LHCb – physics prospects at current and upgraded detector

SuperB Workshop and Kick Off Meeting, Elba, 30/5/11

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on behalf of the LHCb collaboration

Elba: lessons (to us all) from history

The glory years

Emperor of flavour physics

An enforced pause

Plotting the stage-II project

The new campaign

Not quite what was promised in the TDR

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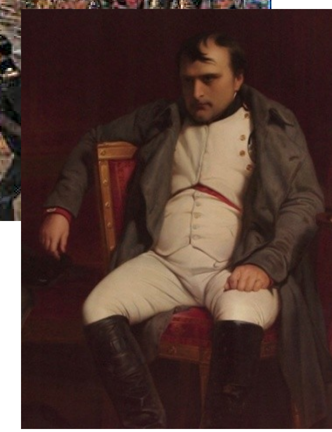
The new campaign



Not quite what was promised in the TDR

History tells us:

- plan carefully
- choose realistic goals
- do not underestimate the competition

Outline

- Current experiment: experience and performance

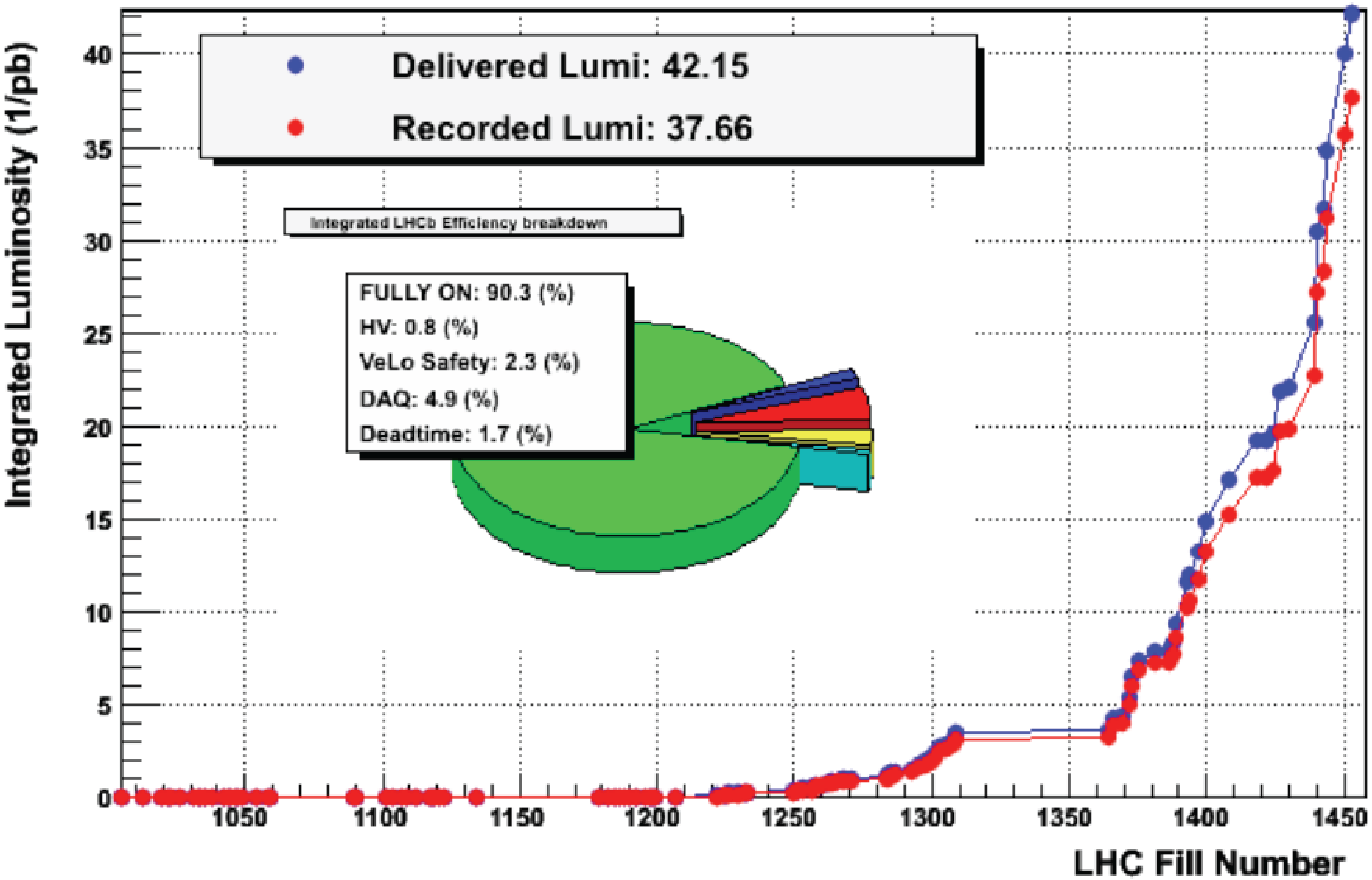
- Path to the upgrade

- Selected flavour physics goals:
  2010, 2011+ and during upgrade era

- Physics beyond flavour

- Summary

Integrated luminosity in 2010

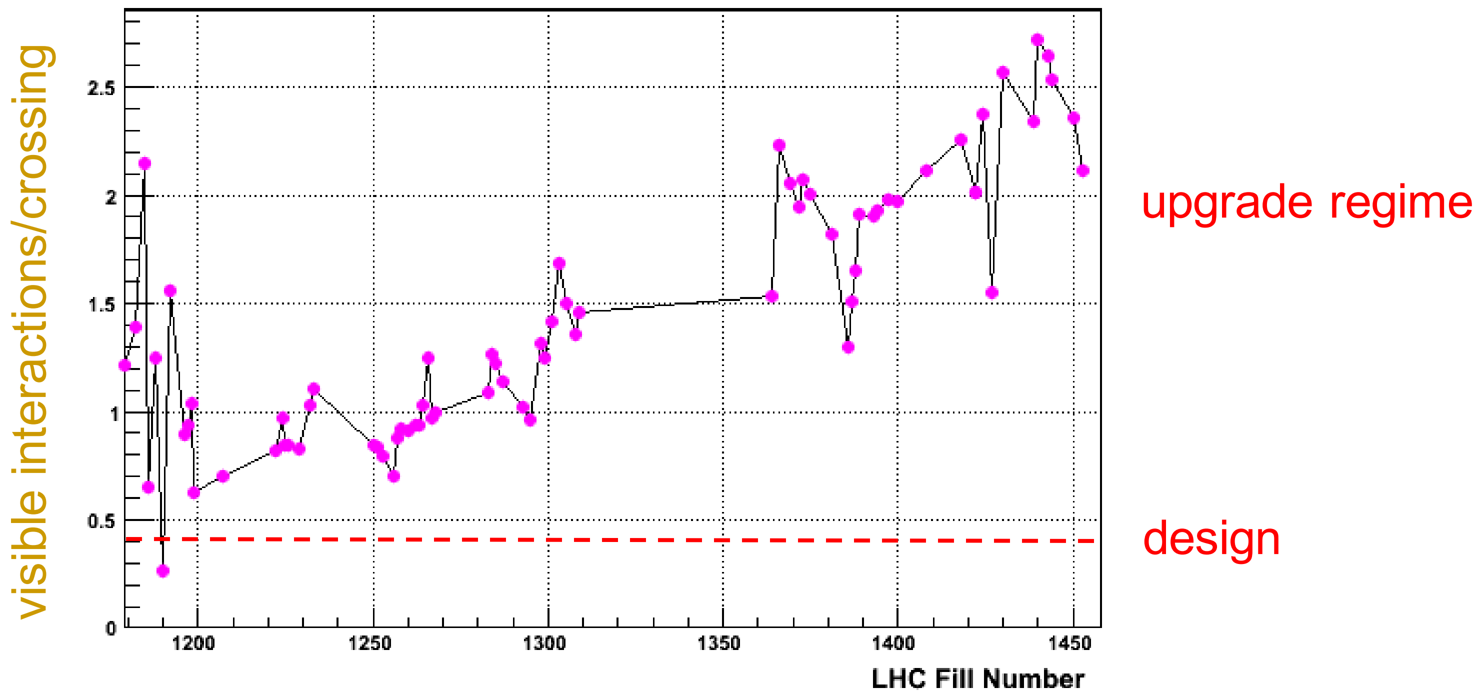


Design luminosity 2 x 10^{32} cm^{-2} s^{-1}. Almost there at end of run!

2010 running conditions

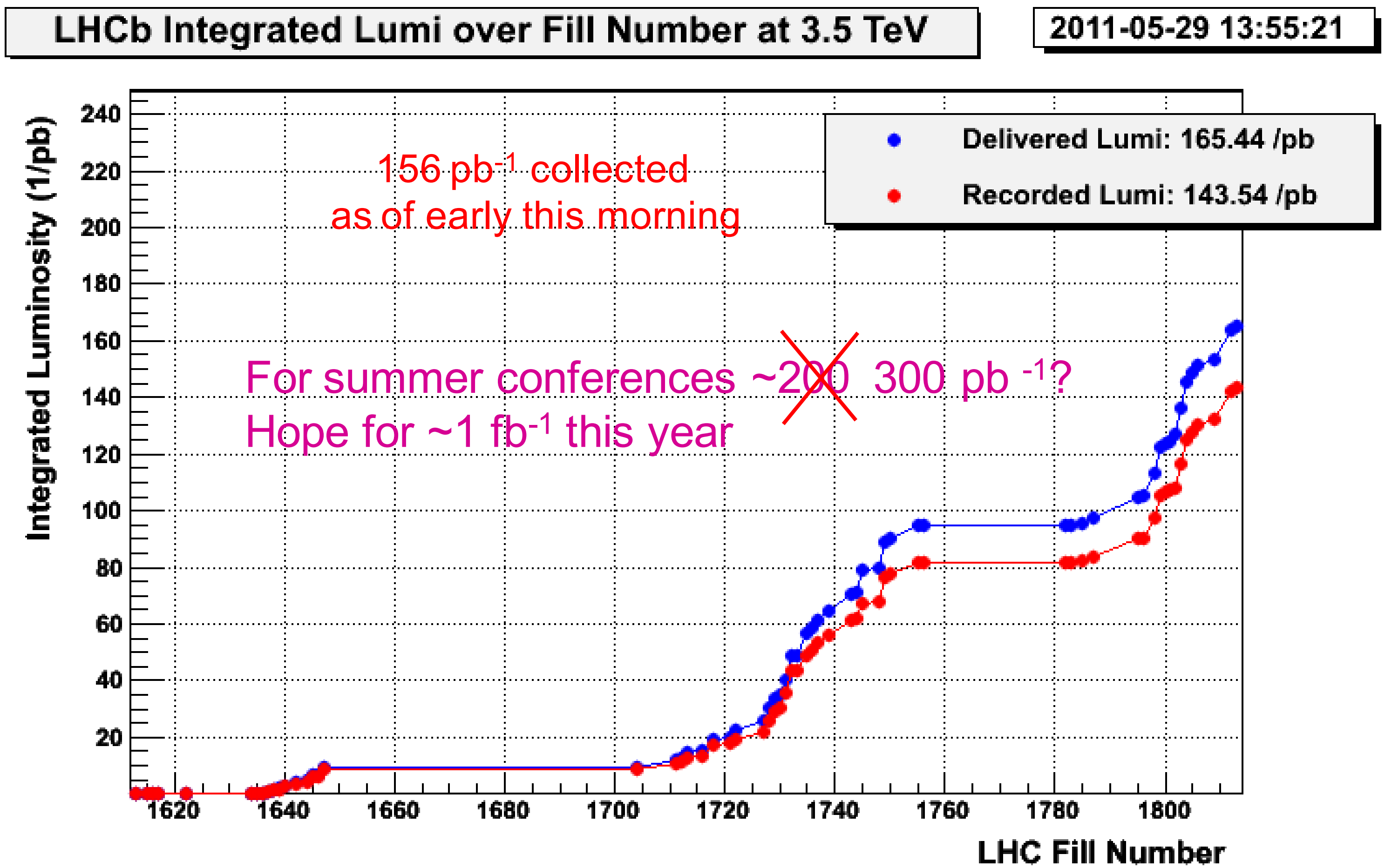
LHCb designed for luminosity of ~2 x 10^{32} cm^{-2} s^{-1} and ~0.4 interaction/crossing

In 2010 machine quickly went to (above) nominal in emittance and bunch charge, whilst still having only a few hundred bunches. It was therefore necessary to run at > 2 interactions/crossing in order to obtain acceptable luminosity.



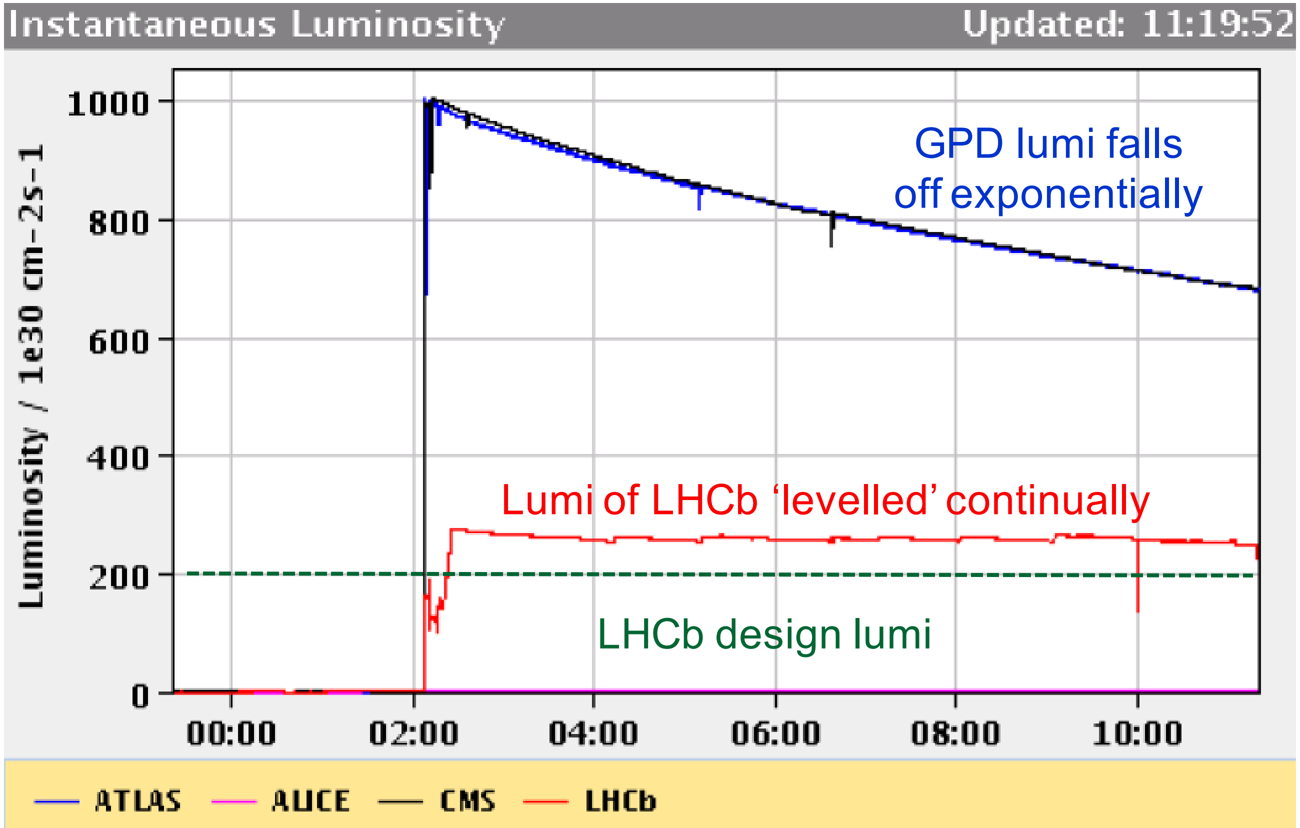
These are the conditions foreseen for upgrade – the experiment performed well!

2011 so far: the dream machine



LHCb running strategy in 2011

Fill from 24/5/11: 912 bunches, LHCb μ (=visible interactions/xing) set to ~1.6



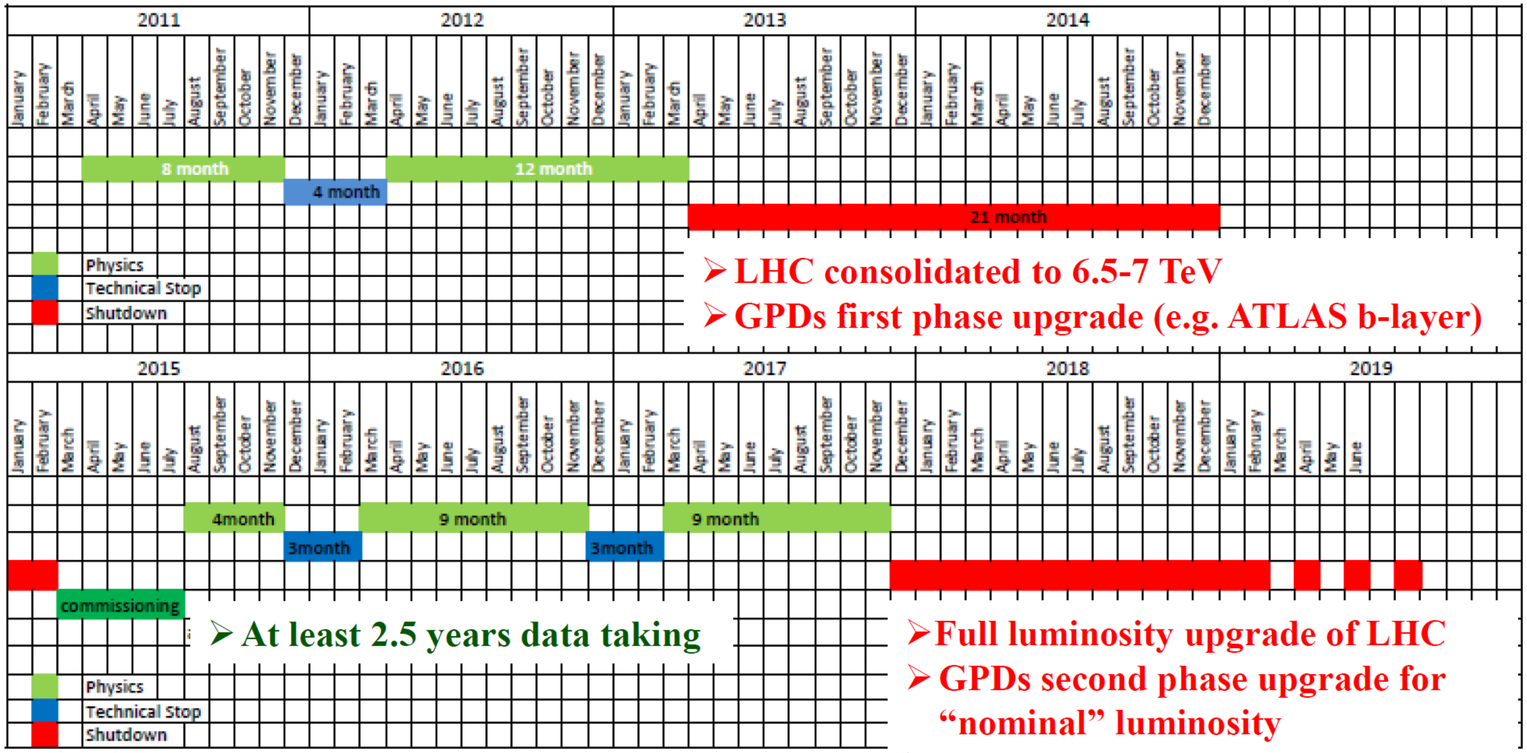
← upgrade regime

LHCb lumi can be raised with # bunches &/or chosen value of μ value

Max. value for safe detector operation is assumed to be ~3 x 10^{32} cm^{-2}s^{-1}

LHC planning

Disclaimer: this is not an official schedule, just a plausible scenario under discussion



- LHC consolidated to 6.5-7 TeV
- GPDs first phase upgrade (e.g. ATLAS b-layer)
- At least 2.5 years data taking
- Full luminosity upgrade of LHC
- GPDs second phase upgrade for "nominal" luminosity
- LHCb full upgrade to 40MHz R/O

4-5 years of data taking with natural window for upgrade in 2nd long shutdown

LHCb, now and in the future

Present experiment:

Collect ~5 fb^{-1} of data integrated over ~5 years at L ~ 3 x 10^{32} $cm^{-2}s^{-1}$ with detector performing as expected (even above nominal !). Then, rather than continuing to accumulate at the same rate, we will take a more rewarding path...

Essentials of upgraded LHCb:

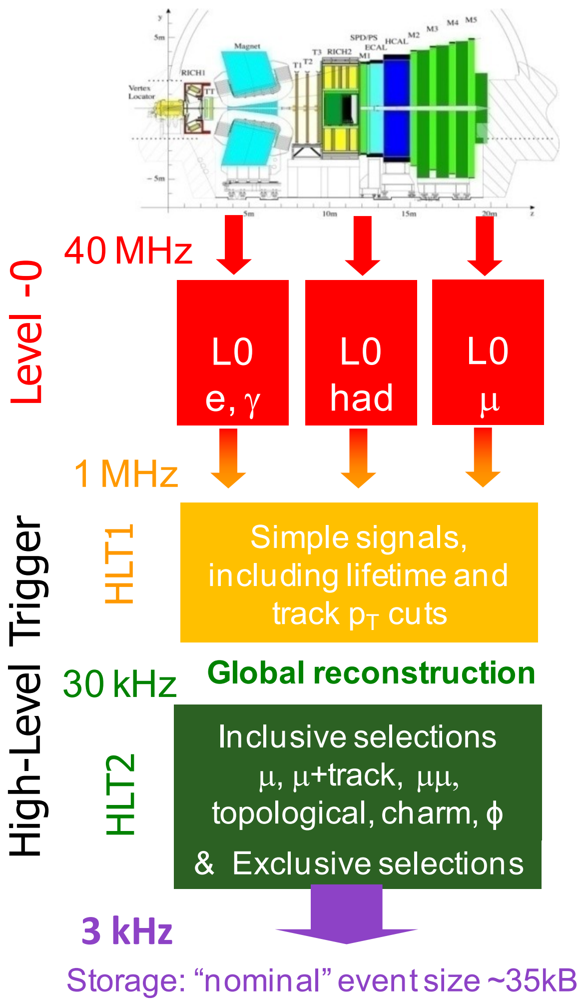
Raise luminosity to 10^{33} $cm^{-2}s^{-1}$:
Easy - LHC has already reached this performance!

Upgrade readout of all subdetectors + DAQ architecture to 40 MHz (driven by full-software trigger – see next slide)

New readout necessitates changes for some subdetectors (VELO, RICH photodetectors, TT/IT) – good opportunity to benefit from new technologies

Collect ~5 fb^{-1} / year, with more efficient and flexible trigger

LHCb trigger – strengths and limitations



Present strategy:

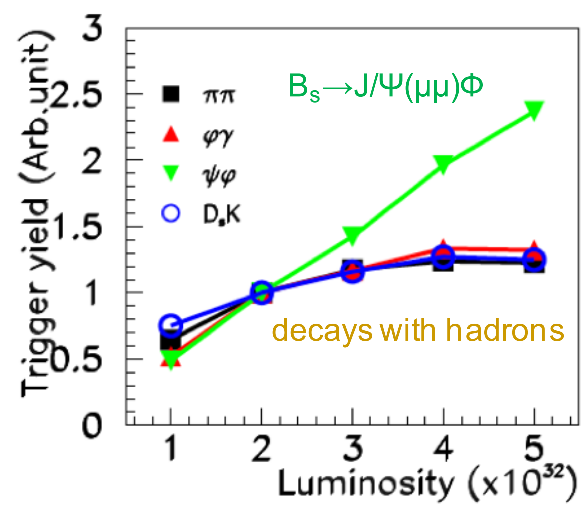
- hardware high p_T signal at earliest level – robust
- *inclusive** signature in HLT – very efficient

Performance even better than anticipated, but yield in hadronic channels does not scale with luminosity

Must raise p_T cuts to stay within 1 MHz readout limit

Decays to leptons - linear gain

Hadronic final states – yield flatlines...



Upgrade solution:

Readout at 40 MHz & use s/w trigger *throughout*

* 'inclusive' = ~ anything LHCb can reconstruct will be selected by trigger

Selected flavour physics goals: from 37 pb^{-1} to 5 fb^{-1} to 50 fb^{-1}

Here cover only the most obvious topics. Many other items already identified, and analysis targets will certainly evolve with time.

Today:

- $B^0_{s,d} \rightarrow \mu\mu$
- CPV in B^0_s mixing ("Φ_s")
- $B^0 \rightarrow K^*\mu\mu$
- B decays to charm – measurement of γ
- Charm physics

Selected flavour physics goals: from 37 pb^{-1} to 5 fb^{-1} to 50 fb^{-1}

Here cover only the most obvious topics. Many other items already identified, and analysis targets will certainly evolve with time.

Other topics:

- Charmless B-decays (incld. gluonic Penguins)
- Rare hadronic B-decays
- Flavour specific asymmetries
- Semileptonic decays
- Other CKM angles: α, β
- $B \rightarrow D^* \tau \nu$
- LFV τ decays
- Sterile Majorana neutrinos

Searching for New Physics at LHCb

Search for (and then characterise) New Physics with two classes of measurement.

Exploration

Focus on decay modes or observables a priori very sensitive to New Physics, but which have not (really) been accessible to previous experiments

e.g.
- Search for $B_s \rightarrow \mu\mu$ down to SM value
- Search for mixing induced CPV in B_s system down to SM value
- Look for non-SM behaviour in A_{FB} of $B^0 \rightarrow K^*\mu\mu$

Precision studies

Measurement of known parameters with improved sensitivity, to allow for more precise comparisons with theory.

e.g.
- Measure CKM angle γ to 3-4^o to permit meaningful CKM tests
- Search for CPV in charm

Searching for New Physics at LHCb upgrade

Search for (and then characterise) New Physics with two classes of measurement.
New exploration topics appear, and existing studies migrate to precision studies

Exploration

Focus on decay modes or observables a priori very sensitive to New Physics, but which have not (really) been accessible to previous experiments

e.g.
- Search for $B^0 \rightarrow \mu\mu$
- Study new kinematical observables in $B^0 \rightarrow K^*\mu\mu$, e.g. $A_T^{(2)}$
- High sensitivity CPV studies with gluonic Penguins, e.g. $B_s \rightarrow \Phi\Phi$

Precision studies

Measurement of known parameters with improved sensitivity, to allow for more precise comparisons with theory.

e.g.
- Measure $BR(B_s \rightarrow \mu\mu)$ to precision of ~10% (assuming SM value)
- Measure Φ_s to <20% of SM value
- Measure γ to $<1^o$ to match anticipated theory progress
- Charm CPV search below 10^{-4}

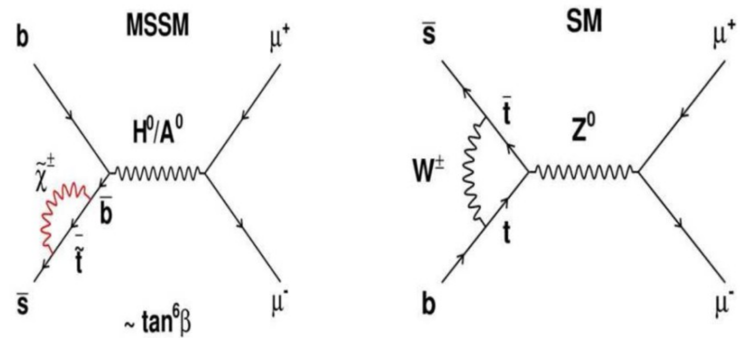
The golden mode: $B_s \to \mu\mu$

B physics rare decay par excellence:

$$BR(B_s \to \mu\mu)_{SM} = (3.35 \pm 0.32) \times 10^{-9}$$

(Blanke et al., JHEP 0610:003,2006)

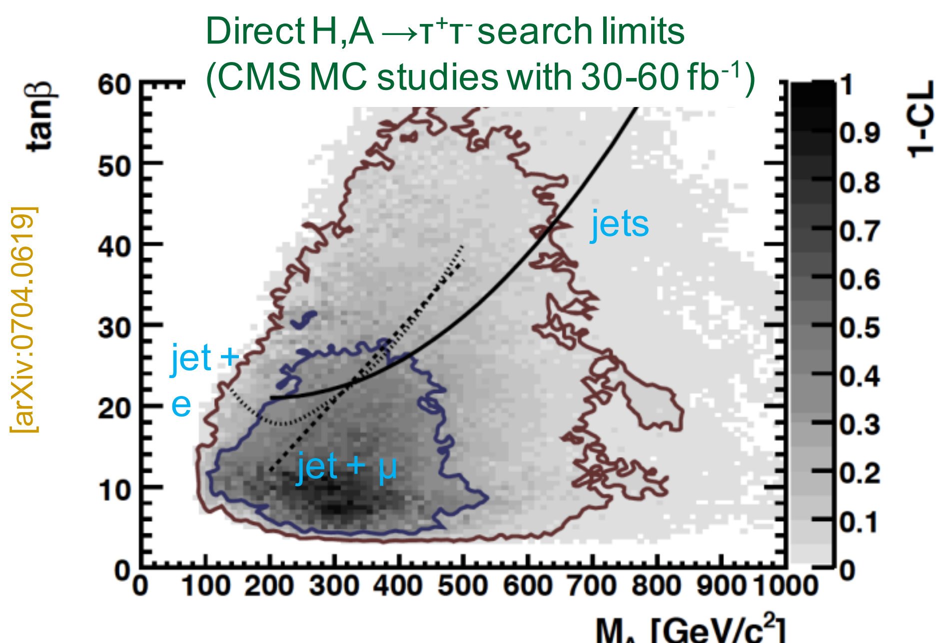
Precise prediction (which will improve) !

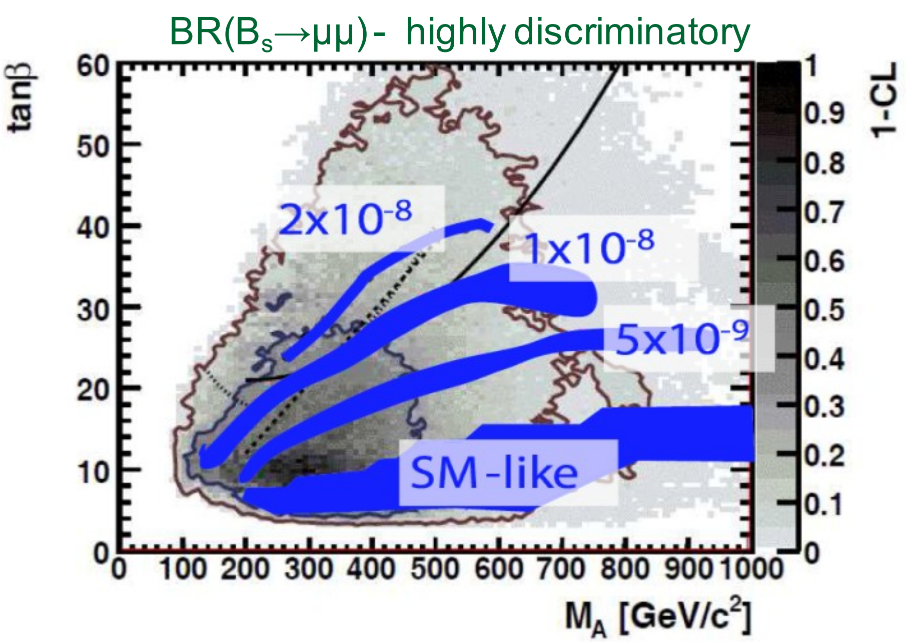


Very high sensitivity to NP, eg. MSSM:

$$Br^{MSSM}(Bq \to l^+l^-) \propto \frac{m_b^2 m_l^2 \tan^6\beta}{M_{A0}^4}$$

One example [O. Buchmuller et al, arXiv:0907.5568] : NUHM (= generalised version of CMSSM)





$B_s \rightarrow \mu\mu$ at LHCb

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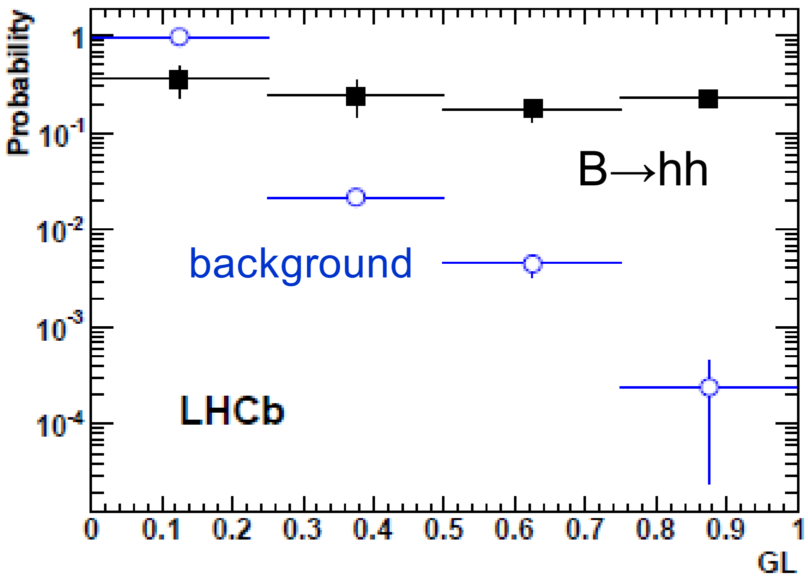
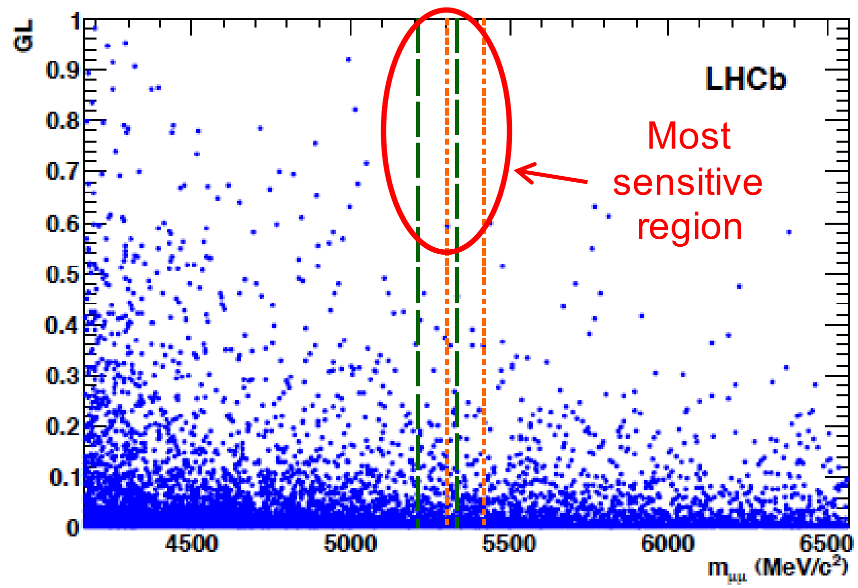
Form geometrical likelihood (GL) out of discriminant variables and look for enhancement in GL vs $m_{\mu\mu}$ space. Data driven analysis; LHCb $B \rightarrow hh$ sample particularly valuable given its identical topology to signal mode.





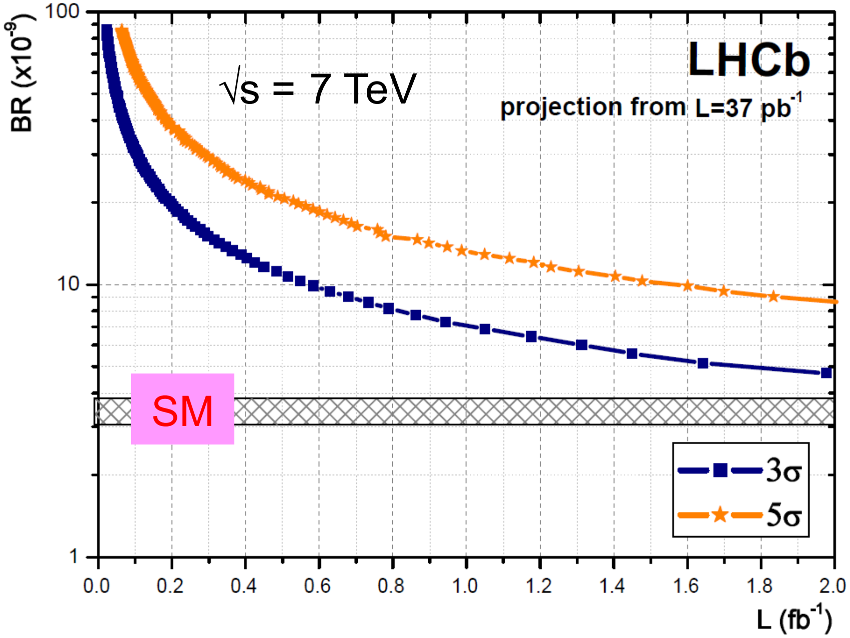
LHCb $BR(B_s \rightarrow \mu\mu) < 5.6 \times 10^{-8}$ at 95% CL with 37 pb^{-1}

CDF $BR(B_s \rightarrow \mu\mu) < 4.3 \times 10^{-8}$ at 95% CL, with 3.7 fb^{-1}

D0 $BR(B_s \rightarrow \mu\mu) < 5.1 \times 10^{-8}$ at 95% CL, with 6.1 fb^{-1}

$B_{s,d} \to \mu\mu$ at upgrade

2011-12 discovery prospects



Current LHCb will reveal NP if large-ish...

...but bigger sample required to look for more subtle effects, and indeed to be certain of reaching SM sensitivity.

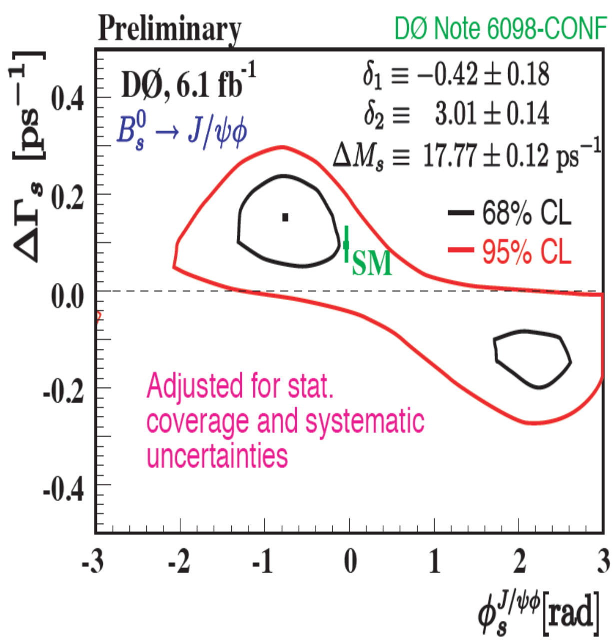
Present experience indicates that bckgd and systematics will be manageable e.g. f_s/f_d – *already* measured at LHCb ~ well as at LEP & better than Tevatron

If at SM value, and present analysis, we will measure BR with ~8% precision with 50 fb^{-1}. Very important consequences for flavour structure of NP, & invaluable constraint on SUSY parameter space, whether or not SUSY discovered at GPDs.

Also unique to upgraded LHCb: possibility to measure $B_d \to \mu\mu$ and get first information on ratio of $B_d \to \mu\mu / B_s \to \mu\mu$, which is critical checkpoint for MFV

CP violation in B^0_s-$\overline{B}^0_s$ mixing

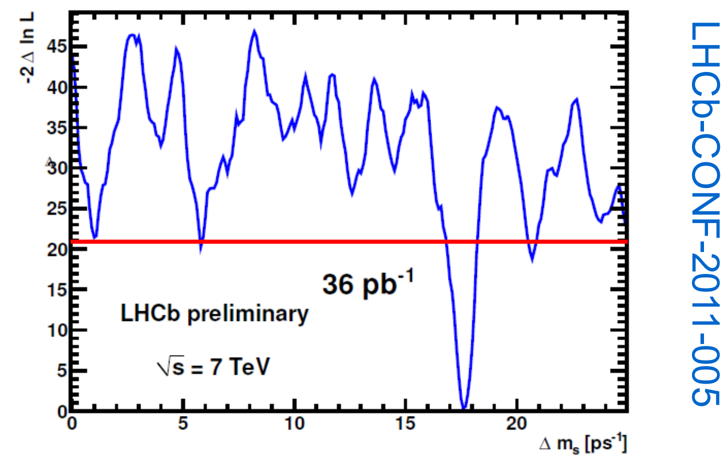
CPV in B^0_s mixing-decay interference, Φ_s, small in SM. A priori excellent place to search for NP. Use $B_s \to J/\Psi\Phi$ decays.



Enticing hints from CDF/D0, strengthened by D0 a_{fs} measurement (CPV in mixing)

And LHCb? Many check-points along way to making Φ_s measurement:

- ability to perform angular analysis
- flavour tagging
- sensitivity to B_s oscillations



Measure Δm_s with $B_s \to D_s(KK\pi)(3)\pi$

$$\Delta m_s = 17.63 \pm 0.11 \text{ (stat.)} \pm 0.04 \text{ (syst.) ps}^{-1}$$

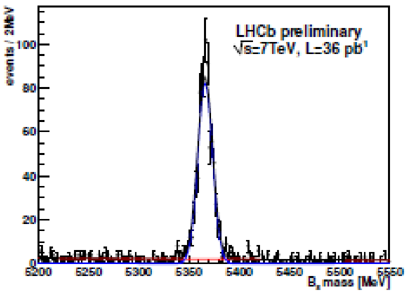
World best !

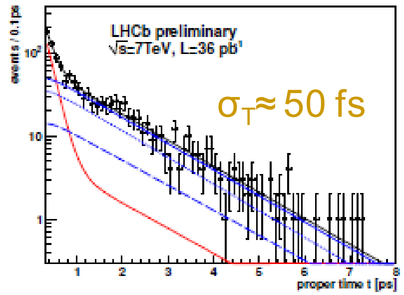
Φ_s at LHCb with 2010 data

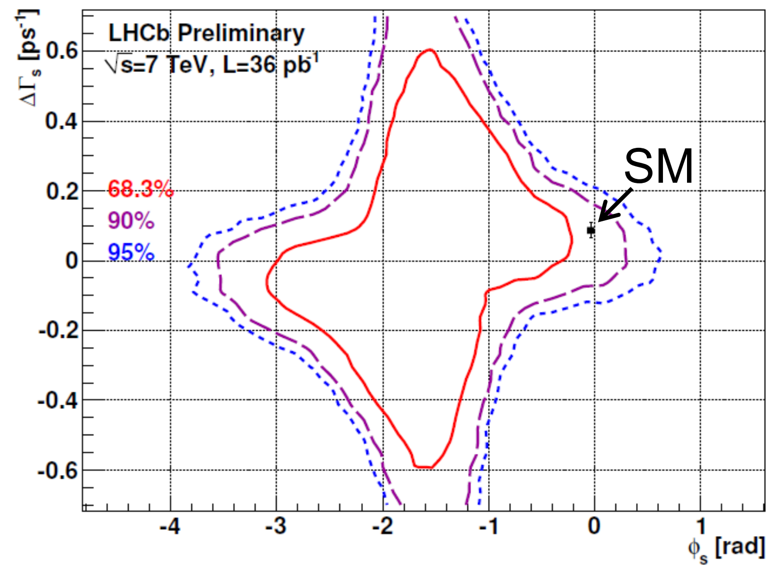
LHCb-CONF-2011-006

Fit made to ~760 events with t > 0.3 ps

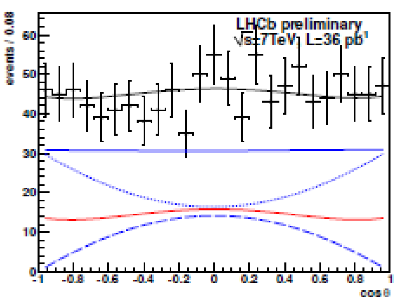
No 'point estimate' with 2010 statistics, rather contours in Φ_s-$\Delta\Gamma_s$ plane

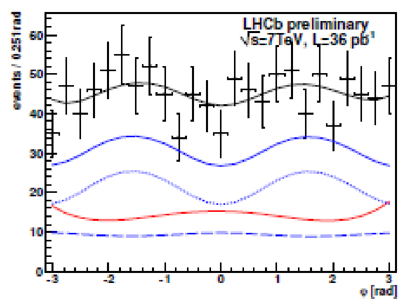


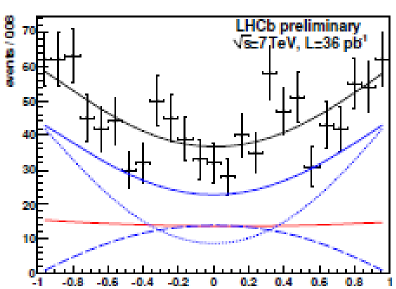




$$\phi_s \in [-2.7, -0.5]\ \text{rad at } 68\%\ \text{CL}$$







Much higher sensitivity expected in 2011:

-Larger sample (x 20 ?)

-Improvement in 'opposite side tagging' (present $\varepsilon D^2 = 2.2 \pm 0.5\%$)

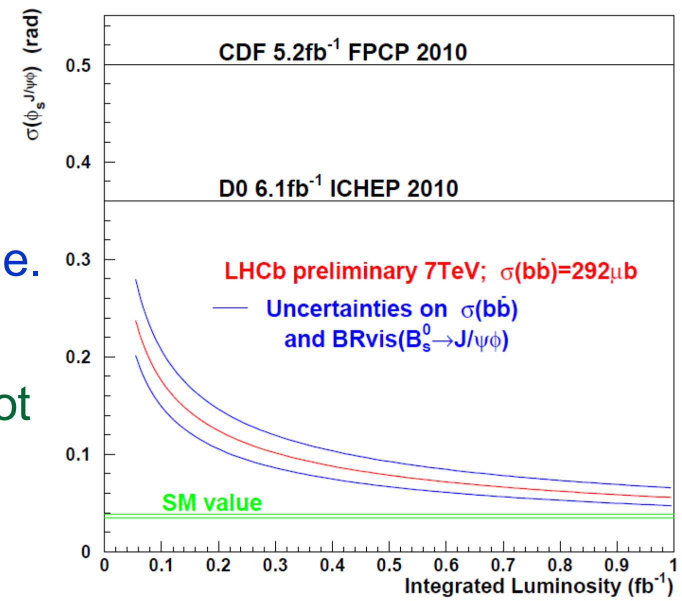
-Inclusion of 'same side' kaon tagger

Φ_s with >> 5 fb^{-1}

High hopes of seeing anomalously high CPV in $B_s \rightarrow J/\Psi\Phi$. What if not? Even after a few fb^{-1} measurement uncertainty ~ size of SM central value.

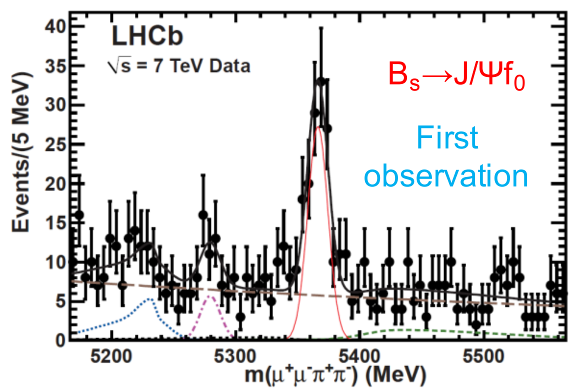
→ If something is observed at this level, much more data needed to understand if its SM or not

(If something seen at higher level, then case for upgrade is straightforward !)



Associated benefits and related issues with 50 fb^{-1}:

- Make precise and experimentally more robust measurements with CP-eigenstate modes e.g. $D_s^+D_s^-$ and $J/\Psi f_0$.
- Combat Penguin uncertainties in SM prediction:
  - Bound from data with $B_s \rightarrow J/\Psi K^{(*)0}$ decays
  - Use Penguin free channel $B_s \rightarrow D^0\Phi$ (s/w trigger will help!)



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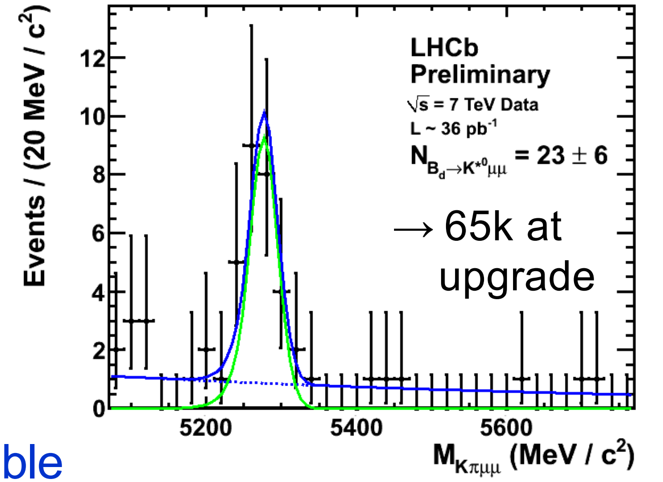
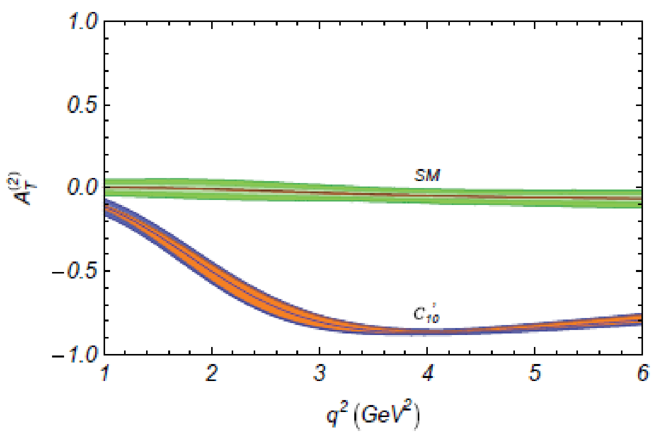
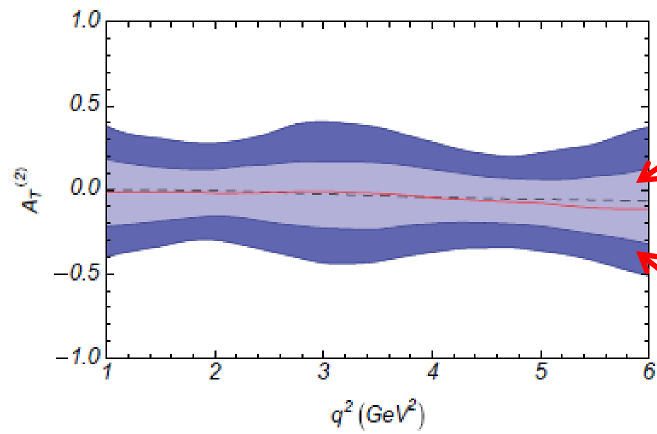
$B^0 \to K^* \mu\mu$: the wonder decay



Angular distributions sensitive to helicity structure of NP. Principal task for current LHCb is to map out A_{FB} curve, & in particular determine 'crossing point'. (B-factories/CDF statistics inadequate)

But several other asymmetries will only be accessible at upgrade, e.g. transversity asymmetry, $A_T^{(2)}$ – highly sensitive to RH currents

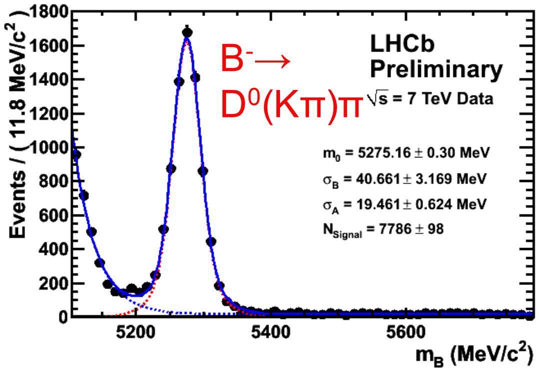


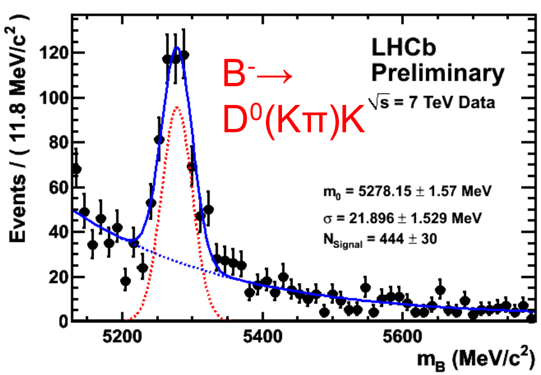


Other modes also become available: $B^0 \to K_2^{*0}\mu\mu$, $B_s \to \Phi\mu\mu$, $B_s \to K^*\mu\mu$, $\Lambda_b \to \Lambda^{(*)}\mu\mu$ (and ~5000 $B^0 \to K^* e^+ e^-$ events, neglecting trigger improvements)

Measuring the least well known angle: γ at LHCb

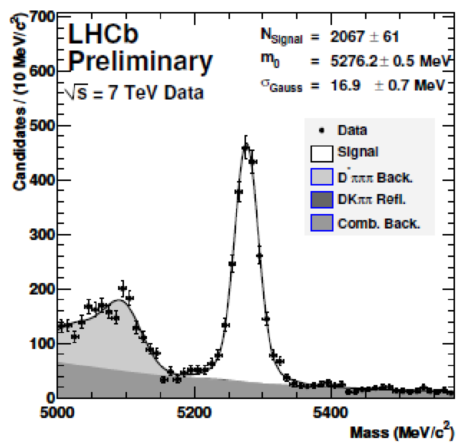
Very clean signals have emerged in B→D(hh)h at ~ expected rate



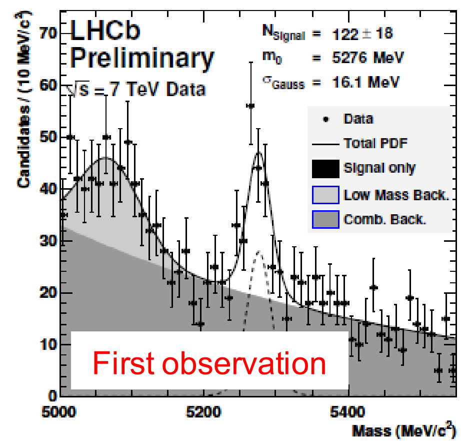


Even in 6 track final states yield and purity excellent – testament to performance of trigger and tracking

$B^0 \to D^+\pi^+\pi^-\pi^+$



$B^- \to D^0K^-\pi^-\pi^+$



LHCb-CONF-2011-024

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+K^-\pi^+\pi^-)}{\mathcal{B}(\bar{B}^0 \to D^+\pi^-\pi^+\pi^-)} = (5.2 \pm 0.9(\mathrm{stat}) \pm 0.5(\mathrm{syst})) \times 10^{-2}$$

2010 B→D(hh)h sample with ~37 pb^{-1} around ¼ size of B-factory yields.

Upgrade will have still higher efficiencies thanks to s/w trigger. Will exploit B→DK strategies, and time dependent B_s methods, and aim for sub-degree precision.

Charm: now & future

LHCb 2010 yields in low multiplicity D decays already comparable to B-factories (x-sec ~ 6 mb* !)

e.g. 1.2×10^5 D^*, $D^0 \to KK$ with 37 pb^{-1}
c.f. 1.1×10^5 with 540 fb^{-1} [Belle, PRL 98 (211803) 2007]

HLT selection now in place for $D \to K^0_S\pi\pi$ to ensure similarly high yields here also.

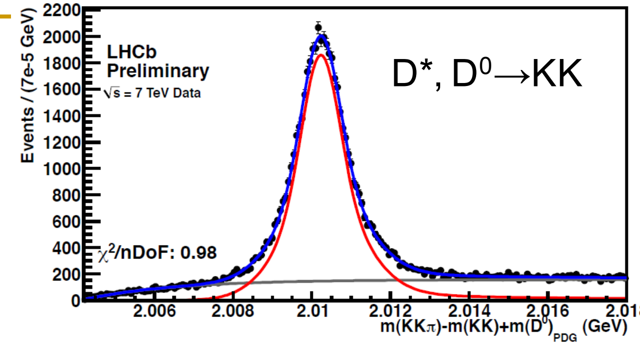
First 2010 data measurement - difference in time integrated CP asymmetry in $D^0 \to KK$ & $D^0 \to \pi\pi$

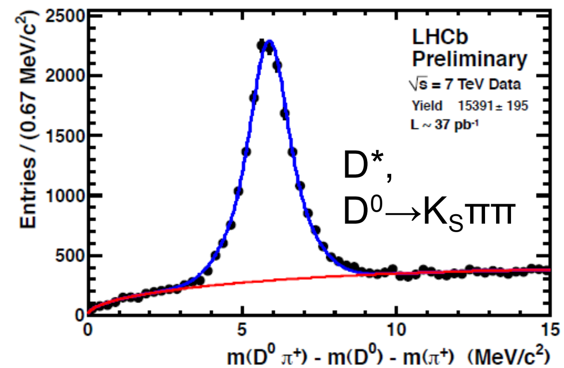
$$\Delta A_{CP} = (-0.28 \pm 0.70 \pm 0.25)\%^{+}$$

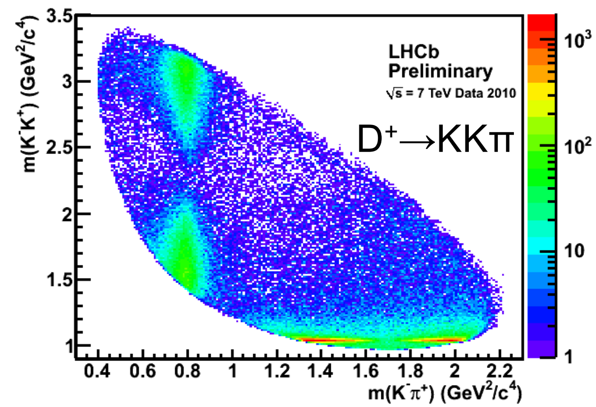
(NB syst.error is itself statistical in nature)

Coming soon: y_{CP}, A_Γ and $D \to KK\pi$ CPV search

LHCb strategy: rare decay searches and CPV studies with 2,3,4 body final states targeting experimentally robust measurements







Upgrade particularly beneficial for high multiplicity charm due to full s/w trigger !

* pp at √s= 7 TeV: LHCb-CONF-2010-013
+ LHCb-CONF-2011-023

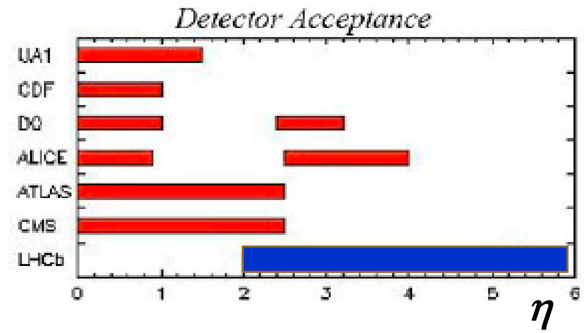
Beyond flavour

Many possibilities – only one example shown here, but suitable topics encompass any LHC phenomena which have forward specific features &/or benefit from precise vertexing / good PID / flexible trigger

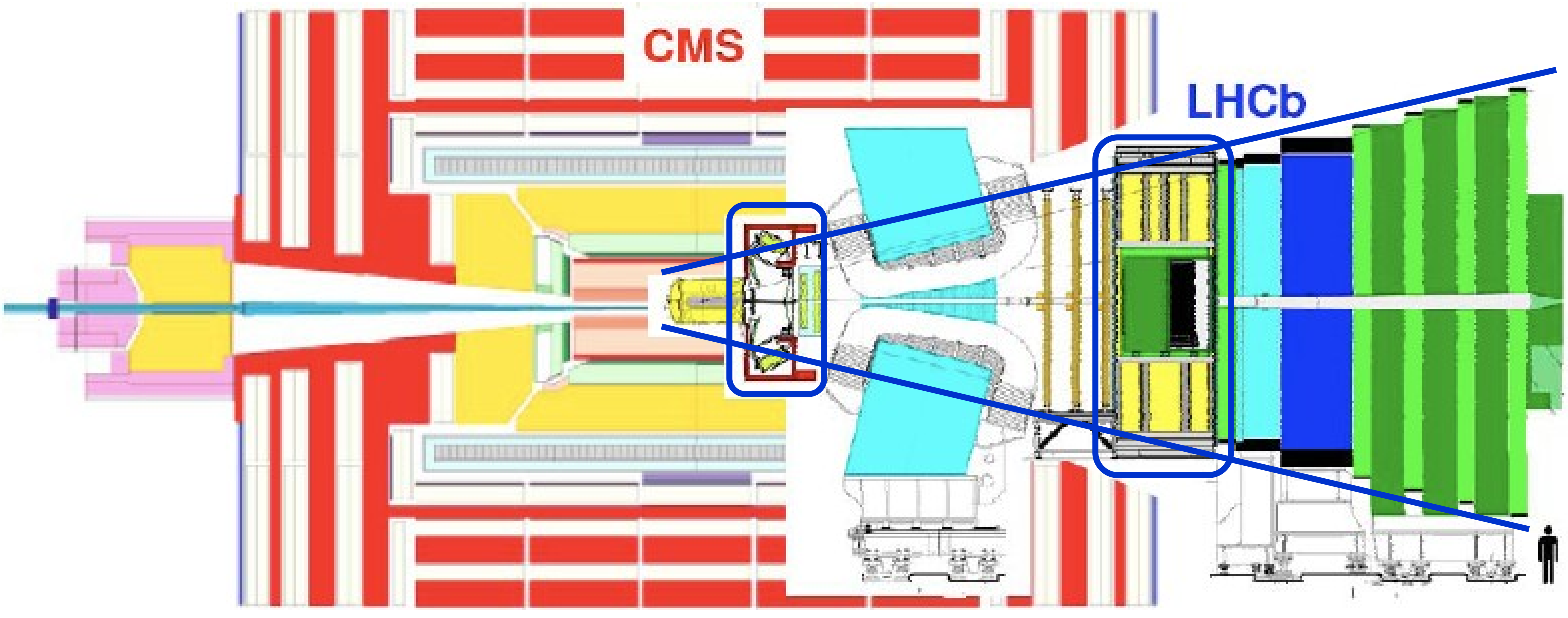
- EW physics and PDF measurements

[Other topics include: onia, QCD (e.g. central exclusive production), forward top physics, search for long lived new particles...]

A GPD in the forward direction



LHCb is as well instrumented as ATLAS and CMS (+ has excellent hadron PID)



but covers a unique pseudorapidity and also has acceptance down to $p_T \sim 0$

LHCb – heavy boson physics & PDF studies

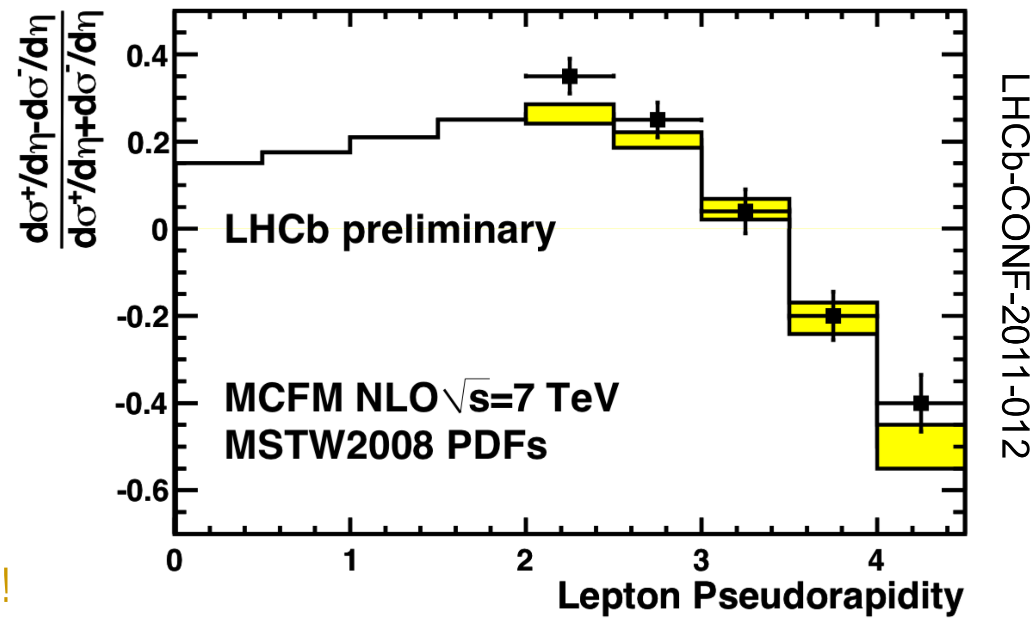
Impact of LHCb's unique acceptance for heavy boson production already clear from preliminary results

e.g. W^+/W^- asymmetry →

Prelim measurement already challenging PDF uncertainties

Precise measurements of W, Z and lower mass Drell-Yan production (benefits from LHCb low p_T acceptance)

→ improve knowledge of PDFs !



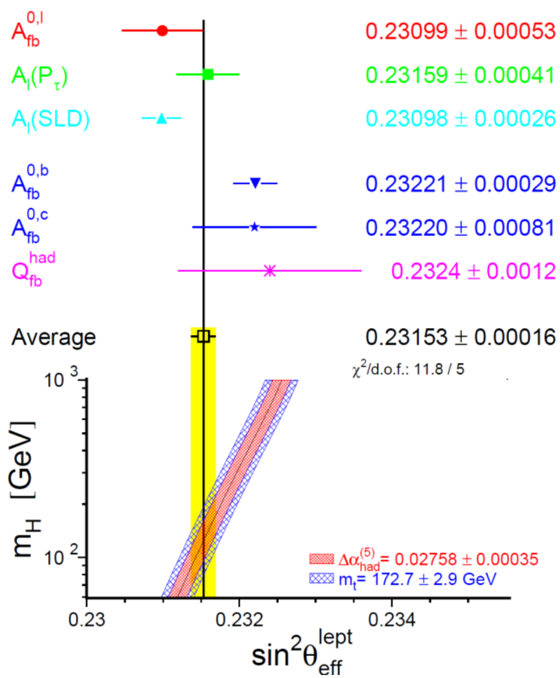
Also, LHCb can make unique measurements to constrain heavy flavour PDFs

$gs \to Wc$, $gc \to Zc$, $gb \to Zb$, $gc \to \gamma c$, $gb \to \gamma b$ ...

Such information will be vital input to precision GPD measurements, e.g. m_W

$\sin^2\theta_{eff}^{lept}$ and A_{FB}

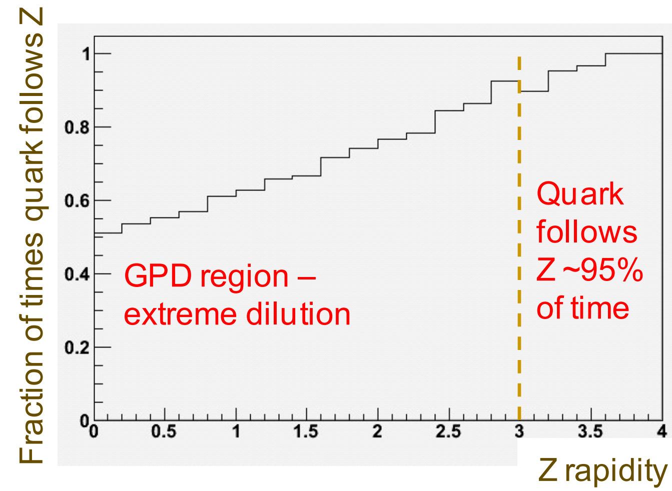
Weak mixing angle a fundamental parameter of EW theory, but no significant progress since LEP/SLD



Note also infamous internal tension between various measurements...

Measure A_{FB} at LHC as was done at LEP, but now initial state is q-qbar...

...need to assign direction to axis – this much easier at LHCb than in GPDs due to dominant valence-sea collisions



(also reduced contribution at LHCb from poorly known s-sbar & c-cbar collisions)

with 50 fb^{-1} can measure $\sin^2\Theta_{eff}$ with stat precision ~2x better than LEP/SLD

Status of approval

LoI on upgrade submitted in March

Positive feedback from LHCC
'..arguments for flavour physics with 50 fb^{-1} very compelling.'

40 MHz readout presently under review

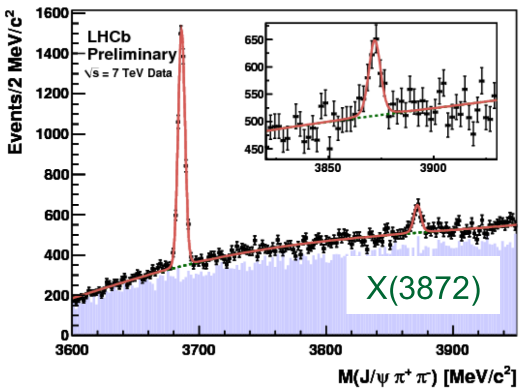
Hope for approval at LHCC June meeting !
→ green light to 2 year R&D period + TDR

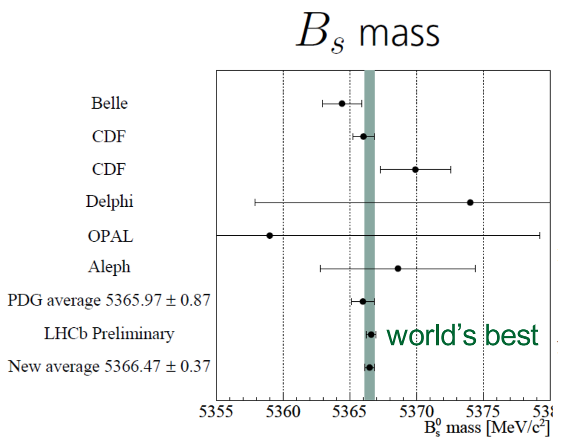
Summary – now and the near horizon

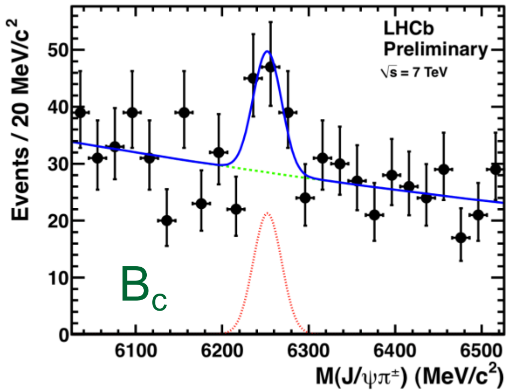
First run in 2010 of LHCb was a great success:

- Trigger and detector performing very close to expectation
- Even with only 37 pb^{-1} have attained current world-best sensitivities in many topics of interest, plus observe new decay modes. A few other highlights not covered today:

LHCb-CONF-2011-021







LHCb-CONF-2011-017

- This was all achieved in pileup conditions foreseen for upgrade !

2011 run has started very well – already have collected >150 pb^{-1}. With ~1 fb^{-1} there is excellent discovery potential in e.g. $B_s \to \mu\mu$, $B_s \to J/\Psi\Phi$, charm CPV...

Summary – looking beyond

Current LHCb experiment collects ~1 fb^{-1}/ yr and will accumulate ~5 fb^{-1} by 2017.
Compelling case to extend flavour programme to ~50 fb^{-1}

- enormous samples of exclusive b- & c-decays, particularly in the B_s sector
- take initial LHCb studies to higher order of precision, and open new frontiers

Unique acceptance of LHCb, & detector capabilities, opens up possibilities in topics beyond flavour, which adds extra dimension to long-term LHC physics programme

What then is needed?

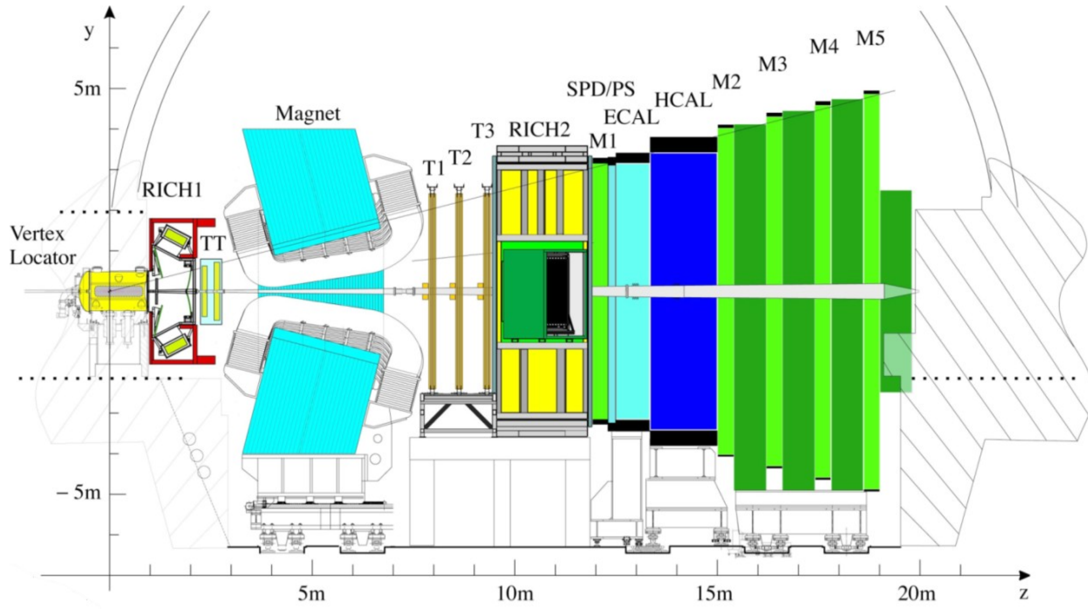
- Nothing new from the machine !
- Detector which can run at ~10^{33} $cm^{-2}s^{-1}$
- Changing to 40 MHz readout and flexible full software trigger
  (→ higher efficiency in many modes)

LHCC approval hoped for in June. Aim to install in 2nd long shutdown (~2018)

Thank you!

Backups

LHCb: differences w.r.t. ATLAS & CMS

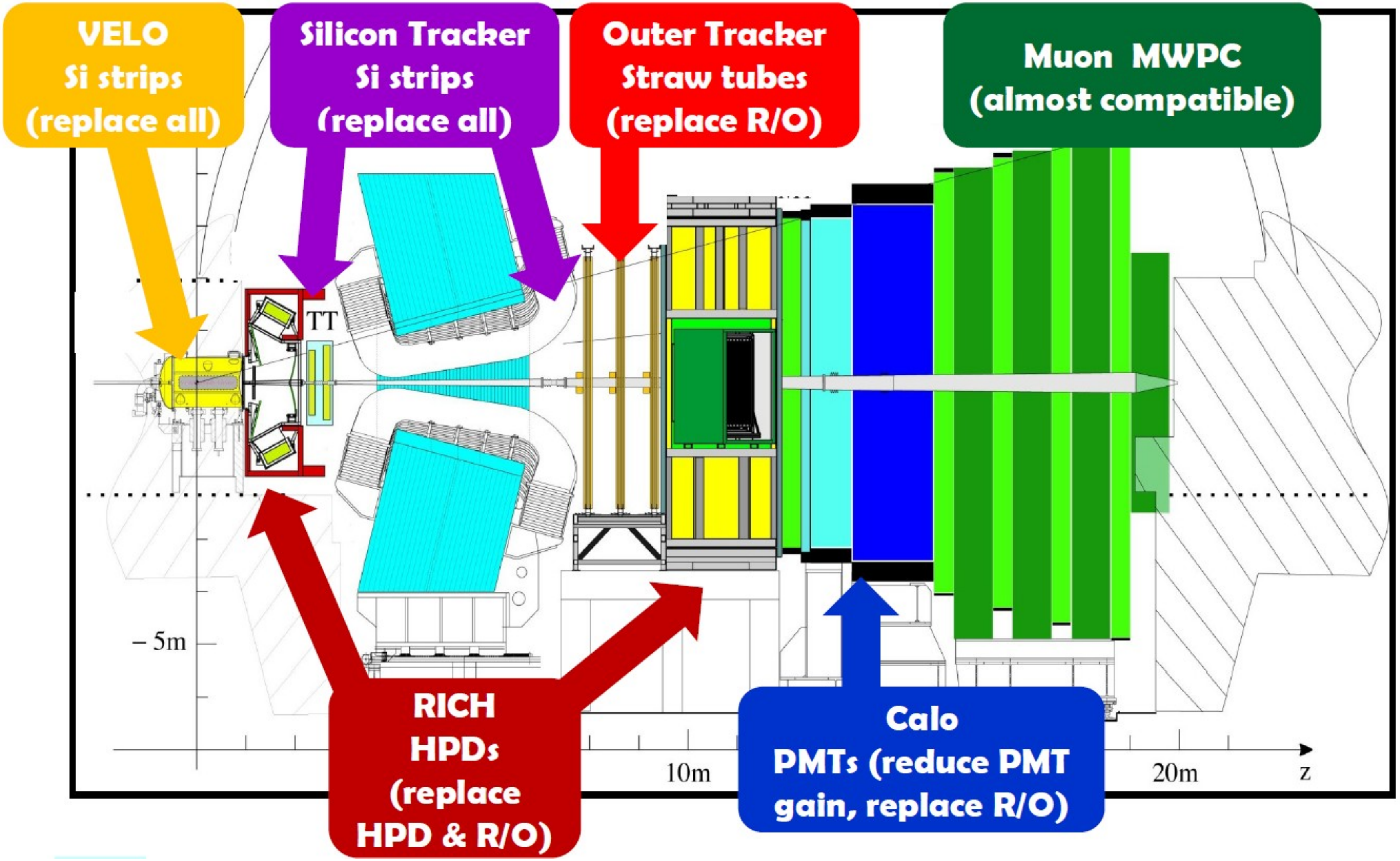


Optimised for flavour physics:

- forward acceptance ($2 < \eta < 5$)
- high bandwidth trigger (3 kHz output)
- acceptance down to low p_T
- precise vertexing (VELO)
- hadron identification (RICHes)

Unique acceptance and high quality instrumentation opens up possibilities in other physics areas!

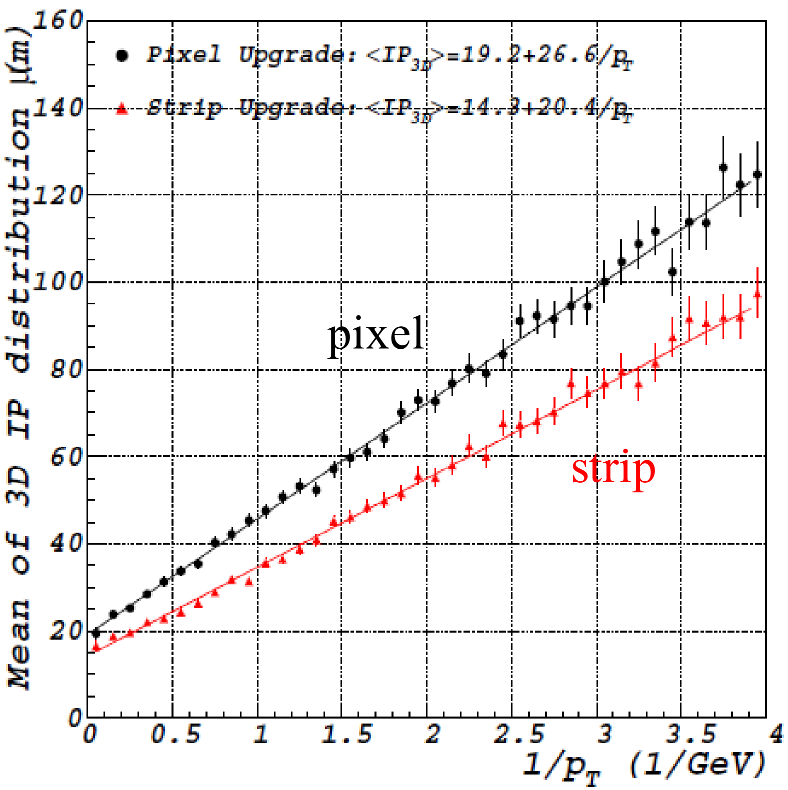
Upgrade of LHCb subsystems



VELO Upgrade

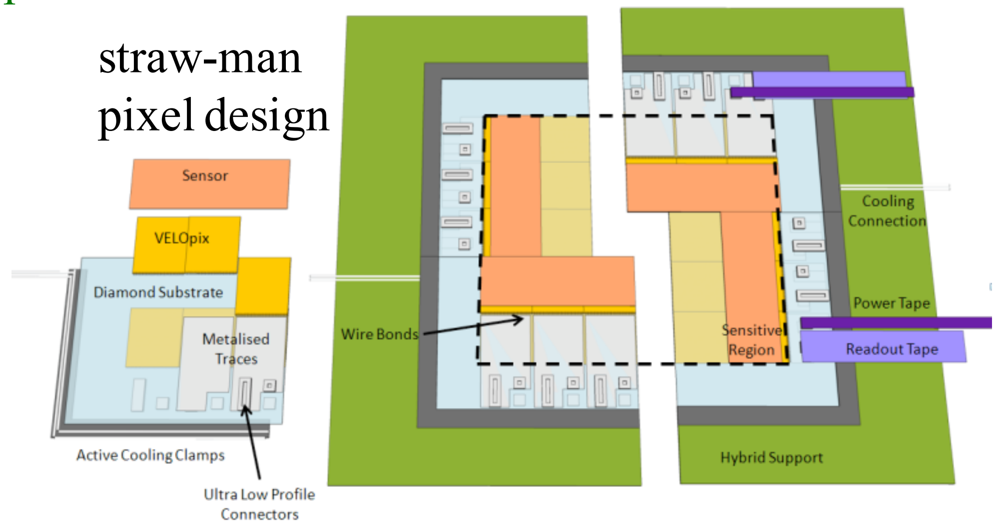
Two options:

- **pixel detector**: VELOPIX based on Timepix chip with 55 µm x 55 µm pixel size advantageous for pattern recognition
- **strip detector**: based on proven design, but with reduced strip pitch and increased number of strips



IP resolution vs $1/P_T$

straw-man pixel design



R&D program :

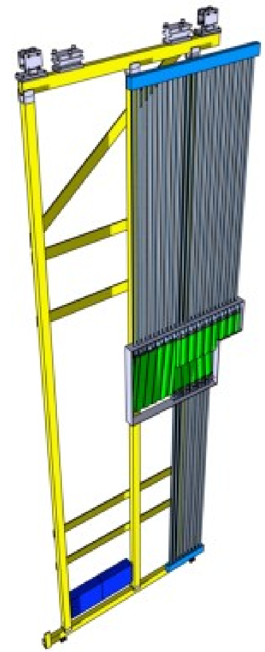
- module structure (X_0)
- sensor options: Planar Si, Diamond, 3D
- CO_2 cooling
- electronics
- RF-foil of vacuum box

Main Tracker upgrade: OT, IT, TT

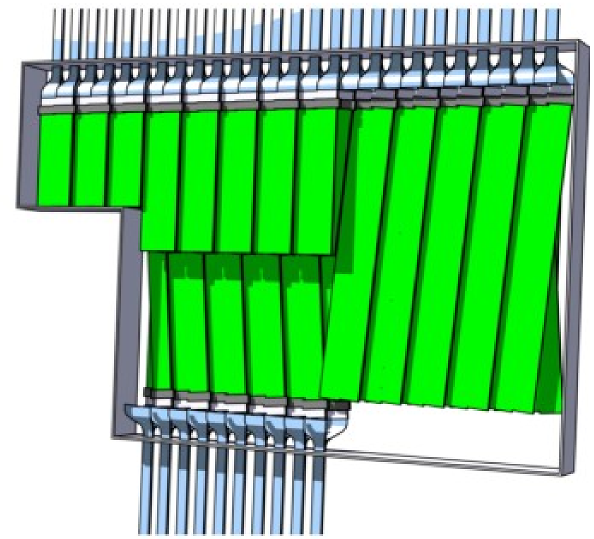
IT and TT detectors must be replaced:
(1 MHz electronics integrated)

Two options:

- Silicon strips (current technology, but R/O outside acceptance?)
- 250 µm Scintillating Fiber Tracker (new technology)



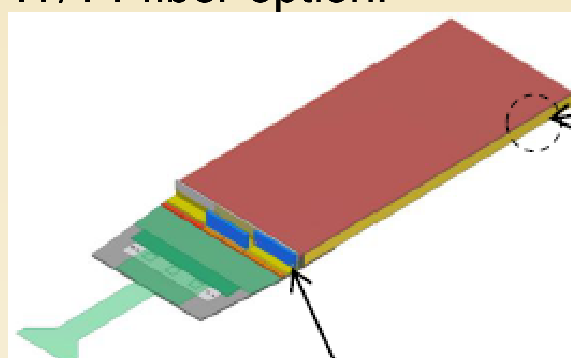
IT-fiber detector layout:



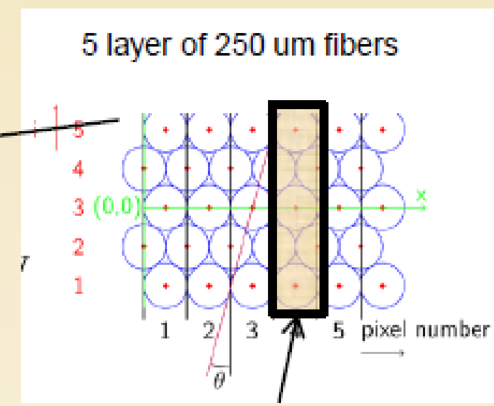
R&D started:

- 250µm scint. fibres (8 layers)
- fibres coupled to SiPM
- SiPM radiation tolerance?
- ASIC investigation started

IT/TT fiber option:



SiPM array



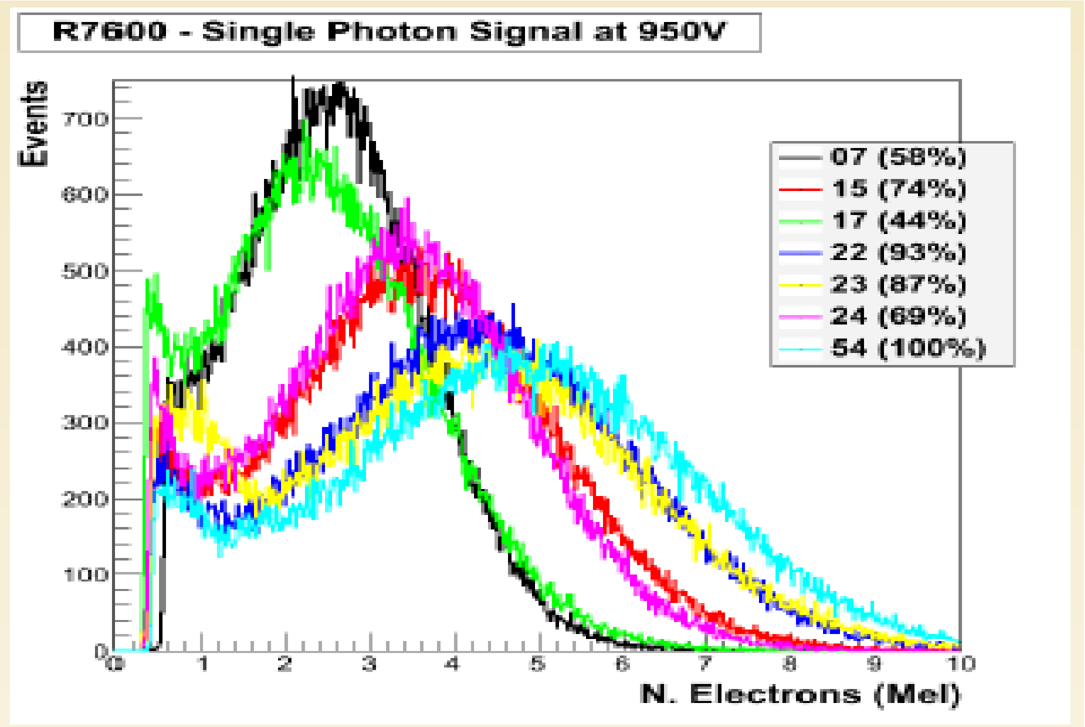
SiPM cell coverage

PID upgrade: RICH detectors

RICH-1 and RICH-2 detectors remain:

- baseline option: replace pixel HPDs by MaPMTs & readout out by 40 MHz ASIC
- alternative: new HPD with external readout

MaPMT (baseline) option



Prototyping using MAROC3:

- Gain compensation
- Binary output

Digital functions in ACTEL

PID upgrade: TORCH

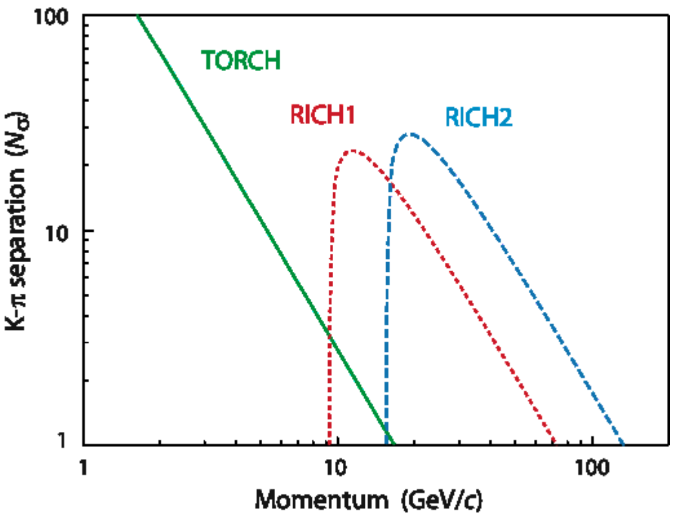
Low momentum tracks:

replace Aerogel by Time-of-Flight detector "TORCH"

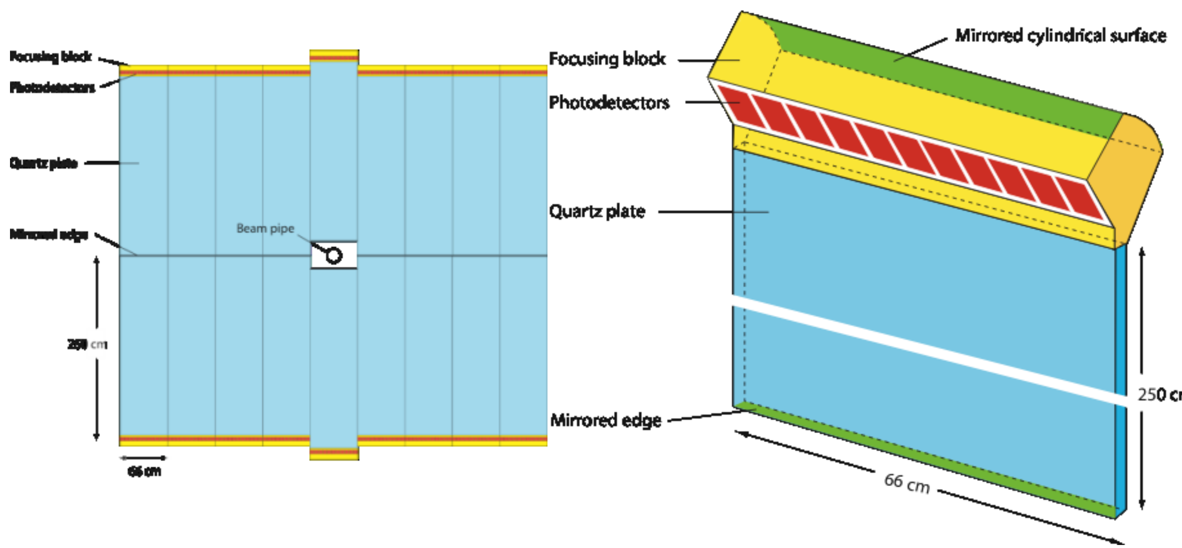
(TORCH=Time Of internally Reflected Cherencov light)

- 1 cm thick quartz plate combining technology of time-of-flight and DIRC
- measure ToF of tracks with 10-15 ps (~70 ps per photon).

K-π separation vs p in upgrade:



TORCH detector:



→ could be installed later than 2018!

Physics strategy – illustrative examples

	Exploration	Precision studies
Current LHCb	Search for $B_s \to \mu^+\mu^-$ down to SM value Search for mixing induced CP violation in B_s system $(2\beta_s)$ down to SM value Look for non-SM behaviour in forward-backward asymmetry of $B^0 \to K^*\mu^+\mu^-$ Look for evidence of non-SM photon polarisation in exclusive $b \to s\gamma^{(*)}$	Measure unitarity triangle angle γ to $\sim 4°$ to permit meaningful CKM tests Search for CPV in charm
Upgraded LHCb	Search for $B^0 \to \mu^+\mu^-$ Study other kinematical observables in $B^0 \to K^*\mu^+\mu^-$, e.g. $A_T(2)$ CPV studies with gluonic penguins e.g. $B_s \to \phi\phi$ Measure CP violation in B_s mixing (A^s_{fs})	Measure $\mathcal{B}(B_s \to \mu^+\mu^-)$ to a precision of $\sim 10\%$ of SM value Measure $2\beta_s$ to precision $< 20\%$ of SM value Measure γ to $< 1°$ to match anticipated theory improvements Charm CPV search below 10^{-4} Measure photon polarisation in exclusive $b \to s\gamma^{(*)}$ to the % level

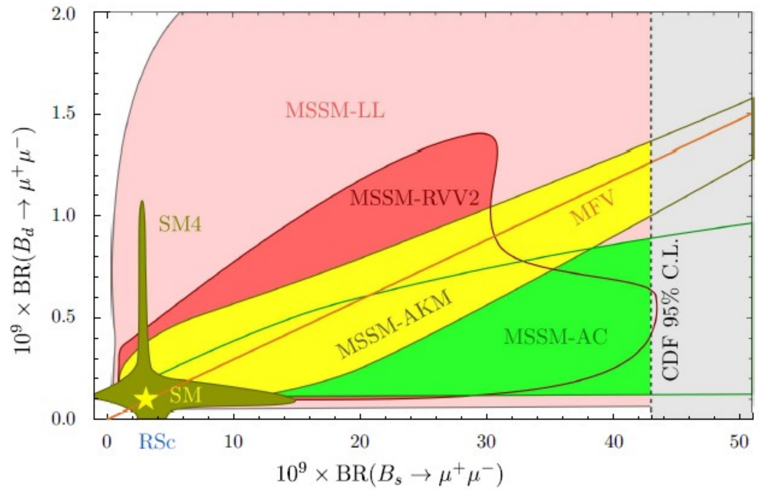
Impact on New Physics Models

LHCb upgrade will provide measurements essential to understand physics landscape that the coming decade will unveil. Lets consider two popular ideas.

Minimal Flavour Violation (MFV) hypothesis

All sources of flavour- and CP-violation in quarks will be same as SM. In this case searches for NP will be fruitless in CPV, but not in rare decays

e.g. In MFV BR($B_s \to \mu\mu$) *can* differ from SM but *not* BR($B_d \to \mu\mu$)/BR($B_s \to \mu\mu$)



SM with 4-families (SM4)

Add 2 new quarks (t', b') plus 5 new quark-mixing parameters

New CPV possibilities that could show up in D^0, B^0 and B_s system

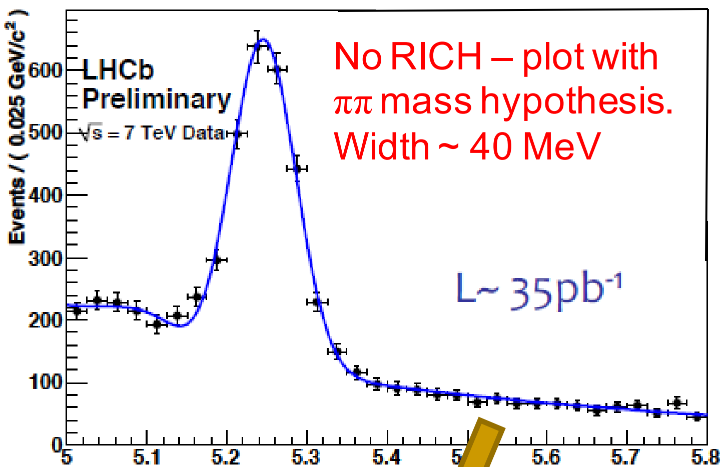
Both proposals can be disproved / strongly constrained with improved flavour data

Two body charmless B-decays

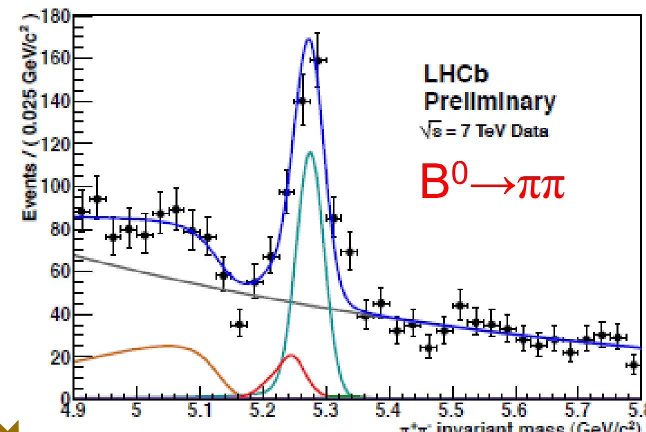
LHCb-CONF-2011-011

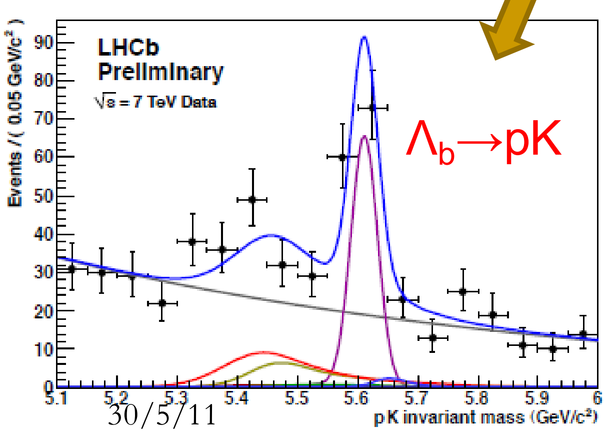
Two-body charmless B-decays central to LHCb physics. The significant contribution of Penguin diagrams provide entry points for new physics.

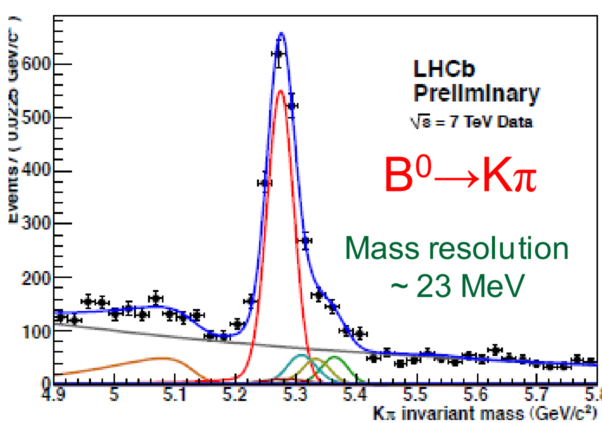
Experimentally, rely on good performance of hadron trigger and RICH system

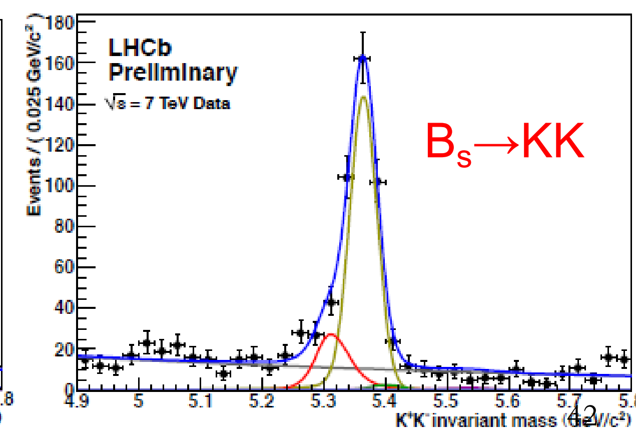


Deploy RICH to isolate each mode



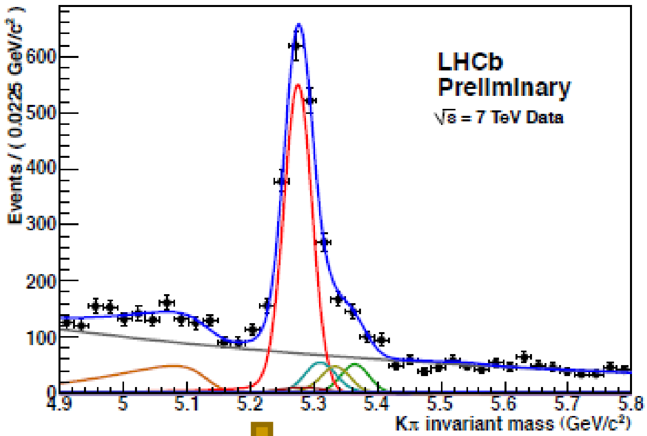




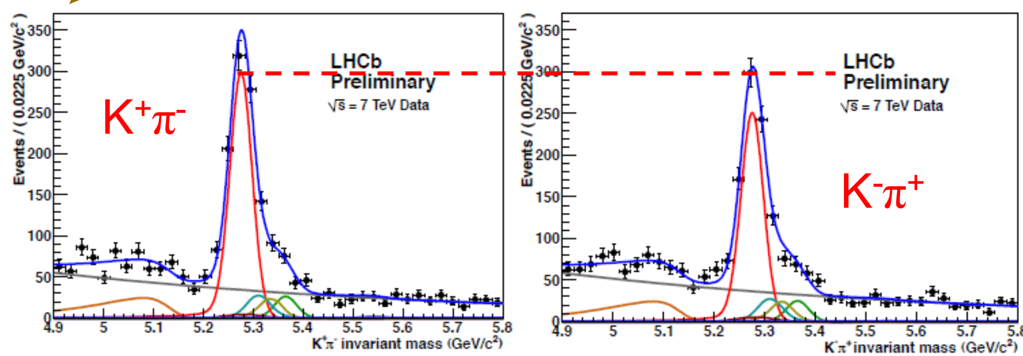


A closer look at B→Kπ

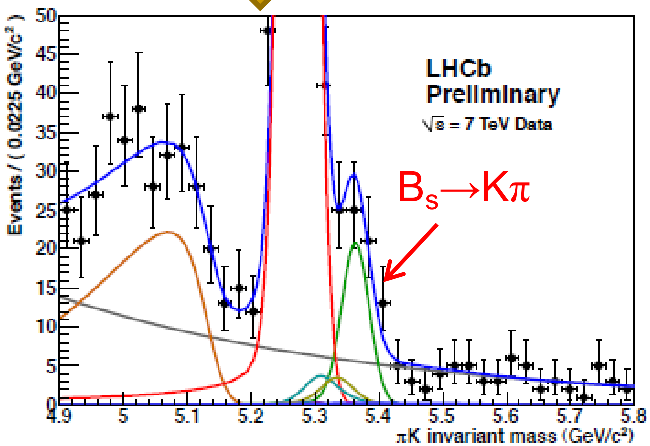
LHCb-CONF-2011-011



Divide into B^0 and B^0-bar



Tighter selection



CP-violation observed at >2σ with central value consistent with world-average:

$$A_{CP}(B^0 \to K^+\pi^-) = -0.074 \pm 0.033 \pm 0.008$$

(uncertainty presently 3x world average), and a corresponding result for $B_s \to K\pi$:

$$A_{CP}(B_s^0 \to \pi^+ K^-) = 0.15 \pm 0.19 \pm 0.02$$

Precision very similar to CDF 1 fb^{-1} result !

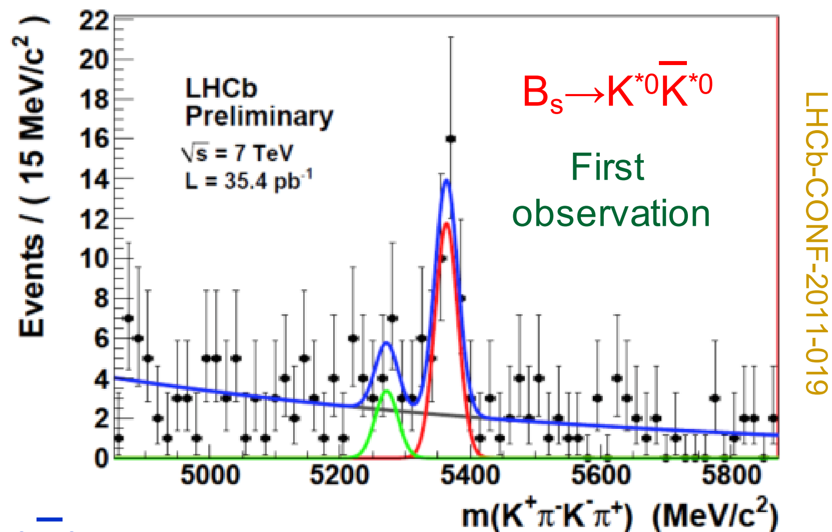
Charmless B decays: now and future

Tasks with the first 5 fb^{-1} – main goal New Physics sensitive γ measurement:

- precise measurement of time-integrated CP asymmetries, relative BRs, and discovery of suppressed modes e.g. $B_s \to \pi\pi$, $B^0 \to KK$
- first time-dependent measurements of $B_s \to KK$ and improved knowledge of $B^0 \to \pi\pi$ asymmetry (resolve BABAR Belle 'tension') $\to \gamma$ determination
- studies of $B \to hhh$: as above, especially *first* exploration of B_s modes, e.g. $K_S\pi\pi$, $K_SK\pi$

And then with 50 fb^{-1}:

- all of the above with much higher sensitivity, esp. B_s modes
- first precise measurements of CP-asymmetry in new 'two-body' modes, e.g. $B_s \to \Phi\Phi$, $B_s \to K^{*0}\overline{K}^{*0}$, $B_s \to K^0\overline{K}^0$



$$\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0}) = (1.95 \pm 0.47(\mathrm{stat.}) \pm 0.51(\mathrm{syst.}) \pm 0.29\,(f_d/f_s)) \times 10^{-5}$$

New physics in a_{fs}^{s}… or in a_{fs}^{d} ?

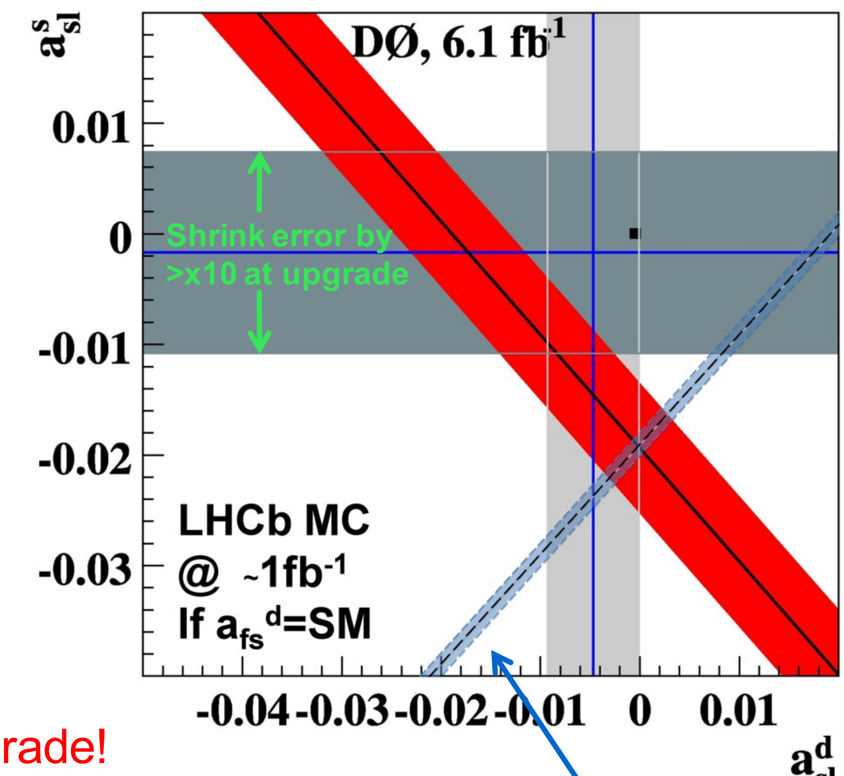
Related measurement is the study of flavour specific asymmetries which are sensitive to CPV in mixing.

Difficult! Semi-leptonic decays carry hard to control systematics

LHCb baseline method will be to determine difference of a_{fs}^{s} and a_{fs}^{d} by looking at difference of asymmetry in common final state $(KK\pi)_{D,D_s}\,\mu\nu$

Promising, but if non-SM result found we need to test whether it is B_s or B_d

Systematically robust $B_s \rightarrow D_s(KK\pi)\pi$ can do this, but requires statistics of upgrade!

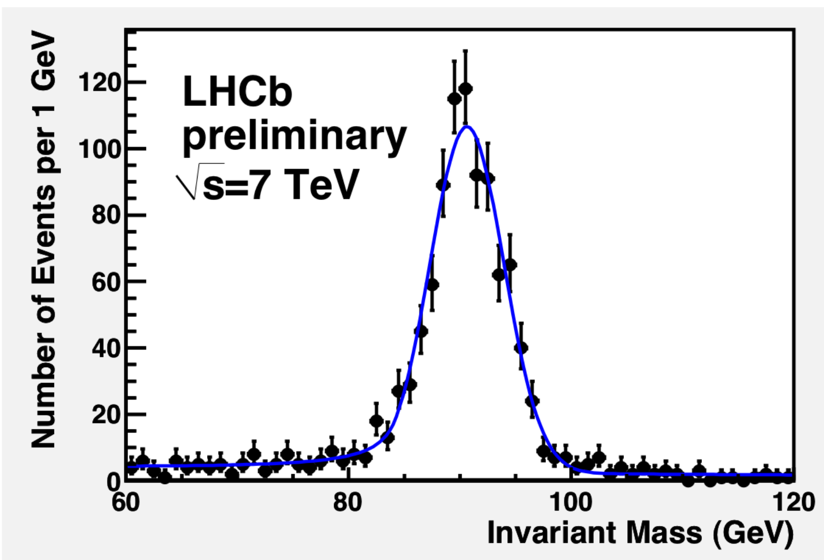


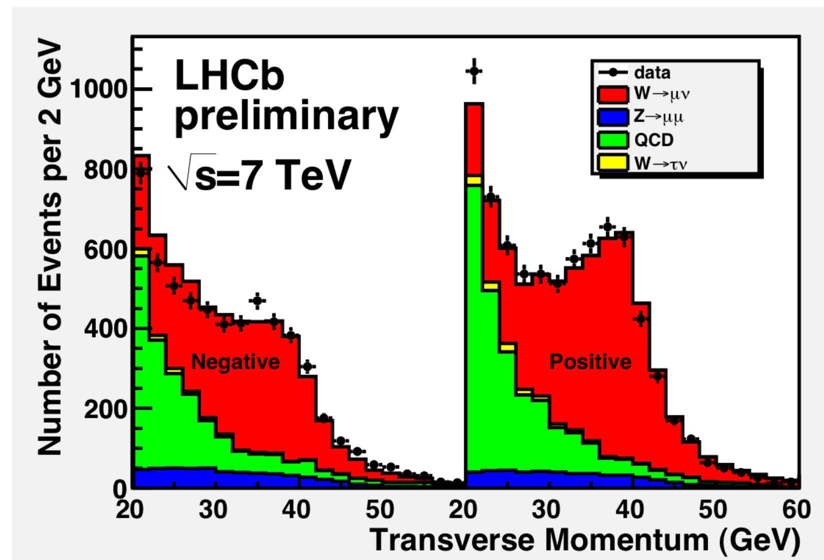
LHCb stat precision with 1 fb^{-1} plotted for D0 central value & no NP in a^{d}_{sl}

Electroweak physics

First W/Z studies at LHCb: ~12,000 W events and ~ 800 Z events in 16.5 pb^{-1}

Very encouraging – but lower statistics than GPDs....





...but forward acceptance gives LHCb advantages/complementarity to GPDs which can be exploited in future measurement programme

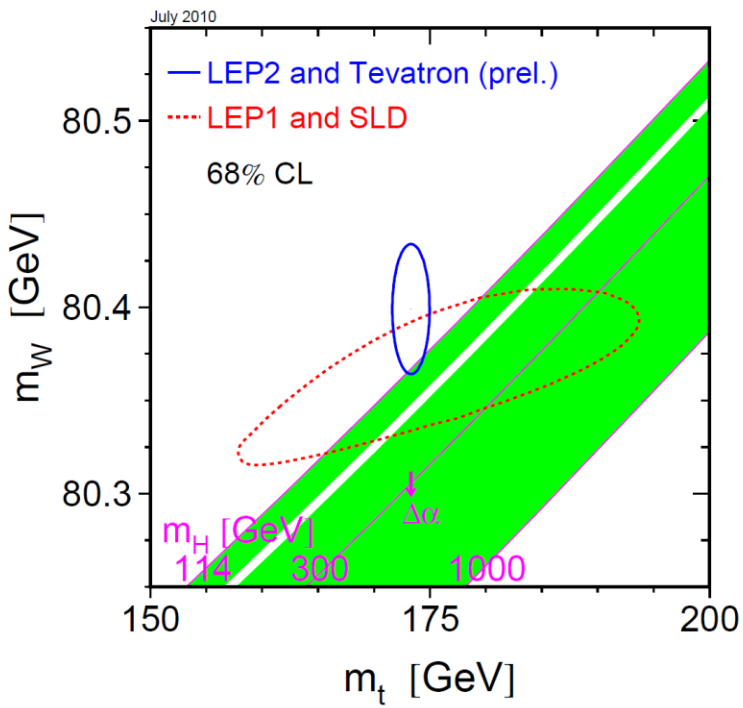
m_W and $\sin^2\theta_{eff}^{lept}$

m_W and the LHC

Constant goal in HEP: to make ever better measurement of m_W (even after Higgs is found!).

Present uncertainty is 23 MeV

Tevatron will improve this, but techniques which work there cannot be imported to the LHC as p-p collisions don't allow for same cross-checks!



arXiv:1004.2597

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–PH–EP/2010-007
TPJU–1/2010
12 March 2010

$\Delta M_W \leq 10$ MeV/c^2 at the LHC: a forlorn hope? †

Abstract

At the LHC, the measurement of the W mass with a precision of $\mathcal{O}(10)$ MeV/c^2 is both mandatory and difficult. In the analysis strategies proposed so far, shortcuts have been made that are justified for proton–antiproton collisions at the Tevatron, but not for proton–proton collisions at the LHC. The root of the problem lies in the inadequate knowledge of parton density functions of the proton. It is argued that in order to reach a 10 MeV/c^2 precision for the W mass, more precise parton density functions of the proton are needed, and an LHC-specific analysis strategy ought to be pursued. Proposals are made on both issues.

M.W. Krasny[1,*], F. Dydak[2], F. Fayette[1], W. Płaczek[3], and A. Siódmok[1,3]

ATLAS and CMS will have the statistics to go to a few MeV, but external systematics problematic

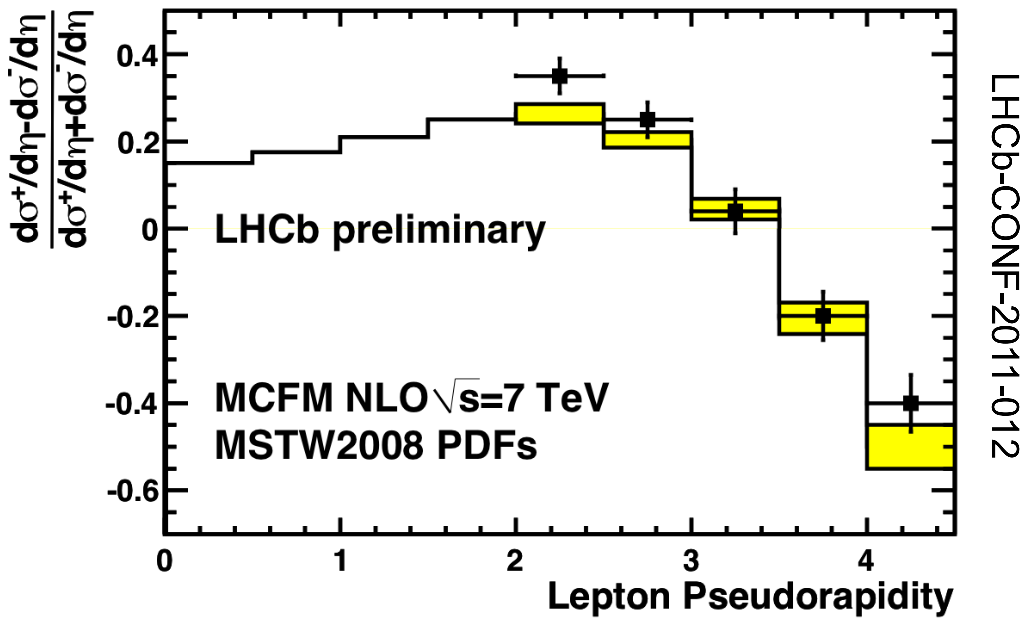
Big problem will be knowledge of PDFs in general, and that of heavy PDFs in particular (20-30% contribution to W production in GPDs)

m_W measurement is a *long term* programme

LHCb input to PDFs and m_W measurement

Impact of LHCb's unique acceptance for heavy boson production already clear from preliminary results

e.g. W^+/W^- asymmetry →



Prelim measurement already challenging theory uncertainties

Precise measurements of W, Z and lower mass Drell-Yan production (benefits from LHCb low p_T acceptance)

→ improve knowledge of PDFs !

Furthermore, LHCb can make unique measurements which will constrain HF PDFs

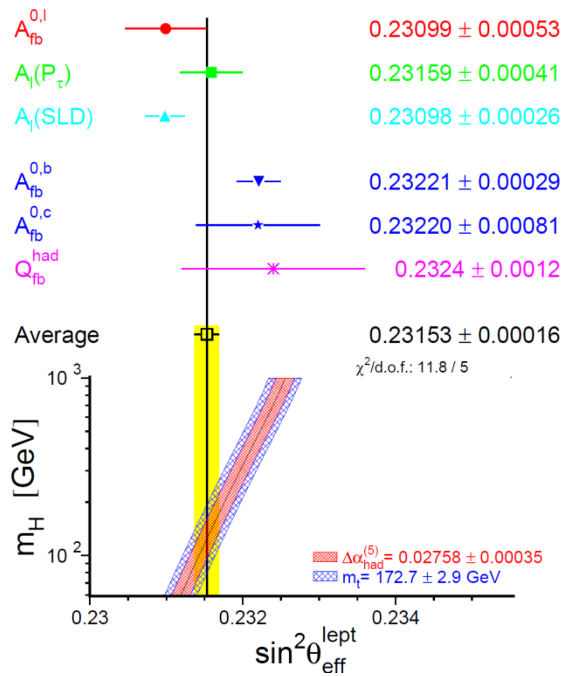
Look for:

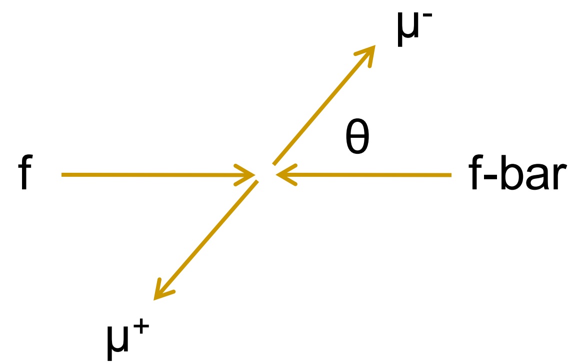
gs→Wc, gc→Zc, gb→Zb, gc→γc, gb→γb ...

$\sin^2\theta_{eff}^{lept}$ and A_{FB}

Weak mixing angle a fundamental parameter of EW theory, but no significant progress since LEP/SLD

Can be measured with A_{FB}, as at LEP, but at LHC the initial state is quark-antiquark, not e^-e^+





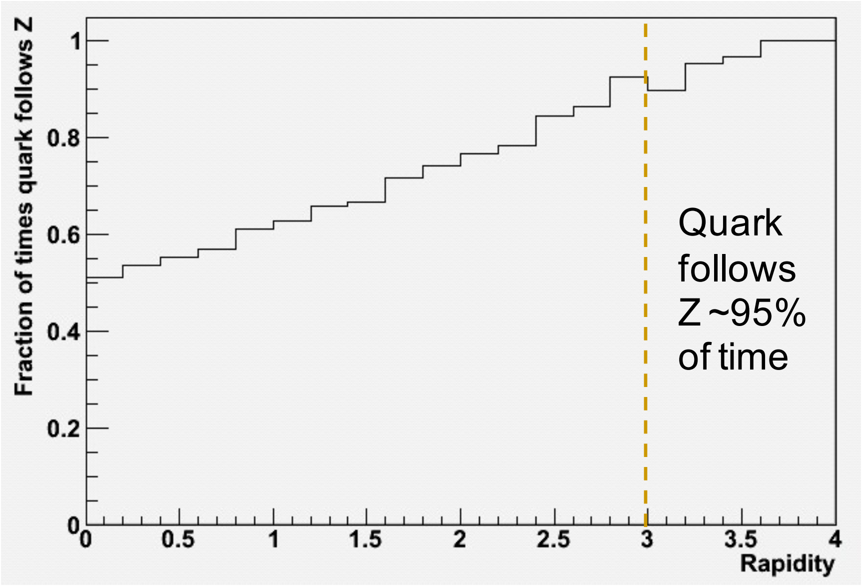
This requires knowing which angle is θ, & so whether it is the q or q-bar which is travelling from left to right.

Note also infamous internal tension between various measurements…

Respective role of valence and sea quarks in collision therefore critical !

$\sin^2\theta_{eff}^{lept}$ and A_{FB}

In very central region not possible to know which direction matter parton going



A side benefit is that LHCb has:

u-ubar → Z
d-dbar → Z

No need to worry about poorly known s-sbar and c-cbar contributions !

But in forward region the collisions are dominated by valence-sea

Conclusion: LHCb *much* better suited to A_{FB} measurement than GPDs.

LHCb with 50 fb^{-1} could achieve $\sin^2\theta$ stat precision ~ twice better than LEP/SLD

Some improvement needed in PDF knowledge, but here LHCb well placed...

Opportunities in QCD: Central Exclusive Production

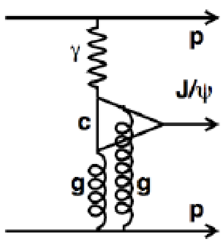
CEP provides clean, novel & promising way to study QCD & nature of new particles e.g. exotics, glueballs...

$pp \rightarrow p + X + p$

rapidity gaps

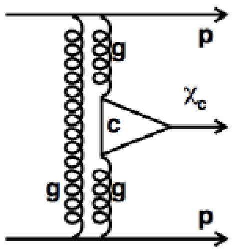
Exclusive J/Ψ, Ψ(2S) production

γ – pomeron

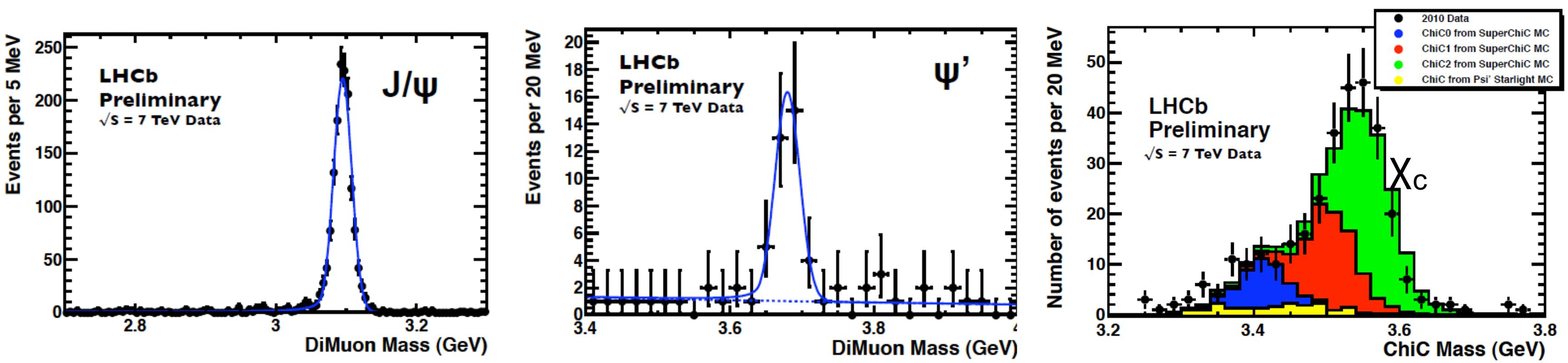


Exclusive χ_c production

pomeron – pomeron



Signature: ~ no activity (even in backward silicon planes) apart from signal



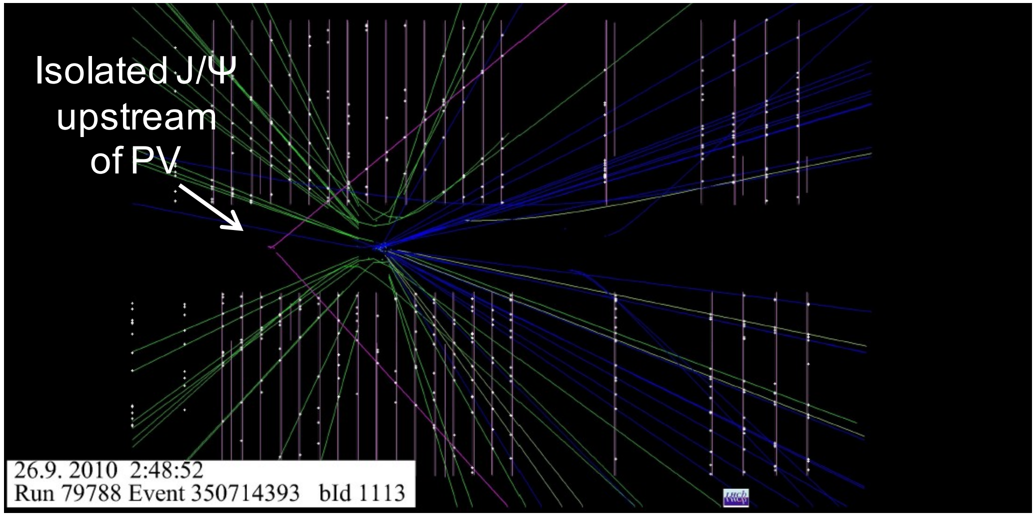
LHCb-CONF-2011-022

Preliminary cross-sections determined: broadly consistent with expectation. With 2011 data will explore ϒ & Φ regions. Extensive programme of study feasible!

Future CEP physics at upgraded LHCb

CEP well suited to LHCb, and will benefit from upgrade:

- Even at 10^{33} LHCb will have many single event interactions (2010 conditions!)
- Even so, with software trigger can select CEP vertices in pileup events



- Low p_T acceptance a big advantage for low mass studies
- Event samples of >10 fb^{-1} needed to perform detailed studies of many states, e.g. χ_b , production x-sec of which x1000 down on χ_c
- As ever, PID a powerful asset