Machine background studies

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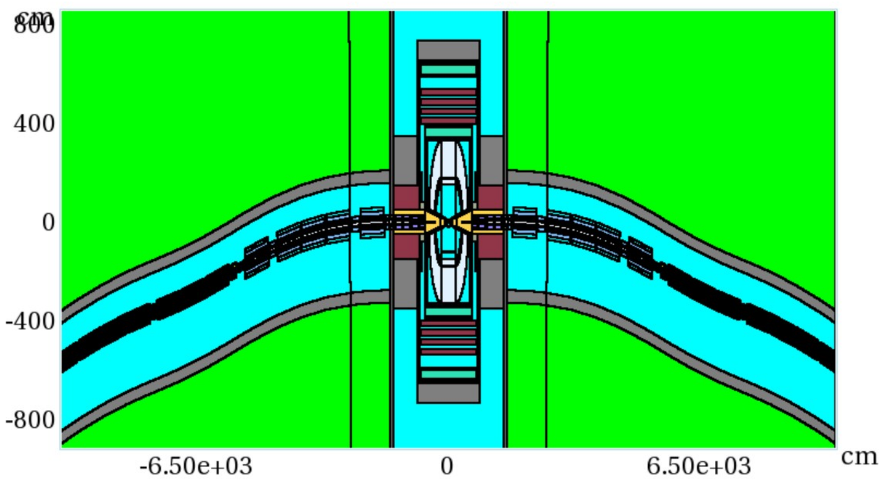
Introduction

- This talk gives an overview of the MARS15 model used by the MAP collaboration to simulate the beam-induced backgrounds for a 125-GeV and a 1.5-TeV muon collider. More details may be found in MAP's publications, like for example:
  - N.V. Mokhov and S.I. Stiganov, "*Detector backgroud at muon colliders*", arXiv:1204.6721v1 (2012);
  - N.V. Mokhov, S.I. Stiganov, and I.S. Tropin, "*Reducing backgrouds in the Higgs factory muon collider*", arXiv:1409.1939v1 (2014).

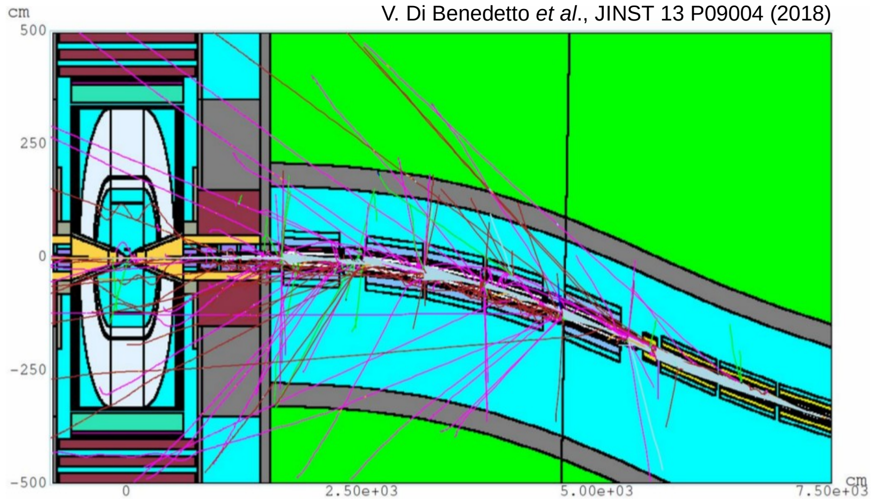
- Talk outline:
  - the MARS15 model of the MAP's muon collider;
  - composition of the beam-induced background;
  - spatial distribution, momentum spectra and timing of the background particles;
  - future plans.

MARS15 simulation

N.V. Mokhov and S.I. Striganov, arXiv:1204.6721v1 (2012)



V. Di Benedetto *et al.*, JINST 13 P09004 (2018)

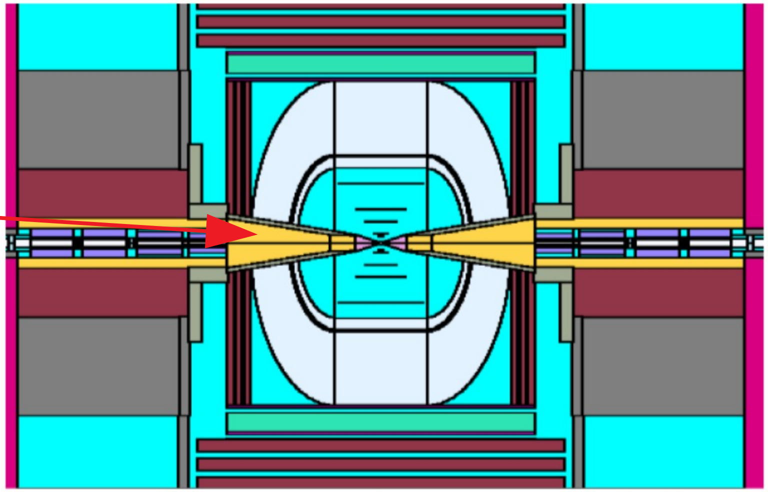


- MARS15 (https://map.fnal.gov) provides a realistic simulation of beam-induced backgrounds in the detector:
  - implements a model of the tunnel ±200 m from the interaction point (with realistic geometry, materials distribution, machine lattice elements and magnetic fields), the experimental hall and the machine-detector interface (MDI);
  - $e^{\pm}$ from $\mu^{\pm}$ decays and synchrotron photons radiated by $e^{\pm}$ interact with the machine components producing hadrons, secondary muons, $e^{\pm}$ and γ;
  - secondary particles are transported to the detector.

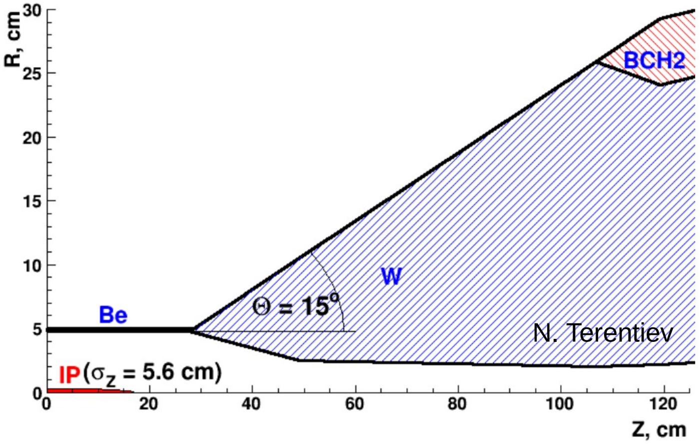
Machine-detector interface

- For each collider energy the machine elements, the MDI and IP have to be properly designed and optimized.
- In particular, the two tungsten nozzles, cladded with a 5-cm layer of borated polyethylene, play a crucial role in background mitigation inside the detector.

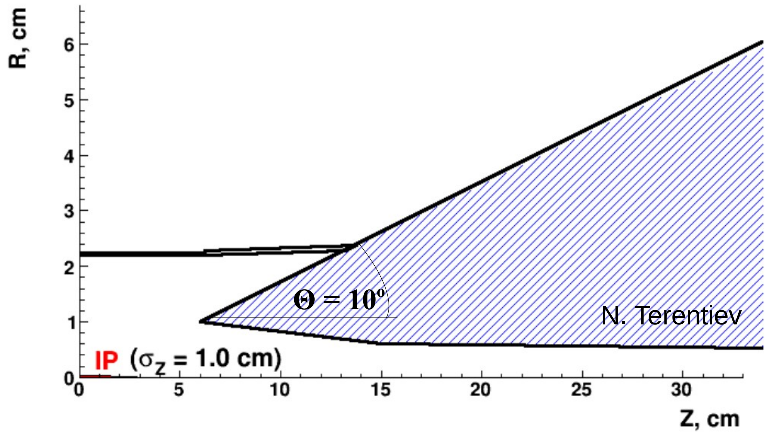
N.V. Mokhov and S.I. Stiganov, arXiv:1204.6721v1 (2012)



IP for a 125-GeV μ collider



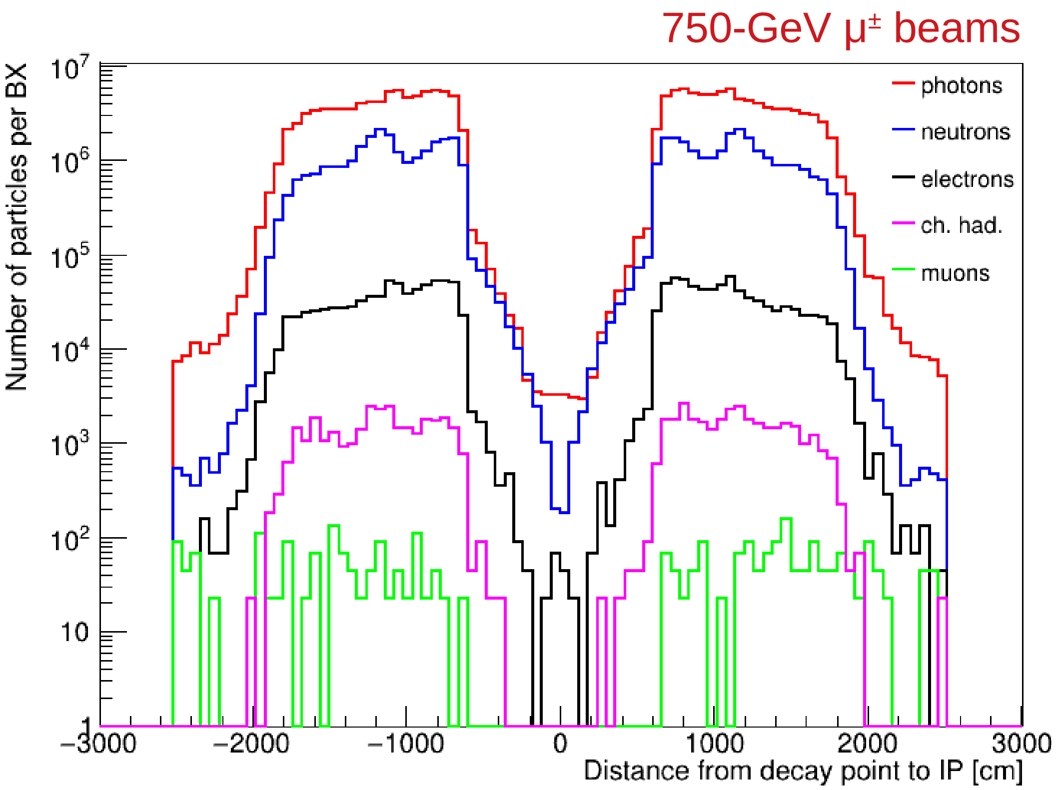
IP for a 1.5-TeV μ collider



Available backgrounds

- Two MARS15 background samples available:
  - 62.5-GeV $\mu^{\pm}$ beams:
    - μ^{+} (μ^{-}) decays simulated in the range $-30 < z < 10$ m ($-10 < z < 30$ m) from IP;
    - production thresholds: 100 keV for photons, electrons, muons, charge hadrons and 0.001 eV for neutrons.
  - 750-GeV $\mu^{\pm}$ beams:
    - μ^{+} (μ^{-}) decays simulated in the range $-25 < z < 1$ m ($-1 < z < 25$ m) from IP ;
    - production thresholds: 100 keV for photons, electrons, muons, charge hadrons and 0.001 eV for neutrons.

Background composition



- Contributions form μ decays outside the simulated range become quickly negligible for all background species but Bethe-Heitler muons, whose range of interest is ±100 m from IP.
- In our background sample, generate for |z| < 25 m, we are missing ~20% of Bethe-Heitler muons.

Backgrounds at 125 GeV vs 1.5 TeV

- The background levels in the detector are strongly dependent on the beam energy and the configuration of the machine-detector interface.

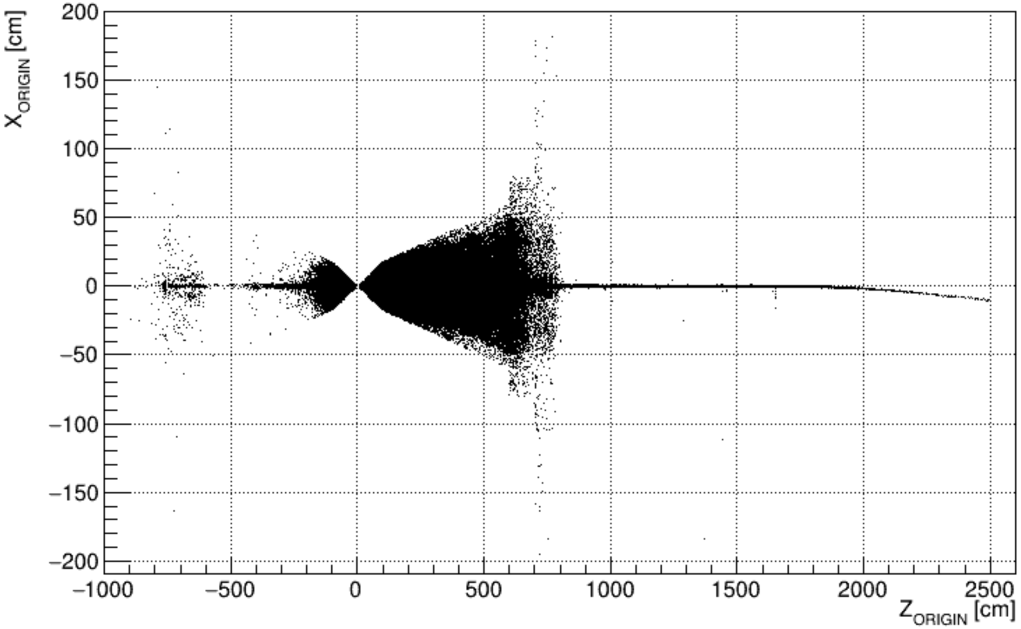
beam energy [GeV]	62.5	750
μ decay length [m]	3.9×10^5	46.7×10^5
μ decays/m per beam (for 2×10^{12} μ/bunch)	51.3×10^5	4.3×10^5
photons/BX (*) ($E_\gamma > 0.2$ MeV)	280×10^6	177×10^6
neutrons/BX (*) ($E_n > 0.1$ MeV)	52×10^6	41×10^6
$e^\pm$/BX (*) ($E_e > 0.2$ MeV)	2×10^6	1×10^6
charged hadrons/BX (*) ($E_h > 1$ MeV)	0.01×10^6	0.048×10^6
muons/BX ($E_h > 1$ MeV)	not available	0.008×10^6

bkg particles entering the detector per bunch-crossing (rows photons/BX through muons/BX)

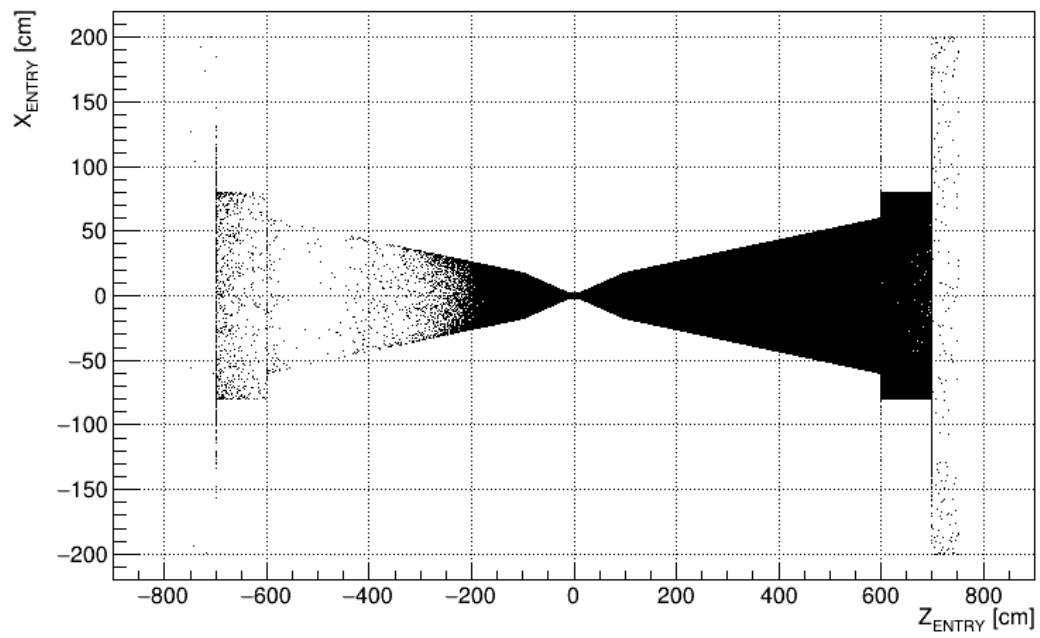
(*) N.V. Mokhov *et al.*, arXiv:1409.1939v1 (2014)

Origin and entry points of bkg particles

production point of the bkg particles
that are reaching the detector

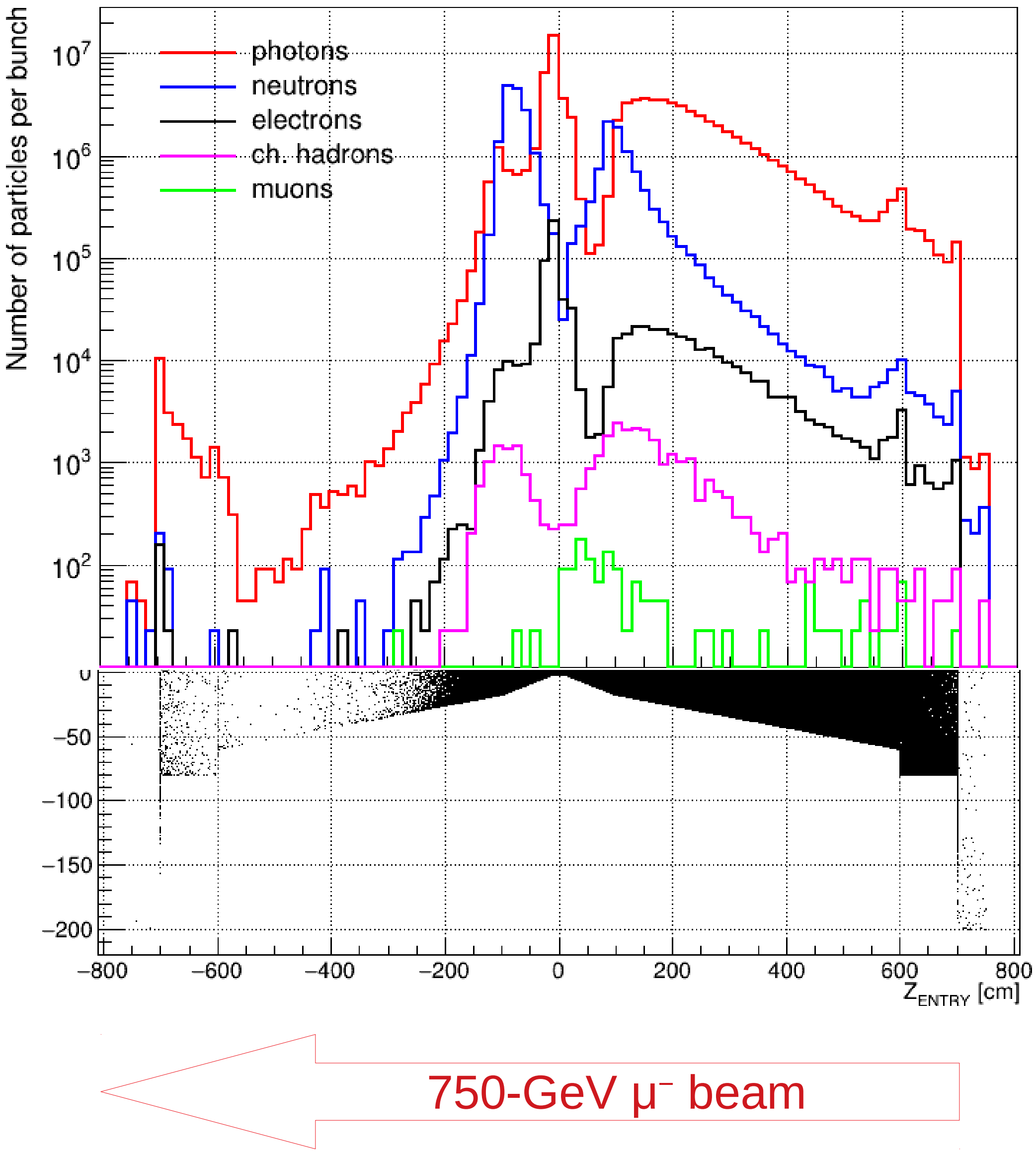


entry point of the bkg particles

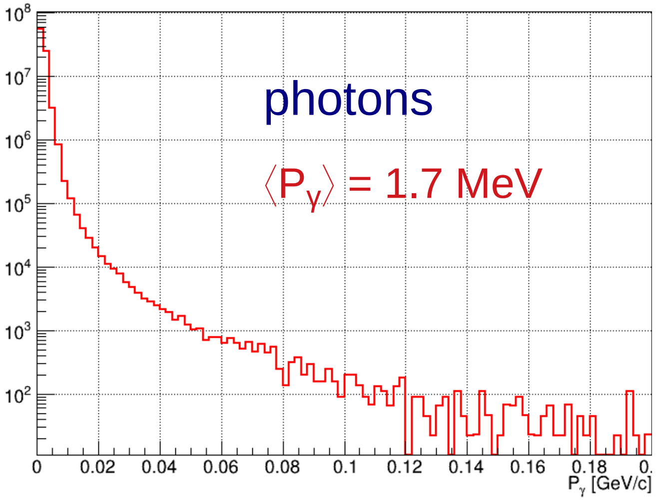


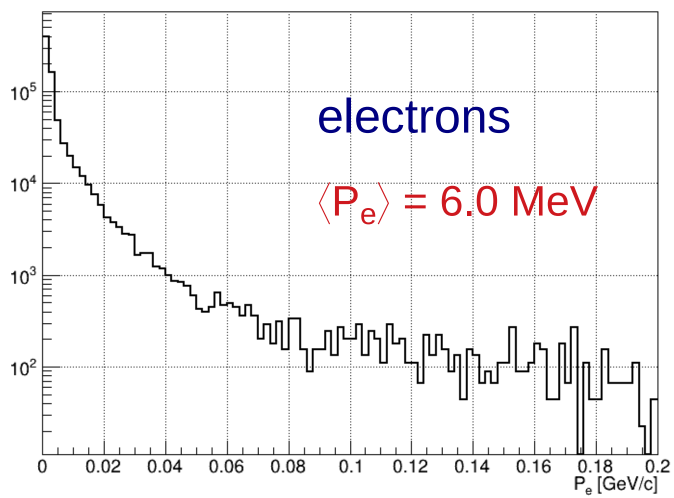
750-GeV μ^- beam

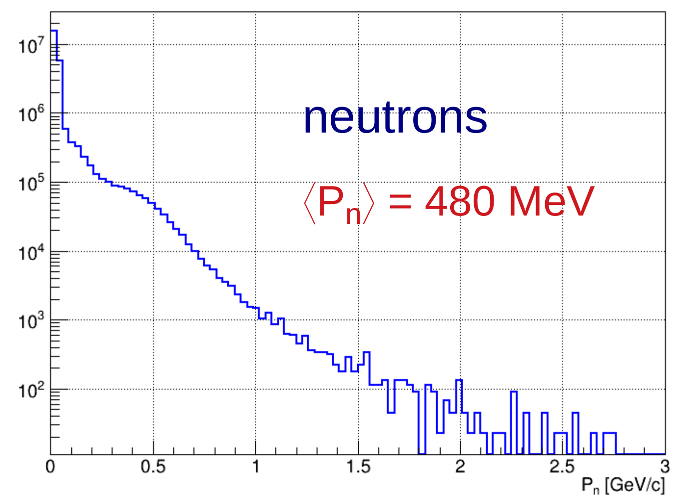
z distribution of bkg particles

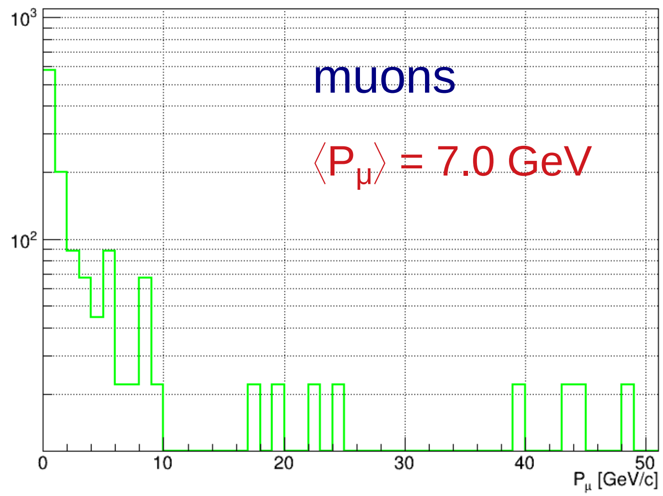


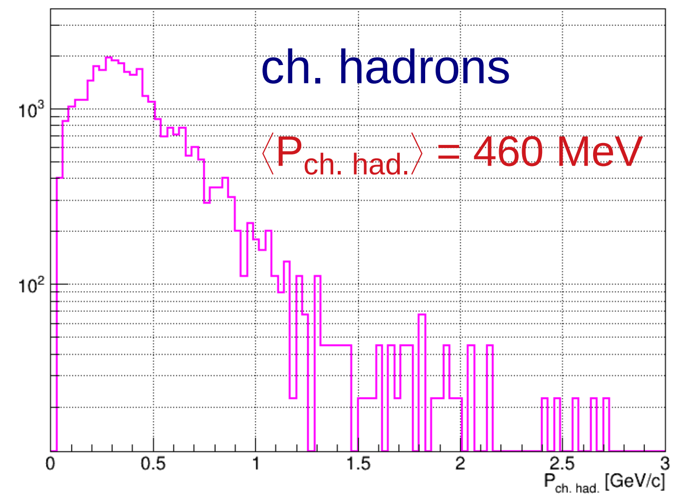
Momentum spectra of bkg particles





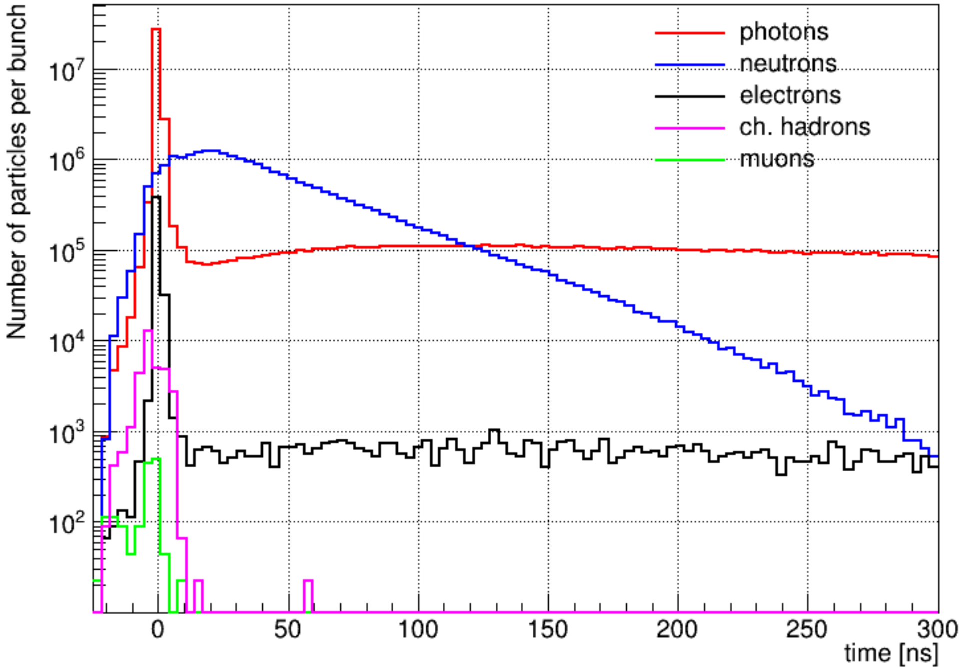


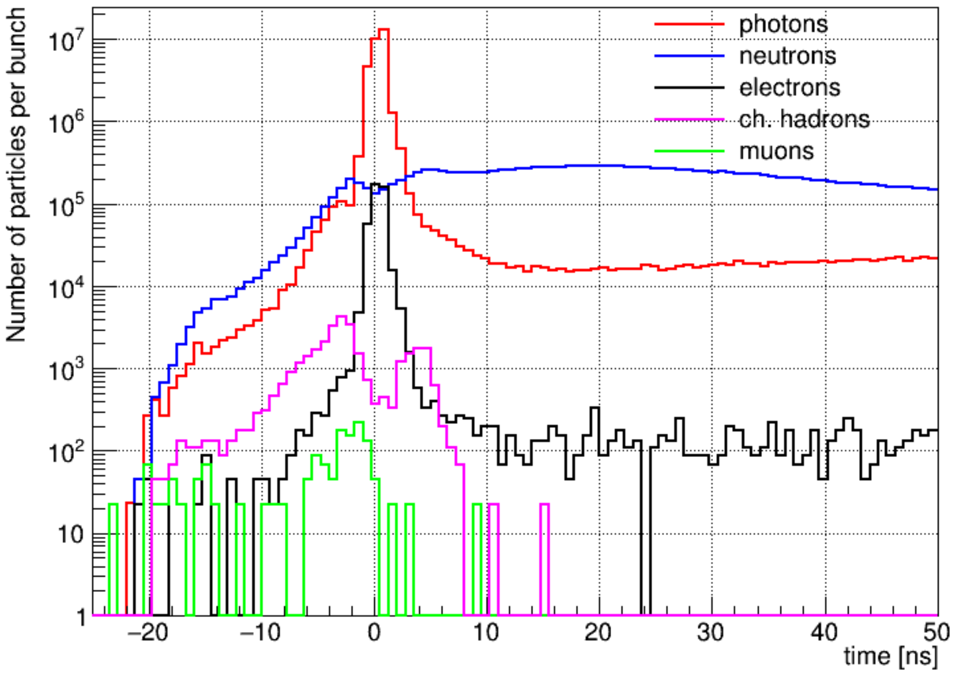




Timing of bkg particles w.r.t. the IP

750-GeV μ⁻ beam





Plans

- Long term plan:
  - simulate and study the LEMMA case, when a detailed machine design is available;
  - rethink the detector in the light of MAP's findings and relying on the latest detector technologies developed for HL-LHC.
- On a shorter time scale:
  - reimplement the MARS15 muon collider model with FLUKA in order to generate the missing muon background, compare with MARS15 results and get ready for the LEMMA phase;
  - refine our detector simulation and analysis tools and produce first results with the MAP's model.