EMPHATIC data into PPFX
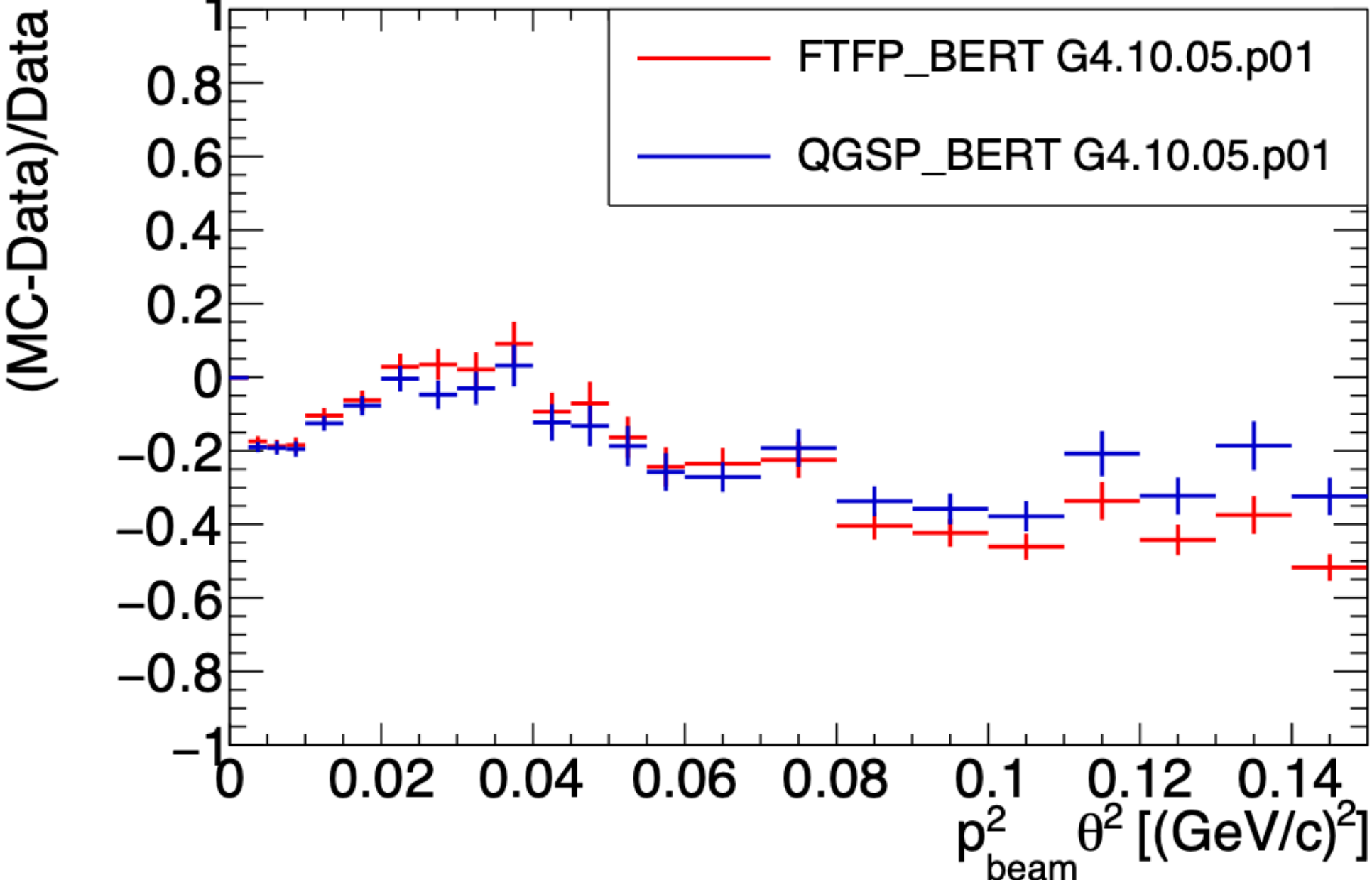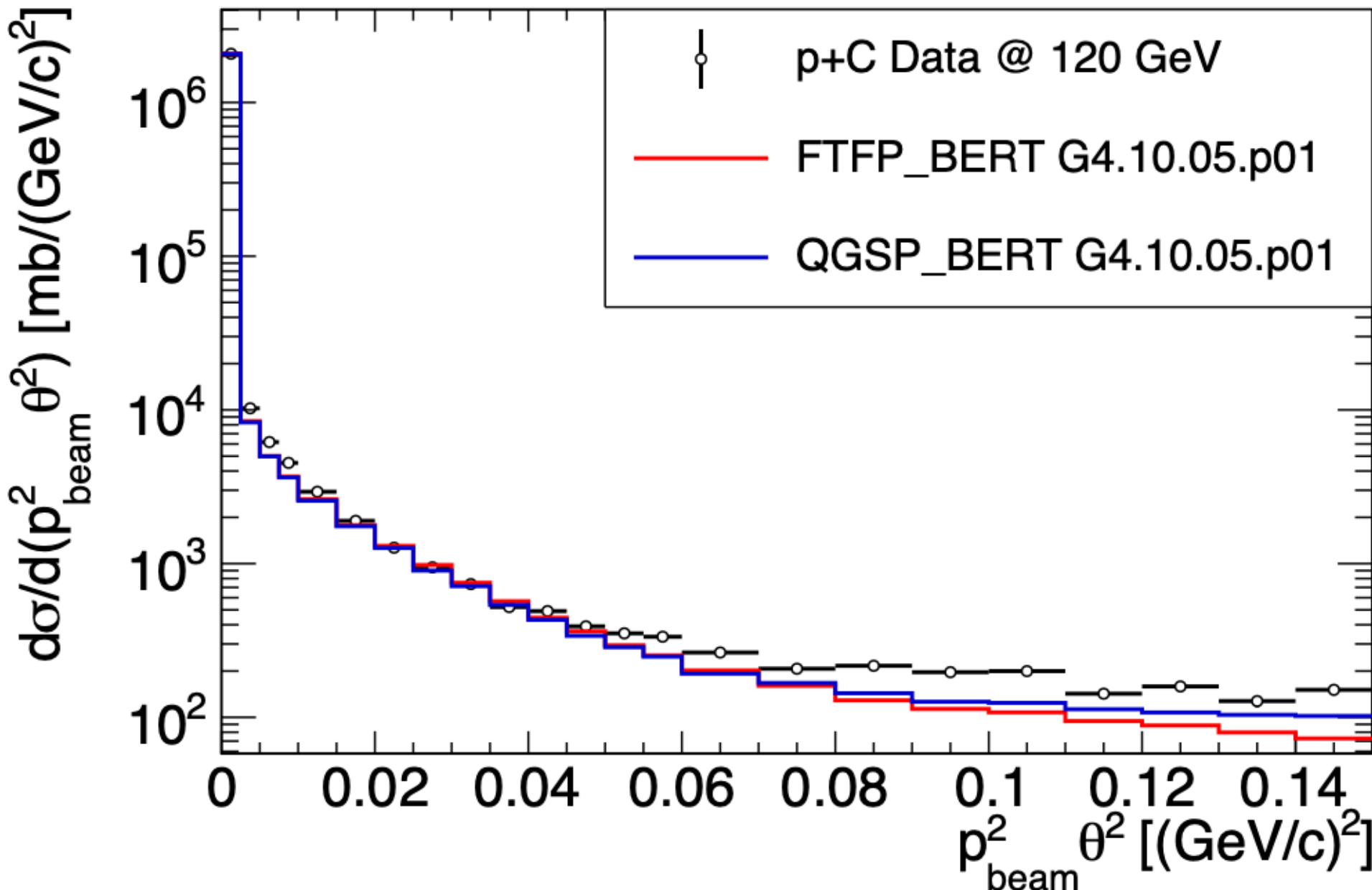
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IIT Hyderabad

December 5, 2023

EMPHATIC 120 GeV/c Data :

EMPHATIC 120 GeV data

https://lss.fnal.gov/archive/2021/pub/fermilab-pub-21-273-e-nd-scd.pdf

G4HP :

```cpp
// Sizes
G4double worldR        = radius + CLHEP::cm;
G4double targetLenght = 2.0*CLHEP::cm*0.5;
G4double worldZ        = targetLenght + CLHEP::cm;

// World
G4Tubs* solidW            = new G4Tubs("World",0.,worldR,worldZ,0.,CLHEP::twopi);
logicWorld                = new G4LogicalVolume( solidW,worldMaterial,"World");
G4VPhysicalVolume* world = new G4PVPlacement(0,G4ThreeVector(),
                                             logicWorld,"World",0,false,0);
// Target volume
G4Tubs* solidT = new G4Tubs("Target",0.,radius,targetLenght,0.,CLHEP::twopi);
logicTarget    = new G4LogicalVolume( solidT,targetMaterial,"Target");
new G4PVPlacement(0,G4ThreeVector(),logicTarget,"Target",logicWorld,false,0);
```
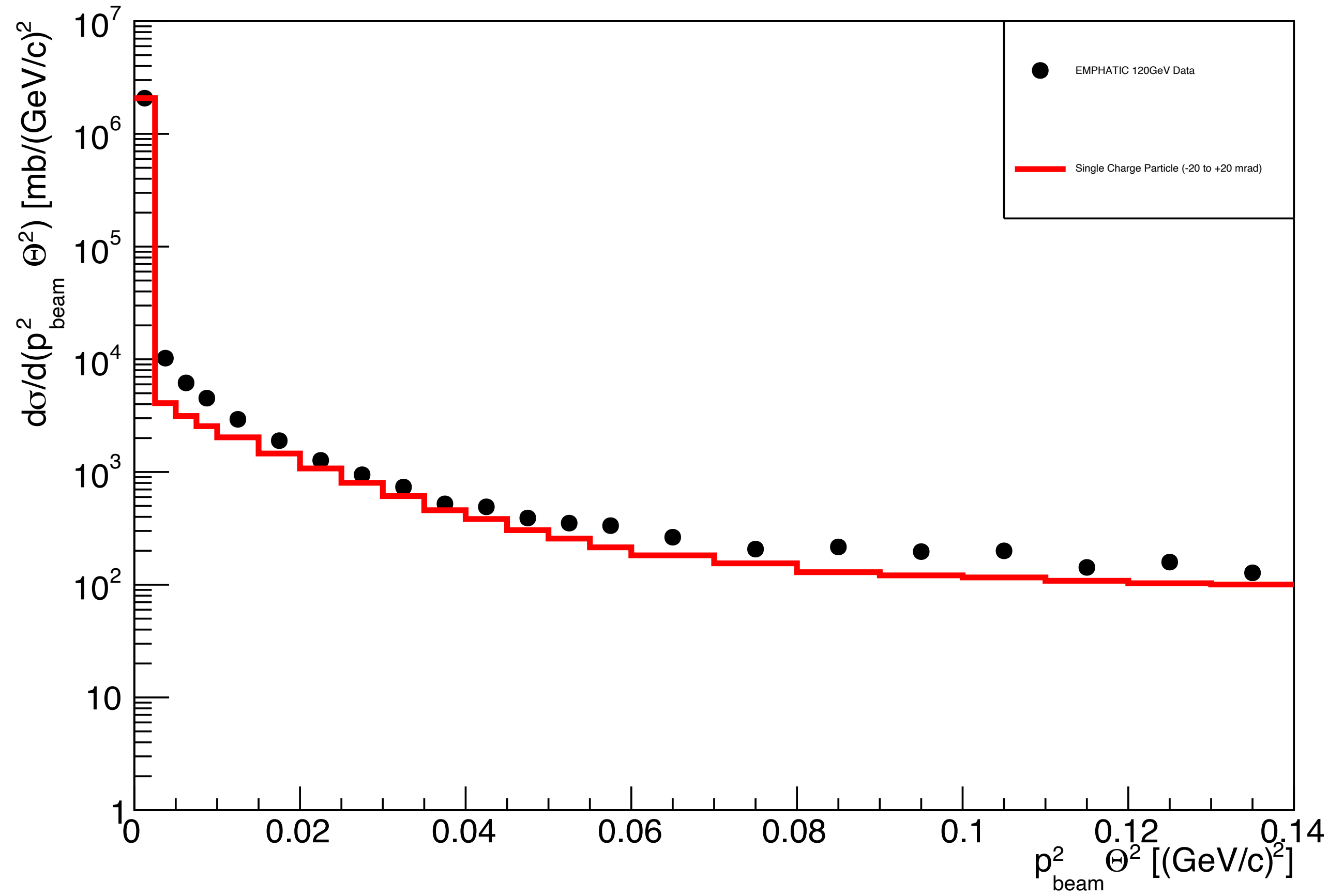
Fig: G4HP Geometry

$$\left(\frac{d\sigma}{d(p_{\mathrm{b}}^2\theta^2)} \right)_i = \frac{1}{N_{pot}} \frac{N_i}{nd \cdot \Delta(p_{\mathrm{b}}^2\theta^2)_i}$$

```cpp
//For cross-section calculation
// these depend on the target geometry & material
const double rho=1.83; // g/cc graphite
const double A=12.01; // g/mol Carbon
const double NA=6.022e23; // atoms/mol
const double dx=2.0;//cm target thickness  // Note: radius = 0
const double cm2_per_mb=1e-27; // conversion factor
const double sigma_factor=1.0/(rho/A * NA * dx * cm2_per_mb);
```
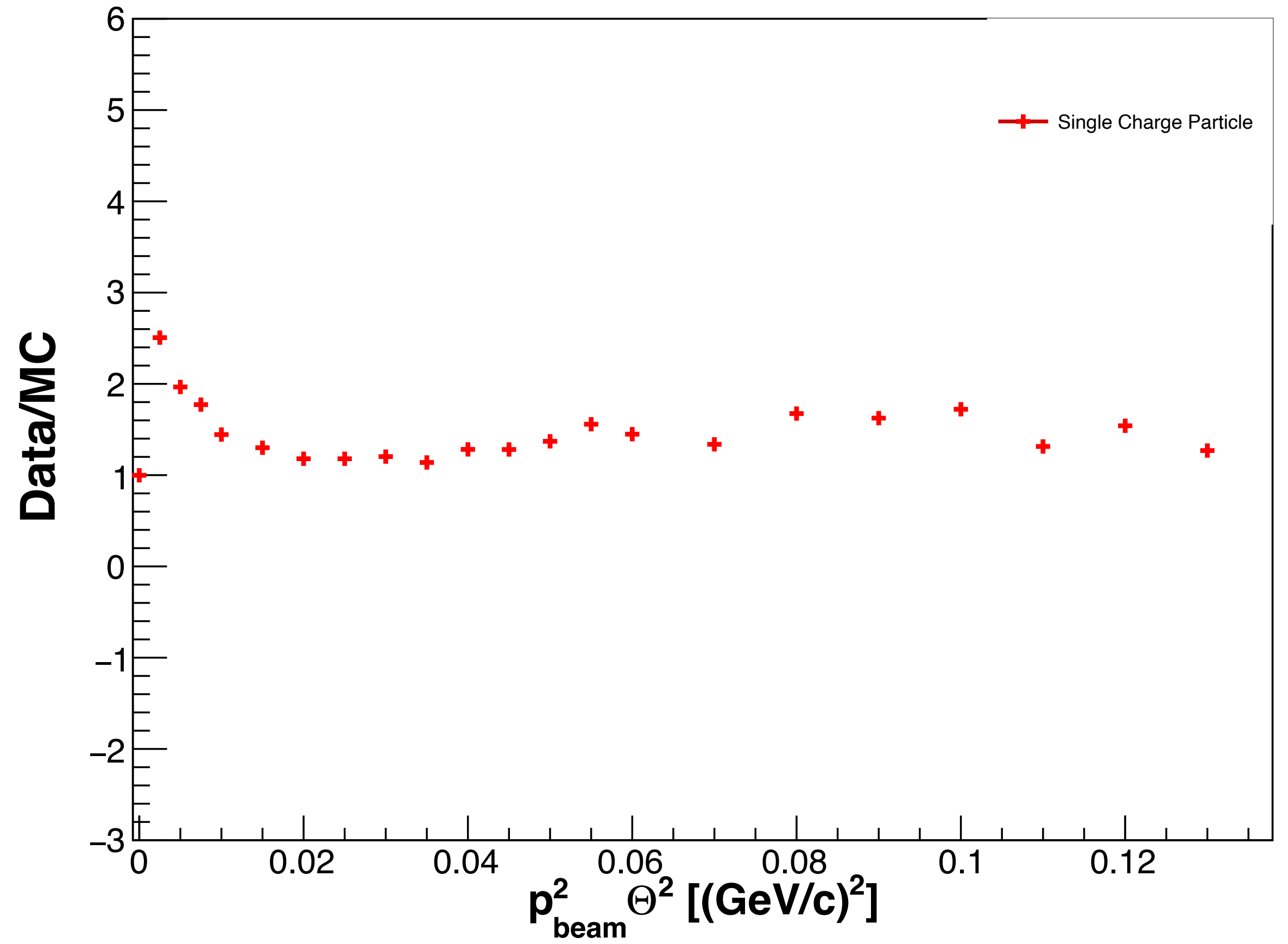
G4HP parameters

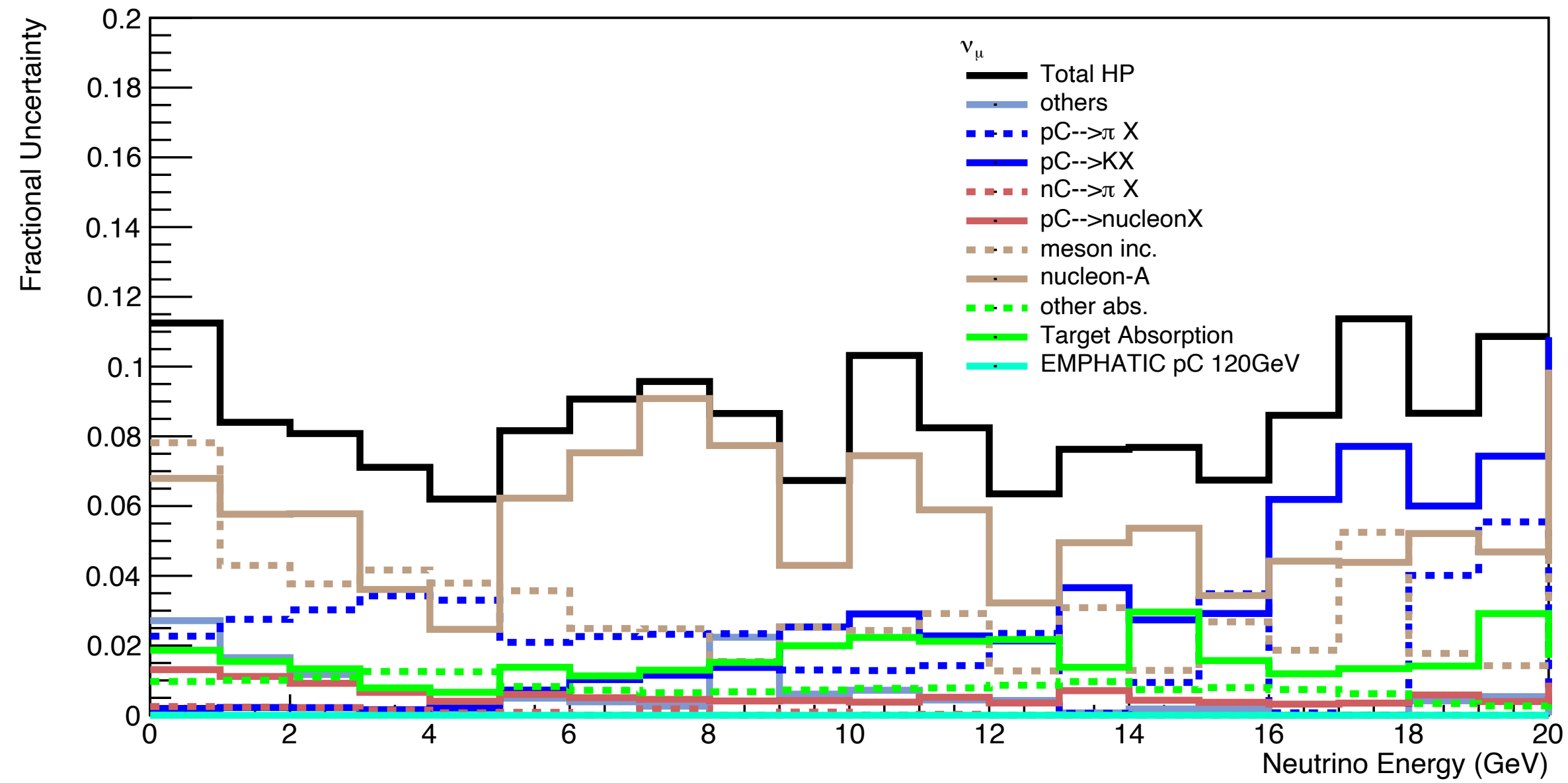$p + C \rightarrow X^{+/-}$ @ 120 GeV/c (within 20 mrad) :
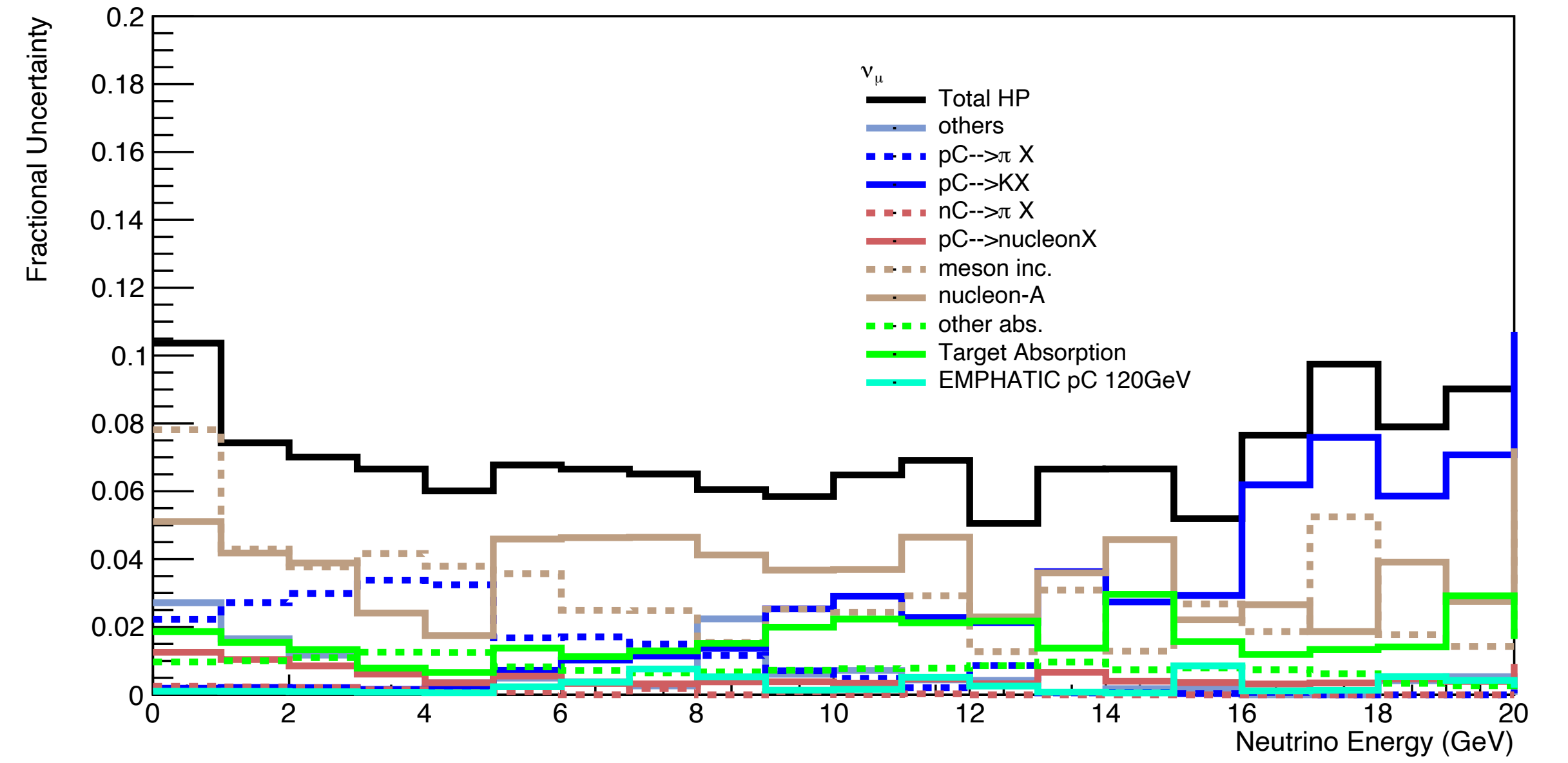

G4HP - QGSP_BERT

G4HP

G4HP/EMPHATIC

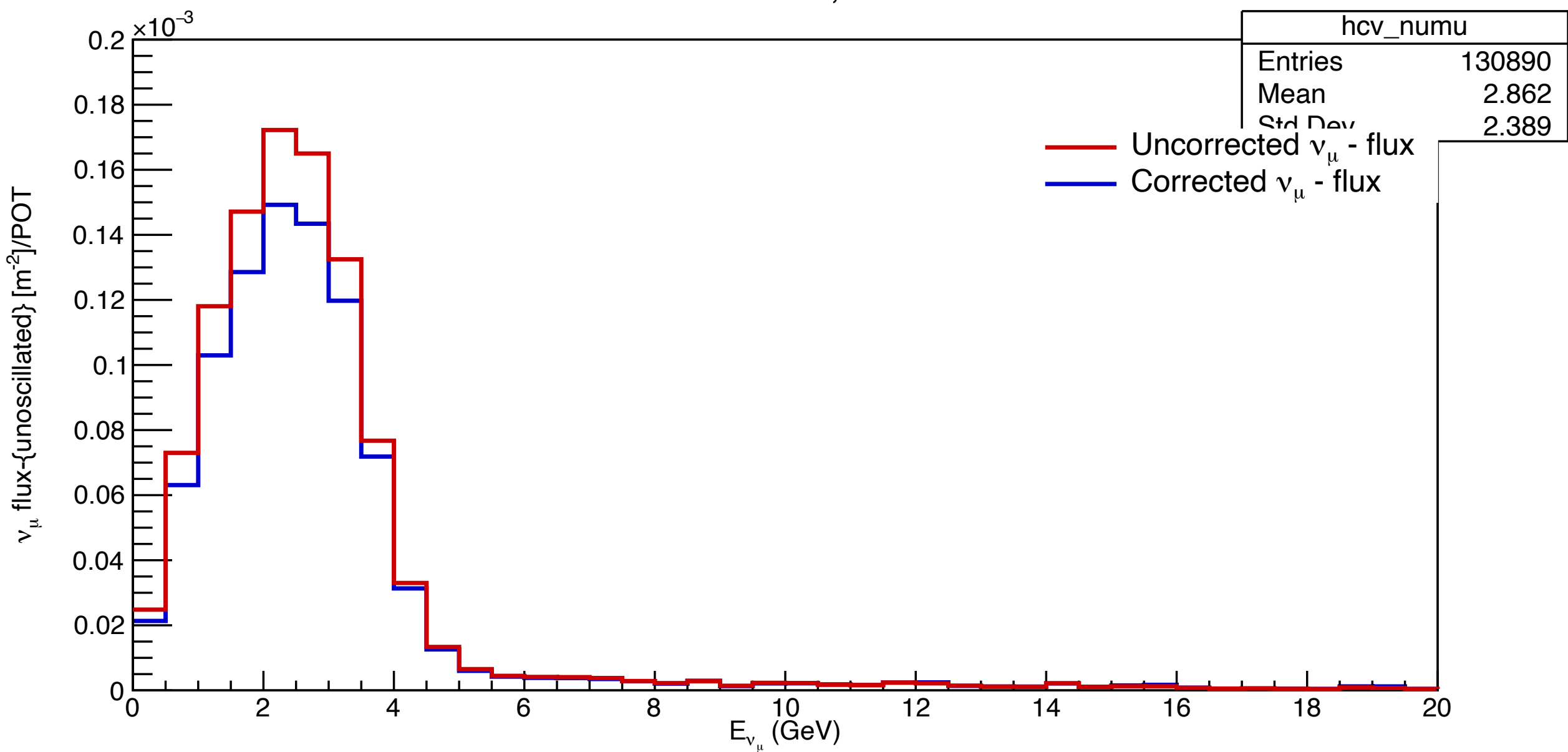# Fractional Uncertainties :

ν_μ - DUNE - EMPHATIC OFF

ν_μ - DUNE - EMPHATIC ON

Fractional uncertainties (DUNE ND)

DUNE ND

EMPHATIC-OFF, DUNE ND

hcv_numu	
Entries	130890
Mean	2.862
Std Dev	2.389

EMPHATIC-ON, DUNE ND

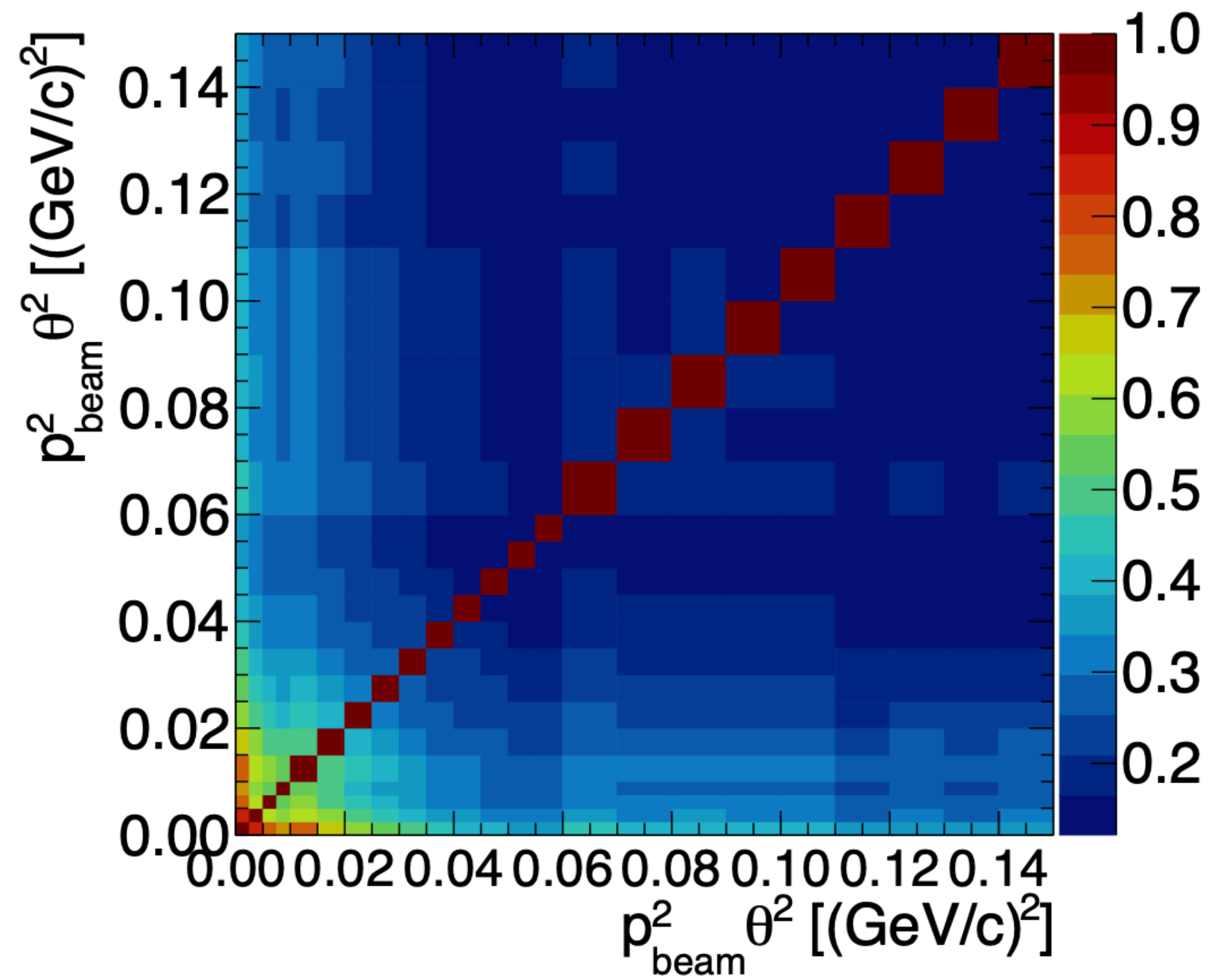| hcv_numu	
Entries	130890
Mean	2.838
Std Dev	2.319

Corrected ν-flux EMPHATIC-OFF/EMPHATIC-ON, DUNE ND

Thank you!

BACKUP SLIDE

Correlation Matrix 120GeV

```cpp
EMPHATICBins* EMPbins =  EMPHATICBins::getInstance();
vbin_emphatic_datacv_p.reserve(EMPbins->GetNbins_pC_pX_EMPHATIC());

 emphatic_data_xs = univPars.getParameterValue("emphatic_pC_p_xsec");

//the number of bins needs to be written from the xmls files
char namepar[100];
for(int ii=0;ii<EMPbins->GetNbins_pC_pX_EMPHATIC();ii++){

  sprintf(namepar,"EMPHATICData_pC_%s_sys_%d","p",ii);
  double data_cv  = cvPars.getParameterValue(std::string(namepar));
  double data_sys = univPars.getParameterValue(std::string(namepar));
  sprintf(namepar,"EMPHATICData_pC_%s_stats_%d","p",ii);
  double data_sta = univPars.getParameterValue(std::string(namepar));
  vbin_emphatic_datacv_p.push_back(data_sta + data_sys - data_cv);
}
```

EMPHATICpCReweighter.cpp

```cpp
    //checking:
    std::string mode(getenv("MODE"));
    if(aa.Inc_pdg != 2212)return false;
    if(aa.Inc_P < 115)return false;    // For 120 GeV Incident Momentum !120 cannot reweight--Ask Expert  !

    //volume check:
    bool is_wrong_volume = aa.Vol != "TGT1" && aa.Vol != "BudalMonitor" && aa.Vol != "Budal_HFVS" && aa.Vol != "Budal_VFHS";
    if( (mode=="REF") || (mode=="OPT") ){
      is_wrong_volume = aa.Vol != "TargetFinHorizontal" && aa.Vol != "TargetNoSplitSegment" && aa.Vol!="tCoreLog";
    }
    if(is_wrong_volume)return false;

 // Checking the produce charge particle
    if(abs(aa.Prod_pdg) != 2212 && abs(aa.Prod_pdg) != 211 && abs(aa.Prod_pdg) != 321 && abs(aa.Prod_pdg) != 3322 && abs(aa.Prod_pdg) != 3222 && abs(aa.Prod_p
dg) != 3112 && abs(aa.Prod_pdg) != 11) return false;

    EMPHATICBins*  EMPBins =  EMPHATICBins::getInstance();
    int bin_p       = EMPBins->EMPHATIC_BinID_pC_p(aa.p2t2,aa.Prod_pdg);
    //std::cout<<bin_p<<std::endl;
    if(bin_p < 0) return false;
    else return true;

  }

  double EMPHATICpCReweighter::calculateWeight(const InteractionData& aa){

    //quick check:
    double wgt = 1.0;
    double low_value = 1.e-18;
    EMPHATICBins*  EMPbins =  EMPHATICBins::getInstance();
    int bin_p = EMPbins->EMPHATIC_BinID_pC_p(aa.p2t2,aa.Prod_pdg);
    if(bin_p < 0){
  //    std::cout<<"No bin found "<< bin_p <<std::endl;
      return aux_par;
    }

    double dataval = -1;
    if( (abs(aa.Prod_pdg)==2212 || abs(aa.Prod_pdg)==211 || abs(aa.Prod_pdg)==321 || abs(aa.Prod_pdg)==3322 || abs(aa.Prod_pdg)==3222 || abs(aa.Prod_pdg)==311
2 || abs(aa.Prod_pdg)==11) && (-0.02>=(aa.Theta)<=+0.02) )dataval = vbin_emphatic_datacv_p[bin_p];
 /*  if(-20.0>=(aa.Theta)<=+20.0){
```

EMPHATICpCReweighter.cpp