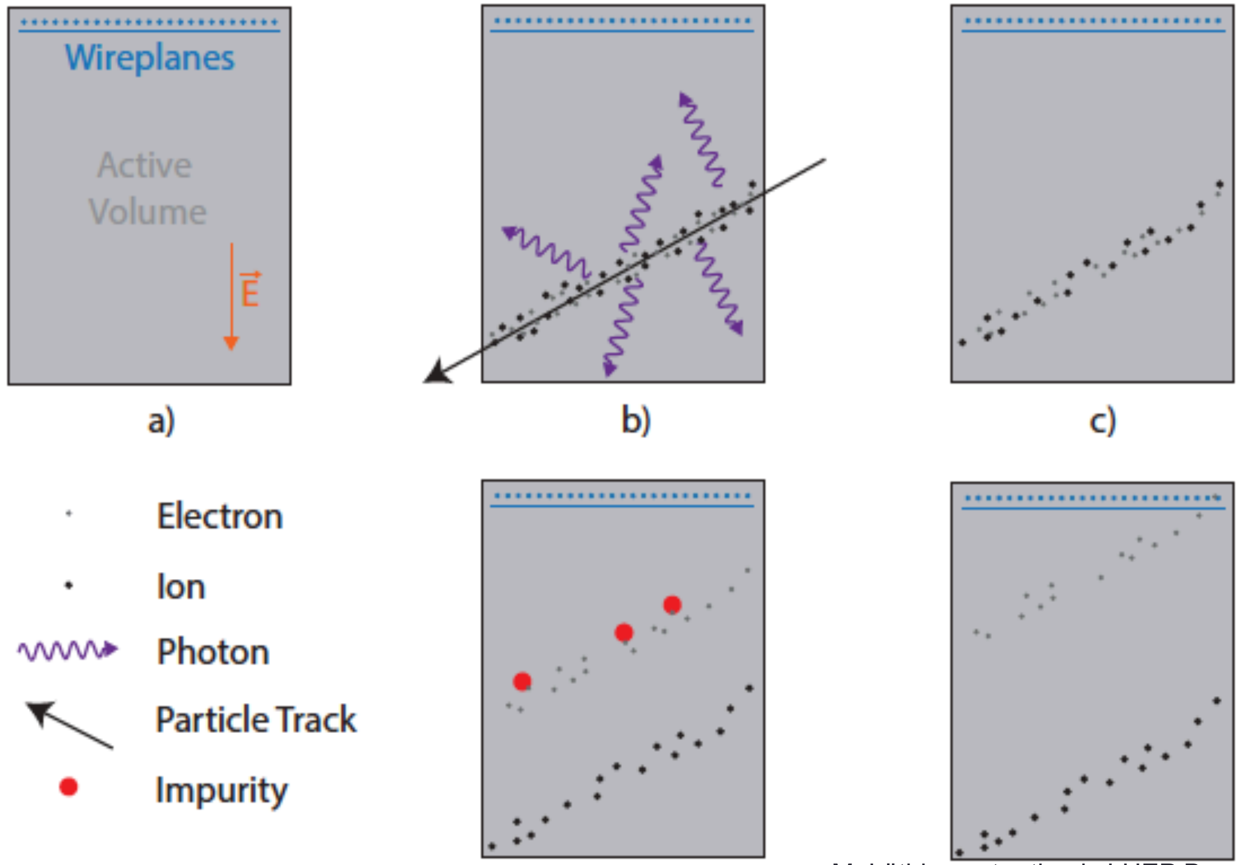
MICROBOONE CALIBRATIONS

Thomas Strauss
For the MicroBooNE experiment

LArTPC

- M.I.P. looses 2.1 MeV/cm
- Ionization
  - Electron-ion pairs
  - Mostly exited molecules
- Excitation
  - Light – see talk Ben Jones



M. Lüthi, master thesis LHEP Bern

- Ratio is given by
  Platzman equation*

$$W_i = E_i + \frac{N_{ex}}{N_i} E_{ex} + E_{se}$$

$$N_{ex}/N_i = 0.26$$

$$W_i = 23.452\,\mathrm{eV}$$

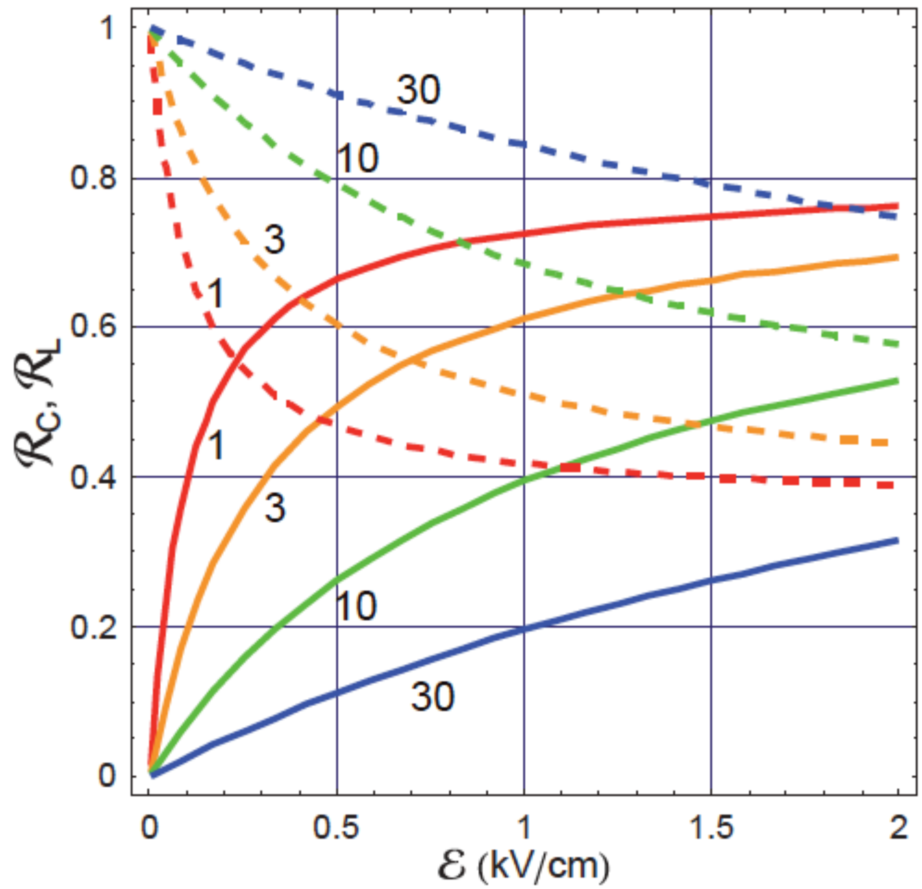
- Measured** $23.6^{+0.5}_{-0.3}\,\mathrm{eV}$

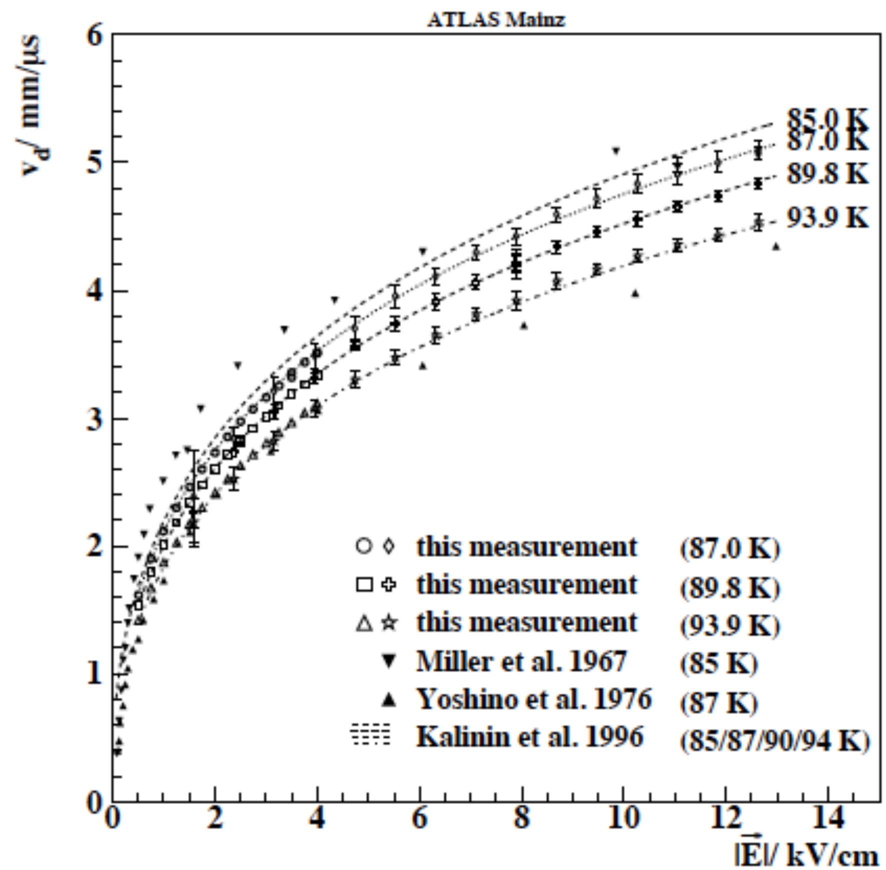
$$R_{Statistical} = \frac{FWHM}{E_0} = \frac{2.35 W_i \sqrt{FN}}{W_i N} = 2.35\sqrt{\frac{F}{N}} \approx 2.5\%.$$

$\mathrm{Ar} + \mathrm{P} \longrightarrow e^- + \mathrm{Ar}^+ + \mathrm{P}$	Ionization
$e^- + \mathrm{Ar} \longrightarrow e^- + \mathrm{Ar}^+ + e^-$	Successive ionization
$\mathrm{Ar}^+ + \mathrm{Ar} \longrightarrow \mathrm{Ar}_2^+$	Formation of excimer molecules
$\mathrm{Ar} + \mathrm{P} \longrightarrow \mathrm{Ar}^{**} + \mathrm{P}$	Excitation
$\mathrm{Ar}^{**} \longrightarrow \mathrm{Ar} + \gamma$	Deexcitation
$\mathrm{Ar}^{**} \longrightarrow \mathrm{Ar}$	Non−radiative relaxation

*The International Journal of Applied Radiation and Isotopes, 10(2{3):116{127, 1961; **Phys. Rev. A,9:1438{1443, Mar 1974; ***NuclearInstruments and Methods, 134(2):353 { 357, 1976

Extract charge





- Recombination (ratio light to charge) depends on applied drift field E

$$\frac{Q}{Q_0} = \frac{1}{\xi}\ln(1+\xi), \quad \xi = \frac{N_0 K_r}{4a^2 u\_E}$$

Image: MicroBooNE Document Database, #2009
Phys. Rev. A, 36:614-616, Jul 1987

- Electron drift speed depends on on applied drift field E and Temperature

$$\vec{v_d} = \mu(E_d, T) \cdot \vec{E}_d.$$

Image: ATL-LARG-99-008, CERN, Geneva, Jul 1999
Phys. Rev., 166:871-878, Feb 1968

Converting the charge to a signal

- Initial charge cloud disperse: Diffusion*

$$\frac{eD}{\mu} = f \cdot \langle E \rangle$$

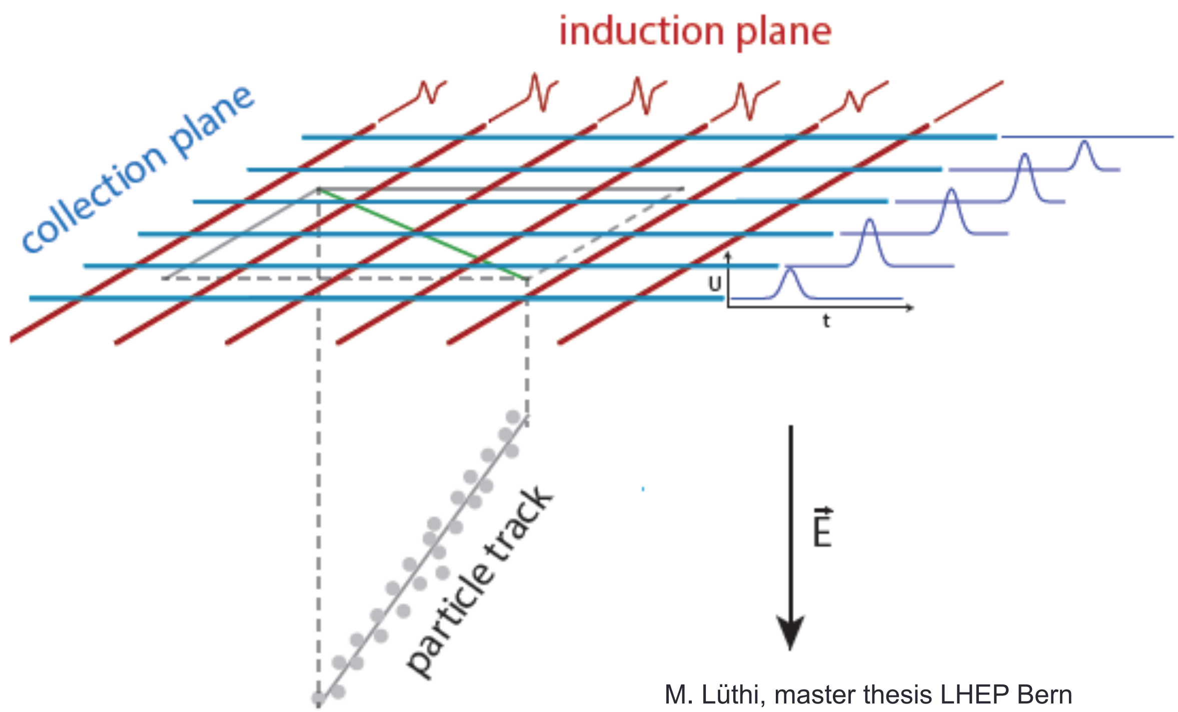
$$\sigma_{L,T} = \sqrt{2tD_{L,T}}$$

- Charge loss due to impurities**

$$N(t) = N_0 e^{-t/\tau_e}$$

$$\tau_e[\mu s] = \frac{300}{P_{O_2 equiv}[ppb]}$$

- Signal on wires
  - Induction
  - Collection



M. Lüthi, master thesis LHEP Bern

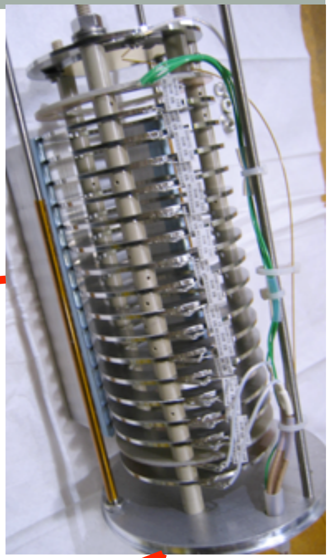
First we need to control:
drift field E, purity and temperature T

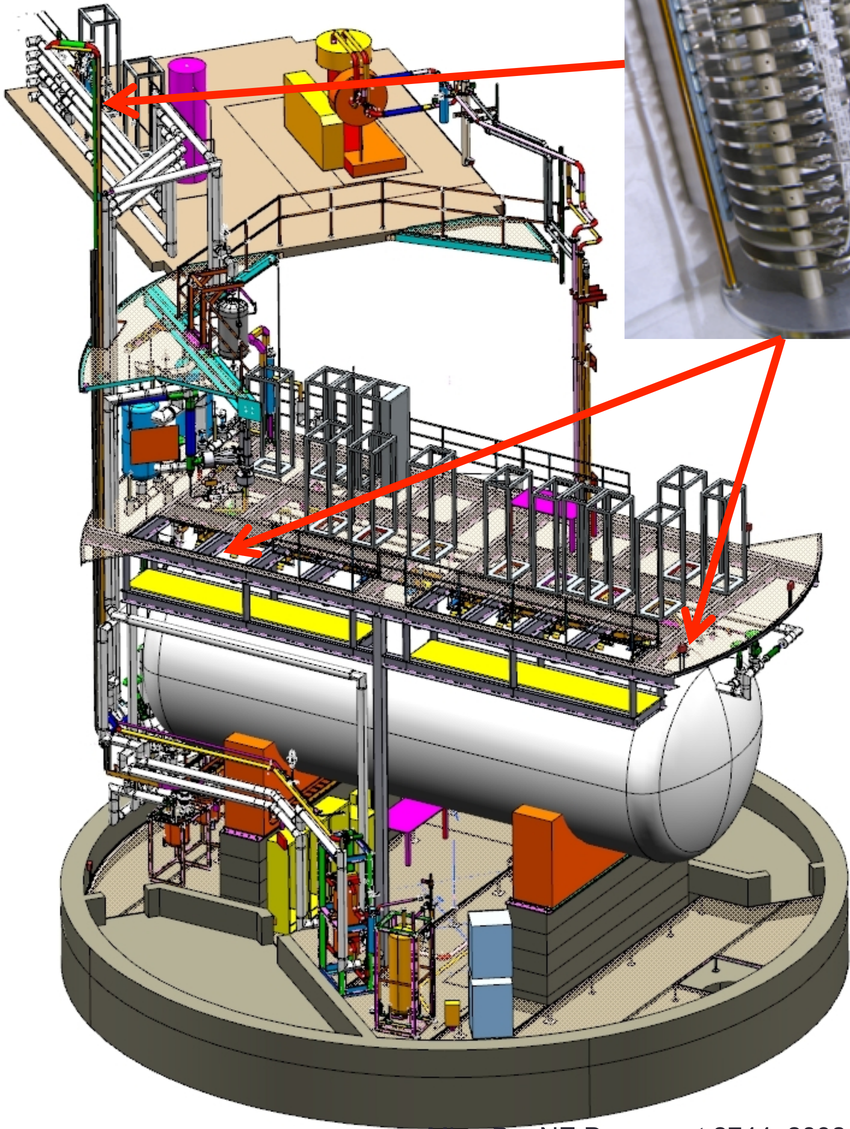
Only after this electronic readout gets involved

*Journal of Instrumentation, 8(04), 2013.
**Noble Gas Detectors. Wiley, 2006
**Nuclear Instruments and Methods, A275(2):364{372, 1989

Cryogenics and purity

- Specification:
  - Oxygen, water < 100ppt
  - Nitrogen level <2ppm
  - Temperature $\Delta T<0.1K$
  - Insulation $<15W/m^2$
- 3 purity monitors for LAr
  - 2 near the TPC volume
  - 1 after the filters
- 1 volume exchange per day
- Gas Purge before fill to remove impurities with 1vol. exch. per 4h
- Temperature probes:
  - GIC THERMODYNAMIC
  - RTD, Platinum 100 Ω,
  - 0.00385 Ω/K
  - $\Delta T<0.1\%$





MicroBooNE Document 2744, 2832, 2932

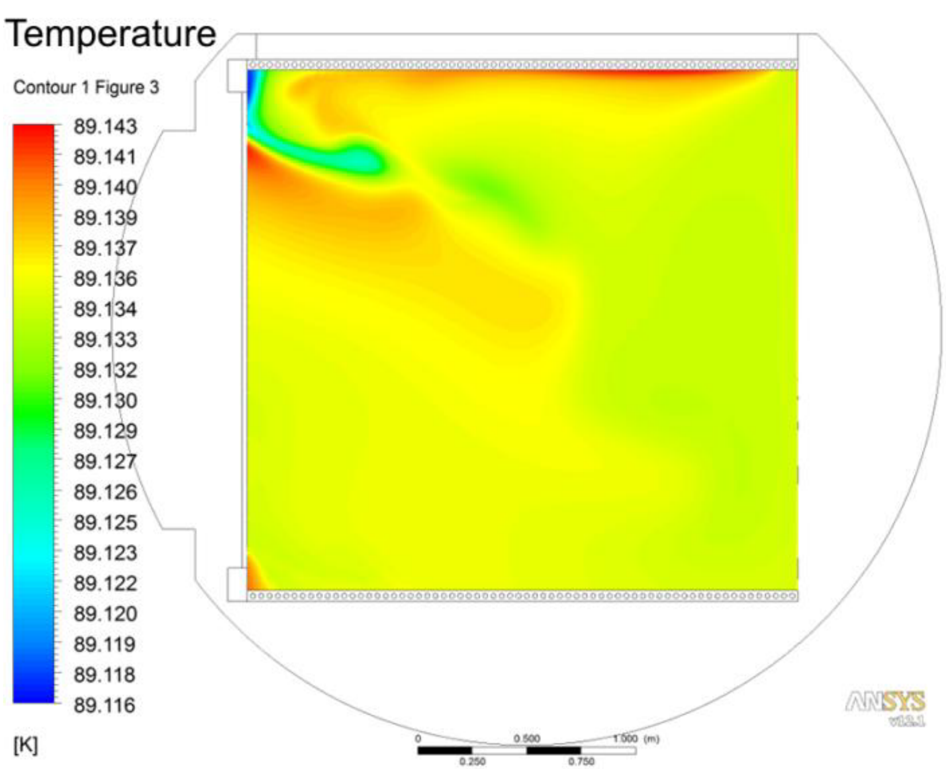
Purity – Gas analyzer

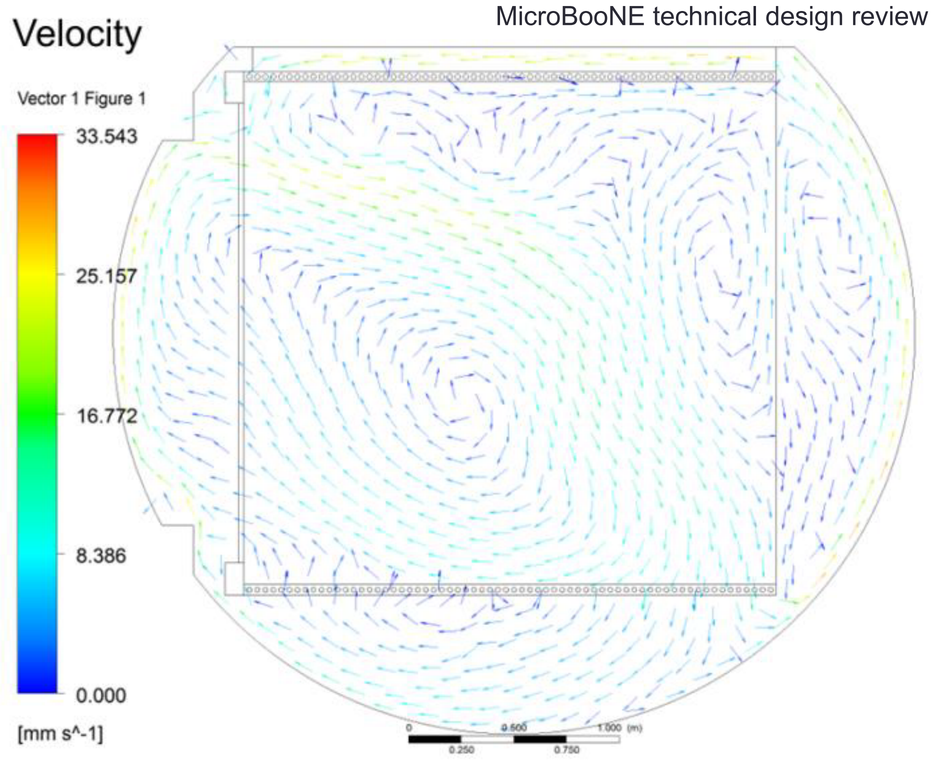
MicroBooNE Document 255, 869, 1565,2202, 2250, 2471

- Servomex DF-310E (O2 sensor).
  - Range: 0 - 500 ppm.
  - Accuracy: greater of +-0.02% range or +-3% reading.
- Servomex DF-560E (O2 sensor).
  - Range: 0 - 20 ppm.
  - Lowest Detection Level: 75 ppt.
- Tiger Optics Halo+ (H2O sensor)
  - Range: 0 - 20 ppm.
  - Lowest Detection Level: 2 ppb.
  - Sensitivity: +-1 ppb.
  - Accuracy: greater of 4% reading or +-1 ppb.
- LDetek LD8000 (N2 analyzer)
  - 0 – 10 ppm, resolution to .1 ppm
  - Accuracy: better than +-1% full scale.
- Actual physics data will allow to measure purity too much better accuracy, but "blind" to source of impurity

Temperature

- Extended ANSYS simulation for technical design review
- Temperature stable <0.1K,
- Heaters on vessel to ensure uniformity
- Spread in drift speed from 0.04-0.002%

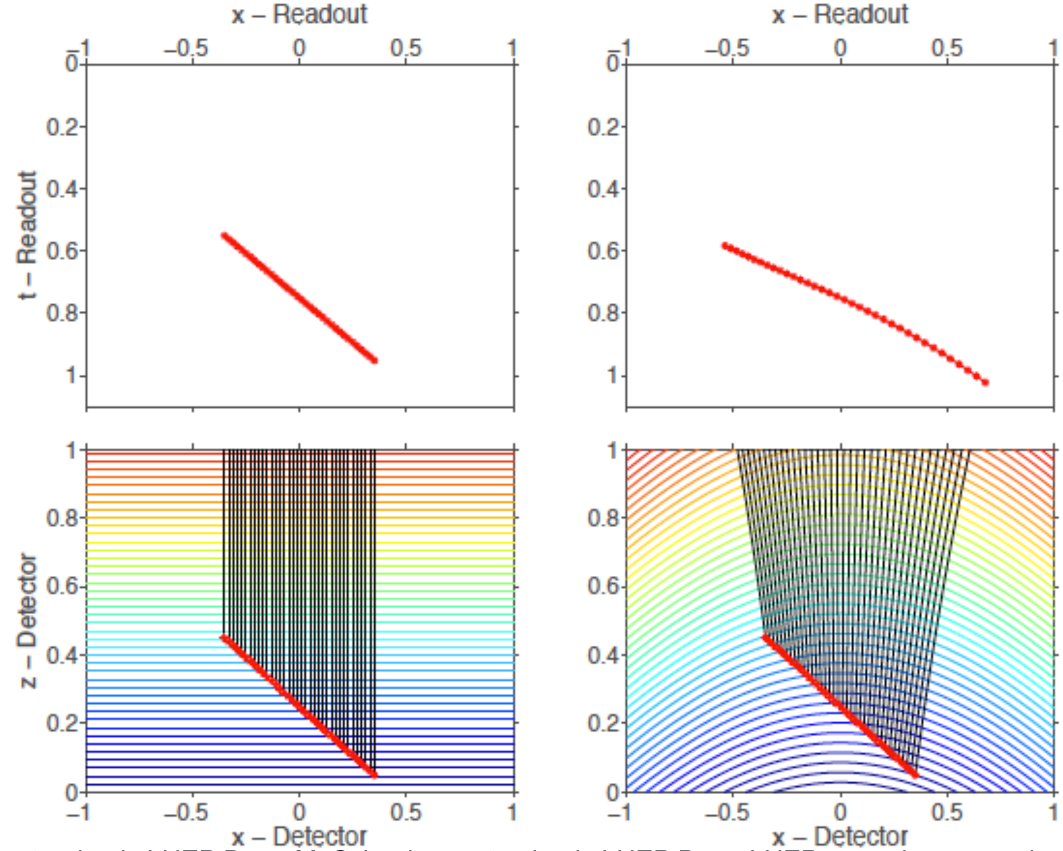




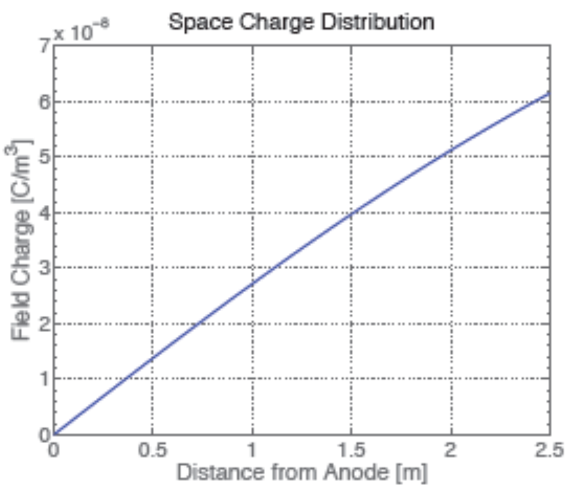
MicroBooNE technical design review

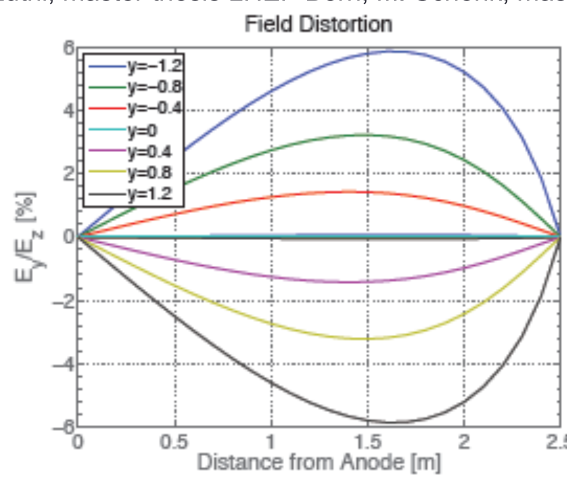
Drift field

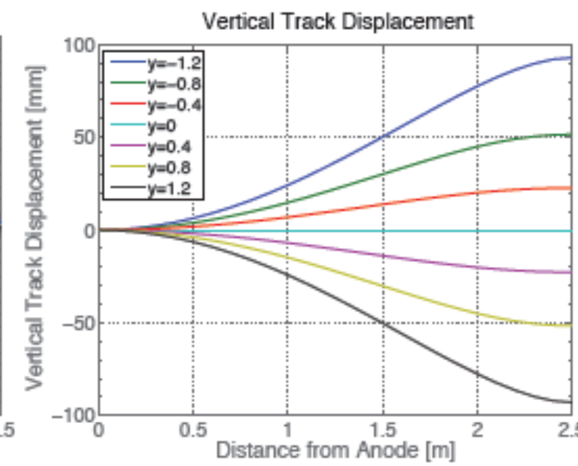
- Field distortion can lead to ‘bend’ tracks
  - Surface location leads to abundance of ions drifting 10^5 slower than e^-
  - HV chain resistance misalignment



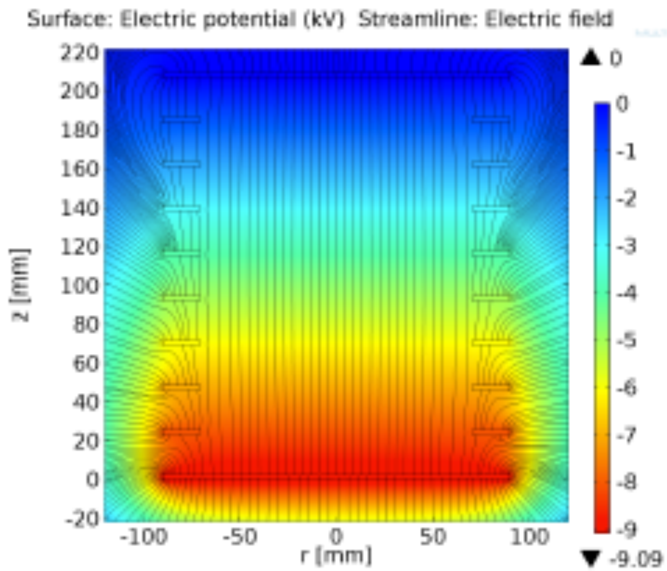
M. Lüthi, master thesis LHEP Bern, M. Schenk, master thesis LHEP Bern, LHEP paper in preparation

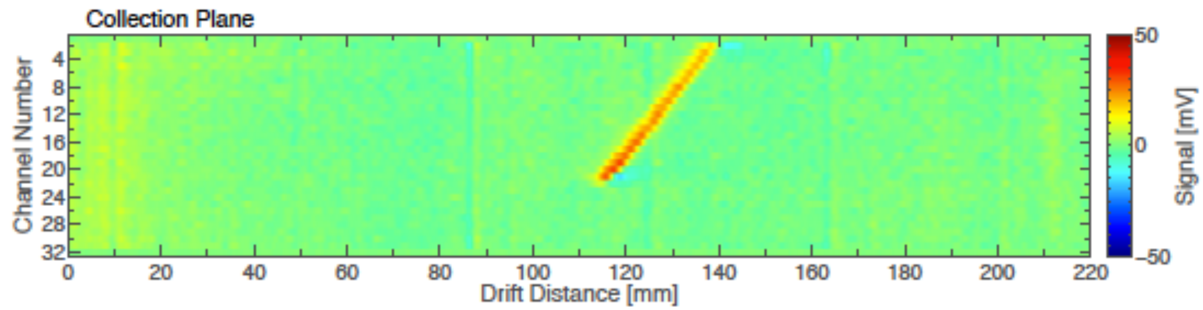






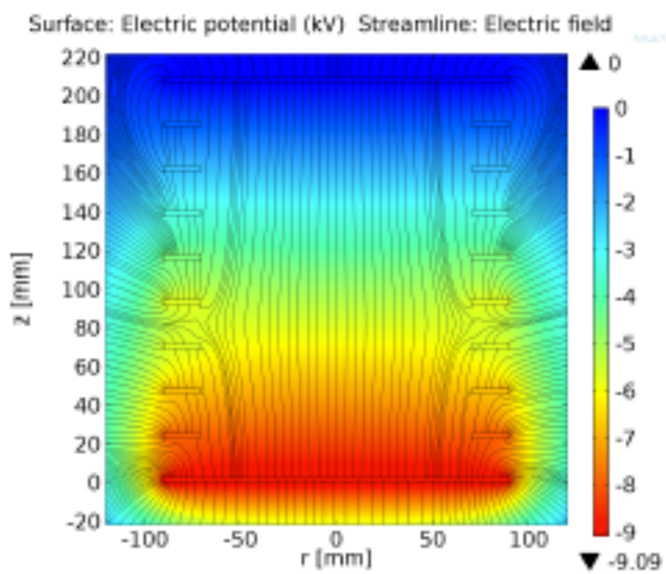
Field inhomogeneity's

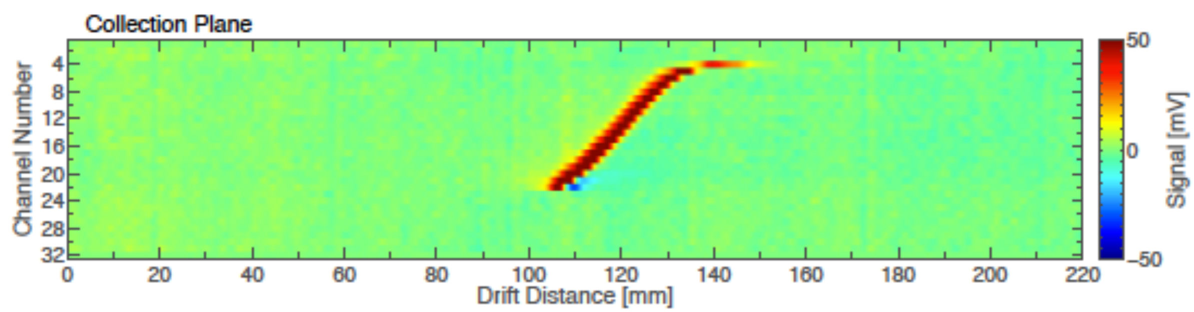


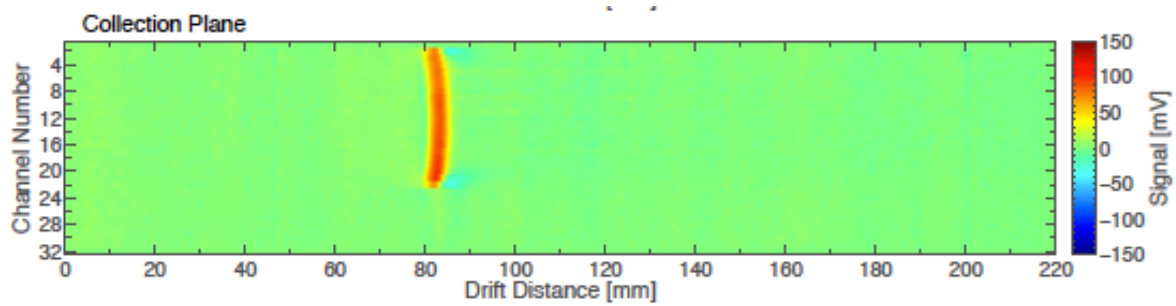


- Track distortion in a controlled way demonstrates the effect of ‘bend’

M. Lüthi, master thesis LHEP Bern

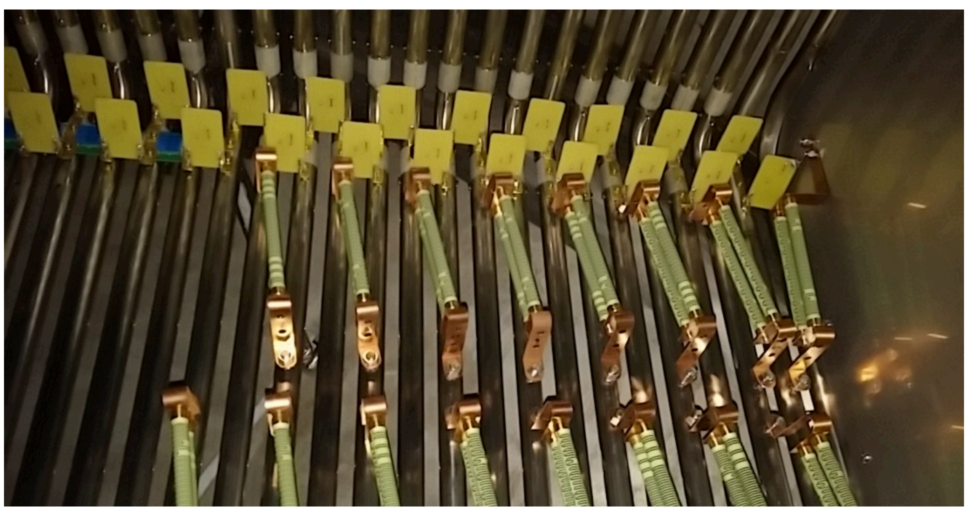


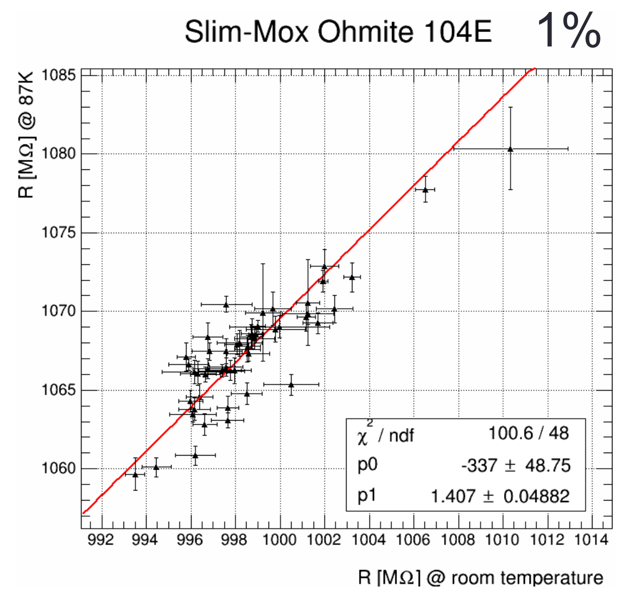


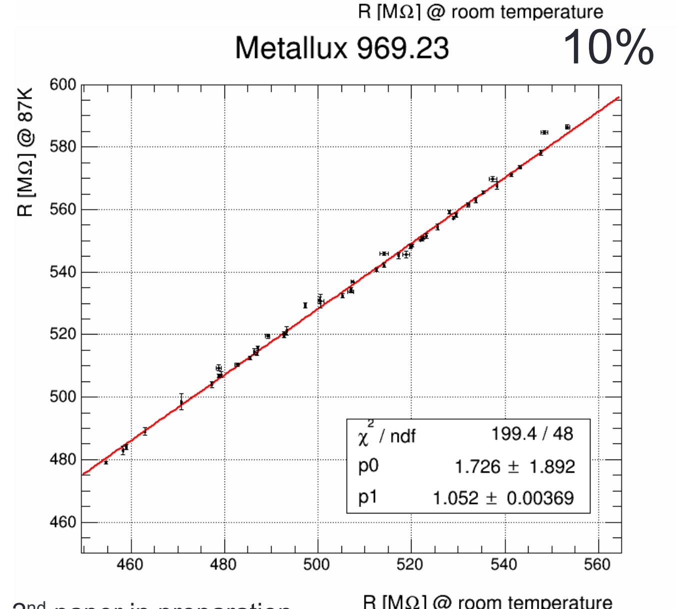


Electric Field – High voltage divider

- Precise study of the resistor chain and its components
- 2 resistor types, one for high, one for low absolute field areas



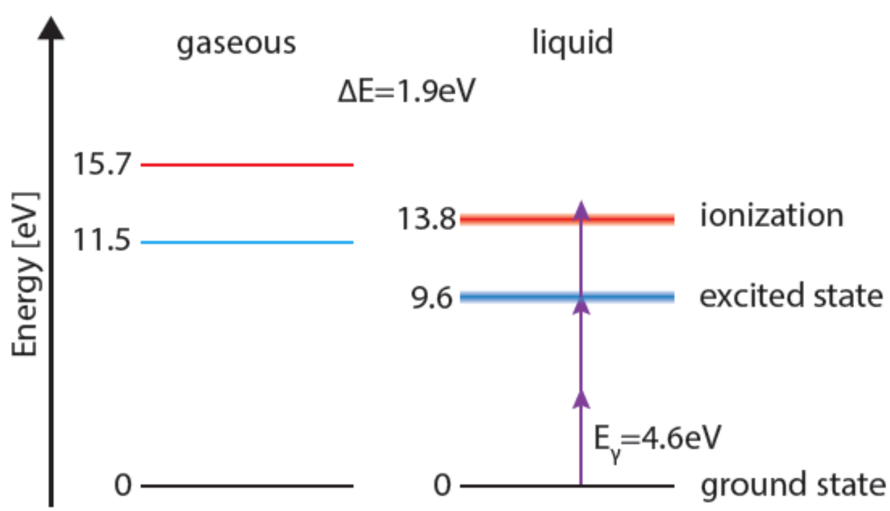


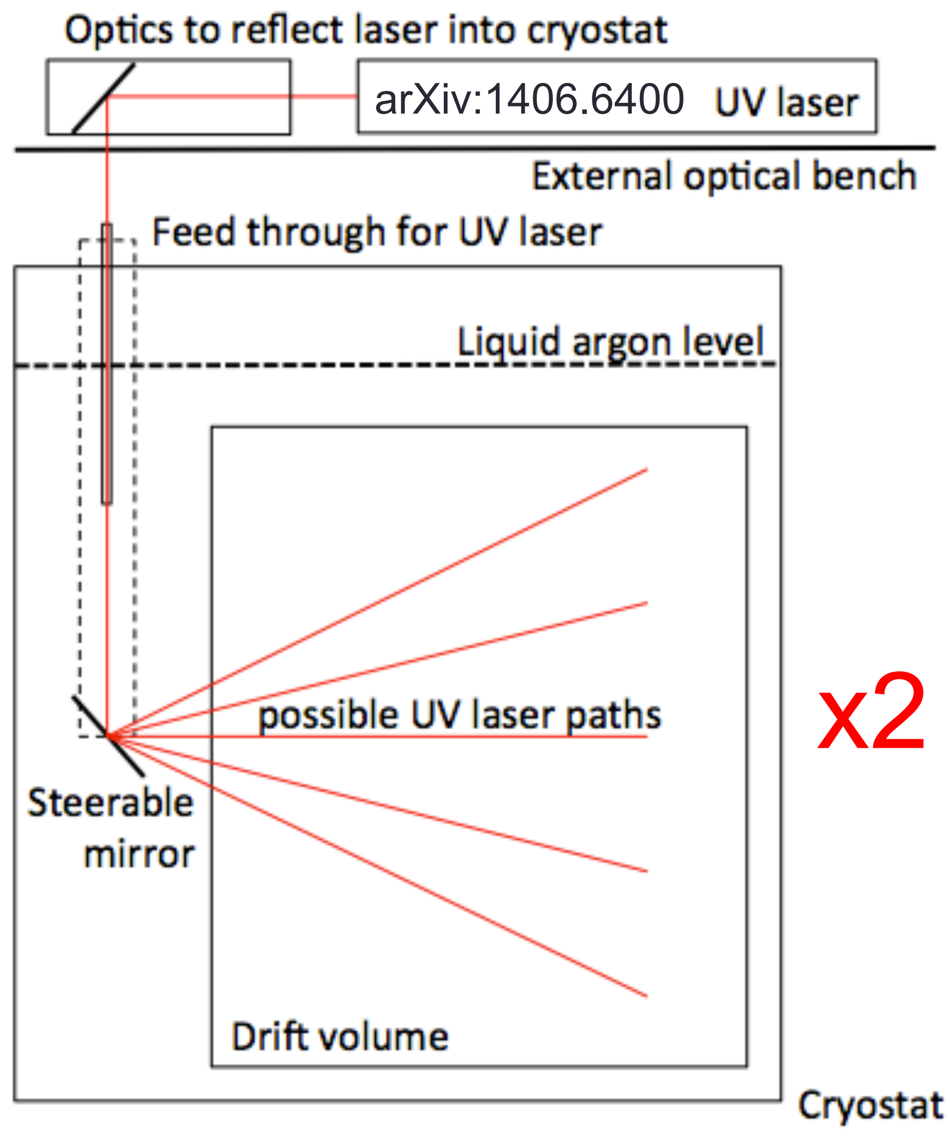


arXiv:1406.5216 + 2nd paper in preparation

Space charge - Drift field calibration with an UV laser

- Space charge will be present
- A 266nm UV laser can be used to ionize liquid argon
- Send laser along different paths to map the drift field from both detector ends

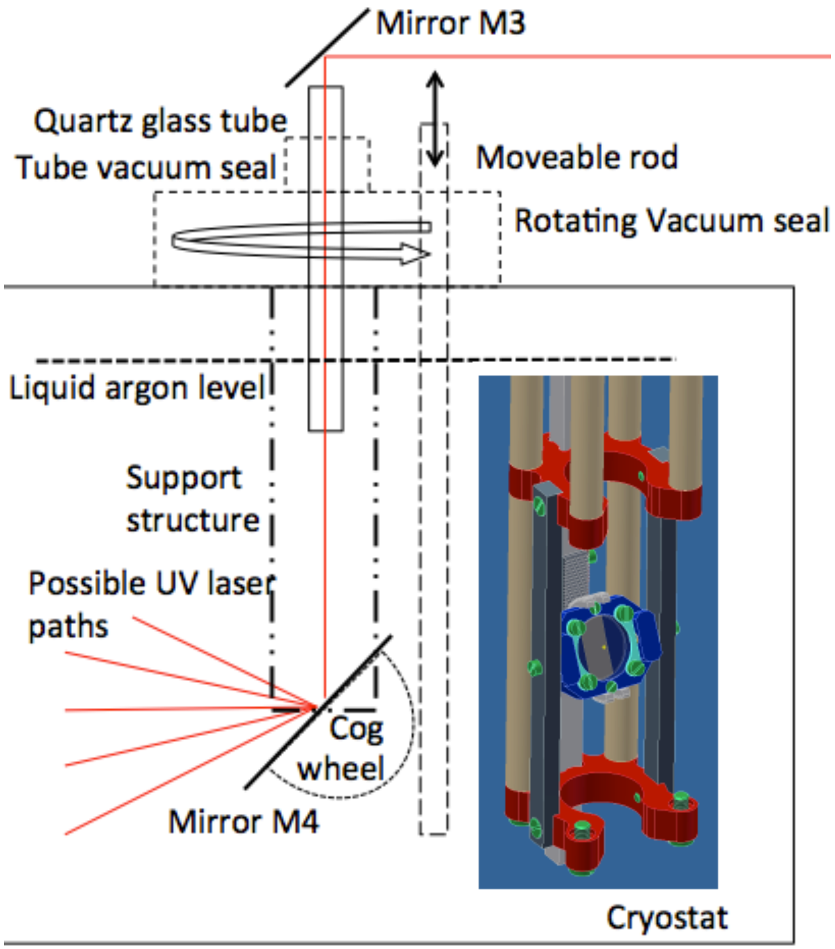


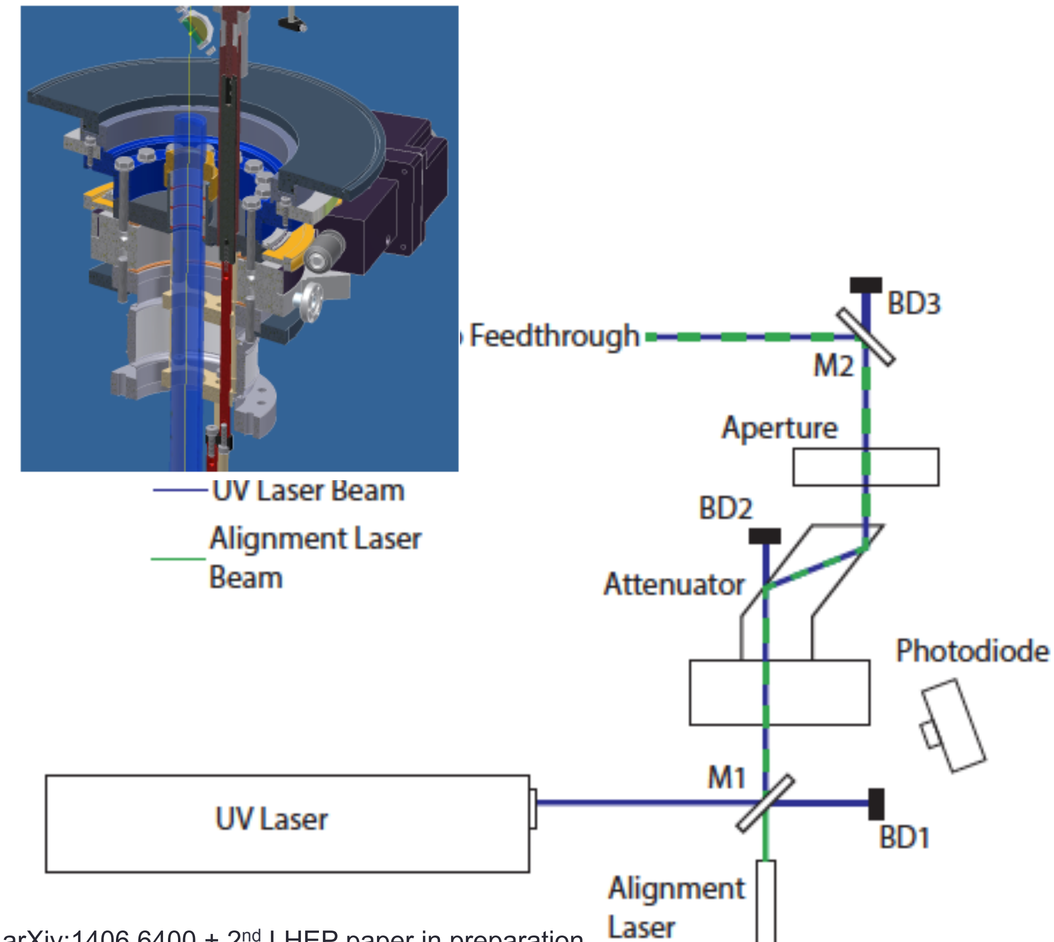


x2

UV laser calibration system

- Automatic system, remote control adjustment for position and UV laser energy, provides trigger to the DAQ



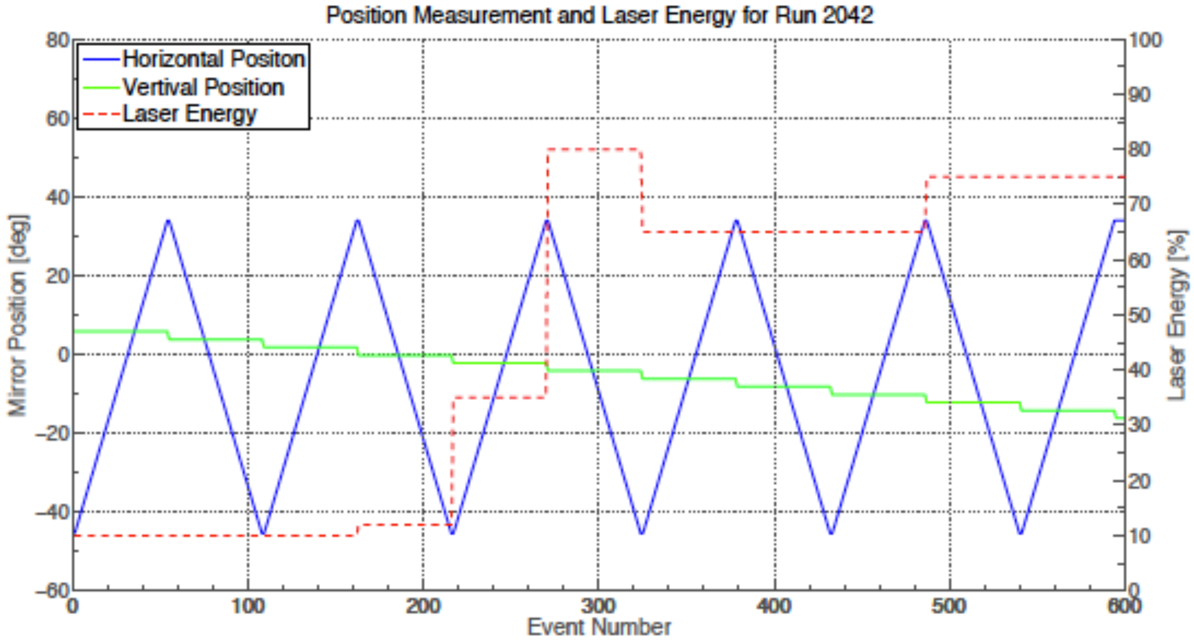


arXiv:1406.6400 + 2nd LHEP paper in preparation

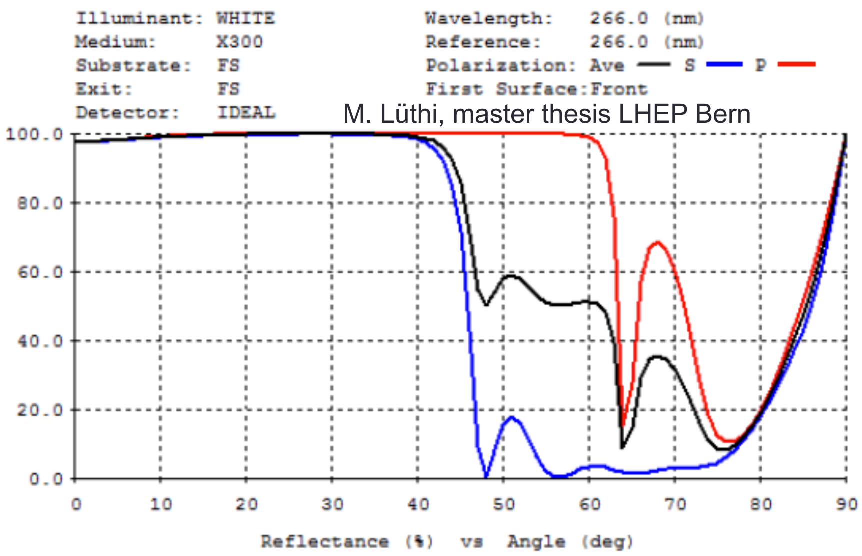
UV calibration system

- Ready for installation, one operating for DAQ tests at DAB

Results from the UV laser system



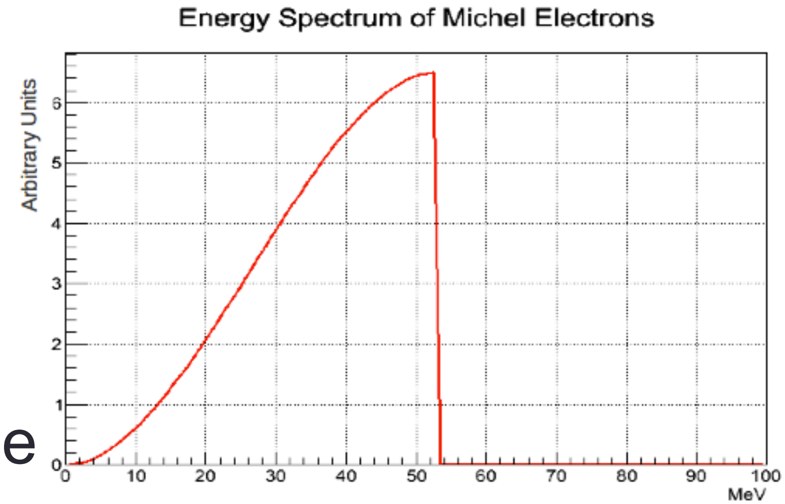
- Automatic position and DAQ readout tested in LHEP Bern
- Modulation of beam intensity depending on mirror position



M. Lüthi, master thesis LHEP Bern

Cosmic Rays – a tool for calibration

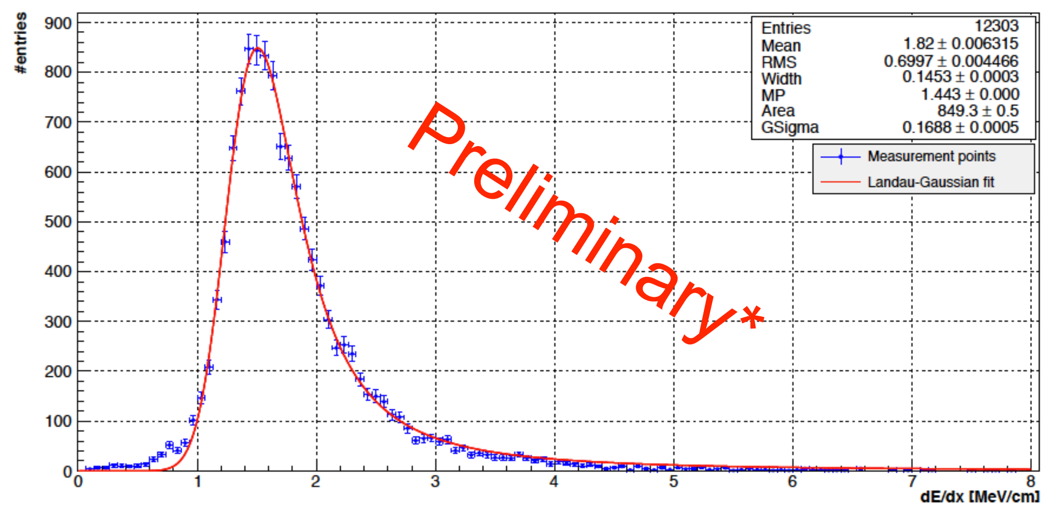
- Many different studies
- Rate
- Energy distribution – Landau shape
- Stopping muons
- Michel electrons



	Detector Rate (s^{-1})	Simulation Rate (s^{-1})
Total Rate	10.21 ± 0.01	9.63 ± 0.04
Vertical Rate	2.73 ± 0.01	1.99 ± 0.02
Diagonal Rate	0.717 ± 0.003	0.87 ± 0.01

Errors are statistical only

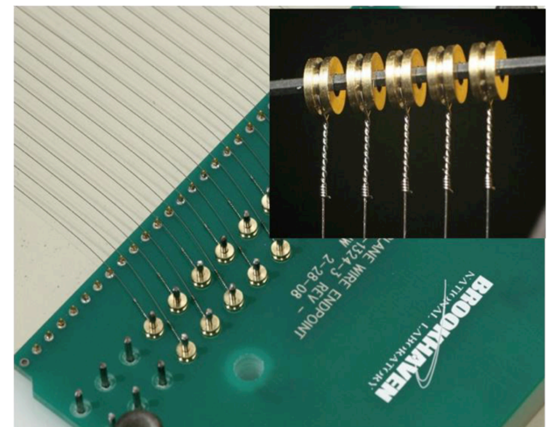
Cosmic-muon rate from Monte Carlo:
3.72 ± 0.01 kHz (stat. error only)
~6 per 1.6-ms readout frame
(~18 muons/event)

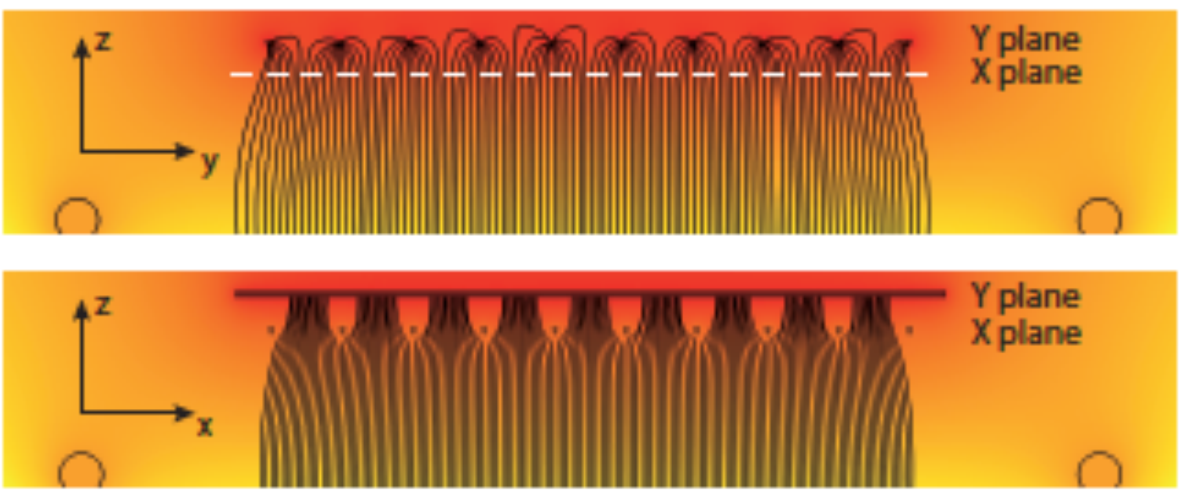


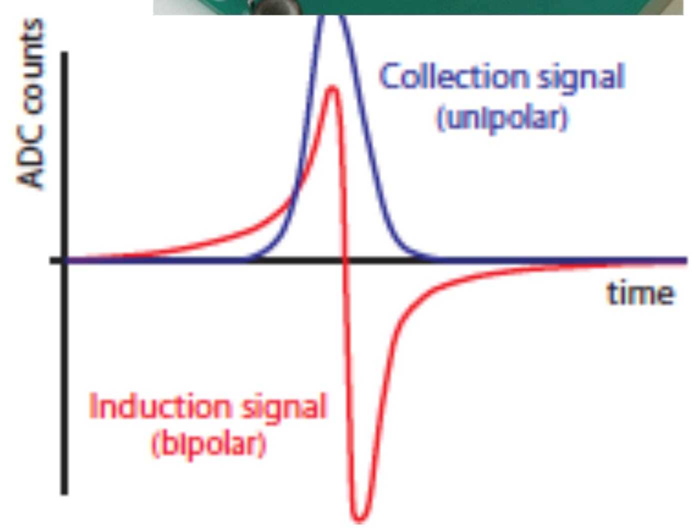
MicroBooNE Document 2374, 2570, 2805, 2806, 2591,3130, 3341, 3474, 3413, 3484, *LHEP paper in preparation

Moving to the readout

- Charge arriving on the sensing readout wires creates either a induction or a collection signal
  - 3 planes, 2400 + 2400 induction, 3456 collection
  - 150μm thick copper/gold plated stainless steel
- Wire distances determines resolution:
  - 3mm, <1mm error for 2m drift



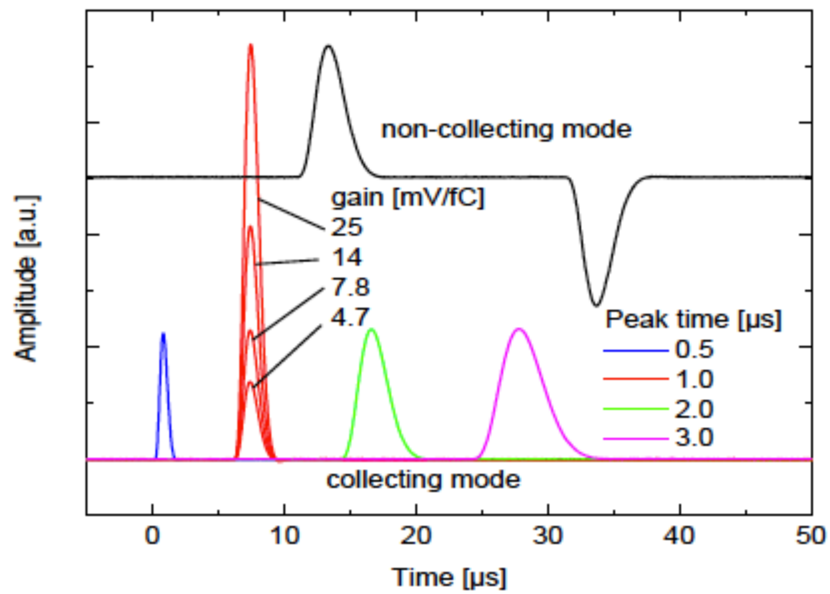




M. Schenk, master thesis, LHEP Bern, MicroBooNE Technical design review

Readout Electronics calibrations

- What we want to measure:
  - Baseline
  - Noise
  - Electronics crosstalk
  - Gain and linearity
  - Signal shape/rising time

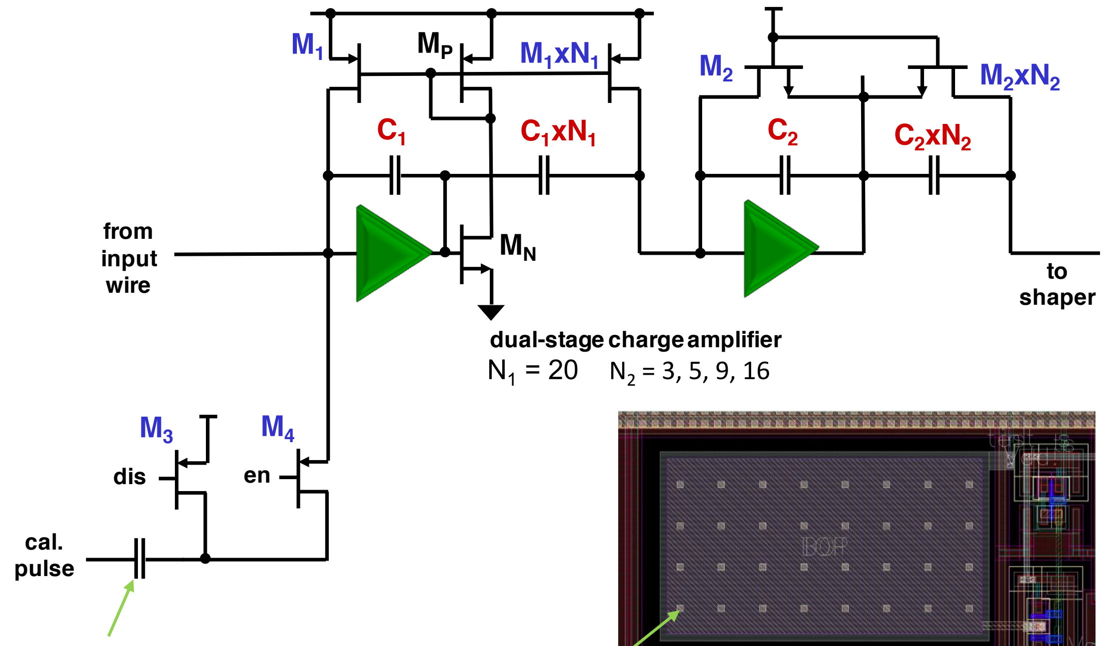


- Ideally, have these values on full vertical slice of readout
  - Wire→cold electronics→cold cable→feedthrough→warm electronics→digitization

Physics Procedia 37 (2012) 1295 – 130

MicroBooNE Cold Electronics Design

Cold Electronics ASIC - Front-End Detail and Calibration Scheme



$C_{INJ} \approx 180$ fF

Integrated injection capacitance (10 x 18 μm²)

Measured with high-precision external capacitance

$$C_{INJ} \approx \begin{cases} 184\ fF & at\ 300K \\ 183\ fF & at\ 77K \end{cases}$$

Charge sensitivity calibration of TPC during assembly, cooling and operation

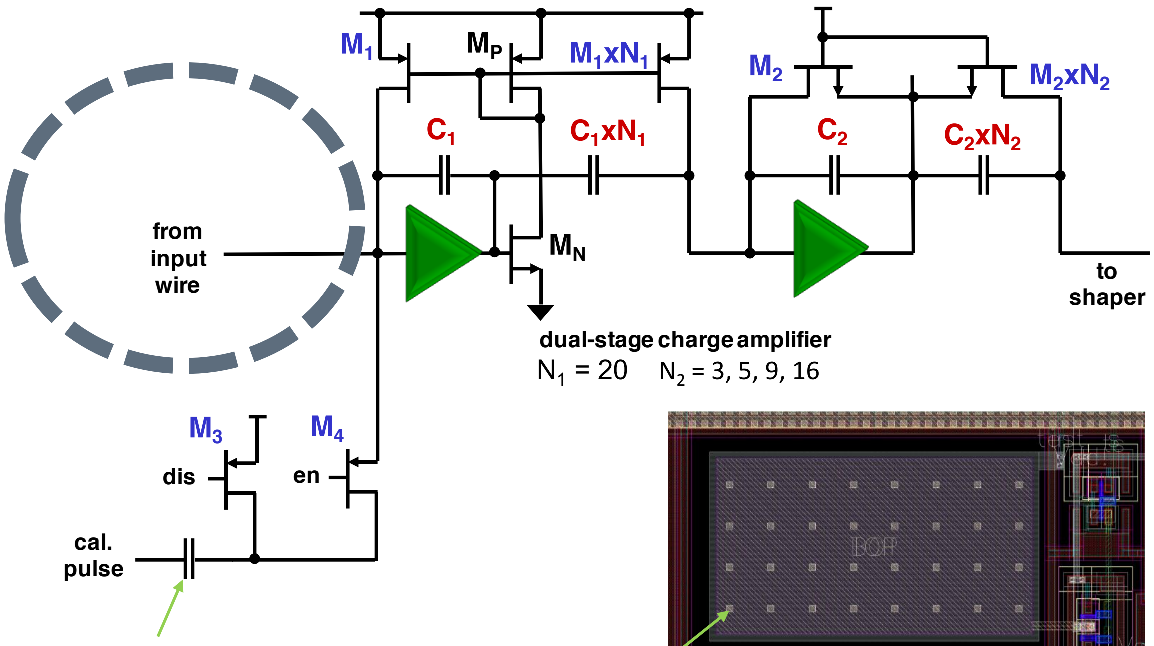
From H. Chen (BNL) – March 2013, LArTPC workshop

Physics Procedia 37 (2012) 1295 – 130

MicroBooNE Cold Electronics Design

Wire input path

Cold Electronics ASIC - Front-End Detail and Calibration Scheme



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MicroBooNE Cold Electronics Design

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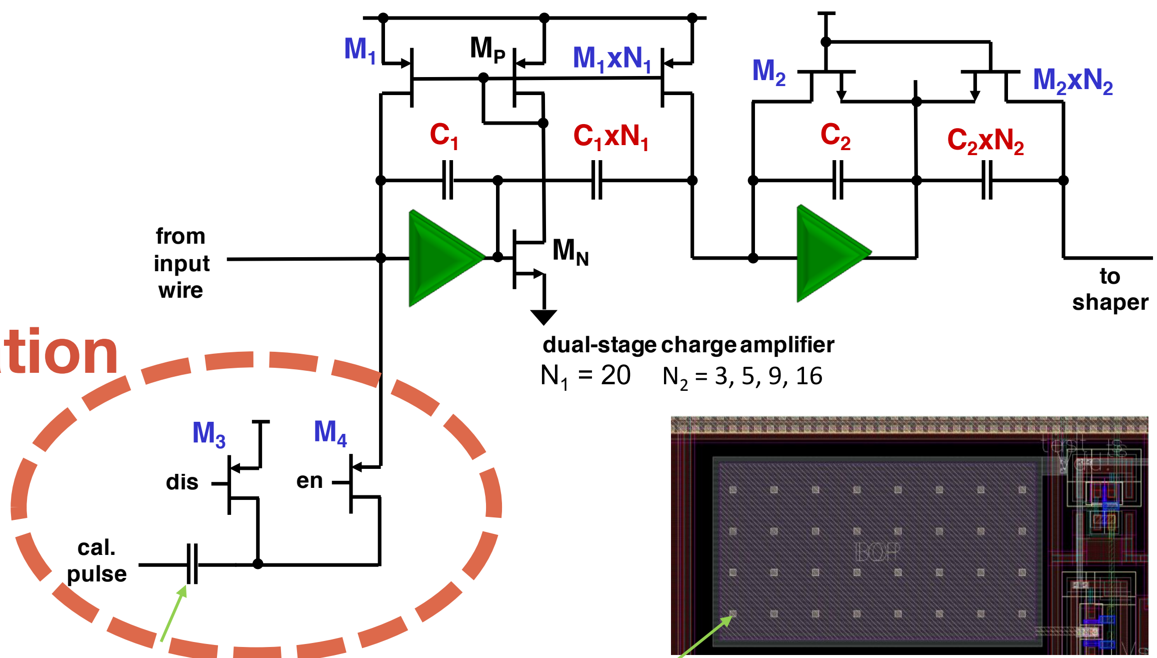
Calibration path



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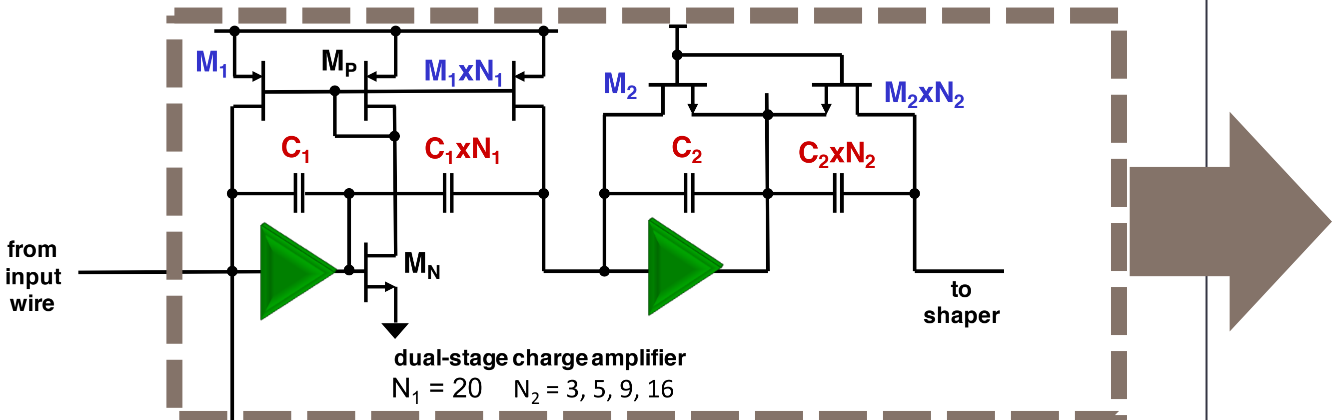


Can use injected calibration pulse to characterize the cold ASIC behavior, and all downstream readout components!

Signal processing

- Amplification
- Shaping

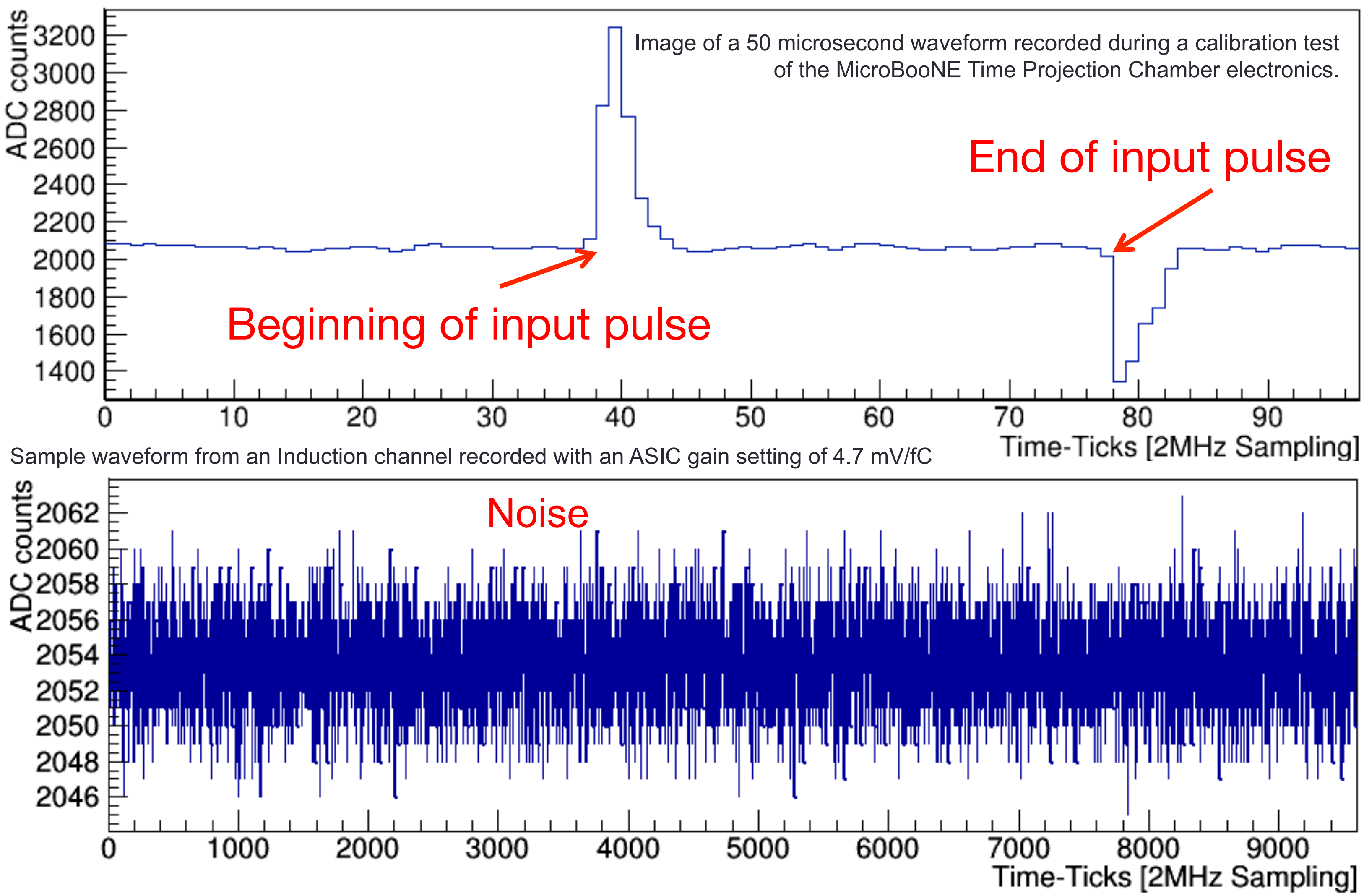
…and all the way down the readout chain!

g and operation

From H. Chen (BNL)

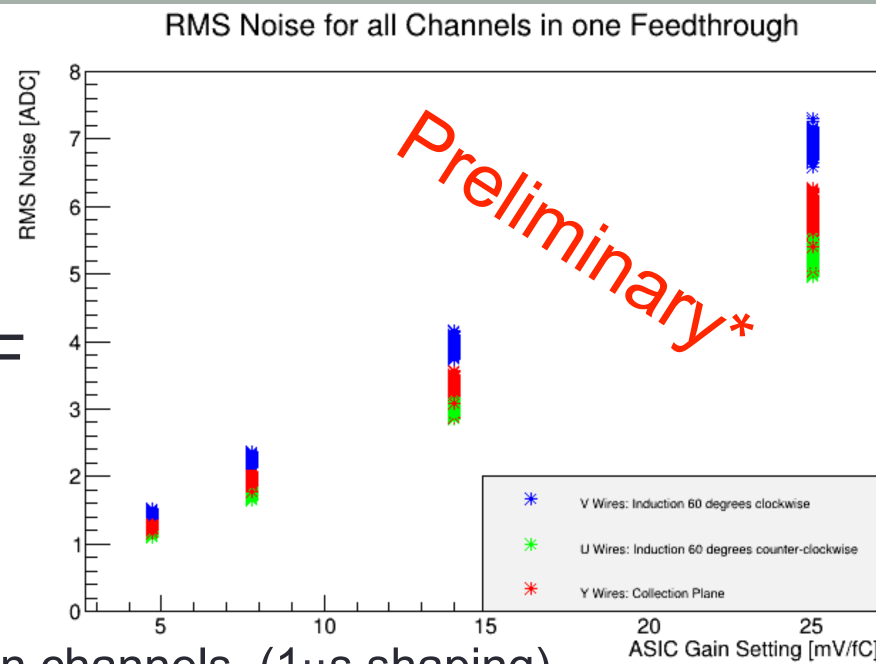
Sample pulse

Input: 20 μs square wave (very sharp rise & fall)

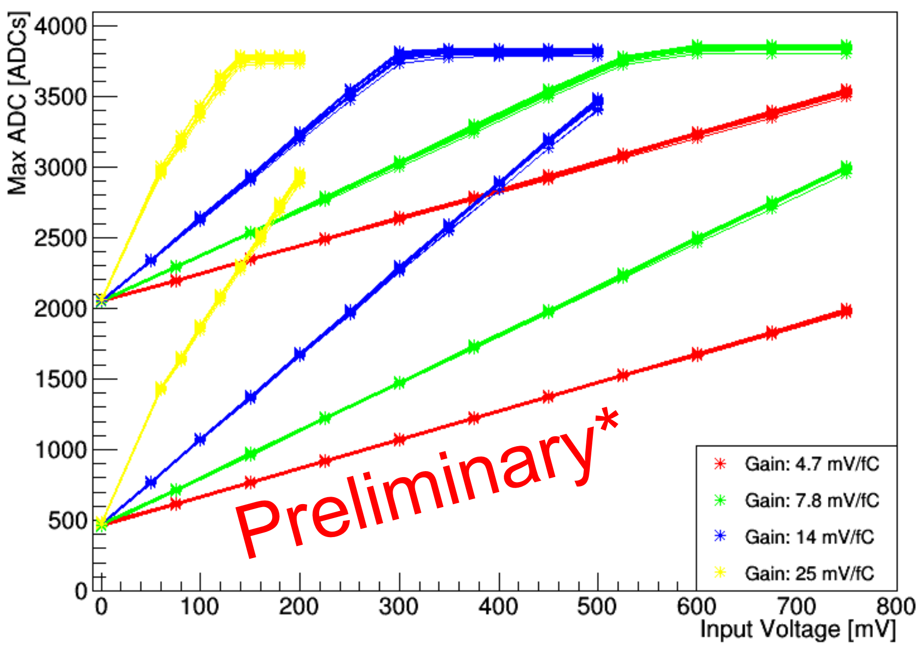


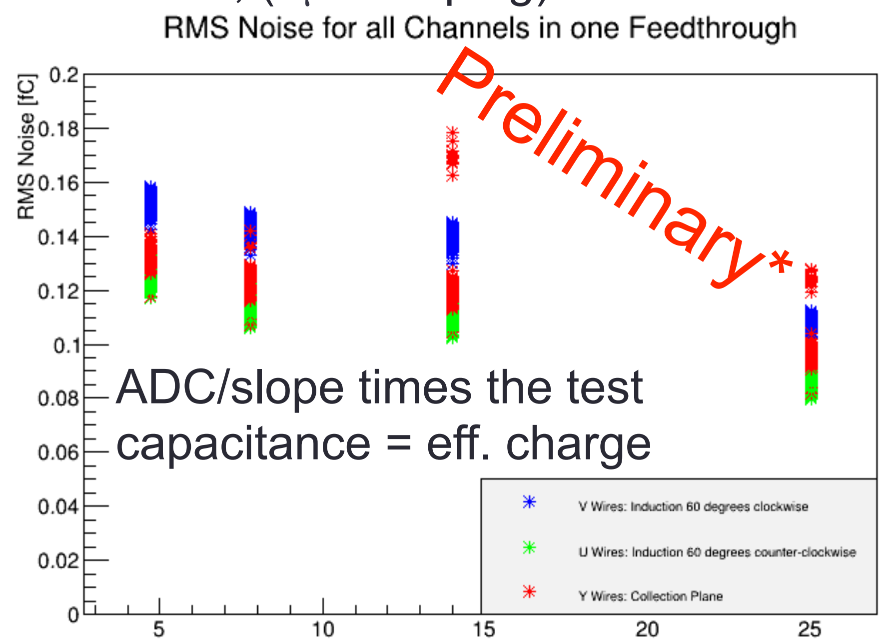
Preliminary results

- One of the ten feedtroughs after detector move to LArTF
- We expect to gain a factor 2-3 in noise reduction by cooling down



32 induction, 32 collection channels, (1μs shaping)





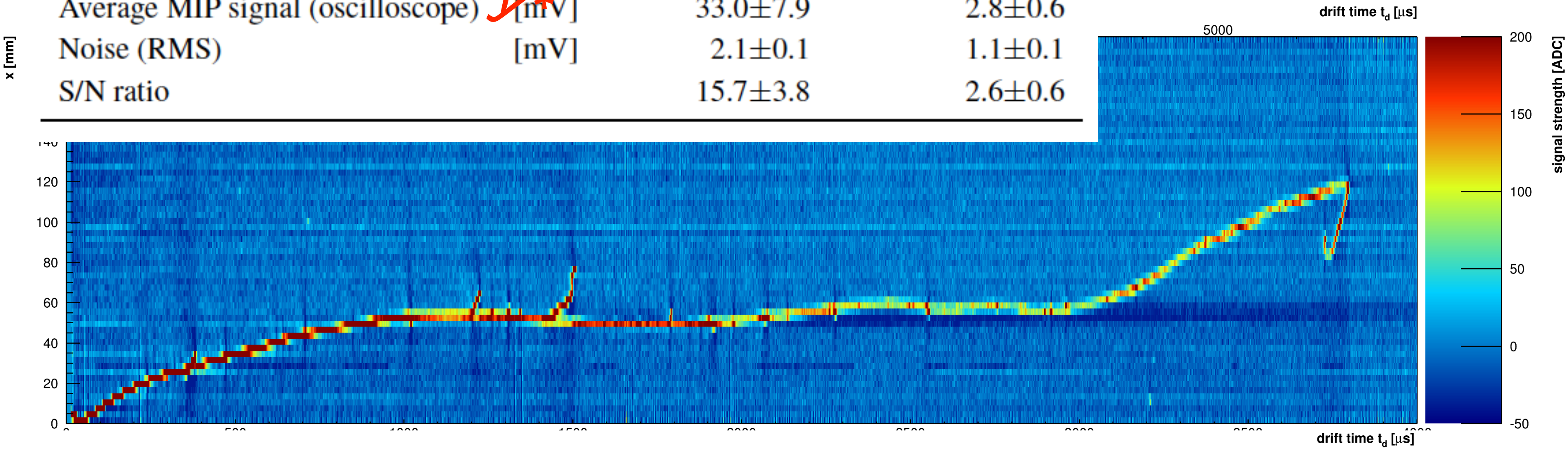
ADC/slope times the test capacitance = eff. charge

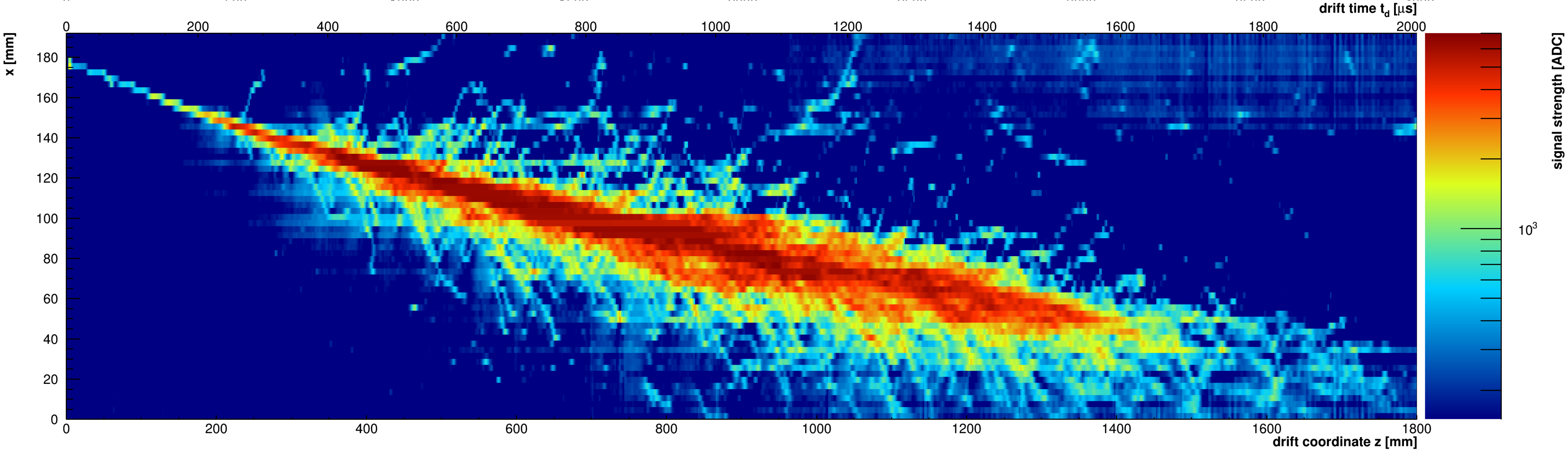
Performance cold vs. warm

Preliminary*

Parameter		LARASIC4 (at 87 K)	Hybrid pre-amp. (at 290 K)
Charge gain	[mV/fC]	25	2.1
Transimpedance	[mV/nA]	117	13
Average MIP signal (oscilloscope)	[mV]	33.0±7.9	2.8±0.6
Noise (RMS)	[mV]	2.1±0.1	1.1±0.1
S/N ratio		15.7±3.8	2.6±0.6

Argontube Events, LHEP paper in preparation





MicroBooNE Optical System

*JINST 8 (2013) T07005
**JINST 8 (2013) P12015
**JINST 8 (2013) P07011

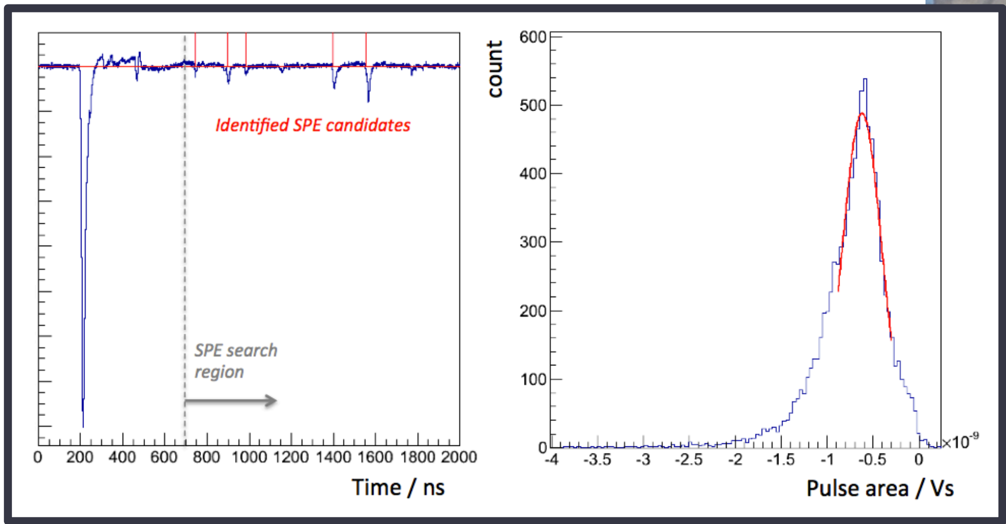
32 PMTs and 4 light-guide detector installed Aug-Sept 2013.

All units were characterized in warm+cold before installation*

A few units selected for more detailed characterizations in the Bo test stand at Fermilab. (stability, linearity and absolute collection efficiency)

Some techniques for MicroBooNE calibration are explored in liquid argon scintillation R&D papers using the MicroBooNE PMT assembly**:

Example of late-light SPE calibration

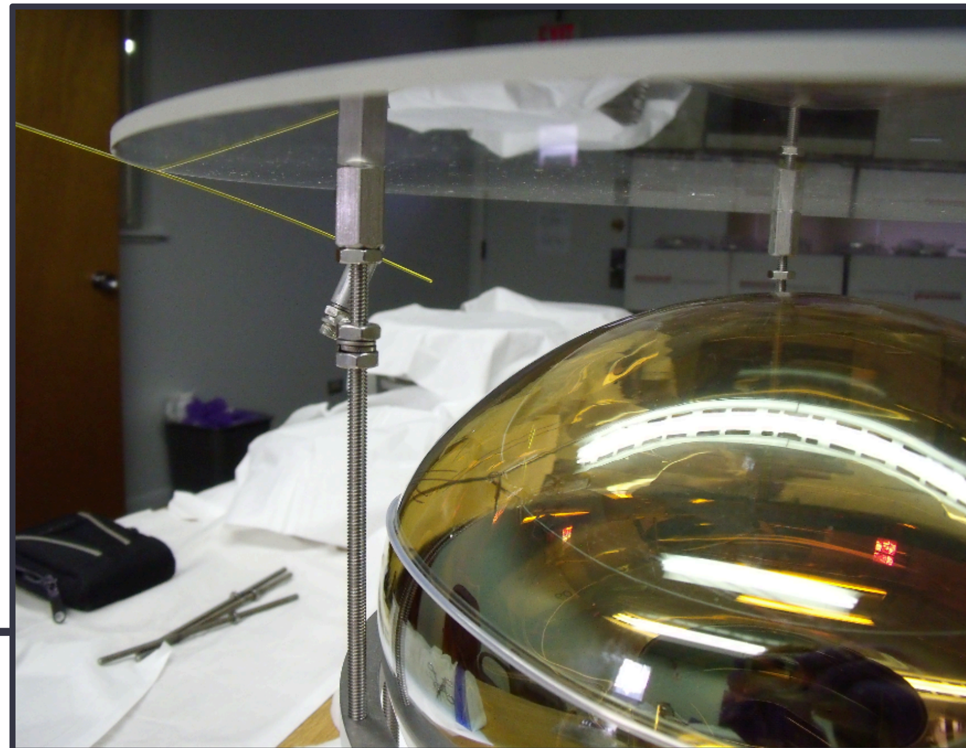


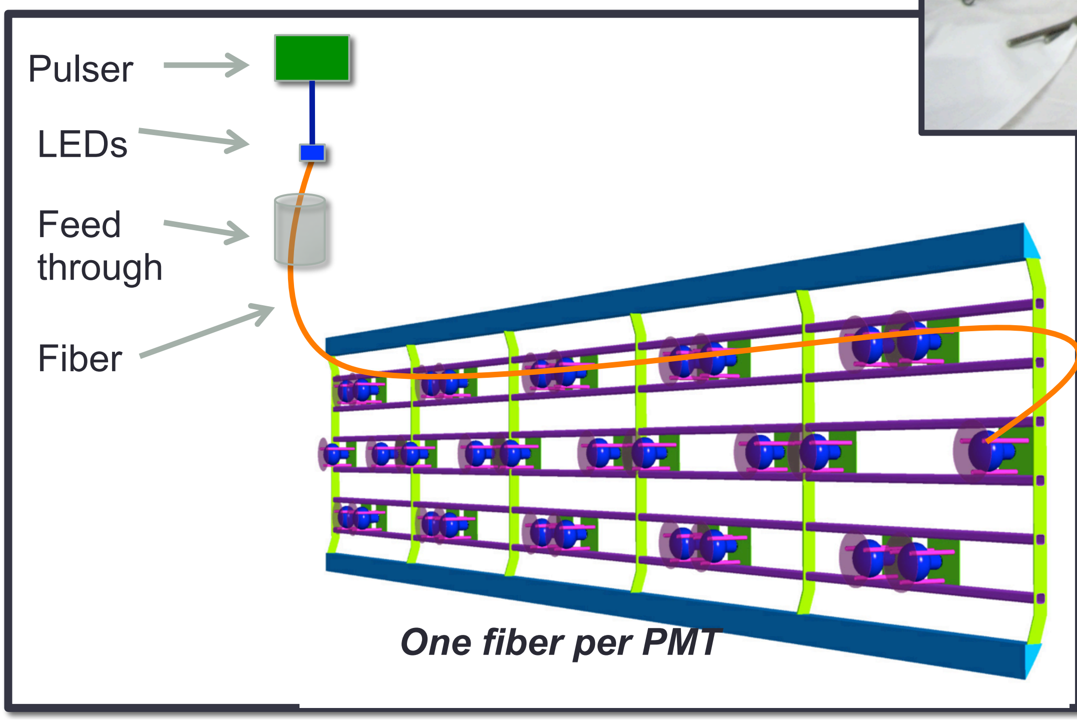
Fiber Calibration System

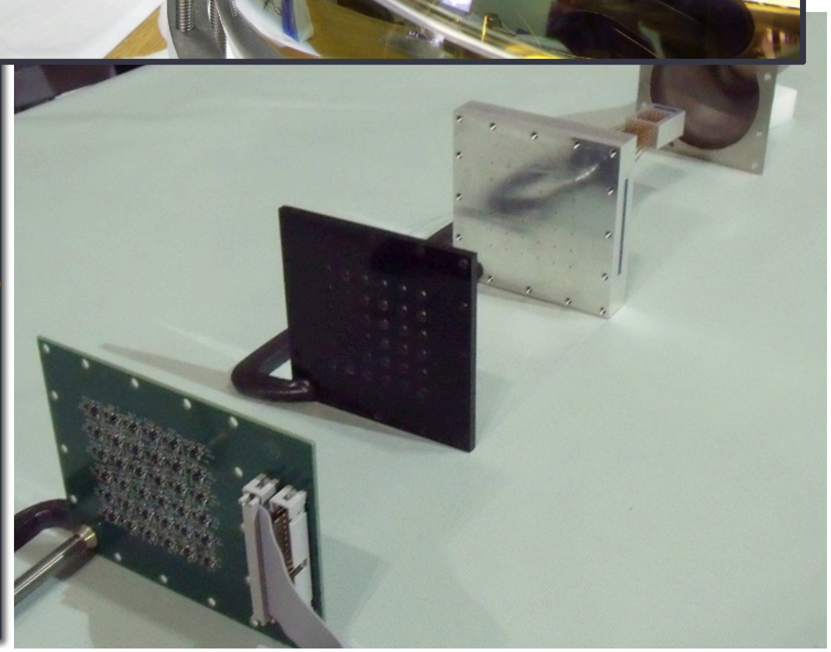
Each PMT has an calibration fiber coupled to an 450 nm LED outside the cryostat for gain and timing characterizations

This system will be used for both routine calibrations and commissioning tests.

Fiber system installed during Sept - Oct 2013, paper in preparation



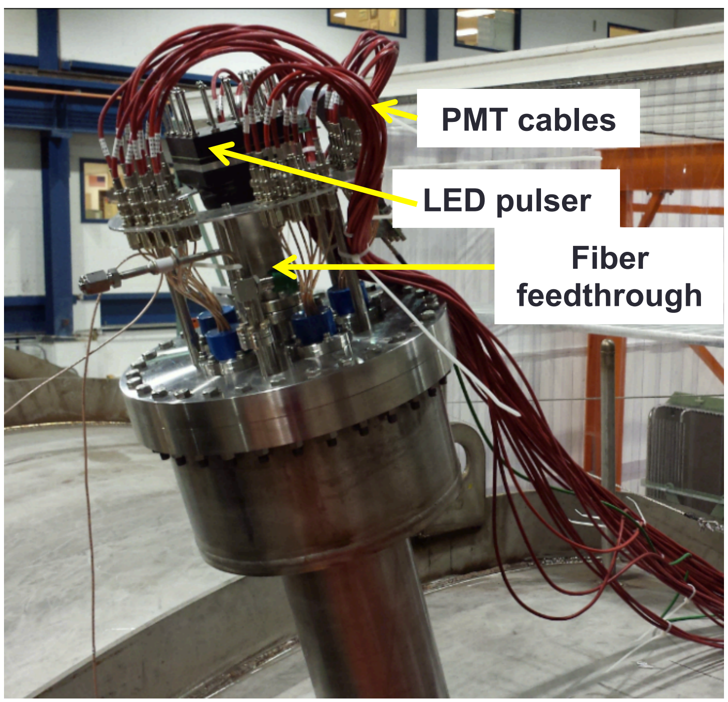




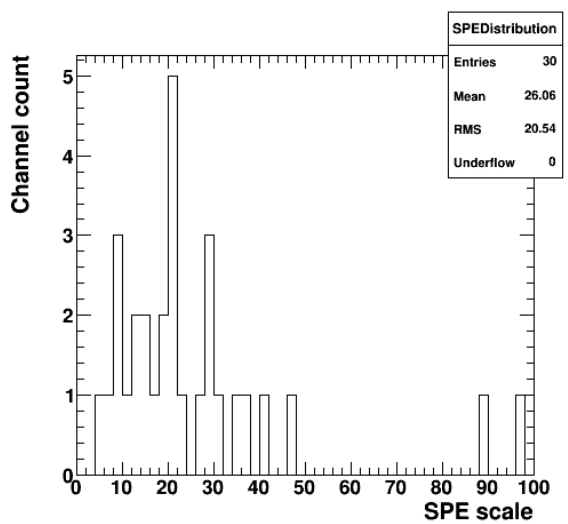
PMT pre-commissioning run

- Successful run of all PMTs, high voltage, fiber calibration system, MicroBooNE DAQ and offline software with installed PMTs
- Some PMT base problems were found and fixed using the LED calibration system. All PMTs verified working before closing detector.
- First version of automatic gain calibration software used to set nominal HV for each channel

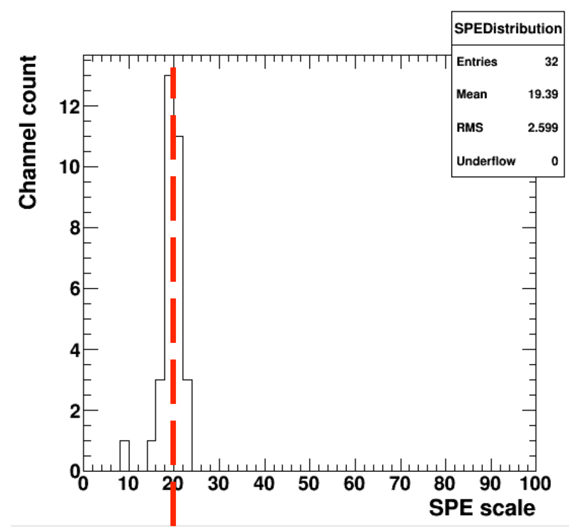
Instrumented PMT feedthrough



Before gain calibration



After gain calibration



Targeted value

Conclusions

- Calibration is not easy
- We know how to do it
- We have great tools that help us to do our job
- Stay tuned for first results