EvtGen Status/Plans

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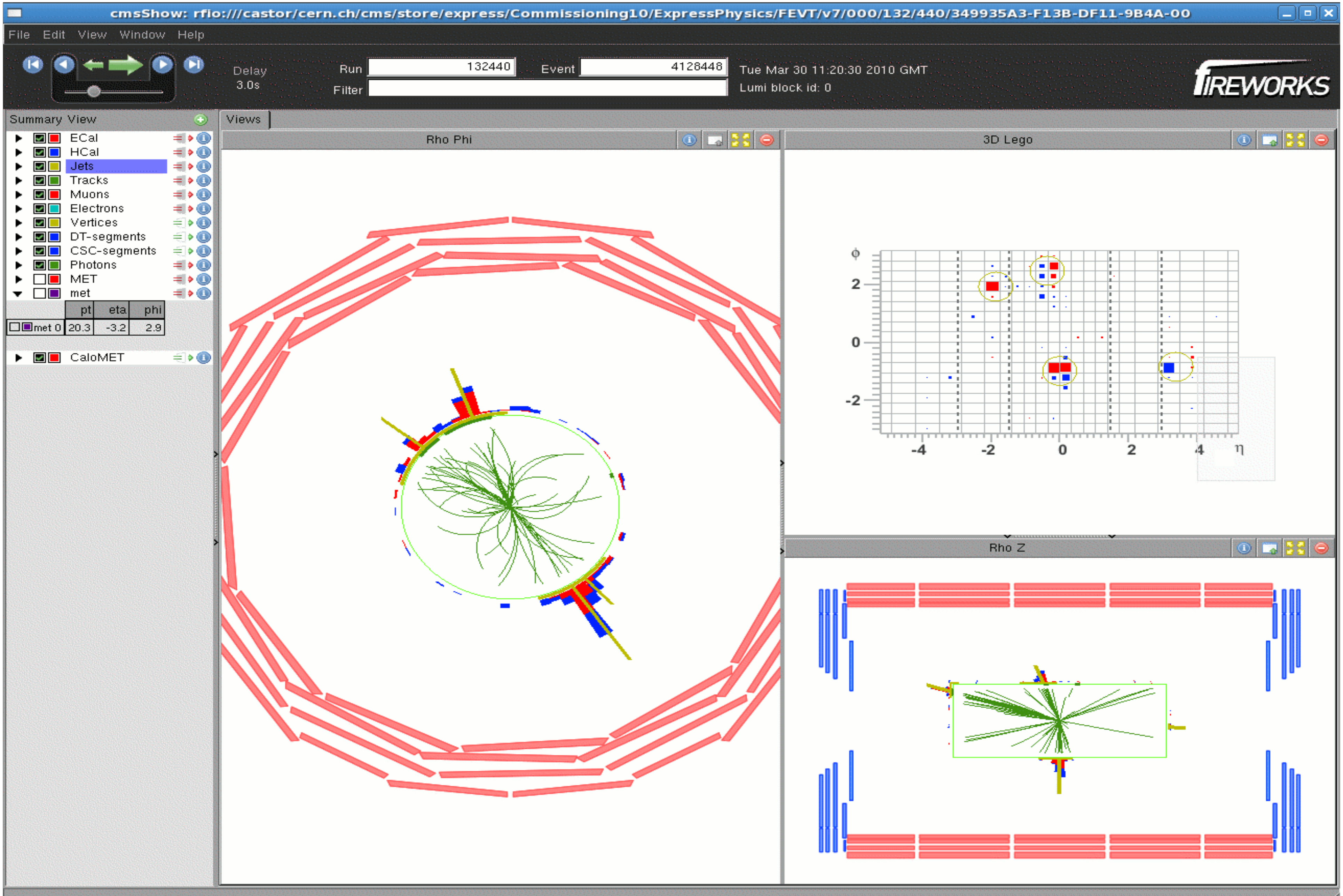
First I have to apologize about the poor preparation for this meeting. But other events took place earlier this week that required my full attention...

...7 TeV collisions at CMS



EvtGen Overview

- Detailed amplitude based description of decays
  - Keeps angular correlations in decay chains
  - Implements CP violations in B decays
- Detailed decay table for most light particles up to the mass of the Upsilon system.

- Main developers: Anders Ryd and David Lange (both in CMS but neither of us have much time to work on this...)
- Many contributions from people on different experiments:
  - BABAR, CLEO, Belle, CDF, LHCb, ATLAS, CMS, Panda

Sequential Decays

- Many decays have interesting sequential decay chains:

$$B \to D^{*}\ell\nu \qquad\qquad B \to D^{*}\ell\nu$$
$$\hookrightarrow D\pi \qquad\qquad\qquad \hookrightarrow D\gamma$$

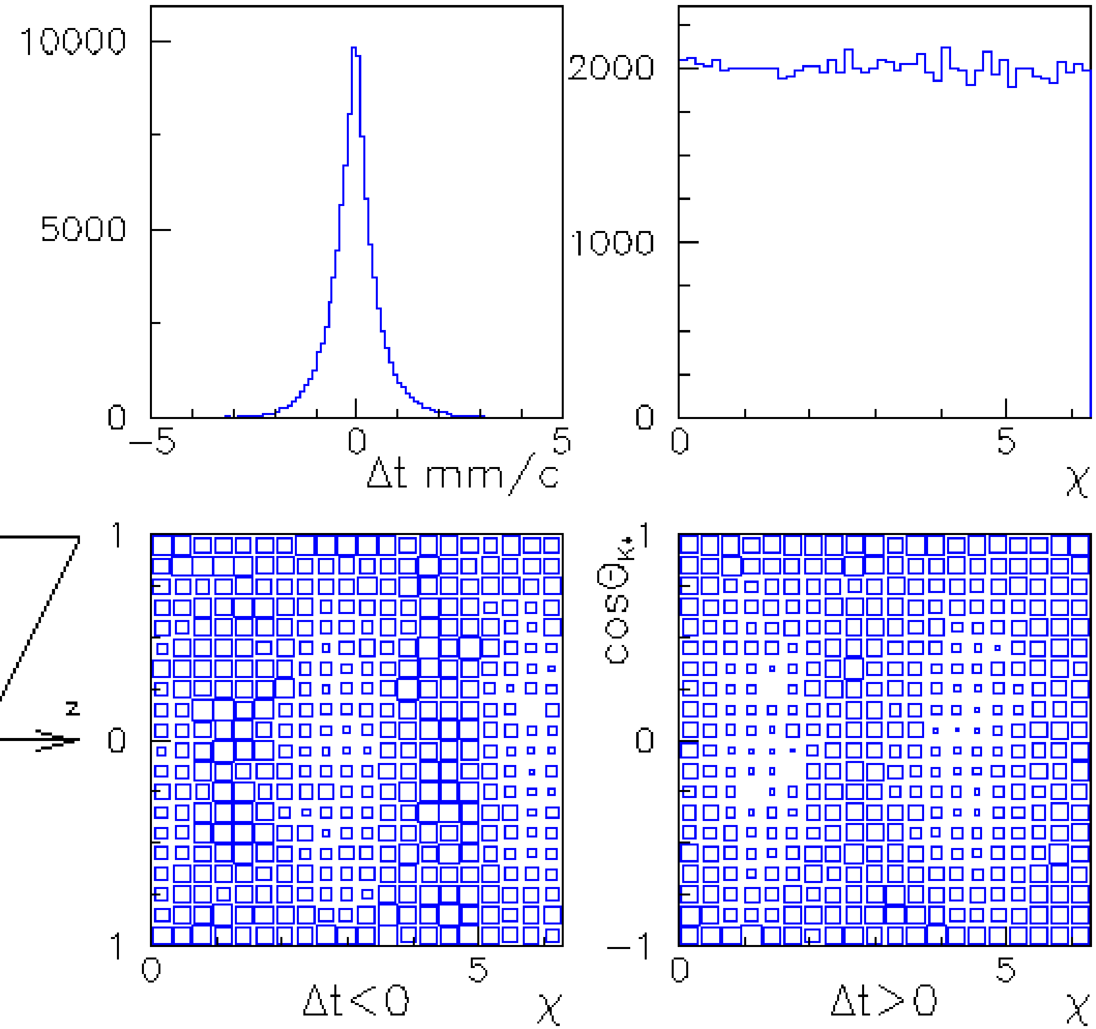
$$B \to D^{*} \quad D^{*} \qquad\qquad B \to D^{*} \quad D^{*}$$
$$\hookrightarrow D\pi \hookrightarrow D\pi \qquad\qquad \hookrightarrow D\pi \hookrightarrow D\gamma$$

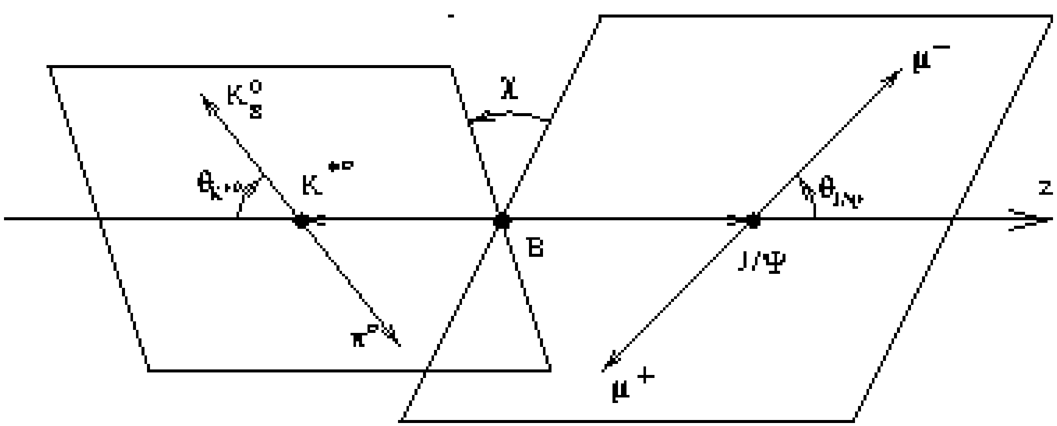
- Want to correctly simulate these decay chains while only implementing the nodes in the decay tree.

$$B \to D^{*}\ell\nu \qquad B \to D^{*}D^{*}$$
$$D^{*} \to D\pi \qquad D^{*} \to D\gamma$$

CP Violating Decays

- *$B \to J/\psi K^{*0}$ ($K^{*0} \to K^0\pi^0$)*
  - Angular correlations and time dependence





'EvtGenLHC'

- In ~2003 LHCb and ATLAS started using EvtGen. They took the current version used at BABAR.
- A number of initial changes were fed back to the BABAR repository. (Where David and I did the main development.)
- But over the years a number of different changes were made to the EvtGenLHC version.
- But most importantly many fixes made at BABAR and CLEO were not propagated to the EvtGenLHC version.
  - This meant that I many times had to trace down the same problems multiple times.

The '2009 Merge'

- A meeting was held in Jan 2009 where different changes made to EvtGen by different experiments were discussed. After this meeting I got patches and new code from ATLAS, CMS, LHCb, CDF, Herwig developers. I also took code from CLEO and merged this into the BABAR repository.
- This new version was tested by e.g. LHCb and a few issues were resolved. LHCb are still looking at some features in the generation of CP violation.
  - I will meet with Patrick Robbe and try to sort out this next week.
  - Then we will release a new version.

EvtGen and tau Decays

- EvtGen decays taus. (Z. Was might discuss this in his talk)
  - Detailed models of leptonic, and final states with one or two hadrons.
  - Higher multiplicity final states are simulated using a V-A modul in JetSet.
- I prefer that EvtGen decays taus produced in B decays as it will automatically take into account the polarization.
- EvtGen can handle two body decays (HELAMP, PARTWAVE) to pairs of taus or tau-neutrino pairs.
- The code in EvtGen is able to handle this, but there has to be an interface to EvtGen that specifies the initial polarization.

Summary

- The main issue with EvtGen from my point of view is that neither David nor I have any time to work on this any more.
- We have had a great deal of help from LHCb, next talk.
- I hope that David and I can find time to release a new version that incorporates the changes from (at least) LHCb.

Backup

Decay amplitudes are used instead of probabilities

- EvtGen works with amplitudes to correctly handle sequential decay.

$$B \to D^* \quad \tau\nu$$
$$\quad\hookrightarrow D\pi \;\hookrightarrow \pi\nu$$

$$d\Gamma = |A|^2 d\phi \qquad A = \sum_{\lambda_{D^*}\lambda_\tau} A^{B\to D^*\tau\nu}_{\lambda_{D^*}\lambda_\tau} A^{D^*\to D\pi}_{\lambda_{D^*}} A^{\tau\to\pi\nu}_{\lambda_\tau}$$

$$A^{B\to D^*\tau\nu}_{\lambda_{D^*}\lambda_\tau} \equiv \langle\lambda_{D^*}\lambda_\tau|H|B\rangle \qquad \sum_{\lambda_{D^*}} |\lambda_{D^*}\rangle\langle\lambda_{D^*}| = I$$

- Nodes in the decay tree are implemented as “models”. The framework of EvtGen handles the bookkeeping needed to correctly generate the full decay tree.

Advantages to using decay amplitudes

- Implementation of decay models is simplified by using amplitudes instead of probabilities.
- Keeping track of the spin density matrices allows us to generate each node of the decay chain independently.
    - More efficient
    - Avoids the need to determine uncountable # of maximum probabilities
- Generalizes to arbitrarily long decay chains
- Calculation of probabilities and spin density matrices are done by the framework. Models specify only the decay amplitudes.
- However: No interference between particles on different branches of decay tree.

Selection algorithm (I)

- Generate the *B->D*l*ν decay

$$P = \sum_{\lambda_{D^*}\lambda_\tau} |A^{B\to D^*\tau\nu}_{\lambda_{D^*}\lambda_\tau}|^2$$

- Compare with maximum probability and accept or reject generated *B->D*l*ν decay.
  - Maximum probability specified in code.
    - Can instead be generated on the fly, however this leads to the output of event *N* depending on the random number sequence used to determine the max probability.
- Regenerate *B->D*l*ν decay until combination is accepted.

Selection algorithm (II)

- Average over τ spin and calculate the *D** spin density matrix:

$$\rho^{D^*}_{\lambda_{D^*}\lambda'_{D^*}} = \sum_{\lambda_\tau} A^{B\to D^*\tau\nu}_{\lambda_{D^*}\lambda_\tau} (A^{B\to D^*\tau\nu}_{\lambda'_{D^*}\lambda_\tau})^*$$

- Generate the *D*->D*π decay

$$P = \sum_{\lambda_{D^*}\lambda'_{D^*}} \rho^{D^*}_{\lambda_{D^*}\lambda'_{D^*}} A^{D^*\to D\pi}_{\lambda_{D^*}} (A^{D^*\to D\pi}_{\lambda'_{D^*}})^*$$

- Compare with maximum probability and accept or reject generated *D*->D*π decay
- Regenerate *D*->D*π decay until accepted. The *B->D*l*ν decay is not regenerated.

Selection algorithm (III)

- Calculate the spin density matrix for the τ

$$\rho^{\tau}_{\lambda_\tau \lambda'_\tau} = \sum_{\lambda_{D^*} \lambda'_{D^*}} \hat{\rho}^{D^*}_{\lambda_{D^*} \lambda'_{D^*}} A^{B\to D^*\tau\nu}_{\lambda_{D^*} \lambda_\tau} (A^{B\to D^*\tau\nu}_{\lambda'_{D^*} \lambda'_\tau})^*$$

- Where:

$$\hat{\rho}^{D^*}_{\lambda_{D^*} \lambda'_{D^*}} \equiv A^{D^*\to D\pi}_{\lambda_{D^*}} (A^{D^*\to D\pi}_{\lambda'_{D^*}})^*$$

- Generate the $\tau \to \pi \nu$ decay

$$P = \sum_{\lambda_\tau \lambda'_\tau} \rho^{\tau}_{\lambda_\tau \lambda'_\tau} A^{\tau\to\pi\nu}_{\lambda_\tau} (A^{\tau\to\pi\nu}_{\lambda'_\tau})^*$$

- Compare with maximum probability and accept or reject generated $\tau \to \pi \nu$ decay.
- Regenerate $\tau \to \pi \nu$ decay until accepted. The *B->D*l*ν and *D*->D*π decays are not regenerated.

States in EvtGen

- EvtGen works with amplitudes. The amplitudes are specified as amplitudes between the initial and final state in a set of basis vector provided by EvtGen.
- EvtGen uses the following representation for the lower spin states:

Class name	Rep.	J	States	Example
EvtScalarParticle	1	0	1	π, B^0
EvtDiracParticle	u_α	1/2	2	e, τ
EvtNeutrinoParticle	u_α	1/2	1	ν_e
EvtVectorParticle	ϵ^μ	1	3	ρ, J/Ψ
EvtPhotonParticle	ϵ^μ	1	2	γ
EvtTensorParticle	$T^{\mu\nu}$	2	5	D_2^*, f_2

- Also J=3/2 EvtRaritaSchwinger 4 states
- Higher spin states are represented by a generic helicity state basis