LHCb results and prospects

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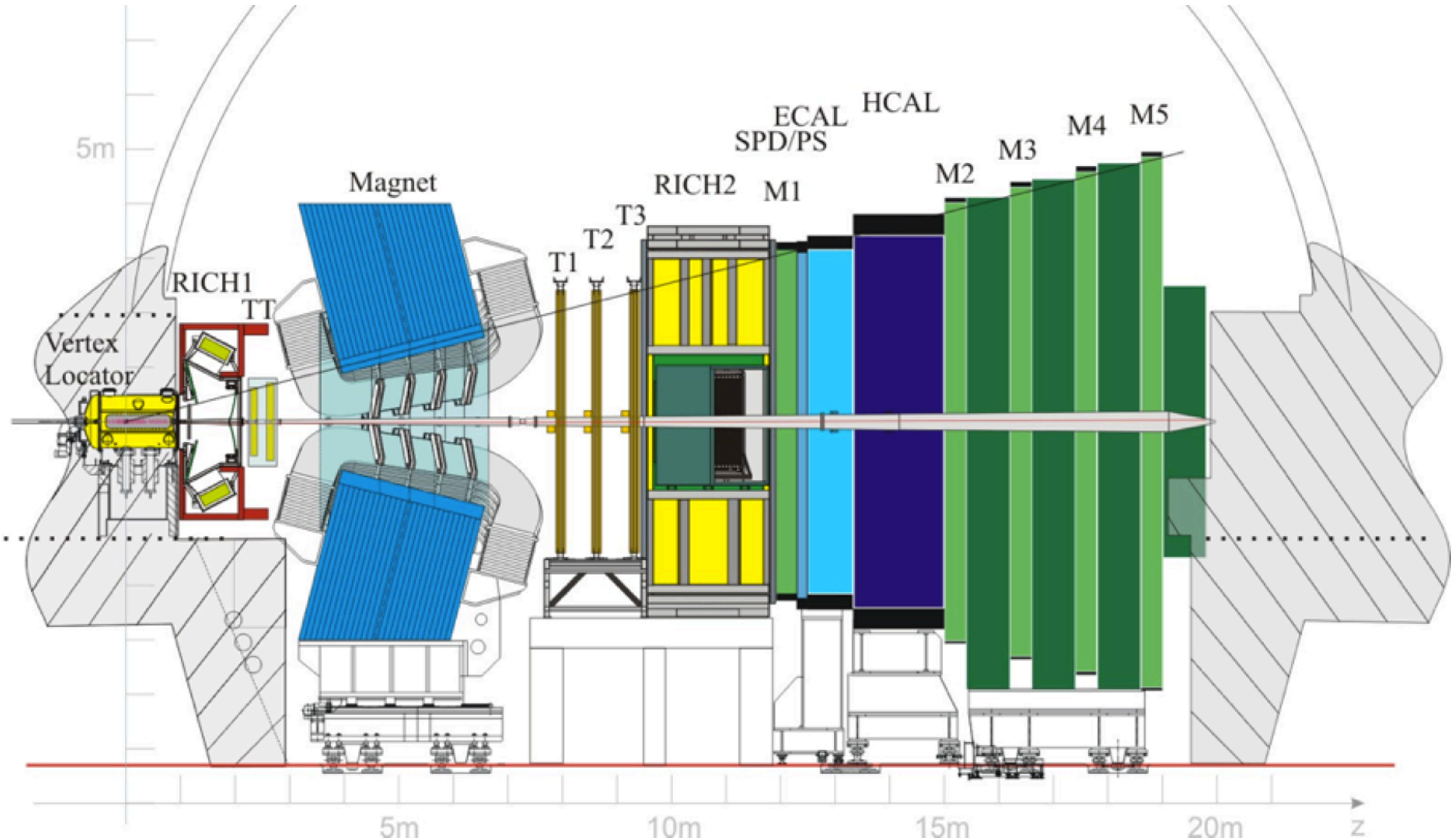
Outline

- *The LHCb detector*
- *Latest LHCb results*
- *The LHCb detector upgrade*
- *Conclusions*

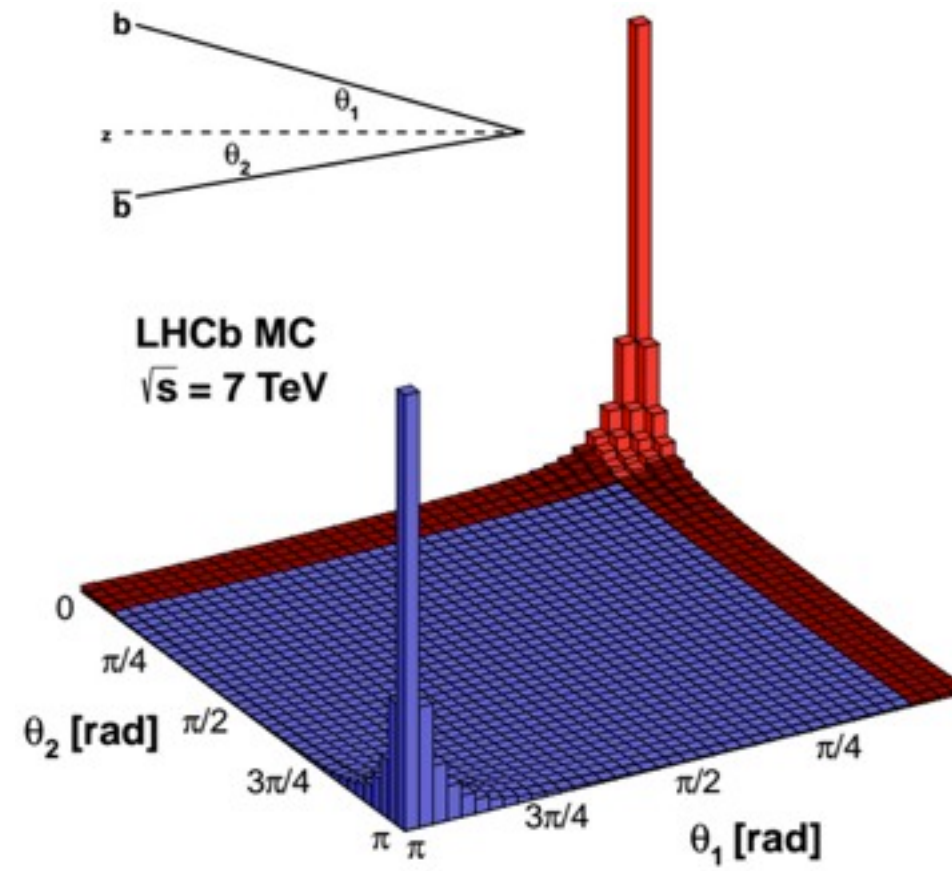
The LHCb detector

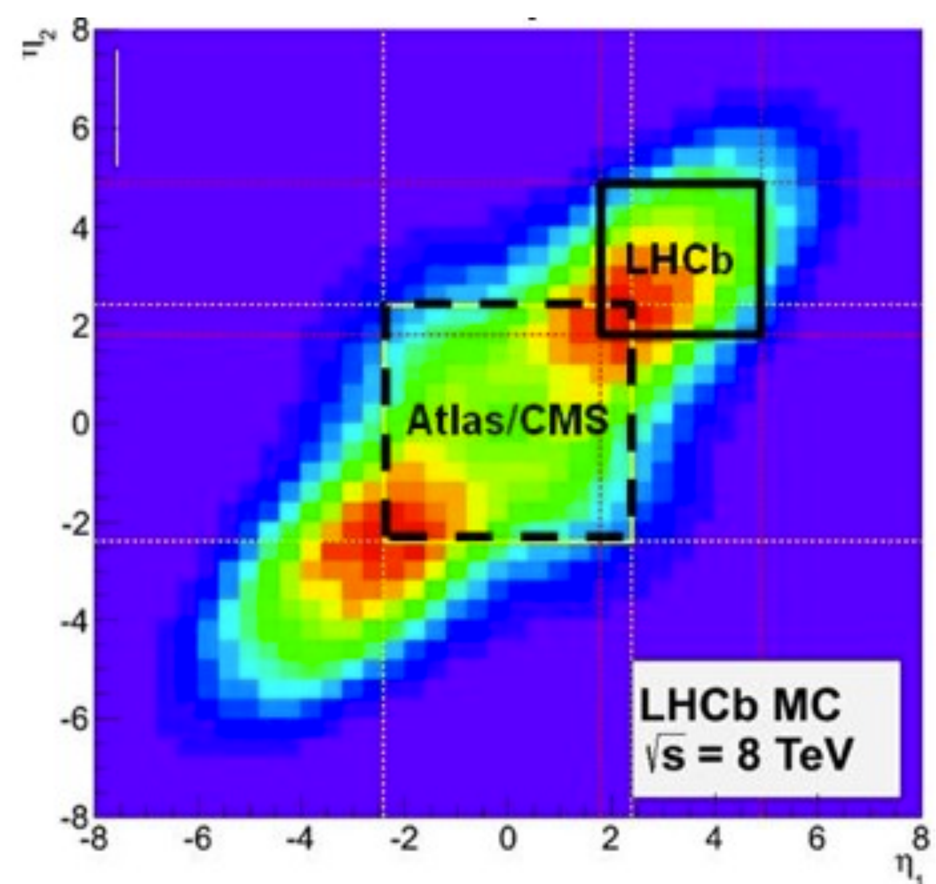


LHCb Collaboration, JINST 3(2008)S08005

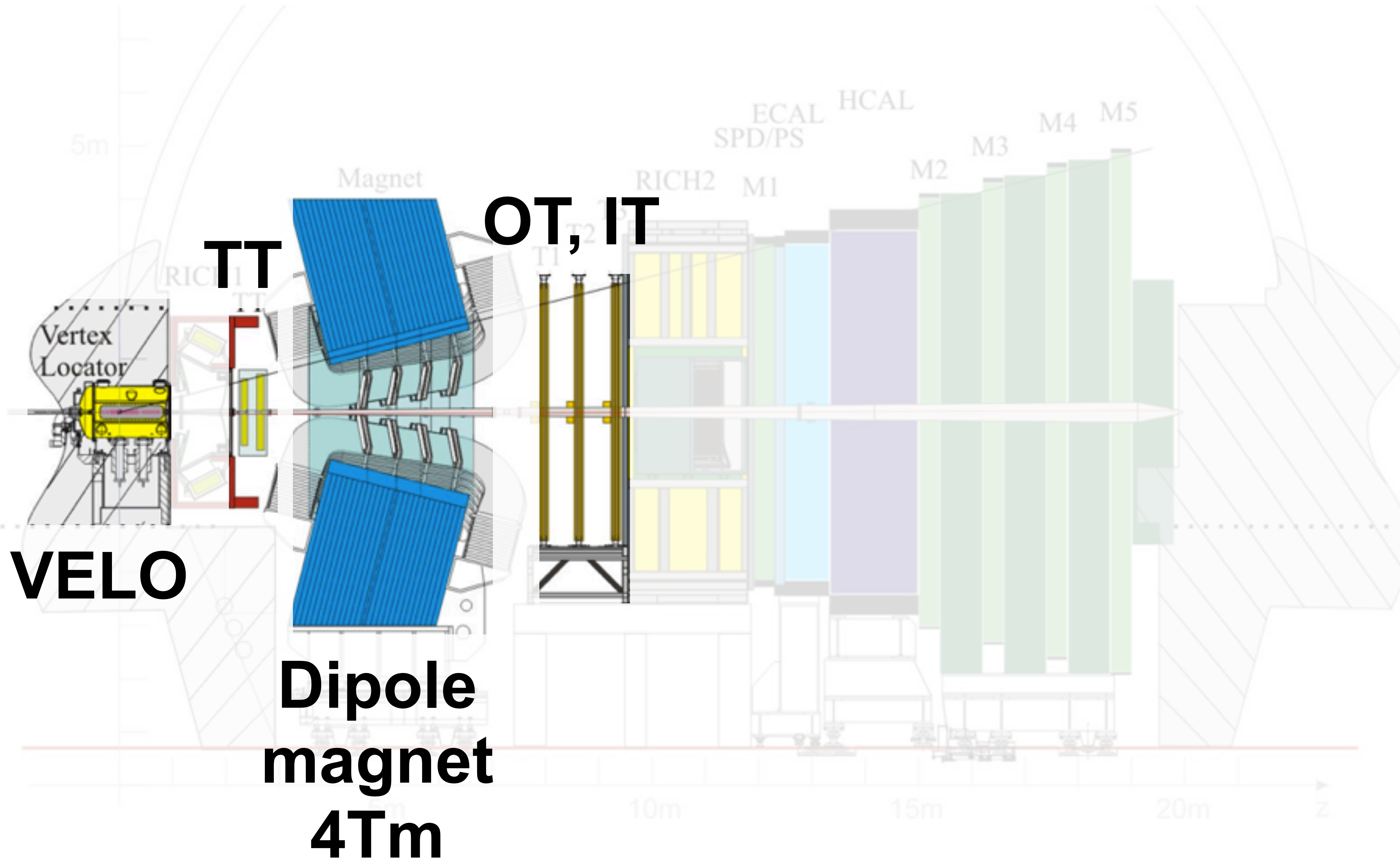
The LHCb detector

- ***LHCb is a forward detector to study flavor physics at LHC!***
- LHC is a flavor factory!
  - Large $b\bar{b}$ and $c\bar{c}$ cross-sections from proton-proton collisions
  - At LHC $b\bar{b}$ and $c\bar{c}$ pairs are produced mostly in the forward or backward regions
- LHCb covers ~4% of solid angle, and captures 40% of $b\bar{b}$ and $c\bar{c}$ cross-section, in the $2<\eta<5$ pseudo-rapidity range
- Great tracking and particle identification performance

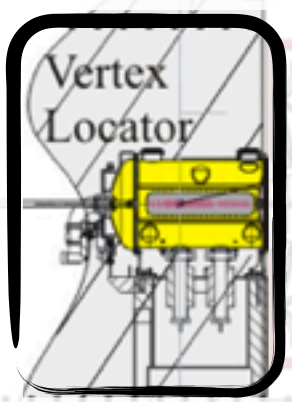




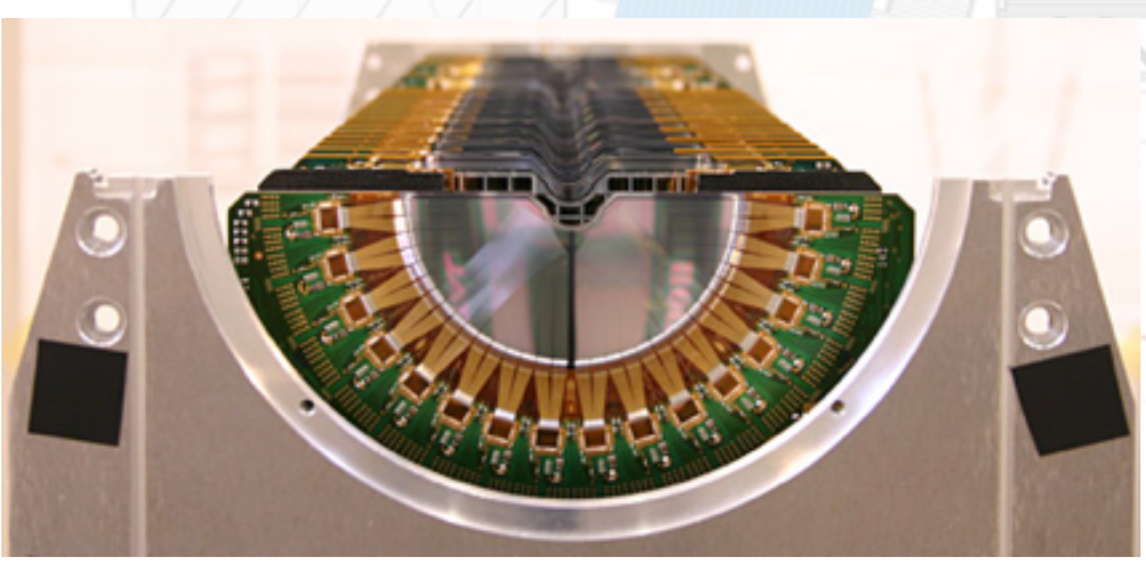
Tracking system

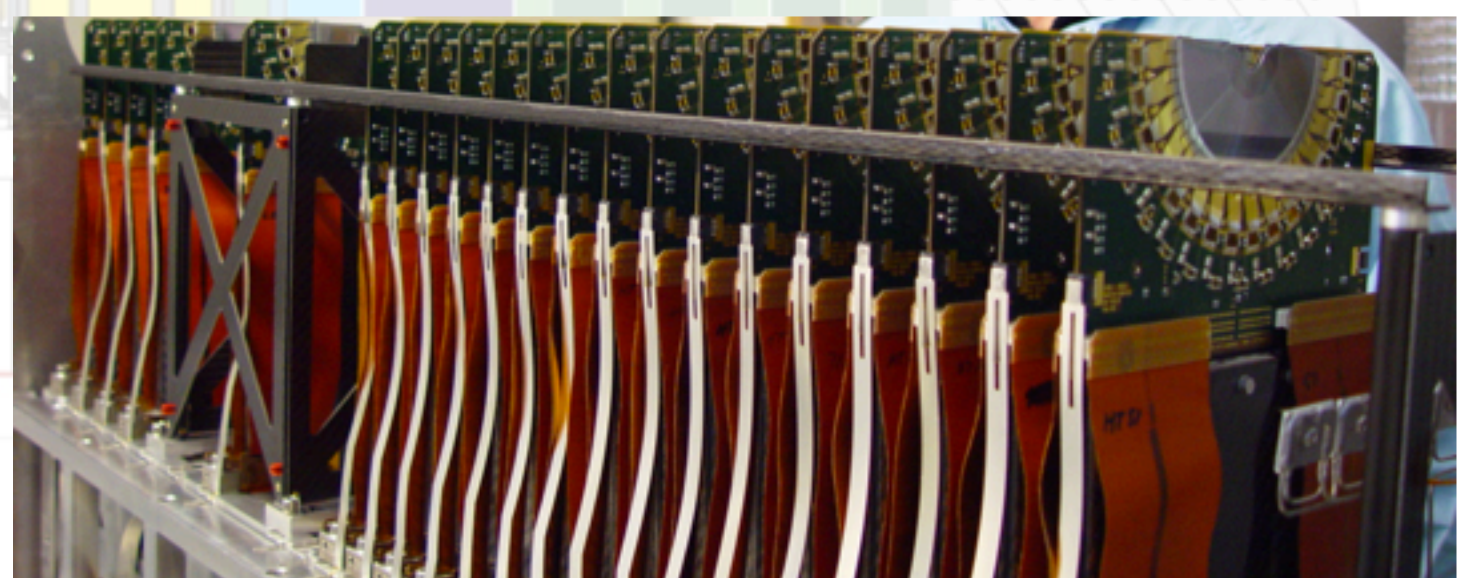


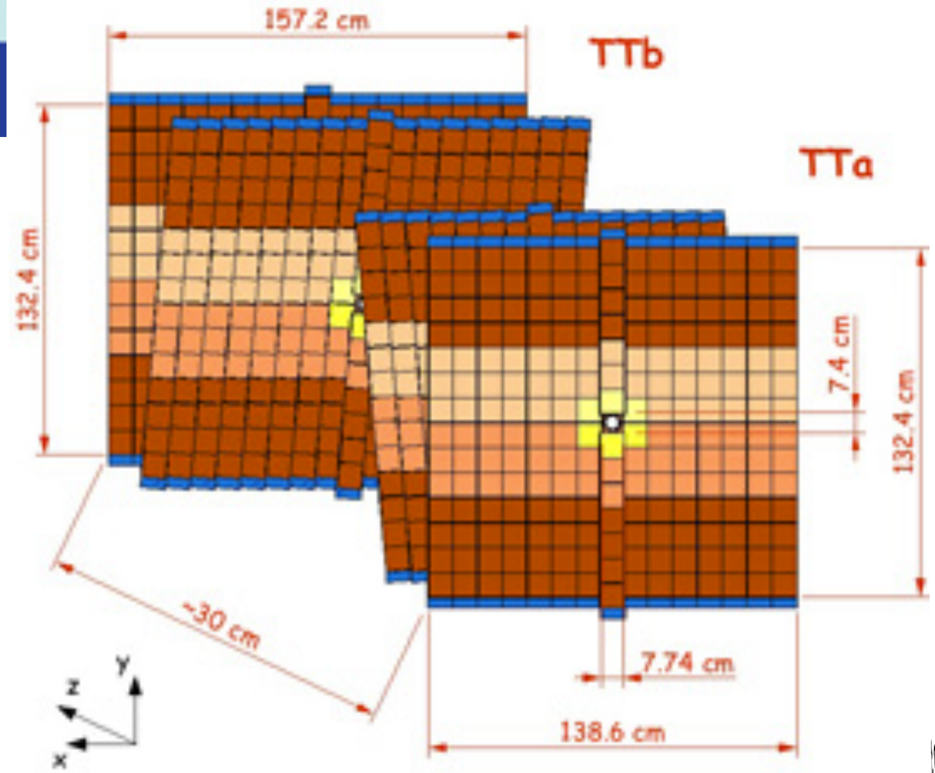
Vertex locator (VELO)

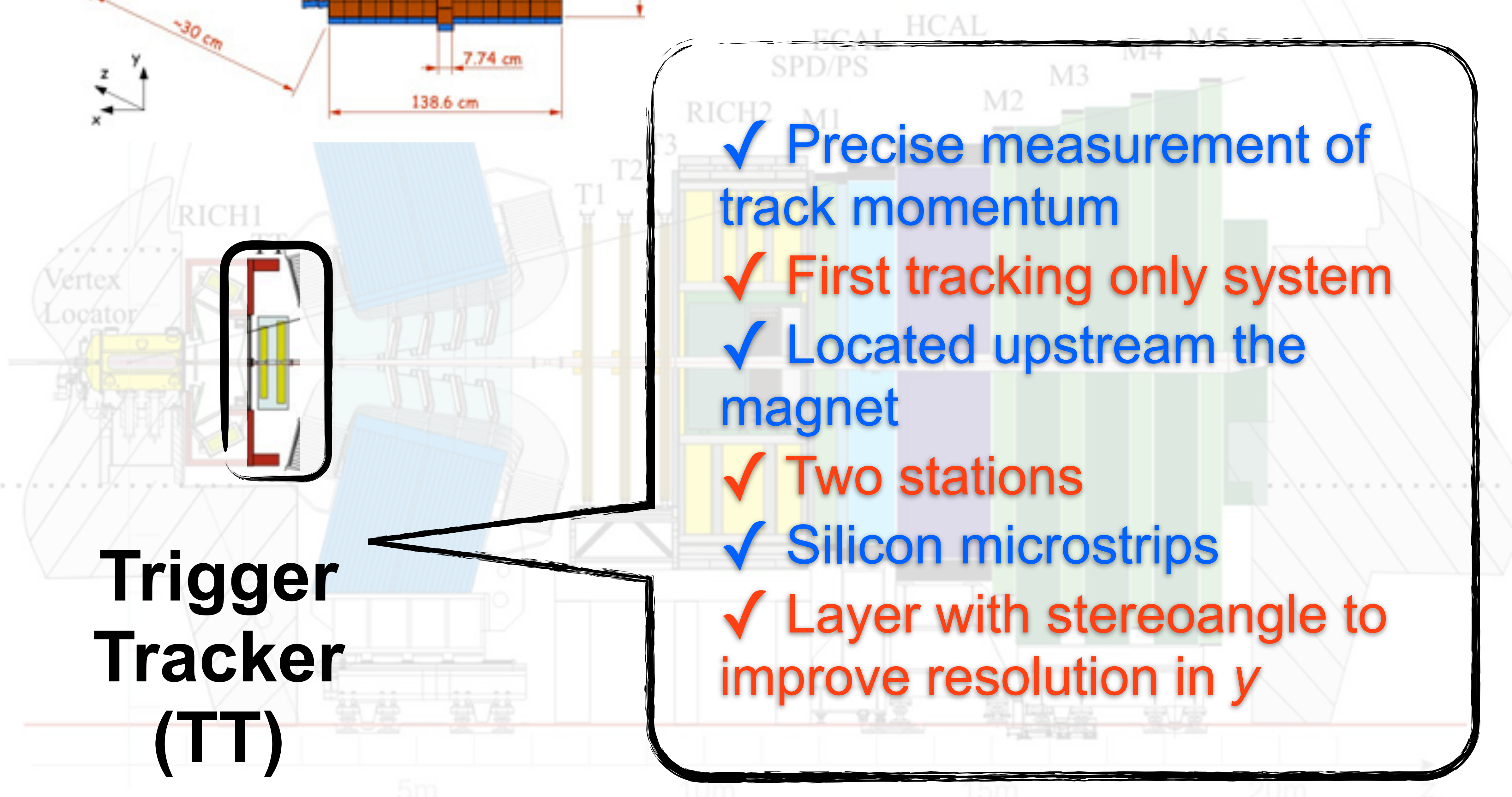


- ✓ Interactions take place at VELO
- ✓ Precise measurement of tracks coordinates near the interaction point
- ✓ Reconstruction of primary and secondary vertices
- ✓ Crucial information for lifetime and impact parameter measurements
- ✓ Series of silicon microstrips, *r* and φ sensors
- ✓ $\sigma_{PV,x/y}$~10μm, $\sigma_{PV,z}$~60μm



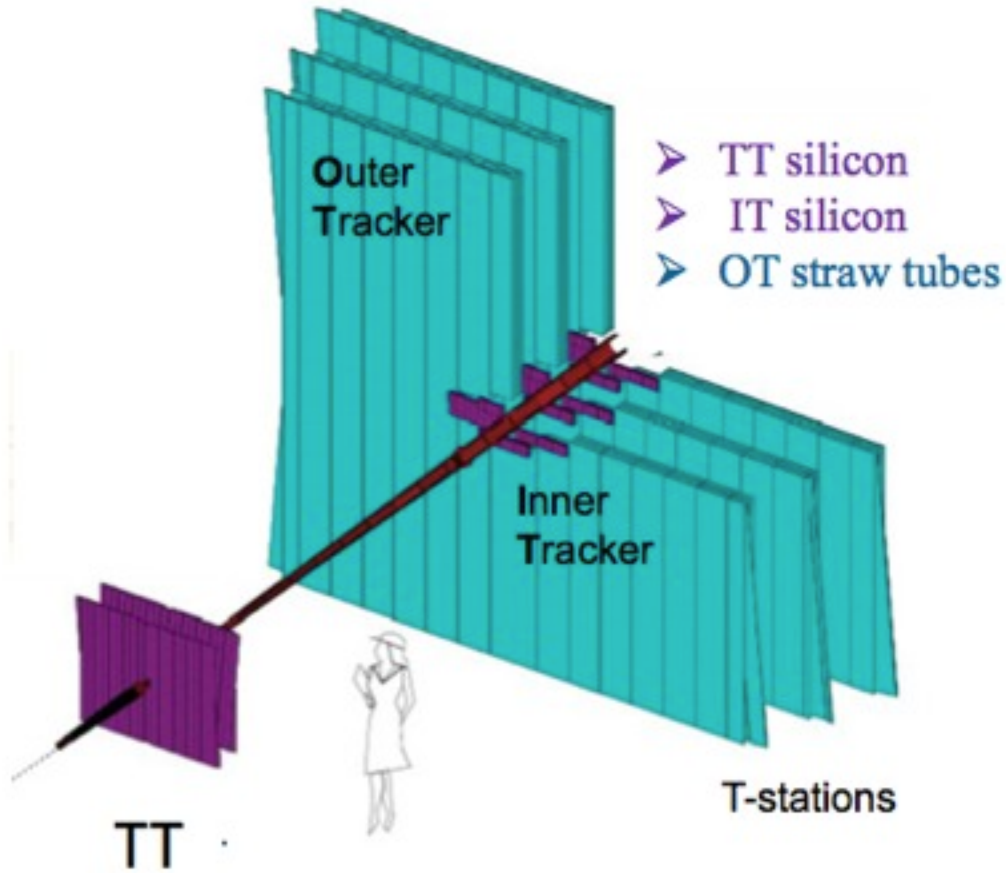




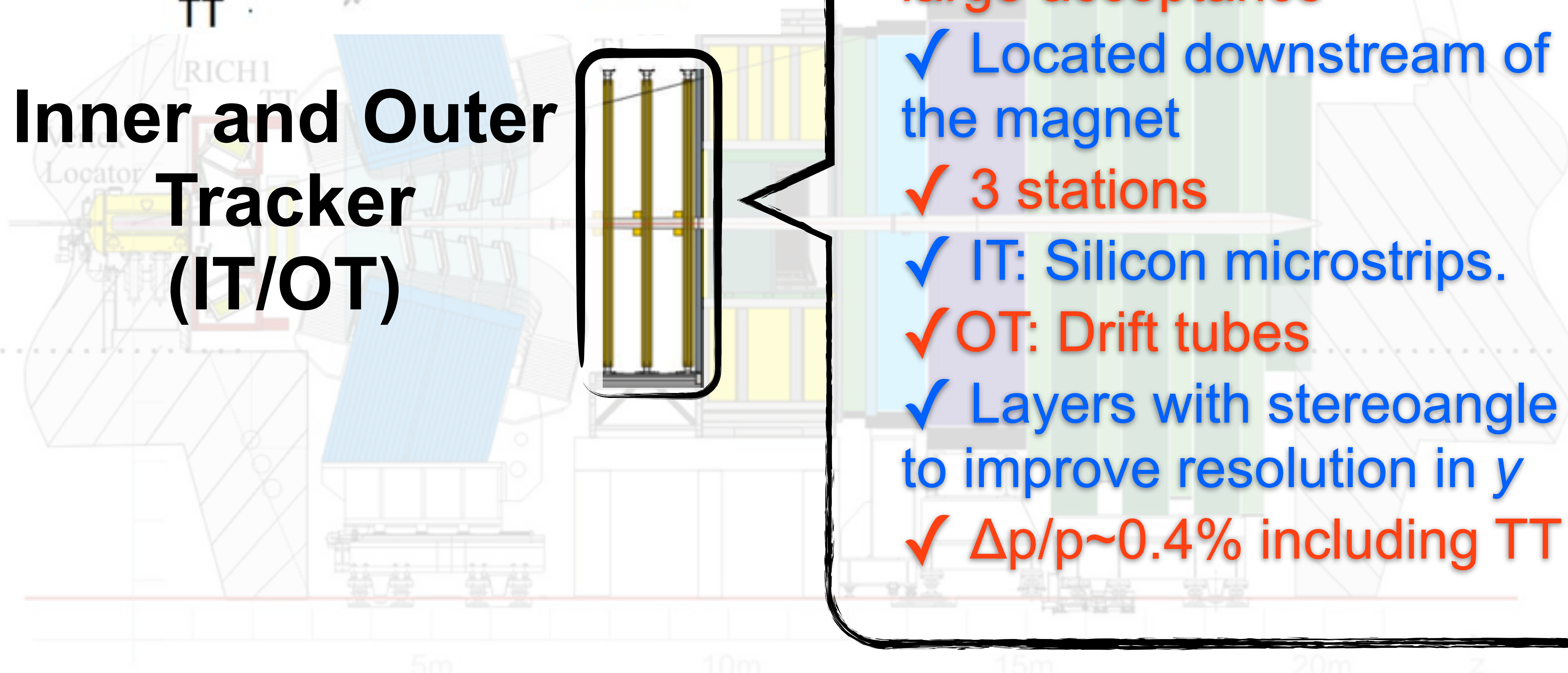


Trigger Tracker (TT)

- ✓ Precise measurement of track momentum
- ✓ First tracking only system
- ✓ Located upstream the magnet
- ✓ Two stations
- ✓ Silicon microstrips
- ✓ Layer with stereoangle to improve resolution in *y*

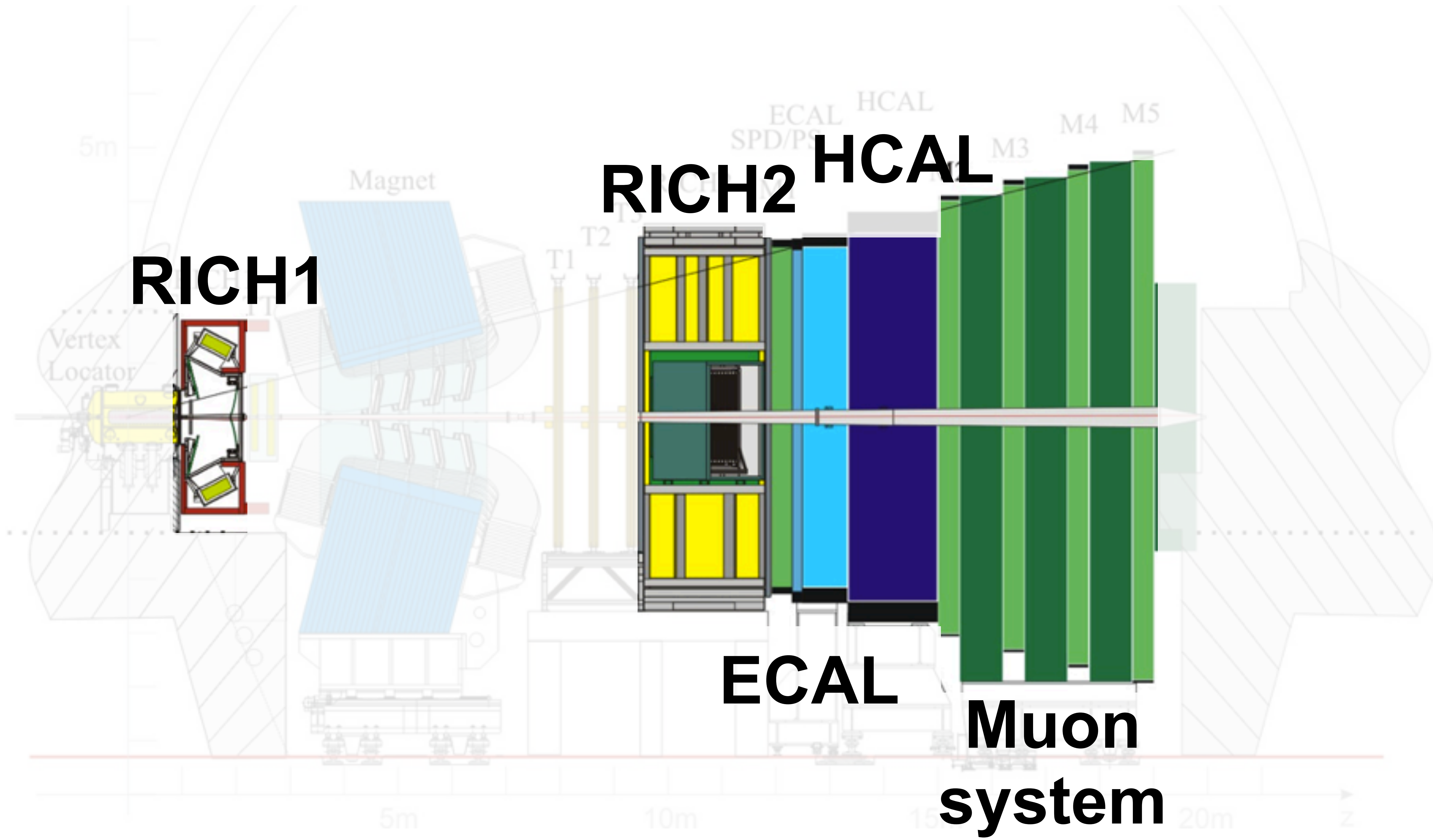


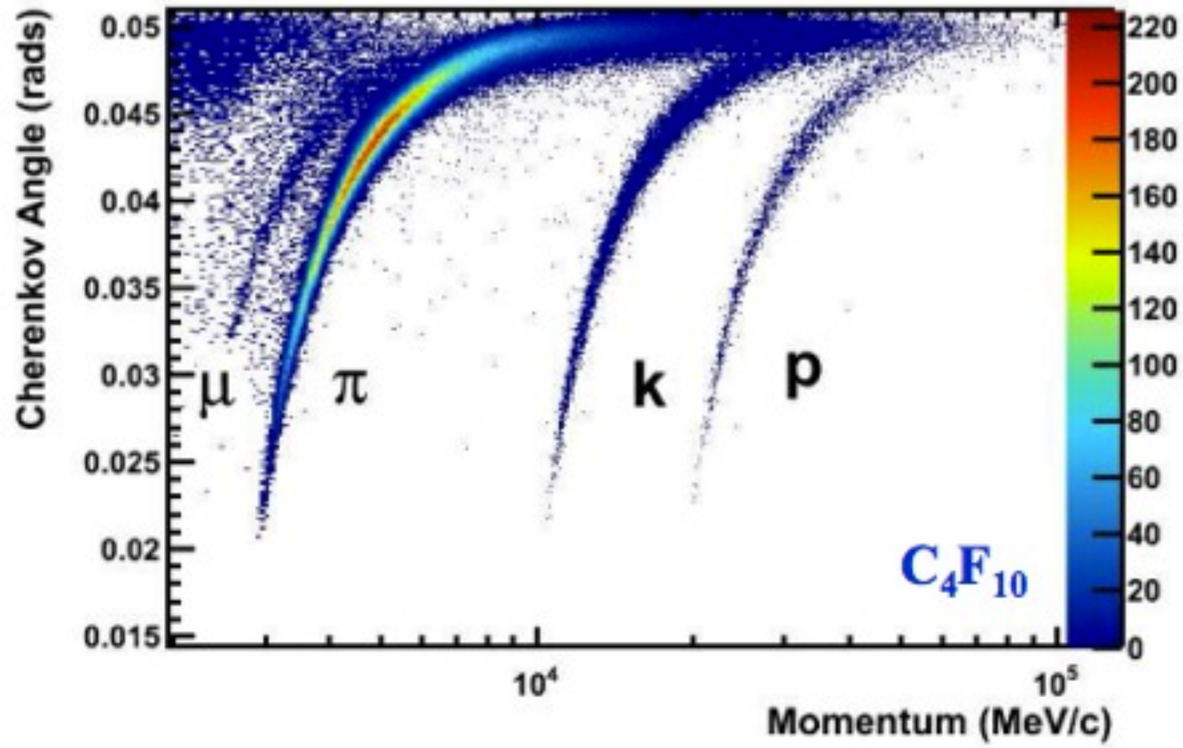
Inner and Outer Tracker (IT/OT)

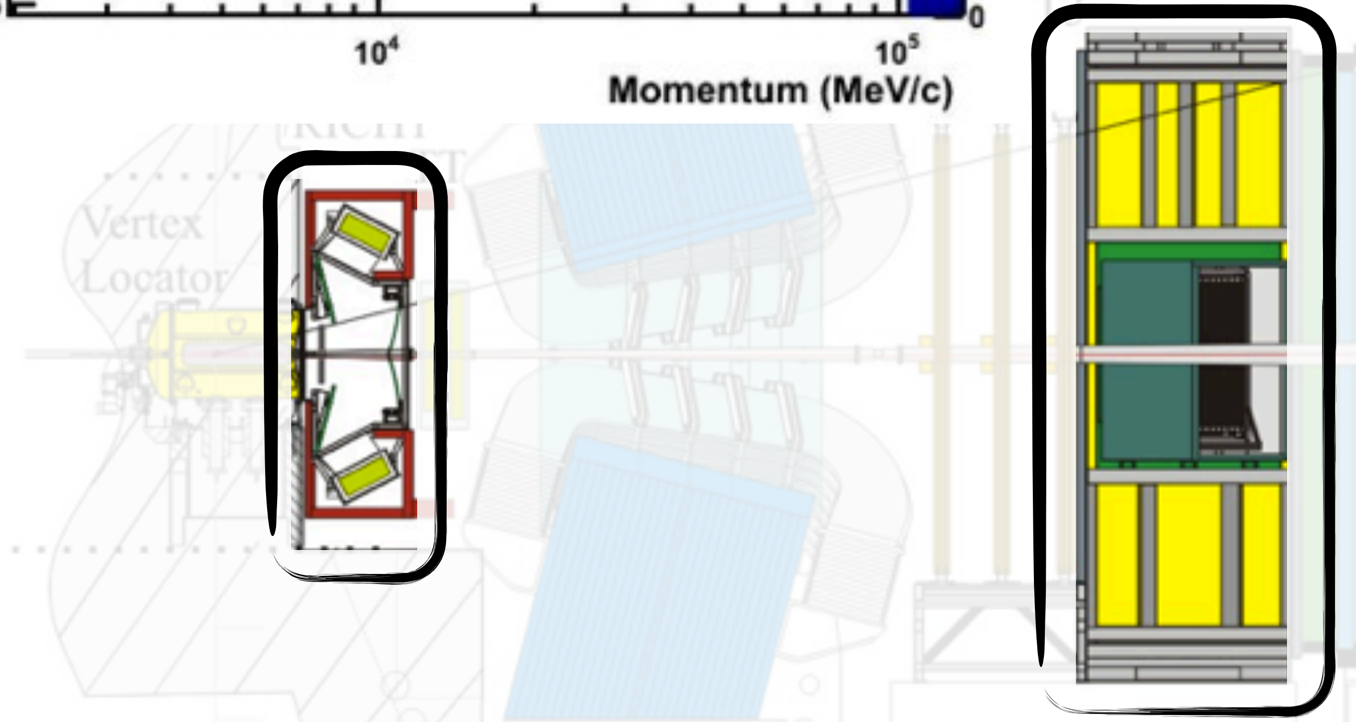


- ✓ Precise measurement of tracks momenta over large acceptance
- ✓ Located downstream of the magnet
- ✓ 3 stations
- ✓ IT: Silicon microstrips.
- ✓ OT: Drift tubes
- ✓ Layers with stereoangle to improve resolution in *y*
- ✓ $\Delta p/p \sim 0.4\%$ including TT

Particle identification

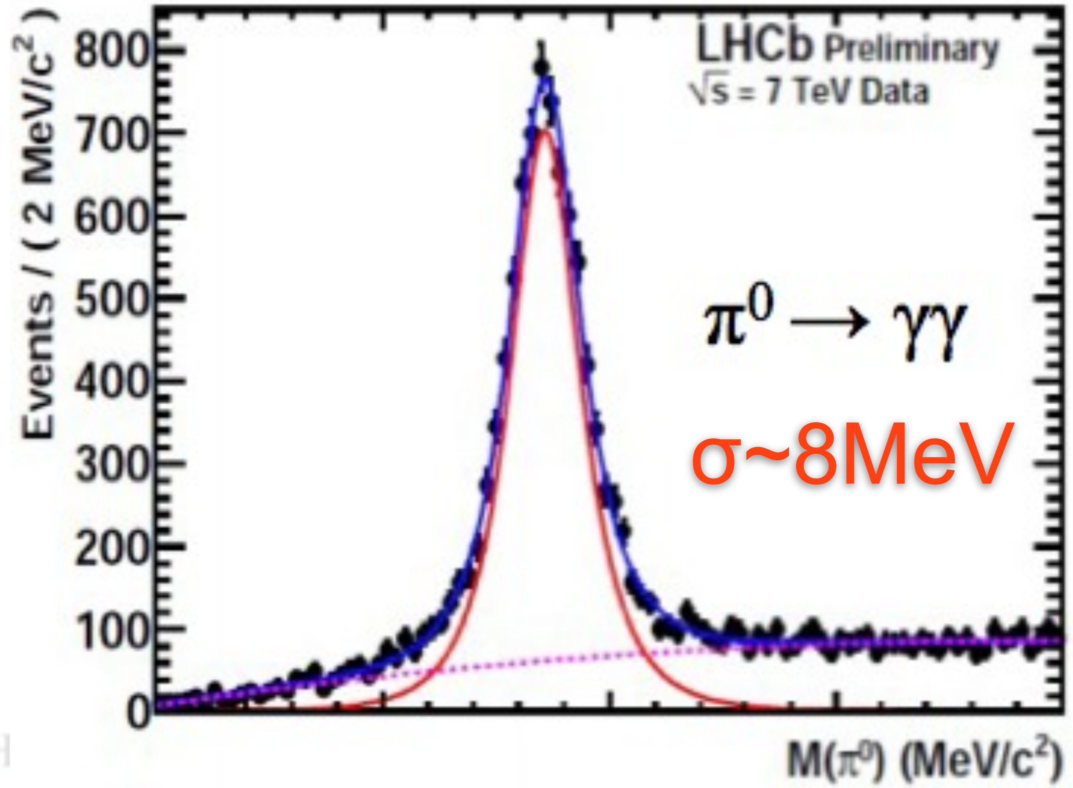




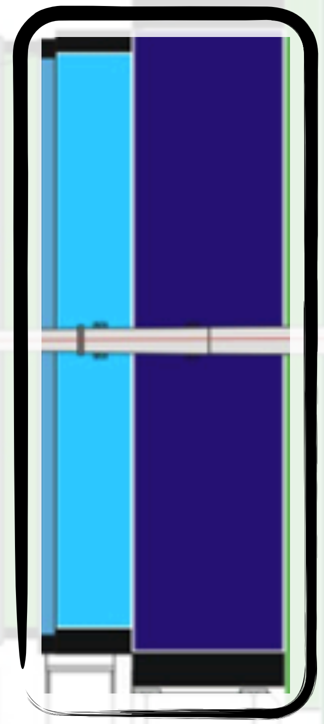


Ring-Imaging Cherenkov detectors (RICH)

- ✓ Separation between kaon, proton and pion tracks
- ✓ RICH1: optimized for tracks up to 60GeV/c
- ✓ RICH2: optimized for high momentum tracks
- ✓RICH1 a mixture of aerogel and C_4F_{10}
- ✓ RICH2 filled with CF_4
- ✓ Uses Hibrid-photon detectors (HPD)
- ✓ Kaon eff ~95% with pion misID rate of ~5%



- ✓ Energy and position measurements of electrons, photons and hadrons
- ✓ Includes preshower (PS) detector and scintillating pad detector (SPD)
- ✓ Used in the first trigger stage.
- ✓ Scintillator and lead/iron (ECAL/HCAL)



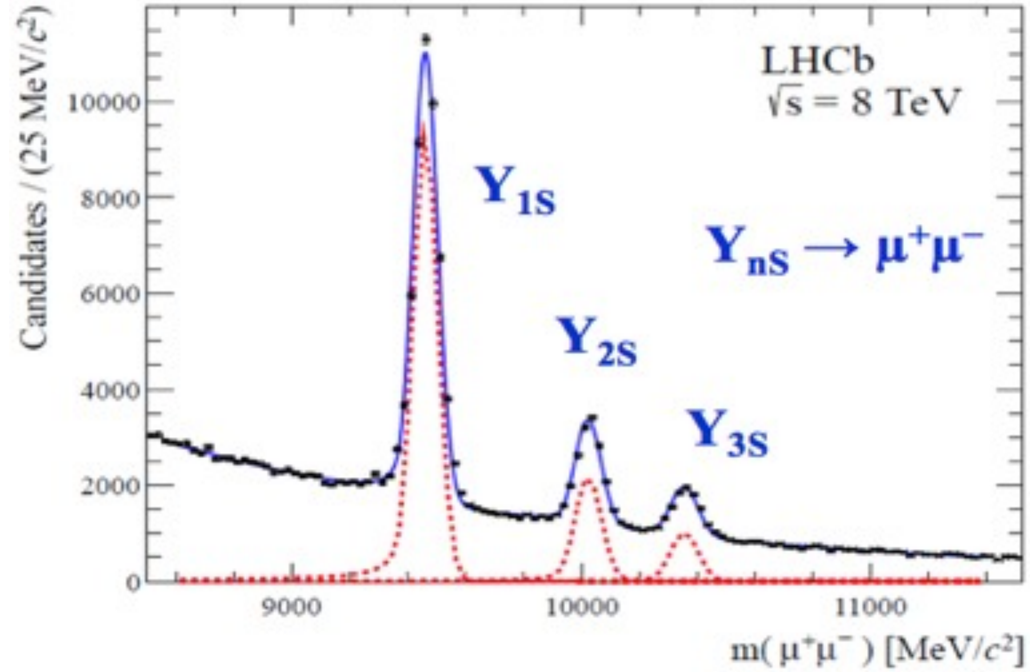
Electromagnetic and hadronic calorimeters (ECAL/HCAL)

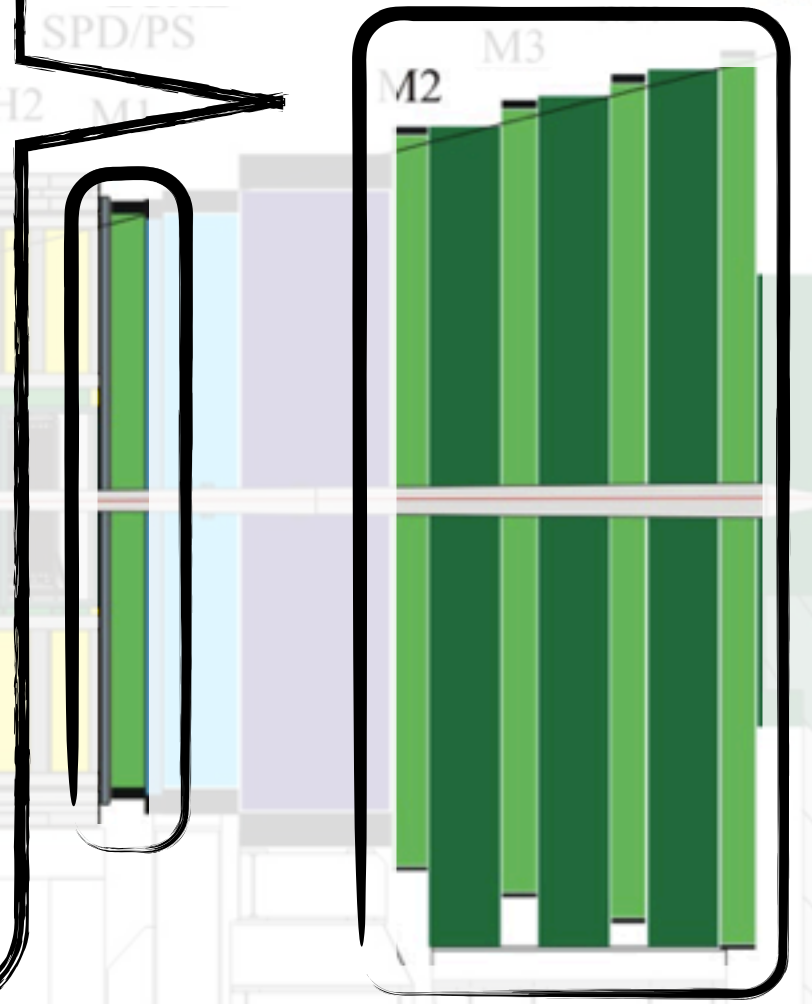
✓ Plays a role in the first trigger stage

✓ 5 stations one of them upstream the calorimeter

✓ Multi-wire proportional chambers used in outer rand triple-GEM detectors in the internal regions

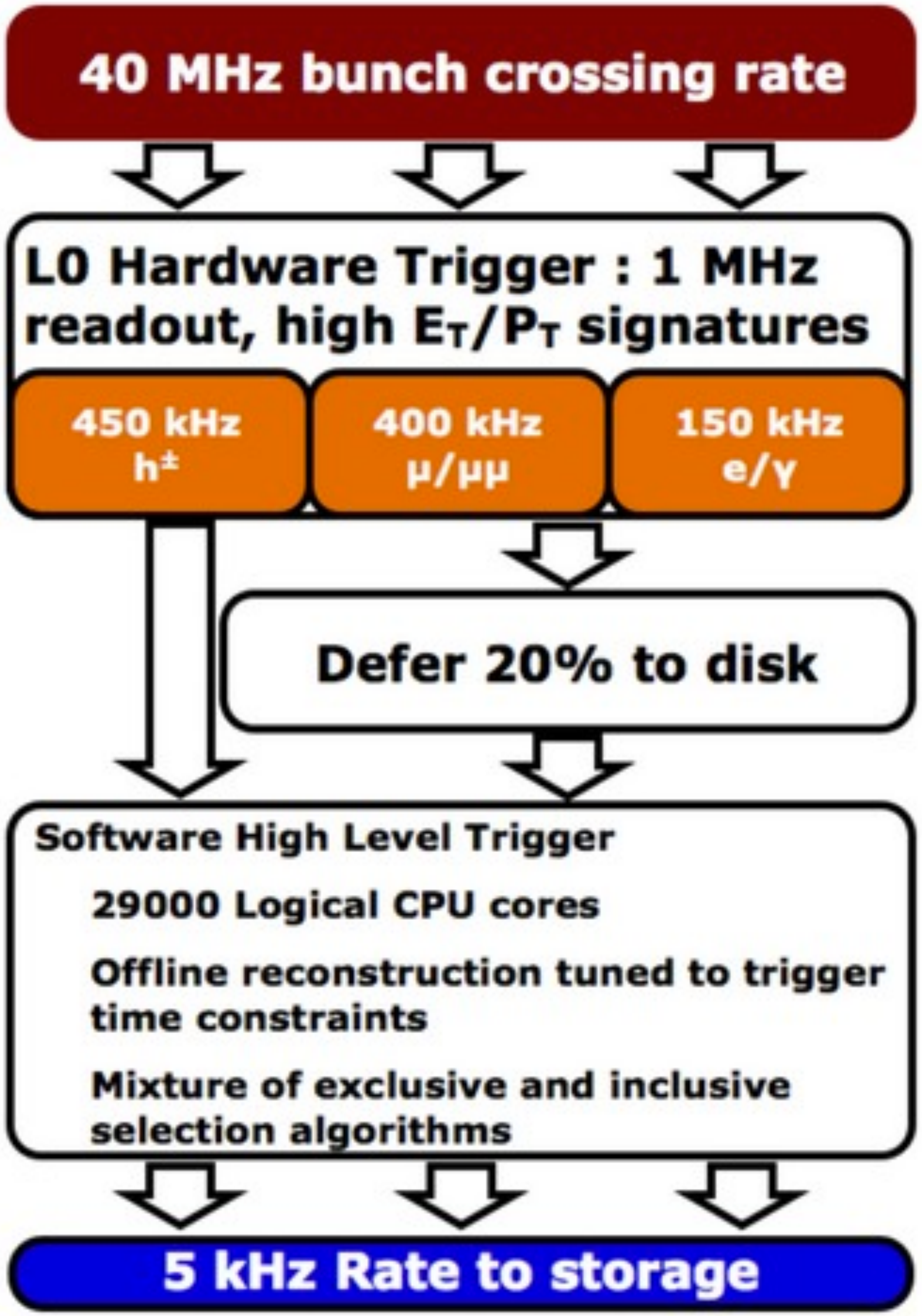
✓ Muon identification efficiency of ~97% with 1-3% pion misID rate





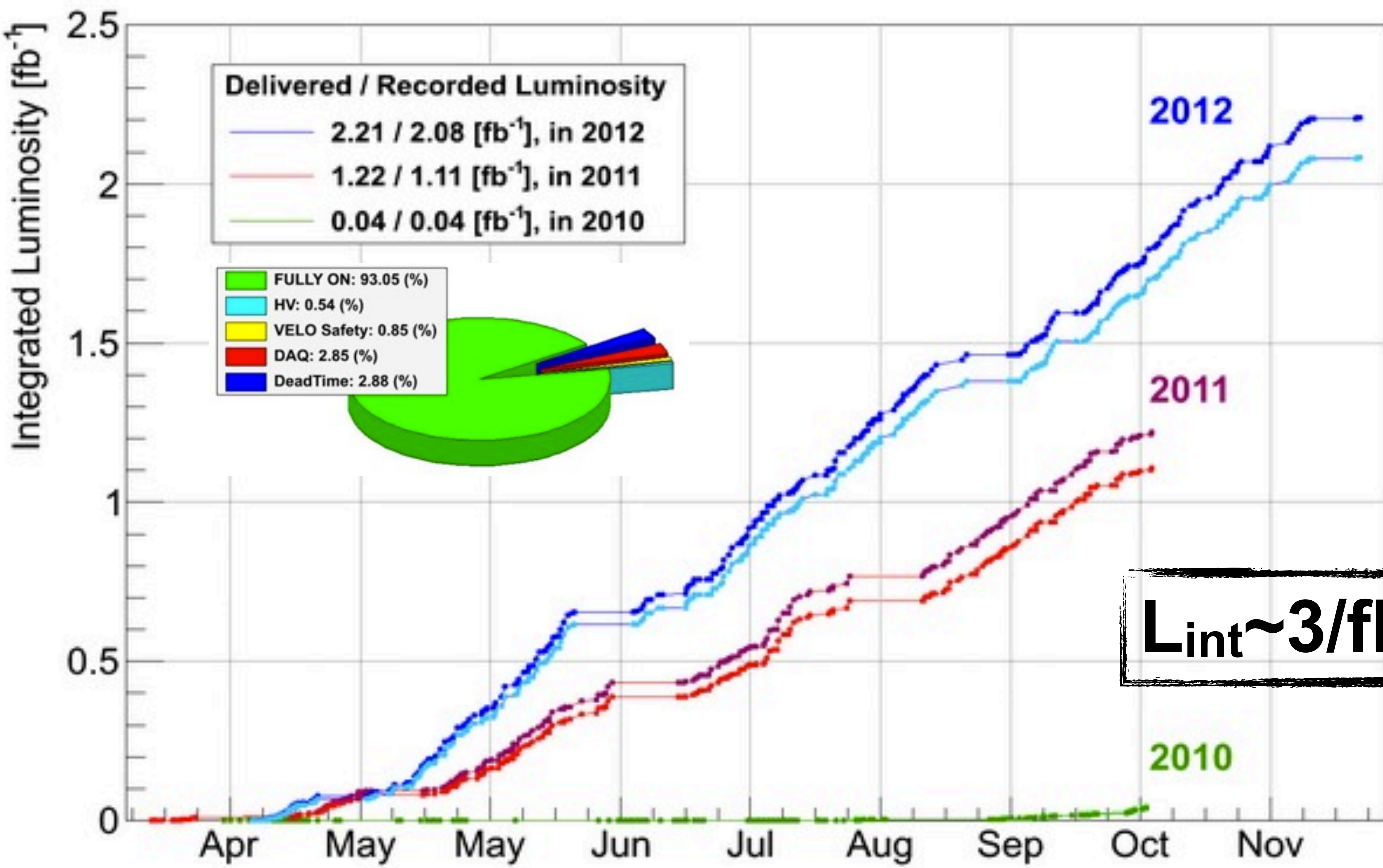
Muon system

LHCb Trigger



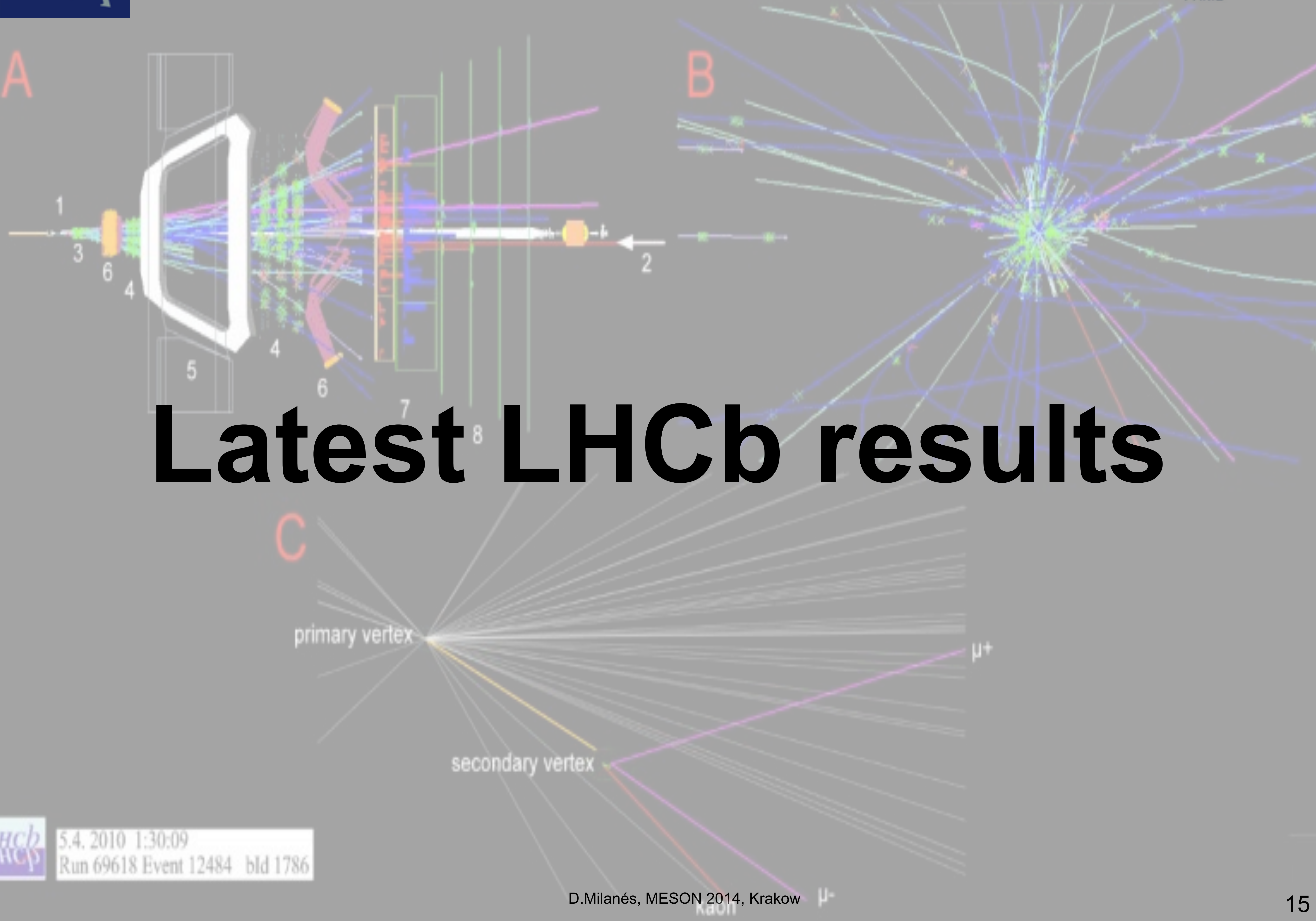
- ***Level-0 (L0)***
  - Hardware stage (1MHz readout)
    - selection of high E_T/p_T particles
      - $E_T(h)>3.5GeV/c$
      - $p_T(\mu)>1.5GeV/c$
      - $p_T(\mu_1)\times p_T(\mu_2) >(1.5GeV/c)^2$
      - ~30(90)% eff. hadron(dimuon)
- ***High level trigger (HLT)***
  - Software stage
    - HLT1: Tracking info and impact parameter cuts
    - HLT2: More complete tracking reconstruction and specific selections

LHCb data sample



L_{int}~3/fb

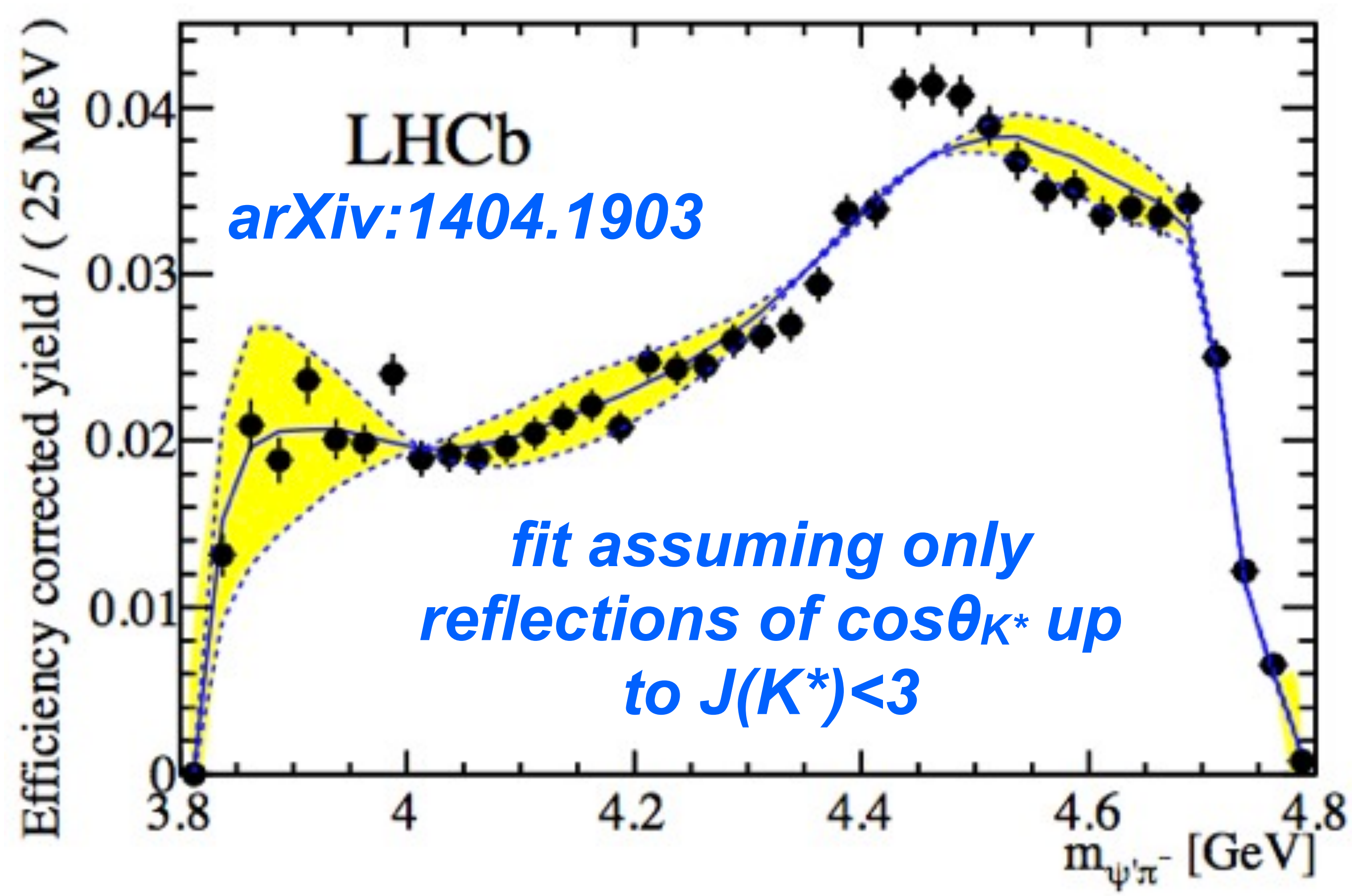
Latest LHCb results



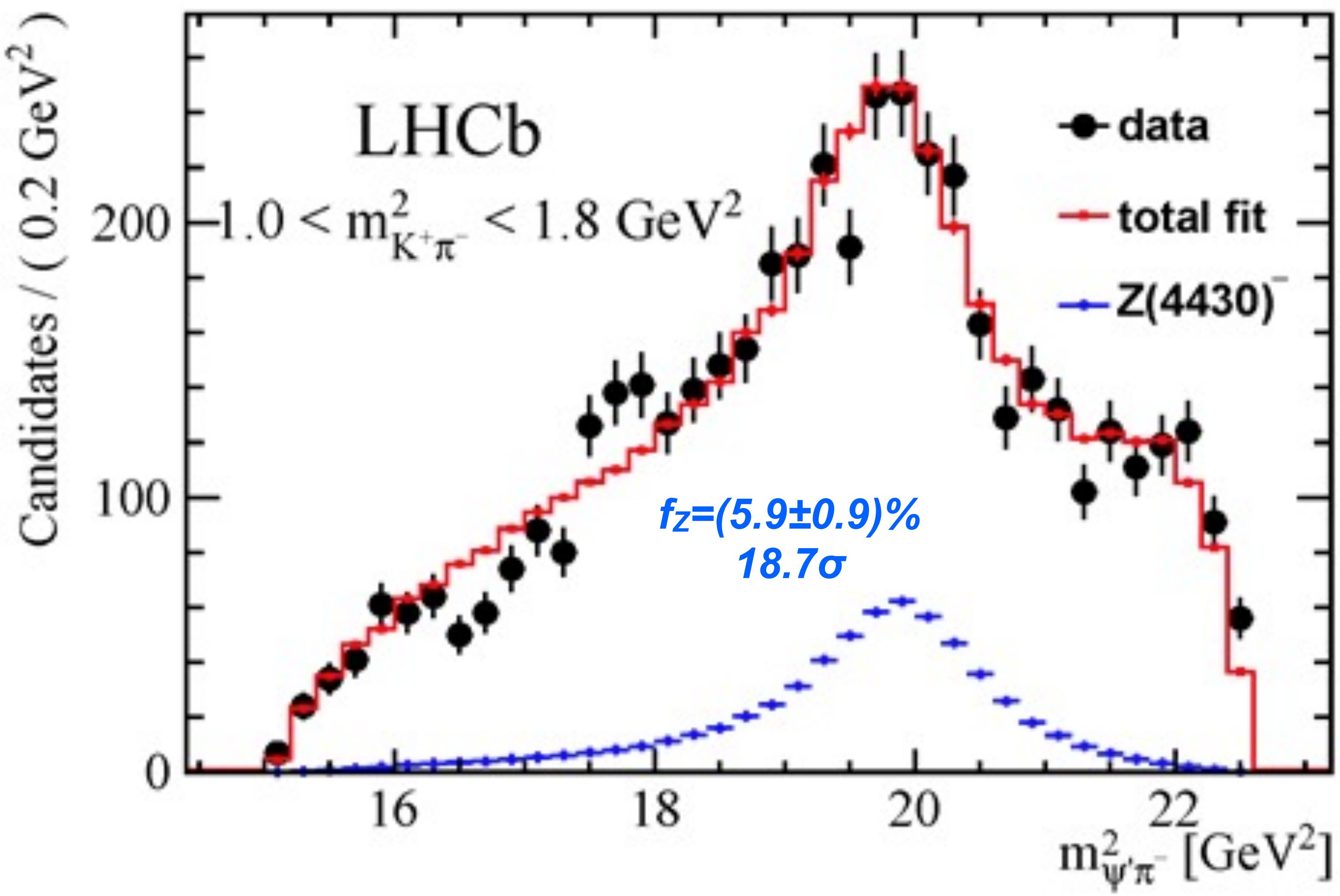
The Z(4430)$^-$ state

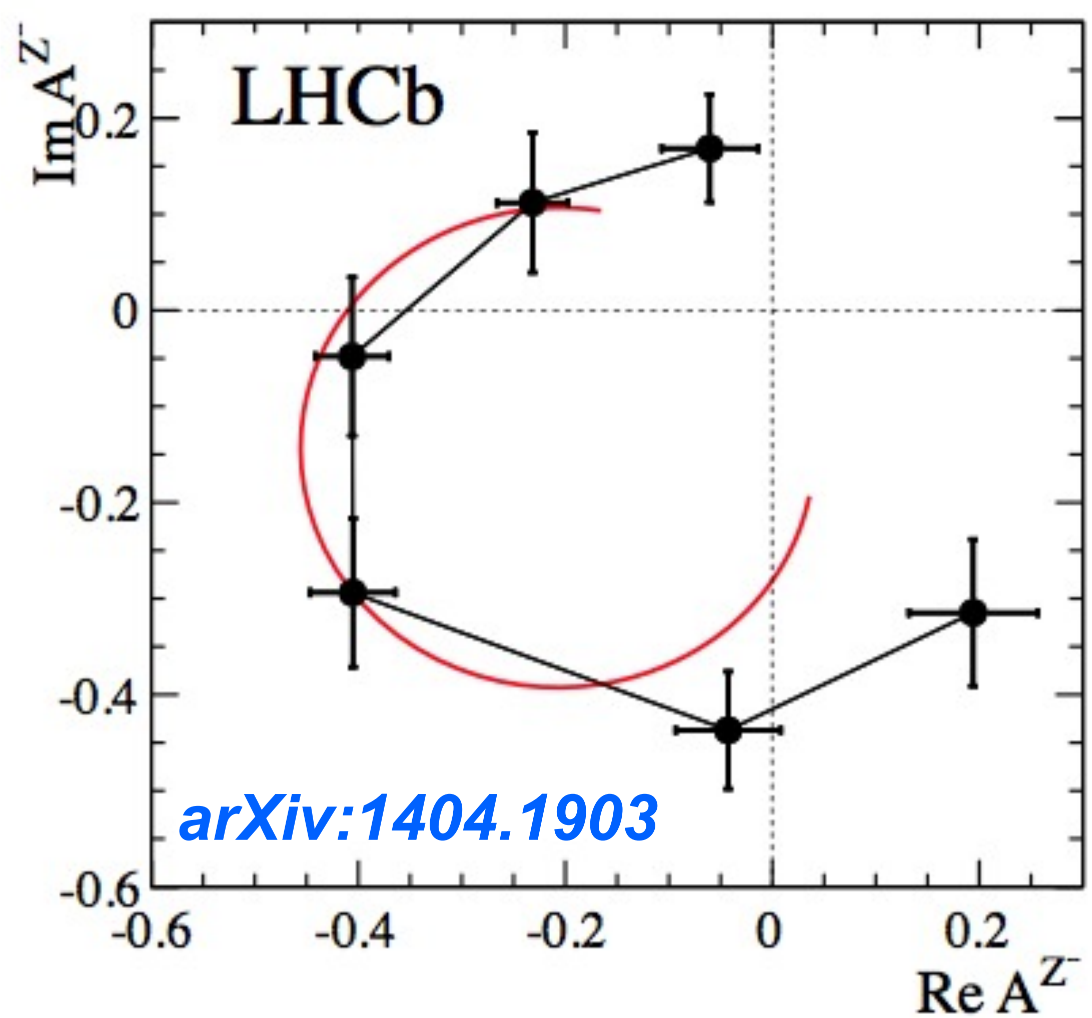
- Belle observed evidence for Z(4430)→ψ'π$^-$, in B→Kπ$^\pm$ψ' *[PRL100(2008)142001]*.
- Minimal quark content c$\bar{c}$d$\bar{u}$, implying the first evidence for an exotic state.
- It was never observed by BaBar. Spectra successfully explained using only K* reflections in a model independent analysis *[PRD79(2009)112001]*

- ***LHCb performed an angular and amplitude analysis of B^0→ψ'π$^-$K$^+$ decay (3/fb)***



The Z(4430)⁻ state



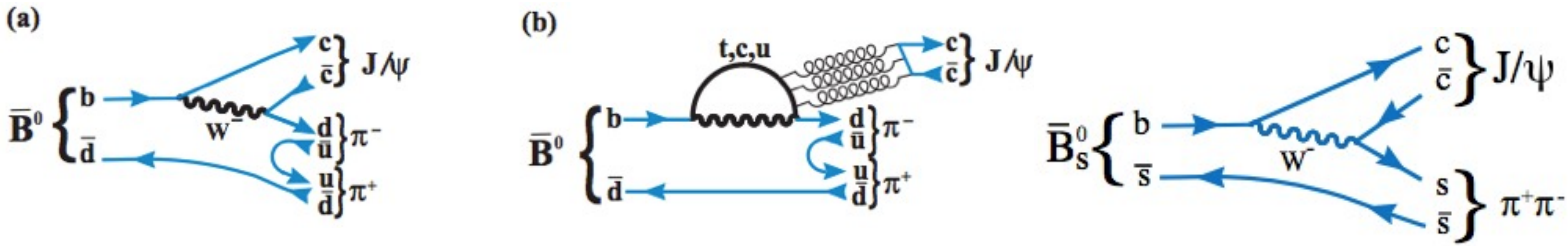


- ***Z(4430) compatible with 1⁺ spin-parity assignment with large statistical significance. Resonant behavior confirmed with Argand diagram.***
- Z(4430) parameters in agreement with Belle

$m(Z_1)$ = 4475 ± 7 $^{+15}_{-25}$ MeV
$\Gamma(Z_1)$ = 172 ± 13 $^{+37}_{-34}$ MeV

more details at M. Kreps talk

Structure of $\bar{B}_{(d,s)} \rightarrow J/\psi \pi^+\pi^-$



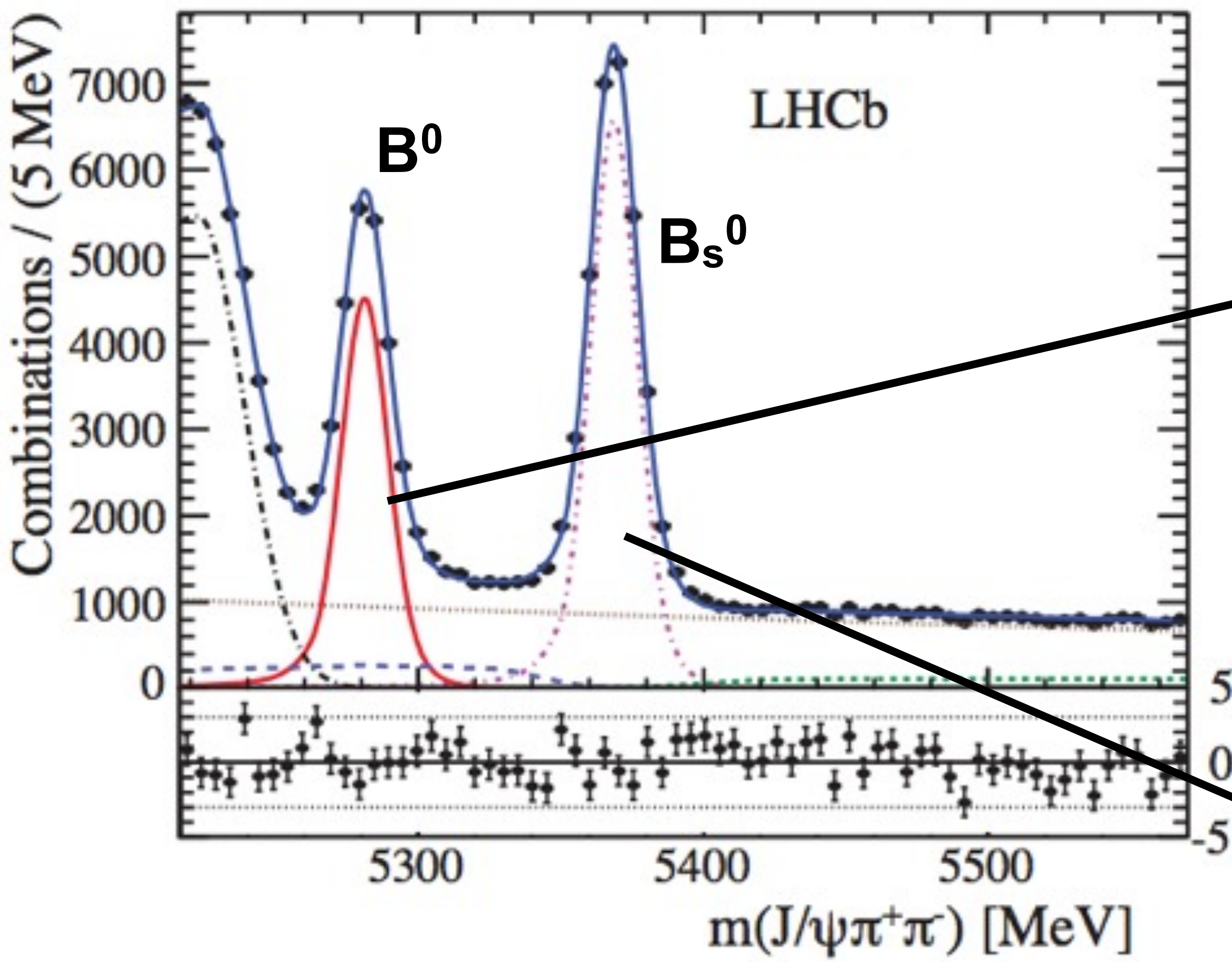
- Enhanced penguin over tree ratio wrt. $J/\psi K_S$. Important for CP violation studies
- Interesting ***light meson substructure in $\pi^+\pi^-$ system***, in particular the study of $f_0(500)$ and $f_0(980)$ nature, long time discussed to be candidates for exotic states ($ud\bar{u}\bar{d}$ and $su\bar{s}\bar{u}$).
- ***LHCb measured the resonant substructure of the decay with a modified amplitude analysis, adding information from angular observables (3/fb)***

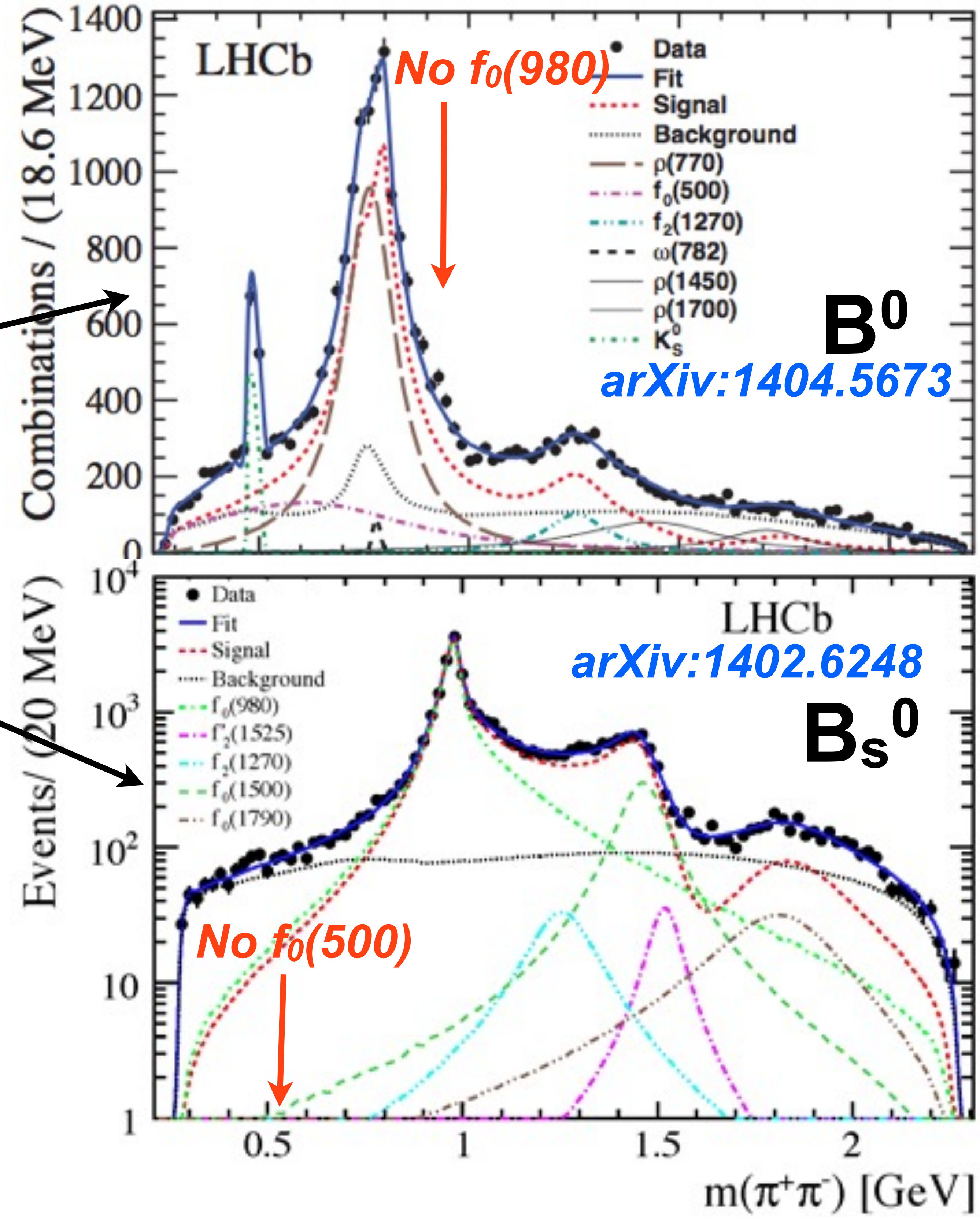
arXiv:1402.6248
arXiv:1404.5673

[*PRL111(2013)062001*]

	$q\bar{q}$	tetraquark
$\frac{\Gamma(\bar{B}^0 \to J/\psi f_0)}{\Gamma(\bar{B}^0_s \to J/\psi f_0)} = \frac{\lvert F^{f_0}_{B^0}(m^2_{J/\psi})\rvert^2}{\lvert F^{f_0}_{B^0_s}(m^2_{J/\psi})\rvert^2} \frac{\lvert V_{cd}\rvert^2 \Phi^{f_0}_{B^0}}{\lvert V_{cs}\rvert^2 \Phi^{f_0}_{B^0_s}}$	$\frac{1}{2}\tan^2\phi$	$\frac{1}{4}$
$\frac{\Gamma(\bar{B}^0 \to J/\psi f_0)}{\Gamma(\bar{B}^0 \to J/\psi \sigma)} = \frac{\lvert F^{f_0}_{B^0}(m^2_{J/\psi})\rvert^2}{\lvert F^{\sigma}_{B^0}(m^2_{J/\psi})\rvert^2} \frac{\Phi^{f_0}_{B^0}}{\Phi^{\sigma}_{B^0}}$	$\tan^2\phi$	$\frac{1}{2}$
$\frac{\Gamma(\bar{B}^0_s \to J/\psi \sigma)}{\Gamma(\bar{B}^0_s \to J/\psi f_0)} = \frac{\lvert F^{\sigma}_{B^0_s}(m^2_{J/\psi})\rvert^2}{\lvert F^{f_0}_{B^0_s}(m^2_{J/\psi})\rvert^2} \frac{\Phi^{\sigma}_{B^0_s}}{\Phi^{f_0}_{B^0_s}}$	$\tan^2\phi$	0
$\frac{\Gamma(\bar{B}^0_s \to J/\psi f_0)}{\Gamma(\bar{B}^0 \to J/\psi \sigma)} = \frac{\lvert F^{f_0}_{B^0_s}(m^2_{J/\psi})\rvert^2}{\lvert F^{\sigma}_{B^0}(m^2_{J/\psi})\rvert^2} \frac{\lvert V_{cs}\rvert^2 \Phi^{f_0}_{B^0_s}}{\lvert V_{cd}\rvert^2 \Phi^{\sigma}_{B^0}}$	2	2

Structure of $\bar{B}_{(d,s)} \rightarrow J/\psi\pi^+\pi^-$

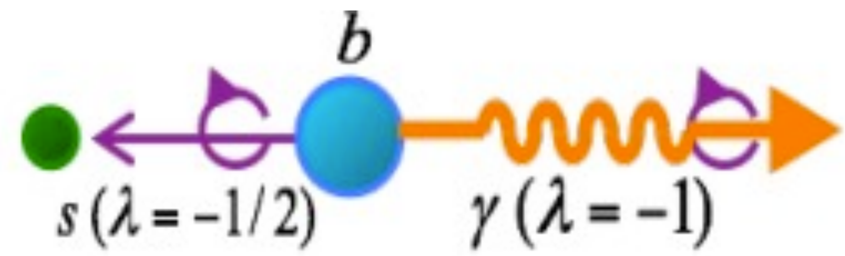


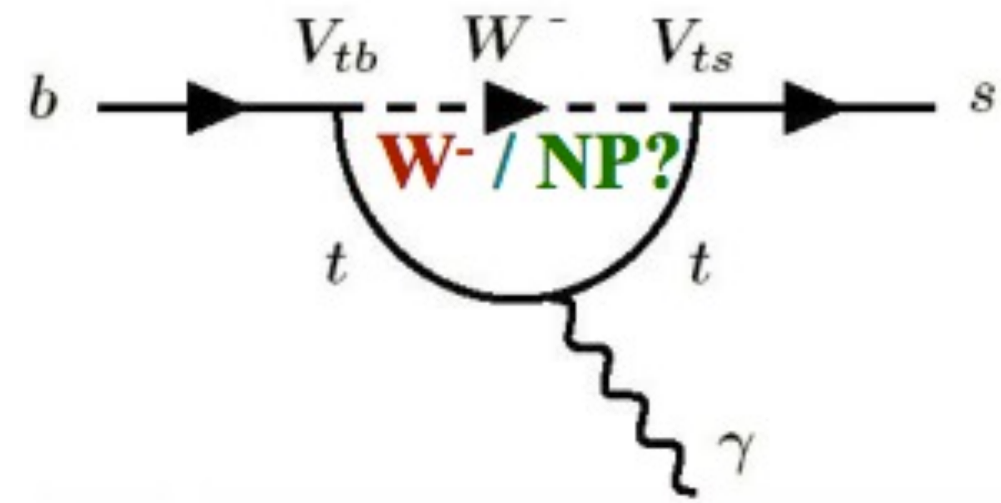


- ***LHCb data disfavors tetra-quark hypothesis for the light scalar meson substructure at about 8σ***

Photon polarization in $b \to s\gamma$

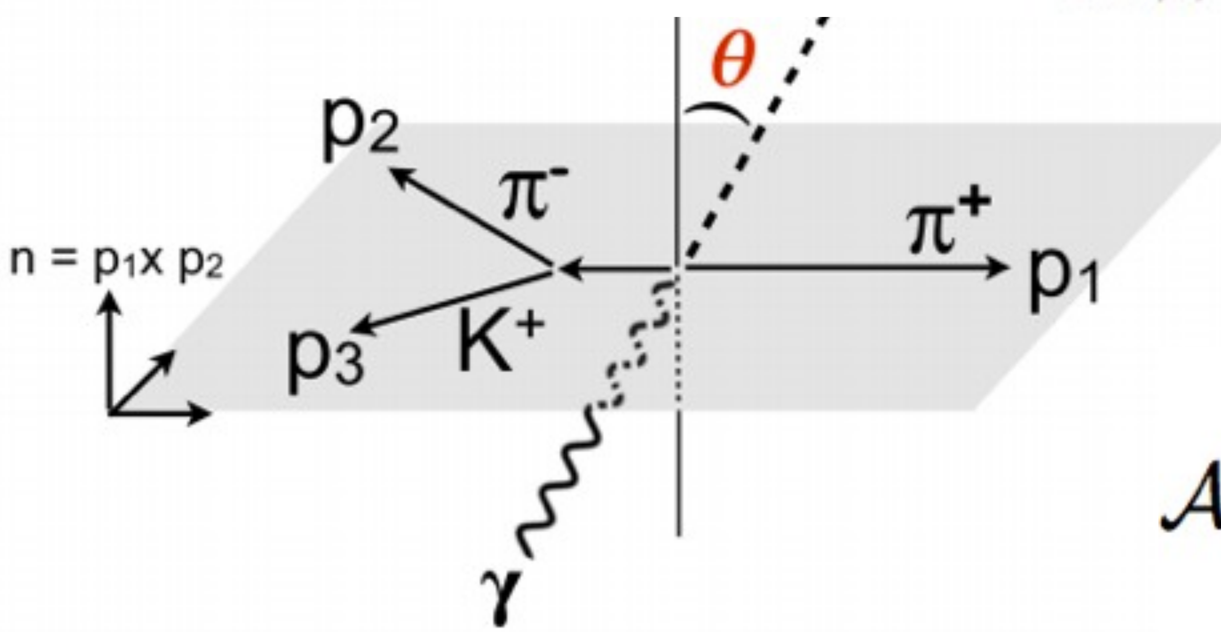
- SM: Photon from $b \to s\gamma$ is predominantly left-handed
- SM extensions predict right-handed polarization *[PRL79(1997)185]*.
- Measured inclusive $b \to s\gamma$ rate in agreement with SM, however no evidence of non-zero photon polarization *[PDG, PRD86(2012)010001]*





$B^+ \to K^+\pi^+\pi^-\gamma$

$$\frac{d\Gamma}{ds\, ds_{13}\, ds_{23}\, d\cos\theta} \propto \sum_{i=0,2,4} a_i(s, s_{13}, s_{23}) \cos^i\theta + \lambda_\gamma \sum_{j=1,3} a_j(s, s_{13}, s_{23}) \cos^j\theta$$



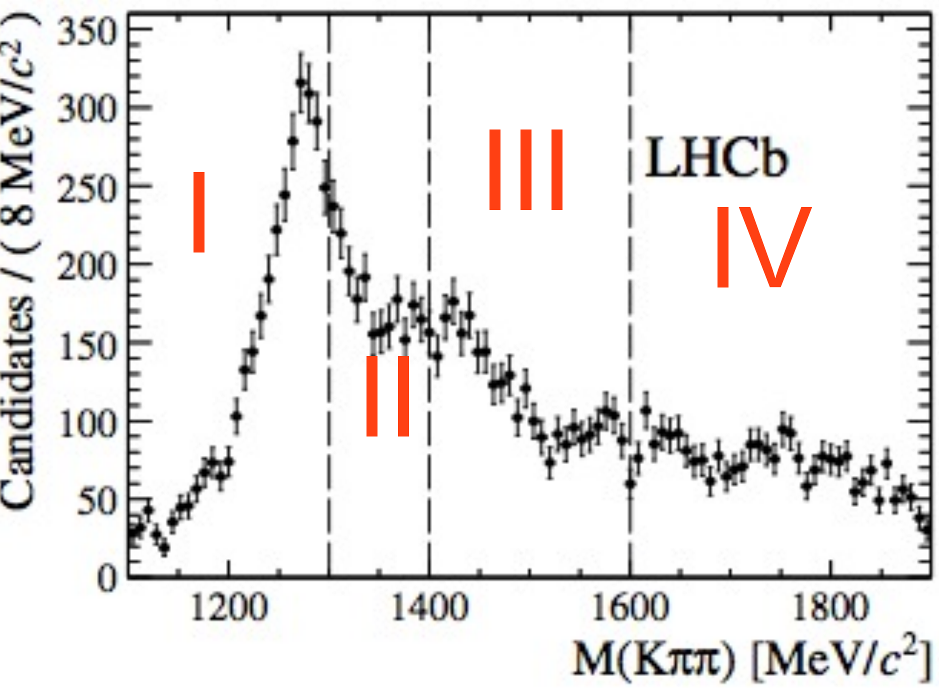
LHCb performed an analysis of $B^+ \to K^+\pi^+\pi^-\gamma$ decays (3/fb) and measures the up-down asymmetry, proportional to λ_γ

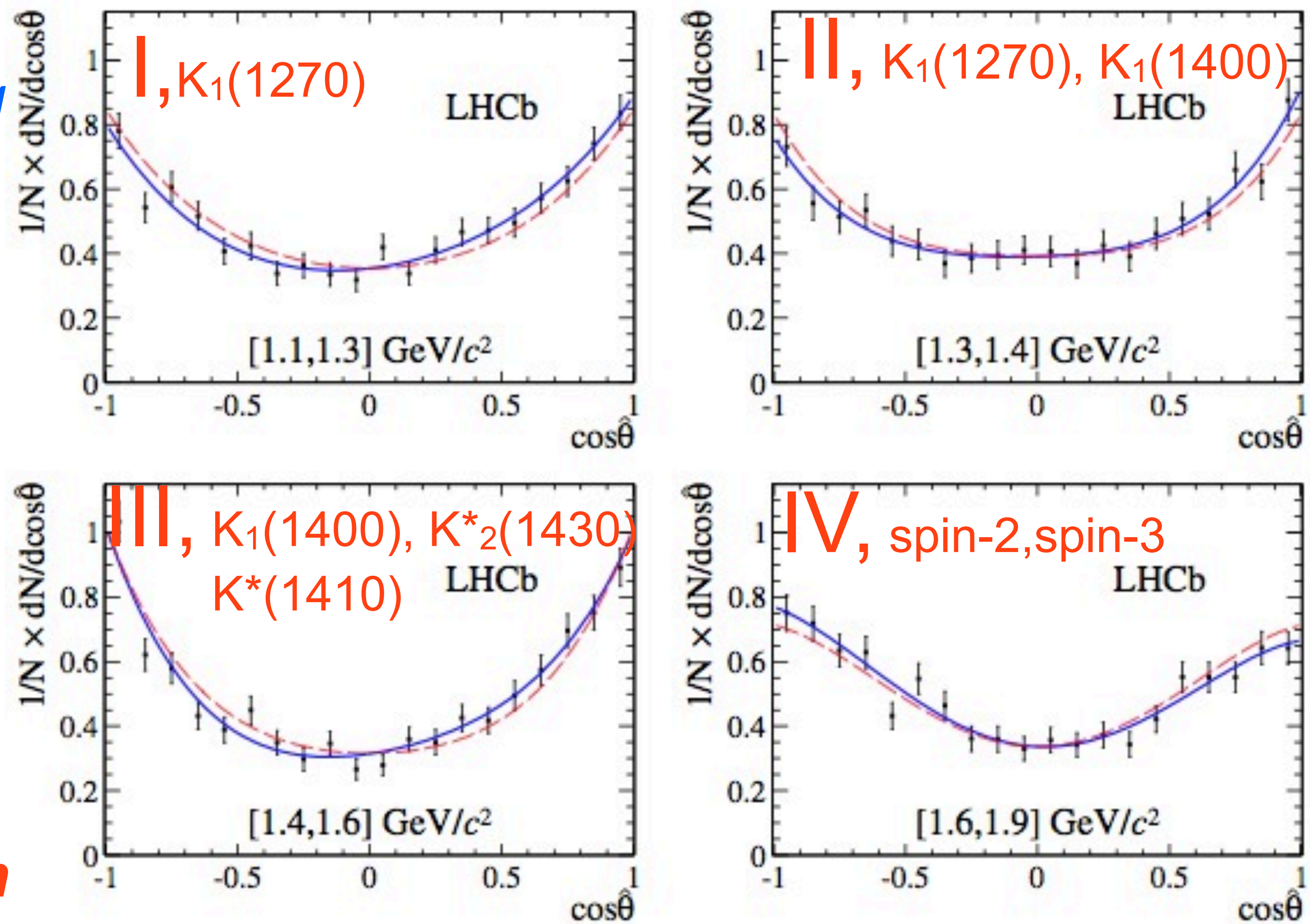
$$\mathcal{A}_{ud} \equiv \frac{\int_0^1 d\cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 d\cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 d\cos\theta \frac{d\Gamma}{d\cos\theta}}$$

Photon polarization in b→sγ

All Legendre polynomials
Even Legendre polynomials

Phys.Rev.Lett. 112 (2014) 161801

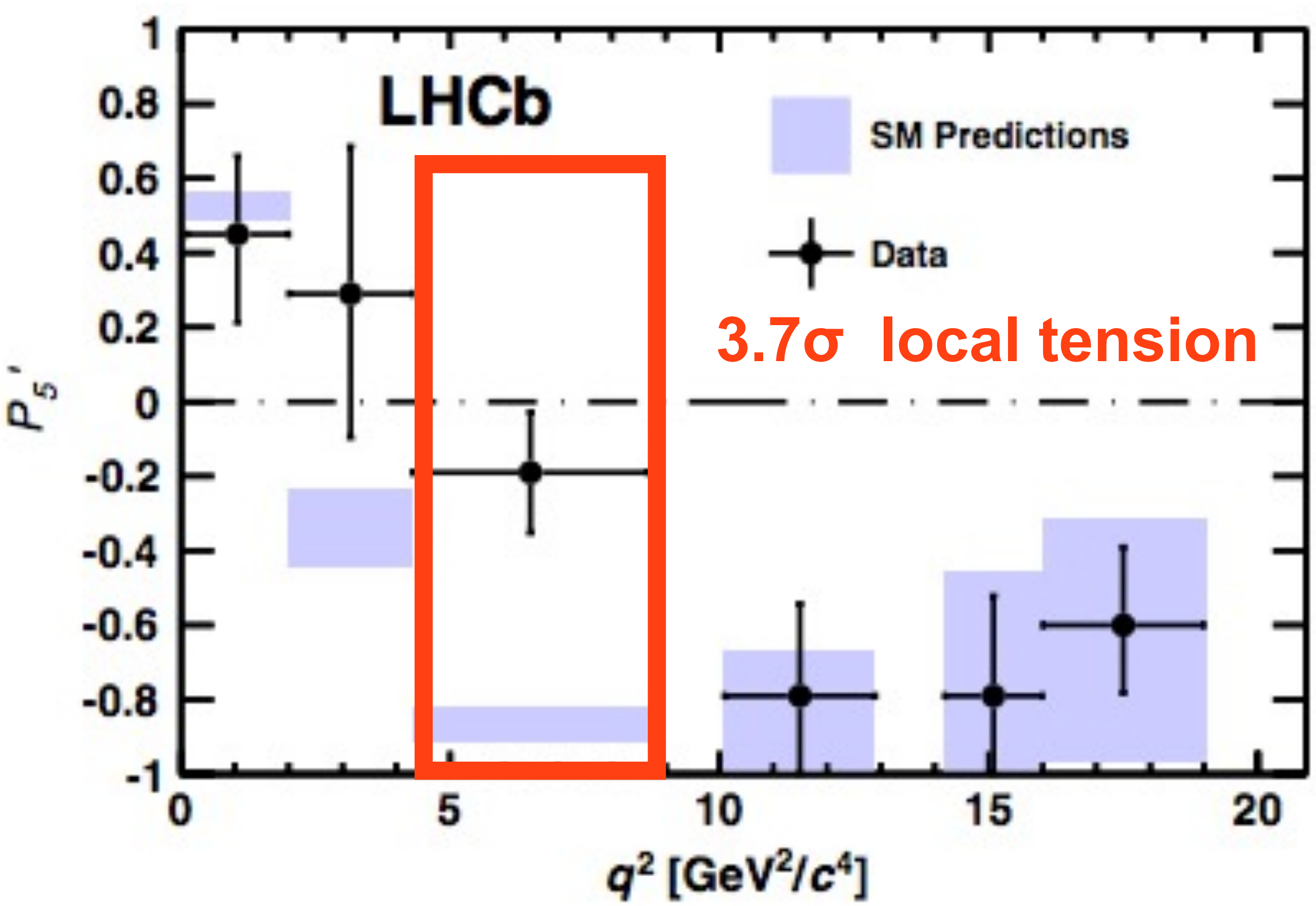




First observation of a parity-violating photon polarization different from zero (5.2σ combined significance)

	I	II	III	IV
$\mathcal{A}_{ud}$	6.9±1.7	4.9±2.0	5.6±1.8	−4.5±1.9

$B \to K^{(*)}\mu^+\mu^-$



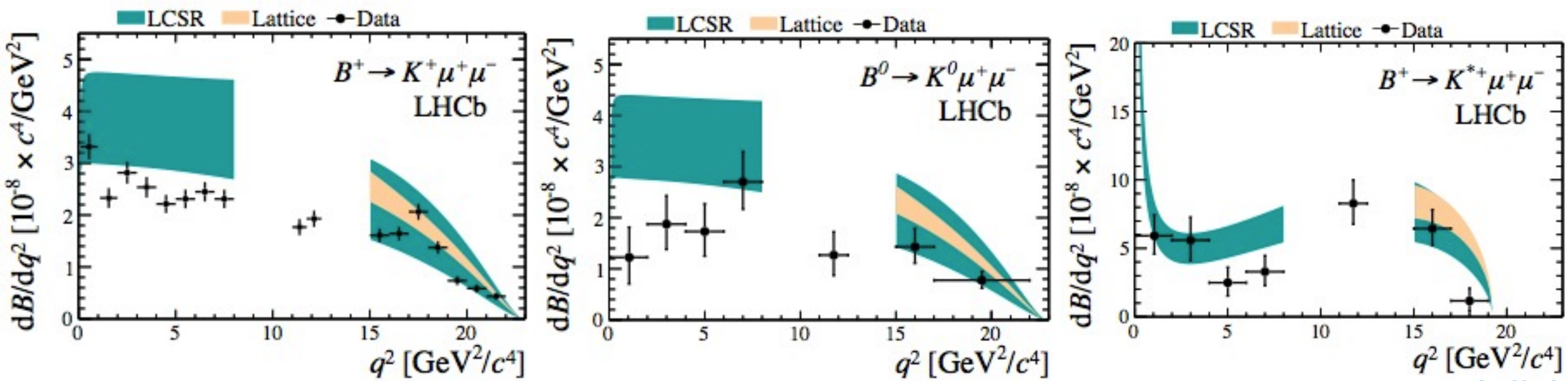
1/fb results, *PRL111 (2013) 191801*
3/fb analysis in preparation!

- ***Excellent scenario to test the loop induced $b \to s$ transitions***
- Sensitive to indirect searches for new physics
- Large set of observables, mostly compatible with SM, but ***some local tension observed by LHCb in P_5'***, from an angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$ decays.
- Underestimation of theoretical uncertainties. ***[arXiv:1310.2478, arXiv:1212.2263]***
- Difficult to explain with SUSY scenarios ***[Altmannshofer, et. al. arXiv:1308.1501]***
- Consistent with Z' with 7TeV mass (!) ***[JHEP1401(2014)069, arXiv:1311.6729]***

➡ ***Necessary to study other $b \to s\mu\mu$ decays and look for more observables!***

Differential BF $B \to K^{(*)}\mu^+\mu^-$

$$\frac{d\mathcal{B}}{dq^2} = \frac{N(B\to K^{(*)}\mu^+\mu^-)}{N(B\to J/\psi K^{(*)})}\cdot\frac{\varepsilon(B\to J/\psi K^{(*)})}{\varepsilon(B\to K^{(*)}\mu^+\mu^-)}\cdot\frac{\mathcal{B}(B\to J/\psi K^{(*)})\mathcal{B}(J/\psi\to\mu^+\mu^-)}{(q^2_{\max}-q^2_{\min})}$$



arXiv:1403.8044 (3/fb)

Theory predictions: [Ball, Zwicky Phys. Rev. D71 (2005) 014029; A. Khodjamirian et al., JHEP 09 (2010) 089, M. Beneke et al., Nucl. Phys. B612 (2001) 25, Eur. Phys. J. C41 (2005) 173; C. Bobeth et al., JHEP 12 (2007) 040, B. Grinstein and D. Pirjol, Phys. Rev. D70 (2004) 114005, U. Egede et al., JHEP 11 (2008) 032]

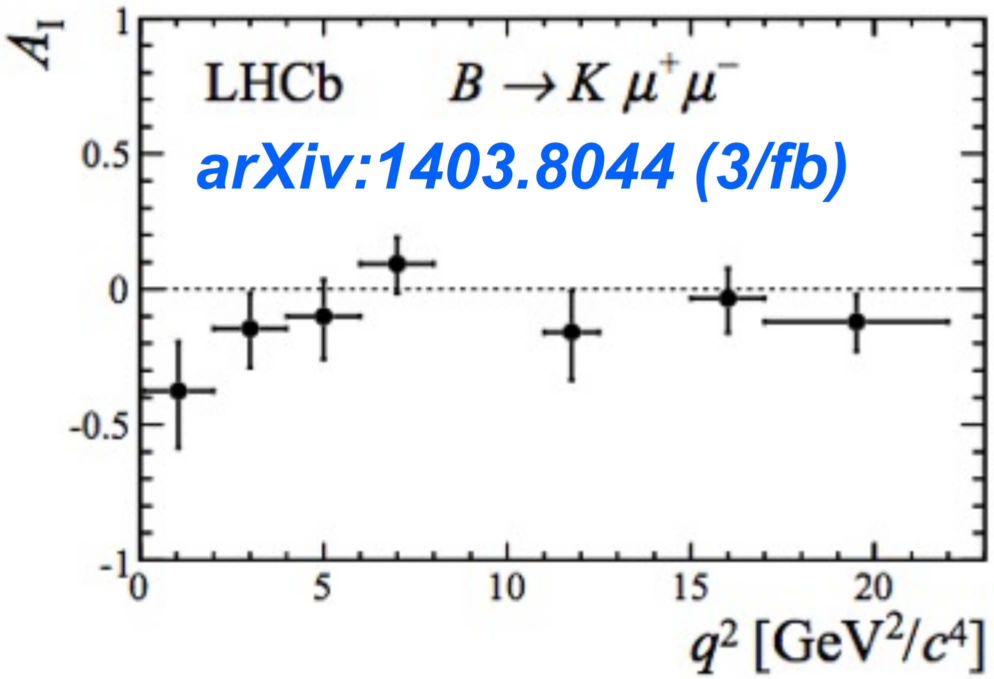
Lattice predictions : [C. Bouchard et al., Phys. Rev. D88 (2013) 054509; R. R. Horgan et al., arXiv: 1310.3722]

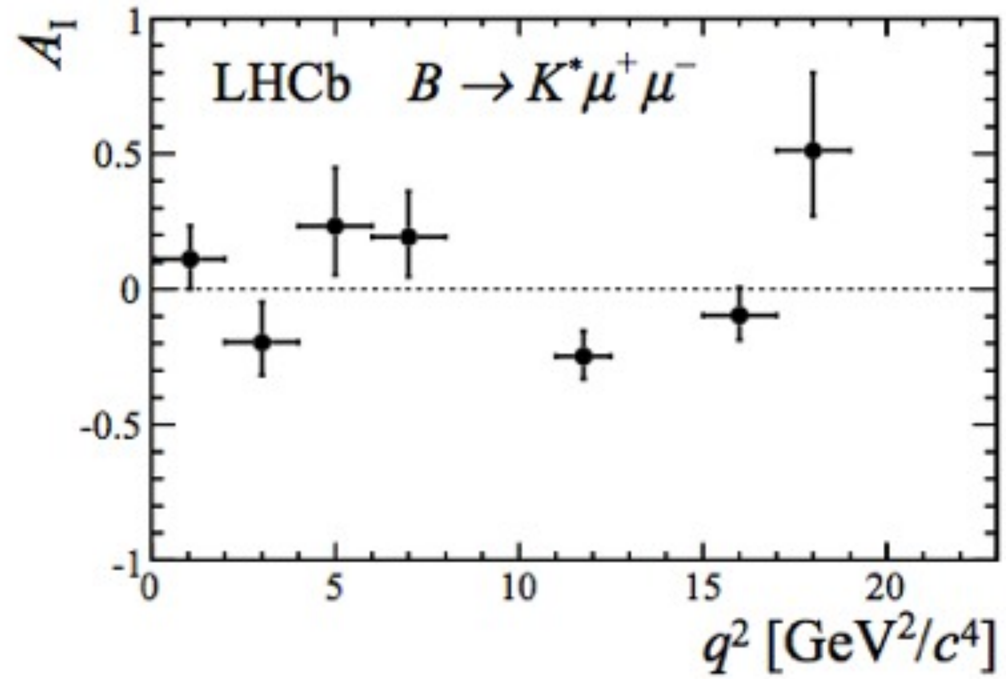
$$\mathcal{B}(B^+\to K^+\mu^+\mu^-) = (4.29\pm0.07\,(\text{stat})\pm0.21\,(\text{syst}))\times10^{-7}$$
$$\mathcal{B}(B^0\to K^0\mu^+\mu^-) = (3.27\pm0.34\,(\text{stat})\pm0.17\,(\text{syst}))\times10^{-7}$$
$$\mathcal{B}(B^+\to K^{*+}\mu^+\mu^-) = (9.24\pm0.93\,(\text{stat})\pm0.67\,(\text{syst}))\times10^{-7}$$

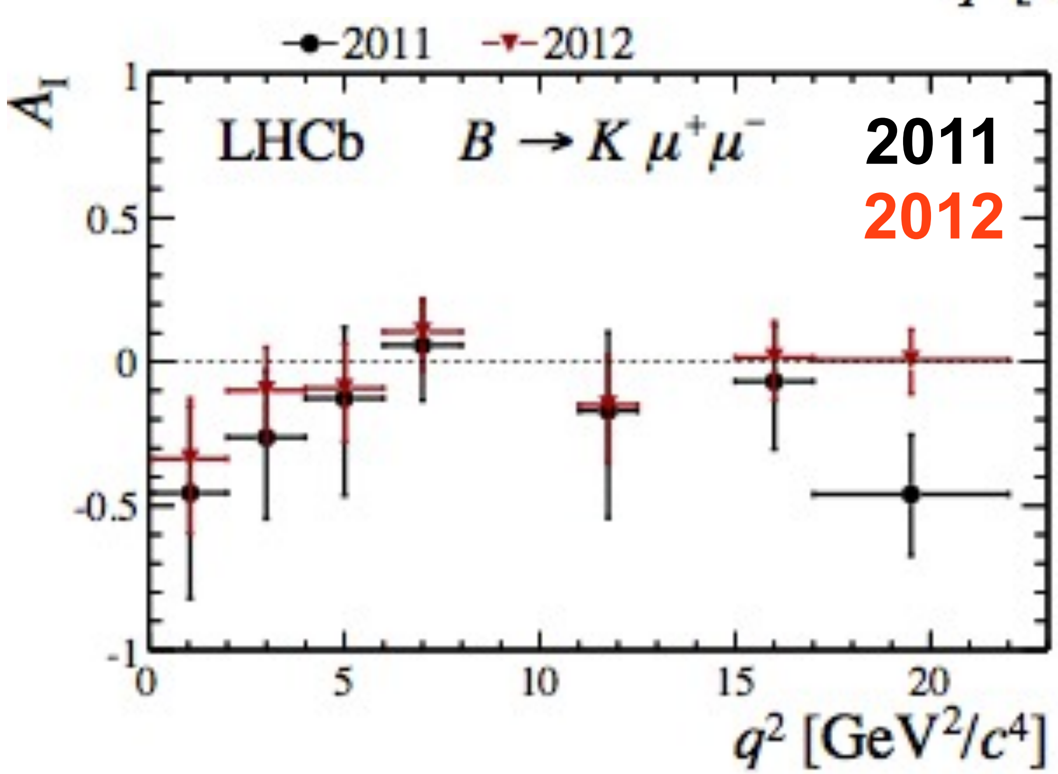
Although no large deviations from predictions observed, 3/fb of LHCb data reports systematically a smaller differential branching fraction than expected

Isospin asymmetries $B \to K^{(*)}\mu^+\mu^-$

$$A_I = \frac{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) - \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) + \frac{\tau_0}{\tau_+}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}$$





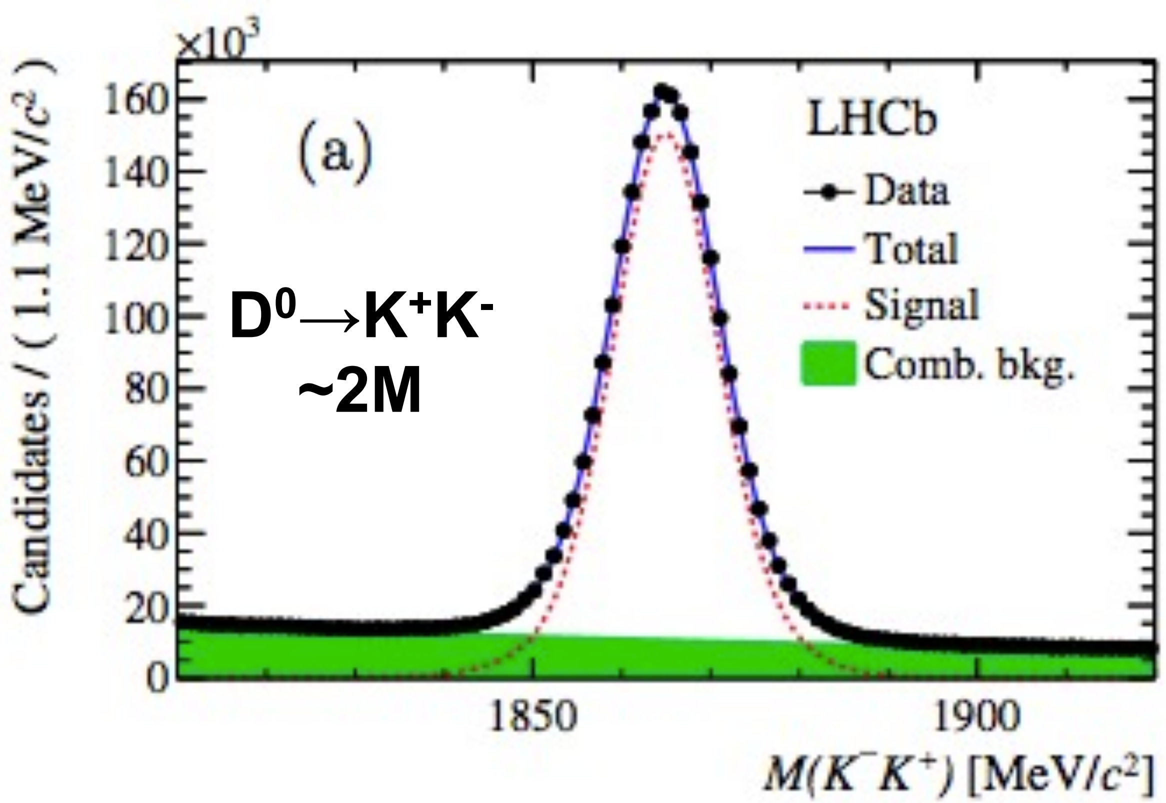


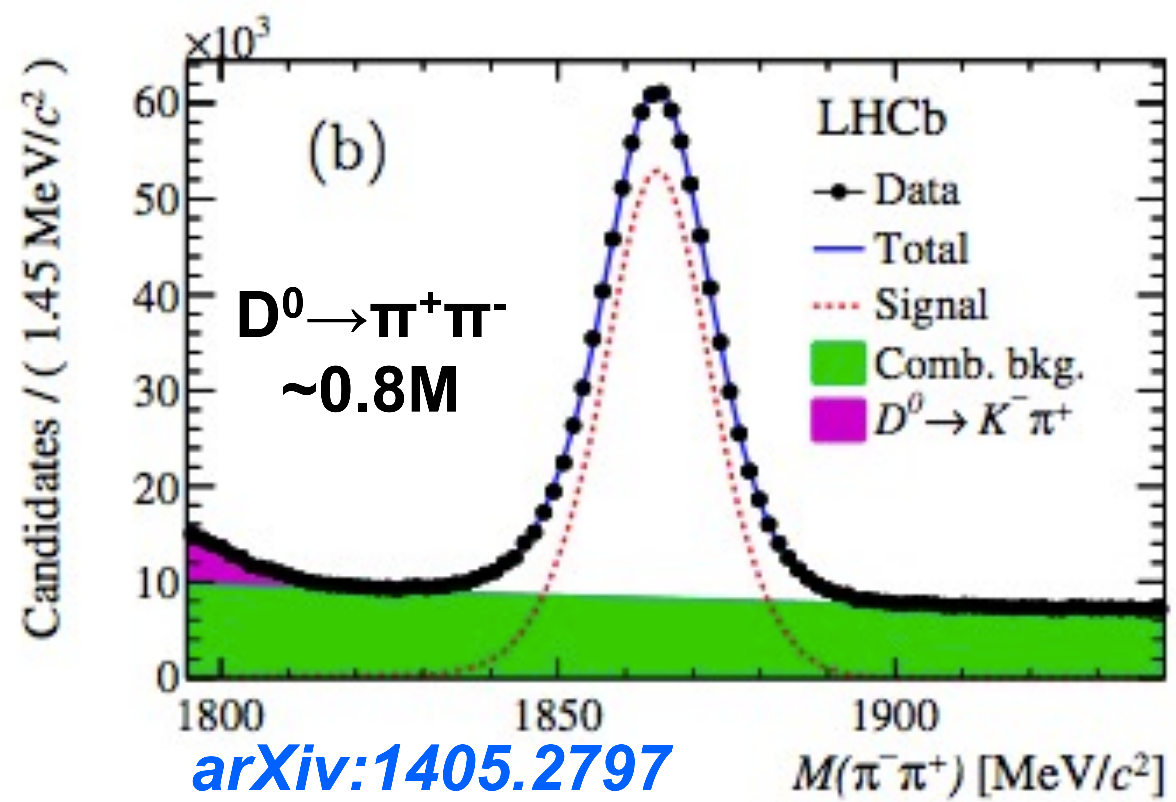
Global tension observed in 2011 data, non zero A_I at 4.4σ [JHEP 07(2012)33], is reduced by adding 2012 data. Agreement with SM predictions (1.5σ)

Angular analysis of $B \to K\mu^+\mu^-$ presented in arXiv:1403.8045

A_{CP} and ΔA_{CP} in $D^0 \to hh$ decays

- CP violation in charm system predicted to be small within the SM, but it could be enhanced in the presence of new physics
- *CP violation not observed up to date in the charm system*
- Difference of CP asymmetries (ΔA_{CP}) in $D^0 \to h^+h^-$ previously measured by LHCb
  [PRL108(2012)111602 (0.6/fb from D*), PLB723(2013)33 (1/fb from B)]
- ***LHCb measured ΔA_{CP} using SCS $D^0 \to K^+K^-, \pi^+\pi^-$ decays, produced in semileptonic B decays (3/fb). Flavour of the D-meson is tagged using the charge of the muon produced in the reaction $B \to D^0 \mu^+ \nu_\mu X$***





arXiv:1405.2797

A_{CP} and ΔA_{CP} in $D^0 \to hh$ decays

$$A_{\rm raw} \equiv \frac{N(D \to f) - N(\overline{D} \to \overline{f})}{N(D \to f) + N(\overline{D} \to \overline{f})} = A_{CP} + A_D(\mu^-) + A_P(\overline{B})$$

$$\Delta A_{CP} = A_{\rm raw}(K^-K^+) - A_{\rm raw}(\pi^-\pi^+) = A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$$

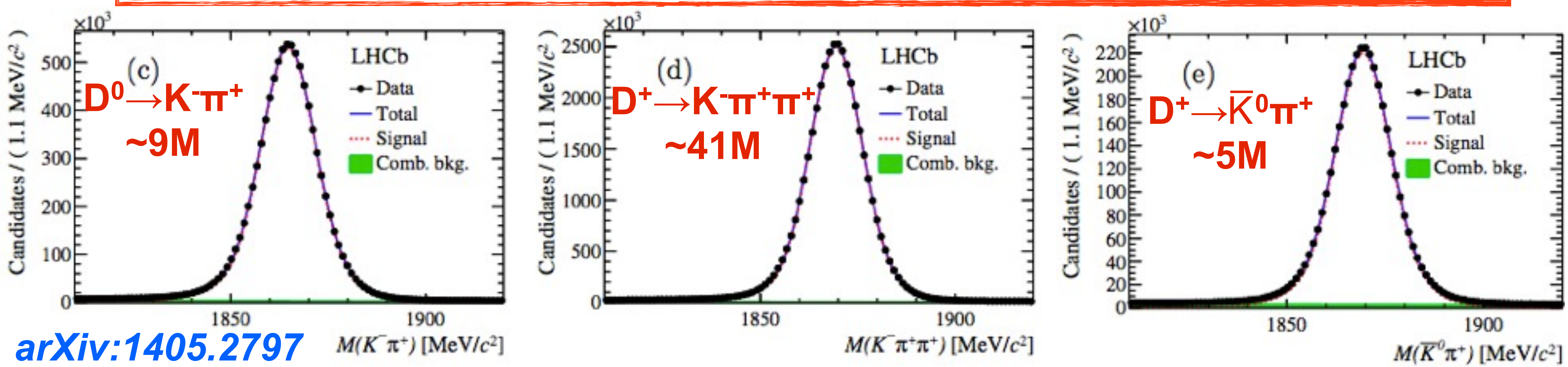
$$A_{\rm raw}(K^-\pi^+) = A_D(\mu^-) + A_P(\overline{B}) + A_D(K^-\pi^+)$$ $D^0 \to K^-\pi^+$ from B

$$A_{\rm raw}(K^-\pi^+\pi^+) = A_P(D^+) + A_D(K^-\pi^+) + A_D(\pi^+)$$ $D^+ \to K^-\pi^+\pi^+$ prompt

$$A_{\rm raw}(\overline{K}^0\pi^+) = A_P(D^+) + A_D(\pi^+) - A_D(K^0)$$ $D^+ \to \overline{K}^0\pi^+$ prompt

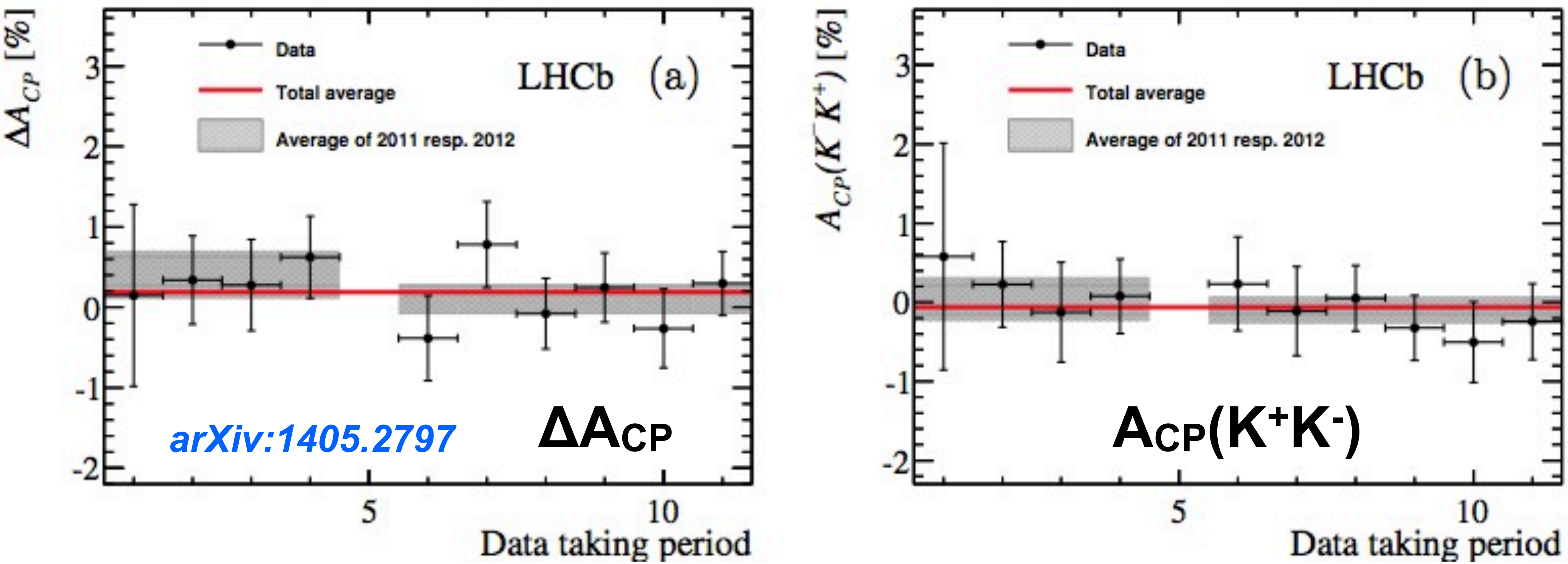
$$A_D(K^-\pi^+) = A_{\rm raw}(K^-\pi^+\pi^+) - A_{\rm raw}(\overline{K}^0\pi^+) - A_D(K^0)$$

$$A_{CP}(K^-K^+) = A_{\rm raw}(K^-K^+) - A_{\rm raw}(K^-\pi^+) + A_D(K^-\pi^+)$$



arXiv:1405.2797

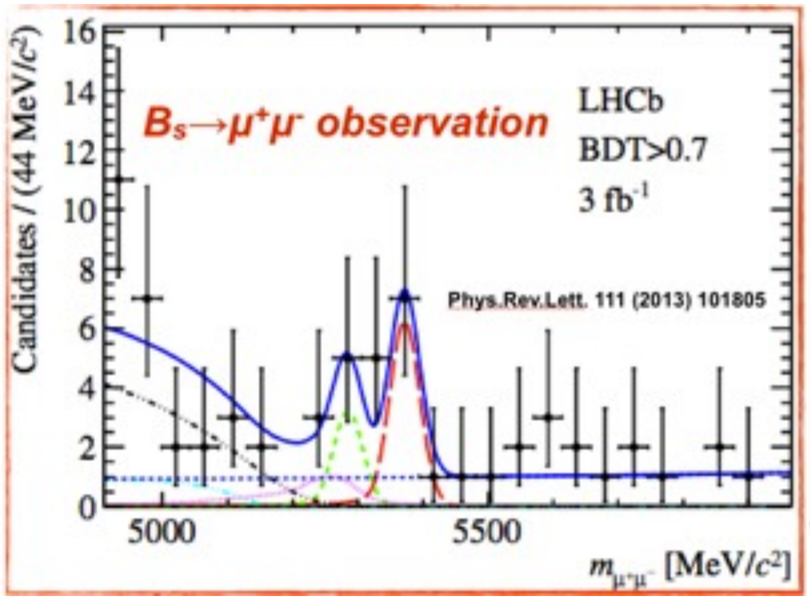
A_{CP} and ΔA_{CP} in $D^0 \to hh$ decays

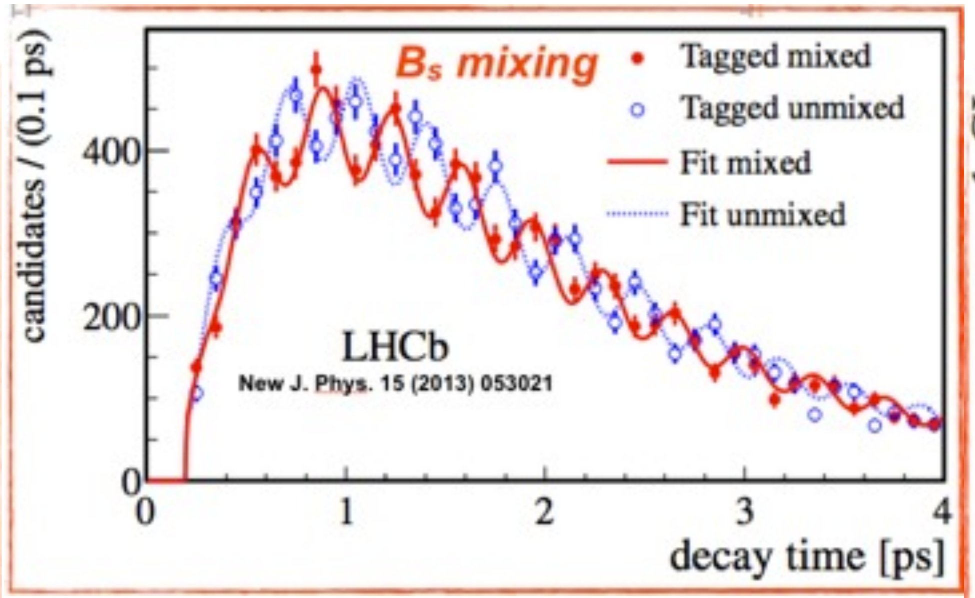


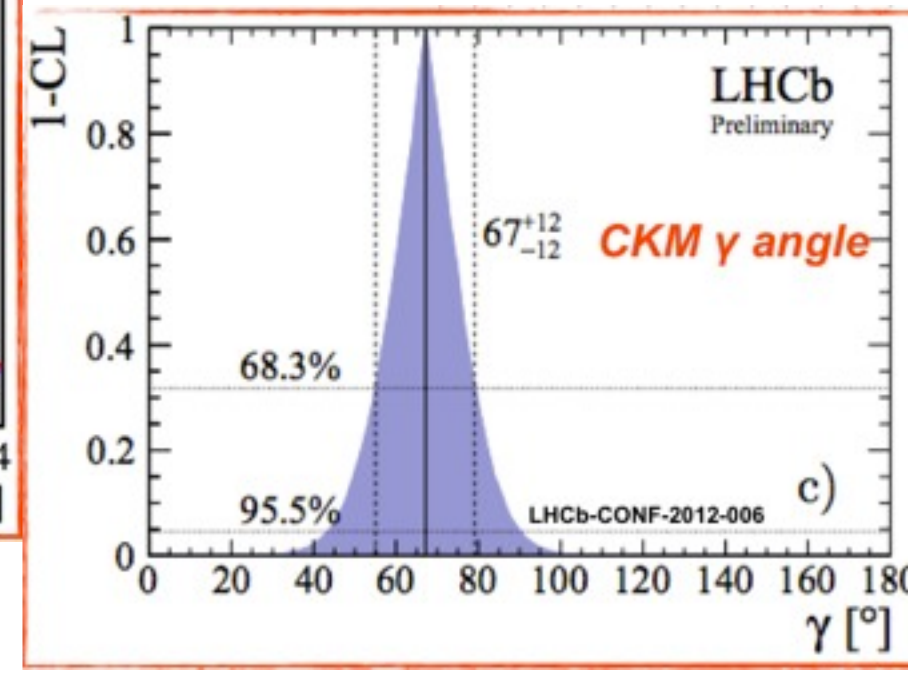
$$\Delta A_{CP} = (+0.14 \pm 0.16\,(\text{stat}) \pm 0.08\,(\text{syst}))\%$$
$$A_{CP}(K^-K^+) = (-0.06 \pm 0.15\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$$
$$A_{CP}(\pi^-\pi^+) = (-0.20 \pm 0.19\,(\text{stat}) \pm 0.10\,(\text{syst}))\%$$

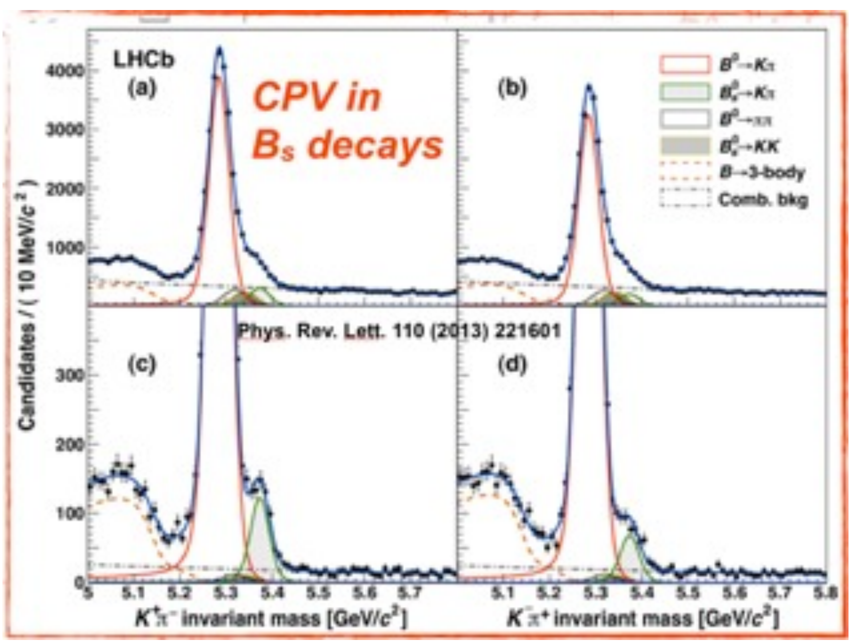
No observation of CPV at the level of 10^{-3}. Most precise measurement of time-integrated CP asymmetries, in charm, from a single experiment

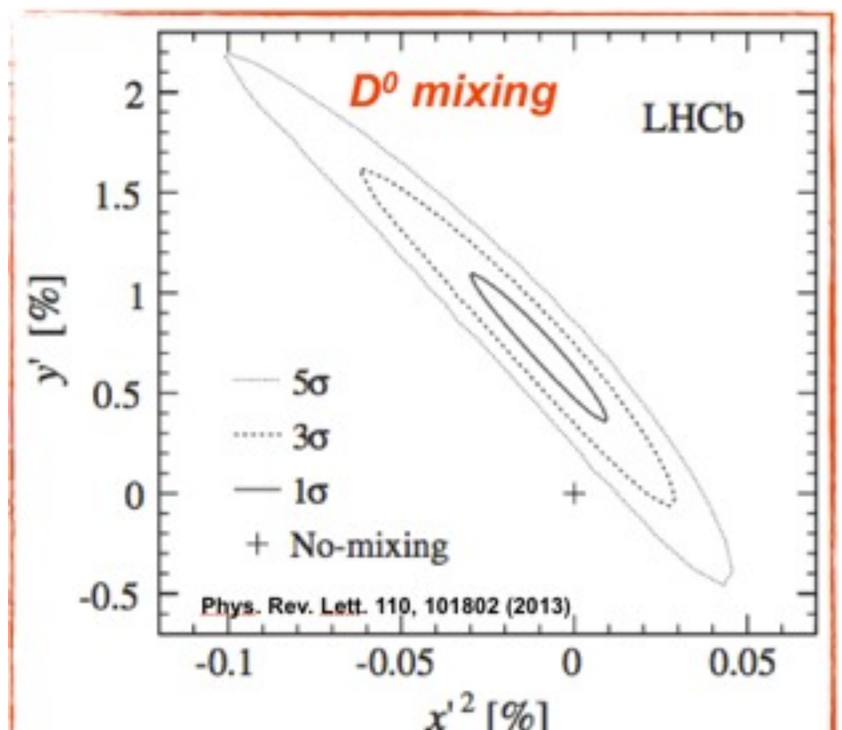
and much more!

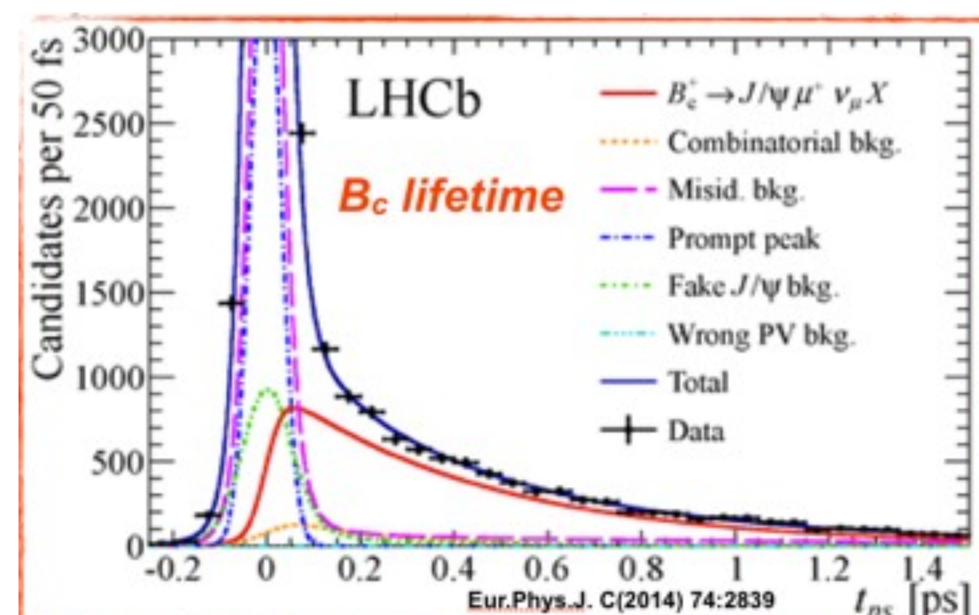




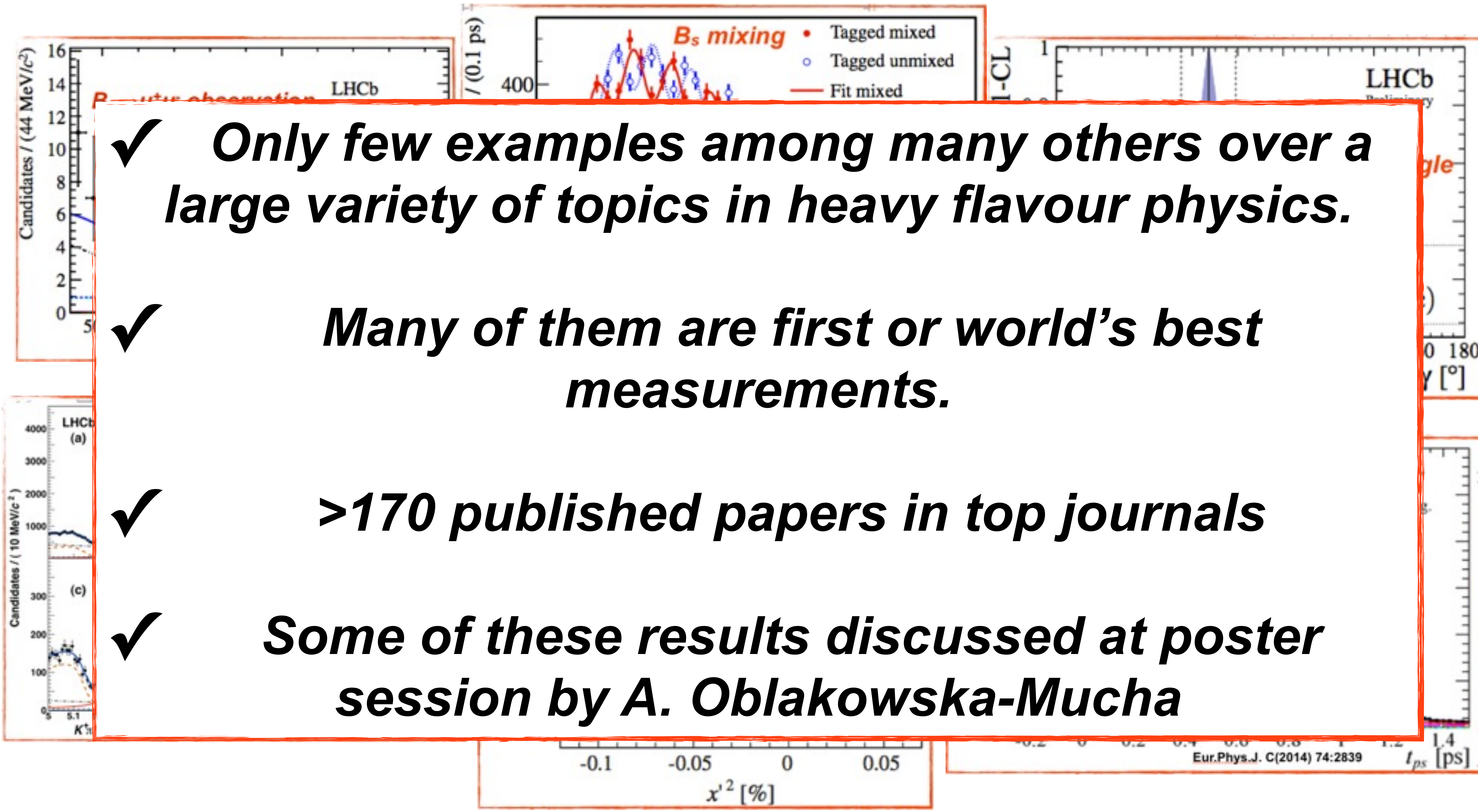






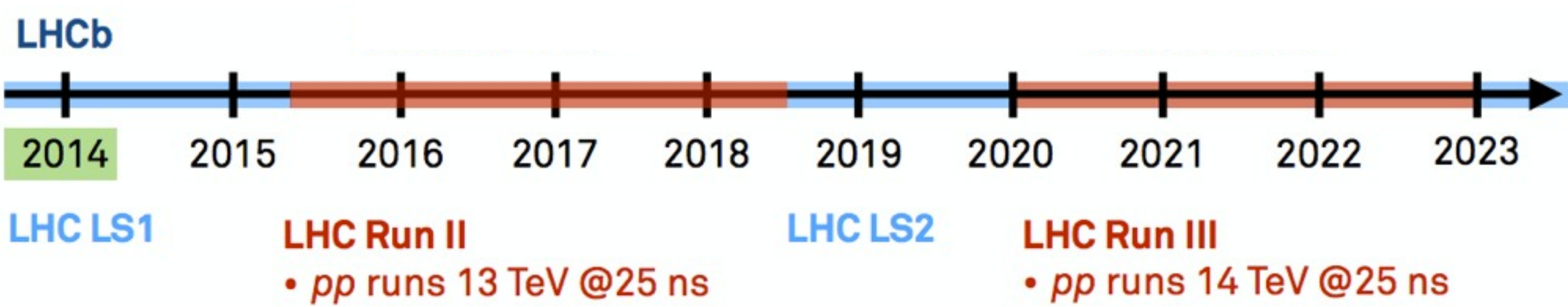


and much more!



- ✓ *Only few examples among many others over a large variety of topics in heavy flavour physics.*
- ✓ *Many of them are first or world's best measurements.*
- ✓ *>170 published papers in top journals*
- ✓ *Some of these results discussed at poster session by A. Oblakowska-Mucha*

The LHCb upgrade



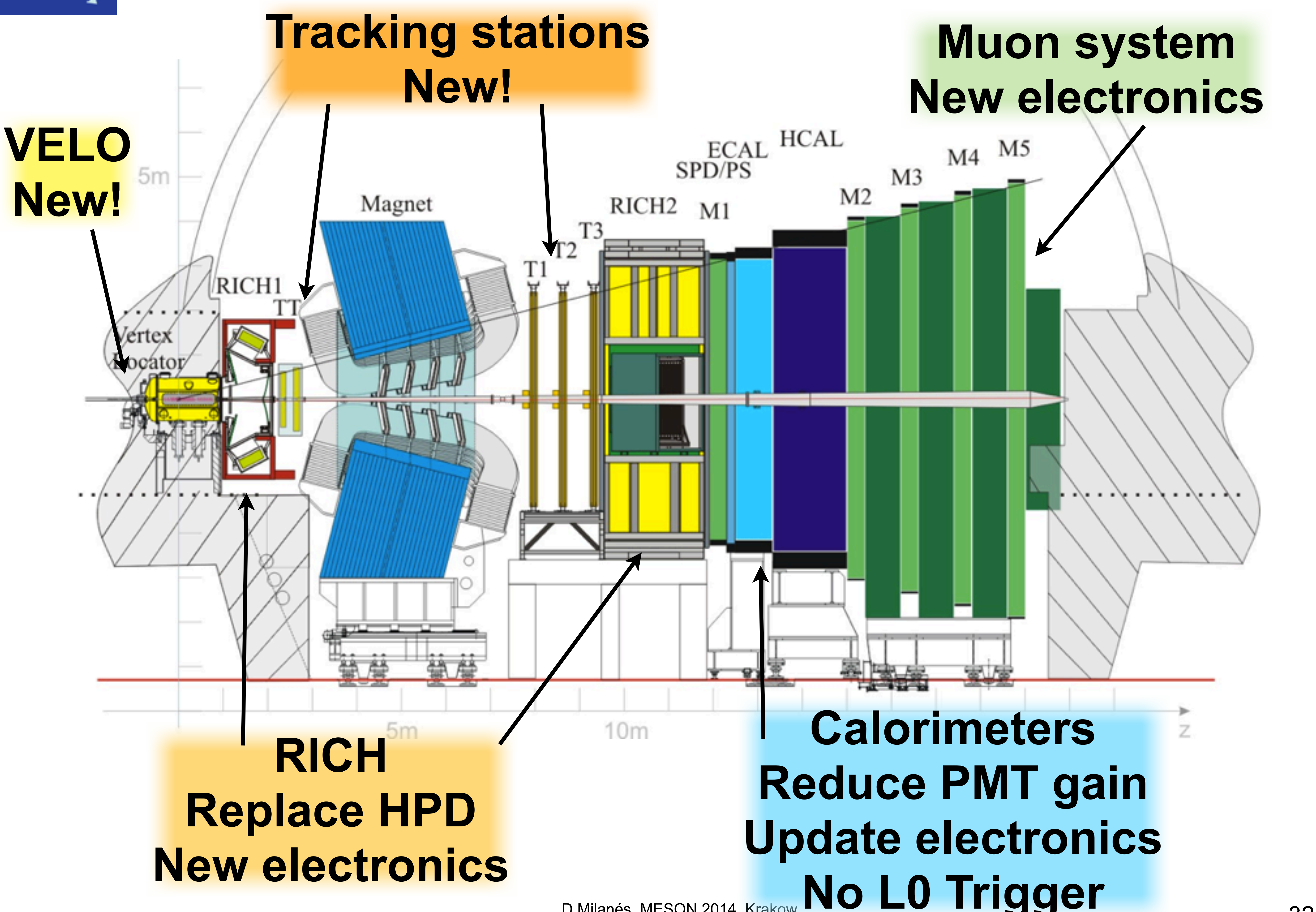
Physics motivations

Framework TDR for the LHCb upgrade: Technical Design Report

Type	Observable	LHC Run 1 (~3/fb)	LHCb 2018 (~8/fb)	LHCb upgrade (~50/fb)	Theory
B_s^0 mixing	$\phi_s(B_s^0 \to J/\psi\,\phi)$ (rad)	0.05	0.025	**0.009**	~ 0.003
	$\phi_s(B_s^0 \to J/\psi\, f_0(980))$ (rad)	0.09	0.05	**0.016**	~ 0.01
	$A_{\rm sl}(B_s^0)$ (10^{-3})	2.8	1.4	**0.5**	0.03
Gluonic penguin	$\phi_s^{\rm eff}(B_s^0 \to \phi\phi)$ (rad)	0.18	0.12	**0.026**	0.02
	$\phi_s^{\rm eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$ (rad)	0.19	0.13	**0.029**	< 0.02
	$2\beta^{\rm eff}(B^0 \to \phi K_S^0)$ (rad)	0.30	0.20	**0.04**	0.02
Right-handed currents	$\phi_s^{\rm eff}(B_s^0 \to \phi\gamma)$	0.20	0.13	**0.030**	< 0.01
	$\tau^{\rm eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	5%	3.2%	**0.8%**	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.04	0.020	**0.007**	0.02
	$q_0^2\,A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	10%	5%	**1.9%**	$\sim 7\%$
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6\,{\rm GeV}^2/c^4)$	0.14	0.07	**0.024**	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	14%	7%	**2.4%**	$\sim 10\%$
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ (10^{-9})	1.0	0.5	**0.19**	0.3
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	220%	110%	**40%**	$\sim 5\,\%$
Unitarity triangle angles	$\gamma(B \to D^{(*)}K^{(*)})$	7°	4°	**1.1°**	negligible
	$\gamma(B_s^0 \to D_s^{\mp}K^{\pm})$	17°	11°	**2.4°**	negligible
	$\beta(B^0 \to J/\psi\, K_S^0)$	1.7°	0.8°	**0.31°**	negligible
Charm *CP* violation	$A_\Gamma(D^0 \to K^+K^-)$ (10^{-4})	3.4	2.2	**0.5**	–
	ΔA_{CP} (10^{-3})	0.8	0.5	**0.12**	–

Statistical precision

Very close to theoretical uncertainties after upgrade!
Challenge to reduce the systematic uncertainties!

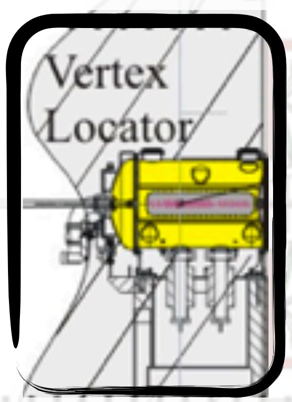


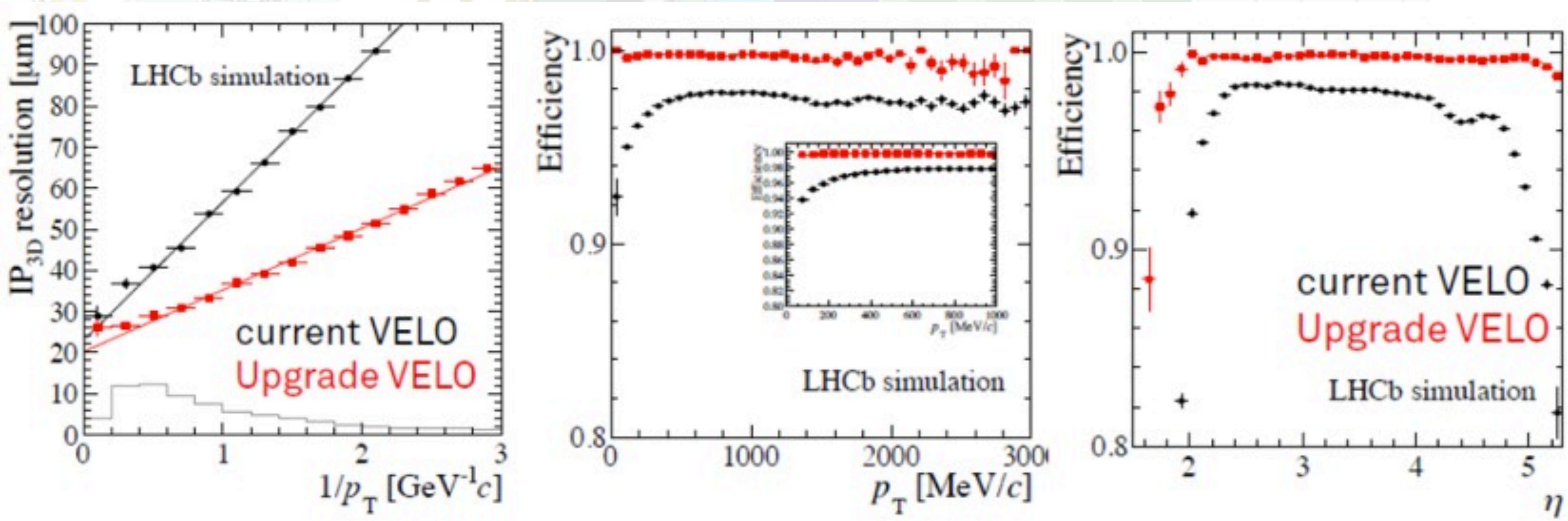
Tracking stations
New!
Muon system
New electronics
VELO
New!
5m
Magnet
ECAL
SPD/PS
HCAL
M4
M5
M3
M2
RICH2
M1
T3
T2
T1
RICH1
TT
Vertex
Locator
5m
10m
z
RICH
Replace HPD
New electronics
Calorimeters
Reduce PMT gain
Update electronics
No L0 Trigger

- *Change from silicon micro-strip to pixel detector*
  - *Reduce material budget*
  - *Easier pattern recognition*
  - *Easier alignment*
  - *Radiation harness*
  - *High data rate ~12Gbit/s*
  - *Higher predicted performance*
    - *Better impact parameter resolution*
    - *Improved efficiency*
    - *Reduced ghost rate*

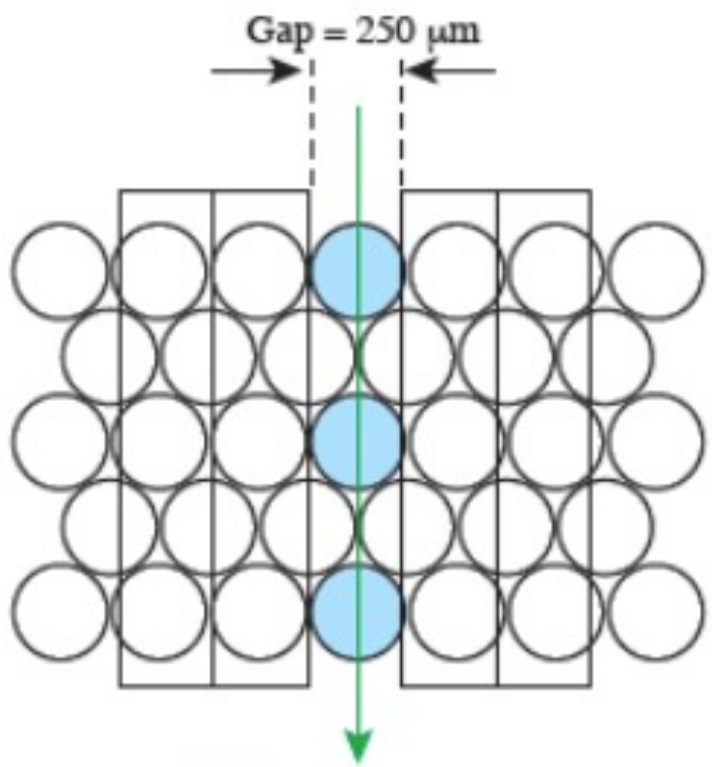
NEW

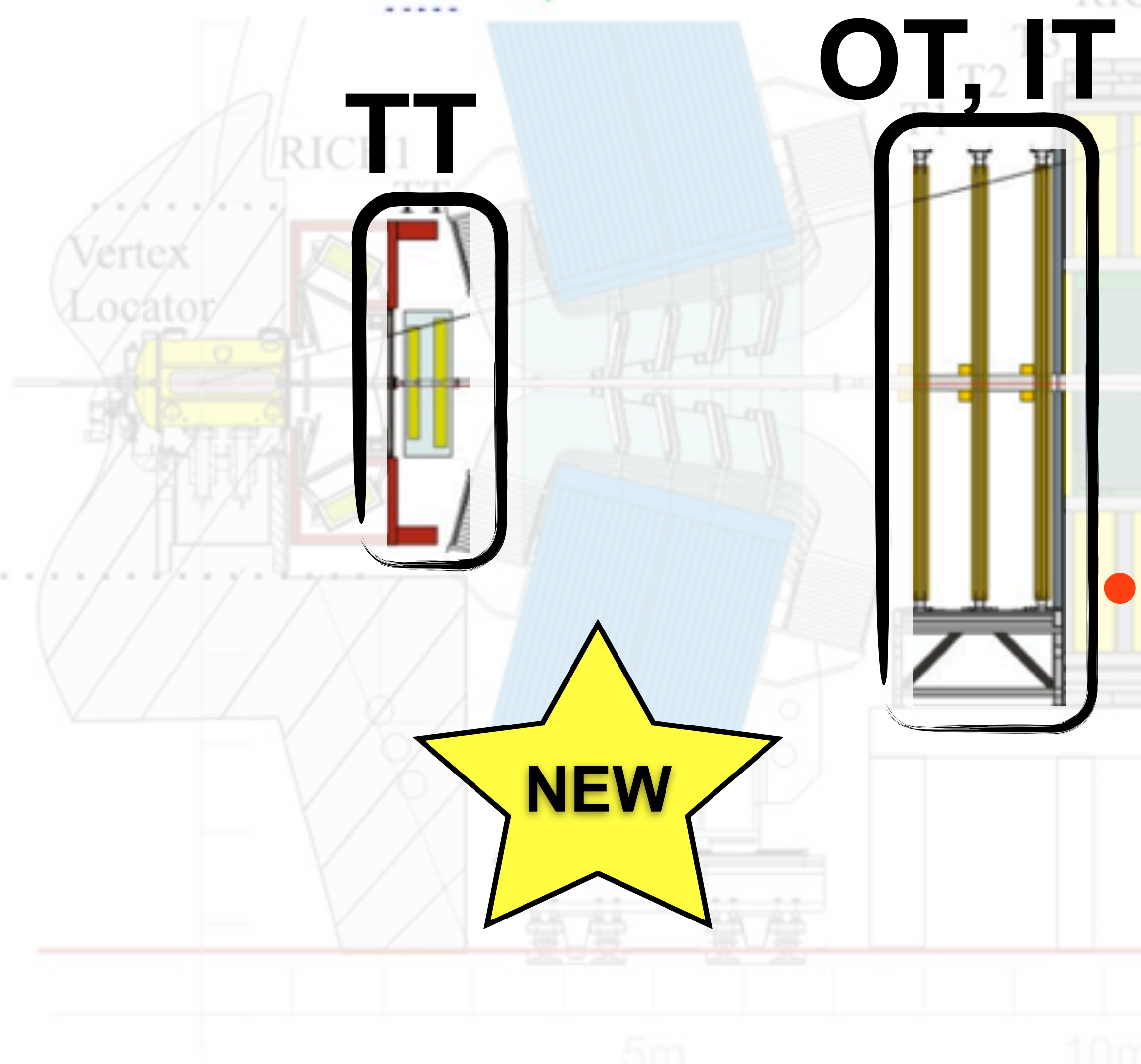
Vertex locator (VELO)





VELO upgrade, TDR, LHCb-TDR-13



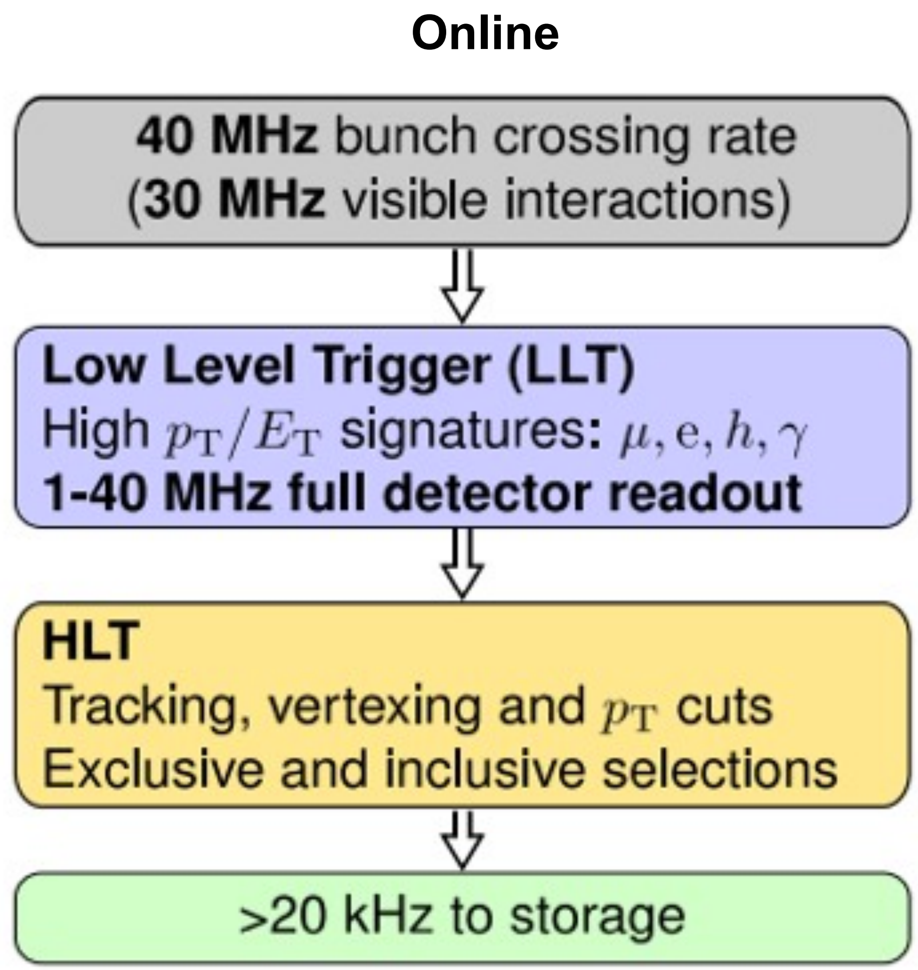


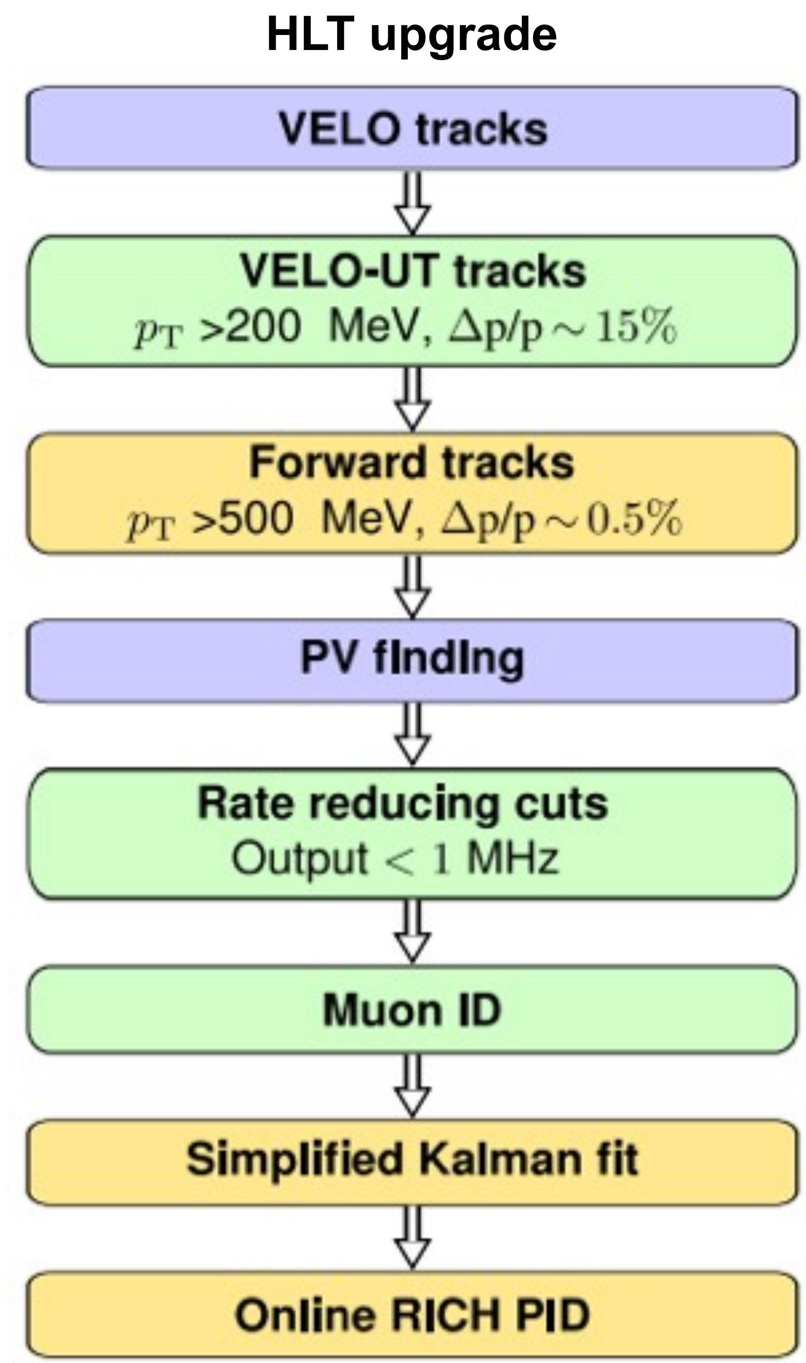
- *TT → UT (Upstream tracker)*
  - *New silicon strips with finer granularity*
  - *Increase acceptance at low η*
  - *Features*
    - *Ghost rates reduction*
    - *high-momentum track online selection (trigger)*
    - *Improved matching with VELO segments*
    - *Improvement of VELO downstream tracks*
- *OT*
  - *From drift tubes to scintillating fibers technology*
  - *SiPM for readout. ~40MHz FEE*
  - *250μm diameter scintillating fibers*
- *IT (Removed)*

Tracking upgrade, TDR, LHCb-TDR-15

Trigger implications

- ***To be improved to cope with our main limitations***
  - Hardware trigger and data acquisition
  - Rate limited by bandwidth
- ***With higher luminosity...***
  - Harder L0 separation. Change to LLT
  - tighter cuts on E_T, p_T
  - bigger track multiplicity
  - much more data!
- ***It is needed***
  - 5 kHz → 20kHz to storage
  - keep high efficiency on muon streams
  - improve gain on hadron streams





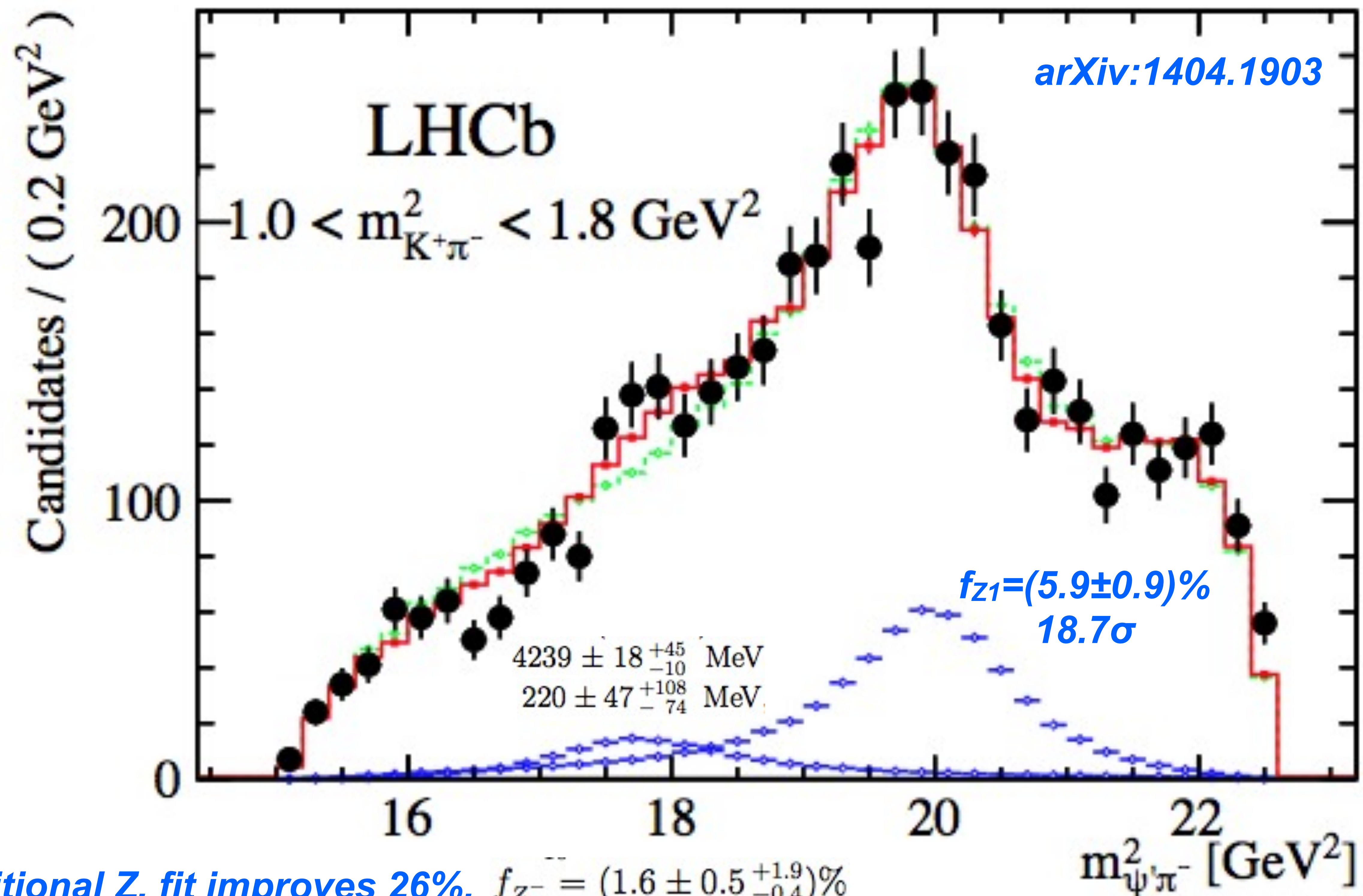
from C.Fitzpatrick, The upgrade of the LHCb trigger system, WIT2014

Conclusions

- ***LHCb detector have shown great capabilities to study a vast range of different topics related to the heavy flavour physics sector.***
- ***LHCb collaboration has accomplished outstanding physics results, after the analysis of the data recorded during LHC-Run1.***
- ***Some selected results were shown but many others have been performed or are under construction. Many results expected with Run1 data by the next years, thus stay tuned and expect more news from us!***
- ***Huge work has been done in R&D targeting the data taking period after LS2, where several interesting channels will be accessible to study.***

Backup

A second Z state

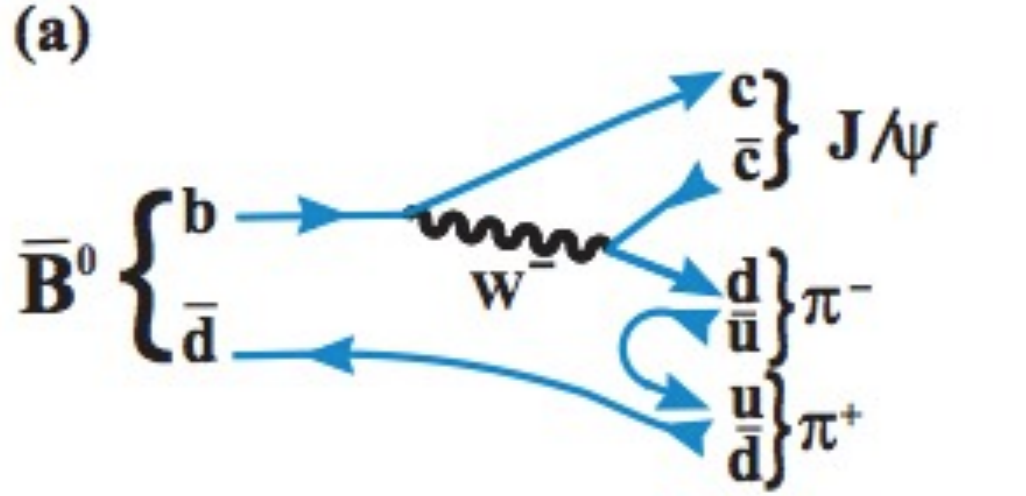


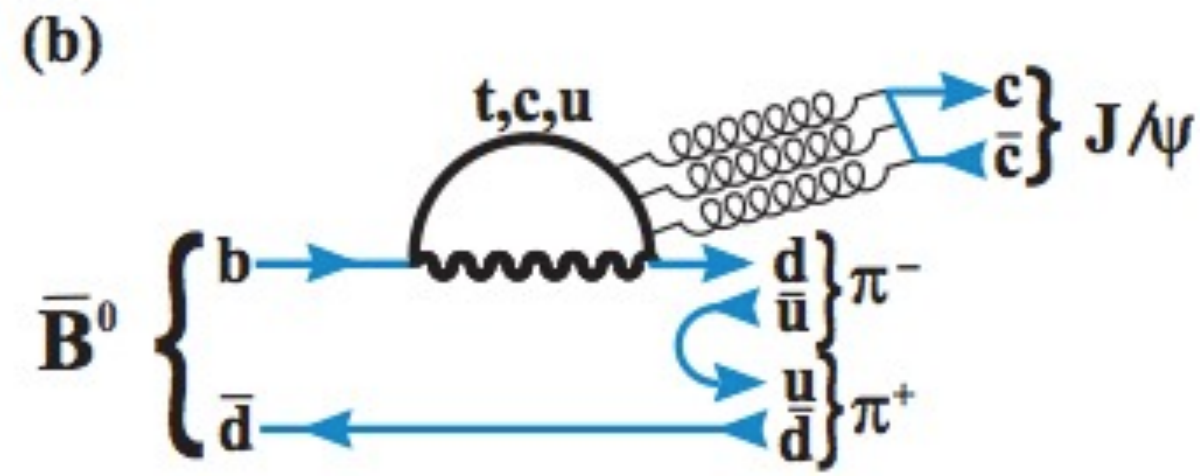
arXiv:1404.1903

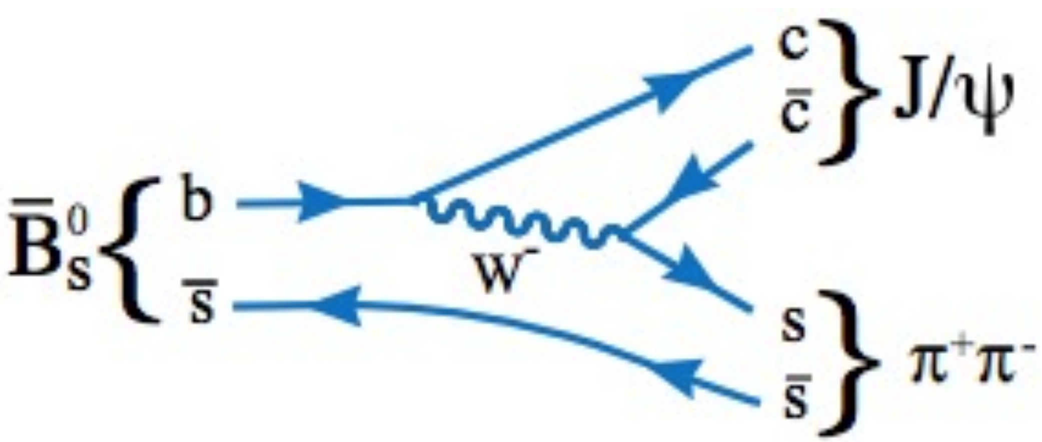
f_{Z1}=(5.9±0.9)%
18.7σ

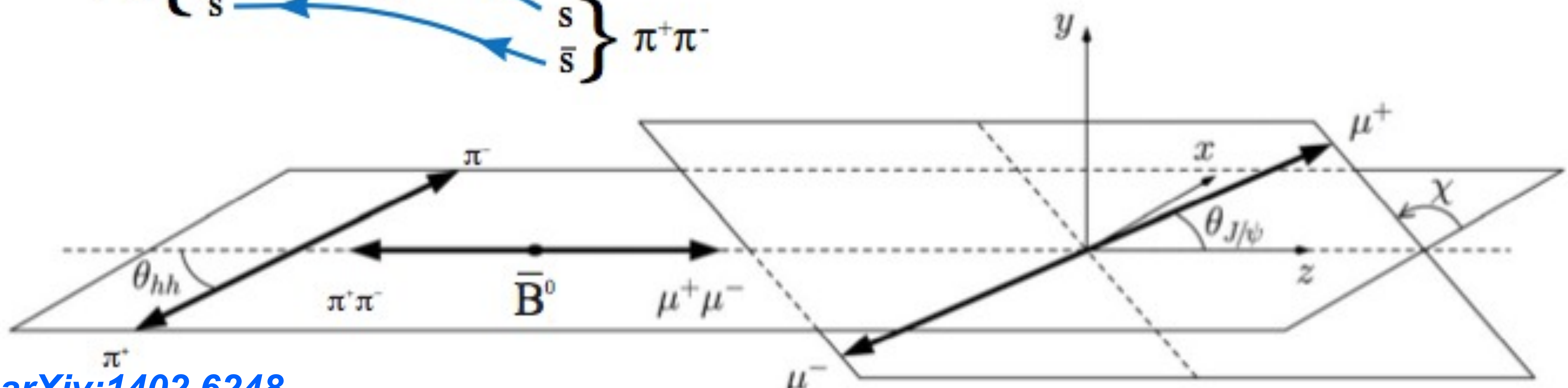
additional Z, fit improves 26%. $f_{Z_0^-} = (1.6 \pm 0.5\,^{+1.9}_{-0.4})\%$
0^+ preferred by the fit

Structure of $\bar{B}_{(d,s)} \rightarrow J/\psi\pi^+\pi^-$



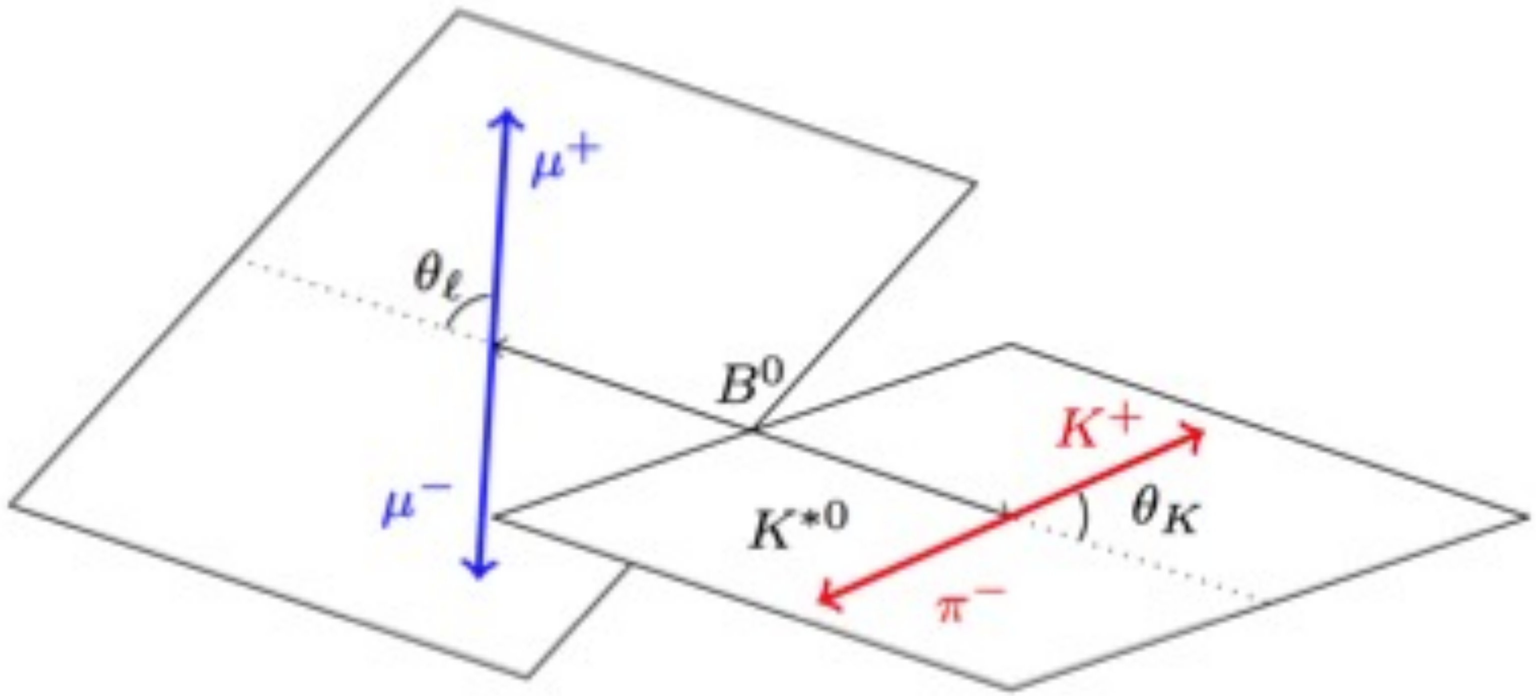






arXiv:1402.6248
arXiv:1404.5673

$B \rightarrow K^{(*)}\mu^+\mu^-$

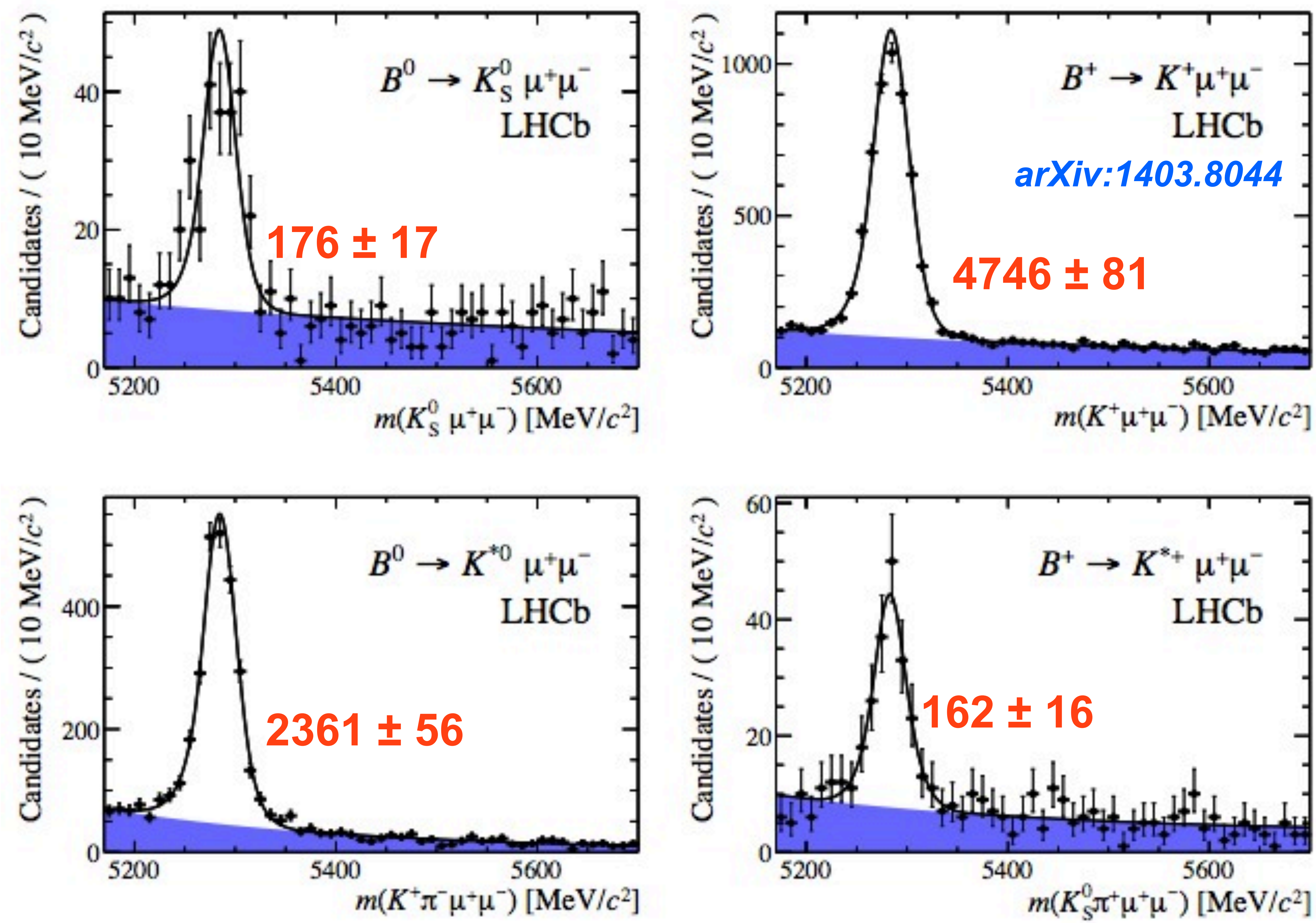


$$\frac{1}{\mathrm{d}\Gamma/dq^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi\,\mathrm{d}q^2} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_\mathrm{L})\sin^2\theta_K + F_\mathrm{L}\cos^2\theta_K + \frac{1}{4}(1-F_\mathrm{L})\sin^2\theta_K\cos 2\theta_\ell$$
$$- F_\mathrm{L}\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi$$
$$+ S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi + S_5\sin 2\theta_K\sin\theta_\ell\cos\phi$$
$$+ S_6\sin^2\theta_K\cos\theta_\ell + S_7\sin 2\theta_K\sin\theta_\ell\sin\phi$$
$$+ S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

$$P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$

Form-factor independent observables

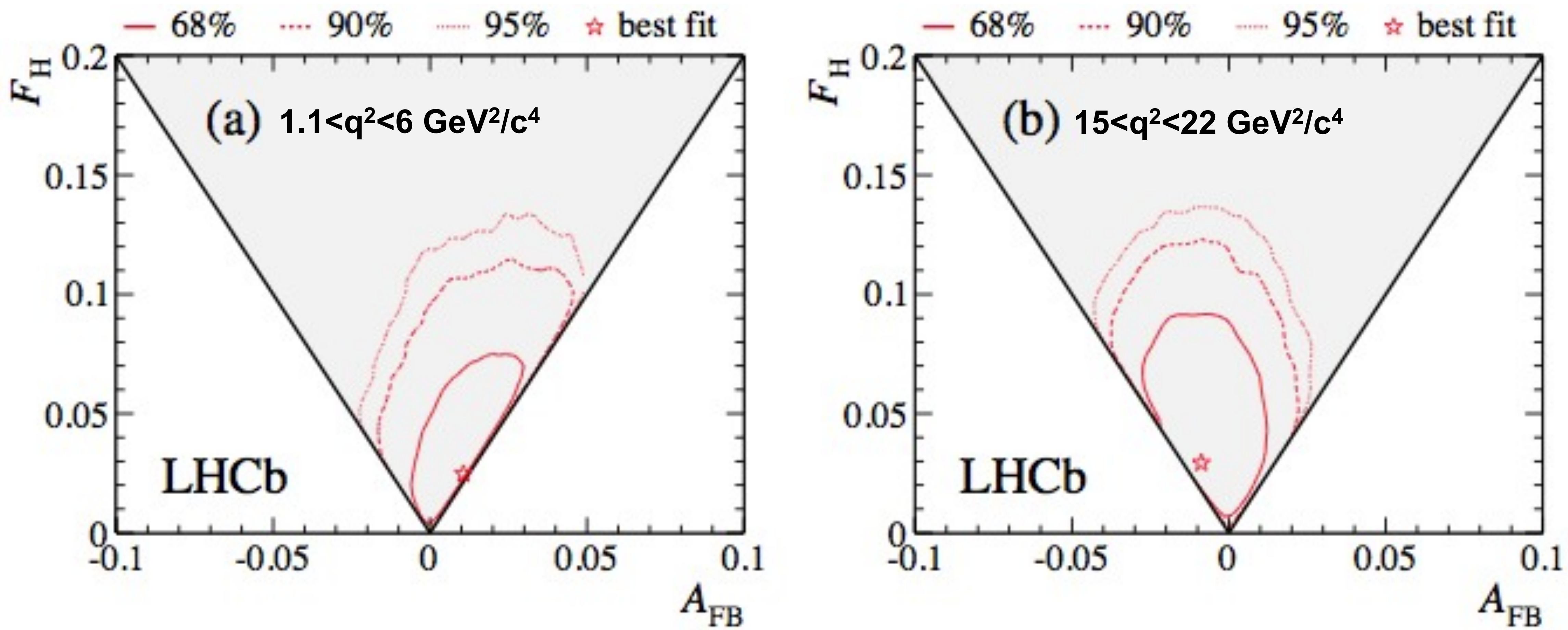
Differential BF $B \to K^{(*)}\mu^+\mu^-$



Angular analysis $B \to K\mu^+\mu^-$

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_l} = \frac{3}{4}(1 - F_H)(1 - \cos^2\theta_l) + \frac{1}{2}F_H + A_{FB}\cos\theta_l$$

$$\frac{1}{\Gamma}\frac{d\Gamma}{d|\cos\theta_l|} = \frac{3}{2}(1 - F_H)(1 - |\cos\theta_l|^2) + F_H$$



Dimuon FB asymmetry and contribution from (pseudo)scalar/tensor amplitudes consistent with zero

arXiv:1403.8045

Trigger for Run2

40 MHz bunch crossing rate

⇩

L0 trigger
High p_T/E_T signatures: μ, e, h, γ
1 MHz detector readout

⇩

HLT 1
Displaced high-p_T tracks

⇩

Buffer
Detector alignment & calibration

⇩

HLT 2
Full event reconstruction

⇩

$\sim$12.5 kHz to storage

- Goal: make trigger more compatible with offline analysis environment
- Requires HLT to perform detector alignment and calibration
  - Move buffering to after HLT1: Buffer at kHz instead of MHz
  - Buffer to disk while alignment is performed
  - Run HLT2 after alignment
- Allows us to use selections similar to offline:
- eg: full RICH PID [EPJC 73 2431], currently used in a limited capacity
- Major advantage: Allows prescaling of Cabbibo-favored charm decays while keeping 100% of DCS.

from C.Fitzpatrick, The upgrade of the LHCb trigger system, WIT2014