Particle distributions, acceptances for a *Forward Hadron Spectrometer*

M. SABATÉ-GILARTE[1,2], F. CERUTTI[1]

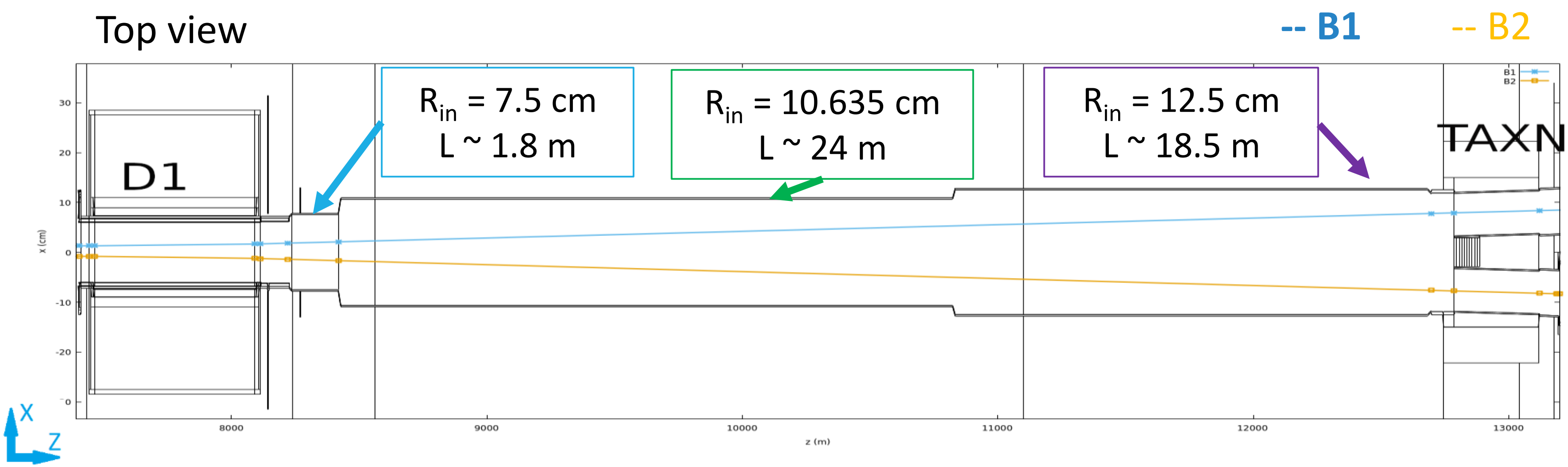
[1]EN-STI-BMI @ CERN

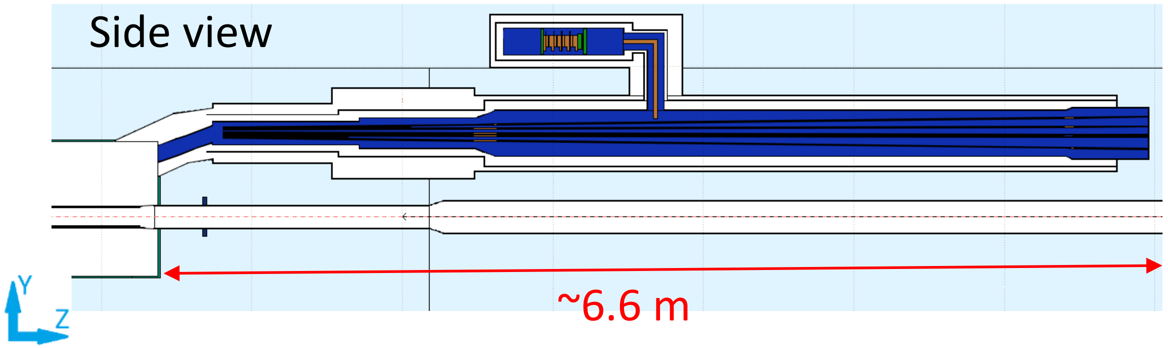
[2]UNIVERSITY OF SEVILLE

Overview

- Outline from D1 to TAXN.
- Effect of the vacuum pipe size.
- Particle distribution at 116 m.
- *(K^-, π^+) and (K^+, π^-) pair from D^0 and D^0-bar.*
- *K^0 and Λ^0.*

Outline from D1 to TAXN





Limited space for the enlargement of the vacuum pipe downstream the D1 due to the presence of the cold diode structure.

Effect of the vacuum pipe size

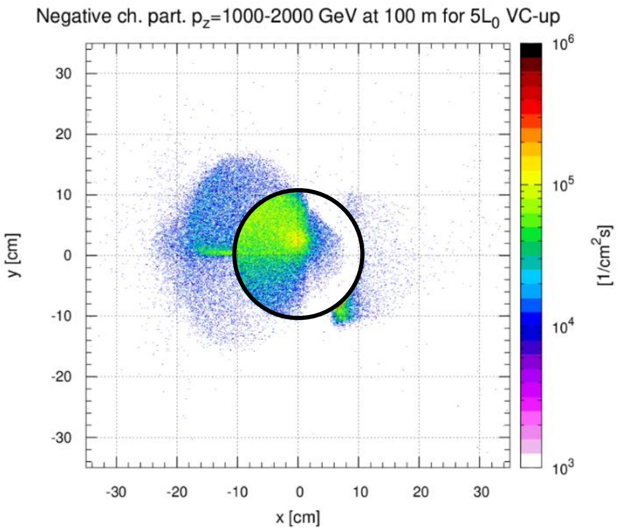
- The size of the vacuum pipe plays an role in the particle distribution due to the interaction of the collision debris with the pipe itself removing high energy particles and generating secondary particle shower.

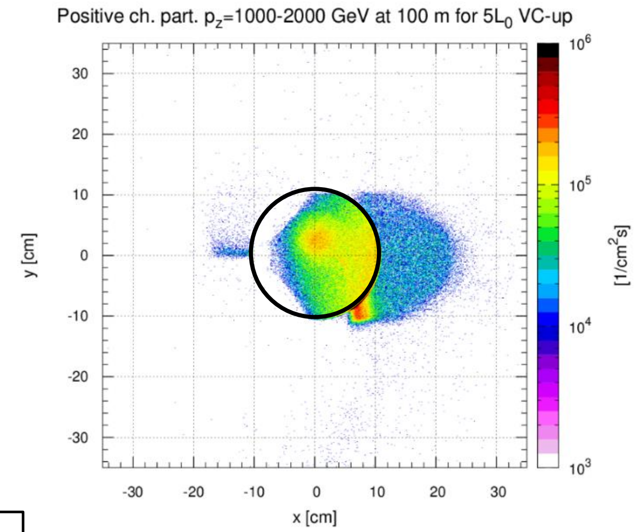
- This section has the aim of showing a comparison of two different set-ups:
  - Reference vacuum pipe layout: 7.5 cm – 10.635 cm – 12.5 cm in radius.
  - Absence of vacuum pipe from 84.3 m onward.

- Simulation conditions:
  - IR5 (CMS).
  - Vertical crossing (VC) of +250 μrad half crossing angle.
  - Instantaneous luminosity of $5 \cdot 10^{34}$ $cm^{-2}s^{-1}$.
  - Cross section for p-p collision 80 mb.
  - Results obtained at 100 m from IP.
  - 1 TeV energy cut applied for all kind of particles.

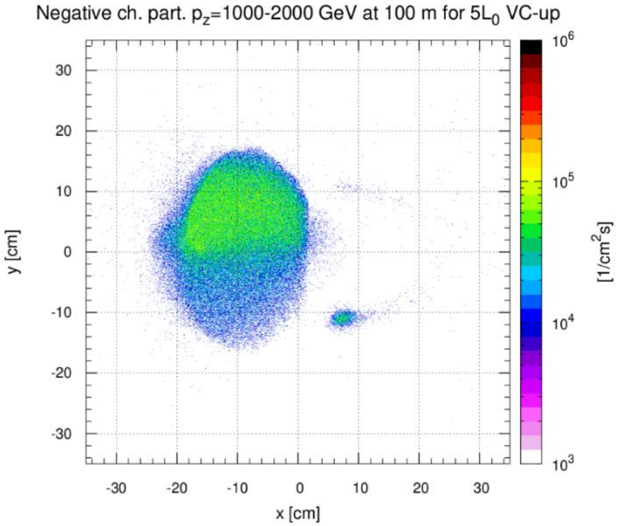
Negative charged particles

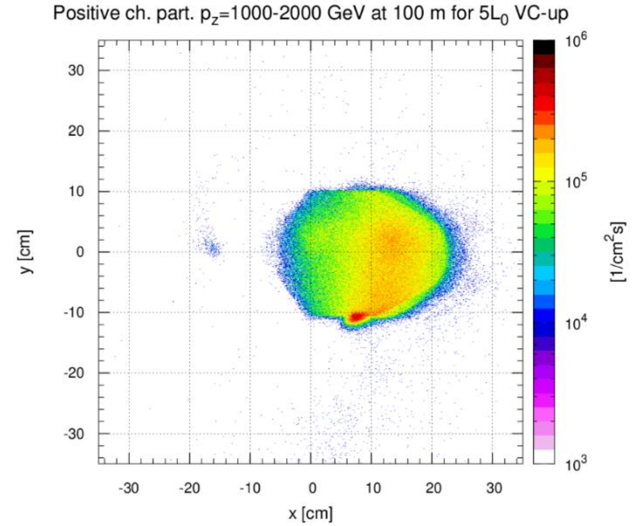
Positive charged particles





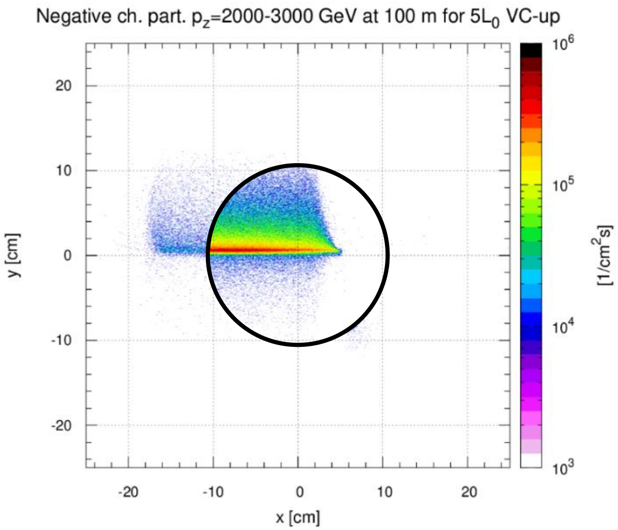
Pz = 1 - 2 TeV

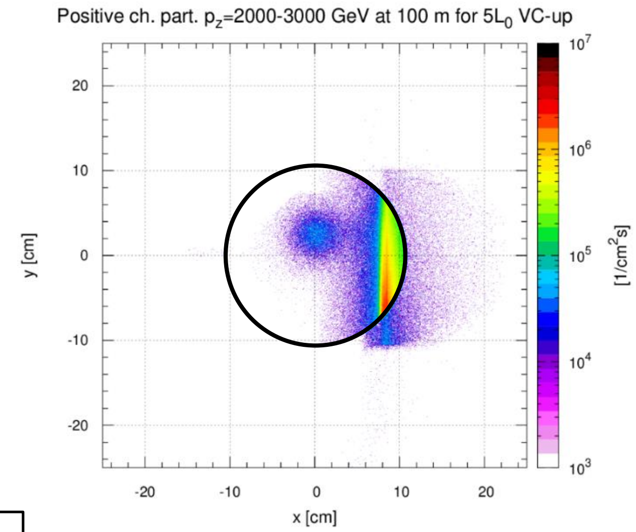




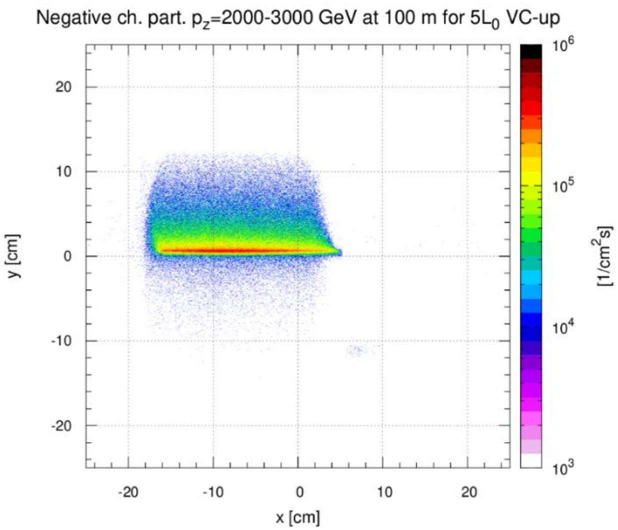
Negative charged particles

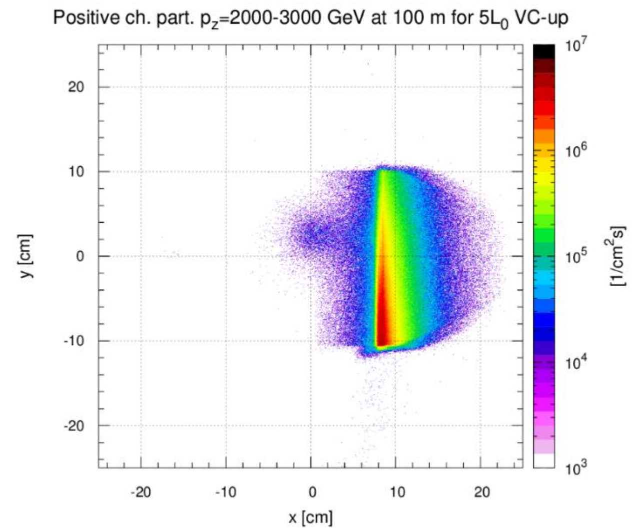
Positive charged particles





Pz = 2 - 3 TeV

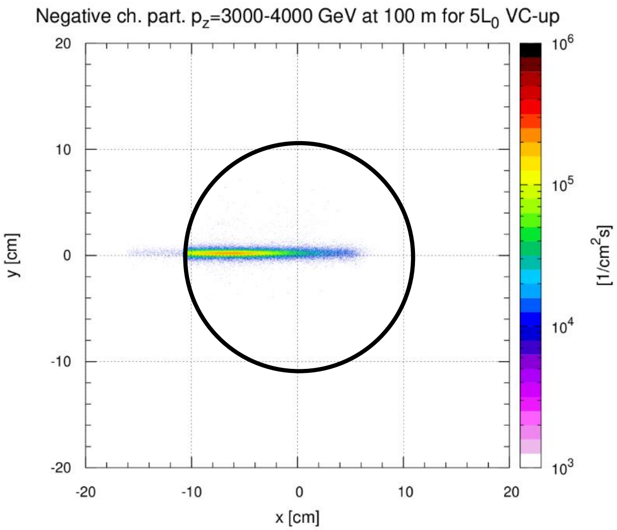


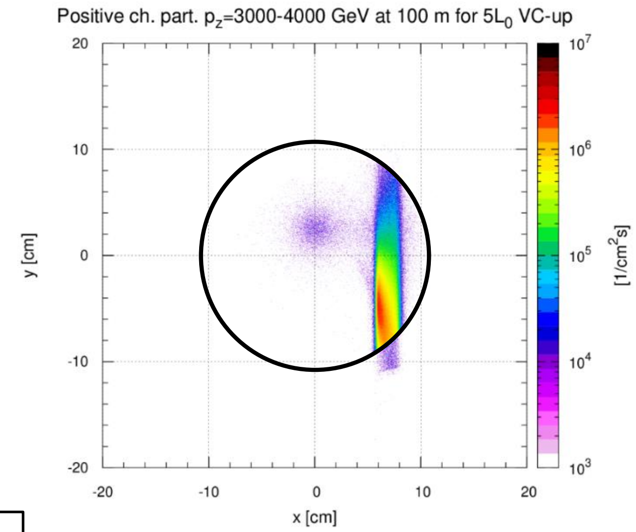


Negative charged particles

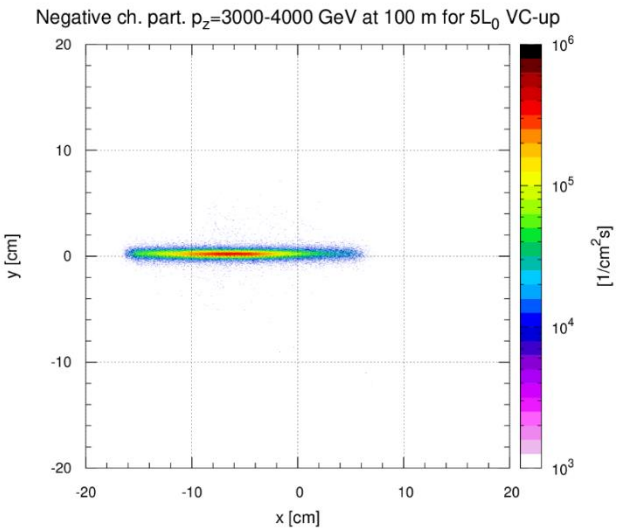
Positive charged particles

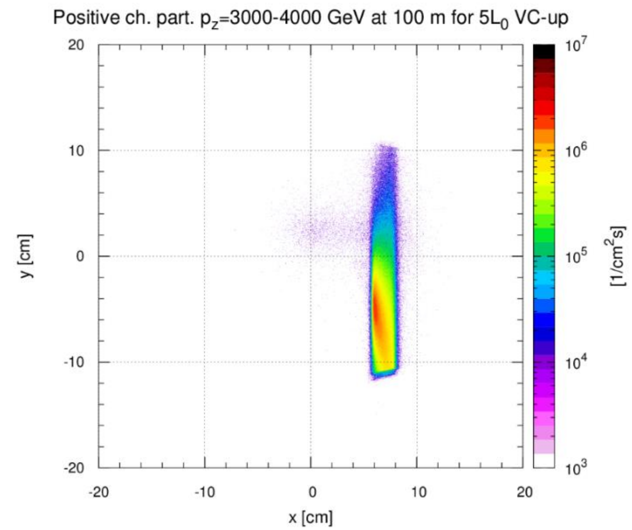
Including pipe effect





Pz = 3 - 4 TeV





Particle distribution at 116 m

- ✓ *Simulation conditions:*
  - ✓ *HL-LHC optics v1.5.*
  - ✓ *ATLAS (**IR1**) and CMS (**IR5**).*
  - ✓ *Instantaneous luminosity: **$5 \cdot 10^{34}$ cm^{-2}s^{-1}**.*
  - ✓ *Cross section for the p-p collision: **80 mb**.*
  - ✓ *Horizontal (**250 μrad**) and Vertical (**+ 250 μrad**) crossing.*
  - ✓ *Energy cut at 1 TeV for all particle type implemented in the simulations.*
  - ✓ *All studies are obtained at **116 m from the IP**.*

- ✓ *Outline:*
  - ✓ *Particle spatial distribution.*
  - ✓ *Particle distribution based on generation number (GN):*
    - ✓ *GN = 1 : original collision products.*
    - ✓ *GN > 2 : re-interaction products.*

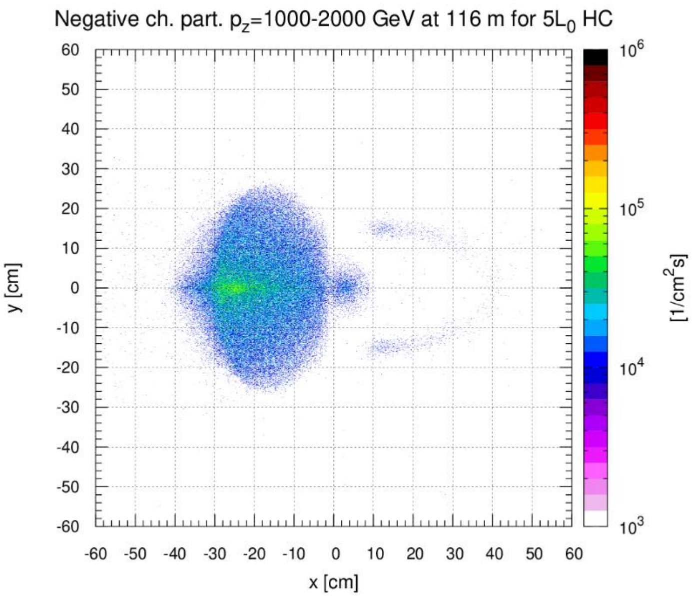
✓ *Particle spatial distribution:*

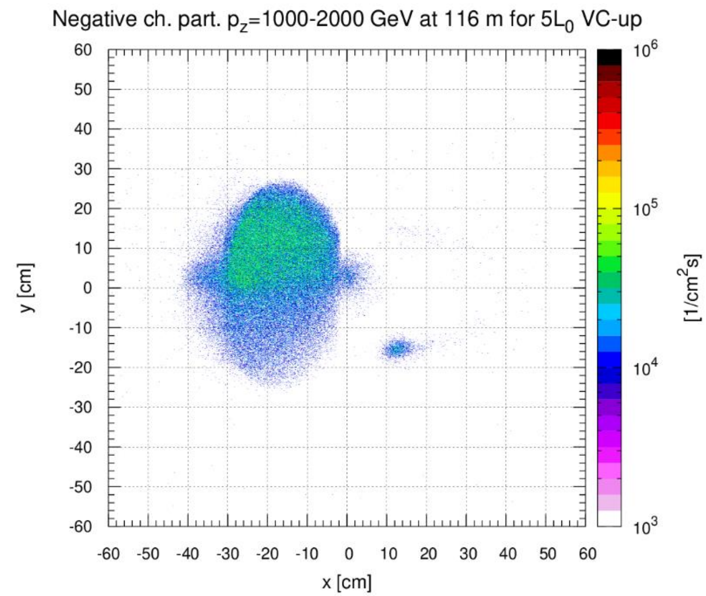
- ✓ *Horizontal crossing in IR1 (ATLAS).*
- ✓ *Vertical crossing in IR5 (CMS).*

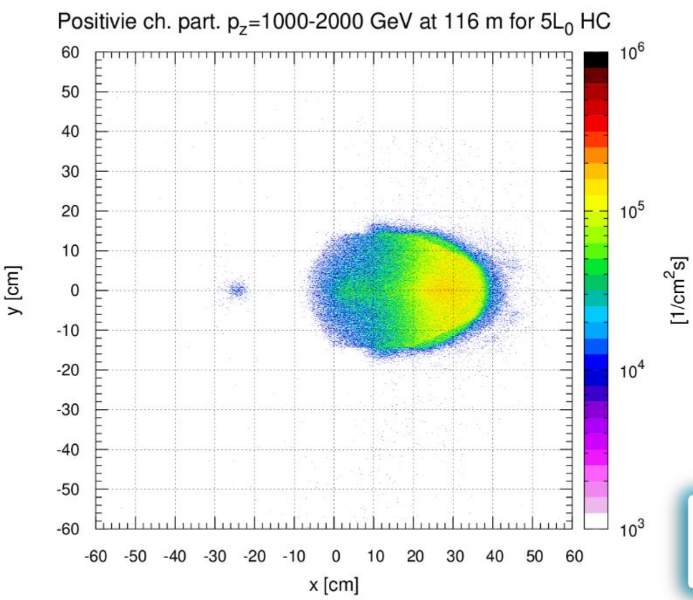
✓ *Particle distribution based on generation number.*

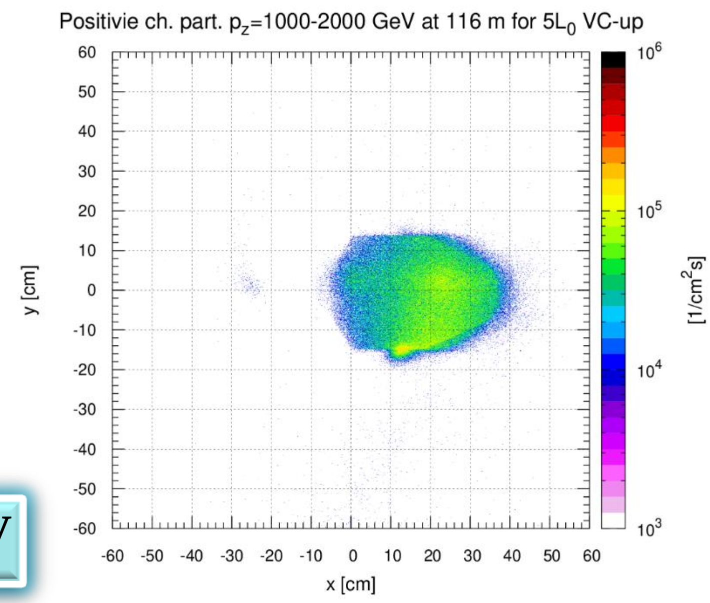
HC

VC-up





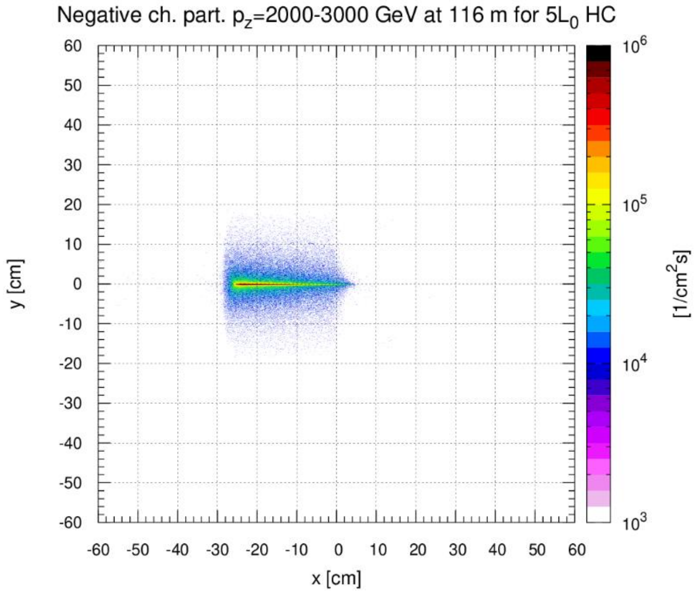


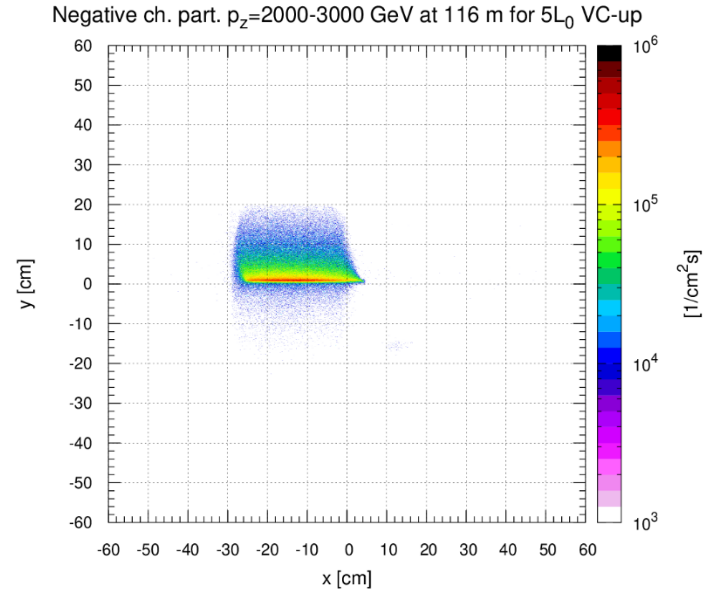


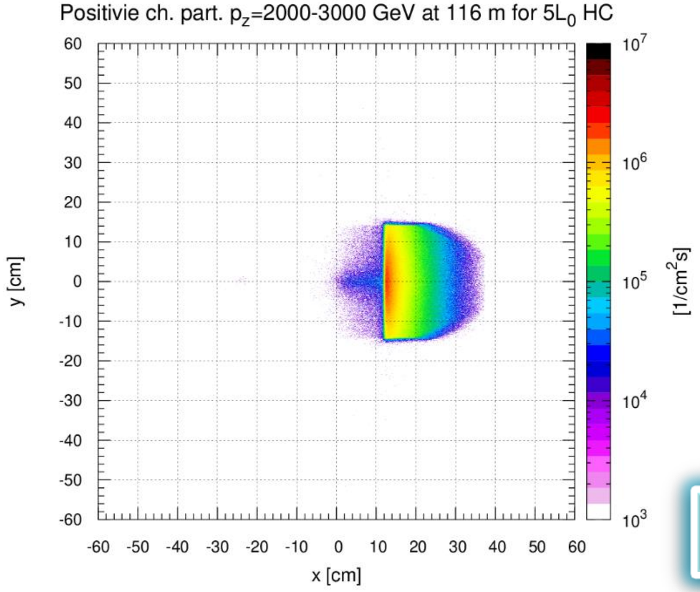
p_z =1-2 TeV

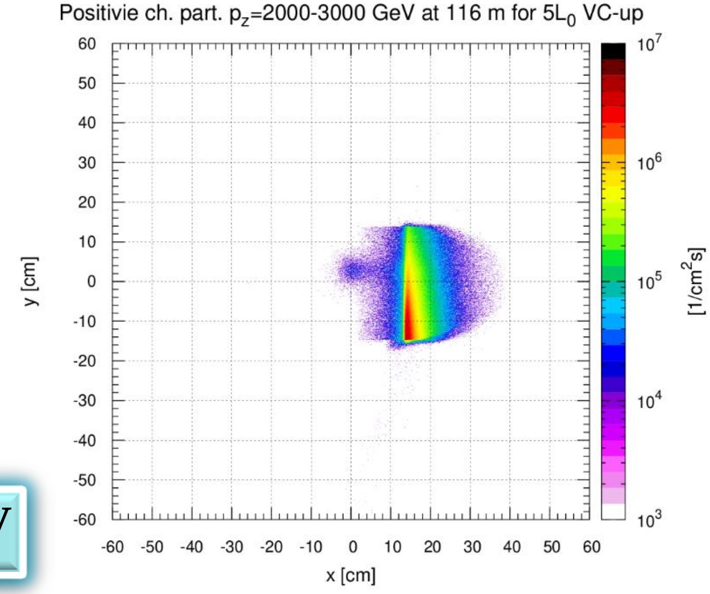
HC

VC-up





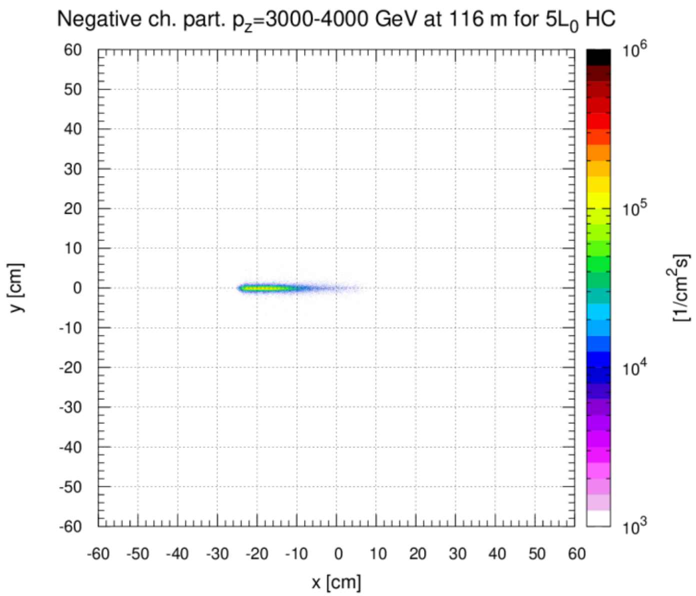


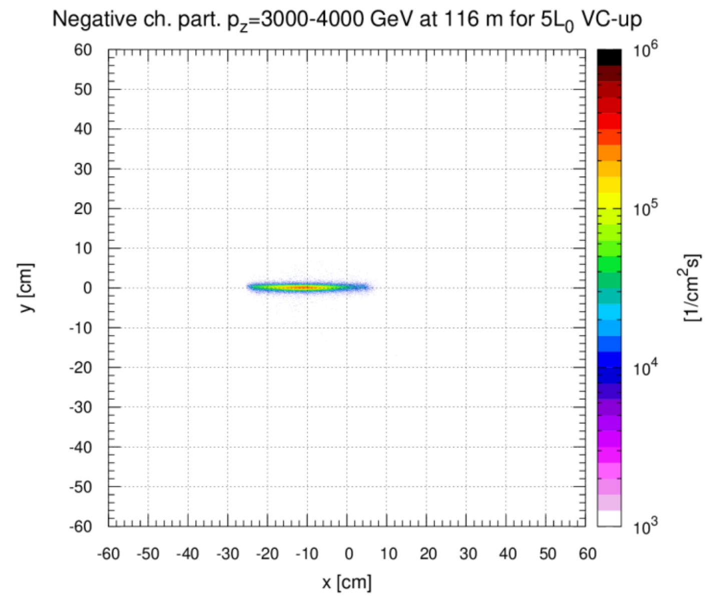


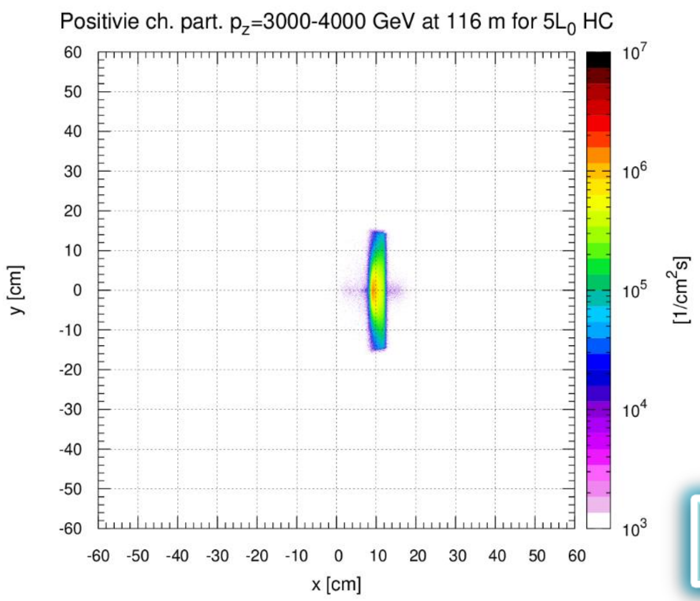
p_z =2-3 TeV

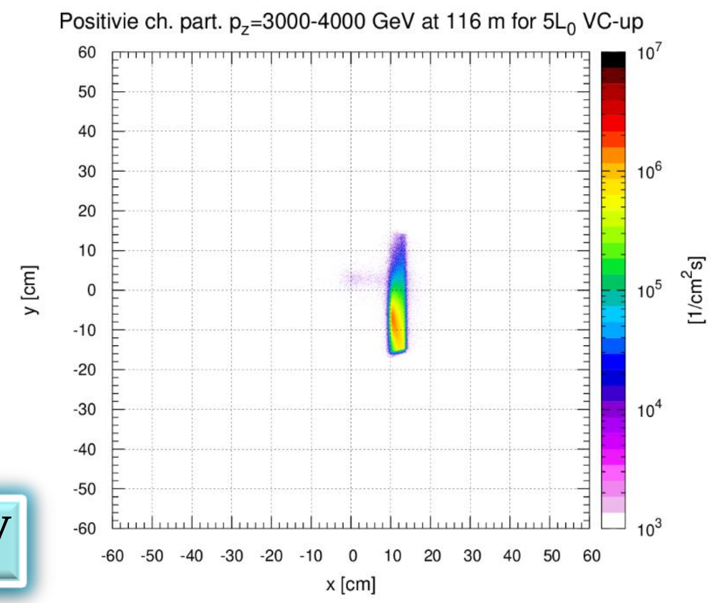
HC

VC-up





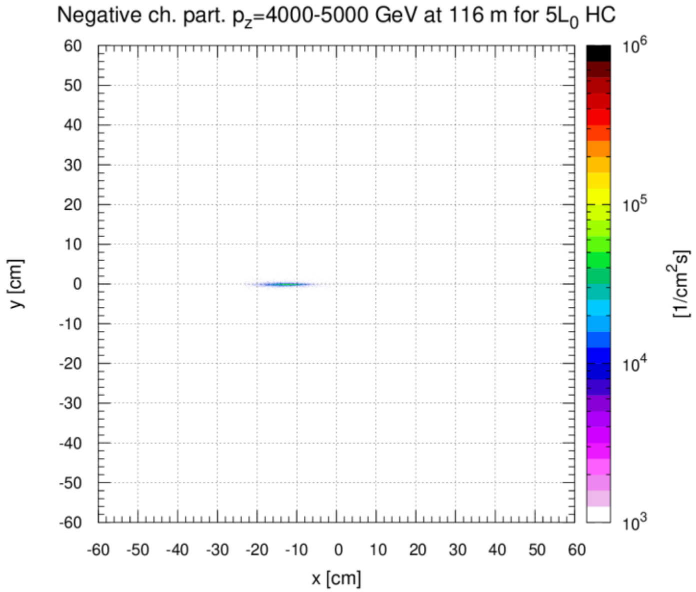


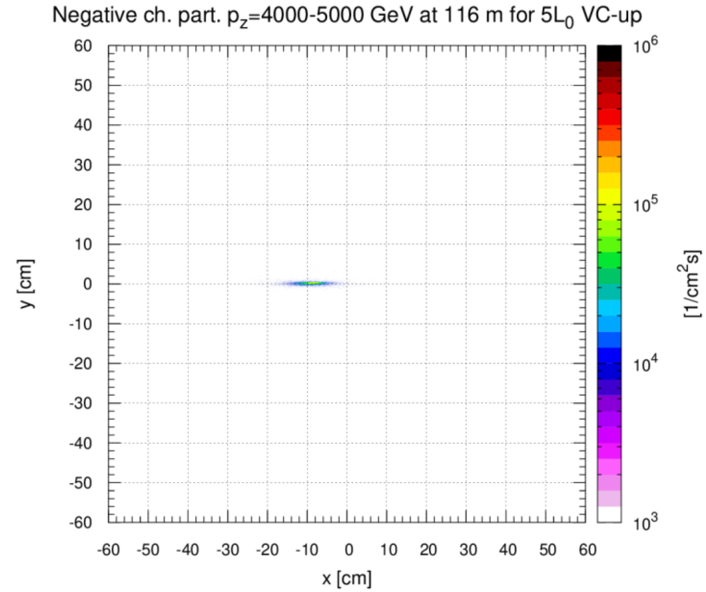


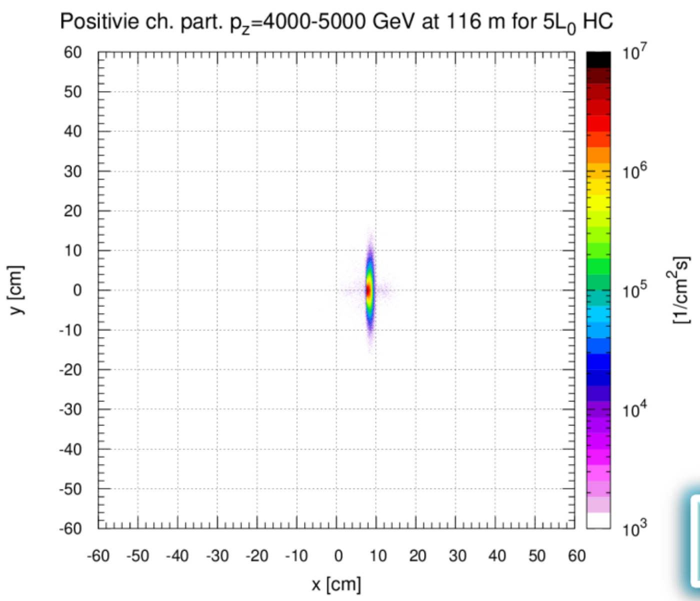
p_z =3-4 TeV

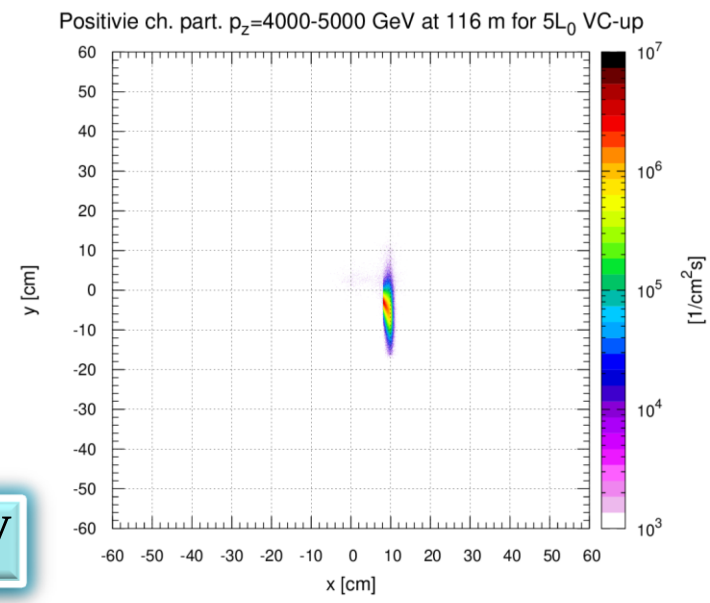
HC

VC-up





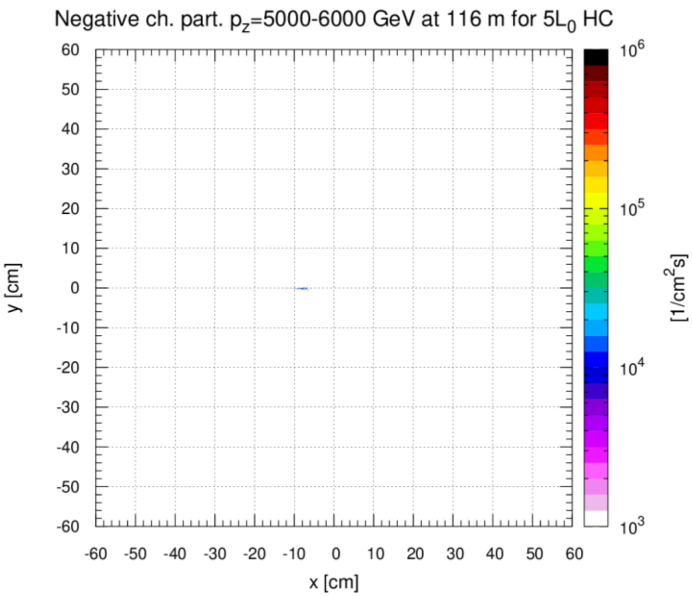


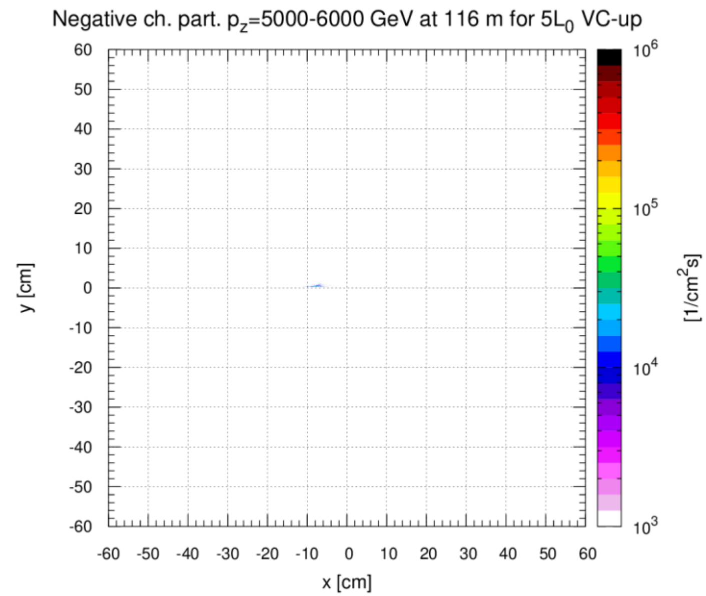


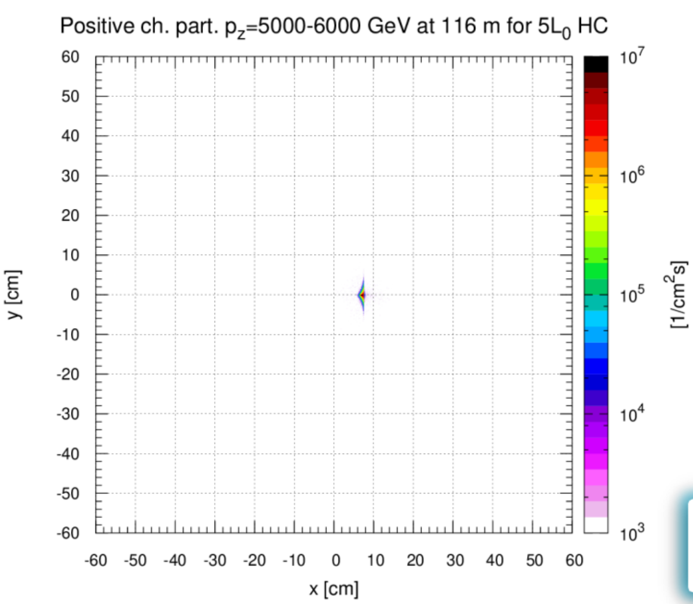
p_z =4-5 TeV

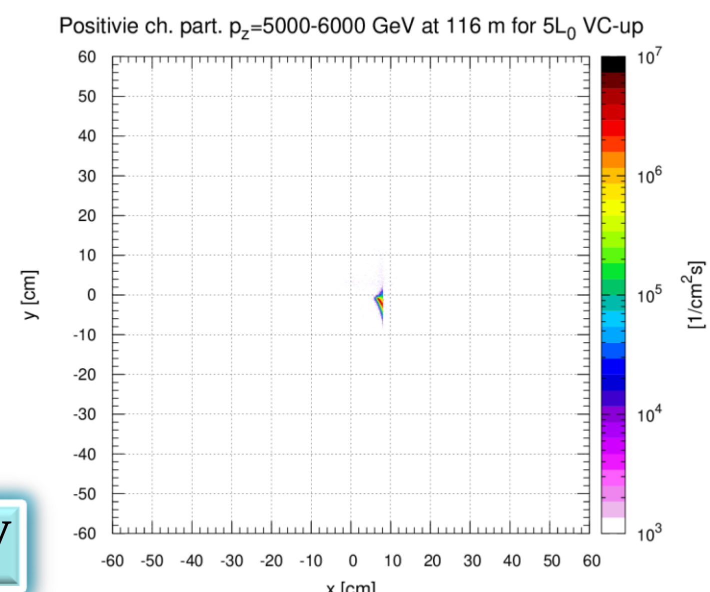
HC

VC-up







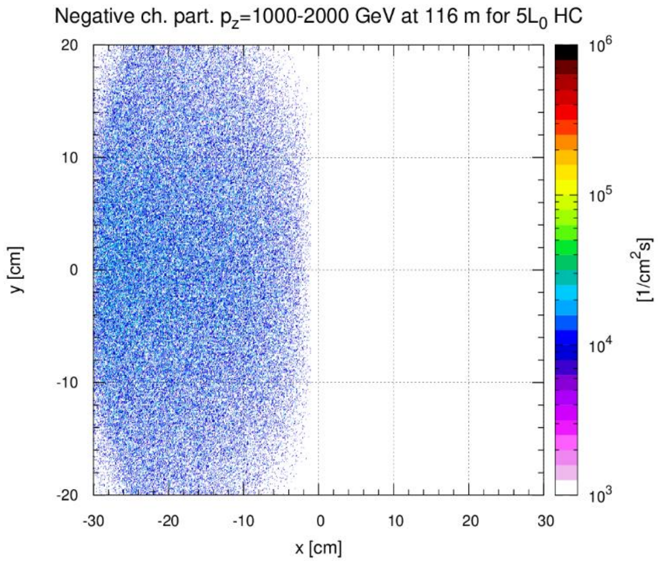


p_z =5-6 TeV

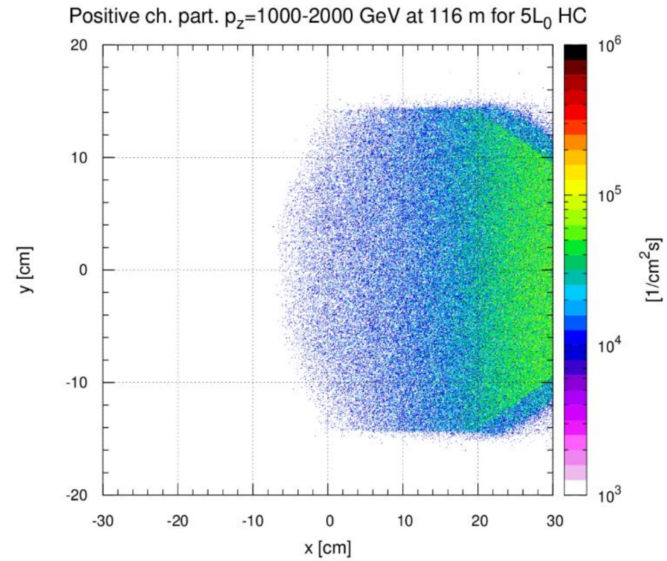
- ✓ *Particle spatial distribution.*
- ✓ *Particle distribution based on generation number:*
  - ✓ *Horizontal crossing in IP1 (ATLAS).*
  - ✓ *Vertical crossing in IP5 (CMS).*

Collision products

Generation Number = 1



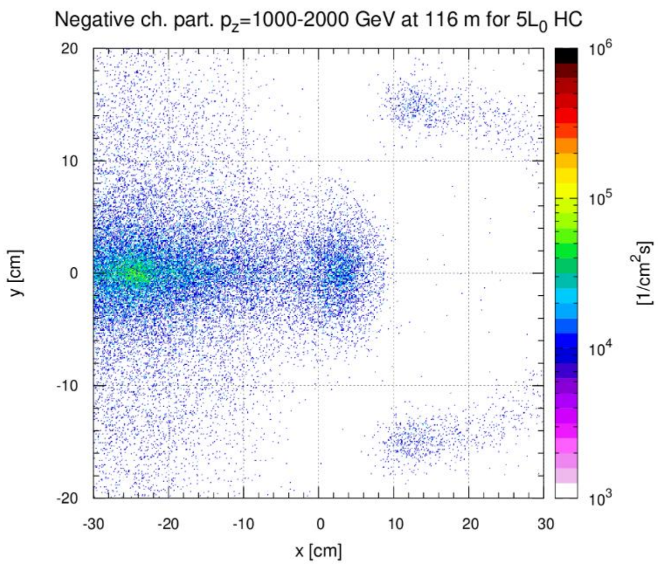
Generation Number = 1



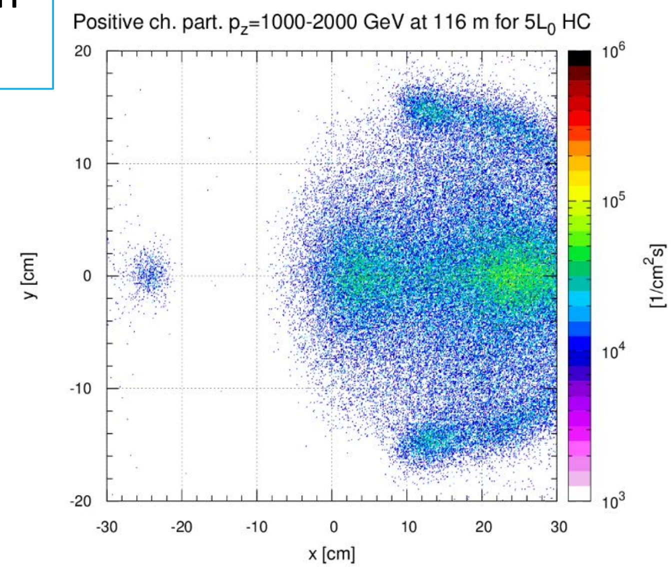
HC

re-interaction products

Generation Number ≥ 2



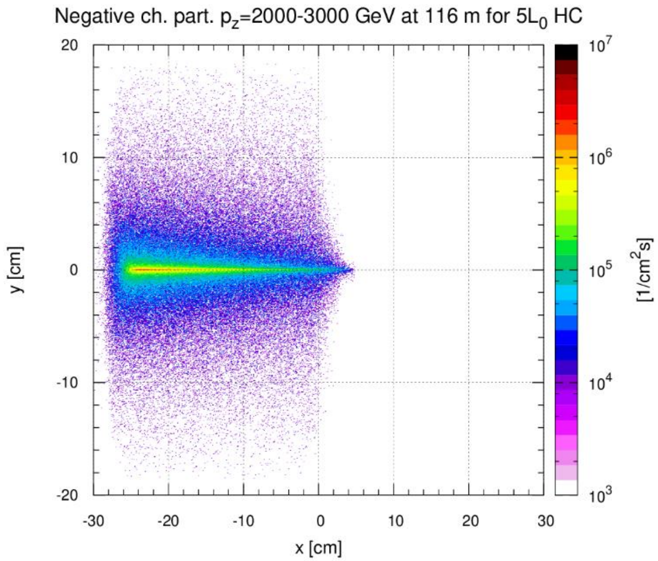
Generation Number ≥ 2



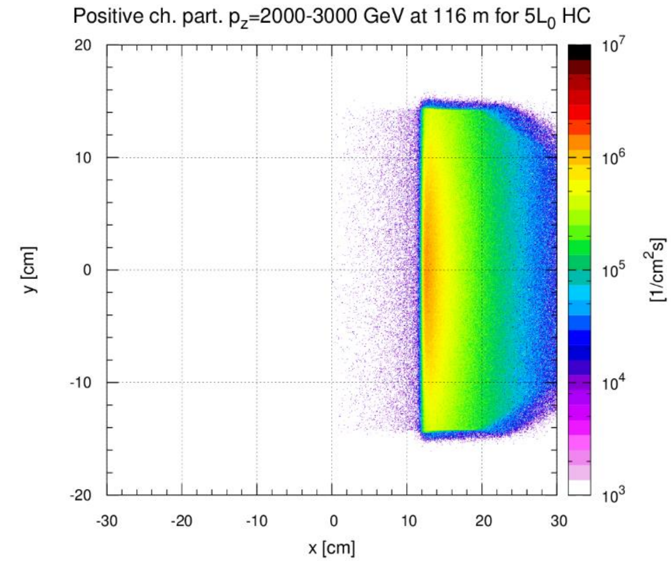
Negative **P_z = 1 – 2 TeV** **Positive**

Collision products

Generation Number = 1



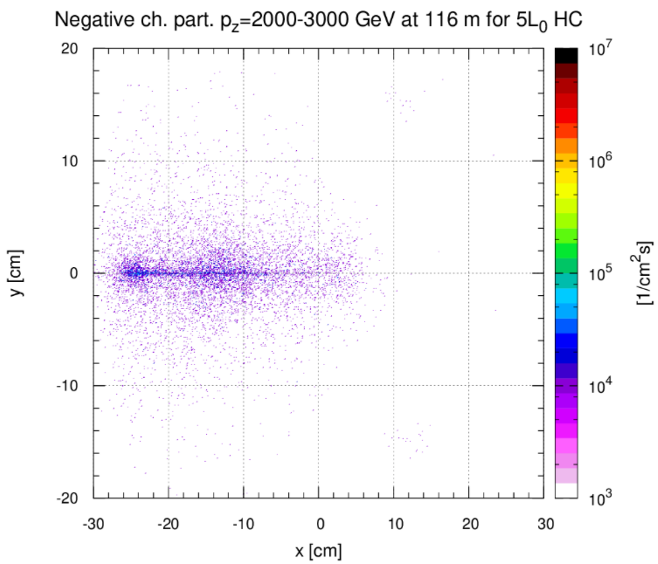
Generation Number = 1



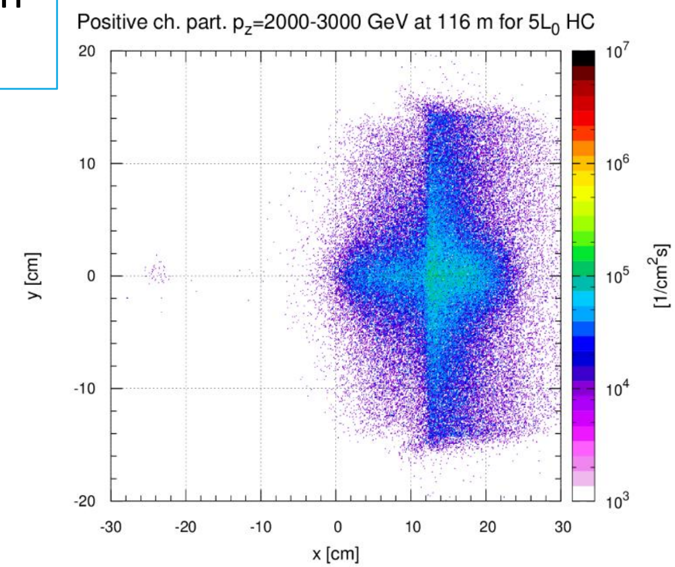
HC

re-interaction products

Generation Number ≥ 2



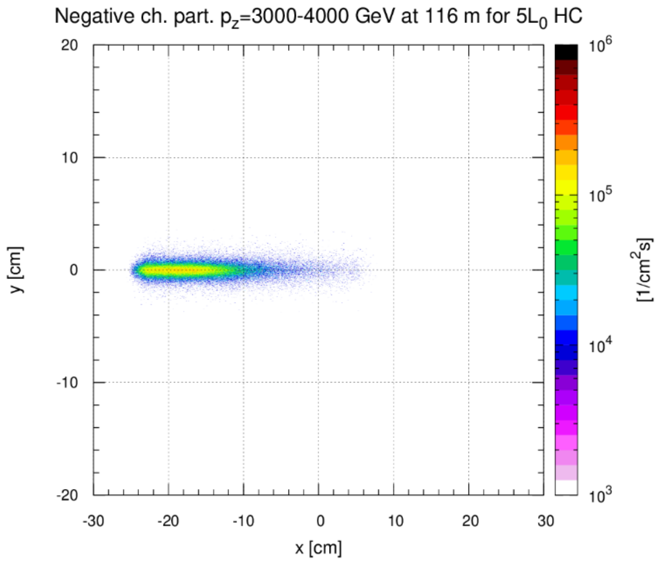
Generation Number ≥ 2



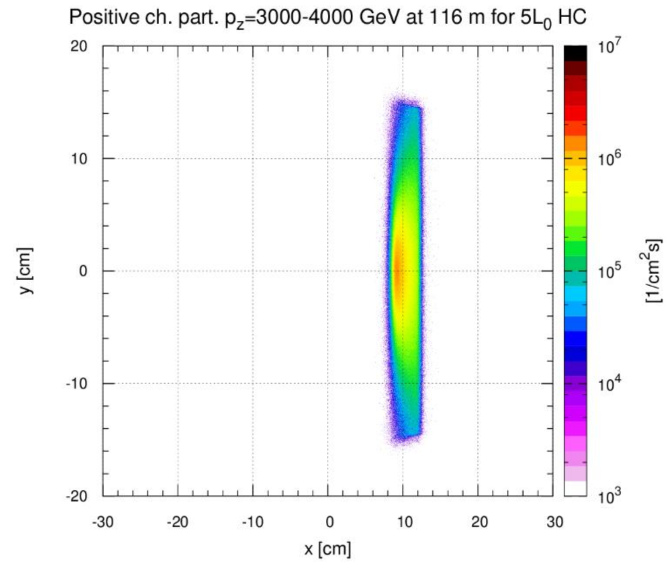
Negative | **P_z = 2 – 3 TeV** | **Positive**

Collision products

Generation Number = 1



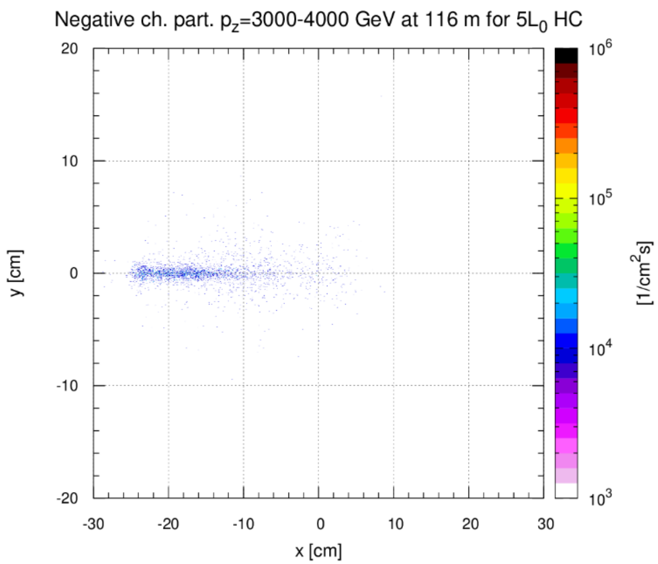
Generation Number = 1



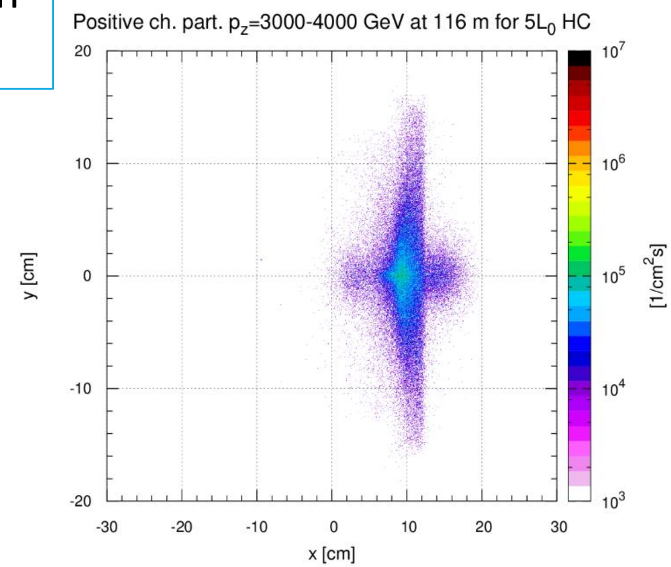
HC

re-interaction products

Generation Number ≥ 2



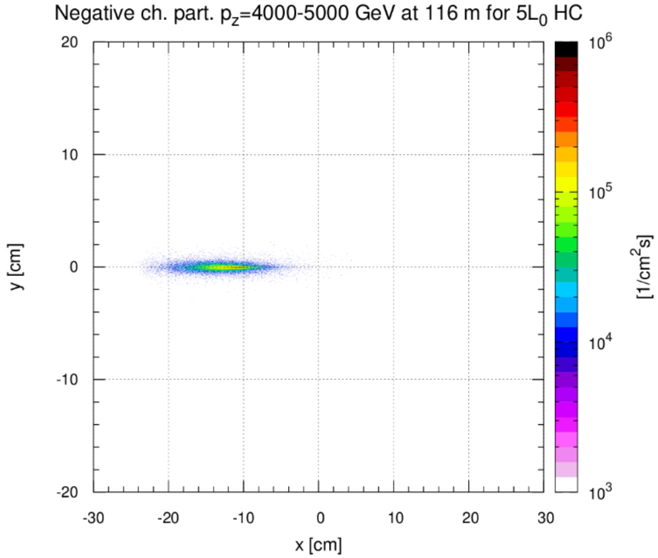
Generation Number ≥ 2



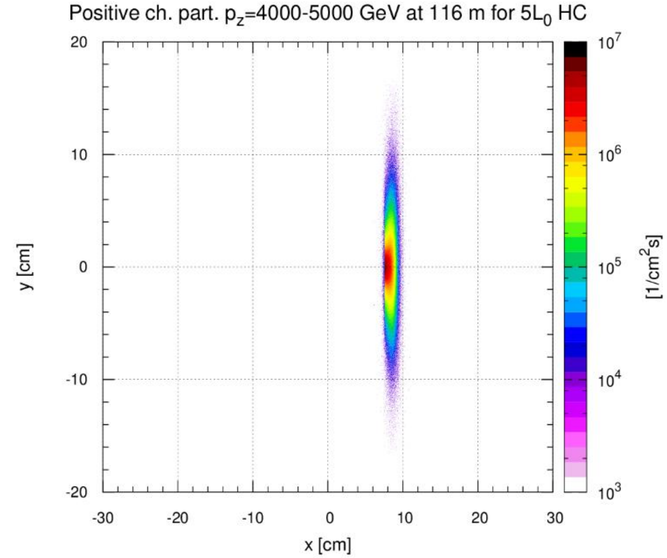
Negative **P_z = 3 – 4 TeV** **Positive**

Collision products

Generation Number = 1



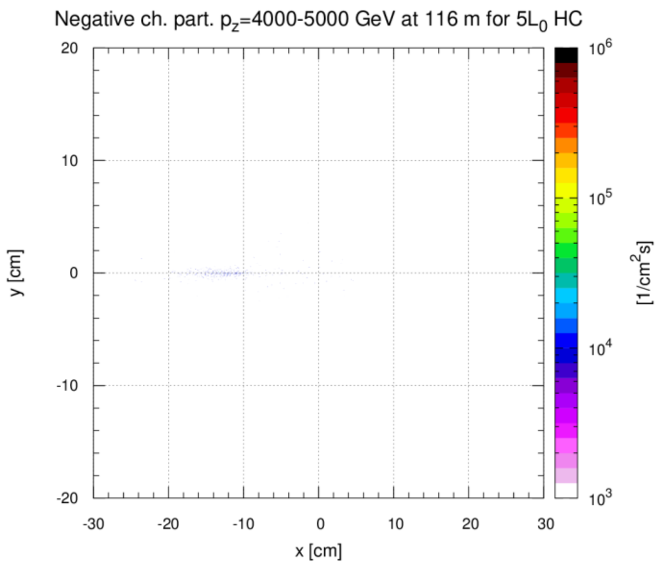
Generation Number = 1



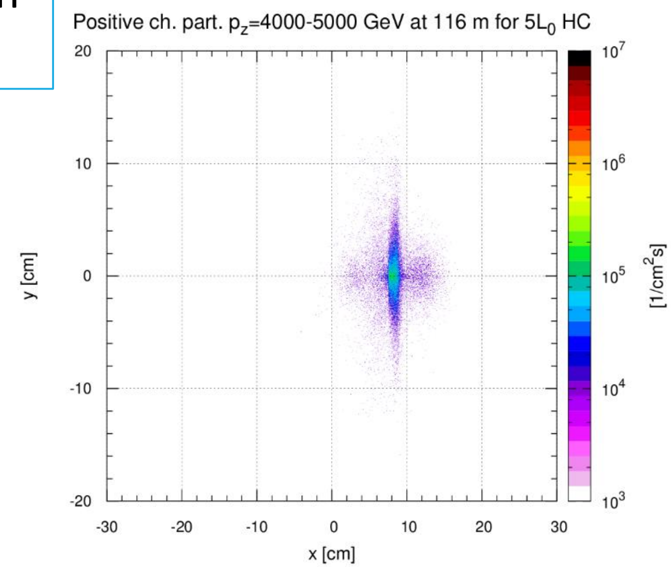
HC

re-interaction products

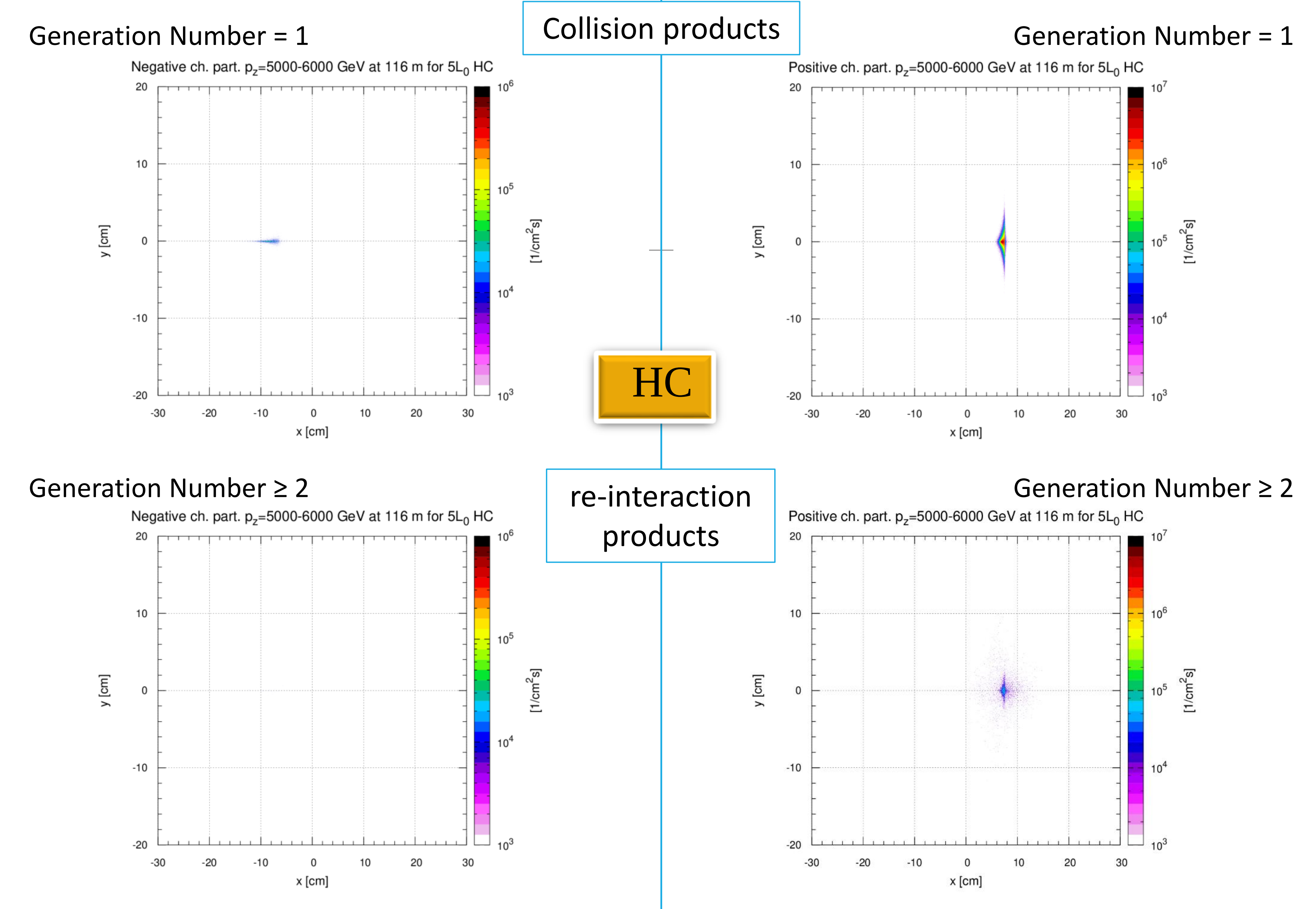
Generation Number ≥ 2



Generation Number ≥ 2



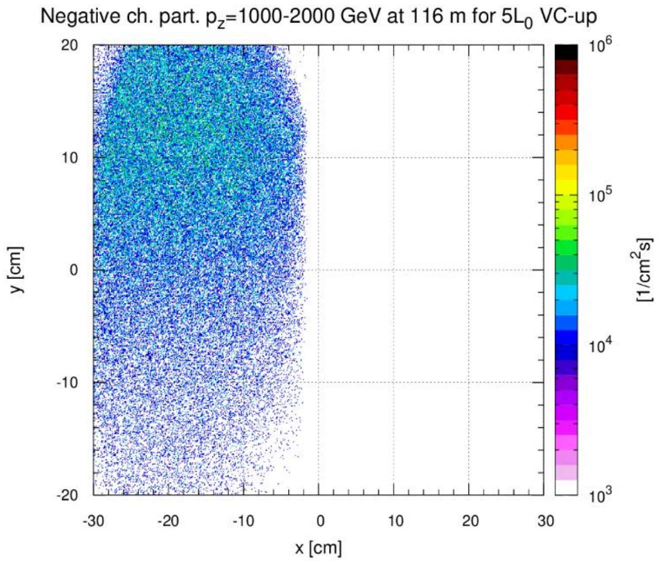
Negative **P_z = 4 – 5 TeV** **Positive**



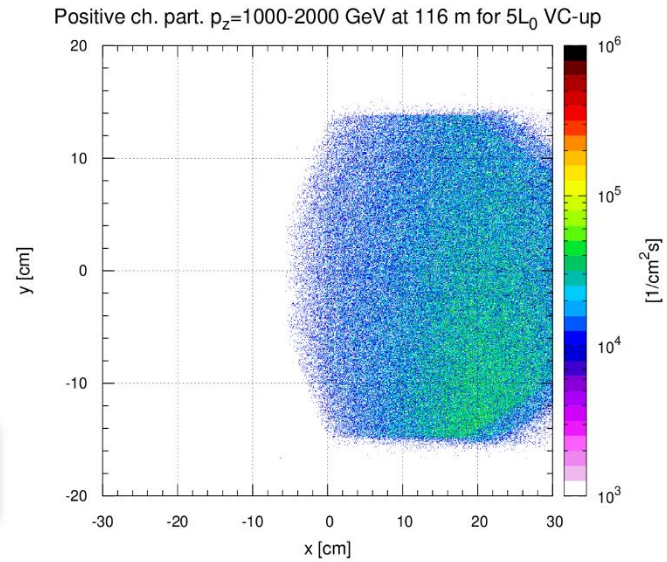
Negative | **P_z = 5 – 6 TeV** | **Positive**

Collision products

Generation Number = 1



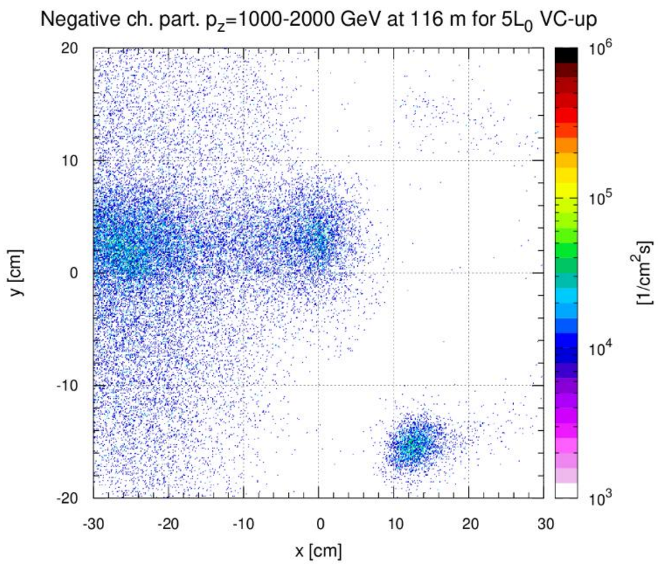
Generation Number = 1



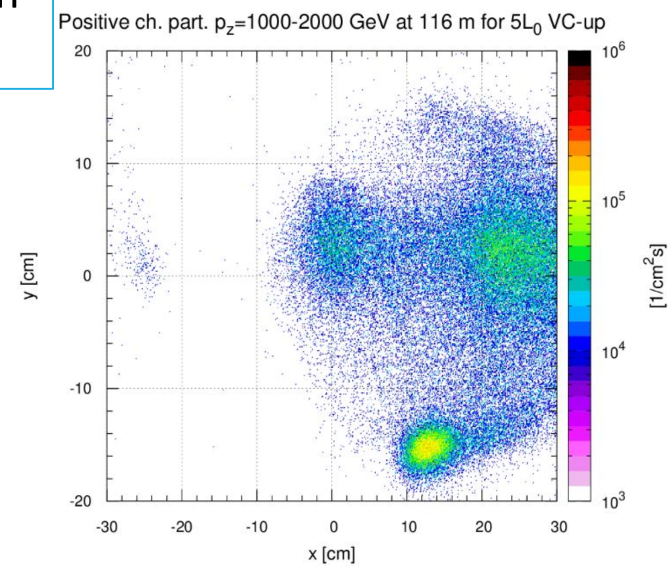
VC-up

re-interaction products

Generation Number ≥ 2



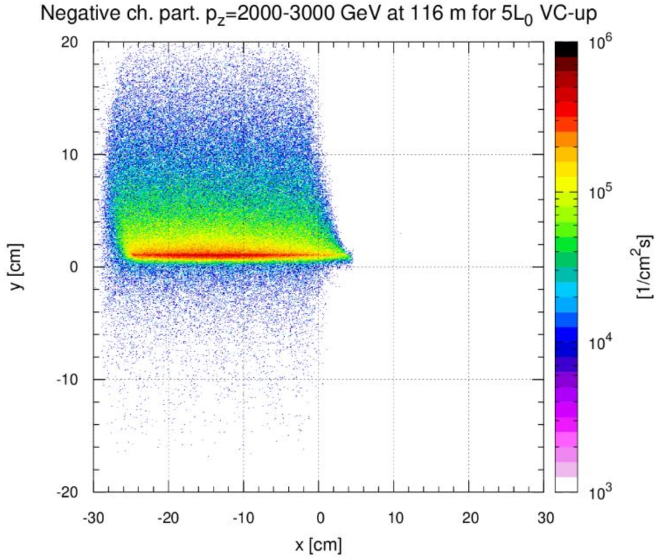
Generation Number ≥ 2



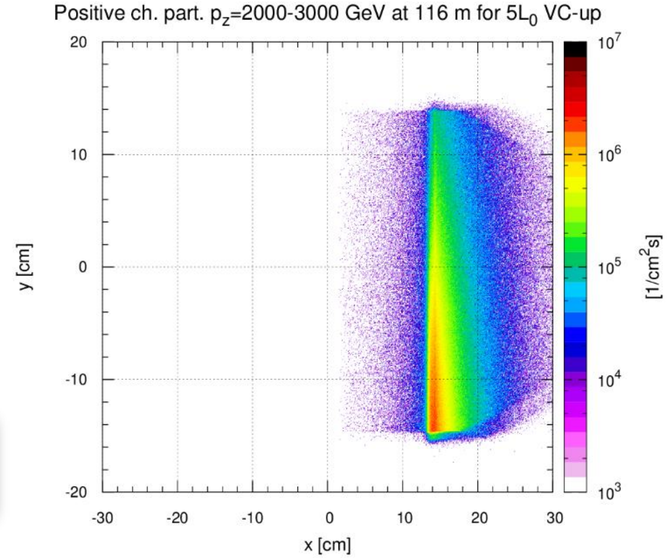
Negative | **P_z = 1 – 2 TeV** | **Positive**

Collision products

Generation Number = 1



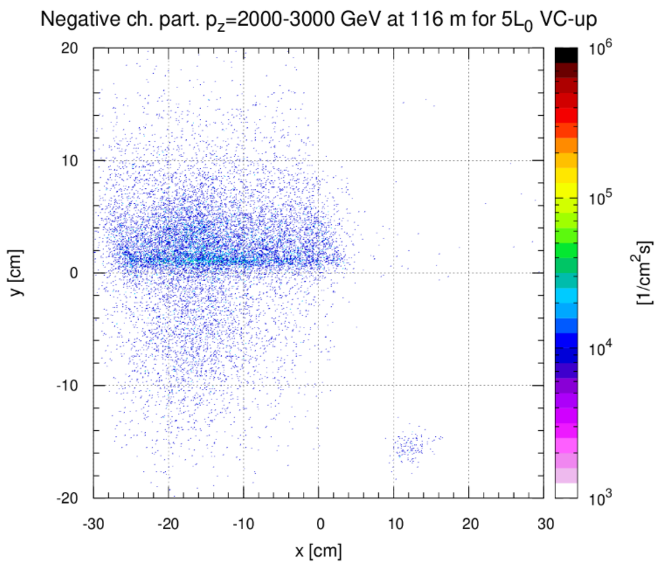
Generation Number = 1



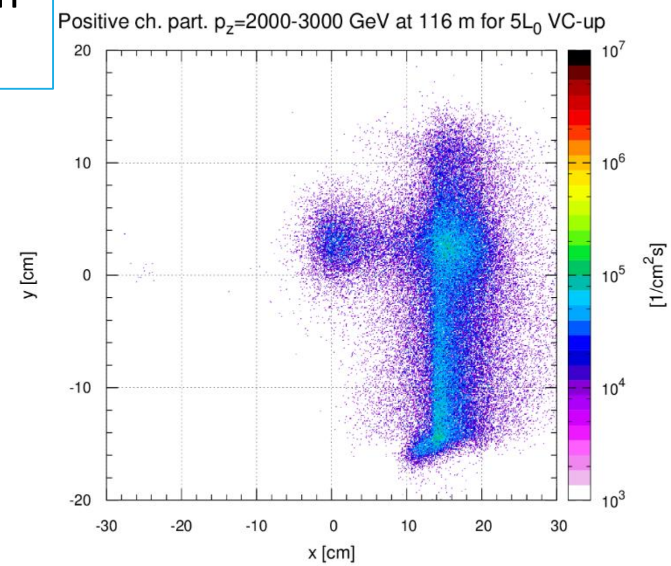
VC-up

re-interaction products

Generation Number ≥ 2



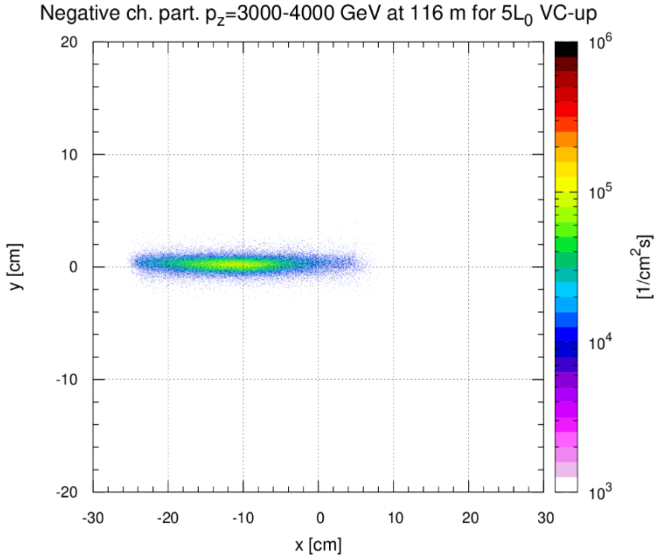
Generation Number ≥ 2



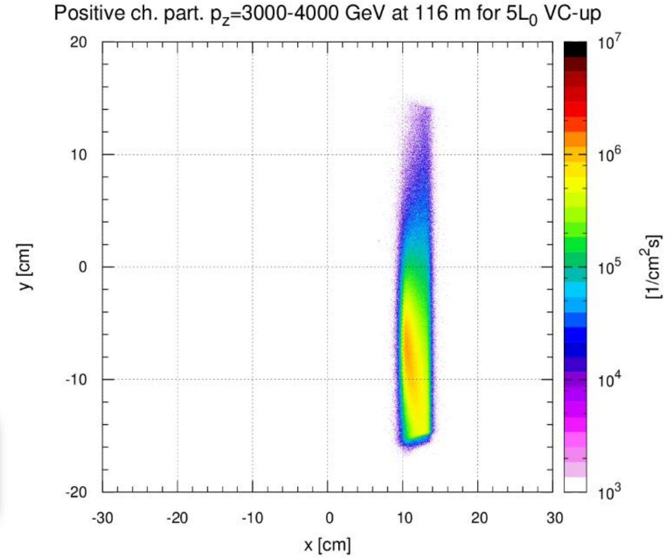
Negative | **P_z = 2 – 3 TeV** | **Positive**

Collision products

Generation Number = 1



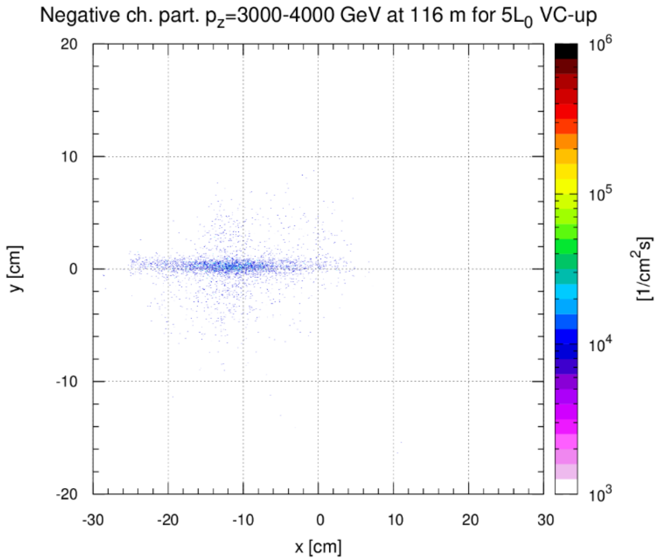
Generation Number = 1



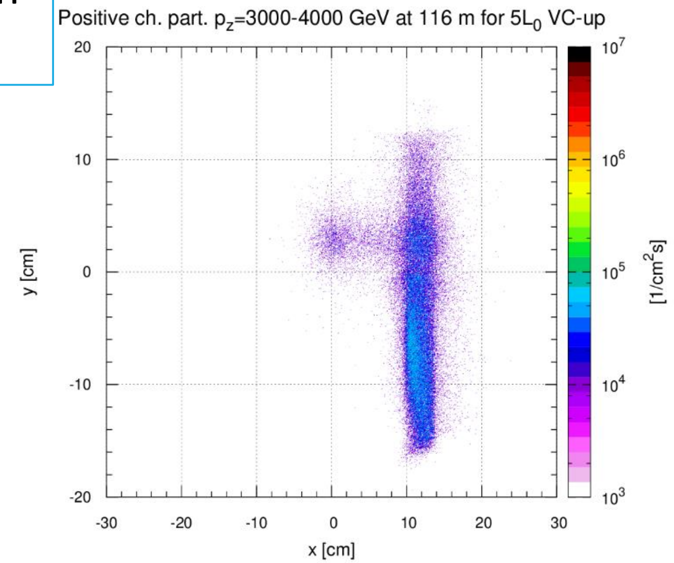
VC-up

re-interaction products

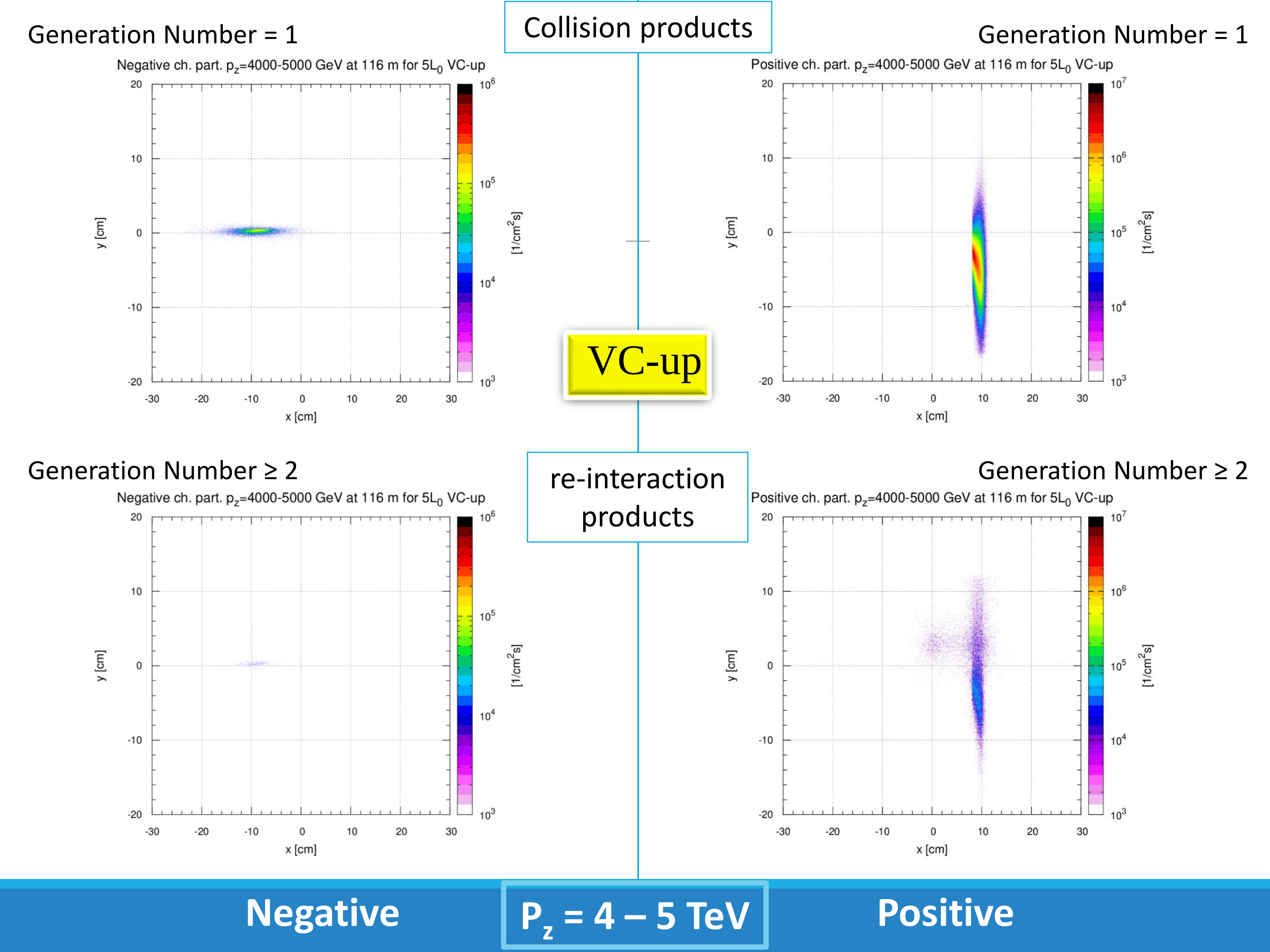
Generation Number ≥ 2



Generation Number ≥ 2

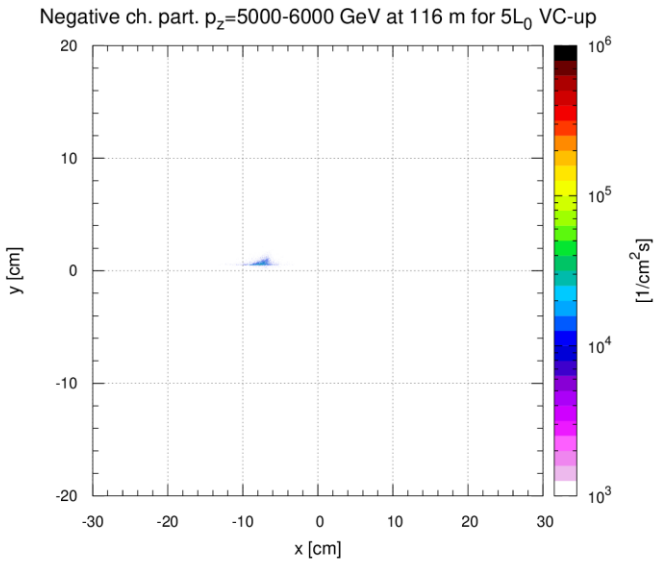


Negative | **P_z = 3 – 4 TeV** | **Positive**

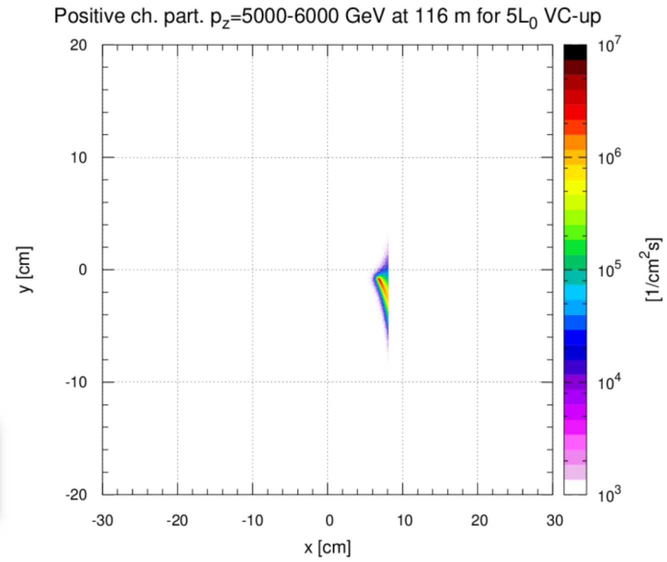

Collision products
Generation Number = 1
Negative ch. part. p_z=4000-5000 GeV at 116 m for 5L_0 VC-up
Positive ch. part. p_z=4000-5000 GeV at 116 m for 5L_0 VC-up
VC-up
re-interaction products
Generation Number ≥ 2
Negative ch. part. p_z=4000-5000 GeV at 116 m for 5L_0 VC-up
Positive ch. part. p_z=4000-5000 GeV at 116 m for 5L_0 VC-up
x [cm]
y [cm]
[1/cm^2s]
Negative
P_z = 4 – 5 TeV
Positive

Collision products

Generation Number = 1



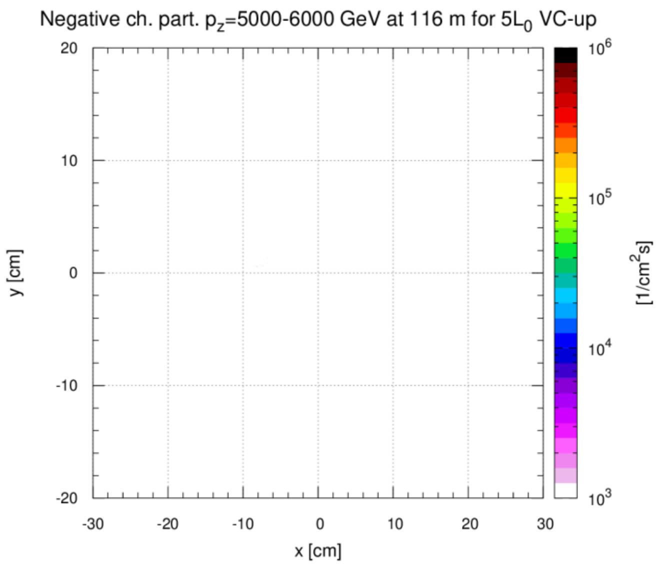
Generation Number = 1



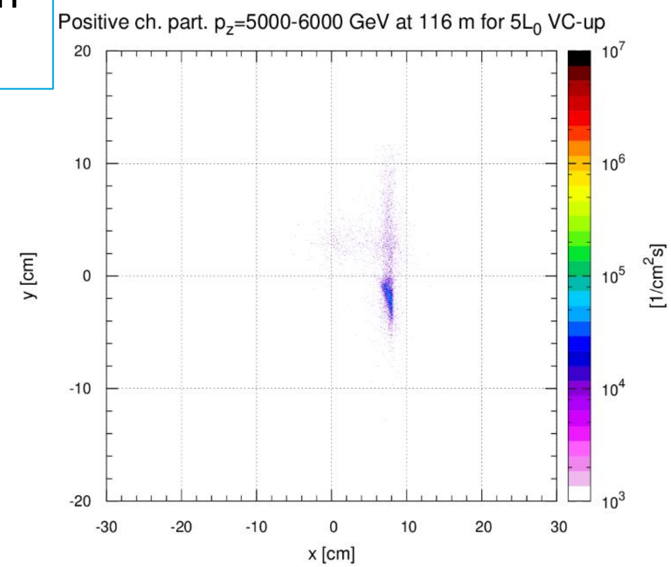
VC-up

re-interaction products

Generation Number ≥ 2



Generation Number ≥ 2



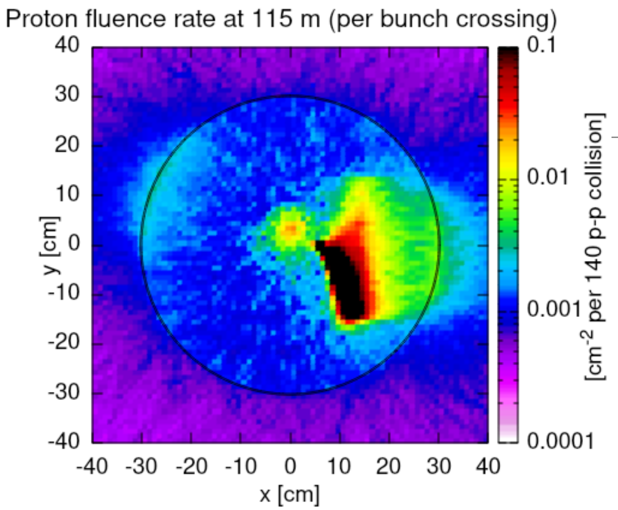
Negative | **P_z = 5 – 6 TeV** | **Positive**

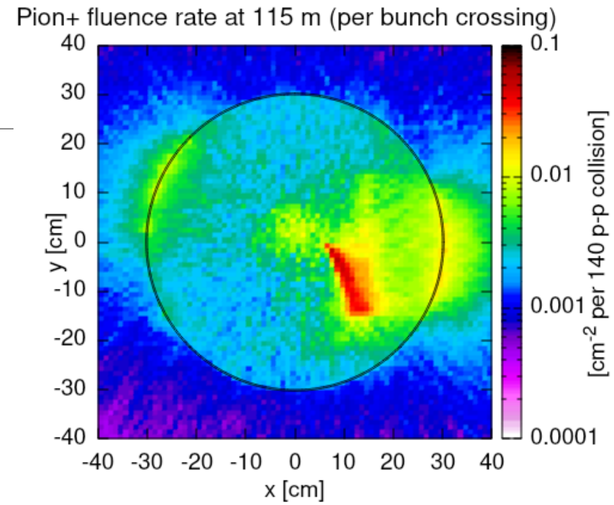
Particle distribution at 116 m

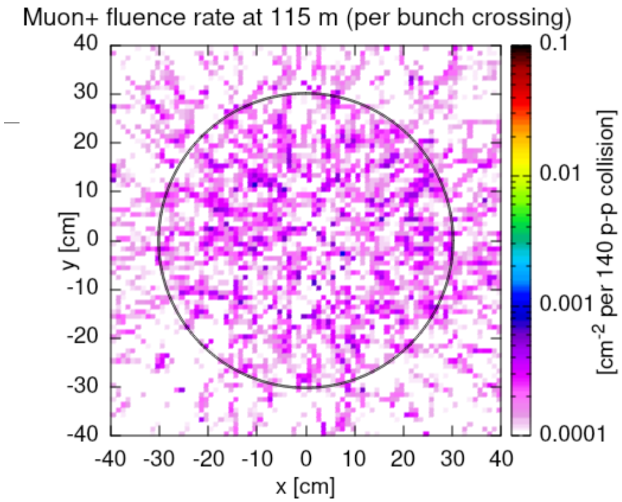
- ✓ *CMS (**IR5**) for HL-LHC optics v1.5: Vertical-up crossing of +**250 μrad** half crossing angle.*
- ✓ *Particle fluence and muon spectra around 115 - 116 m.*
- ✓ *Normalization per bunch crossing (140 p-p collisions).*
- ✓ *No cut in energy.*

PARTICLE FLUENCE RATE per bunch crossing

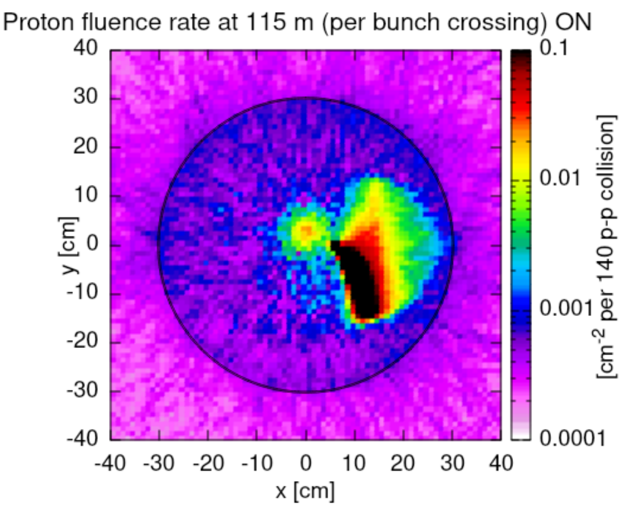
without toroid

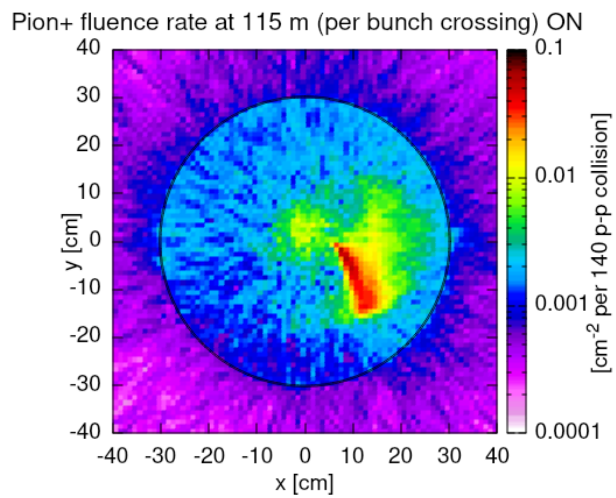


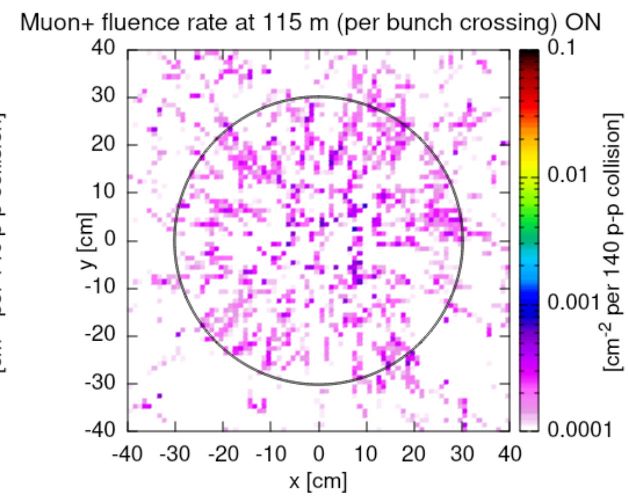




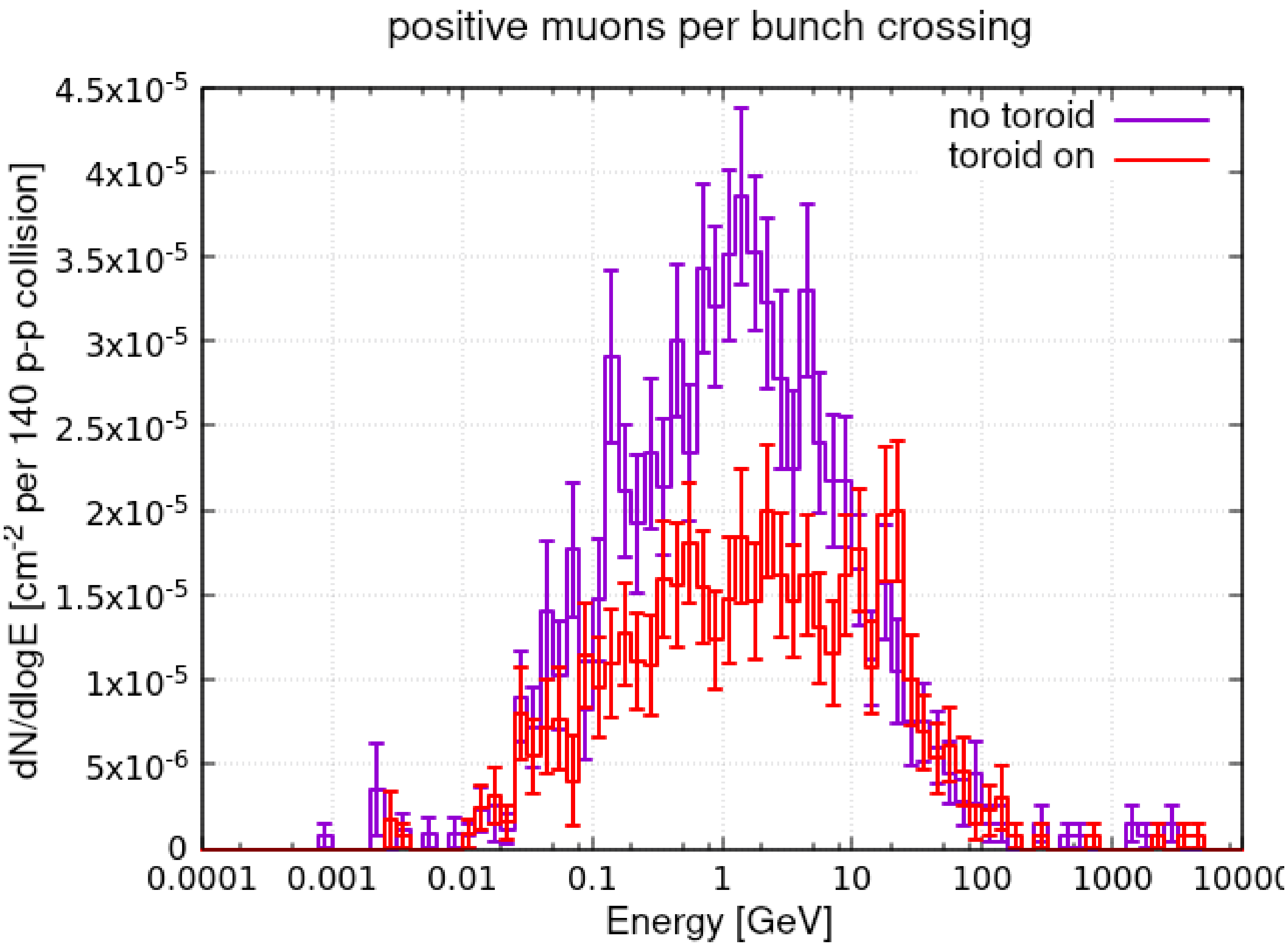
with toroid







MUON SPECTRUM

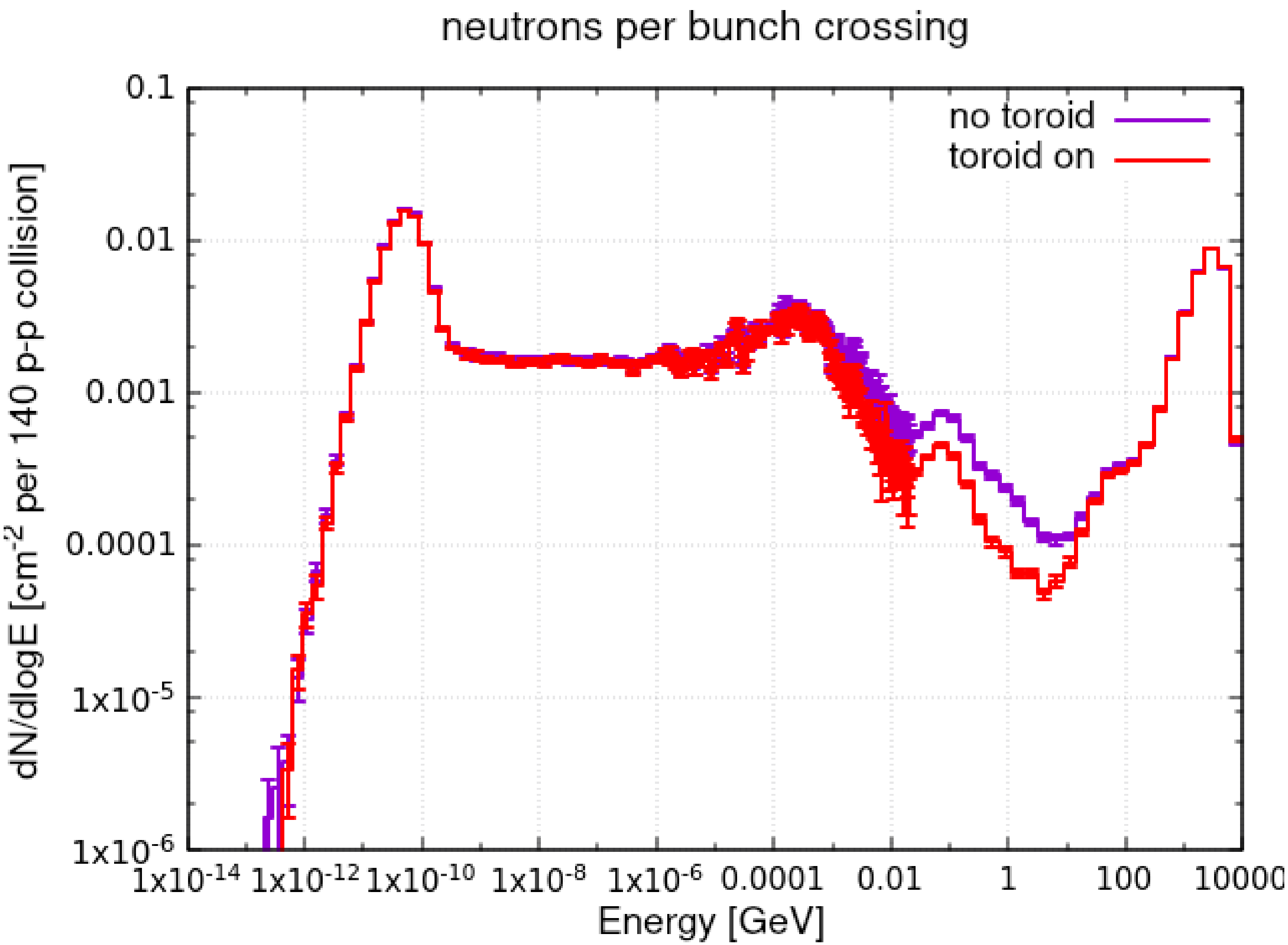


number of muons per bunch crossing (PU=140) inside a 30 cm radius:

0.45 μ^+ (0.45 μ^-)

0.3 μ^+ (0.35 μ^-)

NEUTRON SPECTRUM



number of muons per bunch crossing (PU=140) inside a 30 cm radius:

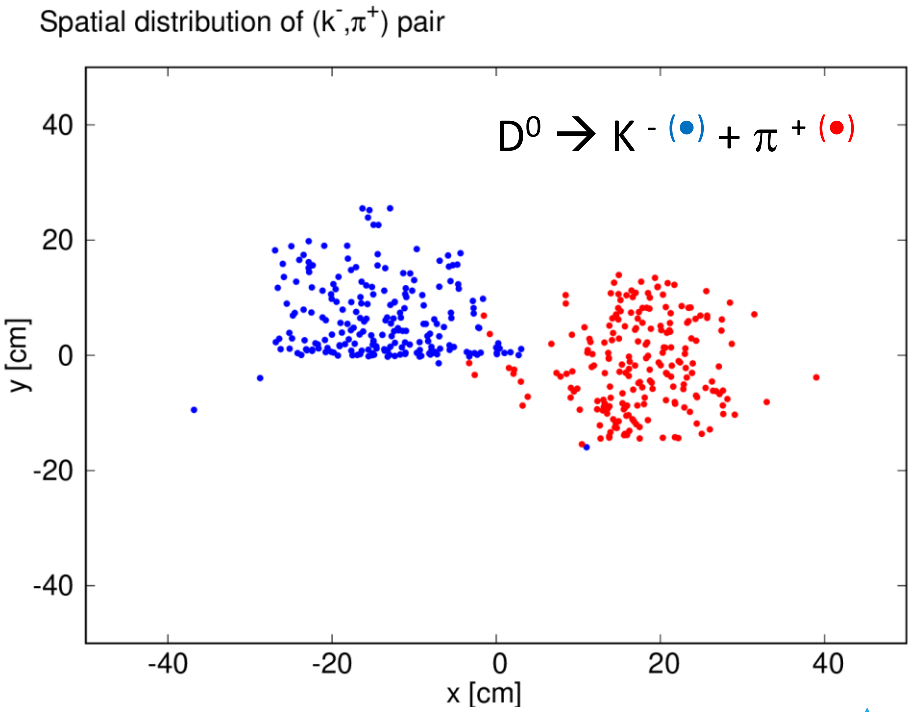
231 n

218 n

(K^-, π^+) and (K^+, π^-) pair from D^0 and D^0-bar

- ✓ *CMS (**IR5**) for HL-LHC optics v1.5.*
- ✓ *Vertical-up crossing of +**250 μrad** half crossing angle.*
- ✓ *Scoring at **116 m from the IP** after the D1 for decay products.*
- ✓ *Correlation to the parent D^o and D^o-bar momentum.*

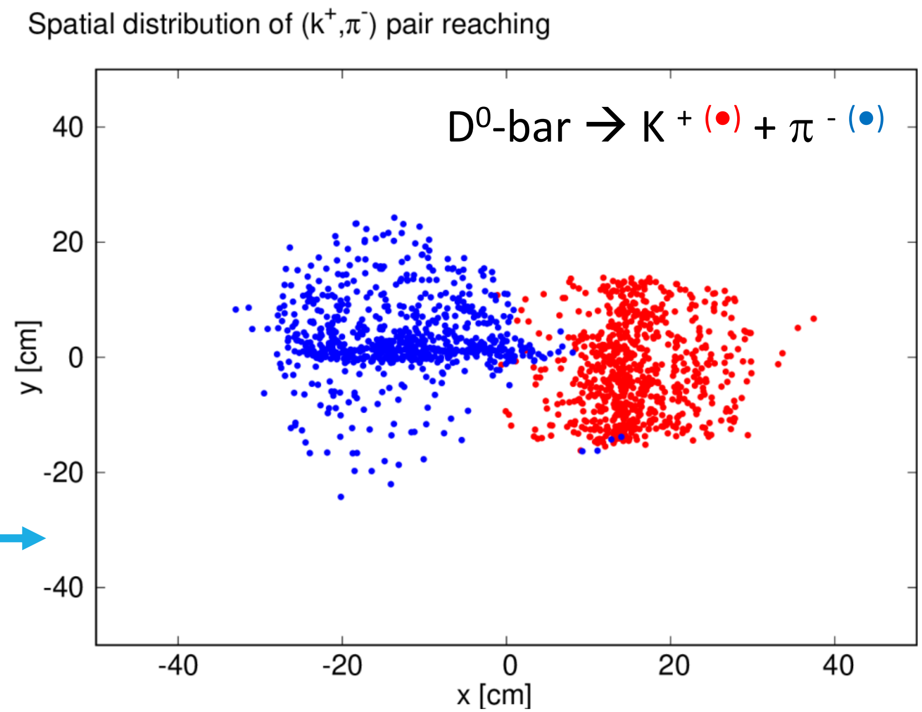
(K^-, π^+) and (K^+, π^-) pair from D^0 and D^0-bar at 116 m



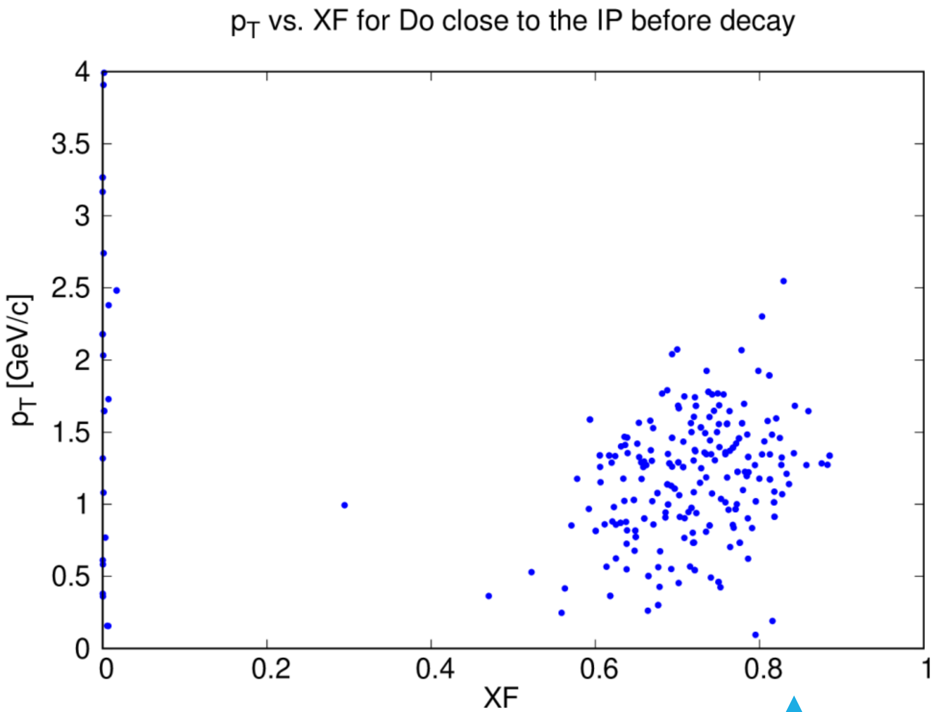
These are meson pairs for which a D^0 or a D^0-bar were generated at the IP with positive momentum, i.e., $p_Z > 0$.

212 (K^-, π^+) pairs out of ~4e9 p-p collisions

735 (K^+, π^-) pairs out of ~4e9 p-p collisions

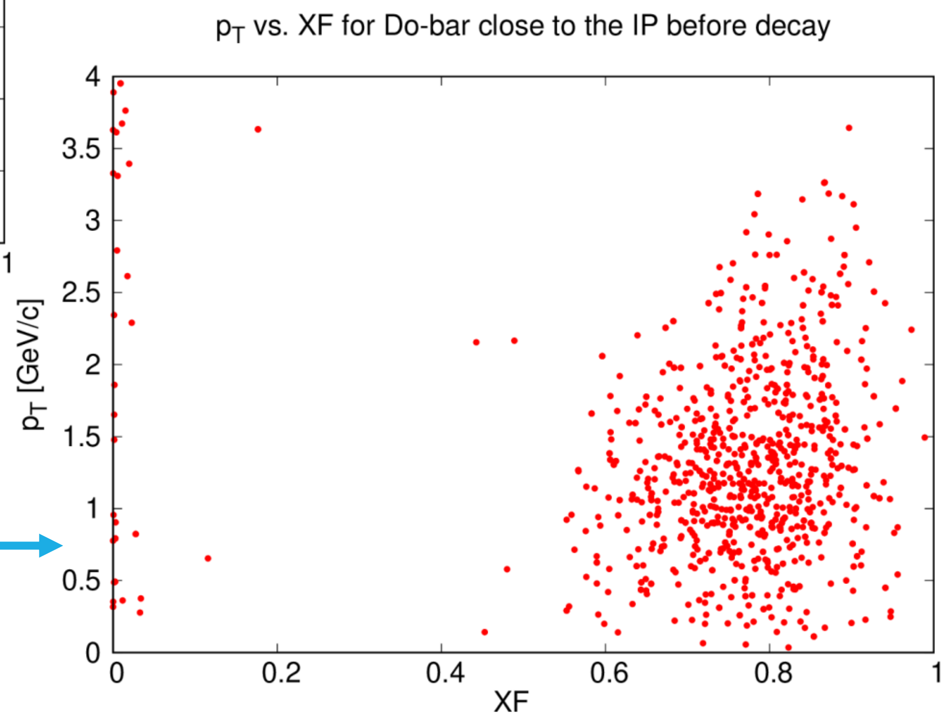


D^o and D^0-bar phase space at production



The number of points are the same as in previous plots BUT in some events (p-p collision) there are more than one D^0 or D^0-bar candidate that could generate the meson pair.

270 D^0 out of ~4e9 p-p collisions

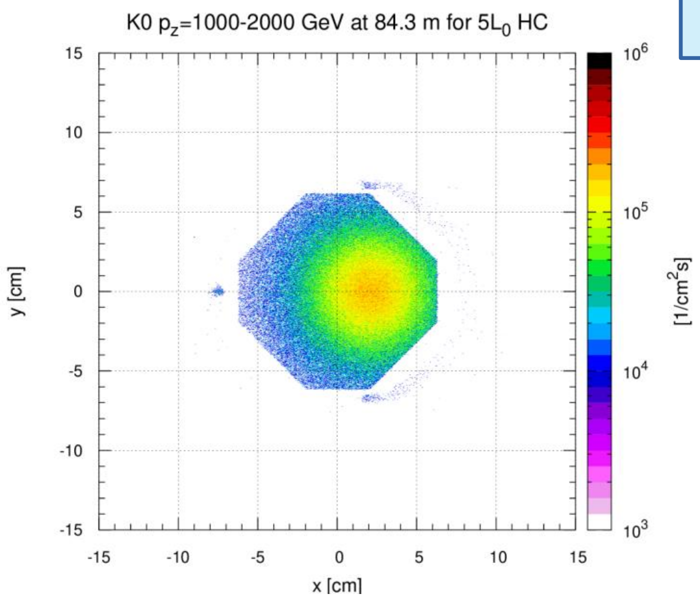


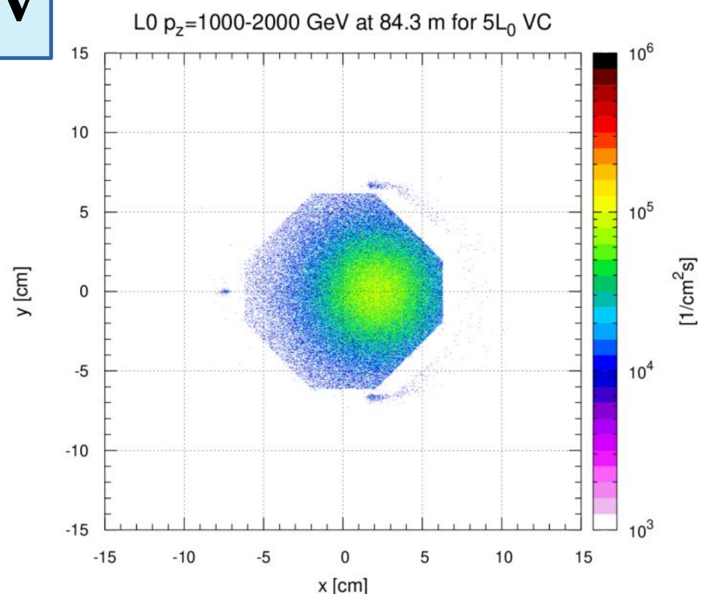
944 D^0-bar out of ~4e9 p-p collisions

K^0 and Λ^0 particle fluence

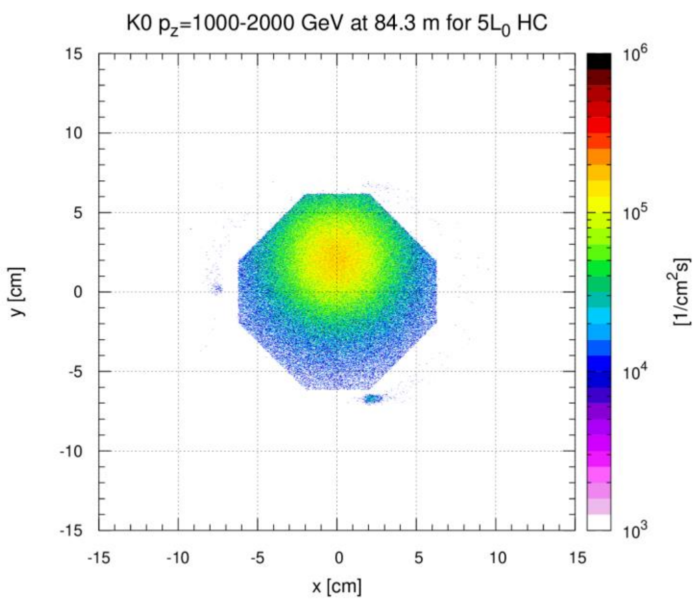
- ✓ *ATLAS (**IR1**) and CMS (**IR5**) for HL-LHC optics v1.5.*
- ✓ *Horizontal and Vertical-up crossing of **250 μrad** half crossing angle.*
- ✓ *Instantaneous luminosity: **$5 \cdot 10^{34}$ cm^{-2} s^{-1}**.*
- ✓ *Scoring at **84.3 m from the IP** after the D1.*
- ✓ *Fluence presented for different p_z ranges.*

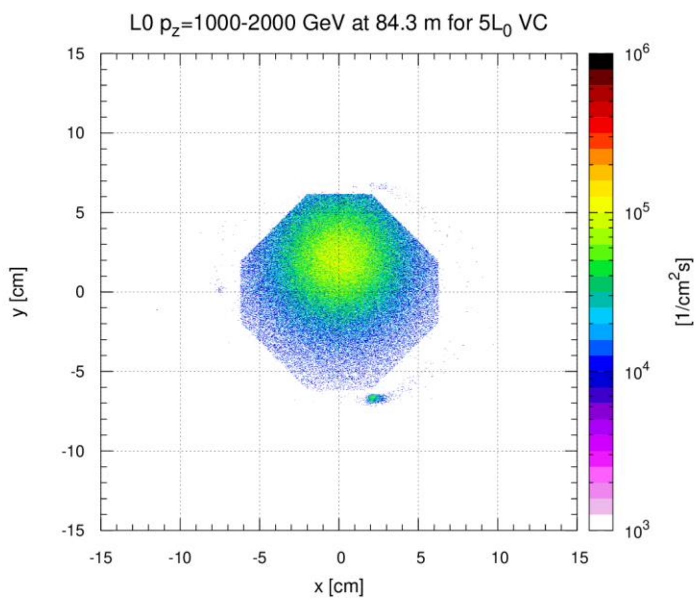
P_z = 1 – 2 TeV





HC



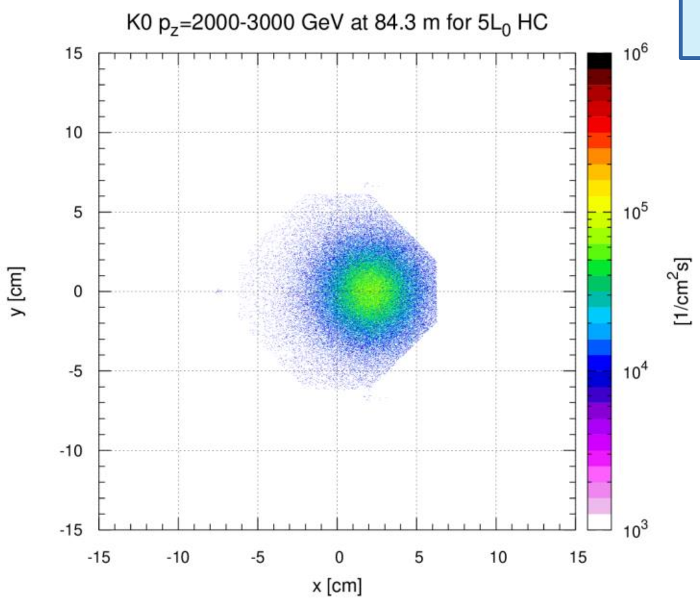


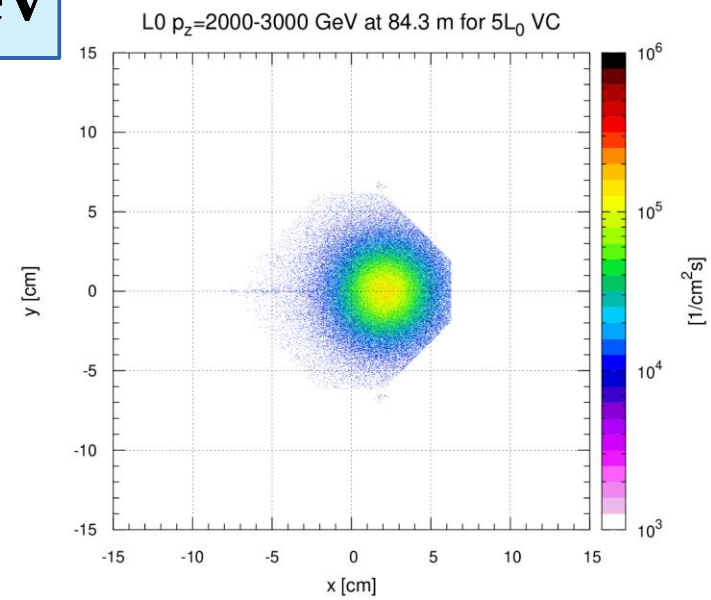
VC-up

K0

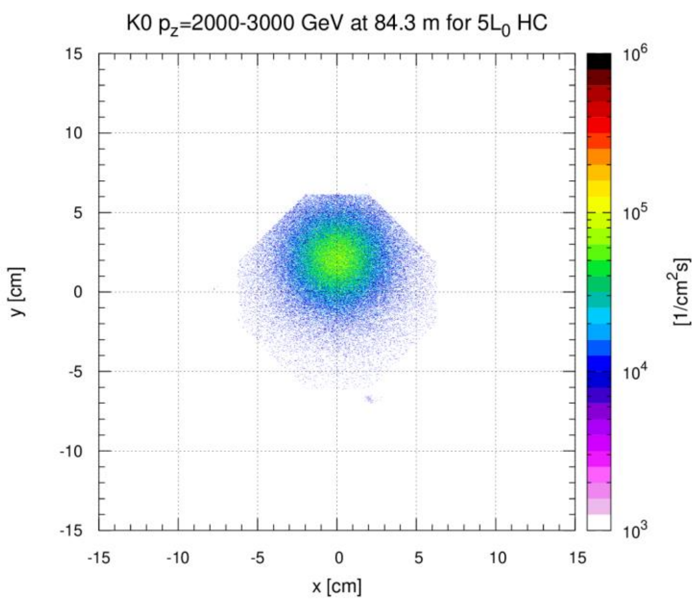
Λ0

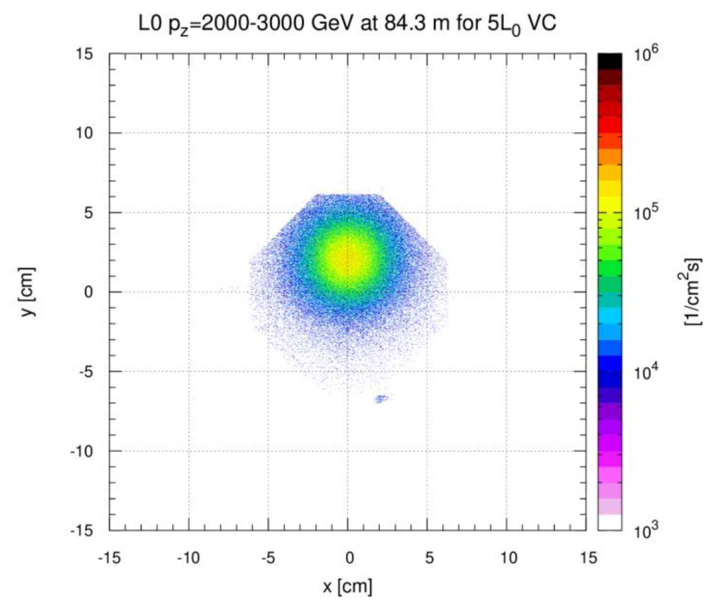
P_z = 2 – 3 TeV





HC





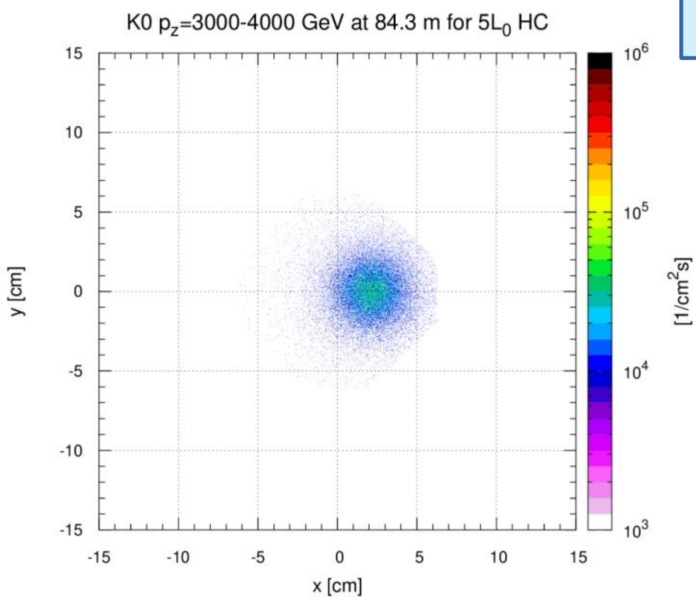
VC-up

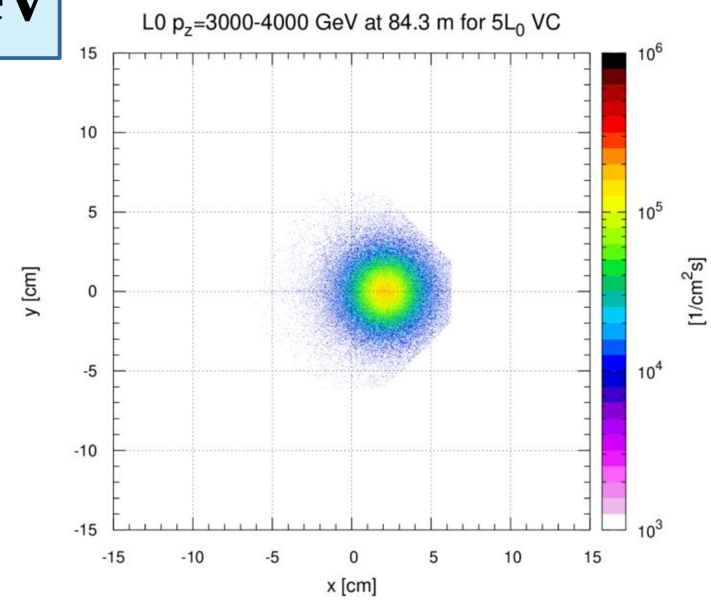
K0

Λ0

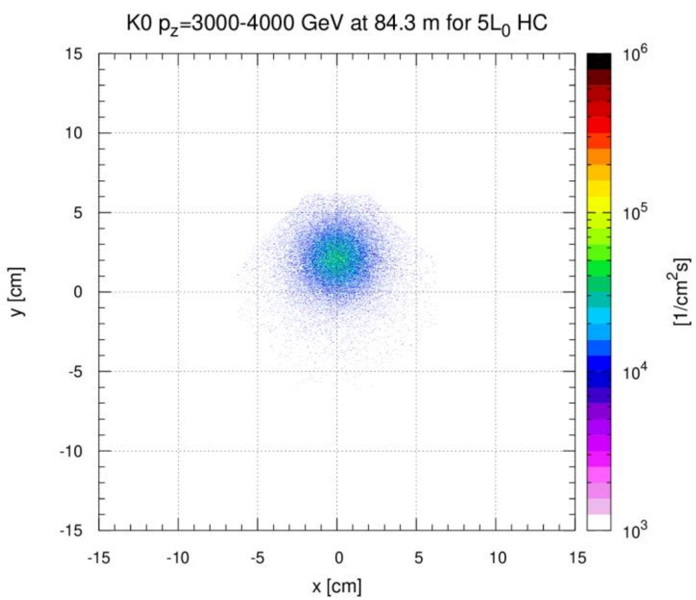
P_z = 3 – 4 TeV

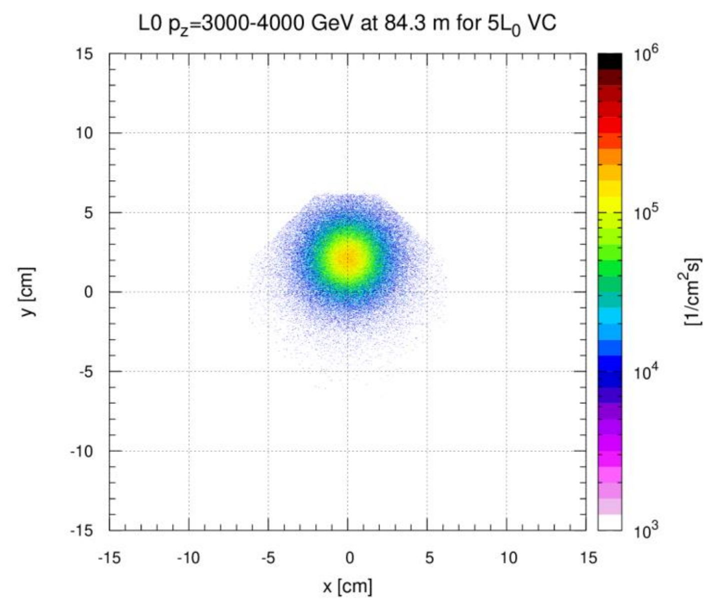
HC





VC-up



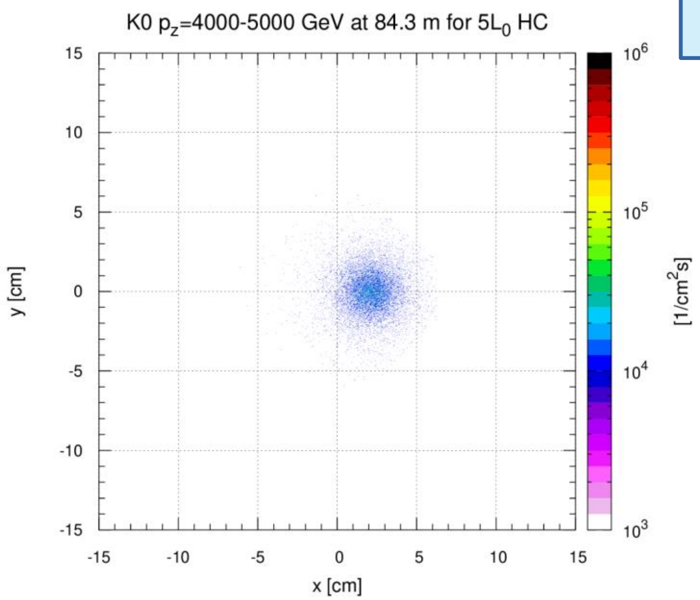


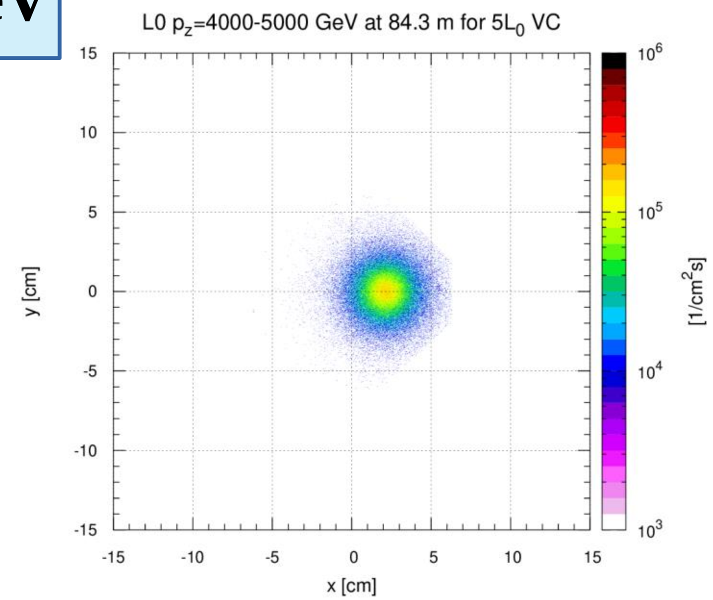
K0

Λ0

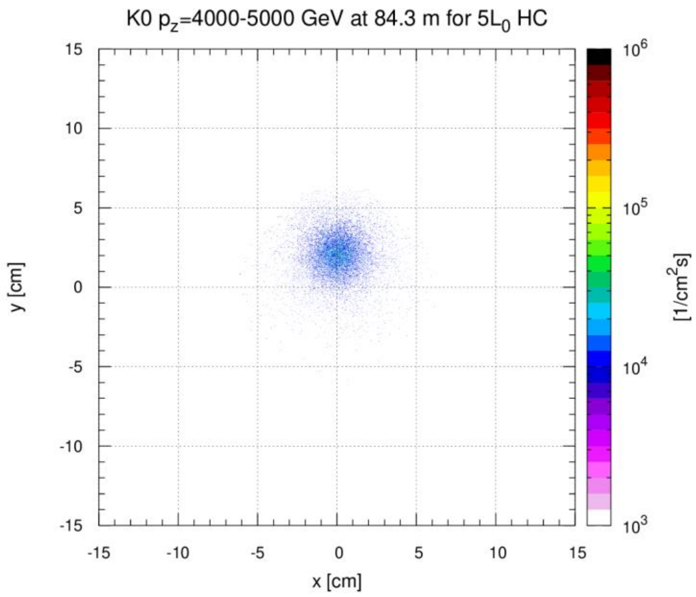
P_z = 4 – 5 TeV

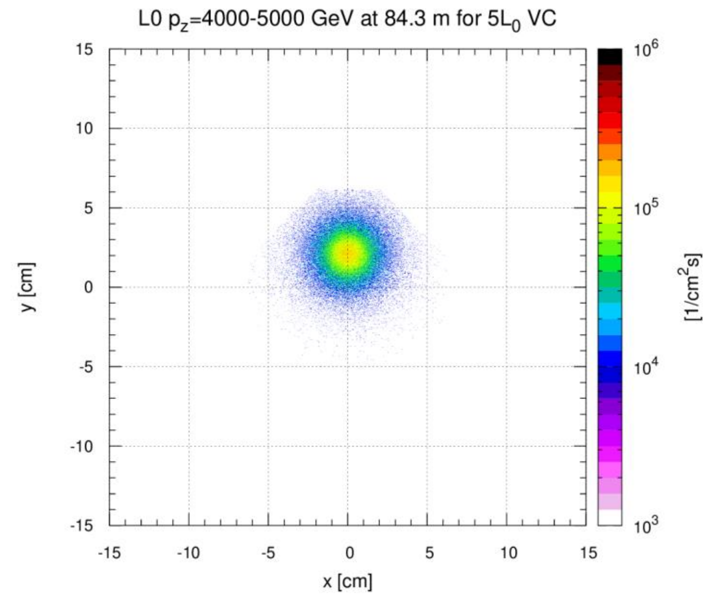
HC





VC-up

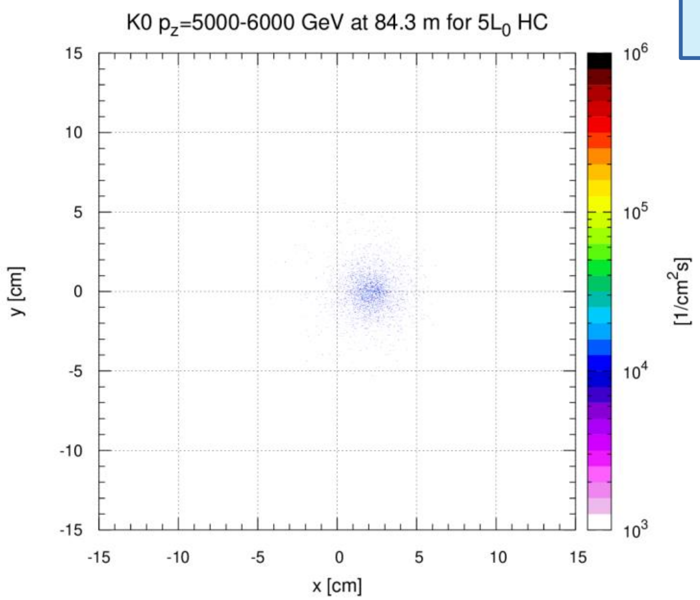


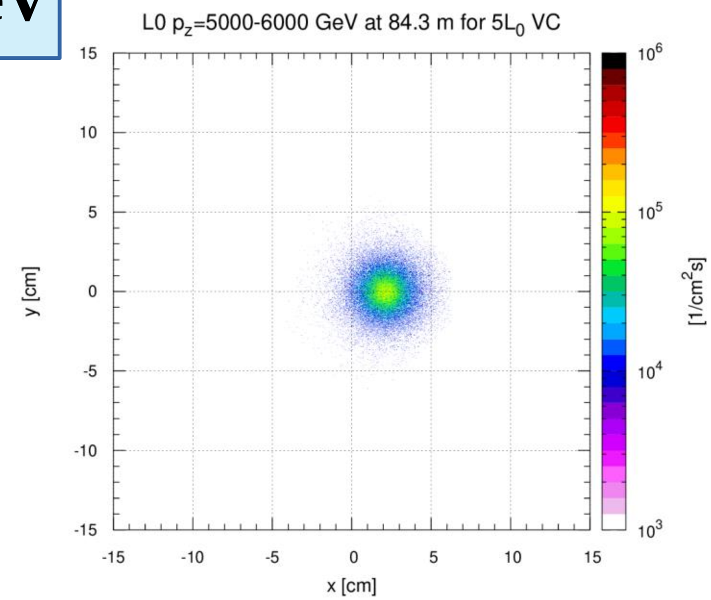


K0

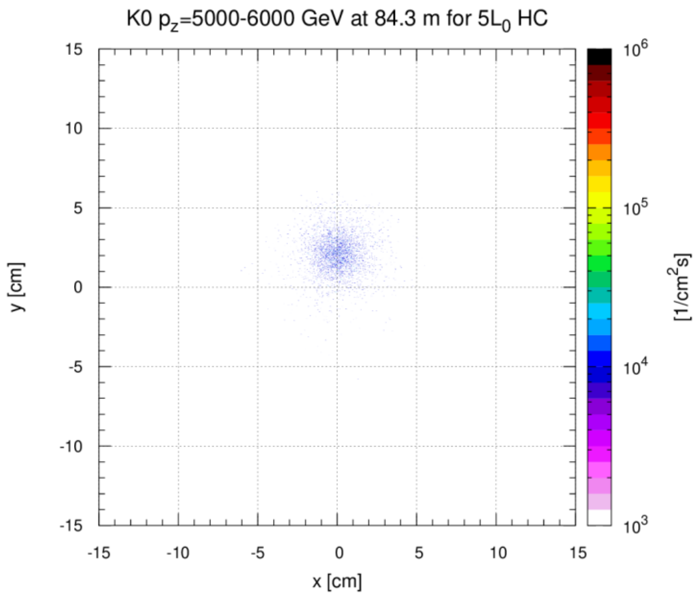
Λ0

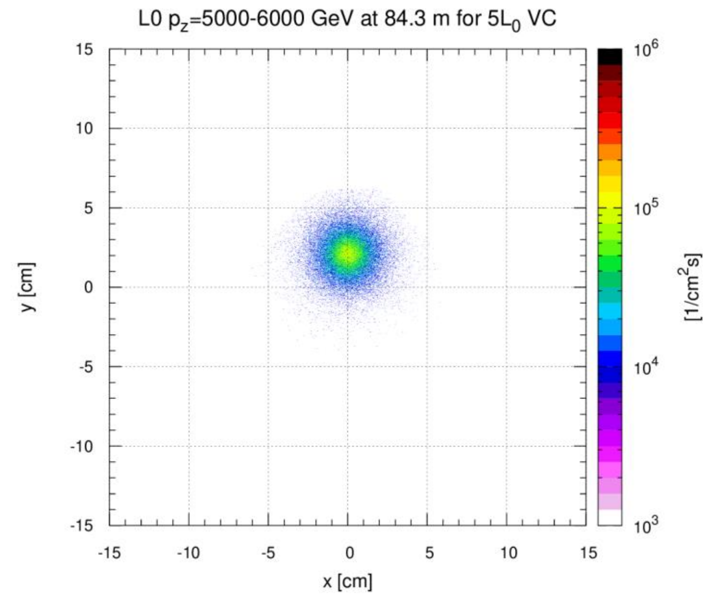
P_z = 5 – 6 TeV





HC





VC-up

K0

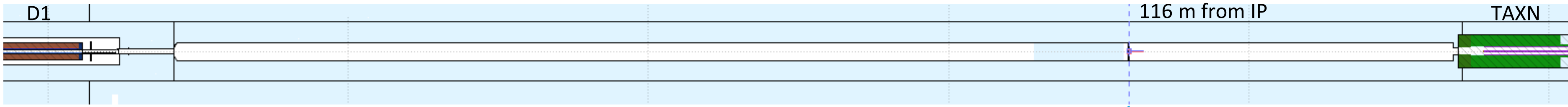
Λ0

Thank you for your attention

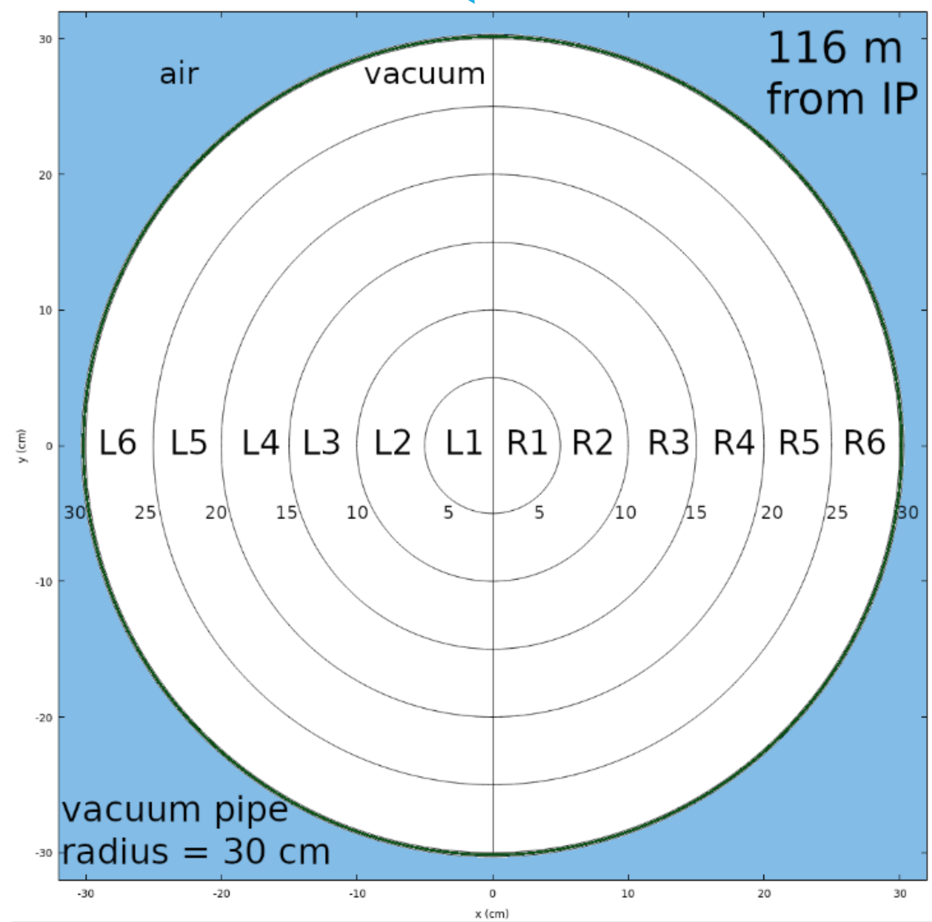
Particle spectra: differential fluence rate

- ✓ ***IR1** (ATLAS).*
- ✓ *HL-LHC optics v1.5.*
- ✓ *Horizontal crossing.*
- ✓ *Half crossing angle of **250 μrad**.*
- ✓ *Instantaneous luminosity: $\mathbf{5 \cdot 10^{34}\ cm^{-2} s^{-1}}$.*
- ✓ *Spectra obtained at **116 m** from the IP.*

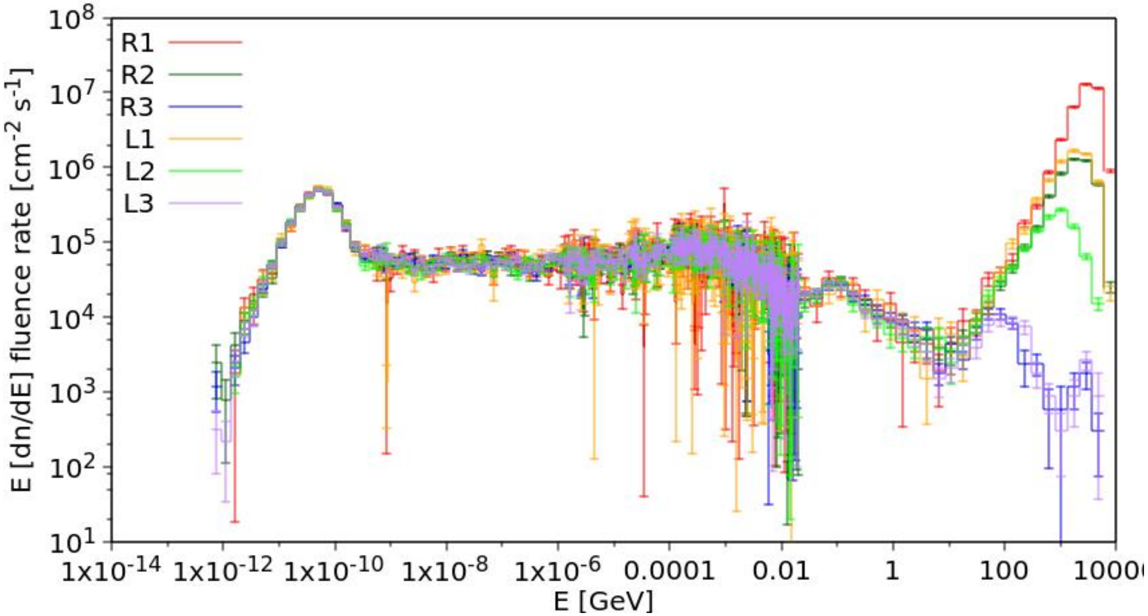
Set-up for the calculation



- Big pipe of R_{in} = 30 cm along ~ 43 m before the TAXN.
- This pipe radius is NOT compatible with the presence of the diode structure after D1.
- The spectra was calculated in different regions centered at 116 m from the IP.
- The differentiation between left and right is related to the asymmetry introduces by the D1 and the effect of the crossing angle that introduces an additional asymmetry wrt the center.

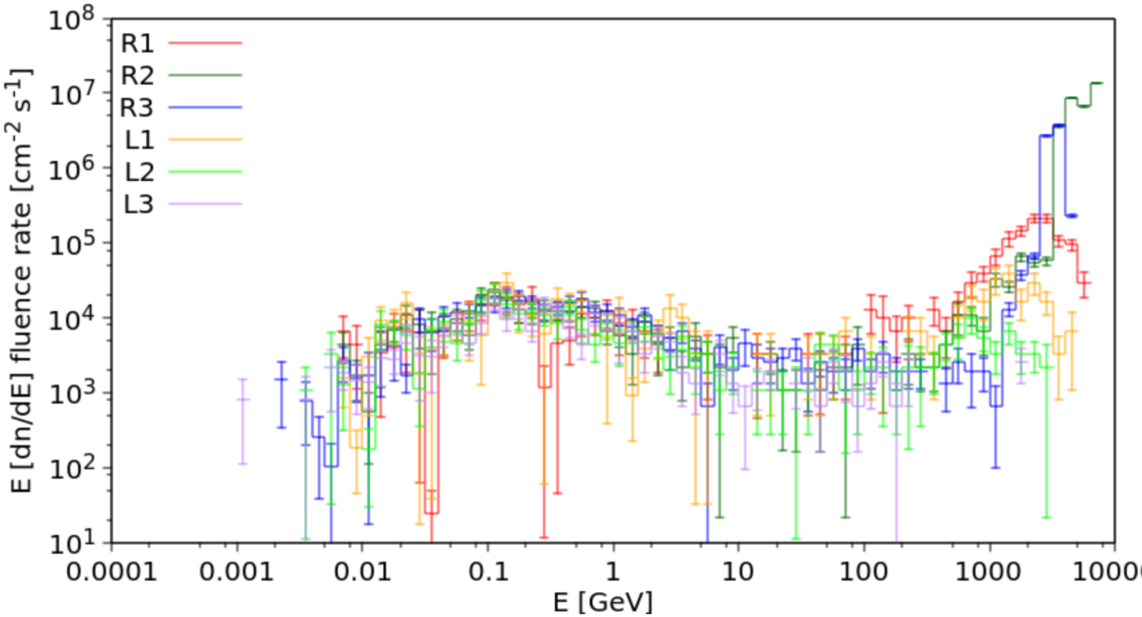


Neutron spectra

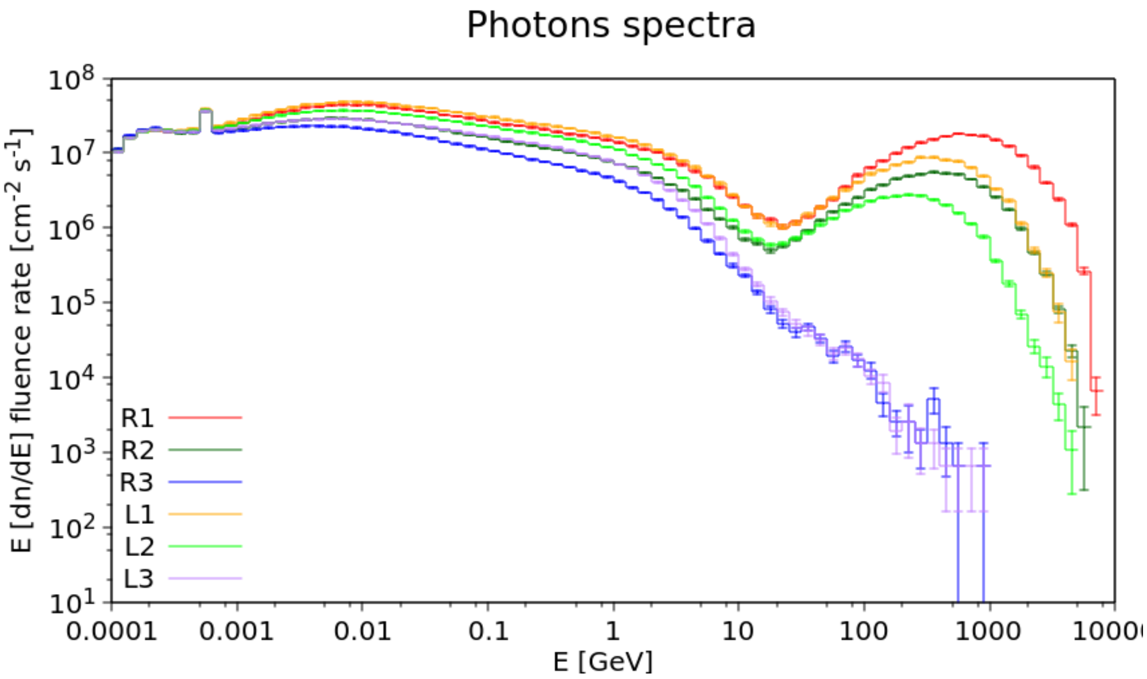


- Thermal neutrons are present.

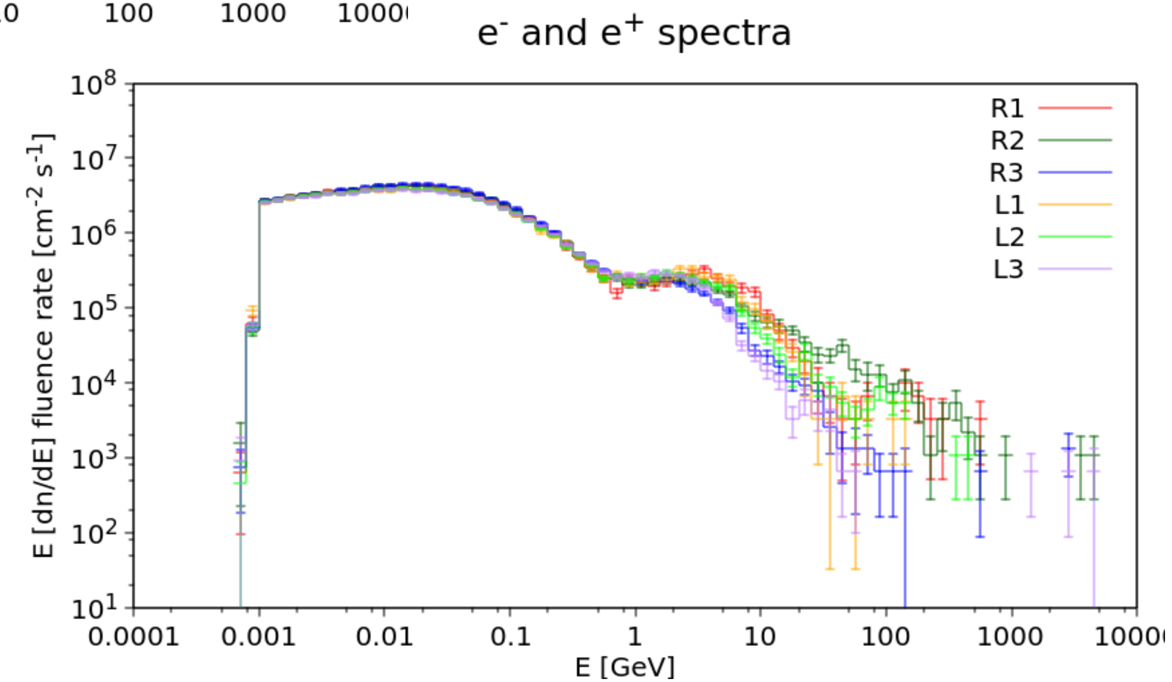
Proton spectra



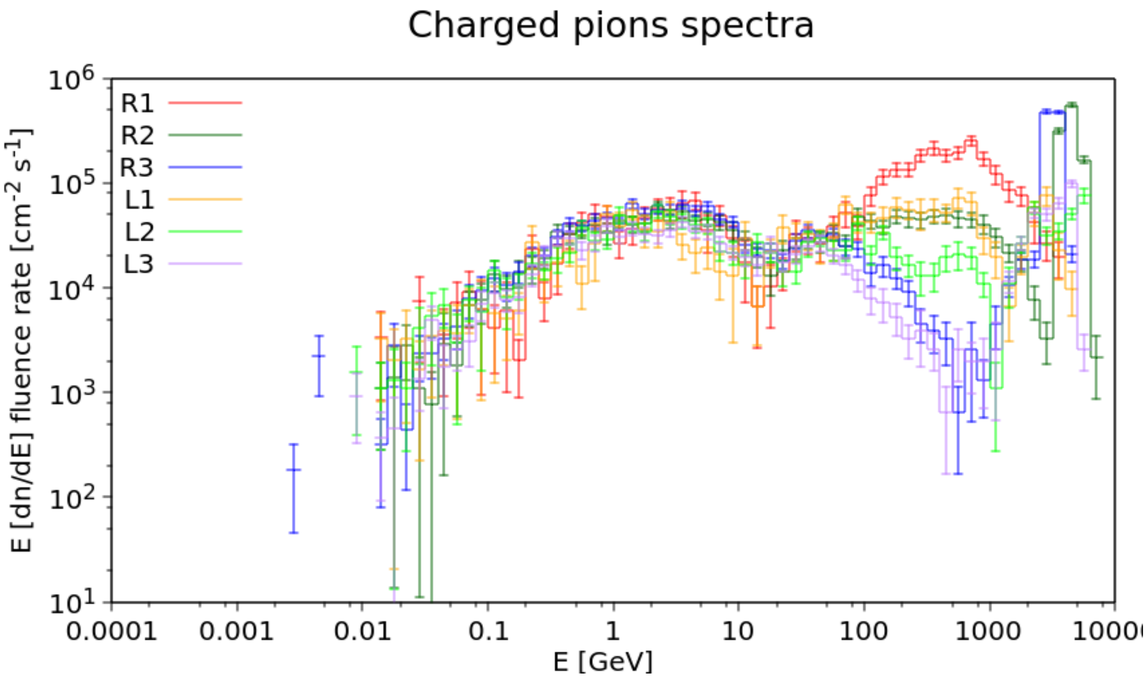
- The spectra are similar up to few hundreds of GeV.
- Diffracting protons are expected at radial position according to the horizontal crossing angle.



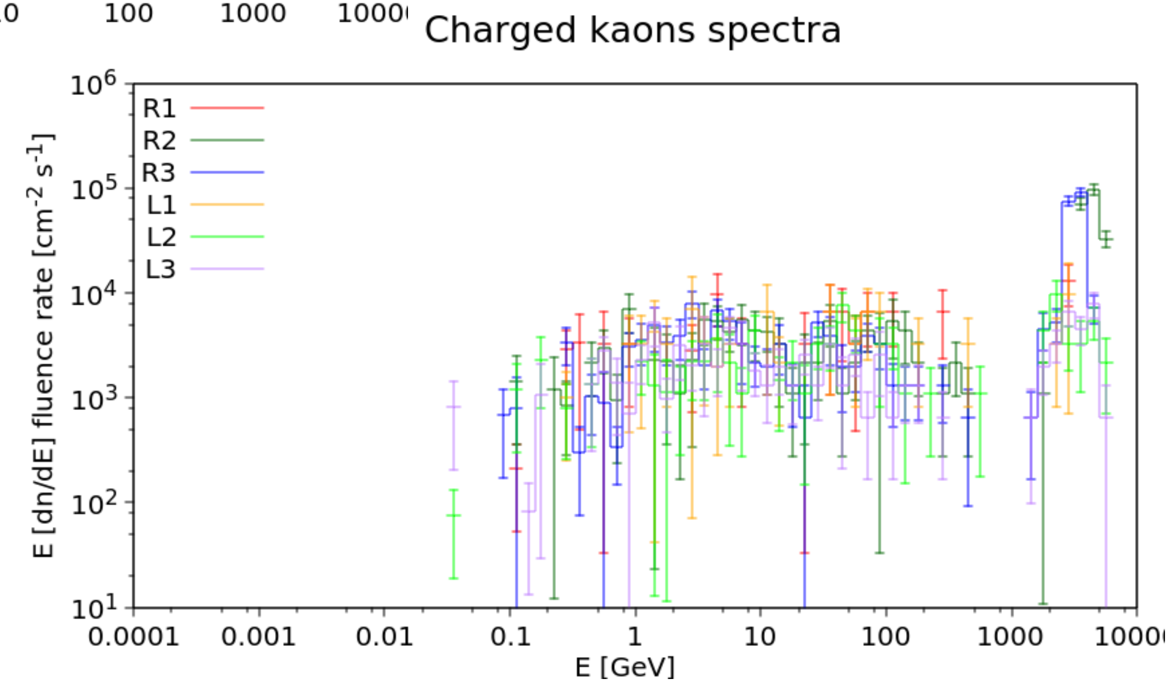
- Similar spatial distribution as neutrons, following the crossing angle direction.
- Photons up to few TeV are present within the first 10 cm. Further from the center, the maximum energy drops down to few hundreds of GeV.



- The population of low energy e^- and e^+ on the right and left side is identical.
- No peak of high energy e^- and e^+ is expected.



- This spectra includes both π^+ and π^-.
- TeV π^+ loosely the proton trayectory.



- This spectra includes both K^+ and K^-.