MACHINE-INDUCED BACKGROUNDS: THEIR ORIGIN AND LOADS ON ATLAS/CMS

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Workshop on Experimental Conditions and
Beam-Induced Detector Backgrounds
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OUTLINE

- Introduction
- Sources of Machine-Induced Backgrounds and MARS15 Modeling
- Beam-Gas & Beam-Halo: Side by Side Comparison
- Sum Rules for ATLAS and CMS
- Modeling in the Detector
- Summary

INTRODUCTION

Compared to the luminosity-driven backgrounds at the IPs, machine-induced backgrounds (MIB) are less studied, their characteristics vary in a broader range, and – at a low luminosity – they can be a serious issue. The collimation system takes care of "slow" losses with a very high efficiency (as expected, see also the Tevatron experience). But still three following components form the MIB at the detectors:

1. Any remnants of a missteered beam uncaptured in the IP6 beam dump system.
2. Tertiary halo generated in the IP3 and IP7 collimation systems ("cleaning inefficiency").
3. Products of beam-gas interactions in straight sections and arcs upstream of the experiments and after the cleaning insertions.

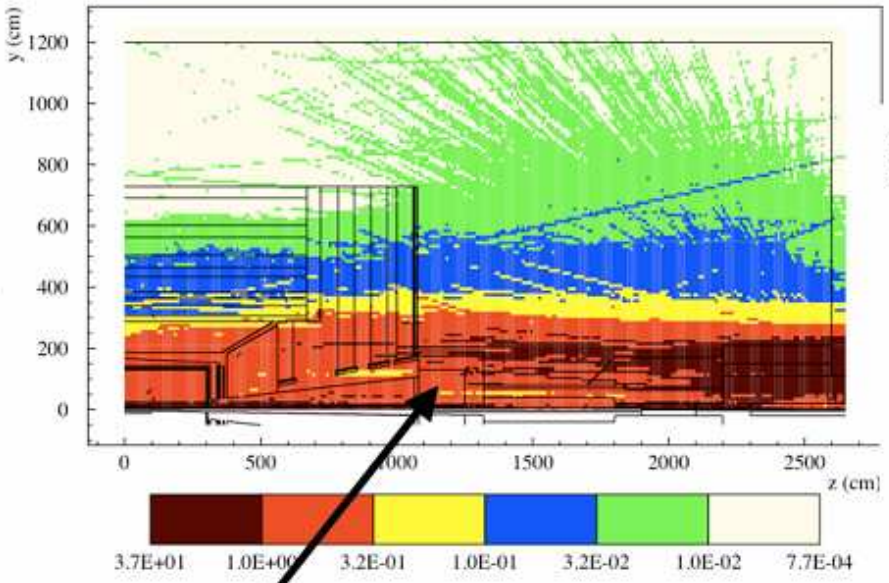
The code and approach successfully benchmarked over 15 years at Tevatron, D0, and CDF

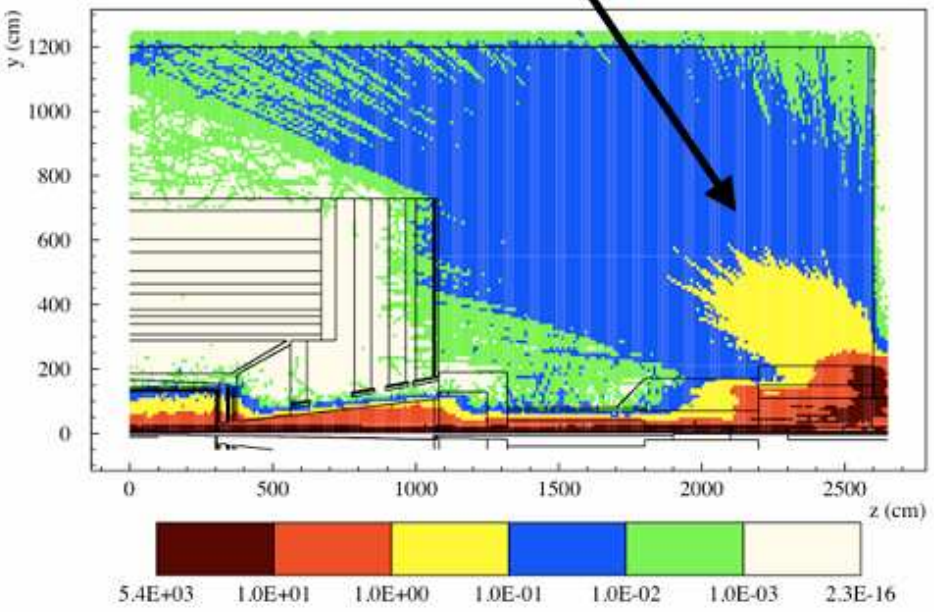
First Complete Studies of Machine Backgrounds at LHC

First complete study in 1996 by Mokhov, Drozhdin and Huhtinen: NIM A 381 (1996) 531

Introduced the concept of "interface plane" at ~26m
(here detector simulations can take over from machine)

request to block tunnel entry
(to stop hadron & Em halo)
Request to never have beam
without TAS present





muons not an occupancy issue
-(compared to pp-background @ 1E34)

Effect on CMS and IP5 SC magnets of a kicker prefire studied first by MDH in 1999

Beam Losses in IP1/IP5 at 7 TeV

1. Betatron cleaning in IP7 for BEAM1 and BEAM2

- *Nominal 10-hr beam life time: 8.3e9 p/s*
- *Transient 0.22-hr beam life time: 3.78e11 p/s*

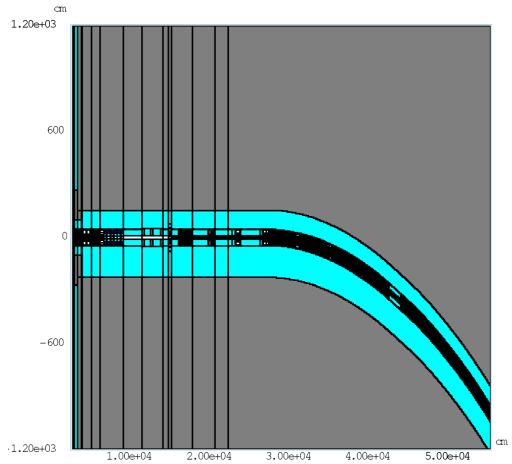
This results in BEAM2 loss rates on IP5 TCTs of 2.12e6 p/s and 9.67e7 p/s, respectively (referred as BH below). Momentum cleaning not considered yet.

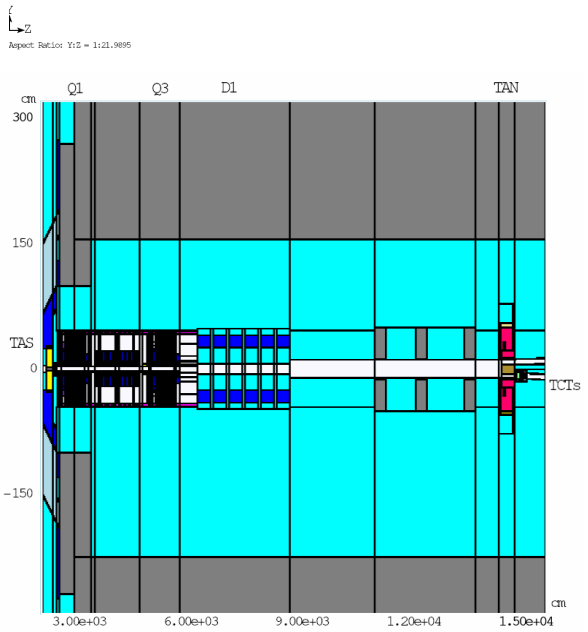
2. Elastic and inelastic nuclear interactions of the beam with gas in the beam pipe in a 550-m region upstream IP1/IP5, 2808 bunches nominal: pressure map → nuclear interaction distribution; 2.23e6 p/s total in the region (referred as BG below).

MIB in IP1/IP5: MARS15 Modeling

- Machine, interface and related detector elements in ± 550 m from IP1 and IP5: 3-D geometry, materials, magnetic fields, tunnel and rock outside (up to 12 m laterally).
- Tungsten tertiary collimators TCTV and TCTH at 145.34 and 147.02 m from IP, respectively, aligned wrt BEAM2 coming to IP5 and BEAM1 coming to IP1.
- First source: tails from betatron cleaning in IP7 – files of proton hits in TCTs for BEAM1 and BEAM2 from Tom Weiler.
- Second source: beam-gas interactions of BEAM2 at 0 to 550-m from IP5 using gas pressure map from A. Rossi and M. Huhtinen

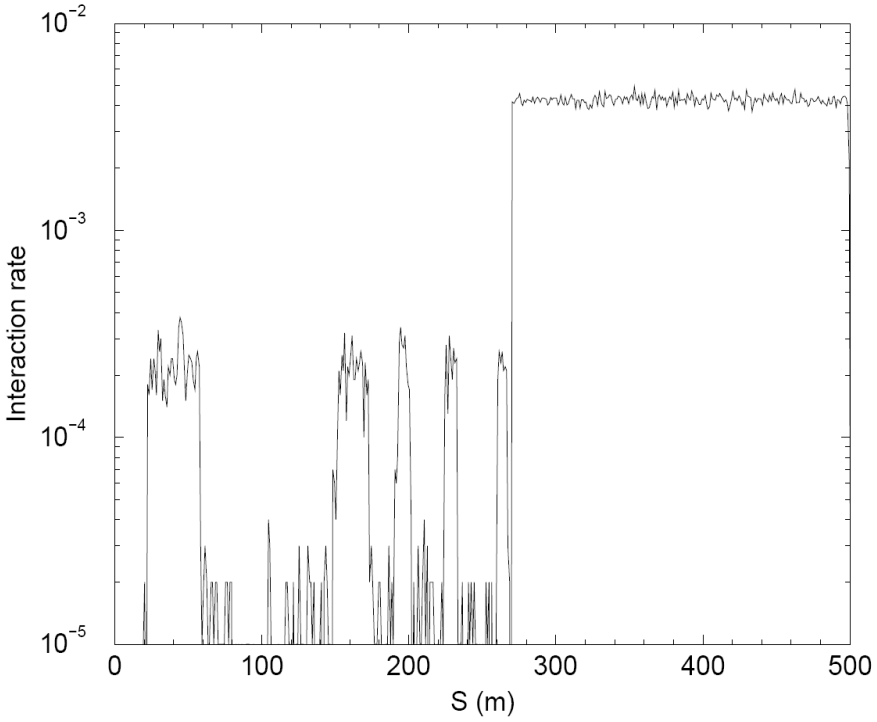
- MARS15 calculations: power density and dynamic heat loads in inner triplet quads, absorbed and residual doses in the entire region, and particle scoring at z=22.6 m at CMS and ATLAS.

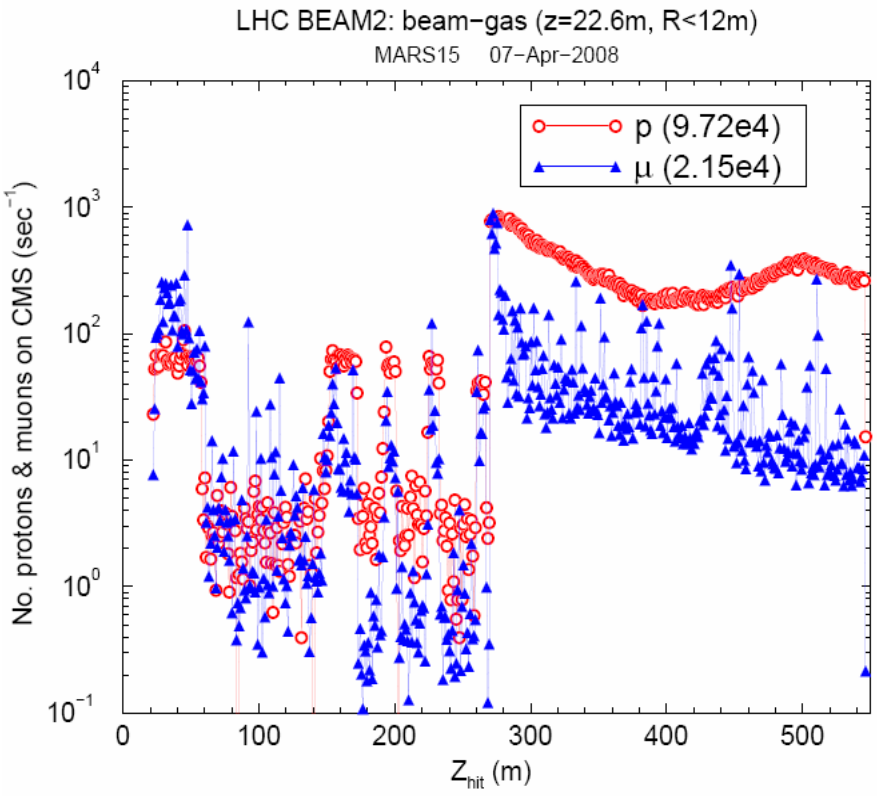




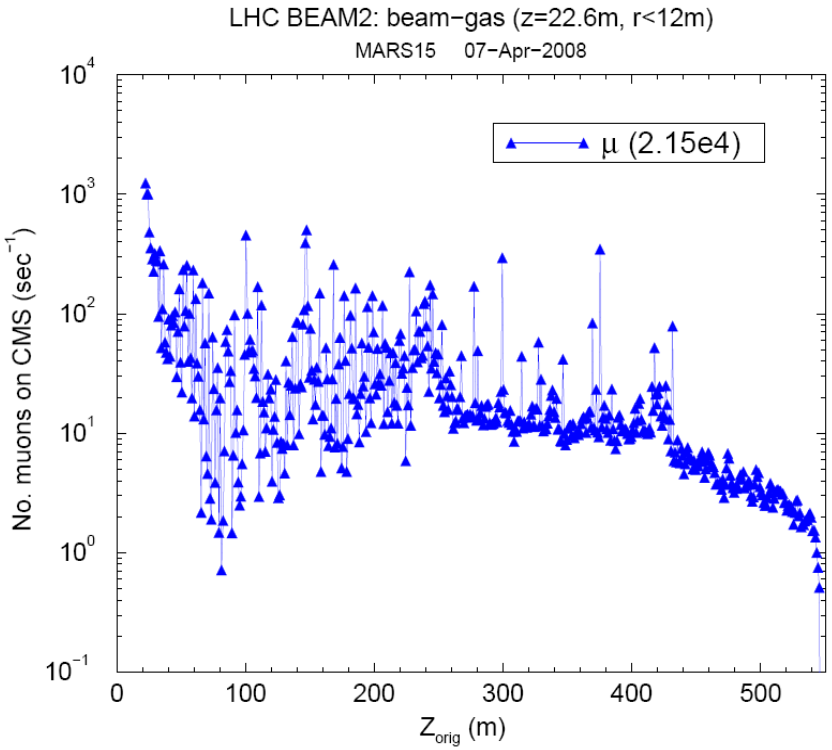
Beam-Gas: Pressure and First-Hit Distributions

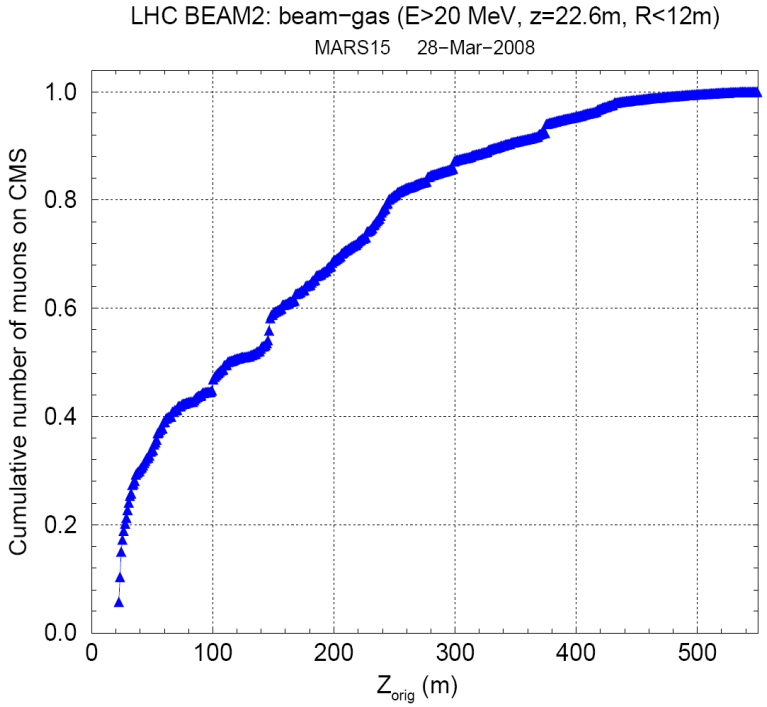
Pressure maps from A. Rossi,
LHC Project Note 783,
implemented by M. Huhtinen (2005)



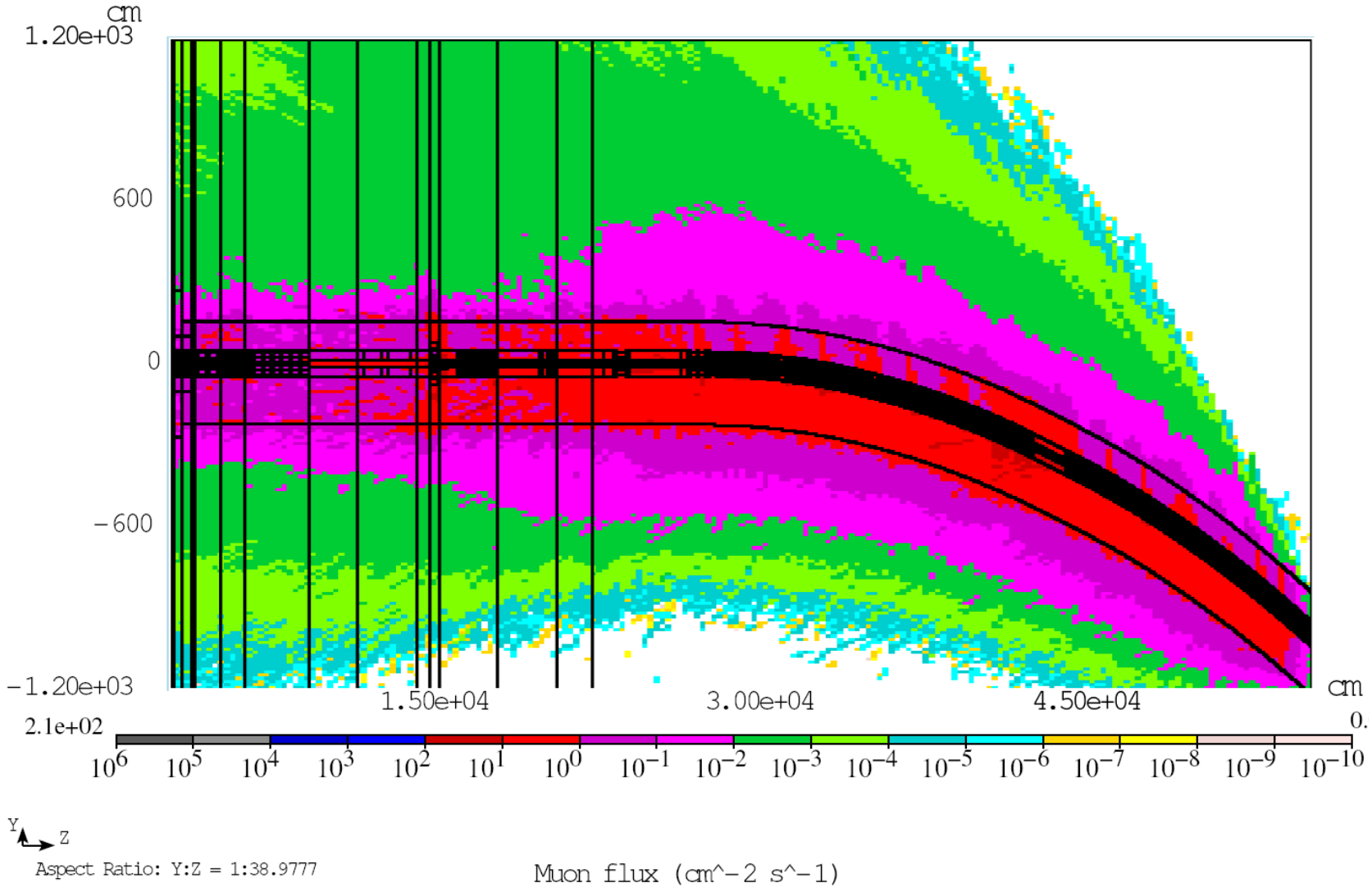


Beam-Gas: z-origin of IP1/IP5 Muons



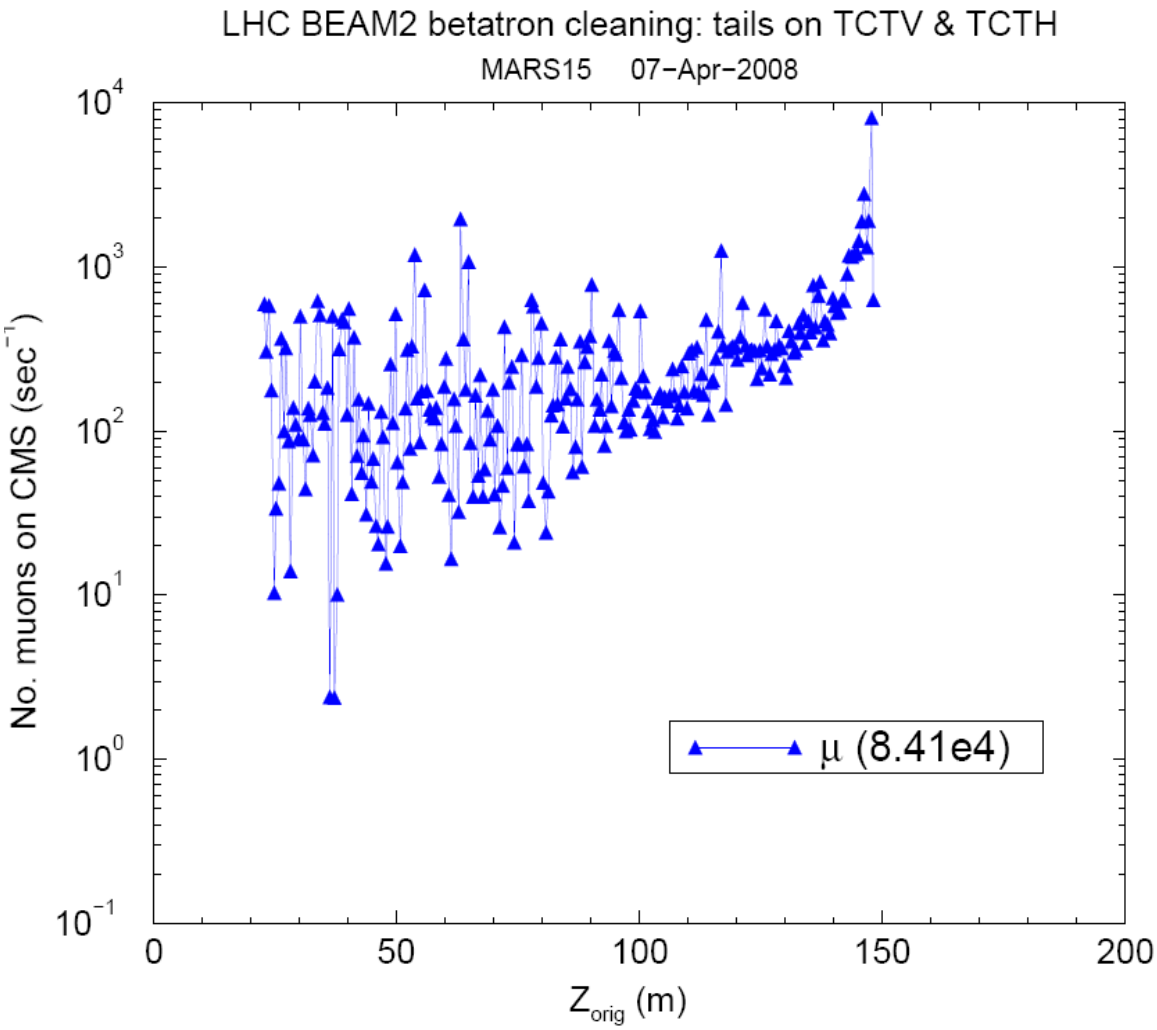


Beam-Gas: Muon Flux Isocontours 20-550 m Upstream IP1/IP5

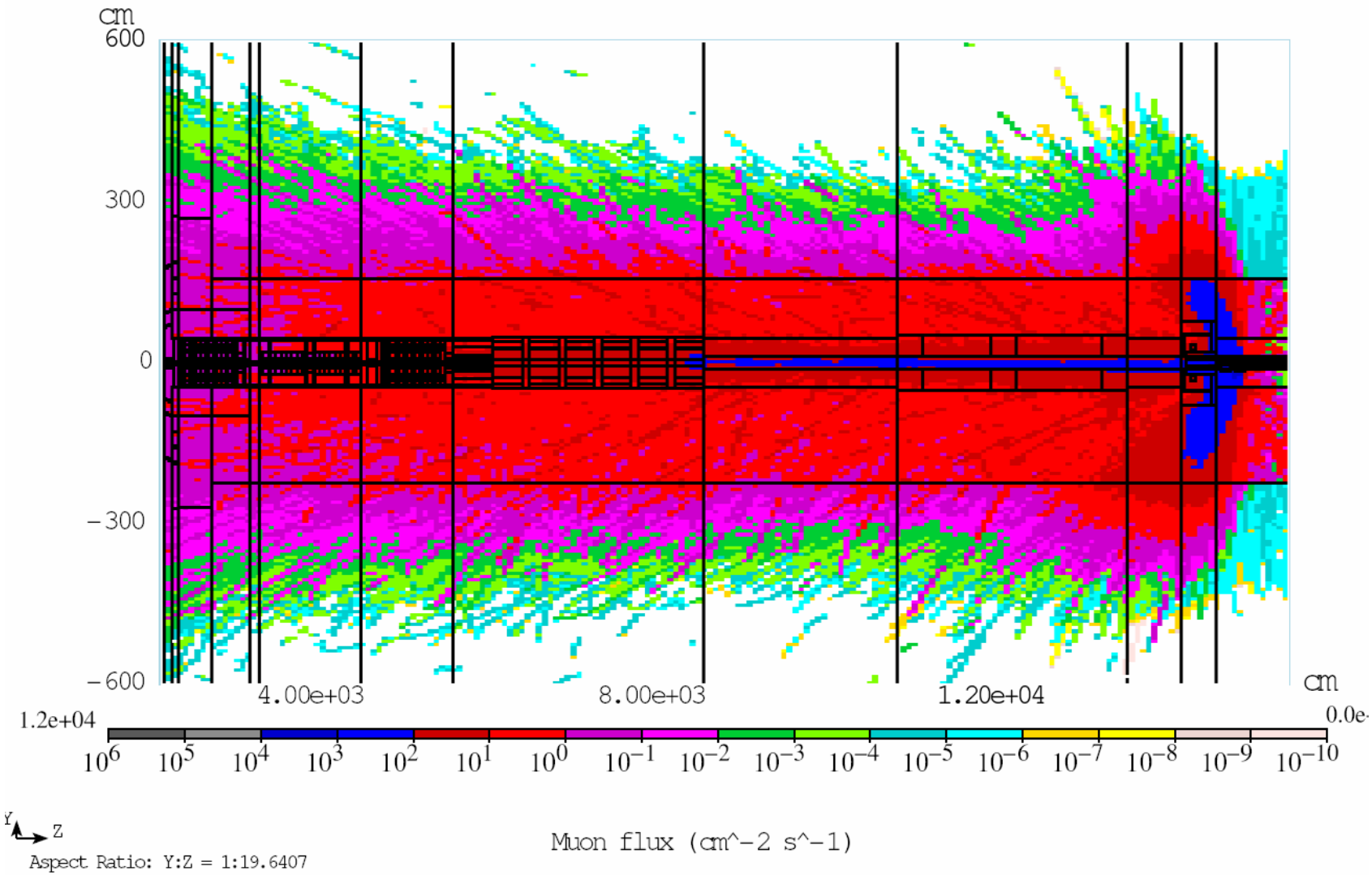


Beam-2 Halo: z-origin of IP5 Muons

Files of protons on the IP1 & IP5 tertiary collimators provided by T. Weiler for the case of betatron cleaning



Beam-2 Halo: Muon Flux Isocontours 20-150 m Upstream IP5

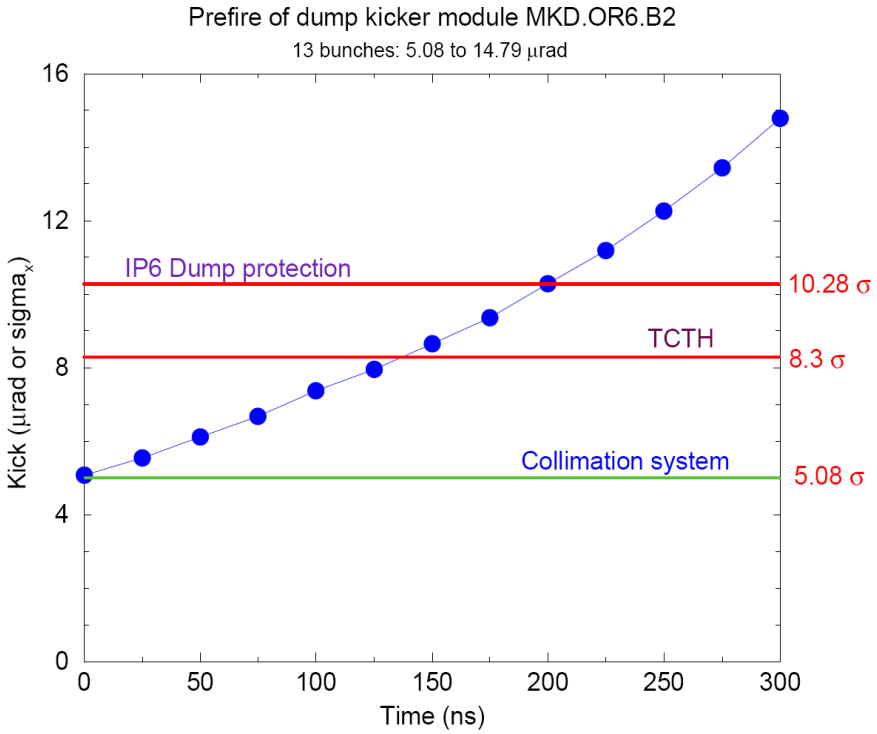


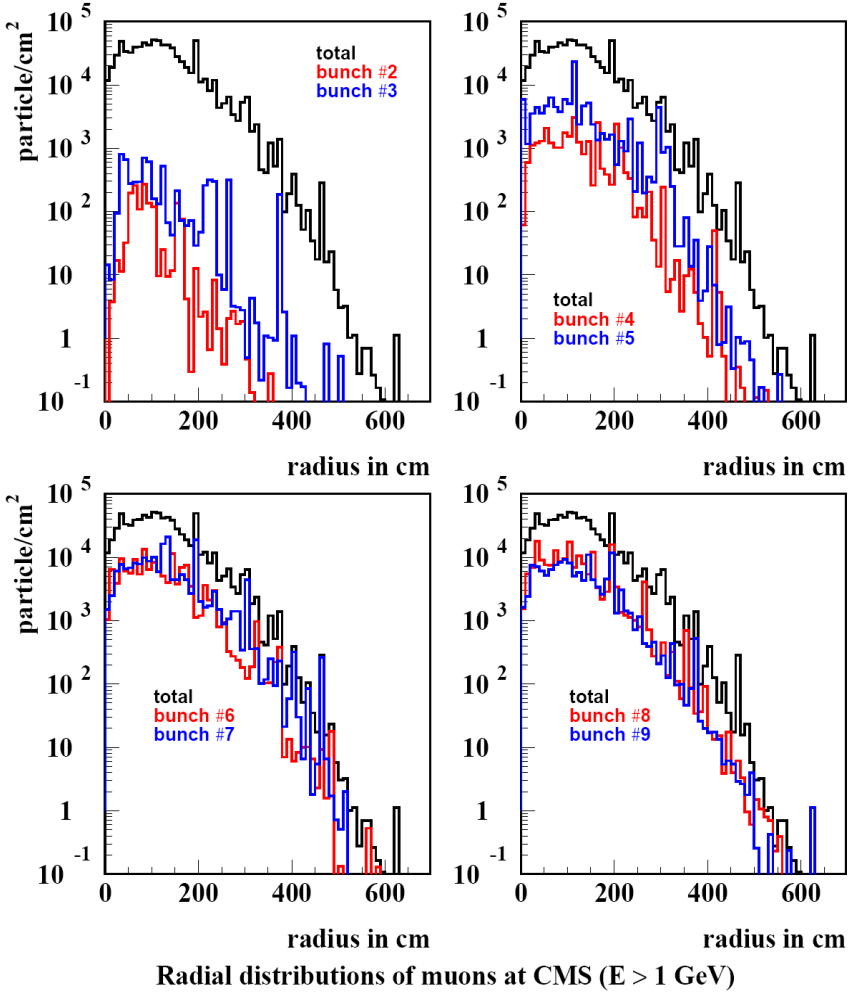
"FAST EVENTS" (not a subject of this talk)

1. Prefire of one of the beam dump kicker modules in the IP6. Nine non-intercepted bunches (5 to 10.3 sigma) of can make to the IP1/IP5, and be lost in the low-beta region or detector, if not protected by tertiary collimators at ~148 m from the IP.
2. Single-pass beam-gas interactions (nuclear elastic scattering) between the IP3 and IP7 cleaning insertions and 550-m regions upstream IP1 and IP5 considered in this study (all processes are considered in these regions).

   Tertiary collimators as the last line of defense are mandatory in colliders as proven at the Tevatron (certainly for these two processes).

Kicker Prefire: Bunch Loss in IP5 and Muons on CMS





MARS15 studies – with input from T. Weiler - just finished. Not a subject of this workshop.

MIB MARS15 Modeling

Beam-gas and Beam-halo backgrounds:

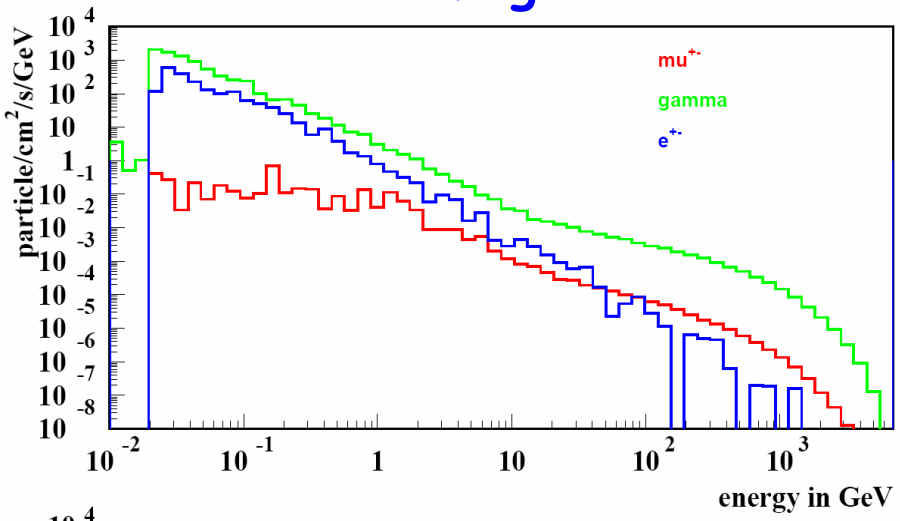
Side-by-Side Comparison

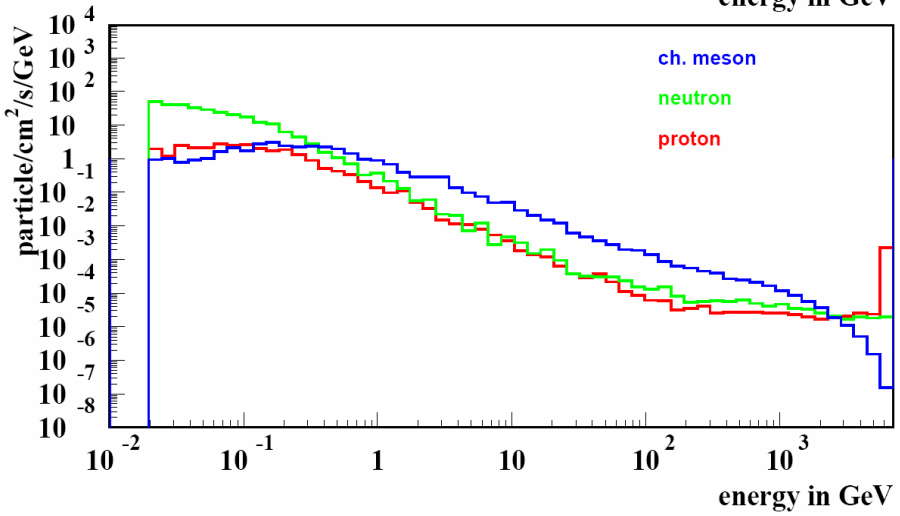
for Beam-2 at IP5

Sum rules for the total loads on ATLAS and CMS are given afterwards

Energy Spectra at 0 < r < 1.7 cm

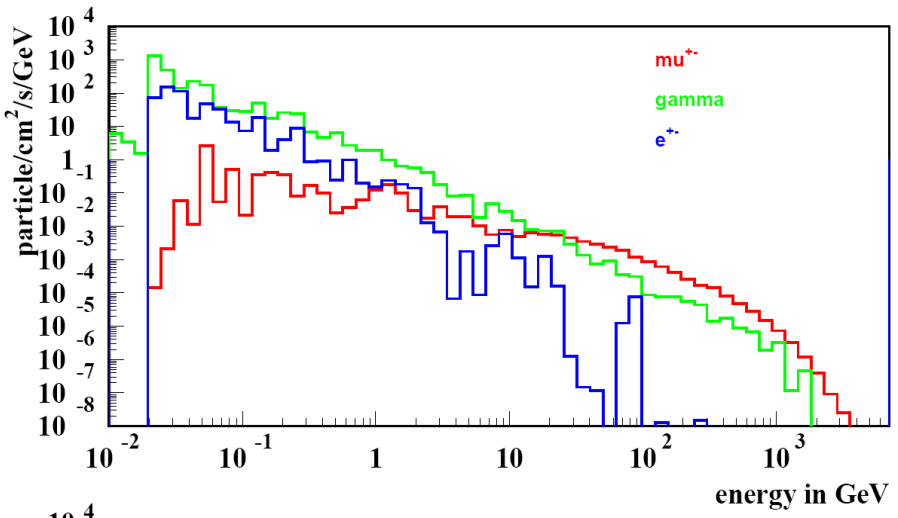
Beam-gas

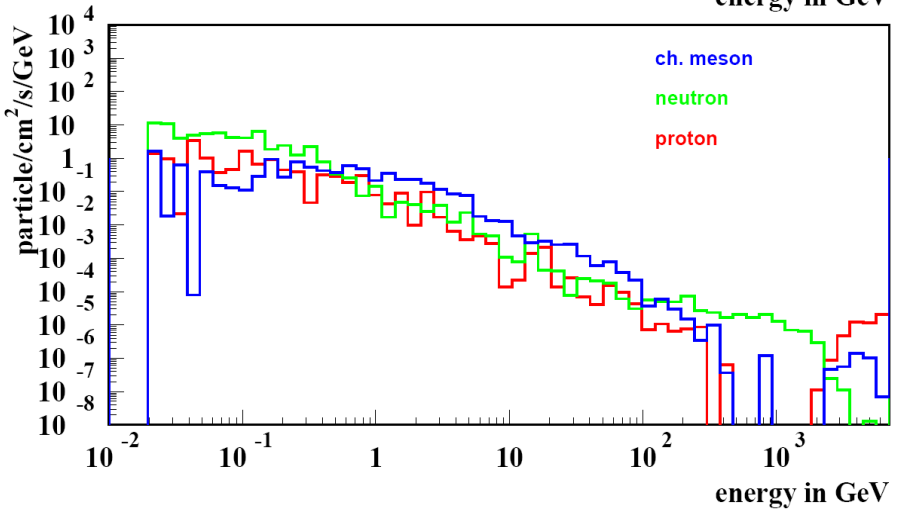




Energy spectra at CMS (0 < r < 1.7 cm): beam-gas, MARS15

Beam-halo

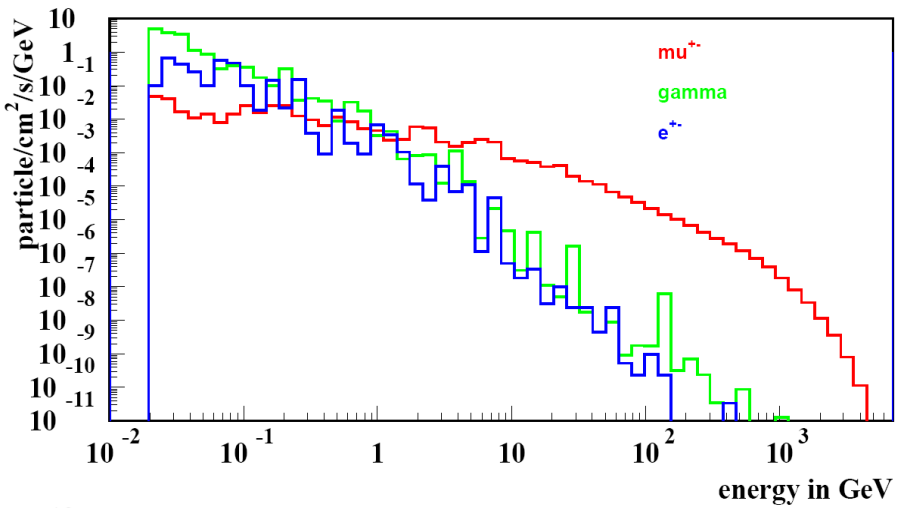


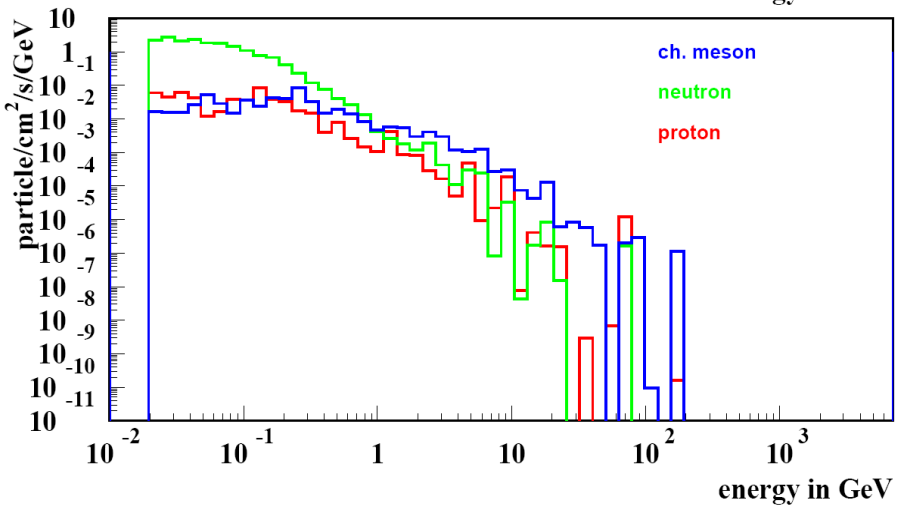


Energy spectra at CMS (0 < r < 1.7 cm): beam-halo, MARS15

Energy Spectra at 1.7 < r < 100 cm

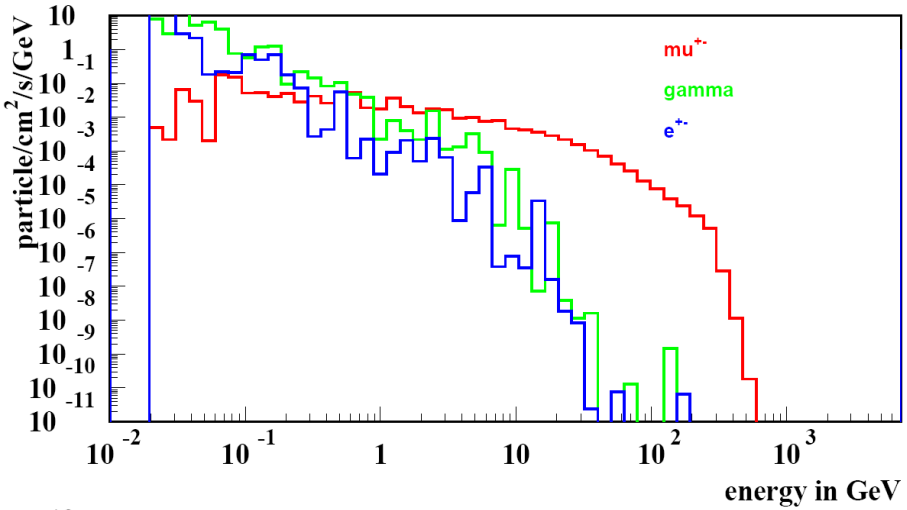
Beam-gas

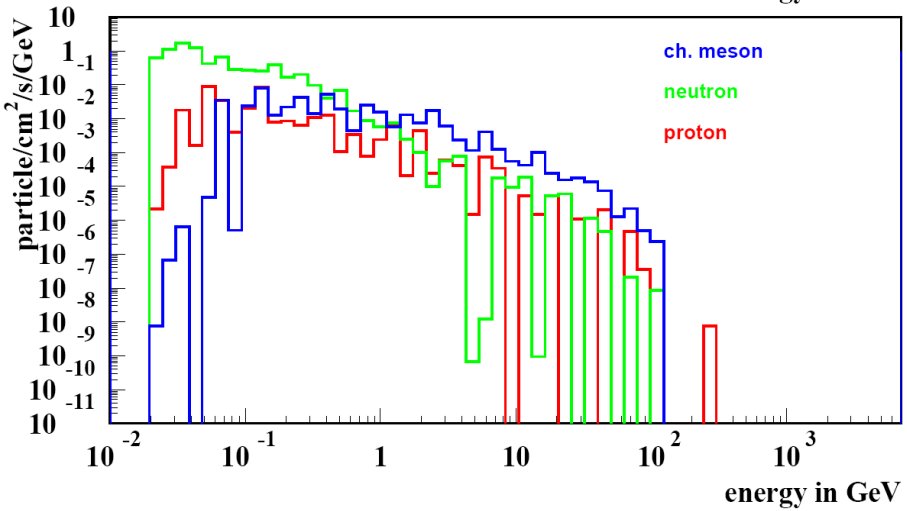




Energy spectra at CMS (1.7 < r < 100 cm): beam-gas, MARS15

Beam-halo

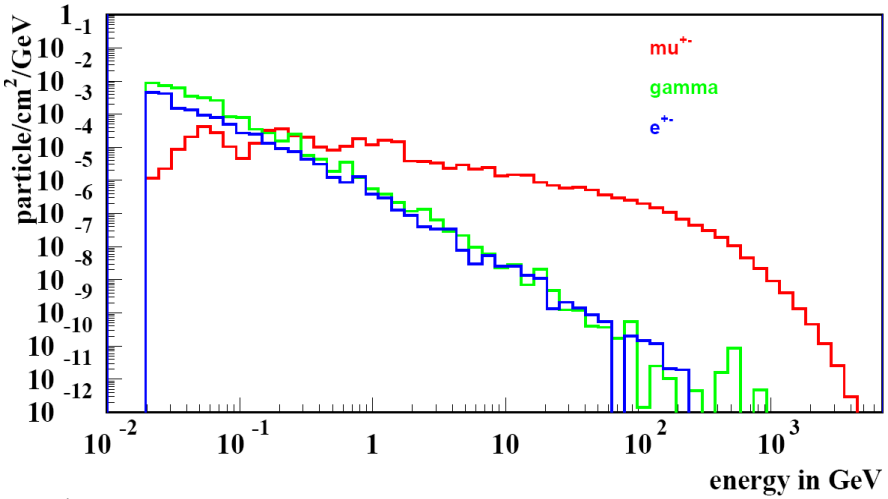


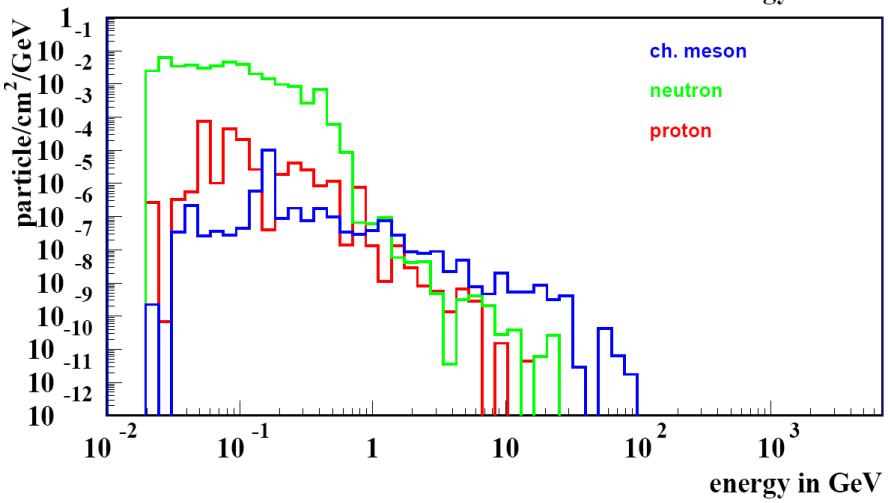


Energy spectra at CMS (1.7 < r < 100 cm): beam-halo, MARS15

Energy Spectra at 100 < r < 300 cm

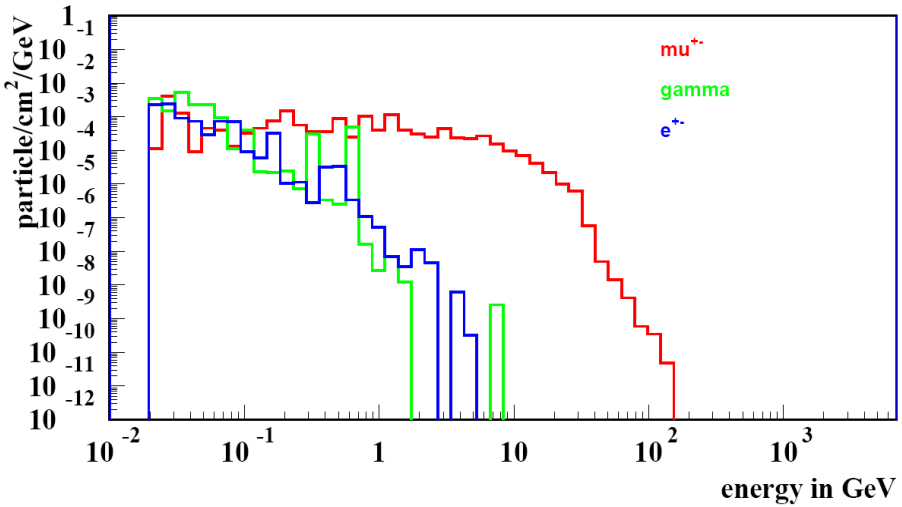
Beam-gas

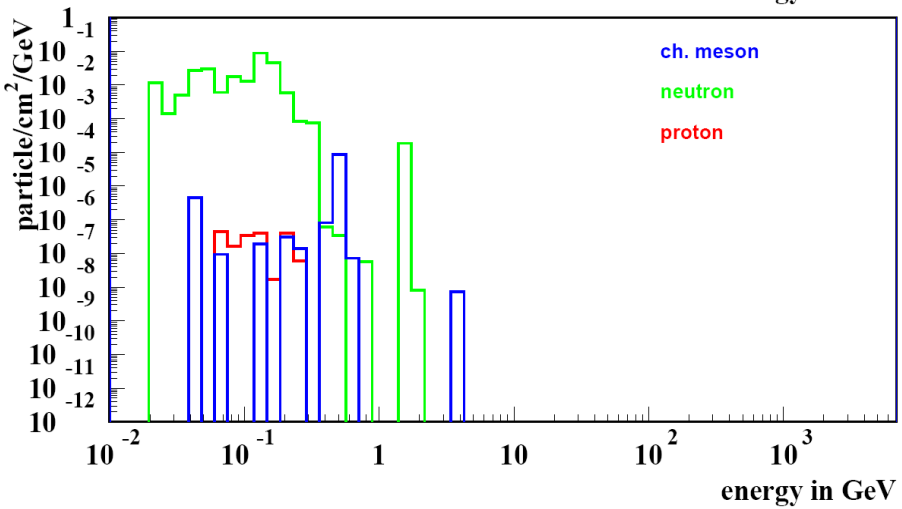




Energy spectra at CMS (100 < r < 300 cm): beam-gas, MARS15

Beam-halo

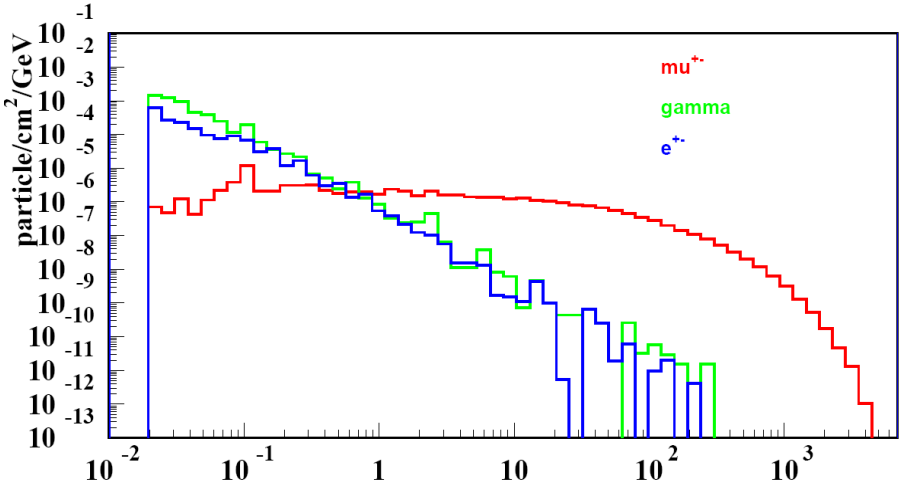


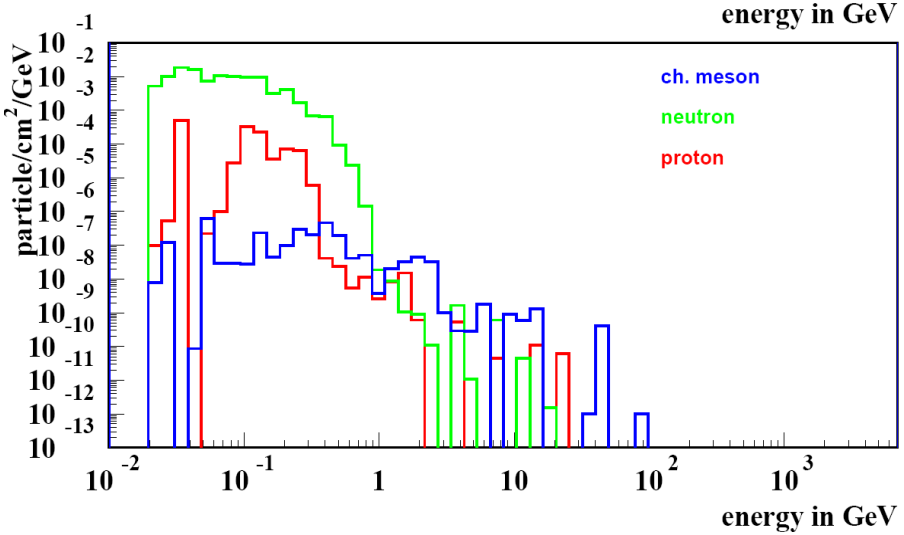


Energy spectra at CMS (100 < r < 300 cm): beam-halo, MARS15

Energy Spectra at 300 < r < 700 cm

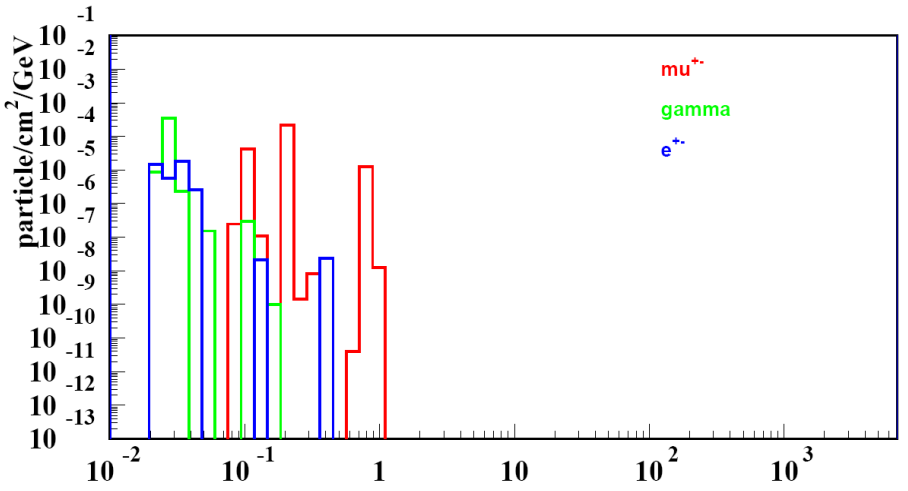
Beam-gas

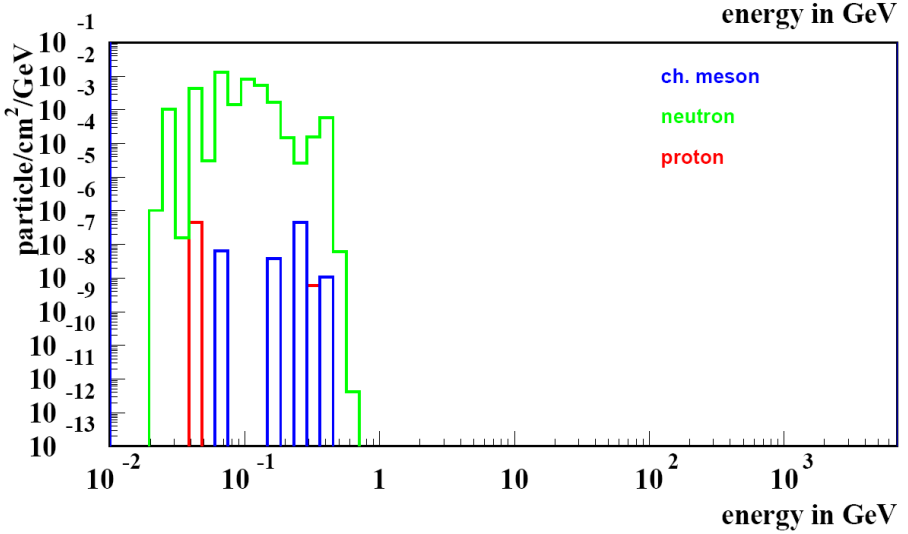




Energy spectra at CMS (300 < r < 700 cm): beam-gas, MARS15

Beam-halo

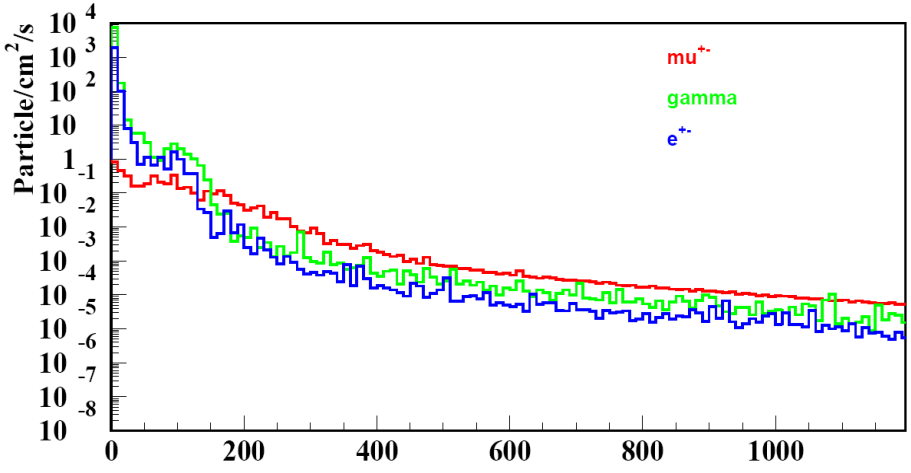


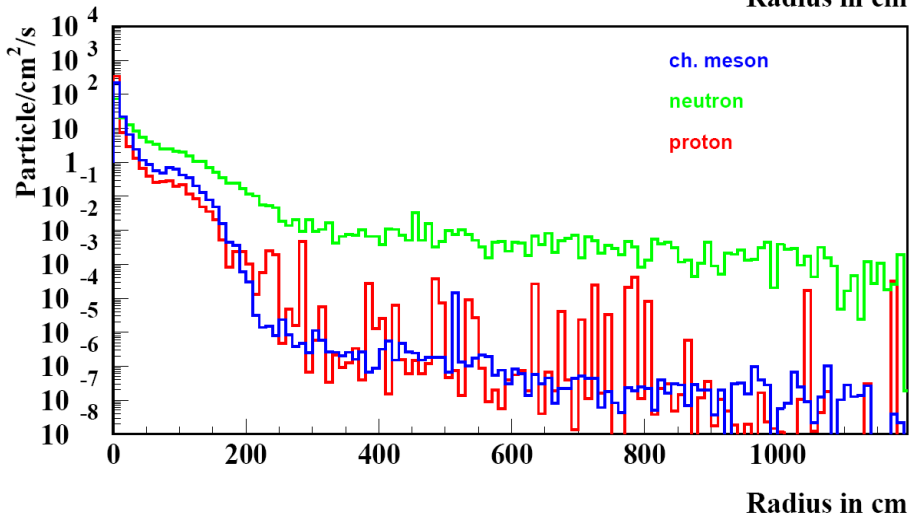


Energy spectra at CMS (300 < r < 700 cm): beam-halo, MARS15

Particle Radial Distributions

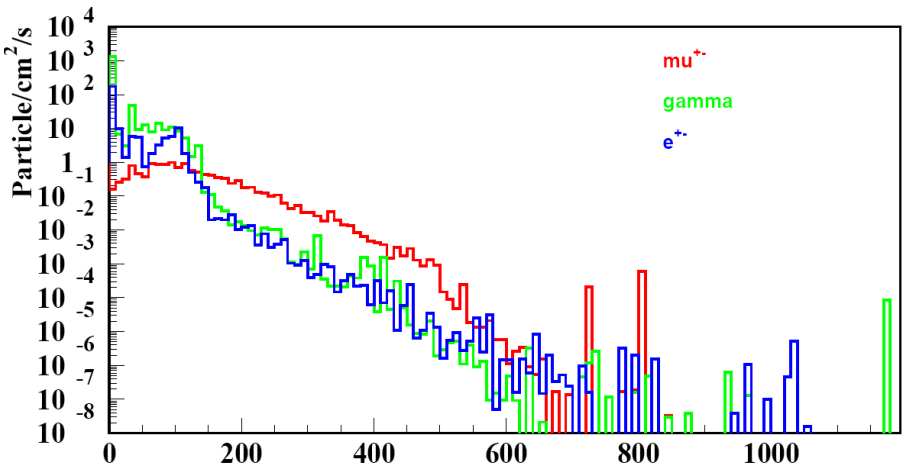
Beam-gas

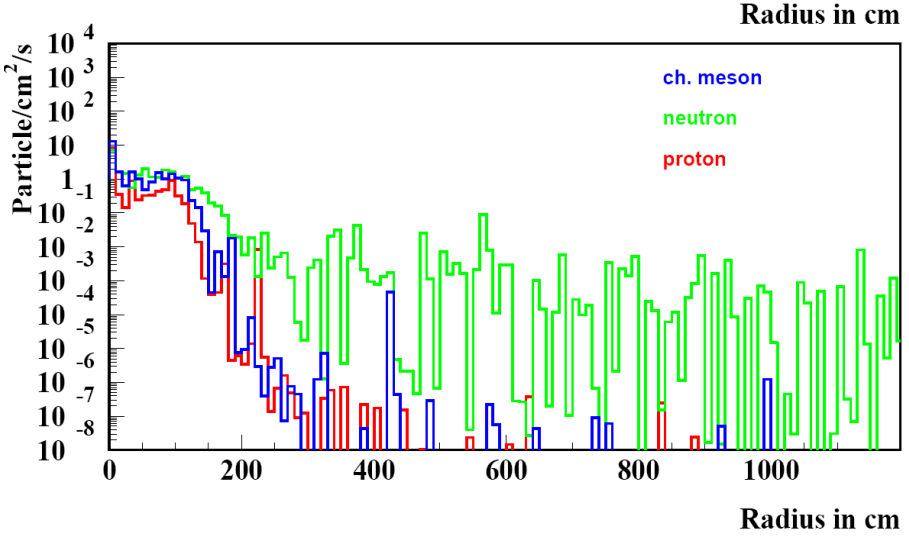




Radial distributions at CMS (E > 0.02 GeV): beam-gas, MARS15

Beam-halo

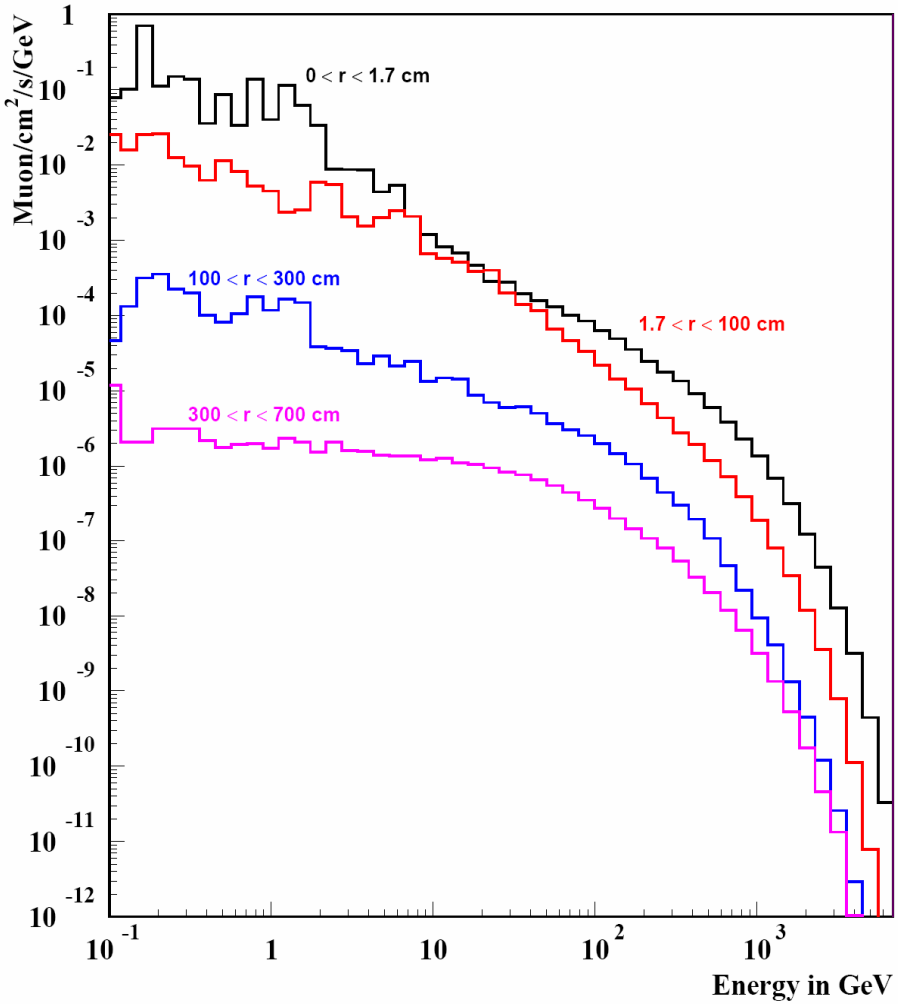




Radial distributions at CMS (E > 0.02 GeV): beam-halo, MARS15

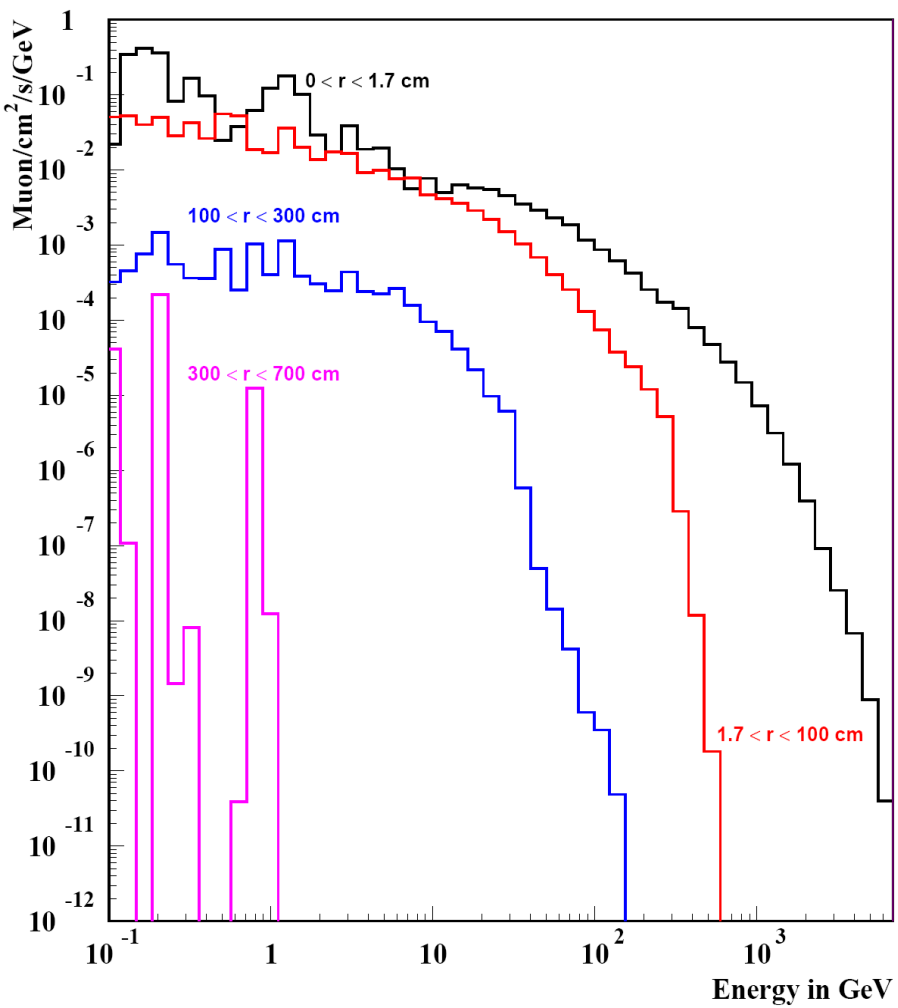
Muon Energy Spectra in 4 Radial Regions

Beam-gas



Muon energy spectra at CMS: beam-gas, MARS15

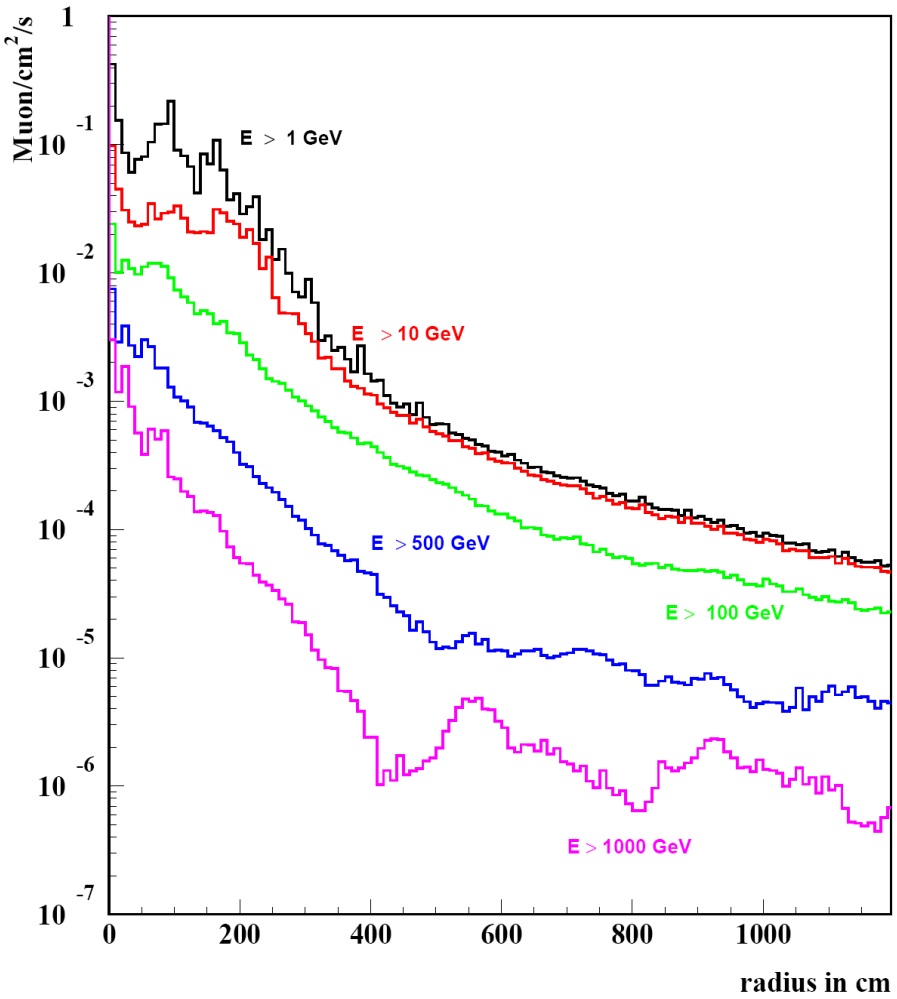
Beam-halo



Muon energy spectra at CMS: beam-halo, MARS15

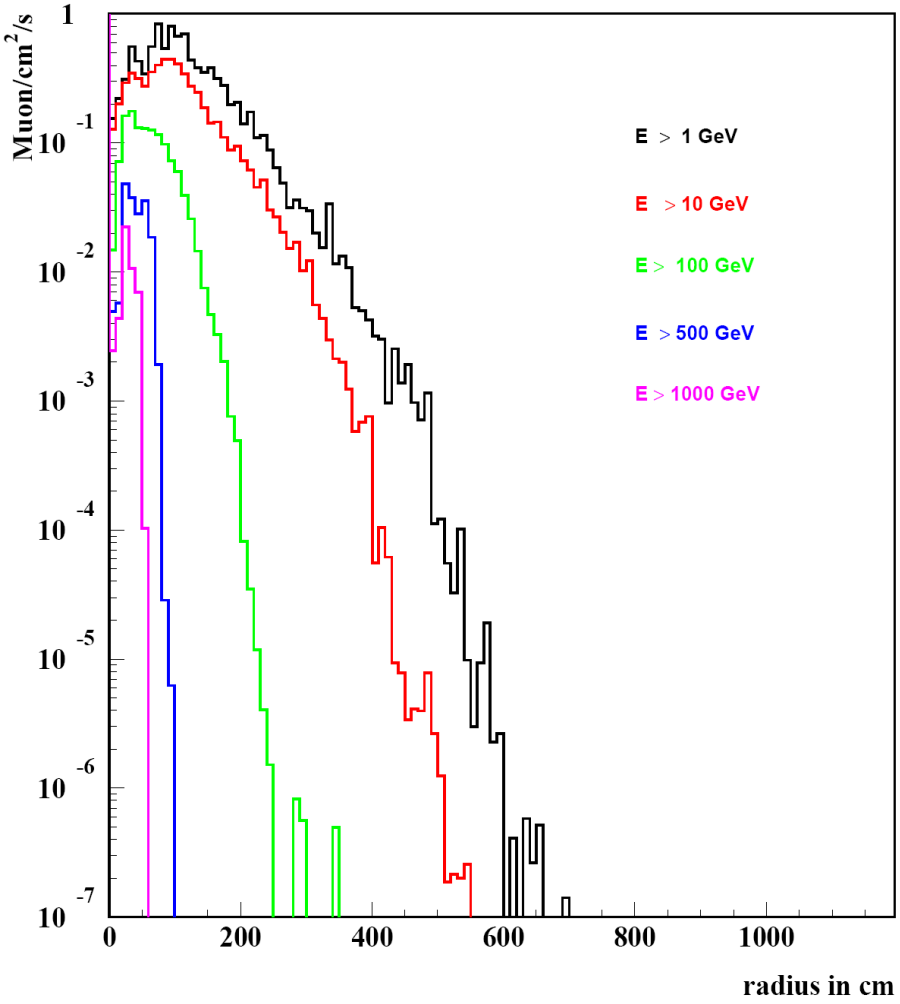
Muon Radial Distributions for 5 Energy Cutoffs

Beam-gas



Muon radial distributions at CMS: beam-gas, MARS15

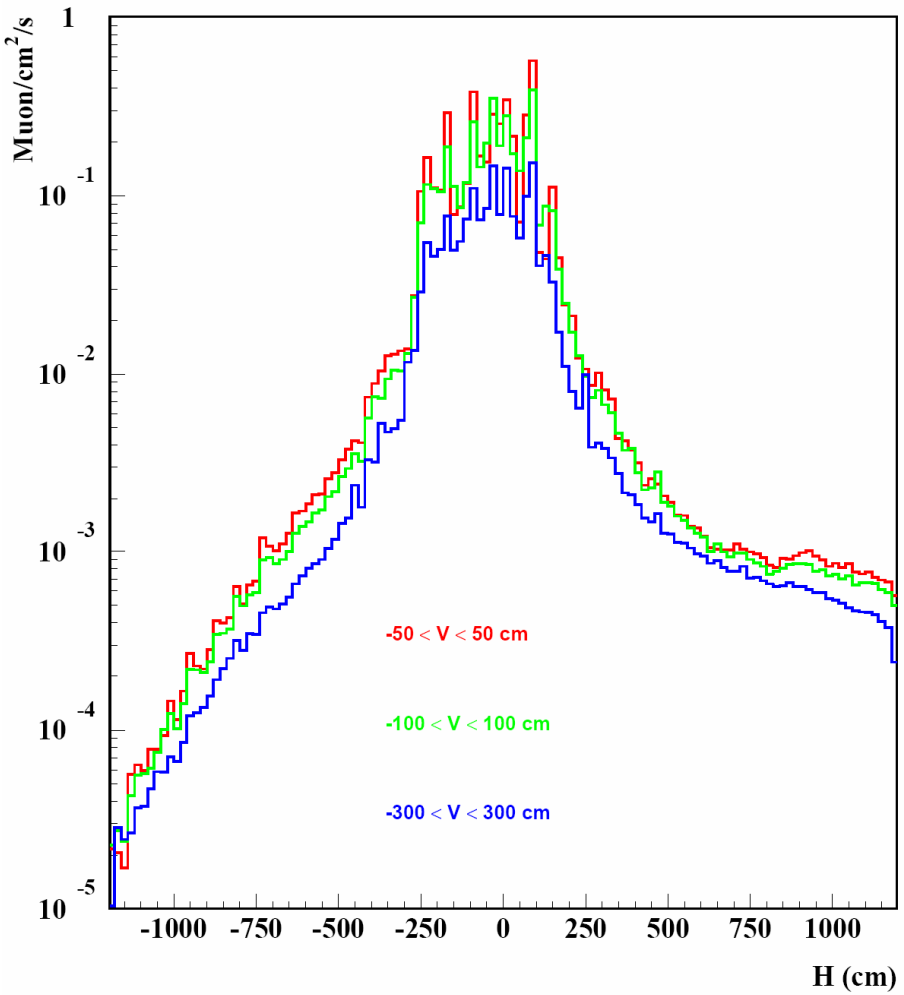
Beam-halo



Muon radial distributions at CMS: beam-halo, MARS15

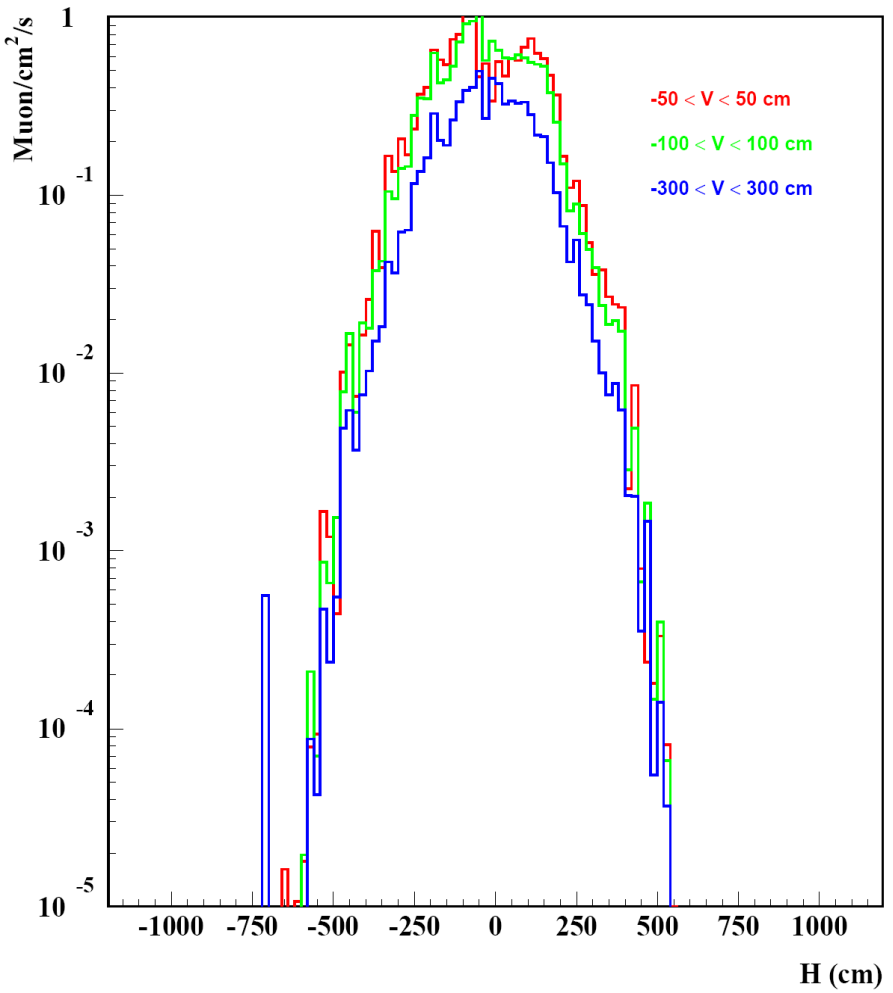
Muon Distributions in Orbit Plane

Beam-gas



Muon horizontal distributions at CMS (E > 1 GeV): beam-gas, MARS15

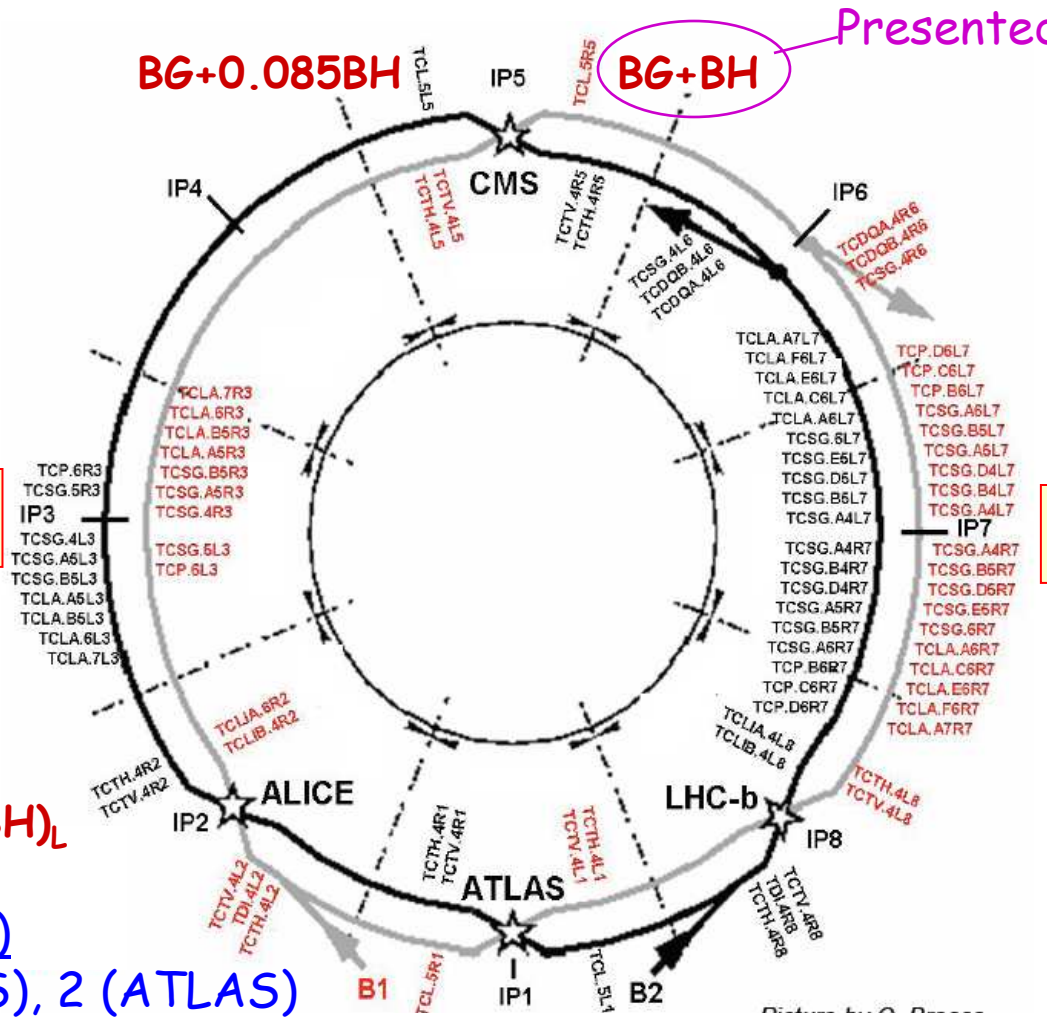
Beam-halo



Muon horizontal distributions at CMS (E > 1 GeV): beam-halo, MARS15

Sum Rules for MIB in ATLAS/CMS

BG = Beam-Gas (B1 = B2)
BH = Betatron Cleaning
(B2 in IP5)
No momentum cleaning



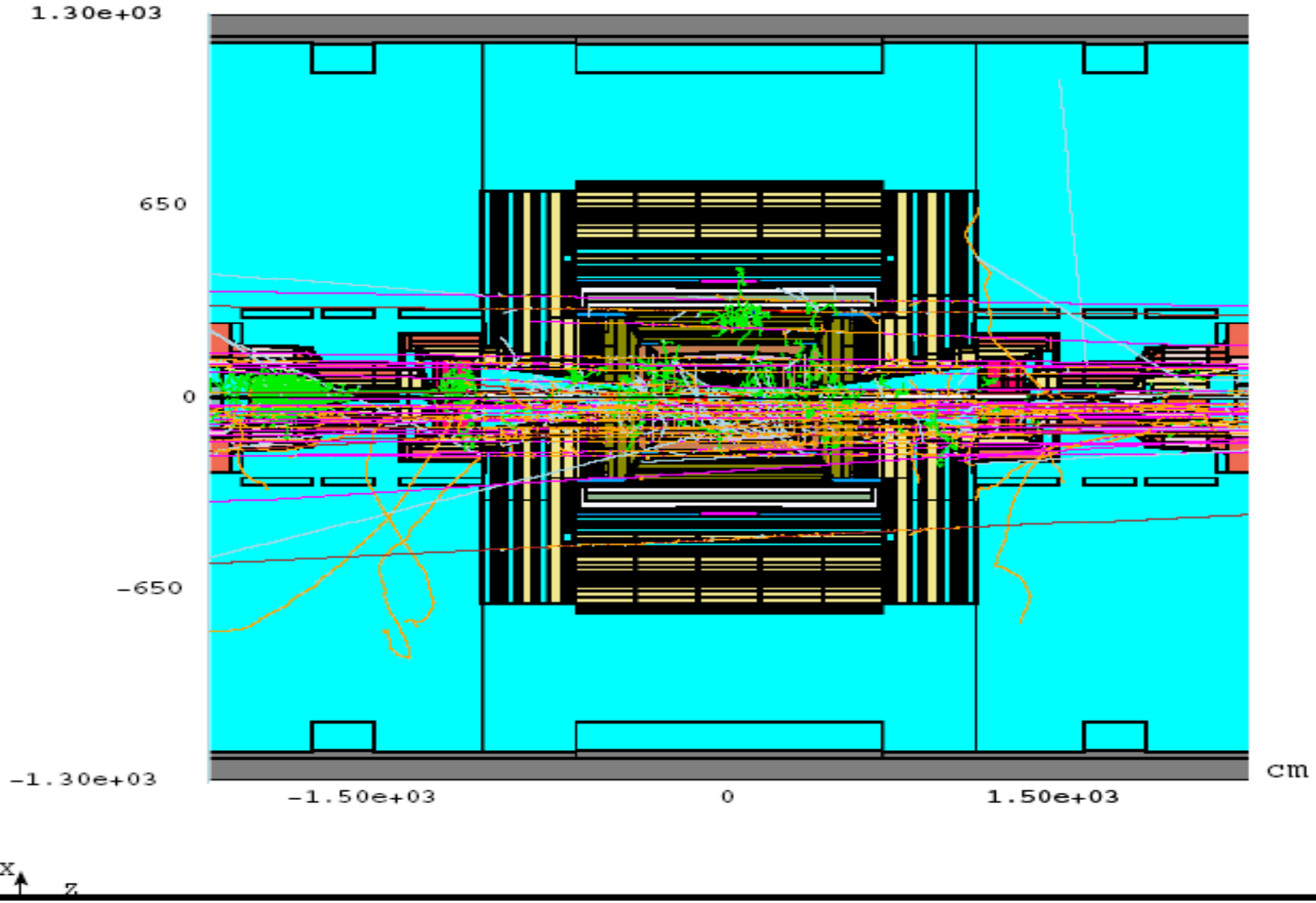
Use BG and BH of this study:

ATLAS: $(BG+0.12BH)_R$ + $(BG+1.64BH)_L$

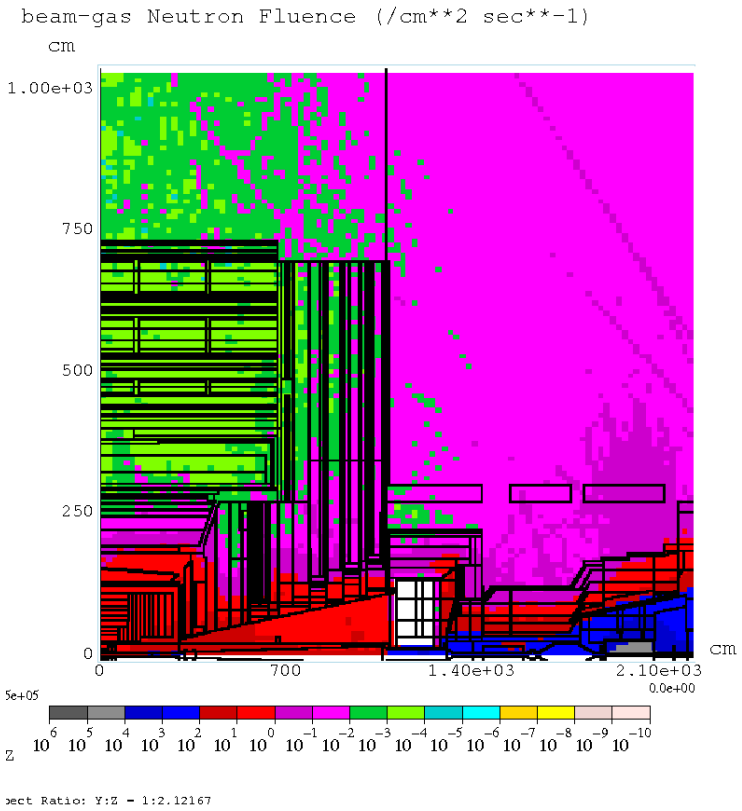
CMS: $(BG+BH)_R$ + $(BG+0.085BH)_L$

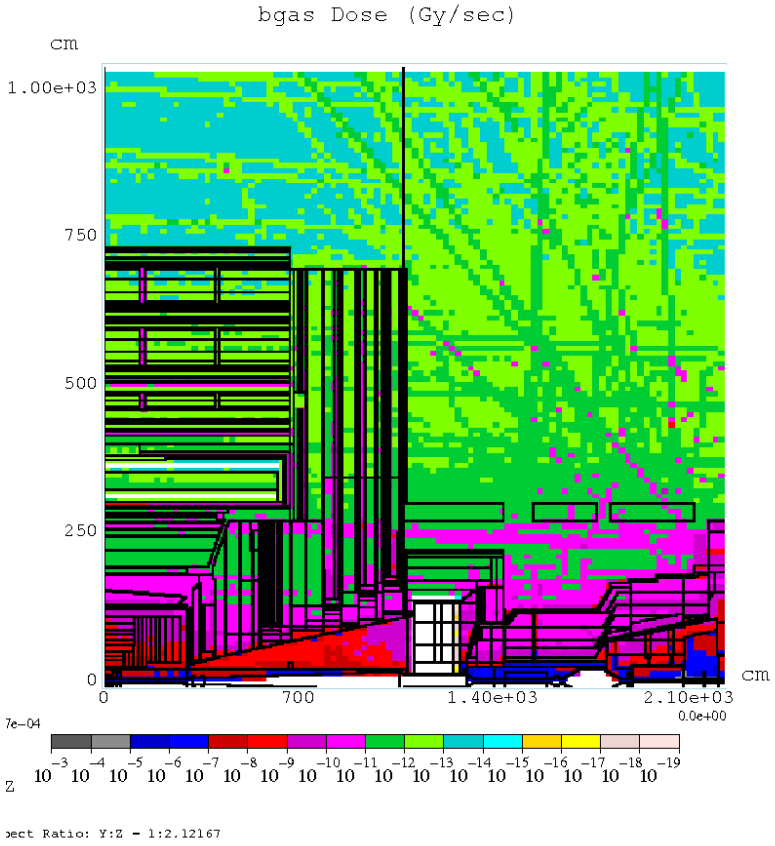
Muon flux at r=1 m (1/cm²/s)
Nominal 10-hr BLT: 1.5 (CMS), 2 (ATLAS)
Transient 0.22 hr: 42 (CMS), 64 (ATLAS)

MARS15 Modeling in CMS: Beam-Gas



Beam-Gas Induced Flux and Dose in CMS

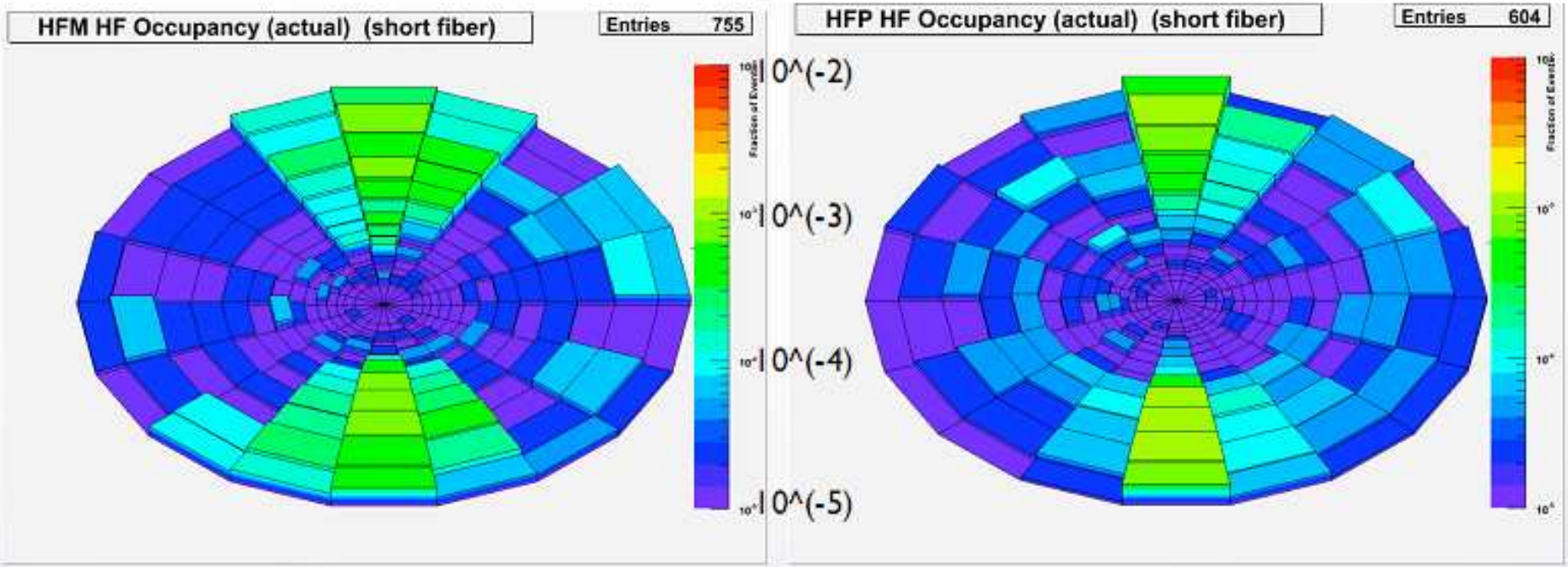




FNAL group: NM, P. Bhat, A. Singh, S. Striganov (MARS15)

BG + BH Occupancy in CMS HF (first shot)

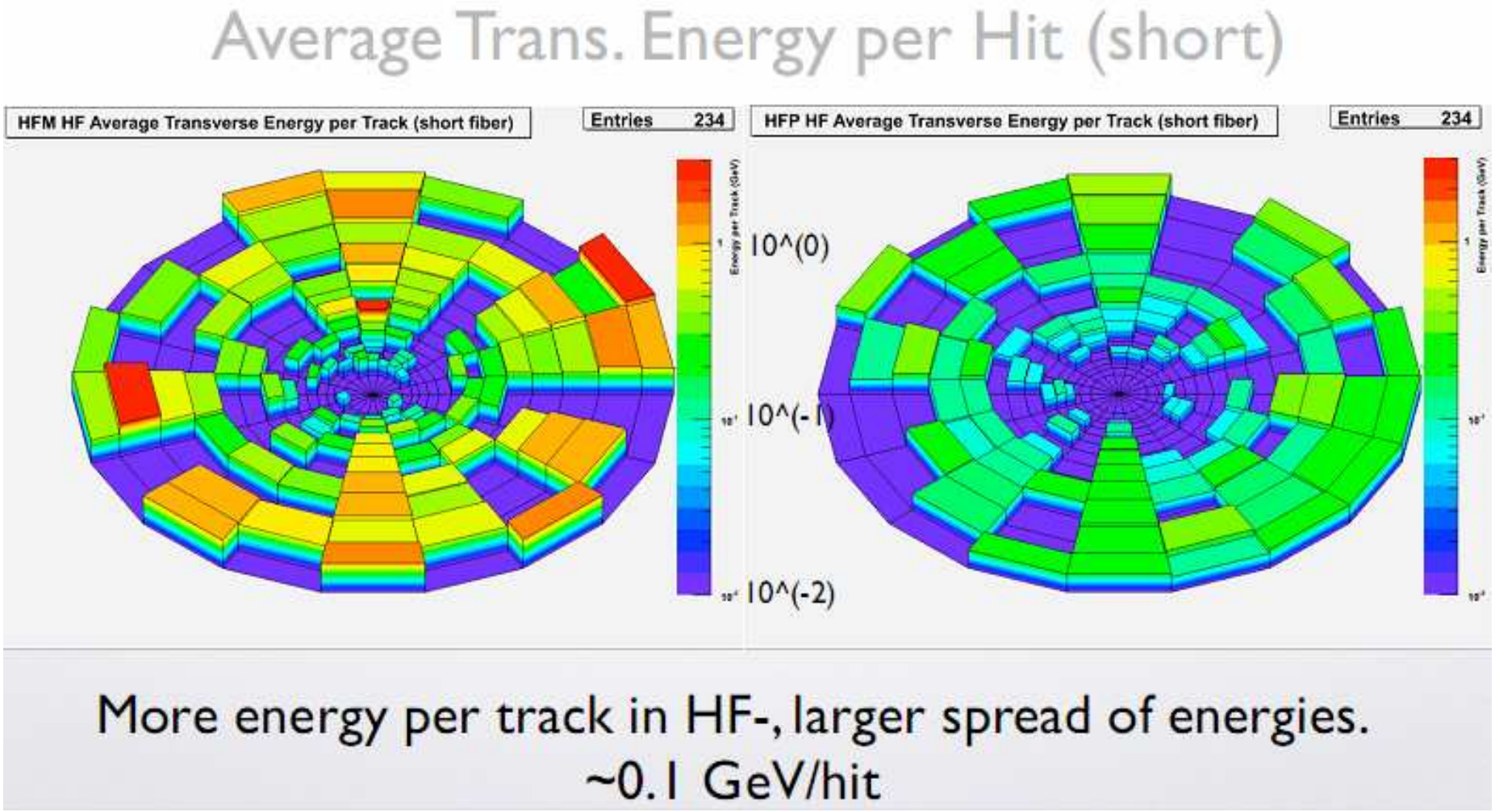
HF +/- Occupancy (short)



HF+ distribution with smaller much smaller spread.
Hits concentrated at phi = 90 degrees, ~10^(-3) Hits/Event

Princeton group (Geant4)

BG + BH Transverse Energy in CMS HF (first shot)



SUMMARY

1. Detailed MARS15 calculations have been performed – for the updated models of IR, gas pressure and beam loss in the vicinity of IP1/IP5 - for the major components of the machine-induced backgrounds in the high-luminosity insertions. New results are pretty consistent with our earlier results of mid-90s.

2. Intermediate files at z=22.6m are available to the detector community since August 2007. Several groups – CERN, FNAL, Princeton - have started detector modeling. Complete files will be released soon.

3. Backgrounds and radiation levels in the CMS and ATLAS detectors are dominated – at nominal luminosity - by pp-collisions. Tertiary collimators protect critical detector components (pixels, tracker) at beam accidents, and reduce machine backgrounds at small radii.

4. Thanks to A. Rossi and M. Huhtinen for a crucial input on gas pressure model, and T. Weiler for comprehensive results on beam loss at tertiary collimators for the betatron cleaning and kicker prefire.