Back-scattering analysis from TB16

Status report

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CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

Collaboration
High precision design

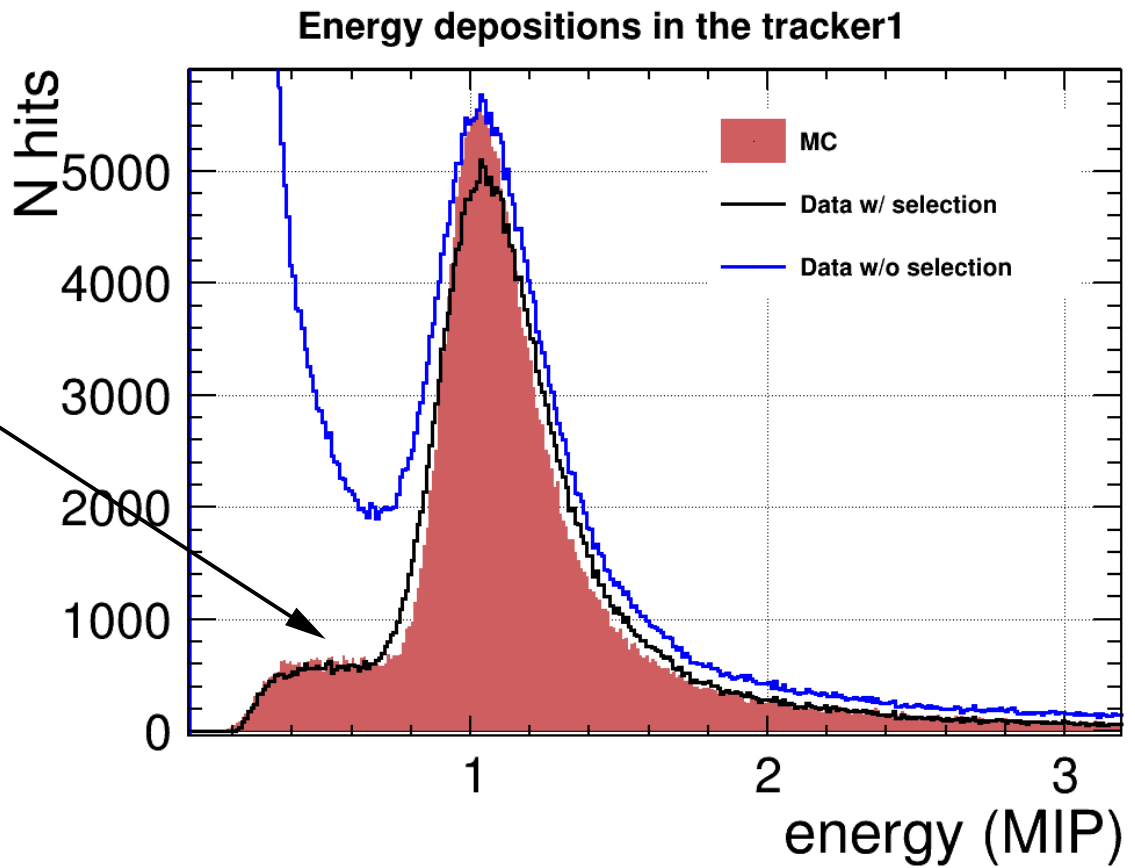
Motivation

Test Geant4 for back-scattering:

- How good Geant4 with describing back-scattering?
- Test different EM physics lists?

Current status of the TB16 data analysis

Implemented signal sharing between pads in the MC (pedestal!)



https://agenda.linearcollider.org/event/9286/#preview:57635

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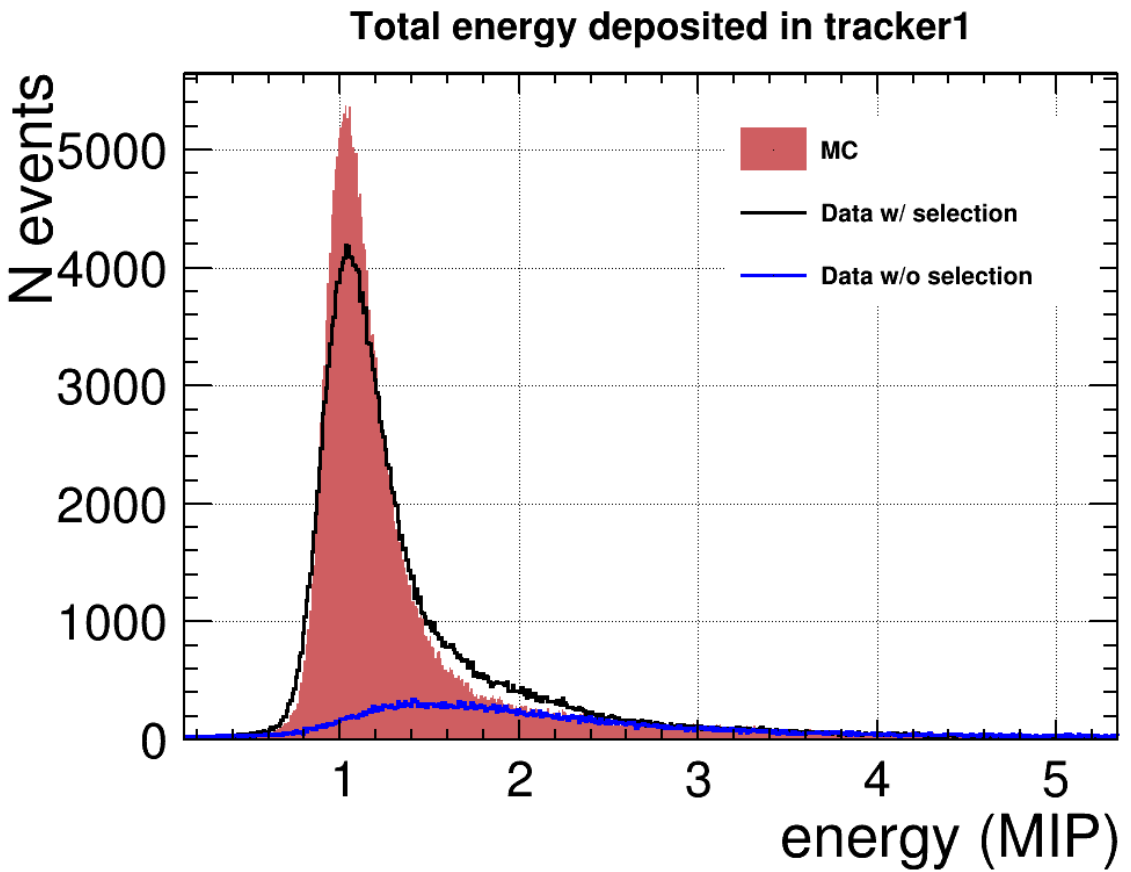
Total energy disagrees a lot.

Of course! We didn't smear with a noise!



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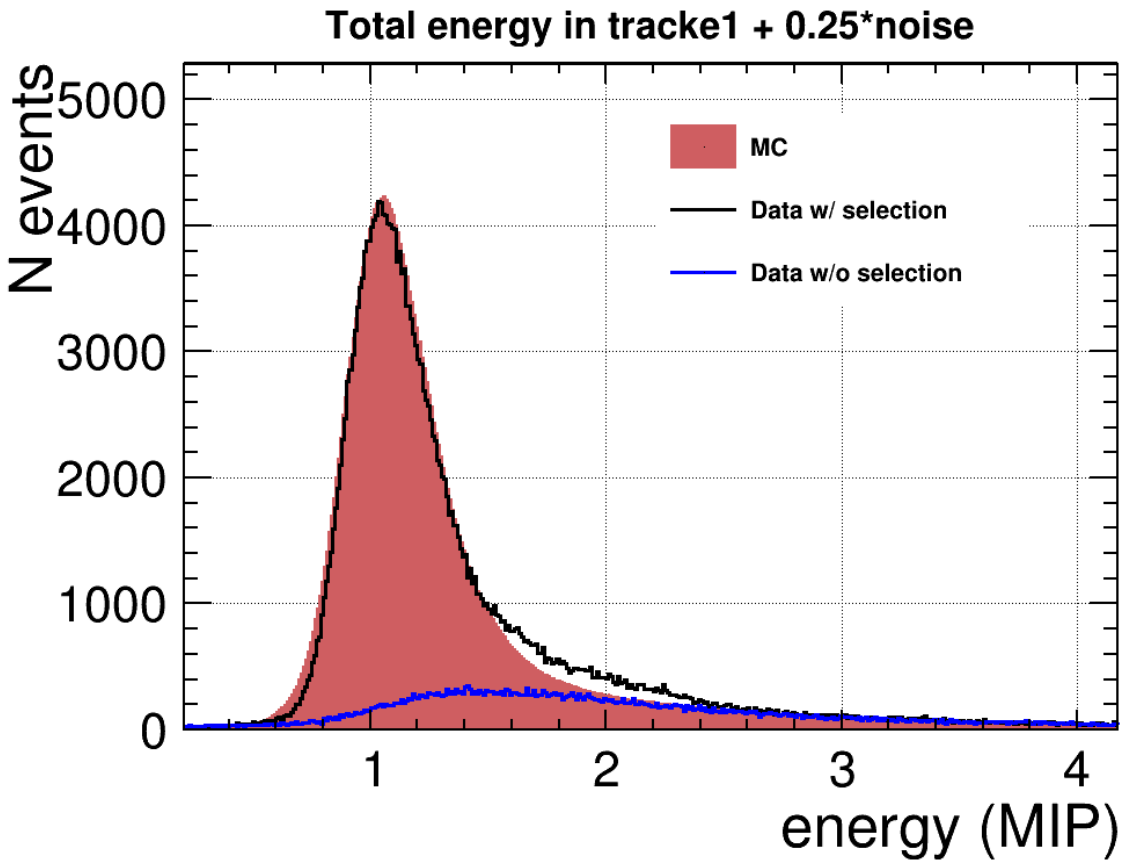

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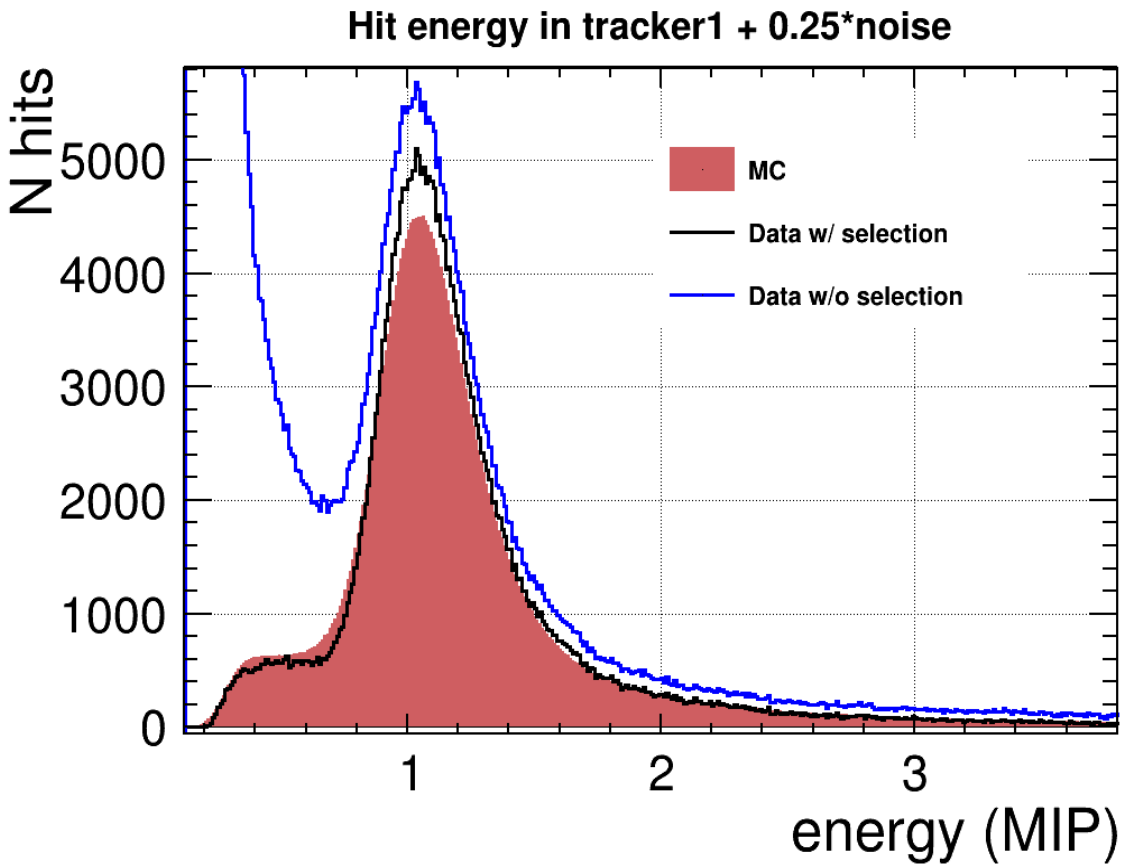
Total energy disagrees a lot.

Of course! We didn't smear with a noise!

Not trivial to get a good agreement



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Motivation

Test Geant4 for back-scattering:

- How good Geant4 with describing back-scattering?
- Test different EM physics lists?

We need very good data/MC agreement:

- Very small difference between EM physics lists
- But how “very small” it actually is? ← *this presentation*

Introduction to the EM physics lists

- G4EmStandardPhysics EM Opt0 (default)
- G4EmStandardPhysics_option1 EM Opt1 - extension name EMV;
- G4EmStandardPhysics_option2 EM Opt2 - extension name EMX;
- G4EmStandardPhysics_option3 EM Opt3 - extension name EMY;
- G4EmStandardPhysics_option4 EM Opt4 - extension name EMZ;
- G4EmLivermorePhysics EM Liv - extension name LIV;
- G4EmPenelopePhysics EM Pen - extension name PEN;
- G4EmStandardPhysicsGS EM GS - extension name _GS;
- G4EmLowEPPhysics EM LE - extension name _LE;
- G4EmStandardPhysicsWVI EM WVI - extension name WVI;
- G4EmStandardPhysicsSS EM SS - extension name _SS;
- G4EmDNAPhysics EM DNA.

reference

Introduction to the EM physics lists

- G4EmStandardPhysics EM Opt0 (default)
- G4EmStandardPhysics_option1 EM Opt1 - extension name EMV;
- G4EmStandardPhysics_option2 EM Opt2 - extension name EMX;
- G4EmStandardPhysics_option3 EM Opt3 - extension name EMY;
- G4EmStandardPhysics_option4 EM Opt4 - extension name EMZ;

I will focus only on options 0-4

Other physics lists are made on top of the of either Opt0 or Opt3 by substituting standard models with some specific ones

reference

Introduction to the EM physics lists

EM options	Descriptions
Opt1 (EMV)	**less precise**, but faster set of electromagnetic physics
Opt2 (EMX)	**less precise**, but faster set of electromagnetic physics
Opt3 (EMY)	**More accurate** simulation of gamma and charged particle transport
Opt4 (EMZ)	the best set of electromagnetic physics models selected from the low energy and standard packages. **Concentrated on the best possible physics**

reference

Introduction to the EM physics lists

Photons in different physics lists:

title	Rayleigh	Photoelectric	Compton	Gamma conversion
Opt0	Livermor-eRayleigh 0-100 TeV	LivermorePhElectric 0-100 TeV	KleinNishina 0-100 TeV	BetheHeitlerLPM 0-100 TeV
Opt1	none	LivermorePhElectric 0-100 TeV	KleinNishina 0-100 TeV	BetheHeitlerLPM 0-100 TeV
Opt2	none	PhotoElectric 0-100 TeV	KleinNishina 0-100 TeV	BetheHeitlerLPM 0-100 TeV
Opt3	Livermor-eRayleigh 0-100 TeV	LivermorePhElectric 0-100 TeV	KleinNishina 0-100 TeV	BetheHeitlerLPM 0-100 TeV
Opt4	Livermor-eRayleigh 0-100 TeV	LivermorePhElectric 0-100 TeV	LowEPComptonModel 0-20 MeV KleinNishina 20 MeV-100 TeV	BetheHeitler5D 0-100 TeV

reference

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No Rayleigh scattering for simplified options

reference

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Different model for Compton scattering < 20 MeV and different gamma conversion option

reference

Introduction to the EM physics lists

Electrons in different physics lists:

	Coulomb scattering	Multiple scattering	Pair pro-duction	Ionisation	Bremsstrahlung
Opt0	eCoulombScat-tering 100 MeV-100 TeV	UrbanMsc 0-100 MeV WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt1	eCoulombScat-tering 100 MeV-100 TeV	UrbanMsc 0-100 MeV; WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt2	eCoulombScat-tering 100 MeV-100 TeV	UrbanMsc 0-100 MeV WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt3	none	UrbanMsc 0-100 TeV	ePair-Prod 0-100 TeV	MollerBhabha 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt4	eCoulombScat-tering 100 MeV-10 TeV	GoudsmitSaunderson 0-100 MeV WentzelVIUni 100 MeV-100 TeV	ePair-Prod 0-100 TeV	LowEnergyIoni 0-100 keV MollerBhabha 100 keV-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV

reference

Introduction to the EM physics lists

Positrons in different physics lists:

	Coulomb scattering	Multiple scattering	Pair pro-duc-tion	Ionisation	Annihilation	Bremsstrahlung
Opt0	eCoulomb-Scattering 100 MeV-100 TeV	UrbanMsc 0-100 MeV WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eplus2gg 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt1	eCoulomb-Scattering 100 MeV-100 TeV	UrbanMsc 0-100 MeV WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eplus2gg 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt2	eCoulomb-Scattering 100 MeV-100 TeV	UrbanMsc 0-100 MeV WentzelVIUni 100 MeV-100 TeV	none	MollerBhabha 0-100 TeV	eplus2gg 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt3	none	UrbanMsc 0-100 TeV	ePair-Prod 0-100 TeV	MollerBhabha 0-100 TeV	eplus2gg 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV
Opt4	eCoulomb-Scattering 100 MeV-100 TeV	GoudsmitSaunderson 0-100 MeV WentzelVIUni 100 MeV-100 TeV	ePair-Prod 0-100 TeV	PenIoni 0-100 keV MollerBhabha 100 keV-100 TeV	eplus2gg 0-100 TeV	eBremSB 0-1 GeV eBremLPM 1 GeV-100 TeV

reference

Generated MC samples

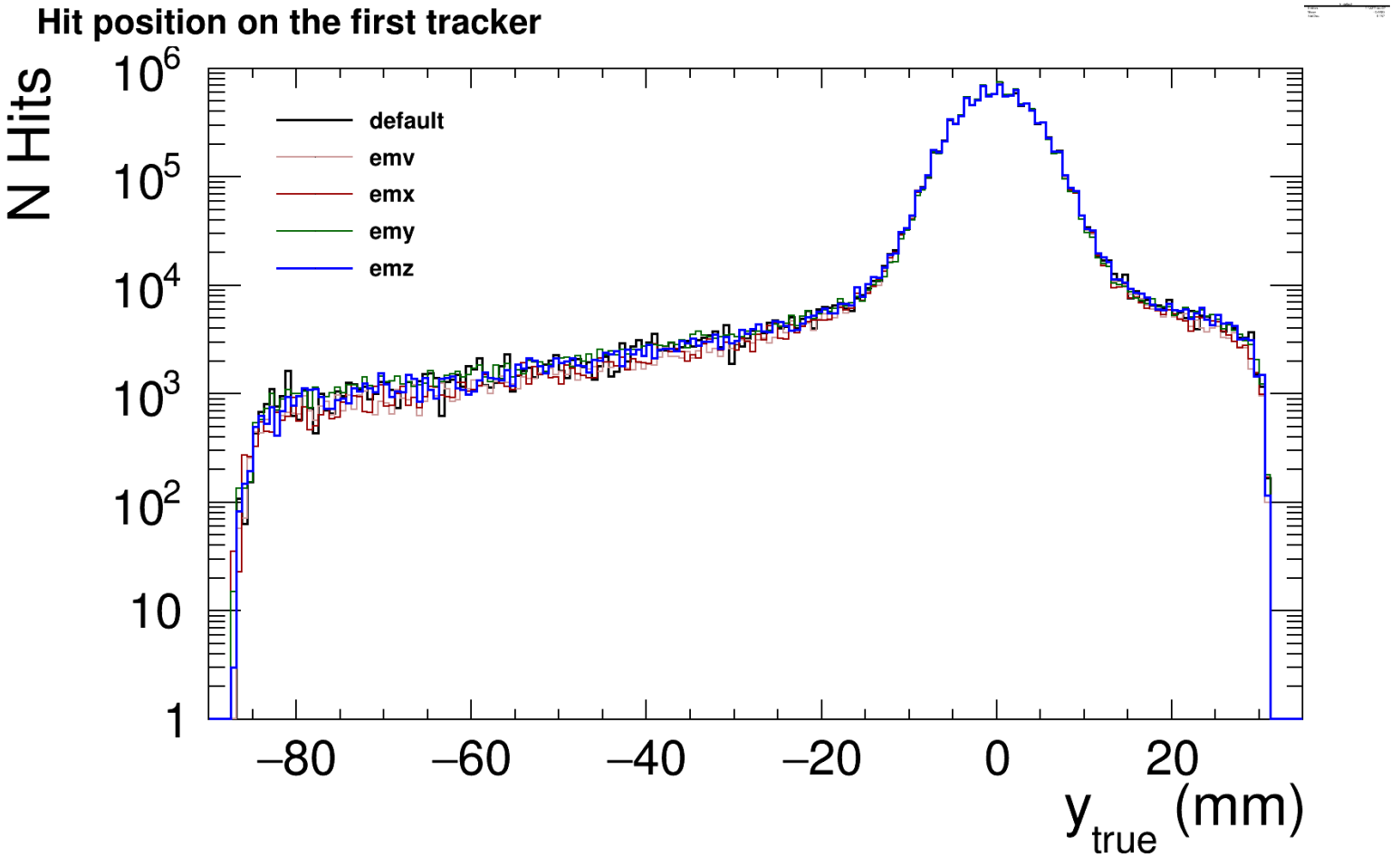
Geant4 version	10.6.2
Statistics per physics list	9 340 000
Hadronic physics list option	FTFP_BERT

```
total 212G
-rw-r--r-- 1 dudarboh af-ilc  37G Jul 13 19:06 e_FTFP_BERT_EMV.root
-rw-r--r-- 1 dudarboh af-ilc  34G Jul 13 20:24 e_FTFP_BERT_EMX.root
-rw-r--r-- 1 dudarboh af-ilc  45G Jul 13 22:48 e_FTFP_BERT_EMY.root
-rw-r--r-- 1 dudarboh af-ilc  47G Jul 14 01:58 e_FTFP_BERT_EMZ.root
-rw-r--r-- 1 dudarboh af-ilc  45G Jun 10 13:36 e_FTFP_BERT.root
```

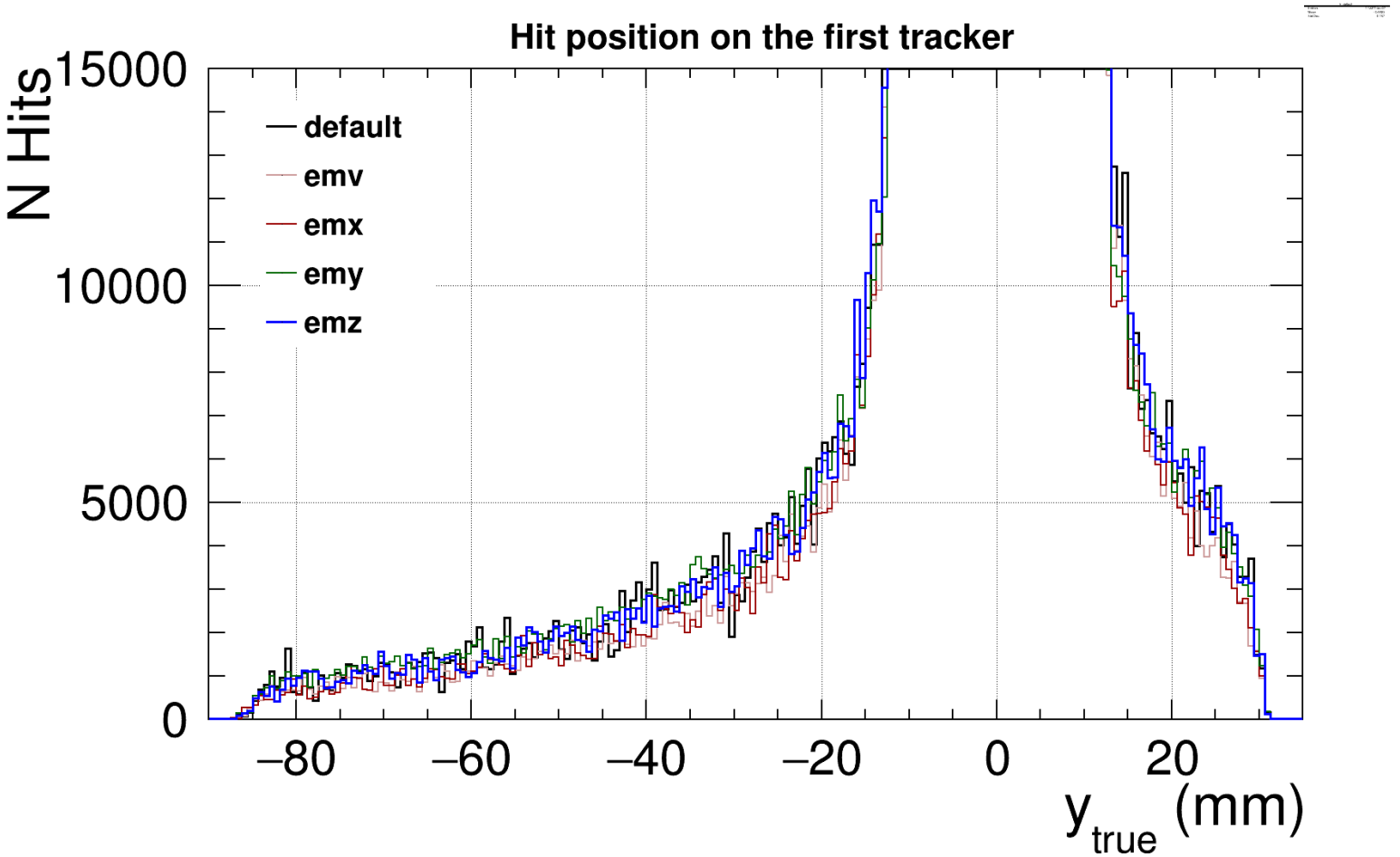
FTFP_BERT is recommended for collider physics applications. It usually produces the best agreement with test beam calorimeter data, including shower shape, energy response and resolution.

reference

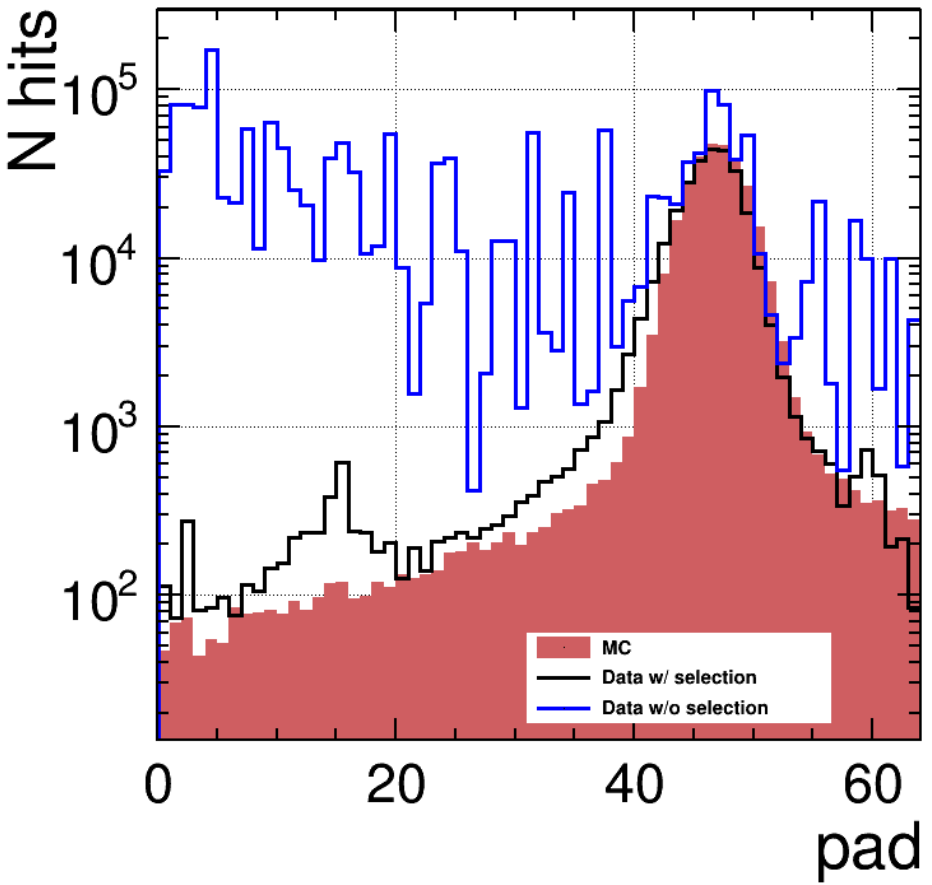
Control plots for the 1st tracker: position



Control plots for the 1st tracker: position

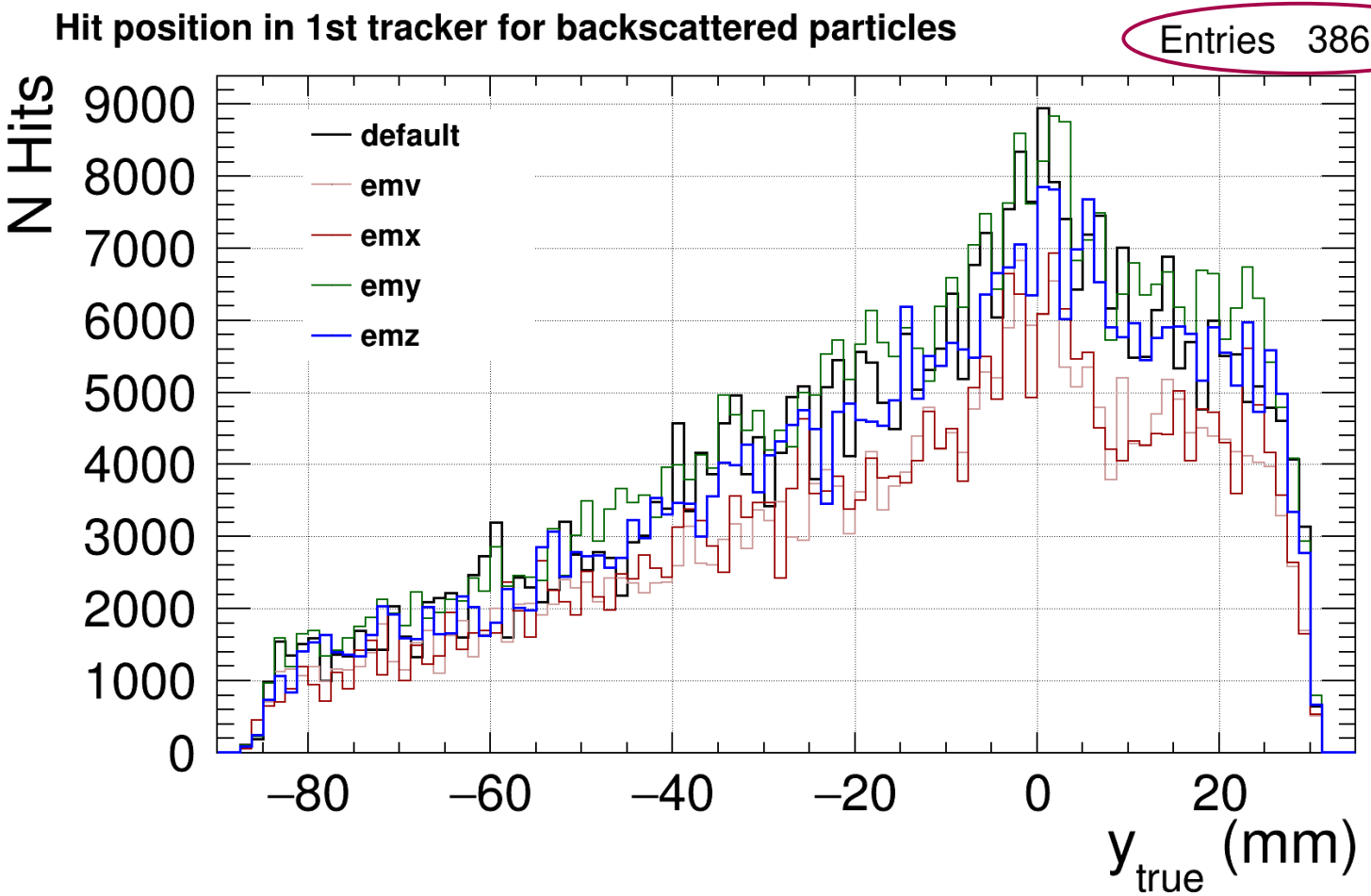


Control plots for the 1st tracker: position

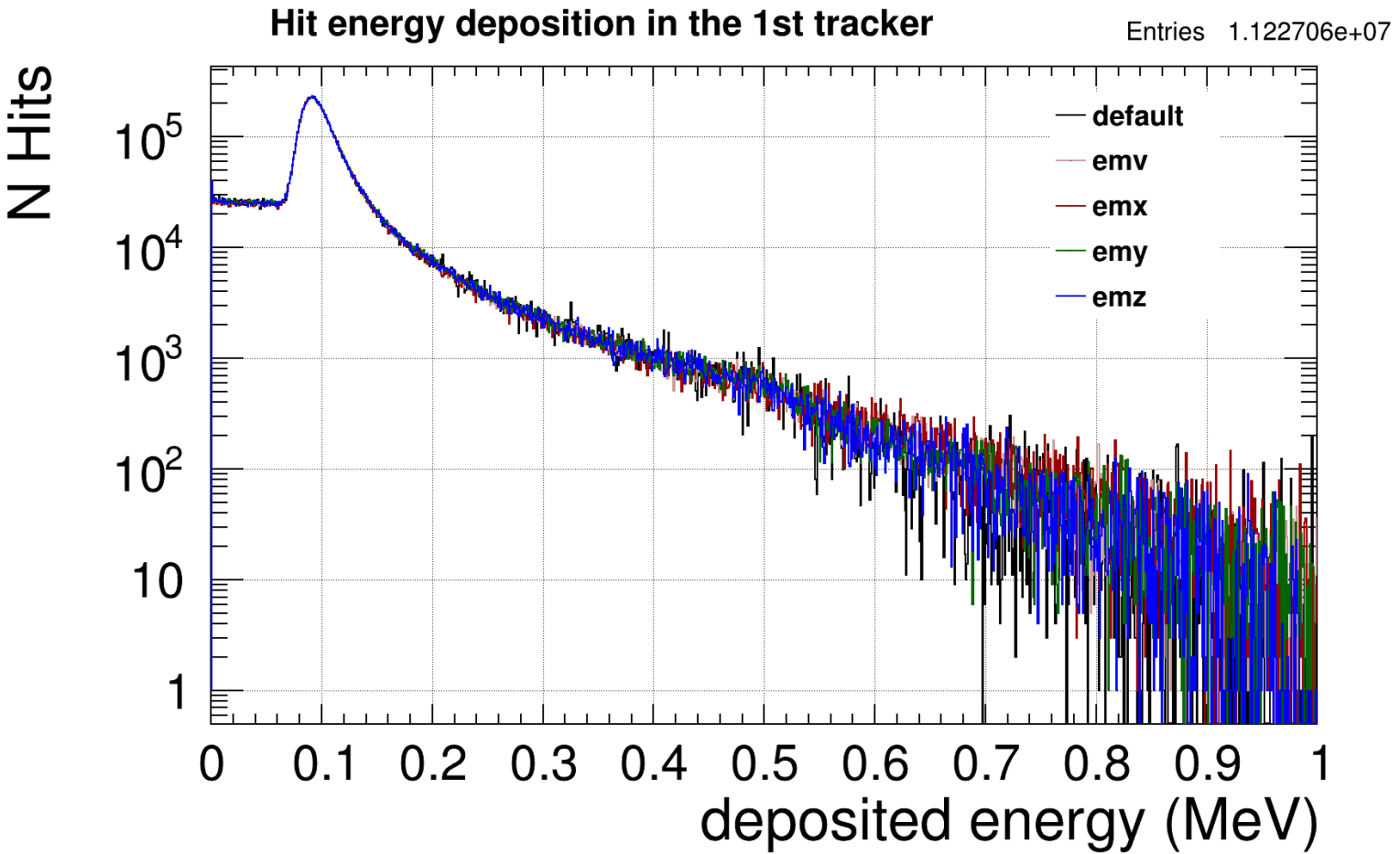


Control plots for the 1st tracker: position

~3.4% of all hits



Control plots for the 1st tracker: deposited energy



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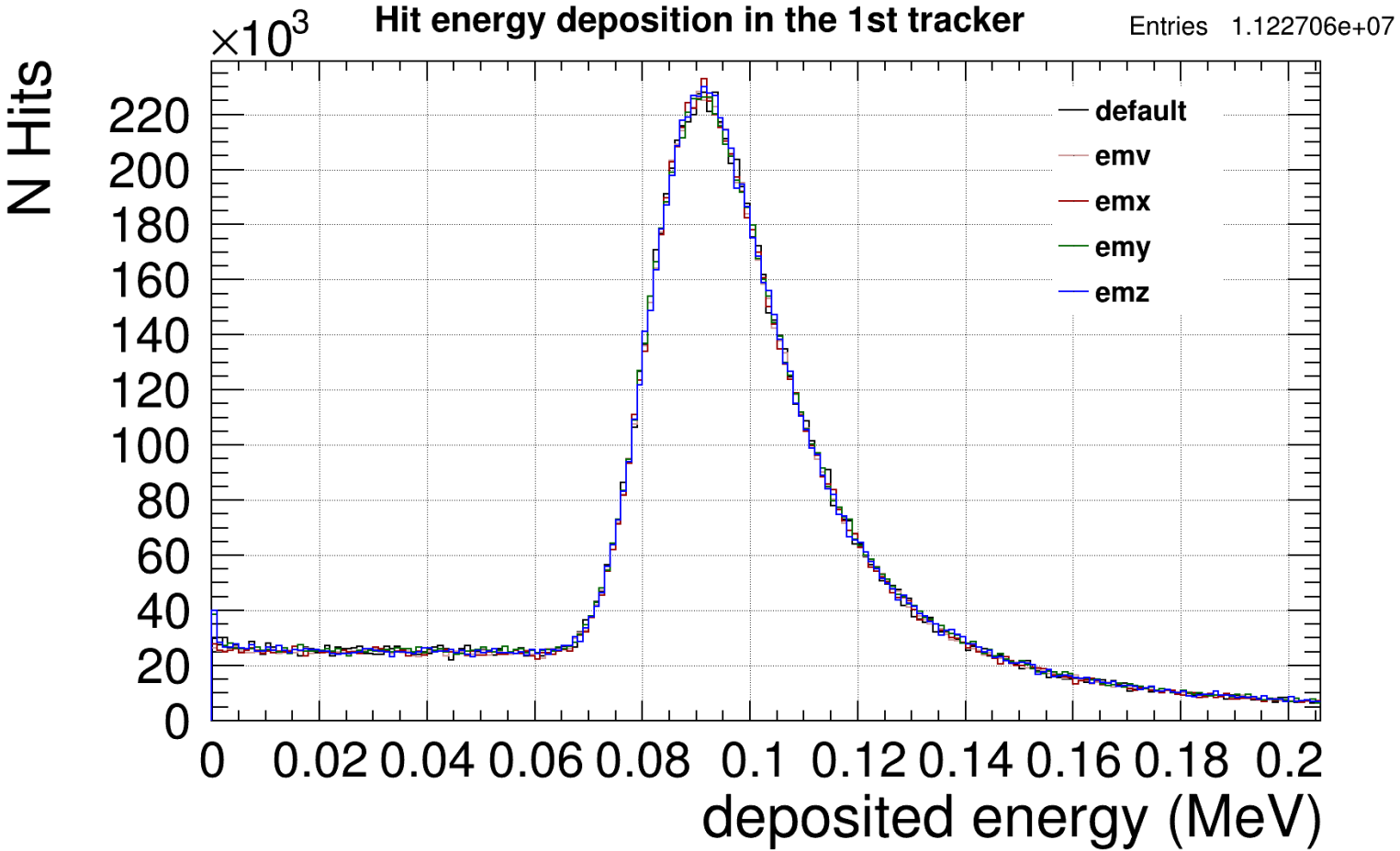

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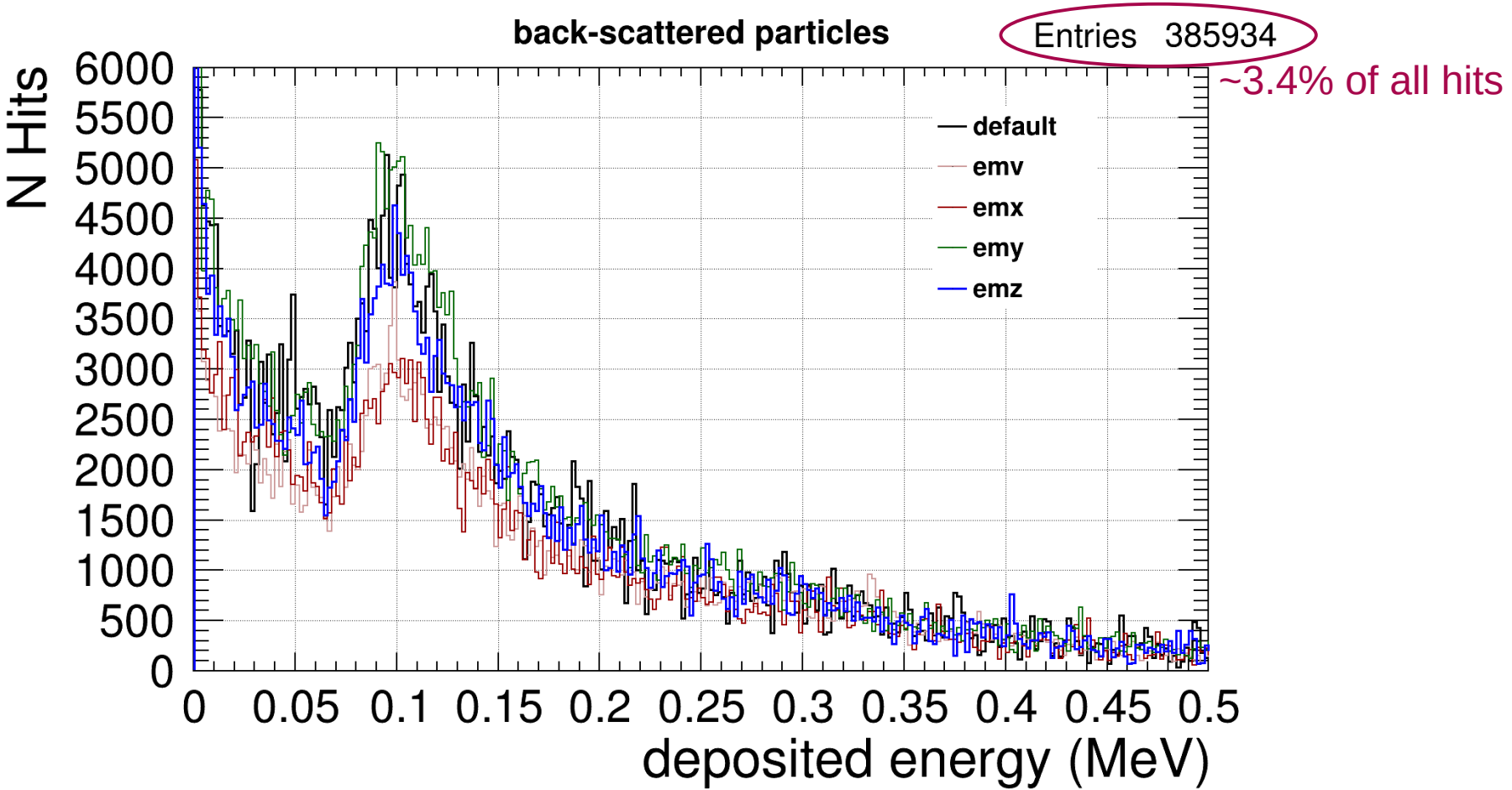

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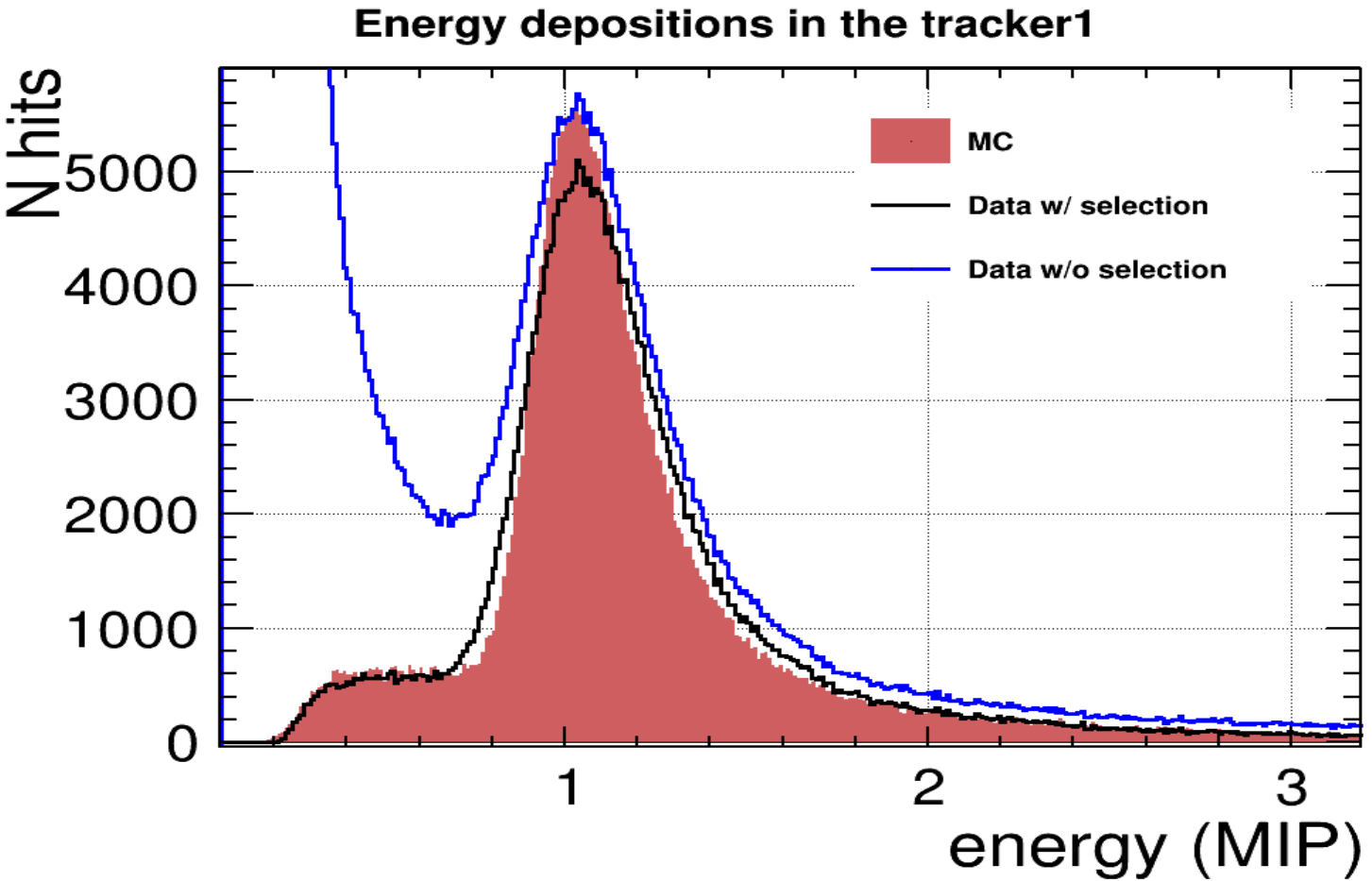
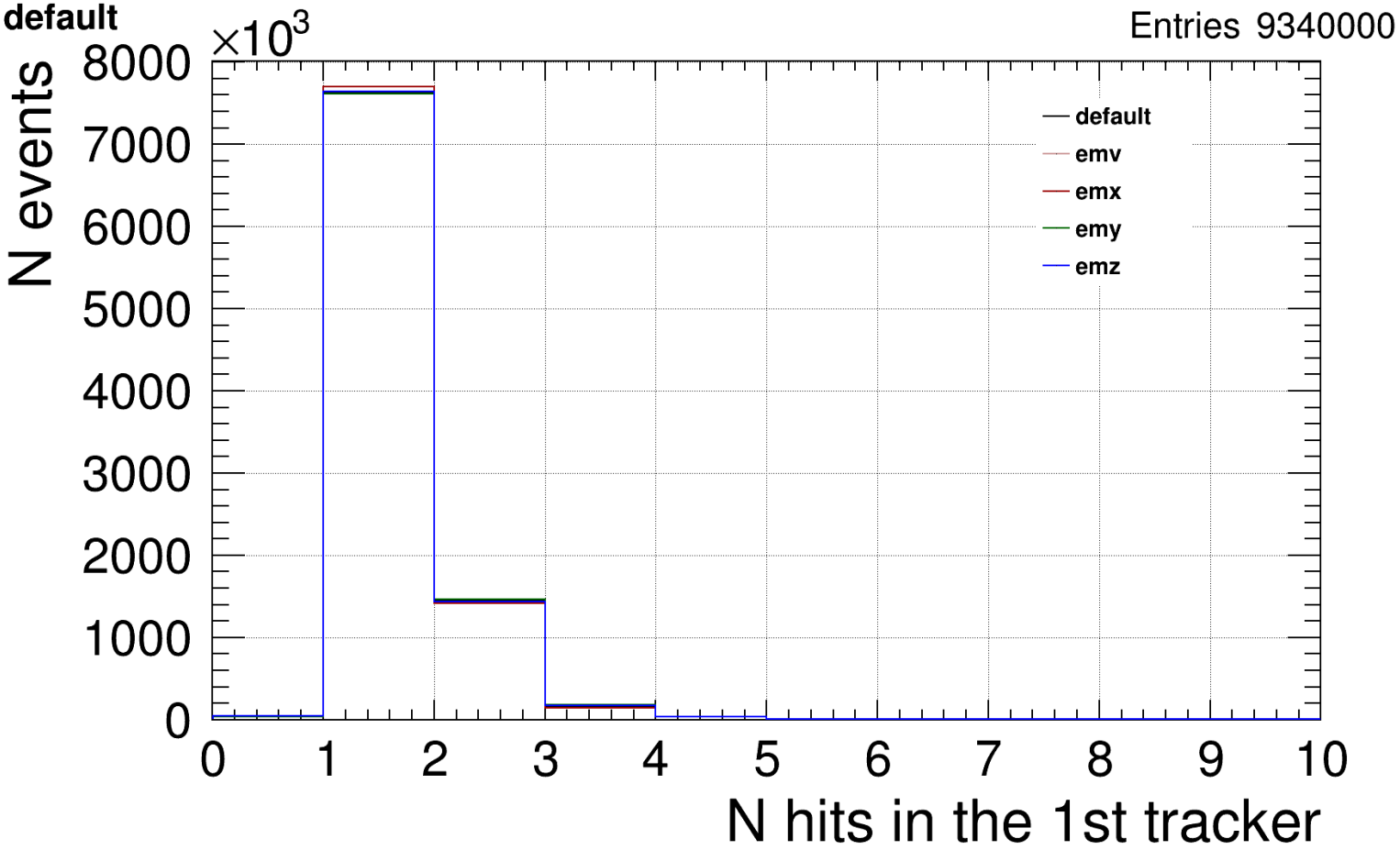


Control plots for the 1st tracker: N hits



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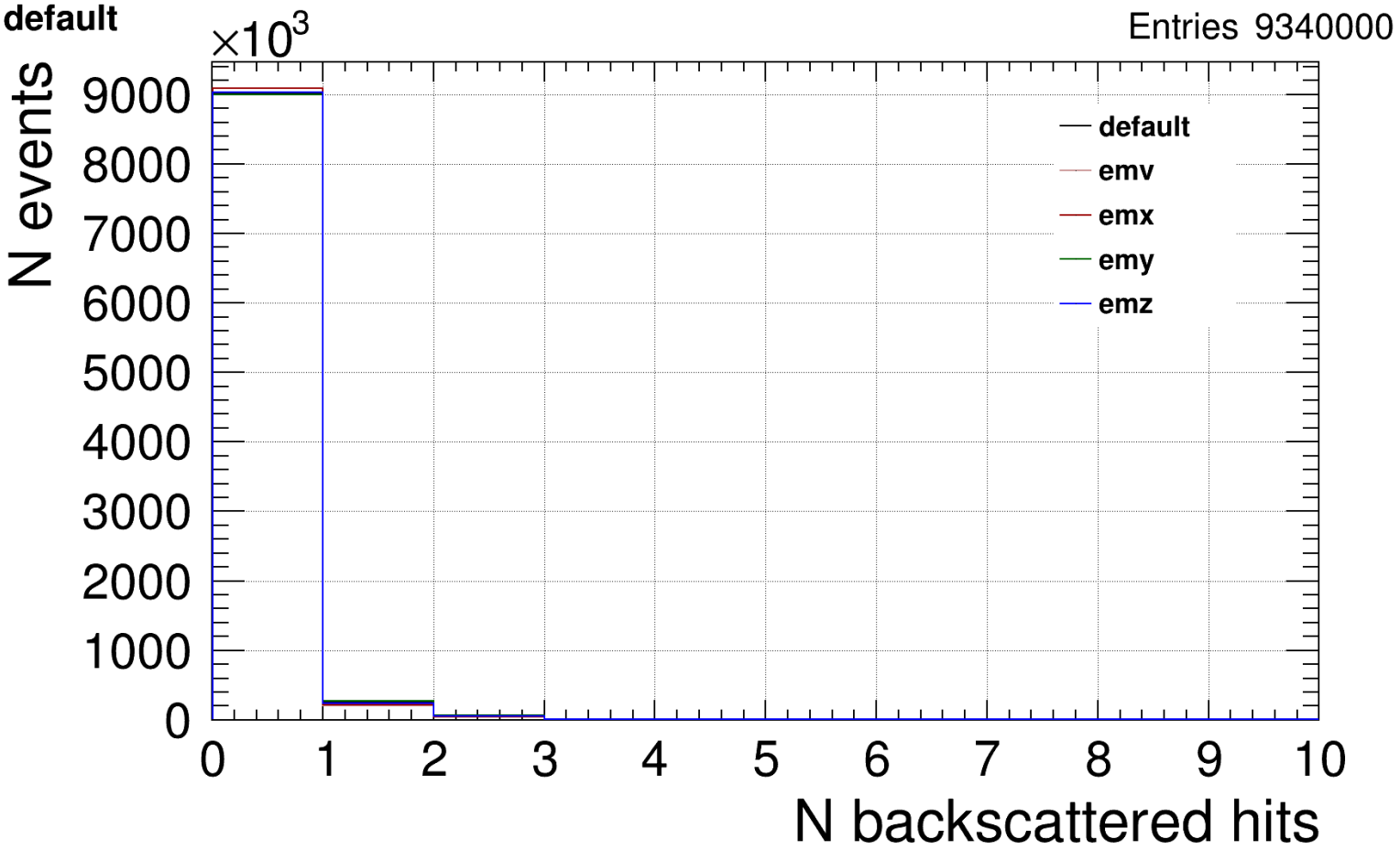
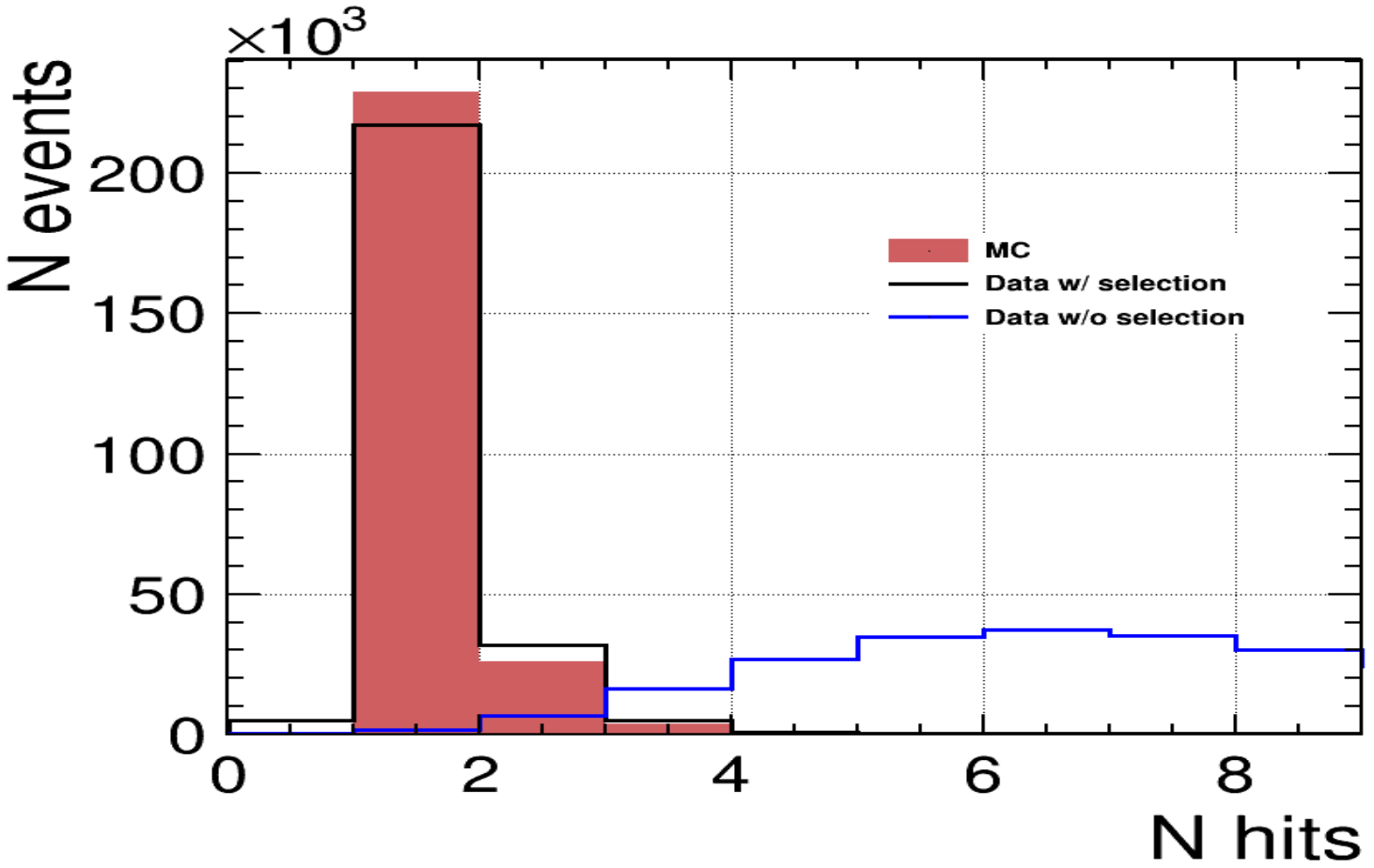
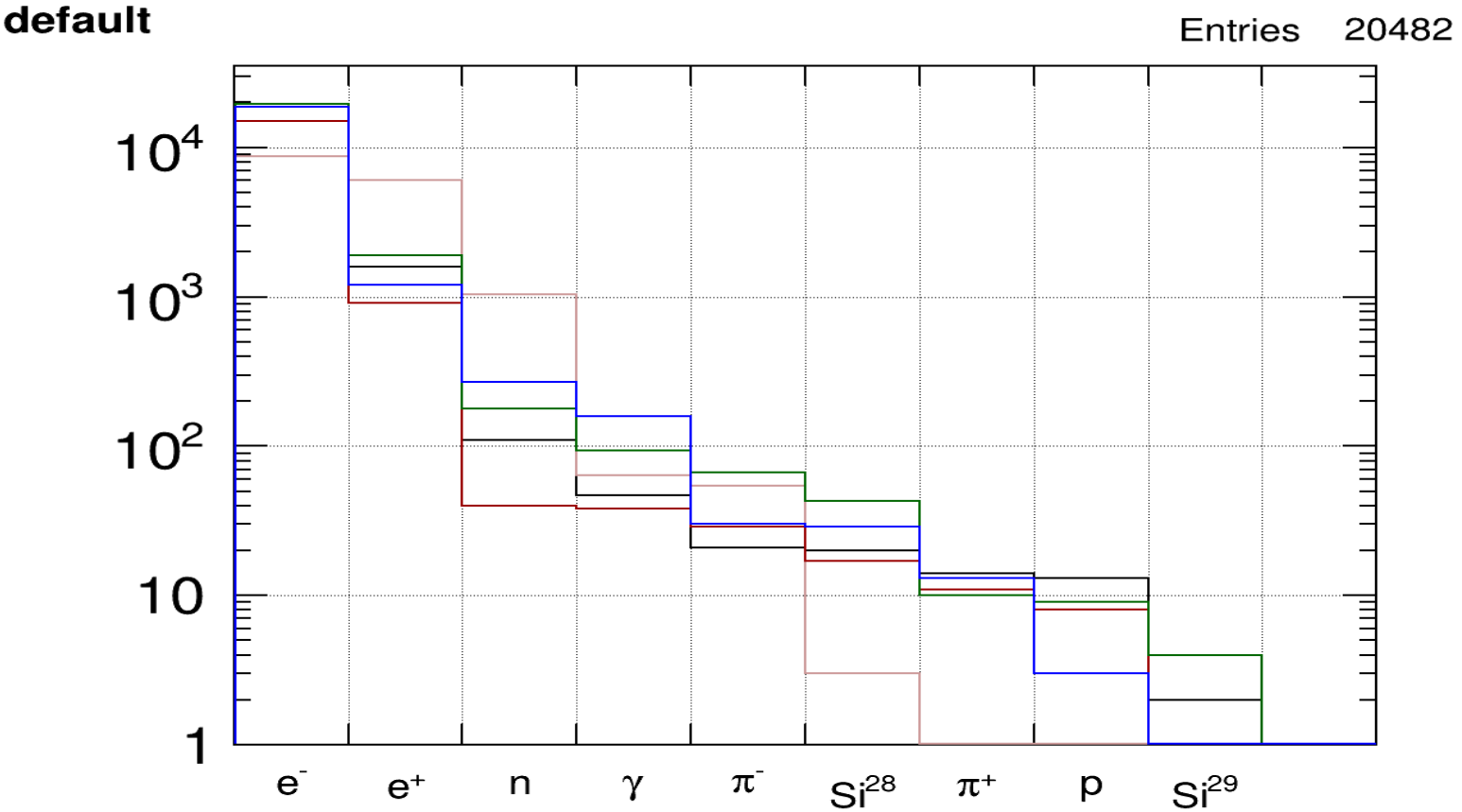


Control plots for the 1st tracker: N hits



Control plots for the 1st tracker: Particle species



Conclusions

EM physics list & motivation:

- No significant difference between: default, EMY, EMZ physics lists
  hurts motivation of the paper
- EMV, EMX show consistently slightly less back-scattered hits
  (aimed for CPU performance)
- Discrepancy between data/MC is larger than any discrepancy between EM physics lists

Work/paper status:

- Needs a lot of work refining the data (good signal definition, noise rejection, etc…)
  if we aim for this level of discrepancies
- Needs a lot of quantitative statistical analysis
  (statistical/systematic uncertainties, etc.)
- It is **not** in “almost ready” state and I don’t have a lot of time

Conclusions

Plenty of new data:

- TB20 in March & TB21 in November (upcoming)
- New FLAME electronics
- New sensors (compared to the TB16)

Great to test FLAME/sensors/noise!

- What is lacking?
- What can be improved?
- What are the goals for the next TB?

I find it way more interesting and useful than still analyzing old TB16 data

I could help making some data/MC distributions for TB20 data in a free time
if not “we wait a paper from you” status

Back up: Geant4 10.7 release notes

Electromagnetic physics

- Results are expected to be similar to release 10.6 for EM calorimeters.
- Expected some measurable CPU speedup.
- Expected improved angular distributions for e+e- pairs.

- G4EmStandardPhysics_option1: switch to use new G4EmBuilder utility; fixed StepFunction definition.
- G4EmStandardPhysics_option3: switch to use new G4EmBuilder utility; use ICRU90 stopping power data for water and air.
- G4EmStandardPhysics_option4: use ICRU90 data.

reference