



# Simulation of a multi-wire drift chamber with the GEANT-Garfield interface

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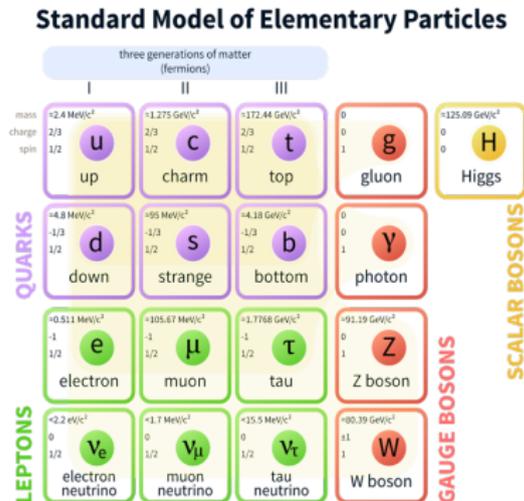
- 1 Motivation
- 2  $\beta$ -spectrum shape
- 3 miniBETA spectrometer
- 4 Simulations
- 5 Outlook

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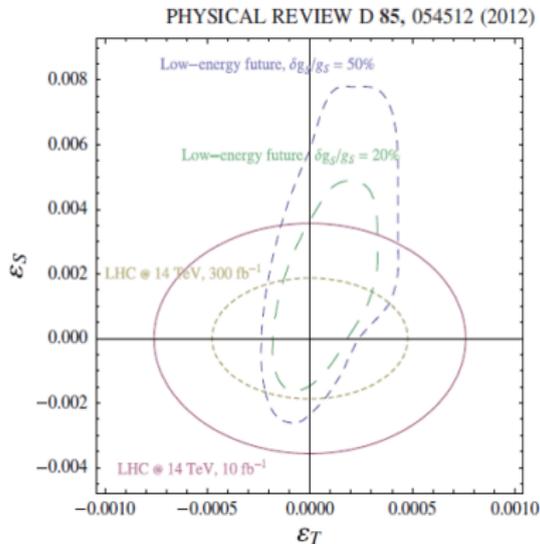
- Problems with the Standard Model(SM)
  - Matter-antimatter asymmetry
  - Parity violation
  - Hierarchy of fermion masses
  - ...

→ Solution: Beyond Standard Models(BSM)

- Supersymmetry(SUSY)
- Grand Unifying Theories (GUTs)
- ...



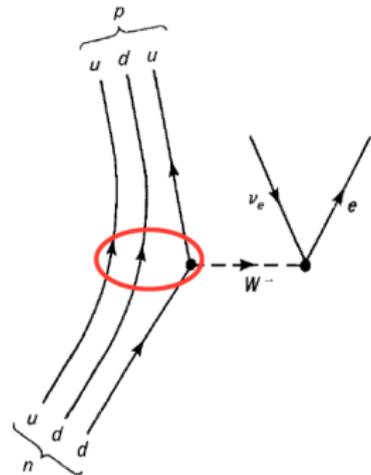
- High energy physics  $\rightarrow$  direct production of new bosons  
 $pp \rightarrow e + MET + X$
- Low energy physics  $\rightarrow$  probe small effects of new bosons/currents on  $\beta$ -decay observables



- Most general Lorentz-invariant Hamiltonian

$$\mathcal{H}_\beta = \sum_{j=V,A,T,S,P} \langle f | \mathcal{O}_j | i \rangle \langle e | \mathcal{O}_j [C_j + C'_j \gamma_5] | \nu \rangle + h.c.$$

- Standard Model: only V-A currents
- Influence of QCD ?



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- The  $\beta$ -spectrum shape for allowed transitions:

$$\frac{dN}{dE} \propto 1 + b_{Fierz} \gamma \frac{m_e}{E_e} + b_{WM} E_e$$

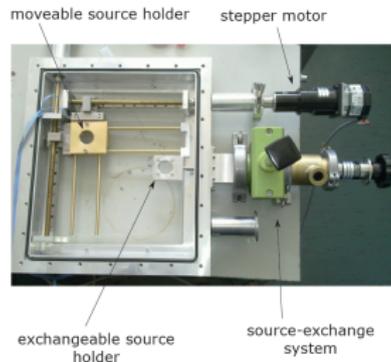
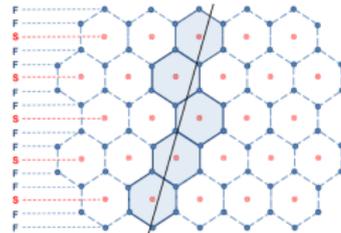
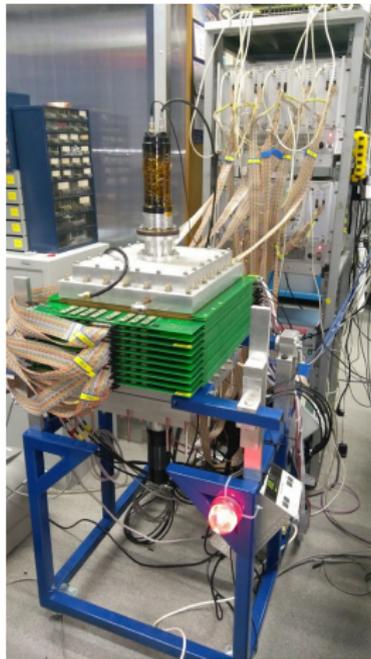
- $b_{Fierz}$  Depends on scalar(Fermi) and tensor(Gamow-Teller) couplings
- $b_{WM}$  Weak magnetism: current induced by QCD
  - Important in *Reactor Antineutrino Anomaly*
- Future experimental precision:  $10^{-3}$ 
  - radiative corrections, nuclear and atomic effects, ...

"High precision analytical description of the allowed  $\beta$  spectrum shape"

L. Hayen et al. Rev. Mod. Phys.

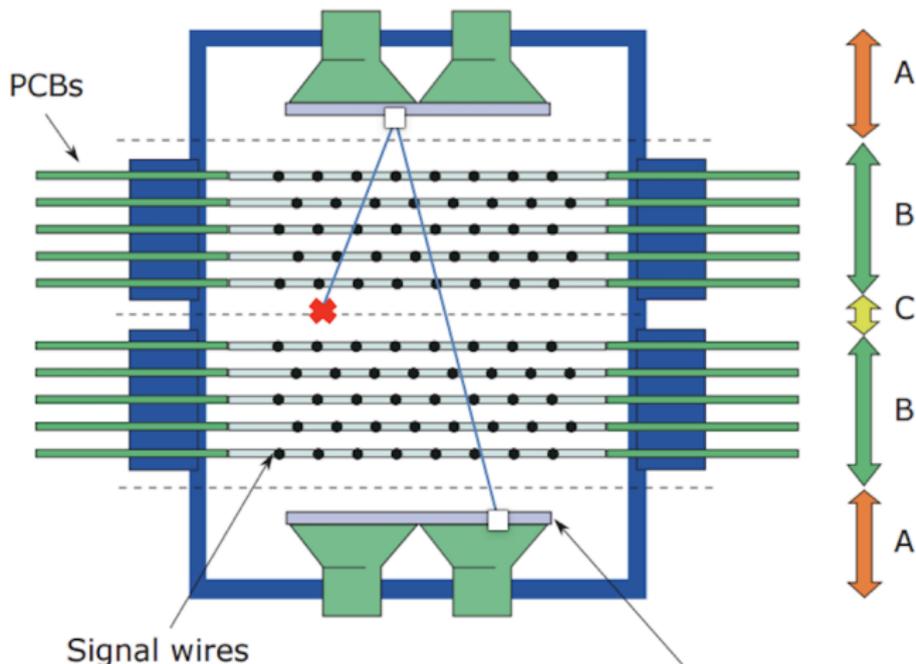
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Energy detector combined with multiwire drift chamber (Krakow University)

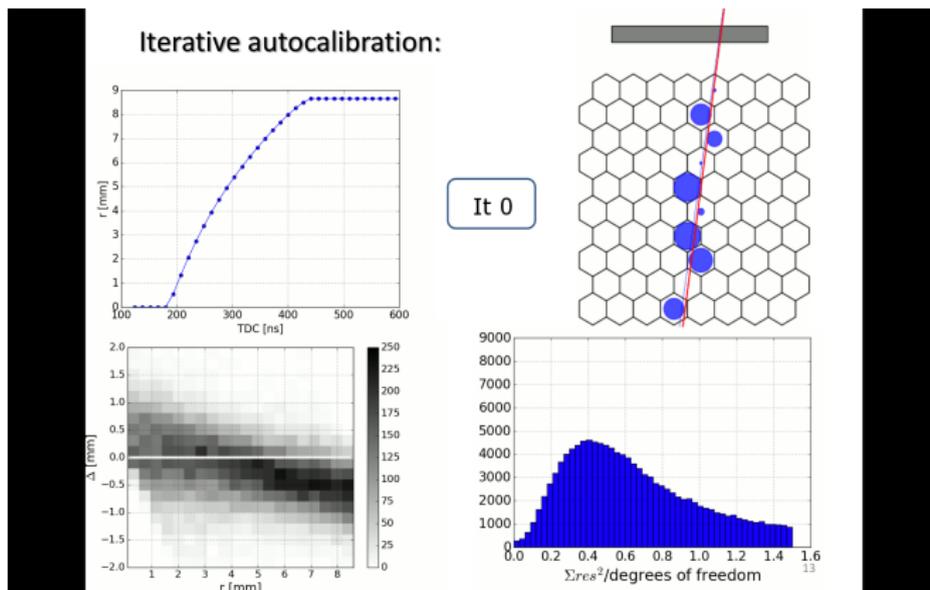


Largest source of uncertainty: **Back scattering!**

→ V-tracking: Energy from detector with correction for backscattering events

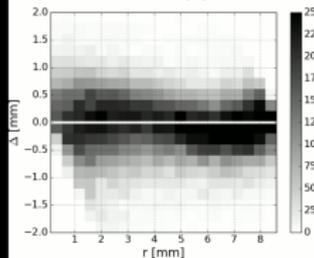
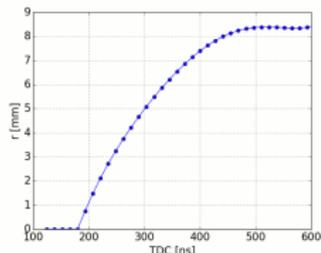


## Iterative calibration of the TDC vs R for each cell

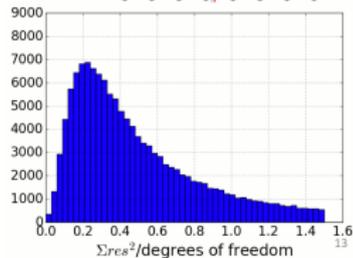
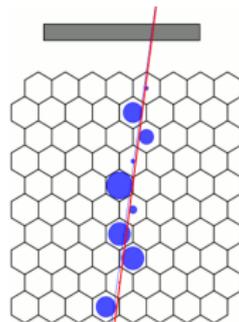


## Iterative calibration of the TDC vs R for each cell

Iterative autocalibration:

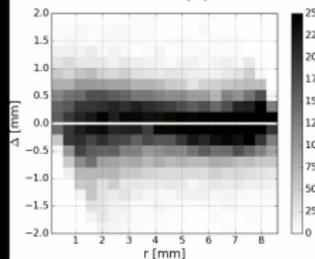
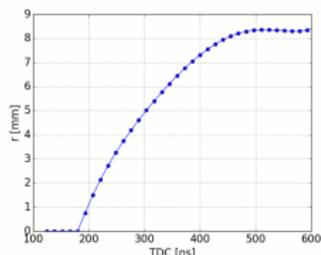


It 1

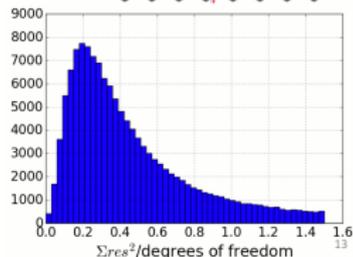
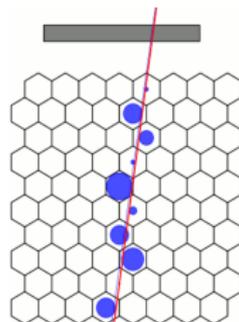


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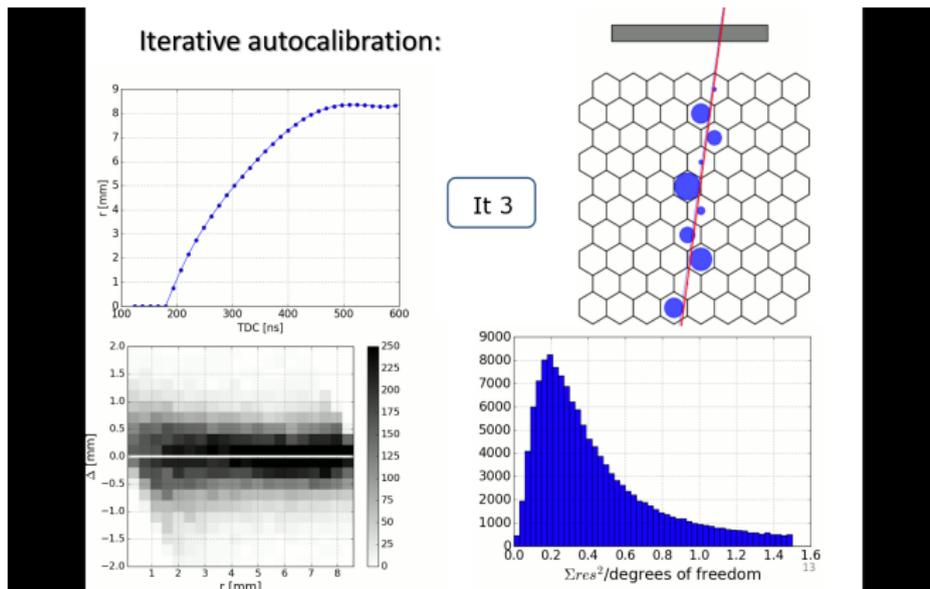
Iterative autocalibration:



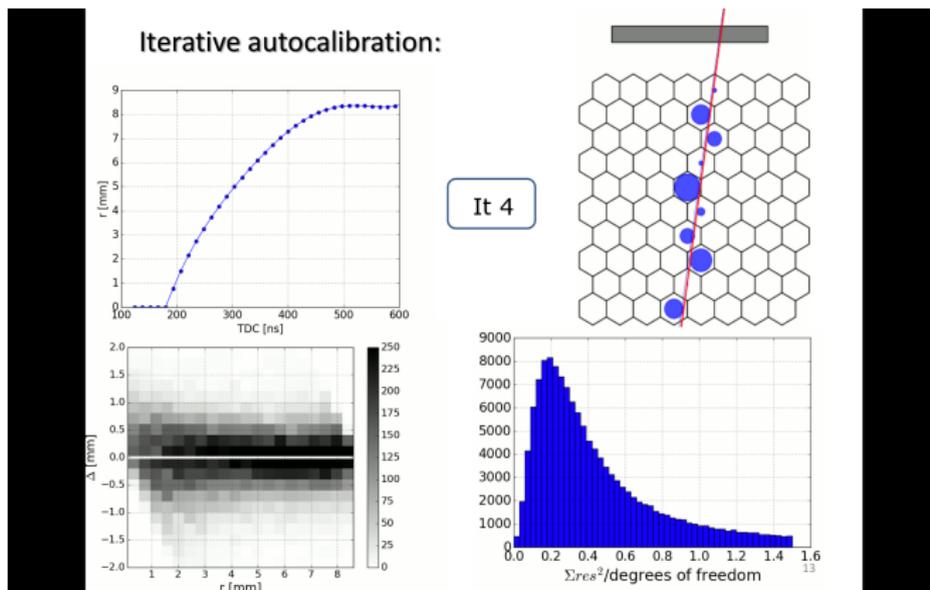
It 2



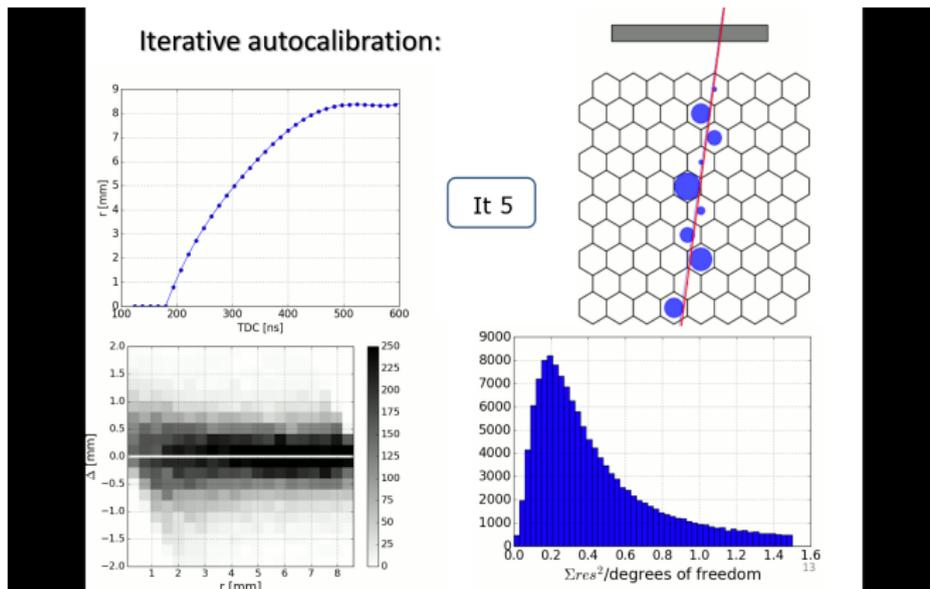
## Iterative calibration of the TDC vs R for each cell



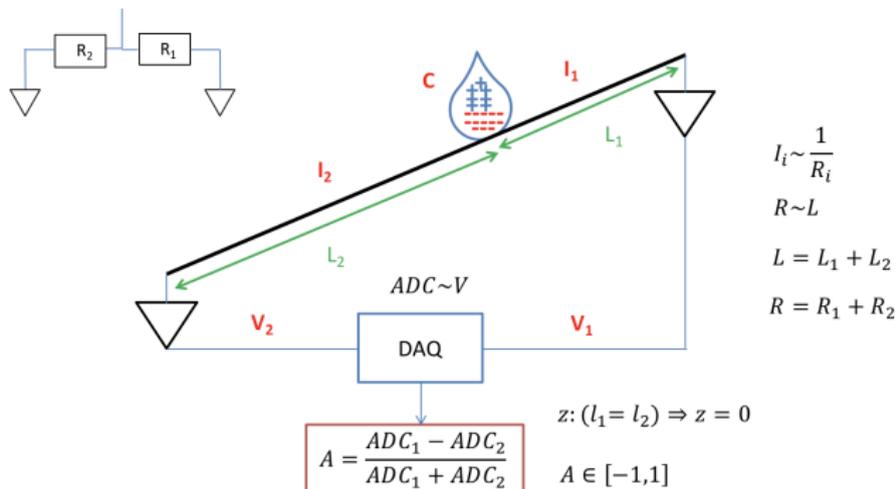
## Iterative calibration of the TDC vs R for each cell



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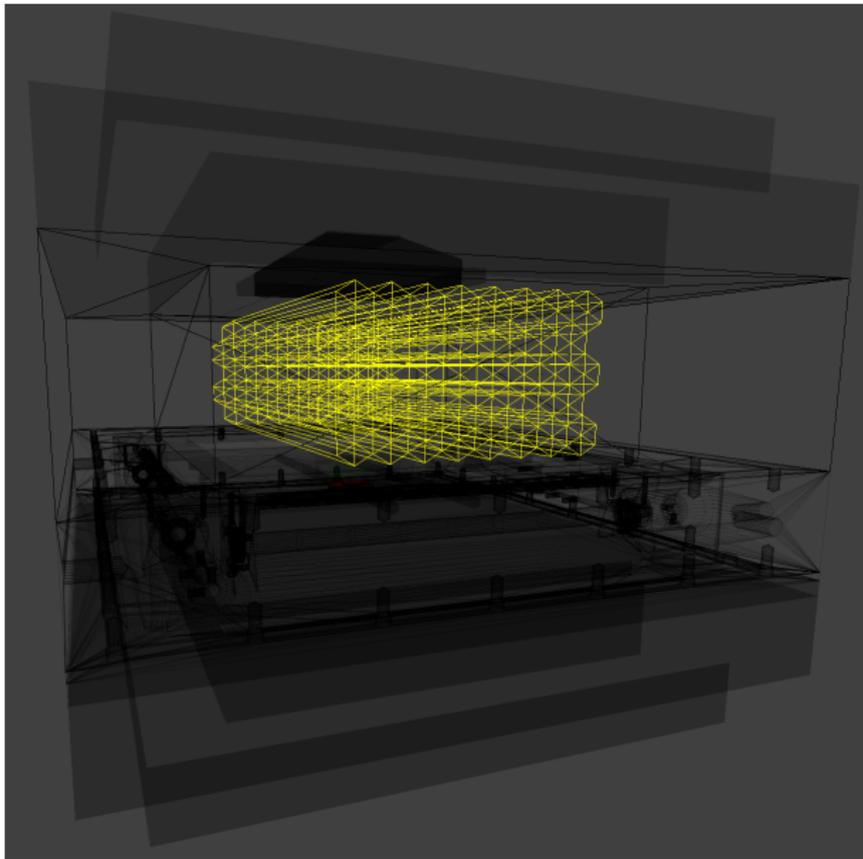
Finding a trajectory in the Z-direction: Charge division technique

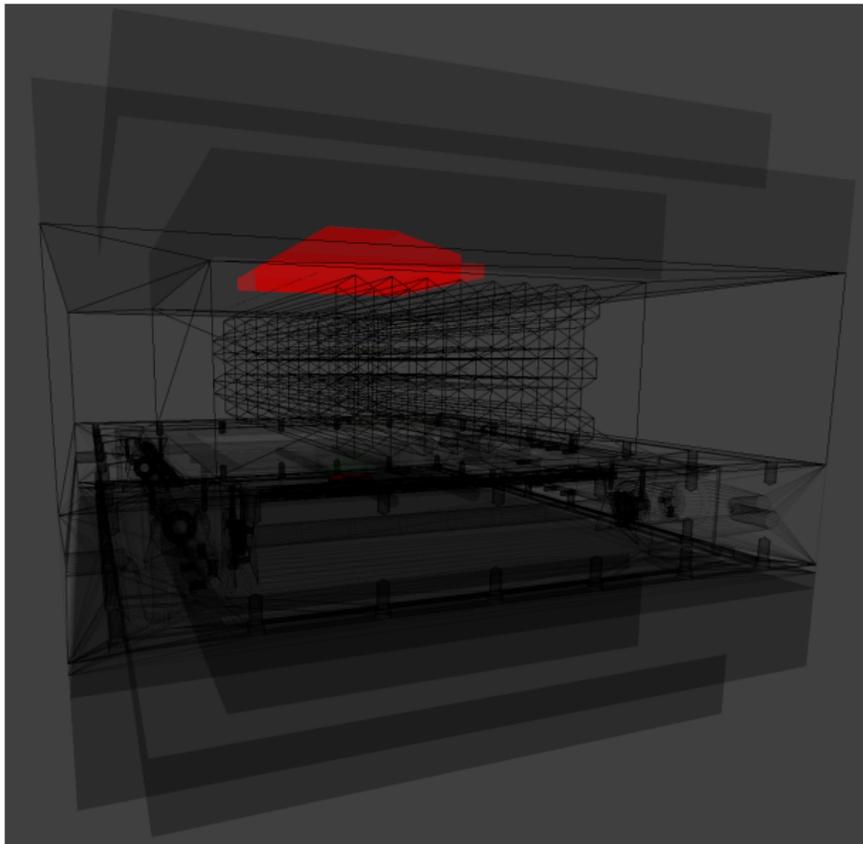


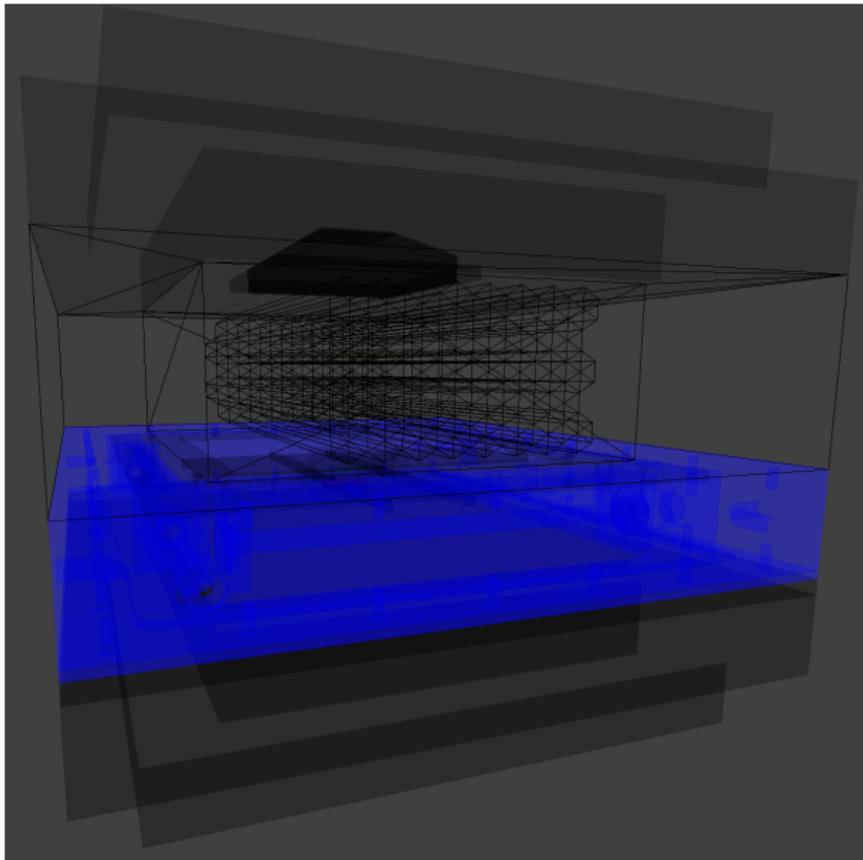
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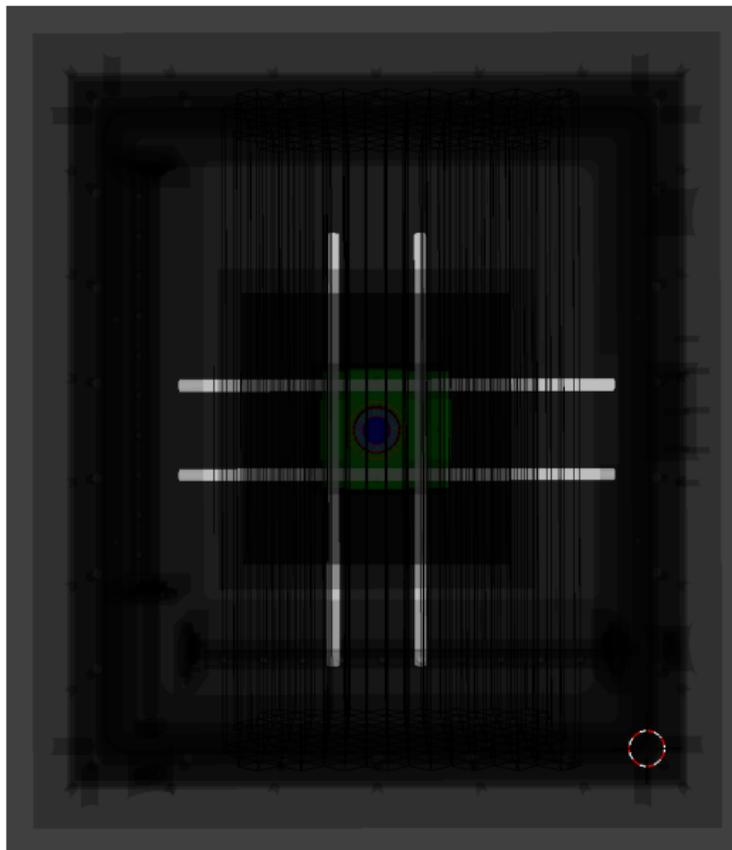
- Geant4
  - Full detector geometry
  - Particle tracking
- Garfield++
  - Ionization and electron drift
  - Signal readout

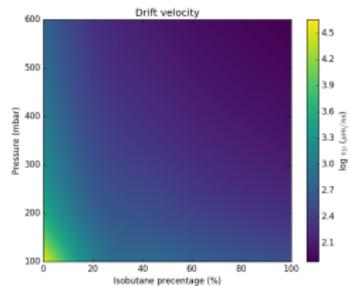
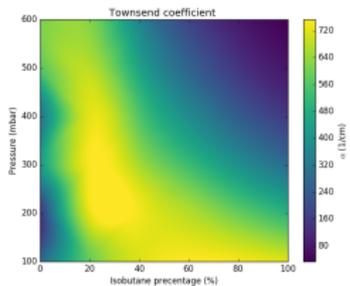
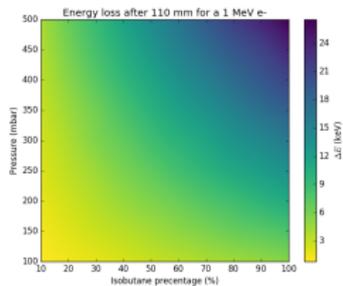
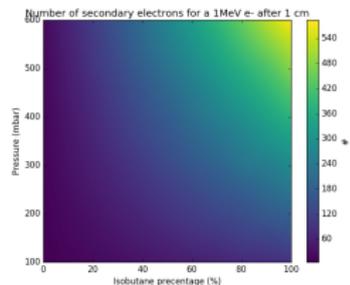
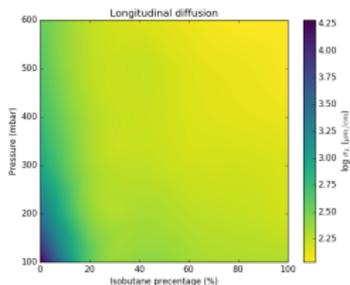
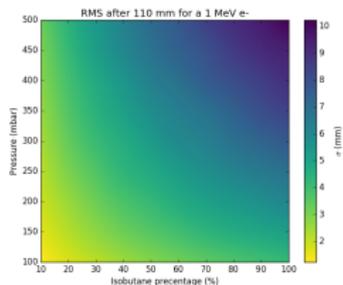
Goal: Interfacing the software packages to fully simulate real events and from that extract optimum parameters and limits on energy resolution



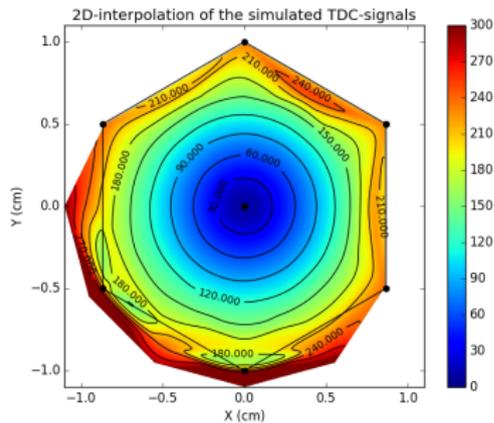
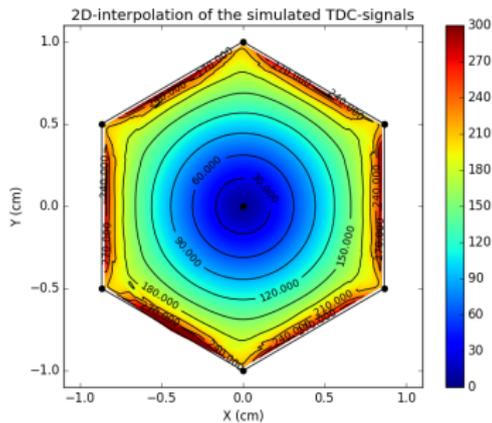




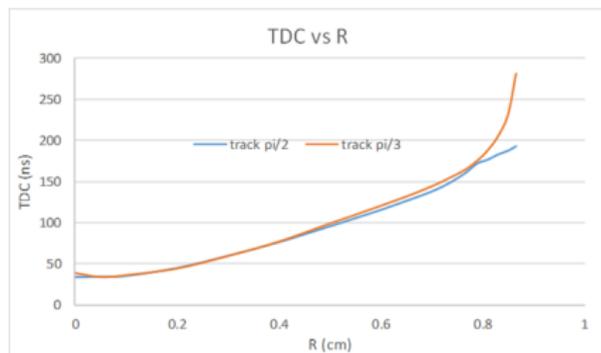
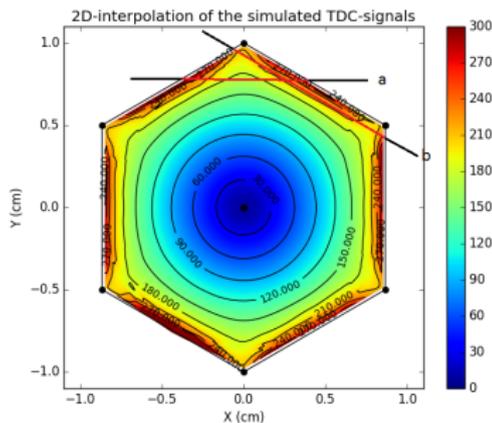




Cell asymmetry is visible in TDC contours



Zooming into TDC dependence for different angles of entering the cell  
( $P = 300$  mbar, 70% Isobutane)

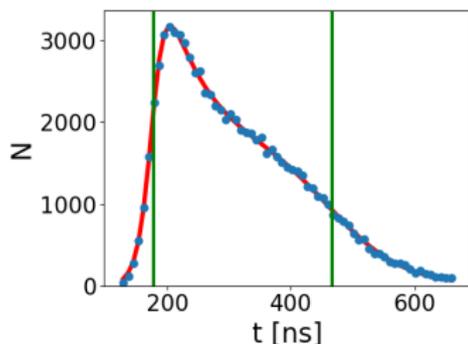


Edge of cell shows significant differences  $\rightarrow$  bad convergence for TDC versus R calibration?

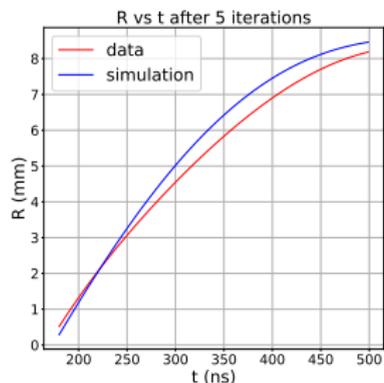
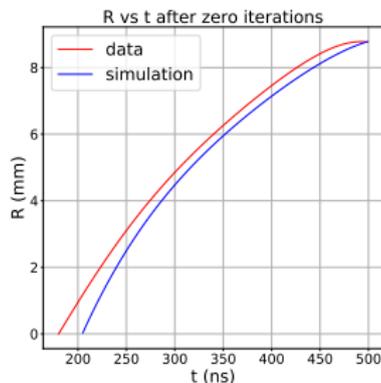
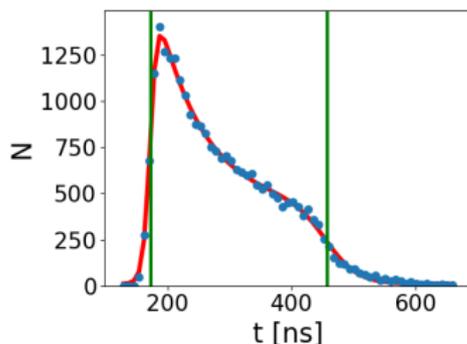
We need an interface between the particle tracking (Geant4) and ionization/electron drift (Garfield++)

- To cross-check experimental results
- To test the data analysis routines
- To scan the full parameter space for optimum with respect to energy resolution and efficiency:
  - Isobutane-helium percentage
  - gas pressure
  - wire voltages

Data



Simulation

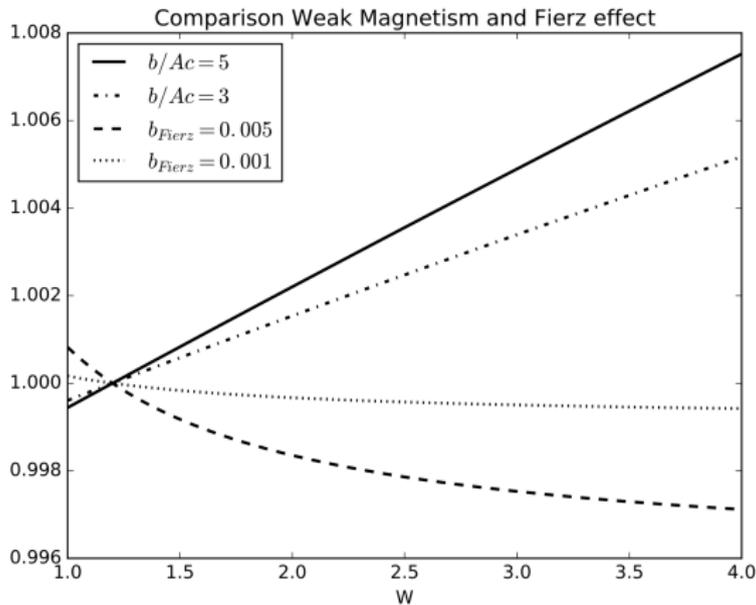


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- Find optimal parameters for detection
- Test other materials: gases, scintillators, ...
- Provide a fully functional simulation package that enables us to **benchmark experimental data**
- Measure  $\beta$ -spectrum shapes for a few sources to provide values for the **weak magnetism** form factor.

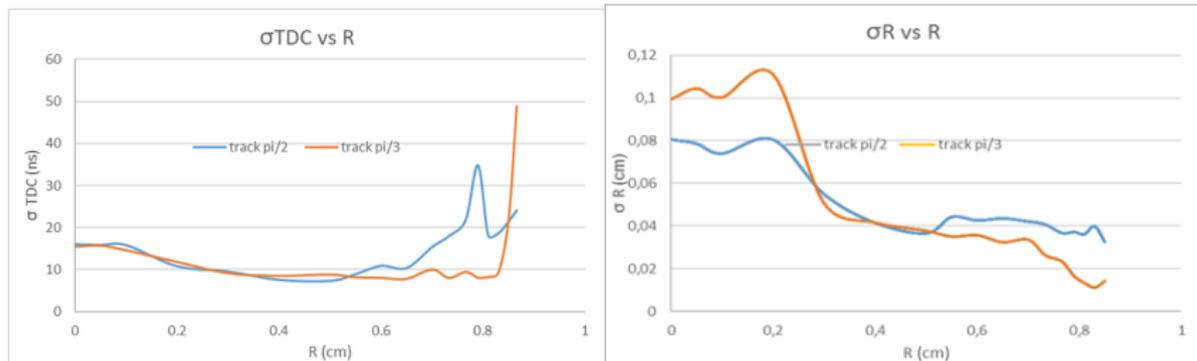
Candidate:  $^{114}\text{In} \rightarrow ^{114}\text{Sn}$ ,  $E_0 = 1.989$  MeV

Sensitivity of Fierz and Weak Magnetism to the  $\beta$ -spectrum shape

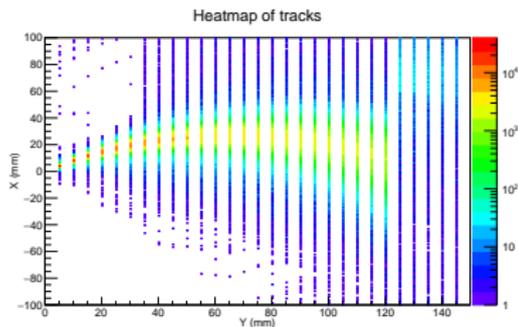


L. Hayen et al. Rev. Mod. Phys.

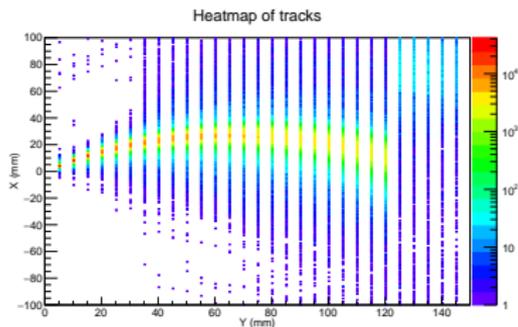
## Error propagation



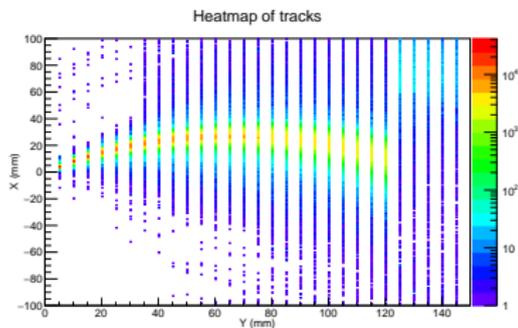
Difference in absolute  $\Delta r$ , high uncertainty close to wire due to low slope  $TDC(r)$



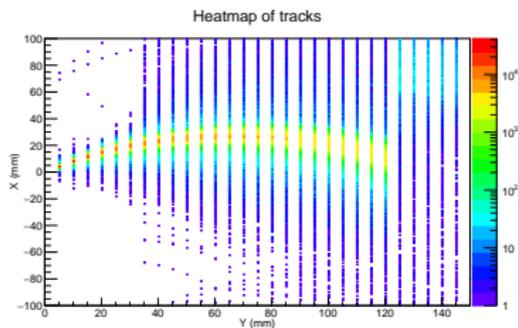
600 mbar - 90% Isobutane



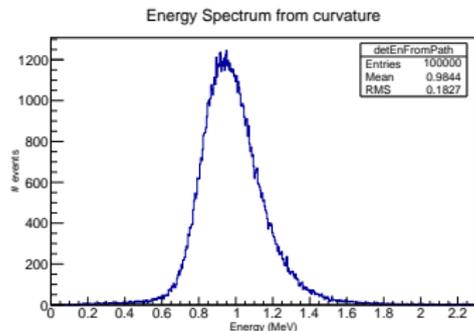
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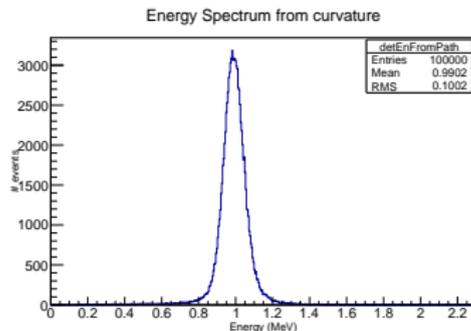
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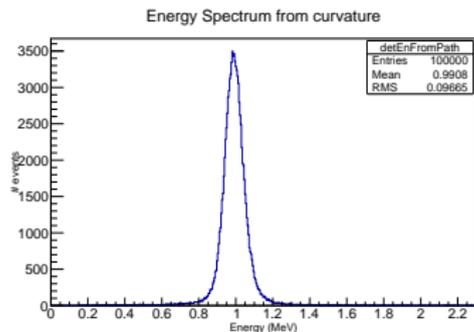
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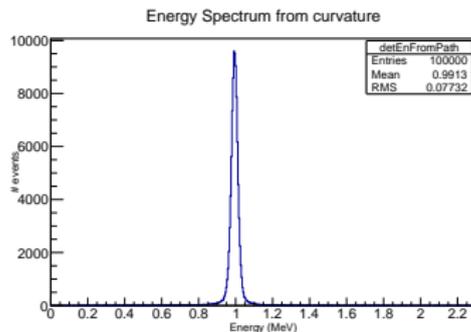
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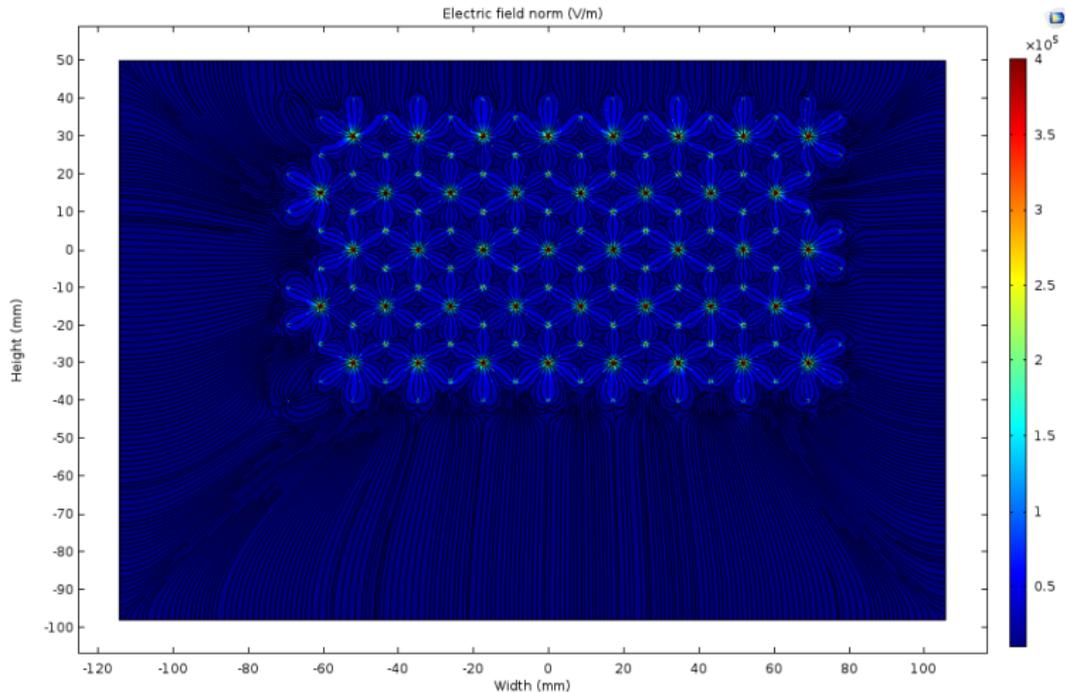
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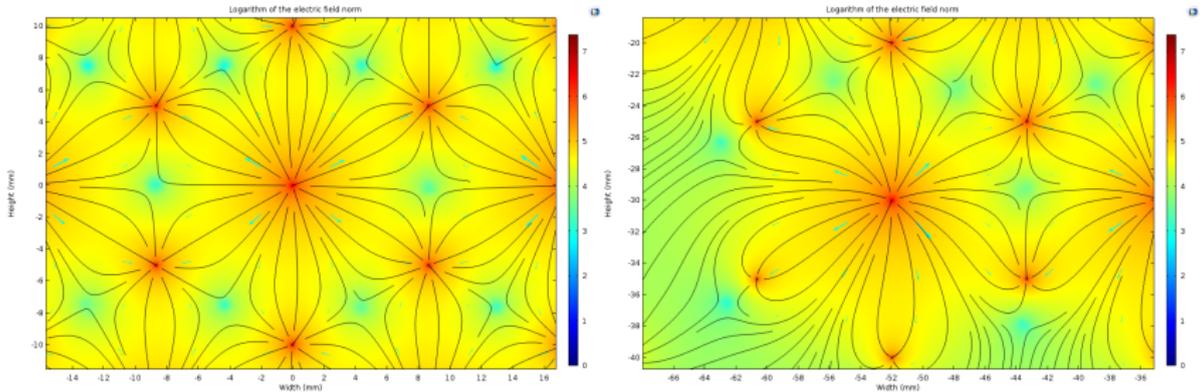


100 mbar - 10% Isobutane



Electric potential and field for a 5 by 8-configuration

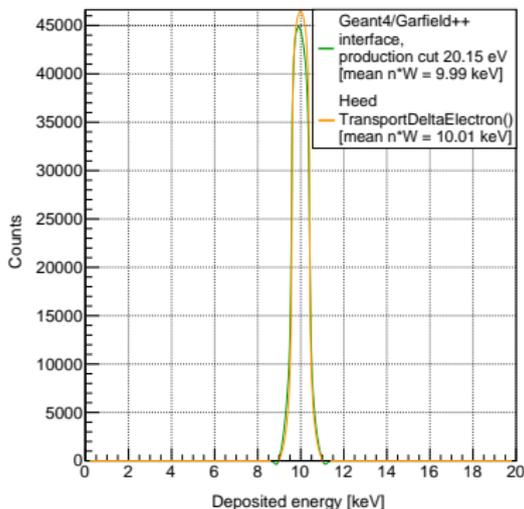
Electric field for a cell in the center versus the electric field for a cell in the corner



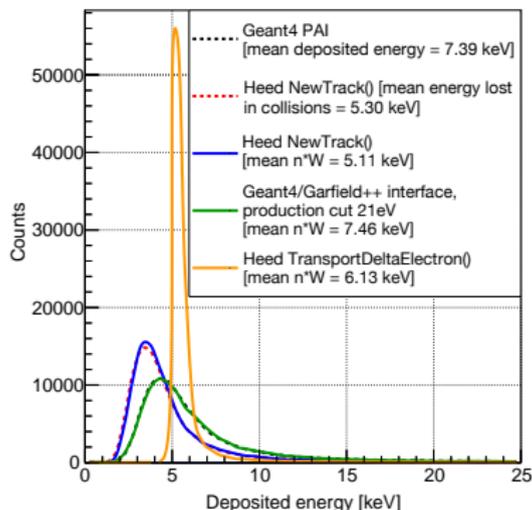
Central (left) and lower left (right) cell electric fields

Significant differences!

## W-value for low and intermediate energies

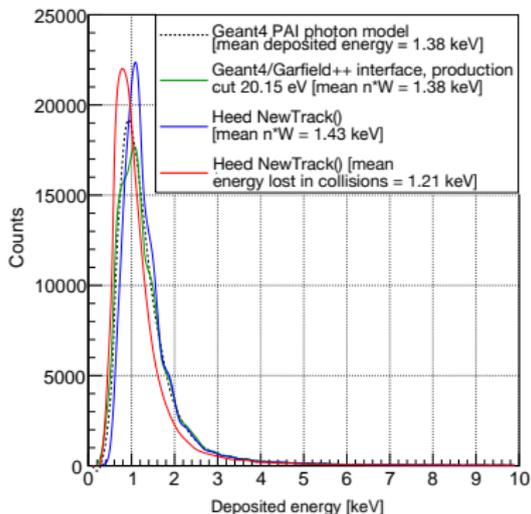


10 keV e- in He/Iso 70/30

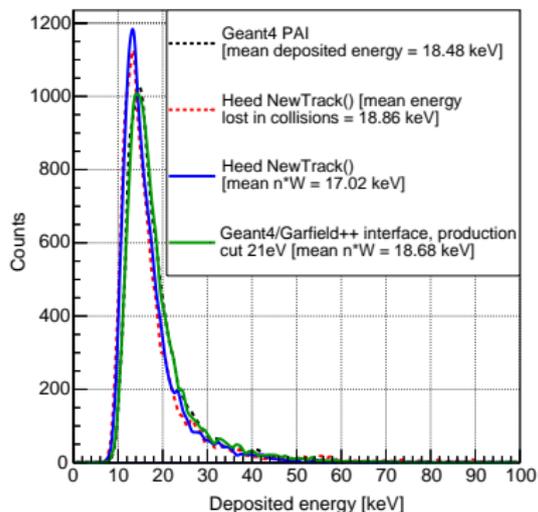


100 keV e- in Ar/CO2 70/30

## W-value for relativistic energies

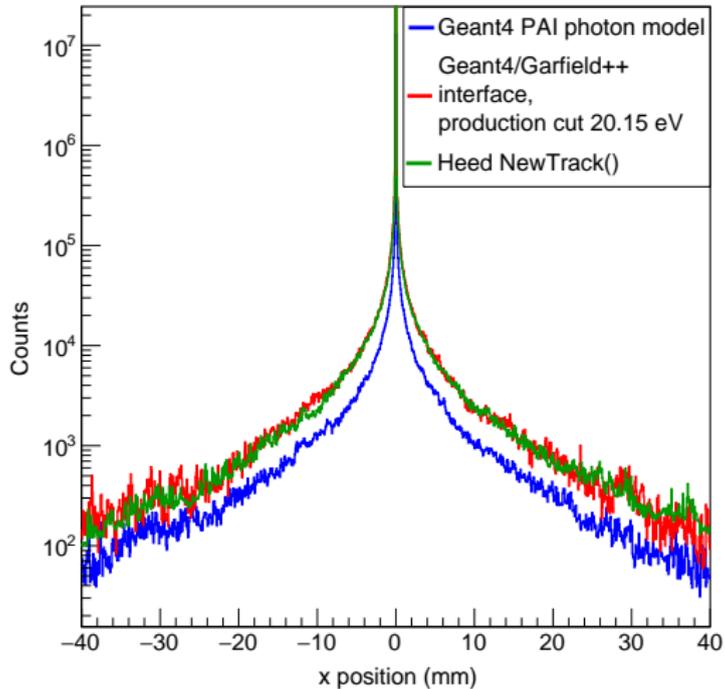


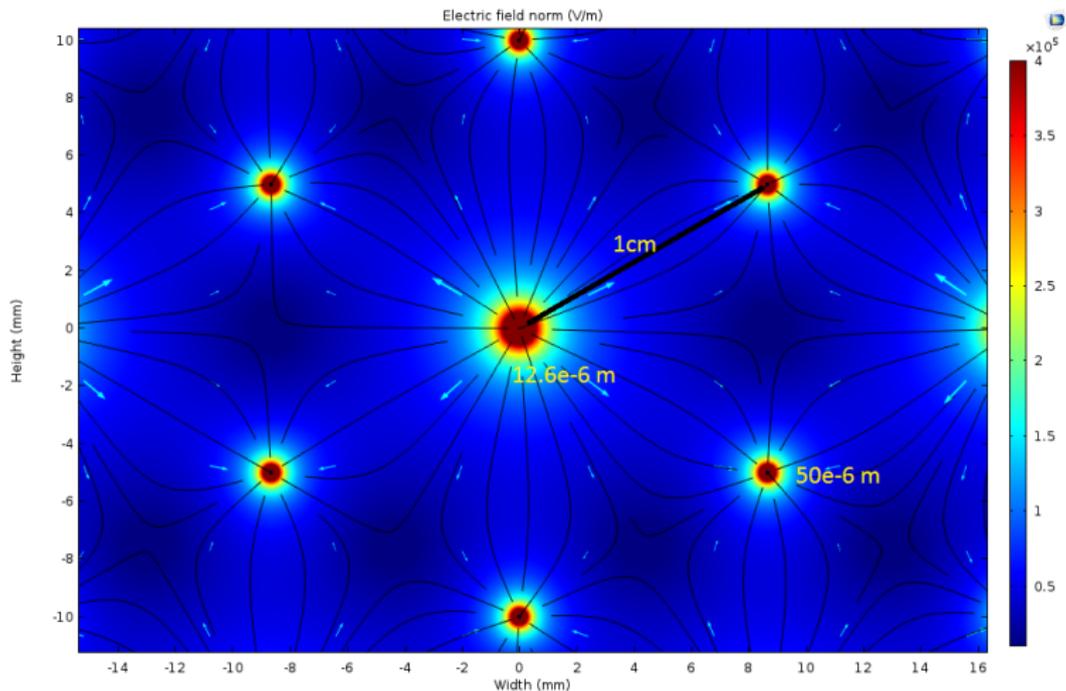
1 MeV e- in He/Iso 70/30



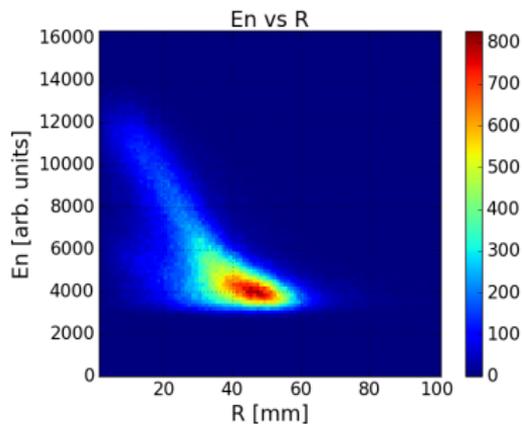
1 GeV alpha in Ar/CO2 70/30

## Spatial distribution of ionization electrons





Data



Simulation

