Study of the rare B-meson decays with the ATLAS experiment

FACULTY
OF MATHEMATICS
AND PHYSICS
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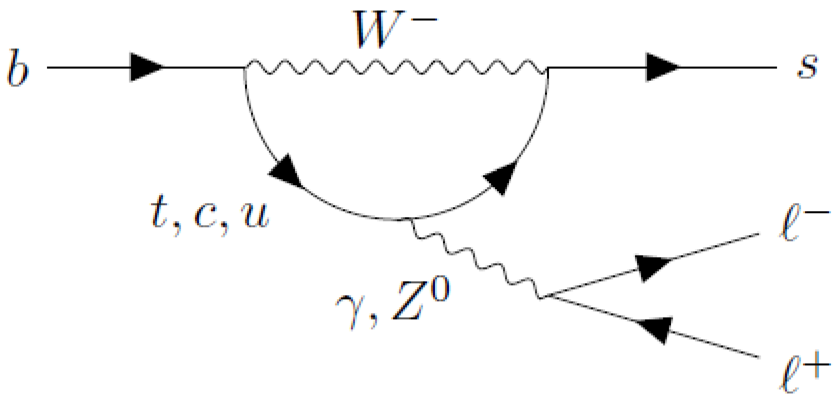
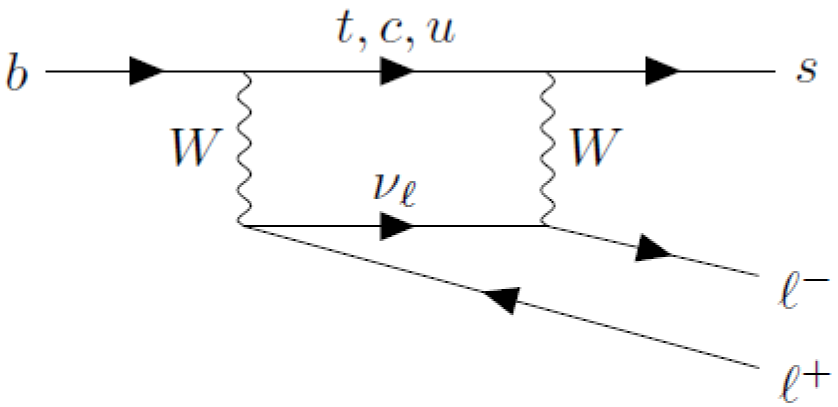
$$B_d^0 \to K^* \mu^+ \mu^-$$



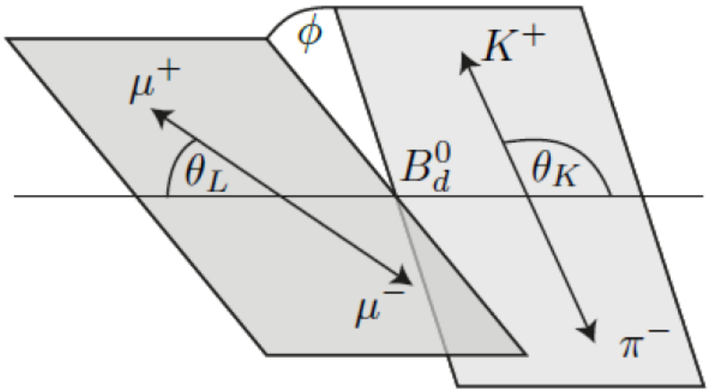


Analysis Folding

$q^2 = [m(\mu^+\mu^-)]^2$

q^2 (GeV^2)	$n_{\rm sig}$	$n_{\rm bkg}$
[0.04, 2.0]	128^{+22}_{-22}	122^{+22}_{-21}
[2.0, 4.0]	106^{+23}_{-22}	113^{+23}_{-22}
[4.0, 6.0]	114^{+24}_{-23}	204^{+26}_{-25}

ϕ veto $q^2 \in [0.98, 1.10]$ GeV^2



Angular Fit

3D differential decay rate: (4 variables, 8 parameters)

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{32\pi}\Bigg[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell$$
$$-F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi$$
$$+S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell$$
$$+S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi$$
$$+S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Bigg].$$

Angular Fit

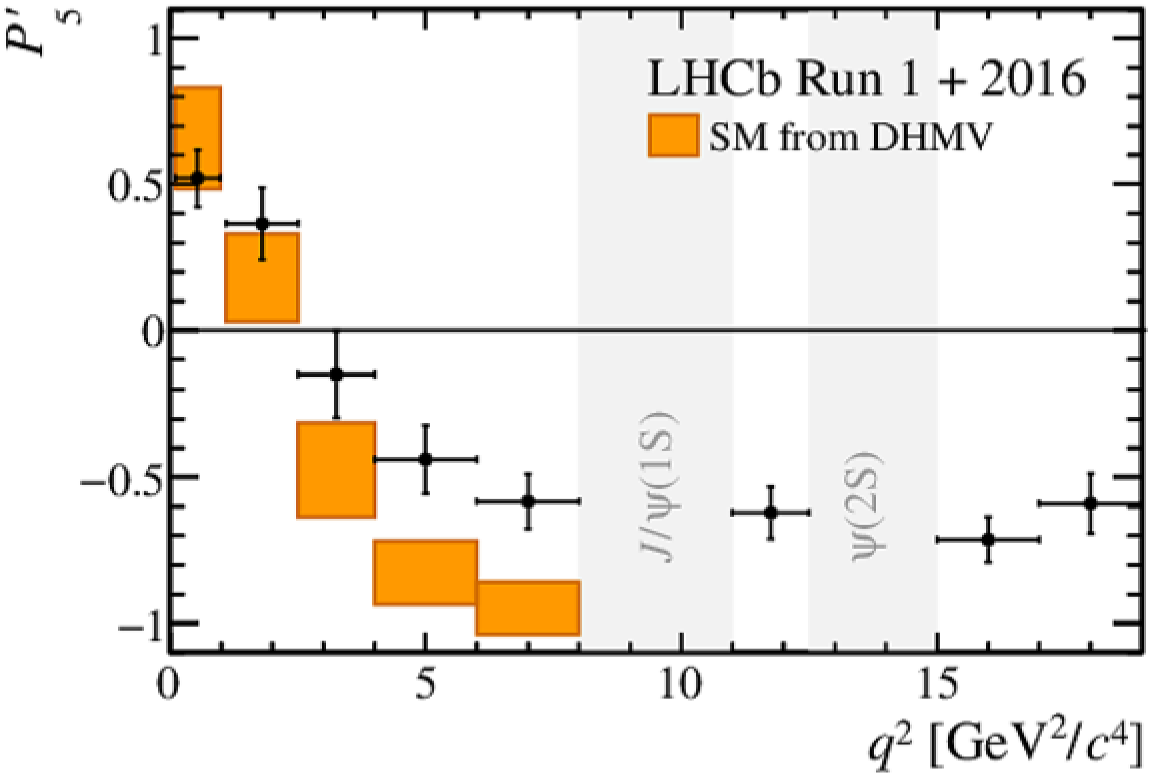
3D differential decay rate: (4 variables, 8 parameters)

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{32\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell \right.$$
$$-F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi$$
$$+S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell$$
$$+S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi$$
$$\left.+S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\right].$$

S_i - large hadronic uncertainties from form-factors

→ cancel at leading order under transformations:

$$P_1 = \frac{2S_3}{1-F_L}$$
$$P_2 = \frac{2}{3}\frac{A_{FB}}{1-F_L}$$
$$P_3 = -\frac{S_9}{1-F_L}$$
$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$


P'_5
LHCb Run 1 + 2016
SM from DHMV
$J/\psi(1S)$
$\psi(2S)$
q^2 [GeV^2/c^4]
1
0.5
0
−0.5
−1
0
5
10
15

Angular Fit - Folding

Not enough statistics for full 3D angular fit → fold distributions, but lost sensitivity to S_6 and S_9 (and thus also A_{FB} = ¾ S_6)

$$F_L, S_3, S_4, P'_4 : \begin{cases} \phi \to -\phi & \text{for } \phi < 0 \\ \phi \to \pi - \phi & \text{for } \theta_L > \frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases}$$

$\cos\theta_L \in [0,1], \cos\theta_K \in [-1,1]$ and $\phi \in [0,\pi]$

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{8\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi\right]$$

$$F_L, S_3, S_5, P'_5 : \begin{cases} \phi \to -\phi & \text{for } \phi < 0 \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases}$$

$\cos\theta_L \in [0,1], \cos\theta_K \in [-1,1]$ and $\phi \in [0,\pi]$

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{8\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi\right]$$

$$F_L, S_3, S_7, P'_6 : \begin{cases} \phi \to \pi - \phi & \text{for } \phi > \frac{\pi}{2} \\ \phi \to -\pi - \phi & \text{for } \phi < -\frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \end{cases}$$

$\cos\theta_L \in [0,1], \cos\theta_K \in [-1,1]$ and $\phi \in [-\pi/2,\pi/2]$

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{8\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi\right]$$

$$F_L, S_3, S_8, P'_8 : \begin{cases} \phi \to \pi - \phi & \text{for } \phi > \frac{\pi}{2} \\ \phi \to -\pi - \phi & \text{for } \phi < -\frac{\pi}{2} \\ \theta_L \to \pi - \theta_L & \text{for } \theta_L > \frac{\pi}{2} \\ \theta_K \to \pi - \theta_K & \text{for } \theta_L > \frac{\pi}{2} \end{cases}$$

$\cos\theta_L \in [0,1], \cos\theta_K \in [-1,1]$ and $\phi \in [-\pi/2,\pi/2]$

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{8\pi}\left[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell - F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi\right]$$

My Contribution to the Analysis

- Toy-MC Studies of the Angular Fit
  - validation of fitted functions

- Event Preselection
  - n-tuple creation from raw ATLAS data (derivations)
  - rough estimation of background yields after application of Run 1 cuts

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Toy-MC Studies of the Angular Fit

Positivity test:

Tested functions $f_i(F_L$ & S_3 & $S_i)$; $i \in 4, 5, 7, 8$

for 3 q^2 bins 0.04-2, 2-4, 4-6 (GeV/c^2)

Fit Validation:

Tested functions $f_i(F_L$ & S_3 & $S_i)$; $i \in 4, 5, 7, 8$

for 3 q^2 bins 0.04-2, 2-4, 4-6 (GeV/c^2)

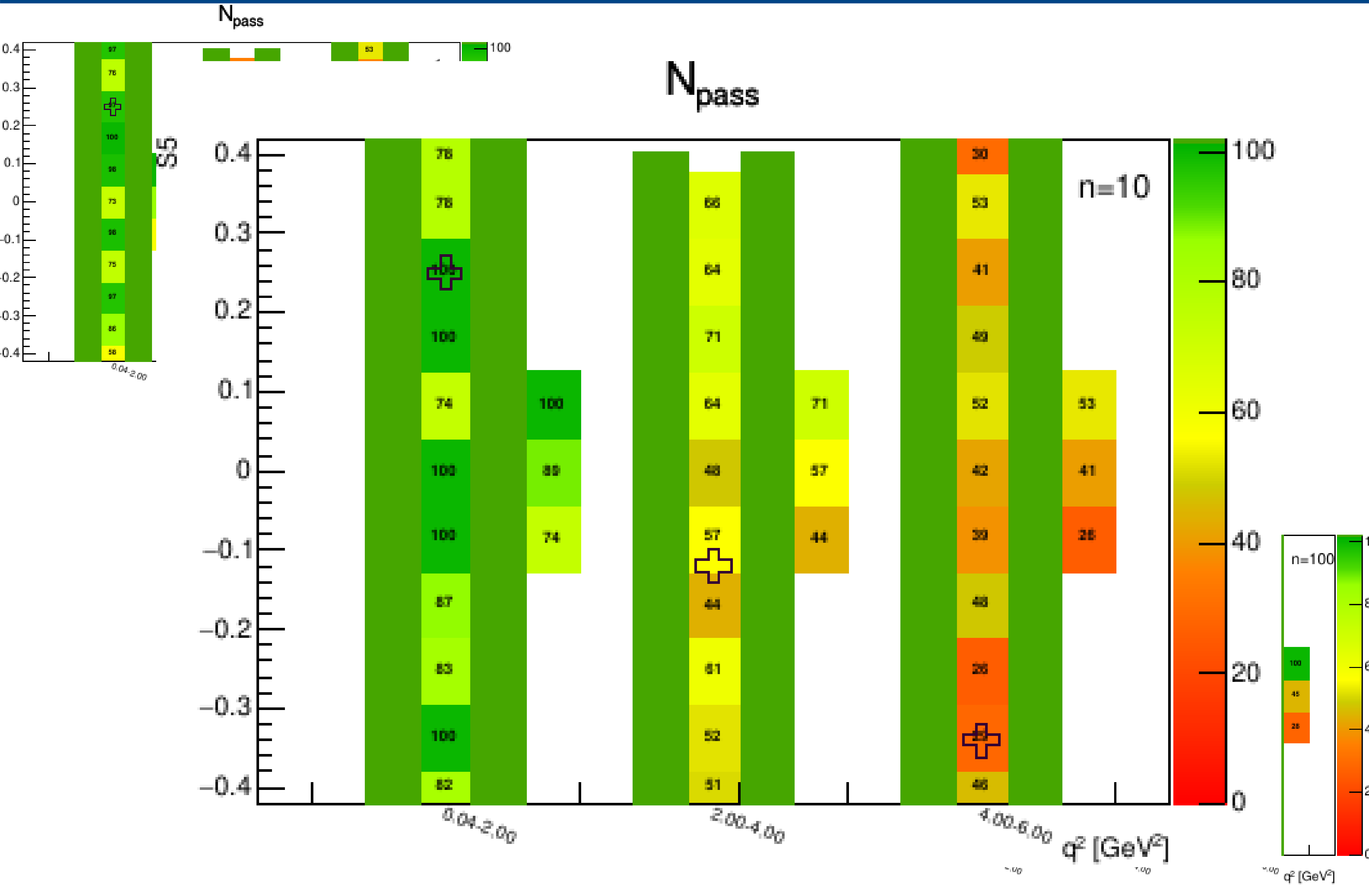
Number of events	1, 10, 100
S2B ratio	0.5, 1, 2
acceptance	1, from Run 1

Toy-MC Studies of the Angular Fit

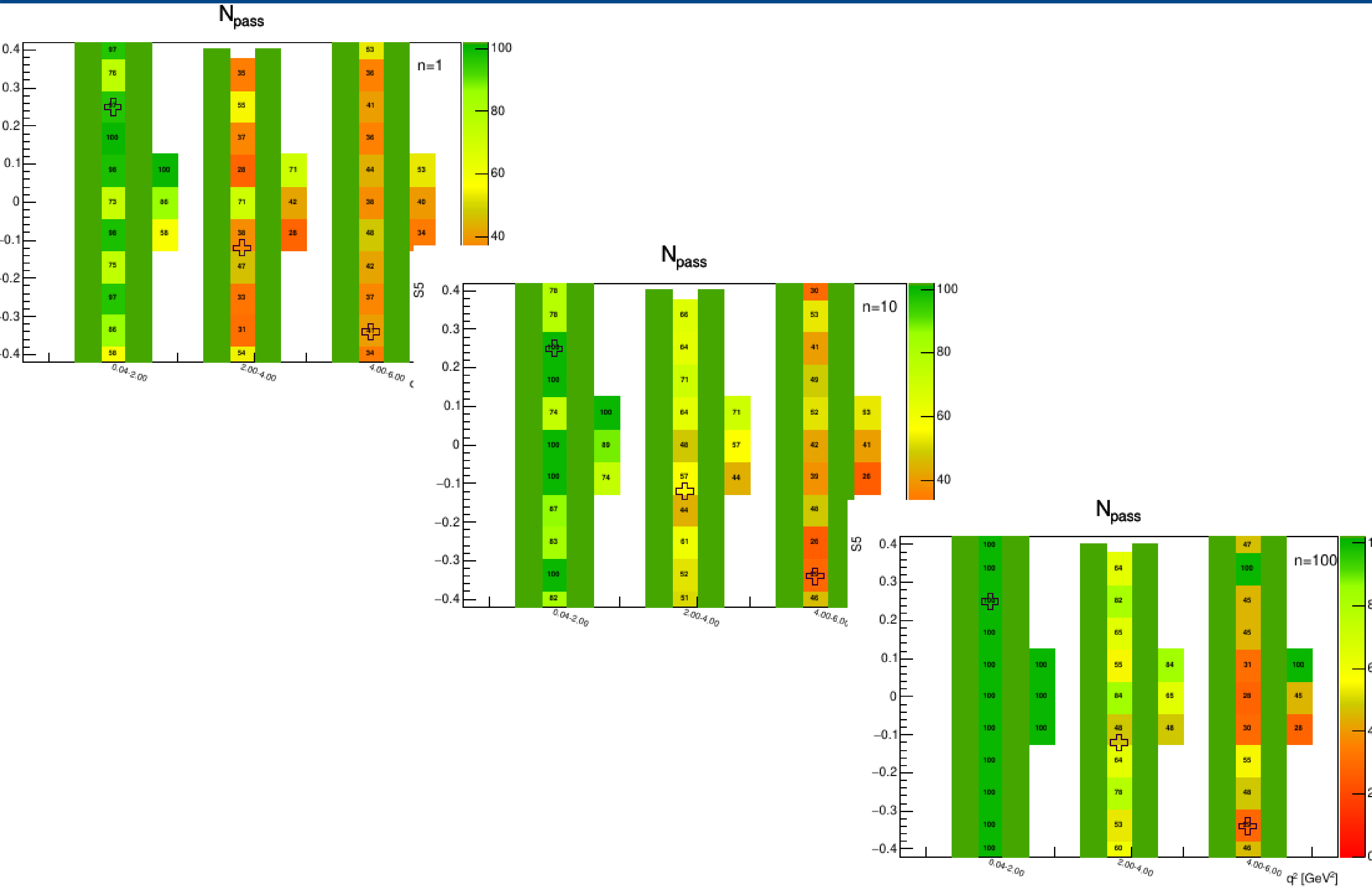
- $F_L \in [0.1, 0.9]$, with step 0.09; ([0.2,0.8] for 4-6 bin of f_{S_5})
- $S_3 \in [-0.1, 0.1]$, with step 0.02; ([-0.06,0.1] for 4-6 and [-0.08,0.1] for 2-4 bin of f_{S_5})
- $S_4 \in [-0.272, 0.272]$, with step 0.068
- $S_5 \in [-0.4, 0.4]$, with step 0.08
- $S_7 \in [-0.4, 0.4]$, with step 0.08
- $S_8 \in [-0.3, 0.3]$, with step 0.06

100 toy MC samples were generated and fitted for each combination

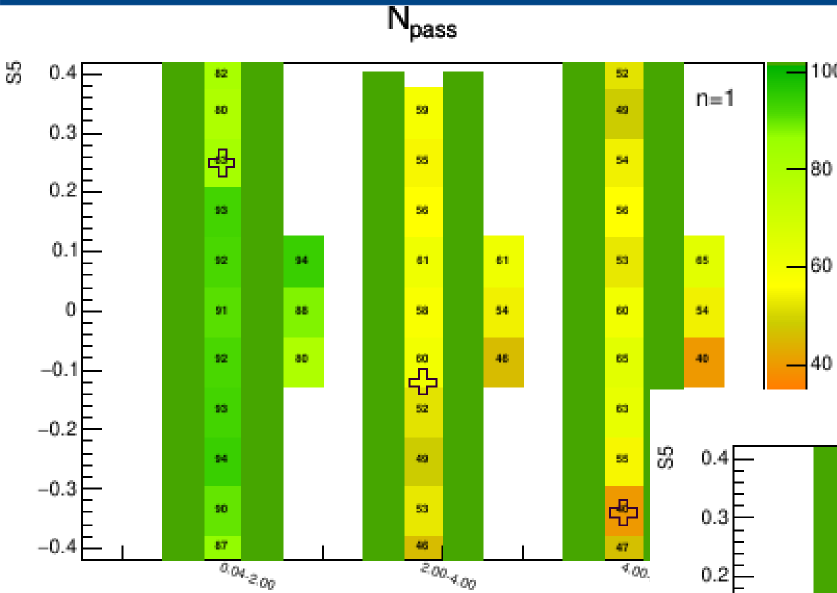
Results f_5, S_5, r = 1, Acc. from RUN1

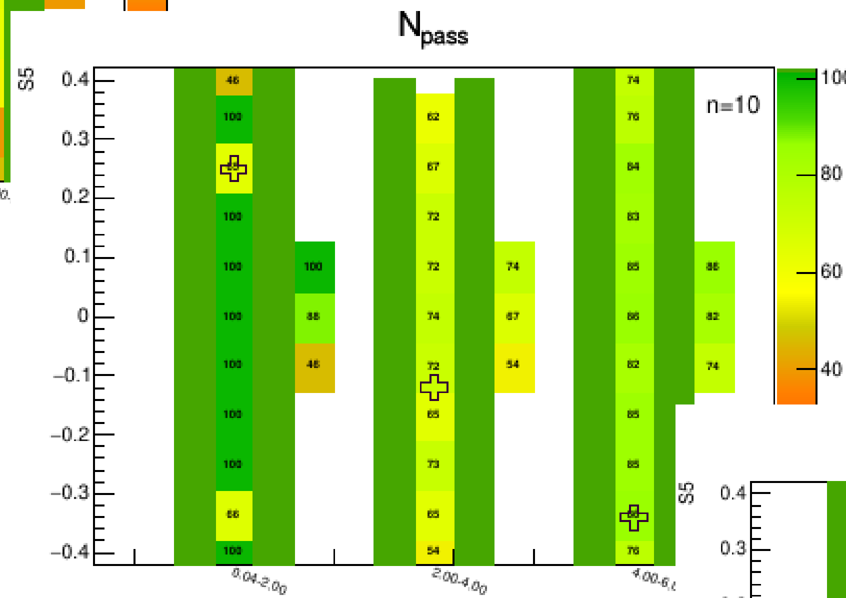


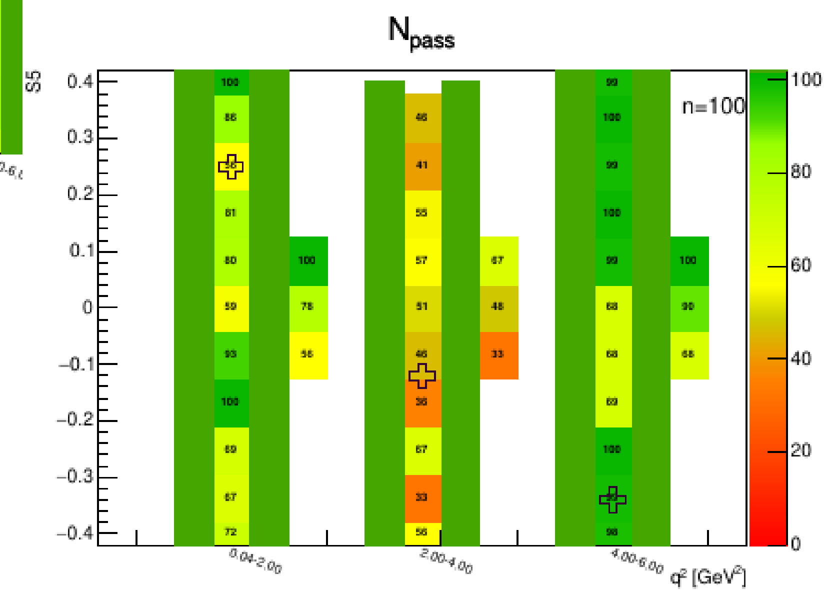
Results f_5, S_5, r = 1, Acc. from RUN1



Results f_5, S_5, r = 1, No Acc.

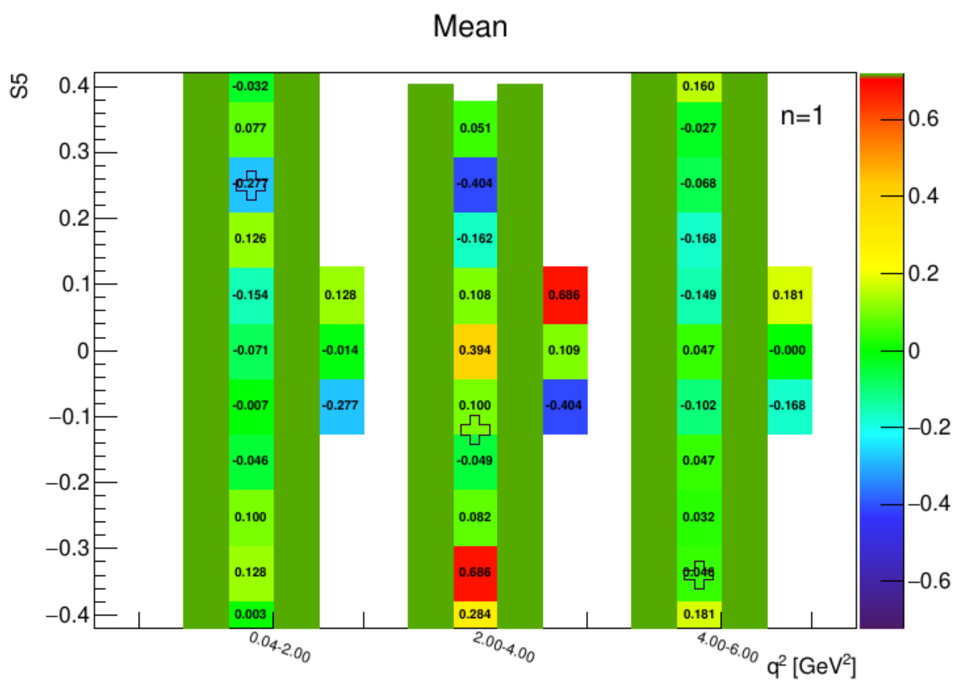


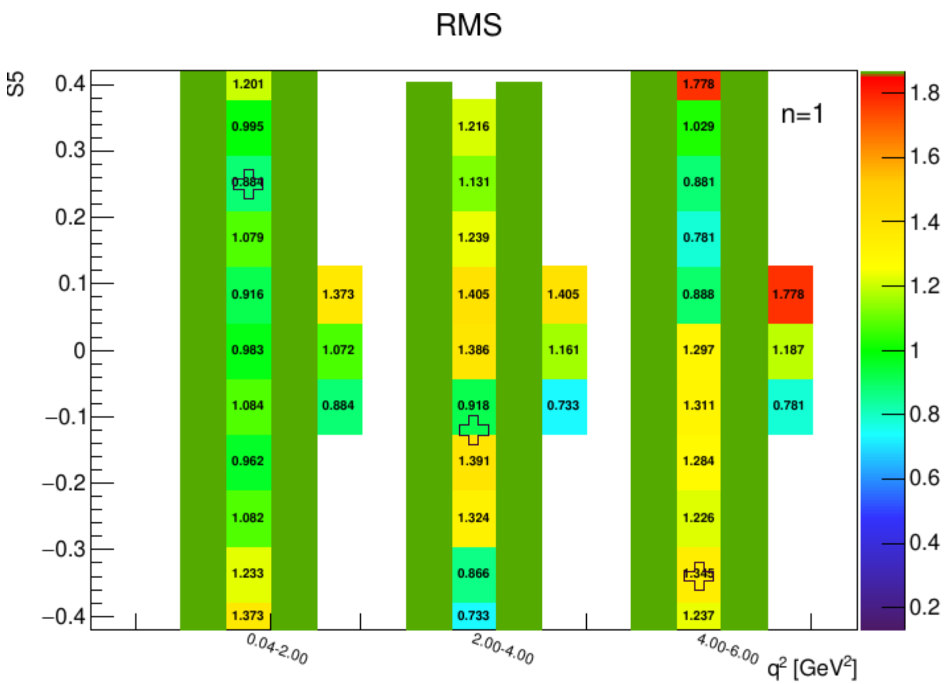




Results f_5, S_5, n = 1,r = 1, Acc. from RUN1

$$p = \frac{Y_i - Y_{init}}{\sigma_i}$$





Conclusion I - Toy-MC Studies

- Toy-MC Studies of the Angular Fit
  - Positivity range
  - Scan of the phase space of the fitted parameters (3195 combinations)
    - N_{pass} (improvement of the acceptance description needed)
    - $\sigma_{\text{fit}}^{\text{mean}} / \sqrt{n}$
    - Fit-bias - pulls
    - Fit-errors bias – pulls RMS

- Plans for future:
  - After derivation from Run 2 data, repeat MC analysis with higher number of generated samples (100->1000) for responding number of sg & bg events, with improved acceptance
  - Find threshold statistics for full fit (FL, S3, S4, S5, S7, S8 – together)
  - Maybe:
    - Test if mass fit & angular fit could be done simultaneously with higher statistics (now: first mass fit, then angular fit)

My Contribution to the Analysis

- Toy-MC Studies of the Angular Fit
  - validation of fitted functions

- Event Preselection
  - n-tuple creation from raw ATLAS data (derivations)
  - rough estimation of background yields after application of Run 1 cuts

Baseline Cuts

- all four tracks, as well as the dimuon, K^* and B^0 systems, are required to be in the ID acceptance and have $|\eta| < 2.5$
- dimuon vertex fit quality $\chi^2/\text{n.d.f.} < 10$
- $p_{\mathrm{T}}(\mu) > 3500\,\mathrm{MeV}$
- ~~$p_{\mathrm{T}}(\pi/K) > 500\,\mathrm{MeV}$~~ ✷
- K^* candidate mass in range $[846, 946]\,\mathrm{MeV}$
- B^0 candidate mass in range $[5150, 5700]\,\mathrm{MeV}$

✷ Applied during derivation

Optimized RUN1 Cuts

- $\tau/\sigma_\tau > 12.75$
- $p_{\mathrm{T}}(K^*) > 3000\,\mathrm{MeV}$
- $\chi^2/\mathrm{n.d.f.}(B^0) < 2$
- $\Delta m_{\mathrm{radiative}} > 130\,\mathrm{MeV}$

$$\Delta m_{\mathrm{rad}}(c\bar{c}) = |(m_{K\pi\mu\mu} - m_{B^0}) - (m_{\mu\mu} - m_{c\bar{c}})| \qquad c\bar{c} = J/\psi \text{ and } \psi(2S)$$

Signal Yield

name	N_S	N_B	N_{PASS}	N_S / N_{PASS}	N_{PASS}/N_{TOT}:
raw data	8645	66798	75443	0.11	100.00%
$\|\eta\|_{4Btracks}$	8546	64644	73190	0.12	97.01%
dimuon vertex	5319	7052	12371	0.43	16.40%
$p_{T\mu}$	5240	6687	11927	0.44	15.81%
m_{K^*}	4102	2402	6504	0.63	8.62%
m_B	3767	637	4404	0.86	5.84%
τ_B/σ_{τ_B}	1132	454	1586	0.71	2.10%
p_{TK^*}	813	74	887	0.92	1.18%
B vertex	726	42	768	0.95	1.02%
$\Delta m_{radiative}$	522	28	550	0.95	0.73%

Table 4.4: Signal and self-background yield after the application of selection criteria for decay $B_d^0 \to K^*(K\pi)\mu^+\mu^-$.

“Antisignal” Yield

name	N_{S}	N_{B}	N_{PASS}	N_{S} / N_{PASS}	$N_{\mathrm{PASS}}/N_{TOT}$:
raw data	8433	64221	72654	0.12	100.00%
$\lvert\eta\rvert_{4Btracks}$	8362	62121	70483	0.12	97.01%
dimuon vertex	5313	7065	12378	0.43	17.04%
$p_{T\mu}$	5246	6719	11965	0.44	16.47%
m_{K^*}	4164	2443	6607	0.63	9.09%
m_B	3317	683	4000	0.83	5.51%
τ_B/σ_{τ_B}	998	478	1476	0.68	2.03%
p_{TK^*}	706	64	770	0.92	1.06%
B vertex	642	46	688	0.93	0.95%
$\Delta m_{radiative}$	485	25	510	0.95	0.70%

Table 4.5: Signal and self-background yield after the application of selection criteria for decay $\bar{B}_d^0 \to \bar{K}^*(K\pi)\mu^+\mu^-$.

Estimated Signal and Background Yields

decay chanel	η^{REC}	N_{TOT}	$\frac{N_{\mathrm{PASS}}^{\mathrm{baseline}}}{N_{\mathrm{TOT}}}$	$\frac{N_{\mathrm{PASS}}^{\mathrm{Run1}}}{N_{\mathrm{TOT}}}$	N_{PASS}	yield
$B_d^0 \to K^*(K^+\pi^-)\mu^+\mu^-$	75.81%	75443	5.84%	0.729%	550	0.51
$\bar{B}^0{}_d \to \bar{K}^*(K^-\pi^+)\mu^+\mu^-$	75.81%	72654	5.51%	0.702%	510	0.49
$B_d^0 \to K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$	74.76%	63052	6.12%	0.033%	21	1.8
$\bar{B}^0{}_d \to \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$	74.61%	63719	5.44%	0.306%	195	17
$B_d^0 \to K^*(K^+\pi^-)\psi(2s)(\mu^+\mu^-)$	74.93%	40605	7.46%	0.039%	16	0.14
$\bar{B}^0{}_d \to \bar{K}^*(K^-\pi^+)\psi(2s)(\mu^+\mu^-)$	75.45%	42770	6.35%	0.426%	182	1.5
$B_d^0 \to K\pi J/\psi(\mu^+\mu^-)$	58.37%	83092	1.64%	0.043%	36	2.5
$\bar{B}^0{}_d \to K\pi J/\psi(\mu^+\mu^-)$	58.53%	40658	1.55%	0.079%	32	4.6
$B_d^0 \to K\pi\psi(2s)(\mu^+\mu^-)$	66.23%	39387	2.80%	0.079%	31	0.36
$\bar{B}^0{}_d \to K\pi\psi(2s)(\mu^+\mu^-)$	64.68%	40164	2.28%	0.132%	53	0.58
$B_s^0 \to \varphi(K^+K^-)\mu^+\mu^-$	78.13%	152231	1.09%	0.102%	155	0.016
$\bar{B}^0{}_s \to \varphi(K^+K^-)\mu^+\mu^-$	78.05%	50643	1.03%	0.087%	44	0.013
$B_s^0 \to \varphi(K^+K^-)J/\psi(\mu^+\mu^-)$	76.73%	47357	1.06%	0.027%	13	0.33
$\bar{B}^0{}_s \to \varphi(K^+K^-)J/\psi(\mu^+\mu^-)$	77.25%	45732	1.08%	0.026%	12	0.32
$B_s^0 \to \varphi(K^+K^-)\psi(2s)(\mu^+\mu^-)$	77.10%	42756	1.27%	0.042%	18	0.034
$\bar{B}^0{}_s \to \varphi(K^+K^-)\psi(2s)(\mu^+\mu^-)$	78.05%	43623	1.31%	0.032%	14	0.026
$B^+ \to K^+\mu^+\mu^-$	46.25%	68788	1.40%	0.084%	58	0.025
$B^- \to K^-\mu^+\mu^-$	47.05%	33213	1.16%	0.018%	6	0.0055
$B^+ \to K^+J/\psi(\mu^+\mu^-)$	45.49%	66466	1.32%	0.113%	75	4.5
$B^- \to K^-J/\psi(\mu^+\mu^-)$	45.67%	33183	0.95%	0.015%	5	0.61
$B^+ \to K^+\psi(2s)(\mu^+\mu^-)$	45.26%	58200	1.91%	0.110%	64	0.36
$B^- \to K^+\psi(2s)(\mu^+\mu^-)$	45.38%	27965	1.51%	0.029%	8	0.095
$B^+ \to \pi^+J/\psi(\mu^+\mu^-)$	45.94%	32698	1.02%	0.037%	12	0.057
$B^- \to \pi^-J/\psi(\mu^+\mu^-)$	44.86%	31941	0.83%	0.013%	4	0.019

$$\eta^{\mathrm{REC}} \equiv \frac{N_{\mathrm{GEN}}^{\mathrm{REC}}}{N_{\mathrm{GEN}}}$$

BR_μ	
J/ψ	0.06
$\psi(2s)$	10^{-3}
η	10^{-6}

Asymmetry – bad reconstruction of B mass

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63052	100.00%
$\|\eta\|_{4Btracks}$	61376	97.34%
dimuon vertex	11010	17.46%
$p_{T\mu}$	10575	16.77%
m_{K^*}	5777	9.16%
m_B	3858	6.12%
τ_B/σ_{τ_B}	1353	2.15%
p_{TK^*}	758	1.20%
B vertex	664	1.05%
$\Delta m_{radiative}$	21	0.03%

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63719	100.00%
$\|\eta\|_{4Btracks}$	61848	97.06%
dimuon vertex	10963	17.21%
$p_{T\mu}$	10592	16.62%
m_{K^*}	5861	9.20%
m_B	3466	5.44%
τ_B/σ_{τ_B}	1259	1.98%
p_{TK^*}	709	1.11%
B vertex	619	0.97%
$\Delta m_{radiative}$	195	0.31%

$$B_d^0 \rightarrow K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$$

$$\bar{B}^0{}_d \rightarrow \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$$

$$\Delta m_{\mathrm{rad}}(c\bar{c}) = |(m_{K\pi\mu\mu} - m_{B^0}) - (m_{\mu\mu} - m_{c\bar{c}})|$$

Conclusion II – Event preselection

- Event preselection
  - n-tuple maker with simple kinematic variables
  - Rough background estimation after application of cuts from Run 1
  - Asymmetry between decay and CP-conjugated decay yields
  - After correction on asymmetry – 12 bg events : 1 sg

- Plan for future:
  - Complete n-tuple (add trigger info, candidate info and true MC info)
  - Event selection – cut/BDT optimization

Thank you for your attention

Backup

Tau cut

•

name	N_S	N_B	N_{PASS}	N_S / N_{PASS}	N_{PASS}/N_{TOT}:
raw data	8645	66798	75443	0.11	100.00%
$\|\eta\|_{4Btracks}$	8546	64644	73190	0.12	97.01%
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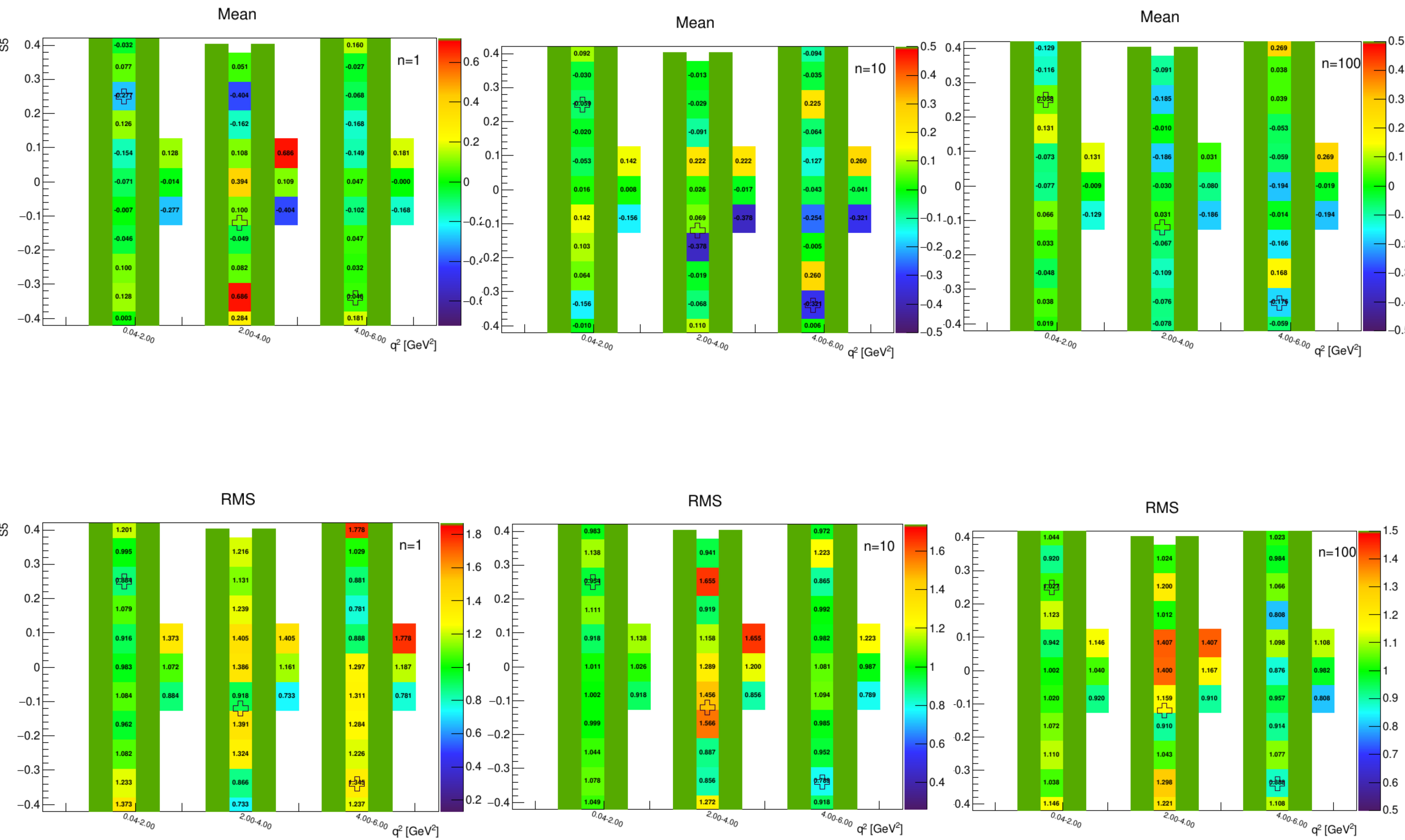
B vertex	726	42	768	0.95	1.02%
$\Delta m_{radiative}$	522	28	550	0.95	0.73%

Tau cut

name	N_S	N_B	N_{PASS}	N_S / N_{PASS}	N_{PASS}/N_{TOT}:
m_B	3767	637	4404	0.86	5.84%
τ_B/σ_{τ_B}	1132	454	1586	0.71	2.10%

- The lifetime cut prefers the long-lived B-mesons and suppresses some short-lived hadrons. (X)
- Combinatorial background: $pp/cc/bb \rightarrow X\ \mu\mu$

Results f5, S5, r = 1, Acc. from RUN1



Asymmetry

decay chanel	η^{REC}	N_{TOT}	$\frac{N_{\mathrm{PASS}}^{\mathrm{baseline}}}{N_{\mathrm{TOT}}}$	$\frac{N_{\mathrm{PASS}}^{\mathrm{Run1}}}{N_{\mathrm{TOT}}}$	N_{PASS}	yield
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$\bar{B}^0{}_d \to \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$	74.61%	63719	5.44%	0.306%	195	17

Asymmetry - low statistics

decay chanel	η^{REC}	N_{TOT}	$\frac{N_{\text{PASS}}^{\text{baseline}}}{N_{\text{TOT}}}$	$\frac{N_{\text{PASS}}^{\text{Run1}}}{N_{\text{TOT}}}$	N_{PASS}	yield
$B_d^0 \to K^*(K^+\pi^-)\mu^+\mu^-$	75.81%	75443	5.84%	0.729%	550	0.51
$\bar{B^0}_d \to \bar{K^*}(K^-\pi^+)\mu^+\mu^-$	75.81%	72654	5.51%	0.702%	510	0.49
$B_d^0 \to K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$	74.76%	63052	6.12%	0.033%	21	1.8
$\bar{B^0}_d \to \bar{K^*}(K^-\pi^+)J/\psi(\mu^+\mu^-)$	74.61%	63719	5.44%	0.306%	195	17
$B_d^0 \to K^*(K^+\pi^-)\psi(2s)(\mu^+\mu^-)$	74.93%	40605	7.46%	0.039%	16	0.14
$\bar{B^0}_d \to \bar{K^*}(K^-\pi^+)\psi(2s)(\mu^+\mu^-)$	75.45%	42770	6.35%	0.426%	182	1.5
$B_d^0 \to K\pi J/\psi(\mu^+\mu^-)$	58.37%	83092	1.64%	0.043%	36	2.5
$\bar{B^0}_d \to K\pi J/\psi(\mu^+\mu^-)$	58.53%	40658	1.55%	0.079%	32	4.6
$B_d^0 \to K\pi\psi(2s)(\mu^+\mu^-)$	66.23%	39387	2.80%	0.079%	31	0.36
$\bar{B^0}_d \to K\pi\psi(2s)(\mu^+\mu^-)$	64.68%	40164	2.28%	0.132%	53	0.58
$B_s^0 \to \varphi(K^+K^-)\mu^+\mu^-$	78.13%	152231	1.09%	0.102%	155	0.016
$\bar{B^0}_s \to \varphi(K^+K^-)\mu^+\mu^-$	78.05%	50643	1.03%	0.087%	44	0.013
$B_s^0 \to \varphi(K^+K^-)J/\psi(\mu^+\mu^-)$	76.73%	47357	1.06%	0.027%	13	0.33
$\bar{B^0}_s \to \varphi(K^+K^-)J/\psi(\mu^+\mu^-)$	77.25%	45732	1.08%	0.026%	12	0.32
$B_s^0 \to \varphi(K^+K^-)\psi(2s)(\mu^+\mu^-)$	77.10%	42756	1.27%	0.042%	18	0.034
$\bar{B^0}_s \to \varphi(K^+K^-)\psi(2s)(\mu^+\mu^-)$	78.05%	43623	1.31%	0.032%	14	0.026
$B^+ \to K^+\mu^+\mu^-$	46.25%	68788	1.40%	0.084%	58	0.025
$B^- \to K^-\mu^+\mu^-$	47.05%	33213	1.16%	0.018%	6	0.0055
$B^+ \to K^+J/\psi(\mu^+\mu^-)$	45.49%	66466	1.32%	0.113%	75	4.5
$B^- \to K^-J/\psi(\mu^+\mu^-)$	45.67%	33183	0.95%	0.015%	5	0.61
$B^+ \to K^+\psi(2s)(\mu^+\mu^-)$	45.26%	58200	1.91%	0.110%	64	0.36
$B^- \to K^+\psi(2s)(\mu^+\mu^-)$	45.38%	27965	1.51%	0.029%	8	0.095
$B^+ \to \pi^+J/\psi(\mu^+\mu^-)$	45.94%	32698	1.02%	0.037%	12	0.057
$B^- \to \pi^-J/\psi(\mu^+\mu^-)$	44.86%	31941	0.83%	0.013%	4	0.019

Asymmetry - B mass

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63052	100.00%
$\|\eta\|_{4Btracks}$	61376	97.34%
dimuon vertex	11010	17.46%
$p_{T\mu}$	10575	16.77%
m_{K^*}	5777	9.16%
m_B	3858	6.12%
τ_B/σ_{τ_B}	1353	2.15%
p_{TK^*}	758	1.20%
B vertex	664	1.05%
$\Delta m_{radiative}$	21	0.03%

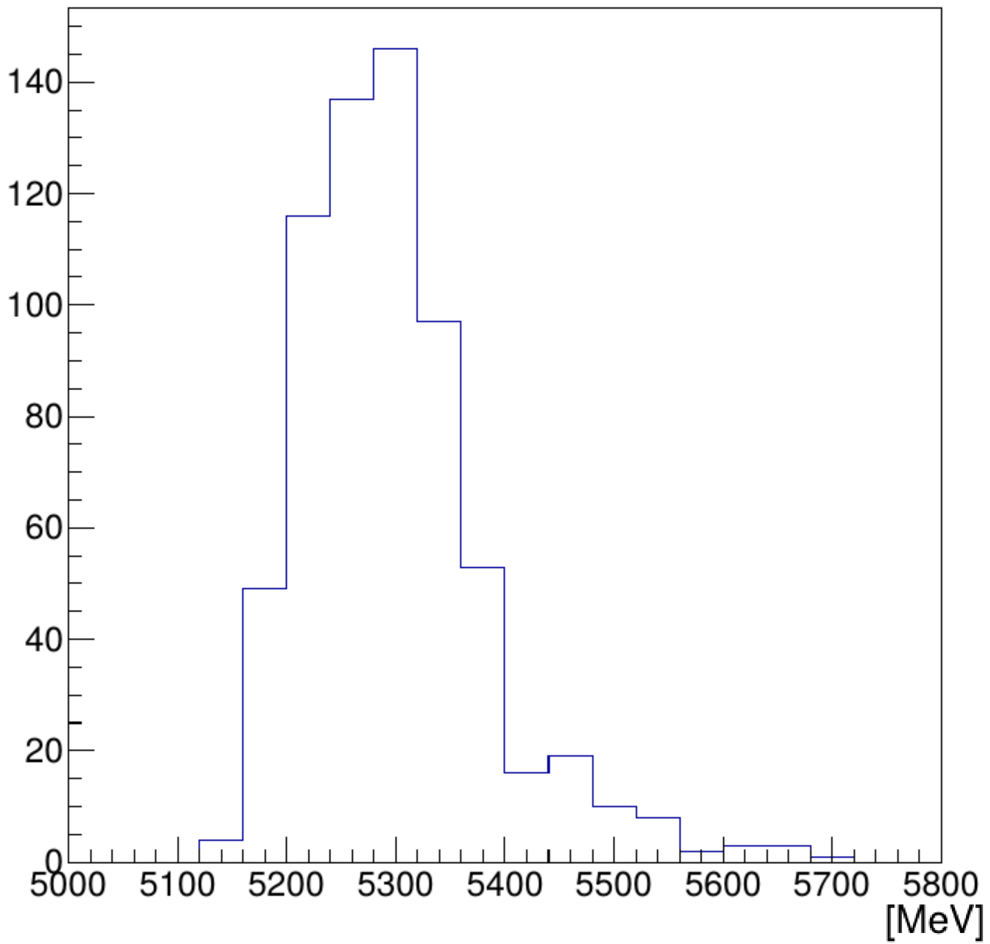
cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63719	100.00%
$\|\eta\|_{4Btracks}$	61848	97.06%
dimuon vertex	10963	17.21%
$p_{T\mu}$	10592	16.62%
m_{K^*}	5861	9.20%
m_B	3466	5.44%
τ_B/σ_{τ_B}	1259	1.98%
p_{TK^*}	709	1.11%
B vertex	619	0.97%
$\Delta m_{radiative}$	195	0.31%

$$B_d^0 \to K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$$

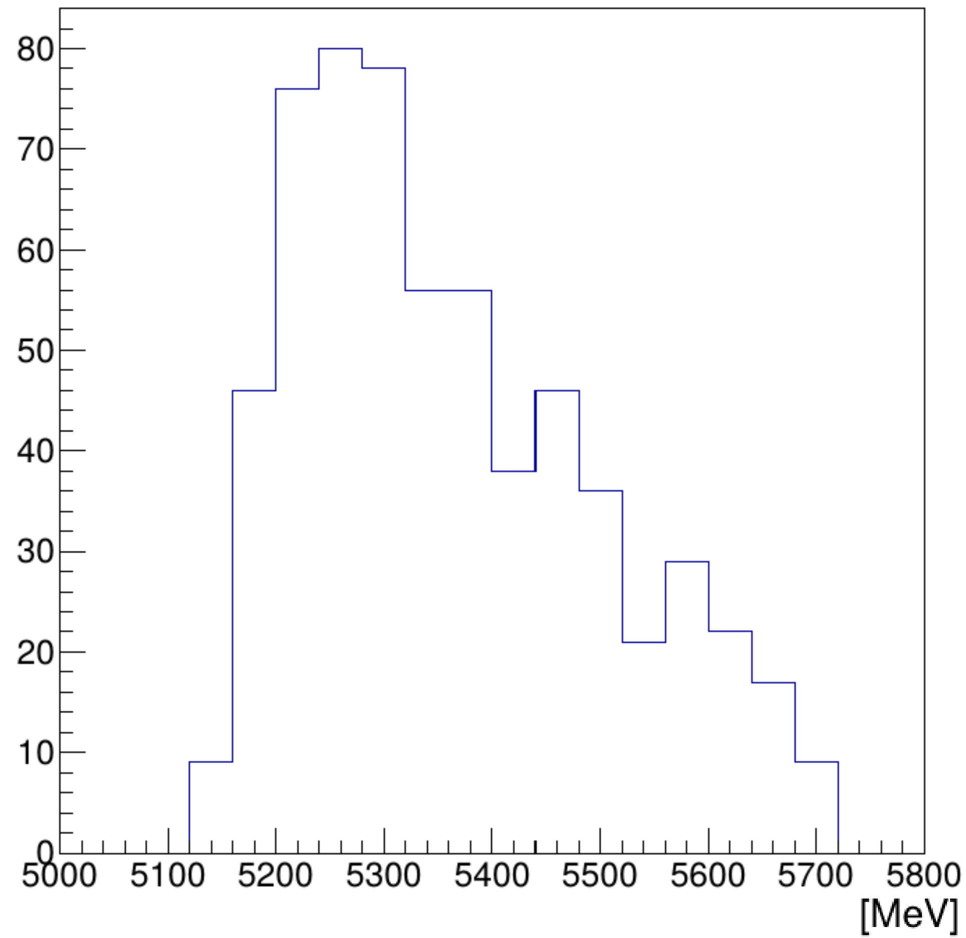
$$\bar{B}^0{}_d \to \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$$

$$\Delta m_{\rm rad}(c\bar{c}) = |(m_{K\pi\mu\mu} - m_{B^0}) - (m_{\mu\mu} - m_{c\bar{c}})|$$

Asymmetry - B mass before last cut

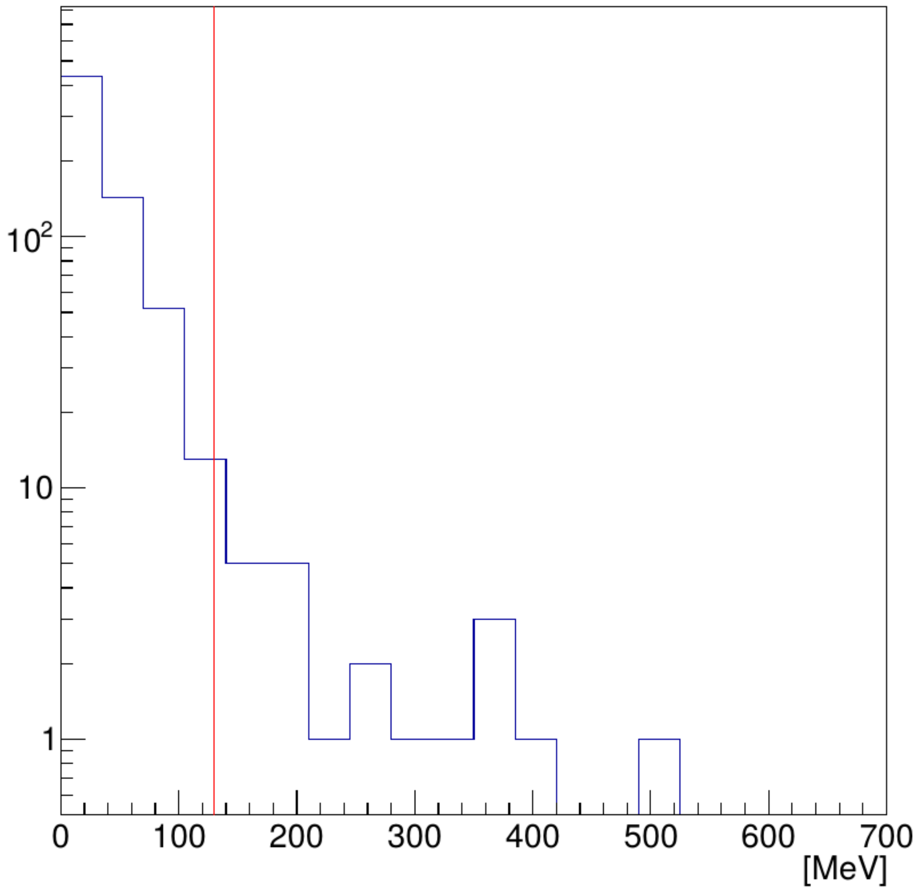


$B_d^0 \rightarrow K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$

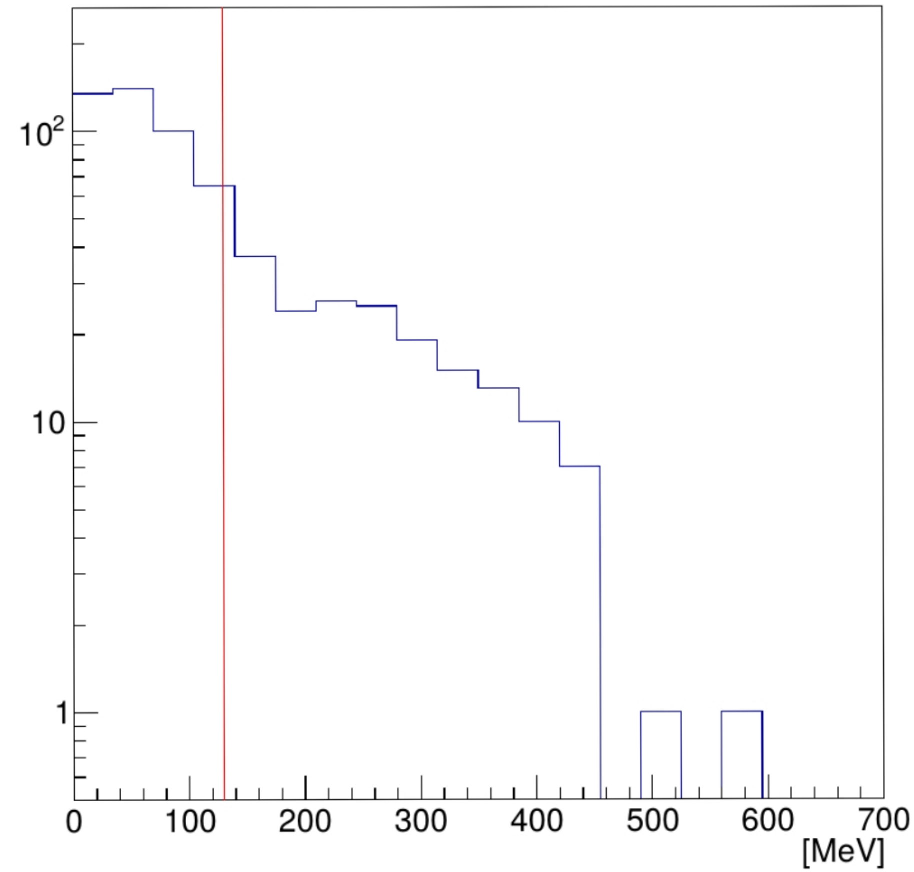


$\bar{B}^0{}_d \rightarrow \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$

Asymmetry - Δm before cut



$$B_d^0 \rightarrow K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$$



$$\bar{B}^0{}_d \rightarrow \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$$

Asymetry - without B mass cut

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63052	100.00%
$\|\eta\|_{4Btracks}$	61376	97.34%
dimuon vertex	11010	17.46%
$p_{T\mu}$	10575	16.77%
m_{K^*}	5777	9.16%
τ_B/σ_{τ_B}	2699	4.28%
p_{TK^*}	1011	1.60%
B vertex	830	1.32%
$\Delta m_{radiative}$	113	0.18%

$$B_d^0 \rightarrow K^*(K^+\pi^-)J/\psi(\mu^+\mu^-)$$

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	63719	100.00%
$\|\eta\|_{4Btracks}$	61848	97.06%
dimuon vertex	10963	17.21%
$p_{T\mu}$	10592	16.62%
m_{K^*}	5861	9.20%
τ_B/σ_{τ_B}	2718	4.27%
p_{TK^*}	1045	1.64%
B vertex	861	1.35%
$\Delta m_{radiative}$	372	0.58%

$$\bar{B}^0{}_d \rightarrow \bar{K}^*(K^-\pi^+)J/\psi(\mu^+\mu^-)$$

$$\Delta m_{\mathrm{rad}}(c\bar{c}) = |(m_{K\pi\mu\mu} - m_{B^0}) - (m_{\mu\mu} - m_{c\bar{c}})|$$

Asymmetry - charged

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	68788	100.00%
$\|\eta\|_{4Btracks}$	66656	96.90%
dimuon vertex	10131	14.73%
$p_{T\mu}$	9628	14.00%
m_{K^*}	3514	5.11%
m_B	961	1.40%
τ_B/σ_{τ_B}	643	0.93%
p_{TK^*}	119	0.17%
B vertex	71	0.10%
$\Delta m_{radiative}$	58	0.08%

$B^+ \to K^+\mu\mu$

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	33213	100.00%
$\|\eta\|_{4Btracks}$	32131	96.74%
dimuon vertex	5195	15.64%
$p_{T\mu}$	4991	15.03%
m_{K^*}	1717	5.17%
m_B	385	1.16%
τ_B/σ_{τ_B}	292	0.88%
p_{TK^*}	22	0.07%
B vertex	8	0.02%
$\Delta m_{radiative}$	6	0.02%

$B^- \to K^-\mu\mu$

Asymmetry - without B mass cut

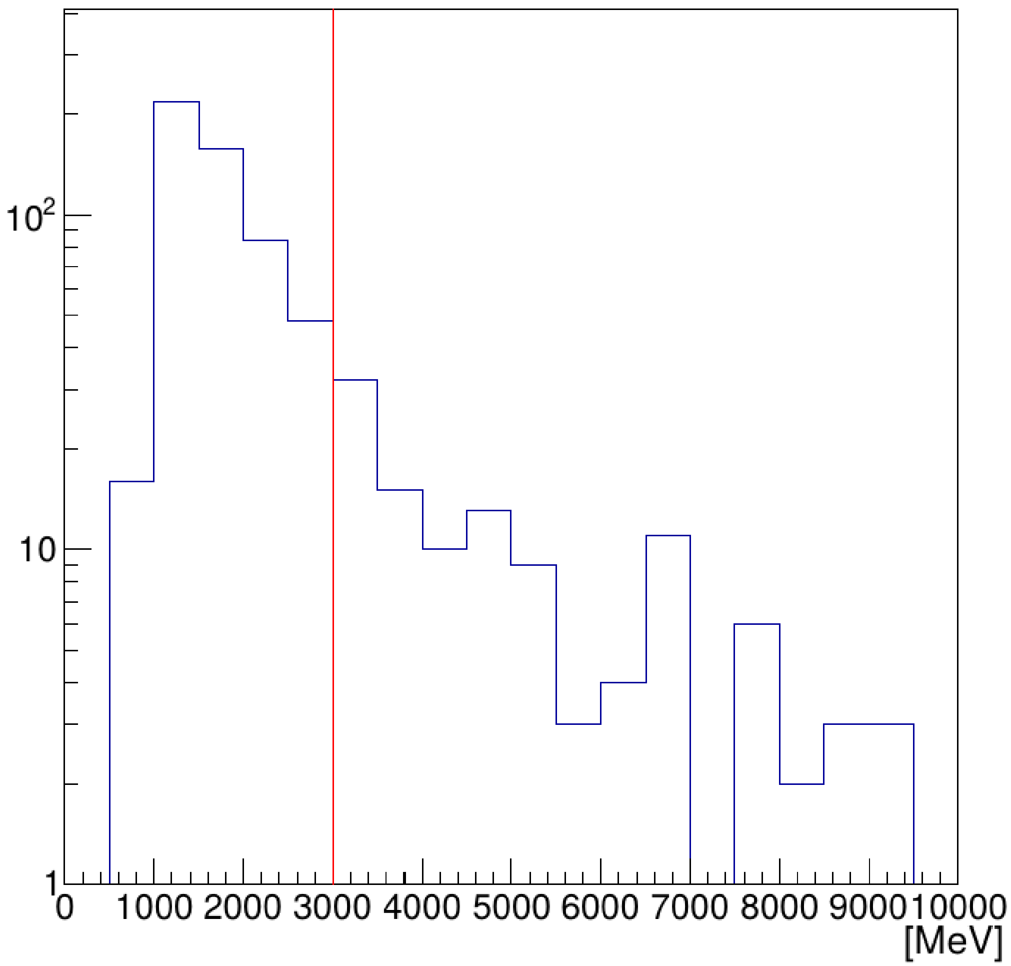
cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	68788	100.00%
$\|\eta\|_{4Btracks}$	66656	96.90%
dimuon vertex	10131	14.73%
$p_{T\mu}$	9628	14.00%
m_{K^*}	3514	5.11%
τ_B/σ_{τ_B}	2806	4.08%
p_{TK^*}	346	0.50%
B vertex	189	0.27%
$\Delta m_{radiative}$	150	0.22%

$B^+ \to K^+\mu\mu$

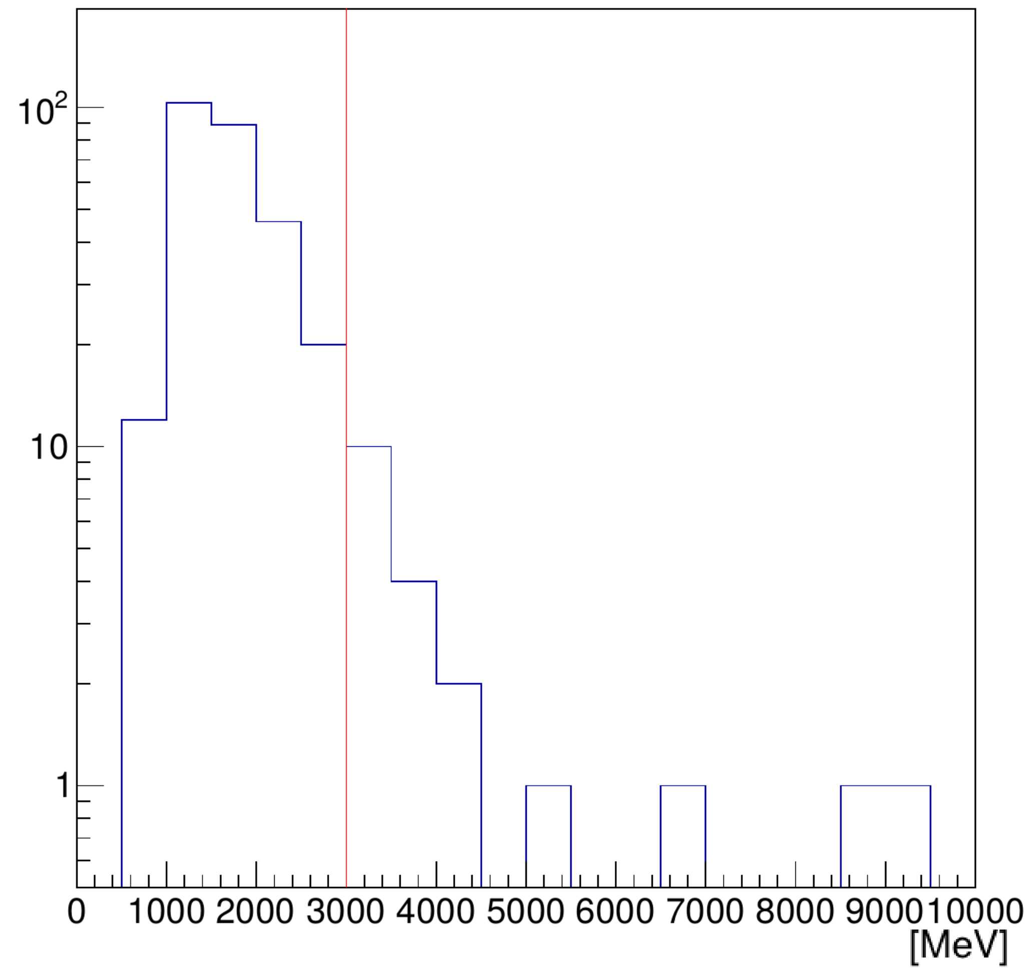
cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	33213	100.00%
$\|\eta\|_{4Btracks}$	32131	96.74%
dimuon vertex	5195	15.64%
$p_{T\mu}$	4991	15.03%
m_{K^*}	1717	5.17%
τ_B/σ_{τ_B}	1366	4.11%
p_{TK^*}	173	0.52%
B vertex	82	0.25%
$\Delta m_{radiative}$	67	0.20%

$B^- \to K^-\mu\mu$

Asymmetry -

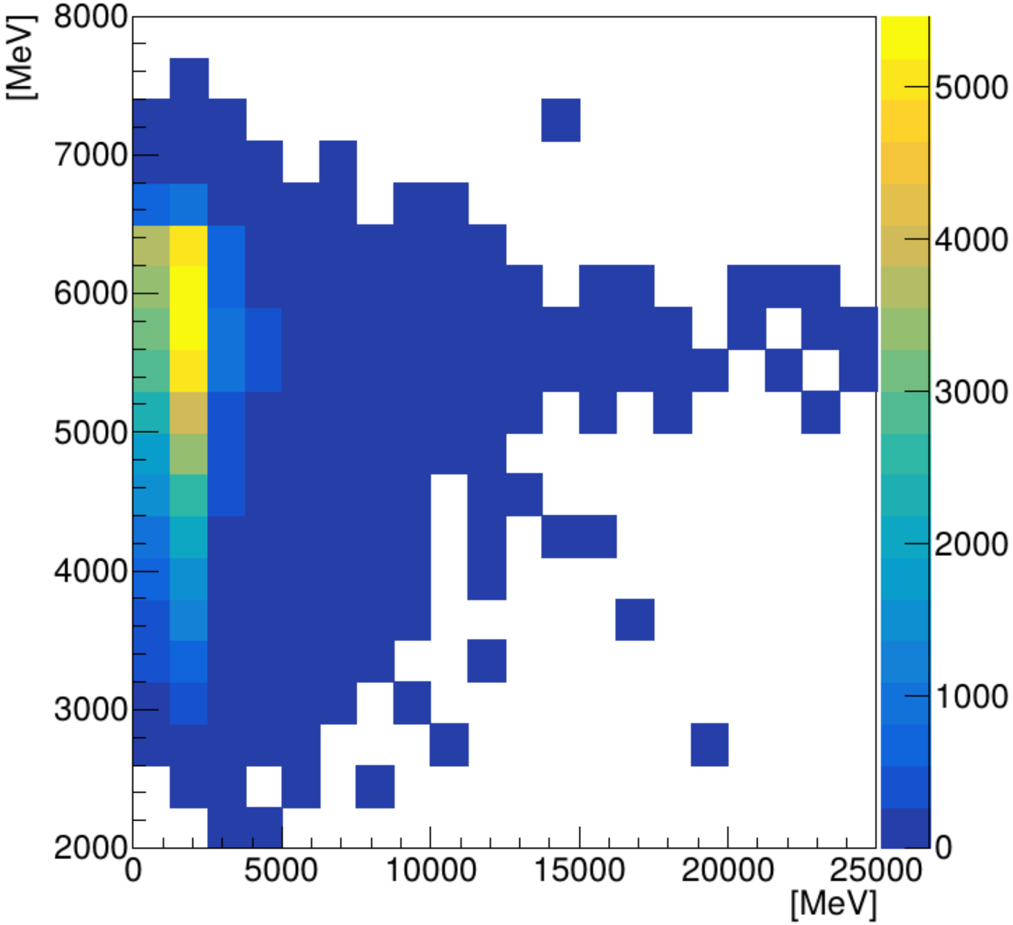


$B^+ \to K^+\mu\mu$

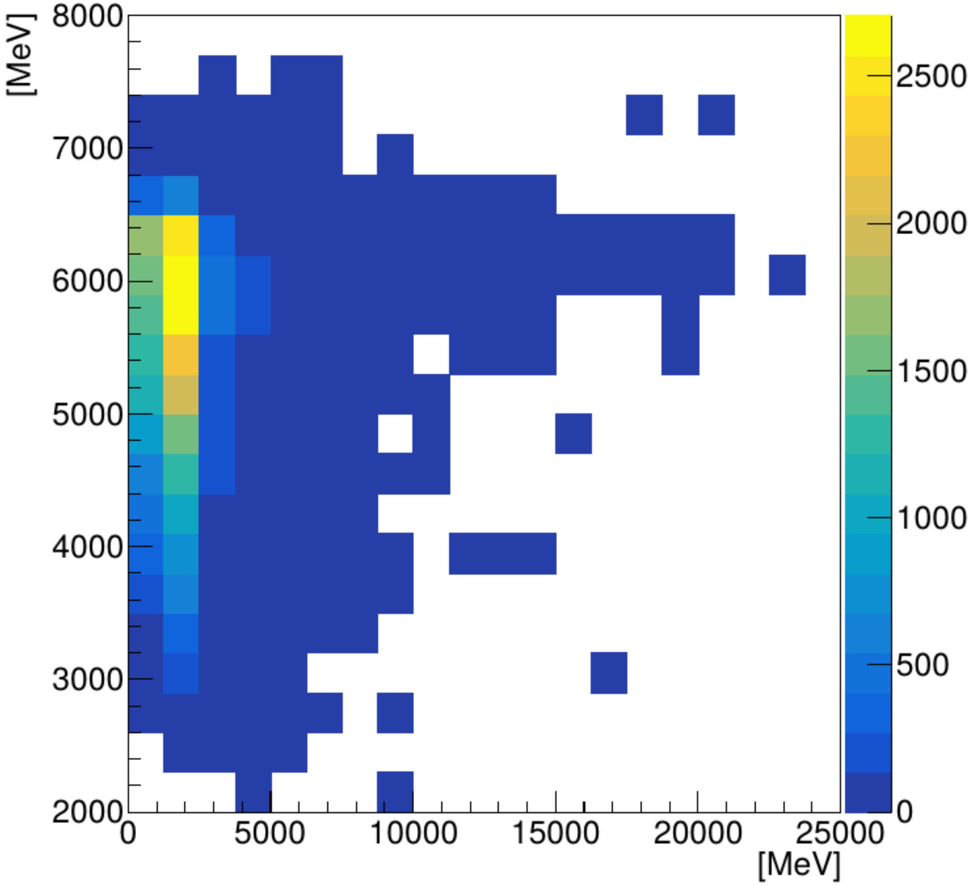


$B^- \to K^-\mu\mu$

Ad 2)



$B^+ \to K^+ \mu\mu$



$B^- \to K^- \mu\mu$

Asymmetry - combined

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	66466	100.00%
$\|\eta\|_{4Btracks}$	64275	96.70%
dimuon vertex	10103	15.20%
$p_{T\mu}$	9605	14.45%
m_{K^*}	3380	5.09%
m_B	876	1.32%
τ_B/σ_{τ_B}	630	0.95%
p_{TK^*}	111	0.17%
B vertex	85	0.13%
$\Delta m_{radiative}$	75	0.11%

cut	N_{PASS}	N_{PASS}/N_{TOT}
raw data	33183	100.00%
$\|\eta\|_{4Btracks}$	32118	96.79%
dimuon vertex	5038	15.18%
$p_{T\mu}$	4826	14.54%
m_{K^*}	1668	5.03%
m_B	314	0.95%
τ_B/σ_{τ_B}	266	0.80%
p_{TK^*}	20	0.06%
B vertex	14	0.04%
$\Delta m_{radiative}$	5	0.02%

$$B^+ \to K^+ J/\psi(\mu^+\mu^-)$$

$$B^- \to K^- J/\psi(\mu^+\mu^-)$$