Comparisons of BIB at different energies

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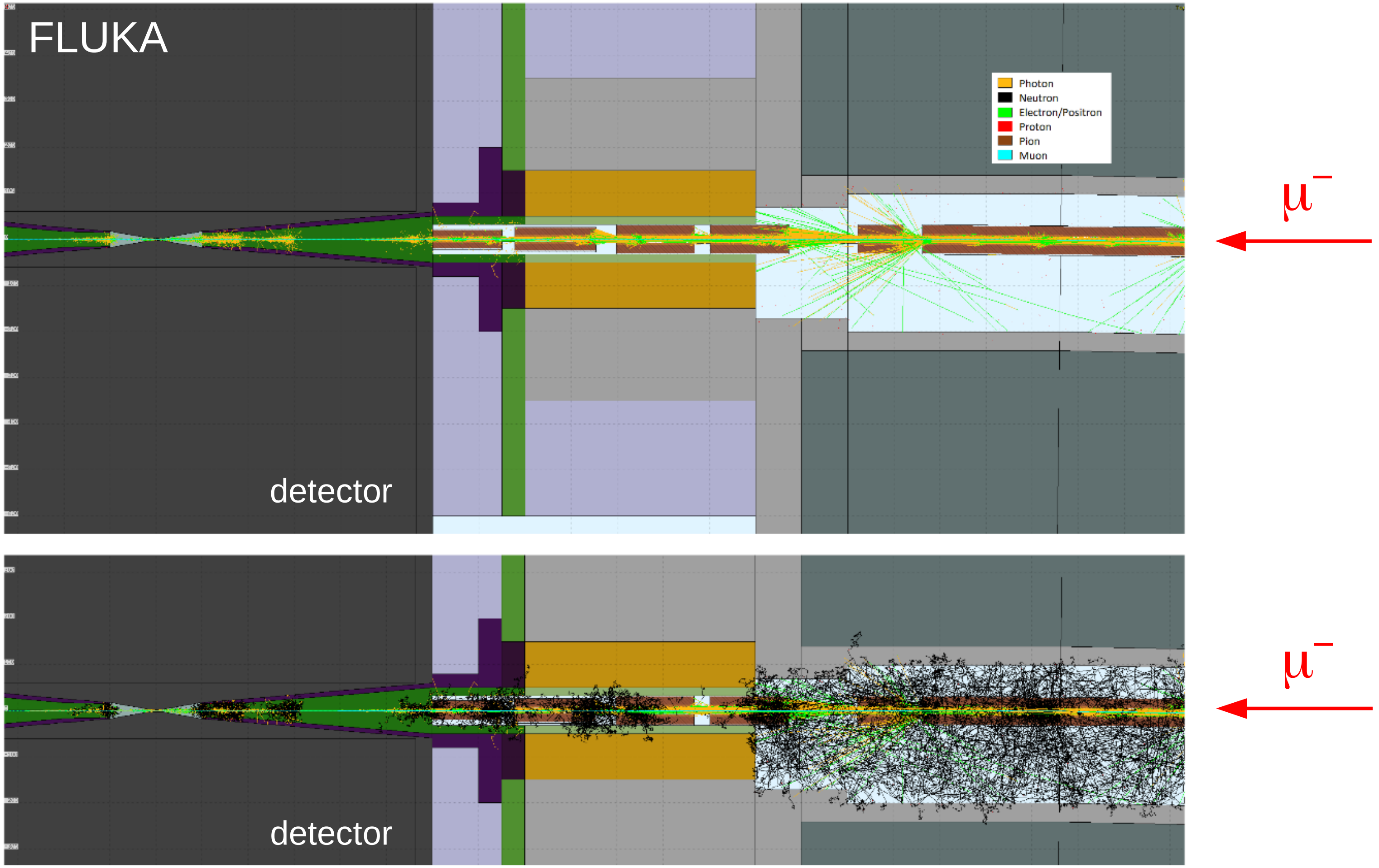
Introduction and caveats

- This is the first attempt of a systematic comparison of the beam-induced background at different energies (which means at different colliders!).
- The main features of the BIB particles reaching the detector will be shown for three colliders operating at:
  - $\sqrt{s}$ = 125 GeV, $\sqrt{s}$ = 1.5 TeV, and $\sqrt{s}$ = 3 TeV.
- Results are obtained for a single μ^- beam arriving from the right.
- Some caveats:
  - the BIB samples used are not uniform: some were generated with MARS15, some with FLUKA. However, a comparison MARS15 vs FLUKA shows compatible results at 1.5 TeV (see the back-up slides);
  - results at 3 TeV are very preliminary: there is still no optimized machine-detector interface and the simulation is using an ideal beam.

BIB in a nutshell

- The particles generated in the interactions of the beam-muons decay products with the machine elements represent the dominant contribution to the machine background in the detector.

F. Collamati *et al.*, arXiv:2105.09116



Available BIB samples

- Particles originating from muon decays, even faraway from the interaction point, may eventually reach the detector: BIB generation requires a detailed modeling of the machine and the machine-detector interface (MDI).

- MARS15 samples (N. Mokhov, FNAL):
  - 62.5-GeV $\mu^{\pm}$ beams: simulated using MAP's Higgs factory design with a dedicated optimized MDI;
  - 750-GeV $\mu^{\pm}$ beams: simulated using MAP's 1.5-TeV machine design with a dedicated optimized MDI.

- FLUKA samples (C. Curatolo and P. Sala, INFN-Milan):
  - 750-GeV μ^{-} beam: simulated using MAP's 1.5-TeV machine design with MAP's optimized MDI;
  - 1500-GeV μ^{-} beam: simulated using MAP's 3-TeV machine design and temporarily with MAP's MDI optimized for $\sqrt{s}$ = 1.5 TeV.

- Particle production thresholds for all BIB samples: 100 keV for photons, electrons, muons, charge hadrons and 0.001 eV for neutrons.

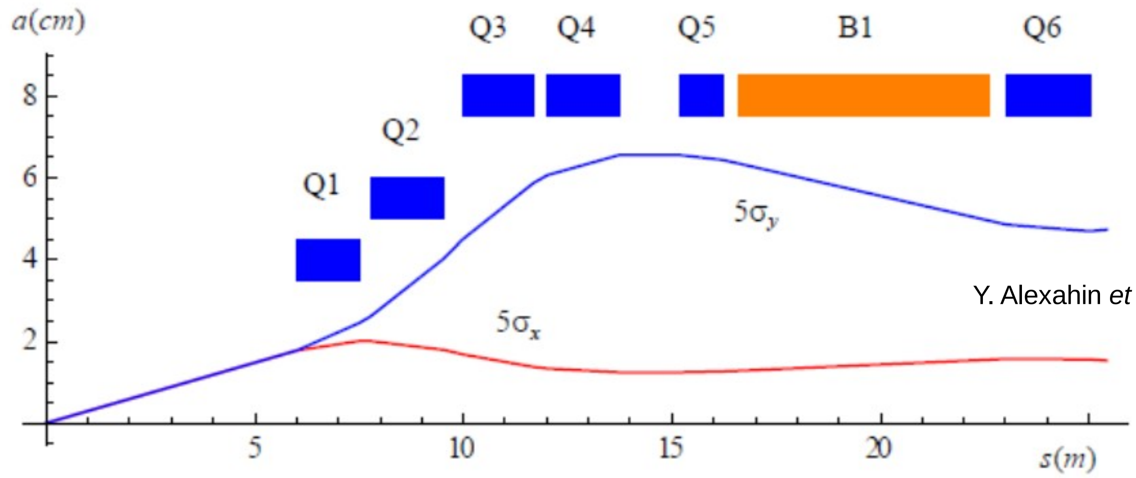
Machine parameters

Y. Alexahin *et al.*, 2018 JINST 13 P11002

beam energy [GeV]	63	750	1500
average inst. lum. [cm^2 s^{-1}]	0.008×10^{34}	1.25×10^{34}	4.6×10^{34}
number of muons/bunch	4×10^{12}	2×10^{12}	2×10^{12}
number of bunches	1	1	1
repetition rate [Hz]	15	15	12
β^* [cm]	1.7	1	0.5
normalized ε_T [π mm rad]	0.2	0.025	0.025
normalized ε_L [π mm rad]	1.5	70	70
bunch length [cm]	6.3	1	0.5
bunch size at IP [μm]	75	6	3
momentum spread [%]	0.004	0.1	0.1

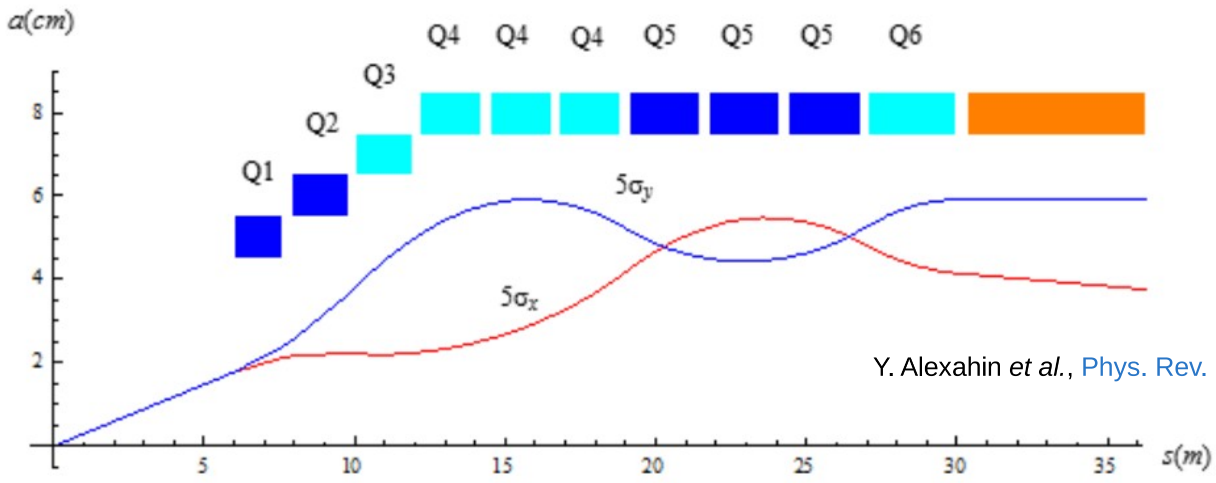
Interaction region structure

1.5-TeV machine



Y. Alexahin *et al.*, 2018 JINST 13 P11002

3-TeV machine

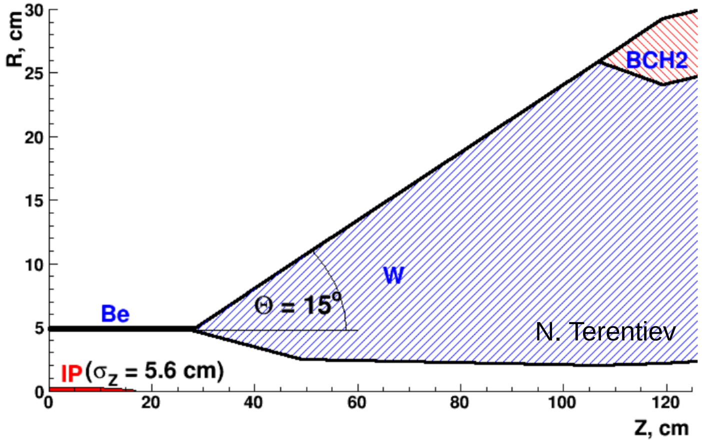


Y. Alexahin *et al.*, Phys. Rev. ST Accel. Beams 14, 061001

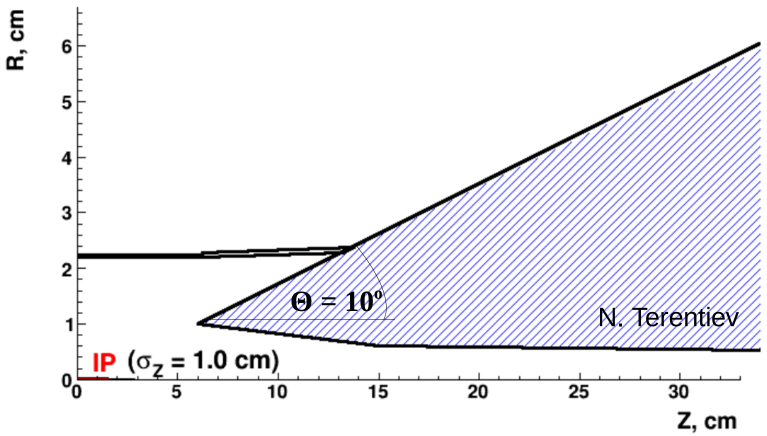
Machine-Detector Interface

- A crucial element of the machine-detector interface is represented by two tungsten shielding cones (nozzles), cladded with a 5-cm layer of borated polyethylene (BCH2).

IP optimized for a 125-GeV μ collider

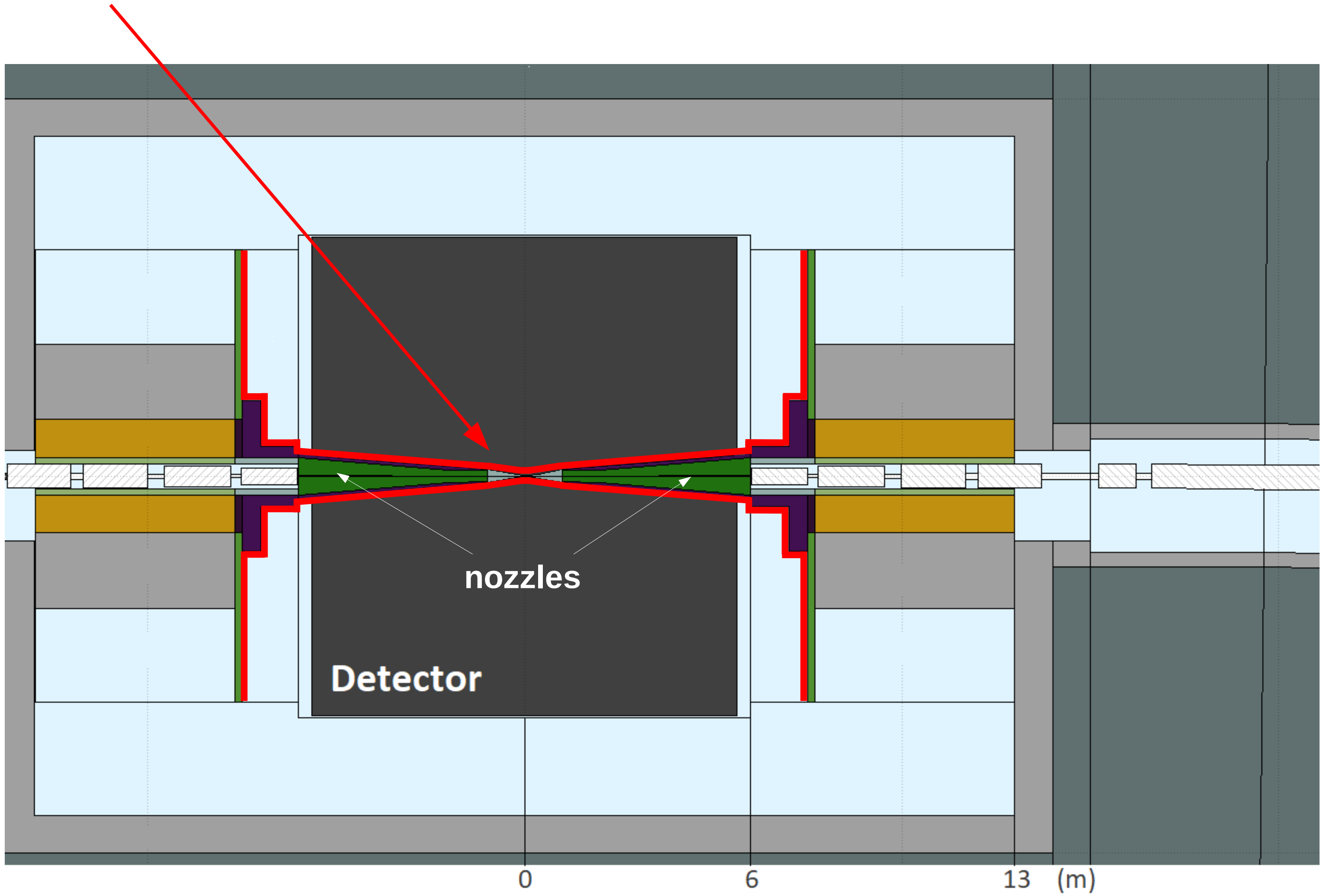


IP optimized for a 1.5-TeV μ collider

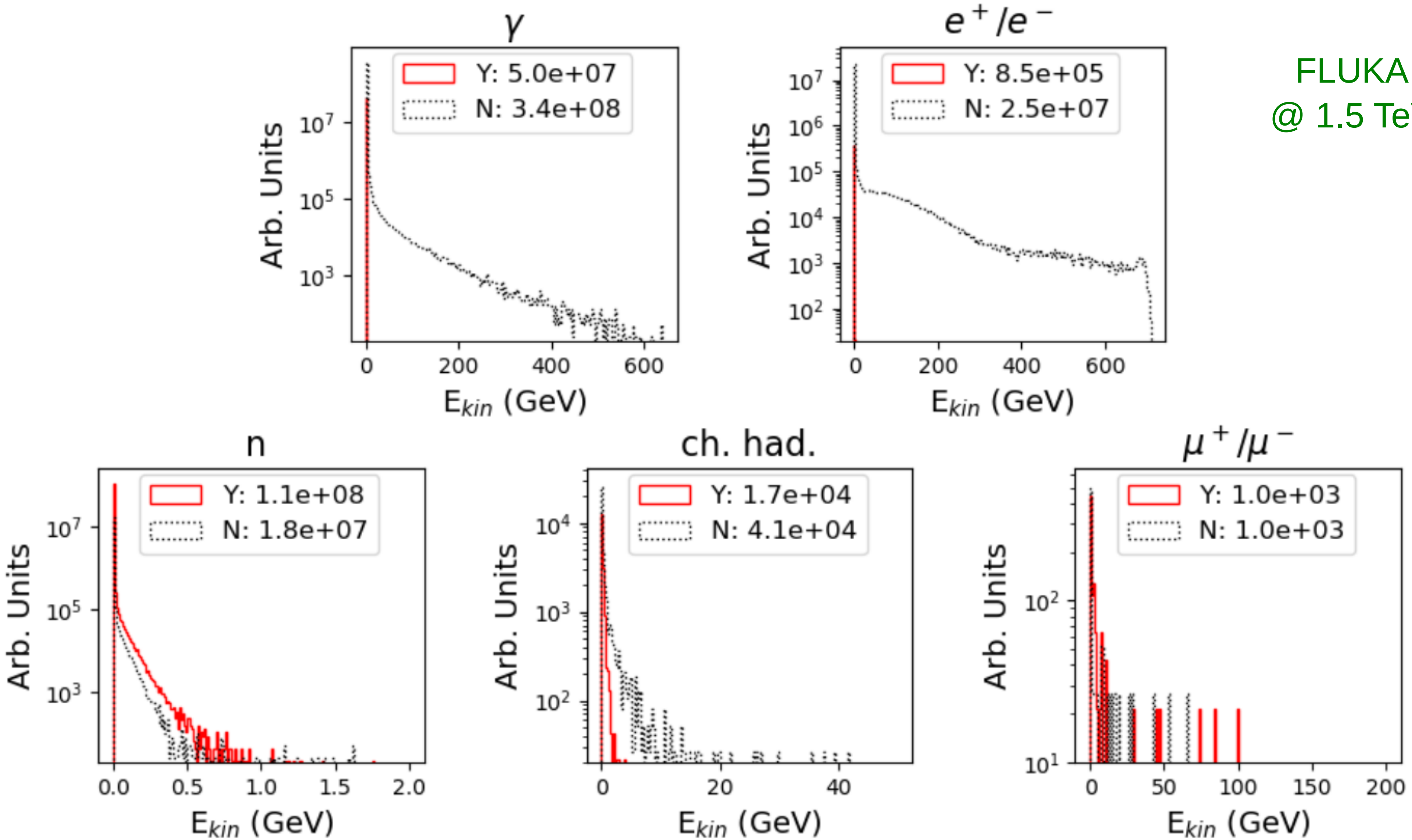


Detector envelop

- Both MARS15 and FLUKA simulate the interaction of the muon decay products with the machine elements and transport the BIB particles up to the detector envelop.



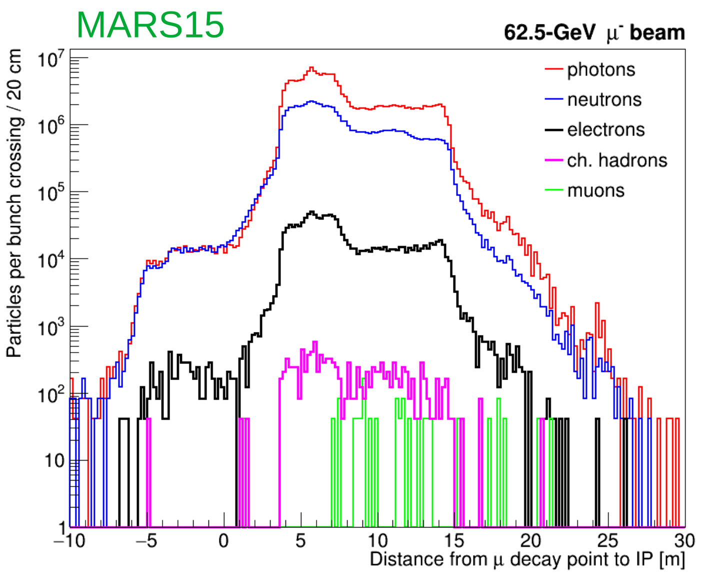
Interlude: effect of nozzles on BIB

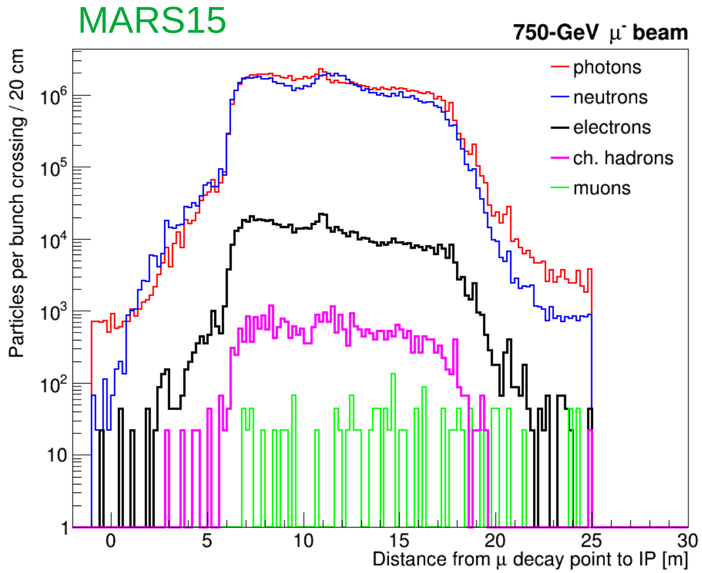


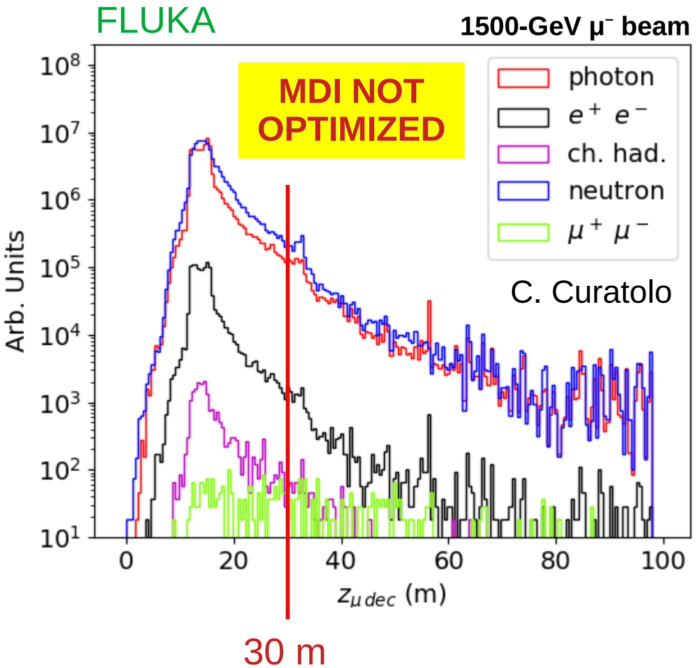
FLUKA
@ 1.5 TeV

F. Collamati *et al.*, arXiv:2105.09116

Muon decay point

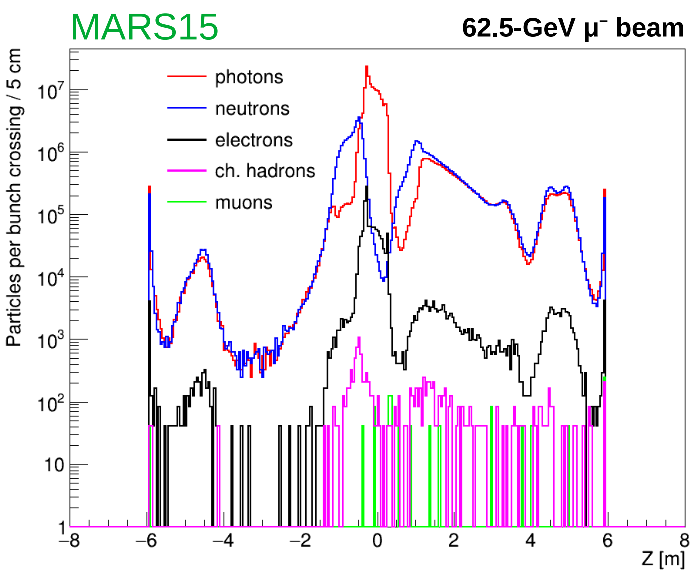


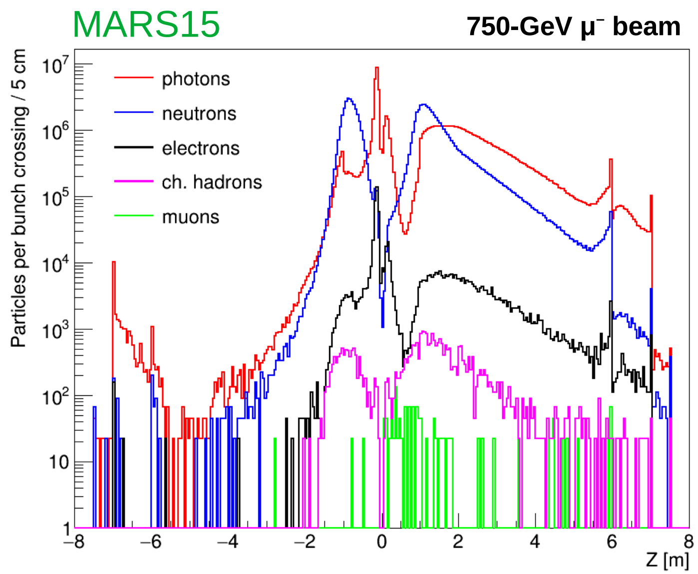


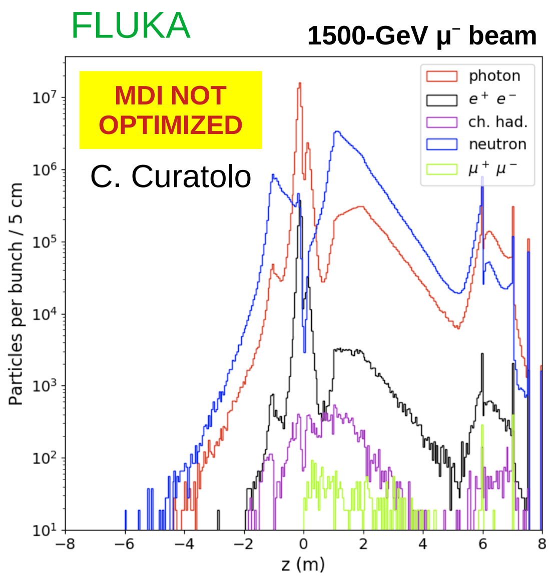


2×10^{12} μ/beam

Entry point into the detector

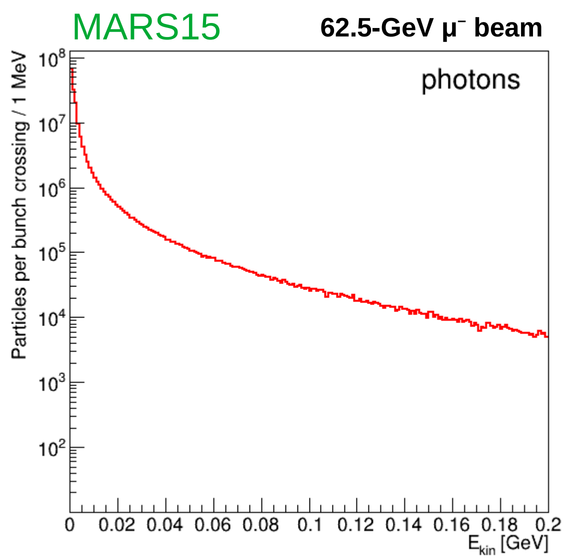


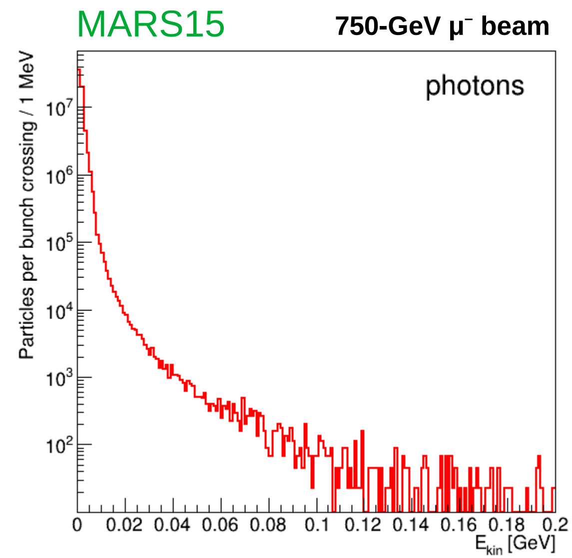


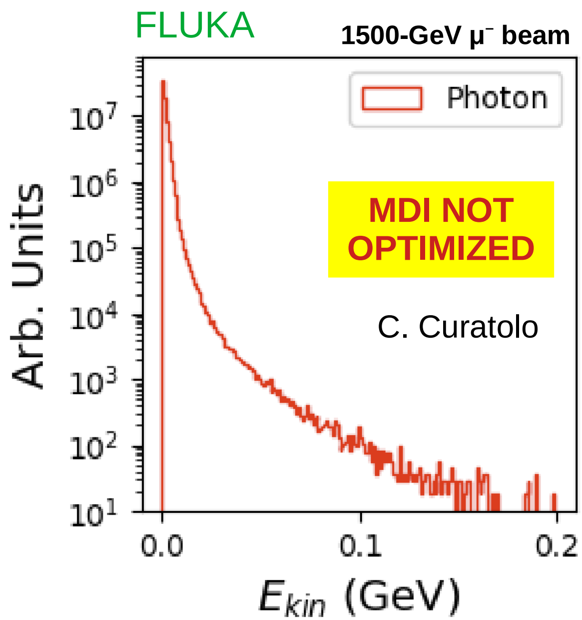


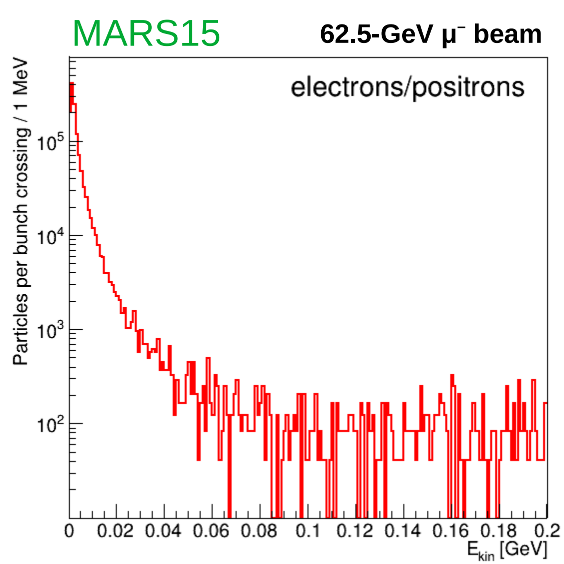
2×10^{12} μ/beam

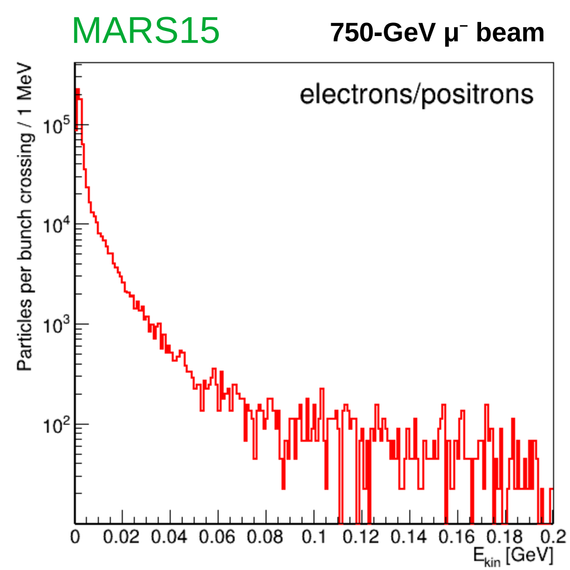
E_{kin} spectra: photons, electrons

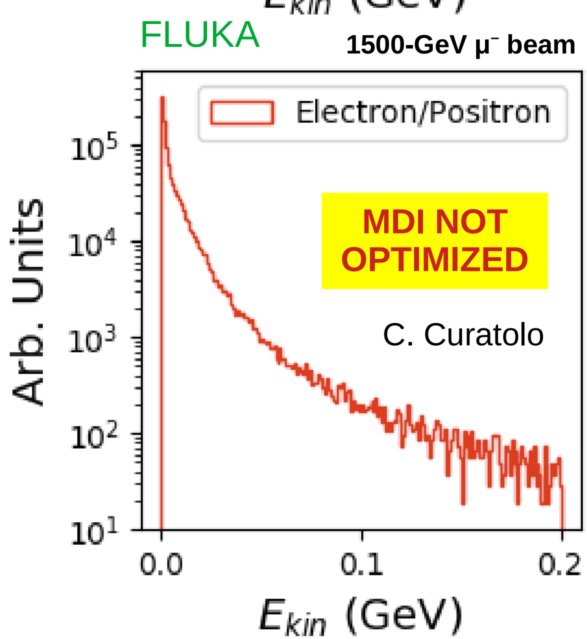






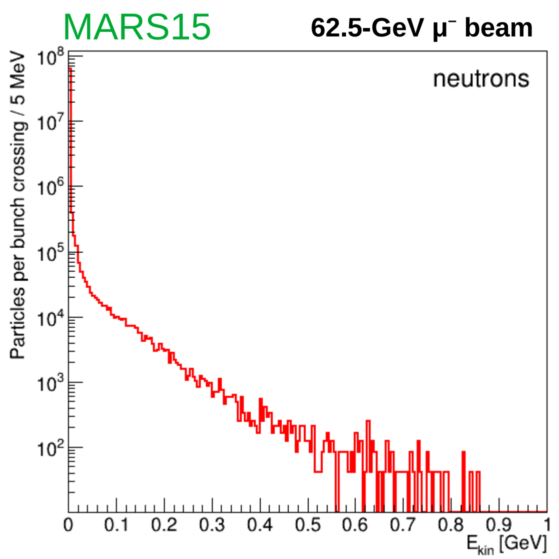


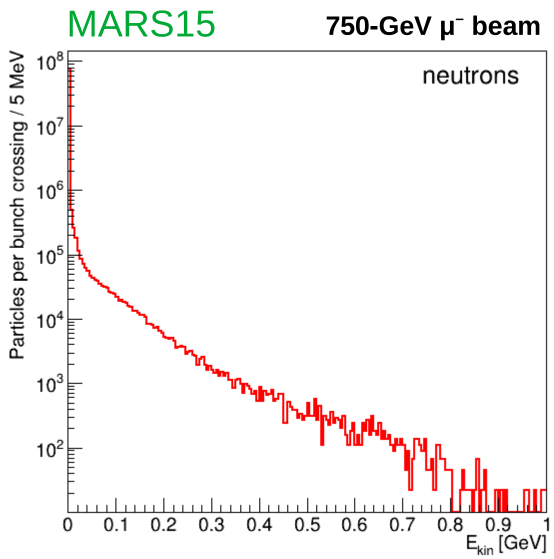


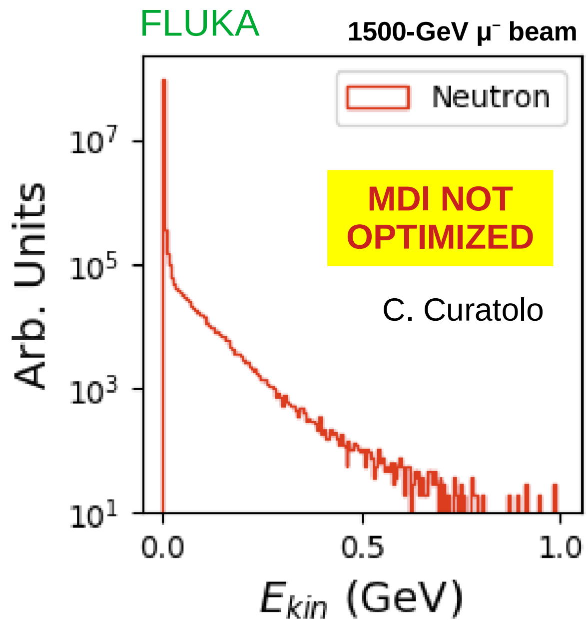


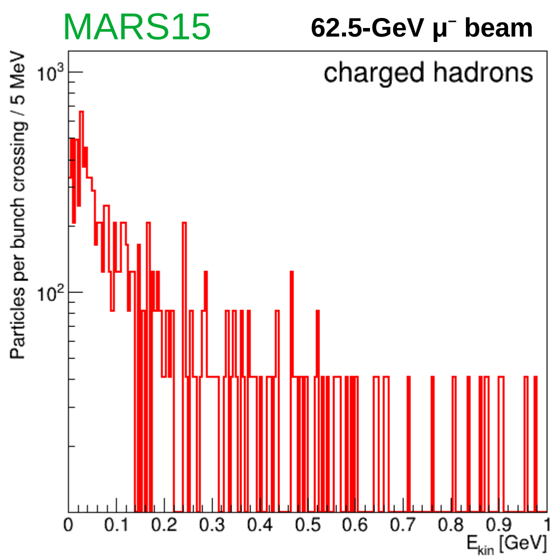
2×10^{12} μ/beam

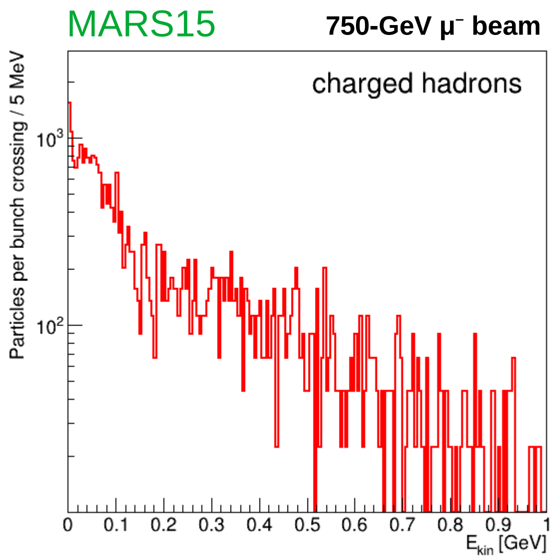
E_{kin} spectra: neutrons, ch. hadrons

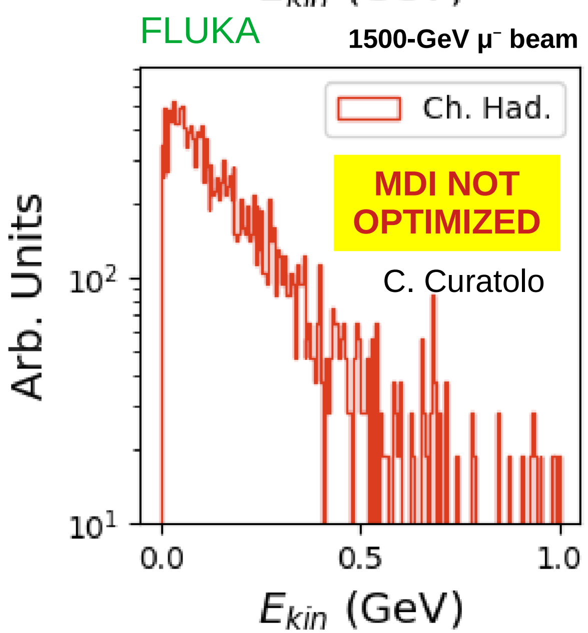






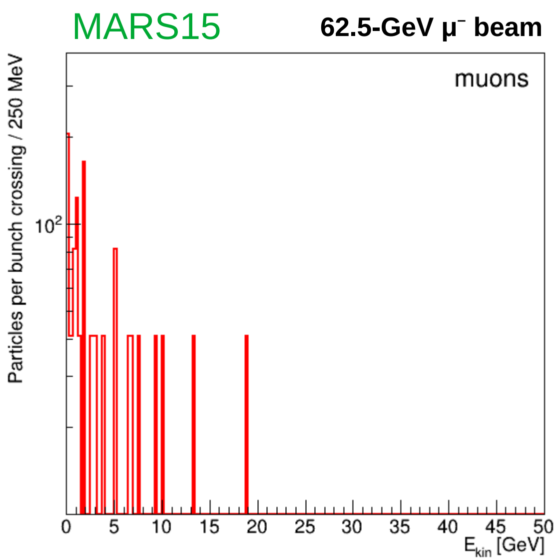


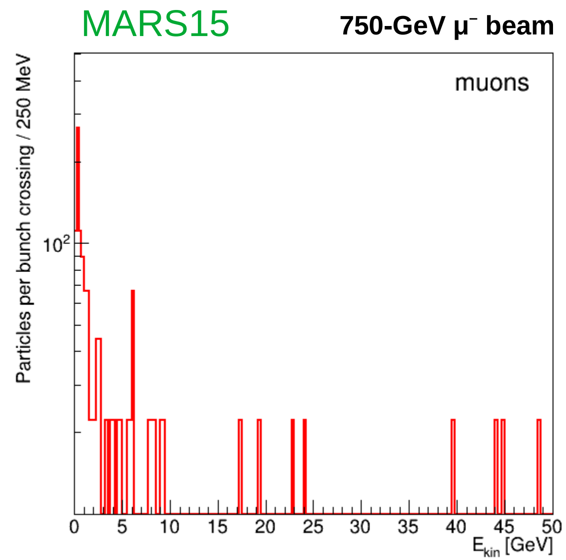


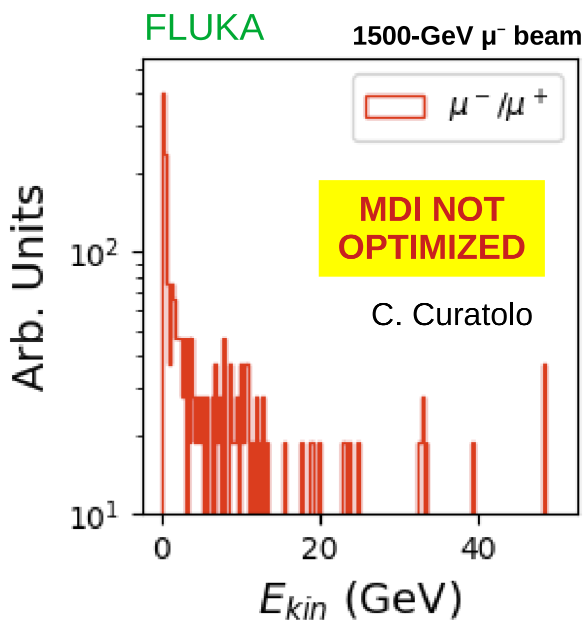


2×10^{12} μ/beam

E_{kin} spectra: secondary muons

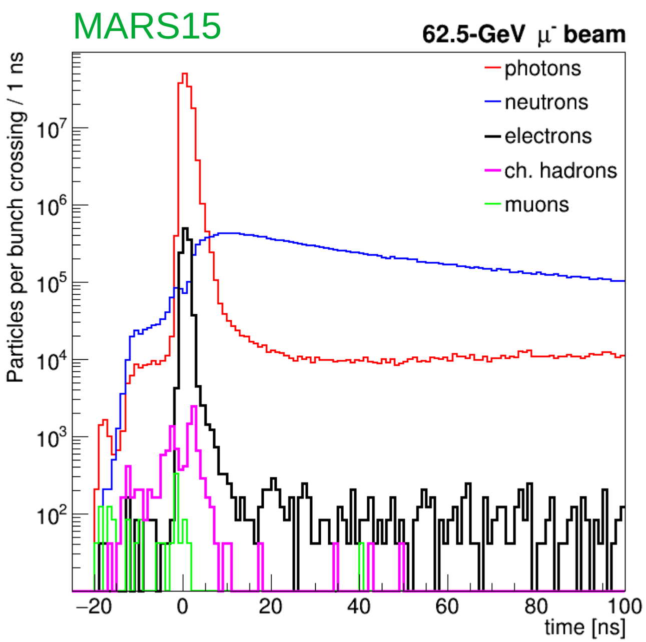


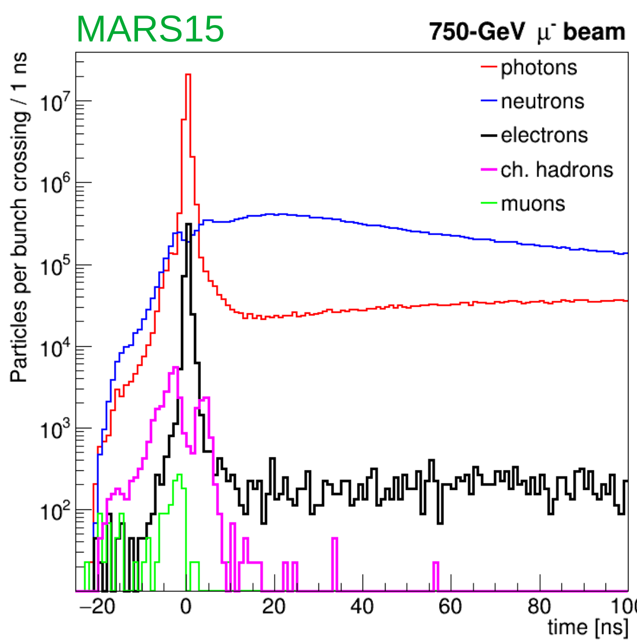


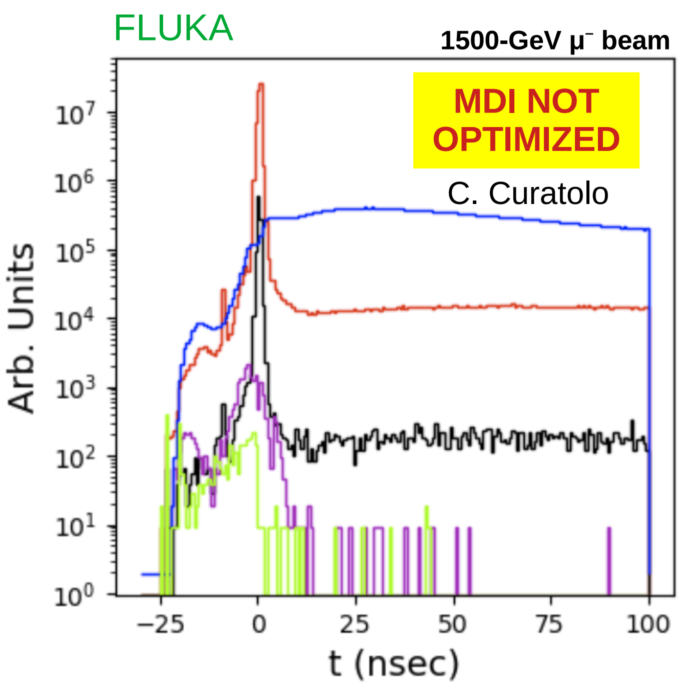


$2\text{x}10^{12}$ μ/beam

Time of arrival at the detector

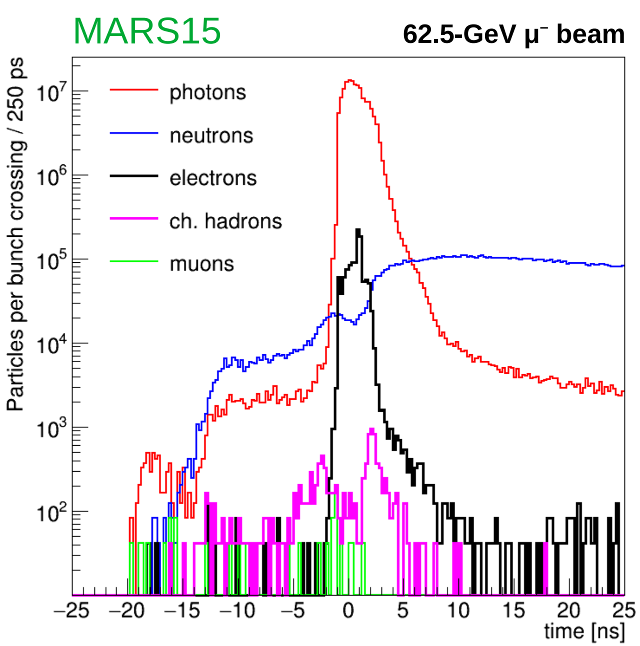


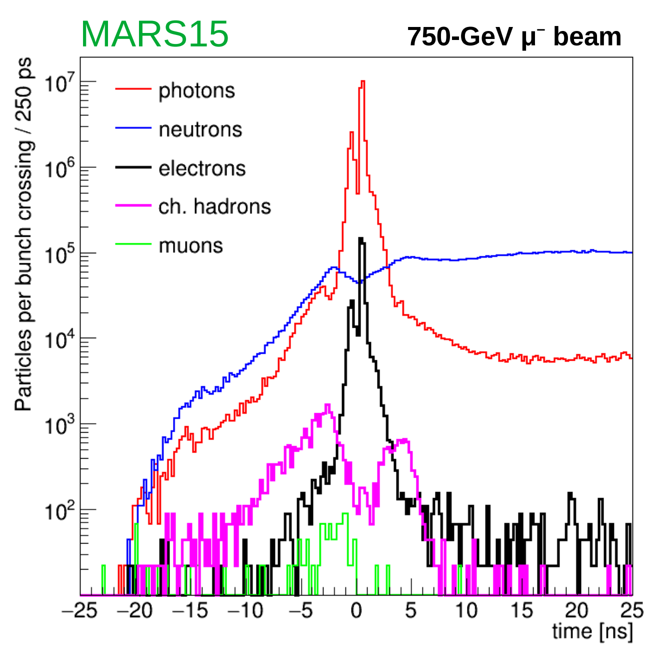


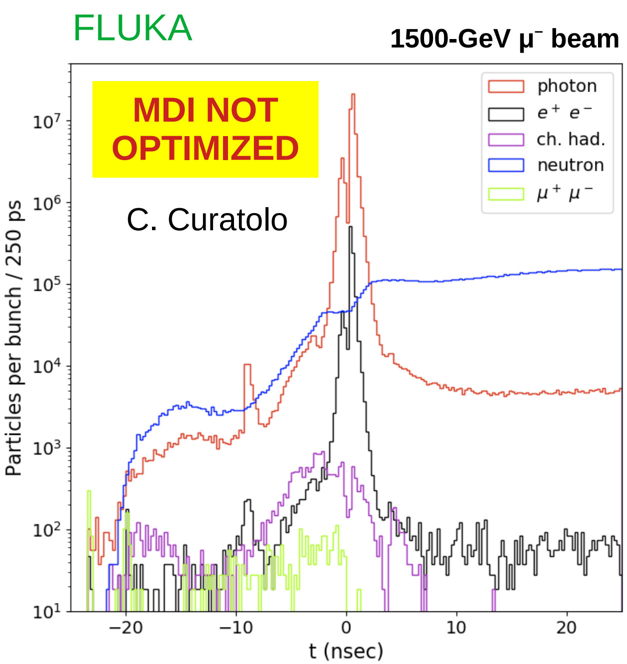


2×10^{12} μ/beam

Time of arrival at the detector (zoom)







2x10^{12} μ/beam

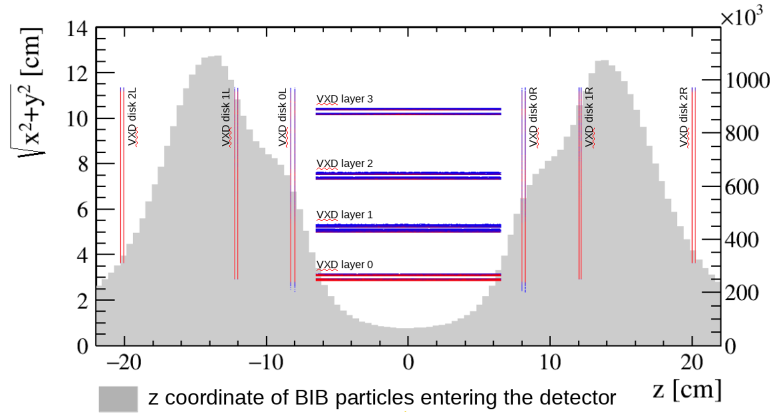
BIB yields

	MARS15	MARS15	FLUKA	FLUKA
beam energy [GeV]	62.5	750	750	1500 MDI NOT OPTIMIZED
μ decay length [m]	3.9×10^5	46.7×10^5	46.7×10^5	93.5×10^5
μ decays/m per beam (for 2×10^{12} μ/bunch)	51.3×10^5	4.3×10^5	4.3×10^5	2.1×10^5
simulation z range [m]	[-10, 30]	[-1, 25]	[0, 100]	[0, 100]
photons/BX ($E_\gamma > 0.1$ MeV)	170×10^6	86×10^6	51×10^6	70×10^6
neutrons/BX ($E_n > 1$ meV)	65×10^6	76×10^6	110×10^6	91×10^6
$e^\pm$/BX ($E_e > 0.1$ MeV)	1.3×10^6	0.75×10^6	0.86×10^6	1.1×10^6
charged hadrons/BX ($E_h > 0.1$ MeV)	0.011×10^6	0.032×10^6	0.017×10^6	0.020×10^6
muons/BX ($E_h > 0.1$ MeV)	0.0012×10^6	0.0015×10^6	0.0031×10^6	0.0033×10^6

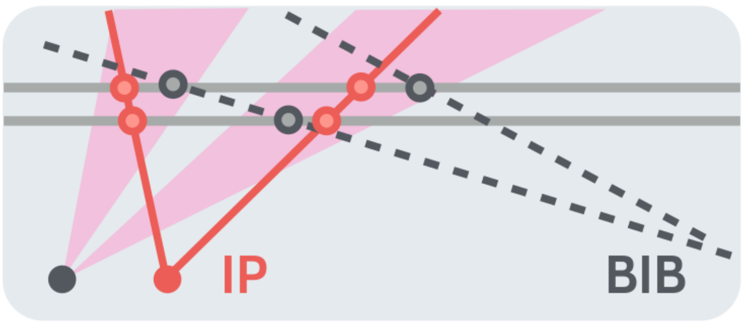
BIB mitigation in the detector

- BIB mitigation strategies have to be adopted also on the detector side. For example in the tracker, with a wise and clever detector design:

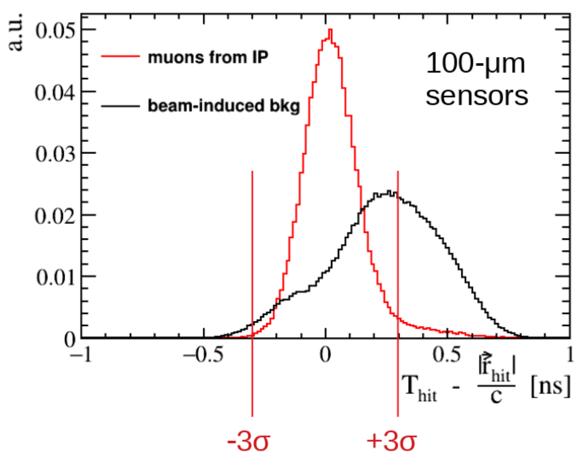
avoiding BIB hot spots



exploiting a double layer structure



exploiting the time information

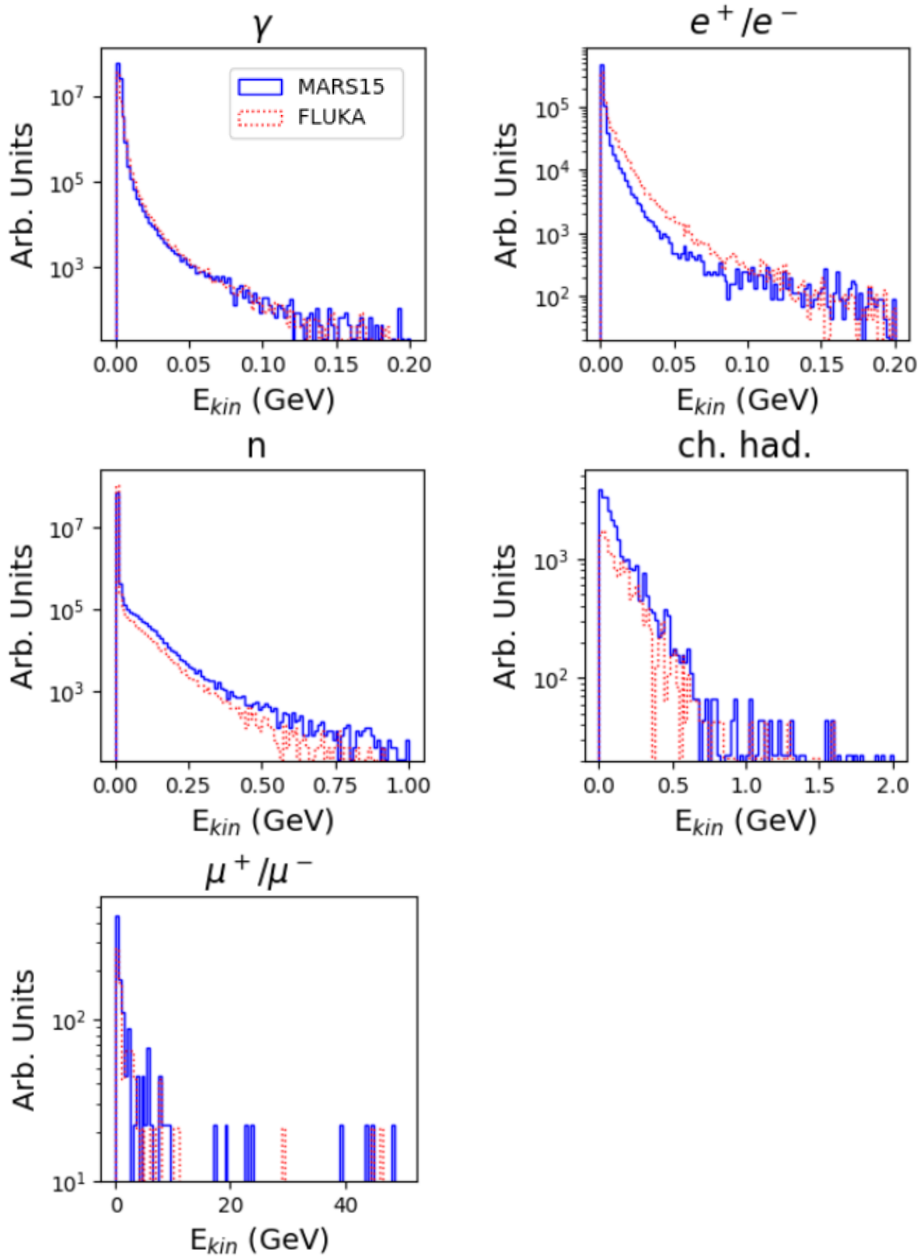


Conclusion

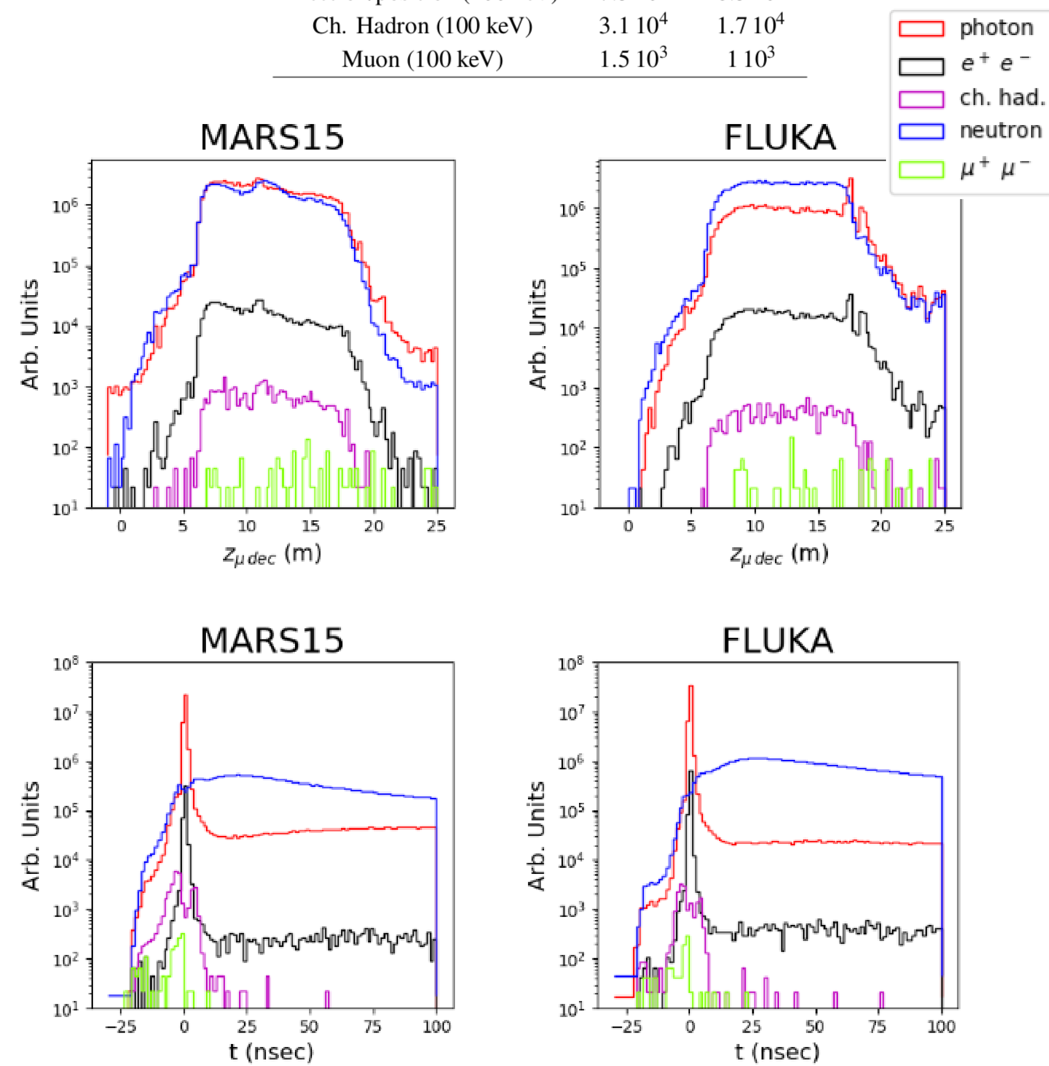
- It's not trivial to predict a priory the amount and behavior of the BIB at different energies. It has to be studied with a detailed simulation of the machine and the machine-detector interface.
- MAP's studies prove that with a dedicated design and optimization of the MDI the BIB may be kept at the ~same level at 125 GeV and 1.5 TeV.
- The case of the 3-TeV machine has yet to be thoroughly studied.

Backup

FLUKA vs MARS15 @ 1.5 TeV



Particle (E_{th})	MARS15	FLUKA
Photon (100 keV)	8.6 10^7	5 10^7
Neutron (1 meV)	7.6 10^7	1.1 10^8
Electron/positron (100 keV)	7.5 10^5	8.5 10^5
Ch. Hadron (100 keV)	3.1 10^4	1.7 10^4
Muon (100 keV)	1.5 10^3	1 10^3



F. Collamati *et al.*, arXiv:2105.09116