Tests of G4 10.6 candidate 0

November 18, 2019
Simulation Meeting

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Introduction

- CMS Simulation application in production is currently using Geant4 version 10.4.p03 and plans to go for the version10.6 and a step to that is 10.6.cand0

- The version 10.6.cand0 was available on November 12 and it works with VecGeom version 1.1.4

- Adaptation of a new Geant4 version or a new Physics List requires validation of the model predictions using existing data

- The current validation results are intended for the future version due in December 2019

- 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

- Use CMSSW version 10_5_0 with private installations of Geant4.10.6.cand0 with and without VecGeom

Warnings and Errors

- Several warning messages used to appear in some recent versions:
  - Warnings about possible overlaps:
  - Warnings during tracking in B-field where some tracks are killed:
  - Error message from hadronic physics:
  - The EMZ physics lists run till end of the jobs but they do have several warnings where the energy deposit is a NaN
- In addition there used to be failures due to two possible sources
  - Miscalculation of step length during propagation
  - Tracks cannot be propagated after 25 attempts (happened with physics list EMY)

The candidate release did not show any failures but showed some warnings in the trials used so far

Dependence on Input Sample (2018 Geometry)

	Geant4+	Native	10.5.ref09	Geant4+	VecGeom	10.6.cand0
	CPU	RSS	Warning	CPU ®	RSS	Warning
50 GeV Muons	0.165 s	0.61 GB	0|0|0	1.030	0.61 GB	3|0|0
50 GeV Muons (barrel)	0.127 s	0.60 GB	0|0|0	0.969	0.60 GB	0|0|0
50 GeV Muons (endcap)	0.149 s	0.69 GB	0|0|0	0.987	0.61 GB	2|0|0
50 GeV Pions	1.109 s	0.59 GB	0|0|0	0.963	0.60 GB	3|0|0
50 GeV Pions (barrel)	1.070 s	0.60 GB	0|0|0	0.988	0.61 GB	0|0|0
50 GeV Pions (endcap)	1.065 s	0.60 GB	0|0|0	0.921	0.67 GB	2|0|0
50 GeV electrons	2.535 s	0.57 GB	0|0|0	0.970	0.58 GB	0|0|0
50 GeV electron (barrel)	2.453 s	0.58 GB	0|0|0	1.013	0.57 GB	0|0|0
50 GeV electron (endcap)	2.262 s	0.57 GB	0|0|0	0.987	0.57 GB	8|0|0
Minimum Bias	9.453 s	0.72 GB	1|0|2	0.911	0.74 GB	156|0|1
t-tbar	53.827 s	0.71 GB	3|0|0	0.954	0.66 GB	402|0|0

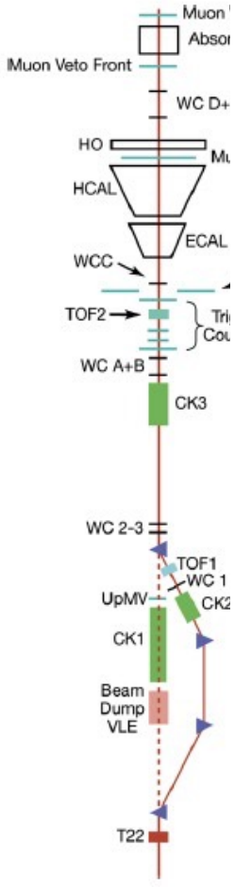
Use the physics list FTFP_BERT for this comparison

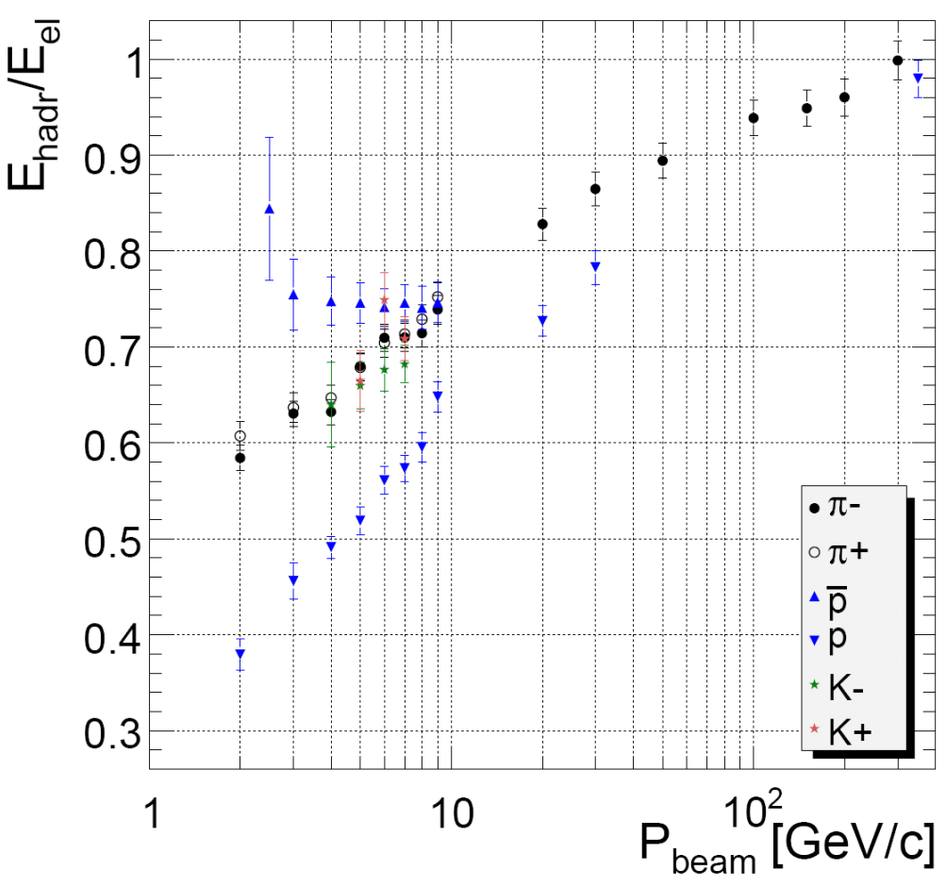
Dependence on Physics List (2018 Geometry)

	Geant4+ CPU	Native RSS	10.5.ref09 Warning	Geant4+ CPU ®	VecGeom RSS	10.6.cand0 Warning
	Input:		Minimum	Bias		
FTFP_BERT_EMM	7.454 s	0.66 GB	0|0|3	0.911	0.69 GB	170|0|3
FTFP_BERT	9.453 s	0.72 GB	1|0|2	0.911	0.74 GB	156|0|1
FTFP_BERT_EMN	7.512 s	0.93 GB	1|0|1	0.907	0.94 GB	174|0|1
	Input:		t-	tbar		
FTFP_BERT_EMM	41.171 s	0.66 GB	4|0|4	0.961	0.67 GB	391|0|0
FTFP_BERT	53.827 s	0.71 GB	3|0|0	0.954	0.66 GB	402|0|0
FTFP_BERT_EMN	42.653 s	0.97 GB	2|0|0	0.949	0.95 GB	367|0|2

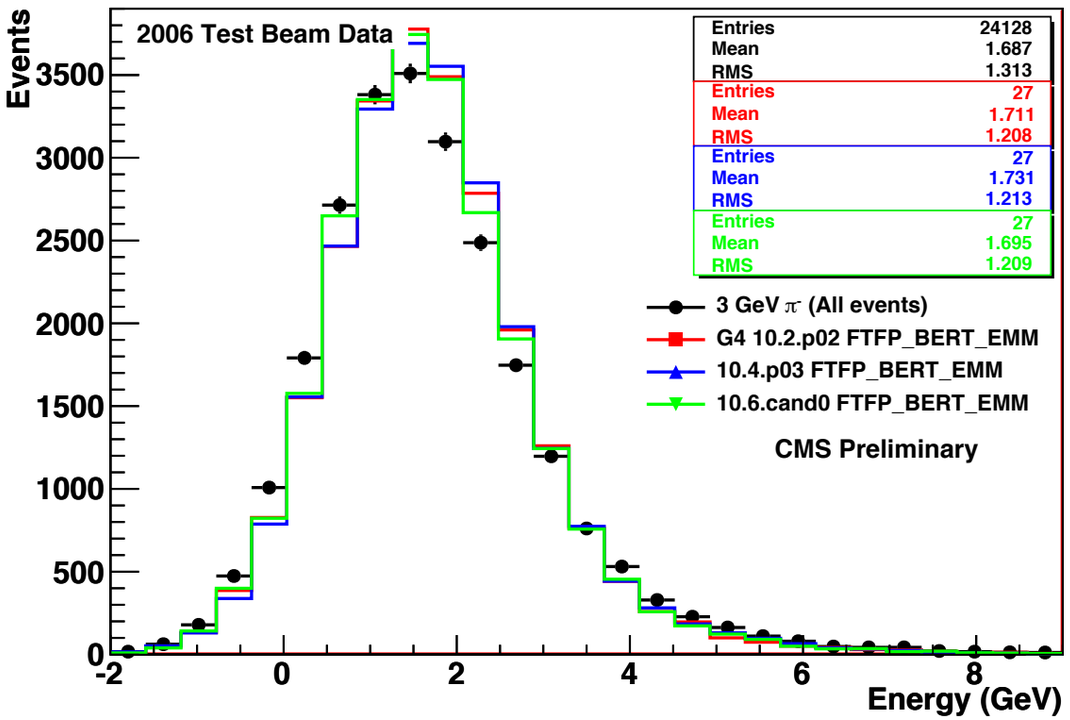
2006 TestBeam Data

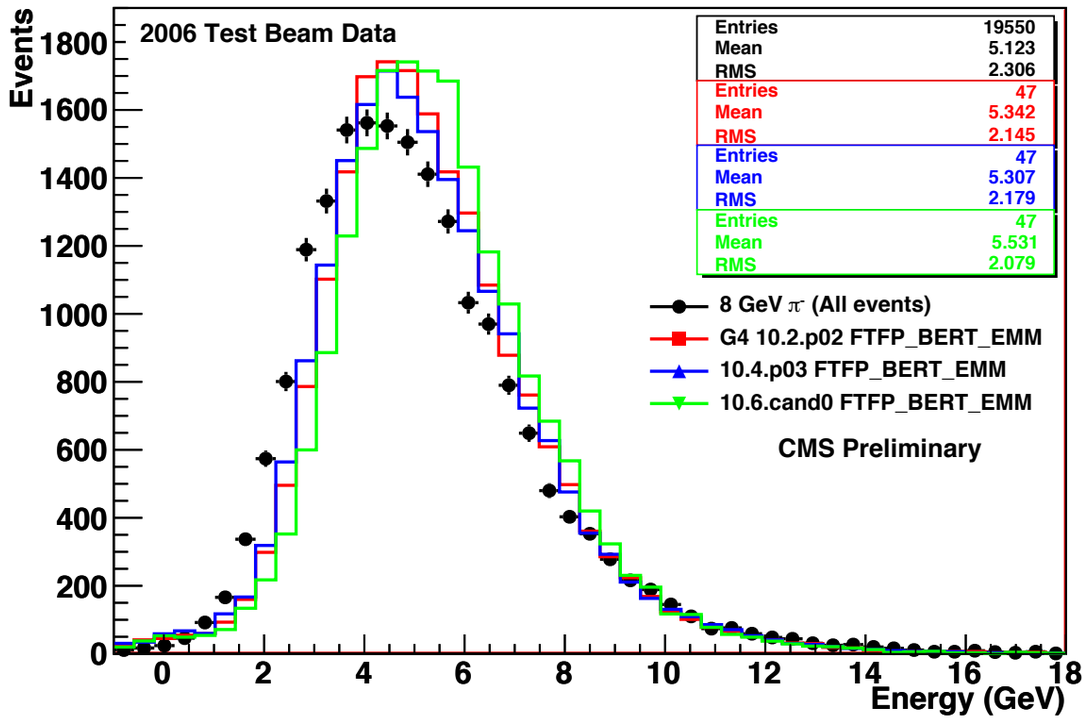
- CMS collected data with prototype of Hadron Calorimeter Barrel and a supermodule of the barrel Electromagnetic Calorimeter in the H2 test beam area at CERN during 2006 with both positive and negative beams of momentum between 1 and 350 GeV
- The analysis utilized particle identification using data 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)
- Comparison was done with Geant4 version 10.5.ref08 for mean response and resolution and reported in earlier PPD meeting

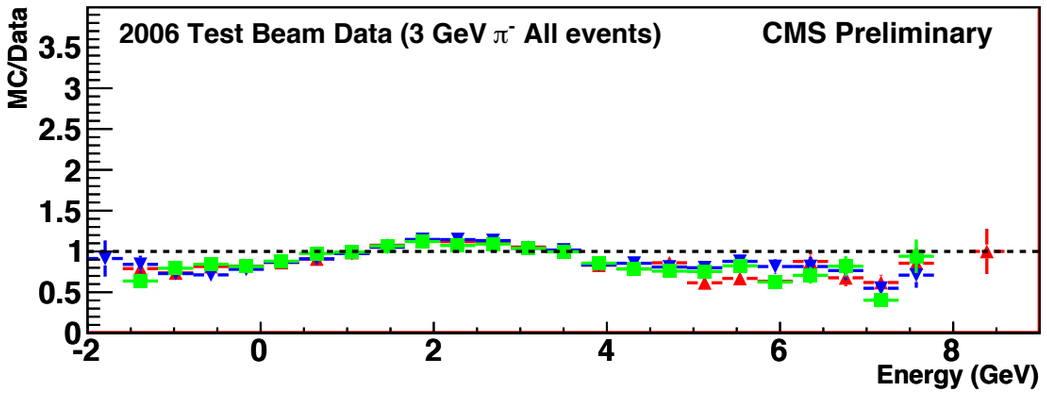


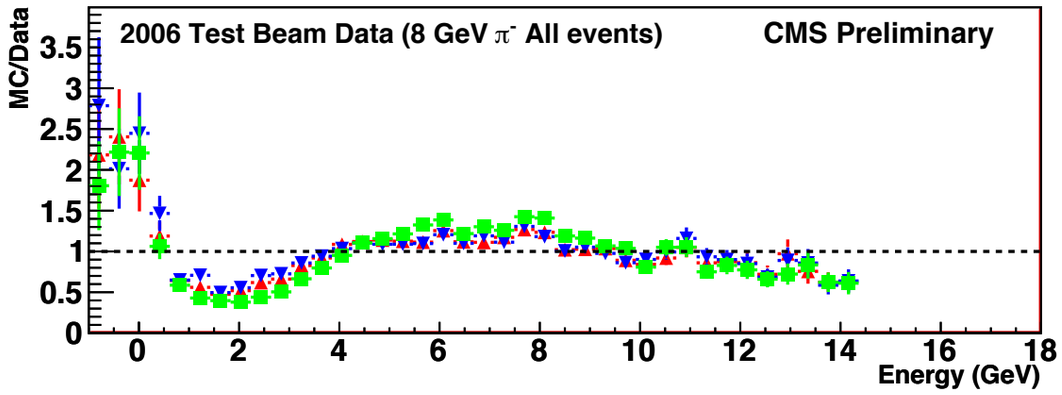


Energy for negative pions









- Energy spectrum in the data is slightly broader and is shifted to higher values for energies above 5 GeV
- Same is observed for positive pions
- No significant shift is observed for protons

Test Beam Data

Mean level of disagreement between MC and data

	π- 10.4.p03	π- 10.6.beta	π- 10.6.cnd0	π+ 10.4.p03	π+ 10.6.beta	π+ 10.6.cnd0	p 10.4.p03	p 10.6.beta	p 10.6.cnd0
2 GeV	14.6±0.9	9.6±0.9	11.9±0.9	11.6±1.2	14.3±1.2	12.0±1.2	6.8±2.5	8.9±0.3	7.4±0.3
3 GeV	10.8±0.6	9.2±0.6	8.3±0.6	8.5±1.7	9.3±1.7	9.0±1.7	2.1±1.0	3.2±1.0	3.4±1,0
4 GeV	15.8±0.5	10.8±0.5	15.6±0.5	12.5±0.5	14.0±0.5	13.8±0.5	12.0±1.2	9.2±1.2	12.7±1.2
5 GeV	10.6±0.5	10.7±0.5	15.9±0.4	9.9±1.0	10.1±0.9	13.4±0.9	11.8±3.1	12.2±3.2	12.8±3.2
6 GeV	12.0±0.5	10.7±0.4	24.5±0.4	11.0±0.9	8.7±0.8	22.5±0.8	5.4±3.2	10.2±3.5	6.1±3.6
7 GeV	14.5±0.5	11.7±0.5	28.8±0.5	12.8±0.7	10.7±0.7	28.1±0,7	8.1±2.9	7.1±2.8	11.3±2.8
8 GeV	17.4±0.6	18.5±0.6	34.4±0.6	14.2±0.7	17,2±0.7	29.0±0.7	4.0±1.0	7.6±1.0	3.8±1.0

Serious disagreement between data and MC for pions of energy above 5 GeV

Isolated Charged Particles

- Compare ratio of calorimeter energy measurement to track momentum for isolated charged hadrons between data and MC

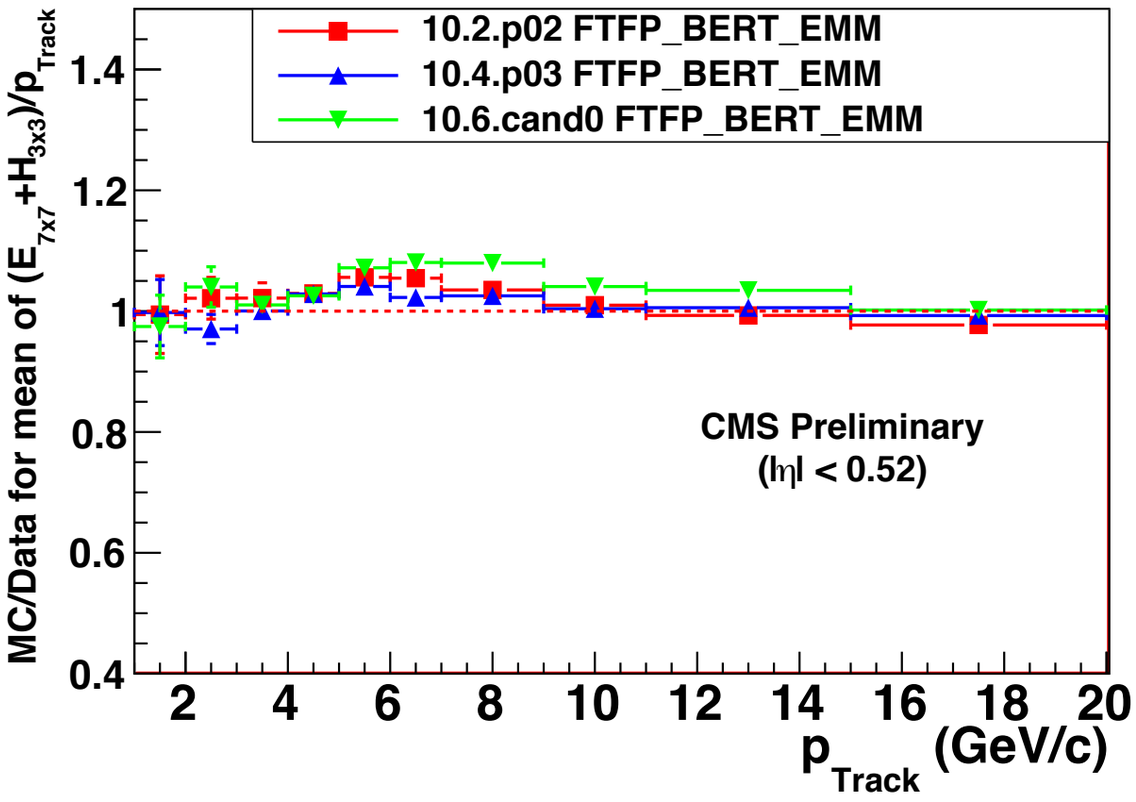
- Select good charged tracks reaching the calorimeter surface

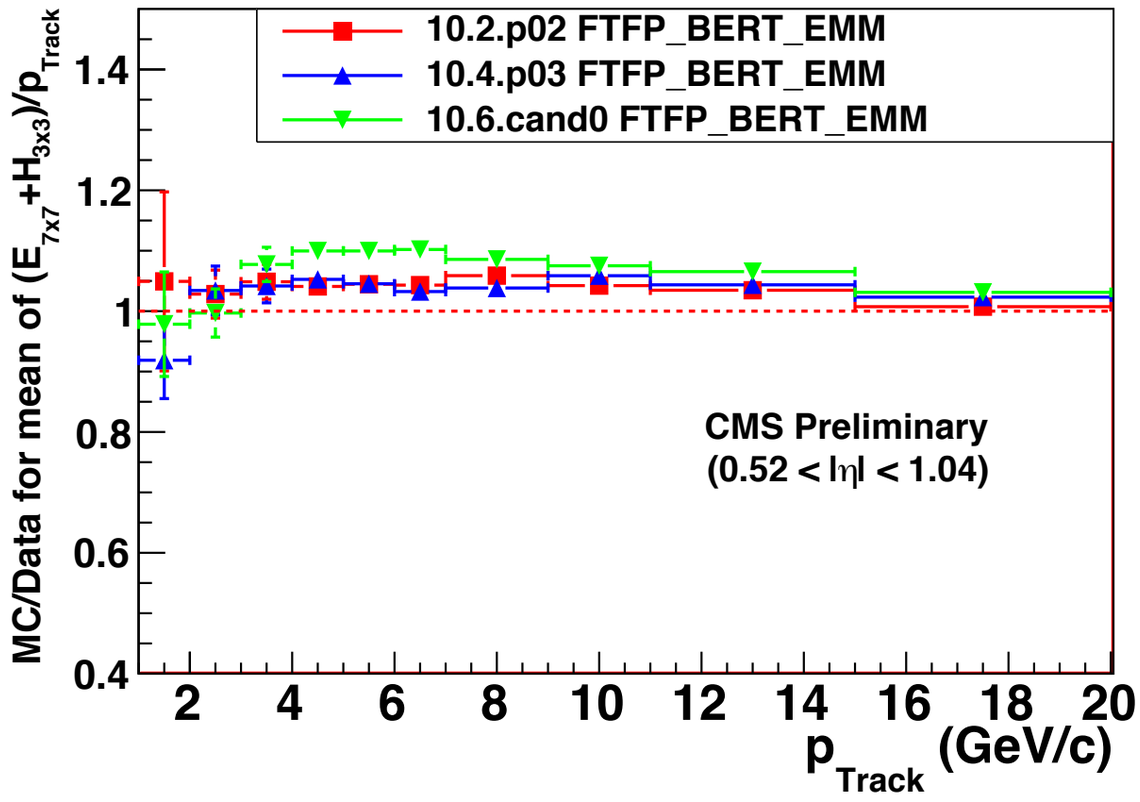
- Impose isolation of these charged particles
  - propagate track to calorimeter surface and study momentum of tracks (selected with looser criteria) reaching ECAL (HCAL) within a matrix of 31x31 (7x7) around the impact point of the selected track for charge isolation
  - study energy deposited in an annular region in ECAL (HCAL) between 15x15 and 11x11 (7x7 and 5x5) matrices for neutral isolation

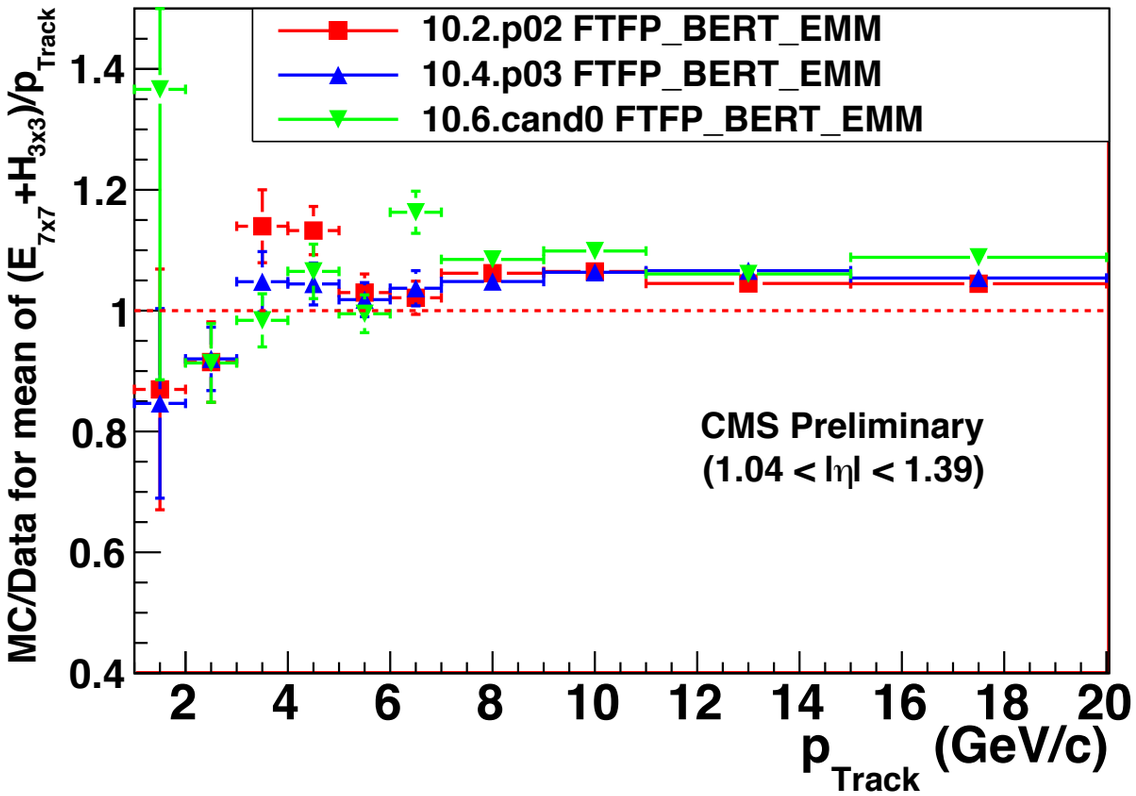
- Two versions of NxN matrix are defined for ECAL and HCAL
  - ECAL uses 7x7 or 11x11 matrix
  - HCAL uses 3x3 or 5x5 matrix

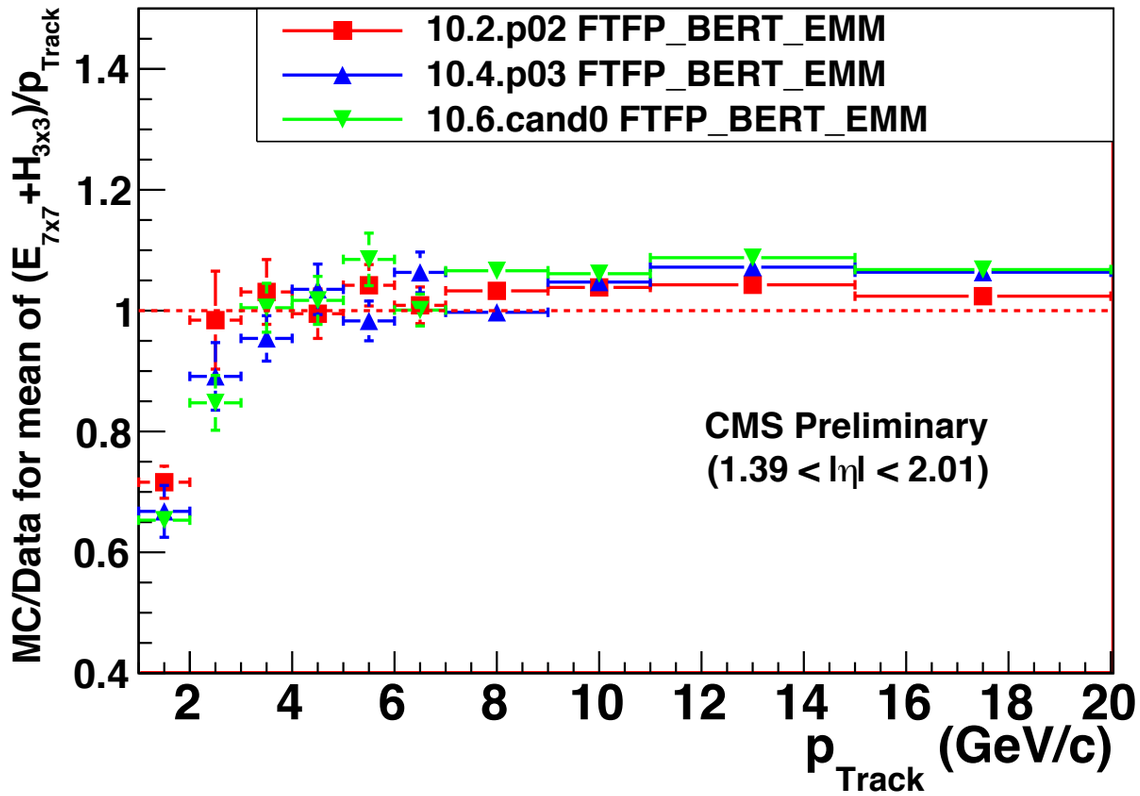
- The methodology was developed using 7 TeV data (PAS: JME-10-008) and this analysis is done using 2016 low pileup data.

Combined Calorimeter Energy Ratio (Narrow Matrix)



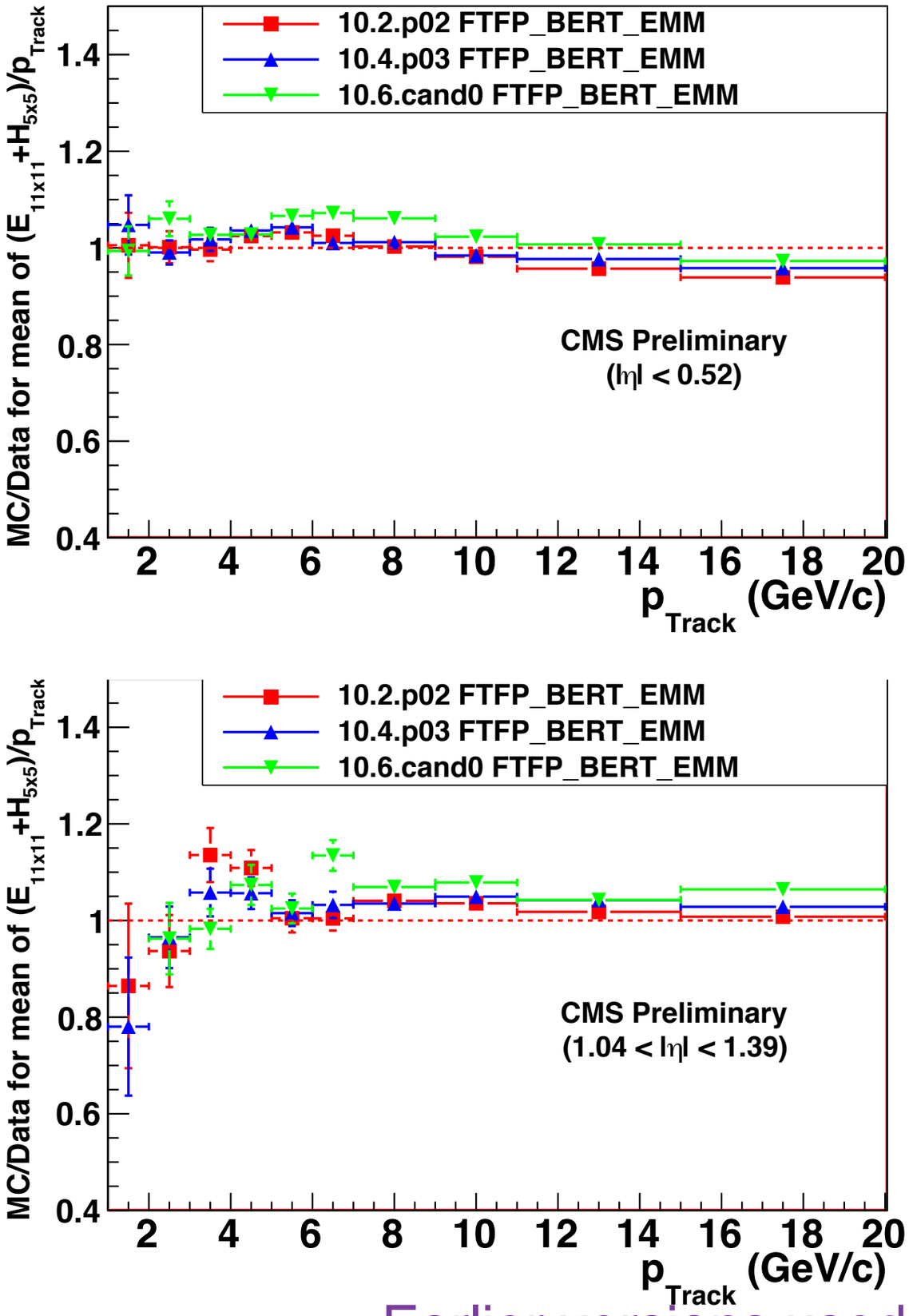


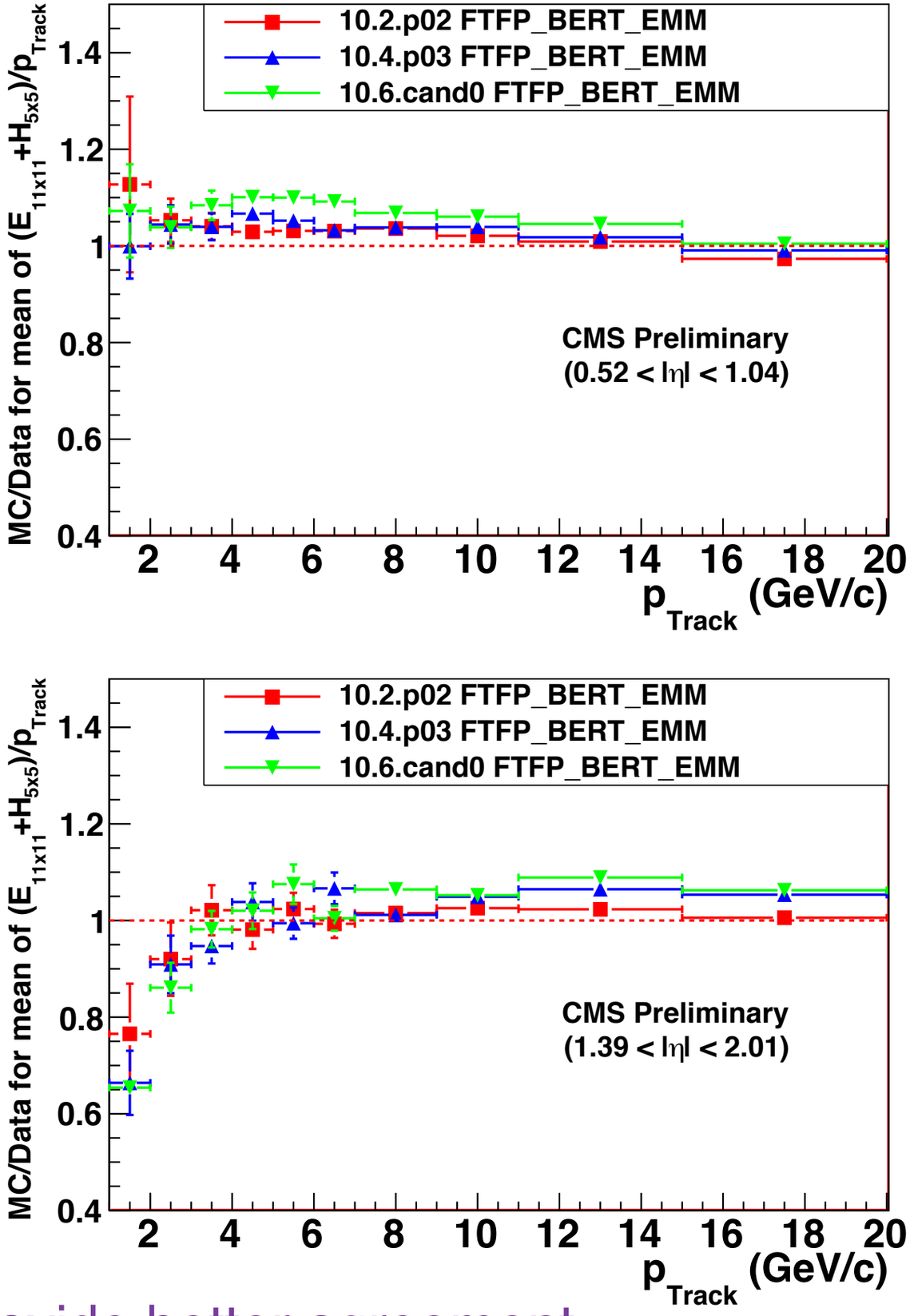




Level of agreement was better in the earlier Geant4 versions

Combined Calorimeter Energy Ratio (Wide Matrix)





Earlier versions used to provide better agreement

Level of Agreement

- The level of agreement between data and MC is between 6 to 11% depending on the region of the detector and has significantly deteriorated in the current version

	$(E_{7x7}+H_{3x3})/p$ 10.2.p02	$(E_{7x7}+H_{3x3})/p$ 10.4.p03	$(E_{7x7}+H_{3x3})/p$ 10.5.ref10	$(E_{11x11}+H_{5x5})/p$ 10.2.p02	$(E_{11x11}+H_{5x5})/p$ 10.4.p03	$(E_{11x11}+H_{5x5})/p$ 10.5.ref10
Barrel 1	(2.4±0.4)%	(1.6±0.4)%	(8.1±0.4)%	(2.6±0.4)%	(2.1±0.4)%	(5.7±0.4)%
Barrel 2	(3.6±0.4)%	(4.0±0.4)%	(10.7±0.4)%	(2.2±0.4)%	(2.8±0.4)%	(8.3±0.4)%
Transition	(4.9±0.4)%	(5.3±0.5)%	(11.4±0.5)%	(2.2±0.4)%	(3.6±0.5)%	(9.0±0.5)%
Endcap	(3.1±0.4)%	(5.5±0.5)%	(10.9±0.5)%	(1.5±0.4)%	(5.0±0.5)%	(9.8±0.5)%

Summary

- Predictions from the new Geant4 version10.6.cand0 using the physics list FTFP_BERT_EMM are compared with the data

- Test beam data with identified particle types are used as one source of validation while isolated charged particles from collision data are used as a second source

- There used to be good agreement between data and Monte Carlo for the physics list FTFP_BERT_EMM which is used as the default by CMS for its current and future event productions. However, the agreement for the version 10.6.cand0 is significantly worse than the earlier version 10.4.p03

- Many of the issues for track propagation in B-field which we observed in earlier reference releases are no longer seen within limited statistics
  - The exception for physics list FTFP_BERT needs further investigations
  - The frequent warnings for overlaps may be due to inadequacy in VecGeom for solids of shape CutTubs

Backups