Laser System Discussion

Cosmics vs Laser

Current arguments

Thoughts from HV side?

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Need to motivate the laser Feedthroughs

- We have to present our request for amended feedthroughs at the **special technical board meeting this Friday, Sep 29**
- Following slides outline specific motivations for a laser system relative to what will be feasible from other information (e.g. cosmics)
  - Also, a more minimal scoping of current laser FT proposal
- Would like to discuss more on what HV system needs are on E-field map?

Reminder: Cosmics

- https://indico.fnal.gov/conferenceDisplay.py?confId=14909 (Vitaly)
  - Overall cosmic flux 4000 per day per 10-kt module
  - Stopping: 40-45 per day
  - Crossing tracks: 200-500 per day
  - Limited angular coverage: No muons at zenith angles >75 degrees
  - Back of the envelope calculations (Jim's workshop): Each collection plane wire is hit only every 2-3 days (Josh?)
- Rock Muon rate: 500 - 1000 per year for each 10-kt module
- **Abysmal cosmic rates, limited angular coverage and the sheer size of DUNE, makes any sort of stability monitoring (time/spatial variations) very difficult**

Laser

- **Laser can broadly help in 4 ways:**
    - Alignment, Stability Monitoring
    - Diagnosing failures
    - E-field map
    - Energy scale (not a strong argument but comes as a possibility)
- **Big picture of Cosmics vs Laser**
    - Yes, you can probably use cosmics to map the entire volume but will take few months to a year **Vs** Laser ~days and some of it (e.g. global alignment) are probably impossible with cosmics

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 cool down:**
  - 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

E-field map

- Biggest criticism: space charge is expected to be low, so no strong motivation for E-field map. But,
    - There are other sources that distort E-field (e.g. APA/CPA locations, resistivity etc.)
    - E-field variations from existing LArTPCs (MicroBooNE, ICARUS) has not agreed with expectations
    - A lot of calibration parameters depend on field (e.g. drift velocity, track distortions)
        - Physics requires < 2% energy scale bias. A 5% uncertainty in the field can lead to about ~1% bias in energy already! Laser precision?
    - If you don't have Laser and you need to independently measure the field with good volume coverage and statistics, what alternate method do we have?

Do we have information on this?
(apologies if we are not looking in right places)

- **Space charge:** no estimate yet for DUNE FD. Laser

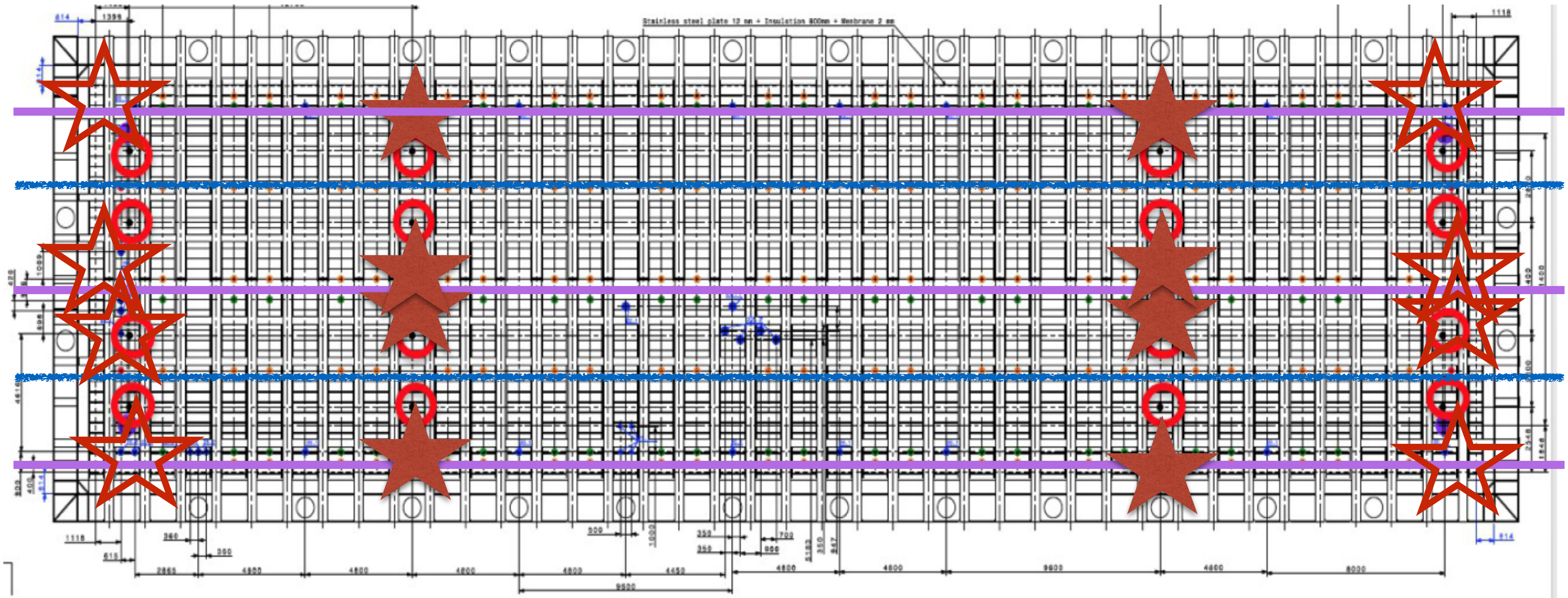
- **ΔE field:** precision achievable by laser, sensitivity to relative changes?

- If we don't have this information, these need to quantified post FT deadline. Definitely for TDR.

E-field: Motivations from HV side?

- Would like to discuss this
  - APA/CPA position offsets, resistivity etc. can distort field
  - HV diagnosis? (e.g. resistor failure across a field cage)
    - Question: what gets covered in HV slow monitoring?
- **What else?**

Laser feedthroughs:
more minimal scoping to minimal configuration?



- 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

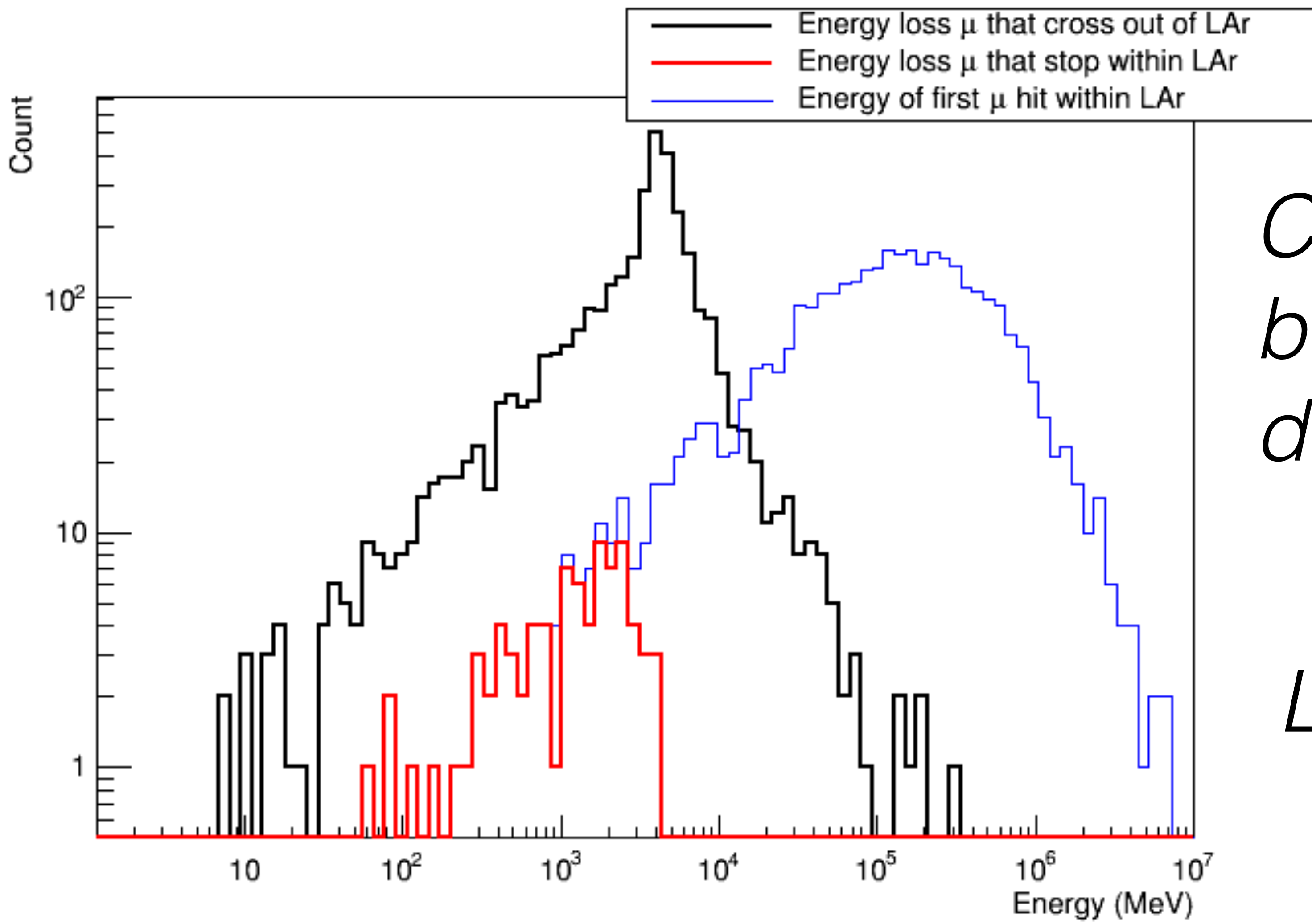
- Laser is motivated as a stability monitor, system for diagnosis, and E-field map
- **Take home thoughts**
  - Any form of stability monitoring, Cosmics~year(s) and Laser~days
  - Some forms of stability monitoring (e.g. global alignment) very difficult/impossible with laser
  - We currently have NO system in the detector which gives us any independent information of the field. We need to be able to include such a system. We base the request on the laser system as an example
- **Cost perspective: Now vs Later?**
  - Per Marzio: highly uncertain to predict now but expect it to go (very) high if later

Backup slides

Cosmics

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

V. Kudryavtsev

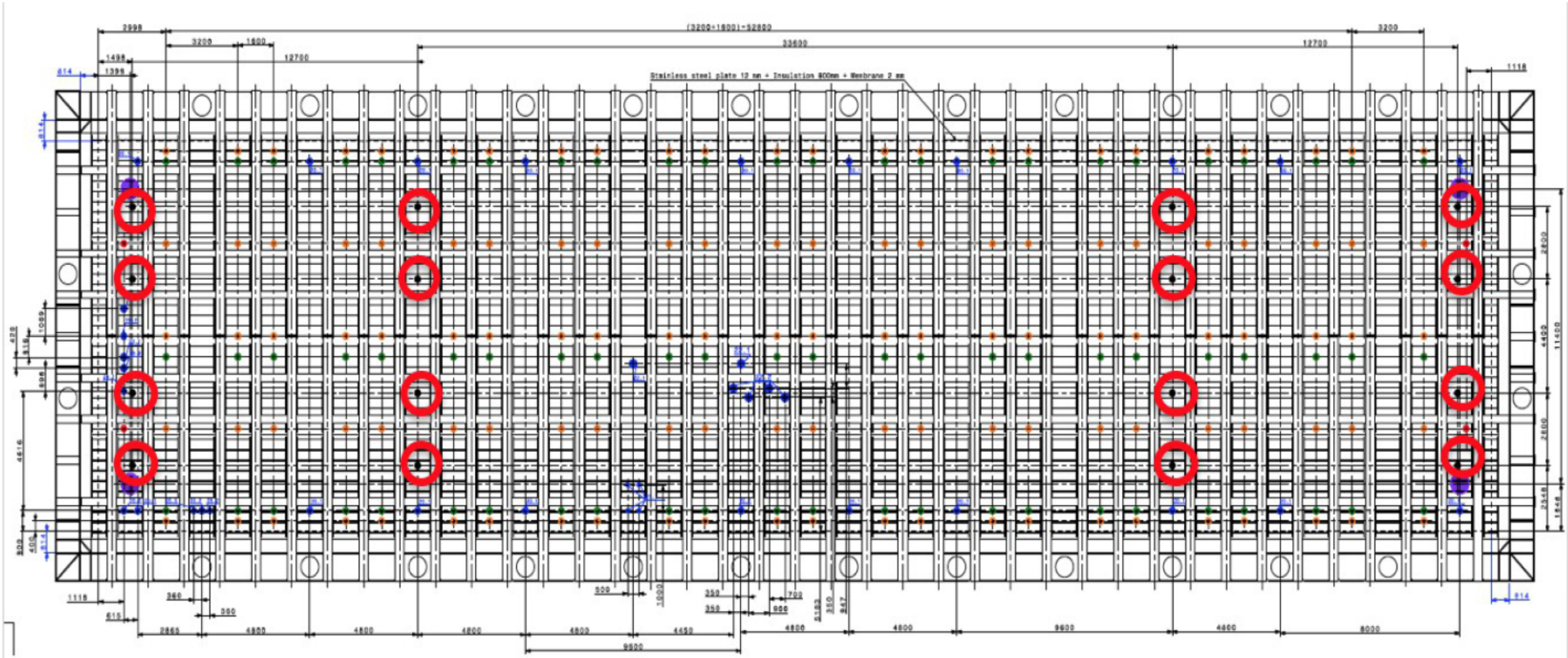


Can map out entire volume but difficult to look for time dependent effects

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

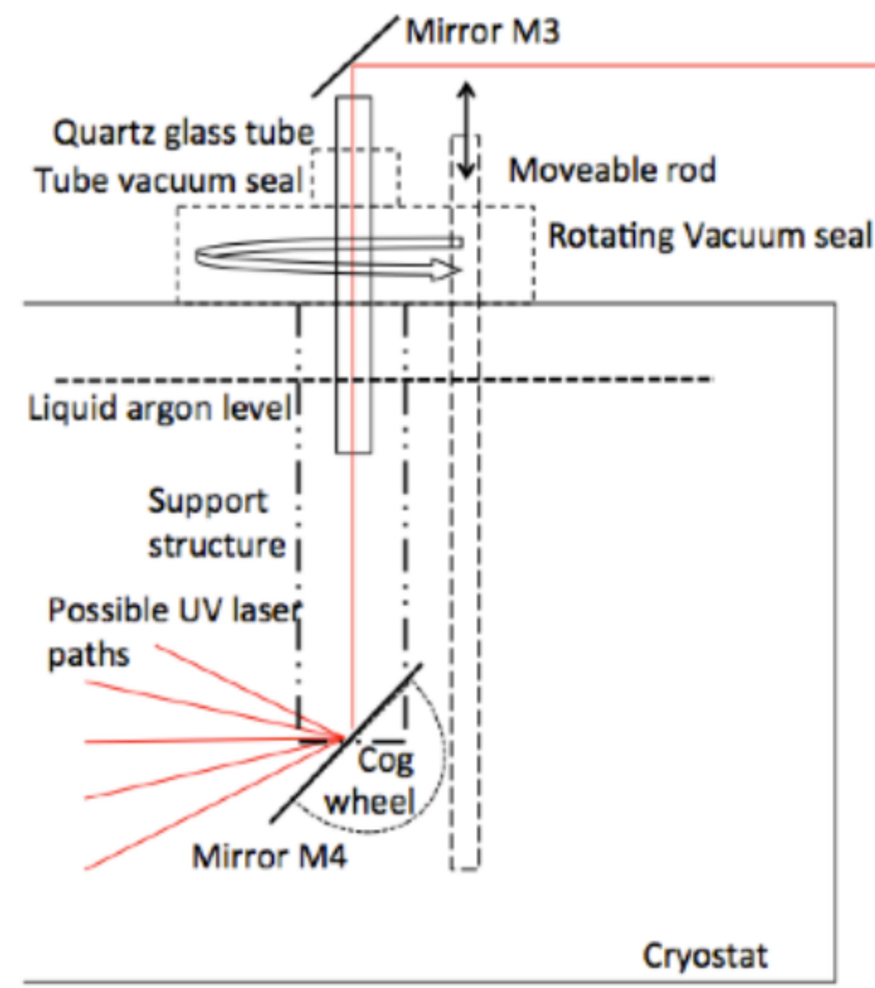
- 16 instrumentation ports
- 250 mm diameter (current design)

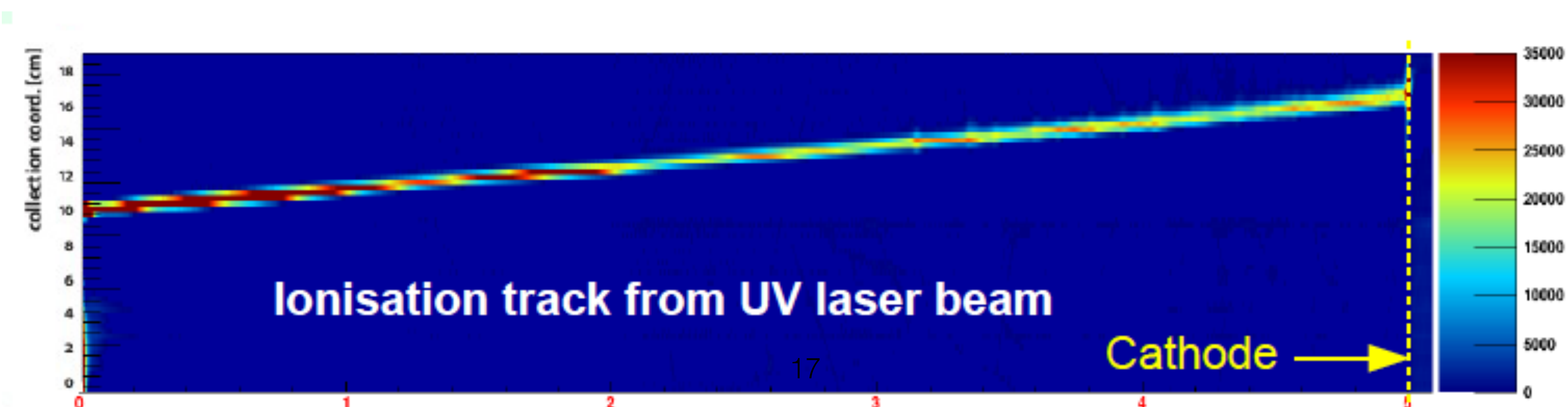
- About 0.5 m clearance on the sides
- About 0.7 m clearance on top from the surface of liquid argon

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:

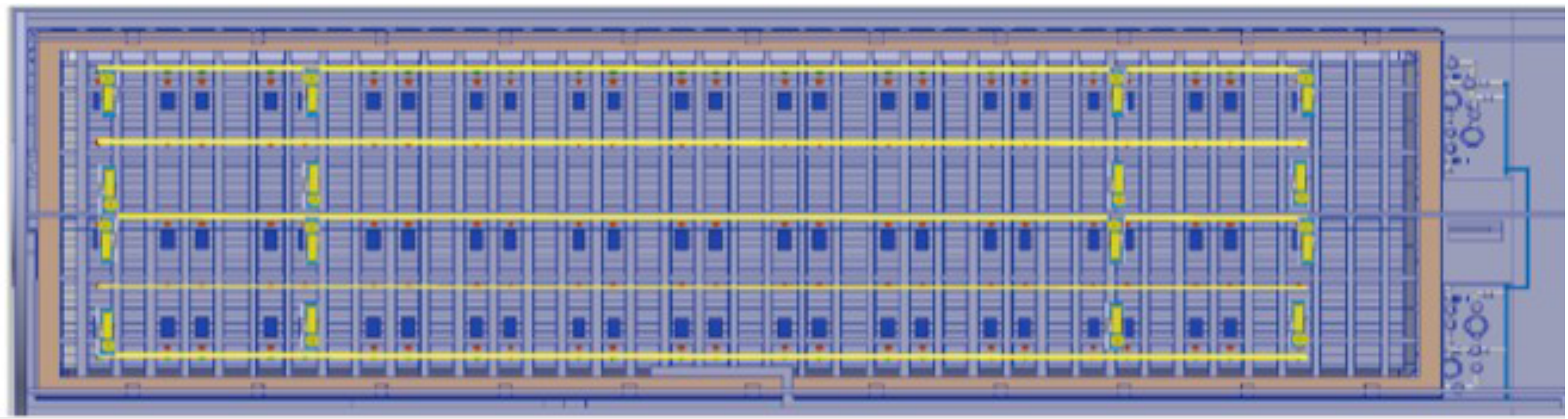
- Operation: what if the mirror gets stuck?
  - Replaceable and accessible so far
- **Do we understand ionization yield? Not MIP like charge?**
- Source of noise?
  - No effect yet seen yet

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

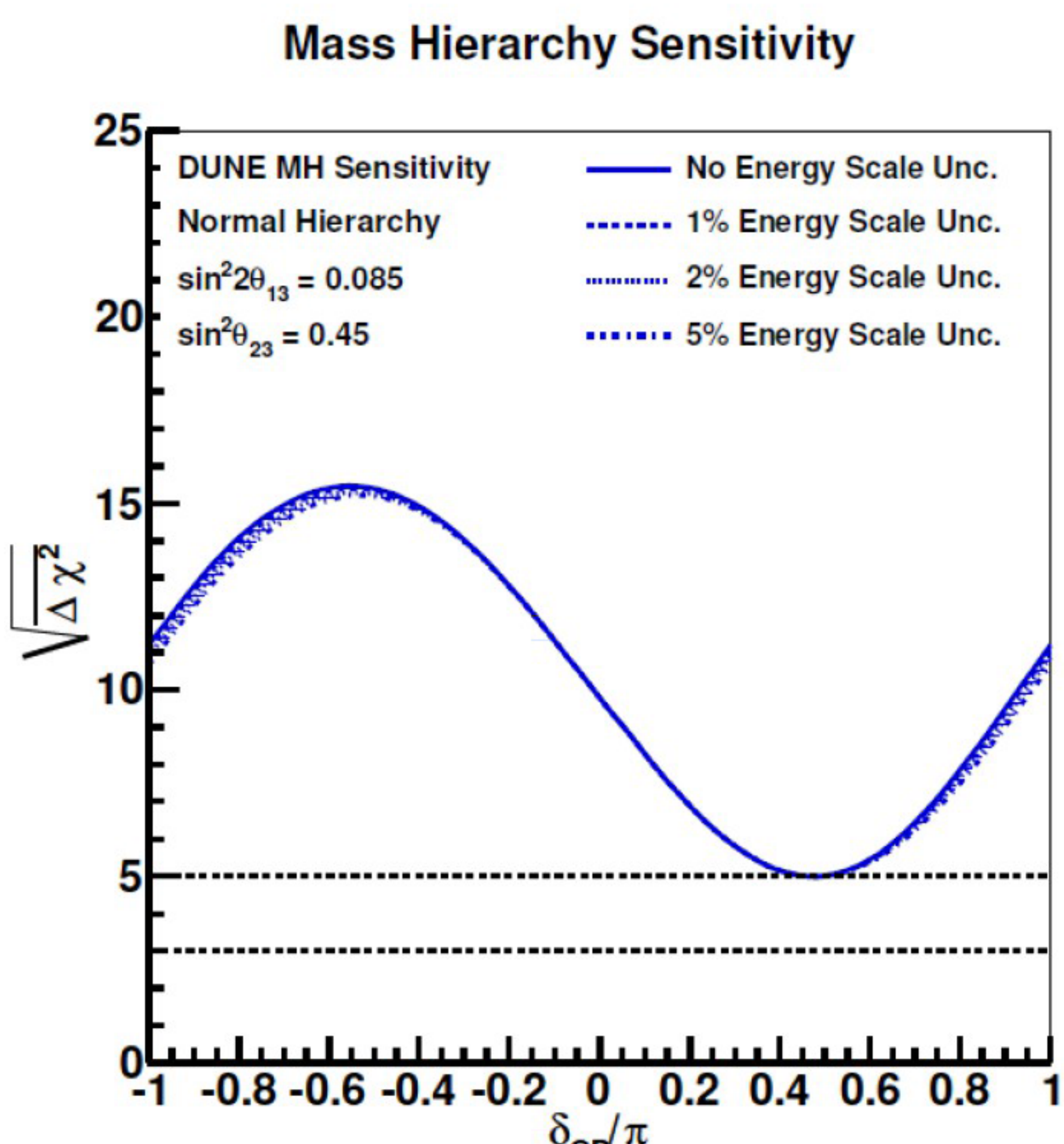


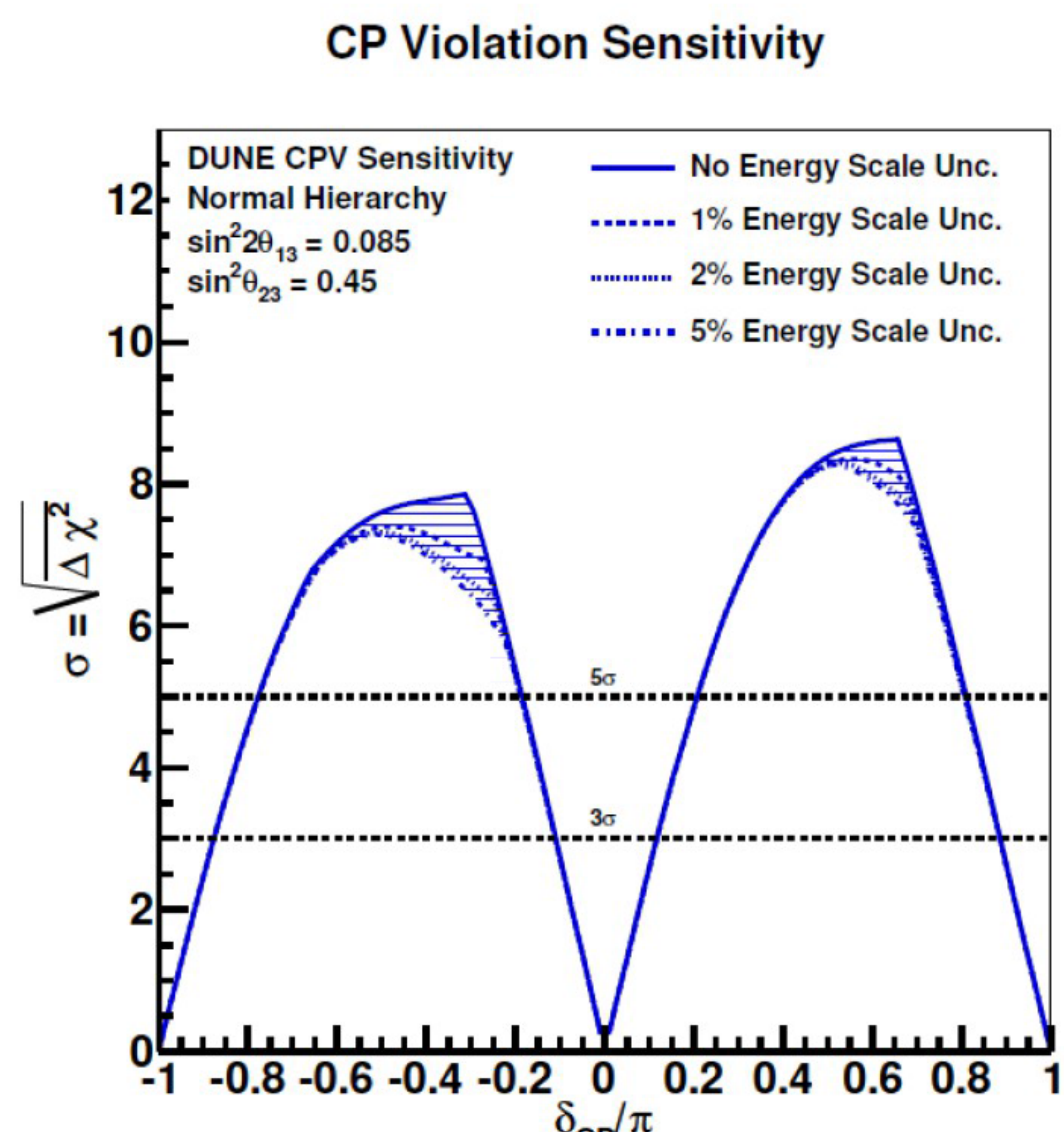
Not proven yet but possible to just use 8 feedthroughs for 60m;16 gives 16m crossing tracks (uB: 10m achieved)

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

Issue: Unprecedented Physics Requirements of DUNE

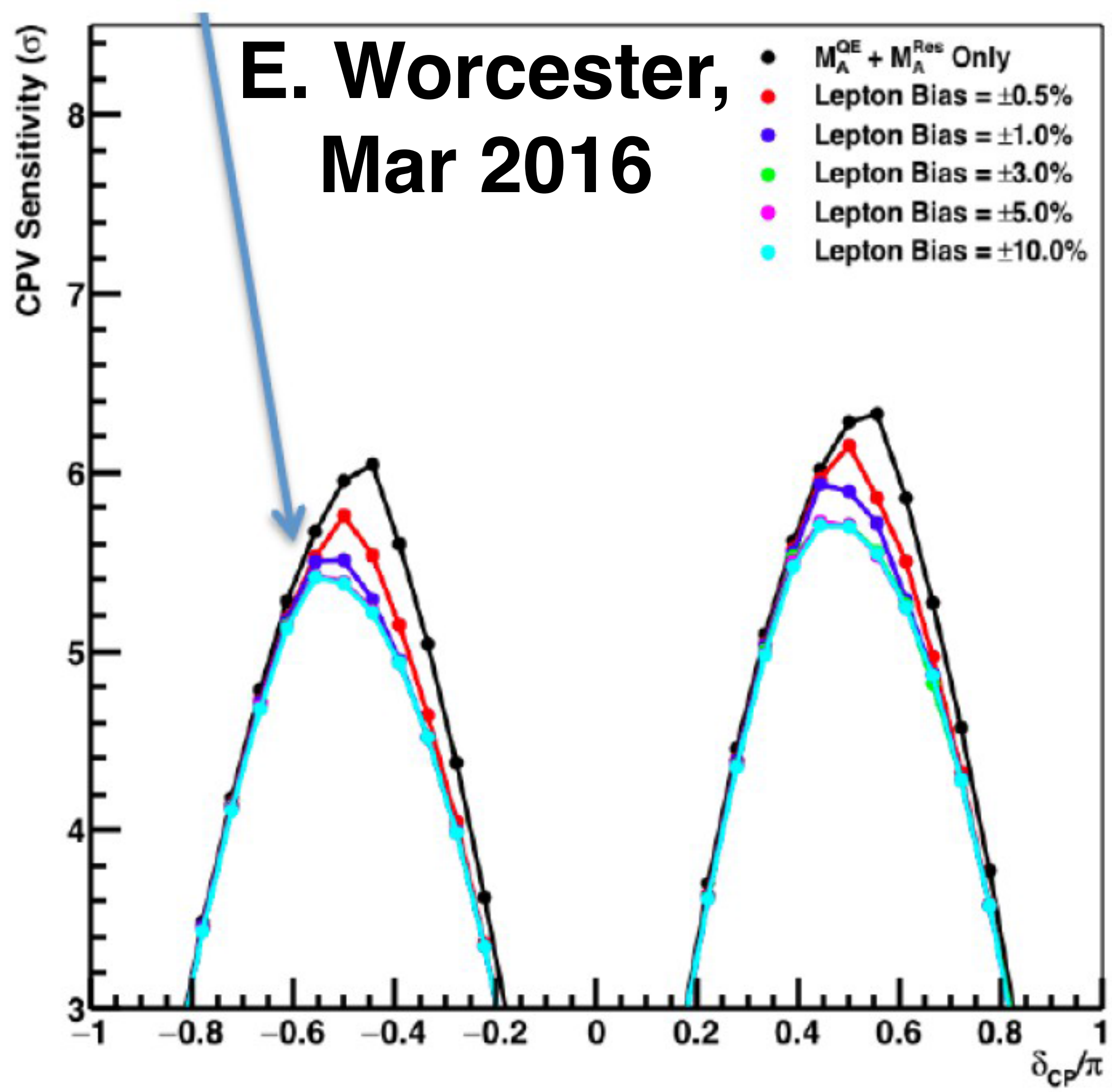
CDR: Uncertainty of 2% on energy scale is already important to physics goals; calibration must be <2%





Issue: Unprecedented Physics Requirements of DUNE

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



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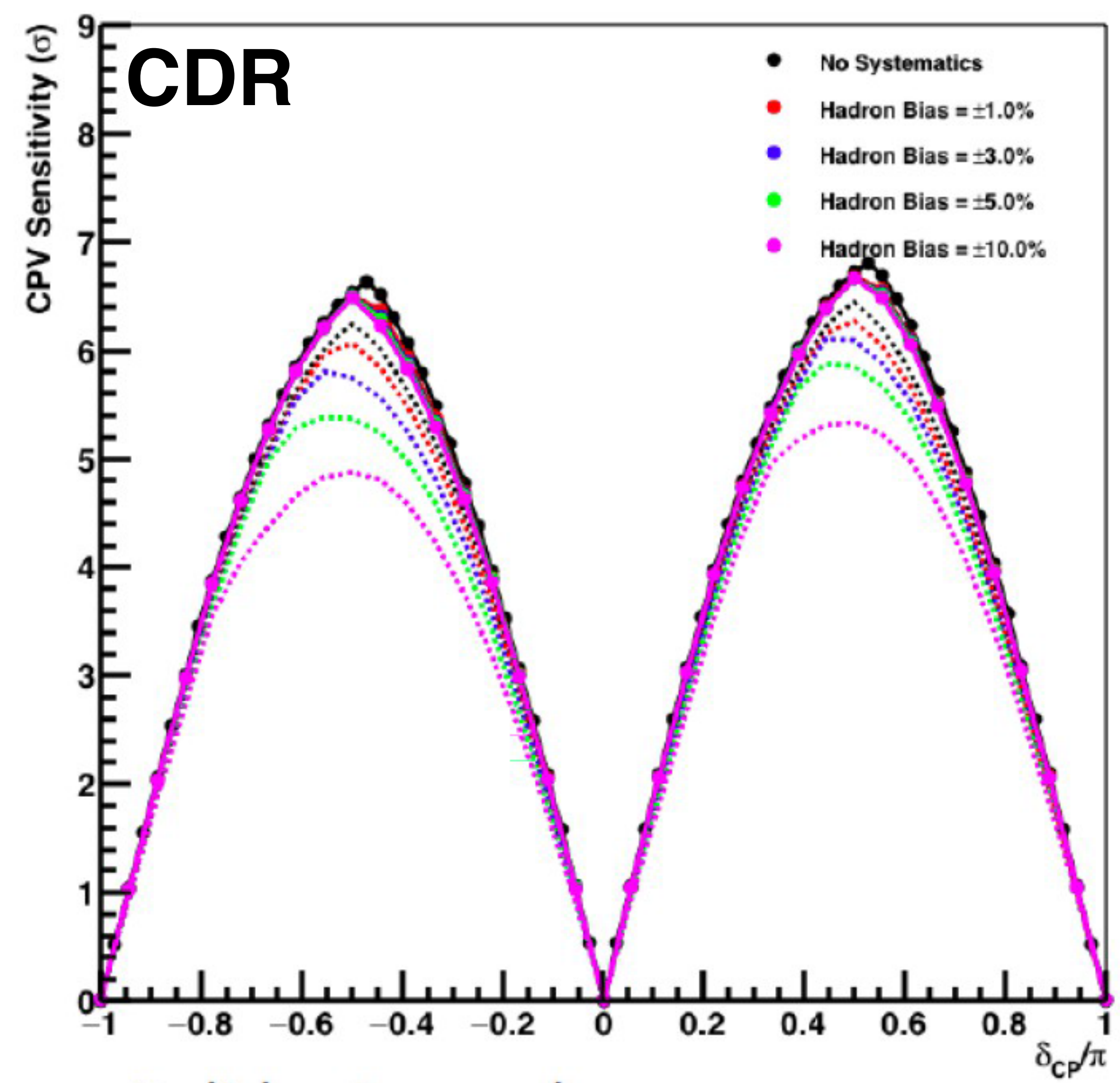

Solid = 4 sample

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