CMS Report

March 23, 2020
Geant4 Technical Forum

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Introduction

- CMS Simulation application in production is currently using Geant4 version 10.4.p03 and there is a plan to go for the version10.6.p01
- The version 10.6.p01 works with VecGeom version 1.1.5 and CLHEP version 2.4.1.3
- The newer release of Geant4 comes with certain advantages
  - Better suited for multi-threading
  - Improvement in transportation in electromagnetic field
    - treatment of unstable particles looping in the detector
    - use of better integration method
  - Improved EM physics for pair production, gamma conversion, multiple scattering
  - Improved hadronic physics
    - use of better set of cross sections for hadronic processes
    - improved string model with better tuned constants for FTF
    - extension of Bertini cascade for strange pair production
    - …..

Physics List used in CMSSW

- Physics List FTFP_BERT_EMM has been CMS default:
  - FTFP_BERT is the Geant4 default
    - Geant4.10.4.p03: Transition energy Bertini-FTFP: 3-12 GeV
    - Geant4.10.6.p01: Transition energy Bertini-FTFP: 3-12 GeV for π and 3-6 GeV for other particles
  - EMM – configuration of EM physics specific for CMS
    - Configuration different for crystal and sampling calorimeters like HCAL or HGCal

- Birk's constant C1 for HCAL is also increased by 15% from a study of tuning the constants using test beam data

- Whenever CMS changes Geant4 version, we perform some basic tests with current CMSSW version and validate that by comparison with some well understood data

- The validation is carried out using 2 sources of data:
  - 2006 test beam with CMS calorimeter prototypes (hadron beams of different types and different energies)
  - Collision data from the CMS experiment utilizing zero bias or minimum bias triggers from low luminosity runs

Performance Issue (1)

- FTFP_BERT_EMM is the default physics list for CMS to be used for Run3

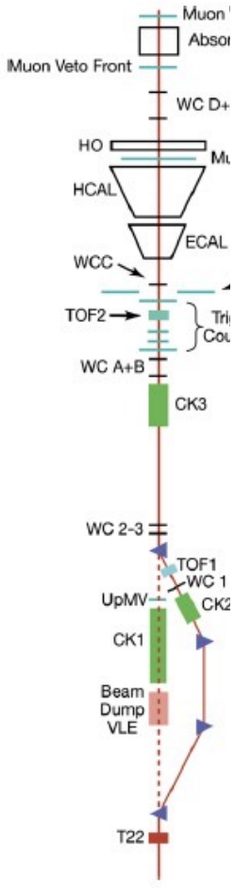
- A different physics list may be needed for Phase2 simulation:
  - FTFP_BERT_EMN uses
    - Goudsmit-Saunderson model for multiple scattering with Mott corrections
    - BS angular generator for bremsstrahlung
    - Sampling of e^+e^- pair production by e^+ and e^-
    - Sampling of fluorescence

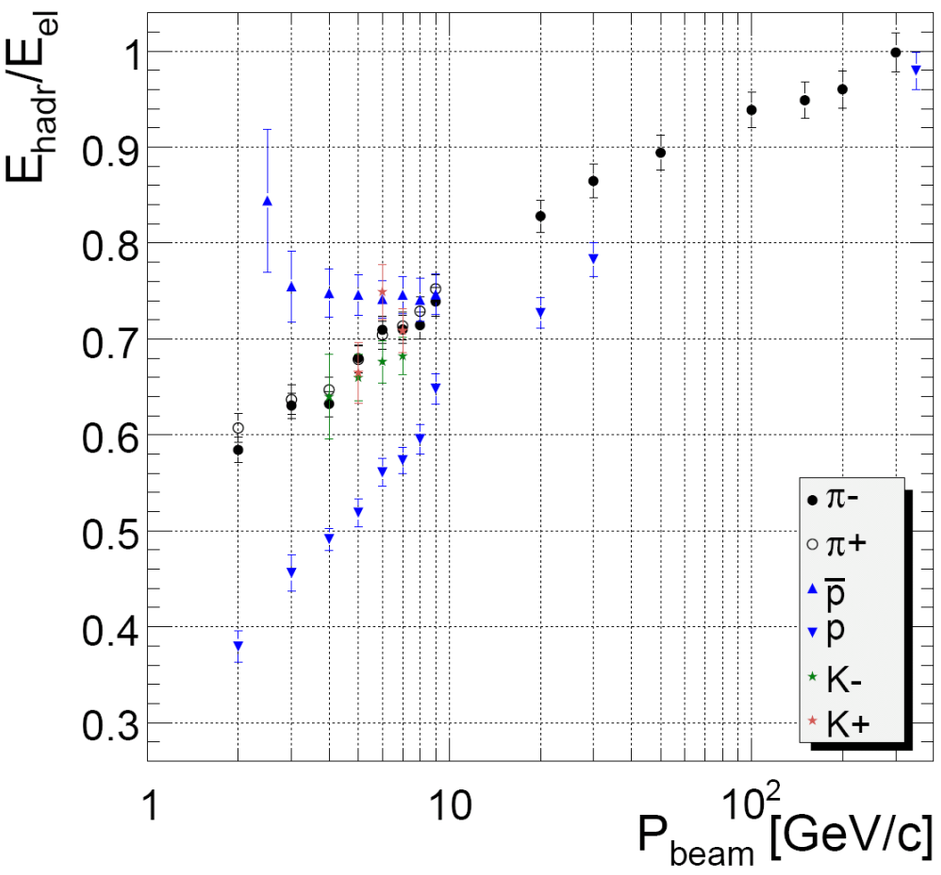
		Geant4 10.4.p03		Geant4 10.6.p01	
		CPU	RSS	CPU	RSS
Minimum Bias	Run 3	7.65 s	0.49 GB	0.95	0.49 GB
	2026D41	26.85 s	0.82 GB	1.01	0.87 GB
t-tbar	Run3	56.05 s	0.51 GB	0.97	0.51 GB
	2026D41	197.74 s	0.87 GB	0.99	0.59 GB

Slightly better performance with the new version

2006 TestBeam Data

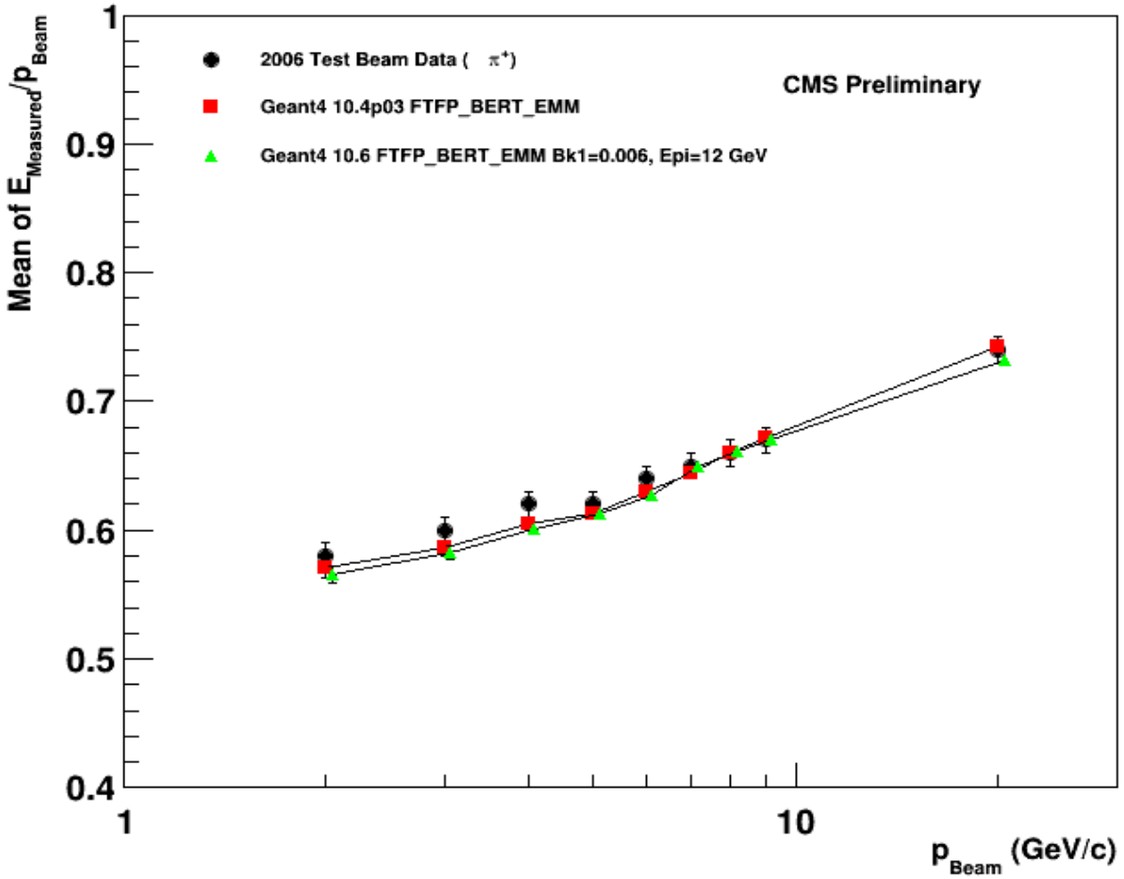
- The setup consists of 2 prototype modules of Hadron Calorimeter Barrel and a supermodule of the barrel Electromagnetic Calorimeter. Data were taken in the H2 test beam area at CERN during 2006 with both positive and negative beams of momentum between 1 and 350 GeV
- The analysis utilized particle identification using data from TOF counters and Cherenkov detectors for beam momentum below 9 GeV
- The results consist of mean energy response (measured as the ratio of the total energy in the calorimeter to the beam momentum) as a function of beam momentum for different beam types and also the energy distribution for particles of a given type at a given momentum (all particles or particles which do not undergo inelastic interactions in Electromagnetic Calorimeter)

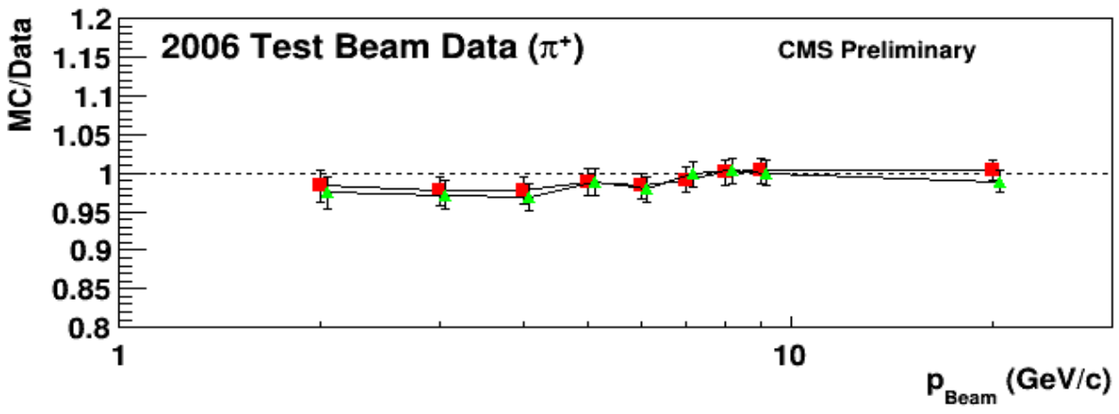




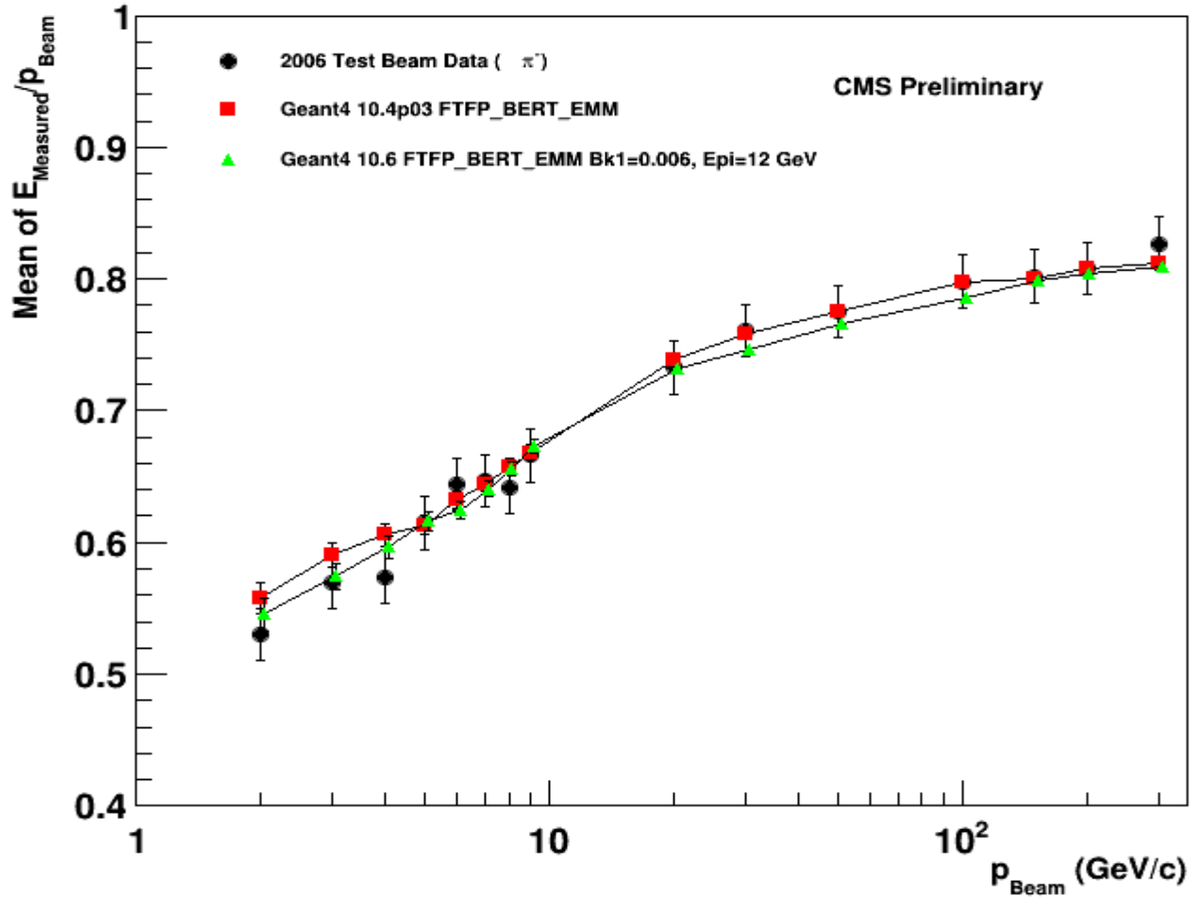
Mean Energy Response for π± (ECAL+HCAL)

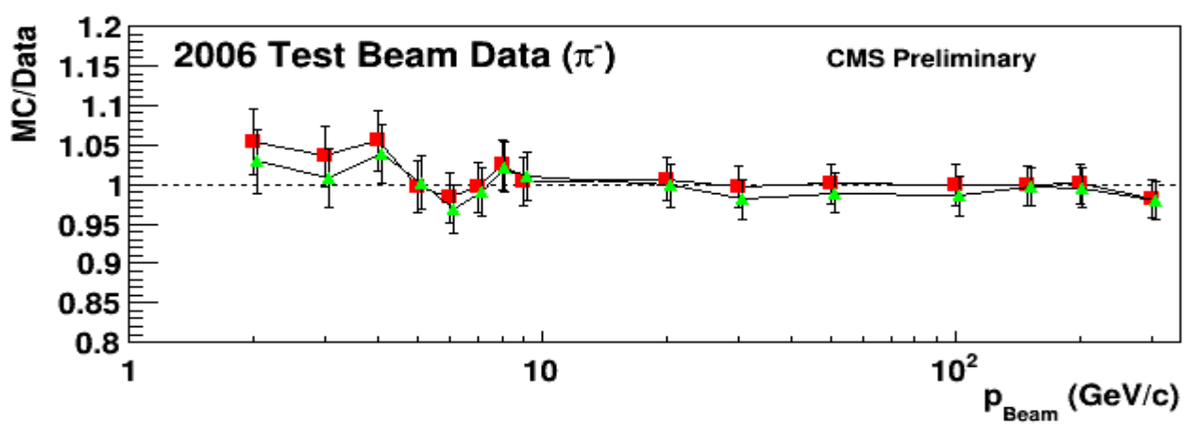
π^+





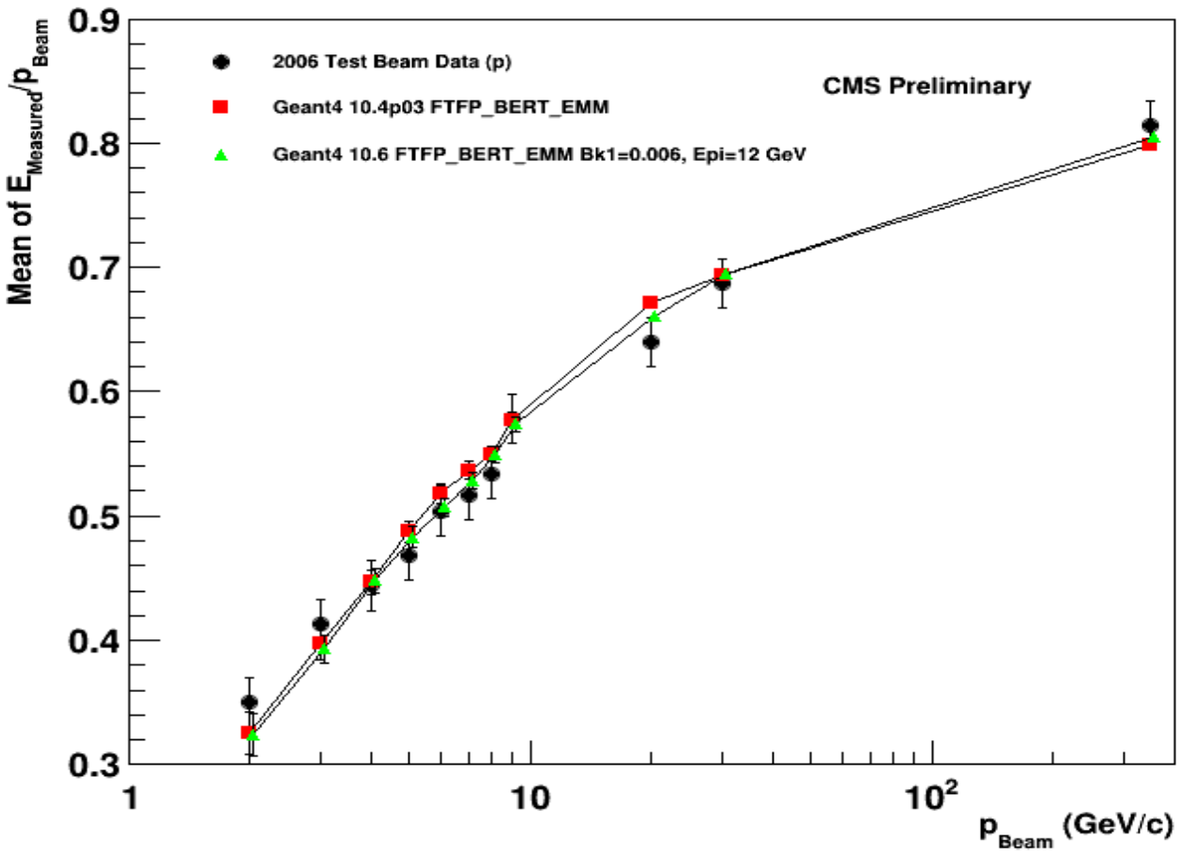
π^-

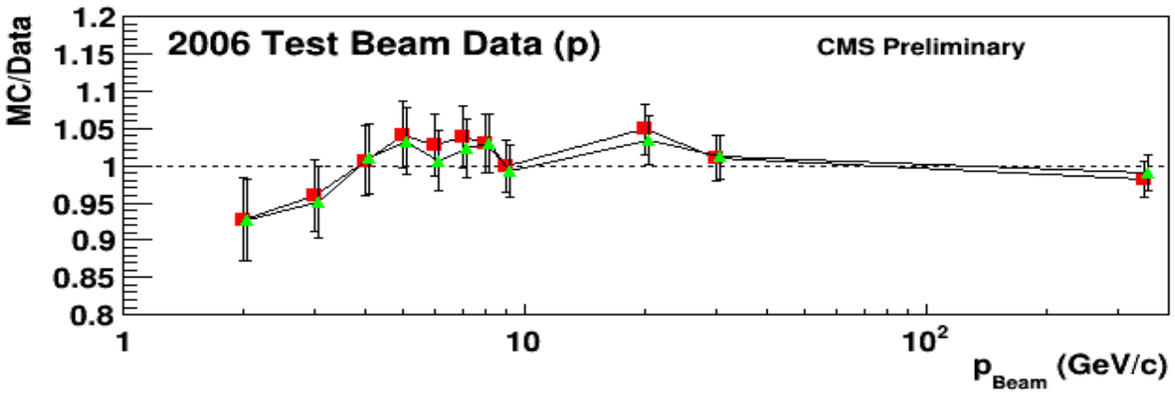




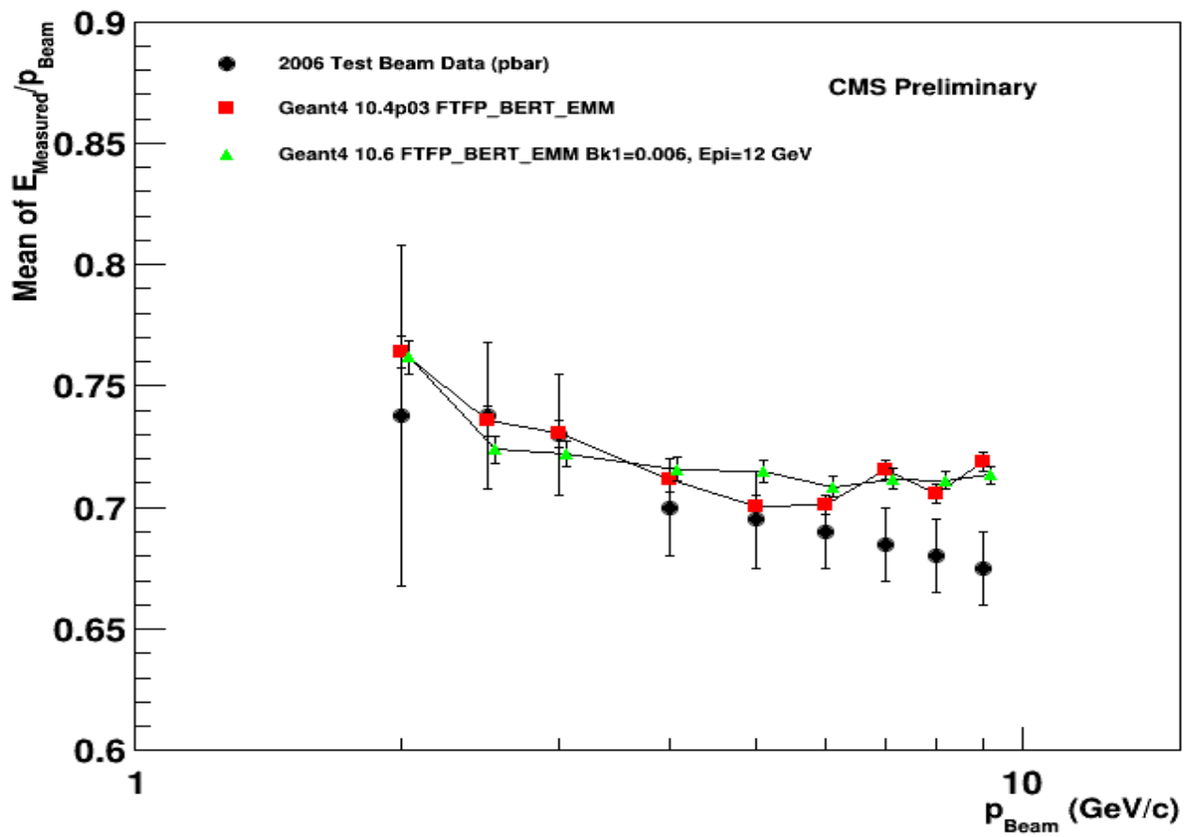
Mean Energy Response for p/pbar (ECAL+HCAL)

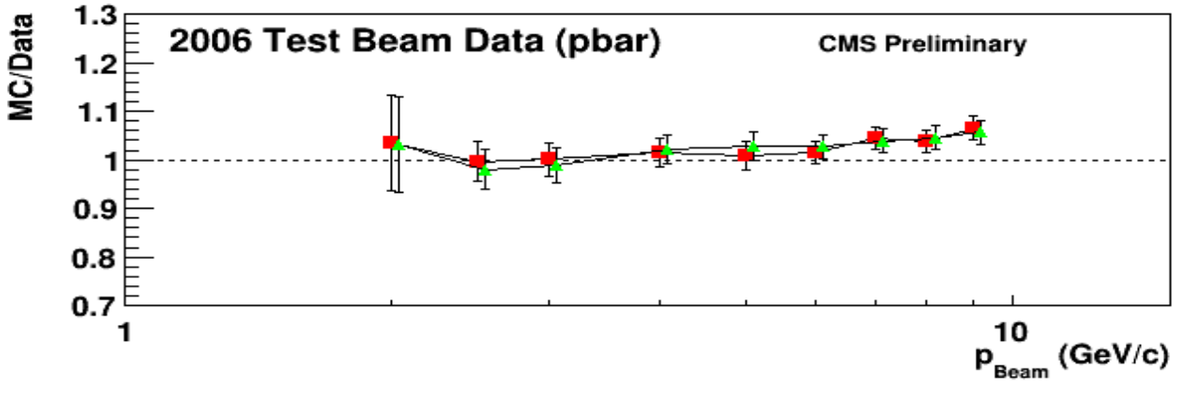
p





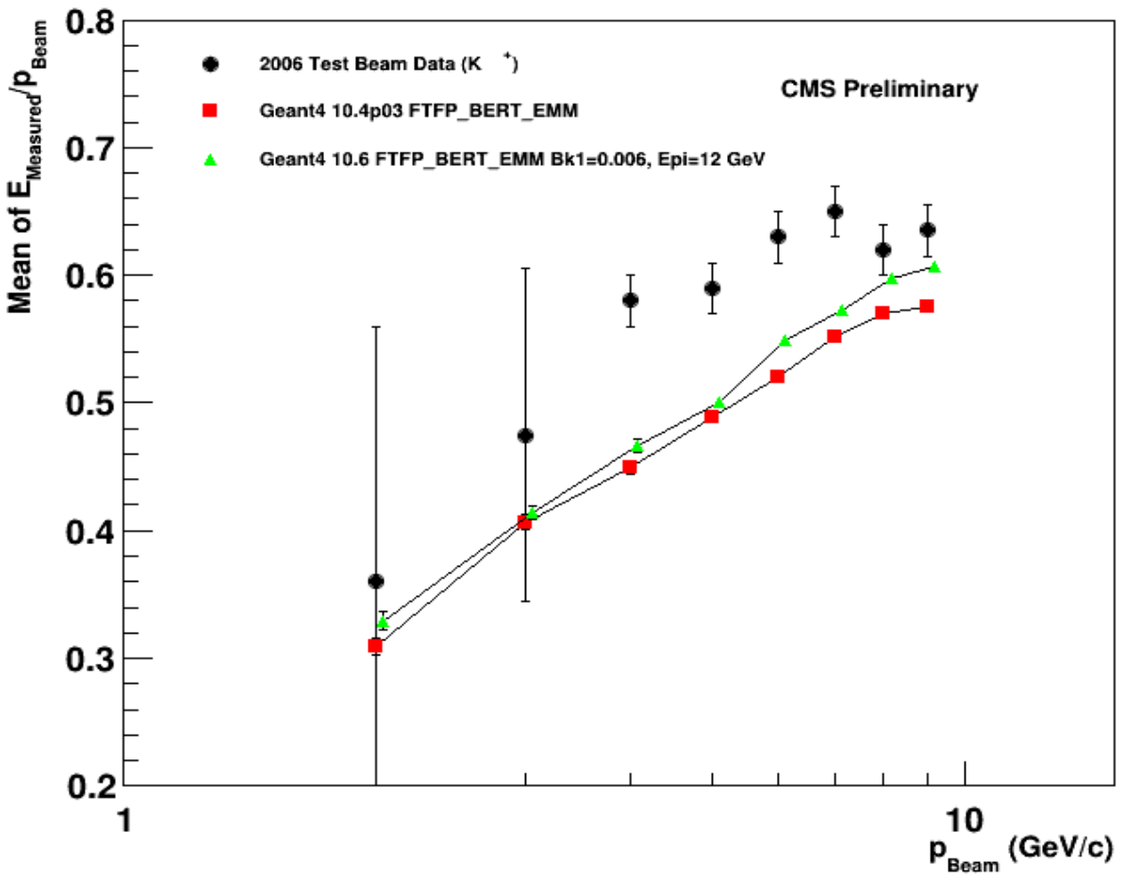
pbar

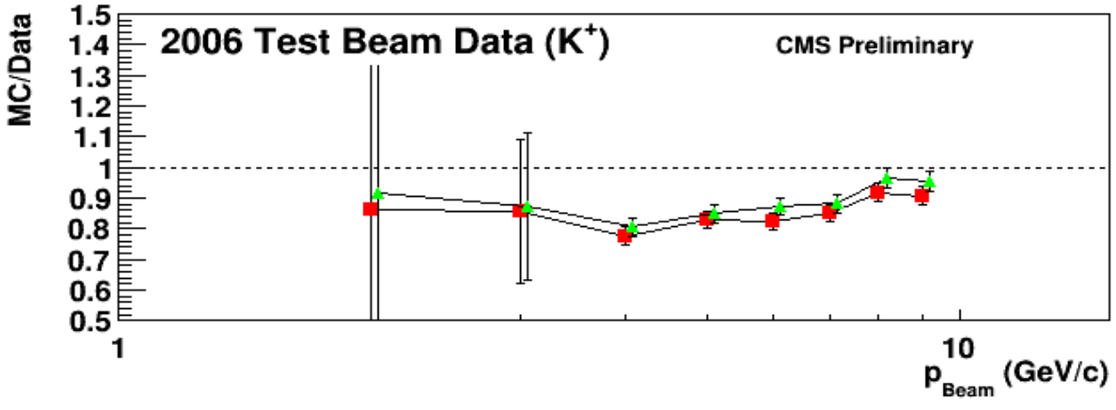




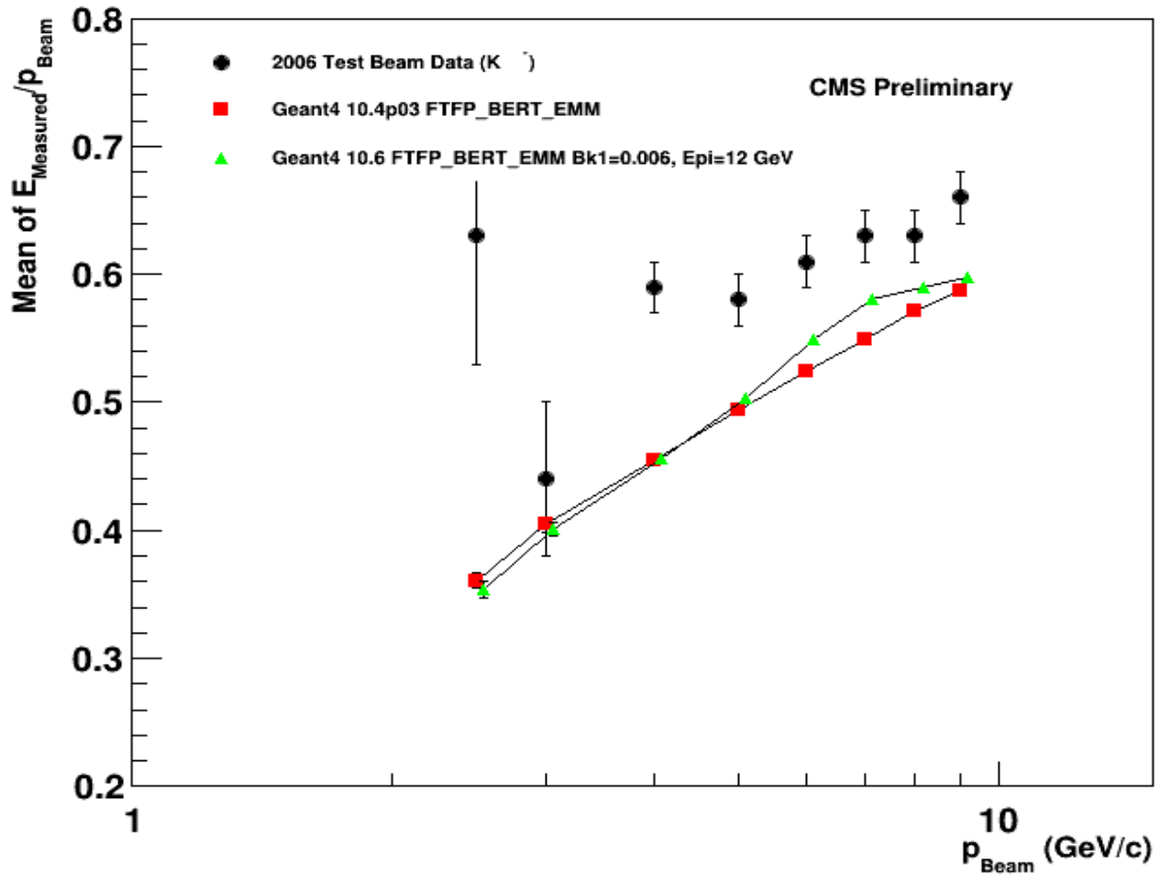
Mean Energy Response for $K^{\pm}$ (ECAL+HCAL)

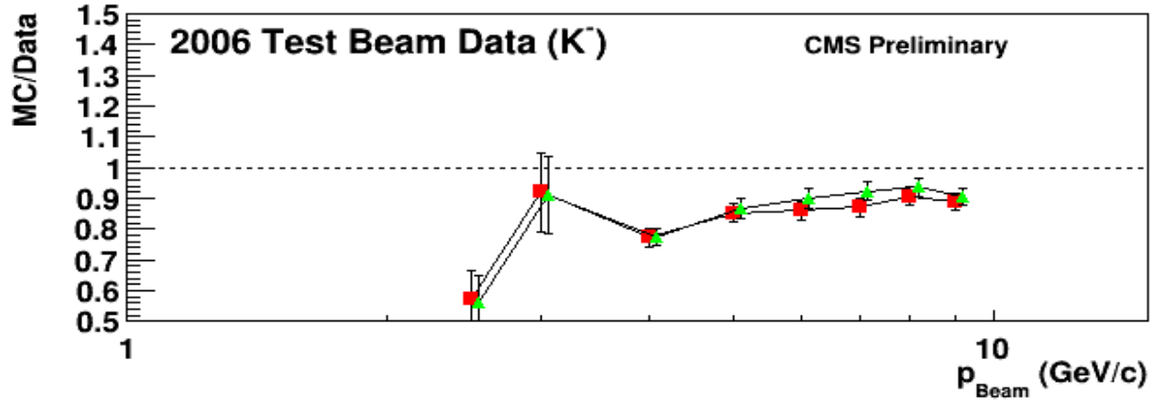
K^+





K^-





Deviation of Ratio Data/MC from 1

Beam	Quantity	10.4.p03	10.6.p01
π-	Mean Response	(1.2 ± 0.7)%	(1.4 ± 0.7)%
	(MIPS in ECAL)	(2.2 ± 0.7)%	(2.0 ± 0.7)%
	Mean Resolution	(8.3 ± 1.2)%	(8.5 ± 1.2)%
	MIP Fraction	(6.7 ± 1.4)%	(7.6 ±1.4)%
proton	Mean Response	(2.6 ± 1.1)%	(2.1 ± 1.1)%
	(MIPS in ECAL)	(3.2 ± 1.0)%	(2.2 ± 1.0)%
	Mean Resolution	(7.9 ± 1.1)%	(9.4 ± 1.1)%
	MIP Fraction	(3.4 ± 1.4)%	(3.2 ± 1.4)%
π+	Mean Response	(1.1 ± 0.6)%	(1.4 ± 0.6)%
K^-	Mean Response	(15.2 ± 1.2)%	(11.6 ± 1.2)%
K^+	Mean Response	(14.7 ± 1.2)%	(12.4 ± 1.1)%
Anti-proton	Mean Response	(3.0 ± 0.9)%	(3.4 ± 0.9)%

Test Beam Data

Mean level of disagreement between MC and data from energy distributions

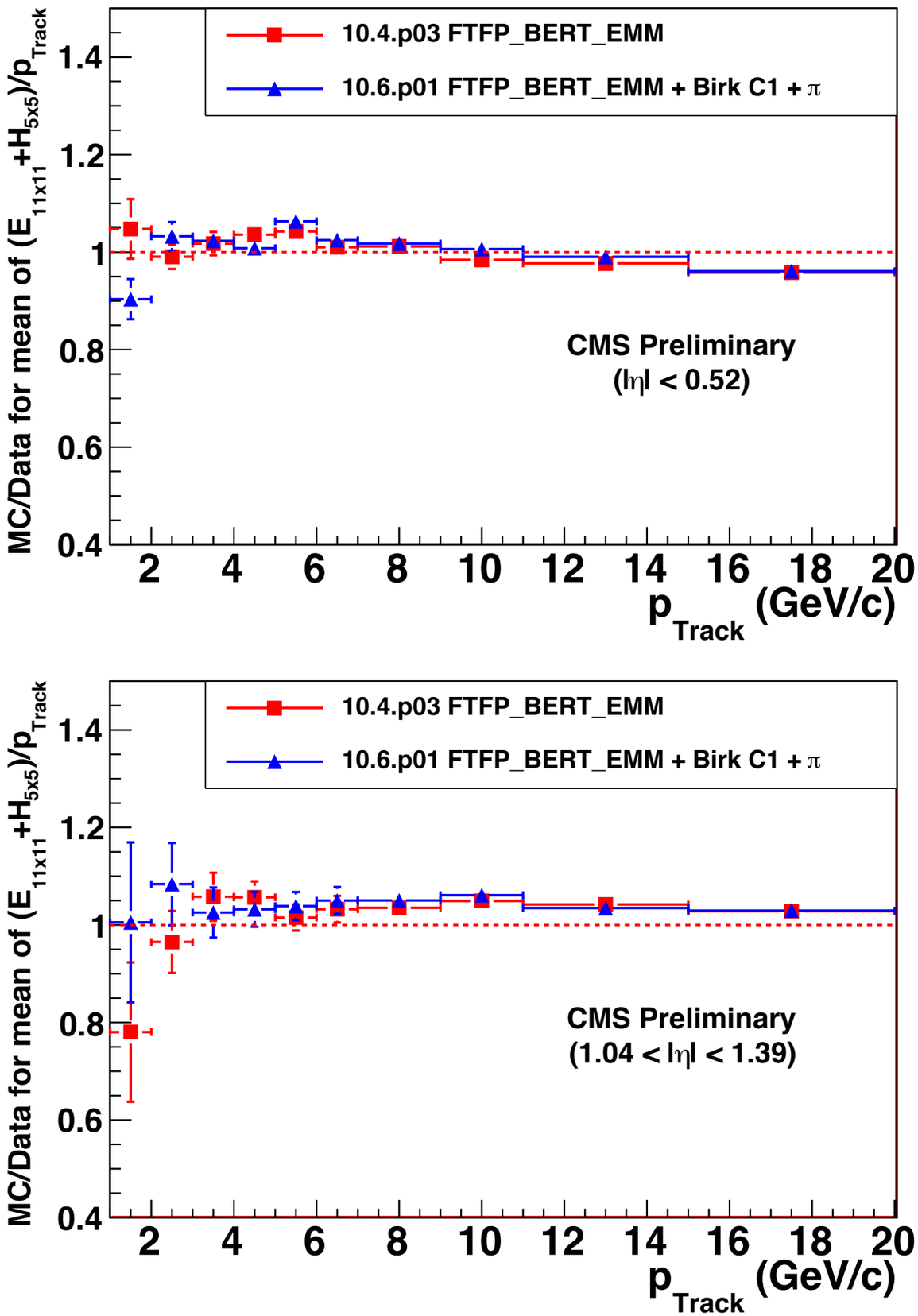
	π- 10.4.p03	π- 10.6.p01	π+ 10.4.p03	π+ 10.6.p01	p 10.4.p03	p 10.6.p01
2 GeV	14.6±0.9	11.7±0.9	11.6±1.2	12.0±1.2	6.8±2.5	7.2±0.3
3 GeV	10.8±0.6	8.4±0.6	8.5±1.7	10.2±1.7	2.1±1.0	2.5±1.0
4 GeV	15.8±0.5	13.3±0.5	12.5±0.5	13.2±0.5	12.0±1.2	12.9±1.2
5 GeV	10.6±0.5	11.5±0.5	9.9±1.0	9.7±0.9	11.8±3.1	12.0±3.2
6 GeV	12.0±0.5	13.4±0.4	11.0±0.9	11.8±0.8	5.4±3.2	7.8±3.5
7 GeV	14.5±0.5	15.3±0.5	12.8±0.7	15.0±0.7	8.1±2.9	11.9±2.8
8 GeV	17.4±0.6	19.6±0.6	14.3±0.7	15.6±0.7	4.0±1.0	0.1±1.0

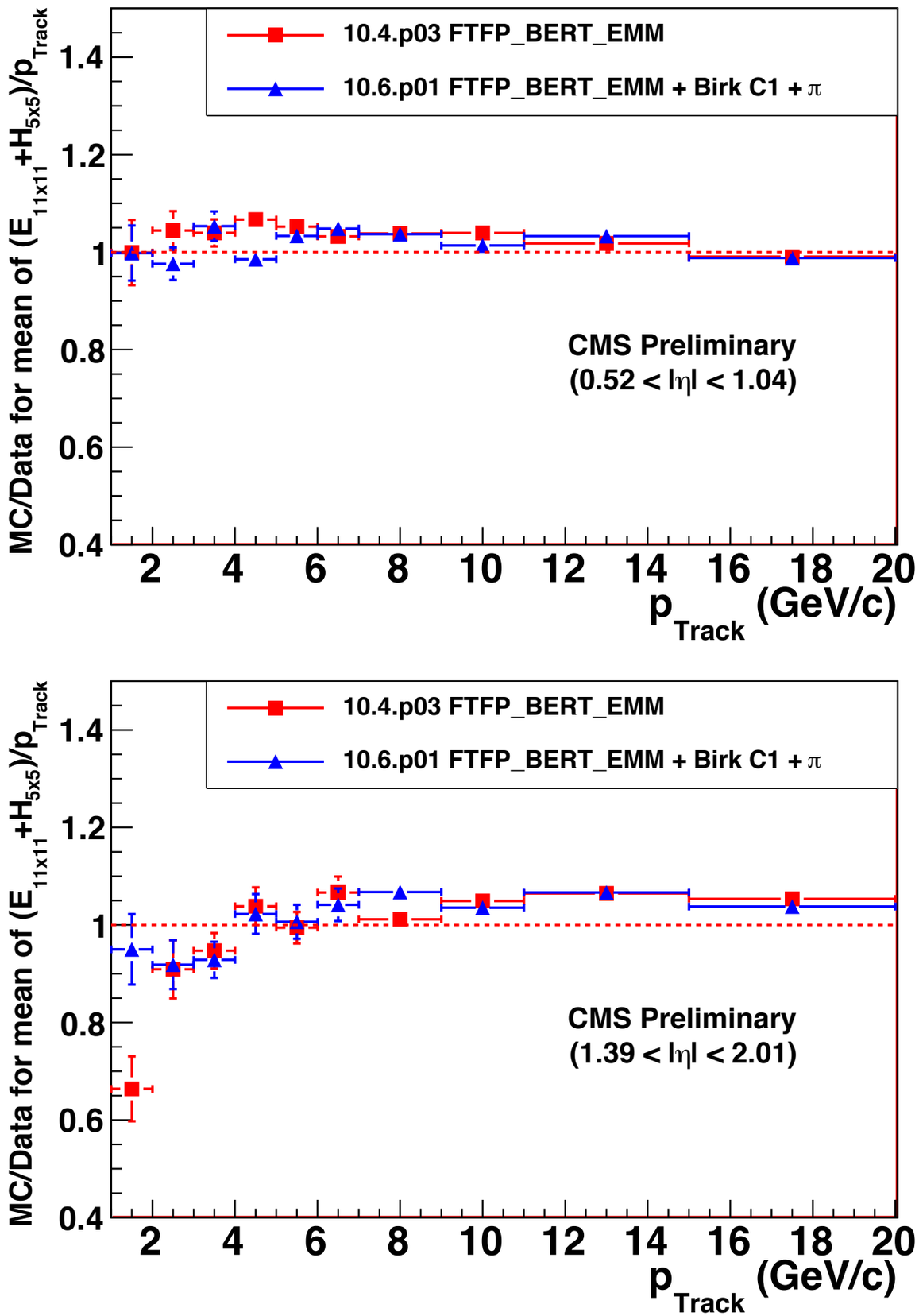
The level of agreement between data and MC remains roughly the same in the two versions

Isolated Charged Particles

- Compare ratio of calorimeter energy measurement to track momentum for isolated charged hadrons between data and MC
- Select good charged tracks reaching the calorimeter surface
- Impose isolation of these charged particles
  - propagate track to calorimeter surface and study momentum of tracks (selected with looser criteria) reaching ECAL (HCAL) within a matrix of 31x31 (7x7) around the impact point of the selected track for charge isolation
  - study energy deposited in an annular region in ECAL (HCAL) between 15x15 and 11x11 (7x7 and 5x5) matrices for neutral isolation
- Two versions of NxN matrix are defined for ECAL and HCAL
  - ECAL uses 7x7 or 11x11 matrix
  - HCAL uses 3x3 or 5x5 matrix
- The methodology was developed using 7 TeV data (PAS: JME-10-008) and this analysis is done using 2016 low pileup data.

Combined Calorimeter Energy Ratio (Wide Matrix)





Level of Agreement

- The level of agreement between data and MC is between 1.9% and 5.4% depending on the region of the detector which is not very dis-similar from the current version (between 1.6% and 5.5%)

	$(E_{7x7}+H_{3x3})/p$ 10.4.p03	$(E_{7x7}+H_{3x3})/p$ 10.6.p01	$(E_{11x11}+H_{5x5})/p$ 10.4.p03	$(E_{11x11}+H_{5x5})/p$ 10.6.p01
Barrel 1	(1.6±0.4)%	(2.6±0.4)%	(2.1±0.4)%	(1.9±0.4)%
Barrel 2	(4.0±0.4)%	(3.9±0.4)%	(2.8±0.4)%	(2.6±0.4)%
Transition	(5.3±0.4)%	(5.4±0.5)%	(3.6±0.4)%	(3.8±0.5)%
Endcap	(5.5±0.4)%	(4.8±0.5)%	(5.0±0.4)%	(4.7±0.5)%

Summary

- Comparisons of predictions from Geant4 versions 10.4.p03 and 10.6.p01 with test-beam and collision data show agreement within statistical uncertainty

- This variant of Geant4 is included in a specific CMSSW build

- A more elaborate validation of this new Geant4 version is proposed to test its production quality
  - Check robustness for production
  - Check physics quality: tracking efficiency, EM shower, multiple scattering effect for muons, ……

- Plans for simulation developments for 2020:
  - Transition to Geant4 version 10.6.p01
  - Optimization of simulation parameters to reach faster production

Backups

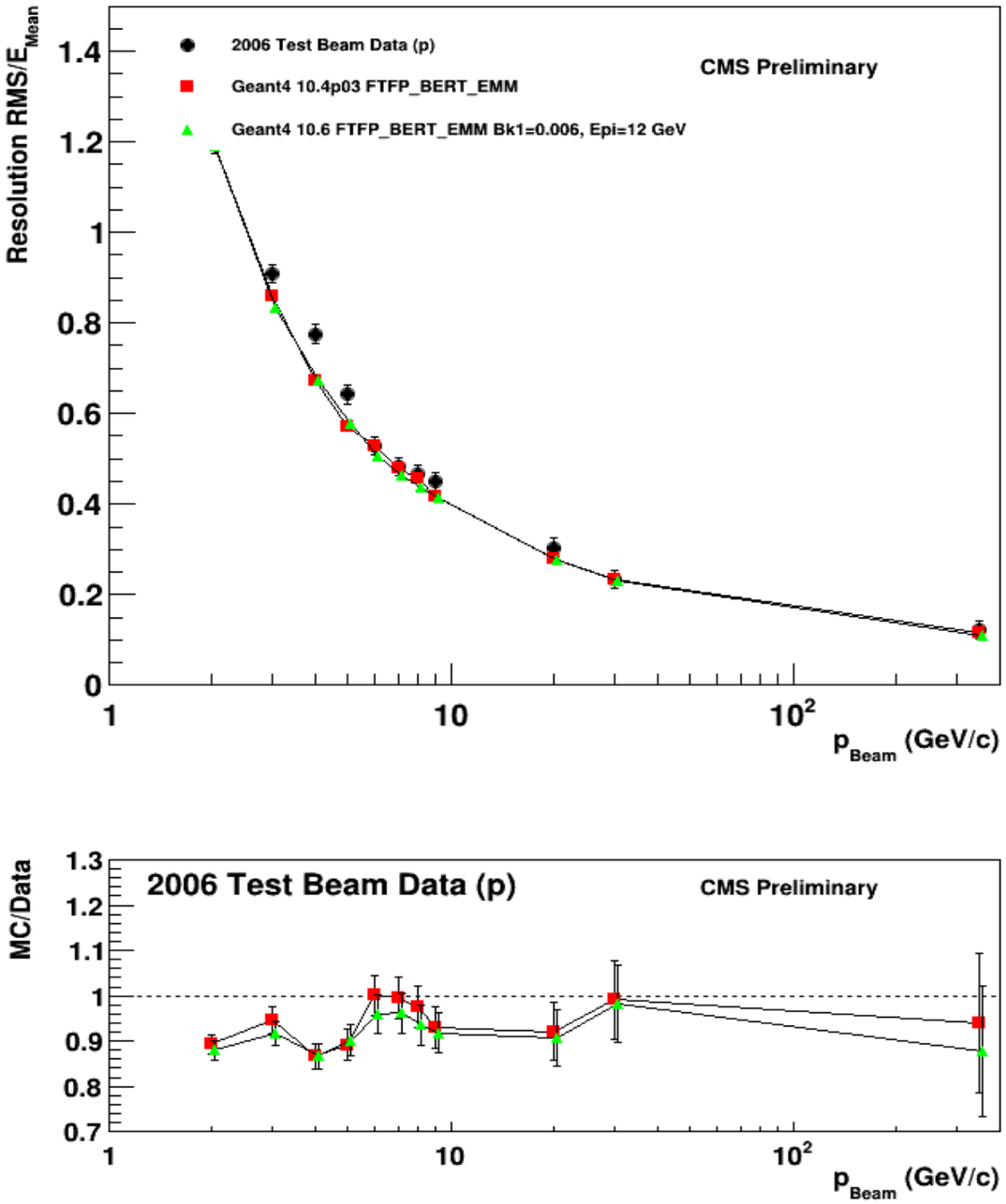
Dependence on Geometry & Physics List

- Use CPU time for Run3 and physics list FTFP_BERT_EMM as a unit of CPU time

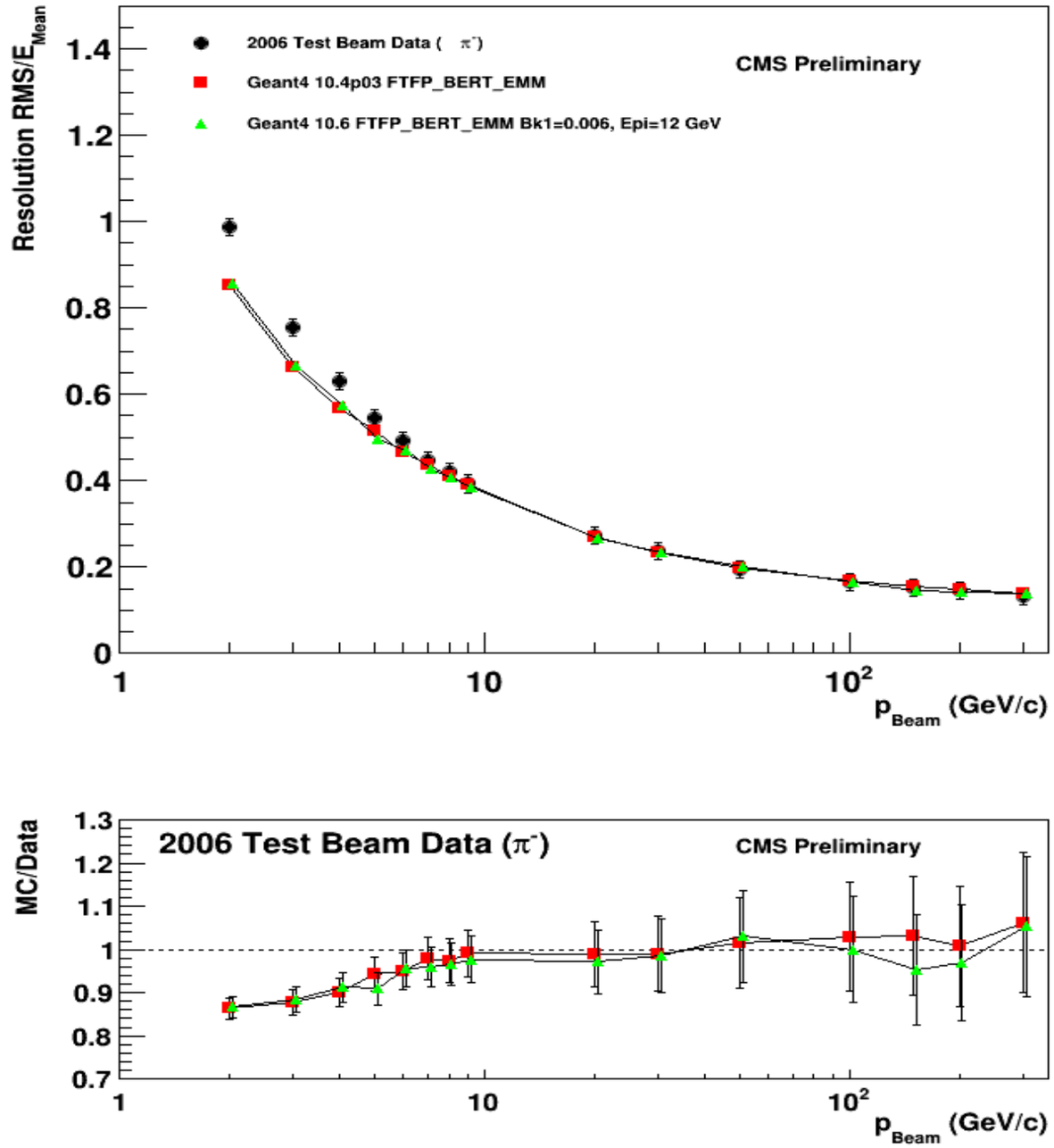
		Geant4 10.4.p3				Geant4 10.6.p1			
		Min. CPU	Bias RSS	t- CPU	tbar RSS	Min. CPU	Bias RSS	t- CPU	tbar RSS
Run3	EMM	1.000	0.49 GB	1.000	0.51 GB	0.954	0.49 GB	0.972	0.51 GB
	EMN	1.032	0.72 GB	1.047	0.74 GB	1.007	0.72 GB	1.035	0.73 GB
	EMY	1.250	0.72 GB	1.284	0.74 GB	1.219	0.72 GB	1.255	0.74 GB
	EMZ	1.663	0.98 GB			1.719	0.99 GB		
Phase2	EMM	2.331	0.56 GB	2.294	0.59 GB	2.242	0.56 GB	2.263	0.59 GB
	EMN	3.512	0.82 GB	3.528	0.87 GB	3.543	0.82 GB	3.489	0.87 GB
	EMY	3.022	0.80 GB	2.341	0.86 GB	2.930	0.80 GB	2.306	0.86 GB
	EMZ	4.142	1.16 GB			4.280	1.15 GB		

Energy Resolution for p & π^- (ECAL+HCAL)

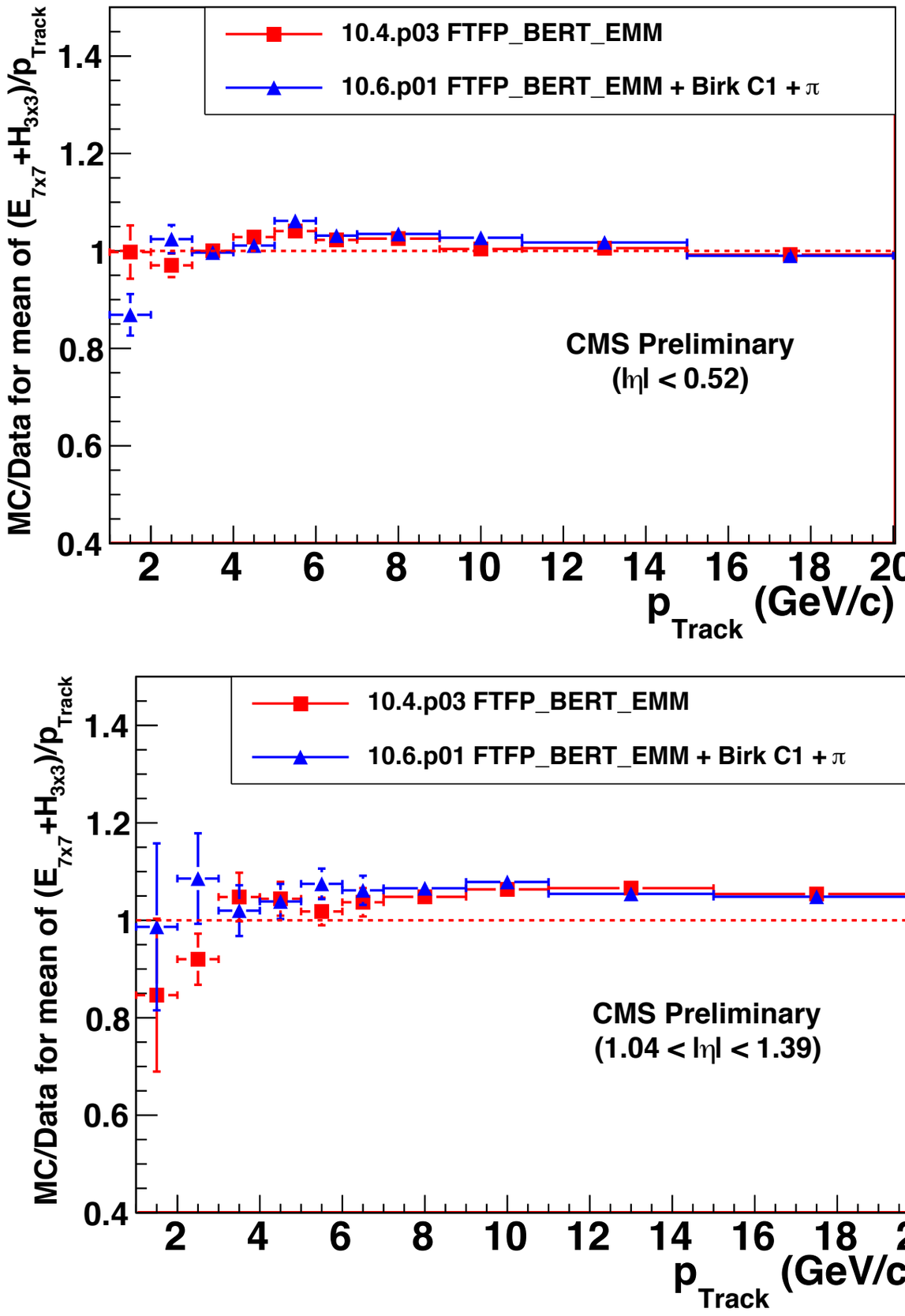
p

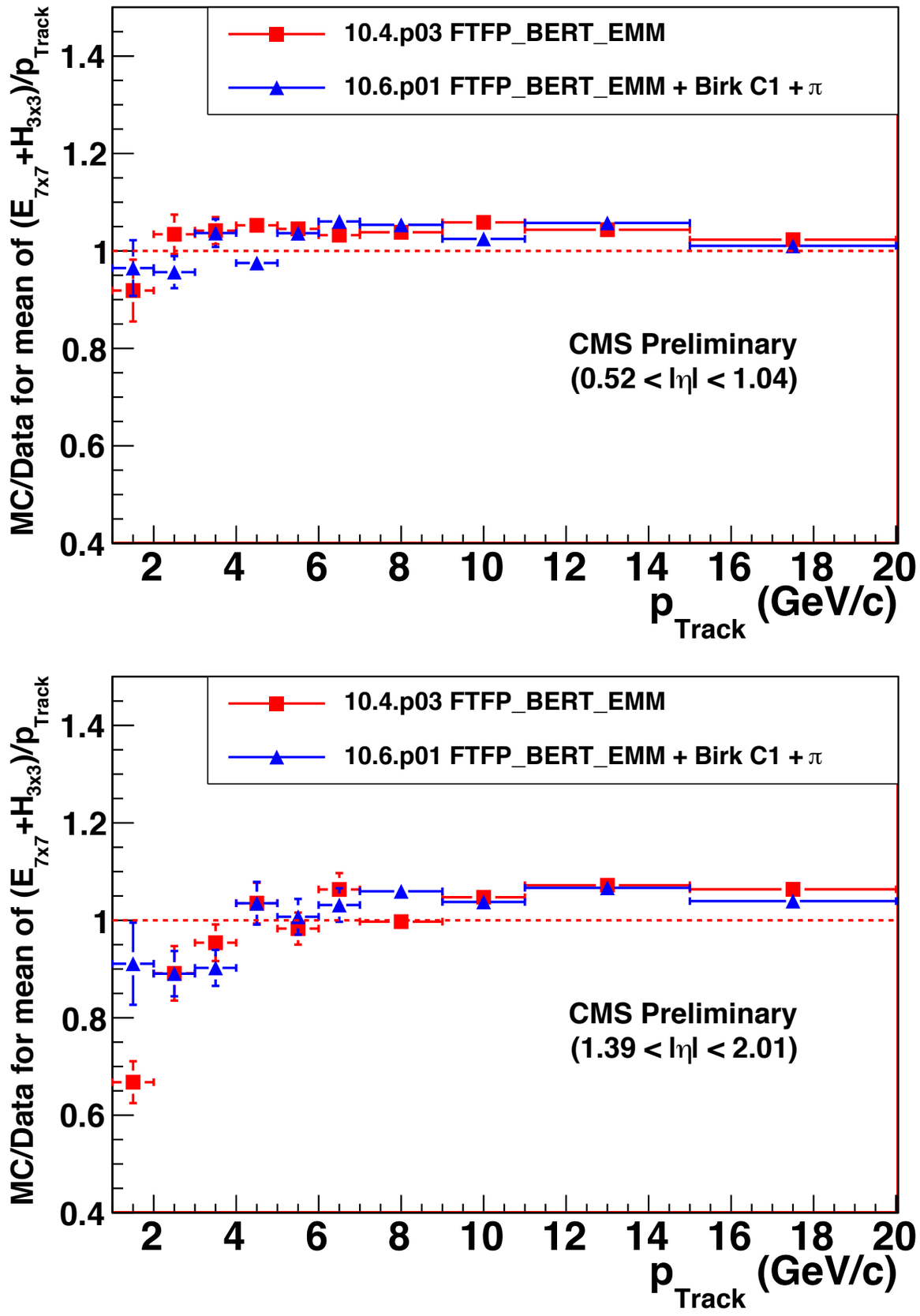


π^-



Combined Calorimeter Energy Ratio (Narrow Matrix)





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