LHC point 8

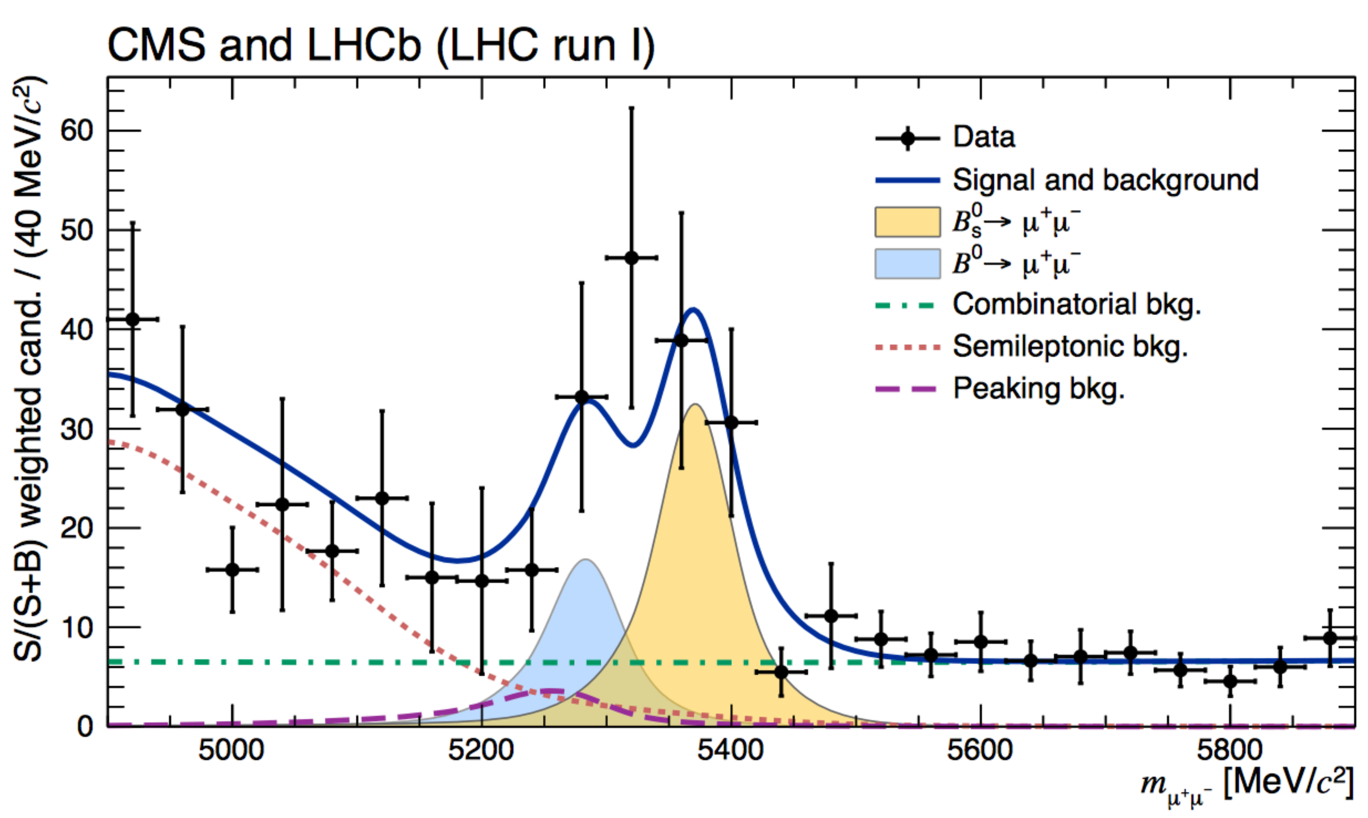
The LHC beam-line runs across the centre of the image. The interaction point is about 1.5m to the right of the blue dipole magnet.

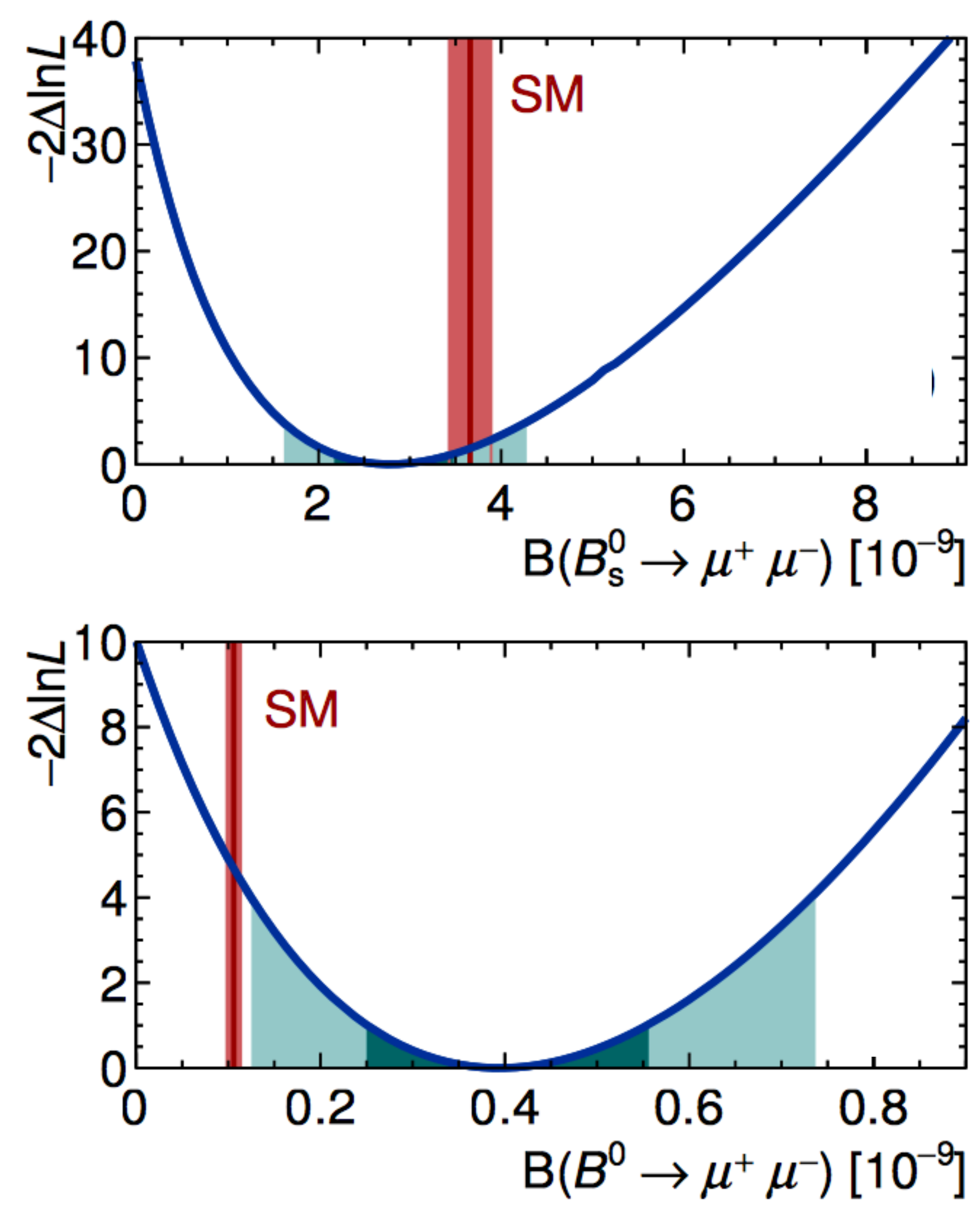
April 2015

B physics: a goldmine for discovery

- The LHC produces all species of B hadrons in unprecedented numbers; reconstruction and recording are the challenge!
- The performance of the accelerator and experiment have allowed a physics harvest beyond all expectation.
- Across huge swathes of heavy-flavour physics, LHCb sets the benchmark.

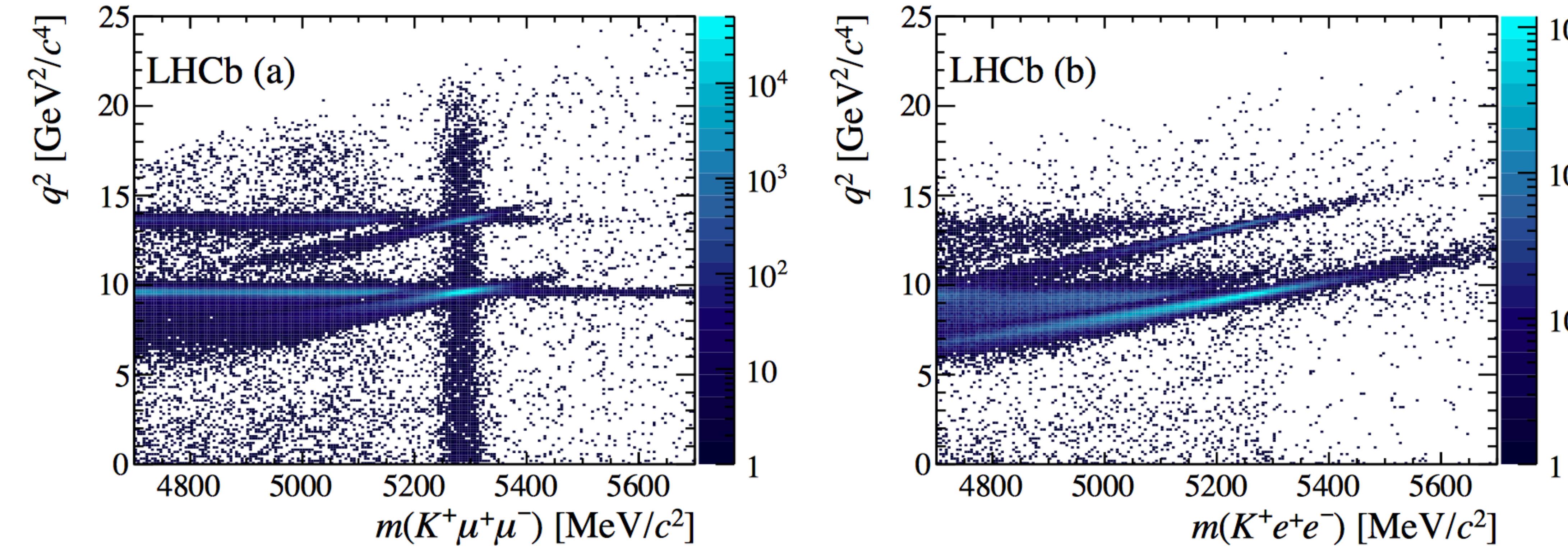
$B^0_{(s)} \to \mu^+\mu^-$





$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = (2.8\,^{+0.7}_{-0.6}) \times 10^{-9} \text{ and}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (3.9\,^{+1.6}_{-1.4}) \times 10^{-10},$$

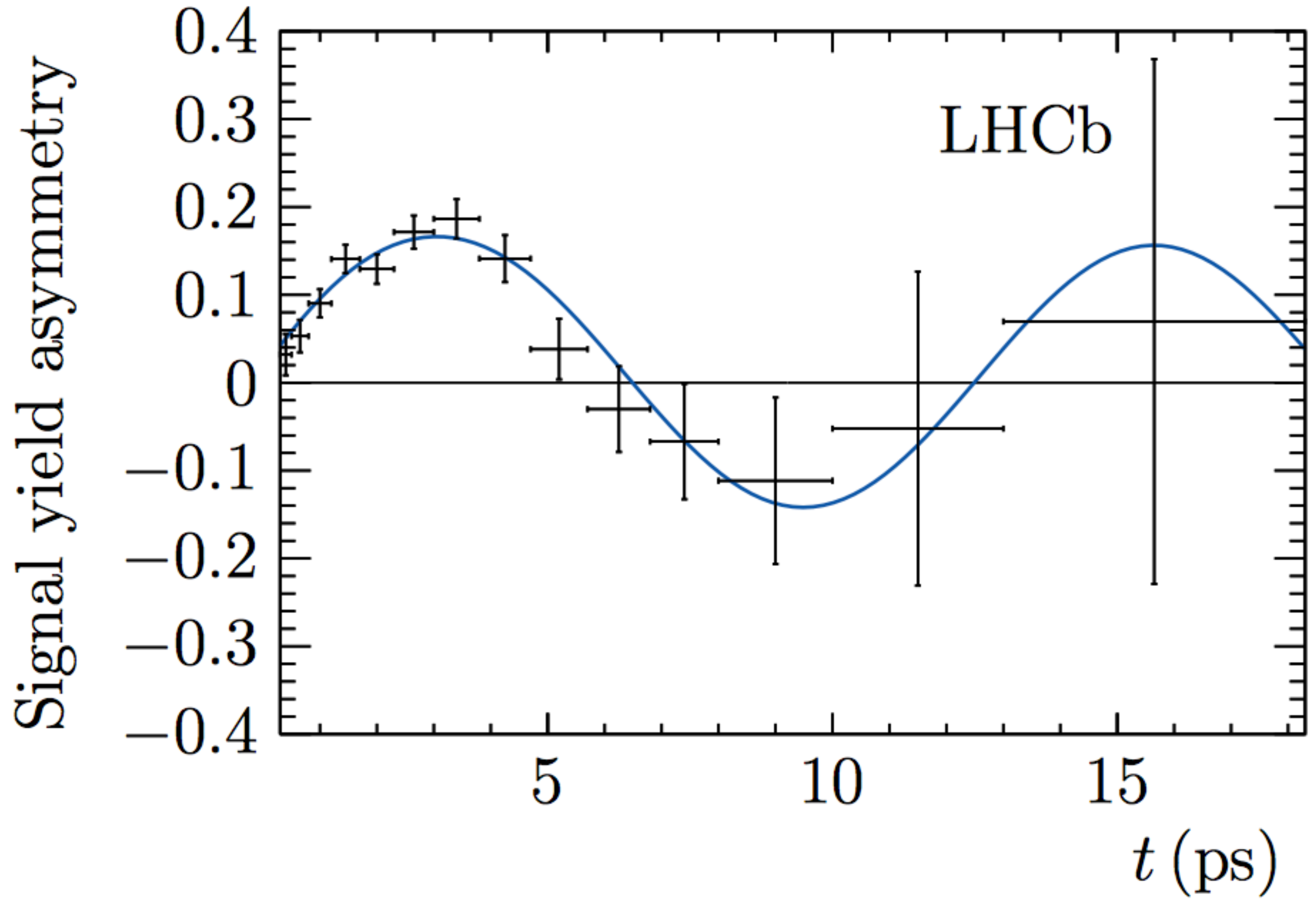
$B^+ \to K^+e^+e^-$ vs. $B^+ \to K^+\mu^+\mu^-$



$$R_K = \frac{\int_{q^2_{\min}}^{q^2_{\max}} \frac{d\Gamma[B^+\to K^+\mu^+\mu^-]}{dq^2} dq^2}{\int_{q^2_{\min}}^{q^2_{\max}} \frac{d\Gamma[B^+\to K^+e^+e^-]}{dq^2} dq^2} = 0.745^{+0.090}_{-0.074}\,(\text{stat}) \pm 0.036\,(\text{syst}).$$

- SM expectation = 1.0

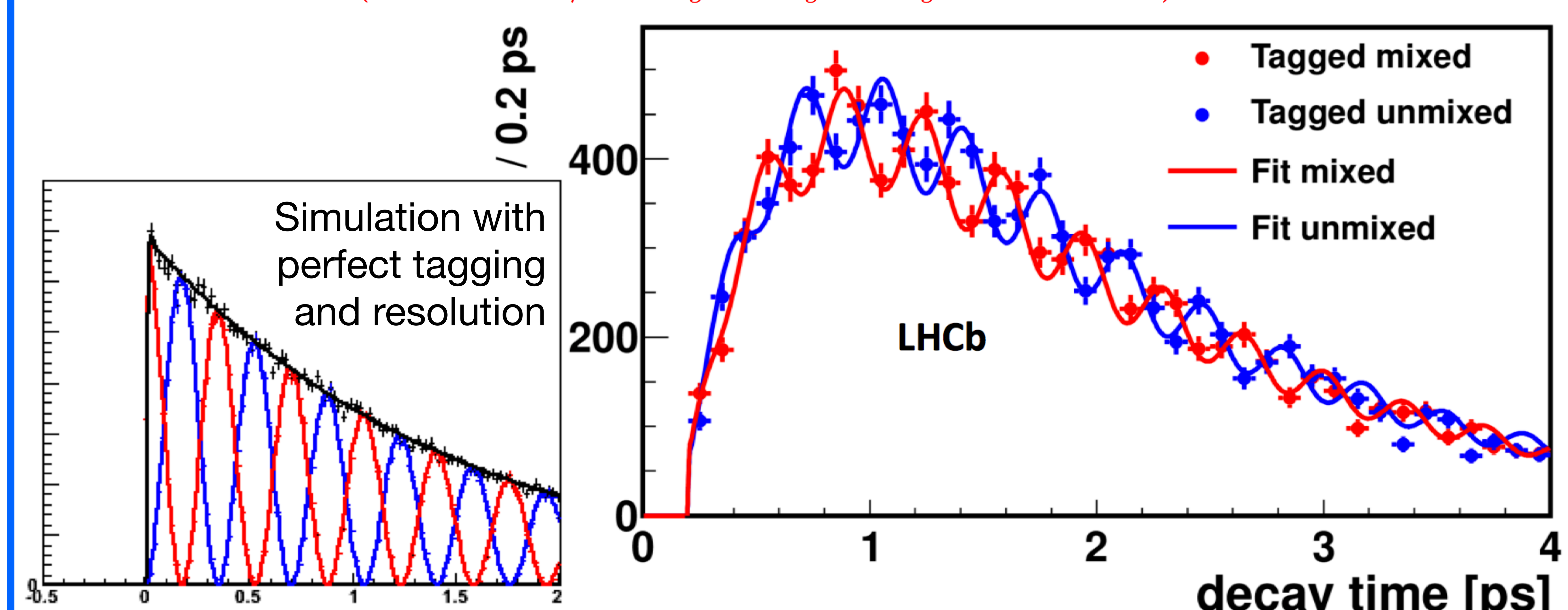
Time dependent CP-asymmetry in $B^0 \to J/\psi K^0_S$



- LHCb $\sin 2\beta = 0.74 \pm 0.04$
- Belle $\sin 2\beta = 0.67 \pm 0.03$
- Babar $\sin 2\beta = 0.69 \pm 0.03$

Resolving B_s oscillations with $B^0_s \to D^-_s\pi^+$ decays

$\Delta m_s = (17.768 \pm 0.023 \pm 0.006)\ \text{ps}^{-1}$
(2.83×10^{12}/sec $B^0_s \to \bar{B}^0_s \to B^0_s$ transistions)



A selection of high-profile results from across the collaboration

April 2015

Waiting to close the Vertex Locator

A "beams-eye" view of LHCb. The two halves of the VeLo open by 6cm until the LHC declares the stable beams for physics

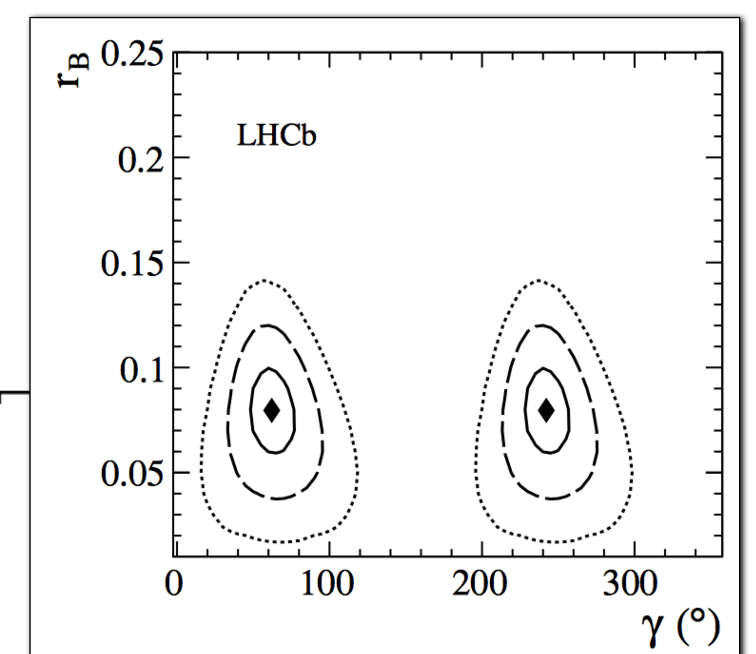
April 2015

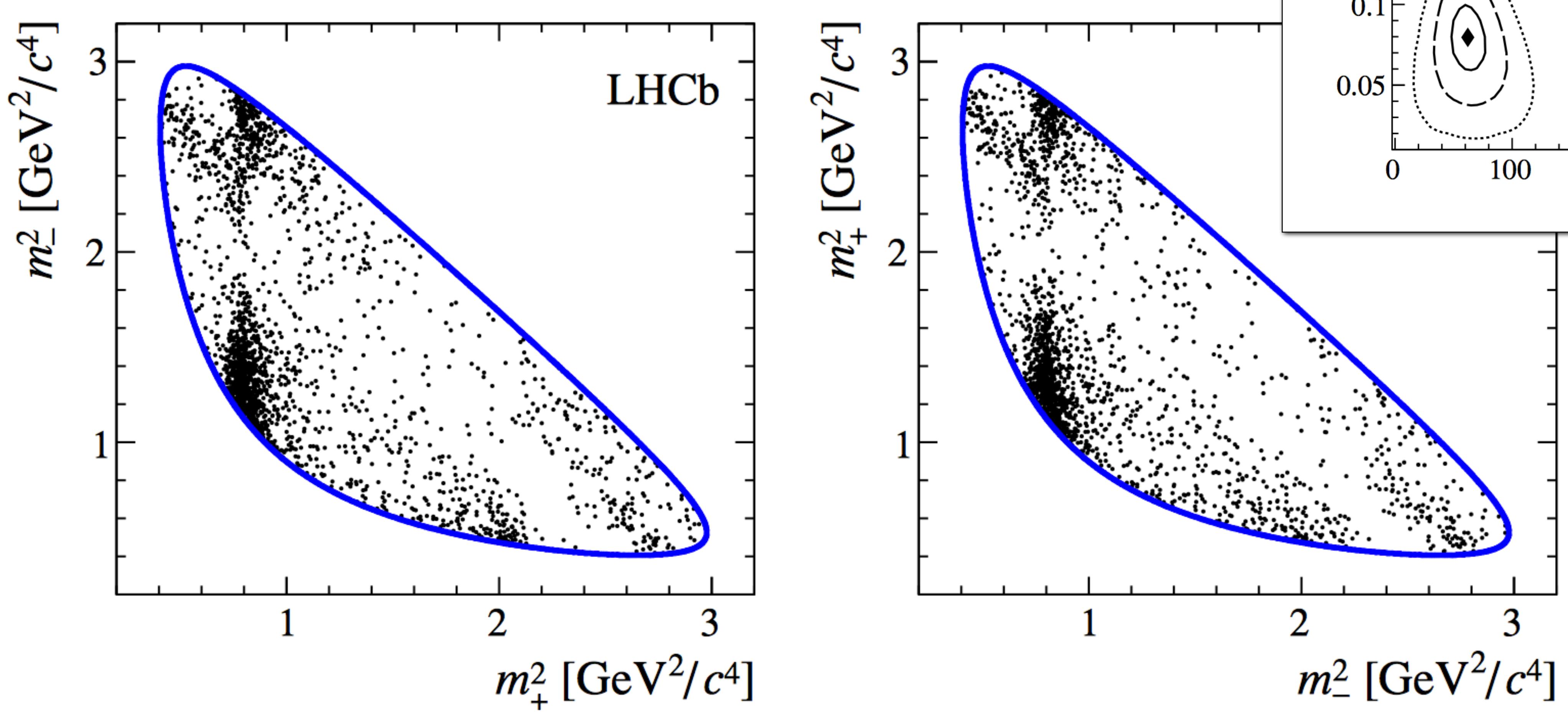
CKM angle γ

- Oxford lead the field in the pursuit of a precision measurement of this benchmark parameter of the Standard Model.
- It is accessible via direct asymmetry measurements of rare hadronic decays containing b→u transitions.
- Key to such analyses is the expert use of the RICH system to cleanly distinguish kinematically similar states.

$B^+ \to DK^+$ with $D \to K^0_S\pi^+\pi^-$

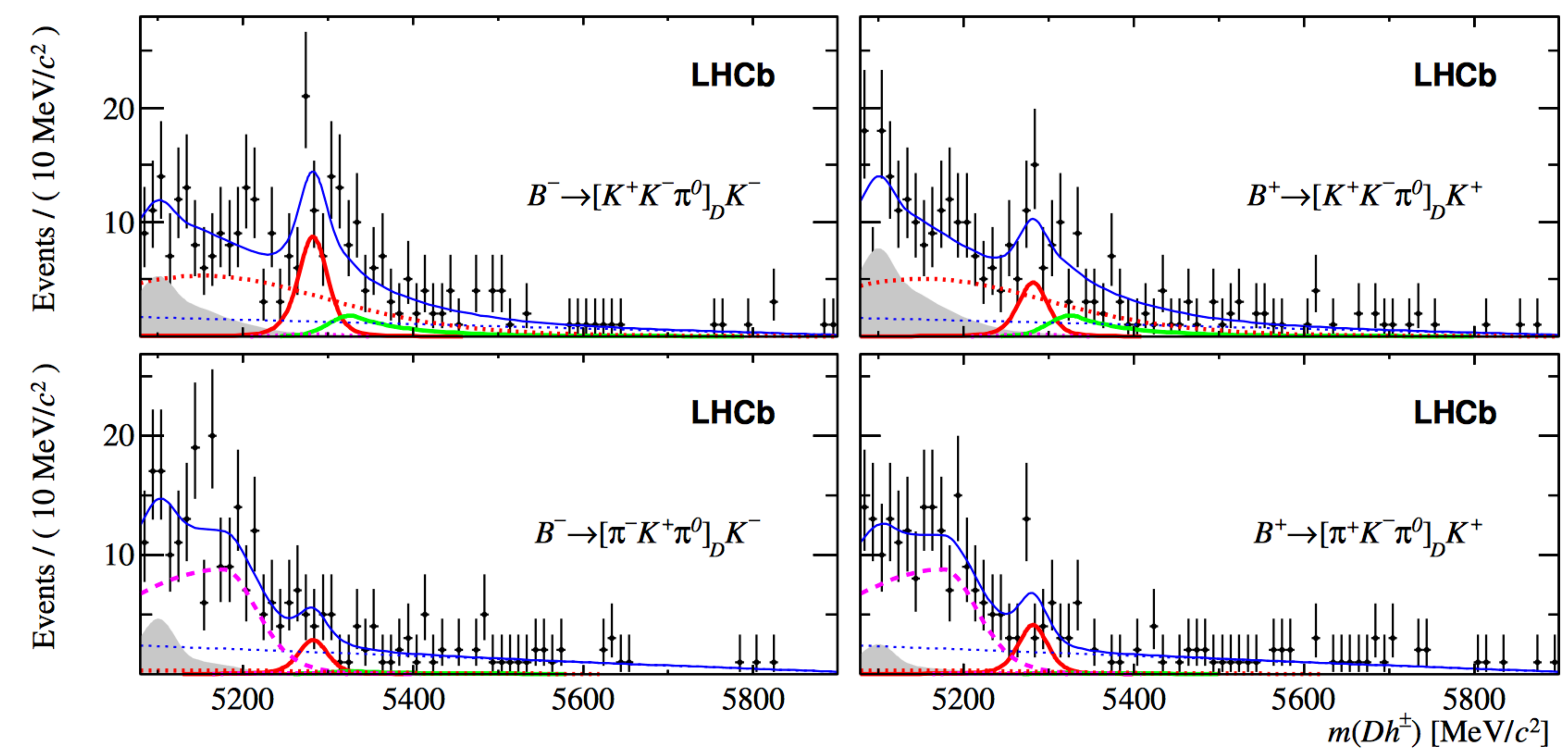
- The CKM angle γ is measured by comparing the populations of two charge-conjugate Dalitz plots.





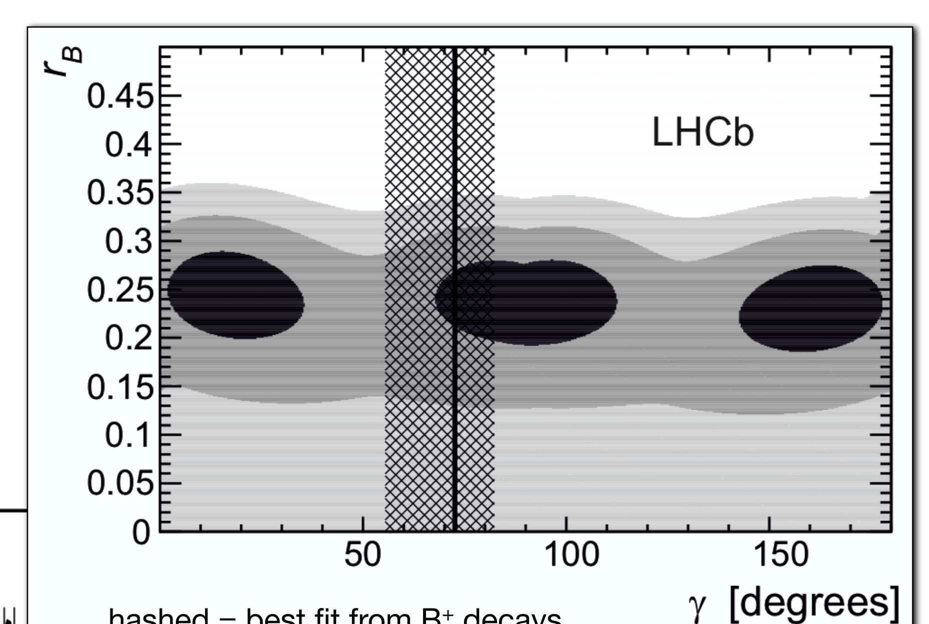
$B^+ \to DK^+$ with $D \to h^+h^-\pi^0$

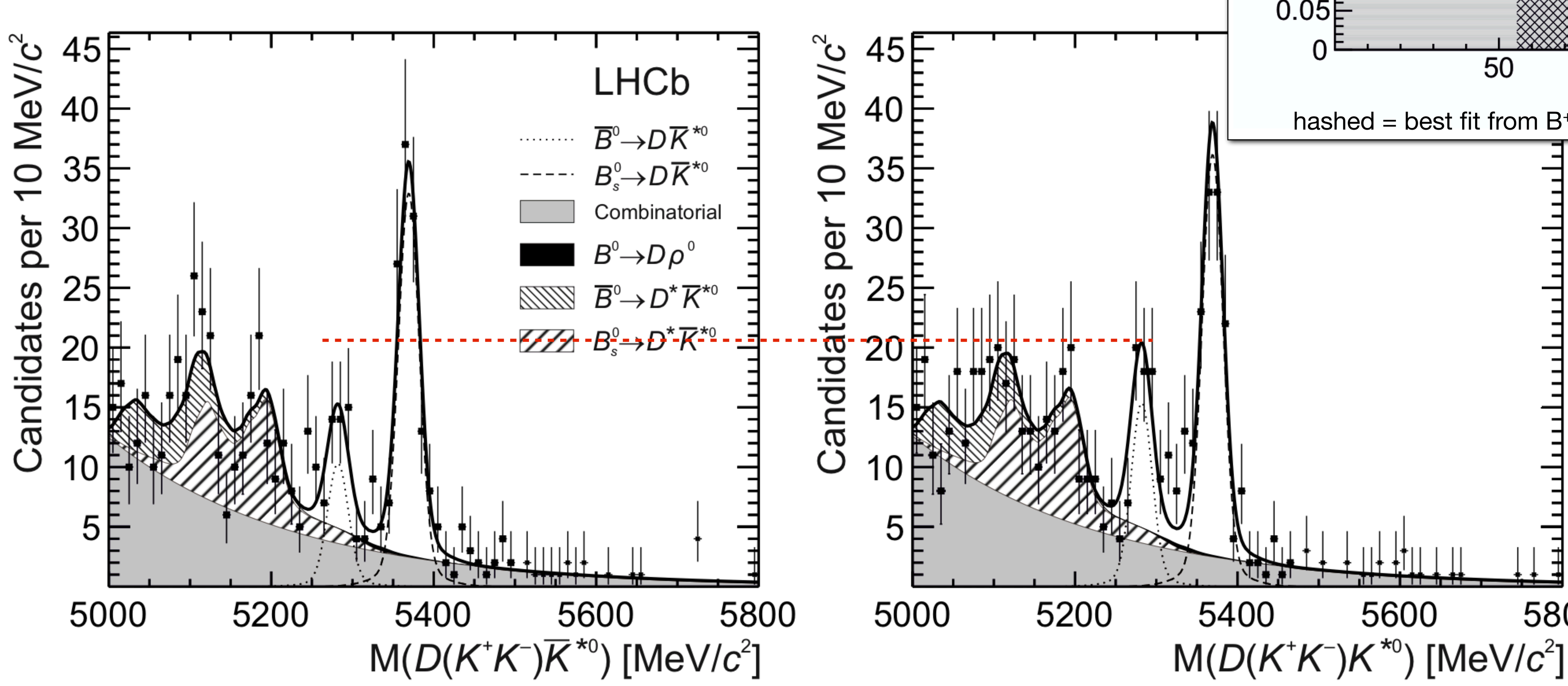
- Pioneering clean *CP* violation analyses involving π^0 mesons



$B^0 \to DK^{*0}$

- Small branching fraction but potentially large *CP* violation due to a large amplitude ratio of, $r_B = A(b\to u)/A(b\to c)$





$B^+ \to DK^+$ with $D \to \pi^+K^-$

- One of the best-known results from LHCb

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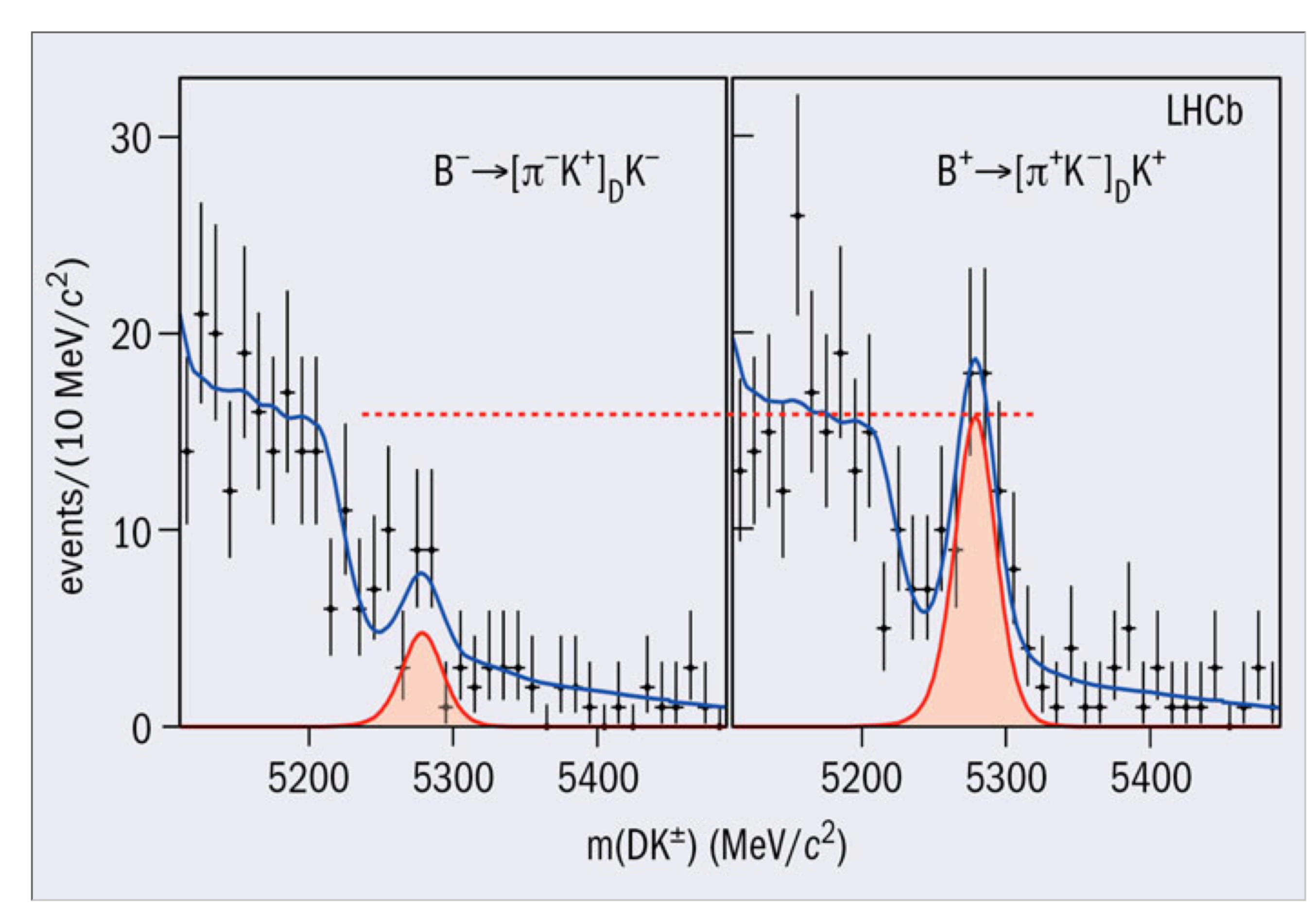


Fig. 3. Invariant mass distributions of ADS candidates from LHCb. The left plots are B⁻ events, B⁺ events are on the right. The data, which were collected during 2011, are shown as black markers. The total fitted function is shown in blue and the signal, which exhibits a large asymmetry, is highlighted in red.

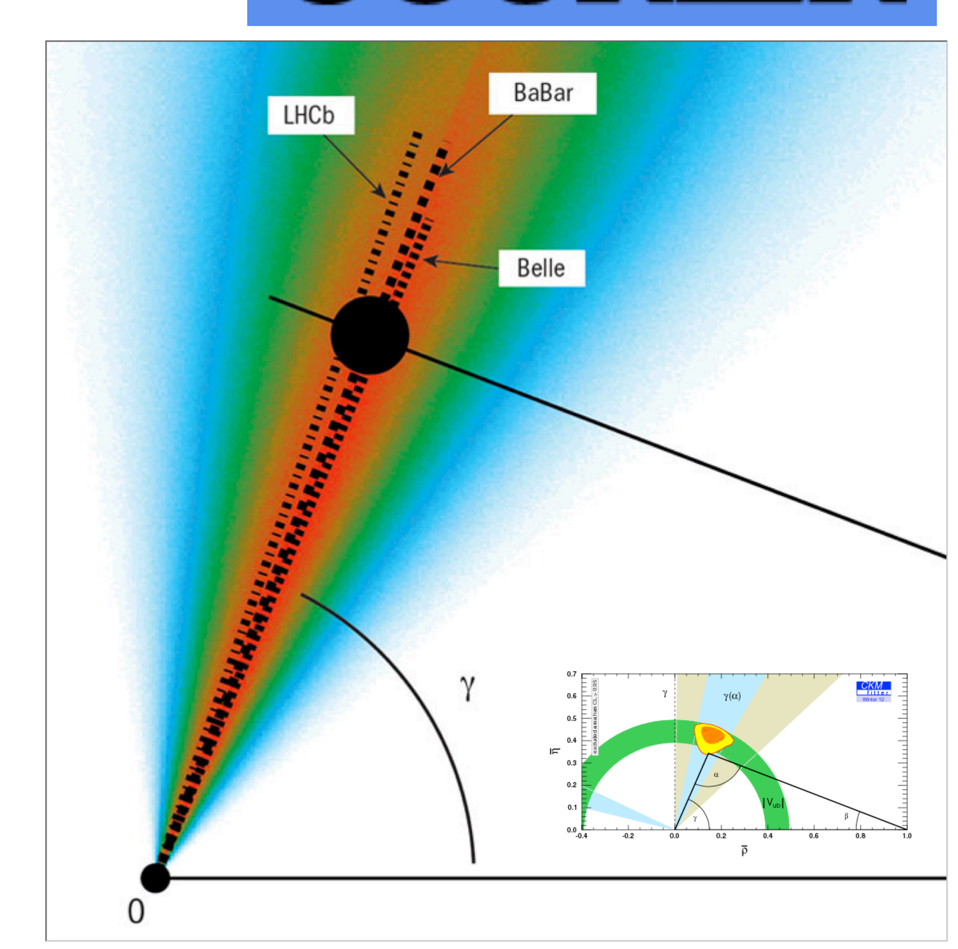


Fig. 1. An illustration of the three independent measurements of γ, as presented at CKM2012. The colouring gives an impression of the total uncertainty based on a combination of the three results. The large black dot indicates the expectation based on measurements of other Standard Model parameters.

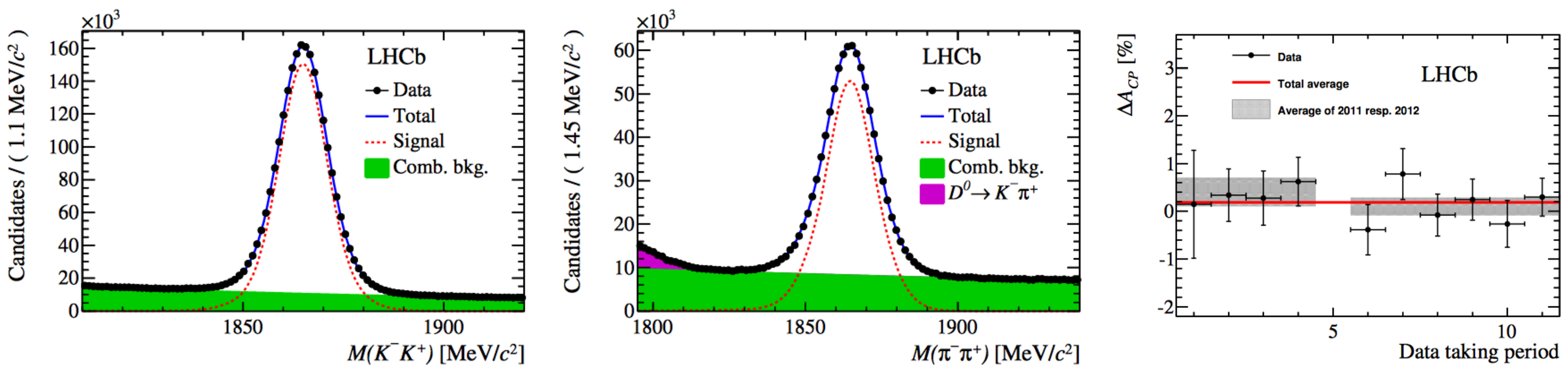
Rings of Cherenkov photons

Hundreds of HPDs sit in a light-tight gas box looking for rings of Cherenkov light. Kaons, pions and protons produce different size rings

Charm meson physics

- The charm cross section at the LHC is ~20 times that of b-quarks.
- The D meson lifetime is only a quarter that of the B mesons; identifying their displaced vertex is trickier!
- SM CP-violation and electroweak penguin amplitudes in charm decays are tiny, hence apt for BSM searches.

Search for direct CP violation in $D \to h^+h^-$



$A_{CP}(K^-K^+) = (-0.06 \pm 0.15\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$

$A_{CP}(\pi^-\pi^+) = (-0.20 \pm 0.19\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$

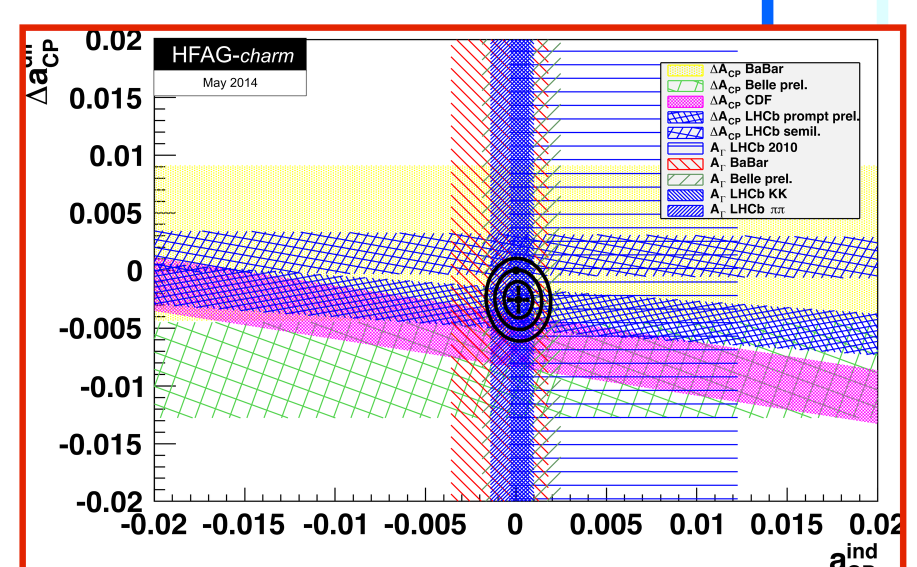
Systematics cancel in the double-difference:

$D^0/\bar{D}^0$ flavour -tagging by:

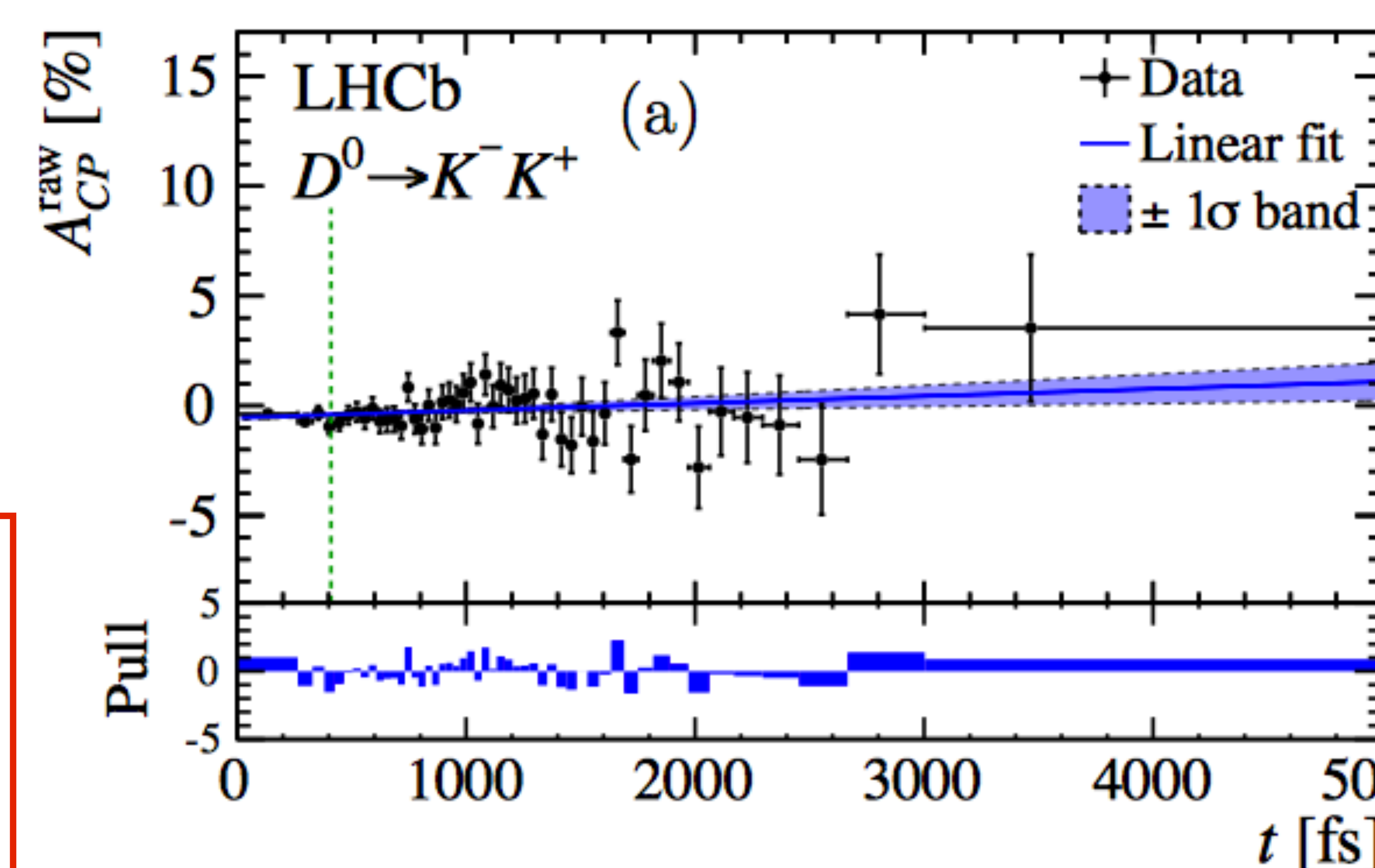
$\Delta A_{CP} \equiv A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$

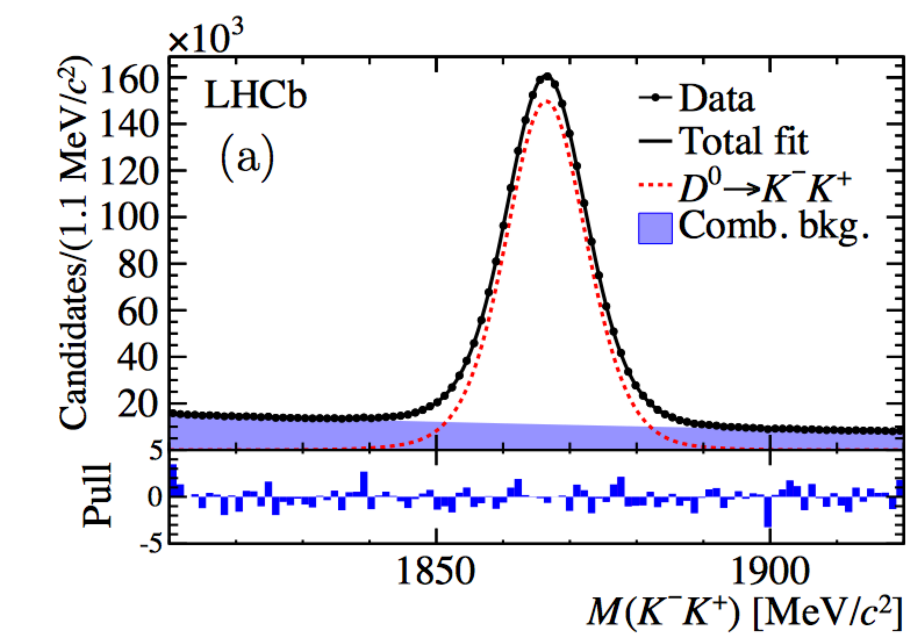
$B^- \to D^0\mu^-$ $\quad \Delta A_{CP} = (+0.14 \pm 0.16\,(\text{stat}) \pm 0.08\,(\text{syst}))\%$

$D^{*+} \to D^0\pi^+$ $\quad \Delta A_{CP} = (-0.34 \pm 0.15 \pm 0.10)\%$



Search for time-dependent CP violation in $D \to h^+h^-$





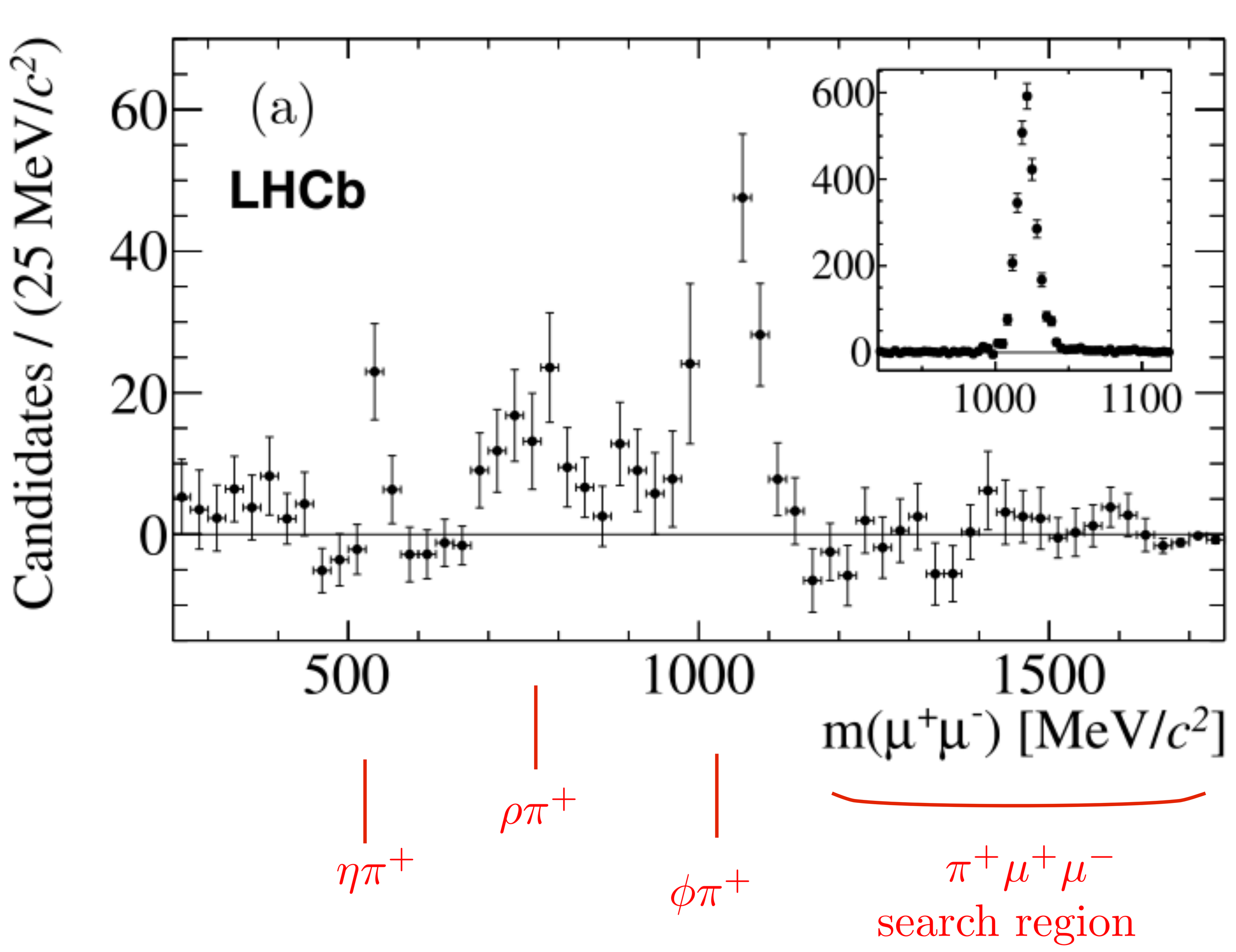
$A_{CP}(t) \approx A_{CP}^{\text{dir}} - A_\Gamma \frac{t}{\tau}$

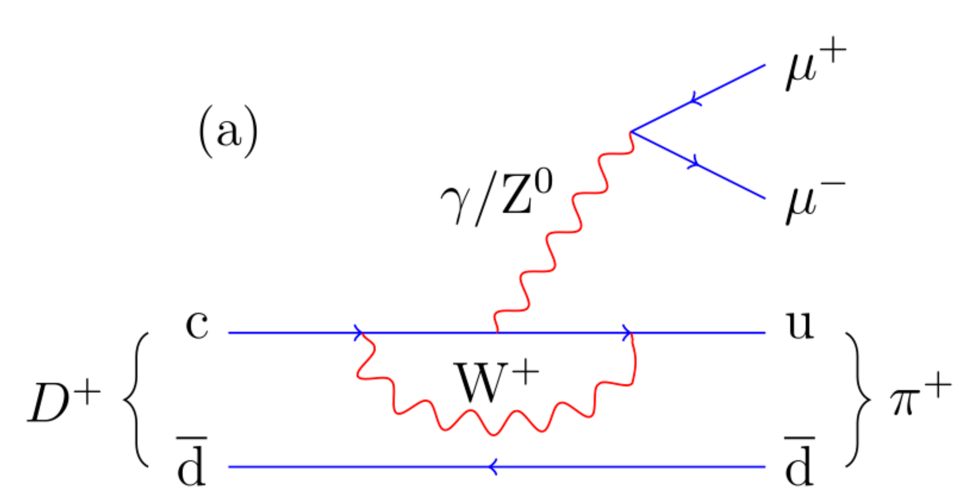
LHCb dominates the precision searches for direct and indirect CP violation in charm

$A_\Gamma(K^-K^+) = (-0.134 \pm 0.077\,^{+0.026}_{-0.034})\%$

$A_\Gamma(\pi^-\pi^+) = (-0.092 \pm 0.145\,^{+0.025}_{-0.033})\%$

Search for electroweak penguins: $D^+ \to \pi^+\mu^+\mu^-$



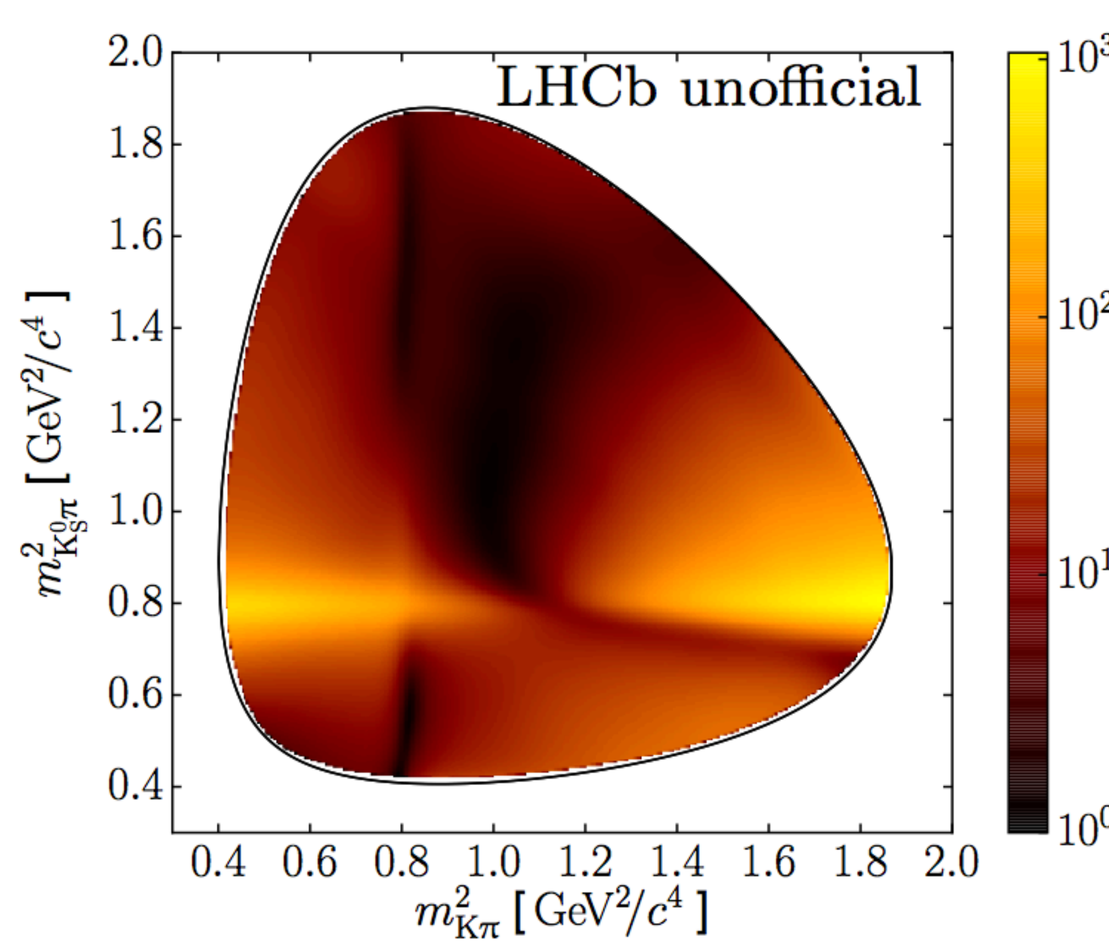


$\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-) < 7.3\,(8.3) \times 10^{-8}$

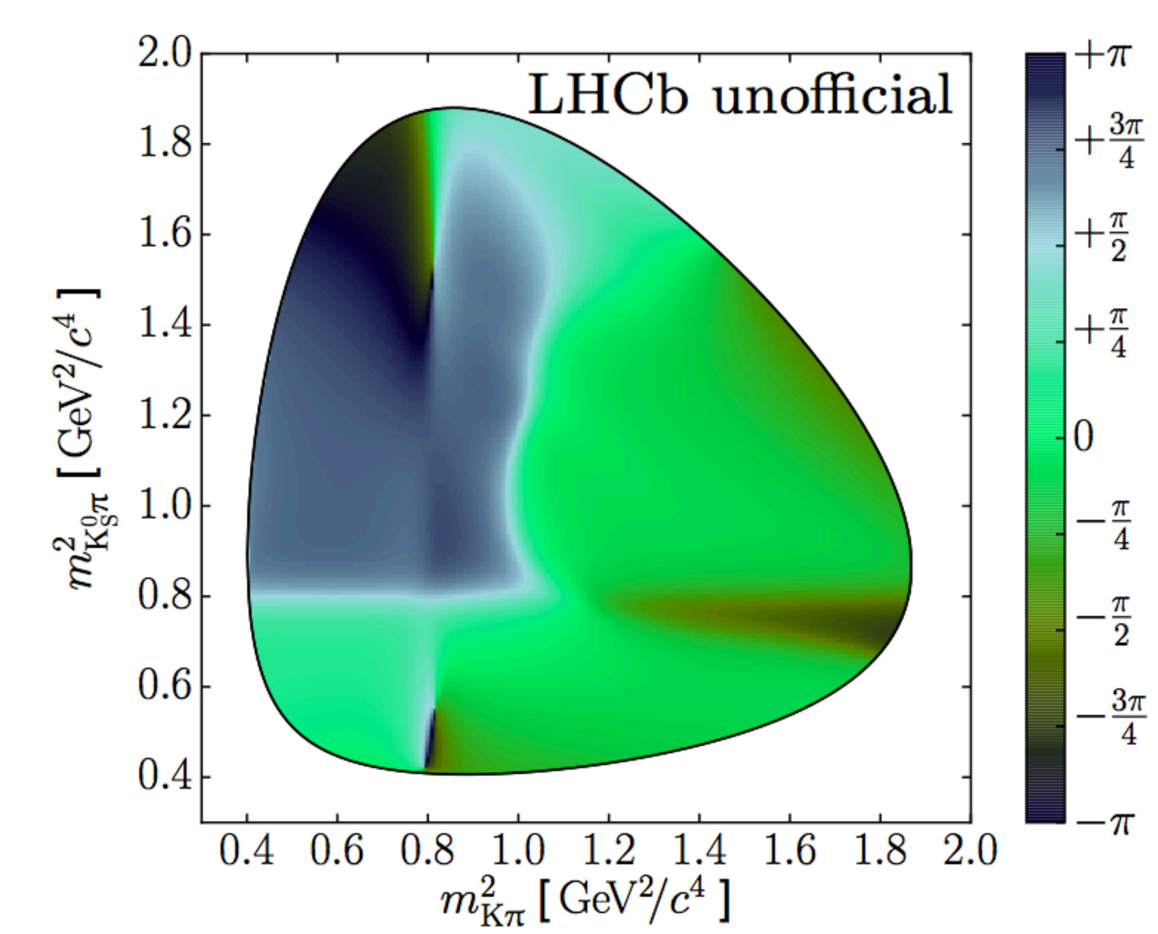
- SM expectation ~10^{-10}

cf. $B(B^+ \to K^+\mu^+\mu^-) = 5 \times 10^{-7}$

State of the art amplitude analysis: $D \to K_S^0 K^+ \pi^-$



$|\mathcal{A}|^2$



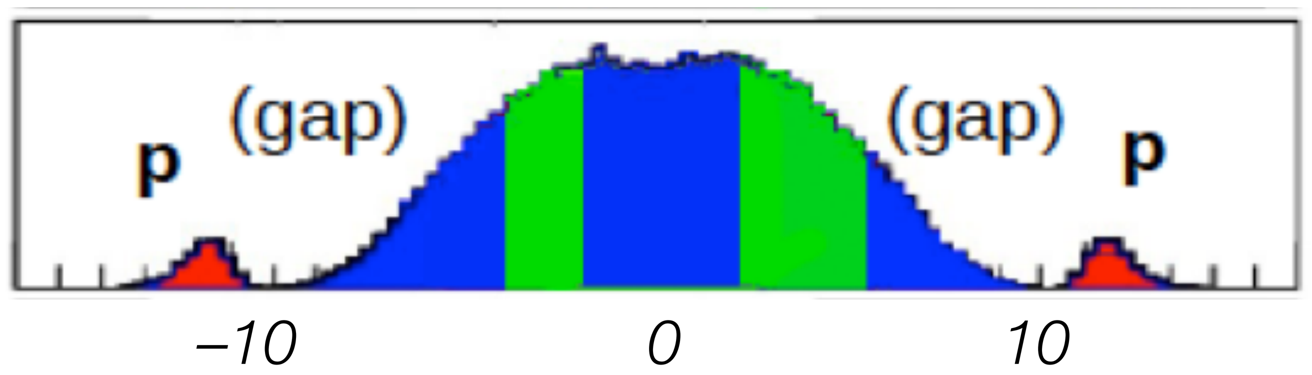
$\arg(\mathcal{A})$

Oxford group analyses

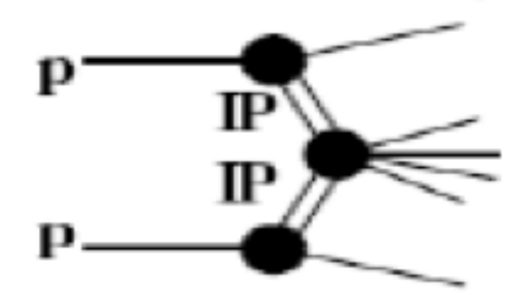
April 2015

Cleanly tagged CEP physics for Run II

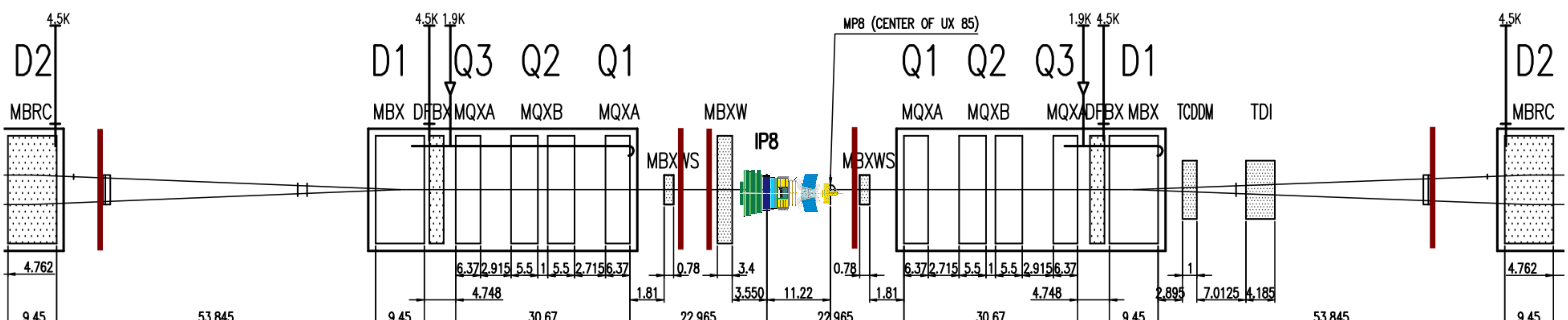
Logorithmic distribution for CEP vs. rapidity



Existing LHCb (VeLo) coverage



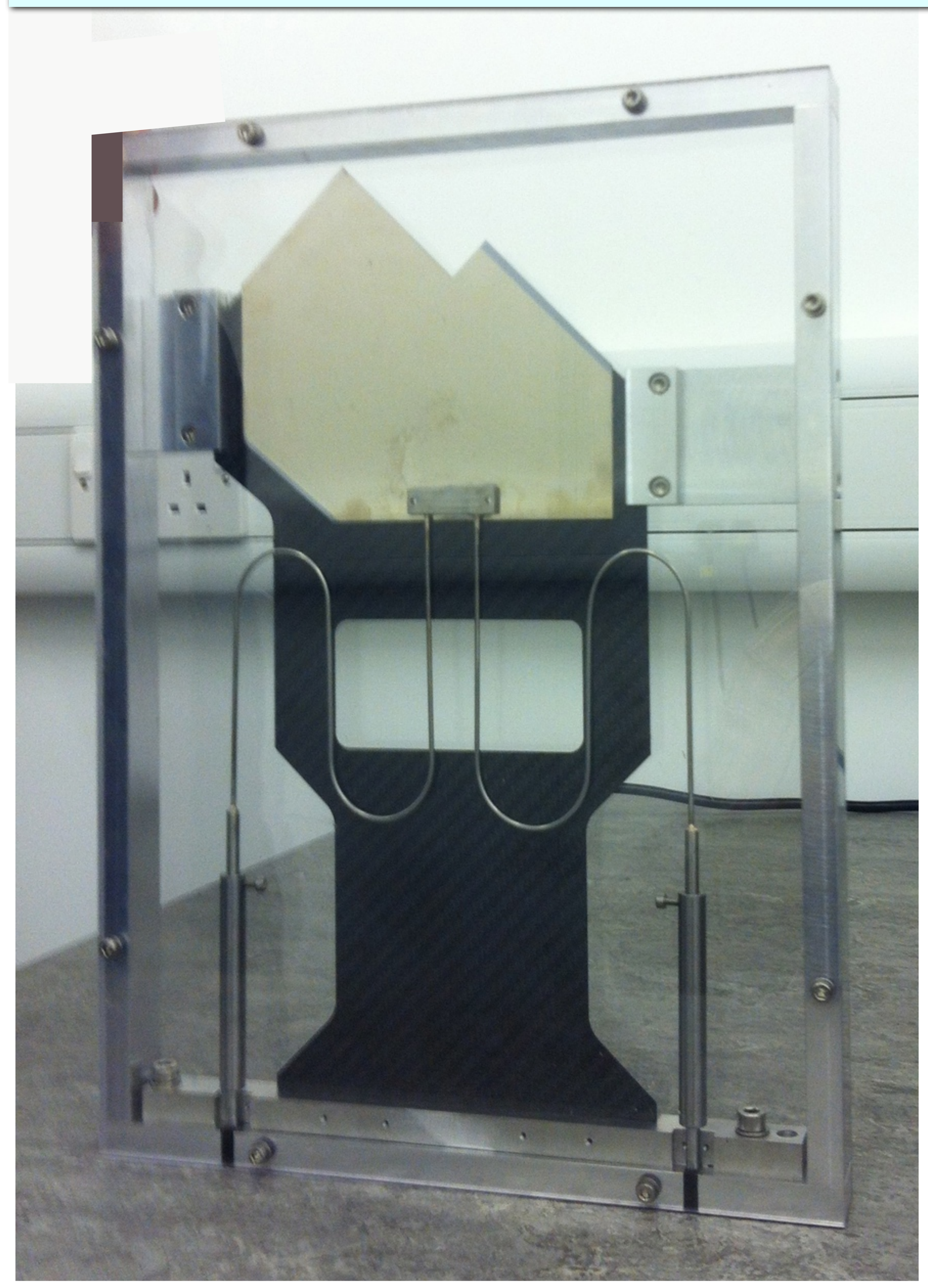
- At the LHC, Central Exclusive Production (CEP) involves momentum transfer without either proton dissociating.
- CEP is identified by the absence of particles ('gaps') both upstream and downstream of the collision point.

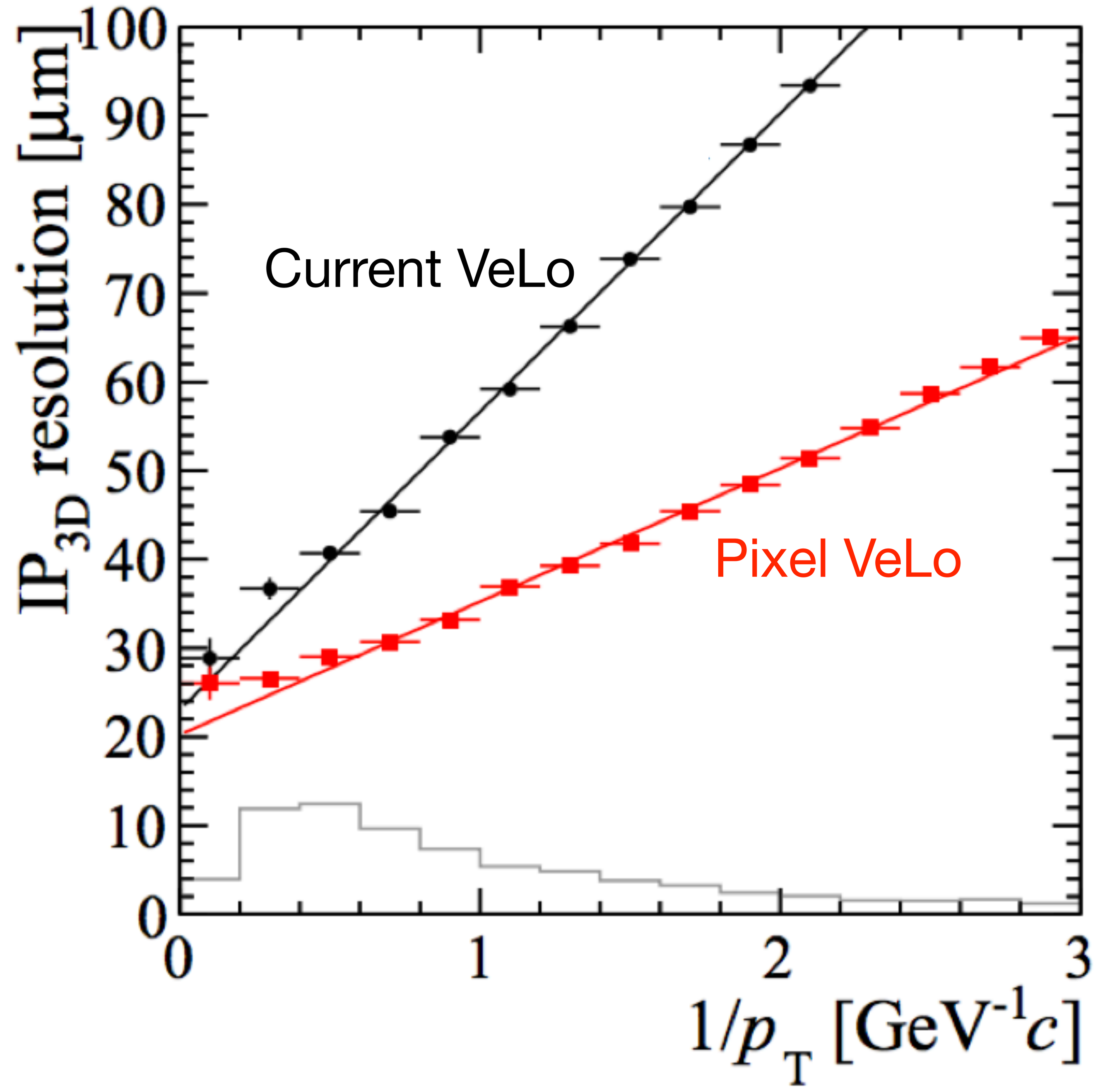


Oxford have initiated HerSChel (High Rapidity Shower Counters at LHCb) to veto low-angle scattering down to 0.01°

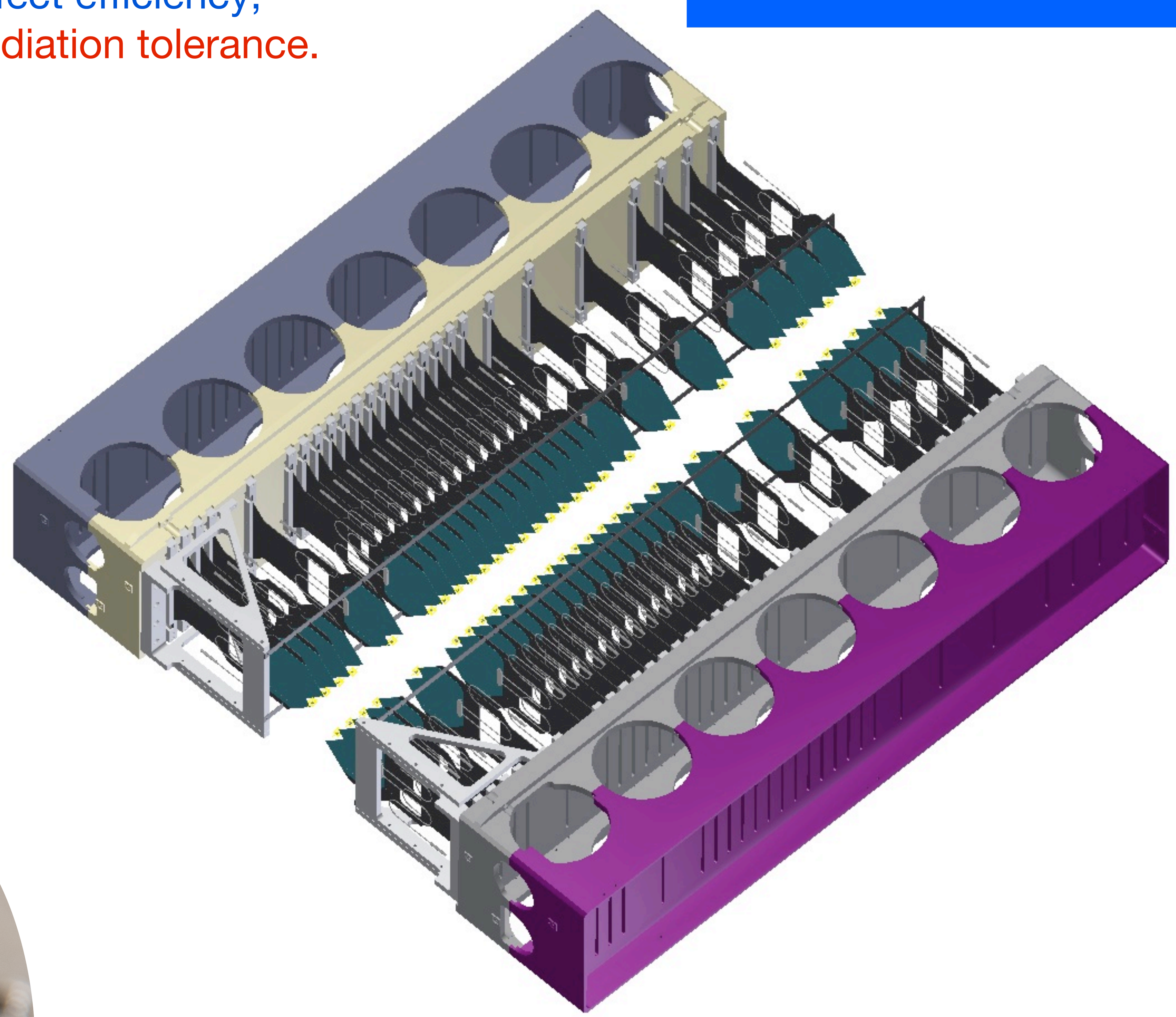
April 2015

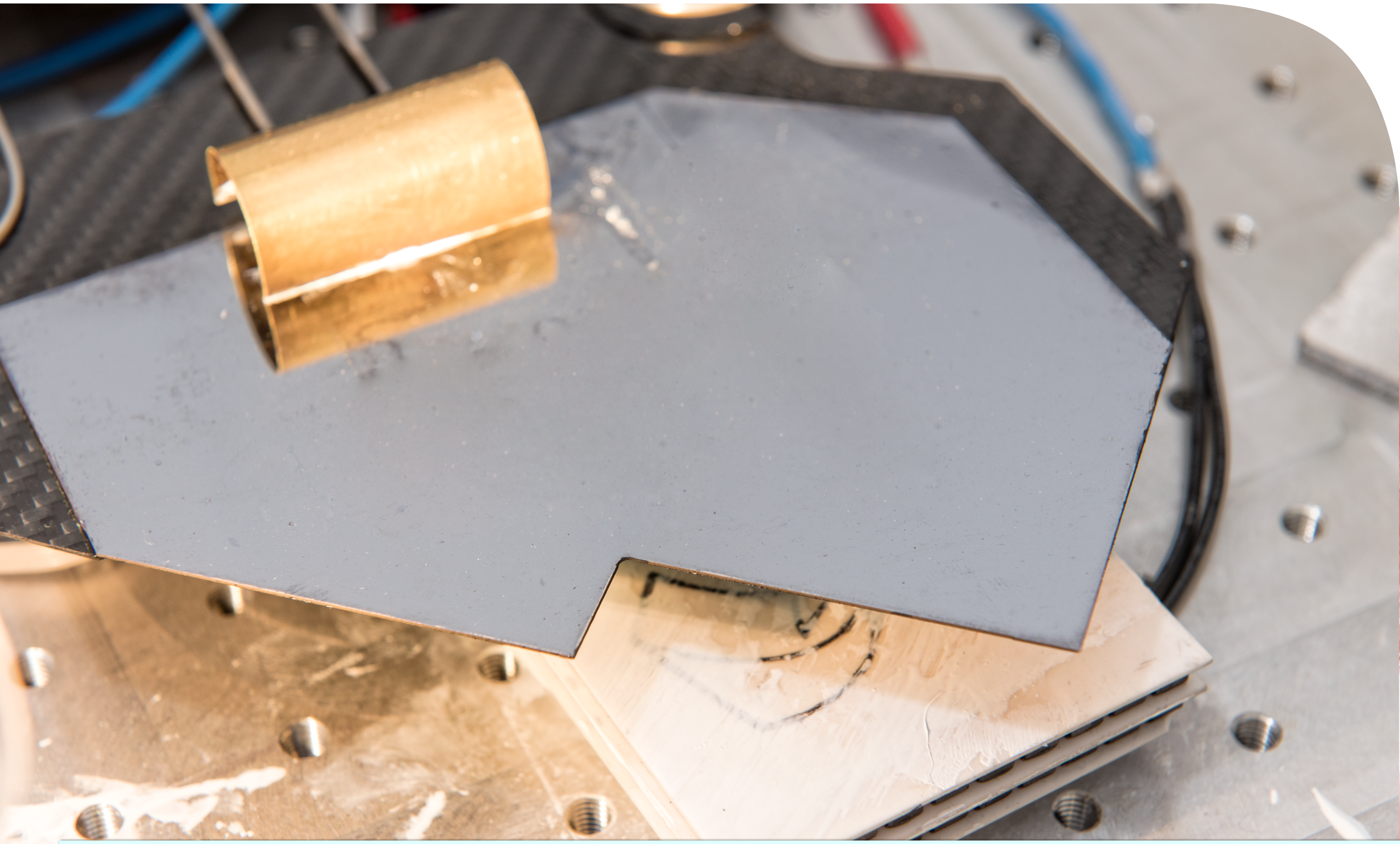
Designing the upgrade: the pixel VeLo

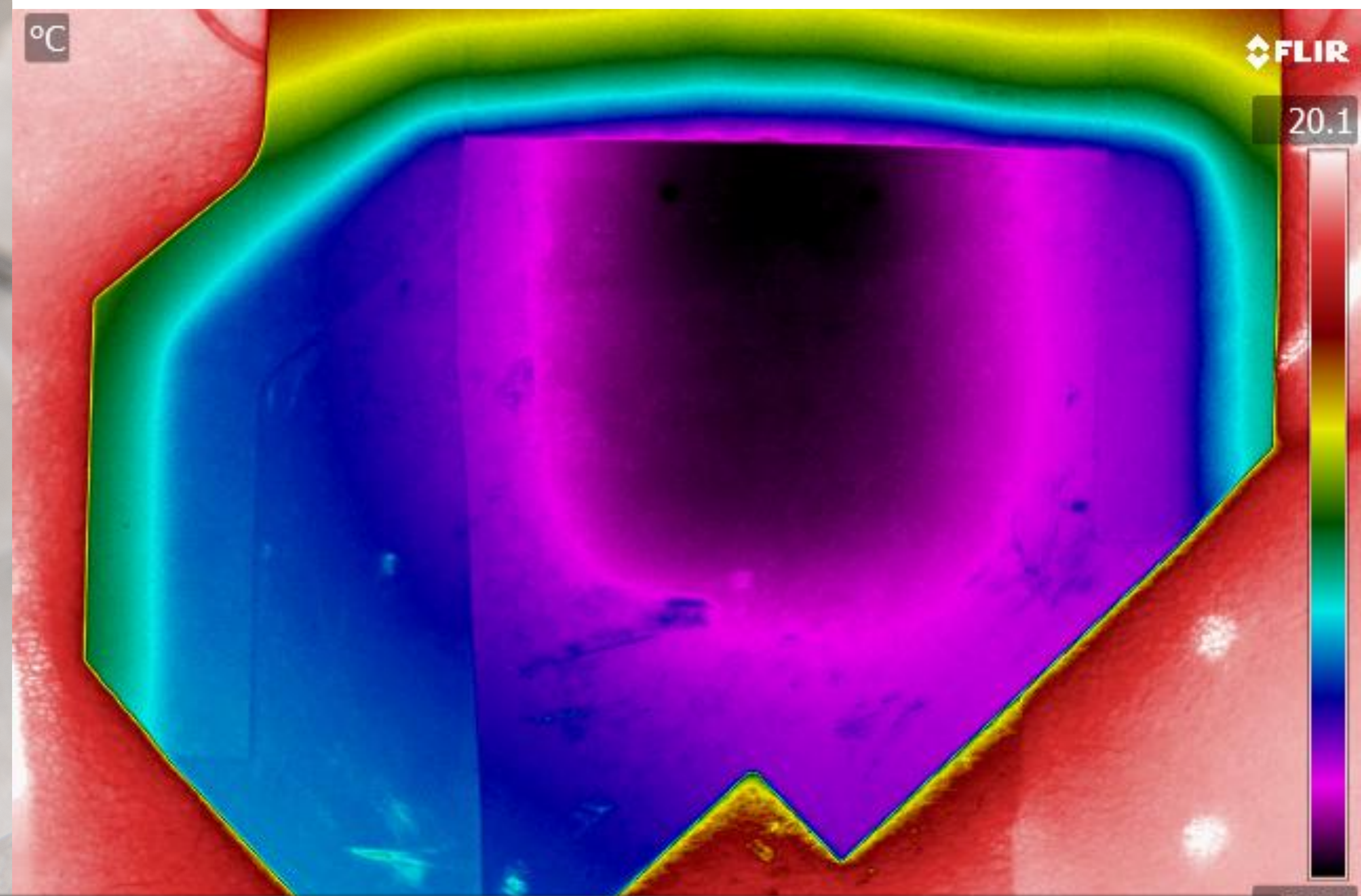




- Closer and more compact design;
- Superior tracking precision;
- Near-perfect efficiency;
- Higher radiation tolerance.







The pixel chips are cooled by bi-phase CO_2 circulating in fifteen 200×120μm^2 microchannels embedded in a 400μm-thick silicon substrate