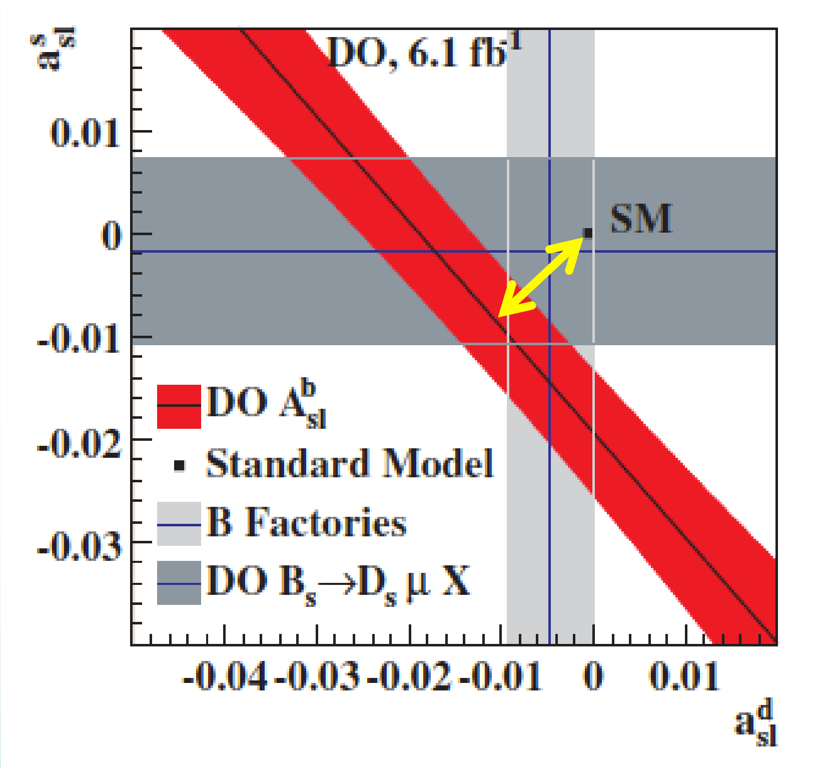
A_{fs}^{s} at LHCb
Time Independent Analysis

On behalf of the LHCb semileptonic taskforce

Motivation

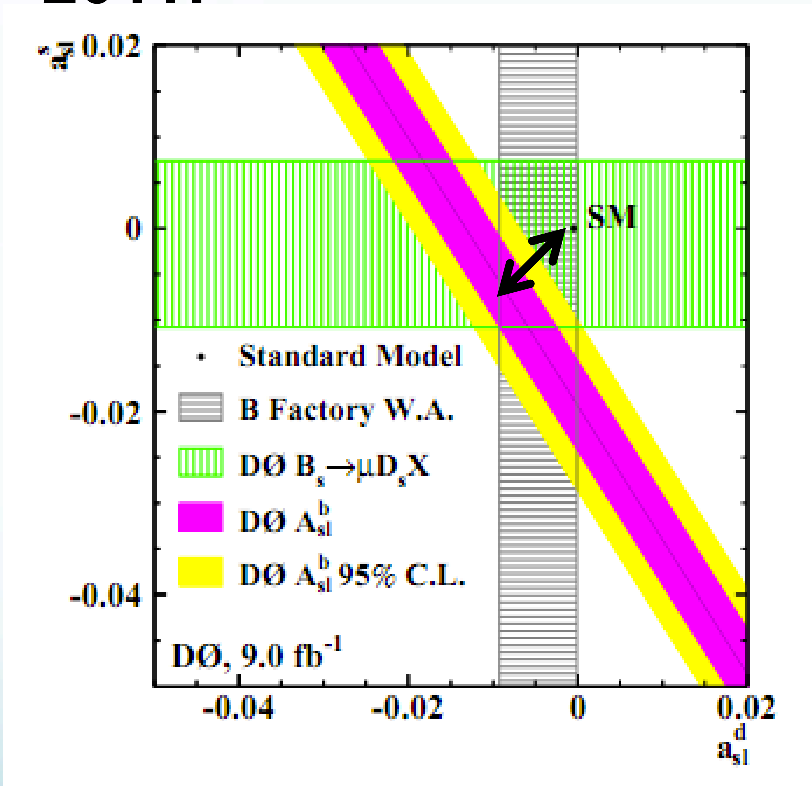
➢ DØ measurement of like-sign dimuon asymmetry in semileptonic b-decays of O(1%):

2010:



3.2σ from SM

2011:



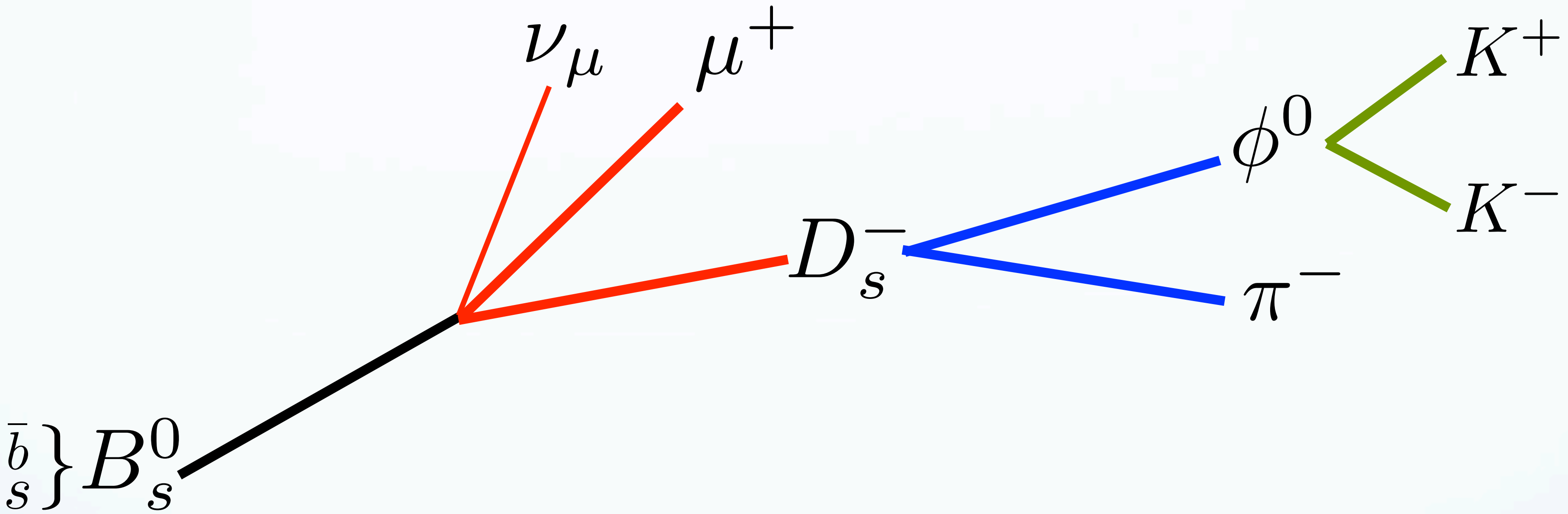
3.9σ from SM

MANCHESTER 1824 The University of Manchester

Approach

LHCb

- Looking initially at the B_s^0 / $\bar{B}_s^0$ system only:



- Large branching fraction
- Initial analysis uses ϕ^0 resonance: ~50% of $D_s \to KK\pi$
- Production asymmetry washes out due to fast oscillations: < ~10^{-4} effect

MANCHESTER
1824
The University of Manchester

Approach

LHCb

- The main formula:

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})}=\frac{a_{fs}^s}{2}+\left(a_p-\frac{a_{fs}^s}{2}\right)\frac{\int_{t=0}^{\infty}e^{-\Gamma t}\cos(\Delta M t)\varepsilon(t)\,dt}{\int_{t=0}^{\infty}e^{-\Gamma t}\cosh(\frac{\Delta\Gamma}{2}t)\varepsilon(t)\,dt}$$

Approach

- The main formula:

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})}=\frac{a_{fs}^s}{2}+\left(a_p-\frac{a_{fs}^s}{2}\right)\frac{\int_{t=0}^{\infty}e^{-\Gamma t}\cos(\Delta M t)\varepsilon(t)dt}{\int_{t=0}^{\infty}e^{-\Gamma t}\cosh(\frac{\Delta\Gamma}{2}t)\varepsilon(t)dt}$$

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})}=\frac{N(D_s^-\mu^+\nu)-N(D_s^+\mu^-\bar{\nu})}{N(D_s^-\mu^+\nu)+N(D_s^+\mu^-\bar{\nu})}$$

1) Measure yields of B_s^0 and $\bar{B}_s^0$

Approach

- The main formula:

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})} = \frac{a_{fs}^s}{2} + \left(a_p - \frac{a_{fs}^s}{2}\right)\frac{\int_{t=0}^{\infty} e^{-\Gamma t}\cos(\Delta M t)\varepsilon(t)dt}{\int_{t=0}^{\infty} e^{-\Gamma t}\cosh(\frac{\Delta\Gamma}{2}t)\varepsilon(t)dt}$$

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})} = \frac{N(D_s^-\mu^+\nu)-N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}}{N(D_s^-\mu^+\nu)+N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}}$$

1) Measure yields of B_s^0 and $\bar{B}_s^0$

2) Measure μ and π tracking efficiencies

Approach

- The main formula:

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})}=\frac{a_{fs}^s}{2}+\left(a_p-\frac{a_{fs}^s}{2}\right)\frac{\int_{t=0}^{\infty}e^{-\Gamma t}\cos(\Delta M t)\varepsilon(t)dt}{\int_{t=0}^{\infty}e^{-\Gamma t}\cosh(\frac{\Delta\Gamma}{2}t)\varepsilon(t)dt}$$

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})}=\frac{N(D_s^-\mu^+\nu)-N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}\times\frac{\varepsilon_{id}(\mu^+)}{\varepsilon_{id}(\mu^-)}}{N(D_s^-\mu^+\nu)+N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}\times\frac{\varepsilon_{id}(\mu^+)}{\varepsilon_{id}(\mu^-)}}$$

1) Measure yields of B_s^0 and $\bar{B}_s^0$

2) Measure μ and π tracking efficiencies

3) μ identification asymmetries

Approach

- The main formula:

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})} = \frac{a_{fs}^s}{2} + \left(a_p - \frac{a_{fs}^s}{2}\right)\frac{\int_{t=0}^{\infty} e^{-\Gamma t}\cos(\Delta M t)\varepsilon(t)\,dt}{\int_{t=0}^{\infty} e^{-\Gamma t}\cosh(\frac{\Delta\Gamma}{2}t)\varepsilon(t)\,dt}$$

$$\frac{\Gamma(D_s^-\mu^+\nu)-\Gamma(D_s^+\mu^-\bar{\nu})}{\Gamma(D_s^-\mu^+\nu)+\Gamma(D_s^+\mu^-\bar{\nu})} = \frac{N(D_s^-\mu^+\nu)-N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}\times\frac{\varepsilon_{id}(\mu^+)}{\varepsilon_{id}(\mu^-)}\times\frac{\varepsilon_{trig}(\mu^+)}{\varepsilon_{trig}(\mu^-)}}{N(D_s^-\mu^+\nu)+N(D_s^+\mu^-\bar{\nu})\times\frac{\varepsilon_{track}(\pi^-)\varepsilon_{track}(\mu^+)}{\varepsilon_{track}(\pi^+)\varepsilon_{track}(\mu^-)}\times\frac{\varepsilon_{id}(\mu^+)}{\varepsilon_{id}(\mu^-)}\times\frac{\varepsilon_{trig}(\mu^+)}{\varepsilon_{trig}(\mu^-)}}$$

1) Measure yields of B_s^0 and $\bar{B}_s^0$

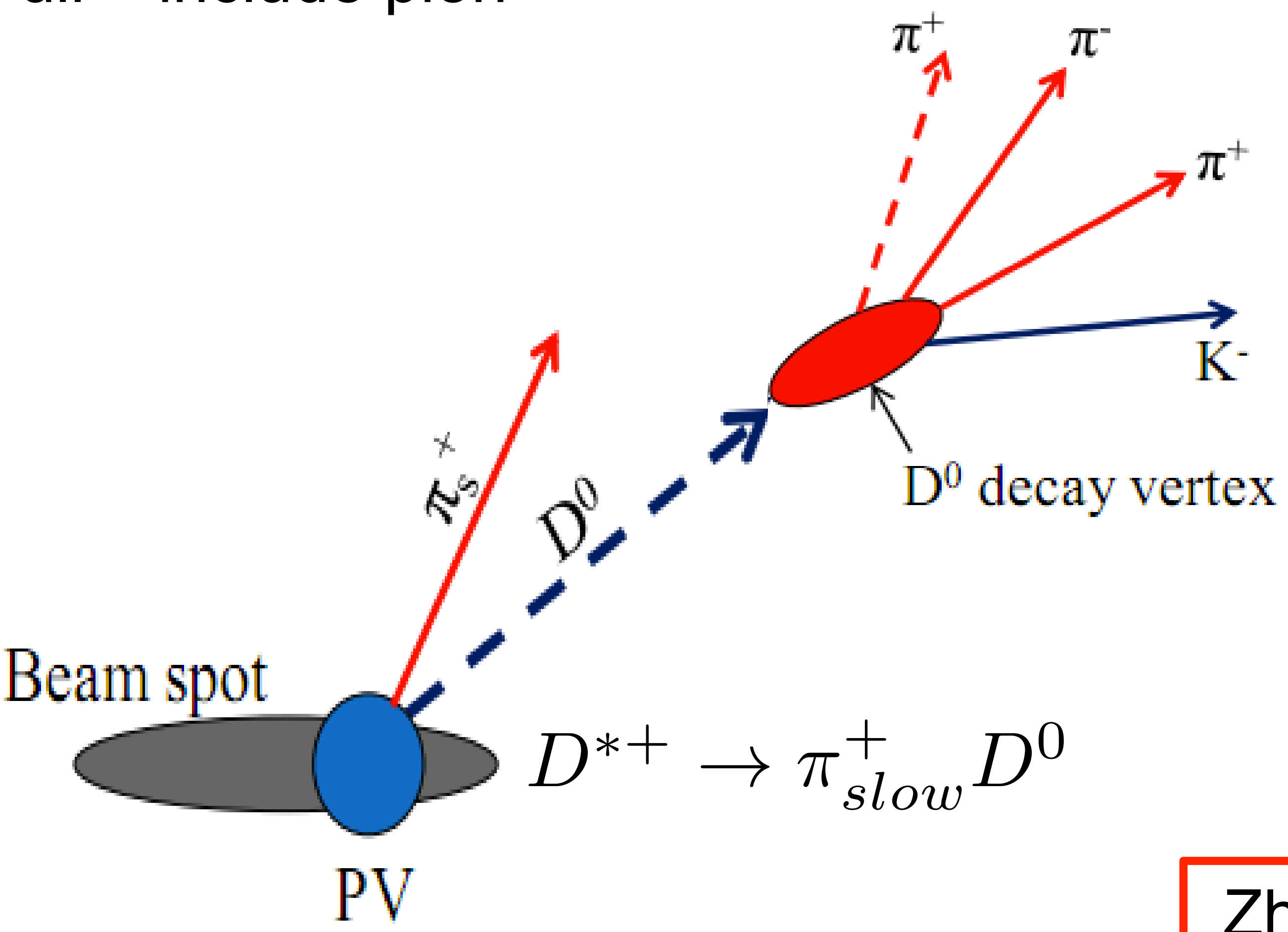
2) Measure μ and π tracking efficiencies

3) μ identification asymmetries

4) Measure trigger bias

Tracking and Pion Efficiencies

- Use full and partial reconstructed for: $D^0 \to K^-\pi^+\pi^+\pi^-$
  - Partial – ignore a pion
  - Full – include pion



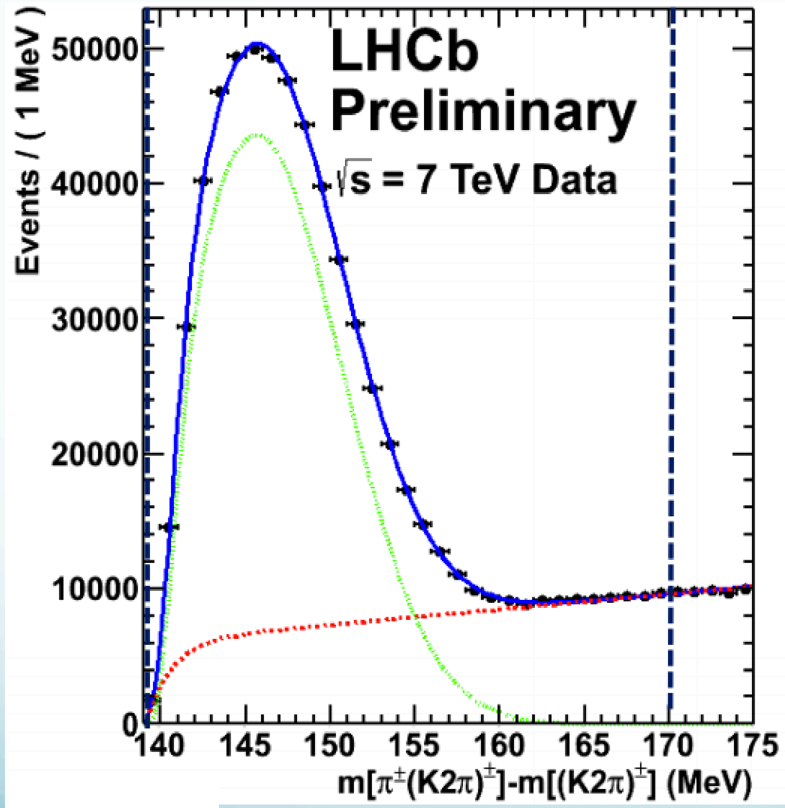
$D^{*+} \to \pi^+_{slow} D^0$

Zhou Xing

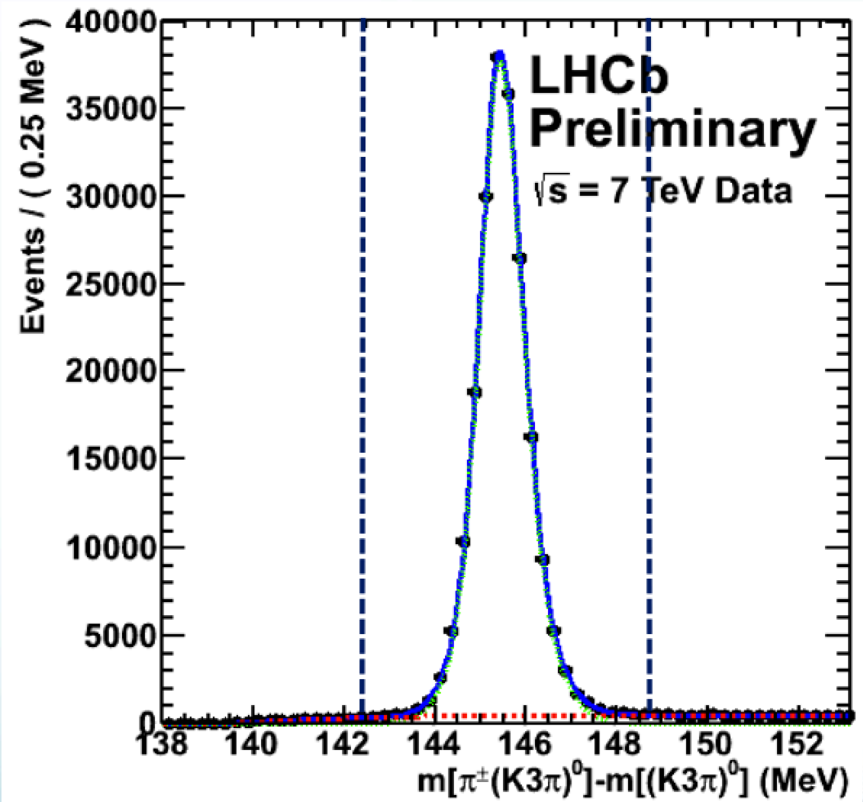
Tracking and Pion Efficiencies

- The ratio of signal yields from the two different reconstructions gives the pion efficiency.

Partial:



Full:

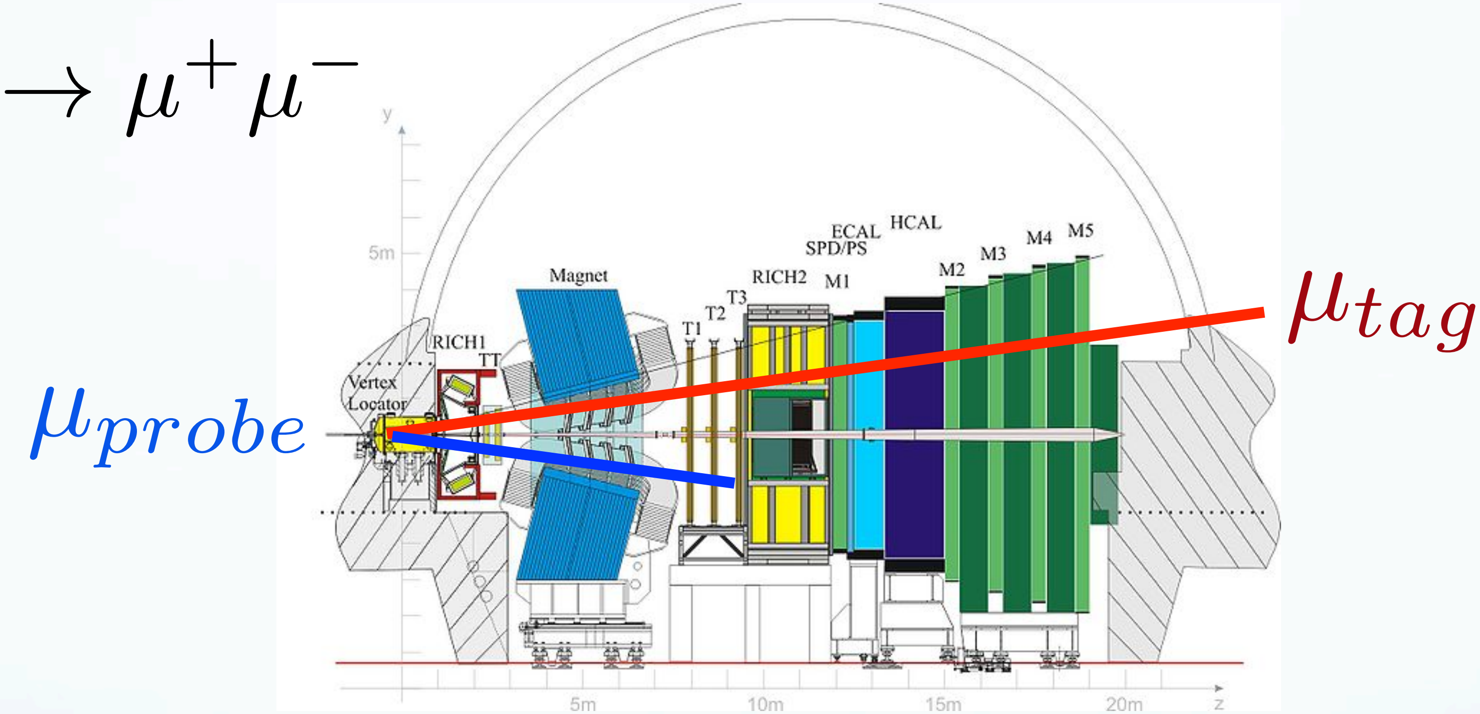


Zhou Xing

Muon Efficiencies

- Large data sample of tag and probe muons:

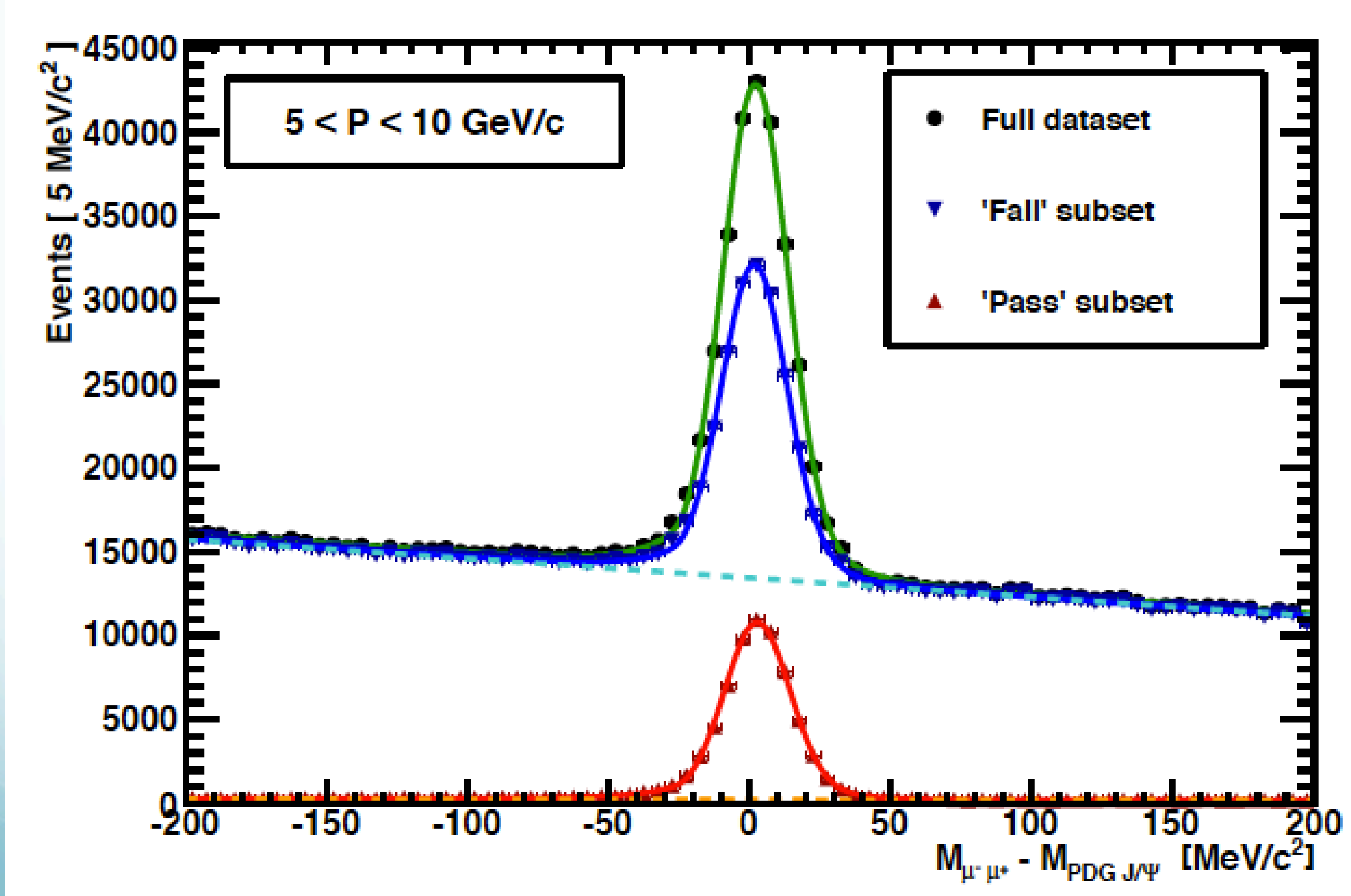
$$J/\Psi \to \mu^+\mu^-$$

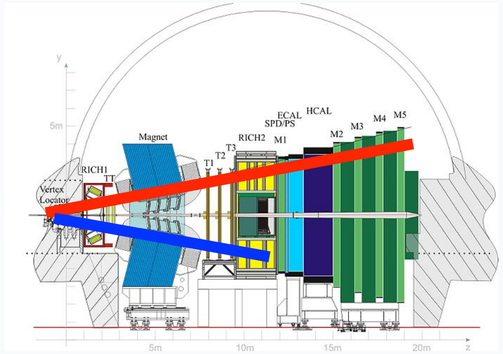


1. Tag is identified as muon
2. Probe is a ‘good’ long track (no muon ID applied)
3. Tag and probe form a good vertex and have invariant mass close to J/ψ mass

Muon Efficiencies

- Use custom RooFit PDF to simultaneously fit J/ψ yields with and without selection cuts applied:



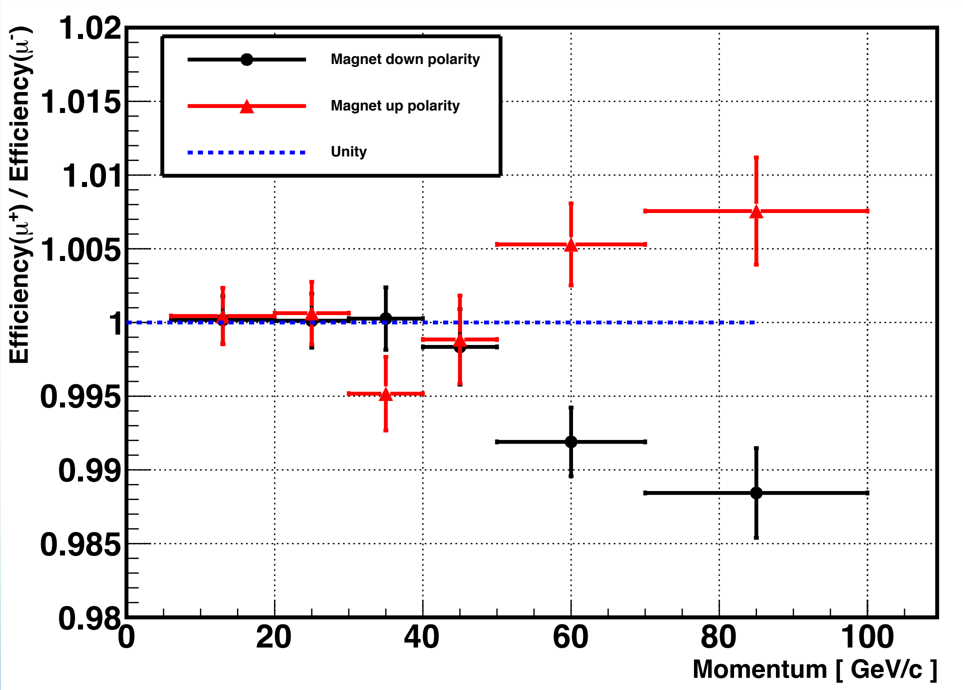


Model:
1. Linear background
2. Double crystal ball for peak
3. Efficiency is directly fitted using yields of 'pass' and 'fail' sub-categories.

Muon Efficiencies

- When applying muon selection cuts we see a charge bias at high momentum:

Ratio of efficiencies :
(mu+) / (mu-)



1. Asymmetry is observed at high muon momentum which flips with magnet polarity.

2. Predominantly an acceptance effect.

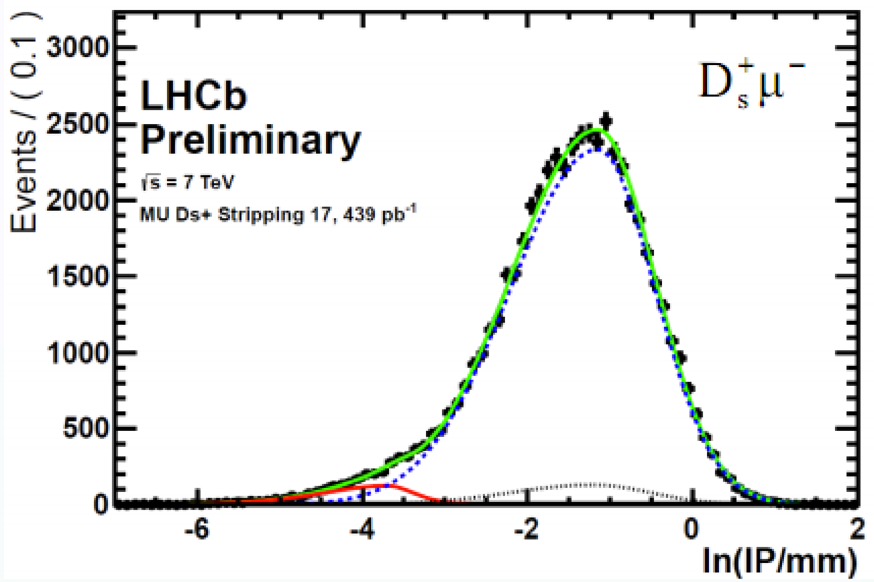
3. Asymmetry of the O(<1%) is precisely measured and simple to correct.

Trigger strategy

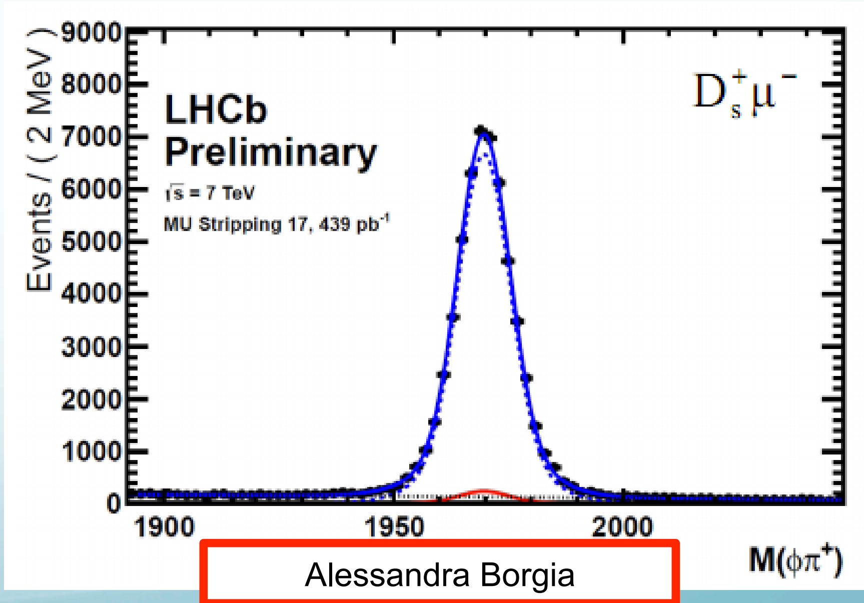
- LHCb has a three stage trigger: L0, Hlt1 and Hlt2.
- Use only triggers that we can accurately measure charge asymmetries.
- Require that the muon is responsible for firing trigger at all levels.
- Also use phi triggers to cross-check results (should be no bias as K^+ and K^- are symmetric).

Signal Fitting

- Separate prompt D's using log(IP) distribution and knowledge of shapes from MC/prompt data:



- Separate D's from combinatoric background using mass distribution:



Outlook

- Well developed data driven methods to measure detector asymmetries

- Using 2011 data we expect statistical accuracy of ~0.3% (magnet down) and ~0.35% (magnet up). Combined up and down statistical error ~0.22% - compared to DØ's 0.17% statistical

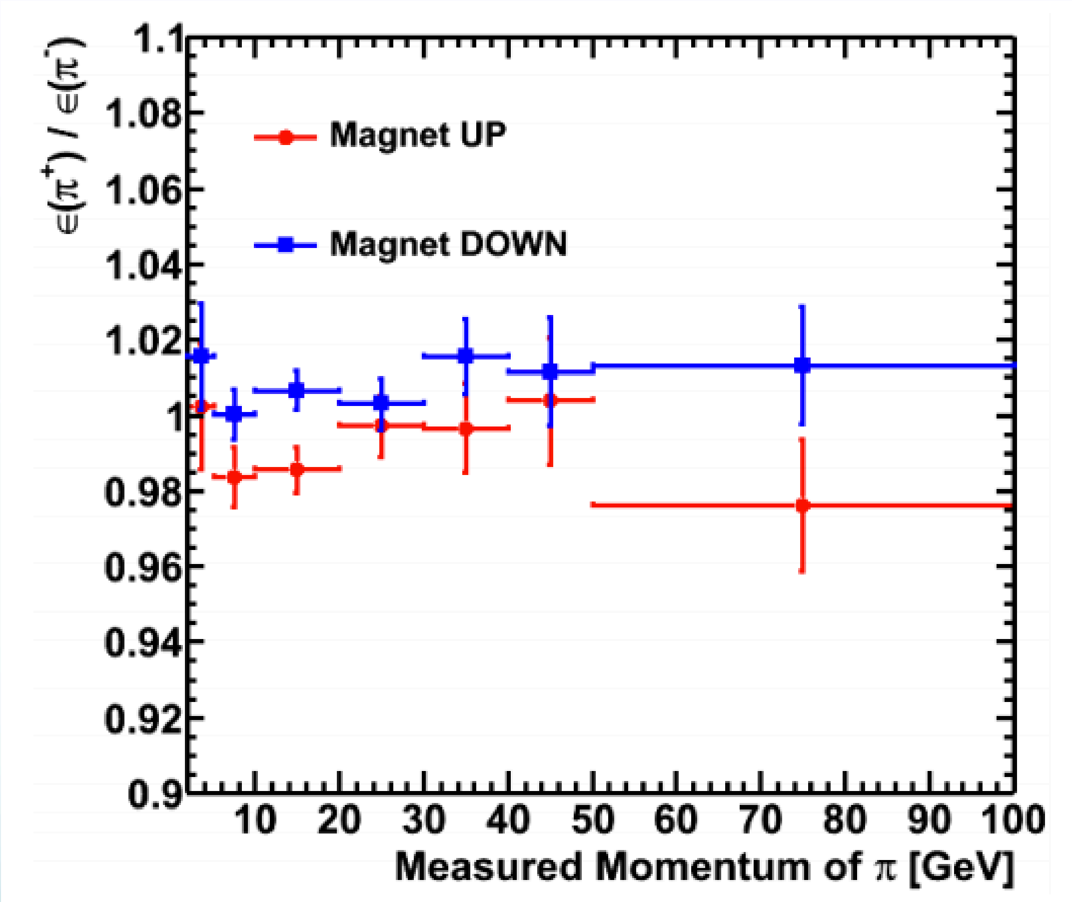
- Currently systematic errors are comparable to statistical

- Blinded results are being analysed now – public results soon.

backup

Tracking and Pion Efficiencies

- Kinematic fitting is used to infer the missing pion momentum.
- Efficiency ratio as a function of momentum:



Zhou Xing

MANCHESTER 1824 The University of Manchester

Selection Cuts - pions

Item	Requirement
$D^0(K\pi^+\pi^-)$ daughters selections	
Track fit quality	$\chi^2/NDOF < 3$
Momentum	$p > 2\,\mathrm{GeV}$
Transverse momentum	$p_\mathrm{T} > 400\,\mathrm{MeV}$
Impact parameter	$IP\,\chi^2 > 4$
Particle Identification	$K : \mathrm{DLL}_{K\pi} > 4$
	$\pi : \mathrm{DLL}_{K\pi} < 10\ ,\ \mathrm{DLL}_{\mu\pi} < 10$
Slow $\pi^\pm$ selections	
Track fit quality	$\chi^2/NDOF < 3$
Transverse momentum	$p_\mathrm{T} > 250\,\mathrm{MeV}$
Impact parameter	$IP\,\chi^2 < 4\ ;\ IP < 0.3\,\mathrm{mm}$
Particle Identification	$\mathrm{DLL}_{K\pi} < 10$

Note: WS ($D^0\,\pi^-$) pre-scale factor = 0.2

Selection Cuts - pions

$D^0(K\pi^+\pi^-)$ selections	
Vertex fit quality	$\chi^2/NDOF < 6$
Flight distance(FD) from Primary Vertex	$\chi^2 > 120$; $FD > 4\,\mathrm{mm}$
DIRA	$\cos\theta > 0.9997$
Impact parameter	$IP\ \chi^2 < 25$
Mass window of $(K\ \pi^+\pi^-)$	$[1.4,1.7]$ GeV
Transverse momentum	$p_T > 3\,\mathrm{GeV}$
$D^{*\pm}$ selections	
Vertex fit quality	$\chi^2/NDOF < 5$
Flight distance(FD) from Primary Vertex	$\chi^2 < 25$
Impact parameter	$IP\ \chi^2 < 25$
Transverse momentum	$p_T > 3\,\mathrm{GeV}$
Misc.	
Mass window on $(\pi^+\pi^-)$	$\lvert m(\pi^+\pi^-) - m_{PDG}(\rho)\rvert < 200\,\mathrm{MeV}$
Q Value	$m(K\pi^+\pi^-\pi_s) - m(K\pi^+\pi^-) - m(\pi_s) < 40\,\mathrm{MeV}$

Selection Cuts - pions

Item	Requirement
Partial reconstruction :	
Kinematically fitted missing π	$P^{inferred}/\sigma(P^{inferred}) > 2$
	$P_T^{inferred}/\sigma(P_T^{inferred}) > 2.5$
Trigger selection	HLT1 and Hlt2 Global TOS on $D^{*+}(K^-\pi^+\pi^-, \pi_s^+)$
Full reconstruction :	
$D^0(K^-\pi^+\pi^-\pi^+)$ selections	
Vertex fit quality	$\chi^2/NDOF < 6$
Mass window of D^0 $(K^- \pi^+\pi^- \pi^+)$	$\lvert m(K^-\pi^+\pi^-\pi^+) - m_{PDG}(D^0)\rvert < 30$ MeV
π selections	
Momentum	$p > 2\,\mathrm{GeV}$
Transverse momentum	$p_{\mathrm{T}} > 300\,\mathrm{MeV}$
Track fit quality	$\chi^2/NDOF < 4$
Clone Killer	CloneDist $<= 0$

Tag and Probe

- We use the MuIDCalibMicroDST line:
  - JpsiFromBNoPIDNoMip

- Selection cuts:

Tag:
- P > 6 GeV/c
- Pt > 1.2 GeV/c
- IP > 0.120 mm
- IP-χ^2 >25

Tag and probe:
- Track(χ^2/nDoF) < 3

Jpsi:
- Vertex(χ^2) < 8

Probe:
- P > 3 GeV/c
- Pt > 0.8 GeV/c
- IP > 0.05 mm
- Globally TIS at all trigger levels

- Data collected in stripping 17 corresponds to:
  - ~8M magnet down probes
  - ~6M magnet up probes

Offline Efficiencies

- To measure the efficiency of the offline muon selection we fit directly for the ratio of J/Psi after/before muon cuts.

Relavent Asl Cuts:

- Non-muon ID specific cuts are applied up front:
  - P > 6 GeV/c
  - Pt > 1.2 GeV/c
  - Track(χ^2/nDoF) < 3

- Asl muon selection:
  - IsMuon == 1
  - PIDMu > 0
  - Nshared==0

Signal selection cuts

Stripping & Analysis Cuts

Kaons:

- TrackChi2<4
- P>2.0GeV
- PT >300MeV
- MinIPChi2> 9
- PIDK > 4

Pions:

- TrackChi2<4
- P>2.0GeV
- PT >300MeV
- MinIPChi2> 9

φ:

- 1000MeV < M < 1040MeV
- VxChi2 <25

Muon:

- PT > 1200 MeV
- P> 3.0GeV
- TRCHI2DOF<3
- MinIPChi2 > 4
- PIDMu > 0
- Nshared=0
- IsMuon = True

Ds:

- ΔM (Ds) < 80 MeV
- ΔM (D+) > - 80 MeV
- Sum PT of daughters > 2100 MeV
- Sum MinIPChi2 of daughters > 4
- VxChi2/ndof < 6
- FDChi2 > 100
- BPVDIRA> 0.99
- BPVIP< 7.4mm

Bs:

- 3.1 GeV< MM < 5.1 GeV
- VxChi2/ndof < 6
- BPVDIRA>0.999
- Vx(DZ) – Vx(BZ) > 0 mm
- $2 \leq \eta < 5$

Additional:

- Long Tracks <250

HLT:

- Hlt2MuTopo2BodyBBDT
- Hlt2MuTopo3BodyBBDT
- Hlt2MuTopo4BodyBBDT
- Hlt2IncPhi
- +….?