5th Forward Physics Facility Meeting

FLUKA estimates of the FPF background rates

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Overview

I. *Introduction*

II. *Muon background rates at FPF*

III. *Sweeper magnet studies*

IV. *Neutron level at FPF*

Introduction

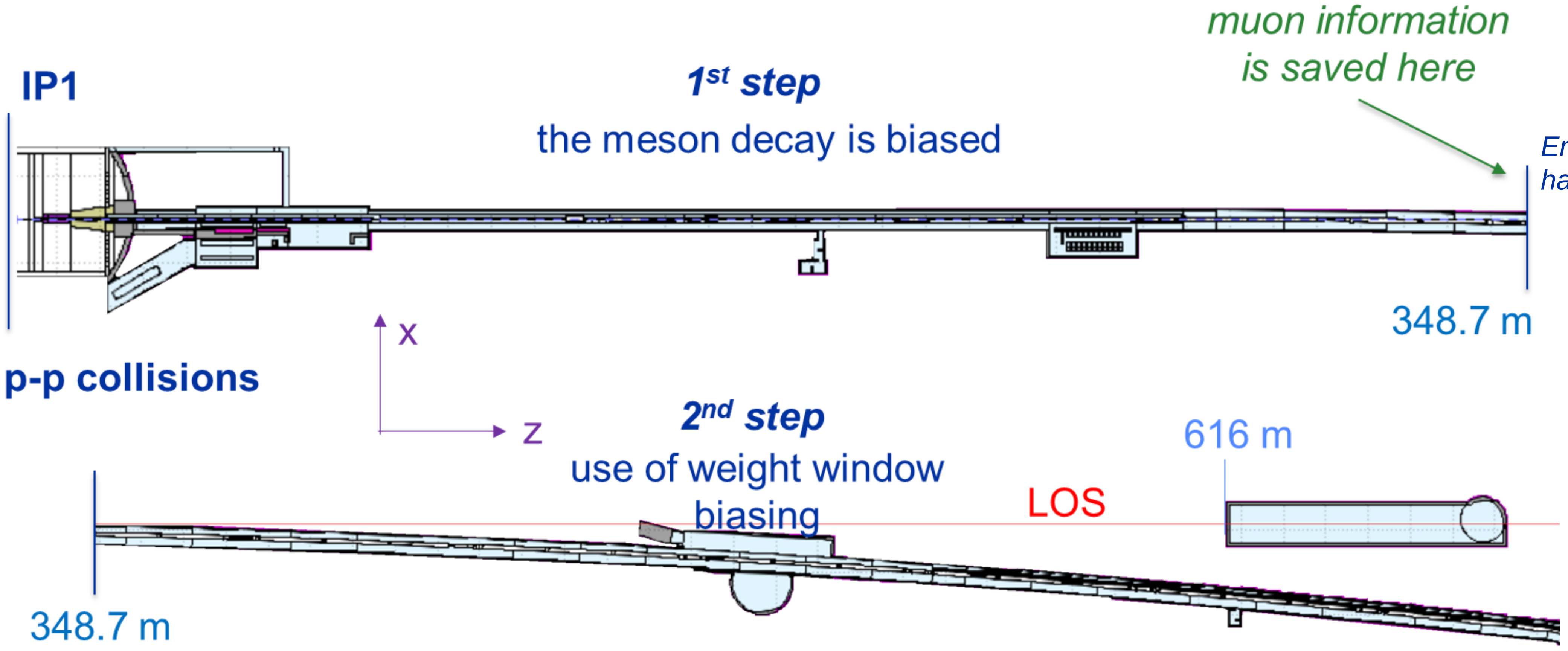
FLUKA simulations

Previous contribution: https://indico.cern.ch/event/1076733/timetable/#20211025.detailed

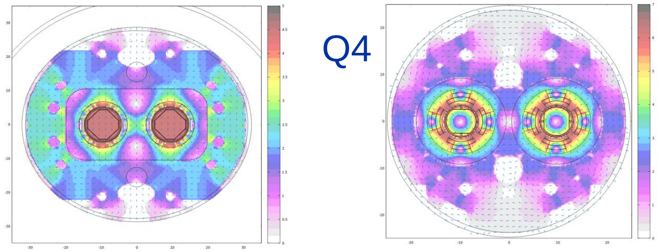
FLUKA simulations overview

IR1 - HL-LHC
Optics v1.5Nov
Horizontal crossing
+250 μrad half crossing angle

In order to get the muon fluence in the FPF cavern:



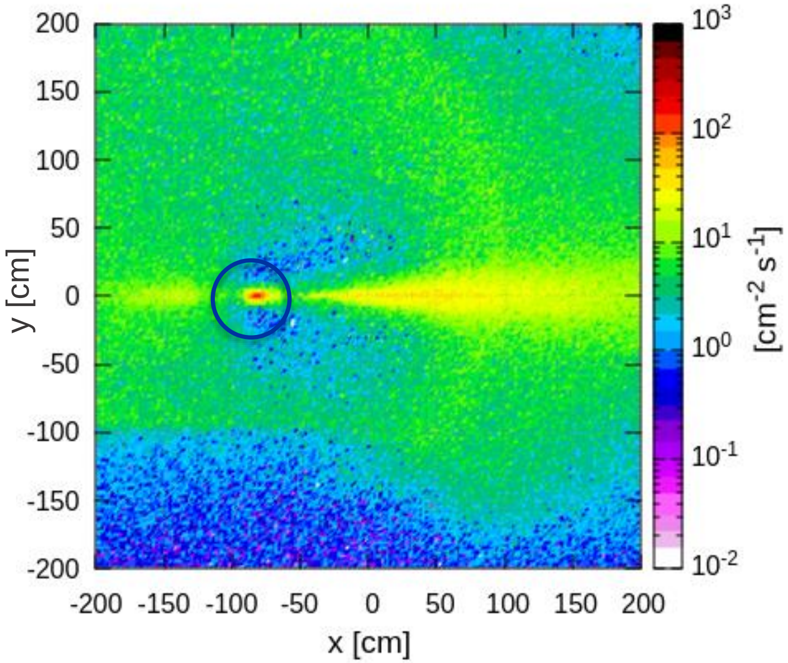
Muons at 348.7 m from IP



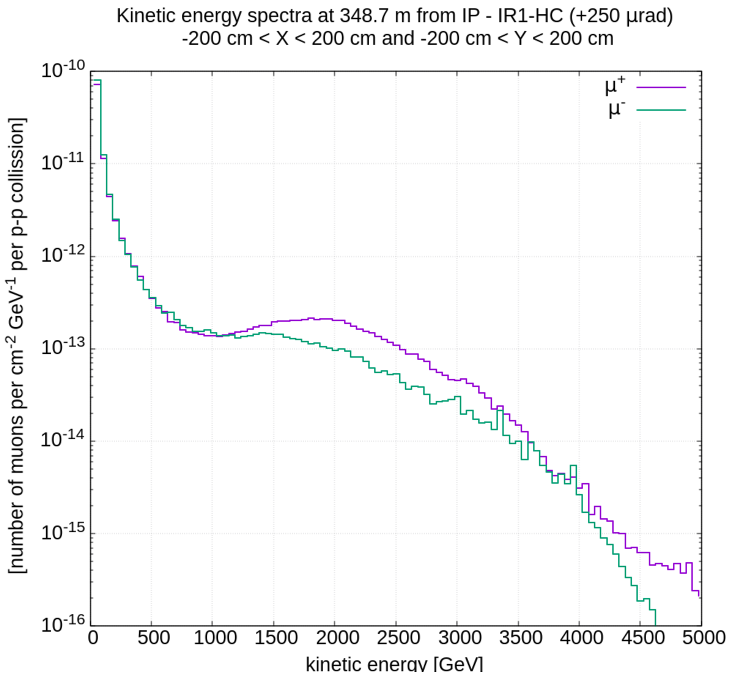
Re-evaluation of the muon distribution considering the magnetic field map of the whole D2 and Q4 magnet, which has an important impact in the muon rate at FPF.

Thanks to the input provided by S. Izquierdo and E.Todesco

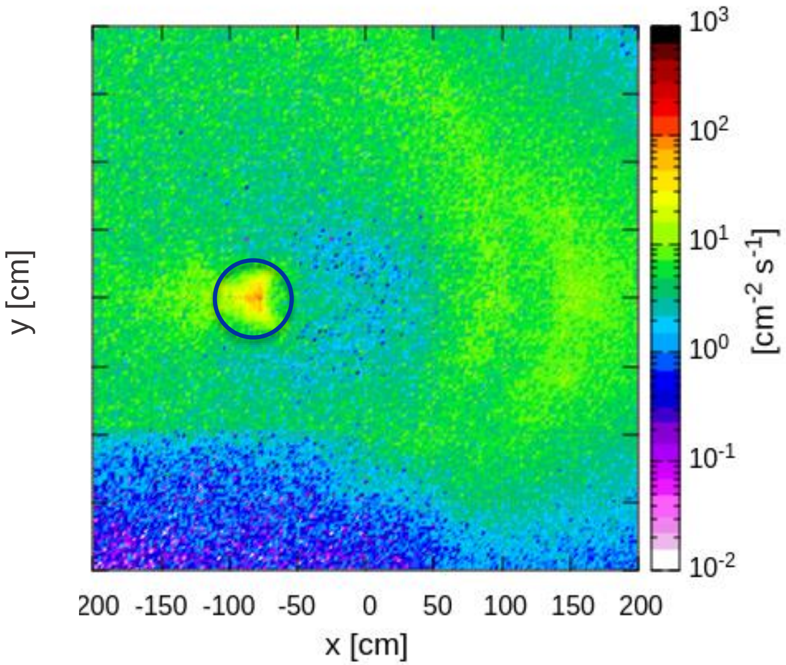
μ^- distribution



energy spectra



μ^+ distribution



Machine location (superconductive magnet section inside the cryostat)

Muon distribution at 348.7 m from IP

Notes on muon distribution at the end of half-cell 9:

- Most of the muons on the horizontal plane come from proton losses in the DS.
- Diffractive protons are over-bent by the DS dipoles towards the inner side.
- Therefore, these protons will impact on the inner side of the mechanical aperture of the external vacuum chamber (outgoing beam).
- The dipole field bends the negative (pions) muons towards the external beam aperture, pushing them outside the ring (positive x).
- Positive muons are generated on the inner side of the external aperture as negative muons. However, they do not experience the dipole field effect thus they are not pushed back through the aperture. Moreover, the opposite field of the internal aperture pushed them towards the external aperture.

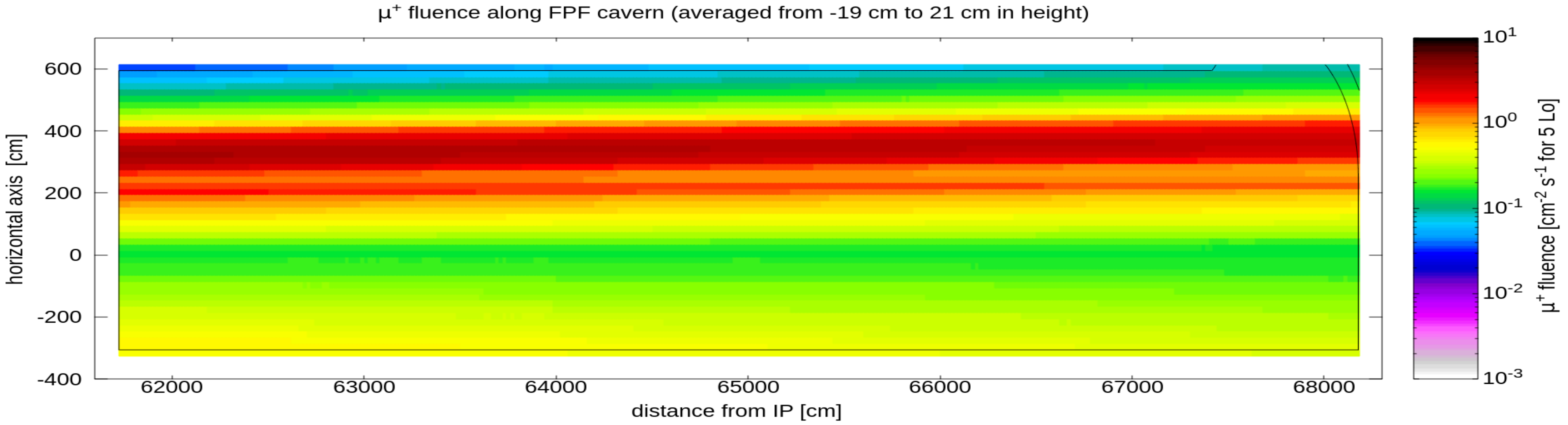
Muon background at FPF

Fluence rates

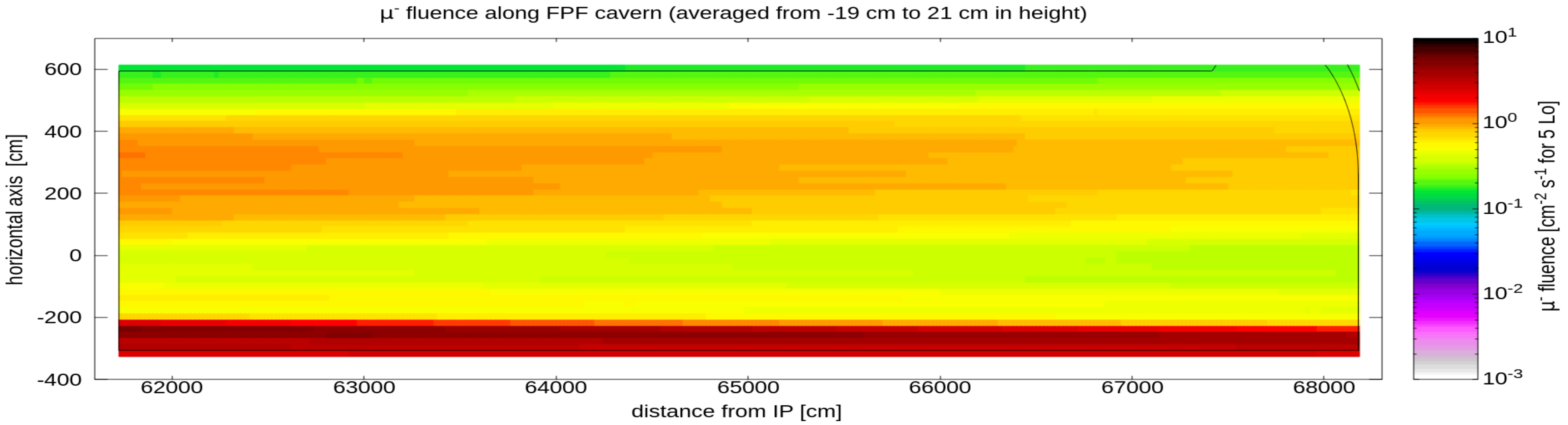
Muon fluence at FPF cavern

Top view of the FPF cavern at beam height

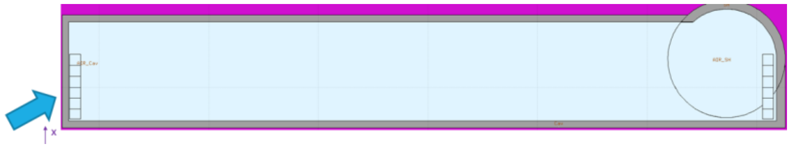
μ^+

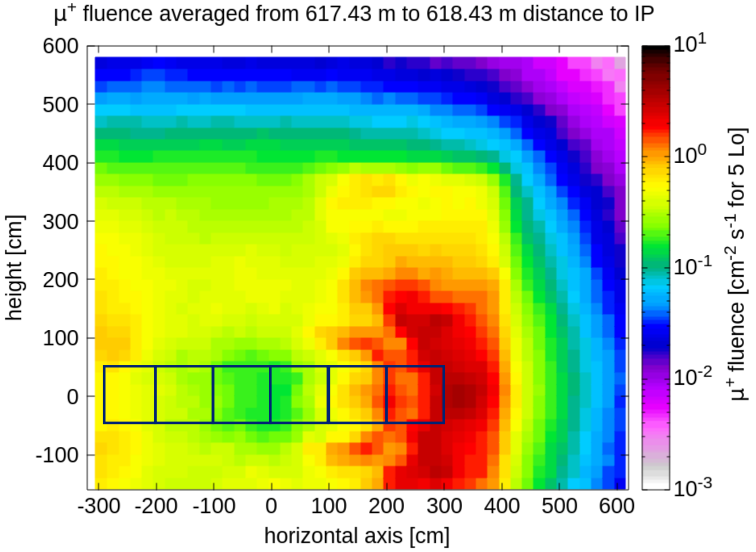


μ^-



Entrance of FPF cavern



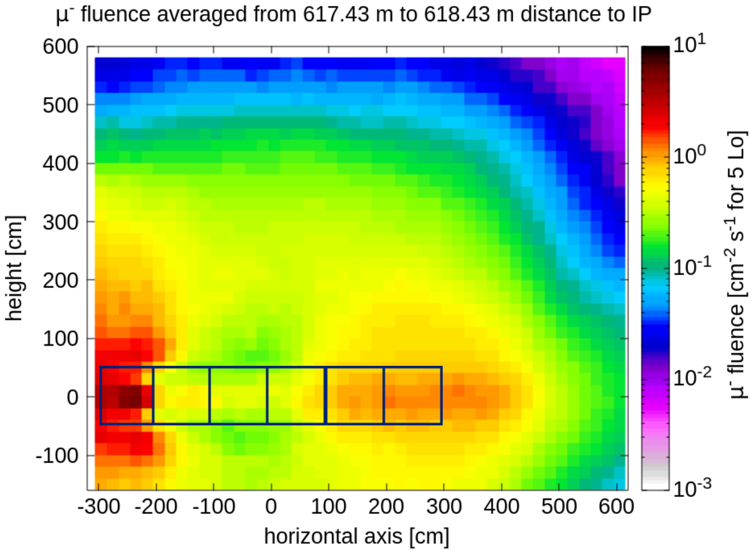


μ^+

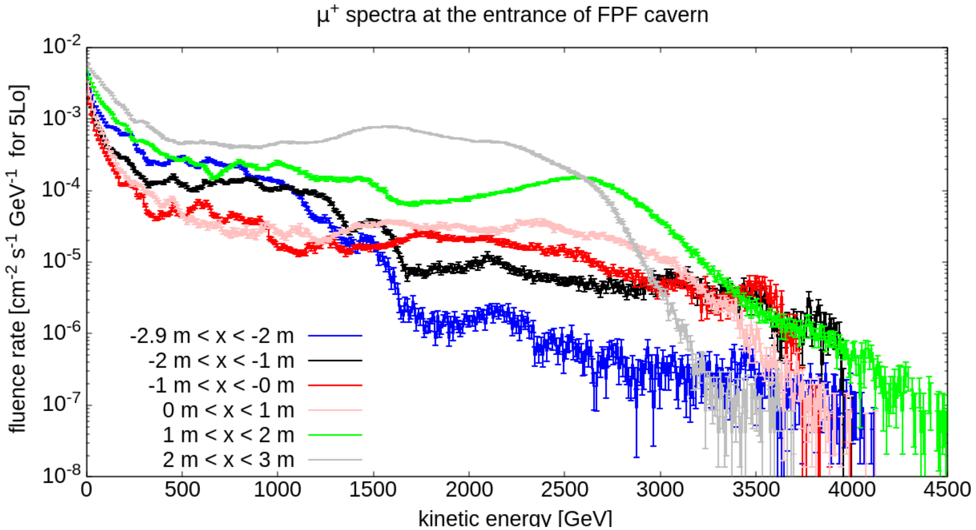
Muon rate at (0,0)

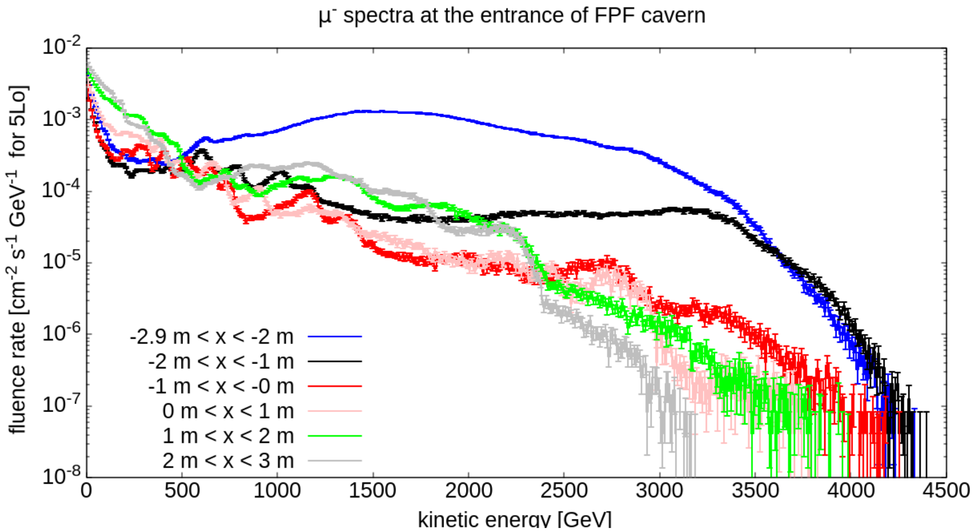
μ^+ : 0.15 $cm^{-2}\,s^{-1}$
μ^- : 0.45 $cm^{-2}\,s^{-1}$

Total : 0.6 $cm^{-2}\,s^{-1}$

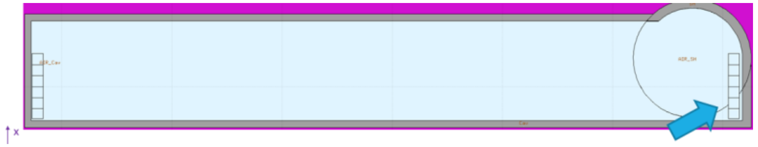


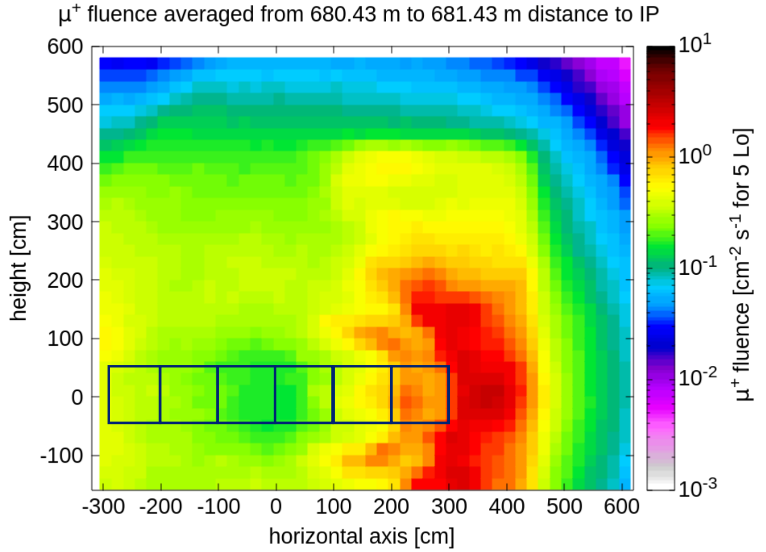
μ^-





End of FPF cavern





μ^+

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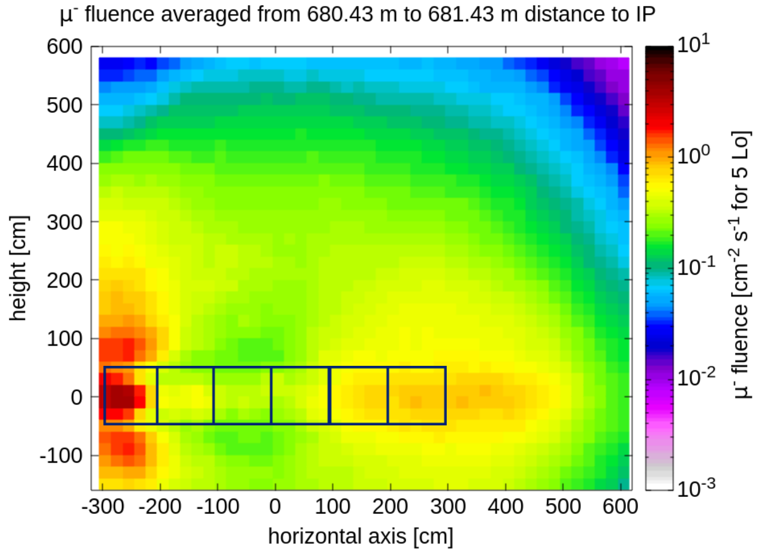
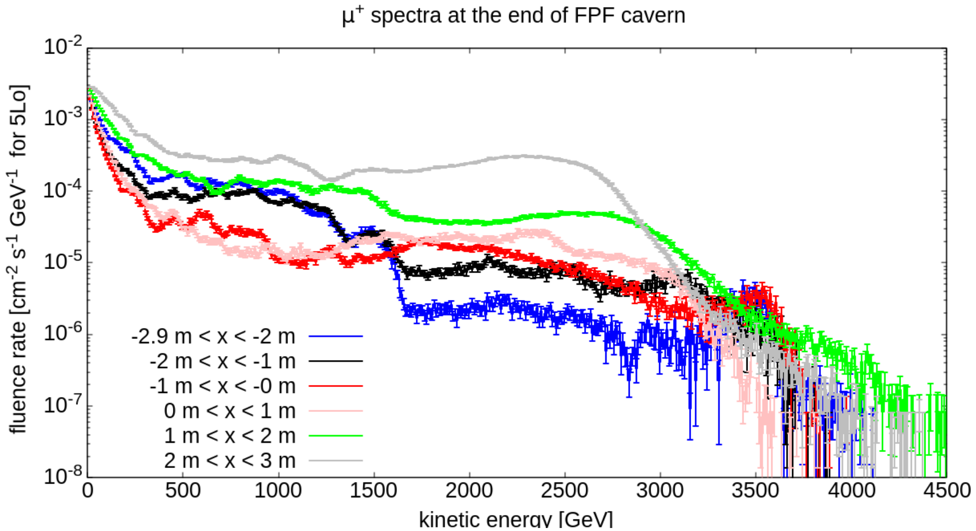
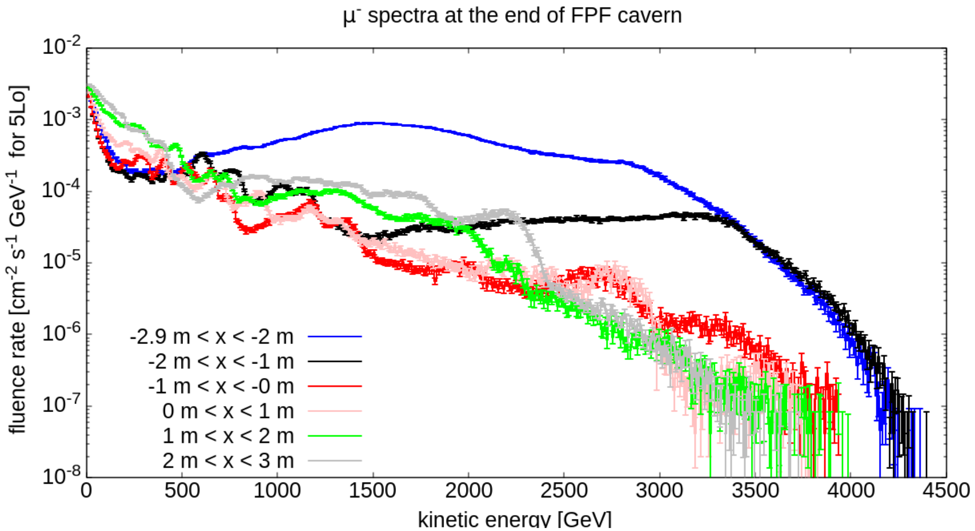


μ^-

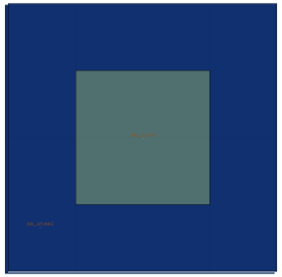




Sweeper Magnet (SM) studies

Fluence rates

Sweeper magnet description

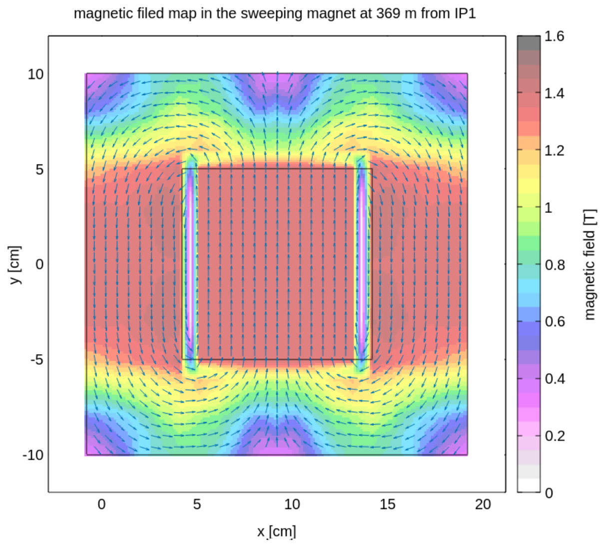


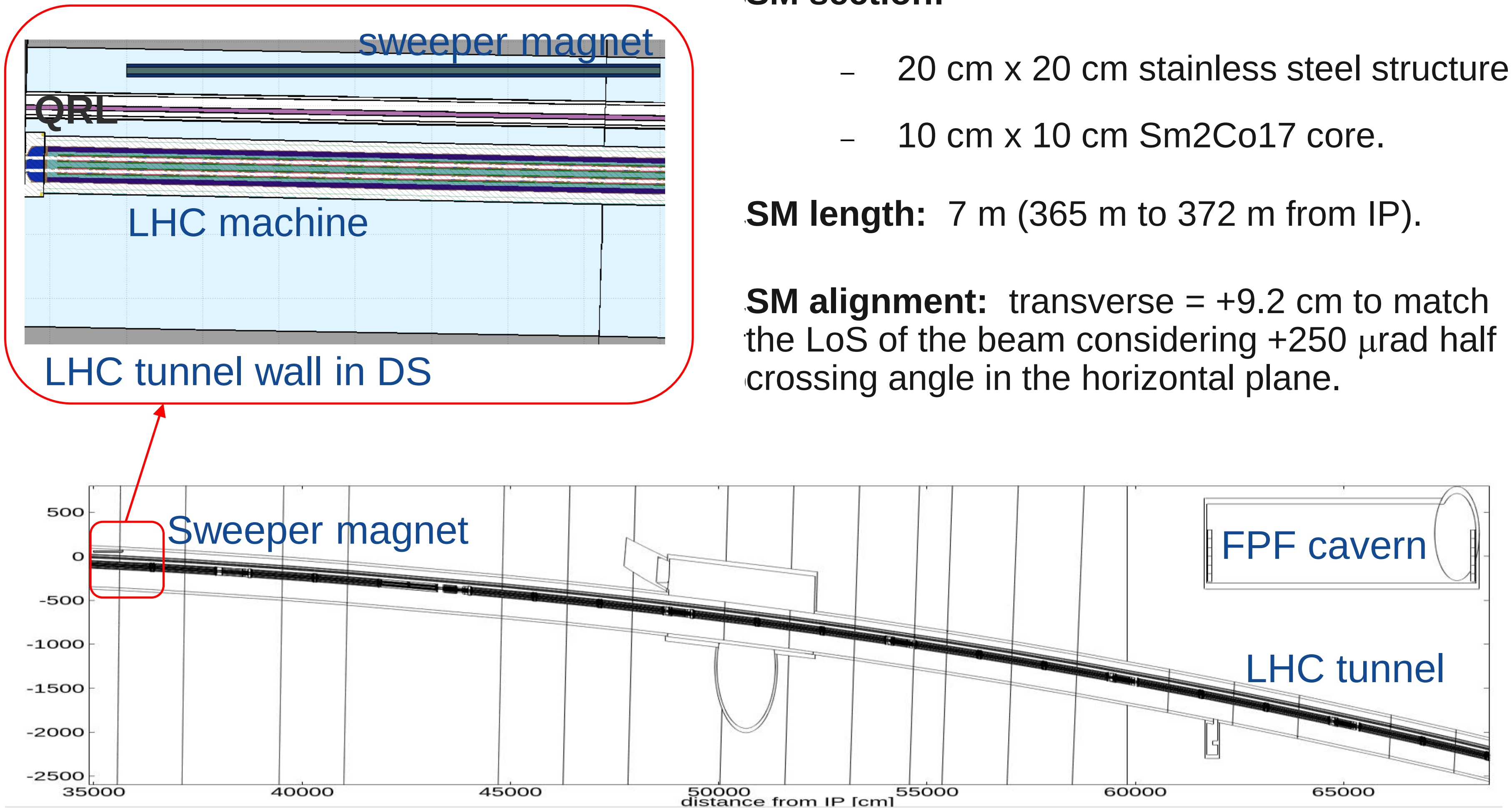
SM section:

- 20 cm x 20 cm stainless steel structure.
- 10 cm x 10 cm Sm2Co17 core.

SM length: 7 m (365 m to 372 m from IP).

SM alignment: transverse = +9.2 cm to match the LoS of the beam considering +250 μrad half crossing angle in the horizontal plane.





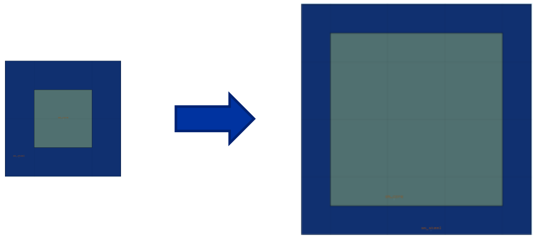
Sweeper magnet configurations

Displace the sm from the LoS to a position whose projection in FPF has higher values of the muon fluence rates:

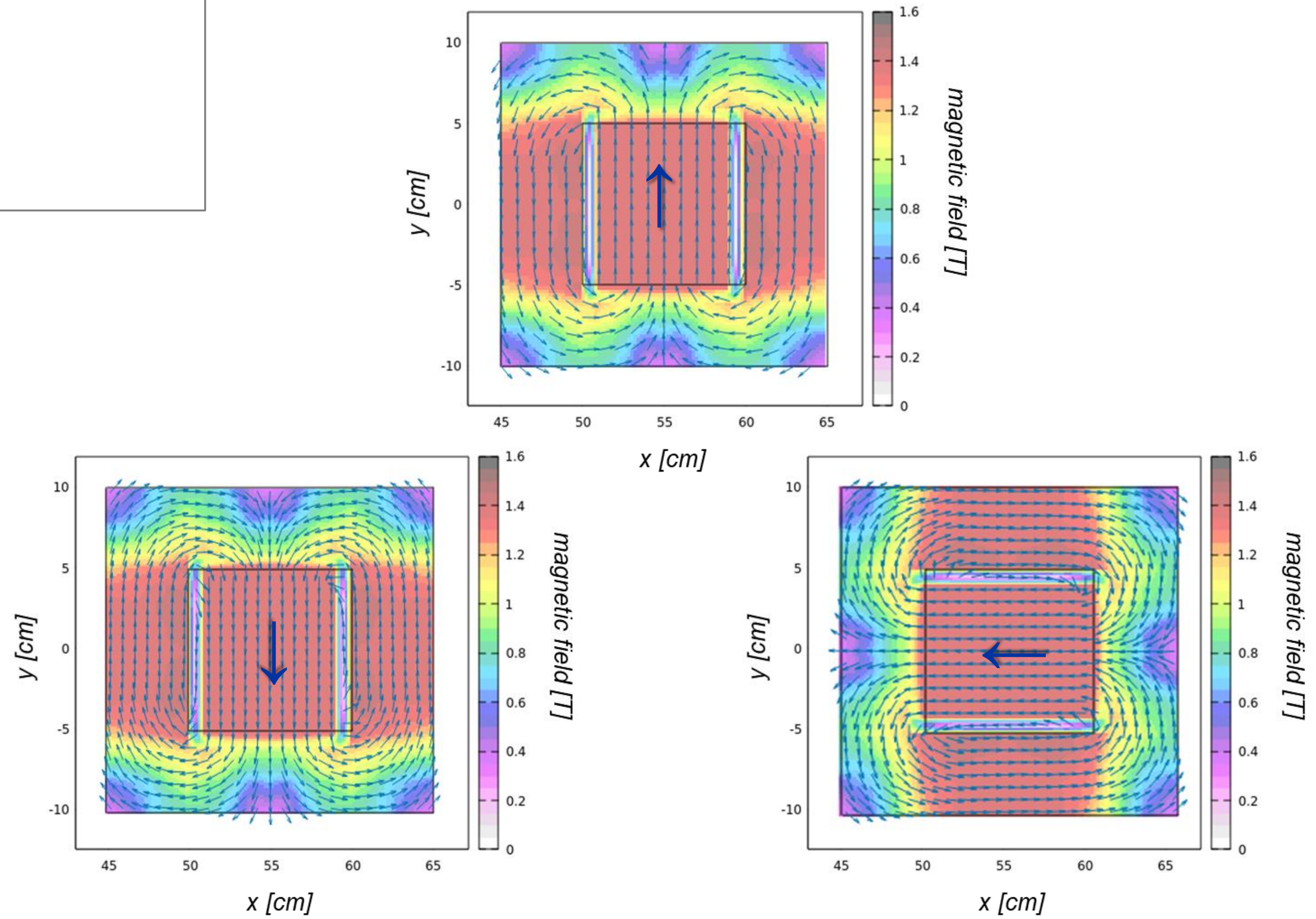
+9.2 cm → +55 cm
L = 7 m
IP distance: 365 m → 350 m

Increase the section of the sm to make it able to intercept more particles:

10 cm x 10 cm → 30 cm x 30 cm
L = 7 m → 6.5 m
IP distance: 365 m → 348.7 m



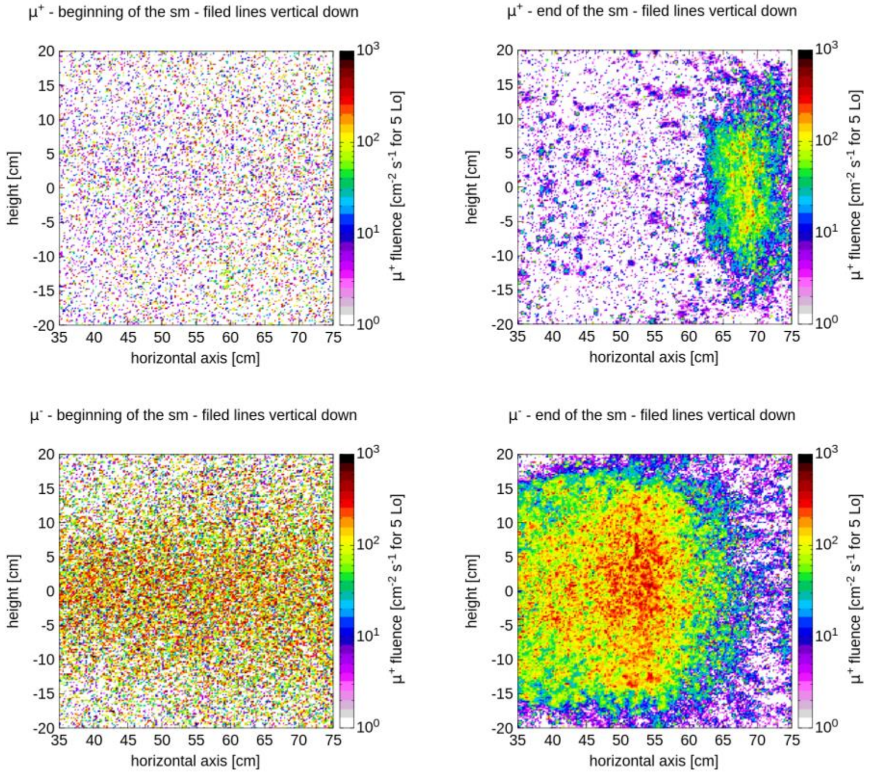
Rotation of the magnetic field:

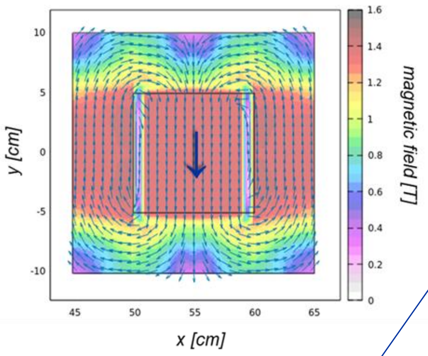


Sweeper magnet configurations

beginning of sm | end of sm

μ+ / μ−

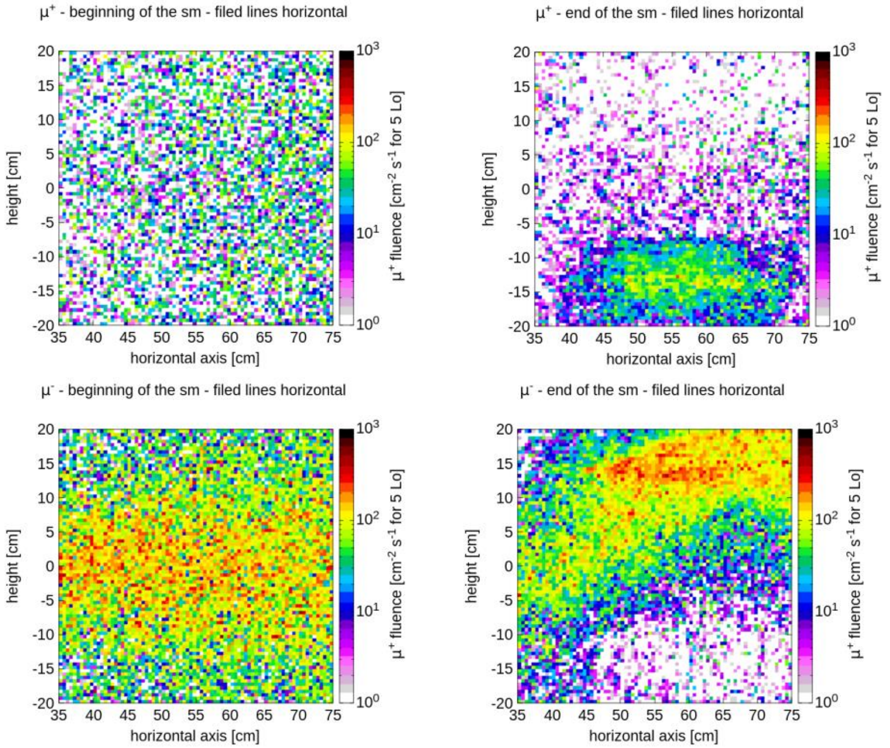


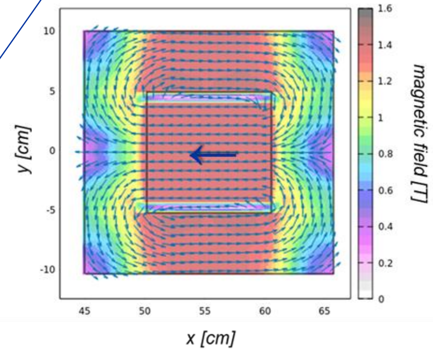


Rotation of the magnetic field:

beginning of sm | end of sm

μ+ / μ−





Muon fluence rate at (0,0) for different sweeper magnet configurations

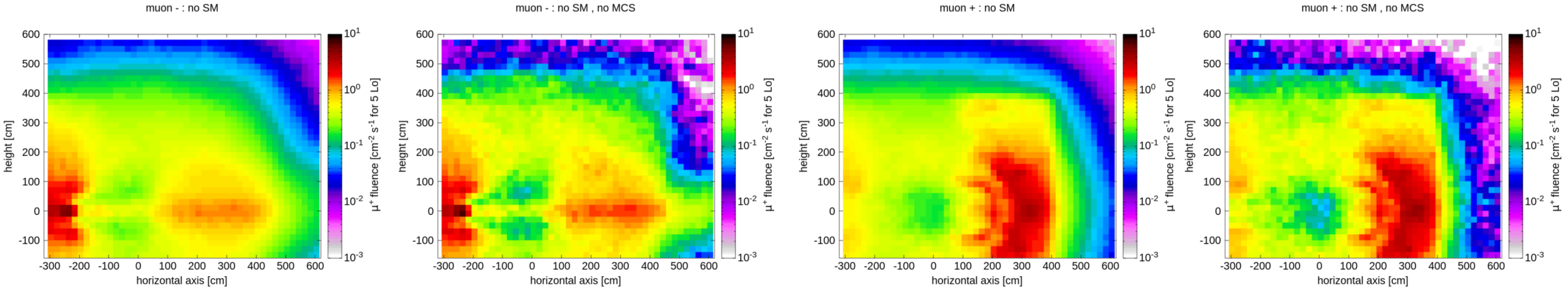
Configuration	Φ (μ^+) (cm^{-2} s^{-1})	Φ (μ^-) (cm^{-2} s^{-1})
Without SM	0.15	0.45
SM in the LoS (+9.2 cm) 10 cm x 10 cm section magnetic field lines ↑	0.17	0.45
SM at + 55 cm 10 cm x 10 cm section magnetic field lines ↑ or ↓ or ←	0.14 - 0.16	0.42 - 0.45
SM at + 55 cm 30 cm x 30 cm section magnetic field lines ↓	0.15	0.5

The displacement of the sm, the rotation of the magnetic field or the increment in the sm section seems not to have any effect in the muon fluence rate in FPF.

WHY?

Muon fluence rate distribution at FPF

- There are 220 m of rock from the location where the muons exit the LHC tunnel and the FPF cavern.
- Muons are scattered in the rock and re-populate the region that was ‘cleaned’ by the sweeper magnet.
- In order to check the impact of the Coulomb scattering, several cases where it was suppressed have been studied.



Muon fluence rate at (0,0) for different sweeper magnet configurations

Configuration	Φ (μ^+) ($cm^{-2}\ s^{-1}$)	*Φ** *(μ^+)* ($cm^{-2}\ s^{-1}$)	Φ (μ^-) ($cm^{-2}\ s^{-1}$)	*Φ** *(μ^-)* ($cm^{-2}\ s^{-1}$)
Without SM	0.15	*0.1*	0.45	*0.35*
SM in the LoS (+9.2 cm) 10 cm x 10 cm section magnetic field ↑ / ←	0.17	*0.13*	0.45	*0.6 / 0.45*
SM at +55 cm 30 cm x 30 cm section magnetic field ↓	0.15	*0.1 – 0.14*	0.55	*0.6*
SM at +55 cm 30 cm x 30 cm section magnetic field ←	0.15	*0.1 - 0.14*	0.5	*0.4*

** Suppressing the multiple Coulomb scattering and nuclear interactions of muons.*

Conclusion on the sweeper magnet effect

- The presence of the sm seems to have a negligible effect in the muon fluence. Similarly, the displacement, enlargement of its section or the rotation of the magnetic field does not vary the muon fluence.

- The studies on the suppression of the Coulomb scattering show that the muon distribution is highly affected by these physics processes that shadow the effect on the sm itself due to the more than 200 m of rock that muons have to travel before reaching the FPF cavern.

- Even neglecting the Coulomb scattering, the effect of the sm does not show a beneficial impact in reducing the muon rate at FPF.

- *Therefore, the effect of the sm, in the proposed location, is negligible at the level of the FPF not contributing to the reduction of the muons fluence rate at (0,0).*

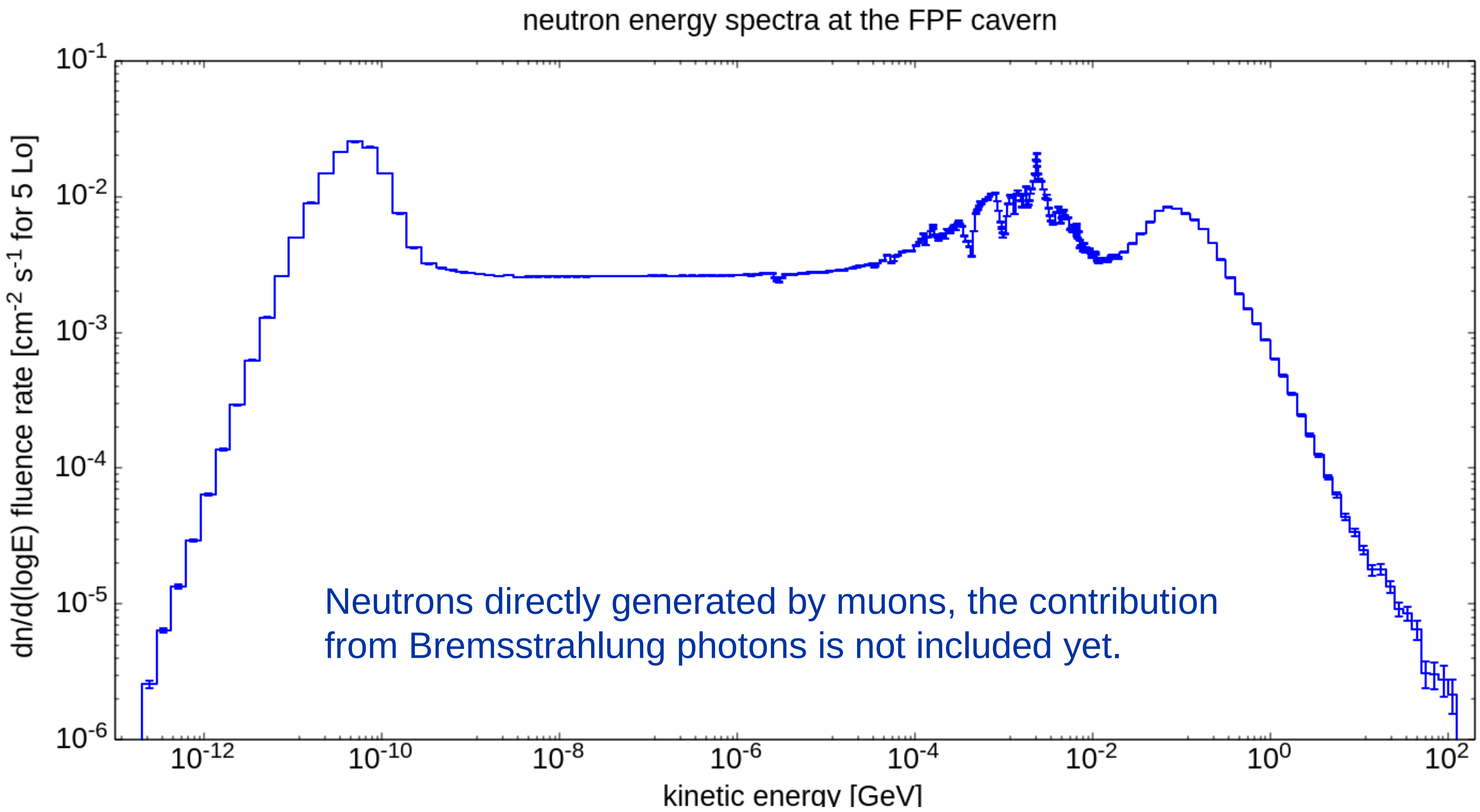
Neutron level at FPF

Neutron fluence

Energy spectra

Neutron energy spectra

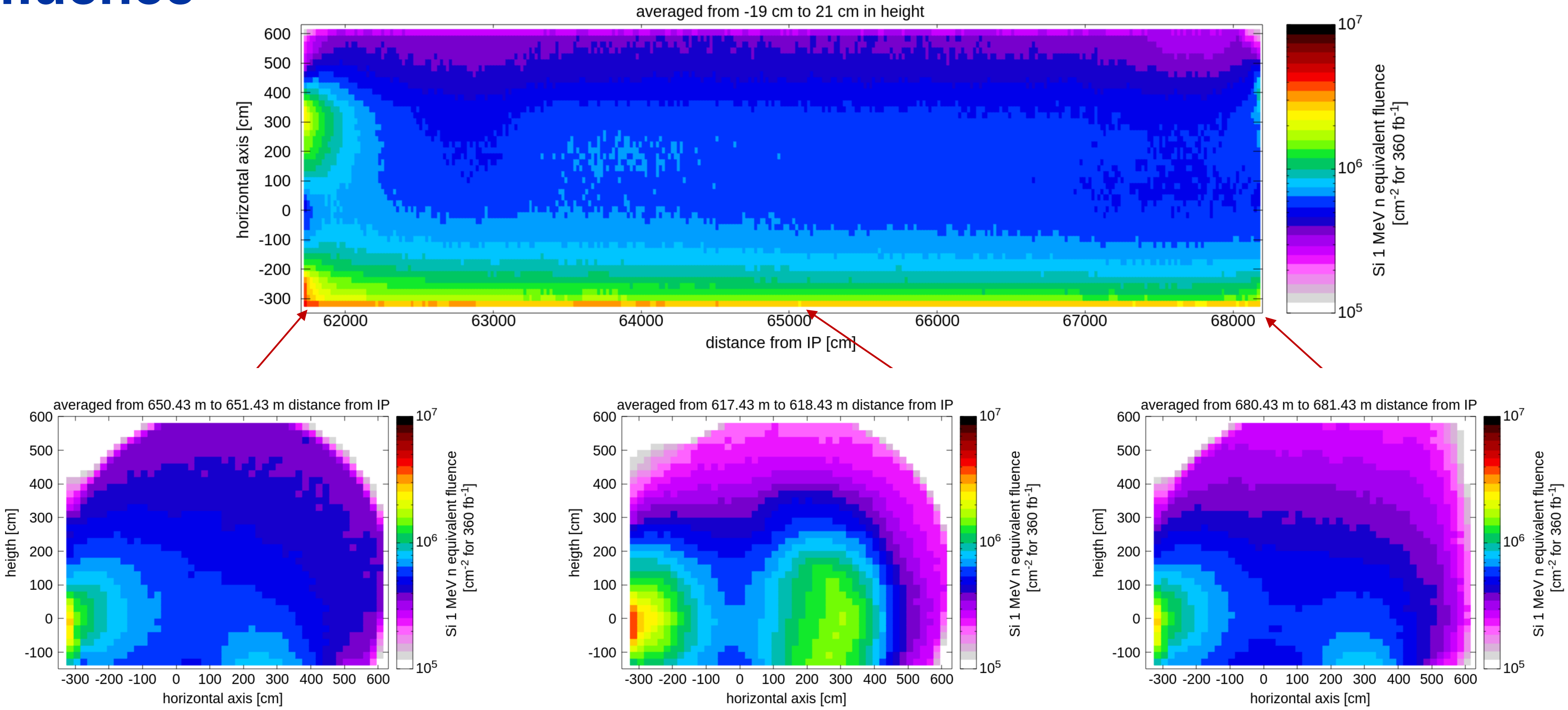
Only muon interaction is considered in the simulations, the electromagnetic component is not included here.



Neutrons directly generated by muons, the contribution from Bremsstrahlung photons is not included yet.

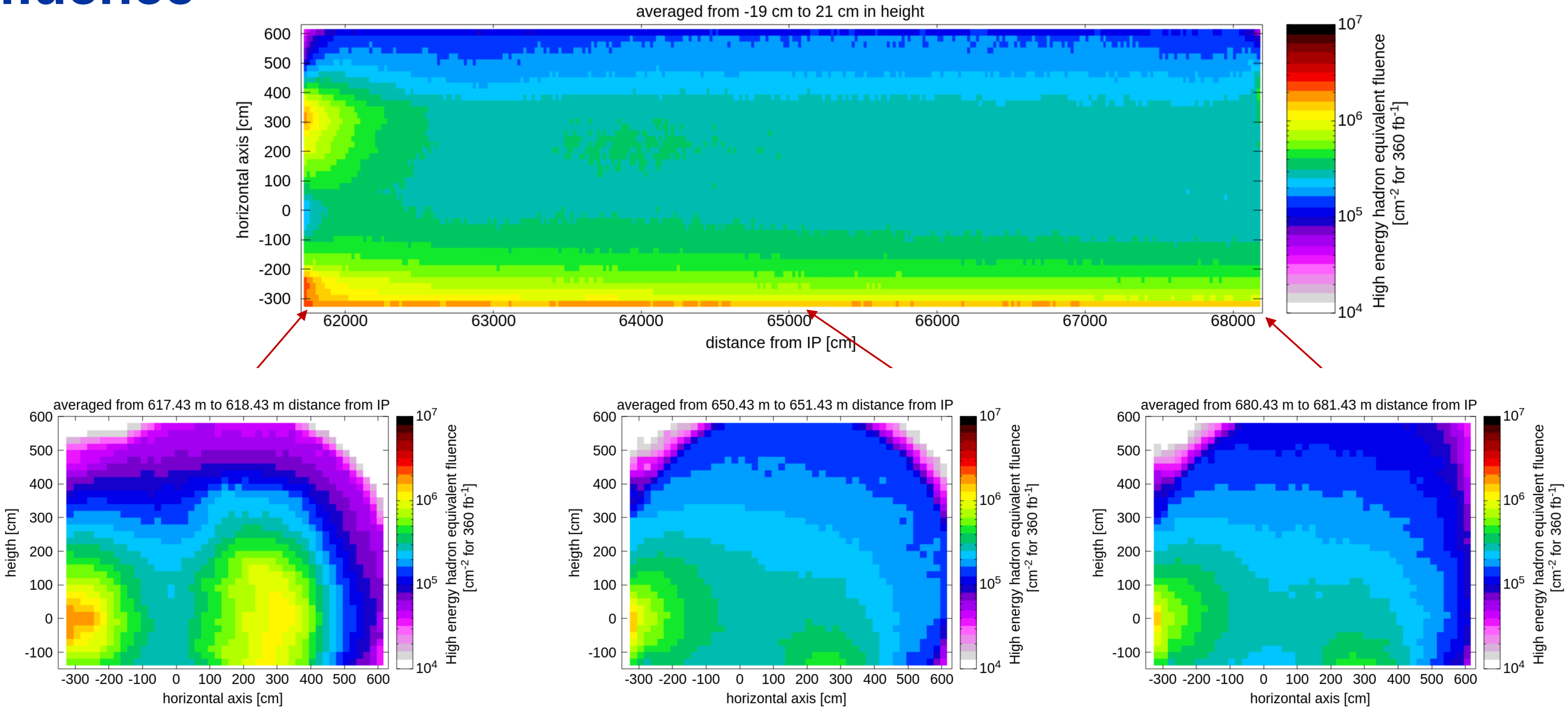
Silicon 1 MeV neutron equivalent fluence

Only muon interaction is considered in the simulations, the electromagnetic component is not included here.



High energy hadron equivalent fluence

Only muon interaction is considered in the simulations, the electromagnetic component is not included here.



Conclusions

- **Muon rate was re-evaluated at FPF considering the complete magnetic field map of D2 and Q4 (in the LSS), what turns to have a positive impact in reducing the muon rate.**

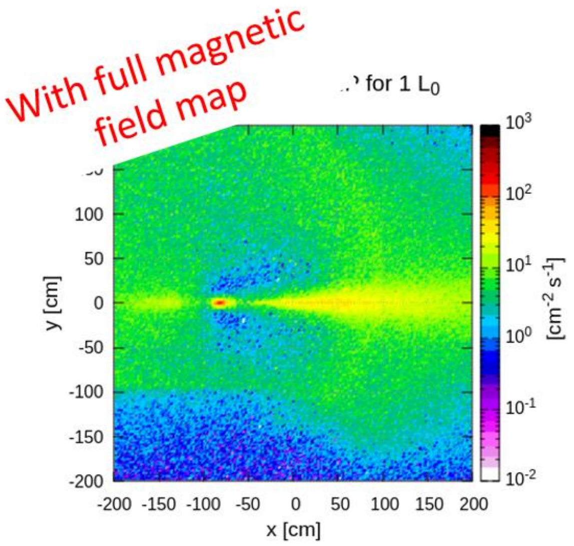
- **There is no evidence that the sweeper magnet is beneficial.**

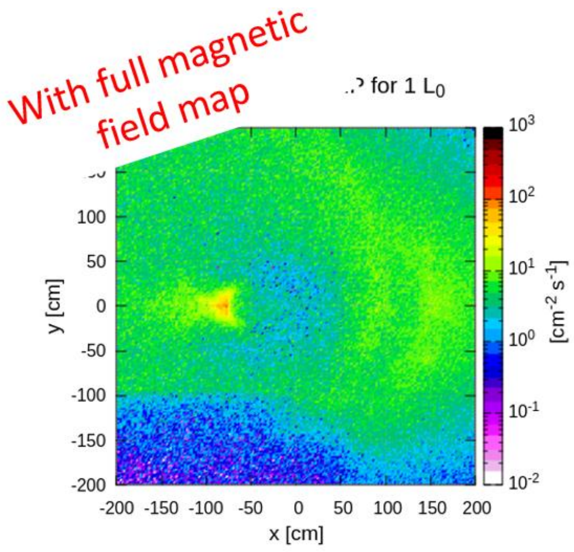
- **A first evaluation of radiation levels (neutrons) was done BUT the contribution from Bremsstrahlung photons still needs to be added.**

Thank you for your attention

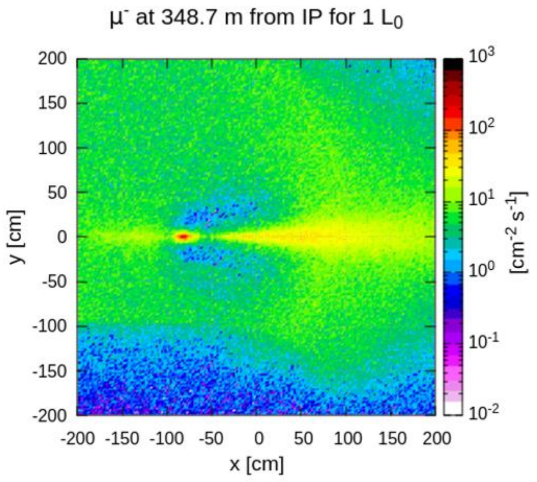
Muon distribution at 348.7 m from IP

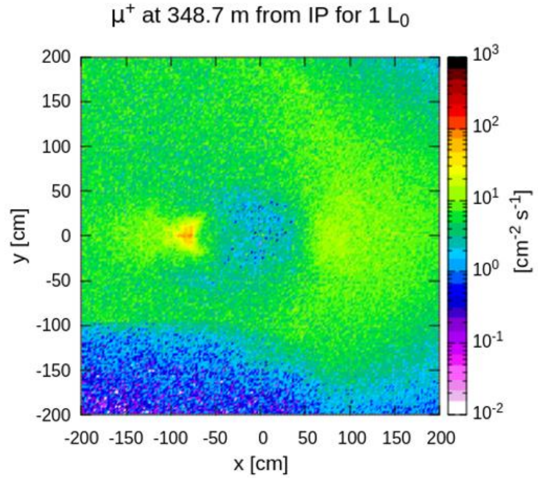
Latest result



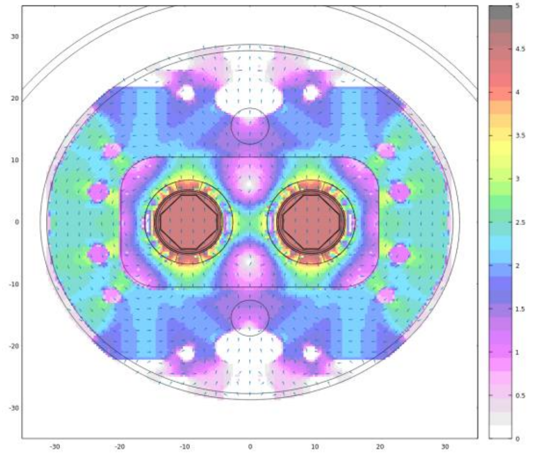


Data shown in previous meeting

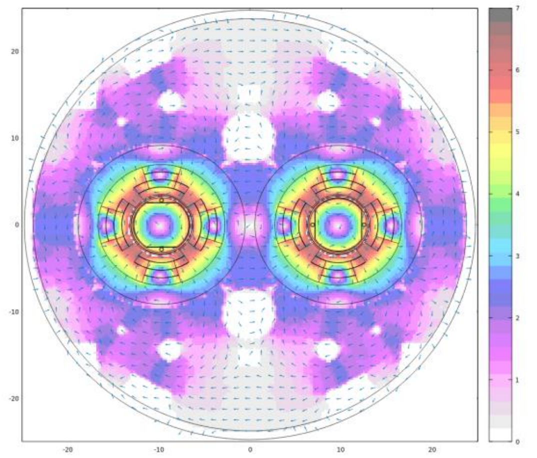




D2 field map



Q4 field map



Thanks to the input provided by S. Izquierdo and E.Todesco

Neutron energy spectra