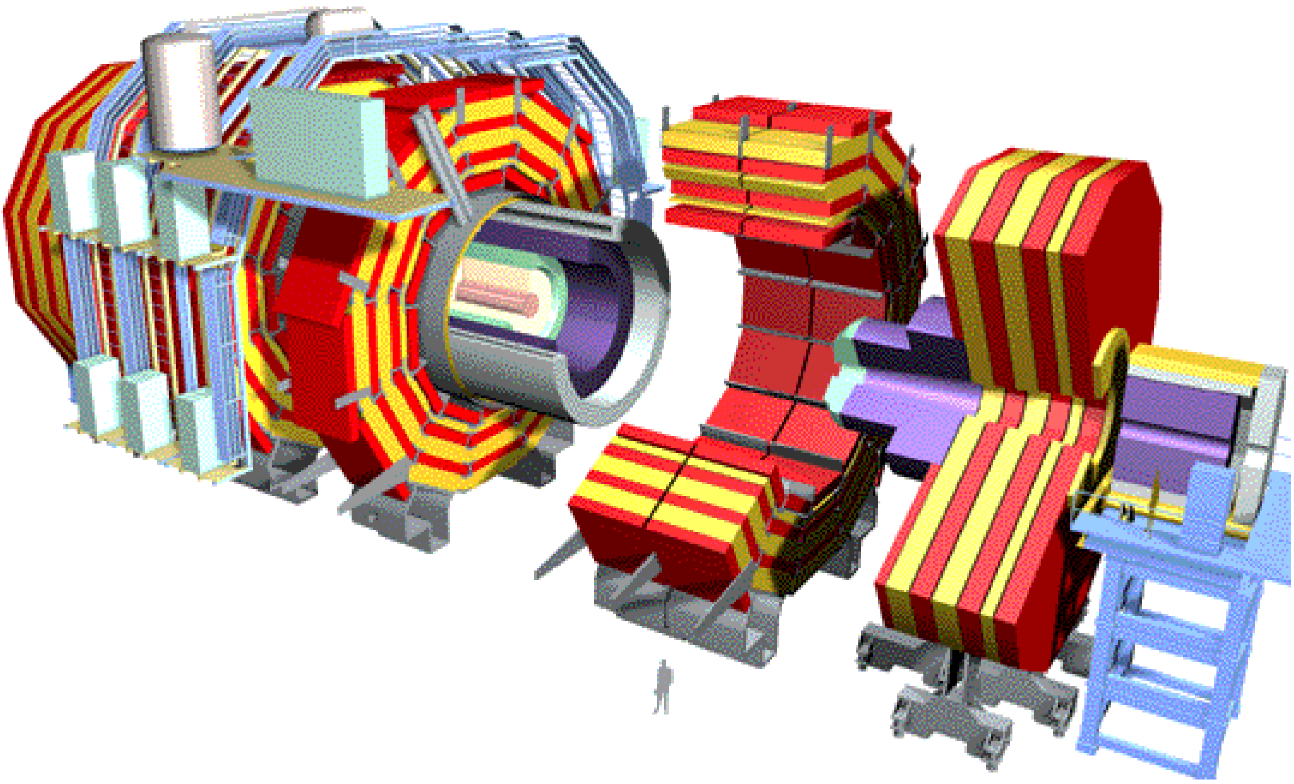
LHC Committee
CERN, 15.01.1998

CMS
Muon Detector
TDR presentation



• **Introduction**	***F. Gasparini***	**10 min.**
• **Drift Tubes**	***F. Gasparini***	**20 min.**
• **CSC**	***G. Mitselmakher***	**20 min.**
• **RPC**	***G. Iaselli***	**10 min.**

Physics with muons

Standard Model Higgs

- $H \rightarrow ZZ^{(*)} \rightarrow 4\mu$ (m_H=130-750 GeV)
  - mass resolution < 1 GeV at m_H=130 GeV

SUSY Higgses

- $h, H, A \rightarrow \mu^+\mu^-$
  - mass resolution < 1 GeV

Superpartners

- $\tilde{q}, \tilde{g} \rightarrow$ multi-*lepton* + multi-*jet* + E_t^{miss}
  - muon recognition in multi-jet environment

Beyond the Standard Model

- $Z' \rightarrow \mu^+\mu^-$
  - p_t^{μ} measurement and sign determ. above 1 TeV

B-physics

- rare decays, e.g. $B_s^0 \rightarrow \mu^+\mu^-$
- CP violation, e.g. $B_d^0 \rightarrow J/\psi_{\rightarrow \mu\mu}\, K_S^0 + \mu_{tag}$
  - low p_t trigger threshold (2-4 GeV)

Heavy Ions

- $\Upsilon, \Upsilon', \Upsilon'' \rightarrow 2\mu$
  - mass resolution ~40 MeV

Specific muon features

- calibration of isolation algorithms
- b-tagging

Requirements

MUON IDENTIFICATION

At least 16 λ of material is present up to $|\eta|=2.4$ with no acceptance losses.

STANDALONE MOMENTUM RESOLUTION

From 8-15% dp_T/p_T at 10 GeV and 20-40% at 1 TeV.

GLOBAL MOMENTUM RESOLUTION

After matching with the Central Tracker:
from 1.0-1.5% at 10 GeV, and from 6-17% at 1 TeV.

Momentum-dependent spatial position matching at 1 TeV less than 1 mm in the bending plane and less than 10 mm in the non-bending plane.

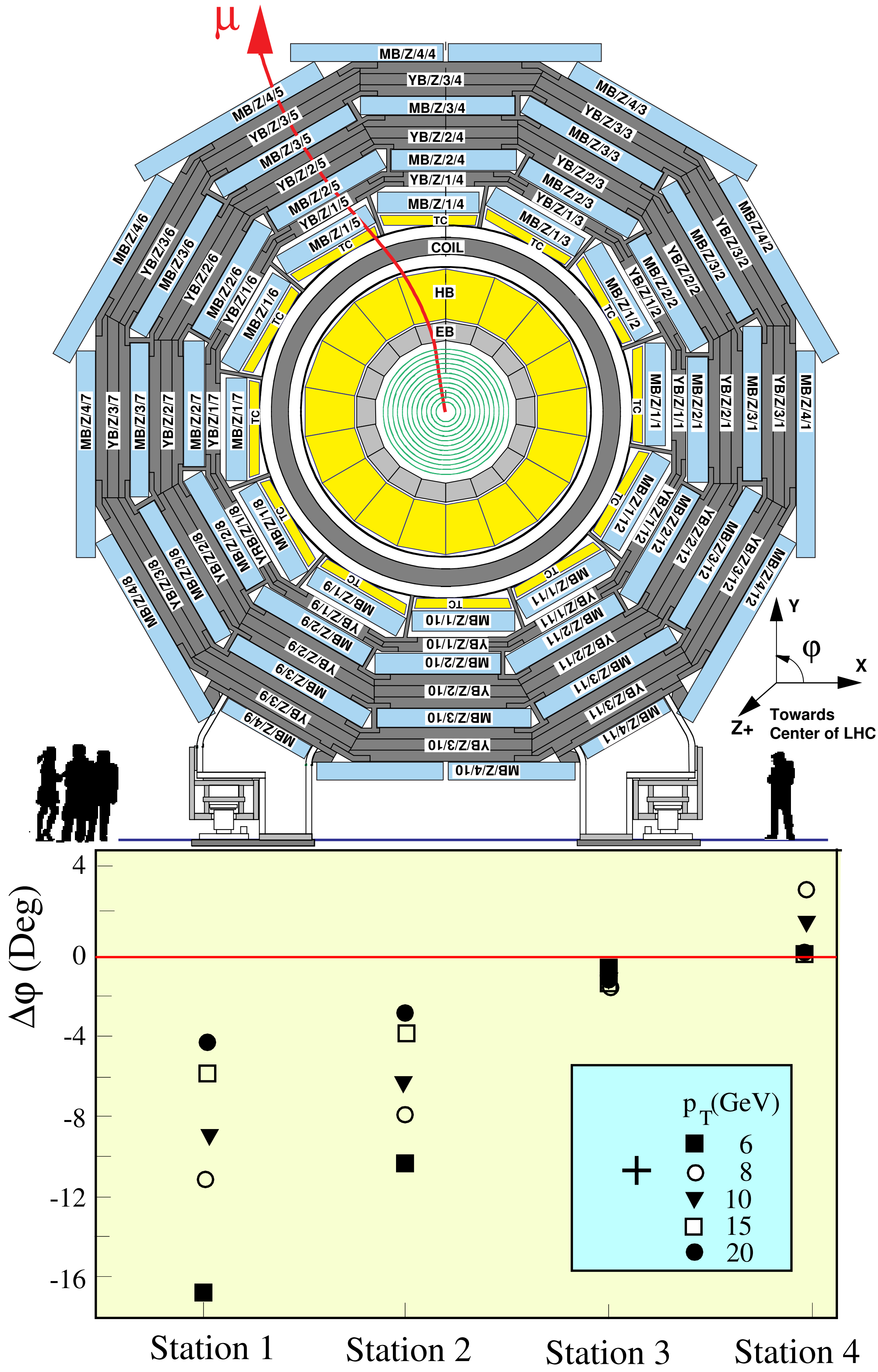
CHARGE ASSIGNMENT

Correct to 99% conf. up to the kinematic limit of 7 TeV.

MUON TRIGGER

The combination of precise muon chambers and fast dedicated trigger detectors provide unambiguous beam crossing identification and trigger on single and multimuon events with well defined p_T thresholds from a few GeV to 100 GeV up to $|\eta|=2.1$.

Muon Bending



Muon Trigger

CMS Level 1 Trigger makes use of the information from both:

- dedicated trigger detectors — RPC
- precise muon chambers — DT/CSC

RPC

use information from 4 stations within the same b.x.

DT/CSC

use information from one station within 3-14 b.x.

They could be affected differently by

- geometrical acceptance
- muon electromagnetic secondaries
- physics and instrumental ghosts
- background hits and tracks

The two component's Trigger provides

- unambiguous b.x. identification
- sharp p_t threshold
- powerful background rejection
- large flexibility:

  p_t cut = ~3-100 GeV at any luminosity

Construction Plan

3 assembly sites = 7 assembly lines:

- ***Aachen*** ***2 lines*** ***70 MB1 / MB2 chambers***
- ***Madrid*** ***2 lines*** ***70 MB1 / MB2 chambers***
- ***Legnaro*** ***3 lines*** ***110 MB3 / MB4 chambers***

Part production in other participating laboratories or in external firms.

The assembly scheme of 1 gluing / day * line allows the full production in 4.5 years.

Mass production of DT chambers

is feasible

and fulfils the required

mechanical precision

and

physics performance

Muon Detector Inventory

13 countries

49 institutions

~400 physicists

	Drift Tubes Barrel	CSC Endcap	RPC Barrel	RPC Endcap
chambers	250	540	360	252
layers / chamber	8 + 4	6	2	2
anode channels	195 000	210 816	80 640	80 642
cathode channels	—	273 024	—	—

Drift Tube parameters

Three field shaping electrodes enable drift velocity saturation in the range from 10-20% of CO_2 and improve performance in the magnetic field.

- **nominal mixture — Ar / CO_2 = 85% / 15 %**
- **nominal voltage**
  - strip = 1800 V
  - wire = 3600 V
  - I-beam = –1800 V
- **gain at nominal setting = $9 \cdot 10^4$**
- **typical charge = 1 pc**
- **cumulated charge in 10 years = 0.1 C/cm**

Drift cell performance checked with several chamber prototypes built by the participating institutes.

CMS Alignment

The CMS alignment is based on

- ***AXIAL ALIGNMENT LINES in the barrel***
- ***RADIAL ALIGNMENT LINES in the endcaps***

The Muon and Tracker alignment systems are stand alone.

They are connected by the link system.

Performance

Redundancy needed for background rejection is provided by the multilayer structure of chambers

- 6 layers with R and ϕ readout in CSC
- 8 layers with ϕ readout and
  4 layers with Z readout in Drift Tubes

Momentum measurement requires the resolution

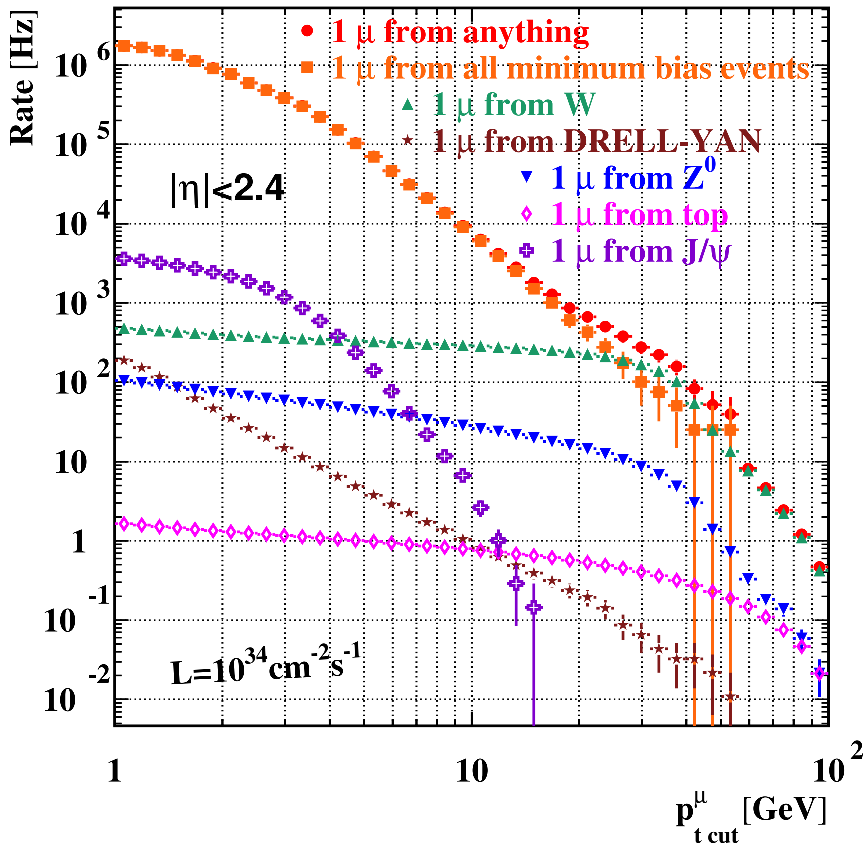
- 75 μm per station in ME1
- 100 μm per station in MB1

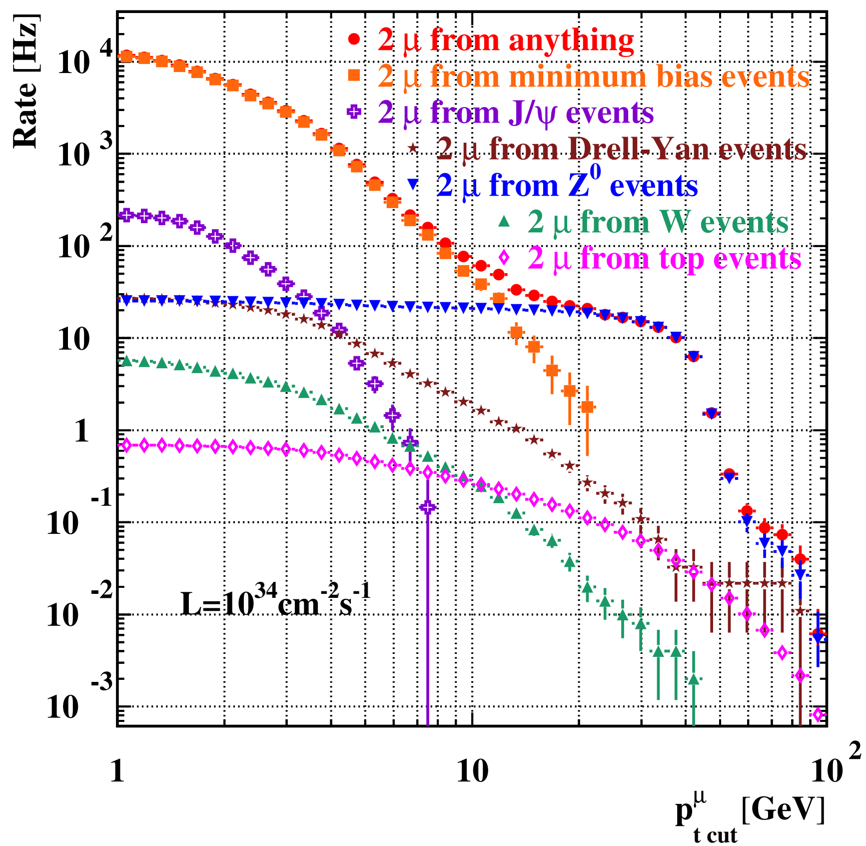
This is equivalent to

- ~150 μm per layer in ME1
- ~250 μm per layer in MB1

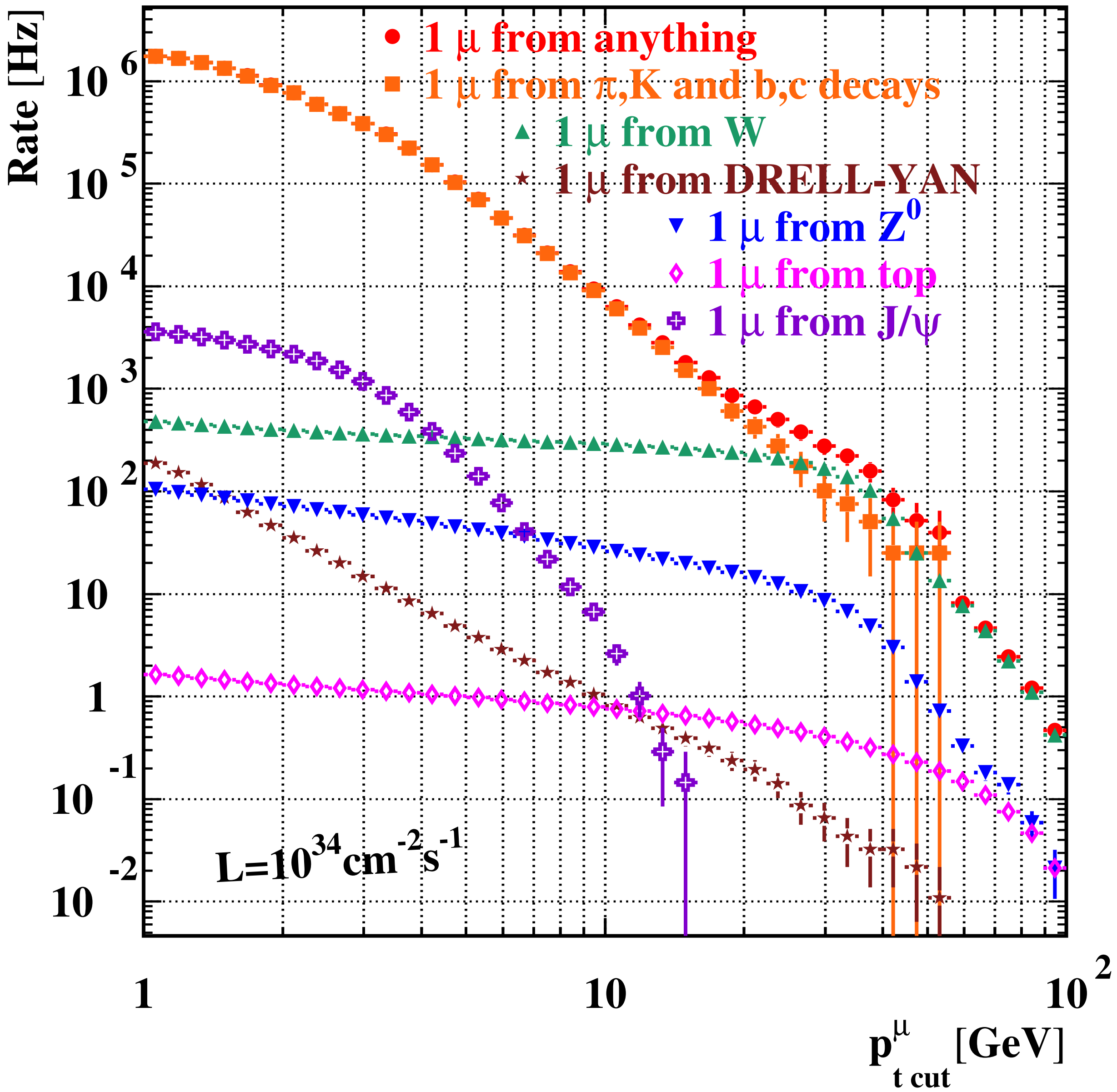
Tracker and Muon detectors must be aligned with a precision < 20 μrad in the bending plane (ϕ coordinate)

Single- and two-muon rates





Muon Sources

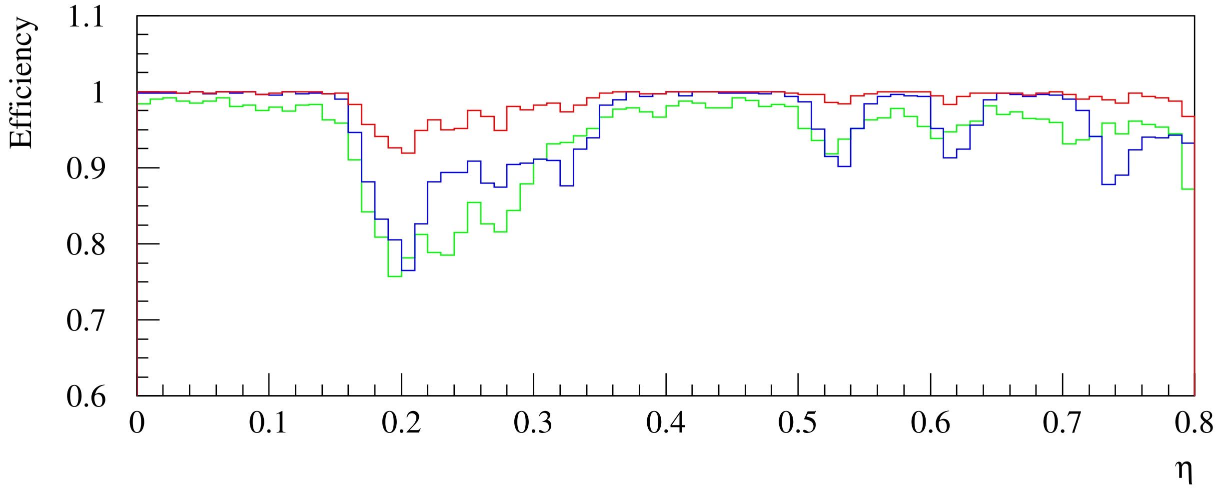


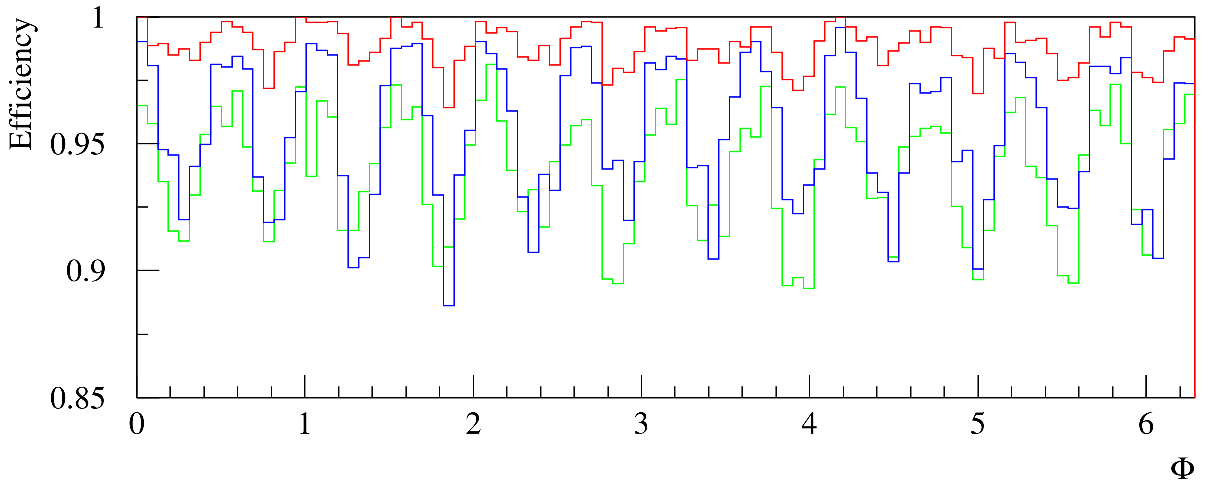
The rate is dominated by π,K decays up to 4 GeV and by b-,c-quark decays from 4 to 25 GeV.

The trigger rate can be adjusted by moving the threshold in a wide range of p_t without loosing much efficiency for heavier objects.

Two muon event rates are 2 orders of magnitude lower.

Global Muon Trigger





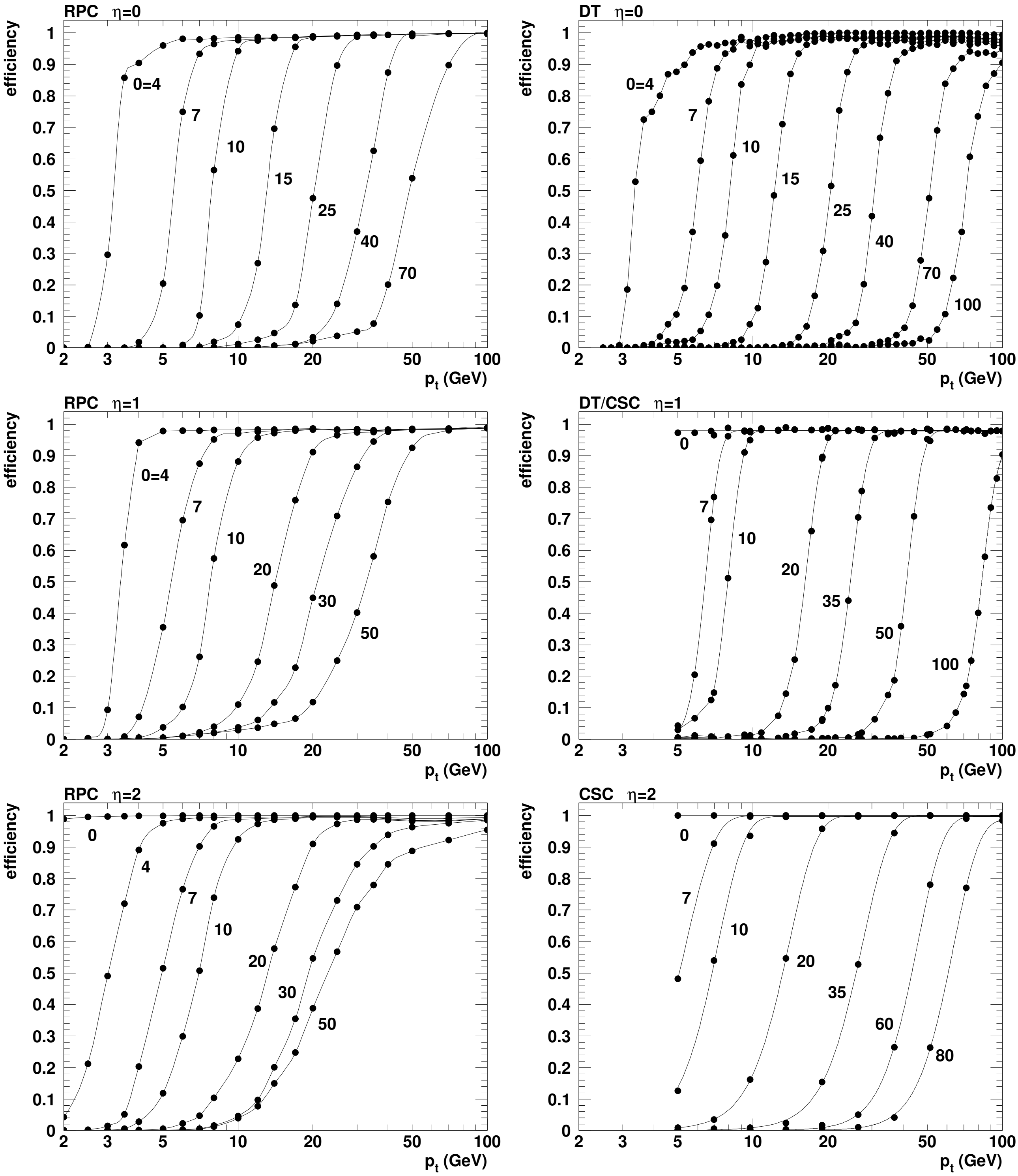
Trigger efficiency [%] for 1 μ events

|η|<0.8	0 μ	1 μ	>1 μ
RPC	4.49 ±0.10	95.49 ±0.61	0.02 ±0.01
DT	6.08 ±0.11	93.70 ±0.60	0.22 ±0.02
GMT	1.04 ±0.05	98.78 ±0.70	0.18 ±0.02

Trigger efficiency [%] for 2 μ events

|η|<0.8	0 μ	1 μ	2 μ	>2 μ
RPC	0.24 ±0.03	8.98 ±0.22	90.72 ±0.93	0.05 ±0.02
DT	0.39 ±0.04	12.75 ±0.27	86.40 ±0.90	0.46 ±0.05
GMT	0.00 ±0.01	2.70 ±0.12	96.87 ±0.98	0.42 ±0.05

Muon Trigger Efficiency



Muon and Calorimeter Trigger Rates

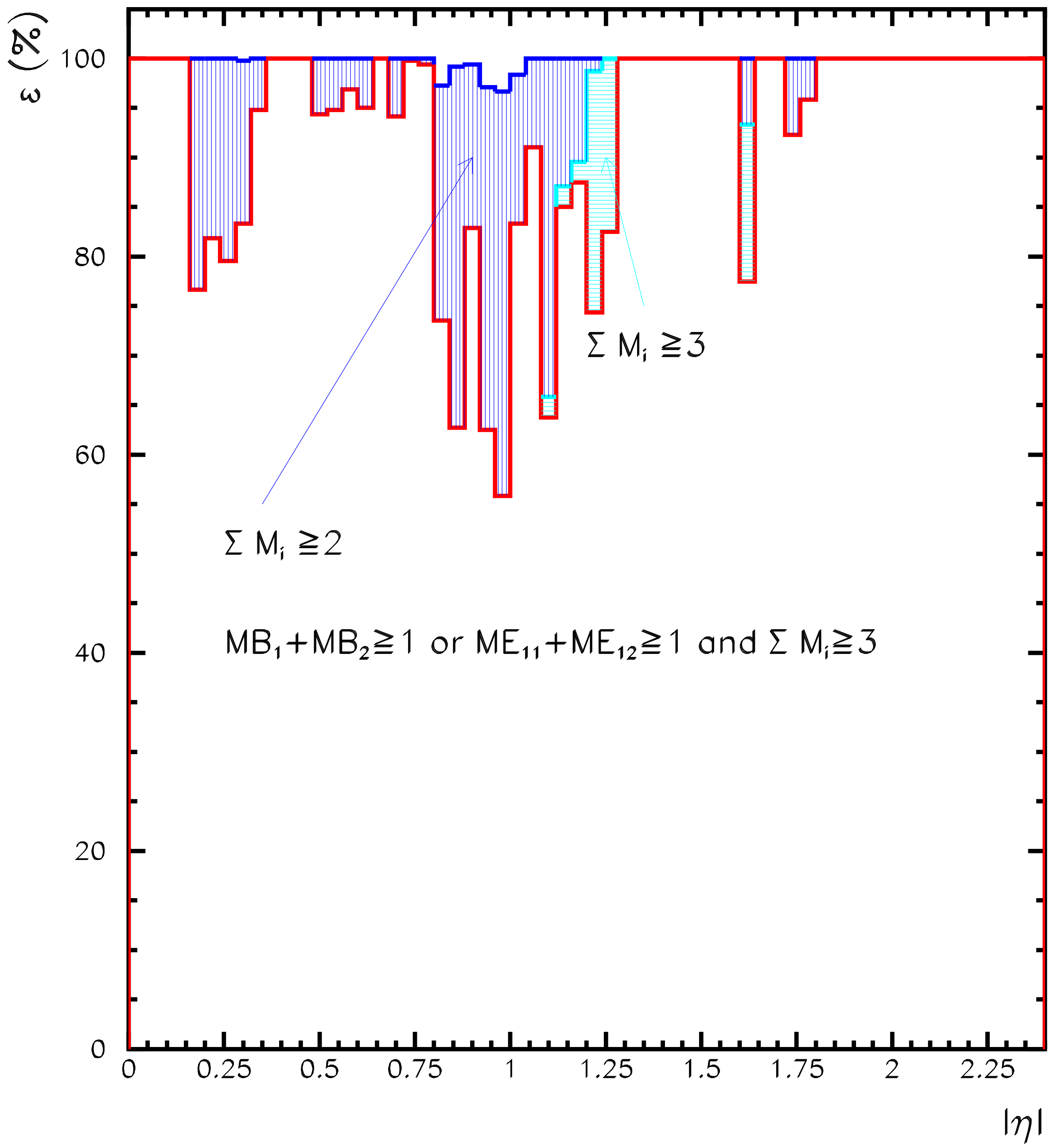
	$L = 10^{33} cm^{-2} s^{-1}$			$L = 10^{34} cm^{-2} s^{-1}$		
trigger type	**threshold [GeV]**	**rate [kHz]**	**cumulative rate [kHz]**	**threshold [GeV]**	**rate [kHz]**	**cumulative rate [kHz]**
μ	**7**	**9.8**	**9.5**	**20**	**7.8**	**7.8**
$\mu\ \mu$	**2-4**	**0.5**	**10.1**	**4**	**1.6**	**9.2**
$\mu\ e/\gamma$	**2-4, 6**	**2.5**	**12.2**	**4, 8**	**5.5**	**14.4**
$\mu\ e_b$	**2-4, 5**	**3.5**	**13.4**	—	—	—
$\mu\ j$	**2-4, 12**	**2.2**	**14.5**	**4, 40**	**0.3**	**14.4**
$\mu\ E_t^{miss}$	**2-4, 40**	**0.8**	**14.7**	**4, 60**	**1.0**	**15.3**
$\mu\ \Sigma E_t$	**2-4, 150**	**0.8**	**14.7**	**4, 250**	**0.2**	**15.3**

threshold = 2-4 GeV means: 4 GeV in the barrel, 2 GeV in the endcaps

muon threshold = transverse momentum threshold
calorimeter threshold = transverse energy threshold

e/γ — electron/photon trigger, e_b — trigger on electron from b-quark decay

Muon Acceptance



Muon reconstruction