Testing the Higgs boson's parity
using $\tau \rightarrow \rho\nu$
status report

on the basis of CERN-TH/2002-054, SLAC-PUB-9154
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Main Topics:

- **Higgs parity.**
- **Classical approach $\tau \rightarrow \pi\nu$.**
- **Why not $\tau \rightarrow \rho\nu$?**
- **Properties of the decay and production**
- **New observable**
- **Conclusion**

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

Paper is not yet out, because all look better than we thought !

Introduction

Any LC aim to measure Higgs boson parity

1. There are many possibilities of the measurement.
2. There are many scenarios of Higgs mechanism: SM, MSSM, ...
3. We will concentrate on $H \to \tau^+\tau^-$ as the data point

We will use:

Universal interface of τ decay library TAUOLA, which can decay τ leptons originating from (pseudo-)scalar Higgs boson including full spin effects.

Note

Physics of the Higgs boson decay is independent from the production and defined by its parity only.

Introduction

Density matrix

Only transverse spin correlations between τ^+ and τ^- are different for scalar and pseudoscalar Higgs

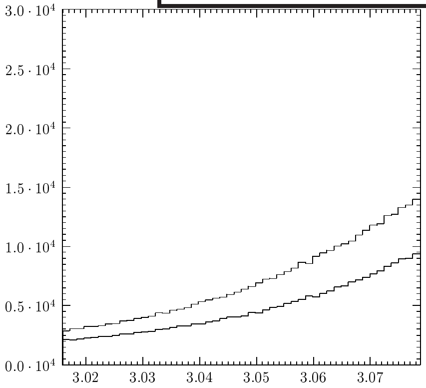
- The correlations can not be measured directly
- One need to measure distributions of τ decay products
- More precisely their transverse (to τ direction in Higgs boson rest frame) momenta
- Most sensitive to spin is $\tau^\pm \to \pi^\pm \nu$
- The largest branching ratio (23 %) has $\tau^\pm \to \pi^\pm \pi^0 \nu$

Classic approach

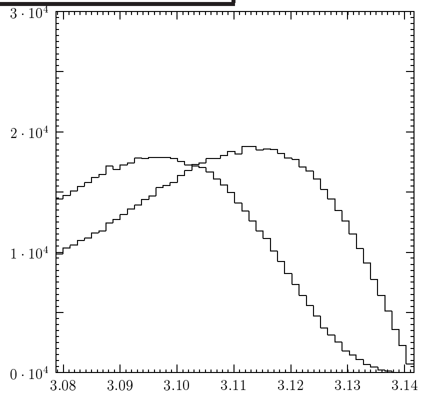
We take the most sensitive to spin $\tau^\pm \to \pi^\pm \nu$ decay channels and we look at $\pi^+\pi^-$ acollinearity in **Higgs boson rest-frame**.

We will reproduce analytical result of Kramer et al first. All later results will be cross checked by two Monte Carlo programs PANDORA by M. Peskin and tauola universal interface by P. Golonka, T. Pierzchala, E. Richter-Was, Z. Was and M. Worek.

Generator level look fine:

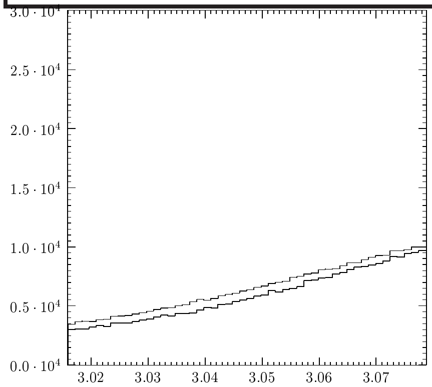


Acolinearity: δ^*

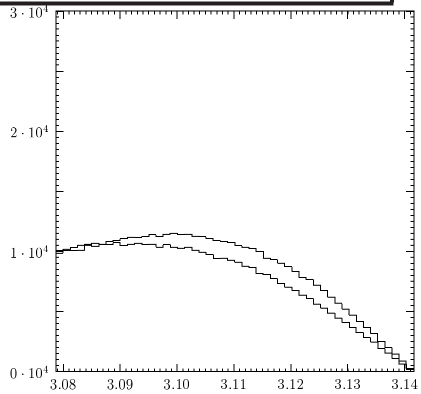


Acolinearity: δ^*

But once detector smearings are in ...



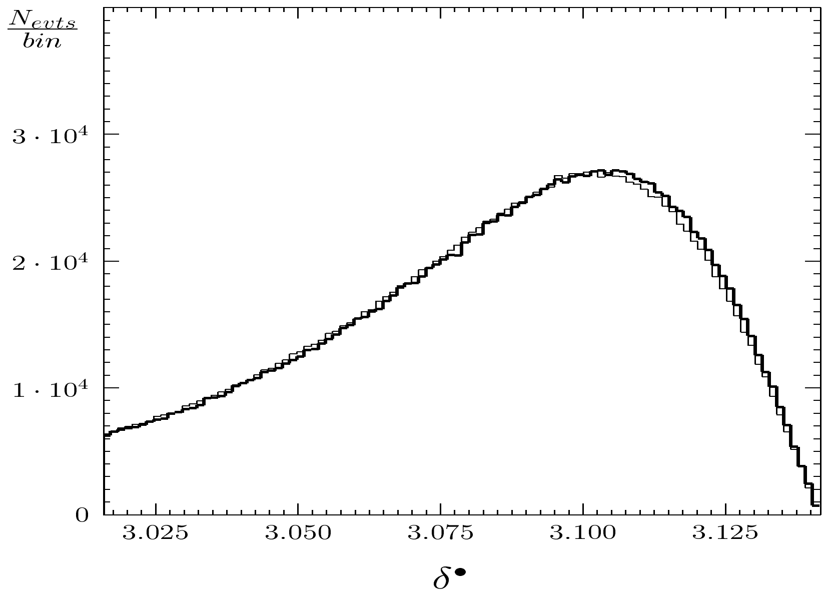
Acol. (rec. H): δ



Acol. (rec. H): δ

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

Let us look at $\tau^\pm$ decay to $\rho^\pm \nu$



Acollinearity for scalar and pseudoscalar look indisuishable

$\tau \to \pi\nu$-decay channel looks tough

$\tau \to \rho\nu$-decay channel looks hopeless

Doubts

Inspiration was needed

- Measurements of tau polarization at LEP 1
- Tests of anomalous couplings
- Why resonstruct Higgs boson rest frame?
- Why calculate acollinearity ?
- Why not get something better for Higgs as well.

Observable in the **rest frame of $\rho^+\rho^-$ pair.**

• Acoplanarity of two planes spanned respectively on decay products of $\rho^+ \to \pi^+\pi^0$ and $\rho^- \to \pi^-\pi^0$

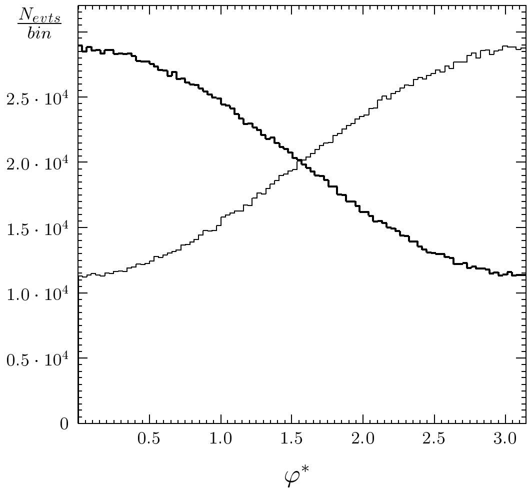
•**price to pay:** cases when $y_1y_2 > 0$ and $y_1y_2 < 0$ must be kept separatelly;

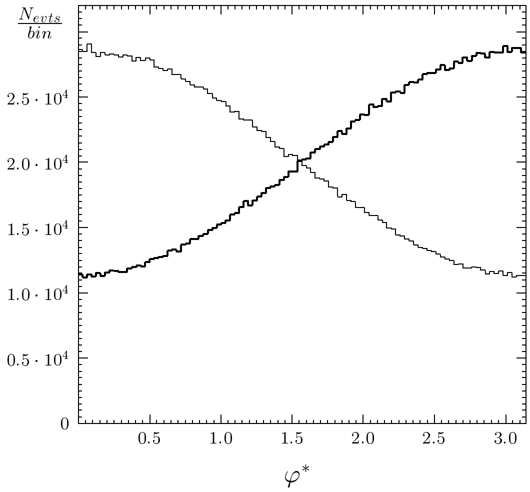
• $y_{1,2} = \frac{E_{\pi^{+,-}} - E_{\pi^0}}{E_{\pi^{+,-}} + E_{\pi^0}}$; energies defined in respective τ rest-frames.

Status January 15, 2002

New observable

Test at generator level looks good



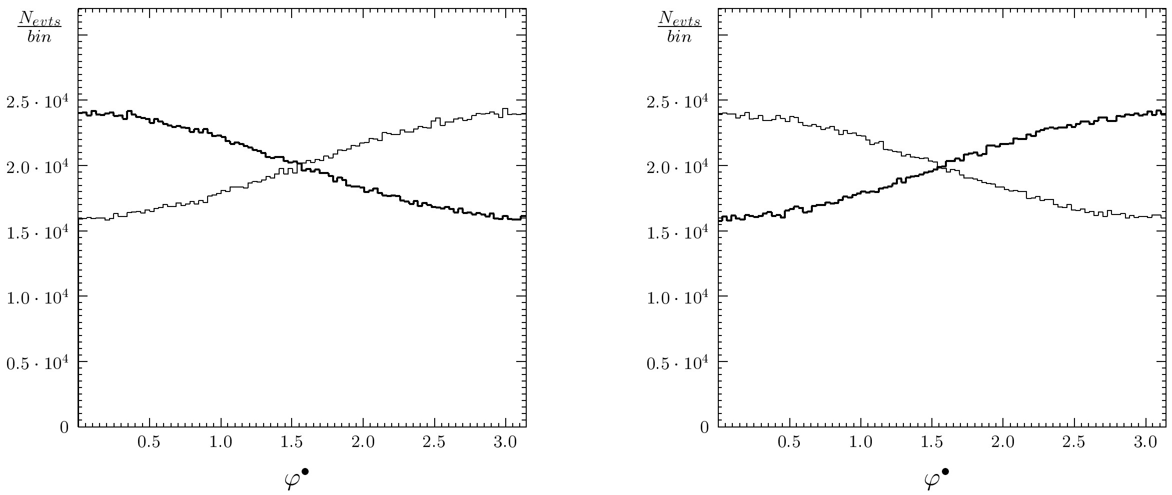


Scalar Boson Thick line, pseudoscalar thin line

Status February 15, 2002

New observable

Reconstructed momenta used



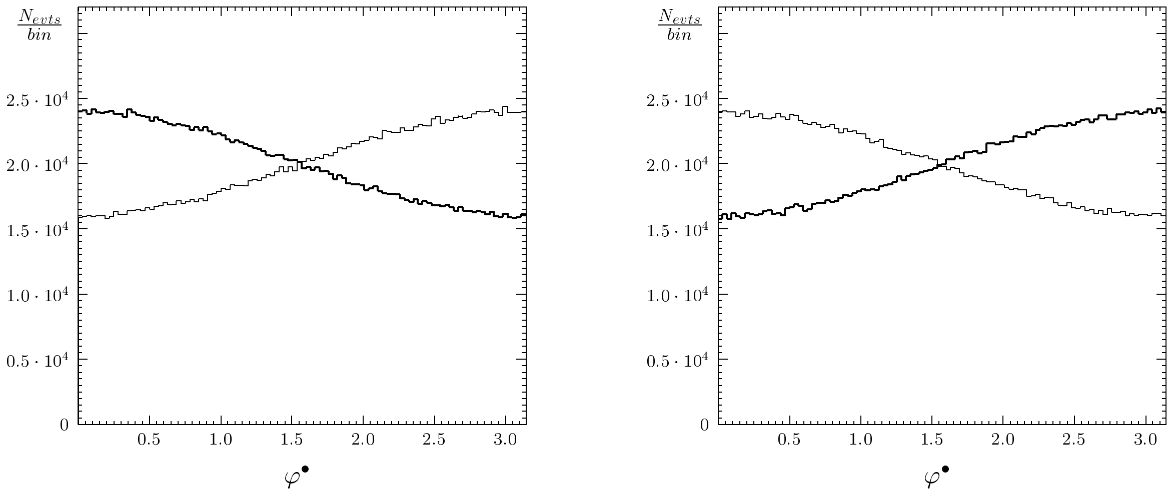
Scalar Boson Thick line, pseudoscalar thin line

Instead of generator level $y_{1,2} = \frac{E_{\pi^{+,-}} - E_{\pi^0}}{E_{\pi^{+,-}} + E_{\pi^0}}$ complicated (but realizable in practice!) procedure was used. Reconstruction of Higgs boson momentum from total energy momentum conservation was used.

Status March 15, 2002

New observable

Test at generator level looks good



Instead of generator level $y_{1,2} = \frac{E_{\pi^{+,-}} - E_{\pi^0}}{E_{\pi^{+,-}} + E_{\pi^0}}$

The following procedure was used to reconstruct $\pi^\pm$ π^0 energies in τ lepton rest-frames: (i) we first boost the reconstructed $\pi^\pm$ π^0 momenta to reconstructed rest-frame of the $\rho^\pm$-pair. (ii) Then, in that frame, we define reconstructed $\tau^\pm$ four-momenta. (iii) As energy we take the half of the Higgs boson mass and we use τ mass constraint to fix momentum normalization. (iv) Finally, for the direction, we use directions of the $\rho^\pm$. Status April 7th

New observable

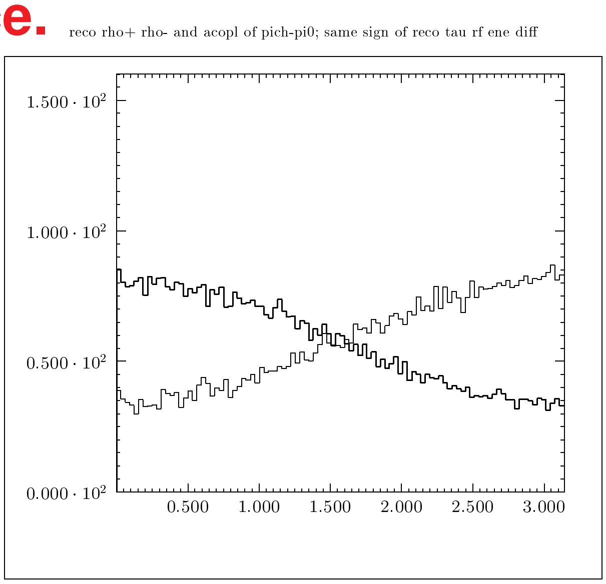
Smearing parameters:

1. **charged pion momentum:** We assume 0.001 spread on its energy and spherical coordinates.

2. **neutral pion momentum:** We assume spread of energy $\frac{5\%}{\sqrt{E[GeV]}}$. For θ and ϕ angular spread we take $\frac{1}{3}\,\frac{2\pi}{1800}$.

All spreads were assumed to be gaussian.

Another optimalization, weighted events $wt = |y_1 \cdot y_2|$. Probably gain of about factor 1.5 in significance.



Status of April 9 ...

Summary

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

Transverse spin effects can be used to distinguish scalar from pseudoscalar at LC .

Preliminary study show that the method look promising and results remain quite stable over assumption on detector smearings etc.

Results are preliminary, but cross checked by two fully independent simulations.

Statistical analysis of the observable is not performed, but it is straightforward.

Discussion of effects such as bremsstrahlung, etc. is missing.

all necessary Monte Carlo tools are available. see my talk on Monte Carlo session.

Subject is fresh.

but ur paper is already out: hep-ph/0204292