Status of the B→hh' Padova Analysis

U.Gasparini, S. Lacaprara, M. Margoni, P. Ronchese, F. Simonetto, M. Tosi

B → μμ Check Point #6, 02/27/2013

- Analysis Strategy
- News since last Check Point
- Preliminary Results
- Next Steps

Analysis Strategy

- Motivation:

Estimate BKG from $B \rightarrow hh'$ in the $B \rightarrow \mu\ \mu$ Analysis

(not a BR measurement!)

  - Use same normalization channel $B^+ \rightarrow K^+ J/\psi$
  - Use different trigger samples:

    HLT_Mu12_eta2p1_DiCentral_40_20_DiBTagIP3D1stTrack_v

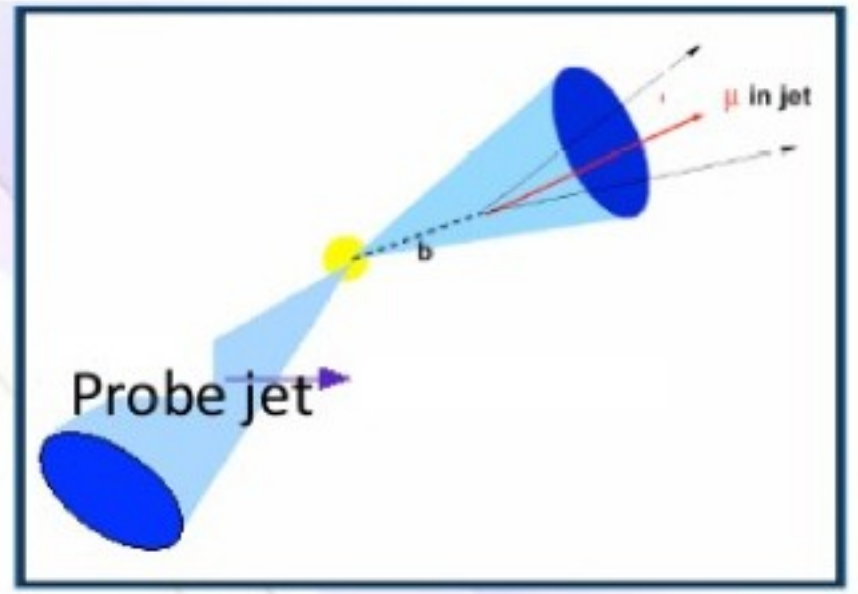
    HLT_Mu40_eta2p1_v

- Two different Strategies:

  - Fast: Start the $B \rightarrow hh'$ reconstruction from the secondary vertices in Jets
  - Strong: Use all the tracks combinations (as in the $\mu\ \mu$ Analysis)

Jet Based Strategy

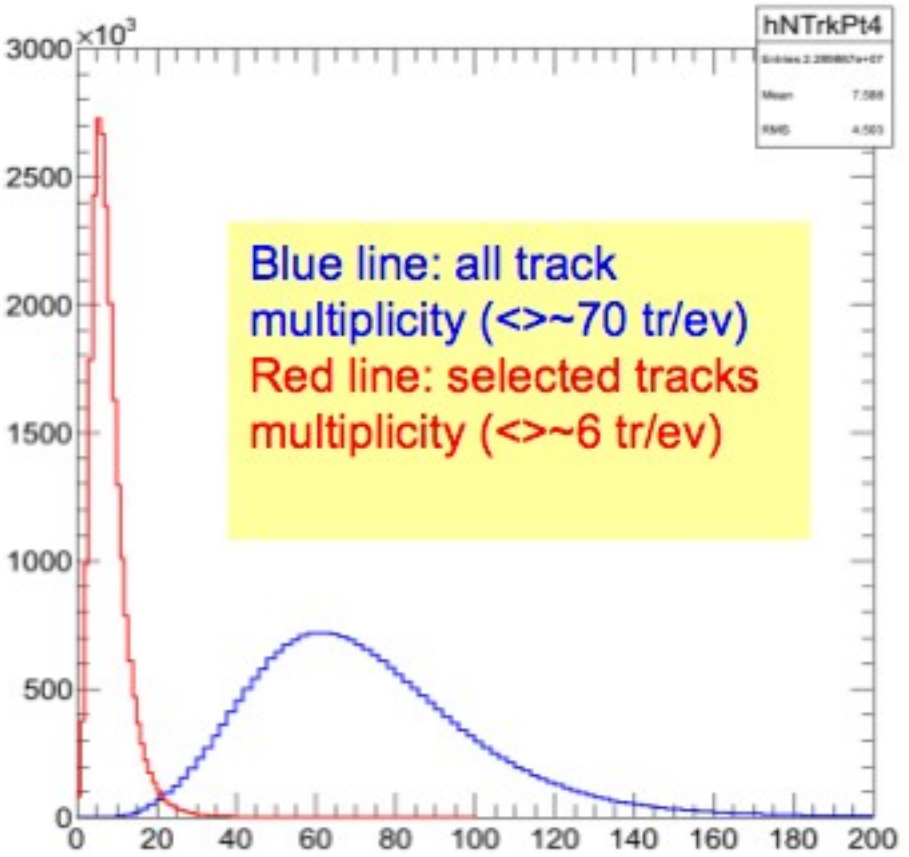
- Jet Based Strategy:
  - Tag a b-jet by means of a High PT μ
  - Reconstruct $B^+ \rightarrow K^+ J/\psi$ & $B \rightarrow hh'$ decays starting from secondary vertices not associated to the Tag jet.



"All Tracks" Strategy

- "All Tracks" Strategy:
  - Tag a b-jet by means of a High PT μ
  - Reconstruct $B^+ \rightarrow K^+ J/\Psi$ & $B \rightarrow hh'$ decays starting from the combinations of all the tracks with PT>4 GeV not belonging to the Tag jet.

- Number of tracks surviving PT cut seems reasonable to allow hh' reconstruction



News since last CP

- The preliminary results shown at the last CP were obtained using the "OR" of several triggers (see list on next slide):
  - DATA: all the triggers prescaled, but
    HLT_Mu12_eta2p1_DiCentral_40_20_DiBTagIP3D1stTrack_v
    HLT_Mu40_eta2p1_v
  - MC: no prescaling for all the triggers
- **The efficiencies computed on MC were wrong!**
- Analysis redone by using only the not-prescaled triggers:
  - DATA statistics:
    - $B^+ \rightarrow K^+ J/\Psi$ reduction ~20%
    - $B \rightarrow hh'$ yield unchanged
  - MC statistics: only ~ 1.5% of the selected events survives the new selection

Old Trigger List

"HLT_Mu5_v*"
"HLT_Mu8_v*"
"HLT_Mu12_v*"
"HLT_Mu17_v*"
"HLT_Mu15_eta2p1_v*"
"HLT_Mu24_eta2p1_v*"
"HLT_Mu30_eta2p1_v*"
"HLT_Mu40_eta2p1_v*"
"HLT_Mu50_eta2p1_v*"

"HLT_Mu12_eta2p1_L1Mu10erJetC12WdEtaPhi1DiJetsC_v*"
"HLT_Mu12_eta2p1_DiCentral_40_20_DiBTagIP3D1stTrack_v*"
"HLT_Mu12_eta2p1_DiCentral_40_20_BTagIP3D1stTrack_v*"
"HLT_Mu12_eta2p1_DiCentral_40_20_v*"
"HLT_Mu12_eta2p1_DiCentral_20_v*"

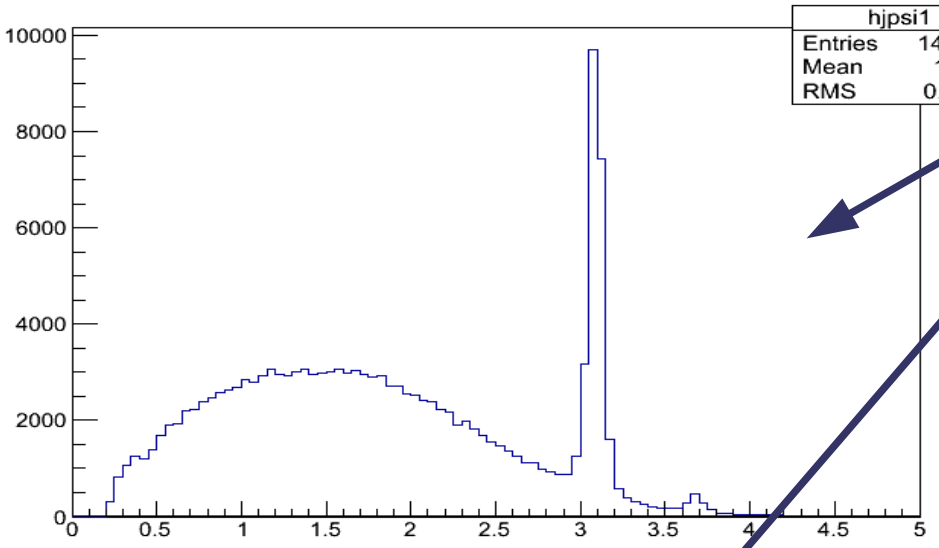
"HLT_Mu15_eta2p1_L1Mu10erJetC12WdEtaPhi1DiJetsC_v*"
"HLT_Mu15_eta2p1_TriCentral_40_20_20_DiBTagIP3D1stTrack_v*"
"HLT_Mu15_eta2p1_TriCentral_40_20_20_BTagIP3D1stTrack_v*"
"HLT_Mu15_eta2p1_TriCentral_40_20_20_v*"

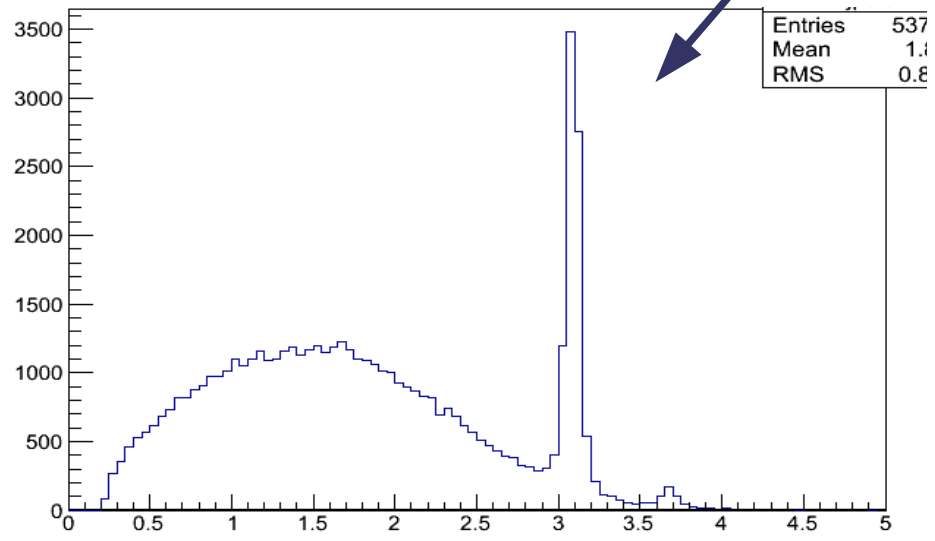
"HLT_DoubleMu4_Jpsi_Displaced_v*"
"HLT_DoubleMu4_JpsiTk_Displaced_v*"
"HLT_DoubleMu3p5_LowMassNonResonant_Displaced_v*"
"HLT_DoubleMu3p5_LowMass_Displaced_v*"
"HLT_DoubleDisplacedMu4_DiPFJet40Neutral_v*"

Triggers not prescaled in Real Data

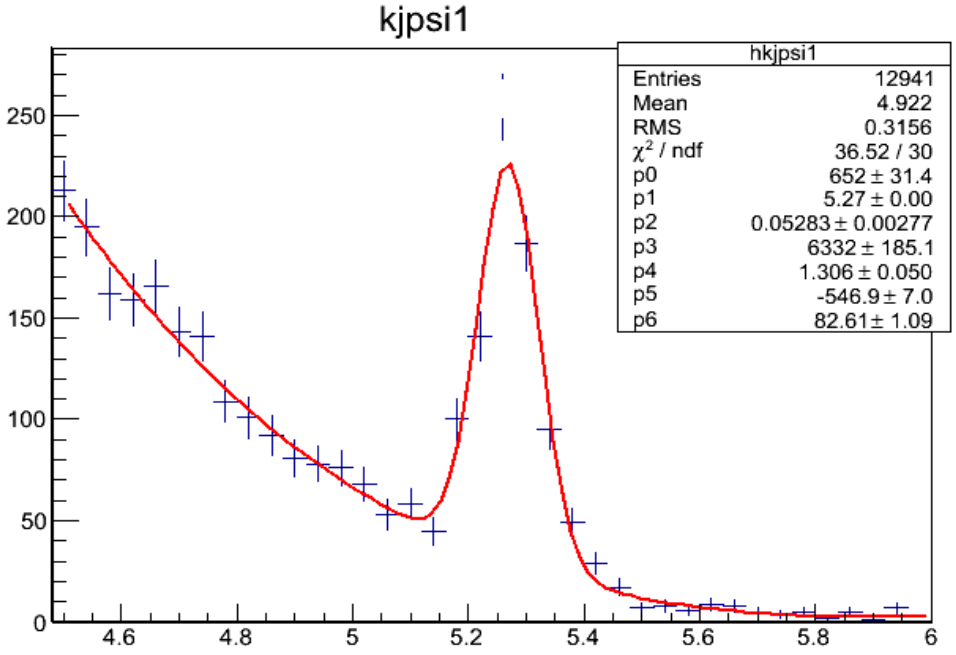
"Jet Based Strategy" Results

- Normalization channel $B^+ \rightarrow K^+ J/\psi$



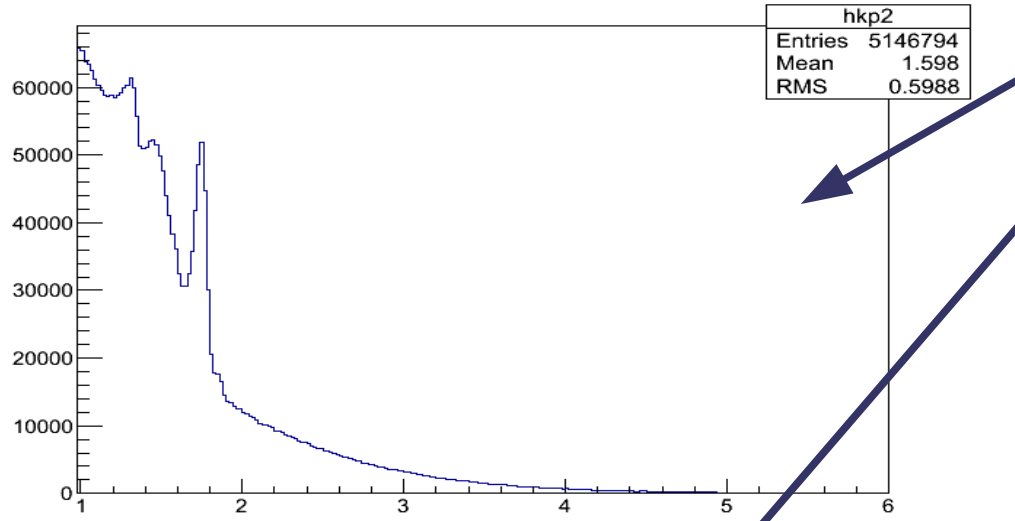


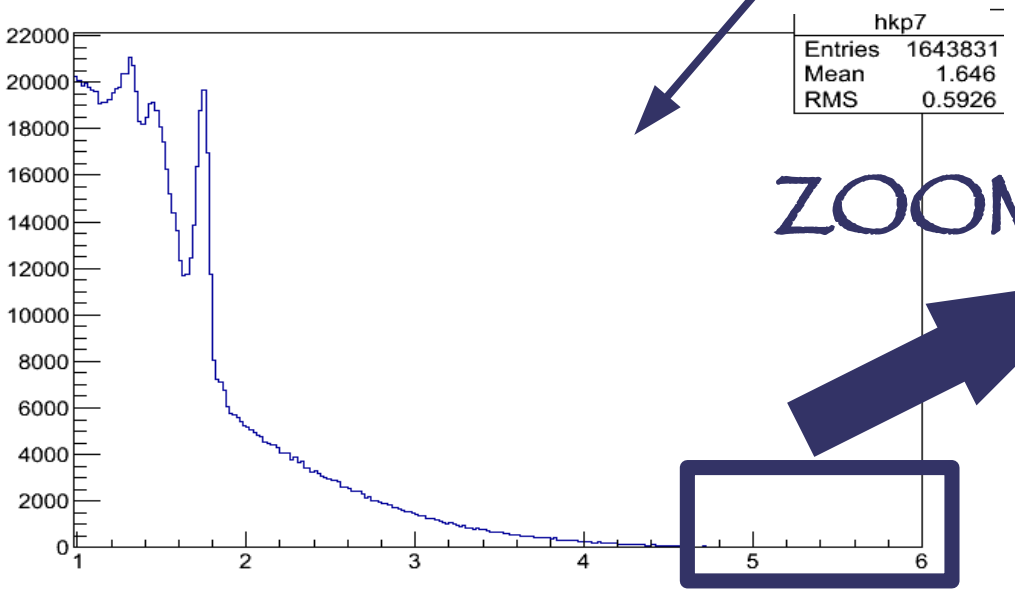
- About 18000 J/ψ in Probe jets out of which 7500 from secondary vertices with 3 tracks
- Assuming the third track is a Kaon: $N(K^+ J/\psi) \sim 650$



"Jet Based Strategy" Results

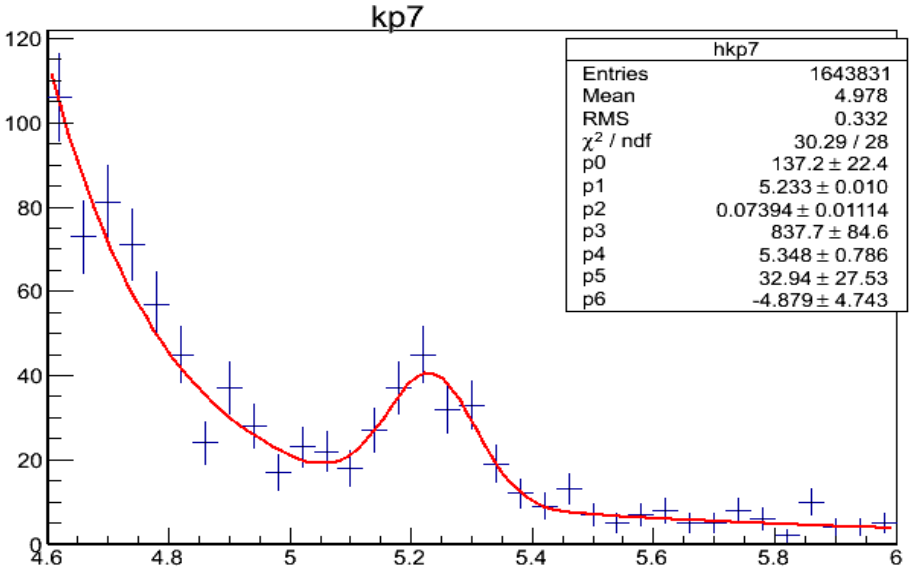
- Signal channel $B \rightarrow hh'$





ZOOM

- Invariant mass of vertices with 2 tracks (PT>3.5GeV) not identified as muons.
- Isolation cut applied on the Sum(PT) over a cone of $\Delta R<0.3$
- μ mass hypothesis for both the particles: $N_{hh'} \sim 140$



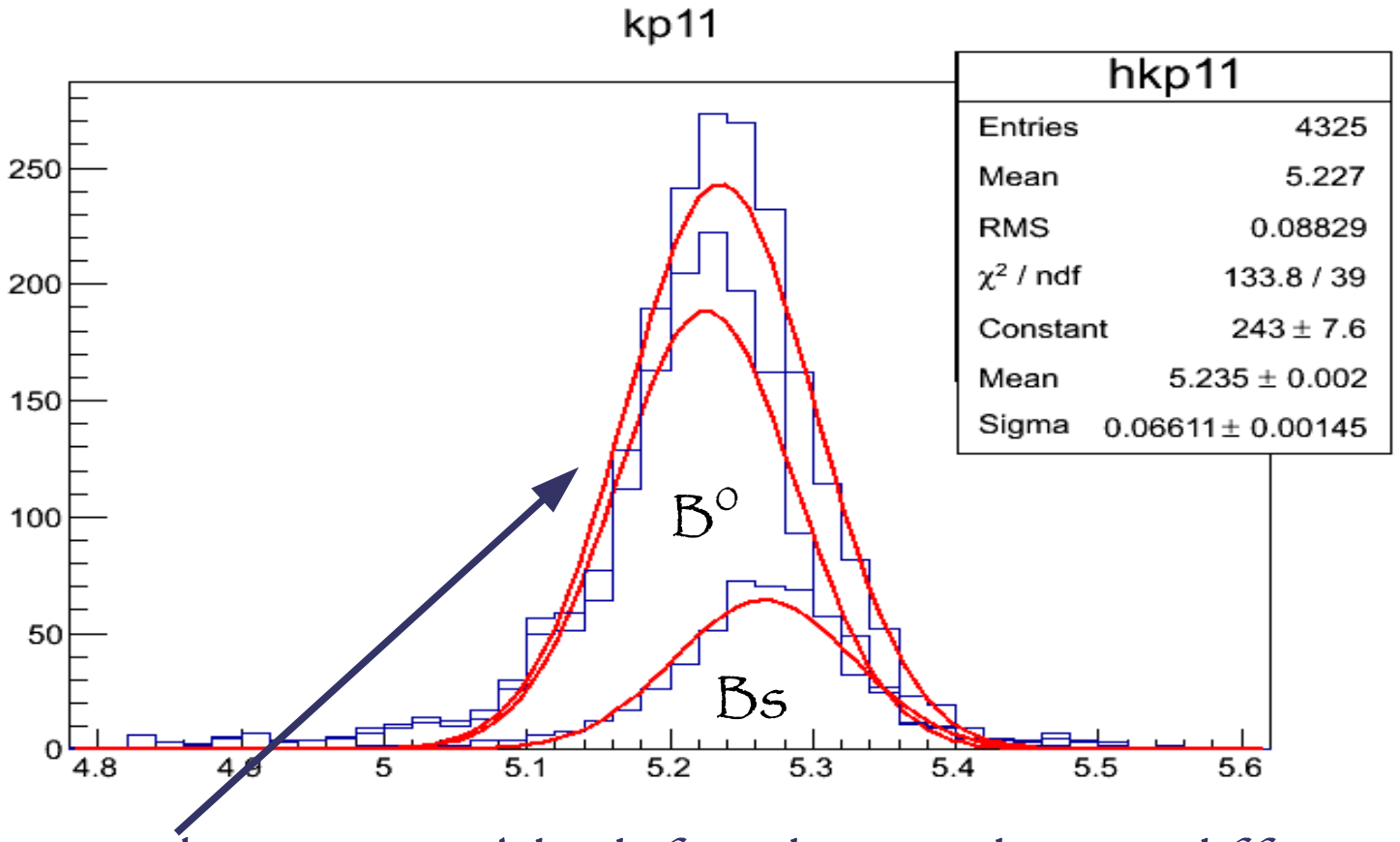
Mass Resolution

- Data:
  - B^+: M_{B+}=5.27 GeV, σ (M_{B+})= 53 MeV
  - hh': $M_{hh'}$=5.23 GeV, σ ($M_{hh'}$)= 74 MeV (μ mass hypothesis)
- MC:
  - B^+: M_{B+}=5.28 GeV, σ (M_{B+})= 45 MeV [PDG: 5.28 GeV]
  - B^0: M_{B0}=5.26 GeV, σ (M_{B0})= 63 MeV [PDG: 5.28 GeV]
  - Bs: M_{B0}=5.35 GeV, σ (M_{Bs})= 63 MeV [PDG: 5.37 GeV]
- MC, μ mass hypothesis:
  - B^0: M_{B0}=5.22 GeV, σ (M_{B0})= 63 MeV
  - Bs: M_{Bs}=5.27 GeV, σ (M_{Bs})= 63 MeV

- μ mass hypothesis lowers M_{B0} (M_{Bs}) by 40 (80) MeV

Mass Resolution

- Worse resolution in Data hh' partially due to B^0 /Bs superposition:



- MC with B^0+Bs yields defined according to different BRs
  - M_B=5.24 GeV
  - σ (M_B)= 66 MeV

Nhh' determination

- Goal: determine the number of hh' events in the $B \to \mu\ \mu$ sample from the extracted $B \to$ hh' signal in the Padova sample.

$$Nhh' = \left(\frac{NBp}{NBp(PD)}\right)\left(\frac{\epsilon_{tot}(Bp, PD)}{\epsilon_{tot}(Bp)}\right)\left(\frac{\epsilon_{tot}(B0)}{\epsilon_{tot}(B0, PD)}\right) Nhh'(PD)\, \omega_{\mu}(B0)$$

- Number of $B^0 \to$ hh' events misidentified as $B \to \mu\ \mu$
- Normalization Sample yields and efficiencies
- Signal Sample efficiencies
- Number of hh' events selected in the Padova Analysis
- Muon misidentification from D* (2012):
  - $\omega_{\mu}(K) = 3.18 \pm 0.44\ 10^{-3}$, $\omega_{\mu}(\pi) = 1.38 \pm 0.36\ 10^{-3}$
  - $\omega_{\mu\ \mu}(K\pi) = 4.4 \pm 1.3\ 10^{-6}$

Inputs from the Official Analysis

- B^+ yield and efficiency from AN_2012_358_v7, Tab 25, page 93

Table 25: Selection efficiency and number of observed events for the normalization sample. The errors are the combined statistical and systematic errors.

Variable	$B^\pm \to J/\psi K^\pm$ Barrel	$B^\pm \to J/\psi K^\pm$ Endcap
Acceptance	0.157 ± 0.005	0.106 ± 0.005
$\varepsilon_{\text{analysis}}$	0.0187 ± 0.0011	0.0093 ± 0.0006
ε_{μ}^{MC}	0.735 ± 0.029	0.738 ± 0.059
$\varepsilon_{\mu}^{MC-TNP}$	0.775 ± 0.031	0.836 ± 0.067
ε_{μ}^{TNP}	0.787 ± 0.031	0.781 ± 0.062
$\varepsilon_{\text{trig}}^{MC}$	0.532 ± 0.016	0.375 ± 0.023
$\varepsilon_{\text{trig}}^{MC-TNP}$	0.831 ± 0.000	0.719 ± 0.001
$\varepsilon_{\text{trig}}^{TNP}$	0.786 ± 0.024	0.728 ± 0.044
ε_{tot}	0.00094 ± 0.00008	0.00022 ± 0.00003
N_{obs}	241967 ± 12116	46855 ± 2355

$NB^+ = 288822 \pm 709 \pm 12322$ (statistical error from Tab. 22)

$\langle \varepsilon_{tot} B^+ \rangle = (6.14 \pm 0.46)\ 10^{-4}$

from weighted average according to the observed number of events in the Barrel vs Endcap corrected for efficiency

Inputs from the Official Analysis

- B^0 efficiency from AN_2012_358_v7, Tab 24 page 93

Variable	$B^0 \to \mu^+\mu^-$ Barrel	$B_s^0 \to \mu^+\mu^-$ Barrel	$B^0 \to \mu^+\mu^-$ Endcap	$B_s^0 \to \mu^+\mu^-$ Endcap
Acceptance	0.237 ± 0.008	0.237 ± 0.008	0.218 ± 0.011	0.218 ± 0.011
$\epsilon_{\text{analysis}}$	0.033 ± 0.001	0.032 ± 0.001	0.019 ± 0.001	0.019 ± 0.001
ϵ_{μ}^{MC}	0.690 ± 0.029	0.679 ± 0.027	0.813 ± 0.066	0.826 ± 0.066
ϵ_{μ}^{MC-TNP}	0.784 ± 0.031	0.785 ± 0.031	0.835 ± 0.067	0.835 ± 0.067
ϵ_{μ}^{TNP}	0.790 ± 0.032	0.792 ± 0.032	0.776 ± 0.062	0.779 ± 0.062
$\epsilon_{\text{trig}}^{MC}$	0.619 ± 0.021	0.620 ± 0.019	0.432 ± 0.029	0.447 ± 0.027
$\epsilon_{\text{trig}}^{MC-TNP}$	0.840 ± 0.025	0.841 ± 0.025	0.748 ± 0.045	0.750 ± 0.045
$\epsilon_{\text{trig}}^{TNP}$	0.793 ± 0.024	0.794 ± 0.024	0.758 ± 0.046	0.759 ± 0.046
ϵ_{tot}	0.0033 ± 0.0002	0.0031 ± 0.0002	0.0014 ± 0.0002	0.0015 ± 0.0002
$N_{\text{signal}}^{\text{exp}}$	0.955 ± 0.096	9.851 ± 1.478	0.260 ± 0.026	3.314 ± 0.497
$N_{\text{cross-feed}}^{\text{exp}}$	0.838 ± 0.126	0.384 ± 0.038	0.653 ± 0.098	0.172 ± 0.017
$N_{\text{non-peak. bg}}^{\text{exp}}$	7.312 ± 1.581	9.474 ± 1.917	3.546 ± 1.041	4.463 ± 1.296
$N_{\text{peak.bg}}^{\text{exp}}$	0.371 ± 0.141	0.099 ± 0.028	0.072 ± 0.027	0.036 ± 0.011
$N_{\text{all bg}}^{\text{exp}}$	7.683 ± 1.587	9.572 ± 1.917	3.618 ± 1.041	4.499 ± 1.296
$N_{\text{total}}^{\text{exp}}$	9.476 ± 1.868	19.808 ± 2.421	4.531 ± 1.163	7.985 ± 1.388
$N_{\text{sidebands}}^{\text{obs}}$	66		33	
N_{obs}	15	9	8	8

$\langle \varepsilon_{tot} Bs \rangle = (2.44 \pm 0.14)\ 10^{-3}$ (total error)

from weighted average according to the expected number of signal events in the Barrel vs Endcap corrected for efficiency

Inputs from the Padova Analysis

- hh' Efficiency from MC

	Nsel	Ngen	ε	fx/fd	BR
$B^0 \to KK$	1	594318	$1.7\pm1.7\ 10^{-6}$	1	$1.3\ 10^{-7}$
$B^0 \to K\pi$	37	99018038	$3.7\pm0.6\ 10^{-7}$	1	$1.95\ 10^{-5}$
$B^0 \to \pi\pi$	6	8683043	$6.9\pm2.8\ 10^{-7}$	1	$5.19\ 10^{-6}$
$B_s \to KK$	63	151351484	$4.2\pm0.5\ 10^{-7}$	0.267	$2.54\ 10^{-5}$
$B_s \to K\pi$	5	9724148	$5.1\pm2.3\ 10^{-7}$	0.267	$5\ 10^{-6}$
$B_s \to \pi\pi$	5	9270586	$5.4\pm2.4\ 10^{-7}$	0.267	$7.3\ 10^{-7}$

$$\langle \varepsilon_{tot}(B^0) \rangle = (4.44\pm0.59)\ 10^{-7}$$

(from average using fx/fd*BR as weight)

- Normalization channel

$B^+ \to J/\psi K^+$	9	4551542	$\varepsilon_{tot}(B^+) = 1.98\pm0.66\ 10^{-6}$

Preliminary Results

$$Nhh' = \left(\frac{NBp}{NBp(PD)}\right)\left(\frac{\epsilon_{tot}(Bp, PD)}{\epsilon_{tot}(Bp)}\right)\left(\frac{\epsilon_{tot}(B0)}{\epsilon_{tot}(B0, PD)}\right) Nhh'(PD)\,\omega_{\mu}(B0)$$

- Without misidentification:

$$Nhh' = \frac{288822 \pm 12343}{652 \pm 31}\,\frac{1.98 \pm 0.66\,10^{-6}}{6.14 \pm 0.46\,10^{-4}}\,\frac{2.44 \pm 0.14\,10^{-3}}{4.44 \pm 0.59\,10^{-7}}(137 \pm 22) = 1075491 \pm 437829$$

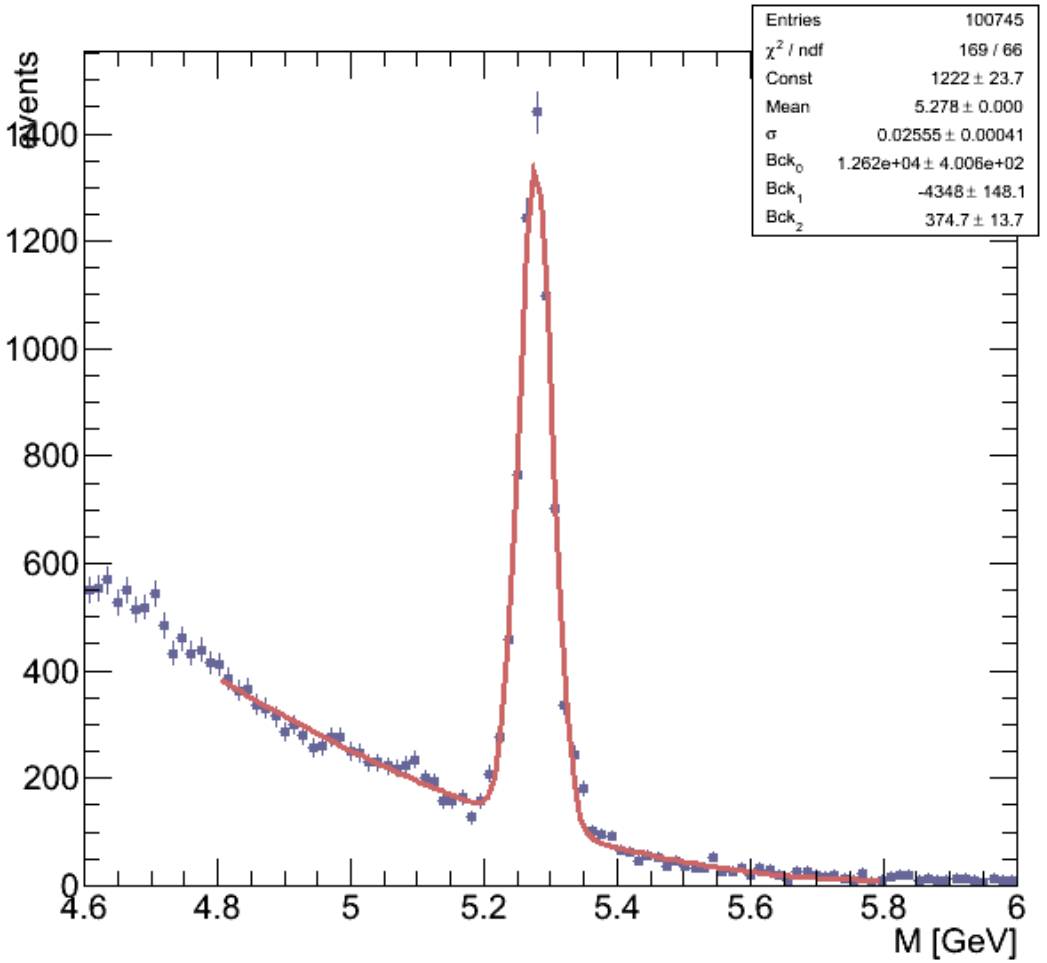
- Assuming $\omega = 4.4 \pm 1.3\ 10^{-6}$ (see slide 11):
  - $Nhh' = 4.7 \pm 1.9(\text{method}) \pm 1.4(\omega)$
- Error dominated by $\epsilon_{tot}(B^+, PD)$:
  - $\sigma\ Nhh'(\epsilon_{tot}(B^+, PD)) = \pm 1.6$
  - Reduce the statistical error: use the "All Tracks" Strat.!

Cross Checks

- Nominal result
  - $N_{hh'} = 4.7 \pm 1.9(\text{method}) \pm 1.4(\omega)$
- Only HLT_Mu12_eta2p1_DiCentral_40_20_DiBTagIP3D1stTrack_v
  - $N_{hh'} = 6.3 \pm 3.2(\text{method}) \pm 1.8(\omega)$
- Only HLT_Mu40_eta2p1_v
  - $N_{hh'} = 3.3 \pm 2.1(\text{method}) \pm 1.0(\omega)$
- Using a tighter hh' selection (40% lower efficiency):
  - $N_{hh'} = 4.9 \pm 2.0(\text{method}) \pm 1.4(\omega)$

"All Tracks" Strategy

- hh' reconstruction on real data sample still to be finalized, however...
- Results for the B^+ normalization channel already available!



"All Tracks" Strategy

- B^+ reconstructed event statistics:

	Jet Based	All Tracks	Generated
MC	9	78	4551542
Efficiency	$(1.98 \pm 0.66)\ 10^{-6}$	$(17.14 \pm 1.94) 10^{-6}$	
DATA	652 ± 31	6093 ± 87	

- Relative error on B^+ efficiency reduced by a factor 3
- Use the "All Tracks" numbers in the B^+ sector of Padova Analysis!

"All Tracks" Strategy

$$Nhh' = \frac{288822 \pm 12343}{6093 \pm 87} \frac{17.14 \pm 1.94\,10^{-6}}{6.14 \pm 0.46\,10^{-4}} \frac{2.44 \pm 0.14\,10^{-3}}{4.44 \pm 0.59\,10^{-7}} (137 \pm 22) = 996251 \pm 258241$$

- Assuming $\omega = 4.4 \pm 1.3\ 10^{-6}$ (see slide 11):
  - Nhh'=4.1±1.1(method)±1.3(ω)
- To be compared with Nhh'=4.7±1.9(method)±1.4(ω)

- Only HLT_Mu12_eta2p1_DiCentral_40_20_DiBTagIP3D1stTrack_v
  - Nhh'=4.6±1.3(method)±1.4(ω)

- Only HLT_Mu40_eta2p1_v
  - Nhh'=3.7±1.9(method)±1.1(ω)

Conclusions & Next Steps

- Solved a bug in the efficiency determination in the MC:
  - Preliminary Results show now a tension wrt the Official Analysis in the peaking BKG prediction

- Next Steps:
  - Cross Check: increase the B^+ statistics in the Jet Based Analysis by removing the secondary vertex requirement for the three tracks
  - Increase the hh' statistics by means of the "All tracks combination" Strategy