Beam Induced Background studies at $\sqrt{s} = 3\ TeV$

D. Calzolari , **L. Castelli***, F. Collamati, A. Lechner, D. Lucchesi

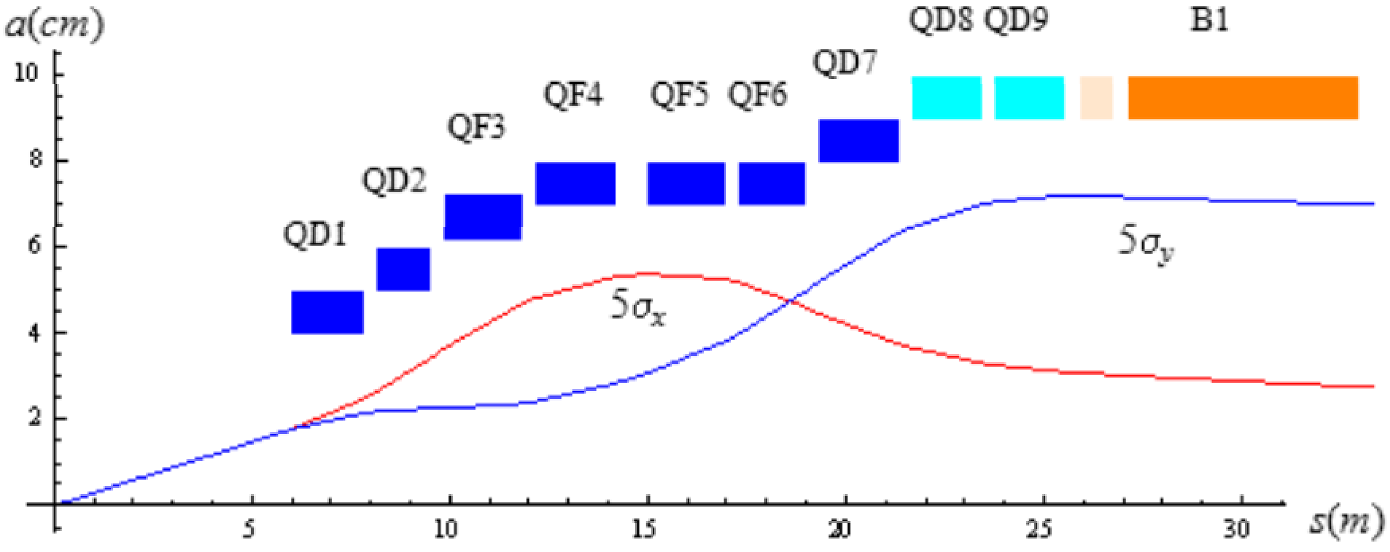
**speaker*

Outline

- **Goal of the study**
  - Objectives
  - Previous studies
- **Fluka simulation**
  - Geometry
  - Simulation set up
- **Beam Induced Background**
  - Particle distribution
  - Energy Spectrum
  - Muon Decay position
  - Arrival Time
- **Next Steps**

Goal of the study

- The MAP design[1] of $\sqrt{s} = 3\ TeV$ Muon Collider is used with the nozzle optimized for $\sqrt{s} = 1.5\ TeV$
- The final goal is to optimize the IR at $\sqrt{s} = 3\ TeV$ to maximizing the detector acceptance while keeping the BIB at manageable levels



5σ beam envelop at IR and final focusing magnets aperture[2]

Quick recall of previous BIB studies

- MAP collaboration studies at $\sqrt{s} = 1.5$ TeV using MARS[3]
- IMCC studies at $\sqrt{s} = 1.5$ TeV using FLUKA[4]
- Comparison between the two simulations
- Preliminary studies at $\sqrt{s} = 3$ TeV [5]

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Detector Backgrounds at Muon Colliders[#]

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Advanced assessment of beam-induced background at a muon collider

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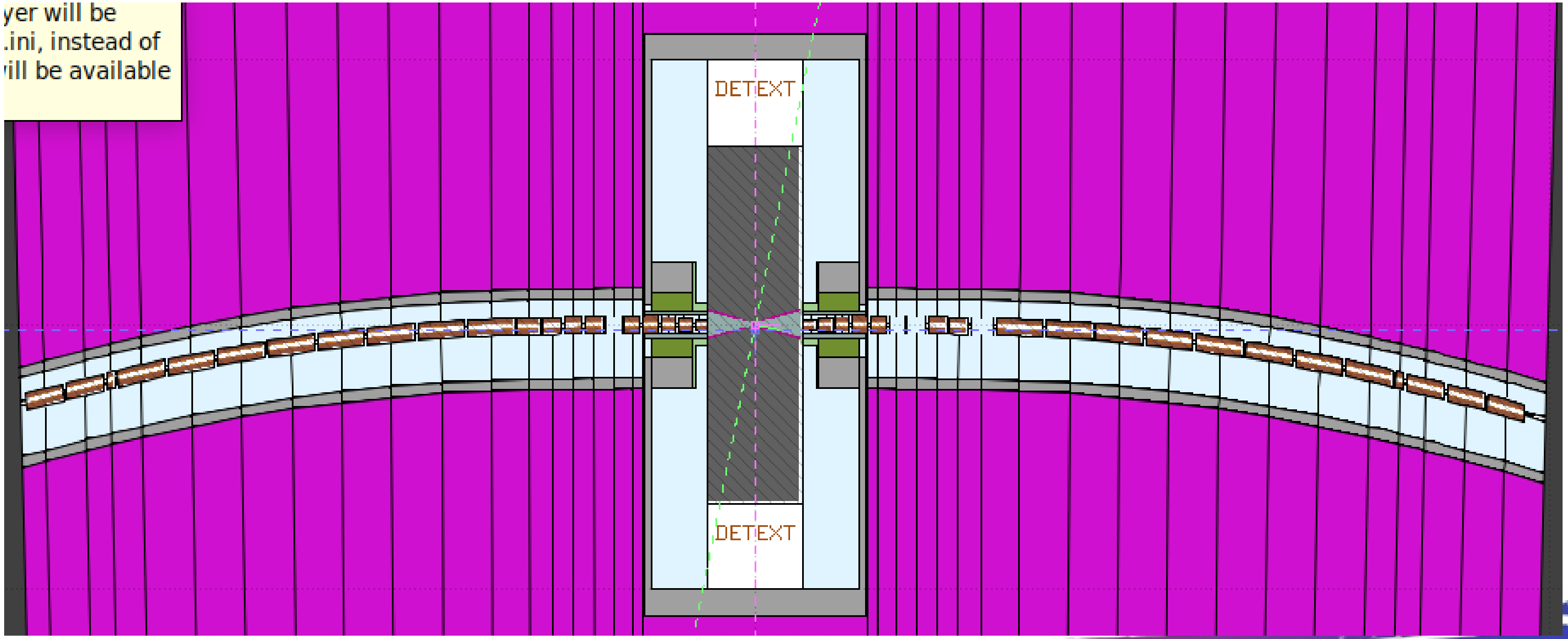
Geometry at $\sqrt{s} = 3\ TeV$

- Muon Collider machine generated with FLUKA LineBuilder[6] up to $\pm 100\ m$ from the IP



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Geometry at $\sqrt{s} = 3\ TeV$

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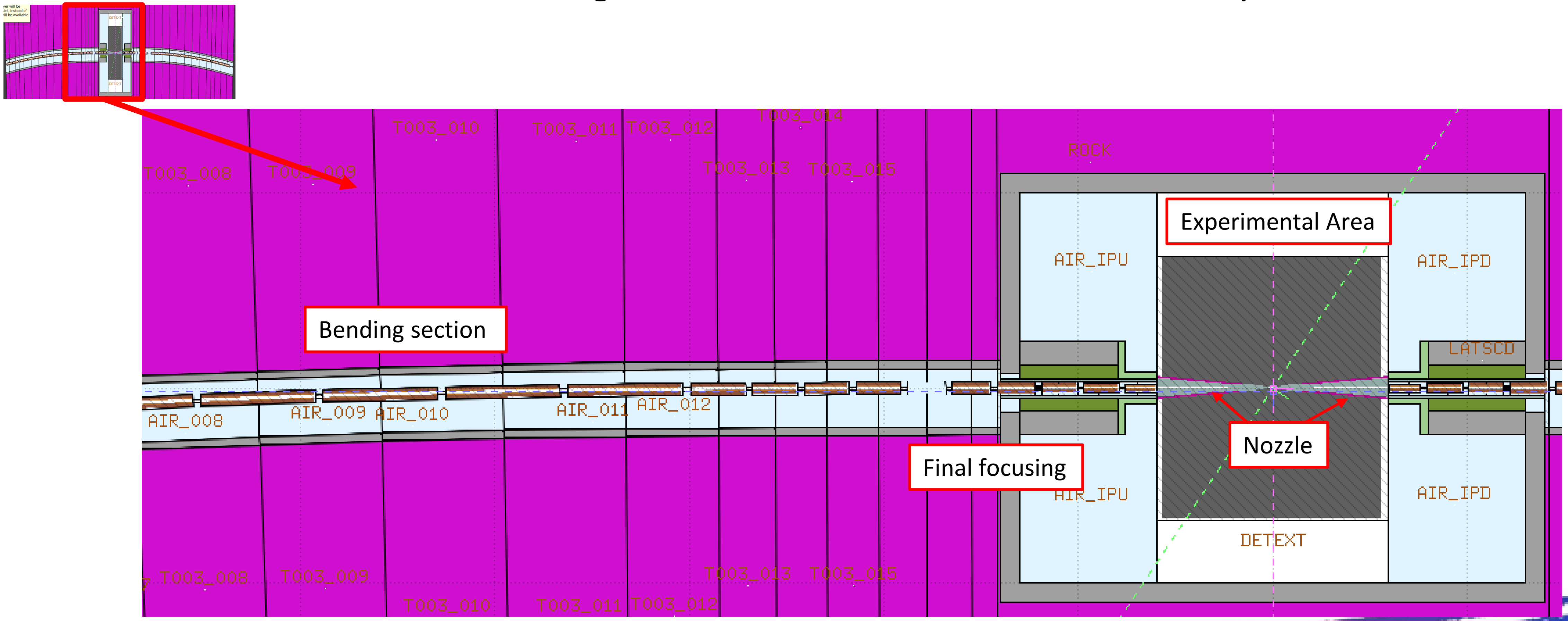
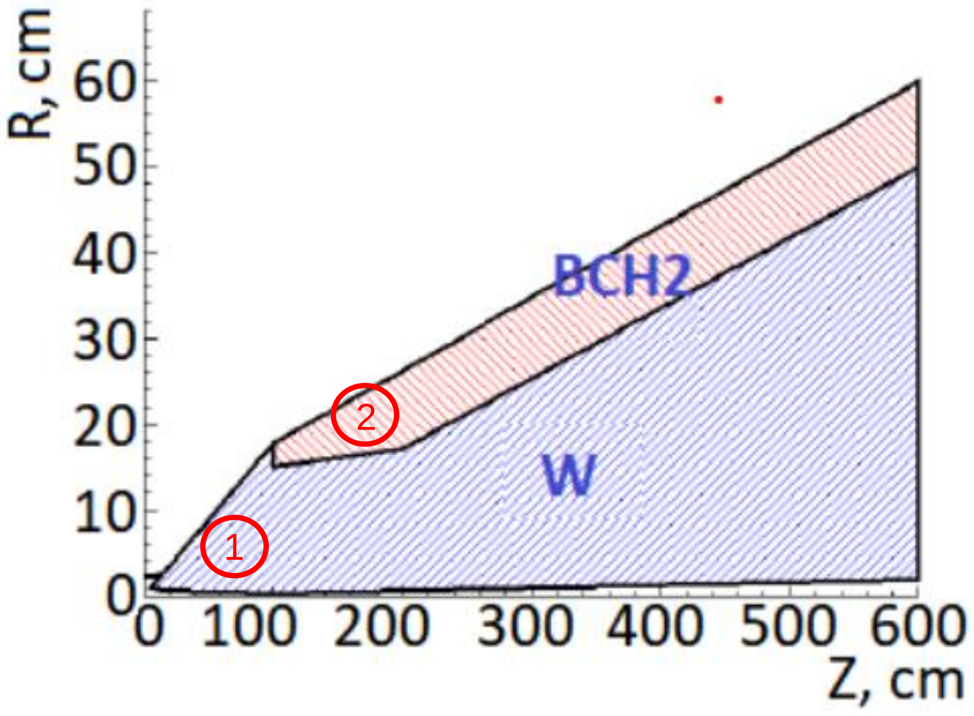


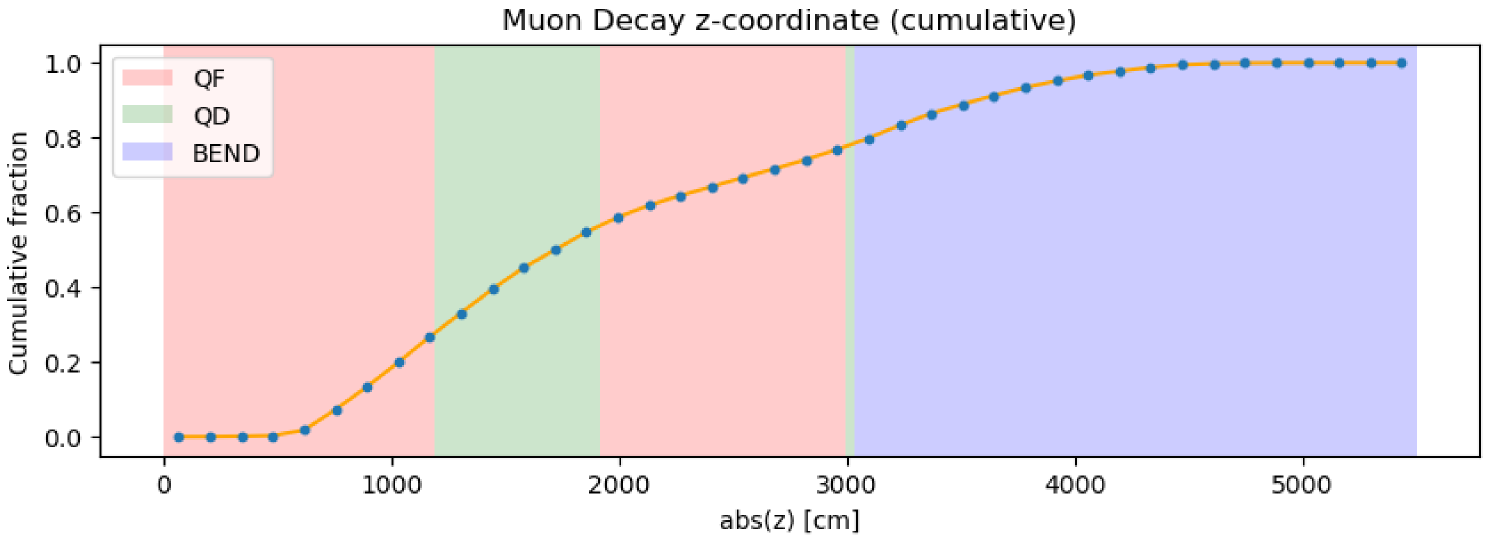
Nozzle at $\sqrt{s} = 3\ TeV$

- Original nozzle optimized by MAP for $\sqrt{s} = 1.5\ TeV$
- Tungsten (W) cone with a borated polyethylene (BCH2) coat
- Angular opening:
    1) $10°$ closest to the IP
    2) $5°$ starting from $z = 100\ cm$



Simulation setup

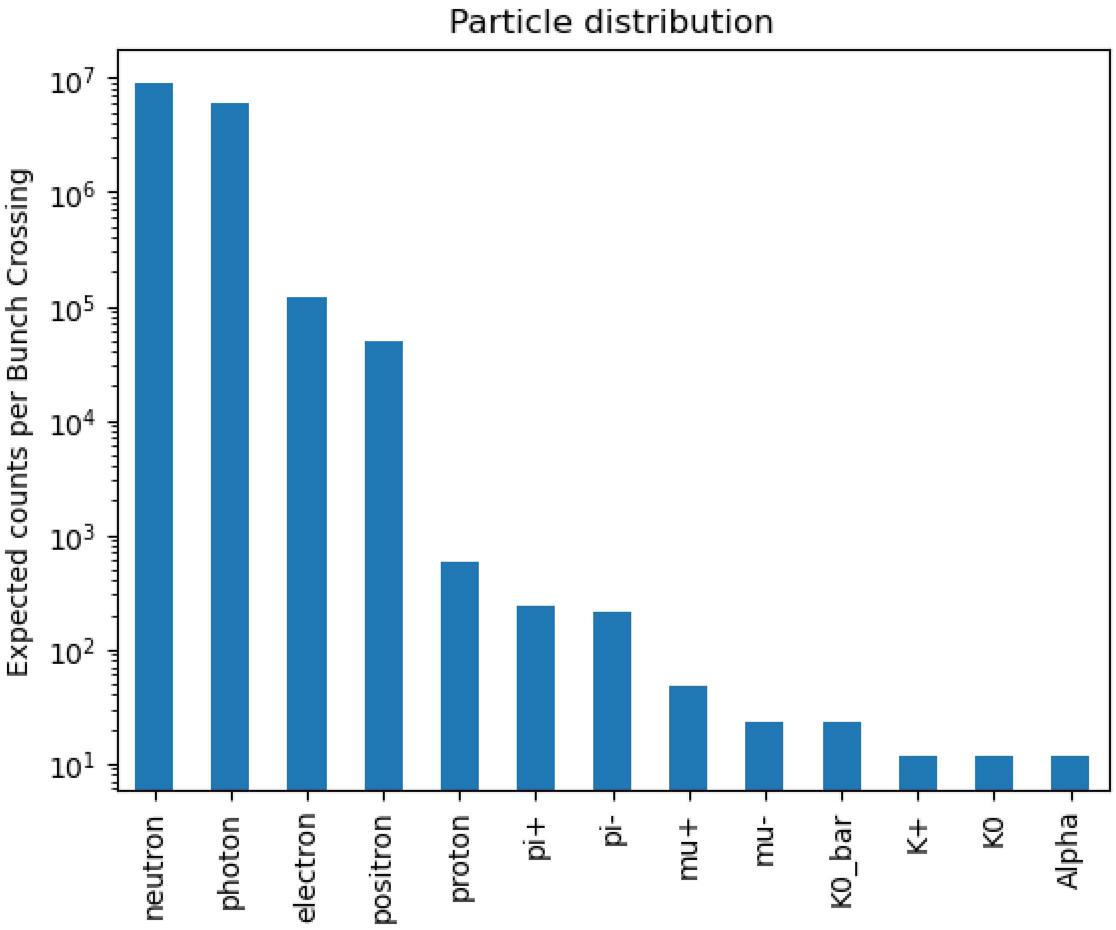
- Generated one beam of μ^+ decays within $\mathbf{55}\ \boldsymbol{m}$ from the IP
- **Energy threshold** for particles production fixed at $\mathbf{100}\ \boldsymbol{keV}$
- Particles which enters the detector area are scored
- Detector assumed a black box



BIB composition

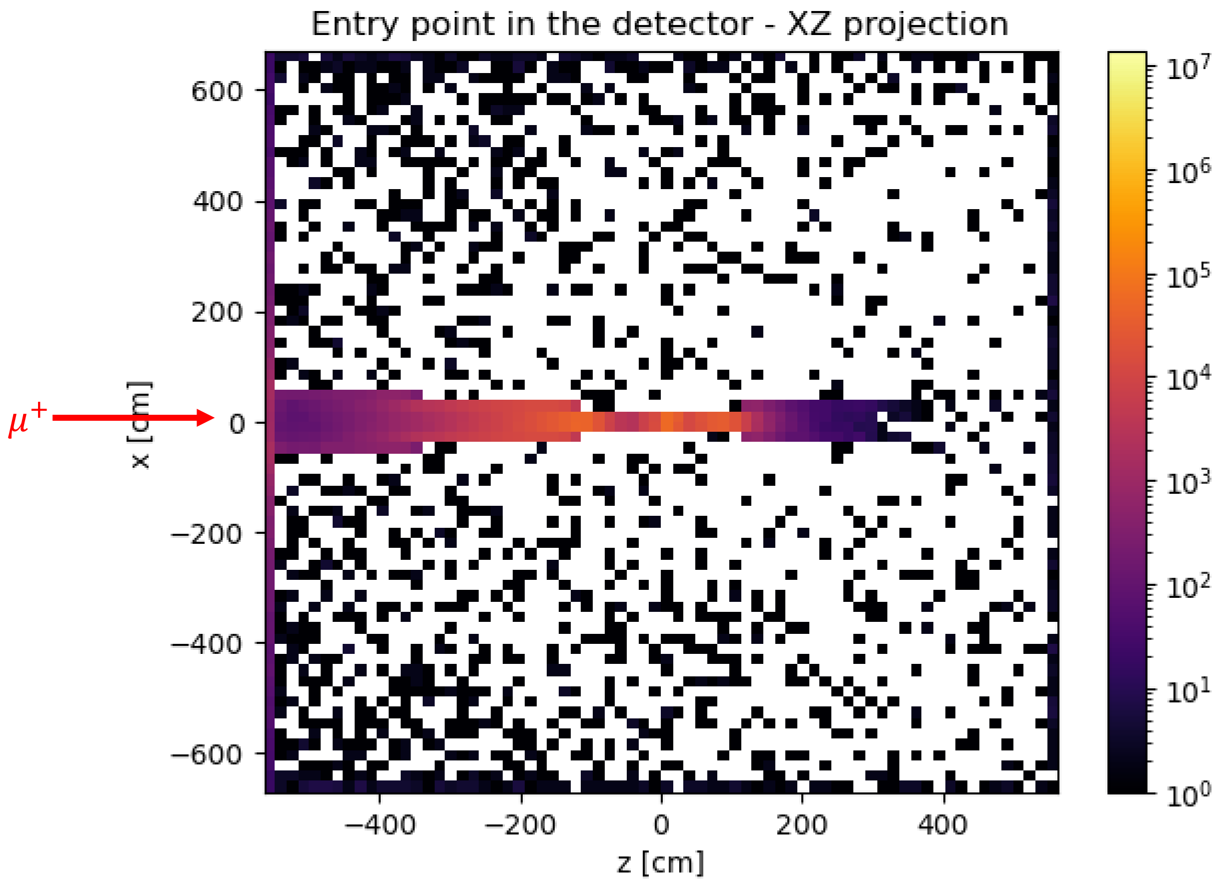
- Expected $1.18 \cdot 10^7$ decays (in the last 55 m) per bunch crossing
- $6.4 \cdot 10^9$ particles per bunch crossing in the detector

Particle	Distribution
Neutron	*59.8 %*
Photon	*39.1 %*
Electron/positron	*1.1 %*
Muons and Hadrons	*<1 %*



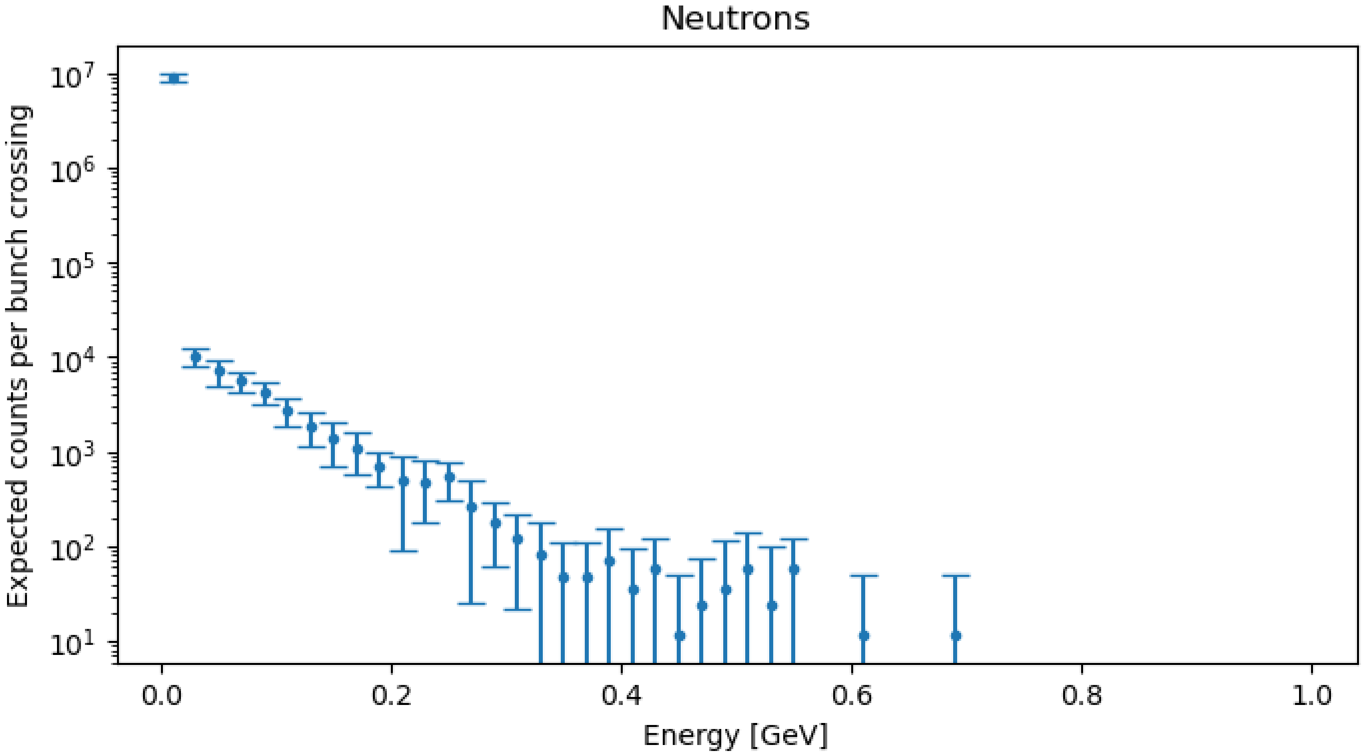
BIB Particles

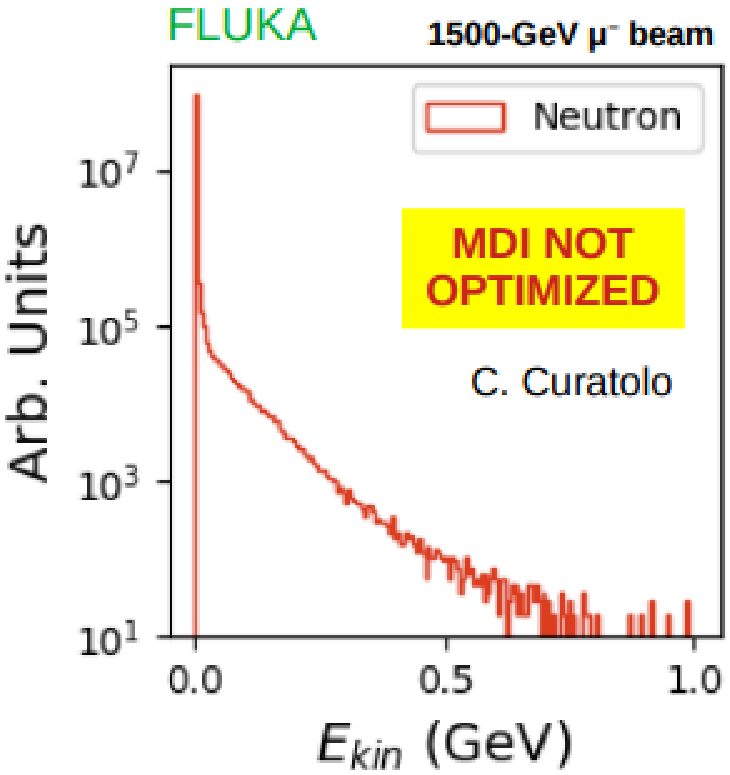
- Most of BIB particles enter in the detector area from the left nozzle
- A non-negligible fraction comes from the left-side, suggesting that more shielding is needed



BIB Particles spectrum: neutron

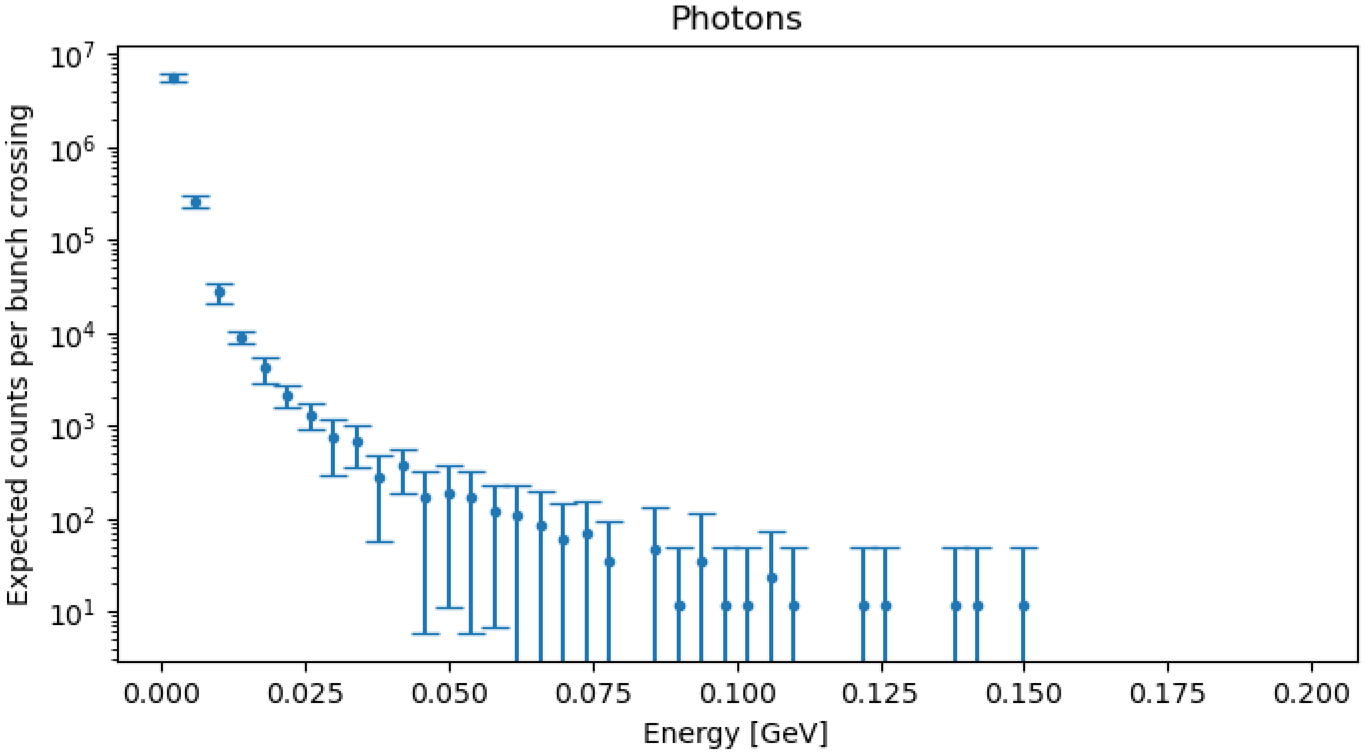
- Neutron dominant component at very low energies

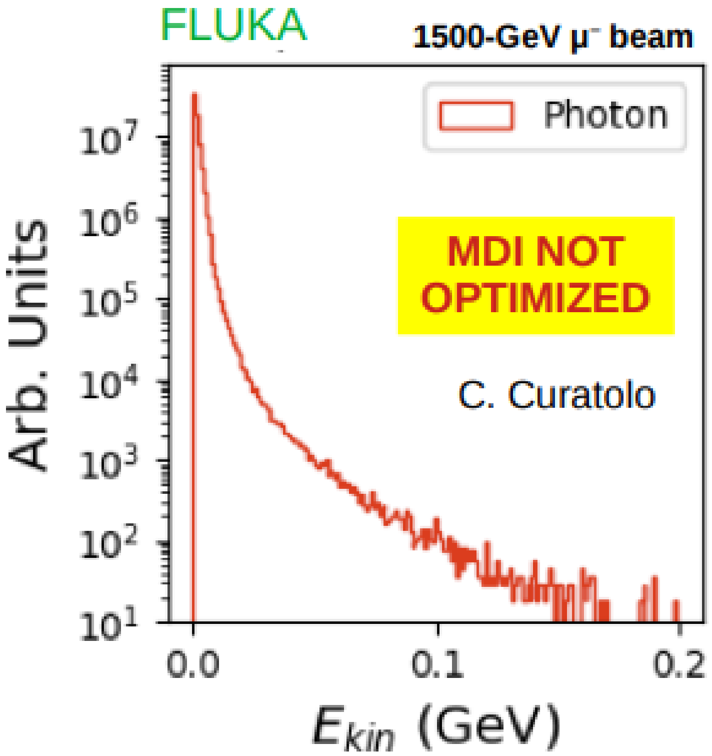




BIB Particles spectrum: photon

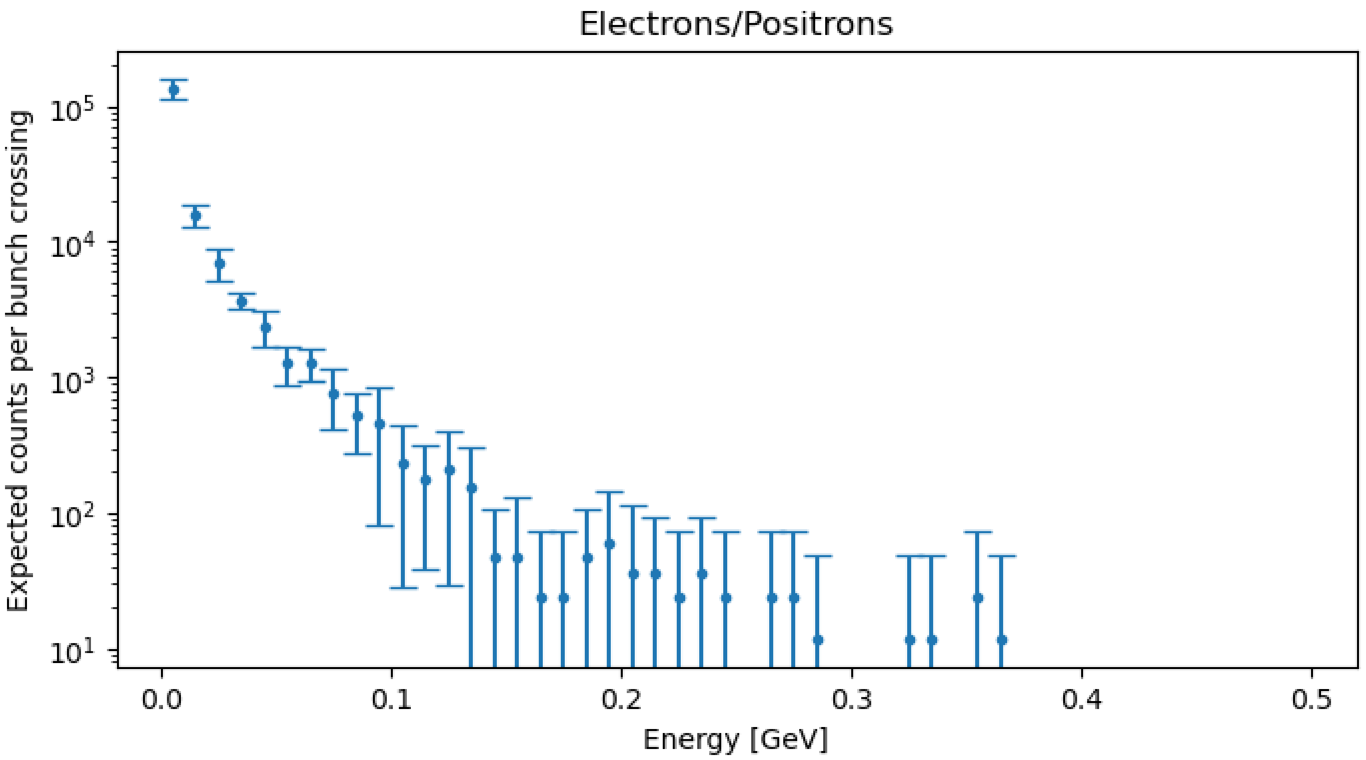
- Photon spectrum tails arrive up to 200 MeV

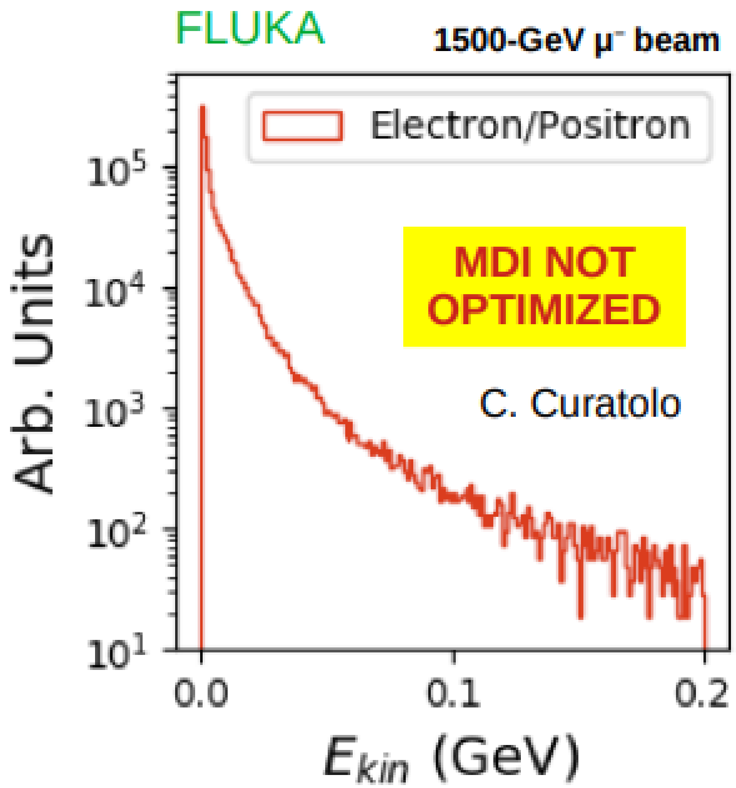




BIB Particles spectrum: $e^+/\ e^-$

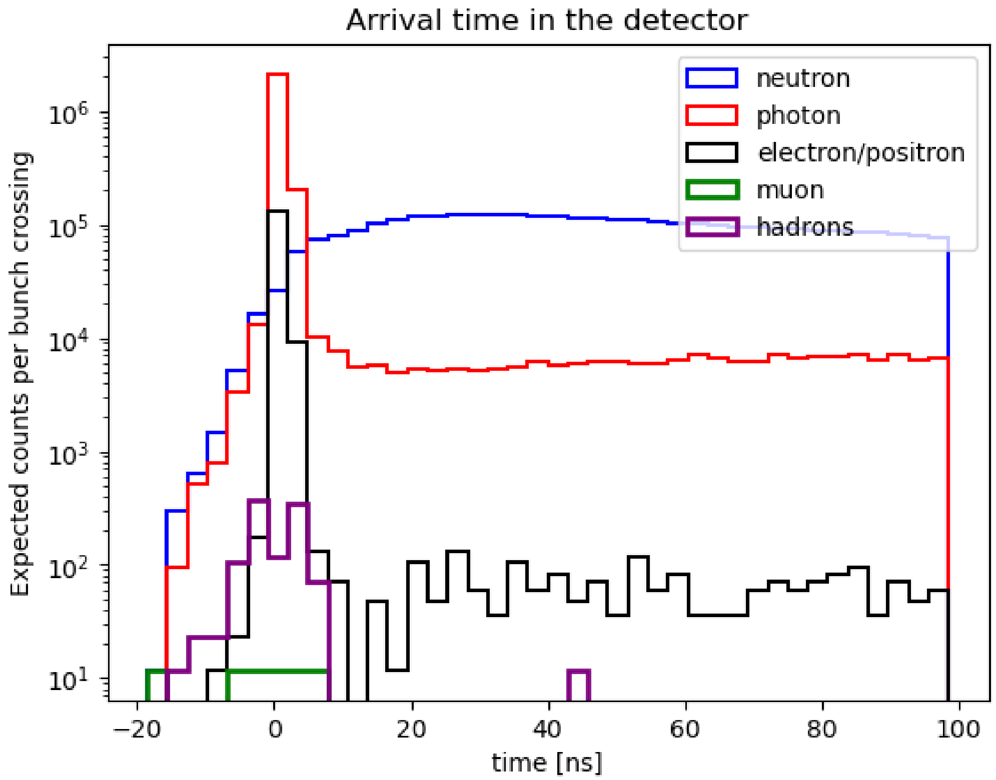
- $e^+/\ e^-$ components have low energy spectrum

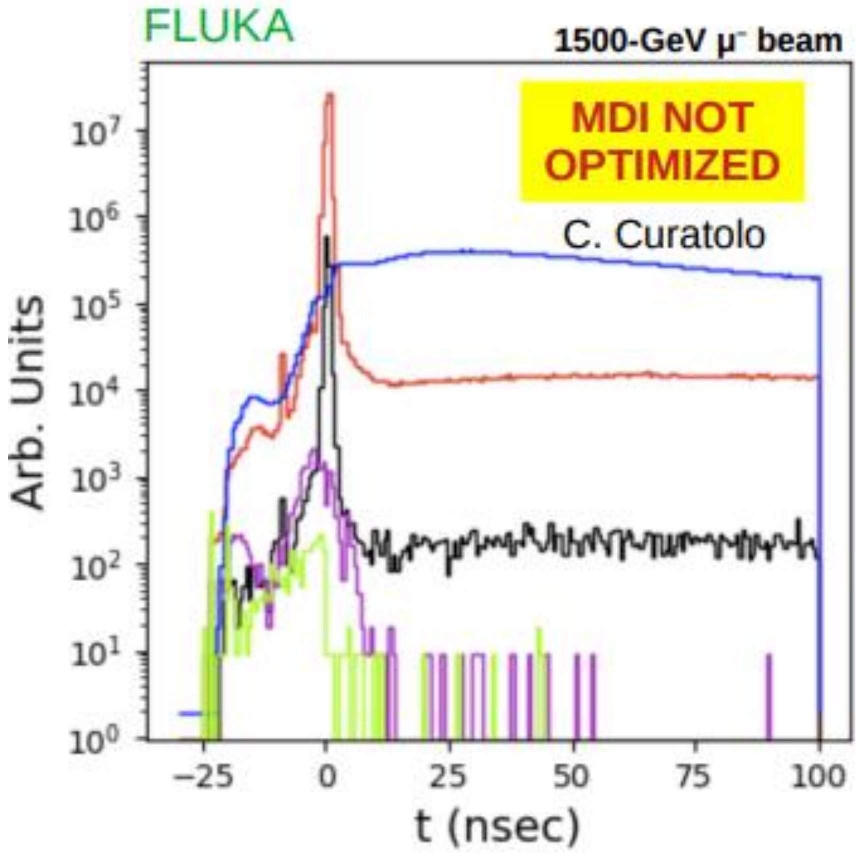




BIB Arrival Time

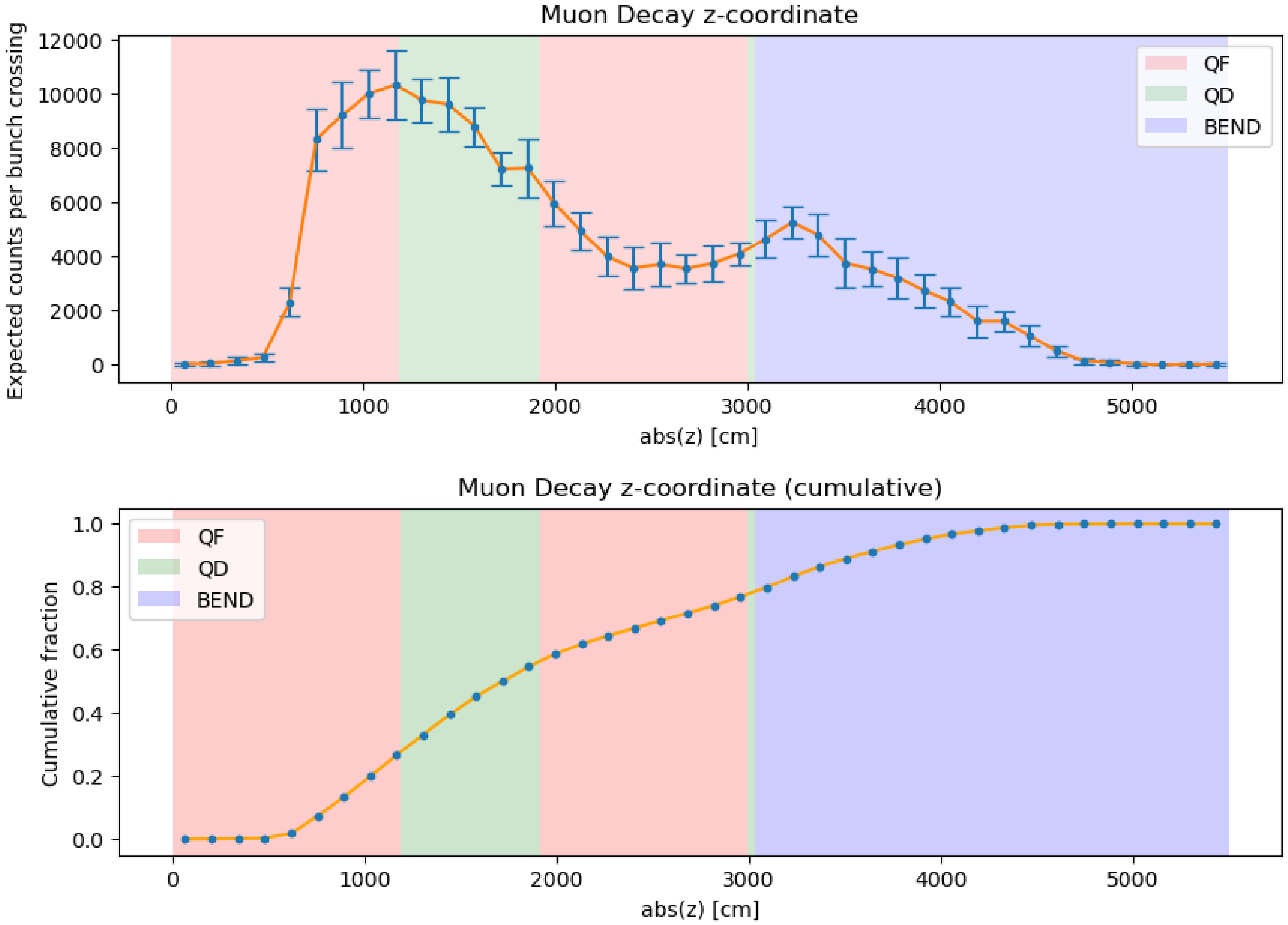
- Significant fraction of BIB particles can be discarded by applying time cuts





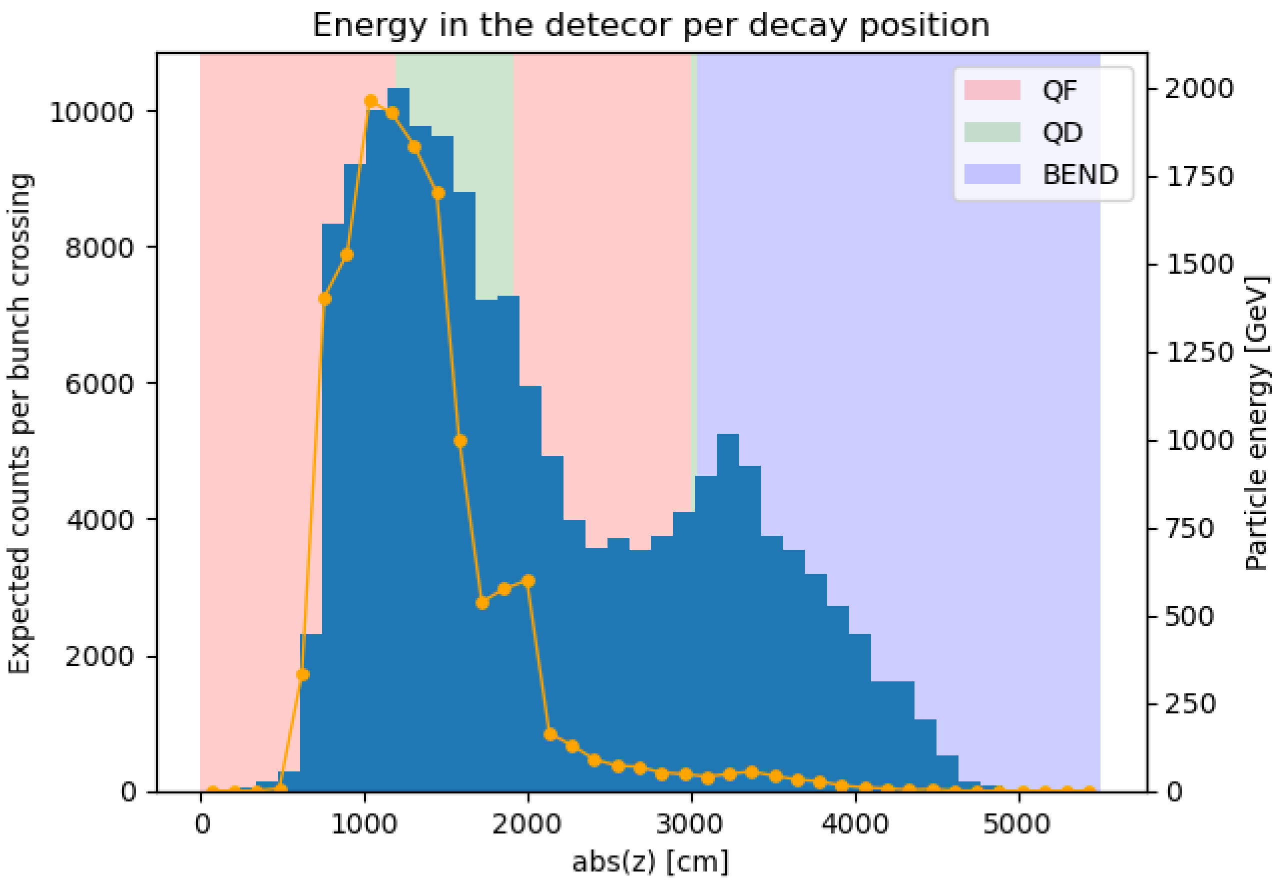
Muon decay position

- Decay position of muons which cause BIB particles in the detector
- Highest contribute from the region $z \in [750, 1750]\ cm$
- Cumulative plot suggest that further z should be considered



Muon decay position

- The **total energy** (orange), of the BIB particle, defined as $E_z = \sum_i E_{zi}$, with
  - $i \rightarrow i$-th BIB particle
  - $z \rightarrow$ decay position of the muon which generated the BIB particle
- Muon decay position (blue histogram)
- No significant correlation are enlightened



Conclusion and next steps

- The results obtained with the new simulation agree with preliminary study performed with a different set up
- Next steps:
  1) Simulating BIB sample with two beams and study the effect on the detector
  2) Optimize the $\sqrt{s} = 3\ TeV$ nozzle design. Help need to optimize the IR lattice.

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Thank you for the attention

References

- [1] Y. Alexahin, E. Gianfelice-Wendt, A 3-TeV MUON COLLIDER LATTICE DESIGN, Insiperhep.net
- [2] Y. Alexahin, E. Gianfelice-Wendt and V. Kapin, MUON COLLIDER LATTICE CONCEPTS, Iopscience.iop.org
- [3] N.V. Mokhov, S.I. Striganov, DETECTOR BACKGROUND AT MUON COLLIDERS, Arxiv.org
- [4] F. Collamati, C. Curatolo et al., ADVANCED ASSESSMENT OF BEAM INDUCED BACKGROUND AT A MUON COLLIDER, Arxiv.org
- [5] M. Casarsa, COMPARISONS OF BIB AT DIFFERENT ENERGIES, Indico.fnal.gov
- [6] THE FLUKA LINEBUILDER, FlukaCern

BACKUP

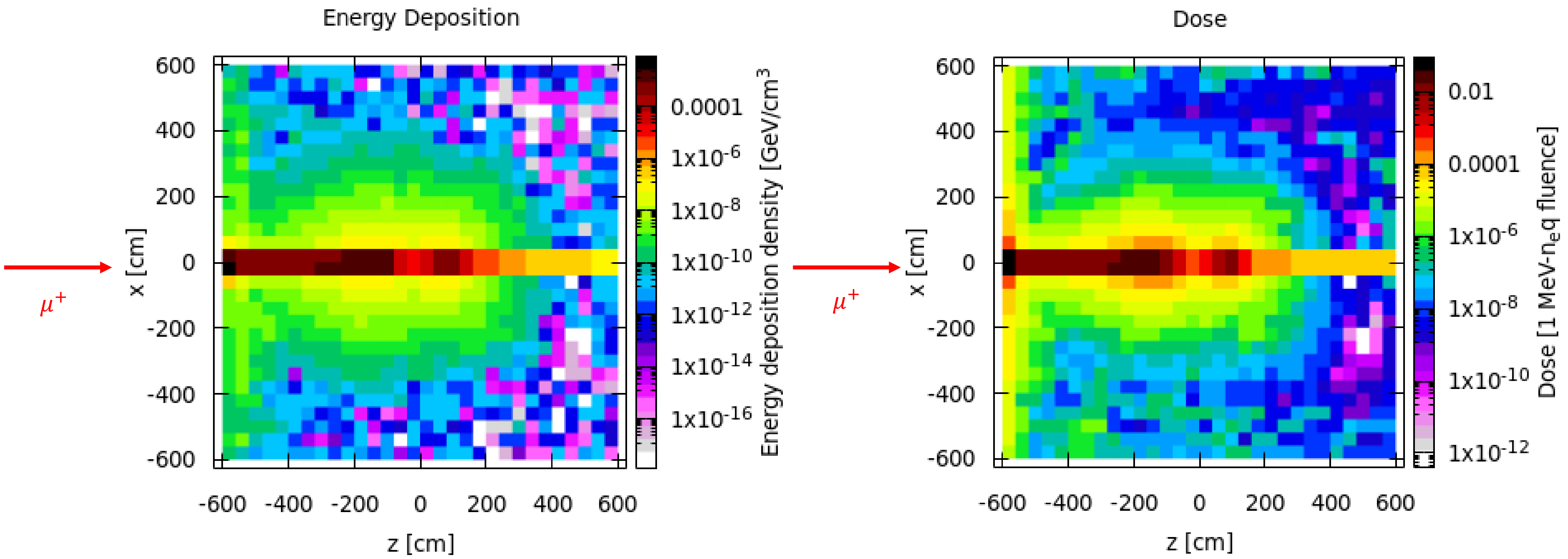
Beam Parameters

Table 5. Muon collider design parameters

Parameter	Higgs Factory		High Energy Muon Colliders		
Collision energy, TeV	0.126[a)]	0.126[b)]	1.5	3.0	6.0*
Repetition rate, Hz	30	15	15	12	6
Average luminosity / IP, $10^{34}/cm^2/s$	0.0017	0.008	1.25	4.6	11
Number of IPs	1	1	2	2	2
Circumference, km	0.3	0.3	2.5	4.34	6
β^*, cm	3.3	1.7	1	0.5	0.3
Momentum compaction factor α_c	0.079	0.079	$-1.3 \cdot 10^{-5}$	$-0.5 \cdot 10^{-5}$	$-0.3 \cdot 10^{-5}$
Normalized emittance, π·mm·mrad	400	200	25	25	25
Momentum spread, %	0.003	0.004	0.1	0.1	0.083
Bunch length, cm	5.6	6.3	1	0.5	0.3
Number of muons / bunch, 10^{12}	2	4	2	2	2
Number of bunches / beam	1	1	1	1	1
Beam-beam parameter / IP	0.005	0.02	0.09	0.09	0.09
RF frequency, GHz	0.2	0.2	1.3	1.3	1.3
RF voltage, MV	0.1	0.1	12	50	150

*The 6 TeV ring design is not completed yet, the numbers are a projection.

Energy deposition and Dose



Particle Fluence