TB 2022: Geant4 simulations & Data Comparison

Veta Ghenescu, Alina Neagu, Mihai Potlog
Institute of Space Science, Bucharest

TB 2022 Simulations Step by Step

- ## geometry

  - complete implementation of all type of sensors – Anton1, Yan1, BeamCal, C72, C74, C75

  - re-numbered the pads to correspond to channels from real sensors

  - macro with commands for easily geometry change

- ## physics list

  - check results with another physics list suggested by Geant4 – QGSP_BERT, QGSP_BIC and those with electromagnetic options (_EMV, _EMX, EMZ..)

  - start / stop hadronic processes to investigate their influence on results

  - implement specific physics list - one developed by Alina a few years ago for FCal

- ## analysis

  - evaluate each pad energy deposition

  - fit the energy deposition histograms to get the MPV

  - evaluate MPV for different setup configurations

  - compare simulation results with data from test beam

  - find the longitudinal shower distribution for different configurations (e.g. 1 to 15 W plates in front of sensor)

Simulations: Number of e-h pairs created

Olga Novgorodova's Thesis:

- Energy deposition in GaAs sensor
- 500 μm thickness
- ^{90}Sr, and 2, 4 & 4.5 GeV mono-energetic e-
- Triggered by 2 / 3 scintillators
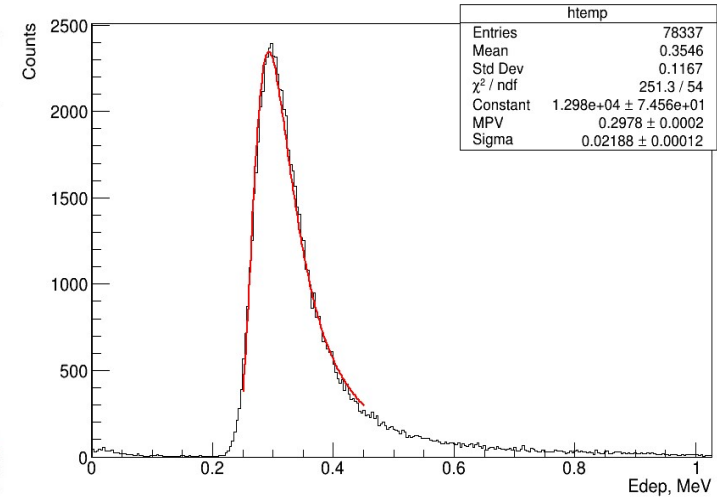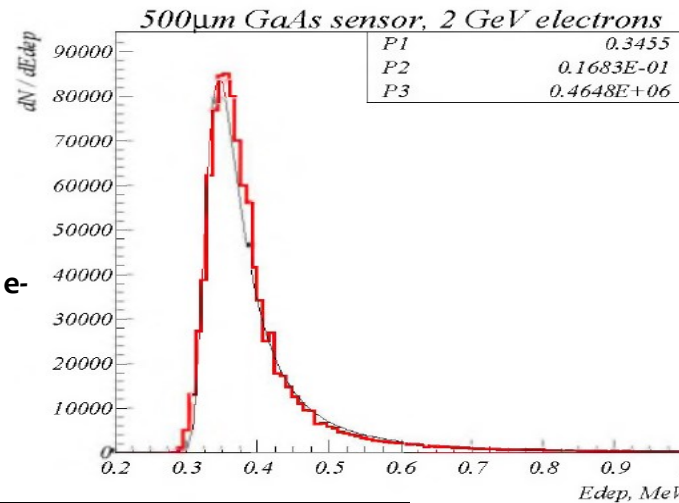
Setup	Dep. En. (MeV)	e-h pairs / μm	Dep. En. (MeV)	e-h pairs / μm
^{90}Sr	0.3512	163.4	0.3555	165.34
2 GeV	0.3455	160.7	0.3546	164.93
4 GeV	0.3513	163.4	0.3558	165.48
4.5 GeV	0.3526	164.0	0.3544	164.84

Why differences?

- which are the characteristics of triggers: dimensions, positions, etc.
- landau fit parameters

- **Thickness: 550 μm**
- E_{e-} = 5 GeV
- E_i = 4.3 eV

Dep. en.   0.3908 MeV

pairs / μm   165.12 e-h
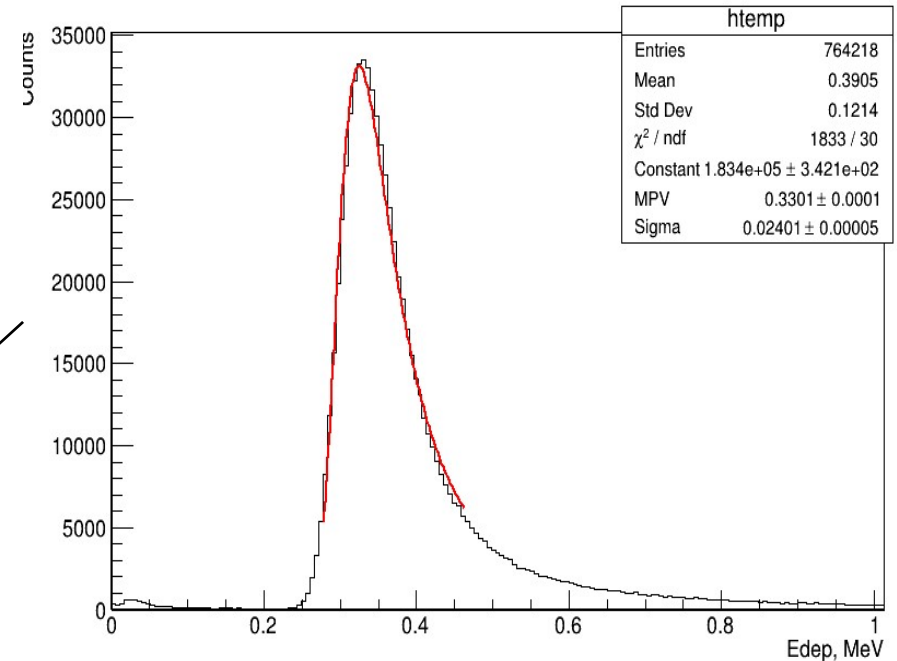
- **Physics list used: FTFP_BERT_EMZ**
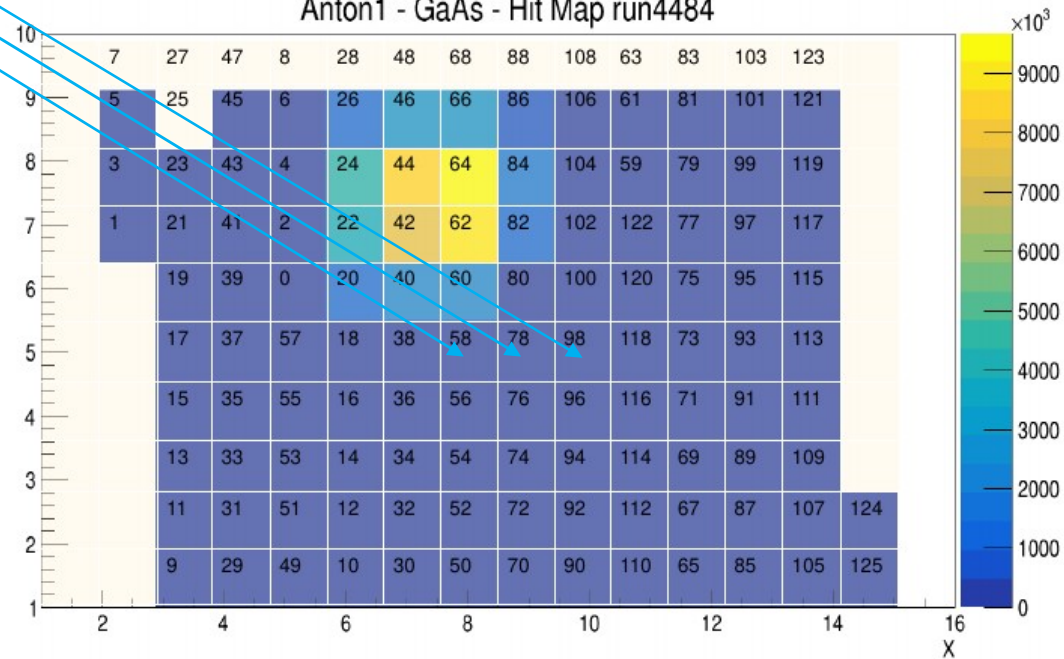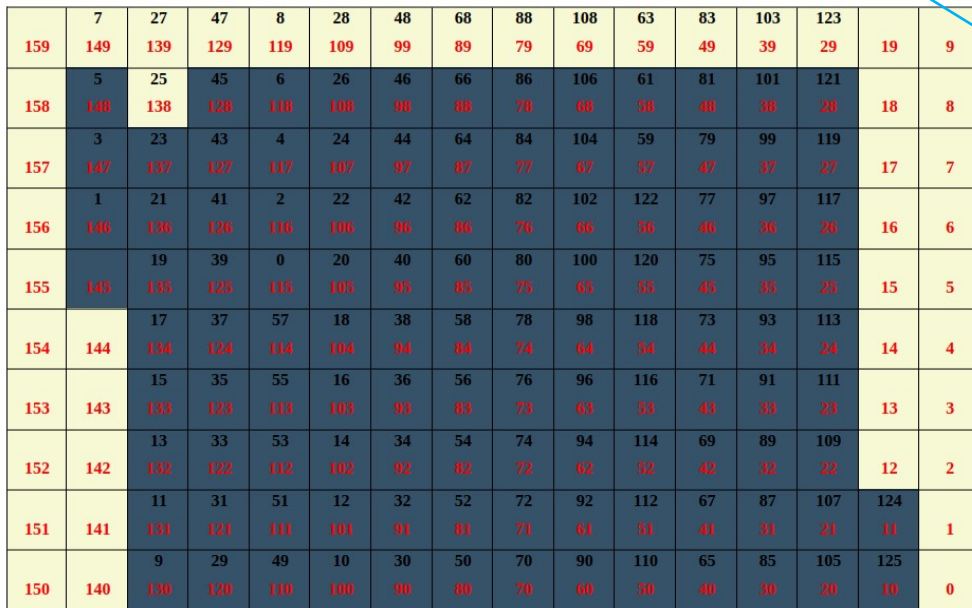
GaAs sensor – Anton1
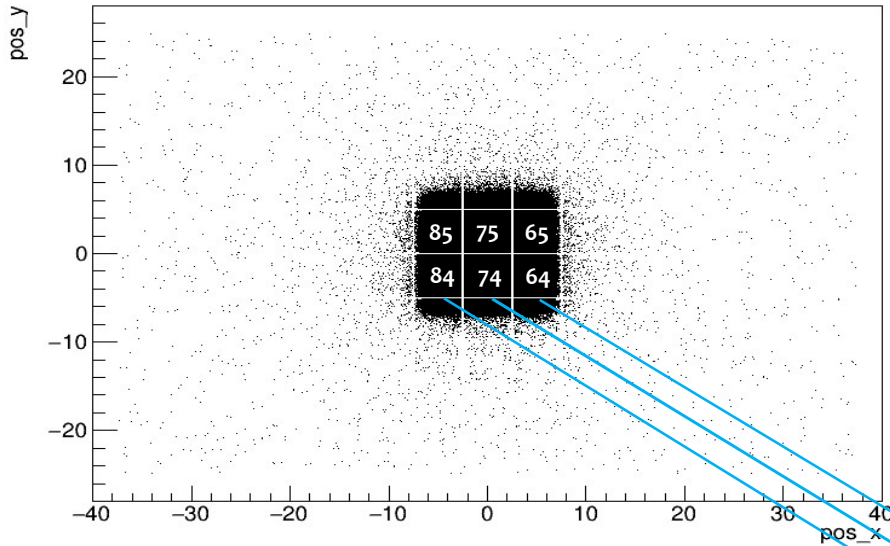
Simulation setup

- **Primary particle: electron**
- **Primary particle energy: 5GeV**
- **Source type:**
  - **squared,**
  - **12 mm x 12 mm**
- **Number of simulated events: 1 000 000**

Hits registered position

- **Centered on pads 64, 65, 74, 75 , 84, 85**
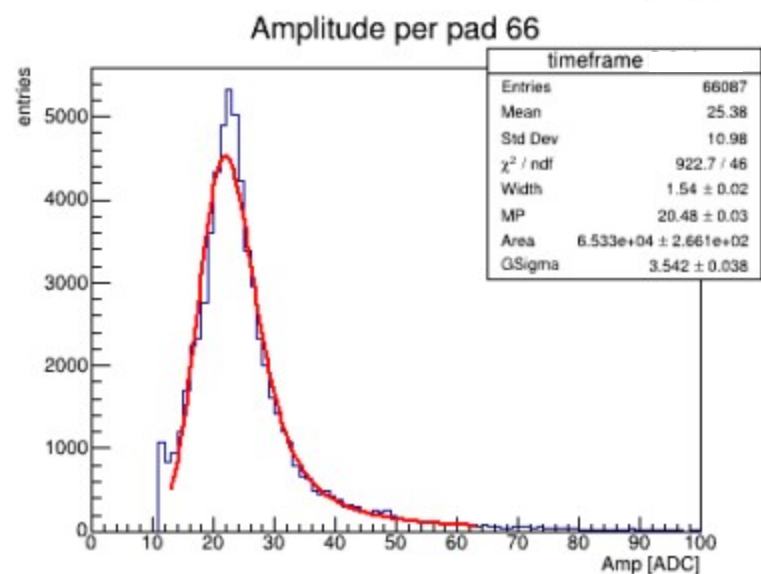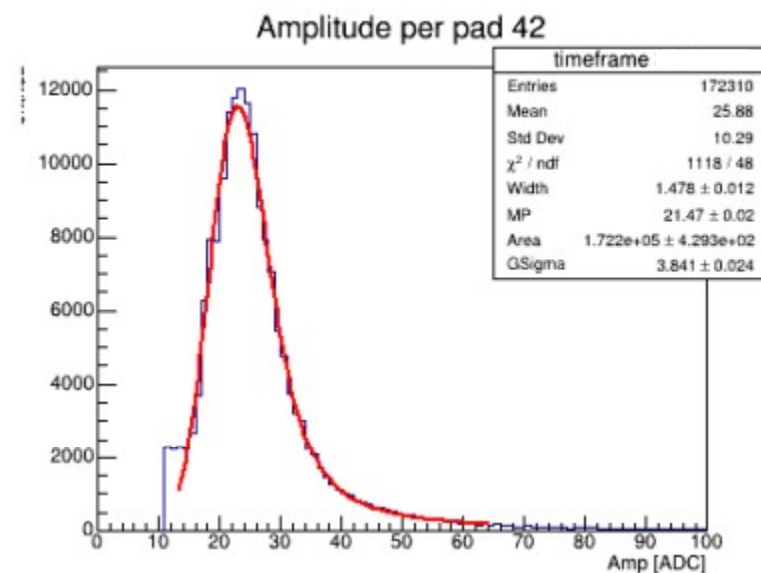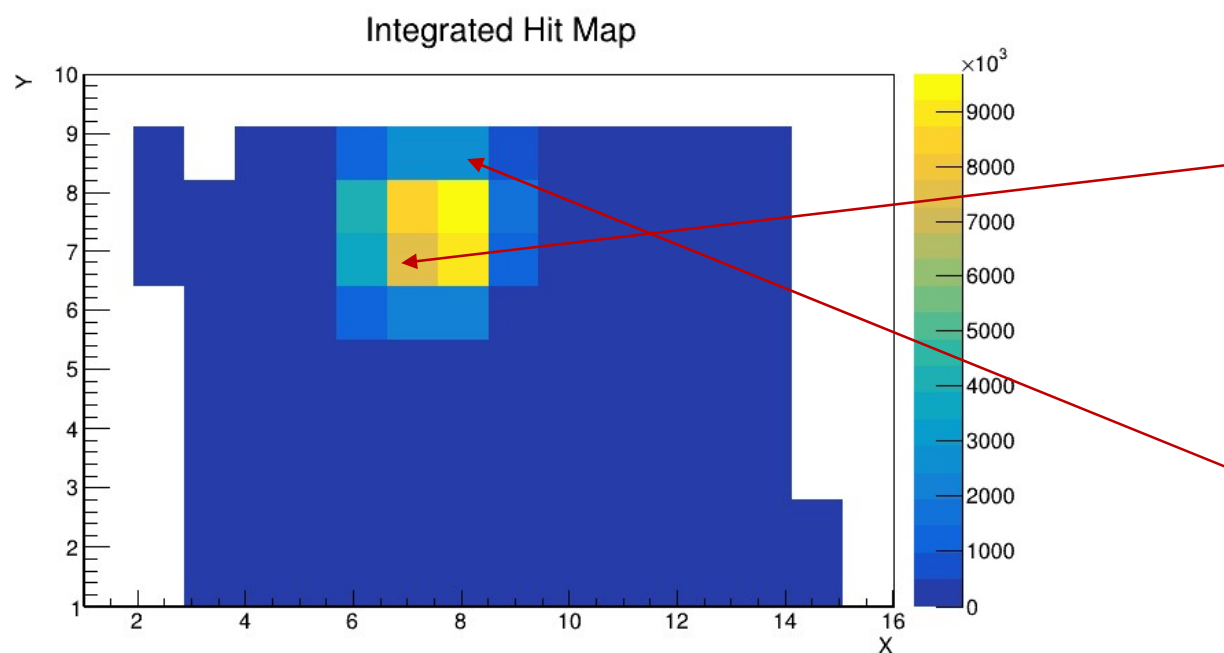- **Converted to channel number from sensor**

2022 TestBeam: MeV to ADC

▪ Channel by channel gain calibration can be done by looking on the response of sensor directly exposed on MIPs deposition in Si sensor

▪ for each pad a (Landau & Gauss) function was fitted to energy spectrum

Integrated Hit Map

Amplitude per pad 42

timeframe	
Entries	172310
Mean	25.88
Std Dev	10.29
χ^2 / ndf	1118 / 48
Width	1.478 ± 0.012
MP	21.47 ± 0.02
Area	1.722e+05 ± 4.293e+02
GSigma	3.841 ± 0.024

Amplitude per pad 66

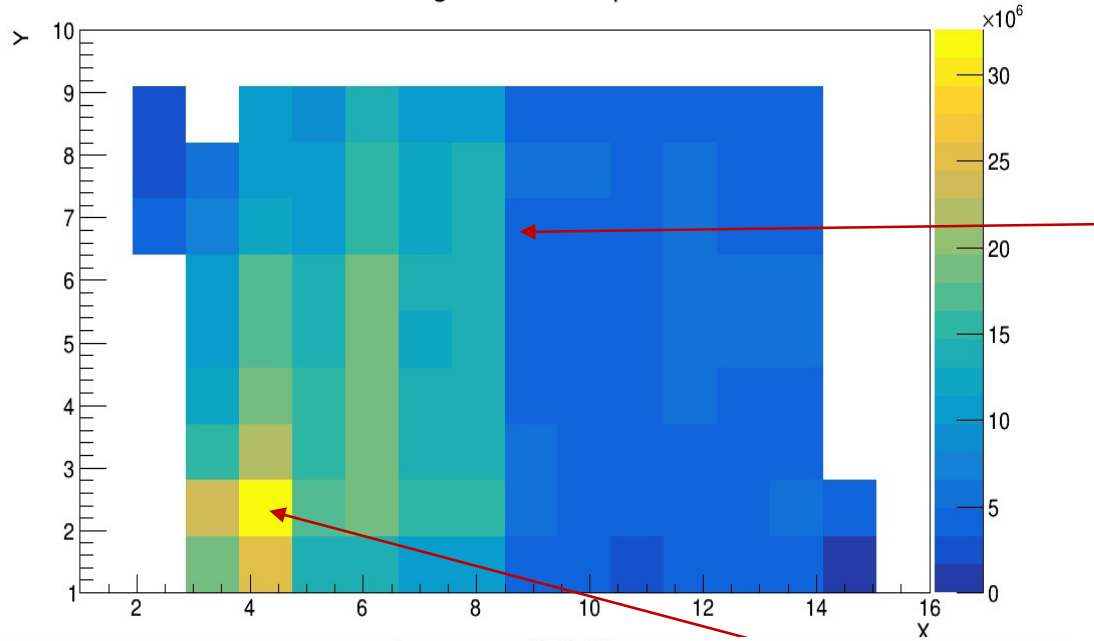| timeframe	
Entries	66087
Mean	25.38
Std Dev	10.98
χ^2 / ndf	922.7 / 46
Width	1.54 ± 0.02
MP	20.48 ± 0.03
Area	6.533e+04 ± 2.661e+02
GSigma	3.542 ± 0.038

Analysis conditions

Data from run4484 – Anton1 sensor

- Beam on pads 42, 44, 62, 64
- Converted to channel number from sensor

- Kept all timeplanes
- Cut on amplitude < 900
- dead channels masked
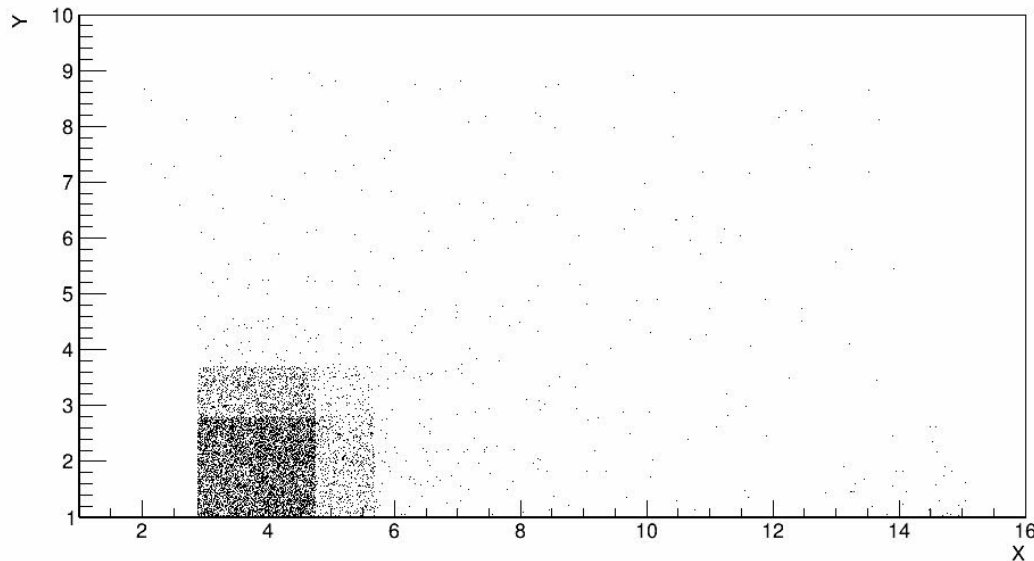- langaus fitted in range [12-64] ADC

GaAs sensor – Anton1

Integrated Hit Map

Amplitude per pad 82

timeframe	
Entries	202739
Mean	23.68
Std Dev	11.06
χ^2 / ndf	486.2 / 25
Width	1.594 ± 0.013
MP	20.89 ± 0.01
Area	1.796e+05 ± 4.714e+02
GSigma	2.688 ± 0.030

Integrated Hit Map

Amplitude per pad 31

| timeframe	
Entries	1333325
Mean	24.2
Std Dev	10.98
χ^2 / ndf	3.293e+04 / 25
Width	1.369 ± 0.006
MP	21.36 ± 0.01
Area	1e+06 ± 3.5e+00
GSigma	2.994 ± 0.013
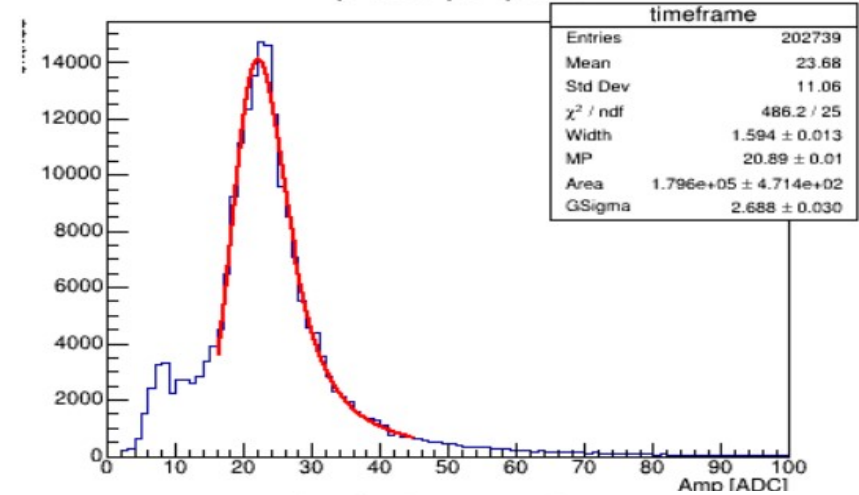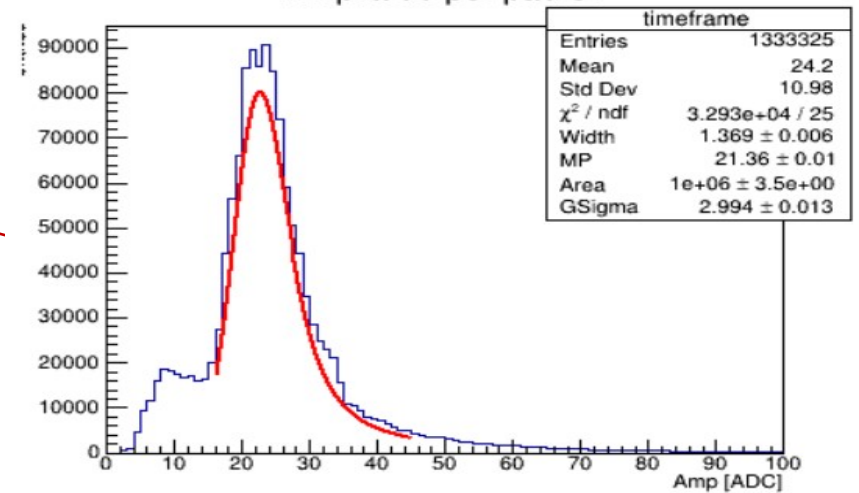
- **merged all data from run4459 till run4491**
- runs with Debug-data-ON or test runs not taken into account
- beam energy: 5 GeV
- greater number of runs and events for the left side of sensor

▪ GaAs sensor – Anton1

- 2 cases investigated: **[run 4484]** & **[run 4459 – run 4491]**
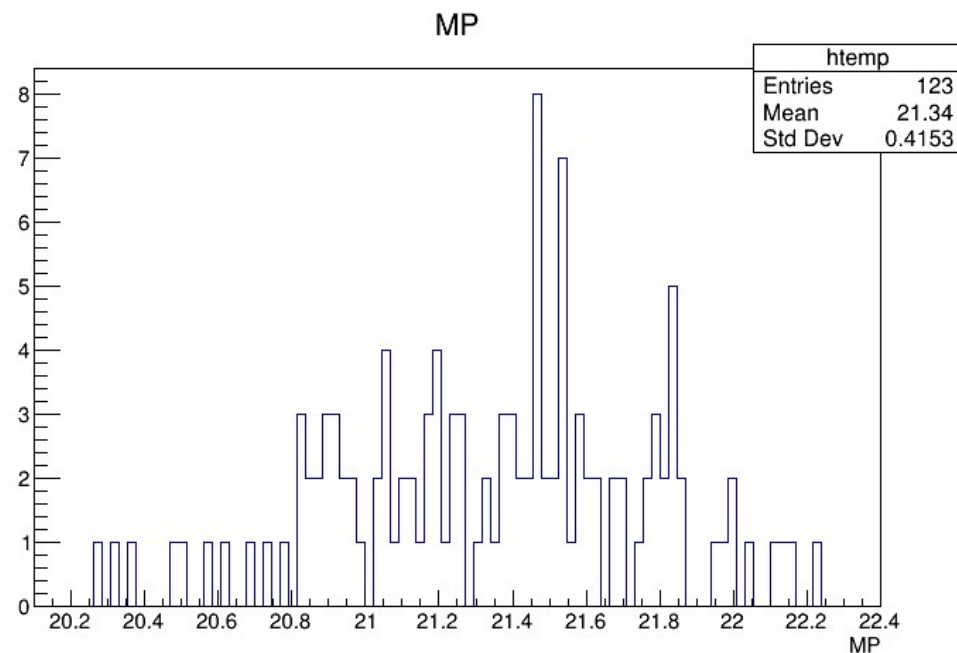- fit with (Landau & Gauss) function all channels in [12-64] ADC range

MP

htemp	
Entries	123
Mean	20.26
Std Dev	0.678
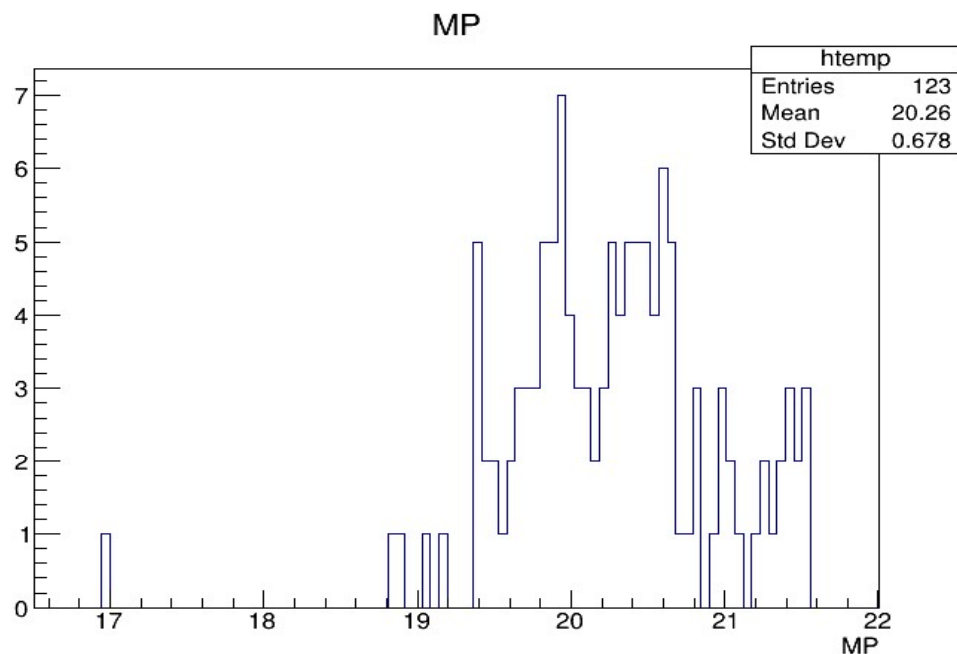
Data from run4484

- **Beam on pads 42, 44, 62, 64**
- **MPV = 20.26 ± 0.68 [ADC]**

MP

htemp	
Entries	123
Mean	21.34
Std Dev	0.4153

Data from merged runs

- **MPV = 21.34 ± 0.42 [ADC]**

TB 2022: Simulations

Simulation setup

- e⁻ with 5GeV
- centered on pads 64, 65, 74, 75 , 84, 85
- source type: squared, 12 mm x 12 mm
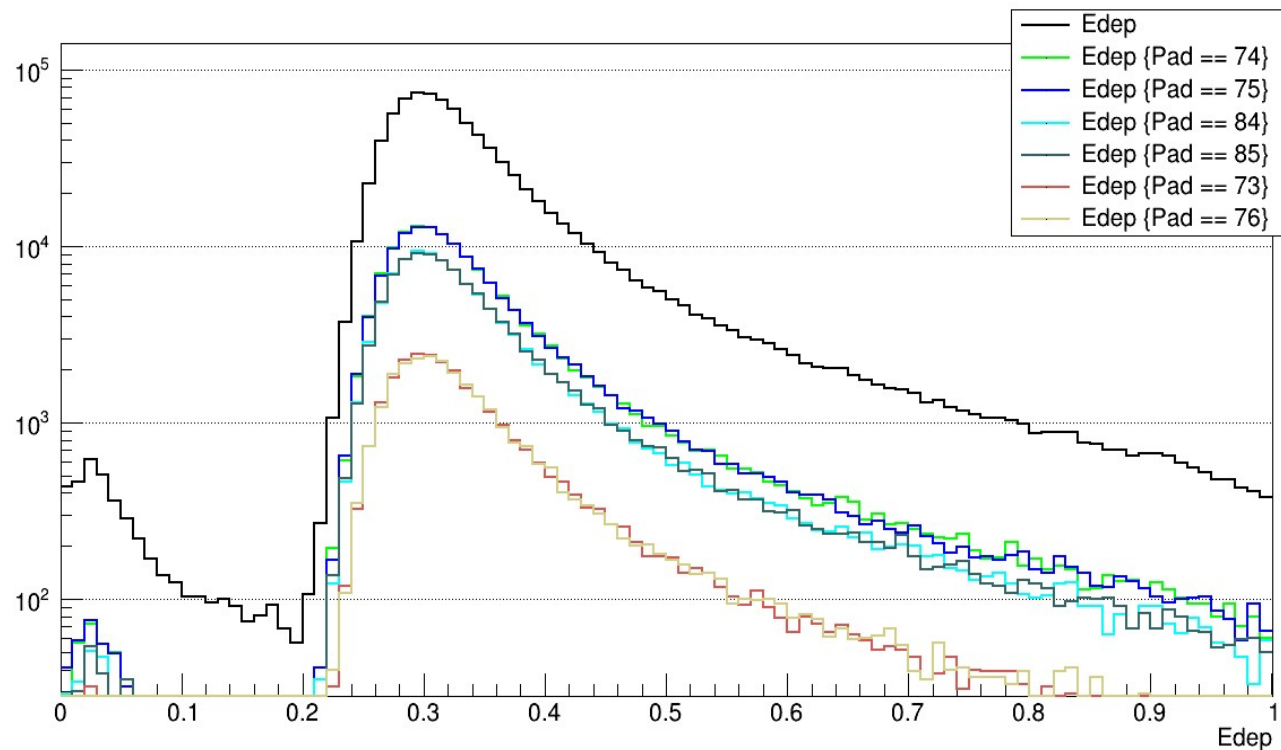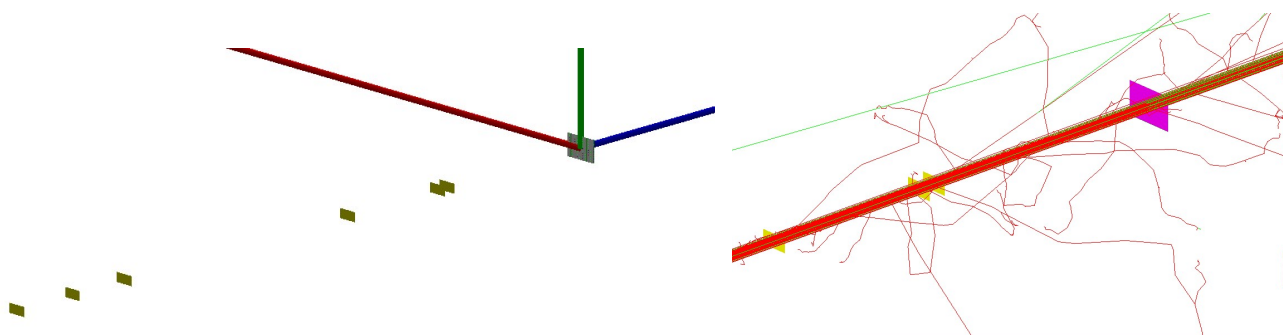- Number of simulated events: 1 000 000
- Similar with run4484

pos_y:pos_x
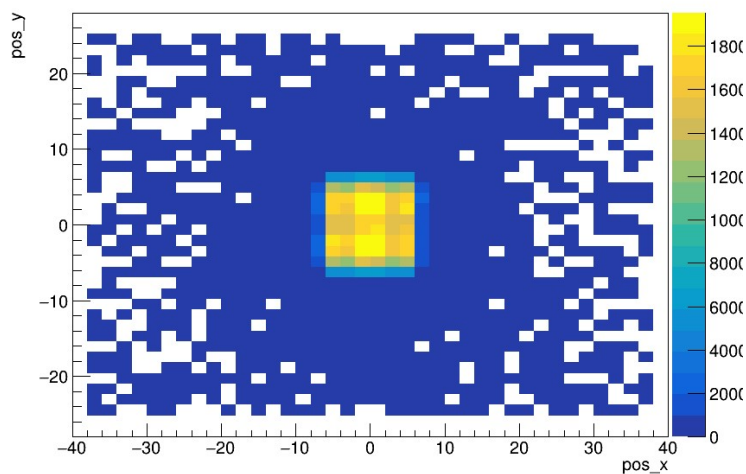
pos_y:pos_x
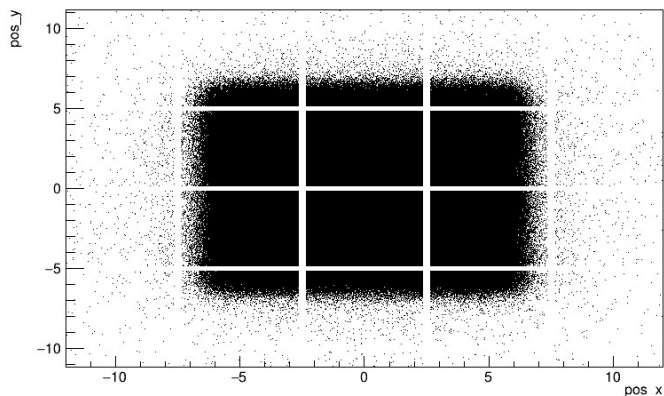
TB 2022: Simulations vs Data

from data, run4484

- 1 MIP = 20.26 ± 0.68 [ADC]

from simulations

- 1 MIP = 0.3569 ± 0.12 MeV

goal: compare simulations with data

- **1 MeV = 56.77 ADC**

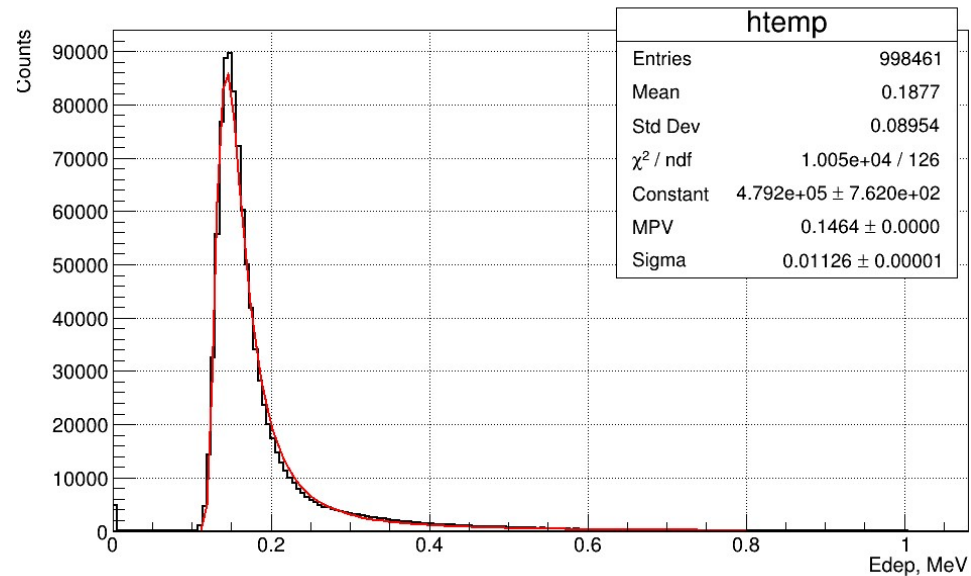Energy deposition for Anton1 sensor

Simulations: Number of e-h pairs created
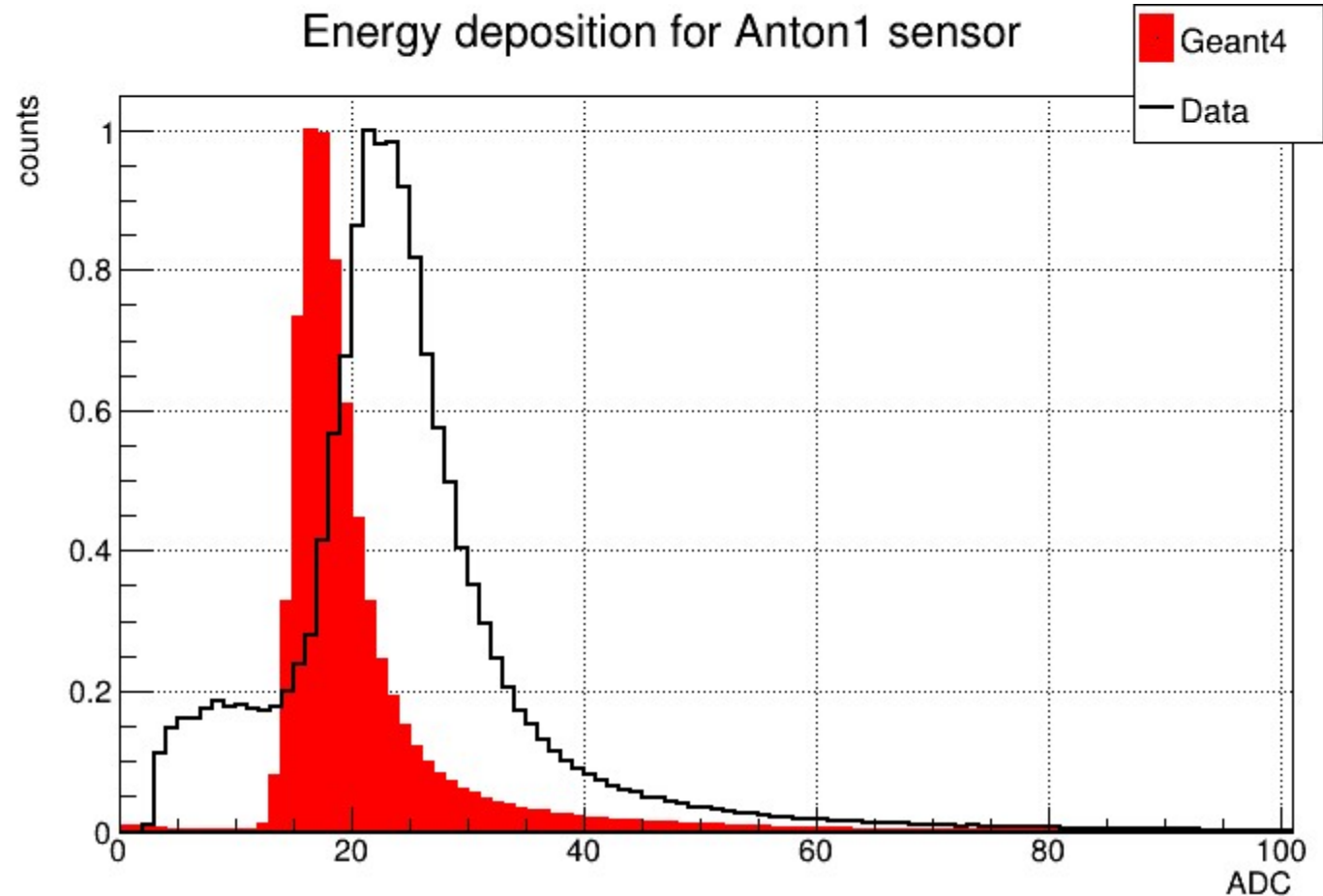
- **Energy deposition in Si sensor**
  - 320 μm thickness
  - 5 GeV mono-energetic e-
  - triggered by 3 scintillators
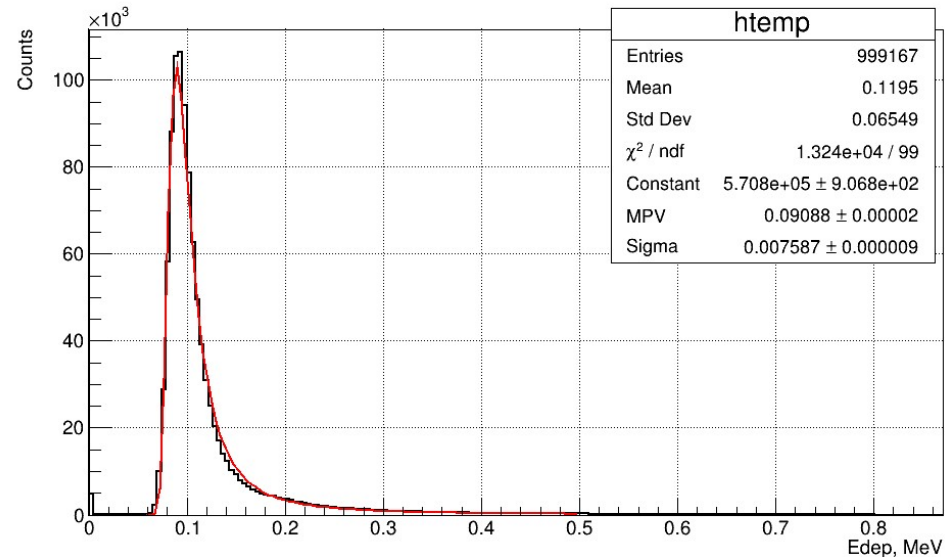
- **Thickness: 320 μm**
- E_{e-} = 5 GeV
- E_i = 3.62 eV

78.45 e-h pairs per μm

- **Energy deposition in Si sensor**
  - 500 μm thickness
  - 3 GeV mono-energetic e-
  - triggered by 3 scintillators

- **Thickness: 500 μm**
- E_{e-} = 3 GeV
- E_i = 3.62 eV

80.88 e-h pairs per μm

- **Physics list used: QGSP_BERT_EMZ**

Si sensor – C75
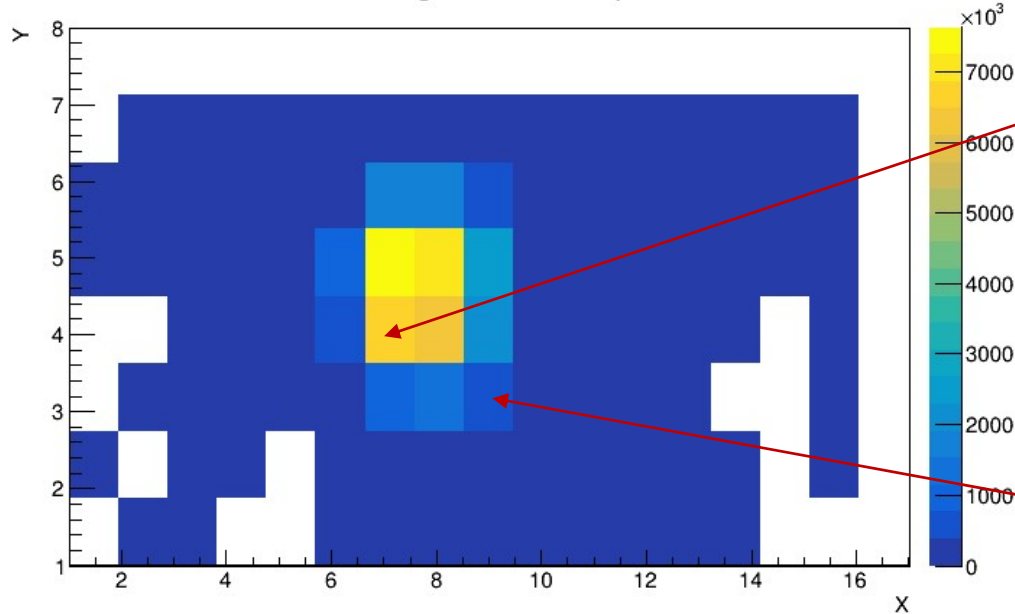
Data from run4436 – C75 sensor

- Beam on pads 49, 51, 59, 61

Analysis conditions
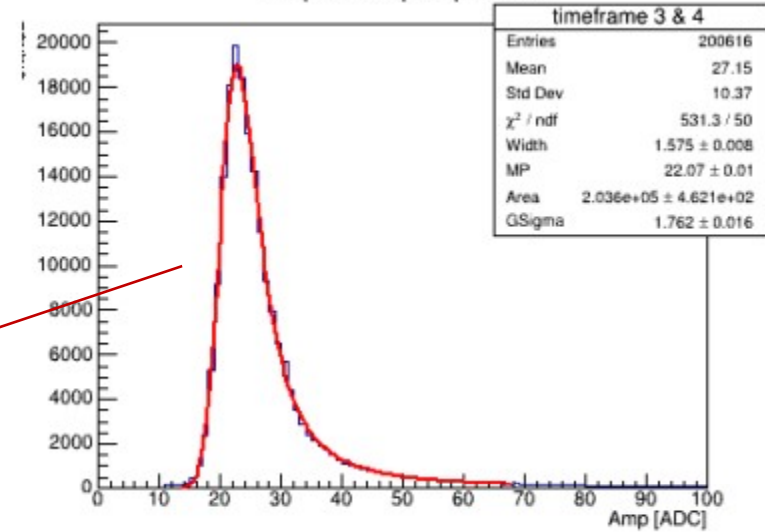
- Kept all timeplanes
- Cut on amplitude < 900
- dead channels masked
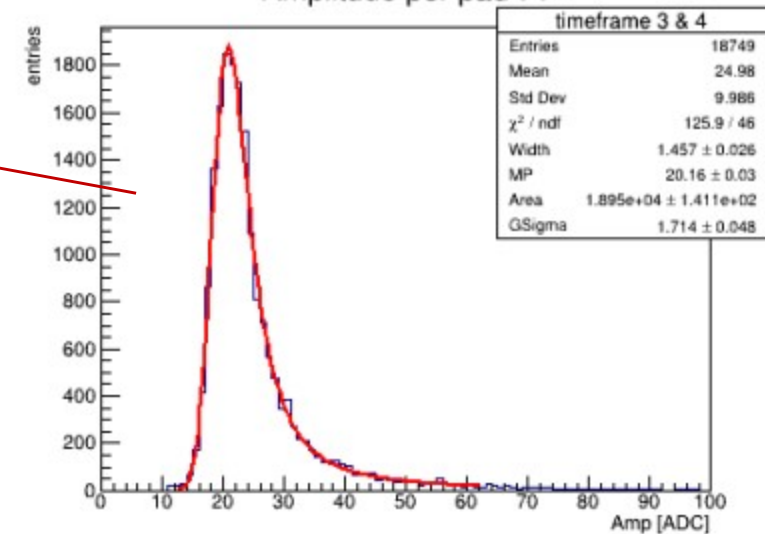- langaus fitted in range [12-64] ADC

Integrated Hit Map

Amplitude per pad 49

timeframe 3 & 4	
Entries	200616
Mean	27.15
Std Dev	10.37
χ² / ndf	531.3 / 50
Width	1.575 ± 0.008
MP	22.07 ± 0.01
Area	2.036e+05 ± 4.621e+02
GSigma	1.762 ± 0.016

Amplitude per pad 71

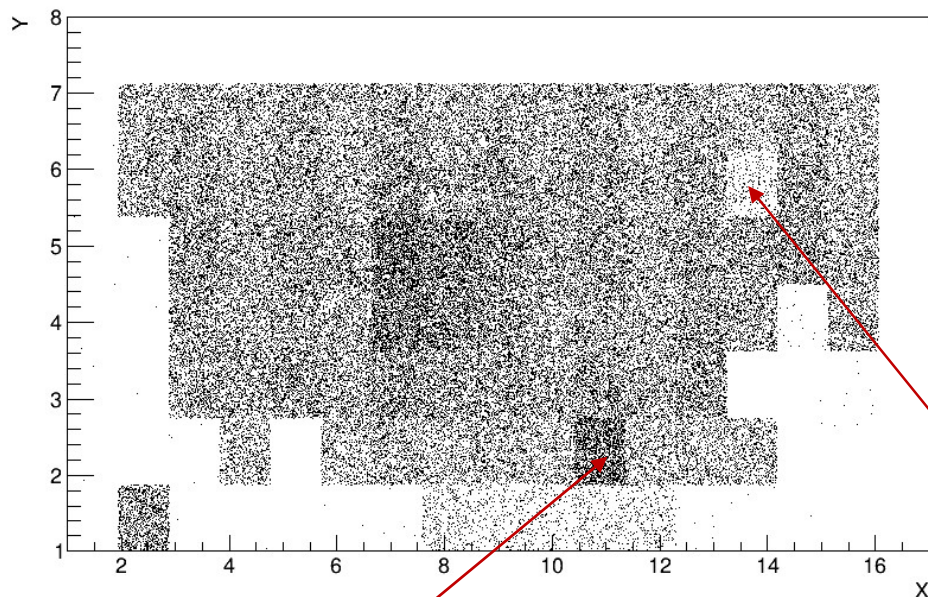| timeframe 3 & 4	
Entries	18749
Mean	24.98
Std Dev	9.986
χ² / ndf	125.9 / 46
Width	1.457 ± 0.026
MP	20.16 ± 0.03
Area	1.895e+04 ± 1.411e+02
GSigma	1.714 ± 0.048

- a lot of channels are dead or unresponsive
- for each pad a (Landau & Gauss) function was fitted to energy spectrum
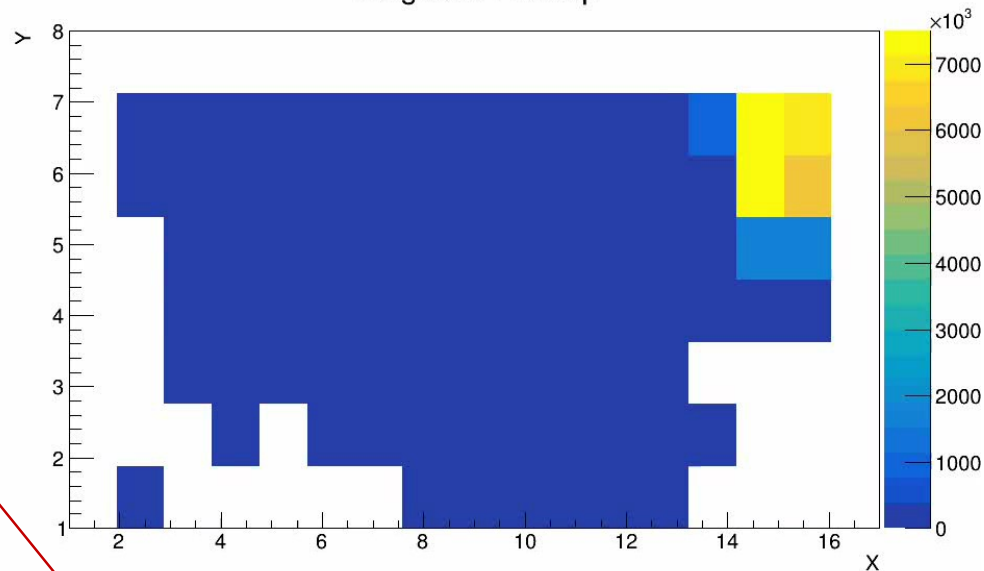- The analysis showed very small deviations from channel to channel

2022 TestBeam: MeV to ADC

Integrated Hit Map
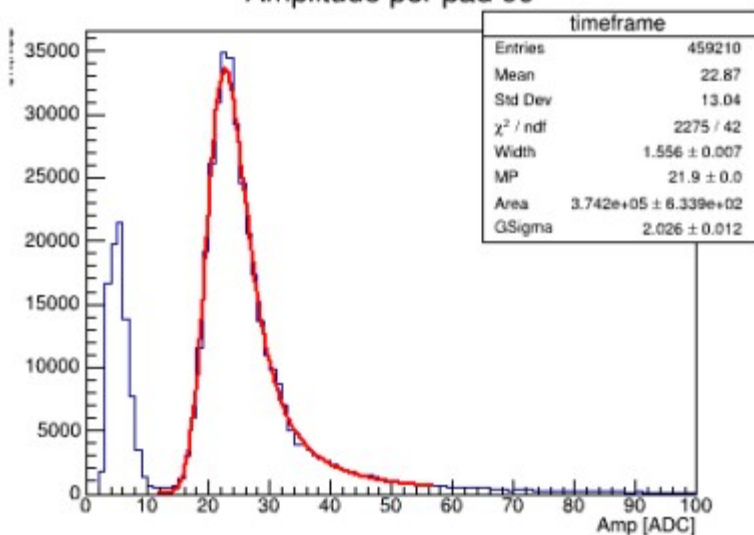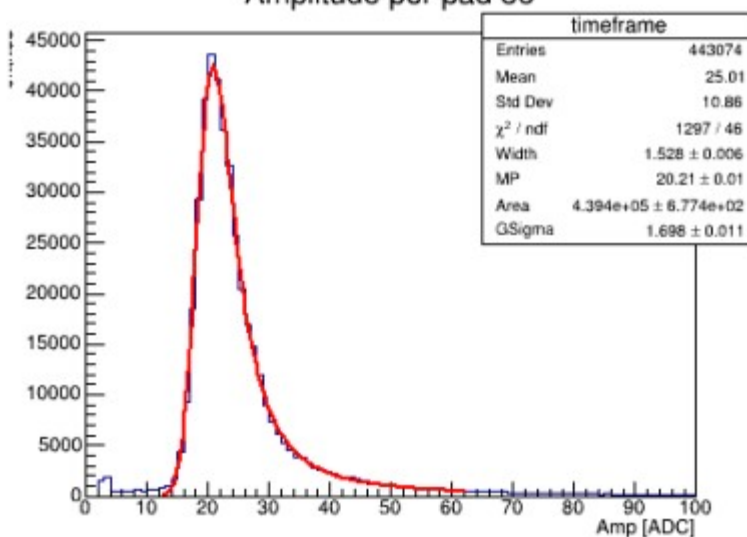

Integrated Hit Map

Amplitude per pad 99

timeframe	
Entries	459210
Mean	22.87
Std Dev	13.04
χ² / ndf	2275 / 42
Width	1.556 ± 0.007
MP	21.9 ± 0.0
Area	3.742e+05 ± 6.339e+02
GSigma	2.026 ± 0.012

Amplitude per pad 86

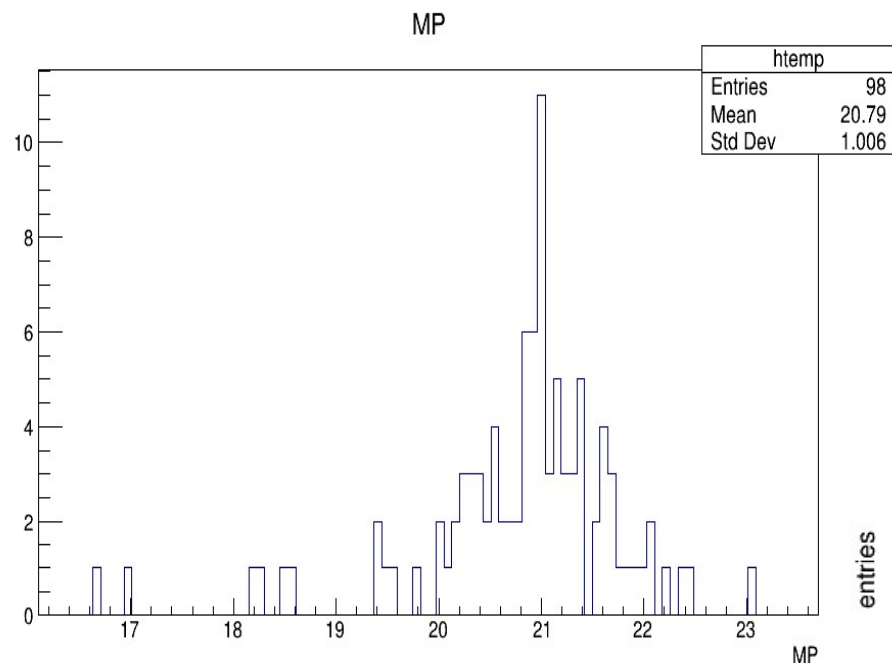| timeframe	
Entries	443074
Mean	25.01
Std Dev	10.86
χ² / ndf	1297 / 46
Width	1.528 ± 0.006
MP	20.21 ± 0.01
Area	4.394e+05 ± 6.774e+02
GSigma	1.698 ± 0.011

- **merged all data from run4422 till run4447**

- runs with Debug-data-ON or crashed runs not taken into account

- beam energy: 5 GeV

- many dead or unresponsive pads

Si sensor – C75
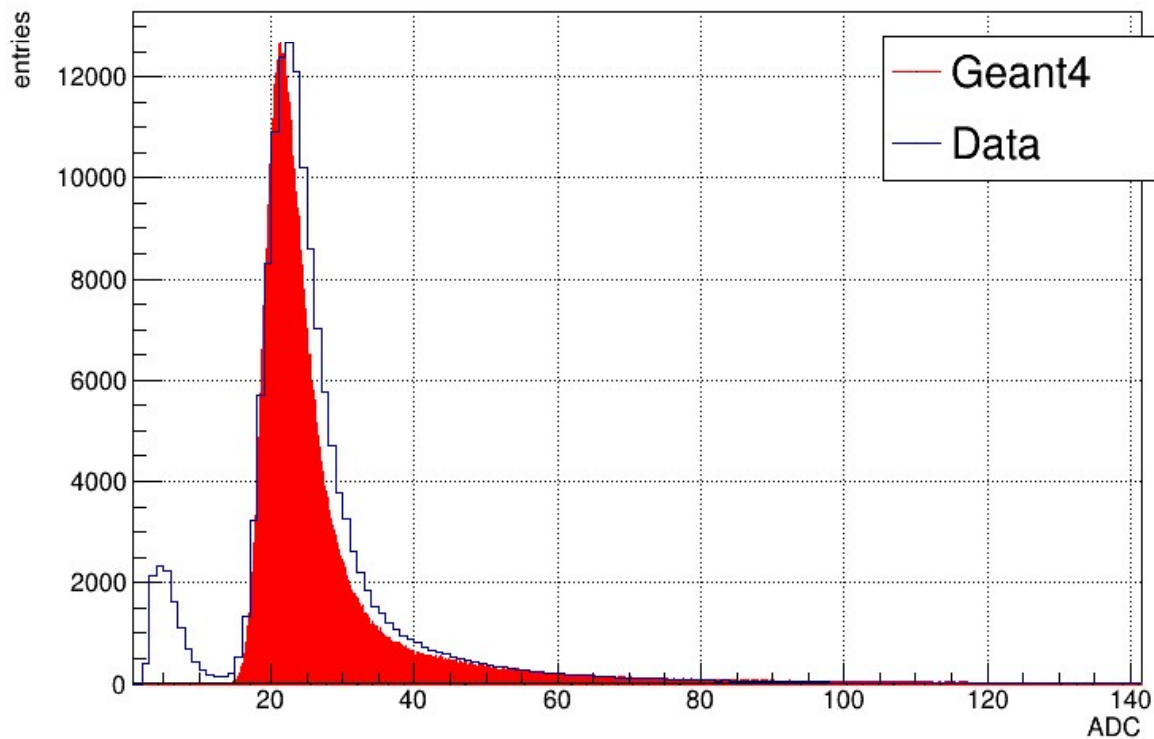

Data from run4436

- Beam on pads 49, 51, 59, 61

- **MPV = 20.79 ± 1.07 [ADC]**

- **1 MeV = 228.79 ADC**

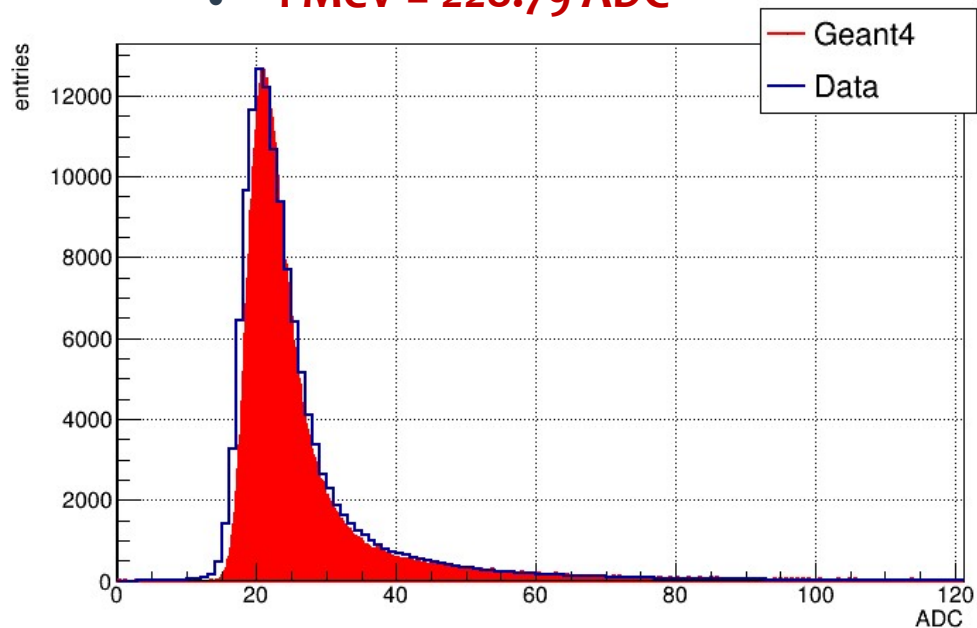# TB 2022: Simulations vs Data

Data from run4545

Integrated Hit Map
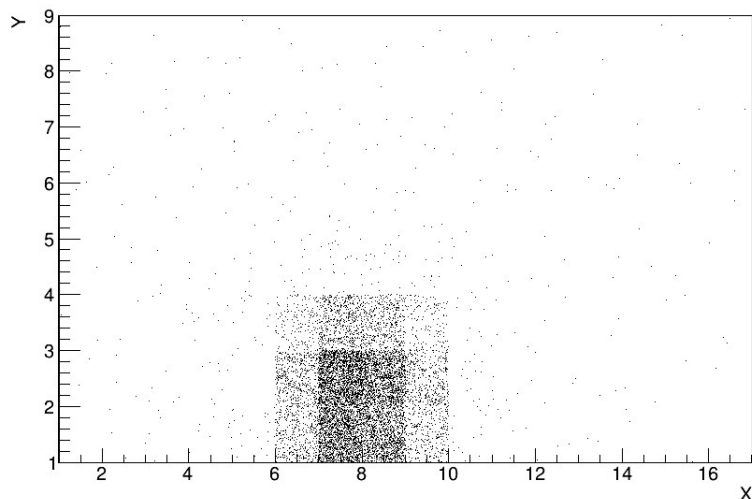
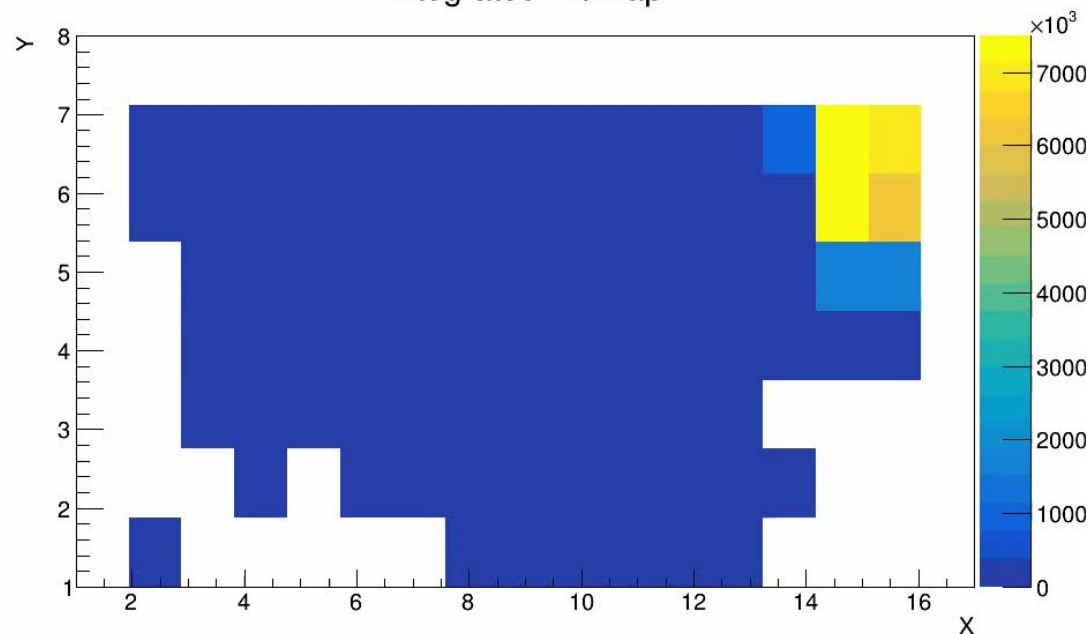**Hitmap of the merged file of C74 sensor - file from run4538 to run4551**

- **1 MeV = 228.79 ADC**

Integrated Hit Map

TB 2022: Simulations vs Data

- **1 MeV = 228.79 ADC**

Geant4: FTFP_BERT_EMZ
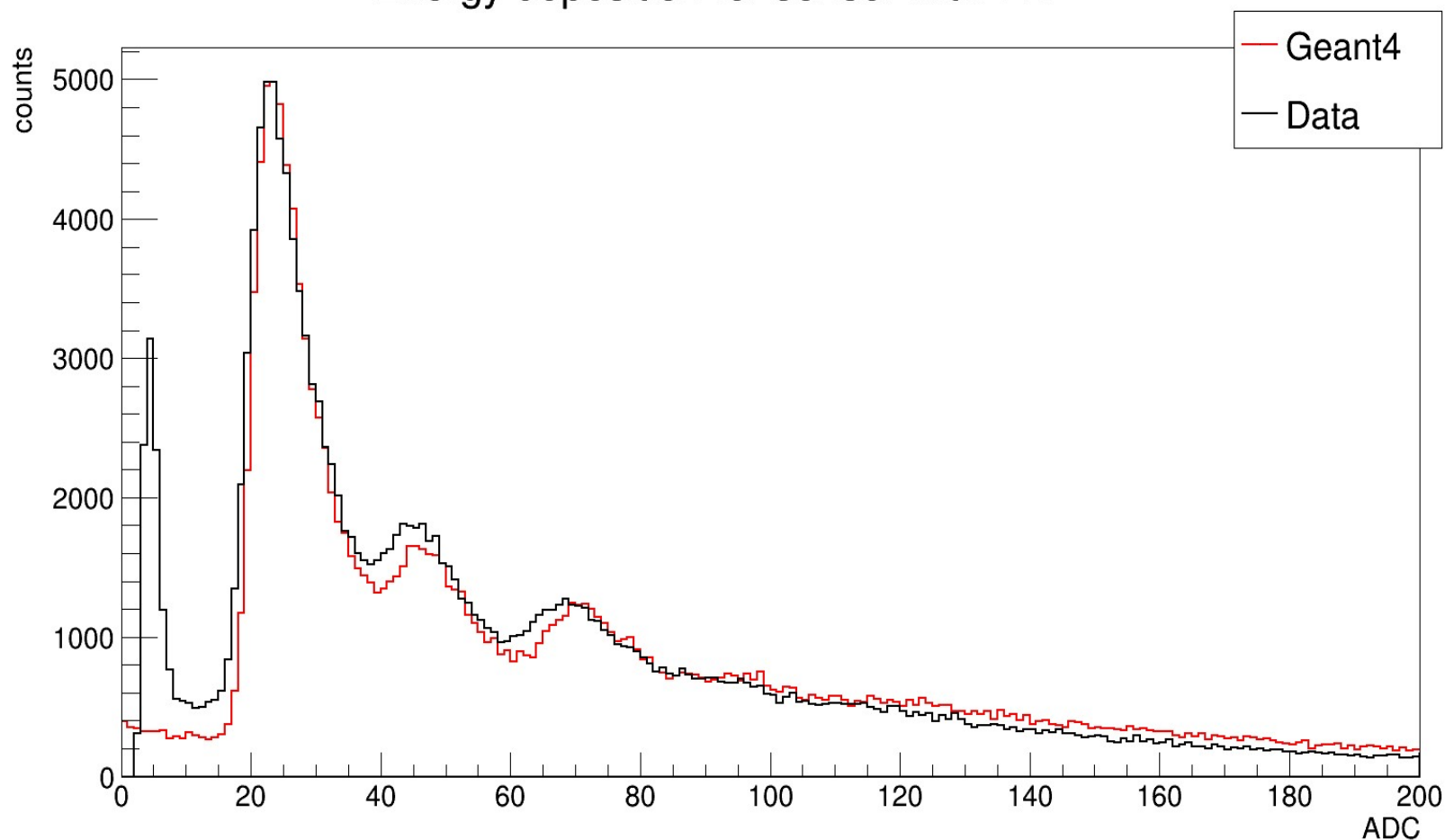
run4749 – C74 sensor with 1 tungsten plate in front

Energy deposition for sensor with 1W

TB 2022: Simulations vs Data

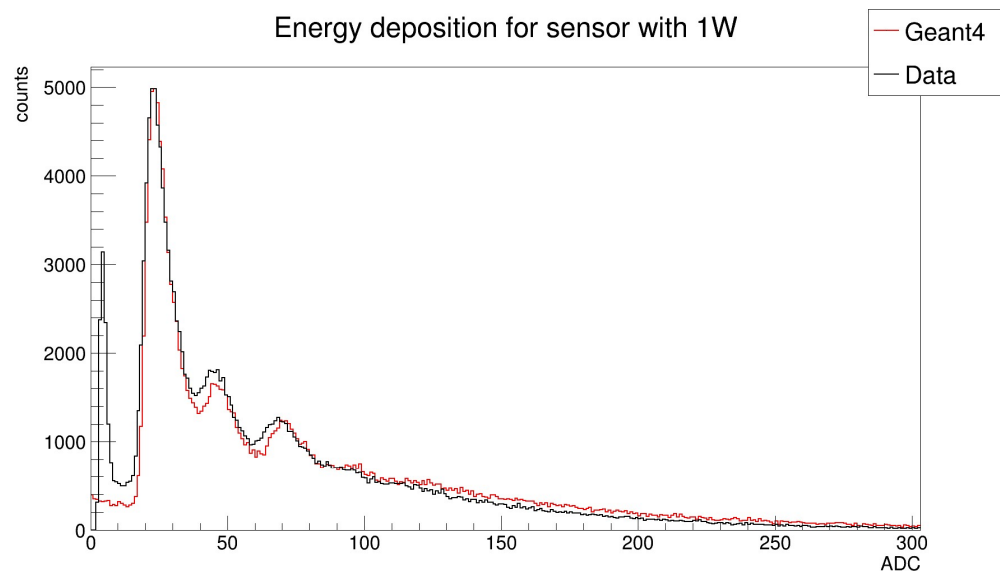## case scenario: Si sensor with W in front

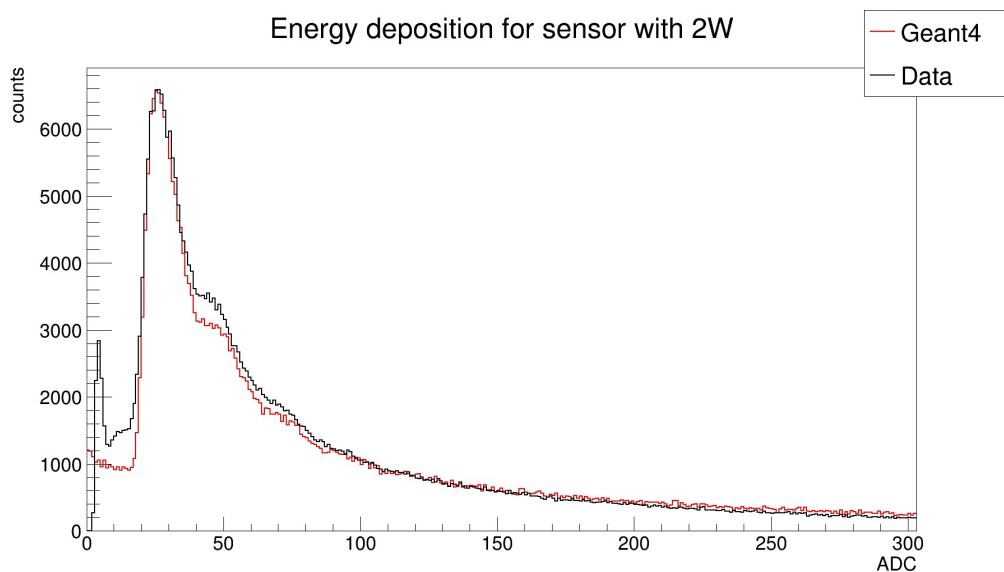- **1 MeV = 228.79 ADC**

  run4749 – 1W
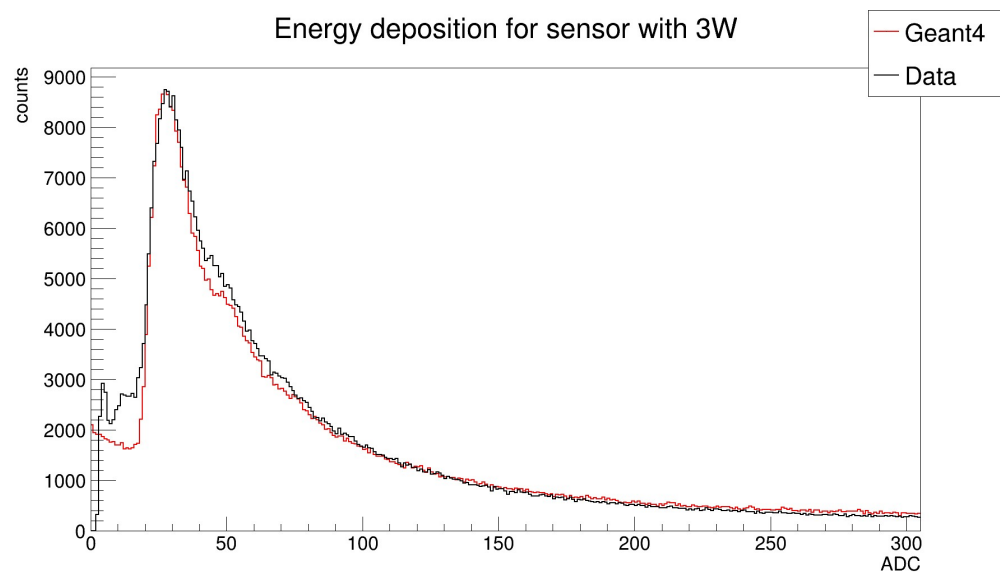
  run4748 – 2W

  run4747 – 3W

Energy deposition for sensor with 1W
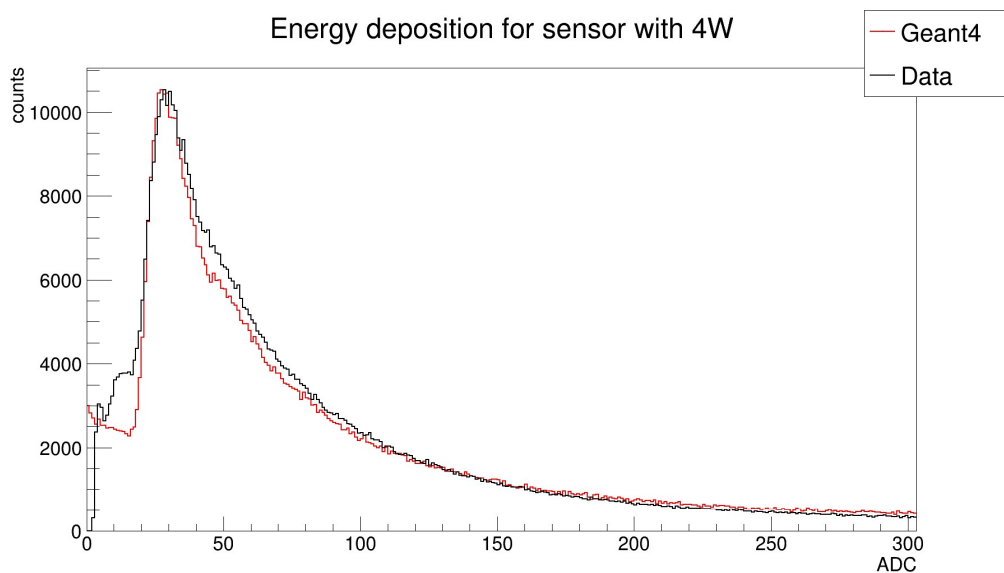

Energy deposition for sensor with 2W

Energy deposition for sensor with 3W
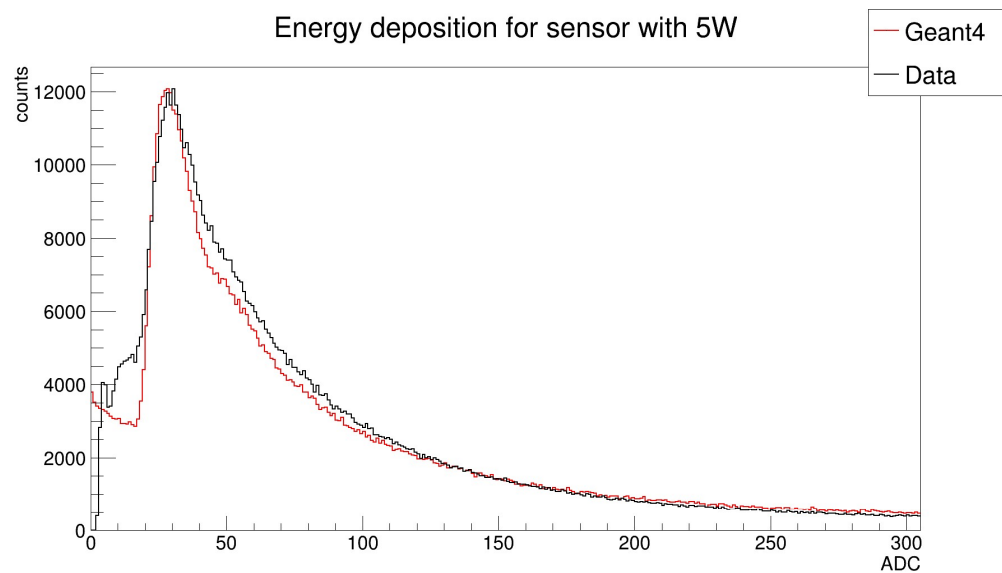
TB 2022: Simulations vs Data

Energy deposition for sensor with 4W

Energy deposition for sensor with 5W

Energy deposition for sensor with 6W

Energy deposition for sensor with 7W

TB 2022: Simulations vs Data
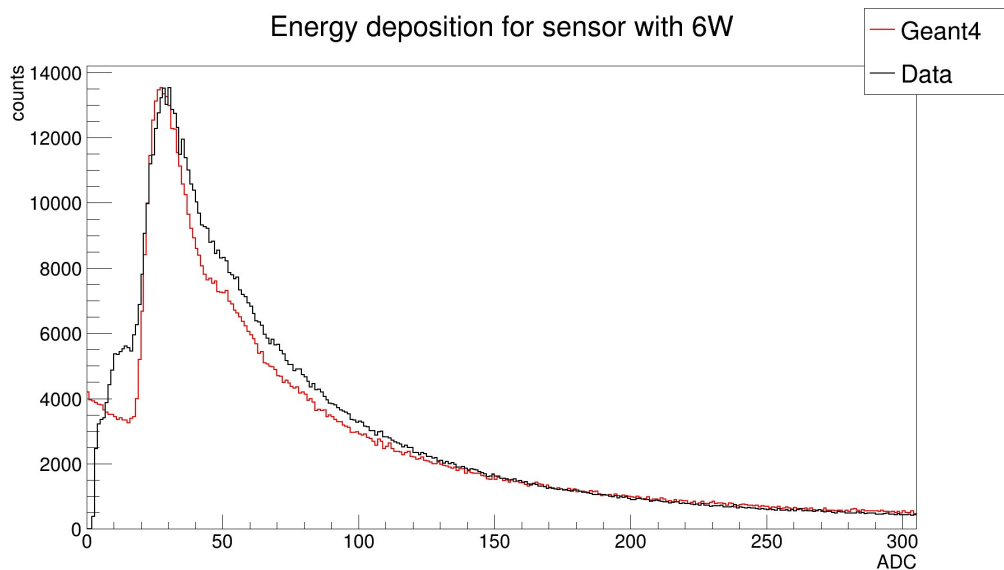

Energy deposition for sensor with 8W
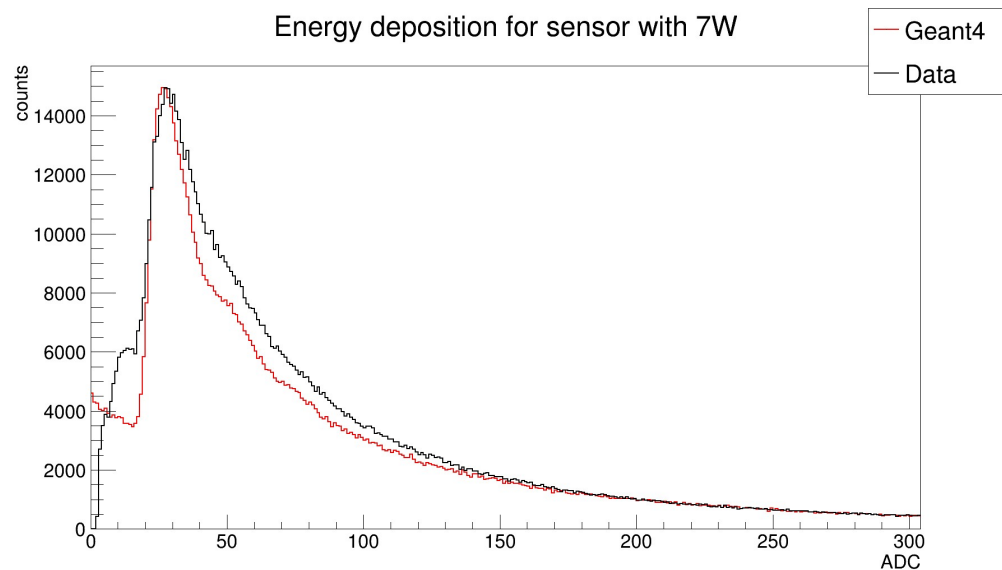
Energy deposition for sensor with 9W

Energy deposition for sensor with 10W

Energy deposition for sensor with 11W
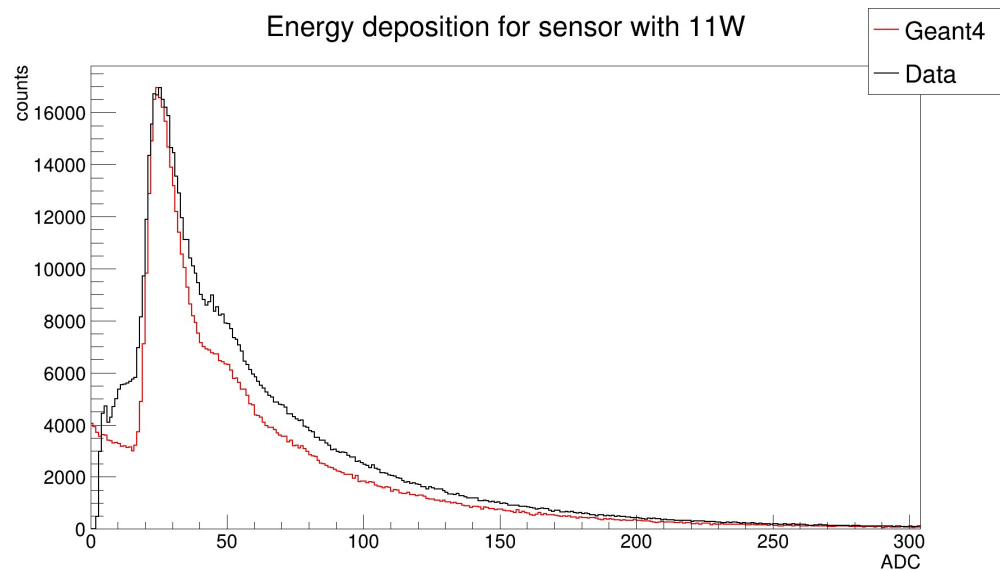
TB 2022: Simulations vs Data

Energy deposition for sensor with 12W
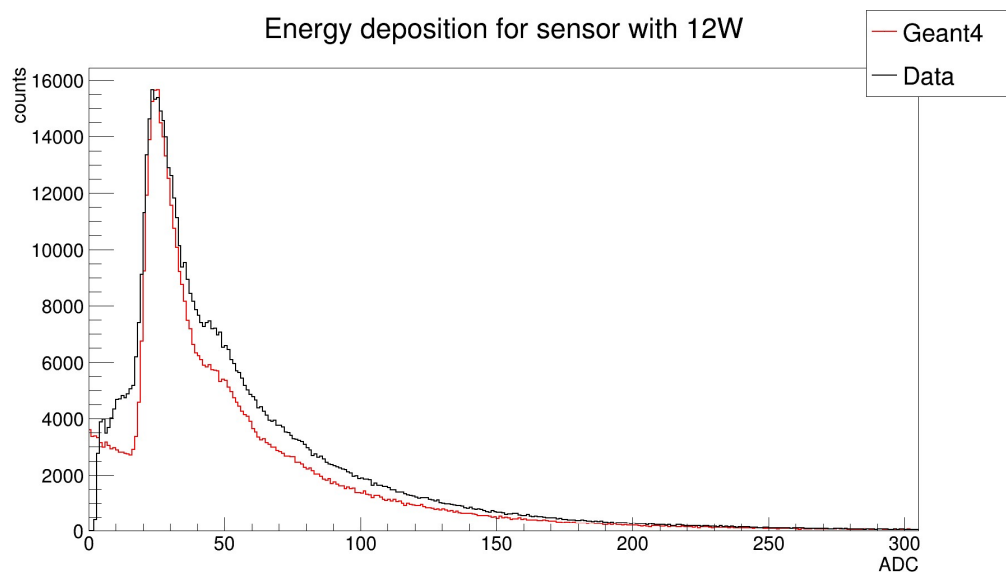
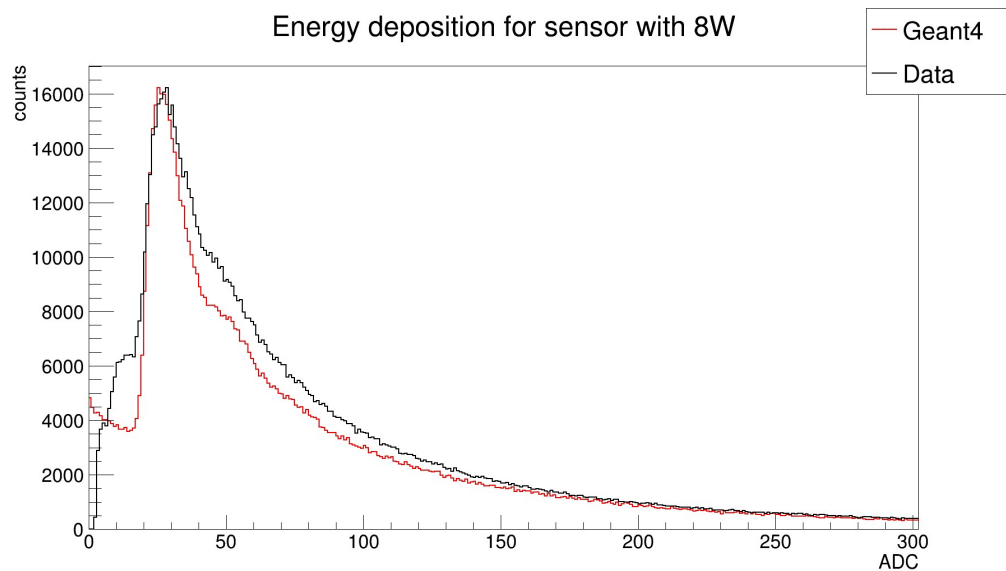Energy deposition for sensor with 13W
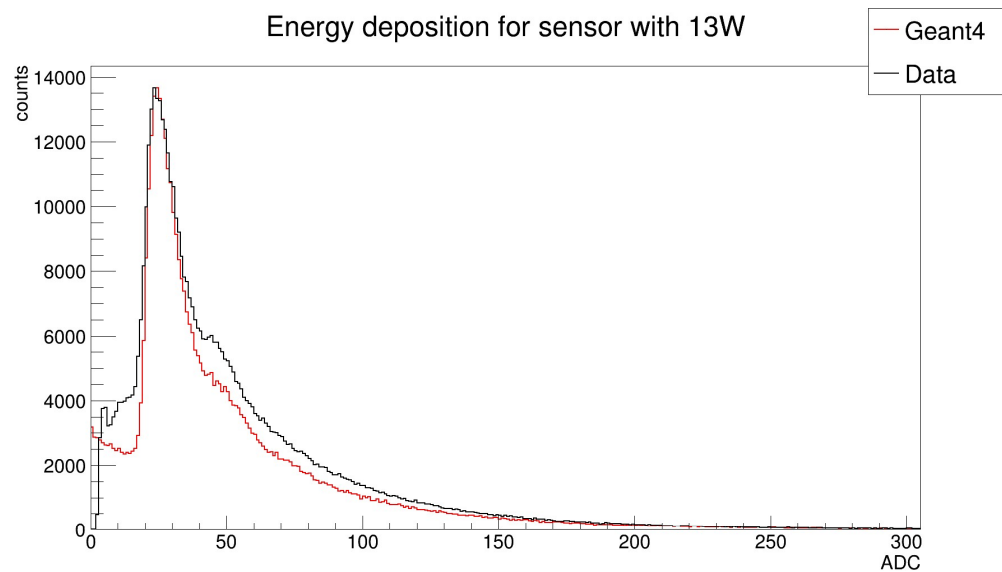
Energy deposition for sensor with 14W

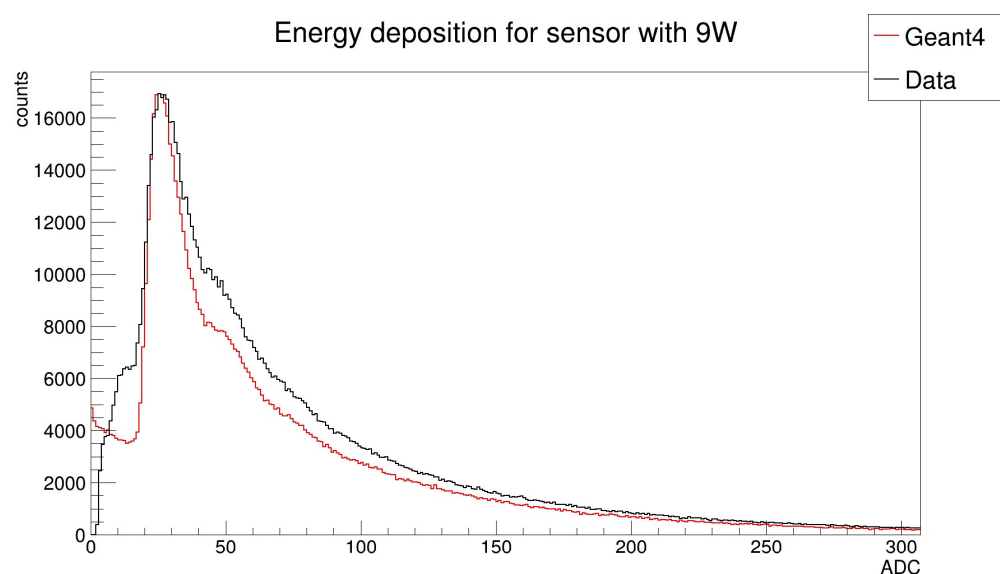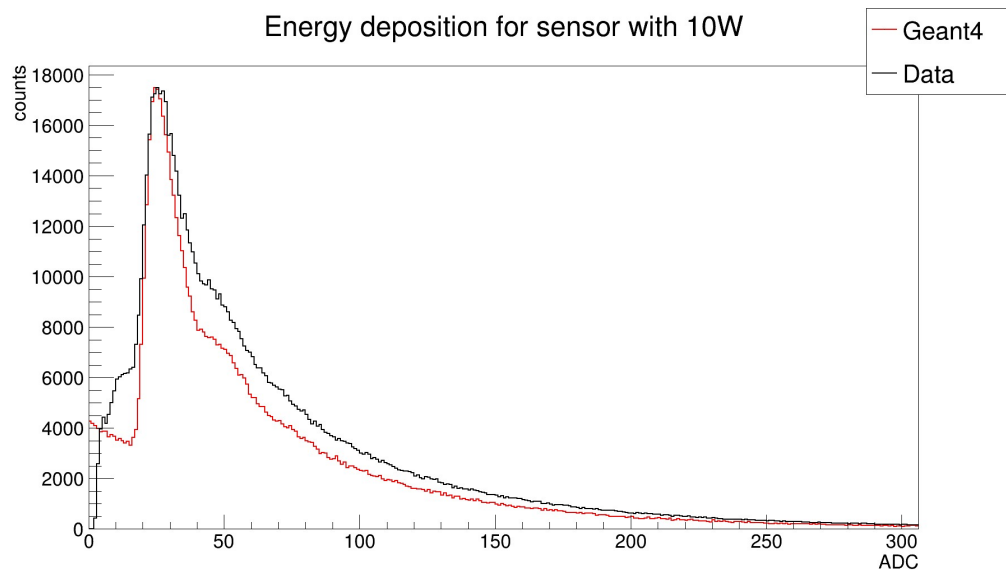Energy deposition for sensor with 15W

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
- ShieldingLEND

Energy deposition for (1W + Si sensor)

Legend: FTFP_BERT, FTFP_BERT_EMV, FTFP_BERT_EMX, FTFP_BERT_EMY, FTFP_BERT_EMZ, FTFP_BERT_LIV, FTFP_BERT_PEN, FTFP_BERT__GS, FTFP_BERT__SS

TB 2022: Geant4 Physics Lists

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
- ShieldingLEND

Energy deposition for (1W + Si sensor)

Legend: FTFP_BERT, FTFP_BERT_TRV, FTFP_BERT_ATL, FTFP_BERT_HP, FTFQGSP_BERT, FTFP_INCLXX, FTFP_INCLXX_HP, FTF_BIC

TB 2022: Geant4 Physics Lists

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
- ShieldingLEND

Energy deposition for (1W + Si sensor)

Legend: FTFP_BERT, LBE, QBBC, Shielding, ShieldingM, NuBeam

TB 2022: Geant4 Physics Lists

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
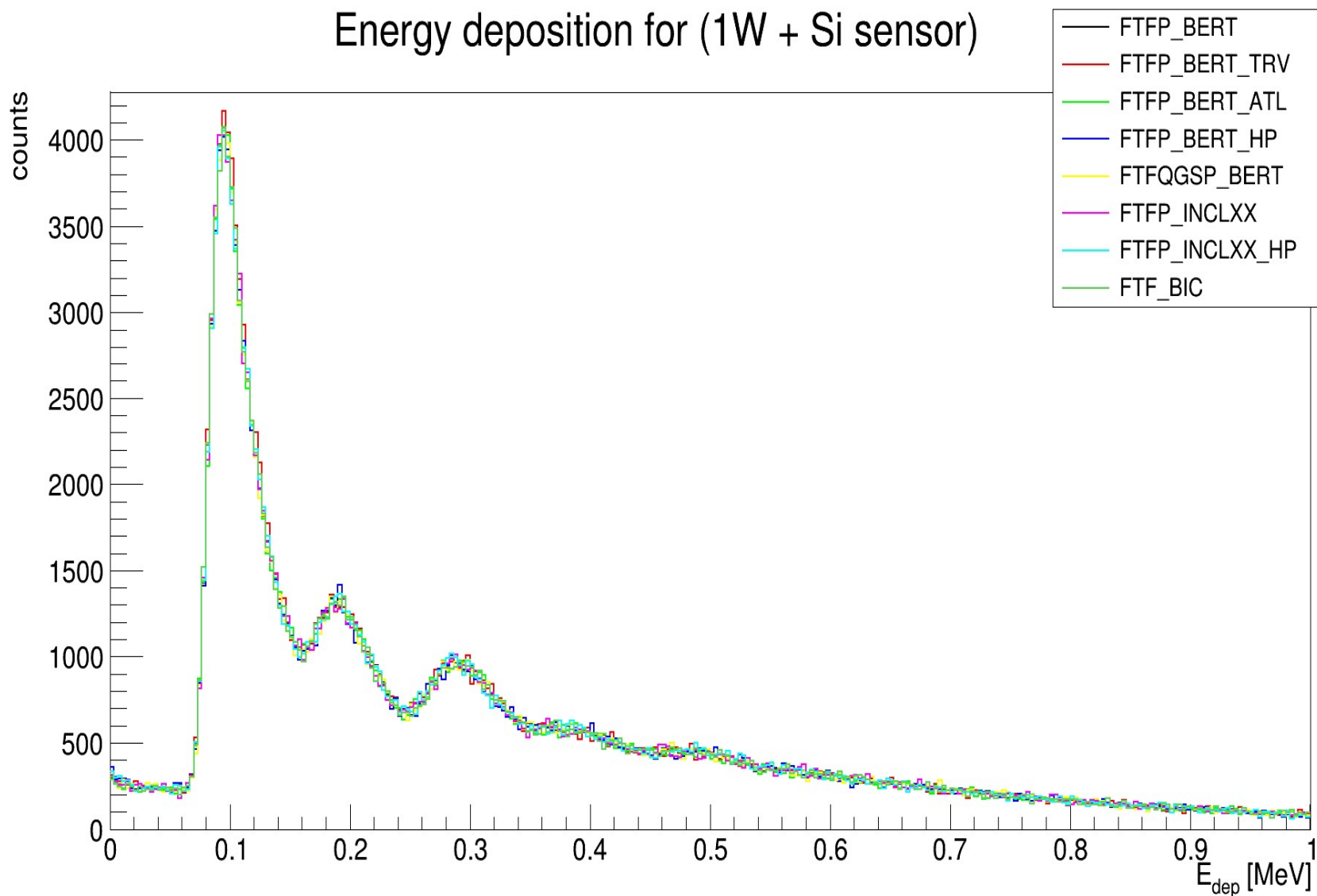- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
- ShieldingLEND

Energy deposition for (1W + Si sensor)

Legend: QGSP_BERT, QGSP_BERT_HP, QGSP_BIC, QGSP_BIC_HP, QGSP_FTFP_BERT, QGSP_INCLXX, QGSP_INCLXX_HP, QGS_BIC

▪ Si sensor – C74 & W

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
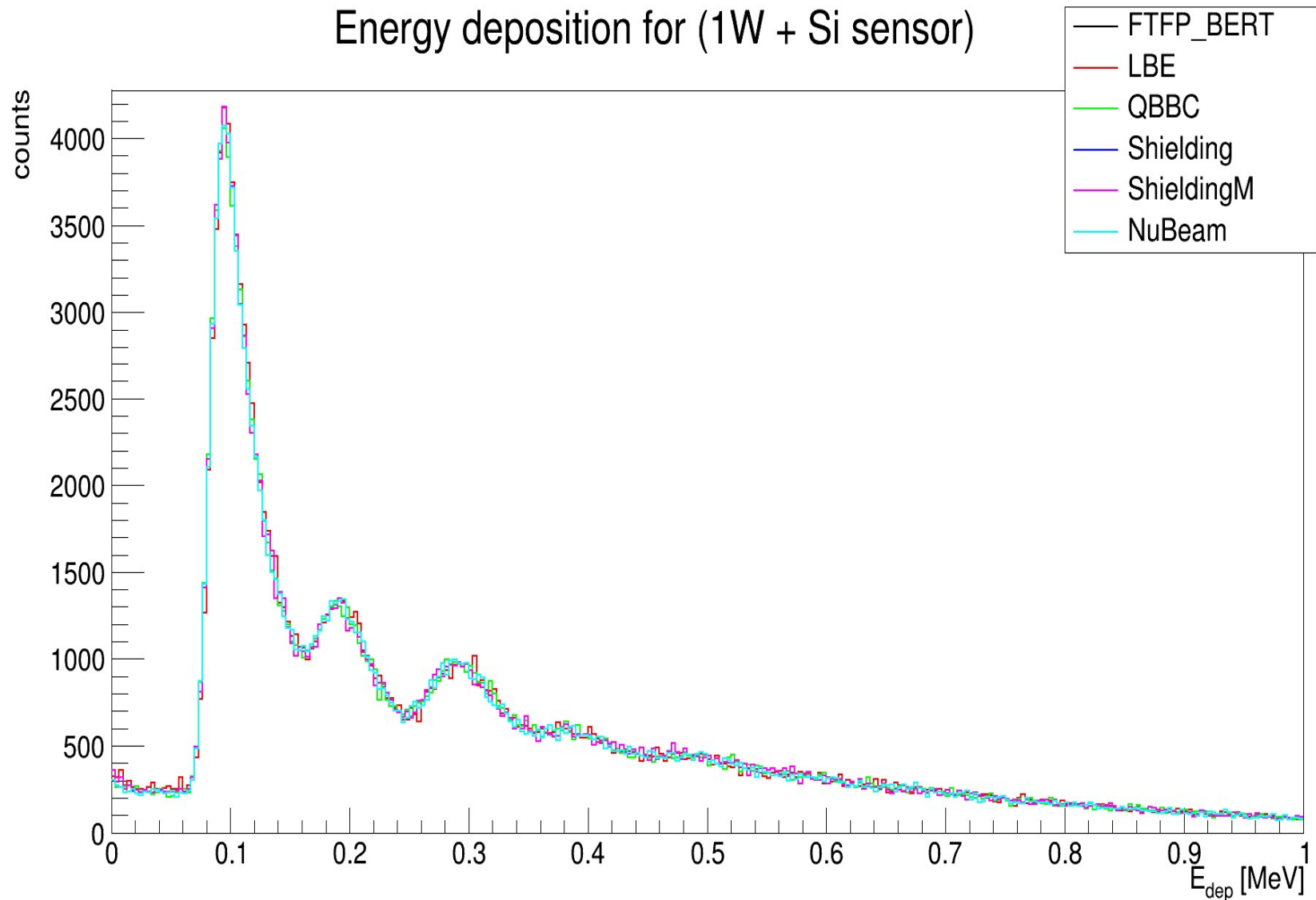- ShieldingLEND

Energy deposition for (1W + Si sensor)

Legend:
- FTFP_BERT
- FTFP_BERT__SS
- LBE
- QGSP_BERT
- Shielding

TB 2022: Geant4 Physics Lists

- FTF_BIC
- FTFP_BERT
- FTFP_BERT_HP
- FTFP_BERT_TRV
- FTFP_BERT_ATL
- FTFP_INCLXX
- FTFP_INCLXX_HP
- FTFP_QGSP_BERT
- LBE
- NuBeam
- QGSP_BERT
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_BIC_AllHP
- QGSP_FTFP_BERT
- QGSP_INCLXX
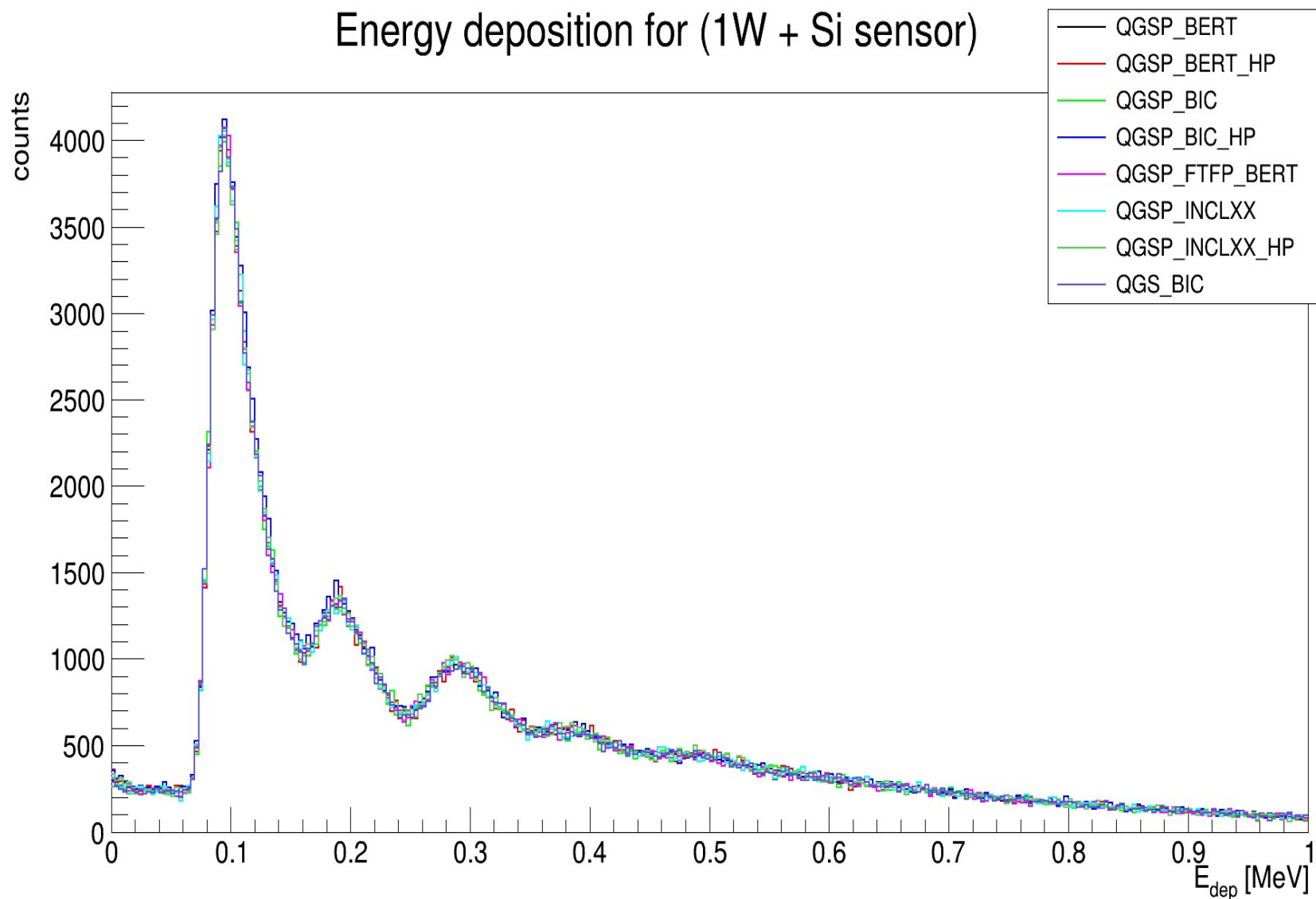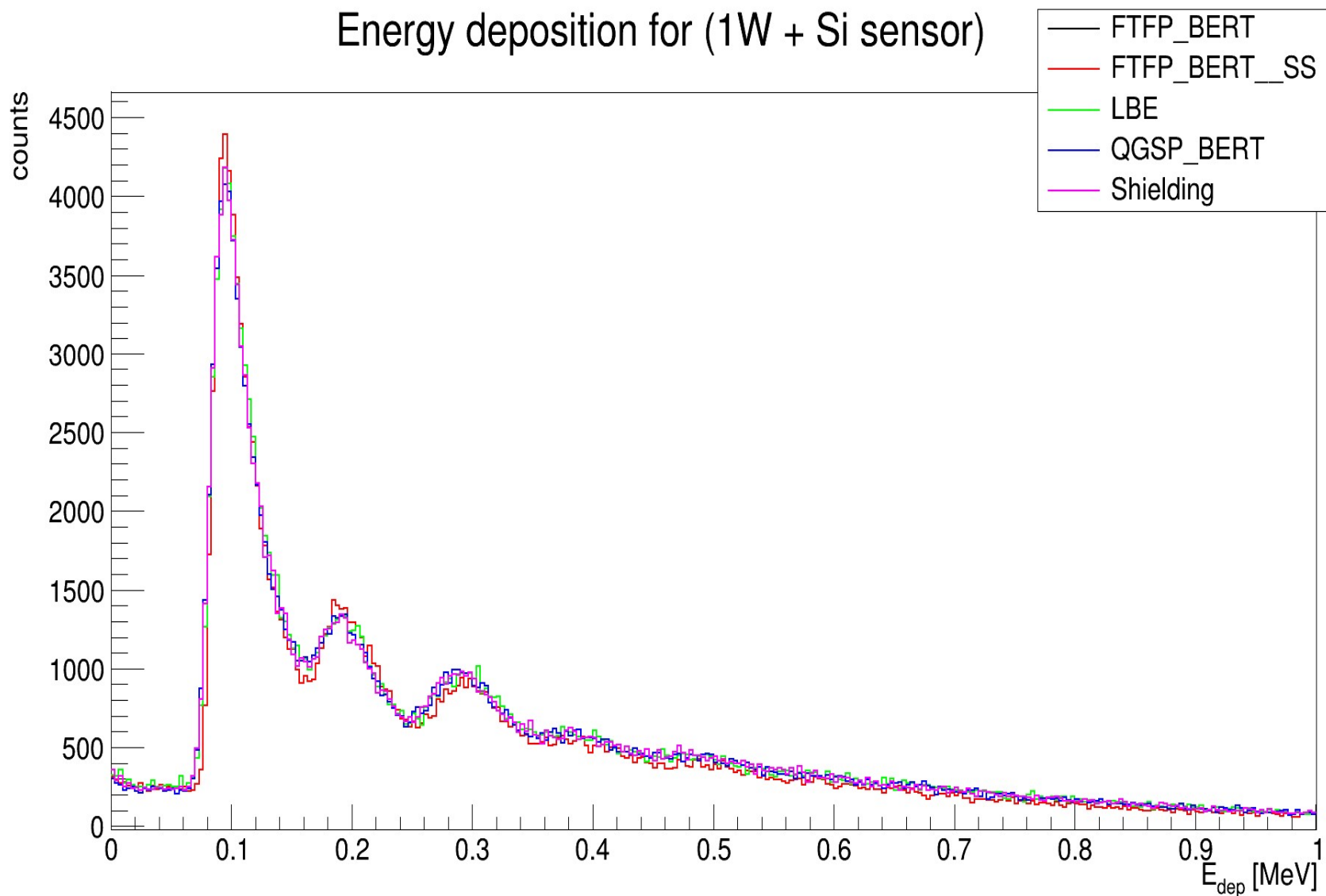- QGSP_INCLXX_HP
- QGS_BIC
- Shielding
- ShieldingLEND

Energy deposition for (1W + Si sensor)

Si sensor – C74 & W

Data

χ² / ndf	228 / 20
Constant	1.302e+05 ± 2.543e+02
MPV	31.49 ± 0.05
Sigma	7.604 ± 0.041

Geant4

χ² / ndf	144.2 / 20
Constant	6.704e+04 ± 1.922e+02
MPV	29.95 ± 0.04
Sigma	5.905 ± 0.033
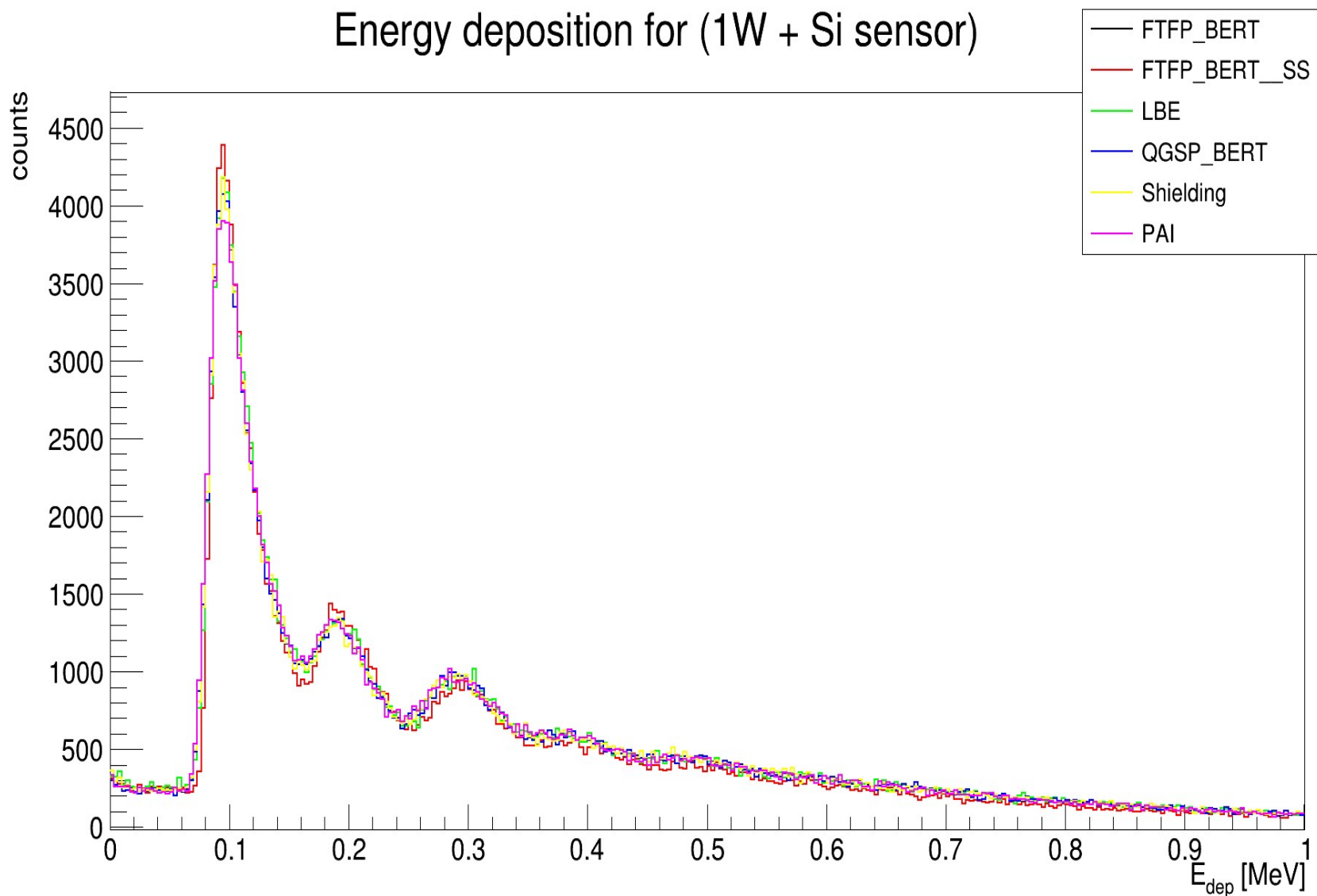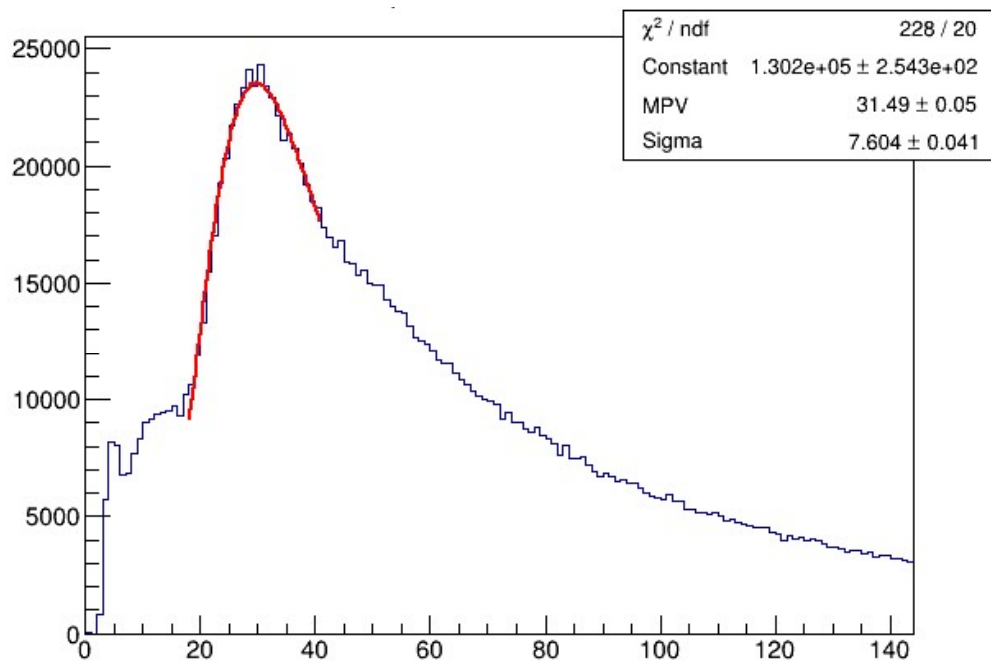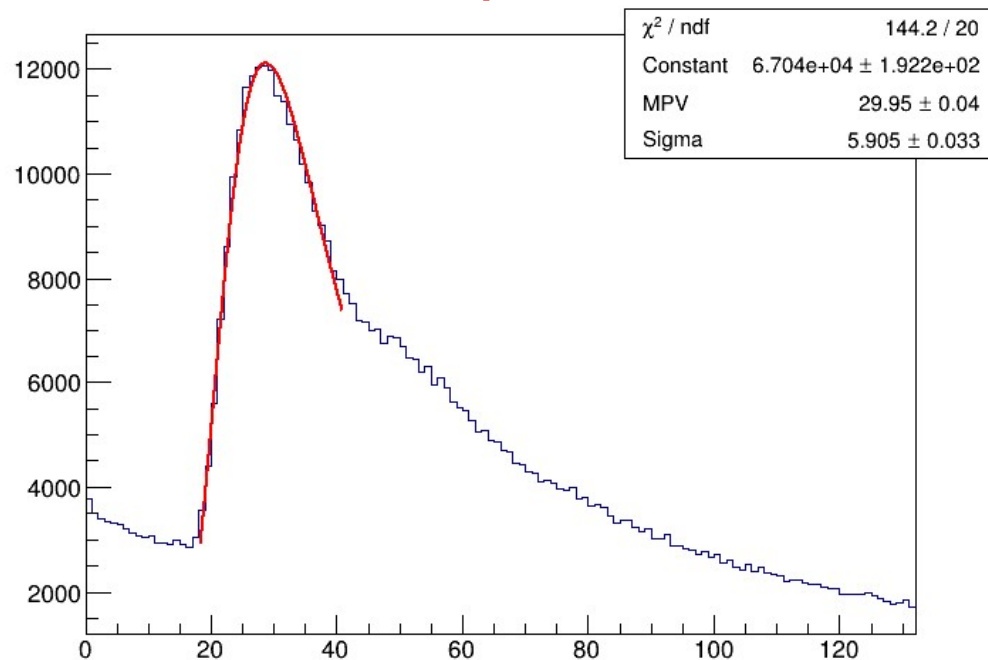
TB 2022: Geant4 vs Data

Longitudinal shower development

TB 2022 Simulations - update

- **Energy deposition on (W + C74 sensor)**

  ▪ placed all tungsten plates in the same position as in test-beam taking into account that the plates where removed one by one starting with the one placed further of the sensor - **no noticeable influence!**

  ▪ checked the composition of each tungsten plate and implemented in Geant4 simulations – **no noticeable influence!**

  ▪ modified the beam profile using a Gaussian shape of the energy distribution for the incoming electrons - **no noticeable influence!**

  ▪ modify the physics list to include / exclude some process – *work in progress.*

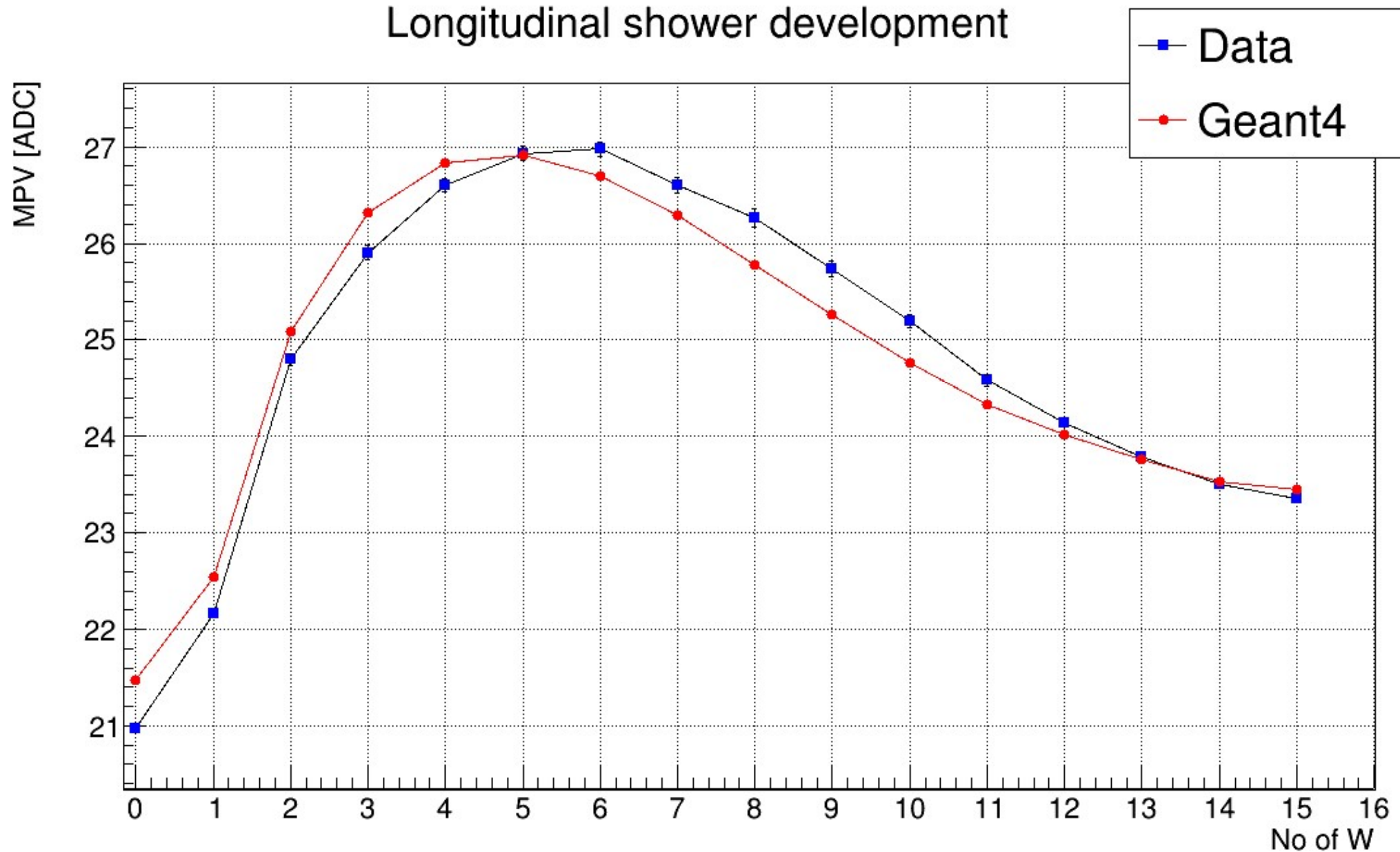| Stack configuration				
V beam V				
Slot 1	Plane "1"	tungsten	3,505	abs95
Slot 2	Plane "3"	tungsten	3,520	abs95
Slot 3	A5	tungsten	3,528	abs95
Slot 4	A2	tungsten	3,550	abs95
Slot 5	Plane "4"	tungsten	3,475	abs95
Slot 6	B12	tungsten	3,550	abs95
Slot 7	A8	tungsten	3,558	abs95
Slot 8	B23	tungsten	3,543	abs95
Slot 9	B21	tungsten		
Slot 10	1 (A3)	tungsten		
Slot 11	B19	tungsten		
Slot 12	B14	tungsten		
Slot 13	7 (MGS2)	tungsten	3,521	abs93
Slot 14	10 (MGS5)	tungsten	3,645	abs93
Slot 15	11 (MGS6)	tungsten	3,470	abs93
Slot 16	---	gap		
Slot 17	Calice 74	sensor		
Slots 18--end	---	empty		

```
/gps/particle e-

/gps/pos/type Beam
/gps/pos/shape Rectangle
/gps/pos/halfx 0.6 cm
/gps/pos/halfy 0.6 cm
/gps/pos/centre 0. 0. -200. cm
/gps/direction 0 0 1

/gps/ene/type Gauss
/gps/ene/mono 5000 MeV
/gps/ene/sigma 50. MeV

/run/beamOn 500000
```

TB 2022: Configurations

- **Geometry implementation in Geant4 - 10 experimental setups - 38 different configurations**
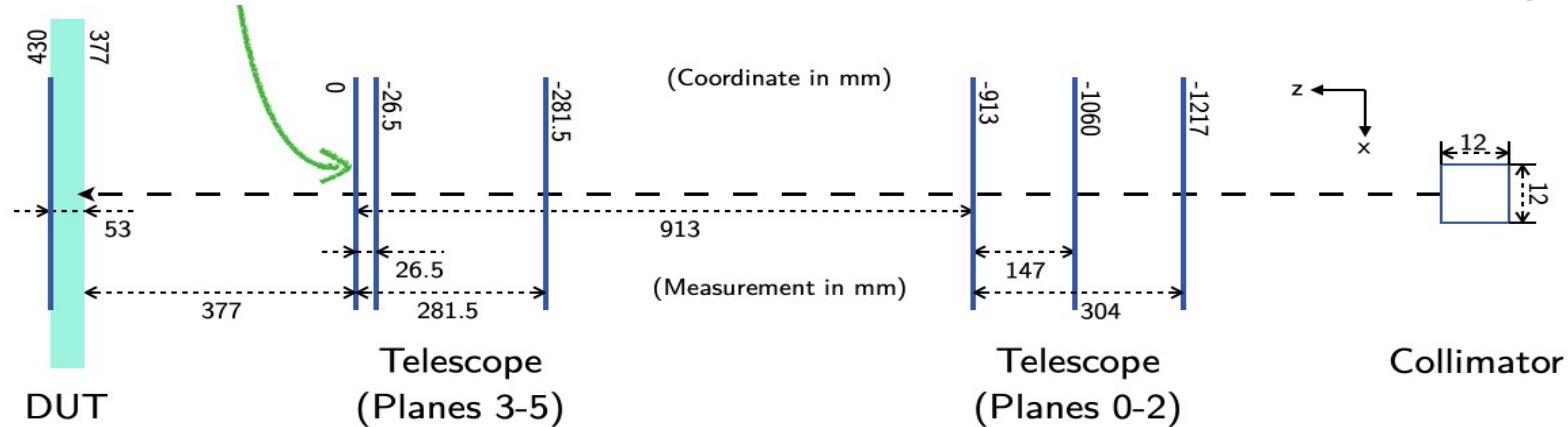
- **Ga-As sensor – Anton1**

    1 exp. setups without any W plates

    Energies: 5 GeV c

- **Ga-As sensor – Yan1**

    1 exp. setup without W plates

    Energies: 5 GeV

    1 exp. setup with 5 W plates

    Energies: 1 GeV, 3 GeV, 5 GeV

    1 exp. setups with decreased no of plates 15 -> 1 W

    Energies: 5 GeV

- **Ga-As sensor – BeamCal**

    1 exp. setups without any W plates

    Energies: 5 GeV

- **Si sensor – C72**

    1 exp. setups without any W plates

    Energies: 5 GeV

- **Si sensor – C74**

    1 exp. setups without any W plates

    Energies: 5 GeV

    1 exp. setup with 5 W plates

    Energies: 1 GeV, 3 GeV, 5 GeV

    1 exp. setups with decreased no of plates 15 -> 1 W

    Energies: 5 GeV

- **Si sensor – C72**

    1 exp. setups without any W plates

    Energies: 5 GeV