LHCb STATUS AND SELECTED PHYSICS RESULTS

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Outline

- Introduction to the LHCb experiment
- Some selected physics results
- Prospects
- Conclusions

Many thanks to P.Campana, J.Albrecht, R.Forty, C.Gaspar and many others for (un) knowingly helping me!

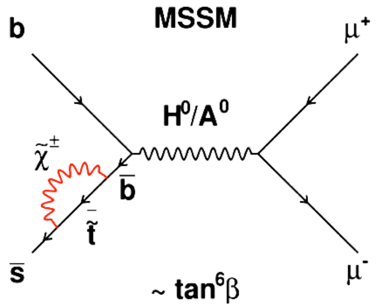
The LHCb Experiment

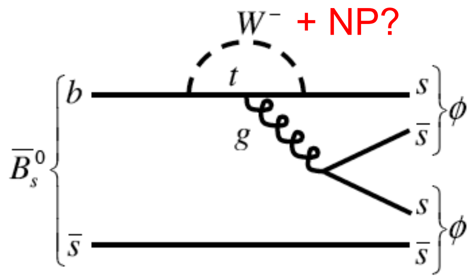
- **LHCb**: an experiment at LHC searching for NP beyond the SM through the study of very rare decays of b and c-flavoured hadrons and precision measurements of CP-violating observables.

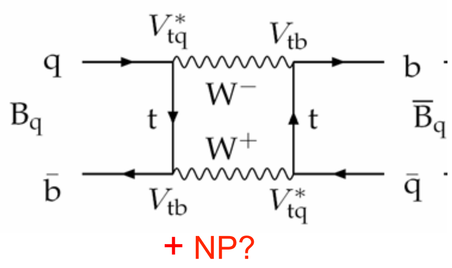
- First results from LHCb have already made a significant impact on flavour physics and proved the concept of a dedicated experiment in the forward region at a hadron collider.

The LHCb roadmap

- Measure processes that are strongly suppressed in the SM and poorly constrained by existing data, but that have sensitivity to new particles at high mass scales via their virtual effects in loop diagrams (complementary approach to direct searches):







- Search for possible inconsistencies in measurements of angles and sides of unitarity triangles: compare results from decays dominated by tree-level diagrams with those that start at loop level to probe validity of SM
- **The precise study of b and c decays, the observation of very rare decay modes, and the accurate measurement of CP violation asymmetries is an essential tool for the identification of New Physics.**

Why the b quark?

- Heavy quarks have a short lifetime t:

  $\tau_{charm} \sim 10^{-12}$ s

  $\tau_{beauty} \sim 1.5\ 10^{-12}$ s

  $\tau_{top} \sim 5\ 10^{-25}$ s

  $$\tau \sim 1/(m^5\ |V_{CKM}|^2)$$

  While the t quark lifetime is too short, the b and c quarks live long enough so that we can study their production and decay sequence in detail.

- The b quark is ideal for experimental study of V_{CKM} and CP violation:
  - relatively long lifetime
  - high mass (many possible decay final states)
    - "A 'b' is the elephant of the particle zoo: it is very heavy and lives a long time" (T.Schietinger).
  - larger CP asymmetries than for s and c
  - theoretical predictions can be precisely compared with experimental results

Why the b quark?

- The b lifetime is long enough for it to propagate an observable distance D when produced at the LHC:

$$D = \beta \gamma c \tau$$

$$\tau_{beauty} \sim 1.5\ 10^{-12}\ s$$

At the LHC:

$\beta = v/c \sim 1$

$\gamma = E/mc^2 \sim 20$

(E: b energy)

$$D = 20 \cdot 3 \cdot 10^{10} \cdot 1.5 \cdot 10^{-12} \sim 1\text{cm}$$

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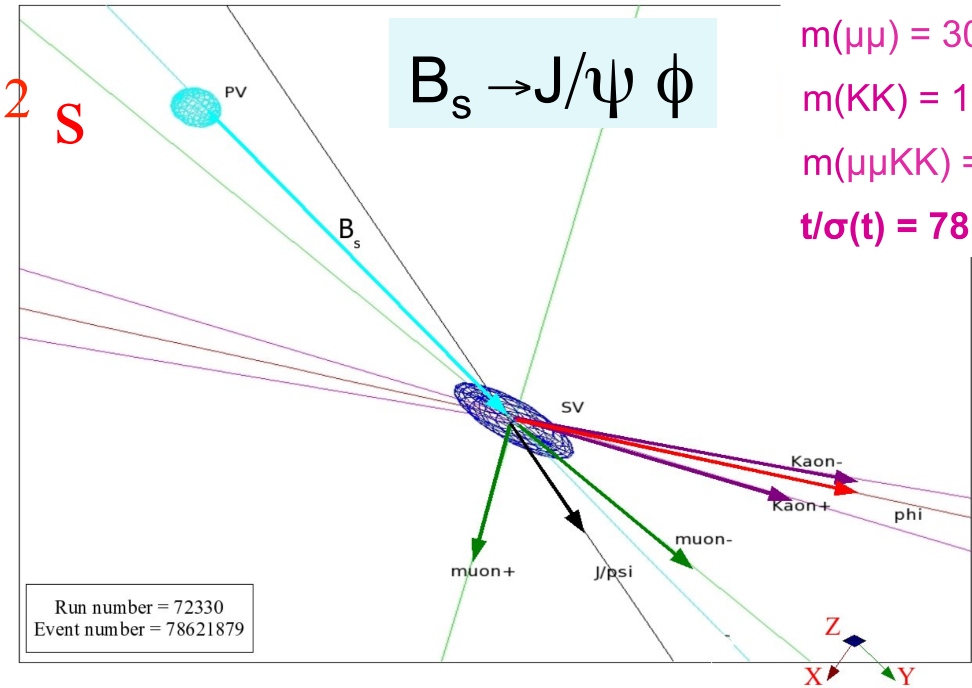

$m(\mu\mu) = 3072\ MeV/c^2$

$m(KK) = 1020\ MeV/c^2$

$m(\mu\mu KK) = 5343\ MeV/c^2$

$t/\sigma(t) = 78$ (L = 20 mm!)

At the LHC:

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$\gamma = E/mc^2 \sim 20$

(E: b energy)

$$D = 20 \cdot 3 \cdot 10^{10} \cdot 1.5 \cdot 10^{-12} \sim 1cm$$

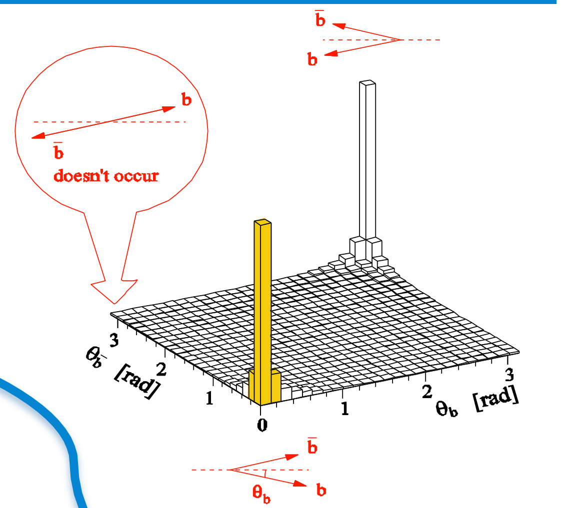
b production at LHC

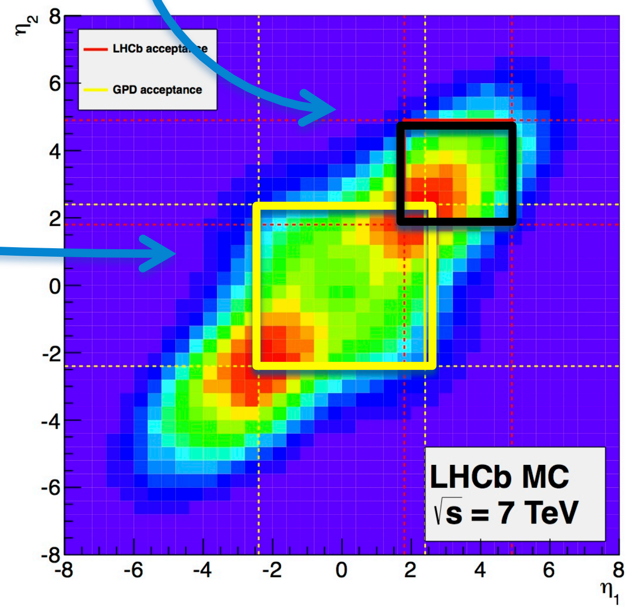
- Advantages of beauty physics at hadron colliders:
  - High value of beauty cross section at LHC:
    - σ_{bb} ~ 250-500 μb @$\sqrt{s}$=7-14 TeV (σ_{bb}@Y(4s) ~1 nb → >10^5 factor)
    - Measured at 7 TeV ~ 280 μb (~70 μb in LHCb acceptance)
    - σ_{cc} is 20 times larger!
  - ~10^{11} b decays (1 fb^{-1})

    ~10^{12} c decays in LHCb acceptance
  - Access to all b-hadrons: $B^{\pm}$, B^0, B_s, B_c, b-baryons
    - In particular can study the B_s (bs) system, not studied at the B factories, but measured by CDF/D0
- The challenges
  - Rate of background events: σ_{inel}~ 60 mb @$\sqrt{s}$=7 TeV
    - → Trigger is essential!

LHCb Acceptance

- Detector designed to maximize b acceptance (in cosθ)
- b-hadrons produced at low angle
  - Forward spectrometer $2<\eta<5$
  - Single arm OK as b quarks are produced in same forward or backward cone
- Rely on much softer, lower P_T triggers than ATLAS/ CMS, efficient also for purely hadronic decays
- ATLAS/CMS: $|\eta|<2.5$
  - Will do B-physics using high P_T μ triggers, mostly with modes involving di-μ
  - Purely hadronic modes triggered by tagging μ



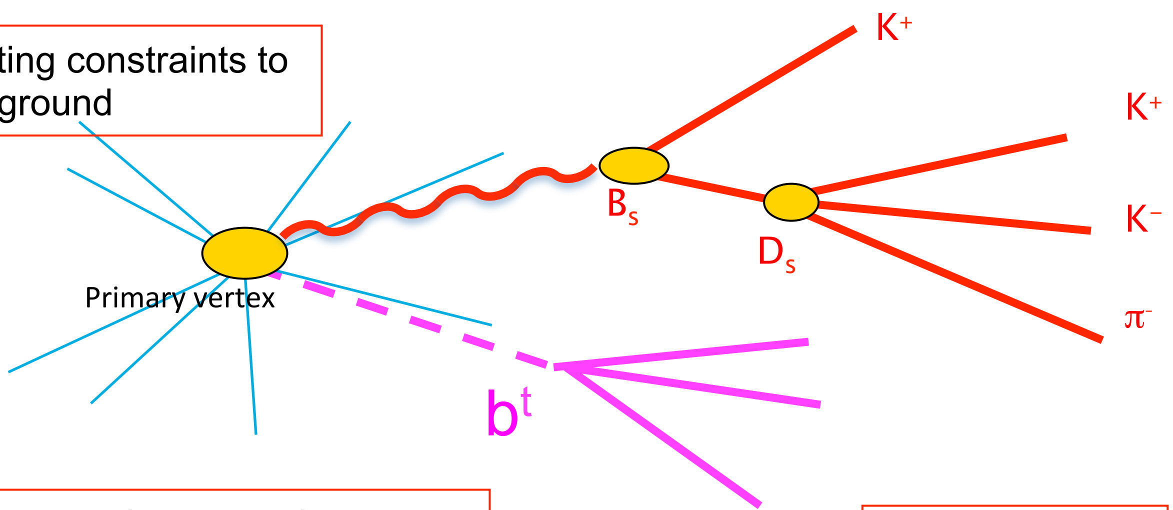


Detector Requirements

- Key features:
  - Highly efficient trigger for both hadronic and leptonic final states to enable high statistics data collection
  - Vertexing for secondary vertex identification, capability to resolve fast B_s oscillations (B_s oscillation period ~350 fs)
  - Mass resolution to reduce background
  - Particle identification

Example: $B_s \rightarrow D_s K$

Mass + pointing constraints to reduce background

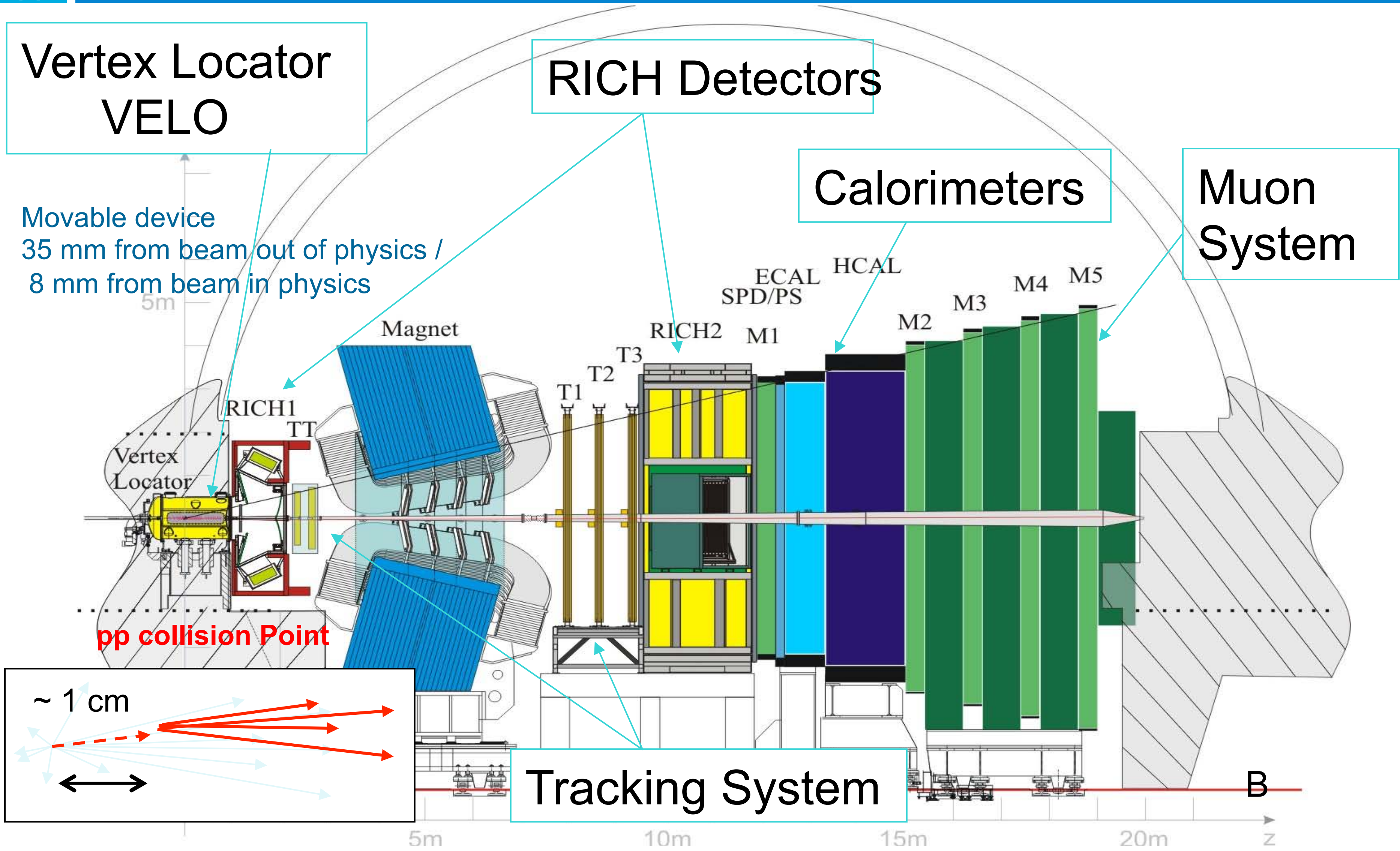


Good K/π separation

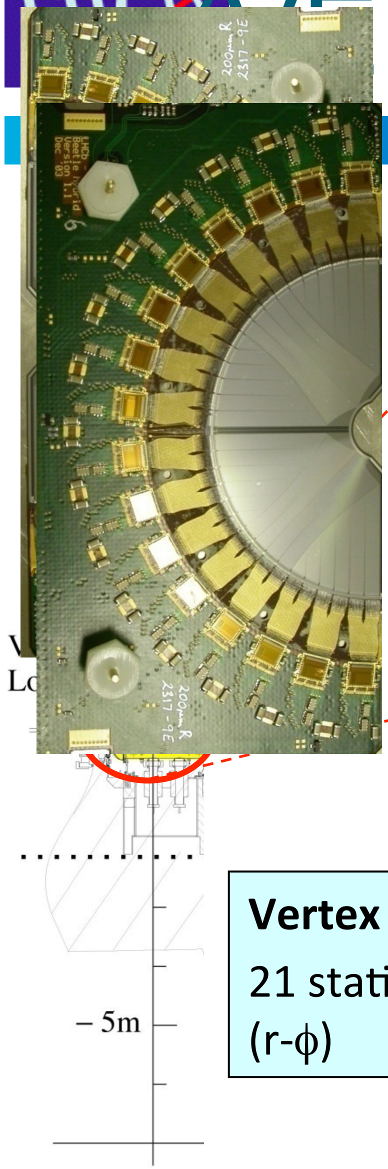
Good primary + secondary vertexing to measure proper time

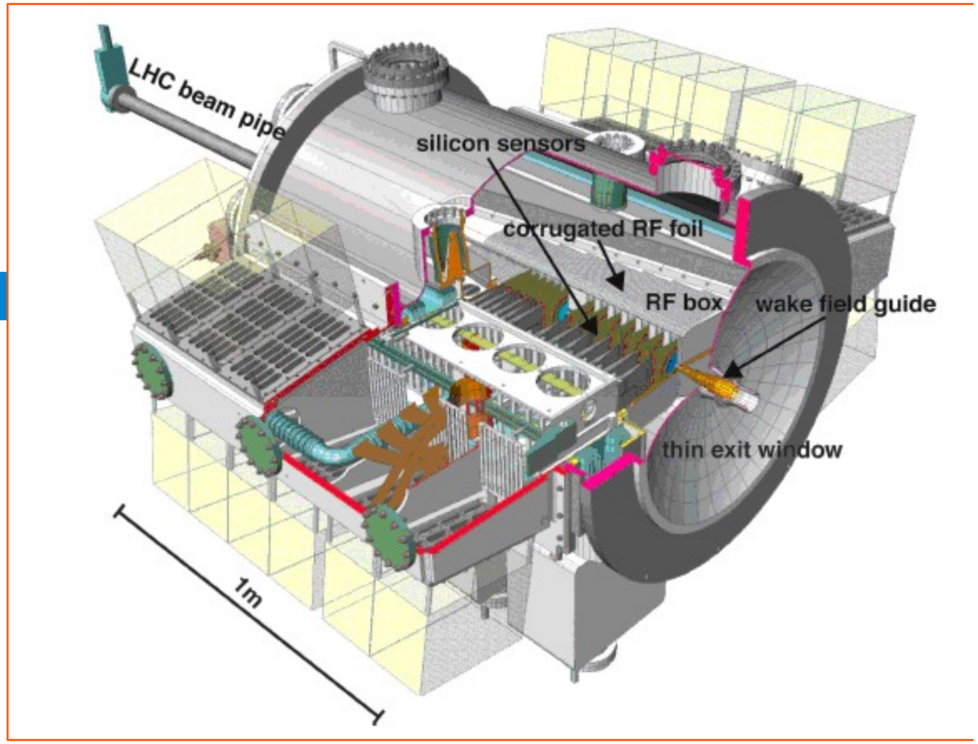
Flavour Tagging

The LHCb Detector



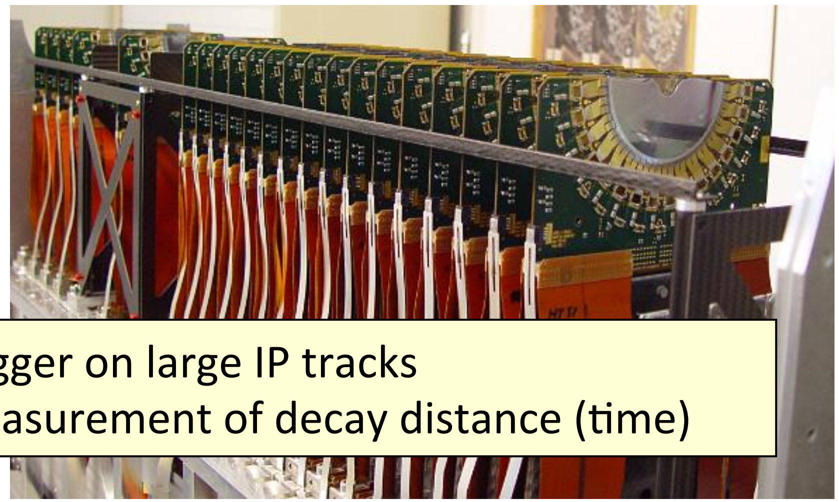
Vertex Locator (VELO)





Vertex Locator (Velo)

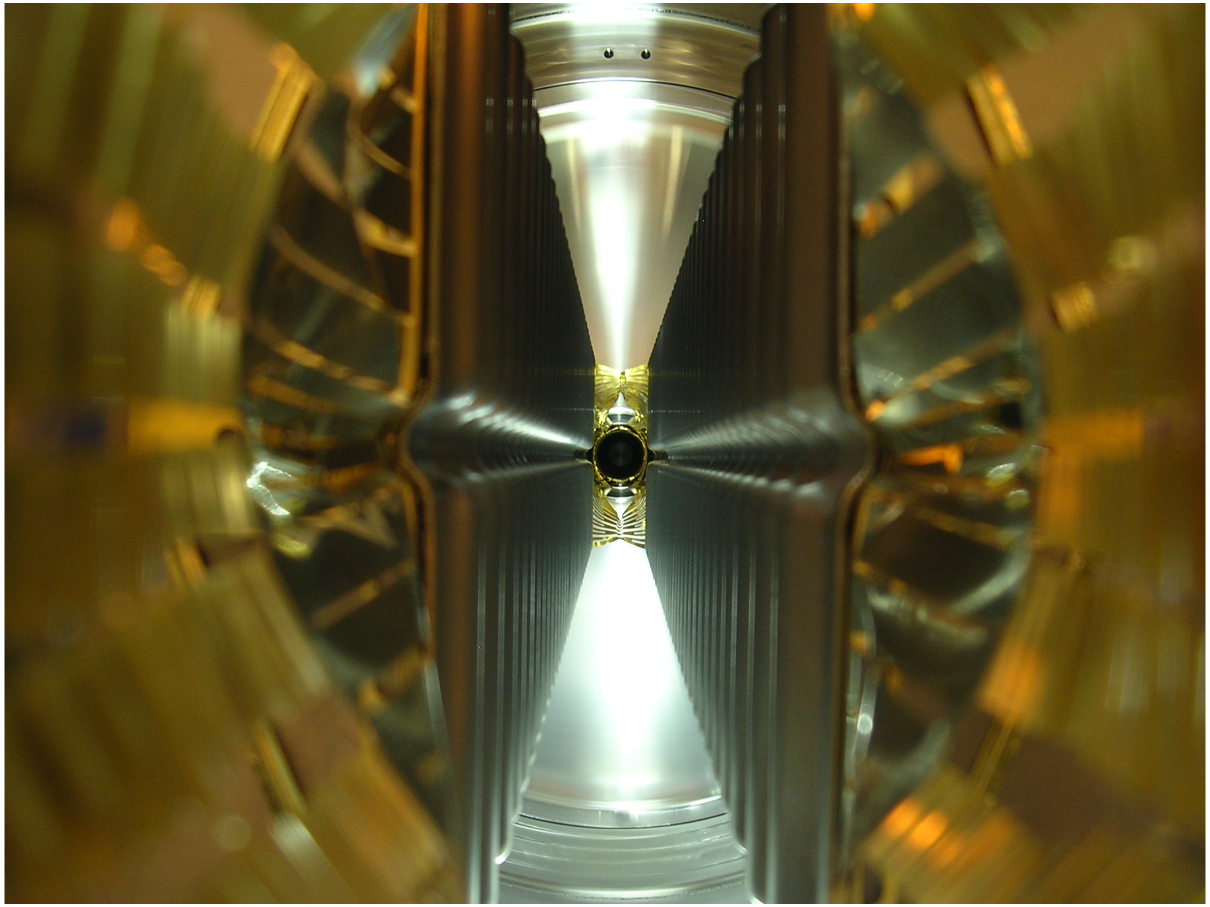
21 stations of silicon strip detectors (r-ϕ)



- Trigger on large IP tracks
- Measurement of decay distance (time)

Vertex Locator (VELO)

- As seen by the colliding protons…

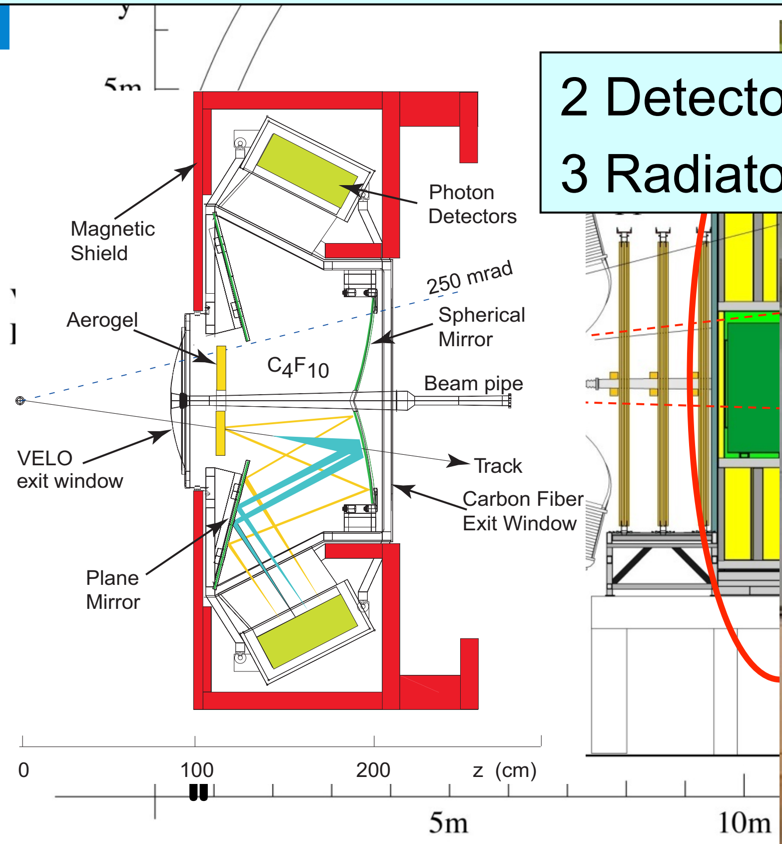


RICH Particle Identification

RICH: K/p identification using Cherenkov light emission angle

2 Detectors

3 Radiators



RICH1 Aerogel (2-10 GeV),
C_4F_{10} (10-60 GeV)

RICH2 CF_4 (16-100 GeV)

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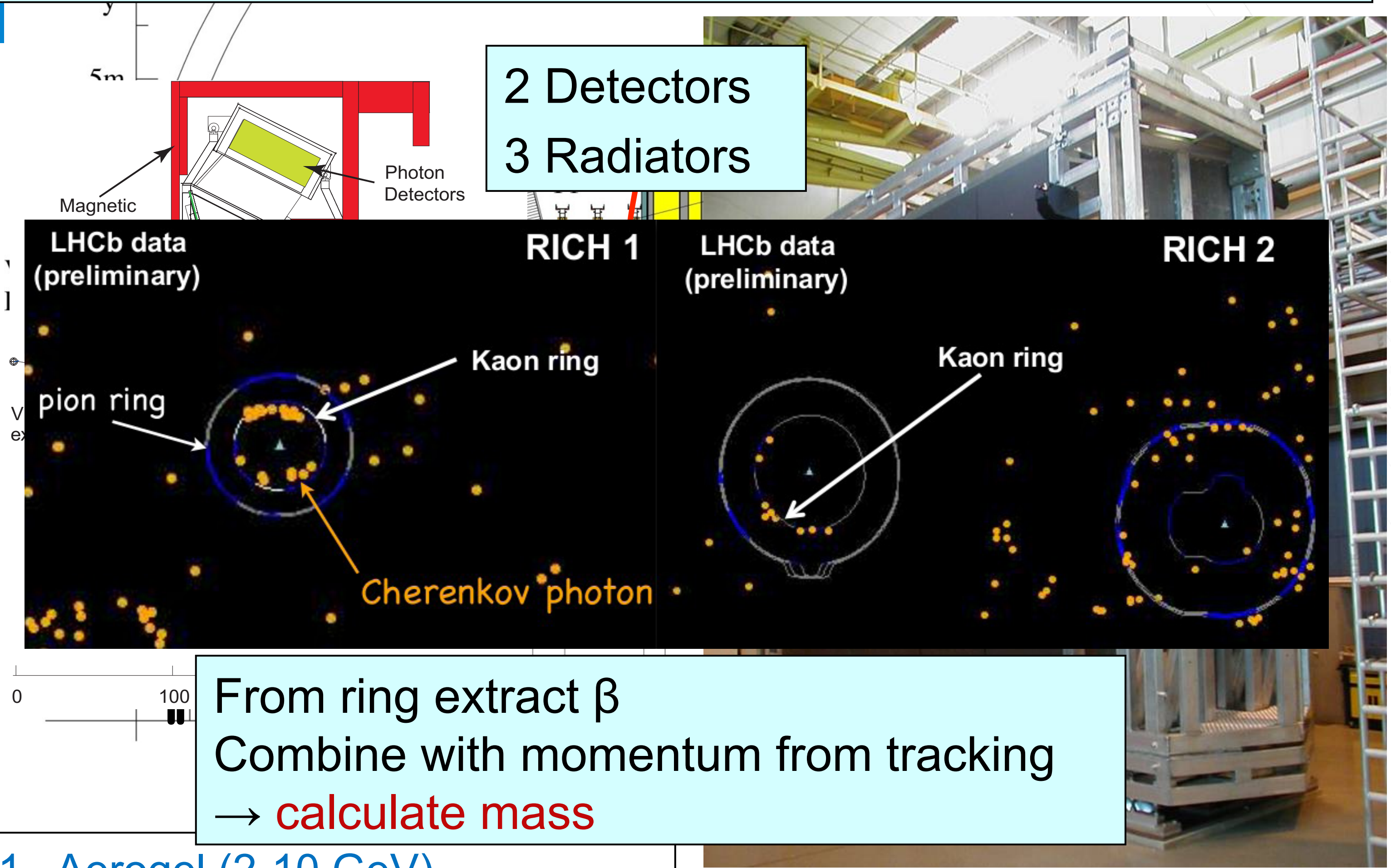


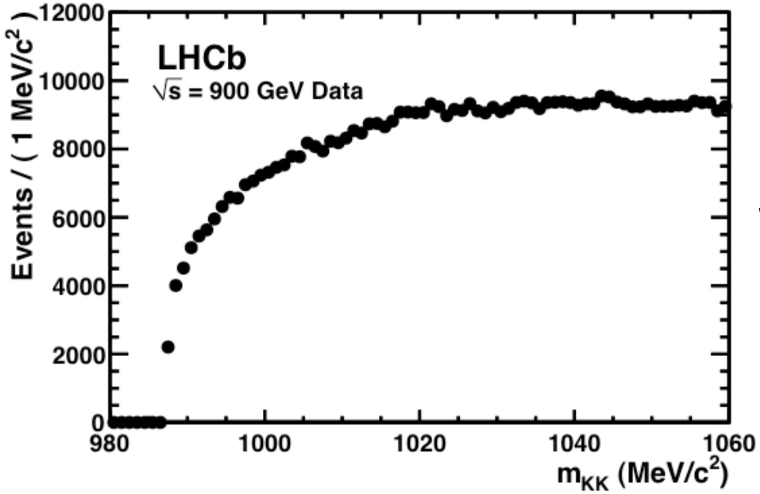
From ring extract β
Combine with momentum from tracking
→ calculate mass

RICH1 Aerogel (2-10 GeV),
C_4F_{10} (10-60 GeV)

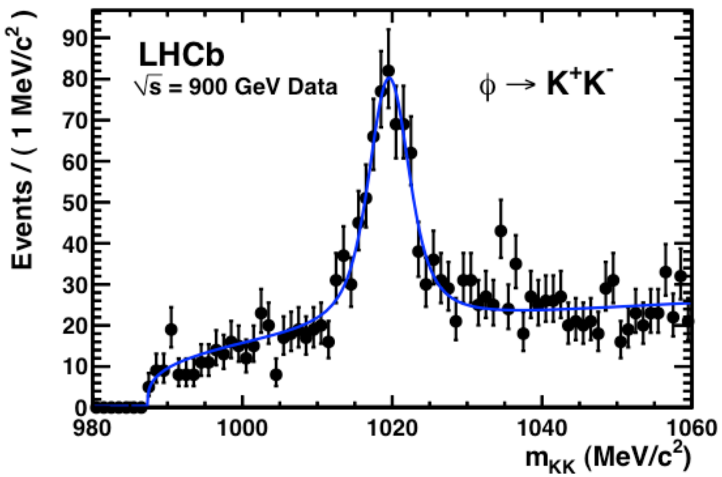
RICH2 CF_4 (16-100 GeV)

RICH Particle Identification

- Allows strong suppression of combinatorial background in hadronic decays e.g. $\phi \rightarrow K^+K^-$



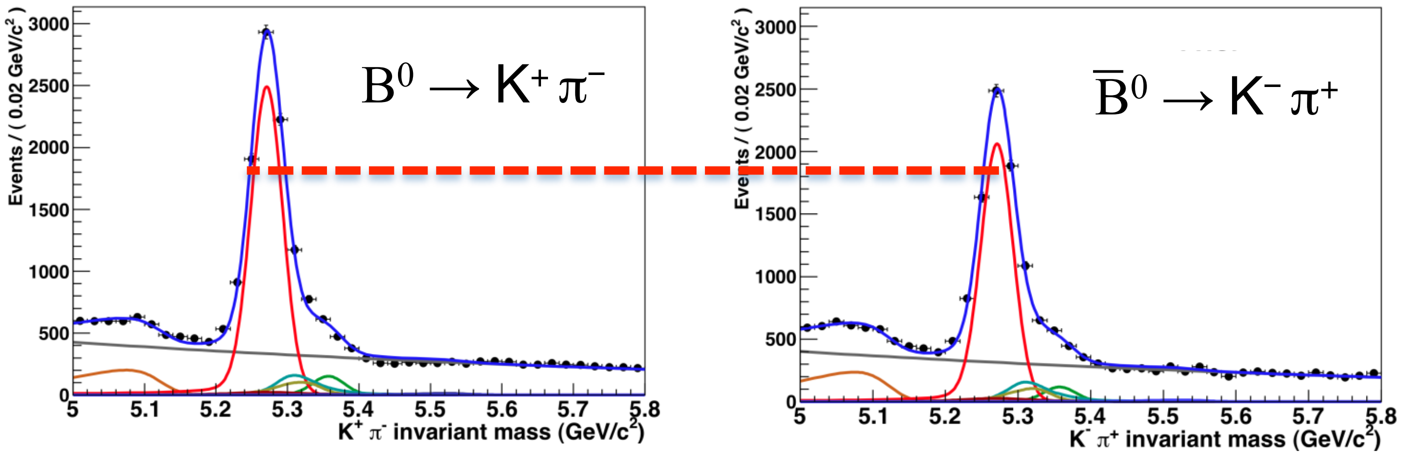
Without RICH



With RICH

CP Violation in B Decays

- Using the PID capability of LHCb, can isolate clean samples in 2-body $B \rightarrow h^+h^-$ decays ($h=\pi$,K,p)
- $B^0 \rightarrow K^+\pi^-$: direct CP violation (in decay) clearly visible in raw distributions

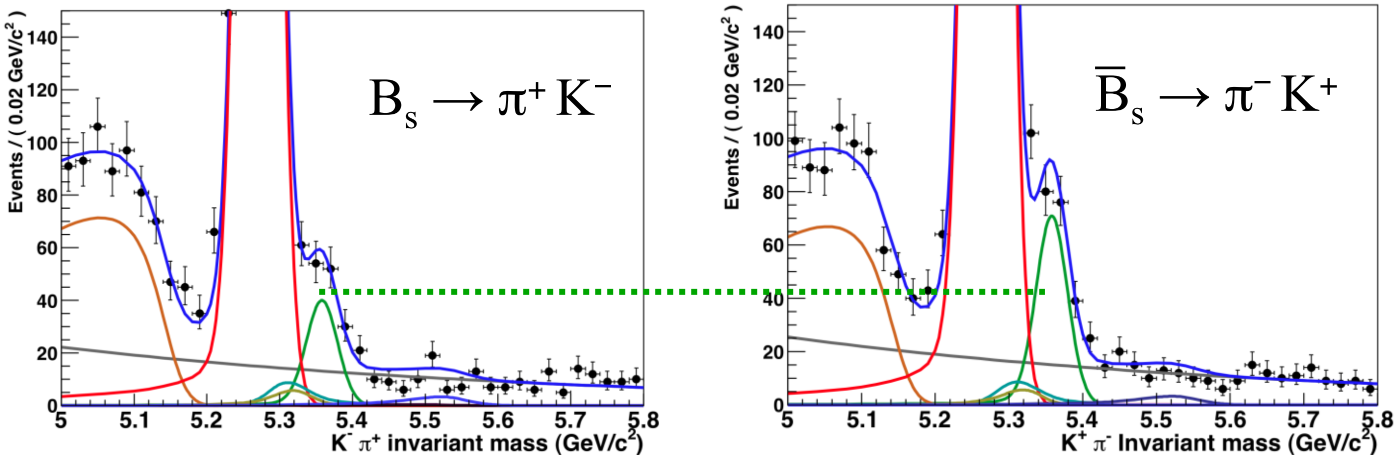


PRL **108** 201601

- Adjusting the selection to enhance the $B_s \rightarrow \pi^+ K^-$ contribution

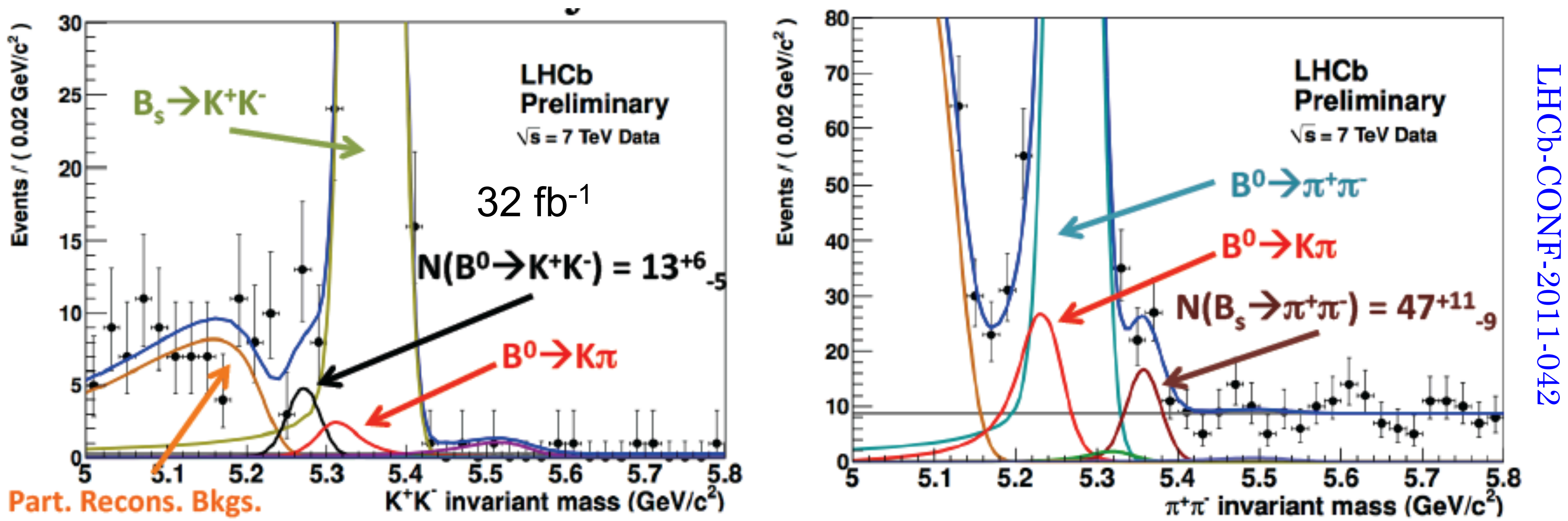
CP Violation in B Decays

- Using the PID capability of LHCb, can isolate clean samples in 2-body B→h^+h^- decays (h=π,K,p)



- $A_{CP}(B_s \to \pi^+ K^-) = 0.27 \pm 0.08 \pm 0.02$
- → First 3σ evidence of CP asymmetry in B_s decays!

Very rare topologies in B→h⁺h⁻



$$BR(B^0 \to K^+K^-) = (0.13^{+0.06}_{-0.05} \pm 0.07)\cdot 10^{-6}$$

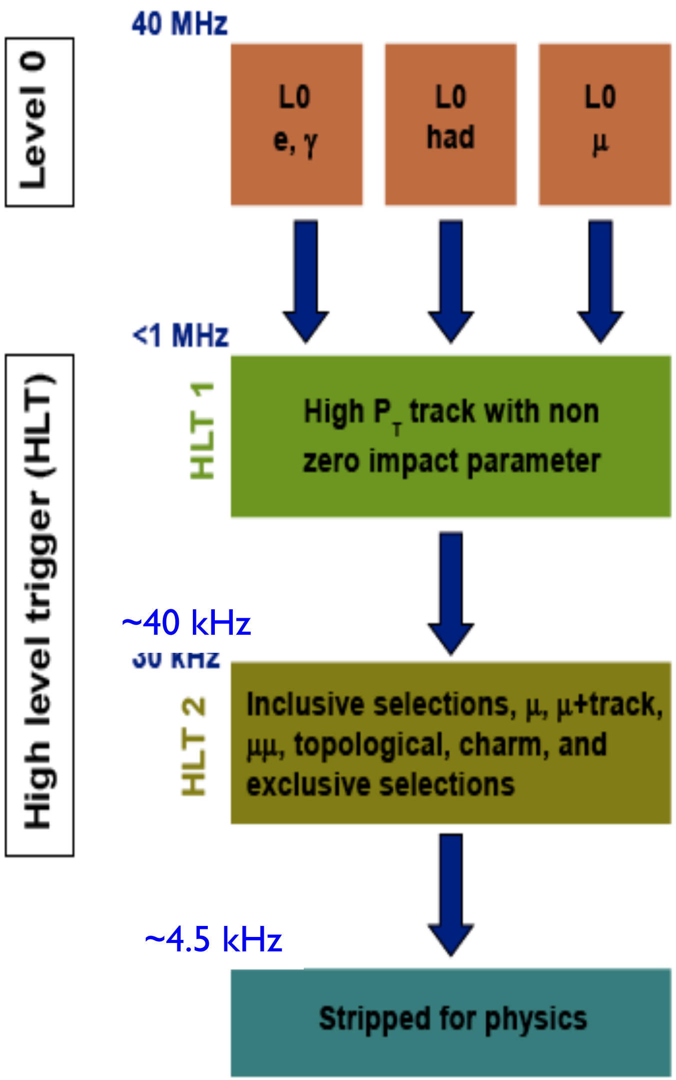
$$BR(B_S^0 \to \pi^+\pi^-) = (0.98^{+0.23}_{-0.19} \pm 0.11)\cdot 10^{-6}$$

- First observation of $B_S \to \pi^+\pi^-$ with 5.3σ significance

LHCb Trigger

- Trigger is crucial as σ_{bb} is less than 1% of total inelastic cross section and B decays of interest typically have BR < 10^{-5}
- b hadrons are long-lived →
  - Well separated primary and secondary vertices
- Have a ~large mass→
  - Decay products with large p_T

LHCb Trigger



Hardware level (L0) 40 MHz of bunch crossing→1MHz

- High-p_T μ, e, γ, hadron candidates (ECAL, HCAL, Muon)
  - CALO P_T>3.5 GeV, MUON P_T>1.4 GeV
  - New data every 25 ns, decision latency ~μs

Software level (**H**igh **L**evel **T**rigger, **HLT**)

- Access all detector data
- Farm with ~1500 PCs (29000 logical cores)
- **HLT1**: Add Impact Parameter cuts
- **HLT2**: Global event reconstruction tuned for HLT time constraints (20-30 ms)→ ~4.5 kHz

HLT needs operational flexibility to adapt to the level of pile-up

- Trigger setting configuration distributed simultaneously to 29000 logical cores

LHCb Trigger

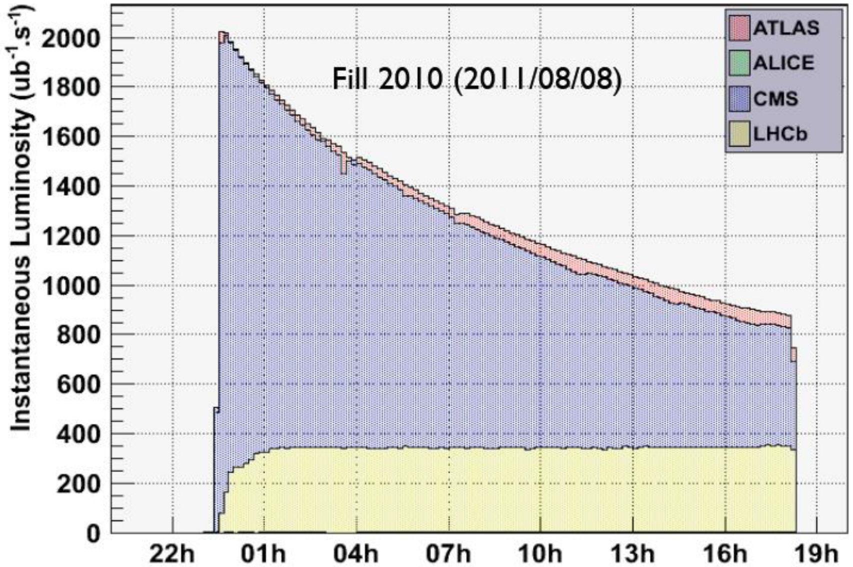
- Trigger efficiency:
  - B decays with $\mu\mu$ $\varepsilon_{\text{(L0 x HLT)}}$ ~ 70-90 %
  - B decays with hadrons $\varepsilon_{\text{(L0 x HLT)}}$ ~ 20-50 %
  - Charm decays : $\varepsilon_{\text{(L0 x HLT)}}$ ~ 10-20 % → LHC is a charm factory !

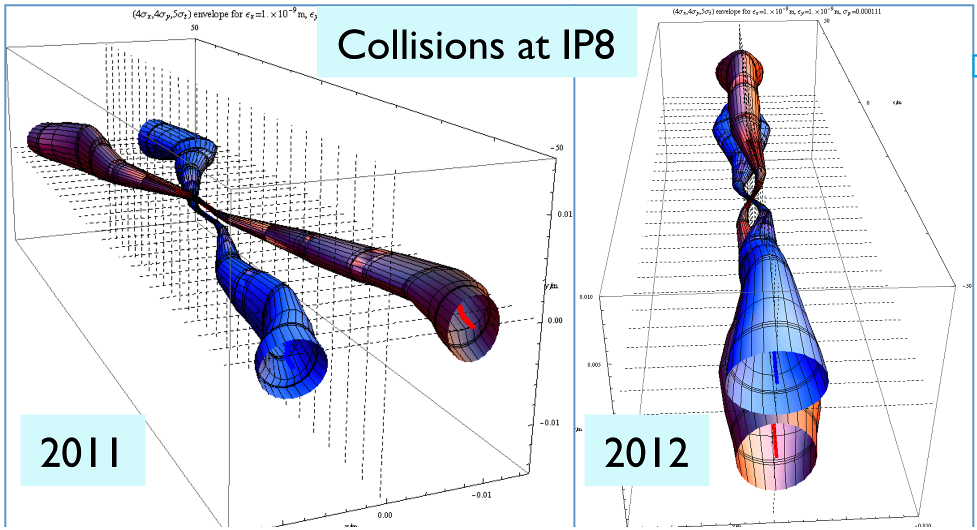
- In 2012 increase (+10%) in no. of CPU installed + "deferred HLT trigger" implemented
  - Exploit the idle time between "fills" (the periods when there are protons colliding in the LHC), which typically last between two and three hours, where no collisions take place and no computing power is required.
  - "Deferred triggering": storing events that cannot be processed online on the local disks of the servers, and later, when the fill is over, processing them on the now idle servers → +20% in CPU

LHCb running conditions

in 2012 -1:10 wrt ATLAS/CMS (L_{int})

- LHCb is running at ~4 10^{32} cm^{-2} s^{-1} (i.e. a factor of 2 above design value)
  - Mean number of interactions/bunch crossing~2, while for ATLAS/CMS >30
- Luminosity is leveled through automatic adjustment of offset of colliding beams– operation in harmony with higher luminosity for ATLAS/CMS

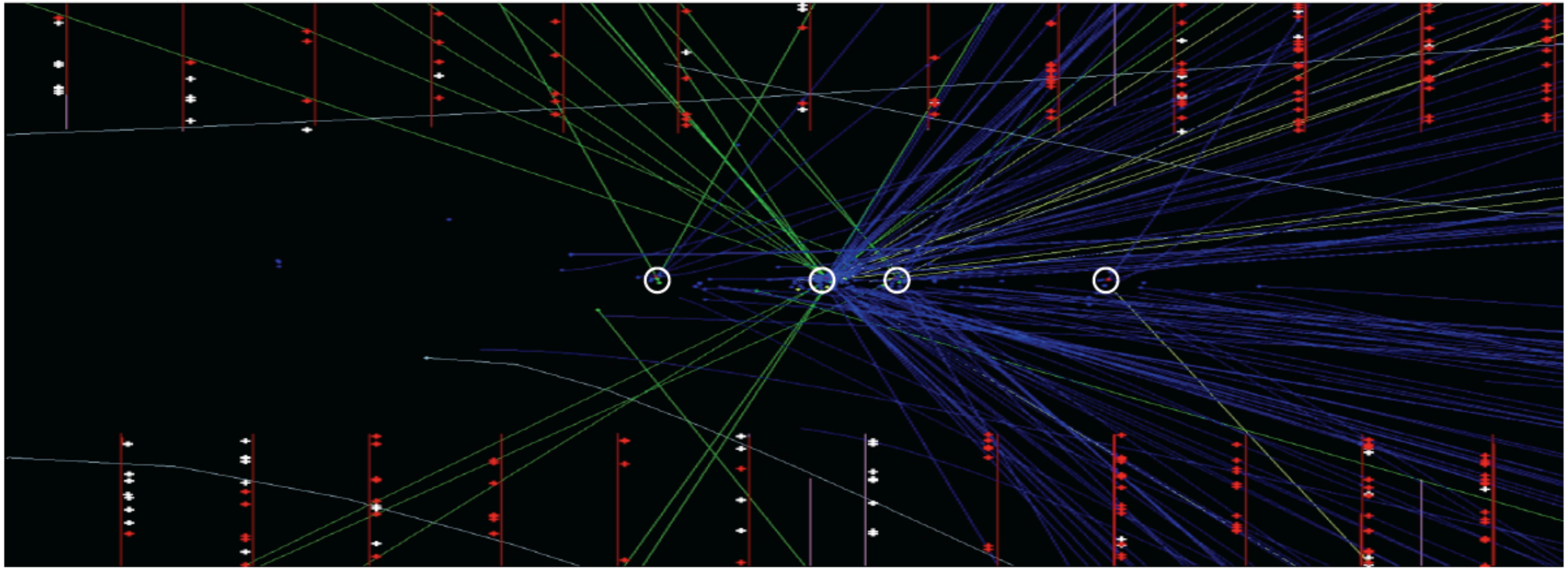




- In 2012 beam optics changed to decouple crossing angle from LHC (V) and spectrometer magnet (H). This minimizes systematic effects when we flip magnet polarity.

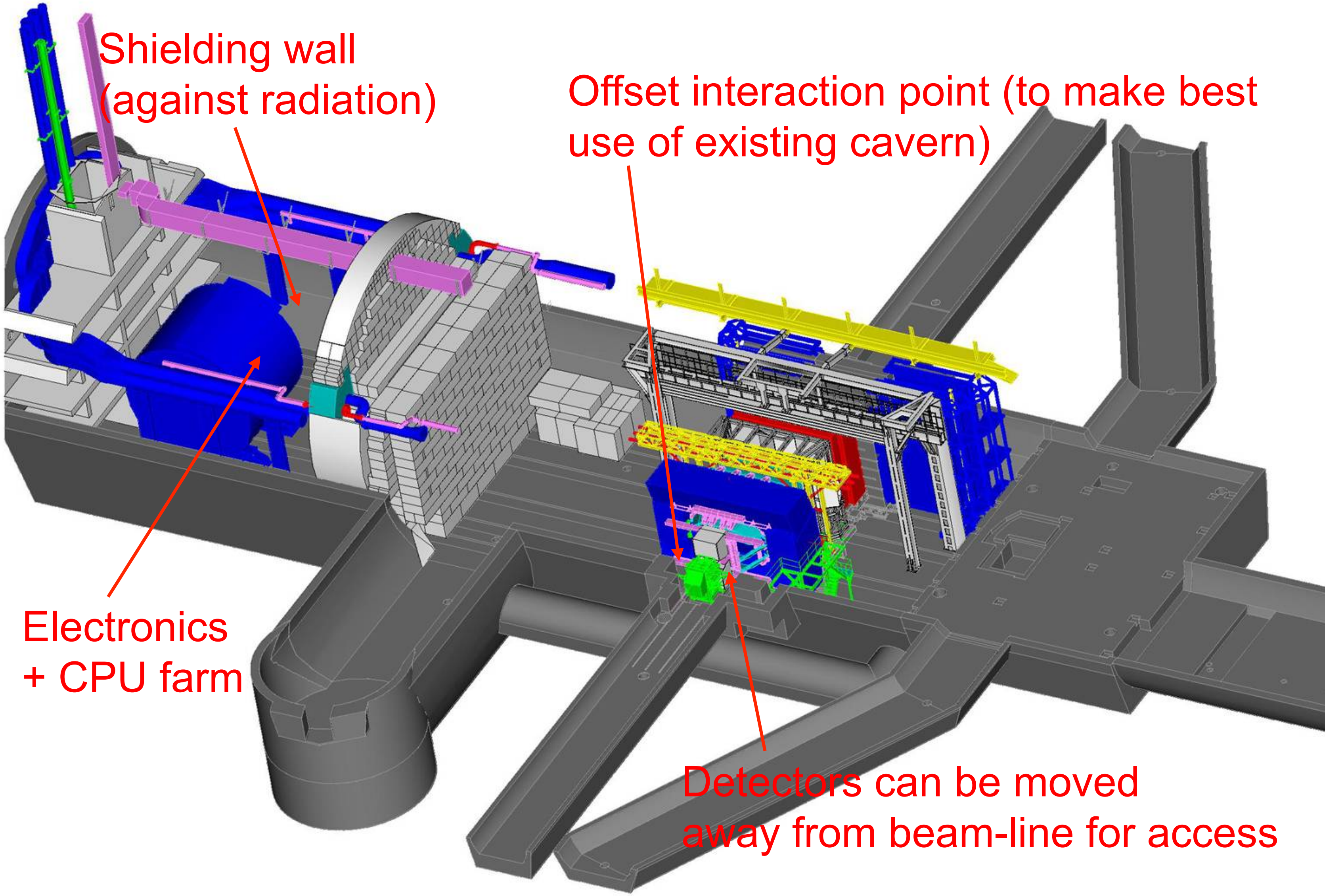
LHCb running conditions

VELO rz view

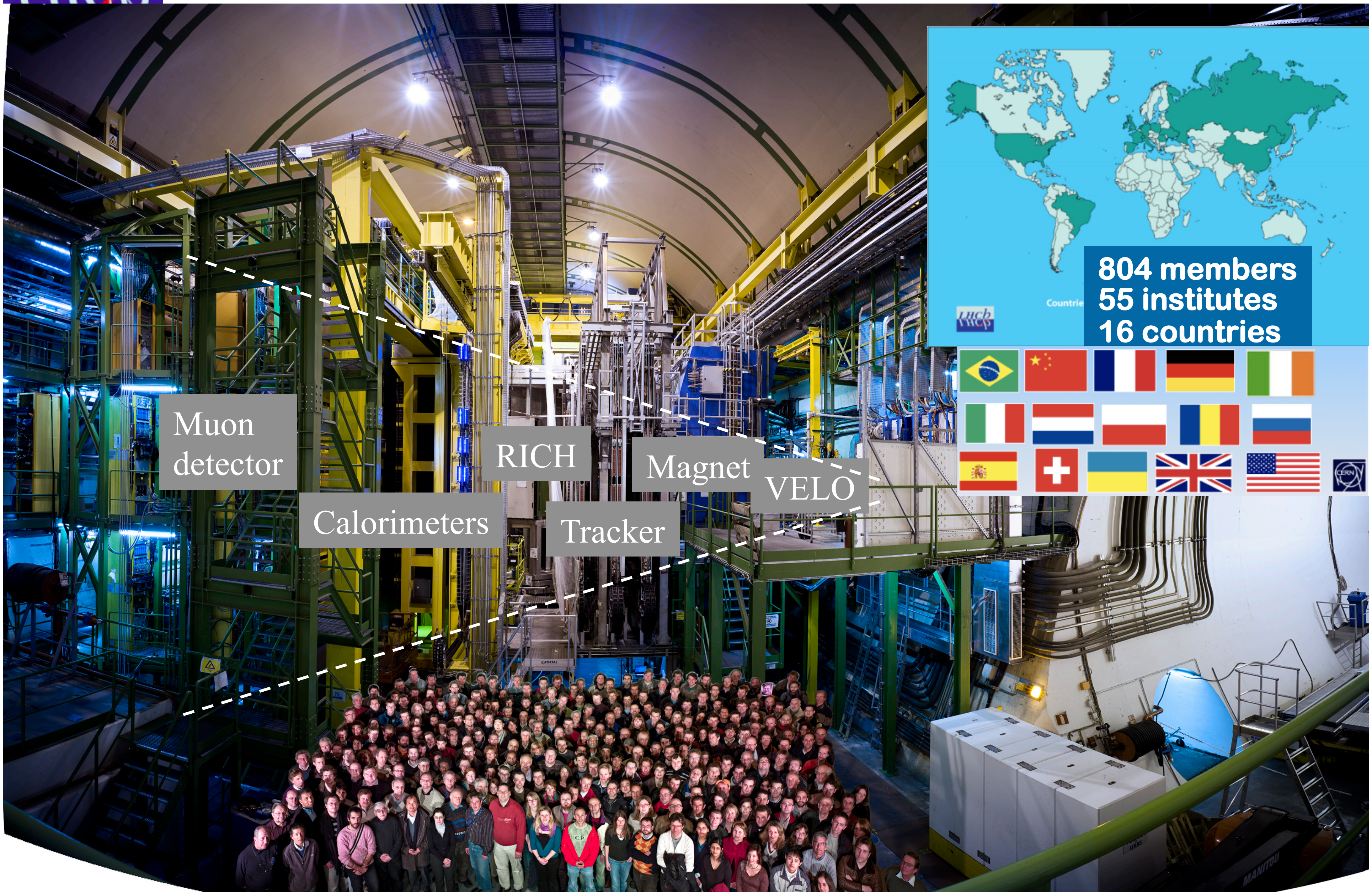


- 20 MHz of bunch crossing (in 2012, with 50 ns bunch spacing) with an average of 2 p-p interactions per bunch crossing → this level of pileup not an issue for LHCb

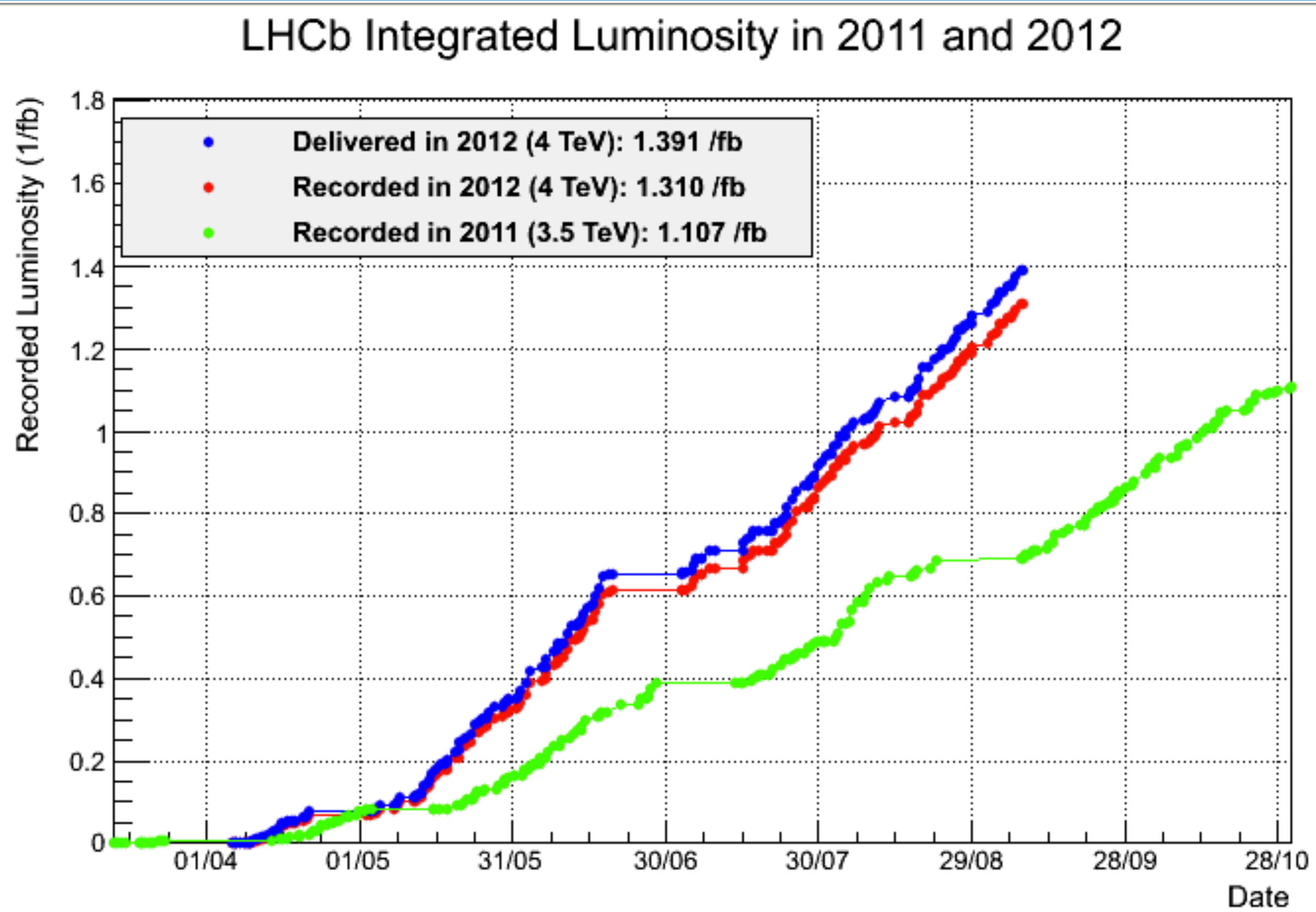
LHCb in its cavern (~100 m deep)



LHCb


Muon detector
Calorimeters
RICH
Tracker
Magnet
VELO
804 members
55 institutes
16 countries

Accumulated statistics and data-taking efficiency



- Target of >~2.2/fb on tape in 2012 (including p-p run extension)

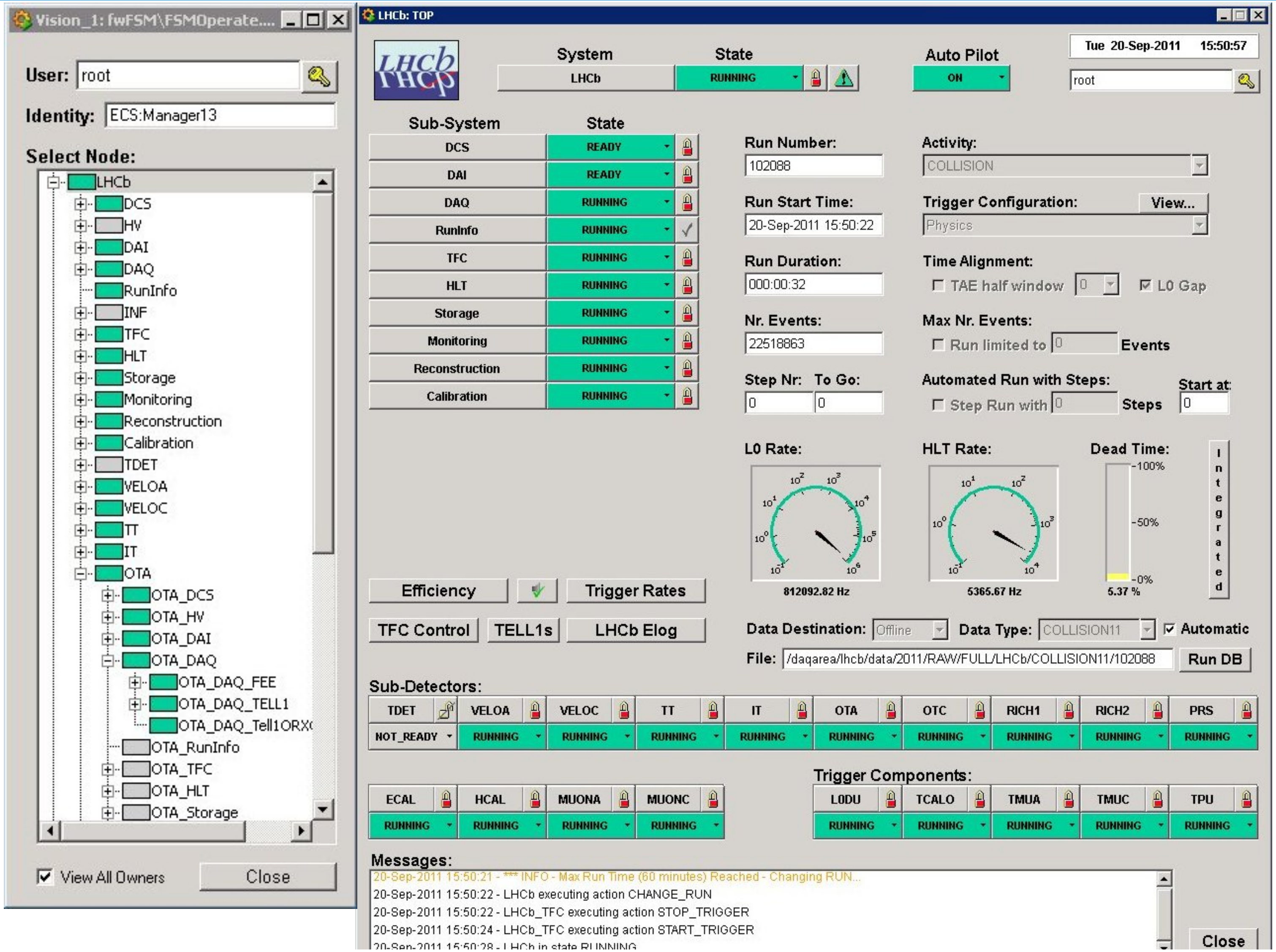
LHCb shift

Two shifters and many experts on call

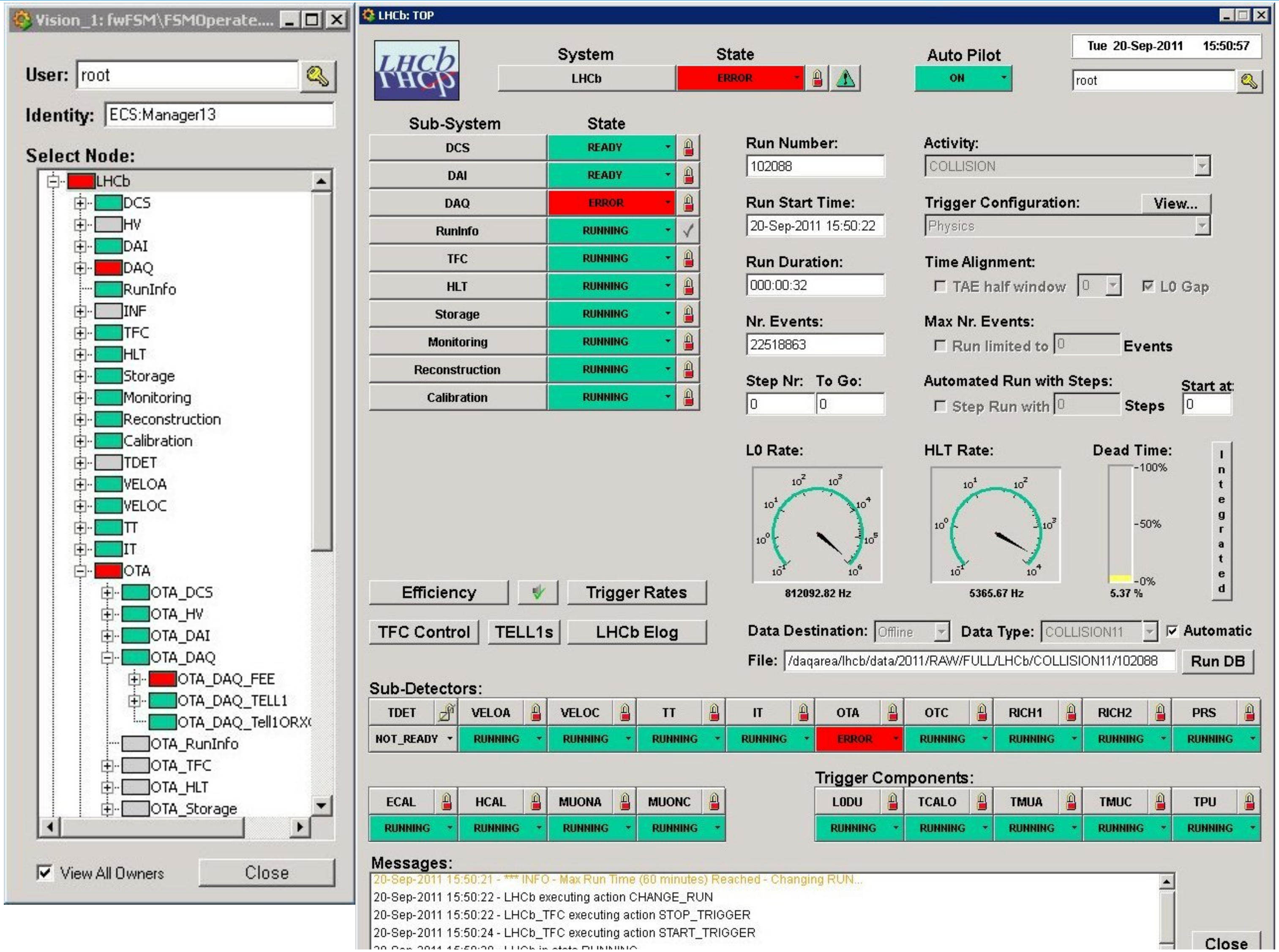
The LHCB Control System: On The Path To Full Automation

- Some examples:
  - High Level Trigger Control (~1500 PCs)
    - Automatically excludes misbehaving PCs (within limits) and (re)include them
  - Run Control
    - Automatically detects and recovers SubDetector desynchronizations
    - Can Reset SDs when problems detected by monitoring
  - Autopilot
    - Knows how to start and keep a run going from any state
  - BigBrother
    - Based on the LHC state, controls SD Voltages, VELO Closure, RunControl

The LHCB Control System: On The Path To Full Automation



The LHCB Control System: On The Path To Full Automation



LHCb physics program

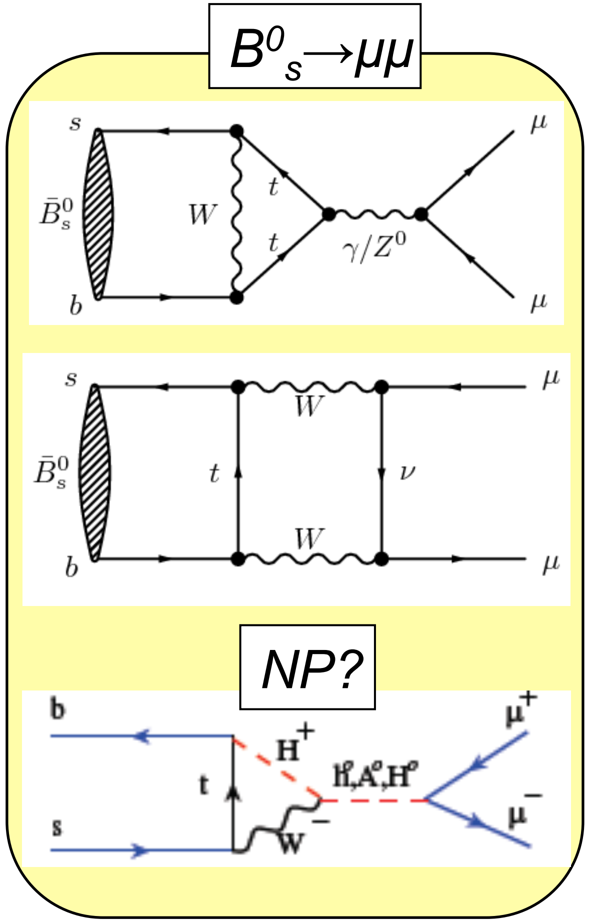
- Rare B decays Radiative, leptonic, electroweak, hadronic
- B decays to Charmonium B mixing parameters, CPV
- B decays to Open Charm CKM γ angle from B→DK, B to double charm
- Charmless B decays B→hh, B→hhh, ..
- Semileptonic B decays CPV, V_{ub}, cross-sections & b-fractions
- Charm physics Production & spectroscopy, CPV&mixing, rare charm decays
- B hadron and Quarkonia Production & spectroscopy
- QCD, EW and exotica Soft & hard QCD processes, particle production (incl. EW bosons), PDFs, exotic long-lived particles, pA collisions

.....

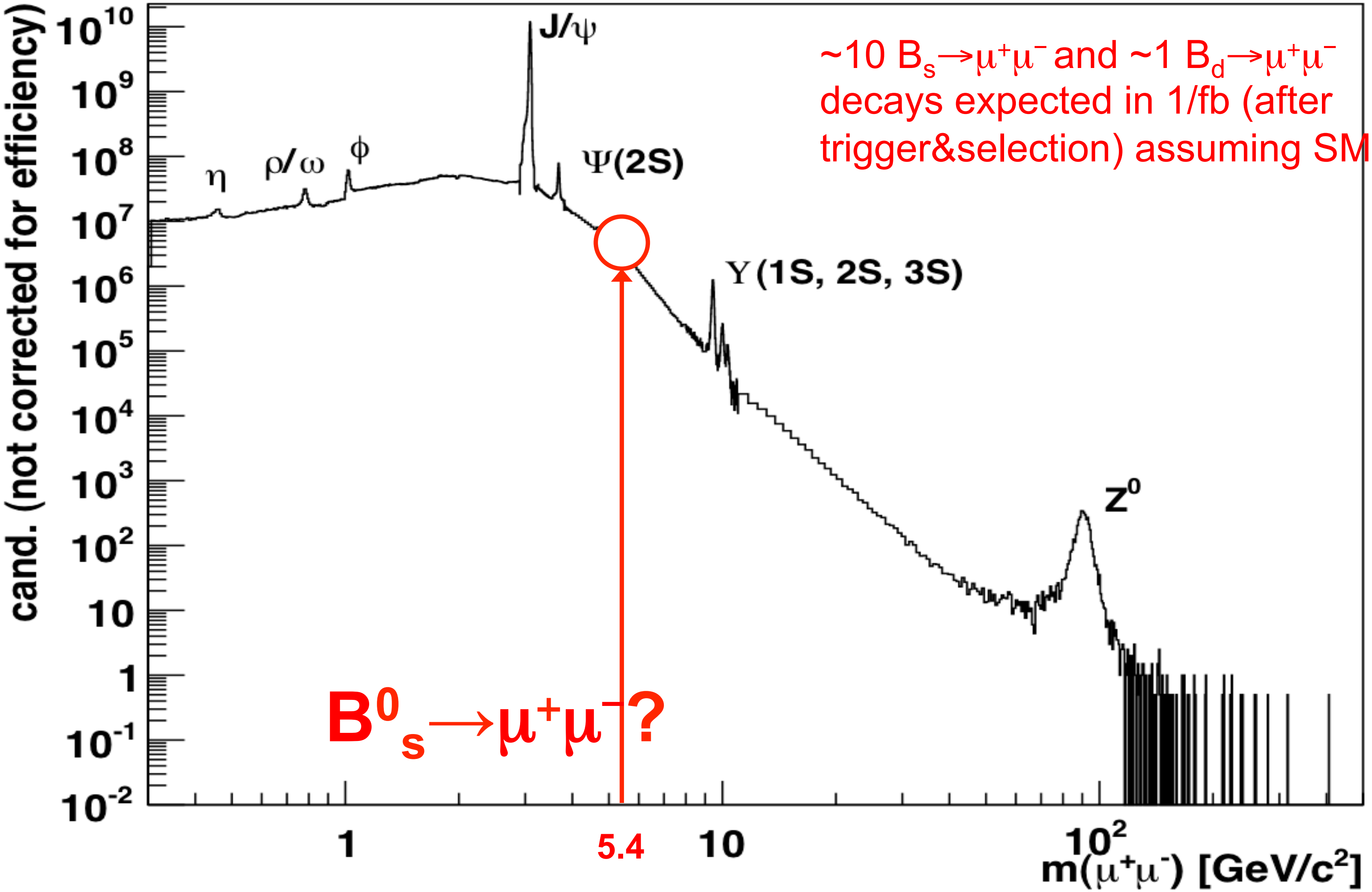
Rare Decays: Search for NP in $B_{s(d)} \to \mu^+\mu^-$

Search for NP in $B_{s(d)} \rightarrow \mu^+\mu^-$

- Highly suppressed in SM - FCNC plus helicity $(m_\mu/M_B)^2$ - and well predicted
  - $BR(B_s \rightarrow \mu^+\mu^-) = 3.2 \pm 0.03\ 10^{-9}$
  - $BR(B_d \rightarrow \mu^+\mu^-) = 0.11 \pm 0.01\ 10^{-9}$
    - A.J.Buras et al: arXiv: 1208.0934
- Sensitive to NP
  - Could be strongly enhanced in SUSY
  - In MSSM scales like $\sim\tan^6\beta$ →
- Limit or measurement of $B_{s,d} \rightarrow \mu^+\mu^-$ will strongly constraint parameter space



Search for $B_s \rightarrow \mu^+\mu^-$

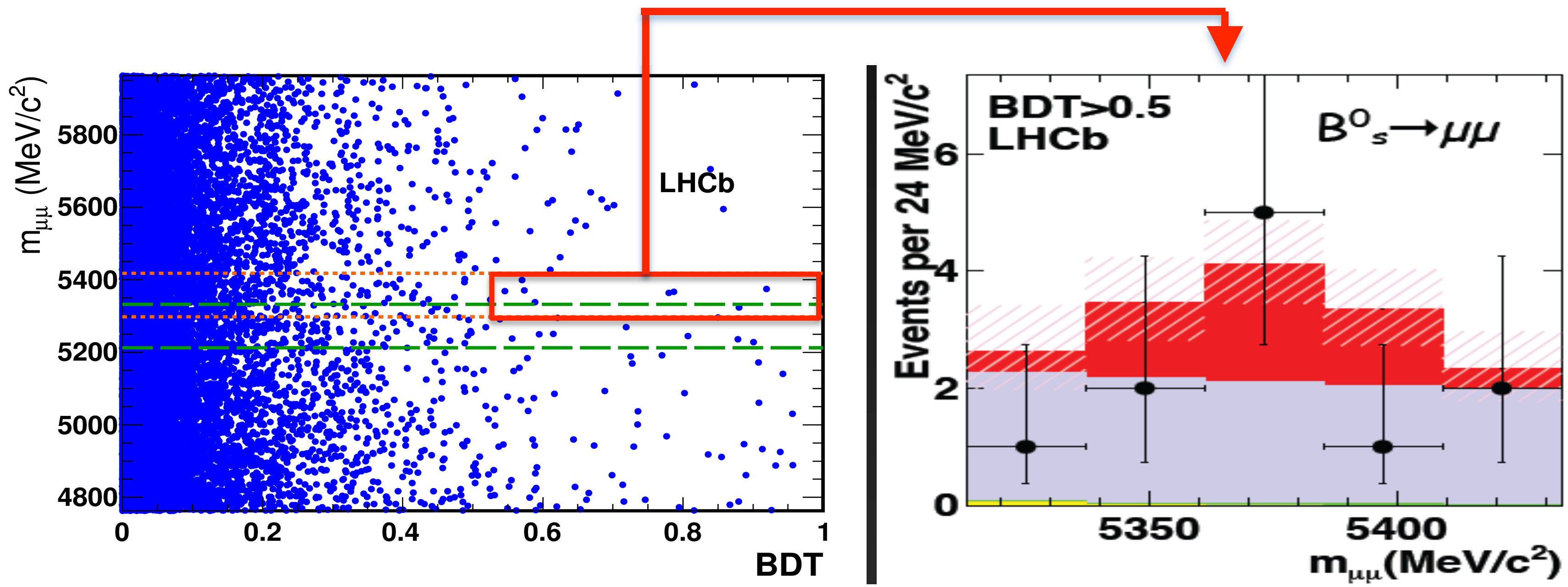


~10 $B_s \rightarrow \mu^+\mu^-$ and ~1 $B_d \rightarrow \mu^+\mu^-$ decays expected in 1/fb (after trigger&selection) assuming SM

Search for $B_s \to \mu^+\mu^-$

- Main issue is rejection of background, dominated by $B \to \mu^+ X$, $B \to \mu^- X$ decays
- Good mass resolution crucial
- Analysis performed in 2D : Multivariate estimator (BDT) combining vertex and geometrical information vs dimuon mass $m_{\mu\mu}$
- Data show a slight excess over background-only hypothesis consistent with presence of a SM signal

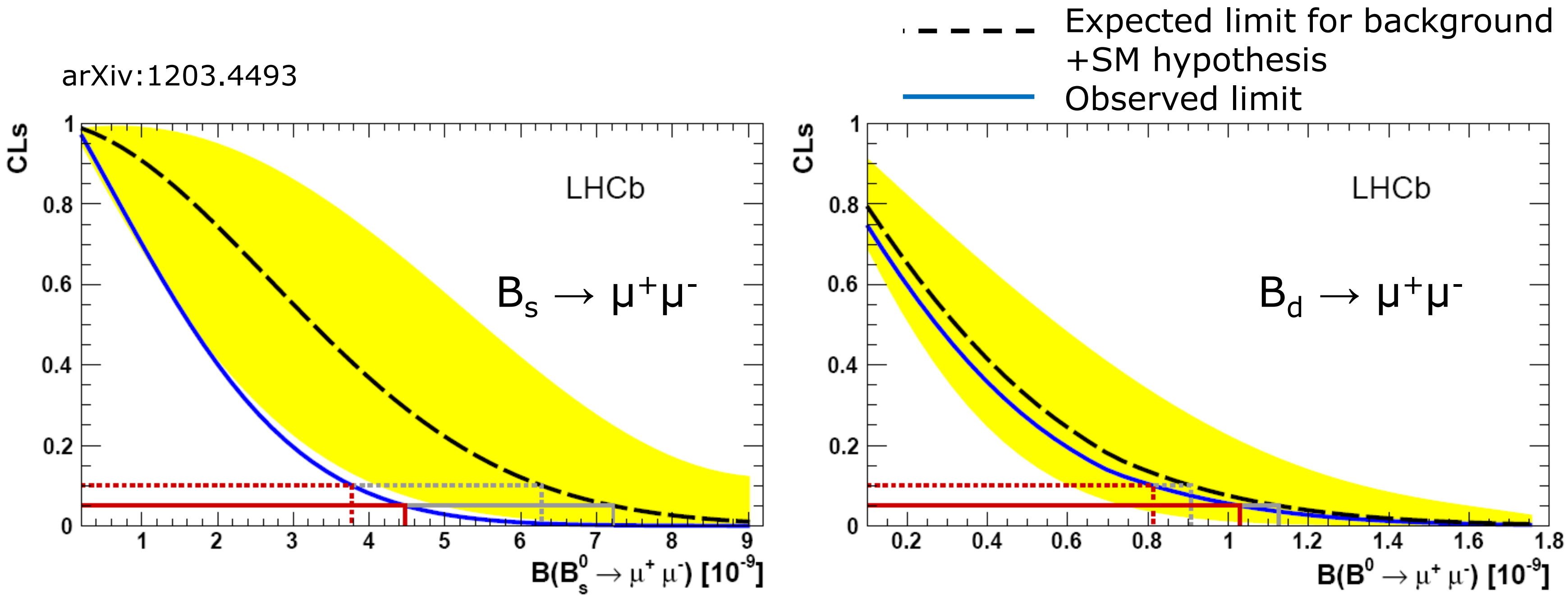
$m_{\mu\mu}$ in sensitive region of BDT



PRL 108, 231801 (2012) [1203.4493]

$B_{s(d)} \rightarrow \mu^+\mu^-$ results with 1fb^{-1}

arXiv:1203.4493



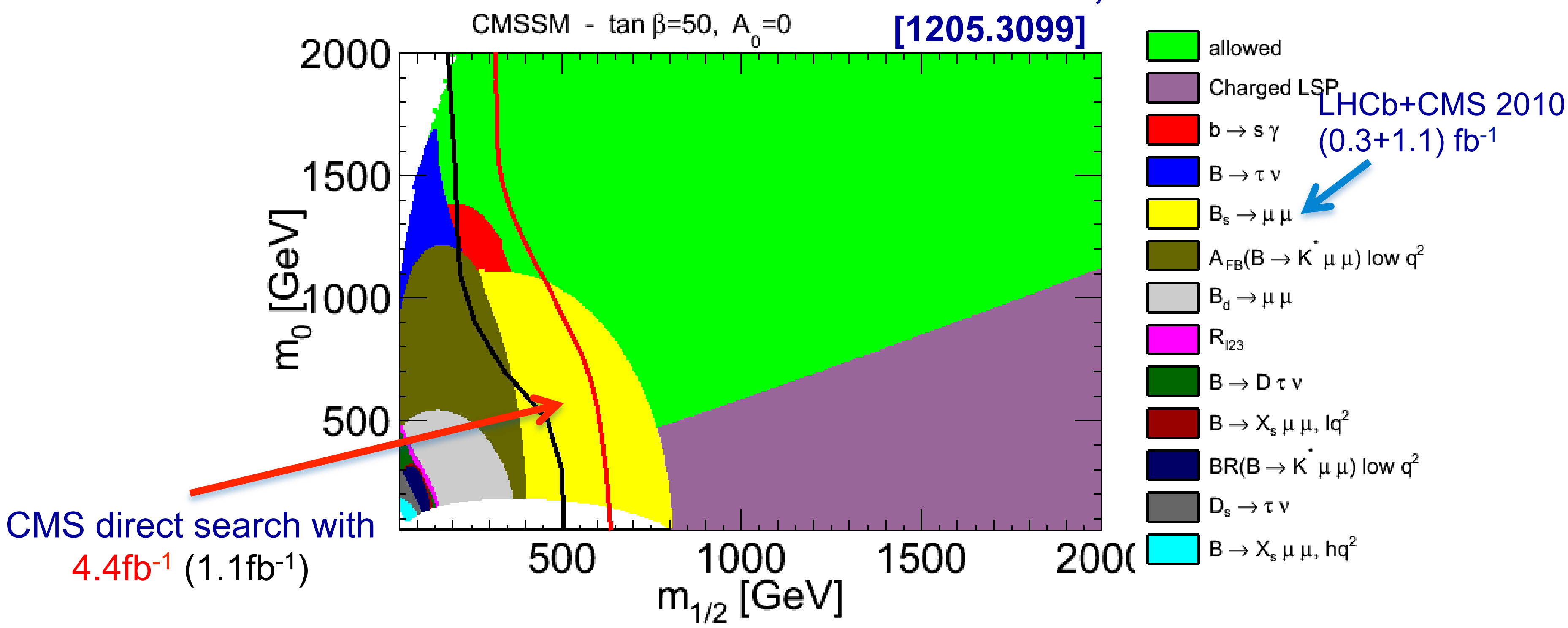
PRL 108, 231801 (2012) [1203.4493]

- LHCb's world's best limits with 1 fb^{-1} @ 95% CL
  - **$BR(B_s \rightarrow \mu^+\mu^-) < 4.5\ 10^{-9}$**
  - **$BR(B_d \rightarrow \mu^+\mu^-) < 1.0\ 10^{-9}$**
- Large enhancement of BR relative to SM expectation is ruled out

Impact of $B_{s(d)} \to \mu^+\mu^-$ on SUSY

- Constraints from flavour observables in SUSY models with few free parameters, such as CMSSM (used here for purely illustrative purpose, as almost excluded by M_H=125 GeV)

F. Mahmoudi, [1205.3099]



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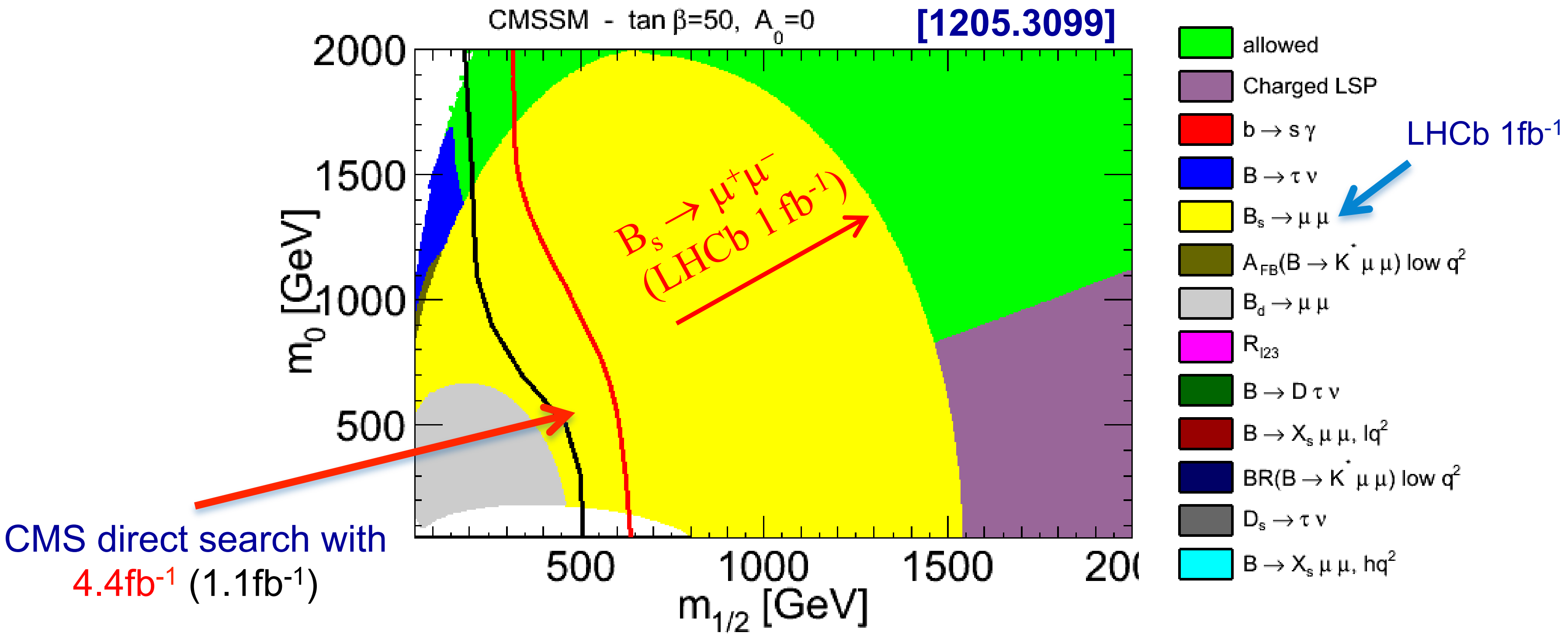

- LHCb limit strongly constrains the CMSSM with large tan β
- Constraints are superior to those from direct searches

Impact of $B_{s(d)} \to \mu^+\mu^-$ on SUSY

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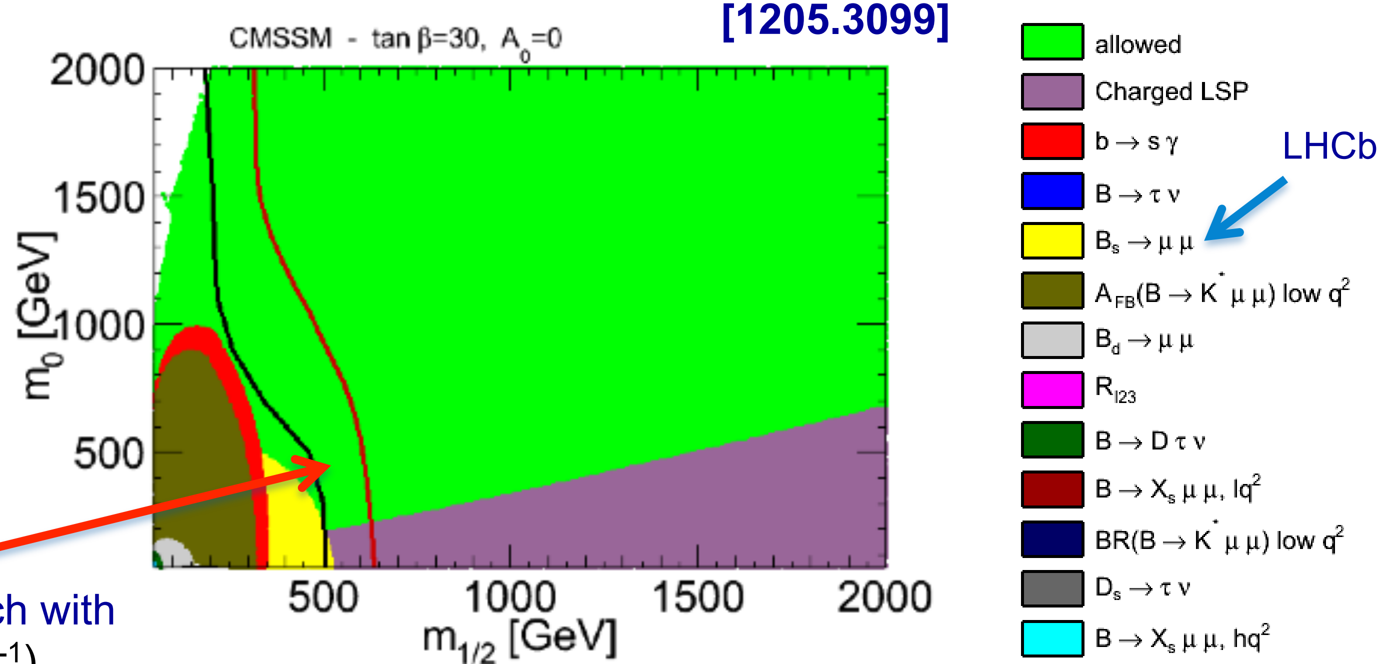
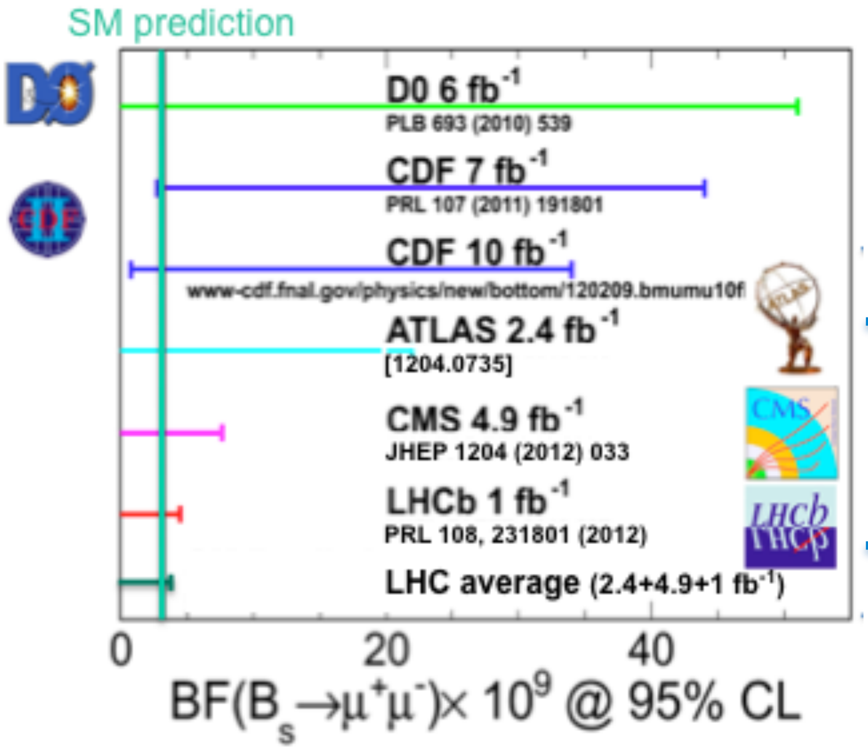


CMS direct search with 4.4fb^{-1} (1.1fb^{-1})

- At low tan β, constraints from $B_s \to \mu^+\mu^-$ lose importance wrt direct searches

$B_{s(d)} \to \mu^+\mu^-$: summary of exp results

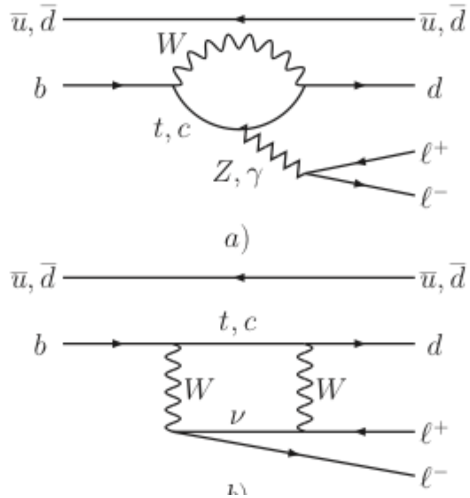


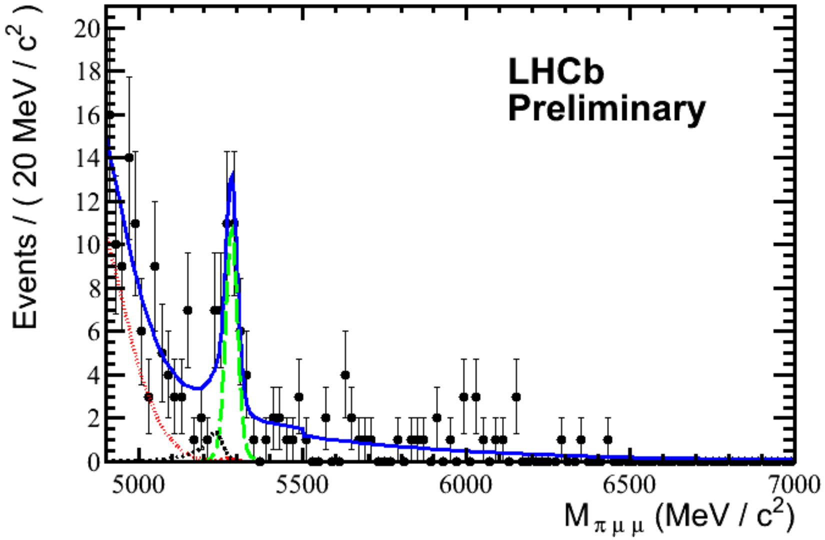
- ATLAS/CMS/LHCb combined @95%CL
  - **$BR(B_s \to \mu^+\mu^-) < 4.2\ 10^{-9}$**
    - Slight excess of events over background, compatible with a SM signal within 1σ
  - **$BR(B_d \to \mu^+\mu^-) < 8.1\ 10^{-10}$**

LHCb-CONF-2012-017, also as CMS-PAS-BPH, ATLAS-CONF

$B^+ \to \pi^+\mu^+\mu^-$: Rarest B decay ever observed!

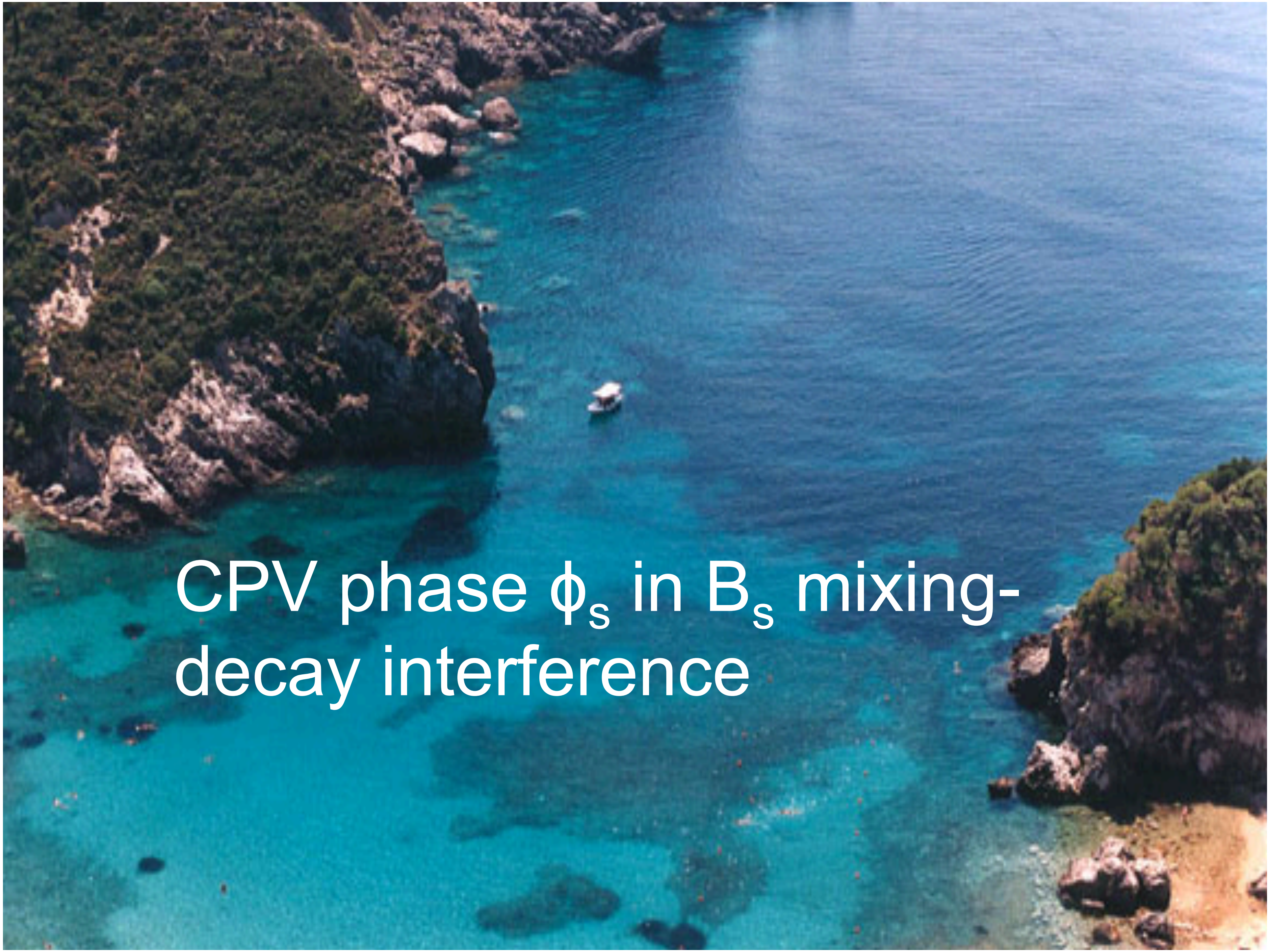
- $B^+ \to \pi^+\mu^+\mu^-$ forbidden at tree level in SM → FCNC : Z/γ penguin or box
- SM prediction: $(1.96 \pm 0.21)10^{-8}$
- Observed for the first time with 5σ significance (with 1/fb)
- BR ($B^+ \to \pi^+\mu^+\mu^-$) = $(2.4 \pm 0.6 \pm 0.2)\ 10^{-8}$





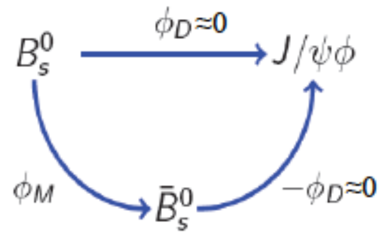
LHCb-CONF-2012-006

CPV phase ϕ_s in B_s mixing-decay interference

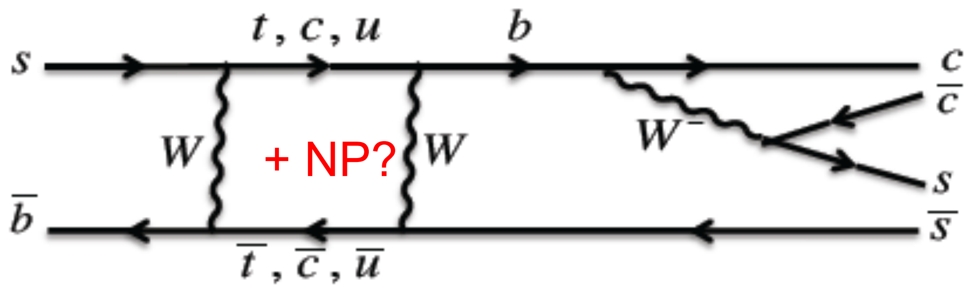


CPV phase ϕ_s in B_s mixing-decay interference

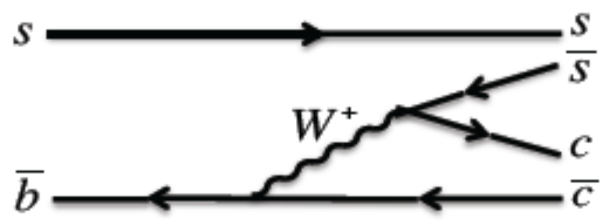
- Measurement of B_s-$\bar{B}_s$ mixing phase ϕ_s in $B_s \to J/\psi\, \phi$ sensitive to NP effects in mixing



- The phase arises from interference between B^0_S decays with and without mixing



Decay amplitude with mixing (φ_s)



Amplitude with direct decay

- ϕ_s is small in SM:

$$\phi_s^{SM} = \phi_s^{M} - 2\phi_s^{D} \simeq -2\beta_s = -2\arg\left(-\frac{\overbrace{V_{ts}V_{tb}^*}^{\text{mixing}}}{\underbrace{V_{cs}V_{cb}^*}_{\text{decay}}}\right) = -(2.1 \pm 0.1)^\circ$$

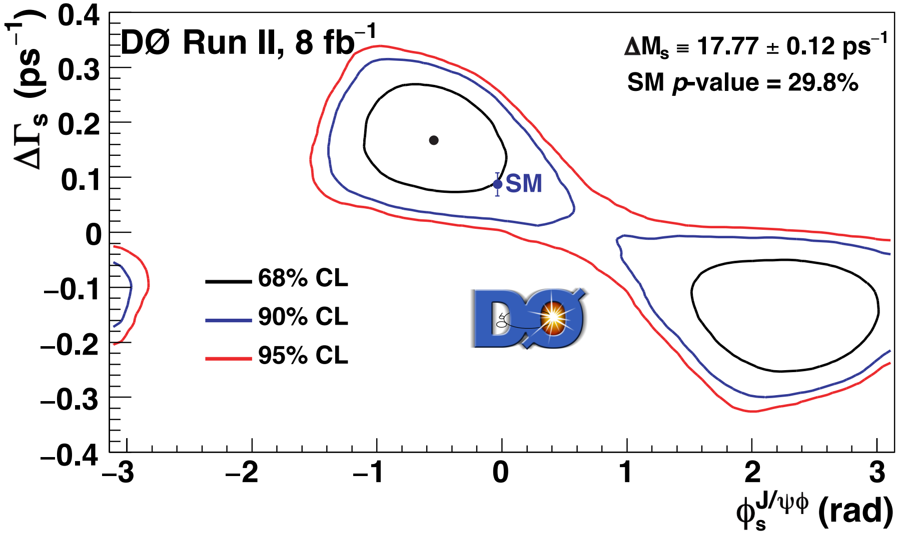
- NP can add large phases:

$$\phi_s = \phi_s^{SM} + \phi_s^{NP}$$

CPV phase ϕ_s in B_s mixing-decay interference

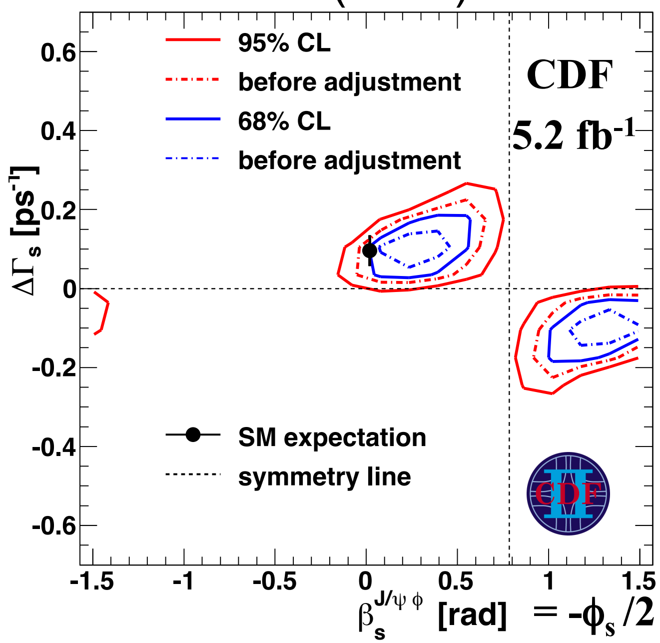
- Interesting Tevatron results with early data and intriguing with analysed sample

PRD 85 (2012) 032006



$\Delta\Gamma_s = \Gamma_L - \Gamma_H$

PRD 85 (2012) 072002



$= -\phi_s/2$

- Results are consistent, both ~1σ away from SM

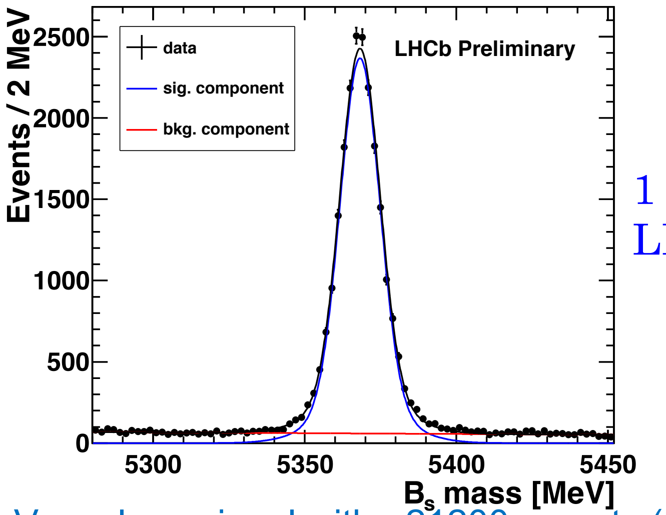
What about LHCb?

Golden channel: $B_s \to J/\psi(\mu^+\mu^-)\ \phi(K^+K^-)$

- Theoretically and experimentally clean
  - $b \to ccs$ tree dominance leads to precise prediction of ϕ_s in SM
  - Relatively large branching ratio and clean topology
  - Easy to trigger on μ from $J/\psi \to \mu^+\mu^-$
- Needs flavour-tagged, time-dependent angular analysis to disentangle CP-even and CP-odd components
  - $P \to VV$ decay:
    - B_s pseudoscalar (spin=0), J/ψ and Φ vectors mesons ($J^{PC}=1^{--}$)
    - Total angular momentum conservation implies $\ell=0,1,2$
  - $CP|J/\psi\ \phi\rangle = (-1)^{\ell}\ |J/\psi\ \phi\rangle \to$
    - Mixture of CP-even ($\ell=0,2$) and CP odd ($\ell=1$) final states
    - Need to fit angular distributions of decay final states as function of proper time
- 6 observables (invariant mass m_B, proper time, 3 angles of the decay products, B_S flavour) → $\phi_s, \Delta\Gamma_s$, Δm_s, 3 amplitude ratios, 3 strong phase differences

$B_s \to J/\psi\ \phi$: key experimental ingredients

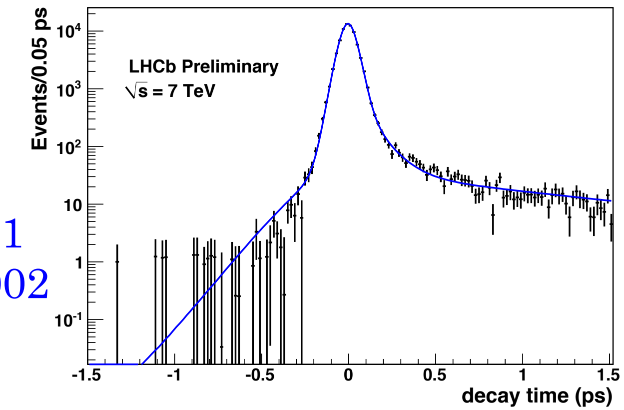
- Selection of signal and control channels



1 fb-1 @ 7TeV in 2011
LHCb-CONF-2012-002

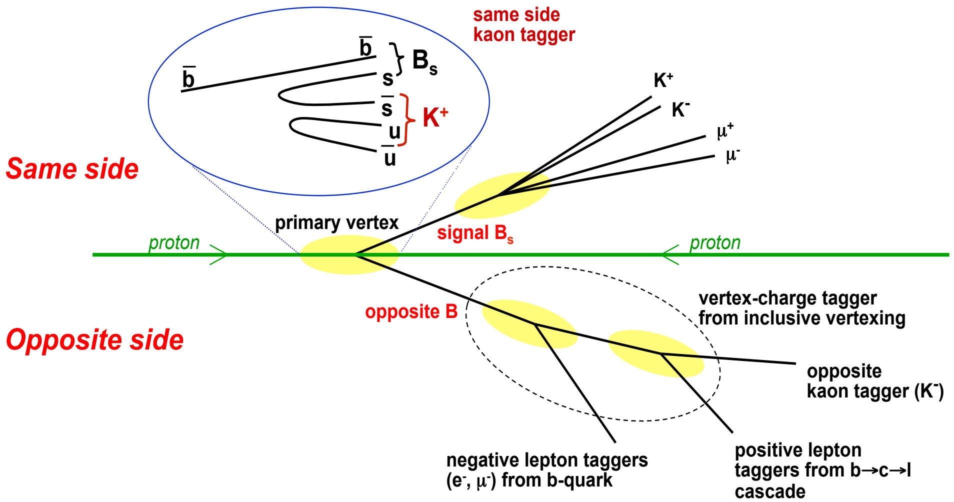
- Very clean signal with ~21200 events (t>0.3 ps)
- ~8 MeV mass resolution

- Decay time resolution



- Effective time resolution ~45 fs from prompt events (B_s oscillation period ~350 fs)

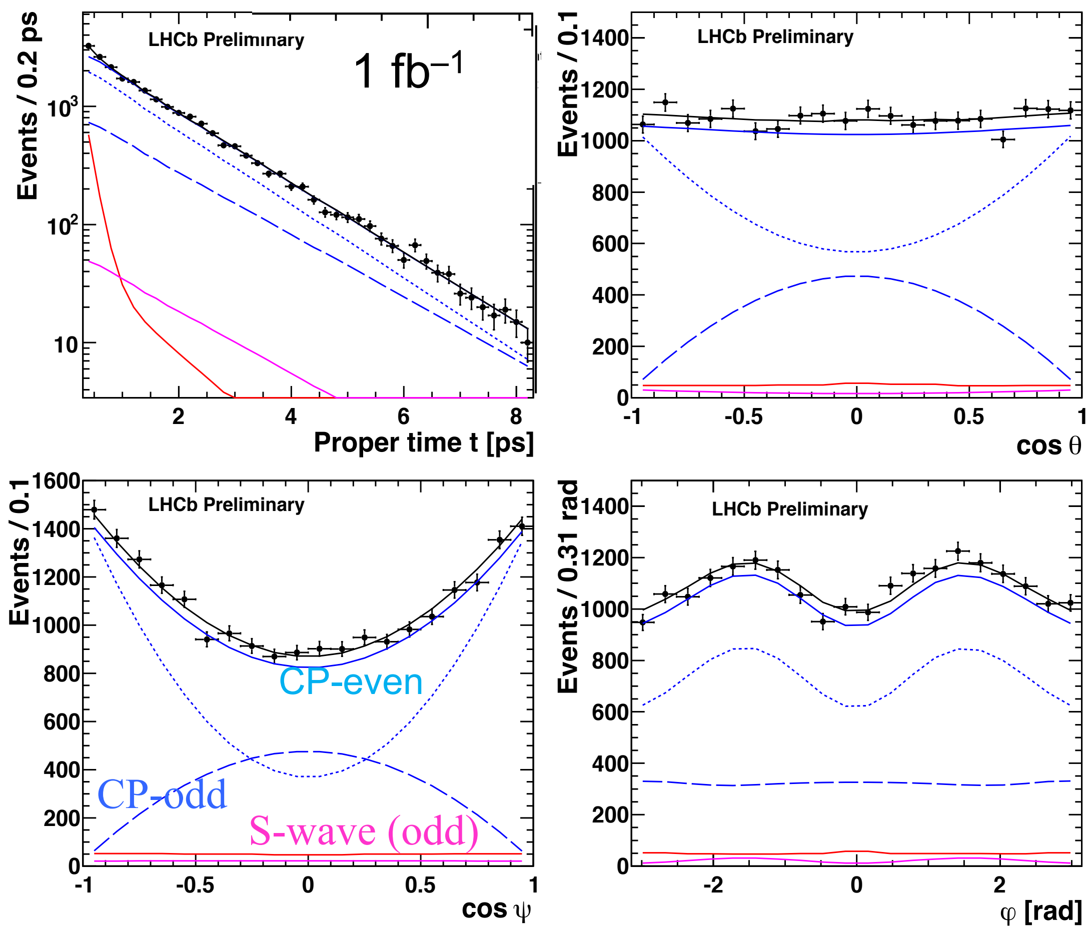
- Tagging of initial flavour ($B/\bar{B}$)
  - Effective tagging efficiency ~2.3% from Opposite Side Tagging (exploits the decay of the other b-hadron in the event) Calibrated with $B^+ \to J/\psi\ K^+$



$B_s \rightarrow J/\psi\ \phi$: fit projections

- Maximum likelihood fit using angular information used to statistically separate different CP eigenstates

LHCb-CONF-2012-002



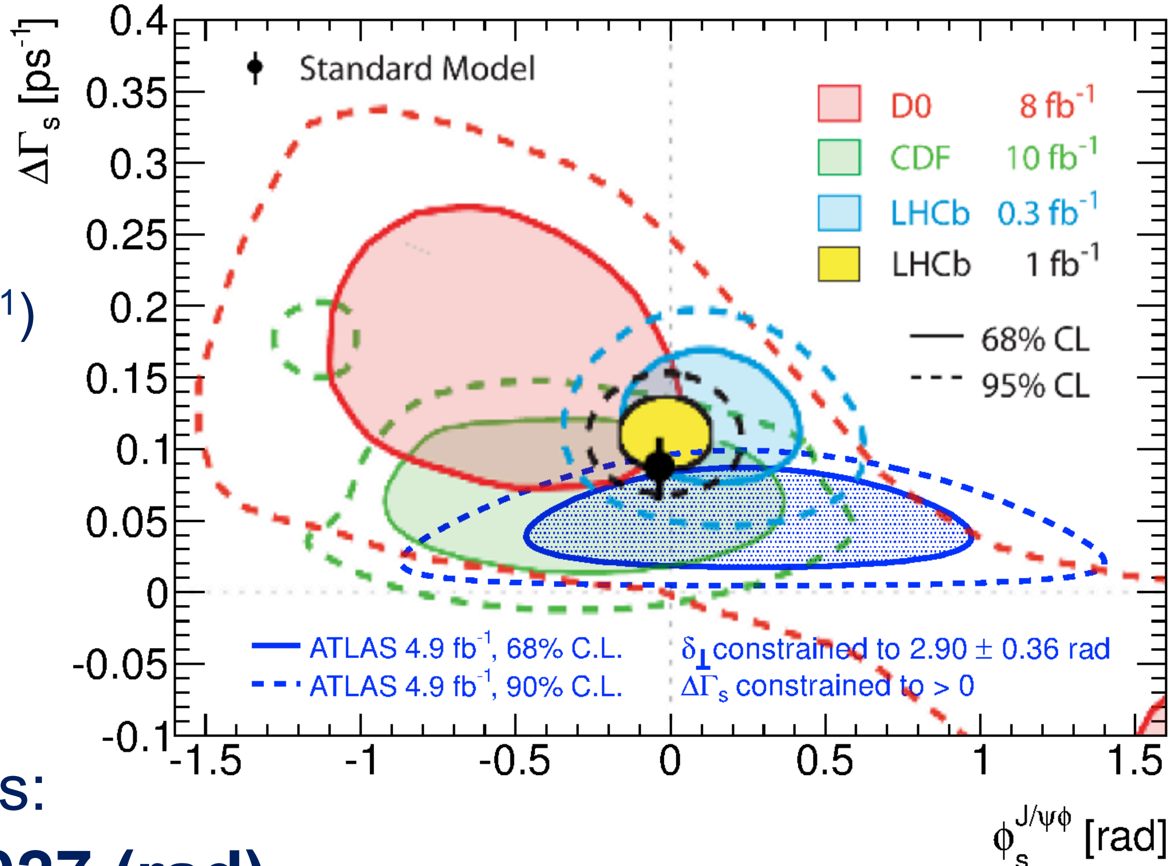
Summary of ϕ_s results (ICHEP 2012)

LHCb alone:

Γ_s=0.6580±0.0054±0.0066 (ps^{-1})

$\Delta\Gamma_s$=0.116±0.018±0.006 (ps^{-1})

ϕ_s=0.001±0.101±0.027 (rad)

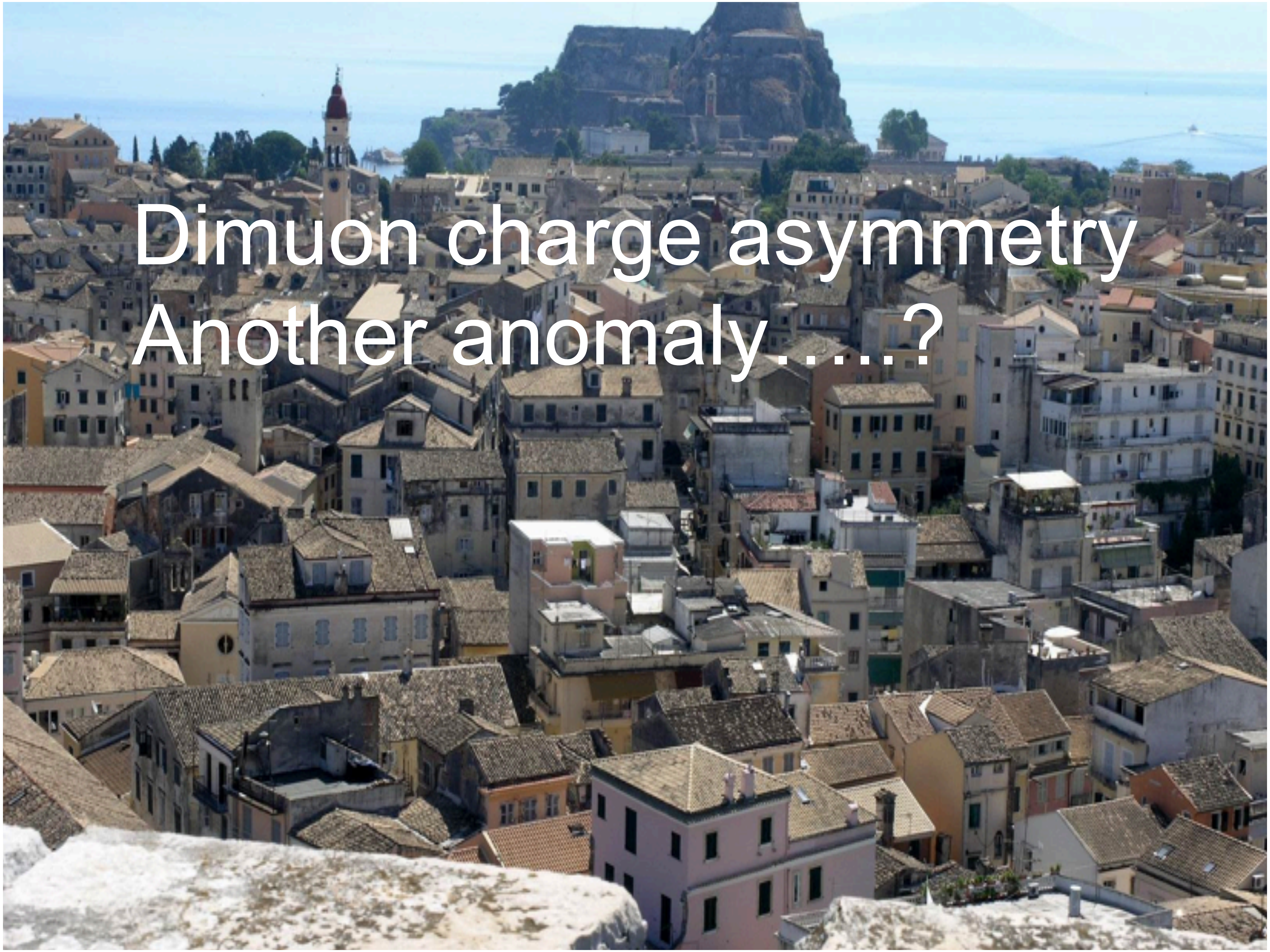


(Palestini, ICHEP 2012)

Combining LHCb results:

ϕ_s= -0.002±0.083±0.027 (rad)

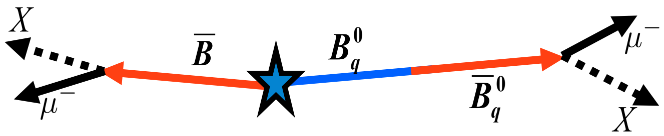
No big NP effects in ϕ_s !! → must increase precision


Dimuon charge asymmetry
Another anomaly…..?

Dimuon charge asymmetry
Another anomaly…..?

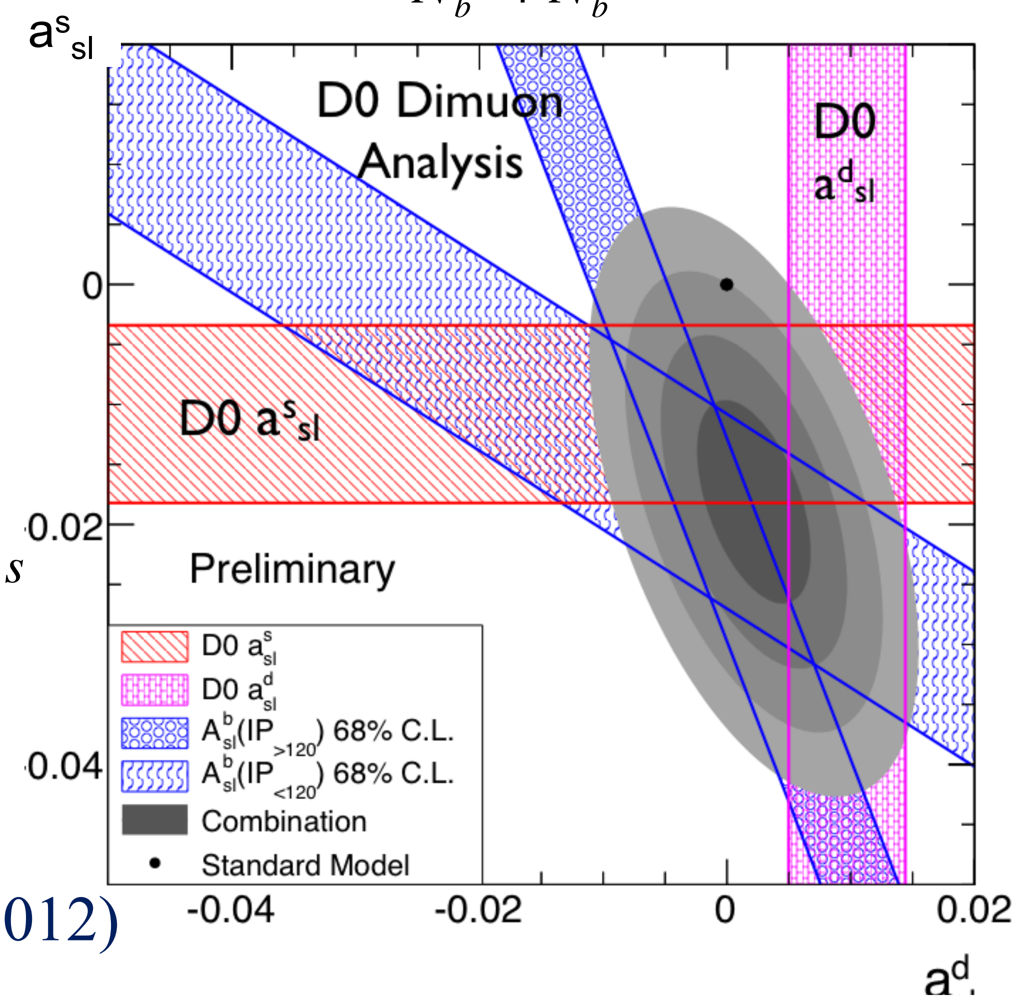
- D0 measures, with dileptons, the ratio: $A_{SL}^{b} = \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$

N_b^{++} (N_b^{--}) – number of same-sign $\mu^+\mu^+$ ($\mu^-\mu^-$) events from $B \rightarrow \mu X$ decay



$$A_{SL}^{b} = \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}} = C_d \cdot a_{sl}^{d} + C_s \cdot a_{sl}^{s}$$

$$a_{sl}^{q} = \frac{\Gamma(\bar{B}_q^0 \rightarrow \mu^+ X) - \Gamma(B_q^0 \rightarrow \mu^- X)}{\Gamma(\bar{B}_q^0 \rightarrow \mu^+ X) + \Gamma(B_q^0 \rightarrow \mu^- X)};\ q = d, s$$



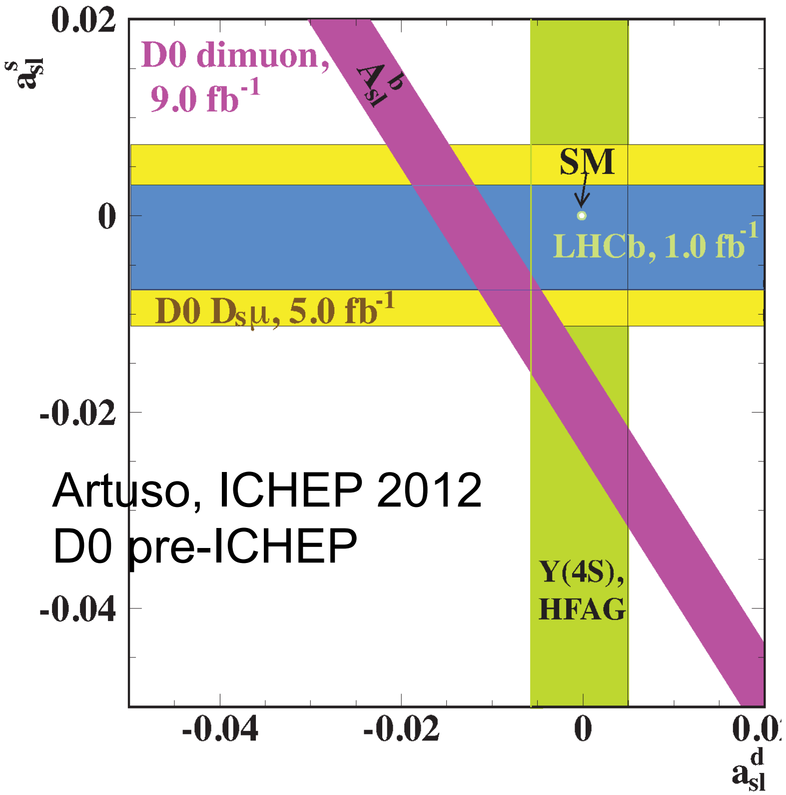
- ~3σ effect (Bertram, ICHEP 2012)

LHCb: Dimuon charge asymmetry

- Use $B_s \to D_s(\phi\pi)\mu\upsilon X$
- Measure time-integrated asymmetry:

$$A_{meas} = \frac{\Gamma(D_s^-\mu^+) - \Gamma(D_s^+\mu^-)}{\Gamma(D_s^-\mu^+) + \Gamma(D_s^+\mu^-)}$$

- Detector asymmetries between $D_s^+\mu^-$ and $D_s^-\mu^+$ addressed by
  - MAGNET UP and MAGNET DOWN samples of almost equal size
  - Calibration samples used to measure experimental biases
- Effect of $B_s/\overline{B}_s$ production asymmetry suppressed by fast B_s oscillations



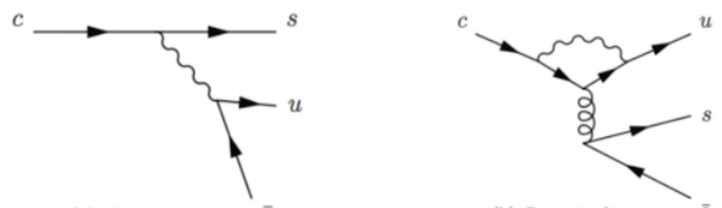
LHCb: a^s_{sl}= (-0.24±0.54±0.33)% LHCb-CONF-2012-022

Results consistent with SM, but more precision needed to conclude on this

Search for direct CPV in charm decays

Search for direct CPV in SCS charm decays

- Direct CPV : amplitudes for a process and its conjugate differ
- Expected small in SM
  - Negligible in Cabibbo favoured modes
- Singly Cabibbo Suppressed decays are an interesting sector to look for CPV as interference between tree and penguin diagrams gives sensitivity to NP



(a) Tree diagram. (b) Penguin diagram.

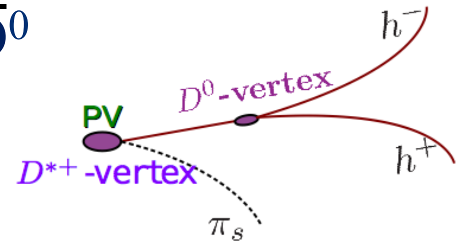
$$c \rightarrow s\bar{s}u,\ c \rightarrow d\bar{d}u$$

$$e.g.\ D^0 \rightarrow K^+K^-, \pi^+\pi^-$$

- LHCb has very large samples (1.4M tagged $D^0 \rightarrow K^+K^-$ and 0.4M $D^0 \rightarrow \pi^+\pi^-$, i.e. statistics in $D^0 \rightarrow hh$ for 2011 data alone are order of magnitude higher than total B-factory yields)
- Clear opportunity for NP search!

CPV in time-integrated D⁰→h⁺h⁻ decay rates

- Select $D^{*+}\rightarrow D^0\pi^+$ and charge conjugate decay
- Charge of slow π tags the initial flavour of D^0 or $\overline{D}^0$



$$A_{raw}(f) = \frac{N(D^{*+}\rightarrow D^0(f)\pi_s^+) - N(D^{*-}\rightarrow \overline{D}^0(\overline{f})\pi_s^-)}{N(D^{*+}\rightarrow D^0(f)\pi_s^+) + N(D^{*-}\rightarrow \overline{D}^0(\overline{f})\pi_s^-)}$$

- Raw asymmetry for tagged D^0 to final state f ($\pi^+\pi^-$ or K^+K^-):

$$A_{CP}^{RAW}(KK) = A_{CP}(KK) + A_D(\pi_S) + A_P(D^*)$$

$$A_{CP}^{RAW}(\pi\pi) = A_{CP}(\pi\pi) + A_D(\pi_S) + A_P(D^*)$$

2 observables — 2 CP asymmetries — 1 detection asymmetry — 1 production asymmetry

- Difference ΔA_{CP} is a good observable!!!

$$\Delta A_{CP} = A_{CP}(KK) - A_{CP}(\pi\pi) = A_{CP}^{RAW}(KK) - A_{CP}^{RAW}(\pi\pi)$$

LHCb, PRL 108, 111602 (2012)

Evidence of CPV in time-integrated $D^o \rightarrow h^+h^-$ decay rates

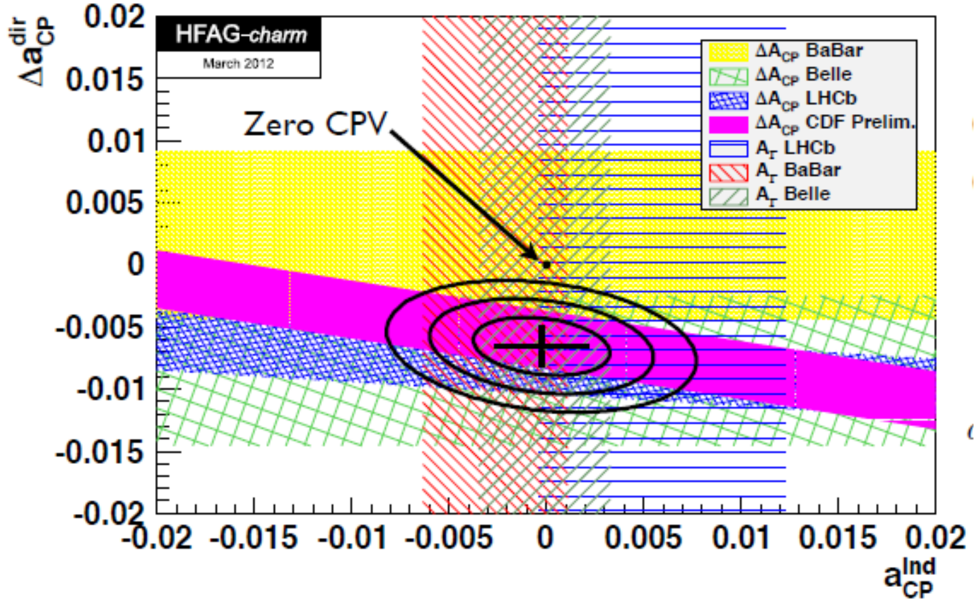
- ΔA_{CP} mainly related to direct CP violation.Contribution from indirect CPV remains if time acceptance is different for $\pi^+\pi^-$ and K^+K^- final states:

$$\Delta A_{CP} = \left[a_{CP}^{\rm dir}(K^-K^+) - a_{CP}^{\rm dir}(\pi^-\pi^+)\right] + \frac{\Delta\langle t\rangle}{\tau} a_{CP}^{\rm ind}$$

- Result, based on 0.62/fb of 2011 data is

$\Delta A_{CP} = (-0.82 \pm 0.21_{stat} \pm 0.11_{syst})\%$

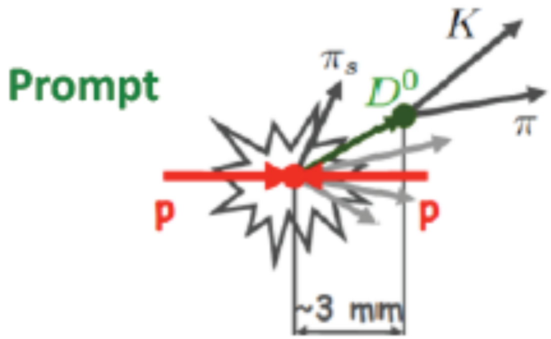
LHCb, PRL 108, 111602 (2012)

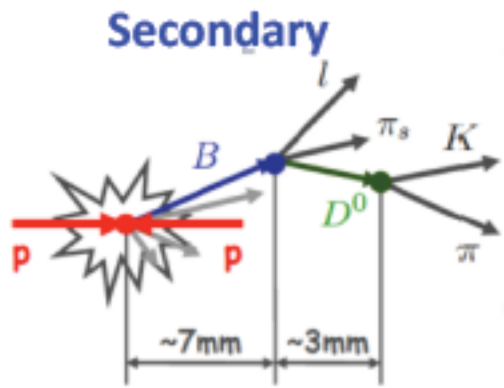


(Note also recent preliminary CDF result: [-0.62 +- 0.21 +- 0.10]% [CDF note 10784])

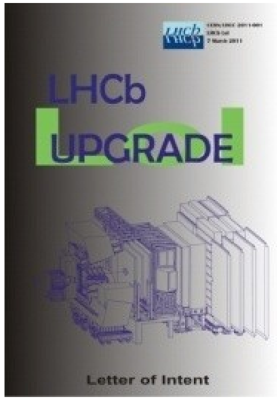
Evidence of CPV in time-integrated $D^o \rightarrow h^+h^-$ decay rates

- Prospects
  - Analysis of remainder of 2011 data is ongoing (~0.4/fb)
  - Published analysis selects prompt charm→ only ~3% of total yield is charm from B
  - Alternative analysis ongoing in which D^0 flavour is tagged using charge of μ in semileptonic B decays → completely different systematics, interesting experimental cross-check
  - Precision study of other SCS modes (e.g. $D+ \rightarrow K^-K^+\pi^+$, $\pi^-\pi^+\pi^+$, ..)





Upgrade of the LHCb Detector



J.Albrecht

LHC(b) Long Term Plan

2009		✧ LHC startup, $\sqrt{s}$ = 900 GeV
2010–2012	50ns	$\sqrt{s}$=7/8TeV; L_{LHCb}= 3-4x10^{32} $cm^{-2}s^{-1}$ → ~1.5fb^{-1}/year
2013–2014	LS1	**LHCb first infrastructure for Upgrade**
2015–2017	25ns	$\sqrt{s}$=13/14TeV; L_{LHCb}= 4x10^{32} $cm^{-2}s^{-1}$ → 1.5-2fb^{-1}/year
2018	LS2	**LHCb Upgrade Installation**
2019–2021	25ns	$\sqrt{s}$=14TeV; L_{LHCb}= 1-2x10^{33} $cm^{-2}s^{-1}$ → >5fb^{-1}/year
2022	LS3	HL-LHC Phase-2 upgrade, IR, crab cavities?
2023 … 2030?	?ns	$\sqrt{s}$=14TeV; L_{LHCb}= ~2x10^{33} $cm^{-2}s^{-1}$

$\int L\,dt$

3/fb

5-7/fb

50/fb

Upgrade of the LHCb Detector

- By the end of 2017 ~ 7/fb collected
- Reaching ultimate theory precision in flavour variables will need more statistics
- Current LHCb limitation is in Hardware Trigger (< 1 MHz) that does not allow us to profit from an increase in L
- **Upgrade plans:**
  - **Remove Harware Trigger, readout LHCb at 40 MHz crossing rate**
  - **Full Software Trigger in CPU farm**
  - **Increase in yields by factor 10–20 at 1–2 × 10^{33} cm^{-2} s^{-1}** (no need for High Luminosity LHC)
- **Framework Technical Design Report submitted to LHCC (June 2012) with first evaluation of upgrade cost (~ 55 MSF) and of time schedule**

Conclusions

- Wealth of LHCb results with the first 1/fb collected in 2001 at "CERN's flavour factory"
  - Everything works (LHC, luminosity leveling, detector, trigger, collaboration, data analysis, ..)
  - World record results on $B_s \rightarrow J/\Psi\phi$, $B_s \rightarrow \mu\mu$, charm…. For some topics we are moving from exploration to precision measurements.
  - Many other analyses ongoing (not only in b and c physics)
- Some new territory already explored but SM still depressingly uncracked
- We'll keep on looking….
- More than double the statistics in 2012
- Working hard to prepare for the future (LHCb Upgrade)