MPD: Response to Spokes' questions & descoping options

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MPD Goals

1.) Articulate (concisely) the goals of the MPD system with regard to measurements that will be performed to impact the neutrino oscillation measurements at DUNE

Goals related to oscillation analysis
Provide data to constrain the neutrino-nucleus interaction systematic uncertainties
Precisely and accurately measure all components of the neutrino flux
Reconstruct neutrino energy via spectrometry and calorimetry
Constrain LArTPC detector response and selection efficiency
Measure particles that leave the LAr near detector component and enter the MPD
Measure energetic neutrons from neutrino-argon interactions via TOF with the ECAL

MPD strengths that enable the oscillation goals

Strengths
High-resolution imaging of particles emerging from neutrino interaction vertex
High-fidelity particle charge determination via magnetic curvature
Precise and independent measurement of particle momentum • For high energy tracks, via magnetic curvature • For lower energy/stopping tracks, via range
Particle ID via dE/dx
Acceptance at high angles
Statistically independent event sample with different systematics than LArTPC
Possible measurement of neutrons in ECAL via TOF (preliminary studies are encouraging)

MPD Descoping Options

2.) Investigate and propose other configurations that minimize cost, including:

- A one atmosphere absolute pressure GArTPC
- A descoped spectrometer system that fulfills the need to track muons from the LAr target

Describe tradeoffs/compromises between these descoped systems and the current concept with regards to impact on the DUNE oscillation measurements.

Fermilab

Considerations for descoping options

- Use T2K and NOvA to understand the impact of systematics on the far detector oscillation analysis
  - After ND constraints, T2K and NOvA achieve 5-10% systematic uncertainties on the FD prediction
  - DUNE aims to make higher precision measurements than both of these experiments, and so we need to reduce the uncertainties to $O(1\%)$
    - Reaching this level of precision will require expanded near detector capabilities relative to NOvA & T2K
- Significant lessons from T2K & NOvA oscillation analyses
  - **Importance of magnetic field**
    - T2K was able to reduce flux uncertainties on the wrong-sign component of the anti-ν_μ beam to ~5% using magnetic field curvature
  - **Importance of same target nucleus at near and far detectors**
    - T2K reduced uncertainties on predicted number of events at the FD using water target data at ND

	ν_μ	ν_e	anti-ν_μ	anti-ν_e
Without ND fit	12%	11.9%	12.5%	13.7%
Using ND fit without water data	7.7%	6.8%	11.6%	11.0%
Using ND fit with water data	5.0%	5.4%	5.2%	6.2%

Descope option 1: Reduce HPgTPC pressure to 1 atm

😕 The pressure vessel is not expected to be a major cost driver, and so only reducing pressure while not changing anything else will not reduce the cost much

😀 1 atm pressure would allow lower reconstruction thresholds than 10 atm (tracks of the same energy are even longer in the lower density gas)

😢 A factor of 10x fewer signal events, but the number of neutrino interactions in surrounding materials will remain the same (worse S/B than 10 atm).

😢 No possibility to do H_2/D_2 measurements

		Goals related to oscillation analysis
not well	orange	Provide data to constrain the neutrino-nucleus interaction systematic uncertainties (degraded due to decreased statistics and need to tighten selection criteria)
not possible	red	Precisely and accurately measure all components of the neutrino flux (not enough stats, especially for intrinsic beam ν_e)
	orange	Reconstruct neutrino energy via spectrometry and calorimetry
	orange	Constrain LArTPC detector response and selection efficiency (very low
ok	green	Measure particles that leave the LAr near detector component and enter the MPD
	orange	Measure energetic neutrons from neutrino-argon interactions via TOF with the ECAL

Descope option 2: 1 atm HPgTPC, no ECAL, reduced B field

😀 1 atm pressure would allow lower reconstruction thresholds than 10 atm (tracks of the same energy are even longer in the lower density gas)

😢 A factor of 10x fewer signal events, but the number of neutrino interactions in surrounding materials will remain the same (worse S/B than 10 atm)

😢 No possibility to do H_2/D_2 measurements

😢 Degraded momentum resolution from reduced B field

😢 No possibility to measure neutrons and pi0s from neutrino interactions, no precise timing from TPC-exiting-to-ECAL tracks

	Goals related to oscillation analysis
	Provide data to constrain the neutrino-nucleus interaction systematic uncertainties (degraded due to decreased statistics and need to tighten selection criteria)
	Precisely and accurately measure all components of the neutrino flux
	Reconstruct neutrino energy via spectrometry and calorimetry
	Constrain LArTPC detector response and selection efficiency
	Measure particles that leave the LAr near detector component and enter the MPD
	Measure energetic neutrons from neutrino-argon interactions via TOF with the ECAL

Descope alt: 10 atm HPgTPC, downstream-only ECAL, reduced B field

- 😀 If only the downstream side of the TPC is covered by ECAL, considerably lower cost
- 😢 Physics impact is not quantified yet, but reduced ECAL certainly limits phase space of some measurements made in gas
- 😢 Degraded momentum resolution from reduced B field

Educated guesses about how this would affect goals – studies required to quantify this option

	Goals related to oscillation analysis
	Provide data to constrain the neutrino-nucleus interaction systematic uncertainties (constraints will be possible for limited phase space)
beam ν_e affected by lack of full ECAL	Precisely and accurately measure all components of the neutrino flux
	Reconstruct neutrino energy via spectrometry and calorimetry (limited phase space)
	Constrain LArTPC detector response and selection efficiency
	Measure particles that leave the LAr near detector component and enter the MPD
	Measure energetic neutrons from neutrino-argon interactions via TOF with the ECAL