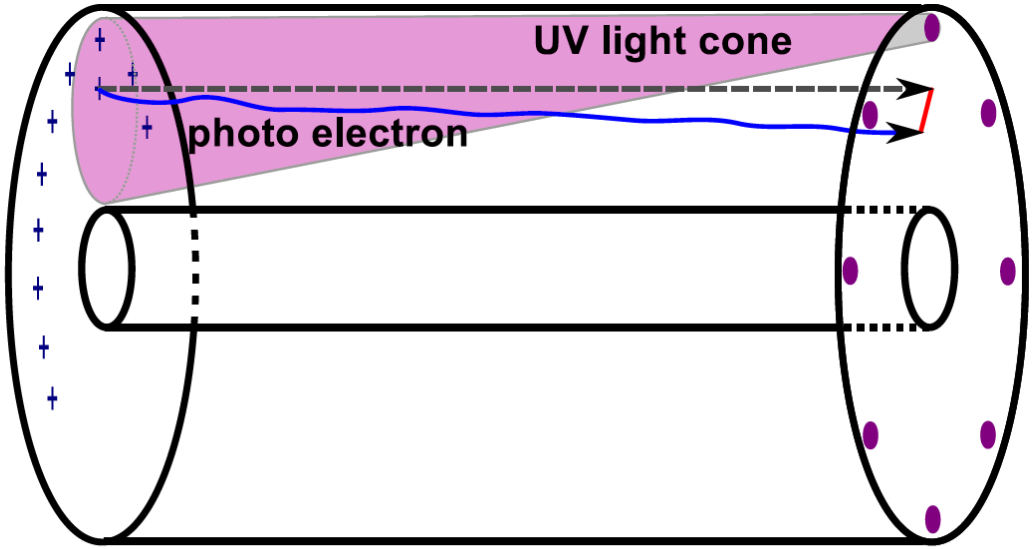
A Monte Carlo simulation for effective electron transport in gaseous detectors

Dimitri Schaab
HISKP, Bonn University
Simulation Meeting
2019-12-11

Motivation

well-known electron starting points:
exactly defined positions of photo-cathode patterns



calibration measurement:

spatially and temporal deviating electrons

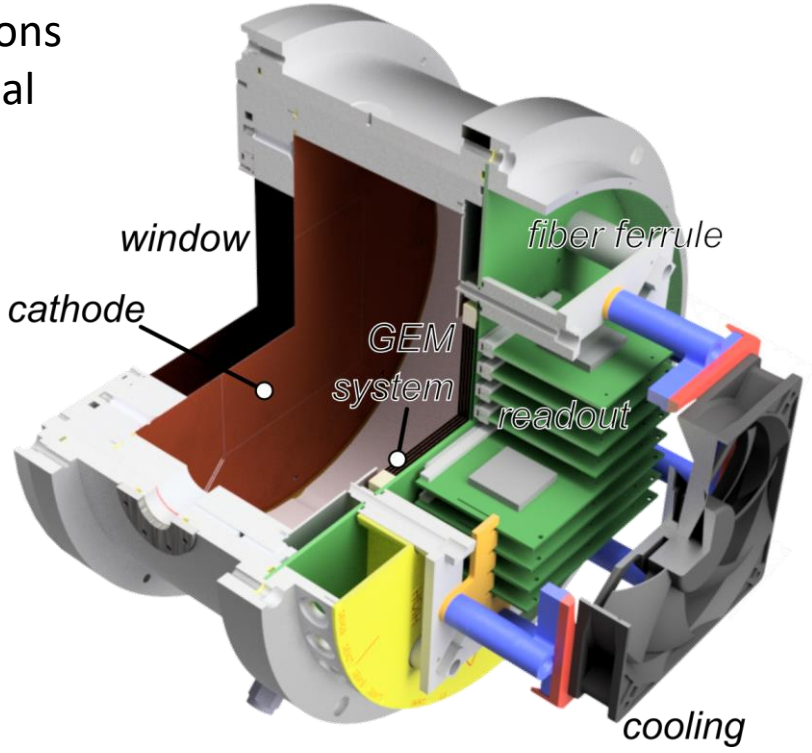
cathode plane
with certain Al-pattern

readout/anode plane
with integrated UV sources

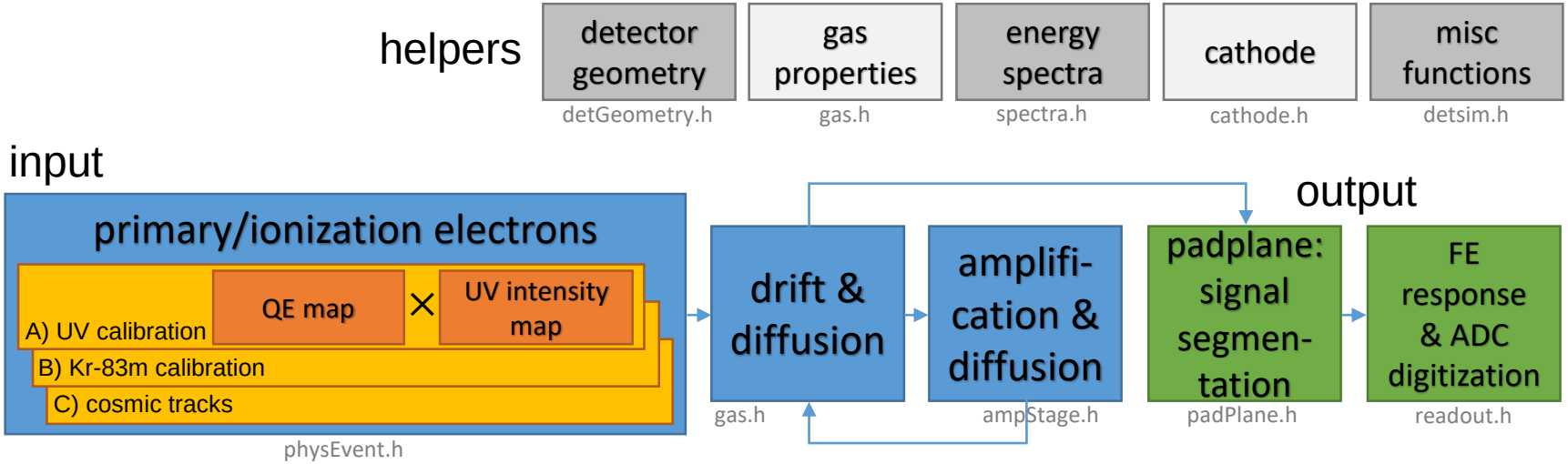
Motivation

simulation goals

- get readout response of specially prepared calibration photocathode
- constraint on pattern structure sizes of photocathode
- ideal-detector-reference without field distortions
- reconstruction performance benchmark for real measurements



Simulation
structure



Simulation
structure

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helpers

detector geometry	gas properties	energy spectra	cathode	misc functions
detGeometry.h	gas.h	spectra.h	cathode.h	detsim.h

input

primary/ionization electrons

A) UV calibration: QE map × UV intensity map

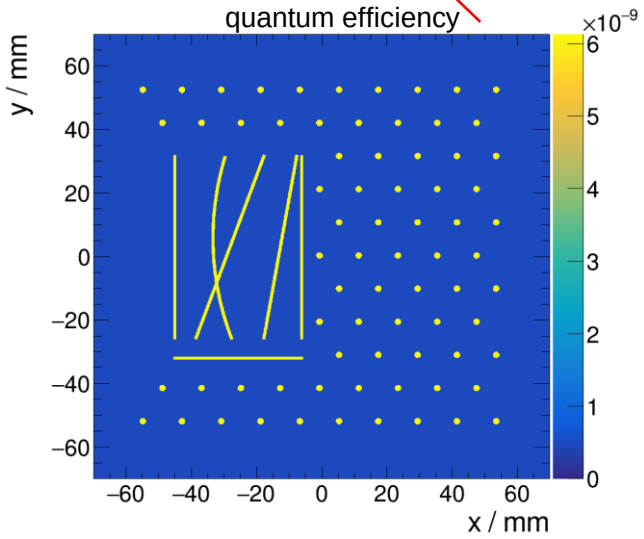
B) Kr-83m calibration

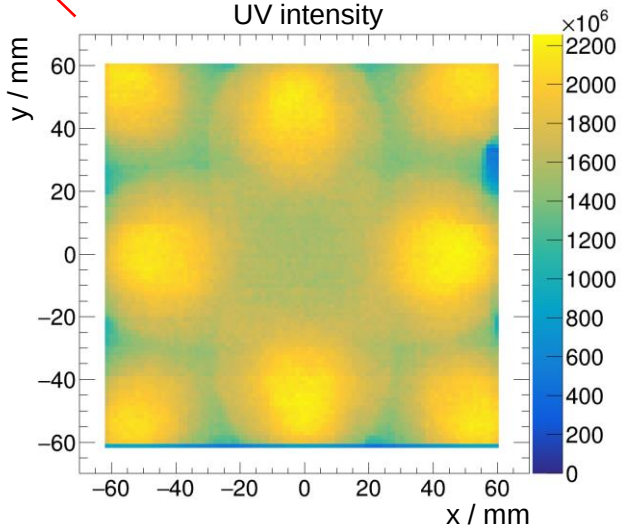
C) cosmic tracks

physEvent.h

output

drift & diffusion (gas.h) → amplifi-cation & diffusion (ampStage.h) → padplane: signal segmen-tation (padPlane.h) → FE response & ADC digitization (readout.h)





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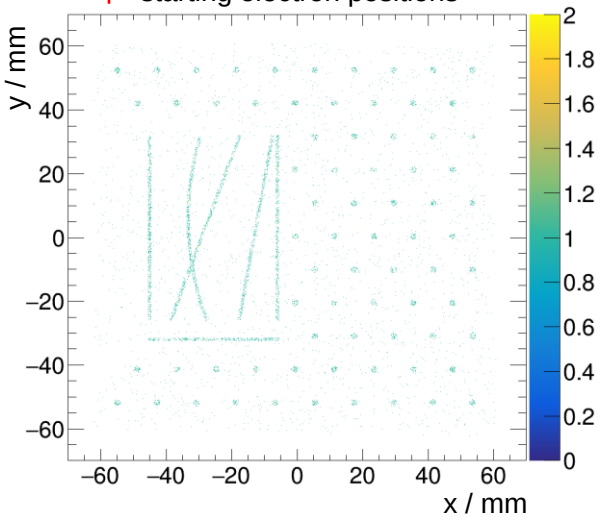
starting electron positions



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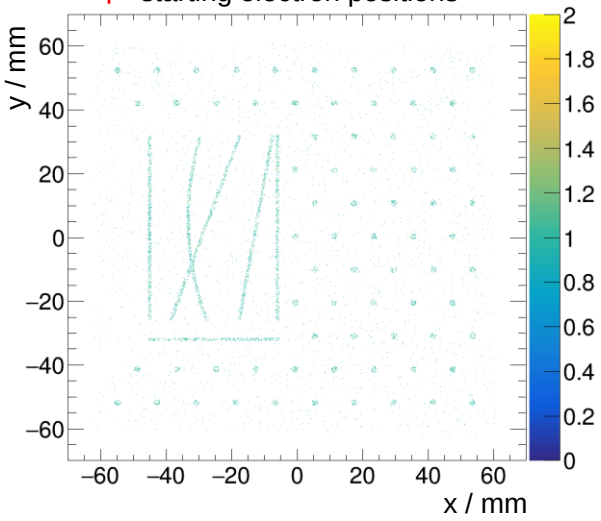

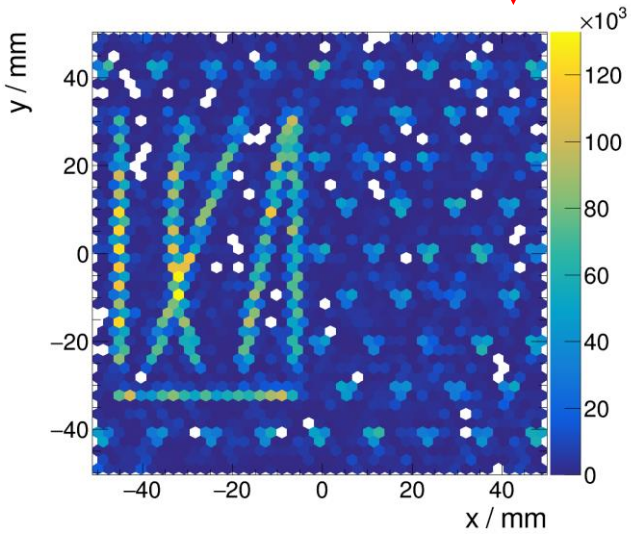

Main program structure

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```
for ( uint i = 0; i < Evts; ++i ) { //loop over events

  // padPlane event histogram preparation
  TH2Poly *myEvtHisto = myPadPlane.histo( myGeometry );
  myPadPlane.prepare( i, myEvtHisto, EDrift, EGEM3R, myGas, myGeometry );

  // generate primaries by physics event
  myPhysEvent.setPrimaries( myGeometry, myCath, mySpectrum, myGas, EDrift );

  // initial drift towards GEM1
  myDrift.driftPrim( myPhysEvent.xPrimVec, myPhysEvent.yPrimVec, myPhysEvent.zPrimVec, myPhysEvent.tPrimVec, EDrift, myGas );

  //= = = = = = = = = traverse GEM1 = = = = = = = = = = = = = = = = = =
  myAmpStage.stdGEM( myDrift.xVec, myDrift.yVec, myDrift.zVec, myDrift.tVec, EDrift,EGEM12,UGEM1 );

  // drift between GEM1 and readout (alternative: further amp stages and drift gaps)
  myDrift.drift( myAmpStage.xVec, myAmpStage.yVec, myAmpStage.zVec, myAmpStage.tVec, dGEM1R, EGEM1R, myGas );

  //____ ____ ____ ____ readout plane ____ ____ ____ ____ ____ ____ ____
  for (uint j = 0; j < uint(myDrift.xVec.size()); j++) {
    myEvtHisto->Fill( myDrift.xVec.at(j), myDrift.yVec.at(j) ); // fill event histo
  }

  //clear objects, vectors [...]
}
```

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  for (uint j = 0; j < uint(myDrift.xVec.size()); j++) {
    myEvtHisto->Fill( myDrift.xVec.at(j), myDrift.yVec.at(j) ); // fill event histo
  }

  //simulate simplified currents on pads
  myPadPlane.measPadCurrents( myDrift.xVec, myDrift.yVec, myDrift.zVec, myDrift.tVec, myEvtHisto, myGeometry );

  //signal processing
  for ( uint padid = 1; padid <= nBinsPadplane; padid++ ) {
    if (myPadPlane.currHistoMap[padid]->Integral() > 0) {//check whether histo is not empty
      myReadout.analogProcessingAnalytic( myPadPlane.currHistoMap[padid], myGeometry, myGas );
      myReadout.ADC(myReadout.analogSigAnalytic, i, padid);
    }
  }

  //clear objects, vectors [...]
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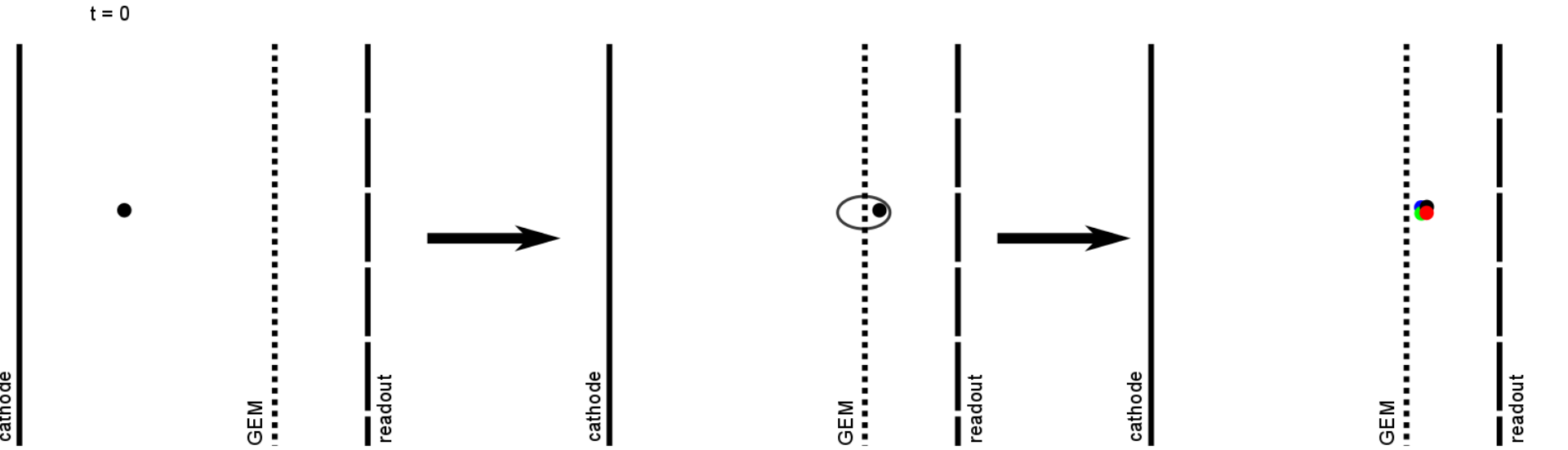
```

Transport and amplification



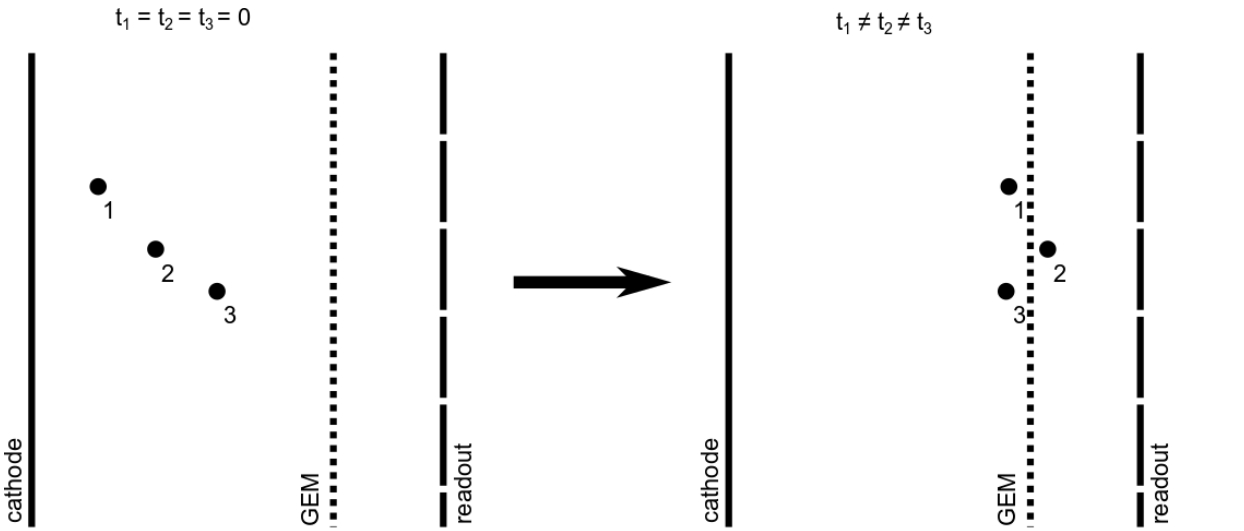
ionization electrons in drift volume before simulation of drift: times are equal

gaussian smearing at amplification plane

amplification after Polya distribution

Timing feature of the simulation

- time of trigger is
  $t = 0$
- no interaction between charges:
  - electrons are considered independent of time in each simulation step
  - correct time decomposition by saving time information of each single electron

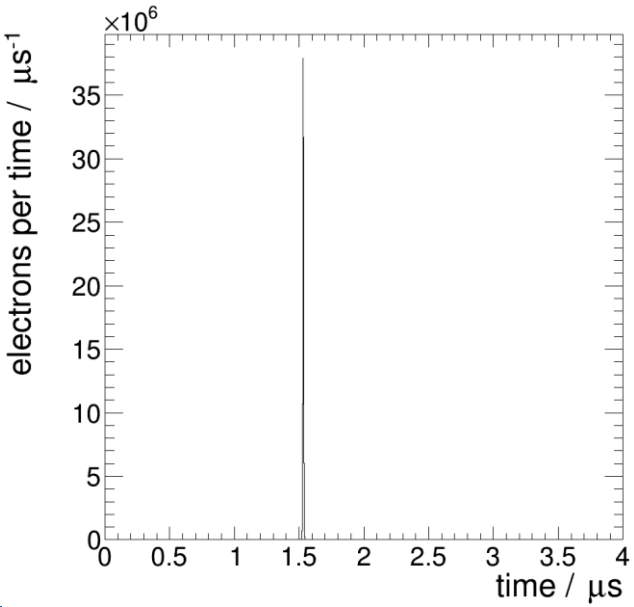


ionization electrons in drift volume before simulation of drift: times are equal

ionization electrons after simulation of drift: positions equal apart from statistical deviations, times are different

Signal formation

- no realistic pad response implemented (yet)
- electrons histogrammed onto padplane without Shockley-Ramo-weighting
- steps of analog processing
    1. count charges landing on each padplane bin as small current contribution in a separate 1D histogram



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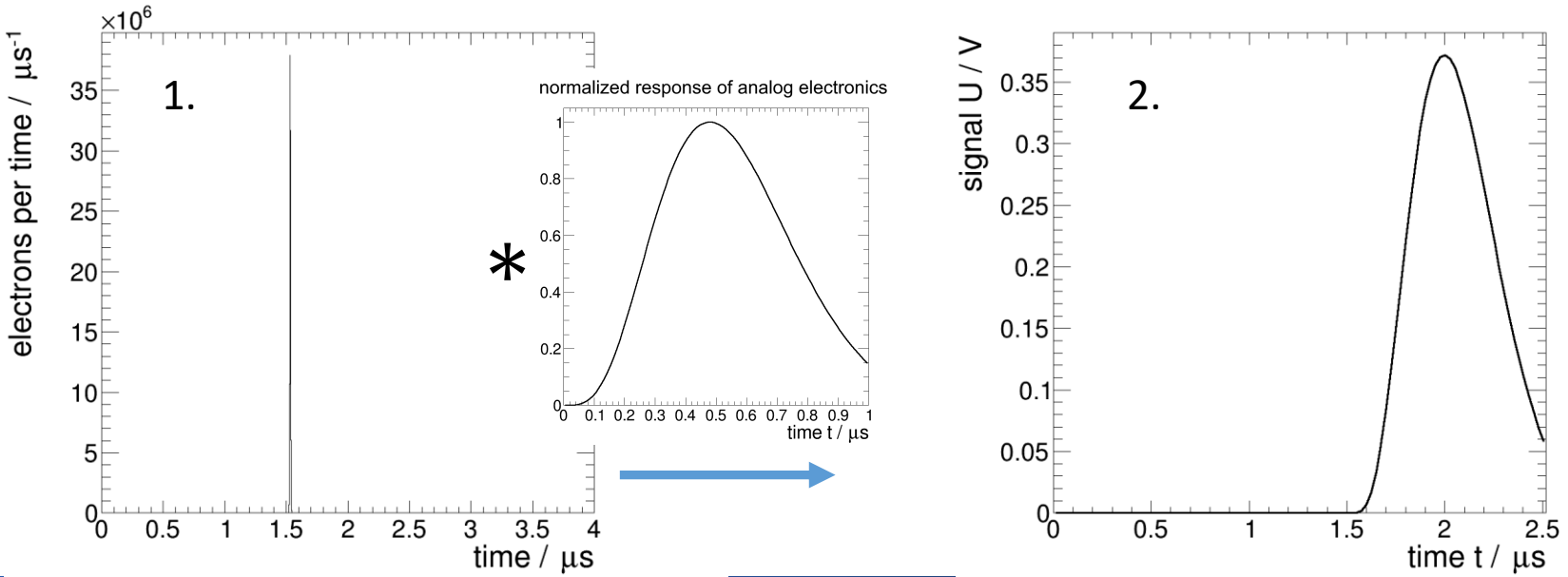

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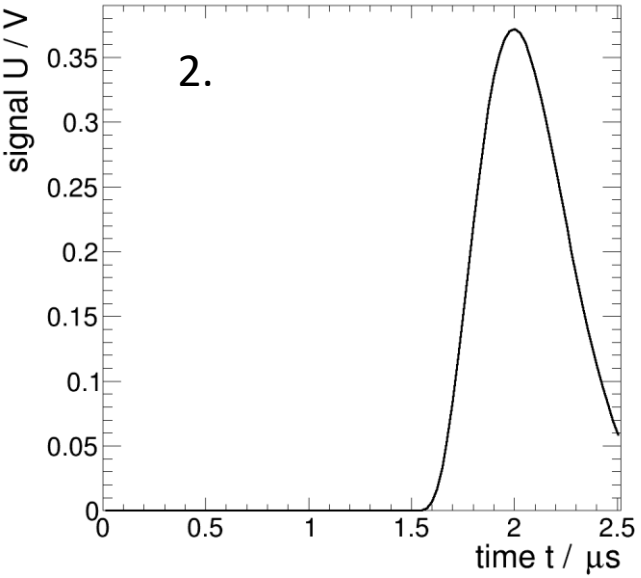

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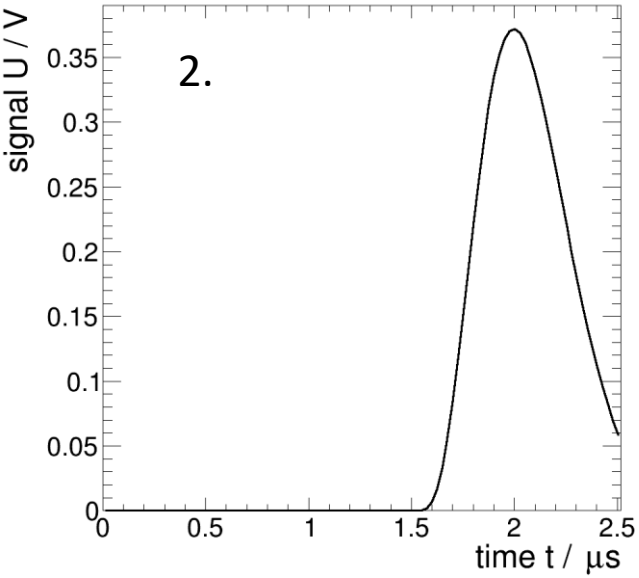
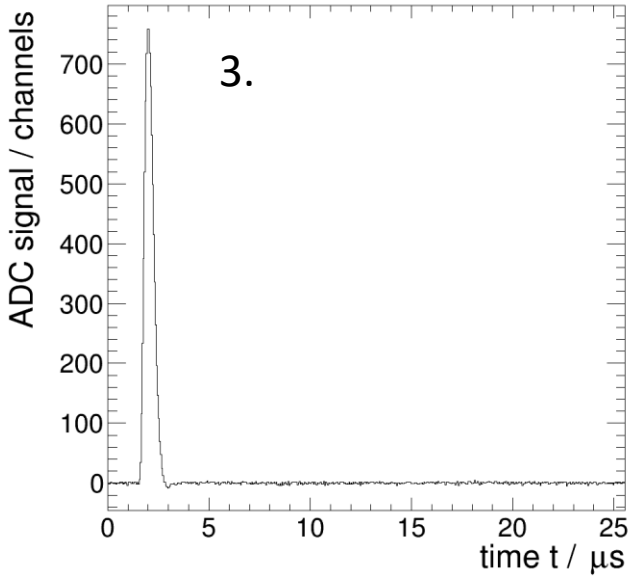
  3. digitization (511 samples) and adding noise





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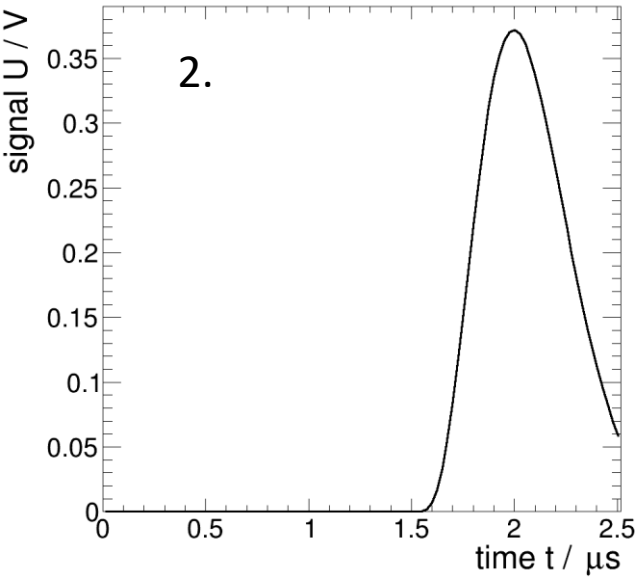
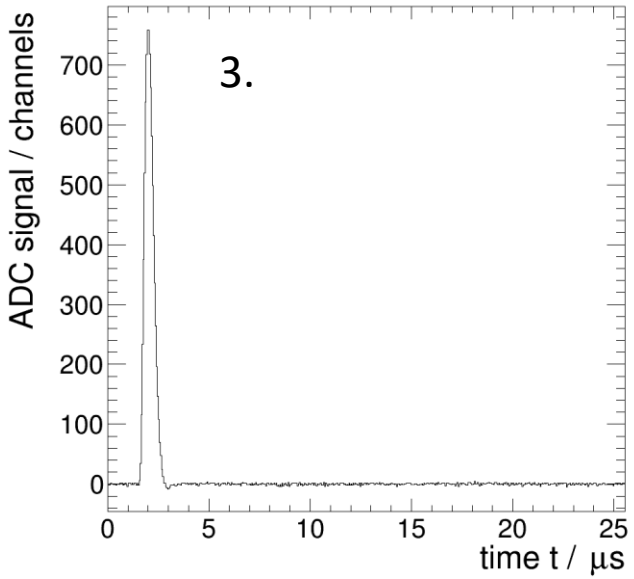
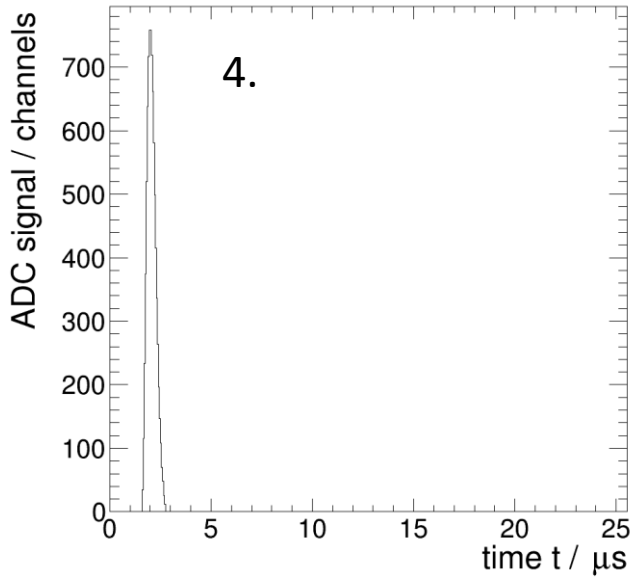
- electrons histogrammed onto padplane without Shockley-Ramo-weighting
- steps of analog processing
  1. count charges landing on each padplane-bin as small current contribution in a separate 1D histogram
  2. convolution with analytic response function of electronics (conversion to voltage)
  3. digitization (511 samples) and adding noise
  4. zero suppression







Signal formation - remarks

- no pad response implemented yet
  - spatial response: simple step of the geometry of the pad (no Shockley-Ramo)
  - time response: approximated by drift velocity and drift distance in the induction gap: $t_i \approx \frac{d_{gap}}{v_{drift}}$