ALICE:
Geant4 Validation

LHC Detector Simulation Workshop

Eva Sicking
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pp@7TeV Test Productions

Real Data run126007 same detector configuration also used in MC (4M events)

PYTHIA Production		physics list	statistics
	GEANT4		
LHC11d6a	9.4.p02	QGSP_BERT_EMV +optical	117,900
LHC11d6b	9.4.p02	QGSP_BERT_CHIPS+optical	118,000
LHC11d6c	9.5.b01	QGSP_BERT_EMV +optical	98,100
LHC11d6d	9.5.b01	QGSP_BERT_CHIPS+optical	94,300
LHC11d6e	9.5.b01	QGPS_FTFP_BERT +optical	100,400
LHC11d6f	GEANT3	-	119,600

(Anti-)nuclei		physics list	statistics
	GEANT4		
LHC11d6g	9.5.b01	QGSP_FTFP_BERT+optical	105,500

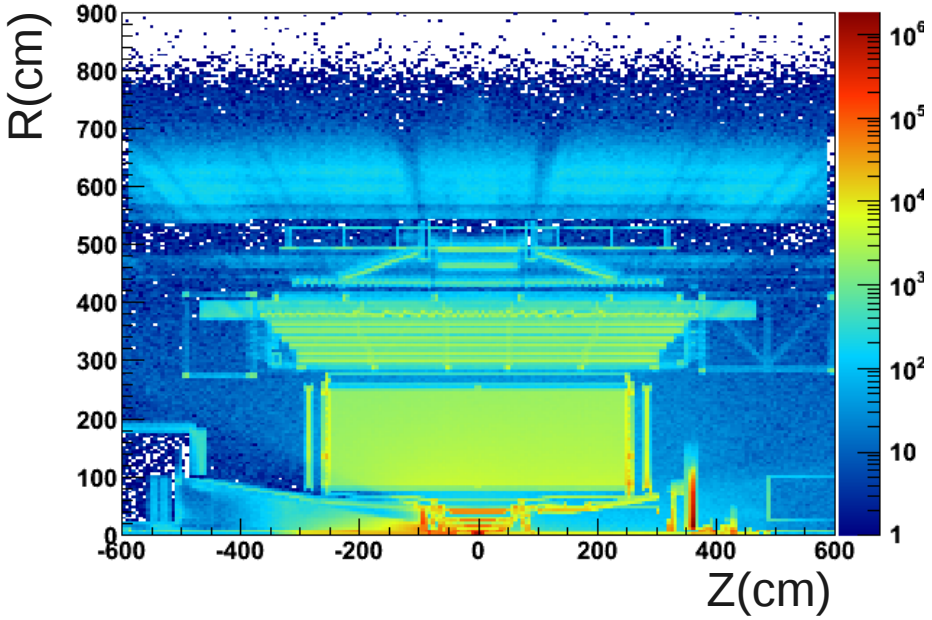
PYTHIA Simulations

-MC Secondaries from Interactions
-Reconstructed Tracks
-Reconstruction Efficiencies

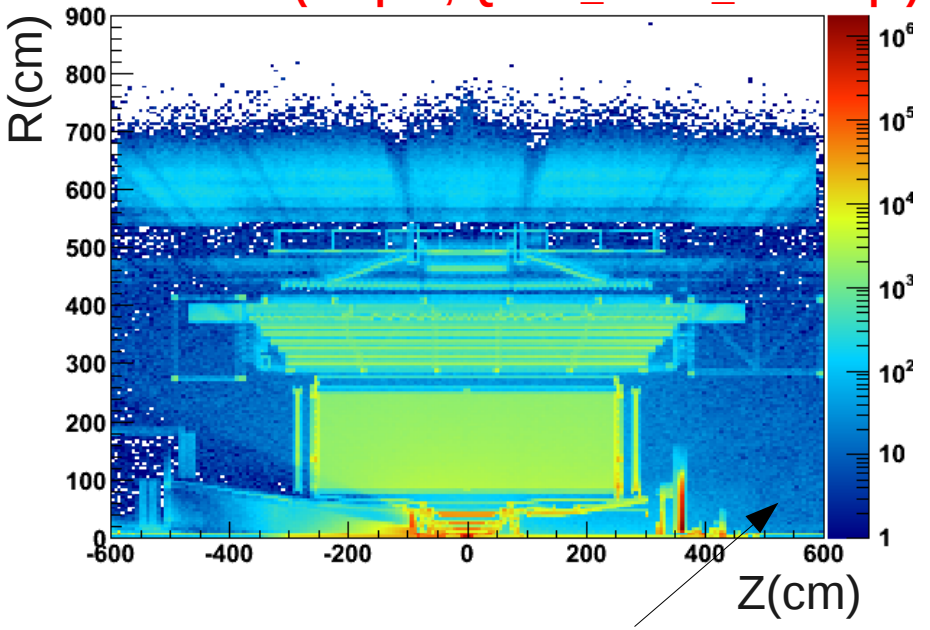
Secondaries from Material Interactions

- Compare properties of charged secondaries generated in transport of PYTHIA events (plots for neutral particles in backup)
  - Point and process of generation, kinetic energy, direction …

Geant3

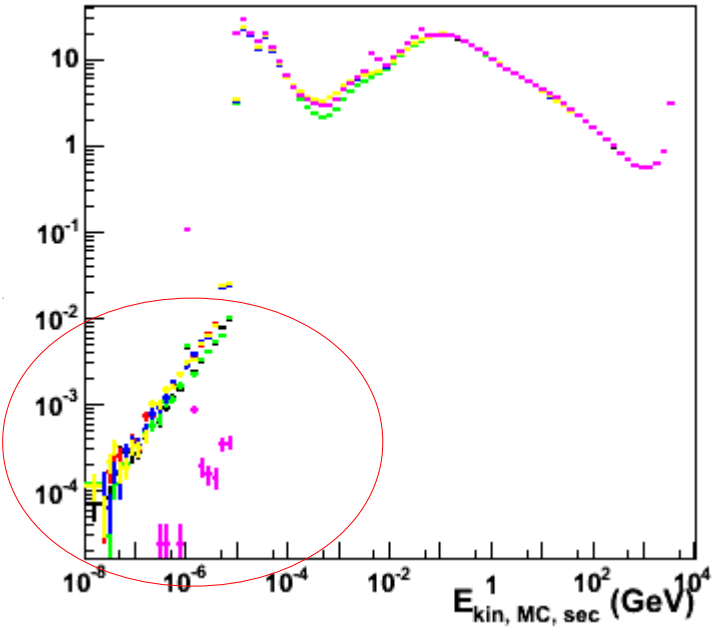


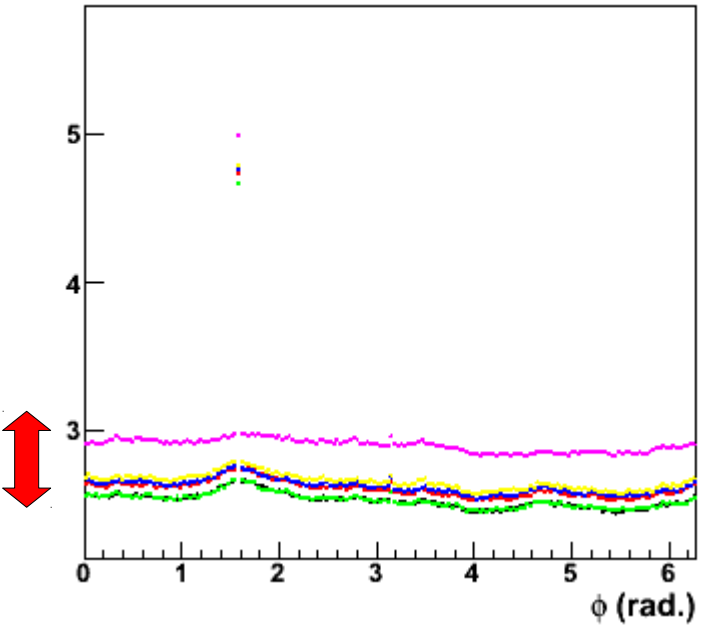
Geant4 (9.4.p02, QGSP_BERT_EMV+opt)

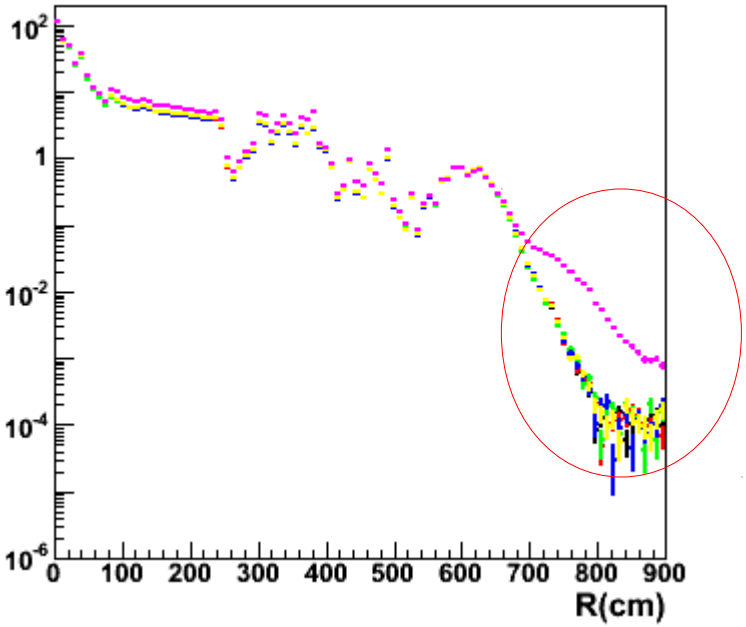


- Geant3 produces more charged secondaries at high radii as Geant4
- Missing support structure (under investigation)

Properties of Charged Secondaries from Material Interactions







Run 126007

9.4.p02 QGSP_BERT_EMV+opt

9.4.p02 QGSP_BERT_CHIPS+opt

9.5.b01 QGSP_BERT_EMV+opt

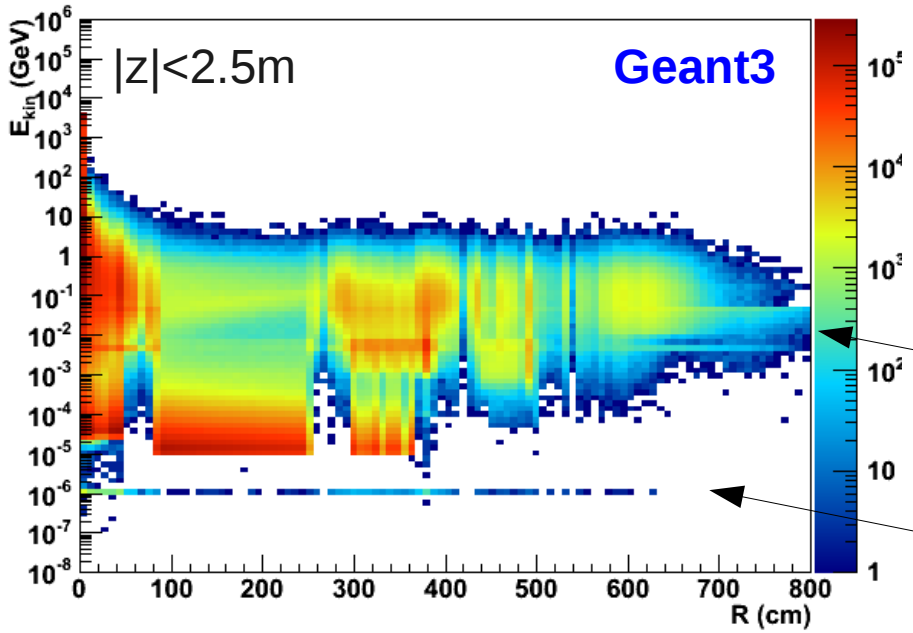
9.5.b01 QGSP_BERT_CHIPS+opt

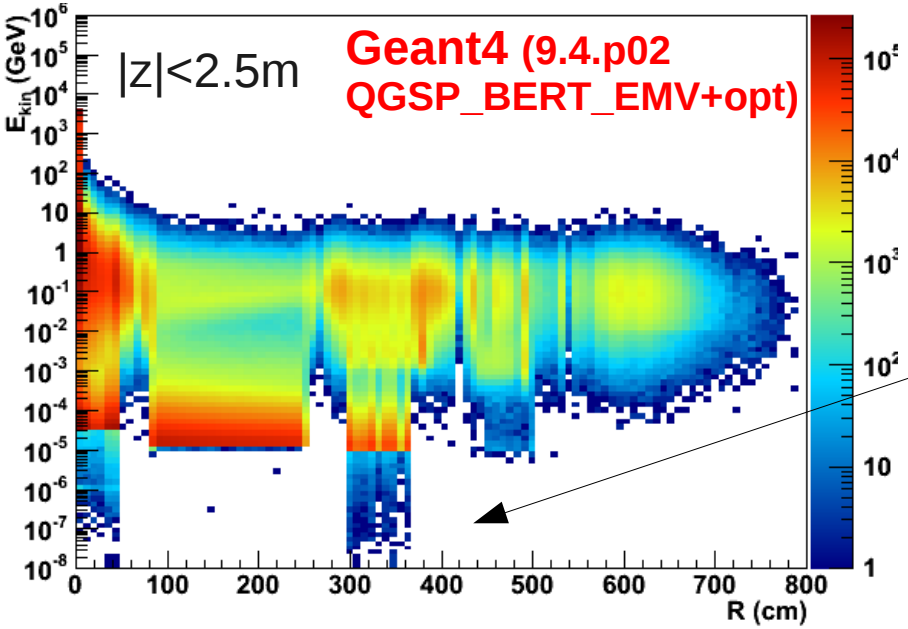
9.5.b01 QGSP_FTFP_BERT+opt

Geant3

- All Geant4 simulations show similar properties of charged secondary particles
- Geant3 shows higher number of secondaries
  - at all Φ
  - especially at R>700cm, which was not observed in the previous G3 production, under investigation
- G4 shows higher number of particles at very low E_{kin}

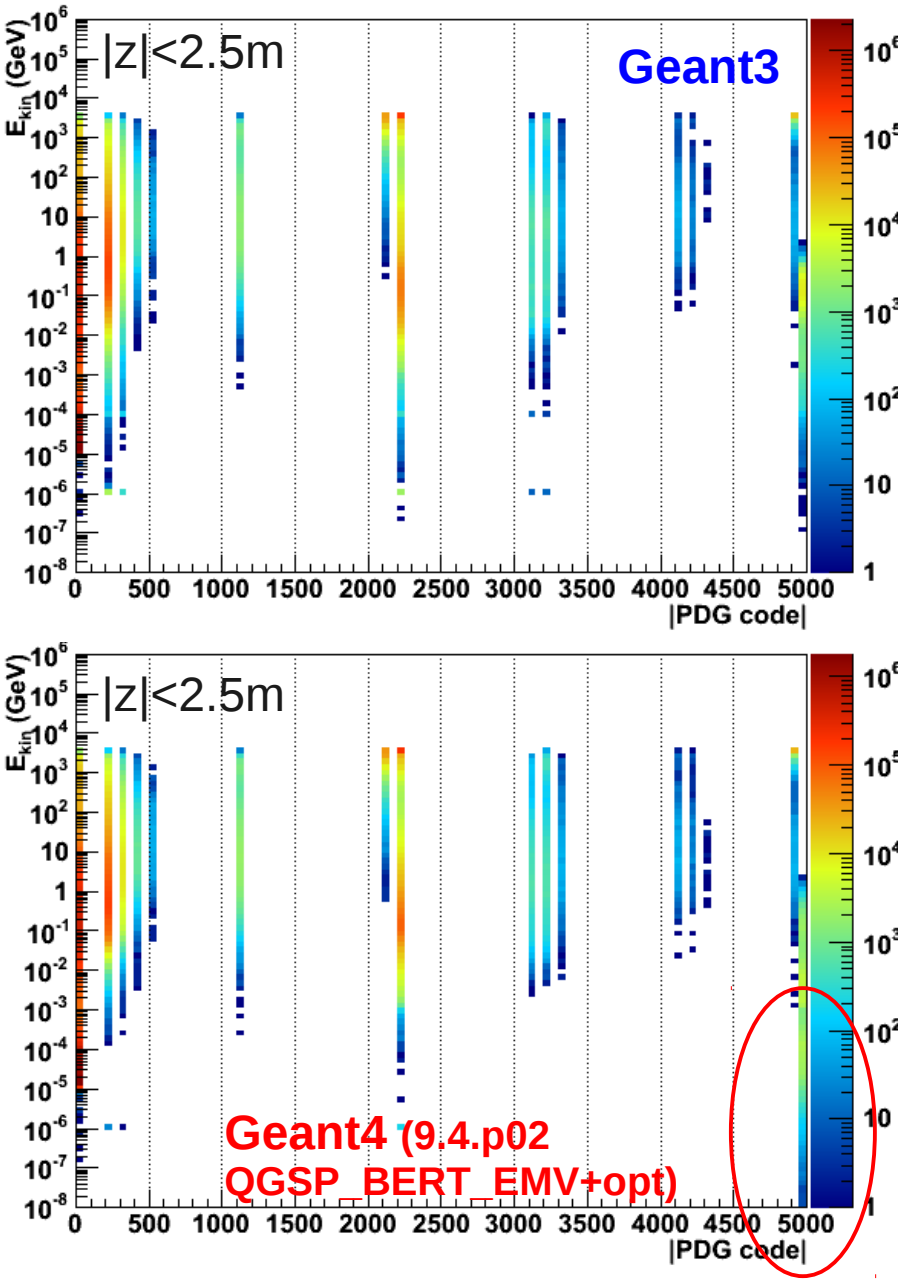
Charged Secondaries: E_{kin}- Generation Point





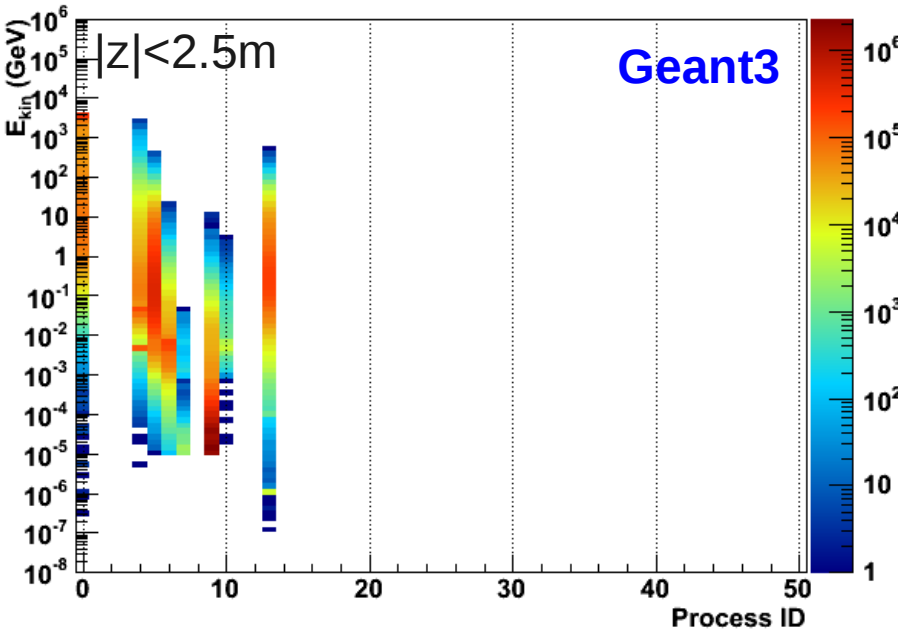
- Similar structures with small deviations:
- Geant3:
  - Band above R>700cm (under investigation, not present in previous Geant3 simulations)
  - Band at $E_{kin}=10^{-6}$ GeV and all R<650cm
- Geant4:
  - Secondaries with low E_{kin} at ITS and TRD → Nuclei, mainly Si and Xe from detector (stopped after first step)

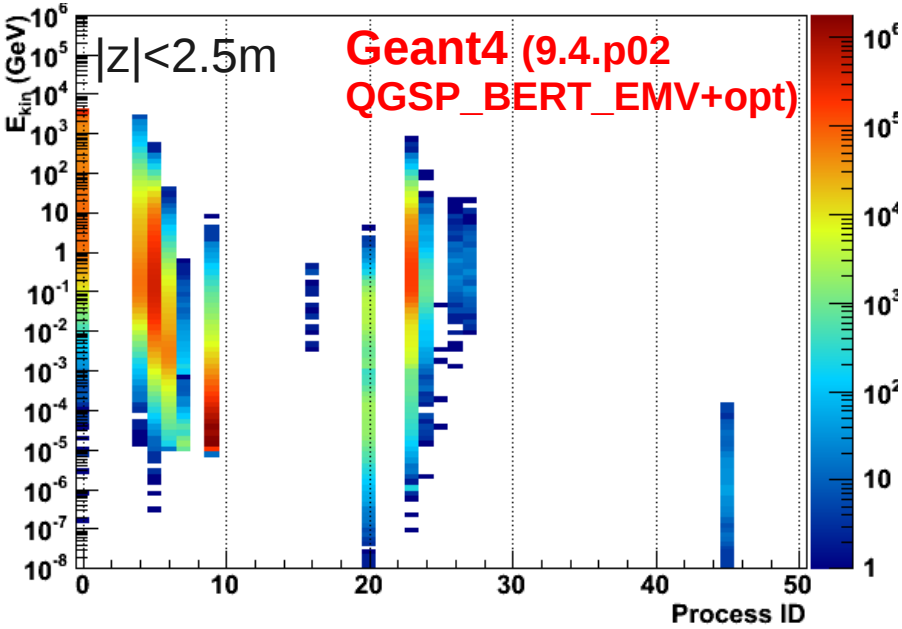
Charged Secondaries: E_{kin}-PDG



- Test: rough separation in terms of |PDG value|
- Geant3 and Geant4 produce similar picture
- Last two bins
  - 1: All particles with 5000<|PDG| <1billion
  - 2: all particles with |PDG|>1billion → nuclei
    - Low energy particles in Geant4 are mostly Si and Xe in ITS and TRD

Charged Secondaries: E_{kin}-ProcessID





ID	G3	G4	Process
0	x	x	Primary interaction
4	x	x	particle decay
5	x	x	photon pair production
6	x	x	Compton scattering
7	x	x	photoelectric effect
9	x	x	delta-ray production
10	x		positron annihilation
13	x		hadronic interaction
16		x	nuclear absorption
20		x	hadronic elastic scattering
23		x	hadronic inelastic scat.
24		x	photon inelastic scattering
25		x	muon nuclear interaction
26		x	electron nuclear interaction
27		x	positron nuclear interaction
45		x	single Coulomb scattering

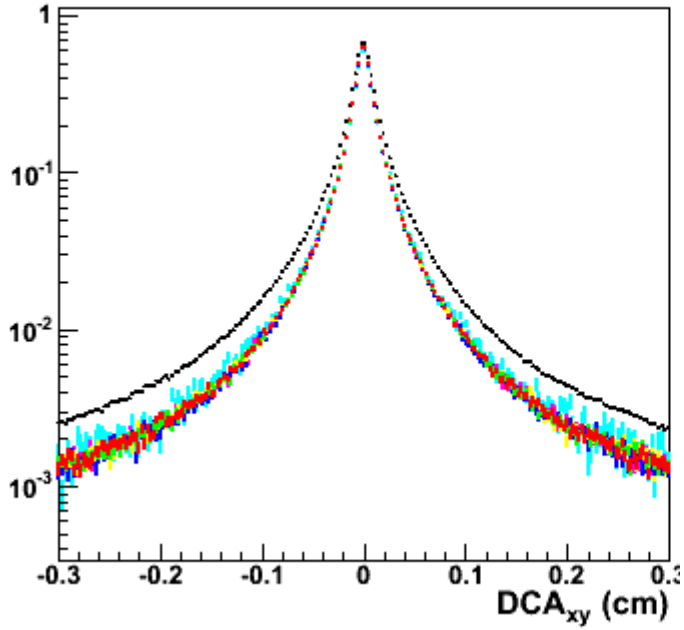
- New processes in Geant4, agreement between in G3 existing processes

Reconstructed Tracks

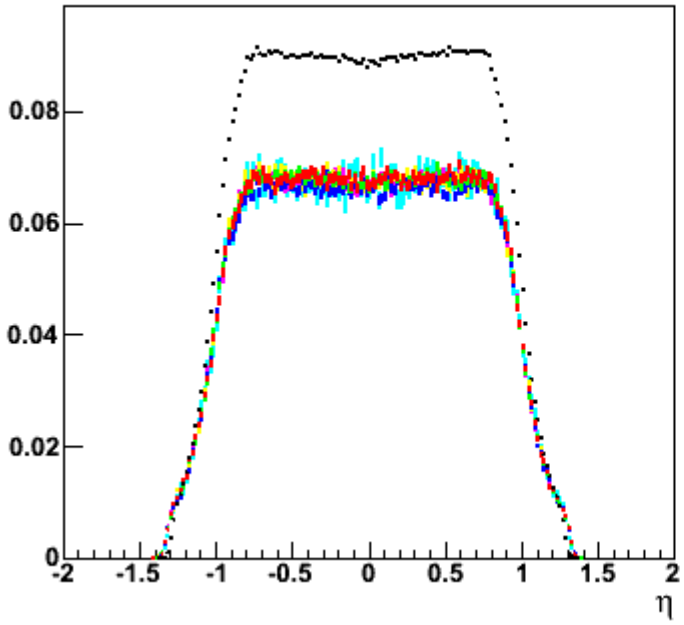
- Different track definitions representing different combinations of tracks measured in ITS and TPC
  - "Global tracks":
    - ITS refit, TPC refit, TPC cluster >70
    - DCA_{xy}<3cm, DCA_{z}<3cm, no kinks
  - "TPC tracks":
    - TPC only track, TPC refit, TPC cluster<70
    - DCA_{xy}<3cm, DCA_{z}<3cm, no kinks, χ^2<4
  - "ITS pure stand alone tracks":
    - ITS refit, tracks are used in global tracking
    - DCA_{xy}<3cm, DCA_{z}<3cm, no kinks

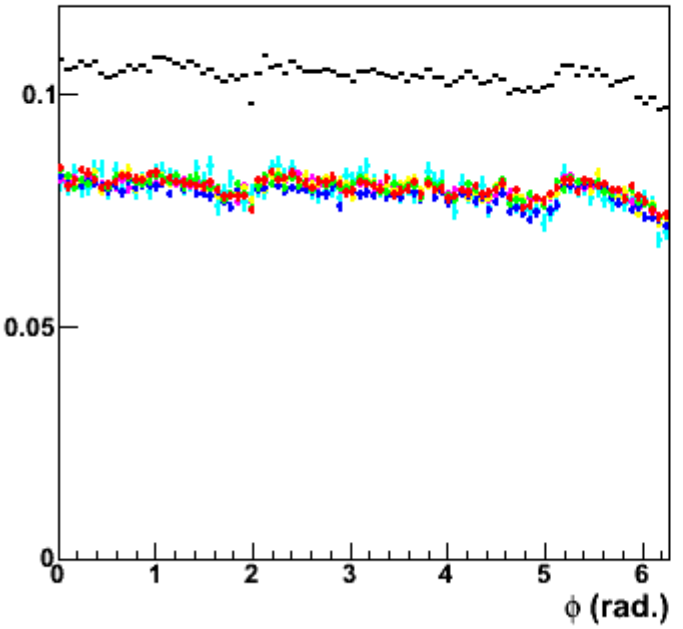
Track Properties (Global)

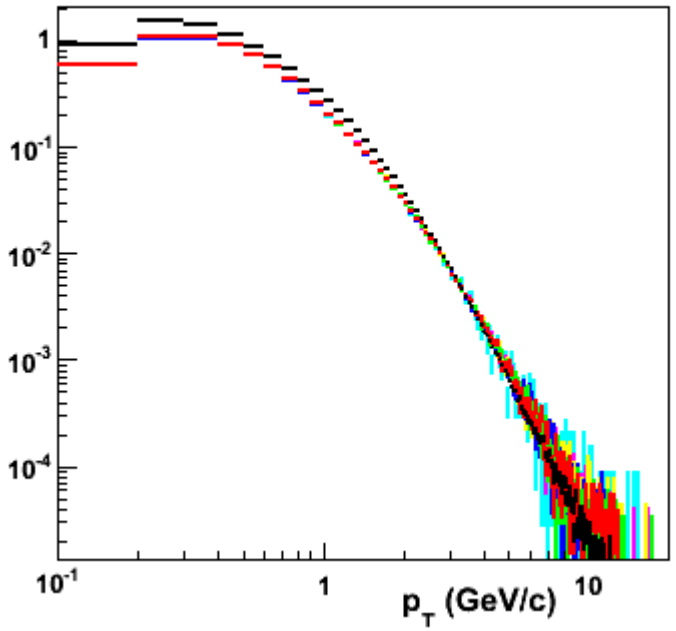
Global tracks



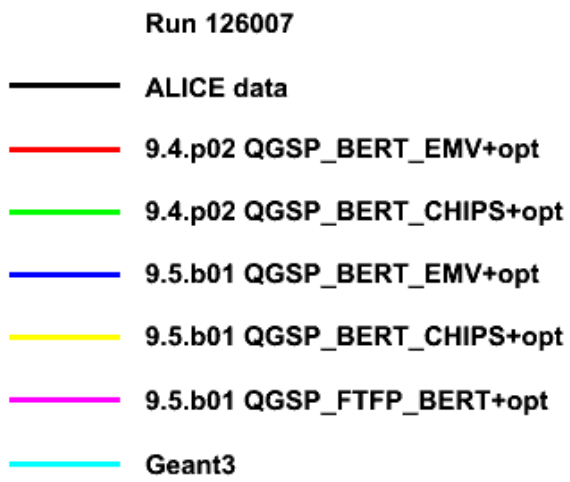
Global tracks





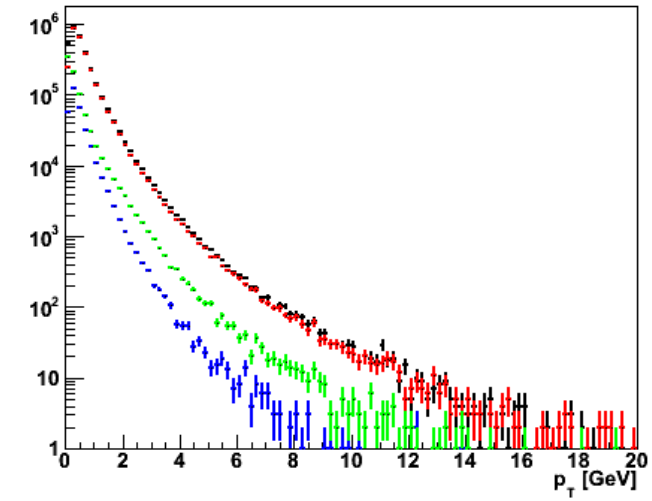


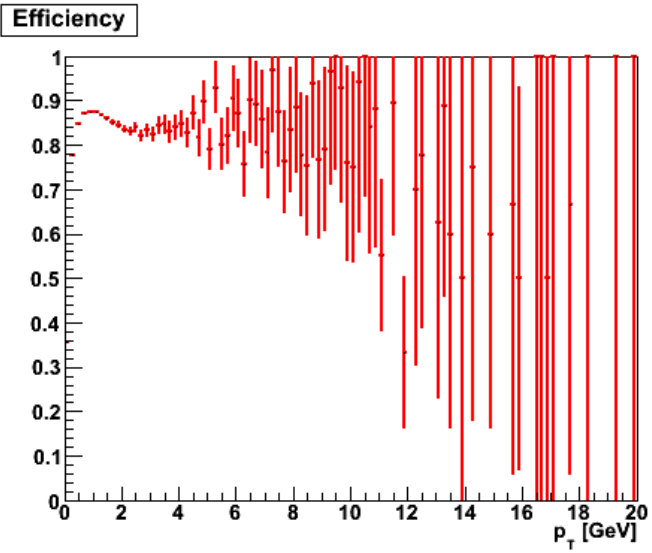
- Properties of reconstructed tracks are similar in Geant3 and Geant4
- Event generator PYTHIA underestimates particle yield but shape of distribution is similar

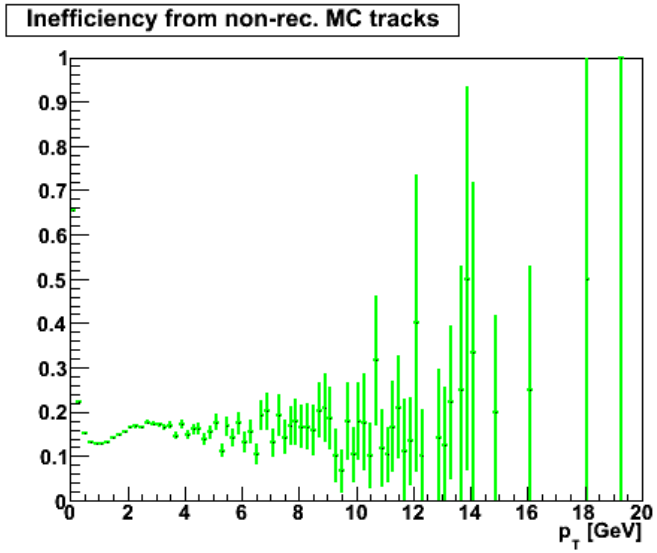


Reconstruction Efficiency (Global Tracks)

As example: **Geant3**

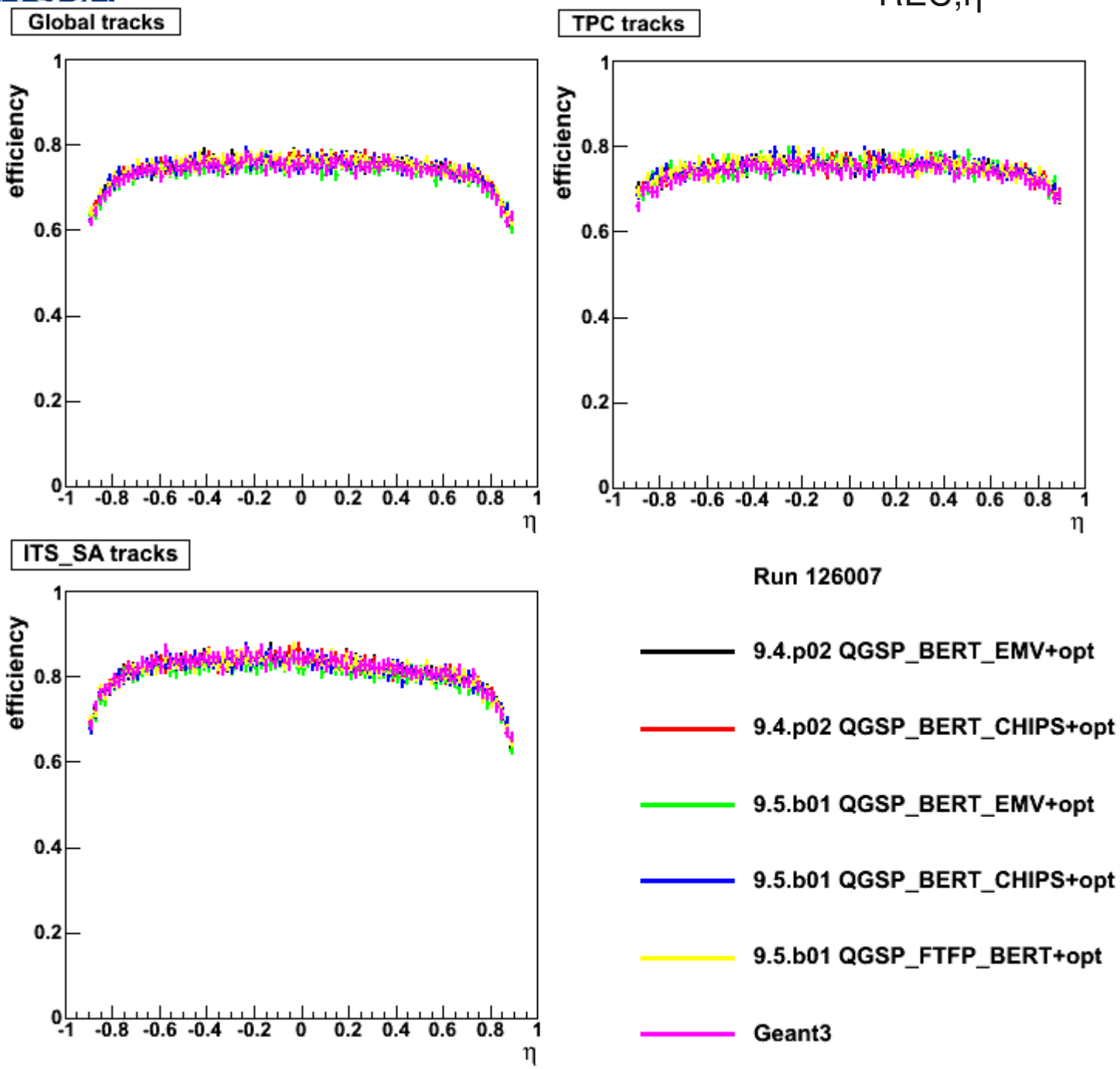






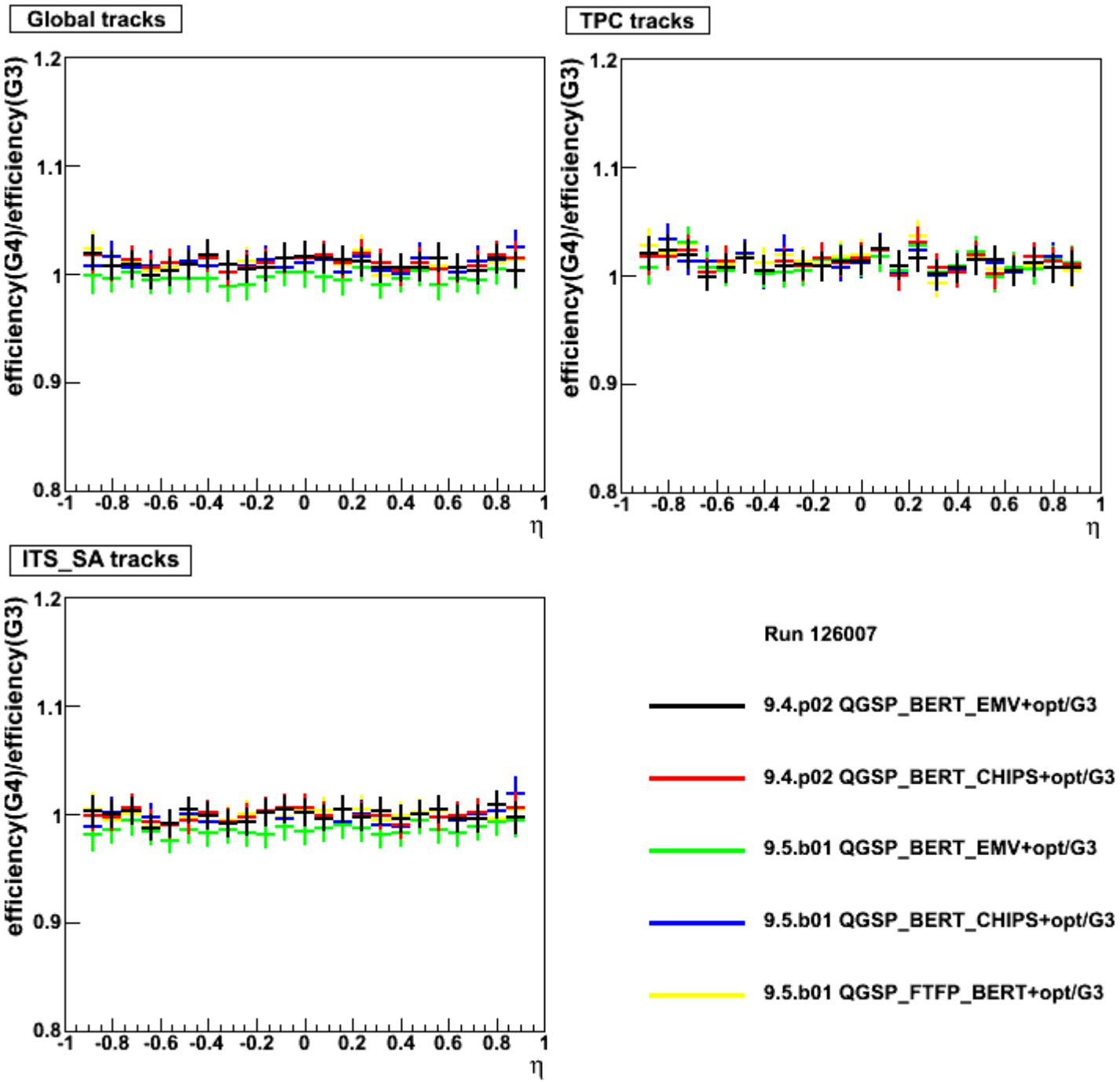
- Compare number of generated and reconstructed tracks and extract reconstruction efficiency and inefficiency
- Here, as example, presentation as function of transverse momentum
- Compare now efficiencies of different simulations to each other
  - η, Φ, p_T
  - Global-, TPC-, and ITS- tracks

Efficiency$_{REC,\eta}$



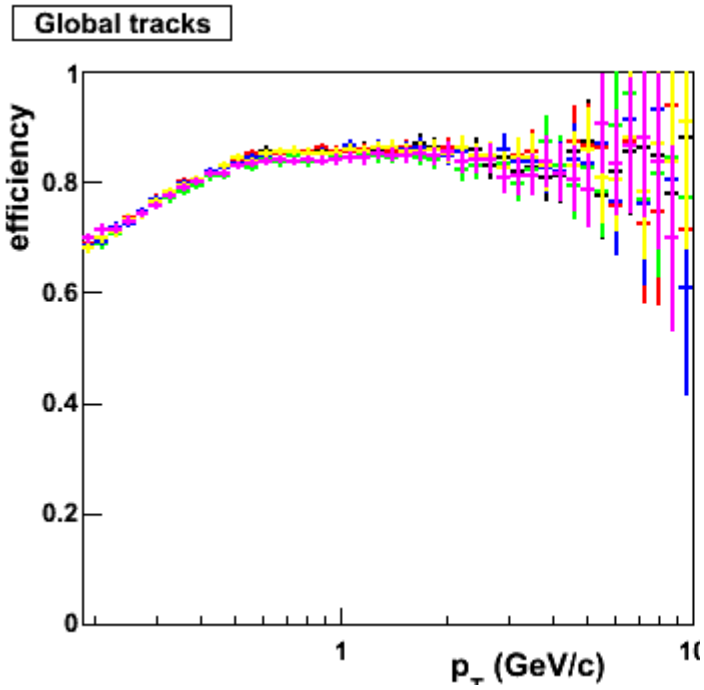
- Averaged efficiencies(η) in Geant3 and Geant4 productions are on top of each others
- Check agreement of G3 and G4 with ratio

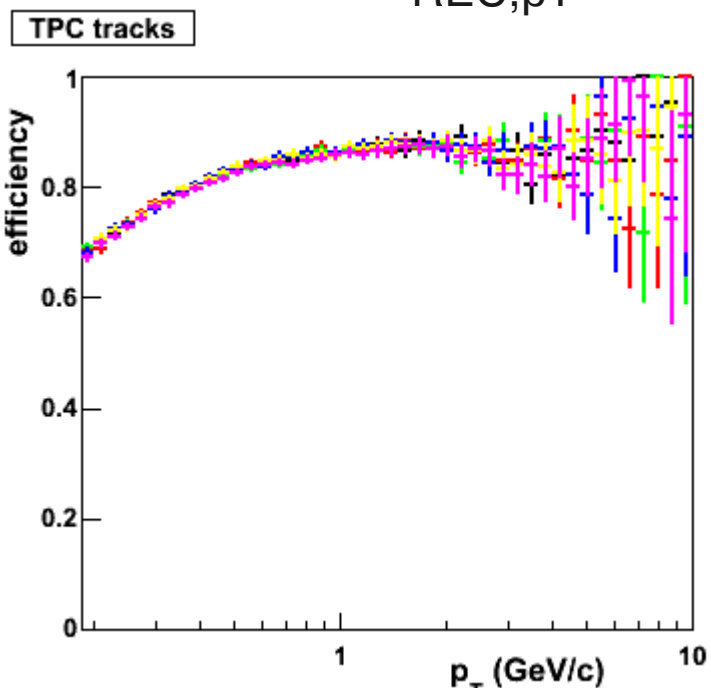
$\text{Efficiency}_{\text{REC},\eta,\text{Geant4}}$ / $\text{Efficiency}_{\text{REC},\eta,\text{Geant3}}$

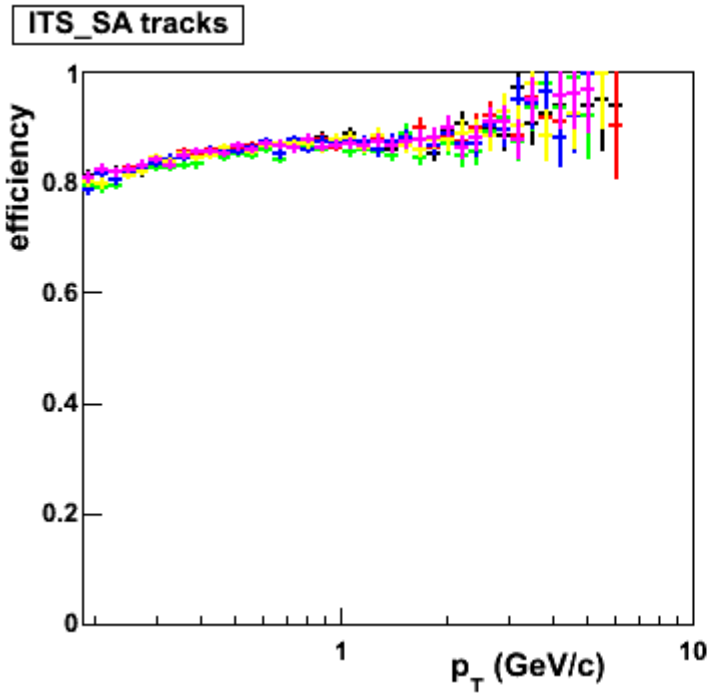


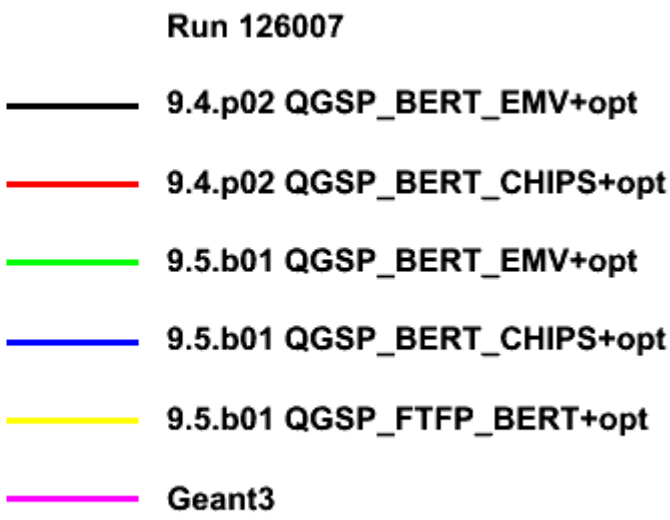
- Averaged efficiencies(η) in Geant3 and Geant4 productions in good agreement

Efficiency$_{REC,pT}$



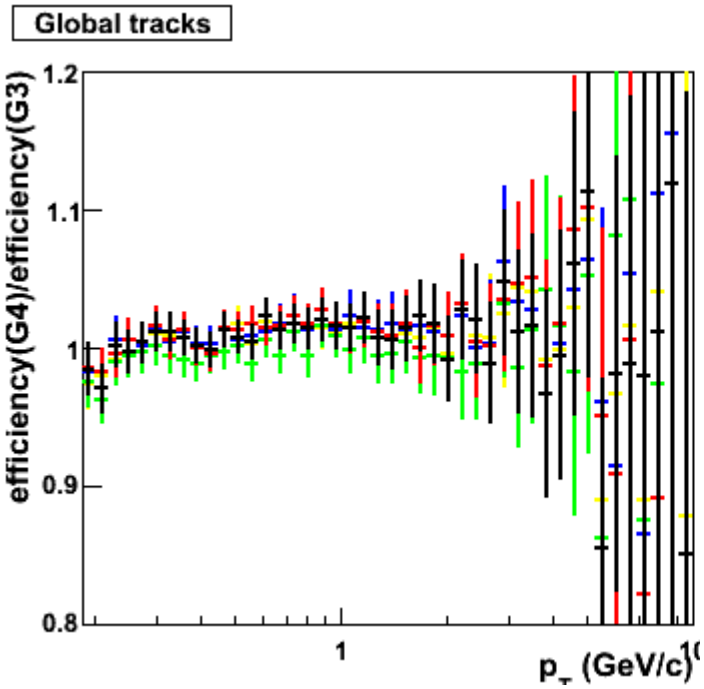


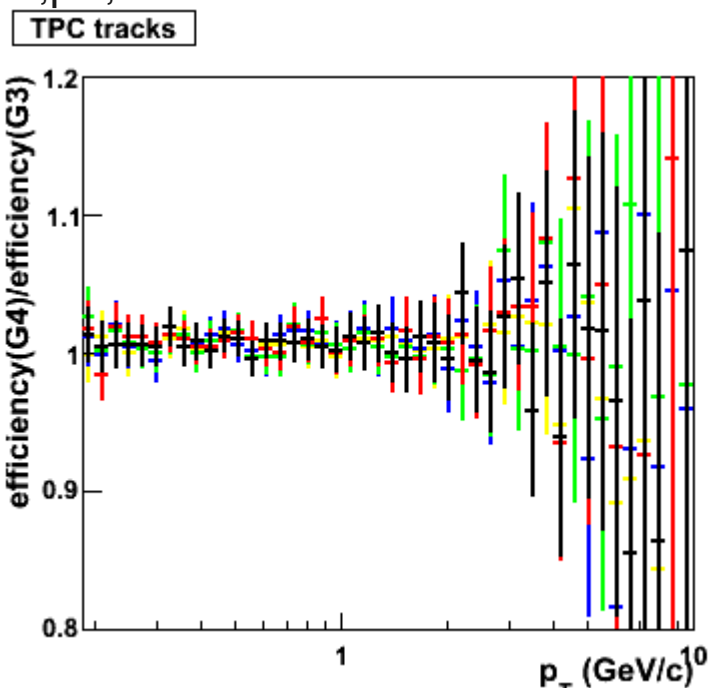


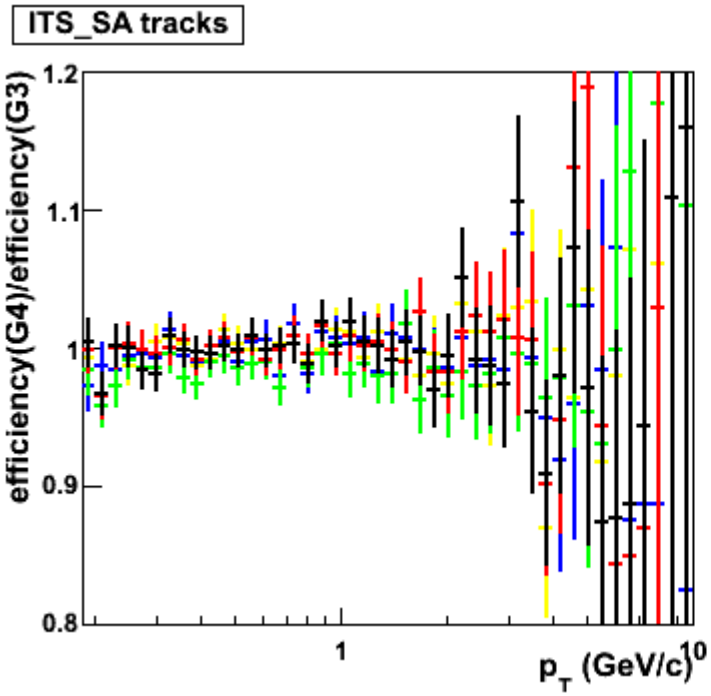


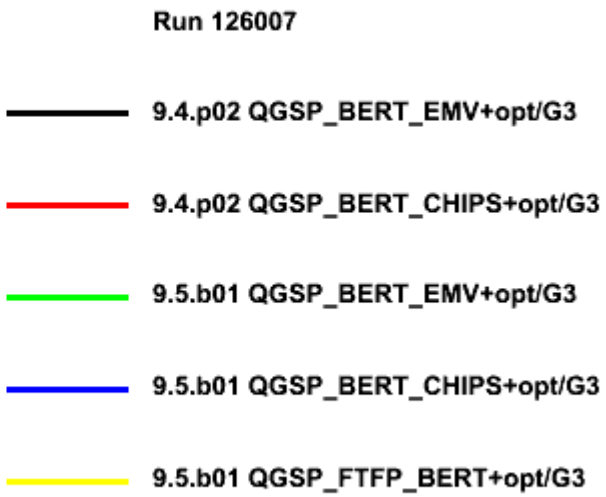
- Averaged efficiencies(p_T) in Geant3 and Geant4 productions differ at low momenta
- Check agreement of G3 and G4 with ratio

Efficiency$_{REC,pT,Geant4}$ / Efficiency$_{REC,pT,Geant3}$



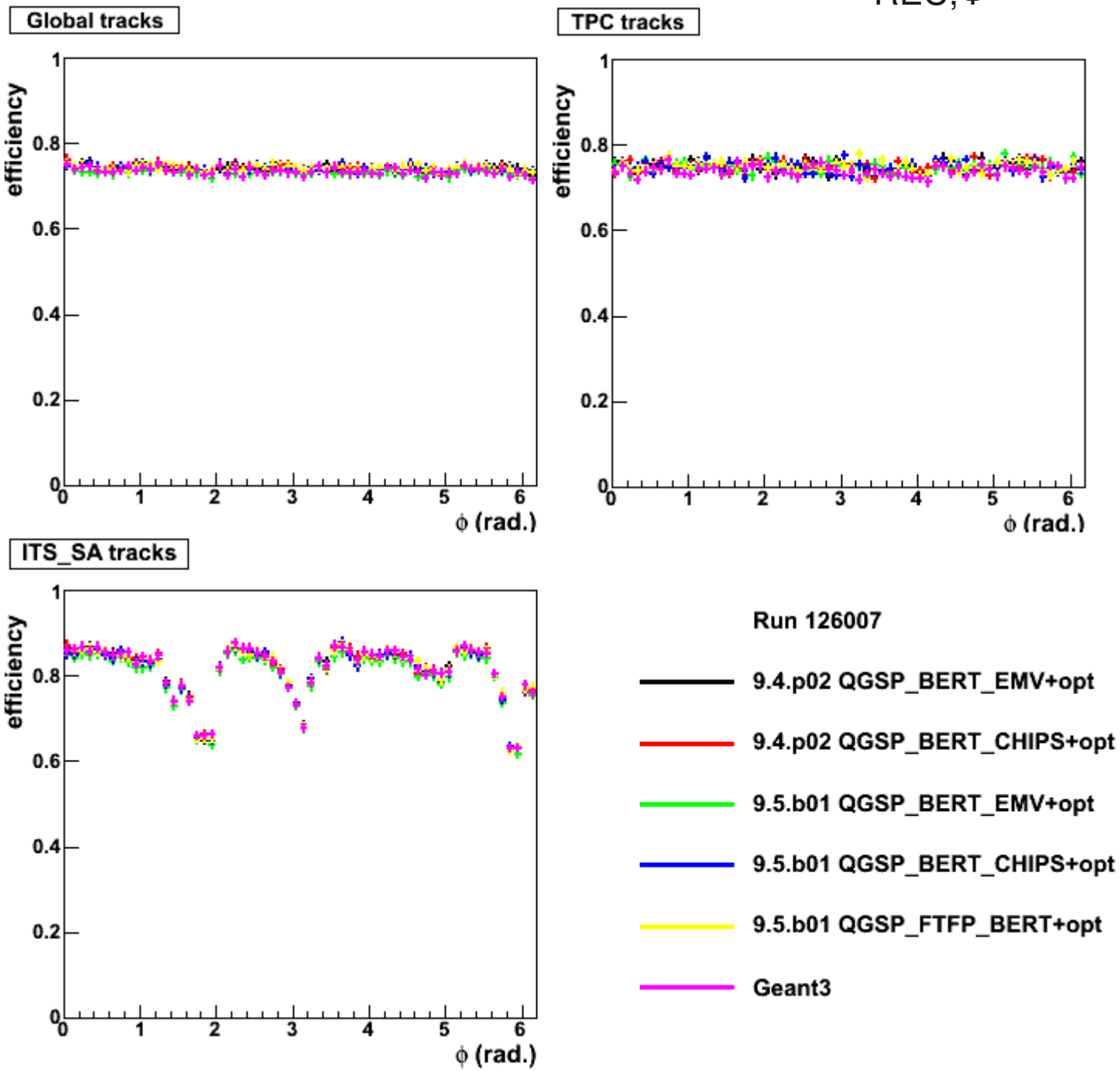






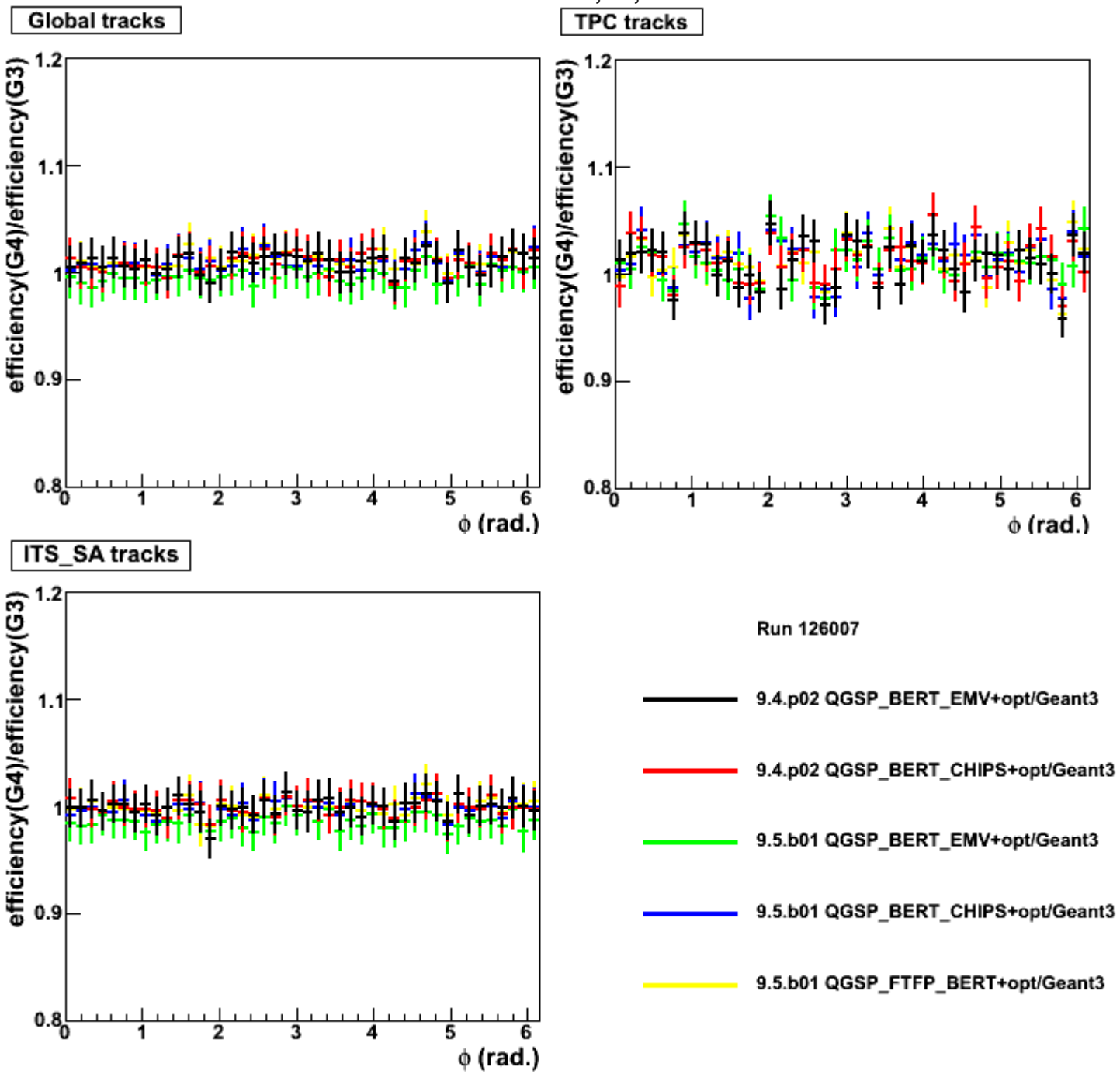
- Good agreement between Geant3 and Geant4 efficiencies in intermediate p_T region
  - Low statistics for high p_T region

Efficiency $_{REC,\Phi}$



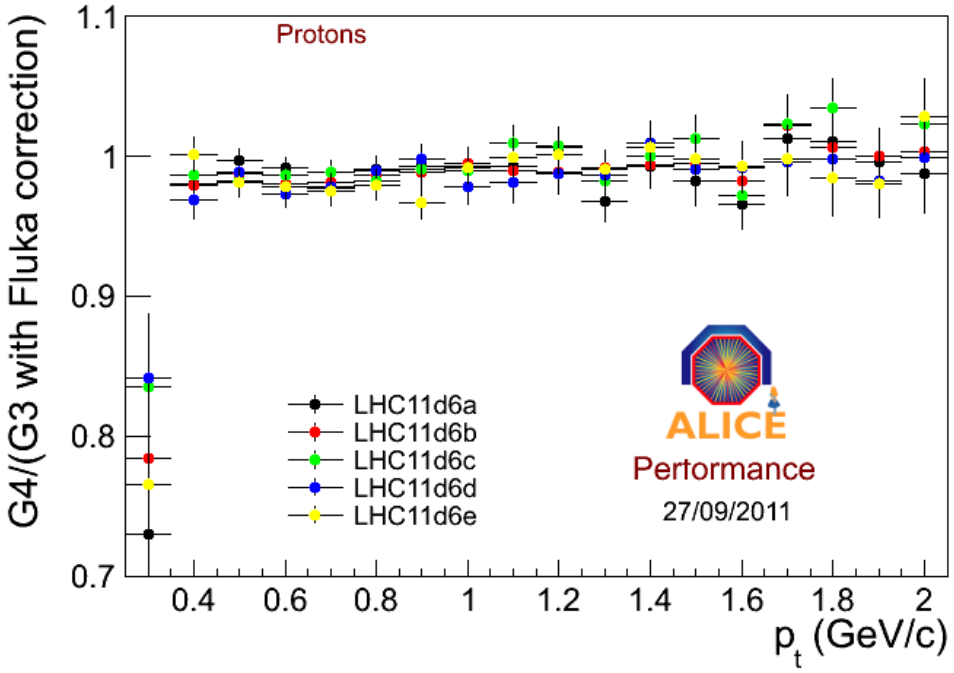
- Averaged efficiencies(Φ) of Geant3 and Geant4 productions are on top of each other
- Check agreement of G3 and G4 with ratio

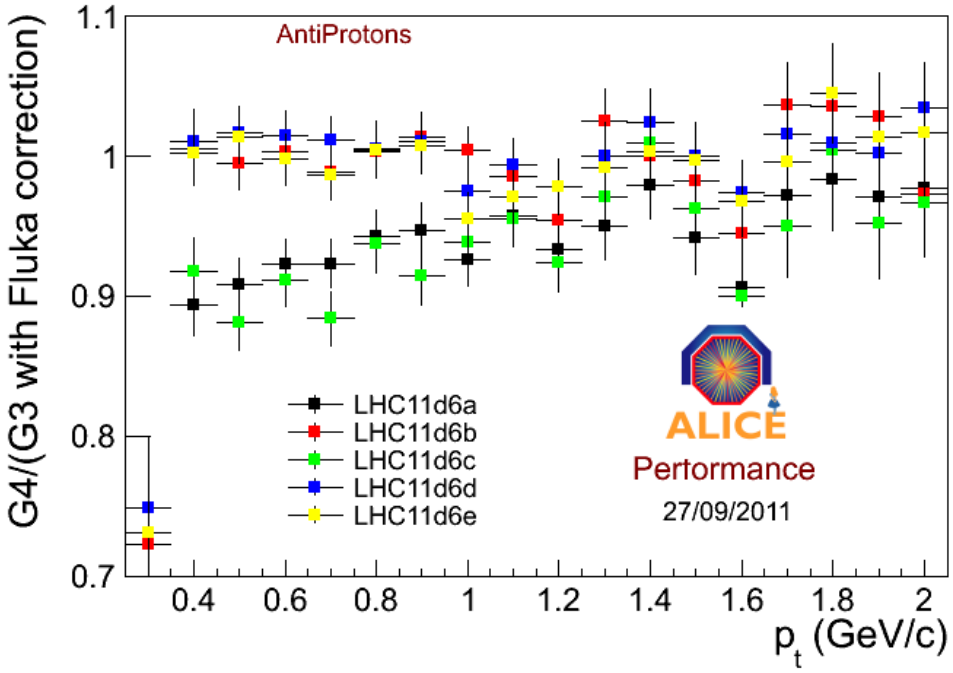
Efficiency$_{REC,\Phi,Geant4}$ / Efficiency$_{REC,\Phi,Geant3}$

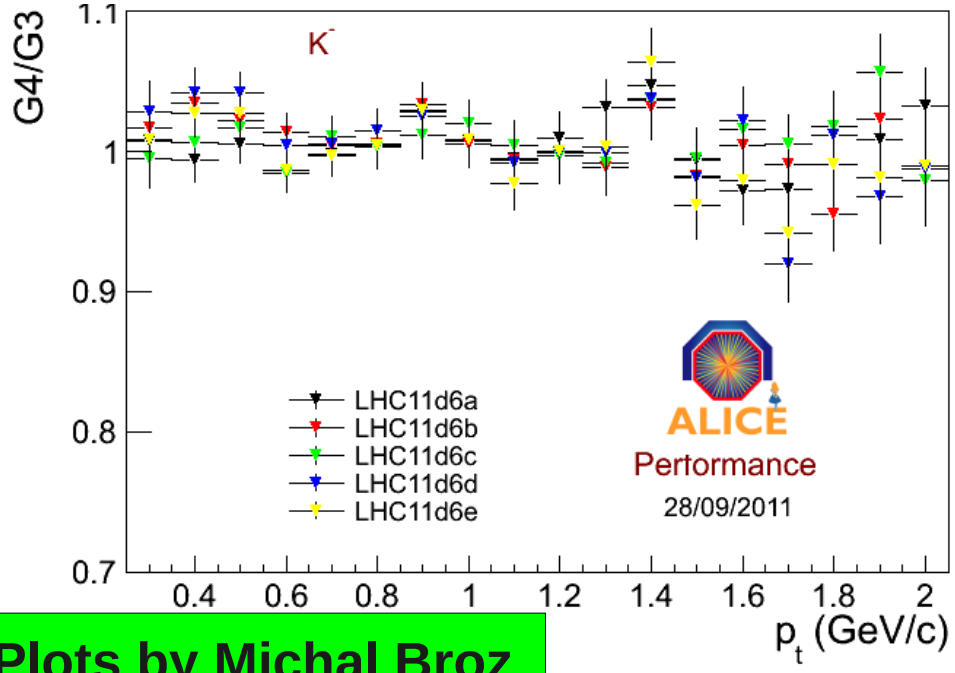


- Averaged efficiencies(Φ) of Geant3 and Geant4 productions agree with each other

Particle Absorption Efficiencies



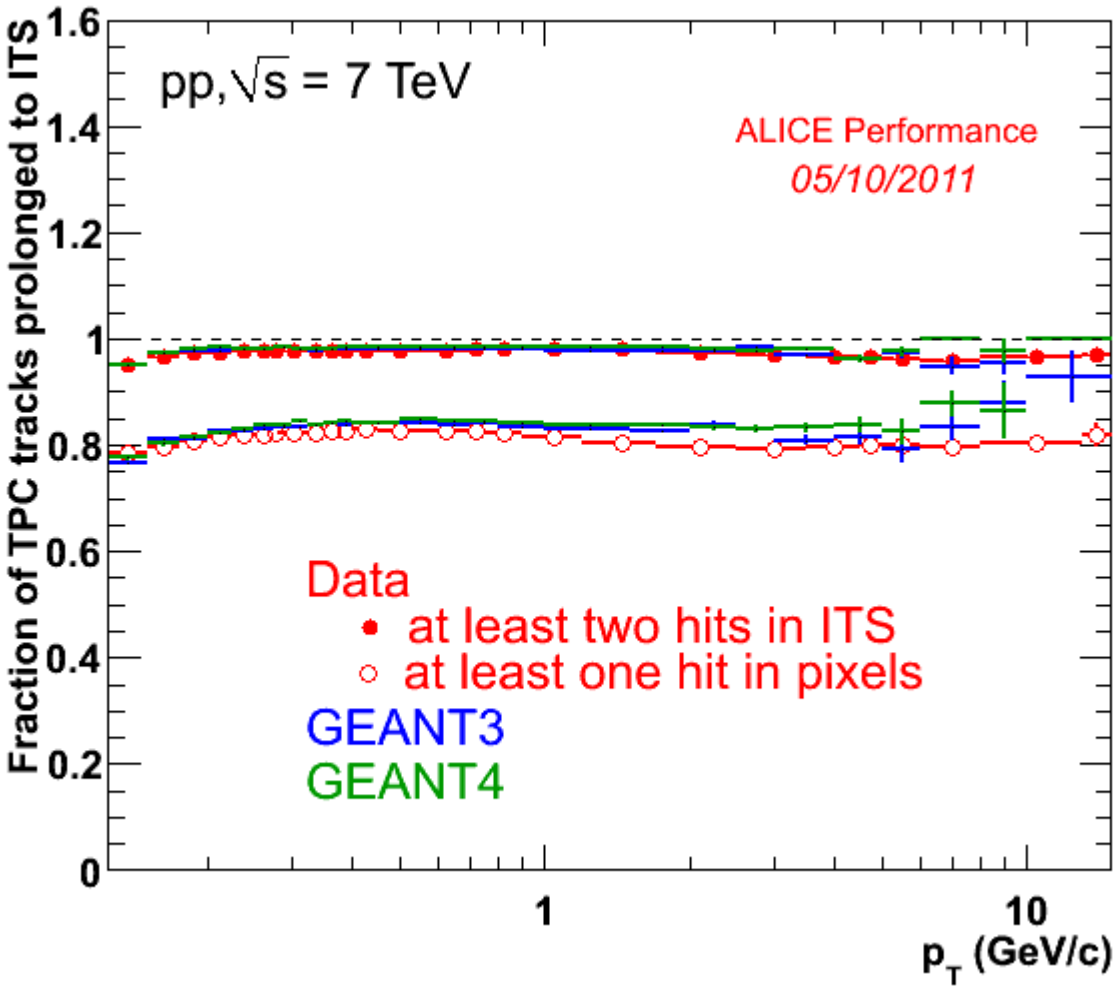




- PL including CHIPS and FTFP give at least as good results as Fluka for p and $\bar{p}$, possibility to use one PL for studies of systematics
- Geant3 does not describe K^- correctly
  - Within statistics, G4 shows same results as G3 → None of the G4 PLs seems any better than G3 for the K^-

Plots by Michal Broz

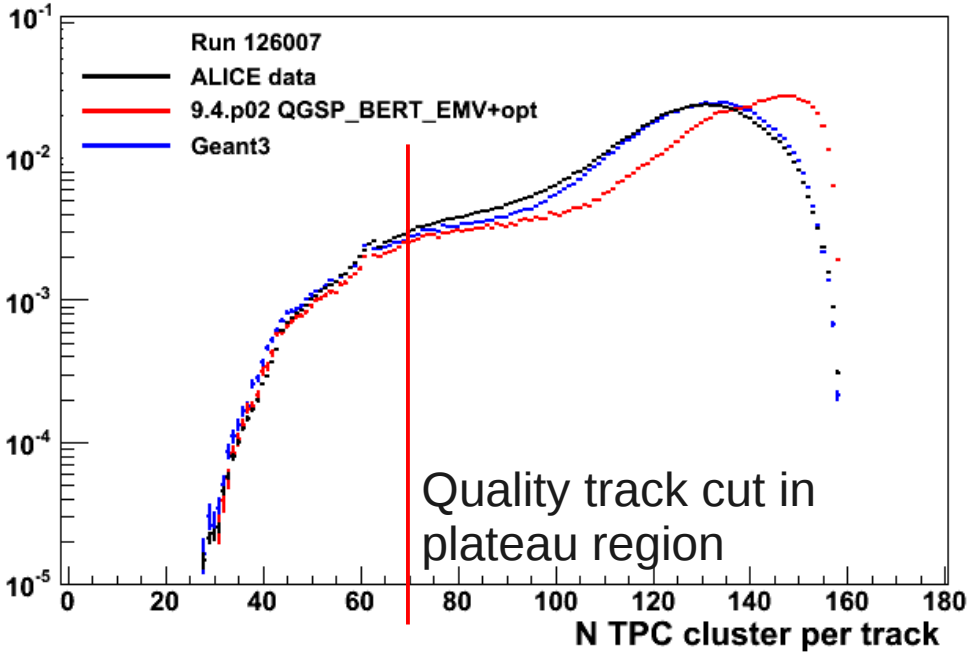
ITS-TPC Prolongation Efficiency



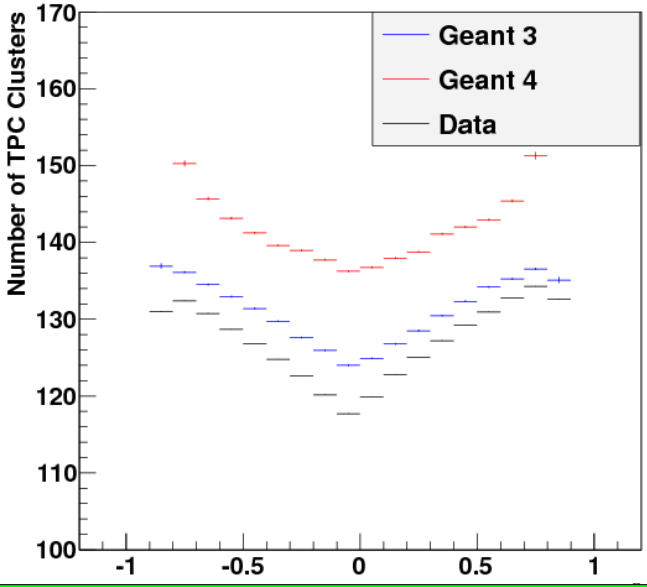
Plot by Andrea Dainese

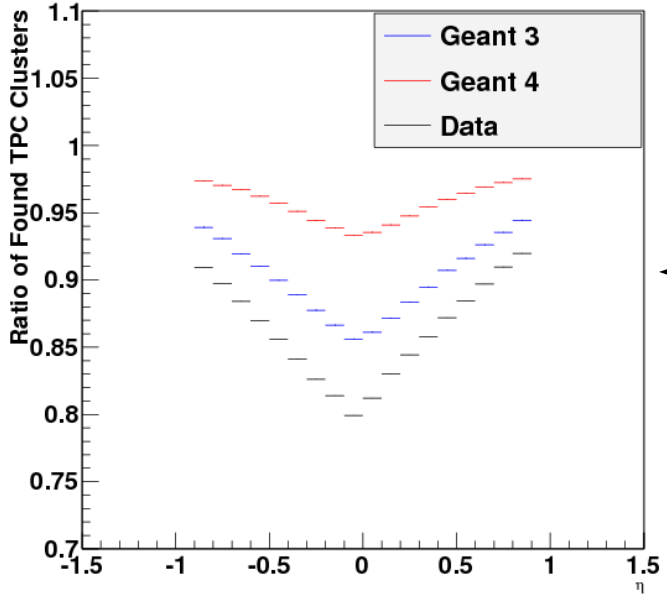
- Similar performance in terms of ITS-TPC prolongation between data Geant3,Geant4
- Difference at high-p_T between data and MC is mainly due to the different content of secondary tracks from strange particle decays
- Simulations using different physics lists have same performance (plots not shown)

Number of TPC Clusters per Track



- Compared to data, the number of clusters per reconstructed TPC track in Geant4 is on average higher
- Geant3 shows also slightly higher number of clusters compared to data

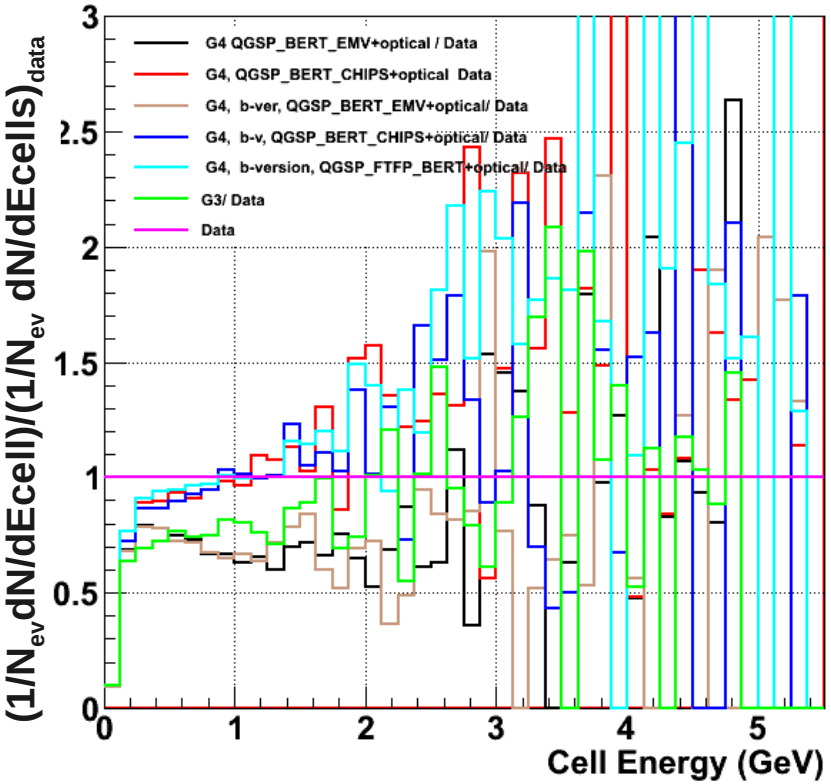




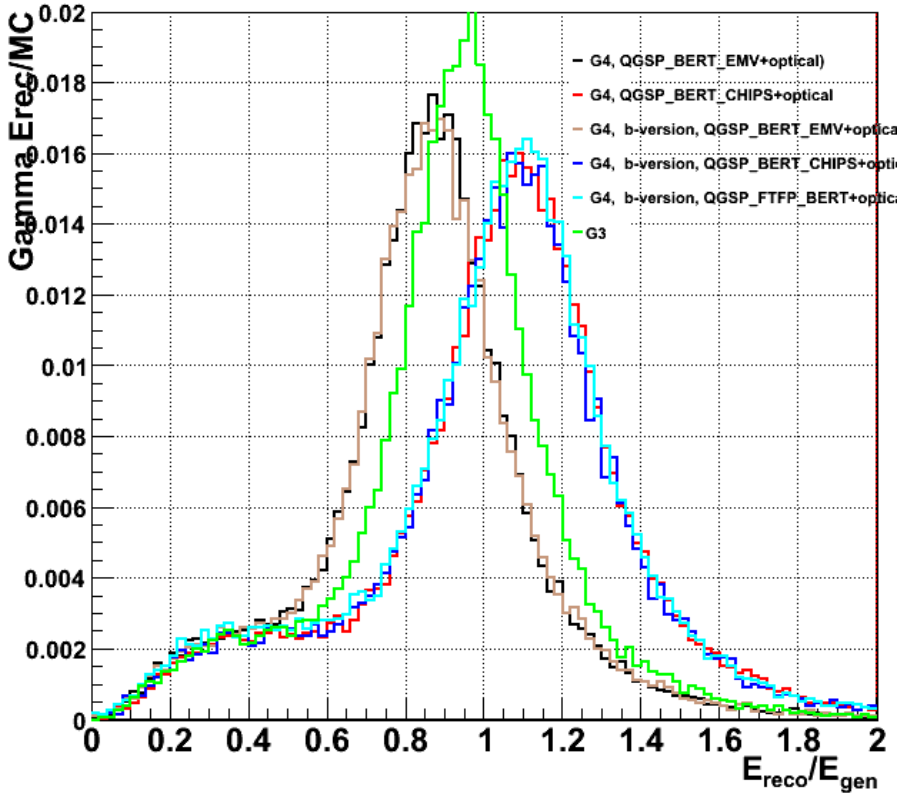
← Also, ratio of found clusters to generated clusters is higher in Geant4

Plots by Weilin Yu

EMCAL



- Different results for different PLs
- Cell energy spectrum is almost reproduced using physics lists including CHIPS and FTFP, it is underestimated using QGSP_BERT_EMV



- Sampling fraction was tuned for Geant3, → E_{rec}/E_{gen} ~1
- Same sampling fraction was used in Geant4 simulations → tune needed
- Different results for different PLs, needs each PL one tune?

Plots by Marie Germain

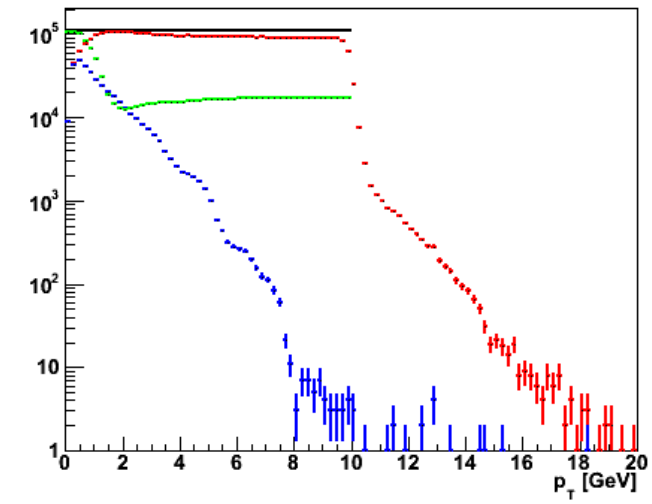
Geant4 Transport of Nuclei and Anti-Nuclei

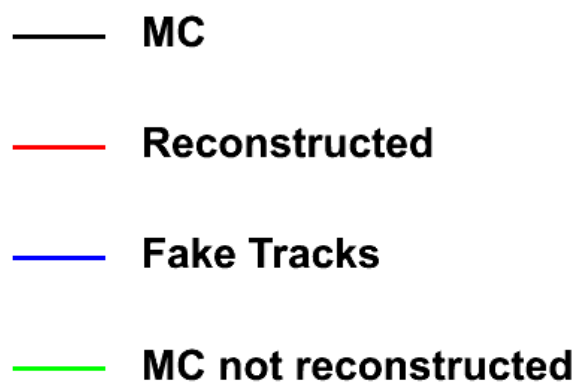
-Reconstruction Efficiencies

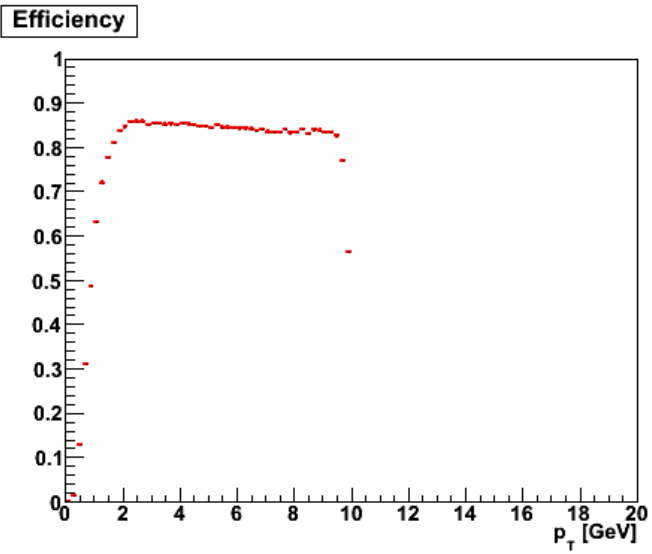
Anti-nucleon transport

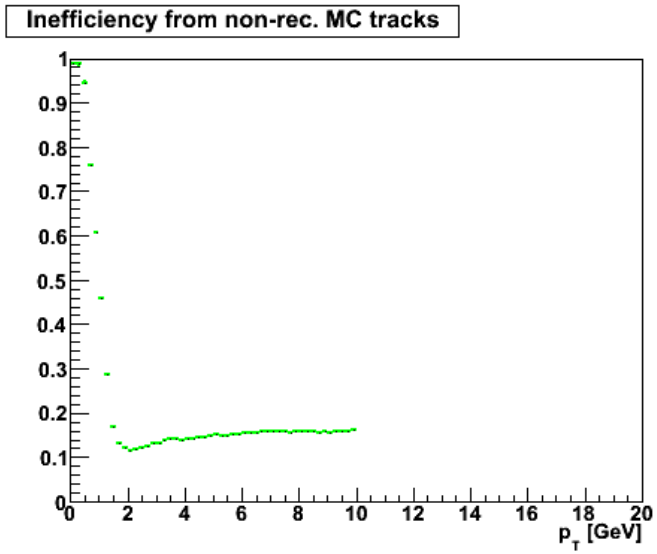
- New physics list QGSP_FTFP_BERT: the annihilation interactions of the anti-nucleons and elastic scattering are available
- Production (LHC10d6g) using cocktail of
  - d, t, ^{3}He, ^{4}He and their anti-particles
  - Flat p_T distribution from 0 to 10 GeV/c
  - Detector configuration of run 126007 (period LHC10d)
- Check reconstruction efficiencies for particles and anti-particles and compare them to each other
  - check influence of annihilation on reconstruction efficiency for anti-particles

All nuclei (global tracks)



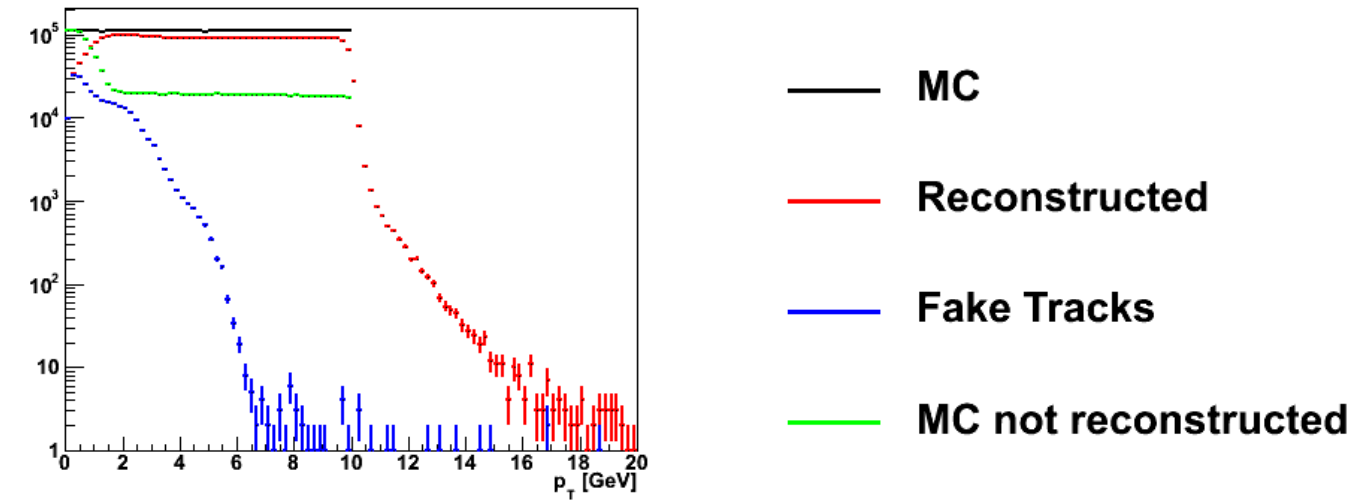


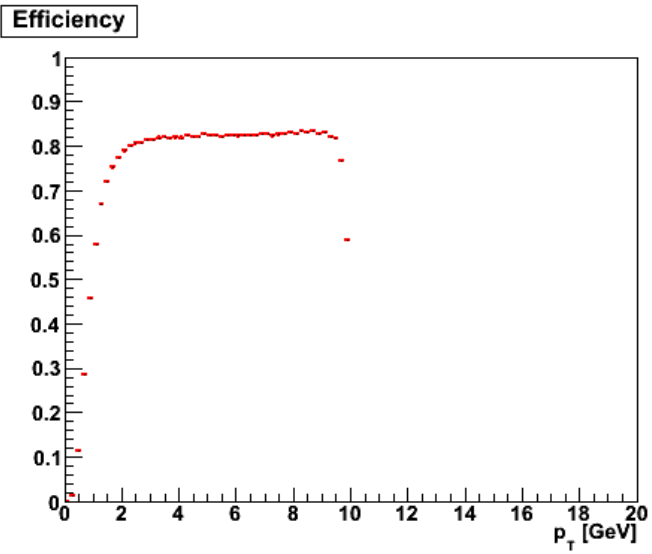


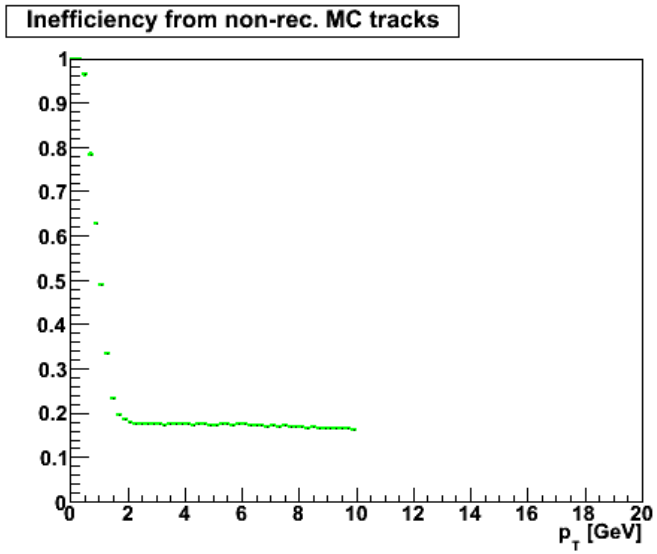


- Test production investigating transport of nuclei and anti-nuclei
- Compare number of generated particles and reconstructed tracks for nuclei and anti-nuclei separately
- Check difference in reconstruction efficiency

All anti-nuclei (global tracks)

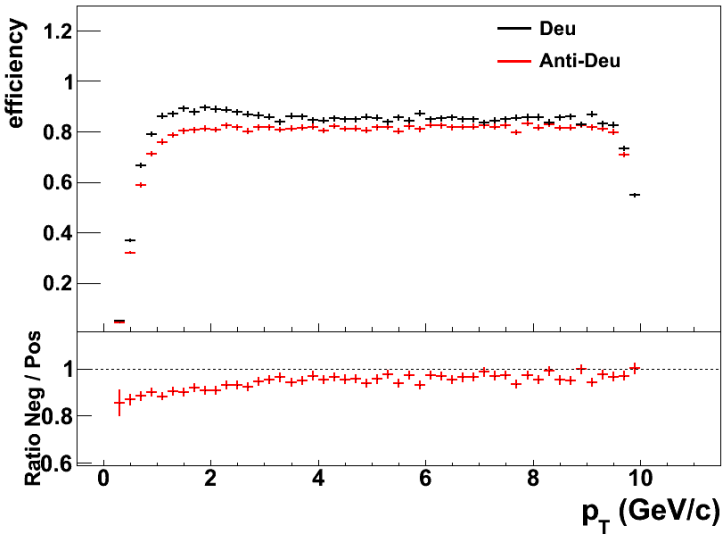


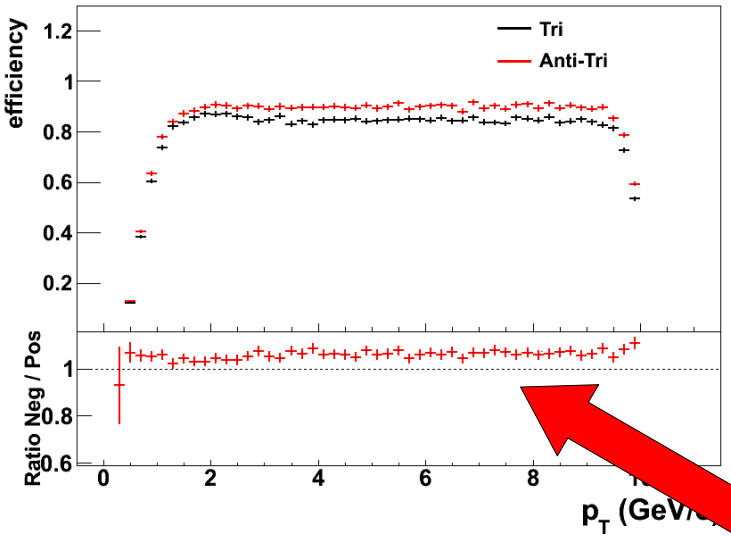


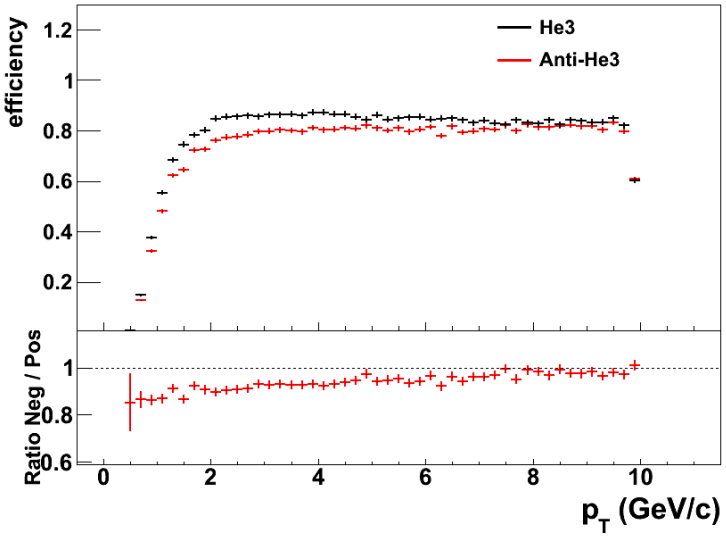


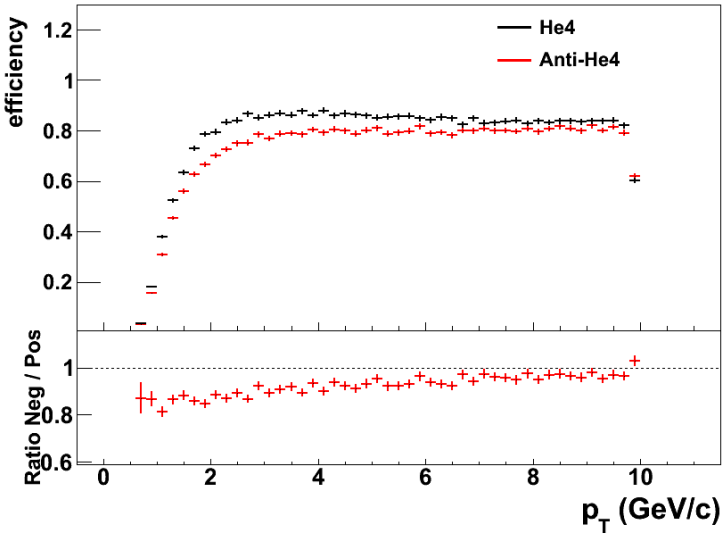
- Test production investigating transport of nuclei and anti-nuclei
- Compare number of generated particles and reconstructed tracks for nuclei and anti-nuclei separately
- Check difference in reconstruction efficiency

Efficiencies separated d, t, He3 and He4









- Results for d, ^{3}He, ^{4}He show lower reconstruction efficiencies for anti-particles at low p_T
- Ratio of reconstruction efficiencies for tritons and anti-tritons is inverted to expected value and constant

Summary

- ALICE used Geant4 transport in Pythia test simulations and simulations of a nuclei cocktail
- Reconstruction efficiencies in Geant4 simulations in ITS and TPC are now similar to those obtained in Geant3
- Reconstruction efficiency of anti-nuclei and nuclei look promising
  - But triton efficiency lower as anti-triton efficiency
- ITS-TPC prolongation efficiency is similar between data, Geant3 and Geant4
- Number of TPC clusters in Geant4 is higher than in real data
- Results of Calorimeter (EMCAL) differ when using different physics lists

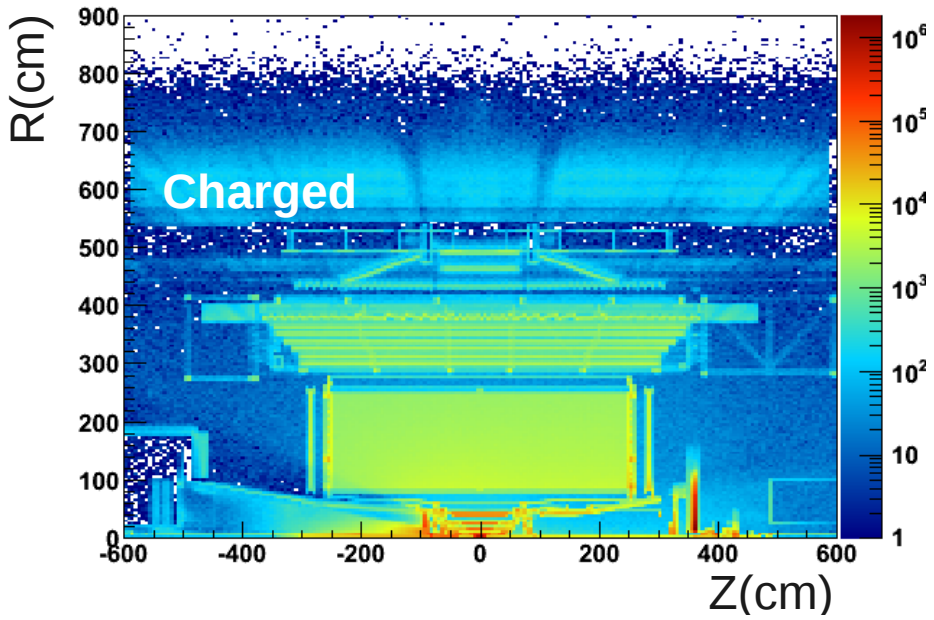
Backup

Physics lists

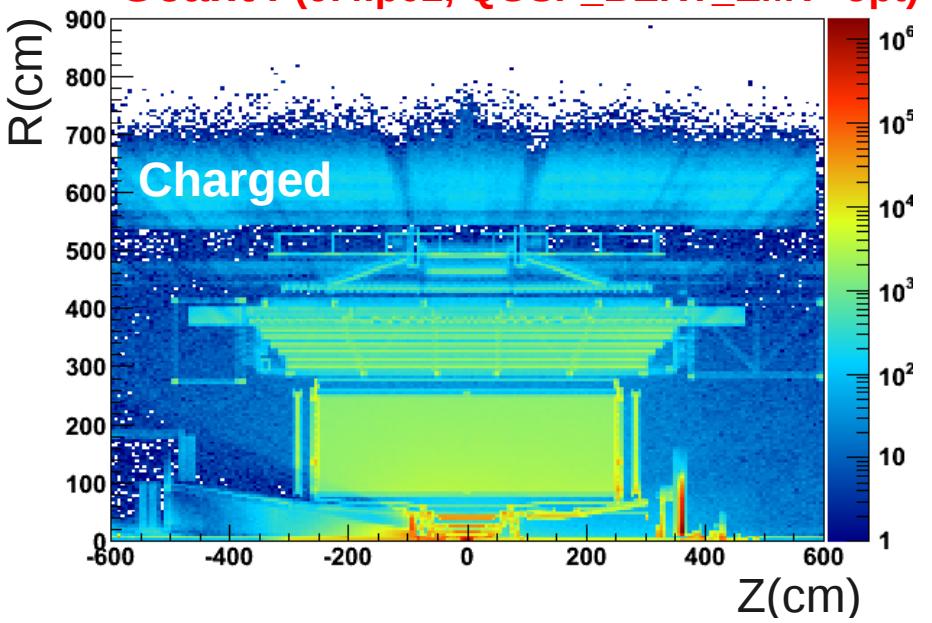
- "QGSP: quark gluon string model for high energy interactions of protons, neutrons, pions, and Kaons and nuclei.
- QGSP_BERT: Like QGSP, but using Geant4 Bertini cascade for primary protons, neutrons, pions and Kaons below ~10GeV.
- QGSP_BERT_EMV is like QGSP_BERT, but parameters of electromagnetic processes tuned to yield better cpu performance with only slightly less precision.
- Optical: optical physics
- CHIPS: Nuclear capture of negative particles and neutrons at rest is modeled using the modeling of the Chiral Invariant Phase Space (CHIPS) model.
- FTFP: The annihilation interactions of the anti-nucleons, elastic scattering are available
- Productions and physics lists:
  - QGSP_BERT_EMV+optical → LHC11d6a, LHC11d6c
  - QGSP_CHIPS_EMV+optical → LHC11d6b, LHC11d6d
  - QGSP_FTFP_BERT+optical → LHC11d6e, LHC11d6g

Secondaries R-Z

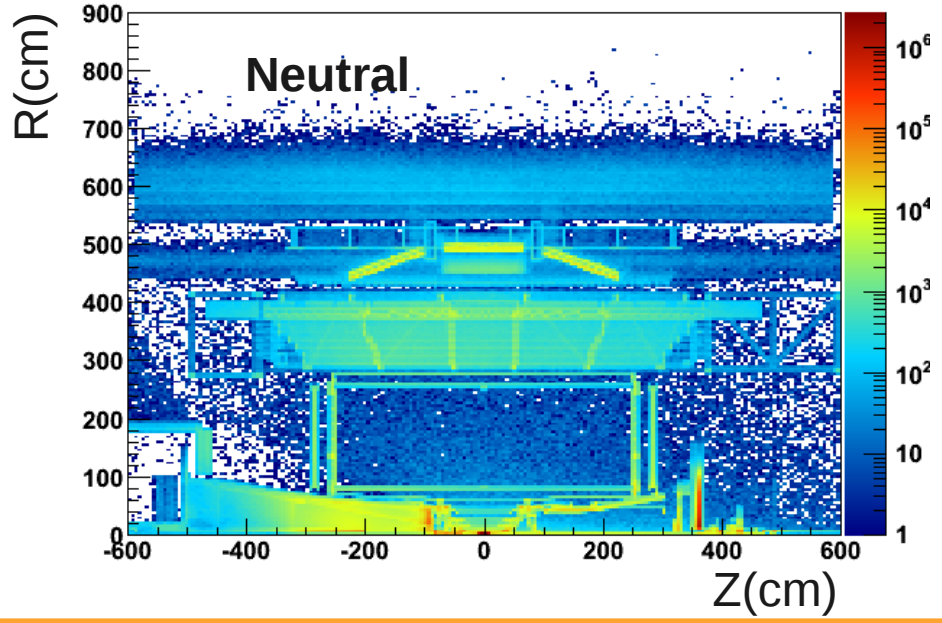
Geant3



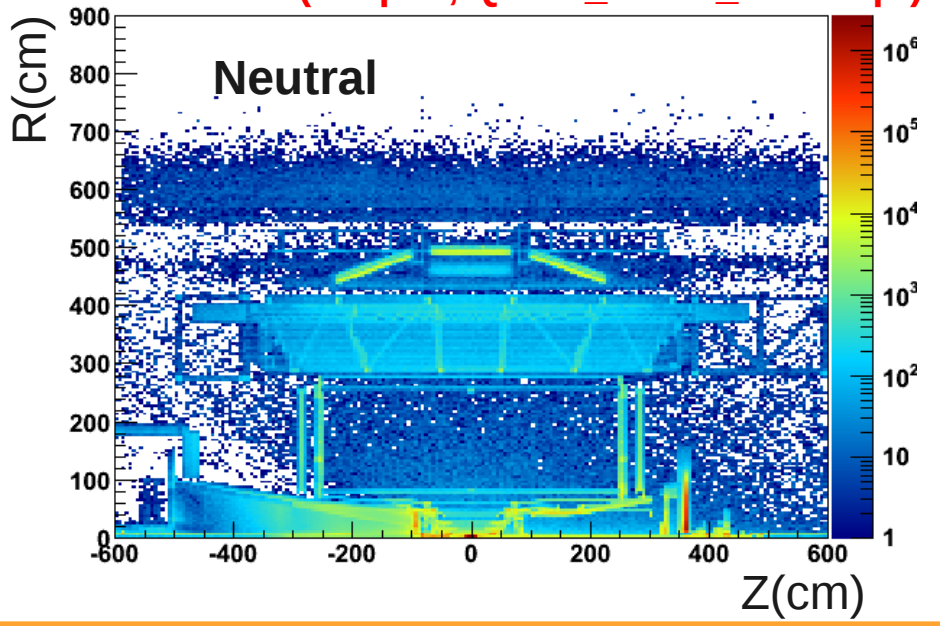
Geant4 (9.4.p02, QGSP_BERT_EMV+opt)



Geant3

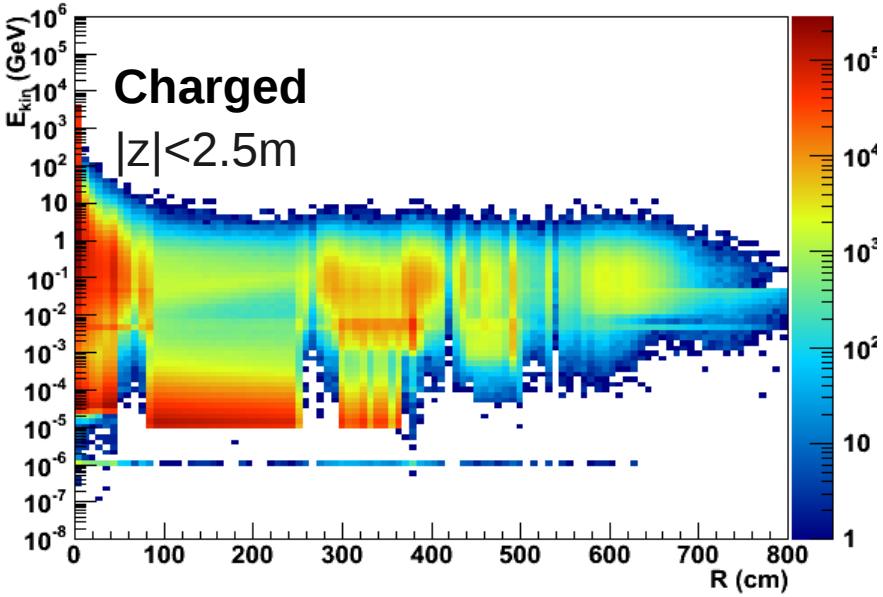


Geant4 (9.4.p02, QGSP_BERT_EMV+opt)



Secondaries Ekin - R

Geant3



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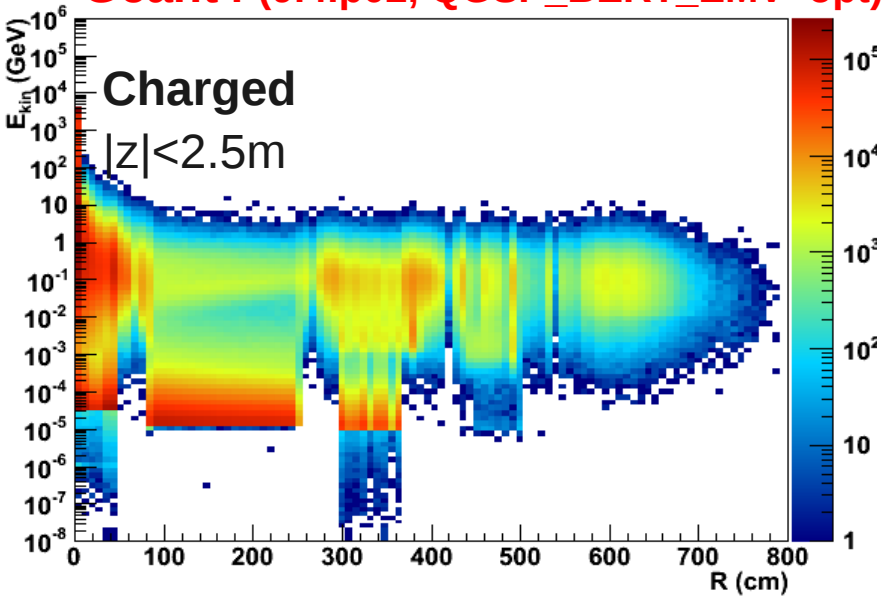
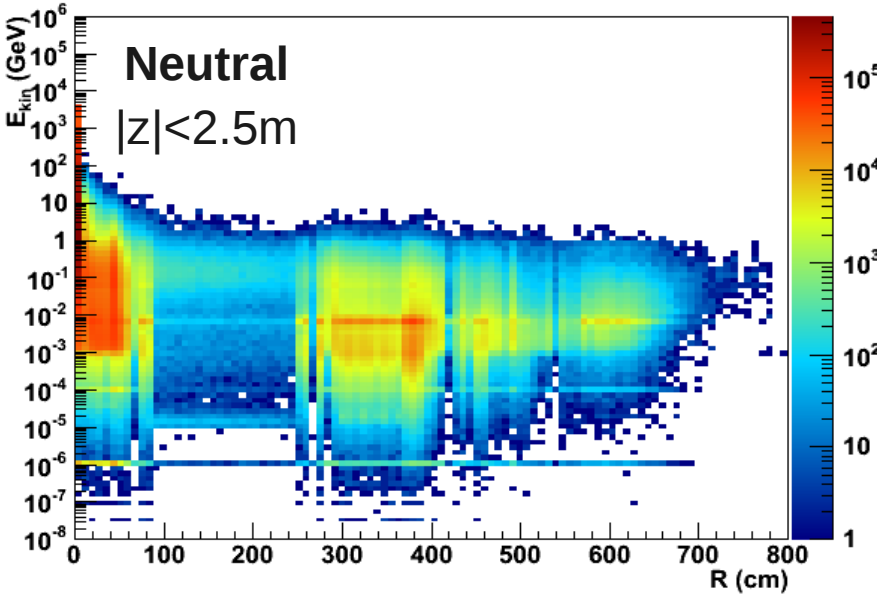
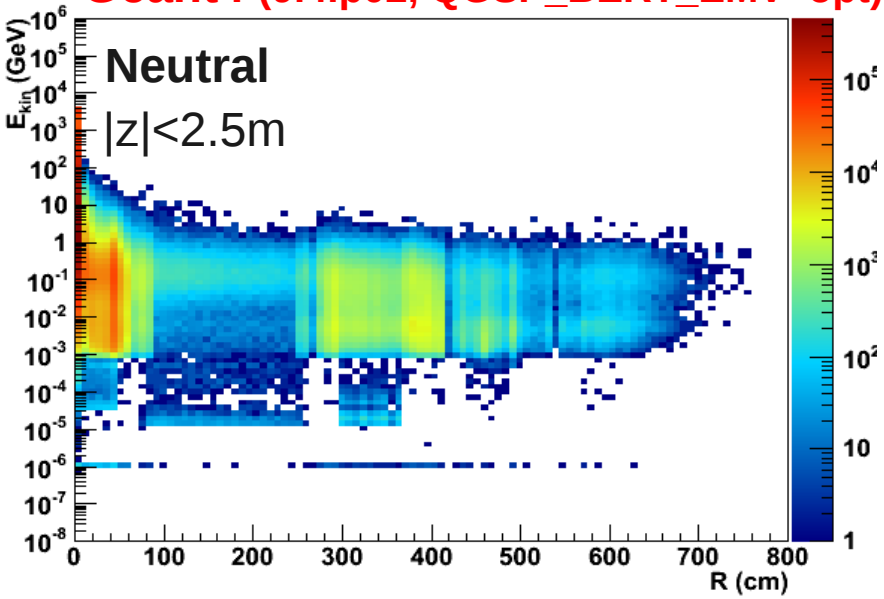


Geant3

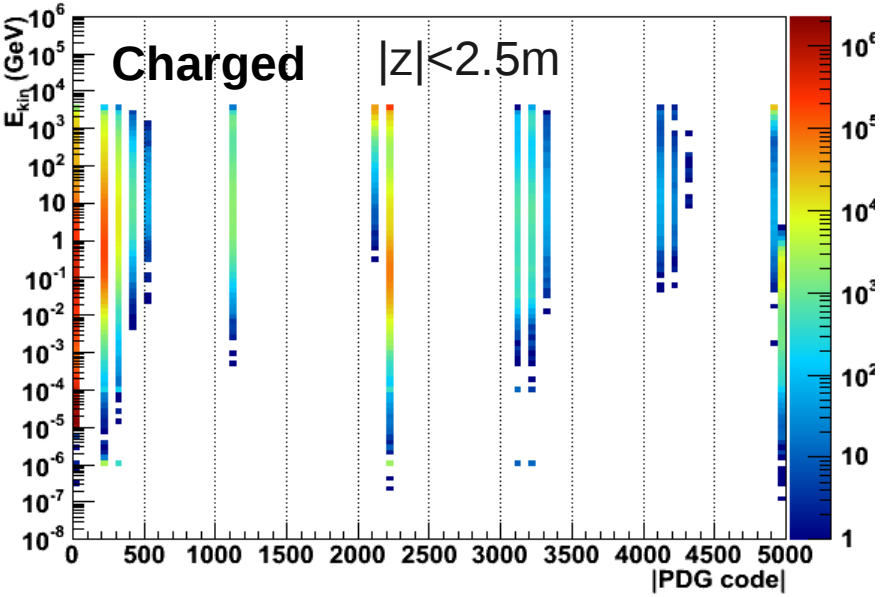


Geant4 (9.4.p02, QGSP_BERT_EMV+opt)

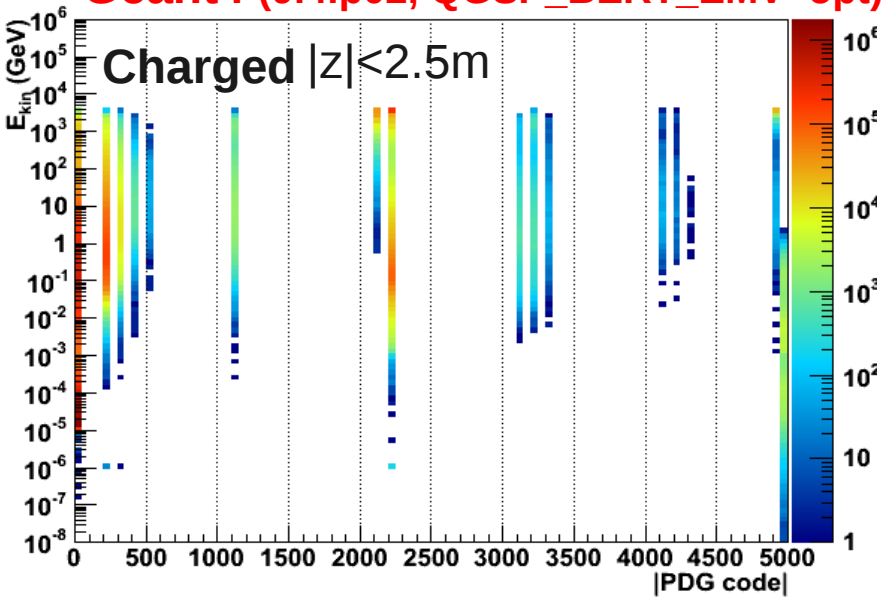


Secondaries Ekin - PDG

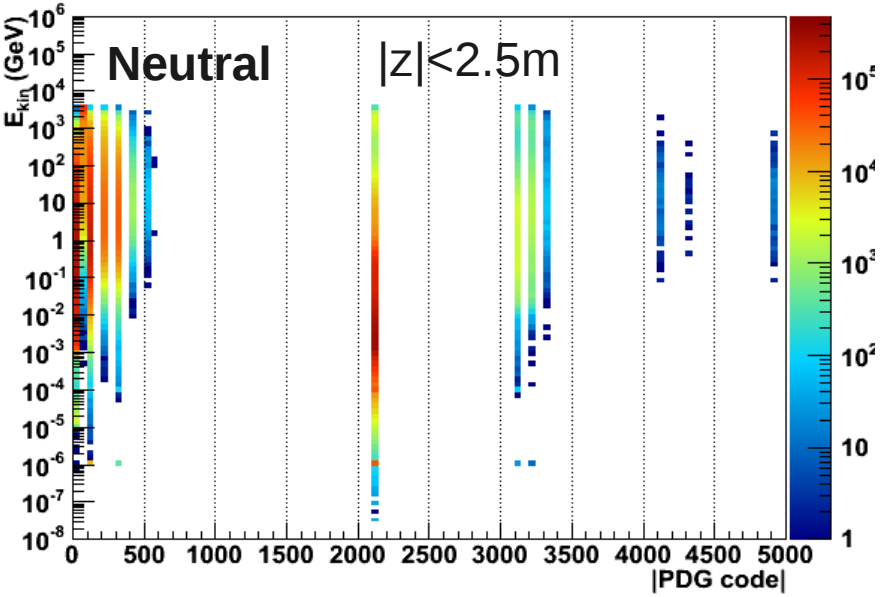
Geant3



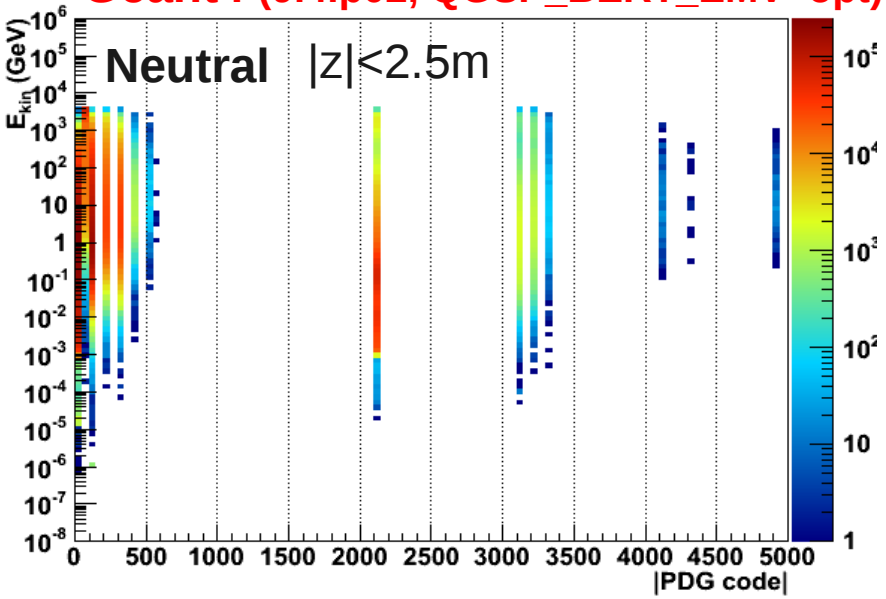
Geant4 (9.4.p02, QGSP_BERT_EMV+opt)



Geant3

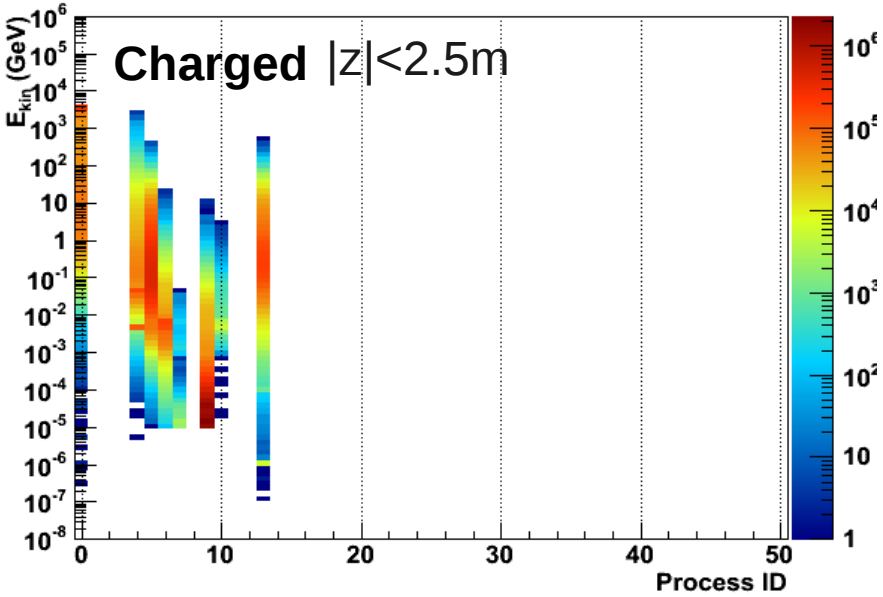


Geant4 (9.4.p02, QGSP_BERT_EMV+opt)

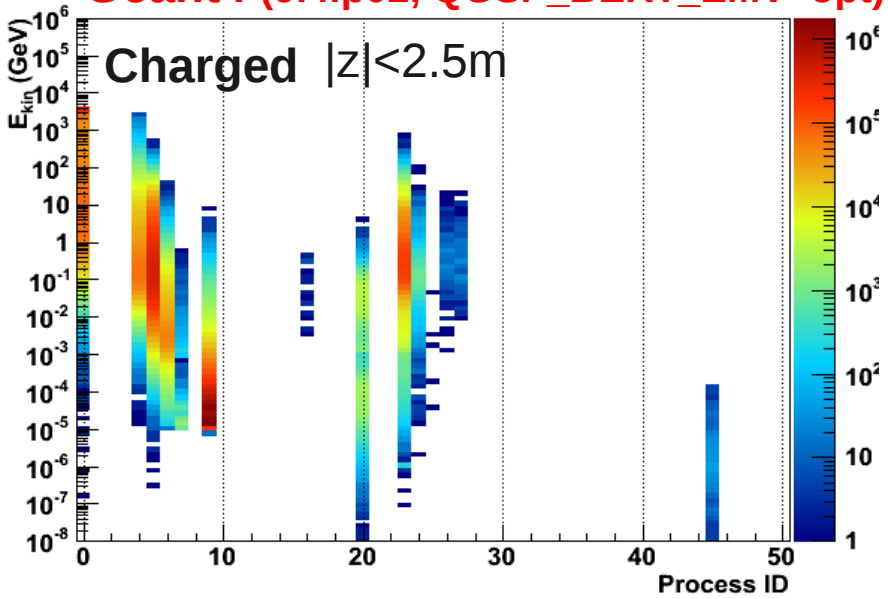


Secondaries Ekin - Process

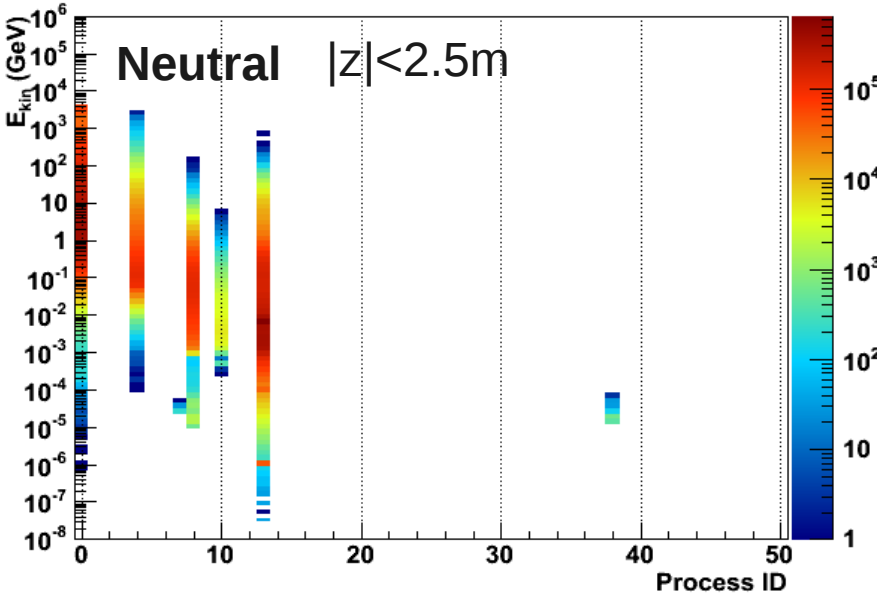
Geant3



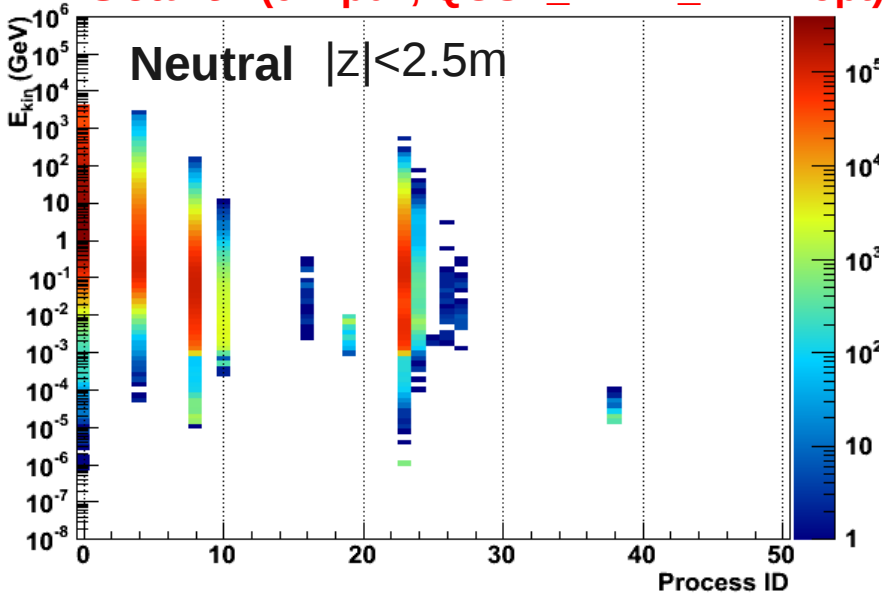
Geant4 (9.4.p02, QGSP_BERT_EMV+opt)



Geant3

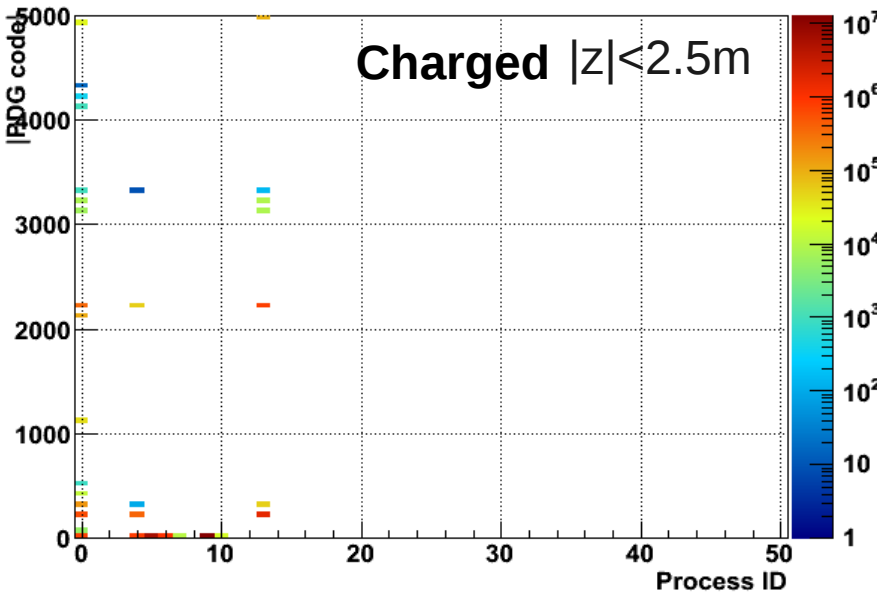


Geant4 (9.4.p02, QGSP_BERT_EMV+opt)

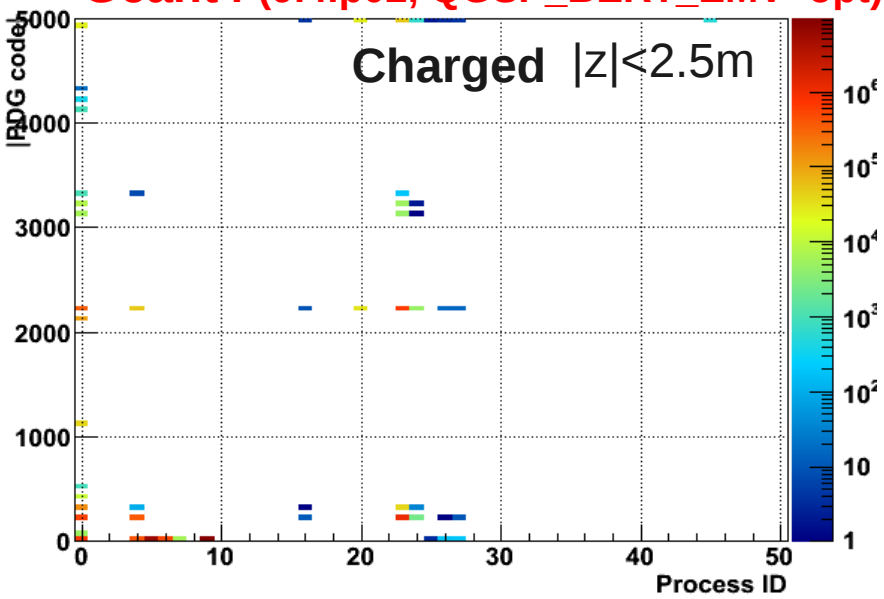


Secondaries PDG - Process

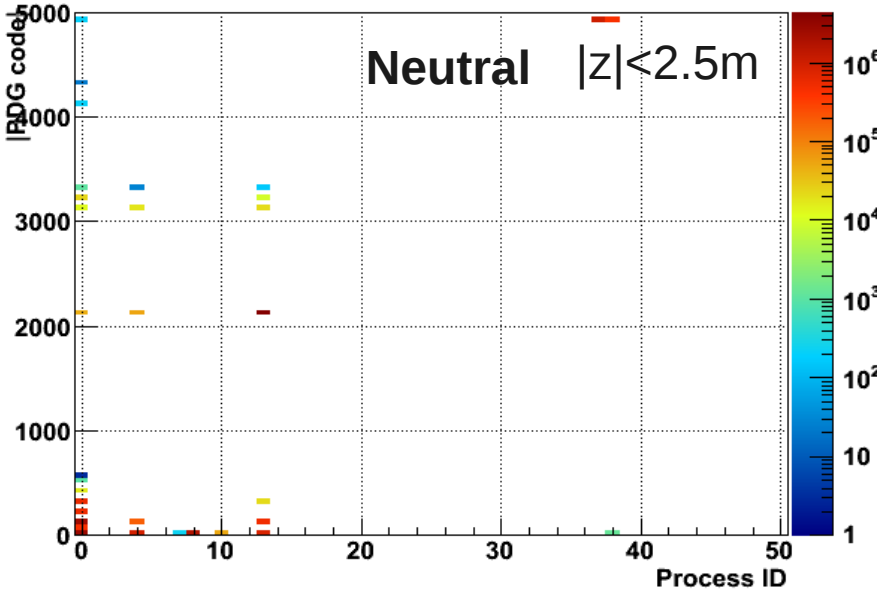
Geant3



Geant4 (9.4.p02, QGSP_BERT_EMV+opt)



Geant3



Geant4 (9.4.p02, QGSP_BERT_EMV+opt)