TAUOLA Monte Carlo to help distinguish scalar from pseudoscalar Higgs

in tau decay channel

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- Interest in $e^+e^- \to H/A, X, n\gamma$, $H/A \to \tau^+\tau^-$.
- Requirements for the detector may be cruicial.
- Available tool, TAUOLA.
- Upgrade for transverse spin effects.
- Future upgrades, precision guarrantee.
- Numerical results.
- Code availability.

Slides are on http://home.cern.ch/wasm

Supported by the European Commission 5-th framework

contract HPRN-CT-2000-00149

Physics point

One of the possible signatures which can be used to distinguish between scalar $(J^{PC}=0^{++})$ and pseudoscalar $(J^{PC}=0^{-+})$ nature of Higgs(-like) particle may rely on transverse spin effects in decay $H/A \to \tau^+\tau^-;\ \tau^\pm \to \nu X^\pm$. For simplicity we will take $X^\pm=\pi^\pm$

Theoretical calculation

This possibility is known since long, see eg. M. Kramer et al. Z. Phys. C64 (1994) 21, but ...

Is it measurable?

Acknowledgement

Stimulating discussion with M. Ronan during ECFA/DESY in Cracow and later with M. Peskin were essential for this work to be started.

Detector requirements.

To ...

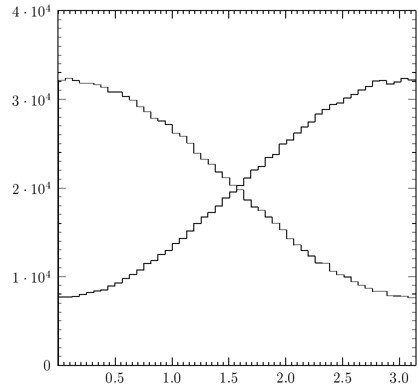
distingush scalar from pseudoscalar we have to:

1. Reconstruct Higgs rest-frame
2. Measure/reconstruct acolinearity angle in the Higgs rest-frame between charged decay products X^+, X^- of $H/A \to \tau^+\tau^-, \tau^\pm \to X^\pm \nu_\tau$
3. Do it all precisely enough ...

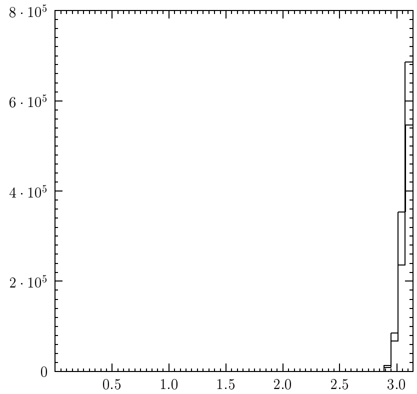
Detector requirements.

If we could reconstruct Higgs rest-frame ...

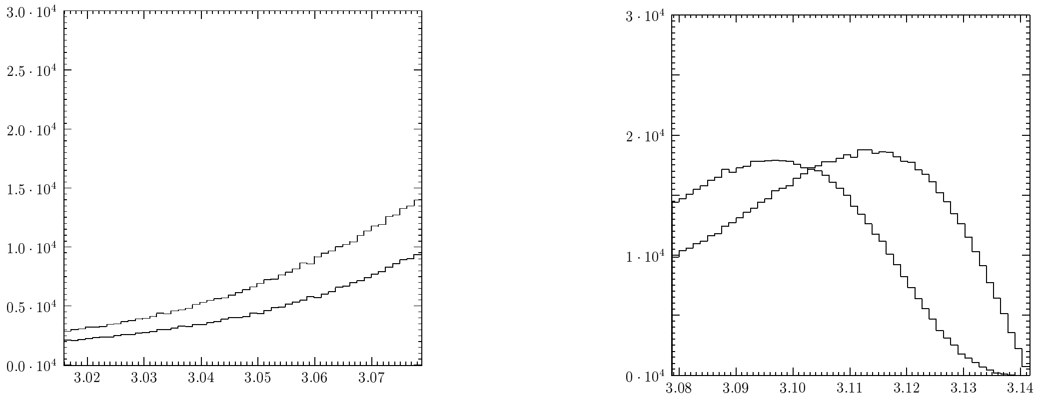
and even better τ-lepton momenta ...



Acoplanarity: ϕ^*



Acolinearity: δ^*



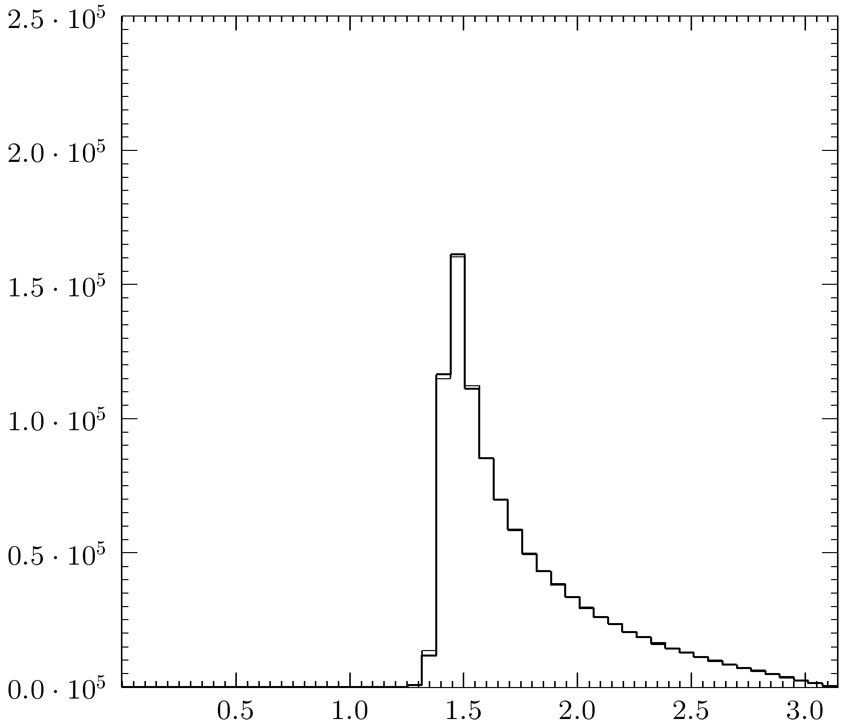
Acolinearity δ^*; regions close to π

All with arbirary high precision. Easy !!!

Thick lines for scalar and thin line for pseudoscalar are very different indeed, $m_H = 120GeV$**.**

Detector requirements.

Let us go now to the distribution in Lab frame



Acollinearity δ, defined in laboratory frame

It looks very different.

CMS 350 GeV, $e^+e^- \to ZH$, Transv. spin corr. on/off

Available tool

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.
- At present it is only in Fortan, no C++ implementation yet
- Difficulties to test due to different flavors of filling the HEPEVT common block
- Interaction user-authors essential at this step.
- No supersymmetric particles allowed in the cascade (yet)

PHOTOS for radiative corr. in decays.

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. $\tau \to e\nu\bar{\nu}\gamma$, $\tau \to \pi\nu\gamma$, $Z \to \mu^+\mu^-\gamma(\gamma)$, $gg \to t\bar{t}\gamma\gamma$.

TAUOLA Monte Carlo for τ decays.

1. R. Decker, S.Jadach, M.Ježabek, J.H.Kuhn, Z. Was, Comput. Phys. Commun. 76 (1993) 361, ibid. 70 (1992) 69, ibid. 64 (1990) 275
2. P. Golonka, Z. Was, TPJU 10/2000, technical stuff only.
3. Alain Weinstein www home page: http://www.cithep.caltech.edu/˜ajw/korb_doc.html#files
4. B. Bloch, private communications.
5. R. Decker, M. Finkemeier, P. Heiliger and H.H. Jonsson, Hep-ph/9410260, now standard 4π formfactors.
6. P. Abreu et al., Phys. Lett. B426 (1998) 411 (alternative 3π formfactors)
7. Sherry Towers aternative formfactors in K$\pi\pi$ modes, hep-ex/9908013

Transverse spin.

It was easy to install in **universal interface** because:

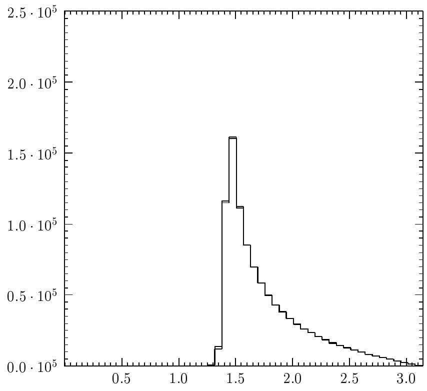
- Example solution available since 15 years: `KORALB`
- Final state radiation (in Higgs decay) can be generated with the help of universal algorithm such as `PHOTOS`
- Higgs boson has spin zero, no need to calculate its polarization state
- Solution independent of production mechanisms, work always.

Future upgrade line

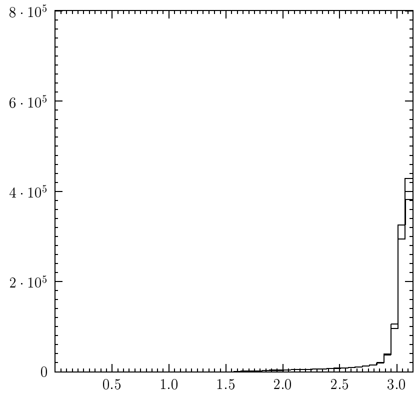
- Development line for precision level of 0.1 % or even better is ready
- see papers by S. Jadach et al. on `KKMC`, `YFSWW`, `KORALW` etc.

Spin effects in $e^+e^- \to H/A \to \tau^+\tau^-$

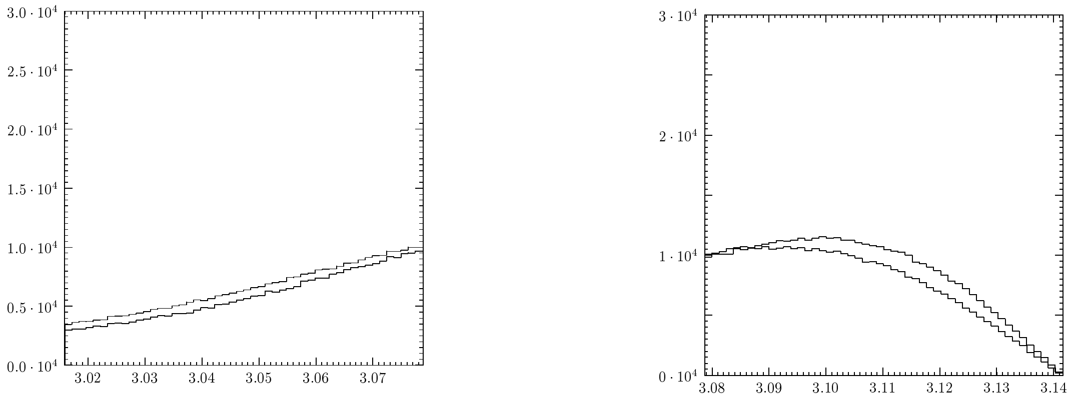
Example of detector-like effect



Acollinearity. (Lab): δ



Acol. (reconstr. H RF.).



Acolinearity $\delta^\bullet$ in reconstr. H RF; regions close to π

CMS 350 GeV, $e^+e^- \to ZH$, Transv. spin corr. on/off. Uniform smearing in H momentum over the range: $\pm 2GeV$ for p_T and $\pm 5GeV$ for p_{Long}.

Conclusions

Transverse spin effects are in:

- for the universal interface of τ decay library TAUOLA and τ leptons originating from scalar/pseudoscalar Higgs boson
- In most SM cases longitudinal spin effects are included
- Case of τ leptons originating from supersymmetric particles need improvements
- Studies of the precision are not done but are straightforward, as well as improvements.
- FORTRAN solution exists at present. Extension to C++ and/or Java requires established data structure for event record.
- At present code available upon request only. Need to keep user author link for tests. Question of flavors of HEPEVT filling by production programs.

For code ask zbigniew.was cern.ch or
gosia friend.phys.us.edu.pl