MC Generators in LHCb

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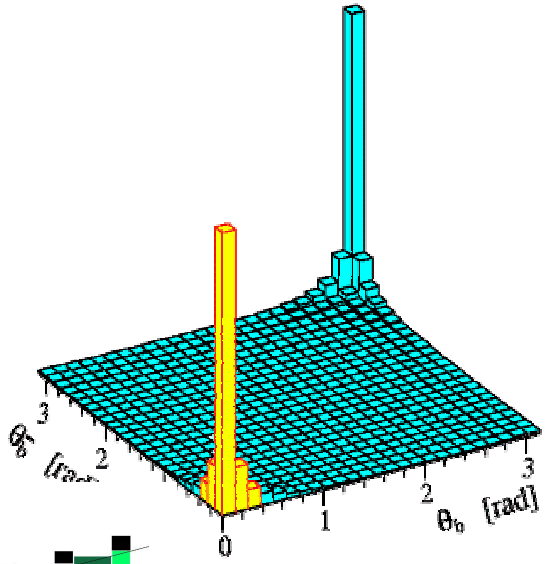
Introduction

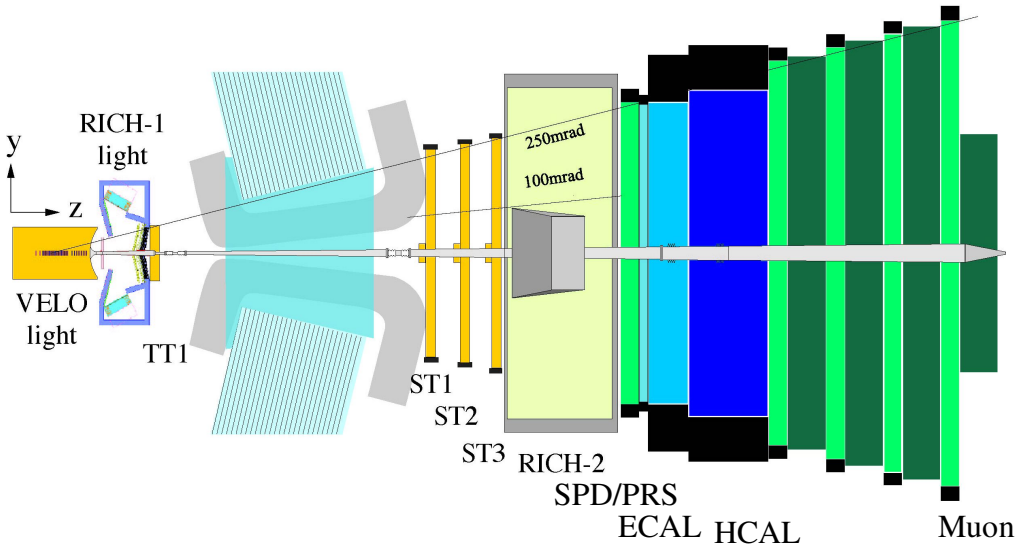
- Use of *Decay Packages in LHCb*:
  - ***The LHCb Experiment***
  - ***Simulation in LHCb***
  - ***Work with EvtGen***
  - ***Open Questions***

The LHCb Experiment

- Use of the **large sample of *B* hadrons** (B^0, B^+, B_s^0, B_c^+, Λ_b,…) produced at the LHC
- Precise measurements of the ***CP* violation parameters** (CKM angles)
- *B* hadrons produced mostly at small angles, by pairs in the same direction (Possibility of tagging)
- **LHCb** : single forward spectrometer.

$b\bar{b}$ angular production

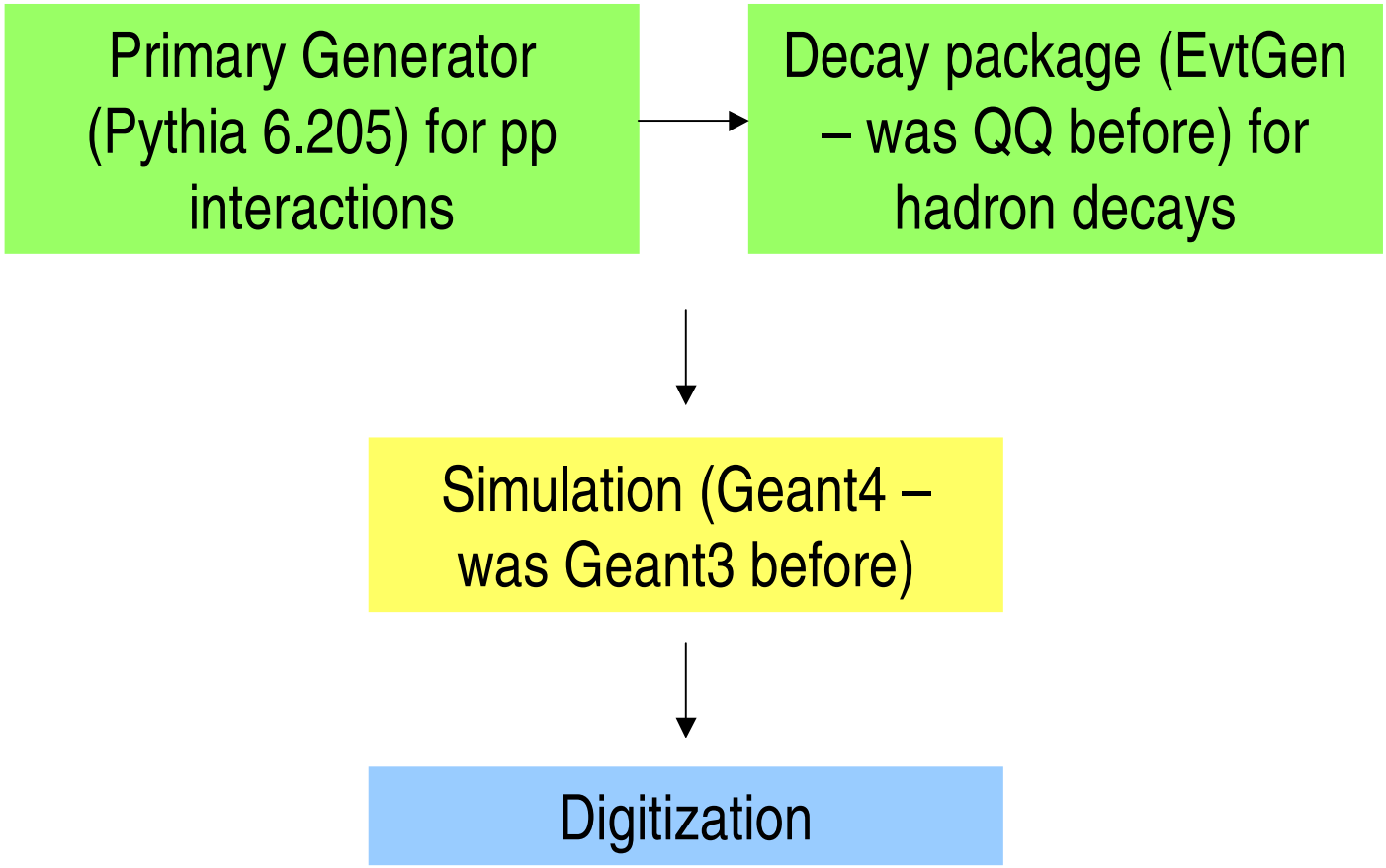




Generator Requirements

- Because of the LHCb physics program :
  - **Detailed and precise description of the decays of *B* hadrons**, for a very large number of decay modes
  - Simulation of **mixing in B_d^0 and B_s^0** meson systems
  - Possibility of simulation of direct and time-dependant ***CP* violation**

Simulation Sequence (1)



Simulation Sequence (2)

- **Each sequence** (Generation, Simulation, Digitization) is independent and **can be run separately**
- **Each sequence** outputs its results as **objects in a ROOT file** (Hits, Tracks, MCTruth,…)
  - The output of the Generation sequence is **HepMC**

Generation Sequence

- **Pythia** generates the production of particles up to the particles declared as stable
- **EvtGen** takes care of the decay of the stable particles
- The decay tree is sent to **Geant4** with particles marked as "*forced decays*"

B production (1)

PYTHIA:

- CTEQ4L structure functions
- multiple interactions assuming varying impact parameter with a Gaussian matter distribution (mstp(82)=3)
- both min-bias and signal event generated with msel=2
  - forced fragmentation to generate particular b-hadrons
  - signal events extracted from min-bias events
  - is there a better way???
- Need for HERWIG

B Production (2)

- The *B* hadron is decayed according to a User signal decay file (or to a generic decay file for the other *B* hadron or for generic events)
- Use of the **random number generator** available from the underlying framework (**Gaudi**) to all pieces of the simulation sequence
- **EvtGen** interfaced "by hand" to **HepMC** :

Interface to HepMC

```
if(part->getNDaug()!=0)
   {
     double ct=(part->getDaug(0)->get4Pos()).get(0);
     double x=(part->getDaug(0)->get4Pos()).get(1);
     double y=(part->getDaug(0)->get4Pos()).get(2);
     double z=(part->getDaug(0)->get4Pos()).get(3);

     HepMC::GenVertex* end_vtx =
       new HepMC::GenVertex(HepLorentzVector(x,y,z,ct));
     hEvt->add_vertex( end_vtx );
     end_vtx->add_particle_in(hPart);

     int ndaug=part->getNDaug();

     for(int it=0;it<ndaug;it++)
       {

         double e=(part->getDaug(it)->getP4Lab()).get(0);
         double px=(part->getDaug(it)->getP4Lab()).get(1);
         double py=(part->getDaug(it)->getP4Lab()).get(2);
         double pz=(part->getDaug(it)->getP4Lab()).get(3);
         int id=EvtPDL::getStdHep(part->getDaug(it)->getId());
         int status=999;

         HepMC::GenParticle* prod_part = new
           HepMC::GenParticle(HepLorentzVector(px,py,pz,e),id,status);

         end_vtx->add_particle_out(prod_part);

         makeHepMC(part->getDaug(it),hEvt,prod_part);

       }
   }
```

Technical work with EvtGen

- Ported EvtGen Windows platform (MS compiler – not Cygwin/gcc) – situation becomes simpler as gcc moves towards ANSI
- Interfaced to PYTHIA 6.2 – work superceeded similar programme of work was ongoing in Belle, D0 etc New release of EvtGen – need to look at adopting
- Part of the PYTHIA 6.2 interface involved consistency of particle properties between EvtGen and PYTHIA

Work with EvtGen

- **Validation of various models** (Comparison with other decay packages : **QQ**)
- Use of **EvtGen** in **sensitivity studies** (Measurement of α with $B^0 \rightarrow \rho\pi$,…)
- In the future, LHCb Monte Carlo production with **EvtGen** as decay package.

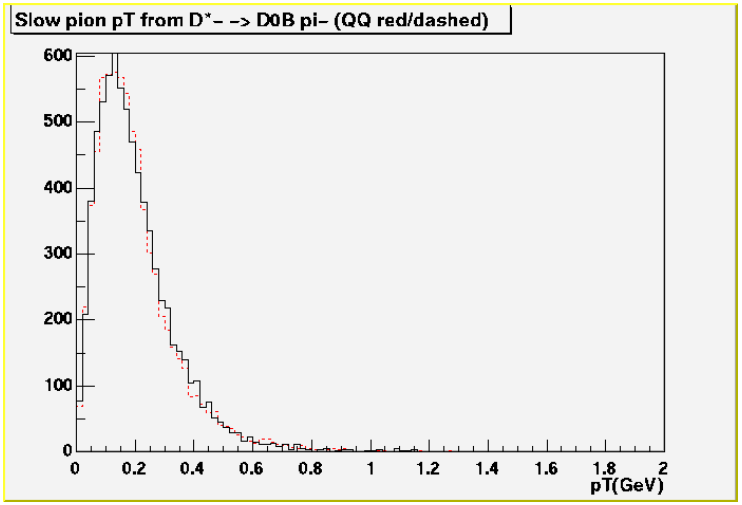
Slow and fast pions in B^0 to $D^{*-}\pi^+$ decay chain

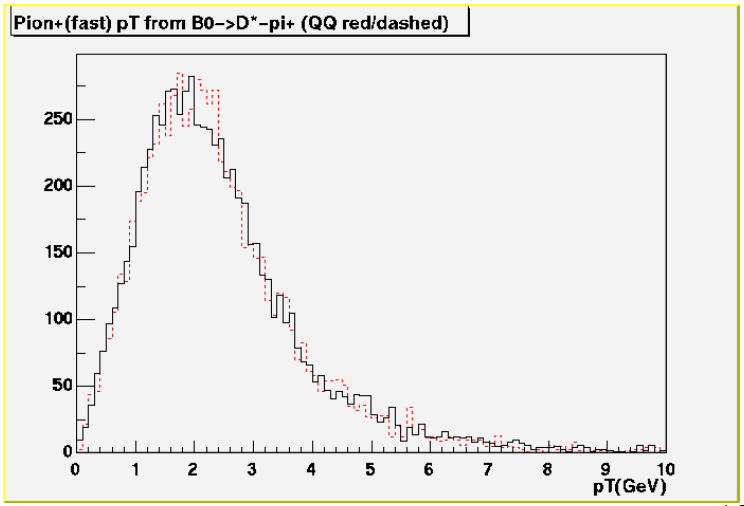
Slow pion from D^{*-} to $D^0B\ \pi^-$

QQ		EvtGen
0.20	(mean)	0.20
0.15	(rms)	0.15

Fast pion from B^0_d to $D^{*-}\ \pi^+$

QQ		EvtGen
2.42	(mean)	2.44
1.40	(rms)	1.45





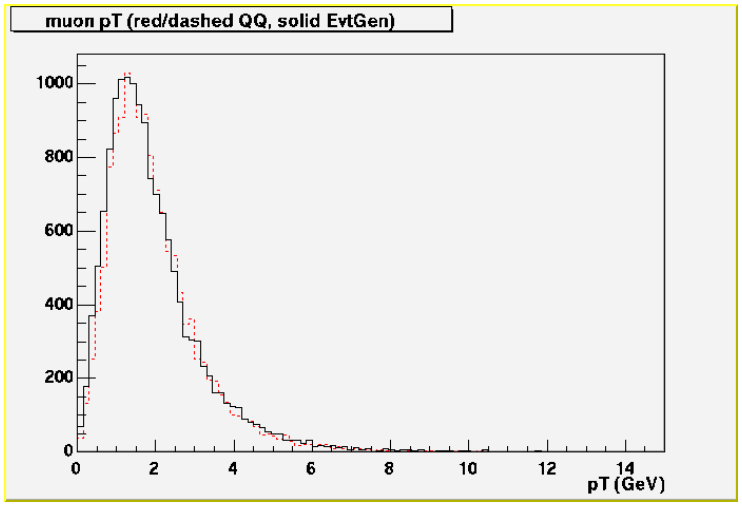
$B \rightarrow J/\Psi K^0_s$: Muon and Pion pT distributions

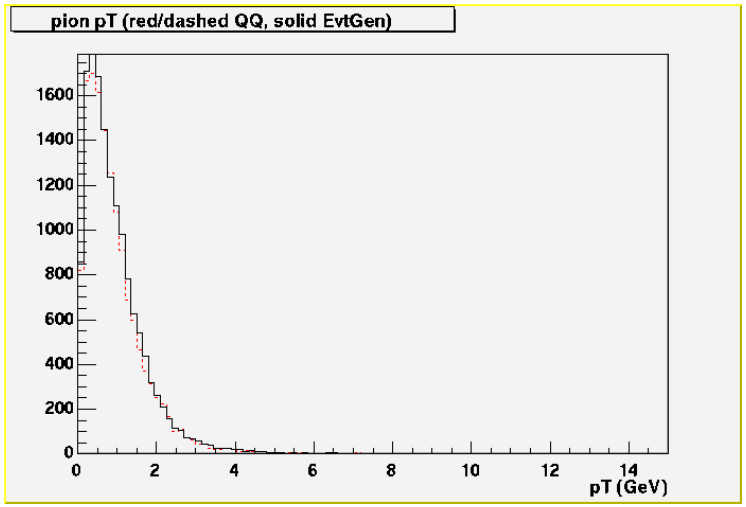
Muon P_T

QQ		EvtGen
1.97	(Mean)	1.93
1.25	(RMS)	1.31

Pion P_T

QQ		EvtGen
0.94	(Mean)	0.95
0.80	(RMS)	0.81



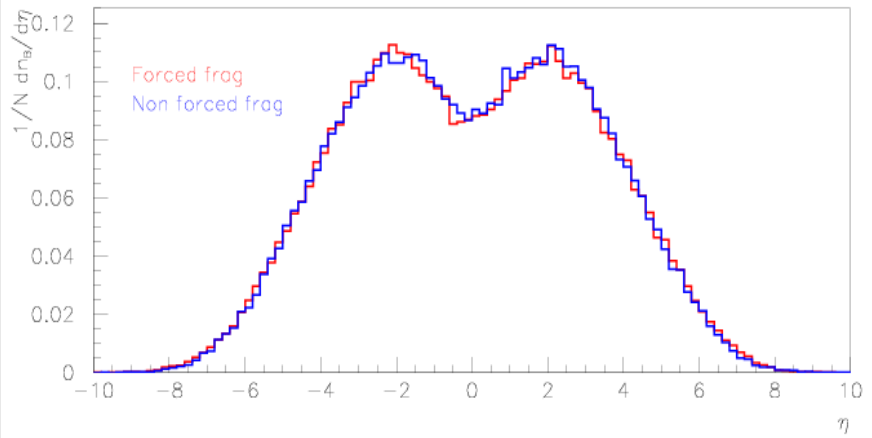
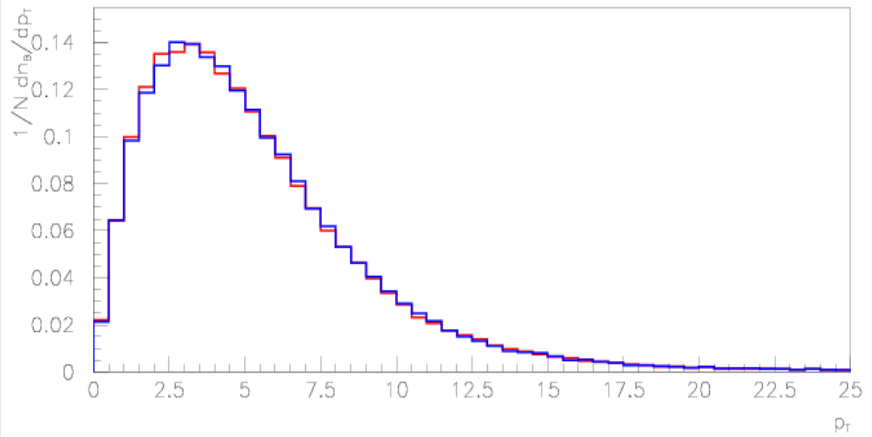


Open Questions

- Best way to implement mixing/CP violation in hadron collider environment ? Mixing in Pythia or in EvtGen ?
- Collaboration with Tevatron for B_s & B_c mesons and B baryons : need for signal and generic decay files.
- Polarisation issues in B production generators : Pythia produces particles without polarisation
- Long term issue of particle properties – use of HepPDT

Conclusions

- **EvtGen integrated** in LHCb software framework.
- Would like **official support** for **EvtGen**.
- Would like **interface to HepMC** inside **EvtGen**.

Pythia - backup

- forced fragmentation mechanism implemented introduces no biases