# FOLLOW-UP ON THE SDHCAL DIGITIZER

D. BOUMEDIENE, G. GRENIER, G. GARILLOT

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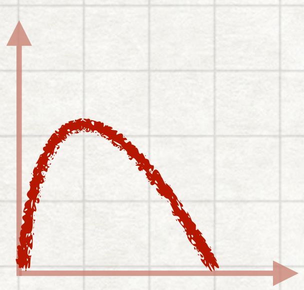
# DIGITISATION STEPS

- 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/**βγ**/angle —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Efficiency

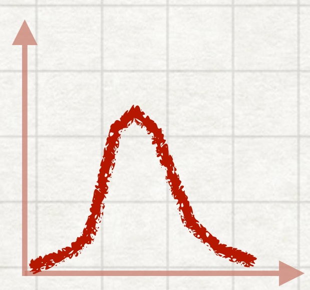
*eg. $e^-$, $\mu$, $\pi$*

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



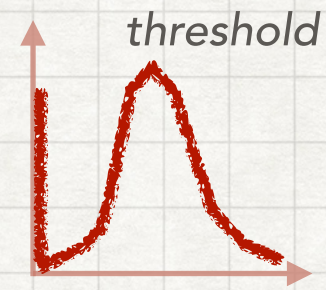
N initial electrons

*eg. $10^8$ electrons*
*or 0 if avalanche dies*



Avalanche charges

*eg. 4 pC*
*efficiency to pass first threshold*



Induced signal
and efficiency

# CURRENT IMPLEMENTATION OF THE DIGITIZER

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

G4 Step preselection

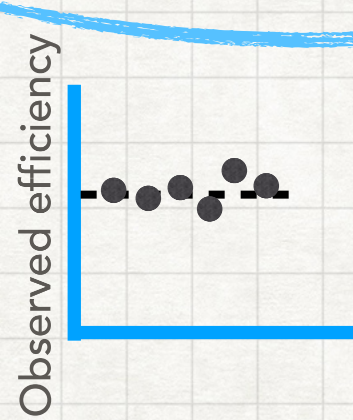
Geant4 (event by event)

- 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

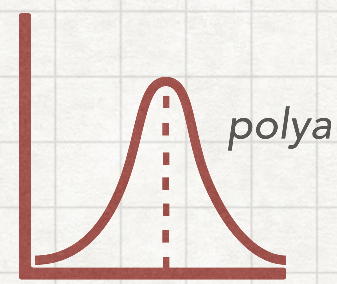
# CURRENT IMPLEMENTATION OF THE DIGITIZER

Particle Type/βγ → (ionisation) → Initial Charges → (avalanche) → Charges → (induction, threshold) → Induced signal Distribution to pads

G4 Step preselection x




x

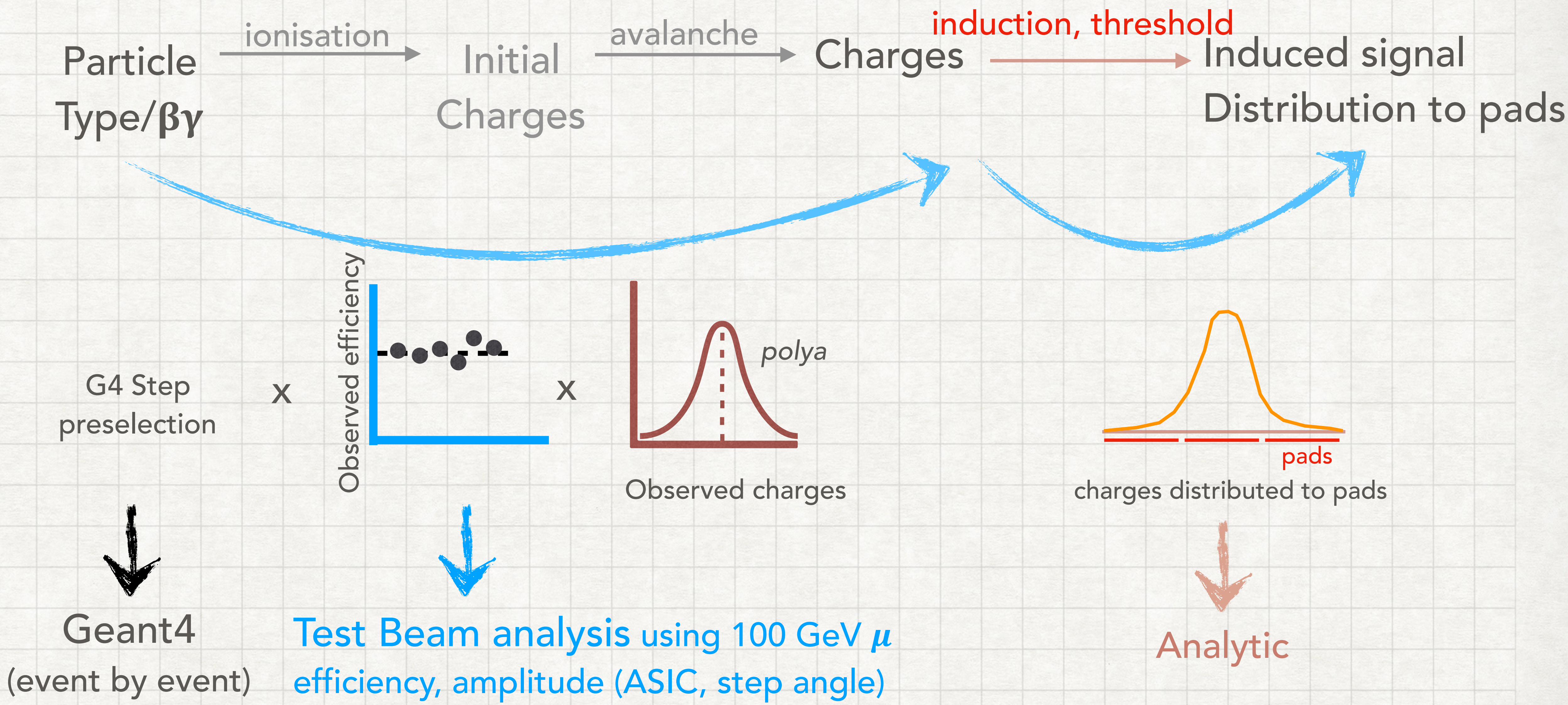



Observed charges

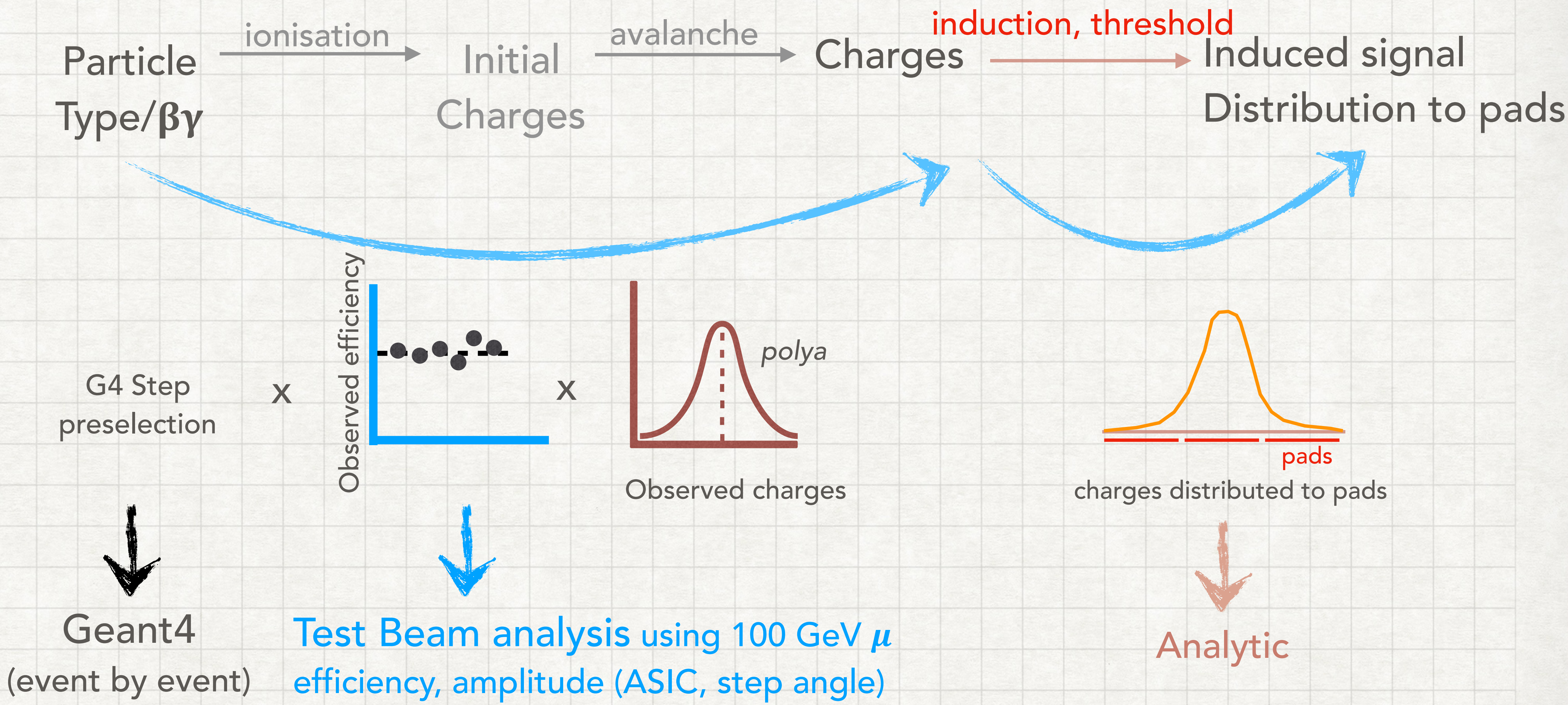
Geant4
(event by event)
binary output:
avalanche or no avalanche

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

# CURRENT IMPLEMENTATION OF THE DIGITIZER



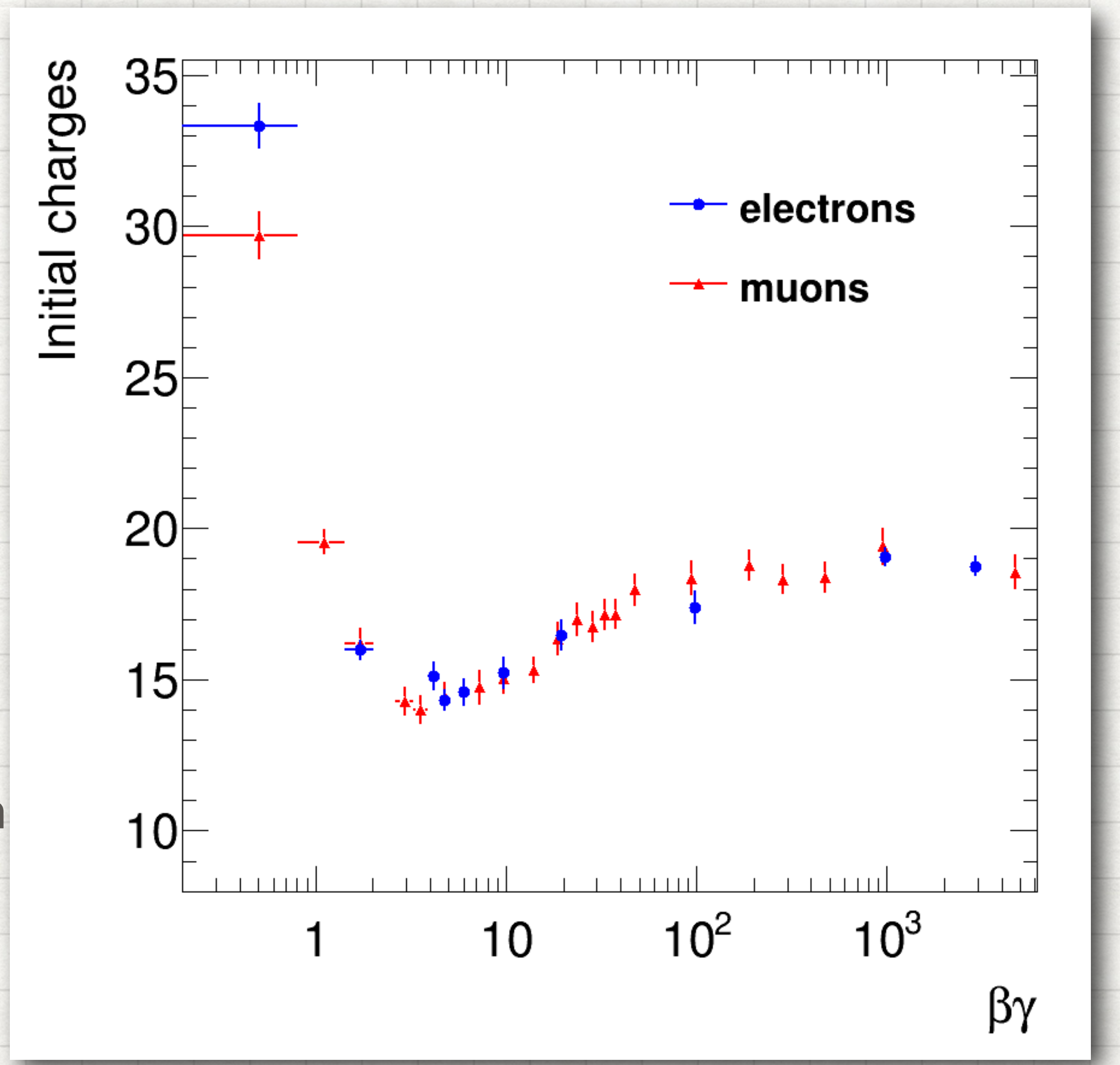
# CURRENT IMPLEMENTATION OF THE DIGITIZER




- Powerful data-driven calibration of the charge and efficiency per ASIC allows to reproduce the $\mu$ 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 βγ

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

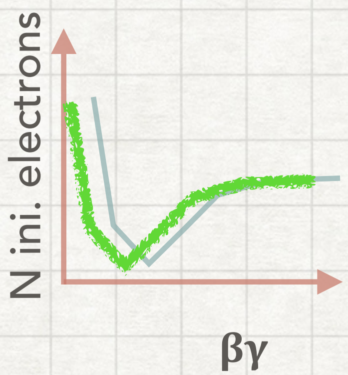




N initial electrons

# IONIZATION DEPENDENCE

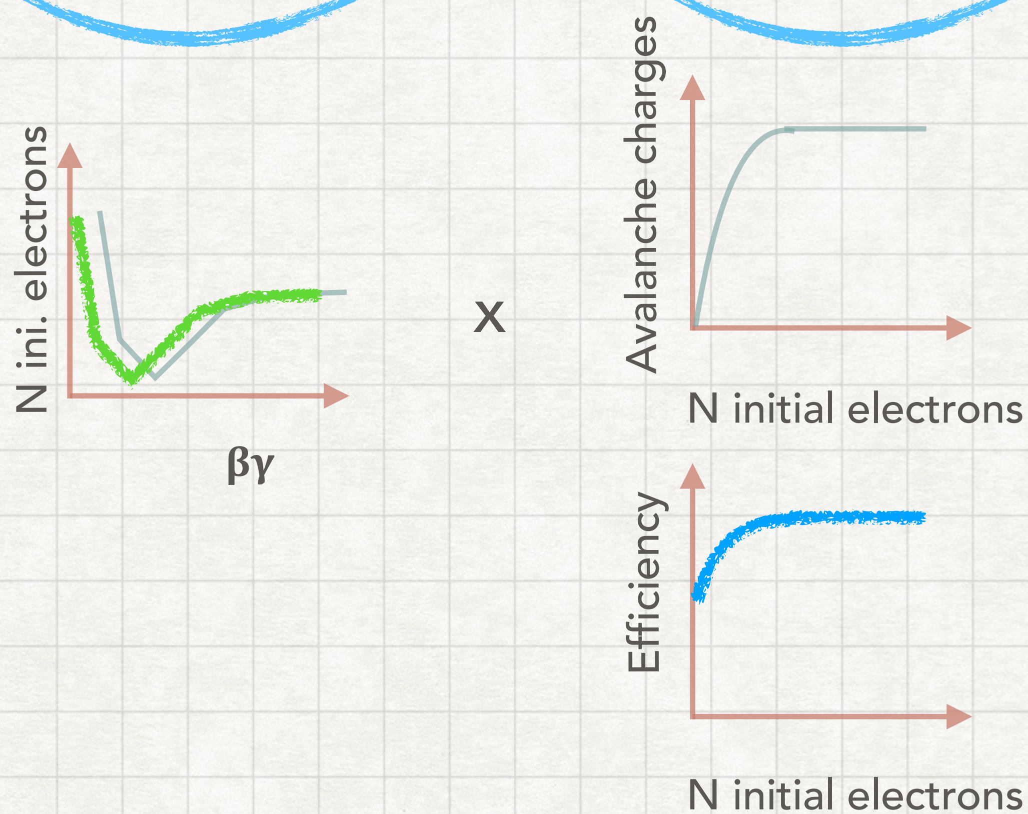
Particle Type/βγ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads




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

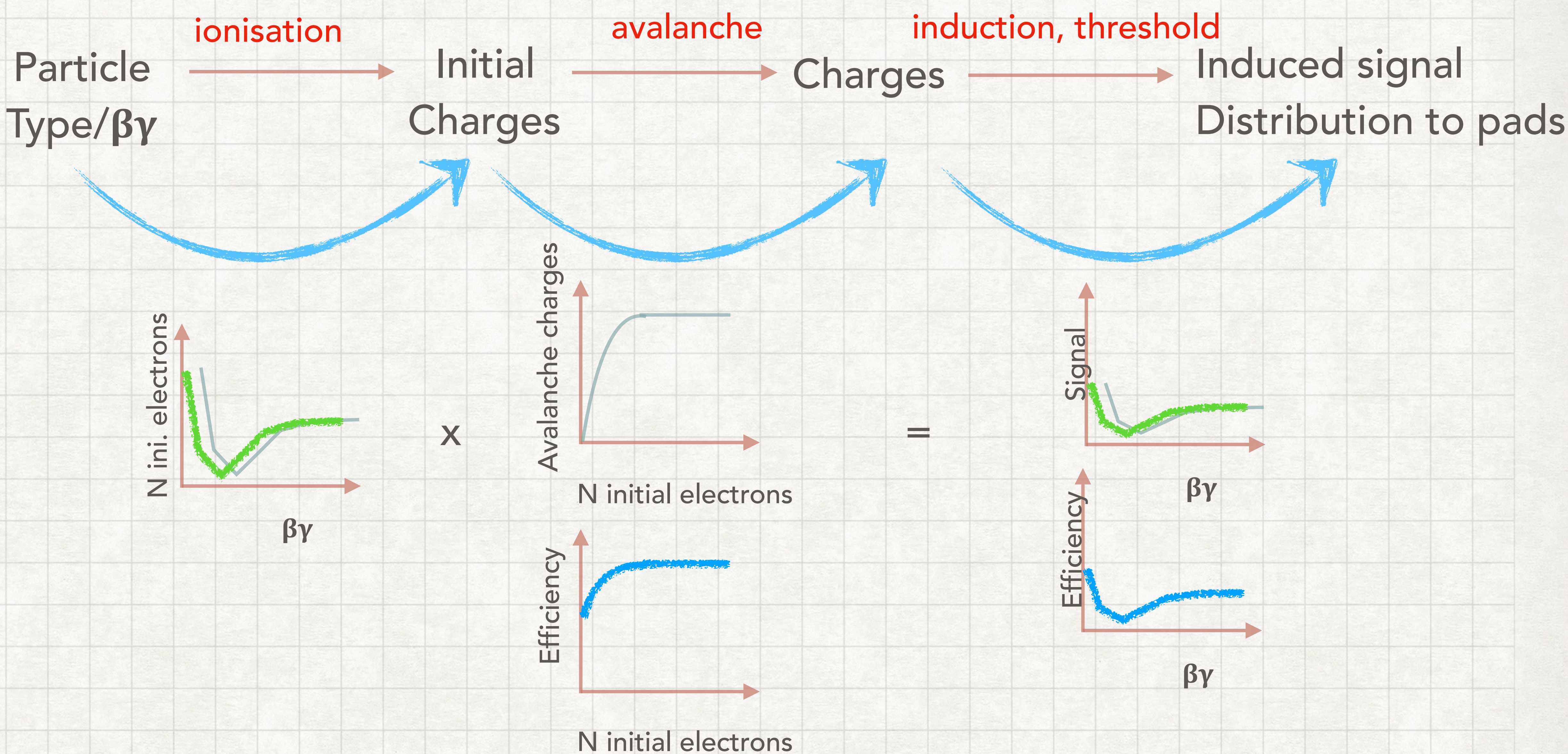
# IONIZATION DEPENDENCE

Particle Type/βγ —ionisation→ Initial Charges —avalanche→ Charges —induction, threshold→ Induced signal Distribution to pads



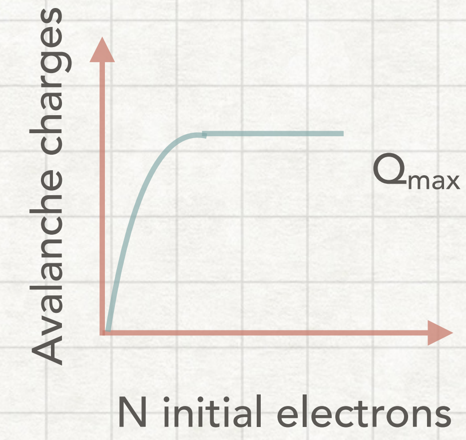

- Relation between total charges (after amplification) and initial charges not trivial
- Probability to have no avalanche to be considered too

# IONIZATION DEPENDENCE




- We want to have the mass and **βγ** 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



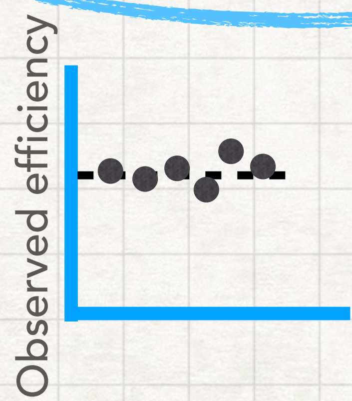

- An ionising particle (mass, $\beta\gamma$) crossing the chamber will create electrons Ne
- Simulation of the avalanches allows to model the relation between charges and initial electrons ➜ Q(Ne)
- 100 GeV calibration muons are ~below plateau level ➜ $Q_{\mu}$=Q(Ne~20)
- (Q(Ne)/$Q_{\mu}$) x Polya(100 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 ($\varepsilon$(Ne)/$\varepsilon_{\mu}$) × $\varepsilon$(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

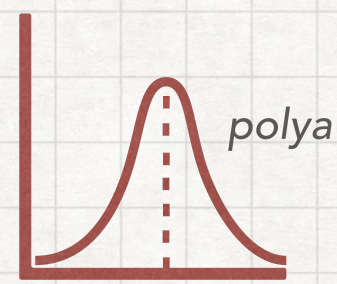
# UPDATE OF THE DIGITISER

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

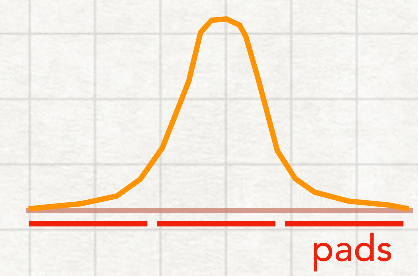
G4 Step preselection

x



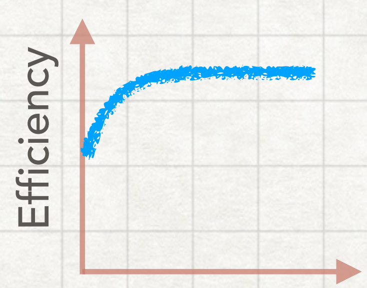




Observed charges



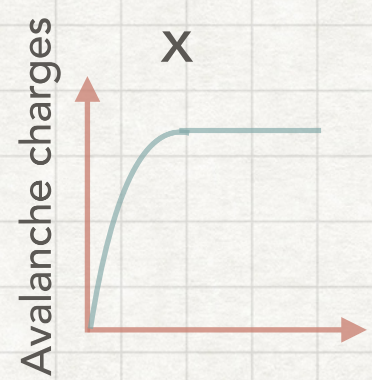

charges distributed to pads

x




N initial electrons

x




N initial electrons

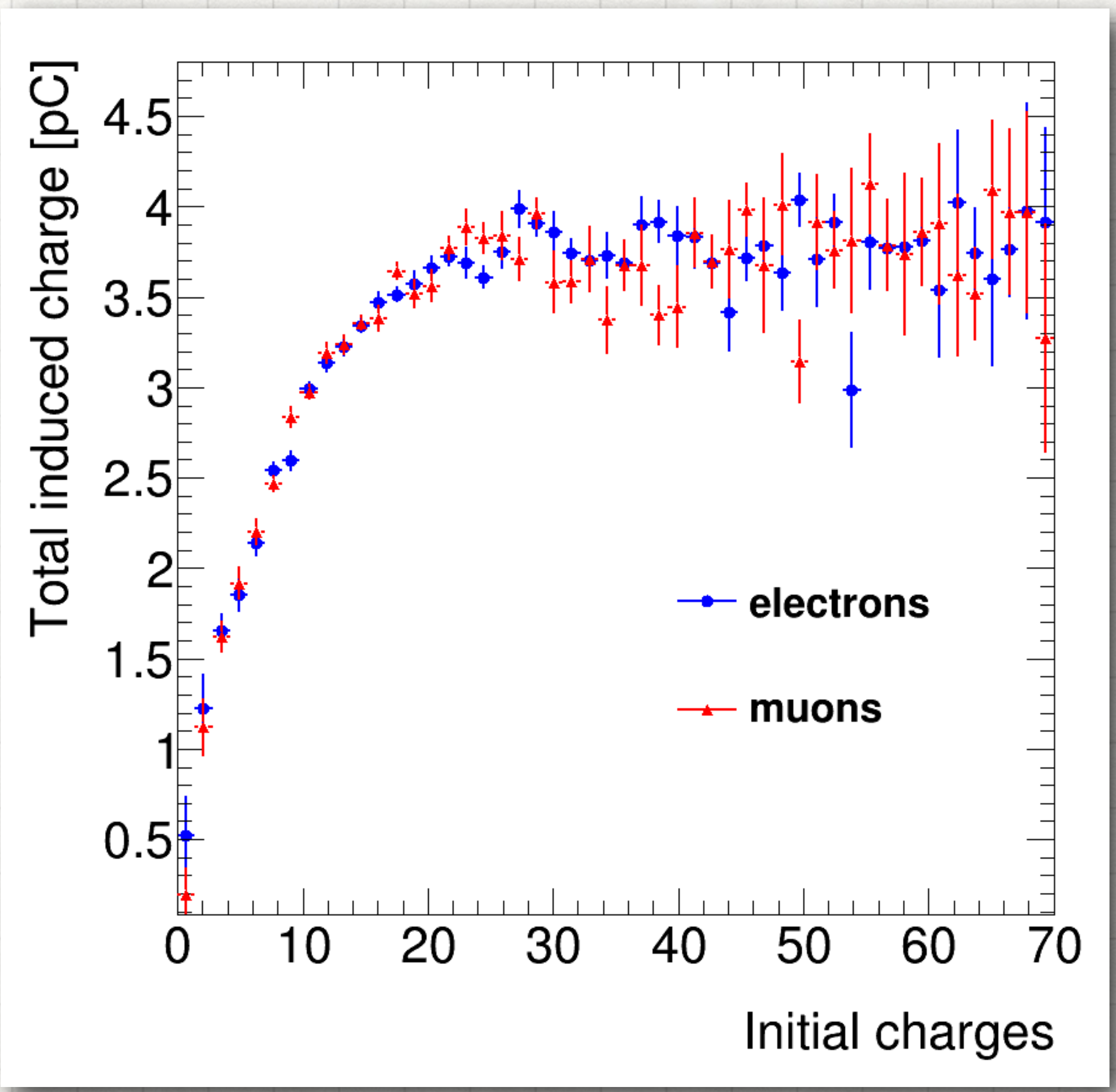
Geant4
(event by event)
steps + Ne

Analytic

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

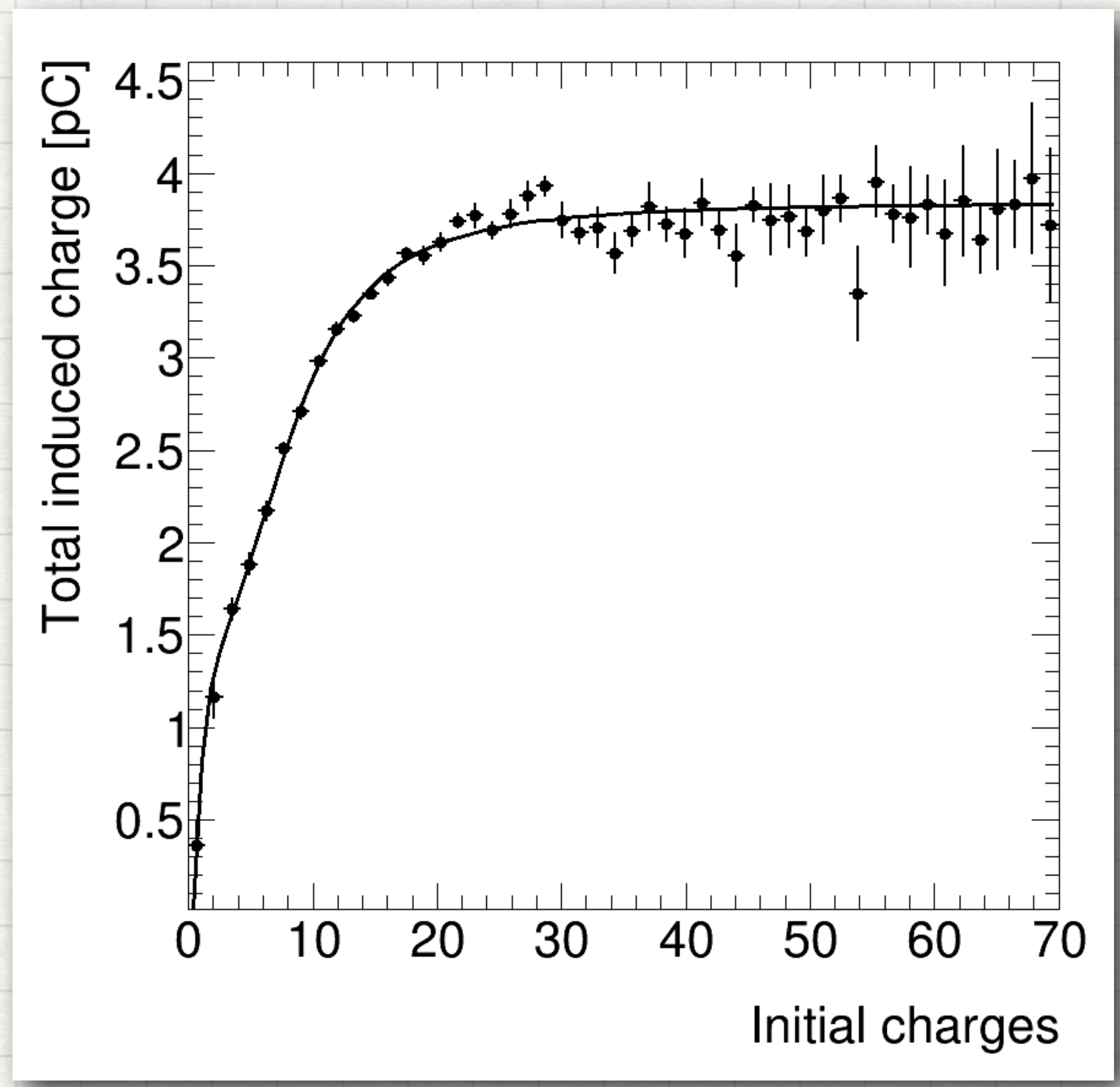
# INGREDIENT: AMPLIFICATION MODELING

- 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