Spin polarization
and Einstein-Podolsky-Rosen paradox
in the MC event records

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Main Topics:

- Usual approach: helicity states.
- When it works?
- When it breaks?
- When it breaks badly?
- Why it does not matter in this case?
- Wen it may matter a lot, and constraints on the data structure for backup solution.

Slides are (will be) on http://home.cern.ch/wasm

Helicity states.

For (nearly) all Monte Carlo architectures we use:

Stadard approach

1. Particles have properties.
2. Particles have origin.
3. Particles have decay products.

Used everywhere:

`HEPEVT, LUJETS, PYJETS, HEPEUP, HEPMC, ...`

but nonetheless ...

Let us have a critical look at it with the help of examples and with the special emphasis on breaking point and when the data structures organized around ’particles’ can lead to the trap.

Helicity states.

Stadard approach

Example: KORALZ at LEP, Monte Carlo program for production of τ-lepton pairs and decay, including QED bremssstrahlung corrections

S. Jadach, B.F.L. Ward, Z. Was Comput. Phys. Commun. 79 (1994) 503

- Generates first pair of τ leptons
- Generates helicity states of both τ^+ and τ^- i.e. approximation is used
- Provides helicty states and relation between τ's restframe and LAB to TAUOLA
- TAUOLA performs decay of 100 % polarized τ's.
- In (nearly) all cases at LEP such approach was sufficient.

That is standard solution used very often, advocated in general idea of `HEPEVT` common block since many years and also recently in discussions for e.g. data structure for LHC and c++.

Helicity states.

If something works in one place why not ...

Universal interface for TAUOLA –

library for τ lepton decay.

T. Pierzchala, E. Richter-Was, M. Worek, Z. Was Acta. Phys. Polon. B32 (2001) 1277.

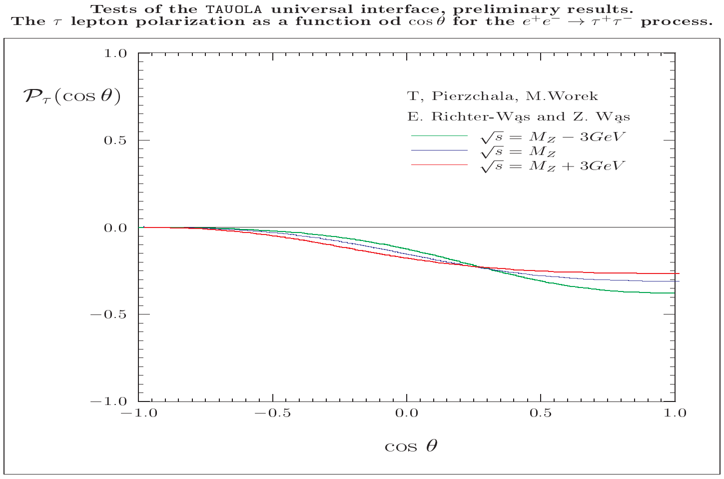
- Search for τ's over `HEPEVT` common block filled by any MC program
- Look through the origin of τ lepton: Z, γ, W, h, $h^\pm$,

$e^+e^-(u\bar{u}, d\bar{d}) \to \tau^+\tau^-$

- Eventually calculate effective incoming beams
- Generate τ helicity states
- Generate τ decay(s)
- Complete event stored in `HEPEVT` common block with the decay products.

Helicity states.

τ-polarization in $e^+e^- \to \tau^+\tau^-$



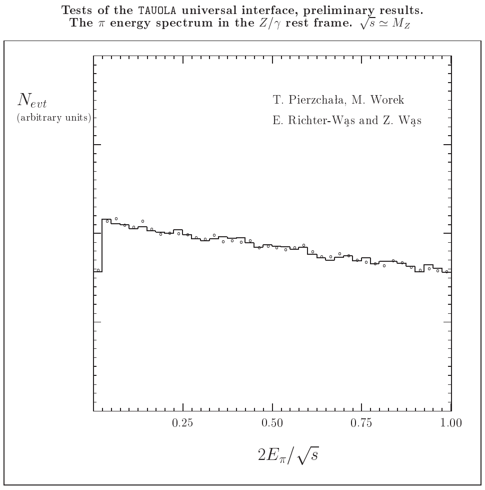
Tests of the TAUOLA universal interface, preliminary results.
The τ lepton polarization as a function od $\cos\theta$ for the $e^+e^- \to \tau^+\tau^-$ process.

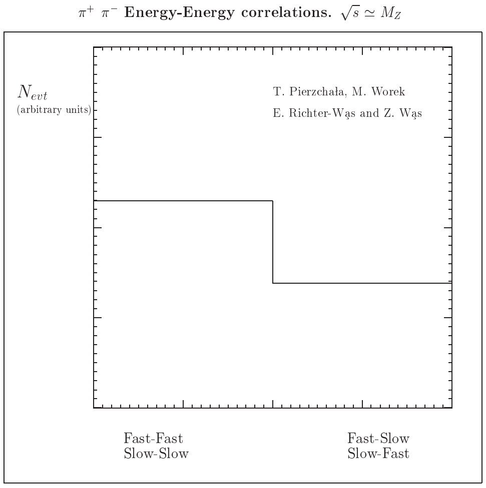
The function used in the interface is taken form KORALZ.

It looks after implementation (equally) OK.

Helicity states.

Test at τ decay products level





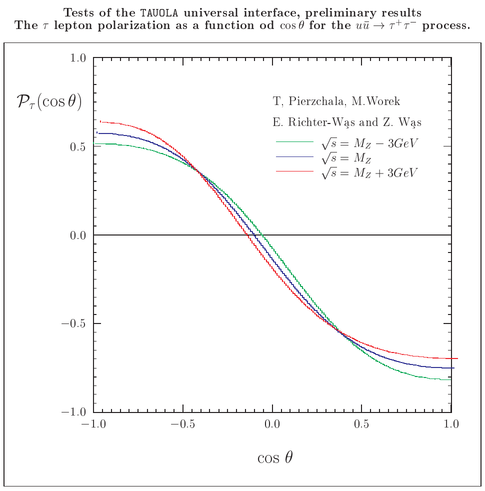
To make spin effects large, we take sample of both τ' decaying into $\pi\nu$. Standard tests are getting reproduced qualitativelly.

We will continue with the more sophisticated tests in future. In particular we need to test the algorithm for matching bremsstrahlung.

Helicity states.

τ-polarization in $q\bar{q} \to \tau^+\tau^-$

Now let us use the same functions for quarks:



Tests of the TAUOLA universal interface, preliminary results
The τ lepton polarization as a function od $\cos\theta$ for the $u\bar{u} \to \tau^+\tau^-$ process.

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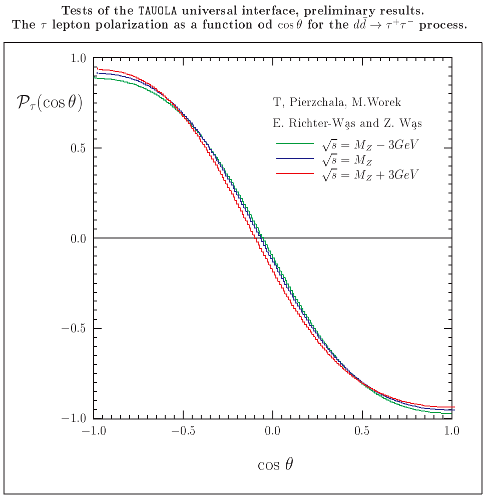

Tests of the TAUOLA universal interface, preliminary results.
The τ lepton polarization as a function od $\cos\theta$ for the $d\bar{d} \to \tau^+\tau^-$ process.

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Doubts

KORALZ

It was based/on the careful downgrading from the full treatment of spin in KORALB (S. Jadach, Z. Was Comput. Phys. Commun. 64 (1991) 267) program for lower than LEP energies and first order radiative corrections only.

Tests of the validity of KORALZ spin treatments were ALWAYS available.

Anyway at LEP it was numerically important to have it only twice:

- For the measurement of transverse spin correlations and weak tests of the Bell inequalities
- For the measurement of the τ lepton lifetime using impact parameters difference method.

Universal interface of TAUOLA

Nothing like such possibility of tests exists,

except comparisons with KORALB KORALZ again ...

Anyway we feel confident

Should we always?

PHOTOS

E. Barberio, B. van Eijk, Z. Was, Comput. Phys. Commun. (1991) .

It was developped starting from the careful downgrading from the full treatment of M.E. in MUSTRAAL (F. Berends, R. Kleiss, S. Jadach, Comput. Phys. Commun. (1982)) For the decay of Z to obtain 'factorizable' form.

Extended to work for the decay of 'any' particle or resonance.

It heavily uses mother-daughter relations in `HEPEVT`

- Thus it is bound to be not better than LL (may be NLL)
- Safety backup: Comparisons with M.E. Monte Carlos whenever available.
- E.g. $\tau \to e\nu\bar{\nu}\gamma, \tau \to \pi\nu\gamma, Z \to \mu^+\mu^-\gamma(\gamma), gg \to t\bar{t}\gamma\gamma.$

In many cases tests are not available ...,

DIRTY OBSERVABLE

Aim:

● Observable that produces unexpected peaks out of background expected to be flat.

● Starting point: $s\bar{s}$ state in $e^+e^- \to s\bar{s}c\bar{c}$ at 350 GeV ($c\bar{c}$ lost in the beam pipe).

● This is not realistic observable, but in principle realizable experimentally.

● Let us look at it with:

(i) full ME.,

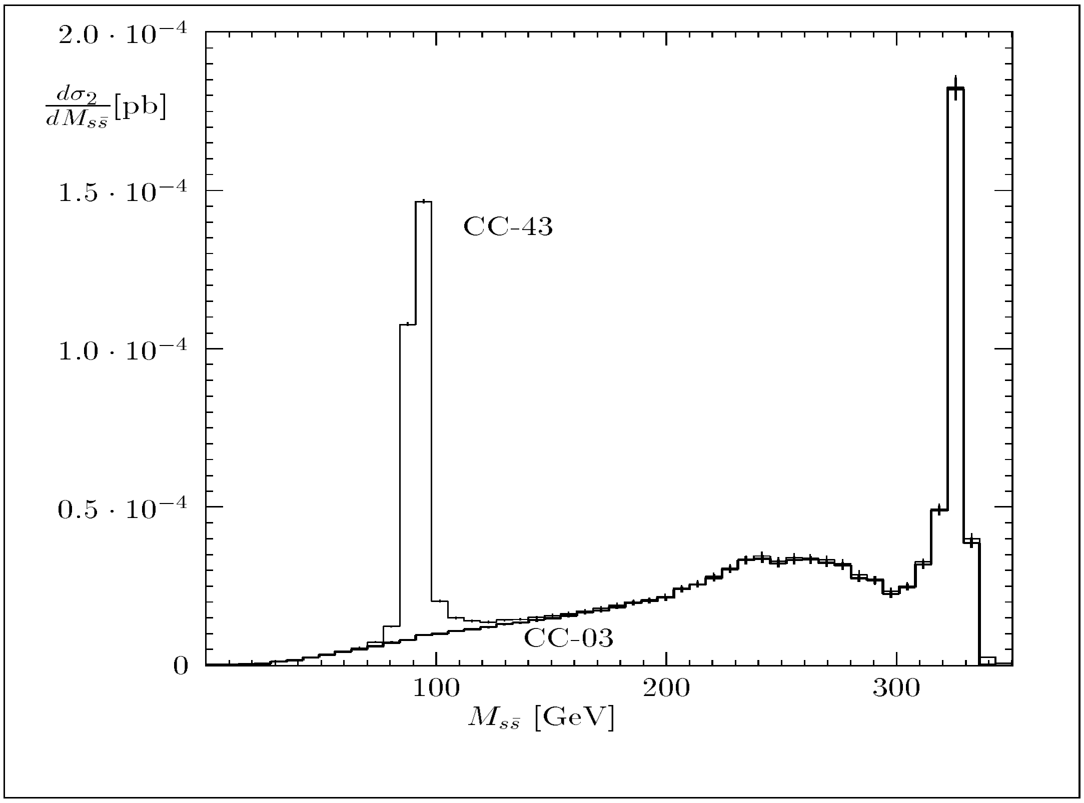
(ii) CC03: WW prodction and decay

(iii) CC03 no transverse spin correlations.

Doubts

What is the origin of the second peak?

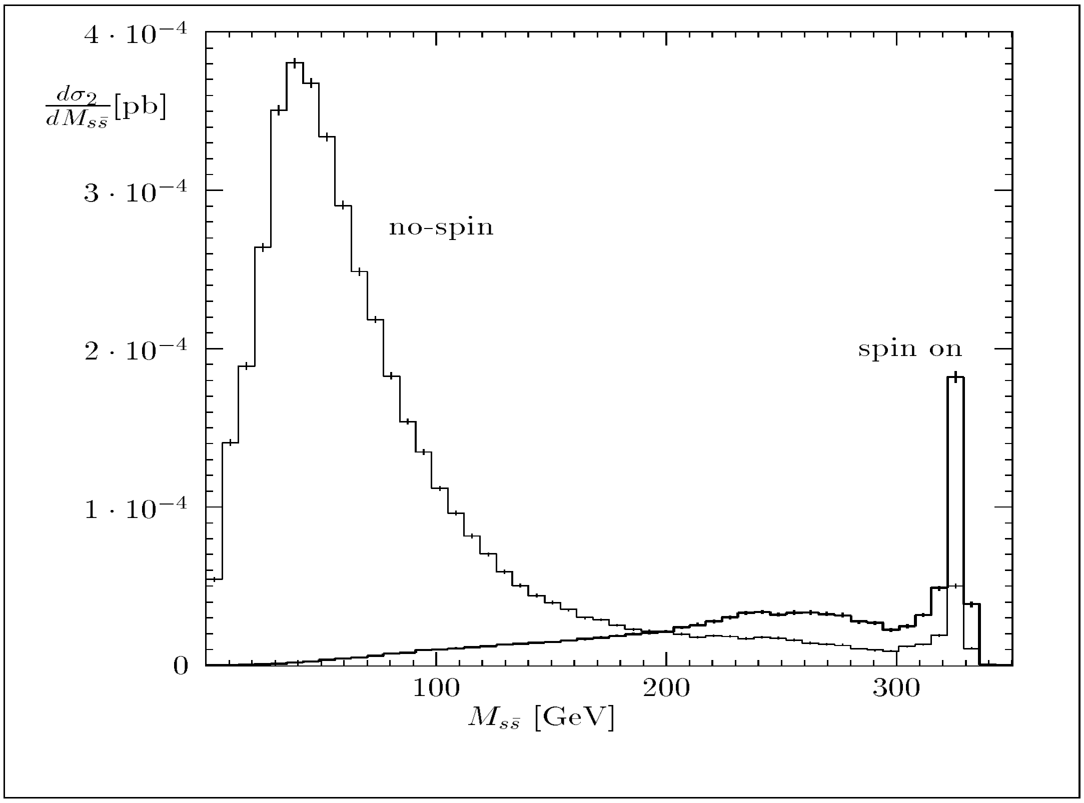
Figure 6: The $\frac{d\sigma_2}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 350 GeV. Input parameters of type 2: CC-03 (thick line); and type 4: CC-43 (thin line). See Appendices A, B for a complete definition of all input parameters.



Doubts

These crazy spin Correlations !!

Figure 5: The $\frac{d\sigma_2}{dM_{s\bar{s}}}$ differential distribution of the "visible" $s\bar{s}$ jets where $c\bar{c}$ jets escape detection. The centre-of-mass energy is 350 GeV. Input parameters of type 1: CC-03 no spin correlation (thin line); and type 2: CC-03 spin correlations switched on (thick line). See Appendices A, B for a complete definition of all input parameters.



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Why it does not matter in this case?

Spin correlations are needed in full.

This second peak has showed up due to full spin correlations deeply related to Einstein-Rosen-Podolsky paradox. That means no hope for generating pair of W each in definite spin state first and later decay.

But anyway ...

1. W's are not narrow resonances
2. Full matrix elements for production and decay combined are available
3. All W decay channels are basically identical
4. Interfering background diagrams need to be taken into account
5. In real life nobody will separate production and decay
6. No need for spin in event record

Final call:

Who cares about full spin degrees of freedom in data structure?

Conclusions

Nobody cares:

Unless:

- One believes that there might be some heavy spiny new particles, rich in physics, produced in pairs at LC.
- This may not at present justify introduction of multi-particle density matrices into event records,
- but nonetheless calls for some thought toward backup solution.

Can we offer something?

- Universal definition of spin quantization frames for all particles in an event, working well in context of agebraic method of generating spin amplitudes:
S. Jadach, B.F.L. Ward, Z. Was, GLOBAL POSITIONING OF SPIN GPS SCHEME FOR HALF SPIN MASSIVE SPINORS. CERN-TH-98-235, hep-ph/9905452
- Working example of interfacing production and decay in complex theoetical environment KKMC
- Coffee time discussions.
- Advice from BaBar, Belle may be useful ...

Conclusions

Technical problem:

Measurable/essential(?) Quantum-Mechanical Effects CAN NOT be defined as 'extended' properties of of particles. They need to be defined as multi-particle density matrices/spin amplitudes.

This counter intuitive effect is simply called paradox. It is also counter objective (c++^{TM}).

Imagine hot days of finding new effects in fresh data which can not be understood with the help of your software and you find that basic data structures classes etc etc need architectonical re-make ...

Will it take then days months or year(s)? That is the question.

Call for the backup solution.

Are there other non-classical-data-object phenomena?

Conclusions

QCD/hadronization

How the situation may look there?

What are the precison threshold which require re-thinking of data structures.

How good are the detectors?

K-factors enough?, LL enough?, pressure on theory builds up?,