Study of $B^0 \to l^+ \tau^-$ using untagged method at Belle

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- **Introduction**

* $B^0 \to e^+\tau^-$, $B^0 \to \mu^+\tau^-$ are forbidden in the Standard Model by lepton-flavor conservation law.

* However, they are predicted to occur in many theories "beyond the Standard Model" including neutrino oscillations.

* In the general flavor-universal Minimal Supersymmetric Standard Model(MSSM), the branching fractions are estimated as below.

$$Br(B^0 \to l^+\tau^-) \approx 2.0 \times 10^{-10}$$

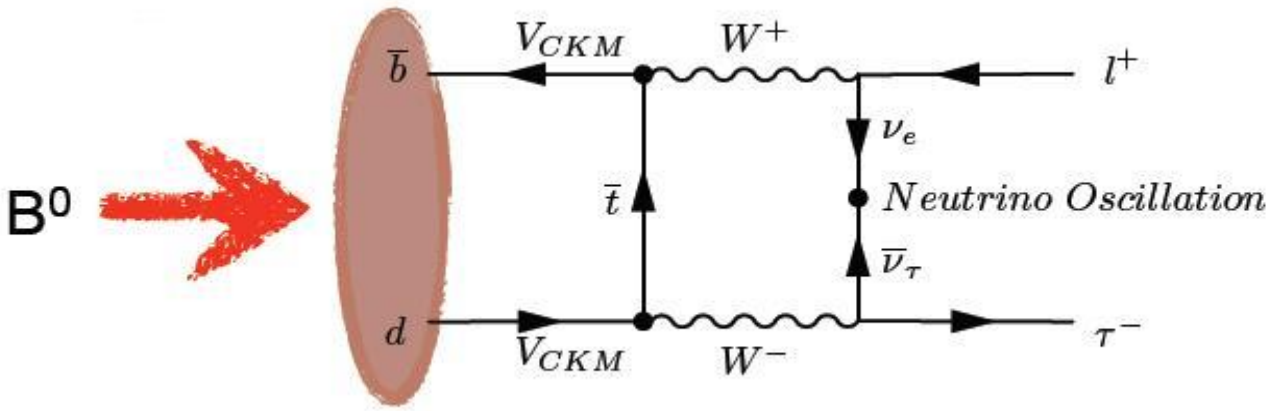


Figure 1: The diagram for $B^0 \to l^+\tau^-$

* Observation of these decays would be clear evidence of physics beyond the Standard Model.

• Existing Measurements

Upper limits on the branching fractions are as follows.

(1)BABAR(342fb^{-1}), PHYSICAL REVIEW D 77 091104(R) (2008) – hadronic tagged

$$Br(B^0 \to e^+\tau^-) < 2.8\times10^{-5} \quad 90\% \quad C.L.$$

$$Br(B^0 \to \mu^+\tau^-) < 2.2\times10^{-5} \quad 90\% \quad C.L.$$

(2) CLEO(9.2fb^{-1}), PHYSICAL REVIEW LETTERS 93 241802 (2004)- untagged

$$Br(B^0 \to e^+\tau^-) < 1.3\times10^{-4} \quad 90\% \quad C.L.$$

$$Br(B^0 \to \mu^+\tau^-) < 3.8\times10^{-5} \quad 90\% \quad C.L.$$

Selection Criteria(1)

- $\Delta r < 2.0cm \qquad |\Delta z| < 5.0cm$
- $\mu : Muid\_mdst.Muon\_likelihood() > 0.9$
- $e : eid.prob(3,-1,5) > 0.9$
- $K : K/\pi \quad atc\_pid(3,1,5,3,2) > 0.6$
- $p : \Pr/\pi \; atc\_pid(3,1,5,4,2) > 0.6$
- $\pi : \pi/K \quad atc\_pid(3,1,5,2,3) < 0.6$

Selection Criteria(2)

* Number of lepton $N_l = 1$

* $M_{bc} : 5.10GeV/c^2 < M_{bc} < 5.29GeV/c^2$

* $\Delta E : -3GeV < \Delta E < 5GeV$

* CM momentum of signal lepton :

$$1.8GeV/c < p_l^* < 3GeV/c$$

* Cosine Thrust Angle :

$$\left|\cos\theta_{TH}^e\right| < 0.61 \quad \& \quad \left|\cos\theta_{TH}^\mu\right| < 0.53$$

*Polar angle of missing (neutrino):

$$\cos\theta_{missing} < 0.9$$

*Cosine BY ($\cos\theta_{BY}$, $Y = \pi + l$):

$$-1 < \cos\theta_{BY} < 1$$

*Number of charged tracks:

$$N\_chg \geq 5$$

• Signal MC Study

We study for $B^0 \to e^+\tau^-$ and $B^0 \to \mu^+\tau^-$ by using the de cay mode $\tau^- \to \pi^-\nu_\tau$. Therefore, final state of B^0 is $B^0 \to e^+\pi^-\nu_\tau$ and $B^0 \to \mu^+\pi^-\nu_\tau$. Since neutrino is undete cted, neutrino is missing particle in the event. The missing energy and momentum in the CM frame are defined as follows.

$$E_{miss} \equiv 2E_{beam} - \sum_i E_i \qquad \vec{P}_{miss} \equiv -\sum_i \vec{P}_i$$

We generated 300,000 events for signal MC both $B^0 \to e^+\tau^-$ and $B^0 \to \mu^+\tau^-$.

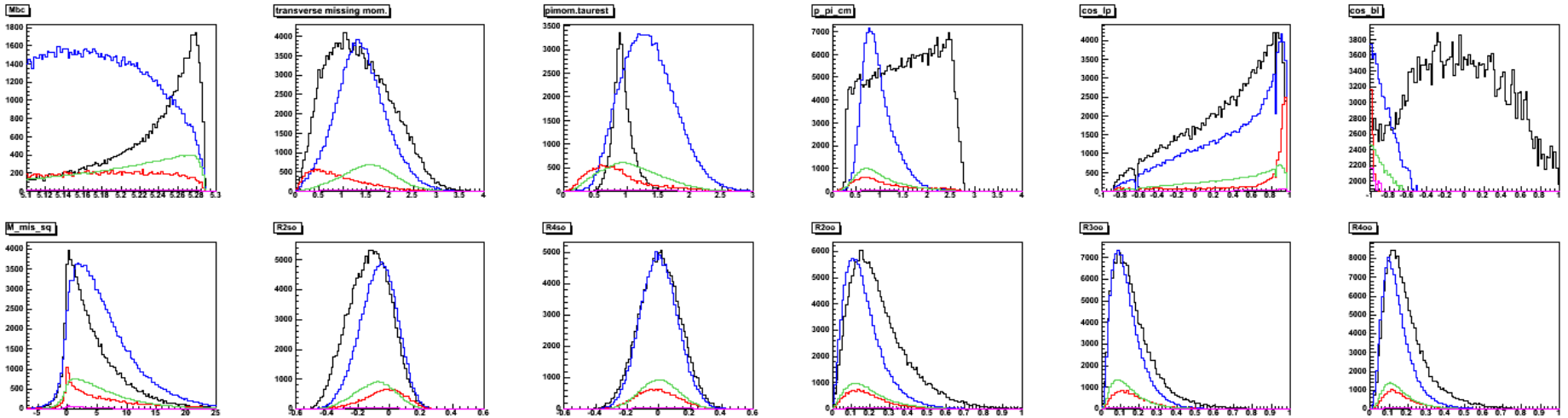
- **Sample used in analysis**

Mode	Process
Generic MC	$B\bar{B},\ \ q\bar{q}$
Ulnu	$B \to X_u l \nu$
Rare B	$b \to s,\ d$

Neural Network ($e\tau$)

* Input variables

Black line: signal
Red line: continuum
Blue line: BBbar
Green line: Ulnu
Pink line: Rare



5.1GeV<Mbc<5.29GeV

-3GeV<de<5GeV

1.8GeV <e mom. <3GeV

-0.61 <cos_thrc< 0.61

costh_missing<0.9

-1<costh_BY< 1

N_chg ≥5

* picture

From left to right;

Top1 : Mbc Top2: transverse missing mom. Top3: pi mom. in tau rest frame
Top4: pion mom in CM frame Top5: cos_lepton Top6: cos_BL
Bot1: M2_miss Bottom2: R2so Bottom3: R4so Bottom4: R2oo Bottom5: R3oo Bottom6: R4oo (sfw 5 moment variables)

Neural Network ($\mu\tau$)

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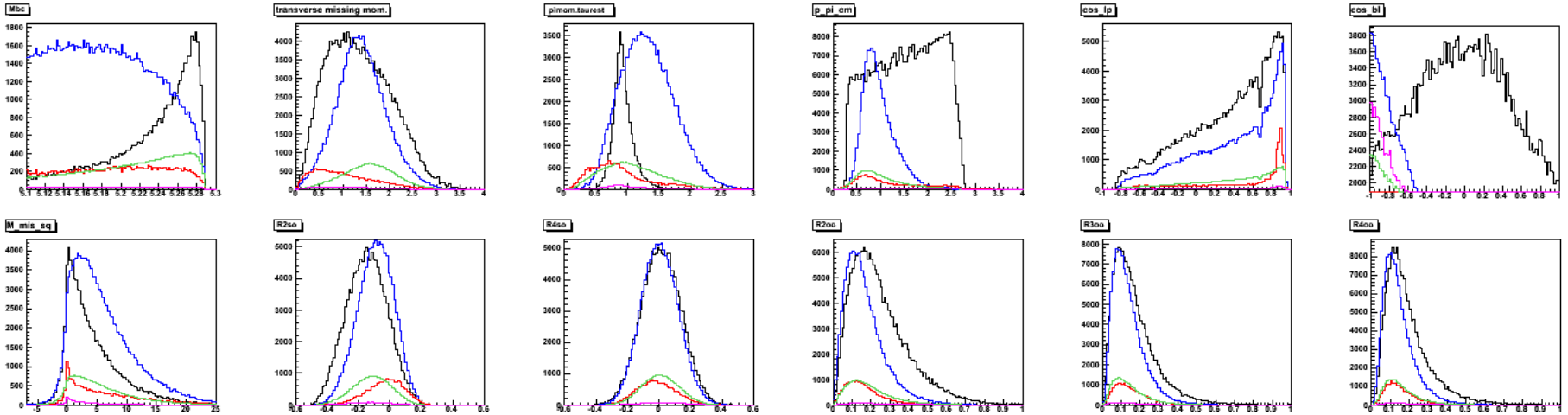

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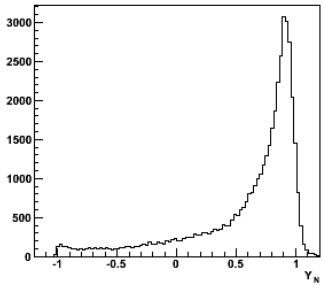
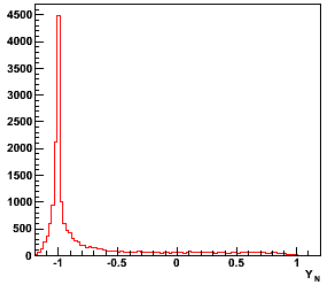
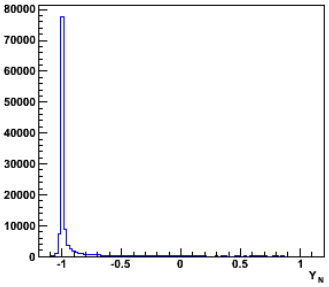
Neural Network Output (Y_n)

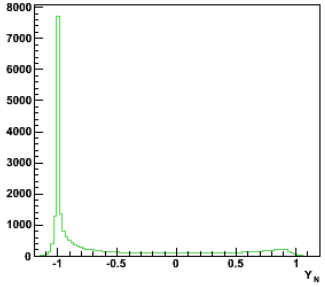
Hidden node: N+2,N +1($e\tau$)

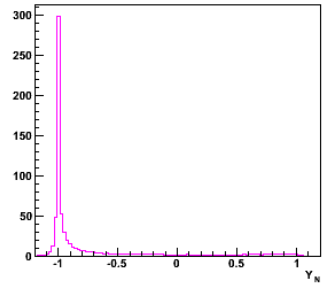
Training sample: signal, cont. BBbar

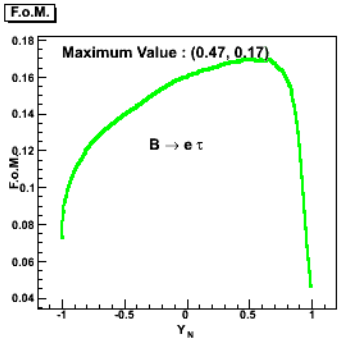












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* Picture

Top left: y_ann distribution of signal

Top middle: y_ann distribution of continuum

Top right: y_ann distribution of BBbar

Bottom left: y_ann distribution of Ulnu

Bottom middle: y_ann of Rare

Neural Network Output (Y_n)

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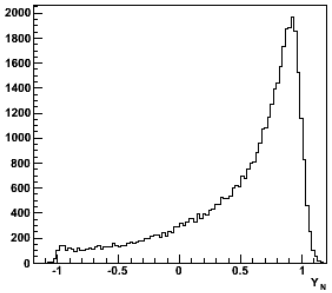

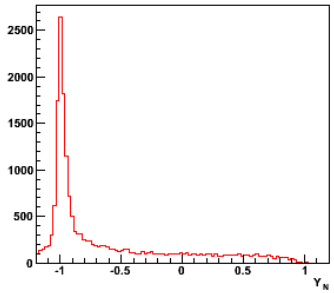

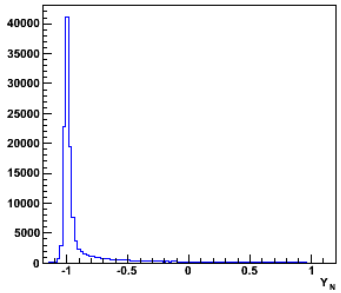

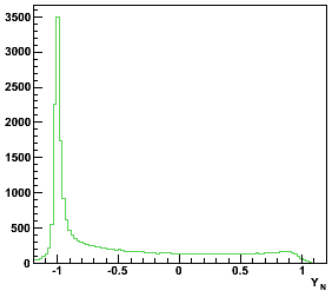

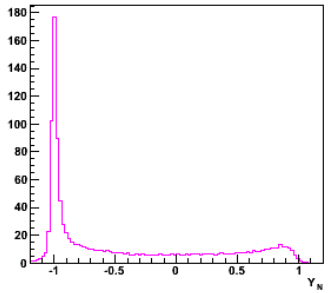

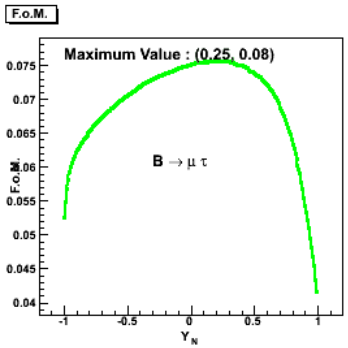

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Top left: y_ann distribution of signal

Top middle: y_ann distribution of continuum

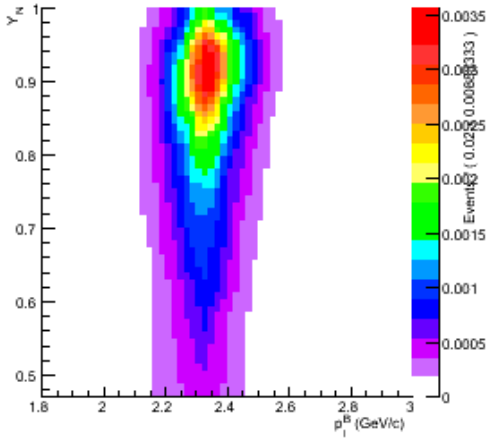
Top right: y_ann distribution of BBbar

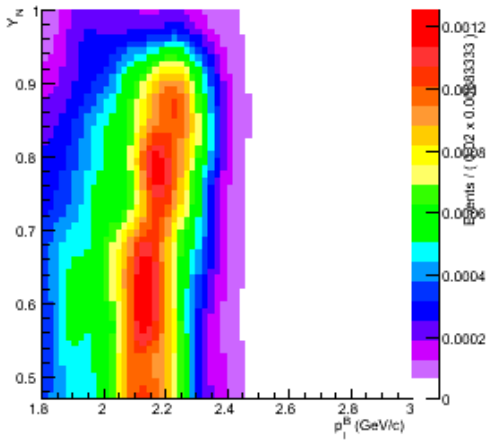
Bottom left: y_ann distribution of Ulnu

Bottom middle: y_ann of Rare

2D PDF $P_l^B : Y_N$ ($e\tau$)

$Y_N > 0.47$

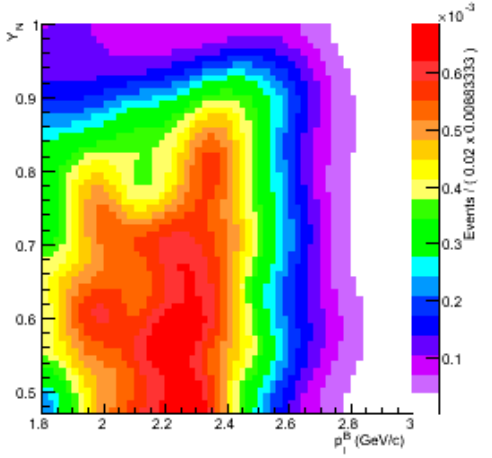


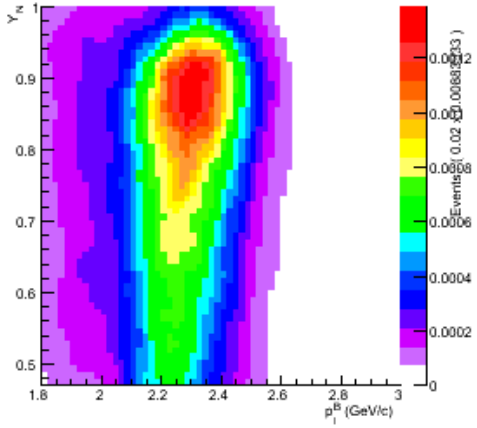


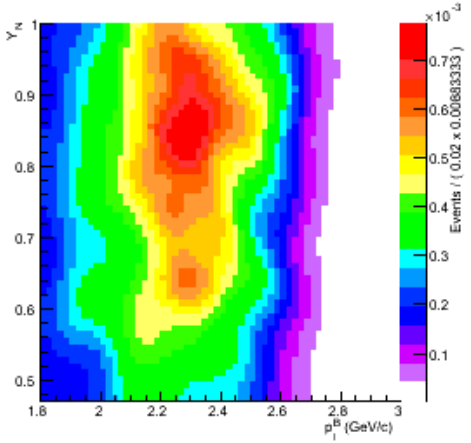
PDF's
by Roo2DKeysPDF

*Picture

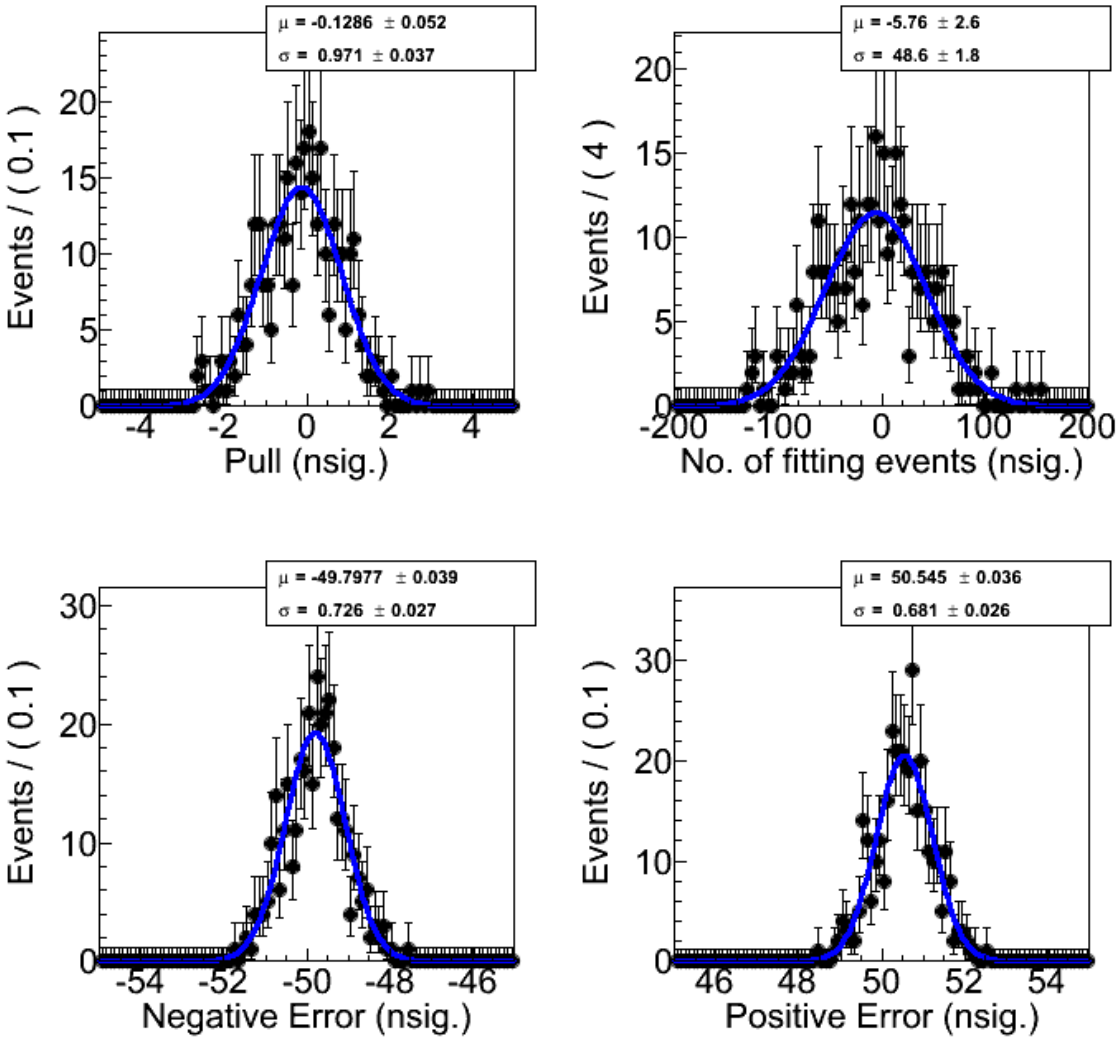
Signal, BBbar
cont. , ulnu , rare





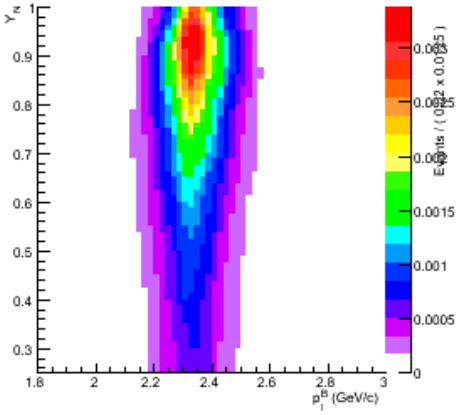


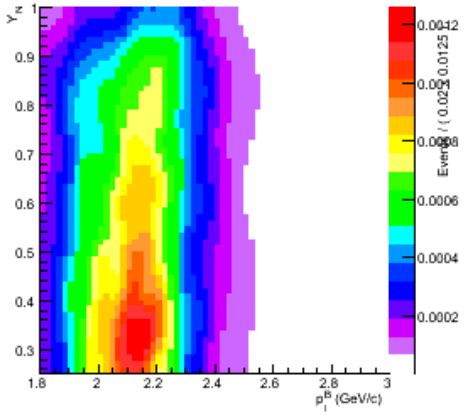
Pull distribution ($e\tau$)



2D PDF $P_l^B : Y_N$ $(\mu\tau)$

$Y_N > 0.25$





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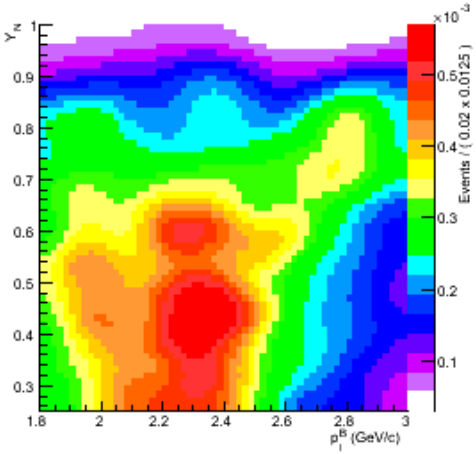
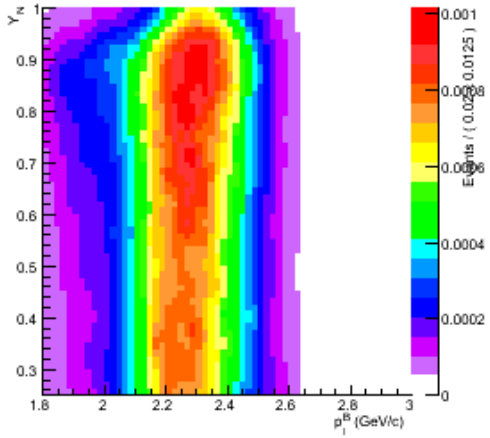
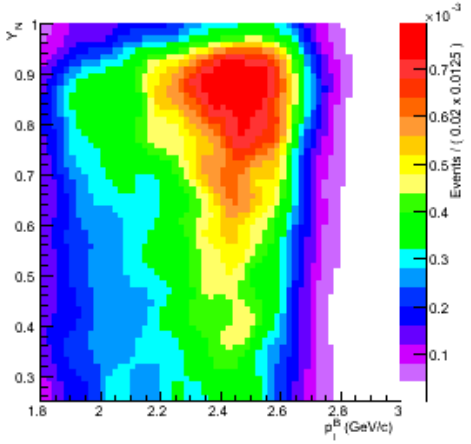
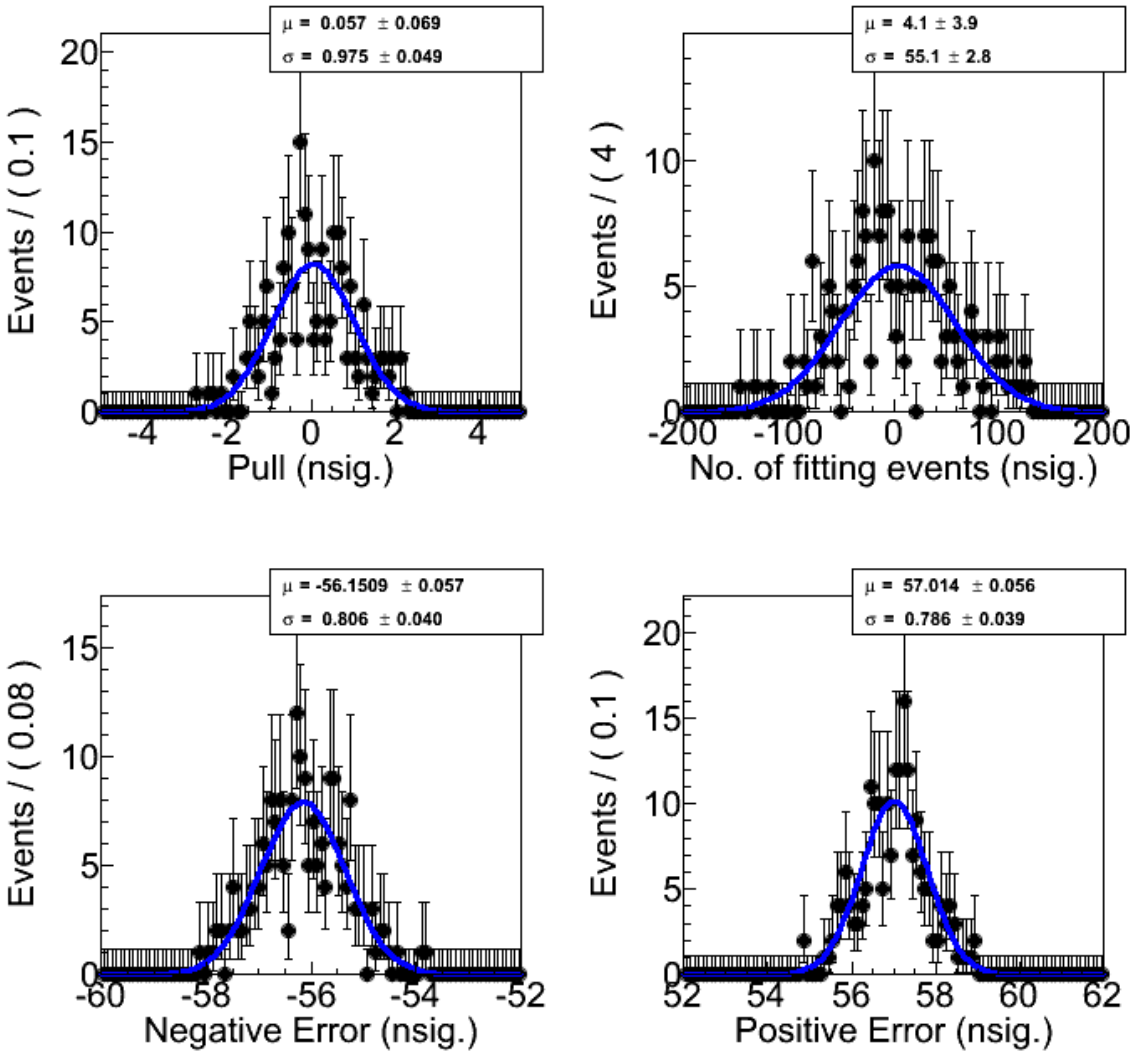






Pull distribution ($\mu\tau$)



Result

$e\tau$

Y_n cut	Signal efficiency (%)	Number of BB/continuum Ulnu/rare	Expected U.L. (10^{-5})
> 0.47	10.64	2083 ± 45.6/1039 ± 32.2 3374 ± 58.1/50 ± 7.1	1.3

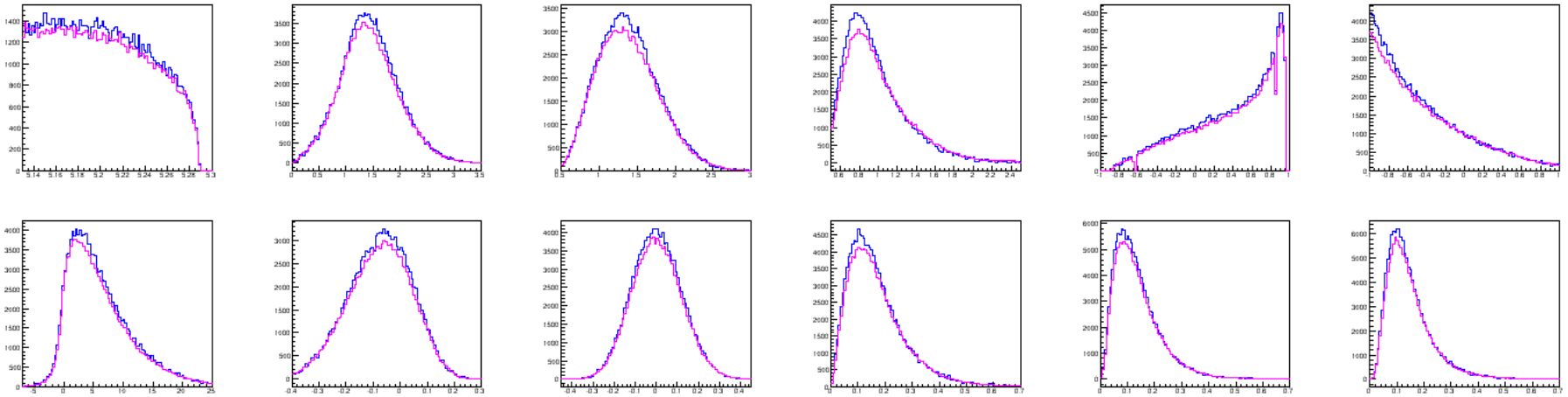
$\mu\tau$

Y_n cut	Signal efficiency (%)	Number of BB/continuum Ulnu/rare	Expected U.L. (10^{-5})
> 0.25	10.59	3636 ± 60.3/2082 ± 45.6 4135 ± 64.3/258 ± 16.1	1.4

Data vs. MC ($e\tau$)

Blue line: On- off data

Pink line: BBbar+Ulnu+Rare



In lepton_mom. sideband region

$$1.8GeV < P_l^* < 2.2GeV$$

* picture

From left to right;

Top1 : Mbc Top2: transverse missing mom. Top3: pi mom. in tau rest frame
Top4: pion mom in CM frame Top5: cos_lepton Top6: cos_BL
Bot1: M_miss2 Bottom2: R2so Bottom3: R4so Bottom4: R2oo Bottom5: R3oo Bottom6: R4oo (sfw 5 moment variables)

Data vs. MC ($\mu\tau$)

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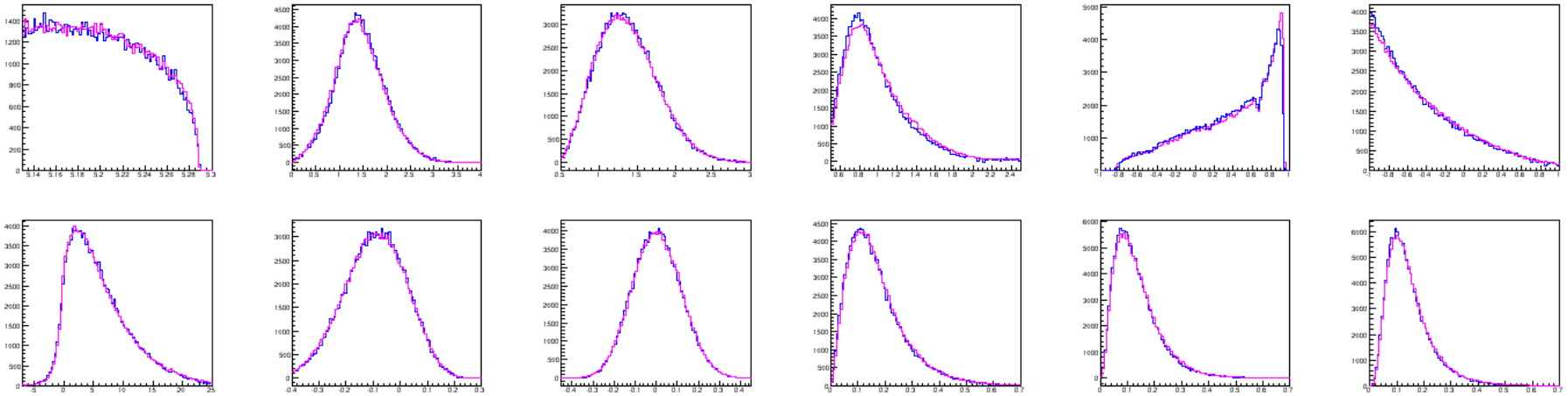

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Systematics

	$e\tau$	$\mu\tau$
N_{BB}	1.4%	1.4%
MC Statistics	0.56%	0.558%
Tracking efficiency	0.7%	0.7%
Lepton ID	1.8%	2.3%
Pion ID	0.9%	0.9%

Plan

* Systematics Study

  - doing Control sample study

    $B^+ \to \bar{D}^0 \pi^+$ to calibrate $B^0 \to l^+ \tau^-$