Progress report on $\tau \to \ell hh$

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This talk concentrates on non-resonant $\tau \to \ell hh$, $\ell = e, \mu$, $h = \pi, K$ states only. (14 channels)

- Pre-selection, SP5/SP6 comparison
- PID, backgrounds
- Selection, cuts optimization
- MC luminocity scaling
- Expected sensitivity

Preselection (similar to $\tau \to \ell\ell\ell$)

The pre-selection is based on **Tau1N** skim, with additional cuts on

- Event has either L3OutDch or L3OutEmc trigger bit set
- Event has BGFMultiHadron filter bit set
- $3 \leq$ nGoodTrkLoose ≤ 5
- neLoose + nmuLoose ≥ 1 (data only)
- Exactly 4 'good tracks' are required in the event. (GTVL, no conversions)
- The total charge of the good tracks is equal to 0.
- 1-3 topology according to thrust hemisphere

Comparison of Run1-3/SP5 and Run4/SP6

Sample	Trig	BGFMH	Tau1N	4 tracks	$\sum Q_i = 0$	1-3 topology	Total
			RUN 1-3 / SP5				
$\tau^- \to e^- K^+ K^- [\%]$	94.4	87.5	55.7	88.2	98.7	99.9	42.4
data [%]	56.6	97.7	100	28.5	86.3	98.1	13.3
$b\bar{b}[\%]$	95.6	99.4	1.03	34.9	65.7	94.9	0.214
$c\bar{c}[\%]$	89.0	97.7	4.94	43.2	75.8	96.8	1.36
$uds[\%]$	83.5	95.1	7.31	51	83.1	97.4	2.39
$\tau\tau[\%]$	37.6	39	60	75.6	98.6	99.9	6.56
di-muon [%]	1.01	15.8	15.8	6.3	79.4	99.2	0.00125
Bhabha [%]	19.9	2.28	27.4	6.37	73.4	99.7	0.0058
			RUN 4 / SP6				
$\tau^- \to e^- K^+ K^- [\%]$	94.2	87.7	56.3	88.7	98.7	99.9	43.2
data [%]	57.1	94.5	100	29	85.8	98	13.2
$b\bar{b}[\%]$	96.2	99.3	0.878	35.1	66.4	94.7	0.185
$c\bar{c}[\%]$	89.8	97.6	4.43	43.2	76.4	96.5	1.24
$uds[\%]$	83.9	95	6.74	50.8	83.6	97.1	2.22
$\tau\tau[\%]$	38.3	39.3	59	74.5	98.5	99.9	6.49
di-muon [%]	0.94	16.4	16.1	5.74	77.7	99.4	0.0011

No significant difference was found between SP5 and SP6 MC (signal and backgrounds). Therefore all data were combined together.

Particle identification

All standard PID selectors were checked for best performance. The suppression of background (estimated as a PID-weight of lumi-scaled MC events) to few events in the *signal* region was required. The PID selectors must be common to all related channels.

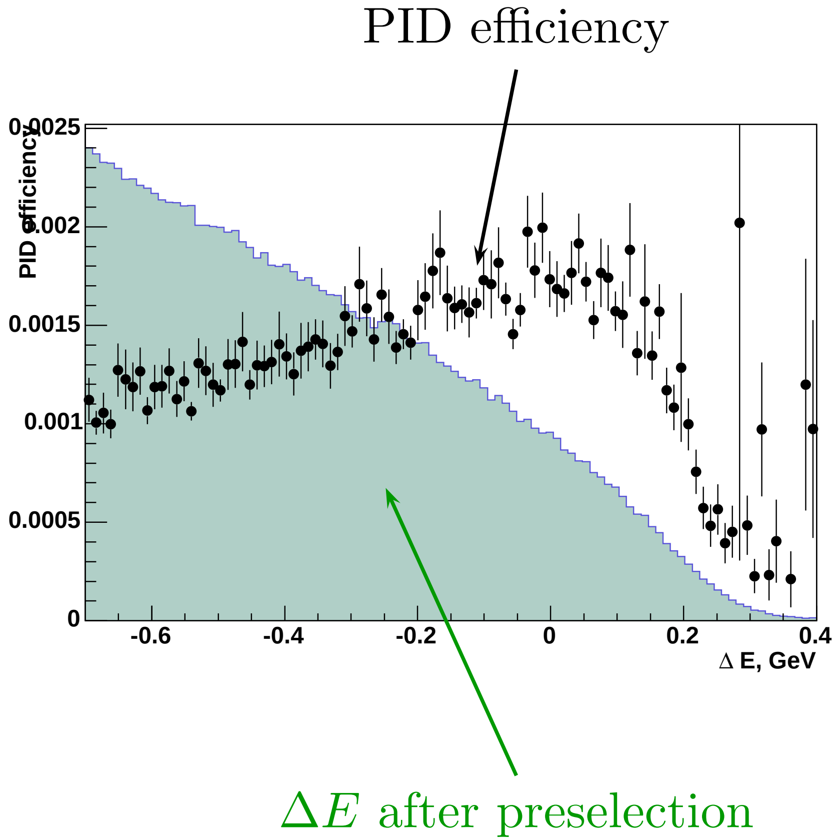
The final list is
PidLHElectrons, muNNTight, KLHTight and piLHLoose.

	Signal	bb	$c\bar{c}$	uds	Bhabha	di-muon	$\tau\tau$	DATA
$\tau^- \to e^- K^+ K^-$	0.551	0.012	0.007	$3.9 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$3.8 \cdot 10^{-4}$	$1.5 \cdot 10^{-5}$	$9.8 \cdot 10^{-4}$
$\tau^- \to e^- K^+ \pi^-$	0.623	0.046	0.030	$4.3 \cdot 10^{-4}$	0.007	0.013	$6.8 \cdot 10^{-5}$	0.004
$\tau^- \to e^- \pi^+ K^-$	0.646	0.034	0.002	$4.1 \cdot 10^{-4}$	0.011	0.004	$7.1 \cdot 10^{-5}$	0.002
$\tau^- \to e^- \pi^+ \pi^-$	0.730	0.098	0.009	0.002	0.103	0.105	0.002	0.096
$\tau^- \to \mu^- K^+ K^-$	0.300	0.008	0.006	0.001	$1.4 \cdot 10^{-7}$	$4.9 \cdot 10^{-5}$	$2.7 \cdot 10^{-4}$	$8.0 \cdot 10^{-4}$
$\tau^- \to \mu^- K^+ \pi^-$	0.387	0.029	0.031	0.002	$1.4 \cdot 10^{-6}$	0.002	$7.4 \cdot 10^{-4}$	0.003
$\tau^- \to \mu^- \pi^+ K^-$	0.394	0.018	0.003	0.003	$2.5 \cdot 10^{-6}$	0.001	0.001	0.002
$\tau^- \to \mu^- \pi^+ \pi^-$	0.475	0.075	0.012	0.016	$2.9 \cdot 10^{-5}$	0.033	0.033	0.038
$\tau^- \to e^+ K^- K^-$	0.532	$1.5 \cdot 10^{-4}$	$3.0 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$	$2.7 \cdot 10^{-5}$	$4.6 \cdot 10^{-4}$	$2.2 \cdot 10^{-6}$	$2.1 \cdot 10^{-5}$
$\tau^- \to e^+ K^- \pi^-$	0.637	0.025	0.003	$5.7 \cdot 10^{-4}$	0.001	0.018	$1.0 \cdot 10^{-4}$	$5.7 \cdot 10^{-4}$
$\tau^- \to e^+ \pi^- \pi^-$	0.731	0.079	0.002	$7.1 \cdot 10^{-4}$	0.014	0.128	$9.8 \cdot 10^{-4}$	0.004
$\tau^- \to \mu^+ K^- K^-$	0.291	$1.5 \cdot 10^{-4}$	$2.1 \cdot 10^{-4}$	$3.0 \cdot 10^{-4}$	$5.0 \cdot 10^{-9}$	$6.9 \cdot 10^{-8}$	$1.3 \cdot 10^{-5}$	$6.5 \cdot 10^{-5}$
$\tau^- \to \mu^+ K^- \pi^-$	0.383	0.014	0.004	0.004	$7.5 \cdot 10^{-8}$	$1.9 \cdot 10^{-6}$	0.001	0.003
$\tau^- \to \mu^+ \pi^- \pi^-$	0.467	0.088	0.007	0.008	$4.1 \cdot 10^{-6}$	0.007	0.018	0.021

Particle identification and $(\Delta M, \Delta E)$

The effect of PID on $(\Delta M,\ \Delta E)$ distribution can not be ignored

1. One needs to divide background samples into subsamples: e.g. $\tau\tau$ has modes with 0, 1, 2 real Kaons in final state; $c\bar{c} \to D^+D^-$, $D^- \to K^+\pi^-e^-\bar{\nu}_e$ or $D^- \to K^+\pi^-\pi^-$.
2. In addition, the correlation between PID efficiency and ΔE is significant while subdivision on subsample is not obvious (like for uds)



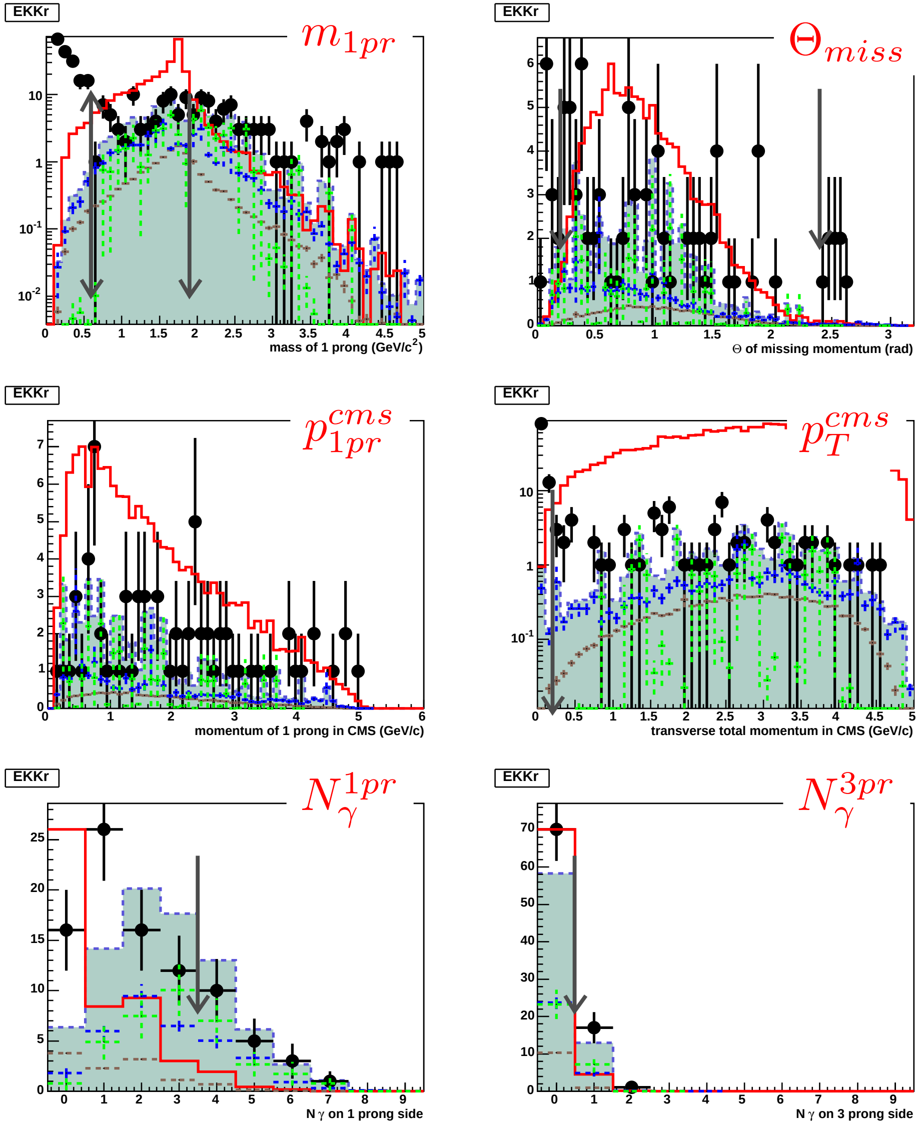
Selection

- mass of one prong side m_{1pr} : $0.6\mathrm{GeV} < \mathrm{m_{1pr}} < 1.9$ GeV where $m_{1pr} = \sqrt{p^{\mu}_{trk1pr} + \sum p^{\mu}_{neut1pr} + p^{\mu}_{miss}}$, $m_{miss} = 0$
- $0.2 < \Theta_{miss} < 2.4$ rad.
- Total $p_T^{cms} > 0.2$ GeV
- no photons ($E_\gamma > 100$MeV) on 3 prong side
- no more than 3/0 photons ($E_\gamma > 100$MeV) on 1 prong side for channels with electron/muon final state. $\tau^- \to \mu^+ K^- K^-$ channel has no more than 3 unassociated photons.

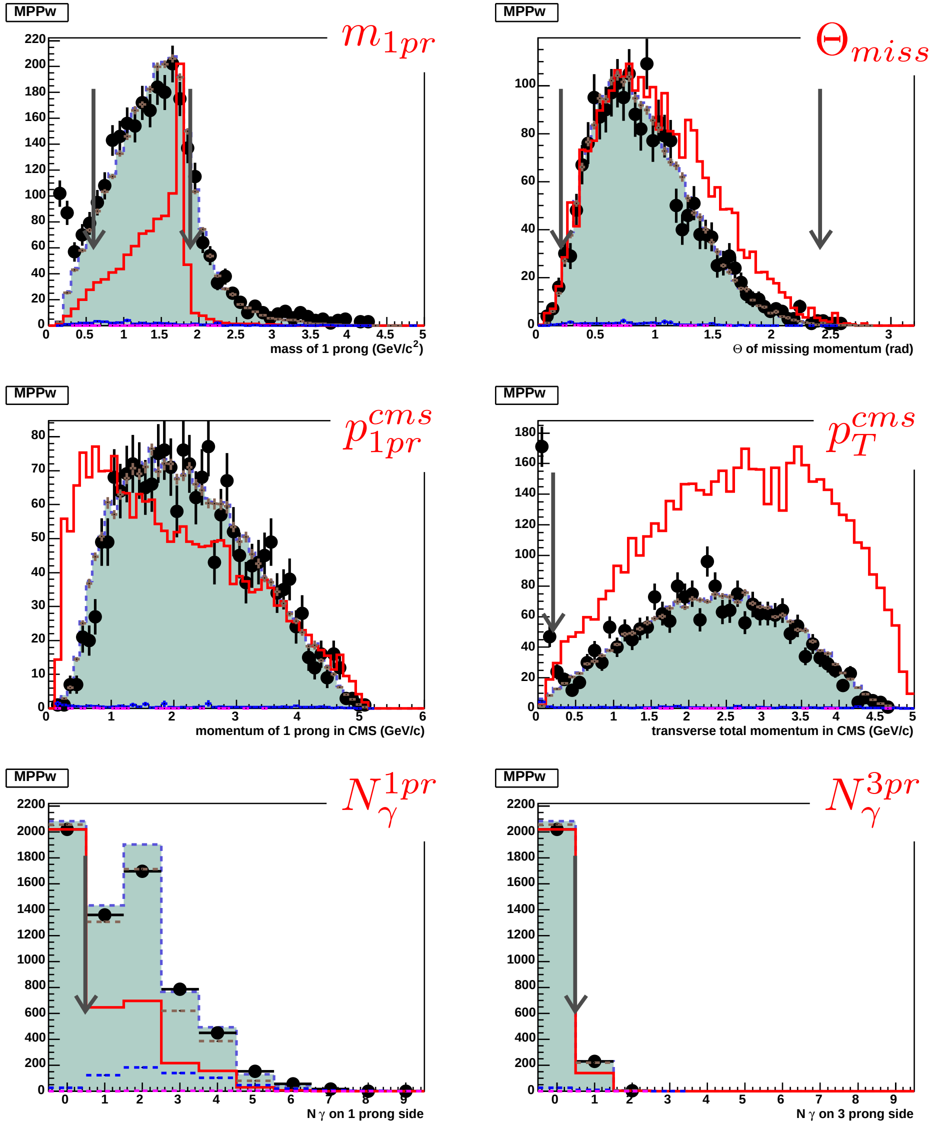
Other cuts which have been considered are cut on p^{cms}_{1pr}, on α_{13} (angle between 1 and 3-prong sides), N_{badtrk}, veto on N_ℓ on 3 prong side. These cuts were not found to be effective.

Selection variables

$\tau^- \to e^- K^+ K^-$



$\tau^- \to \mu^+ \pi^- \pi^-$

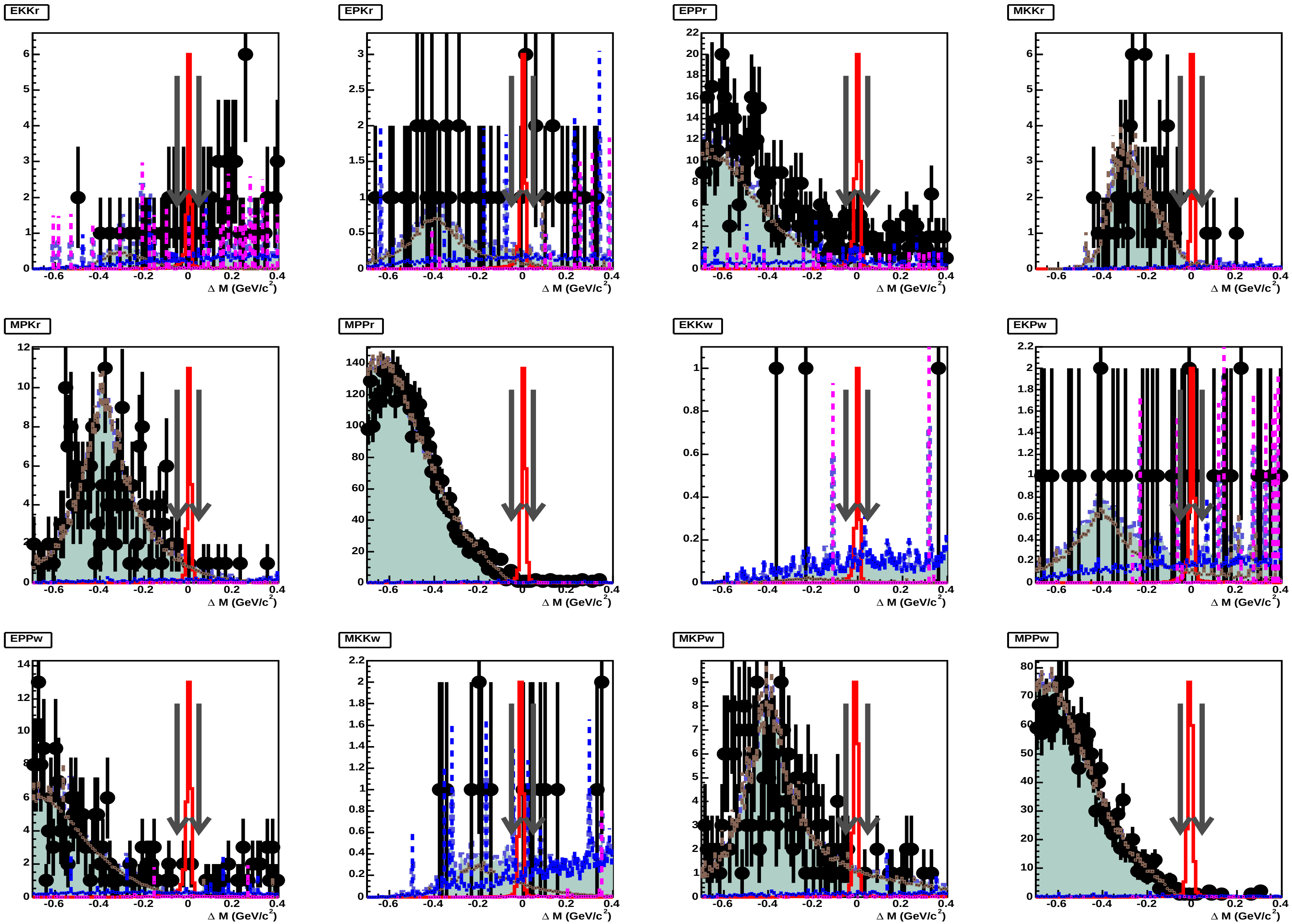


points - data, red - signal, shade - background, lumi scaled

Selection efficiency

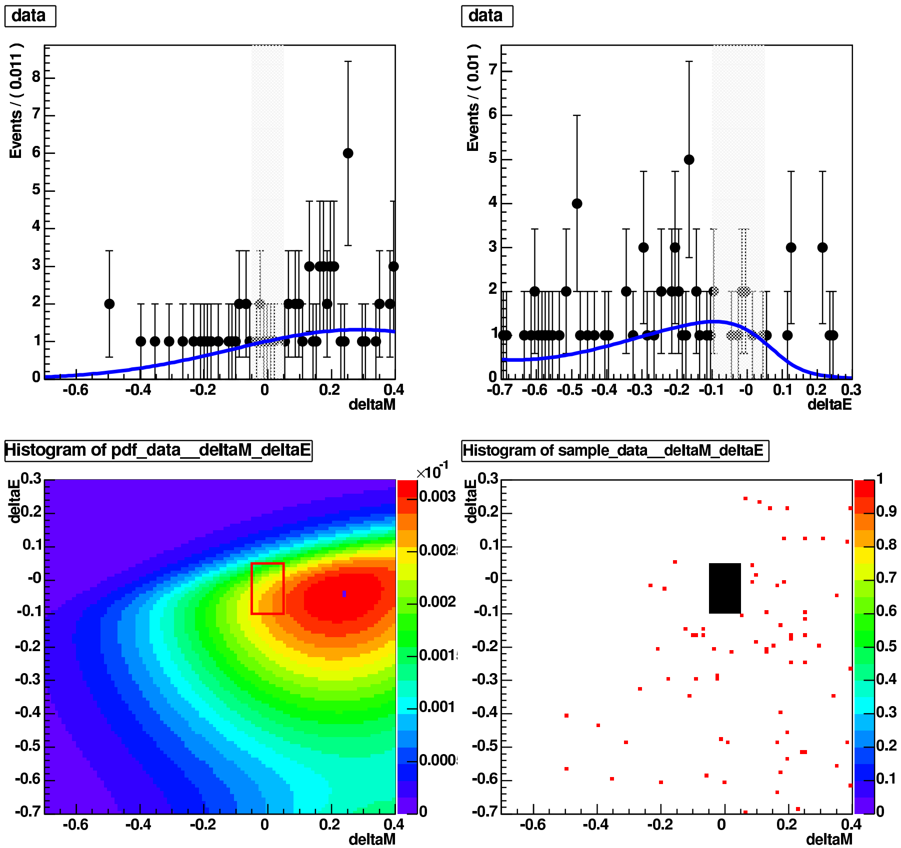
	Signal	$b\bar{b}$	$c\bar{c}$	uds	Bhabha	di-muon	$\tau\tau$	DATA
$\tau^- \to e^- K^+ K^-$	0.4859	0.0355	0.0396	0.0900	0.0690	0.0277	0.3320	0.0481
$\tau^- \to e^- K^+ \pi^-$	0.3672	0.0279	0.0270	0.0756	0	0.0412	0.2008	0.0315
$\tau^- \to e^- \pi^+ K^-$	0.3692	0.0317	0.0250	0.0740	0	0.0400	0.1995	0.0116
$\tau^- \to e^- \pi^+ \pi^-$	0.3580	0.0218	0.0062	0.0500	0	0.0526	0.1891	0.0058
$\tau^- \to \mu^- K^+ K^-$	0.2999	0.0035	0.0024	0.0048	0	0.0106	0.1209	0.0510
$\tau^- \to \mu^- K^+ \pi^-$	0.3015	0.0059	0.0022	0.0044	0.0123	0.0168	0.1241	0.0367
$\tau^- \to \mu^- \pi^+ K^-$	0.2967	0.0060	0.0019	0.0043	0.0145	0.0173	0.1229	0.0525
$\tau^- \to \mu^- \pi^+ \pi^-$	0.2829	0.0015	0.0006	0.0029	0	0.0214	0.1144	0.0926
$\tau^- \to e^+ K^- K^-$	0.4908	0.0341	0.0380	0.0879	0.0667	0.0509	0.3321	0.0857
$\tau^- \to e^+ K^- \pi^-$	0.3707	0.0300	0.0250	0.0739	0	0.0430	0.1991	0.0373
$\tau^- \to e^+ \pi^- \pi^-$	0.3587	0.0228	0.0061	0.0501	0	0.0471	0.1891	0.0502
$\tau^- \to \mu^+ K^- K^-$	0.5349	0.0341	0.0380	0.0879	0.0667	0.0509	0.3321	0.1667
$\tau^- \to \mu^+ K^- \pi^-$	0.2962	0.0060	0.0019	0.0043	0.0141	0.0152	0.1233	0.0537
$\tau^- \to \mu^+ \pi^- \pi^-$	0.2895	0.0015	0.0006	0.0029	0	0.0223	0.1148	0.0919

ΔM plot before fit (MC - lumi scaled, data blinded)

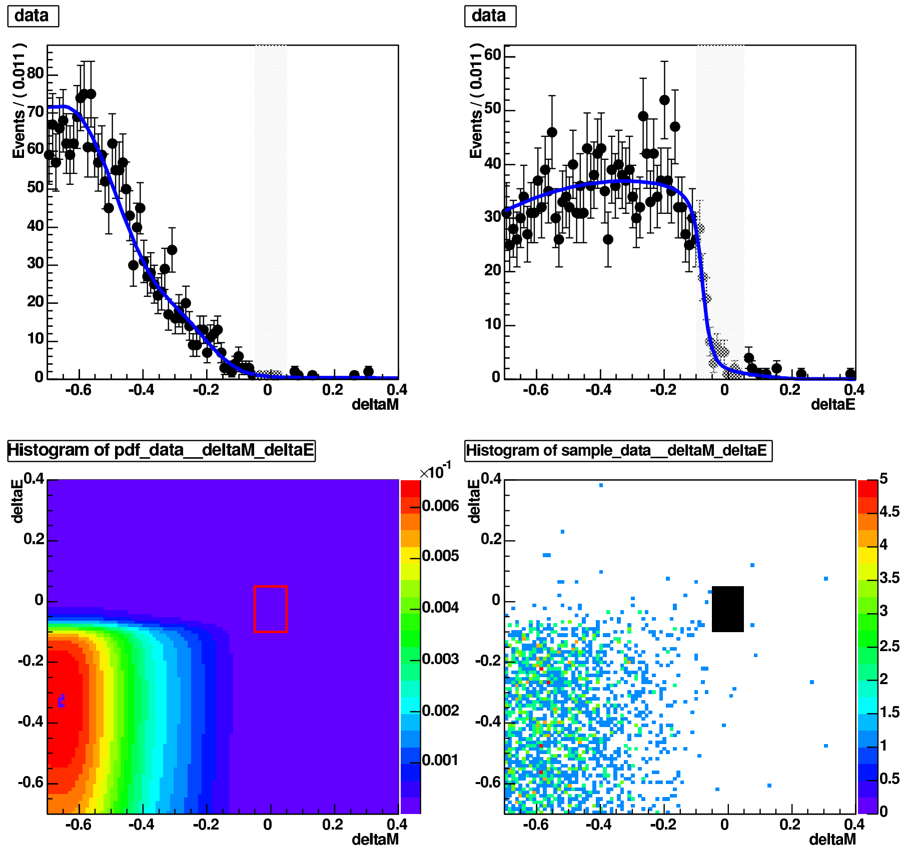


data fit

$\tau^- \to e^- K^+ K^-$



$\tau^- \to \mu^+ \pi^- \pi^-$



Expected sensitivity for 220 fb^{-1}

Channel	Efficiency	exp Bkgr	Sensitivity	CLEO
$\tau^- \to e^- K^+ K^-$	6.43%	2.3	$1.66 \cdot 10^{-7}$	$6.0 \cdot 10^{-6}$
$\tau^- \to e^- K^+ \pi^-$	6.36%	3.11	$1.84 \cdot 10^{-7}$	$3.8 \cdot 10^{-6}$
$\tau^- \to e^- \pi^+ K^-$	6%	0.912	$1.39 \cdot 10^{-7}$	$6.4 \cdot 10^{-6}$
$\tau^- \to e^- \pi^+ \pi^-$	7.3%	6.99	$2.05 \cdot 10^{-7}$	$2.2 \cdot 10^{-6}$
$\tau^- \to \mu^- K^+ K^-$	2.92%	0.222	$2.48 \cdot 10^{-7}$	$15 \cdot 10^{-6}$
$\tau^- \to \mu^- K^+ \pi^-$	3.85%	0.791	$2.16 \cdot 10^{-7}$	$7.4 \cdot 10^{-6}$
$\tau^- \to \mu^- \pi^+ K^-$	3.39%	0.86	$2.45 \cdot 10^{-7}$	$7.5 \cdot 10^{-6}$
$\tau^- \to \mu^- \pi^+ \pi^-$	4.48%	2.07	$2.37 \cdot 10^{-7}$	$8.2 \cdot 10^{-6}$
$\tau^- \to e^+ K^- \pi^-$	6.07%	0.709	$1.37 \cdot 10^{-7}$	$2.1 \cdot 10^{-6}$
$\tau^- \to e^+ \pi^- \pi^-$	7.45%	1.83	$1.34 \cdot 10^{-7}$	$1.9 \cdot 10^{-6}$
$\tau^- \to \mu^+ K^- K^-$	4.88%	0.495	$1.48 \cdot 10^{-7}$	$6.0 \cdot 10^{-6}$
$\tau^- \to \mu^+ K^- \pi^-$	3.42%	1.35	$2.68 \cdot 10^{-7}$	$7.0 \cdot 10^{-6}$
$\tau^- \to \mu^+ \pi^- \pi^-$	4.42%	1.1	$2.07 \cdot 10^{-7}$	$3.4 \cdot 10^{-6}$

Even without fine cut tuning and (ΔM,ΔE) optimization the expected sensitivity is very good.

Conclusions

- Main ingredients are in place : efficiency, background analysis, fit.
- Cut optimization needs a final tuning, hopefully will go very fast
- Systematic uncertainties will be adopted from $\tau \to \ell\ell\ell$ analysis with correction for CM2 difference and PID-weighting
- Will probably make a preliminary result for 14 channels to show at TAU2004
- The final publication (PRD) should follow very soon after, with $\tau \to \ell h^0$, $h^0 \to h^+h^-$ and update of $\tau \to \ell\ell\ell$ added.