

2x2 demonstrator FNAL location study

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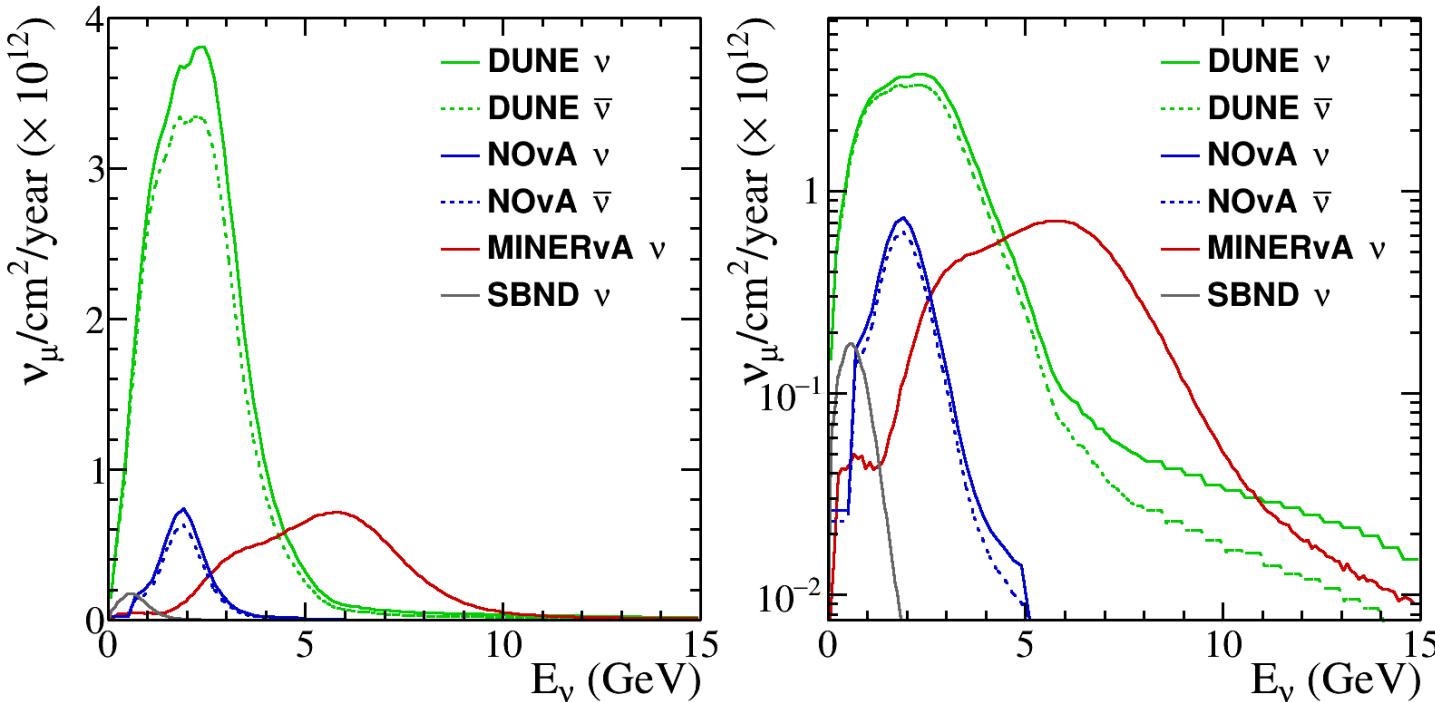
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Task and aims

- ▶ Could the 2x2 have interesting physics output if put in an FNAL beamline?
- ▶ Consider three different locations in neutrino and antineutrino mode (where available):
 - ▶ NuMI M.E. off-axis (NOvA flux)
 - ▶ NuMI M.E. on-axis (MINERvA flux)
 - ▶ BNB flux (SciBooNE/SBND hall)
 - ▶ *DUNE flux for reference (three-horn optimized)*
- ▶ **Note:** I do not consider putting the 2x2 in a charged particle beam, *but that could be more useful* for reconstruction tests etc
- ▶ For each configuration, generate 2.5M GENIE v2.12.8 events (“ValenciaQEbergerSehgalCOHRES” configuration)
- ▶ Look at rates, basic event distributions etc...

Study details



- ▶ Event rates are calculated for the 1.7t demonstrator *active volume*, for 1 year of expected POT:
 - ▶ NuMI: 5.06×10^{20} (FY17)
 - ▶ BNB: 3.3×10^{20} (FY17)
 - ▶ DUNE: 1.1×10^{21} (projected)
- ▶ Assuming NuMI and BNB beam will deliver the same POT as in FY17:

http://programplanning.fnal.gov/wp-content/uploads/2017/12/AnnOpsSum2017_TM2664.pdf

Charged current

Interaction modes

Beam	CC-INC	CCQE	CC-2p2h	CC-RES	CC-Other	NC-INC
SBND ν	49k	26k	4k	16k	2k	14k
NOvA ν	145k	40k	9k	64k	31k	42k
NOvA $\bar{\nu}$	42k	11k	3k	20k	7k	14k
MINERvA ν	1743k	192k	48k	489k	1013k	537k
DUNE ν	2188k	500k	116k	885k	686k	654k
DUNE $\bar{\nu}$	743k	169k	55k	352k	166k	252k

Interaction topologies

Beam	CC-INC	CC0 π	CC1 π^\pm	CC1 π^0	CC-N π	NC-INC
SBND ν	49k	35k	9k	3k	1k	14k
NOvA ν	145k	62k	39k	15k	19k	42k
NOvA $\bar{\nu}$	42k	19k	12k	4k	4k	14k
MINERvA ν	1743k	341k	363k	154k	491k	537k
DUNE ν	2188k	800k	566k	231k	395k	654k
DUNE $\bar{\nu}$	743k	305k	220k	80k	95k	252k

Neutral current

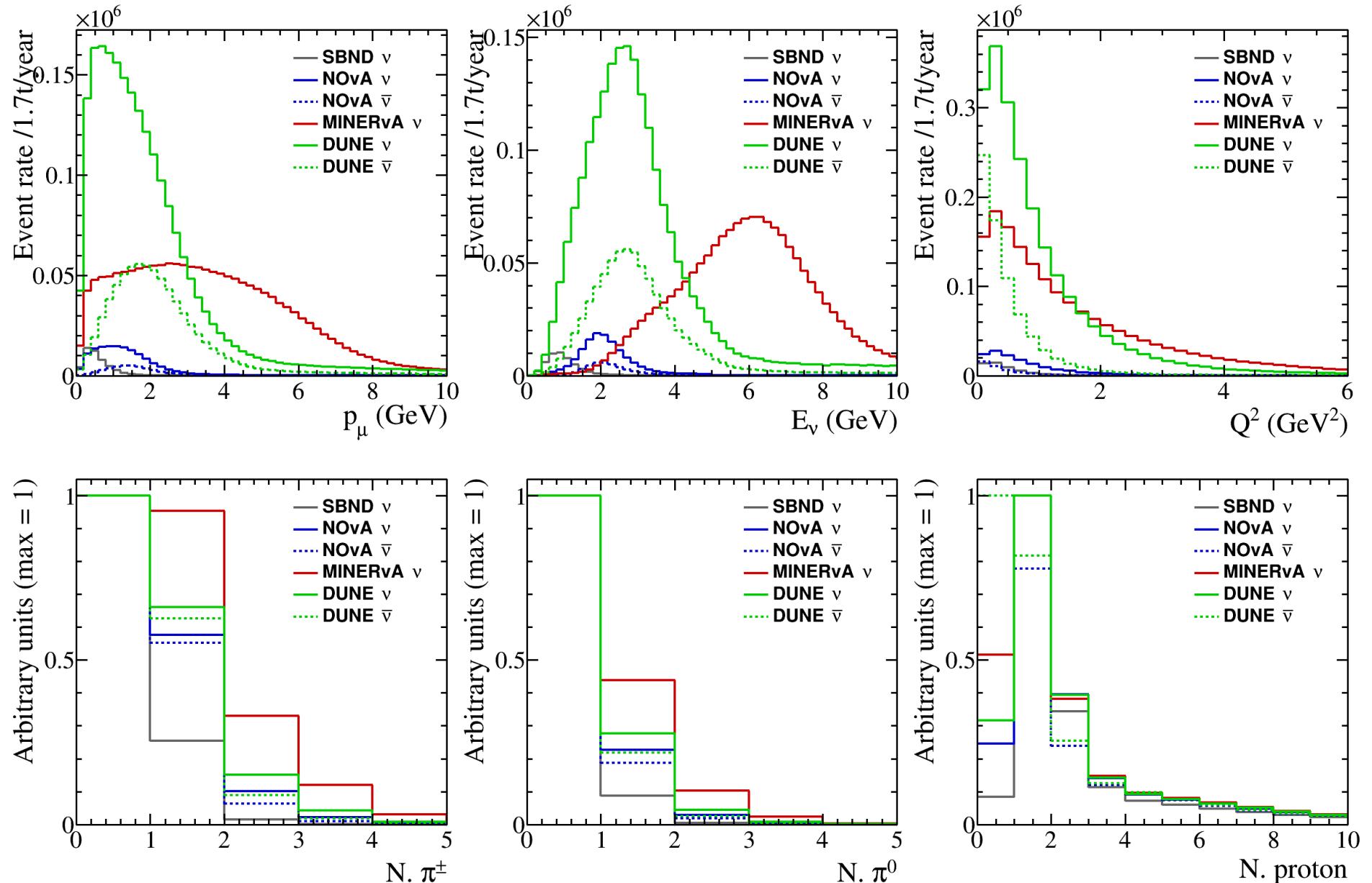
Interaction modes

Beam	NC-INC	NCEL	NC-RES	NC-Other	CC-INC
SBND ν	14k	8k	5k	0k	49k
NOvA ν	42k	11k	21k	10k	145k
NOvA $\bar{\nu}$	14k	5k	7k	2k	42k
MINERvA ν	537k	54k	159k	323k	1743k
DUNE ν	654k	140k	289k	223k	2188k
DUNE $\bar{\nu}$	252k	74k	114k	63k	743k

Interaction topologies

Beam	NC-INC	NC0 π	NC1 π^\pm	NC1 π^0	NC-N π	CC-INC
SBND ν	14k	9k	1k	2k	0k	49k
NOvA ν	42k	15k	8k	9k	6k	145k
NOvA $\bar{\nu}$	14k	6k	2k	3k	1k	42k
MINERvA ν	537k	89k	89k	76k	163k	1743k
DUNE ν	654k	206k	129k	127k	132k	2188k
DUNE $\bar{\nu}$	252k	102k	48k	52k	38k	743k

CC-inclusive kinematics

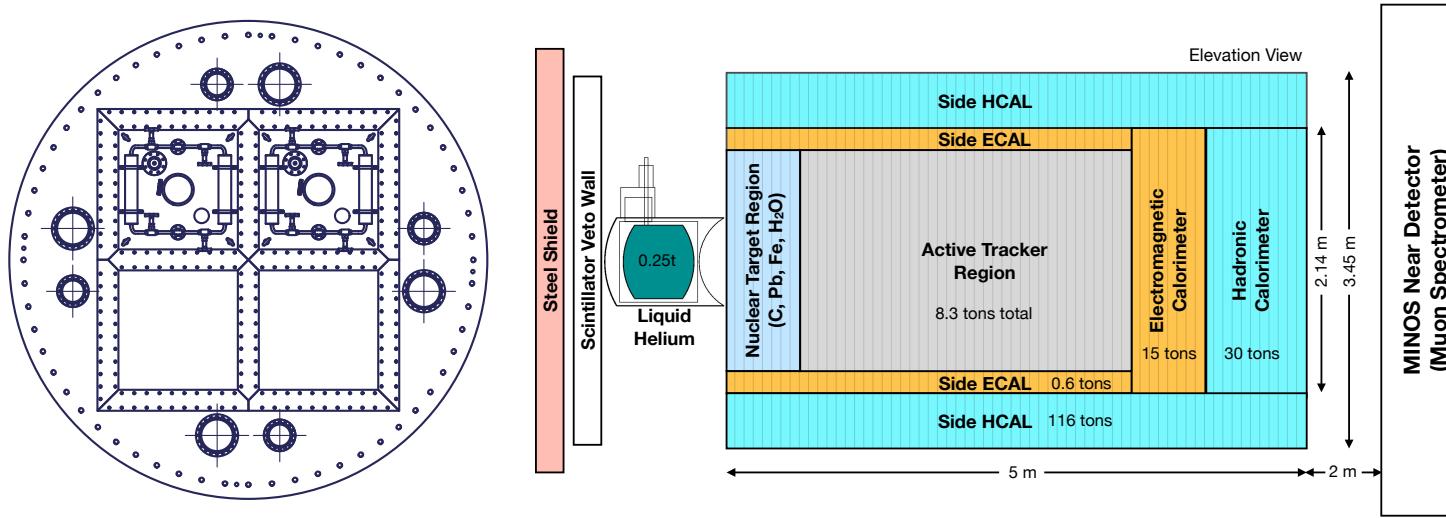


Rates summary

Beam	CC-INC	NC-INC
SBND ν	49k	14k
NOvA ν	145k	42k
NOvA $\bar{\nu}$	42k	14k
MINERvA ν	1743k	537k
DUNE ν	2188k	654k
DUNE $\bar{\nu}$	743k	252k

- ▶ Clearly, the 2x2 would have a high rate in existing FNAL beams.
- ▶ BNB is very weak, so probably a bad option with such a small detector
- ▶ NOvA is closer to the DUNE energy, and has a rate likely to make any measurements stats limited. But unclear if it adds anything that the DUNE ND can't provide
- ▶ MINERvA has a similar rate to the DUNE ND/ unit volume, so a useful test of the reconstruction. But, with more boosted (forward) events, unclear how reconstruction will perform (further study required)

MINERvA acceptance



- ▶ MINERvA uses MINOS (ND) as a muon spectrometer: limits MINERvA measurements to $\theta_\mu \leq 20^\circ$ (17°) for the tracking (nuclear targets) region
- ▶ If the 2x2 were placed upstream of MINERvA, acceptance would be $\theta_\mu \lesssim 15^\circ$, depending on how close you could put the 2x2 to MINERvA
- ▶ **Advantage:** identify and reconstruct muon energy and separate μ^+/μ^-
- ▶ **Disadvantage:** increased backgrounds in MINERvA (an issue with the Helium target) → downstream calorimeter? Possible energy reconstruction of escaping particles...

MINERvA-MINOS rates

CC interaction modes

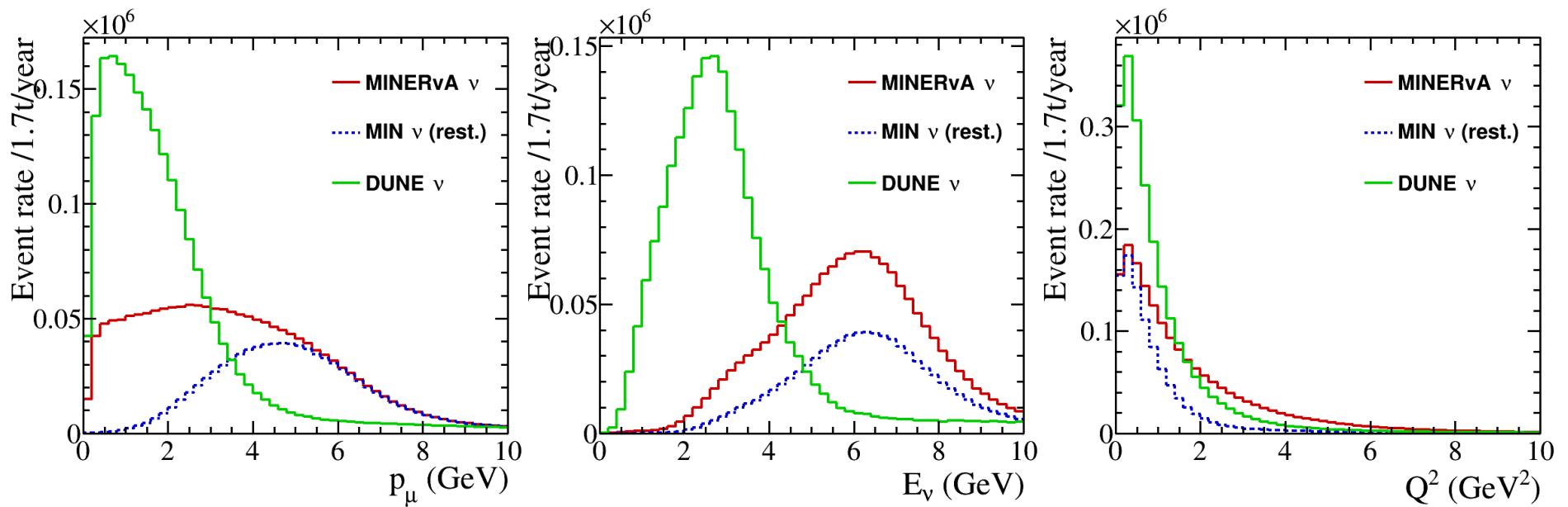
Beam	CC-INC	CCQE	CC-2p2h	CC-RES	CC-Other	NC-INC
MINERvA ν	1743k	192k	48k	489k	1013k	537k
MINERvA ν (rest.)	959k	157k	45k	324k	432k	537k
DUNE ν	2188k	500k	116k	885k	686k	654k

CC interaction topologies

Beam	CC-INC	CC0 π	CC1 π^\pm	CC1 π^0	CC-N π	NC-INC
MINERvA ν	1743k	341k	363k	154k	491k	537k
MINERvA ν (rest.)	959k	275k	224k	90k	209k	537k
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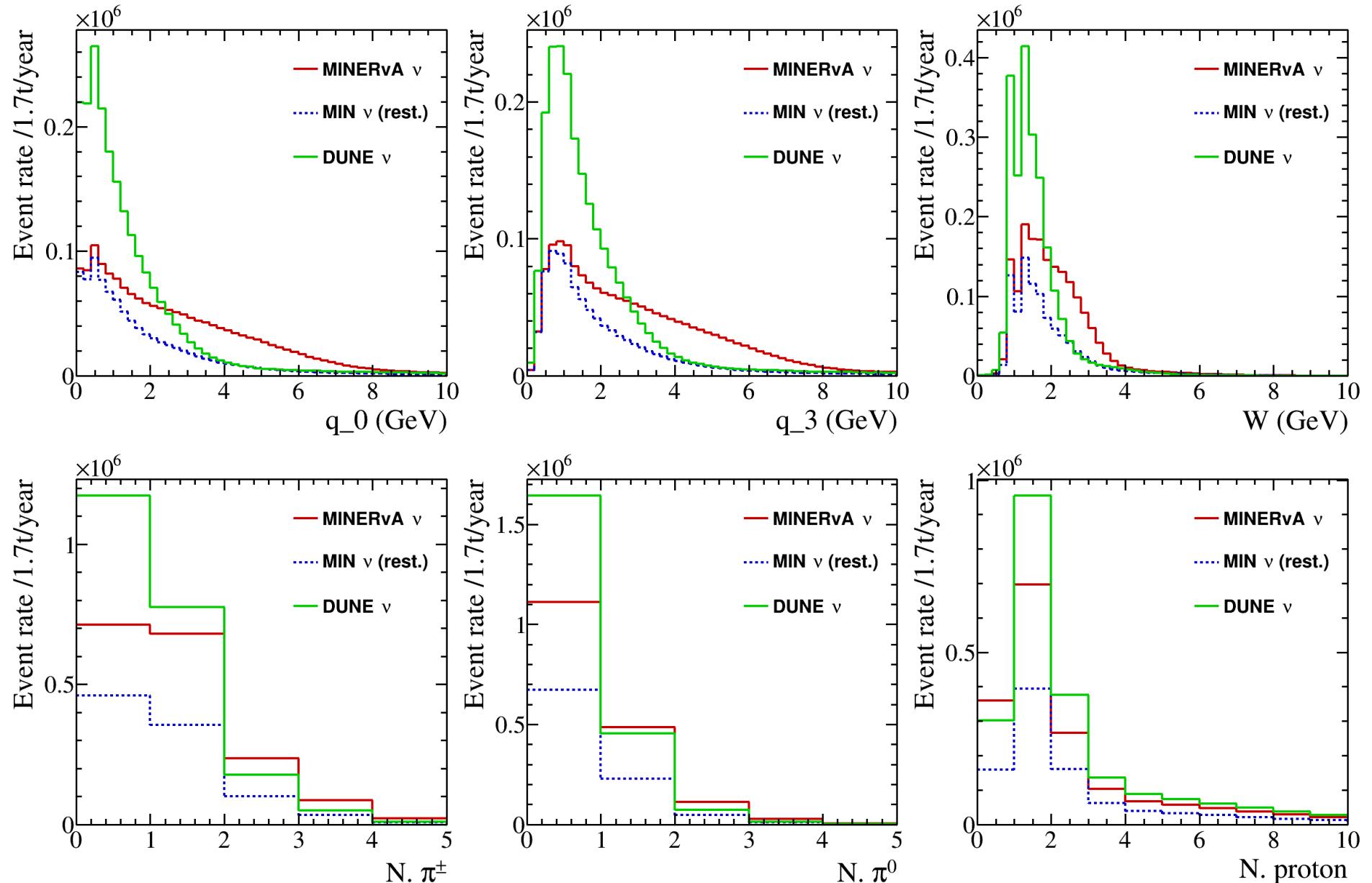
- ▶ Note that the restricted PS only affects “useful” events for cross section measurements
- ▶ Still a high rate for reconstruction tests

CC-inclusive kinematics

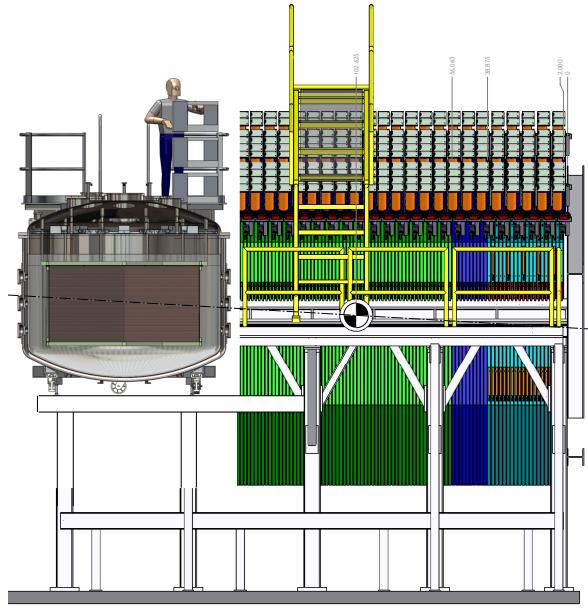


- ▶ Acceptance cuts out high Q^2 events, and biases the E_ν distributions away from the DUNE distribution
- ▶ But, this is the region where there is no coverage from existing experiments (SBND/MicroBooNE)
- ▶ Useful physics results to use as an input for DUNE

More CC-inclusive kinematics



CAPTAIN-MINERvA



- ▶ Proposal to remove the nuclear targets region, and put the CAPTAIN LAr cryostat (5t active volume) against the MINERvA central tracking region
- ▶ Strongly supported by MINERvA, submitting to the FNAL PAC in 2015, *but not funded*
- ▶ Using the 2x2 in the same way would have some advantages:
 - ▶ Resolves the background issue by integrating the detectors
 - ▶ Increases muon angular acceptance in MINOS by a few degrees
 - ▶ Makes it viable to reconstruct escaping particle energies with the well understood MINERvA detector

Concluding remarks

- ▶ NuMI is so powerful that the 2x2 would have a high event rate on- or off-axis. On-axis probably the most viable option (MINOS-ND)
- ▶ To get useful information, from the 2x2, complementarity with another detector to catch escaping particles is important (2x2-MINERvA?)
- ▶ Can clearly make a physics case for moving the 2x2 to an FNAL neutrino beam. **But many questions outside scope of the talk:**
 - ▶ Would that fit with other hardware/reconstruction development goals?
 - ▶ Could it be done on a useful timescale?
 - ▶ Would there be sufficient funding?
 - ▶ Could enough time be invested in analysis?

Backup

True CC-inclusive kinematics

