International MUON Collider Collaboration

MuCol

CERN

10 TeV Muon Collider: MDI update: pair production and nozzle tip studies

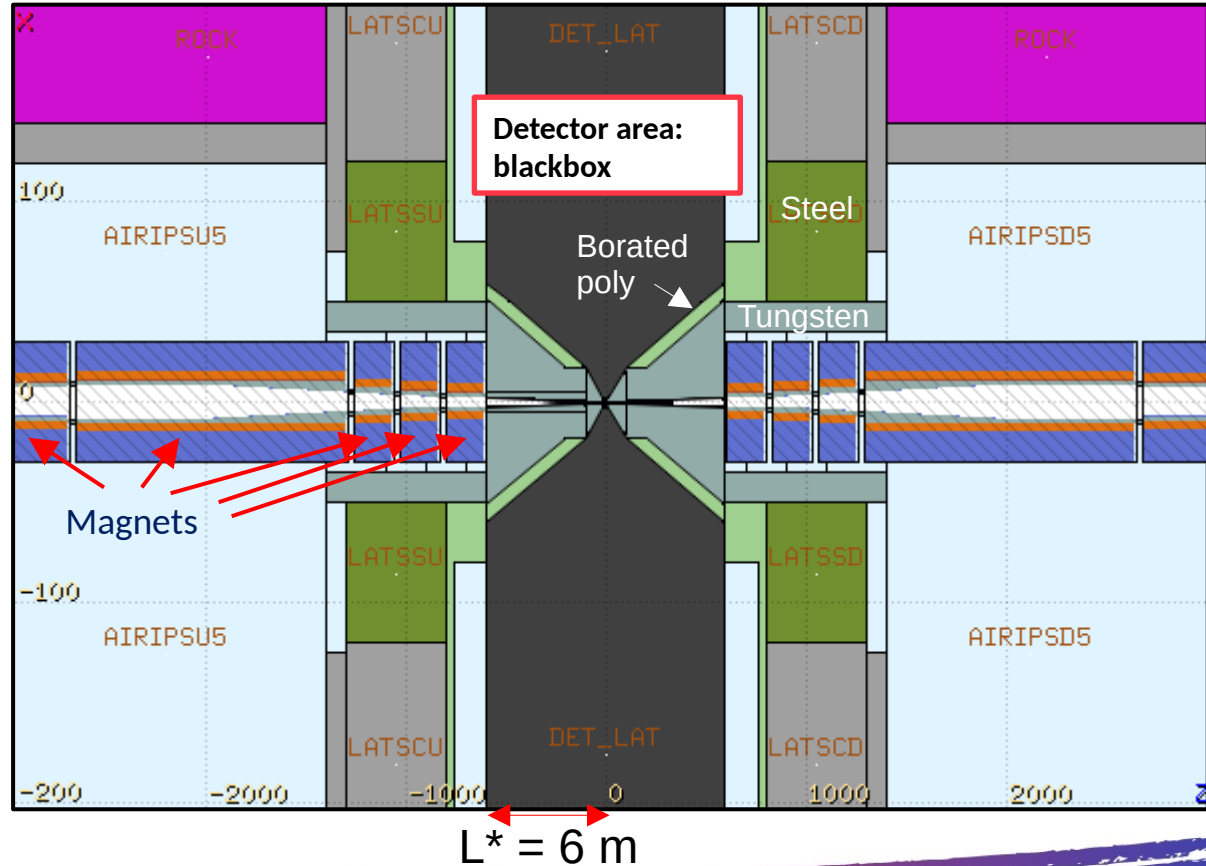D. Calzolari (CERN – SY/STI/BMI) on behalf of the IMCC
April 2024

Outline

- **Machine-Detector Interface (MDI):**
  - Geometry of the interaction region
  - Current version of the nozzle
- **Luminosity:**
  - Beam-beam effects and luminous region
- **New incoherent pair production sample**
- **Electron fluences in the first tracker layers:**
  - Incoherent pair production
  - Muon decay background
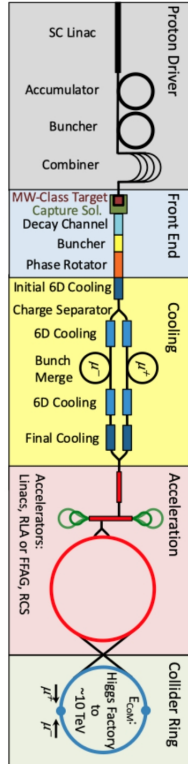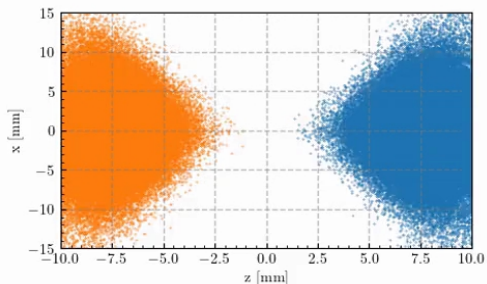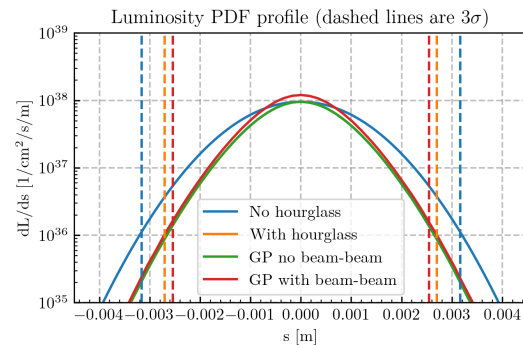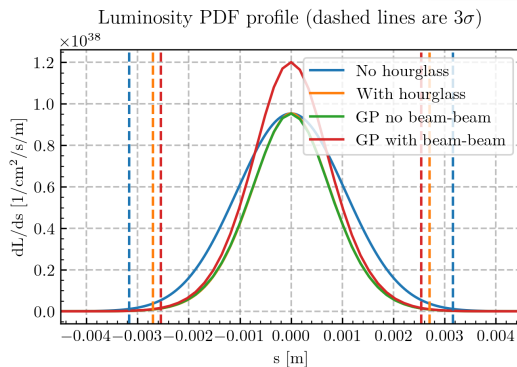
MDI: geometry of a 10 TeV collider

Luminosity: some consideration

- As shown during the annual meeting (see <u>this presentation</u>), the luminosity is enhanced due to the pinch effect.

- S. P. Griso raised another point: what is the extension of the luminous region? In other words, where are collision happening?

- I calculated the luminous region with and without beam effects. In all cases, the interactions will occur in the very close proximity of the IP.

Tiny luminous region:
σ << 1 cm

Important hourglass effect: β depends on s

Incoherent pair production: new sample

▪ With Guinea-Pig, I produced a new incoherent pair production background sample.

▪ The new software version allows to fully simulate the interaction between muons, while in the past the interactions were simulating with a mass scaling of the electrons.

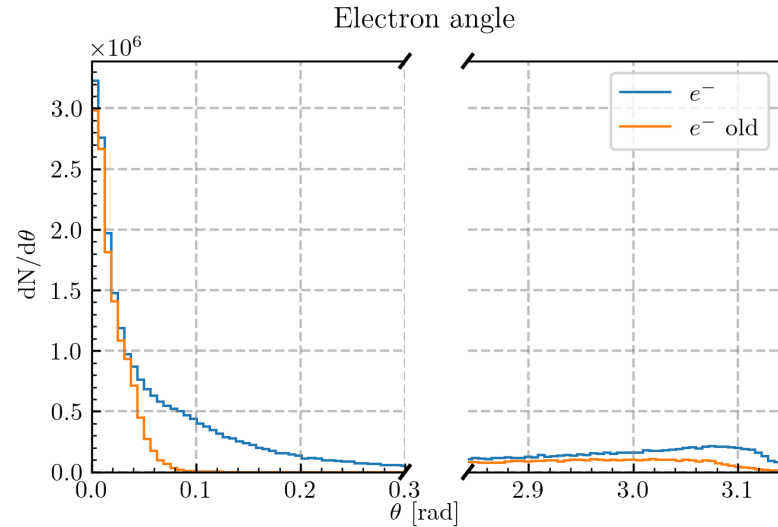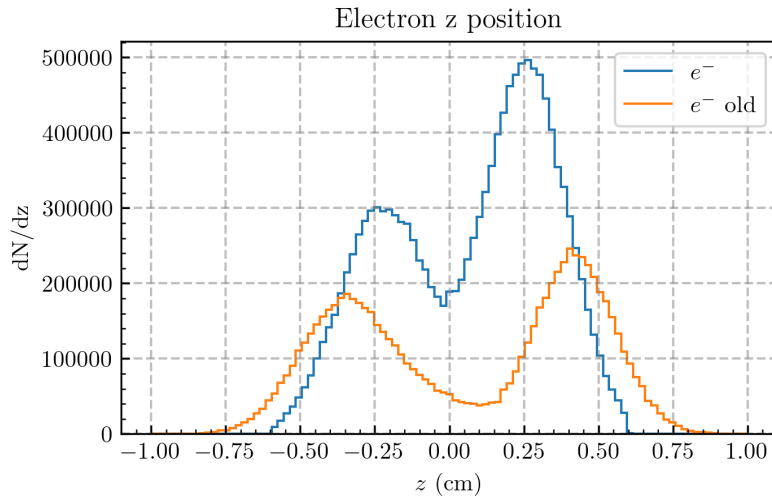▪ With higher virtuality, pairs can have more kinetic energy

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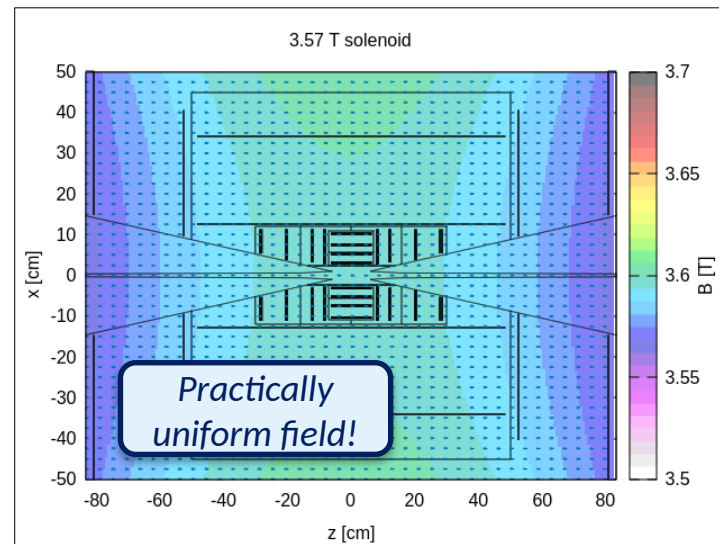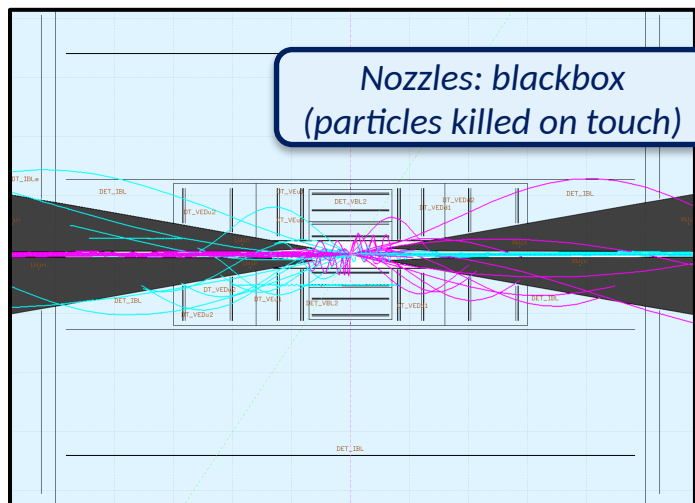- With higher virtuality, pairs can have more kinetic energy

Incoherent pair production: fluences in trackers

- A large fraction of electron (positrons) are not intercepted by the nozzle, and will travel in the trackers without shielding.

- To calculate these fluences, I modeled the nozzle as a blackbox to observe only the "direct" fluences

Nozzles: blackbox
(particles killed on touch)

Practically uniform field!

Incoherent pair production: fluences in trackers

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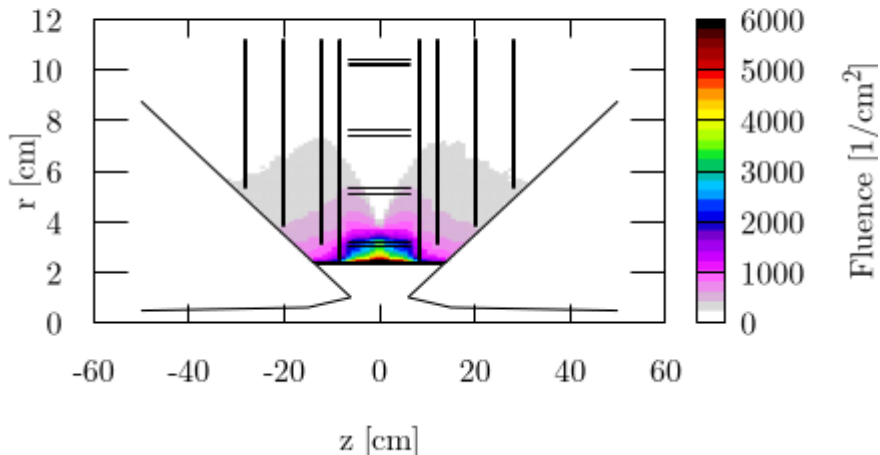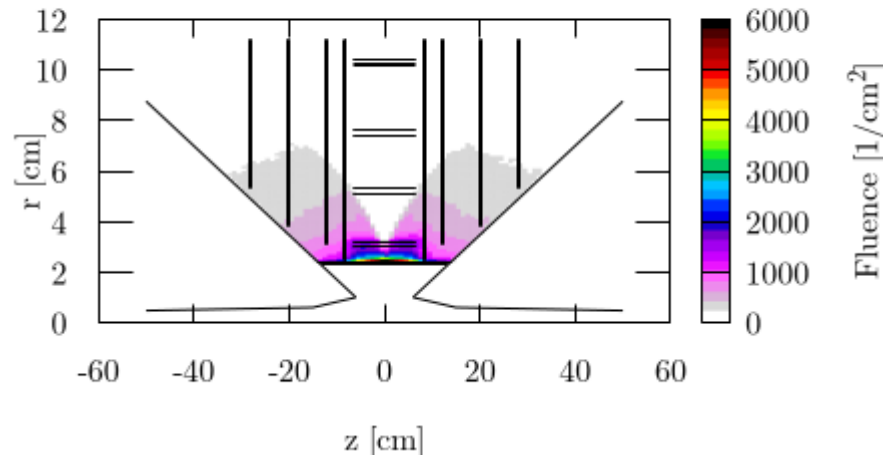- To calculate these fluences, I modeled the nozzle as a blackbox to observe only the "direct" fluences.

- With an higher field, the first double layer has a lower $e^{+/-}$ fluence and the second layer is spared

Electron/positron fluences with 3.57 T solenoid

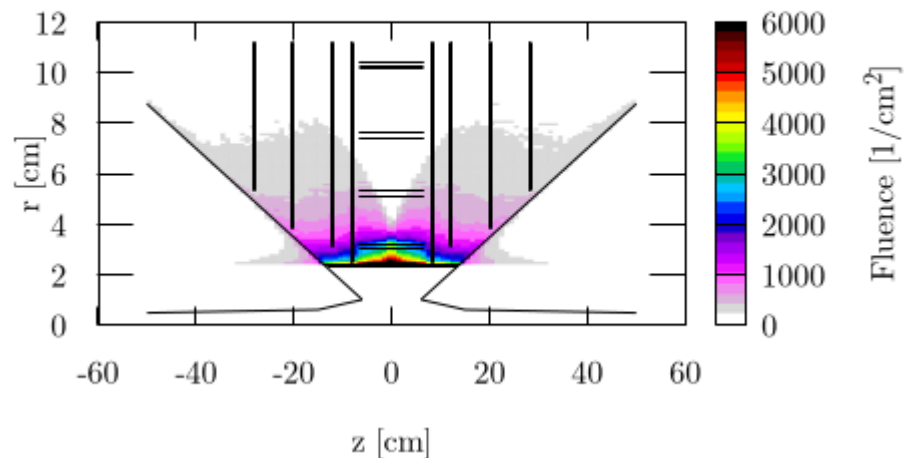Electron/positron fluences with 5 T solenoid
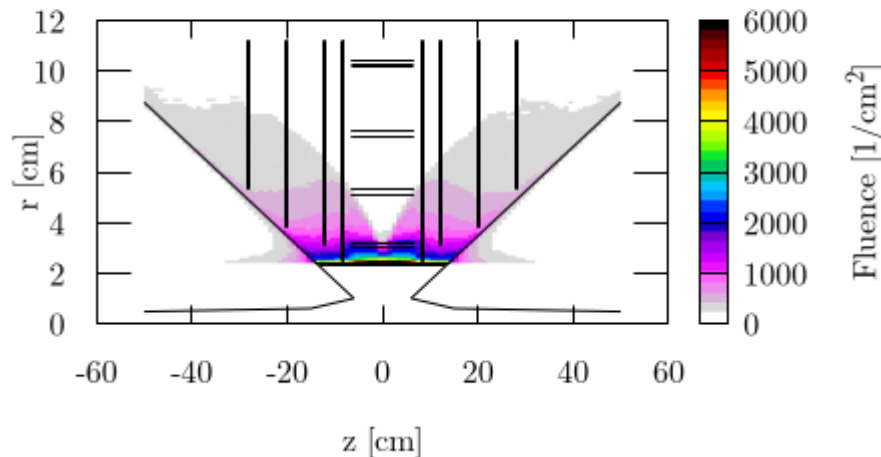
Incoherent pair production: fluences in trackers

- When including the contribution of the interactions with the nozzles, there is an additional fluence of secondary particles.

- The contribution from these secondary particles is not a dominant factor in the overall background

Electron/positron fluences with 3.57 T solenoid (w nozzle)

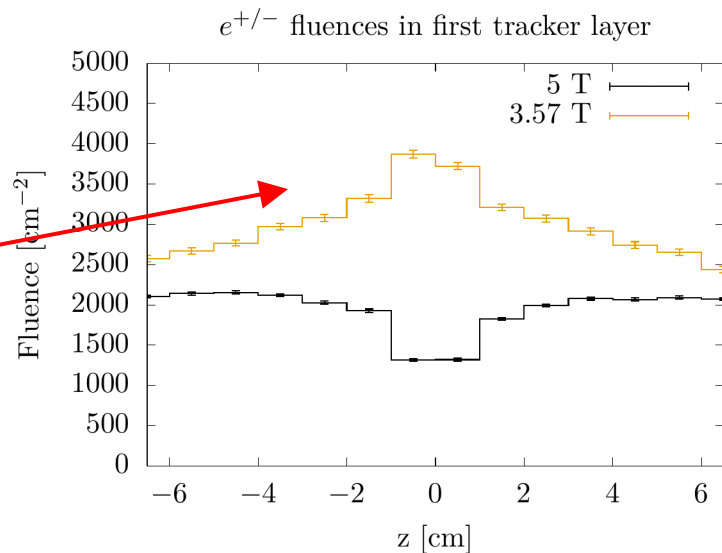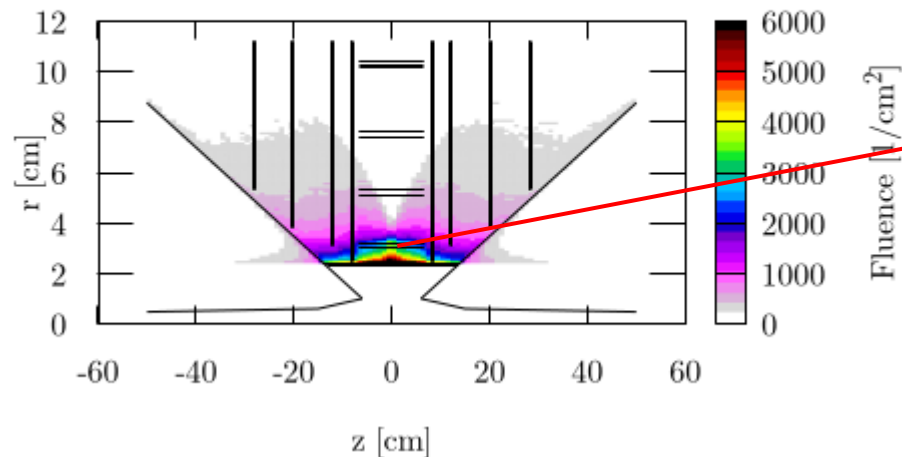Electron/positron fluences with 5 T solenoid (w nozzle)

Incoherent pair production: comparison fields

- When including the contribution of the interactions with the nozzles, there is an additional fluence of secondary particles.

- The contribution from these secondary particles is not a dominant factor in the overall background

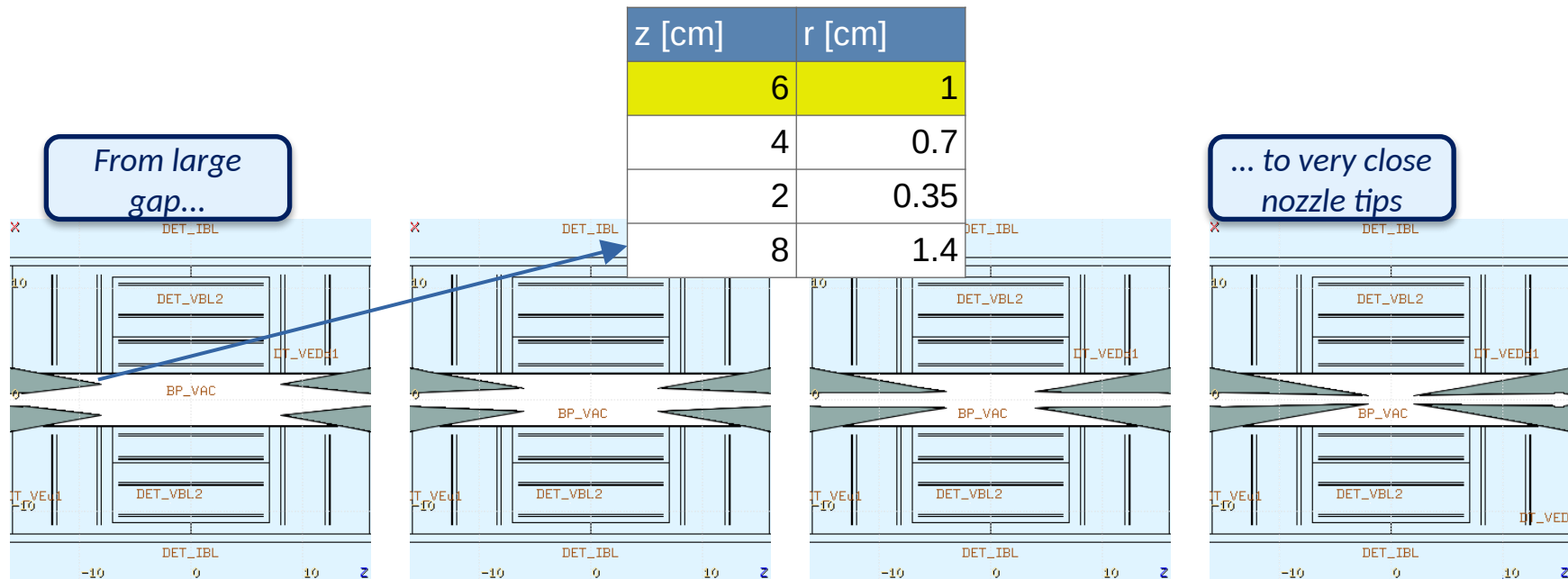Electron/positron fluences with 3.57 T solenoid (w nozzle)

$e^{+/-}$ fluences in first tracker layer

Decay background: nozzle tip influence

- To continue study the effect of the BIB on the first tracker layer, I simulated the fluence in case of different nozzle tip shapes

z [cm]	r [cm]
6	1
4	0.7
2	0.35
8	1.4

From large gap...
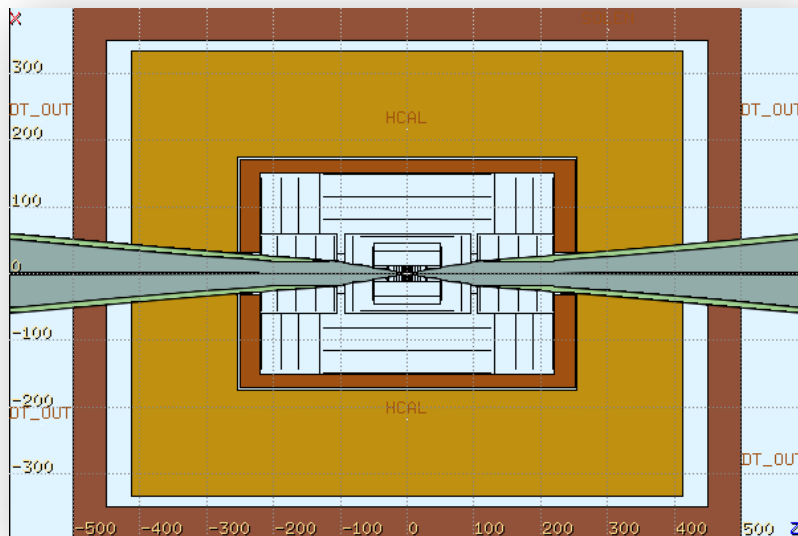
... to very close nozzle tips

Decay background: nozzle tip influence

- To continue study the effect of the BIB on the first tracker layer, I simulated the fluence in case of different nozzle tip shapes.

- The geometry of the nozzle area is shown in figure. The only relevant parts are the nozzles and the trackers.

- No timecuts are applied (but can be done for future simulations)

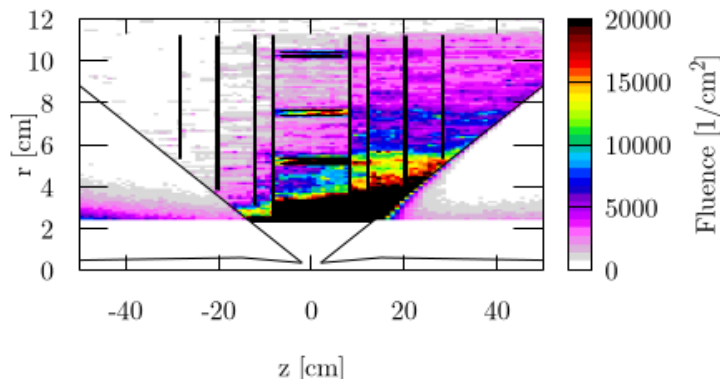| Number of original decays simulated	Total number of secondaries produced	Secondaries produced per decay	Expected number of decays	Expected number of secondaries to nozzle area
9.22E+04	2.85E+07	308.77	1.18E+07	3.64E+09

Decay background: nozzle tip influence

- Three possible configuration are shown

- For the 2 cm, the tip position cause a necking in the inner cone aperture. The results show that this should be avoided

Fluence with nozzle tip at 2 cm

Fluence with nozzle tip at 6 cm

Fluence with nozzle tip at 8 cm

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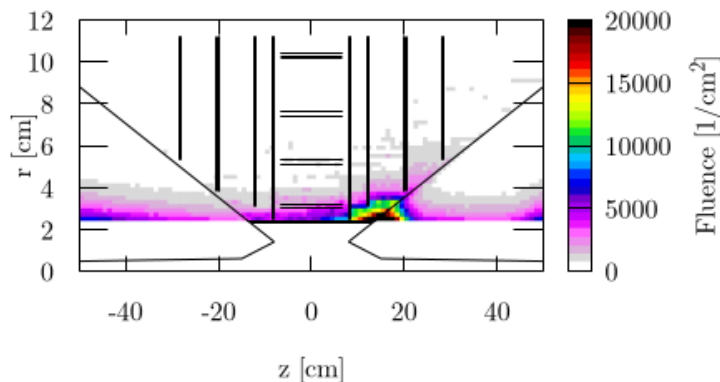
Fluence with nozzle tip at 2 cm

Fluence with nozzle tip at 6 cm
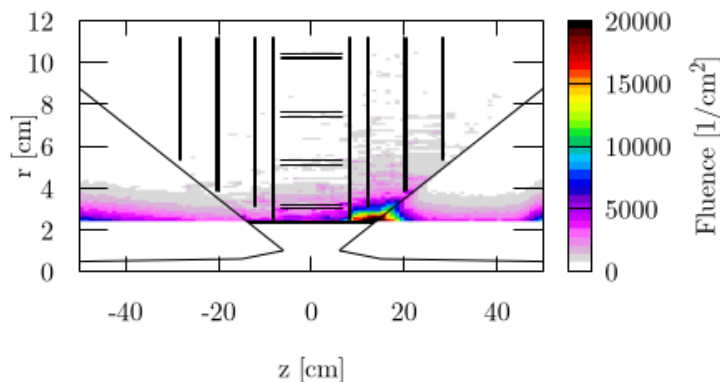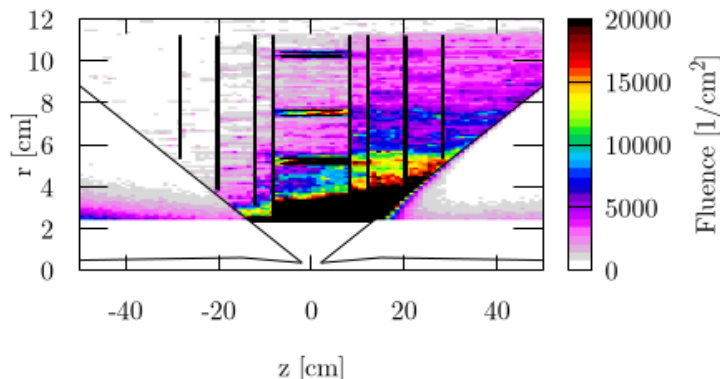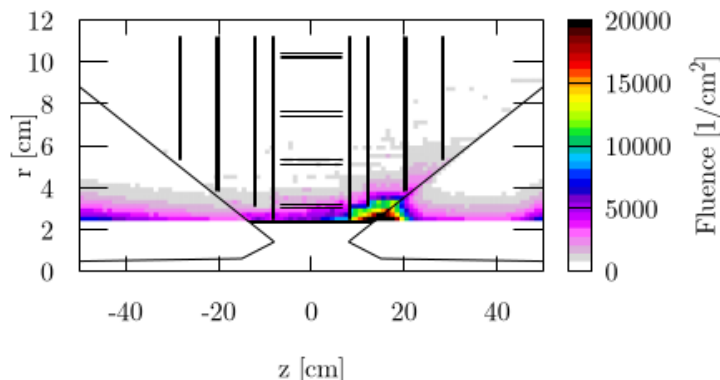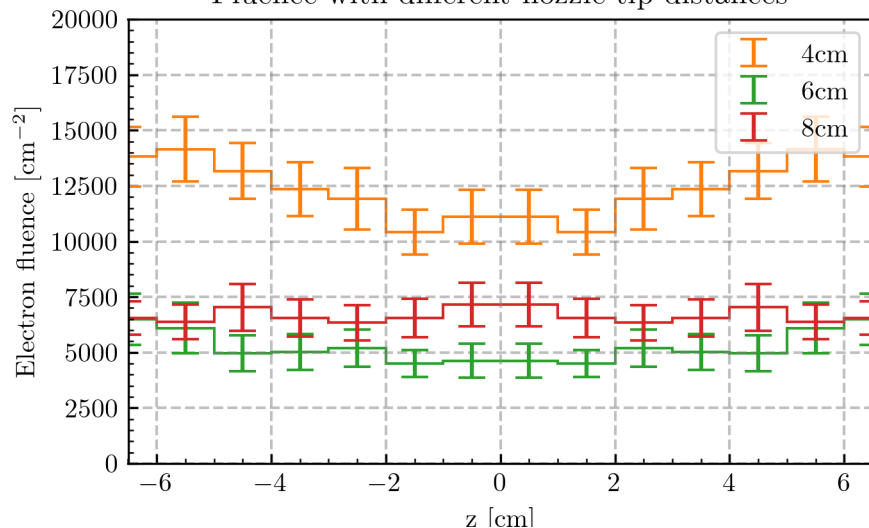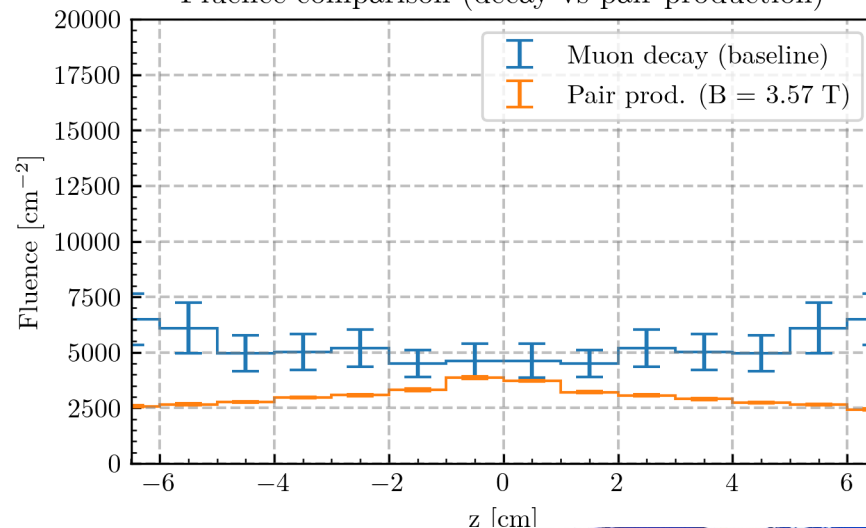
Fluence with nozzle tip at 8 cm

- The comparison between different nozzle tip position is shown. This time includes contribution from both beams.

- The results show better performances with larger gaps. This is advantageous also from the mechanical engineering perspective (larger relative tolerances)

Conclusions

- Guinea-pig software was used for the calculation of the luminous zone and the generation of the incoherent pairs.

- The **luminous zone** has very **small longitudinal size**. The real shape can be used for detector performance simulations to sample the "real" vertex position.

- **Incoherent pairs** with the new Guinea-pig version have **harder spectra and more abundant particle multiplicity**.

- **Solenoidal field intensity has an influence in the e$^{+/-}$ fluences**. Using a realistic magnetic field map is not strictly required for simulation within the tracker region.

- The **nozzle tip** has a strong influence on the electron fluences in the first tracker layers. A distance of **4 cm or more is required** to avoid EM showers reaching the detectors from the nozzle tip.
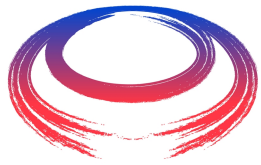
Thank you
for your attention!

Workflow in the IMCC
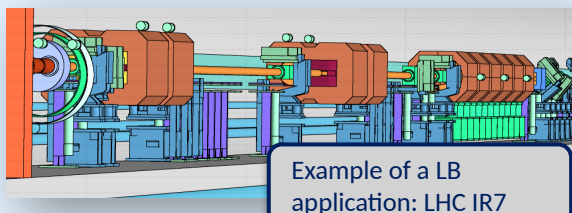
Machine-Detector Interface: MDI

1. Lattice design

The magnet optics is computed via dedicated codes (e.g. MAD-X).

The output is a twiss file, containing the machine elements in a sequence

2. FLUKA geometry model

Via LineBuilder (LB), complex geometries are assembled in a FLUKA input file

Example of a LB application: LHC IR7

3. BIB simulation

With the built geometry, a FLUKA simulation is run.

The position and momentum of the decay muons are sampled from the matched phase-space

Iteration with lattice design experts to mitigate the BIB

BIB data to detector experts

CERN STI/BMI is currently responsible for the geometry built at √s = 3 and 10 TeV