GENERAL CHARACTERISTICS OF DETECTOR BACKGROUND

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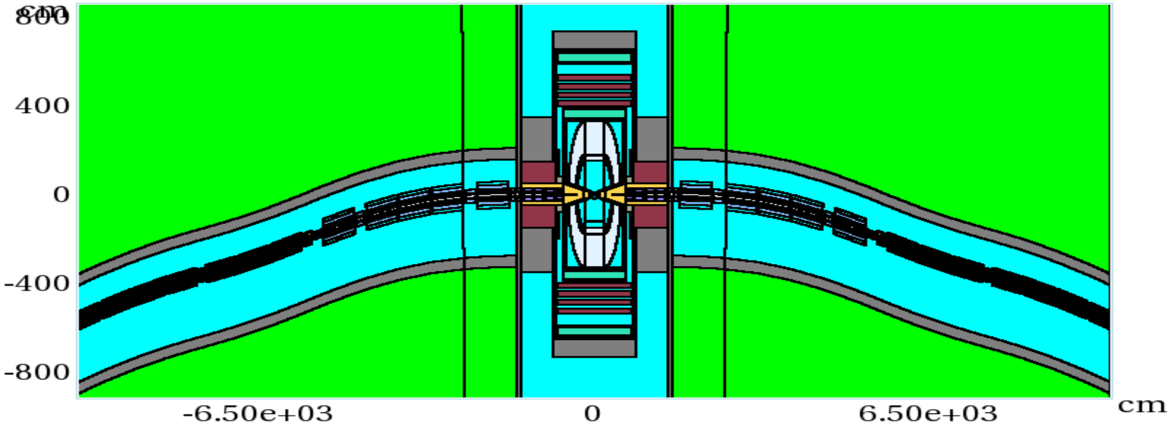
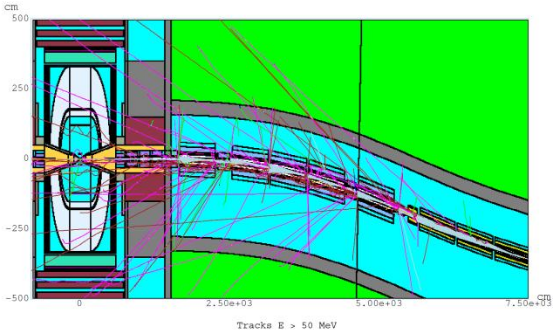
Sources of Background

1. **IP incoherent e^+e^- pair production:** x-section 10 mb which gives rise to background of 3×10^4 electron pairs per bunch crossing (manageable with nozzle & detector B)
2. **Muon beam decays:** Unavoidable bilateral detector irradiation by particle fluxes from beam-line components and accelerator tunnel – **major source** at MC: For 0.75-TeV muon beam of 2×10^{12}, 4.28×10^5 dec/m per bunch crossing.
3. **Beam halo:** Beam loss at limiting apertures; severe, can be taken care of by an appropriate collimation system far upstream of IP.

MARS15 Modeling

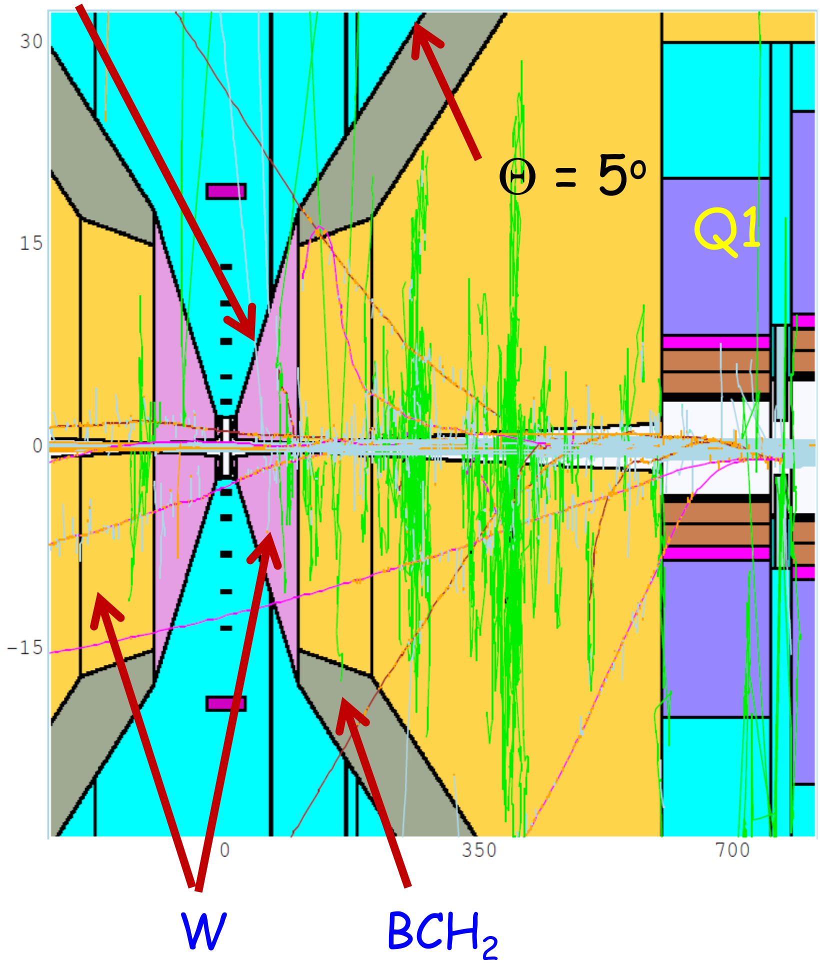


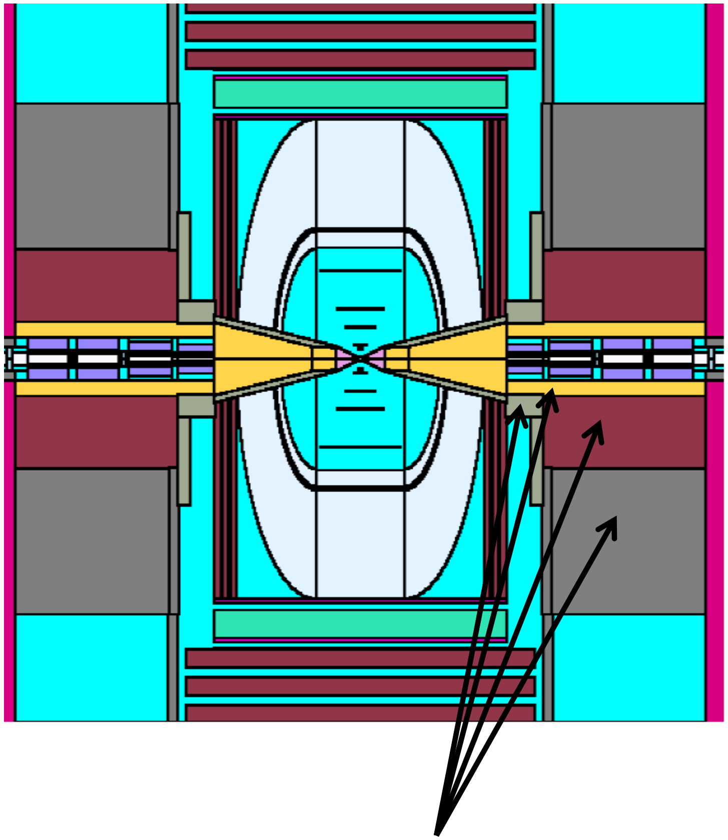


- Detailed magnet geometry, materials, magnetic fields maps, tunnel, soil outside and a simplified experimental hall plugged with a concrete wall.
- Detector model with B_z = 3.5 T and tungsten nozzle in a BCH_2 shell, starting at ±6 cm from IP with R = 1 cm at this z.
- 750-GeV bunches of 2×10^{12} μ^- and μ^+ approaching IP are forced to decay at $|S| < S_{max}$, where S_{max} up to 250 m at 4.28×10^5 / m rate.
- Cutoff energies optimized for materials & particle types, varying from 2 GeV at ≥100 m to 0.025 eV (n) and 0.2 MeV (others) in the detector.

Machine-Detector Interface

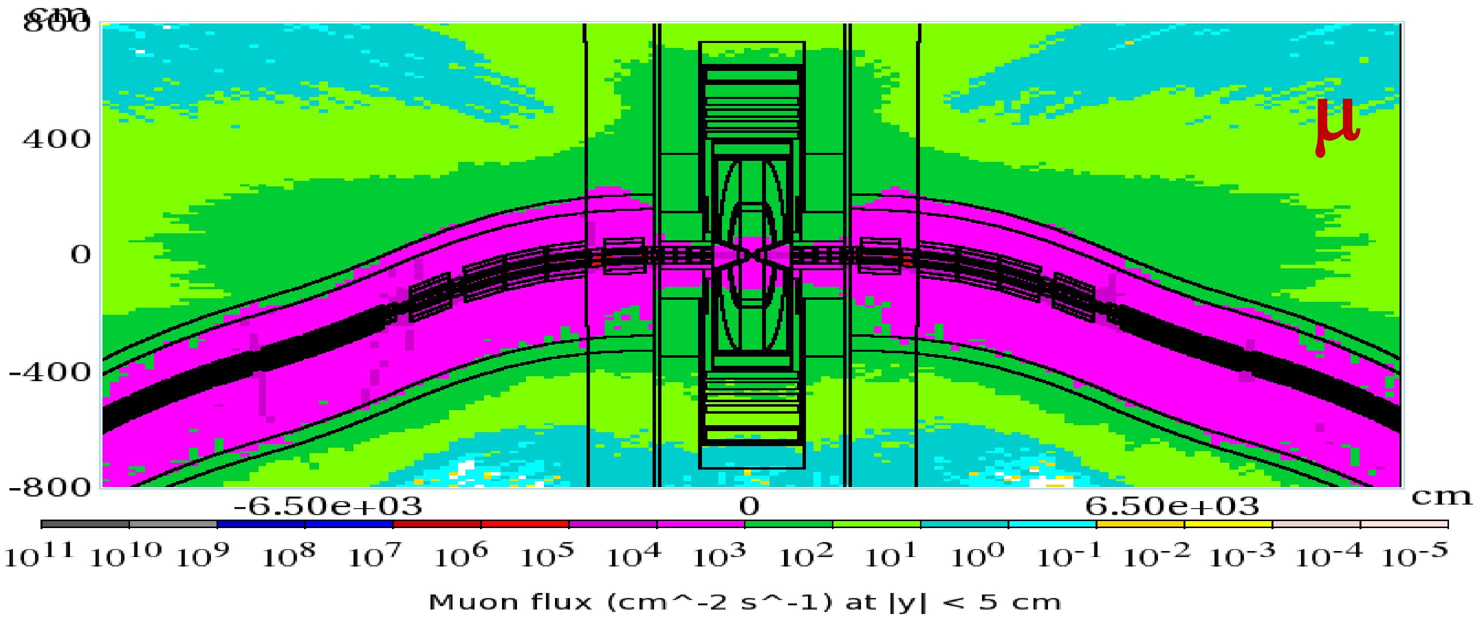
$\Theta = 10^o$ 6 < z < 600 cm x:z = 1:17





Sophisticated shielding:
W, iron, concrete & BCH_2

Background Suppression



Dipoles close to the IP and tungsten masks in each interconnect region help reduce background particle fluxes in the detector by a substantial factor. The tungsten nozzles, assisted by the detector solenoid field, trap most of the decay electrons created close to the IP as well as most of incoherent e^+e^- pairs generated in the IP. With additional MDI shielding, total reduction of background loads by more than three orders of magnitude is obtained.

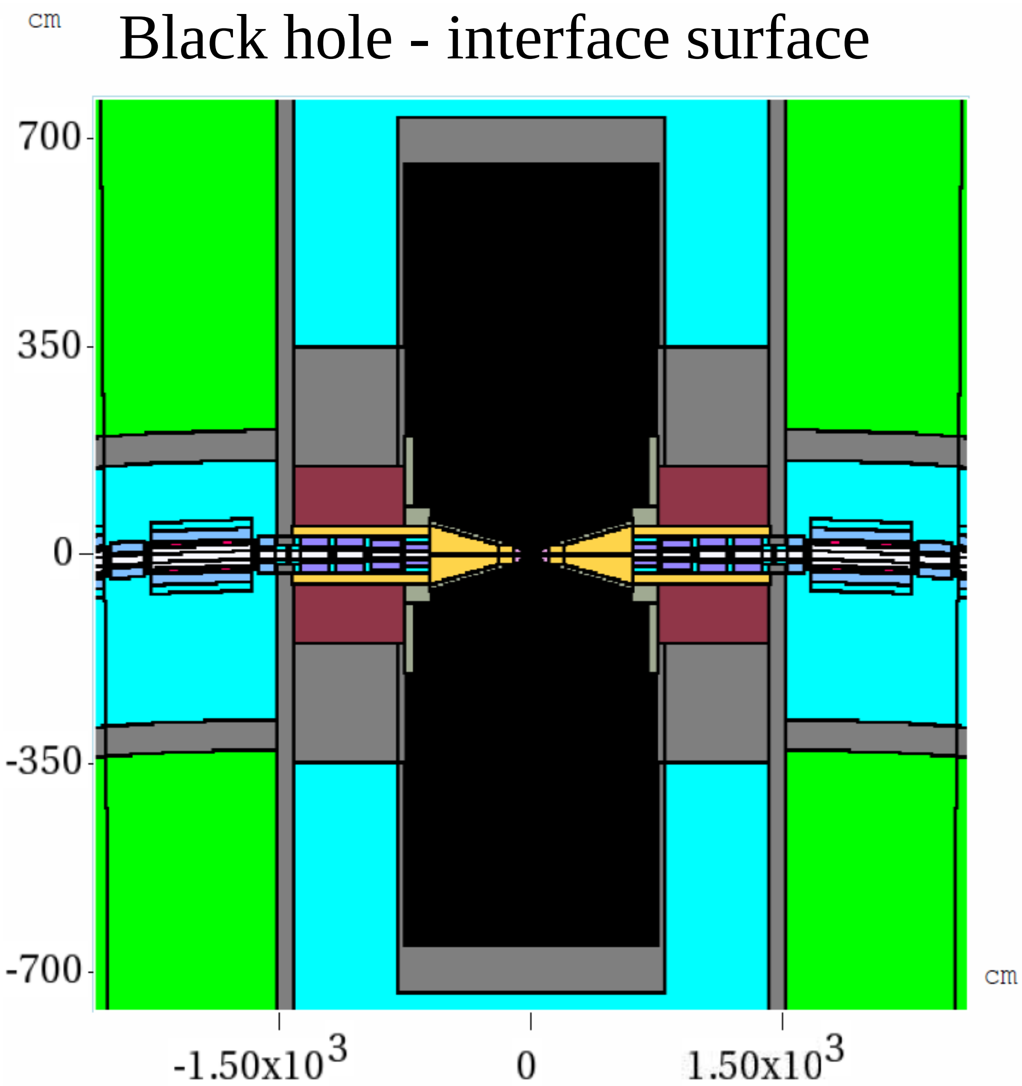
Background simulation

Muon decay points are simulated randomly from -200 to 200 m from IP. Muon position and angle is sampled from precalculated accelerator structure functions. Electron/positron has large momentum and small angle relatively muon trajectory, so it could flight inside beam pipe few meters before start shower in accelerator elements. Simulation is stopped at interface surface – entrance to detector. Following results were obtained with cutoff energies (±25 m from IP):

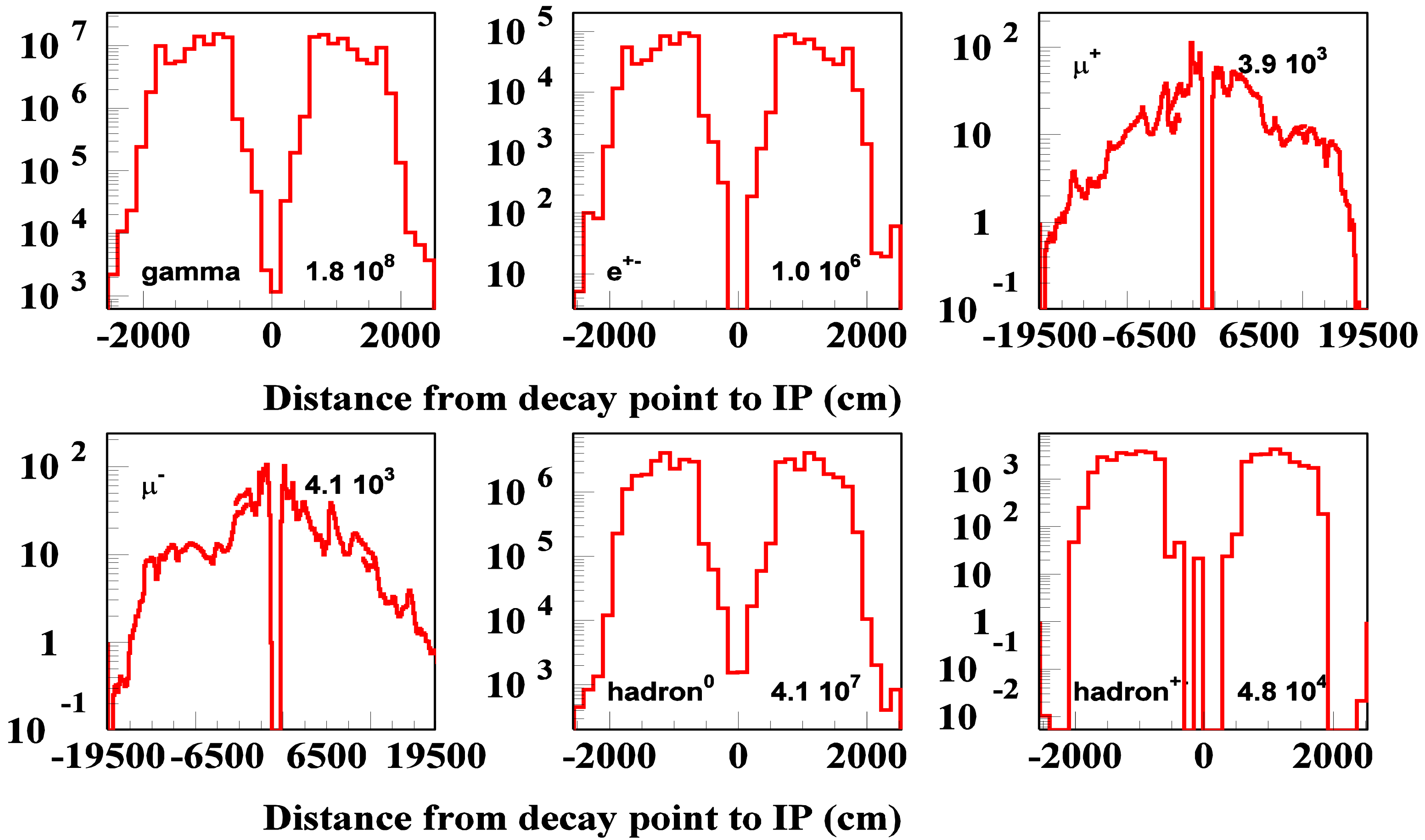
gamma, $e^{\pm}$ - 200 keV

neutron - 100 keV

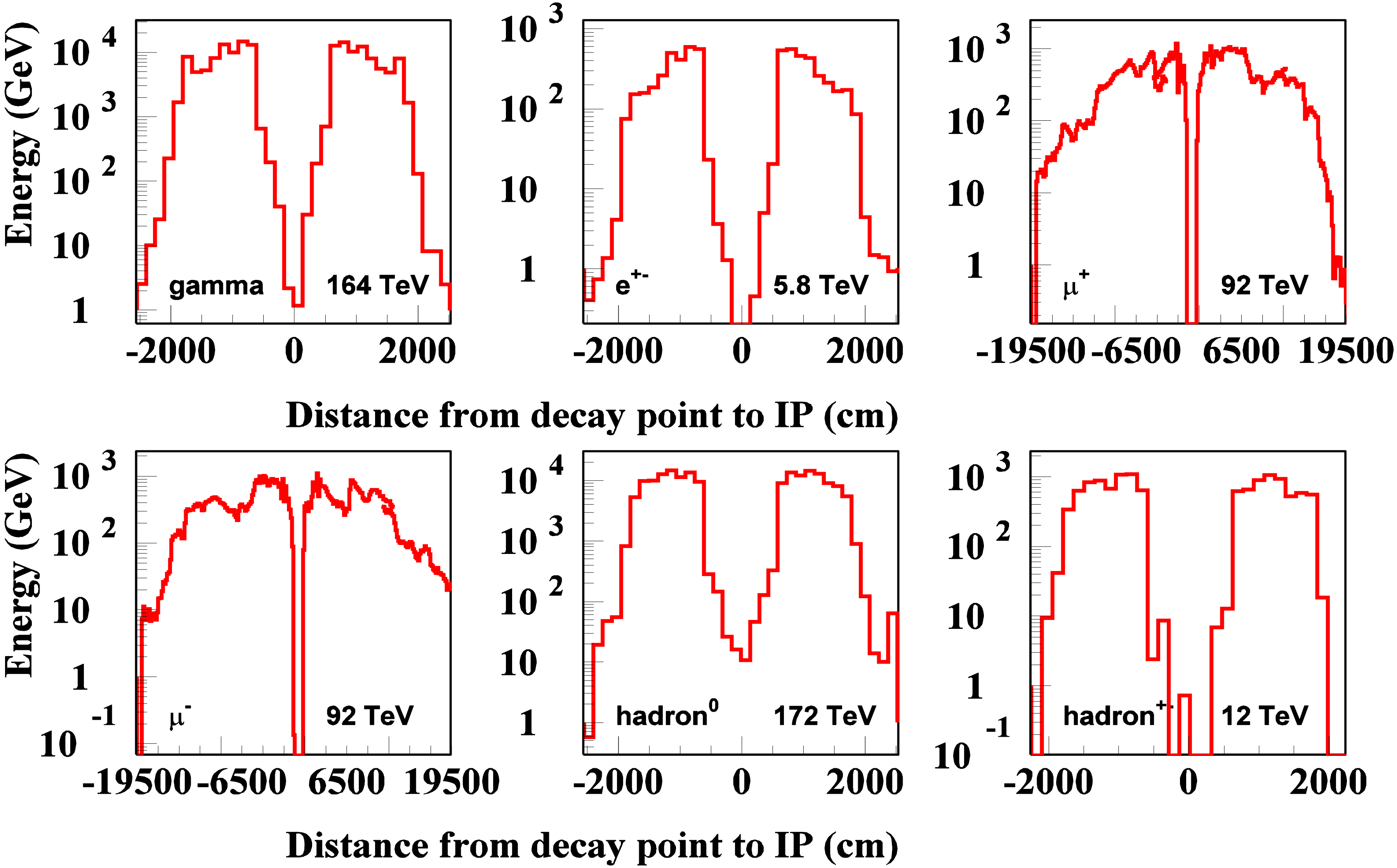
muon, charged hadron – 1 MeV.



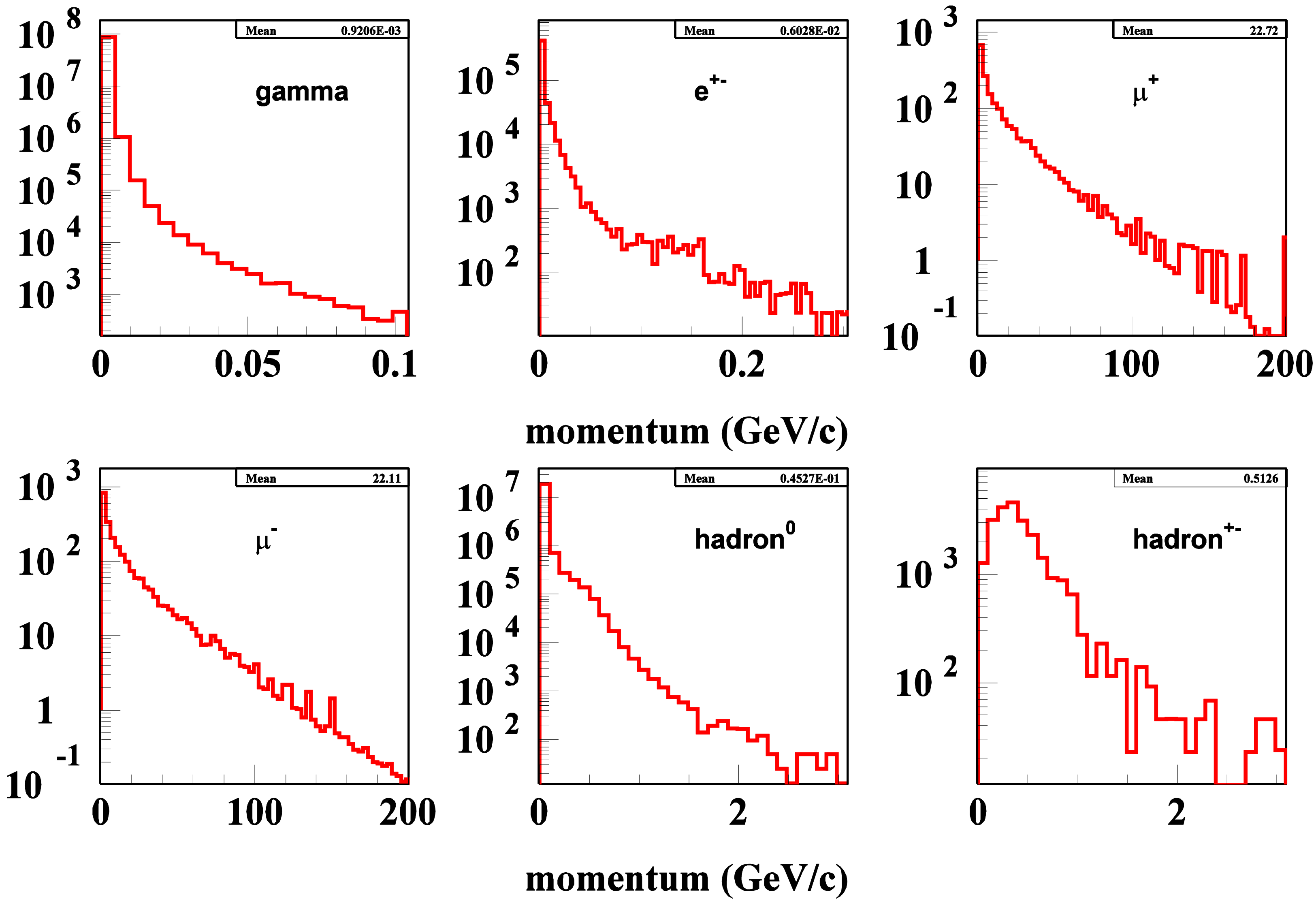
Where is Background Produced?
Number of Particles Entering Detector



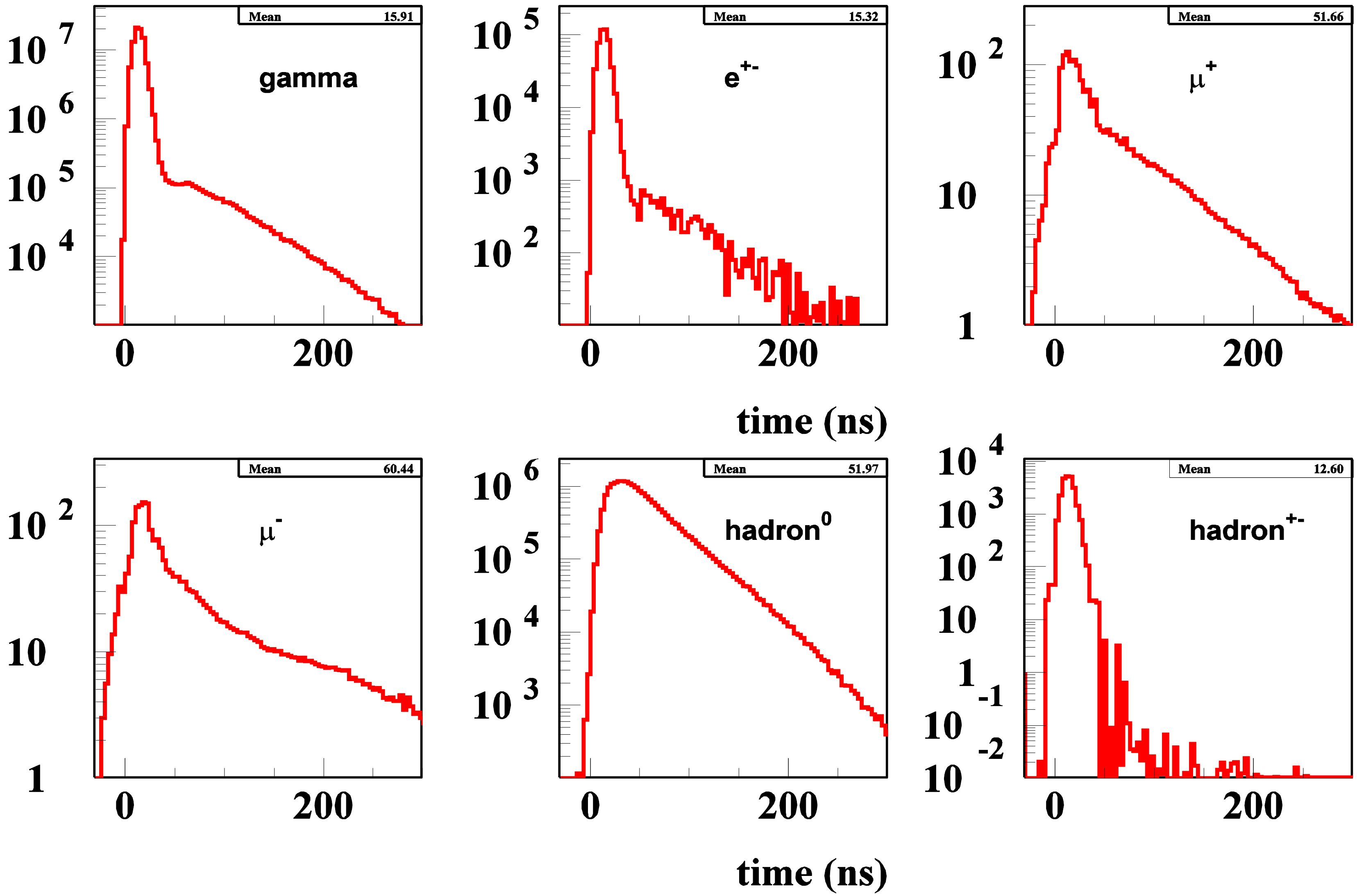
Where is Background Produced?
Energy Flow Entering Detector



Energy Spectra Entering Detector



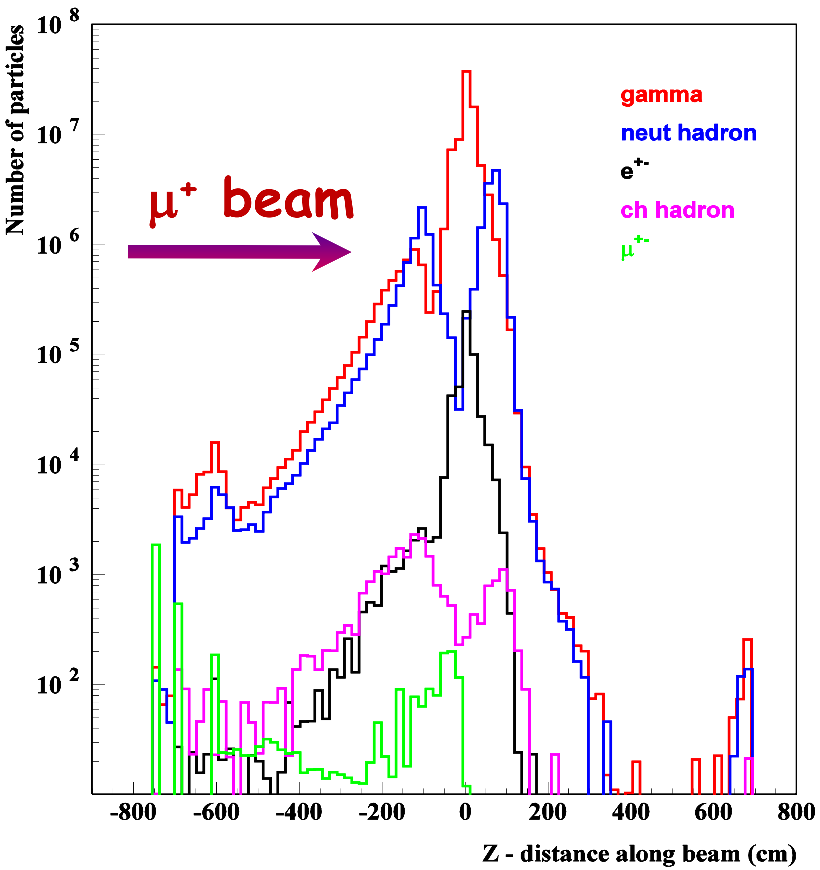
Time Distribution wrt Bunch crossing at Detector Entrance



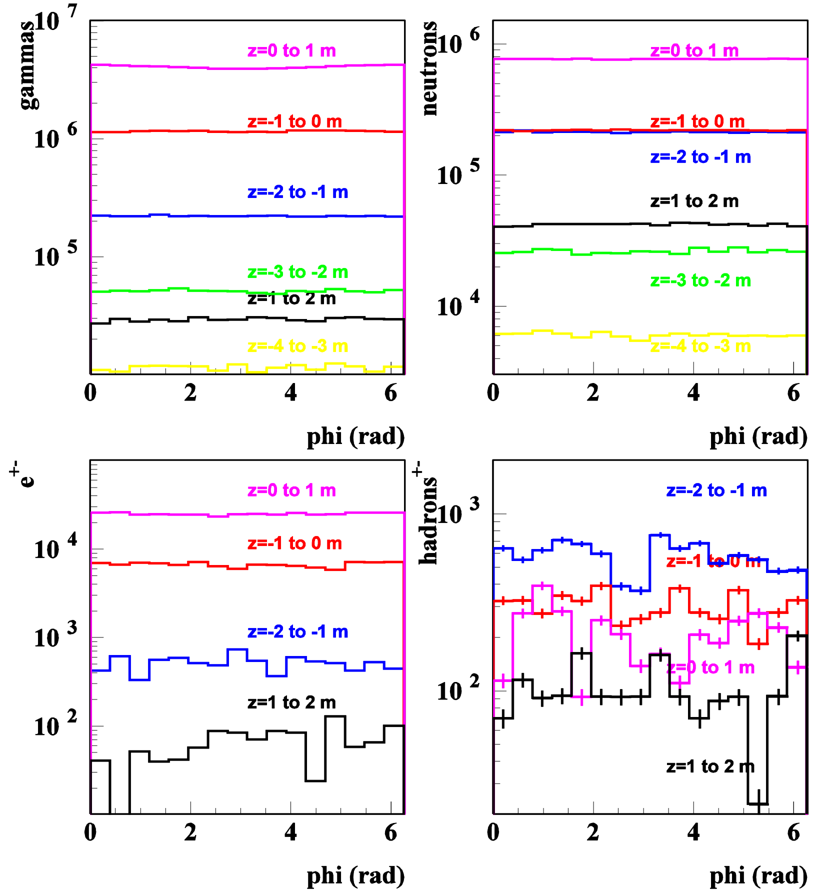
Spatial Distribution at Detector Entrance

Most of particles come to detector through nozzle surface (±6m) ; for muons this fraction is 30%

Background (except muons) on nozzle surface weakly depends on azimuthal angle



Particles at interface surface (one bunch)

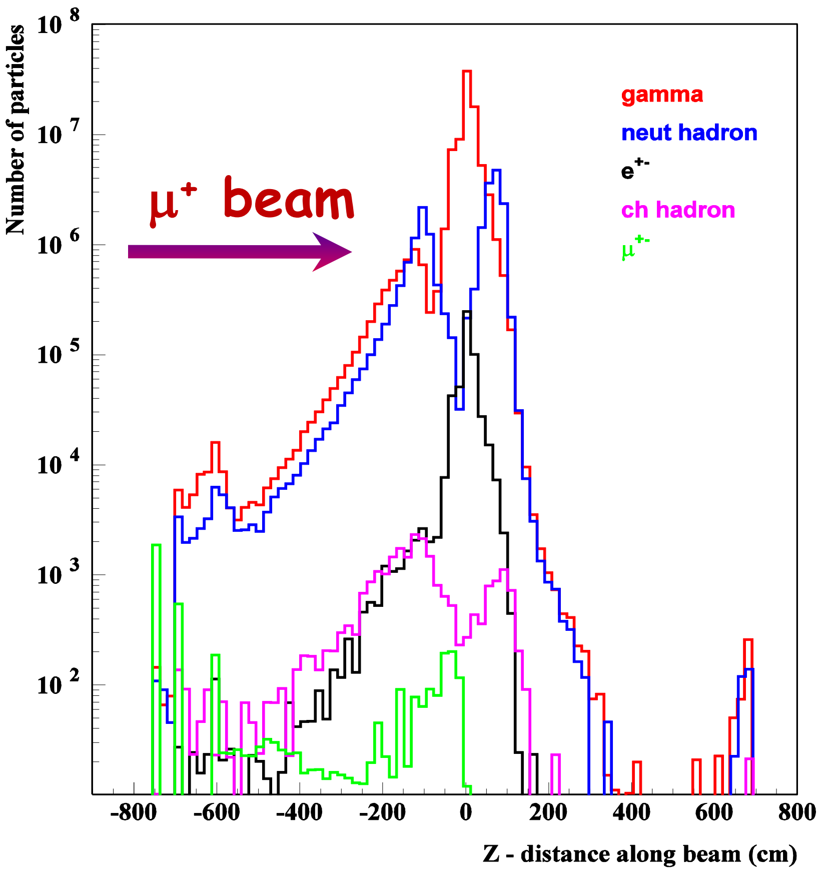


Azimuthal distribution at interface surface (one bunch)

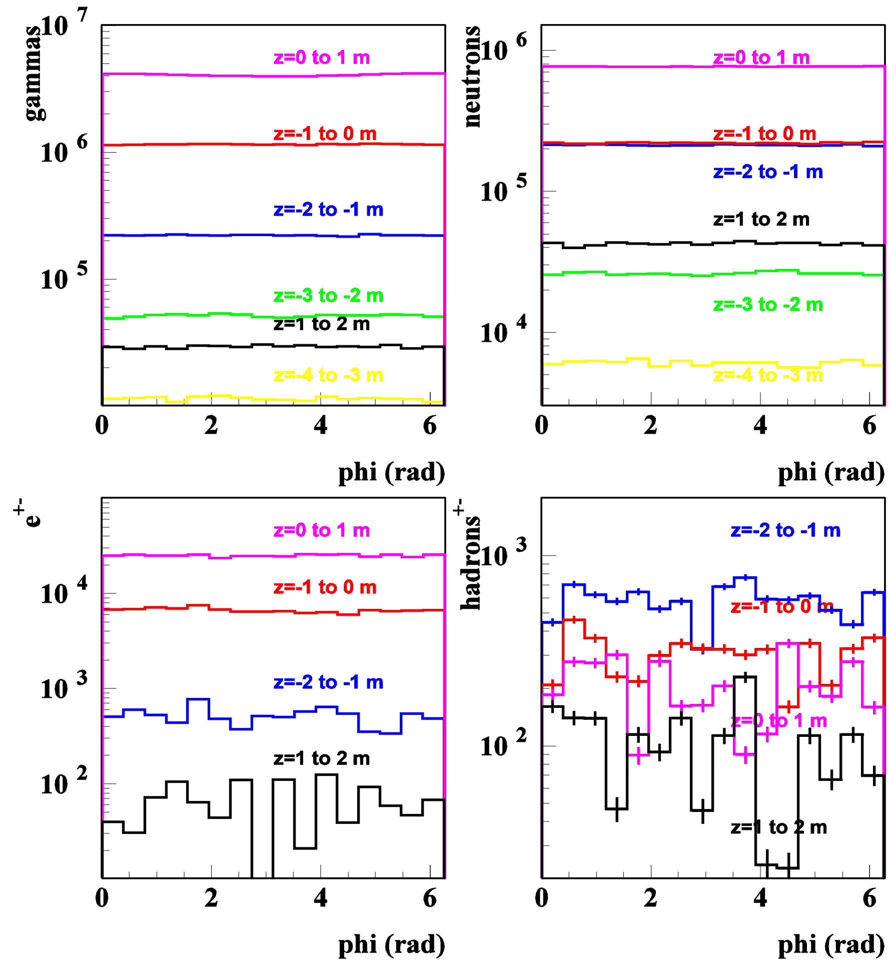
Angular Distribution of Background at Detector Entrance

Most of particles come to detector through nozzle surface (±6m); for muons this fraction is 30%

Background (except muons) on nozzle surface weakly depends on azimuthal angle



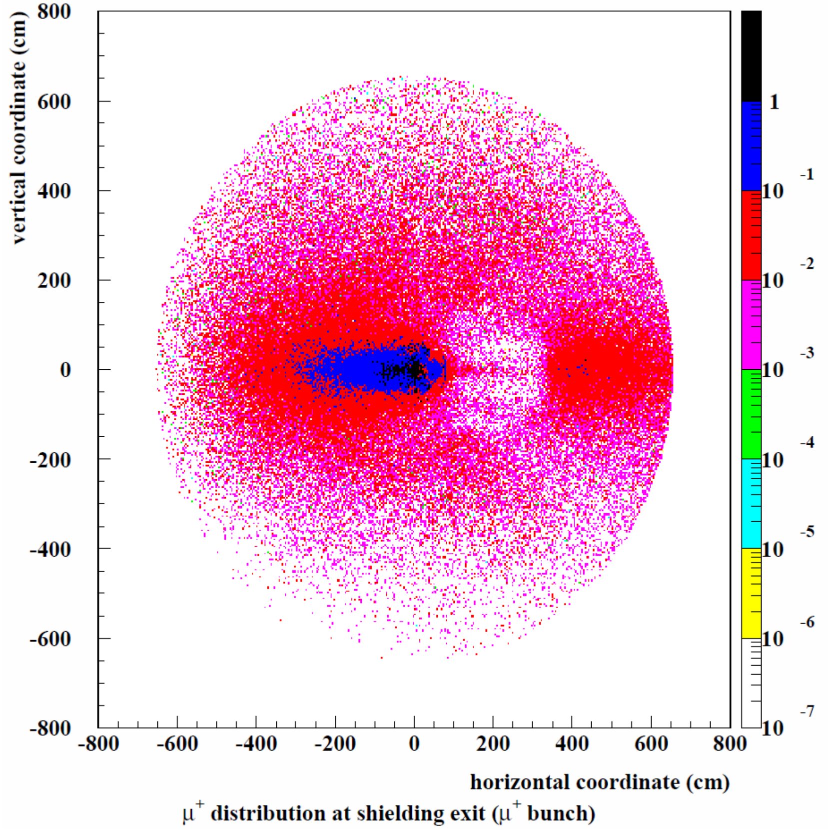
Particles at interface surface (one bunch)



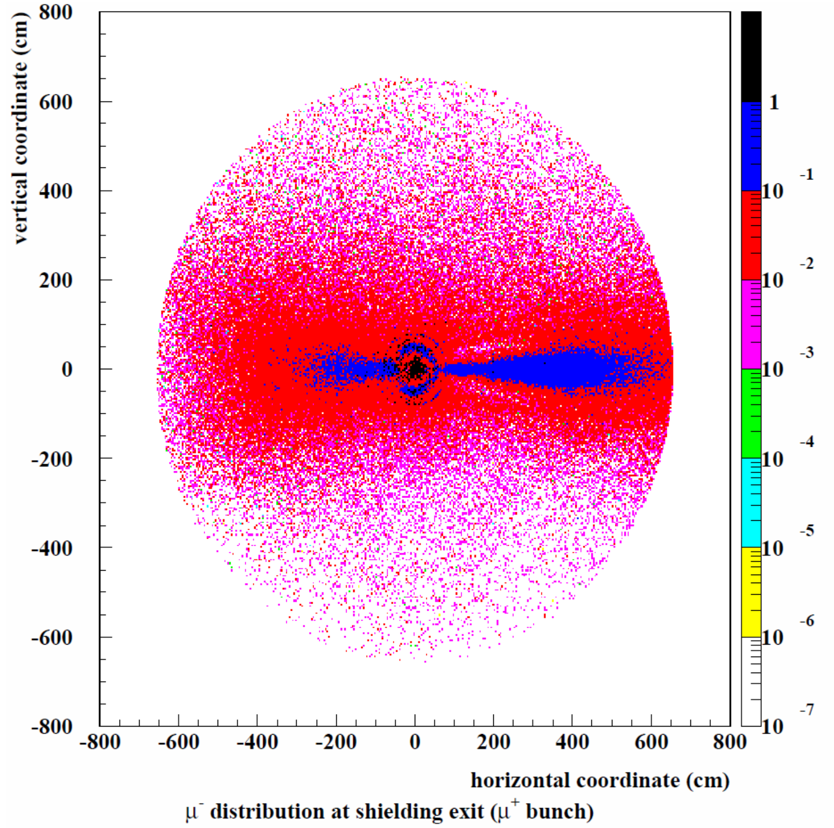
Azimuthal angle distribution at interface surface (one bunch)

Muon Lateral Distribution at Detector Entrance from Side of Positive Muon Beam

Positive muons deflected by beam-line magnetic field to negative direction



Negative muons deflected by beam-line magnetic field to positive direction



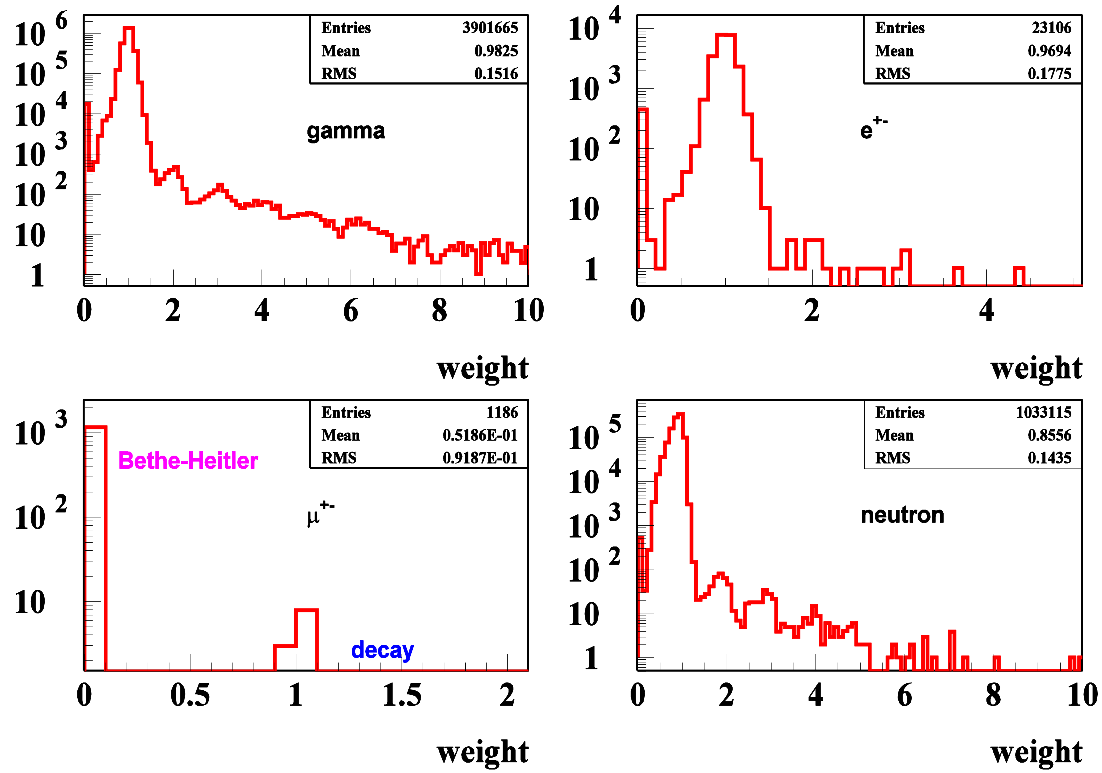
Weights

We can simulate only part of real number of muon decays due to CPU limits yet. Now we are using files corresponding to 4% of decays from 26 meters. First source of weights is normalization to bunch.

Other source of weight – MARS simulation models. Some of them simulate one secondary particles instead few with statistical weight corresponding to average multiplicity of such particles.

Important Bethe-Heitler muons are produced with low probability. We produce more such muon in simulation than in nature but reduce its weight to have correct description of muon fluxes, spectra …

MARS weight



Background files

MARS background simulation results are available to the community:
http://www-ap.fnal.gov/users/strigano/mumu/mixture
There are four files containing background particle coming from
μ^+ ark - (-189 to -25 m and -25 to 1m) and μ^- ark - (189 to 25 m and 25to -1 m).
This is text files. Each row corresponds to one particle and contains comprehensive information about particle and its origin (look at readme file).

We simulated 4.8 10^5 decays close to IP in each arks (-25 to 1m and 25 to -1m). So, after normalization per bunch background particles have weight about 23 and more. We could split all particles except muons using azimuthal symmetry. Muons have weight about one in this files, because we was using corresponding muon multiplication factor.

We simulated 2.4 10^7 decays far from IP in each arks (-189 to -25m and 189 to 25m). Weights in this files are much lower than one. We could take or reject particles for further simulation according to its weight.

Background files - new release

Weight fluctuations in MARS was reduced after current version of background files were prepared

Detector simulation shows that significant part of low energy background particles could be rejected by timing window/stamps. May be we could rise thresholds in simulation - simulate more decays - reduce normalization weight

Description of collider ring magnets was improved/changed after current release

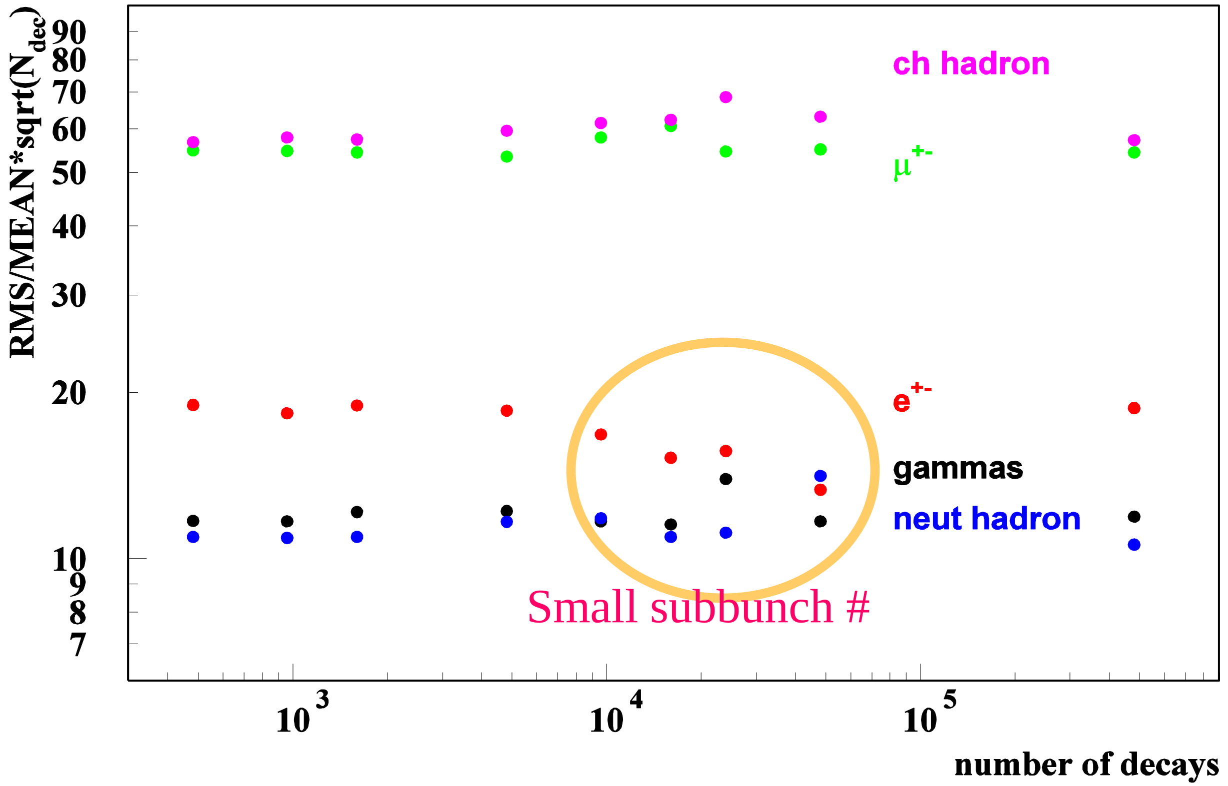
Users proposals/corrections/suggestions are welcomed before production of new background files

Fluctuation of background energy coming into detector : for bunch N_{dec} = 1.1128 10^7

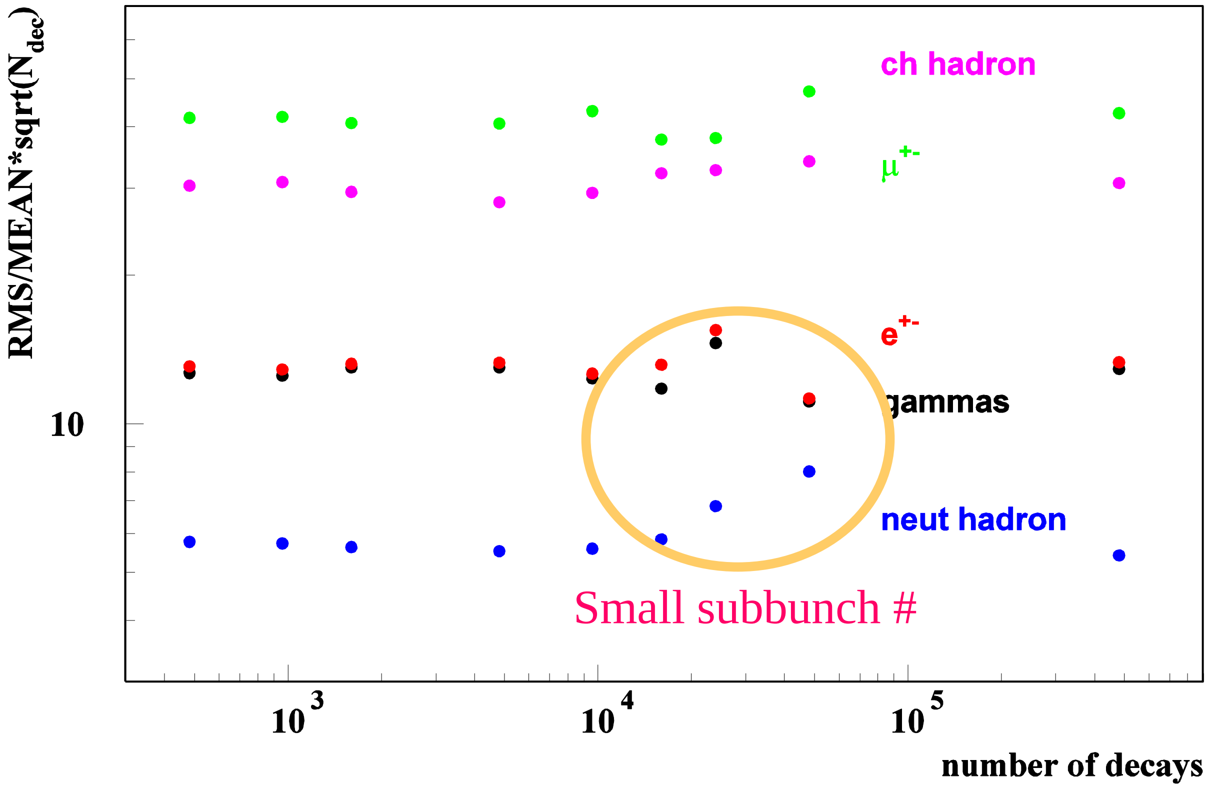
Background sample contains results of 480000 decays from 26 meters. To estimate energy fluctuation lets look at distribution of 1000 energies coming from 480 decays, 100 energies coming from 4800 ...

Other way – calculate energy distribution from ONE decay. One can use RMS of this distribution to calculate width of energy distribution from large enough numbers of decays.

For bunch decaying along 26m fluctuation of background energy coming into detector are not large => RMS/MEAN =0.003

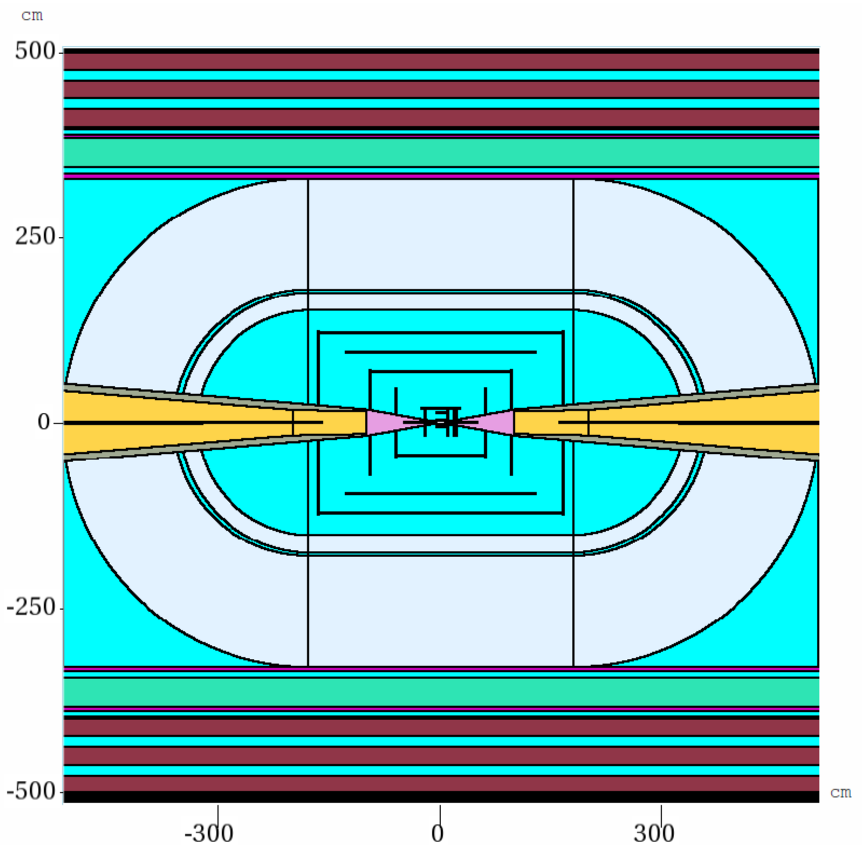


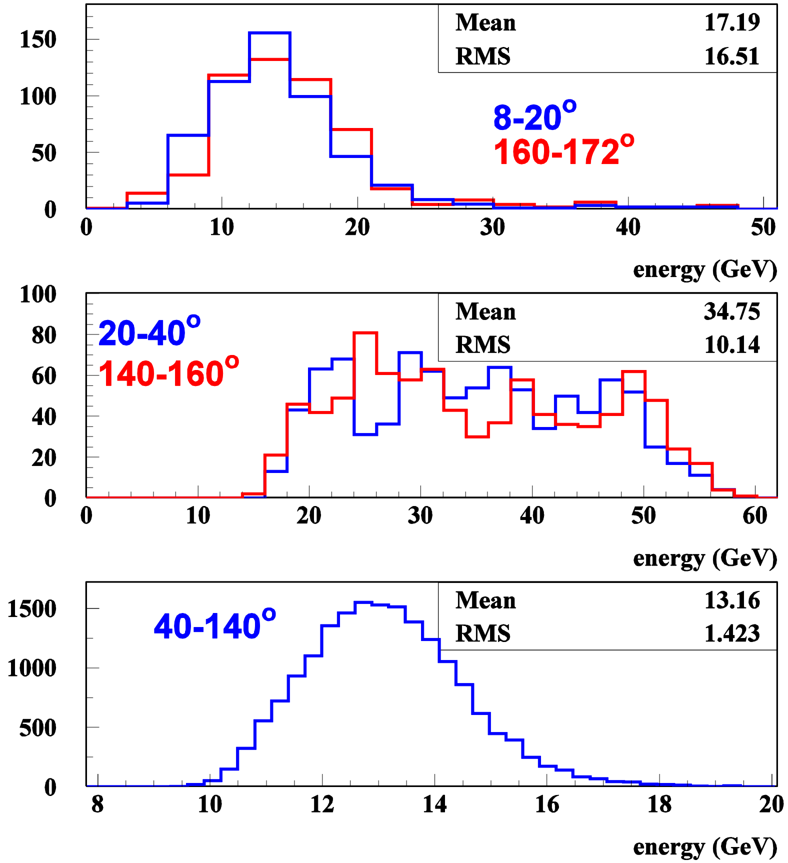
Fluctuation of number of background particles coming into detector: for bunch N_{dec} = 1.1128 10^7



Fluctuation of background energy coming to calorimeter-I

Barrel – 152 cm radius, 360 cm long - 72x252 towers from 40 to 140 degrees => 3x3 cm^2 per tower
Endcaps – 152 cm radius - 15x60 towers at 20- 40 and 140 - 160 degrees = 3x3 cm^2 per tower
9x60 towers at 8 - 20 and 160 - 172 degrees = 3x3 cm^2 per tower

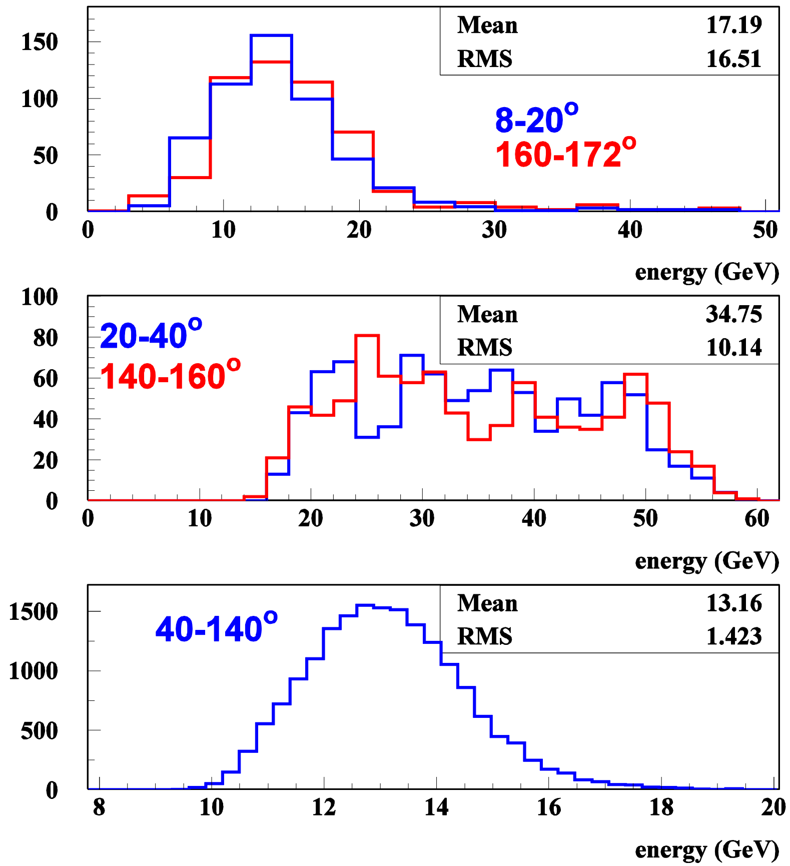




Fluctuation of energy coming to hadronic calorimeter

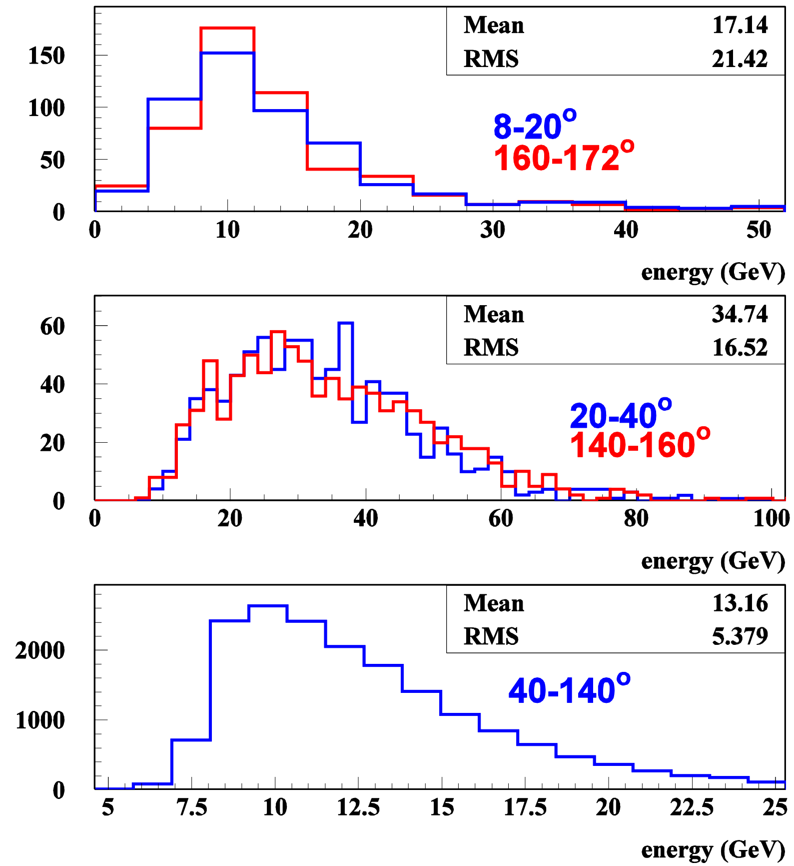
Fluctuation of background energy coming to calorimeter - II

Simulation with splitting – each background particle with weight W was spited to W particles with weight = 1 using azimuthal symmetry



Fluctuation of energy coming to hadronic calorimeter

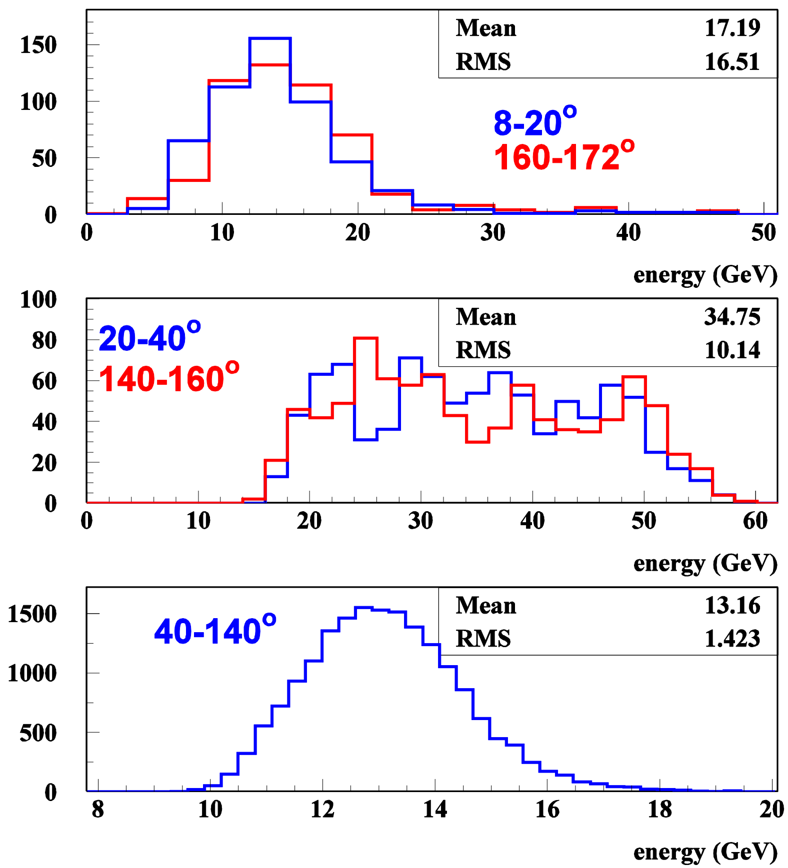
Simulation without splitting



Fluctuation of energy coming to hadronic calorimeter

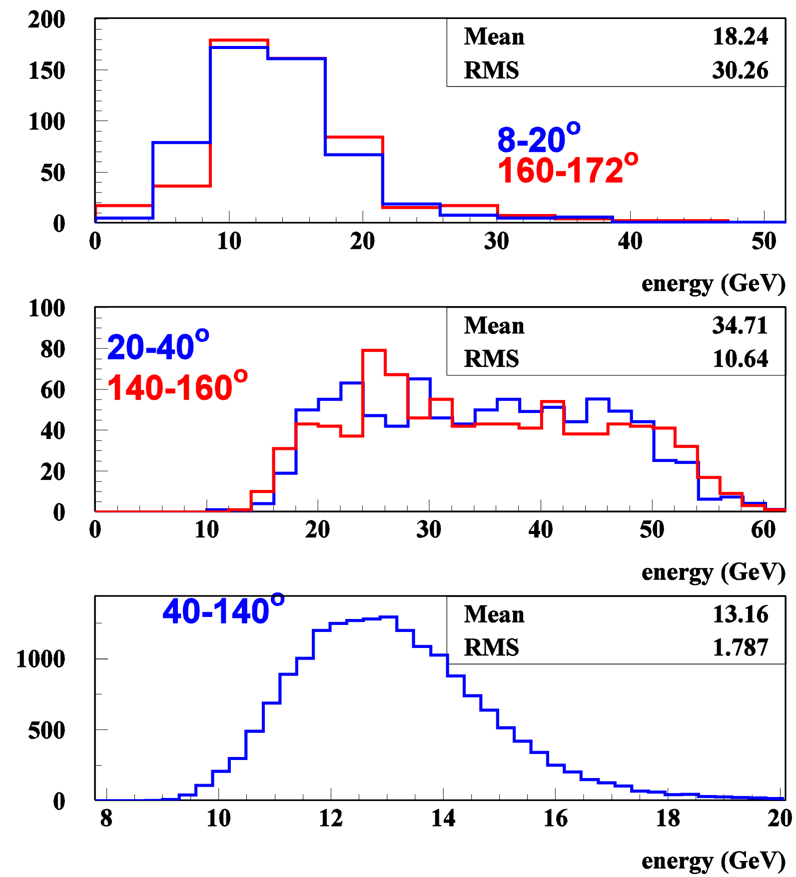
Fluctuation of background energy coming to calorimeter - III

Simulation with splitting – each background particle with weight W was spited to W particles with weight = 1 using azimuthal symmetry



Fluctuation of energy coming to hadronic calorimeter

Simulation with splitting – each background particle with weight W was spited to W/2 particles with weight = 2 using azimuthal symmetry



Fluctuation of energy coming to hadronic calorimeter

Summary

• Detector background simulations are advancing well, MDI optimization is underway, files are available to the community.

• Main features of background loads on the detector have been studied and are well understood.

• Fluctuation of background energy coming to calorimeter is about 10% at 90 degree and larger for lower angles.

• User feedback could be very useful for coming new release of background files.

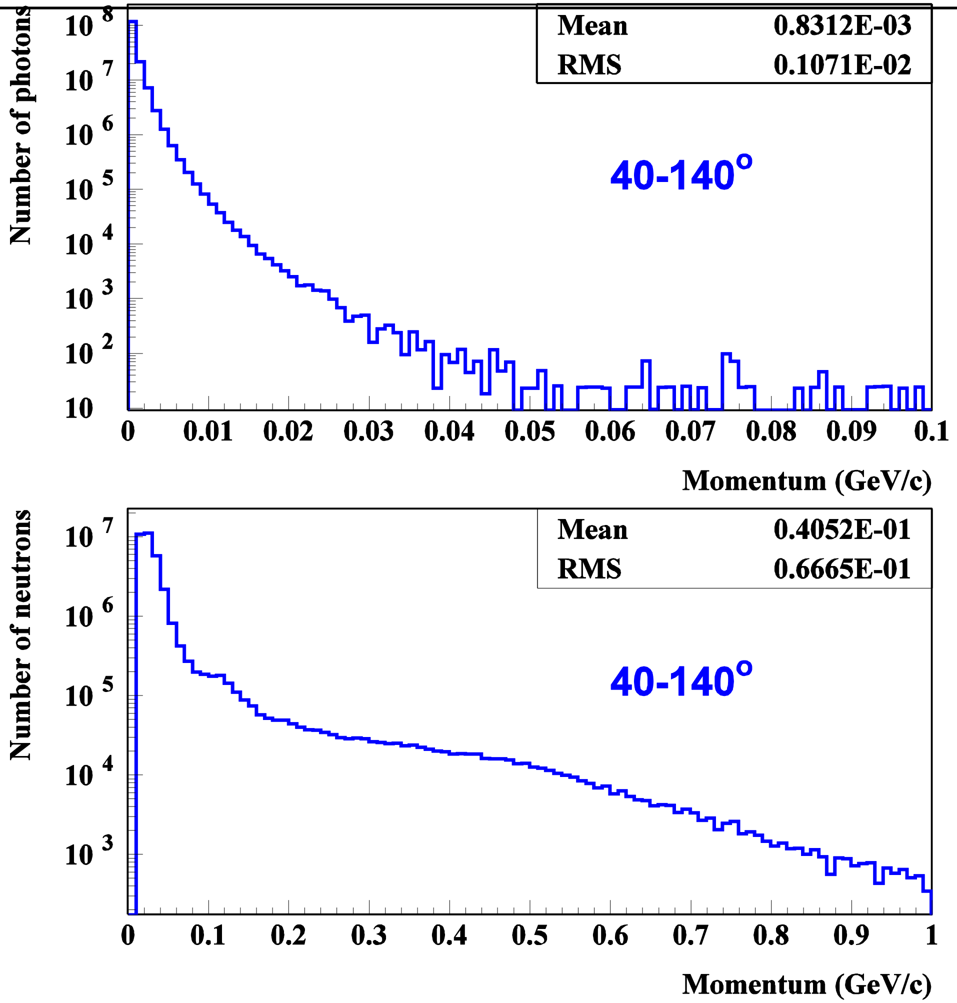
Backup

“Coming” vs visible energy

ILCroot results – energy visible in the tower, i.e reconstructed energy

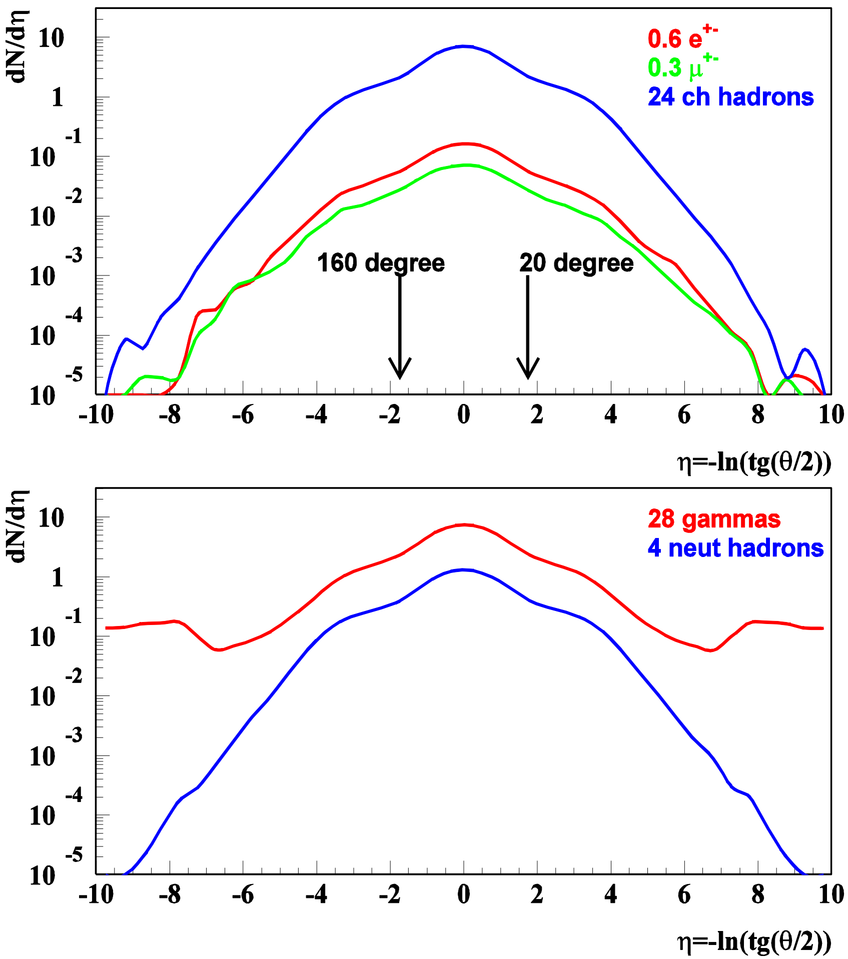
MARS results – energy coming to tower.

This energies should be close enough for energetic particles, but background particles have very low momentum.

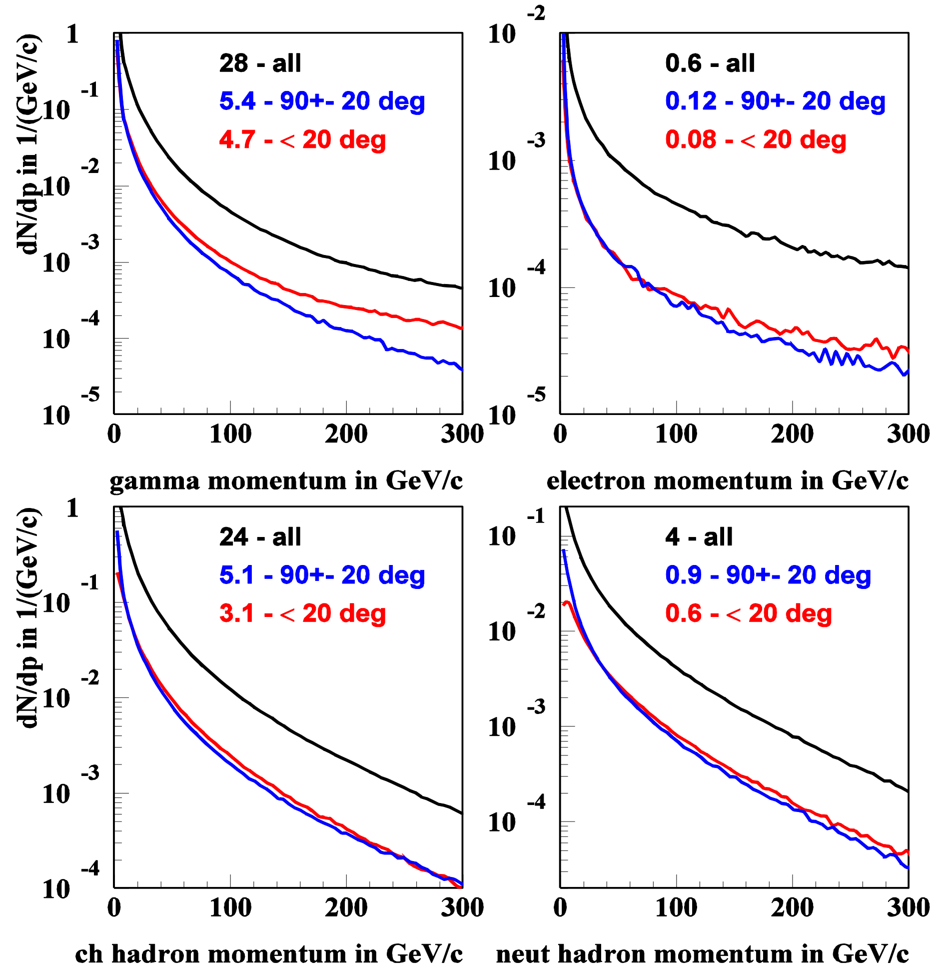


Momentum spectrum of particles coming to hadronic calorimeter

$\mu^+\mu^- \rightarrow \gamma^*/Z^0$ events
"detectable" energy - 1300 GeV

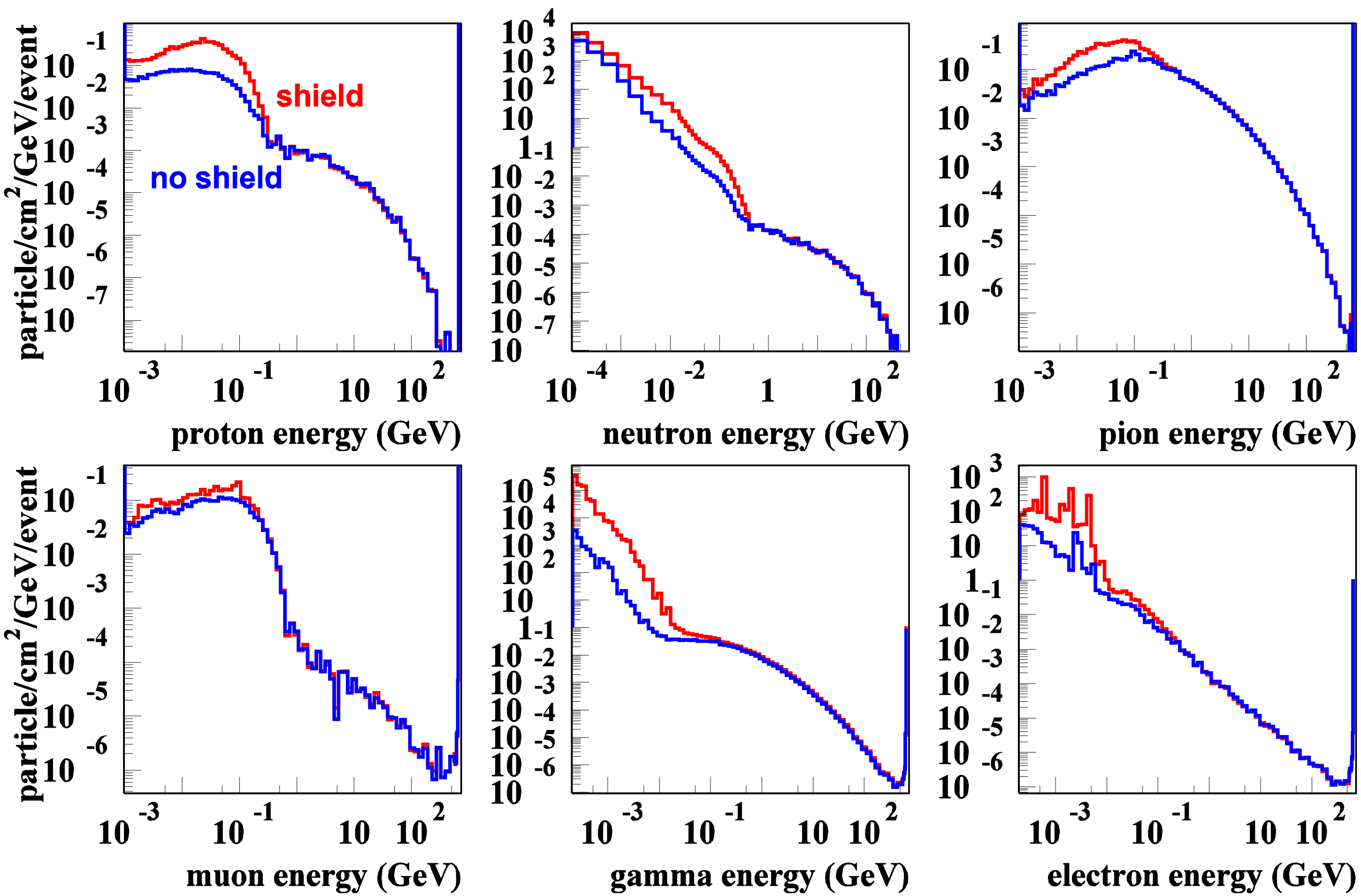


$\mu^+ \mu^- \rightarrow \gamma^*/Z^0$ at 1500 GeV (1.34 pb)



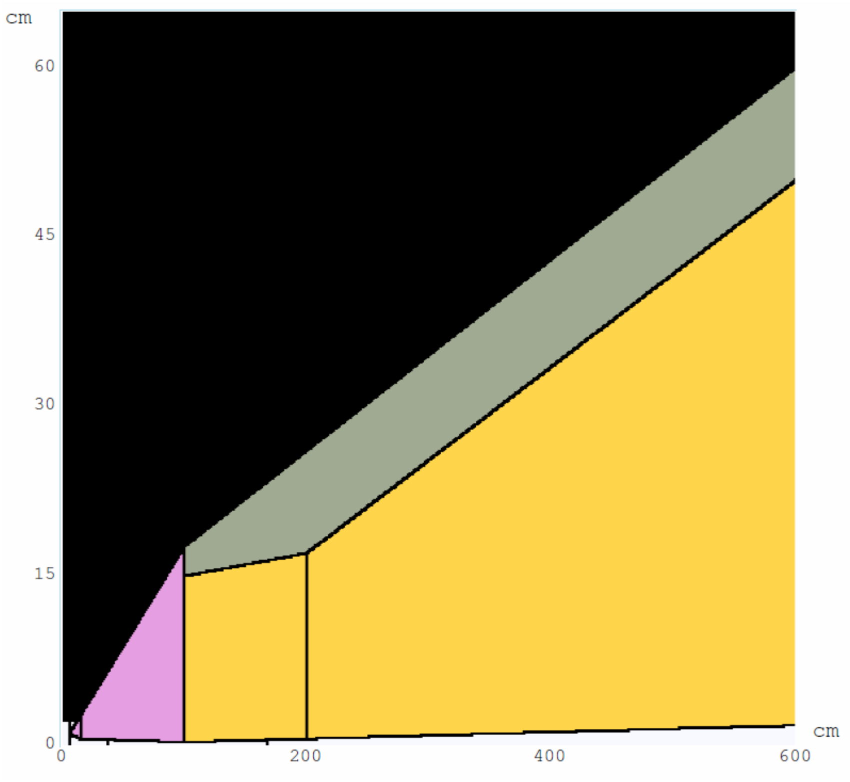
$\mu^+ \mu^- \rightarrow \gamma^*/Z^0$ at 1500 GeV (1.34 pb)

Energy spectra in tracker (+-46x46x5cm) with and without tungsten shielding

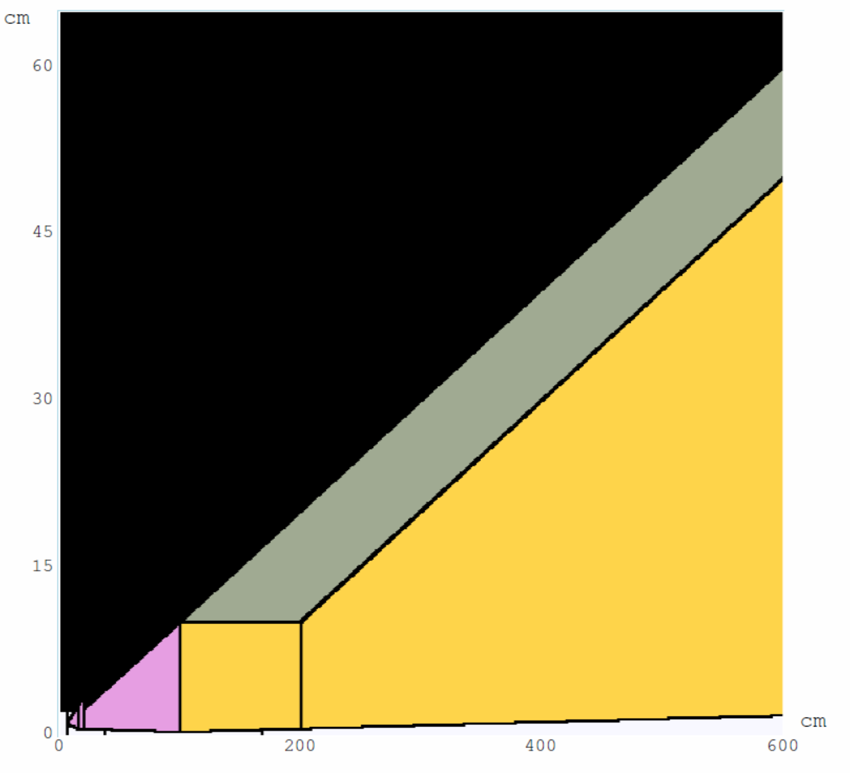


Nozzle geometry in MARS

Standard 10 degree nozzle



New nozzle



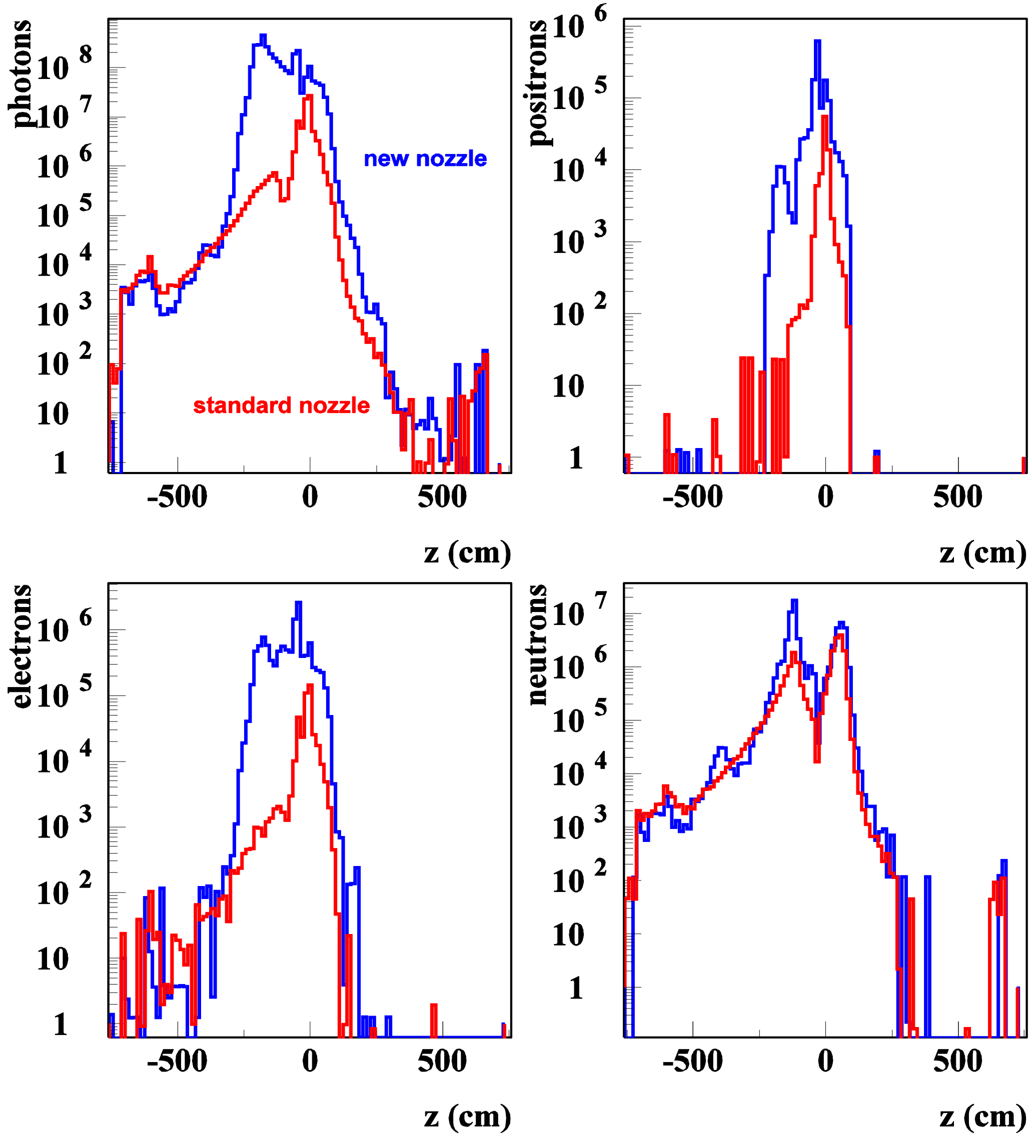
Comparison new and old shielding

Tungsten radiation length – 0.35 cm

Tungsten nuclear interaction length – 10 cm.

10 cm tungsten -29 gamma/electron interactions.

10 cm tungsten – 1 proton/neutron interaction.



Ratio new/old shielding

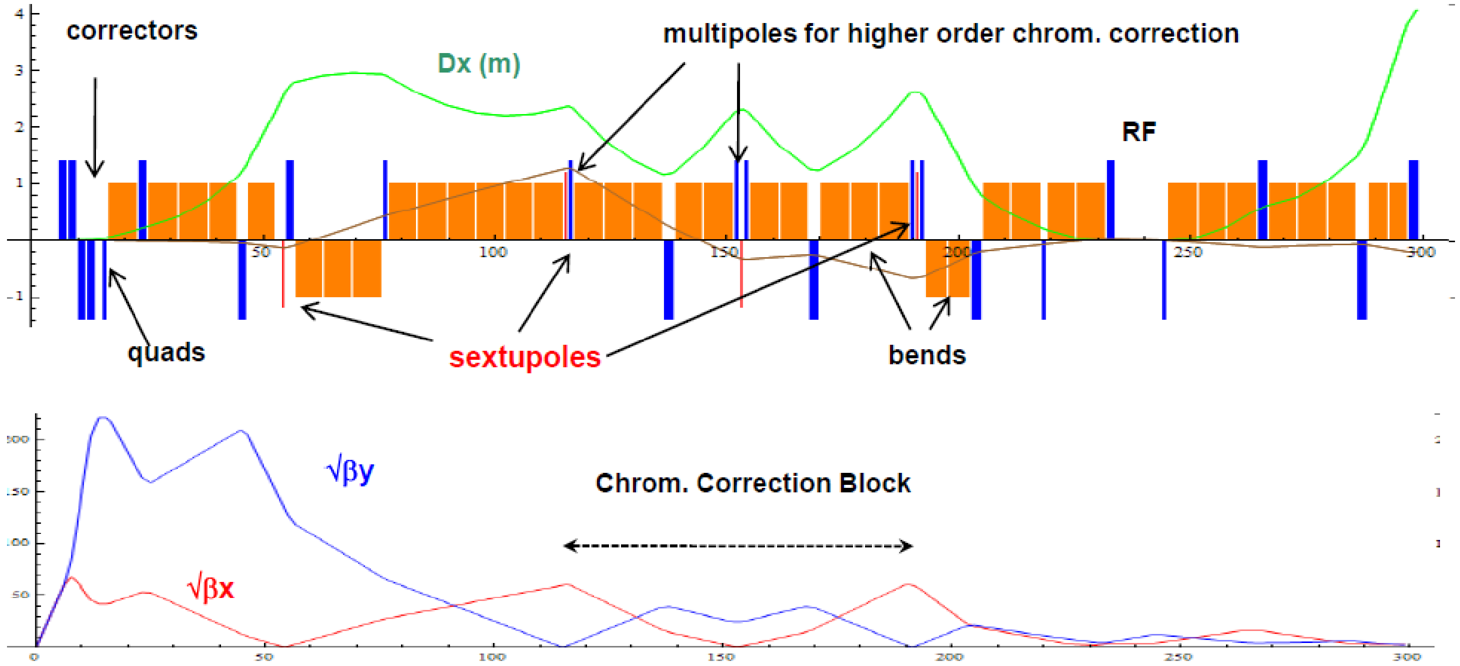
================================

	number	energy
Gamma	26	28
Positron	14	8
Electron	26	15
Muon	38	3.5
Neutron	3.2	2.2
Ch hadron	2.5	2.8

Introduction

Physics goals of a Muon Collider (MC) can only be reached with appropriate design of the ring, interaction region (IR), high-field superconducting magnets, machine-detector interface (MDI) and detector. All - under demanding requirements, arising from the short muon lifetime, relatively large values of the transverse emittance and momentum spread, unprecedented dynamic heat loads (0.5-1 kW/m) and background particle rates in collider detector.

IR & Chromatic Correction Section



8-T dipoles in IR to generate large D at sextupoles to compensate chromaticity and sweep decay products; momentum acceptance 1.2%; dynamic aperture sufficient for transverse emittance of 50 μm; under engineering constraints.

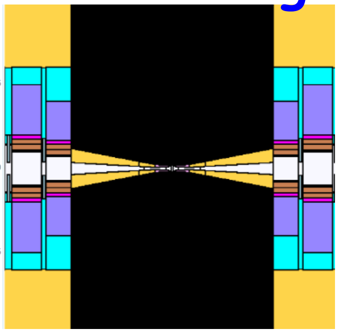
Iterative studies on lattice and MDI with magnet experts:
High-gradient (field) large-aperture short Nb_3Sn quads and dipoles.

Load to Detector: Two Nozzles

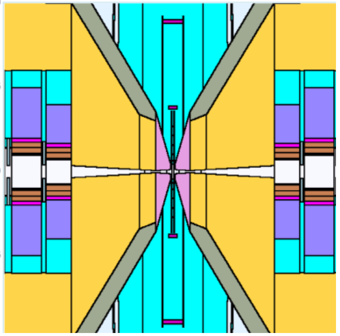
Number of particles per bunch crossing entering detector, starting from MARS source term for S_{max}=75m

Particle	Minimal 0.6-deg	10-deg
Photon	1.5×10^{11}	1.8×10^{8}
Electron	1.4×10^{9}	1.2×10^{6}
Muon	1.2×10^{4}	3.0×10^{3}
Neutron	5.8×10^{8}	4.3×10^{7}
Charged hadron	1.1×10^{6}	2.4×10^{4}

0.6-deg



10-deg



No time cut applied, can help substantially
All results below are presented for 10-deg nozzle

** MU+ 10 deg exc all (ICEM 4=2 !!!!) BIAS 3=-23.18 24*2e4 decays -25 to 1 m 2.e4= 58:10:22 -- 77:17:40

4800	76.7161832543768	0.112077905663565	8.39060561377955	84.9132435508737	2.88009394307052	calo
4800	12.3905147243018	53.0328180018331	70.7134074725628	11.9840631156813	97.6362312105334	calo rms/m*sqrt(nd)

4800	82.3254643888752	2.90338306651510	14.6216299178616	87.0786474921861	6.217	source
4800	12.1989224282923	18.5235672560626	53.4342619232943	11.6513173575062	59.54	sourcrms/m*sqrt(nd)

4800	173.012204267764	calo tot
4800	9.86809889579672	rms/m*SQRT(ND)

ND=480000*23 ==> RMS/MEAN = 2.97E-3

Outline

- Introduction
- Background Sources
- MDI and Background Load Modeling
- Main Characteristics of Backgrounds