Machine Beam Spread (MBS) in KKMC

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We discuss in this note:

- How MBS is implemented in KKMC?
- Is implementation of MBS in KKMC incorrect or rather inefficient?
- Danger for $w = 1$ events in KKMC
- One possible fix

MBS in KKMC was originally for LEP

- The machine beam energy spread (MBS) was introduce in KKMC for LEP.
- At the time of its implementation resonances like psi or phi we not considered. We had in mind Z resonance, for which the beam spread is much smaller than the Z resonance width.
- RRes package was never tested with the nonzero beam spread, that is with nonzero input parameter DelEne =xpar(2).

How MBS is implemented in KKMC?

The Gaussian beam energy random variation is realized using

`SUBROUTINE KarLud_SmearBeams` in the file KK2f/Karlud.f

Unfortunately the comment in front of this routine

```
*//   This is correct only for very small spread $<$ 2GeV //
```

is incorrect because:

- The MBS should be small compared to the relevant resonance width. The scale 2GeV is here meant to be the Z width. In reality for low energies MBS should be small compared the width of the low energy resonances

- If the above is not true, then the actual MC implementation is not ”INCORRECT” (although it can be in some cases, see discussion below) but rather it is mathematically correct, however, its implementation is ”INEFFICIENT”, from the point of view of the MC weight variation.

Is implementation of MBS in KKMC incorrect or inefficient?

Let me elaborate a little bit more on the above: In the MC algorithm for ISR (see KK2f/Karlud.f, bornv/BornV.f) we memorize photon spectrum
$f(v) = \rho_{ISR}(v) * Born(s(1-v))$.
In the presence of the narrow resonances this function has peaks at $v_i = 1 - M_i^2/s$, where M_i is mass of the resonance.
This $f(v)$ is memorized once for ever in the MC initialization phase.
In the presence of the machine beam spread (MBS) we cannot change $E = \sqrt{s}$ event-per-event, because changing s redefines $f(v)$, in particular positions v_i of the peaks will move!

What I said is only half true – we can change s, but we have to compensate this change EXACTLY by the MC weight which involves the ration $w = f(v_X)/f(v)$, where $v_X = 1 - s(1-v)/s_X$ is shifted due to MBS.
This weight w will contain in particular the ratio of two Breit-Wigners.
Mathematically, this solution is CORRECT, but obviously if the beam spread is bigger than width of the resonance than the weight will go crazy.
One may live with the crazy MC weight and still get correct results for weighted MC events.

Danger for $w = 1$ events in KKMC

What may be really dangerous is to use KKMC for MBS and narrow resonances for weight$= 1$ events (the default)!

In this case events which internally have $w =$m_WtMain $>$ m_WTmax may lead to strongly distorted distributions. (In fact the resonances may get severely distorted).

In principle one should always scrutinize and control very well statistics of such "overweighted events", and if there are too many of them, then one should increase parameter WTmax, see input data:

```
   9          1.0e0   WtMax =xpar( 9)   Maximum weight for rejection
 517          5.0e0   WtMax Maximum weight for rejection d-quark
```

Unfortunately, setting WtMax=1000 or so can be very wasteful, in view of the fact that the overweighted events concentrate in a very small part of the phase space, while we will reject 999/1000 events everywhere.

(Weight distribution will have along tail – all of the tail will come from the narrow resonances, which form small fraction of the total cross section!).

One possible fix

However, in KKMC there is an interesting protection mechanism for the case of many ”overweighted events”, see part of code in KK2f/KK2f.f

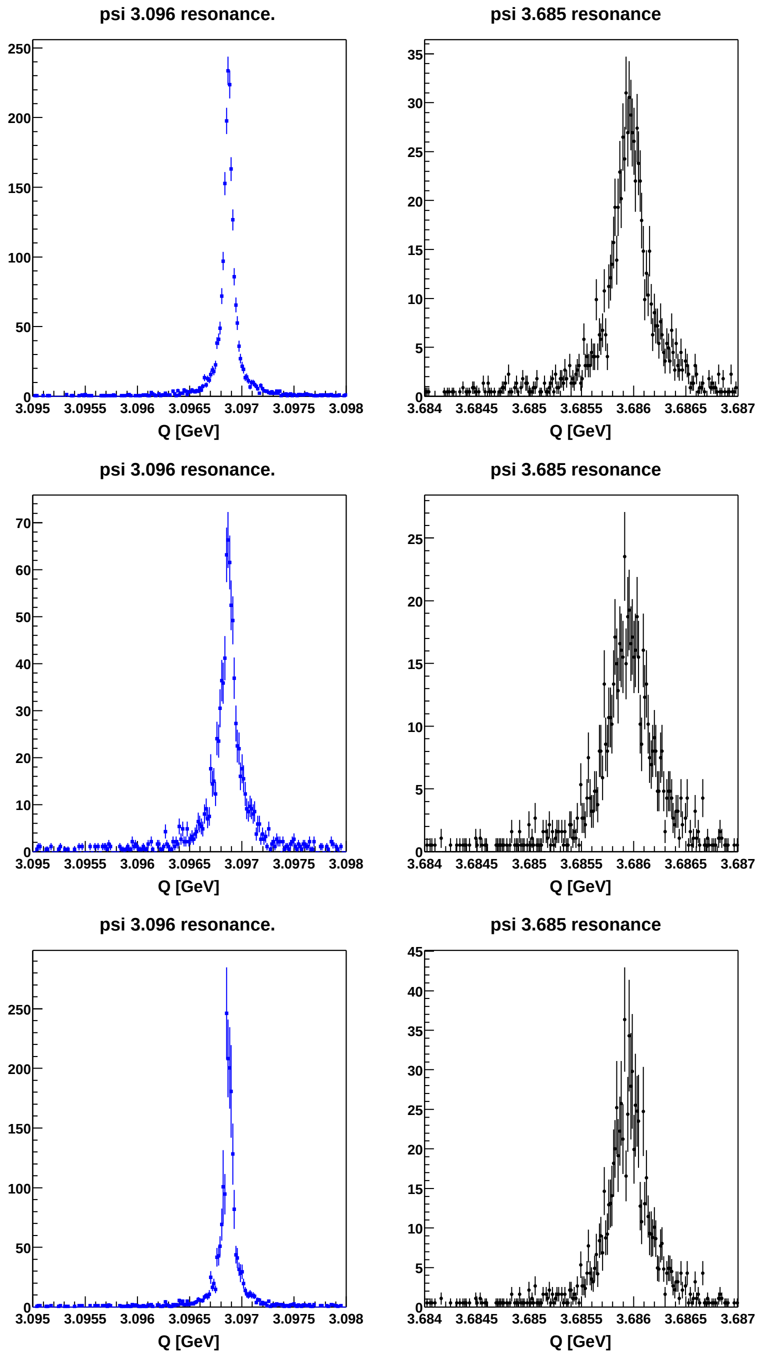
```
WtScaled = m_WtMain/m_WTmax
IF( WtScaled .GT. 1d0) THEN
   m_WtMain = WtScaled
ELSE
   m_WtMain = 1.d0
ENDIF
```

The abnormal events with m_WtMain $>$ m_WTmax are still assigned the ”scaled weight” assigned to m_WtMain.

Most of events will have m_WtMain=1, but there might be a small subset of ”abnormal” events with weight$>$1.

The possible fix is the following: It is perhaps not very convenient, but by using this weight WtMain event for so called “unweighted events” allows us safely to avoid the worst pitfalls, leading to completely wrong result, like what you have seen.

In a sense we use then a mixture of weighted and unweighted events.



Numerical examples

The distribution of the effective mass Q of the final state (excluding ISR photos). All results at $\sqrt{s} = 10GeV$. All five quarks. No FSR. Plotted regions of two lightest charm resonances.

- Upper plot for zero machine beam spread, 500k of wt=1 events.
- Middle plot for machine beam spread 4MeV each beam, 500k of $wt = 1$ events. Resonance eroded due to large amount of $wt > 1$ events.
- Lower plot for machine beam spread 4MeV each beam, 500k events, MC weight $wt = 1$ for normal events and $wt > 1$ weight is booked in the histogram. Resonance of right size but large fluctuations of the weight, see error bars!.

Final remarks

- The above numerical data with psi resonance reduced in size seems to be consistent with what was found in BaBar test.
- Possible fix is to keep WtMain. This does not require any modification of KKMC.
- Radical solution is to introduce in KKMC the Gaussian beamstrahlung distribution which mimics MBS. This is relatively easy, but requires modification/extension of the KKMC code.