International MUON Collider Collaboration

SAPIENZA UNIVERSITÀ DI ROMA

Machine-Detector Interface for $\sqrt{s} = 3$ TeV Muon Collider

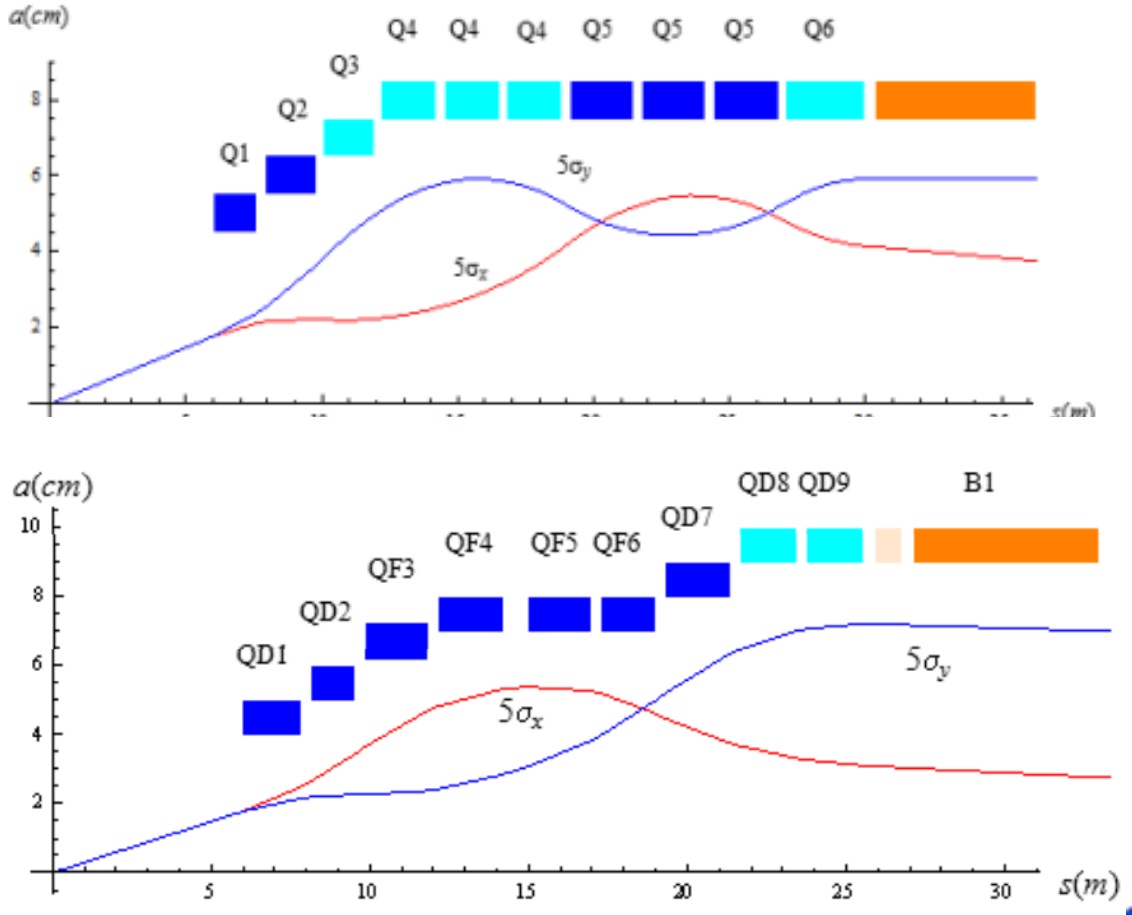
D. Calzolari , **L. Castelli***, F. Collamati, A. Lechner, D. Lucchesi

**speaker*

Goals of the study

- **In this presentation**:
  - Characterization of $\sqrt{s} = 3\ TeV$ Beam Induced Background
- **Final goal**
  - Optimization of the Interaction Region at $\sqrt{s} = 3\ TeV$ since current design is based on $\sqrt{s} = 1.5\ TeV$ studies

5σ beam envelop at IR and final focusing magnets aperture [1]



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]

TIPP 2011 - Technology and Instrumentation in Particle Physics 2011

Detector Backgrounds at Muon Colliders[#]

N.V. Mokhov *, S.I. Striganov

Fermilab, Batavia, IL 60510, USA

Advanced assessment of beam-induced background at a muon collider

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[b] *University of Padova and INFN Sezione di Padova, Padova, Italy*
[c] *CERN, Geneva, Switzerland, currently at Fondazione CNAO, Pavia, Italy*
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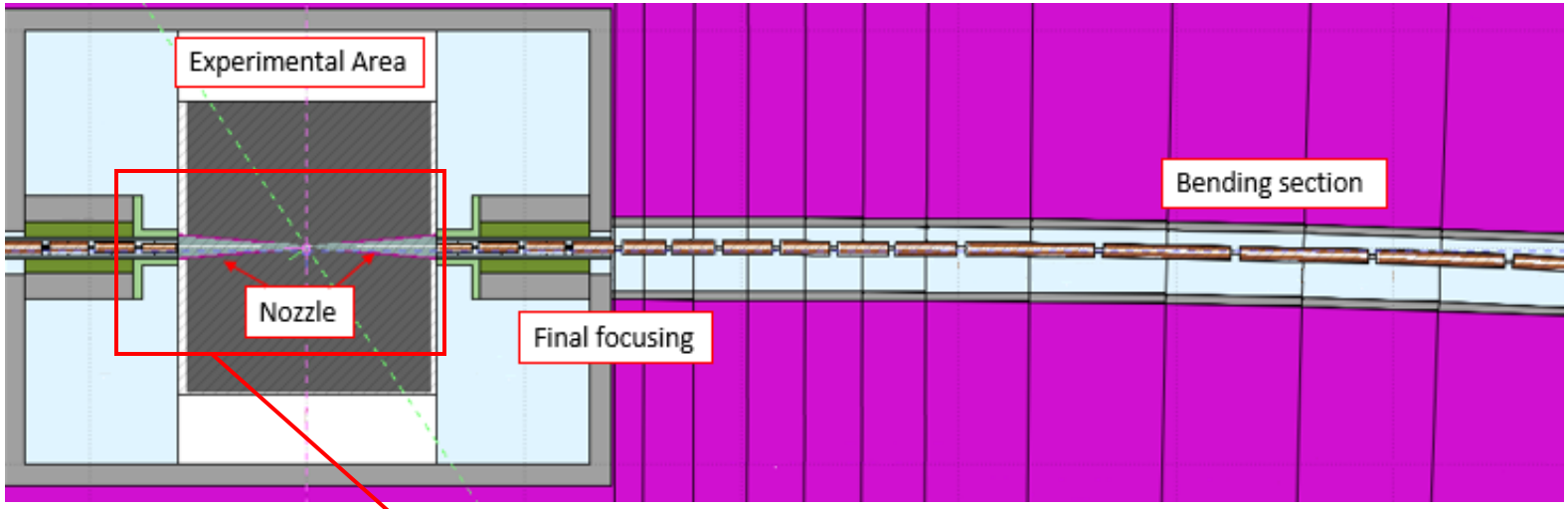
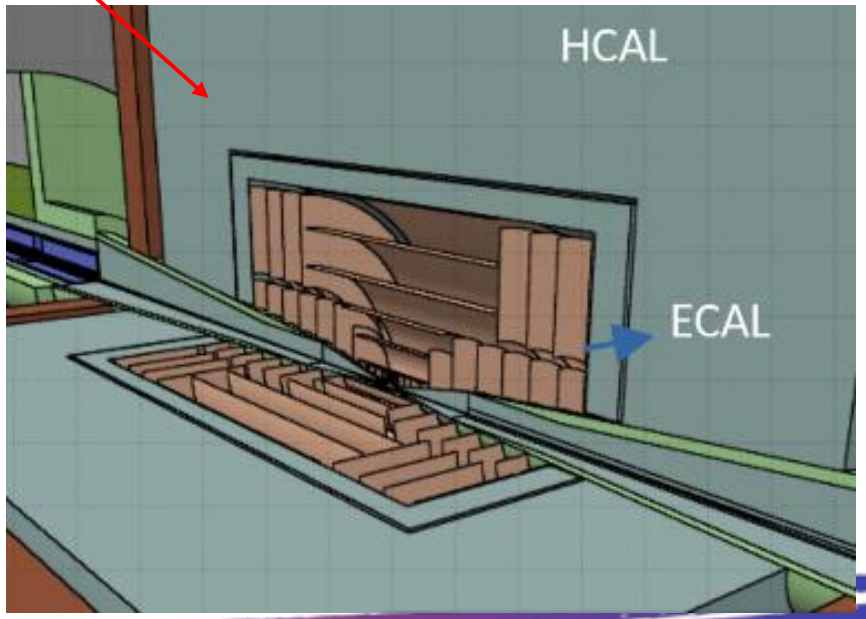
[e] *Brookhaven National Laboratory, Upton, New York, U.S.A.*
[f] *INFN Sezione di Milano, Milano, Italy*

Machine Detector Interface

- Final focusing and Interaction Region implemented in FLUKA
- Shielding nozzle are a unique feature of the Muon Collider
- Designed for $\sqrt{s} = 1.5\ TeV$

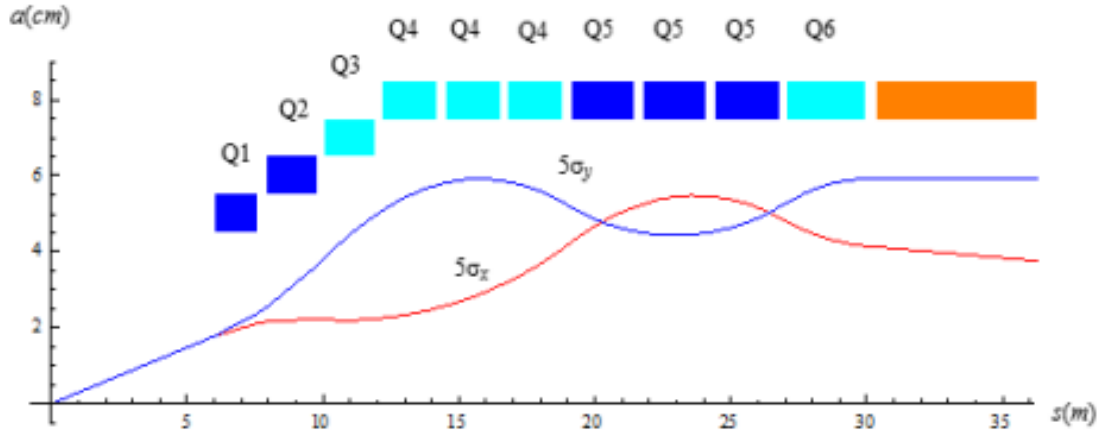


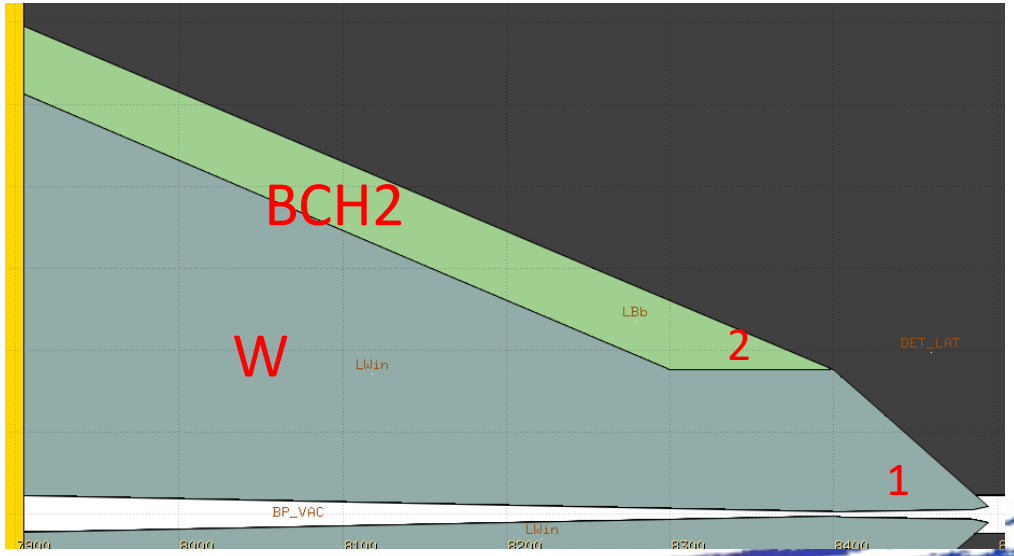


Courtesy of D. Calzolari

MDI configuration

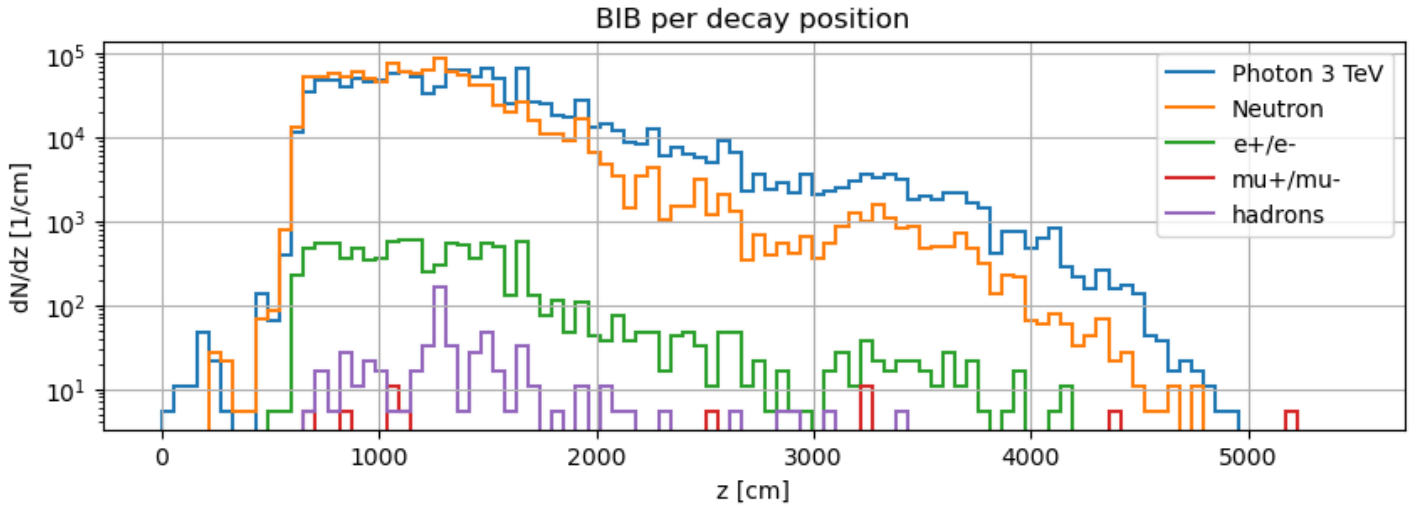
- Quadruplet FF magnet configuration [1]
- MAP nozzle design:
  1) 10° closest to the IP
  2) 5° starting from $z = 100\ cm$
- Tungsten (W) cone with a borated polyethylene (BCH2) coat

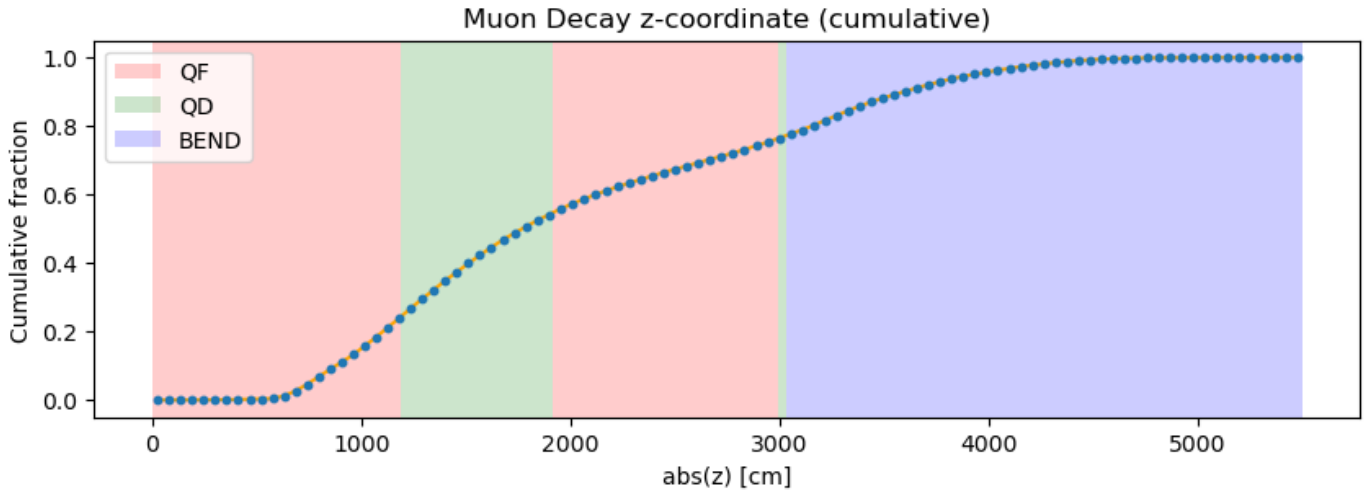




Simulation Setup

- Generated one beam of μ^+ decays within $\mathbf{55}\ \boldsymbol{m}$ from the Interaction Point
- **Energy threshold** for particles production fixed at $\mathbf{100}\ \boldsymbol{keV}$
- Field in the detector: $\boldsymbol{B} = \mathbf{3.57}\ \boldsymbol{T}$
- Particles which enters the detector area are scored

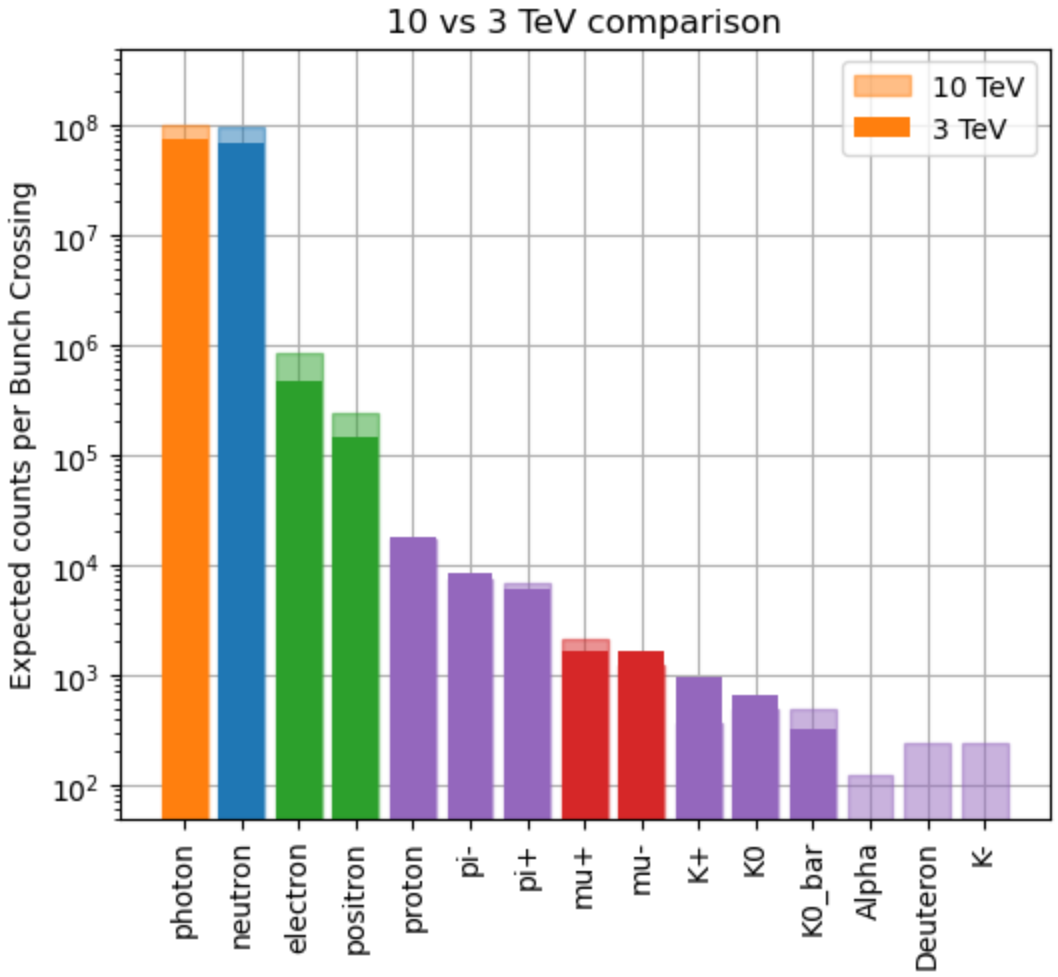




BIB composition

	*1.5 TeV**	*3 TeV*	*10TeV**
Photon	$6.0 \cdot 10^7$	$7.6 \cdot 10^7$	$1.0 \cdot 10^8$
Neutron	$6.2 \cdot 10^7$	$6.8 \cdot 10^7$	$9.4 \cdot 10^7$
e^+/e^-	$4.7 \cdot 10^5$	$6.1 \cdot 10^5$	$1.1 \cdot 10^6$
μ^+/μ^-	$3.4 \cdot 10^3$	$3.2 \cdot 10^3$	$3.3 \cdot 10^3$
hadrons	$2.2 \cdot 10^4$	$3.5 \cdot 10^4$	$3.3 \cdot 10^4$

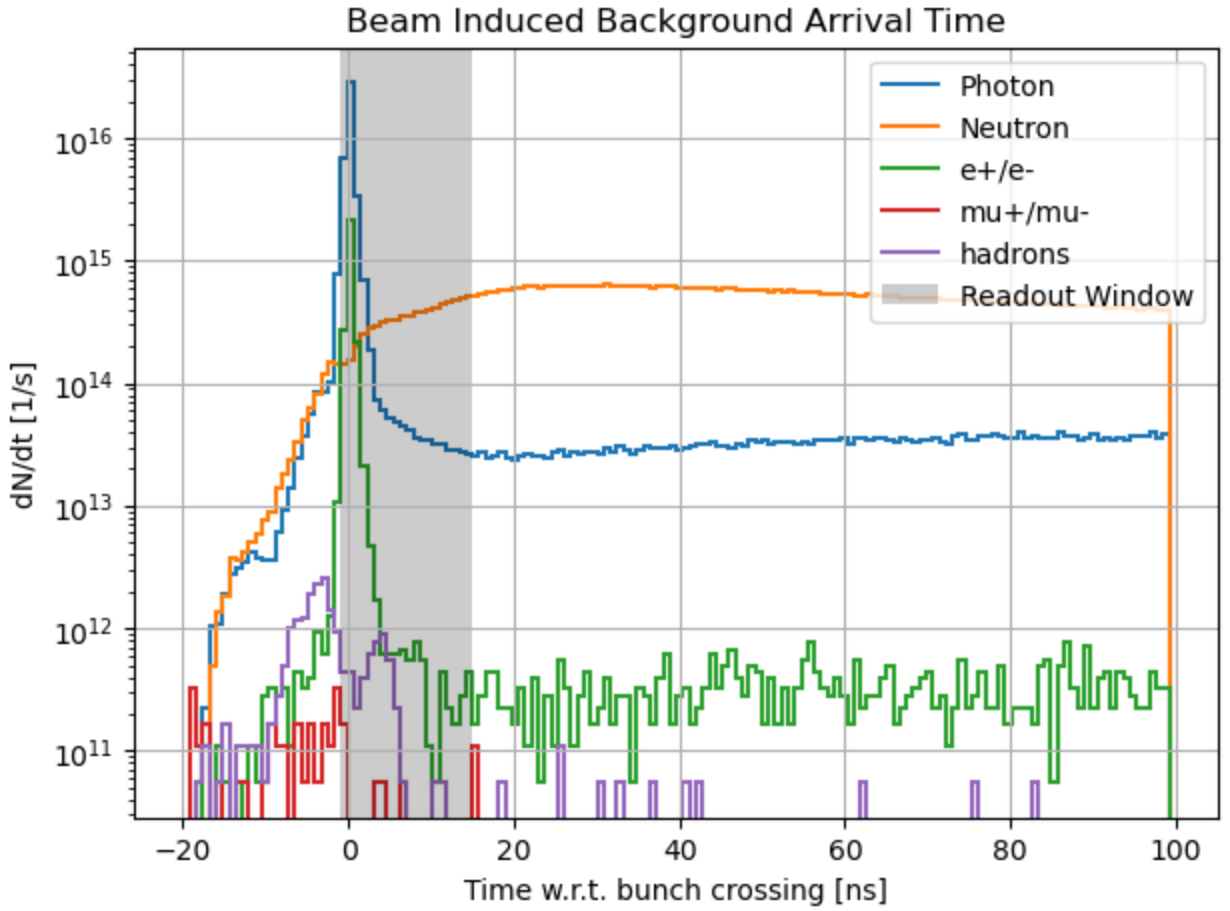
BIB particles per bunch crossing



*Fluka simulation with $B = 3.57\ T$

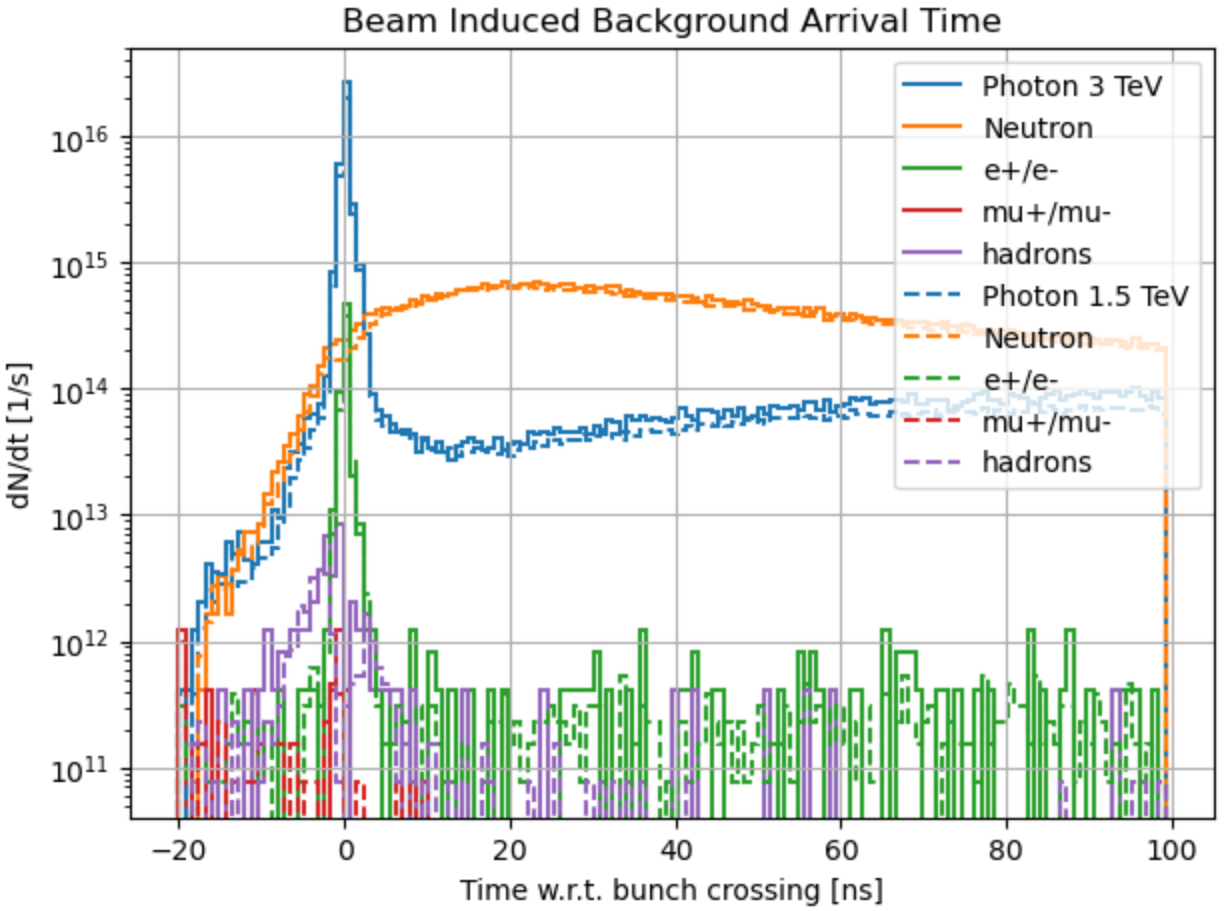
Arrival time

- Arrival time in the detector with respect to the bunch crossing
- Read-out window: $[-1; 15]\ ns$



Arrival time

- Arrival time in the detector with respect to the bunch crossing
- Read-out window: $[-1; 15]\ ns$
- Comparison with $\sqrt{s} = 1.5\ TeV$



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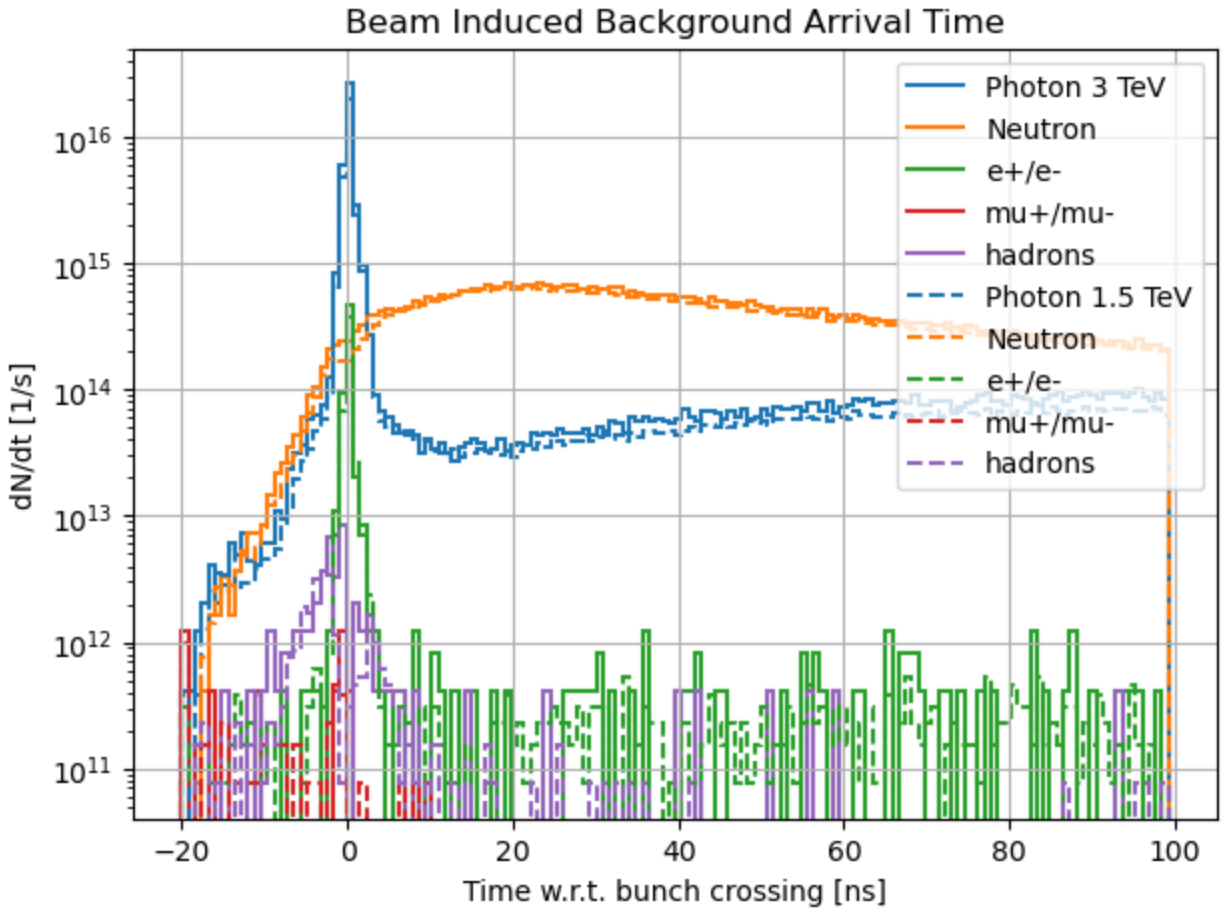
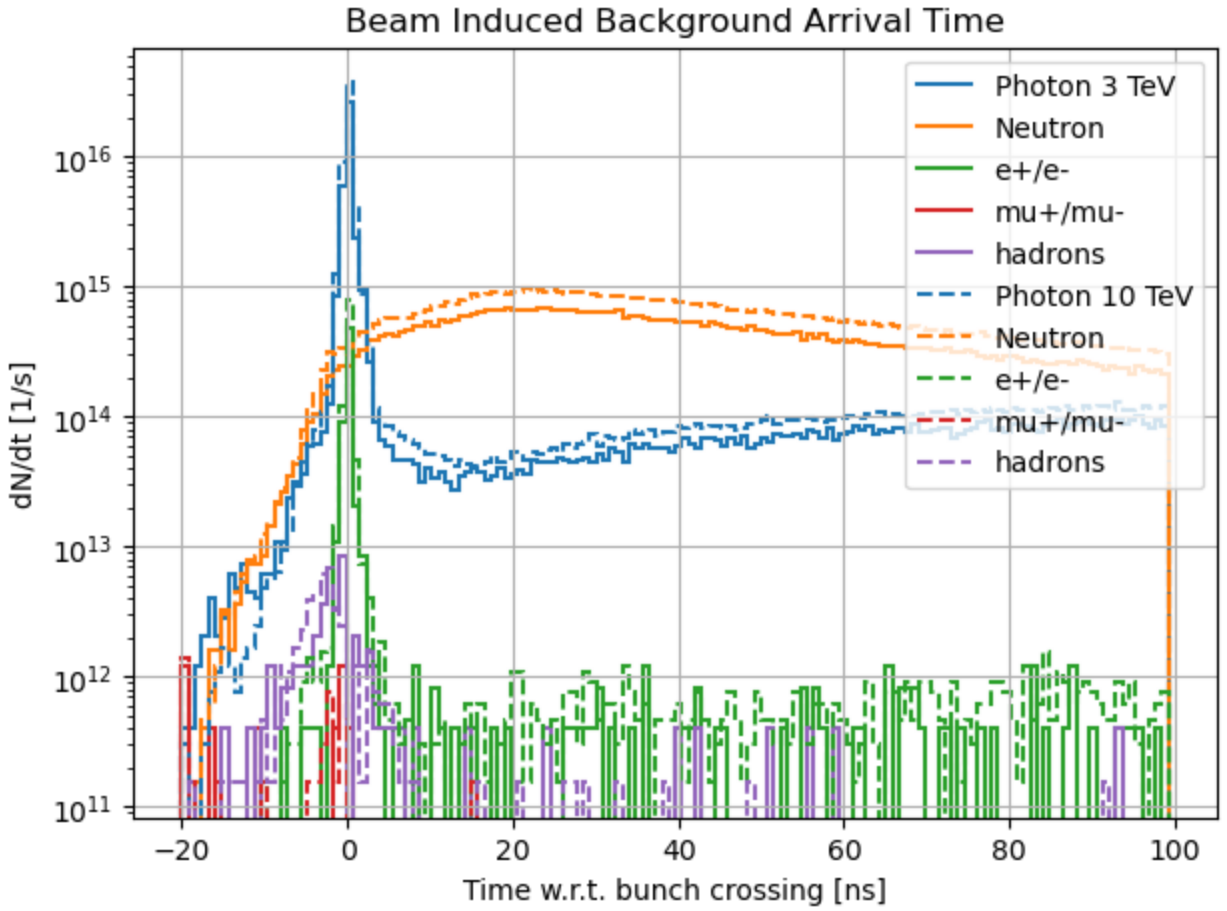
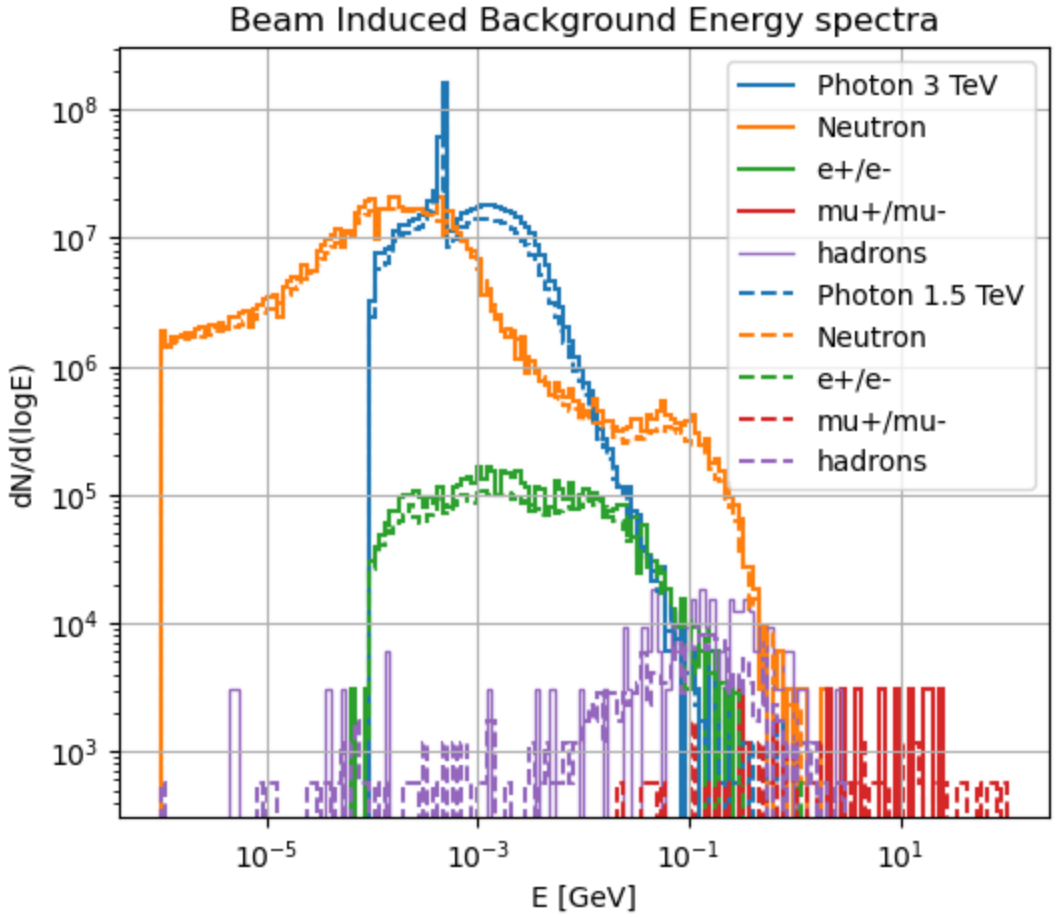


Arrival time

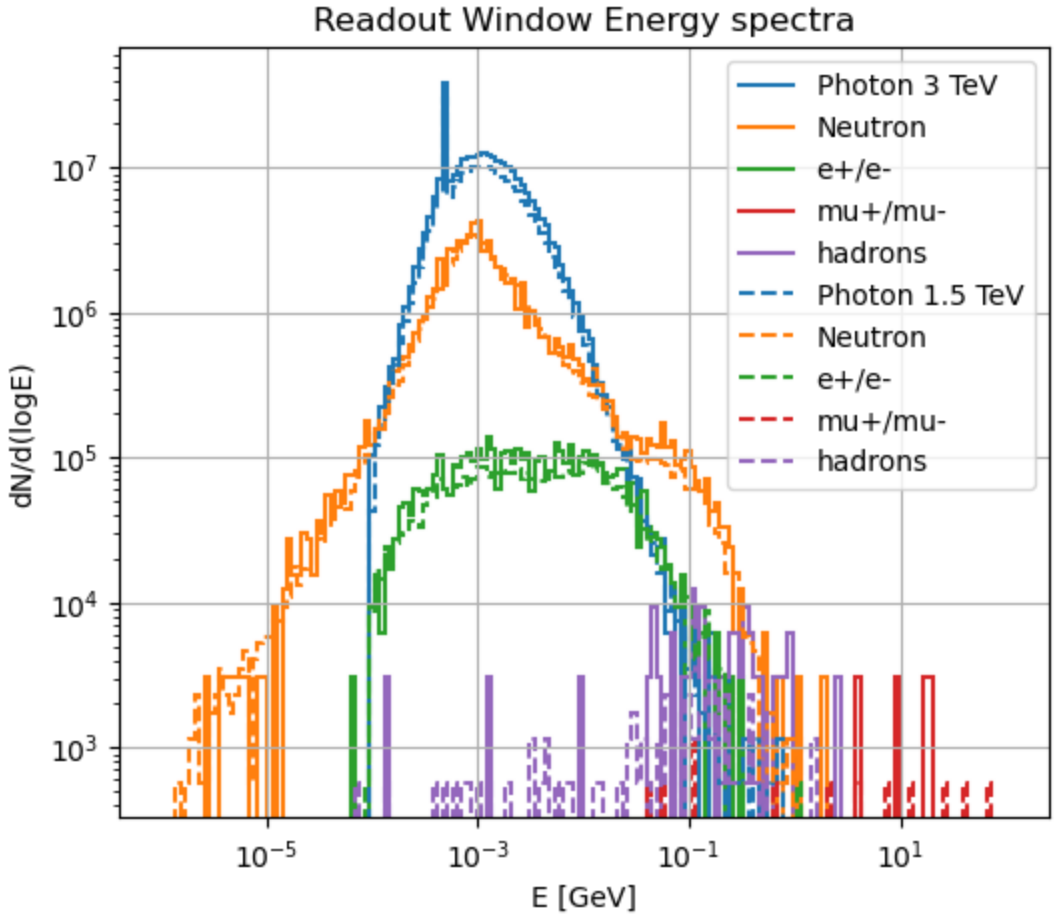
- Arrival time in the detector with respect to the bunch crossing
- Read-out window: $[-1; 15]\ ns$
- Comparison with $\sqrt{s} = 10\ TeV$



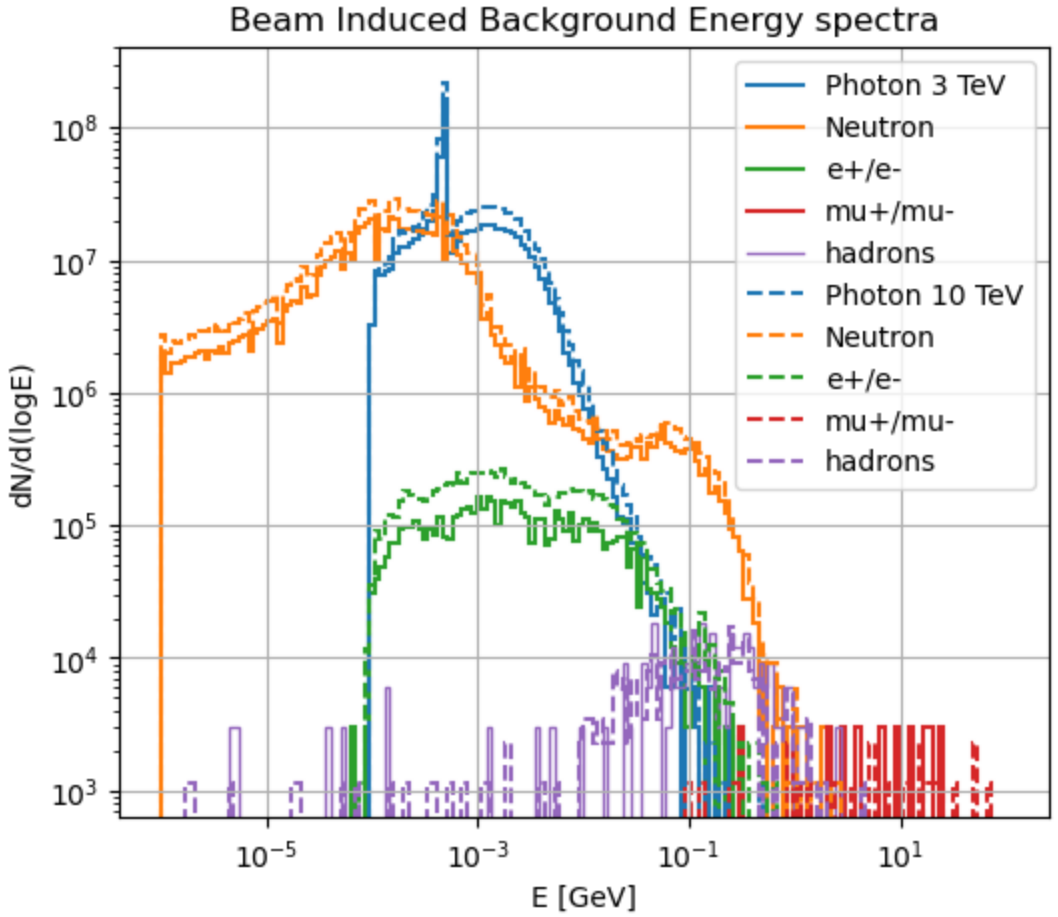
BIB Energy spectrum



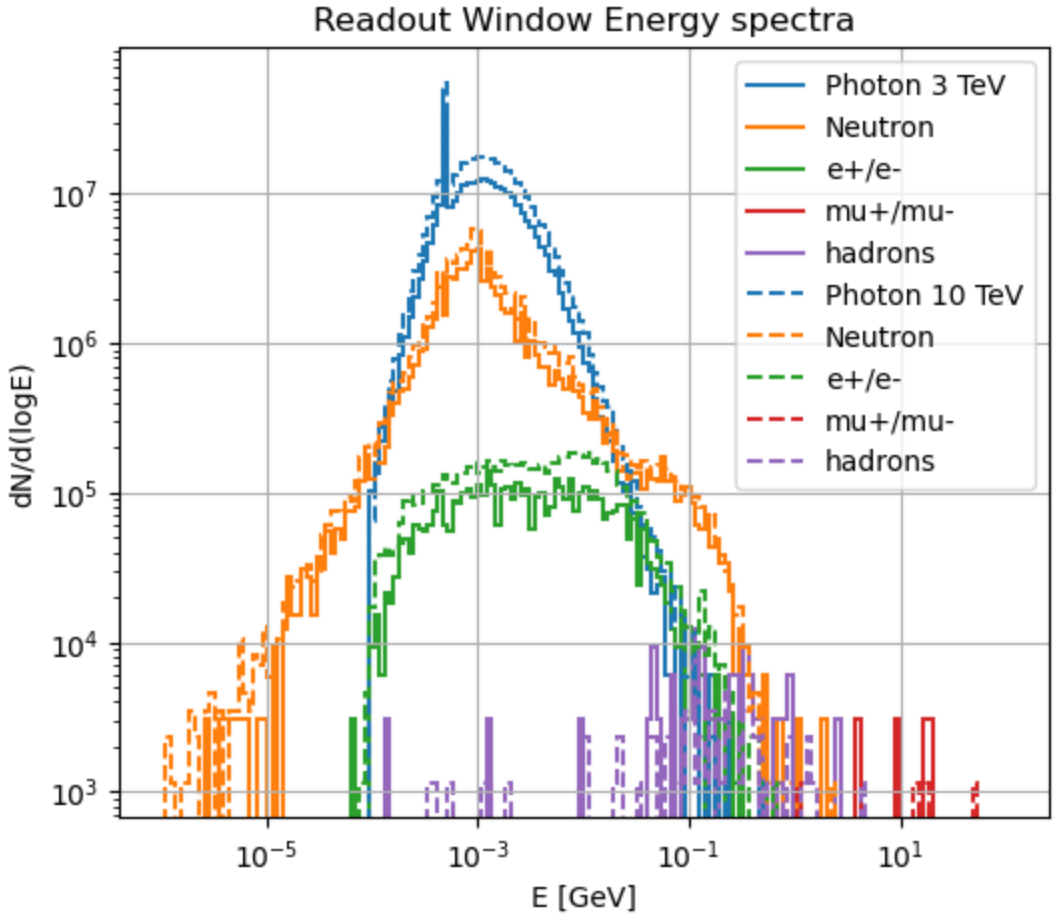
Readout window [-1, 15]ns



BIB Energy spectrum

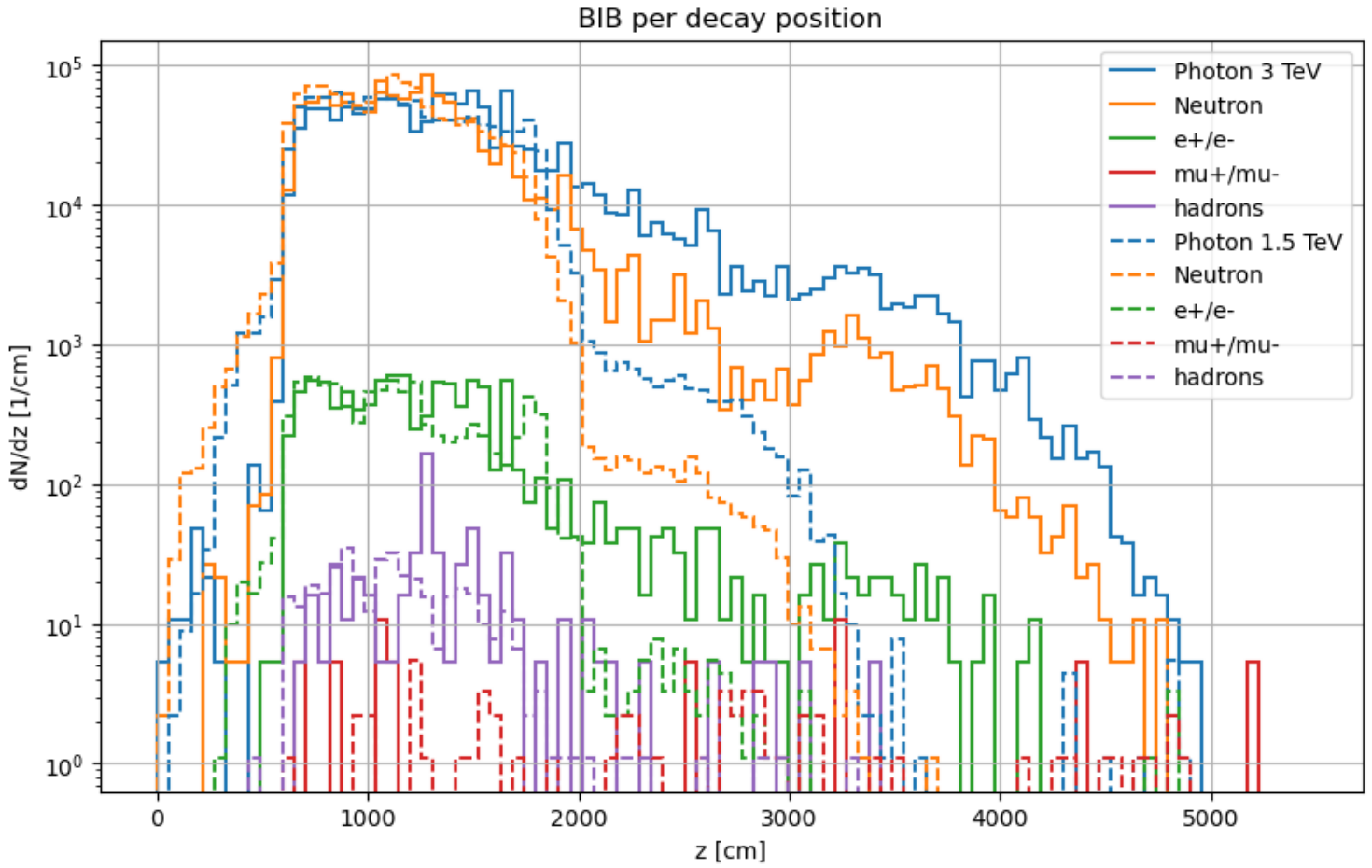


Readout window [-1, 15]ns



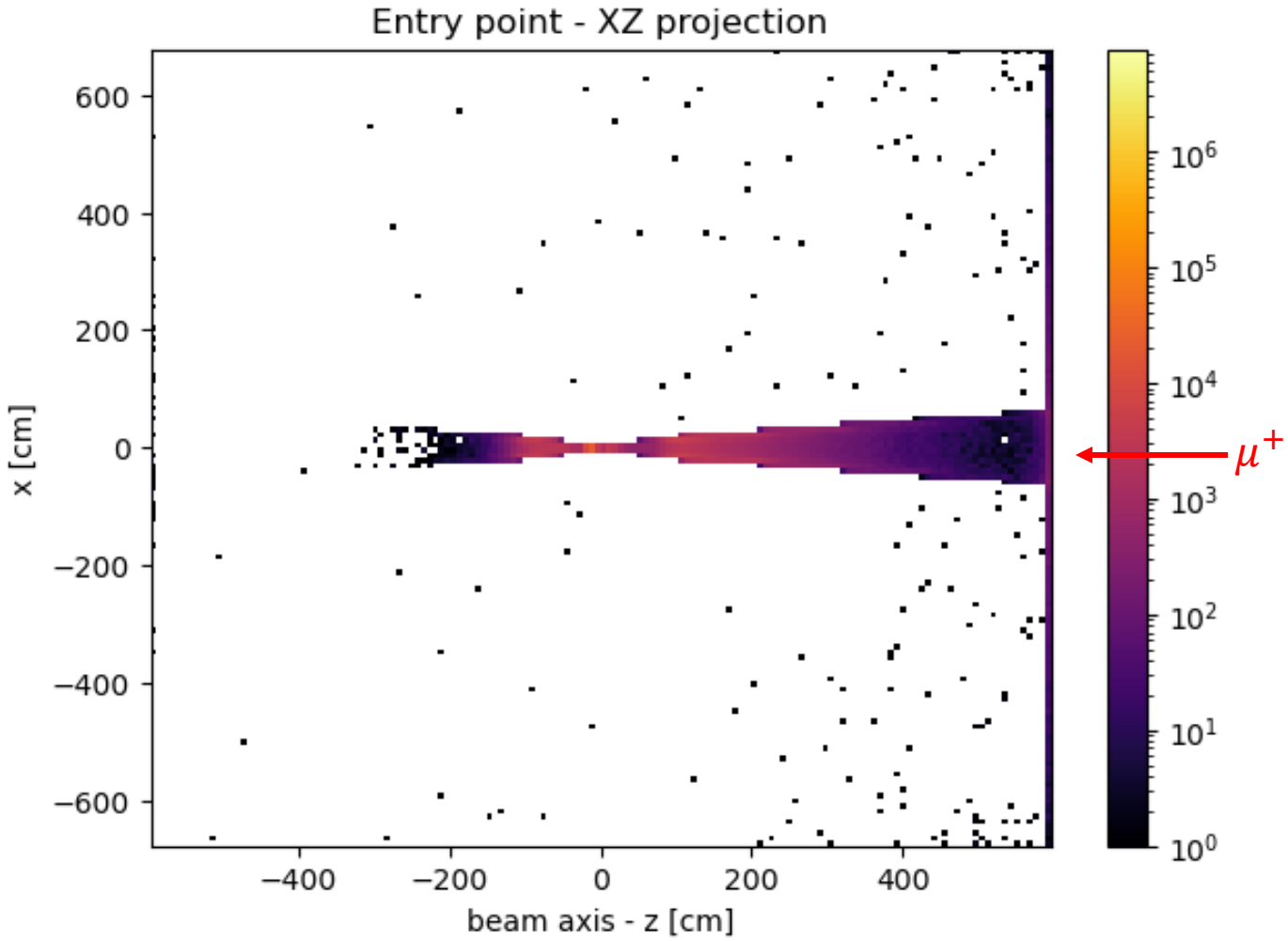
Muon Decay Position

- Muons cause BIB if they decay up to $\sim 50\ m$ from the IP
- For $\sqrt{s} = 1.5\ TeV$ case, after $\sim 40\ m$ the BIB contribution become negligible

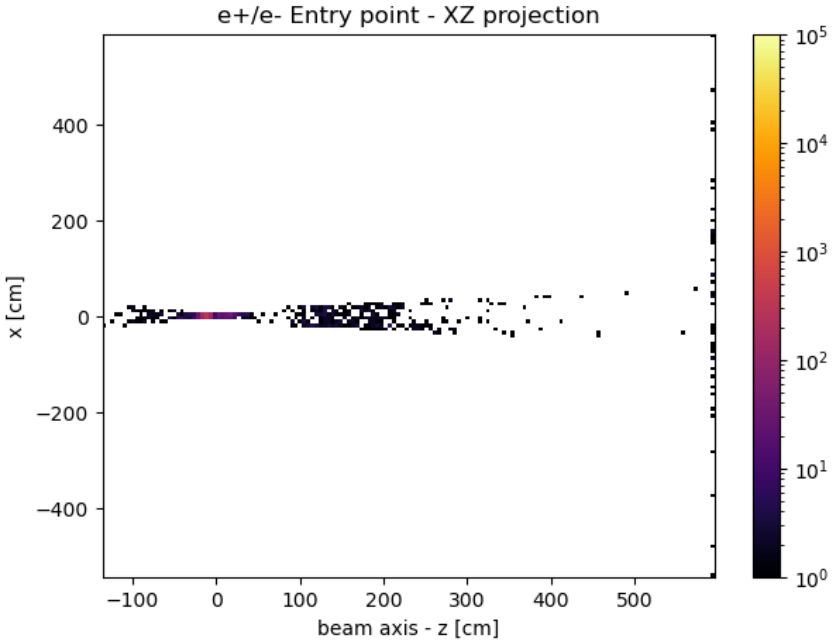


Detector surface crossing

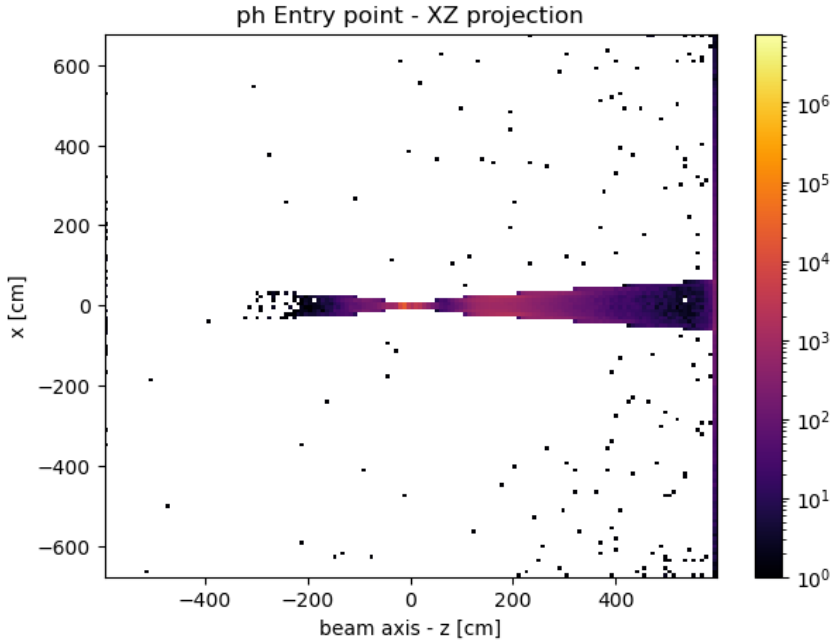
- Most of BIB particles enter in the detector area from the nozzles
- A fraction comes from the right-side, suggesting that more shielding is needed



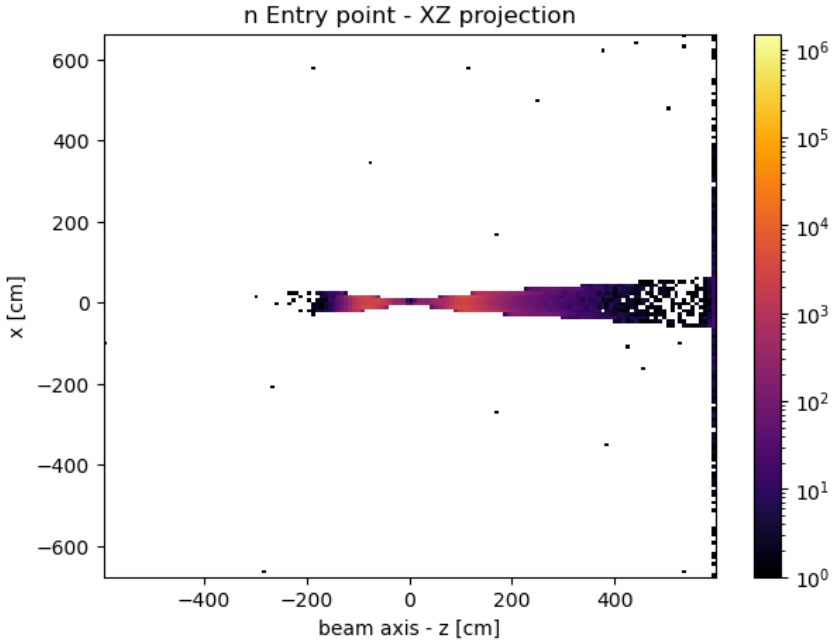
Detector surface crossing



e^+e^-



photons



neutrons

Conclusion and next steps

- A complete overview of the Beam Induced Background at $\sqrt{s} = 3\ TeV$ has been achieved using an unoptimized Machine Detector Interface design
- Next steps:
  - Investigation of new nozzle geometries
  - Identification of figures of merit on which optimize (common effort with detector people)
  - Investigating Machine-Learning approaches to nozzle optimization

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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

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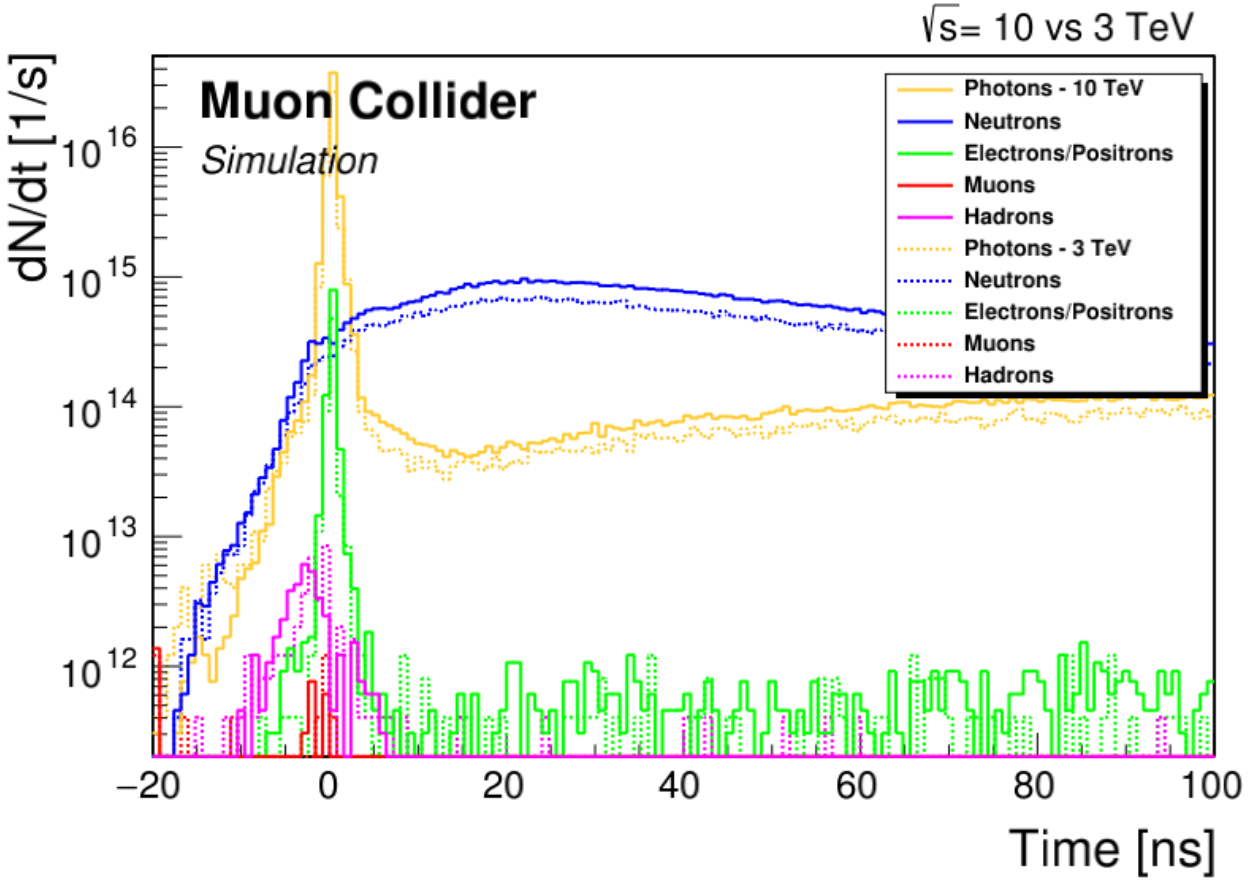
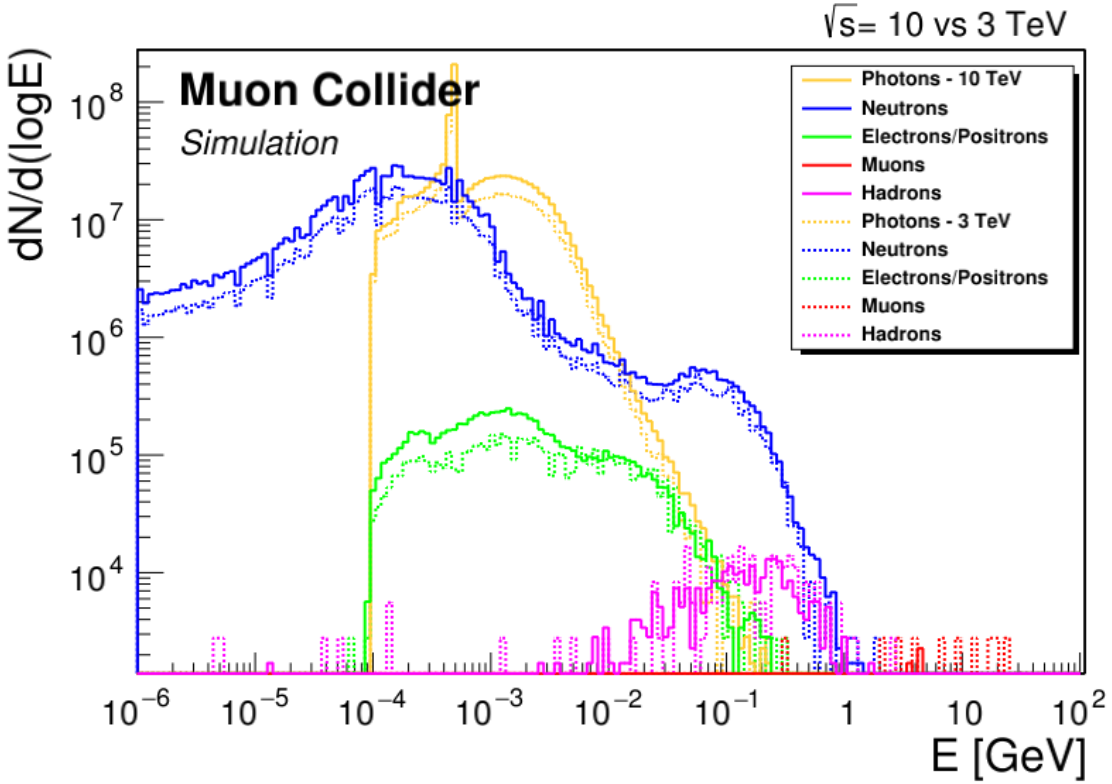
BACKUP

Arrival time

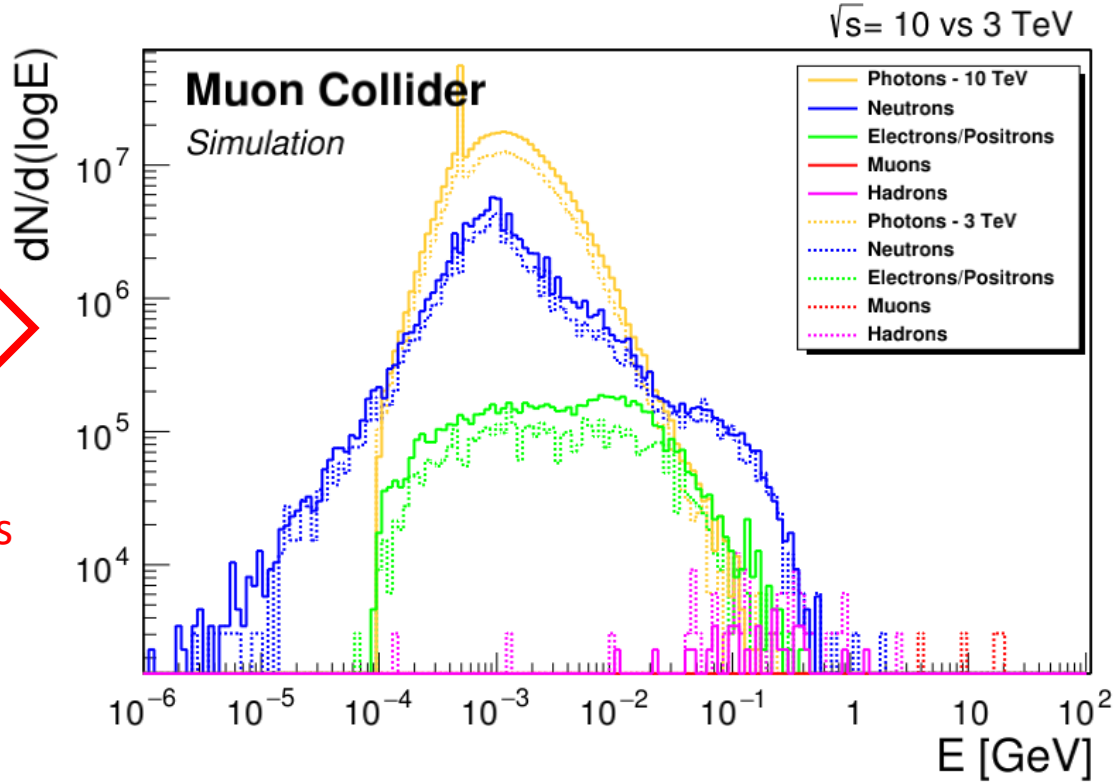
- Arrival time in the detector with respect to the bunch crossing
- Read-out window: $[-1; 15]\ ns$
- Comparison with $\sqrt{s} = 10\ TeV$
- Same plot as slide 6, different style



BIB Energy spectrum



Readout window [-1, 15]ns



Same plot as slide 10, different style

BIB composition

	*1.5 TeV**	*3 TeV*	*10TeV***
Photon	$6.0 \cdot 10^7$	$7.6 \cdot 10^7$	$9.6 \cdot 10^7$
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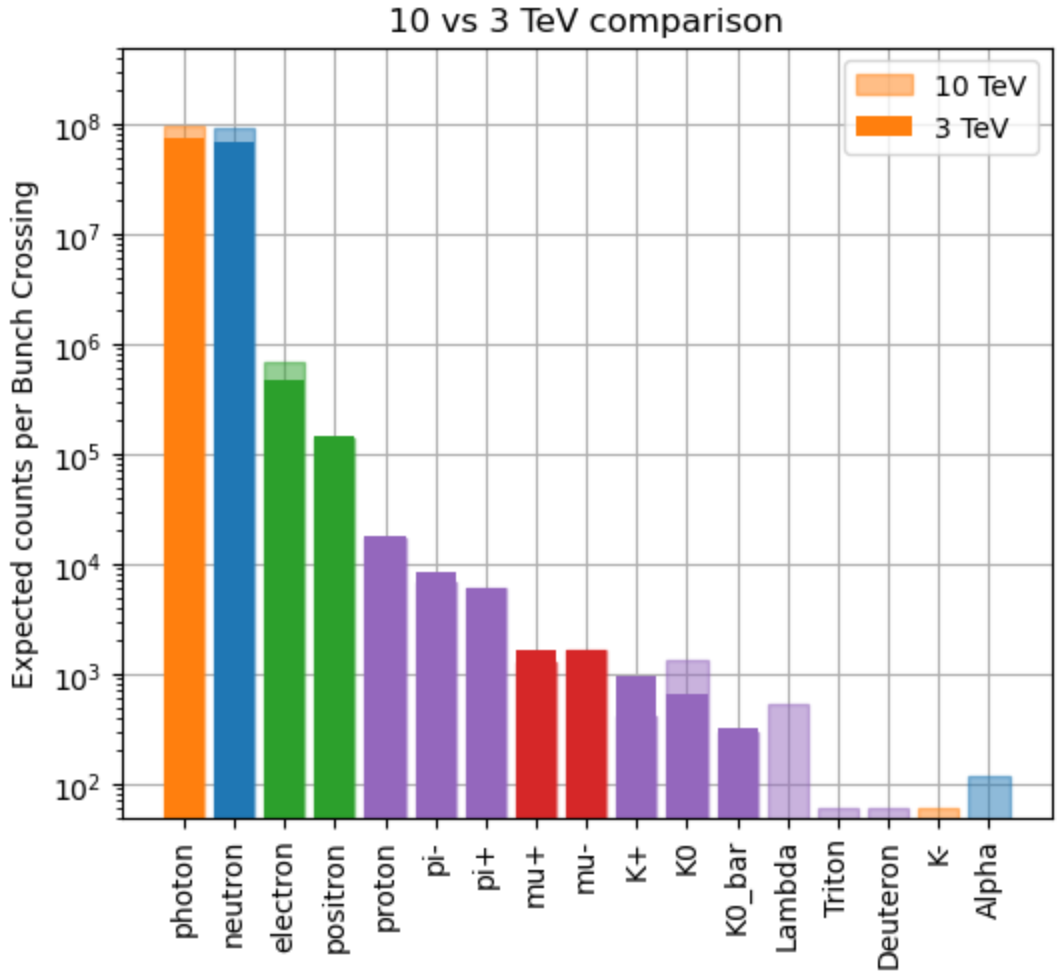
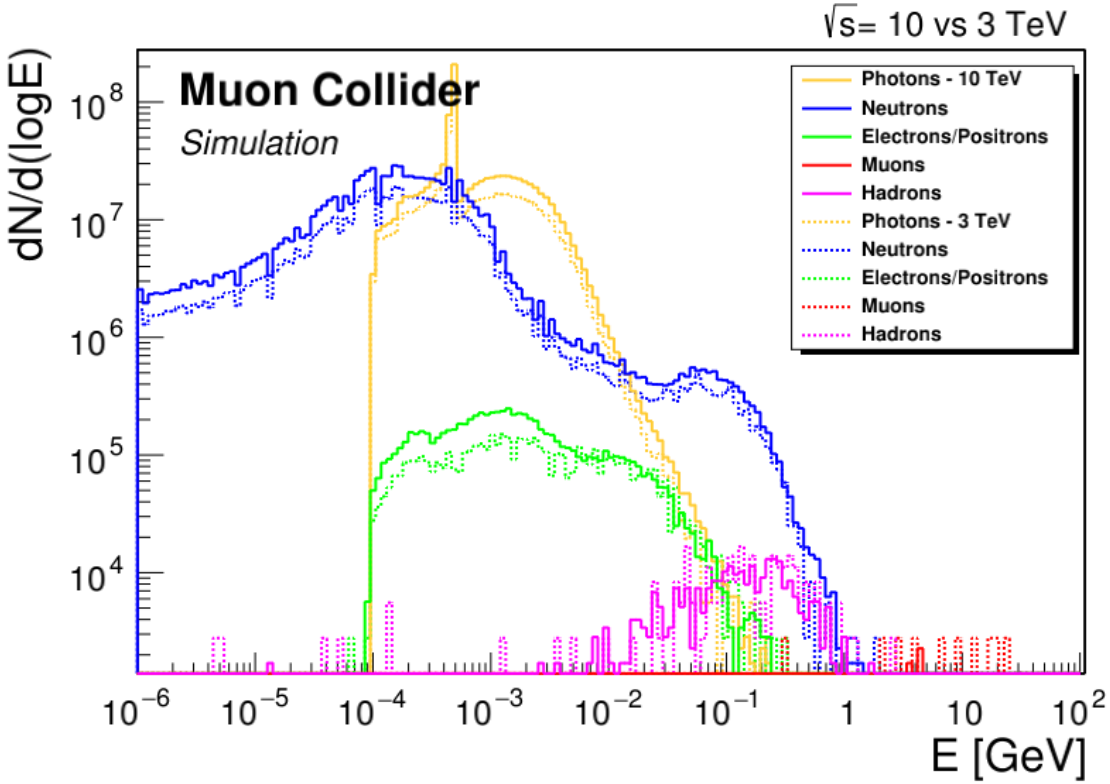
e^+/e^-	$4.7 \cdot 10^5$	$6.1 \cdot 10^5$	$8.3 \cdot 10^5$
μ^+/μ^-	$3.4 \cdot 10^3$	$3.2 \cdot 10^3$	$2.9 \cdot 10^3$
hadrons	$2.2 \cdot 10^4$	$3.5 \cdot 10^4$	$3.3 \cdot 10^4$

BIB particles per bunch crossing

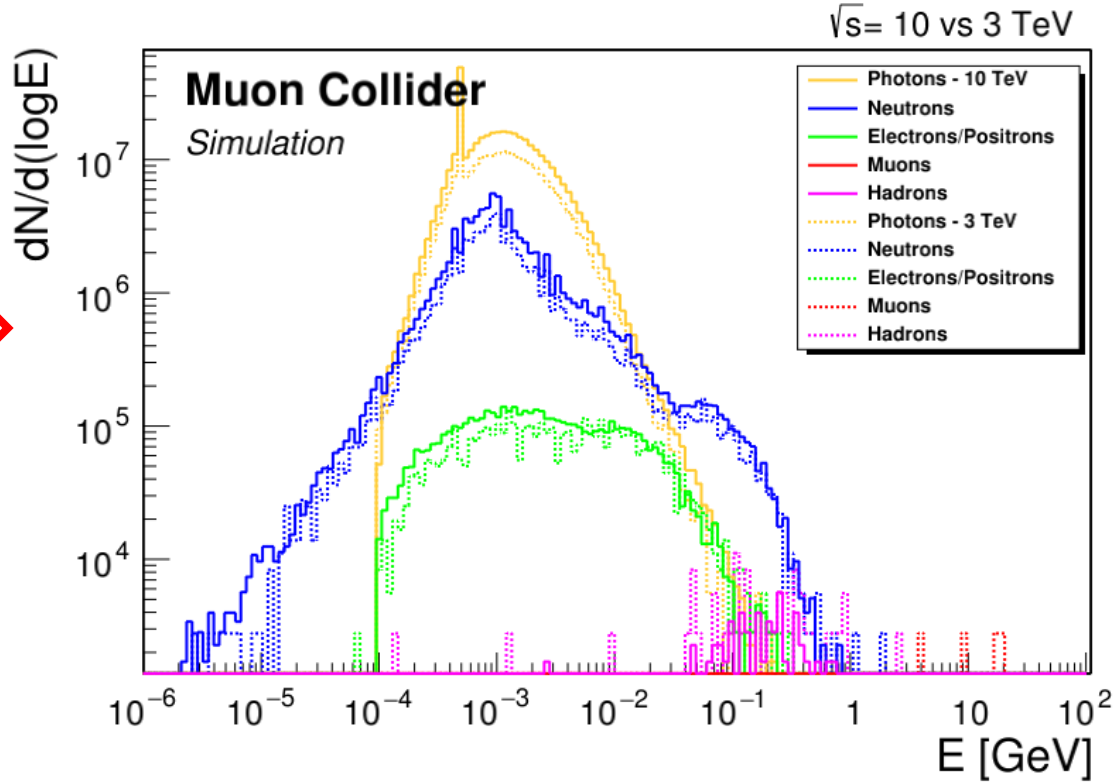


*Fluka simulation with $B = 3.57\ T$
*Fluka simulation with $B = 5\ T$

BIB Energy spectrum



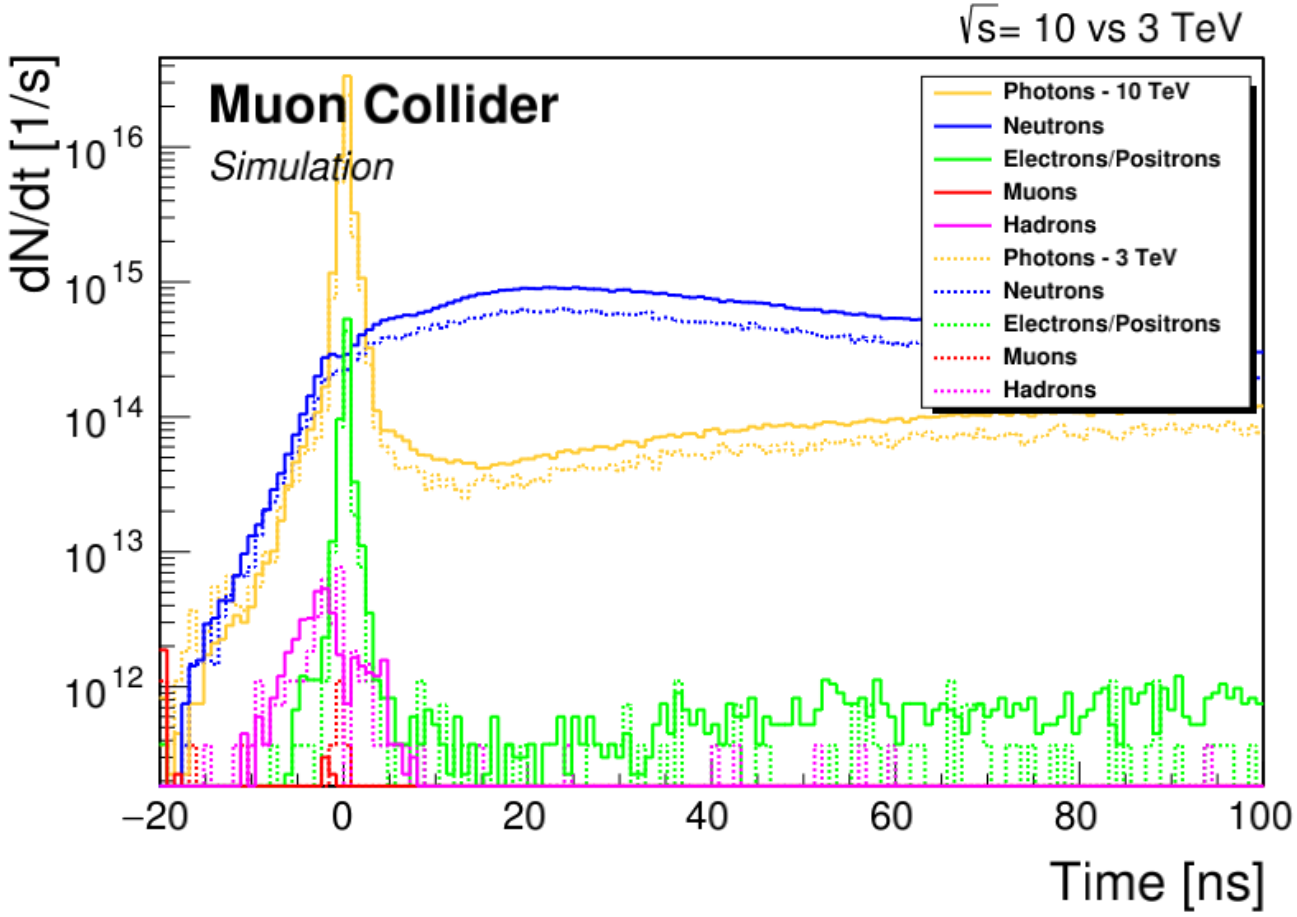
Readout window [-1, 15]ns



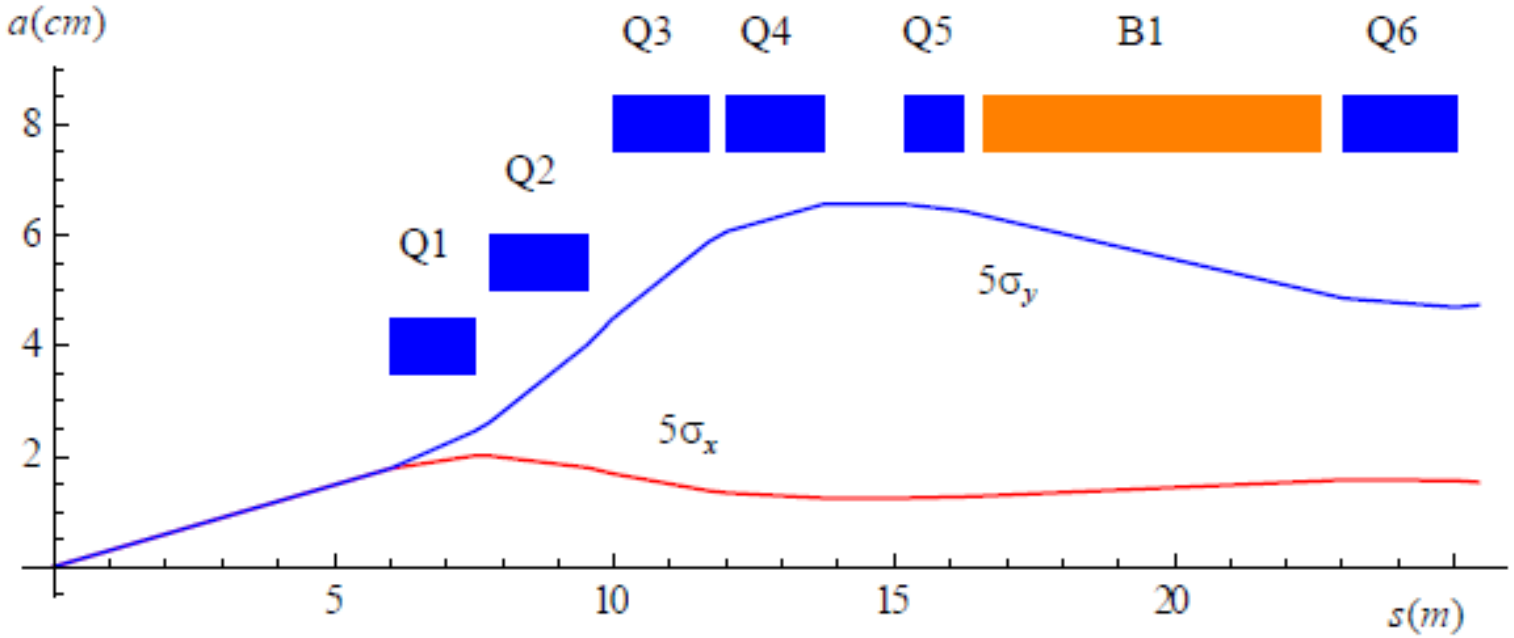
Simulation at 10 TeV with B = 5 T

Arrival time

- Arrival time in the detector with respect to the bunch crossing
- Read-out window: $[-1; 15]\ ns$
- Comparison with $\sqrt{s} = 10\ TeV$, B = 5 T

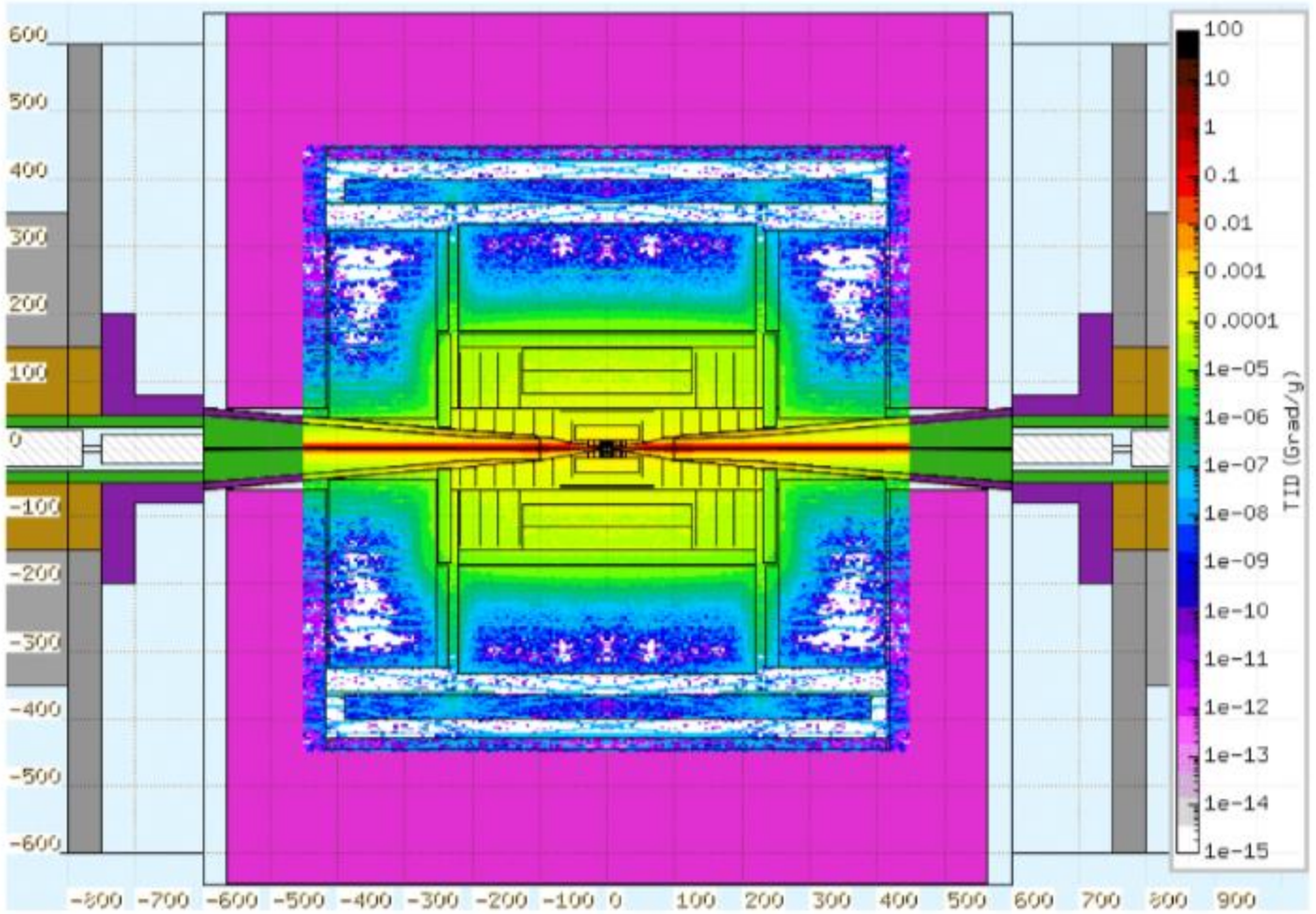


$\sqrt{s} = 1.5\ TeV$ Design



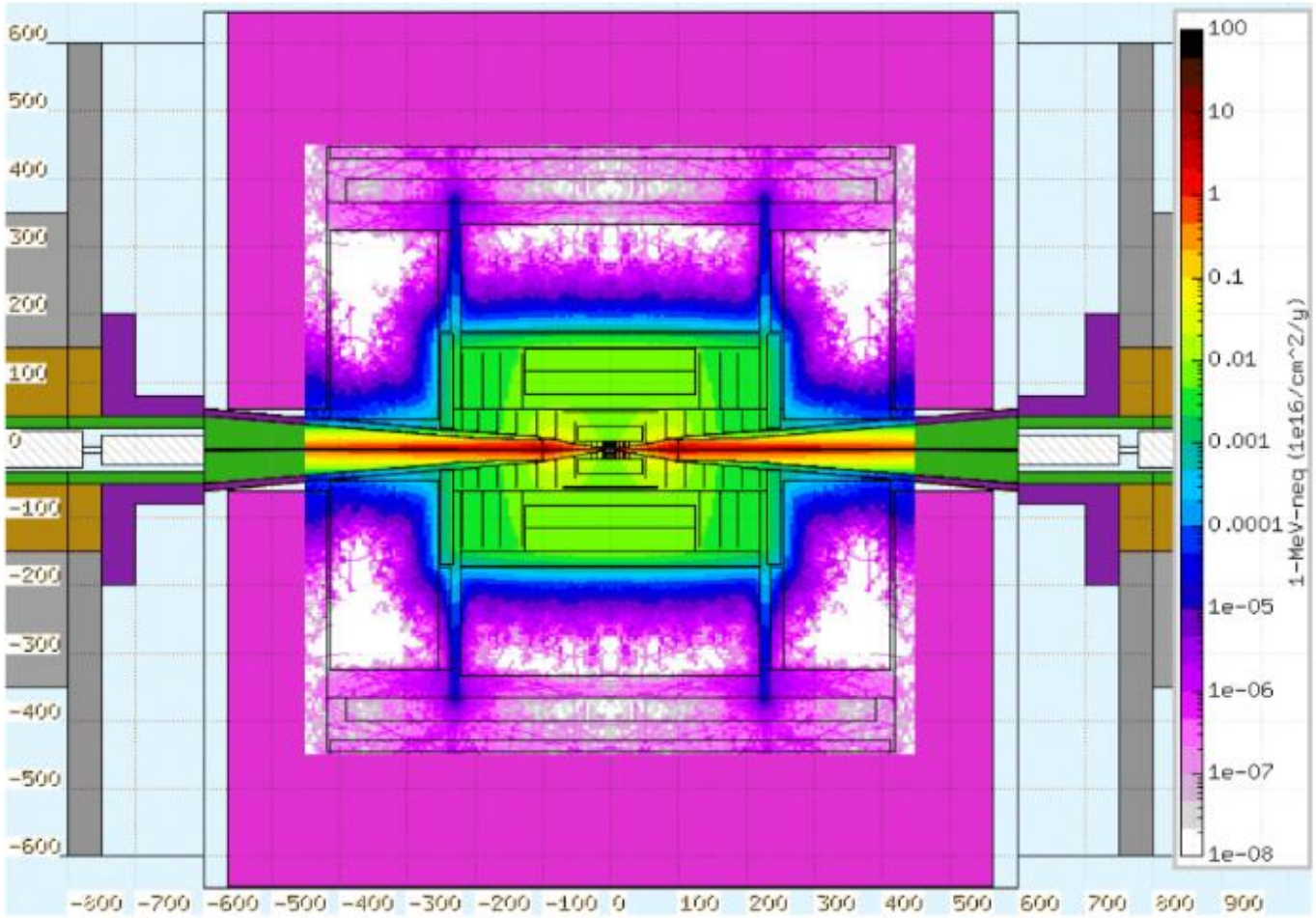
Dose

- Considering 200 operational days/year, total ionizing dose is expected to be:
  - $\sim 10^{-3}\ Grad \cdot y^{-1}$ in the tracker
  - $\sim 10^{-4}\ Grad \cdot y^{-1}$ in the electromagnetic calorimeter

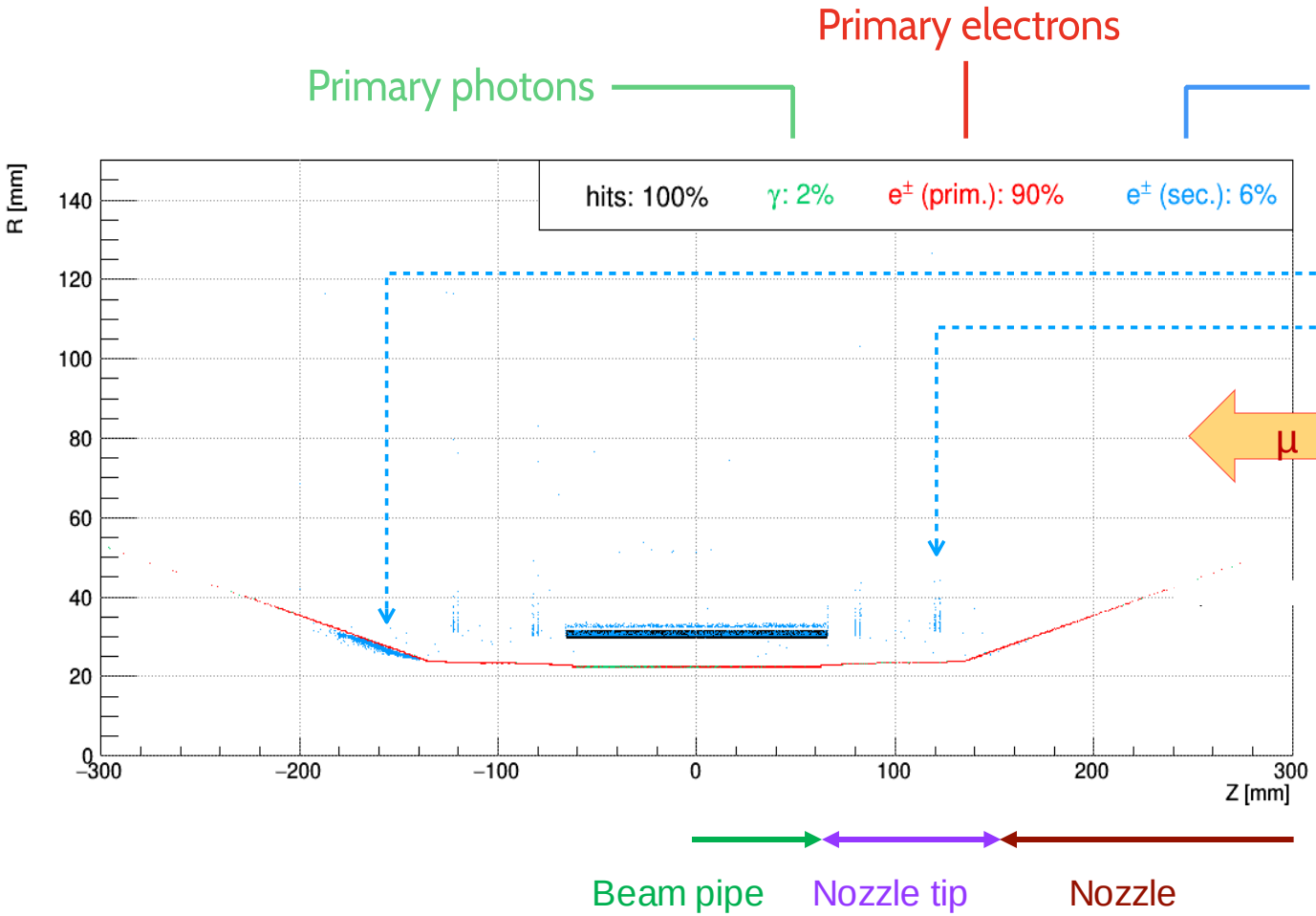


Dose

- Considering 200 operational days/year, 1-MeV-neq fluence is expected to be:
  - $\sim 10^{14-15}\ cm^{-2}y^{-1}$ in the tracker
  - $\sim 10^{14}\ cm^{-2}y^{-1}$ in the electromagnetic calorimeter



Occupancy in the tracker



created by interaction of primary photons with:

- MDI material
- detector material