FOLLOW-UP ON THE SDHCAL DIGITIZER

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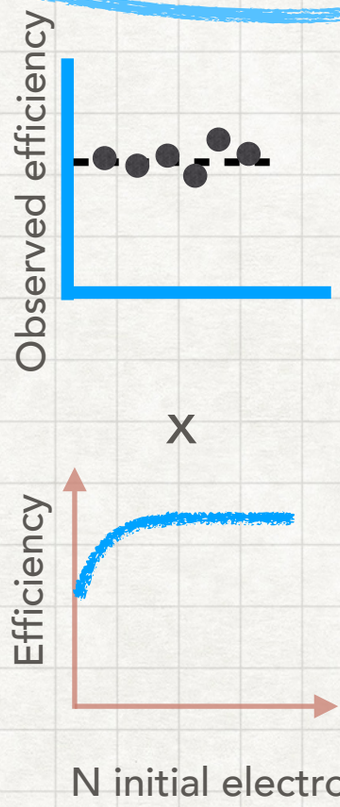
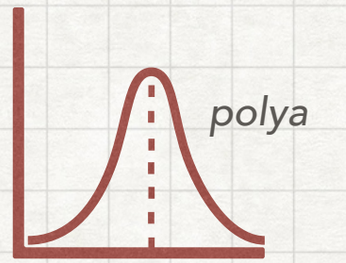
UPDATE OF THE DIGITISER

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads

G4 Step preselection

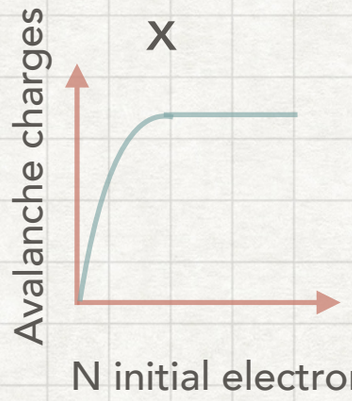
x

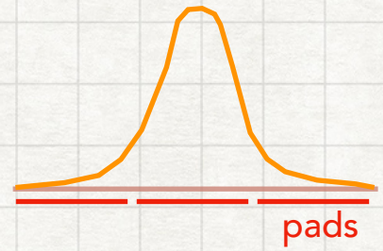




Observed charges

x





charges distributed to pads

Geant4
(event by event)
steps + Ne

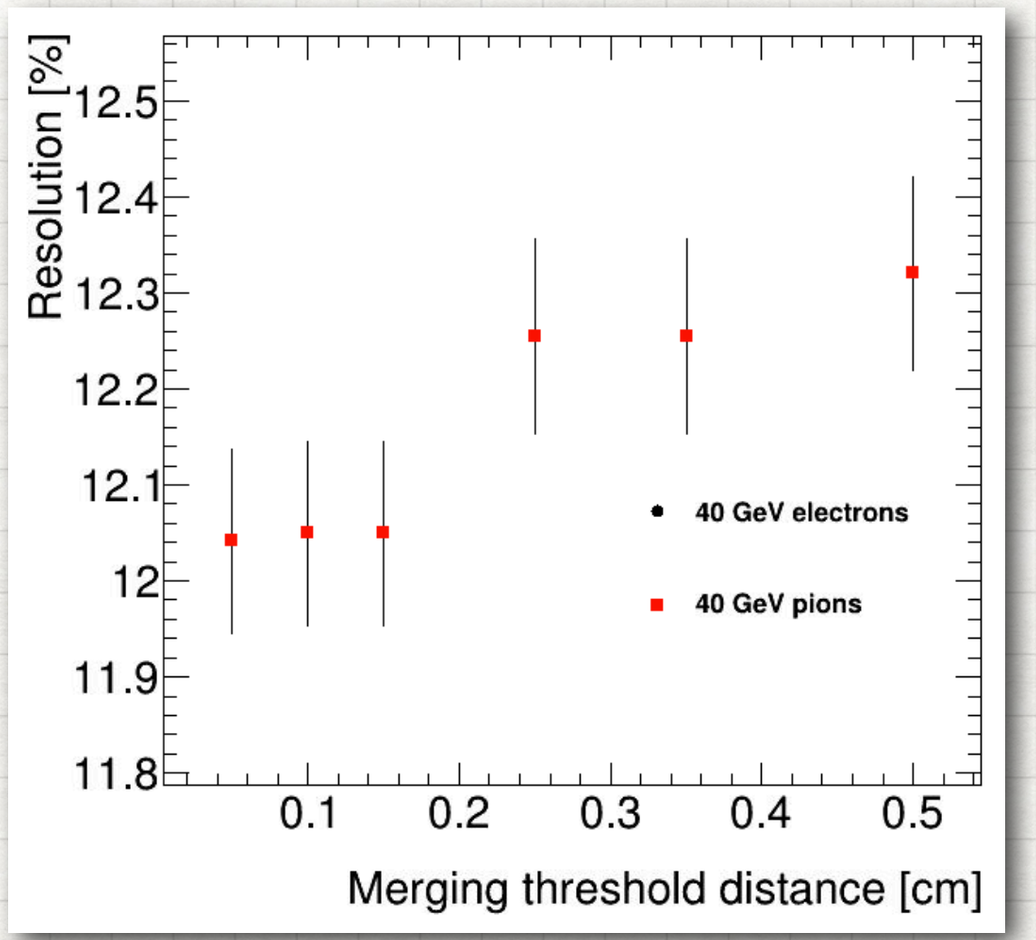
Analytic

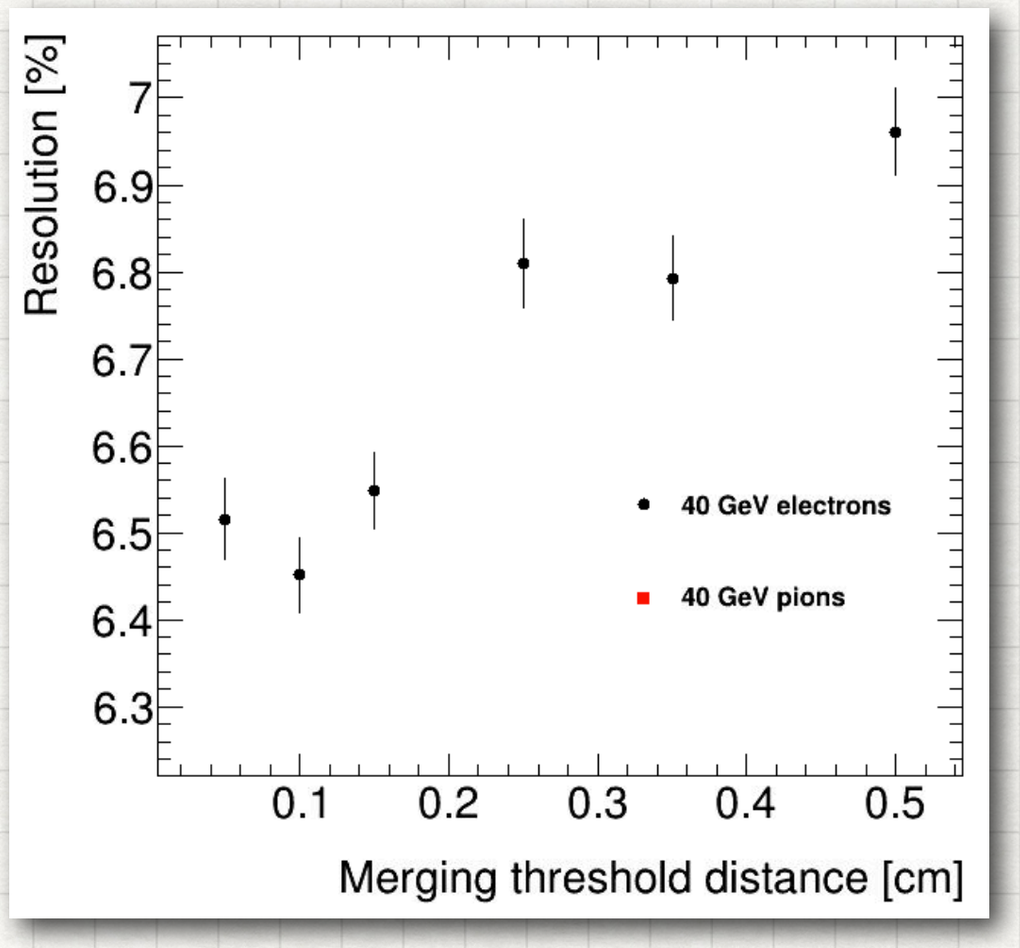
Test Beam analysis using 100 GeV μ
efficiency, amplitude (ASIC, step angle)
x correction from avalanche simulation

- Aim of the study is to review the impact of each step of the digitisation
- Process several simulations of electrons and pions with different digitisations
- Find a figure of merit:
    - Ideally data/simulation comparison
        - energy resolution, linearity, efficiency, …
        - requires to re-derive the polya param & efficiencies
        - ongoing with Guillaume's instructions
    - Today
        - use the energy resolution with a digital configuration

- Producing simulations of 10k e^- and 10k π^- with scan of:
    - step overlap removal **done**
    - avalanche correction **done**
    - charge spread **jobs are running**

STEP OVERLAP SUPPRESSION



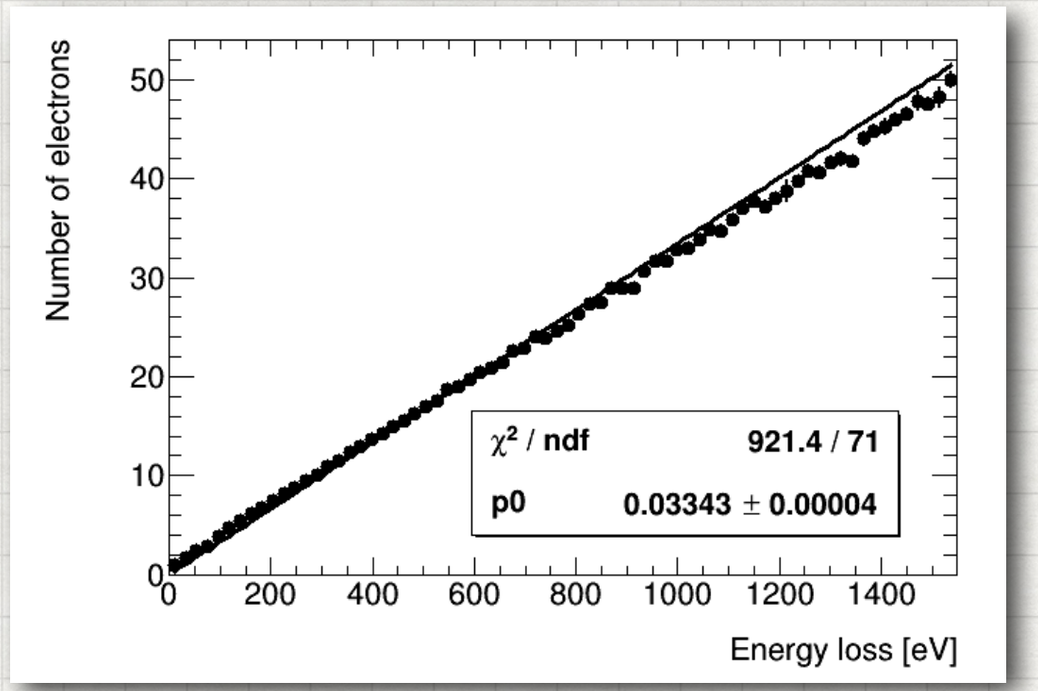


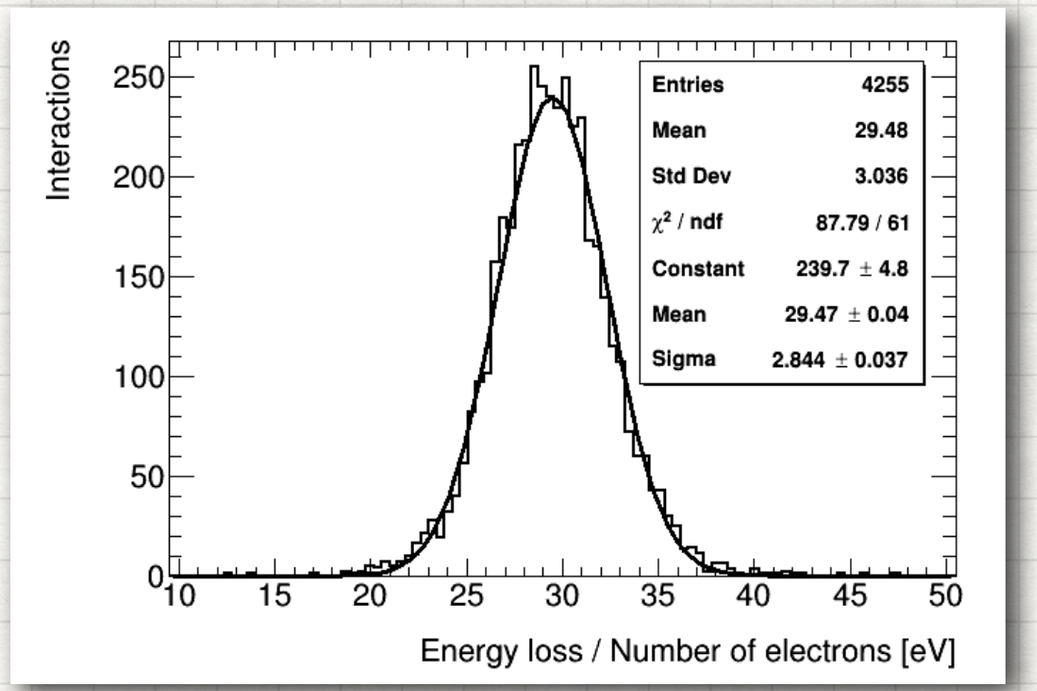
- Overall impact on the resolution is ~0.4%
- If two steps that are too close one of them is suppressed
- Threshold in distance is used
- Impact of this threshold is more important in relative on electrons
- Option of merging the step initial charges (instead of killing the step) not implemented

INITIALIZATION OF THE AVALANCHE

NUMBER OF ELECTRONS VERSUS ENERGY LOSS

- Geant 4 provides only energy loss per step → use of Heed to get the relation between energy loss and number of ionisations

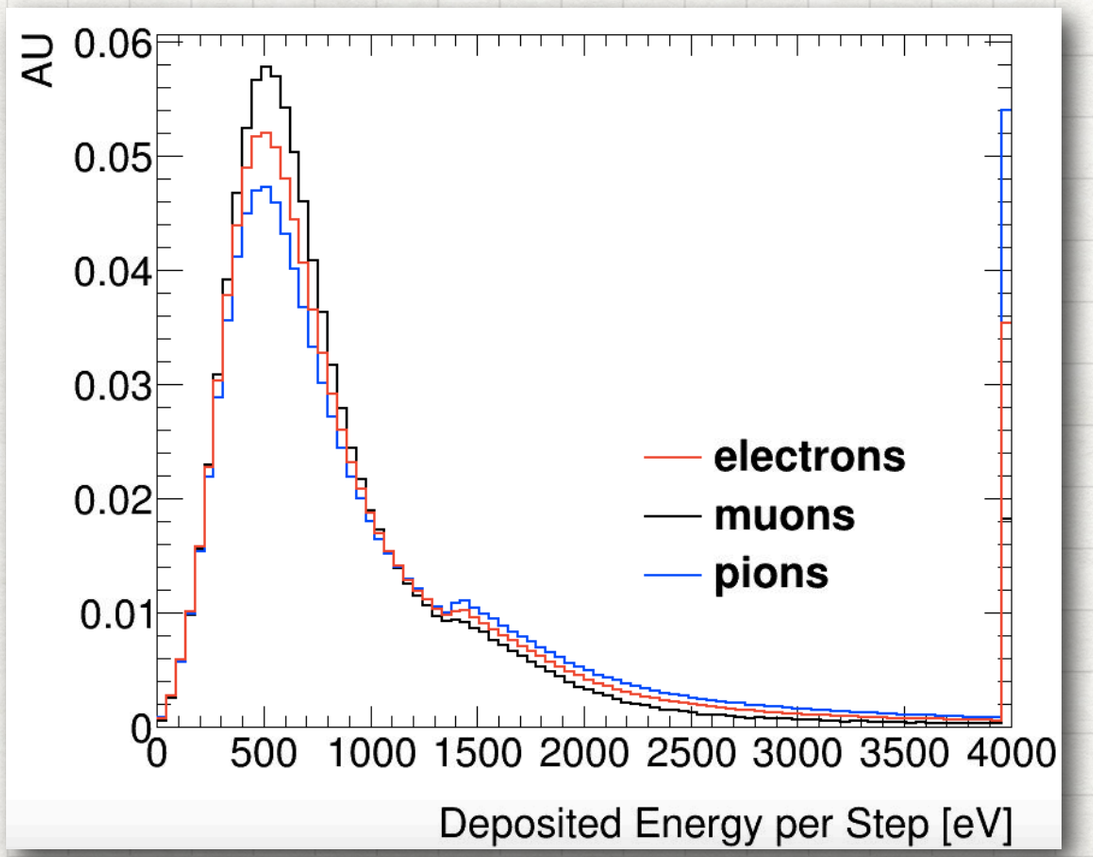




- In average, 1 ionisation electron created for each 29.7 eV loss
  - This energy fluctuates (fluctuation of ionisation/non ionisation fractions, …)
  - Energy ~stable w.r.t to small changes of the fractions of SF6, C2F4H2, CO2

AVALANCHE CORRECTION

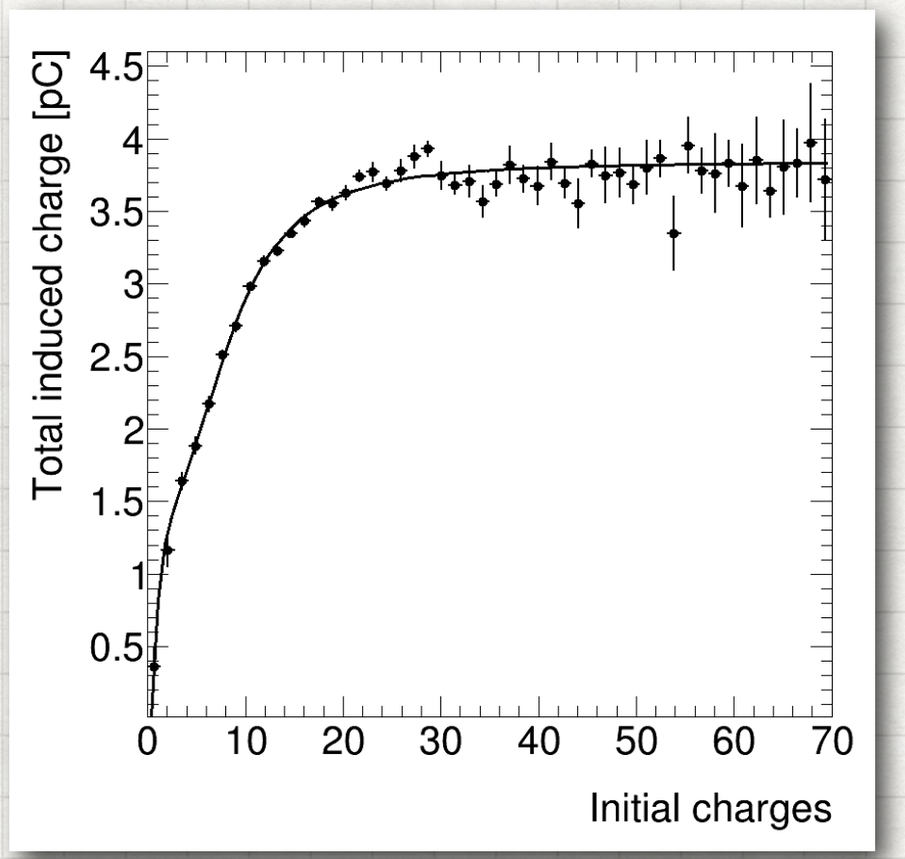
Geant 4 output (step by step)



Heed

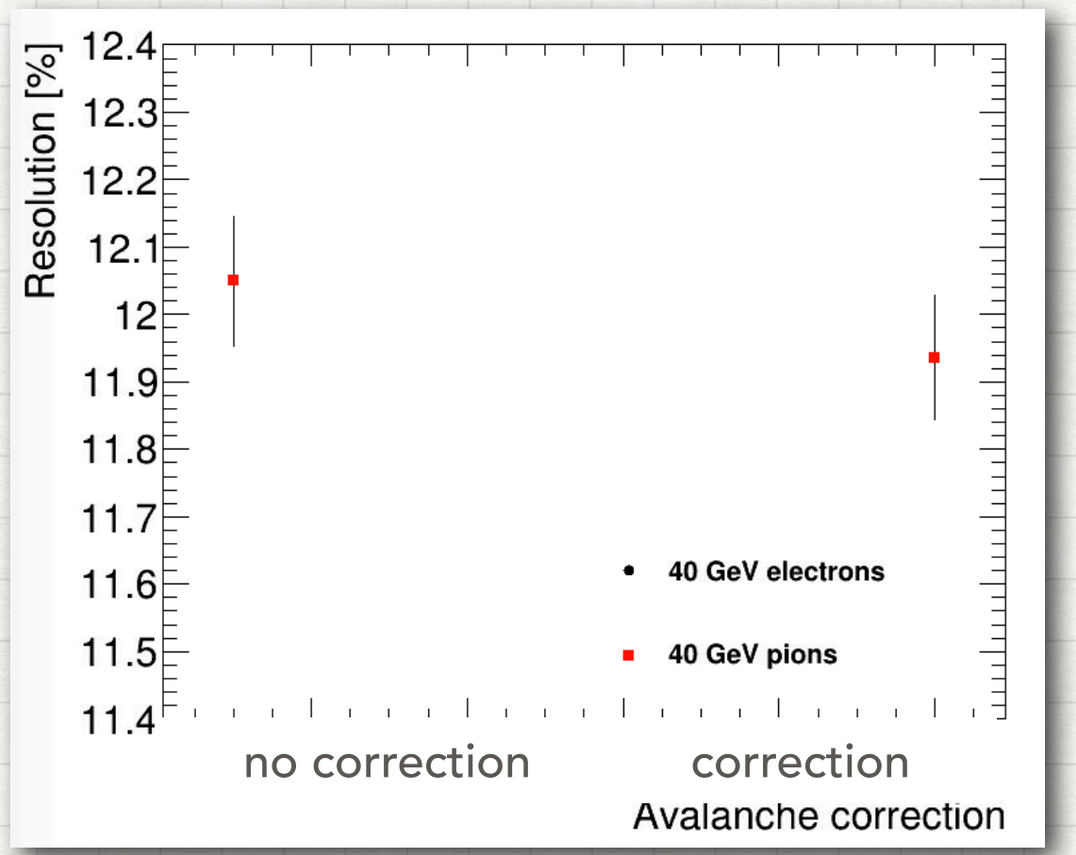
/ 29.7 x

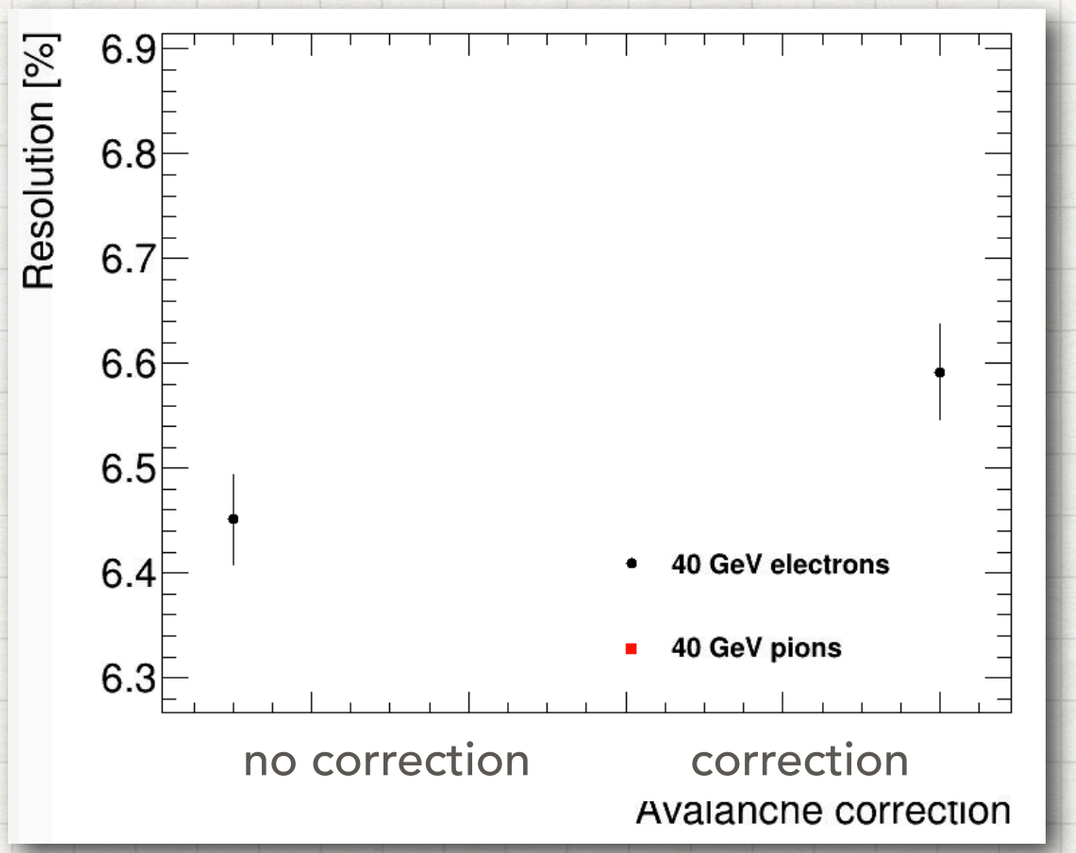
Avalanche modeling



0 energy steps removed from this plot

AVALANCHE CORRECTION





- Overall impact on the resolution is ~0.2%
- Opposite effect on electrons and muons
- Impact on the efficiency (as steps with small energy deposits are killed) to be checked too

BACKUP

DIGITISATION STEPS

- Digitisation is an important step of the simulation
- It converts Geant 4 inputs into hits: the striating point is a charged particle that deposits energy in the chamber of the RPC
- It describes many effects

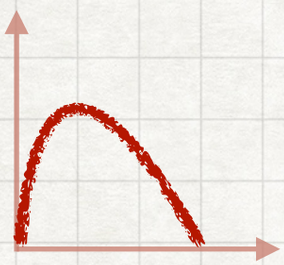
Particle Type/$\beta\gamma$/angle

eg. e^-, μ, π

ionisation →

Initial Charges

eg. ~1-40 electrons
~1-20 clusters

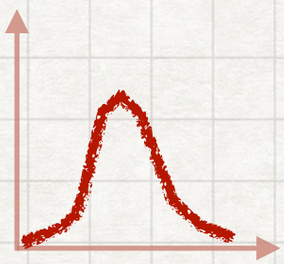


N initial electrons

avalanche →

Charges

eg. 10^8 electrons
or 0 if avalanche dies

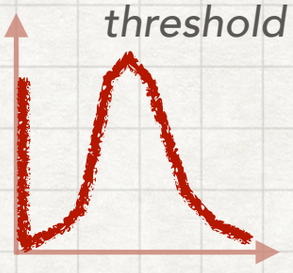


Avalanche charges

induction, threshold →

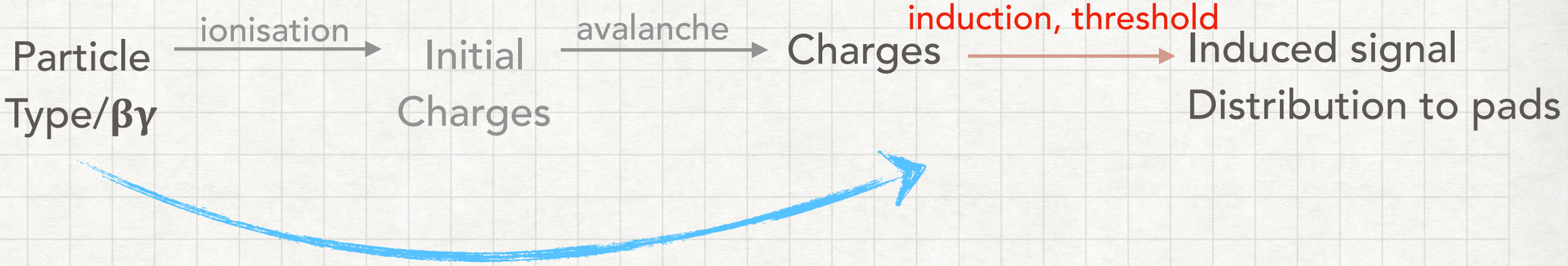
Induced signal Efficiency

eg. 4 pC
efficiency to pass first threshold



Induced signal and efficiency

CURRENT IMPLEMENTATION OF THE DIGITIZER



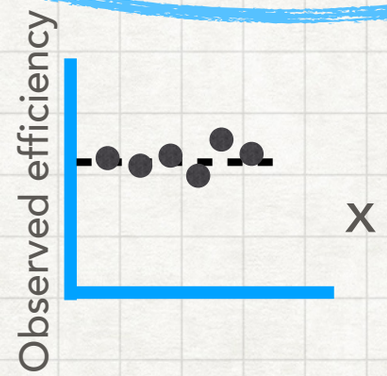
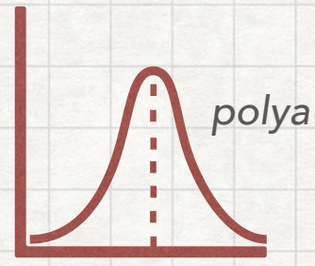
G4 Step preselection

Geant4 (event by event)

- Steps that are too close to another removed keeping leading one
- G4 Threshold
- Each step that passes an efficiency will lead to an avalanche
- binary output: avalanche or no avalanche

CURRENT IMPLEMENTATION OF THE DIGITIZER

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads

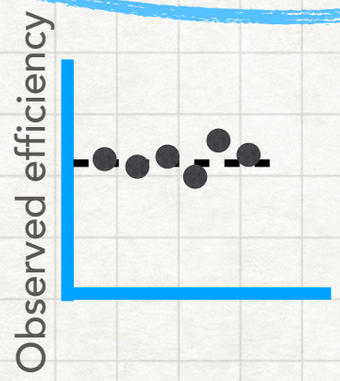
G4 Step preselection x  x 

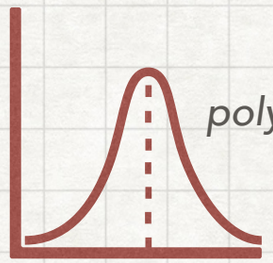
Geant4
(event by event)
binary output:
avalanche or no
avalanche

Test Beam analysis using 100 GeV μ
- measured efficiency (ASIC)
- measured amplitude: polya function (ASIC, step angle)

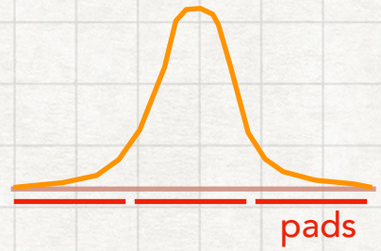
CURRENT IMPLEMENTATION OF THE DIGITIZER

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads

G4 Step preselection x 

x 

Observed charges



charges distributed to pads

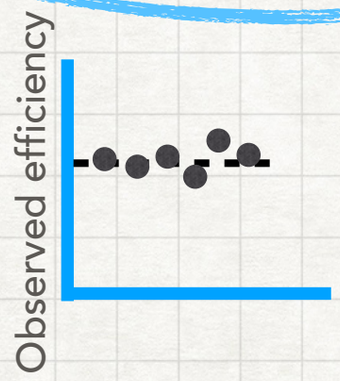
Geant4
(event by event)

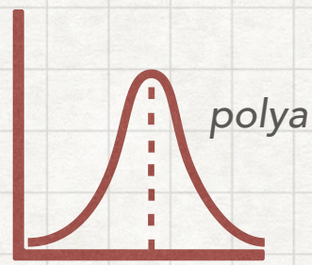
Test Beam analysis using 100 GeV μ
efficiency, amplitude (ASIC, step angle)

Analytic

CURRENT IMPLEMENTATION OF THE DIGITIZER

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads

G4 Step preselection x 

x 

Observed charges

charges distributed to pads

Geant4 (event by event)

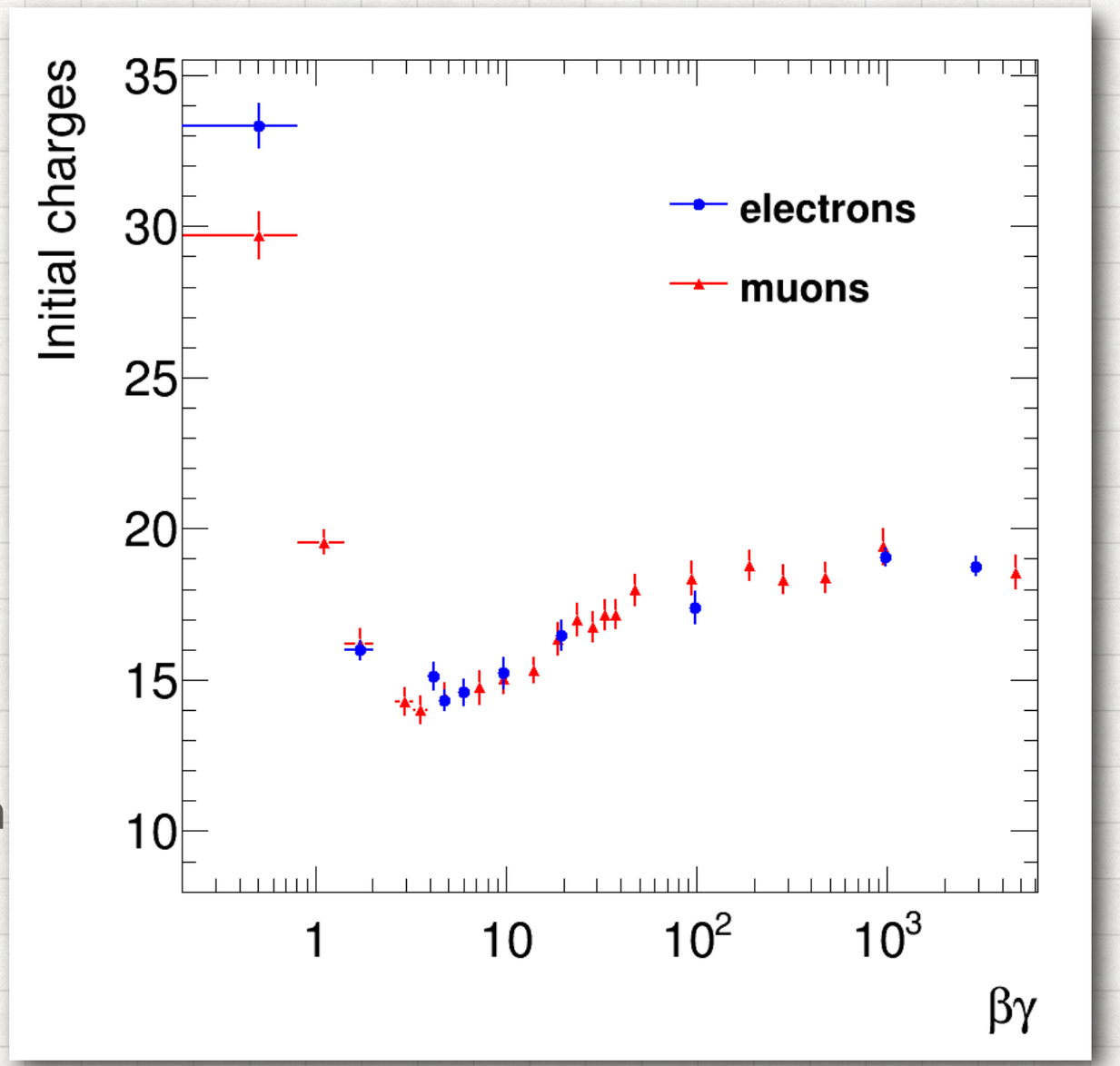
Test Beam analysis using 100 GeV μ efficiency, amplitude (ASIC, step angle)

Analytic

- Powerful data-driven calibration of the charge and efficiency per ASIC allows to reproduce the μ data and account for any effect (mechanics, electronics, sensors, gaz) in average
- Extrapolation to low momentum, massive/light particles (eg., electrons, pions, …) not considered as expected in a shower (no mass or $\beta\gamma$ dependence)

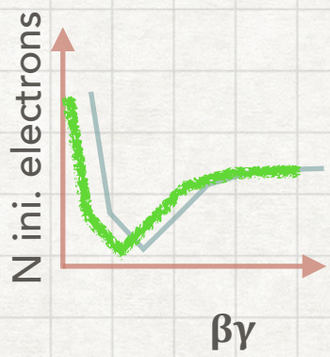
INITIAL CHARGES VERSUS $\beta\gamma$

- We typically start with 20 electrons
- Number can vary with particle type
- Has a distribution for each $\beta\gamma$ (event/event fluctuations)
- Illustrative Figure obtained with Garfield/Heed but same information can be taken directly from Geant 4



IONIZATION DEPENDENCE

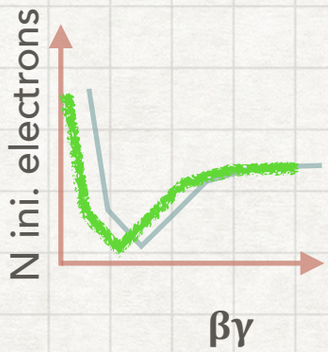
Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads



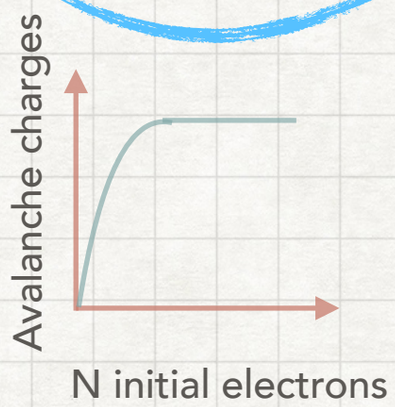
- Ionisation depends on particle type/p etc
- different initial number of electrons for each avalanche

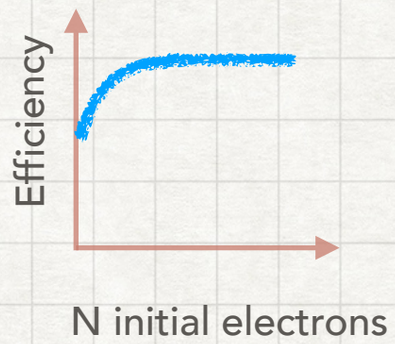
IONIZATION DEPENDENCE

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads



x

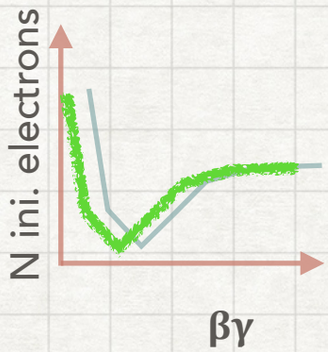




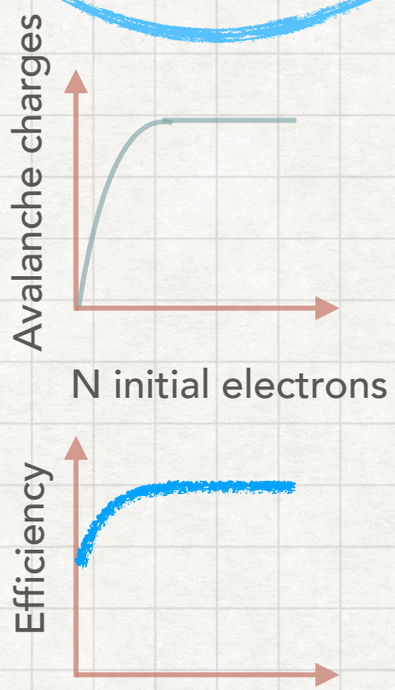
- Relation between total charges (after amplification) and initial charges not trivial
- Probability to have no avalanche to be considered too

IONIZATION DEPENDENCE

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads



x



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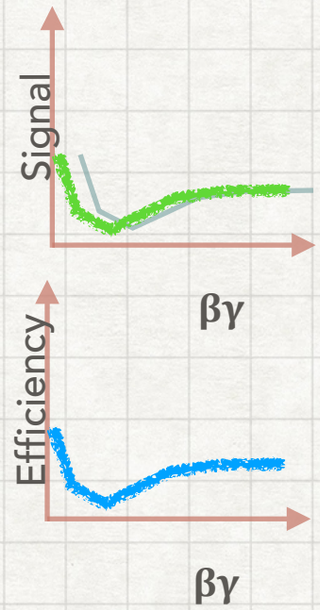
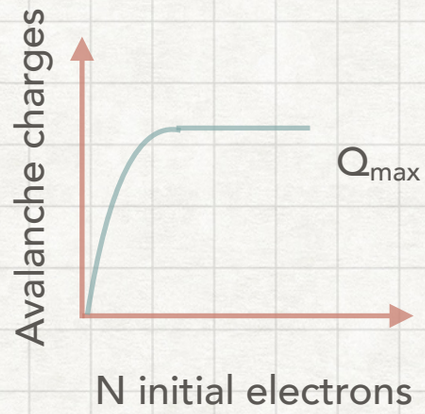


- We want to have the mass and $\beta\gamma$ dependence to account for the large spread of particles in a shower (and not a single Polya per ASIC)
- But we want also to use the data-driven calibration of the charge and efficiency per ASIC

UPDATE OF THE DIGITISER

- An ionising particle (mass, $\beta\gamma$) crossing the chamber will create electrons Ne



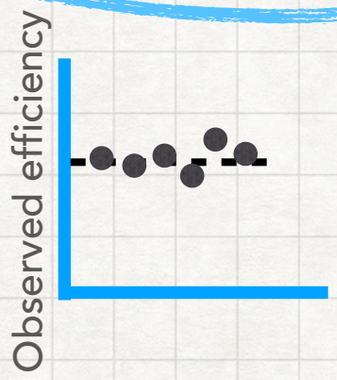
- Simulation of the avalanches allows to model the relation between charges and initial electrons ➜ Q(Ne)
- 100 GeV calibration muons are ~below plateau level ➜ Q_μ=Q(Ne~20)
- (Q(Ne)/Q_μ) x Polya(100 GeV muons) can be used to model the signal induced by any particle keeping the data calibration per ASIC
- Same correction applied to the efficiency (ε(Ne)/ε_μ) × ε(100 GeV muons)
- Ne can be taken from Geant4 (digitizer) or Garfield/Heed (standalone studies)
- Strategy: Keep current digitiser + G4 step by G4 step correction of amplitude and efficiency

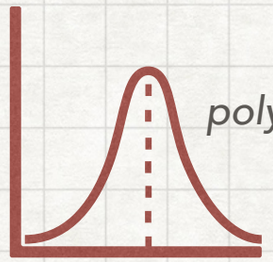
UPDATE OF THE DIGITISER

Particle Type/$\beta\gamma$ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads

G4 Step preselection

x

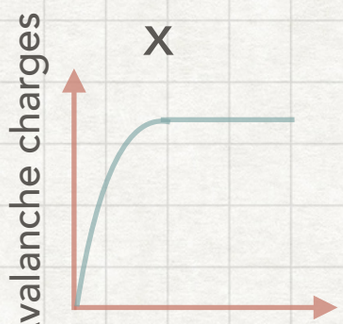


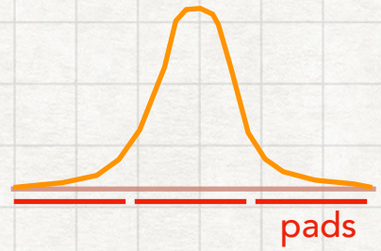


Observed charges

x

x





charges distributed to pads

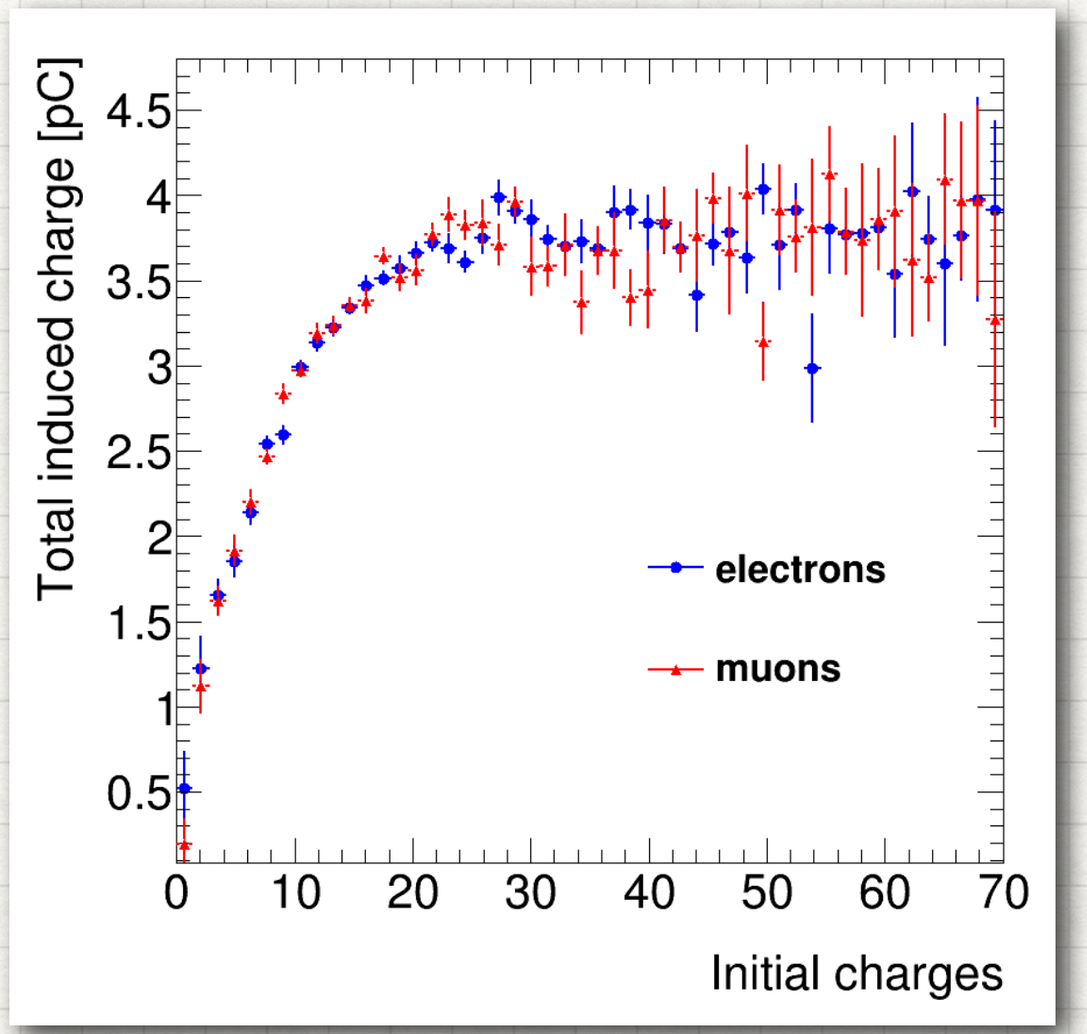
Geant4
(event by event)
steps + Ne

Analytic

Test Beam analysis using 100 GeV μ
efficiency, amplitude (ASIC, step angle)
x correction from avalanche simulation

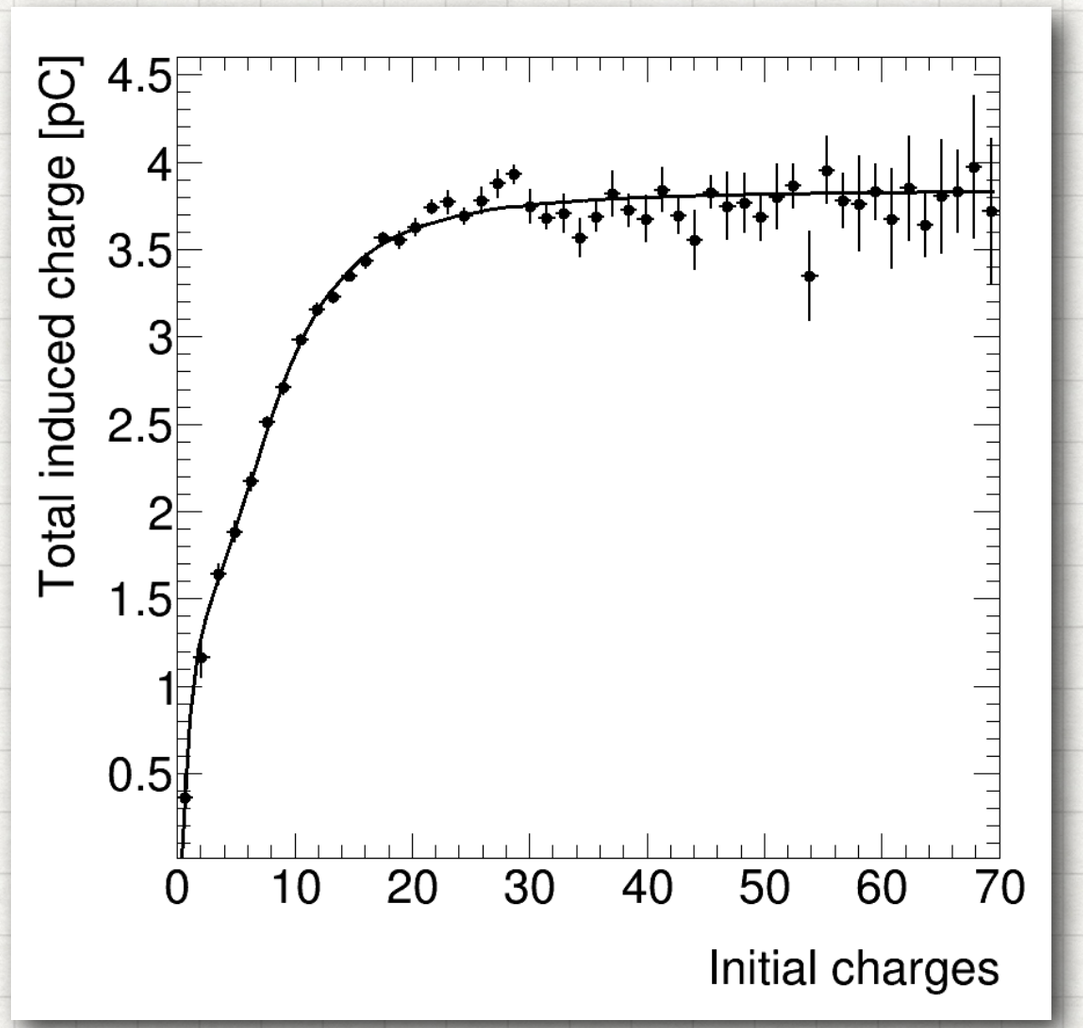
INGREDIENT: AMPLIFICATION MODELING

- We check that the relation between signal and initial charges depends only on initial charges
- Clear saturation effect: no dependence to Ne>~30 electrons
- Significant drop in amplitude if number of initial electrons < 20
- This figure is based on a 2D simulation of 32050 avalanches that required ~8500 CPU hours



INGREDIENT: AMPLIFICATION MODELING

- Dependence modelled with an analytical function that is injected in the digitiser
- **This is the output of the avalanche simulation to be injected in the digitizer**
- Takes as input G4 charges of each step
- It is used to correct the average of the Polya measured on data
- Equivalent Figure produced for the efficiency



ONGOING

- Correction function ready and implemented in digitiser
- To be tested on a full shower simulation
- Efficiency correction to be added too

SOME IDEAS OR PENDING QUESTIONS

- The modelling of the avalanche depends on gas type/ HV
- The data driven Polya has a “width”:
  - This measured width includes the effect of
    - fluctuations of the amplification
    - spread of number of initial charges.
  - The simulation will reproduce the fluctuations of the initial charges on top of the observed spread → double counting
- Could use the simulation not to correct the average signal but the Polya parameters

- Distribution of number of charges created by a 100 GeV mono-energetic muon in the RPC chamber

- Large distribution will contribute to the width of the induced signal