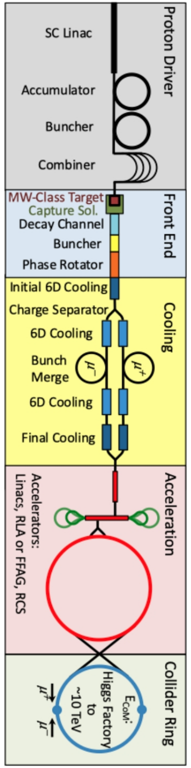
MDI studies update: tracker hits in FLUKA

D. Calzolari (CERN – SY/STI/BMI)
24/10/2023

Outline



- **MDI geometry:**
  - Lattices under study
- **High statistics run with 5 T solenoid**
- **Detector implementation in FLUKA:**
  - Realistic description of Vertex, approximate Inner and Outer trackers
- **Realistic solenoid implementation in FLUKA**
- **First studies for tracker hits in FLUKA**
- **Consideration on algorithms**
- **Conclusions**

Workflow in the IMCC

Machine-Detector Interface: MDI

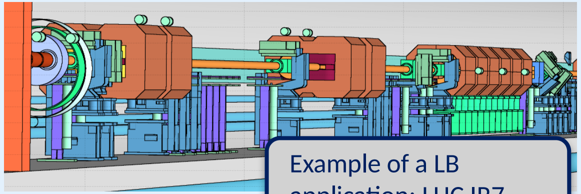
1. Lattice design

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 $\sqrt{s}$ = 3 and 10 TeV

Workflow in the IMCC

International
MUON Collider
Collaboration

Machine-Detector Interface: MDI

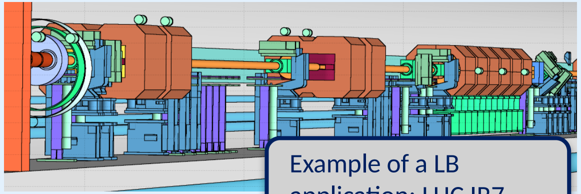
n

ts is
cated

s file,
chine
nce

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

BIB detector propagation in FLUKA

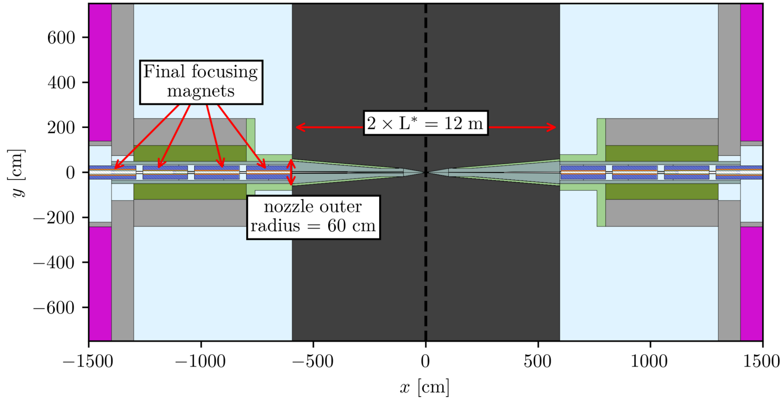
Iteration with lattice design experts to mitigate the BIB

BIB data to detector experts

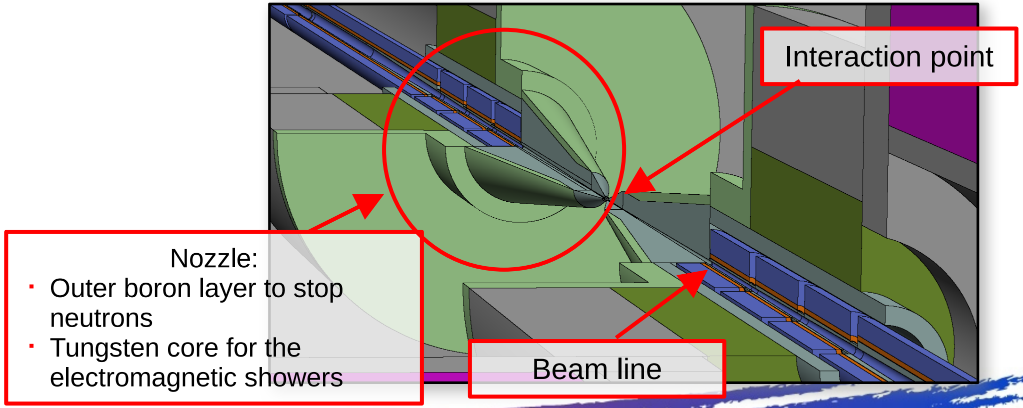
ently responsible for the geometry built at $\sqrt{s}$ = 3 and 10 TeV

Interaction region: MDI

- MDI is a **difficult challenge** for the muon collider. First studies were done by the MAP collaboration (energies up to 6 TeV). So far, IMCC focused on studies for energies up to 10 TeV.
- Objectives of the new studies:
  - Devise a conceptual IP design achieving **background** levels **compatible** with **detector operation**, both in terms of physics performance and acceptable cumulative radiation damage.
  - The focus energies are 3 TeV and 10 TeV.



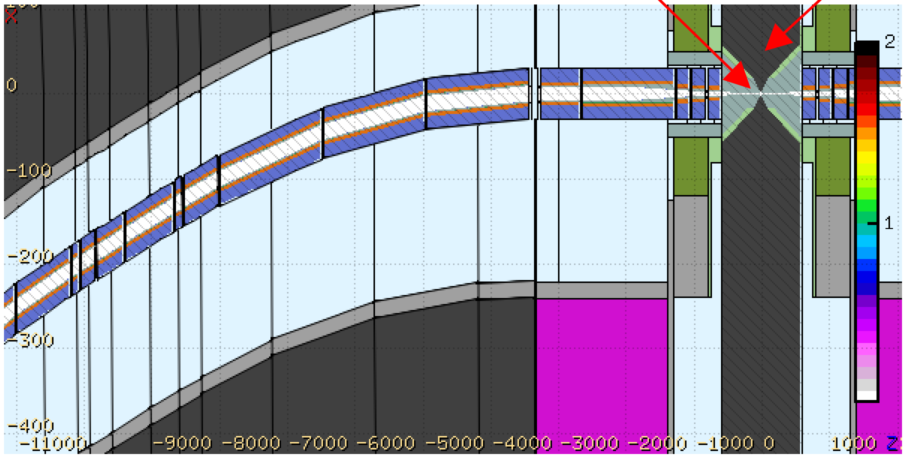
Geometry of the MDI

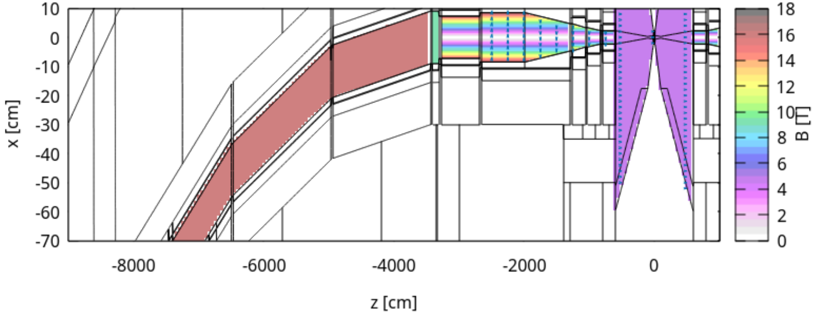


MDI: lattice v.0.4

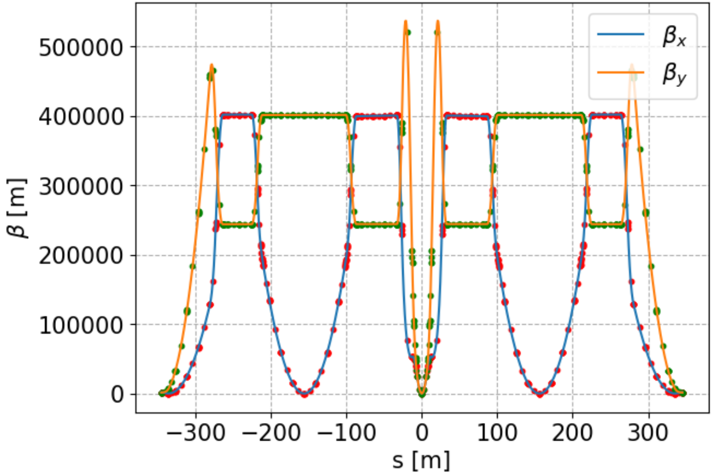
Nozzle (shielding)

Detectors (not modeled)



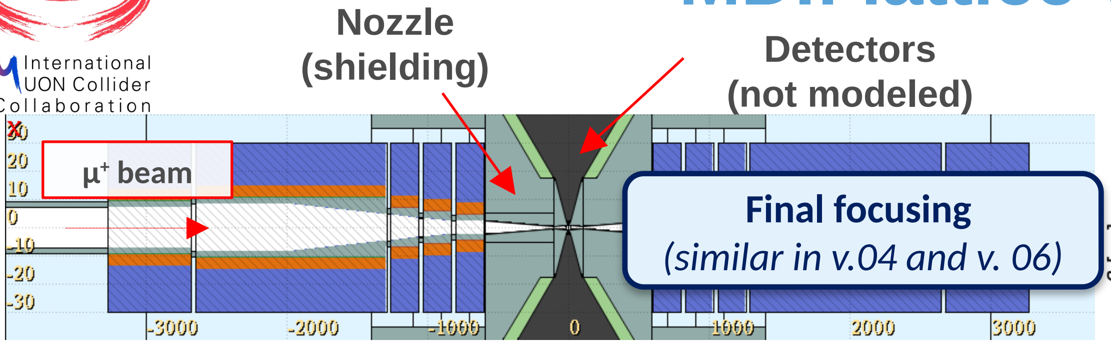


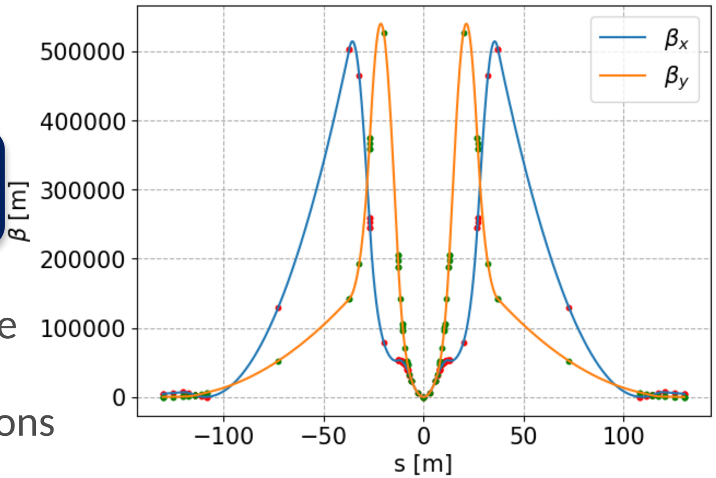
- The v.0.4 is the first having both the final focusing region and the chromaticity correction.



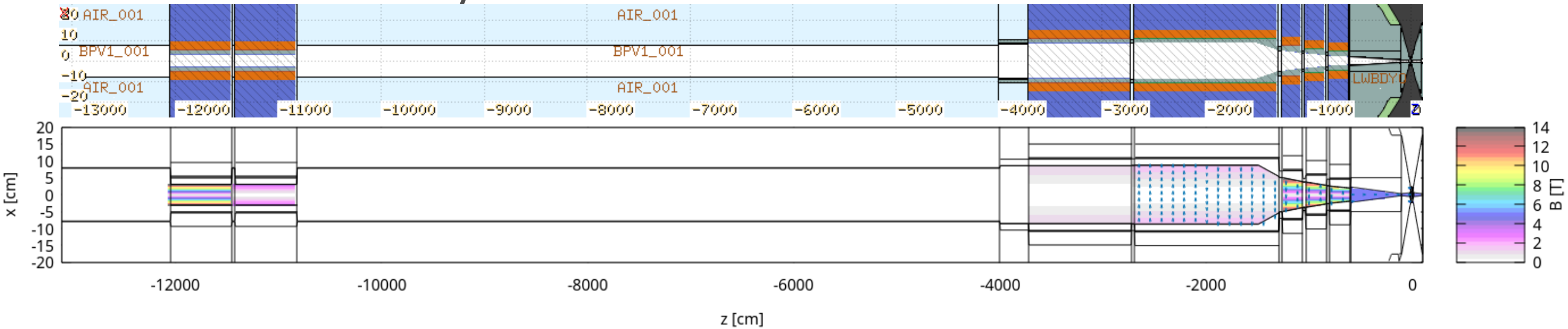
International MUON Collider Collaboration

MDI: lattice v.0.6



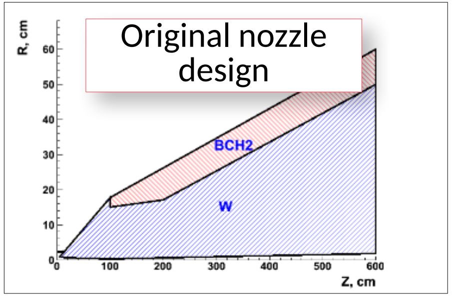


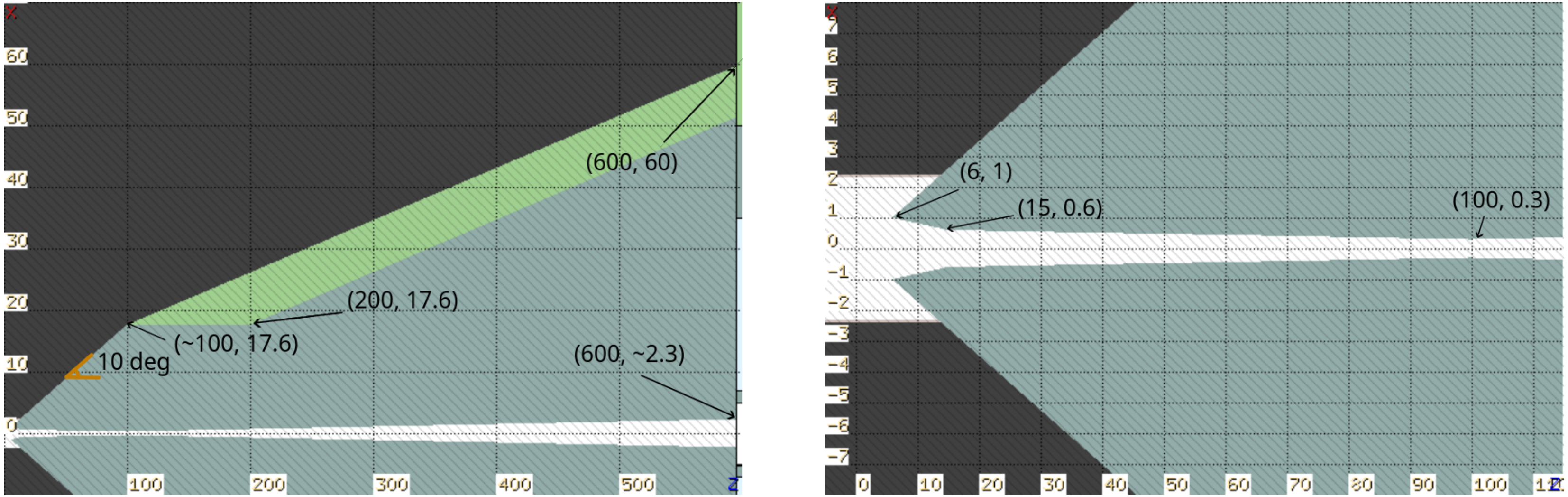
- Differently from previous versions, v06 does not have dipole components after the final focus
- As a consequence, higher BIB is expected coming from regions far away from the IP
- Results for BIB are **not yet used for detector studies**



MDI: nozzle details

- Our implementation of the nozzle follows the original design from MAP collaboration
- These details are shared in the **parameters document**



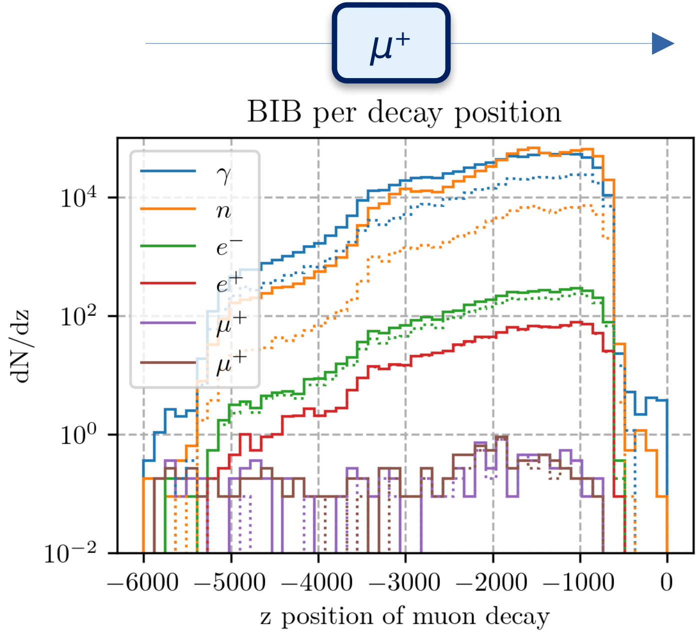


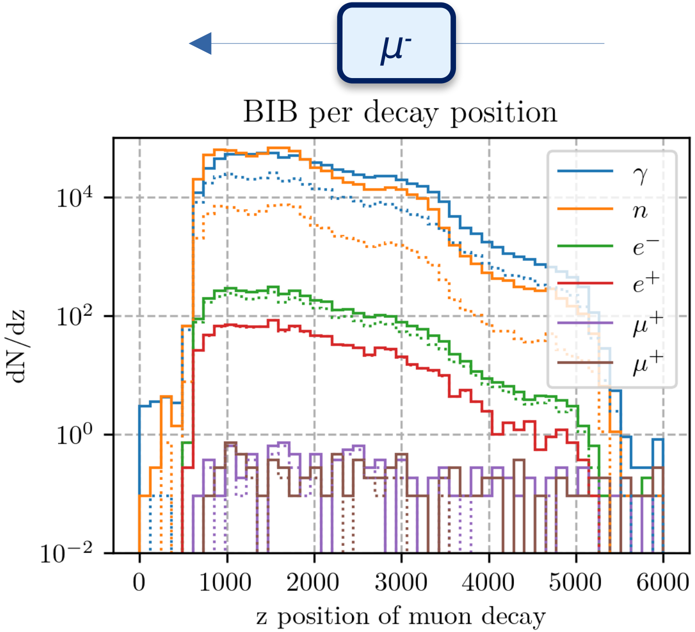
(a) Nozzle shape

(b) Tip details

μ decay @ √s = 10 TeV: high statistics sample
5 T uniform field

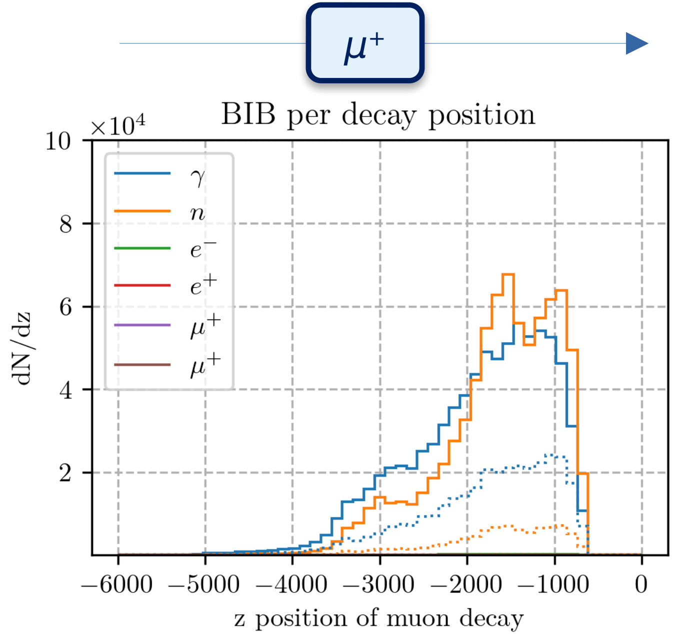
- A high statistic sample has been produced. This confirms that the two beams are equivalent for what concerns the BIB contribution

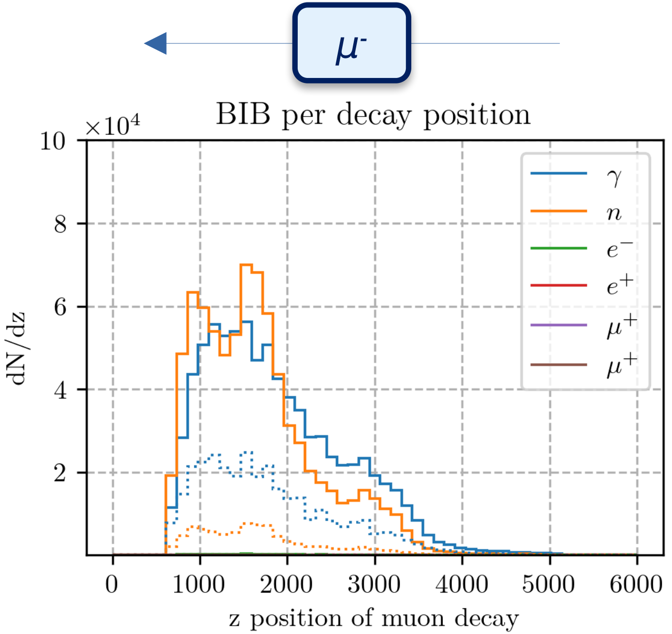




μ decay @ √s = 10 TeV: high statistics sample 5 T uniform field

- A high statistic sample has been produced. This confirms that the two beams are equivalent for what concerns the BIB contribution

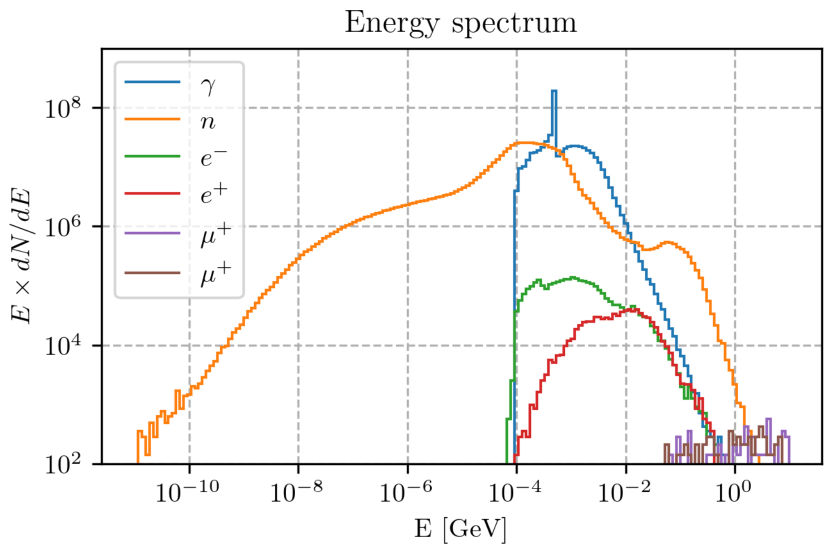




μ decay @ √s = 10 TeV: energy spectra 5 T uniform field

International UON Collider Collaboration

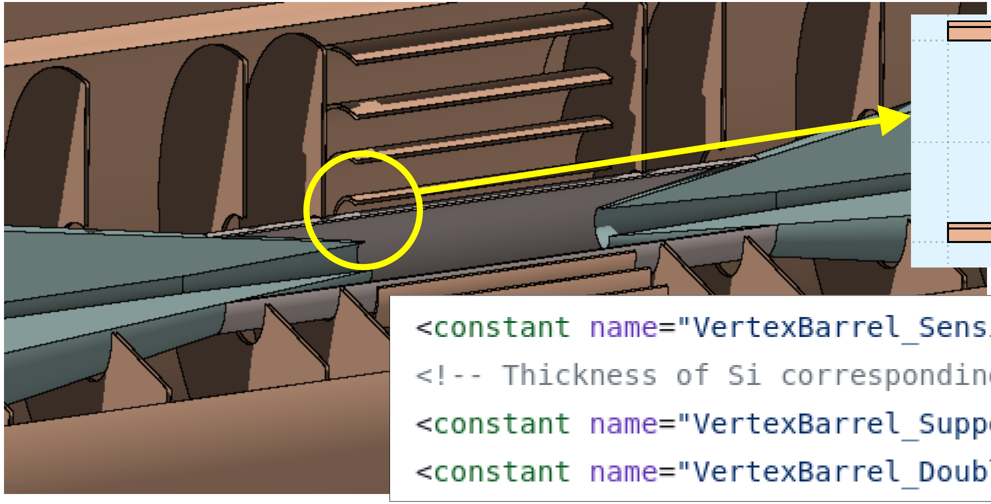
- The most abundant particles are the neutrons and the electrons. Most of them arrive late in time. The electrons and positrons are more quick, but they can still be discriminated in the tracker.

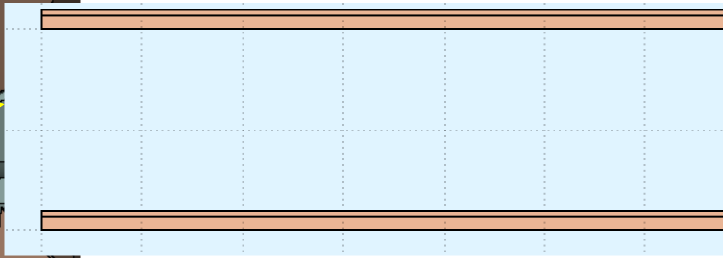


Particle	Total counts	Total counts is [-5, 15] ns
γ	9.85e+07	3.95e+07
n	9.65e+07	1.06e+07
e^-	4.88e+05	3.77e+05
e^+	1.24e+05	1.22e+05
μ^+	1.13e+03	6.78e+02
μ^-	1.22e+03	7.12e+02

Detector implementation in FLUKA

- For the **trackers** I refer to https://github.com/MuonColliderSoft/detector-simulation
  - The vertex trackers are faithfully reproduced, assuming a cylindrical shape
  - The inner and the outer trackers have a simplified geometry description (only sensitive volume, no support structure yet)



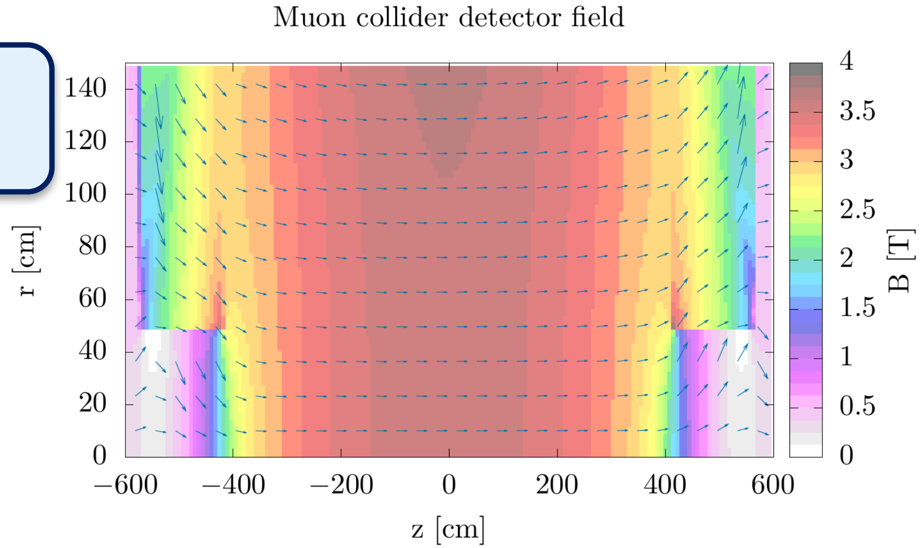


```
<constant name="VertexBarrel_Sensitive_Thickness" value="50e-03*mm"/>
<!-- Thickness of Si corresponding to all the passive material in 1 layer -->
<constant name="VertexBarrel_Support_Thickness"   value="140e-03*mm"/>
<constant name="VertexBarrel_DoubleLayer_Gap"     value="2.0*mm"/>
```

Magnetic field implementation in FLUKA

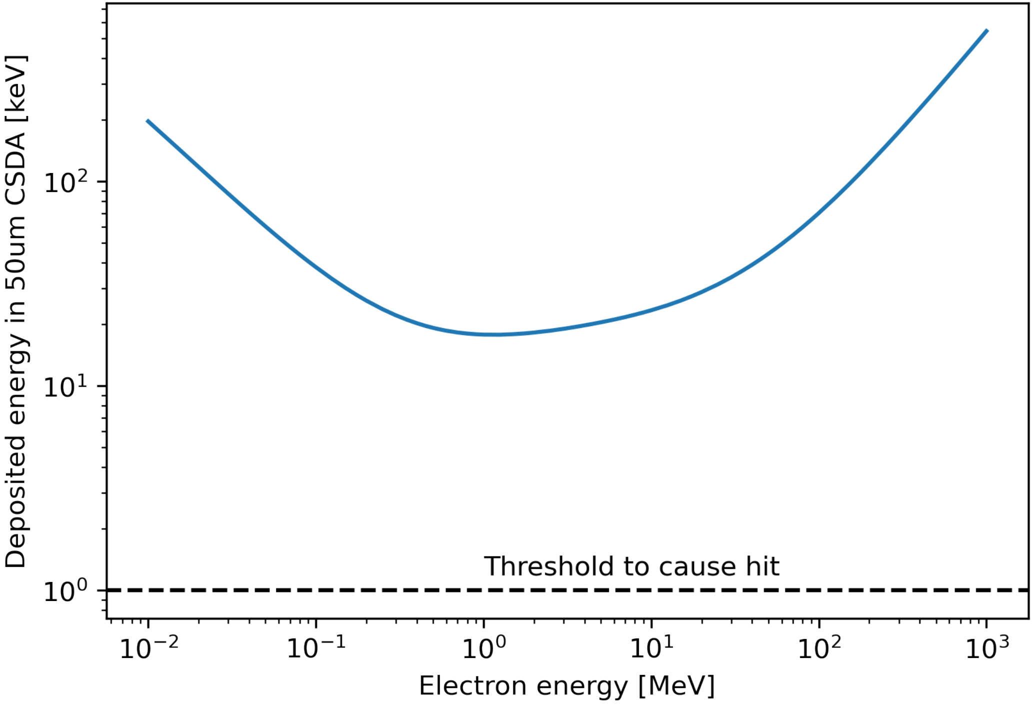
- Profiting from the Detectors magnet meeting: https://indico.cern.ch/event/1324236/, I asket Matthias Mentink for a possible magnetic field configuration. I will test it with a FLUKA simulation

Not yet used for BIB simulations

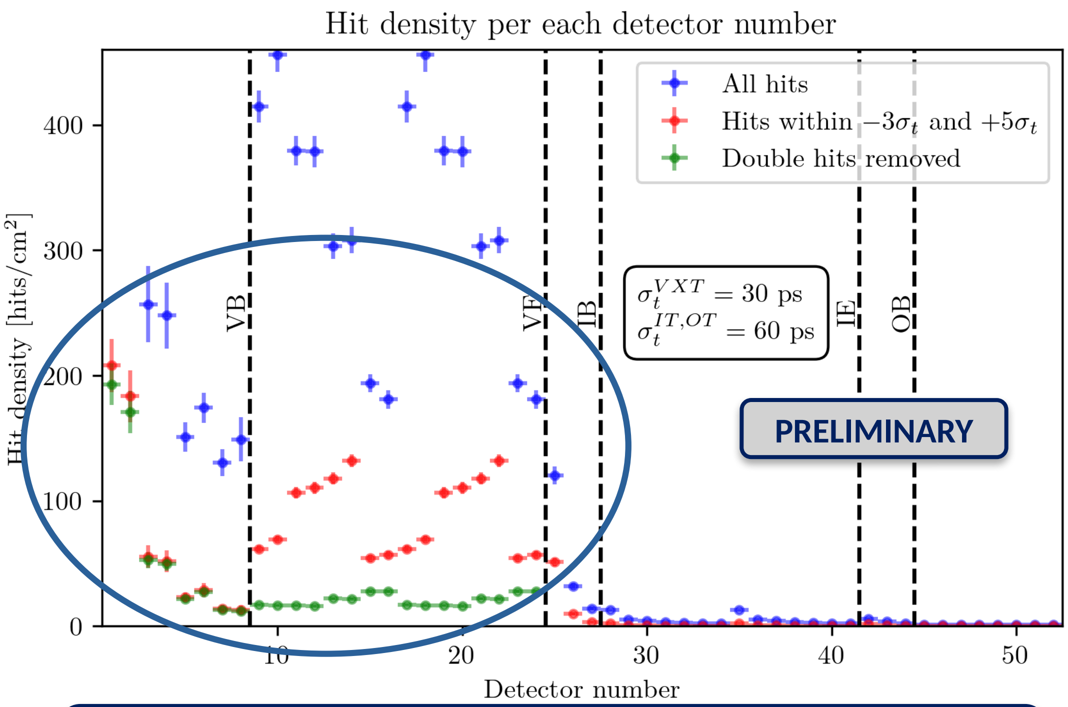


Tracker hits in FLUKA

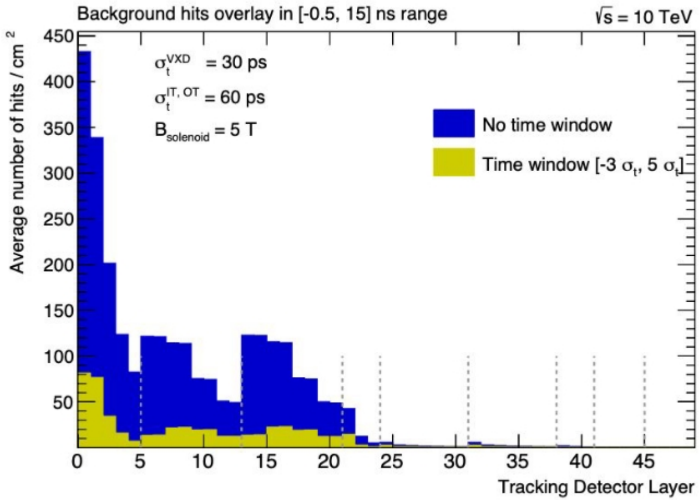
- **Assumption**:
  All electrons (and positrons) touching the silicon sensitive element will cause an hit
- Ultimately, the particle hits are registered thanks to the energy deposited by the secondary electrons produced



Tracker hits in FLUKA: results



From F. Meloni:
[MDI meeting 24-10-2023]



Some differences: I tend to overestimate the number of hits, in particular for endcaps

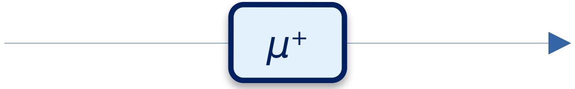
Tracker hits in FLUKA: possible reasons for discrepancies

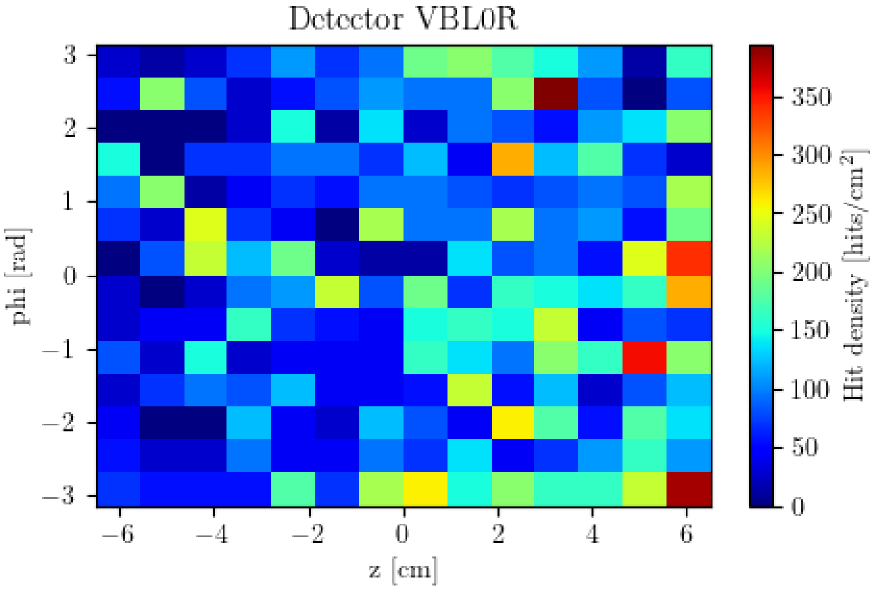
- The BIB sample used for the studies is the same. The machine configuration (field in the solenoid region is the same and equal to 5 T.
- I considered a cyclindrical vertex barrel. Perhaps the real geometry (slabs) is less prone to low energy electons hits. This does not explain the difference in the endcaps.
- Some low energy delta ray electrons are produced in clusters in the proximity of the sensitive volume. They would cause a single hit (cause they fall all in the same pixel), but I am counting them all.
- Bug on my side (the scoring is *PRELIMINARY*)
- **Other suggetstions?**

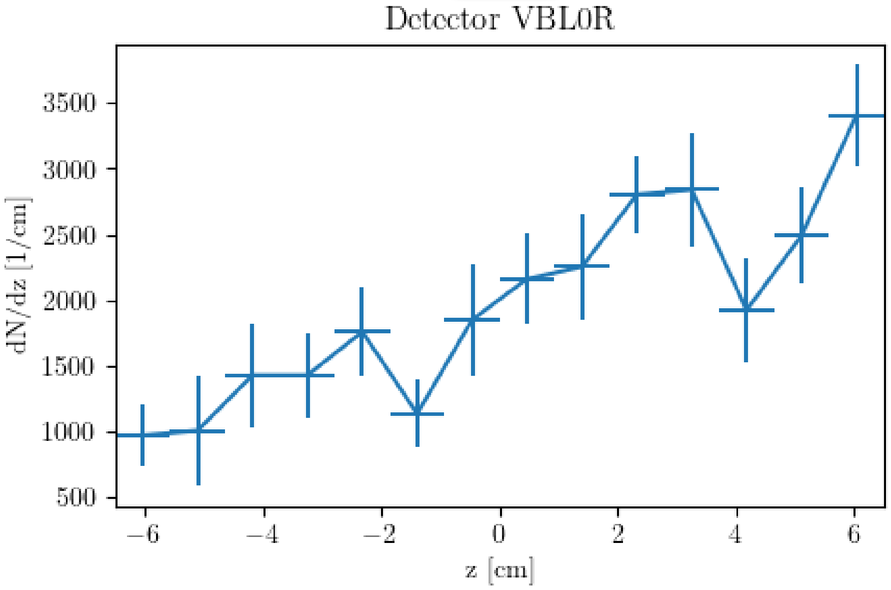
International
MUON Collider
Collaboration

Innermost tracker: hit density

- I did not sampled uniformly in the azimuthal coordinate, I just loaded the BIB particles
- The statistics to be improved

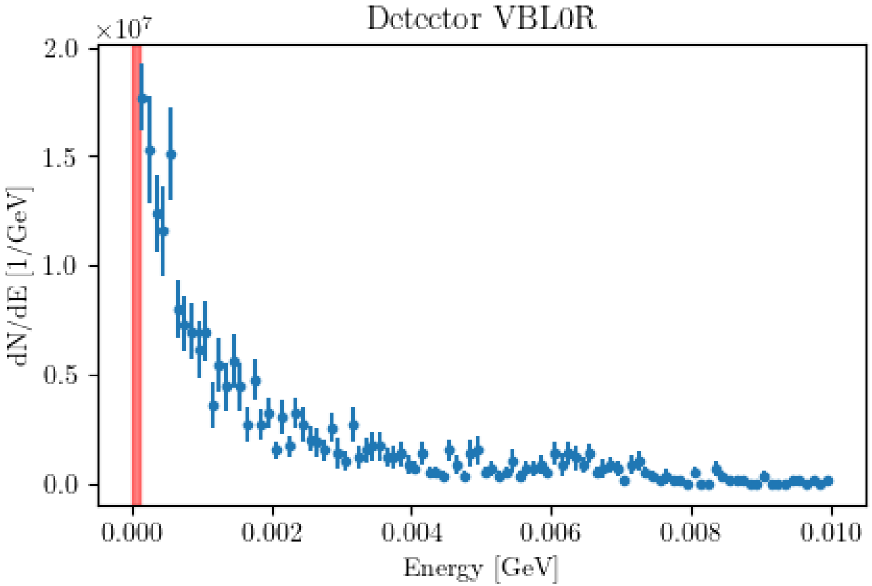






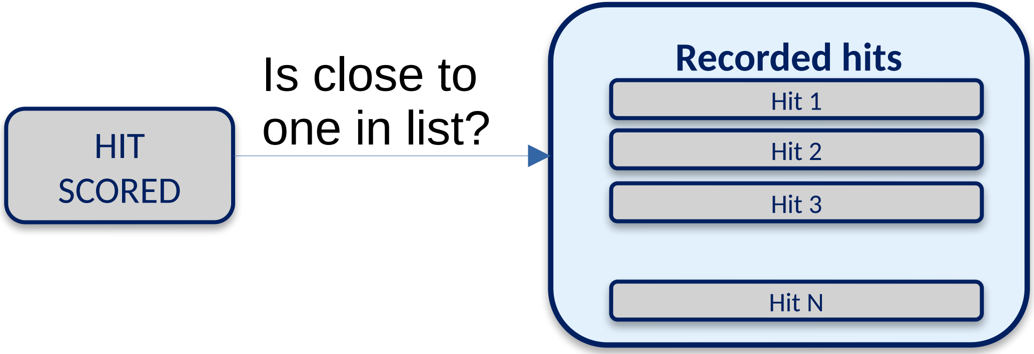
Innermost tracker: energy of hits

- Majority of hits occours at relatively low energies.



Consideration on possibility of multiple hits in the same pixel

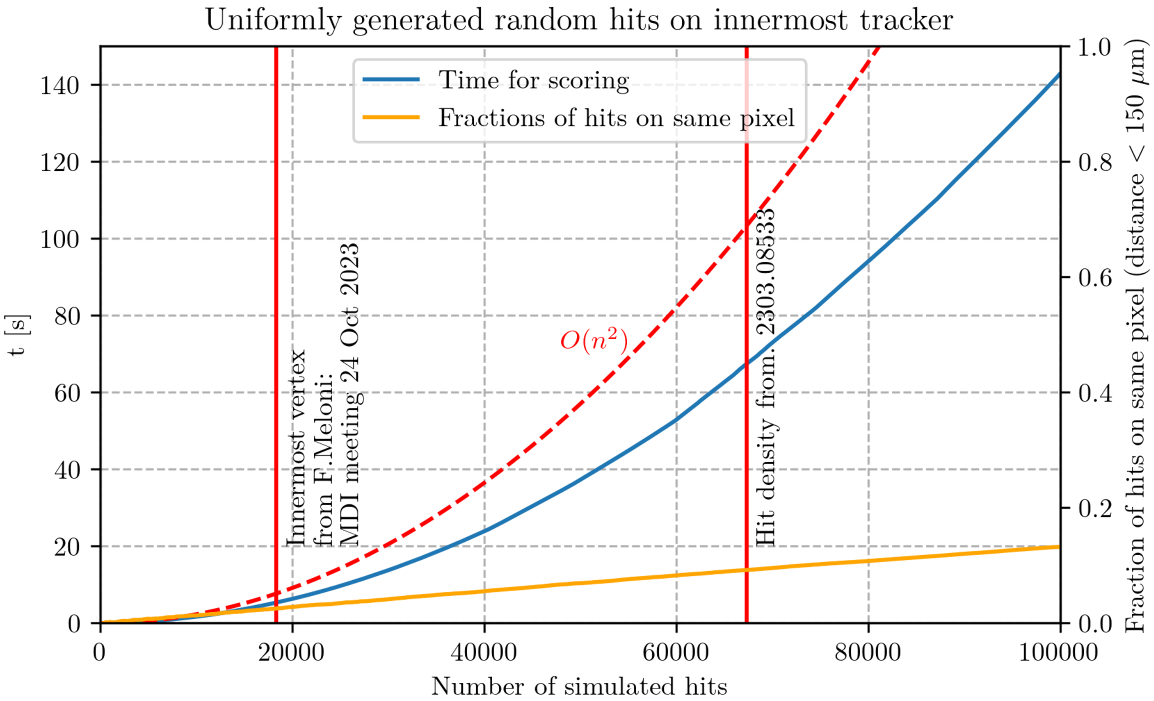
- I considered a dummy case of the innermost tracker (the one with the largest hit density).
- I produced an uniform distribution of hits.
- Feeding this hits to a possible FLUKA user routine for scoring (FORTRAN) I checked how much time I would need to spend to check if the hit is landing on a pixel already turned on



- YES: ignore it and continue
- NO: add it to the list

Consideration on possibility of multiple hits in the same pixel

- Fast in comparison with simulation time
- If worse cases scenarios happen (detailed studies on the outer trackers), dedicated algorithms and data structures can help (skip lists, ...)



Conclusions

- High statistics run performed. The contribution from negative and positive muons is identical
- Realistic solenoid field implemented in FLUKA. Simulations will follow
- ‘Framework’ to propagate BIB particles in FLUKA through detectors enstablished. This allows us to have a figure of merit for the nozzle optimization **during the simulation.**
- The hit density in the vertex tracker shows some discrepancies with the one obtained with ddsim. I will investigate what is the reason.

International
MUON Collider
Collaboration

CERN

Thank you
for your attention!