A Geant4 simulation to estimate the RPC sensitivity to neutral radiation

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Introduction

Cavern background

radiation mainly caused by particles interacting with the **detector material** or the **beam pipe**
photons and neutrons dominate the population in cavern background

Detector hit rates

in the **muon spectrometer** are due primarily to background rather than “true” muons.

Level-1 muon trigger is also **sensitive** to background, either from the random coincidence of individual background hits or from correlated hits by charged particles.

Technical Design Report for the Phase-II Upgrade of the ATLAS Muon Spectrometer

Neutron equivalent flux

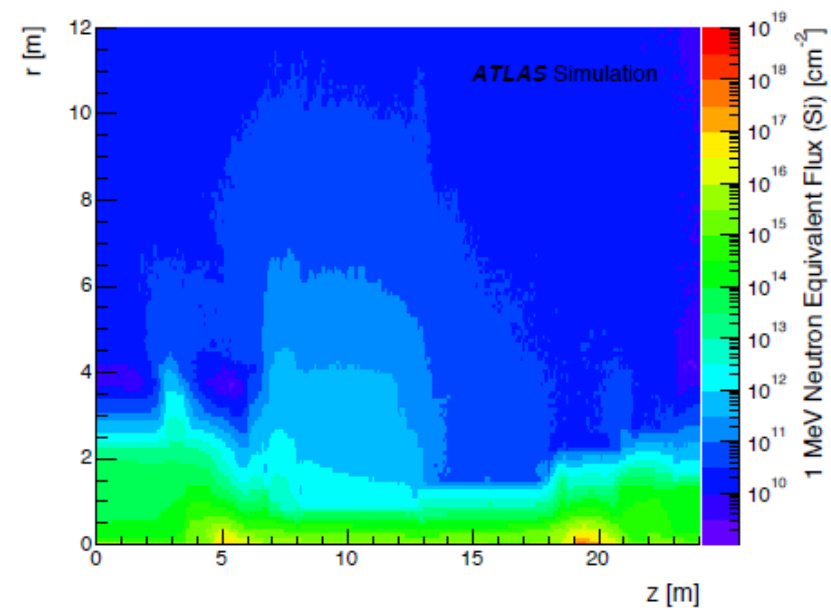


Figure A.2: Map of the simulated 1-MeV neutron equivalent flux for 1000 fb^{-1}.

Neutron equivalent flux

Table A.2: Summary table for the estimates of the 1-MeV neutron equivalent flux in units of 10^{11} n/cm^2. The maximum value in each region is listed. For the high-η tagger, both the minimum and the maximum values are listed.

Integrated $\mathscr{L}$	BI1–6	BIS7/8	BM	BO	EIL4/5	EE	EM	EO	High-η
1000 fb^{-1}	1.1	3.3	0.92	0.43	3.0	1.2	1.1	0.34	$(0.1–1.8) \times 10^4$
3000 fb^{-1}	3.3	9.9	2.8	1.3	9.0	3.6	3.3	1.0	$(0.3–5.4) \times 10^4$

Motivation

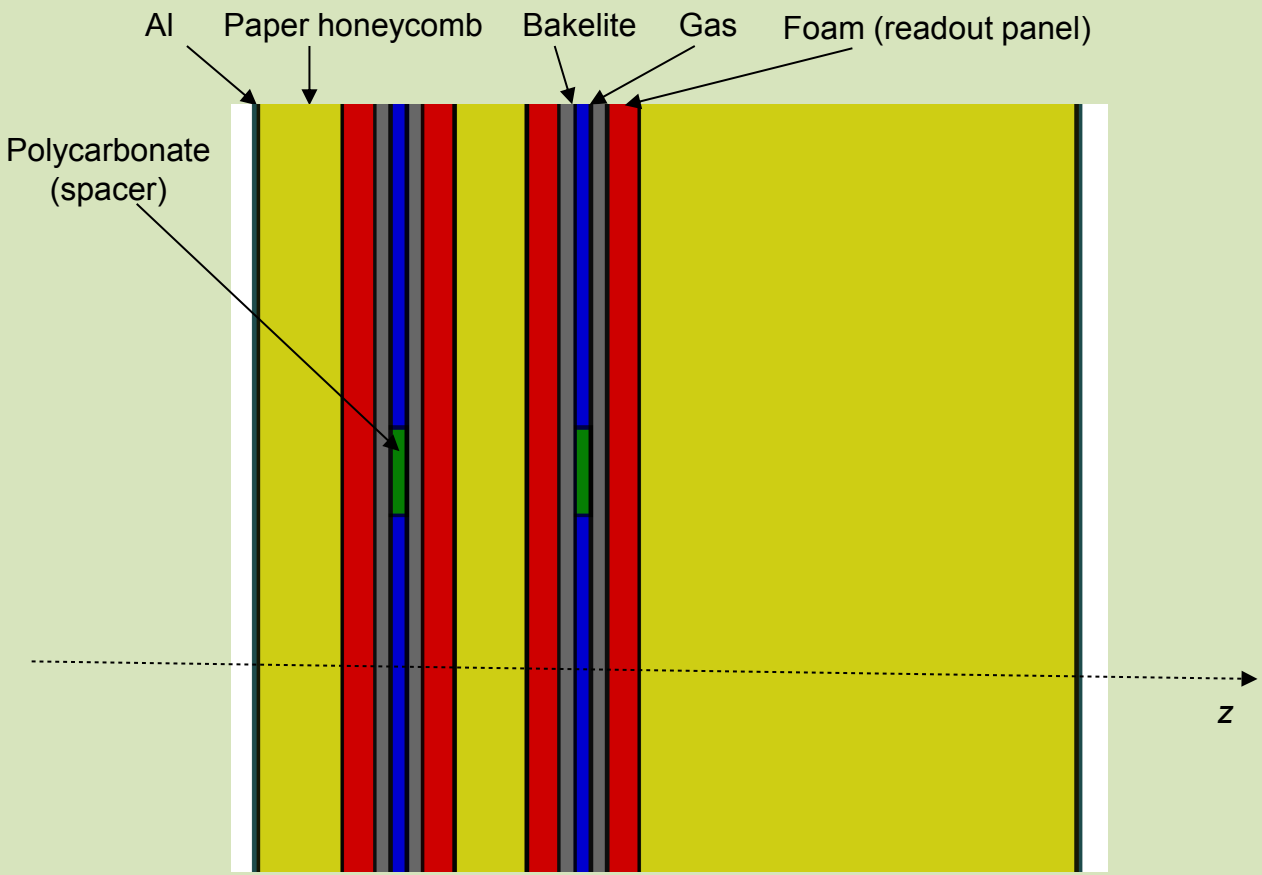
Estimates of the background rates **for ATLAS RPCs** seem to **be higher than measurements**

assuming **constant sensitivity** for low energy neutrons below 10^(-4) GeV

Goal : Derive RPC sensitivity to neutrons and photons using Geant4

Sensitivity starting definition:
fraction of events causing ionization in gas
(produced by charged secondary particles)

RPC model for Geant4



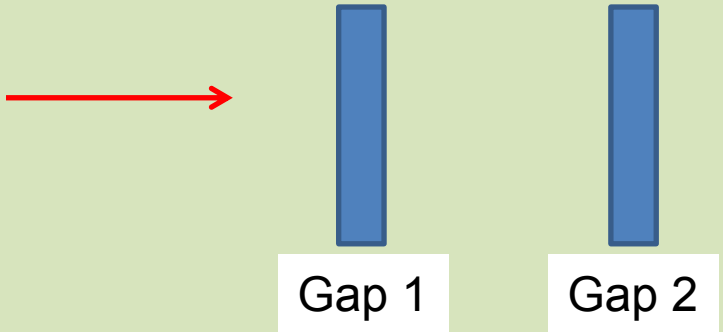
Standalone standard **2mm ATLAS double-layer** RPC simulated in Geant4
Spacers included in gas gap:
1.0 cm diameter and 10.0 cm pitch in both x,y
Possibility to include **electric field** in the gap

Simulation setup

Event generator parameters

Particle gun : gamma or neutron
Point of origin : just outside the RPC,
uniformly distributed in a 30cm side square (to include spacer effect)
Direction : normal or isotropic (angular ranges: $\phi=[0,2\pi]$, $\theta=[0,\pi/2]$)

Physics list: QGSP_BERT_HP or QGSP_BIC_HP
Standard Geant4 lists using the data driven
high precision neutron package (NeutronHP) to transport neutrons
below 20 MeV down to thermal energies



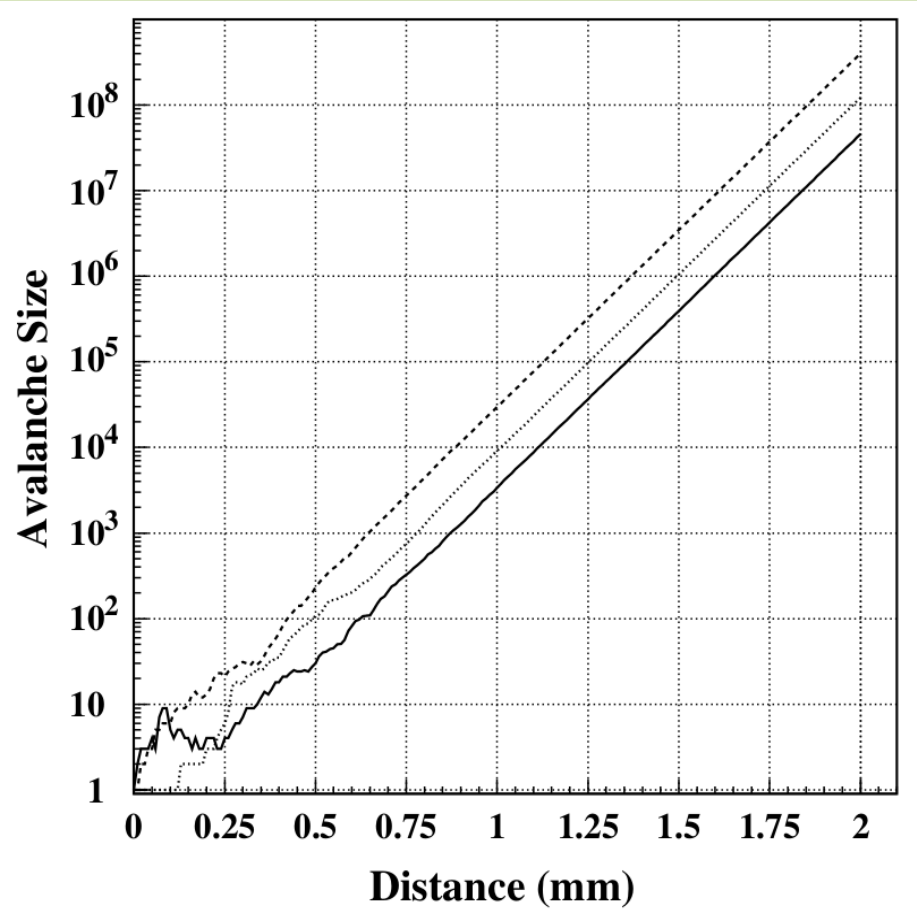
Inactive regions in the gas gap

The sensitivity values include geometrical inefficiency due to **spacers**

Step size in the gas gap **0.05 mm**
allowing identification of the **point** where the ionization occurs

Study the possible impact of
partially active gaps :
need sufficient avalanche development
in order to produce a signal
dependence on the ionization position

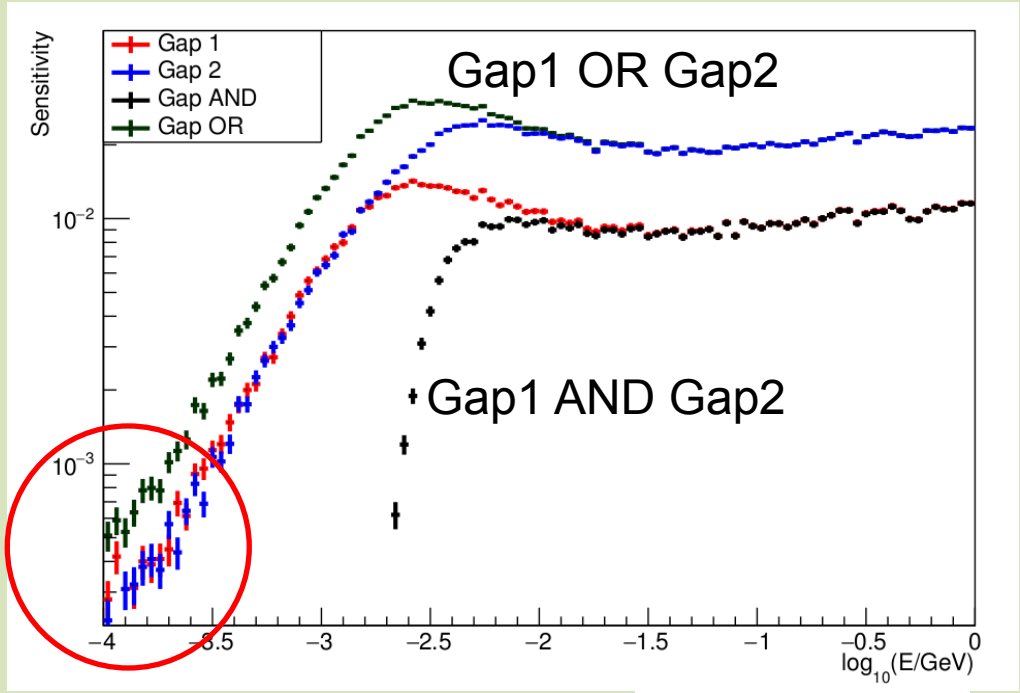
Size of an avalanche started by a single electron at z=0 (for some RPC configuration)
Riegler et al, NIM A 500 (2003) 144



Sensitivity to gamma I

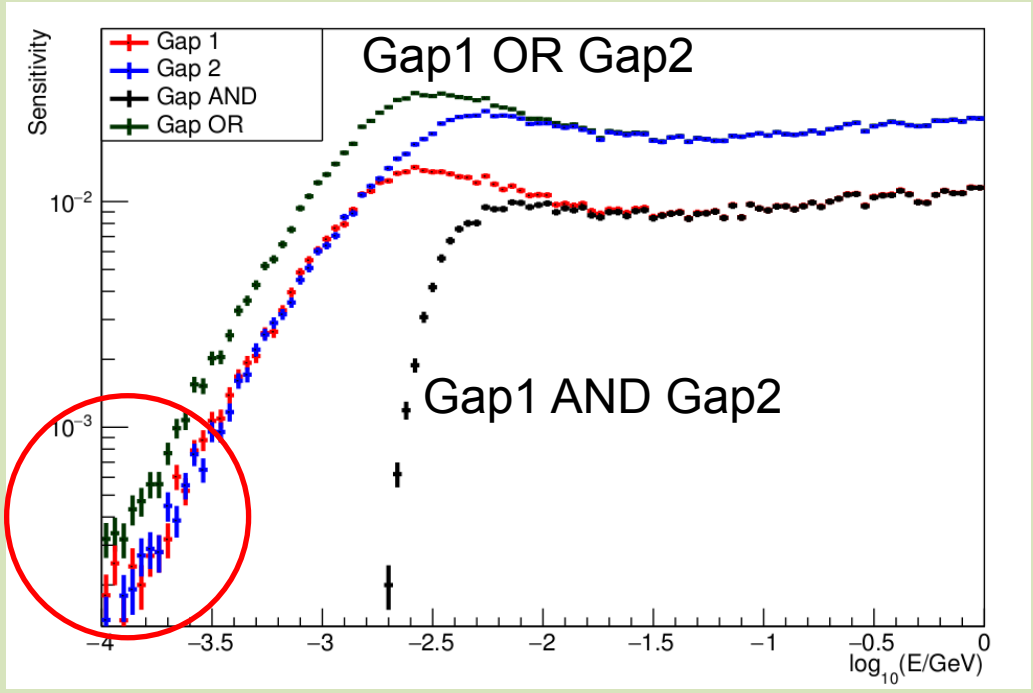
No electric field, different active size

Active gas thickness: 2 mm



Energy (GeV)

Active gas thickness: 1 mm

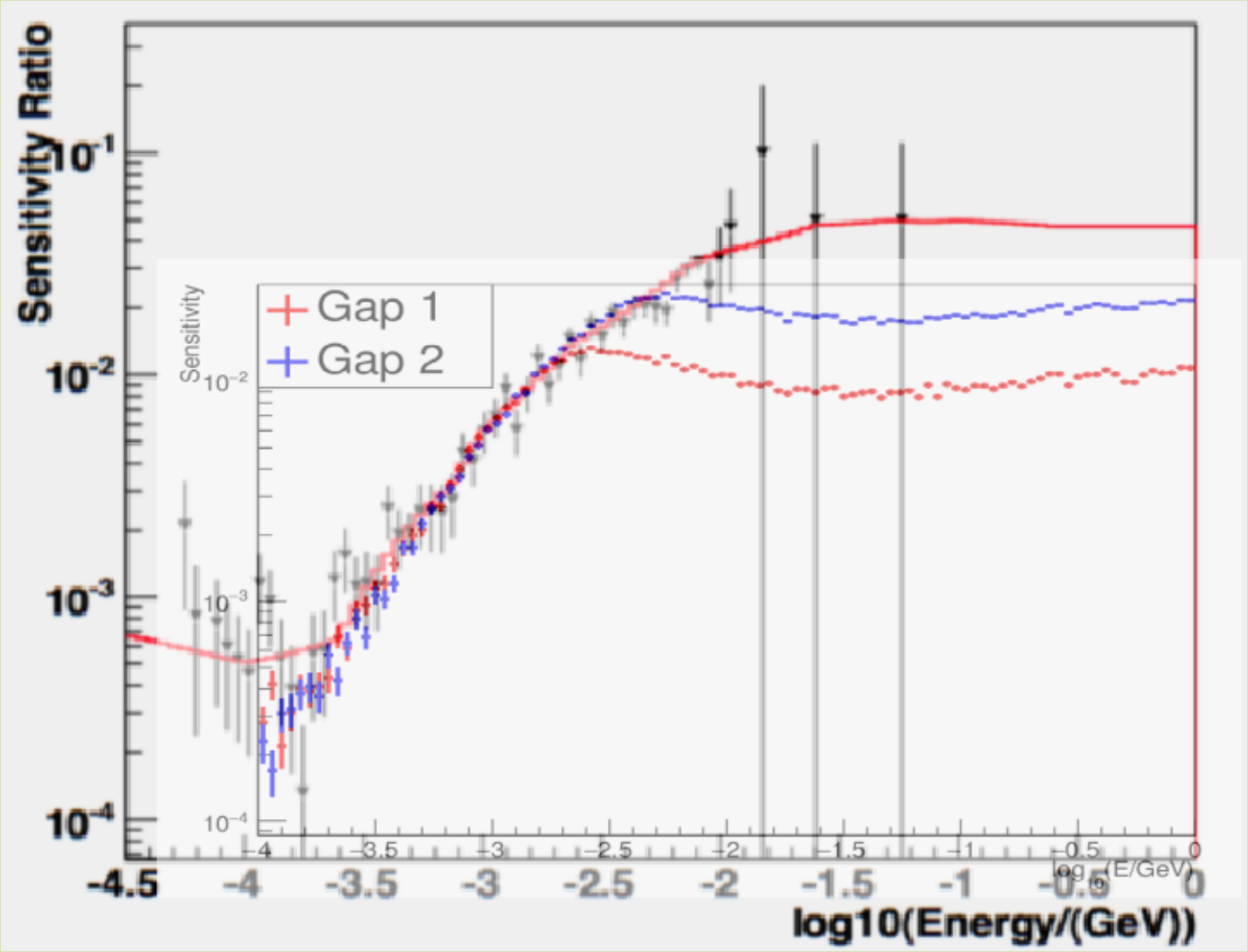


Energy (GeV)

A reduction of the **active gas thickness** has **small impact** on sensitivity in particular at low energy

Sensitivity to gamma II

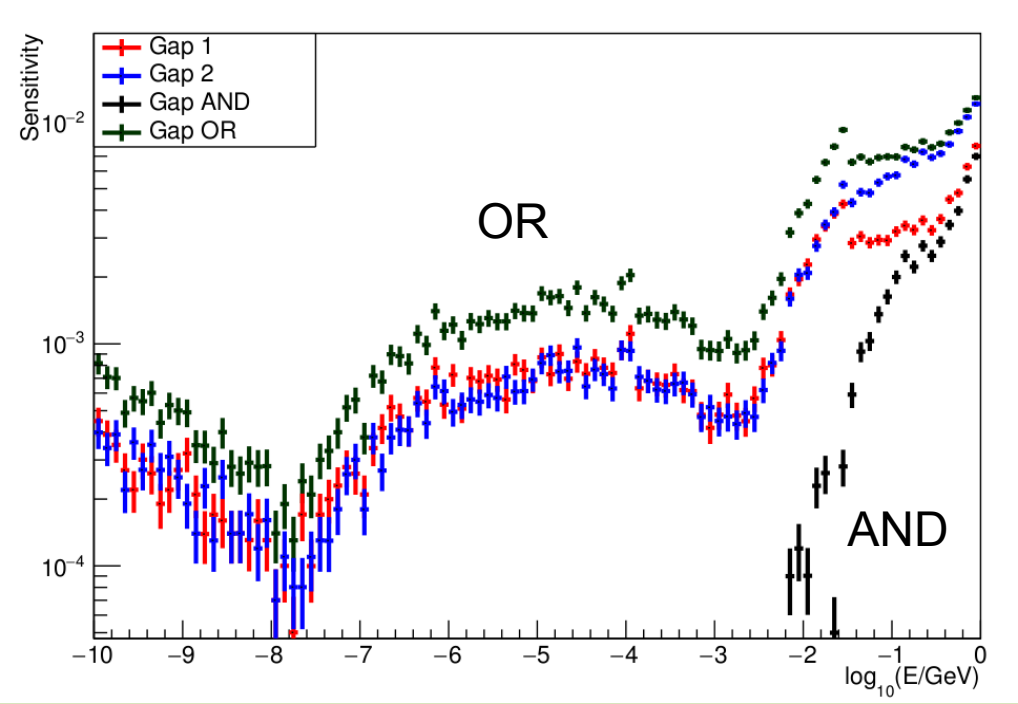
Comparison with current curves in use (single gap) : substantial agreement



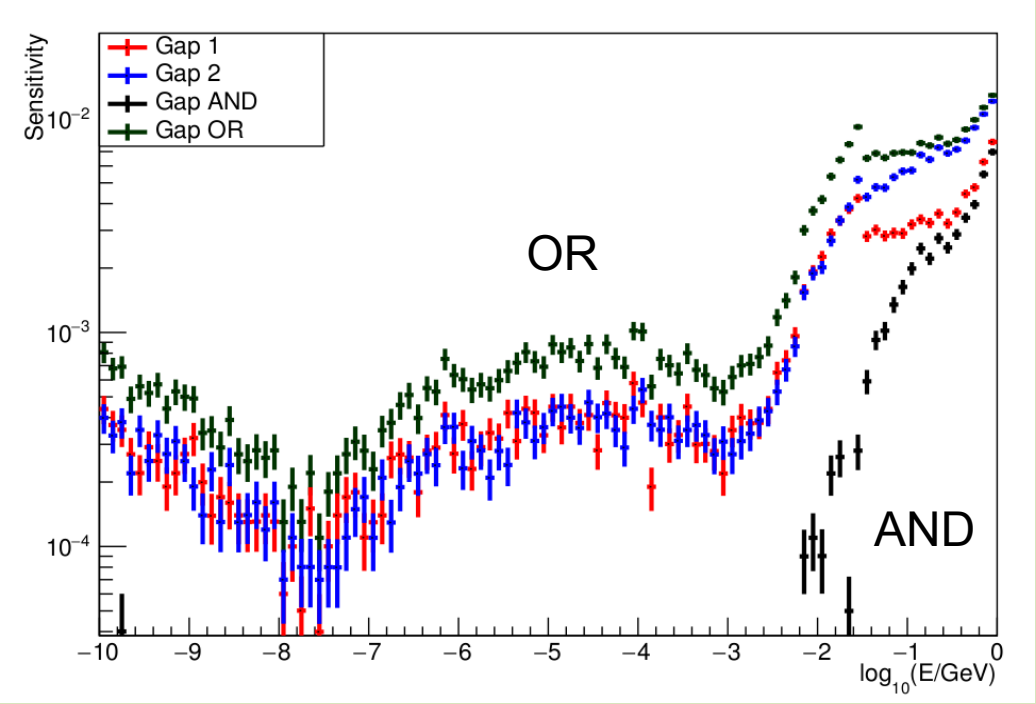
Sensitivity: neutrons I

No electric field, different active size

Active gas thickness: 2 mm



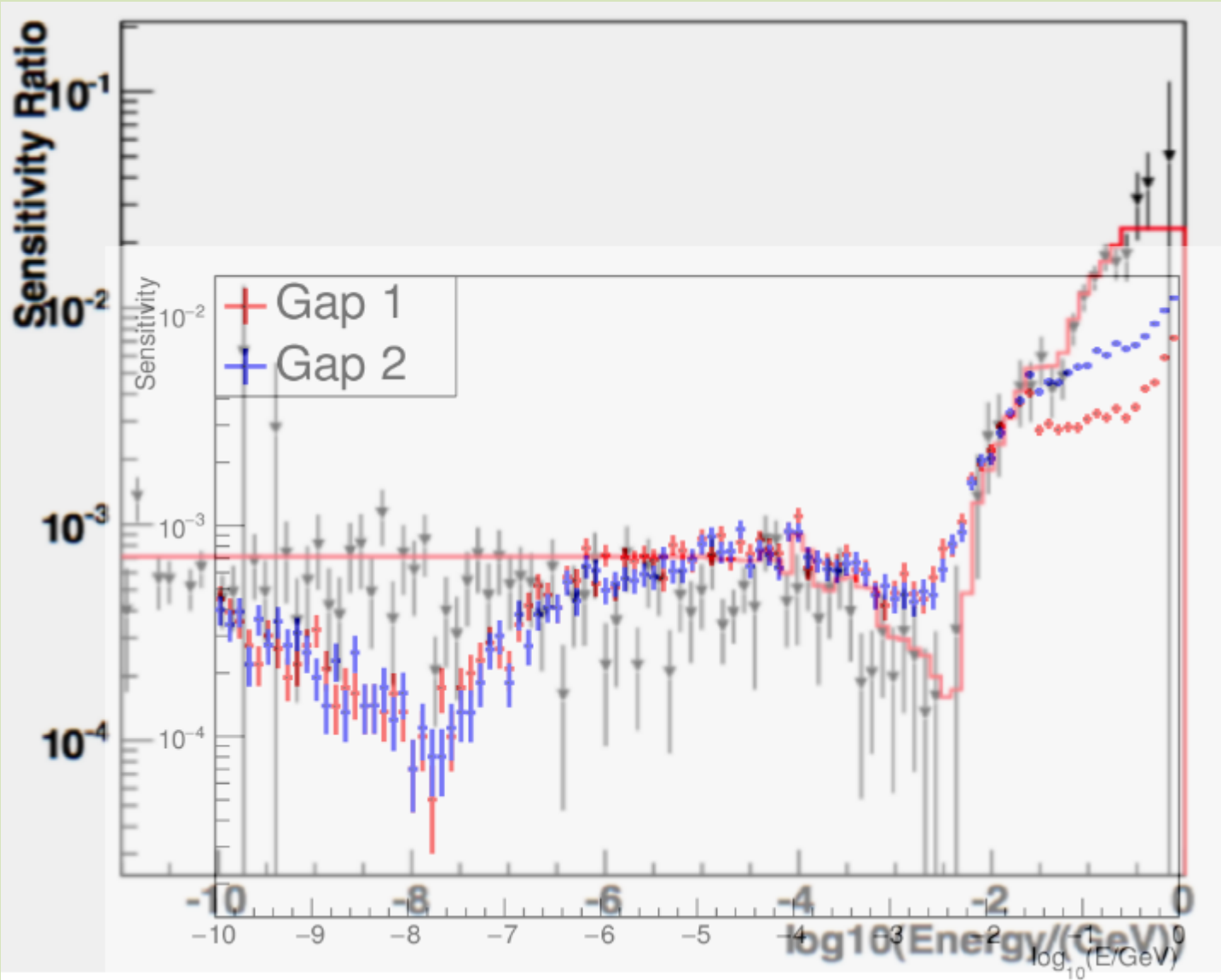
Active gas thickness: 1 mm



A reduction of the **active gas thickness** has **small impact** on sensitivity
Not flat behavior for low energies as previously assumed

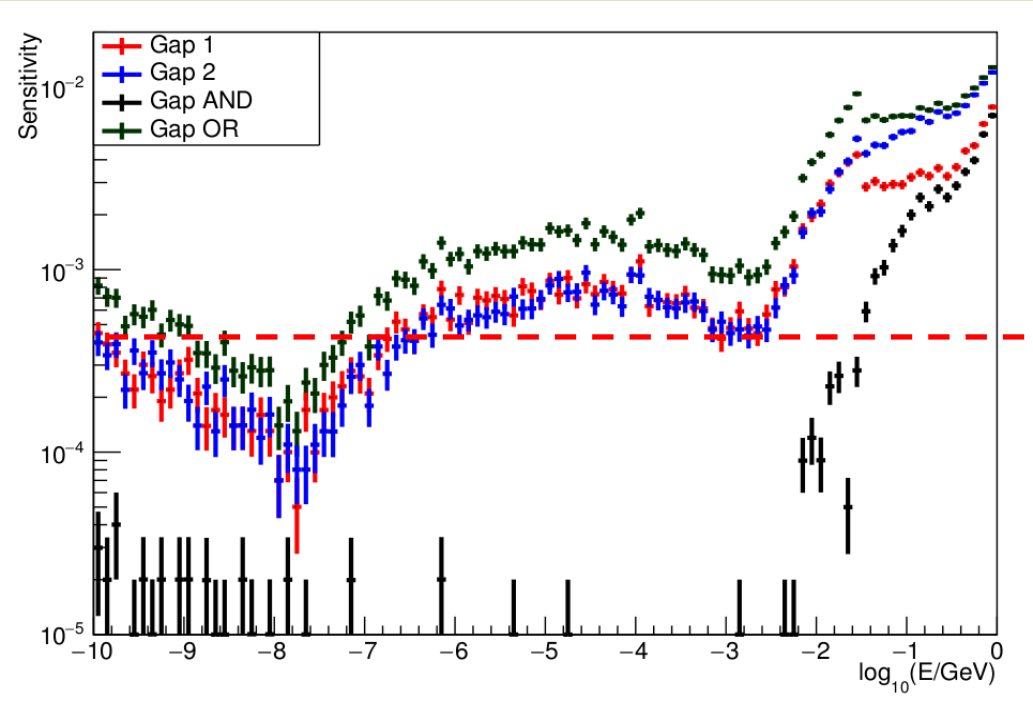
Sensitivity to neutrons II

Comparison with current curves in use (single gap) : disagreement at low energies

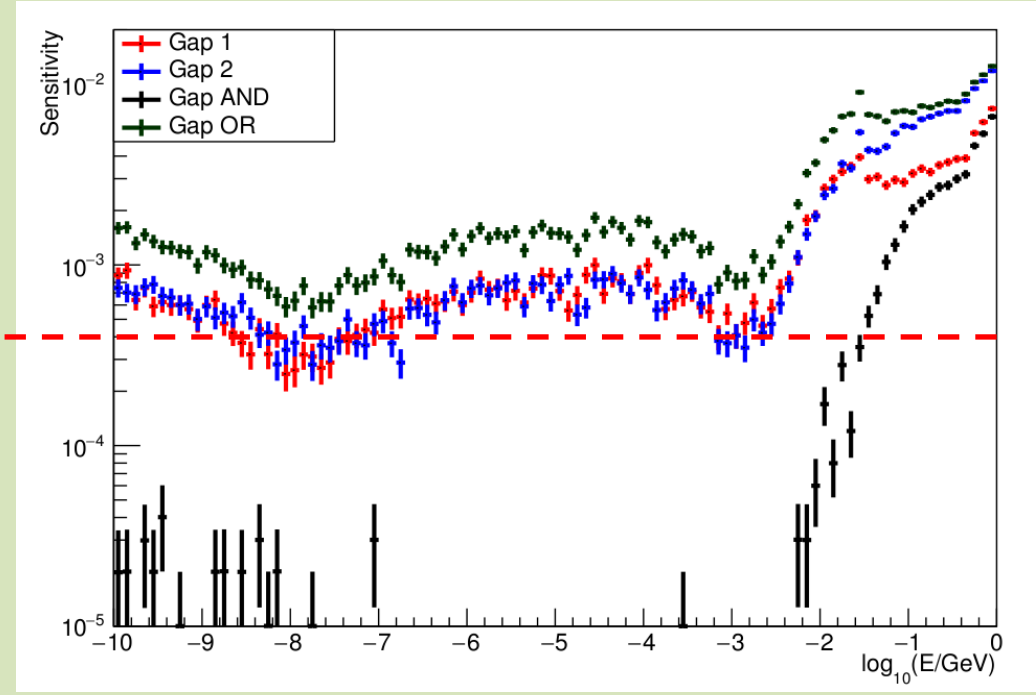


Electric Field Effect

Neutrons : no electric field in gas gap



Neutrons : electric field in gas gap



Electric field turned on :
increased sensitivity at low energy due to the **production of protons and nuclei** (ionized) in the gas gap **accelerated by the electric field**

For photons the electric field produces no such effects

Ionization Clusters using Garfield ++

Geant4 provides the **energy deposition**

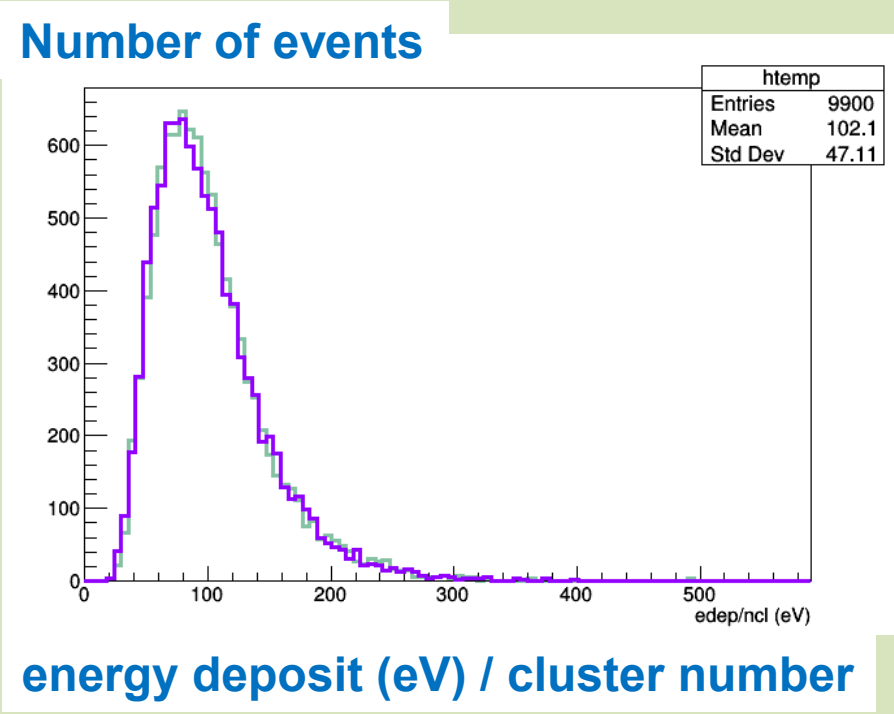
Need to relate it to the **visible observables** (hits)

Garfield++ allows us to determine the **number of ionization clusters** corresponding to Geant4 output

Need to redefine sensitivity

fraction of events causing ionization in gas

Mean energy for cluster production ~100eV



Conclusions

Photon sensitivity behavior results as expected

Neutrons require further studies but possibly understood

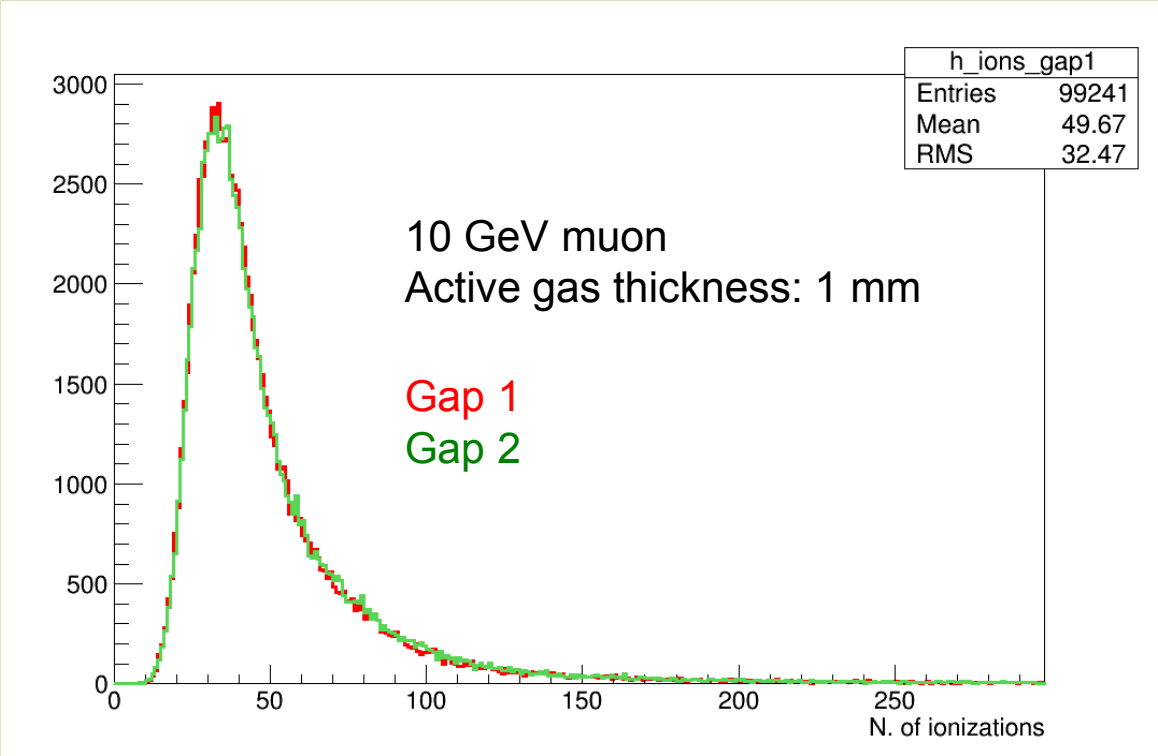
Geant4 : Sensitivity for low energy neutrons lower than Geant 3

Simulation is essential for cavern background studies for
the ATLAS Muon Spectrometer upgrade

Thank you

Not to show Ionization

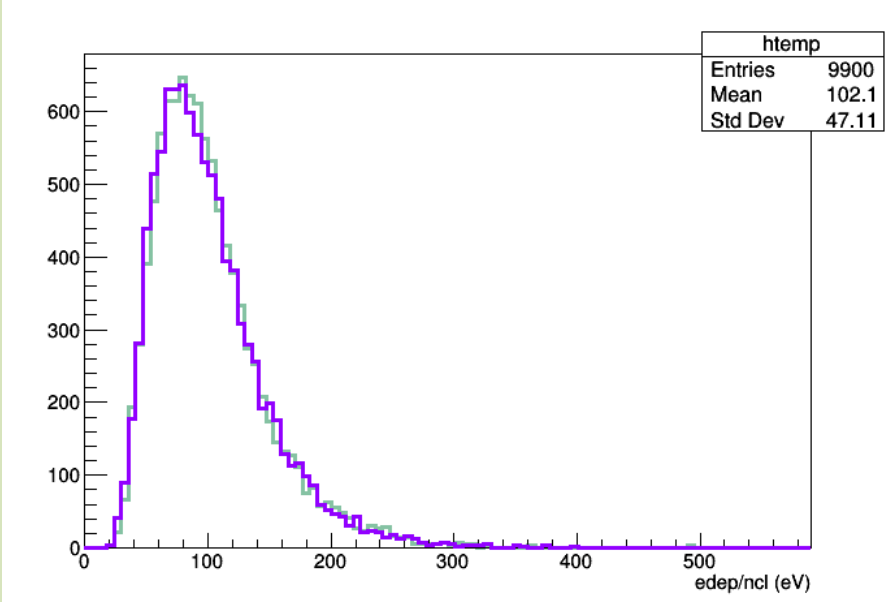
Number of ionizations computed by Geant4 from energy deposition in the gas gap ΔE:
- ionization energy provided by the user (20 eV in our case)
- random number extracted from a poissonian with mean ΔE/20 eV



Is this realistic? How many ionizations expected per mm for a MIP?

Cluster number vs Released Energy

Number of events



energy deposit (ev) / cluster number

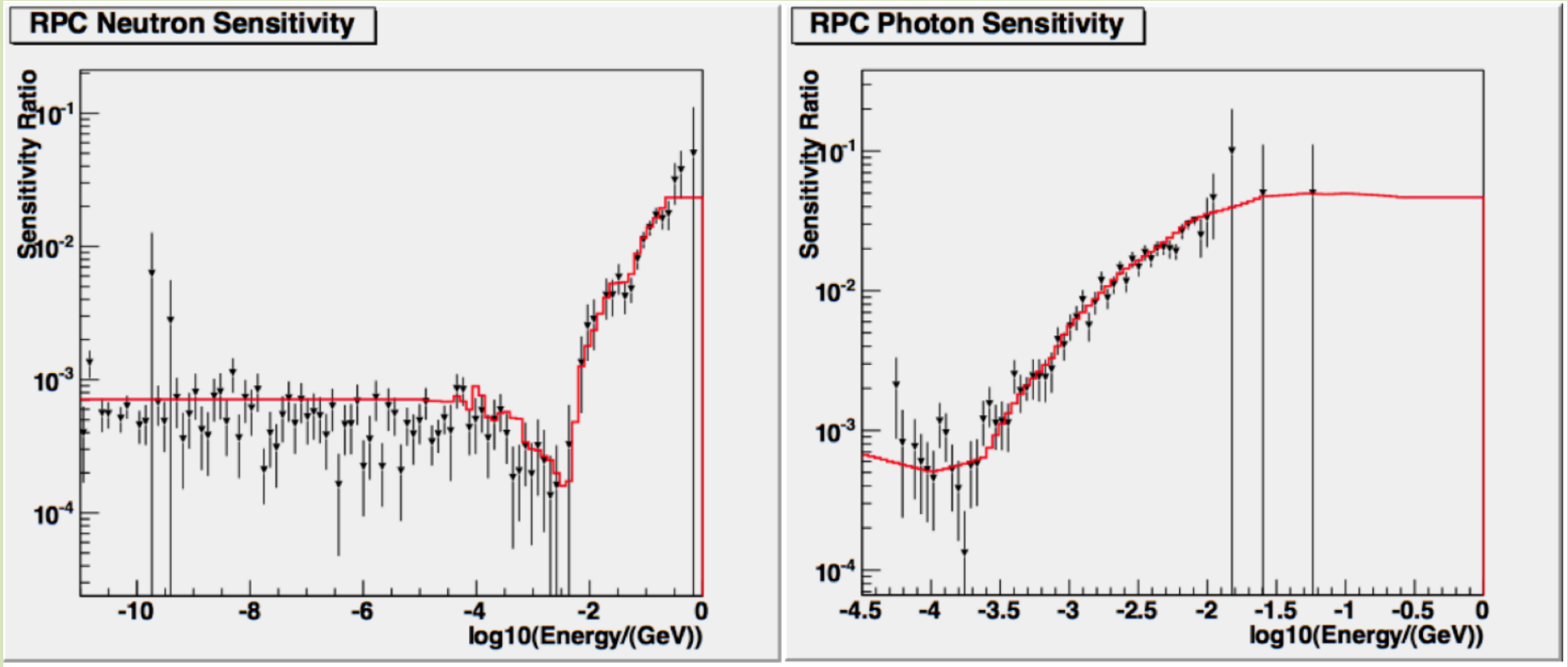
Motivation

As current estimates of the background rates in the ATLAS RPCs seem to overestimate measurements

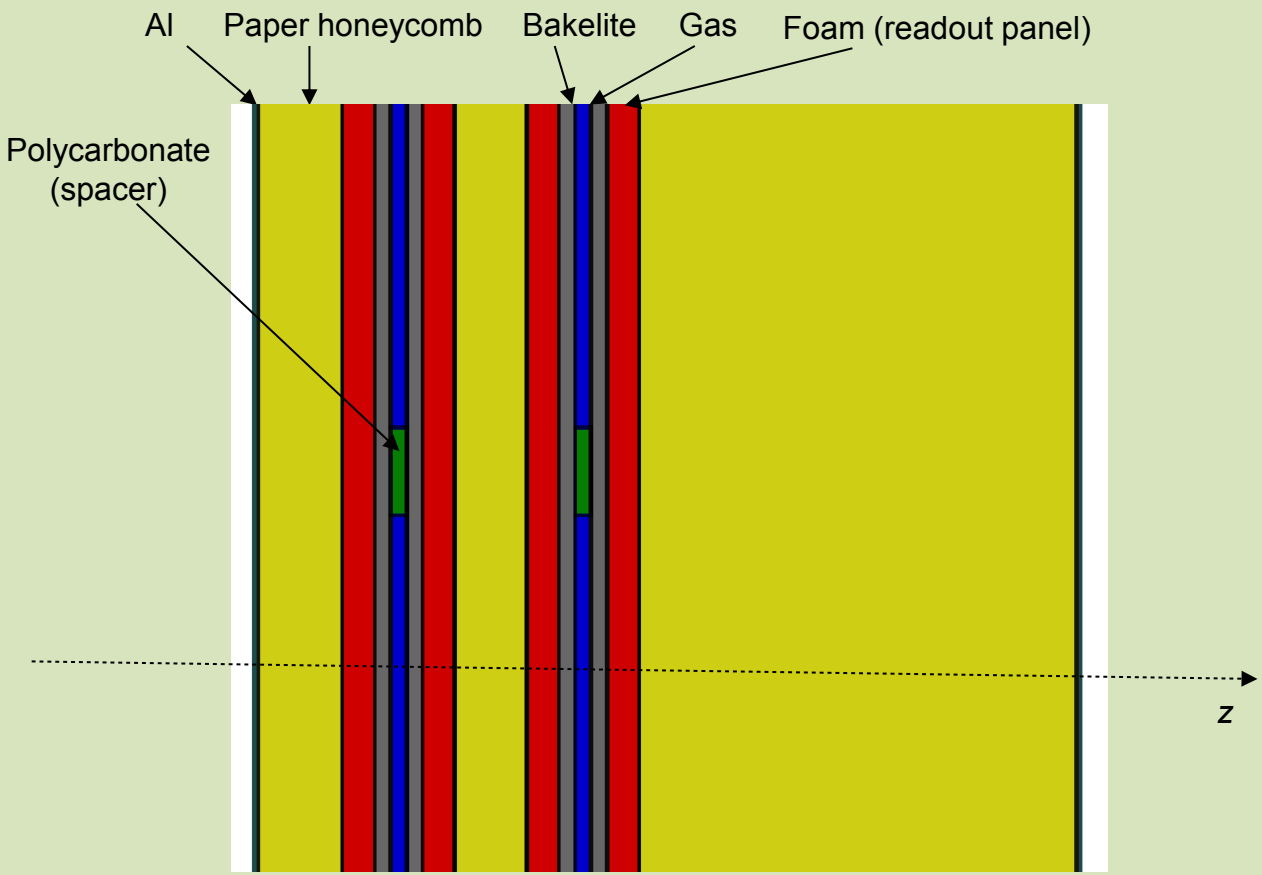
Sensitivity is assumed flat for low energy neutrons below 10^(-4) GeV

Goal: derive RPC sensitivity to neutrons and photons using Geant4

Single-gap RPC sensitivity from ATL-SOF-INT-2013-001



RPC model



Standalone ATLAS double-layer RPC simulated in Geant4
Spacers included in gas gap:
1.0 cm diameter and 10.0 cm pitch in both x,y
Possibility to include electric field in the gap (5.5 kV/mm)

Garfield ++

Garfield++ provides the simulation of charged particle propagation in the gas
and the avalanche development

Basic unity is not GEANT4 single ionization but Cluster of Ionization

Test
Muons of 10 GeV energy (uniform signal along the gap)

GEANT4 – how much deposited energy

Garfield – cluster number in the gap

Obtain a correlation between lost energy and cluster number

Garfield ++

Ionization energy is input for Geant4

Garfield++ provide the simulation of charged particle propagation in the gas
and the avalanche development

Basic unity is not GEANT4 single ionization but Cluster of Ionization

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