LHCb Status Report

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on behalf of LHCb Collaboration

133rd LHCC Meeting - Open Session

Feb 28th, 2018

Outline

- Operations
  - YETS and 2018 data taking
  - Computing resources and use of online farm
- Physics (selection of results since the last LHCC meeting)
  - CP violation in beauty
  - Searches
  - Production and cross sections
- Upgrade
  - Status and plans

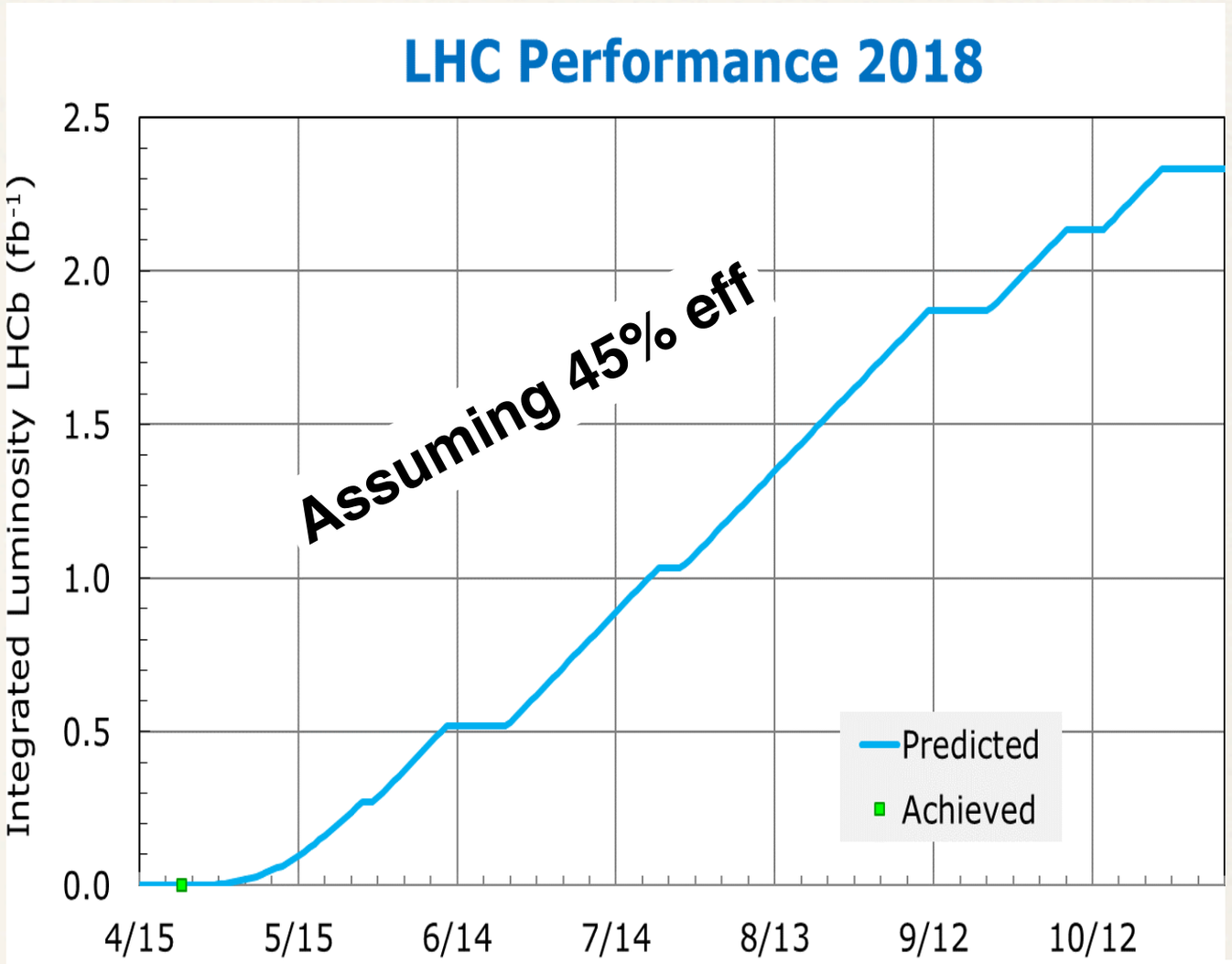
Operations

YETS Progress Report

- Detectors: **no major issues**
- Opening for Service and small repair work
  - Dec-Jan, Completed: MUON side A, CALO side C
  - Feb-March, Ongoing: MUON side C, CALO side A, Change RICH2 HPD
- **Advance work for LS2/Upgrade:**
  - Cable trays
  - Cooling circuits
  - Detector assembly facilities
  - Access structure
  - ….

Luminosity Prediction

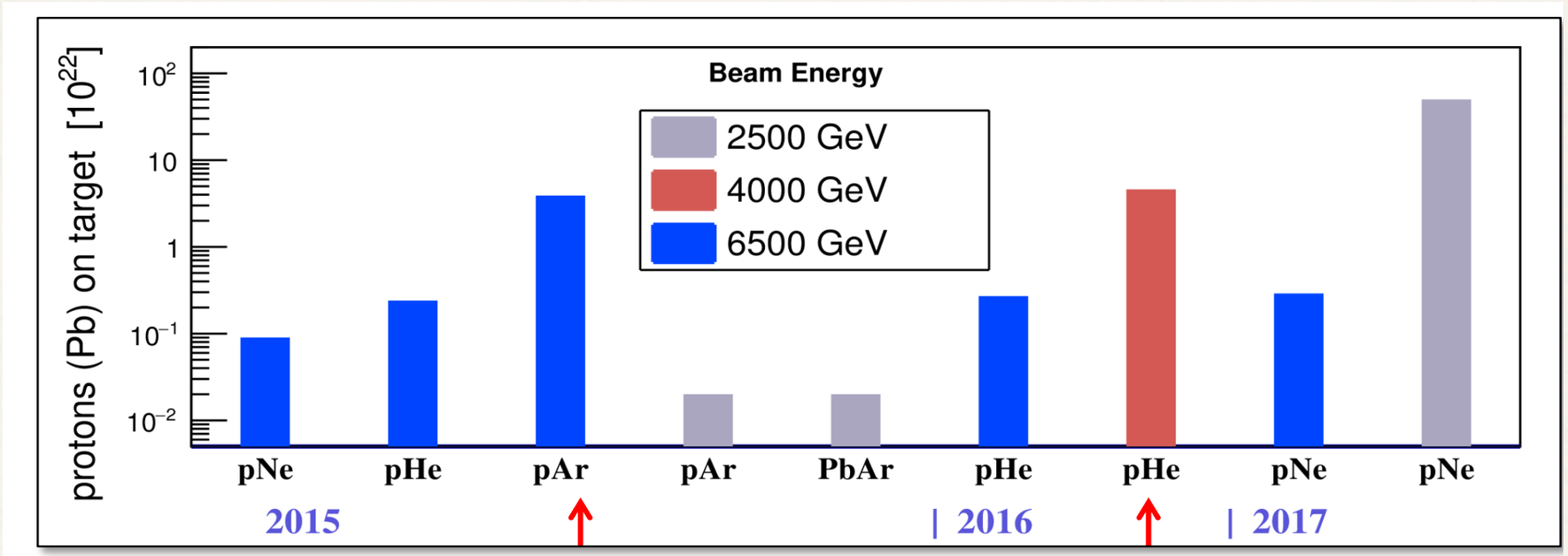
- Estimated delivered lumi **~2.3 fb^{-1}**
  - **2332** colliding bunches
  - **45%** stable beams efficiency (conservative, probably larger)



J.Wenninger, Chamonix, 29 Jan 2018

- <u>This additional statistics could make a "significant" difference for some crucial measurements</u>

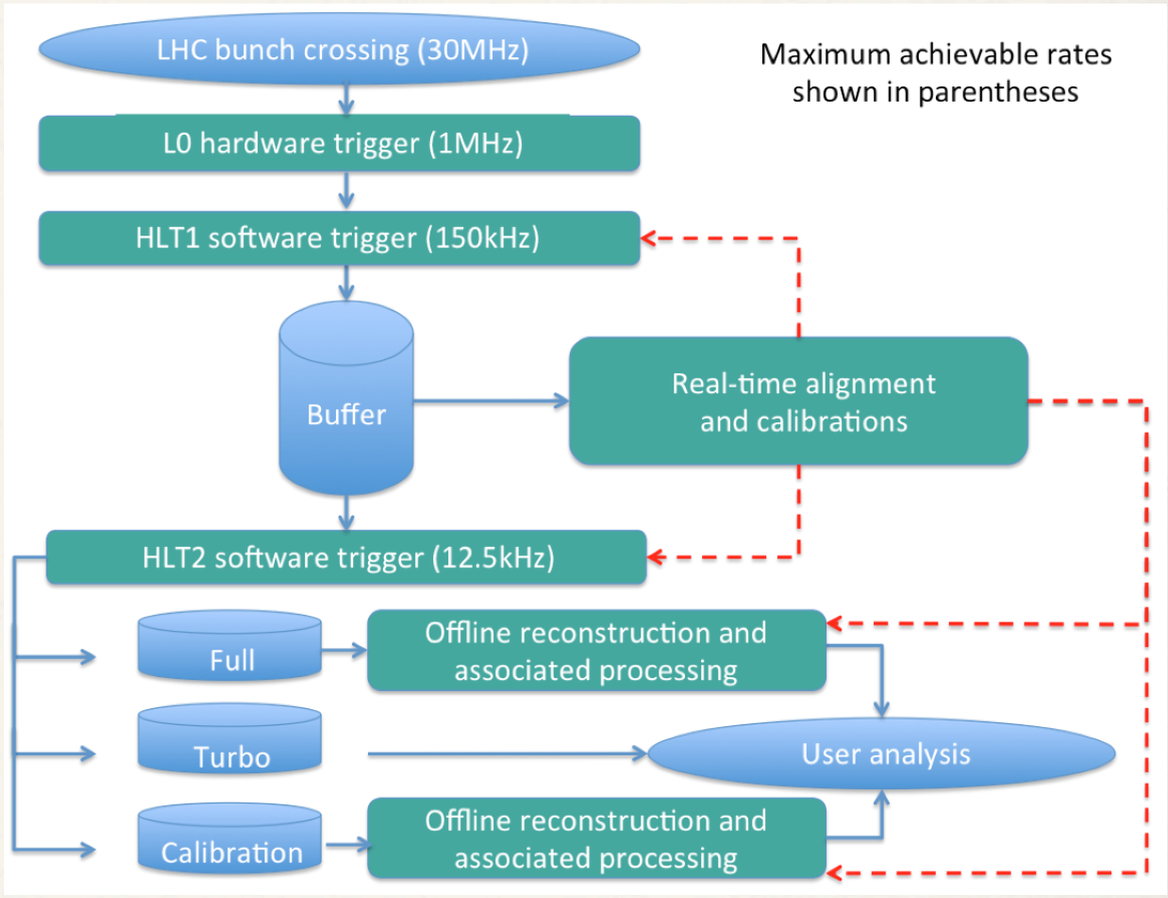
Special Runs

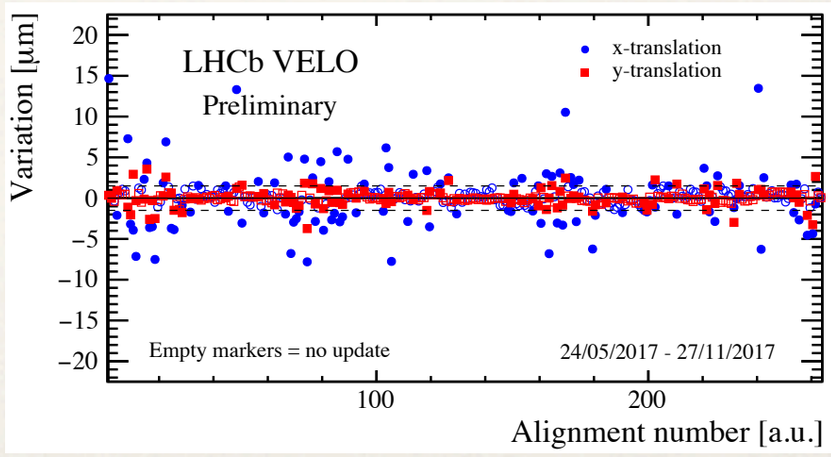


- LHCb can operate in **fixed target mode**, using its internal gas target **SMOG** (System to Measure the Overlap integral with Gas)
- Low-E run, pHe for cosmic ray physics: LHCb could benefit only from E_{beam}=900 GeV and stable beams
- Pb-Pb and Pb-Ne run: simultaneous data acquisition for Pb-Pb collisions and Pb-Ne fixed target, analogously as in 2017 with p-p and p-Ne

Trigger, Reconstruction, Alignment

- Expected **conditions very similar to 2017** and keep them **stable:**
  - Real-time alignment and calibration
  - Same trigger configuration throughout the year
  - During the luminosity ramp up, possible additional trigger lines for charmed baryon studies

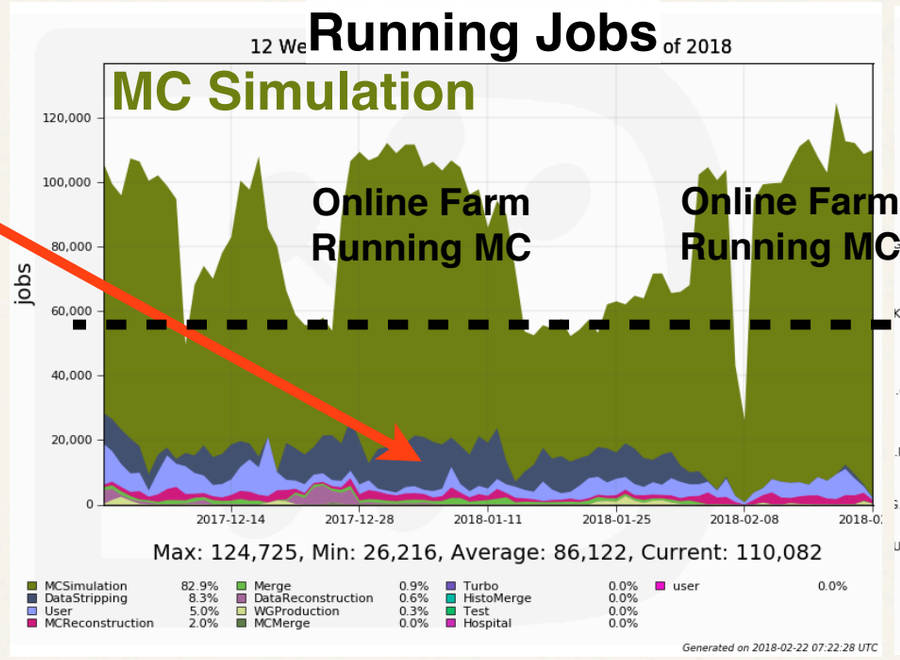


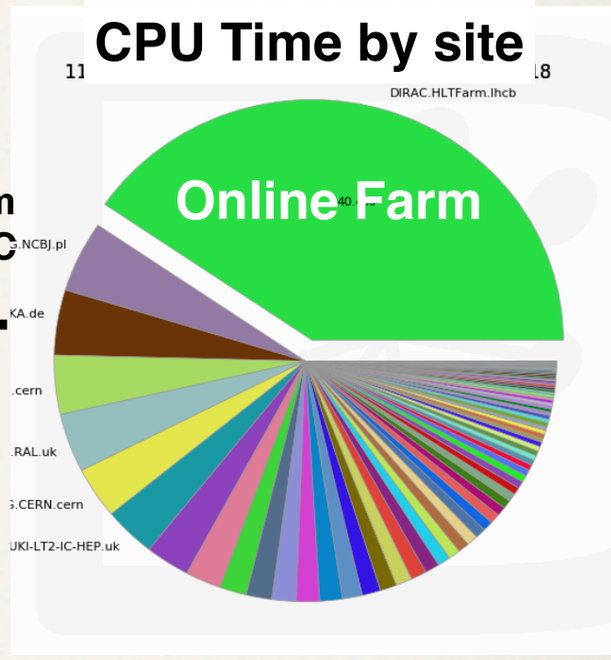


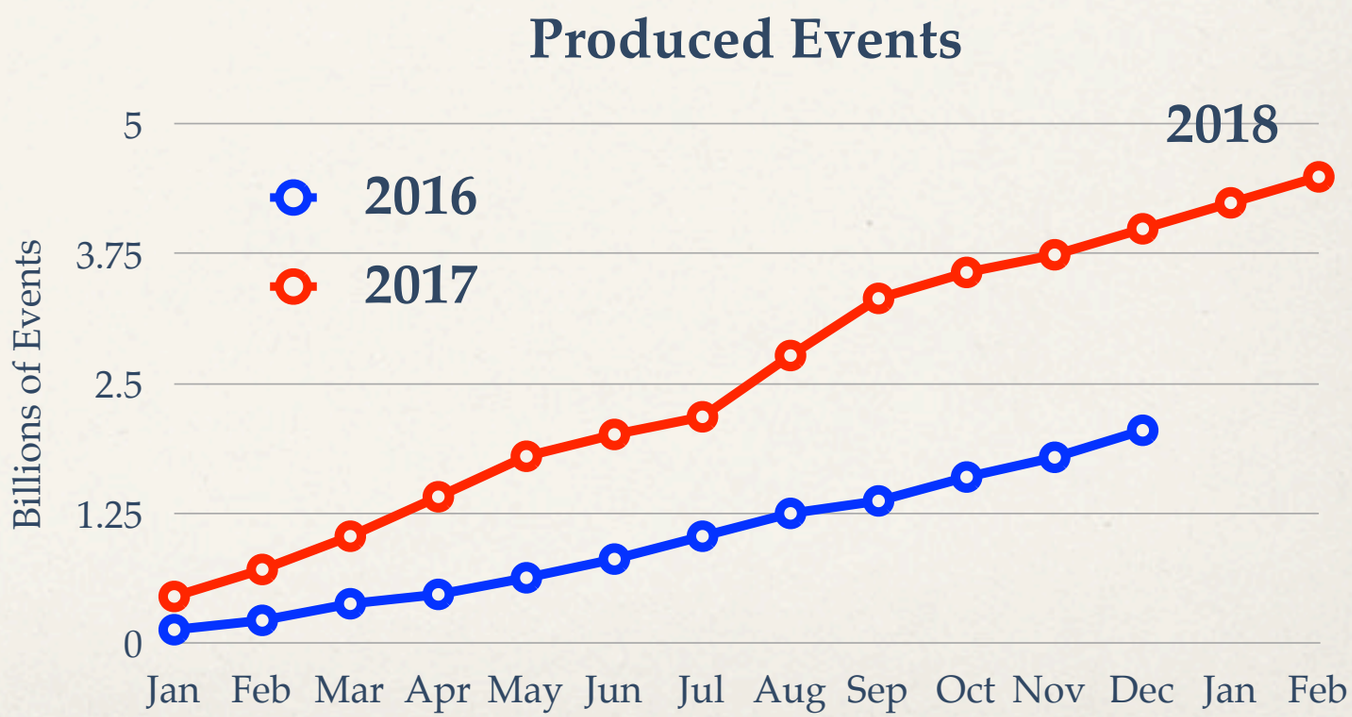
Software Activities

- **Restripping:**
  - 2015/2016 data finished
  - 2017 just started
- **Optimal use of resources:**
  - MC production run on the Online Farm + Grid
  - 40% of simulated events produced on Online Farm
- MC simulation: after filtering, **produced 4 billion events last year**
  - 450 millions during YETS

Computing during YETS



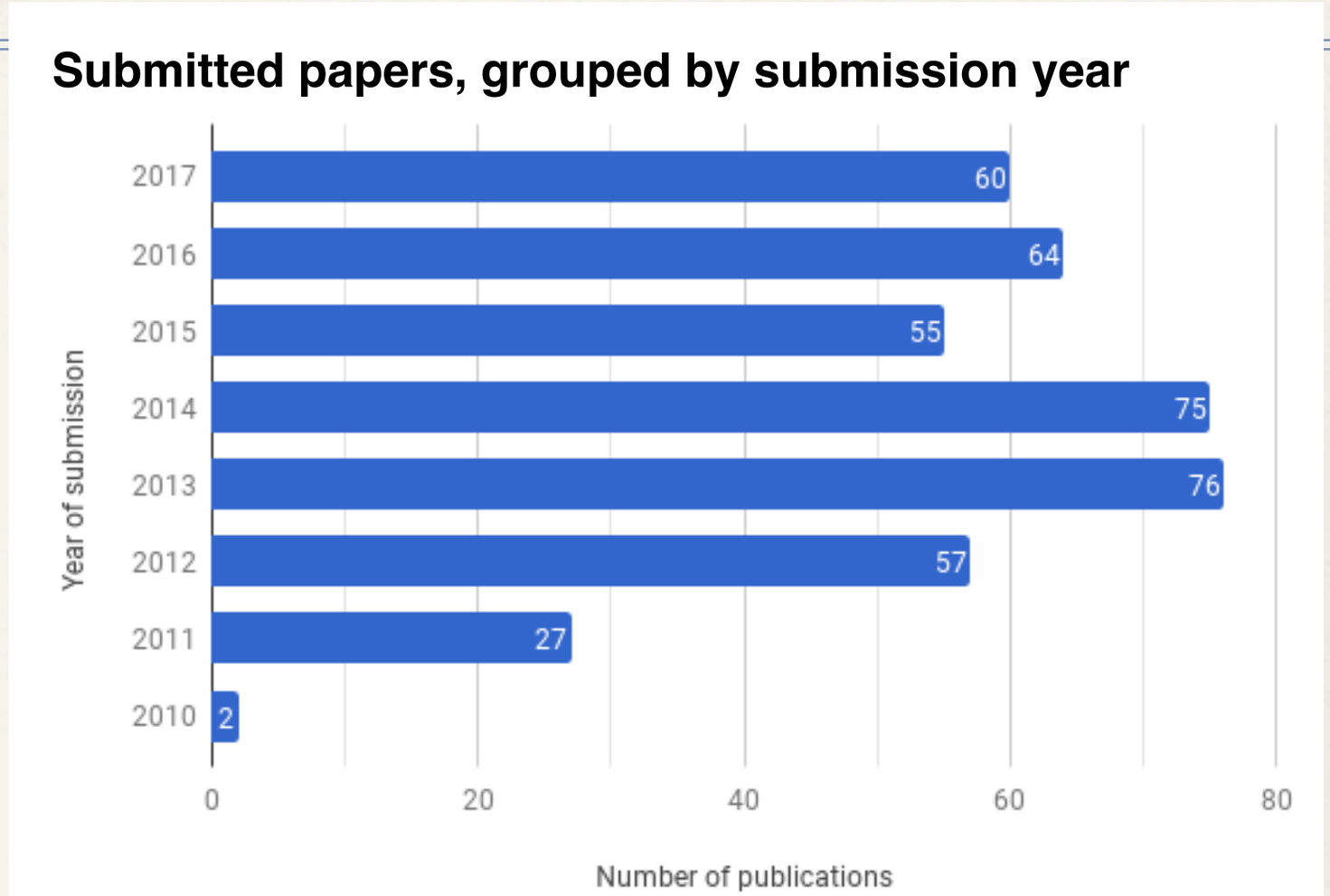


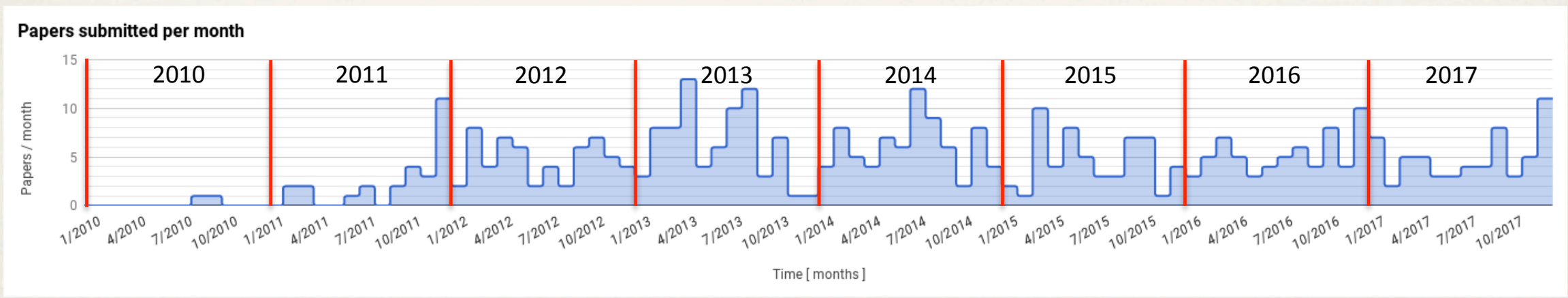


Physics

Paper Status

- Submitted papers: **416**
- Additional 12 to be released for the winter conferences





Paper Status

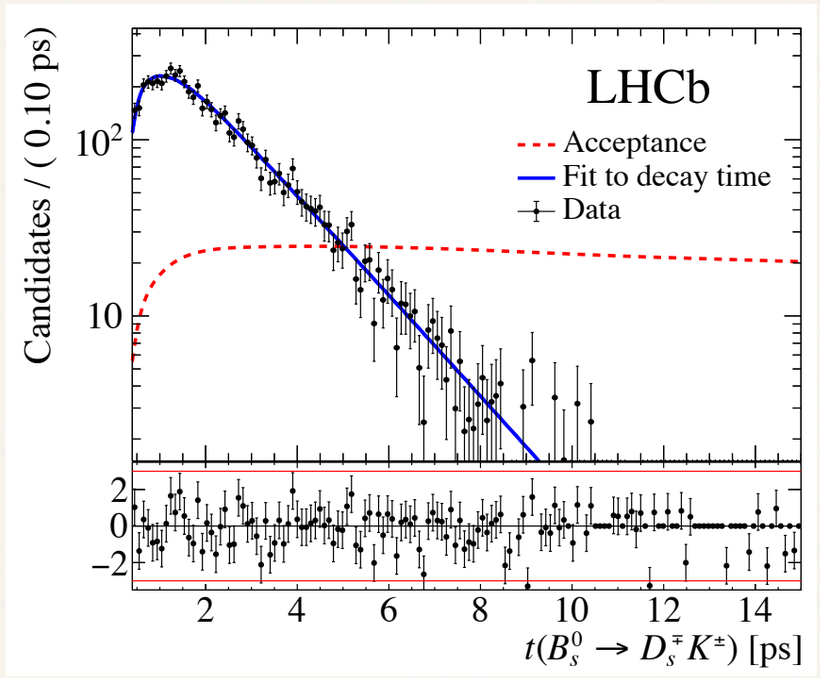
- **Submitted since last LHCC meeting**
  - 2017-033 Amplitude analysis of the decay $B^0 \to K_s^0\pi\pi$ and first observation of $B^0 \to K^*\pi$
  - 2017-039 Search for the rare decay $\Lambda_c^+ \to p\mu^+\mu^-$
  - 2017-040 Studies of the resonance structure in $D^0 \to K\pi\pi\pi$ decays
  - 2017-042 Search for excited B_c^+ states
  - 2017-043 A search for weakly decaying b-flavored pentaquarks
  - 2017-044 Search for direct CPV in $\Lambda_c^+ \to pKK$ and $\Lambda_c^+ \to p\pi\pi$ decays using semileptonic Λ_b^0 decays
  - 2017-045 Search for B_c^+ decays to two charm mesons
  - 2017-046 Update of D^0-$\overline{D}^0$ mixing parameters and CP violation in $D^0 \to K^+\pi^-$ decays
  - 2017-047 CP asymmetry in $B_s^0 \to D_s^{\mp}K^{\pm}$ decays
  - 2017-048 CP-violating phase ϕ_s^{dd} in quasi-two-body $B^0 \to (K\pi)(K\pi)$ decays
  - 2017-049 Evidence for the rare decay $\Sigma^+ \to p\mu\mu$
- **Preliminary**
  - 2017-050 Forward top pair production in the dilepton channel in pp collisions at 13 TeV
  - 2018-002 Upsilon production cross-section in pp collisions at $\sqrt{s}$=13 TeV
  - 2018-003 Inelastic pp cross-section at a centre-of-mass energy of 13 TeV
  - 2018-00X Ultra-peripheral Charmonium Production in Pb-Pb

The following slides will focus on the papers in red

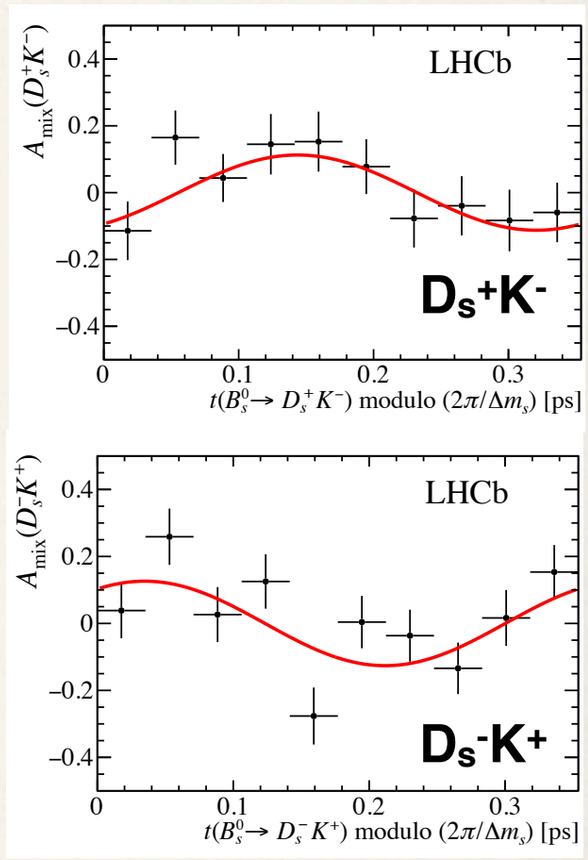
CP Asymmetry in $B^0_s \to D^{\mp}_s K^{\pm}$ Decays

- Update of previous results on 1 fb^{-1} [JHEP 11 (2014) 060]
- Fit to B_s and D_s invariant mass, extract signal weights using sPlot technique
- Flavour tagging, $\varepsilon = 5.7\%$
- Fit to weighted decay-time distribution to extract CP parameters
  - Per-candidate time uncertainty
- Control channel $B^0_s \to D^-_s \pi^+$
- Systematic contributions: correlation among variables, detection asymmetry, tagging, fit

arXiv:1712.07428 **LHCB-PAPER-2017-047**



Run1 Data



$$C_f = 0.73 \pm 0.14 \pm 0.05$$
$$A_f^{\Delta\Gamma} = 0.39 \pm 0.28 \pm 0.15$$
$$A_{\overline{f}}^{\Delta\Gamma} = 0.31 \pm 0.28 \pm 0.15$$
$$S_f = -0.52 \pm 0.20 \pm 0.07$$
$$S_{\overline{f}} = -0.49 \pm 0.20 \pm 0.07$$

$$\gamma = (128\,^{+17}_{-22})^\circ$$
$$\delta = (358\,^{+13}_{-14})^\circ$$
$$r_{D_sK} = 0.37\,^{+0.10}_{-0.09}$$

3.8 sigma evidence of CP violation and most precise determination of gamma from Bs0

Search for the Rare Decay $\Lambda^+_c \to p\mu^+\mu^-$

arXiv:1712.07938 LHCB-PAPER-2017-039

Run1 Data

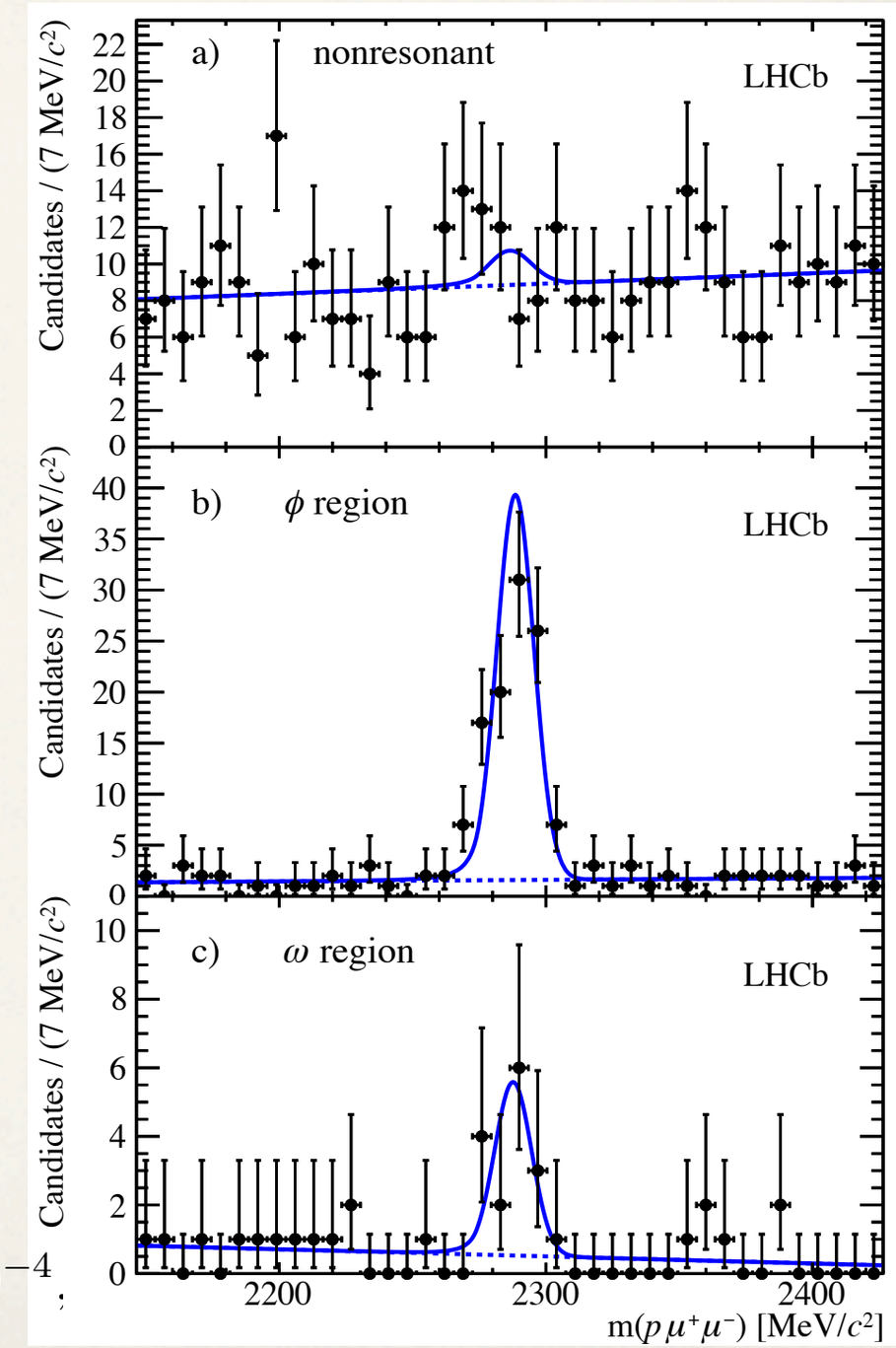
- Highly suppressed decay, FCNC
- Normalization channel $\Lambda^+_c \to p\varphi(\mu^+\mu^-)$
- Largest systematics: error on efficiency ratio, Data/MC discrepancy on BDT training samples, PID calibration
- No event observed over the background, UL computed using CLs method @95%(90%) CL

$$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 9.6\ (7.7) \times 10^{-8}$$

2 orders of magnitude better than Babar [PRD 84 (2011) 072006]

- **First observation for ω resonance**

$$\mathcal{B}(\Lambda_c^+ \to p\omega) = (9.4 \pm 3.2\ (\text{stat}) \pm 1.0\ (\text{syst}) \pm 2.0\ (\text{ext})) \times 10^{-4}$$



Search for Weakly Decaying b-flavored Pentaquarks

- Additional charmonium pentaquark states, not observed yet
- Scan for peak, step size 4 MeV
- No significant signal was observed
- Normalization channel

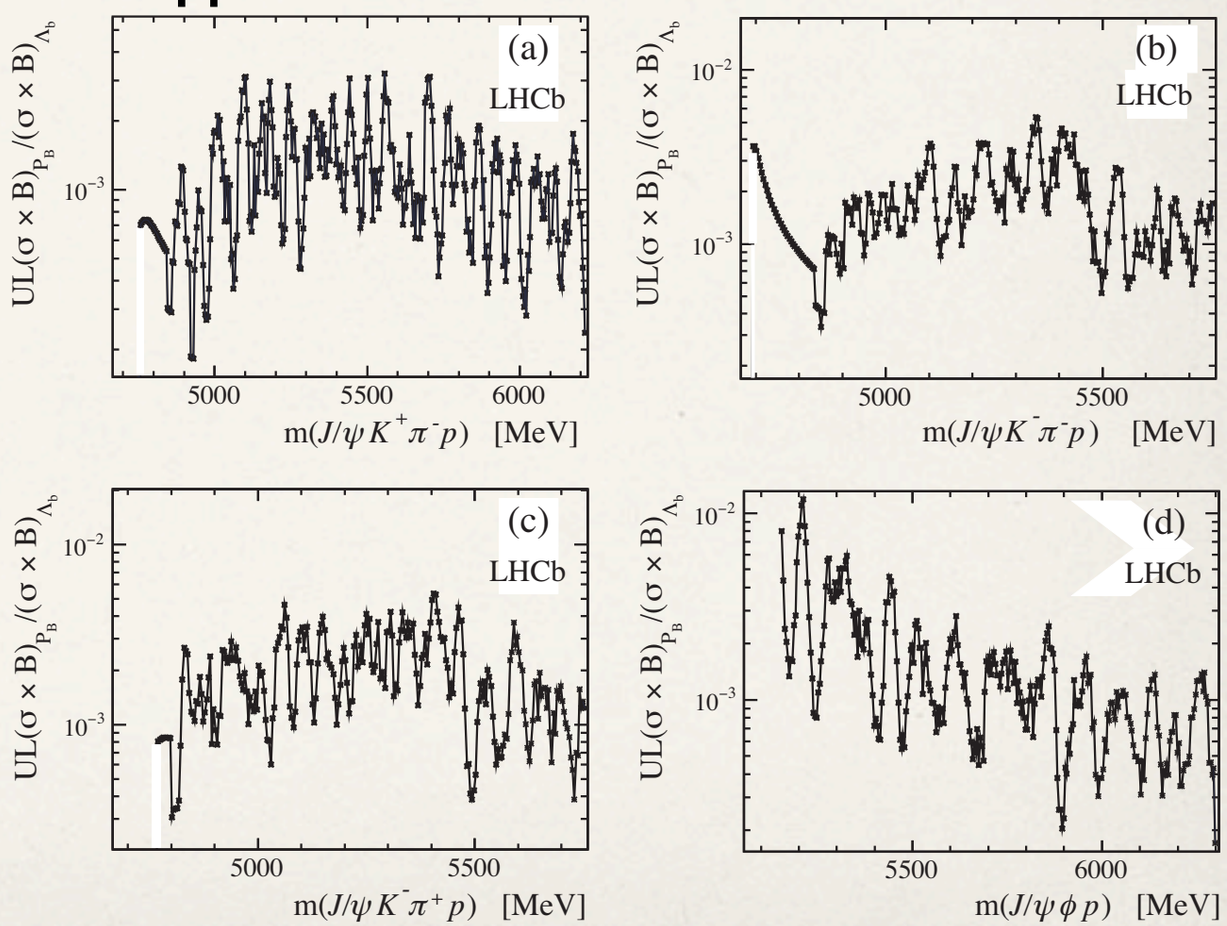
$$\Lambda_b^0 \to J/\psi\, K^- p$$

- Largest systematics from different selection of signal and normalization channels

arXiv:1712.08086 **LHCB-PAPER-2017-043**

Mode	Quark content	Decay mode	Search window
I	$\bar{b}duud$	$P^+_{B^0 p} \to J/\psi\, K^+\pi^- p$	4668–6220 MeV
II	$b\bar{u}udd$	$P^-_{\Lambda_b^0\pi^-} \to J/\psi\, K^-\pi^- p$	4668–5760 MeV
III	$b\bar{d}uud$	$P^+_{\Lambda_b^0\pi^+} \to J/\psi\, K^-\pi^+ p$	4668–5760 MeV
IV	$\bar{b}suud$	$P^+_{B_s^0 p} \to J/\psi\, \phi p$	5055–6305 MeV

Upper limits vs mass **Run1 Data**



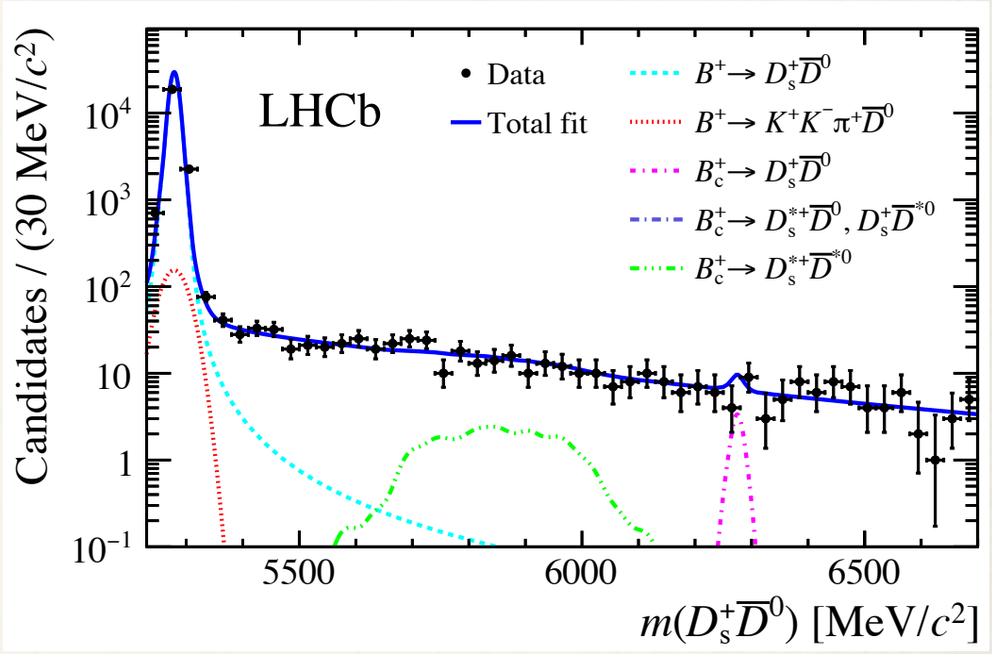
Search for B^+_c Decays to Two Charm Mesons

- $B_c^+ \to D_{(s)}^{(*)+} D^{(*)}$

arXiv:1712.04702 LHCB-PAPER-2017-045

- Useful for getting γ measurement, but rate is very small (small BFs and low ε)

Refs.
PLB 286 (1992) 160
PRD 62 (2000) 057503
PRD 65 (2002) 034016
PRD 75 (2007) 097304



- Normalization mode $B^+ \to D_{(s)}^+ D$

Run1 Data

- No significant signal was observed

$$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^+ \overline{D}^0)}{\mathcal{B}(B^+ \to D_s^+ \overline{D}^0)} = (\ \ 3.0 \pm 3.7) \times 10^{-4}\ [< 0.9\,(1.1) \times 10^{-3}]$$

$$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^{*+} \overline{D}^0) + \mathcal{B}(B_c^+ \to D_s^+ \overline{D}^{*0})}{\mathcal{B}(B^+ \to D_s^+ \overline{D}^0)} = (-0.1 \pm 1.5) \times 10^{-3}\ [< 2.8\,(3.4) \times 10^{-3}]$$

$$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^{*+} \overline{D}^{*0})}{\mathcal{B}(B^+ \to D_s^+ \overline{D}^0)} = (\ \ 3.2 \pm 4.3) \times 10^{-3}\ [< 1.1\,(1.3) \times 10^{-2}]$$

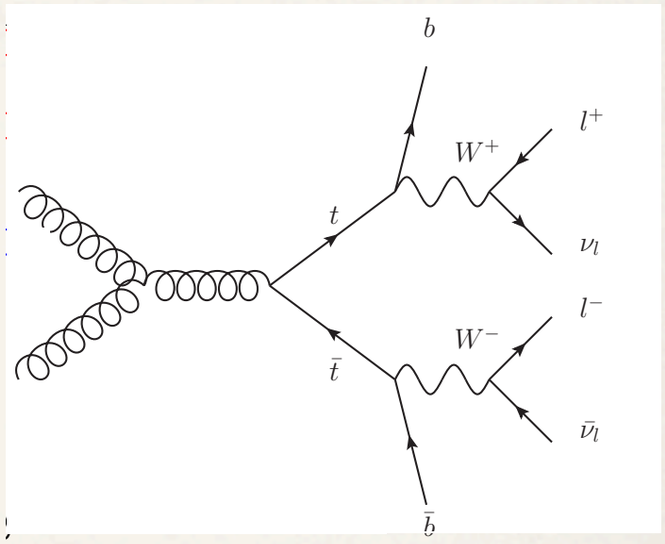
- Largest systematic contribution from bkg model

f_c/f_u: B_c/B production ratio

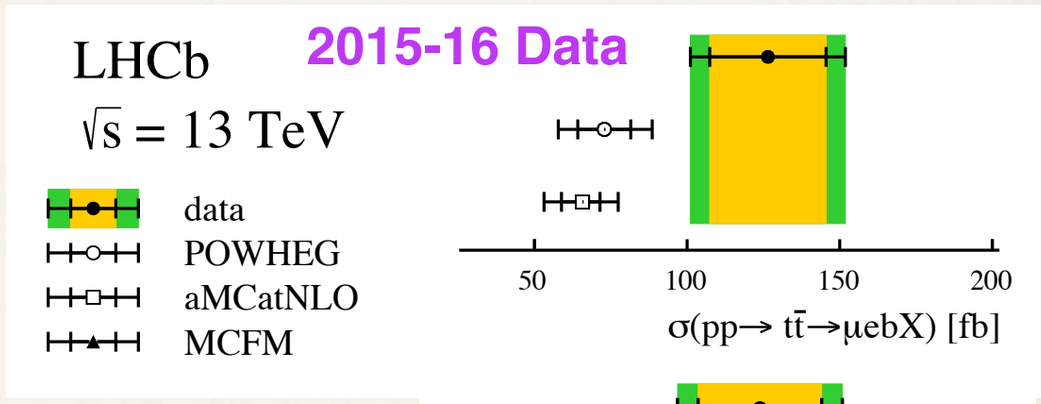
Forward Top Production in Dilepton Channel @13TeV

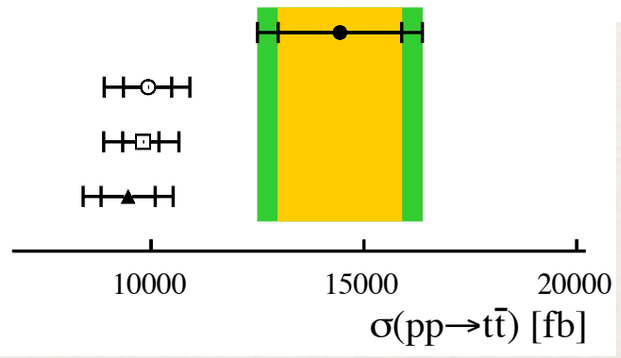
LHCB-PAPER-2017-050

- First analysis of top production in the dilepton final state
- Reconstructed state: **μeb** (opposite sign leptons), ~ 87% purity, 44 events
- Highest systematics from jet-tagging



$$\sigma_{t\bar{t}} = 126 \pm 19\,(\text{stat}) \pm 16\,(\text{syst}) \pm 5\,(\text{lumi})\ \text{fb}$$





- Good agreement with theoretical predictions
- With more data can significantly constrain gluon PDF

Upsilon Production Cross-section @13 TeV

LHCB-PAPER-2018-002

- Useful to constrain heavy quarkonium production mechanisms
- **Double-differential cross section (p_T,y)**
- Systematics dominated by trigger efficiency and luminosity uncertainties
- Reported also various cross-section ratios: 13/8 TeV, Υ(xS)/Υ(1S) with reduced uncertainties

Run1 measurement: JHEP 11 (2015) 103

Total cross-section results over $0< p_T <15$ GeV/c and $2.0< y <4.5$:

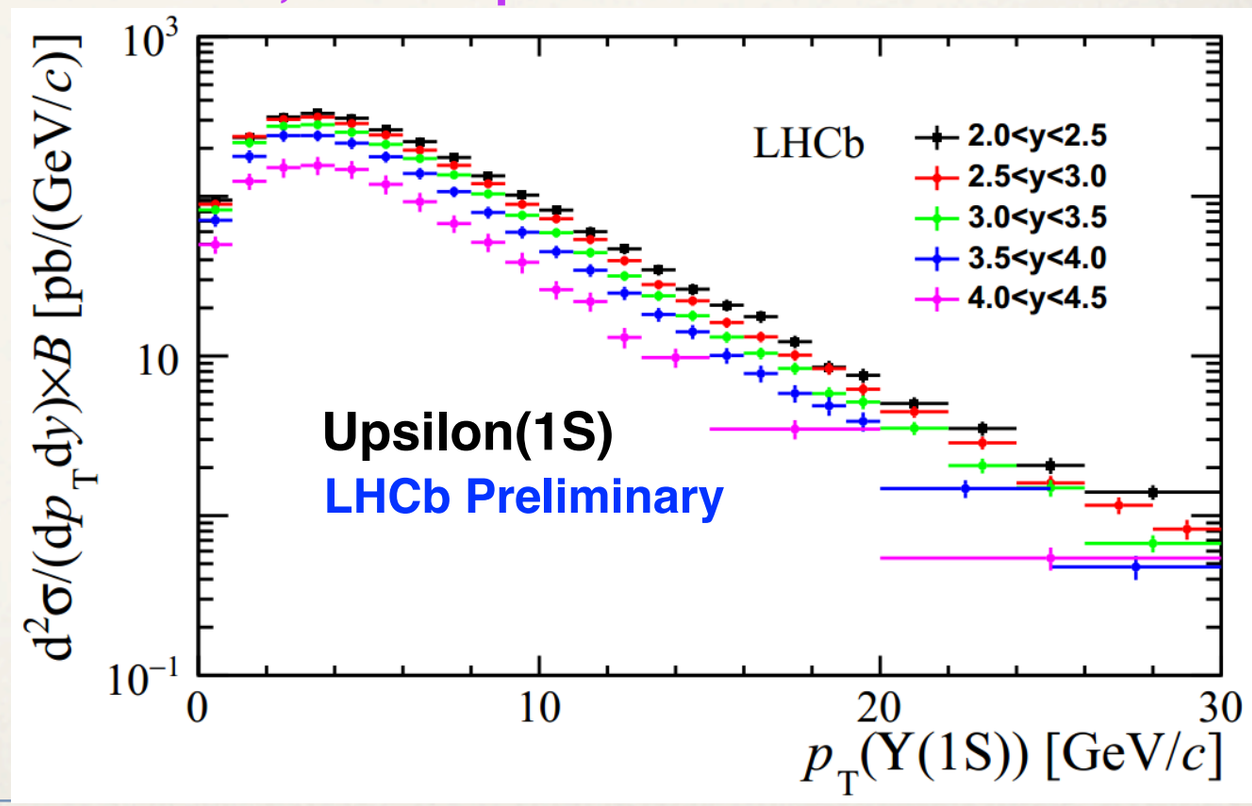
LHCb Preliminary

$$\mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-) \times \sigma(\Upsilon(1S)) = 4687 \pm 10\,(stat.) \pm 294\,(syst.)\ \text{pb}$$

$$\mathcal{B}(\Upsilon(2S) \to \mu^+\mu^-) \times \sigma(\Upsilon(2S)) = 1134 \pm 6\,(stat.) \pm 71\,(syst.)\ pb$$

$$\mathcal{B}(\Upsilon(3S) \to \mu^+\mu^-) \times \sigma(\Upsilon(3S)) = 561 \pm 4(stat.) \pm 36(syst.)\ pb$$

2015 Data, 277±11 pb^{-1} with same L0 threshold



Inelastic pp Cross-section @13 TeV

LHCB-PAPER-2018-003

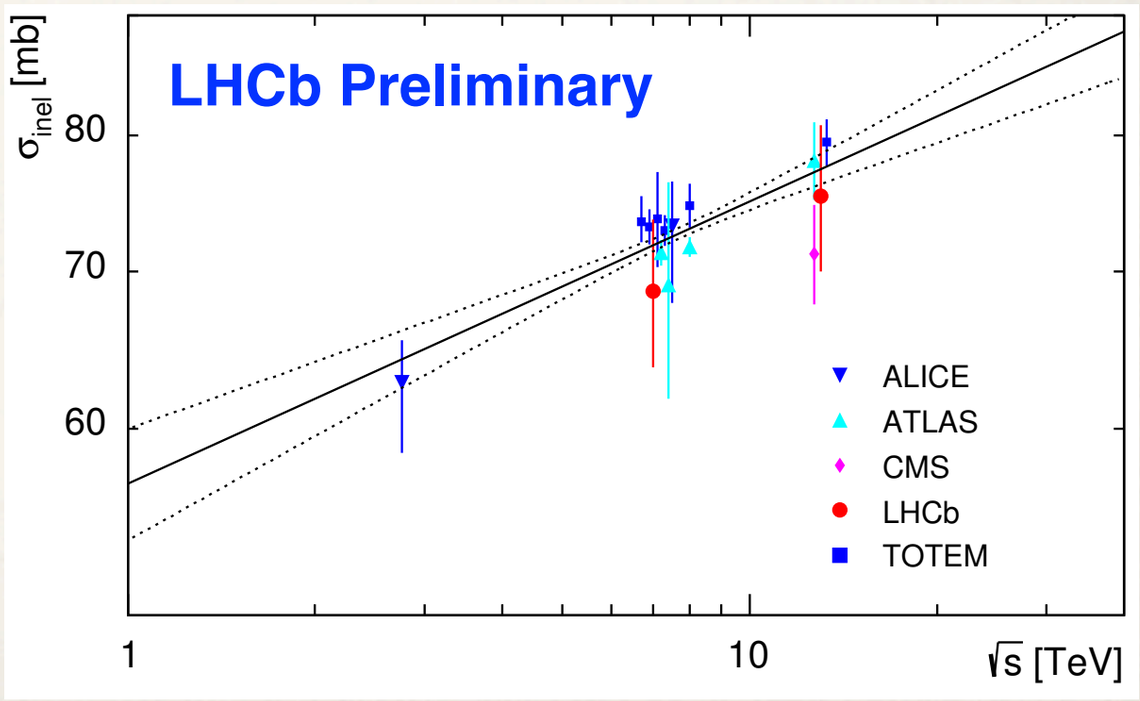
- Cross-section in the acceptance
  - Measurement performed using events with at least one prompt long-lived charged particle with momentum p > 2 GeV/c in the LHCb acceptance, counting empty events on unbiased data
  - Updated luminosity measurement, uncertainty 4%

$$\sigma_{\text{acc}} = 62.2 \pm 0.2 \pm 2.5_{\text{lumi}}\ \text{mb}$$

Early 2015 Data, ~700M evts
No-bias triggered data

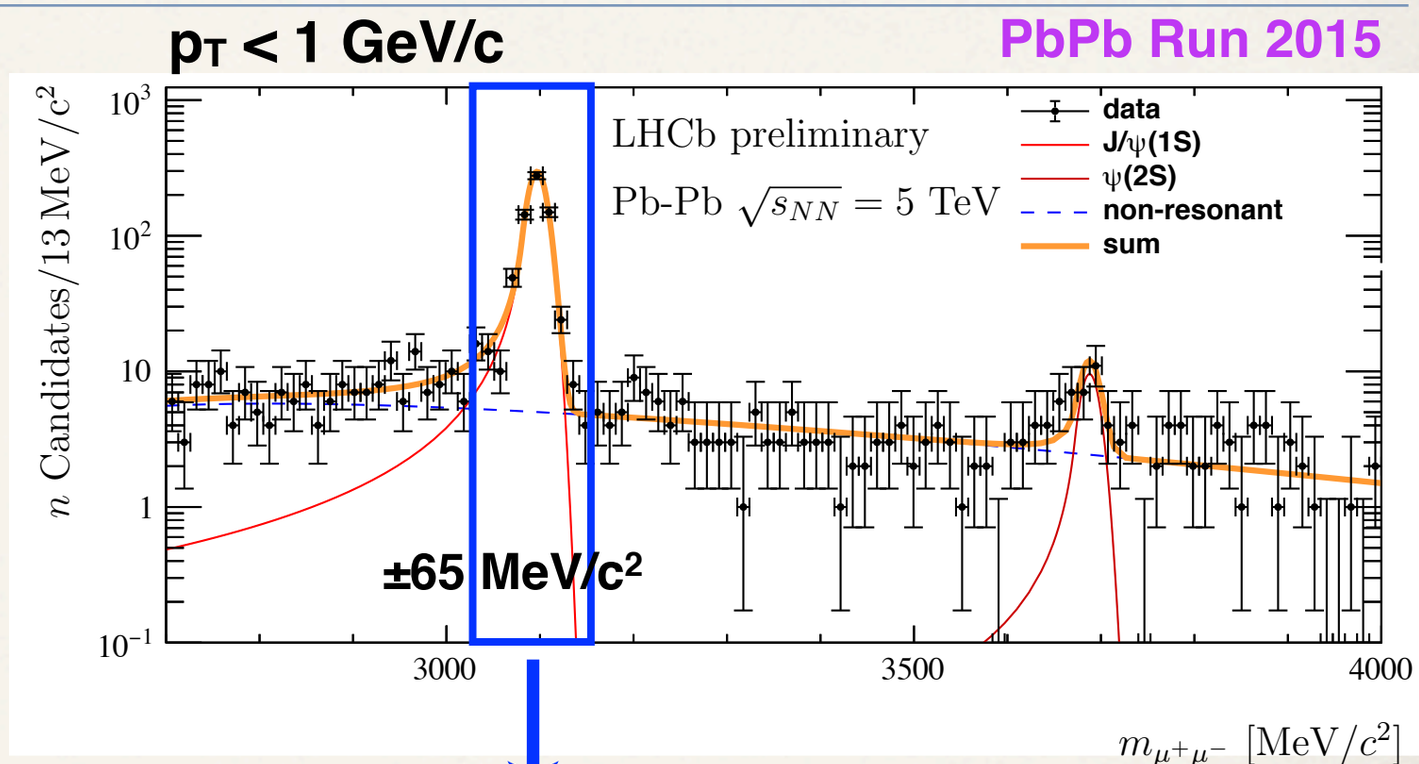
- Total inelastic cross-section
  - Extrapolation factor computed using Pythia 8
  - $\sigma_{\text{inel}} = 75.4 \pm 3.0_{\text{exp}} \pm 4.5_{\text{extr}}\ \text{mb}$
- Updated inelastic cross-section at 7 TeV
  - Benefit from decreased luminosity uncertainty, error 3.5% → 1.7%
  - $\sigma_{\text{inel}} = 68.7 \pm 2.1_{\text{exp}} \pm 4.5_{\text{extr}}\ \text{mb}$

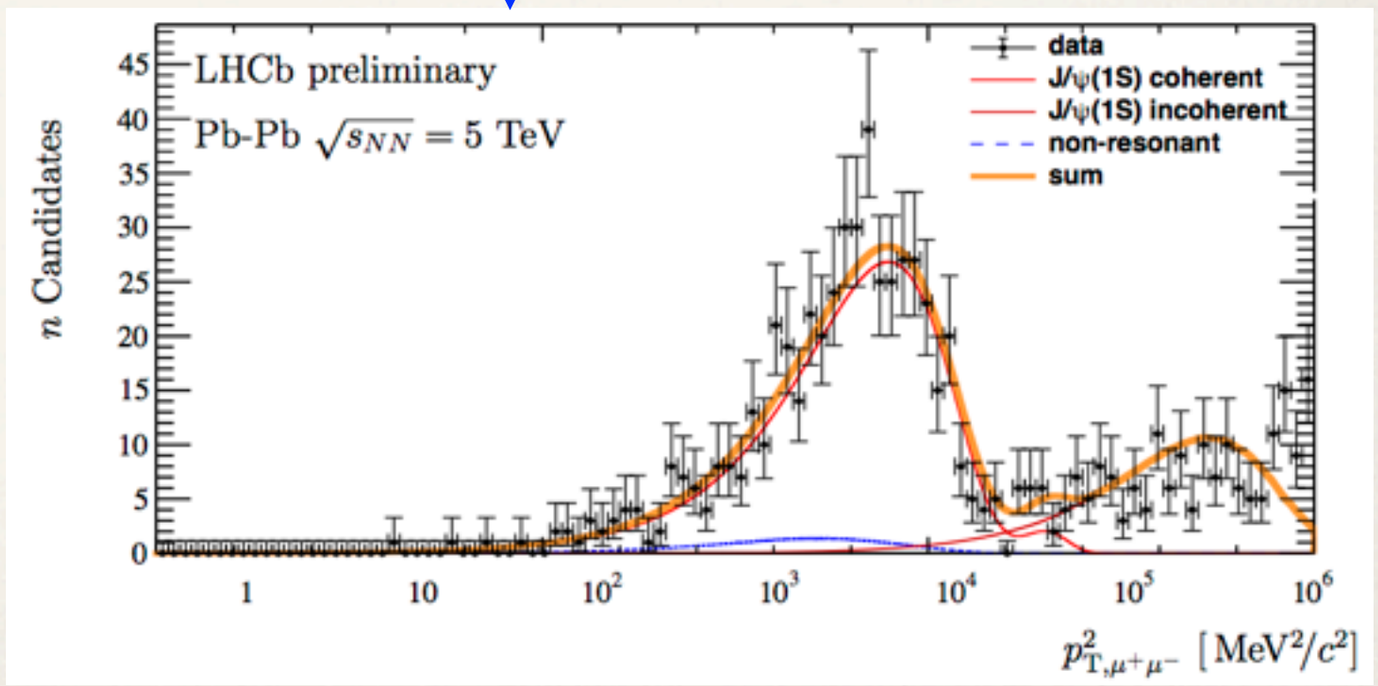
Overview of cross-section results



Ultra-peripheral Charmonium Production in Pb-Pb

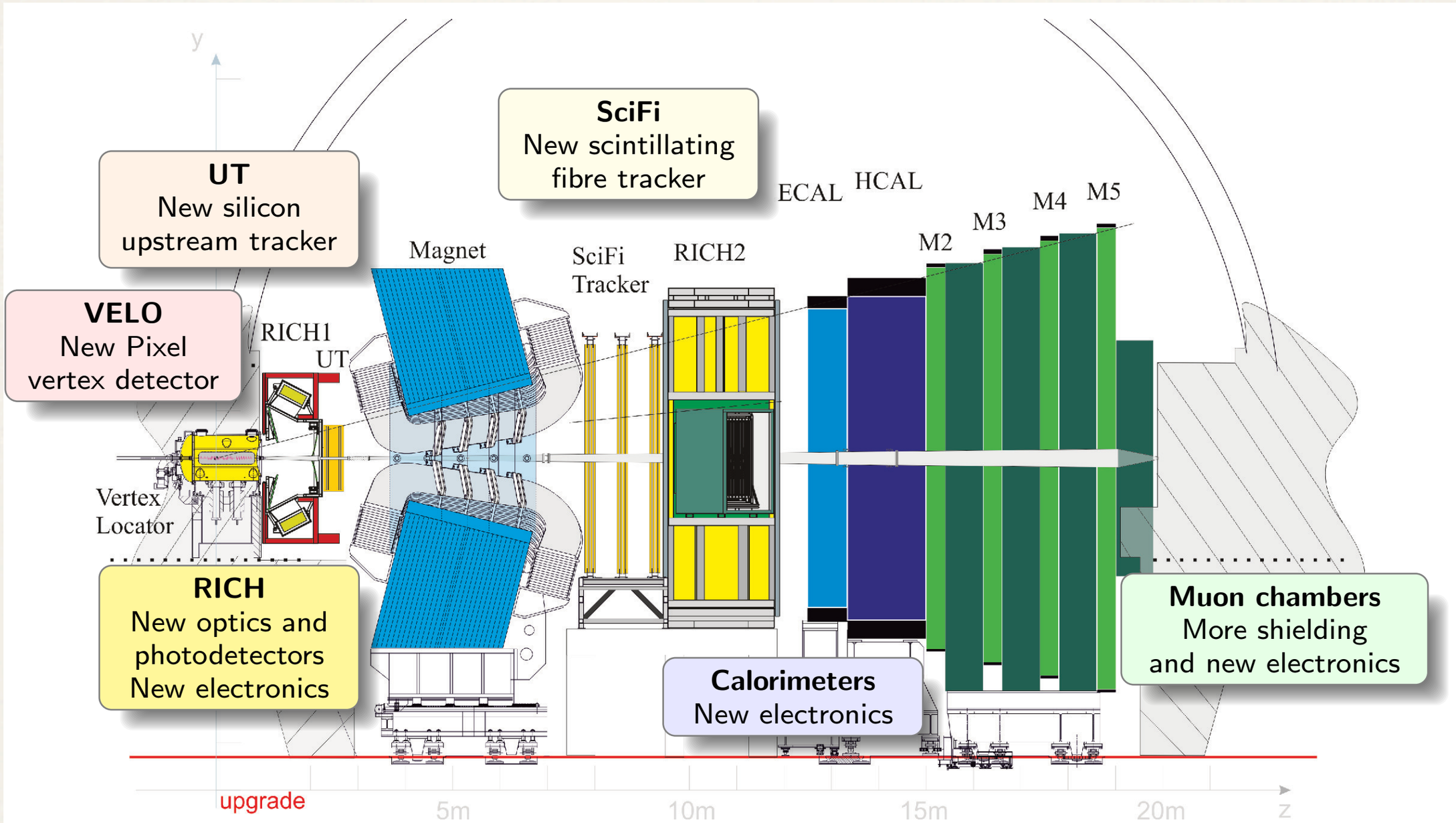
- J/ψ and ψ(2S) ultra-peripheral production in Pb-Pb collisions at 5 TeV
  - One ion collides with the electromagnetic field of the other
  - Studied by Alice, Nucl.Phys. A967 (2017) 273-276
- **Fit templates from the STARLIGHT generator to the log(p_T^2) distribution of J/ψ mesons**
  - Excellent agreement with data and clear observation of coherent production
- Not enough statistics to study **ψ(2S)** coherent production
  - Would benefit from more data from the 2018 Pb-Pb run





Upgrade

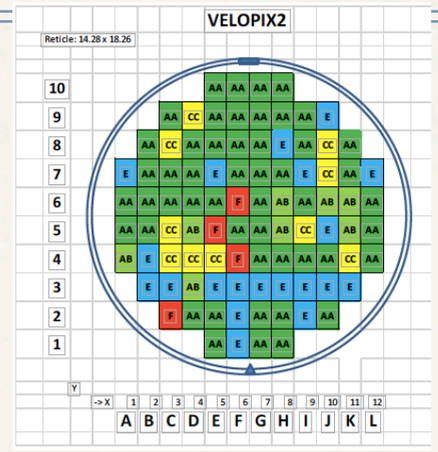
LHCb Upgrade

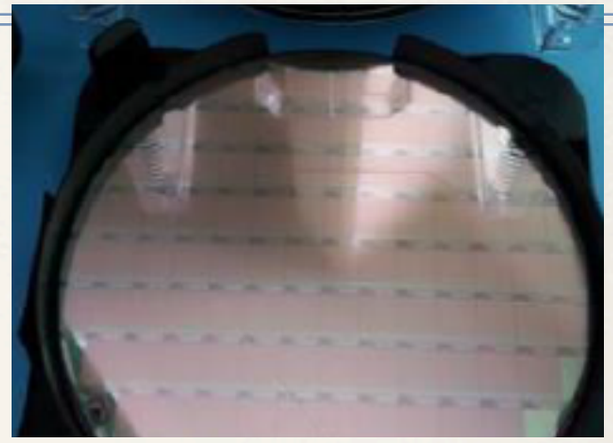


- **Installation in LS2, operation in Run 3**
- **40 MHz readout, flexible software-only trigger**

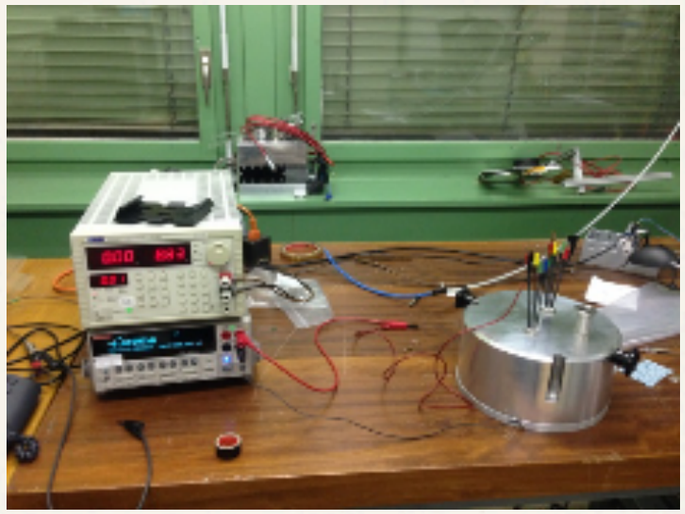
LHCb Upgrade - VELO

- ASIC:
  - First wafer tested
  - ~70% yield

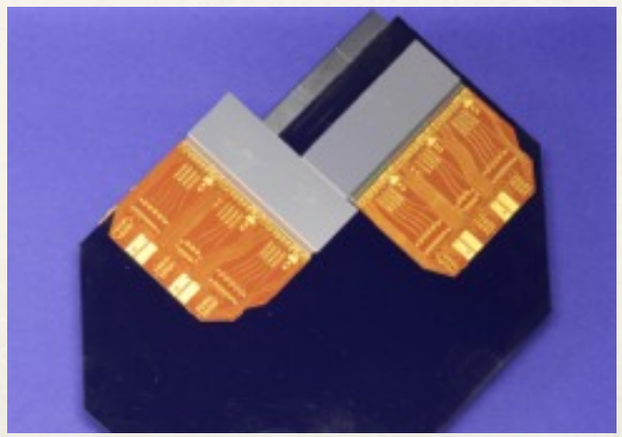


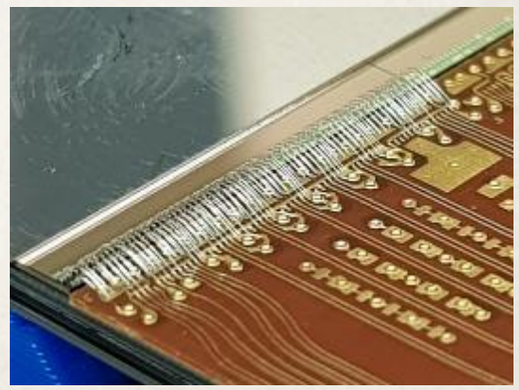


- Test of 3-sensor tiles: bonds and IV function:
  - Design a dedicated jig for testing with probe station in vacuum
  - See LHCC poster, Vinicius F. Lima



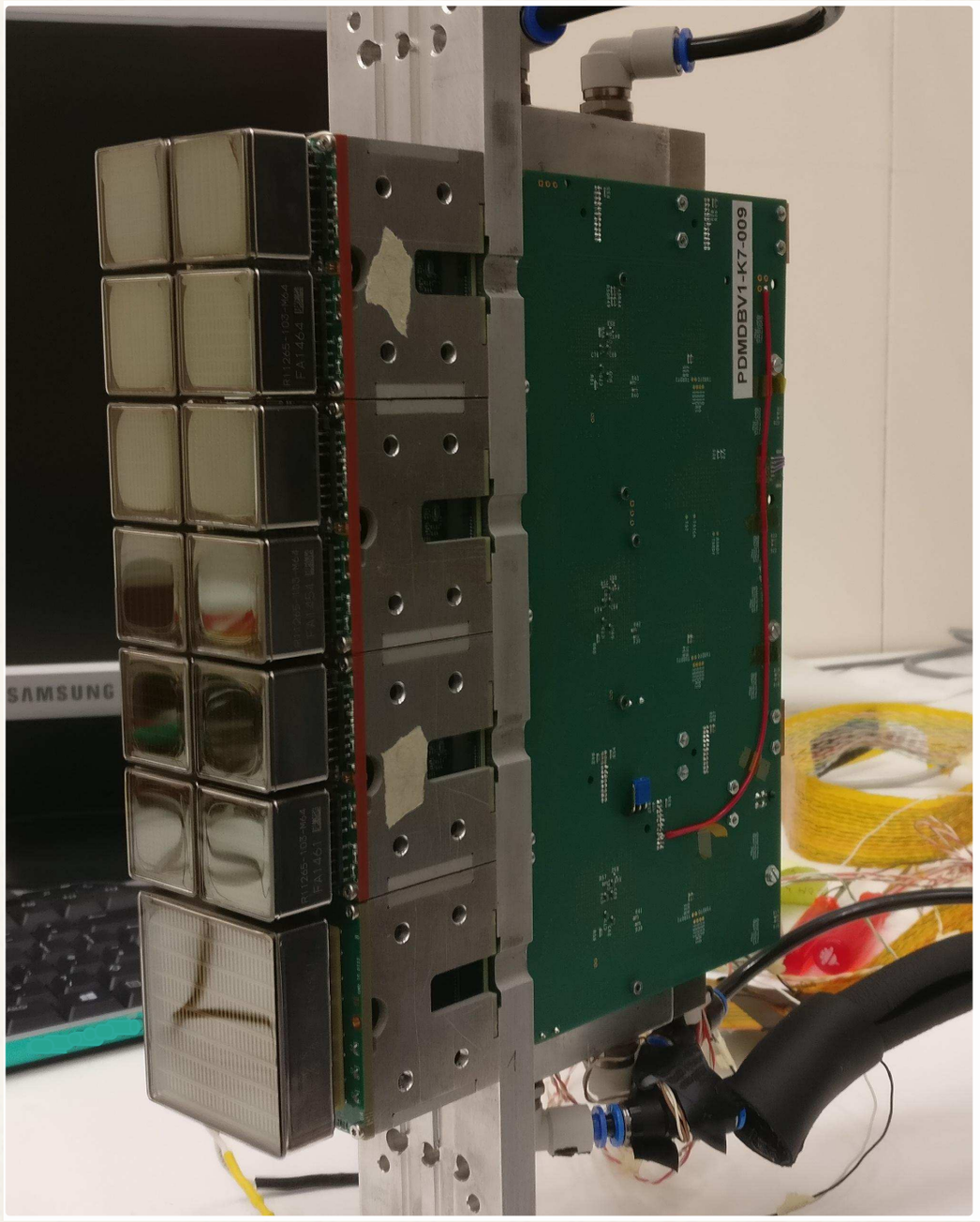
- Modules:
  - Progress on integration
  - Working on final details and tools for module assembly procedure





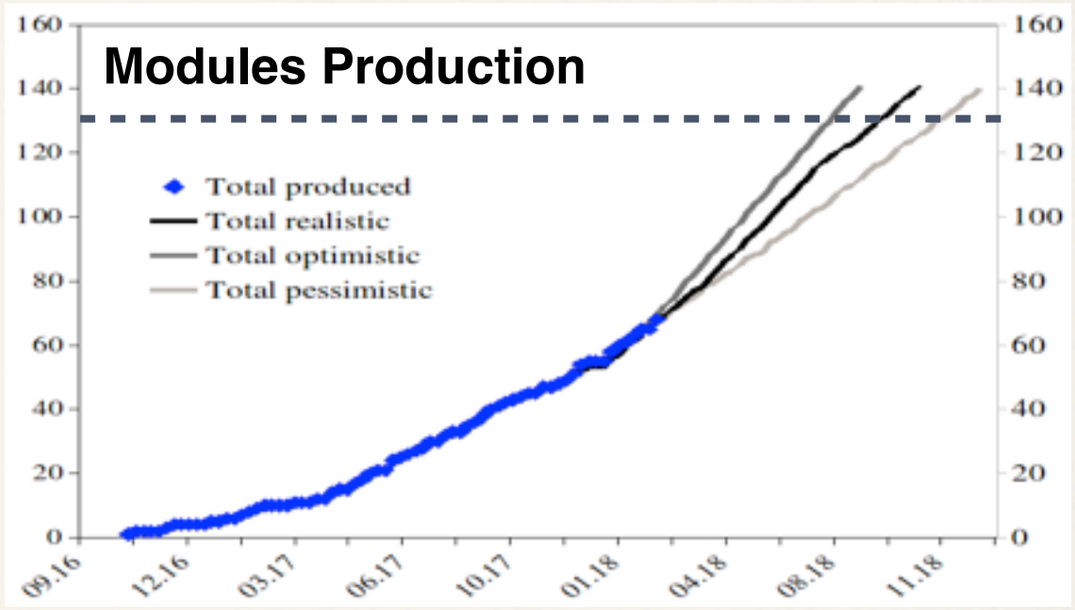
LHCb Upgrade - RICH

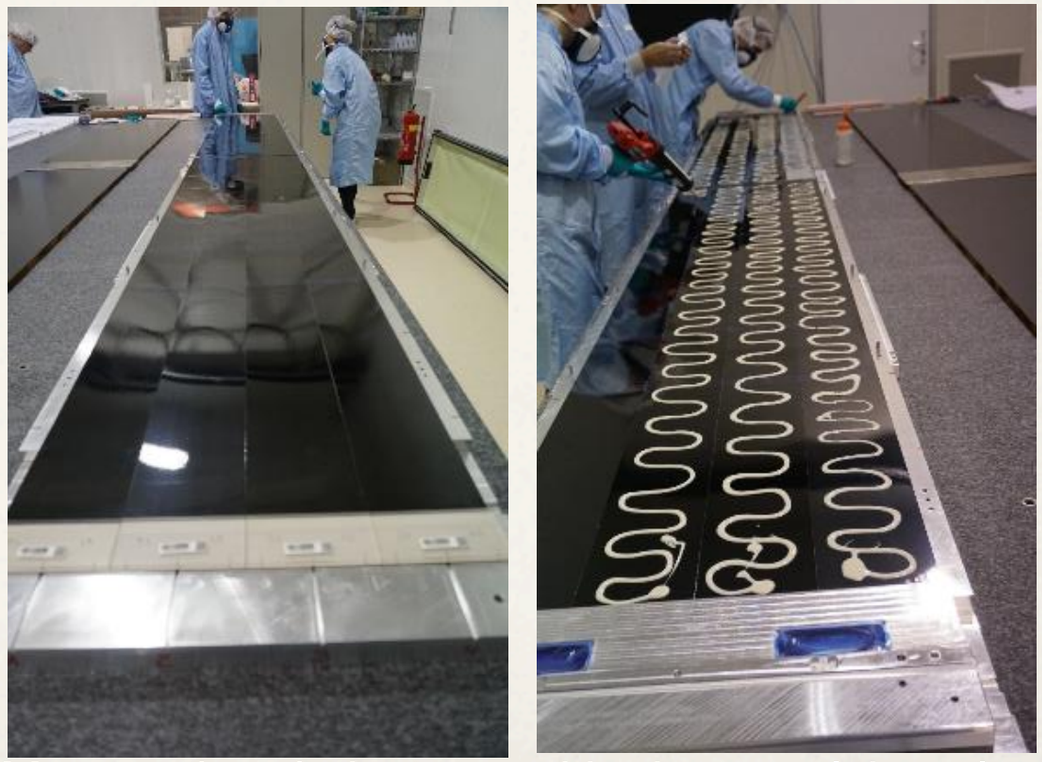
- Full Photon Detector Module being installed inside RICH2:
  - 4 Elementary Cells, 2 digital boards, final mechanics, DAQ prototype
  - Placed in high occupancy region on A-side: possibility to have partial illumination
- **Complete vertical slice**, goal is to perform a <u>fully operational test for the whole 2018 run</u>
  - No operational impact expected on the current RICH



LHCb Upgrade - SciFi

- Fibres received and tested (11'000 km)
- <u>Mat</u> production:
  - Running at 4 sites
  - **85%** completed
- <u>Module</u> production:
  - **65** modules produced
  - Second production site just came online
  - First beam pipe module produced





Mats and end pieces positioning, applying glue

LHCb Upgrade - All The Others

- UT
  - First production batch of sensors was received, staves are under construction, good progress on peripheral electronics, mechanics, cooling, integration
  - Readout ASIC chip (SALT) under close scrutiny for issues with analog performance: fixes implemented already in stalled wafers from last submission (changes in metallization)
- CALO & MUON
  - Steady progress on upgraded frontend electronics, plus controls, calibration, monitoring, etc.
  - Many CALO electronics parts ready for production
- Online
  - Ready to sign contract for production of new DAQ board (PCIe40)
  - Starting test of servers to host DAQ and Event Builder

LHCb Posters

Search for the Lepton Flavour Violating decay $B \to \tau\mu$ at LHCb
Speaker: Joan Arnau Romeu (Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France)

Angular analysis of the rare decay $\Lambda_b \to \Lambda\mu\mu$ at LHCb
Speaker: Georgios Chatzikonstantinidis (University of Birmingham (GB))

Time-dependent CP violation in $B \to hh$ decays at LHCb
Speaker: Davide Fazzini (Universita & INFN, Milano-Bicocca (IT))

Measurement of ϕ_s using $B_s \to J/\psi\pi^+\pi^-$ at LHCb
Speaker: Xuesong Liu (Tsinghua University (CN))

BsJpsipipi_LHCC_p...

Time-dependent CP violation in $B^0 \to D^{*\pm}D^{\mp}$ at LHCb
Speaker: Margarete Schellenberg (Technische Universitaet Dortmund (DE))

LHCC2018_MSchell...

Lepton Universality test in $B \to p\bar{p}l\nu$ decay at LHCb
Speaker: Matthew James Tilley (Imperial College (GB))

Ξ_{cc} decay and properties at LHCb
Speakers: Murdo Thomas Traill (University of Glasgow (GB)), Murdo Thomas Trai

Charmonia production using hadronic final states at LHCb
Speaker: Andrii Usachov (Université Paris-Saclay (FR))

poster_usachov_LH...

Searches for Long-Lived Particles at LHCb
Speaker: Mr. Matthieu Marinangeli (EPFL - Ecole Polytechnique Federale Lausanne (CH))

Poster_LHCC_LLP.pdf

Luminosity measurements at LHCb for Run II
Speaker: George Coombs (University of Glasgow (GB))

LHCC_LHCb_Lumin...

Monitoring radiation damage in the LHCb Silicon Tracker
Speaker: Elena Graverini (Universitaet Zuerich (CH))

poster.pdf

LHCb full-detector real-time alignment and calibration: latest developments and perspectives
Speaker: Samuel Maddrell-Mander (University of Bristol (GB))

Studies on a the SALT ASIC, a novel front end electronics for the LHCb Upgrade Silicon Tracker
Speaker: Iaroslava Bezshyiko (Universitaet Zuerich (CH))

The LHCb RICH Upgrade: Development of the DAQ and control systems
Speaker: Giovanni Cavallero (INFN e Universita Genova (IT))

Cavallero_RICHUpgr...

IV testing of highly irradiated sensors in vacuum for the LHCb VELO Upgrade
Speaker: Vinicius Franco Lima (University of Liverpool (GB))

Conclusions

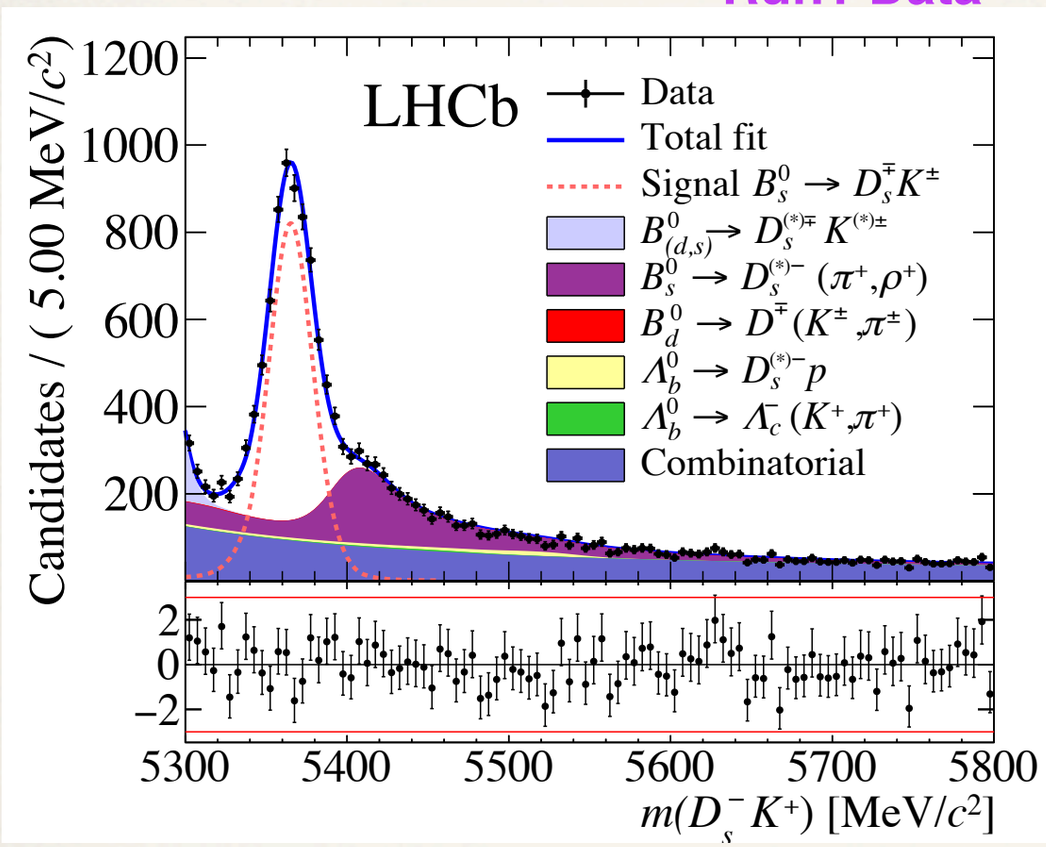
- LHCb Operations
  - Detector is ready to restart data taking, eager to get even more statistics this year
  - Running conditions similar to 2017, goal is to keep them very stable
  - Optimal and dynamic use of resources, actions to increase MC statistics are paying back
- LHCb Physics
  - 11 papers submitted since the last LHCC meeting
  - Some new results were presented today, but more will be ready for Winter conferences
- LHCb Upgrade
  - Steady progress on detector and software
  - Computing TDR to be delivered in mid-Spring
  - Meeting in Annecy for LHCb Upgrade II on March 21st-23rd
    - Document on the physics case in preparation

Backup

CP Asymmetry in $B^0_s \to D^{\mp}_s K^{\pm}$ Decays

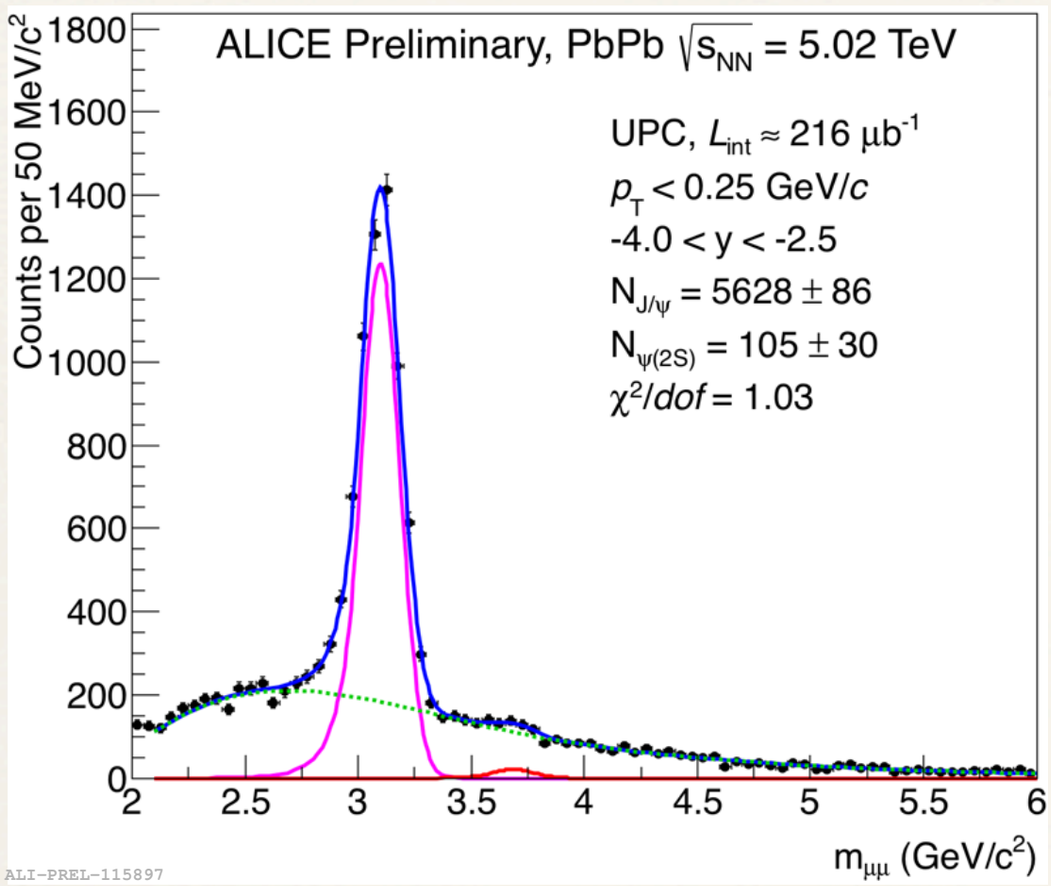
arXiv:1712.07428 LHCB-PAPER-2017-047

Run1 Data



Photoproduction of heavy vector mesons in ultra-peripheral Pb-Pb collisions (ALICE)

Nucl.Phys. A967 (2017) 273-276



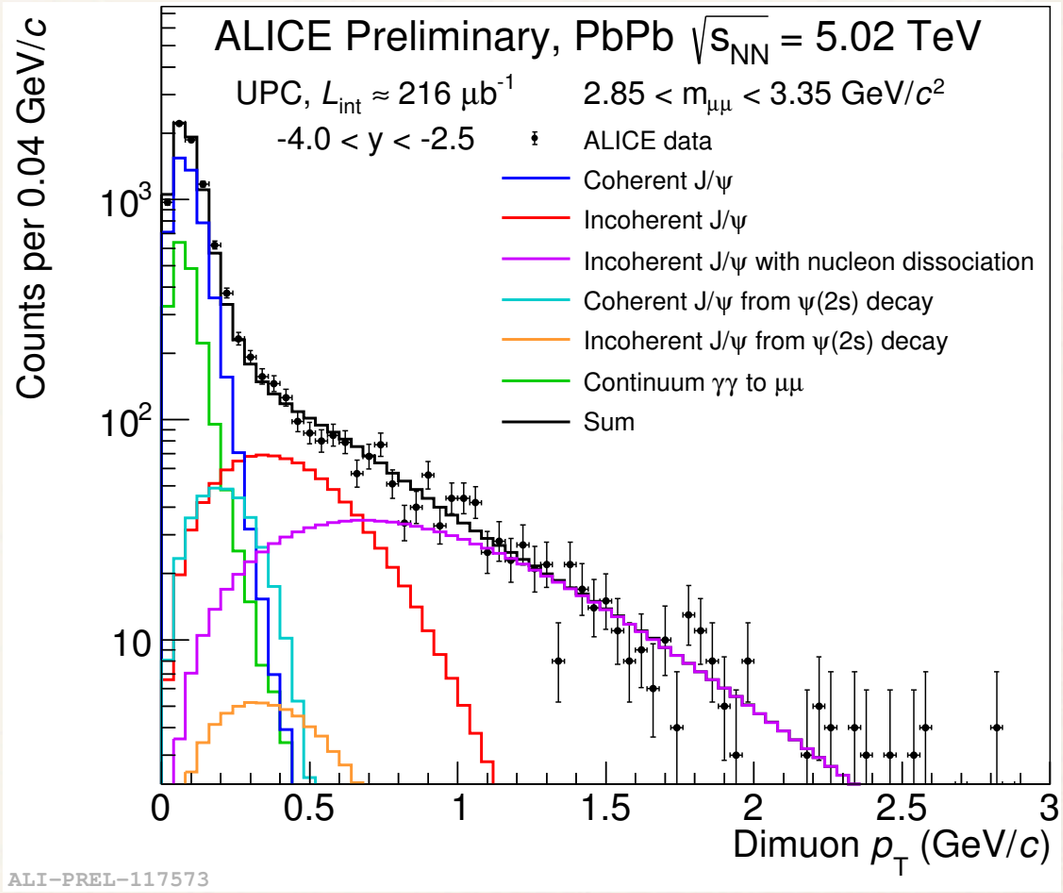


Fig. 1. Left: invariant mass distribution for unlike-sign dimuons with pair $p_T < 0.25$ GeV/c and rapidity $-4.0 < y < -2.5$ in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Right: transverse momentum distribution for unlike-sign dimuons around J/ψ mass fitted summing six diffirent Monte Carlo templates.

LHCb Upgrade - SciFi

- Mats production status