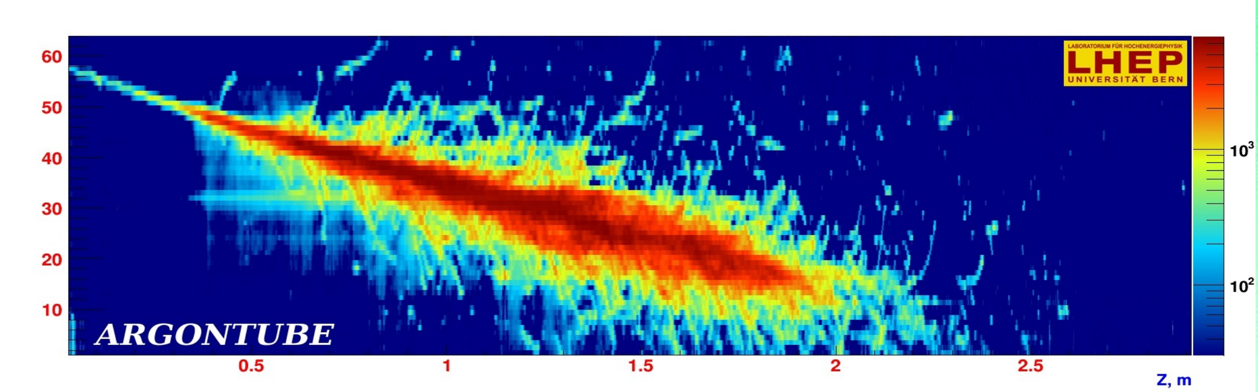
UNIVERSITÄT BERN
AEC ALBERT EINSTEIN CENTER FOR FUNDAMENTAL PHYSICS

LABORATORIUM FÜR HOCHENERGIEPHYSIK LHEP UNIVERSITÄT BERN

LArASIC4 Noise Results in Liquid Argon Long Drift Tests



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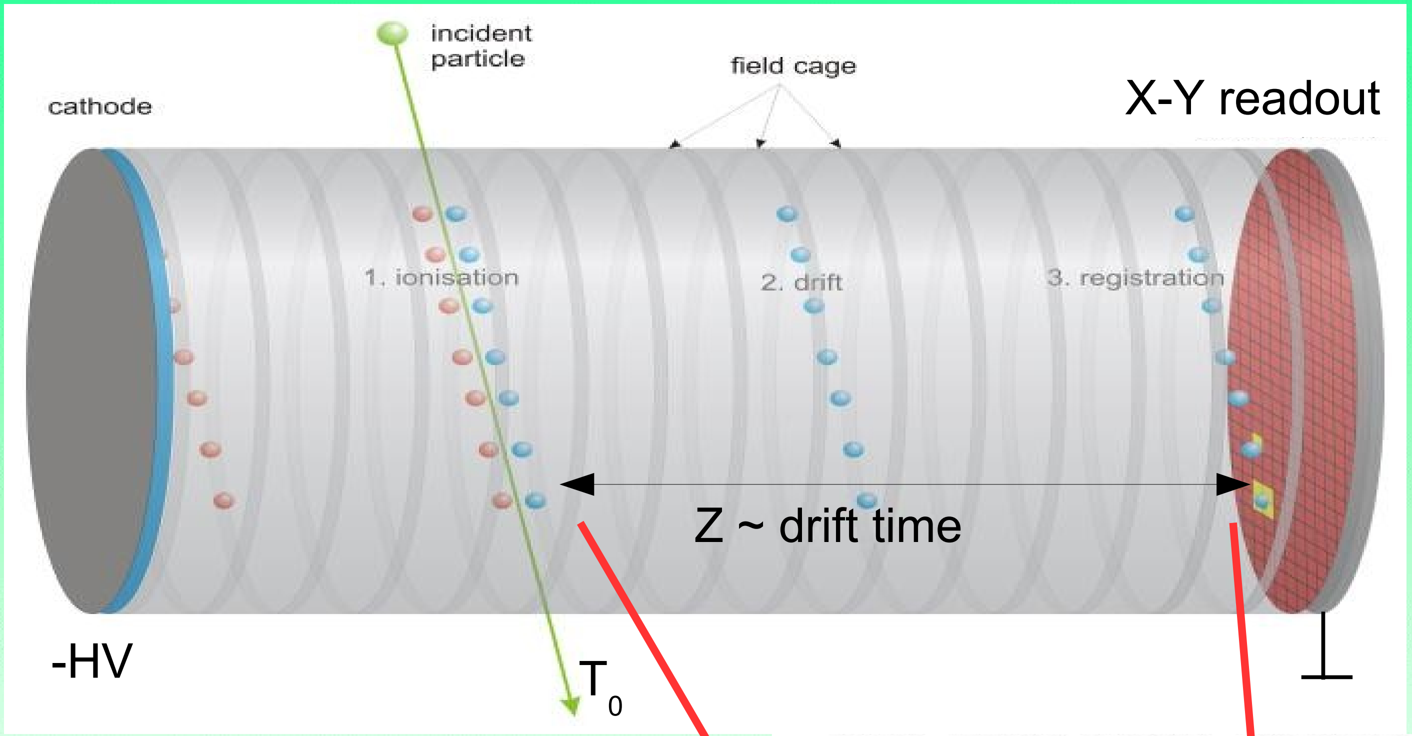
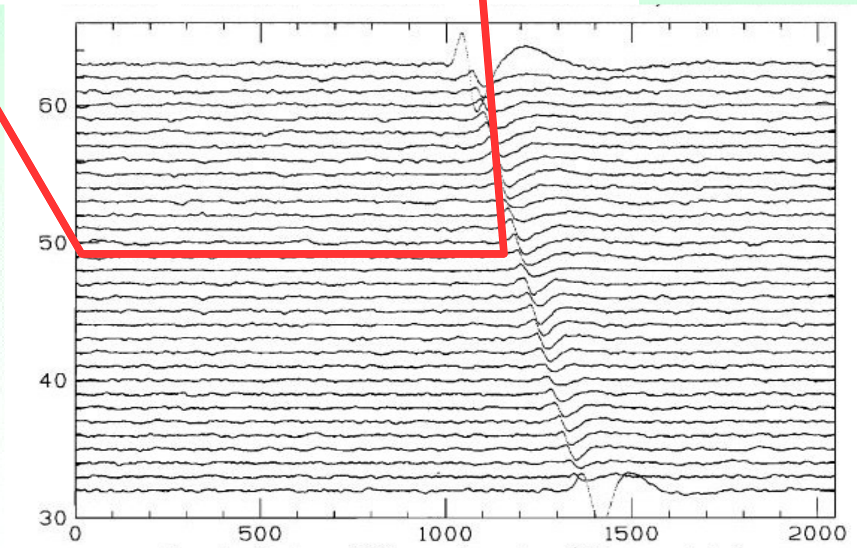
I. Kreslo, M. Lüthi, C. Rudolf von Rohr, M. Schenk,
T. Strauss, M. Weber, M. Zeller

Liquid Argon Time Projection Chamber

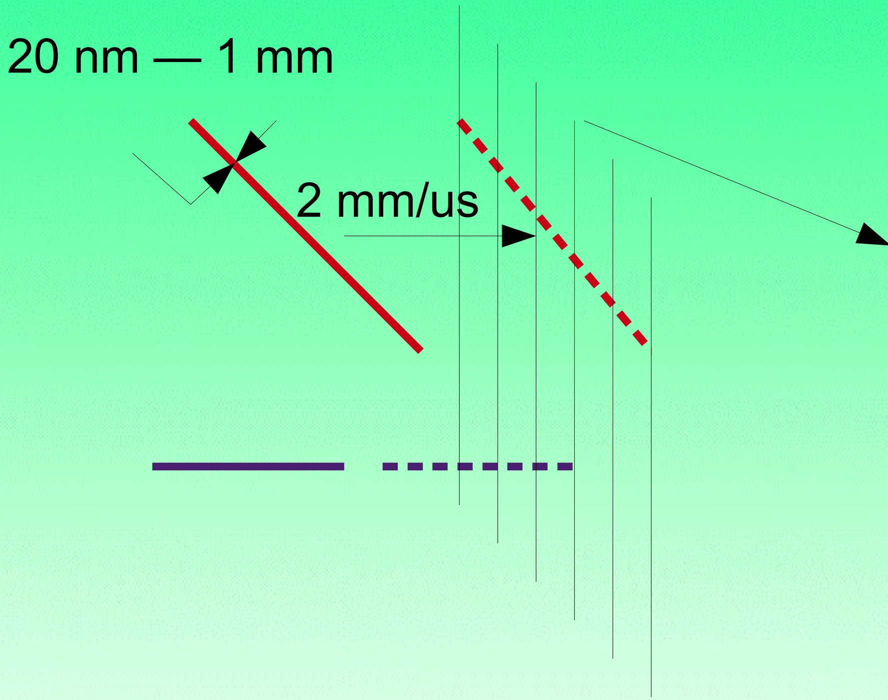


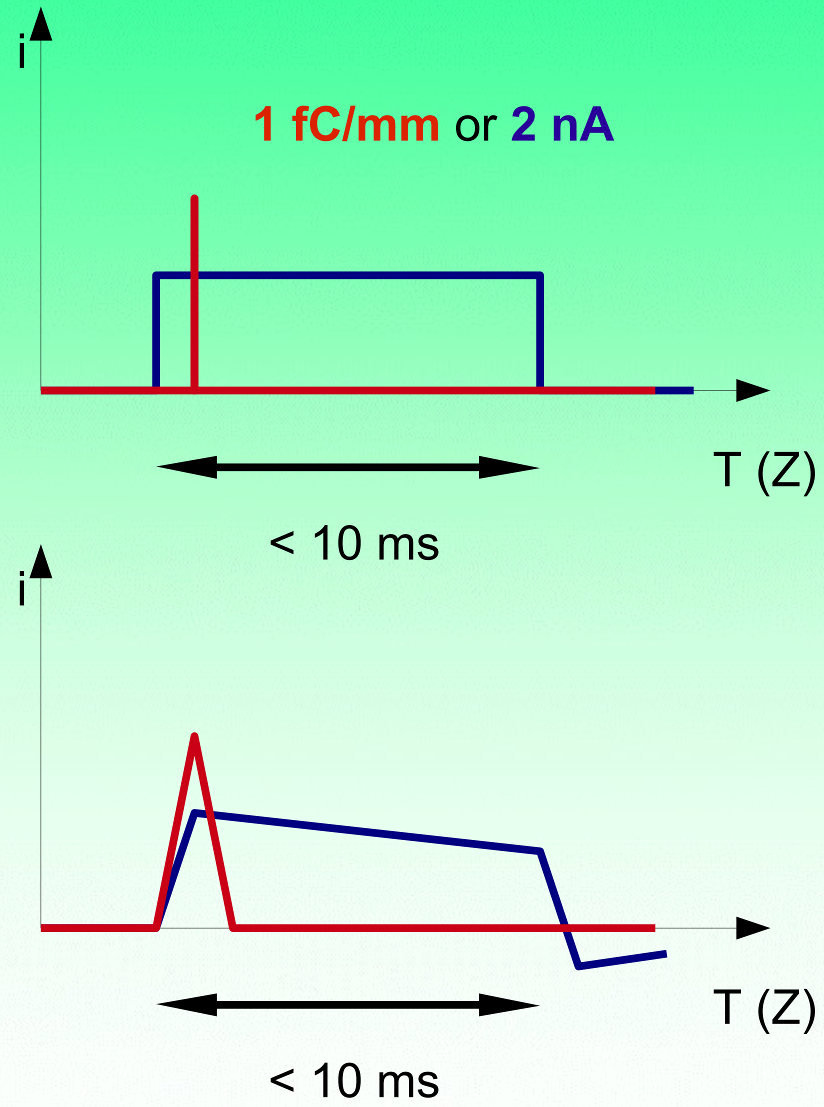


Charge yield ~ 9000 e/mm (1.5 fC/mm)
T_0 by scintillation

Charge readout:
X: Induction (non-destructive)
Y: Collection

Liquid Argon Time Projection Chamber



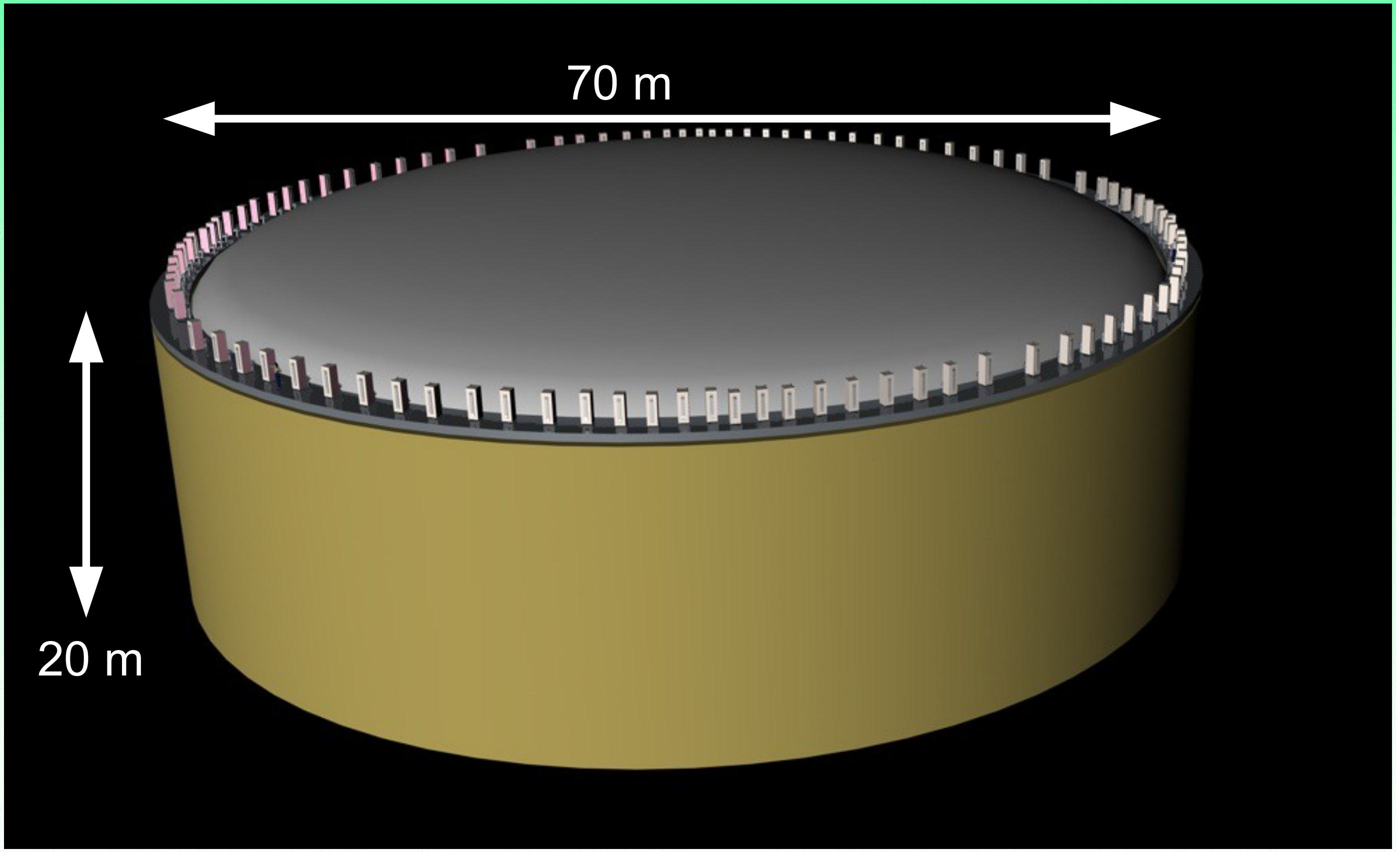


Charge integrator regime: mV/fC

Transimpedance regime: mV/nA

Cryogenic charge readout FE:
a very attractive solution !!!

GLACIER 100 kton LAr TPC for neutrino physics



ARGONTUBE: step towards 100kt high granularity TPC

Multi-kiloton TPCs: drift distance order of 10 m

Drift voltages: order of Mega-volts

Many opened questions → gradual feasibility study

ARGONTUBE detector at LHEP, Uni-Bern
(2007 — now)

Drift length: 4.76m

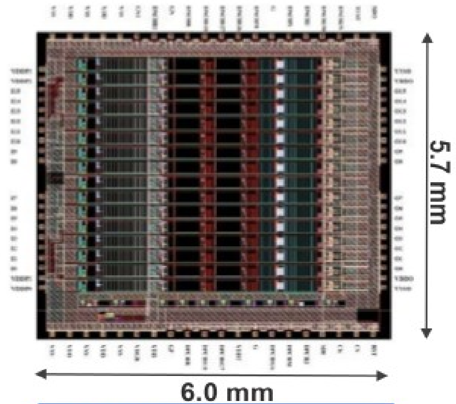
Active volume : 200 l

X-Y readout: wire planes with 3mm pitch, 64x64 ch

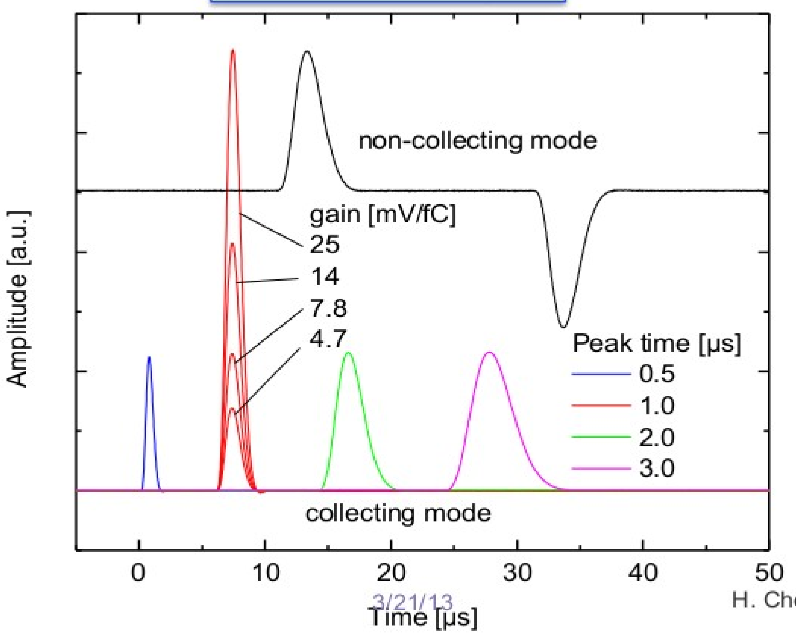
Tracks observed: cosmic muons and electrons

LARASIC4 parameters (courtesy of BNL)

MicroBooNE Cold Electronics

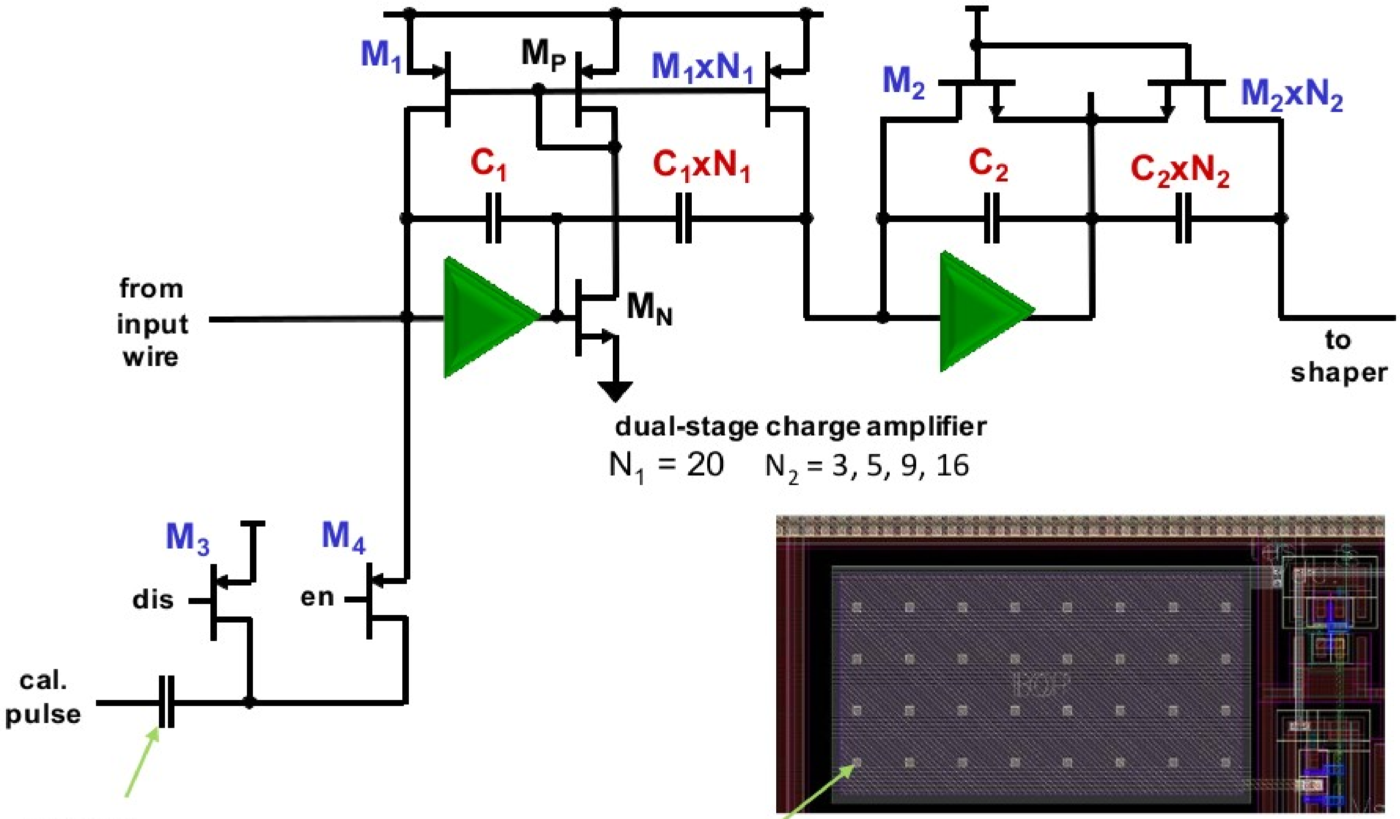


CMOS FE ASIC Layout



- **CMOS Analog Front End ASIC**
  - **16 channels per chip**
  - **Charge amplifier, high-order filter**
  - **Adjustable gain: 4.7, 7.8, 14, 25 mV/fC (55, 100, 180, 300 fC)**
  - **Adjustable filter time constant (peaking time): 0.5, 1, 2, 3 μs**
  - **Selectable collection/non-collection mode (baseline)**
  - **Selectable dc/ac (100 μs) coupling**
  - **Rail-to-rail analog signal processing**
  - **Band-gap referenced biasing**
  - **Temperature sensor (~ 3mV/°C)**
  - **136 registers with digital interface**
  - **5.5 mW/channel (input MOSFET 3.6 mW)**
  - **~ 15,000 MOSFETs**
  - **Designed for long cryo-lifetime**
  - **Technology CMOS 0.18 μm, 1.8 V, 6M, MIM, SBRES**

Cold Electronics ASIC - Front-End Detail and Calibration Scheme



$C_{INJ} \approx 180$ fF

Integrated injection capacitance (10 x 18 μm²)

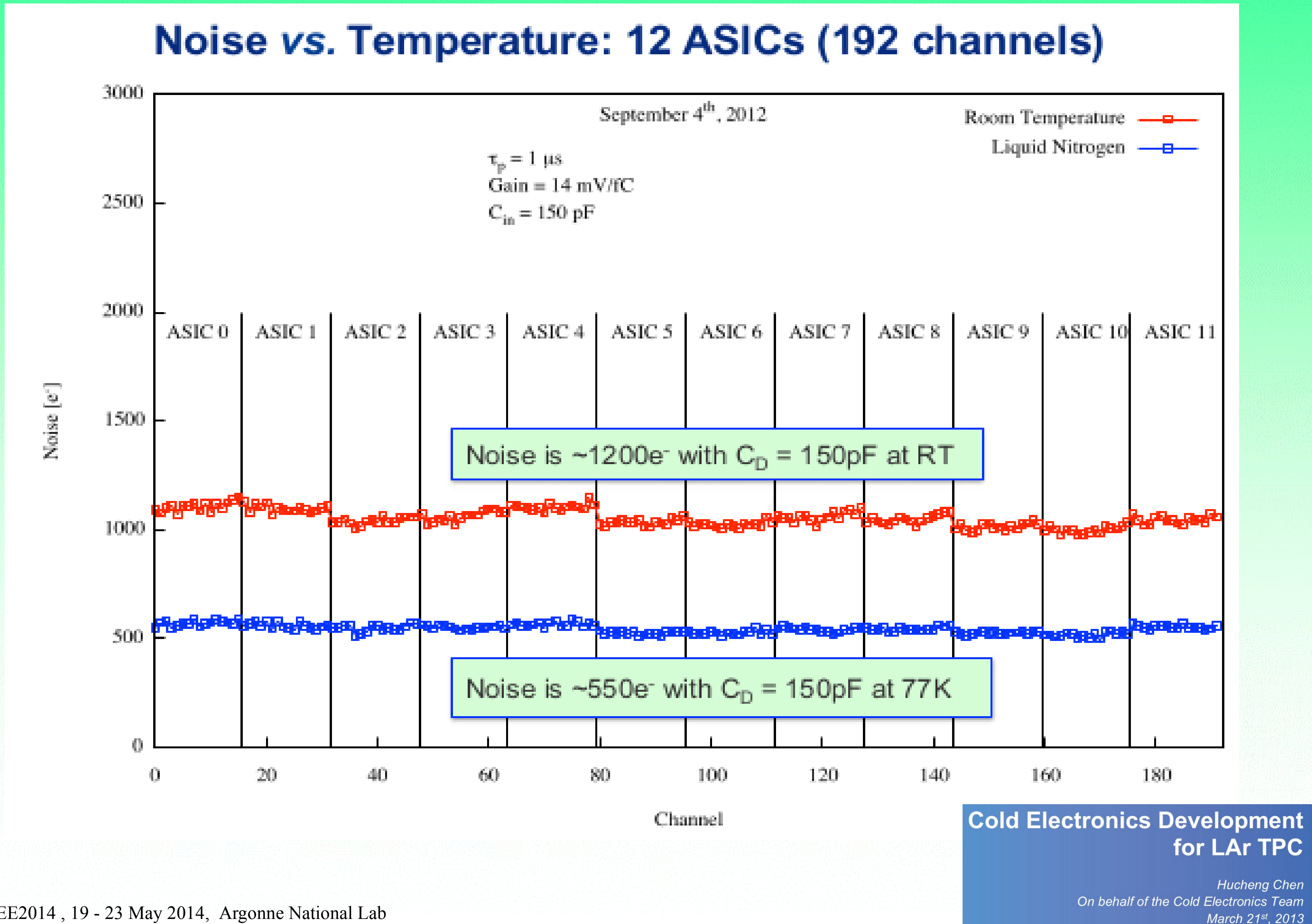
Measured with high-precision external capacitance

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

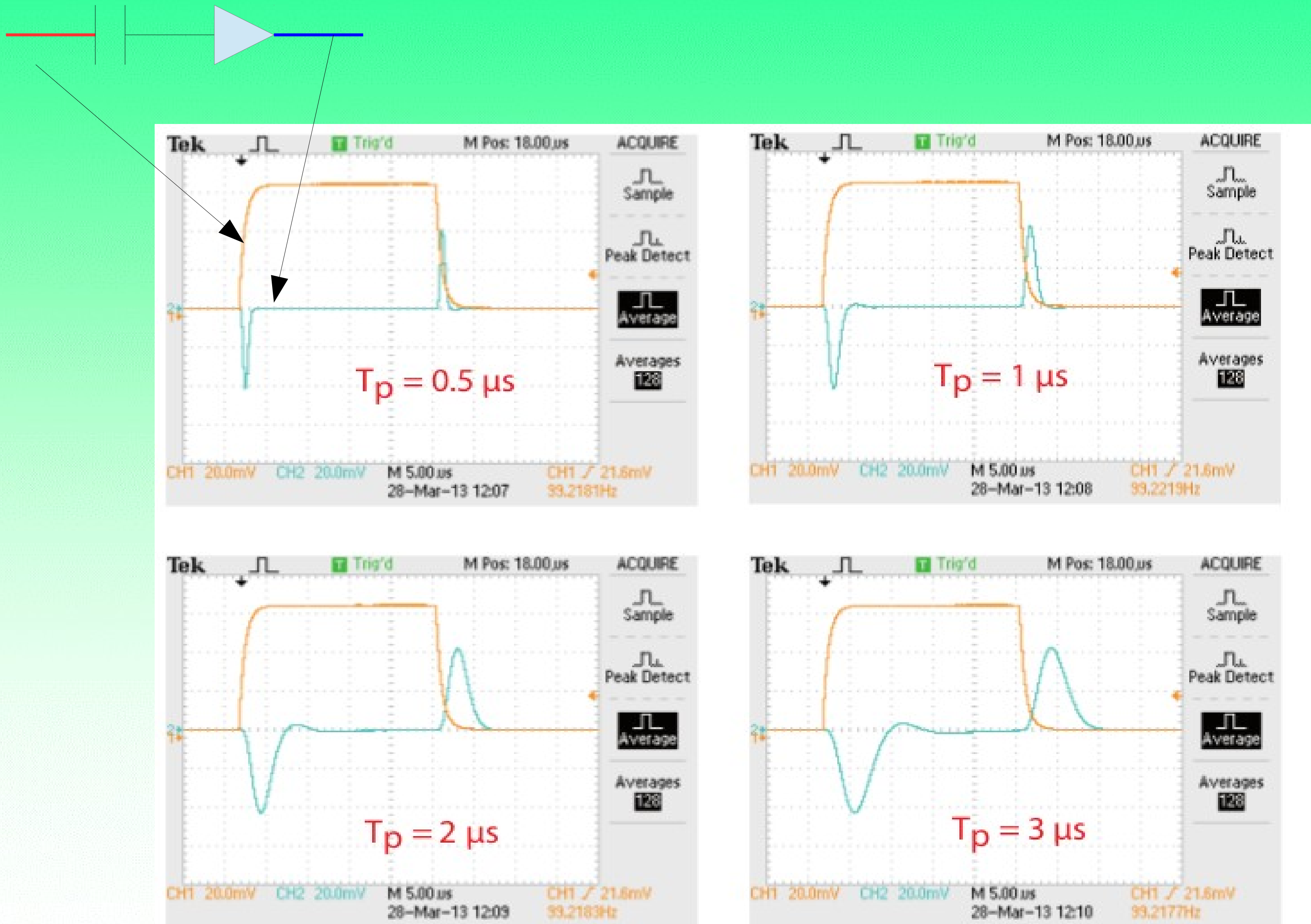
Cold Electronics Development for LAr TPC

Hucheng Chen
On behalf of the Cold Electronics Team
March 21st, 2013

LARASIC4 noise (lab test, courtesy of H. Chen, BNL)



LARASIC4 table-top test in Bern

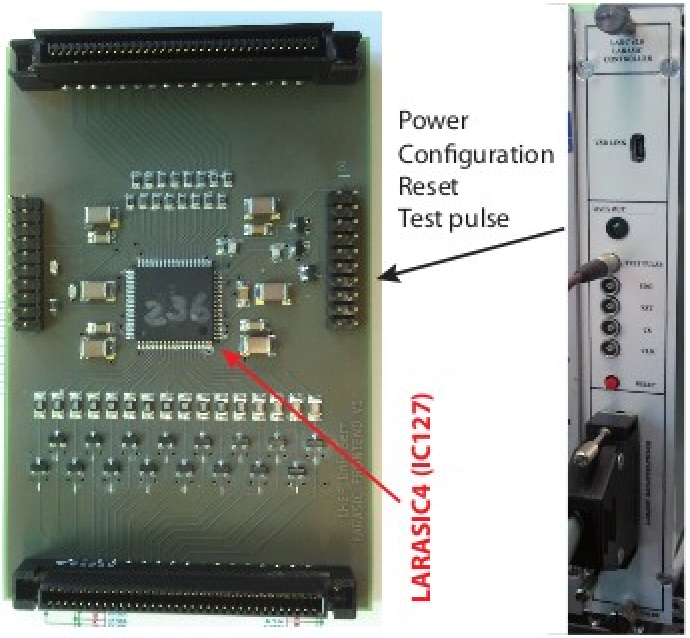


LARASIC4 as FE for ARGONTUBE

- Huge efforts were made by **Veljko Radeka, Hucheng Chen, Gianluigi De Geronimo** and **Dean Shooltz** to support us.
- Provided LARASIC4 chips and precious advice on how to set it all up.

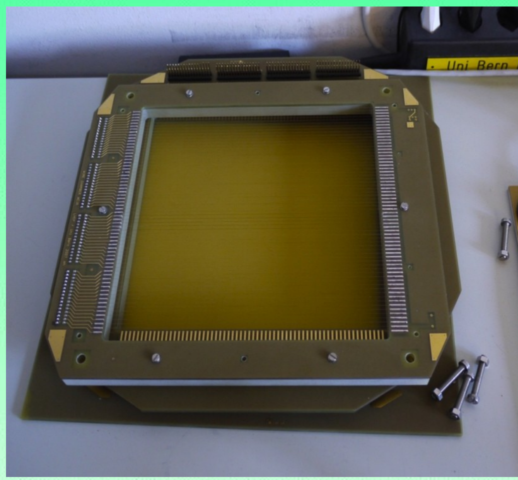
  ⇒ Design of NIM module controller and Argontube frontend PCB at LHEP.

- **Argontube test run** made in June 13.
  - *Direct comparison* of 'warm' and 'cold' preamps.
  - 64 out of 128 CH new 'cold'.
  - Wireplane with 'cold' chips operable in collection *or* induction mode.

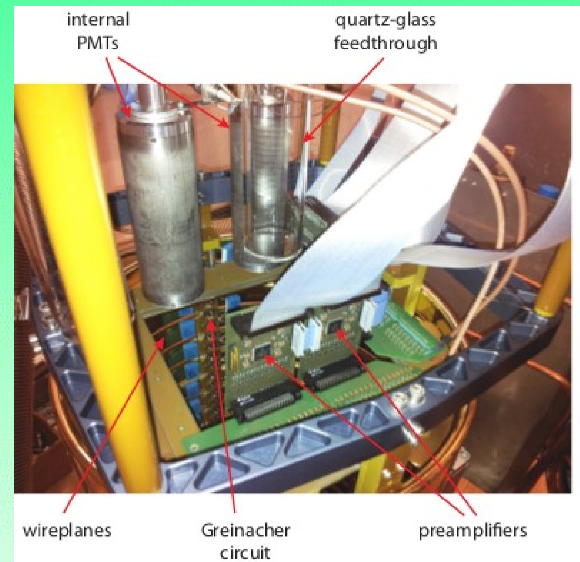


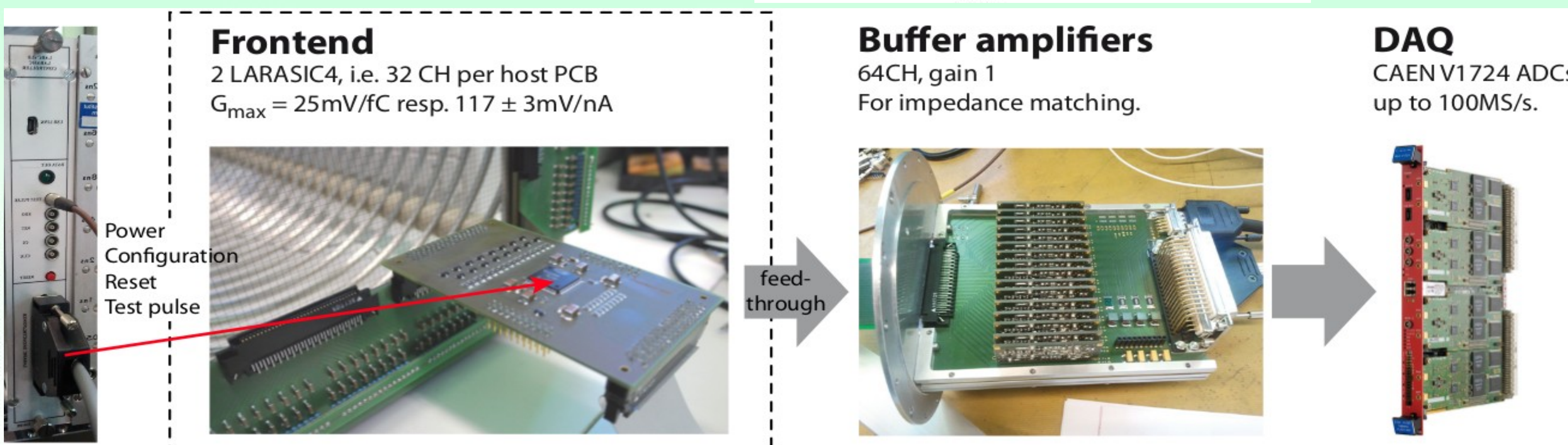
ARGONTUBE LAR TPC charge readout

Charge readout:
wire planes, induction-collection scheme (XY coordinates)



LARASIC4 cryo-amplifiers boards mounted on the readout plane





LHEP
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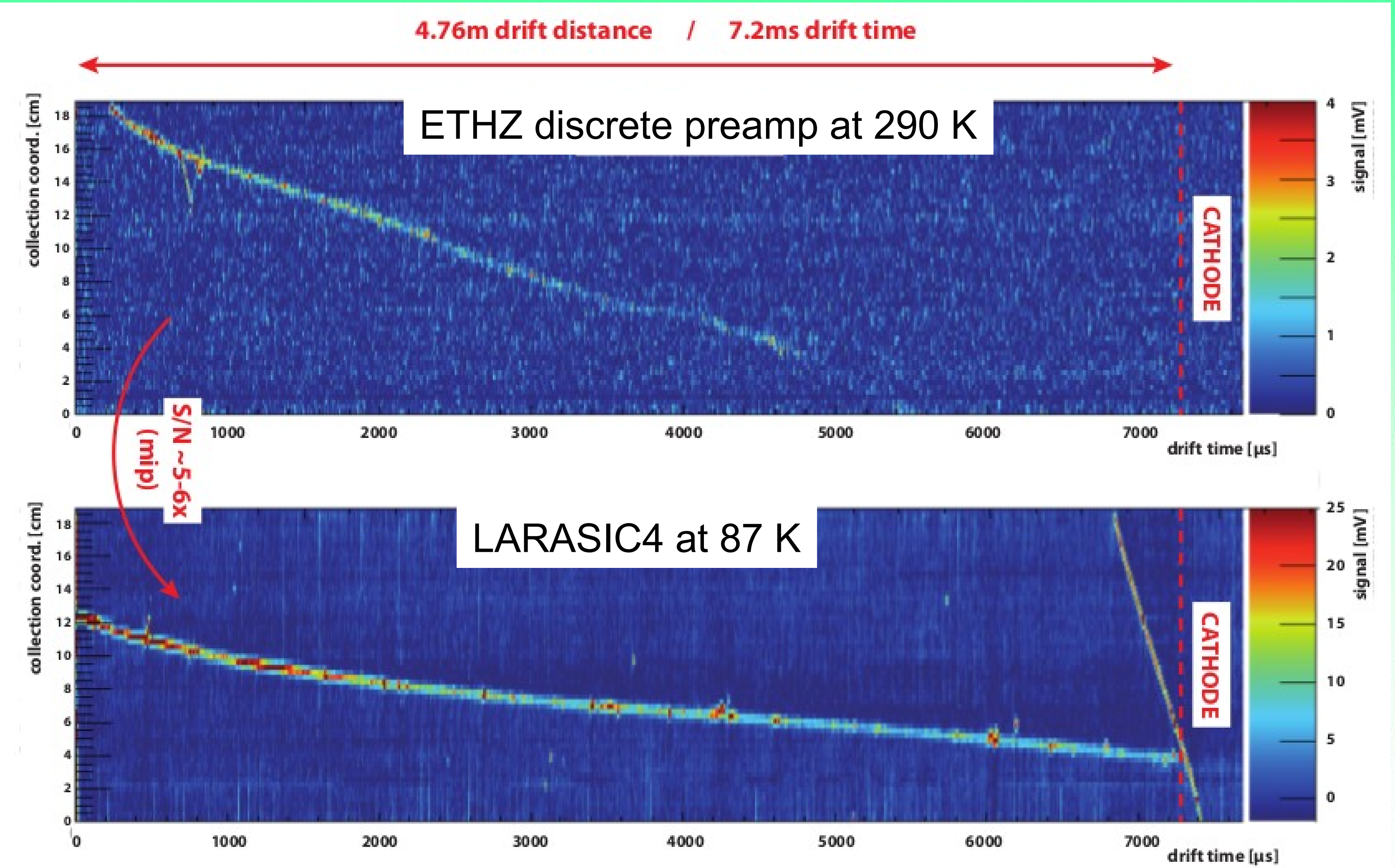
LARASIC4 table-top test in Bern

- *Charge gain* $G = 25 \pm 1\text{mV/fC}$
- *Transimpedance* @ $T_p = 1\,\mu\text{s}$: $Z = 39 \pm 3\,\text{mV/nA}$
- *Droop* (important for longitudinal tracks) $2\,\%/\text{ms}$
- *Noise* with $C_{\text{det}} \approx 1\,\text{pF}$
  - @ $T_p = 0.5\,\mu\text{s}$ $\text{RMS} = 194\,\text{e}$
  - @ $T_p = 3\,\mu\text{s}$ $\text{RMS} = 375\,\text{e}$
- In Argontube, $C_{\text{det}} \approx 7 - 10\,\text{pF}$.

Perfect match to specifications.

LARASIC4 vs ETHZ warm preamp
Muon track: 5-6x better S/N!



LARASIC4 vs warm preamp

- Amount of charge/mm expected from mip

  $\left(\frac{dE}{dX}\right)_{mip} \approx 0.21\,\mathrm{MeV/mm},\ W_e \approx 23.6\,\mathrm{eV},\ R \approx 0.35 \pm 0.04\ \ @200\mathrm{V/cm}$

  $\Rightarrow \frac{\Delta Q}{\Delta x} \approx 8'900\,\mathrm{e/mm}$

- Analyze transversal mip. tracks passing close to the readout plane.
- *RMS noise*

  $N_{warm} = 1.1 \pm 0.1\,\mathrm{mV},$

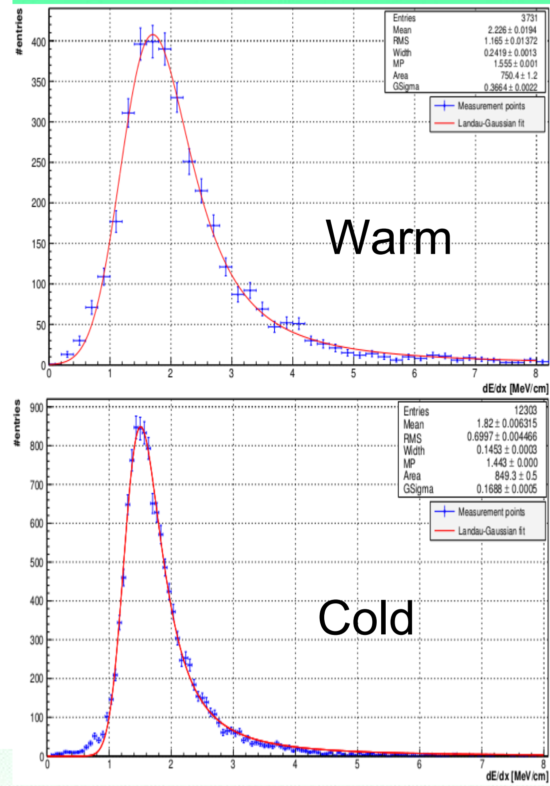
  $N_{cold} = 2.1 \pm 0.1\,\mathrm{mV} \approx 525e^{-}(ENC)$
- *MIP signal*

  $S_{warm} = 2.8 \pm 0.6\,\mathrm{mV}$

  $S_{cold} = 33.0 \pm 7.9\,\mathrm{mV} \approx 8'100\,\mathrm{e/mm}$

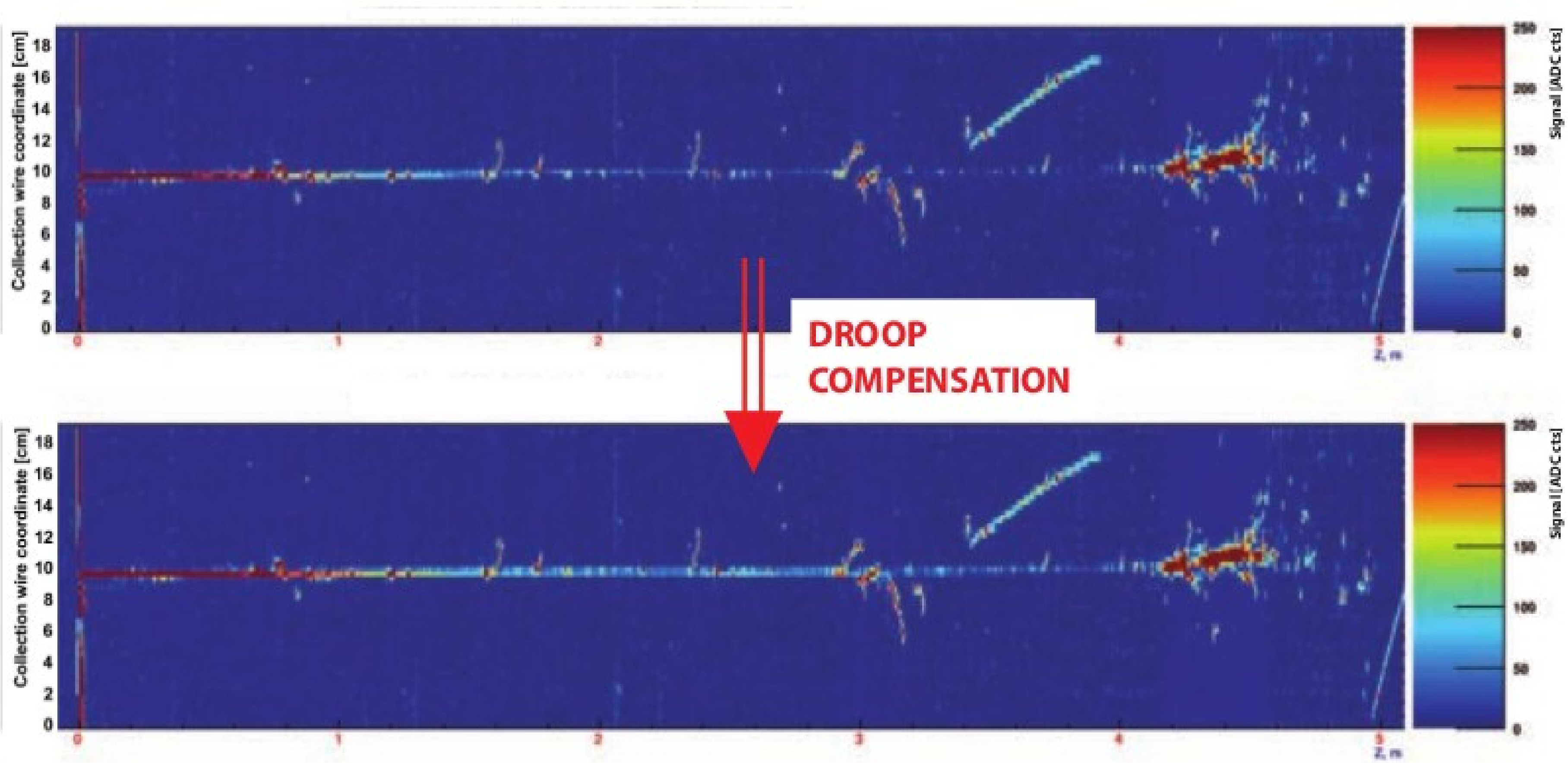
$\Rightarrow$ **Signal to noise ratios**

$S/N_{warm} = 2.6 \pm 0.6 \qquad S/N_{cold} = 15.7 \pm 3.8$



LARASIC4 droop compensation

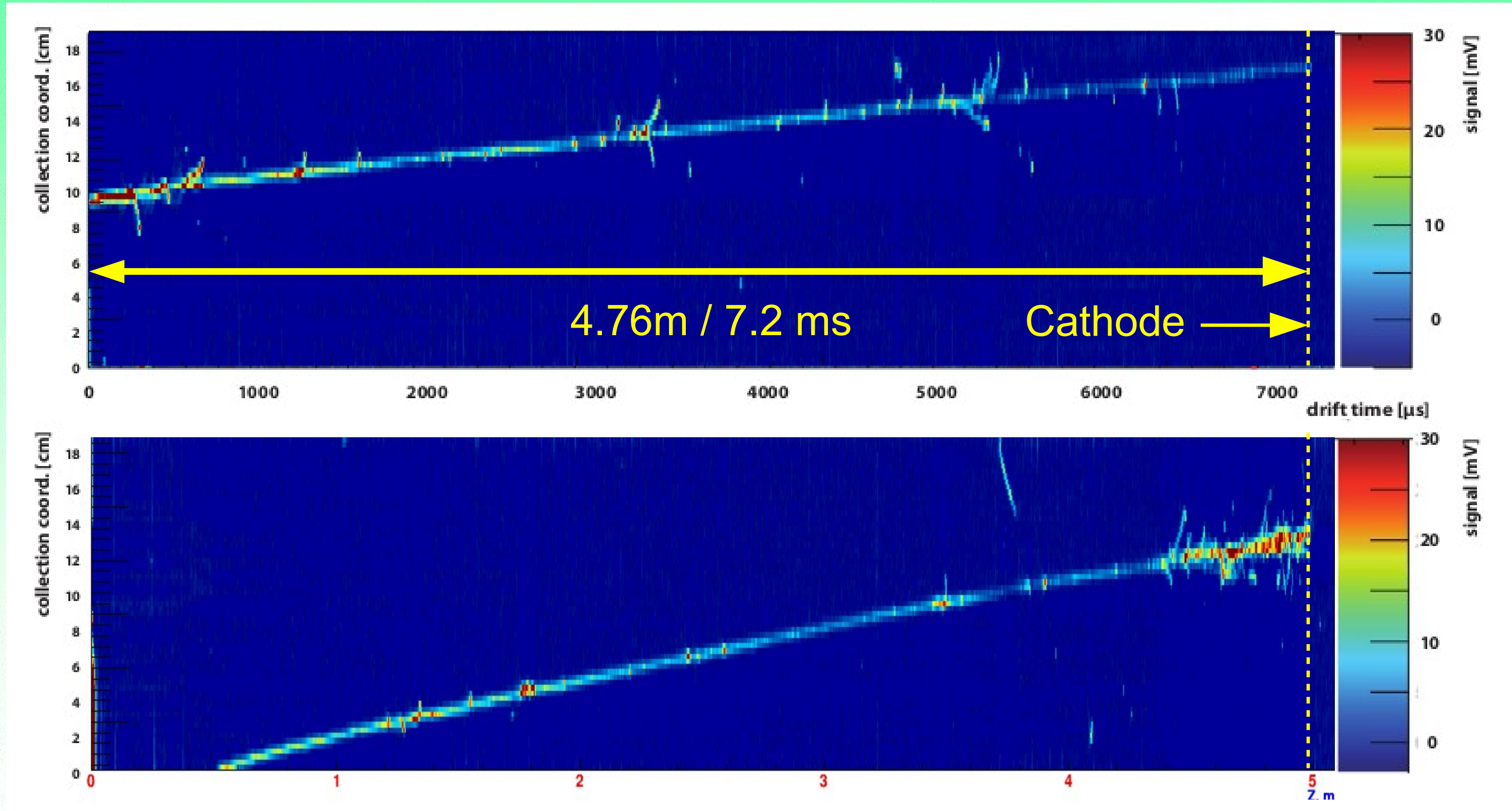
- Charge from longitudinal track is mainly deposited on one channel.
  - ⇒ Droop correction (2%/ms) must be applied.



ARGONTUBE LAR TPC performance: cosmic muons

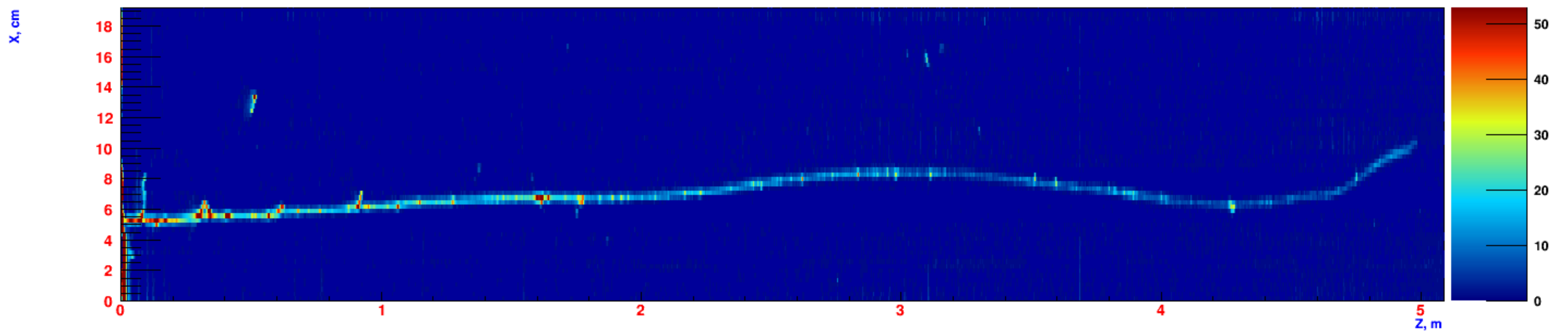
5 m long electrons drift in LAR: first time!

S/N for MIP ~ 16

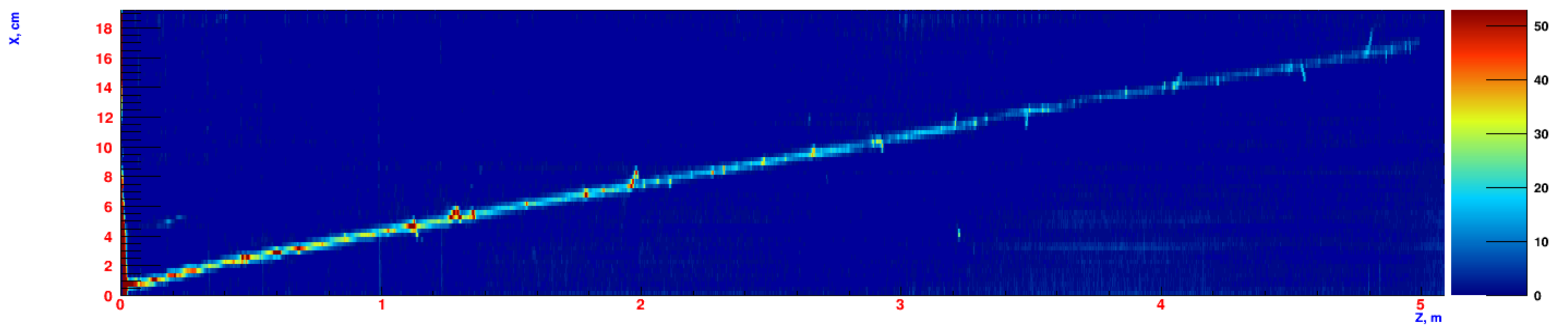


ARGONTUBE event gallery

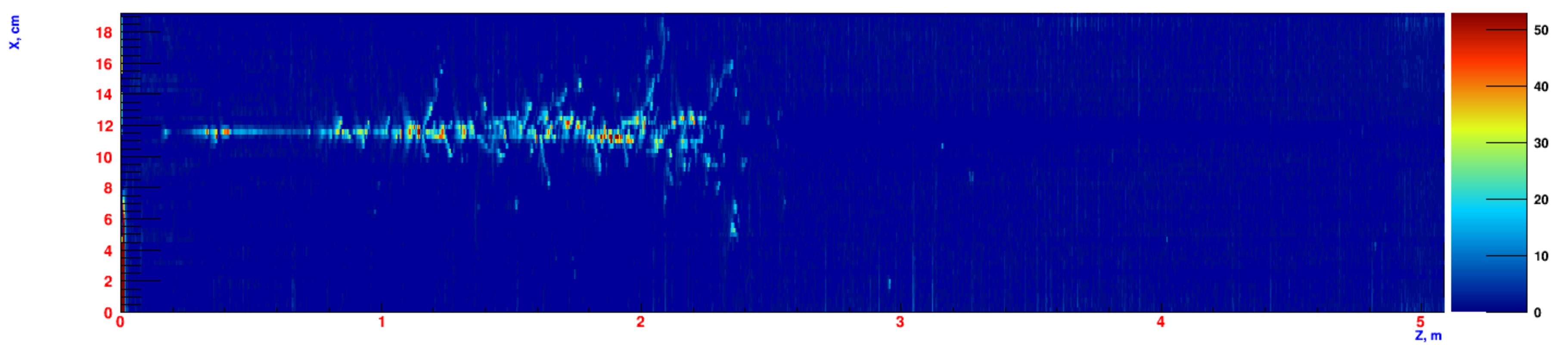
Collection, Run 8197 Event 27. Trigger pattern: I1 T



Collection, Run 8204 Event 43. Trigger pattern: I1 B T



Collection, Run 8257 Event 3. Trigger pattern: I1 T



ARGONTUBE event gallery

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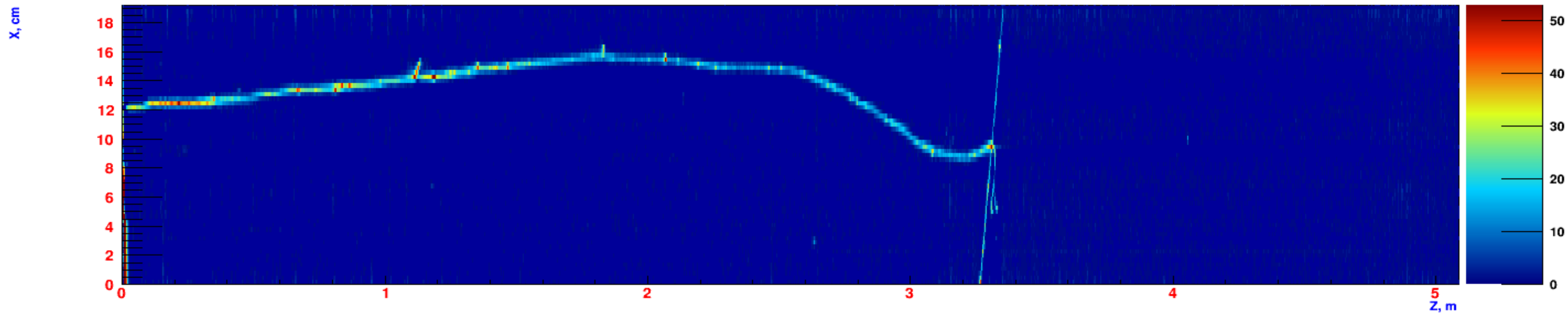
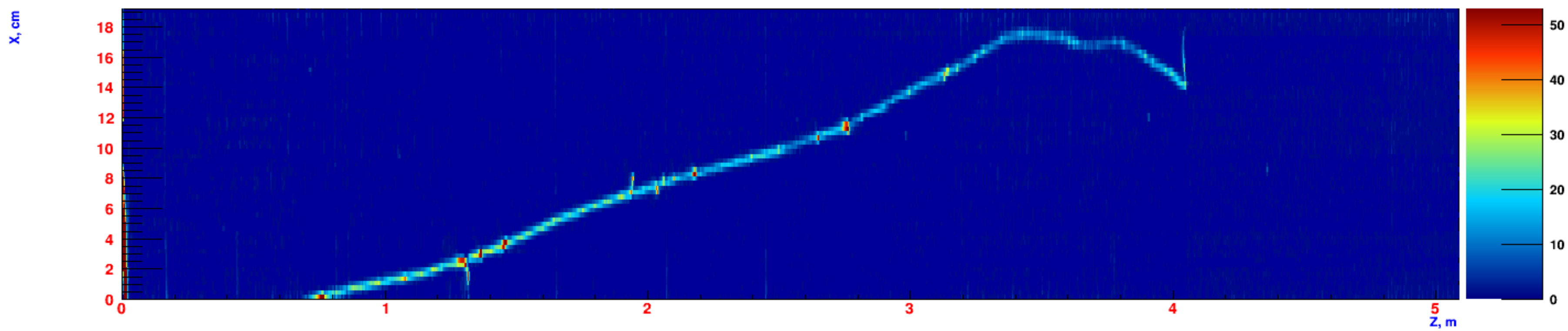
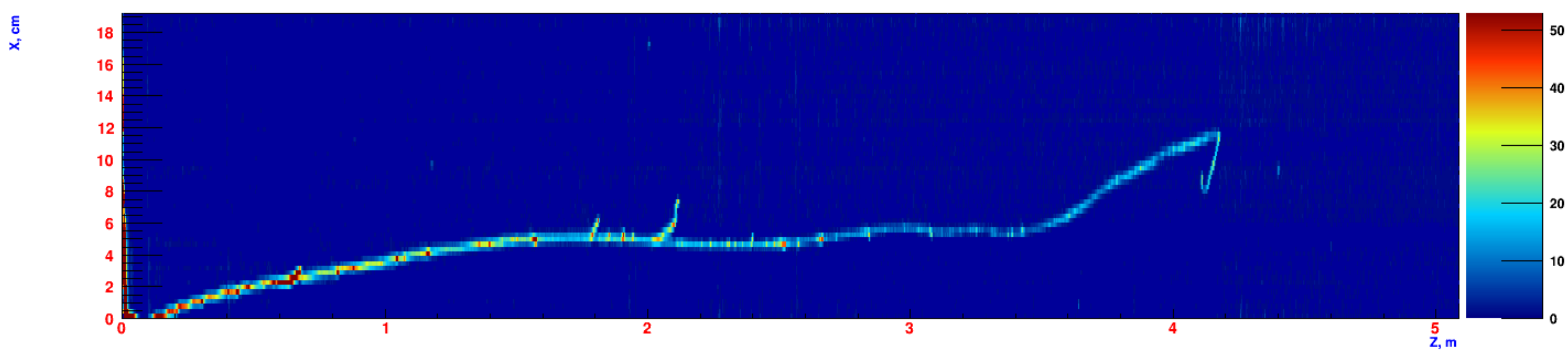
Collection, Run 8203 Event 33. Trigger pattern: I1 T



Collection, Run 8203 Event 135. Trigger pattern: I1 I2 T

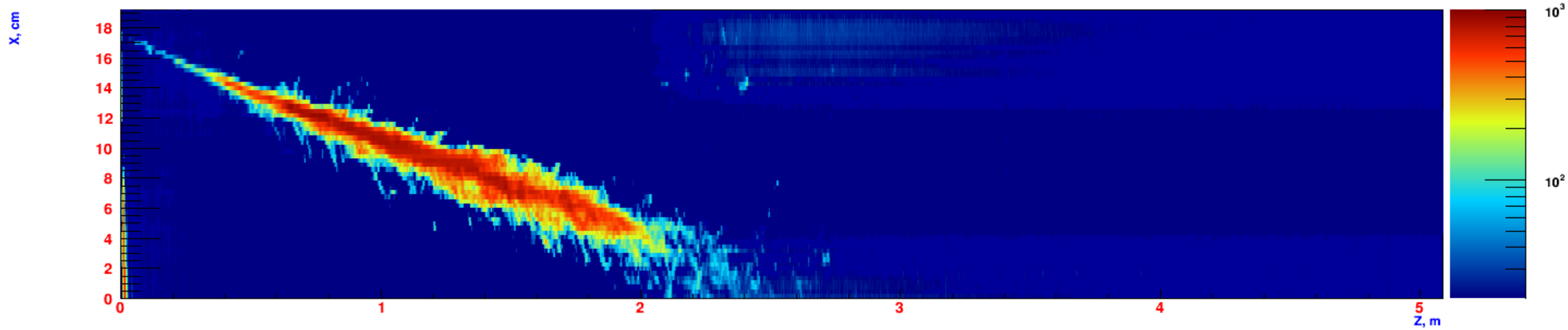


Collection, Run 8200 Event 142. Trigger pattern: I1 I2 T

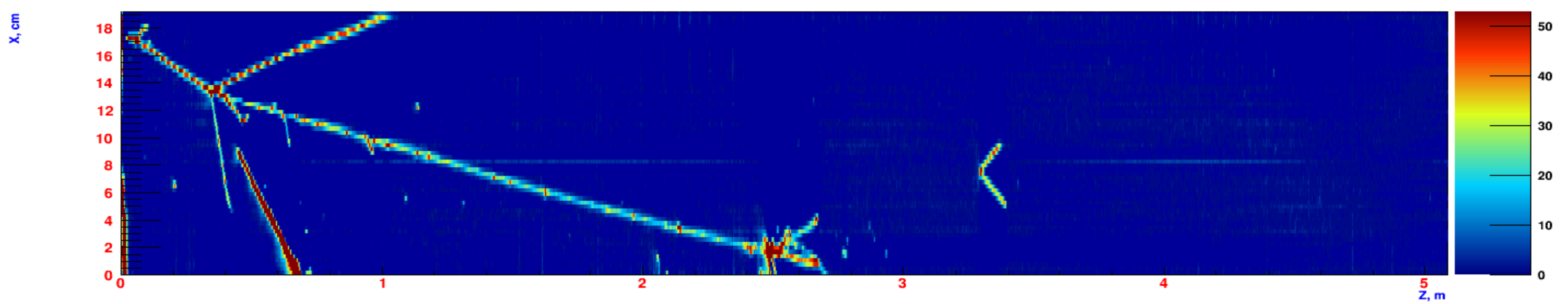


ARGONTUBE event gallery

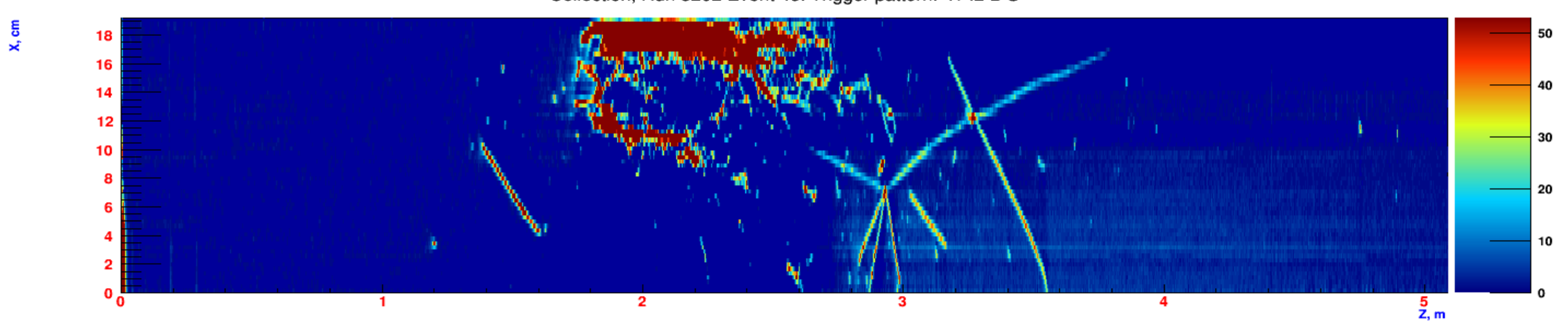
Collection, Run 8135 Event 74. Trigger pattern: I1 I2 S



Collection, Run 8200 Event 145. Trigger pattern: I1 I2 S



Collection, Run 8202 Event 45. Trigger pattern: I1 I2 B S



Summary

- LARASIC4 FE performs very well in long drift LAr TPC
- Minimum ionizing particles detected with S/N ~16
- Factor 5-6 improvement in S/N compared to R.T. electronics
- Opens a way to more complicated R/O structures:

  on-board ADCs

  pixelized R/O instead of projections

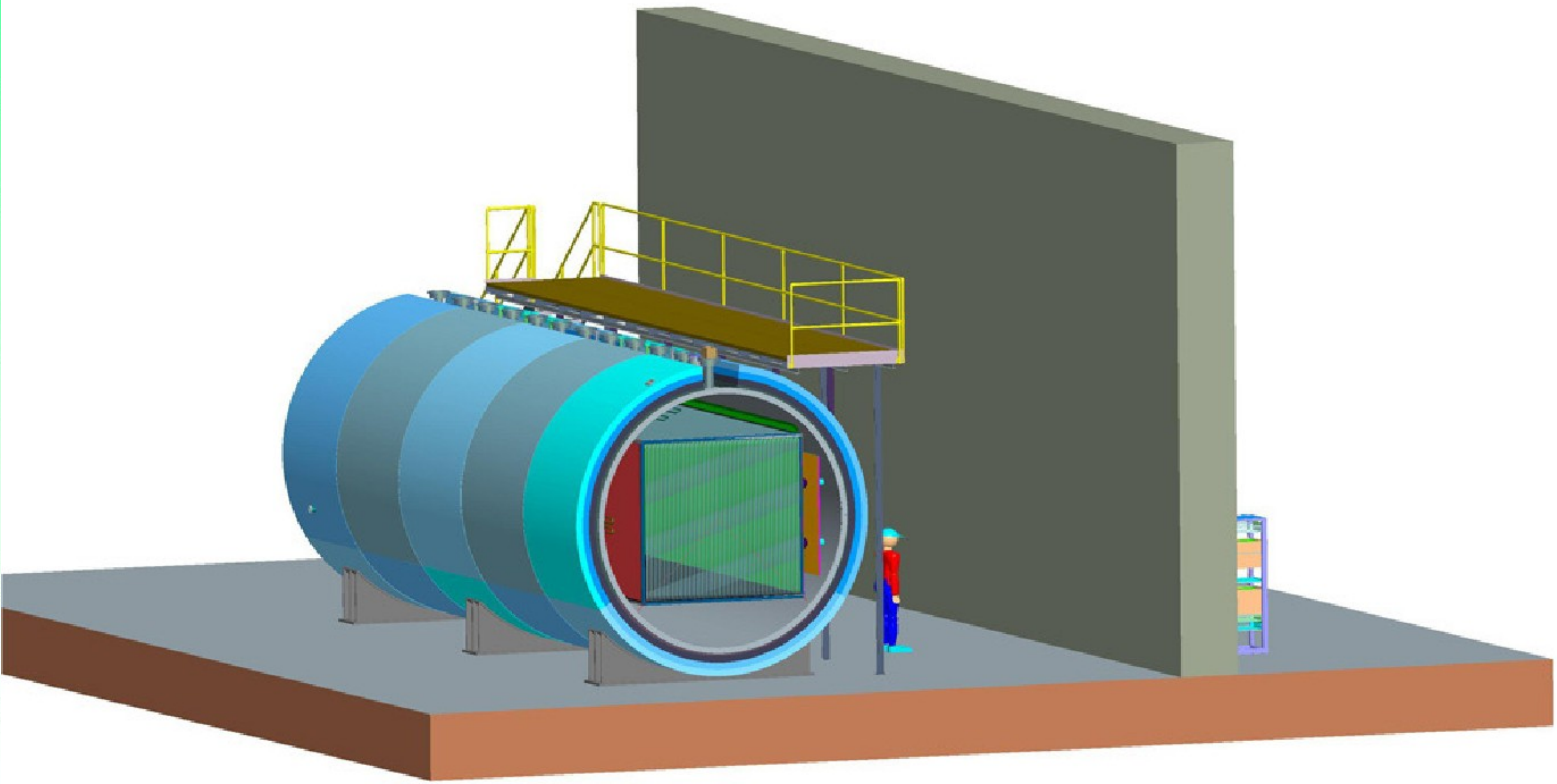
  zero-suppression logic

  channel multiplexing

  etc...
- Thanks to BNL electronics design group for support!

BACKUP SLIDES

MicroBooNE TPC at FNAL



Why test uBooNE FE in ARGONTUBE ?

	µBooNE (design values)	Argontube (stable conditions)
d_d [cm]	250	476
V_{cat} [kV]	-125	-100
E_d [V/cm]	***500***	***~ 200***
t_d [ms]	***1.6***	***7.2***
τ_e [ms]	***> 3***	***2.5 - 3.0***

Very low drift field

$\Rightarrow$ much longer drift time and stronger recombination.

ARGONTUBE

the 4.76m drift LAr TPC at LHEP is well-suited to study LARASIC4 performance under real conditions.