Digitization procedure of MC simulation of LUXE ECAL

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Goals and analysis setup

- Goals:
  - Propose a procedure of converting energy deposits from Geant4 simulation into ADC units,
  - Adjust calibration parameters to obtain agreement between TB results and MC simulation
- Files used:
  - TB_FIRE_4533.root: TB data collected on 15.09.2022 with CALICE 74 Si sensor (500um), 1M events, electron energy: 5GeV
  - Si-e-5GeV-500um-ev500k.root: Geant4 simulation, 500k events, 500um CALICE sensor, electron energy: 5GeV, generated by Mihai Potlog

Convoluted Gaussian and Landau distribution

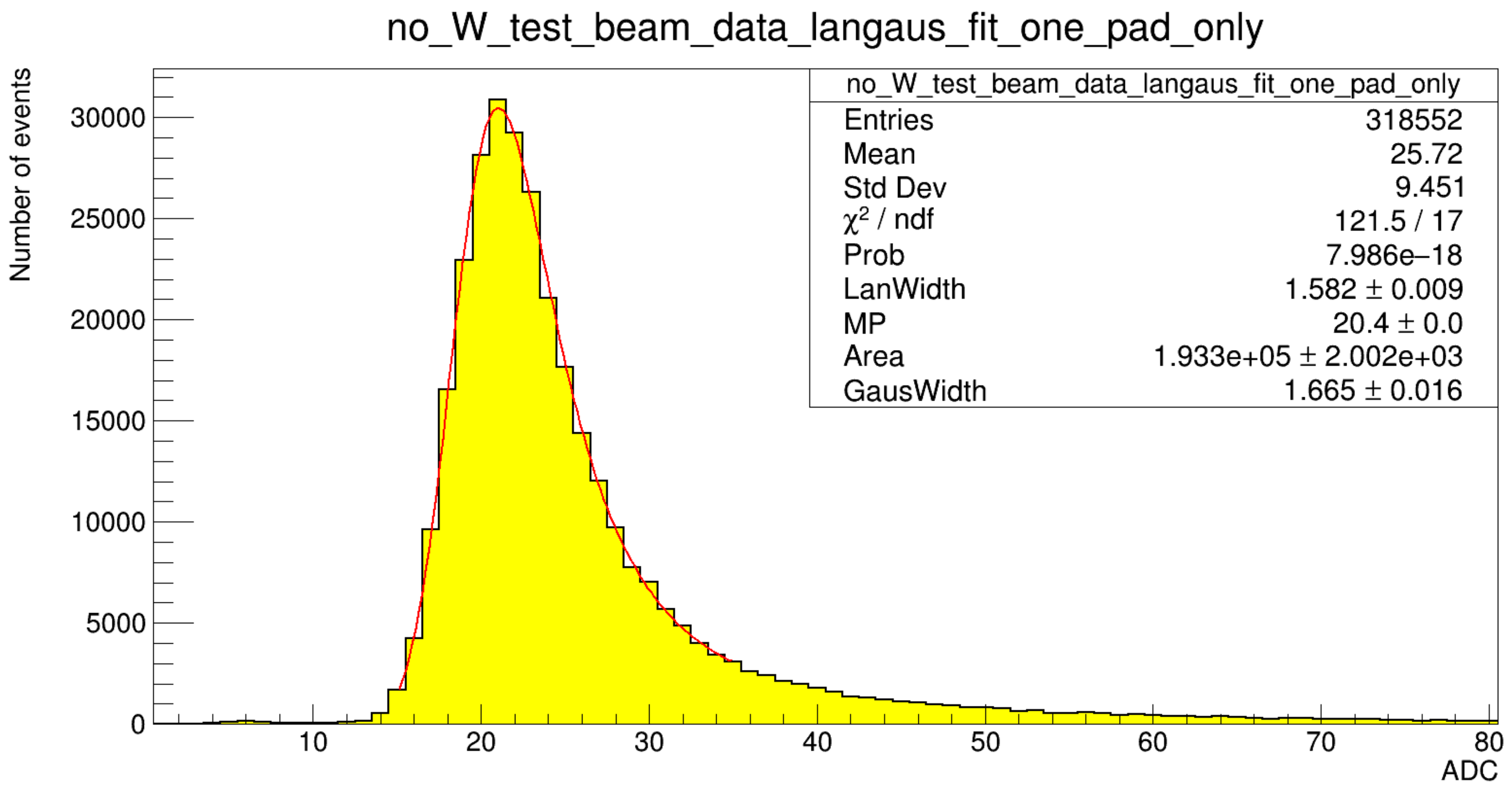
- Shan Huang implementation of convoluted Landau and Gaussian distribution was used,
- Based on Tmath::Landau function from ROOT,
- Parameters:
  - par0 – LanWidth,
  - par1 – MP,
  - par2 – Area,
  - par3 – GausWidth.

```
Double_t langaufun(Double_t x, Double_t par0, Double_t par1, Double_t par2, Double_t par3) {
      Double_t invsq2pi = 0.3989422804014;   // (2 pi)^(-1/2)
      Double_t mpshift  = -0.22278298;       // Landau maximum location
      // Control constants
      Double_t np = 100.0;      // number of convolution steps
      Double_t sc =   5.0;      // convolution extends to +-sc Gaussian sigmas
      // Variables
      Double_t xx;
      Double_t mpc;
      Double_t fland;
      Double_t sum = 0.0;
      Double_t xlow,xupp;
      Double_t step;
      Double_t i;
      // MP shift correction
      mpc = par1 - mpshift * par0;
      // Range of convolution integral
      xlow = x - sc * par3;
      xupp = x + sc * par3;
      step = (xupp-xlow) / np;

      // Convolution integral of Landau and Gaussian by sum
      for(i=1.0; i<=np/2; i++) {
         xx = xlow + (i-.5) * step;
         fland = TMath::Landau(xx,mpc,par0, 0) / par0;
         sum += fland * TMath::Gaus(x,xx,par3);

         xx = xupp - (i-.5) * step;
         fland = TMath::Landau(xx,mpc,par0, 0) / par0;
         sum += fland * TMath::Gaus(x,xx,par3);
      }
      return (par2 * step * sum * invsq2pi);
}
```

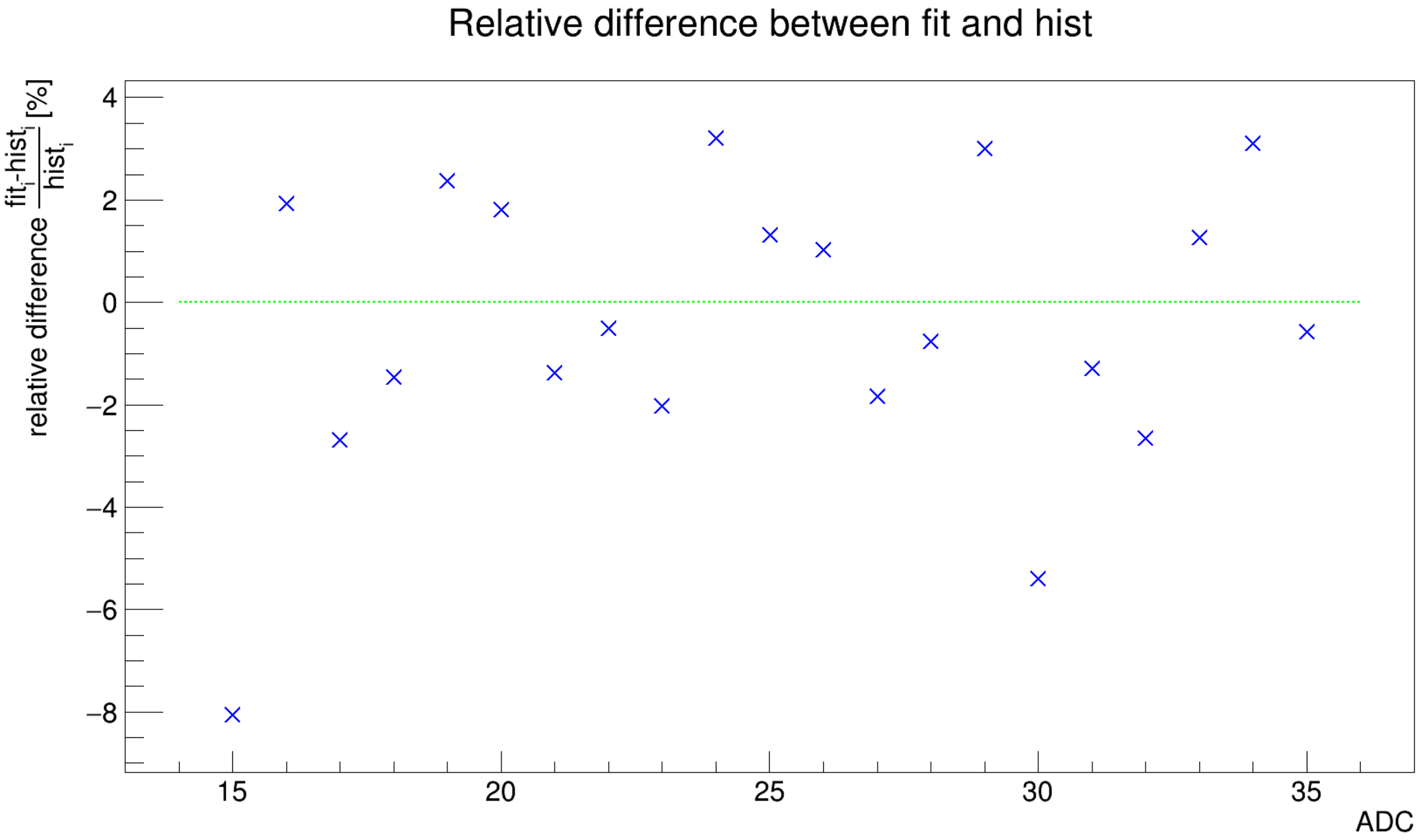
Fit setup

- Langaus function has four parameters:
  - LanWidth: scale parameter of Landau distribution
  - MP: MPV of Landau distribution
  - Area: total area, normalization constant
  - GausWidth: sigma of convoluted Gaussian function
- Langaus function was fitted to histogram with distribution of energy deposits in sensor in each event
- Events with only one hit were selected to minimize effects caused by secondary particles

Langaus fit to TB data



Langaus fit to TB data



Conversion procedure

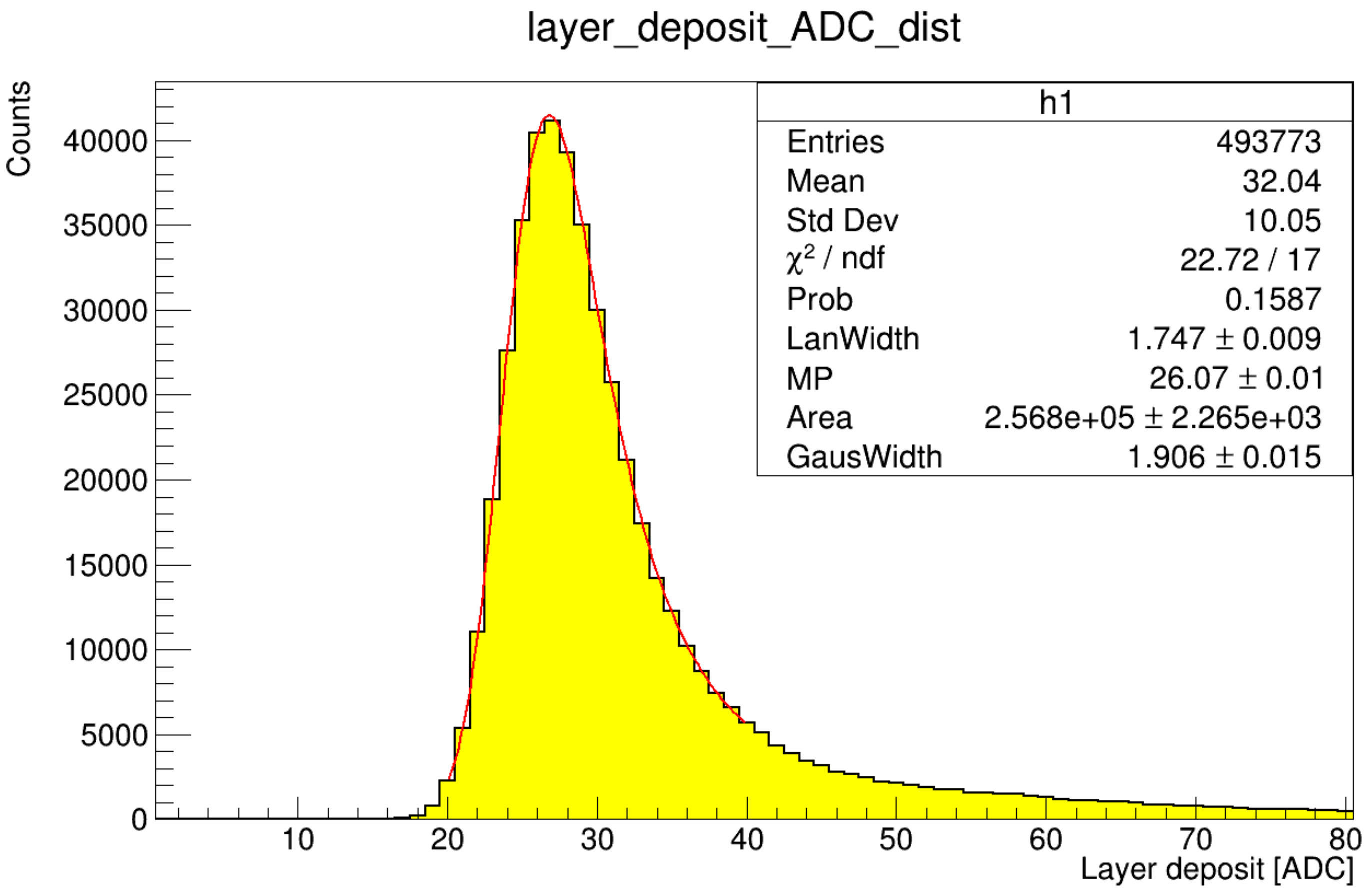
- Conversion procedure from MeV to ADC:
  - Conversion from MeV to fC using calibration factor: a*3.6 eV/fC, where a is an adjustable parameter,
  - Conversion from fC to ADC using gain factor for high-gain: 4.07 ADC/fC, saturation at 200 fC,
  - Applying Gaussian variation with sigma equal to noise parameter, which is taken from pedestal measurements,
  - (Adding number from Landau distribution with mean equal to zero and adjustable scale parameter (LanPar) to deposit in ADC).
- Only events with deposit in one pad was selected

Noise level

- Level of electronics noise was calculated as a mean of standard deviations of pedestals measured before data taking during TB in 2022,
- Noise data was provided by Marek Idzik,
- Pedestals collected at 10:18 on 15.09.2022 were used,
- Mean of the pedestals’ standard deviations is 1.478 ADC, channels with zero pedestal’s standard deviation were omitted.

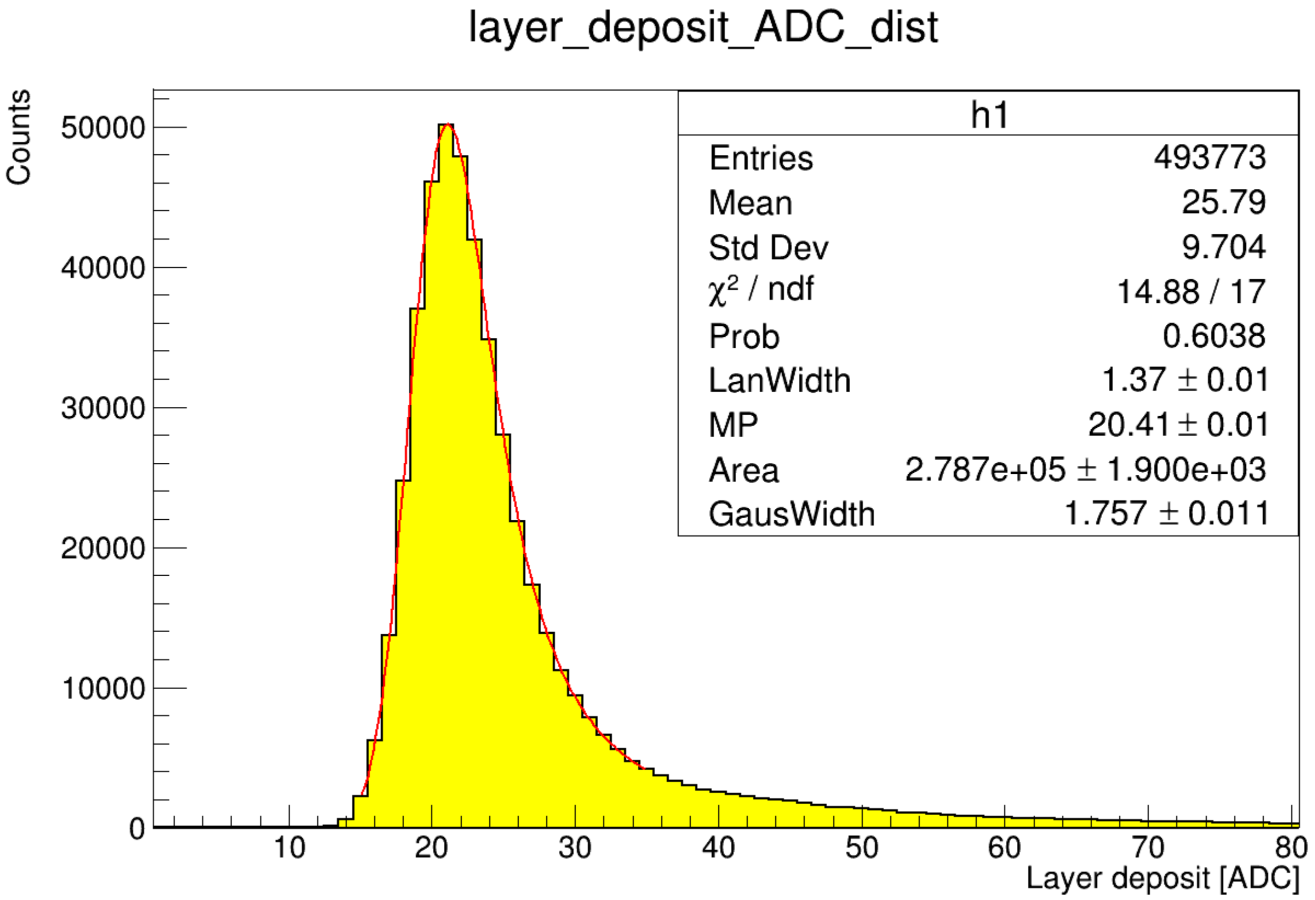
Langaus fit to MC sample

- noise = 1.478 ADC
- a = 1
- LanPar = 0
- MP value bigger than in TB
- GausWidth too big
- LanWidth too big



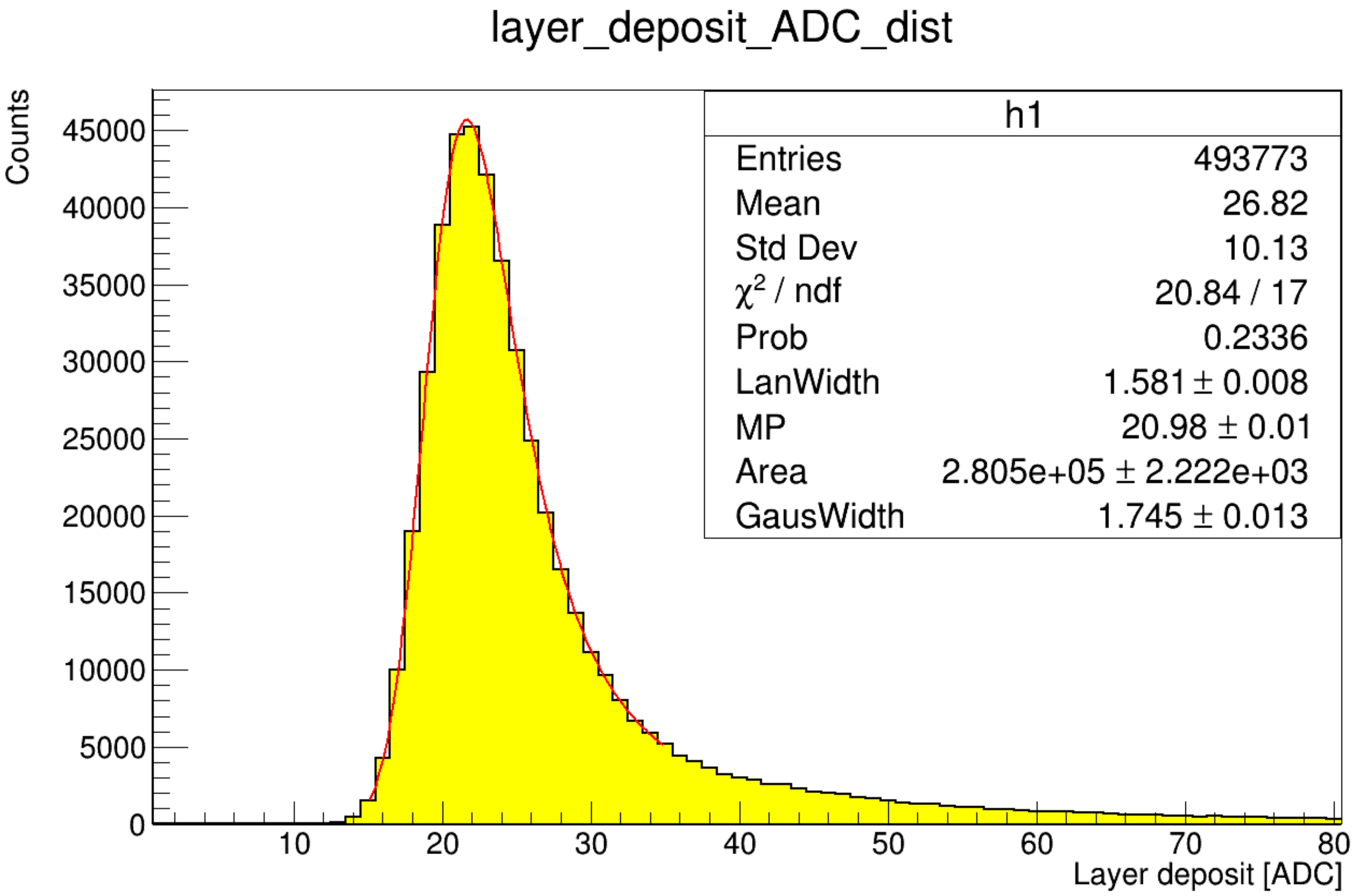
Applying calibration factor

- noise = 1.478 ADC
- a = 26.07/20.4 = 1.2779
- LanPar = 0
- MP value in agreement with TB
- GausWidth slightly too big
- LanWidth too small



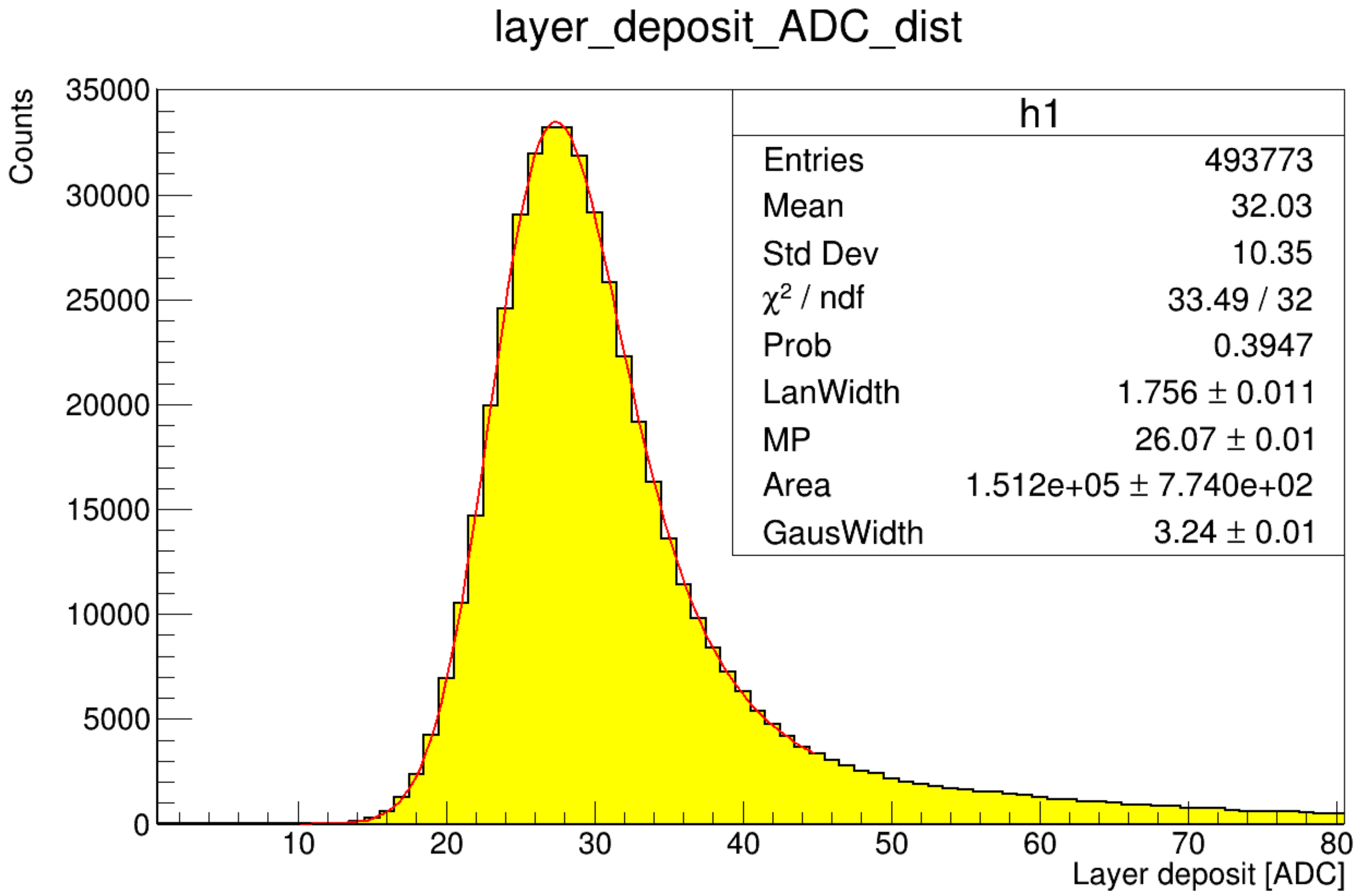
Adjusting LanPar

- noise = 1.478 ADC
- a = 26.07/20.4 = 1.2779
- LanPar = 0.212
- MP slightly too big
- GausWidth slightly to big
- LanWidth in agreement with TB



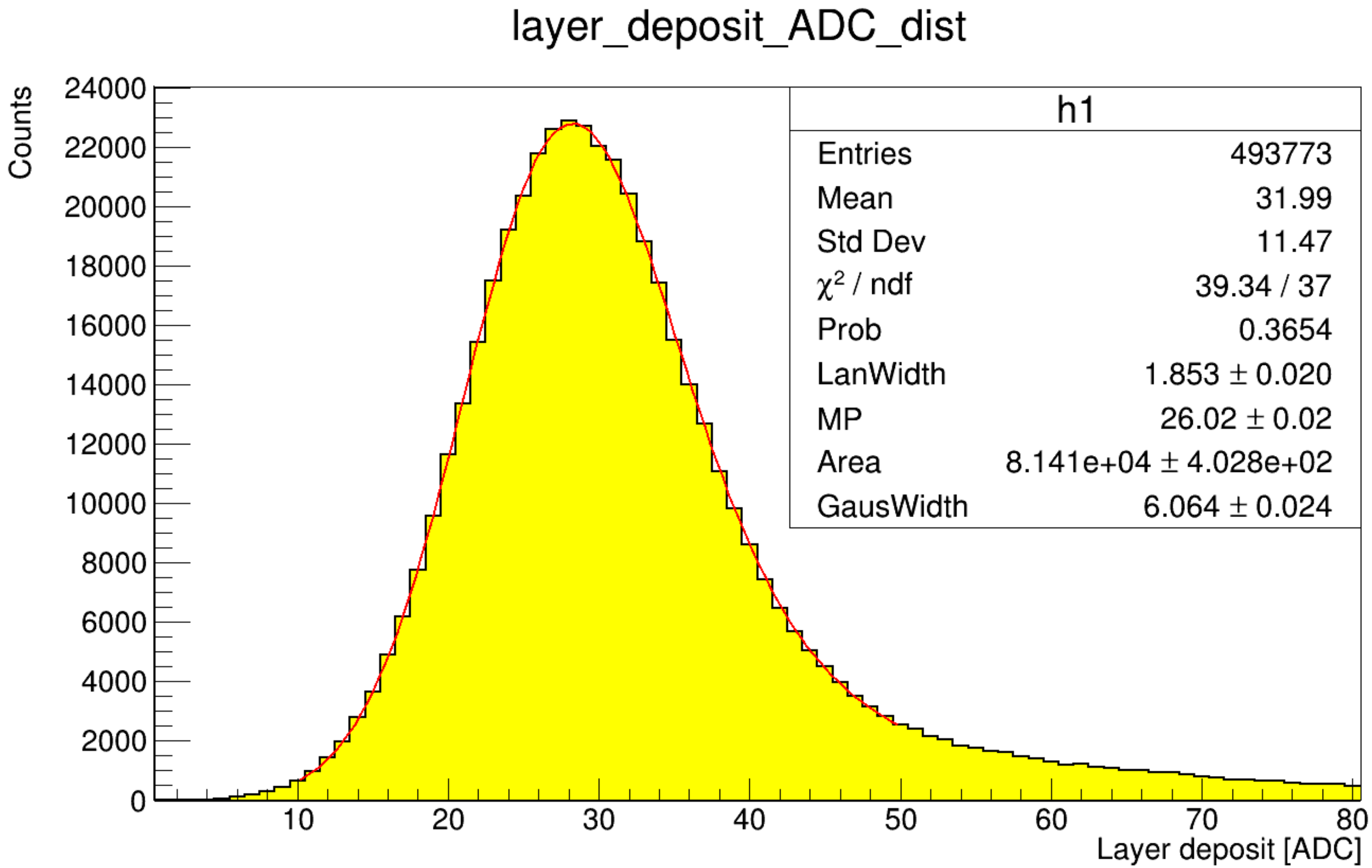
Fit with different noise

- noise = 3 ADC
- a = 1
- LanPar = 0
- GausWidth changes comparing to fit from slide 9



Fit with different noise

- noise = 6 ADC
- a = 1
- LanPar = 0
- GausWidth changes comparing to fit from slide 9
- LanWidth weakly depends on noise



Conclusions

- Changing noise influences only GausWidth parameter, not the MPV and LanWidth,
- Adding noise from empty channels shifts MPV, GausWidth and LanWidth towards bigger values,
- Parameters of conversion procedure (noise, calibration factor, LanPar) can be adjusted to reproduce the shape of deposits distribution from TB (work in progress),
- Why the width of Landau distribution doesn’t agree between TB and MC?

References

1) Jakub Moroń, *FLAME SoC readout ASIC for electromagnetic calorimeter,* TWEPP 2022,
2) Marek Idzik, *The FLAME and FLAXE ASICs,* XII Front-End Electronics Workshop 2023,
3) Wikipedia – properties of Landau distribution.