TRD Simulation Algorithm Review

Christoph Blume

Detector Response / Generation of Hits

- Microscopic simulation of energy loss and TR photon production
  - Generation of electron cluster (`AliTRDhit`) at

    each ionization step

    each TR photon absorbtion point
- Part of slow simulator: `AliTRDv1::StepManager()`
- Simulation of TR photons: `AliTRDsim`
  - Creation of TR photons `AliTRDsim::CreatePhotons()`
  - X–ray absorbtion cross sections `AliTRDsim::GetMuXe()`
- Hits data structure
  - Compression algorithm taken from TPC (M. Ivanov)

    `AliTRDtrackHits`

Energy Loss (i)

- Probability for primary ionization:

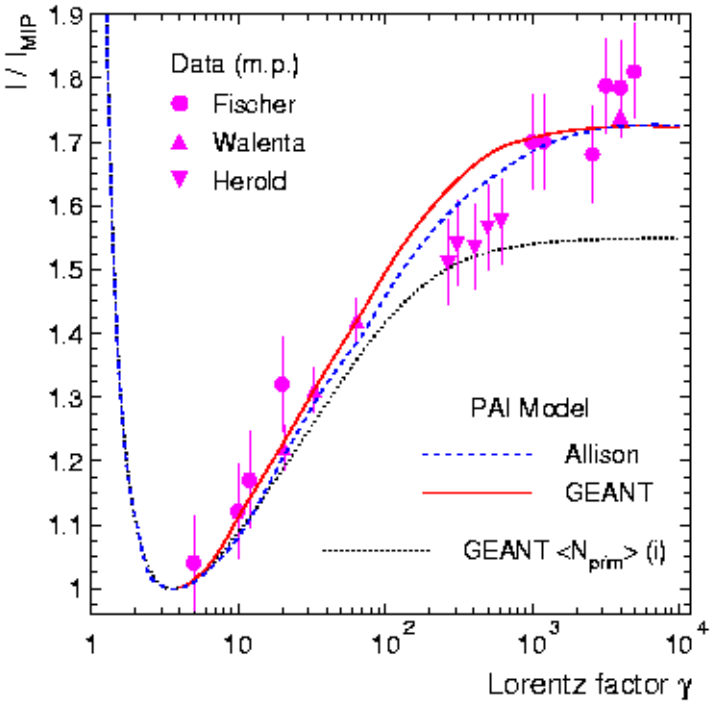
$$P(s) = \frac{1}{D} \exp\left(\frac{-s}{D}\right)$$

- Distance between primary ionizations:

$$D = \frac{1}{\langle N_{prim} \rangle f(\beta\gamma)}$$

- Parameter:

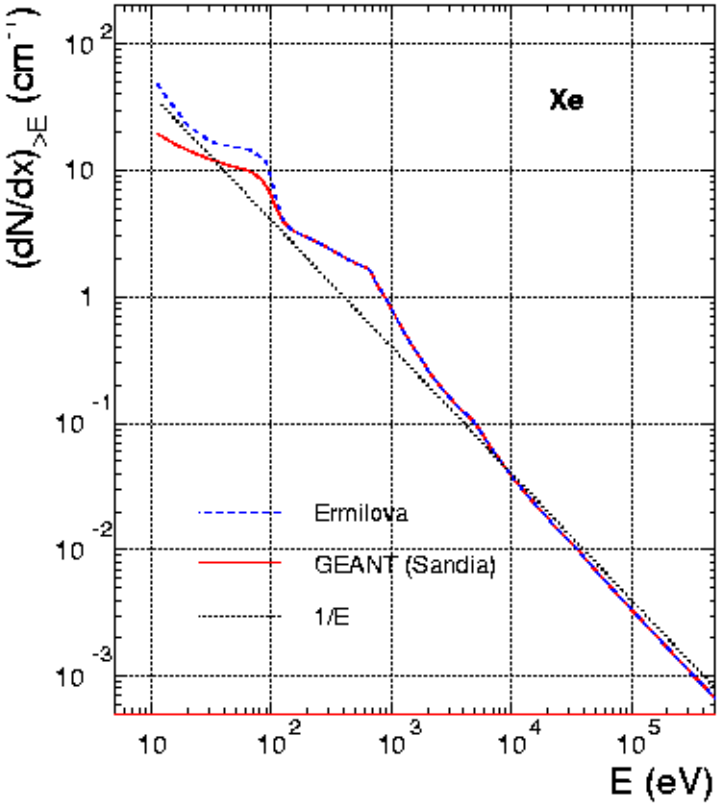
	GEANT	Sauli(1)	Ermilova(2)
$\langle N_{prim} \rangle$ (1/cm)	20.5	44.0	48.0
Fermi plateau (mean)	1.56	––	1.36



(1) F. Sauli, CERN Report 77–09 (1977)
(2) V.C. Ermilova et al., Nucl. Instr. Meth. 145 (1977) 555

Energy Loss (ii)

- Energy spectrum of δ–electrons
  - Integrated spectum
  - Ermilova, based on PAI model
  - GEANT, x–ray cross sections from Sandia
  - Standard: 1/*E*
- First ionization potential for Xe: I_{pot} = 12.1 eV
- δ–rays from GEANT above 10 keV
- "Worst case scenario"
  - GEANT Fermi plateau + Ermilova spectrum
  - High ionization worsens PID capabilities
  - MIP: 280 e^-/cm



$$N_{tot} = \frac{E - I_{pot}}{W}, \quad W \simeq 22\,eV$$

Transition Radiation (i)

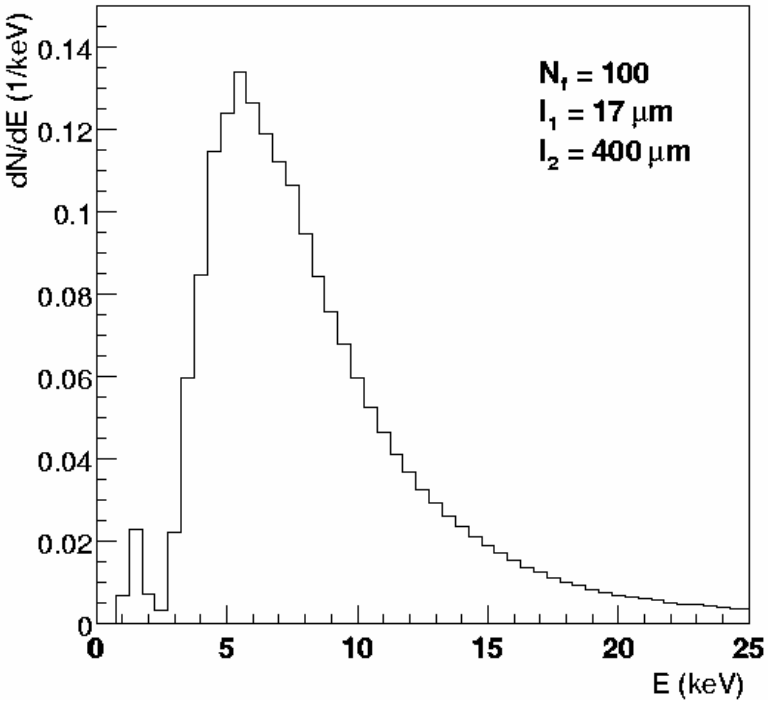
- Not included in GEANT 3.21
- Analytical description for regular foil stack

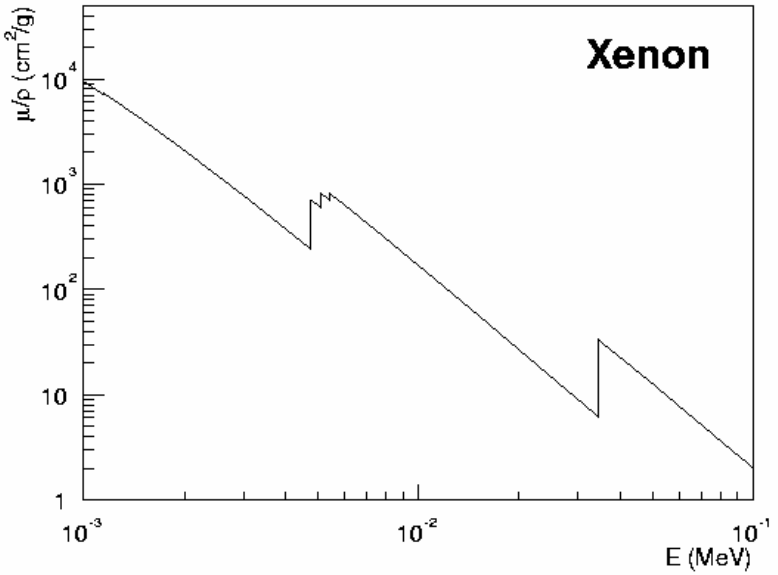
$$\frac{dW}{d\omega}=\frac{4\alpha}{\sigma(\kappa+1)}(1-\exp(-N_f\sigma))\ \times\ \sum_{n=1}^{\infty}\theta_n\left(\frac{1}{\rho_1+\theta_n}-\frac{1}{\rho_2+\theta_n}\right)^2[1-\cos(\rho_1+\theta_n)]$$

$$\rho_i=\omega l_i/2c(\gamma^{-2}+\xi_1^2),\ \ \kappa=l_2/l_1,\ \ \theta_n=\frac{2\pi n-(\rho_1+\kappa\rho_2)}{1+\kappa}>0$$

C.Fabjan et W. Struczinski

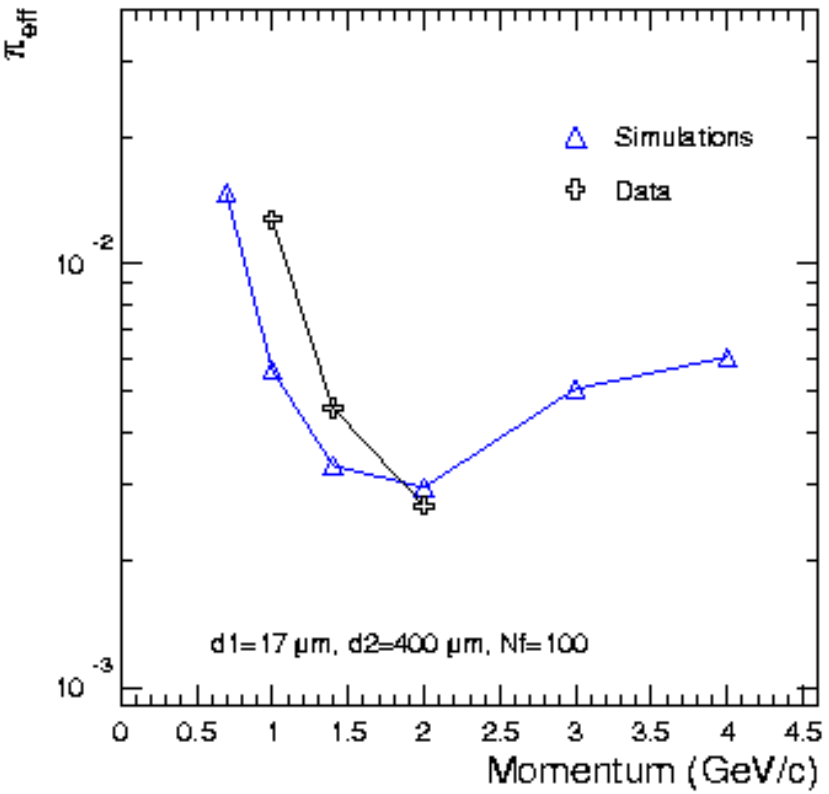
- Tune parameter to match test beam data
- Procedure:
  - Generate TR photon at entrance window for each entering electron
  - Determine absorbtion position by:
    - mass attenuation coefficient μ/ρ
    - direction of incoming particle





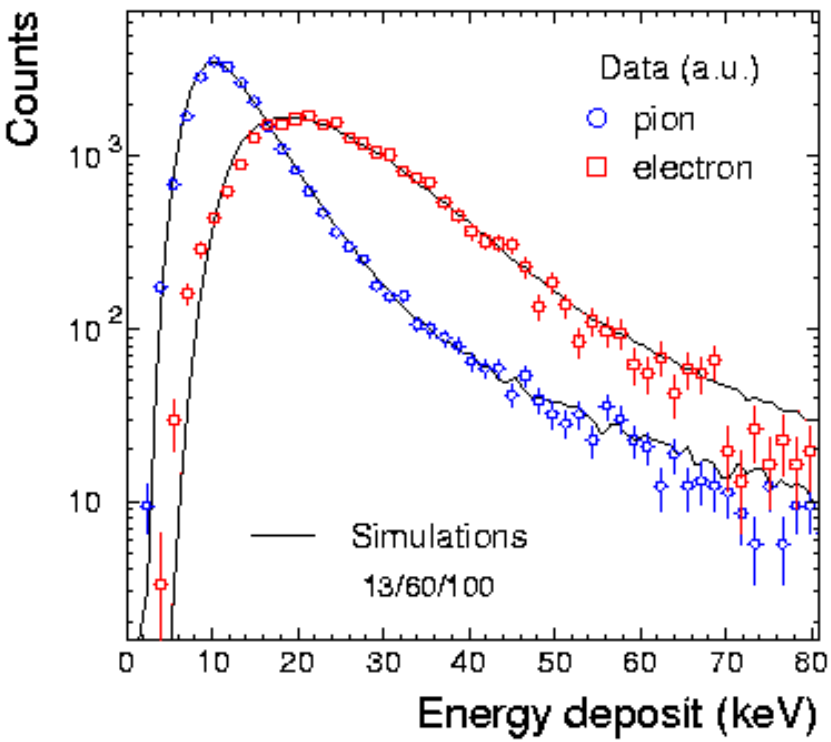
Transition Radiation (ii)

- Parameters tuned to p = 2 GeV/c
- <u>But:</u> No way to get the correct momentum dependence with a unique set of parameter
- Deterioration for of pion efficiency for high momentum ?
- Need for detailed TR simulation ?
  - TR photon generation and tracking in Geant ?
  - Typical energy 5–10 keV
  - Emission angle very narrow (1/γ)
  - Difficulty is rather to model spectrum at different momenta



Transition Radiation (iii)

- Very good agreement of simulation to test beam data for fixed momentum!
- Stand–alone simulation, but same algorithm than implemented in AliRoot



Signal Generation (Digitizer)

- `AliTRDdigitizer`
- Included Effects:
  - Diffusion
  - E x B
  - Gas gain fluctuations
  - Time response
  - Pad response
  - Cross talk
  - Electronics noise
  - Digital filter
- Procedure:
  - Follow each electron of hits along drift
  - Add up the signals induced on a given pad
  - Merging / digitization / noise
- `AliTRDparameter`
  - Contains all digitzation parameter
  - Simulation independent of geometry

Digits Data Structure

- TRD digits object `AliTRDdigit`

  `fAmp, fId`

  `fRow, fCol, fTime`

- Data is stored in arrays
  - Based on TPC design (M. Ivanov)

    `AliTRDsegmentArray`

    `AliTRDdataArray`

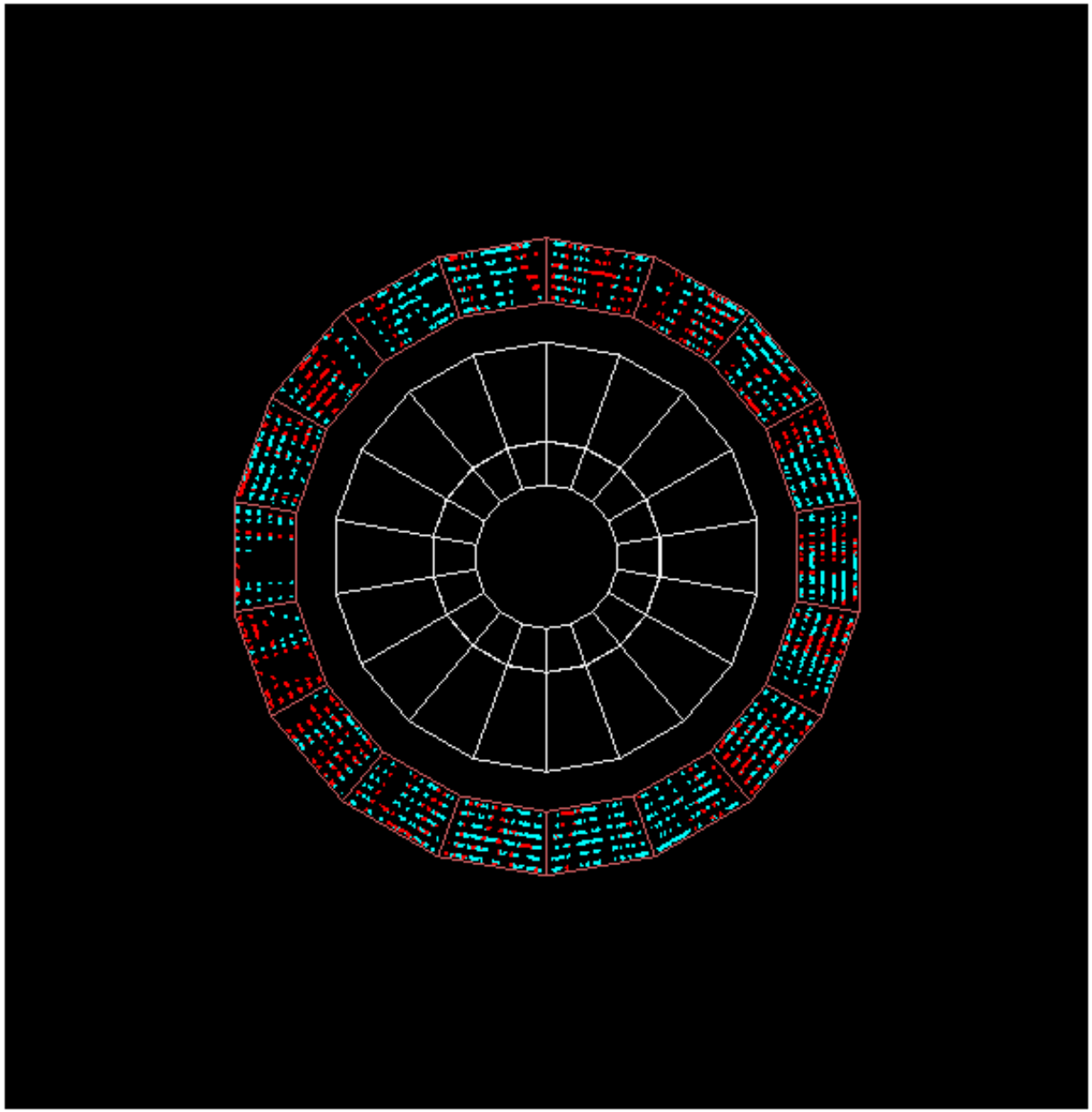
- Manager class
  - I/O of digits
  - Handling of track dictionary

    `AliTRDdigitsManager`

Digitization

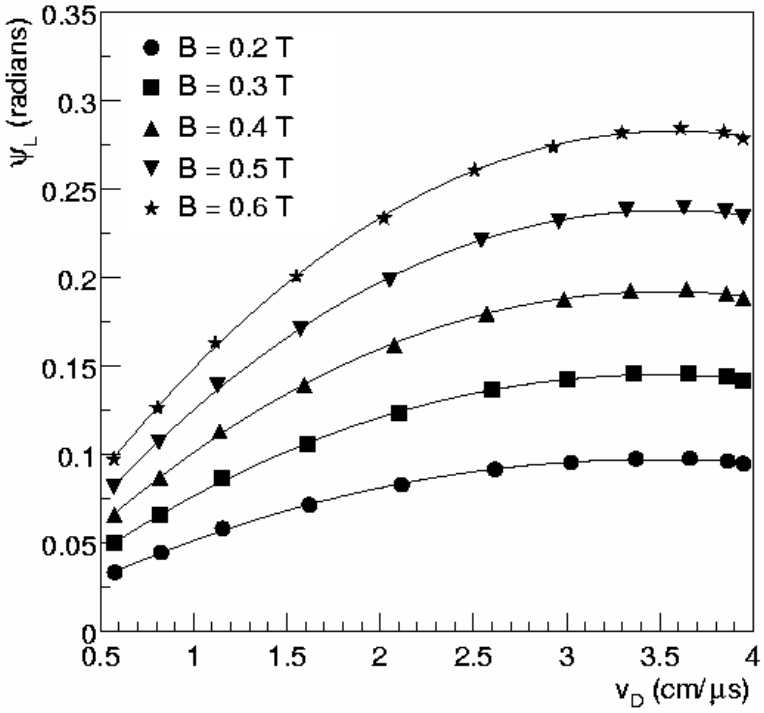
- Display of two merged events

  `AliTRDdisplayDigits3D.C`



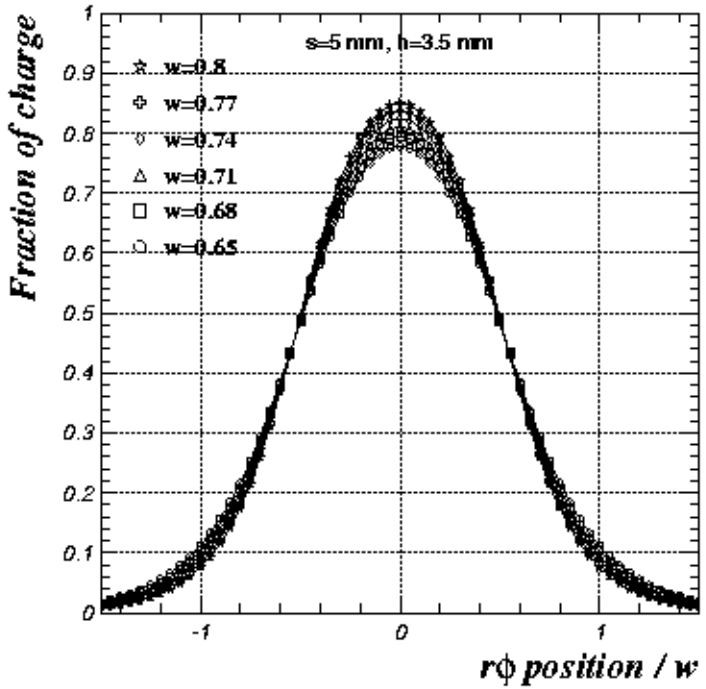
Diffusion + ExB

- Diffusion coefficients + Lorentz angle Ψ_L
  - Depend on drift velocity v_D and B–field strength
  - AliRoot implementation uses parametrization of dependency
  - Based on Garfield calculations

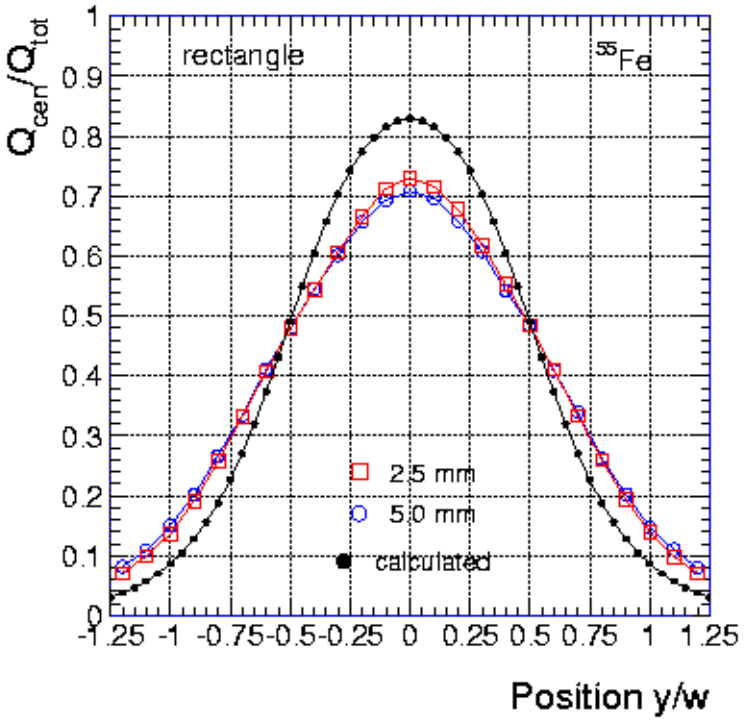


Pad Response Function

- Mathieson formalism
  - 1–dimensional (inside a pad–row)
  - Depends on detector plane (different pad widths)

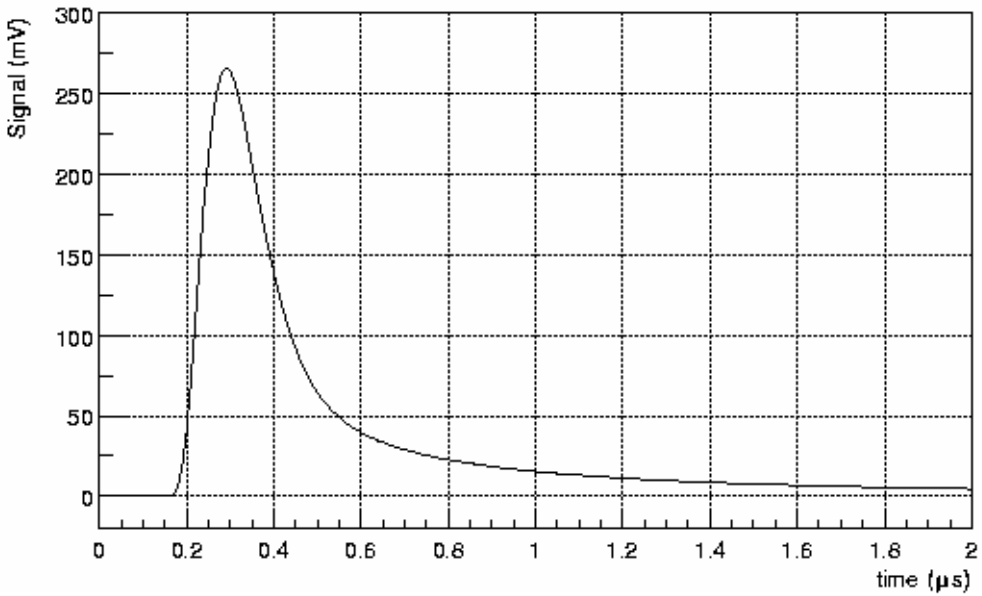


- Comparison to measurement with ^{55}Fe source
  - Cross talk



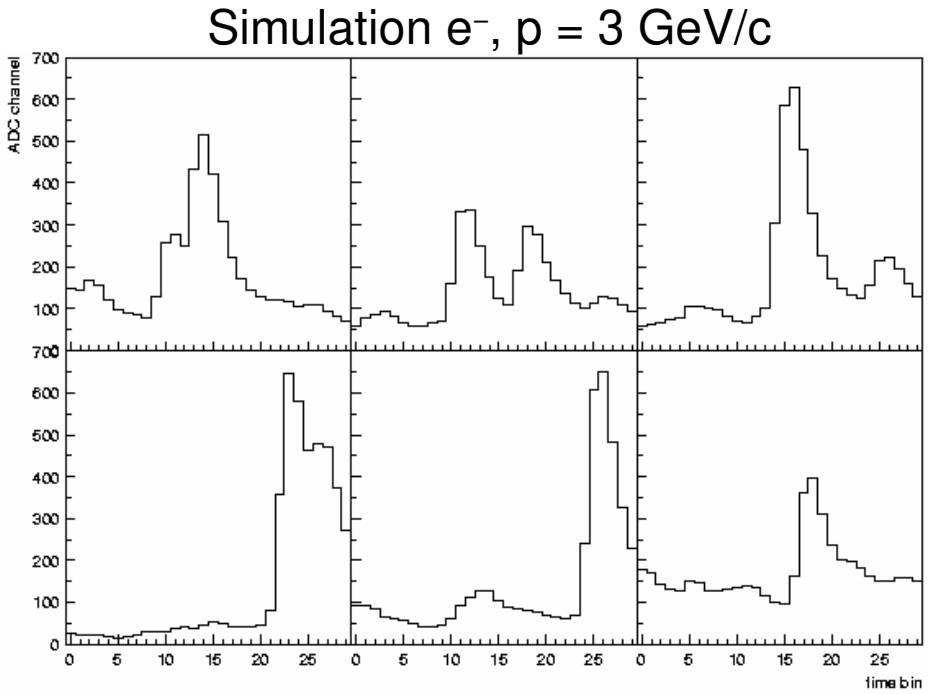
Time Response

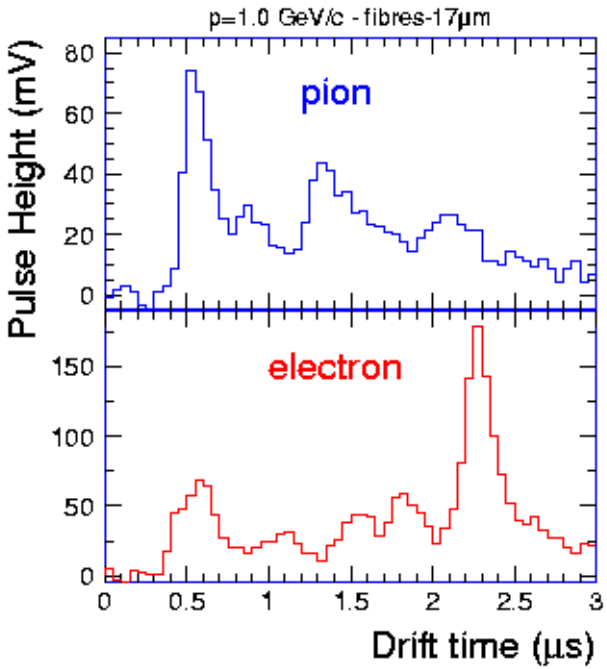
- TRF determined by:
  - Slow drift of Xe ions
  - Non–isochronity of the electron drift
  - PASA response
- Simulated with Cadence and Garfield
- Assumed ratio of integrated charge to input signal: 0.4



Time Response (ii)

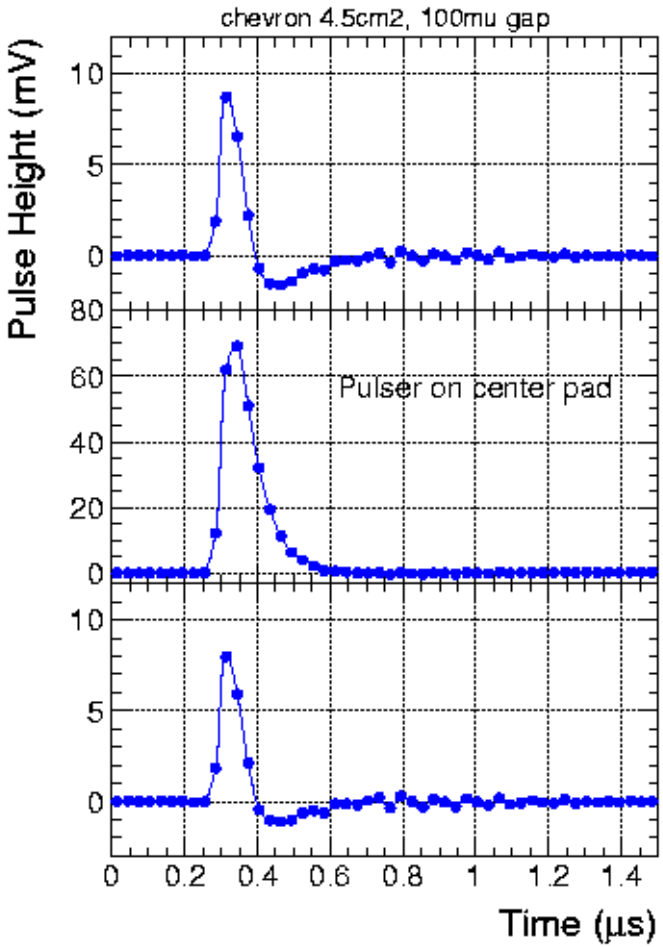
- Long tails in signal distribution
- Introduction of digital filter
  - 2 exponential filter
  - In TRD digitization included
  - Same as in FEE





Cross Talk

- Measured effect 4% (integrated over 1μs)
- Now included in digitzation
- Taken from Cadence simulation
  - pad ground capacitance: 25 pF
  - pad pad capacitance: 6 pF
  - scaled to match data



Other Digitization Parameter

- Gas gain fluctuations:

  $\bar{q} = 4.5 \cdot 10^3$

  $$P(q) = \frac{1}{\bar{q}} \exp\left(-\frac{q}{\bar{q}}\right)$$

- Electronics noise

  1000 e^-

- Conversion gain

  12.4 mV/fC

- Drift velocity

  v_D = 1.5 cm/µs

- ADC range

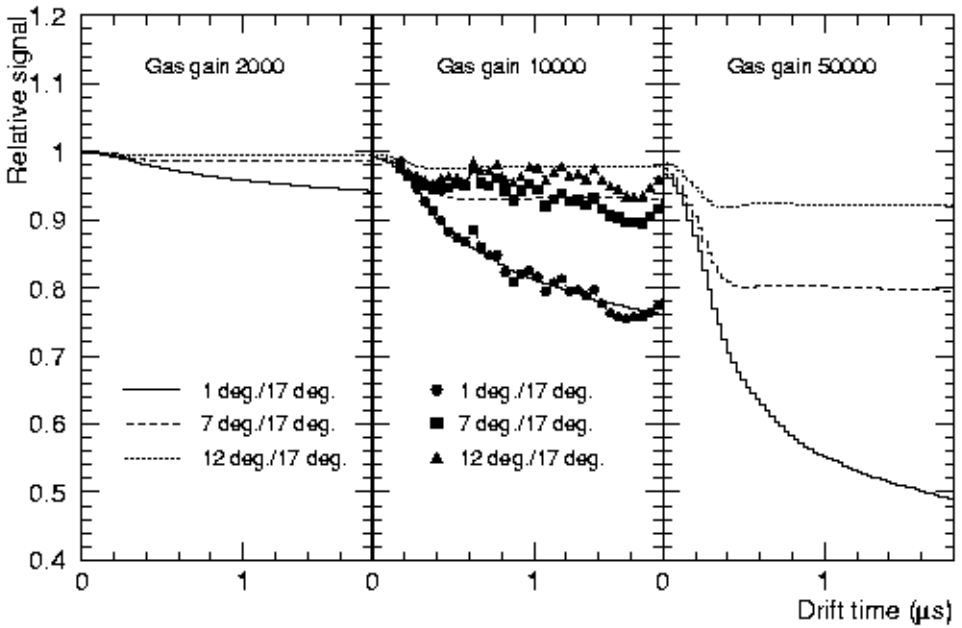
  1V

- ADC resolution

  10 bit

Saturation

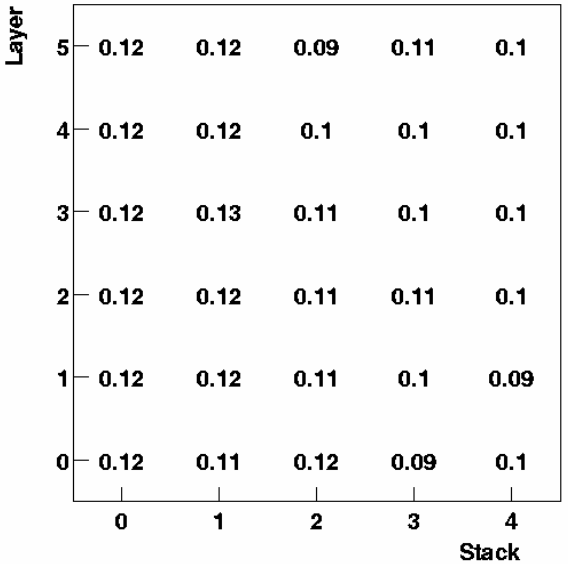
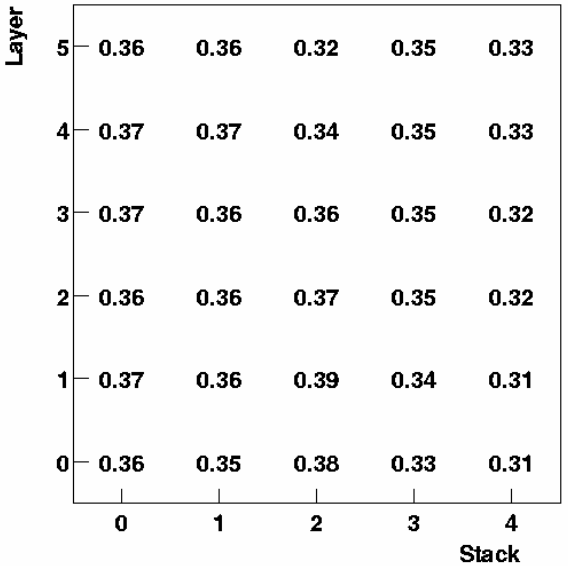
- Saturation effects
  - Seen in test beam data
  - Can be nicely described
  - Depends on incidence angle and gas gain
- Not implemented in AliRoot



Occupancy

- TRD occupancy using parametrized HIJING

  $dN_{ch}/dy = 2000$ (upper)

  $dN_{ch}/dy = 8000$ (lower)

- Maximum ≈ 40%
- Effect of very inclined and/or highly ionizing particles?