The tracking

Present situation
Short term actions
Long term actions
FUTURE

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Present situation

TODO list

BUG FIXES AND THINGS TO BE ADDED:

1. Check on the tracking of any charged particle and of neutral particles
2. In the helix <--> parabola contructors sometimes the transformation is not possible and it fails: a comment is needed to explain why (it is due to the SD/SC transformation failure)
3. `PropagateToLength(0)` must be fixed (peraphs in FORTRAN) to be able to propagate to track length = 0 (i.e. don’ t move)
4. Check the option 'O’ (= only); it should perform the tracking only of the mean values without the errors. If it is so, a function to use it must be added to the interface
5. Add the covariance matrix in MARS (6X6) in `FairTrackParH`
6. Check the tracking along the z axis
7. Fix bug to prevent crash (e.g. in xmm55)

A MORE GENERAL IDEA:

1. A general “restyling” of `FairGeanePro` is needed in some points, to uniform the function names and optimize them: for example `PropagateToPCA(pca)`/`PropagateToPCA(pca, dir)` to be unified in one!

FINALLY, IN THE INTERFACE BETWEEN GEANE AND GENFIT:

1. I wrote the `GeaneTrackRep::getPosMomCov` function but there is a problem in the transformation to MARS, which may fail sometimes due to MARS/SD/SC transformations → a comment is needed (and I will put the implementation in svn)

2. Exception of `getMom` in `PndGenfitAdapters` (see thread: *Bugs, Fixes, Releases: Bug in GenfitTrack2PndTrack*); we should decide whether to put it within a "try&catch" or to handle the exceptions directly inside `getPos/Mom/PosMom/PosMomCov`?

3. Bug in SPU still needs to be corrected (see forthcoming post in the forum)

Long term actions

How much long?

I think about a period of six months

(depending on man power)

1. tracking for electrons/positrons
2. Kalman filter for electrons/positrons
3. Implementation of GEANT 4E

1. Tracking of electrons/positrons

Bremsstrahlung

The radiative energy loss straggling distribution for the energy E of a particle of incident energy E_0 on an absorber of thickness x, was first deduced by Heitler [28], using an approximate expression for the bremsstrahlung cross section:

$$f(E) = \frac{1}{E_0\Gamma(l)} \left(\ln \frac{E_0}{E}\right)^{l-1} , \quad l = \frac{x}{X_0 \ln 2} , \tag{18}$$

where X_0 is the radiation length of the absorber and Γ is the gamma function.

$$\begin{aligned} \langle E \rangle &= E_0 \frac{1}{2^l} , \qquad \langle E^2 \rangle = E_0^2 \frac{1}{3^l} \\ \sigma^2[E] &= \langle E^2 \rangle - \langle E \rangle^2 = E_0^2 \left(\frac{1}{3^l} - \frac{1}{4^l} \right) . \end{aligned}$$

Tracking for electrons

Bremsstrahlung

GEANE is OK for the mean value

absorber	energy (GeV)	Heitler equation μ	Heitler equation σ	GEANT3 μ	GEANT3 σ	GEANT4 μ	GEANT4 σ
10 cm Ar	0.5	0.4995	0.0097	0.4995	0.0097	0.4995	0.0105
10 cm Ar	1.0	0.9991	0.0194	0.9991	0.0198	0.9991	0.0203
1 cm Al	0.5	0.447	0.098	0.444	0.100	0.444	0.098
1 cm Al	1.0	0.894	0.195	0.891	0.203	0.891	0.201
1 cm Al	10	9.01	1.95	8.96	2.04	8.95	2.06

Table 2: comparison between the mean energy μ and standard deviation σ (MeV) from the the GEANT3 and GEANT4 simulated distributions relative to 10^5 electrons and from the Heitler formula after passing some absorbers.

Tracking for electrons

Improvements (done)

- New error calculation in energy loss for heavy particles (truncated Landau and Urban)

- New error calculation for bremsstrahlung

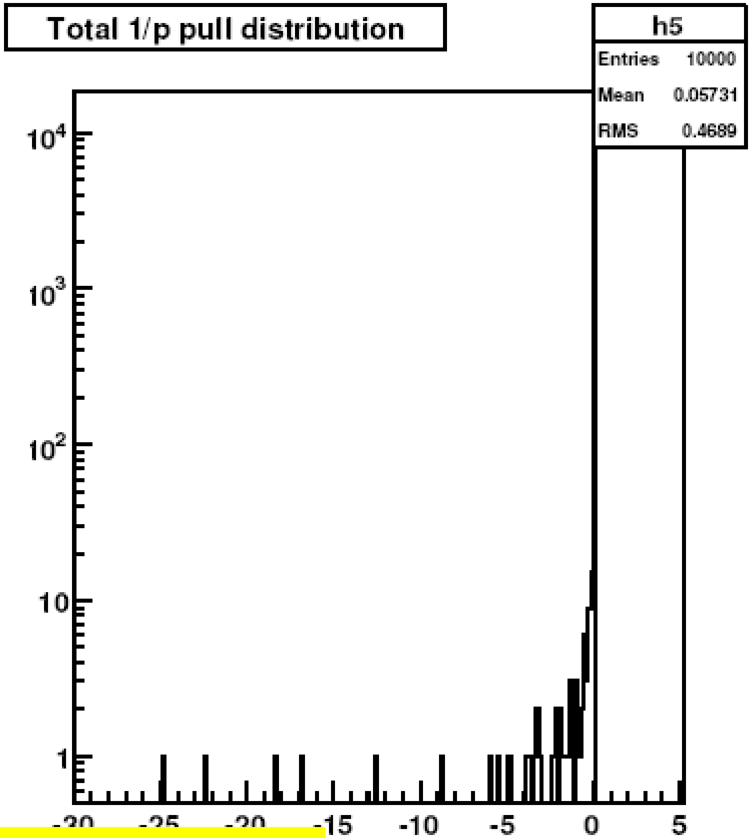
The effects are only in the energy pulls,
because only the (1,1) element
of the covariance matrix is involved

Tracking for electrons

Bremsstrahlung

1/p distribution has no variance!
We use the 1 σ E interval transformed in 1/E

$$
\begin{aligned}
\sigma[1/E] &= 0.5\,[1/E_2, 1/E_1]\,, \qquad \text{where} \\
E_2 &= \mathrm{Min}(E_0, \langle E\rangle + \sigma[E])\,, \\
E_1 &= \begin{cases} \langle E\rangle - \sigma[E] & \text{if} \;\; E_2 = \langle E\rangle + \sigma[E] \\ E_0 - 2\sigma[E] & \text{if} \;\; E_2 = E_0 \end{cases} .
\end{aligned}
$$



The covariance matrix for bremsstrahlung was absent in the original GEANE
Implemented in the last GEANE version (last summer)
Tests with electrons have to be done
However, this is not enough for KALMAN

2. KALMAN filter requires gaussian shapes.
How to proceed??

Beyond Kalman: not gauusian models (electrons)

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Computer Physics Communications

Computer Physics Communications 154 (2003) 131–142

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A Gaussian-mixture approximation of the Bethe–Heitler model of electron energy loss by bremsstrahlung

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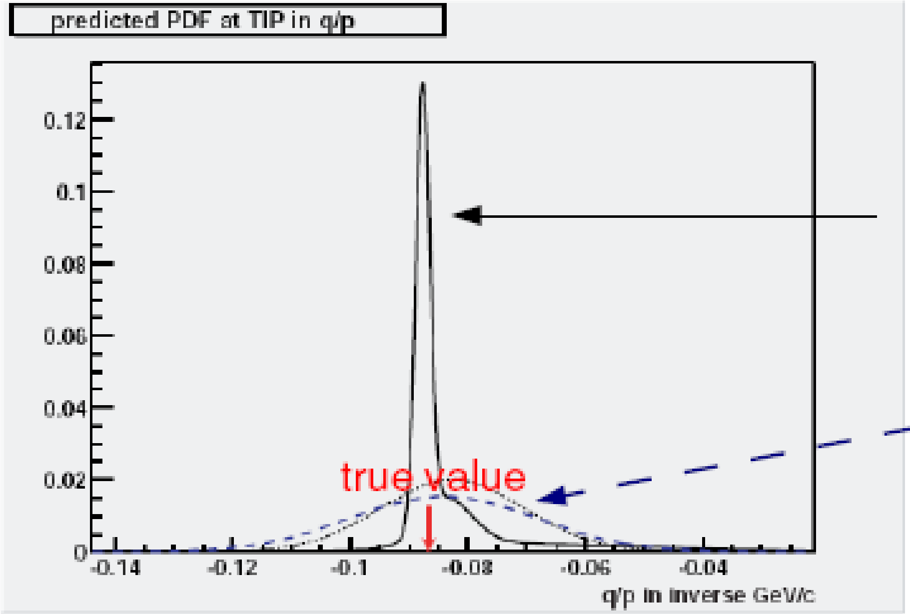
- idea: describe P(z) as a weighted sum of several Gaussian distributions
- split fit in different component, one for each Gauss. add up the final results.



From Adam, Fruhwirth,Strandlie,Todorov. This plot shows the result from a single fit.

PDF of sum of components from Gaussian Sum Filter

PDF of result from normal Kalman Filter, describing e-loss with single gaus

- but
  - number of components can become very large ... must run many fits to fit a single track

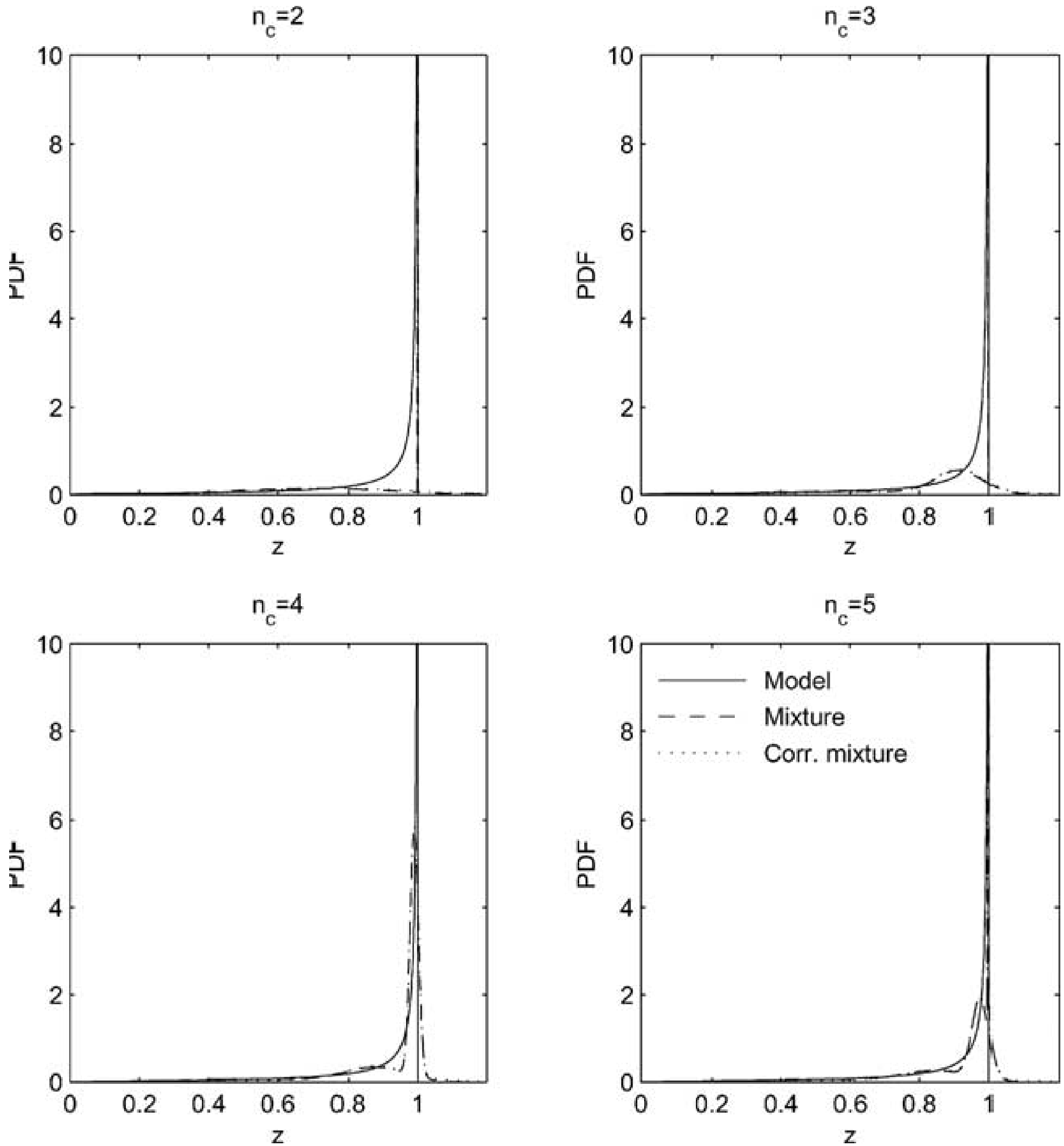


Fig. 9. PDFs of the model and of CDF-mixtures for $t = 0.02$.

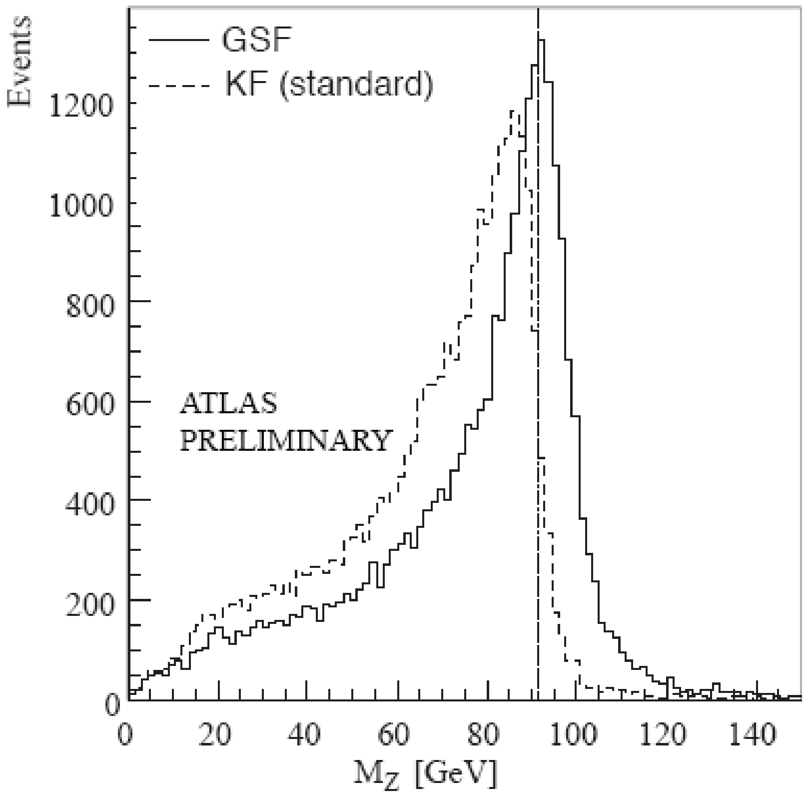


Figure 6. Improvement of the Z mass distribution for $Z \to e^+e^-$, when the electron tracks are (re-)fitted with the Gaussian sum filter instead of the standard ATLAS Kalman filter. In the standard Kalman filter, energy loss is applied only as mean ionisation loss and even approximated as being Gaussian distributed.

3. GEANT4E

Timing GEANE vs GEANT4E

10k mu+ 20 GeV cross all the detector (time in msec/evt CPU: Athlon 1 GHz)

- Same number of steps in GEANT3 and GEANT4

GEANT3		GEANT4	
GEANT3	0.39	GEANT4	1.22
GEANE: Forward or backward	**0.45**	**GEANT4E: Forward or backward**	**1.65**
GEANE: no error Forward or backward	0.28	GEANT4E: no error Forward or backward	1.30

- GEANT4 is 2.5 times slower than GEANT3
- GEANT4E is 3.5 times slower than GEANE
- Most of the time is taken by GEANT4 field propagation
- Error propagation is ~1/3 of total time

☺ Results have been checked by profiling

VERY PRELIMINARY:

Time in full CMS:

- GEANE: 55 msec/track
- GEANT4E: 44 msec/track

! But 3.5 X more steps in GEANE

Summary and plans

- First prototype of GEANT4E is ready with similar functionality as GEANE
- Simple example shows it is 3.5 times slower as GEANE (0.8 in real detector, although with bigger steps)
- Many optimisation options available

Next steps:

- Release in GEANT4
- Check in a real detector reconstruction (CMS)
  - Baseline software for track error propagator in CMS Cosmic Challenge (May 2006)
- Try different optimisation options

FUTURE

- Join different detectors
- Track merging
- Vertex fit + track fit
- ………………………