LHCb Status Report

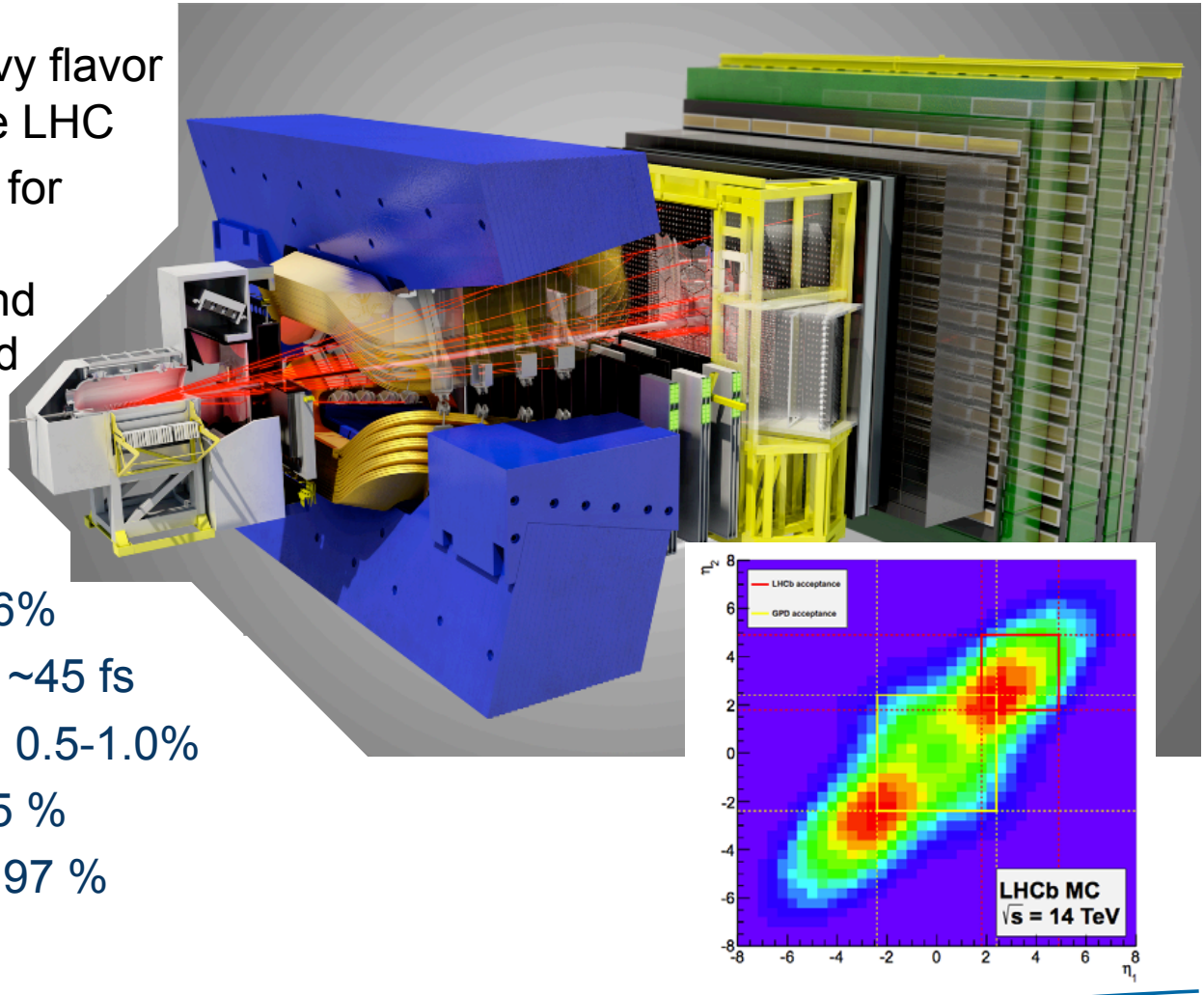
Silvia Borghi
On behalf of the LHCb Collaboration

Outline

- Introduction
- New physics results
- Run2 operation and performance
- Special runs: beam gas and heavy ion collisions
- LHCb upgrade
- Conclusion

LHCb experiment

- LHCb is a dedicated heavy flavor physics experiment at the LHC
- Its primary goal is to look for indirect evidence of new physics in CP violation and rare decays of beauty and charm hadrons

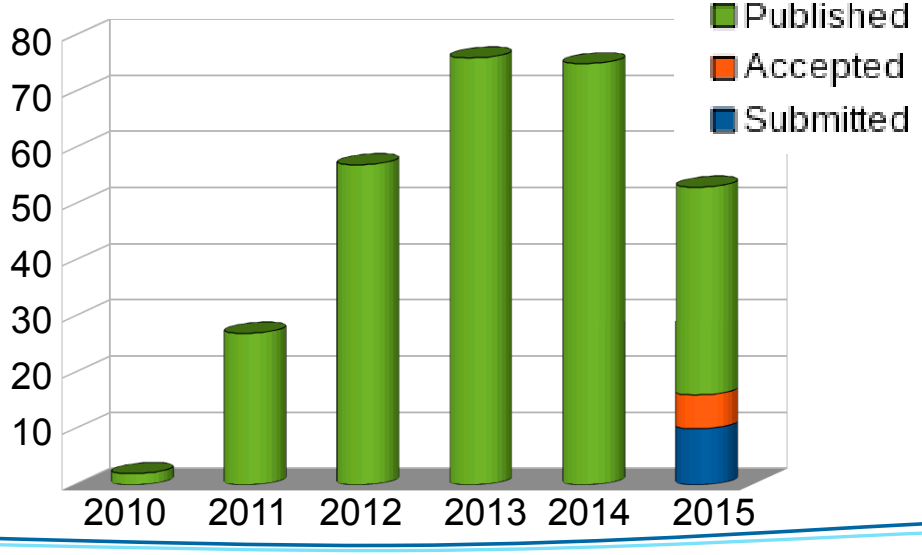


- **Excellent performance**:
  - tracking efficiency >96%
  - decay time resolution ~45 fs
  - momentum resolution 0.5-1.0%
  - kaon ID efficiency ~95 %
  - muon ID efficiency: ~ 97 %

Physics publication

Year	Published	Submitted	Accepted	Total	CONF
2010	2			2	7
2011	27			27	61
2012	57			57	34
2013	76			76	13
2014	75			75	4
2015	**37**	10	6	**53**	**5**
Total	**274**	**10**	**6**	**290**	**124**

- **37 published papers in 2015**
- New from last LHCC:
  - 12 Submitted
  - 14 Published
- Still a lot results with the Run1 data in the pipeline



New papers

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{}$ = 13 TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

New papers

b-hadrons

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{}$ = 13 TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

New papers

Charm

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{} = 13$ TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

New papers

Quarkonia

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{} = 13$ TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

New papers

Electroweak

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{} = 13$ TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

New papers

Heavy ion

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{} = 13$ TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV;

New papers

Heavy ion

- PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{} = 13$ TeV. Submitted to JHEP; arXiv:1510.01707
- PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039
- PAPER-2015-040 Measurements of long-range near-side a **Presented at last LHCC** proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV;

Latest News

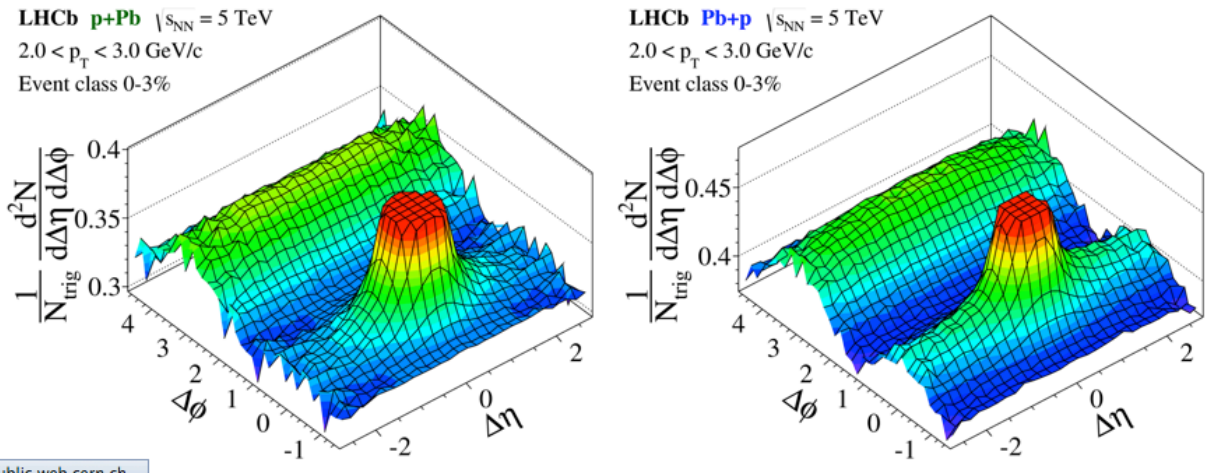
http://lhcb-public.web.cern.ch/lhcb-public/

2 December 2015: A mysterious ridge effect.

The LHCb collaboration has submitted today a paper reporting the study of correlations in particle production in proton(p)-lead(Pb) ion collisions at the LHC. The plots (see below) showing the angular distribution of these correlations show features similar to a "ridge" in a mountain landscape. Therefore physicists name this kind of analysis a study of "ridge effect".

Two sets of data were taken: p-lead and lead-p, where in the second case the direction of the proton and lead ion beams were reversed. This allowed the LHCb detector, recording the particles only on one side of the interaction point, to make measurements in the case of proton beam pointing towards the LHCb detector as well as in the opposite case of lead beam pointing to it.

The idea of analysis is simple. LHCb physicists plotted differences Δ between production angle of particle pairs both in angle θ along the direction of incoming proton or lead beams, and in angle φ around this direction. The difference in angle θ is plotted as the difference of a related variable, pseudo-rapidity η, where η=-ln(tan(θ/2)). In this way the plot bin sizes closer to the beam direction are expanded.



This result was presented at last LHCC

New papers

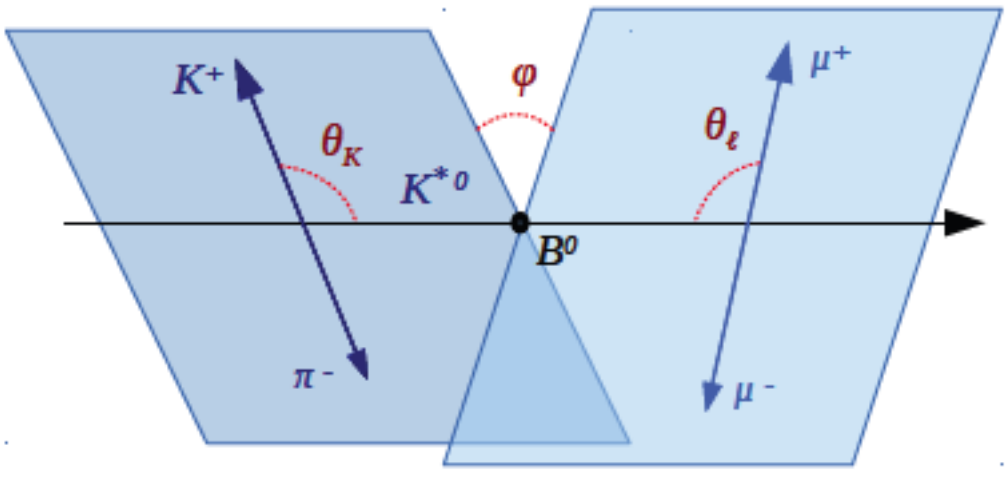
b-hadrons
Charm
Electroweak

- **PAPER-2015-051 Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay. To be submitted to JHEP**
- PAPER-2015-043 First observation of the decay $D^0 \to K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
- PAPER-2015-047 Evidence for the strangeness-changing weak decay $\Xi^-_b \to \Lambda^0_b\pi^-$. Accepted by Phys. Rev. Lett.; arXiv:1510.03829
- PAPER-2015-044 Search for the rare decays $B^0 \to J/\psi\gamma$ and $B^0_s \to J/\psi\gamma$. Accepted by Phys. Rev. D; arXiv: 1510.04866
- **PAPER-2015-048, Search for the lepton-flavour violating decay $D^0 \to e^\pm mu^\mp$. Submitted to Phys. Lett. B; arXiv:1512.00322**
- PAPER-2015-041 Measurements of prompt charm production cross-sections in pp collisions at $s\sqrt{}$ = 13 TeV. Submitted to JHEP; arXiv:1510.01707
- **PAPER-2015-042 Model-independent measurement of mixing parameters in $D0 \to K^0_S\pi^+\pi^-$ decays. Submitted to JHEP; arXiv:1510.01664**
- PAPER-2015-046 Production of associated Y and open charm hadrons in pp collisions at $\sqrt{s}$=7 and 8 TeV via double parton scattering. Submitted to JHEP; arXiv:1510.05949
- PAPER-2015-038 A model-independent confirmation of the $Z(4430)^-$ state. Submitted to Phys. Rev. D; arXiv: 1510.01951
- **PAPER-2015-049 Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8TeV. Submitted to JHEP; arXiv:1511.08039**
- PAPER-2015-040 Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region. Submitted to Phys. Lett. B; arXiv 1512.00439
- CONF-2015-005 Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV

Angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay

Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

- Flavour-changing neutral current b→s via loop (or box) in SM
- Rate and angular observables can be affected by presence of virtual new particles (if there are any)
- Full angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay
  - System fully described by q^2 and three angles $\Omega=(\cos\theta_l, \cos\theta_k, \phi)$



Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

- Differential decay rate

$$\frac{d^4\Gamma[\overline{B}^0 \to \overline{K}^{*0}\mu^+\mu^-]}{dq^2\, d\vec{\Omega}} = \frac{9}{32\pi}\sum_j I_j(q^2) f_j(\vec{\Omega})$$

$$\frac{d^4\bar{\Gamma}[B^0 \to K^{*0}\mu^+\mu^-]}{dq^2\, d\vec{\Omega}} = \frac{9}{32\pi}\sum_j \bar{I}_j(q^2) f_j(\vec{\Omega})$$

- I_j are q^2-dependent angular observables
- q^2-dependent CP averages S_i and CP asymmetries A_j defined as [arxiv:0811.1214]

$$S_j = (I_j + \bar{I}_j) \Big/ \left(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\right)$$

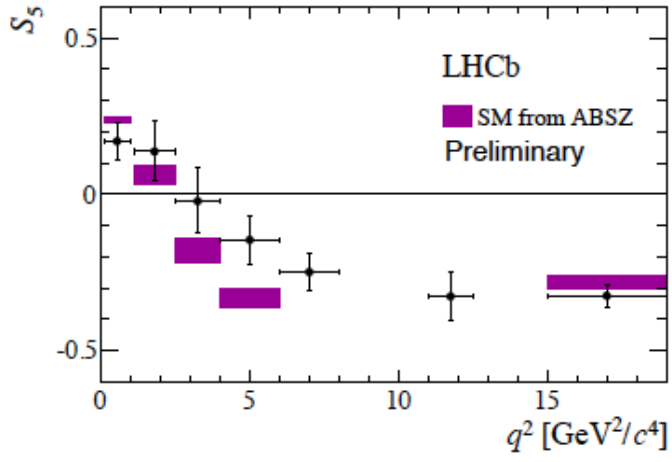
$$A_j = (I_j - \bar{I}_j) \Big/ \left(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\right)$$

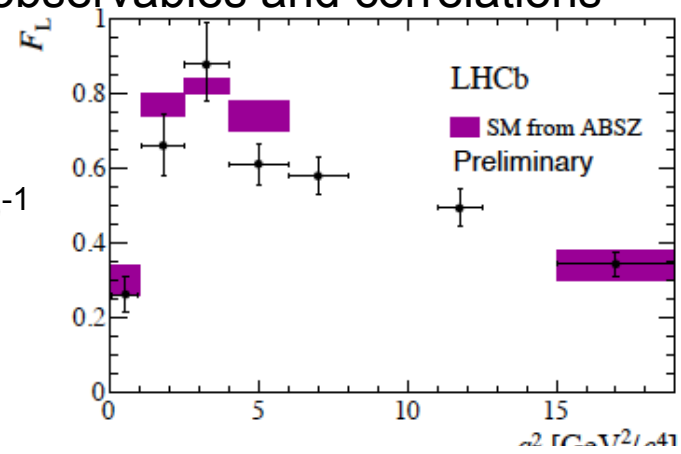
- CP-averaged observables
  - the forward-backward asymmetry of the dimuon system $A_{FB} = \frac{3}{4} S_{6s}$
  - the longitudinal polarisation fraction of the K^{*0} $F_L = S_{1c}$
- "Optimized-theoretical clean" observables [arxiv:1303.5794]

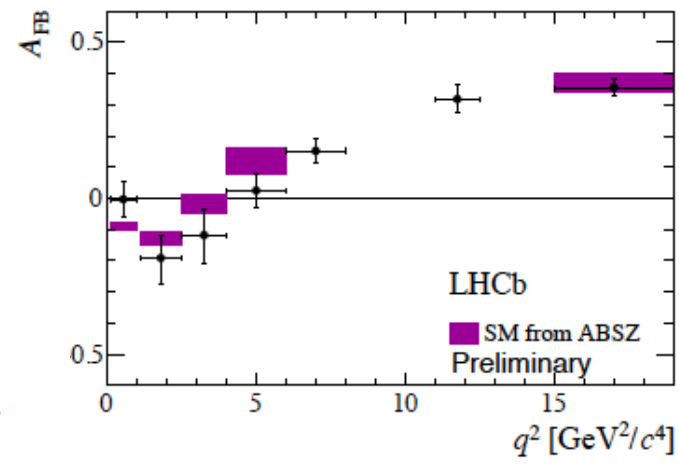
$$P'_{4,5} = S_{4,5} / \sqrt{F_L(1 - F_L)}.$$

Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

- Update of [LHCb-CONF-2015-002]
- Inclusion of the scalar S-wave component in Kπ system in angular analysis
- Three analysis methods with different strengths
- **Fit full angular distribution ➔** complete set observables and correlations
  - Fit performed in bins of $q^2 \sim 2$ GeV^2/c^4
  - B^0 and $\overline{B^0}$ separately
- Yield: 624±30 in $q^2 \in [1.1,6]$ GeV^2/c^4 in L= 3 fb^{-1}



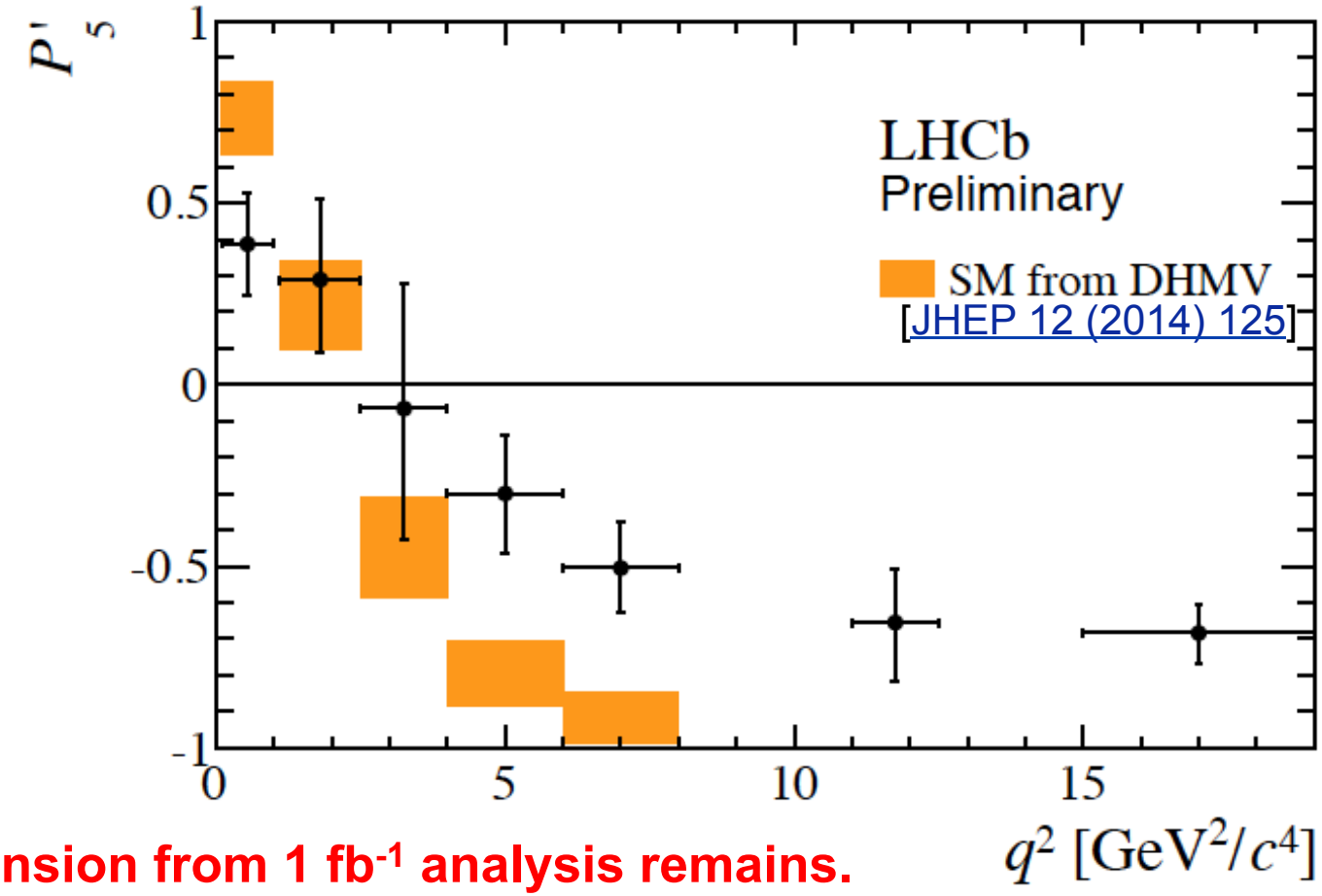




All CP asymmetries consistent with zero

All observables consistent with SM except S_5

Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay



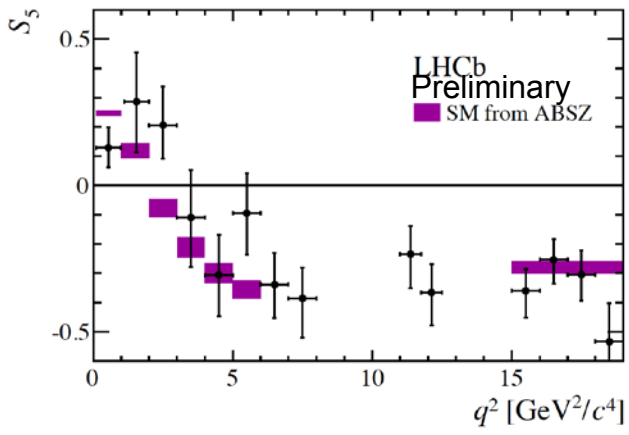
Tension from 1 fb^{-1} analysis remains.

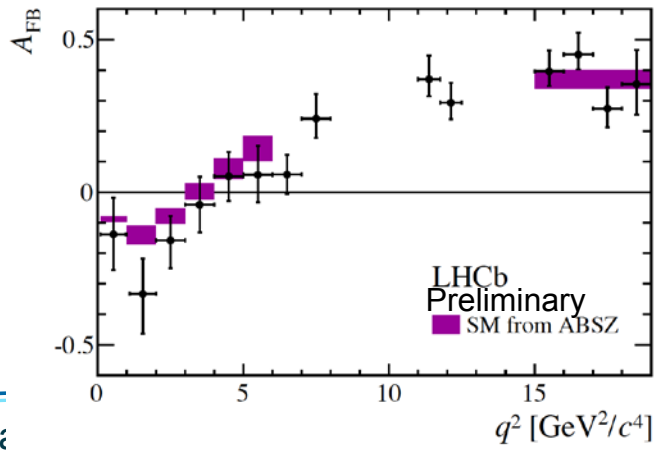
Now split over two bins of 2.8σ and 3.0 σ (q^2 bins [4.0,6.0] GeV^2 and [6.0,8.0] GeV^2) when comparing to [DHMV, JHEP 12 (2014) 125].

Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

Method of moments

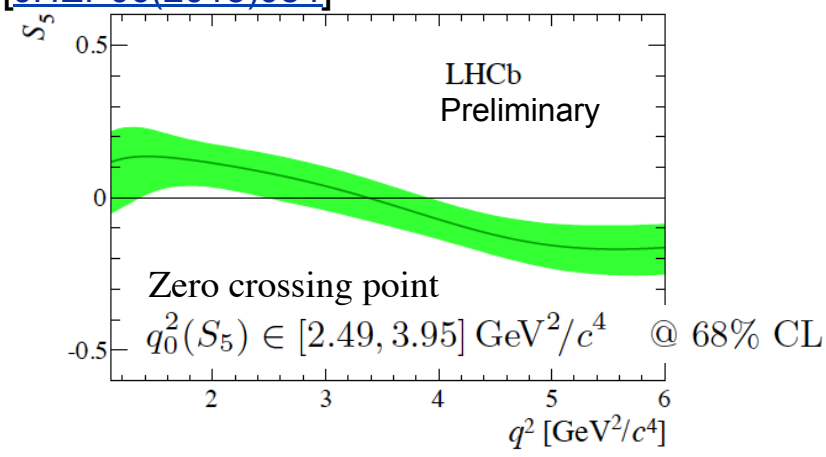
- Counting method, less precise but more robust [Phys.Rev.D91(2015)114012].

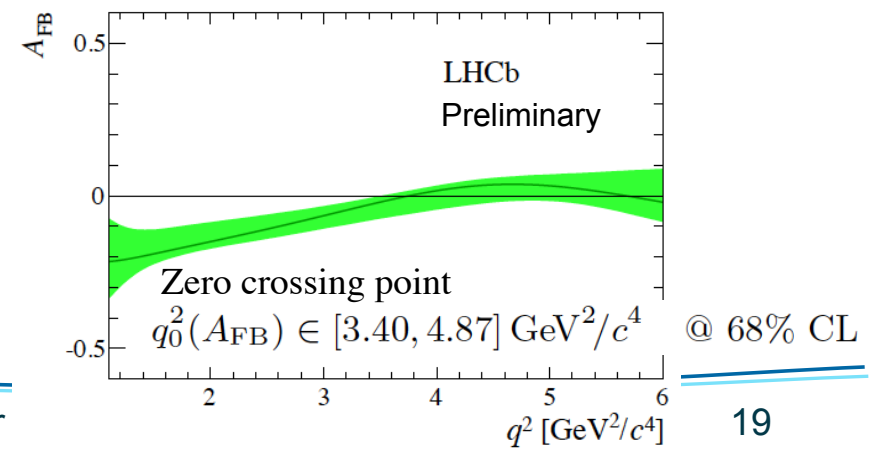




Amplitude fit

- Modelling the q^2 dependence of the amplitudes ➔fit for zero-crossing points [JHEP06(2015)084]

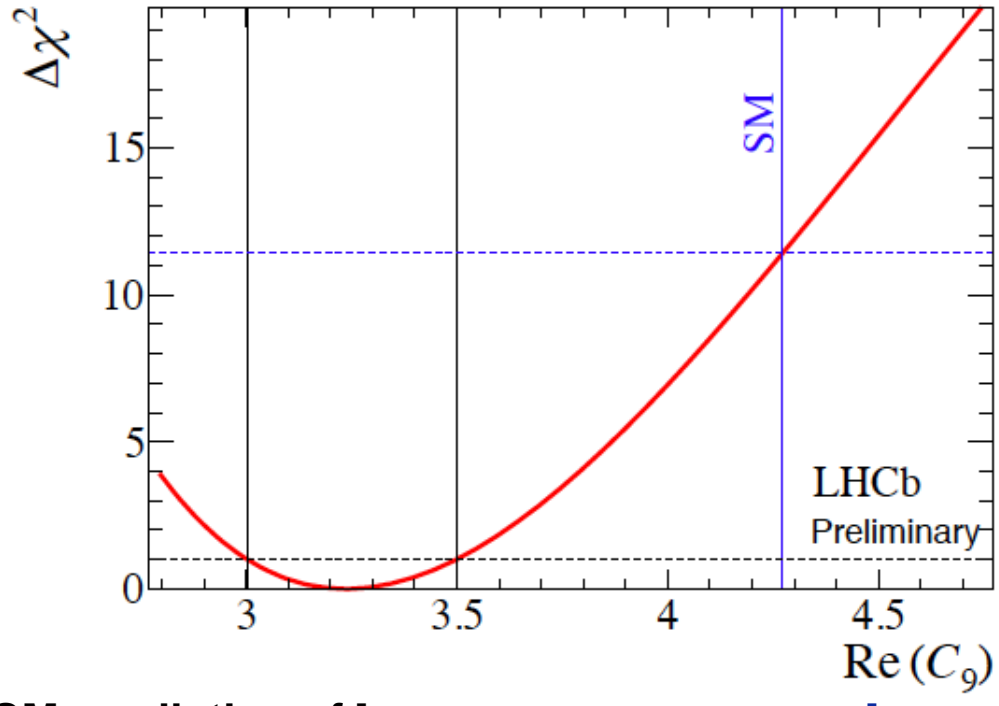




Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

- Perform χ^2 fit of measured: F_L, A_{FB}, $S_{3..9}$ to extract Re(C9) fixing all other Wilson coefficients to their SM value
- Use EOS software package [JHEP07(2010)098] to test compatibility with SM.
- Float a generic vector coupling a.k.a. Wilson Coefficient Re(C9)

$\Delta\mathcal{R}e(C9) = -1.04 \pm 0.25$

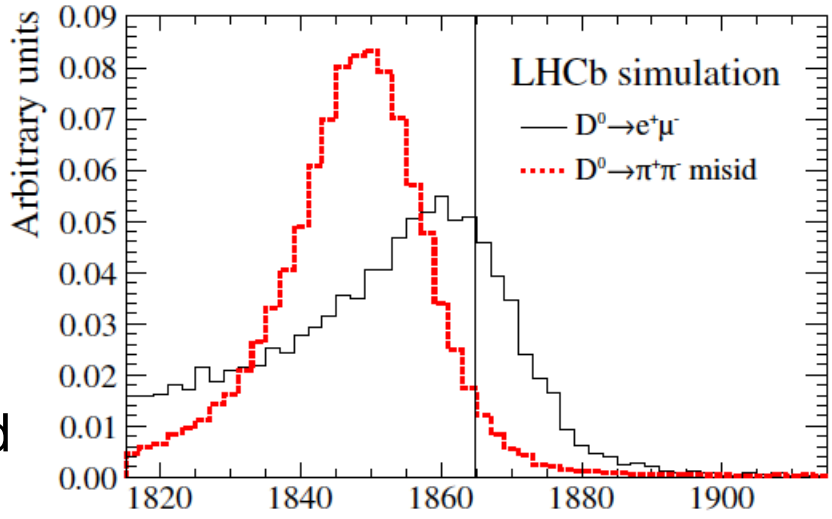


- **Best fit to data is 3.4 σ from the SM prediction** of [Eur. Phys. J. C74 (2014) 2897]
- Caused by a contribution from a new non-SM particle or by unexpectedly large hadronic effect, underestimated in SM predictions [Altmannshofer, Straub, EPJC 75 382 (2015) and others]

Search for the lepton-flavour violating decay $D^0 \rightarrow e^{\pm}\mu^{\mp}$

Search for the lepton-flavour violating decay $D^0 \to e^{\pm}\mu^{\mp}$

- The decay $D^0 \to e^{\pm}\mu^{\mp}$ is a forbidden decay, in which lepton flavour is not conserved.
- The decay is predicted with $\mathcal{B}$ of $\mathcal{O}(10^{-6})$ in several models BSM
  - e.g. SUSY with R-parity violation and leptoquark model
- Candidate signal events are selected using the decay $D^{*+} \to D^0\pi^+$ and the measurements are normalized to $D^{*+} \to D^0(\to K^-\pi^+)\pi^+$ decays
- Most dangerous background mis-ID $D^0 \to \pi^-\pi^+$



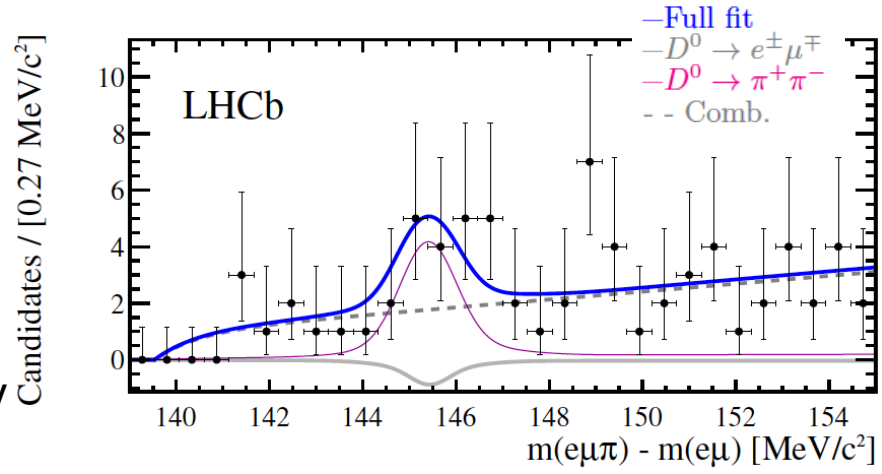
$D^0 \to \pi^+\pi^-$ and $D^0 \to e^+\mu^-$ reconstructed as $e^+\mu^-$

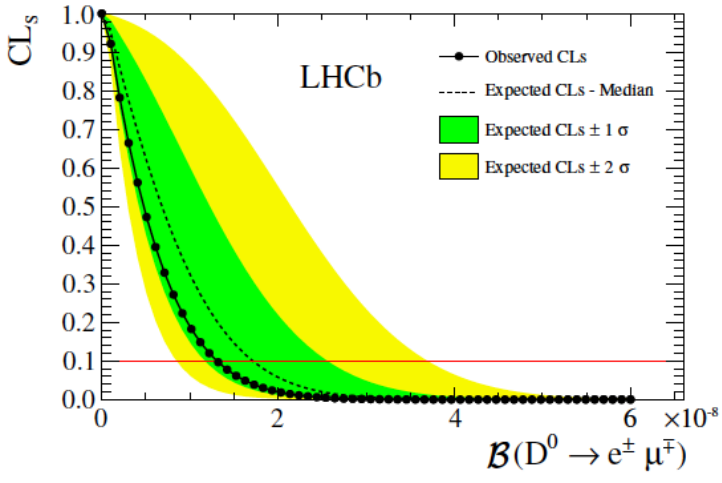
Search for the lepton-flavour violating decay $D^0 \to e^{\pm}\mu^{\mp}$

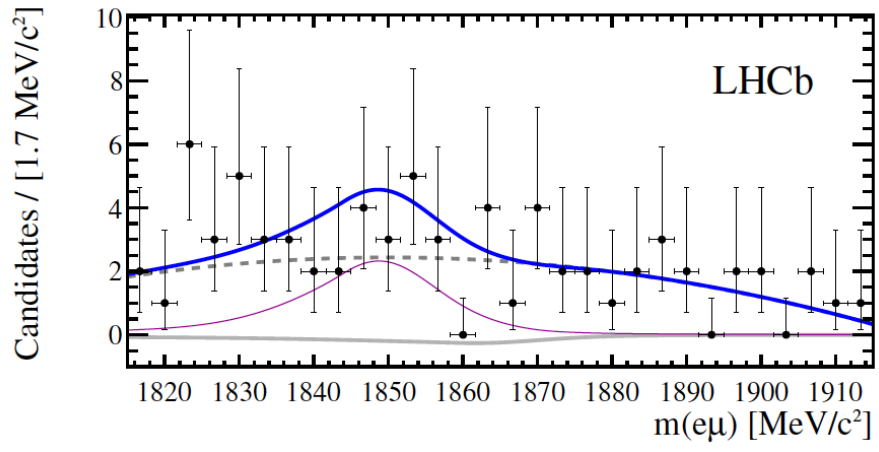
- No signal observed in 3 fb^{-1}
- Set world best limit

$\mathcal{B}(D^0 \to e^{\pm}\mu^{\mp}) < 1.3 \times 10^{-8}$ at 90% CL

- Improving by an order of magnitude on previous limits
- Result further constrains products of couplings in SUSY models with R-parity violation and constrains the parameter space in some leptoquark models.



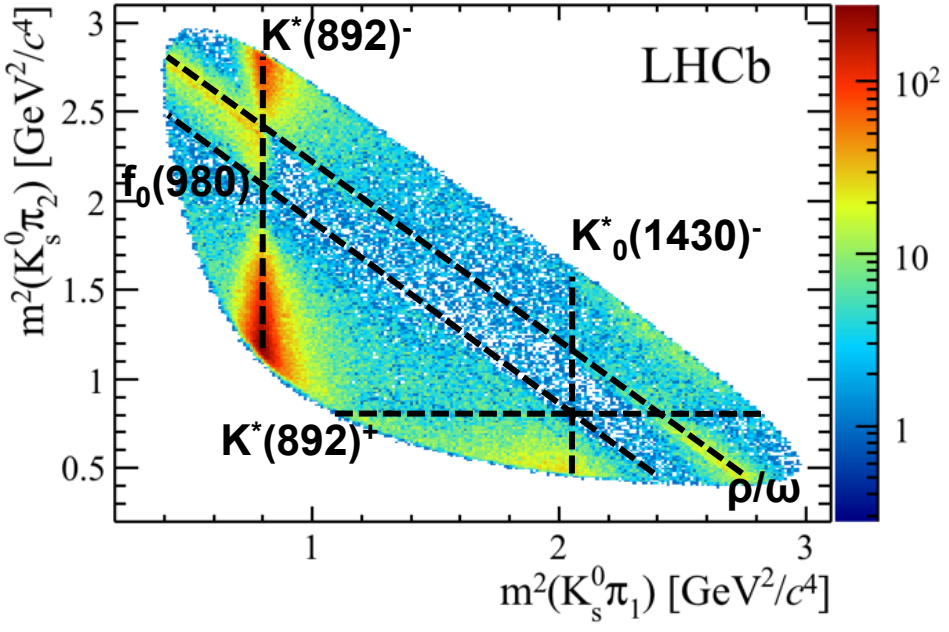




Model-independent measurement of mixing parameters in $D^0 \rightarrow K^0_S \pi^+ \pi^-$ decays

Model-independent measurement of mixing parameters in $D^0 \to K^0_S \pi^+ \pi^-$ decays

- Different superposition of amplitudes at each point in phase-space
- Interfering amplitudes enhance the sensitivity to mixing
- Requires a challenging time-dependent Dalitz plot analysis
  - Dalitz plane divided in 16 bins with constant strong phase difference
  - Model-independent approach
  - Constrain hadronic parameters (T_i, c_i, s_i) to values measured by the CLEO experiment [PRD 82 (2010) 112006]

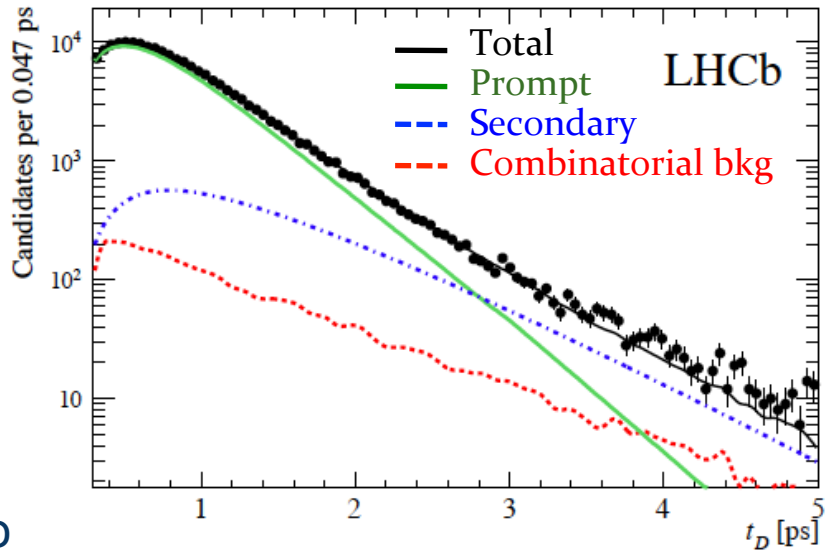


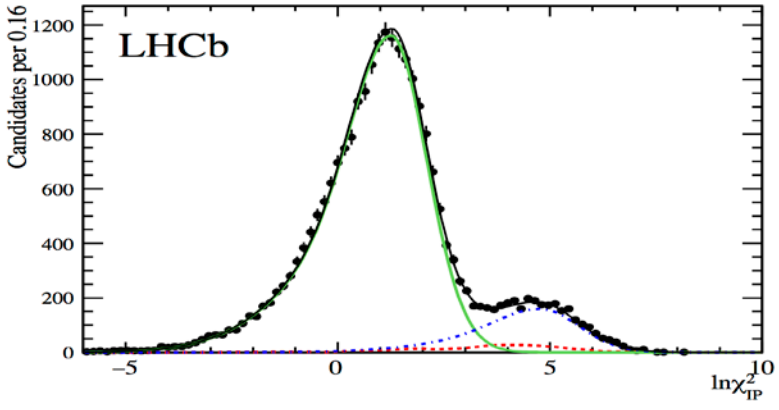
- Time dependent decay rate:

$$\mathcal{P}_{D^0} = e^{-\Gamma t}\left[T_i - \Gamma t\sqrt{T_i T_{-i}}\left(y c_i + x s_i\right)\right]$$

Model-independent measurement of mixing parameters in $D^0 \to K^0_S \pi^+ \pi^-$ decays

- Integrated luminosity of 1 fb^{-1} (only 2011 data)
- Yield: 178k with a purity of 97.4%
- Flavour tagging provided by $D^{*+} \to D^0 \pi^+$
- Simultaneous fit to all Dalitz bins
  - Separate signal from background by Δm-$m(D^0)$ fit
  - Determine the time evolution by two dimensional fits of D^0 decay time and $\ln(\chi^2_{IP})$ to distinguish charm prompt and D^* from $B \to D^* X$ decays
- Decay-time acceptance determined by a data driven method [JHEP 04 (2012) 129; Phys.Lett. B707 (2012) 349]





LHCB-PAPER-2015-042
Submitted to JHEP
arXiv: 1510.01664

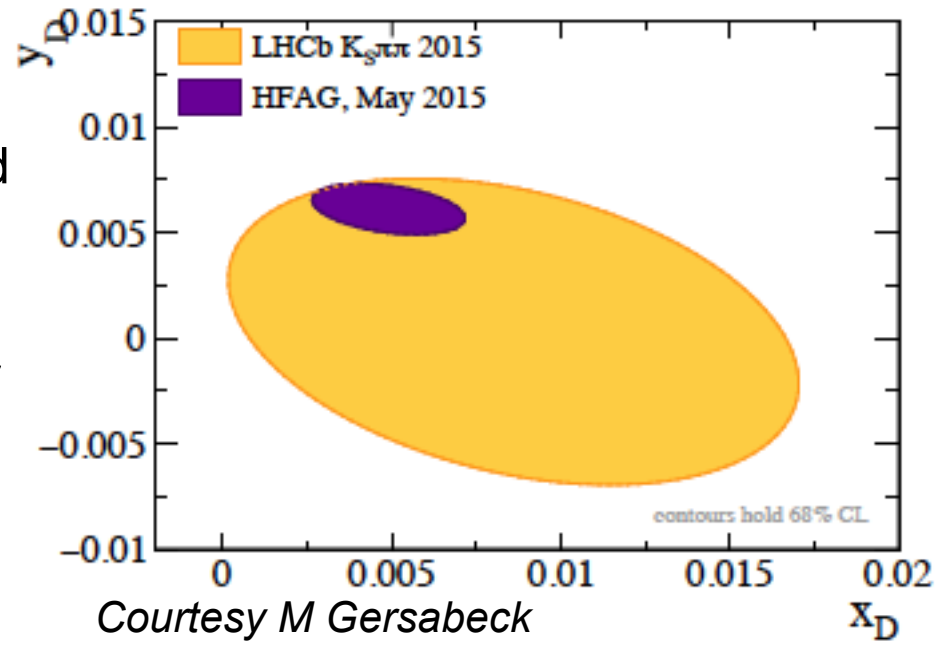
Model-independent measurement of mixing parameters in $D^0 \to K^0_S \pi^+ \pi^-$ decays

- First model-independent measurement of x and y

  $x = (0.86 \pm 0.53 \pm 0.17) \times 10^{-2}$

  $y = (0.03 \pm 0.46 \pm 0.13) \times 10^{-2}$

- Compatible with current HFAG world averages (but not yet competitive) with other experiments
- **~10x more signal yield** in the other 2 fb^{-1} collected in Run1 thanks to improved trigger
- **Signal yield in 2015 equivalent to** the full sample collected in **Run1**

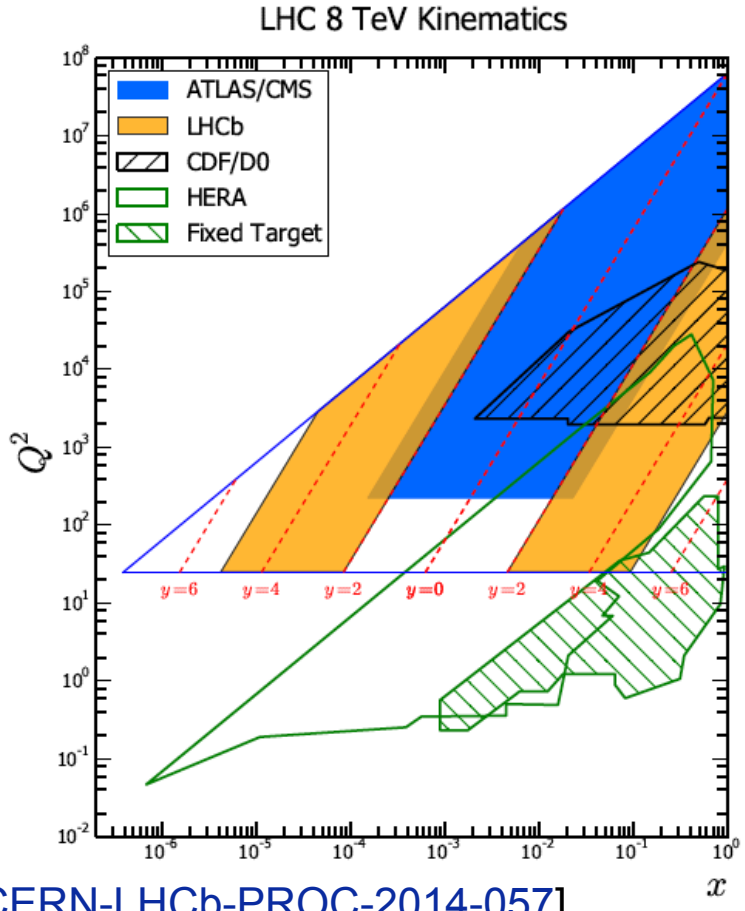


Courtesy M Gersabeck

Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

- Cross-sections and ratios can be used to test the SM
- Parton density functions parameterised as functions of x and Q^2.
- Two distinct regions low- and high-x covered due to forward acceptance $2 < \eta < 4.5$.
  - High-x well known HERA, Tevatron.
  - Low-x unexplored.
- Potential to improve constraints on parton density function at low Bjorken-x values down to 10^{-4}.

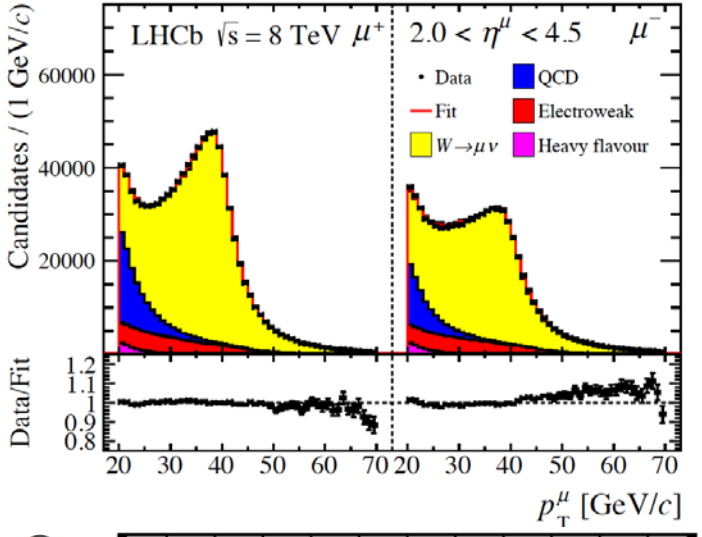


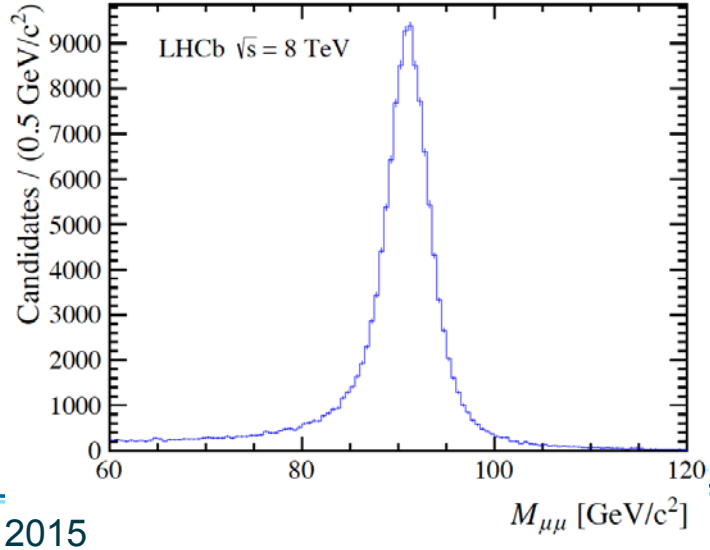
[CERN-LHCb-PROC-2014-057]

LHCB-PAPER-2015-049
Submitted to JHEP
arXiv:1511.08039

Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

- Data sample:
  - 2 fb^{-1}collected in 2012
  - ~140k Z candidates with purity of (99.3±0.2)%
  - ~1.7M W^+ and W^- candidates with purity of 79.3% (78.0%) for W^+ (W^-)
- Fiducial region
  - P^{μ}_T > 20 GeV/c and $2<\eta_\mu<4.5$
  - For Z: $60<M_{\mu\mu}<120$ GeV/c^2
- Cross section measured
  - For W in bin of muon η
  - For Z in bin of boson *y*, p_T and ϕ*

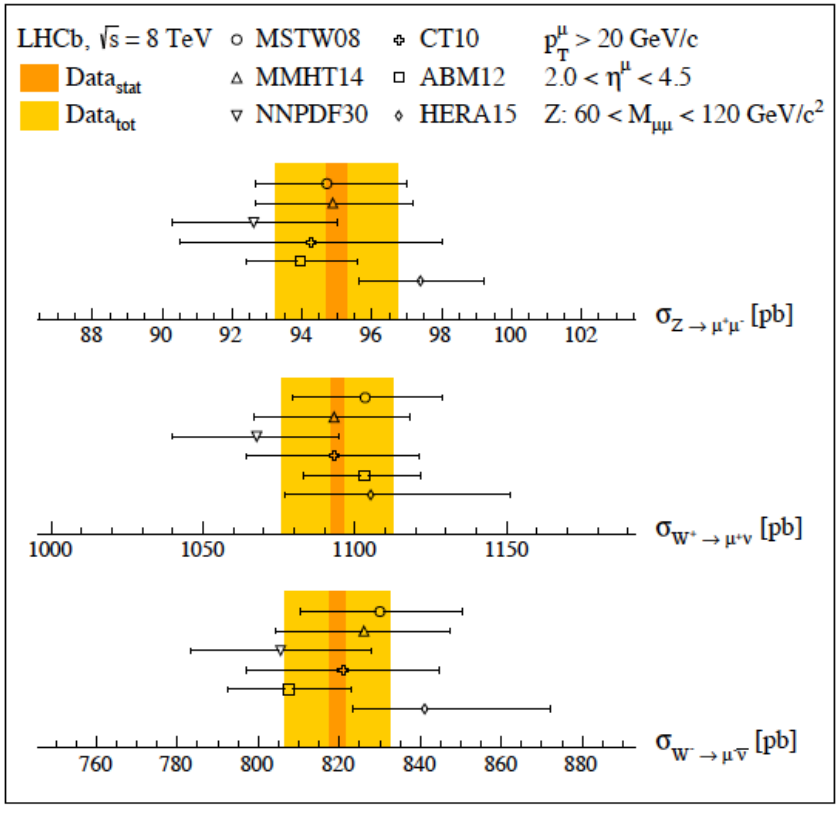




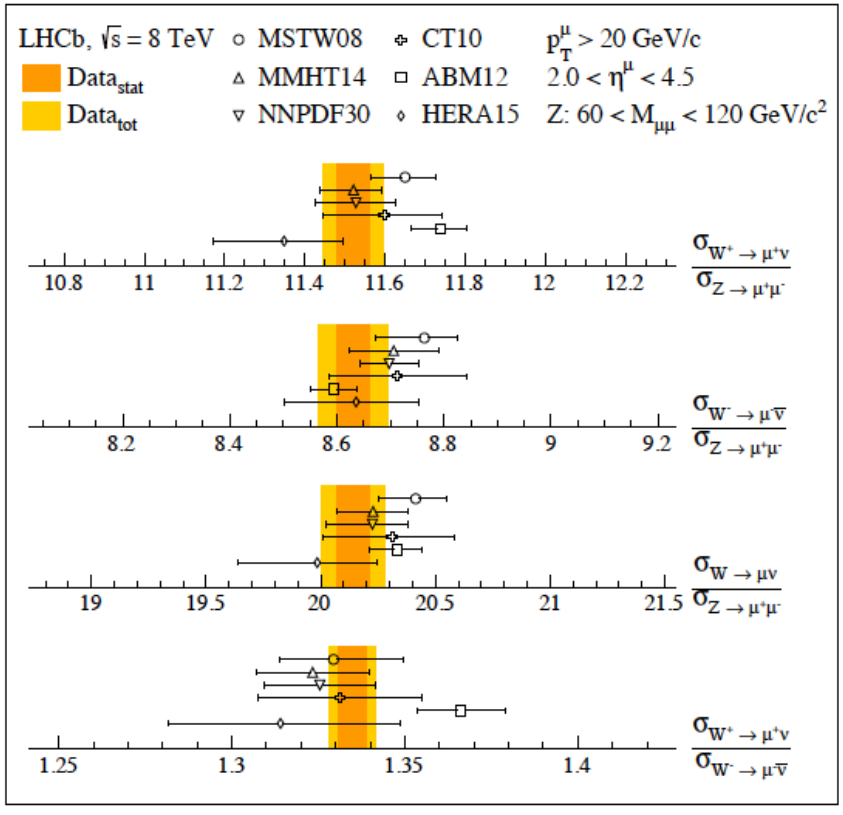
LHCB-PAPER-2015-049
Submitted to JHEP
arXiv:1511.08039

Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

Cross sections



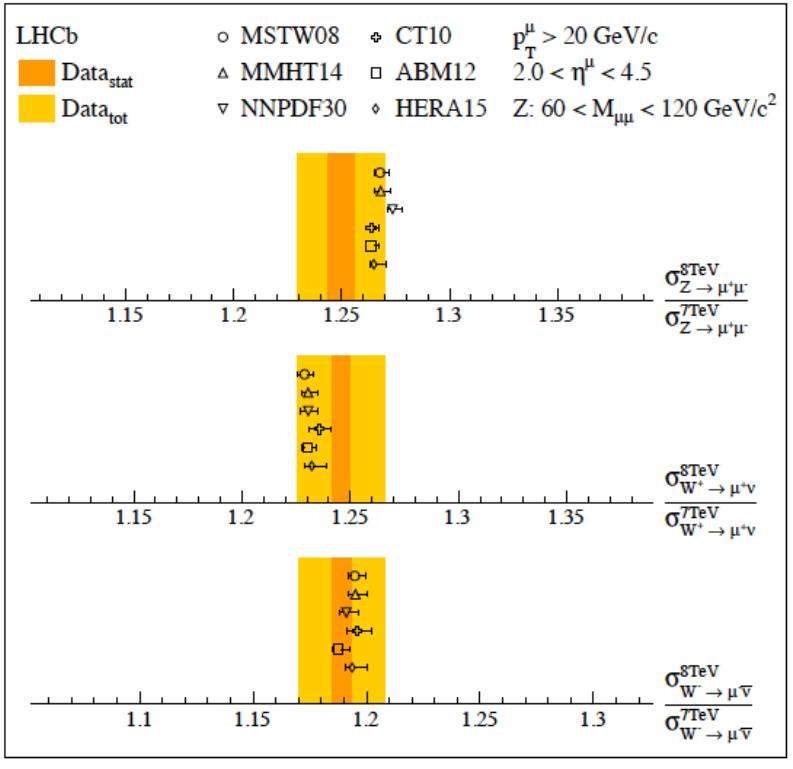
Cross section ratios



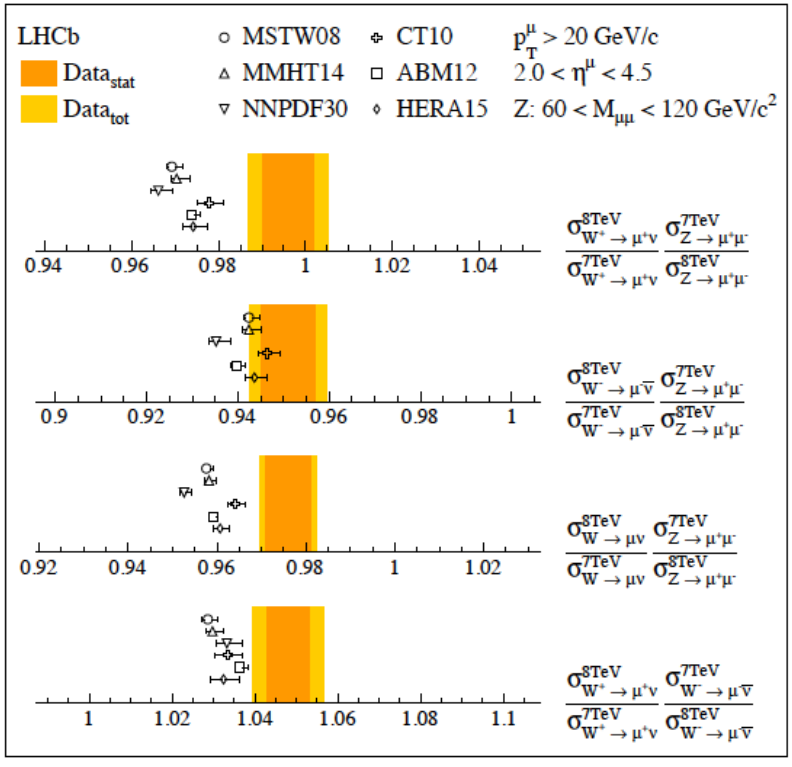
Very good agreement with theory

Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

Ratios at different √s



Double ratio at different √s



Maximum deviation of double ratio is 2 σ

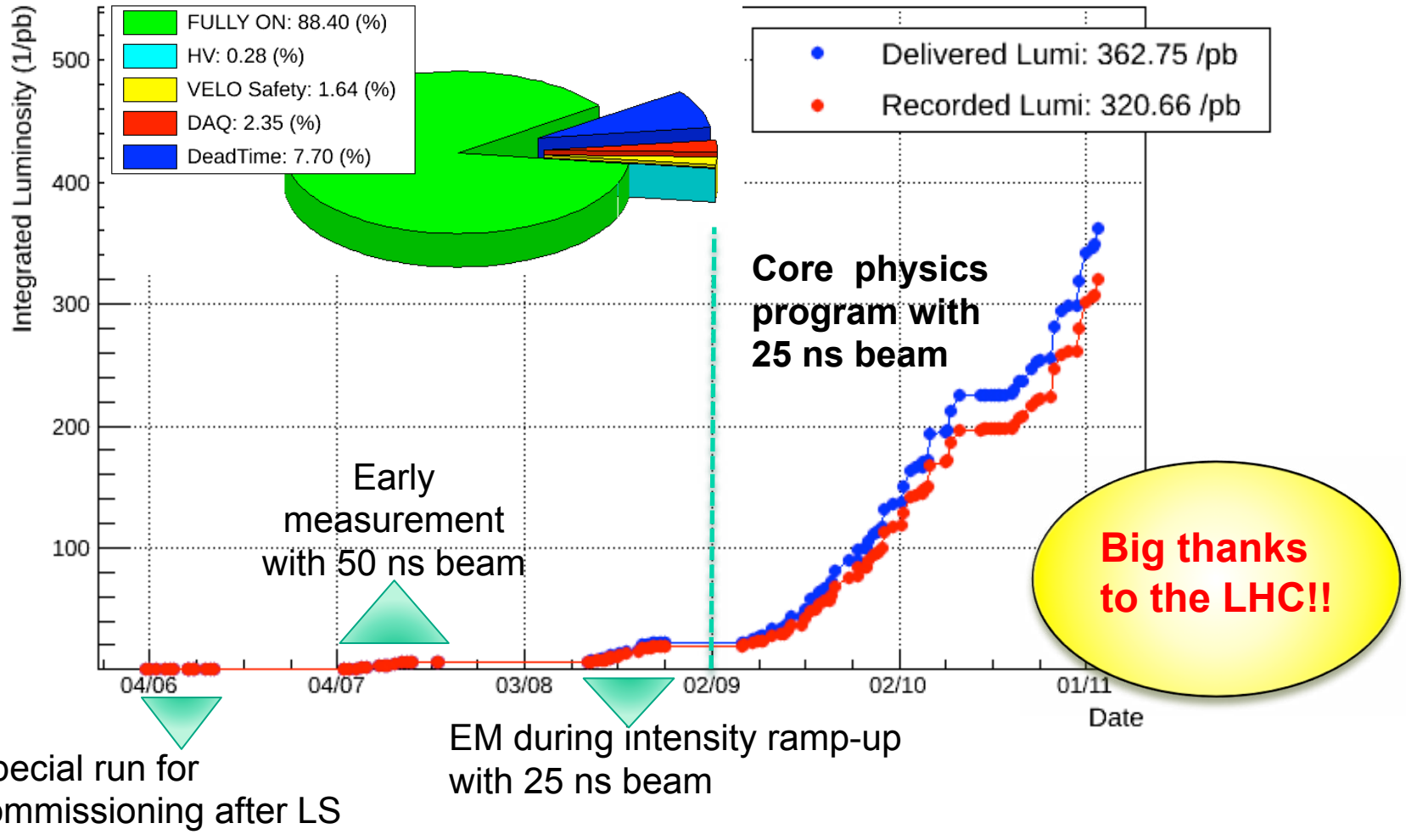
These measurements could potentially improve the determination of the parton density functions in this region

Next results…

- Lots more results still to come from Run1 and Run2 data
- Upcoming new results:
  - New Lepton flavour universality tests
  - New measurements of γ
  - W and Z production at 13 TeV
  - First results from PbPb and beam-gas data
  - More exotic spectroscopy
  - CP violation and mixing measurements in charm
  - . . .

Run2 operation and performance

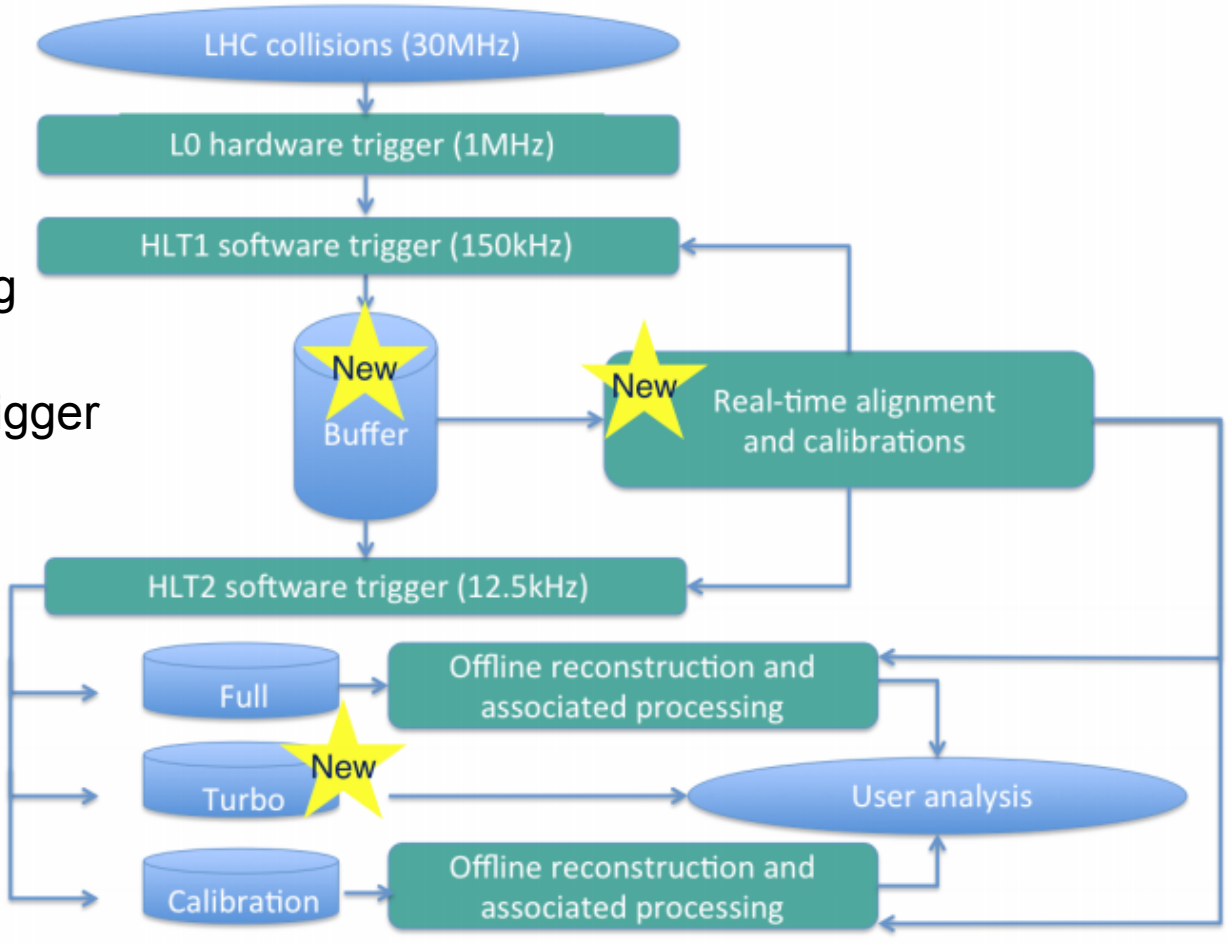
Run 2 data taking: pp collisions



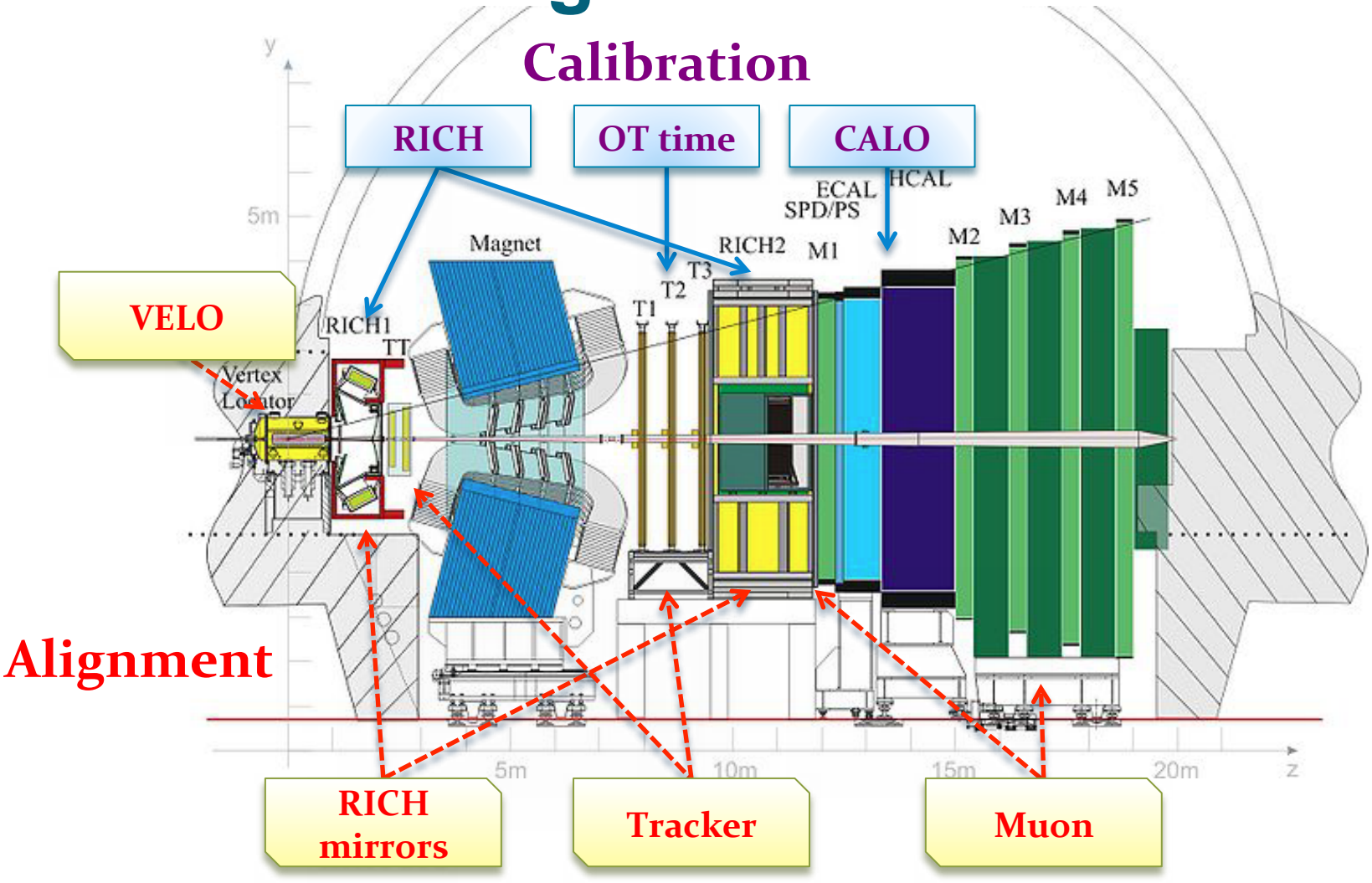
New strategy in Run 2

- Buffer all events to disk before running 2nd software level trigger (HLT2)
- Perform calibration and alignment of the full tracking sub-detectors in real-time

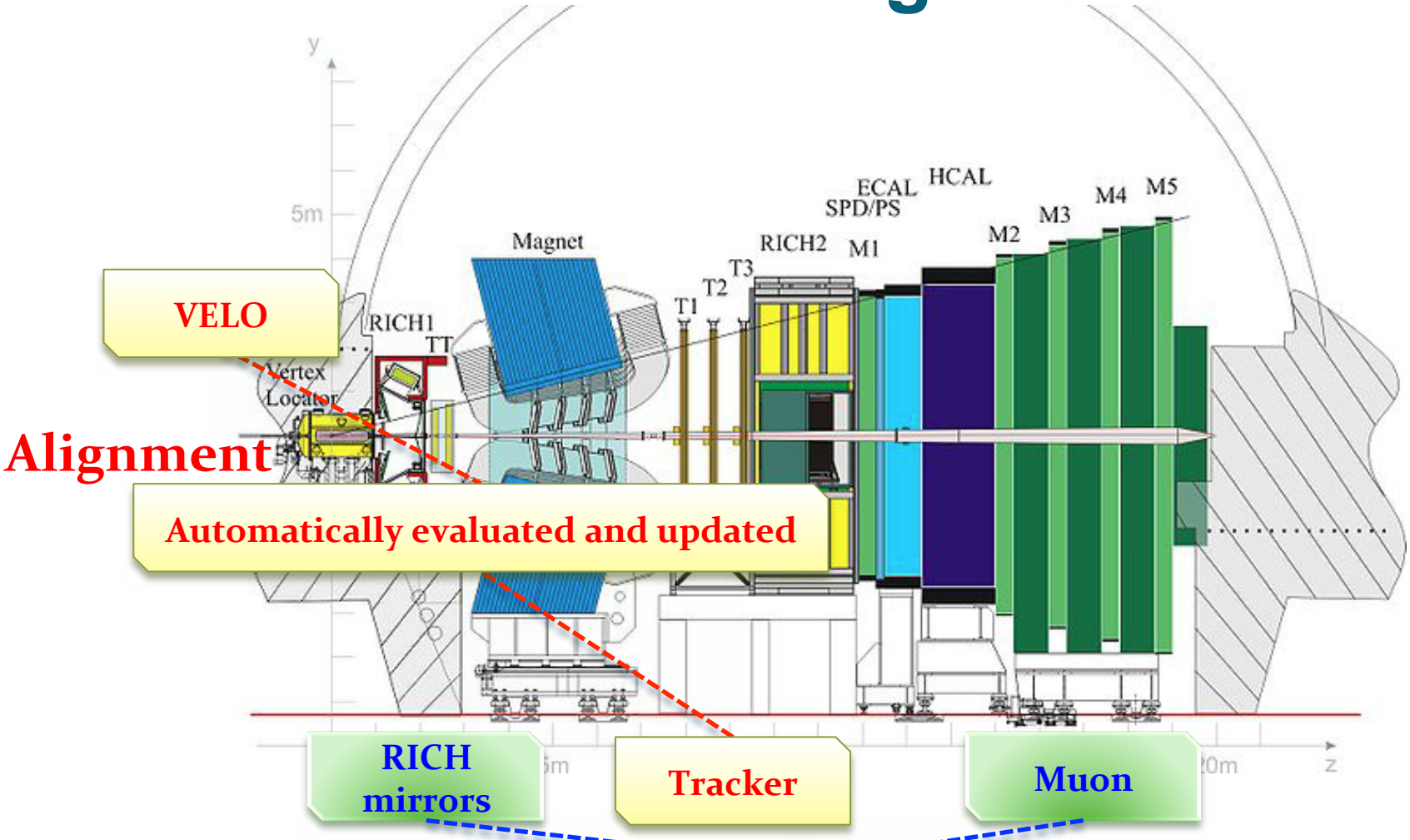
  ➔ same constants in the trigger and offline reconstruction
- Last trigger level runs the same offline reconstruction
- Some analyses performed directly on the trigger output
  - Storing only selected candidates to reduce event size



Real-time alignment and calibration



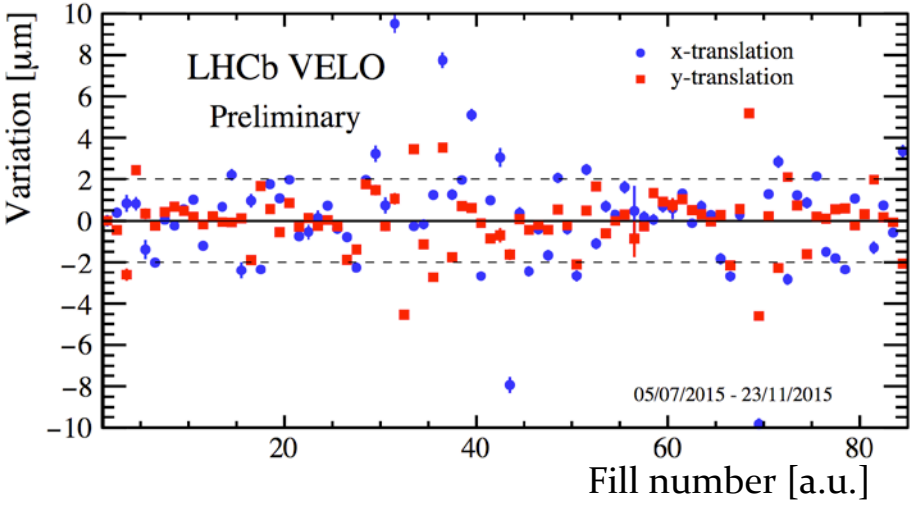
Real-time alignment

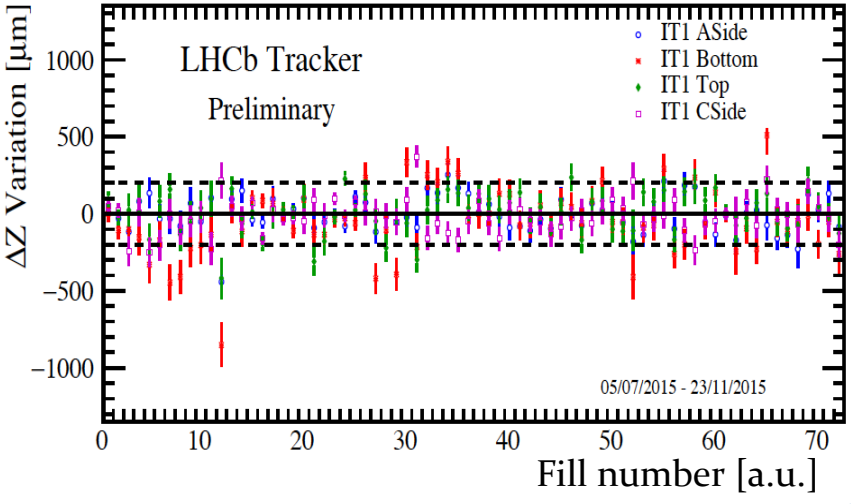


Real-time alignment

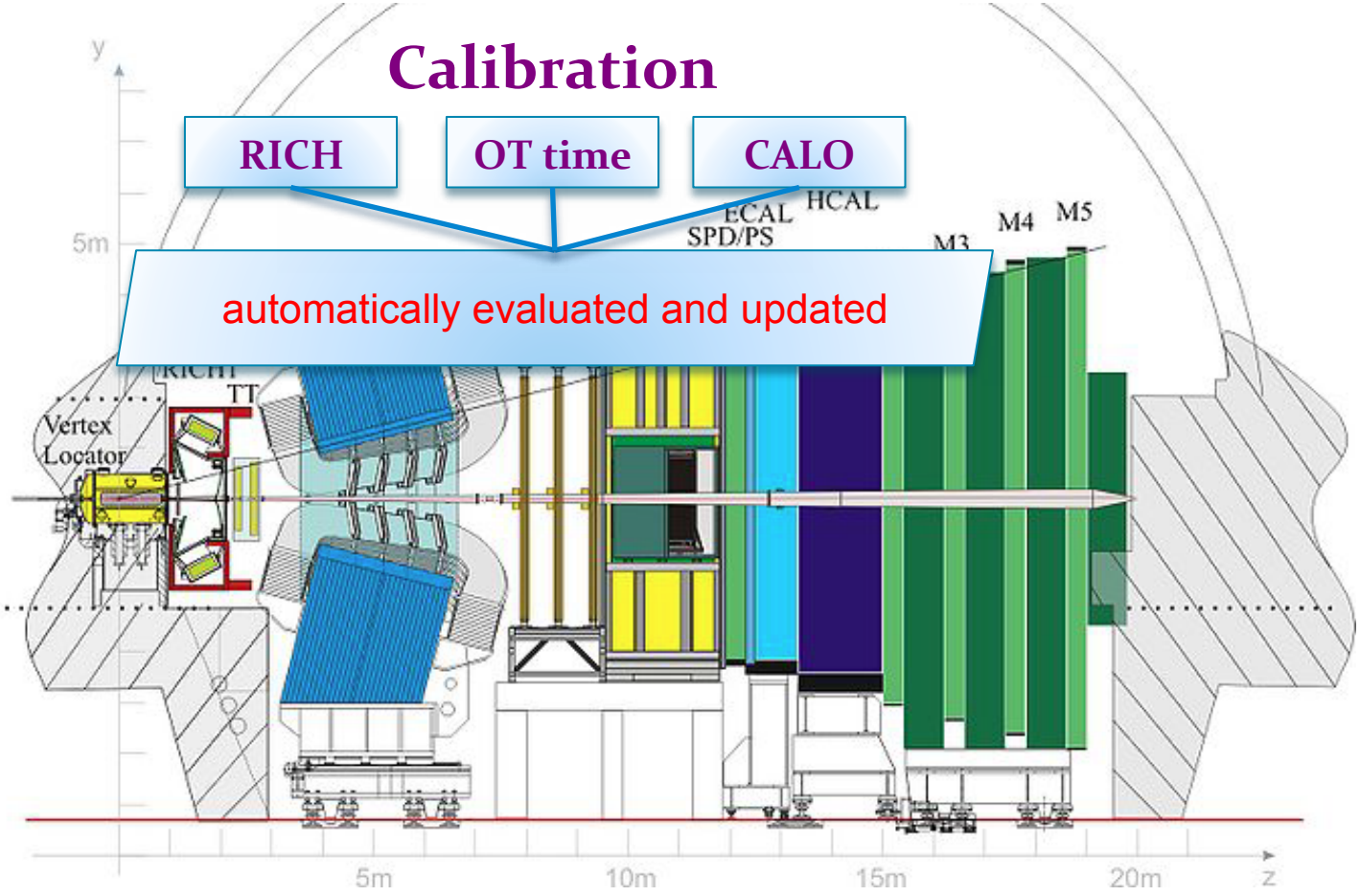
- Alignment of the full tracking system, about **1700** elements
- Same alignment algorithm based on global χ^2 minimisation that uses the default Kalman track fit [Nucl. Instrum. Meth. A600 (2009) 471; Nucl. Instrum. Meth. A712 (2013) 48]
- Run automatically for each fill
- Update of the constants only when needed
- Time required ~**7 minutes** for each task
- Alignment updates in Run2:
  - each 2/3 fills for the VELO
  - after each magnet polarity switch for the tracker
  - no update required, as expected, for the Muon chambers

Evaluated automatically for each fill and updated if needed

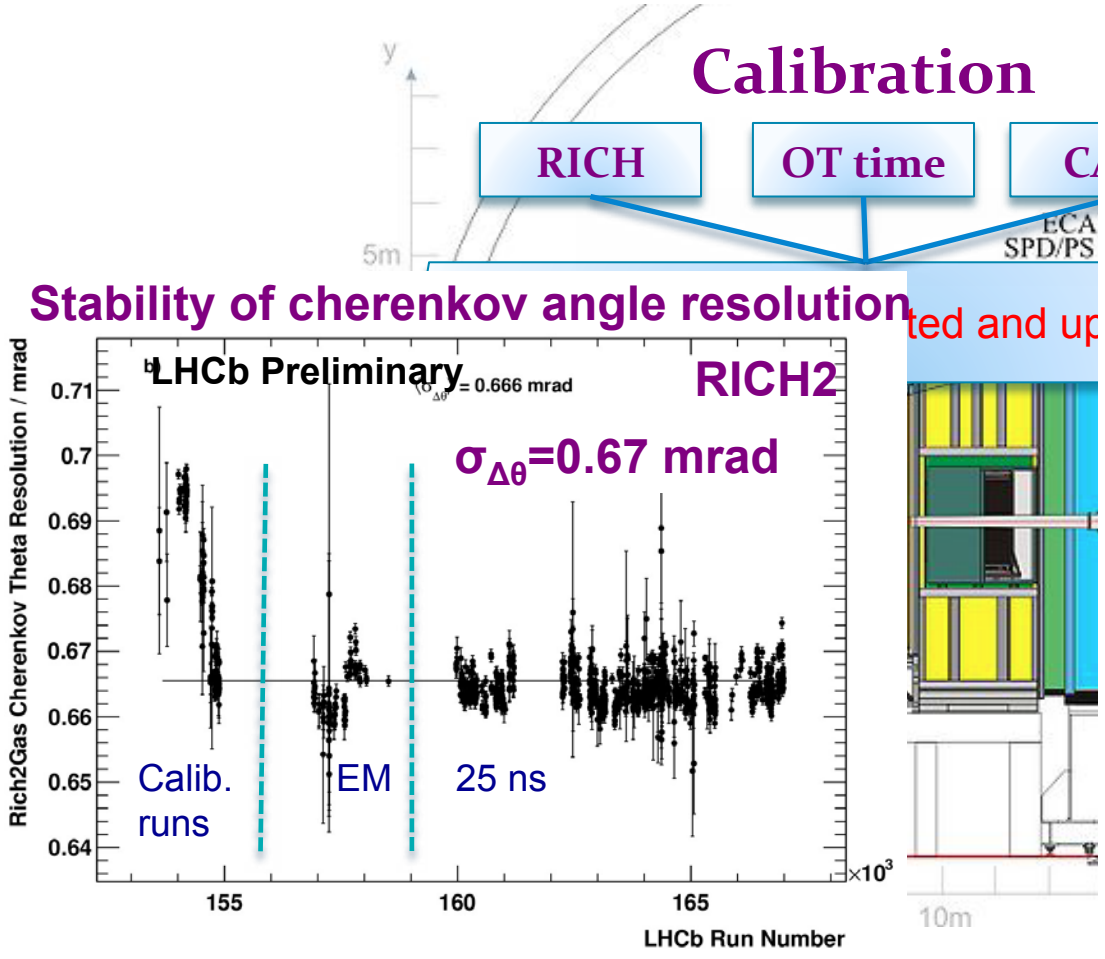




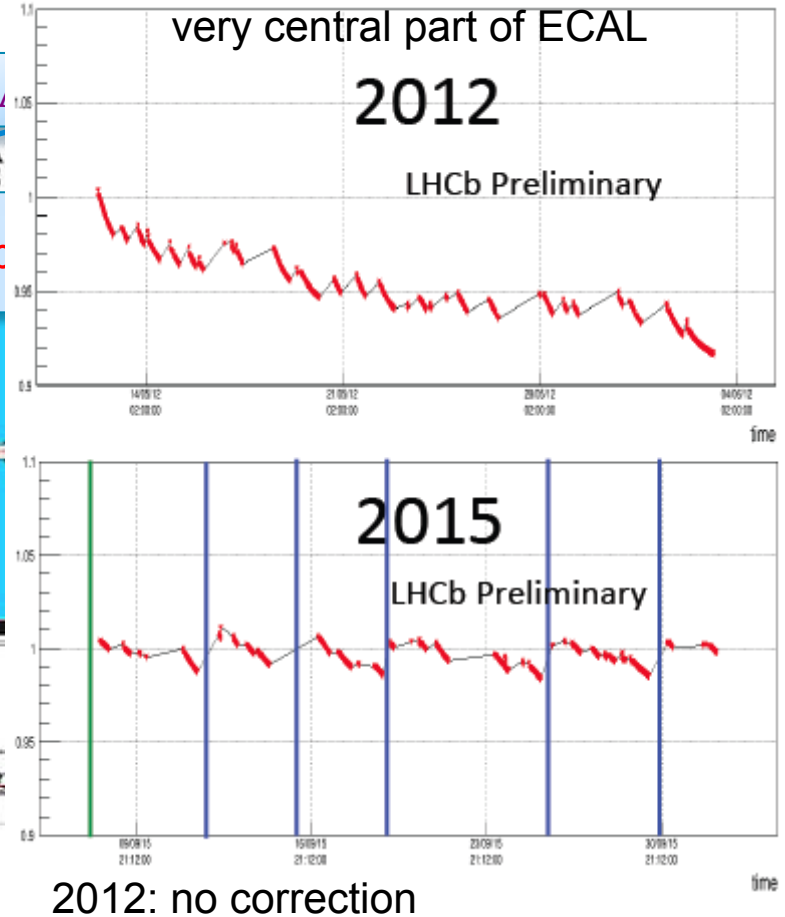
Real-time calibration



Real-time calibration



LED average over 456 cells in the very central part of ECAL



2012: no correction

2015: applied new π^0 calibration

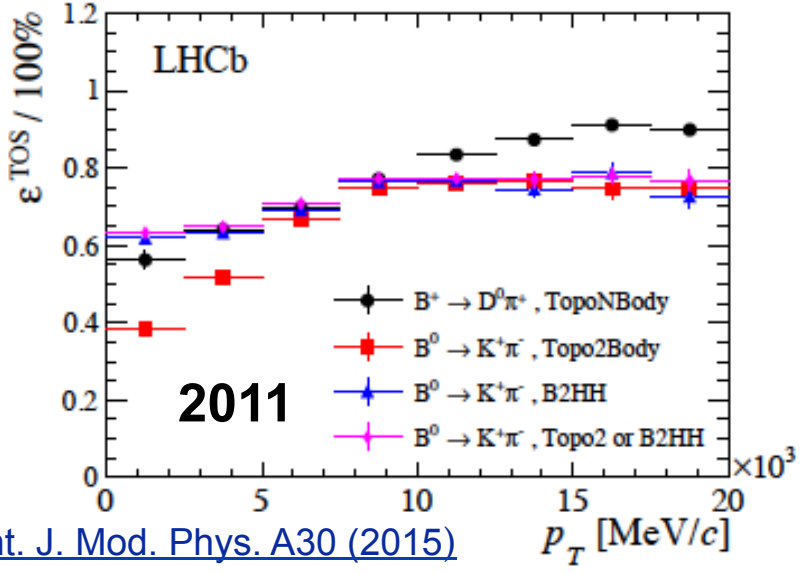
applied new LED corrections

Performance

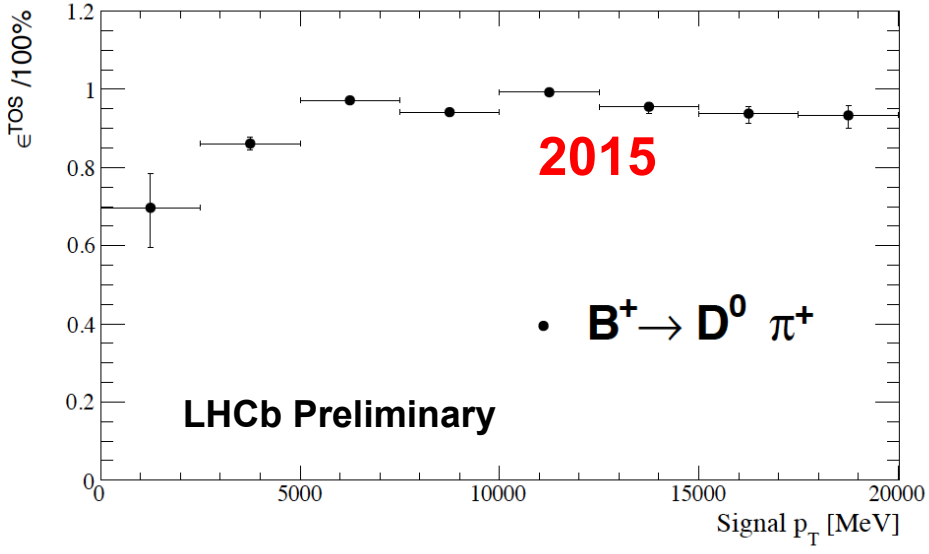
Trigger performance in Run 2

- Improvement of the trigger efficiency thanks to e.g.
  - Run the same offline reconstruction in HLT2
  - Having the detector fully calibrated and aligned
  - Using PID selection in the trigger

Efficiency of the HLT2 inclusive beauty trigger as a function of B p_T



Int. J. Mod. Phys. A30 (2015)

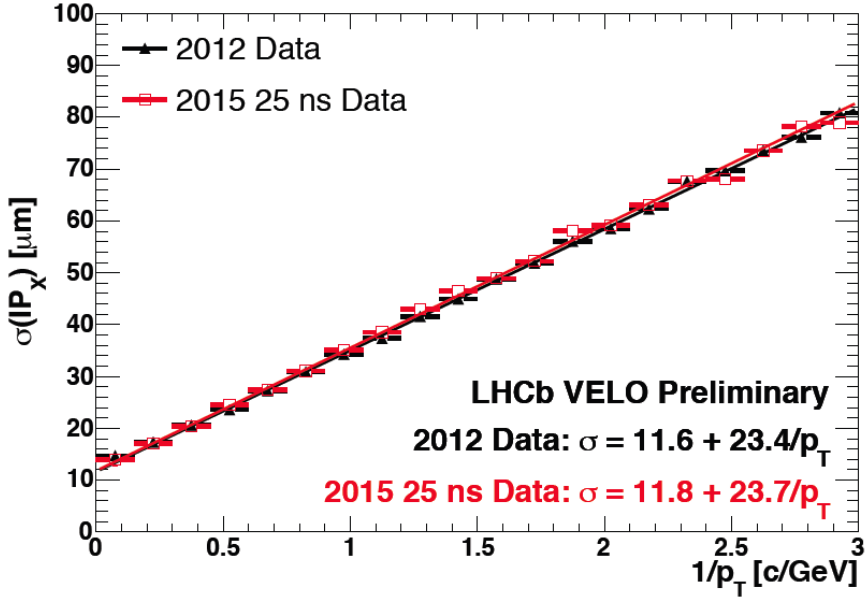


Efficiency for $B^+ \to D^0\pi^+$ is ~75% → Efficiency for $B^+ \to D^0\pi^+$ is >90%

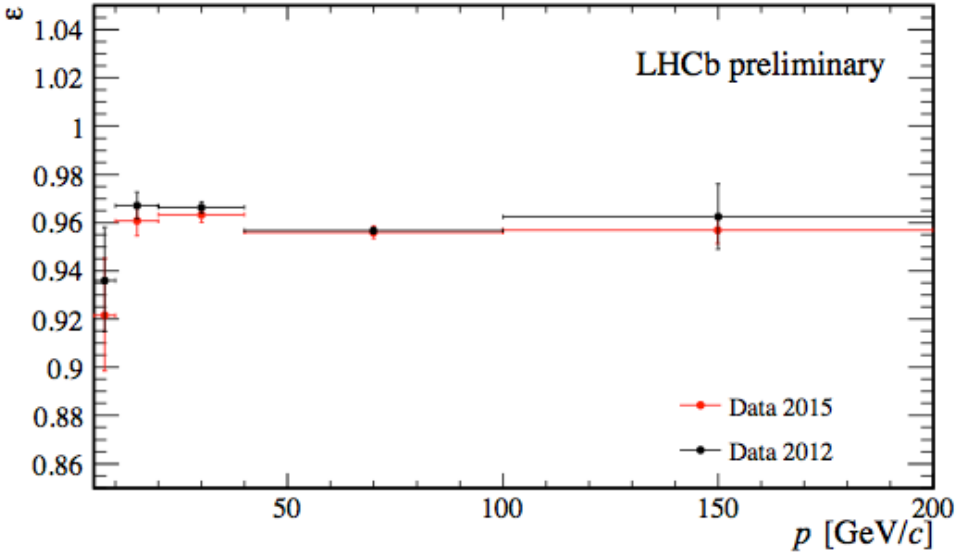
Tracking Performance of Run 2 data

- **Same offline performance as in Run1 directly in HLT2**

IP resolution



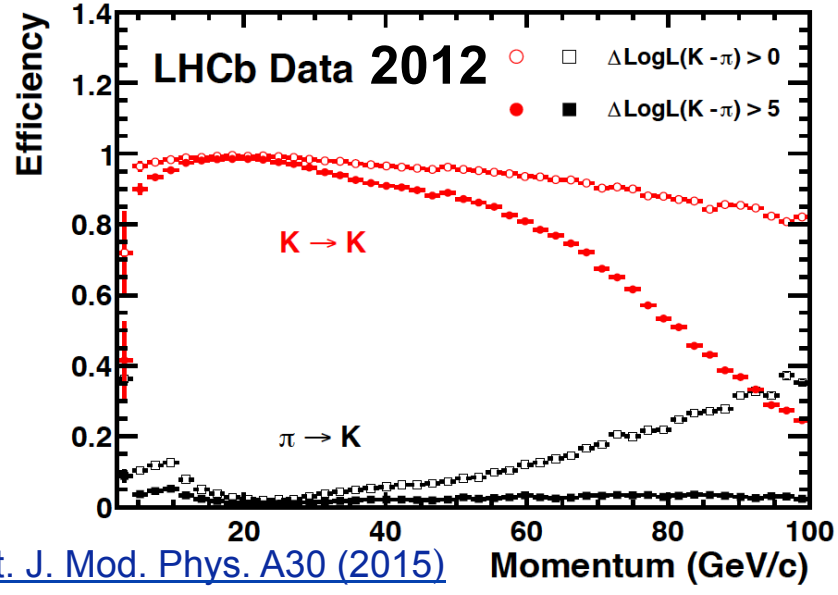
Track efficiency



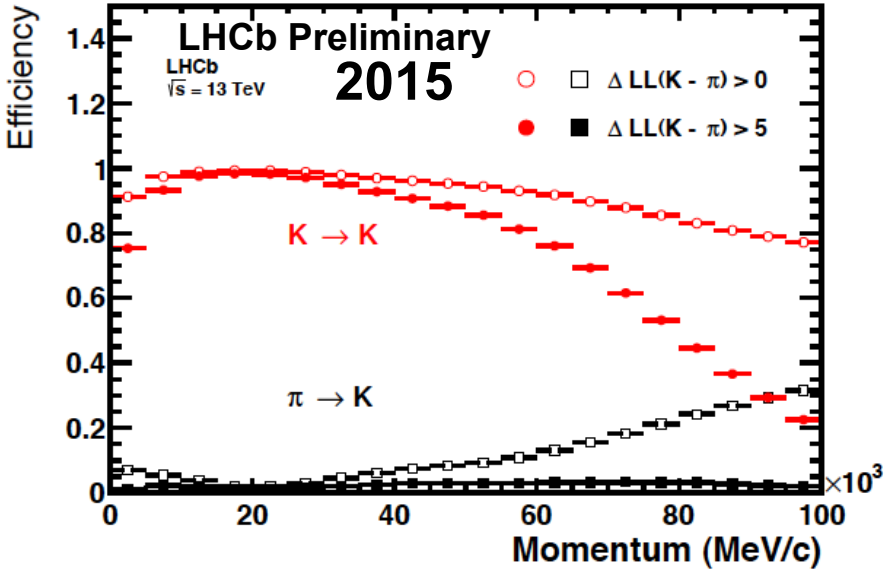
PID Performance of Run 2 data

- **Similar performance as in Run1**

Kaon identification efficiency and pion misidentification rate



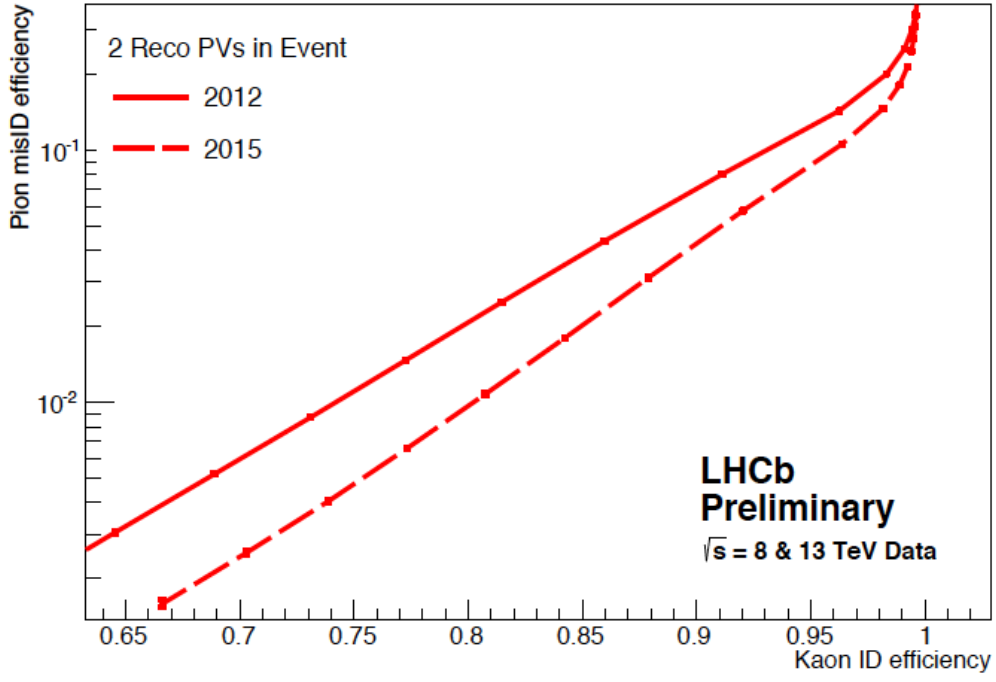
Int. J. Mod. Phys. A30 (2015)



PID Performance of Run 2 data

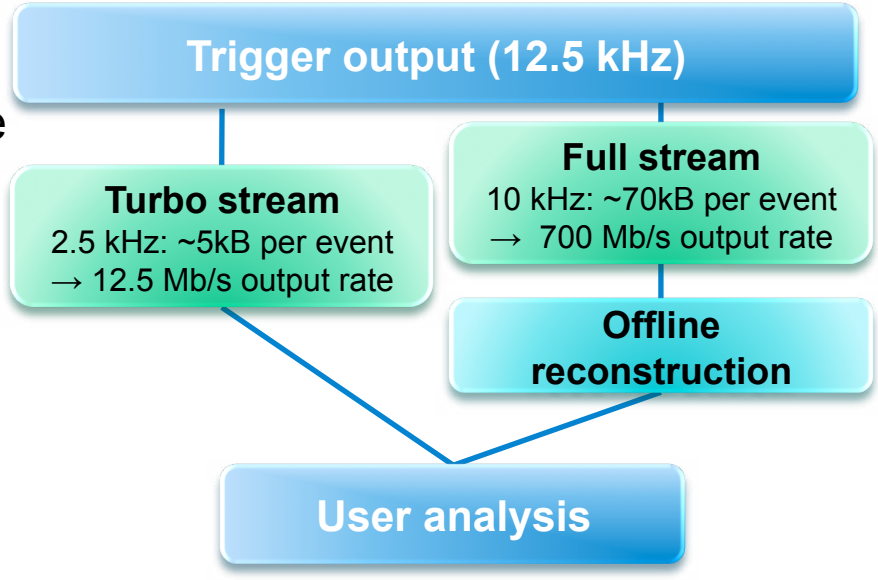
- **Similar performance as in Run1**

  Pion misidentification efficiency vs Kaon identification efficiency



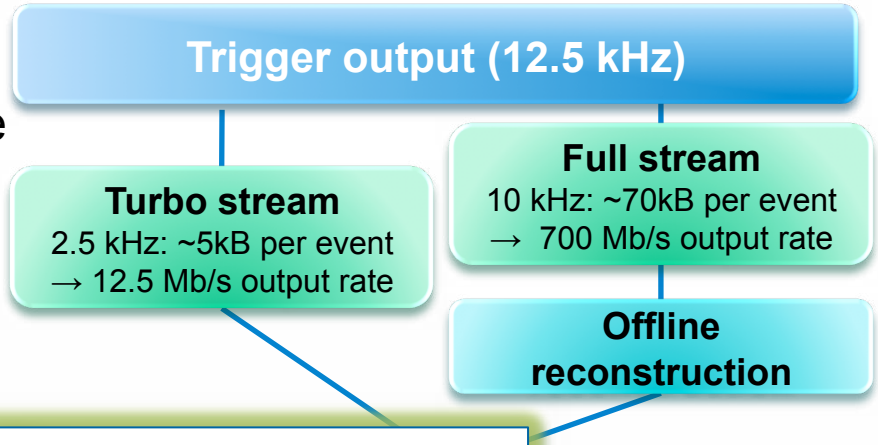
Turbo stream

- Some analyses performed directly on the trigger output
- Storing only selected candidates to reduce event size ➔ Save ~90% of space
- Analysis with large yields: possible to reduce the pre-scaling of all the channels that were trigger output rate constrained



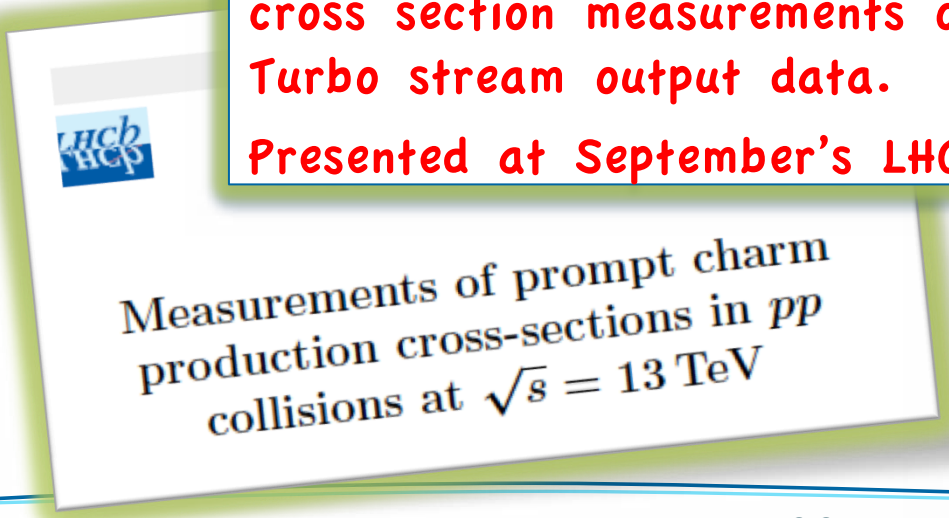
Turbo stream

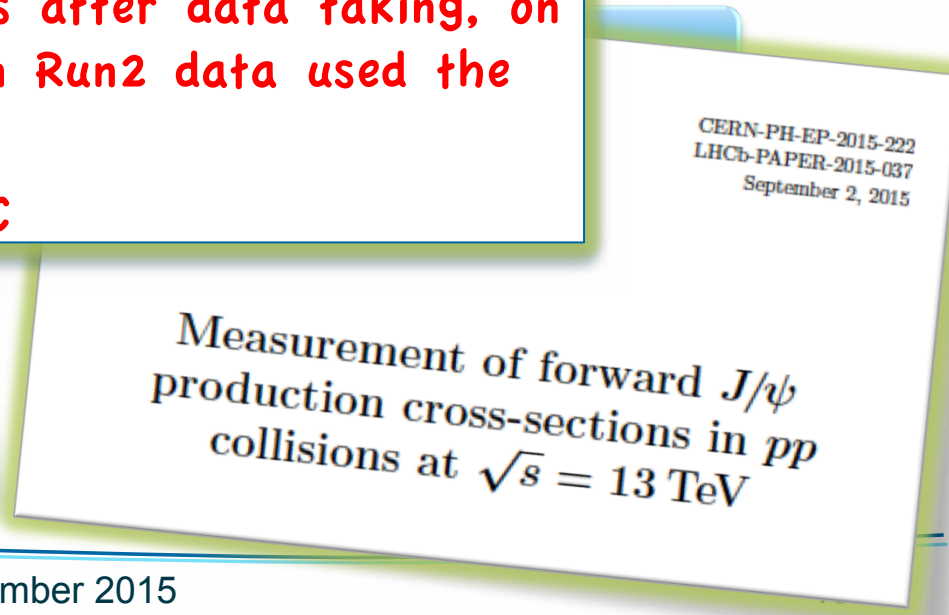
- Some analyses performed directly on the trigger output
- Storing only selected candidates to reduce event size ➔ Save ~90% of space
- Analysis with large yields: possible to reduce the pre-scaling of all the channels that were trigger output rate constrained



The first 2 papers, few weeks after data taking, on cross section measurements on Run2 data used the Turbo stream output data.

Presented at September's LHCC


Measurements of prompt charm production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV


CERN-PH-EP-2015-222
LHCb-PAPER-2015-037
September 2, 2015

Measurement of forward J/ψ production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV

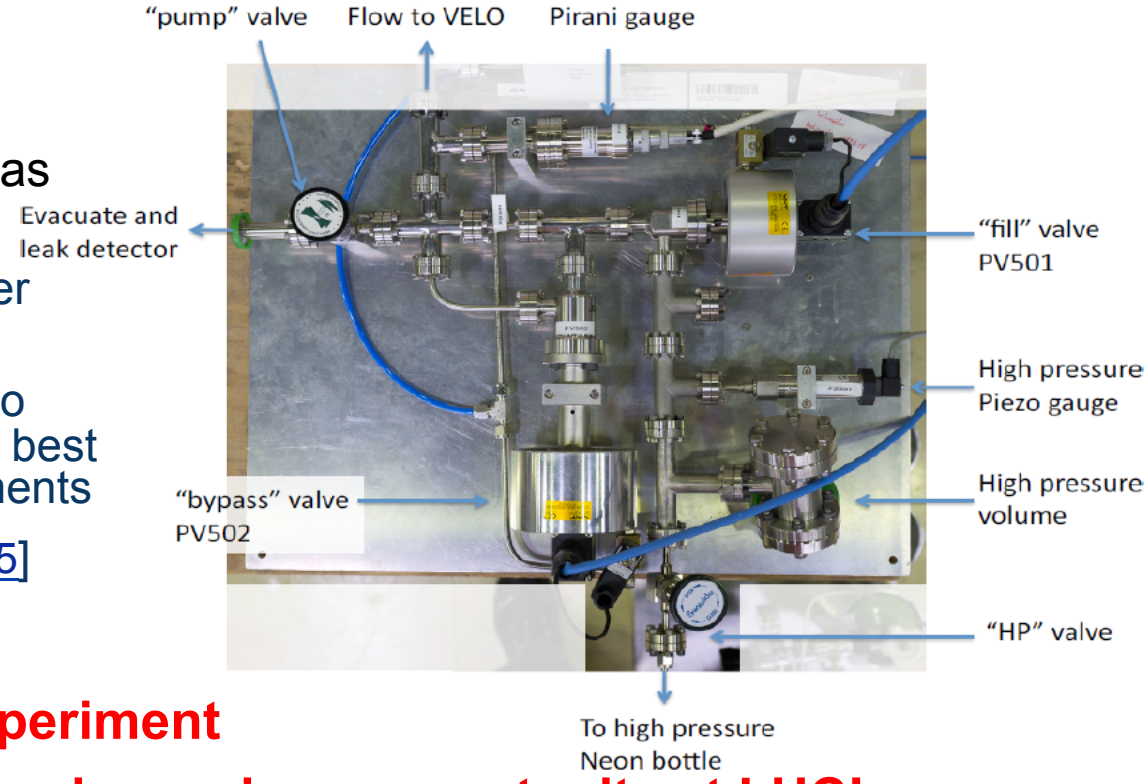
Special runs: beam gas and heavy ion collisions

Beam gas collisions

SMOG: System for Measuring the Overlap with Gas

- System to inject gas in the VELO region
- Used for luminosity measurements by Beam Gas Imaging Method
  - Alternative to Van der Meer Scan method
  - The combination of the two techniques 1.1% in Run1: best precision for LHC experiments

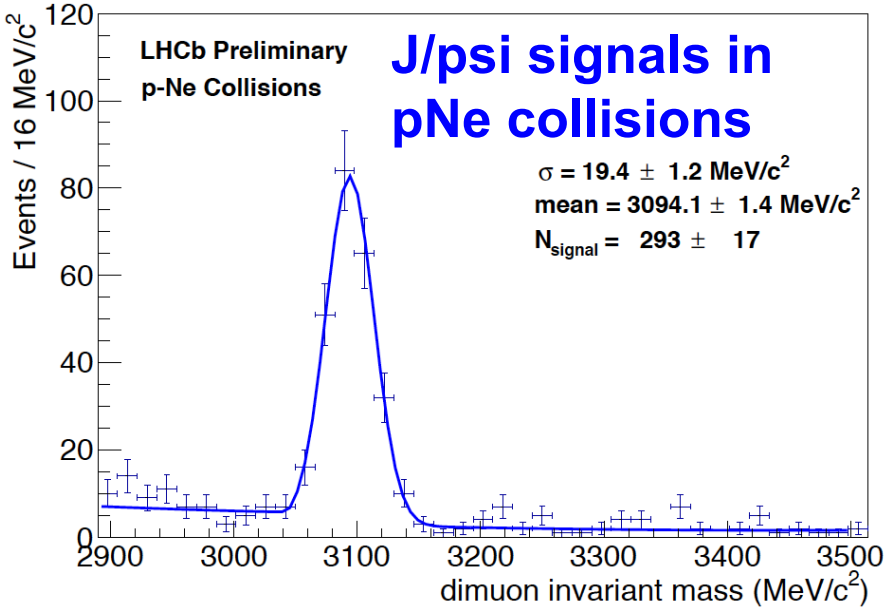
[JINST 9(2014) 12, P12005]



➔ Allowing the LHCb experiment to do also fixed target physics, unique opportunity at LHC!

Beam-gas collisions

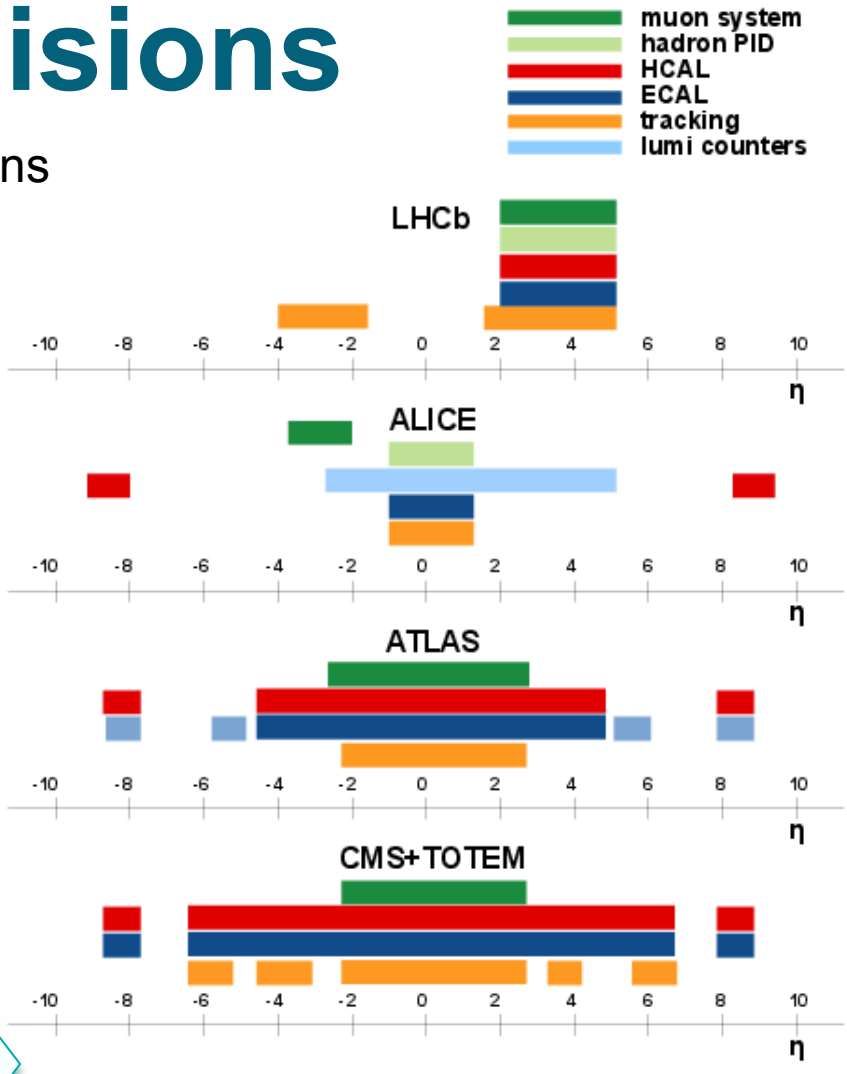
- Exploiting the SMOG system with different noble gases: Ar, He, Ne
- Physics motivations:
  - Input to the understanding of nucleus-nucleus collisions
  - Sensitive probes of nuclear structure
  - Measurement of σ(pHe→p̄X). the largest uncertainty in the AMS results showing antiproton excess is due to the theoretical precision of the production σ(pHe→p̄X) [AMS-02 Coll., CERN 15.04.2015]
  - Probe quark gluon plasma (QGP)
  - Reference sample for heavy ion collisions



	√s	Date in 2015	Data sample
pNe	110.4GeV	25-26 Aug.	2 fills (~13h)
pHe	110.4GeV	8 Sept.	1 fill (~8 h)
pAr	110.4GeV	15-18 Oct.	7 fills(~29 h)

PbPb collisions

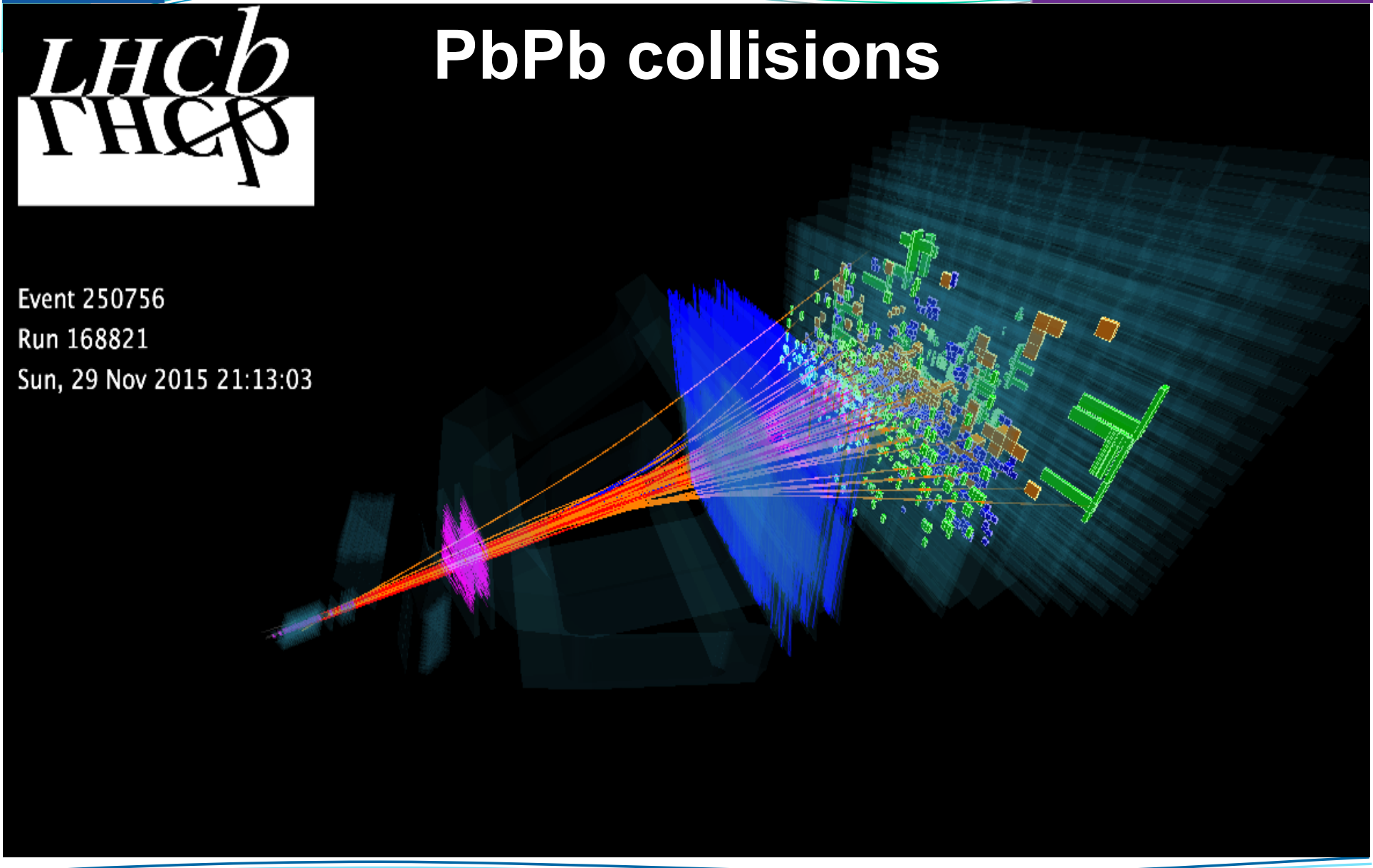
- LHCb is participating in Pb-Pb collision runs
- Unique fully instrumented experiment in the forward region
- Physics motivations:
  - Probe colour screening and quark gluon plasma (QGP) temperature through sequential melting of quarkonium states
  - Structure of nucleons, hadronisation, central exclusive production, …
  - Focus on peripheral collisions in Pb-Pb, with a centrality up to 50%



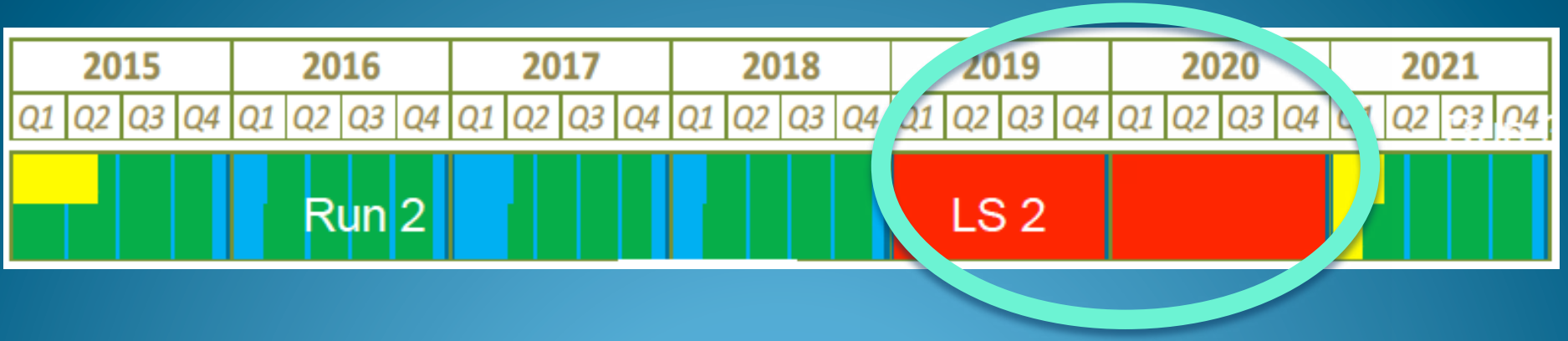
	Date	Data sample
PbPb	25 Nov.-….	
PbAr	27 Nov.-…	

Data taking ongoing

PbPb collisions

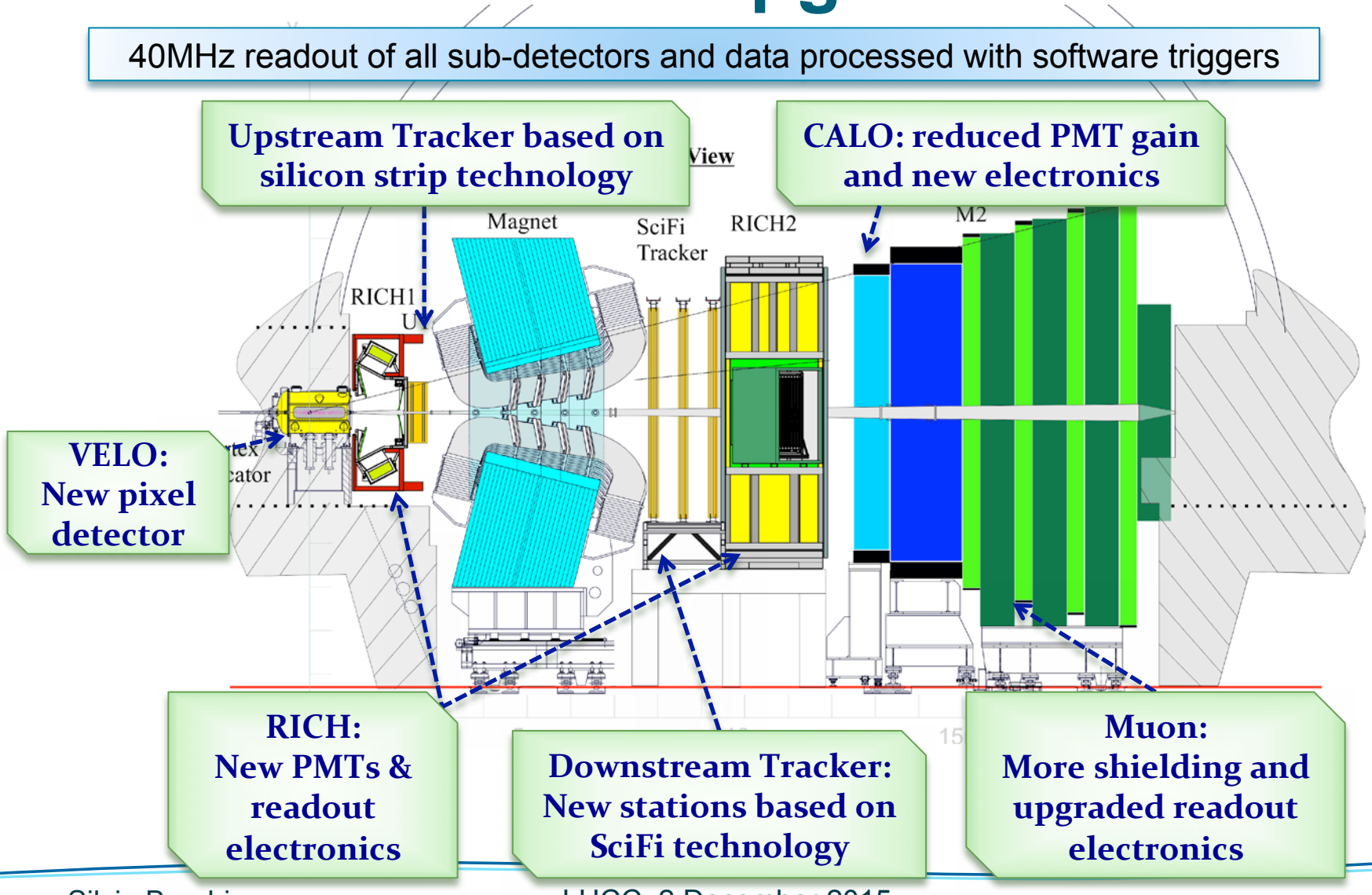


LS2 LHCb Upgrade



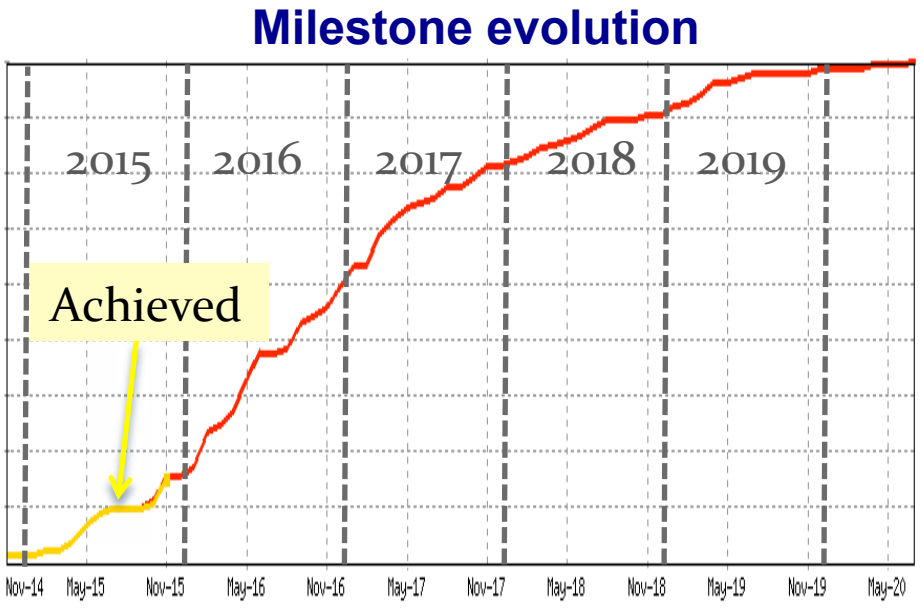
LHCb upgrade

40MHz readout of all sub-detectors and data processed with software triggers



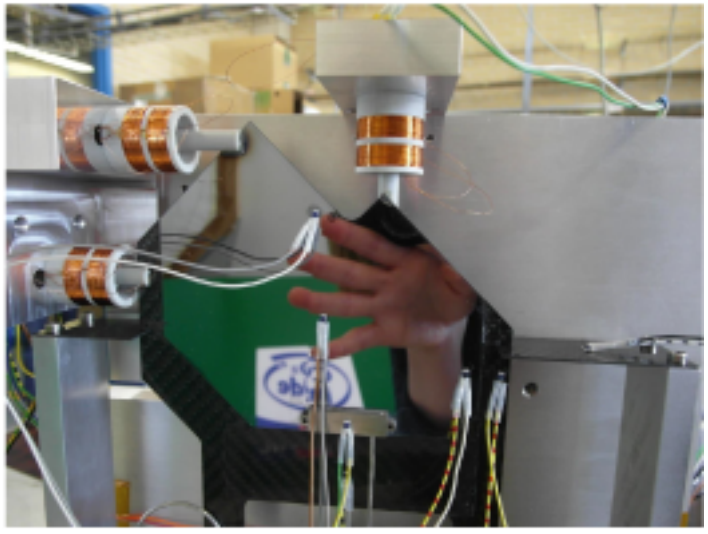
LHCb Upgrade

- The upgrade project is progressing well
- Many important Engineering Design Reviews since June
- Sub-detector projects are now moving to the construction phase
- Procurement is already started or about to start
- First Production Readiness Reviews expected for Q1 2016

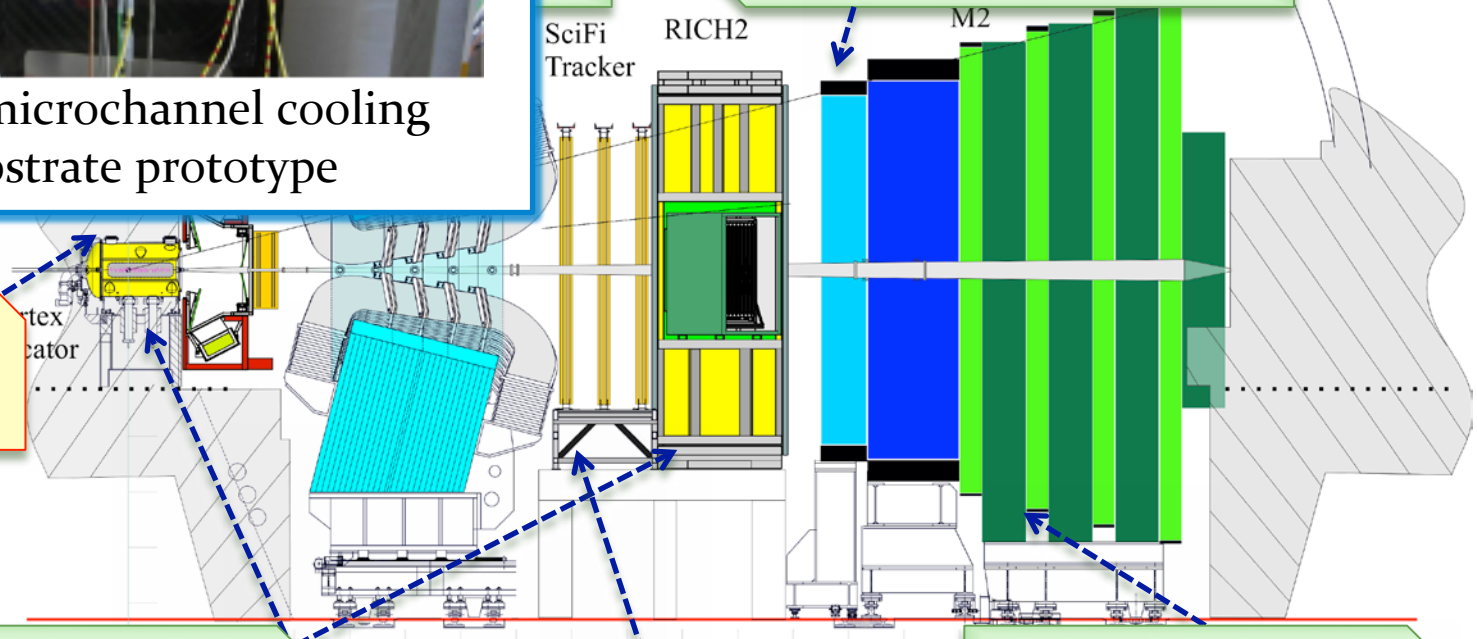


b upgrade

s and data processed with software triggers



VELO microchannel cooling substrate prototype



CALO: reduced PMT gain and new electronics

VELO: New pixel detector

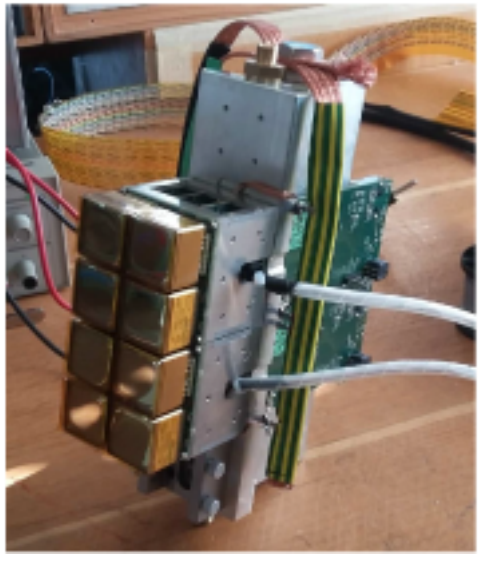
RICH: New PMTs & readout electronics

Downstream Tracker: New stations based on SciFi technology

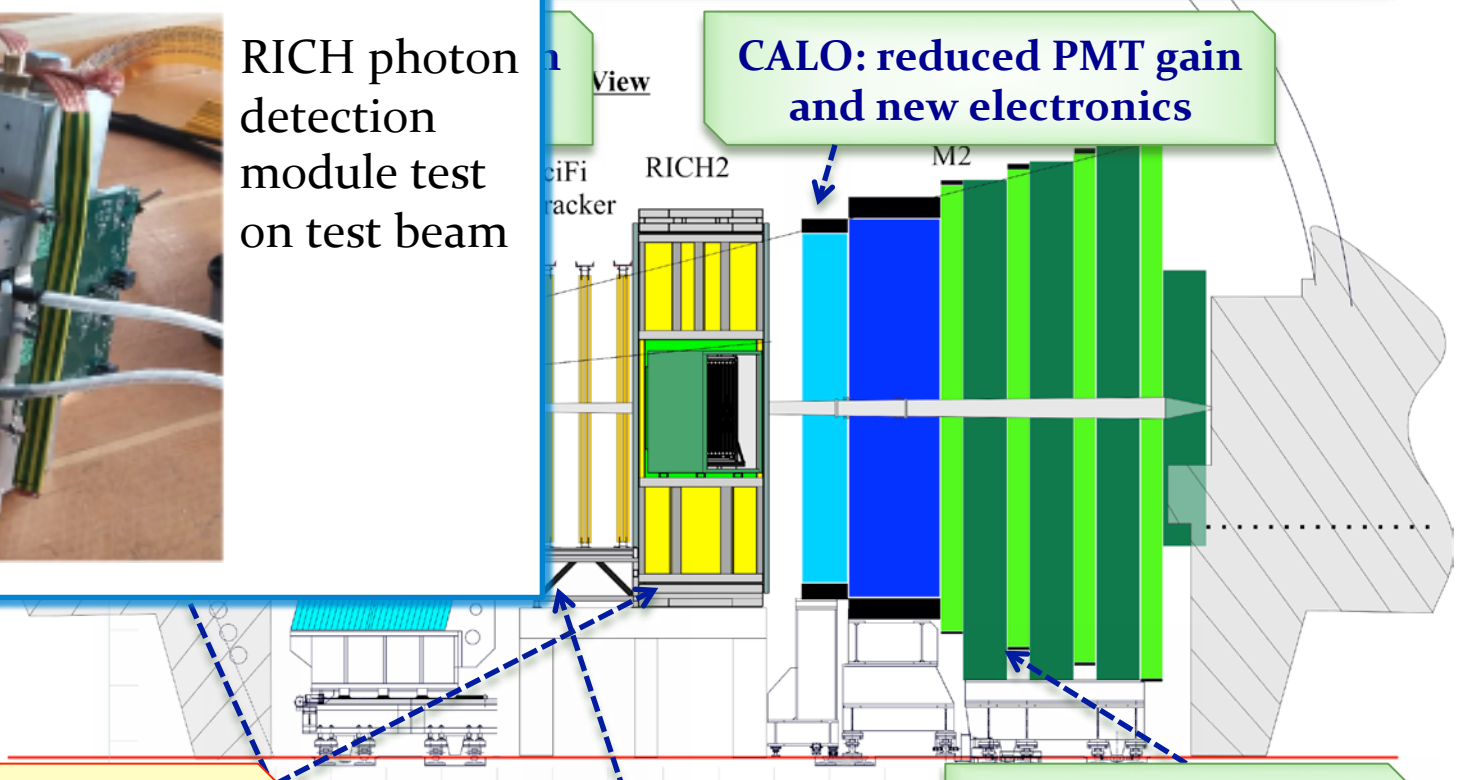
Muon: More shielding and upgraded readout electronics

LHCb upgrade

40MHz readout of all sub-detectors and data processed with software triggers



RICH photon detection module test on test beam



CALO: reduced PMT gain and new electronics

RICH: New PMTs & readout electronics

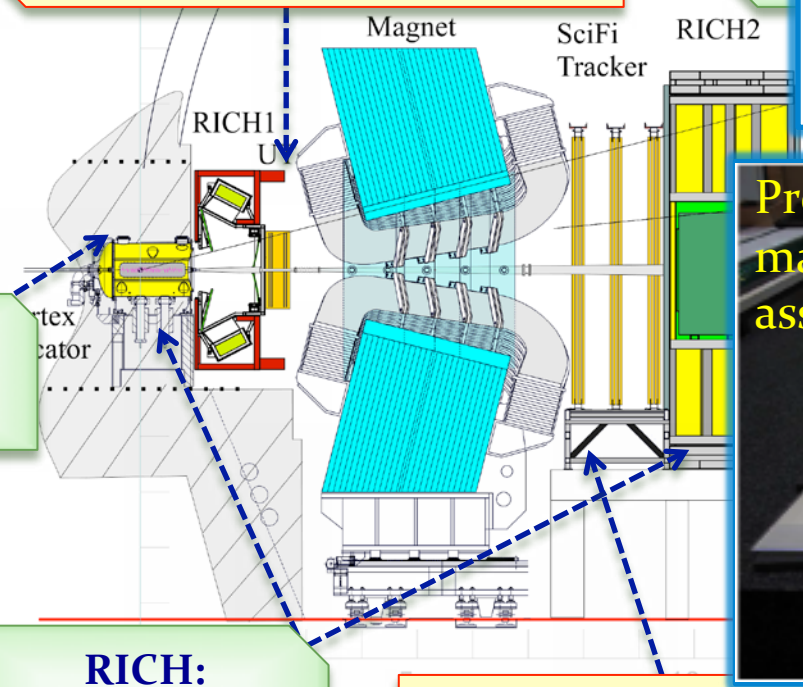
Downstream Tracker: New stations based on SciFi technology

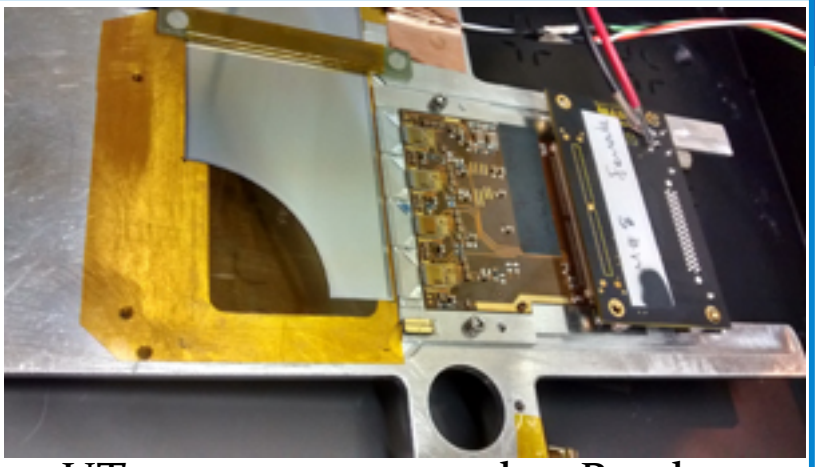
Muon: More shielding and upgraded readout electronics

LHCb upg

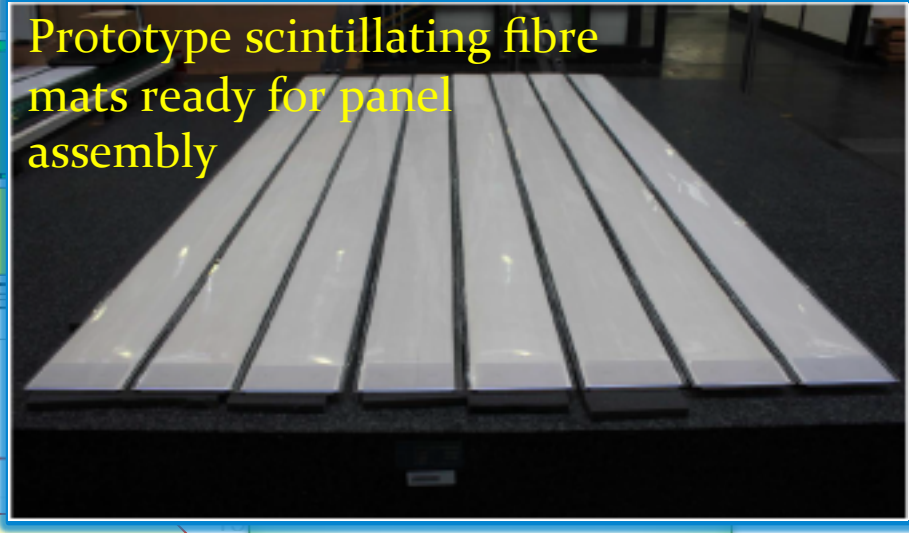
40MHz readout of all sub-detectors and data p

Upstream Tracker based on silicon strip technology





UT sensor connected to Beetle readout for the testbeam



Prototype scintillating fibre mats ready for panel assembly

VELO: New pixel detector

RICH: New PMTs & readout electronics

Downstream Tracker: New stations based on SciFi technology

More shielding and upgraded readout electronics

Conclusion

Conclusion

- Wide physics programme with many results in the pipeline
  - New measurements of γ, CPV and mixing in the charm sector, lepton flavour universality tests, spectroscopy, W and Z production…
- Enriched programme in Run2 by the study of
  - beam-gas (Ar, He, Ne) collisions
  - lead ion collisions on Pb-Pb runs
- Major change in the Run2 strategy:
  - Automatic alignment and calibrations in real-time
  - Running the same offline reconstruction in 2nd level trigger
  - Dedicated Turbo stream to analyse the output of the trigger without offline reprocessing

➔ Fully commissioned and operational

➔ First 2 analyses from the trigger output published few weeks after the data taking

- Detector performance is similar to Run1, with the great advantage to profit from this in the second level software trigger.
- Upgrade work is progressing well

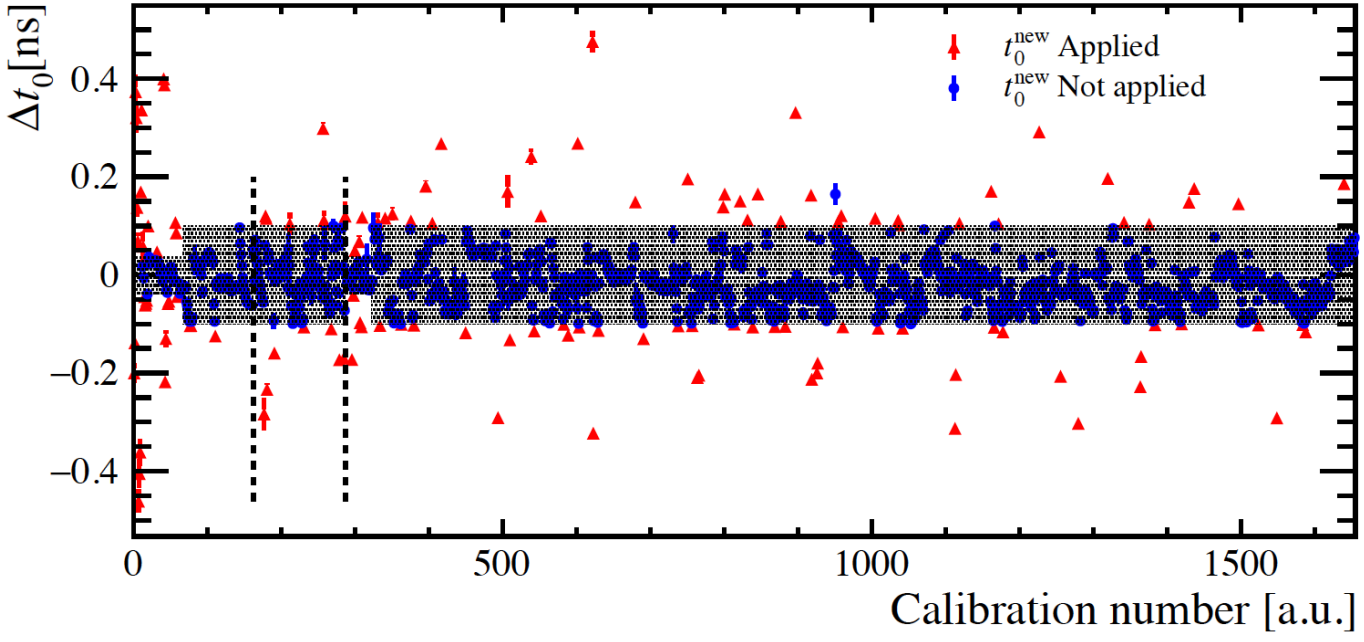
Backup

Real-time OT calibration

- Global time offset related to the synchronization between the OT time and the collision time

Evaluated automatically for each run and updated if needed

- A shift of 0.5 ns leads to tracking inefficiency of ~2.5‰

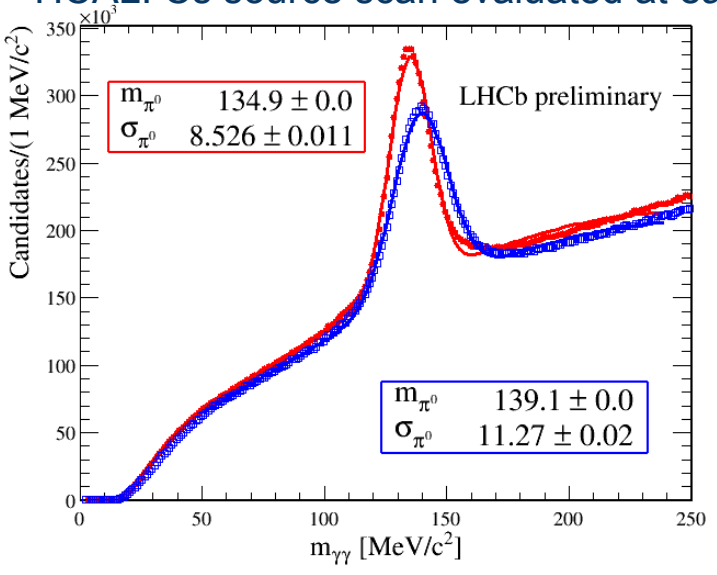


Real-time Calorimeter calibration

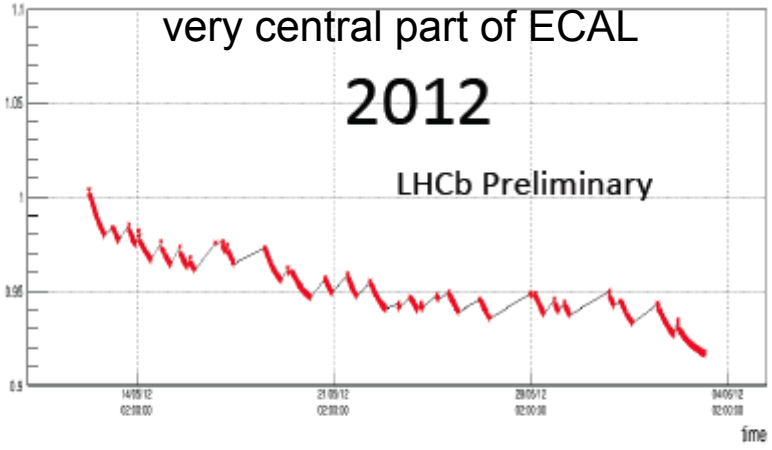
- The LED measurements to compensate the ageing of the PMTs for ECAL and HCAL

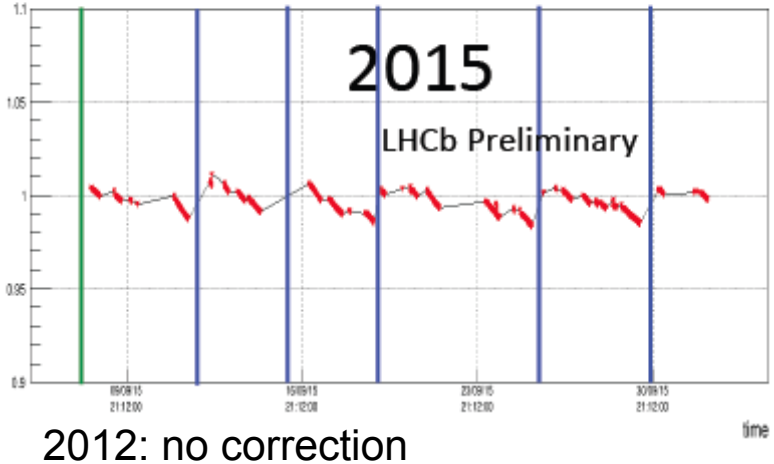
automatically performed and update each fill

- Method based on detector occupancy is under commissioning
- Absolute calibration
  - ECAL: π^0 calibration evaluated each 2 months
  - HCAL: Cs source scan evaluated at each TS



LED average over 456 cells in the very central part of ECAL





2012: no correction

2015: applied new π^0 calibration

applied new LED corrections

LHCB-PAPER-2015-049
Submitted to JHEP
arXiv:1511.08039

Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}$=8 TeV

- Data sample:
  - 2 fb^{-1} collected in 2012
  - ~140k Z candidates with purity of (99.3±0.2)%
  - ~1.7M W^+ and W^- candidates with purity of 79.3% (78.0%) for W^+ (W^-)
- Fiducial region
  - P^{μ}_T > 20 GeV/c and $2<\eta_\mu<4.5$
  - For Z: $60<M_{\mu\mu}<120$ GeV/c^2
- Cross section measured
  - For W in bin of muon η
  - For Z in bin of boson *y*, p_T and ϕ^*

Cross sections

$\sigma_{Z\to\mu^+\mu^-} = 95.0\pm0.3_{stat}\pm0.7_{syst}\pm1.1_{beam\ en.}\ \pm1.1_{lumi}$pb

$\sigma_{W^+\to\mu^+\nu} = 1094.1\pm2.1_{stat}\pm7.1_{syst}\pm10.9_{beam\ en.}\pm12.7_{lumi}$pb

$\sigma_{W^-\to\mu^+\nu bar} = 819.4\pm1.9_{stat}\pm5.1_{syst}\pm7.1_{beam\ en.}\ \pm9.5_{lumi}$pb

Cross section ratios

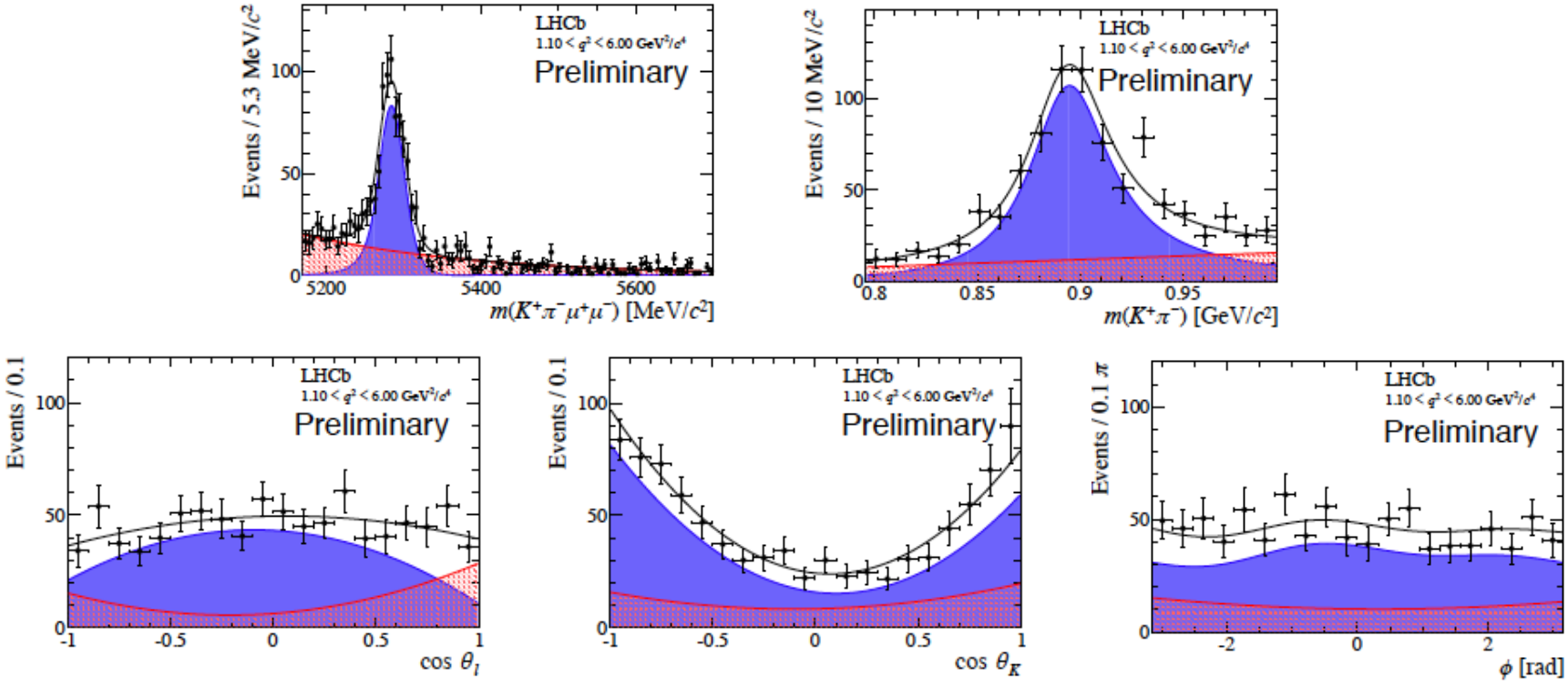
$R_{W+Z}=\frac{\sigma_{W^+\to\mu^+\mu^-}}{\sigma_{Z\to\mu^+\mu^-}}=11.52\pm0.04_{stat}\pm0.06_{syst}\pm0.02_{beam\ en.}$

$R_{W-Z}=\frac{\sigma_{W^-\to\mu^+\nu}}{\sigma_{Z\to\mu^+\mu^-}}=8.63\pm0.03_{stat}\pm0.04_{syst}\pm0.03_{beam\ en.}$

$R_{W\pm}=\frac{\sigma_{W^-\to\mu^+\nu bar}}{\sigma_{W^-\to\mu^+\nu bar}}=1.335\pm0.004_{stat}\pm0.005_{syst}\pm0.002_{beam\ en.}$

Angular analysis of the $B^0_d \to K^{*0}\mu^+\mu^-$ decay

- Yield: 624±30 in the region $q^2 \in [1.1,6]$ GeV^2/c^4 in L= 3 fb^{-1}
- Fit angular distribution in bins of ~ 2 GeV^2/c^4 to determine the CP averaged observables and CP asymmetries (B^0 and B^0bar separately)

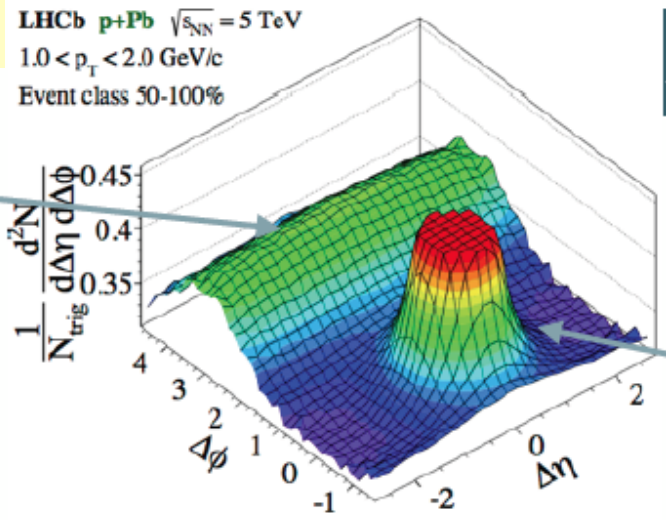


Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5 TeV proton-lead collisions in the forward region.

Presented at last LHCC

Study $\Delta\eta$ and $\Delta\phi$ in pPb collisions to probe collective effects

Conservation of momentum so corresponding far side ridge



Isolated structure dominates at (0,0) due to fragmentation around the initial parton

In large events, strong interactions with the media cause near-side ridge