Laser system vs. cosmics

current arguments

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Purpose of talk: motivation of laser for feedthroughs

- We have to present our request for amended feedthroughs at the special technical board meeting this Friday

- Following slides outline specific motivations for a laser system relative to what will be feasible from other information (e.g. cosmics)

  - Also, a cartoon request of possible locations

- Would like feedback on each topic (support or criticism)

- End of talk includes future (TDR) studies to expand or confirm current estimations or assertions

Commissioning

- **Time to read out charge on every wire:**
  - Channel map check // signal on wire x electronics
  - laser: ~days vs. cosmics: ~years? (confirming time) TJ: "Induction planes hit lots, collection planes can get unlucky"

- **MicroBooNE experience during cooldown:**
  - loose wire? electronics issue? broken wire? ~6 months of work to assess.
  - Deployed a steerable camera to scan the entire wire planes (10 m of it) to visually check for broken wires. None found. But, we cannot do the same for DUNE, DUNE is huge!

Alignment scale, issues

- Alignment affects measurement of muon momentum from multiple scattering
- ICARUS saw ~2.5cm misalignment, 35t saw Δx, Δz ~3mm
- **Mechanical changes during cooldown:** (V. Guarino)
  - Uniform shrinking of 7mm across detector from cool down
  - Δx: increased from 3 mm to 7 mm due to bowing during cool down at half height of the CPA.
  - Δy: unknown, bowing will affect this
  - Δz: Field cage constraint makes this negligible? ? Resolve: If hang all 25 APA, few cm across all, but may be different between each APA (T. Junk)

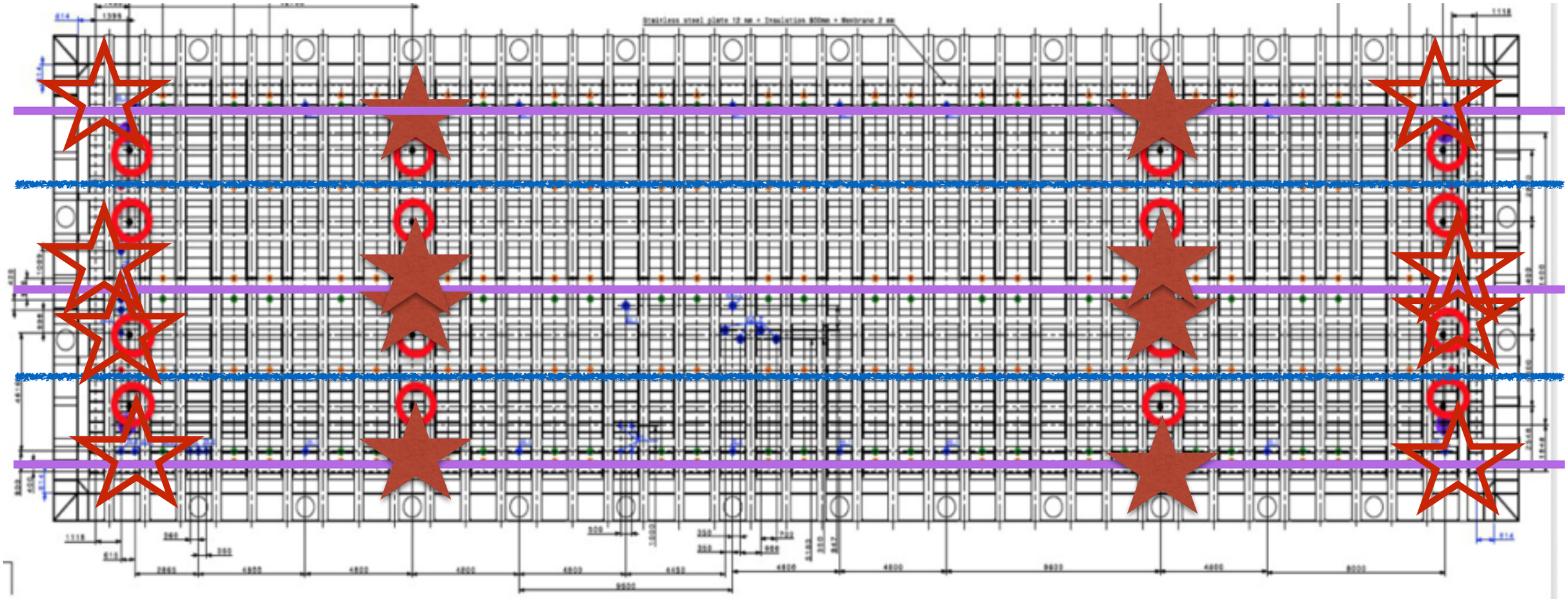
Detector Alignment

- **APA-APA precision "local" alignment**: Cosmics much better than mechanical (0.05mm!) vs. laser (2mm)
  - T. Junk slides: https://indico.fnal.gov/getFile.py/access?contribId=15&resId=0&materialId=slides&confId=14909
    - Δy may depend on angular distribution of cosmics
    - Time to local alignment: laser: ~days vs. cosmics: year (Confirming)
- **All-APA "global" alignment:** difficult/impossible with cosmics, laser only
- **Motion of support structure:** difficult/impossible with cosmics, laser?

Diagnosing failures, stability

- **Cathode flatness:** not possible with cosmics, laser?
- **Cathode resistance changes:** not possible with cosmics, laser? (feasible?)
- **Wire displacements:** ~150 micron, maybe more (T. Junk) not accessible by either (TDR: Field OK?)
- **Resistor failure on field cage:** laser, if steered close enough to field cage (feasible?)
- **Sudden changes to wires/electronics:** not possible with cosmics, laser

Cartoon of laser feedthroughs



- Lasers in red stars
- APA in purple line
- CPA in blue line
- Spares (which can also provide crossing track lasers) in open stars. 4 manholes on corners of cryostat already, maybe only 4 more?

Summary

- **Laser is motivated as a stability monitor, system for diagnosis**

- **To do for Friday:**

  - Confirm locations of laser specific feedthroughs, feasibility or not of manhole use.

  - Quantify, if possible, field distortion sensitivity of laser to instantaneous failures

  - Confirm scale of mis-alignment distortions (ideal, mechanical case, and possible worst cases)

Additional Studies for TDR

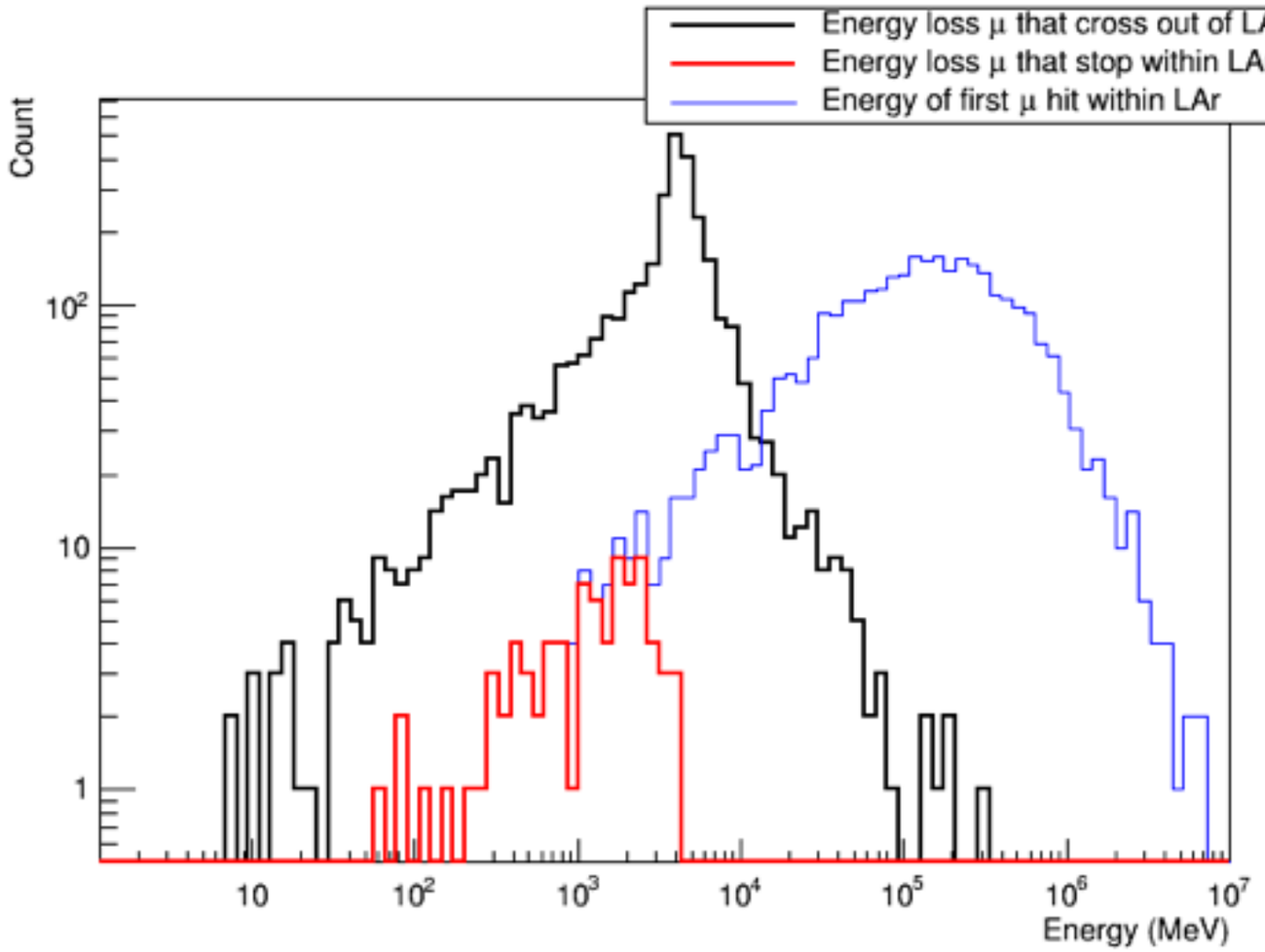
- **Space charge:** no estimate yet for DUNE FD. Laser
- **ΔE field:** precision achievable by laser, sensitivity to relative changes

Backup slides

Cosmics

https://indico.fnal.gov/conferenceDisplay.py?confId=14909

V. Kudryavtsev

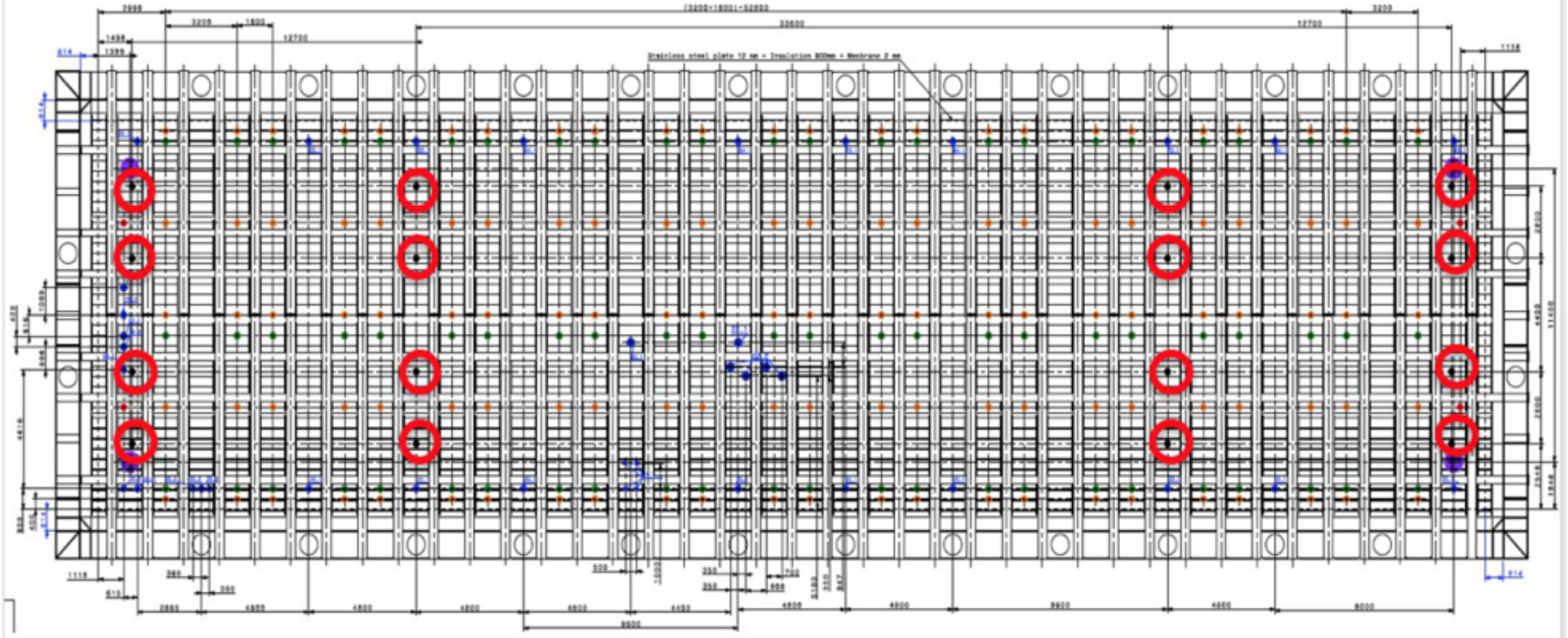


Can map out entire volume but difficult to look for time dependent effects

Limited angular reach

- Stopping: 40-45 per day
- Crossing tracks: 200-500 per day
- No muons at zenith angles >75 degrees

Current design for cryostat penetrations
(only showing the instrumentation ports)



Pos.	Diameter [mm]	Quantity	Description
1	Ø250	120	Support
2	Ø250	72	Cable
3	Ø250	4	High voltage
4	Ø250	16	Instrumentation
5	Ø800	4	Manholes

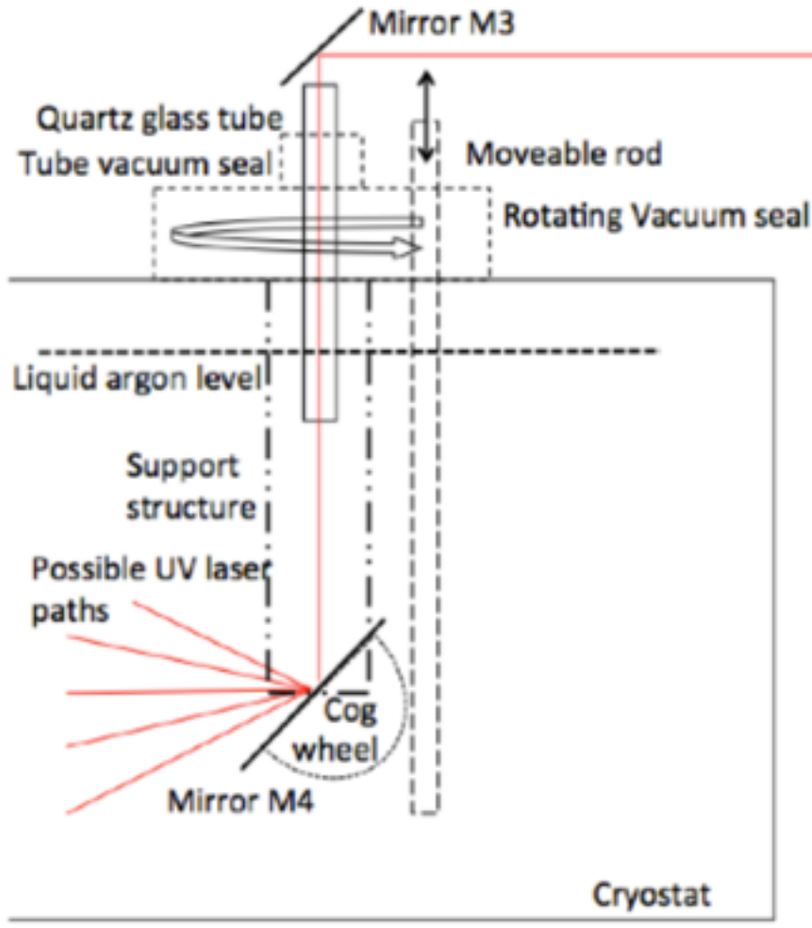
- 16 instrumentation ports
- 250 mm diameter (current design)

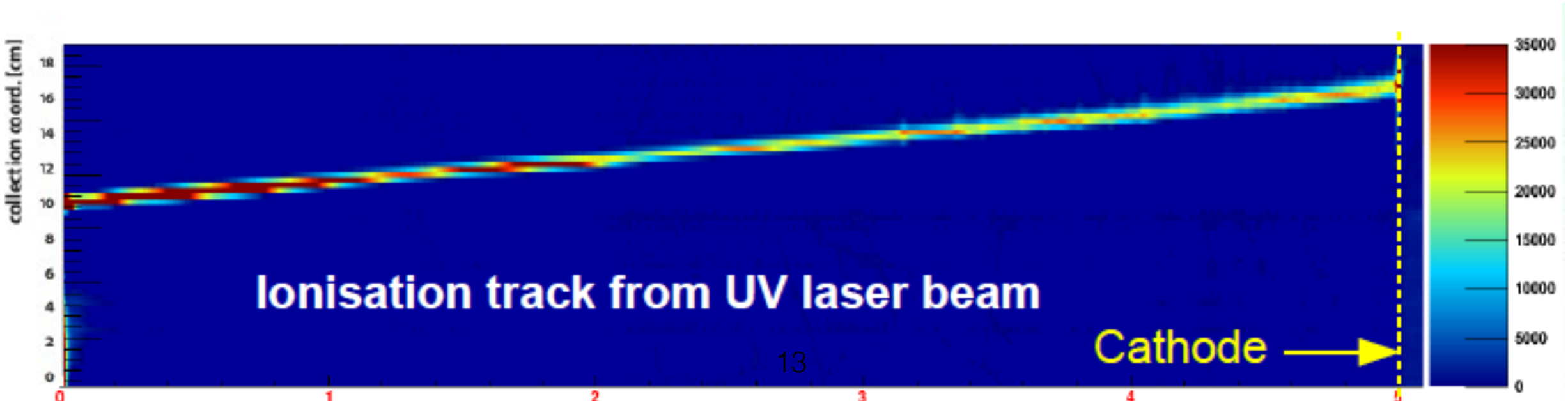
- About 0.5 m clearance on the sides
- About 0.7 m clearance on top from the surface of liquid argon

MicroBooNE, SBND laser system

Ionize the liquid Ar using 266nm laser

- Steerable mirror to alter path, crossing tracks for field map:
  - Is the field linear as expected? What about deformations or changes with time?
- Straight tracks (no MCS, no delta rays), no recombination





Observable ionization depends on:

M. Weber, mini-workshop: https://indico.fnal.gov/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=14909

- Beam divergence: nominal 0.5 mrad
  (can change at the mirrors!)
- Beam absorption: does not seem to be an issue…
  λ_{att} > 100 m at 266 nm
  "Attenuation of vacuum ultraviolet light in liquid argon" , Eur. Phys. J. C (2012)
- Rayleigh scattering (40m at 266 nm)
- Refraction on density gradients
- Non-linear effects (Kerr-induced self-focusing)

Advantages:

- Field map via crossing tracks
- Track reconstruction
- Charge density (dE/dx)
  - Commissioning wire response vs. time for cosmic on all wires
- Redundancy with purity monitors (charge attenuation)
- Diffusion (track divergence), end track peak (longitudinal)
- Cross calib of light for photon systems?

Disadvantages, questions:

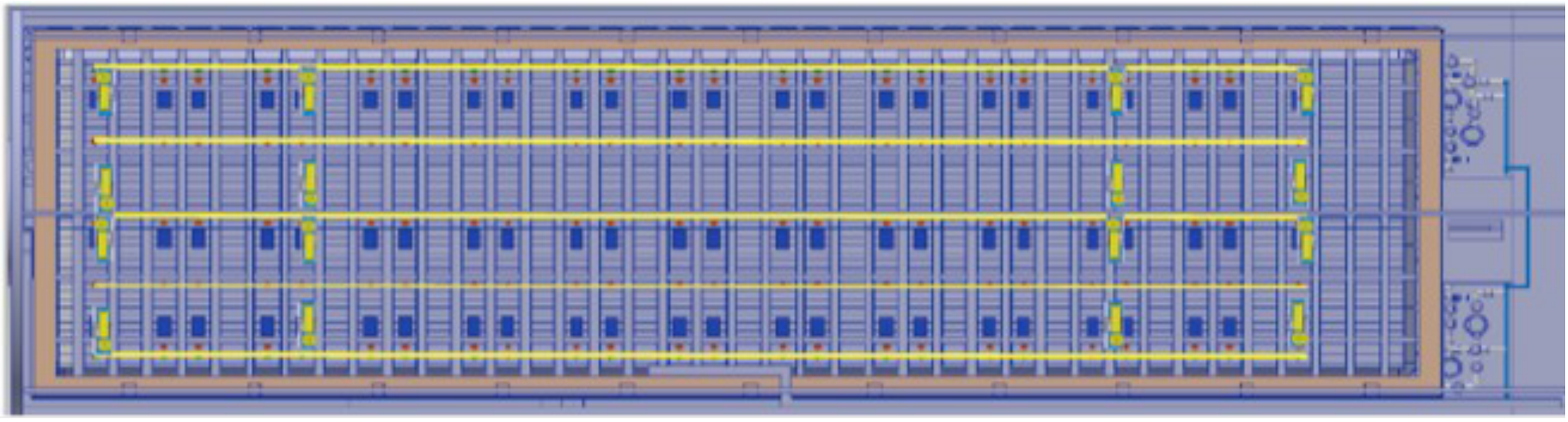
- Operation: what if the mirror gets stuck?
  - Replaceable and accessible so far
- **Do we understand ionization yield? Not MIP like charge?**
- Source of noise?
  - No effect yet seen yet

What about MIP-like charge?

- Laser tracks are wider (5mm vs. 50nm) than cosmics
- But, charge on a wire is comparable to a MIP (integrated over 3mm)

Proposal for laser feedthroughs

DUNE calibration concept study document: https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=4769

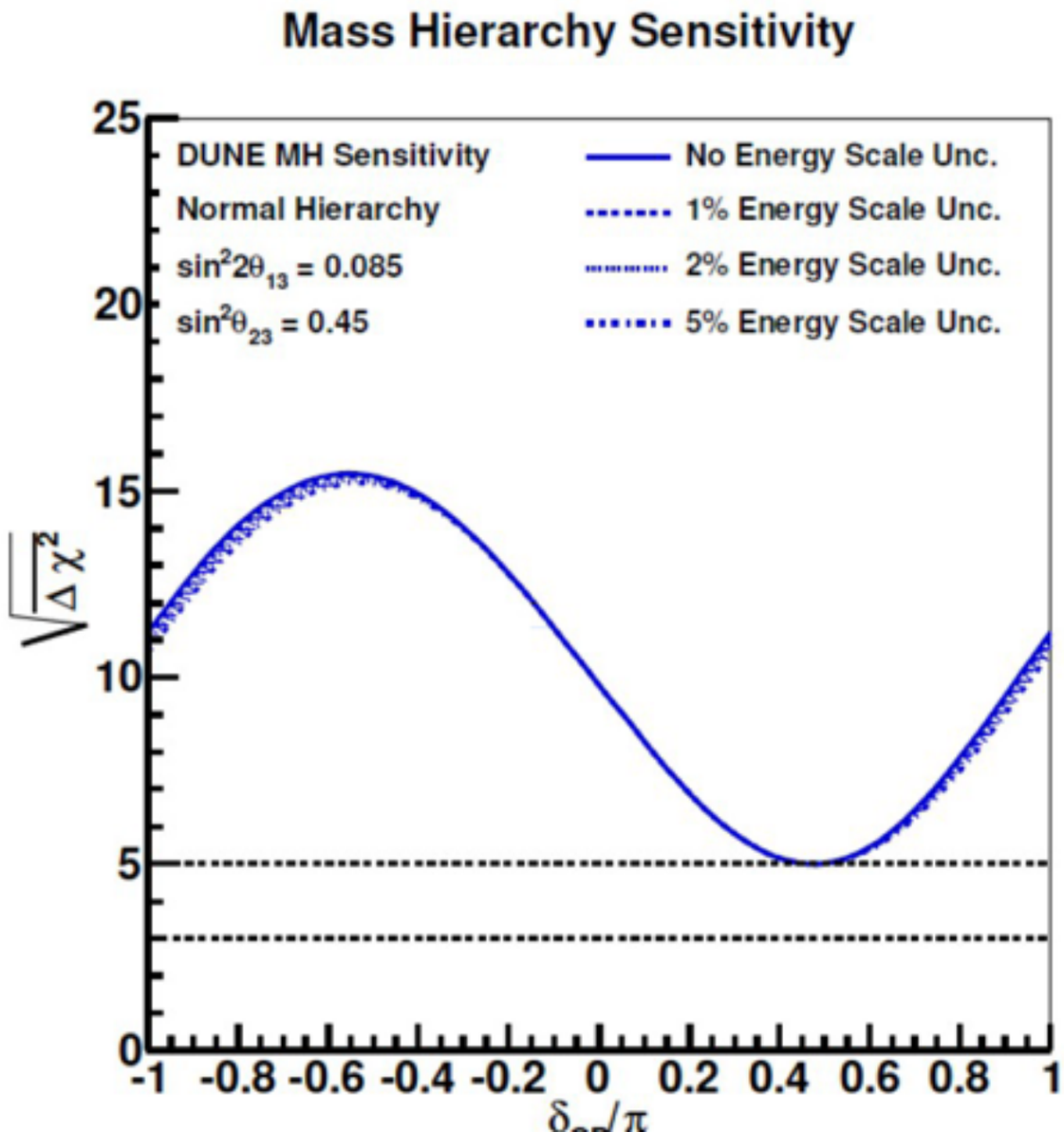


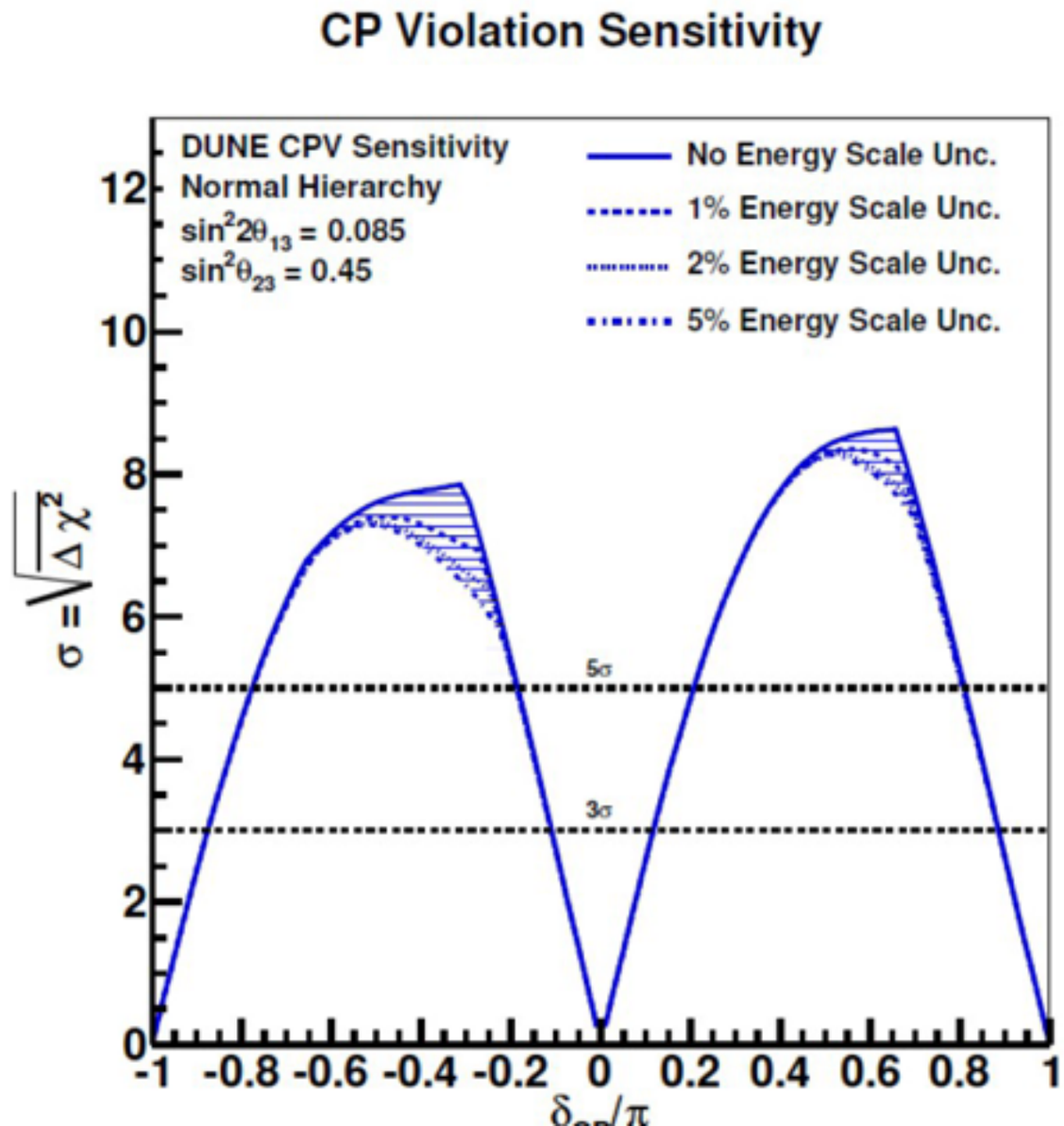
Not proven yet but possible to just use 8 feedthroughs for 60m;16 gives 16m crossing tracks (uB: 10m achieved)

CF200 size needed for laser system with contingency. Rotating head which may pose an issue for sharing

Issue: Unprecedented Physics Requirements of DUNE

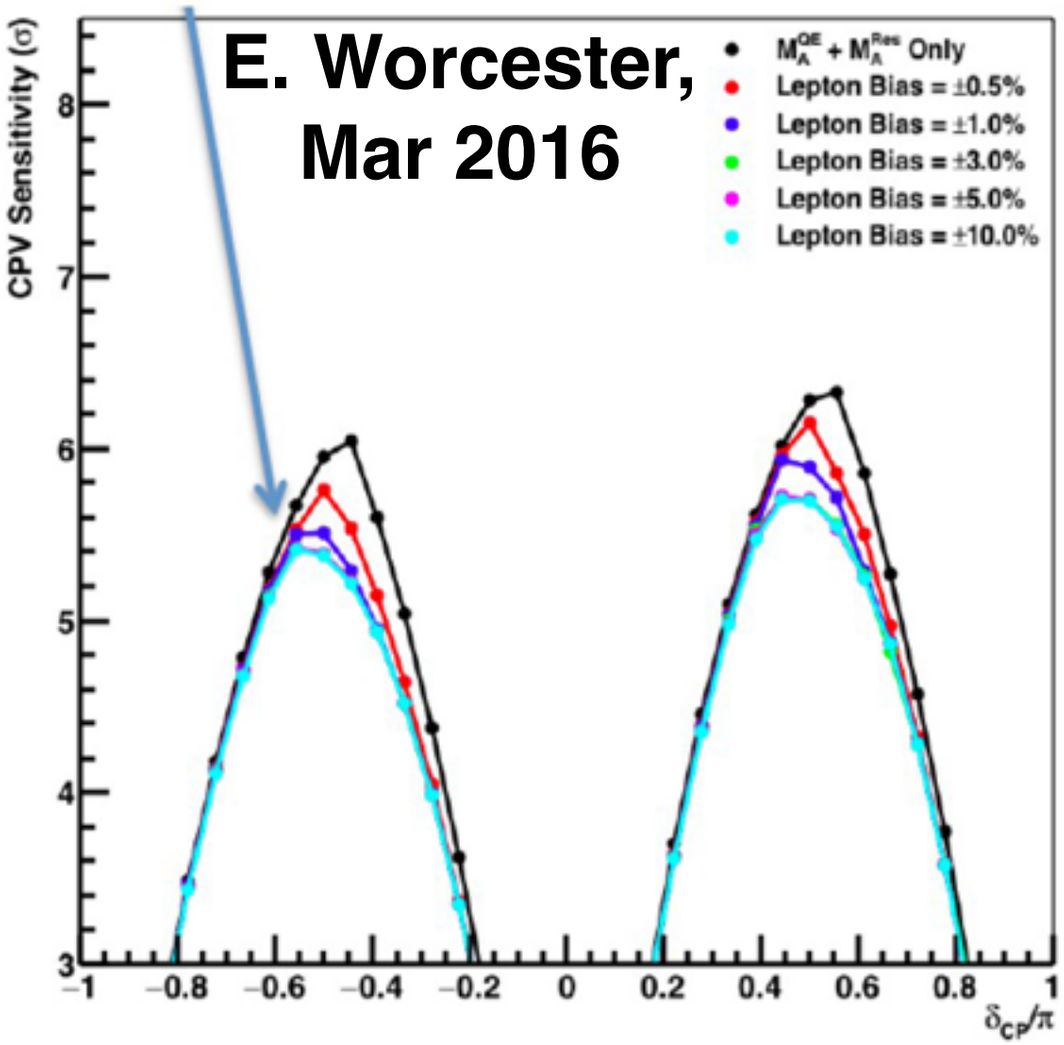
CDR: Uncertainty of 2% on energy scale is already important to physics goals; calibration must be <2%

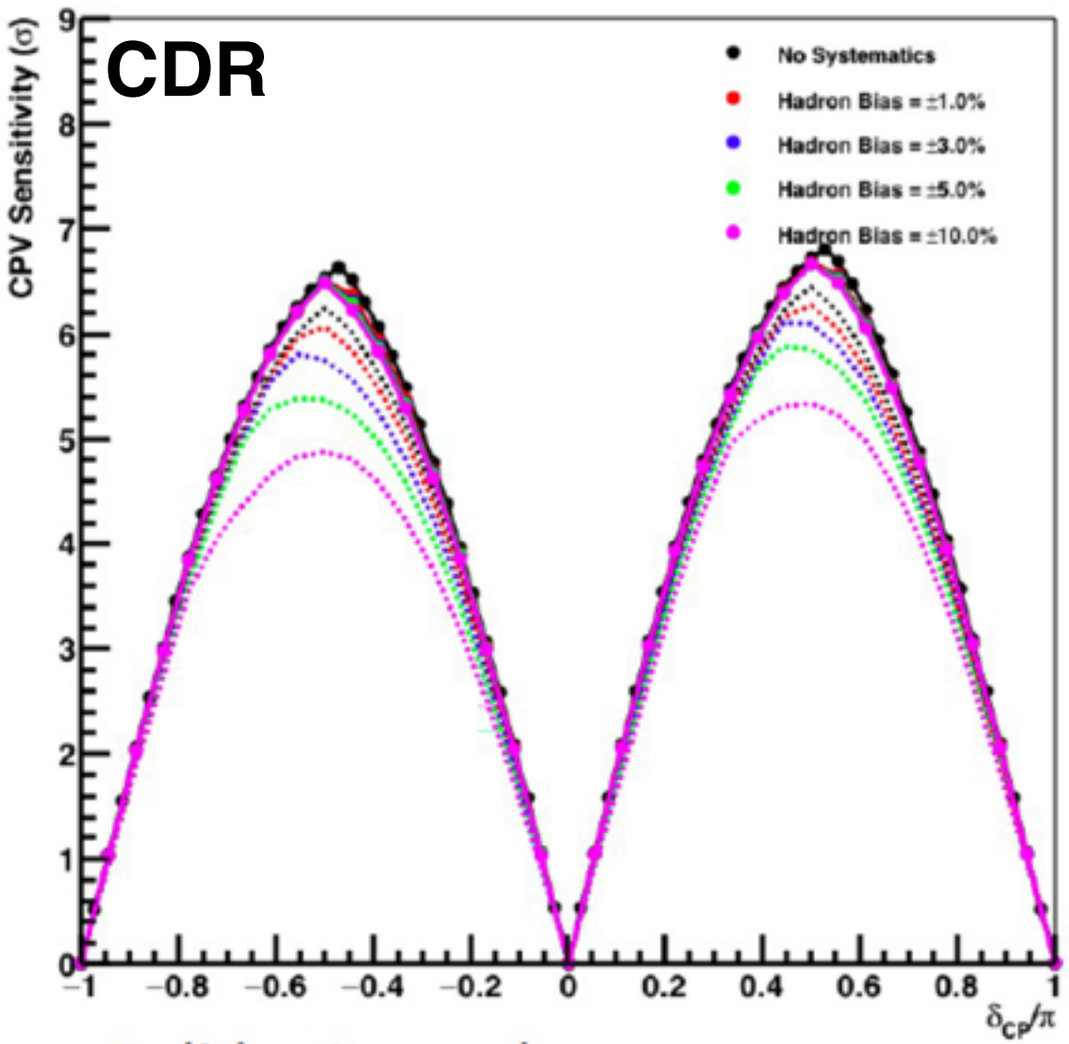




Issue: Unprecedented Physics Requirements of DUNE

1% Lepton energy bias is already important to physics goals; calibration must be <1%





https://indico.fnal.gov/contributionDisplay.py?contribId=4&confId=11718

Solid = 4 sample
Dashed = ν_e only

Calibration Task Force

- **Long term:** Develop clear ties between high level physics requirements and knowledge of calibration parameters
  - How well does the field map need to be known? 1% fiducial volume = 1% drift velocity
  - What does 1% energy bias mean for recombination lifetime, electronics calibration?
- **Short term:** Confirm or adjust cryostat interfaces for calibration
  - Collate arguments for how we will achieve necessary precision

This talk: discuss multiple TPC laser systems, usage, physics impact. Discuss pros and cons for DUNE