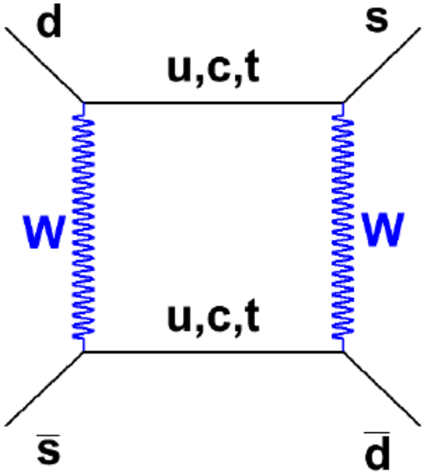
IGFAE activities in LHCb & BSM

Diego Martínez Santos
Axencia Galega de Innovacion

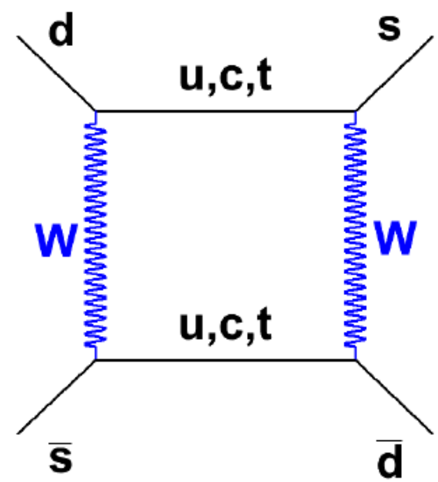
The LHCb experiment

- The **LHCb physics program** focuses mostly on CP violation and rare decays
- Both correspond to **indirect searches for New Physics** (i.e, new particles),
- Indirect approach has been very successful in the past
  - Neutral Currents
    (Z^0 inferred ten years before direct observation)
  - Kaon mixing
    (top-quark inferred 30 years before direct observation)



The LHCb experiment

- The **LHCb physics program** focuses mostly on CP violation and rare decays
- Both correspond to **indirect searches for New Physics** (i.e, new particles),
- Indirect approach has been very successful in the past
  - Neutral Currents
    (Z^0 inferred ten years before direct observation)
  - Kaon mixing
    (top-quark inferred 30 years before direct observation)

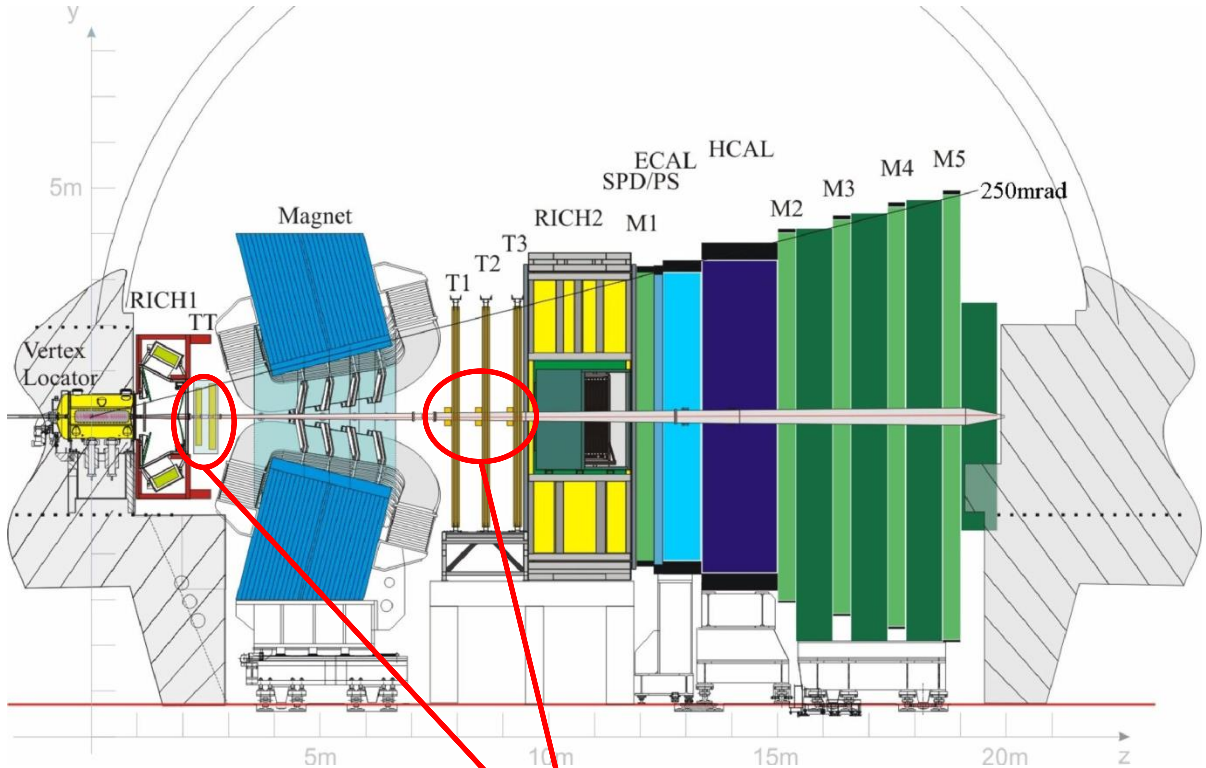


(you may also notice Earth' radius was inferred indirectly 2.3k years before direct observation…)

Eratosthenes

~2.3 K years till the direct observation…

The LHCb experiment



Main modes (historically)

+Properties of Bs oscillation (Φs)

+Bs→μμ

But the program expanded a lot with time

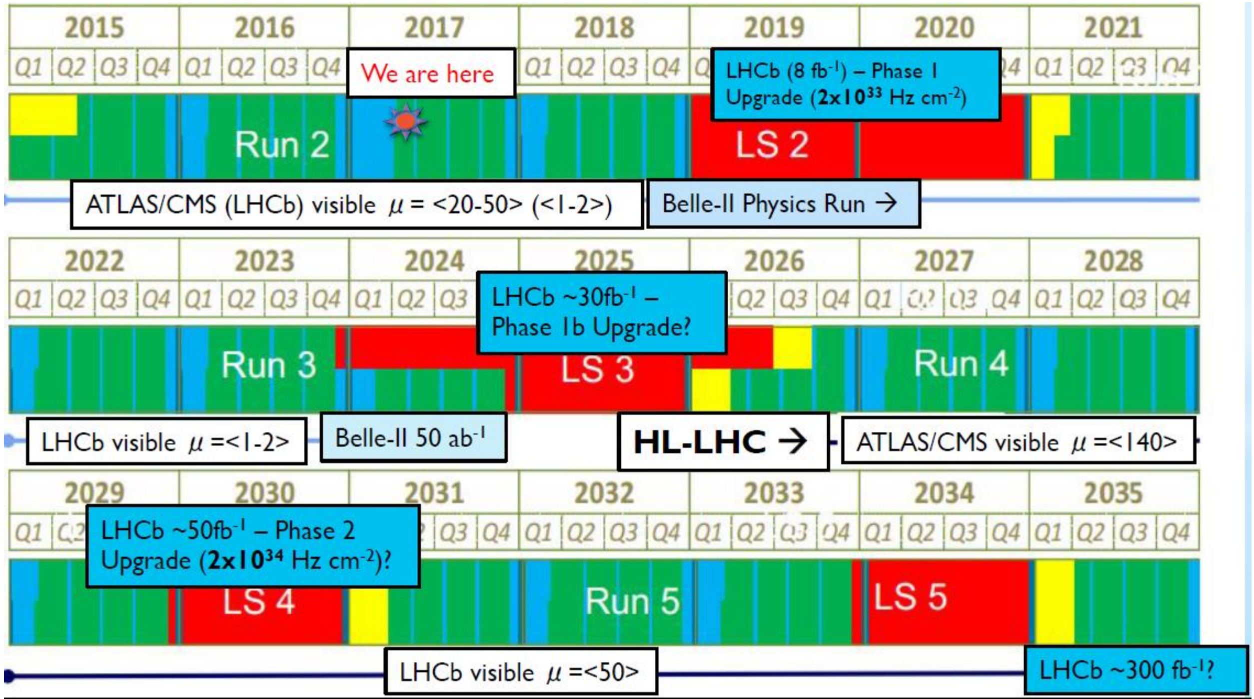
Santiago is founding member

ST (4.5 M.Euro construccion, manpower), A.Gallas P.L 2011-2014

Computing (Tier2, Tier3, manpower)

HLT: sw, manpower, J.Prisciandaro (USC) in charge of muon HLT together with F.Dettori (Liverpool)

LHCb



LHCb-upgrade: approved
USC contributes to the VELO and HLT (MoU in progress)

LoI for Phase2 LHCb-upgrade to run till 2035

	LHC Run	Period of data taking	Maximum $\mathcal{L}$ $[\mathrm{cm^{-2}s^{-1}}]$	Cumulative $\int \mathcal{L}\,dt$ $[\mathrm{fb^{-1}}]$
Current detector	1 & 2	2010–2012, 2015–2018	4×10^{32}	8
Phase-I Upgrade	3 & 4	2021–2023, 2026–2029	2×10^{33}	50
Phase-II Upgrade	5 $\rightarrow$	2031–2033, 2035 $\rightarrow$	2×10^{34}	300

Ongoing (& past) results

$B_s \rightarrow \mu\mu$

- $B_s \rightarrow \mu\mu$ are golden modes in NP searches, specially SUSY

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.0 \pm 0.6\,^{+0.3}_{-0.2}) \times 10^{-9}$$

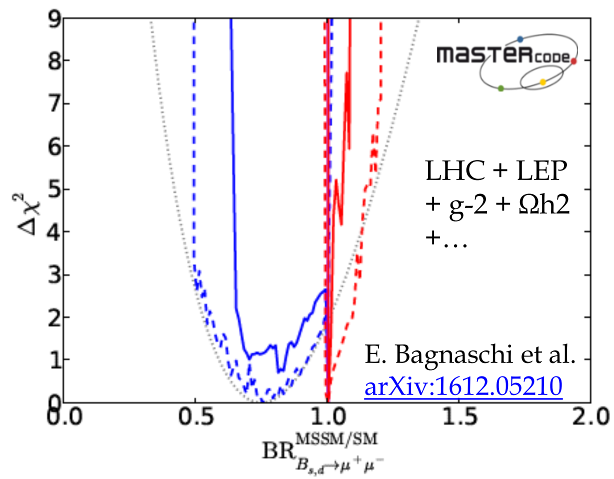
LHCb, arXiv:1703.05747 PRL 118, 191801 (2017)

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-)_{\mathrm{SM}} = (3.65 \pm 0.23) \times 10^{-9}$$

C. Bobeth et al., arXiv:1311.0903.

- Deviations from SM allowed despite LHC bounds on NP
- Expected precision

$\sigma(BR(B_s \rightarrow \mu\mu))$, 50 fb^{-1} ~ 3.1×10^{-10}
$\sigma(BR(B_s \rightarrow \mu\mu))$, 300 fb^{-1} ~ 2.7×10^{-10}



$B_s \to \mu\mu$

LHCb POTENTIAL TO MEASURE/EXCLUDE THE BRANCHING RATIO OF THE DECAY $B_s \to \mu^+\mu^-$

LHCb-PUB-2007-033

DIEGO MARTINEZ
Universidade de Santiago de Compostela
Campus Universitario Sur, E-15706, Spain

JOSE ANGEL HERNANDO, FREDERIC TEUBERT
PH Department, CERN
Geneva 23, CH-1211, Switzerland

2007

potential to exclude the interesting region between 10^{-8} and the SM prediction with very little luminosity (~0.5 fb^{-1}), and has the potential to claim a 3σ (5σ) observation (discovery) of the SM prediction with ~2 fb^{-1} (~6 fb^{-1}) of data.

$B_s \to \mu\mu$

LHCb-PUB-2007-033

LHCb POTENTIAL TO MEASURE/EXCLUDE THE BRANCHING RATIO OF THE DECAY $B_s \to \mu^+\mu^-$

DIEGO MARTINEZ
Universidade de Santiago de Compostela
Campus Universitario Sur, E-15706, Spain

JOSE ANGEL HERNANDO, FREDERIC TEUBERT
PH Department, CERN
Geneva 23, CH-1211, Switzerland

2007

potential to exclude the interesting region between 10^{-8} and the SM prediction with very little luminosity (~0.5 fb^{-1}), and has the potential to claim a 3σ (5σ) observation (discovery) of the SM prediction with ~2 fb^{-1} (~6 fb^{-1}) of data.

Phys. Rev. Lett. 108, 231801 (**2012**)
→ exclude down to 4.5×10^{-9} w/ 1 fb^{-1}

Phys. Rev. Lett. 110, 021801 (**2013**)
→ 1st 3σ evidence w/ 2.1 fb^{-1}

Phys. Rev. Lett. 118, 191801 (**2017**)
→ 1st single experiment >5σ w/ 4.4 fb^{-1}

$B_s \to \mu\mu$

$B_s \to \mu\mu$
PLB 699 330 (2011)
CERN-LHCb-CONF-2011-047
PLB 708 55 (2012)
CERN-LHCb-CONF-2012-017
PRL 108 231801 (2012)
PRL 110 021801 (2013)
PRL 111 101805 (2013)
CERN-LHCb-CONF-2013-012
Nature 522 68 (2015)
PRL 118 191801 (2017)

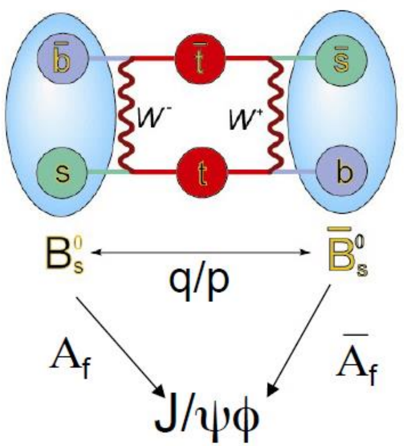
USC involved:, X. Cid, JA Hernando, D. Martinez

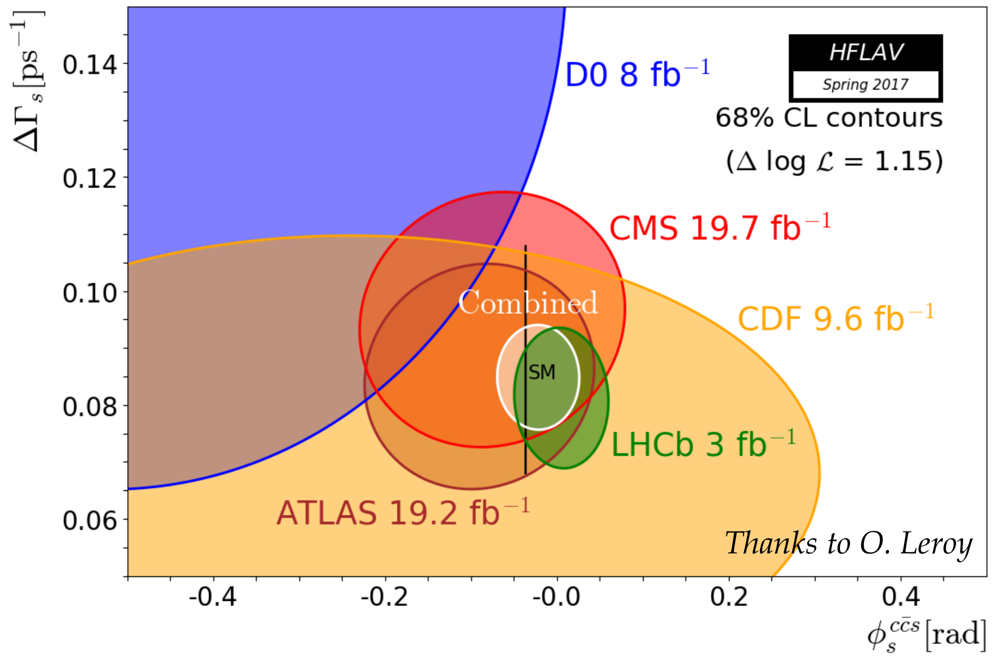
I was main contributor till ~2013, since then my involvement is mostly assistance

We are restarting some bigger involvement here (Martino, me, Miguel).

Pioneered other very rare decays (DMS) : $B \to 4\mu$, $\tau \to 3\mu$...

B_s mixing phase: Φ_s





CPV in interference mixing-decay:

$$\sin(\boldsymbol{\phi_s}) \equiv \sin\left(-arg\left(\frac{q}{p}\frac{A_f}{\overline{A_f}}\right)\right) \neq 0$$

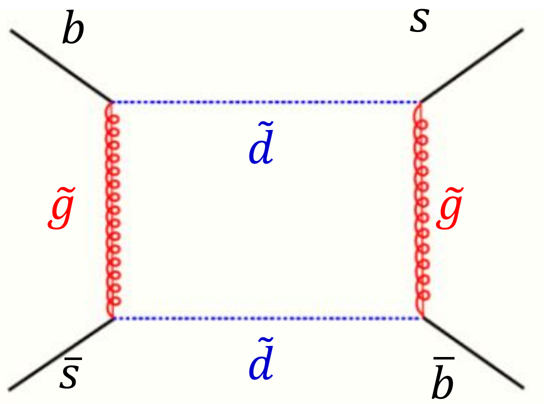
$$\phi_S^{EXP} = -0.021 \pm 0.031\, rad$$

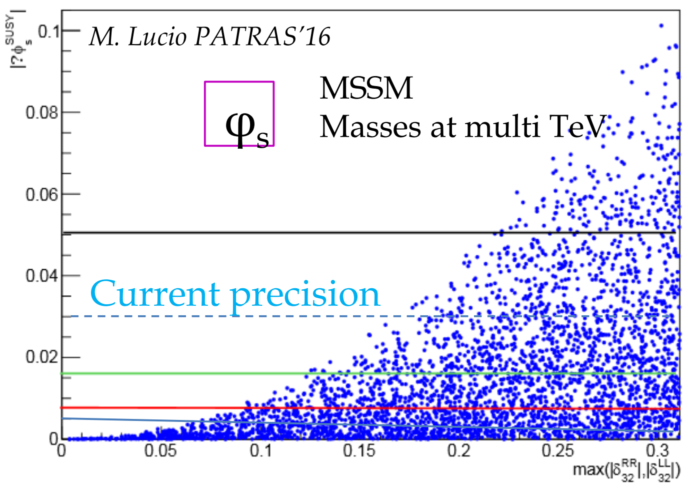
Which in b→cc decays corresponds to the mechanical phase of the Bs mixing. In SM:

$$\phi_s \overset{\text{SM}}{=} -2\arg\left(\frac{V_{tb}V_{ts}^*}{V_{cb}V_{cs}^*}\right) \equiv -2\beta_s = -0.0376 \pm 0.0008\,\text{rad}$$

B_s mixing phase: Φ_s

- Neutral meson mixing ($\Delta F = 2$ transitions) are extremely sensitive to new source of flavour violation. eg, for O(1) couplings bounds on Λ_{NP} at **100 – 10^5 TeV**
- eg, in SUSY the B mesons can mix via gluino box





USC: Analysis of the differential decay rate of Bs→J/ψKK in Ω,t, flavour tagging, m_{KK}.

Main channel for the measurement of Φ_s , Γ_s , $\Delta\Gamma_s$, important also for ΔMs

B_s mixing phase: Φ_s

- Publication ongoing (USC: V. Chobanova, M.Lucio, D.Martinez)
- (two previous when I was at Nikhef)

Potential sources of SM uncertainties to Φ_s can be controlled by experimental analysis of the related channel $B_s \rightarrow J/\psi K\pi$ pioneered by us

$B_s \rightarrow J/\psi K\pi$
LHCb-CONF-2011-025. D. Martinez(CERN), Juan Saborido (USC)
Phys. Rev. D 86, 071102(R) (2012), “” & Paula
JHEP 11 (2015) 082, “” & Carlos Vazquez (thesis) , & NIKHEF & CPPM

Lepton Universality Violation

LHCb observed some interesting deviations in the ratios

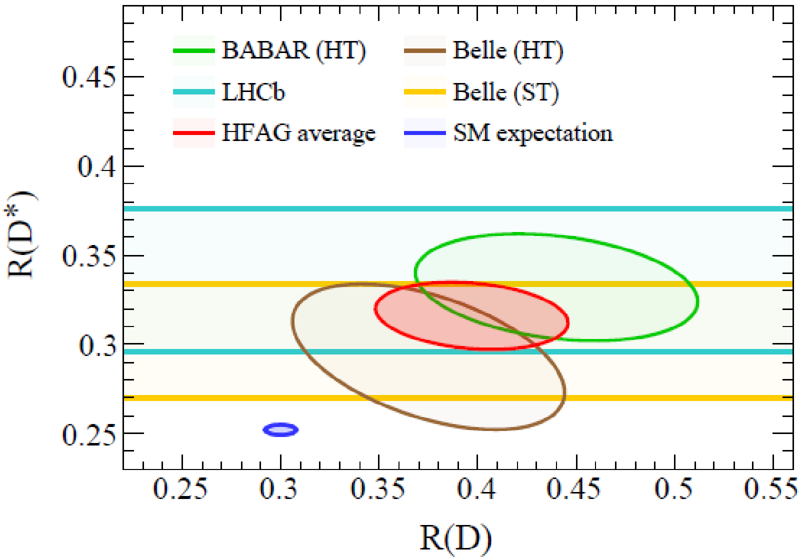
$$\mathcal{R}_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+ J/\psi(\to \mu^+\mu^-))} \Big/ \frac{\mathcal{B}(B^+ \to K^+e^+e^-)}{\mathcal{B}(B^+ \to K^+ J/\psi(\to e^+e^-))}$$

$$\mathcal{R}_{K^{*0}} = \frac{\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to \mu^+\mu^-))} \Big/ \frac{\mathcal{B}(B^0 \to K^{*0}e^+e^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+e^-))}$$

$$R(X_c) = \frac{\mathcal{B}(X_b \to X_c\tau\nu)}{\mathcal{B}(X_b \to X_c\ell\nu)}$$

Contributions from M. Borsato (RK*), A. Romero (RD*-hadronic) and others from USC

More details in Maria´s talk



Charmless B decays

Sophisticated analyses of B decays into 4 charged hadrons, dominated by VV topology (similar to J/ψΦ, K*)

- BR's, Polarization fractions
- $\Phi_s^{K^*K^*}$, & its penguin pollutions
- CKM parameter α, important to improve SM predictions in several flavour observables. There are chances that LHCb overtakes Belle by using B→ρρ.

Decay Mode	Publication
$B_s^0 \to K^{*0}\bar{K}^{*0}$	Phys.Lett. B709 (2012) 50-58
$B_s^0 \to \phi\bar{K}^{*0}$	JHEP 1311 (2013) 092
$B^0 \to \phi K^{*0}$	JHEP 05 (2014)069
$B^0 \to \rho^0\rho^0$	Phys.Lett. B747 (2015) 468-478
Update of $B_s^0 \to K^{*0}\bar{K}^{*0}$	JHEP 1507 (2015) 166
Time dependent $B_s^0 \to K^{*0}\bar{K}^{*0}$	Soon
$B^0 \to K^{*0}\bar{K}^{*0}$	Soon
$B^0 \to \rho^0 K^{*0}$	Soon

Many USCers involved:
(B. Adeva, **P. Alvarez**(1), X. Cid, A. Dosil, **J. Garcia**(2), D. Martinez, M. Plo, A. Romero, JJ Saborido, **B. Sanmartin**(1), C. Santamarina, **M. Vieites**(2)...)

(1) Defended a thesis on the subject
(2) Thesis to be defended soon

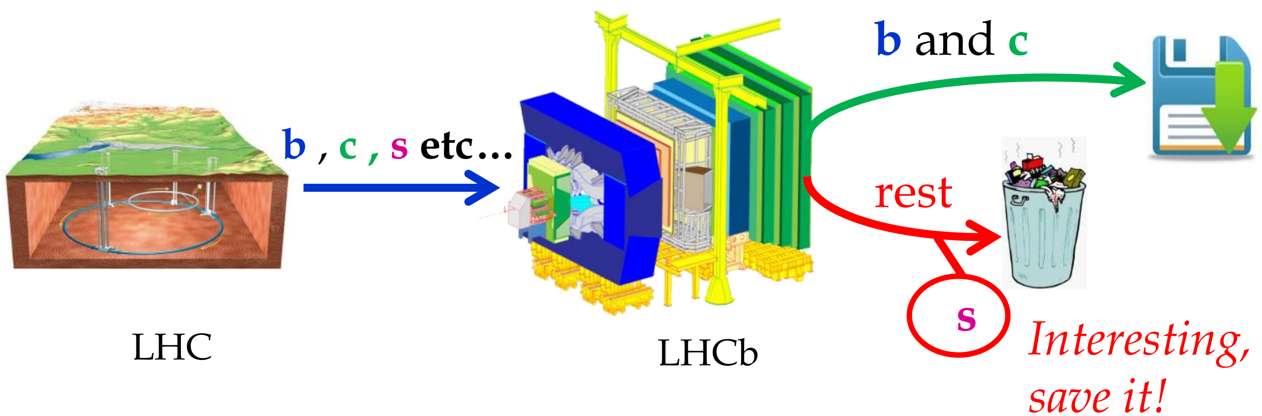
More details in Julian´s talk

Strangeness decays

Adapt LHCb for rare decays of **strange** particles :

→ make a **kaon (& hyperon) experiment ("LHCs") using existing infrastructure**

LHCb collects world leading samples of **b** and **c** quark decays. Everything else is rejected because of bandwidth reasons



However, if BSM above few TeV (LHC energy scale), **s**-hadron decays are of central **importance (very sensitive to non-MFV)**. But most of them are (were) lost !

Strangeness decays

- ERC project focused mostly on developing triggers for strangeness decays
- V.Chobanova, X.Cid, M.Lucio, D.Martinez, J. Prisciandaro, M. Ramos
- LHCb upgrade will have full software trigger
- This can potentially boost the efficiencies to ~100%
- Simulation studies show that trigger output rates can be controlled (V. Chobanova)

→ **For Strange decays, the LHCb upgrade is much more than "just" a luminosity gain**

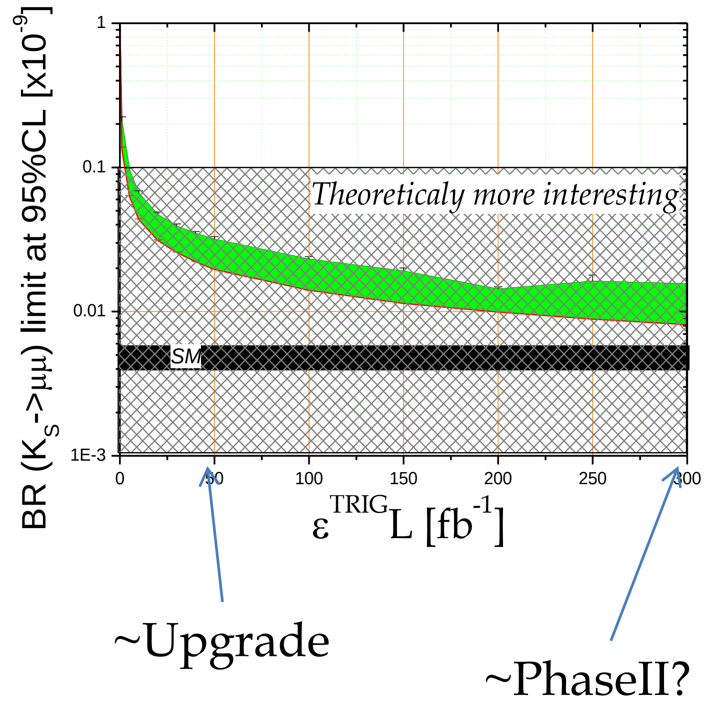
- In the mean time, we improved the efficiency in the current Run by a factor ~x10 already

PERIOD	Efficiency ($K \to \mu\mu$)
2011	~ 1%
2012	~2.4 %
Run-II (expected)	~18 %
Full sw trigger	O(100%)

Trigger efficiencies are normalized to events that would have been selected offline

Strangeness decays

- $K_S \rightarrow \mu\mu$: sensitive to NP scalars, complementary to other $P \rightarrow \mu\mu$
  - Run-II: explore 10^{-10} region
  - 50 fb-1 → BR < 10^{-10} region
  - 300 fb-1 → go further, down to near SM

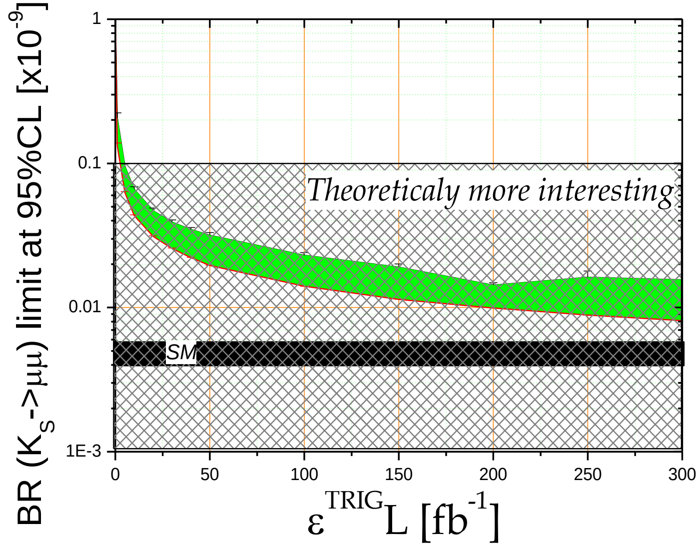


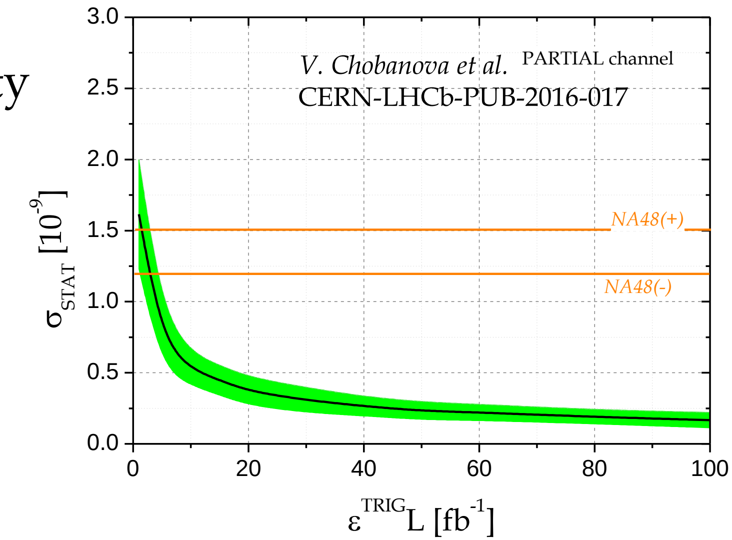
Strangeness decays

- $K_S \rightarrow \mu\mu$: sensitive to NP scalars, complementary to other $P \rightarrow \mu\mu$
  - Run-II: explore 10^{-10} region
  - 50 fb-1 → BR < 10^{-10} region
  - 300 fb-1 → go further, down to near SM

- $K_S \rightarrow \pi^0\mu\mu$:
  - $K_L \rightarrow \pi^0\mu\mu$ is an important mode in several NP scenarios (eg, ED)
  - SM precision dominated by EXP uncertainty on $K_S \rightarrow \pi^0\mu\mu$ (NA48)
  - LHCb upgrade can improve it
  - Dimuon spectum and LFV also interesting

- Several other Kaon and hyperon measurements





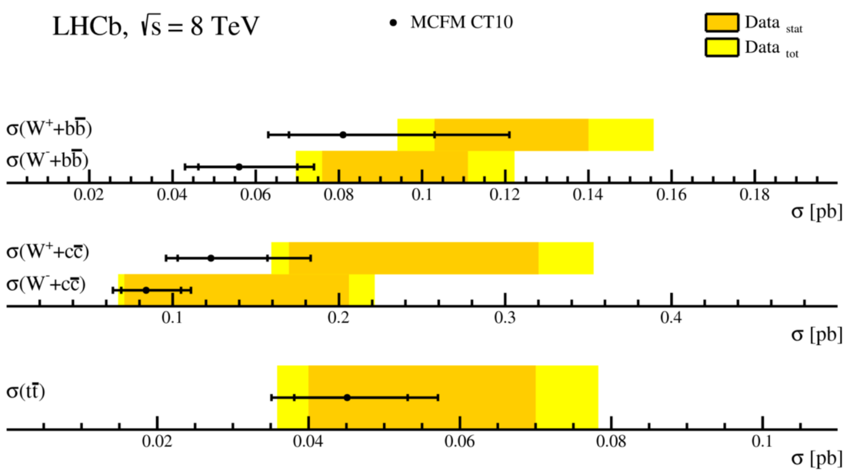
Strangeness decays, USC publications

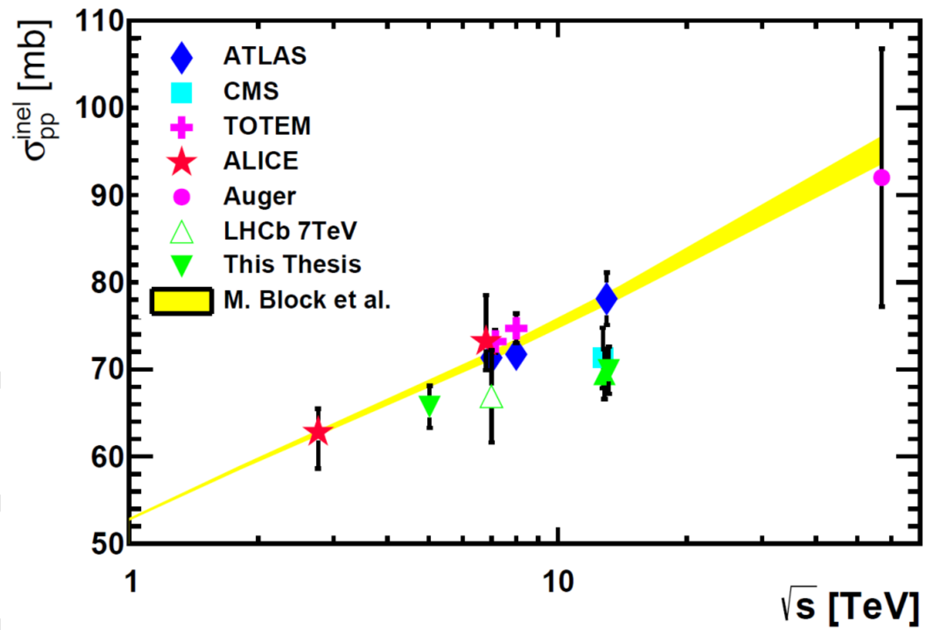
Physics results	
$K_S \to \mu\mu$ (first result from LHCb) x30 better limit than previous exp.	JHEP 01 (2013) 090
$K_S \to \mu\mu$ update	LHCb-CONF-2016-012
$K_S \to \mu\mu$ update	EPJC, 77 10 (2017) 678
Sensitivity $K^0_S \to \pi^0\mu\mu$	CERN-LHCb-PUB-2016-017
Sensitivity $K^0_S \to \pi\pi ee$	CERN-LHCb-PUB-2016-016
$\Sigma \to p\mu\mu$ update	Ongoing
Measurement of K+ mas	Ongoing
$K_S \to \mu\mu\gamma$ update	Ongoing
Technical stuff	
Muon reconstruction	CERN-LHCb-PUB-2017-007
HLT performance	CERN-LHCb-PUB-2017-023

HLT upgrade status: writing trigger lines, drafting Memorandum of Understanding

Not only flavour

Physics with jets and EW physics: W, Z, Higgs and top





(SM Higgs Limits LHCb)	LHCb-CONF-2016-006	Xabier
W+bb, W+cc e tt,	PLB 767 (2017) 110	Xabier , Maria
search for Dark Photons	arXiv:1710.02867	MIT, contributions from Xabier
pp xsection at 5 and 13 TeV	Soon	Alvaro's thesis
Search for A1 light Higgs	Soon (end of ERC WP2)	Martino, Xabier, Diego, C. Vazquez thesis

USC in the Working Groups structure of LHCb

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

PWG	
QEE	**QCD, EW, Exotica**
B&Q	B decays and Quarkonia (spectroscopy)
Charm	(charm)
RD	**Rare decays (e.g. B→μμ)**
B2CC	**B decays to Charmonia (Φs and related)**
B2OC	B decays to Open Charm
B2noC	**Charmless B decays**
SLB	**Semileptonic**
IFT	*Ion Fix Target* NEW

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

PWG	Staying convener (Jan 2017- Mar 2019)		Appointed convener(s) (Jan 2018-Mar 2020)		
	Name	Laboratory	Name	PhD	Laboratory
QEE	Will Barter	Manchester	Stephen Farry	2012	Liverpool
B&Q	Sebastian Neubert	Heidelberg	Yanxi Zhang	2013	LAL
Charm	Andrea Contu	CERN→Cagliari	Maurizio Martinelli	2011	EPFL
RD	Christoph Langenbruch	Aachen	Simone Bifani	2008	Birmingham
B2CC	Francesca Dordei	CERN→Cagliari	Veronika Chobanova	2015	Santiago
B2OC	Matt Kenzie	Cambridge	Mark Whitehead	2012	CERN→ Aachen
B2noC	Sean Benson	Nikhef	Wenbin Qian	2010	Warwick→UCAS
SLB	Greg Cziezarek	CERN	Lucia Grillo	2015	Manchester
IFT			Michael Winn Frederic Fleuret	2016 1997	LAL LLR

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

PWG	Staying convener (Jan 2017- Mar 2019)		Appointed convener(s) (Jan 2018-Mar 2020)		
	Name	Laboratory	Name	PhD	Laboratory
QEE	Will Barter	Manchester	Stephen Farry	2012	Liverpool
B&Q	Sebastian Neubert	Heidelberg	Yanxi Zhang	2013	LAL
Charm	Andrea Contu	CERN→Cagliari	Maurizio Martinelli	2011	EPFL
RD	Christoph Langenbruch	Aachen	Simone Bifani	2008	Birmingham
B2CC	Francesca Dordei	CERN→Cagliari	Veronika Chobanova	2015	Santiago
B2OC	Matt Kenzie	Cambridge	Mark Whitehead	2012	CERN→ Aachen
B2noC	Sean Benson	Nikhef	Wenbin Qian	2010	Warwick→UCAS
SLB	Greg Cziezarek	CERN	Lucia Grillo	2015	Manchester
IFT			Michael Winn Frederic Fleuret	2016 1997	LAL LLR

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

PWG	Staying convener (Jan 2017- Mar 2019)		Appointed convener(s) (Jan 2018-Mar 2020)		
	Name	Laboratory	Name	PhD	Laboratory
QEE	Will Barter	Manchester	Stephen Farry	2012	Liverpool
B&Q	Sebastian Neubert	Heidelberg	Yanxi Zhang	2013	LAL
Charm	Andrea Contu	CERN→Cagliari	Maurizio Martinelli	2011	EPFL
RD	Christoph Langenbruch	Aachen	Simone Bifani	2008	Birmingham
B2CC	Francesca Dordei	CERN→Cagliari	Veronika Chobanova	2015	Santiago
B2OC	Matt Kenzie	Cambridge	Mark Whitehead	2012	CERN→ Aachen
B2noC	Sean Benson	Nikhef	Wenbin Qian	2010	Warwick→UCAS
SLB	Greg Cziezarek	CERN	Lucia Grillo	2015	Manchester
IFT			Michael Winn Frederic Fleuret	2016 1997	LAL LLR

Finishing: Xabier Cid (**QEE**, in office: 2016-early 2018),
Previously: Diego Martinez Santos (**B2CC**, in office: 2013- early 2015)

Subconveners

Each WG is divided into subgroups (→ subconveners)

Currently:

V. Chobanova (CP Tools and Techniques)
M. Borsato (Exotica&Higgs)
J. Prisciandaro (Very Rare Decays)
A. Romero (semitauonic)

& J.Dalseno, (B2OC-AmpAn)

In the past:
J.A. Hernando (Bmm), X. Cid (Exotica)

	USC		**Rest LHCb-ES**	
	Now	Total hist.	Now	Total hist.
Conveners	1	3	0	0
Subconv.	4-5	6-7	1	1(?)

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

Physics performance WG´s

	Staying convener(s)		Appointed convener(s) (Jan 2018-Mar 2020)		
PPWG	Name	Laboratory	Name	PhD	Laboratory
PID&CO	Donal Hill Martino Borsato	Oxford Santiago	Anton Poluektov Jean-Francois Marchand	2007 2009	Warwick LAPP
T&A	Agnieszka Dziurda Francesco Polci	CERN LPNHE	Giulio Dujany	2017	LPNHE
Flavour Tagging	Simon Akar	Cincinatti	Manuel Schiller	2011	Glasgow
Simulation	Gloria Corti	CERN	Michal Kreps Phil Ilten	2004 2013	Warwick Birmingham
Stripping	Stefanie Riechert	Dortmund	Carlos Vazquez Sierra	2016	Nikhef

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

Physics performance WG´s

	Staying convener(s)		Appointed convener(s) (Jan 2018-Mar 2020)		
PPWG	Name	Laboratory	Name	PhD	Laboratory
PID&CO	Donal Hill Martino Borsato	Oxford Santiago	Anton Poluektov Jean-Francois Marchand	2007 2009	Warwick LAPP
T&A	Agnieszka Dziurda Francesco Polci	CERN LPNHE	Giulio Dujany	2017	LPNHE
Flavour Tagging	Simon Akar	Cincinatti	Manuel Schiller	2011	Glasgow
Simulation	Gloria Corti	CERN	Michal Kreps Phil Ilten	2004 2013	Warwick Birmingham
Stripping	Stefanie Riechert	Dortmund	Carlos Vazquez Sierra	2016	Nikhef

Physics Coordinator: Marie-Helene Schune
Deputy: Marc–Olivier Bettler

Physics performance WG´s

	Staying convener(s)		Appointed convener(s) (Jan 2018-Mar 2020)		
PPWG	Name	Laboratory	Name	PhD	Laboratory
PID&CO	Donal Hill Martino Borsato	Oxford Santiago	Anton Poluektov Jean-Francois Marchand	2007 2009	Warwick LAPP
T&A	Agnieszka Dziurda Francesco Polci	CERN LPNHE	Giulio Dujany	2017	LPNHE
Flavour Tagging	Simon Akar	Cincinatti	Manuel Schiller	2011	Glasgow
Simulation	Gloria Corti	CERN	Michal Kreps Phil Ilten	2004 2013	Warwick Birmingham
Stripping	Stefanie Riechert	Dortmund	Carlos Vazquez Sierra	2016	Nikhef

insight. Frederic, thank you also for the extensive reading of this document. Most particularly, I want to thank my friend Diego, who as my postdoc-without-a-Ph. D. answered all my questions.

I would also like to acknowledge the galician horde, Abe, Xavier, Daniel and Diego, who make CERN building 13 such a lively[1] place.

M.O. Bettler thesis

GPU

Research in the usage of GPU's for HEP analysis

Started in an EPLANET stay in UFRJ

Quickly developed a full framework "Ipanema" arXiv:1706.01420 [hep-ex]

- Shown great reduction on the timing for realistic analyses:
  - Found gains of 100 or even 1000x
  - But gain from hardware seems ~~60x for a GTX 980 Ti to a single core device
  - Implementing(thus understanding) your own problem from scratch gives the extra factor (up to 28x)

GPU

Research in the usage of GPU's for HEP analysis

Started in an EPLANET stay in UFRJ

Quickly developed a full framework "Ipanema" arXiv:1706.01420 [hep-ex]

- Shown great reduction on the timing for realistic analyses:
  - Found gains of 100 or even 1000x
  - But gain from hardware seems ~~60x for a GTX 980 Ti to a single core device
  - Implementing(thus understanding) your own problem from scratch gives the extra factor (up to 28x)

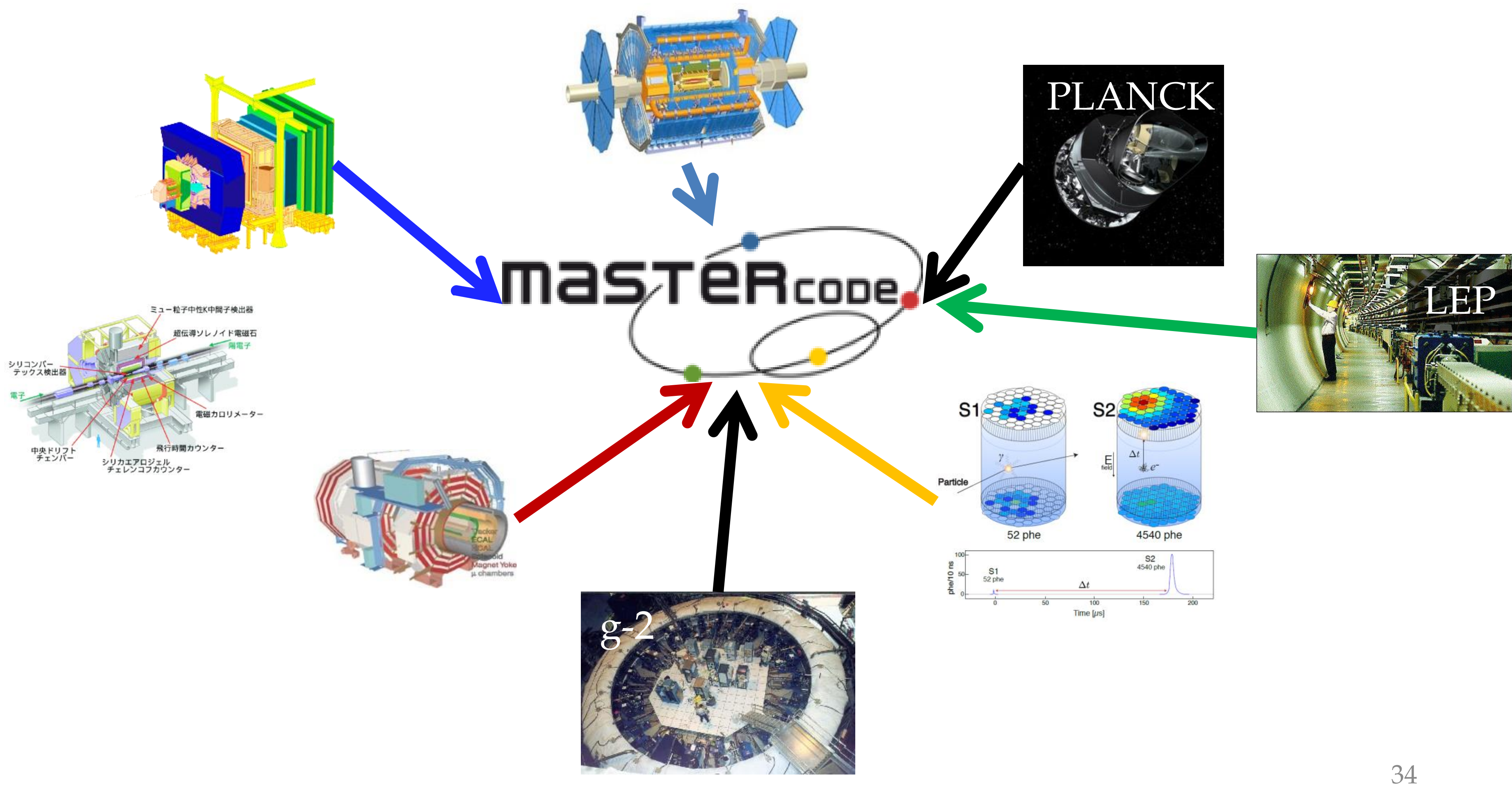
Most USC analyses migrated to this

Involved in ITN proposal in which USC will provide the training on GPU

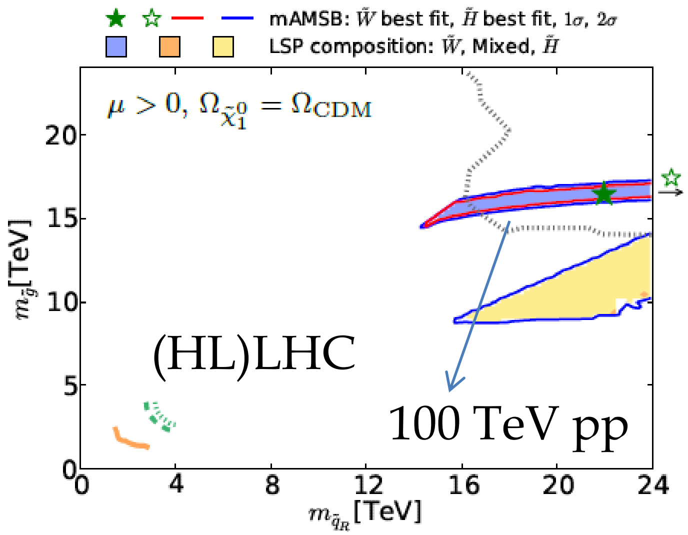
BSM Phenomenology

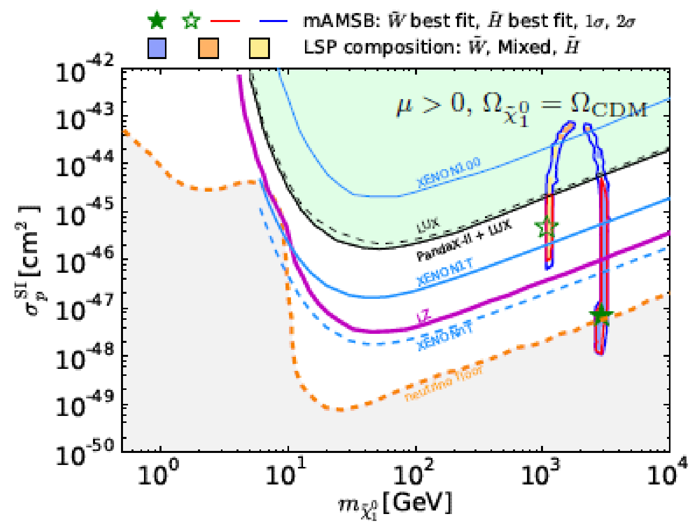
SUSY global analyses

Data from different experiments combined into SUSY global fits.



SUSY global analyses





Eg, for Anomaly mediation

- Impossible for LHC direct searches
- Some (minor) potential effects in low-E (e.g., Bs→μμ)
- But its explanation for DM can be totally ruled out in future by a combination of LZ&AMS data


MASTERcode
VidyoDesktop™ - MasterCode_Workshop@vidyoportal.cern.ch
MSSM

SUSY global analyses

I was recruited in 2011, beginning of LHC, when at CERN (6 papers in 2011-2014)

→ USC gets involved in 2015.
→ 6 papers produced in the period 2015-2017. One Master Thesis (Isabel Suarez)
USC does:
+ Flavour observables/inputs
+ Wino relic density prediction
+ Recast of ATLAS & CMS searches
+ Parameter scans for mAMSB and CMSSM

2015-2017
arXiv:1508.01173 (Dark Matter, Run 1)
arXiv:1504.03260 (pMSSM10)
arXiv:1610.10084 (SU(5) GUT)
arXiv:1612.05210 (mAMSB)
arXiv:1710.11091 (pMSSM11)
arXiv:1711.00458 (SubGUT)

(this is the one with largest USC involvement)

Flavour pheno

Also do other (smaller, more modest) collaborations to study specific effects in flavour

+ With N. Mahmoudi for the so called B anomalies (LUV and others).

  PRD 96, 095034 (2017) USC: D. Martinez

  JHEP 1707 (2017) 025 USC: D. Martinez, V. Chobanova

  (few other pub. Before I arrived to USC)

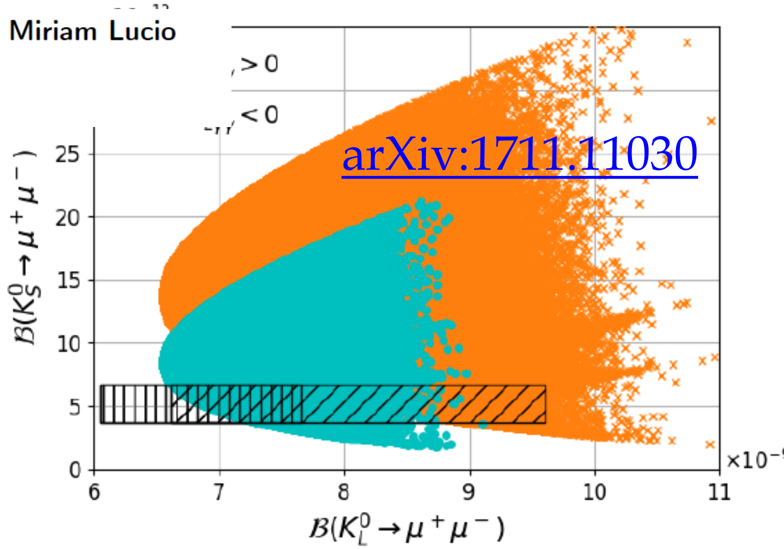
+ Working on TH prospects for proton-EDM collab.

+ Recently started to collaborate with T. Kitahara for effects of SUSY FV terms in low Energy (Kaons, B's, EDM's).

Veronika Chobanova,[a] Giancarlo D'Ambrosio,[b] Teppei Kitahara,[c,d] Miriam Lucio Martínez,[a] Diego Martínez Santos,[a] Isabel Suárez Fernández[a] and Kei Yamamoto[e,f]

Implement SUSY contributions in our GPU sw (Ipanema) and scan large parameter spaces.

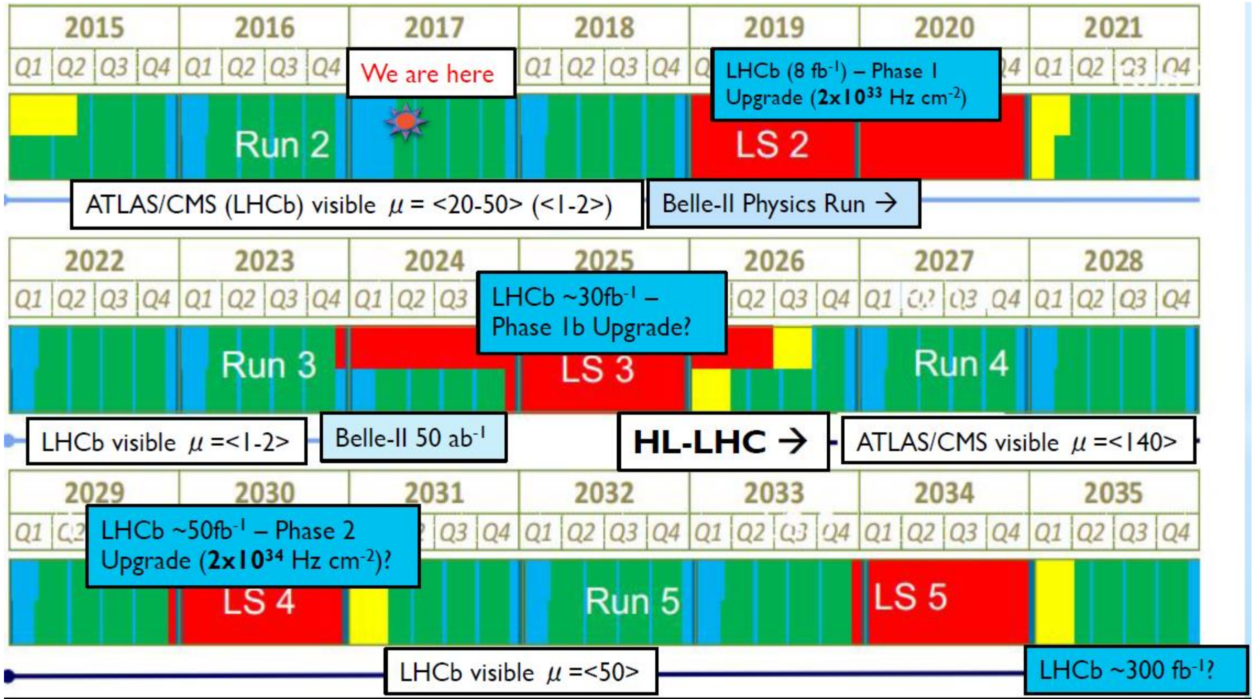
Large SUSY effects in $K_S \rightarrow \mu\mu$ allowed



arXiv:1711.11030

Future

LHCb



LHCb-upgrade: approved
USC contributes to the VELO and HLT (MoU in progress)

LoI for Phase2 LHCb-upgrade to run till 2035

	LHC Run	Period of data taking	Maximum $\mathcal{L}$ [$cm^{-2}s^{-1}$]	Cumulative $\int \mathcal{L}\,dt$ [fb^{-1}]
Current detector	1 & 2	2010–2012, 2015–2018	4×10^{32}	8
Phase-I Upgrade	3 & 4	2021–2023, 2026–2029	2×10^{33}	50
Phase-II Upgrade	5 →	2031–2033, 2035 →	2×10^{34}	300

LHCb

RD:

- Strangeness will keep increasing (two new master students, new postdoc)
- Increase also involvement in B→μμ in 2018
- Interest by Martino to continue RK*, applied for a "La Caixa" student

B2CC: Strong involvement by Veronika till march 2020 at least.

Exotica:

- Very interesting proposal from Xabier for LLP's → StG application
- A1→μμ: No plans for update (unless a signal is found)

QCD: Will continue. (Oscar Boente taking over Alvaro's legacy)

- Update of RppB, (K,π,p)
- Plenty of room in, eg, IFT

BnoC: work will also continue, many channels stat limited also for upgrade

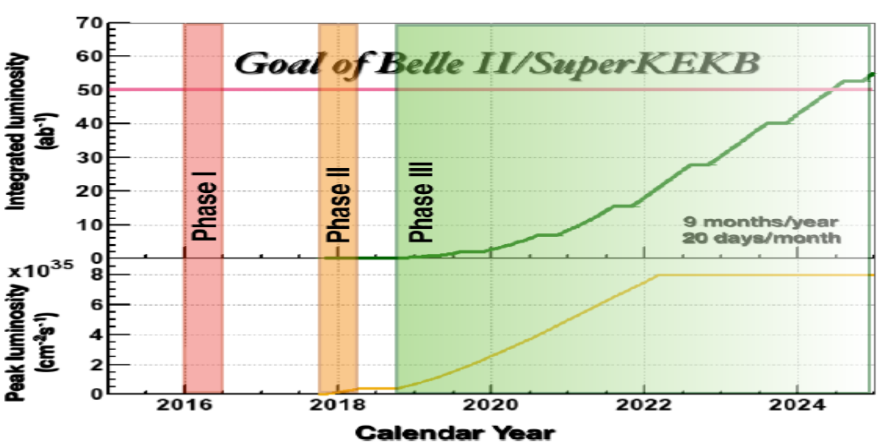
SL: work will continue (Beatriz Garcia, possibly another student)

Spectroscopy (i.e, pentaquarks) : Maybe the only important group in which we don't participate actively. We have the expertise, but to the best of my knowledge nobody in the group is interested

Other flavour experiments

Several other flavour experiments: BelleII, BESIII, KLOE, NA62…
(thanks to J. Dalseno for help in compiling information)

	M&O	service	Data taking
BESIII (cc factory)	0	y	2018-2025
KLOE (Φ factory)	0	y	Ends march 2018, then start data analysis
BelleII (Y factory)	1.8k (→ needs CIFPA ok)	y	2018-2025



Maybe is a realistic option for IGFAE programs with modest logistic (eg, Global Talent)

(warning I : XXXX doesn't like this much)
(warning II: Membership of two collabs. is usually discouraged –and forbidden in the case of LHCb+Belle)

Observable class of observables)	SM prediction	Ultimate th. error	Present result	Future (S)LHCb	Future SuperB	Future Other
$\lvert V_{us}\rvert$ $[K \to \pi\ell\nu]$	input	$0.1\%_{(\mathrm{Latt})}$	0.2252 ± 0.0009	-	-	
$\lvert V_{cb}\rvert$ $[\times 10^{-3}]$ $[B \to X_c \ell\nu]$	input	1%	40.9 ± 1.1	-	$1\%_{\mathrm{excl}}, 0.5\%_{\mathrm{incl}}$	
$\lvert V_{ub}\rvert$ $[\times 10^{-3}][B \to \pi\ell\nu]$	input	$5\%_{(\mathrm{Latt})}$	4.15 ± 0.49	-	$3\%_{\mathrm{excl}}, 2\%_{\mathrm{incl.}}$	
γ $[B \to DK]$	input	$< 1^\circ$	$(70^{+27}_{-30})^\circ$	0.9°	1.5°	
$S_{B_d \to \psi K}$	2β	$\lesssim 0.01$	0.671 ± 0.023	0.0035	0.0025	
$S_{B_s \to \psi\phi, \psi f_0(980)}$	$2\beta_s$	$\lesssim 0.01$	-0.002 ± 0.087	0.008	-	
$S_{[B_s \to \phi\phi]}$	$2\beta_s^{eff}$	$\lesssim 0.05$	-	0.03	-	
$S_{[B_s \to K^{*0}\bar{K}^{*0}]}$	$2\beta_s^{eff}$	$\lesssim 0.05$	-	0.02	-	
$S_{[B_d \to \phi K^0]}$	$2\beta^{eff}$	$\lesssim 0.05$	-	0.03	0.02	
$S_{[B_d \to K^0_S \pi^0 \gamma]}$	0	$\lesssim 0.05$	-0.15 ± 0.20	-	0.02	
$S_{[B_s \to \phi\gamma]}$	0	$\lesssim 0.05$	-	0.02	-	
$A_{\mathrm{CP}}(b \to s\gamma)$	< 0.01	< 0.01	-0.012 ± 0.028	-	0.004	
$A_{\mathrm{CP}}(b \to (s+d)\gamma)$	$\sim 10^{-6}$	-	-0.060 ± 0.060	-	0.02	
$A^d_{\mathrm{SL}}[\times 10^{-3}]$	-0.5	0.1	-5.8 ± 3.4	0.2	4	
$A^s_{\mathrm{SL}}[\times 10^{-3}]$	2.0×10^{-2}	$< 10^{-2}$	-2.4 ± 6.3	0.2	~ 0.6	
$\mathcal{B}(B \to \tau\nu)[\times 10^{-4}]$	1	$5\%_{\mathrm{Latt}}$	(1.14 ± 0.23)	-	$4 - 5\%$	
$\mathcal{B}(B \to \mu\nu)[\times 10^{-7}]$	4	$5\%_{\mathrm{Latt}}$	< 13	-	$2 - 3\%$	
$\mathcal{B}(B \to D\tau\nu)[\times 10^{-2}]$	1.02 ± 0.17	$5\%_{\mathrm{Latt}}$	1.02 ± 0.17	[under study]	2%	
$\mathcal{B}(B \to D^*\tau\nu)[\times 10^{-2}]$	1.76 ± 0.18	$5\%_{\mathrm{Latt}}$	1.76 ± 0.17	[under study]	2%	
$\mathcal{B}(B_s \to \mu^+\mu^-)[\times 10^{-9}]$	3.2	$5\%_{\mathrm{Latt}}$	< 4.2	0.15	-	
$R(B_{s,d} \to \mu^+\mu^-)$	0.29	$\sim 5\%$	-	$\sim 35\%$	-	
$q_0(A^{FB}_{B \to K^*\mu^+\mu^-})[\mathrm{GeV}^2]$	4.26 ± 0.34			2%	[under study]	
$A_{\mathrm{T}}^{(2)}(B \to K^*\mu^+\mu^-)$	$< 10^{-3}$			0.04	[under study]	
$A_{\mathrm{CP}}(B \to K^*\mu^+\mu^-)$	$< 10^{-3}$			0.5%	1%	
$B \to K\nu\bar{\nu}[\times 10^{-6}]$	4	$10\%_{\mathrm{Latt}}$	< 16	-	0.7	
$\lvert q/p\rvert_{D-\mathrm{mixing}}$	1	$< 10^{-3}$	0.91 ± 0.17	$O(1\%)$	2.7%	
ϕ_D	$\lesssim 0.1\%$		$-$	$O(1^\circ)$	1.4°	
$a^{\mathrm{dir}}_{\mathrm{CP}}(\pi\pi)(\%)$	$\lesssim 0.3$		0.20 ± 0.22	0.015	[under study]	
$a^{\mathrm{dir}}_{\mathrm{CP}}(KK)(\%)$	$\lesssim 0.3$		-0.23 ± 0.17	0.010	[under study]	
$a^{\mathrm{dir}}_{\mathrm{CP}}(\pi\pi\gamma, KK\gamma)$	$\lesssim 0.3\%$			[under study]	[under study]	
$\mathcal{B}(\tau \to \mu\gamma)[\times 10^{-9}]$	0		< 44	-	2.4	
$\mathcal{B}(\tau \to 3\mu)[\times 10^{-10}]$	0		$< 210(90\%\ \mathrm{CL})$	1-80	2	
$\mathcal{B}(\mu \to e\gamma)[\times 10^{-12}]$	0		$< 2.4(90\%\ \mathrm{CL})$			~ 0.1 MEG ~ 0.01 PSI-future ~ 0.01 Project X
$\mathcal{B}(\mu N \to eN)(Tl)$	0		$< 4.3 \times 10^{-12}$			10^{-18} PRISM
$\mathcal{B}(\mu N \to eN)(Al)$	0		-			10^{-16} COMET, Mu2e
$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})[\times 10^{-11}]$	8.5	8%	$17.3^{+11.5}_{-10.5}$			$\sim 10\%$ NA62 $\sim 5\%$ ORKA [illegible]

D. Martinez Santos, G. Isidori (editors)
Input for European Strategy (2012)

Conclusions

- LHCb has a far reaching Physics program
- It will improve in precision (and expand in topics) during the LHCb upgrade
- The flexible trigger foreseen allows overtaking the difficulties that a hardware trigger would imply for hadronic decays
- Also to better access the very low pt of strangeness decays
- A Phase-II upgrade would collect a two orders of magnitude bigger data sample than LHCb currently has

$B_s \to \mu\mu$ / $B_d \to \mu\mu$

- The ratio of BR's B_d/B_s is considered a golden mode for testing new sources of flavour violation
- LHCb upgrade can reach <30% precision (stat. limited)
- Phase-II could achieve ~12% (…and still stat limited)