Introduction

- Welcome
- Summary of the workshop before the workshop
  - What's new
  - Beyond the B
  - What's next
  - Prospects for Run II
  - Prospects for Runs III and IV

IVth Implications Workshop
Geneva, 15–17/10/2014

Patrick Koppenburg

Welcome

Welcome to our theorist friends and LHCb colleagues
for this IVth edition of the LHCb Implications Workshop

On behalf of the organising committee

John Ellis, Tim Gershon, Gino Isidori, Patrick Koppenburg, Gilad Perez, Frederic Teubert, Vincenzo Vagnoni, Andreas Weiler

and the stream conveners (who did the actual work)

Jennifer Girrbach-Noe, Sneha Malde, Fernando Rodrigues, Sebastian Jäger, Fatima Soomro, Kostas Petridis, Andreas Crivellin, Francesco Dettori, Angelo di Canto, Juan Rojo, Zhenwei Yang, Simone Bifani

And many thanks to everyone, speakers and attendees.
Let's make this an enjoyable experience.

Purpose of the Workshop

- Follow on from successful previous workshops, Nov.10-11, 2011, Apr.16-18, 2012, Oct. 14–16, 2013.
- discuss latest results and more ideas of exploitation of Run I dataset
- Develop new ideas for future analysis
  - Ideas for Run II.
    - → **This is the last moment to add new trigger lines for 2015**
  - Ideas for Run III and the LHCb upgrade

Beyond the workshop

- We like a close collaboration with the theory community.
- If you have an idea, feel free to contact us to check its feasibility.
- And/or show it in one of our physics working group meetings.

The spirit of the Filtration Plant

We won't show anything secret (we don't have secrets)

➜ The agenda is open to the world. If you are uncomfortable with that let me know. We can protect some slides.

- The room is not open to everyone.

➜ We will be a bit more open about prospects than we would at ICHEP.

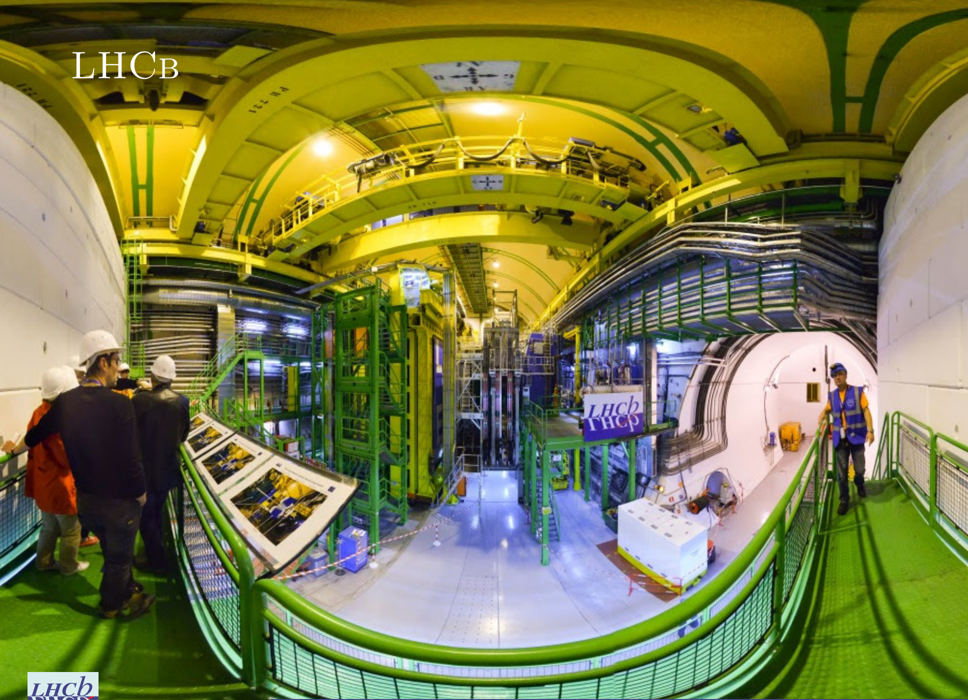
We want to discuss!

- Talks should be triggering fruitful discuss rather than transmit a lot of data

➜ Timing will have to be respected

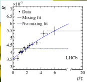
- I'll try to show the example by being shorter than my allocated time

LHCb

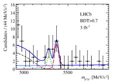


LHCb Physics Programme

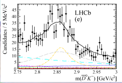
CKM and *CP* violation with *b* and *c* hadrons

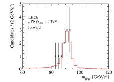


Rare decays of *b* hadrons and *c* hadrons

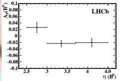


Spectroscopy in *pp* interactions and *B* decays

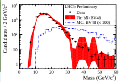




Electroweak and QCD measurements in the forward acceptance



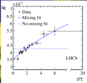
Heavy quark production



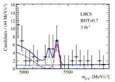
Exotica searches

LHCb Physics Programme discussed here

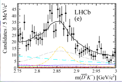
CKM and CP violation with b and c hadrons

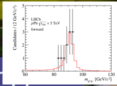


Rare decays of b hadrons and c hadrons

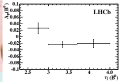


Spectroscopy in pp interactions and B decays

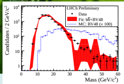




Electroweak and QCD measurements in the forward acceptance



Heavy quark production

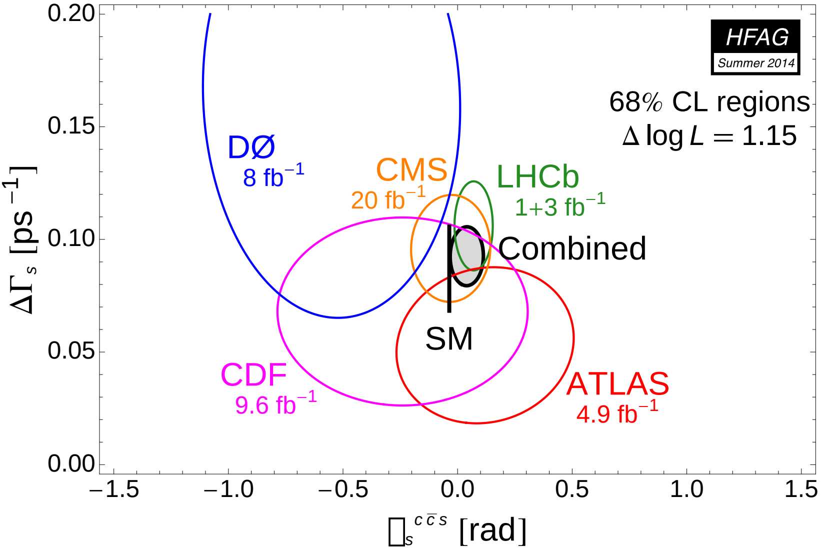


Exotica searches

CPV in B decays

Jennifer Girrbach, Sneha Malde, Fernando Rodrigues

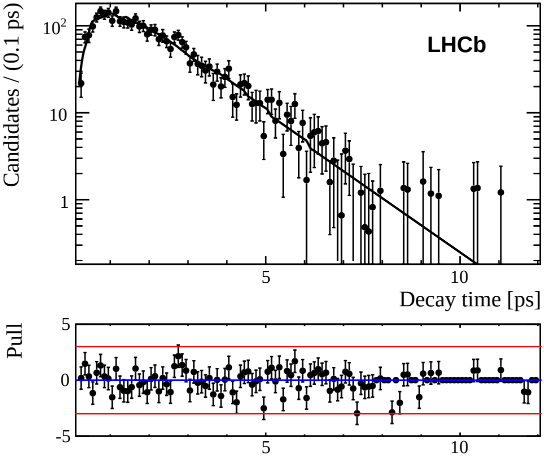
$\Delta\Gamma_s$ versus ϕ_s in Summer 2014



[LHCb, submitted to Phys. Rev. Lett., arXiv:1409.4619]

Diego Martinez Santos
This Morning

ϕ_s FROM $B_s^0 \to D_s^+ D_s^-$



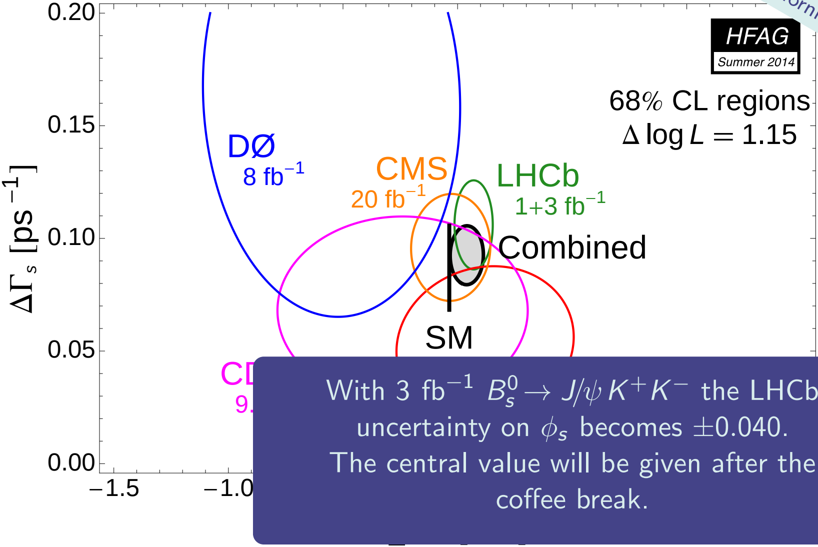
- Time dependent CP analysis of $B_s^0 \to D_s^+ D_s^-$ with $B^0 \to D^- D_s^+$ as control.
- Time acceptance from data and resolution from MC
- Excellent tagging power of 5.3%

$$\phi_s = 0.02 \pm 0.17 \pm 0.02 \text{ rad}$$

(or $\phi_s = 0.02 \pm 0.17 \pm 0.02$ rad with CPV $|\lambda| = 0.91\,^{+0.18}_{-0.15} \pm 0.02$)

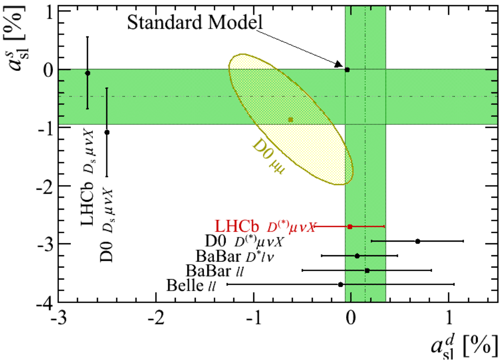
$\Delta\Gamma_s$ versus ϕ_s in Summer 2014

Diego Martinez Santos
This Morning



With 3 fb^{-1} $B_s^0 \to J/\psi K^+K^-$ the LHCb uncertainty on ϕ_s becomes ± 0.040.
The central value will be given after the coffee break.

Semileptonic B^0 asymmetry $A^d_{\rm sl}$



- Surprising deviation from SM expectation in $(a^d_{\rm sl}, a^s_{\rm sl})$ plane from D0 results [Phys. Rev. D 89, 012002 (2014), arXiv:1310.0447]
- LHCb measured $a^s_{\rm sl}$ with 1 fb^{-1} [Phys. Lett. B728 (2014) 607]

➜ New LHCb result of $a^d_{\rm sl}$ with 3 fb^{-1}

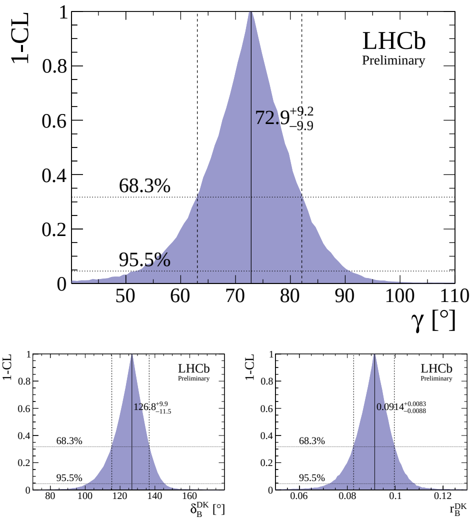
- The $a^s_{\rm sl}$ update will come soon

$$a^d_{\rm sl} = (-0.02 \pm 0.19 \pm 0.30)\%$$

[LHCb, LHCb-CONF-2014-004]

γ combination for CKM

Chris Thomas
Tomorrow Afternoon

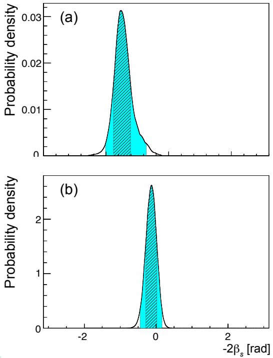


- Using only $B \to DK$ gets $\gamma = 73\,^{+\,9}_{-\,10}$
  - ➜ **More precise than B factory combination**

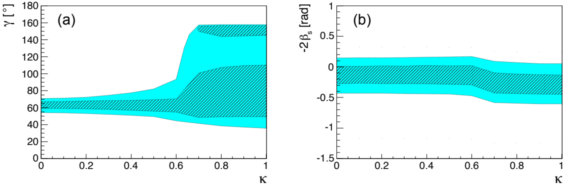
γ AND ϕ_s FROM $B \to hh$

Vincenzo Vagnoni
Tomorrow Afternoon

- Global fit to *CP* parameters in $B_s^0 \to K^+K^-$ and $B^0 \to \pi^+\pi^-$ is sensitive to γ or β_s. Needs U-spin symmetry assumptions. [Fleischer]
- Two fits, one fitting for γ assuming β_s from HFAG, one for β_s assuming γ from UTFit.
  - ➜ $\gamma = [56^\circ, 70^\circ]$ and $-2\beta_s = [-0.28, 0.02]$ rad at 68% CL



- Depends on the level of U-spin breaking κ allowed. The above numbers assume 50%.

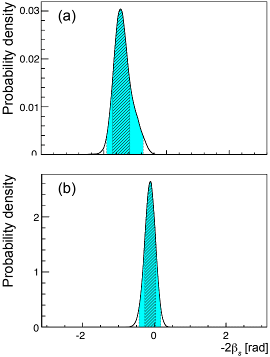


[LHCb, submitted to Phy… ett. B, arXiv:1408.4368]

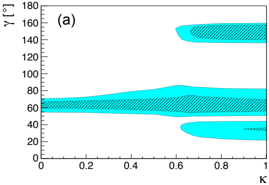
Vincenzo Vagnoni
Tomorrow Afternoon

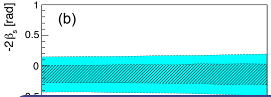
γ AND ϕ_s FROM $B \to hh$

- $B^+ \to \pi^+\pi^0$ and $B^0 \to \pi^0\pi^0$ from B-factories add more constraints [Gronau, London]
- Two fits, one fitting for γ assuming β_s from HFAG, one for β_s assuming γ from UTFit.
  - ➜ $\gamma = (63.5\,^{+\,7.2}_{-\,6.7})^\circ$ and $-2\beta_s = -0.12\,^{+\,0.14}_{-\,0.16}$ rad



- Depends on the level of U-spin breaking κ allowed. The above numbers assume 50%.
- More stable with respect to assumptions





Is that the end of the story?

[LHCb, submitted to Phys. Rev. D, arXiv:1408.5373]

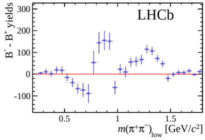
CP violation in $B^+ \to h^+h^-h^+$

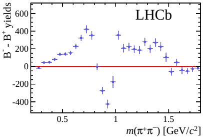
Alberto Correa
Thursday Afternoon

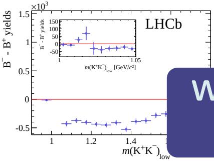
CP asymmetries of $B^+ \to h^+h^-h^+$ with 3 fb^{-1} (181k–6k depending on mode):

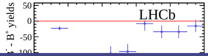
$$A_{CP}(B^\pm \to K^\pm\pi^+\pi^-) = +0.025 \pm 0.004 \pm 0.004 \pm 0.007 \quad [2.8\sigma]$$
$$A_{CP}(B^\pm \to K^\pm K^+ K^-) = -0.036 \pm 0.004 \pm 0.002 \pm 0.007 \quad [4.3\sigma]$$
$$A_{CP}(B^\pm \to \pi^\pm K^+ K^-) = +0.058 \pm 0.008 \pm 0.009 \pm 0.007 \quad [4.2\sigma]$$
$$A_{CP}(B^\pm \to \pi^\pm K^+ K^-) = -0.123 \pm 0.017 \pm 0.012 \pm 0.007 \quad [5.6\sigma]$$

Positive CP asymmetries in $1 < m_{hh} < 1.5\ \text{GeV}/c^2$ regions for $\pi^+\pi^-$ modes and negative for K^+K^- modes. Indication of rescattering effects as CPT forces sum to be 0.



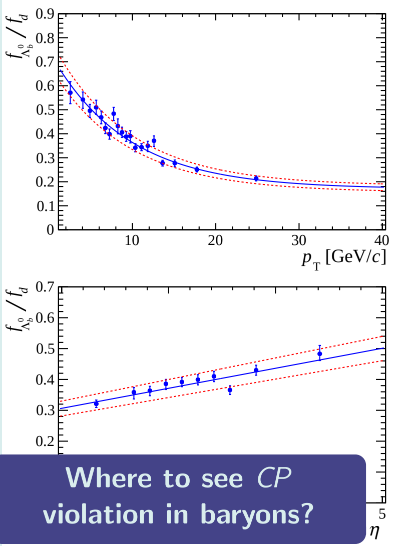






What do we learn from it?

p_{T} dependence of $f_{\Lambda_b^0}/f_d$



Where to see CP violation in baryons?

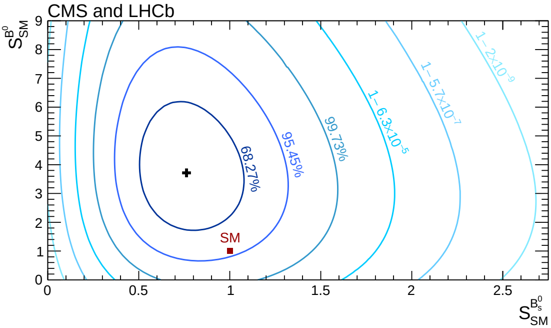
- Determine the p_{T} and η dependence of $f_{\Lambda_b^0}/f_d$ using $\Lambda_b^0 \to \Lambda_c^+\pi^-$ and $\overline{B}^0 \to D^+\pi^-$
  - Very similar decays
  - Absolute scale normalised using semileptonc decays [Phys. Rev. D 85, 032008 (2012), arXiv:1111.2357]
- Clear increase of Λ_b^0 at low p_{T} and large η
  - ➜ Many more Λ_b^0 in LHCb than central detectors
- By-product $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+\pi^-) = (4.30 \pm 0.03\,^{+0.12}_{-0.11} \pm 0.26\,(\frac{f_{\Lambda_b^0}}{f_d}) \pm 0.21\,(\mathcal{B})) \cdot 10^{-3}$

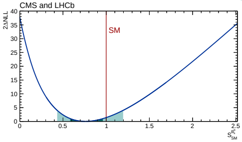
Rare B decays

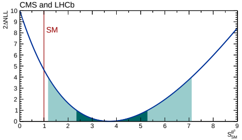
Sebastian Jäger, Fatima Soomro, Kostas Petridis

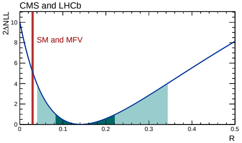
$B \to \mu^+\mu^-$ combination of CMS & LHCb

Siim Tolk This Afternoon







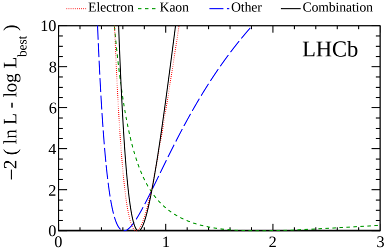


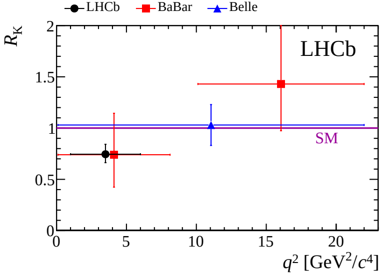
- Signal strength determined wrt SM, including exp and theory uncertainties
- B_s^0 BF as expected
- B^0 BF on the high side by 2.2σ

✗ Nothing to get too excited about yet

Lepton universality with $B^+ \to K$

Patrick Owen
Tomorrow Morning





- Measure ratio R_K of $B^+ \to K^+\mu\mu$ to $B^+ \to K^+ee$ in $1 < q^2 < 6\ \mathrm{GeV}^2$
  - ✔ Signal clearly visible in $K^+\mu^-\mu^+$
- Separate K^+ee by electron, hadron and other L0 triggers
  - Use different mass pdf depending on the number of bremsstrahlung photons
- Build a double ratio $R_K =$

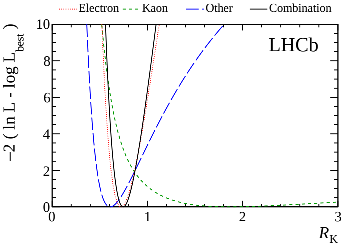
$$\left(\frac{\mathcal{N}_{K^+\mu^+\mu^-}}{\mathcal{N}_{K^+e^+e^-}}\right)\left(\frac{\mathcal{N}_{J/\psi\, K^+e^+e^-}}{\mathcal{N}_{J/\psi\, K^+\mu^+\mu^-}}\right)$$

$$= 0.745\,^{+\,0.090}_{-\,0.074} \pm 0.036$$

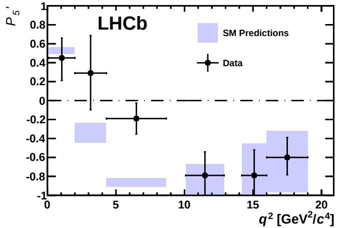
2.6σ from unity

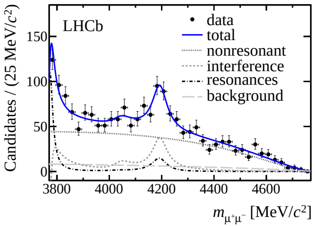
Excited?

R_K AND P_5' AND $c\bar{c}$



- R_K 2.6σ from SM [Phys. Rev. Lett. 113 (2014) 151601]
- P_5' 3.7σ away in one bin [Phys. Rev. Lett. 111 (2013) 191801]
- Leptophobic Z'? [Altmannshofer, Phys.Rev. D89 (2014) 095033, arXiv:1403.1269]
- But how well do we control $c\bar{c}$? [Phys. Rev. Lett. 111 (2013) 112003]





[LHCb, Phys. Rev. Lett. 112 (201… 161801, arXiv:1402.6852]

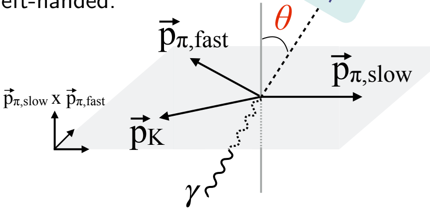
Martino Borsato
This Afternoon

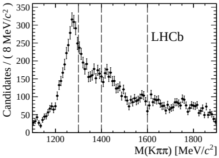
Photon polarisation in $b \to s\gamma$

- The SM predicts the photon in $b \to s\gamma$ is left-handed.
- Compute up-down asymmetry

$$\mathcal{A}_{\text{ud}} = \frac{\int_0^1 \mathrm{d}\cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \mathrm{d}\cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \mathrm{d}\cos\theta \frac{d\Gamma}{d\cos\theta}}$$

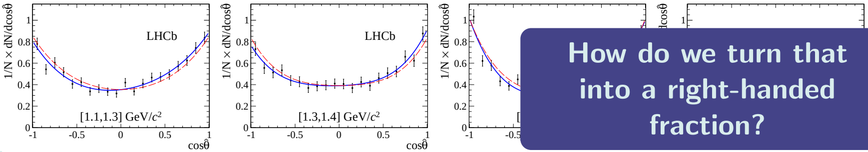
$$= 6.9 \pm 1.7,\ 4.9 \pm 2.0,\ 5.6 \pm 1.8,\ -4.5 \pm 1.9\%$$





➜ 5.2σ first observation of photon polarisation

- Need theory input and/or amplitude analysis to determine photon polarisation



How do we turn that into a right-handed fraction?

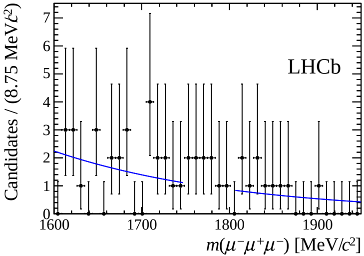
New physics searches in charm, τ and kaon decays

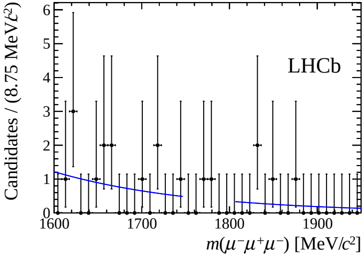
Andreas Crivellin, Francesco Dettori, Angelo di Canto

[LHCb, submitted to JHEP, arXiv:1409.8548]

$\tau^- \to \mu^-\mu^+\mu^-$

Basem Khanji
Friday Morning





- Search for $\tau^- \to \mu^-\mu^+\mu^-$
  - SM prediction $\mathcal{B} = \mathcal{O}(10^{-40})$
  - Best limit $\mathcal{B} < 2.1 \times 10^{-8}$ (90%)

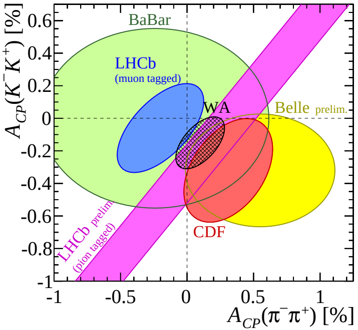
    [Belle, PLB 687 (2010) 139, arXiv:1001.3221]
  - 1 fb^{-1} limit $\mathcal{B} < 8.0 \times 10^{-8}$ (90%)

    [LHCb, Phys. Lett. B724 (2013) 36, arXiv:1304.4518]
- 3D search: $m_{3\mu}$ and 2 MVA, $\mathcal{M}_{\mathrm{PID}}$ and $\mathcal{M}_{\mathrm{3body}}$ (blending of 10 MVAs)
  - Calibrated on $D_s^- \to \phi(\mu^+\mu^-)\pi^-$
  - Most τ^- come from D_s^- decays
- No excess seen in mass distributions
  - Here most significant bins shown for 7 (top) and 8 (bottom) TeV
  - Main peaking background is $D_s^- \to \eta(\mu^+\mu^-\gamma)\,\mu\mathrm{m}\nu$ (removed by $\mu^+\mu^-$ mass cut)

[LHCb, JHEP 07 (2014) 041, arXiv:1405.2797]

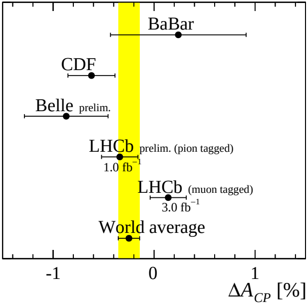
CP violation in SL-tagged $D \to hh$

Jolanta Brodzicka
Tomorrow morning



- Select $D^0 \to K^+K^-$ (2M) and $D^0 \to \pi^+\pi^-$ (800k) from semileptonic (μ) decays in 3 fb^{-1}
- Measure CP asymmetry difference
- $A_{CP}(\pi^+\pi^-)$ is computed from K^+K^- and ΔA_{CP}

$$\Delta A_{CP} = (+0.14 \pm 0.16 \pm 0.08)\%$$
$$A_{CP}(K^+K^-) = (-0.06 \pm 0.15 \pm 0.10)\%$$
$$A_{CP}(\pi^+\pi^-) = (-0.20 \pm 0.19 \pm 0.10)\%$$



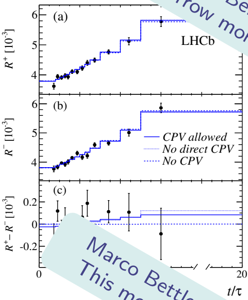
More Charm and Strangeness

Andrea Contu, Benoît Viaud: Tomorrow morning

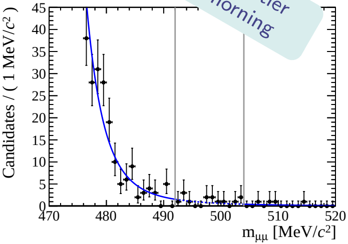
Rare charm decays: We have many analyses in the pipeline. Can short- and long-distance effects be disentangled? Is there a clean measurement?

Mixing and y_{CP}: More to come... **Where to find *CP* violation in charm?**

Rare Kaon decays: We searched for $K^0_S \to \mu^+\mu^-$, but there's more we can do



Marco Bettler This morning



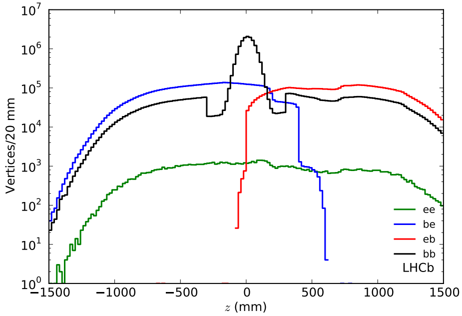
[LHCb, Phys. Rev. Lett. 111 (2013) 251801, arXiv:1309.6534]

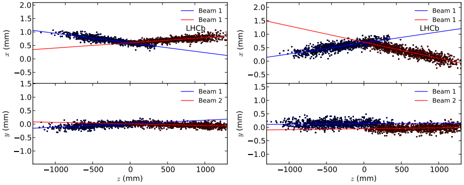
[LHCb, JHEP 01 (2013) 090, arXiv:1209.4029]

Forward electroweak physics

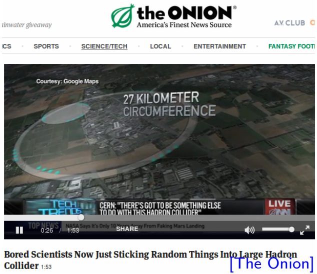
Juan Rojo, Zhenwei Yang, Simone Bifani

Precision luminosity measurement





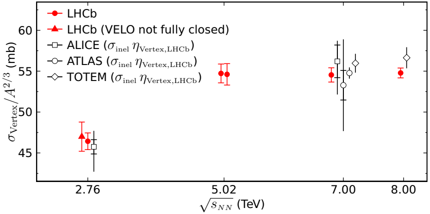
- The luminosity at LHCb is measured with two methods: Beam-gas imaging (BGI) and van der Meer scan (VDM)
- In the BGI method we use neon injected in the beam pipe to reconstruct the beams



[The Onion]

Precision luminosity measurement

Method	Absolute calibration σ_{vis} (mb)	Absolute calibration Weight	Absolute calibration Uncertainty	Relative calibration uncertainty	Total uncertainty
pp at $\sqrt{s} = 8\,\text{TeV}$					
BGI	60.62 ± 0.87	0.50	1.43% (0.59%)		
VDM	60.63 ± 0.89	0.50	1.47% (0.65%)		
Average	60.62 ± 0.68		1.12%	0.31%	1.16%
pp at $\sqrt{s} = 7\,\text{TeV}$					
BGI	63.00 ± 2.22	0.13	3.52% (1.00%)		
VDM	60.01 ± 1.03	0.87	1.71% (1.00%)		
Average	60.40 ± 0.99		1.63%	0.53%	1.71%
pp at $\sqrt{s} = 2.76\,\text{TeV}$					
BGI	52.7 ± 1.2		2.20%	0.25%	2.21%
pPb at $\sqrt{s_{NN}} = 5\,\text{TeV}$					
VDM	2126 ± 49		2.05%	1.03%	2.29%
Pbp at $\sqrt{s_{NN}} = 5\,\text{TeV}$					
VDM	2120 ± 53		2.36%	0.82%	2.50%



- The luminosity at LHCb is measured with two methods: Beam-gas imaging (BGI) and van der Meer scan (VDM)
- Best results for 8 TeV data:
  - BGI has 1.43% uncertainty
  - VDM 1.47%
  - ➜ 1.12% combined
  - For 7 TeV it's 1.63%
- Cross-sections for the *Vertex* obervable are compared to other experiments (scaled to LHCb eff.)

W cross section at 7 TeV

Stephen Farry This Afternoon

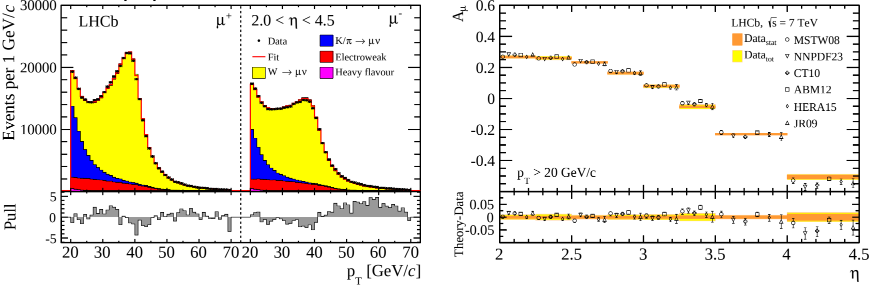
- Fit p_{T} distribution to extract signal and asymmetry

$$\sigma_{W^+ \to \mu^+\nu} = 861.0 \pm 2.0 \pm 11.2 \pm 14.7 \text{ pb}$$

$$\sigma_{W^- \to \mu^-\overline{\nu}} = 675.8 \pm 1.9 \pm 8.8 \pm 11.8 \text{ pb}$$

$$R_W = \frac{\sigma_{W^+ \to \mu^+\nu}}{\sigma_{W^- \to \mu^-\overline{\nu}}} = 1.274 \pm 0.005 \pm 0.009$$

First paper to use new lumi calibration [LHCb, submitted to JINST, arXiv:1410.0149]

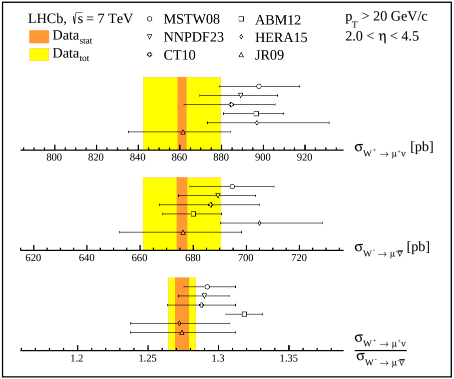


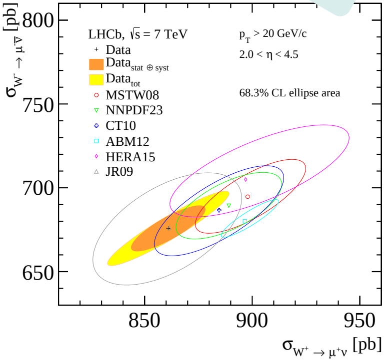
[LHCb, submitte JHEP, arXiv:1408.4354]

Stephen Farry
This Afternoon

W CROSS SECTION AT 7 TEV

- Comparison with models shows good agreement

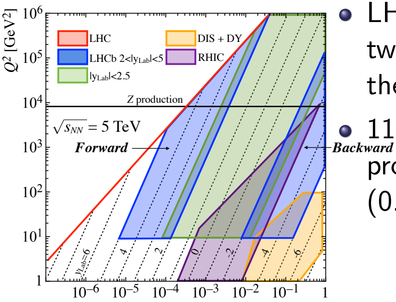


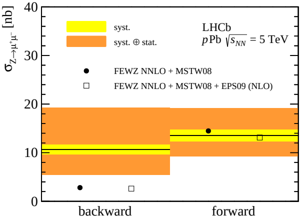


Can theory match the 1% lumi uncertainty?

[LHCb, JHEP 09 (2014) 030, arXiv:1406.2885]

Z IN PROTON-LEAD





- LHCb has a unique rapidity coverage in two regions depending on the direction of the proton beam
- 11 $Z \to \mu^+\mu^-$ candidates with forward proton ($1.1\,\text{nb}^{-1}$) and 4 with backward ($0.5\,\text{nb}^{-1}$) in $2 < \eta(\mu^\pm) < 4.5$:

$$\sigma(\text{fwd}) = 13.5\,{}^{+5.4}_{-4.0} \pm 1.2\ \text{nb}$$

$$\sigma(\text{bwd}) = 10.7\,{}^{+8.4}_{-5.1} \pm 1.0\ \text{nb}$$

- In the overlap region $2.5 < \eta(\mu^\pm) < 4$

$$R_{\text{FB}} = 0.094\,{}^{+0.104}_{-0.062}\,{}^{+0.004}_{-0.007},$$

which is sensitive to collective nucleus effects. This is only 2.2σ from unity.

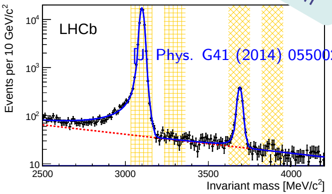
More Forward electroweak physics

Daniel Johnson
This Afternoon

Central exclusive production: We have a unique potential, especially in run II with the installation of Herschel

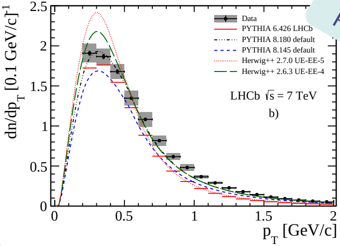
$t\bar{t}$: We do *b*-jets and *W*. On our way to the top.

Impact on MC Tuning: Effect of LHCb on generators



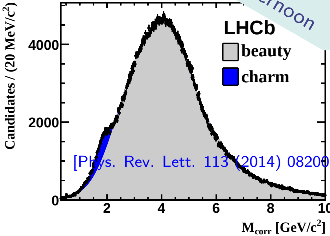
[J. Phys. G41 (2014) 055002]

Victor Coco
This Afternoon



Phil Ilten
Friday Morning

[Eur. Phys. J. C74 (2014) 2888]



[Phys. Rev. Lett. 113 (2014) 082003]

What's next

What's next (sanitised slide)

$\sin 2\beta$: In the pipeline

$B^0 \to K^{*0}\mu^+\mu^-$: In the pipeline

$B^0 \to K^{*0}e^+e^-$: In the pipeline

A^s_{SL}: In the pipeline

$D^0 \to hh$ ΔA_{CP} and y_{CP}: In the pipeline

γ: More channels in the pipeline

You'll hear more on prospects during the next three days.

Run II prospects

How will our stats scale in run II?

How many civilizations in the galaxy?

Drake equation:

$$N = R_* \cdot f_p \cdot n_e \cdot f_\ell \cdot f_i \cdot f_c \cdot L$$

R_*: the average rate of star formation in our galaxy

f_p: the fraction of those stars that have planets

n_e: the average number of planets that can potentially support life per star that has planets

f_ℓ: the fraction of planets that could support life that actually develop life at some point

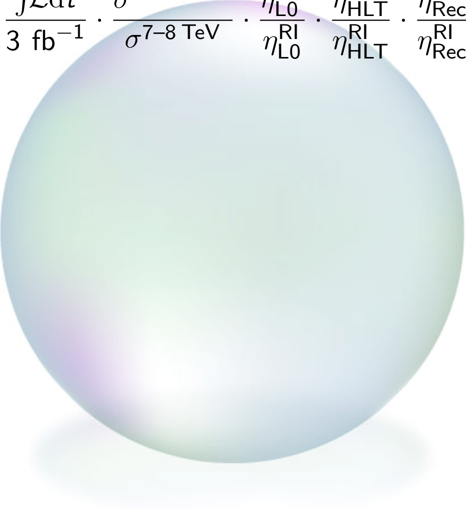
f_i: the fraction of planets with life that actually go on to develop intelligent life (civilizations)

f_c: the fraction of civilizations that develop a technology that releases detectable signs of their existence into space

L: the length of time for which such civilizations release detectable signals into space

How will our stats scale in run II?

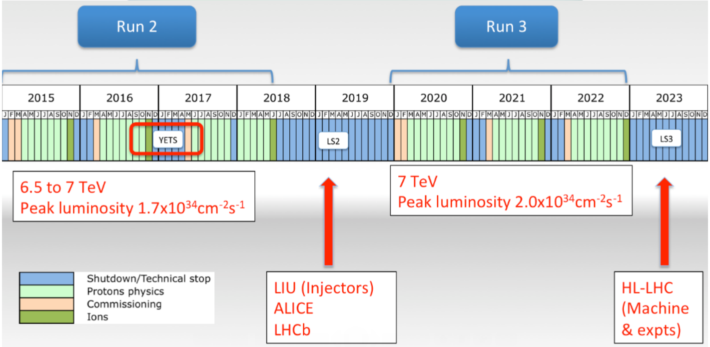
$$\frac{N^{\text{RI+II}}}{N^{\text{RI}}} = \left(1 + \frac{\int \mathcal{L} \mathrm{d}t}{3\ \text{fb}^{-1}} \cdot \frac{\sigma^{\text{13–14 TeV}}}{\sigma^{\text{7–8 TeV}}} \cdot \frac{\eta_{\text{L0}}^{\text{RII}}}{\eta_{\text{L0}}^{\text{RI}}} \cdot \frac{\eta_{\text{HLT}}^{\text{RII}}}{\eta_{\text{HLT}}^{\text{RI}}} \cdot \frac{\eta_{\text{Reco}}^{\text{RII}}}{\eta_{\text{Reco}}^{\text{RI}}}\right) \frac{\eta_{\text{Sel}}^{2018}}{\eta_{\text{Sel}}^{2014}} \cdot f_{\text{Brain}}$$



How will our stats scale in run II?

$$\frac{N^{\text{RI+II}}}{N^{\text{RI}}} = \left(1 + \underbrace{\frac{\int\mathcal{L}\mathrm{d}t}{3\ \text{fb}^{-1}}}_{\sim 1.5\text{–}2} \cdot \frac{\sigma^{13\text{–}14\ \text{TeV}}}{\sigma^{7\text{–}8\ \text{TeV}}} \cdot \frac{\eta^{\text{RII}}_{\text{L0}}}{\eta^{\text{RI}}_{\text{L0}}} \cdot \frac{\eta^{\text{RII}}_{\text{HLT}}}{\eta^{\text{RI}}_{\text{HLT}}} \cdot \frac{\eta^{\text{RII}}_{\text{Reco}}}{\eta^{\text{RI}}_{\text{Reco}}}\right) \frac{\eta^{2018}_{\text{Sel}}}{\eta^{2014}_{\text{Sel}}} \cdot f_{\text{Brain}}$$

$\int\mathcal{L}\mathrm{d}t$: Assuming we stay at $\mathcal{L} = 4\cdot 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, expect 6 fb^{-1} by end of 2018 (if we run for the whole of 2018, 4.5 else), more if we increase $\mathcal{L}$, less if the LHC under-performs



How will our stats scale in run II?

$$\frac{N^{\text{RI+II}}}{N^{\text{RI}}} = \left(1 + \underbrace{\frac{\int\mathcal{L}\mathrm{d}t}{3\ \text{fb}^{-1}}}_{\sim 1.5\text{–}2} \cdot \underbrace{\frac{\sigma^{13\text{–}14\ \text{TeV}}}{\sigma^{7\text{–}8\ \text{TeV}}}}_{\sim 2} \cdot \frac{\eta_{\text{L0}}^{\text{RII}}}{\eta_{\text{L0}}^{\text{RI}}} \cdot \frac{\eta_{\text{HLT}}^{\text{RII}}}{\eta_{\text{HLT}}^{\text{RI}}} \cdot \frac{\eta_{\text{Reco}}^{\text{RII}}}{\eta_{\text{Reco}}^{\text{RI}}}\right) \frac{\eta_{\text{Sel}}^{2018}}{\eta_{\text{Sel}}^{2014}} \cdot f_{\text{Brain}}$$

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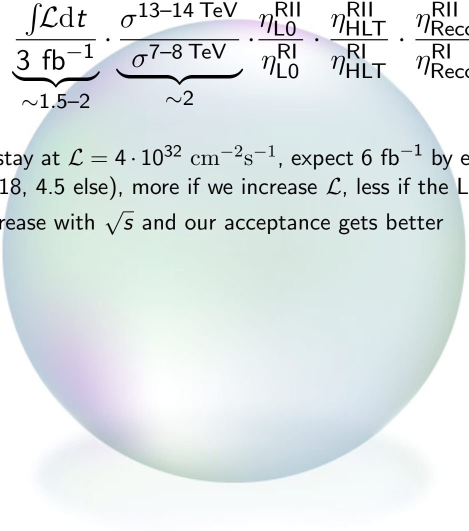
σ: Cross-sections increase with $\sqrt{s}$ and our acceptance gets better



How will our stats scale in run II?

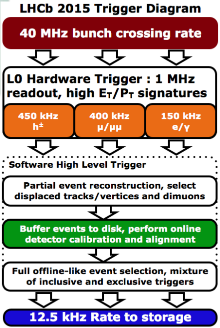
$$\frac{N^{\text{RI+II}}}{N^{\text{RI}}} = \left(1 + \underbrace{\frac{\int\mathcal{L}\mathrm{d}t}{3\ \text{fb}^{-1}}}_{\sim 1.5\text{–}2} \cdot \underbrace{\frac{\sigma^{13\text{–}14\ \text{TeV}}}{\sigma^{7\text{–}8\ \text{TeV}}}}_{\sim 2} \cdot \underbrace{\frac{\eta^{\text{RII}}_{\text{L0}}}{\eta^{\text{RI}}_{\text{L0}}}}_{0.5\text{–}1} \cdot \underbrace{\frac{\eta^{\text{RII}}_{\text{HLT}}}{\eta^{\text{RI}}_{\text{HLT}}}}_{\geq 1} \cdot \frac{\eta^{\text{RII}}_{\text{Reco}}}{\eta^{\text{RI}}_{\text{Reco}}}\right) \frac{\eta^{2018}_{\text{Sel}}}{\eta^{2014}_{\text{Sel}}} \cdot f_{\text{Brain}}$$

$\int\mathcal{L}\mathrm{d}t$: Assuming we stay at $\mathcal{L} = 4 \cdot 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, expect 6 fb^{-1} by end of 2018 (if we run for the whole of 2018, 4.5 else), more if we increase $\mathcal{L}$, less if the LHC under-performs

σ: Cross-sections increase with $\sqrt{s}$ and our acceptance gets better

L0: The higher multiplicity and energy will force us to raise L0 thresholds. Dimuon channels will not be much affected. Others will. ➜ Solved in Run III upgrade

HLT: We have a very smart trigger group who will get most out of the data. Especially for charm. (12.5 kHz rate will help)



How will our stats scale in Run II?

$$\frac{N^{\text{RI+II}}}{N^{\text{RI}}} = \left(1 + \underbrace{\frac{\int\mathcal{L}dt}{3\text{ fb}^{-1}}}_{\sim 1.5\text{–}2} \cdot \underbrace{\frac{\sigma^{13\text{–}14\text{ TeV}}}{\sigma^{7\text{–}8\text{ TeV}}}}_{\sim 2} \cdot \underbrace{\frac{\eta_{\text{L0}}^{\text{RII}}}{\eta_{\text{L0}}^{\text{RI}}}}_{0.5\text{–}1} \cdot \underbrace{\frac{\eta_{\text{HLT}}^{\text{RII}}}{\eta_{\text{HLT}}^{\text{RI}}}}_{\geq 1} \cdot \underbrace{\frac{\eta_{\text{Reco}}^{\text{RII}}}{\eta_{\text{Reco}}^{\text{RI}}}}_{\sim 1}\right) \underbrace{\frac{\eta_{\text{Sel}}^{2018}}{\eta_{\text{Sel}}^{2014}}}_{\sim 1} \cdot \underbrace{f_{\text{Brain}}}_{\geq 1}$$

$\int\mathcal{L}dt$: Assuming we stay at $\mathcal{L} = 4 \cdot 10^{32}\ \text{cm}^{-2}\text{s}^{-1}$, expect 6 fb^{-1} by end of 2018 (if we run for the whole of 2018, 4.5 else), more if we increase $\mathcal{L}$, less if the LHC under-performs

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HLT: We have a very smart trigger group who will get most out of the data. Especially for charm. (12.5 kHz rate will help)

Reco & PID: Tracking and PID may suffer a bit from 25 ns and multiplicites. These are small effects.

Selection: We are constantly improving thanks to better understanding of signal and backgrounds. But not by large amounts.

f_{Brain}: We regularly realise we can be smarter and add more final states, relax mass cuts, improve methods. . .

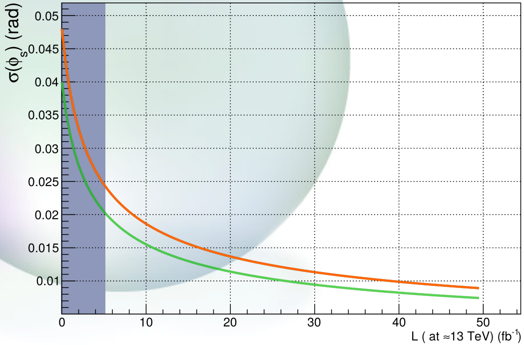
How will our stats scale in run I

Tim Gershon
This Morning

$$\frac{N^{\mathrm{RI+II}}}{N^{\mathrm{RI}}} = \left(1 + \underbrace{\frac{\int \mathcal{L}\mathrm{d}t}{3\ \mathrm{fb}^{-1}}}_{\sim 1.5\text{–}2} \cdot \underbrace{\frac{\sigma^{13\text{–}14\ \mathrm{TeV}}}{\sigma^{7\text{–}8\ \mathrm{TeV}}}}_{\sim 2} \cdot \underbrace{\frac{\eta^{\mathrm{RII}}_{\mathrm{L0}}}{\eta^{\mathrm{RI}}_{\mathrm{L0}}}}_{0.5\text{–}1} \cdot \underbrace{\frac{\eta^{\mathrm{RII}}_{\mathrm{HLT}}}{\eta^{\mathrm{RI}}_{\mathrm{HLT}}}}_{\geq 1} \cdot \underbrace{\frac{\eta^{\mathrm{RII}}_{\mathrm{Reco}}}{\eta^{\mathrm{RI}}_{\mathrm{Reco}}}}_{\sim 1}\right) \underbrace{\frac{\eta^{2018}_{\mathrm{Sel}}}{\eta^{2014}_{\mathrm{Sel}}}}_{\sim 1} \cdot \underbrace{f_{\mathrm{Brain}}}_{\geq 1}$$

➜ 4–5 times the samples we already have.

Here precision on ϕ_s from $J/\psi K^+K^-$ (now 0.049) and adding $J/\psi\pi^+\pi^-$ (now 0.040)



How will our systematics scale in run II?

Take $B_s^0 \to J/\psi K^+ K^-$ [LHCb, LHCb-PAPER-2014-059, in preparation]

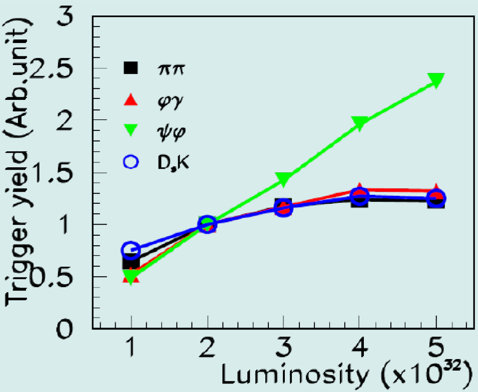
Quantity	$\Delta\Gamma_s$	ϕ_s	
Statistical	0.0091	0.049	See previous slide
Mass factorisation	0.0007	0.002	Tested on data
Signal weights	0.0008		Tested on data
Resonant background	0.0004	0.002	Tested on data
Ang. Efficiency	0.0002	0.004	MC stats
Decay time resol.		0.002	MC stats
Track reconstruction	0.0029	0.001	MC stats
Length scale			Cancels in $\Delta\Gamma_s$ and ϕ_s

As for many other LHCb measurements we are ages away from being systematics limited.

Run III–IV

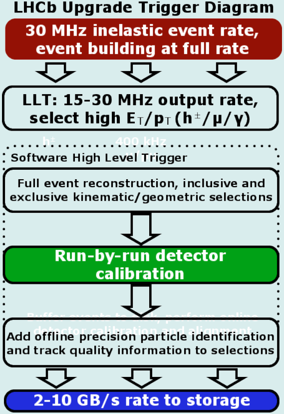
LHCb Upgrade plans

- Expect that integrated luminosity increases linearly with time. After 6 fb^{-1}, would take ∼3 years to double statistics
  - Need an order of magnitude increase in luminosity ➜ 2×10^{33}
  - ✔ Most of the detector can cope, efficiencies don't degrade
- ✗ L0 saturates for hadronic channels
  - p_{T} is not a discriminating variable any more



LHCb Upgrade plans

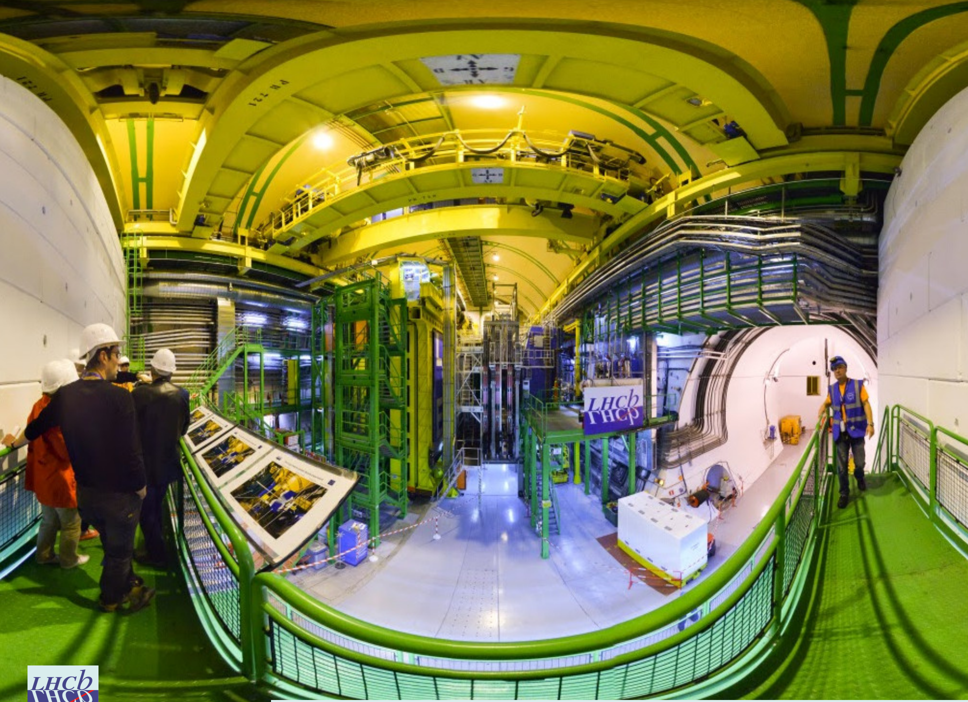
- Expect that integrated luminosity increases linearly with time. After 6 fb^{-1}, would take ∼3 years to double statistics
  - Need an order of magnitude increase in luminosity ➜ 2×10^{33}
  - ✔ Most of the detector can cope, efficiencies don't degrade
- ✗ L0 saturates for hadronic channels
  - p_{T} is not a discriminating variable any more
- ➜ Read all out at 40 MHz
  - Most of the electronics to be replaced
  - Run HLT on all events
- Velo and Trackers replaced to cope with higher multiplicity



Conclusion

Enjoy the workshop!

Backup

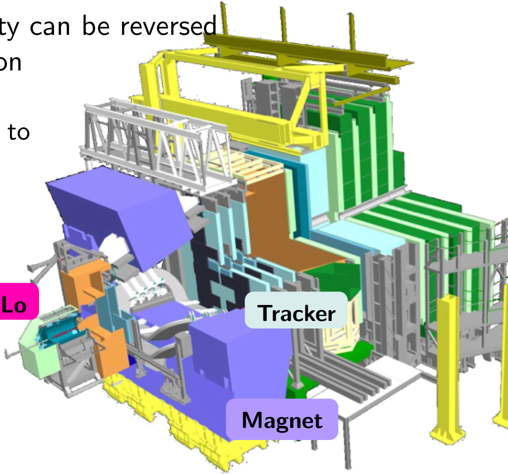

LHCb

LHCb Detector

Forward detector (b hadrons produced forward at LHC, $(75 \pm 5 \pm 13)\ \mu b$ in acceptance [Physics Letters B 698 (2011) 14, arXiv:1102.0348])

- Warm dipole magnet. Polarity can be reversed

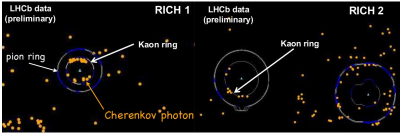
✔ Good momentum and position resolution
  - Vertex detector gets 8mm to the beam

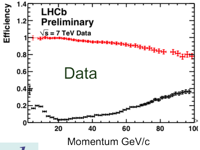


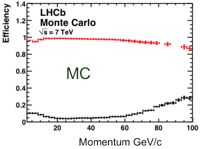
LHCb Detector & performance

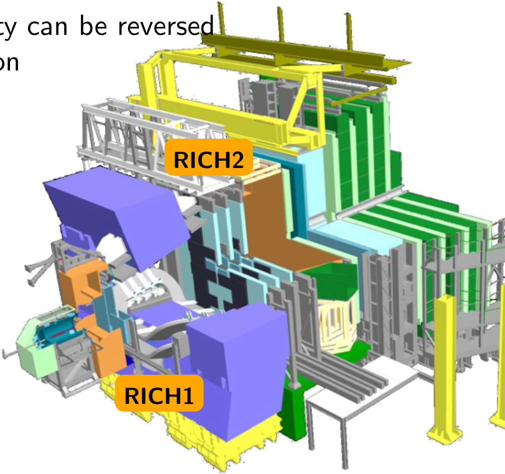
Forward detector (b hadrons produced forward at LHC, $(75 \pm 5 \pm 13)\ \mu$b in acceptance [Physics Letters B 698 (2011) 14, arXiv:1102.0348])

- Warm dipole magnet. Polarity can be reversed
- ✔ Good momentum and position resolution
- ✔ Excellent Particle ID









LHCb Trigger

Forward detector (b hadrons produced forward at LHC, $(75 \pm 5 \pm 13)$ μb in acceptance [Physics Letters B 698 (2011) 14, arXiv:1102.0348])

- Warm dipole magnet. Polarity can be reversed
- ✔ Good momentum and position resolution
- ✔ Excellent Particle ID
- ✔ Versatile two stage trigger
  - Hardware-based L0 trigger: moderate p_{T} cuts ➜ 1 MHz
  - Whole data sent to trigger farm
  - 3 kHz output rate (2011)
  - 4.5 kHz in 2012 (some of it deferred)
  - ∼12 kHz from 2015