First observation of $B^0_s \to J/\psi\ f_0(980)$ decays

Michael Cutajar
on behalf of group B Collaboration
(CLASHEP April 2011)

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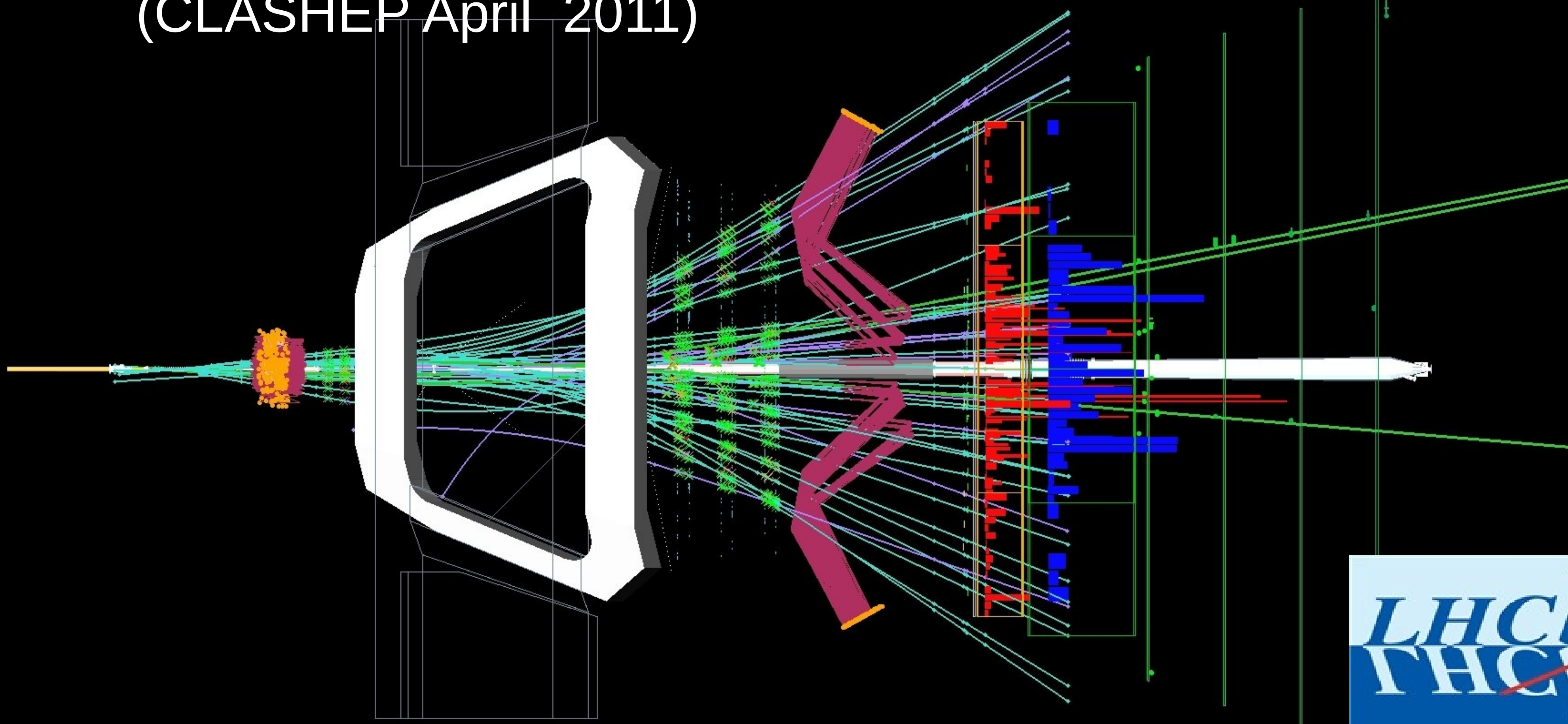
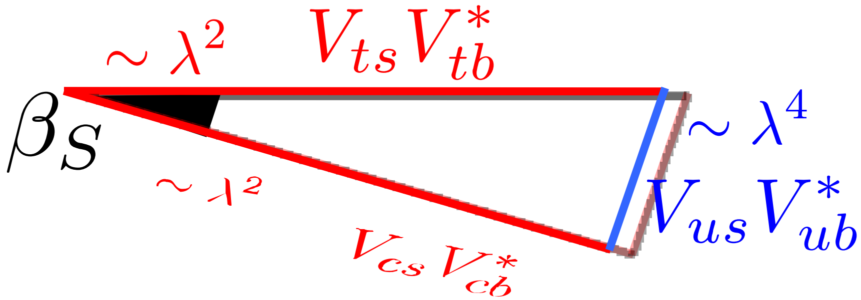


CP violation on B^0_s decay



$$\beta_s = \arg(-V_{ts}V_{tb}/V_{cs}V_{cb})$$

$B_s^0 \to J/\psi\phi$

$B_s^0 \to J/\psi f_0$

$B_s^0 \to VV \quad (J^{PC}):(0^{-})\to(1^{--})(1^{--})$

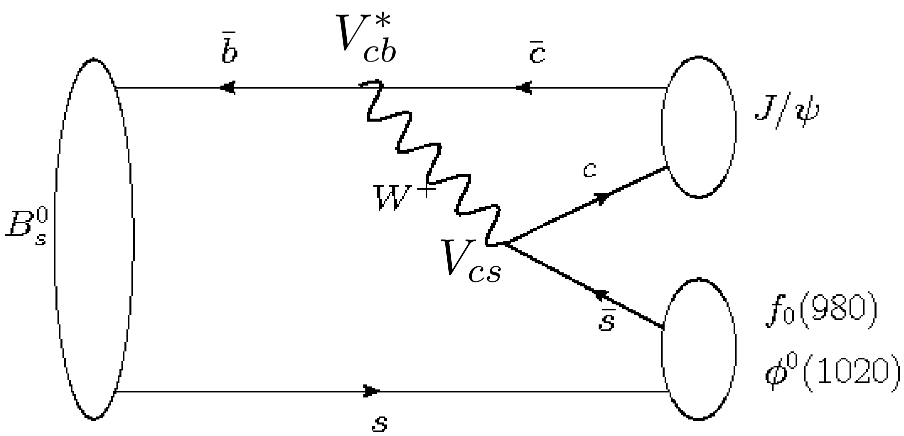
$D_s^+ \to f_0\pi^+$

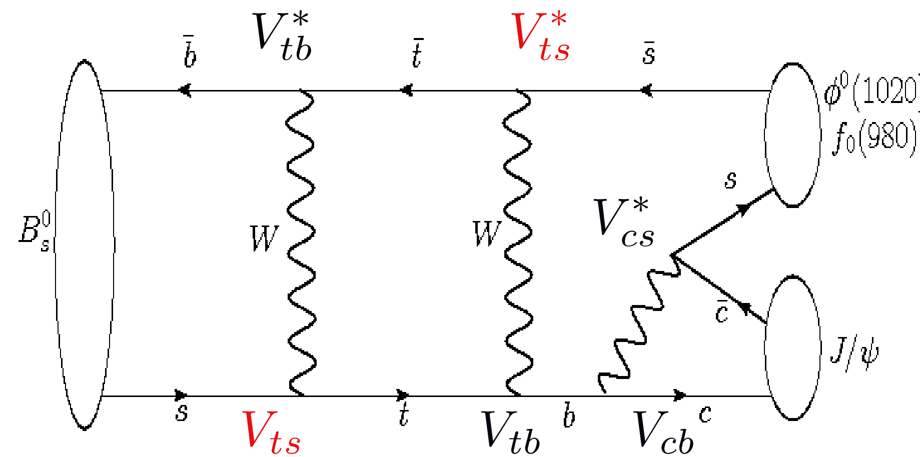
$$R_{f_0/\phi} = \frac{\Gamma(B_S^0 \to J/\Psi f_0,\ f_0 \to \pi^+\pi^-)}{\Gamma(B_S^0 \to J/\Psi \phi,\ \phi \to K^+K^-)} \approx 20\%$$

β_s

CP violation on B^0_s decay

SM: ~~CP~~ in the interference between the mixing and the direct decay.





One can be sensitive to ~~CP~~ in respect to β_S,by the interference of:

$$\delta_s = \delta_{mixing} - \delta_{direct} \sim \beta_s$$

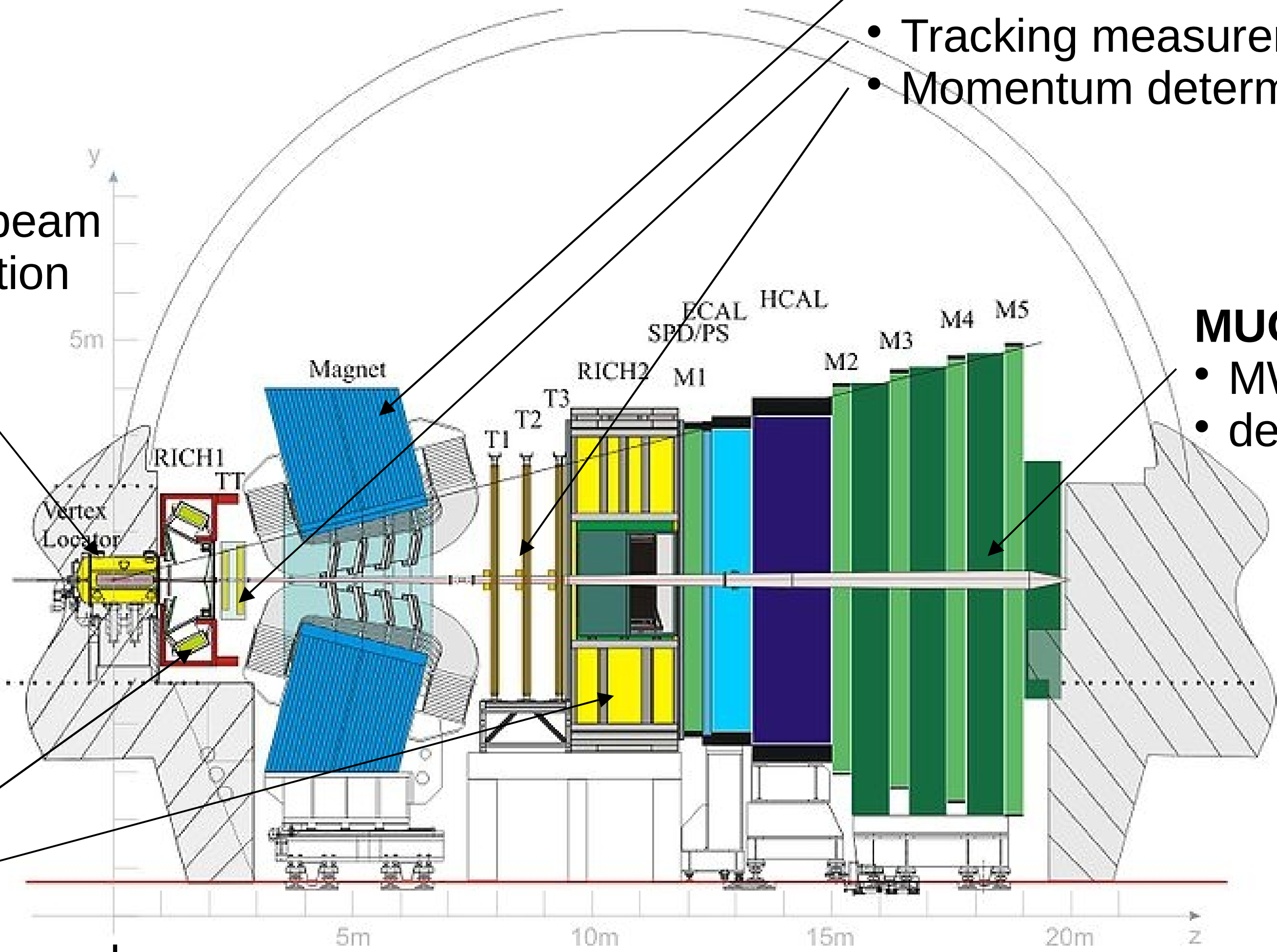
Measuring the ~~CP~~:

$$A_{CP} = \frac{-sin(\phi_S)sin(\Delta m_S t)}{cosh(\frac{\Delta\Gamma_S t}{2}) - cos(\phi_S)sinh(\frac{\Delta\Gamma_S t}{2})}$$

LHCb Detector Overview

SILICON LAYERS + MAGNETS
- Tracking measurement
- Momentum determination

VELO
- 8mm from the beam
- High PV resolution

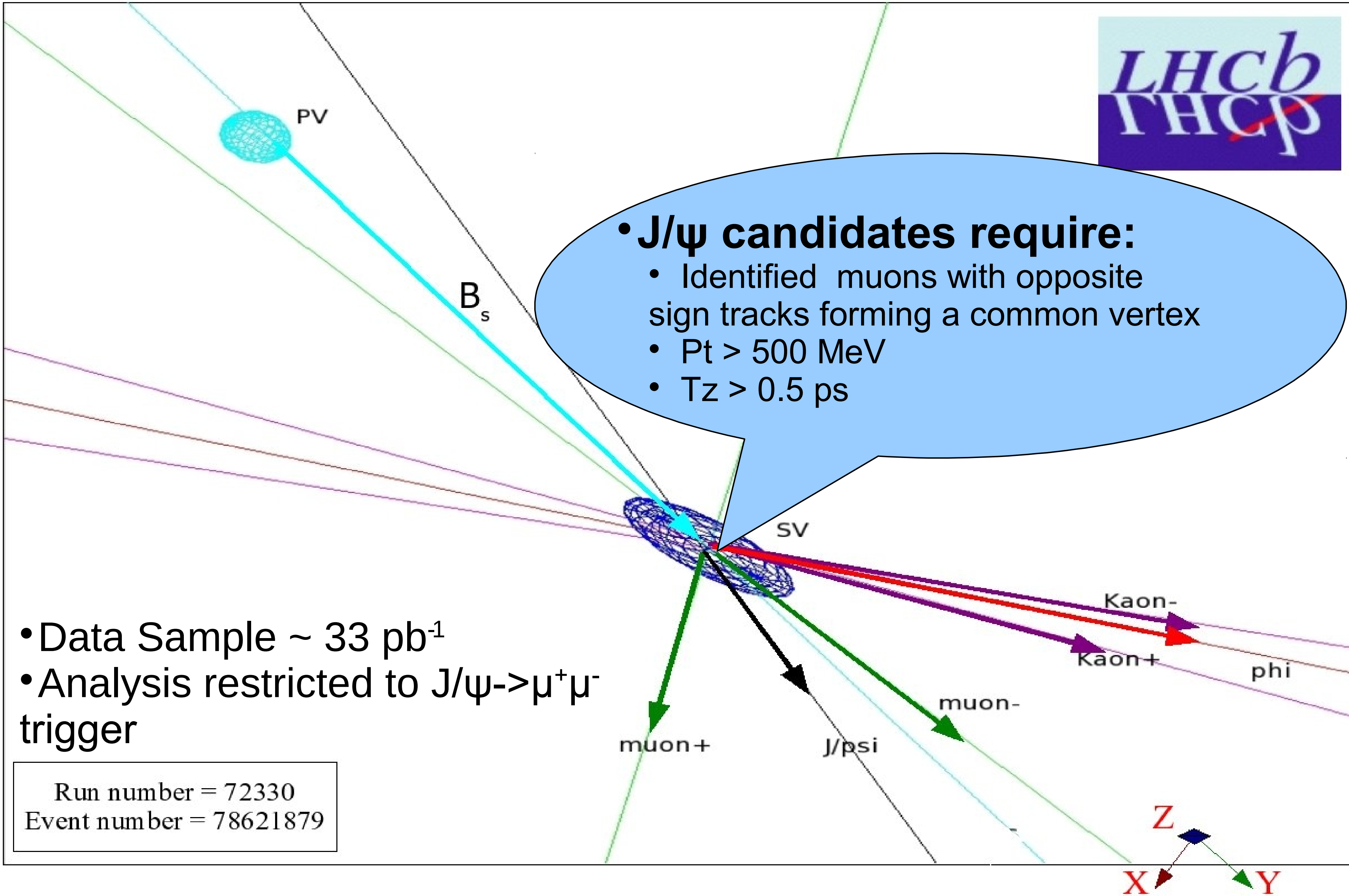


MUON
- MWPC/triple-GEM
- detection/triggering

RICH 1,2
- Ring Imaging Cherenkov
- Pion/Kaon separation

The **forward coverage** of the LHCb detector and its **high resolution on the primary vertex** determination is essential for the study of **b-hadrons production**.

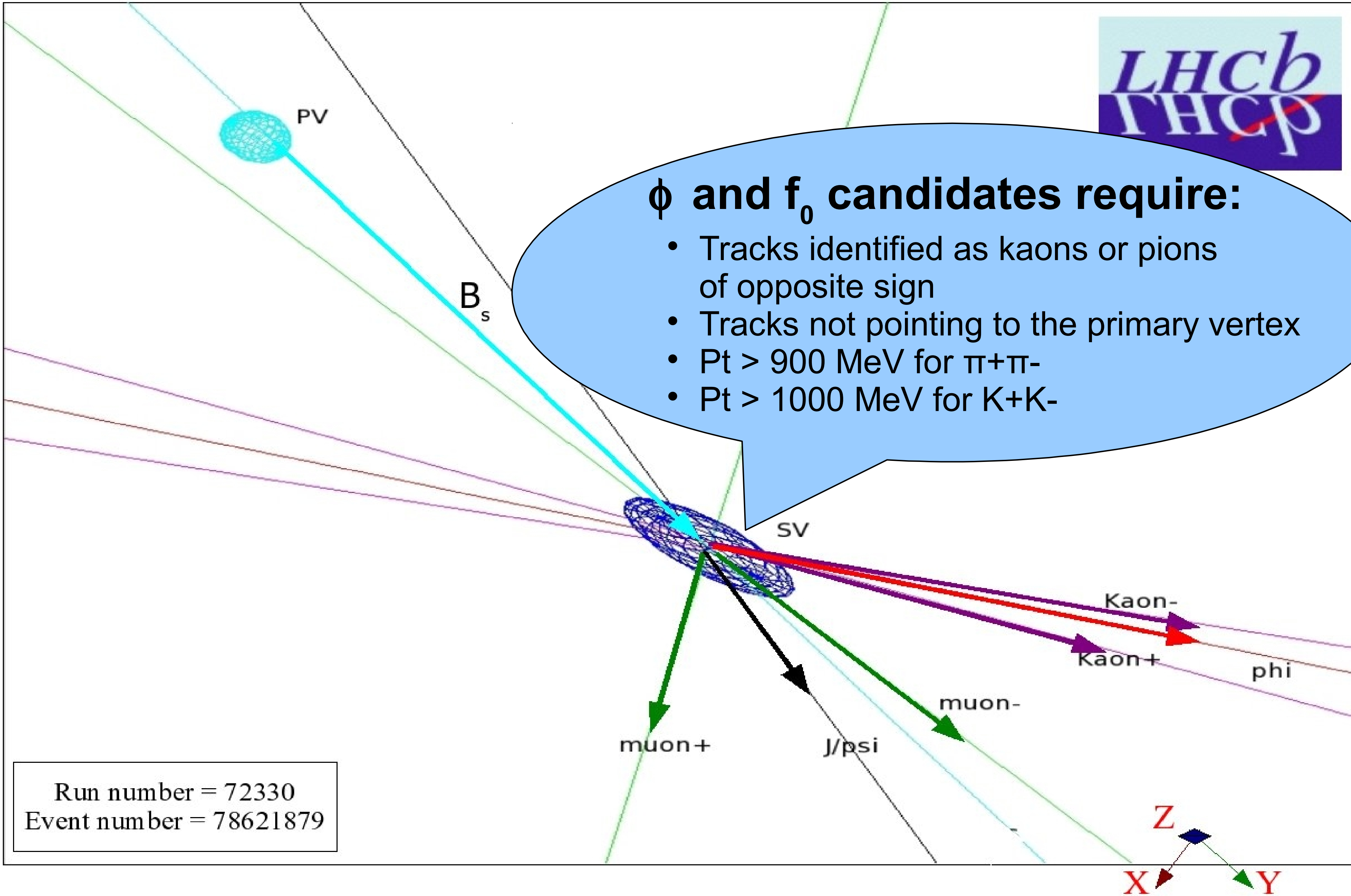
$B^0_s \rightarrow J/\psi(\mu^+\mu^-)\ \phi$ event



- **J/ψ candidates require:**
  - Identified muons with opposite sign tracks forming a common vertex
  - Pt > 500 MeV
  - Tz > 0.5 ps

- Data Sample ~ 33 pb^{-1}
- Analysis restricted to $J/\psi \to \mu^+\mu^-$ trigger

$B^0_s \rightarrow J/\psi\Phi$ or $B^0_s \rightarrow J/\psi f_0$ event

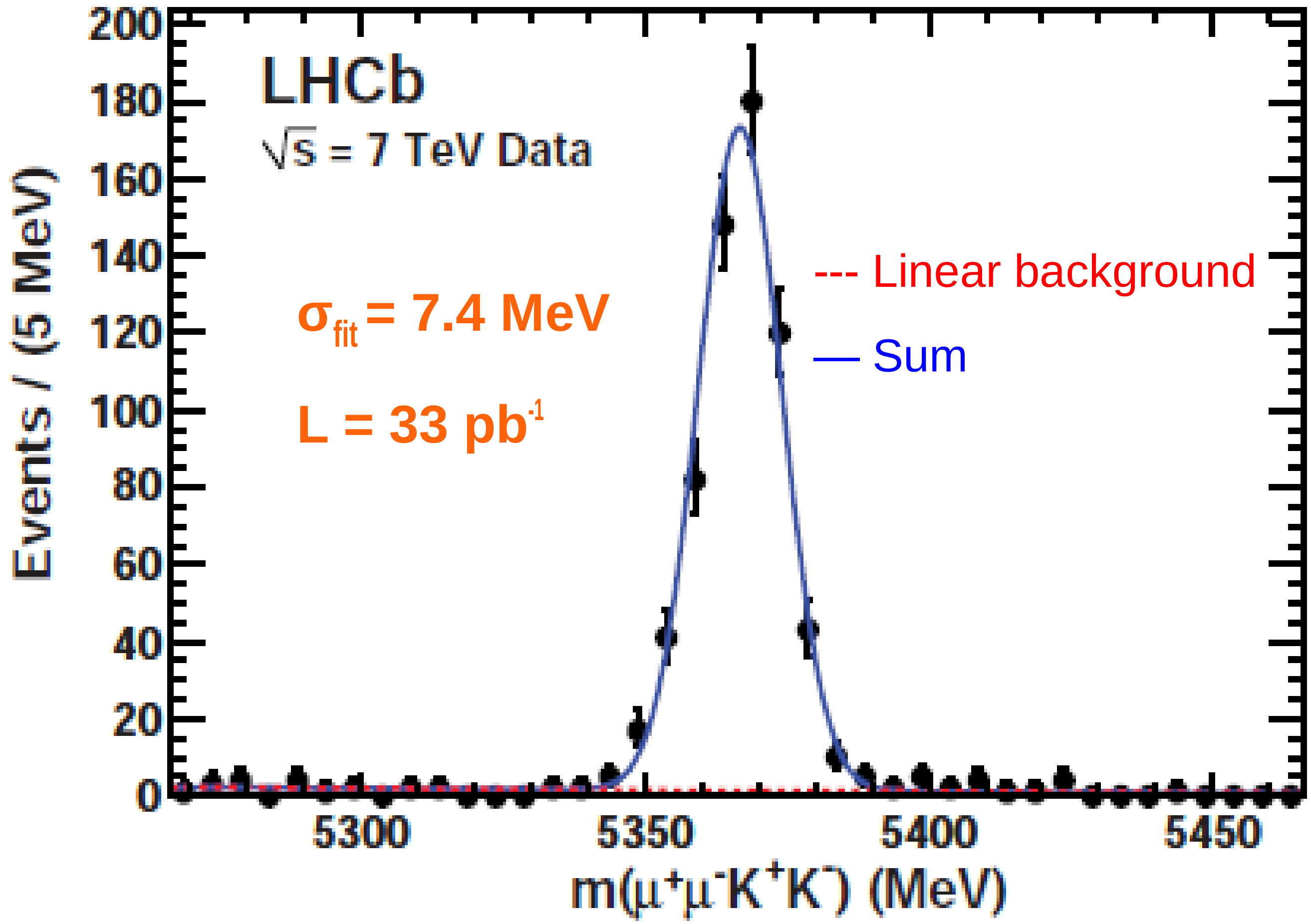


ϕ and f_0 candidates require:

- Tracks identified as kaons or pions of opposite sign
- Tracks not pointing to the primary vertex
- Pt > 900 MeV for $\pi^+\pi^-$
- Pt > 1000 MeV for K^+K^-

$B^0_s \rightarrow J/\psi\ \Phi \rightarrow \mu^+\mu^-\ K^+K^-$

- $|m_{KK} - m_{\Phi}| < 20$MeV
- $m_{\mu\mu} = m_{J/\psi}$



- $BR(B_0^s \rightarrow J/\psi\ \Phi) = 1.3 \cdot 10^{-3}$
- **$m_{B^0_s}$ (PDG) = 5366.3±0.6MeV**

- **$M_{B_0^s}$ = 5366.7±0.4MeV**
- **N_{events} = 635± 26**

$B^0_s \rightarrow J/\psi\ f_0(980) \rightarrow \mu^+\mu^-\pi^+\pi^-$

$|m_{\pi\pi} - m_{f_0(980)}| < 90$ MeV

$m_{\mu\mu} = m_{J/\psi}$

— Signal

----- Combinatorial background

----- $B^+ \rightarrow J/\psi\ K^+(\pi^+)$

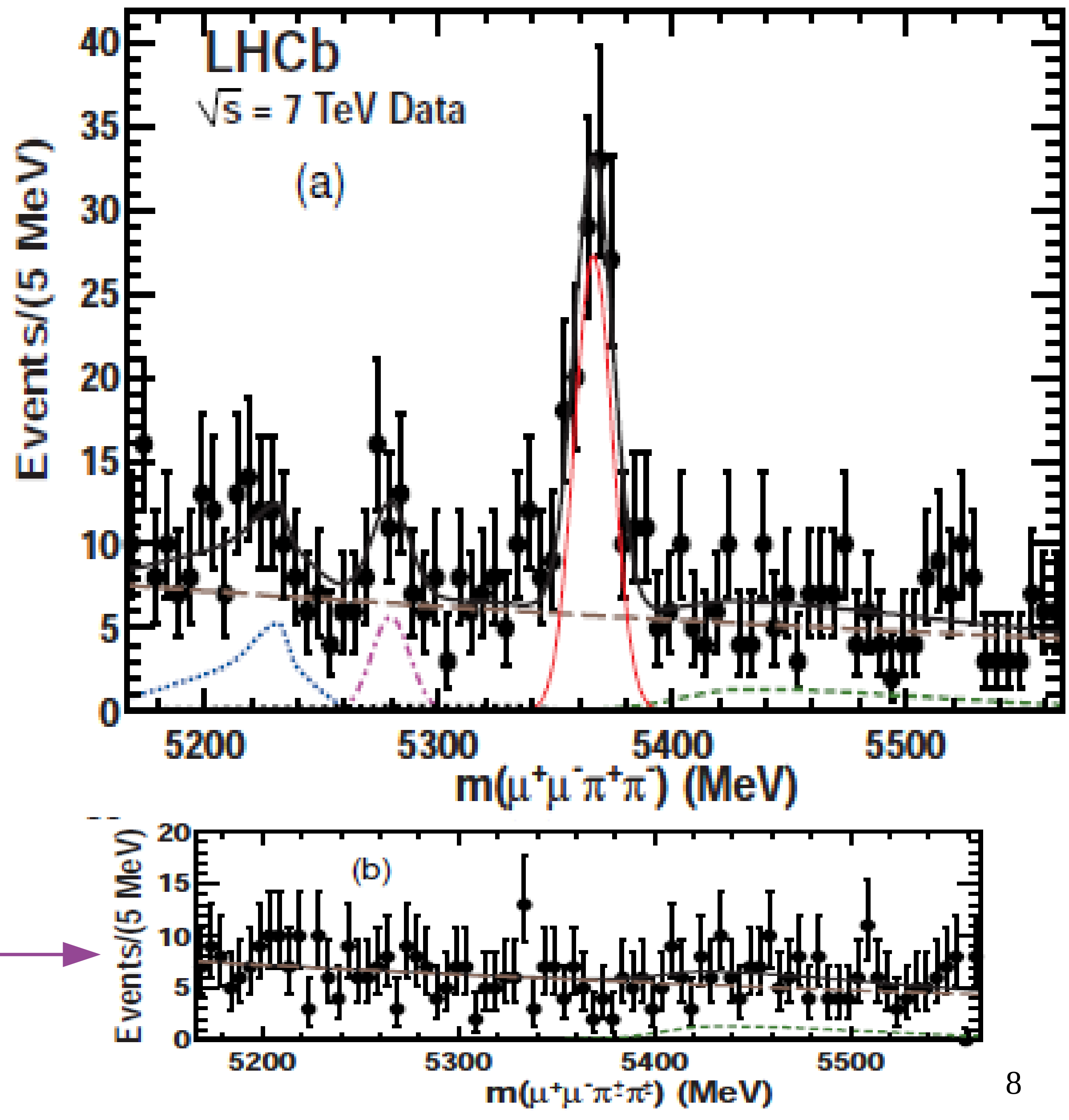
······ $B_0 \rightarrow J/\psi K^*_0$ (MC shape)

-·-·- $B_0 \rightarrow J/\psi\ \pi^+\pi^-$ (MC shape)

······ $B_0^s \rightarrow J/\psi\ \eta' + B_0^s \rightarrow J/\psi\ \varphi$ (MC shape)

—Total

Like sign di-pion events



$B^0_s \to J/\psi\ f_0(980) \to \mu^+\mu^-\pi^+\pi^-$

$|m_{\pi\pi} - m_{f_0(980)}| < 90$ MeV

$m_{\mu\mu} = m_{J/\psi}$

— **Signal**

----- **Combinatorial background**

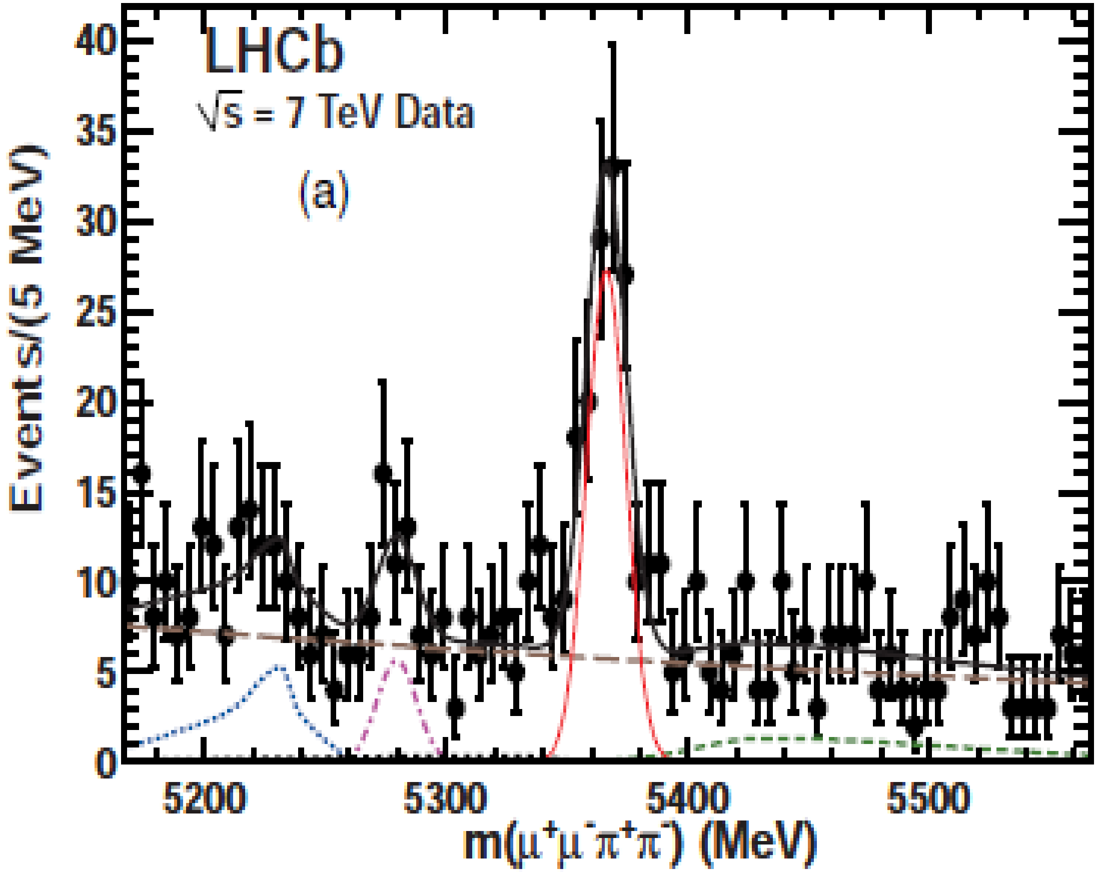
----- **$B^+ \to J/\psi\ K^+(\pi^+)$**

······ **$B^0 \to J/\psi K^{0*}$ (MC)**

-·-·- **$B^0 \to J/\psi\ \pi^+\pi^-$ (MC)**

······ **$B^0_s \to J/\psi\ \eta' + B^0_s \to J/\psi\ \varphi$ (MC)**

—Total



$M_{B^0_s} = 5366.1 \pm 1.1$ MeV

$\sigma_{fit} = 8.2$MeV

$N_{events\ (B^0_s)} = 111 \pm 14$

12.8 standard deviation of significance

Checking the spin of f_0 candidate

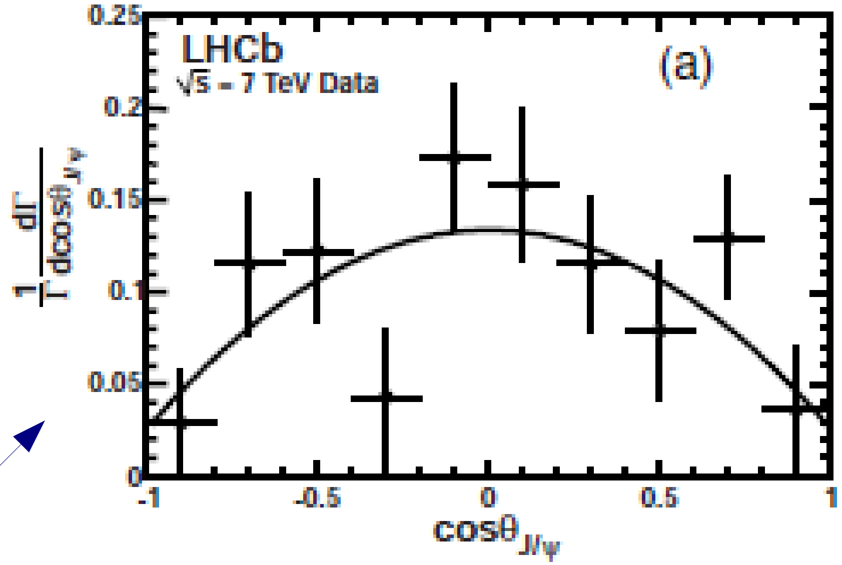
$J = S_{B^0_s} + S_{J/\psi} + L$

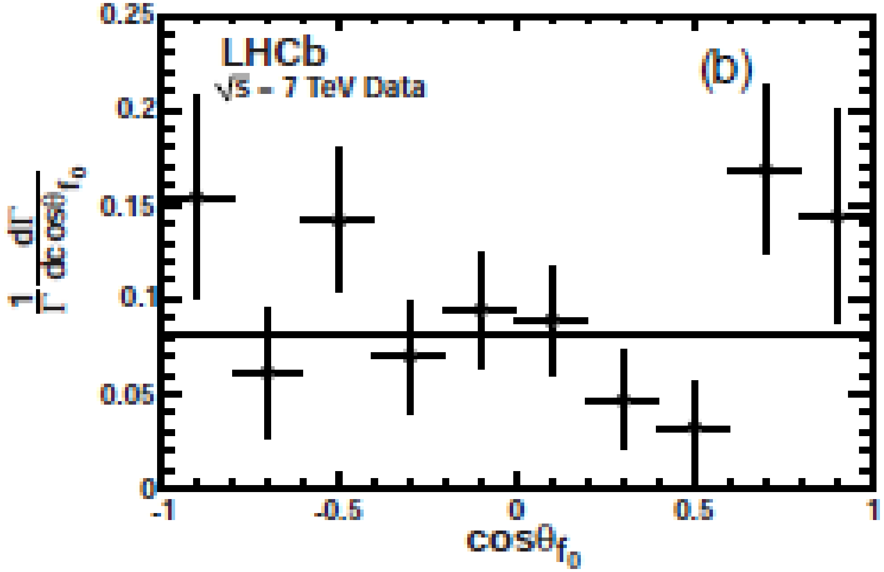
B^0_s rest frame → **J**=0 → **L**=1

	B^0_s	J/Ψ	f_0
Spin	**0**	**1**	**0**

1) $f(\theta_{J/\psi}) = 1 - \cos^2(\theta_{J/\psi})$

2) $f(\theta_{f0})$ = constant





"The angular distributions agree with the expectation for spin 0"

$\pi^+\pi^-$ spectrum

$|m(J/\psi\ \pi^+\pi^-) - m(B^0_s)| < 30$ MeV

Low statistics – enough to reconstruct the $f_0(980)$ resonance.

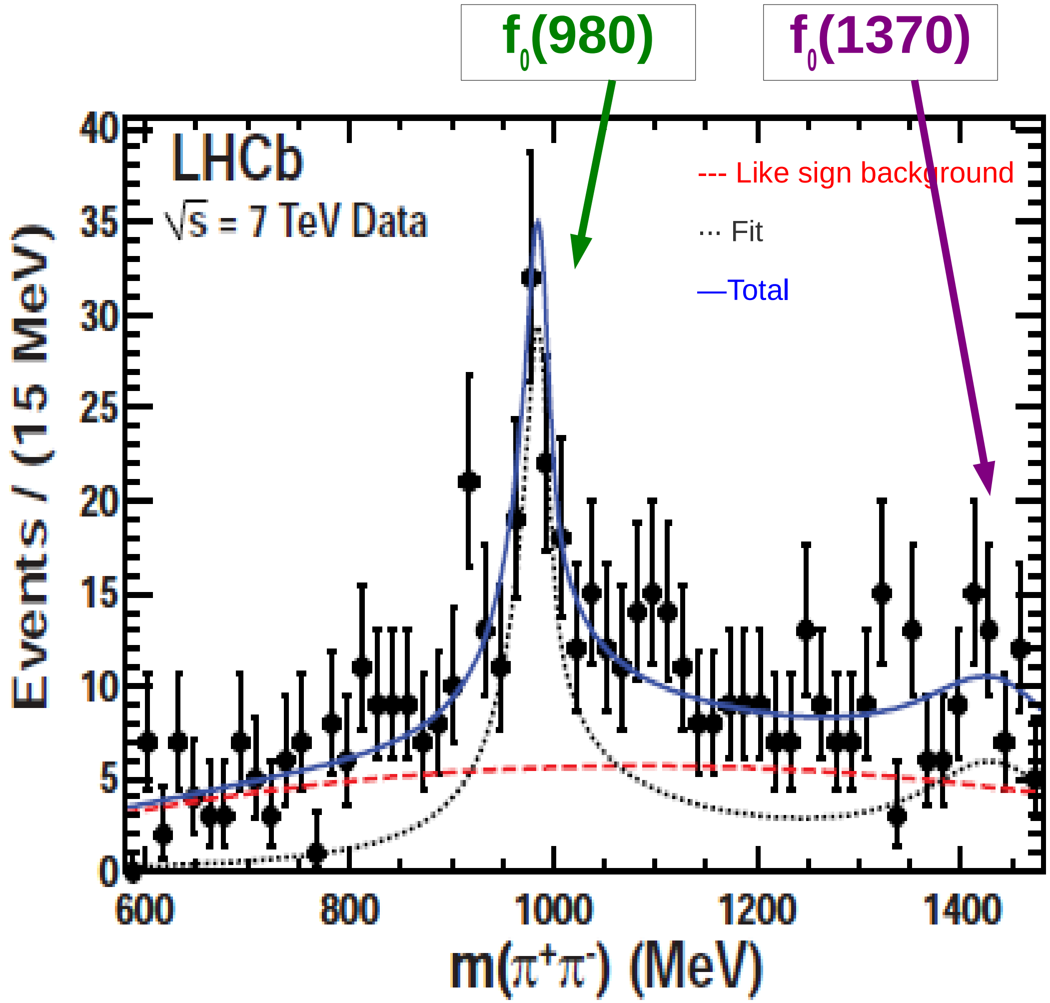
Signal events = 265 ± 26

64%(+10%-6%) correspond to $f_0(980)$

12%(±4%) correspond to $f_0(1370)$

24% (+2%-6%) correspond to interference

12.5 standard deviation of significance



$$|A(m)|^2 = N_0\, m\, p(m)\, q(m) [\, Flatt\acute{e}[f_0(980)] + A_1 \exp^{(i\delta)} BW[f_0(1370)]\,]^2$$

Ratio Measurement

- 169 f_0(980) events and 635 Φ events:

$$R_{f_0/\phi} \equiv \frac{\Gamma(B_s^0 \to J/\psi\, f_0, f_0 \to \pi\pi)}{\Gamma(B_s^0 \to J/\psi\, \phi, \phi \to K K)} = 0.252^{+0.252+0.027}_{-0.032-0.033}$$

- Cross-check with fit to B^0_s mass distribution (no uncertainties related to $\pi^+\pi^-$ fit)
- Within mass window of f_0(980).
- Ratios are compatible within errors

$$R' \equiv \frac{\Gamma(B_s^0 \to J/\psi\, \pi+\pi, |m(\pi\pi)-980\ \ MeV|<90\ \ MeV)}{\Gamma(B_s^0 \to J/\psi\, \phi, \phi \to K K)}$$

$$R' = 0.162 \pm 0.022 \pm 0.016$$

Theory: *R'* = 0.20 (S. Stone and L. Zhang, PRD**79,**2009)

Systematics uncertainties

Parameter	Negative change	Positive change
$f_0(1370)$ mass	0.3	1.9
$f_0(1370)$ width	2.3	2.6
$\pi^+\pi^-$ mass dependent efficiency	2.3	2.3
$m_0 g_1$	4.2	3.6
g_2/g_1	0.7	0.7
Addition of non-resonant $\pi^+\pi^-$	7.3	0
MC statistics (efficiency ratio)	2.3	2.3
B_s^0 p_T distribution	0.5	0.5
B_s^0 mass resolution	0.5	0.5
PID efficiency	1.0	1.0
ϕ detection	9.0	9.0
Total	13.1	10.8

Main uncertainties due to:

- **Efficiency of detecting Φ -> K^+K^- versus Φ -> $\pi^+\pi^-$**
- **Assumptions made in choice of decay amplitudes used in the fit to m($\pi^+\pi^-$).**
- **Fit parameters.**

Conclusions

- LHCb has observed for the first time the f_0 (980) resonance in the $B^0_s \rightarrow J/\psi\ f_0 \rightarrow \mu^+\mu^-\ \pi^+\pi^-$ decay.
- Data has been successfully fitted, so far the background is under control.
- $R_{f_0/\Phi} = 0.252$ is an observable independent of the efficency of the detection of the B^0_s.
- More statistics will allow to distinguish B^0_s and $\overline{B}^0_s$ in order to measure the β_s angle.


Group B Collaboration
Daniel
Geraldo
Patricia
Michael
Kenyi
Bruno
Xitzel
Sarah
Alberto Gago
Carlos
Rafael
Thiago
Alvaro
Rafael
Edson
Hernán
Flavia
Photography by Lucia Duarte

BACK UP

CP violation on B^0_s decay

CKM matrix

CKM unitarity triangle

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{ui}V^*_{uj} + V_{ci}V^*_{cj} + V_{ti}V^*_{tj} = 0 \quad (i \neq j)$$

Back up slides

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$$\text{Flatté}(m) = \frac{1}{m_0^2 - m^2 - i m_0 (g_1 \rho_{\pi\pi} + g_2 \rho_{KK})}$$