WP3: flux and cross section studies

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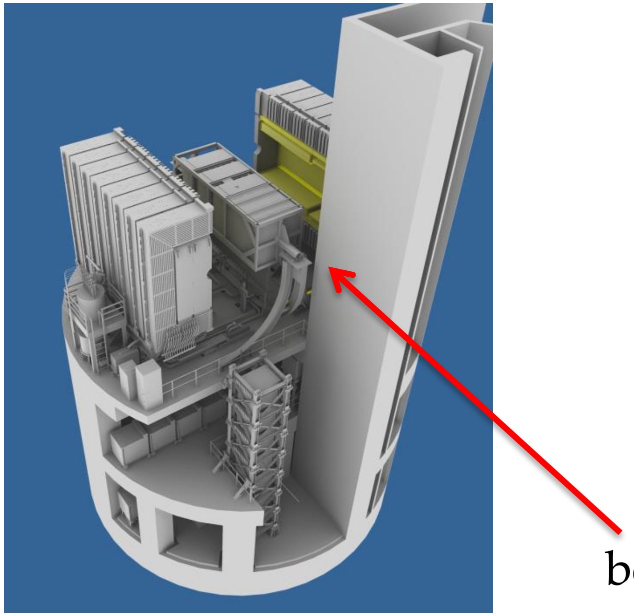
Outline

Some examples of ongoing work within WP3

- Study of neutrino-nuclei and search for Meson Exchange Current interactions
- Study of anti-neutrino interactions
- Neutrino interaction in the sand and rock surrounding the near detector



Near detector

- Measures the neutrino interactions near the beam production point
  - Cross sections measurements
  - Tuning the simulation (flux and cross section parameters) to the data

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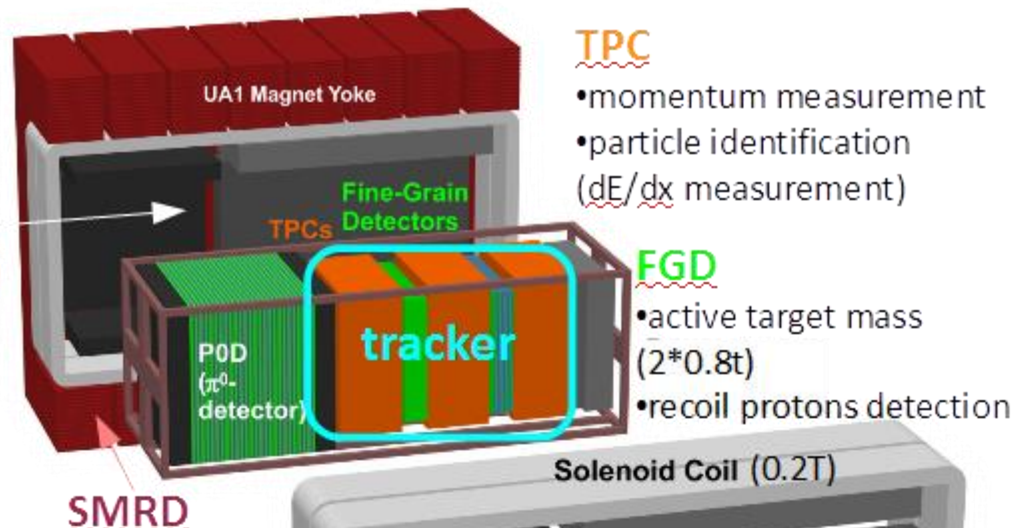
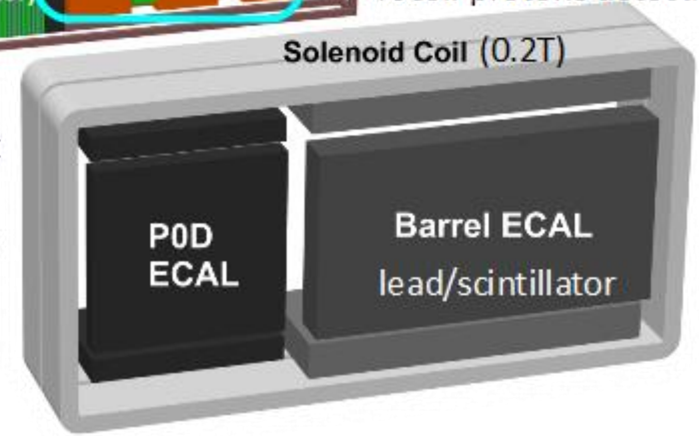
    constrained systematic uncertainties in the oscillation analysis

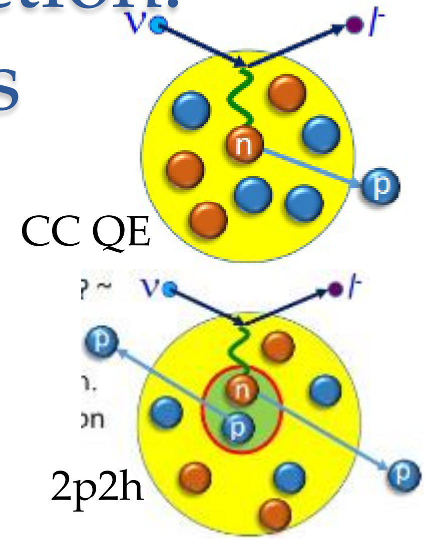




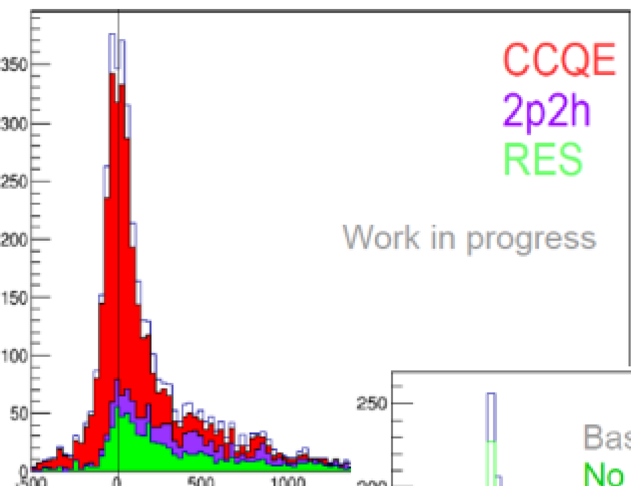
Current systematic uncertainties

	ν_μ sample $1R_\mu$ FHC	ν_e sample $1R_e$ FHC	$\bar{\nu}_\mu$ sample $1R_\mu$ RHC	$\bar{\nu}_e$ sample $1R_e$ RHC
ν flux w/o ND280	7,6%	8,9%	7,1%	8,0%
ν flux with ND280	3,6%	3,6%	3,8%	3,8%
ν cross-section w/o ND280	7,7%	7,2%	9,3%	10,1%
ν cross-section with ND280	4,1%	5,1%	4,2%	5,5%
ν flux+cross-section	2,9%	4,2%	3,4%	4,6%
Final or secondary hadron int.	1,5%	2,5%	2,1%	2,5%
Super-K detector	3,9%	2,4%	3,3%	3,1%
Total w/o ND280	12,0%	11,9%	12,5%	13,7%
Total with ND280	**5,0%**	**5,4%**	**5,2%**	**6,2%**

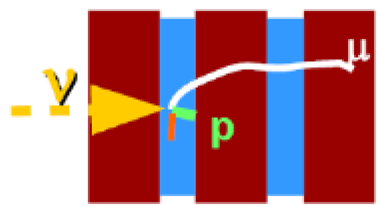
Towards measurement of 2p-2h interaction: search for low-momentum protons

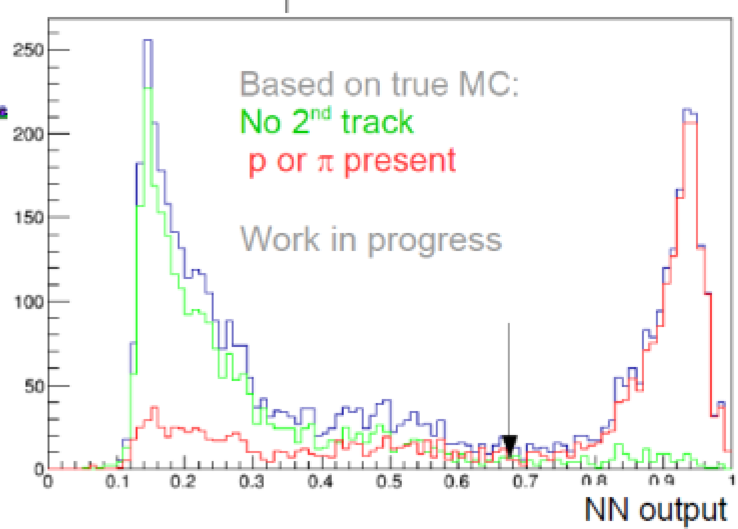


- Interactions on correlated pair of nucleons (2p-2h) are characterized by two or more protons leaving nucleus after interaction. If 2nd proton is not reconstructed then 2p-2h has the same signature as CCQE interaction.
- Finding low-momentum protons which are not reconstructed as tracks by standard reconstruction algorithms will help to **tag 2p-2h interactions**.



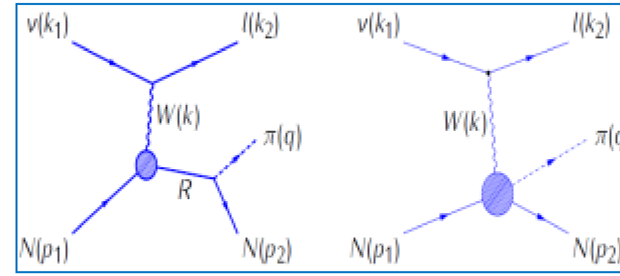
Vertex Activity (energy deposited near the interaction Vertex)



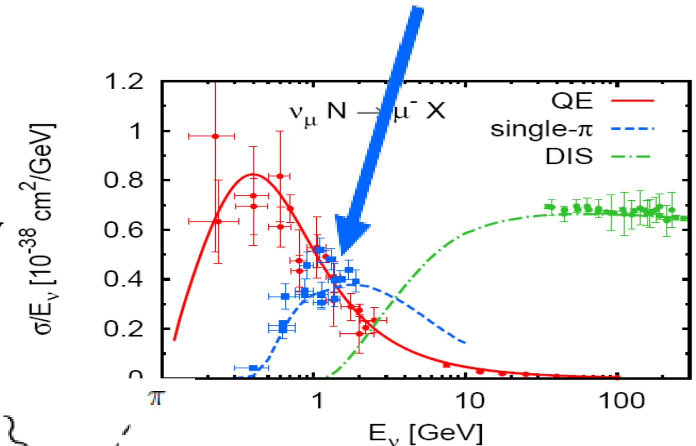


- For selected events with reconstructed 2 tracks (μ and *p)* an additional short track has been searched using set of vertex activity variables given to a **neural network**
- For neural network output >0.7 the fraction of events with *p* or π is as large as 90% giving clear separation from events with no additional particles.
- It is planned to design neural network which will further discriminate between short *p* and π tracks.

Single pion production in Neutrino-Nucleon Reaction

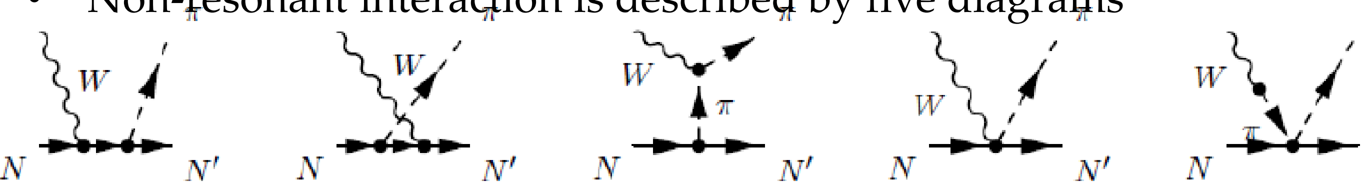


- Single pion can be produced mainly by decay of nucleon resonances, or directly by non-resonant interaction.
- **Rein-Sehgal** model describes resonant interaction based on helicity amplitudes, and it is a default model in **NEUT** and **GENIE** for single pion production.



The new model consists of resonant and non-resonant interactions and their interference effects based on a paper by D.Rein(1987)

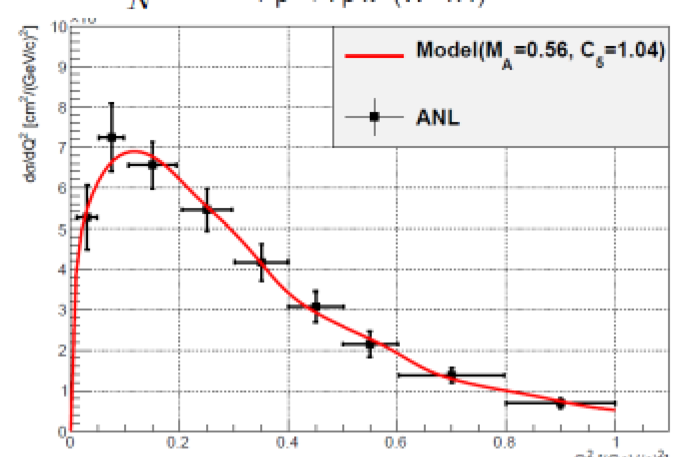
- Lepton mass effects are included.
- Non-resonant interaction is described by five diagrams



They are calculated in the helicity basis too.

- The model has good agreement with bubble chamber data which predicts less systematic uncertainties for T2K measurements after implementation in T2K neutrino generator (NEUT)

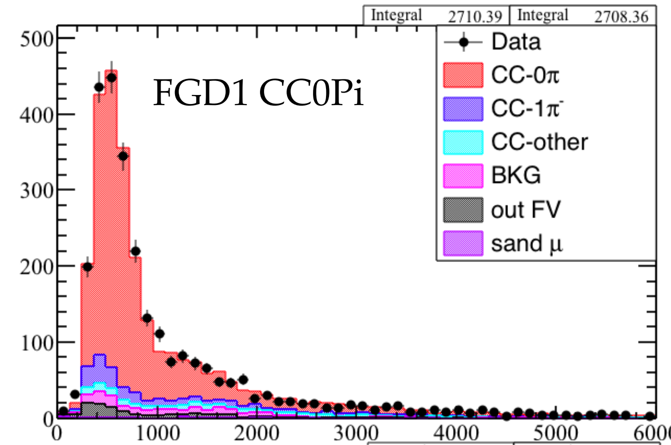
ν p → l p π⁺ (W<1.4)

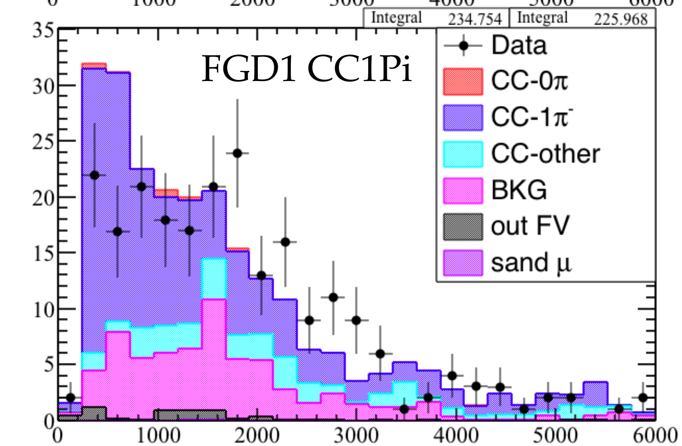


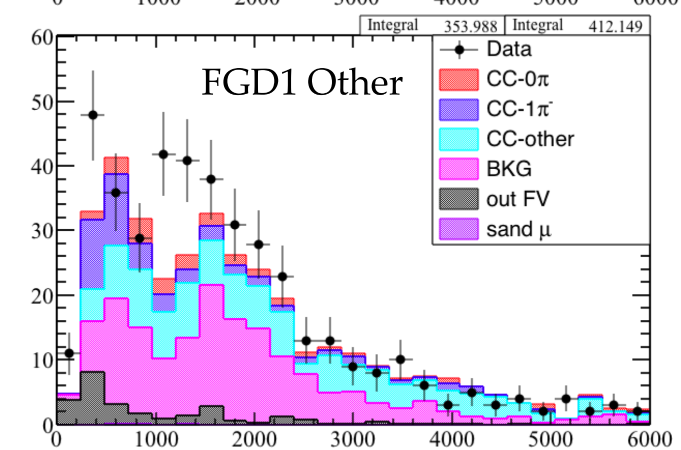
Antineutrino pion selection in ND280

- Previously, antineutrino sample was split into two categories, now we want get a grip on different interaction channels
- The interactions are divided into three classes depending on the pion multiplicity. These classes are dominated by CCQE, RES and DIS interactions, respectively and are later used in the fit to minimize systematic errors
- The basic selection is finalized for FGD1 and FGD2, systematics calculation is under way
- Next step is to include ECal information to improve **pion tagging** and thus increase the purity
- In future, **cross-section measurement** is planned for single pion events

Purities	CC0pi sample	CC1pi sample	CCOthers sample
true CC0pi	**74%**	1%	6%
true CC1pi	9%	**52%**	12%
true CCOthers	6%	14%	**31%**
background	11%	33%	50%

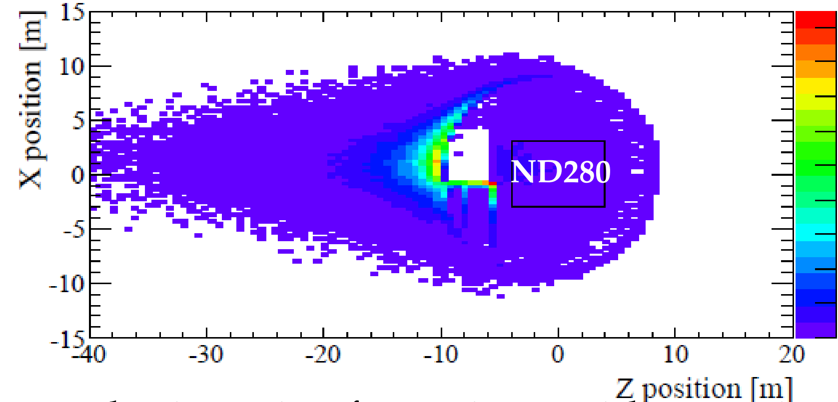






Neutrino interactions outside of near detector

- Neutrinos travelling through sand can interact there and the products of the interaction may enter the detector
  - A dedicated simulation shows the muons reach ND280 even from 40m

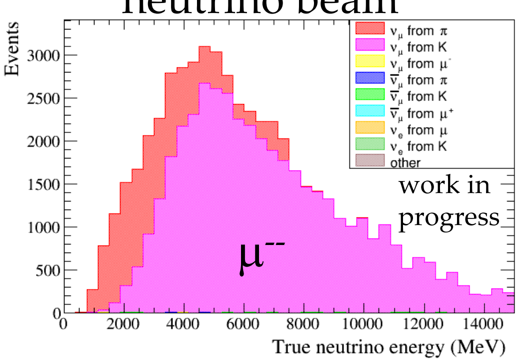


production points for ntering particles, top view

- Tuning of the simulation to improve data-MC agreement was performed
  - Studies on sand density and corrections
  - Discrepancy for antineutrinos reduced from 30% to 10%
- The sand particles can be background but also a useful tool for testing and calibration purposes. Can sand muons provide more information on the ν flux?
  - they probe high energy tail of the beam
  - their parent neutrinos come mostly from kaon decays
  - they are much more numerous than ND280 samples

studies are ongoing

neutrino beam



true energy of parent neutrino (color denotes origin of neutrino)

antyneutrino beam