The two-year anniversary of the pheno group at the VUB

- A 5-year GOA (Geconcentreerde Onderzoeksactie) project on "Supersymmetric models and their signatures at the LHC" since October, 2010
  - Ben Craps, Alexander Sevrin, Alberto Mariotti (theory)
  - Catherine De Clercq, Jorgen D'Hondt (experiment)
  - Fabio Maltoni (pheno) - CP3/UCL
- The main goal of the project is
  - to establish a complete chain from fundamental theory to experiment.
  - to use this chain to study possible signatures of SUSY models at the LHC.
- Pheno members
  - Kentarou Mawatari (from U. Heidelberg) - Project leader
  - Phillip Grajek (from KEK, Japan) - PD since 2010
  - Priscila de Aquino (from UCL) -PD since 2012
  - Bettina Oexl (from U. Tuebingen) - PhD since 2010
  - Karen De Causmaecker (from U. Ghent) - PhD since 2011
  - Thomas in't Veld (from U. Leuven) - master student in Leuven

MadGraph BSM Meeting in Vrije Universiteit Brussel 2010

The MadGraph 2010 fall meeting will be hosted by the Vrije Universiteit Brussel (VUB) at the Inter-university Institute for High Energies (IIHE), where Kentarou and Phil will be starting in Oct 2010. This is also a chance for the team to share ideas and discuss projects related to BSM and in particular SUSY which is the main research theme of the new born GOA initiative.

Agenda

Indico agenda here

Participants (all confirmed)

1. Priscila de Aquino (UCLouvain)
2. Céline Degrande (UCLouvain)
3. Claude Duhr (IPPP)
4. Benjamin Fuks (Univ. Strasbourg)
5. Phil Grajek (VUB)
6. Kaoru Hagiwara (KEK)
7. Junichi Kanzaki (KEK)
8. Qiang Li (PSI)
9. Fabio Maltoni (UCLouvain)
10. Olivier Mattelaer (UCLouvain)
11. Kentarou Mawatari (VUB)
12. Tim Stelzer (UIUC)
13. Yoshitaro Takaesu (KEK)
14. Paolo Torrielli (EPFL)
15. Marco Zaro (UCLouvain)
16. Adam Alloul (Univ. Strasbourg)
17. Guillame Serret (Univ. Strasbourg)
18. Hiroshi Yokoya (Univ. Strasbourg)

+ Jorgen, Alexis, Ben, Alex, Alberto, ...anybody interested in the morning talks from VUB/ULB/UCL...!

TauDecay: a library to simulate polarized tau decays via FR and MG5

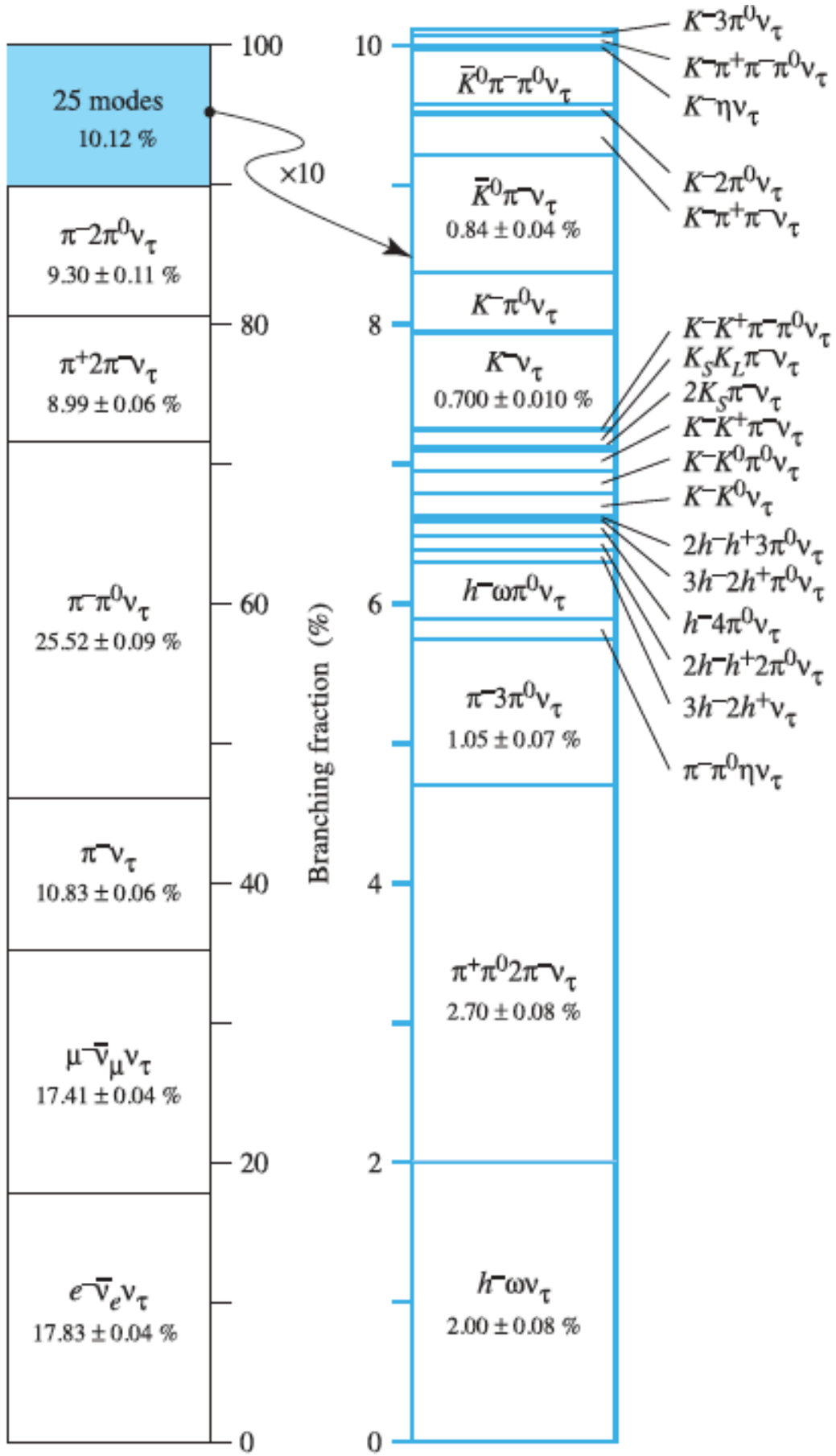
Kentarou Mawatari

Vrije Universiteit Brussel

[arXiv:1210.XXXX], in collaboration with
Kaoru Hagiwara, Junya Nakamura (KEK, Japan)
Tong Li (Monash U., Melbourne)

Outlines

- Effective vertices for hadronic tau decays
- Validation: TauDecay vs. Tauola
- Physics applications



Effective vertices for hadronic tau decays

$$\pi \text{ mode}: \quad \tau^- \to \nu\pi^-,$$
$$\rho \text{ mode}: \quad \tau^- \to \nu\rho^- \to \nu\pi^-\pi^0,$$
$$a_1 \text{ mode}: \quad \tau^- \to \nu a_1^- \to \nu\pi^0\rho^- \to \nu\pi^0\pi^0\pi^-,$$
$$\tau^- \to \nu a_1^- \to \nu\pi^-\rho^0 \to \nu\pi^-\pi^-\pi^+.$$

$$\mathcal{L}_\pi = \sqrt{2}G_F f_1\, \bar{\tau}\gamma^\mu P_L \nu_\tau\, \partial_\mu \pi^- + h.c.$$

$$f_1 = f_\pi \cos\theta_C$$

$$\mathcal{L}_\rho = \sqrt{2}G_F f_2\, \bar{\tau}\gamma^\mu P_L \nu_\tau\, (\pi^0 \partial_\mu \pi^- - \pi^- \partial_\mu \pi^0) + h.c.$$

$$f_2 = \sqrt{2}\cos\theta_C F_\rho(Q^2)$$

$$F_\rho(Q^2) = [B_\rho(Q^2) + \alpha B_{\rho'}(Q^2)]/(1+\alpha)$$

$$B_V(Q^2) = \frac{m_V^2}{Q^2 - m_V^2 + i\sqrt{Q^2}\Gamma_V(Q^2)}$$

Effective vertex for a_1

The effective vertex, or the decay amplitude, for the a_1 mode is

$$\mathcal{M}_{a_1} = \sqrt{2} G_F \, \bar{\tau} \gamma^\mu P_L \nu_\tau \, J_\mu, \tag{13}$$

where the hadronic current J^μ is given by [8,9]

$$J^\mu = f_3 \left[F^{13} (q_1^\mu - q_3^\mu - G^{13} Q^\mu) + (1 \leftrightarrow 2) \right] \tag{14}$$

with $Q = q_1 + q_2 + q_3$ for $\tau^- \to \nu \pi^-(q_1) \pi^-(q_2) \pi^+(q_3)$.

The form factors are

$$f_3 = \frac{4}{3 f_\pi} \cos\theta_C B_{a_1}(Q^2), \tag{15}$$

$$F^{i3} = F_\rho(Q^2_{i3}), \quad G^{i3} = \frac{Q \cdot (q_i - q_3)}{Q^2}, \tag{16}$$

[1] INPUT option of the function WRITEUFO in FR allows us to include such a vertex [5].

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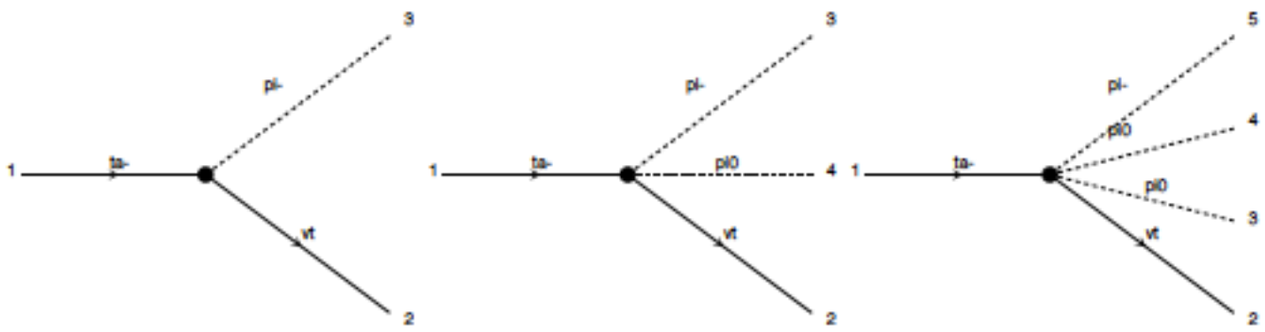


Validation: TauDecay vs. Tauola

π mode : $\tau^- \to \nu\pi^-$,

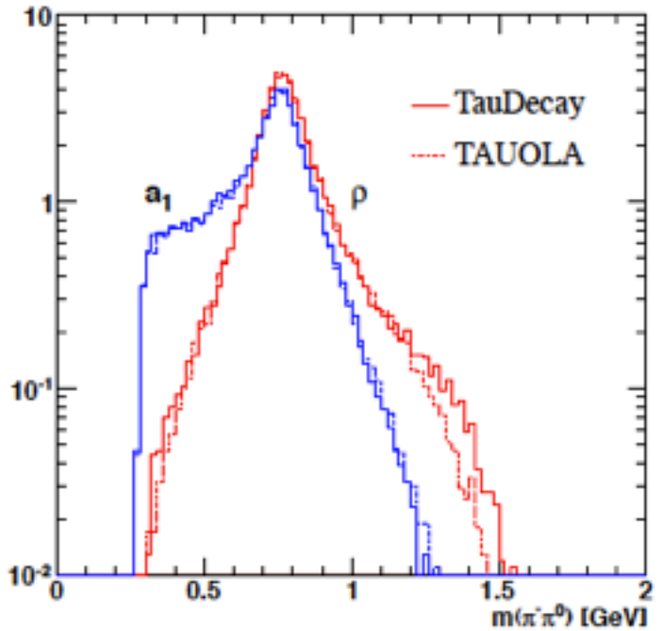
ρ mode : $\tau^- \to \nu\rho^- \to \nu\pi^-\pi^0$,

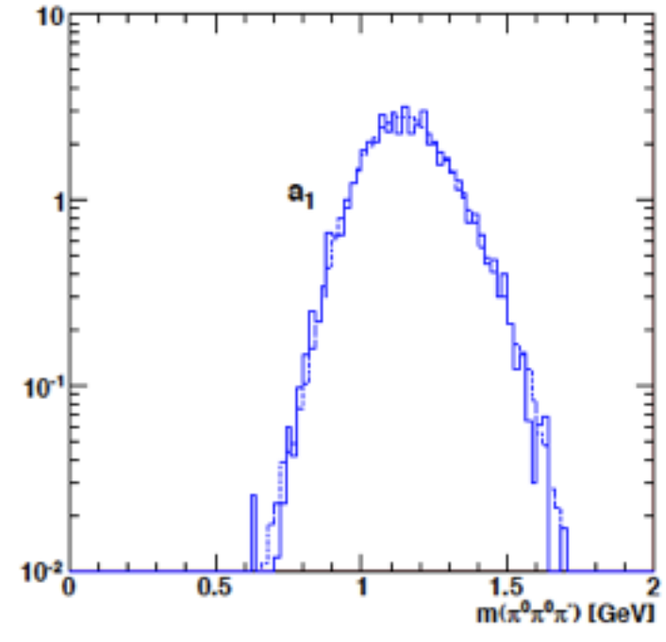
a_1 mode : $\tau^- \to \nu a_1^- \to \nu\pi^0\rho^- \to \nu\pi^0\pi^0\pi^-$,

$\tau^- \to \nu a_1^- \to \nu\pi^-\rho^0 \to \nu\pi^-\pi^-\pi^+$.

mode	width [10^{-13} GeV]		
	PDG [2]	TAUOLA [10]	TauDecay
$e^-\bar{\nu}$	4.04	4.02	4.04
$\mu^-\bar{\nu}$	3.94	3.91	3.94
π^-	2.45	2.47	2.42
$\pi^-\pi^0$	5.78	5.39	5.39
$\pi^0\pi^0\pi^-$	2.11	2.25	2.27
$\pi^-\pi^-\pi^+$	2.04	2.21	2.22

Table 3. τ decay partial widths.





Polarized tau decays

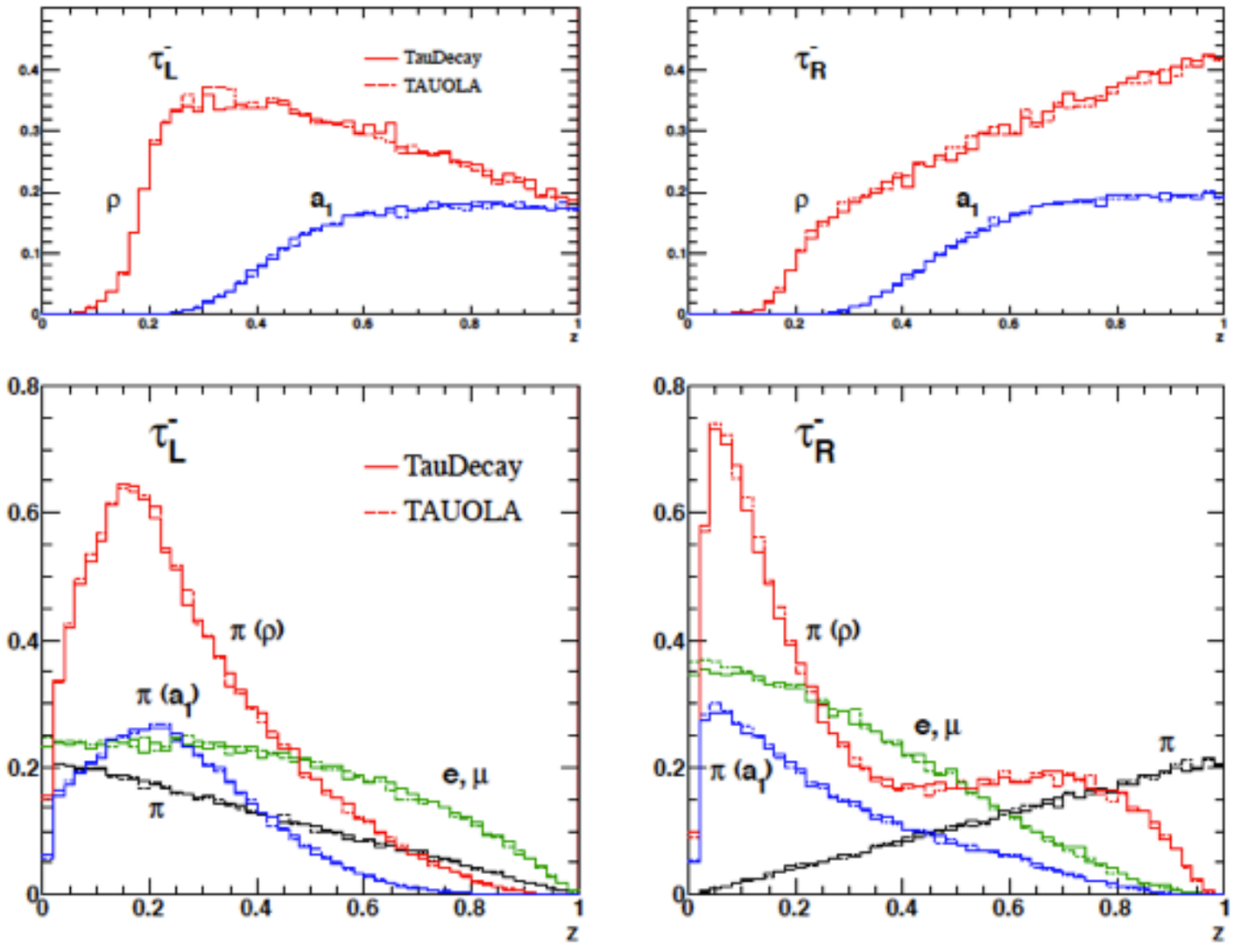
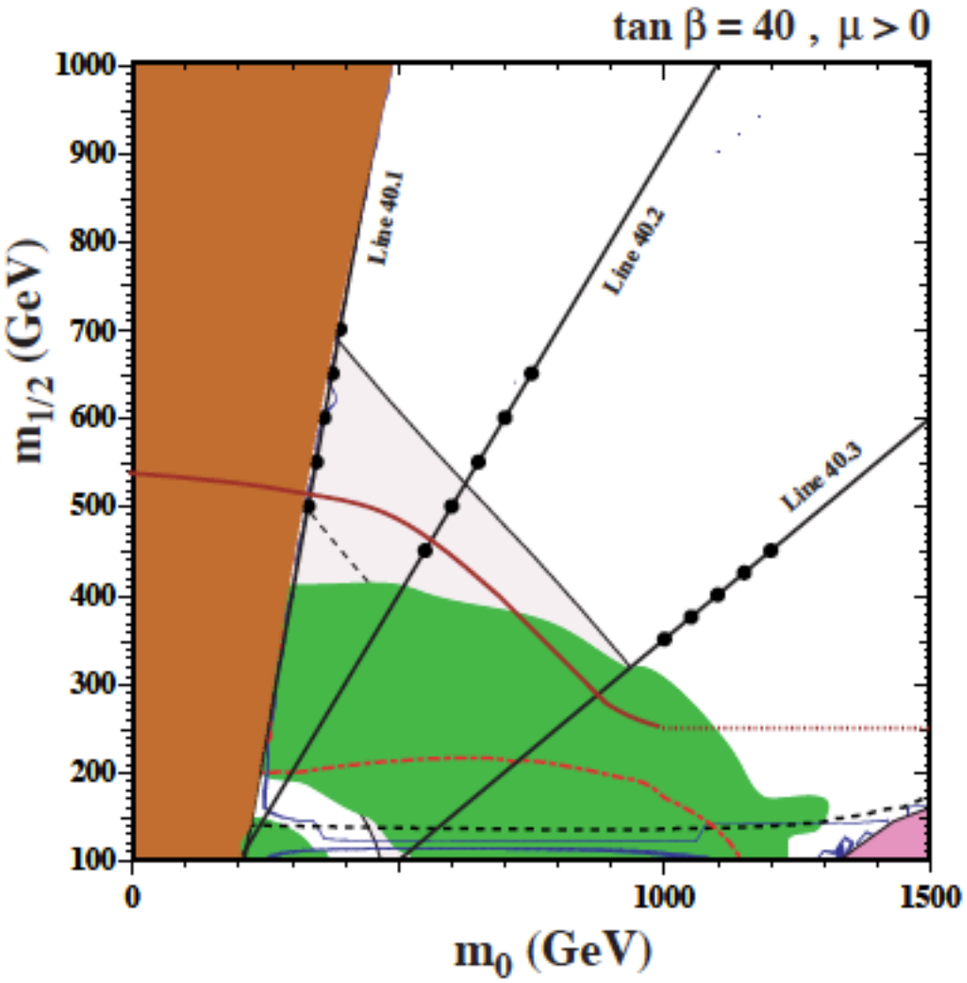


Fig. 3. The fractional energy distributions of ρ and a_1 (top) and 1-prong π^- (bottom) from left-handed τ^- (left) and right-handed τ^- (right) at $E_\tau = 50$ GeV, normalized to the respective branching ratios. The leptonic decay mode is also shown.

Physics applications: off-shell tau decays

[arXiv:1109.3859]



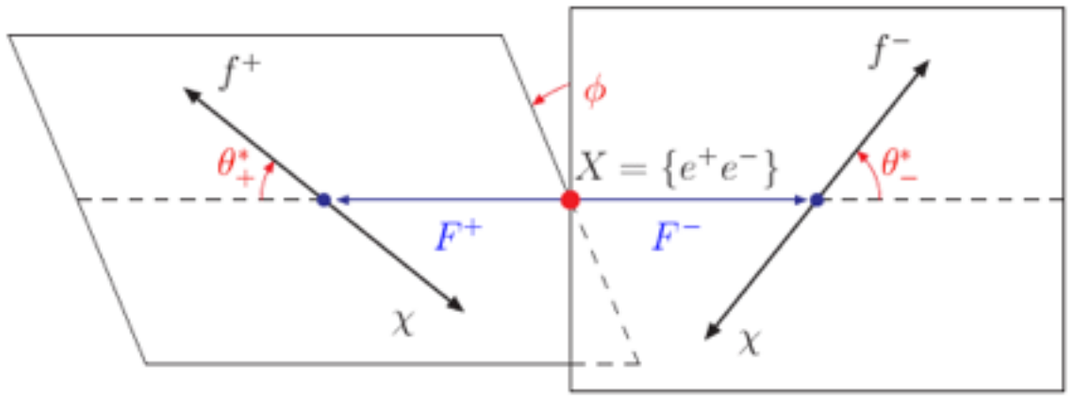
cmssm40.1.2

```
1000014     5.00310058E+02   # ~nu_muL
1000015     2.30320133E+02   # ~tau_1
2000015     4.81537785E+02   # ~tau_2
1000016     4.52844297E+02   # ~nu_tauL
1000021     1.25843315E+03   # ~g
1000022     2.28690867E+02   # ~chi_10
1000023     4.35799527E+02   # ~chi_20
```

```
#         PDG            Width
DECAY   1000015    0.00000000E+00   # stau_1 decays
#
#         PDG            Width
DECAY   2000015    2.82697315E+00   # stau_2 decays
#          BR         NDA      ID1       ID2
     1.65666959E-01    2     1000022        15   # BR(~tau_2 -> ~chi_10  tau-)
     1.82867770E-02    2     1000023        15   # BR(~tau_2 -> ~chi_20  tau-)
     3.45180868E-02    2    -1000024        16   # BR(~tau_2 -> ~chi_1-  nu_tau)
     3.14392734E-01    2     1000015        25   # BR(~tau_2 -> ~tau_1   h)
     4.67135443E-01    2     1000015        23   # BR(~tau_2 -> ~tau_1   Z)
#
```

Physics applications: spin correlations

- (trivial) helicity correlation



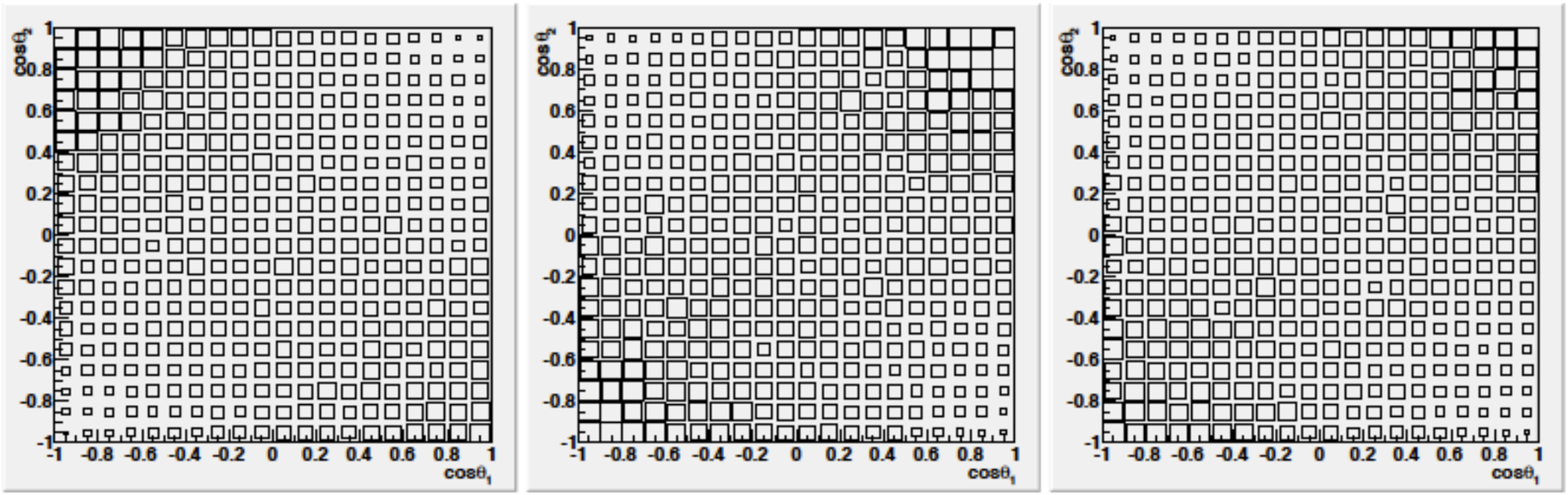


Fig. 6. $\cos\theta_1$-$\cos\theta_2$ correlation in $pp \to X \to \tau^-(\to \pi^-\nu)\tau^+(\to \pi^+\bar{\nu})$ for $X = Z$ (left), H (middle), and A (right).

Physics applications: spin correlations

- (non-trivial) polarization correlation

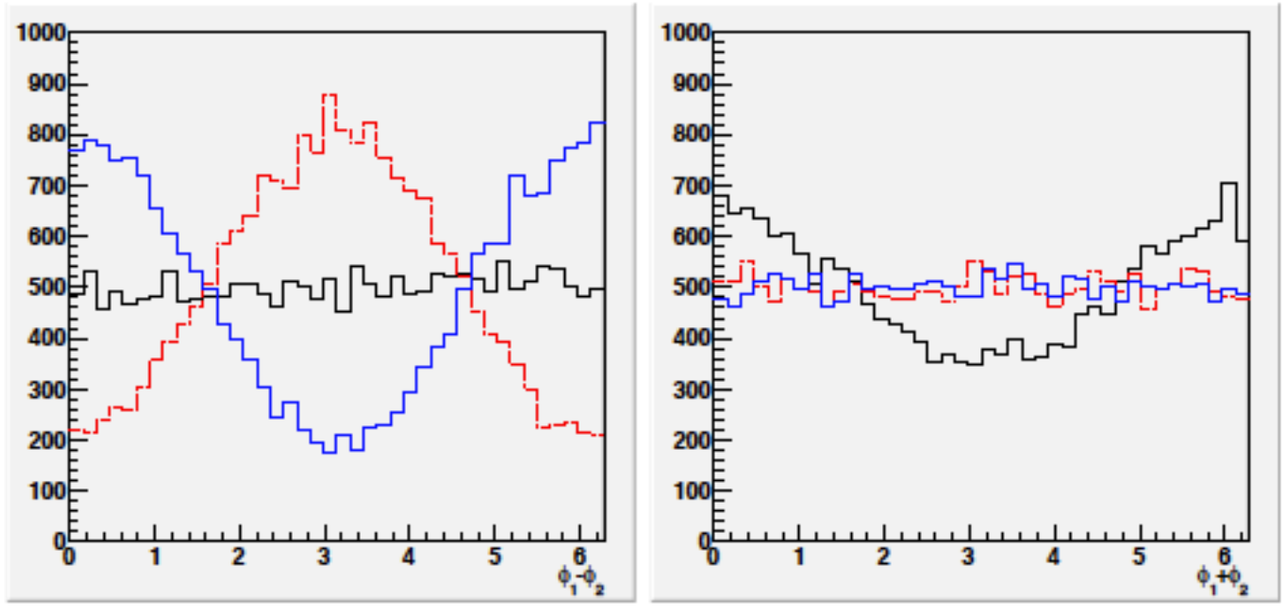


Fig. 10. Azimuthal angle correlations, $\phi_1-\phi_2$ (left) and $\phi_1+\phi_2$ (right), in $pp \to X \to \tau^-(\to \pi^-\nu)\,\tau^+(\to \pi^+\bar{\nu})$ for $X = Z$ (black-solid), H (red-dashed), and A (blue-dotted).