UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Panel 4: Ancillary activities

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Ancillary?

- Any support activity to the main measurements.
- Main task is to reduce systematic errors.
- Broad spectra:
  - theory (neutrino-Nucleus interactions,…)
  - experiments providing key measurements.
  - improvement on detector simulation (hadron-nucleus interactions).
  - improvement on neutrino flux predictions (LBL & atmospheric).
  - Development of new experimental techniques related to the above points.

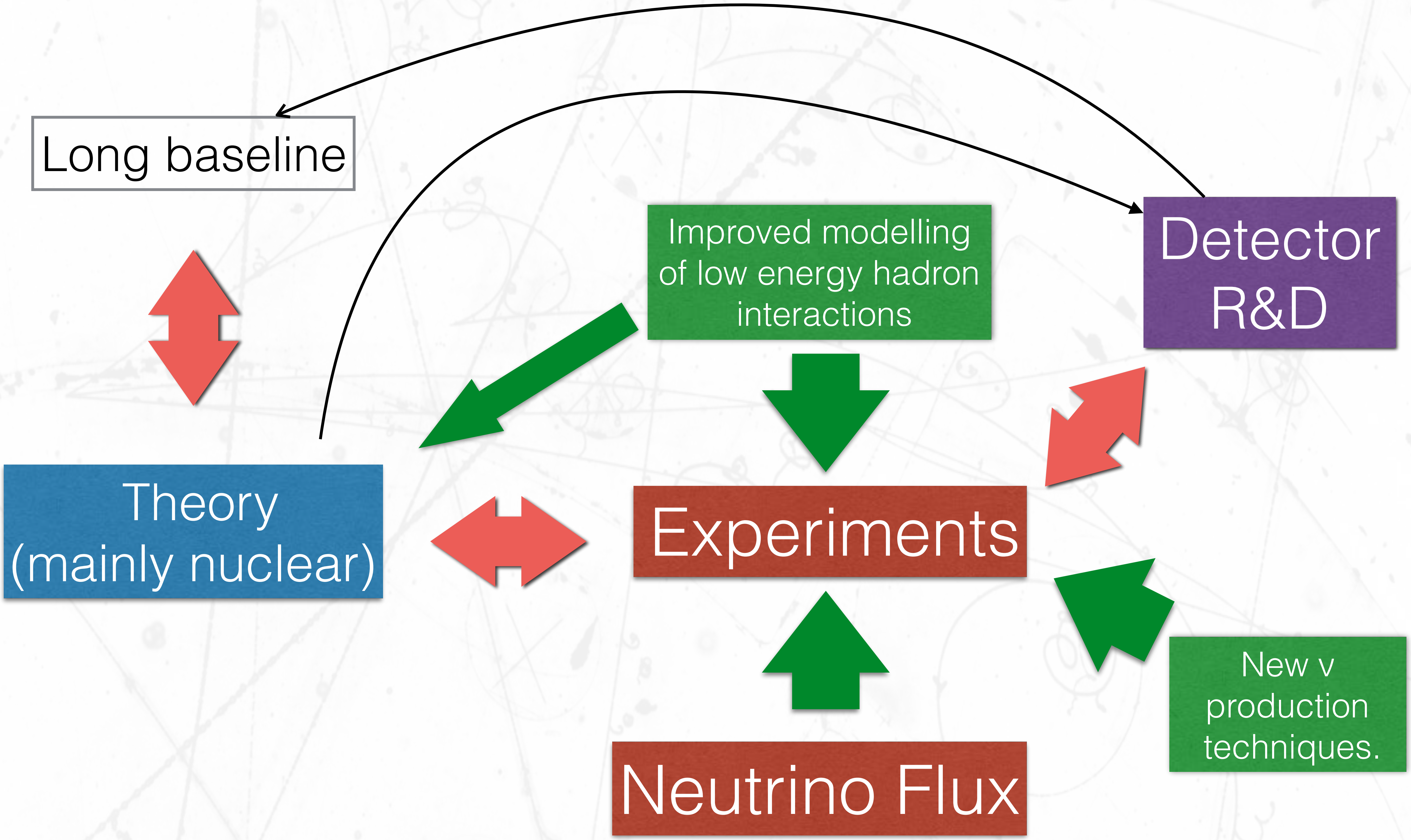
Long base line

- LBL neutrino energy spectrum is not monochromatic:
  - we need to determine event by event the energy of the neutrino.
- This estimation is not perfect and the cross-section does not cancels out in the ratio.

$$\frac{N^{far}_{events}(E_\nu)}{N_{events}(E_\nu)} = \frac{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)P_{osc}(E'_\nu)dE'_\nu}{\int \sigma(E'_\nu)\Phi(E'_\nu)P(E_\nu|E'_\nu)dE'_\nu}$$

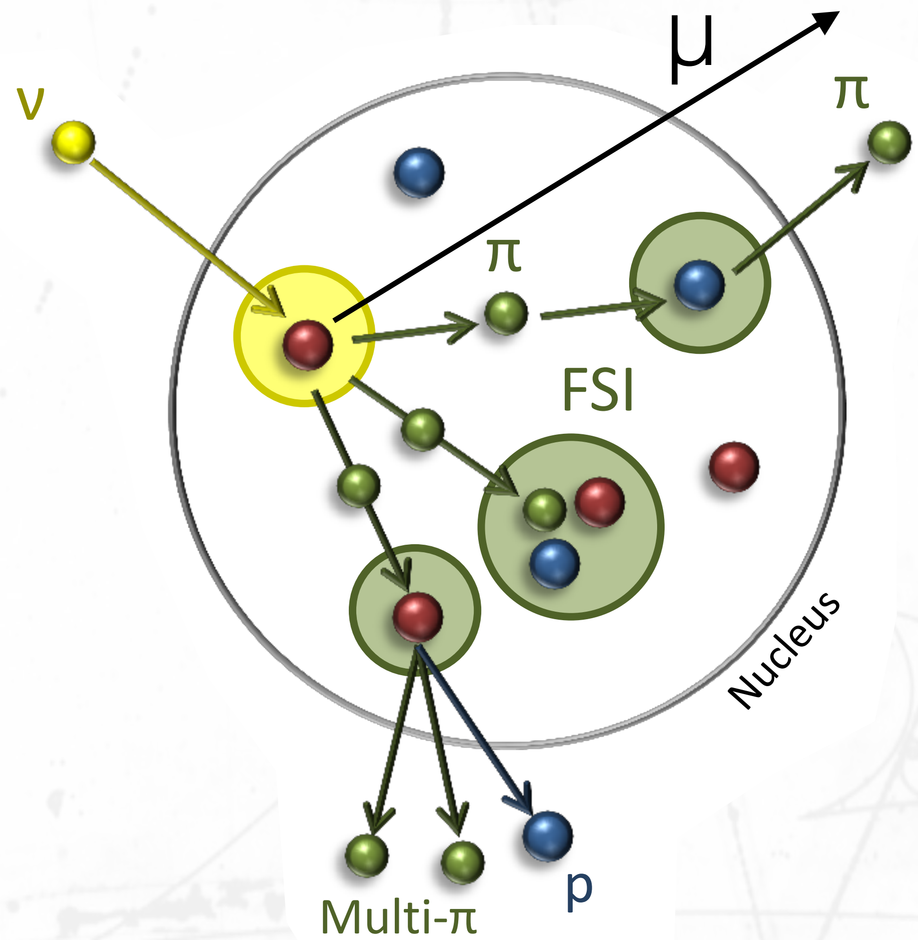
- The neutrino oscillations introduce differences in the flux spectrum and the ratio does not cancel the cross-sections.

The landscape around ν exp.



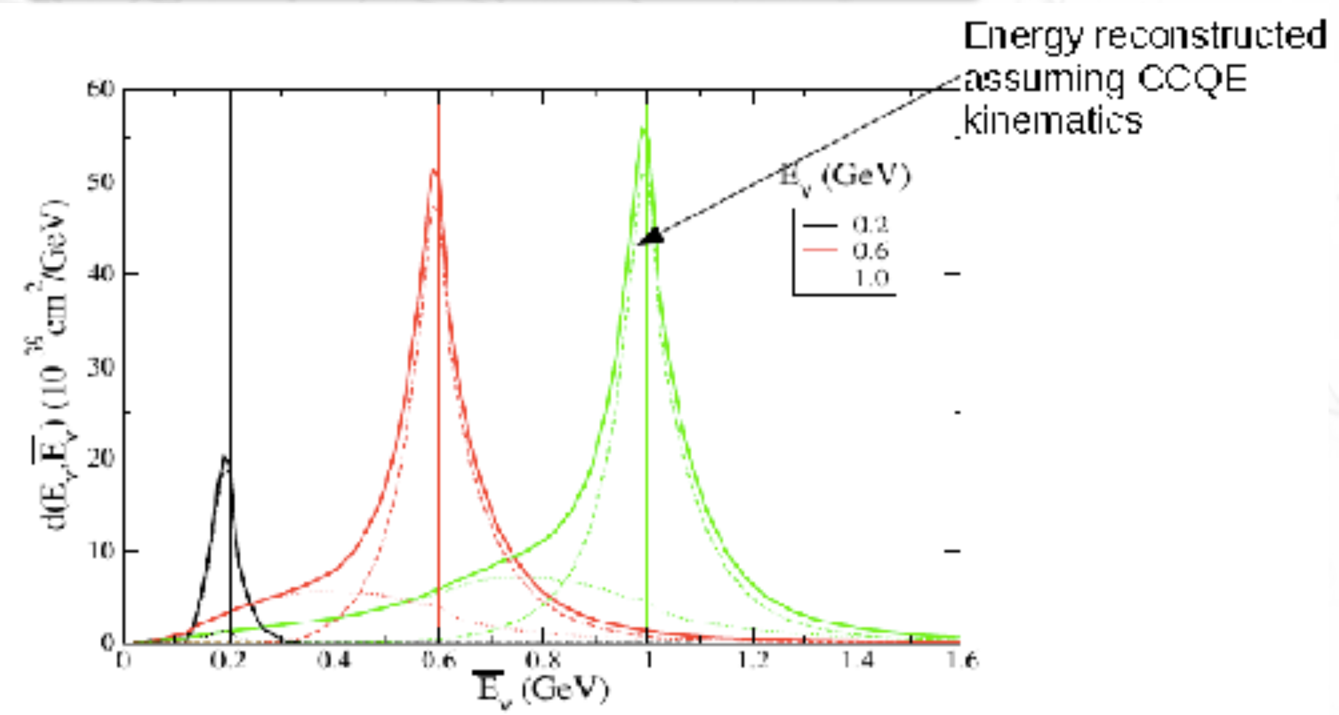
Theory

Huge progress during the last decade



- Initial nuclei state description.
- ν-nucleon cross-sections:
    - quasi elastic, pion production, SIS, DIS, …
- Final state re-interactions.
- Particles and kinematics in final state outside the nucleus.
- Threshold effects related to charge lepton mass.
- …

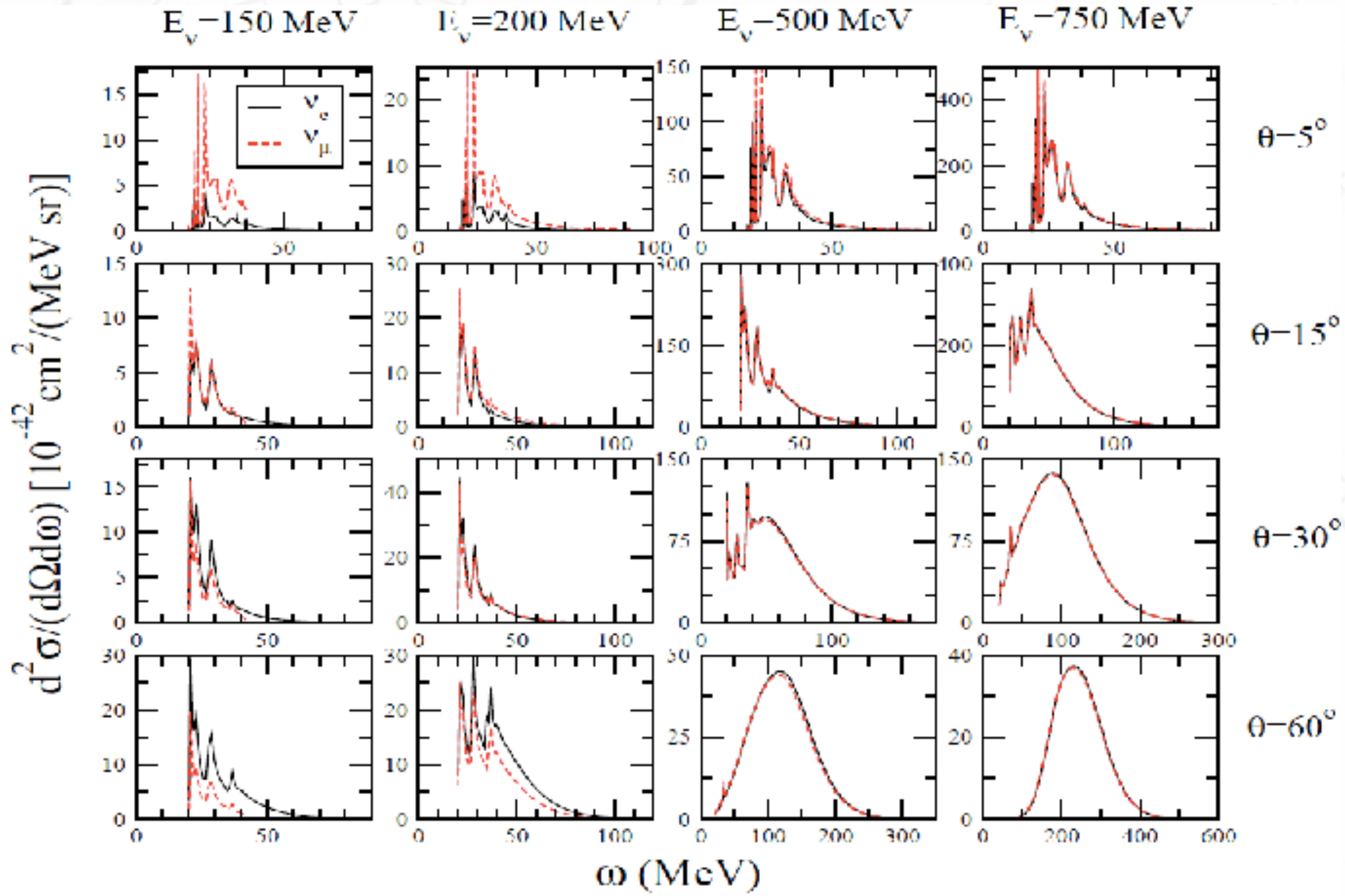
i.e. energy reconstruction in T2K



- Different problems to be faced by Low energy (T2(H)K), medium energy (Dune) & high energy(atmospheric).
- eA community not very advanced in exclusive interaction description needed by neutrinos.
- Background determinations (NCπ^0 & NCπ^{+-} production).

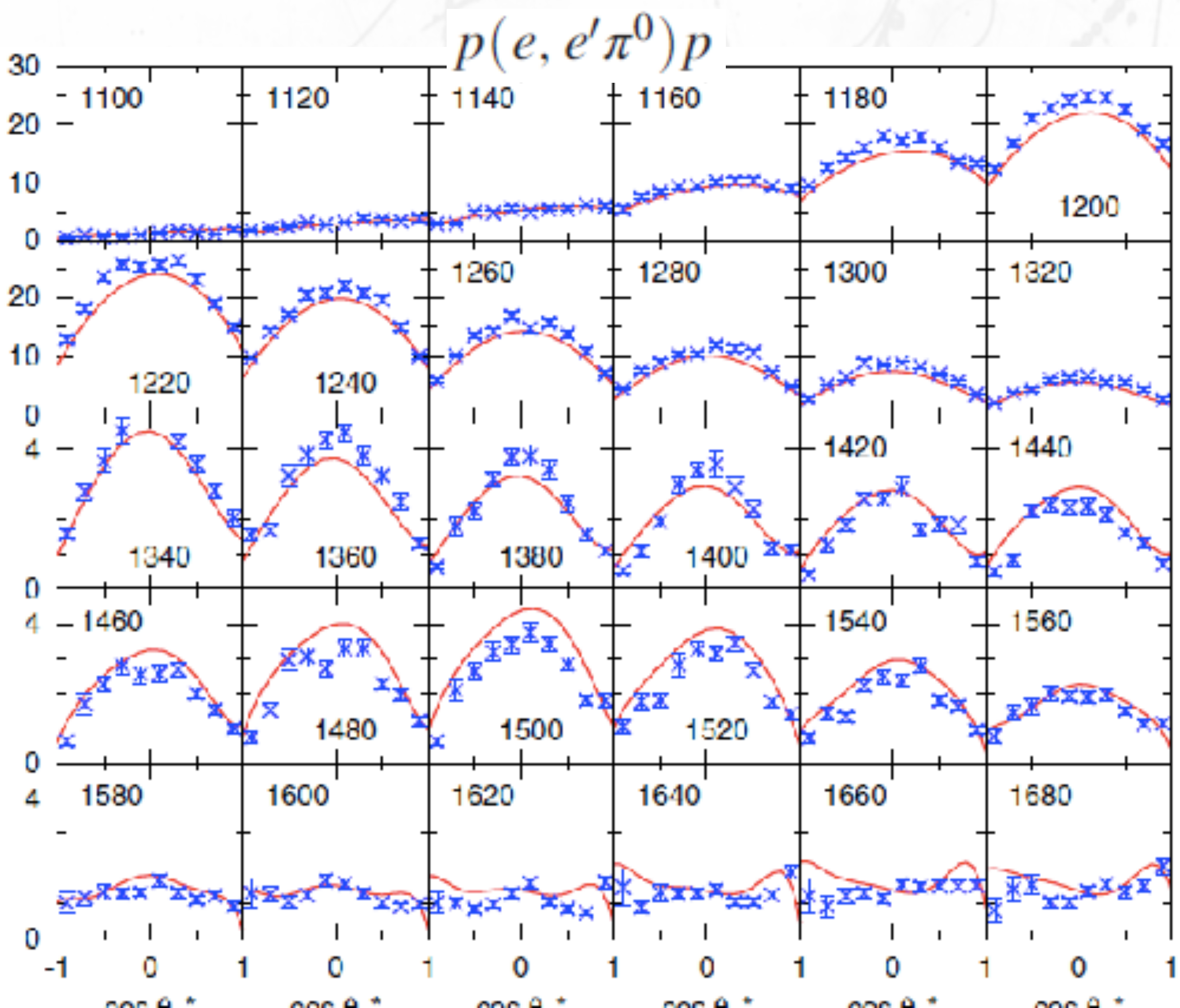
$\sigma_{\nu e}/\sigma_{\nu\mu}$?

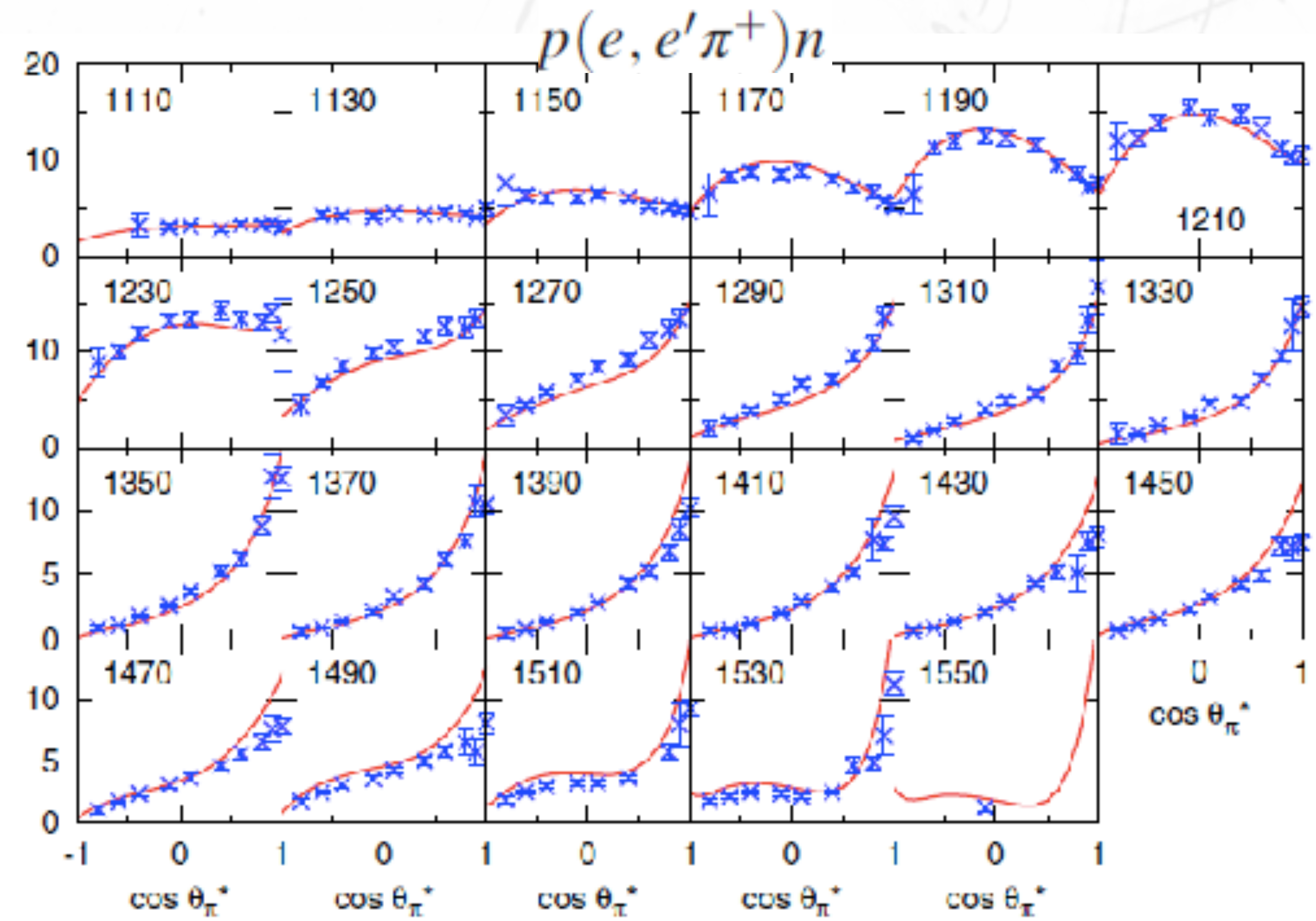
- Fundamental quantity for running and future oscillation (bot only LBL) experiments.
- Estimations might be more complex than simple phase-space.
    - Bremsstrahlung corrections.
    - nuclear effects.



Doing νA cross-section without ν's: (e,e')A & γA

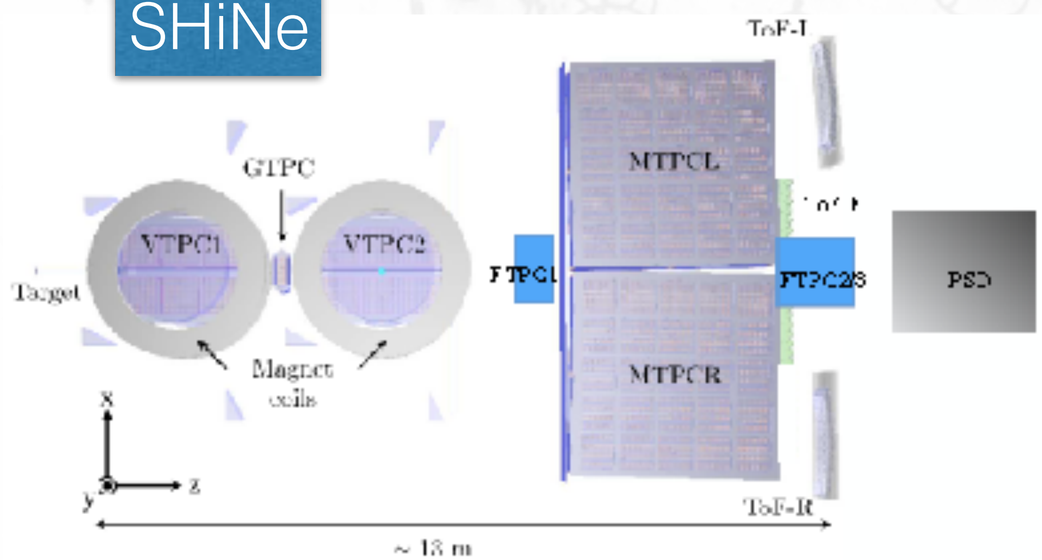
- There is a lot of data outside.
    - Models need to comply with them.
    - It might be an interesting place to derive models beyond limited neutrino data.



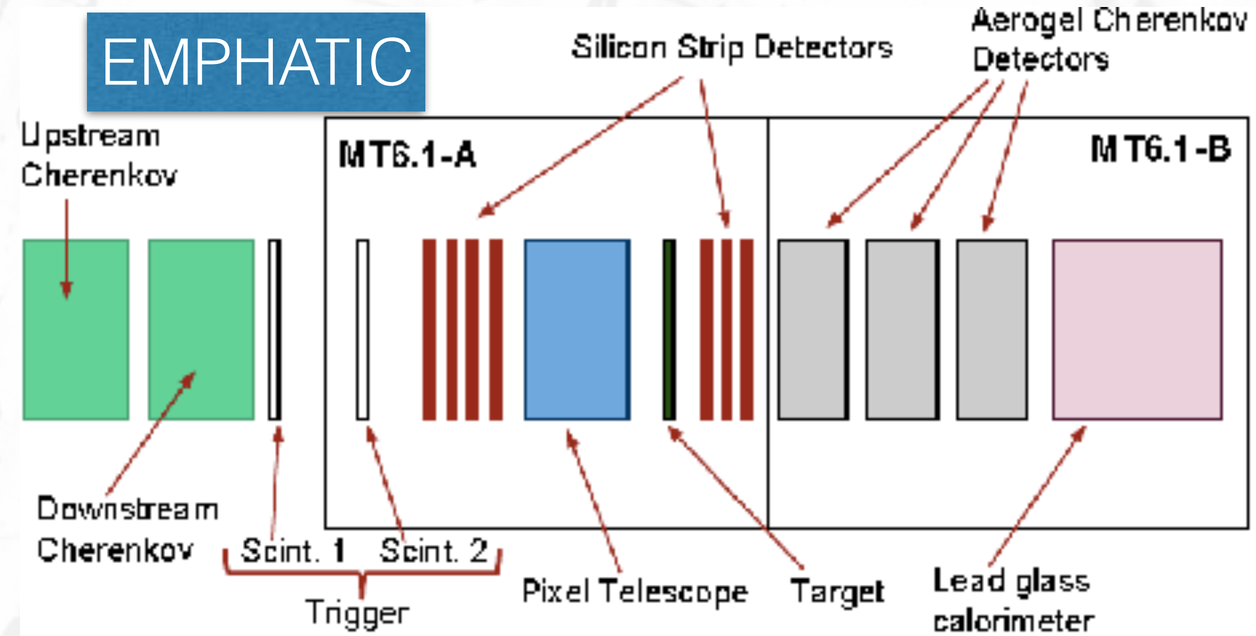


ν Flux

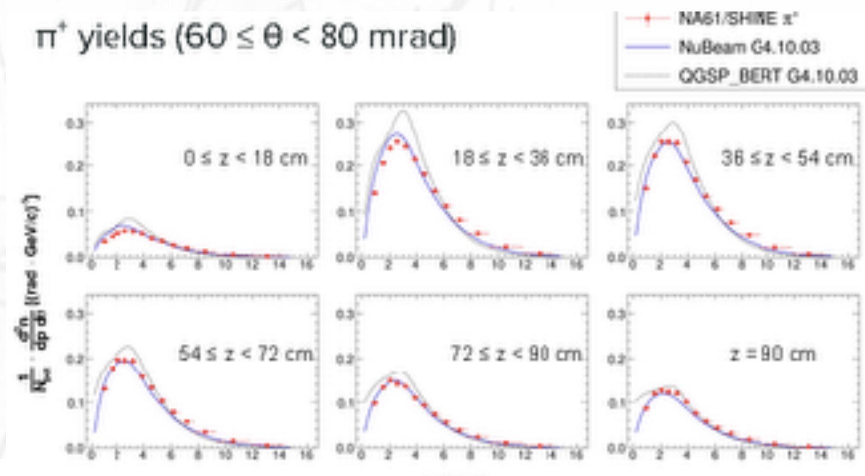
SHiNe



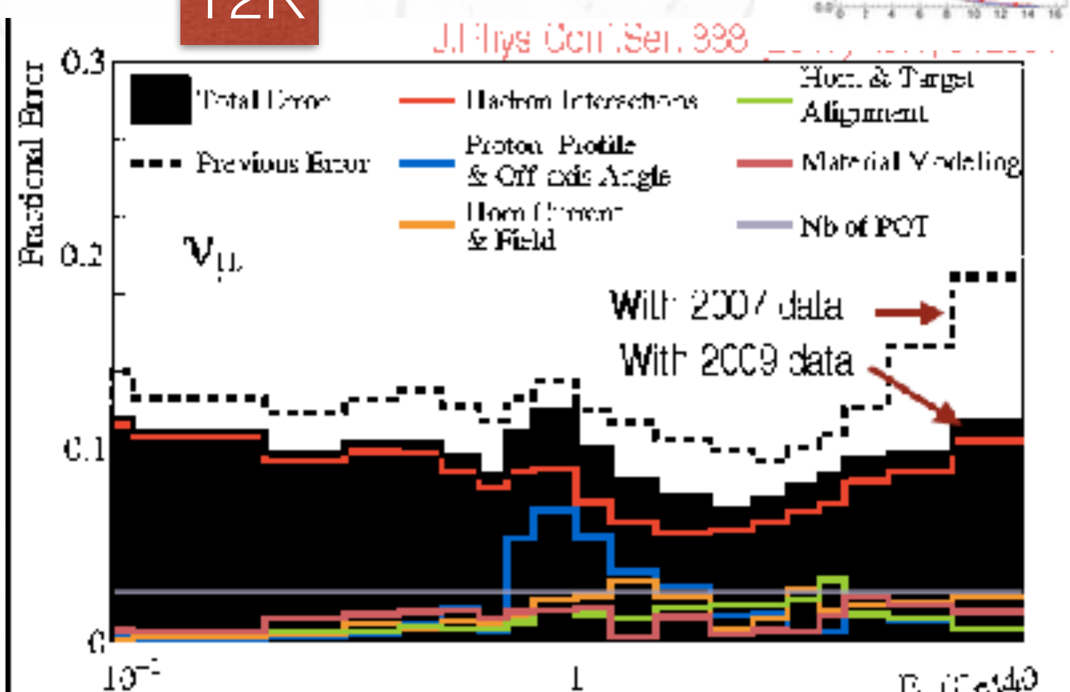
EMPHATIC



$$\frac{d^2\sigma_{pA}}{dp_{\pi,K,\ldots}\, d\theta_{\pi,K,\ldots}}$$

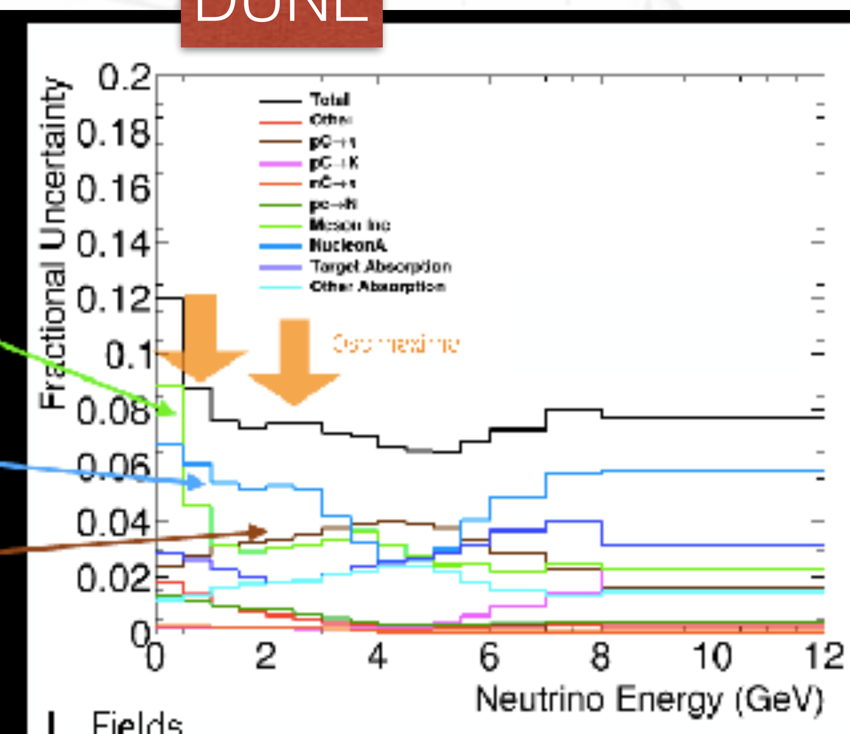


T2K



DUNE

- Dominated by
  - Pion and Kaon re-interactions
  - Nucleon interactions not covered by data
  - Errors on existing pC data



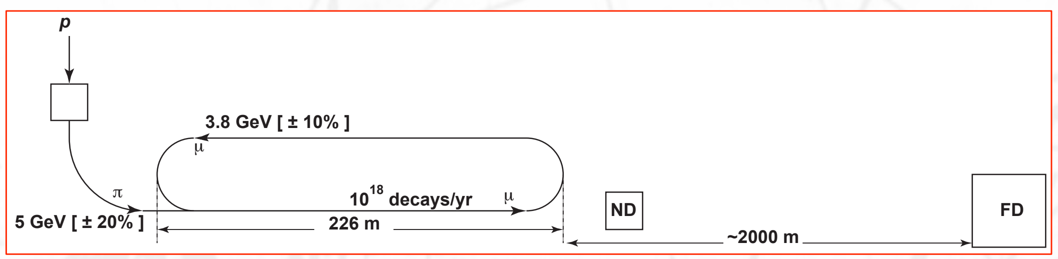
L. Fields

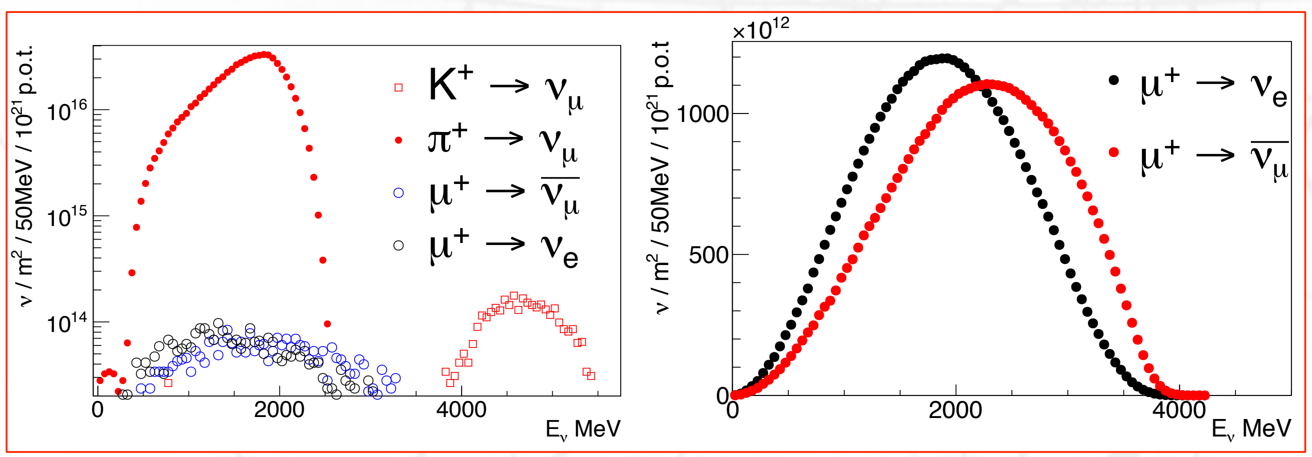
New experimental techniques

Direct control of neutrino flux & enhance ν_e flux

NUSTORM

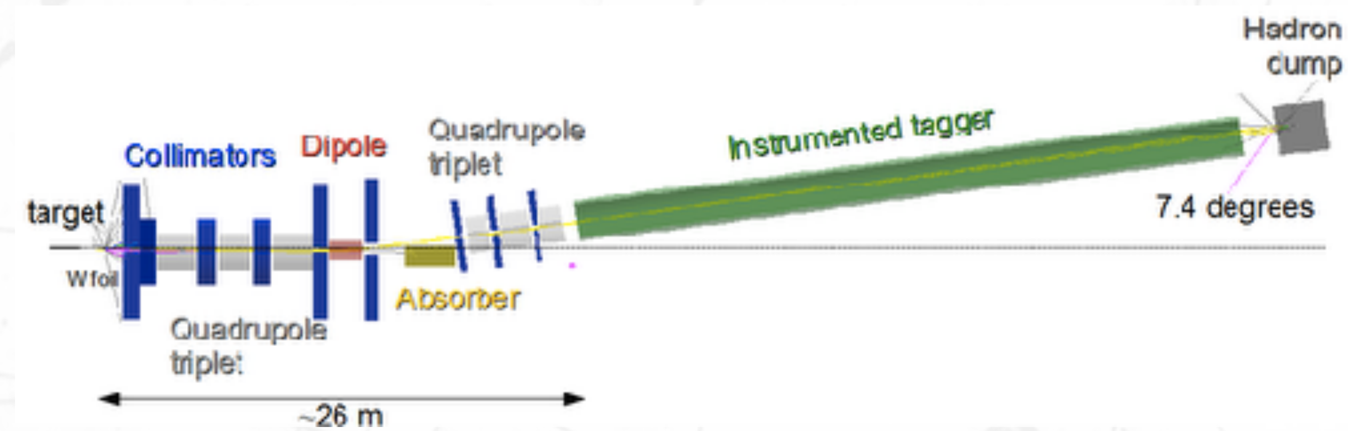
Neutrinos from stored muons



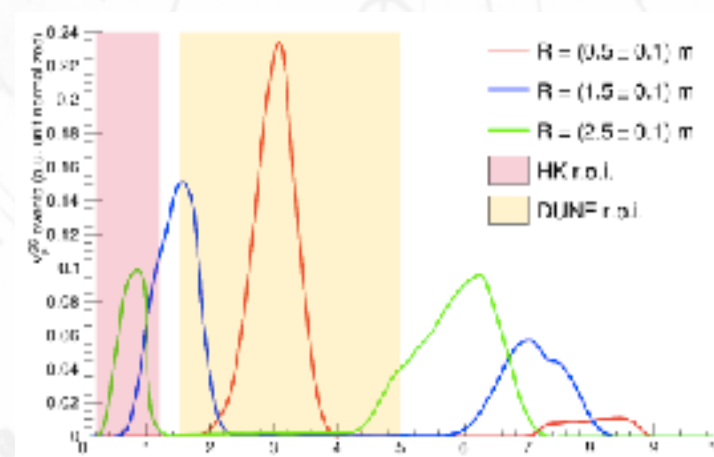


+ Perfectly known flux
+ 50% (ν_μ) 50% (ν_e)

ENUBET

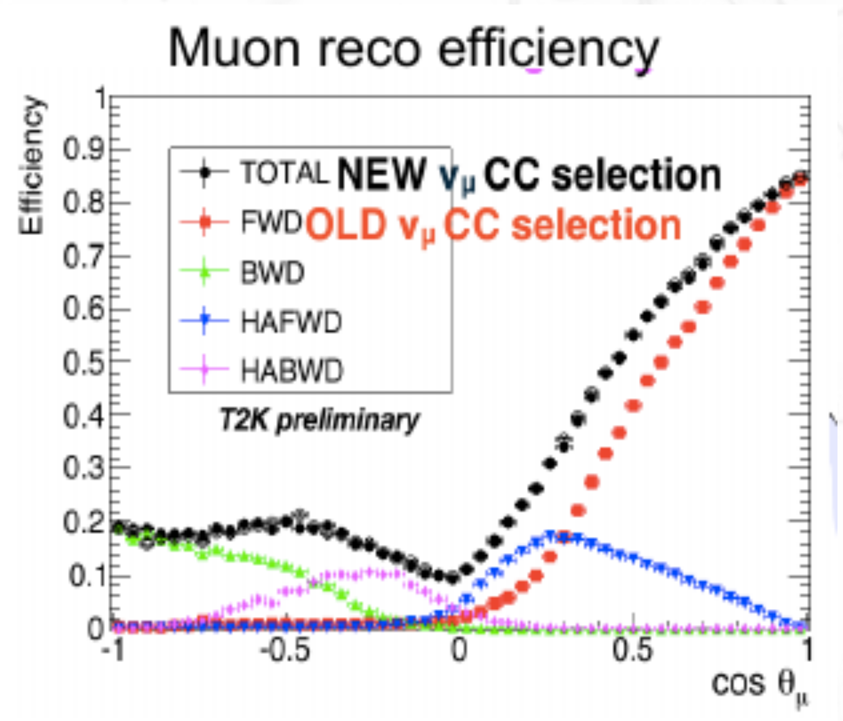


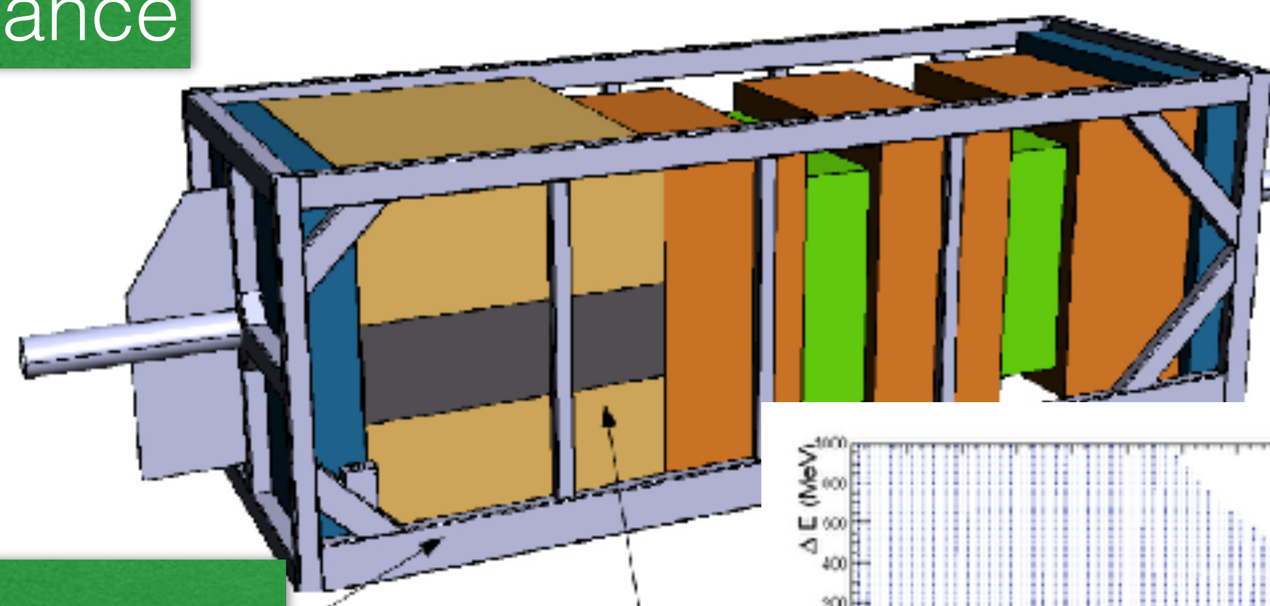
- ✓ **a direct measurement of the fluxes**
- ✓ a narrow band beam: **energy known a priori** from beam width
- ✓ a beam covering the region of interest **from sub- to multi-GeV**

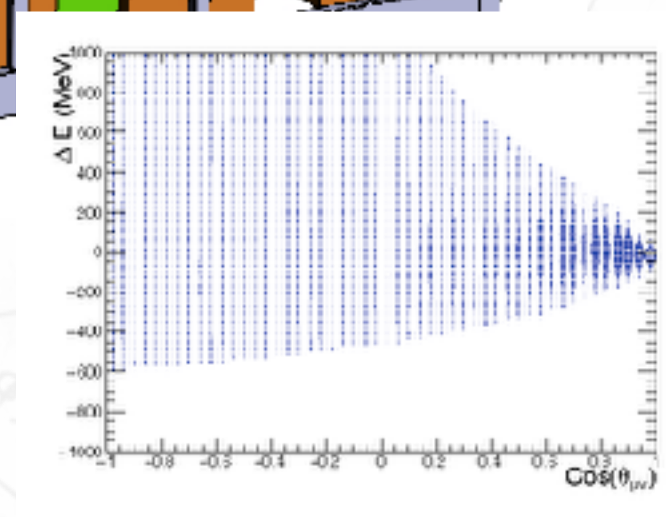


New detector technology

4π acceptance

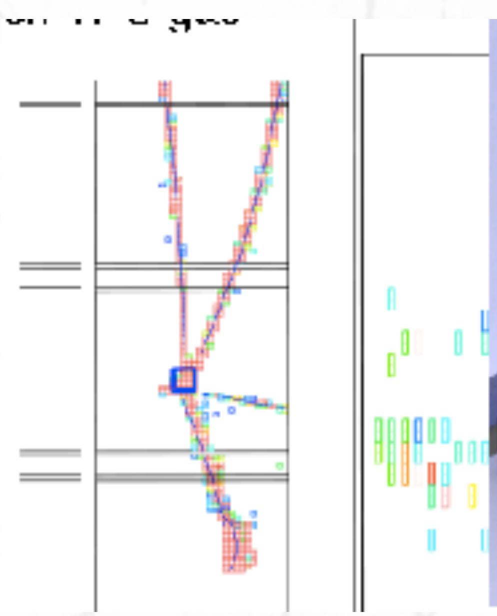


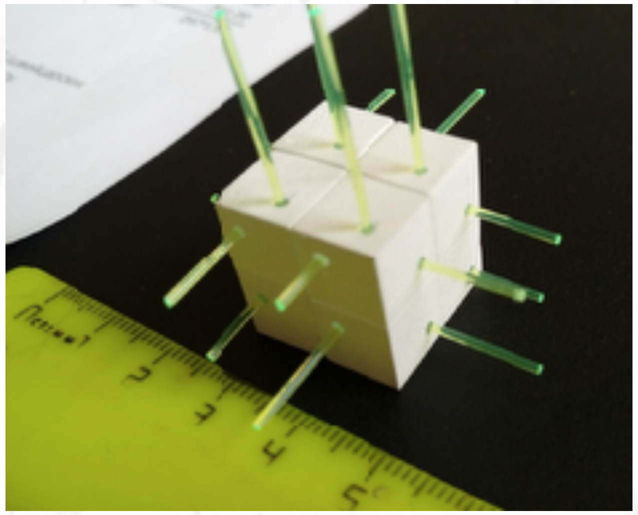


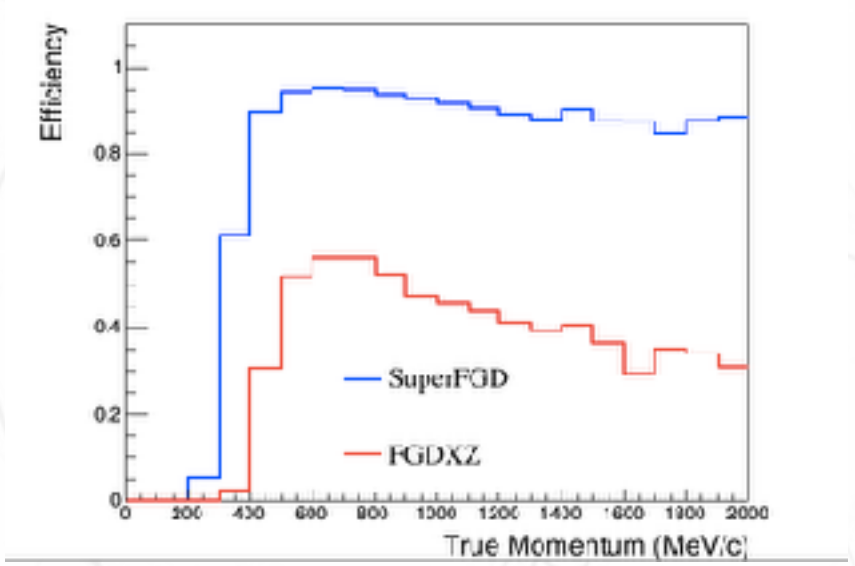


or
same far/near acceptance

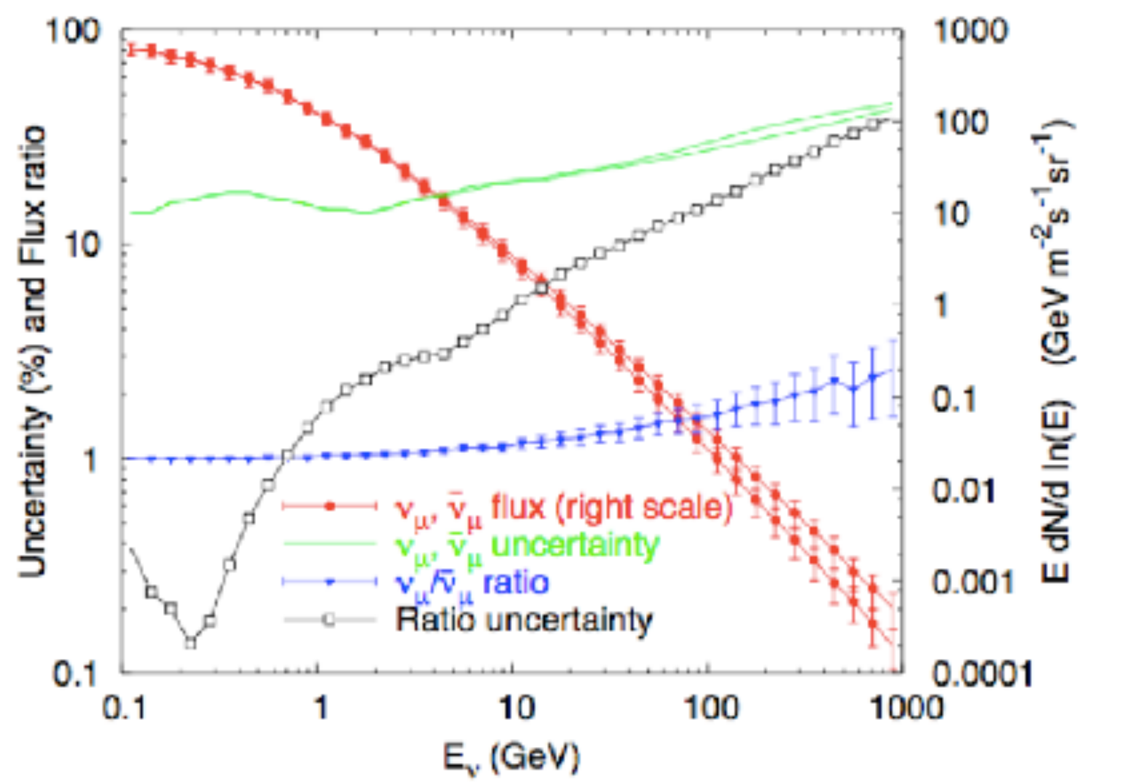
Low momentum threshold





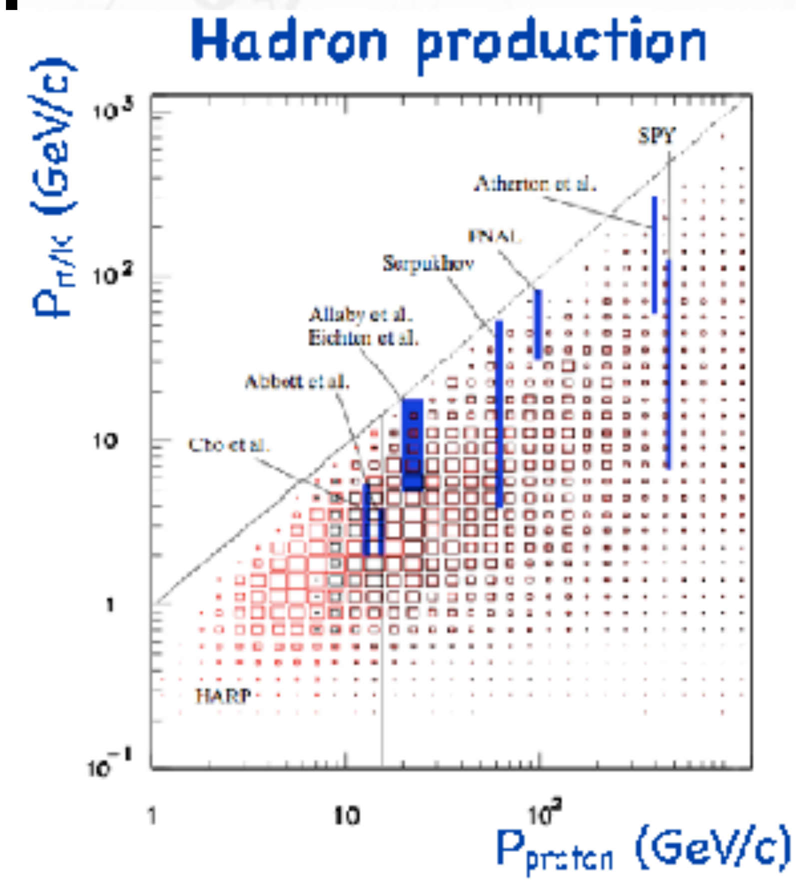


Beyond LBL: atmospherics



- Atm. ν flux normalization error is ~12% (SK assumes 25% error with 21% discrepancy)
- Uncertainty in ratio is small

FLUX



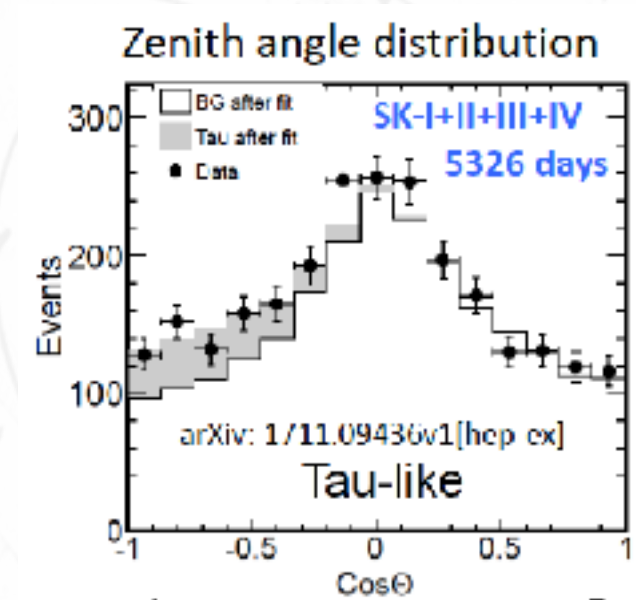
E_i (GeV)	Pions				Kaons		
<8	10%		30%		40%		
8–15	30%	10%		30%	40%		
15–30	20	10	5%	10%	30	20	10%
30–500	30	15%			40	30%	
>500	30	15%+Energy dep.			40	30%+Energy dep.	

x_{LAB}: 0 0.5 1 (Pions); 0 0.5 1 (Kaons)

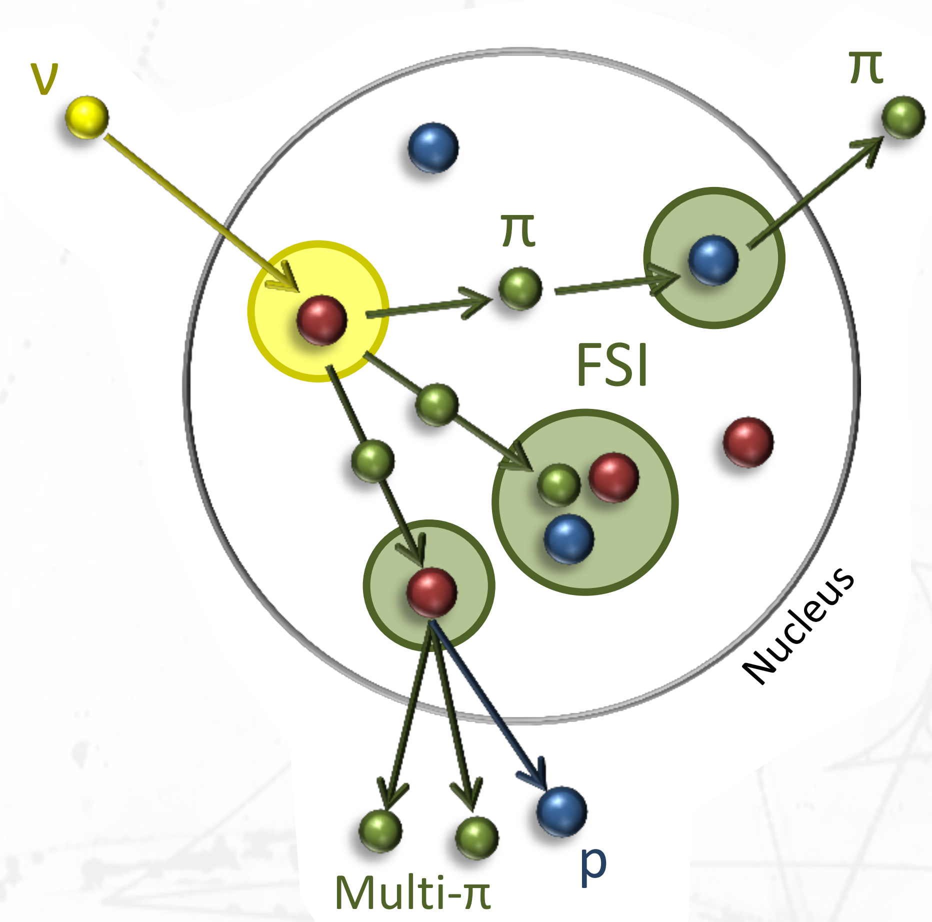
x-section

- ν_e/ν_μ
- anti-neutrino/neutrino

& ν_τ's @ threshold



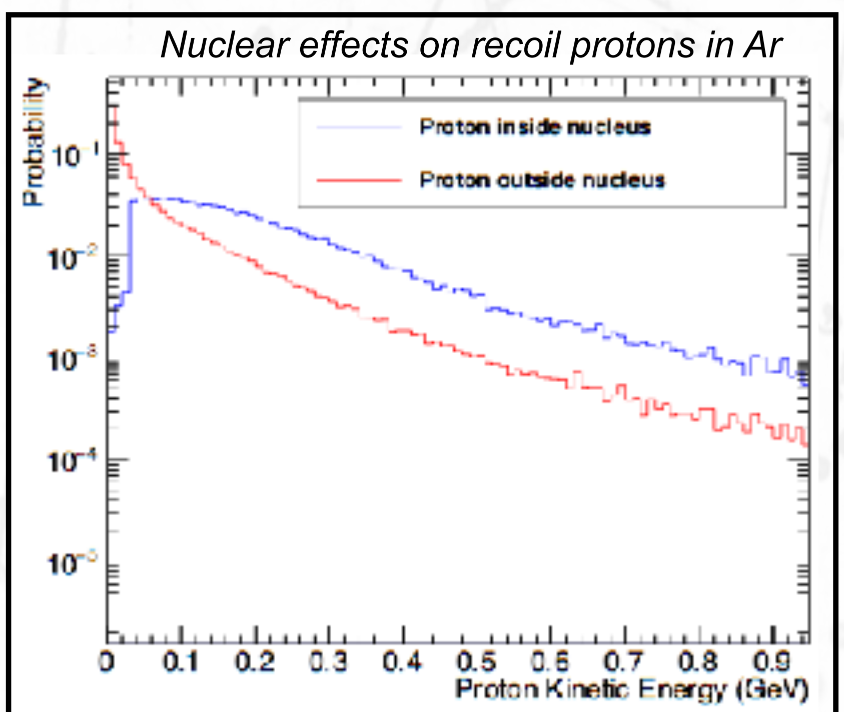
Hadron interactions



- Neutrino event reconstruction relies on observing final state particles
  - Significantly affected by hadronic scattering within nuclei
- **In particular, very few measurements of proton scattering exist!**
- New measurements essential for constraining crucial part of interaction models

+ Interactions in detector material.

protons lose large fraction of energy in hadronic scattering within Ar nucleus



Almost no data on Ar above 50 MeV!