New results from the 10x10 cm² LAr LEM-TPC

Devis Lussi

on behalf of
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Project overview, references

- **Proof of principle with 10x10 cm² double phase Ar LEM-TPC prototype:**
  - A. Badertscher et al., *"Operation of a double-phase pure argon Large Electron Multiplier Time Projection Chamber: Comparison of single and double phase operation " NIM A617 (2010)* p.188-192
  - A. Badertscher et al., *"First operation of a double phase LAr Large Electron Multiplier Time Projection Chamber with a two-dimensional projective readout anode" NIM A641 (2011)* p.48-57

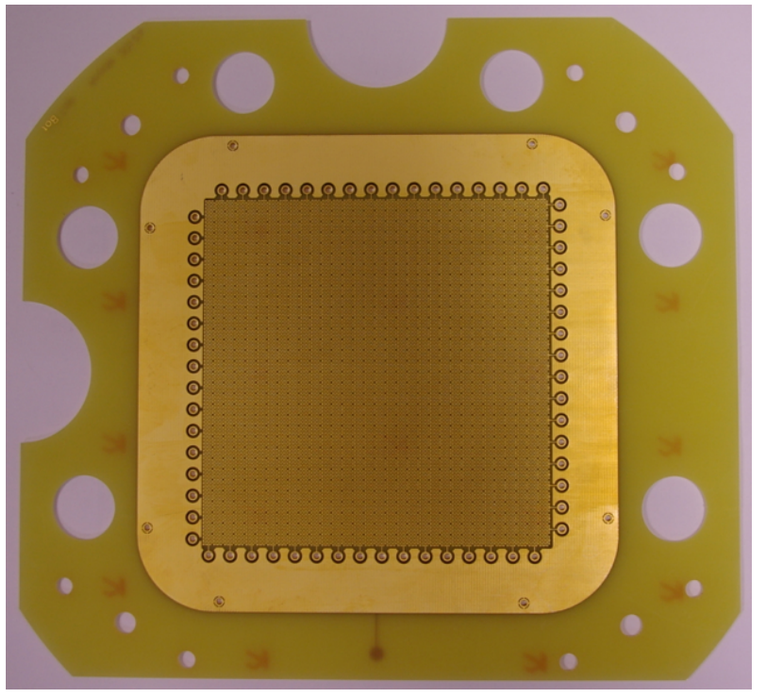
- **First successful operation of a 40x80 cm² device in November 2011**
  - A. Badertscher et al., *"First operation and drift field performance of a large area double phase LAr Electron Multiplier Time Projection Chamber with an immersed Greinacher high-voltage multiplier "*JINST 7 (2012) P08026
  - A. Badertscher et al., *"First operation and performance of a 200 lt double phase LAr LEM-TPC with a 40x76 cm² readout"*, JINST 8 (2013)P04012, will be available shortly at http://dx.doi.org/10.1088/1748-0221/8/04/P04012

- **10x10 cm² double phase Ar LEM-TPC prototype: further R&D towards final, simplified charge readout for GLACIER**
  - first results presented TPC-symposium, Paris

- **next future: 6x6x6 m³ prototype to be operated at CERN NA in a charged particle and neutrino beam**
  - pending approval by CERN SPSC

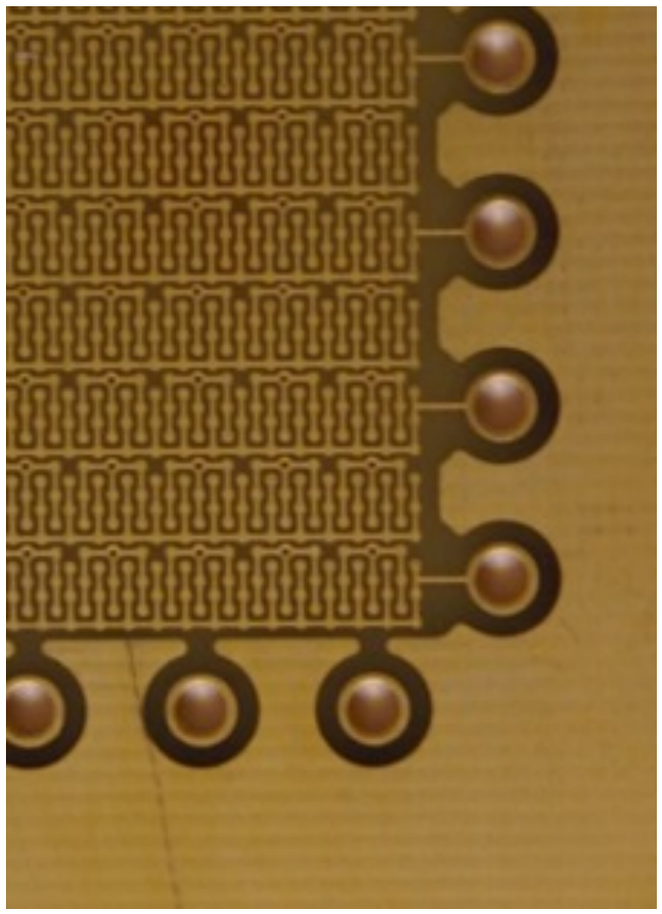
- **final goal: Giant LAr LEM TPC as far detector for a Long Baseline Neutrino Oscillation (LBNO) experiment (SPSC-EOI-007)**

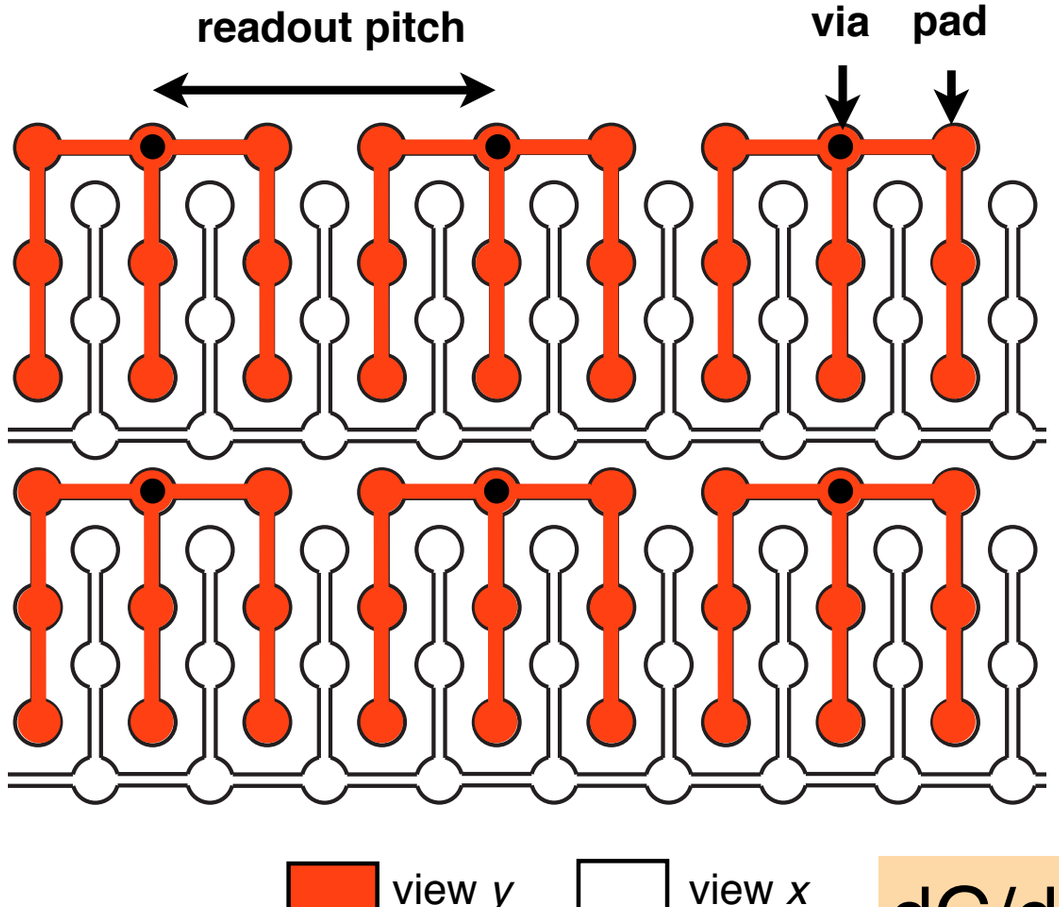
New 2D anode design



towards large area readout (0.5x0.5 m² modules)

- Readout capacitance of Kapton-type anode ≈600 pF/m
(GLACIER readout design strip length: up to 4 m, => C>2 nF)
  ➡capacitance reduction needed, due to noise requirements...
- Mass production: simple PCB preferable to Multilayer Kapton

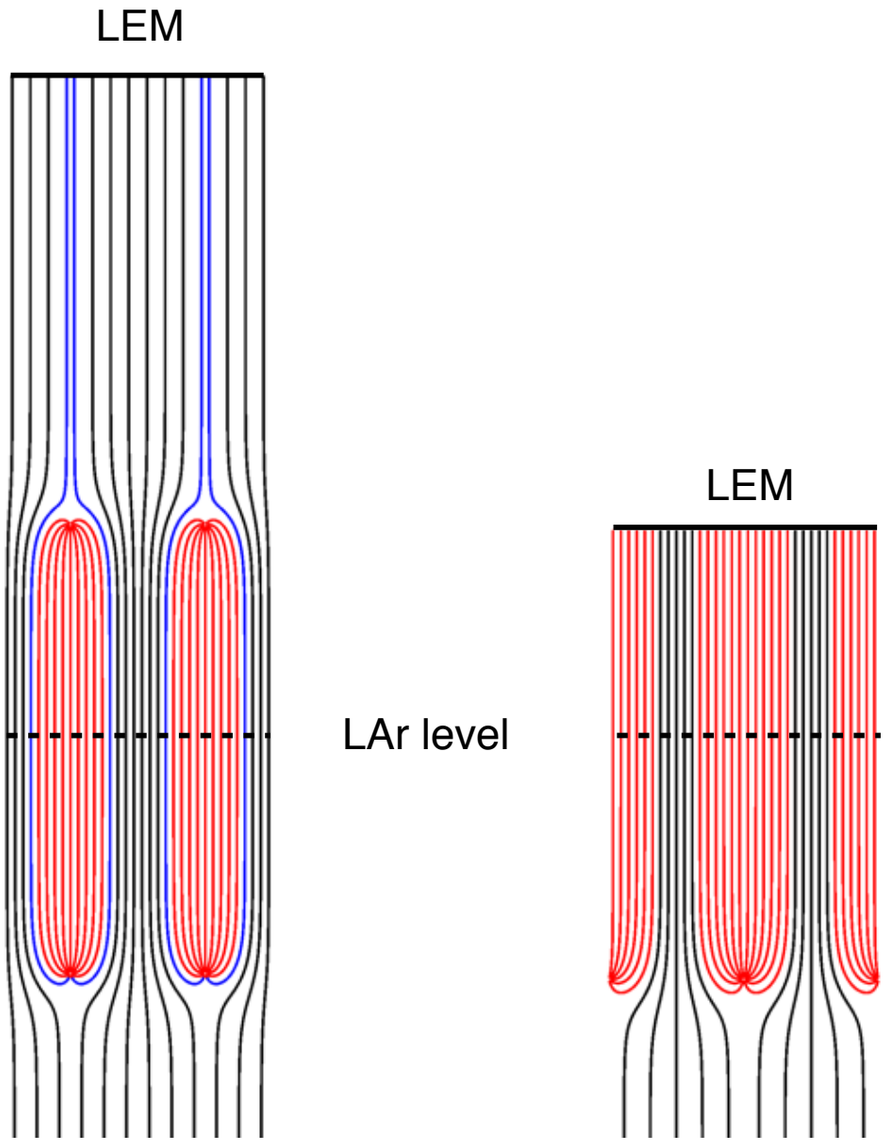




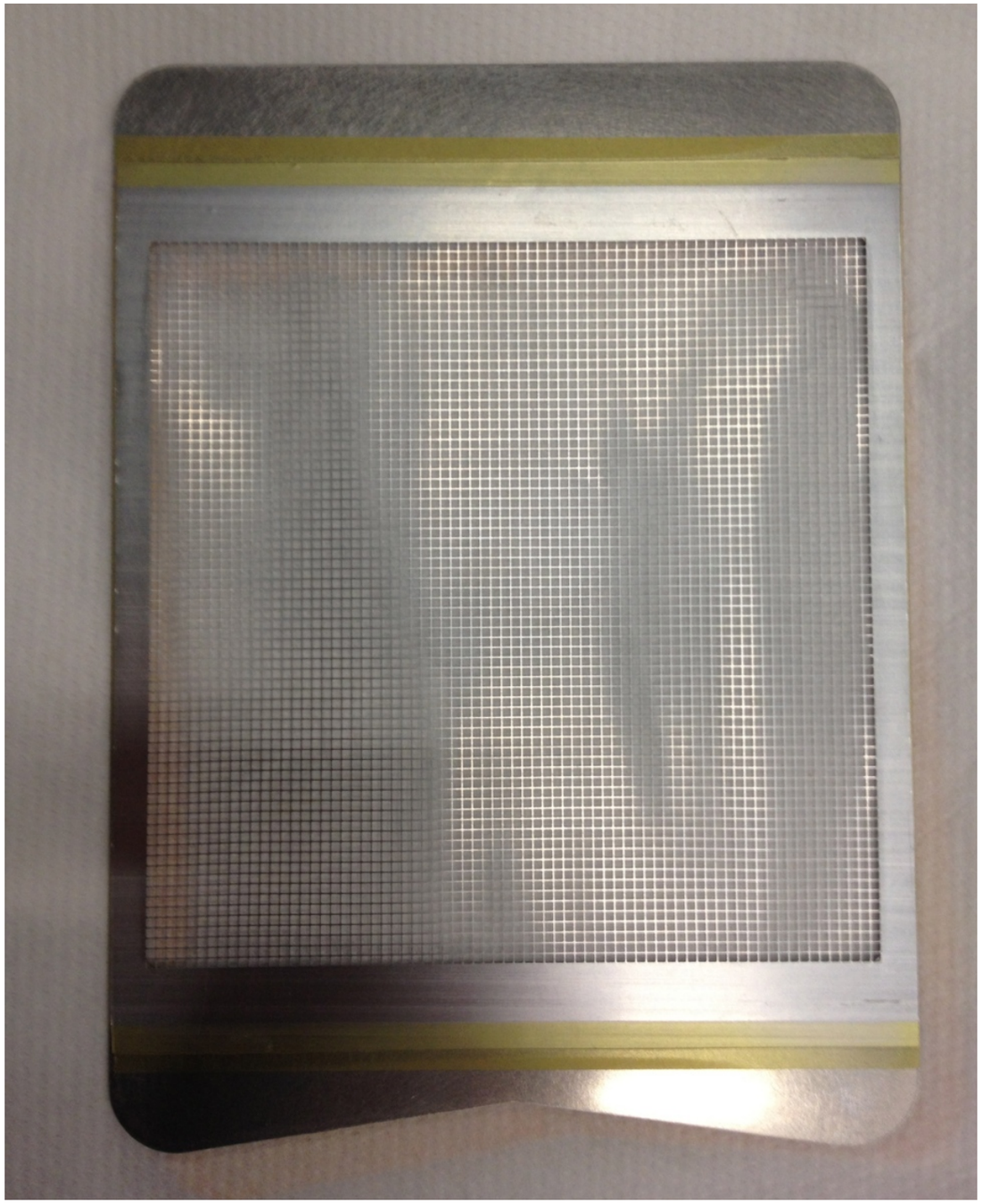
dC/dl=230 pF/m

Single extraction grid configuration

•higher transparency possible (no alignment of grids needed)
•simplified scheme
•less absolute voltage
➡Anode can be operated at ground



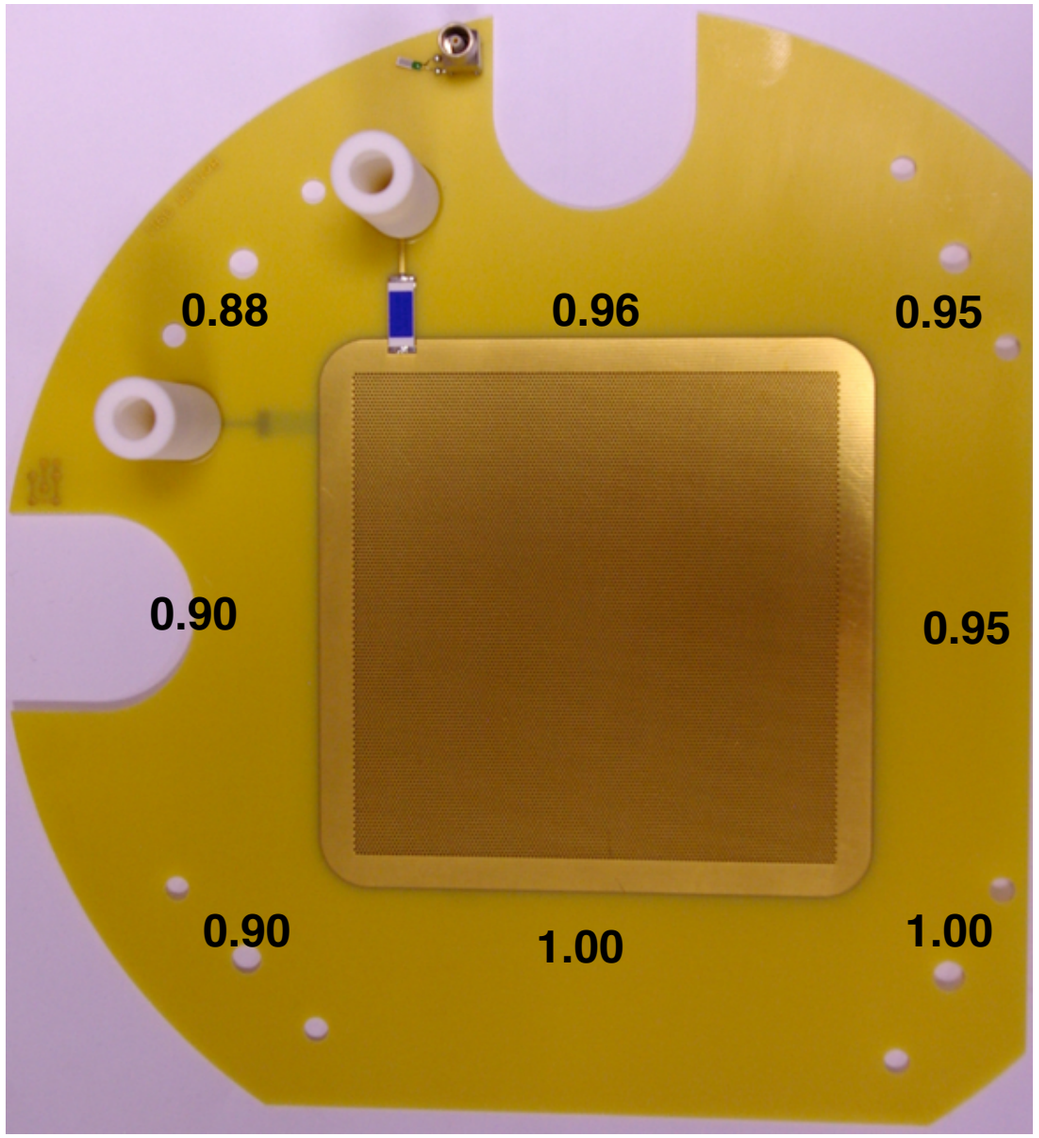
1.5 mm pitch extraction grid

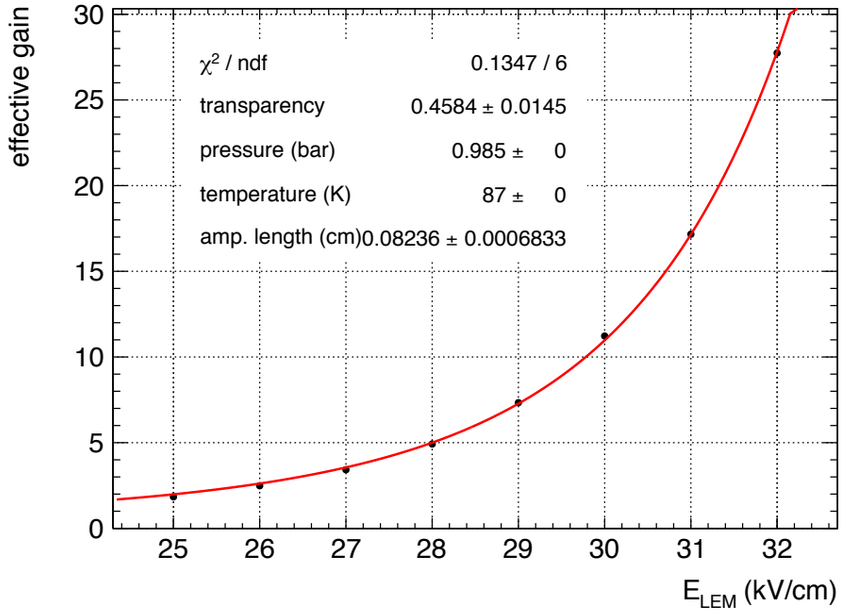


LEM: some considerations

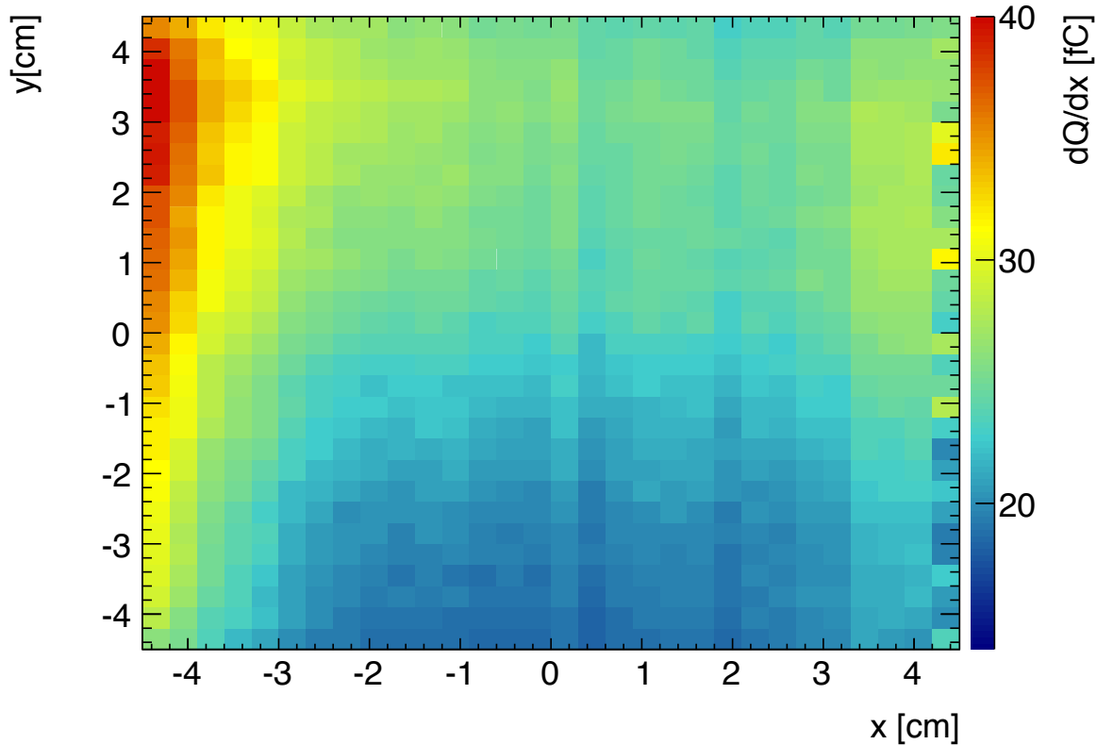
previously seen gain non-uniformity is due to thickness fluctuations of the FR4
➡10% thickness fluct. leads to large gain fluct.

Thickness measurements (1 mm LEM)

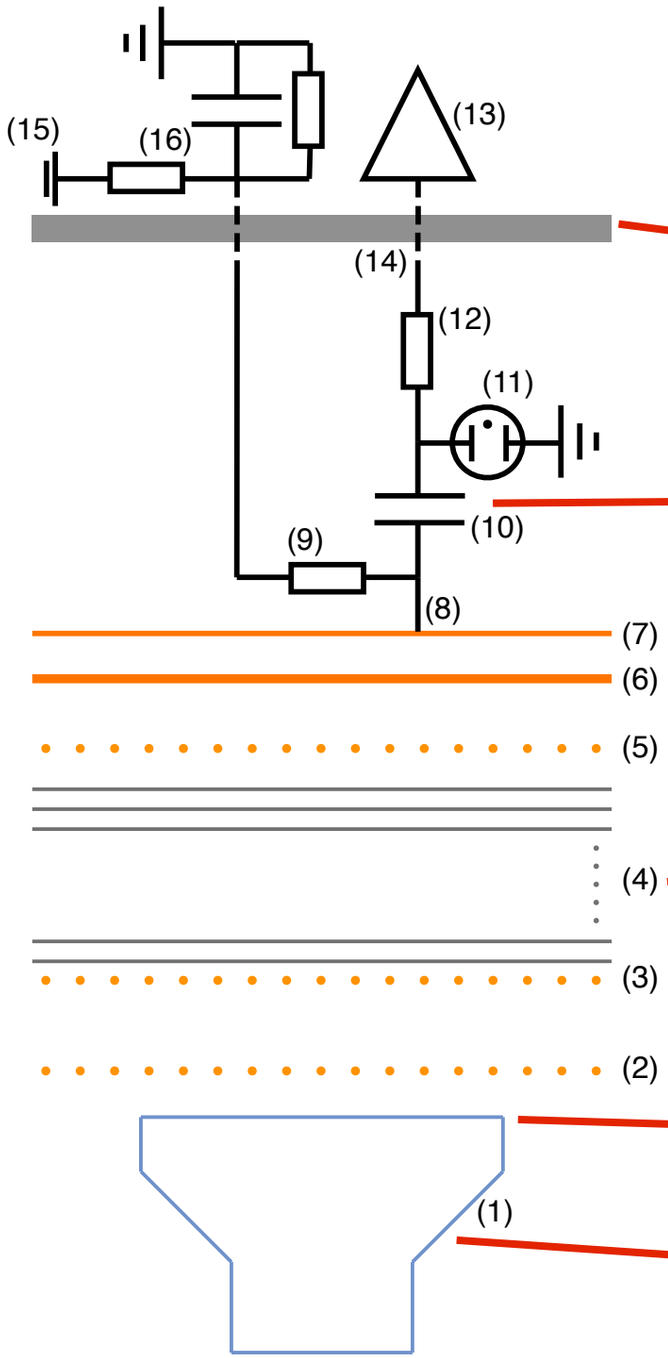




Gain vs x/y



10x10x20 cm³ setup: overview



signal routing / interface to signal cables

HV decoupling capacitors

LEM and 2D readout anode

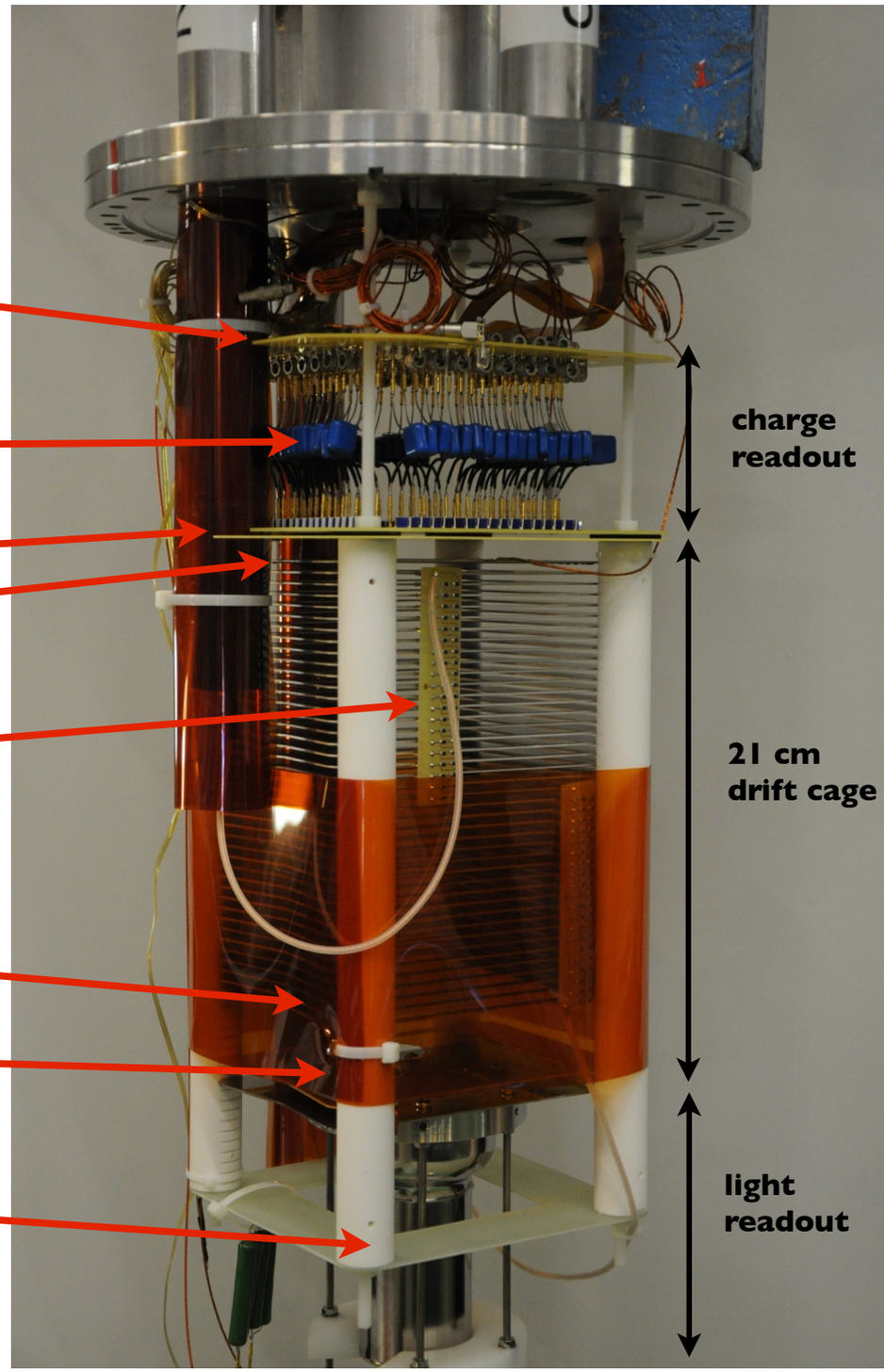
(single) extraction grid

voltage divider

transparent cathode grid

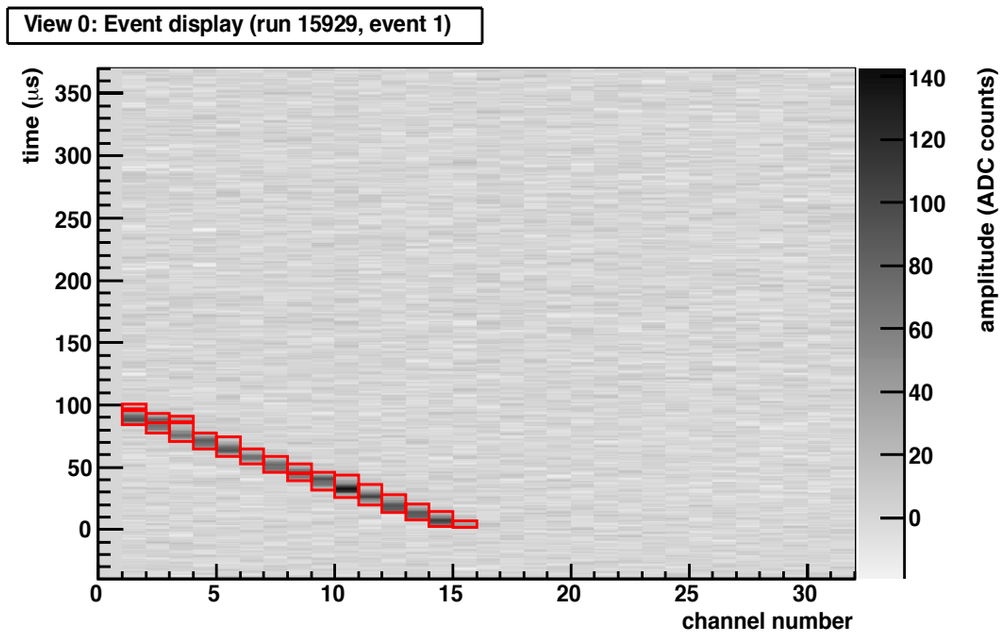
Makrolon window, coated with TPB WLS

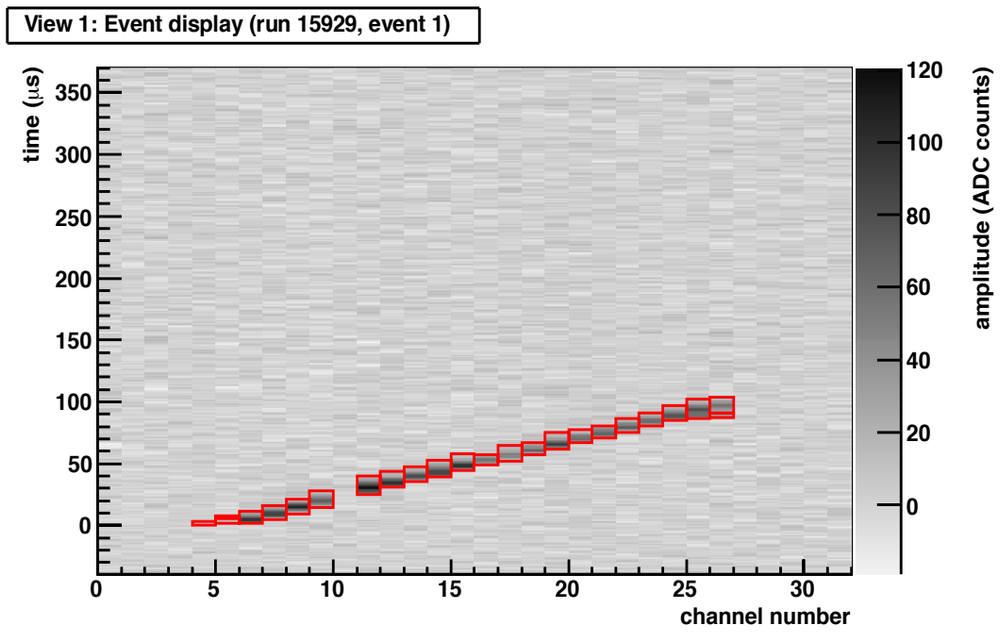
cryogenic PMT with base

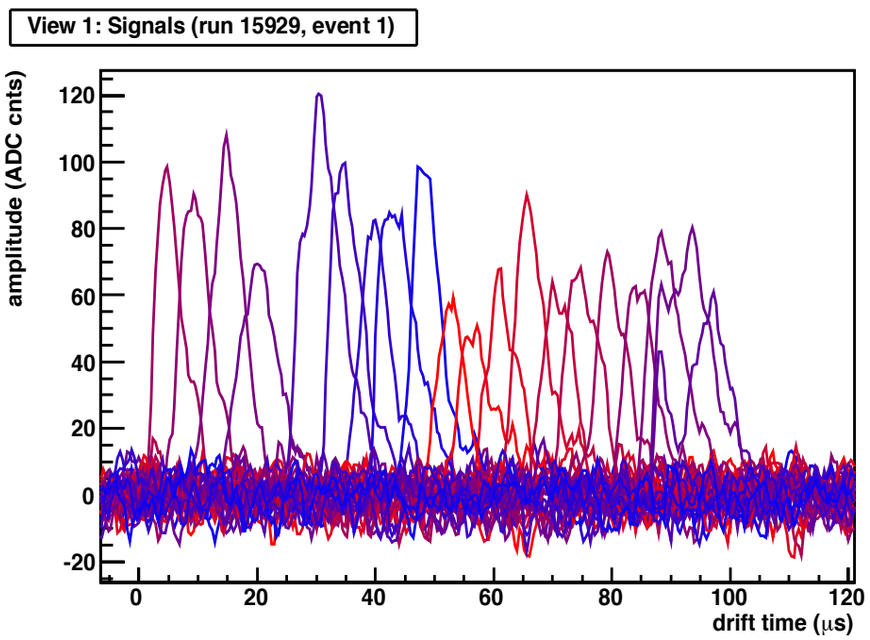


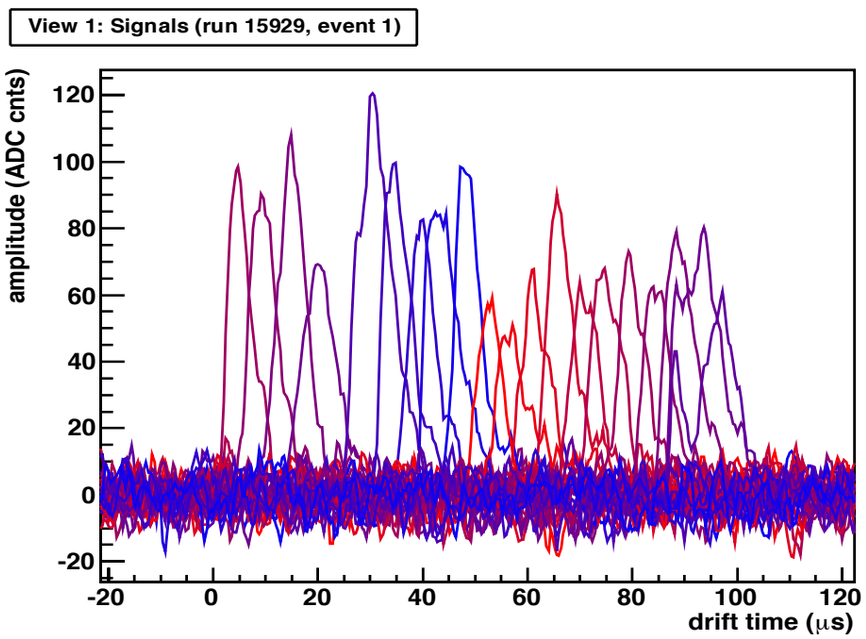
LEM operated with moderate gain ~5

LEM: 27 kV/cm, induction: 5 kV/cm, extraction: 2 kV/cm, drift: 0.5 kV/cm



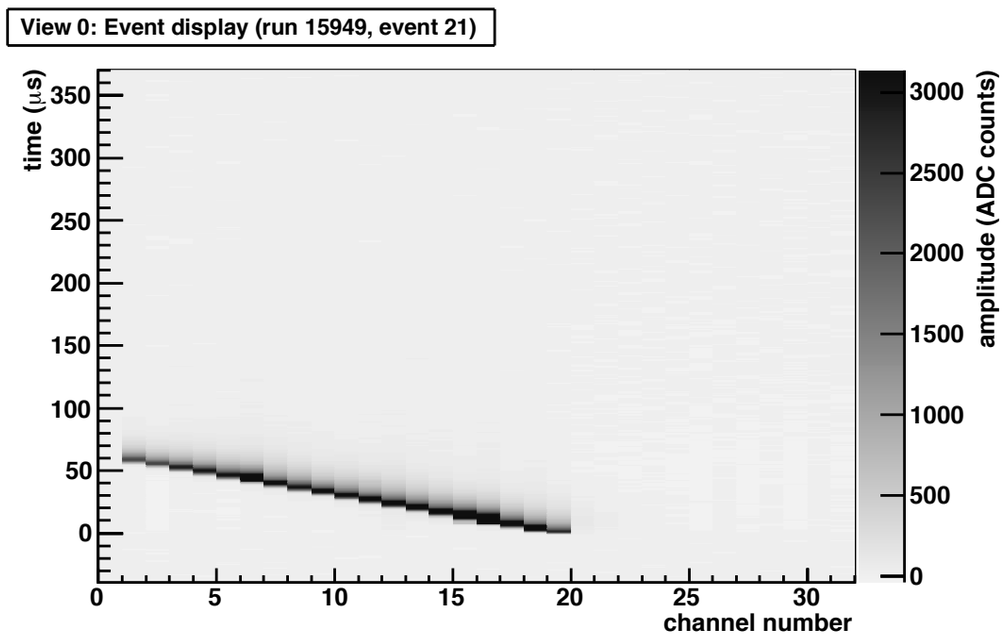


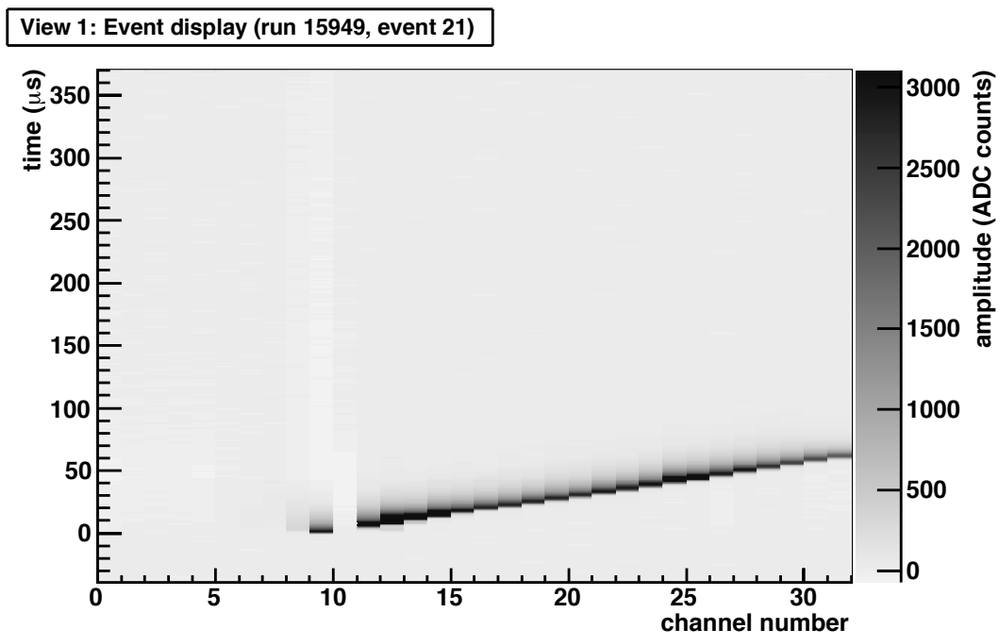


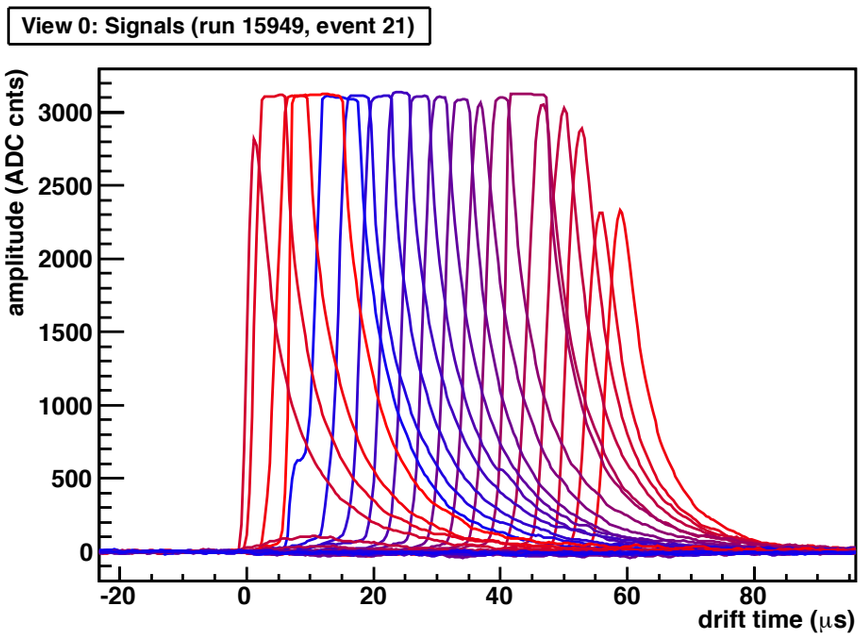


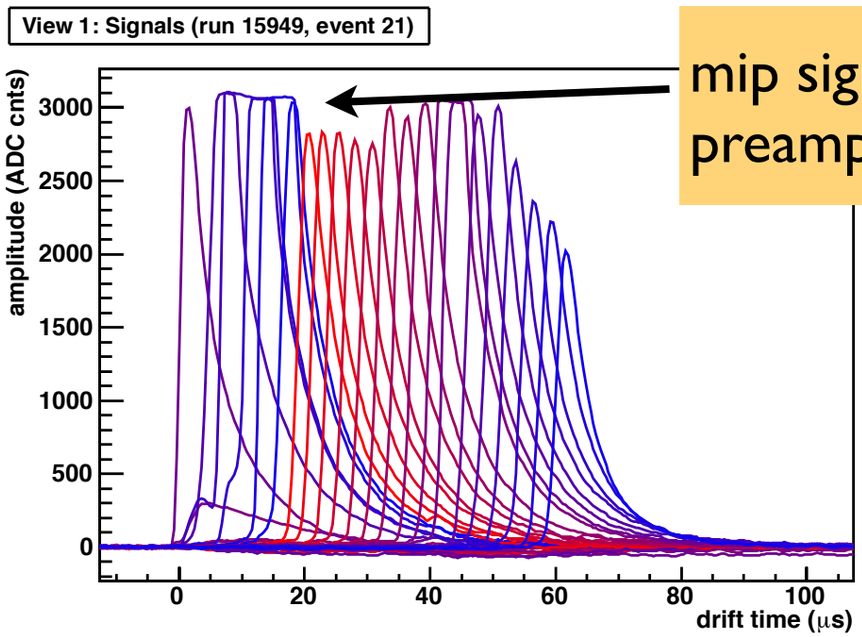
LEM operated with highest gain >90!

LEM: 35 kV/cm, induction: 5 kV/cm, extraction: 2 kV/cm, drift: 0.5 kV/cm



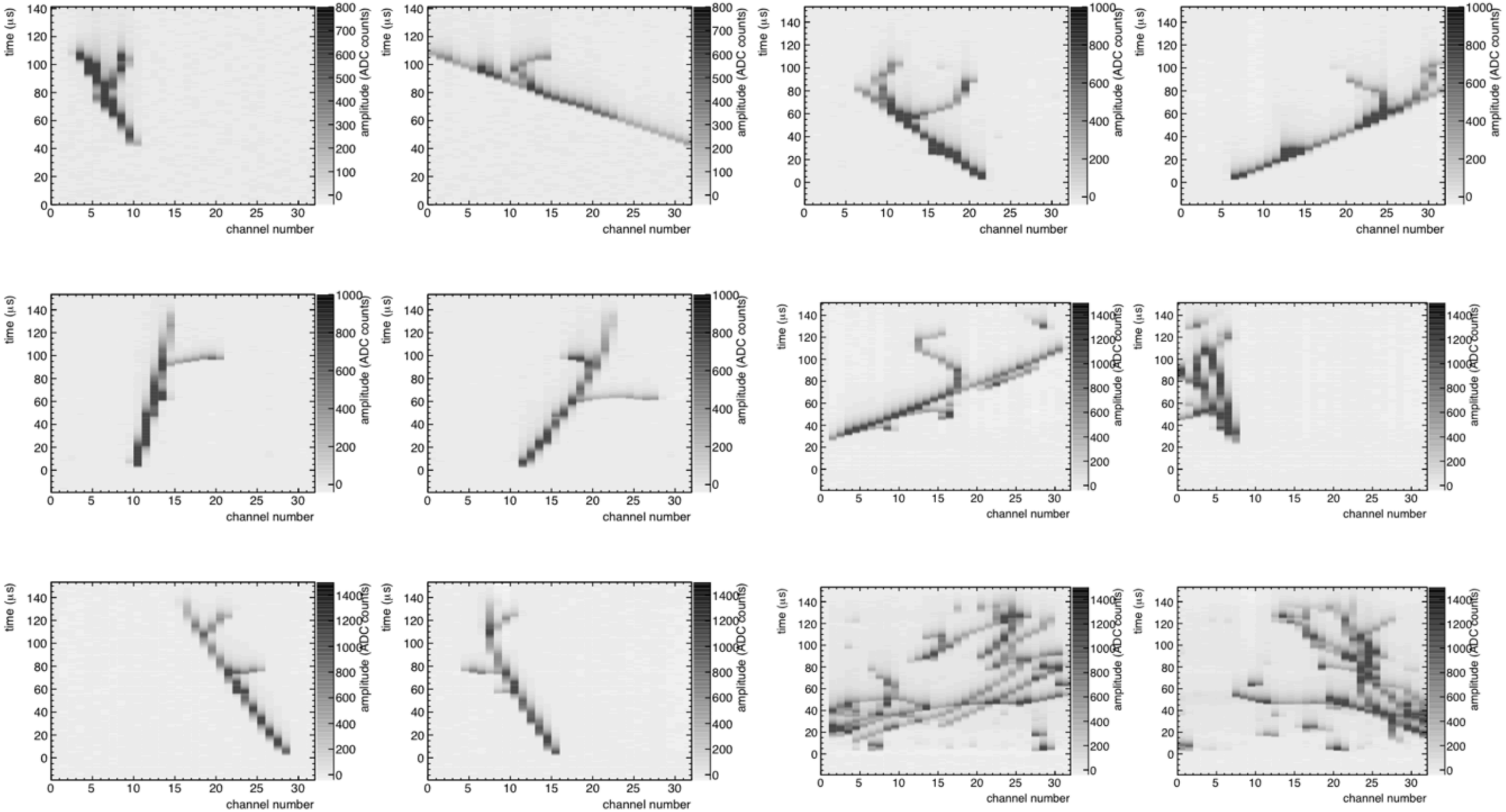




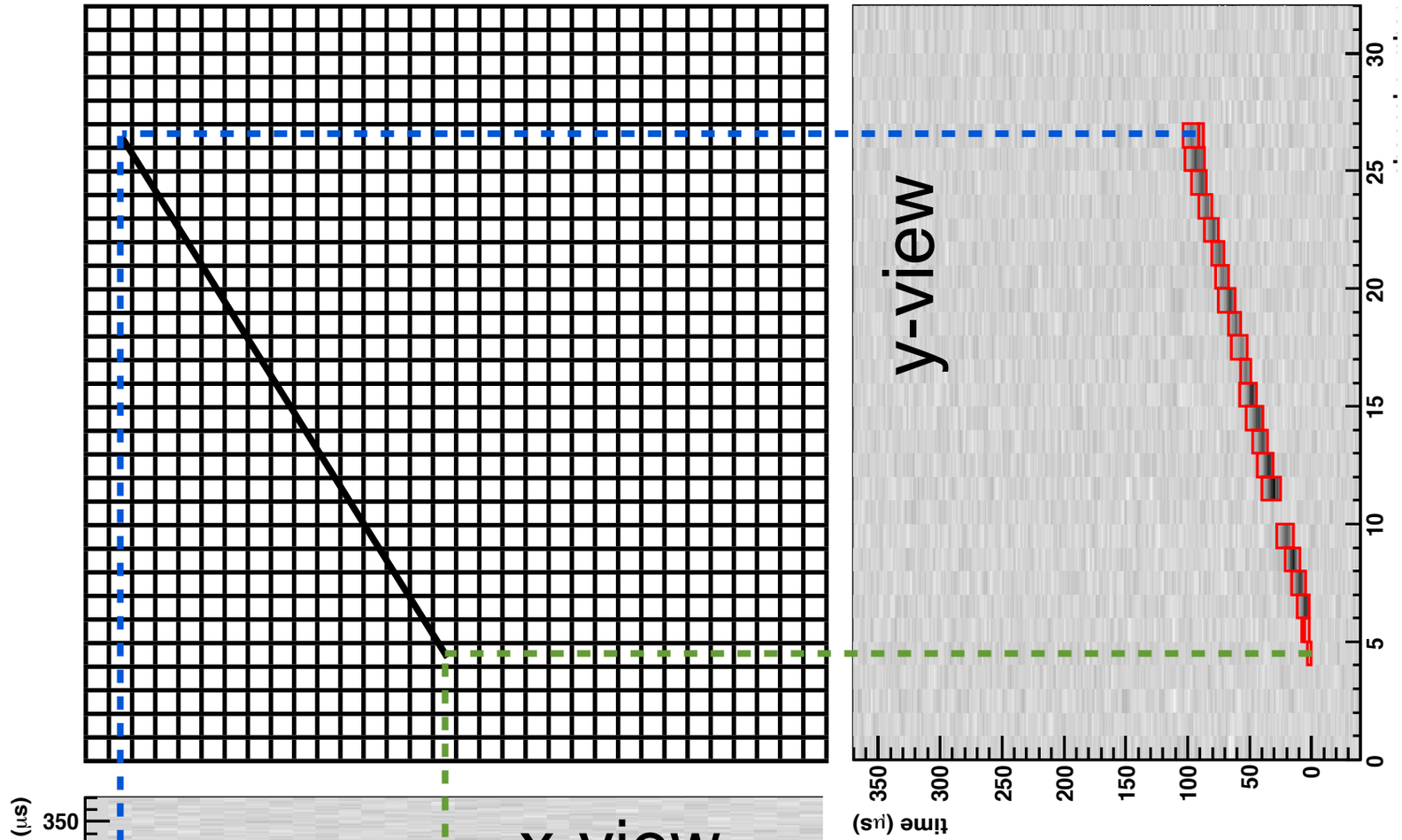


mip signals saturate preamplifier!

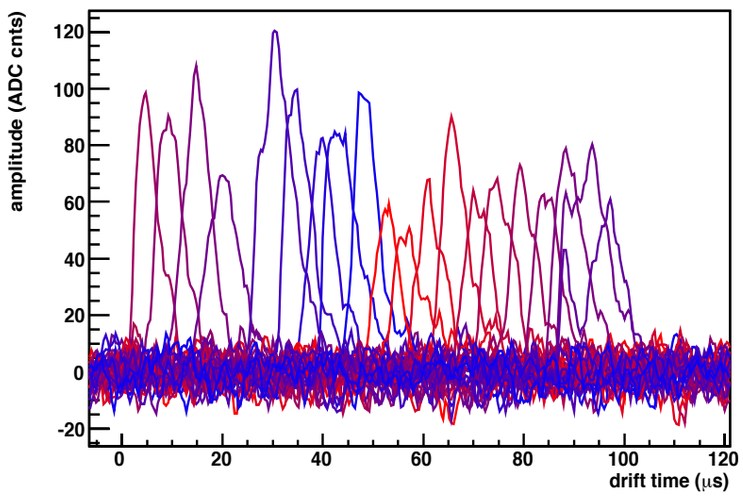
more events with gain ~30



Track reconstruction procedure



signals:

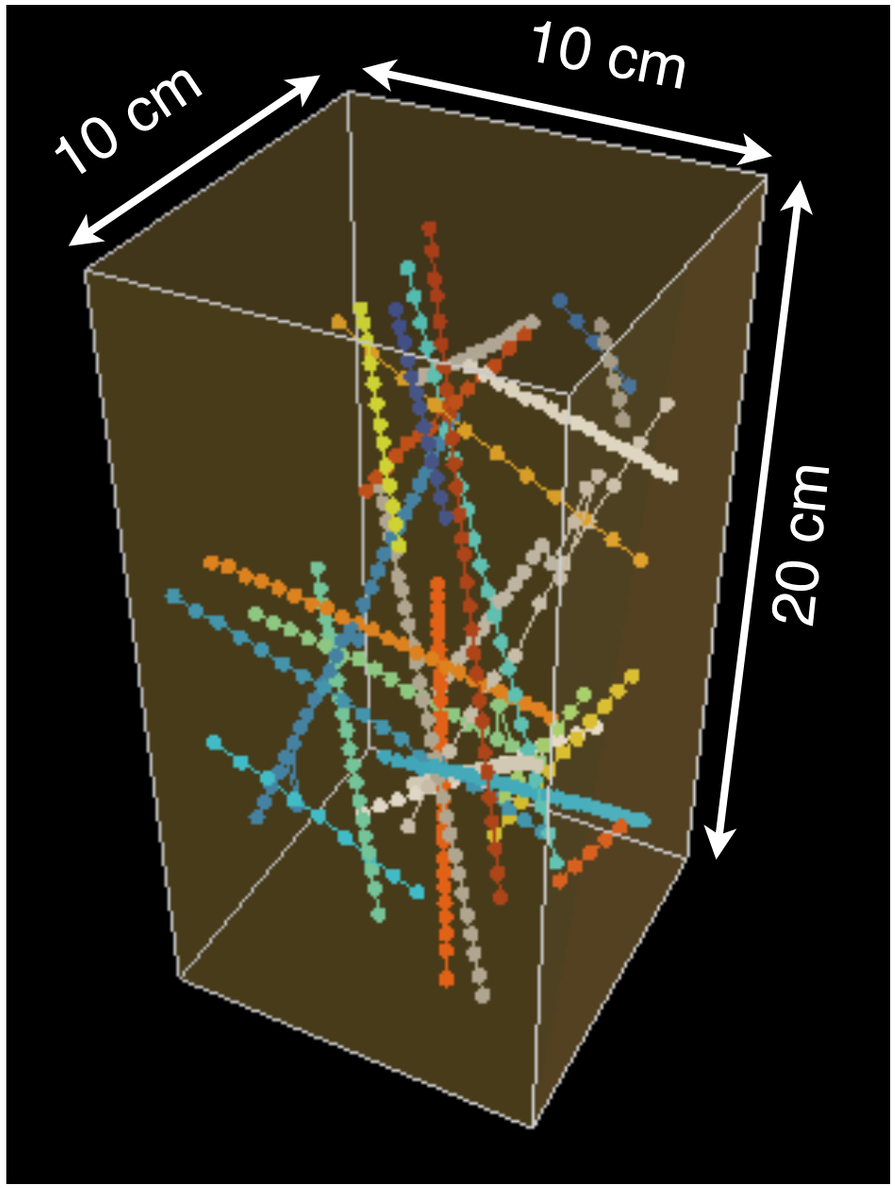


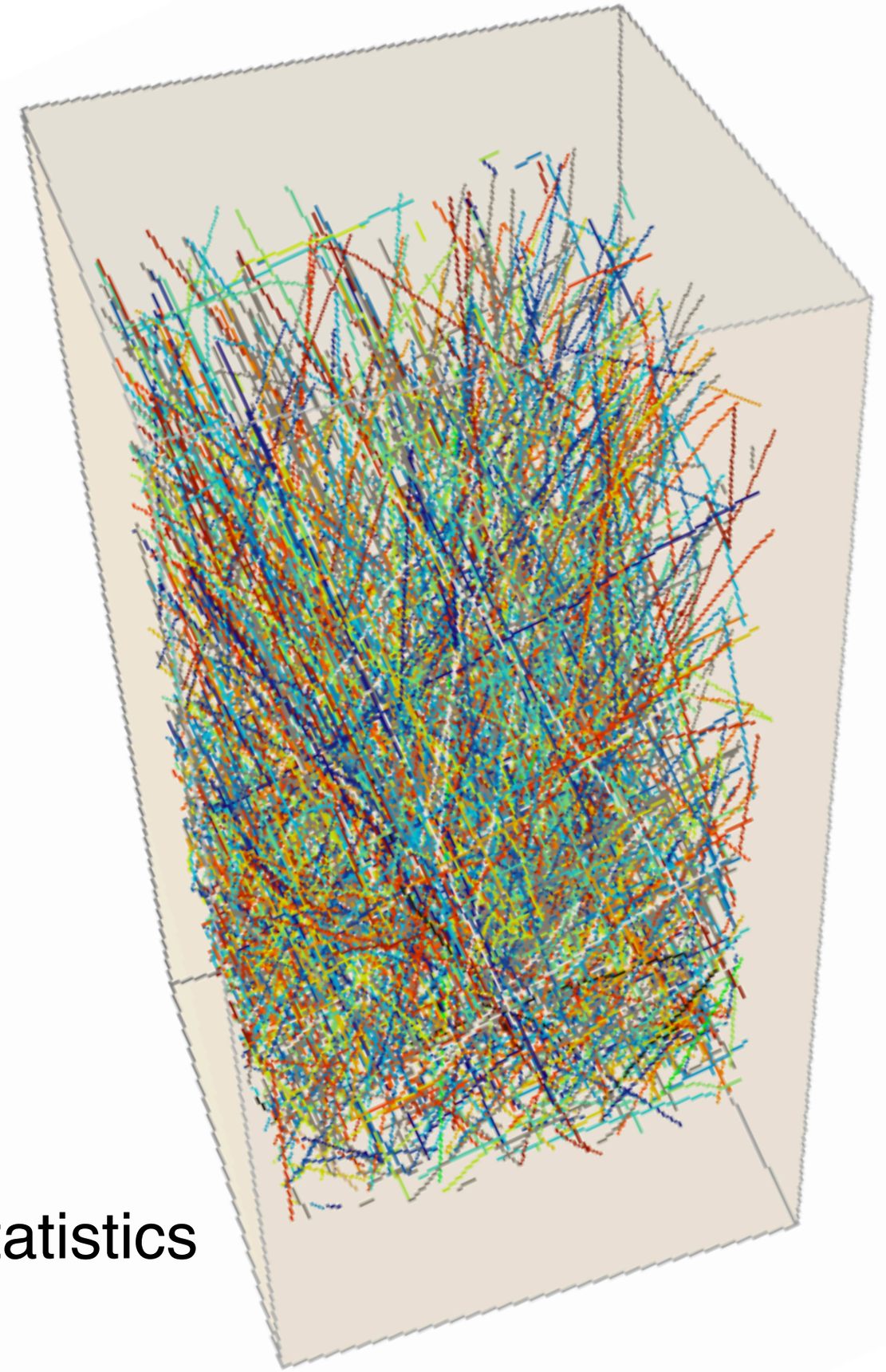
2 orthogonal projections (=views) are recorded

1. subtract noise, find signals (=hits, red boxes)
2. find straight tracks in each view
3. reconstruct 3D coordinates by matching coincident hits

➡ ΔQ and Δx (3 dimensional track segment!) for each view, literature: ΔQ/Δx=10 fC/cm (mip)

3D reconstructed tracks





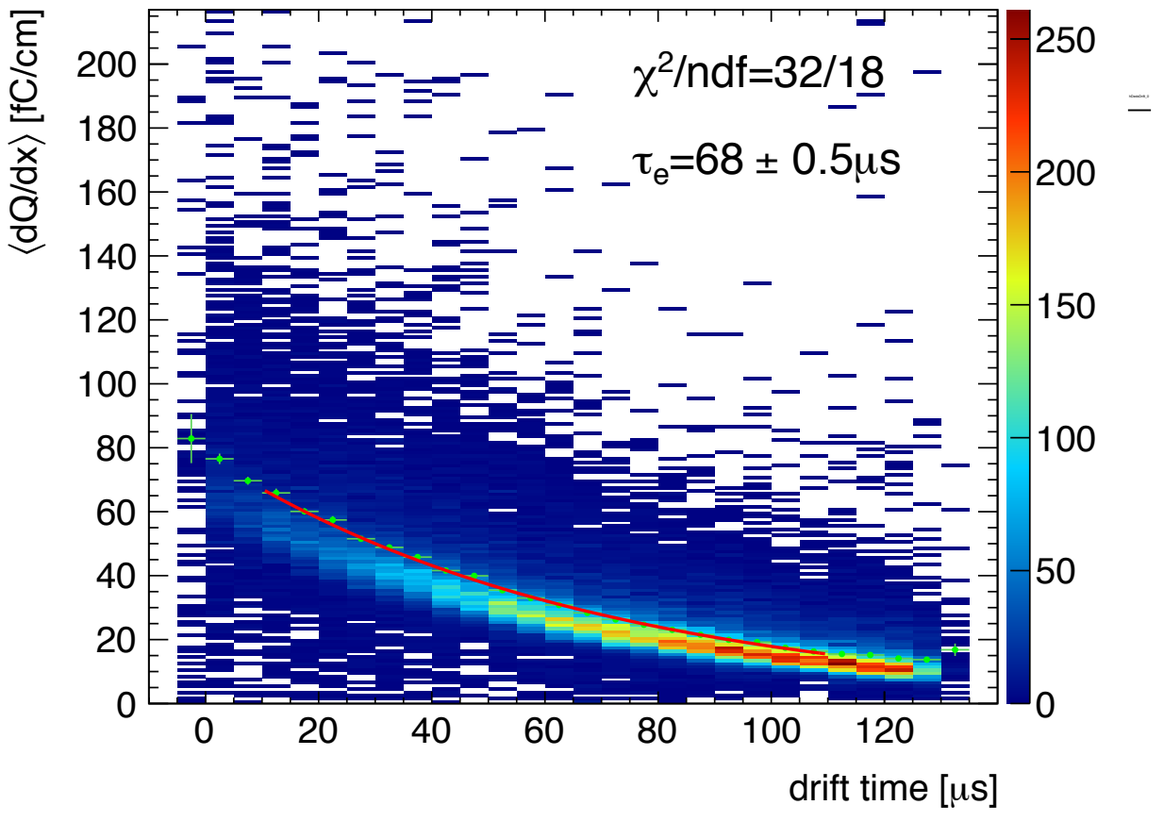
large statistics

Calibration: drift attenuation

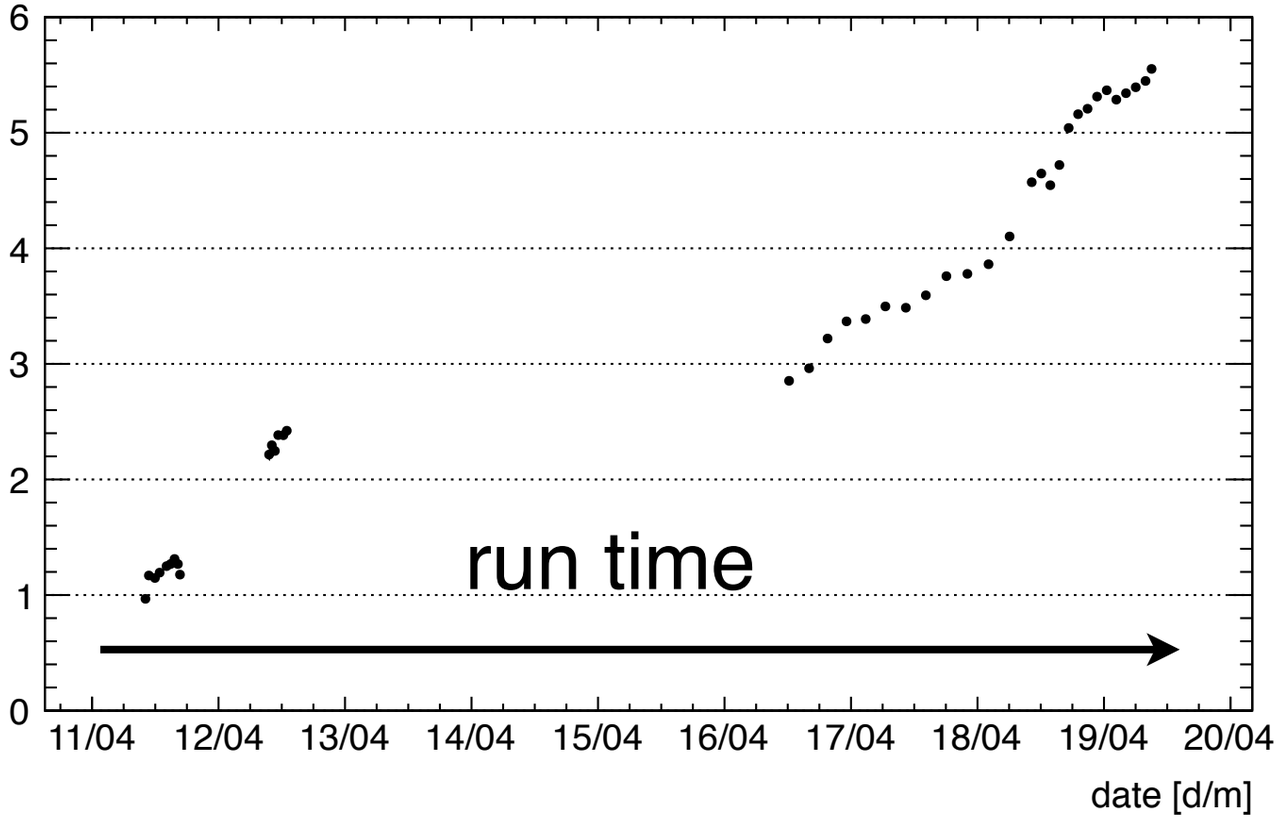
free electrons trapped by impurities => Corrections necessary!

$$[O_2]_{eq} \approx 300\ \mu s\ /\ \tau$$

$\Delta Q/\Delta x \sim \exp(-t_{drift}/\tau)$:



purity evolution:



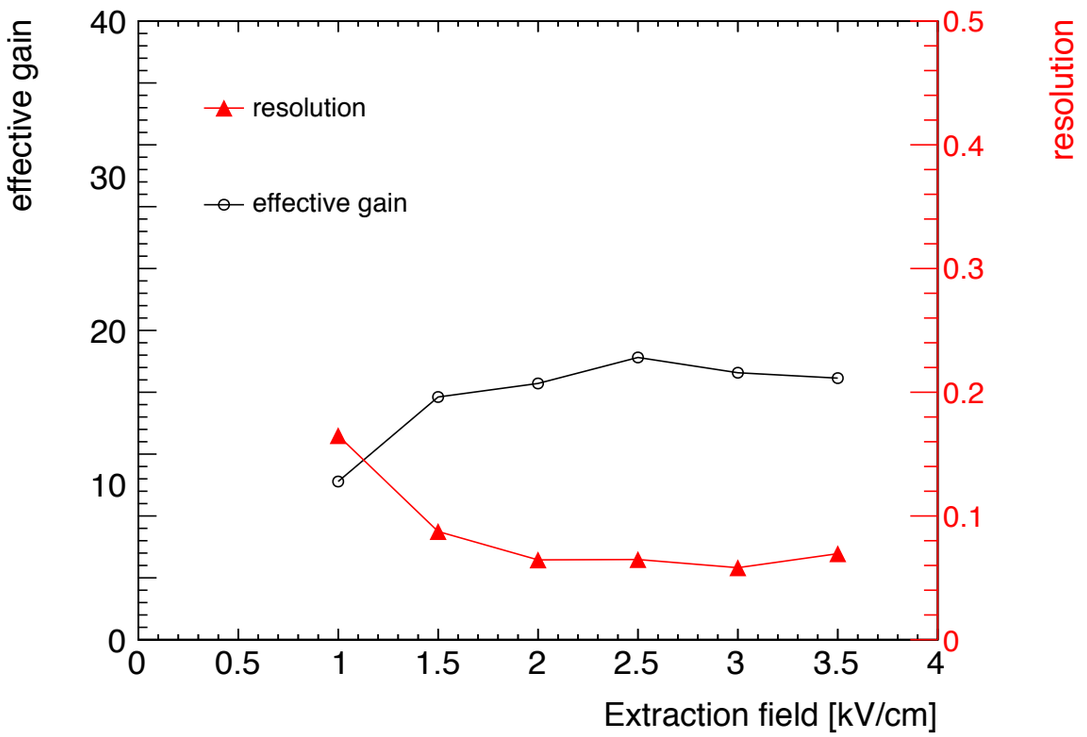
extraction field scan

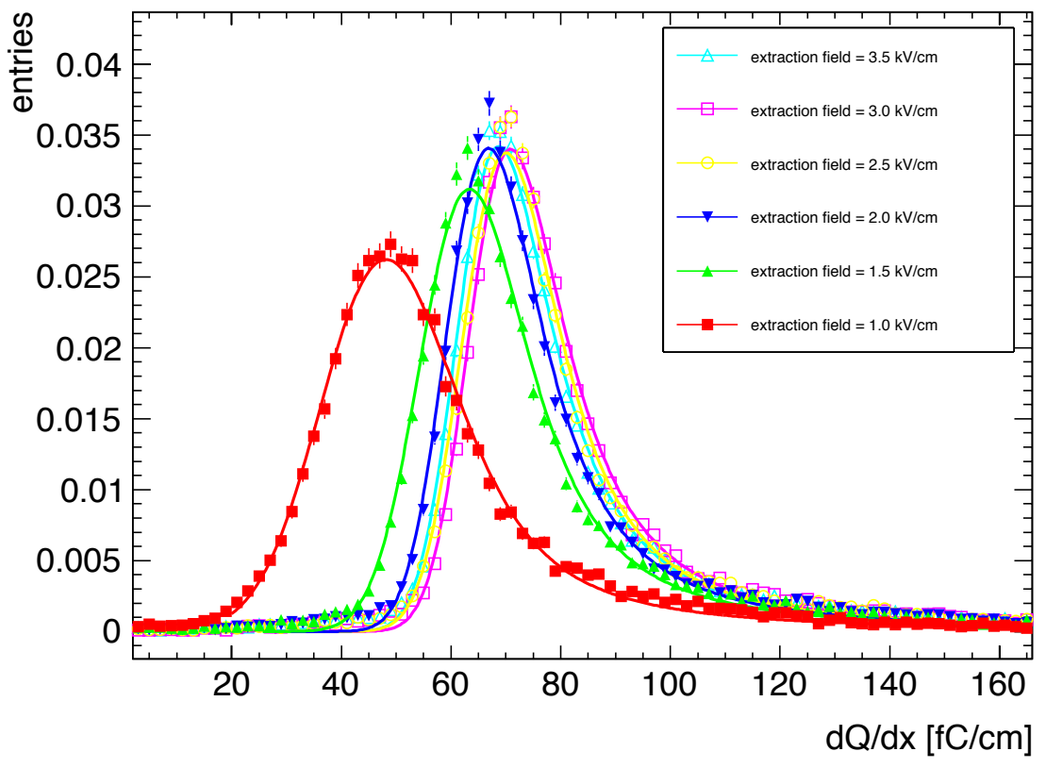
• drift, LEM and induction fields were kept constant while increasing the extraction field
• electron emission from LAr to GAr is flat above 1.5 kV/cm
•std value: 2 kV/cm

electric field configurations

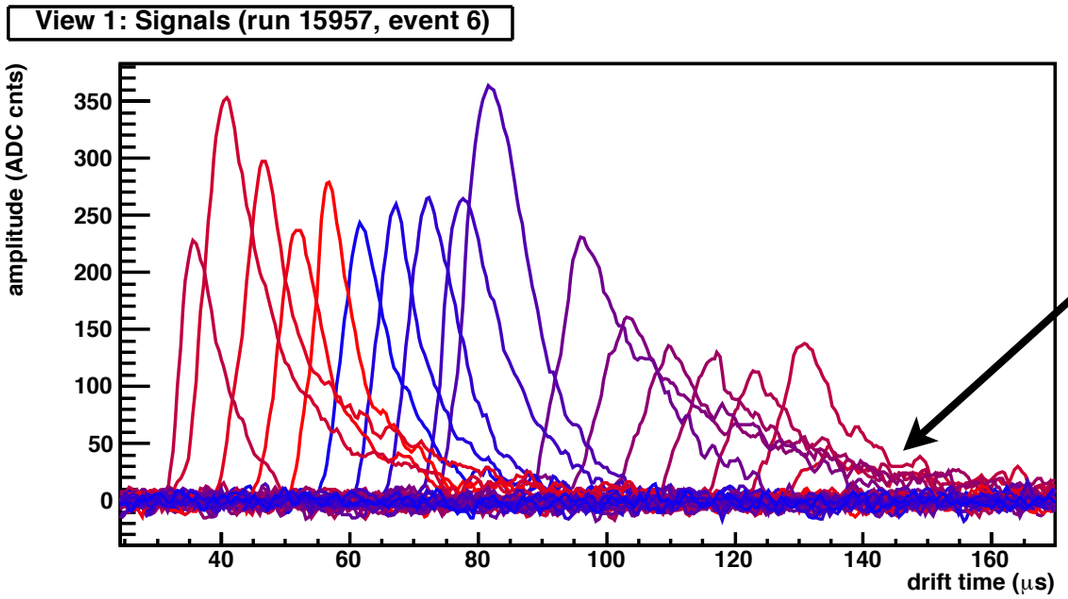
induction	7 kV/cm
LEM	28 kV/cm
extraction	1.0-3.5 kV/cm
drift	500 V/cm

events with 1 kV/cm extraction field

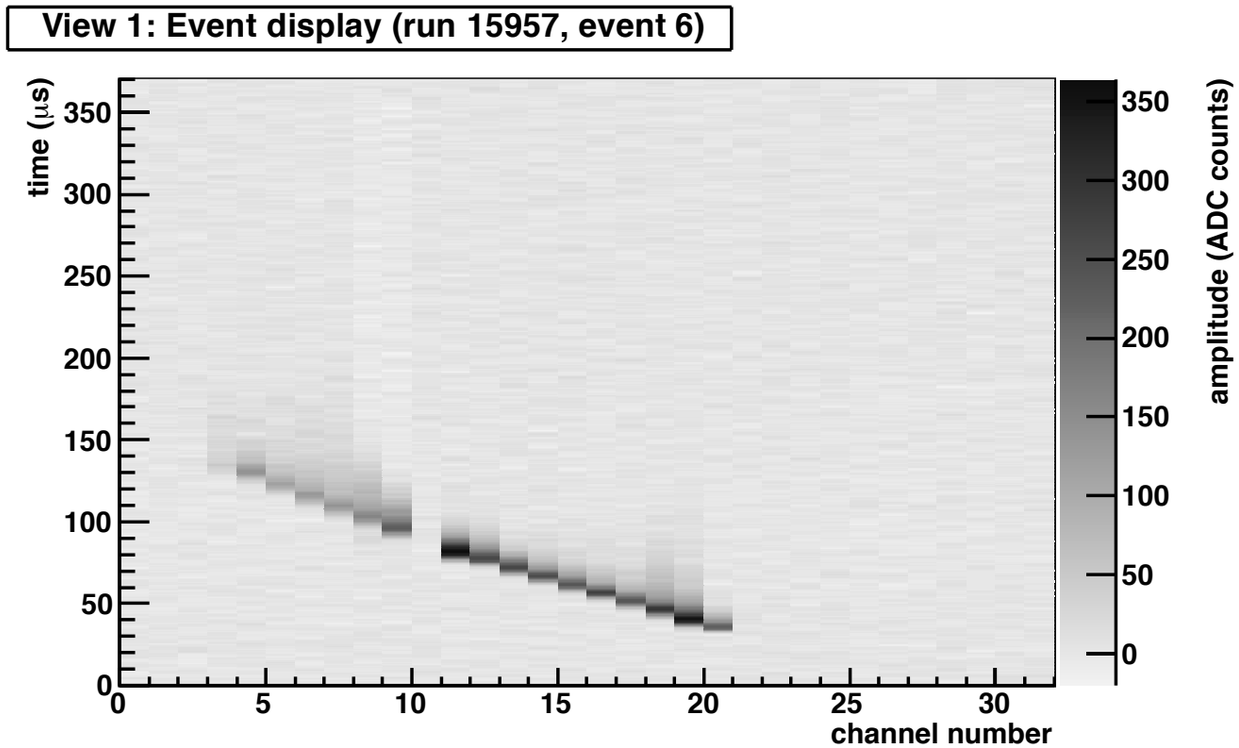




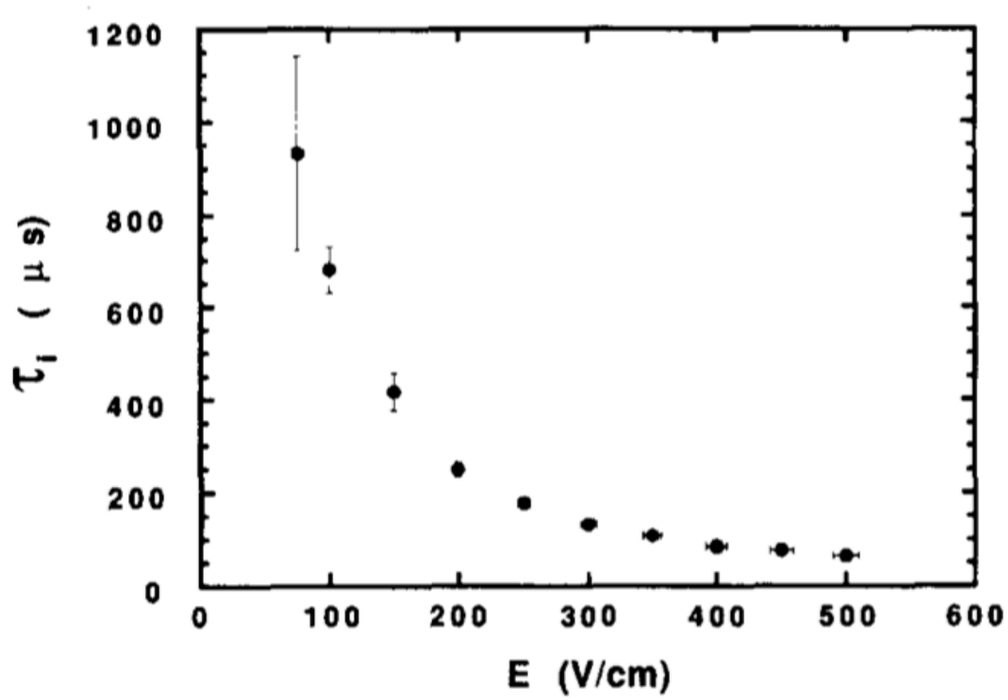
What happens at low extraction fields?



tails, due to slow electron emission at low fields (here: 1.5 kV/cm)



Literature:



Borghesani et al., *"Electron transmission through the Ar liquid-vapor interface"*, Phys. Lett. A149 (9)

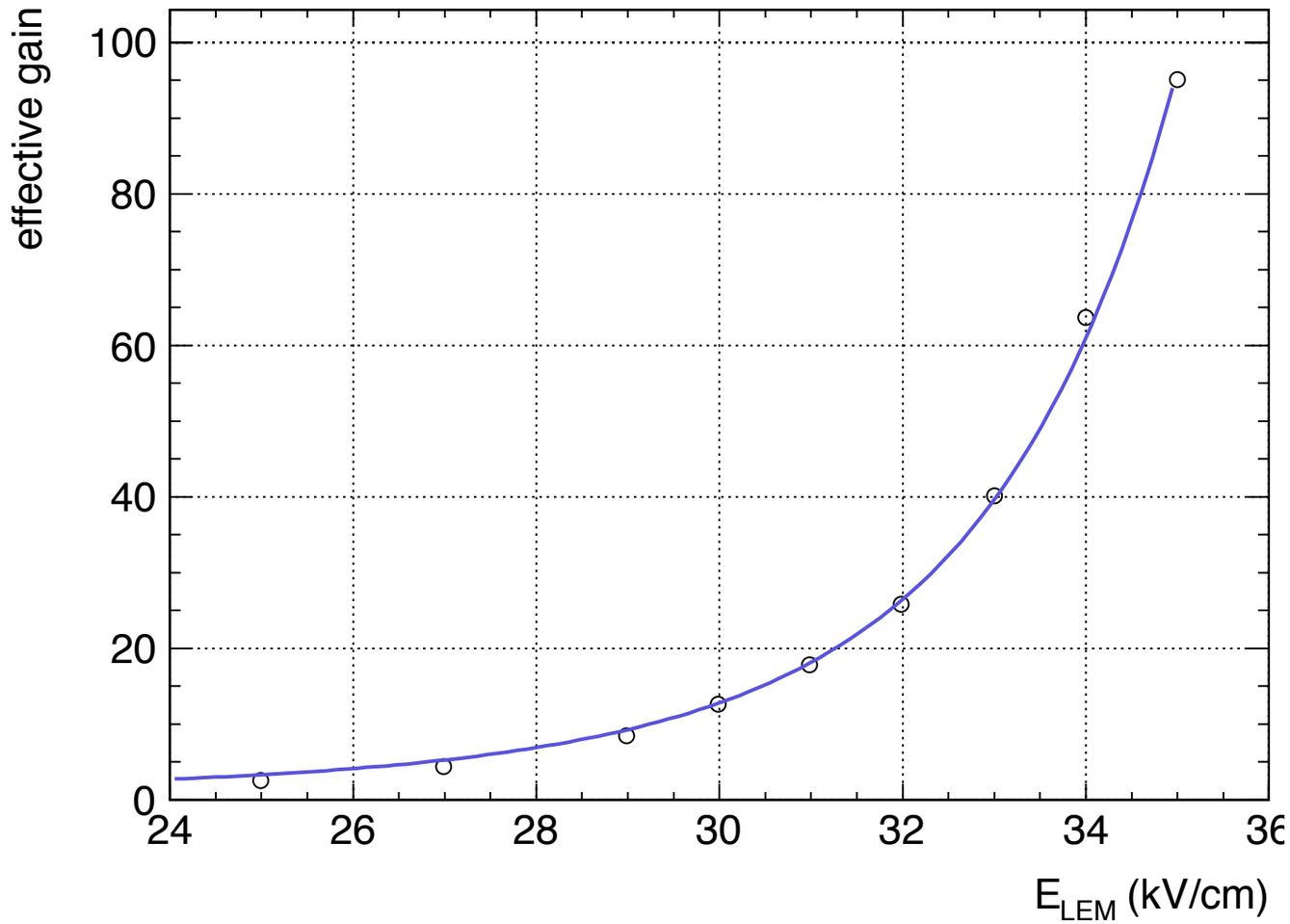
LEM field scan up to gain 90!

- drift, extraction and induction fields were kept constant while increasing the LEM field
- onset of discharges @ gain 90!

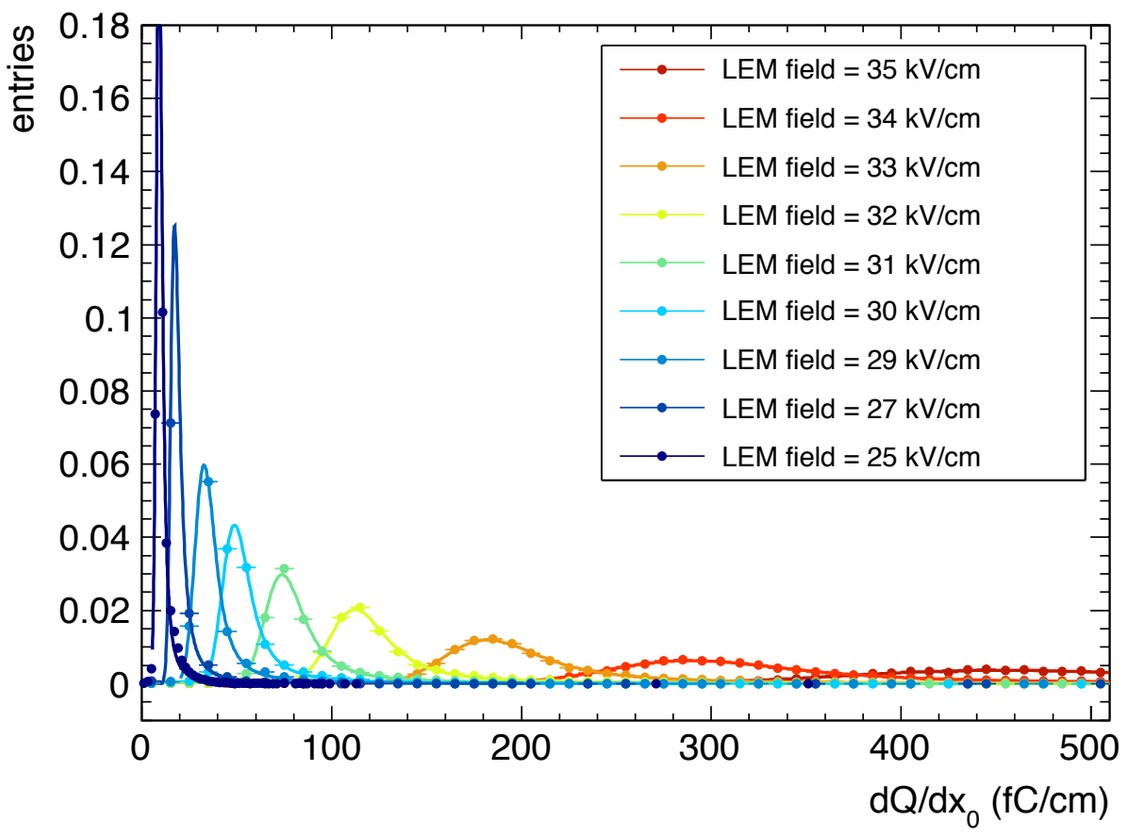
electric field configurations

induction	5 kV/cm
LEM	25-35 kV/cm
extraction	2.0 kV/cm
drift	500 V/cm

Gain vs. LEM field

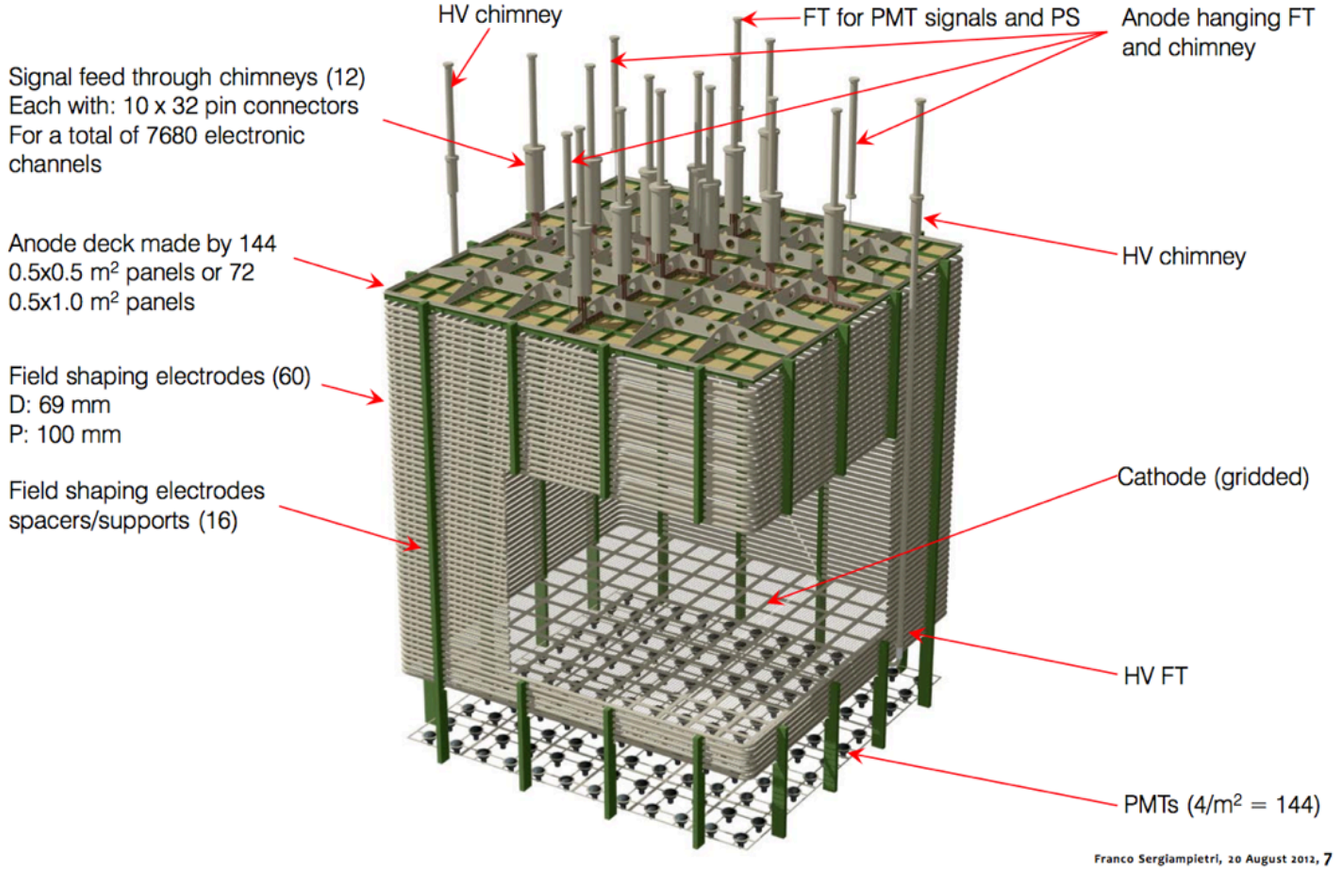


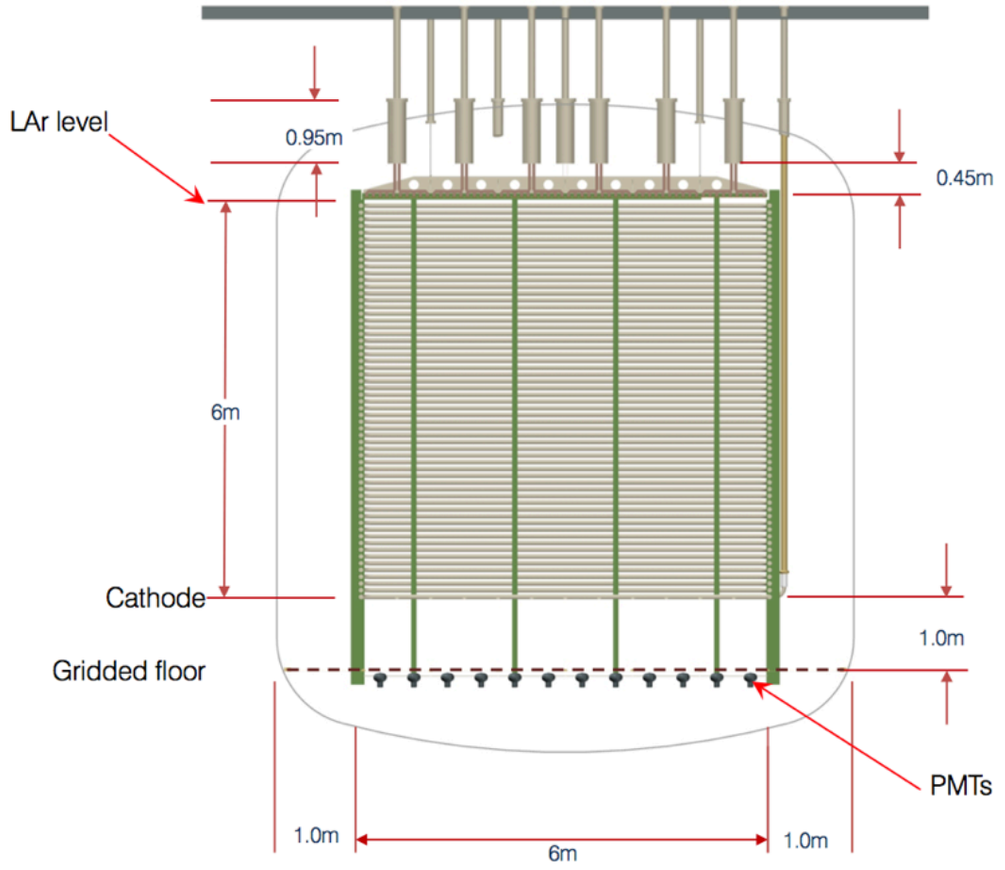
Landau distributions with diff. gains



LAGUNA prototype @CERN

•6x6x6m^3 prototype to be constructed and operated at CERN, as a prototype of the far detector double-phase TPC
•Charged test beams to collect the large controlled data set allowing electromagnetic and hadronic calorimetry and PID performance to be measured, simulation and reconstruction to be improved and validated
•Detector to be positioned in the North Area in an extension of the EHN1 building
•Timescale: facility for preparation of full LAGUNA-LBNO proposal
•Pending approval by CERN SPSC





Conclusions

10x10 cm² prototype results

- new simplified anode and single grid configuration successfully tested
- gains up to 90 were reached
- We are currently collecting more data to study stability and discharge behavior

next steps:

- a next test with a further simplified anode is in preparation
- a new LEM design is being developed (PCB workshop)
- Technical design for 6x6x6 m³ LAr TPC @NA,CERN in preparation