

# Probing background with Method of Moments for $B^0 \rightarrow K^* \mu \mu$

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University of  
Zurich<sup>UZH</sup>



- 1 Reminder
- 2 Theory introduction
- 3 Background regions
- 4 Results
- 5 Summary



## Plan

### Method of moments:

- 1 Last meeting showed how orthogonality of the does magic for method of moments.
- 2 Using toy MC (experimental math) checked the errors estimates.
- 3 Checked that it does not suffer from boundary conditions.
- 4 Many thanks to Tom for checking all my calculations.

### For today:

- 1 How this method behaves in terms of background?

## What do we start with

Let's assume for simplicity we have our pdf:

$$\begin{aligned}
 \frac{d^4\Gamma}{\Gamma dq^2 d\cos\theta_k d\cos\theta_l d\phi} = & \frac{9}{32\pi} \left( \frac{3}{4}(1-F_l) \sin^2\theta_k + F_l \cos^2\theta_k + \left( \frac{1}{4}(1-F_l) \sin^2\theta_k \right. \right. \\
 & \left. \left. - F_l \cos^2\theta_k \right) \cos 2\theta_l + S_3 \sin^2\theta_k \sin^2\theta_l \cos 2\phi + S_4 \sin 2\theta_k \sin\theta_l \cos\phi + \right. \\
 & \left. S_5 \sin 2\theta_k \sin\theta_l \cos\phi + (S_{6s} \sin^2\theta_k) \cos\theta_l + \right. \\
 & \left. S_7 \sin 2\theta_k \sin\theta_l \sin\phi + S_8 \sin 2\theta_k \sin 2\theta_l \sin\phi + S_9 \sin^2\theta_k \sin^2\theta_l \sin 2\phi \right) \quad (1)
 \end{aligned}$$

What did we assume:

- $S_{1x}, J_{2x}$  can be parametrized by  $F_l$ .
- $S_{6c} = 0$ .
- In short what was in the paper.

# Obtained moments 1

Lets see how this works in practice:

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin^2 \theta_k = \frac{2}{5}(2 - F_l) \quad (2)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \cos^2 \theta_k = \frac{1}{5}(1 + F_l) \quad (3)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin^2 \theta_k \cos 2\theta_l = -\frac{2}{25}(2 + F_l) \quad (4)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \cos^2 \theta_k \cos 2\theta_l = -\frac{1}{25}(1 + 8F_l) \quad (5)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin^2 \theta_k \cos \theta_l = \frac{2S_{6s}}{5} \quad (6)$$

## Obtained moments 2

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \cos^2\theta_k \cos\theta_l = \frac{S_{6s}}{10} \quad (7)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin^2\theta_k \sin^2\theta_l \cos 2\phi = \frac{8S_3}{25} \quad (8)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin 2\theta_k \sin 2\theta_l \cos\phi = \frac{8S_4}{25} \quad (9)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin 2\theta_k \sin\theta_l \cos\phi = \frac{2S_5}{5} \quad (10)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin 2\theta_k \sin\theta_l \sin\phi = \frac{2S_7}{5} \quad (11)$$

$$\frac{d^3\Gamma}{\Gamma d\cos\theta_k d\cos\theta_l d\phi} \sin 2\theta_k \sin 2\theta_l \sin\phi = \frac{8S_8}{25} \quad (12)$$

# Studied background region

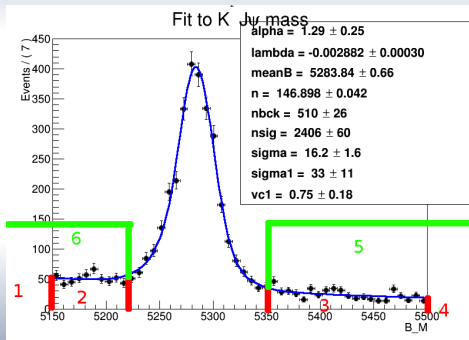
- Defined  $B^0$  mass bins:  
 $1 : (5, 5, 15) \cup 2 : (5.15, 5.22) \cup 3 : (5.35, 5.5) \cup 4 : (5.5, 6)$  GeV

① Region 5:(5.35, 6)

② Region 6:(5, 5.22)

- use the old  $q^2$  bins:

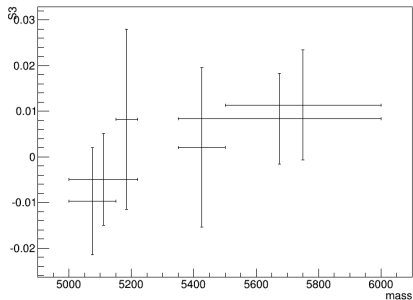
- 0:0, 2
- 1:2, 4.3
- 2:4.3, 8, 6
- 3:10.1, 12.9
- 4:14.2, 16
- 5:16, 19



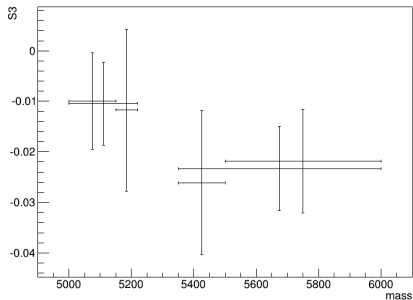
Please remember the numbers, we will need then later on.

# Measurement of background moments

Q2\_0\_S3



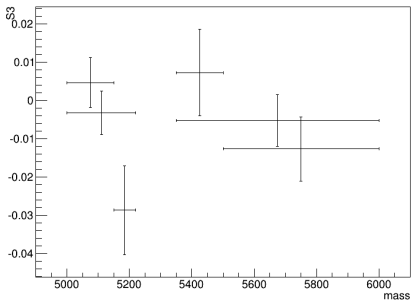
Q2\_1\_S3



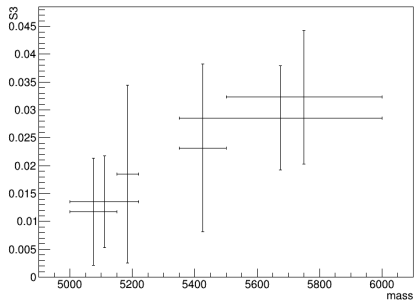


# Measurement of background moments

Q2\_2\_S3

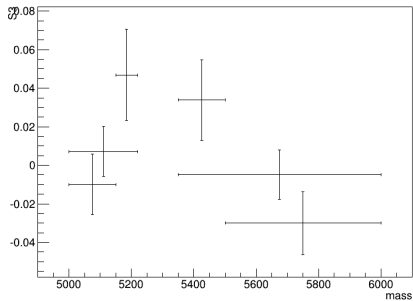


Q2\_3\_S3

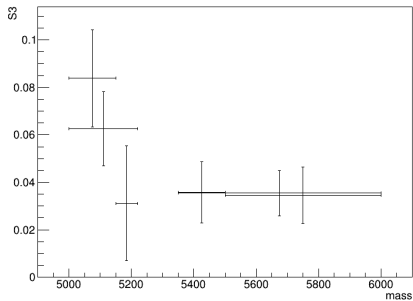


# Measurement of background moments

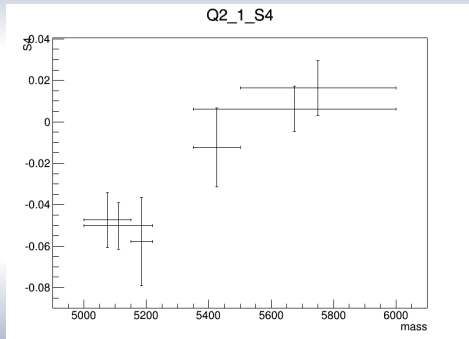
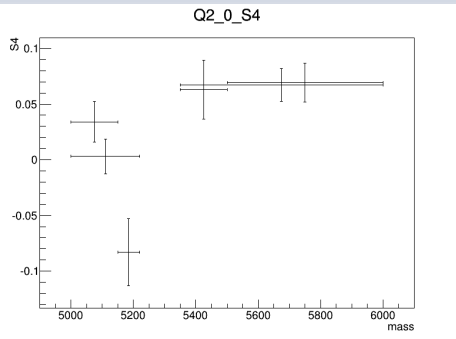
Q2\_4\_S3



Q2\_5\_S3

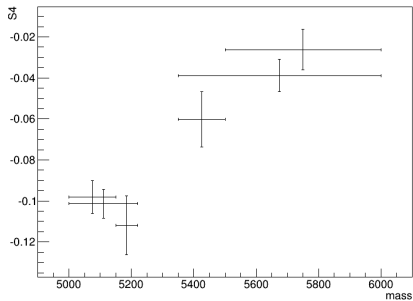


# Measurement of background moments

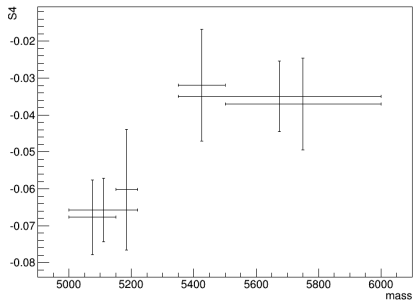


# Measurement of background moments

Q2\_2\_S4

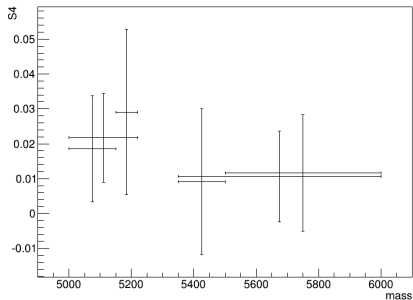


Q2\_3\_S4

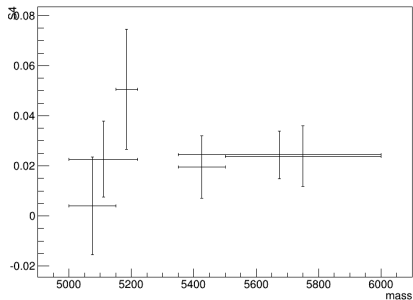


# Measurement of background moments

Q2\_4\_S4

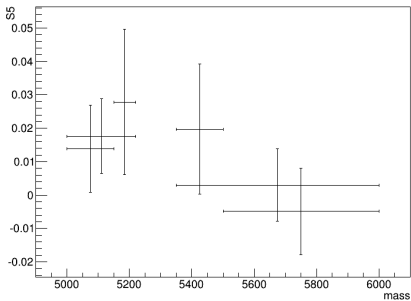


Q2\_5\_S4

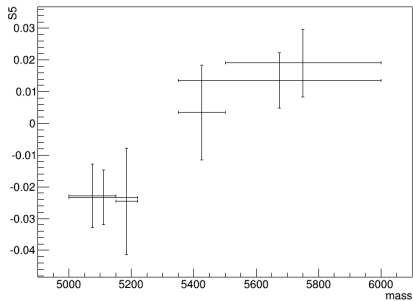


# Measurement of background moments

Q2\_0\_S5

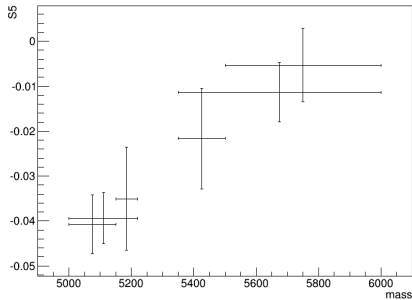


Q2\_1\_S5

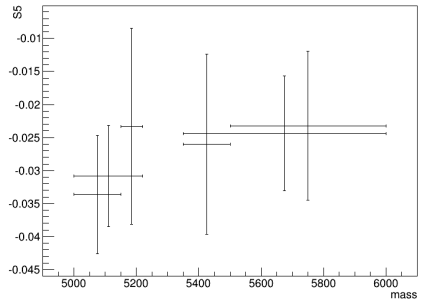


# Measurement of background moments

Q2\_2\_S5

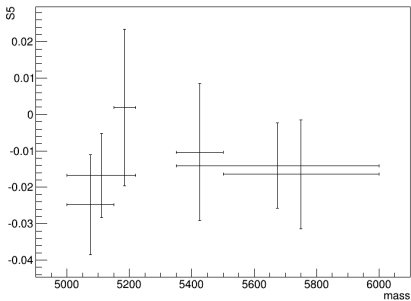


Q2\_3\_S5

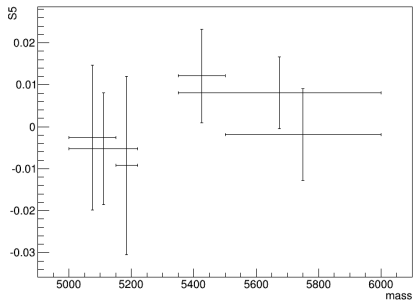


# Measurement of background moments

Q2\_4\_S5



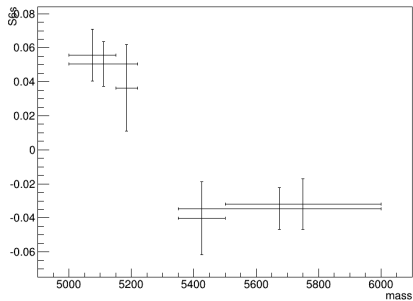
Q2\_5\_S5



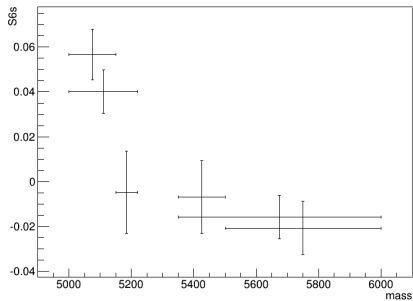


# Measurement of background moments

Q2\_0\_S6s

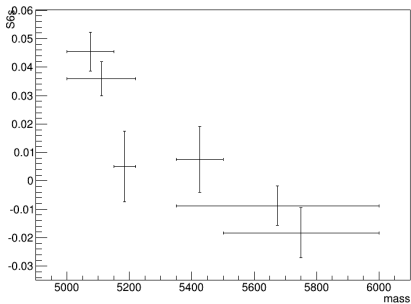


Q2\_1\_S6s

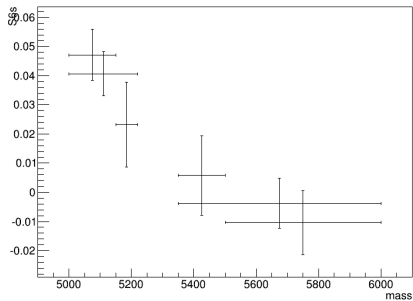


# Measurement of background moments

Q2\_2\_S6s

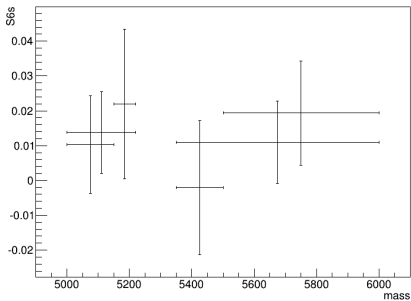


Q2\_3\_S6s

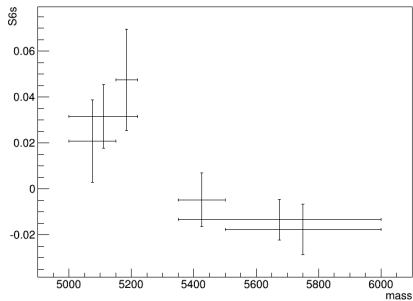


# Measurement of background moments

Q2\_4\_S6s

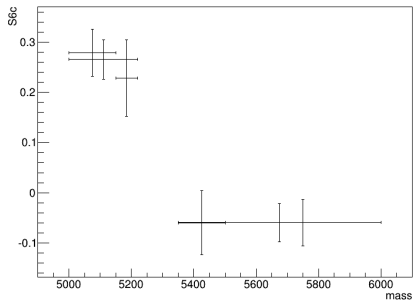


Q2\_5\_S6s

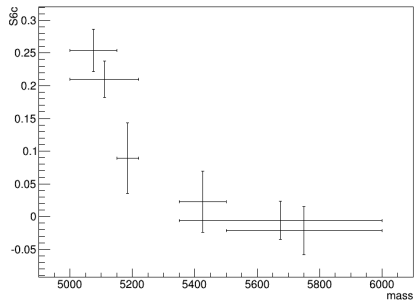


# Measurement of background moments

Q2\_0\_S6c

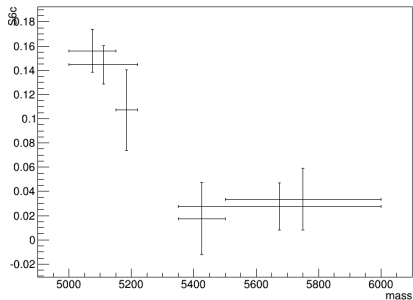


Q2\_1\_S6c

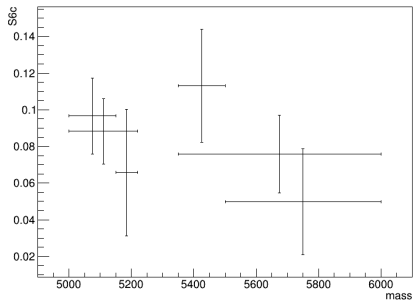


# Measurement of background moments

Q2\_2\_S6c

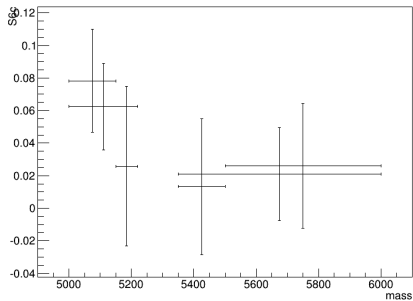


Q2\_3\_S6c

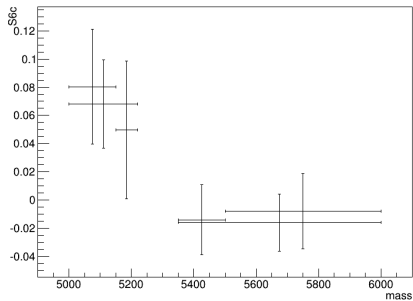


# Measurement of background moments

Q2\_4\_S6c

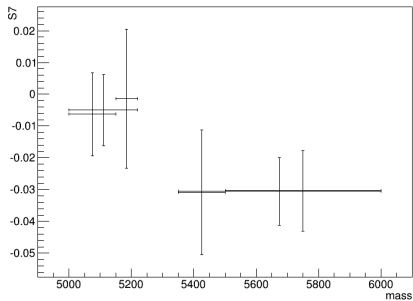


Q2\_5\_S6c

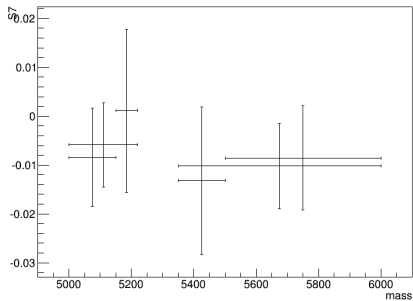


# Measurement of background moments

Q2\_0\_S7

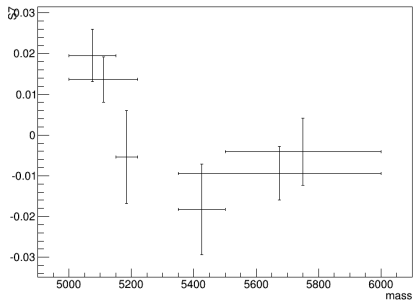


Q2\_1\_S7

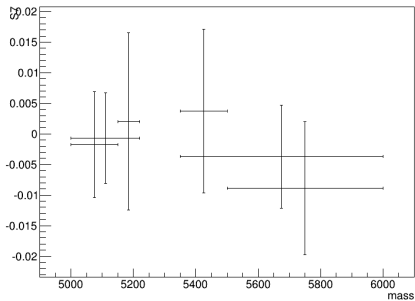


# Measurement of background moments

Q2\_2\_S7



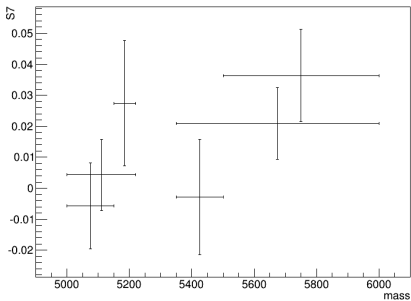
Q2\_3\_S7



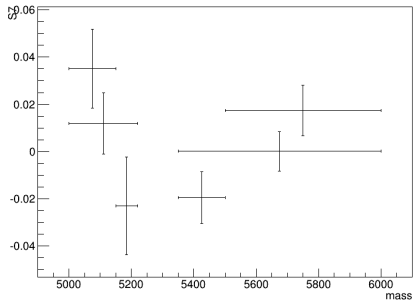


# Measurement of background moments

Q2\_4\_S7

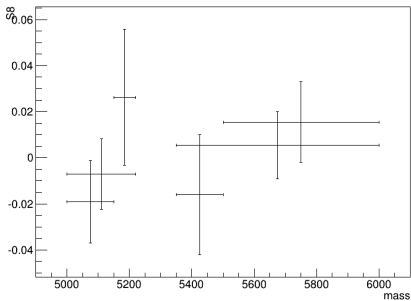


Q2\_5\_S7

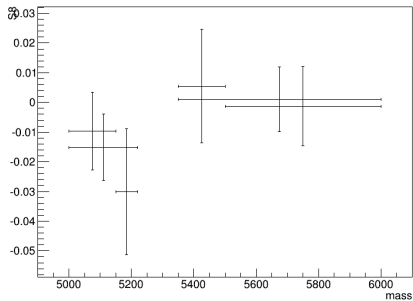


# Measurement of background moments

Q2\_0\_S8

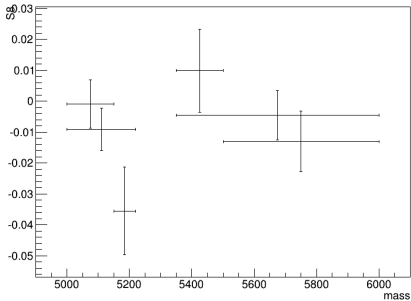


Q2\_1\_S8

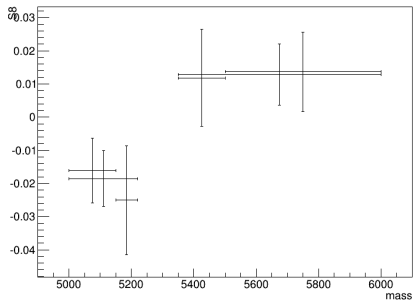


# Measurement of background moments

Q2\_2\_S8

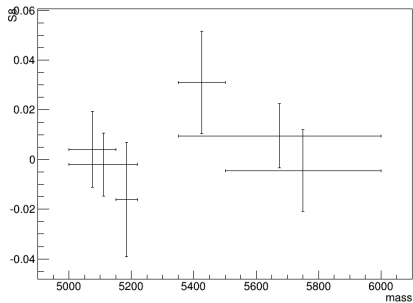


Q2\_3\_S8

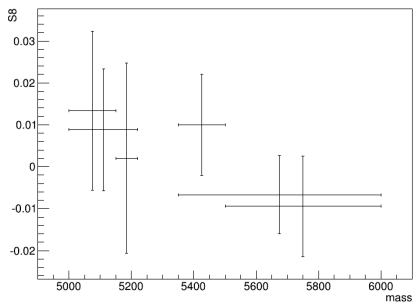


# Measurement of background moments

Q2\_4\_S8

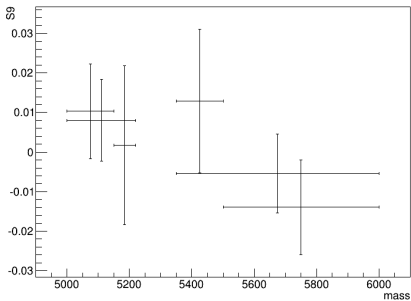


Q2\_5\_S8

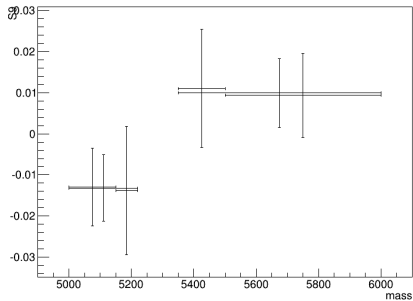


# Measurement of background moments

Q2\_0\_S9

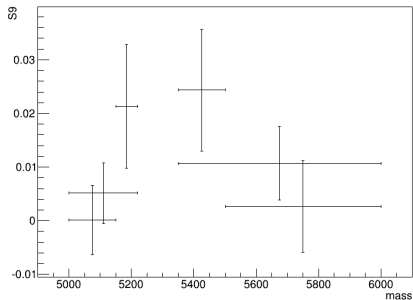


Q2\_1\_S9

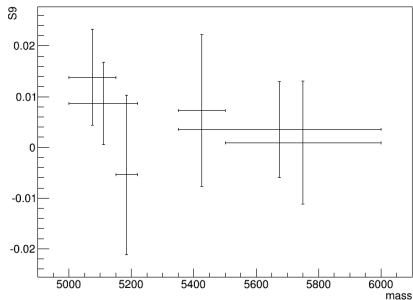


# Measurement of background moments

Q2\_2\_S9

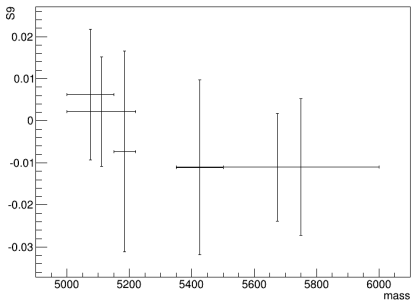


Q2\_3\_S9

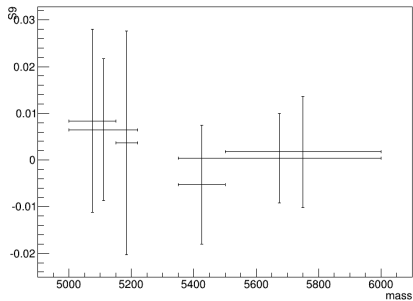


# Measurement of background moments

Q2\_4\_S9

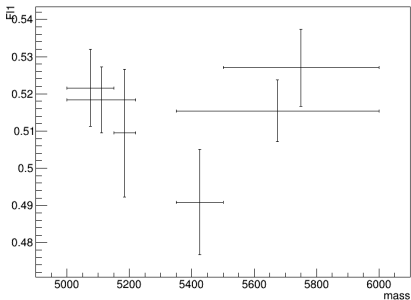


Q2\_5\_S9

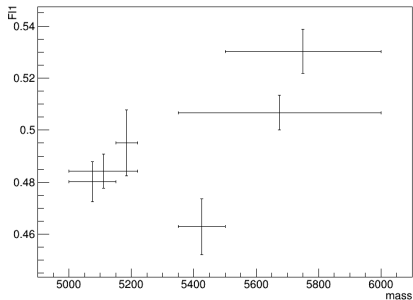


# Measurement of background moments

Q2\_0\_Fl1



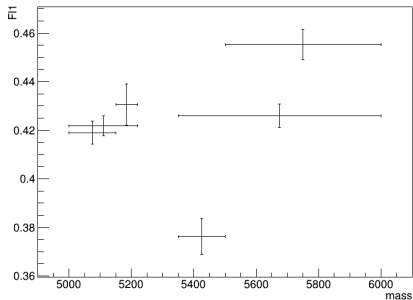
Q2\_1\_Fl1



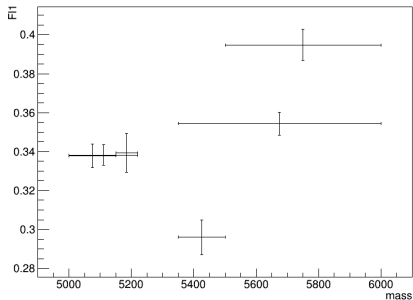


# Measurement of background moments

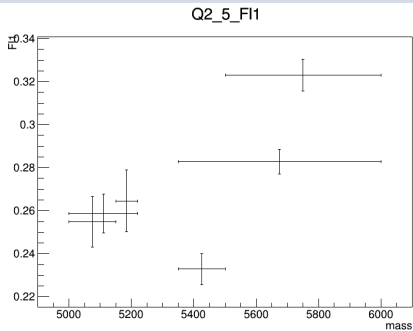
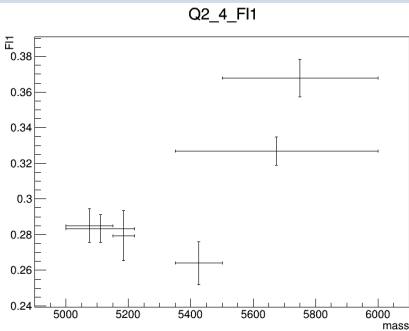
Q2\_2\_Fl1



Q2\_3\_Fl1

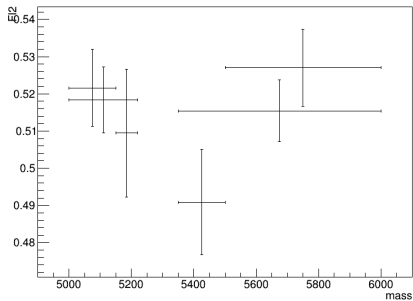


# Measurement of background moments

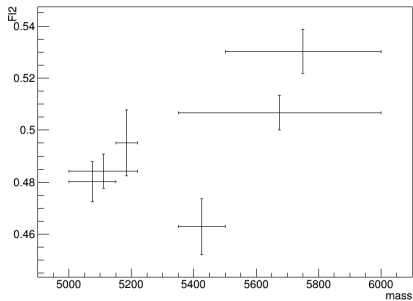


# Measurement of background moments

Q2\_0\_FI2

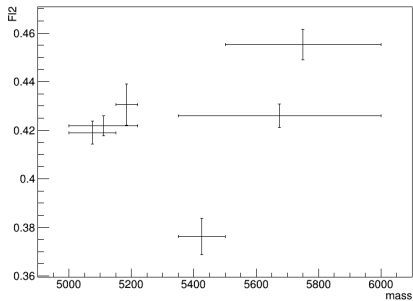


Q2\_1\_FI2

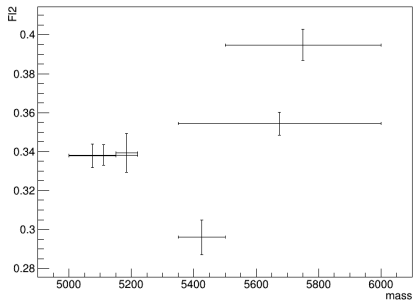


# Measurement of background moments

Q2\_2\_FI2

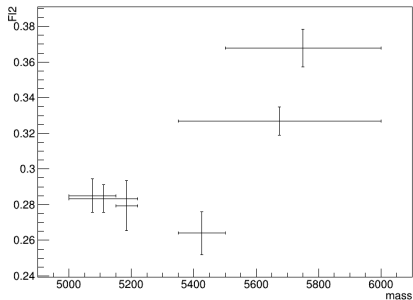


Q2\_3\_FI2

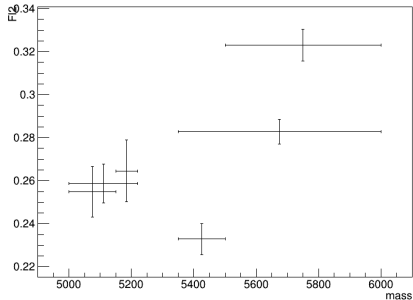


# Measurement of background moments

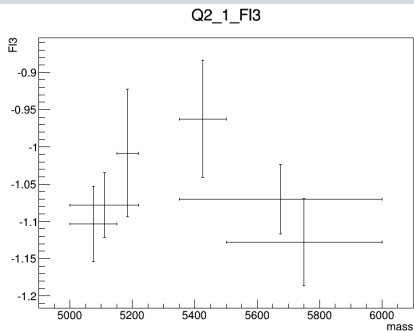
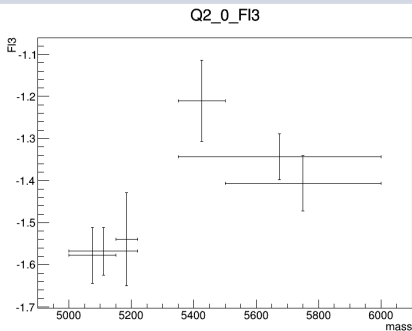
Q2\_4\_FI2



Q2\_5\_FI2

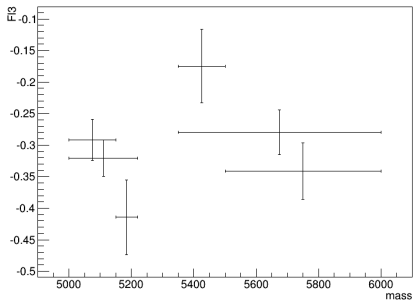


# Measurement of background moments

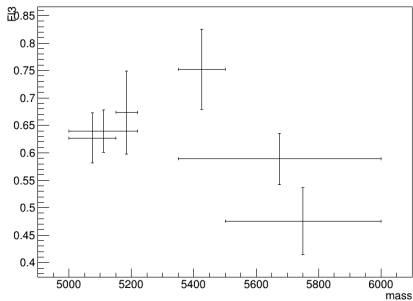


# Measurement of background moments

Q2\_2\_F13

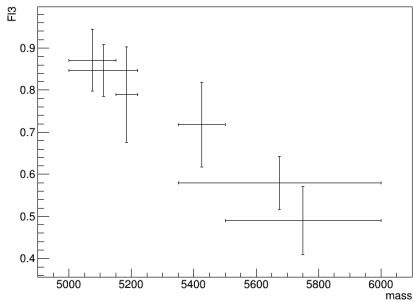


Q2\_3\_F13

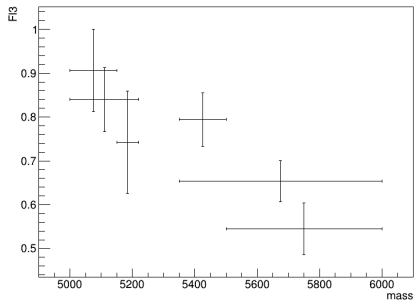


# Measurement of background moments

Q2\_4\_FI3



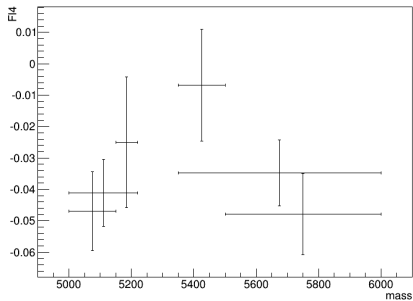
Q2\_5\_FI3



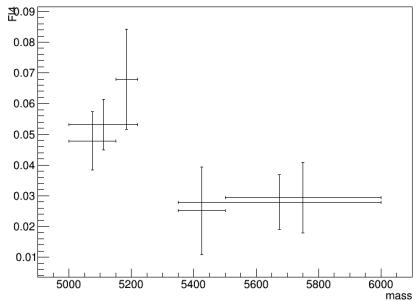


# Measurement of background moments

Q2\_0\_F14

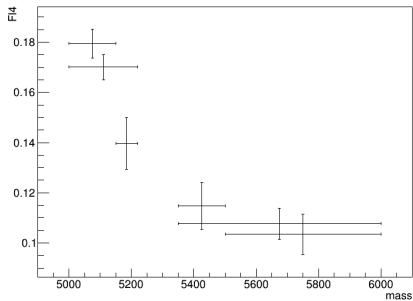


Q2\_1\_F14

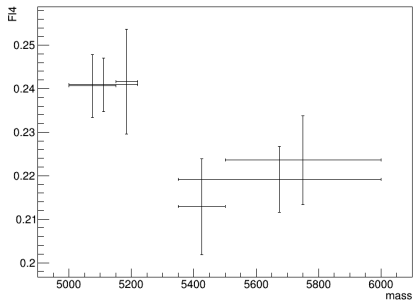


# Measurement of background moments

Q2\_2\_FI4

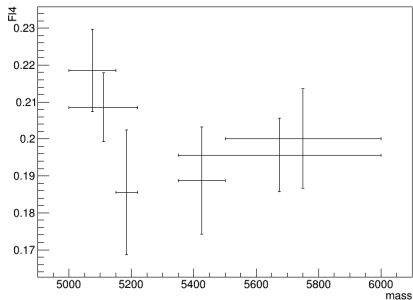


Q2\_3\_FI4

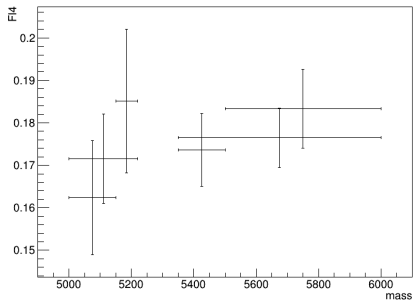


# Measurement of background moments

Q2\_4\_FI4



Q2\_5\_FI4





## Summary

- Background moments are effectively 0
- Apart from  $F_1$  and  $S_6$
- $S_6$  is sizeable at the left hand sideband for certain bins, evidence of partially reconstructed semileptonic decays?
- Because the moments are small, they should have small effect on the final result :)

Wish list:

- Repeat the same with smaller  $q^2$  bins.
- Optimise the binning in  $q^2$  taking into account background systematics and error on signal
- Do unfolding.