Update on the MELA hypothesis test

Nello Bruscino

Università degli Studi di Napoli “Federico II” & INFN di Napoli

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On behalf of the MEGA group:
N. Bruscino, F. Cirotto, F. Conventi, C.Dionisi, S. Giagu, G. Gustavino, V. Ippolito, C. Maiani, M. Rescigno, E. Rossi + ANL/UC Chicago

Outline

Updated Hypothesis tests:

Reminder:

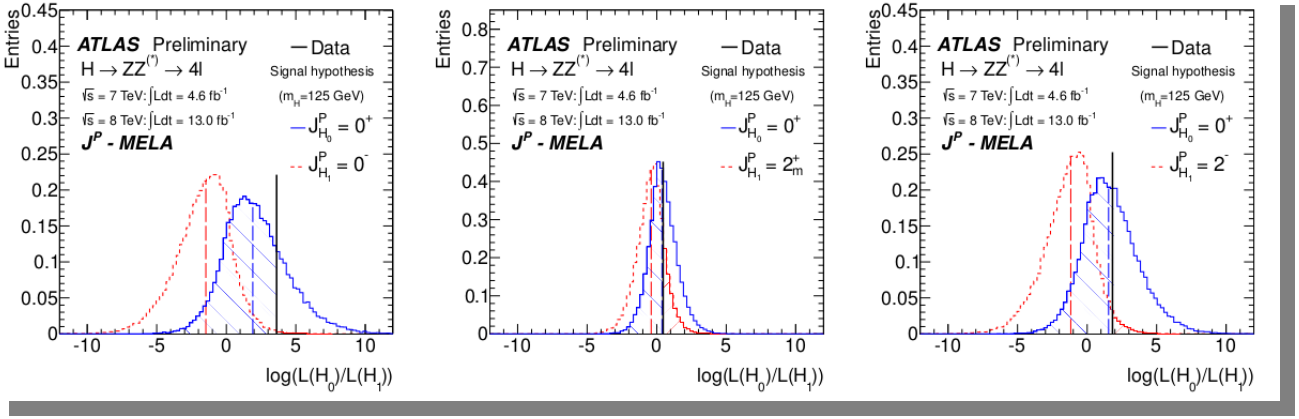
- latest results on hypothesis test (MELA)

new 2^-_h samples:

- recostructed/truth distributions
- WP/RP fraction
- closure test, $cos(\theta^*)$ disagreement
- investigate Collins-Soper rest frame
  partial results

Reminder

Latest results on hypothesis test (MELA)



expected/observed CLs change as follows:

test	CL_S (exp)	CL_S (obs)
0^+ vs 0^-	99.8 %	99.4 %
0^+ vs 1^+	99.6 %	99.4 %
0^+ vs 1^-	99.9 %	95.7 %
0^+ vs 2^+	91.4 %	79.3 %
0^+ vs 2^+ (25% qq)	90.0 %	88.3 %
0^+ vs 2^+ (50% qq)	90.6 %	93.5 %
0^+ vs 2^+ (75% qq)	91.4 %	95.4 %
0^+ vs 2^+ (100% qq)	90.7 %	94.1 %

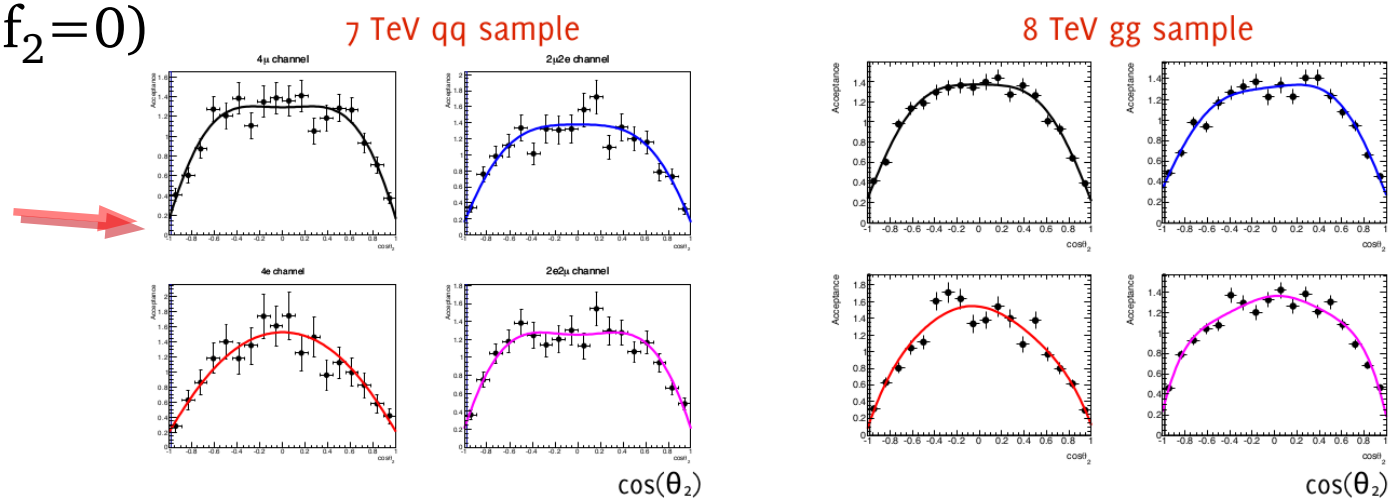
workspaces published on /afs/cern.ch/atlas/groups/HSG2/H4l_2013/Moriond/workspaces_spincp/MELA

New 2^-_h samples

added new 2^-_h samples:

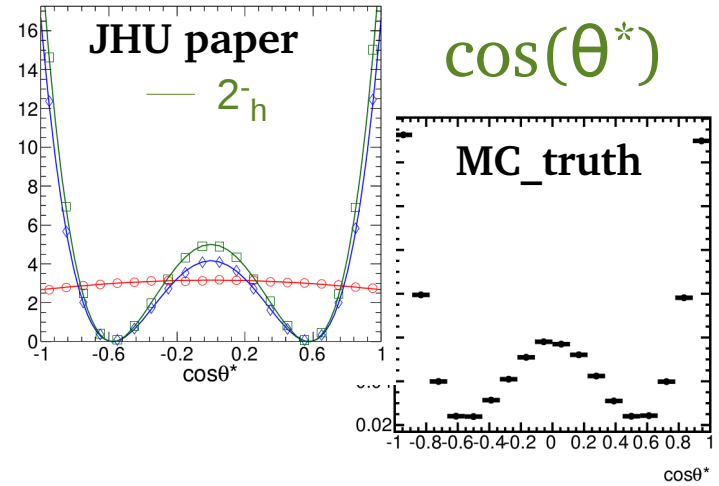
- run 4l selection on the 2-h MC JHU samples
- add $g_i(2^-_h)$ to build MELA pdf
  gg/qq→H: pseudo-tensor, $g_8=1$
  ($f_0=1$ or 0, $f_1=0$ or 1, $f_2=0$)
- acceptances for both 7 and 8 TeV samples ready

2^+_m	2^-	2^-_h	2^-_h (f_{qq}=100%)
$g_1=g_5=1$	$g_8=g_9=1$	$g_8=1$	$g_8=1$
$f_0\neq0$	$f_0=0$	$f_0=1$	$f_0=0$
$f_1=0$	$f_1=0$	$f_1=0$	$f_1=1$
$f_2\neq0$	$f_2=1$	$f_2=0$	$f_2=0$

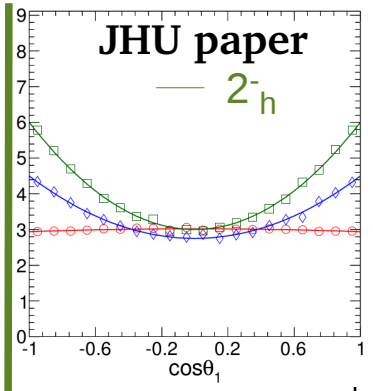


ready to run full hypothesis testing machinery

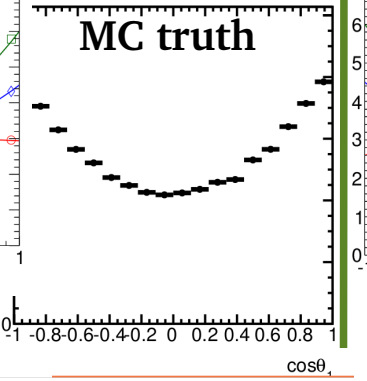
Truth angular distributions

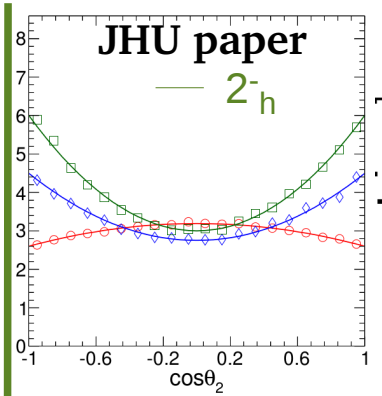


$\cos(\theta^*)$

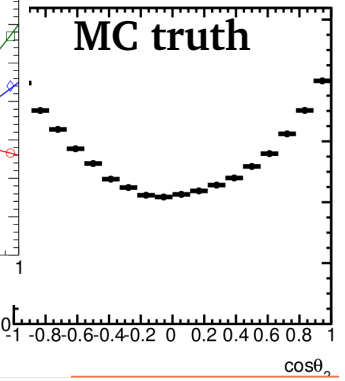


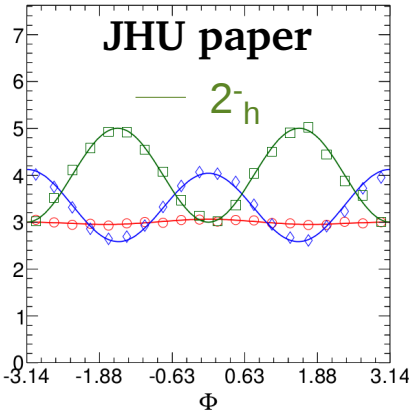
$\cos(\theta_1)$



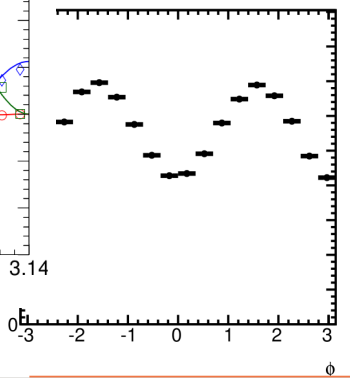


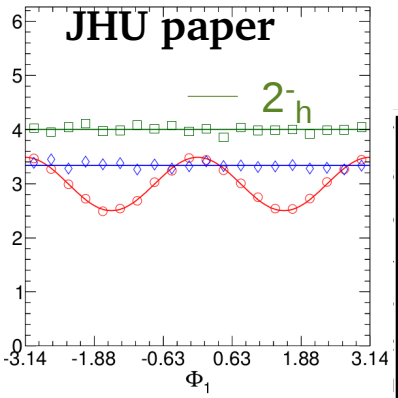
$\cos(\theta_2)$



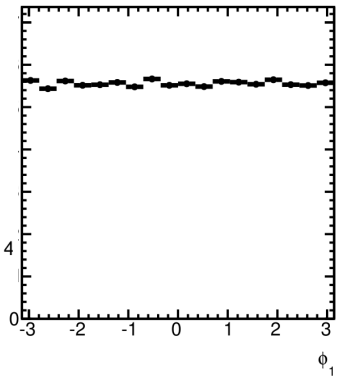


φ





φ_1

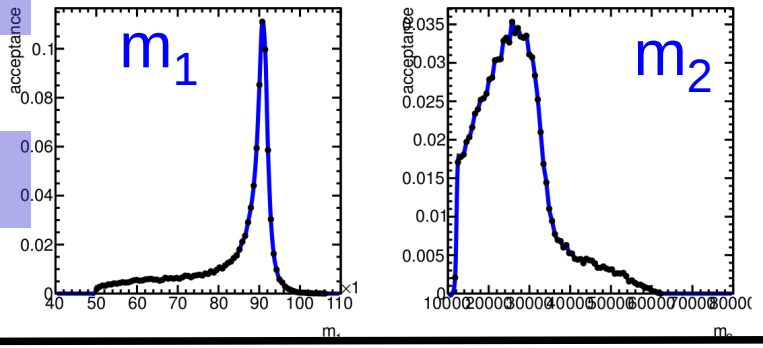


✔ MC truth distributions are in <u>good agreement</u> with JHU theoretical paper: **2^-_h production OK**!

New 2^-_h samples

0^+

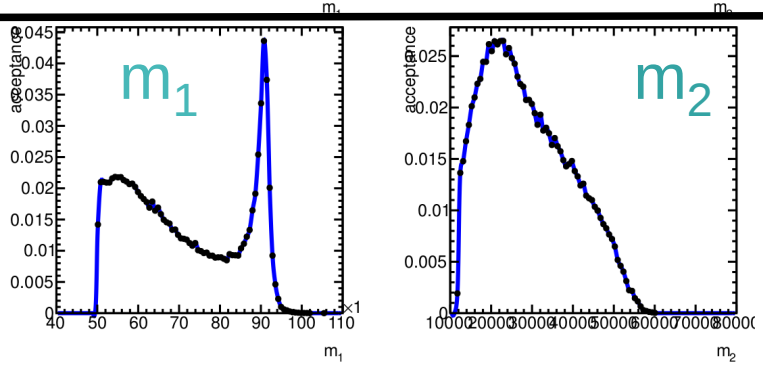
	GP (fraction)	WP (fraction)
4mu	8034 (90.8%)	817 (9.2%)
2m2e		
2e2mu		
4e	4240 (89.8%)	480 (10.2%)



Good-pair and wrong-pair fractions:

the kinematics of spin 2^-_h involves, downstream of the selection, a WP fraction very high compared to "standard" cases.

Applying the signal selection, the wrongpair fraction for 2^-_h samples results ≈50% ("usual" WP fraction).



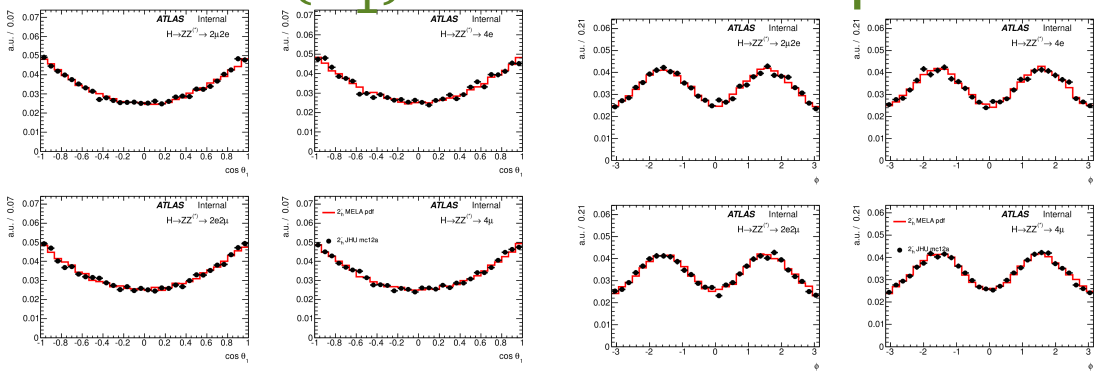
2^-_h

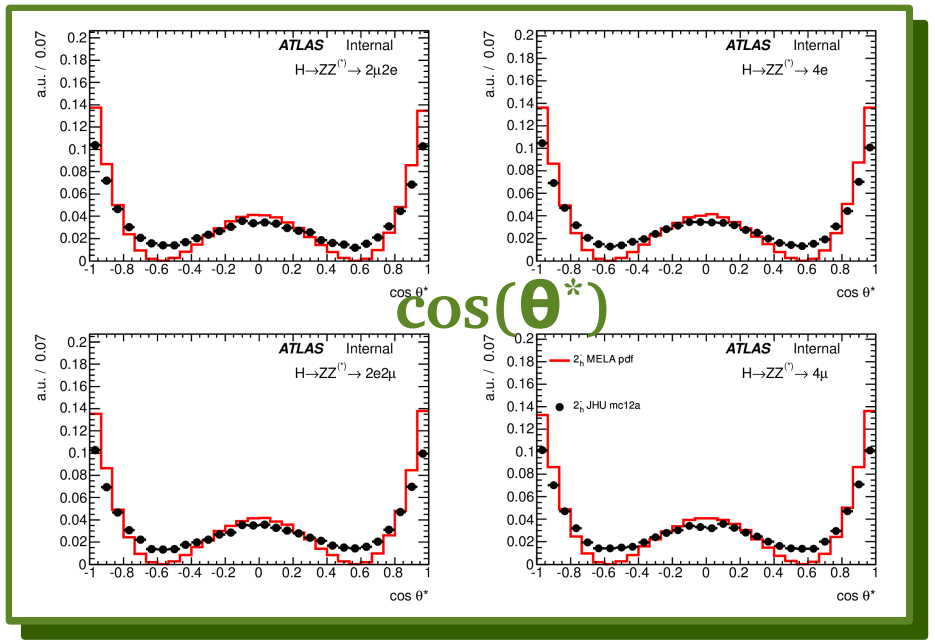
	GP (fraction)	WP (fraction)
4mu	9498 (53.8%)	8166 (46.2%)
2m2e		
2e2mu		
4e	4109 (52.0%)	3787 (48.0%)

New $2^-_h(f_{qq}=0\%)$ samples:closure test

First check: **closure test** for new spin cases

$\cos(\theta_1)$ φ





$\cos(\theta^*)$

Compare **pdf(MELA)** to **MC JHU truth** distribution.
GOOD agreement in almost all closure tests:
some discrepancies in $\cos(\theta^*)$.

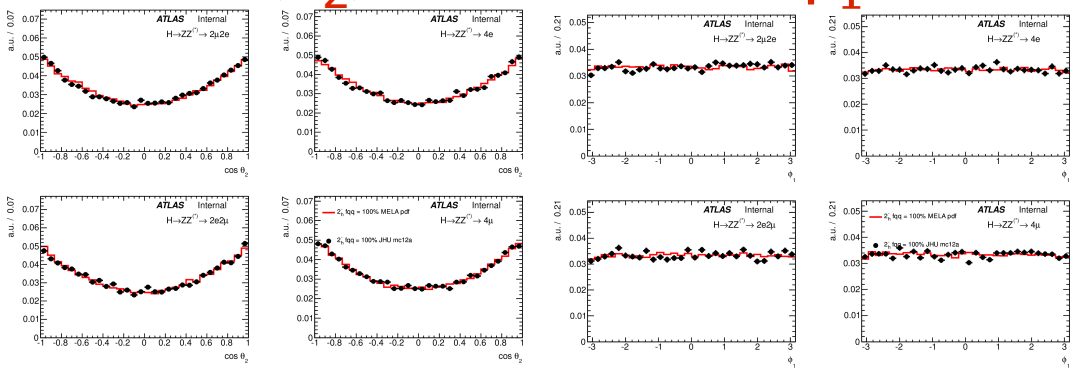
Truth selection (2013):

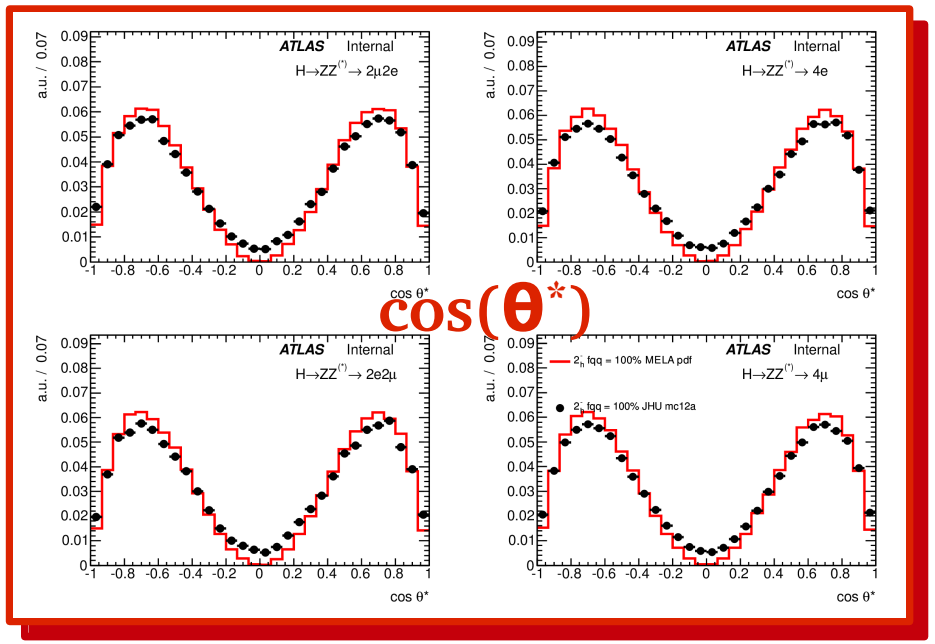
$50\ \text{GeV} < m_{12} < 106\ \text{GeV}$
$12\ \text{GeV} < m_{34} < 115\ \text{GeV}$
$115\ \text{GeV} < m_{4l} < 130\ \text{GeV}$

New 2^-_h (f_{qq}=100%) samples: closure test

First check: **closure test** for new spin cases

$\cos(\theta_2)$ φ_1





$\cos(\theta^*)$

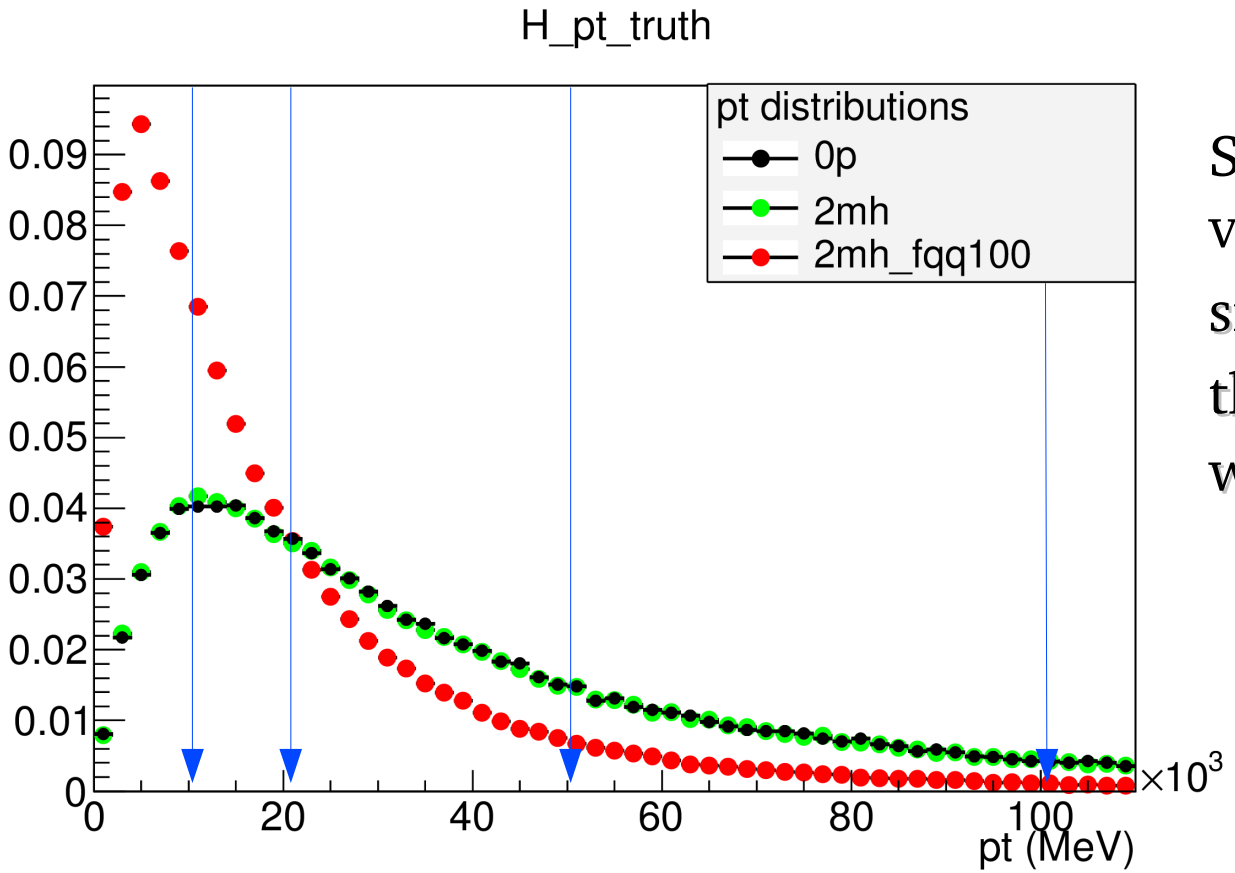
Similarly for $2^-_h(f_{qq}=100\%)$ GOOD agreement in almost all closure tests:
some discrepancies in $\cos(\theta^*)$, smaller than $2^-_h(f_{gg}=100\%)$.

p_T reweighting **only for spin 0^+ case!**

Truth selection (2013):

$50\ \text{GeV} < m_{12} < 106\ \text{GeV}$
$12\ \text{GeV} < m_{34} < 115\ \text{GeV}$
$115\ \text{GeV} < m_{4l} < 130\ \text{GeV}$
p_T reweighting

Truth distributions of p_T(Higgs)



Study MC truth distributions in various range of p_T:
signal events with "high" p_T of the four-lepton system could warp $cos(\theta^*)$ distribution.

Select 6 p_T ranges (spin 2^-_h), with relative fractions of events.

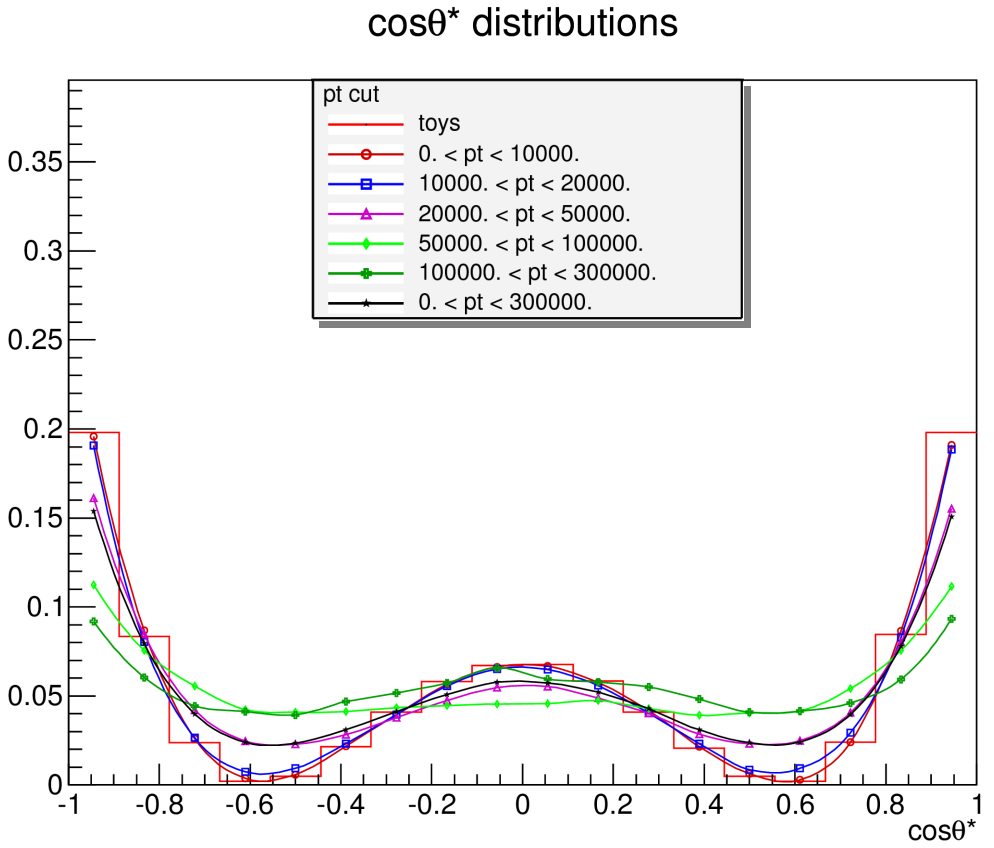
6 p_T ranger:

1. **[0.,10] GeV ≈ 10% events**
2. **[10,20] GeV ≈ 25% events**
3. **[20,50] GeV ≈ 35% events**
4. **[50,100] GeV ≈ 20% events**
5. **[100,300] GeV ≈ 10% events**
6. **full range**

$cos(\theta^*)$ in the Collins-Soper frame

$cos(\theta^*)$ is $p_{T\ Higgs}$ dependent :

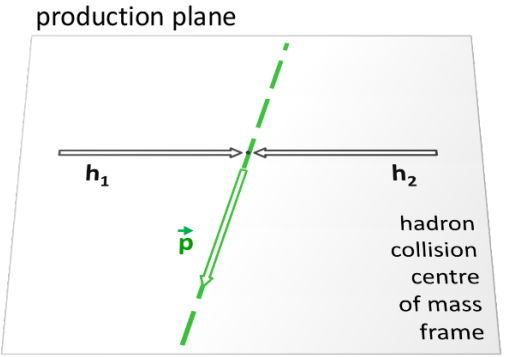
a good agreement with pdf(MELA) (i.e. JHU paper distribution) only for p_T<20 GeV.

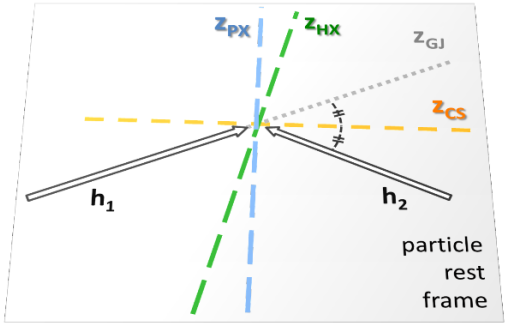


To minimize the effect of the transverse momentum, the "alternative" choice is to adopt the Collins–Soper frame (CS frame):

- z-axis (z_{CS}) = the bisector of the incoming beam momentum and negative of the target momentum in the rest frame of the vector bosons pairs

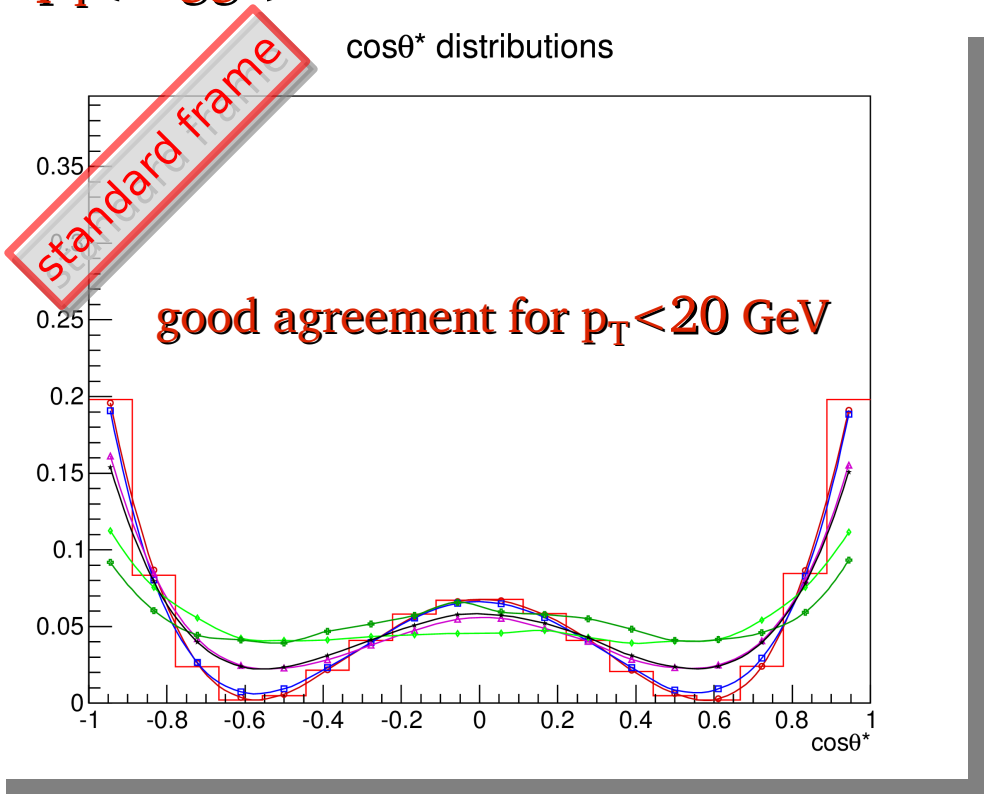
(beam and target not collinear when $p_T(Higgs) \neq 0$, considerably)

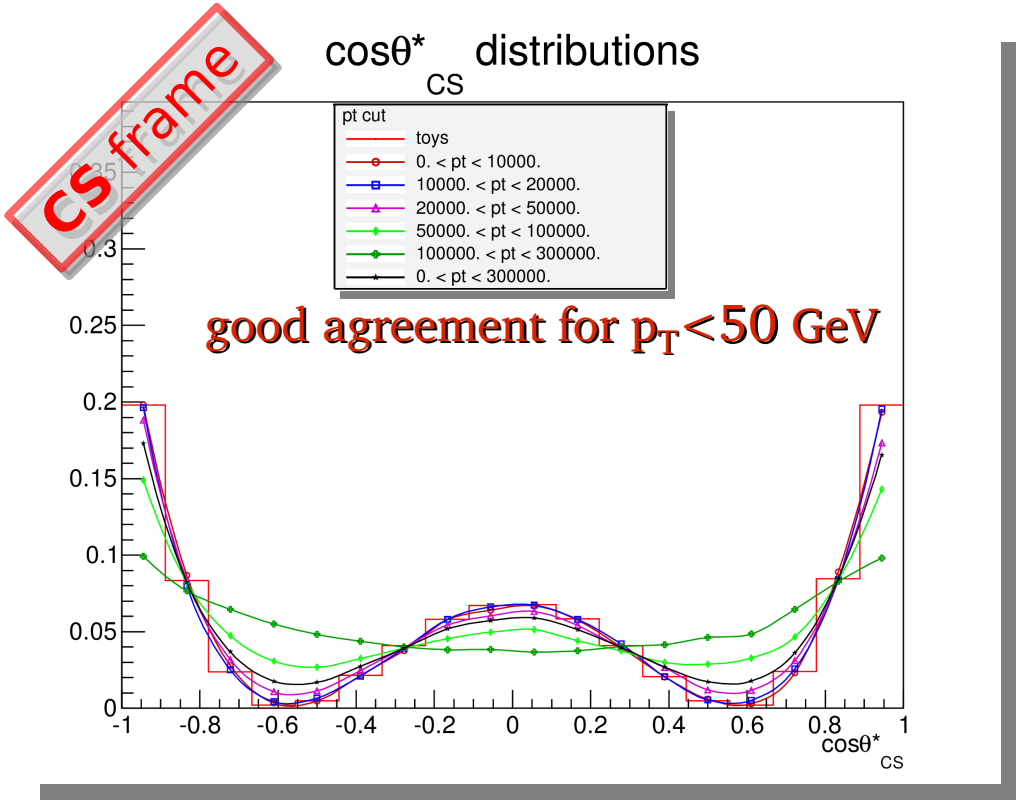




$cos(\theta^*)$ in the Collins-Soper frame

In the Collins-Soper rest frame $cos(\theta^*)$ partially loses dependence from p_T(Higgs).





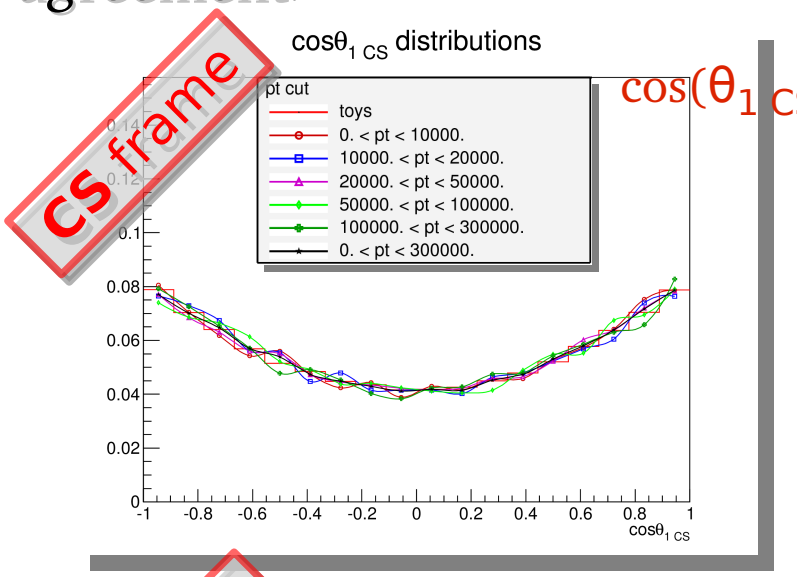
A good agreement with pdf(MELA) for p_T<50 GeV.

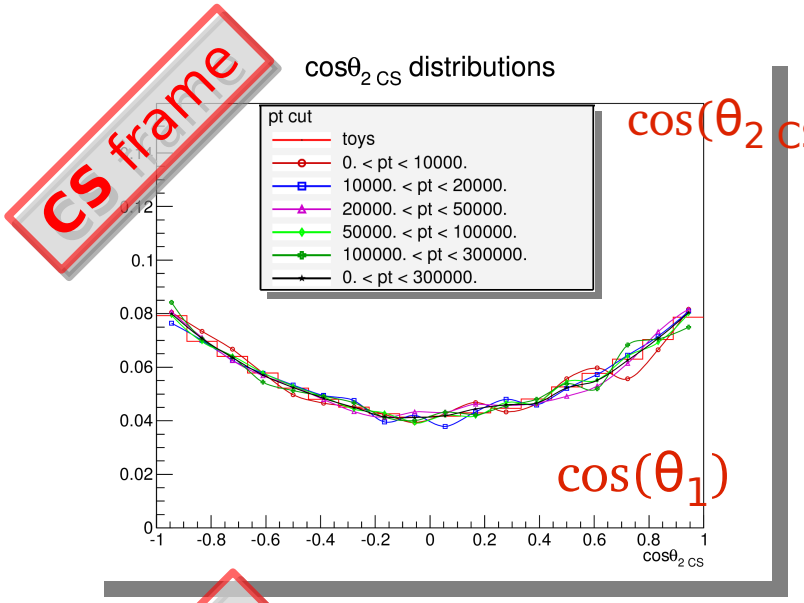
An excellent agreement with pdf(MELA) for p_T<20 GeV.

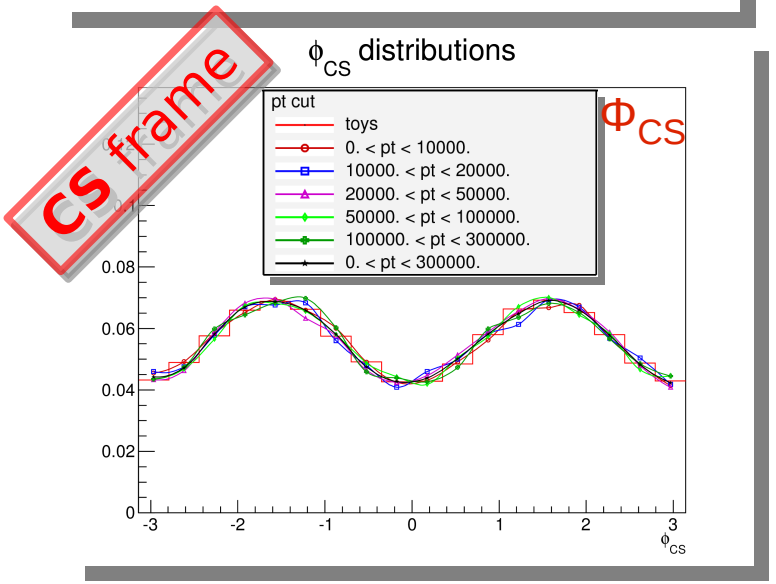
All the other angular variables are not significantly changed (not influenced by the change of reference frame).

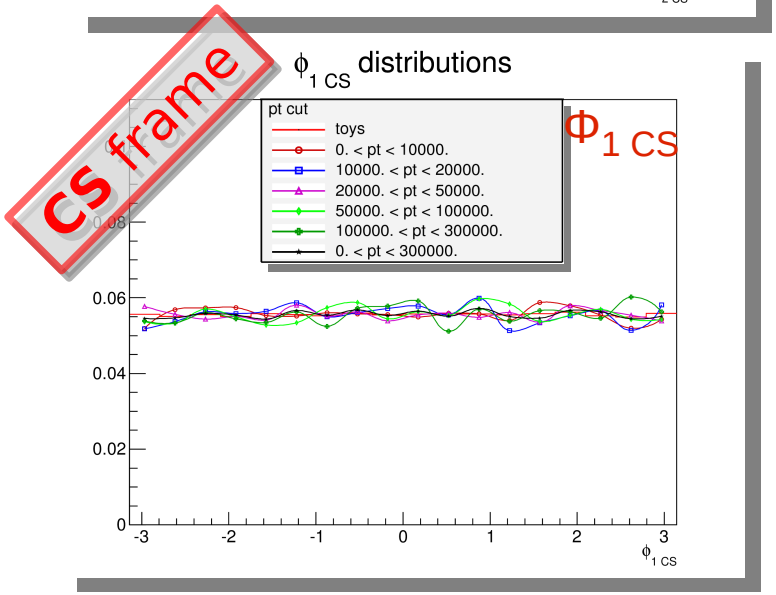
$cos(\theta^*)$ in Collins-Soper frame

All other angular variables are not significantly changed: there's still a good agreement.

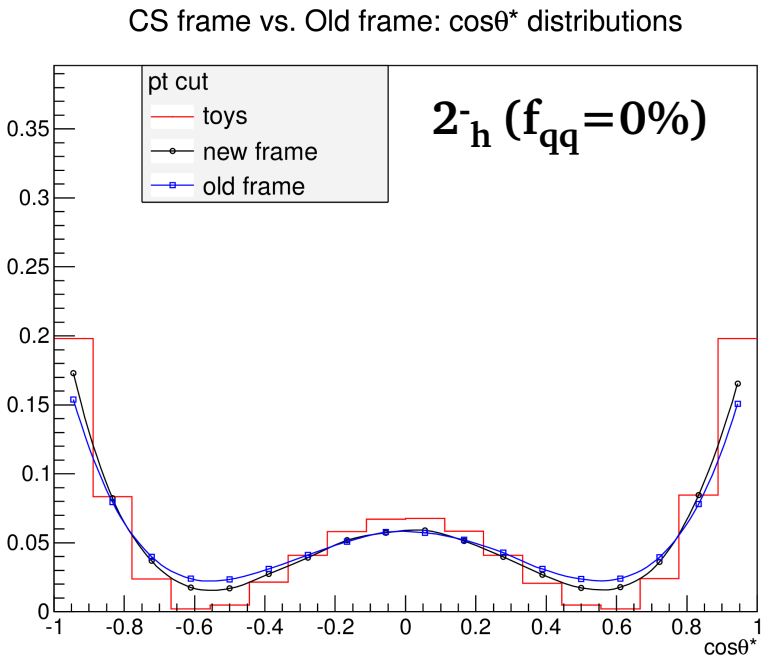








C-S rest frame vs. standard rest frame



The C-S rest frame produces an improvement to understand and reproduce more realistically the new 2^-_h samples.

2^-_h (f_{qq}=0%)

CS rest frame: chi2/ndf = 21/17

Standard frame: chi2/ndf = 30/17

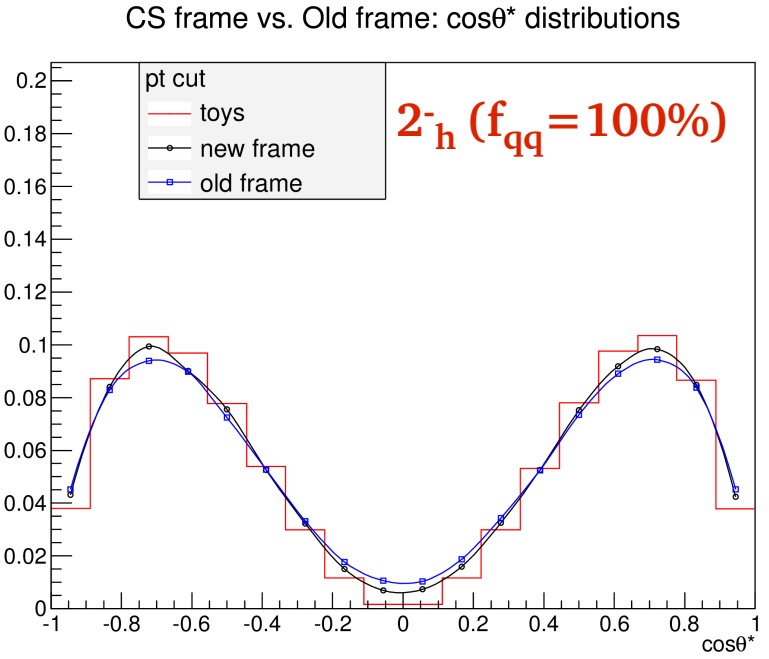
2^-_h (f_{qq}=100%)

CS rest frame: chi2/ndf = 7/17

Standard frame: chi2/ndf = 12/17

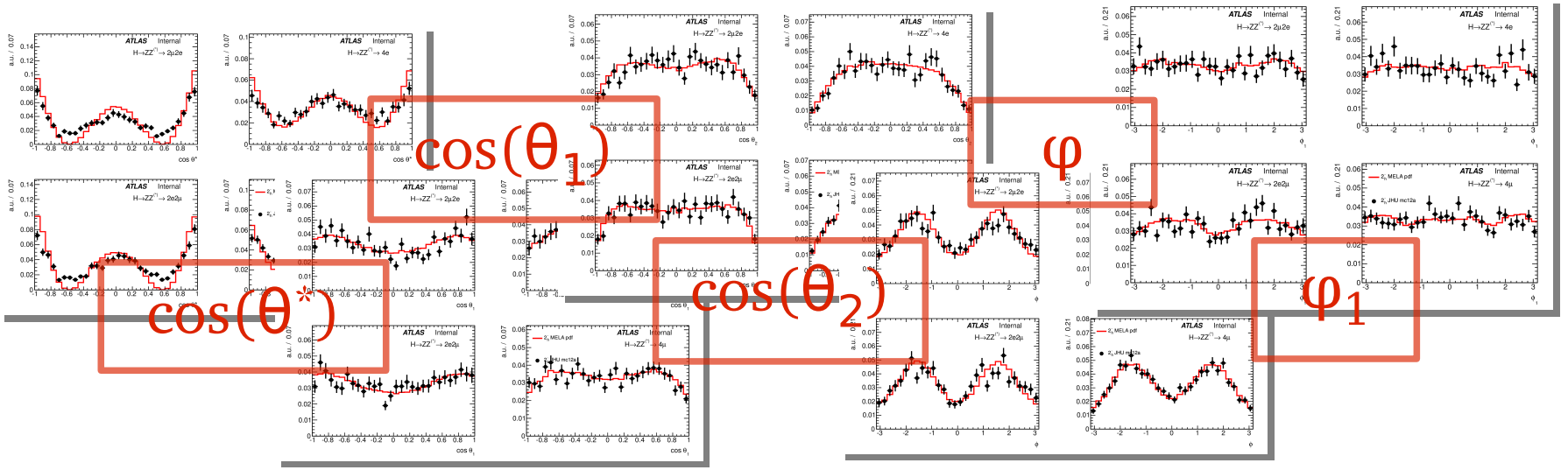
In each spin case chi2 is improved: there is still a residual discrepancy.

However we are further checking...

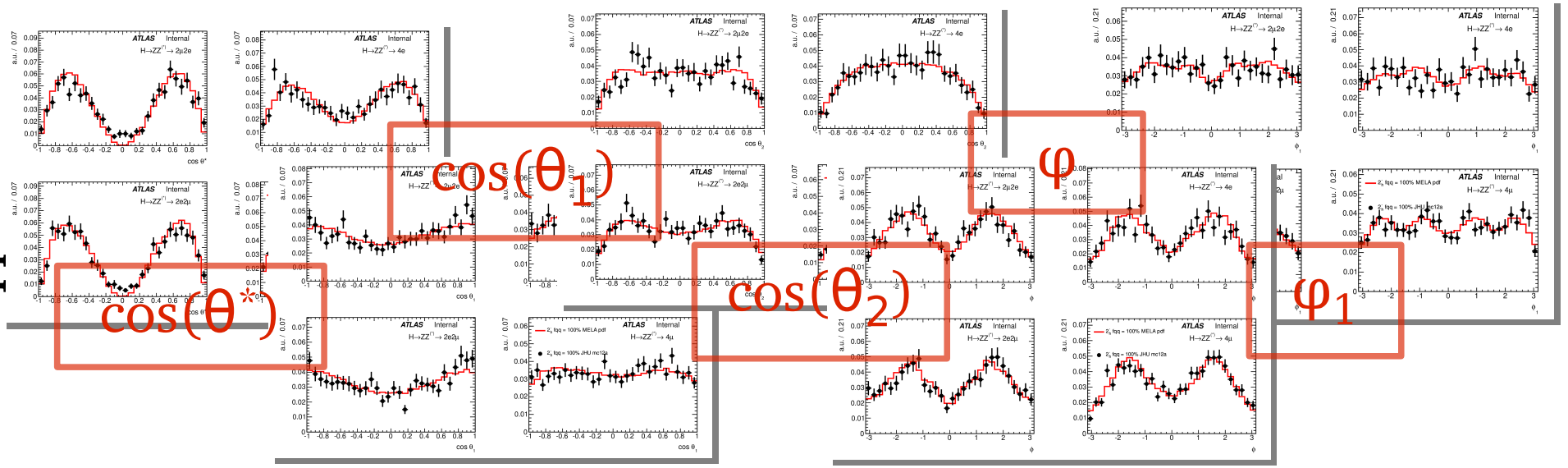


Reco distributions: closure test

$2^-_h(f_{qq}=0\%)$



$2^-_h(f_{qq}=100\%)$



- ✔ Reco distributions are in **good agreement** with pdf(MELA)×Acc(m_1,m_2,Ω): **closure OK**!

Conclusions

- new 2^-_h(qq/gg) samples added, ready for hypothesis testing (produced acceptance fit functions)
- WP fraction in spin case 2^-_h is different from the other spin samples: 10% -> 50%
- trying to minimize dipendence of $cos\theta^*$ from p_T(Higgs) adopting CS frame
- good agreement (MC vs. pdf) for other angular variables (indipendent from p_T) using CS frame
- improvement for reproducing spin case 2^-_h, using Collins-Soper rest frame (improvements for residuals and χ^2 test)

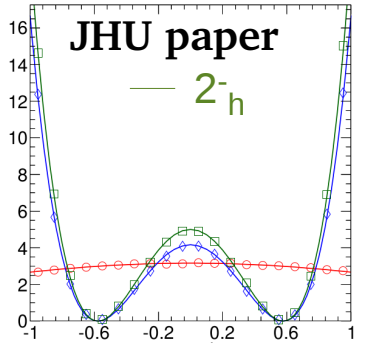
Ongoing work and plans:

- study reco distributions in CS rest frame (spin 2^-_h)
- study truth distributions for other spins: any improvement using CS rest frame?
- implement with latest version of selection
- review and finalization of the workspace (splitting of the theoretical effects, etc) to be more flexible for a possible combination with other channels.

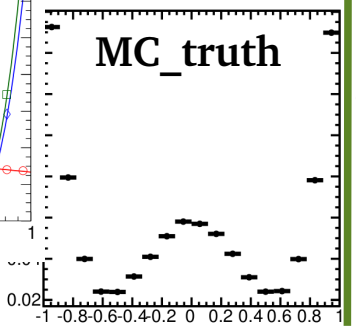
Back up

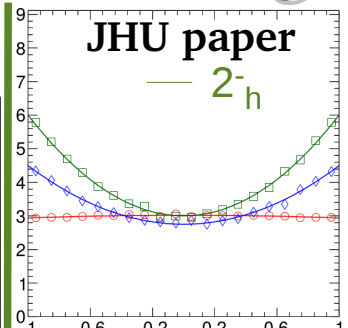
Truth/reco angular distributions

truth

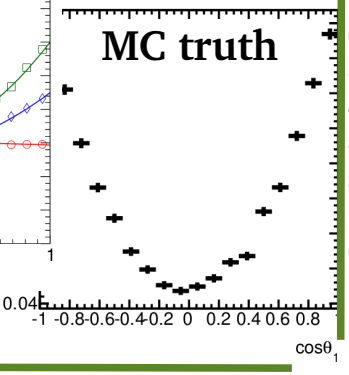


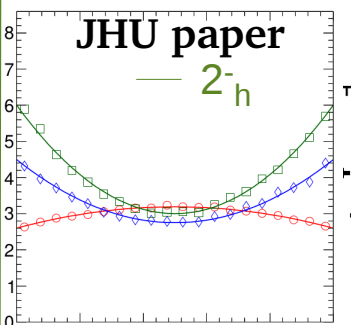
cos(θ*)



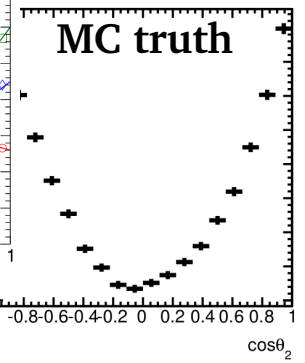


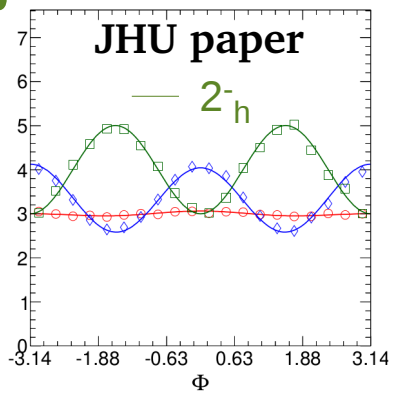
cos(θ1)



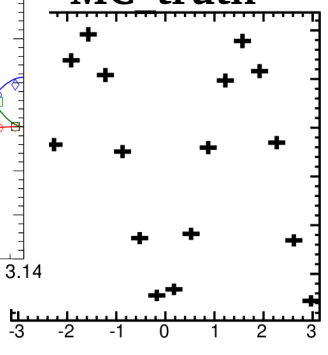


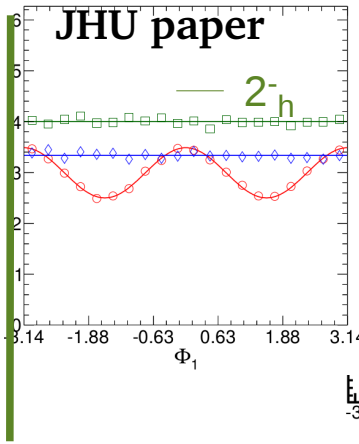
cos(θ2)



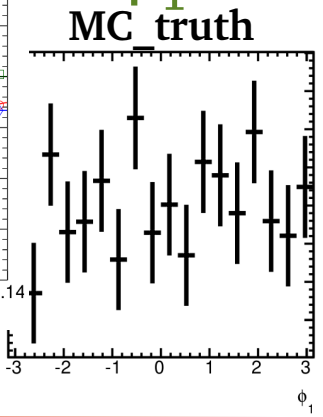


φ



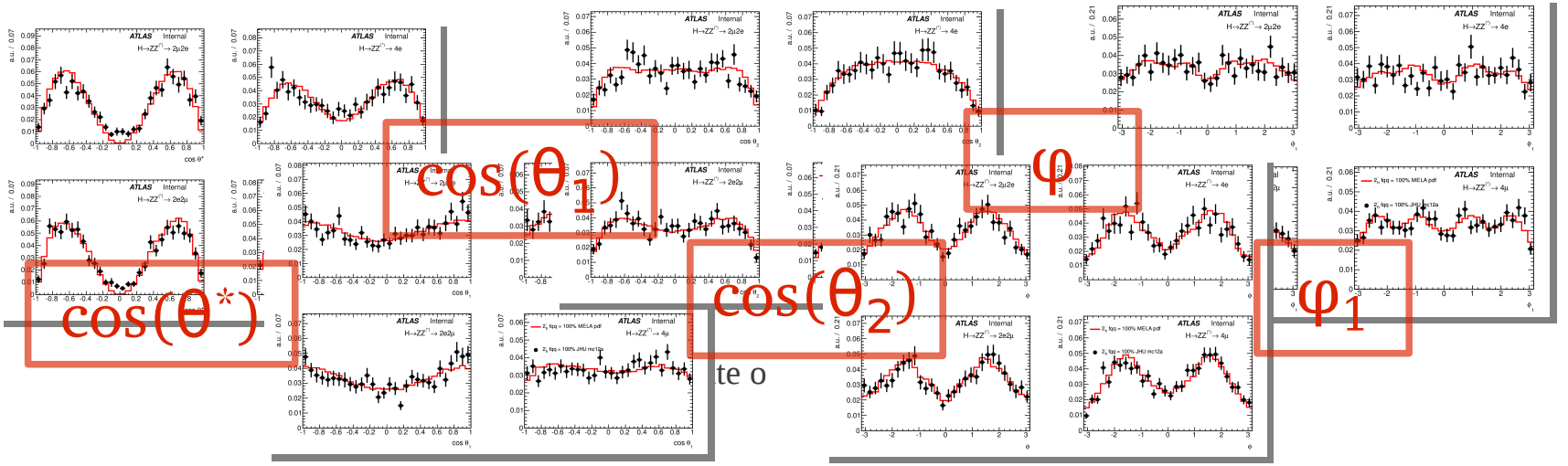


φ1



- ✔ MC truth distributions are in <u>good agreement</u> with JHU theoretical paper: **2^-_h production OK**!
- ✔ Reco distributions are in **good agreement** with pdf(MELA): **closure OK**!

reco



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New 2^-_h samples

0^+

	Total events	selected events	Efficiency	GP (fraction)	WP (fraction)
4mu	11813	8851	74.9%	8034 (90.8%)	817 (9.2%)
2m2e	7960	5326	66.9%		
2e2mu	9723	6891	70.9%		
4e	6567	4720	71.9%	4240 (89.8%)	480 (10.2%)

Goodpair and wrongpair fractions:

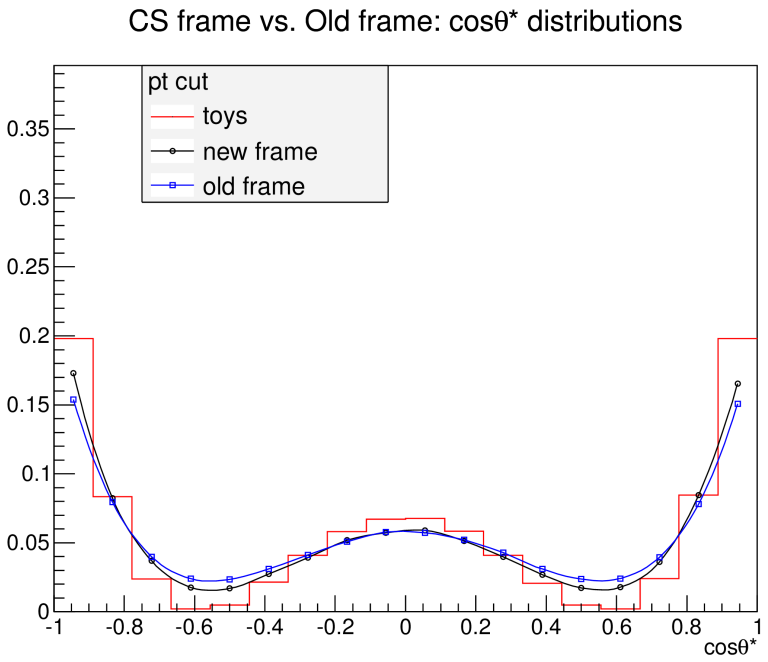
the kinematics of spin 2^-_h involves, downstream of the selection, a WP fraction very high compared to "standard" cases.

Applying the signal selection, the wrongpair fraction for 2^-_h samples results greater then 10% ("usual" WP fraction).

2^-_h

	Total events	selected events	Efficiency	GP (fraction)	WP (fraction)
4mu	21799	17664	81.0%	9498 (53.8%)	8166 (46.2%)
2m2e	14998	9250	61.7%		
2e2mu	16730	10592	63.3%		
4e	11256	7896	70.2%	4109 (52.0%)	3787 (48.0%)

C-S rest frame vs. standard rest frame



The CS rest frame produces an improvement to understand and reproduce more realistically the new 2^{-}_{h} samples.

Residues show this improvement quantitatively.

CS rest frame: chi2/ndf = 21/17

Standard frame: chi2/ndf = 30/17

(MC_truth – pdf(MELA))/MC_truth