Studies of $b \to s\ell^+\ell^-$ and $b \to s\gamma$ for BTeV

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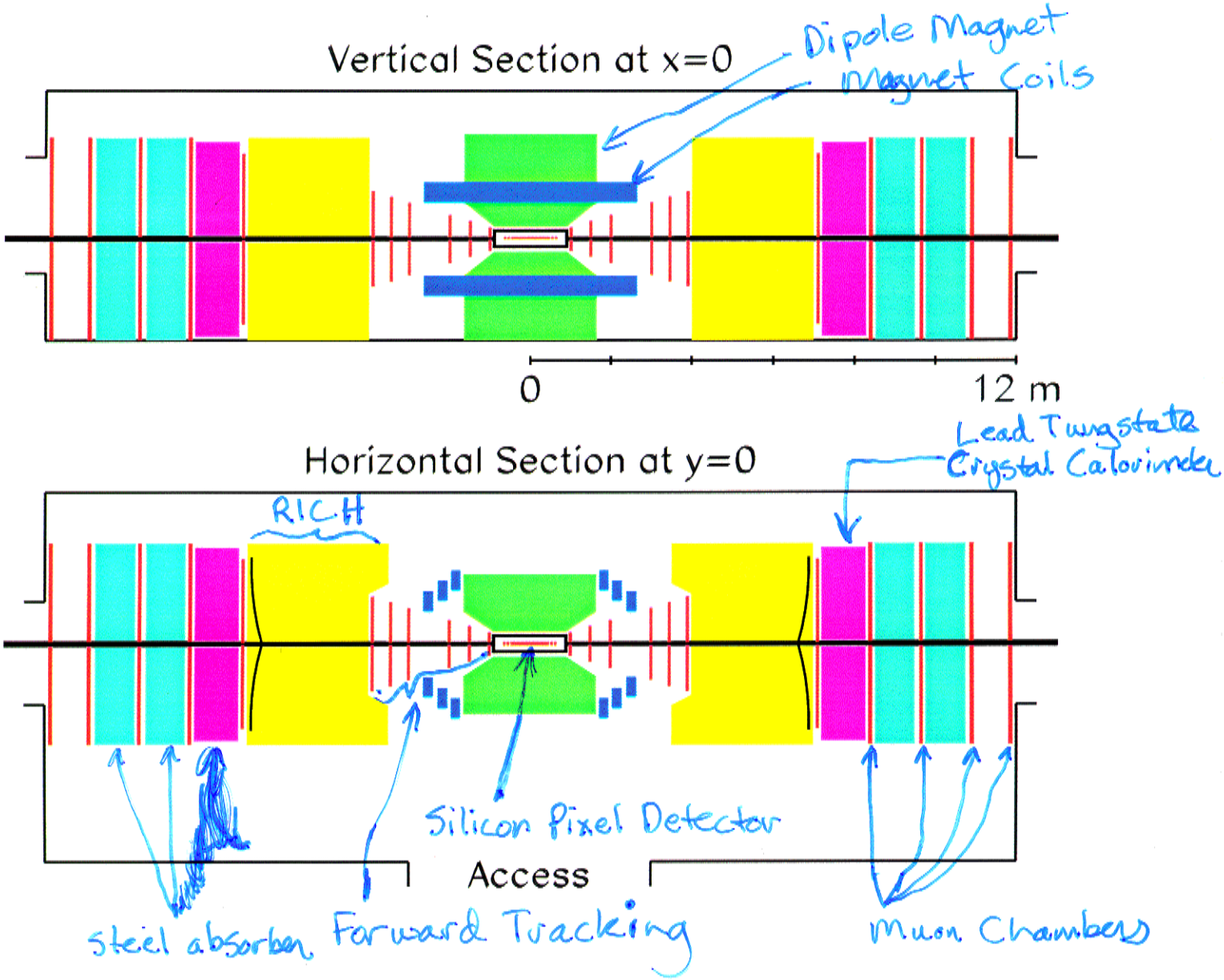
- Status of BTeV simulations
- General plan
- What has been done with $B^+ \to K^+\mu^+\mu^-$
- Plans
- Conclusions

BTeV at CØ


Vertical Section at x=0
Dipole Magnet
Magnet Coils
0
12 m
Horizontal Section at y=0
Lead Tungstate
Crystal Calorimeter
RICH
Silicon Pixel Detector
Access
steel absorber
Forward Tracking
Muon Chambers

Status of BTeV Simulations

- MCFAST:
  - New geometry for the BTeV Proposal available a few weeks ago (Silicon pixel doublets rather than triplets)
  - MCFAST version 5.0 (necessary for ~~for~~ new geometry) released a few weeks ago
  - Shower algorithm similar to CDF
- BTeVGEANT
  - Available a few weeks ago
  - Uses "BTeV Proposal" geometry
  - New shower clustering algorithm available (similar to CLEO)

General Plan

- Set up infrastructure (essential for generating large MC samples)
  - Set up MCFAST and BTEV libraries at Minnesota
  - Learn MCFAST, write NTUPLE maker/analysis code
  - Set up Monte Carlo FARM scripts
- Understand $B^+ \to K^+\mu^+\mu^-$, $B^0 \to K^{0*}\mu^+\mu^-$ ($K^{0*} \to K^+\pi^-$)
  - All charged tracks -- MCFAST should do a good job
  - Use these simple decays to test new geometry and MCFAST
- Use BTeVGeant to study states with e^+e^-
- Use BTeVGeant to simulate $b \to s\gamma$ signal
- It is likely we will have to rely on MCFAST to simulate many backgrounds, therefore:
  - Comparisons between GEANT and MCFAST will need to be done
- Inclusive analyses of $b \to s\ell^+\ell^-$ and $b \to s\gamma$

Exclusive $B^+ \to K^+\mu^+\mu^-$ Analysis

- Look at distributions in signal and background to see which cuts to use
- Background sample ~~is~~ :
  - Pre-select to contain a b-bbar pair and at least two muons
  - Can generate >3M week at MN
  - Presently only write out NTUPLE (events are very large)
  - 250K used in this analysis, 2.5M generated with NTUPLE bug--couldn't be used, but can regenerate in ~5 days ($10\ pb^{-1}/5$ days)
- Fully tagged $K^+\mu^+\mu^-$ combinations used for signal distributions

L1 trigger
(di-muon and vertex)

$p(\mu^+) > 5$ GeV/c
$p(\mu^-) > 5$ GeV/c
$p(K^+) > 4$ GeV/c

File: */data/cleo11/smith/btev/prod/ntuple/bkmumu_bckg_0.rz

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	101	1	******/1144	4.1765E+04	2.144	1.492
4	1	-31	******/1144	336.0	2.716	1.165
4	102	1	******/1144	2.7952E+04	3.609	1.645
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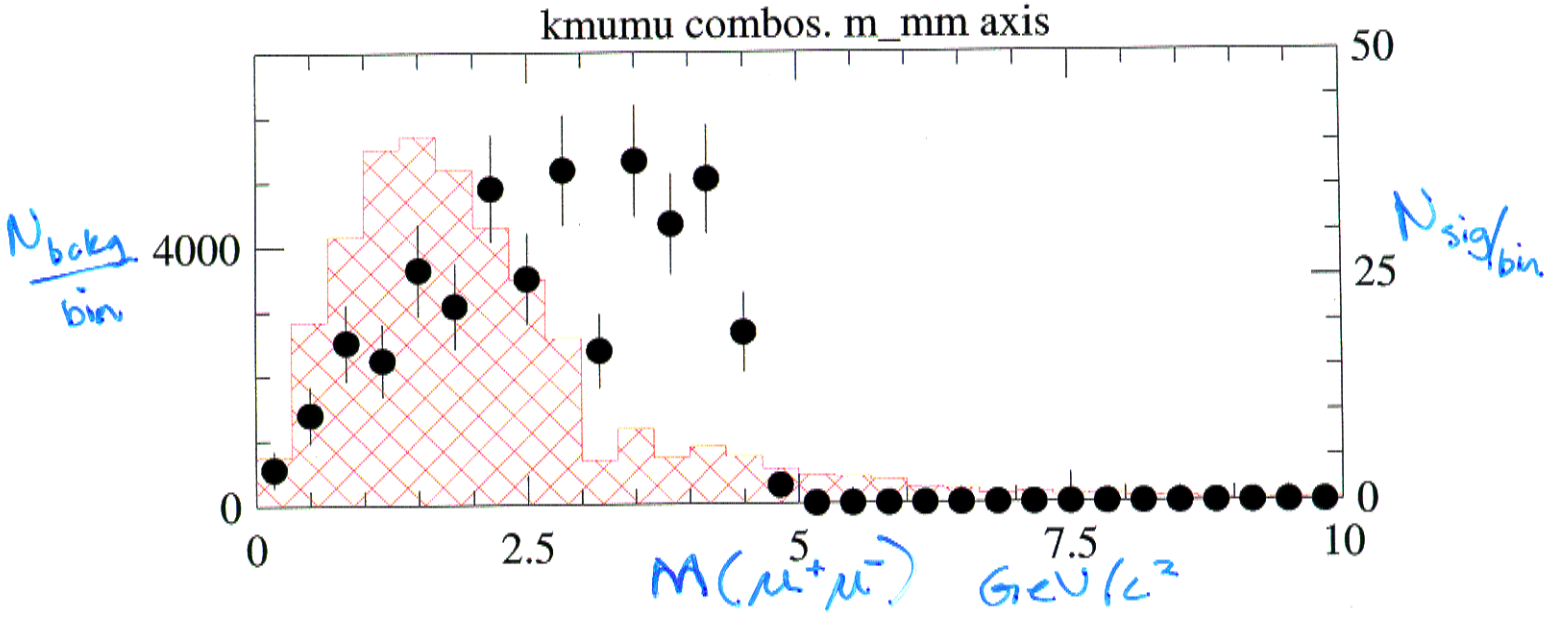

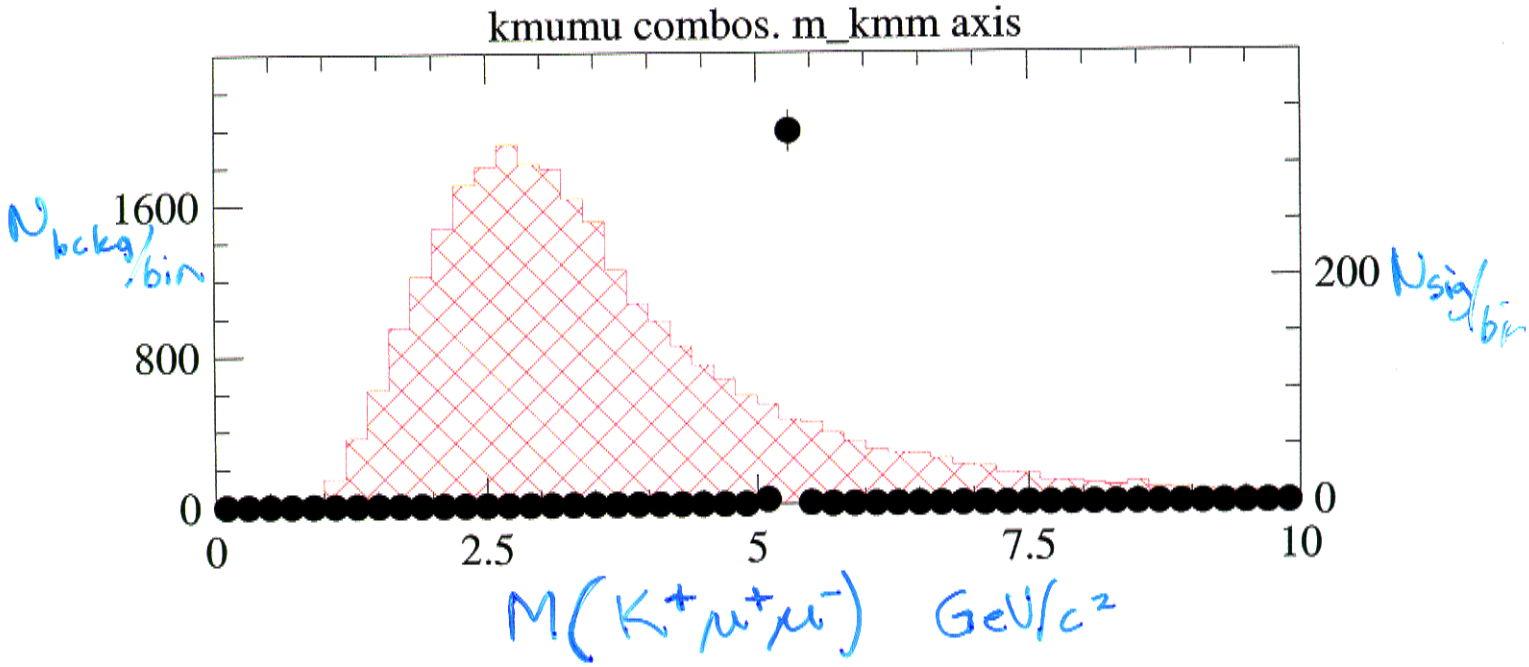

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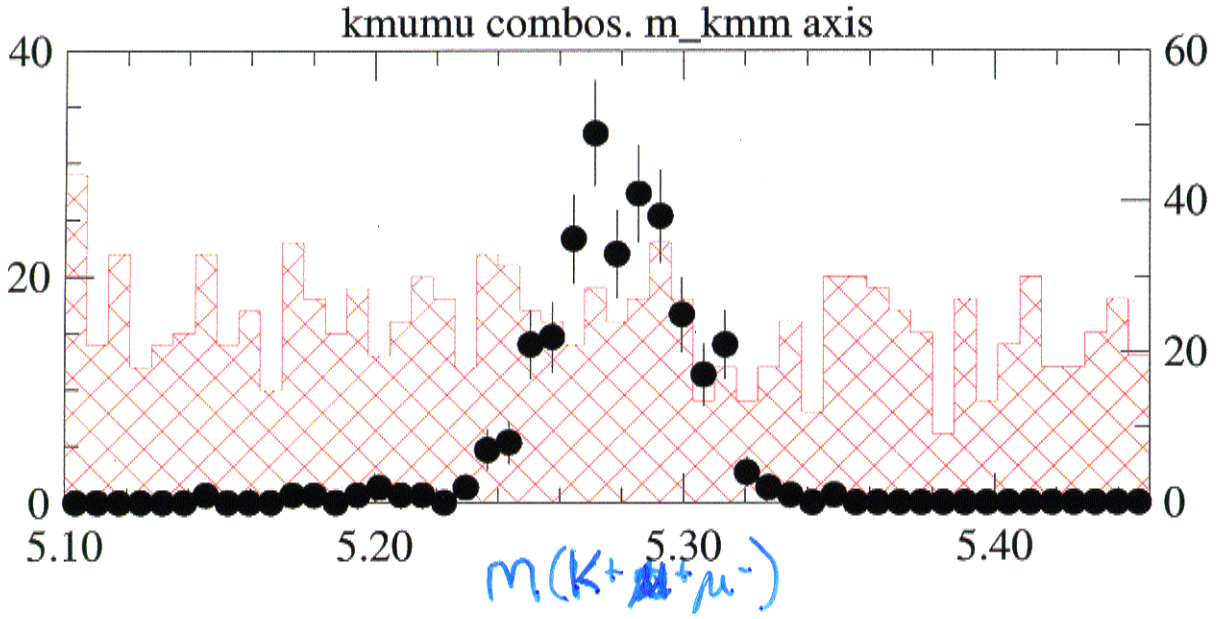
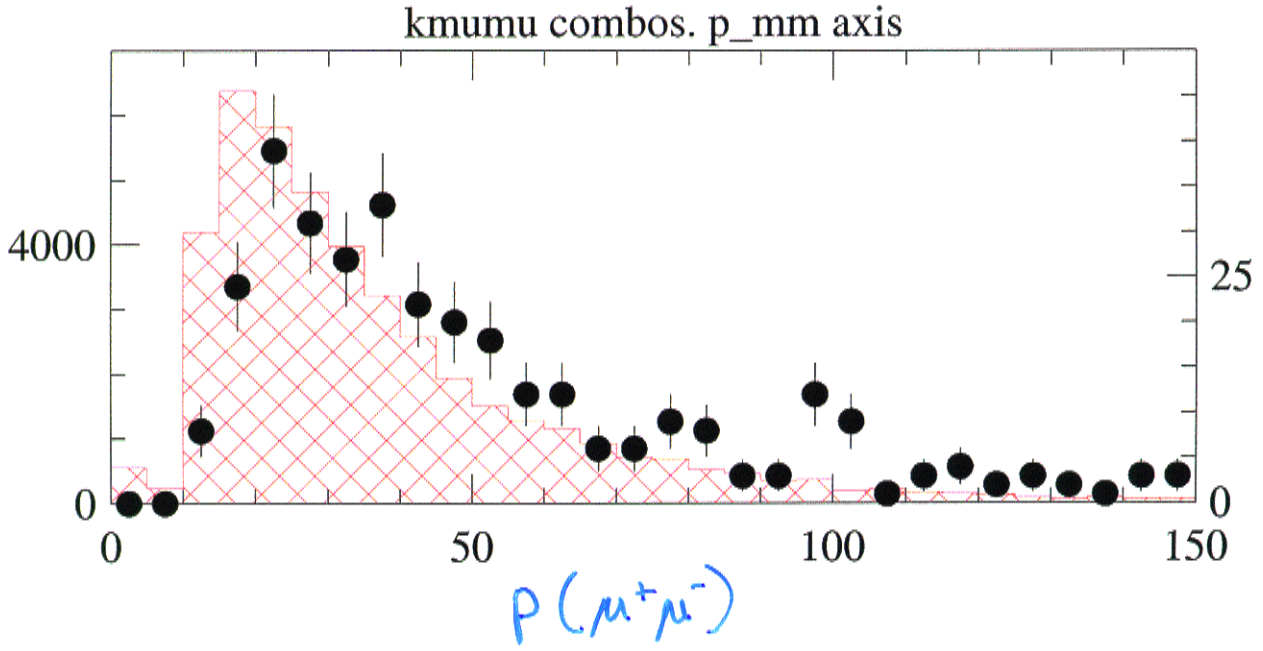
4	103	1	******/1145	801.0	5.267	0.1010
4	3	-31	******/1144	335.0	5.278	2.4895E-02
4	104	1	******/1145	4.2903E+04	36.56	24.34
4	4	-31	******/1144	324.0	50.25	31.33





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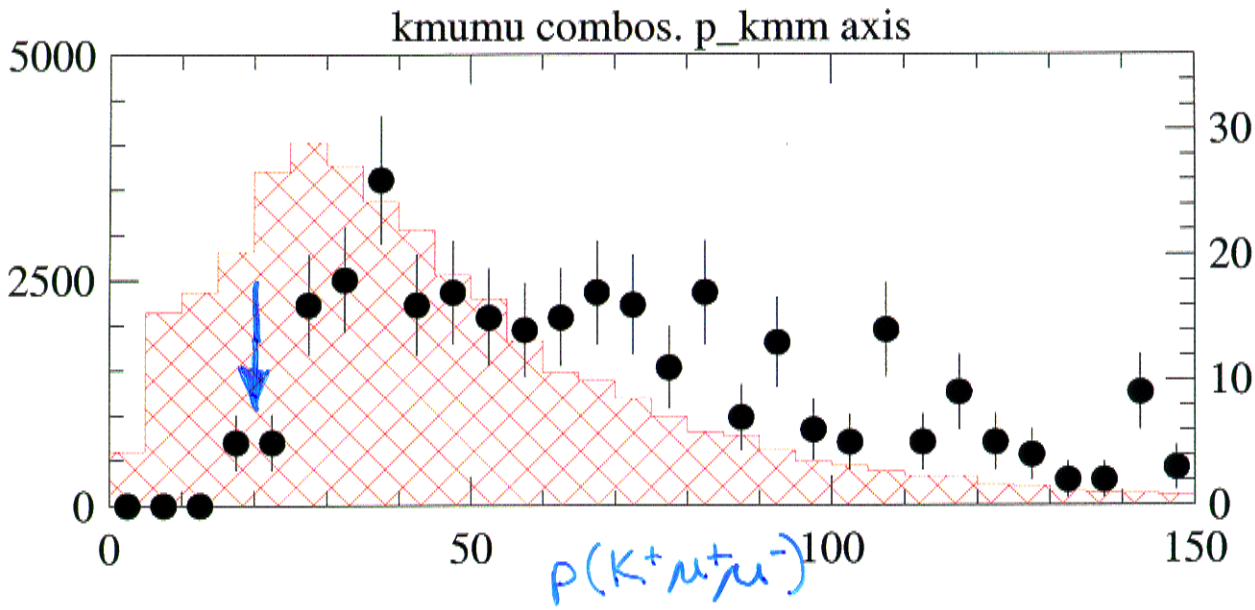
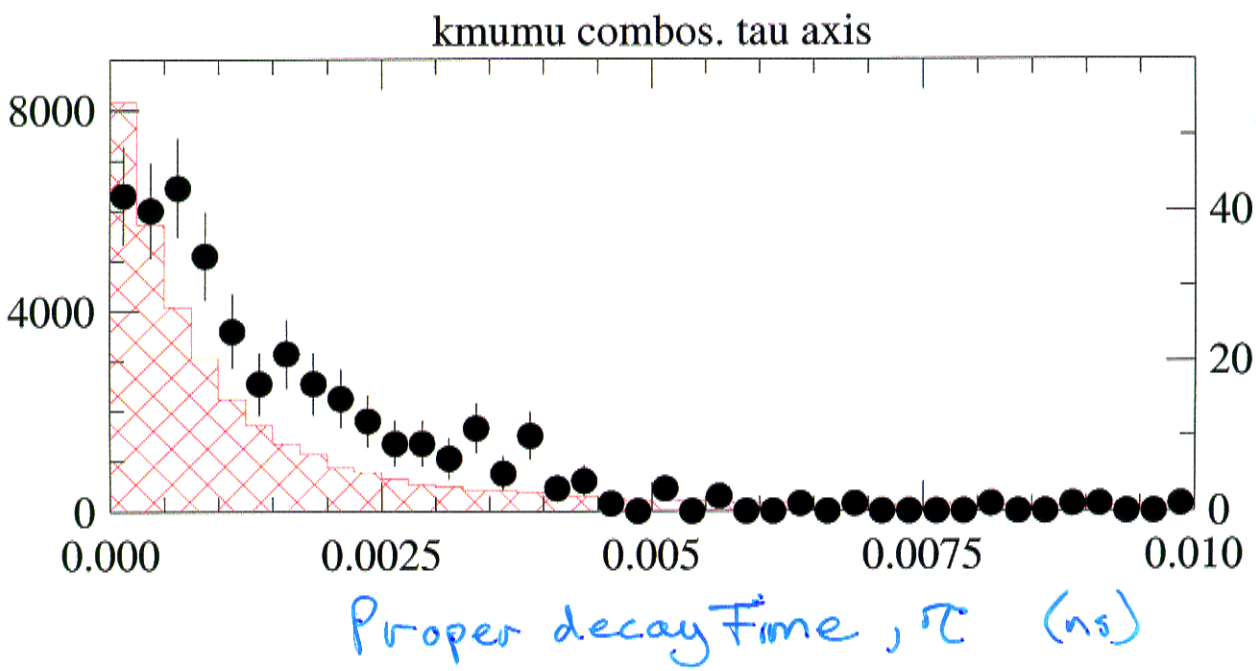
4	105	1	******/1145	4.2557E+04	44.19	28.50
4	5	-31	******/1144	292.0	69.20	32.85
4	106	1	******/1145	3.5882E+04	1.5375E-03	1.9820E-03
4	6	-31	******/1144	335.0	1.5802E-03	1.5222E-03





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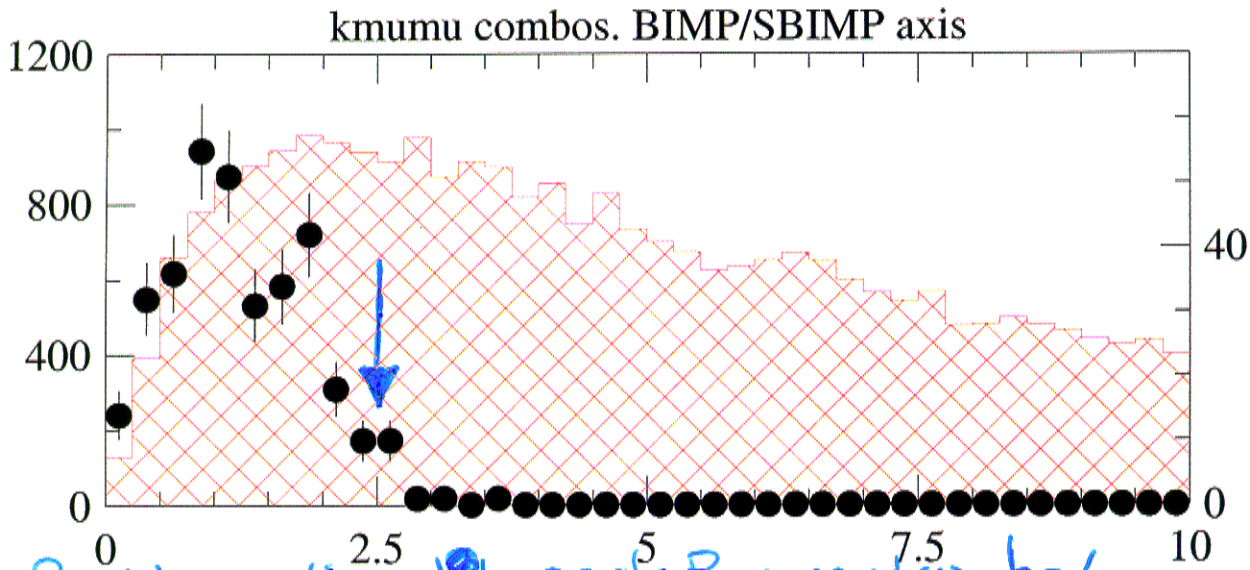
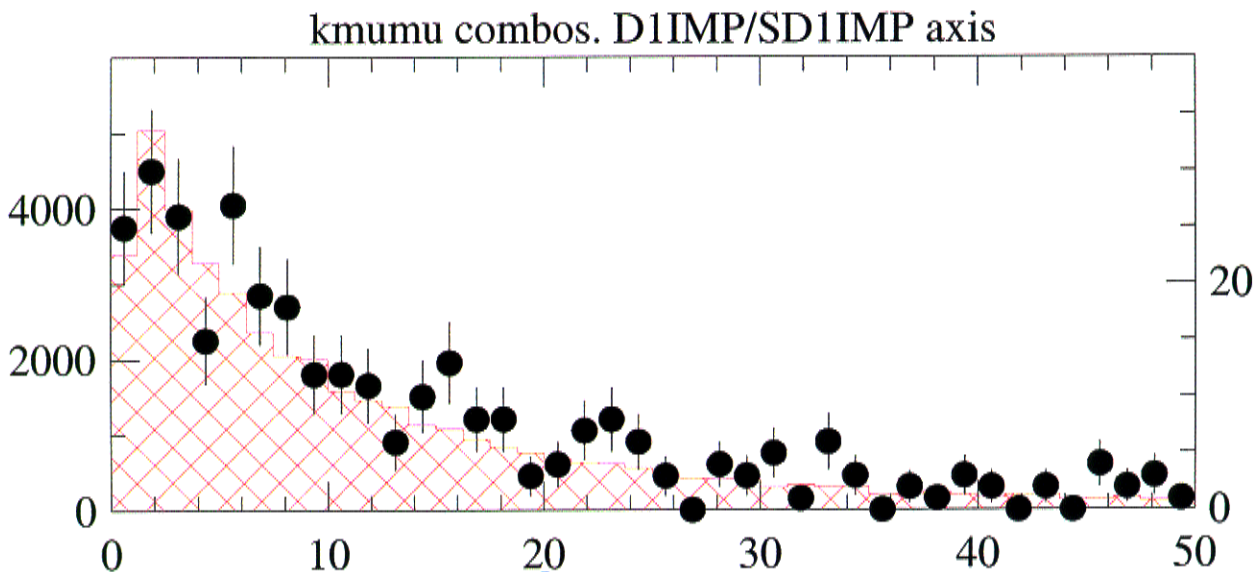
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	107	1	******/1145	2.7068E+04	4.519	2.633
4	7	-31	******/1144	336.0	1.239	0.6537
4	108	1	******/1145	4.1538E+04	11.16	10.75
4	8	-31	******/1144	313.0	12.72	11.81



B Normalized Impact Parameter, b_B/σ_{b_B}



Muon 1 (μ^+) Normalized Impact Parameter, $b_{\mu^+}/\sigma_{b_{\mu^+}}$

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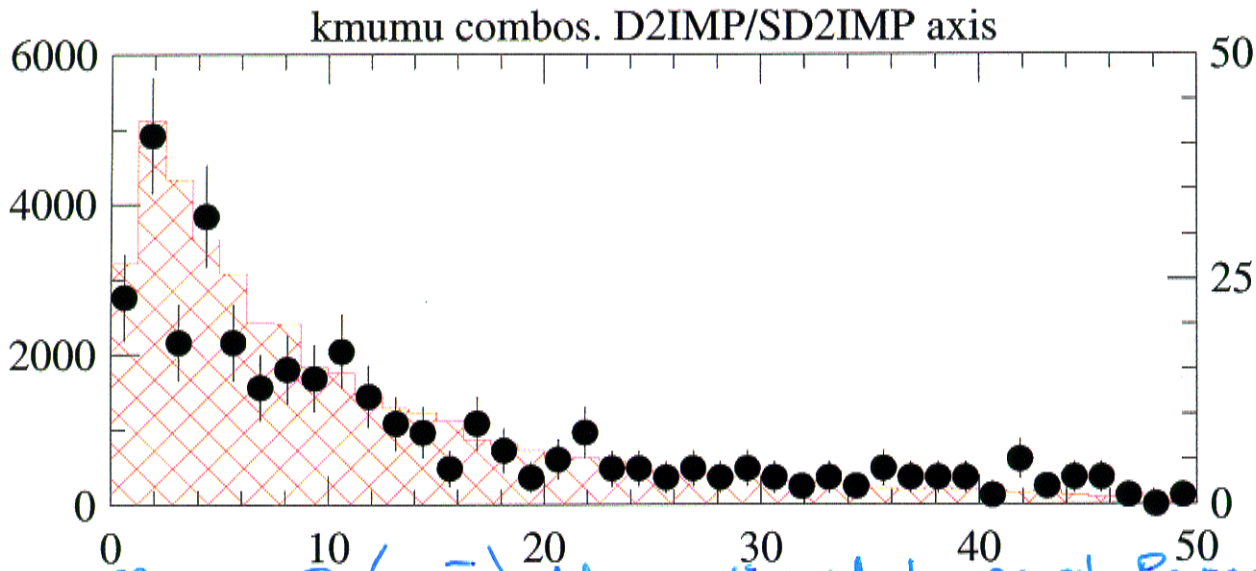
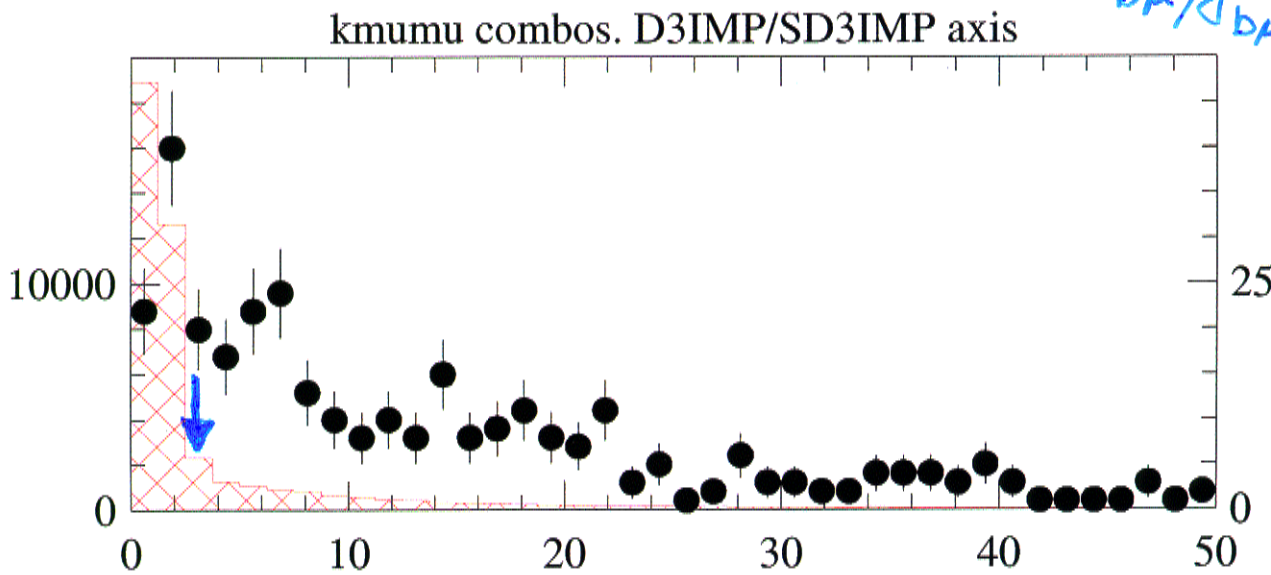
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	109	1	******/1145	4.1824E+04	10.65	10.32
4	9	-31	******/1144	316.0	12.77	12.20
4	110	1	******/1145	4.3000E+04	3.786	6.557
4	10	-31	******/1144	323.0	13.40	12.09



Muon 2 (μ^-) Normalized Impact Parameter $b_{\mu^-}/\sigma_{b_{\mu^-}}$



Kaon Normalized Impact Parameter, $b_{K^+}/\sigma_{b_{K^+}}$

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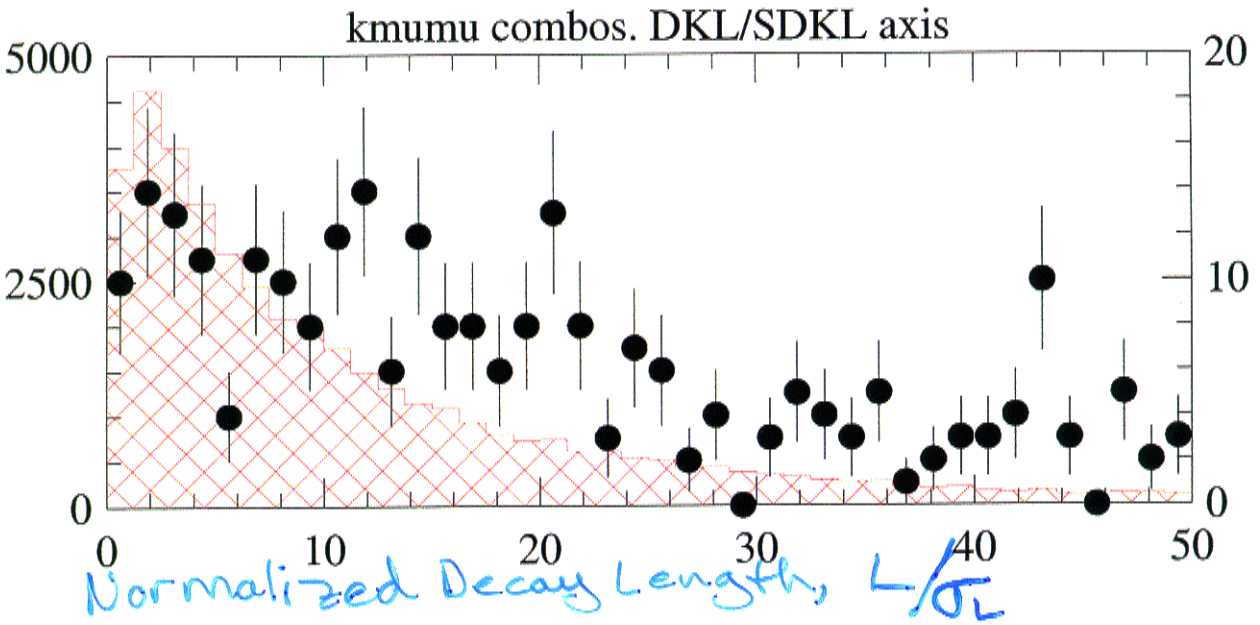
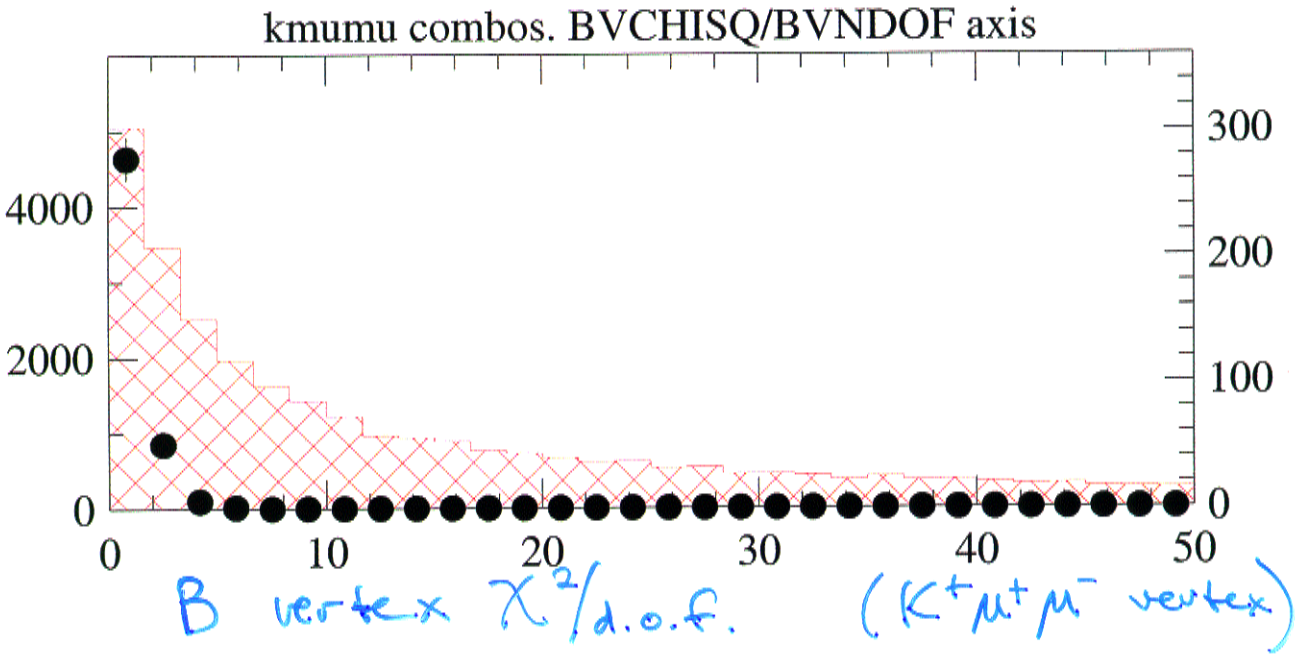
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	111	1	******/1145	4.1629E+04	11.00	10.54
4	11	-31	******/1144	254.0	18.41	13.53
4	112	1	******/1145	2.9166E+04	13.28	13.10
4	12	-31	******/1144	336.0	1.161	0.7663





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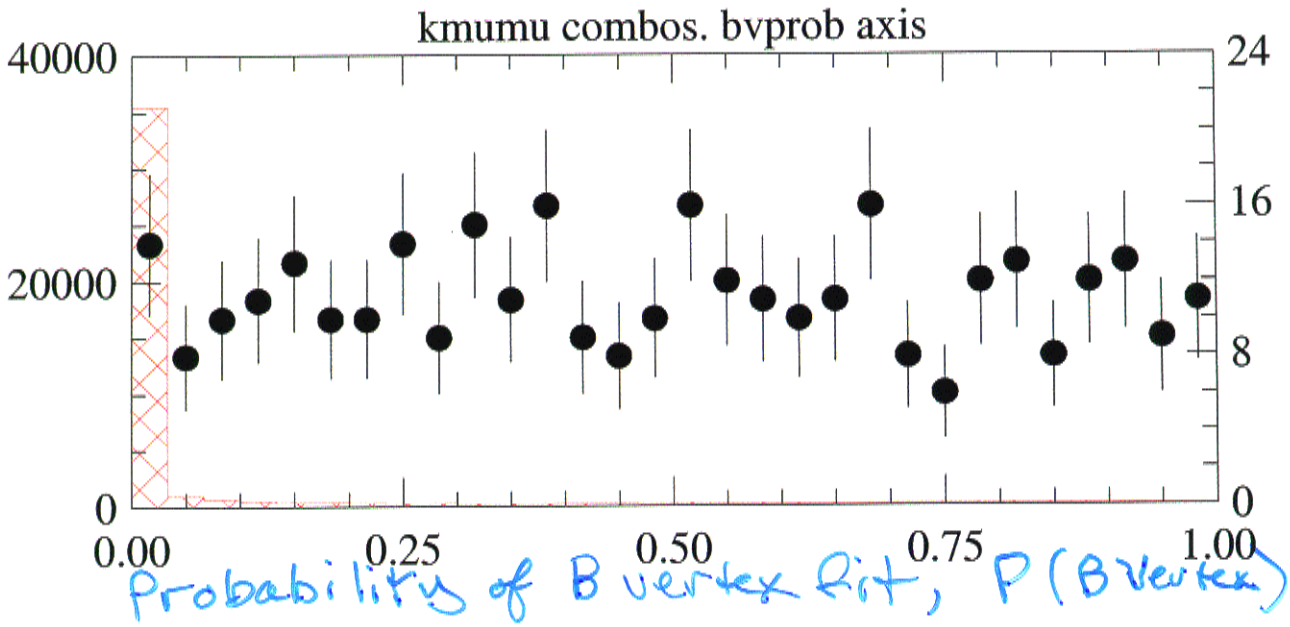
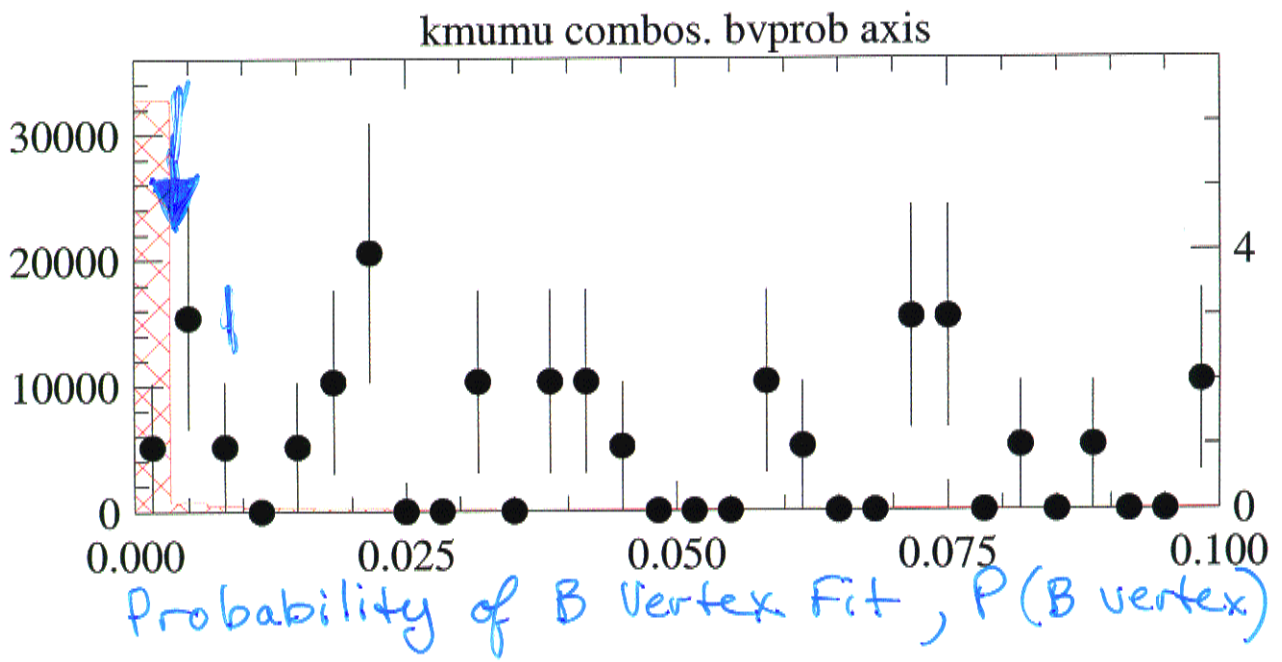
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	113	1	******/1145	4.3236E+04	7.9574E-02	0.1798
4	13	-31	******/1144	336.0	0.4944	0.2857
4	114	1	******/1145	3.7181E+04	5.3504E-03	1.3805E-02
4	14	-31	******/1144	32.00	4.4271E-02	2.9235E-02





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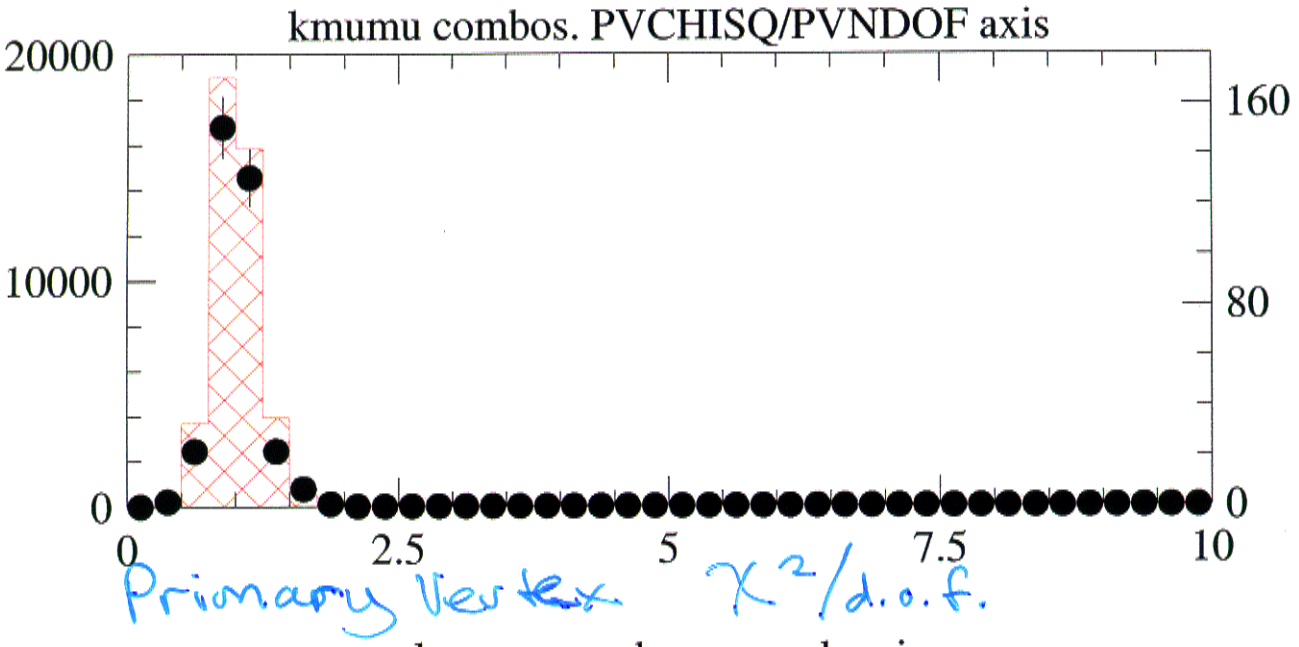
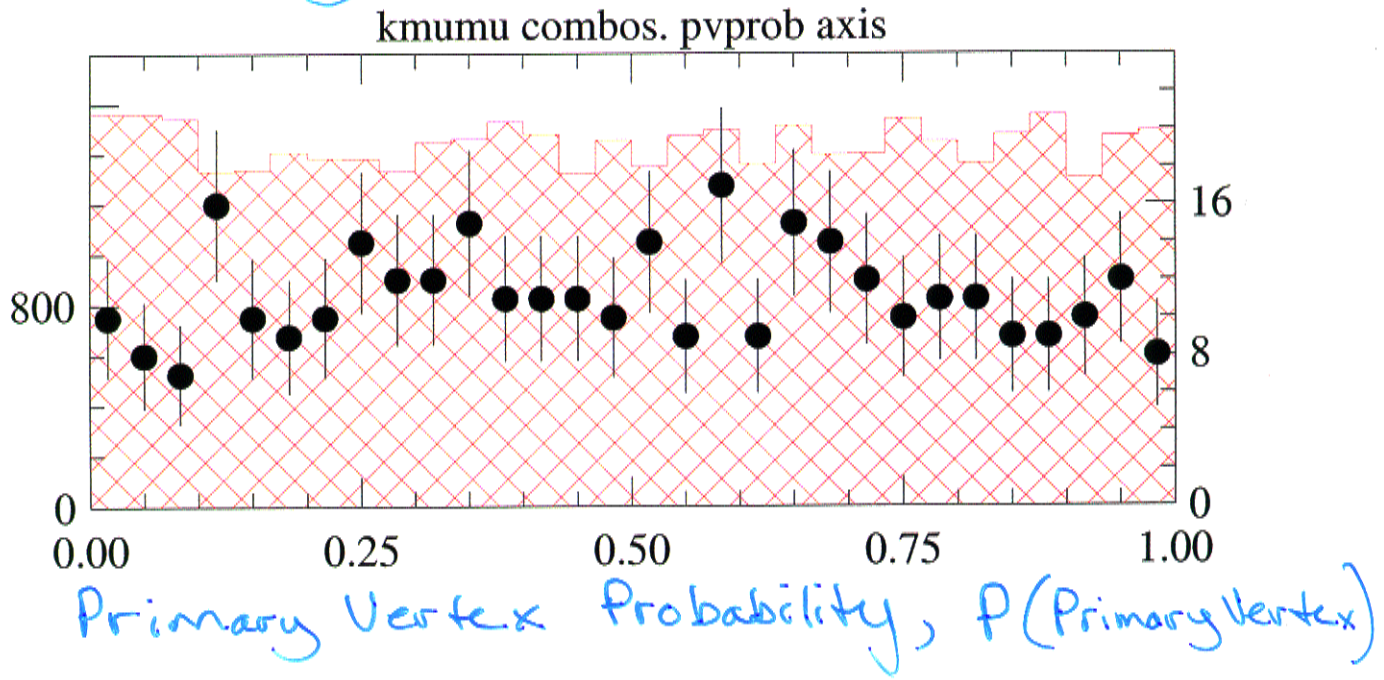
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	115	1	******/1145	4.3228E+04	1.002	0.2160
4	15	-31	******/1144	336.0	1.004	0.2104
4	116	1	******/1145	4.3236E+04	0.5000	0.2902
4	16	-31	******/1144	336.0	0.4987	0.2760





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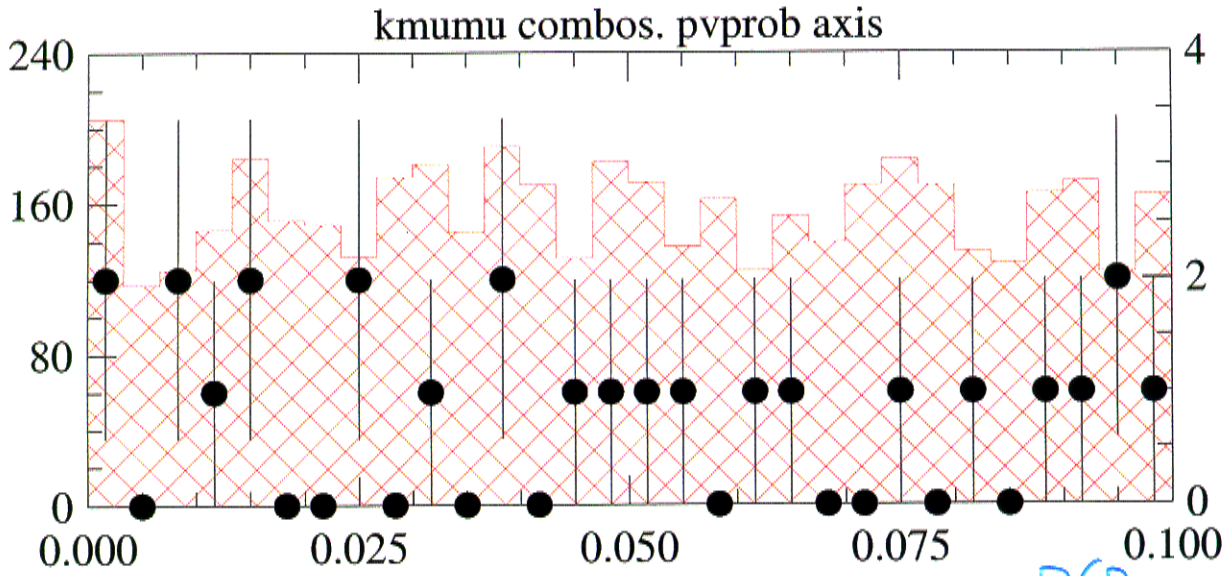
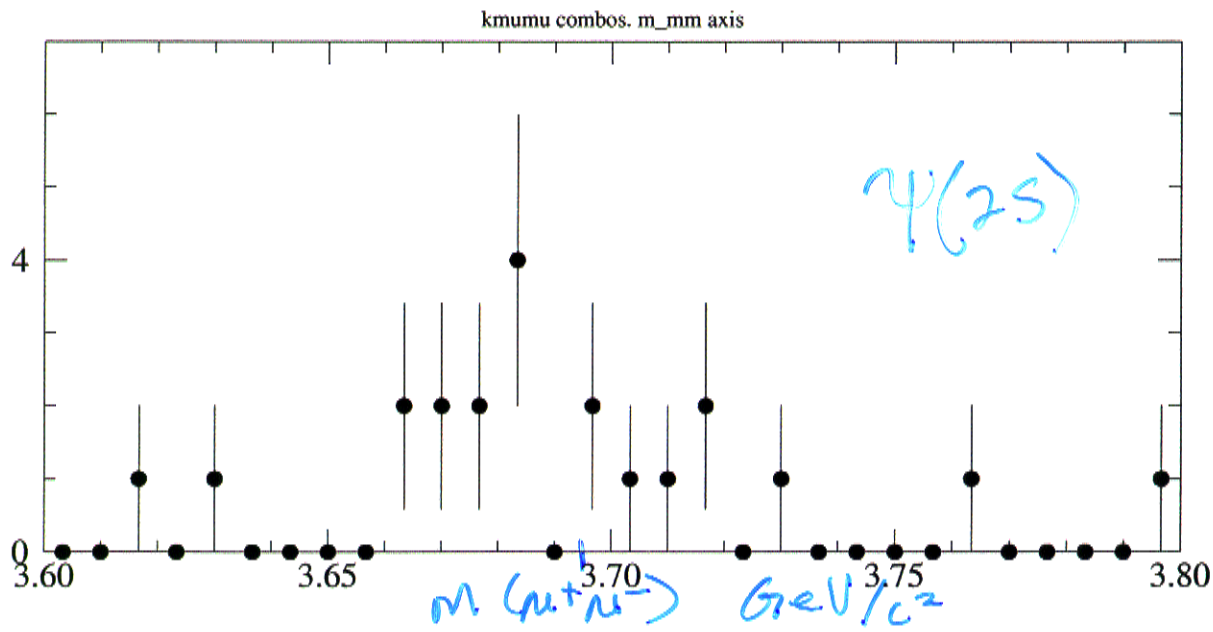
ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
4	117	1	******/1145	4674.	4.9720E-02	2.8692E-02
4	17	-31	******/1144	25.00	4.6867E-02	3.1820E-02

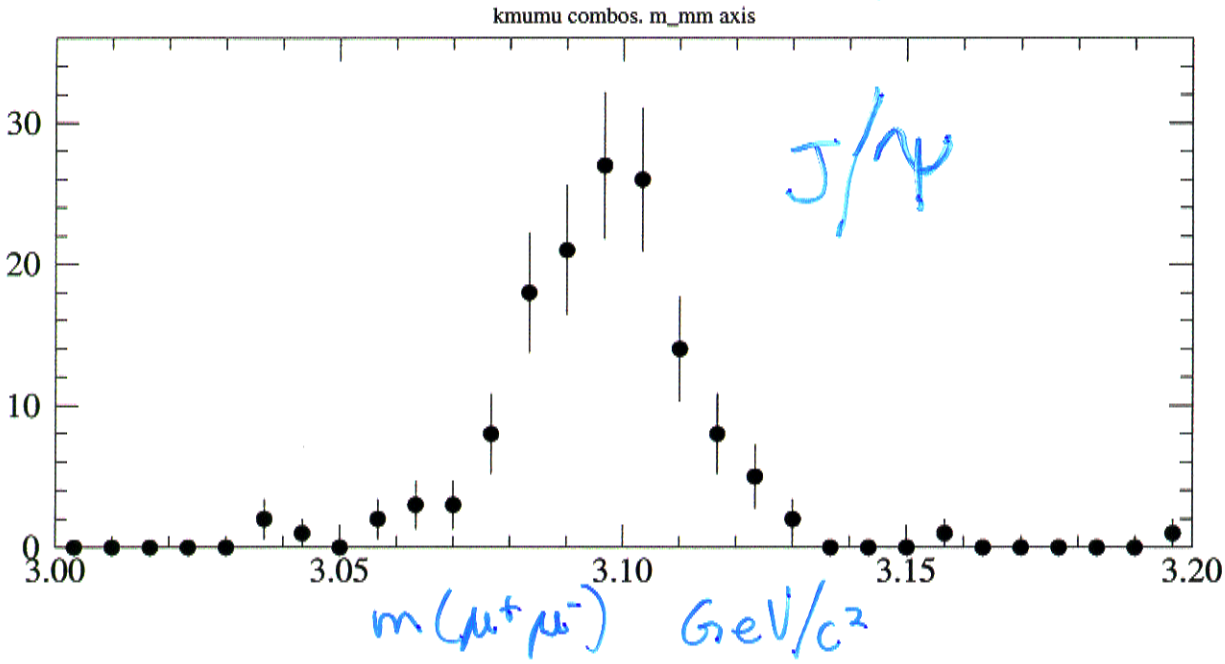


Probability of Primary Vertex, P(PrimaryVertex)

File: */data/cleo11/smith/btev/prod/ntuple/bkmumu_bckg_0.rz

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
1000001	0	-31	******/1309	21.00	3.692	3.9098E-02
1000002	0	-31	******/1310	142.0	3.096	1.9174E-02



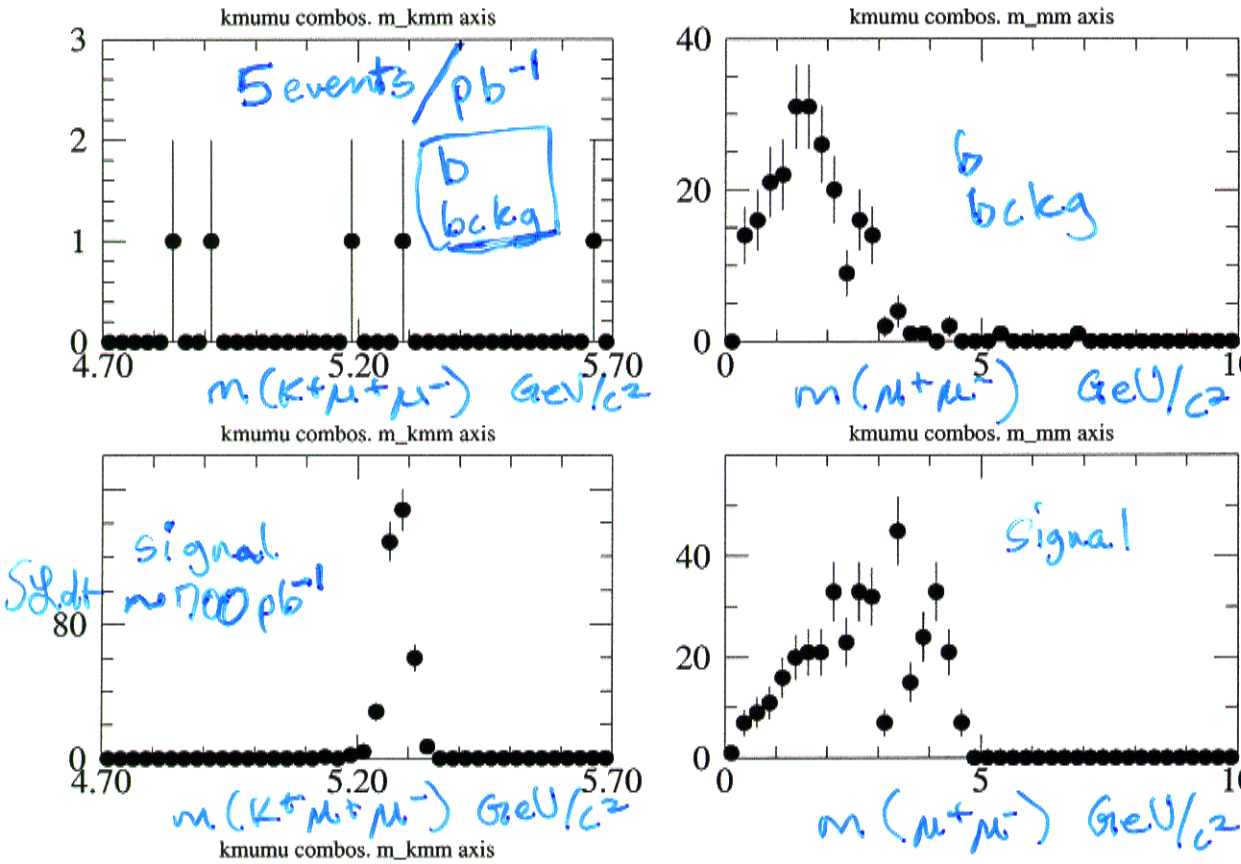


Exclusive $B^+ \to K^+\mu^+\mu^-$ Selection Criteria

- Decay length : $L/\sigma_L > 7$ (Need non-B background to optimize)
- B vertex probability : PROB(b vertex) > 0.01
- Primary vertex probability : PROB(primary vertex) > 0.01
- B impact parameter : $b_B/\sigma(b_B) < 2.5$
- K impact parameter : $b_K/\sigma(b_K) > 2.5$
- B momentum : p(B) > 20 GeV/c
- J/psi and psi' mass: Cut 100 MeV/c^2 about PDG value

File: */data/cleo11/smith/btev/prod/ntuple/bkmumu_bckg_0.rz

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
1000001	0	-31	******/1305	5.000	5.177	0.2944
1000002	0	-31	******/1305	232.0	1.700	0.9000
4	1	-31	******/1305	379.0	5.278	2.5147E-02
4	2	-31	******/1305	379.0	2.696	1.110
1000000	0	-31	******/1305	384.0	5.277	4.3398E-02



Estimates of Sensitivity

Quantity	pTDR Cuts	pTDR/new geom	New cuts/geom.
Eff(signal) • Eff(trig)	2.0 ~~2.5%~~	2.0%	1.9%
~~Eff(trig)~~	~~80.0%~~	~~80.0%~~	~~80.0%~~
N(bckg) (4.7-5.7)/int(L)	1/?	13/pb-1	5/pb-1
N(bckg) (4.7-5.7)/year	40,000	26000 ~~23,000~~	10000 ~~8000~~
N(bckg) under signal	3000	1950 ~~1716~~	750 ~~600~~
N(signal)/year	1120	1120 ~~896~~	1064 ~~851~~
Signal/Bckg	0.4	0.6	1.4

Summary of Exclusive $B^+ \to K^+\mu^+\mu^-$

- Significant improvement in S/B from previous pTDR estimate, primarily due to
  - Optimized b vertex cut
  - Cut to kaon impact parameter relative to primary vertex
  - Cut to B momentum
- b and b-daughter hadron impact parameter cuts look very promising
- Need to understand non-B physics and beam backgrounds
  - What kind of background rejection will b vertex and impact parameter cuts give us?
- Regeneration of large b background sample underway

Inclusive $b \to s\ell^+\ell^-$

- CLEO technique:
  - Select $\ell^+\ell^-$
  - Select K and 0-4 pions (<=1 π^0)
  - Form figure-of-merit based on beam-constrained mass and energy conservation
- BTeV situation:
  - No beam constraint
  - But, B impact parameter (point-back) sensitive to wrong combinations (momentum conservation)
  - Cuts to daughters which point back to the primary vertex will reduce combinatorics from non-B tracks
  - Excellent K/π separation from RICH
  - Preliminary $B^+ \to K^+\mu^+\mu^-$ results on background rejection look encouraging

Inclusive $b \to s\gamma$

- CLEO technique:
  - Select γ
  - Select K and 1-4 pions (<=1 π^0)
  - Two techniques:
    - Form figure-of-merit based on beam-constrained mass and energy conservation
    - Event shapes variables (eg, thrust axis, Fox-Wolfram moment, etc.) as input to a neural network
- BTeV situation:
  - No beam constraint
  - Hard photon p_T spectrum relative to background
  - Excellent K/π separation from RICH

Plans

- Main goal is the BTeV proposal (May):
  - Exclusive $b \to s\, \mu^+\mu^-$ (and $b \to s\, e^+e^-$)
  - Inclusive studies of $b \to s\ell^+\ell^-$
  - $b \to s\gamma$
- For the workshop document
  - Anything we can get done in time
- We have laid much of the groundwork for this to happen:
  - BTeV(GEANT) and MCFAST set up on MN cluster (>3 million MCFAST/week) MCFARM running as I speak
  - Analysis package/NTUPLE working
  - We understand the cuts for the leptonic channels
- Preliminary $B^+ \to K^+\mu^+\mu^-$ signal/background estimates look encouraging