BEAM INDUCED BACKGROUND

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Introduction

Muon Collider detector performance depends on the rate of background particles arriving to each subdetector

- Muon decays is the major source of background, just a back of the envelope calculation
  - beam 0.75 TeV $\lambda = 4.8{\times}10^6$m, with $2{\times}10^{12}\mu$/bunch $\Rightarrow 4.1{\times}10^5$decay per meter of lattice therefore the number and the distribution of particles at the detector depends on the lattice

Detailed studies performed by MAP Collaboration for √s=1.5 TeV collider

- [1] N.V. Mokhov, S.I. Striganov *Detector Backgrounds at Muon Colliders*, TIPP 2011, Physics Procedia 37 (2012) 2015 – 2022
- [2] N.K. Terentiev, V. Di Benedetto, C. Gatto, A. Mazzacane, N.V Mokhov, S.I. Striganov *ILCRoot tracker and vertex detector hits response to MARS15 simulated backgrounds in the muon collider*, TIPP 2011, Physics Procedia 37 (2012) 104-110

Setting the scene

- Electrons from muon decay inside the ring magnets radiate energetic synchrotron photons tangent to the electron trajectory.
- Electromagnetic showers induced by electrons and photons interacting with the machine components generate hadrons, secondary muons and electrons and photons.

Muon Collider physics reaches can be obtained only tacking into account the background

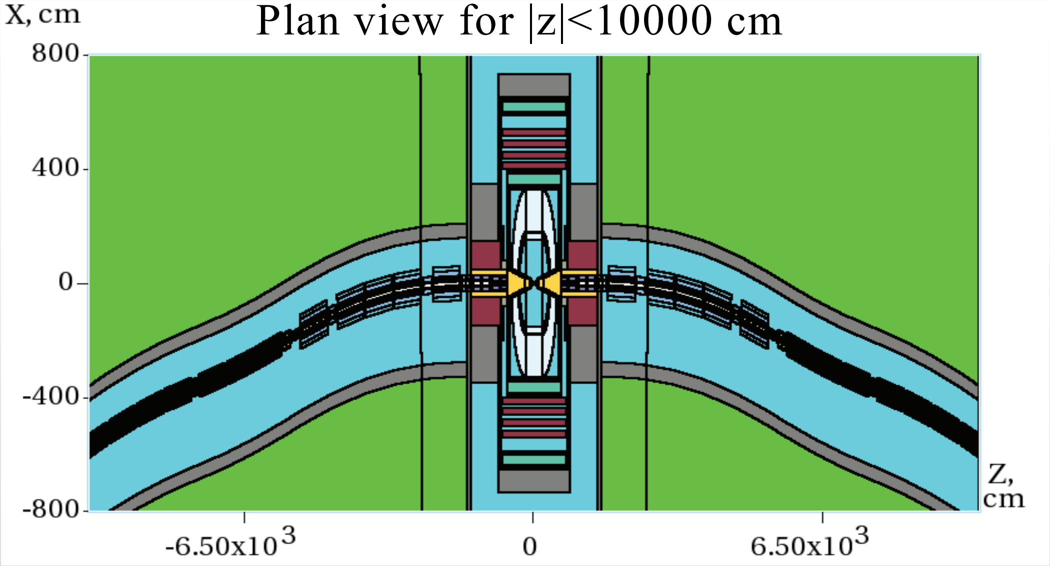
MAP Collaboration mitigated the background contributions with

- High-field SC dipoles, interlaced with quadrupoles and tungsten shields implemented in the final focus region
- Nozzles made of Tungsten with proper angles depending on beam energy very close to the Interaction Region
- Performant detectors exploiting timing gates

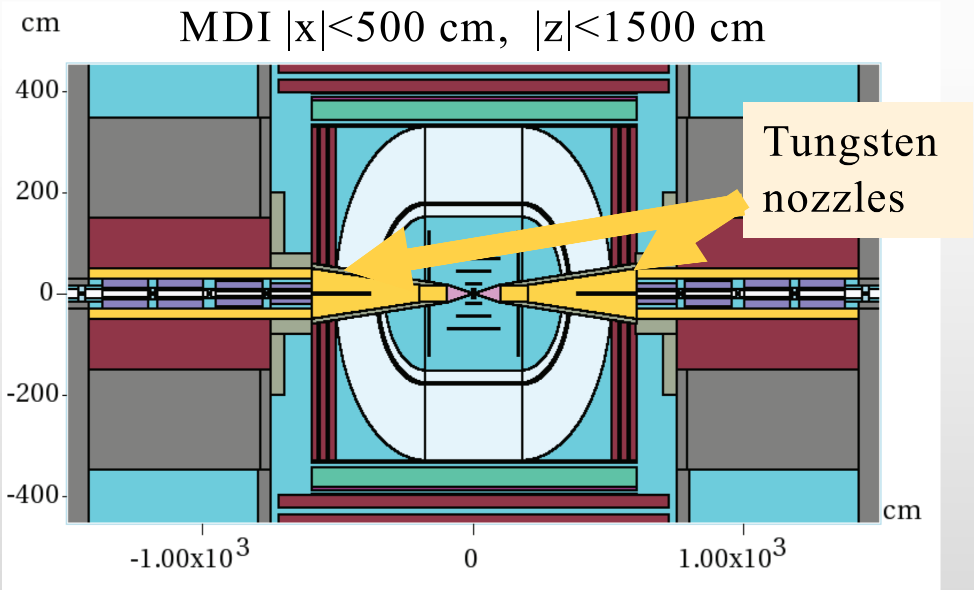
Background Simulation

Machine Background is produced with MARS15

- simulation of particle transport and interactions in accelerator, detector and shielding components.
- It takes into account all the related details of geometry, material distributions and magnetic fields for collider lattice elements in a given region from IP
- Muon beams of 0.75 TeV, $2\times10^{12}\mu$/bunch
- Muon decays background considered in the straight region of ±25 m from the Impact Point (IP).

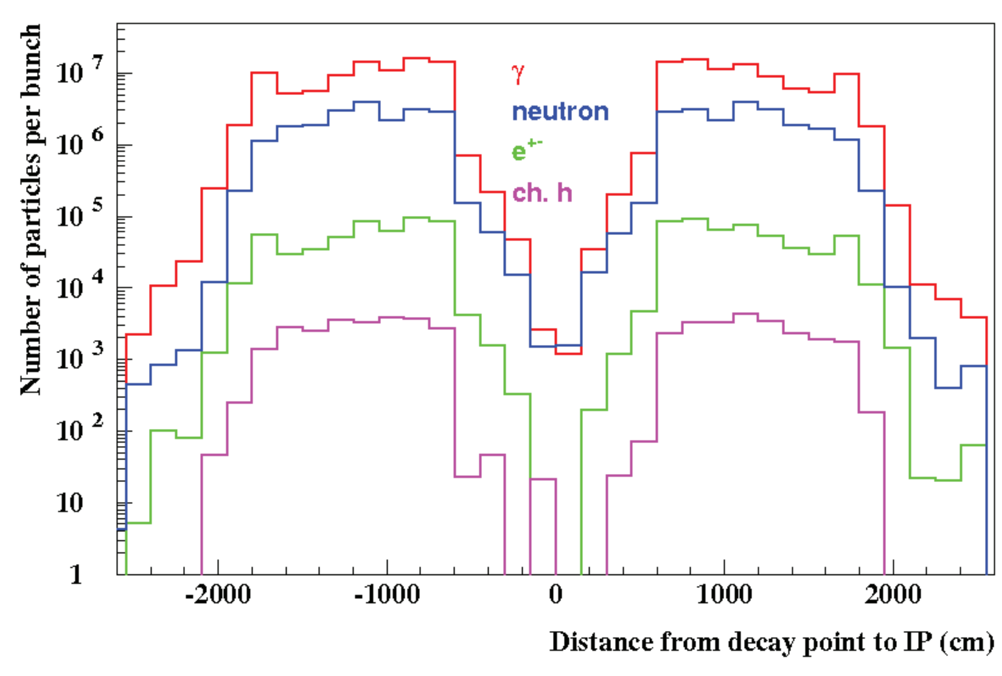


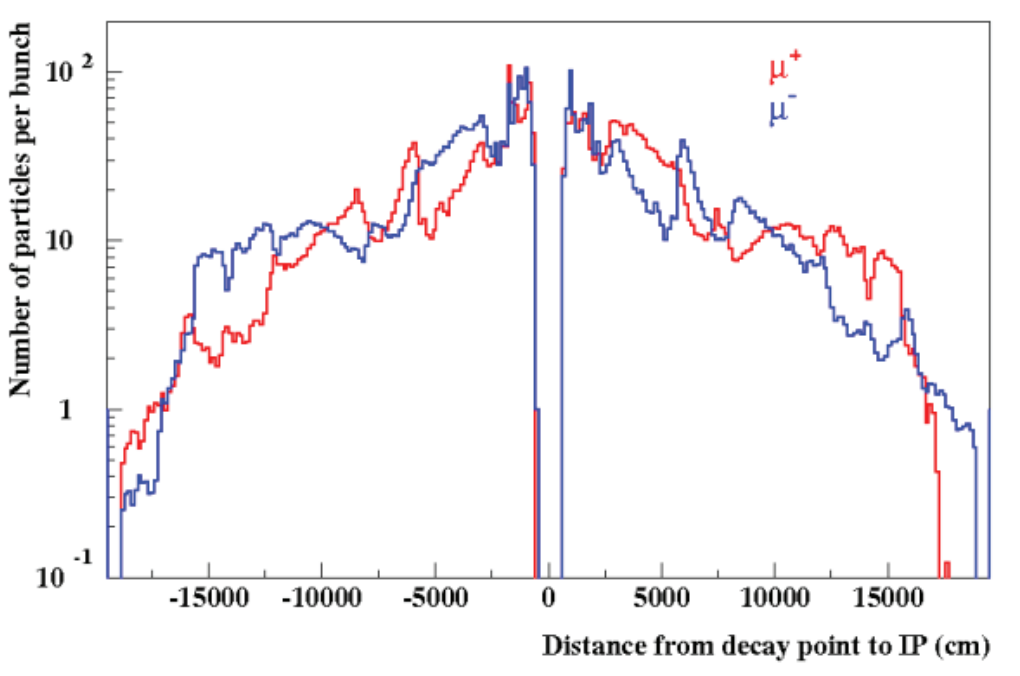
Ref. [1]



Background Characteristics

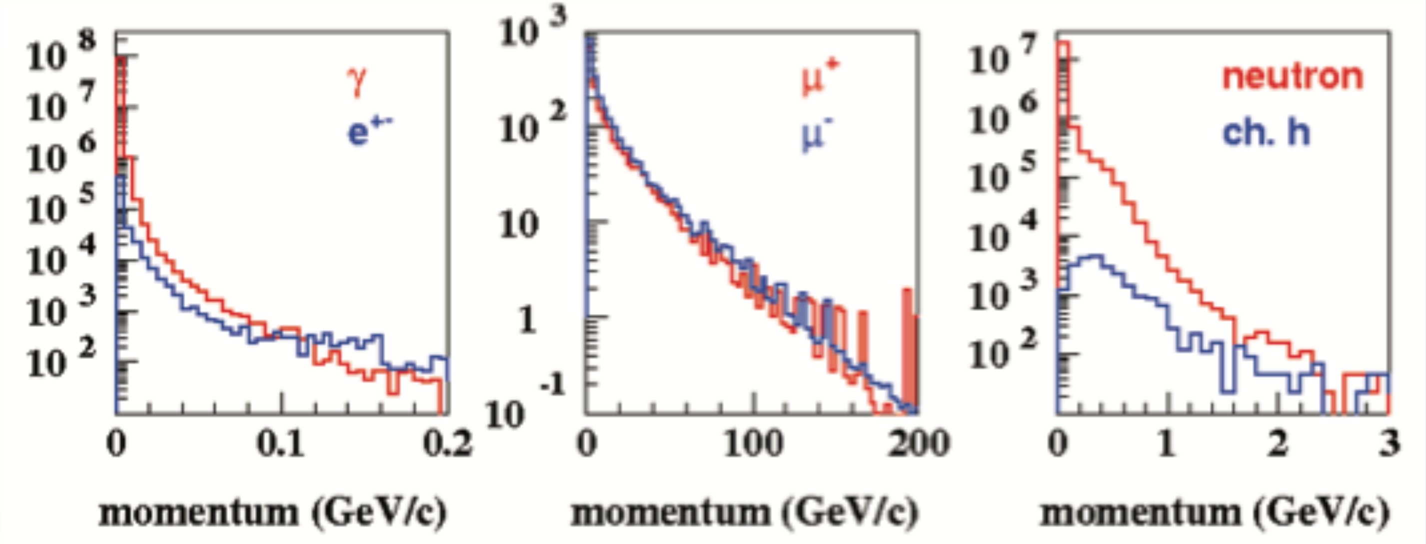
- Muon beams of energy of 0.75 TeV and intensity $2\times10^{12}\mu$/bunch
- Muon decays background considered in the region of ±25 m from the Impact Point, optimized nozzles and Machine Detector Interface almost eliminate the background for |z|>25 m.
- Bethe-Heitler muons are created in the lattice as far as 200 m from IP





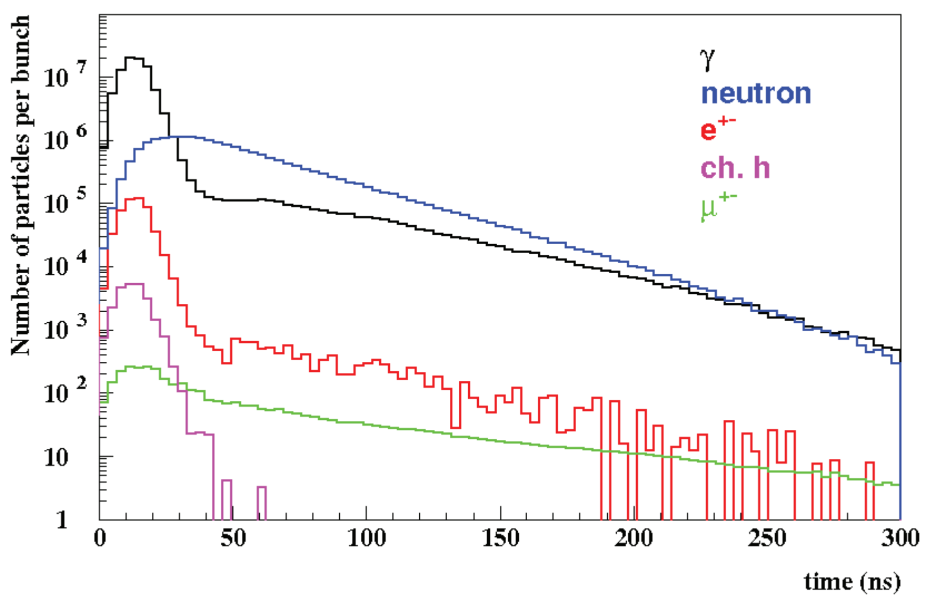
Ref. [1]

Background Characteristics cont'd



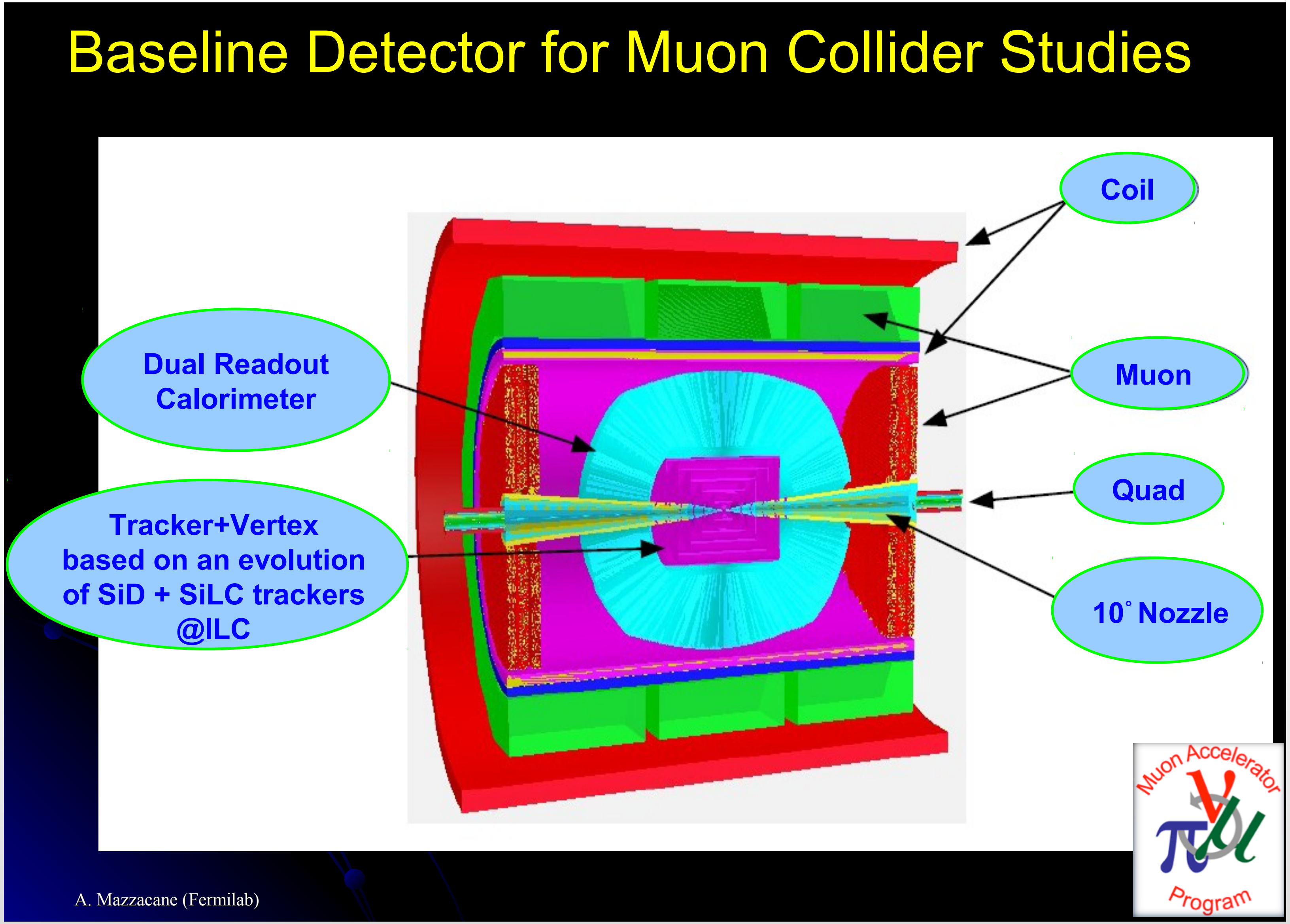
Minimal cut-off energies go from 0.001 eV neutrons up to 1 MeV muons and charged hadrons

Ref. [1]



Time of flight of background particles at the detector entrance with respect to bunch crossing

New generation detectors with excellent time resolution can solve several issues



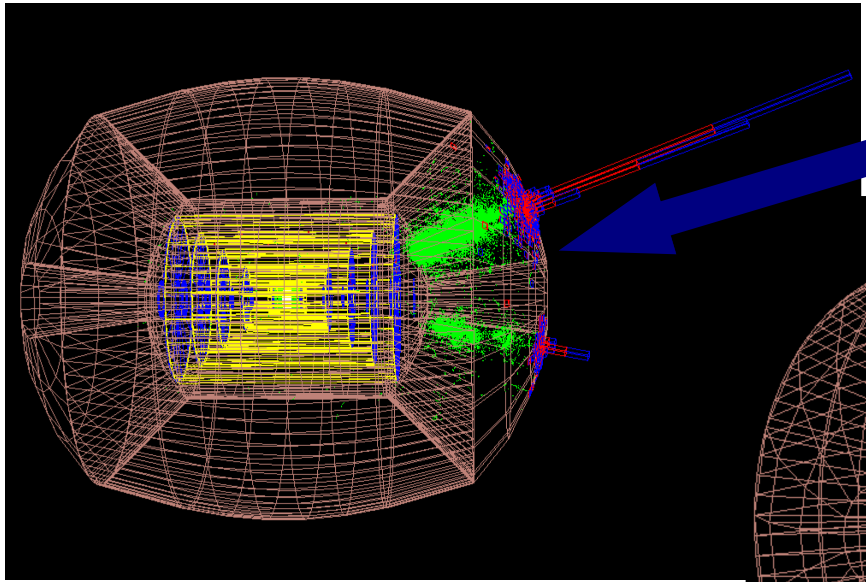
MAP Collaboration has full detector simulation

The ILCRoot framework:

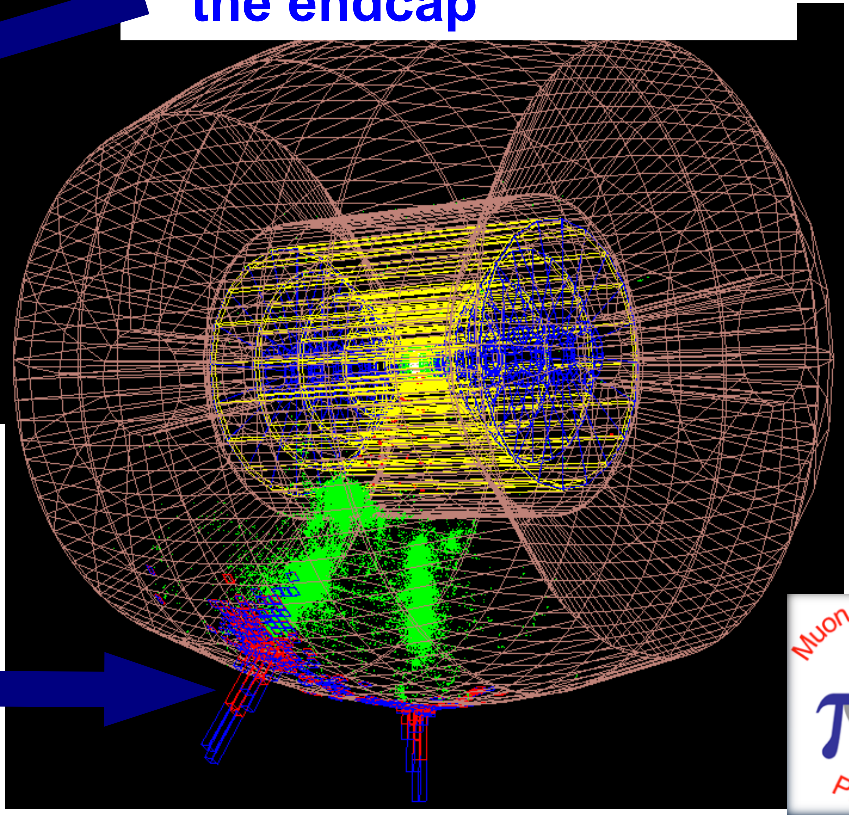
- can be interfaced to MARS15, FLUKA output data and other formats.
- allows merging background particles hits in the detector with the hits from physics event.

A. Mazzacane
Muon Collider Detector Studies - LBNE Collaboration Meeting

Study of $\mu^+\mu^- \to \nu_\mu\nu_\mu + Z^0 \to \nu_\mu\nu_\mu + jet + jet$



Jets with energy of 435GeV and 68GeV in the endcap



Jets with energy of 234GeV and 117GeV in the barrel

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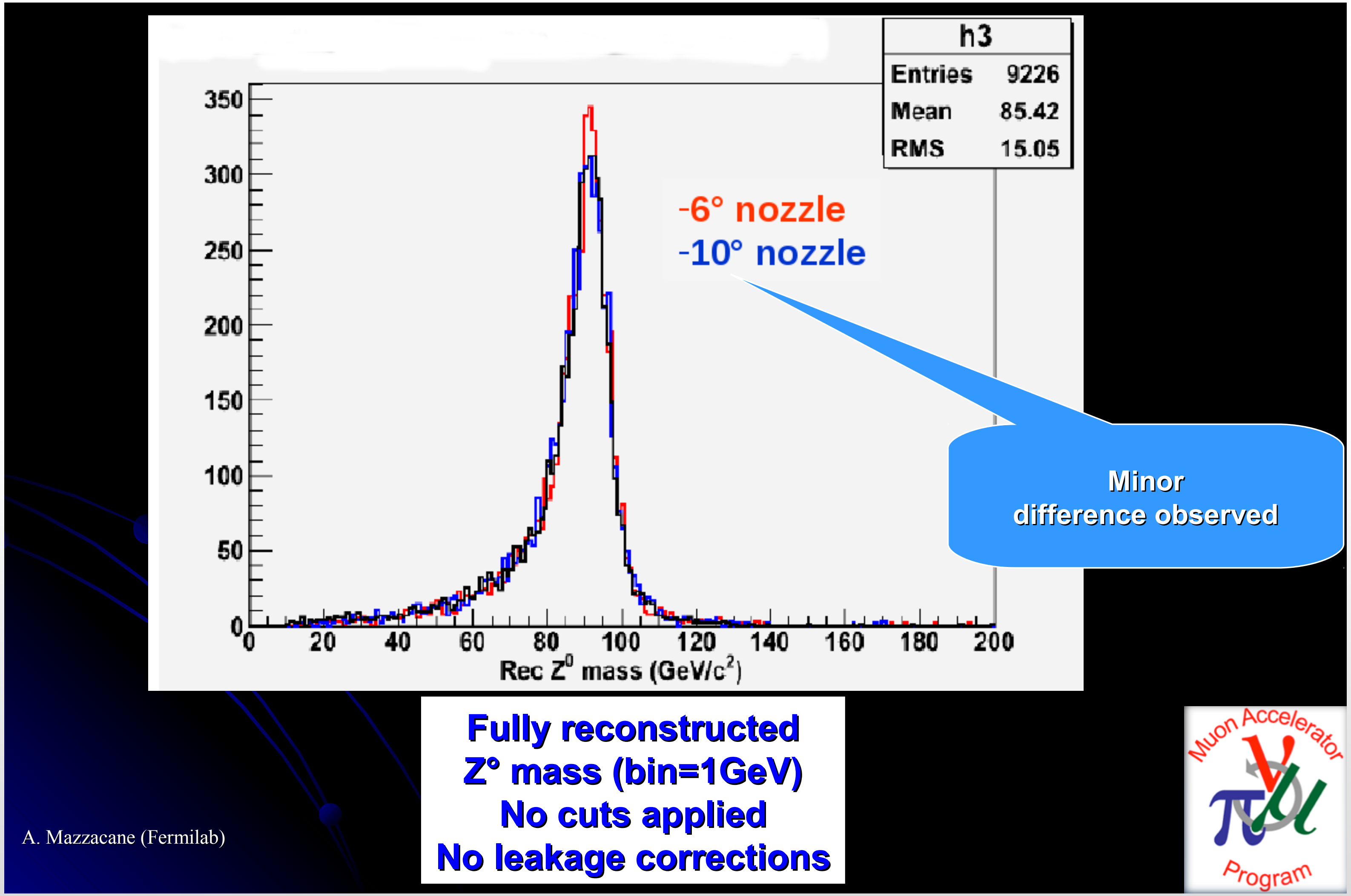
Study of $\mu^+\mu^- \rightarrow \nu_\mu\nu_\mu + Z^0 \rightarrow \nu_\mu\nu_\mu + jet + jet$



A. Mazzacane
Muon Collider Detector Studies -
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New Studies

Given the renewed interest in Muon Collider, the MAP simulation group gave to us the ILCRoot package. Thanks to Anna Mazzacane and Fermilab management who allows her to work with us to transfer know-how and code.

We prepared a VM image that can be run everywhere with all the code, currently on the INFN-Padova cloud.

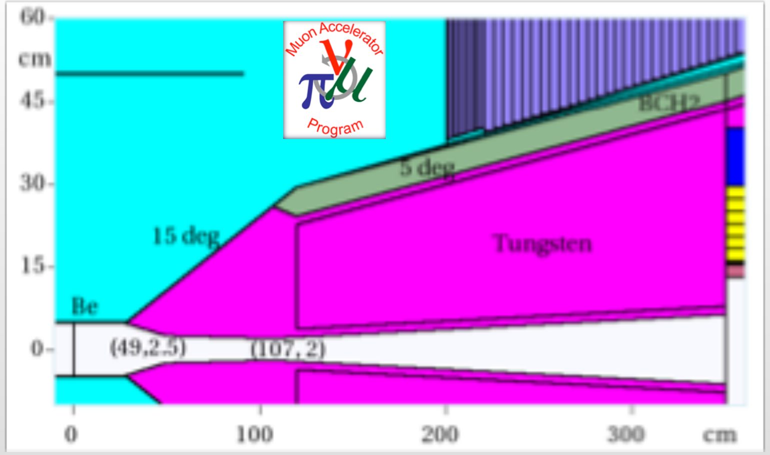
Plan:

- Study the Higgs line-shape to determine the final resolution for Higgs Factory using the MAP configuration: this will demonstrate that the background can be kept under control even if not easy!
- Study other physics benchmarks with multi-TeV $\sqrt{s}$ energy
- Re-do the background generation with FLUKA

Higgs Factory Background

Muon decay probability 12 times higher respect to 1.5 √s !
Beam 62.5 GeV $\lambda = 4\times10^5$m, with $2\times10^{12}\mu$/bunch ⇒ 5×10^6decay per meter of lattice
So far the worse case we can have in terms of background!

Used the MAP configuration:
S.I. Striganov, N.V. Mokhov, I.S. Tropin *Reducing Backgrounds in the Higgs Factory Muon Collider Detector* Fermilab-Conf-14-184-APC TUPRO029, and Proc. IPAC2014, Dresden, Germany, June 2014, p.1084



- $2\times10^{12}\mu$/bunch, beam energy E=62.5 GeV
- IR and MDI designed with longer open region at IP due to longer bunch length
- Nozzles angles really critical for background reduction

N.V. Mokhov gave to the group a MARS15 file generated at the Higgs mass energy

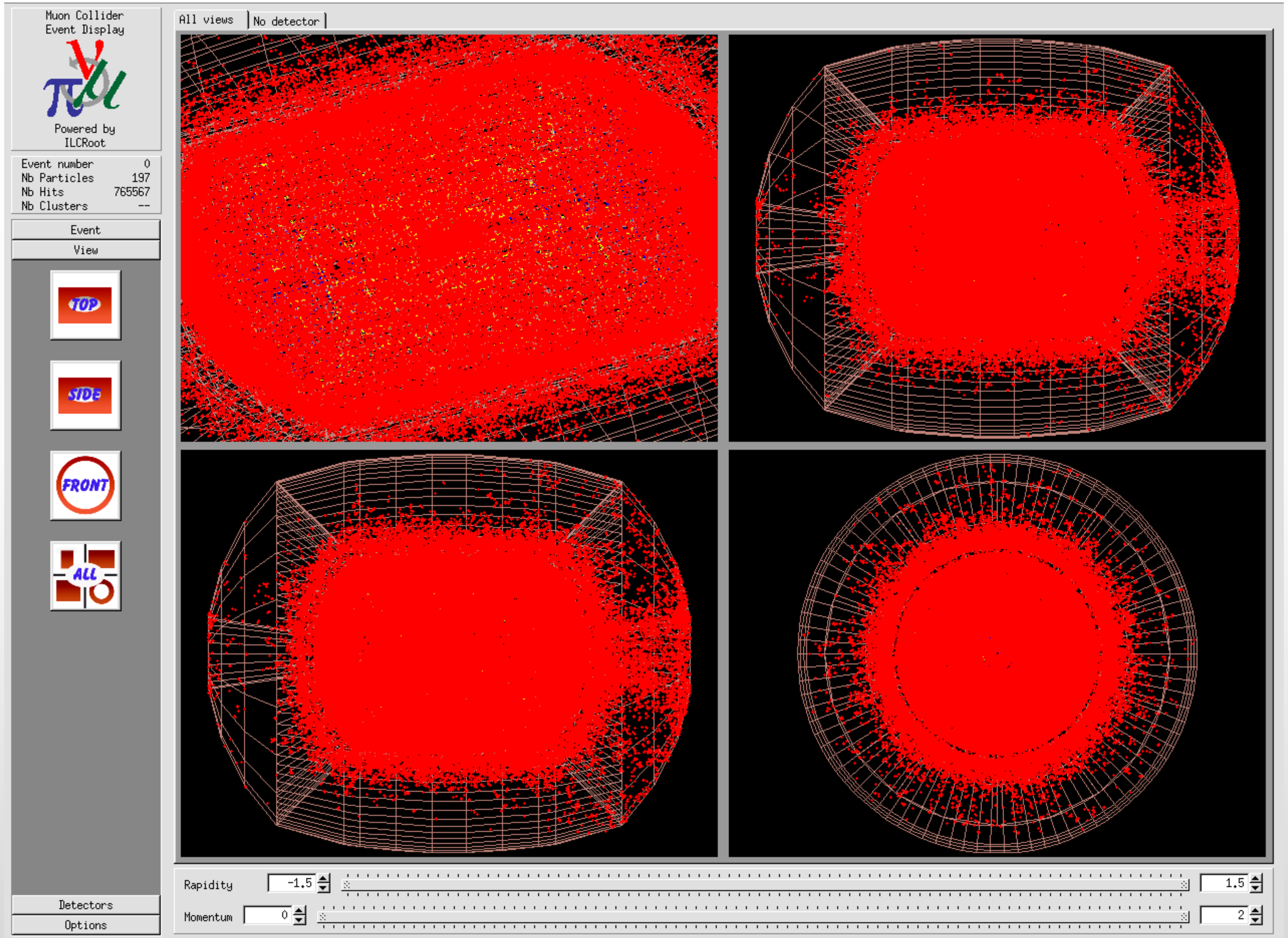
Higgs Factory Background Display

Background generated by Mokhov: one beam only of $\boldsymbol{\mu^-}$

ILCRoot package used

No cuts on particles, generated with cut-off:

- 10 - 100 KeV for e^+, e^-, γ
- 0.001 eV for neutron



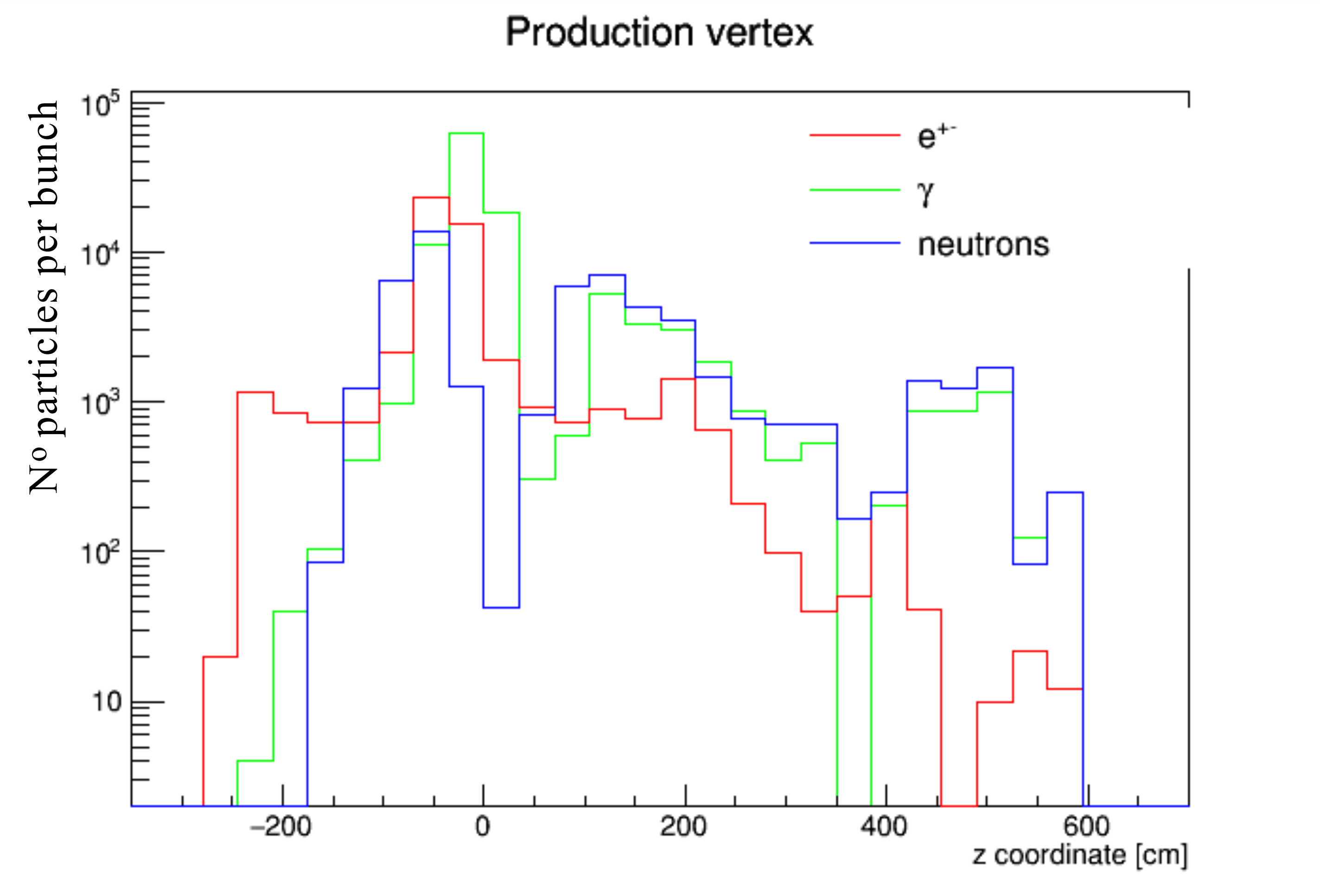
Higgs Factory Background Production Point

Background generated by Mokhov: one beam only of μ^-

ILCRoot package used

No cuts on particles, generated with cut-off:

- 10 - 100 KeV for e^+, e^-, γ
- 0.001 eV for neutron



Higgs Factory Background Composition

Background generated by Mokhov: one beam only of $\boldsymbol{\mu}^{-}$

ILCRoot package used

No cuts on particles, generated with cut-off:

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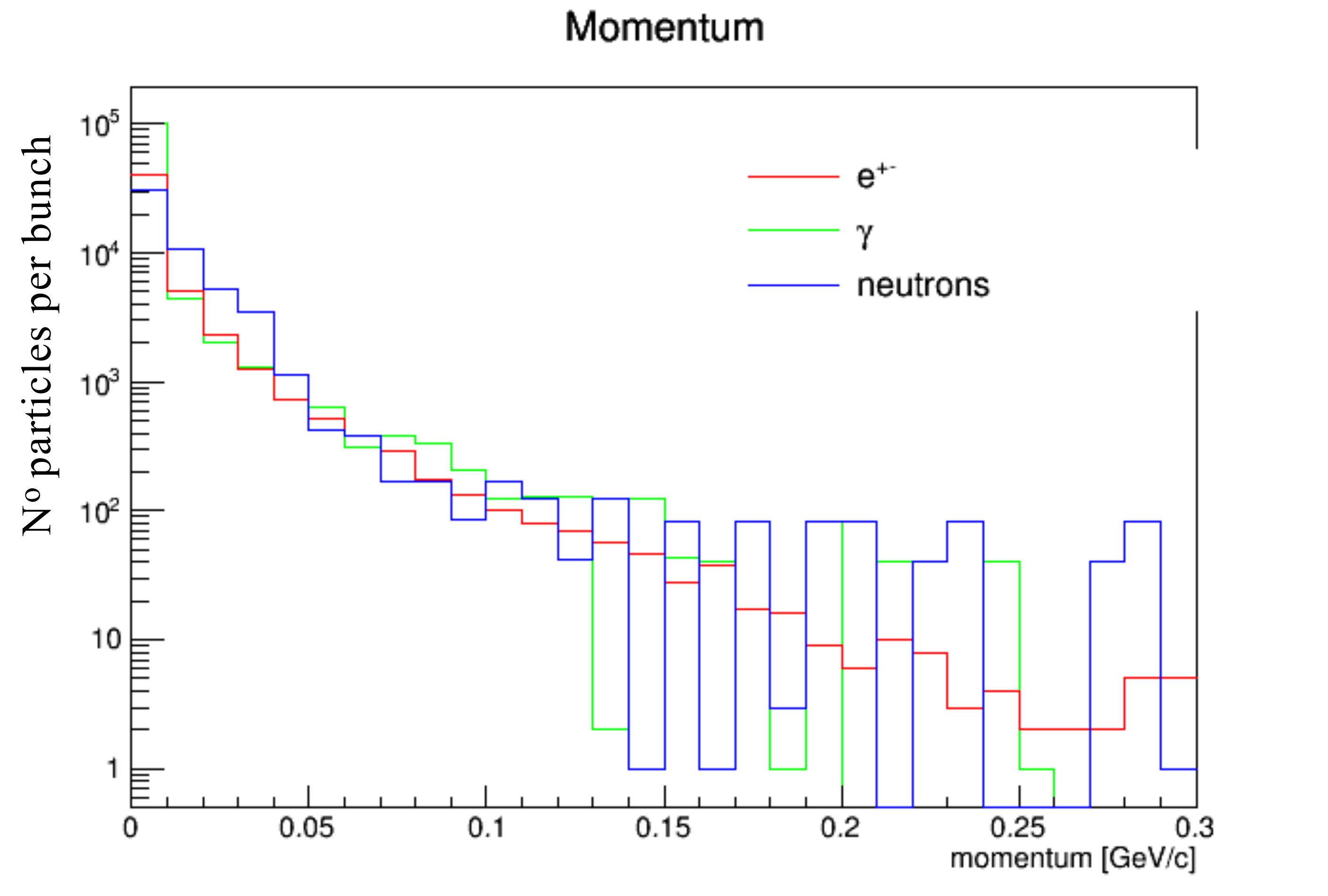


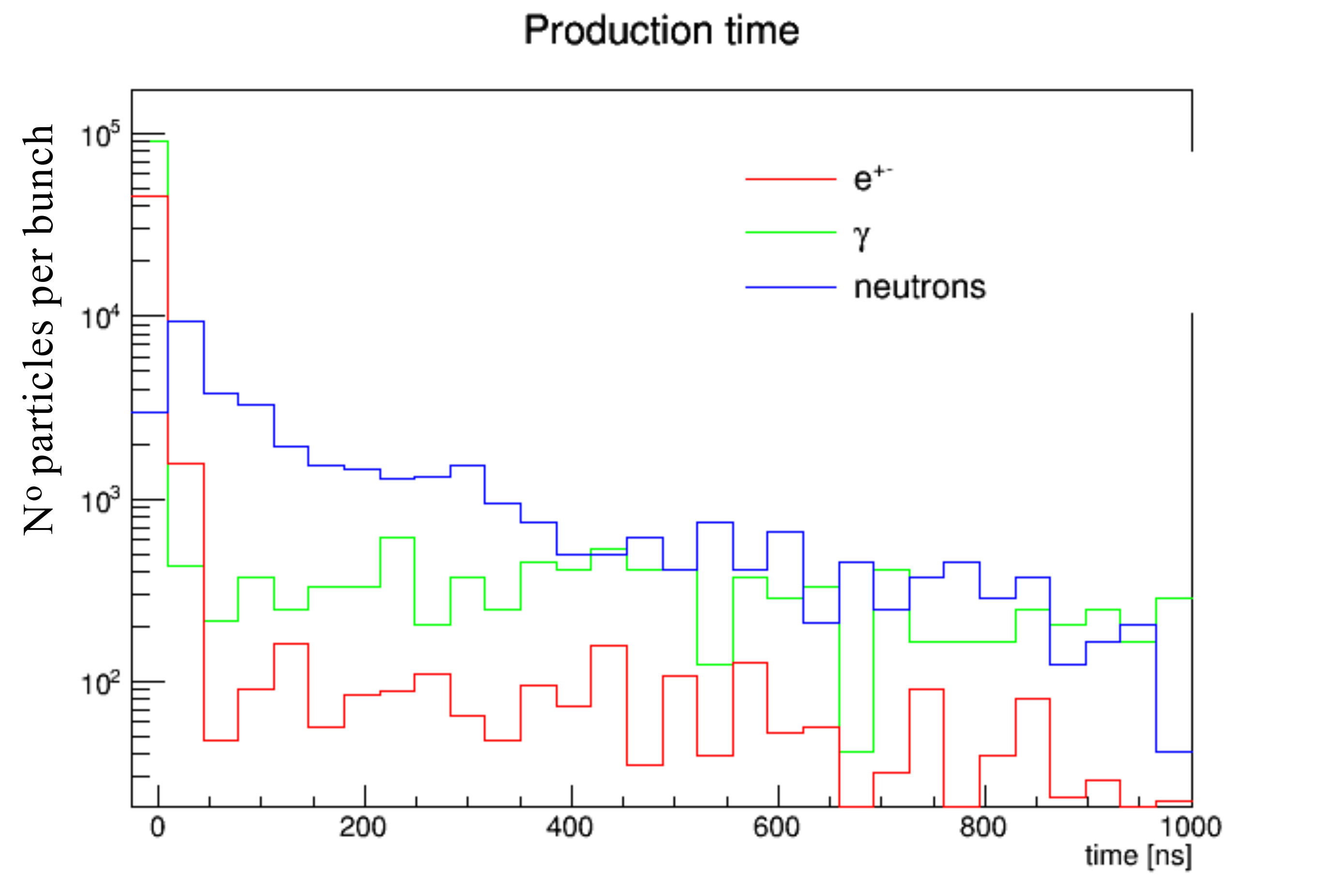
Higgs Factory Background Arrival Time

Background generated by Mokhov: one beam only of $\boldsymbol{\mu}^{-}$

ILCRoot package used

No cuts on particles, generated with cut-off:

- 10 - 100 KeV for e^{+}, e^{-}, γ
- 0.001 EV for neutron



Summary

- Physics reaches at muon collider strongly depend on machine background which depends on beam characteristics and machine lattice in particular on the IR design
- MAP collaboration has studied in details cases for 1.5 TeV center of mass energy and did start the Higgs factory simulation
- We resumed the MAP simulation package with goals
    - Study the Higgs line-shape, this is the most difficult case due to the overwhelming background
    - Evaluate performances for physics benchmarks in the high energy case to be compared with other colliders
    - Compare the muon decay background obtained with MARS with the one simulated with FLUKA
    - Study physics benchmarks for other sources of muons, this can be done only in strong collaboration with accelerator experts to define IR and MDI

We are starting a working group that meets every two weeks to perform physics case studies