HBT analysis of ALICE data at GSI

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- ***intro: what is an "HBT analysis"***
- ***my analysis scheme***
  - ***experiment independence***
  - ***multidimensional histograms***
- ***some results***

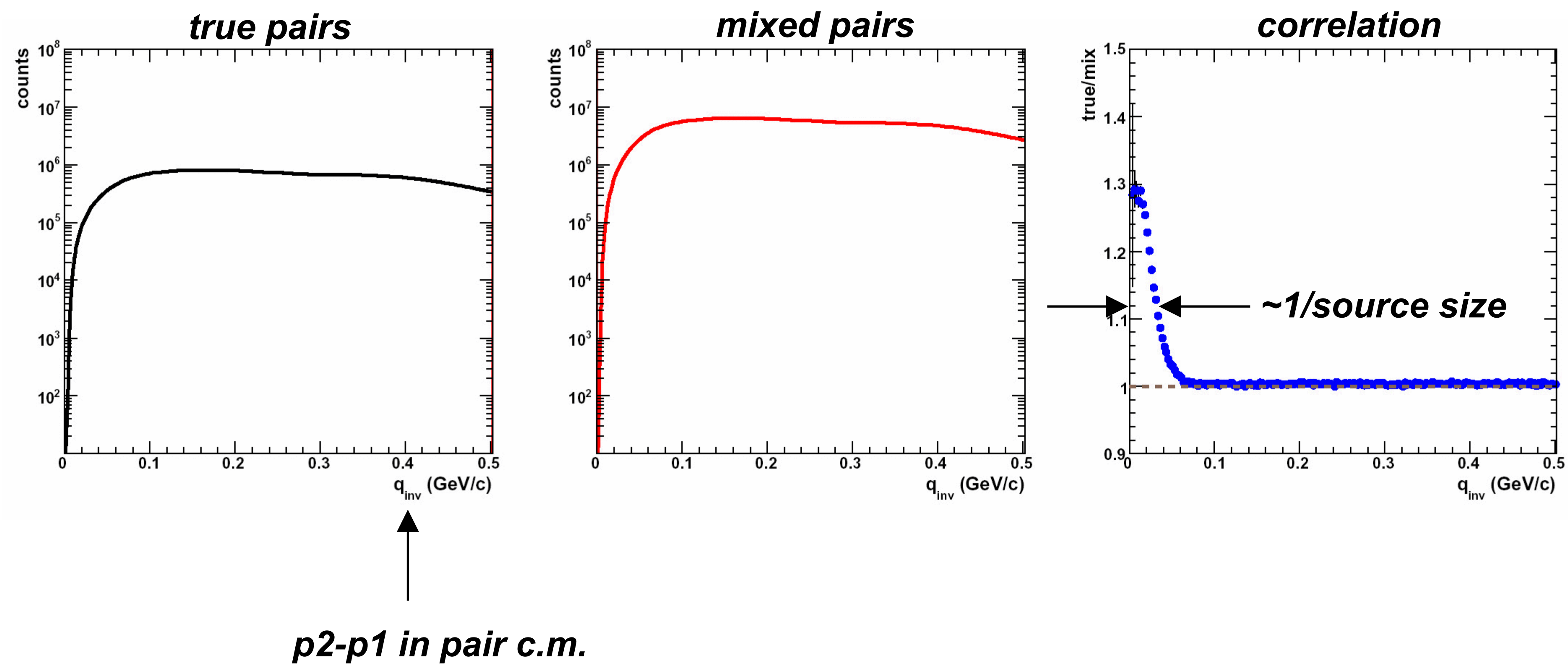
the simplest HBT analysis

D. Antonczyk, thesis intro

- *loop over events*
- *make pi-pi- pairs*
- *fill a p2-p1 histogram*

- *mix events*
- *make pi-pi- pairs*
- *fill a p2-p1 histogram*

- *divide tru/mix*



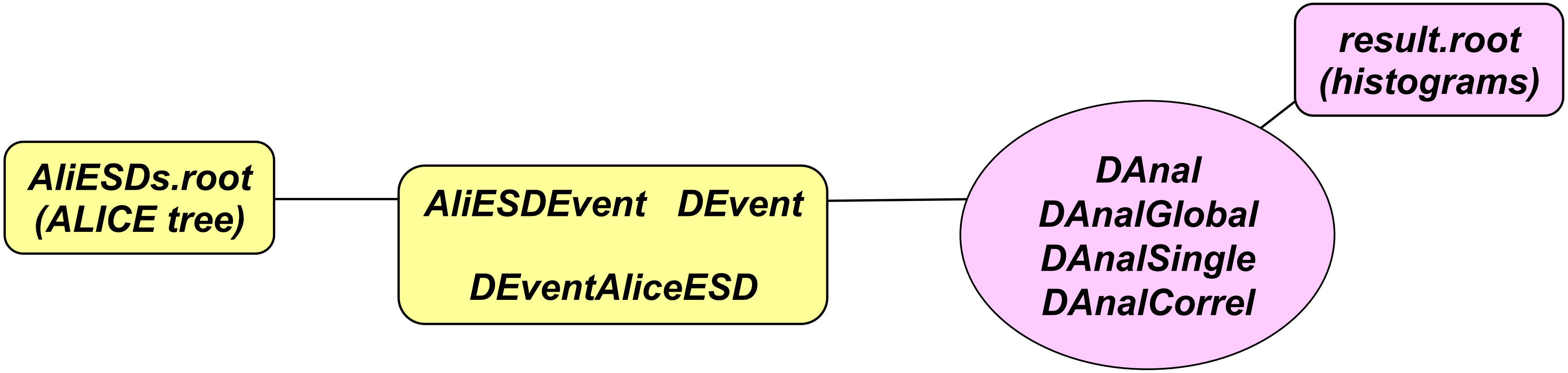
real analysis

- ***p2-p1 is a vector → correlation function is 3-dim***
- ***pair-y and pair-pt dependent***
- ***finite two-track resolution → suppress close pairs***
- ***correction for Coulomb and momentum resolution***

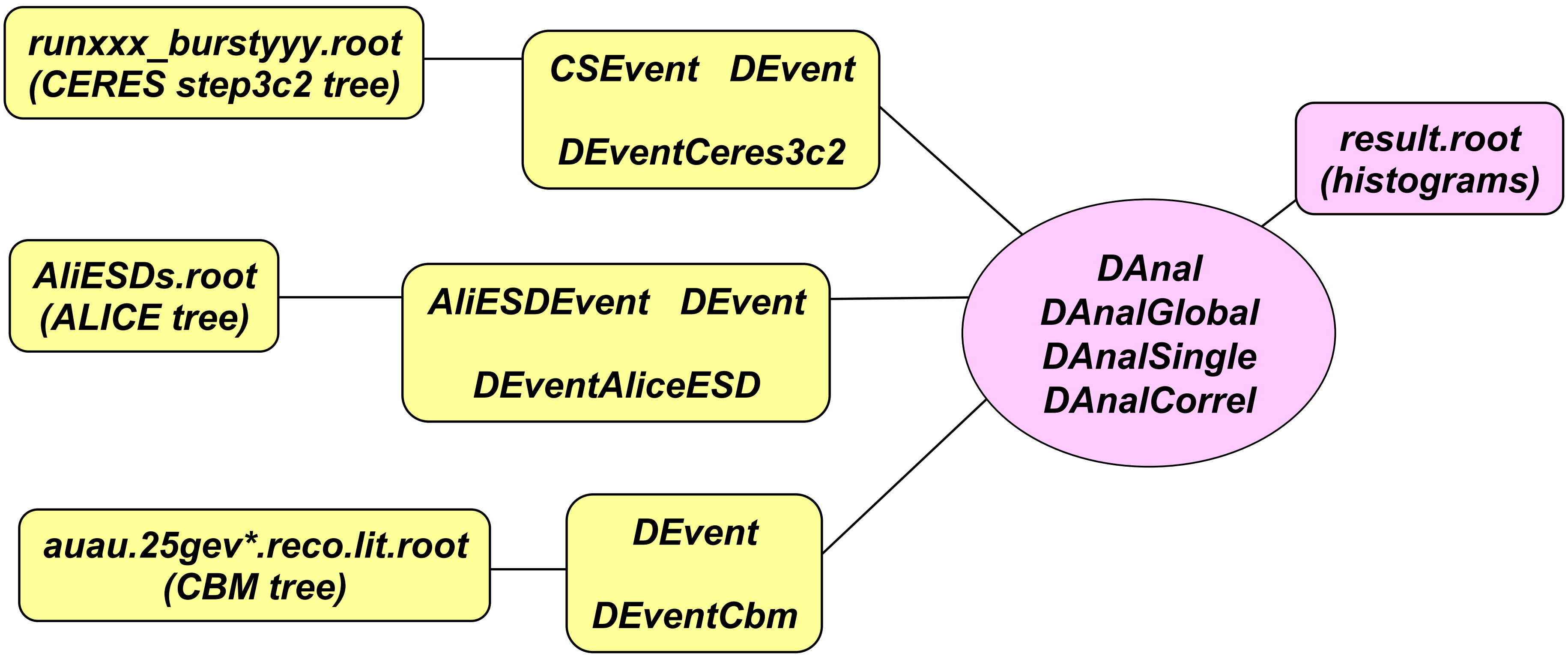
what is special about this analysis

- ***experiment independent***
- ***extensive use of multidimensional histograms***

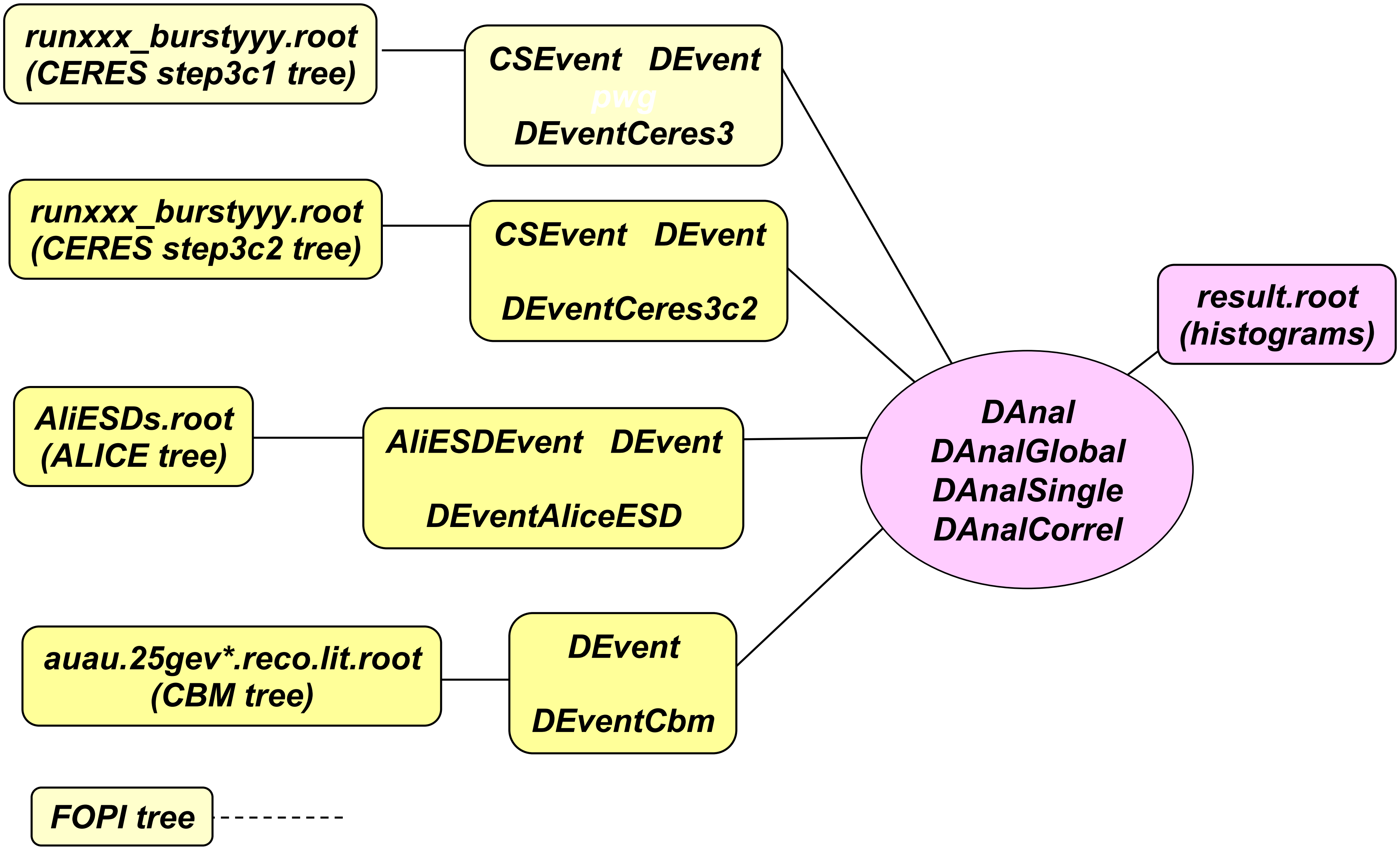
analysis scheme



can at present handle ALICE, CERES, and CBM data

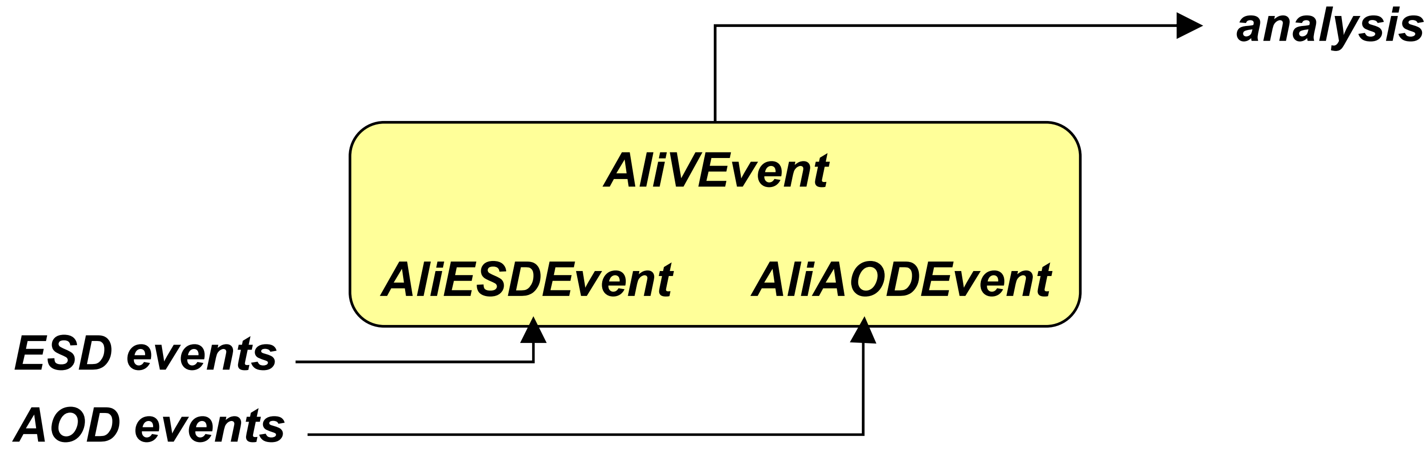


... and can easily be extended to other data



event format independence idea inspired by Alice way handling ESD/AOD

ALICE solution



my solution

DEventAliceESD

my solution

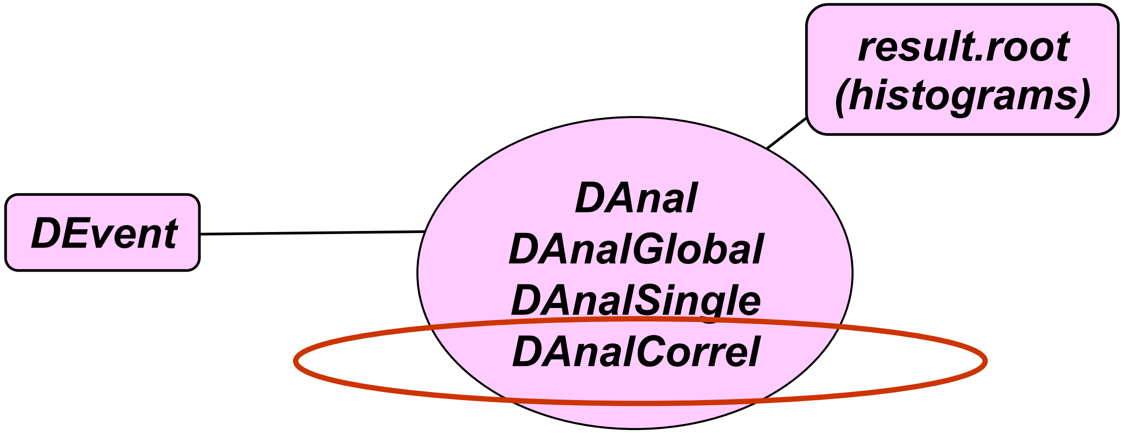

```
class DEventAliceESD : public DEvent, public AliESDEvent {

 public:
                DEventAliceESD();
  virtual      ~DEventAliceESD();
  void          AttachTree(TTree *tr) {ReadFromTree(tr);}
  void          CopyFrom(const AliESDEvent& source); // shallow import of event
  Bool_t        Good() const;
  Double_t      Centrality() {return 0.9999*exp(-NParticles()/20.0);} // OK for pp
  void          RP(Double_t &qx, Double_t &qy) const {qx=0; qy=0;}
  Double_t      Zver() const {return AliESDEvent::GetPrimaryVertex()->GetZv()/5.0;}
  Int_t         NParticles() const {return AliESDEvent::GetNumberOfTracks();}

  Bool_t        ParticleGood(Int_t i, Int_t pidi) const;
  Int_t         ParticleSign(Int_t i) const {return 1; // to be fixed}
  Double_t      ParticleP(Int_t i)     const {return AliESDEvent::GetTrack(i)->GetConstrainedParam()->P();}
  Double_t      ParticlePhi(Int_t i)   const {return AliESDEvent::GetTrack(i)->GetConstrainedParam()->Phi();}
  Double_t      ParticleTheta(Int_t i) const {return AliESDEvent::GetTrack(i)->GetConstrainedParam()->Theta();}

  ClassDef(DEventAliceESD,0)
```

analysis part



DAnalCorrel.h

```
class DAnalCorrel : public DAnal {

 public:
  DAnalCorrel(Char_t *nam="correl", Int_t pid0=0, Int_t pid1=0);  // constructor
  virtual ~DAnalCorrel();                                          // destructor
  // process one (tru) or two (mix) events
  void Process(Int_t tmr, DEvent *ev0, DEvent *ev1, Double_t phirot);

 protected:
  Int_t    fPid0;                          // particle species 0
  Int_t    fPid1;                          // particle species 1
  Double_t fMass0;                         // mass 0
  Double_t fMass1;                         // mass 1
  DPair    fPa;                            // pair buffer for calculations
  DHN*     fPair;                          // pair multi-histogram
  void     Fill(Int_t flag, Double_t cent, Double_t rpphi, DPair *pa);
                                           // fill pair histograms
  ClassDef(DAnalCorrel,1)
```

8-dimensional histogram

8-dimensional pair histogram creation

```
TAxis *ax[8];
ax[0] = new TAxis(3,-0.5,2.5);ax[0]->SetTitle("trumixrot");
ax[1] = new TAxis(5,0,0.5);    ax[1]->SetTitle("centrality");
ax[2] = new TAxis(4,2,3);      ax[2]->SetTitle("pair y");
ax[3] = new TAxis(8,-pi,pi);   ax[3]->SetTitle("pair phi"); // wrt event plane
double a0[]={0,0.1,0.2,0.3,0.5,1.0};
ax[4] = new TAxis(5,a0);       ax[4]->SetTitle("(pair pt)/2 (GeV)");
ax[5] = new TAxis(8,0,pi);     ax[5]->SetTitle("q-theta");
ax[6] = new TAxis(16,-pi,pi);  ax[6]->SetTitle("q-phi");
double a1[100];
for (int i=0;i<20;i++) a1[i]=i*0.005;
for (int i=0;i<45;i++) a1[20+i]=0.1+i*0.02;
ax[7] = new TAxis(64,a1);      ax[7]->SetTitle("q (GeV/c)");
fPair = new DHN("pair",8,ax);
for (int i=0; i<8; i++) delete ax[i];
fHistos.Add(fPair);
```

P. Danielewicz's dream: two-particle tensor!
Complete info, like pair ntuple -- but binned.

19660800 bins, 150 MB. Too big?

for comparison: traditional way of histogramming

```
for (fl=0; fl<2; fl++) {
for (pp=0; pp<5; pp++) {
for (th=0; th<3; th++) {
for (ph=0; ph<1; ph++) {
  sprintf(myst,"%s%d%d%d%s%s_%s",trmi[fl],pp,th,ph,pnam[i0],pnam[i1],"qinv");
  h1[fl][pp][th][ph][i0][i1][0] =  new TH1D(myst,myst,500,0,5);
  sprintf(myst,"%s%d%d%d%s%s_%s",trmi[fl],pp,th,ph,pnam[i0],pnam[i1],"minv");
  h1[fl][pp][th][ph][i0][i1][1] =  new TH1D(myst,myst,500,0,5);
  sprintf(myst,"%s%d%d%d%s%s_%s",trmi[fl],pp,th,ph,pnam[i0],pnam[i1],"dtheta:dphi");
  h2[fl][pp][th][ph][i0][i1][0] =  new TH2D(myst,myst,50,-250,250,50,-50,50);
  sprintf(myst,"%s%d%d%d%s%s_%s",trmi[fl],pp,th,ph,pnam[i0],pnam[i1],"qper:qpar");
  h2[fl][pp][th][ph][i0][i1][1] =  new TH2D(myst,myst,20,0.0,0.2,40,-0.2,0.2);
  sprintf(myst,"%s%d%d%d%s%s_%s",trmi[fl],pp,th,ph,pnam[i0],pnam[i1],"qout:qside:qlong");
  h3[fl][pp][th][ph][i0][i1][0] =  new TH3D(myst,myst,30,-0.15,0.15,30,-0.15,0.15,30,-0.15,0.15);
}
}
}
}
```

array of histograms, same size, less convenient handling

some results

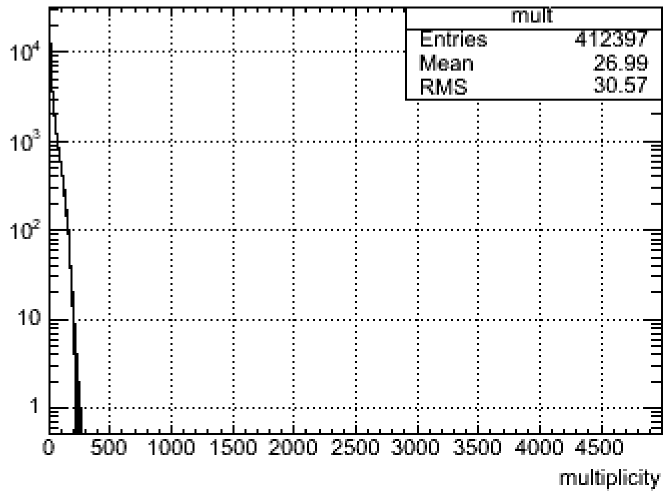
caution:

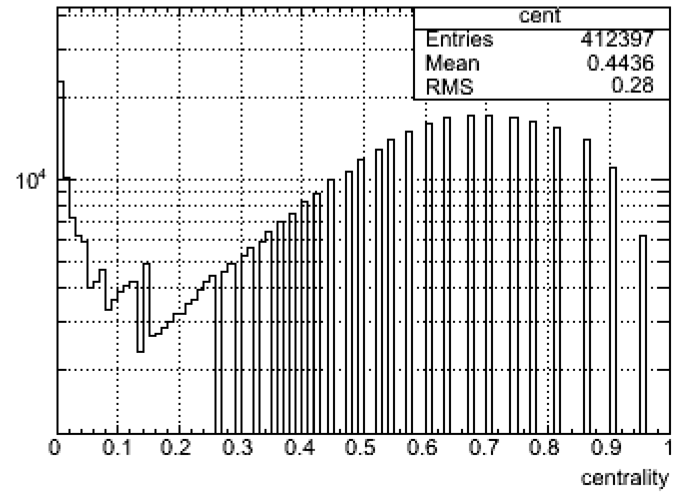
- *no particle identification*
- *no two-track cut*
- *low statistics: ceres 24k (out of 30M Pb+Au data)*

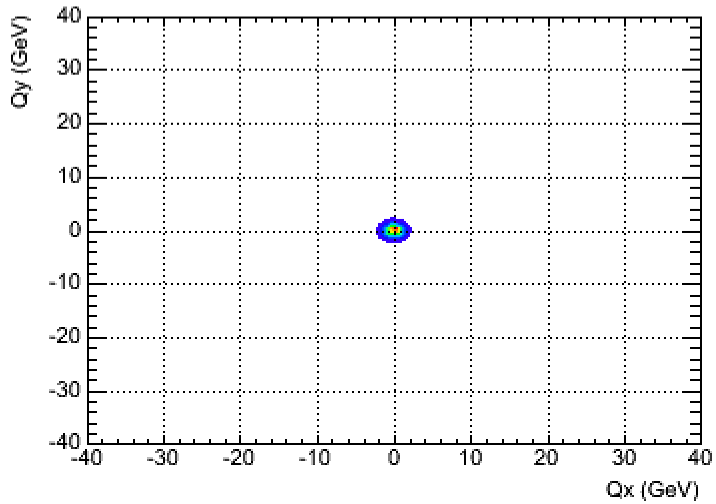
  alice 400k (Silvia Masciocchi's p+p simulation)

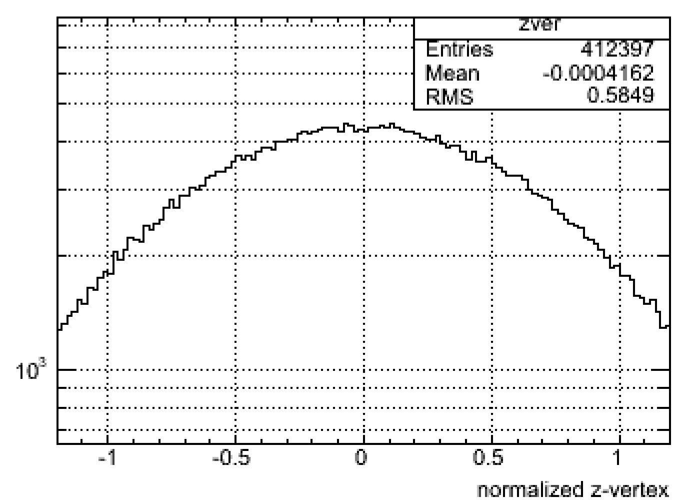
  cbm 44k (simulated central Au+Au at 25 A GeV)

ALICE global variables

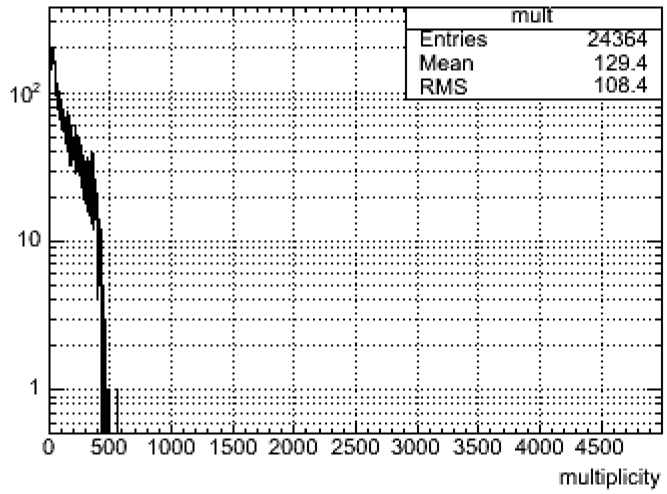


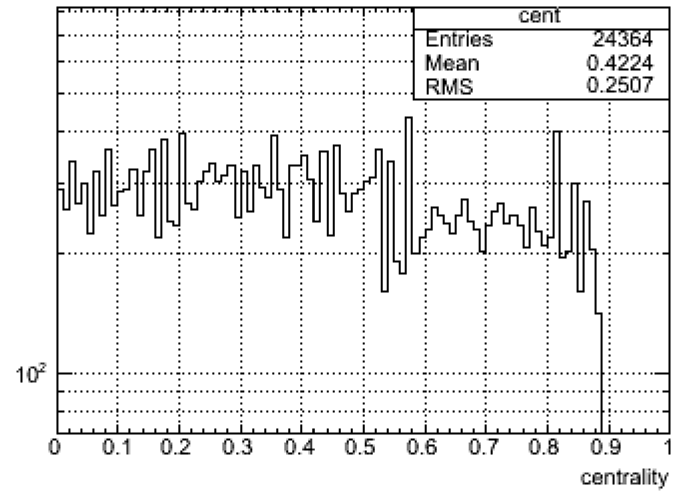


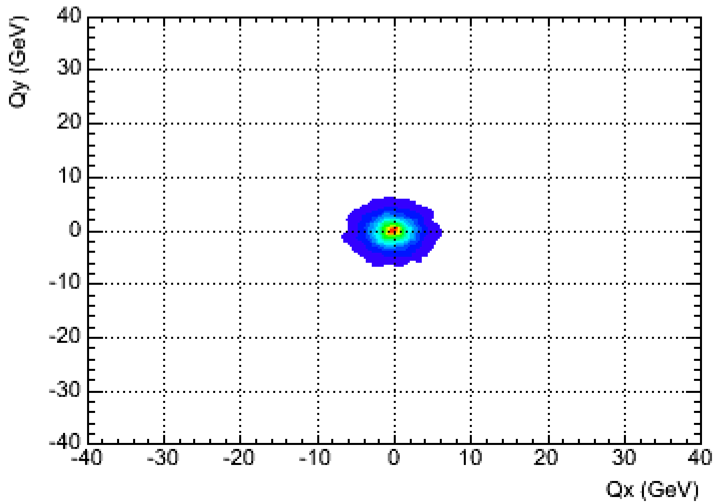


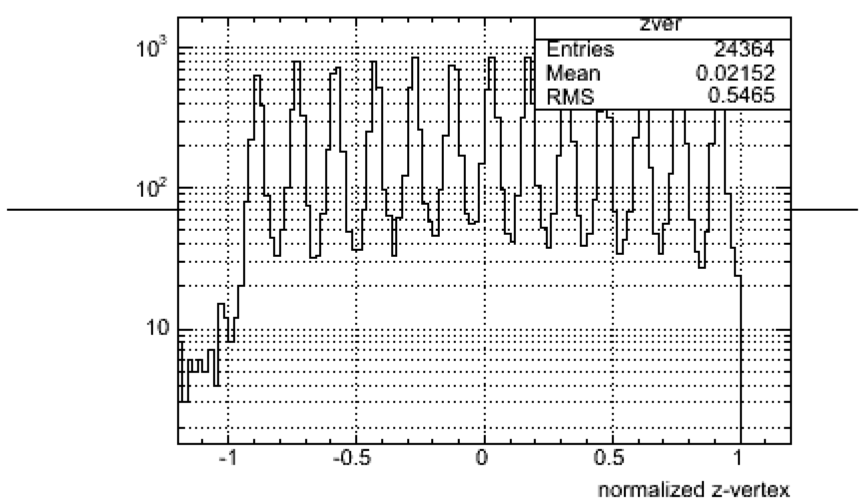


CERES global variables

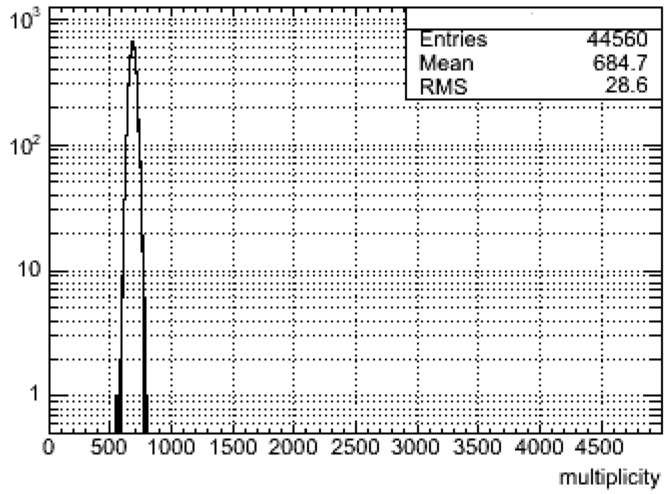


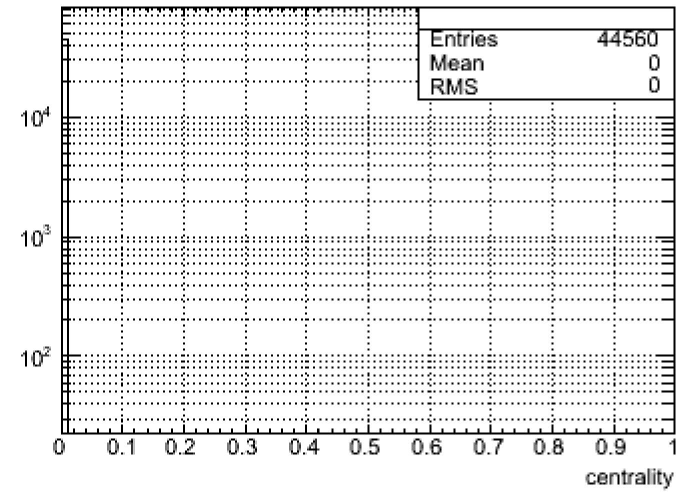


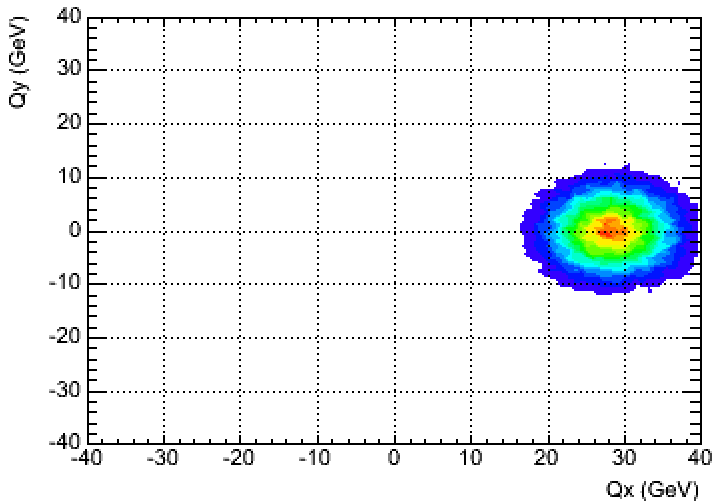


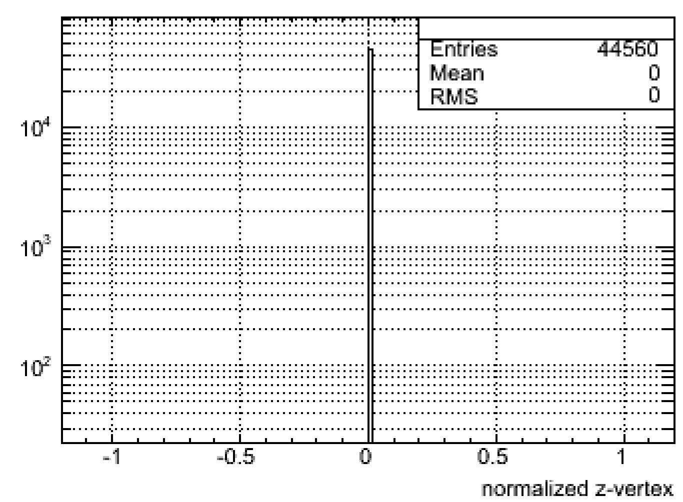


CBM global variables

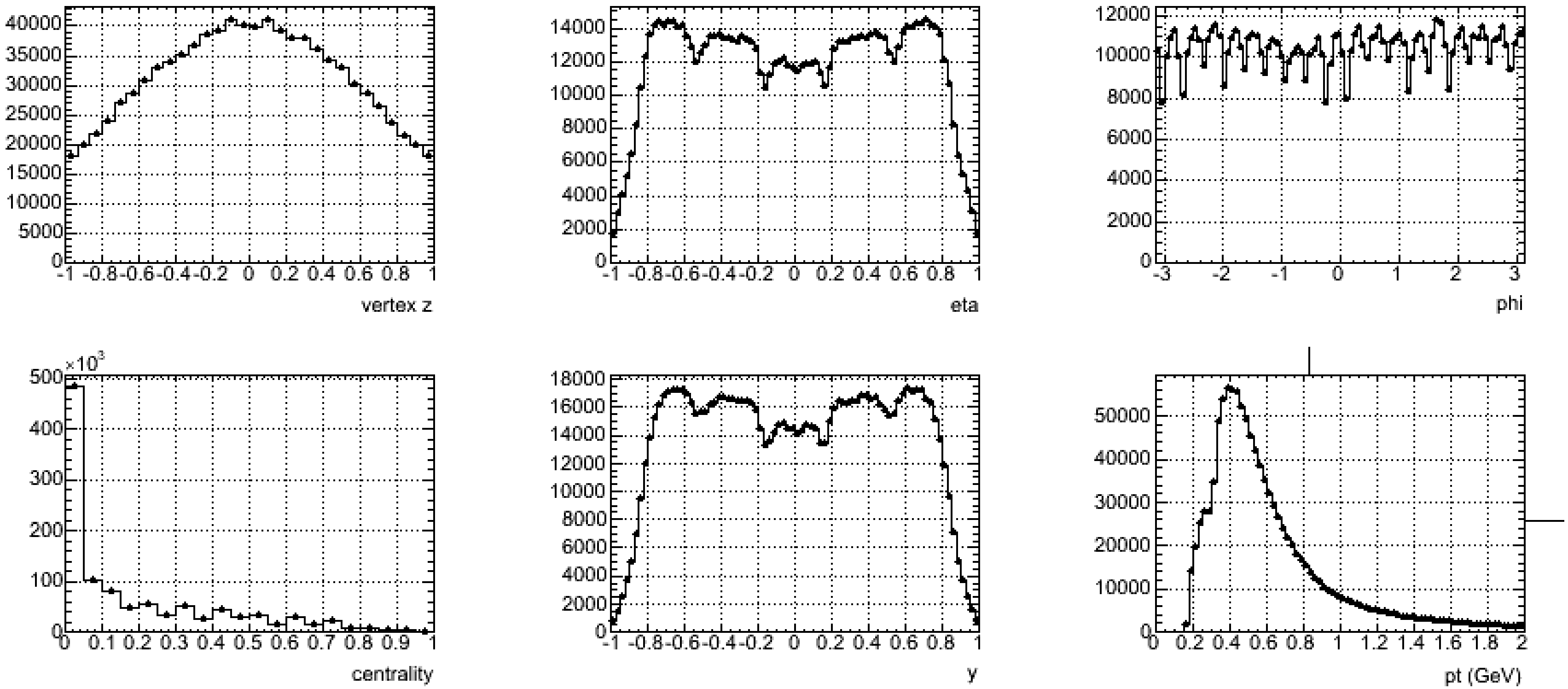




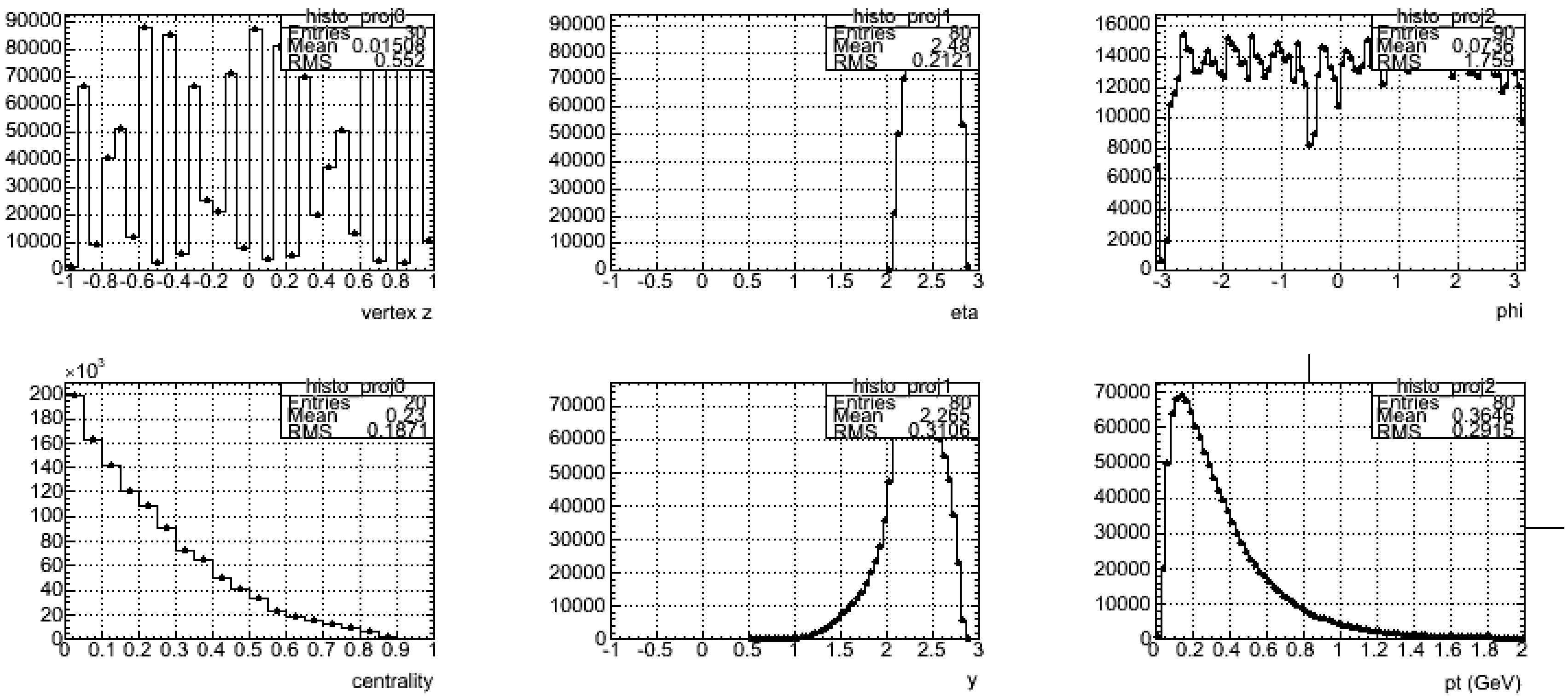




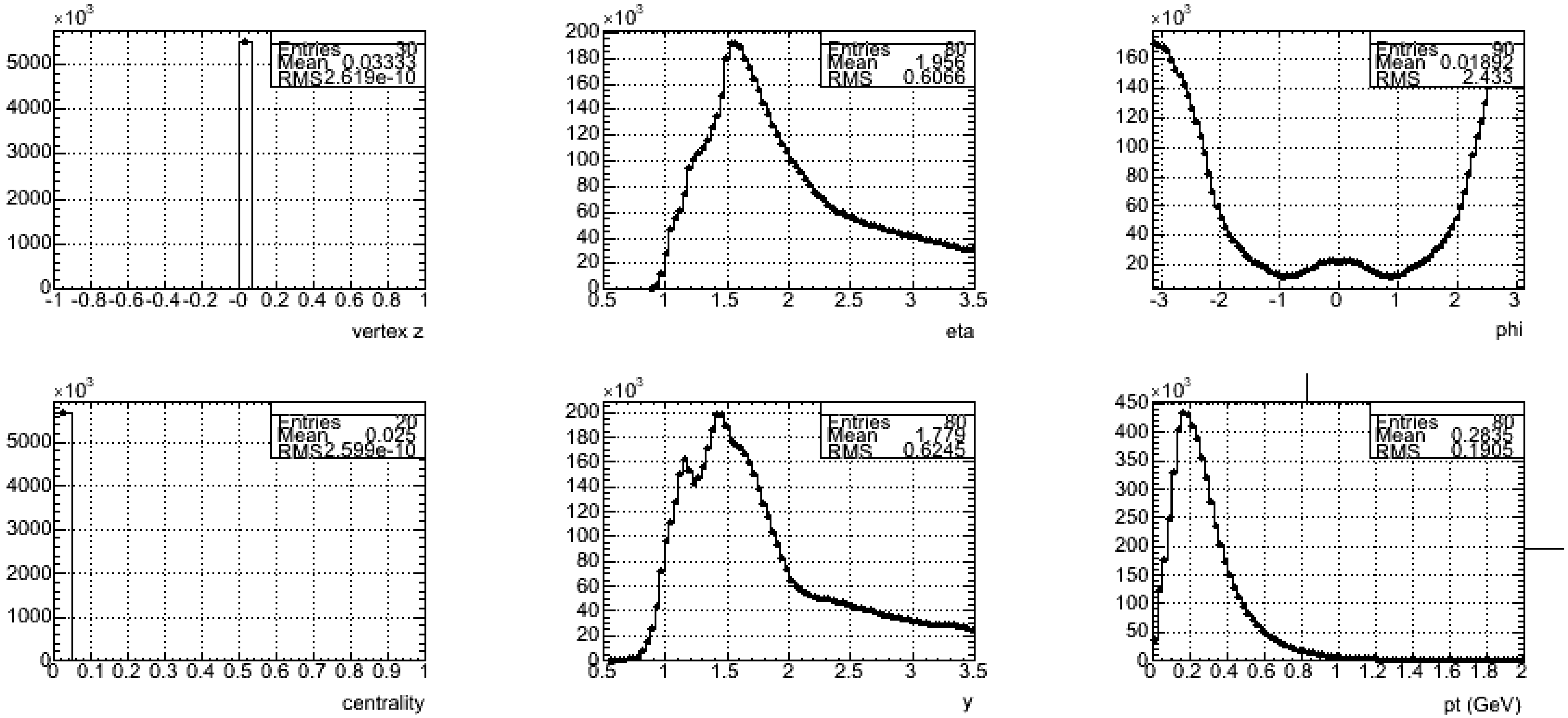
ALICE singles



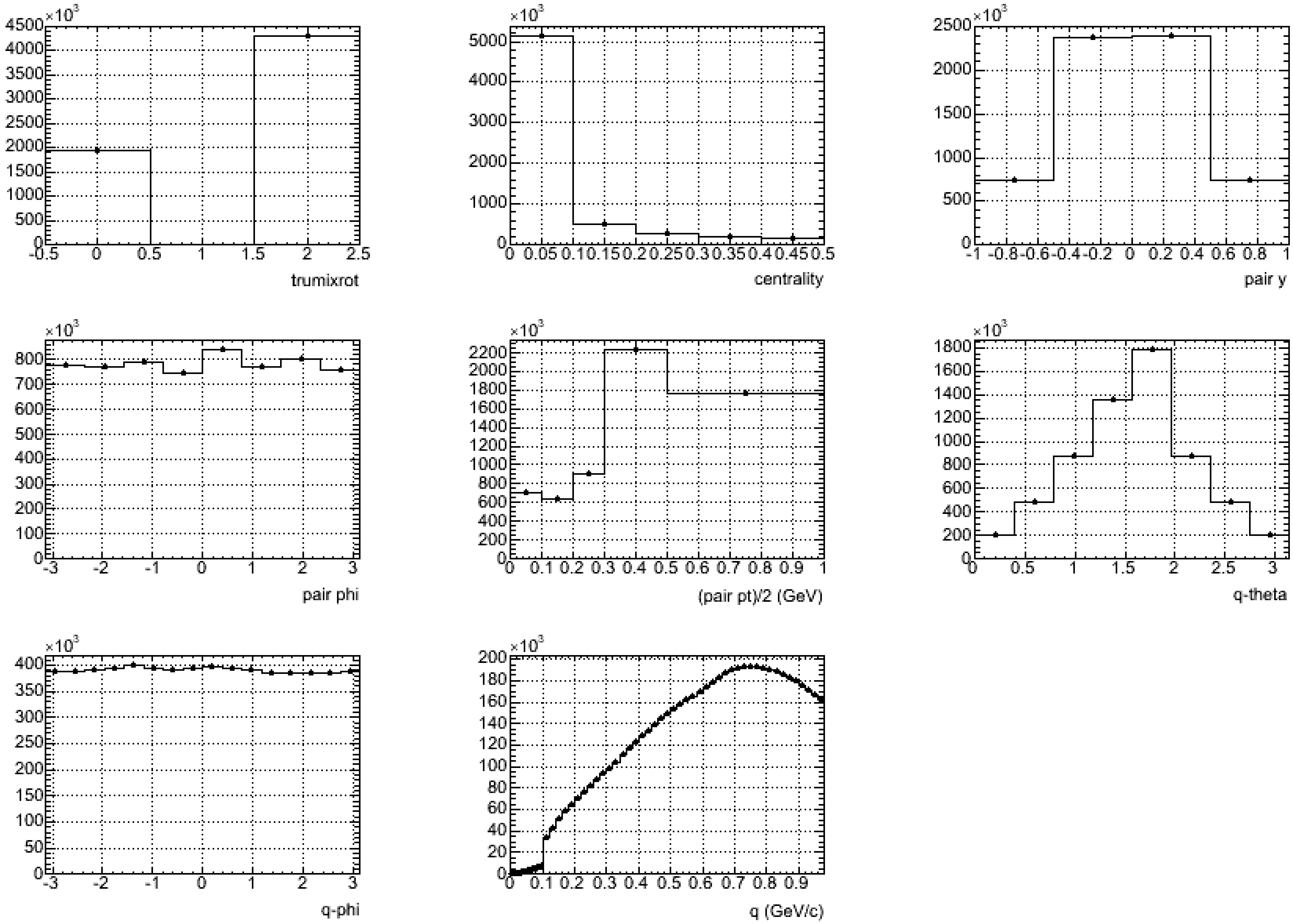
CERES singles



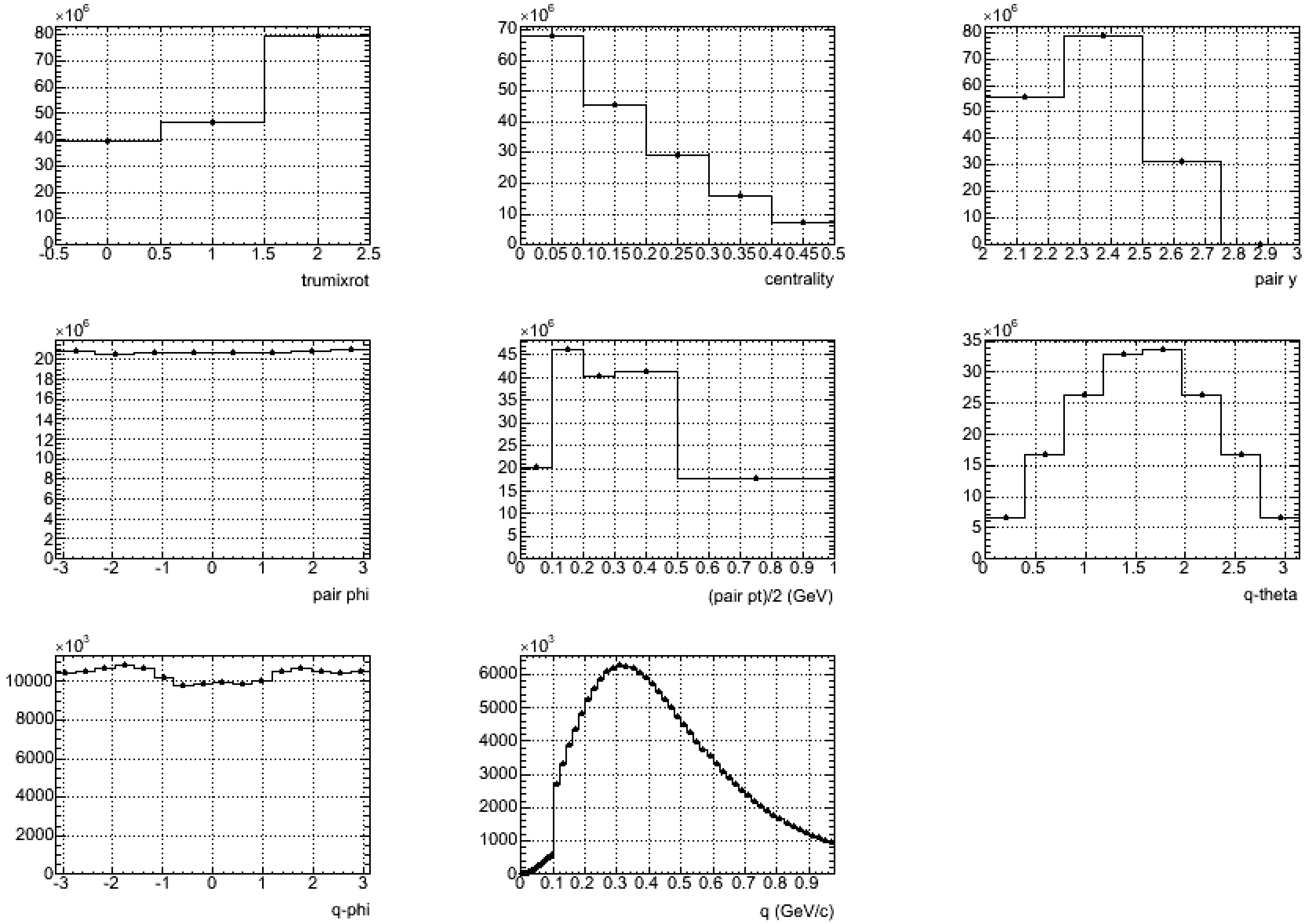
CBM singles


Entries 30
Mean 0.03333
RMS2.619e-10
vertex z
Entries 80
Mean 1.956
RMS 0.6066
eta
Entries 90
Mean 0.01892
RMS 2.433
phi
Entries 20
Mean 0.025
RMS2.599e-10
centrality
Entries 80
Mean 1.779
RMS 0.6245
y
Entries 80
Mean 0.2835
RMS 0.1905
pt (GeV)

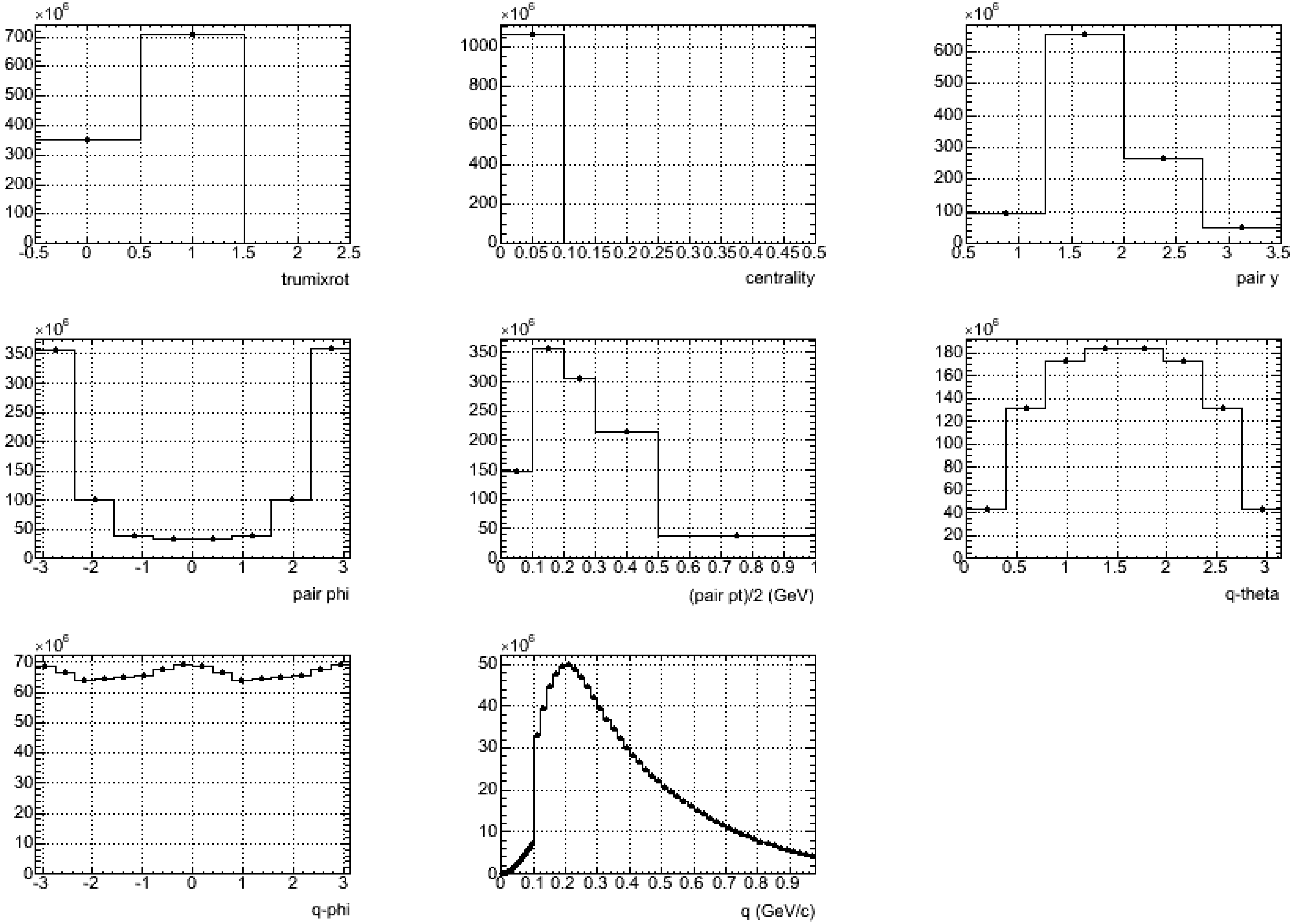
ALICE correlations (projections)



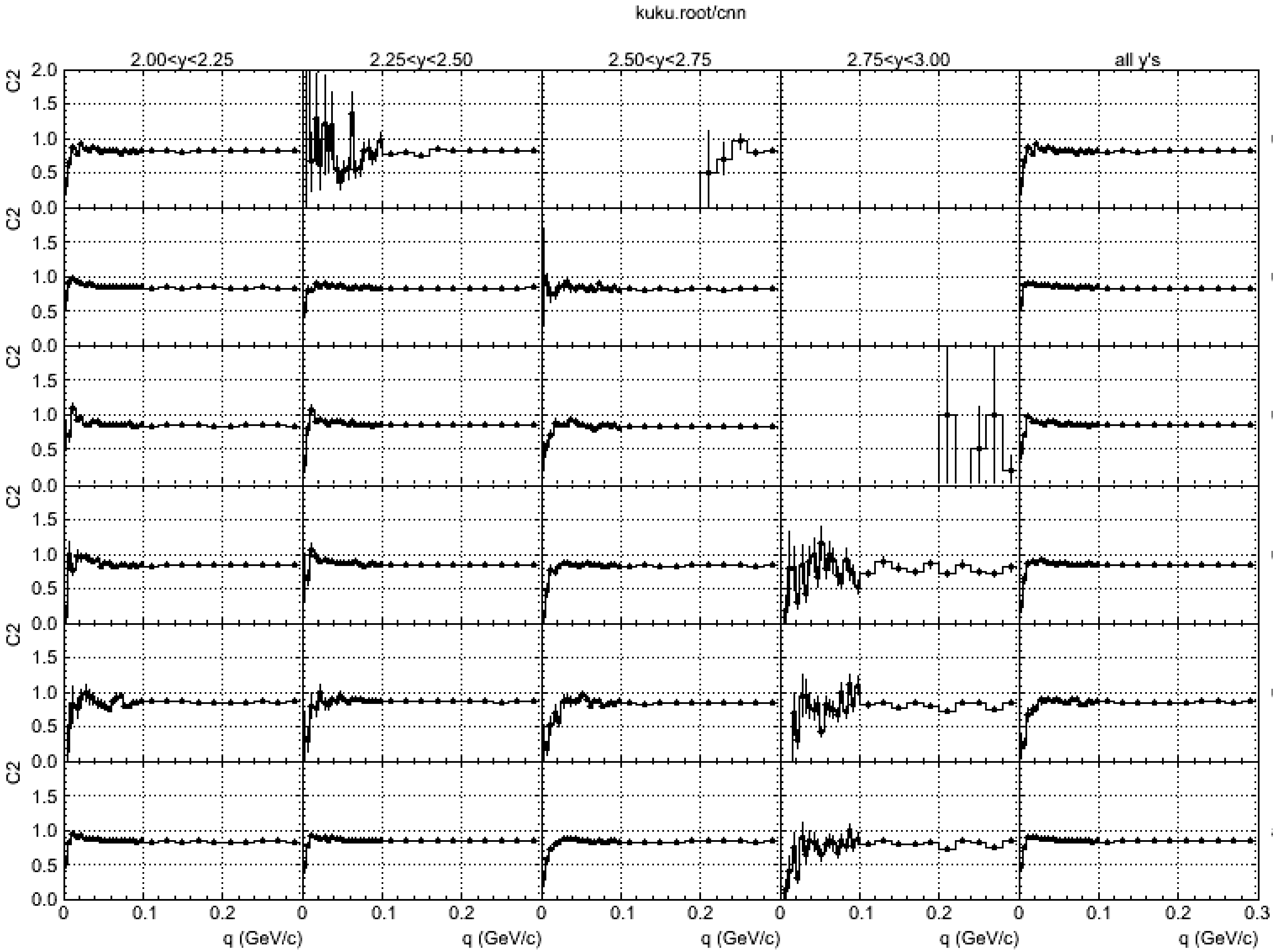
CERES correlations (projections)



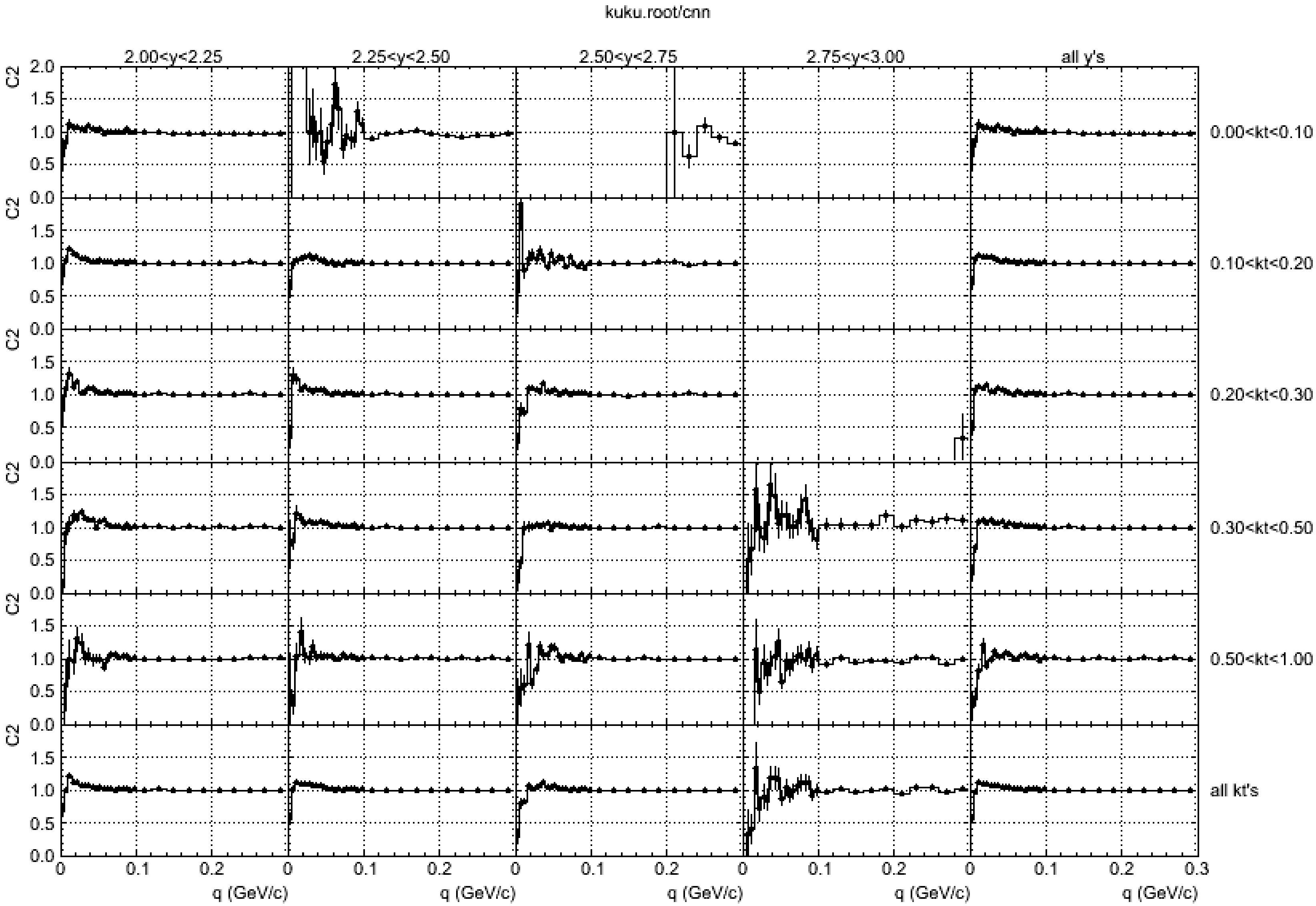
CBM correlations (projections)



CERES correlations (denominator by event mixing)

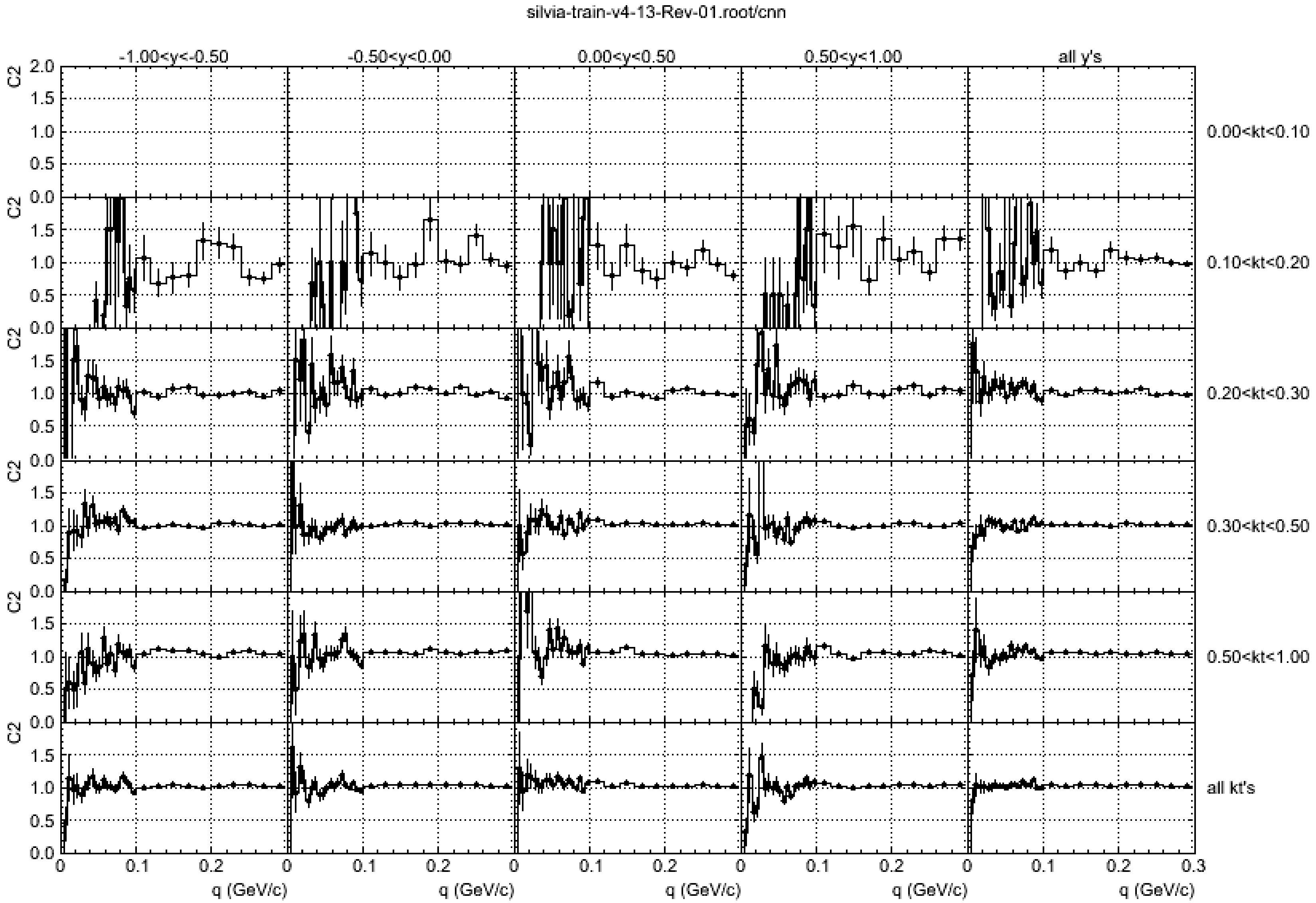


CERES correlations (denominator by rotating)

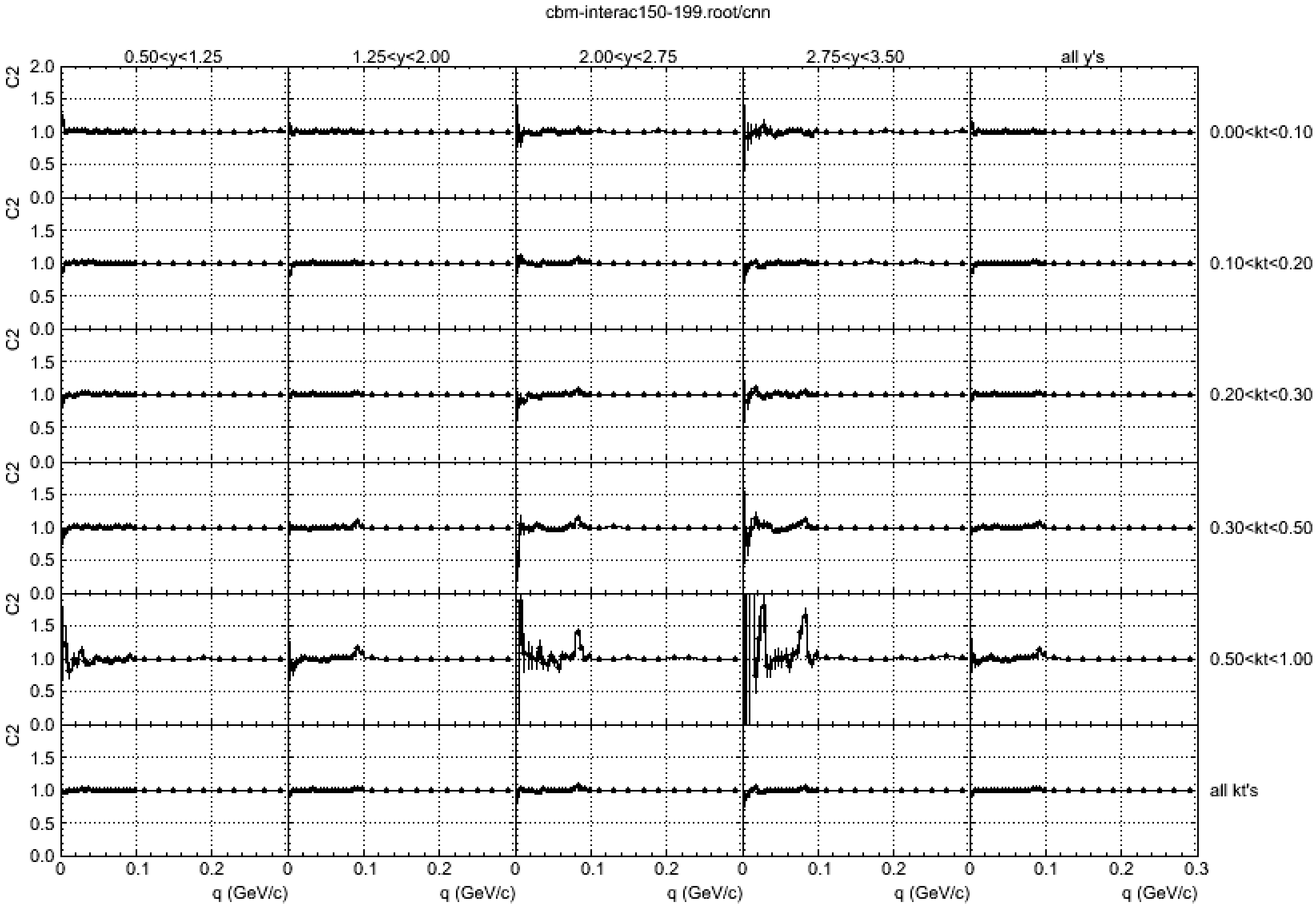


ALICE correlations (denominator by rotating)

(1.2 M event, actually)



CBM correlations (denominator by event mixing)



summary: main features of this analysis

- ***experiment independence → easy comparison***
- ***multidimensional histograms → efficient storage of results***
- ***simplicity → easy debugging, good for quick start***

what I like most in this analysis: it is short

- analysis part:	1397 lines of code
- ceres3c2 interface:	143 lines of code
- alice ESD interface:	99 lines of code
+ analysis task	130 lines of code
- cbm interface:	131 lines of code
--	
	1900 lines of code

backup

pair loop and histogramming in DAnalCorrel

```
// loop over pairs

for (int i=0; i<ev0->NParticles(); i++) {
  if (!ev0->ParticleGood(i,fPid0)) continue;
  for (int j=0; j<ev1->NParticles(); j++) {
    if (ev0==ev1 && phirot==0 && j==i) continue;
    if (ev0==ev1 && phirot==0 && j<i && fPid0==fPid1 ) continue;
    if (!ev1->ParticleGood(j,fPid1)) continue;
    fPa.Set0(fMass0,ev0->ParticleP(i),ev0->ParticleTheta(i),ev0->ParticlePhi(i));
    fPa.Set1(fMass1,ev1->ParticleP(j),ev1->ParticleTheta(j),ev1->ParticlePhi(j)+phirot);
    if (ev0==ev1 && phirot==0 && fPid0==fPid1 && ran.Rndm()>=0.5) fPa.Swap();
    fPa.CalcLAB();
    fPa.bbeta = fPa.beta; // CM will mean pair c.m.s.
    fPa.CalcCM();
    double phi = TVector2::Phi_mpi_pi(fPa->p.Phi()-rpphi);
    fPair->Fill(flag,                   // 0 for tru, 1 for mix, 2 for rot
            cent,                       // centrality
            fPa->p.Rapidity(),          // pair rapidity
            phi,                        // pair phi wrt reaction plane
            fPa->p.Pt()/2.0,            // half of pair pt
            fPa->QCMTheta(),            // polar angle of Q
            fPa->QCMPhi(),              // azimuthal angle of Q
            fPa->QCM(),                 // |p2-p1| in c.m.s.
            1.0);                       // weigth
  }
}
```

multidimensional histogram class DHN

424 lines of code

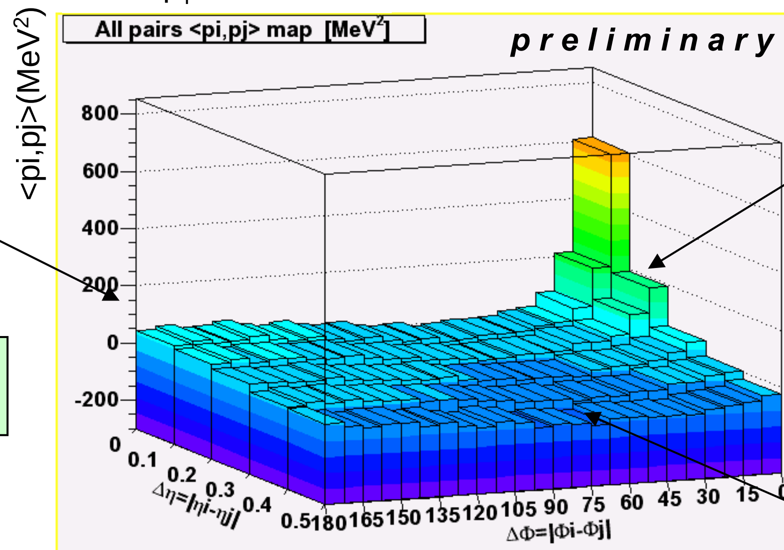
```
class DHN : public TH1D {

 public:

  DHN();                                          // default constructor
  DHN(Char_t *nam, Int_t ndim, TAxis **ax);  // constructor from scratch
  DHN(Char_t *filename, Char_t *name);        // constructor from file
  virtual ~DHN();                                 // destructor
  Int_t GetNdim()                                 {return fNdim;}
  TAxis *GetAxis(Int_t i)                        {return &fAxis[i];}
  void Fill(Double_t *xx, Double_t y=1);     // fill histo
  void Fill(Double_t x0=0, Double_t x1=0,
            Double_t x2=0, Double_t x3=0,
            Double_t x4=0, Double_t x5=0,
            Double_t x6=0, Double_t x7=0,
            Double_t x8=0, Double_t x9=0,
            Double_t x10=0) {                   // fill histo; fNdim-th arg is weight
    Double_t xx[fMaxNdim+1] = {x0,x1,x2,x3,x4,x5,x6,x7,x8,x9,x10};
    Fill(xx,xx[fNdim]);}
  Int_t Write();                                  // save histo and axis on file
  Int_t Write(const char *, Int_t, Int_t)    {return Write();}
  // project along (integrate over) one axis
  DHN  *ProjectAlong(char *nam, Int_t dim, Int_t first=-1, Int_t last=-1);
  // project on 1-dim histogram
  TH1D *ProjectOn(char *nam, Int_t dim, Int_t *first=0, Int_t *last=0);
  // project on 1-dim histogram
  TH1D *ProjectOn(char *nam, Int_t dim, Double_t *first, Double_t *last);
  // project on 2-dim histogram
  TH2D *ProjectOn(char *nam, Int_t dim0, Int_t dim1, Int_t *first=0, Int_t *last=0);
```

pt fluctuation intro, CERES data

$0.1 < p_T < 1.5$ GeV/c



away-side correlations

elliptic flow, jets?

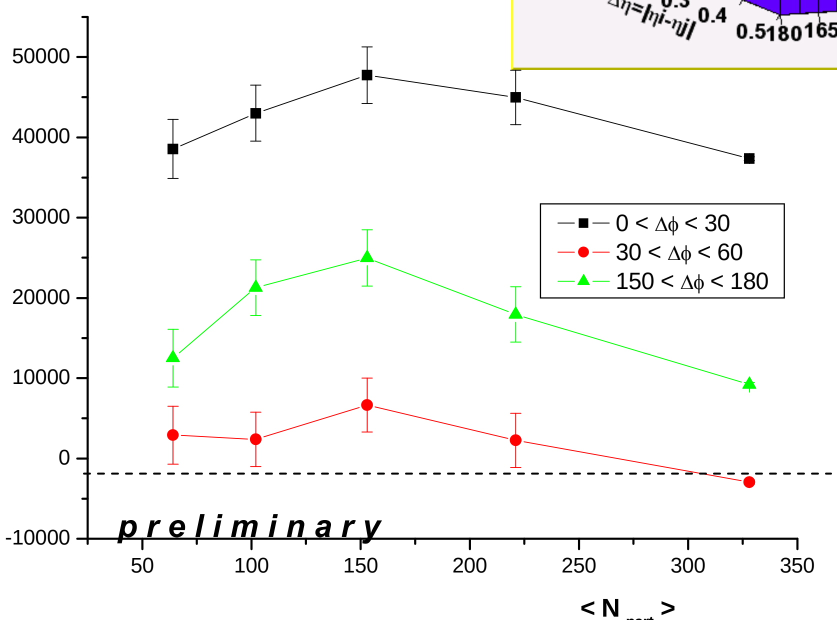
short range correlations

confined to Q_{INV}<70 MeV
narrower and weaker for unlike pairs → HBT and Coulomb?

rich structure → averaging over Δφ and Δη is not good

decline with Δη

reproduced with event mixing
trivial effect of pt(η) dependence?



short range and away-side correlation produce the observed centrality dependence

region around Δφ = 45º is not affected by the elliptic flow, HBT, Coulomb, jets
→ look here for the critical point

CBM pt-fluctuations