Simulation of the background particle flow for the Upgrade II ECAL

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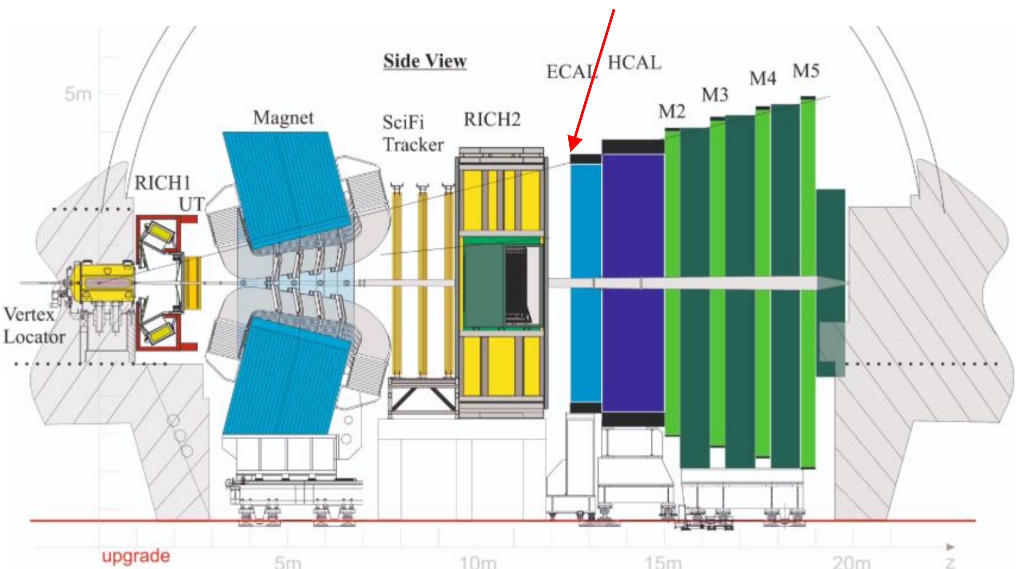
Outline

- Introduction
- Simulation
- Results
- Summary

Introduction

- The proposed LHCb Upgrade II is to make full use of the high-luminosity LHC (HL-LHC)
- With the increase of luminosity, the background in ECAL, which refers to trivial events of pp collisions, is expected to increase significantly
- Information of the background in ECAL, e.g. occupancy, energy flow and transverse energy flow, could be essential for many studies, full simulation or fast simulation

The surface of Ecal



Simulation

- Use Gauss v51r2 for the simulation

- Luminosities set to a few values between $2 \times 10^{32}\ \mathrm{cm}^{-2} s^{-1}$ to $2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

- Information of particles ($\gamma, e^{\pm}, \pi^{\pm}, K^{\pm}, n/\bar{n}, p/\bar{p}$, etc.) arriving at the surface of the ECAL is recorded as a TTree
  - ✓ The particles arriving at the ECAL surface within 10 ns since the first particle arrives at the surface (most particles arrive in this time interval)
  - ✓ The particles arriving at the surface after 25 ns since the first particle arrives at the surface
    - ✓ Important to study the spillover in ECAL

Information recorded

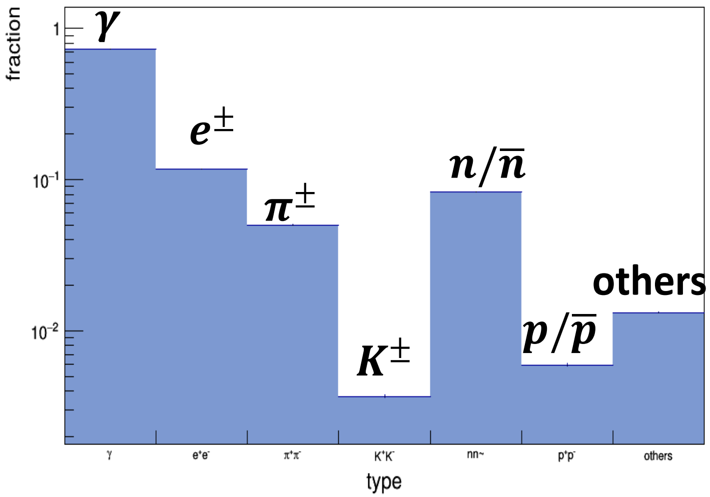
- ➢ Types of the particles

- ➢ For each particle, the following information is recorded:
  - ✓ energy,
  - ✓ momentum,
  - ✓ position
  - ✓ and arrival time

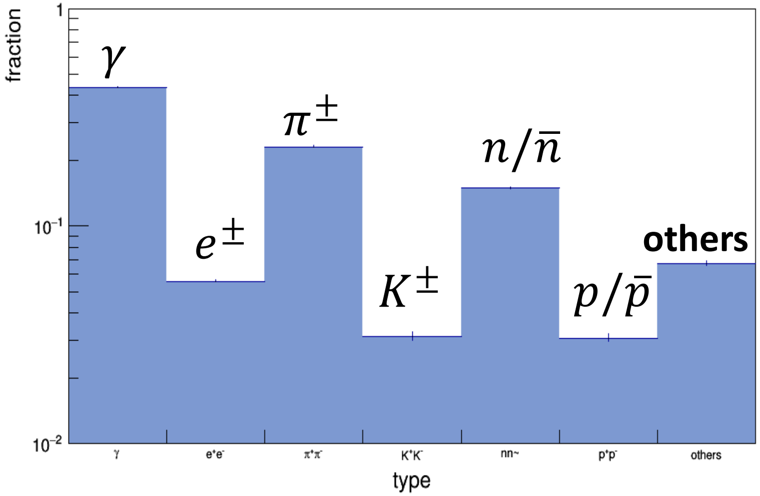
These information can be used as inputs of other simulation for ECAL studies

Particles per event within 10 ns

fraction of particles



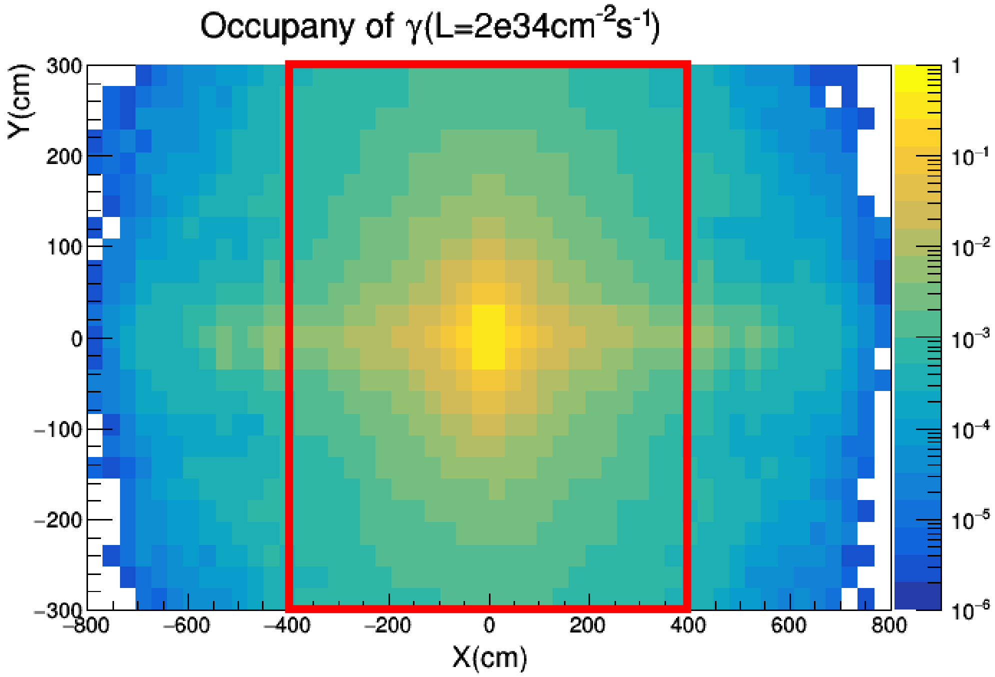
Fraction of the total energy



450 events are used

- More γ's than other particles, and $K^{\pm}$ and $p/\bar{p}$ are less than other particles
- γ's carry more energy but their average energy is smaller than other particles
- $n/\bar{n}$ carry a significant amount of the total energy

Occupancy of γ within 10 ns

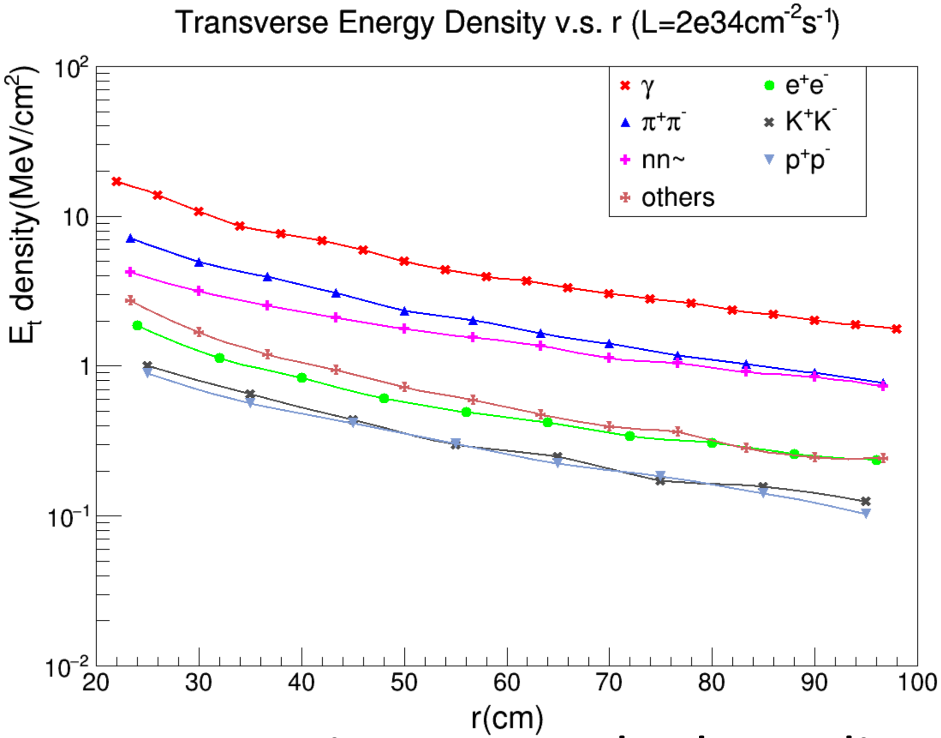


n/cm^2

The red box is the real size of ECAL

- Highest occupancy of γ is found near the beamline as expected
- These kind of xy plots with proper bins are useful for fast simulation like delphes to take these background information into account.

Transverse energy (r in 20-100cm) within 10 ns



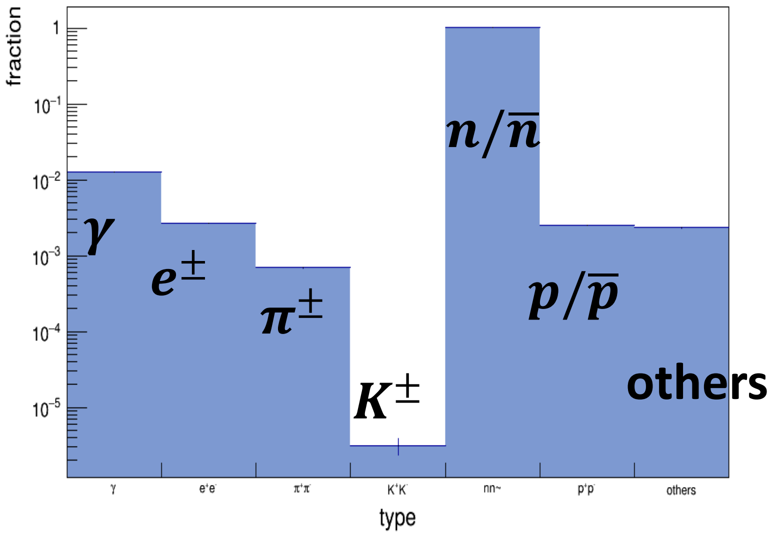
r: Distance to the beamline

- The transverse energy of a certain particle is larger near the beamline ($r = 0$)
- Our interested signal will be affected by the transverse energy of background,
- This plot can tell us the average transverse energy of the background attached to the signal.

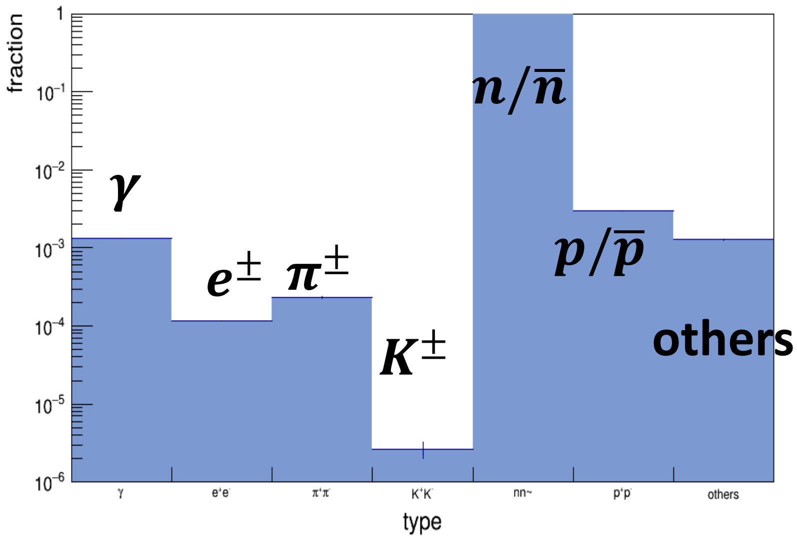
Particles per event after 25 ns

The neutron kinetic energy cut in the simulation is 10 MeV (default)

fraction of particles



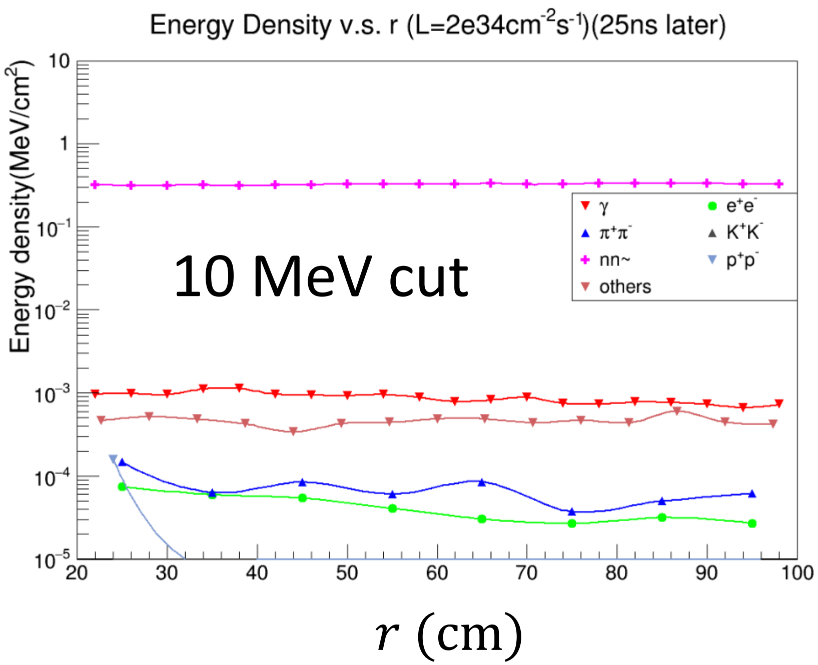
Energy fraction of particles

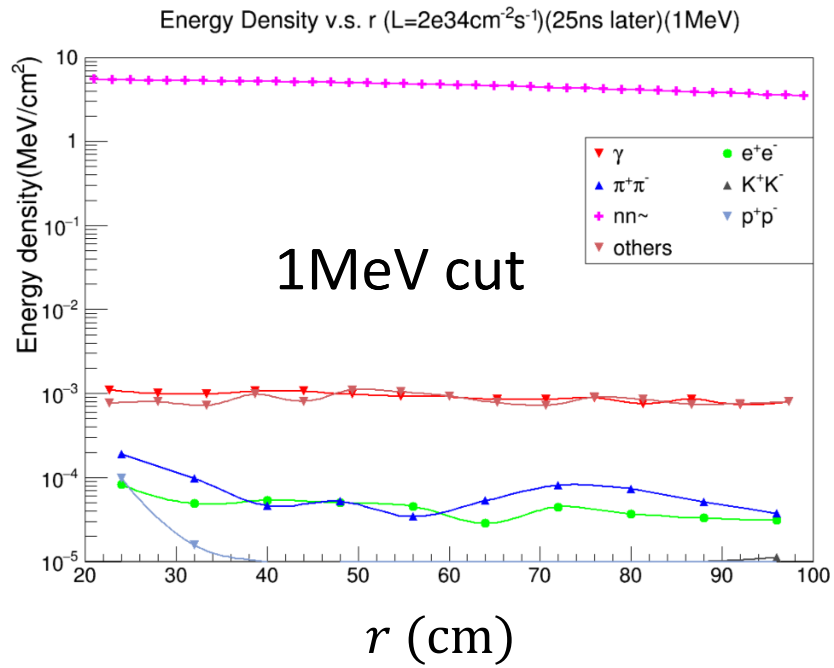


22700 events are used.

- After 25 ns, the neutron and antineutron dominate

Energy flow after 25 ns (r 20-100 cm)





- When neutron kinetic energy cut is 10 MeV, an interesting result is that the energy flow of neutron and antineutron is nearly uniform
- When neutron kinetic energy cut is 1 MeV, energy flow of neutron decreases slightly with the increasing of r, nearly uniform
- The energy flow of neutron with kinetic energy cut equal to 1 MeV increases a lot than 10 MeV

Summary

- A first simulation of the background particle flow for Upgrade II ECAL was made

- Information of the particles is recorded in a TTree, and the occupancy, energy flow and transverse energy are studied for different arrival time

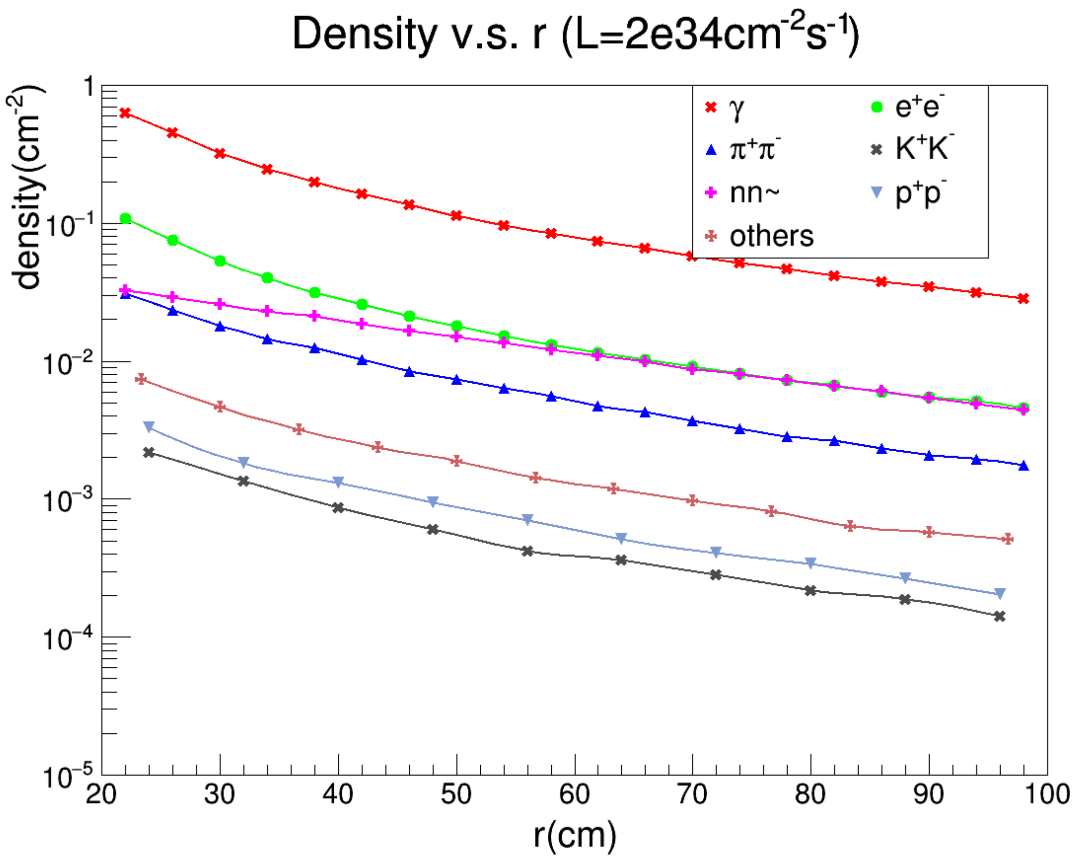
- The ntuples produced in the simulation have been used in other studies, e.g. Markus' Geant4 standalone simulation study

- It can also be used in fast simulation like Delphes to take the background information into account. This can make the results of fast simulation more reliable.

Thanks for you attention!

Backup slides

Occupancy (20-100cm) within 10 ns

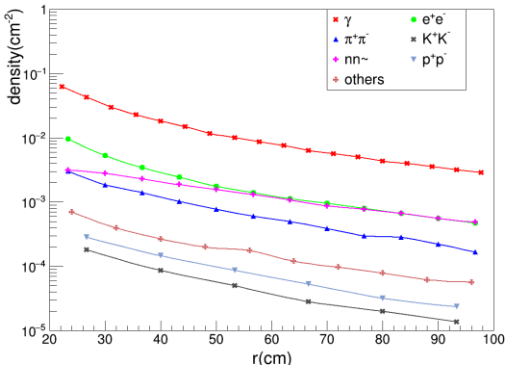


- The fraction of different particles is shown.
- The number of certain kind of particles are larger near the beamline.

Occupancy (20-100cm) within 10 ns

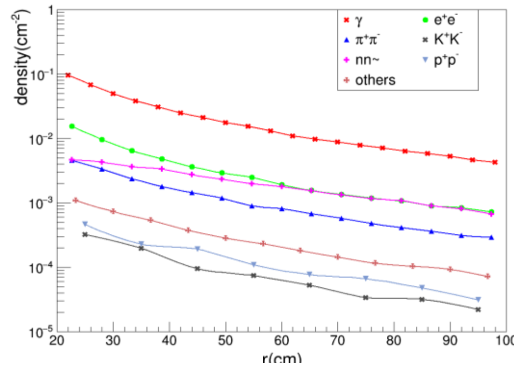
$L = 2 \times 10^{33} cm^{-2} s^{-1}$

n/cm^2



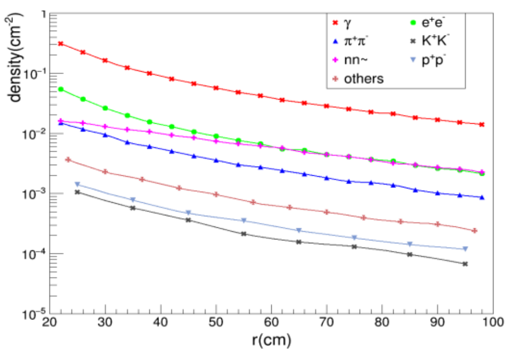
$L = 3 \times 10^{33} cm^{-2} s^{-1}$

n/cm^2



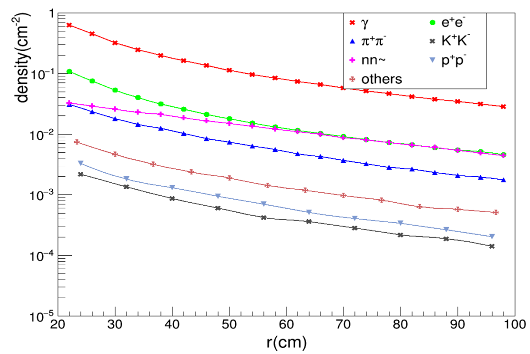
$L = 1 \times 10^{34} cm^{-2} s^{-1}$

n/cm^2



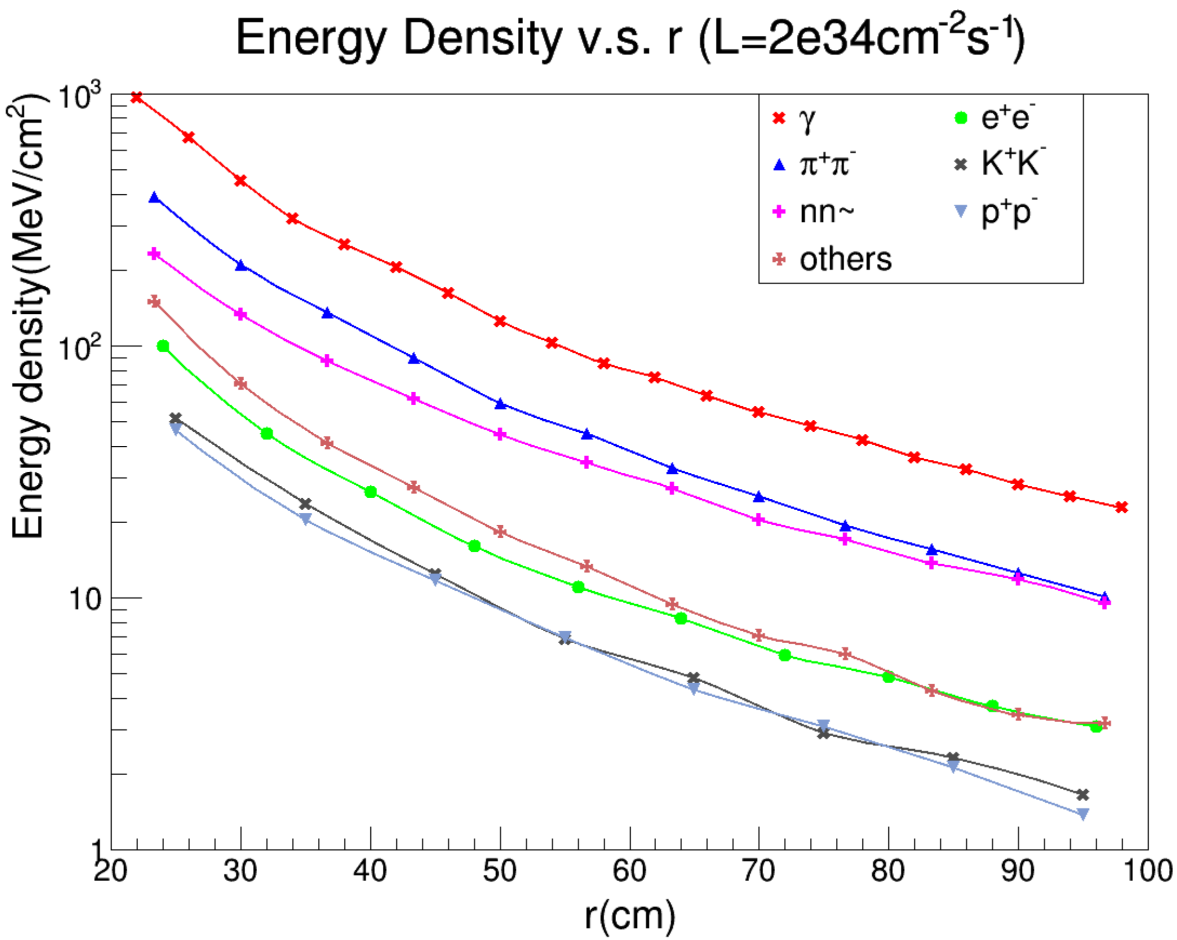
$L = 2 \times 10^{34} cm^{-2} s^{-1}$

n/cm^2



- For all four plots, the occupancy of certain particle increases with the increasing of luminosity.

Energy flow (20-100cm) within 10 ns

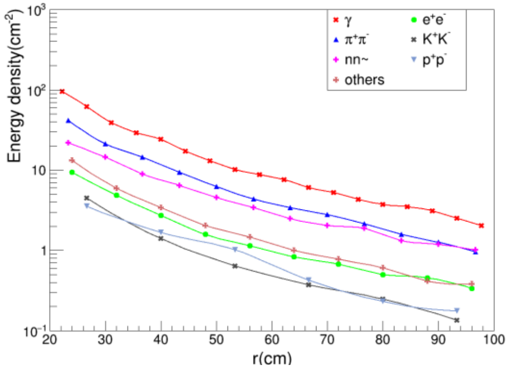


- The fraction of energy flow of different particles is shown.
- The energy flow of certain kind of particle is larger near the beamline.

Energy flow (20-100cm) within 10 ns

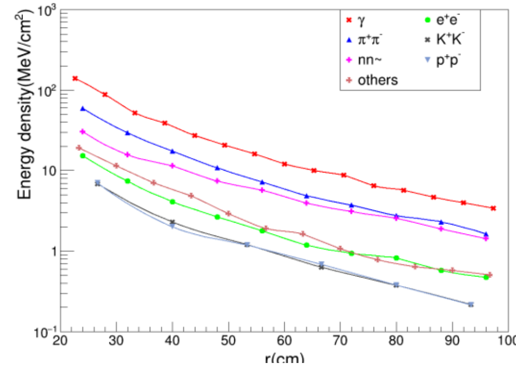
$L = 2 \times 10^{33} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



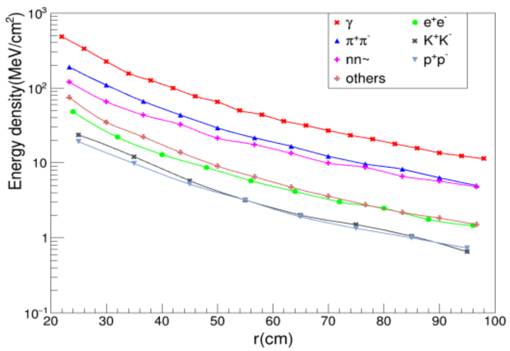
$L = 3 \times 10^{33} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



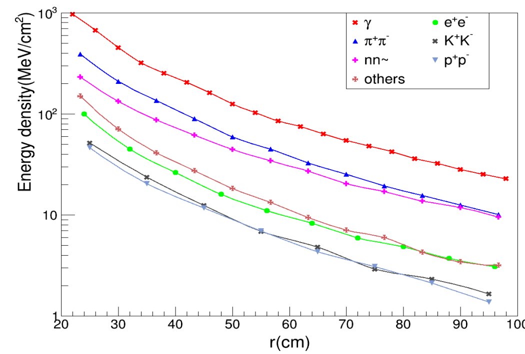
$L = 1 \times 10^{34} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



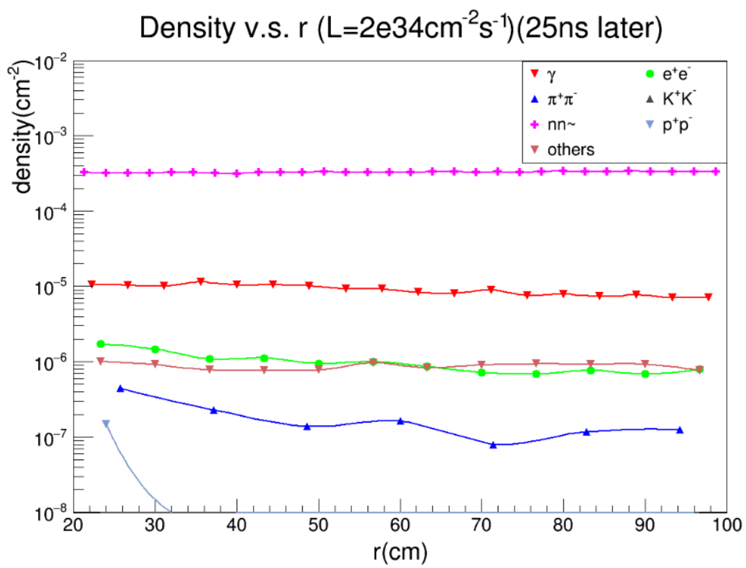
$L = 2 \times 10^{34} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$

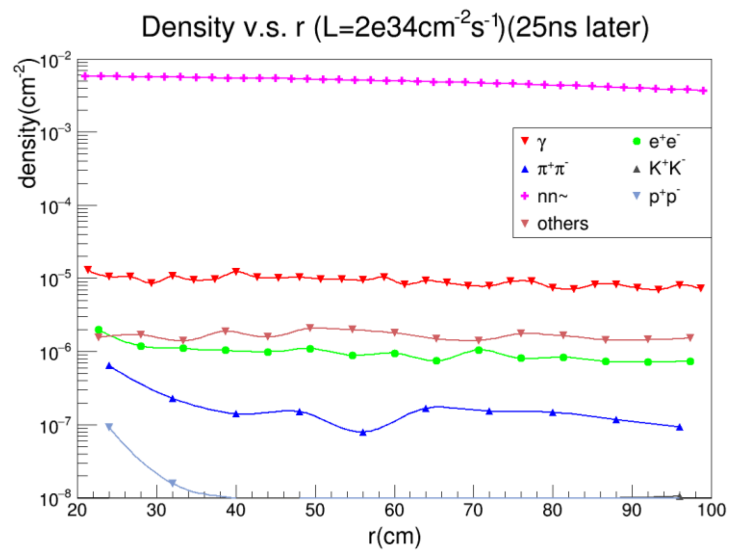


- For all four plots, the energy flow of certain particle increases with the increasing of luminosity.

Occupancy after 25 ns range (r 20-100 cm)



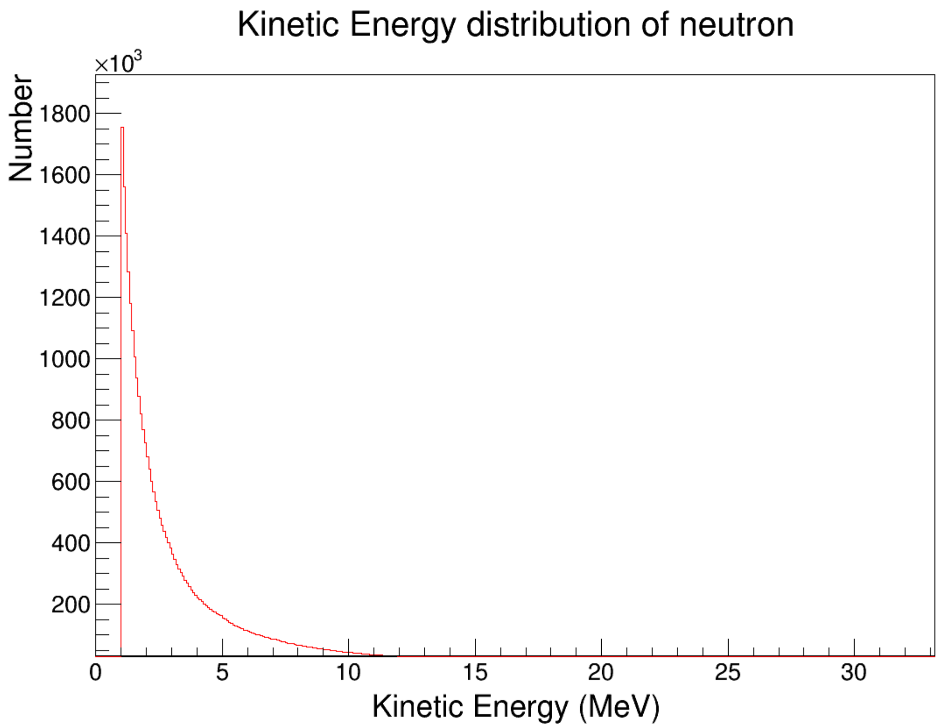
10MeV cut



1MeV cut

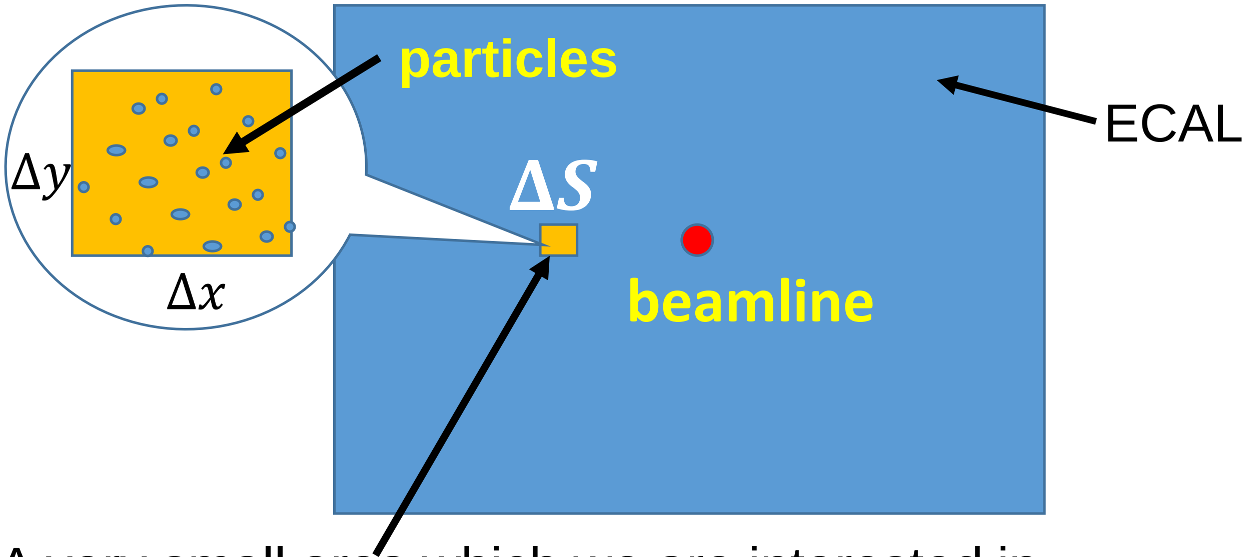
- When neutron kinetic energy cut is 10MeV, an interesting result is that the occupancy of neutron plus antineutron is nearly uniform.
- When neutron kinetic energy cut is 1MeV, occupancy decrease slightly with the increasing of r, nearly uniform.
- The occupancy of neutron kinetic energy cut equal to 1MeV increase a lot than 10MeV.
- Similar results for energy flow.

Kinetic energy distribution for n



- A large fraction of neutron is under 10 MeV. So it is trivial that the energy flow with 1MeV cut is much larger than 10MeV cut.

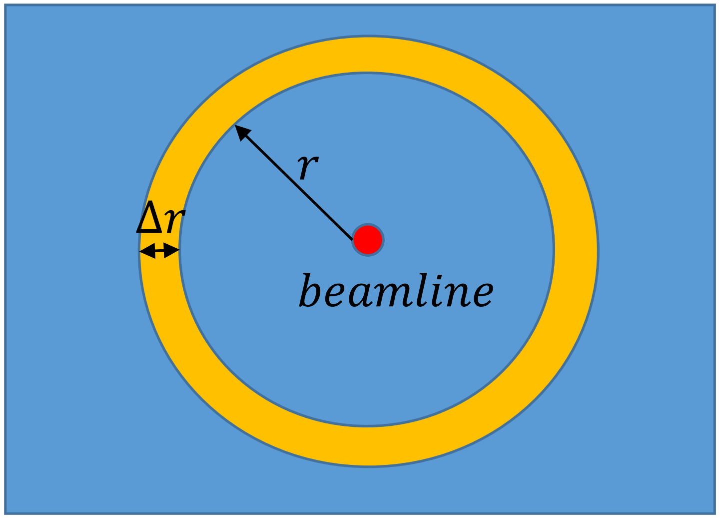
Occupancy

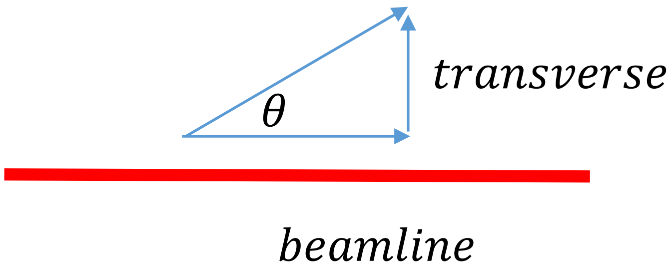


A very small area which we are interested in

$$\text{occupancy} = \frac{\text{number of particles in } \Delta S}{\Delta x \cdot \Delta y}$$

Another definition of occupancy and energy flow





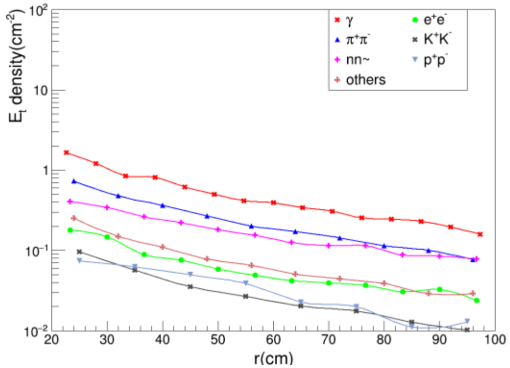
- $\text{occupancy} = \frac{\text{number of particles}}{2\pi r \Delta r}$
- $\text{energy flow} = \frac{\text{energy of particles}}{2\pi r \Delta r}$
- $\text{transverse energy} = E \sin\theta = E \frac{\sqrt{x^2+y^2}}{\sqrt{x^2+y^2+z^2}}$

(x, y, z) is the position of the particle at arrival

Transverse energy (r in 20-100cm) within 10 ns

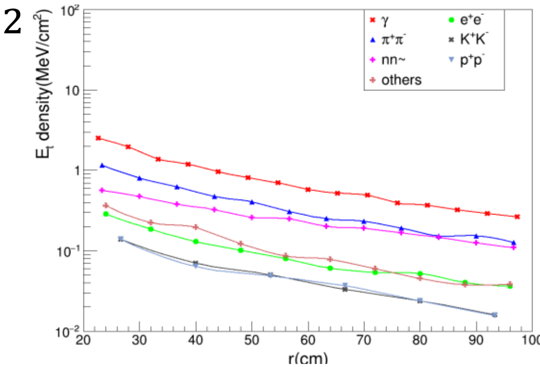
$L = 2 \times 10^{33} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



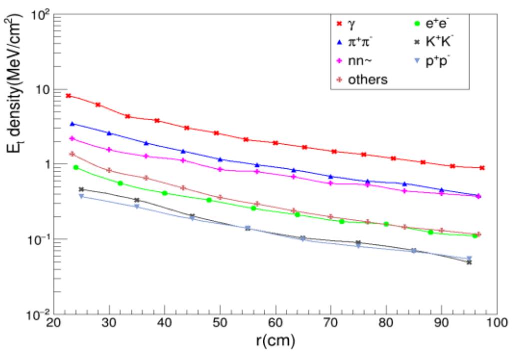
$L = 3 \times 10^{33} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



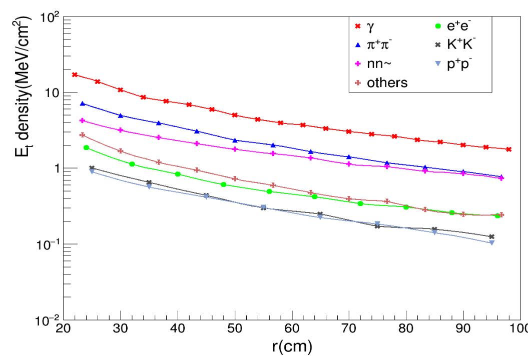
$L = 1 \times 10^{34} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



$L = 2 \times 10^{34} cm^{-2} s^{-1}$

$\mathrm{MeV/cm^2}$



- For all four plots, transverse energy flow of certain particle increases with the increasing of luminosity.
- So do occupancy and energy flow.