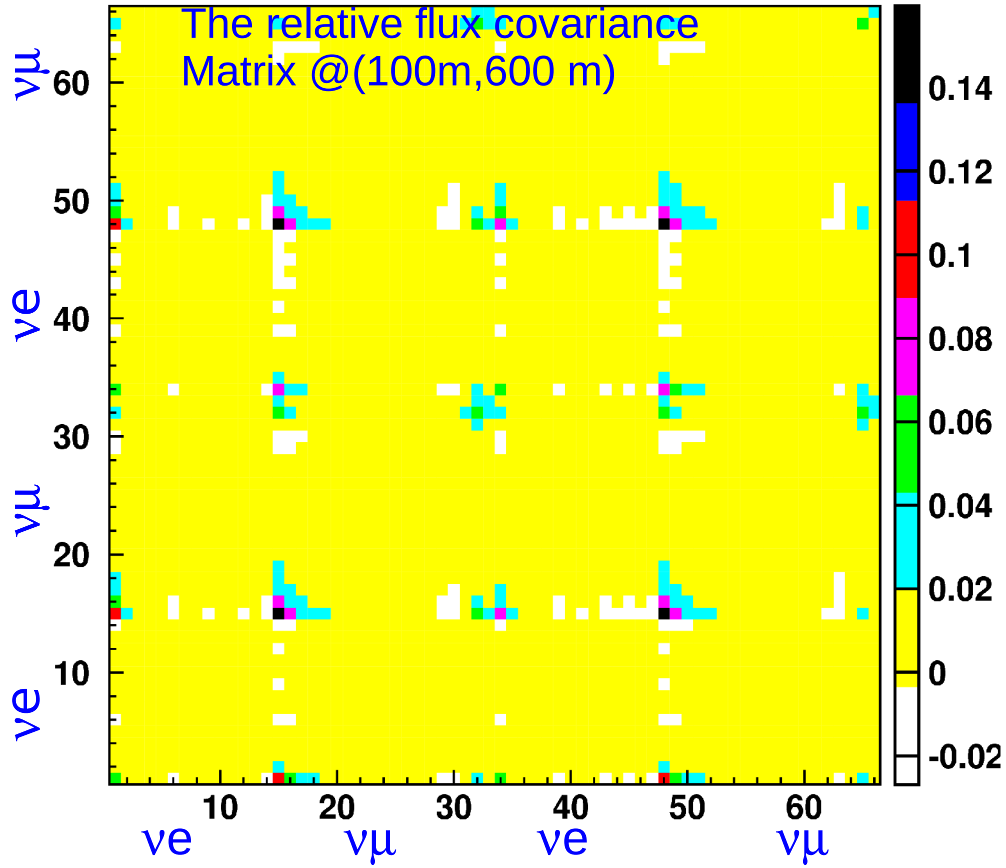
- Permits a straigthforward transformation from the νCC error matrix V(νCC) to the measurement error matrix $U(n_e)$

$$U(n_e) = T \ V(\nu CC) \ T^T$$

- In this scheme the inclusion of additional contributions to the error matrix is also quite natural and simple both for the terms affecting the νCC spectrum (like e.g. those generated by the neutrino cross section systematic error) and for those directly associated to the measured quantities (the most trivial example is the statistical fluctuations affecting n_e)

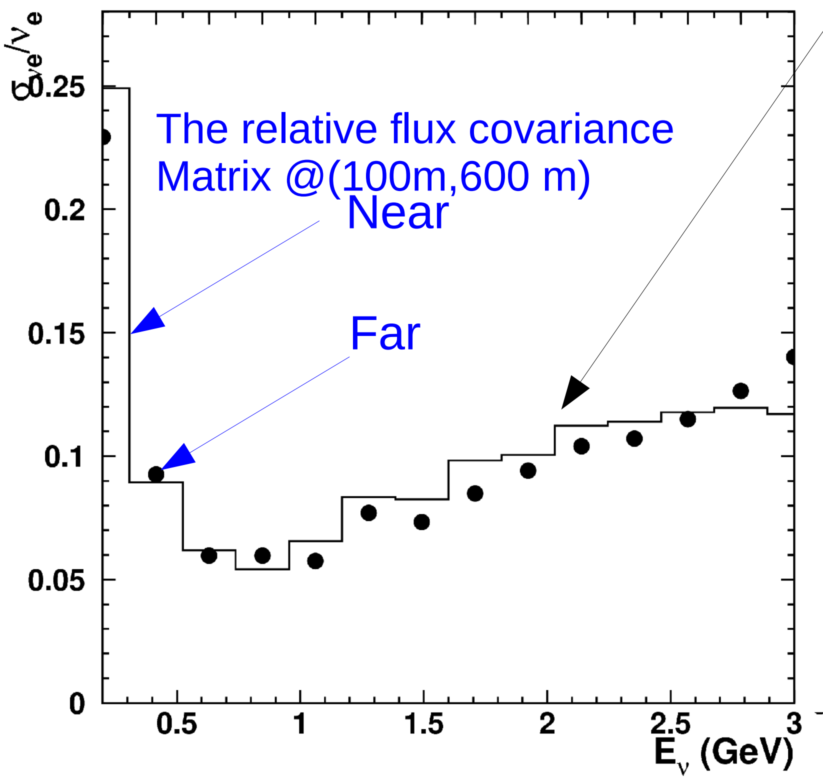
Flux systematic contribution to V(νCC) error matrix

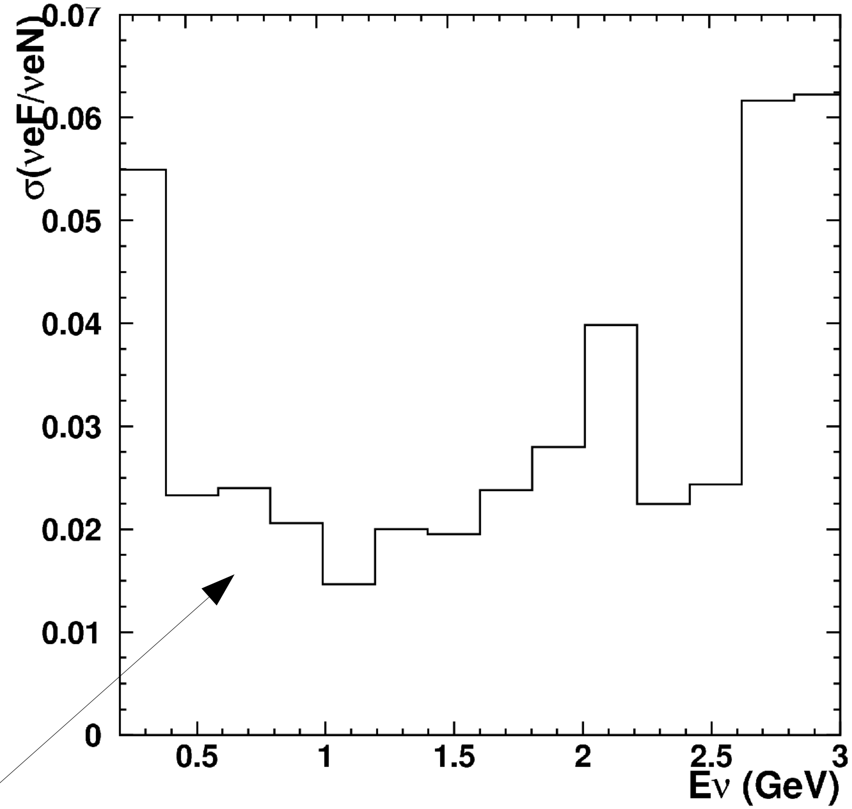
- In the V(νCC) error matrix is contained the BNB flux systematic error, provided by Corey (SBN Doc 47-v1) as a 4-fold error matrix correlating both νe and νμ flavors and the 100m and 600m sites.
- These matrixes are quite complex with plenty of information



Flux systematic (2)

- Typical uncertainty on the diagonal for νe is ≈6-7% (representative of the absolute error in predicting the flux at a detector





- flux errors cancel out to ≈2% in the comparison of Near and Far detector

Flux systematic (3)

- It is useful to look at the correlation between the integrated fluxes of the νe and $\nu\mu$ and at different location
- The absolute prediction for the integral flux is 6% ($\nu\mu$) 7% (νe) in each detector.
- Each flavor permits to predict the other one with similar (≈6%) precision.
- The prediction of the same flavor Far from Near is very precise: 4‰($\nu\mu$) 9‰ (νe)

		Near		Far	
		νe	$\nu\mu$	νe	$\nu\mu$
Near	νe	**7**	**6**	**0,9**	**6**
	$\nu\mu$	**6**	**6**	**6**	**0,4**
Far	νe	**0,9**	**6**	**7**	**6**
	$\nu\mu$	**6**	**0,4**	**6**	**6**

N.B. Numbers are in %

- The same conclusions are true also for the reconstructed electron neutrino events n_e

Sensitivity computation

- At the moment the oscillation excess is searched for exploiting the ratio $R_{eNF}(E_{REC})=n_{e\ Far}/n_{e\ Near}$. In this way we make use of the excellent precision predicted by the BNB MC for extrapolating the Far beam once it has been measured the Near site.
- $R_{eNF}(E_{REC})$ measures the *change* in the oscillation probability with the distance i.e. the *relative* variations of spectrum at Far Vs Near
- $R_{eNF}(E_{REC})$, a part from second order effects, is robust against any *common* Near/Far systematic uncertainty
- This approach is robust even against common spectral unmodeled distortions in the Near and Far sites which could generate a fake signal in the case of a shape only analysis
- the only residual systematic effects still affecting $R_{eNF}(E_{REC})$ are due to different behavior/response/experimental in the Near w.r.t. Far detector: all this kind of effects have to be carefully considered and kept under control

Example of computation

T600 (red) and T1200 (Green)

Still progressing

- Finalize the study of required efficiency/exposure to achieve the necessary sensitivity
- Parameterize the effect of different kind of systematics, common and relative in view of establishing their maximum acceptable level, to provide feed back on the requirements which have to be fulfilled by the experiment
- More robust estimate of the misidentification ν bck and bracketing its impact on the final sensitivity
- Addition of possible cosmic bck and study its possible impact on the experimental sensitivity
- Address the $\nu\mu$ disappearance
- ...