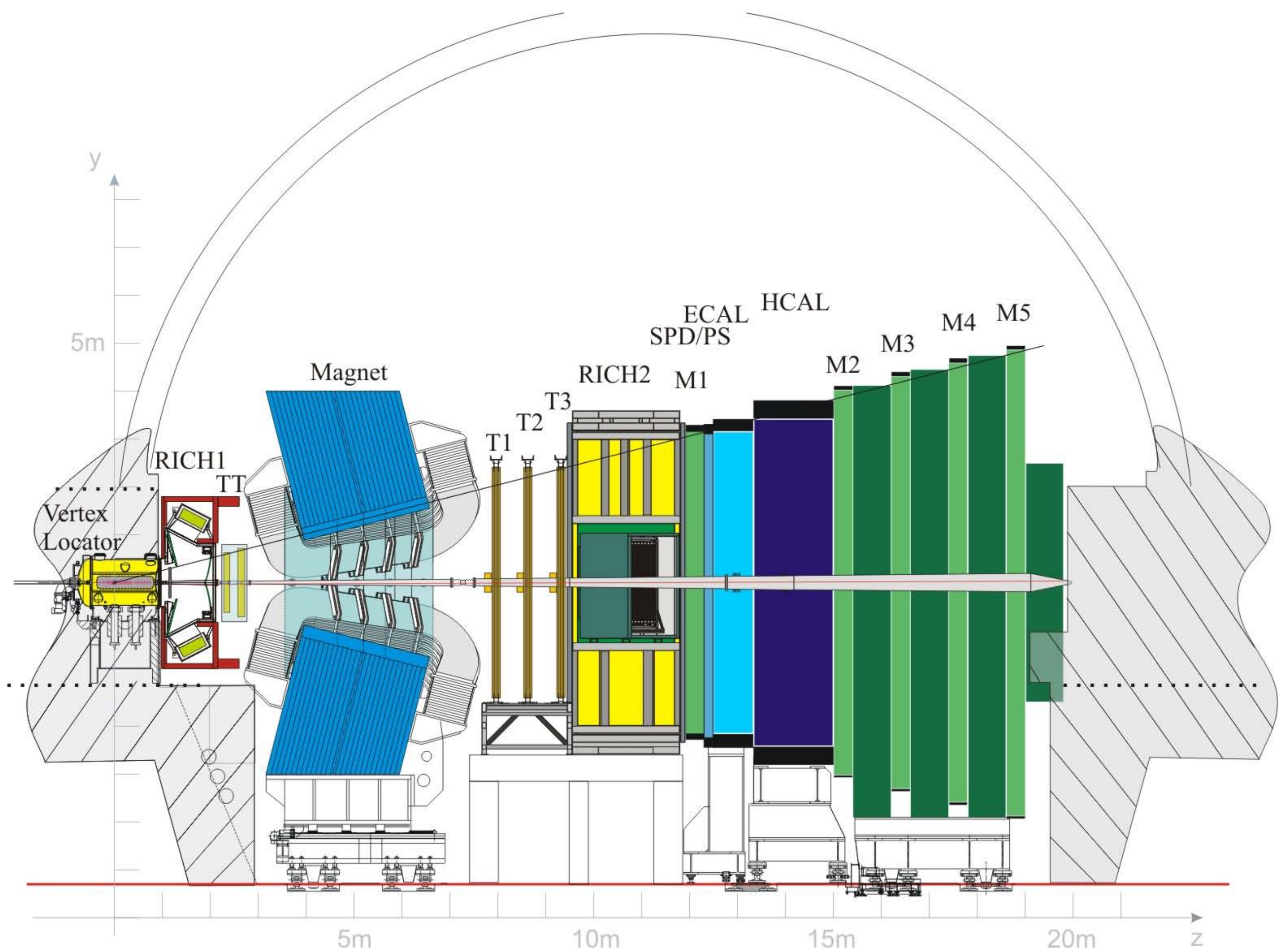
Status Report

Angelo Di Canto (University of Heidelberg)
on behalf of the LHCb collaboration

European Research Council
Established by the European Commission

115th LHCC Meeting (Open Session) - 25 September 2013

The LHC-beauty experiment



- Forward detector designed to search for New Physics by studying CP violation and rare decays of heavy flavored hadrons
- Complementary to general purpose experiment for QCD/EW/Exotica studies in the forward direction

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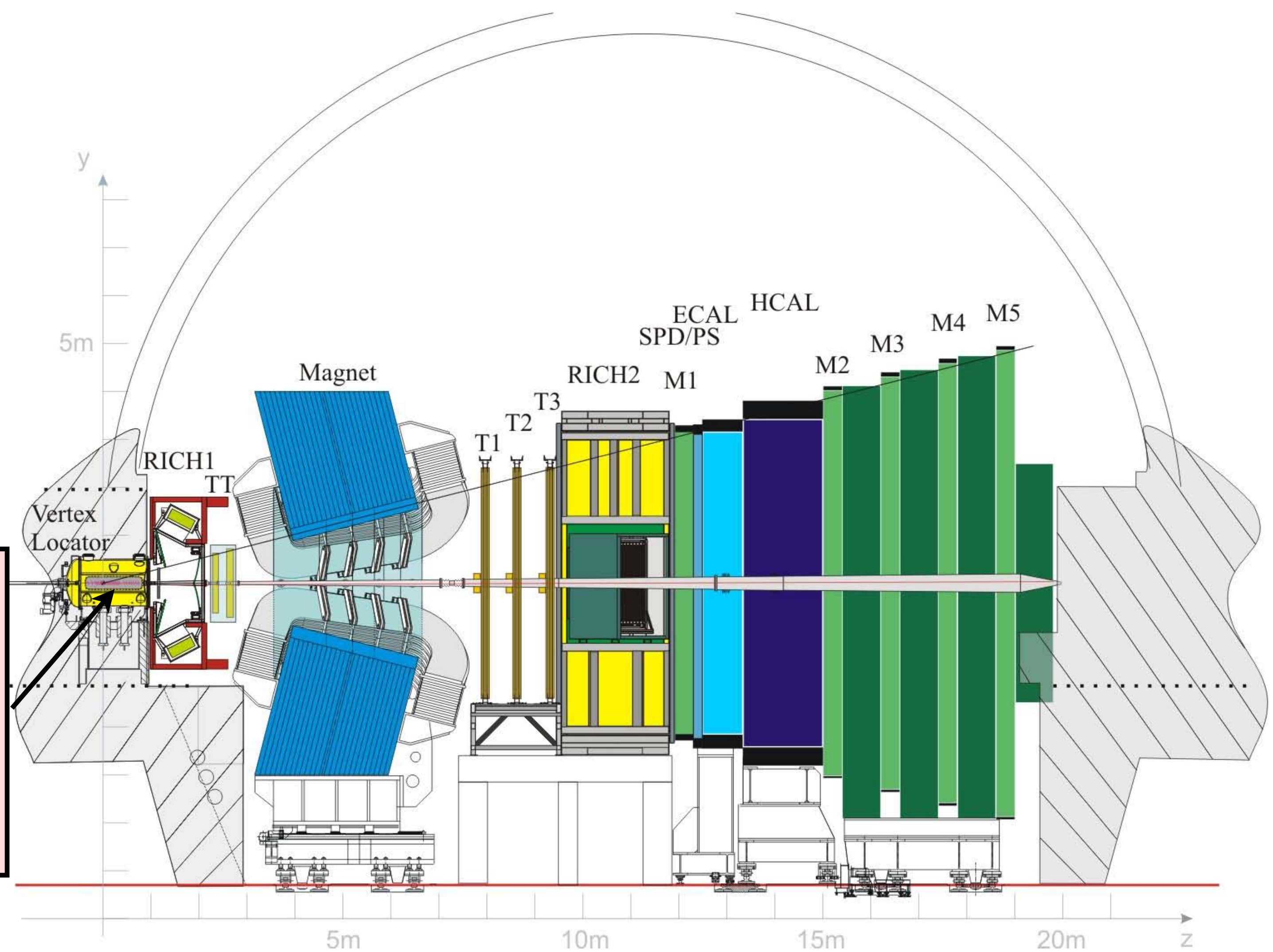

20μm IP resolution, i.e. ~45 ps decay-time resolution for 2-body decays

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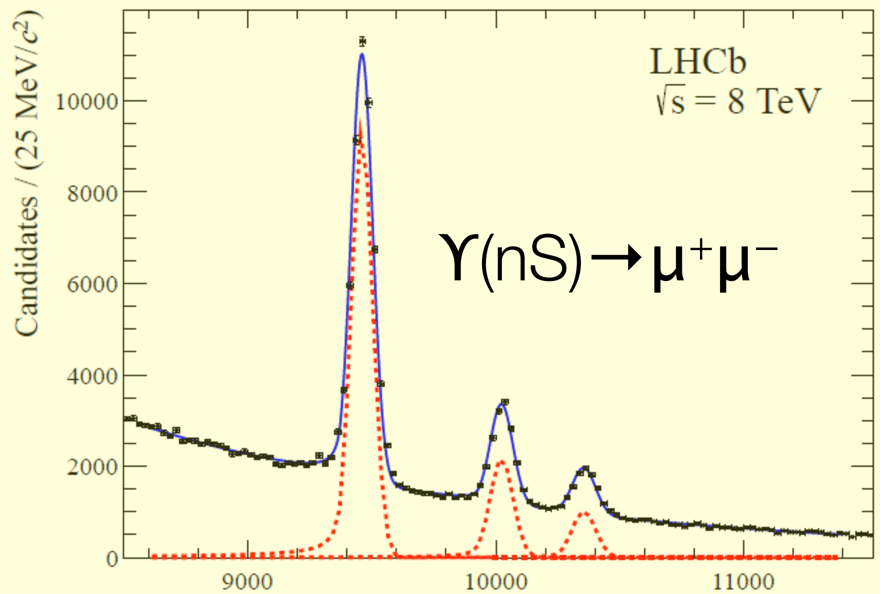
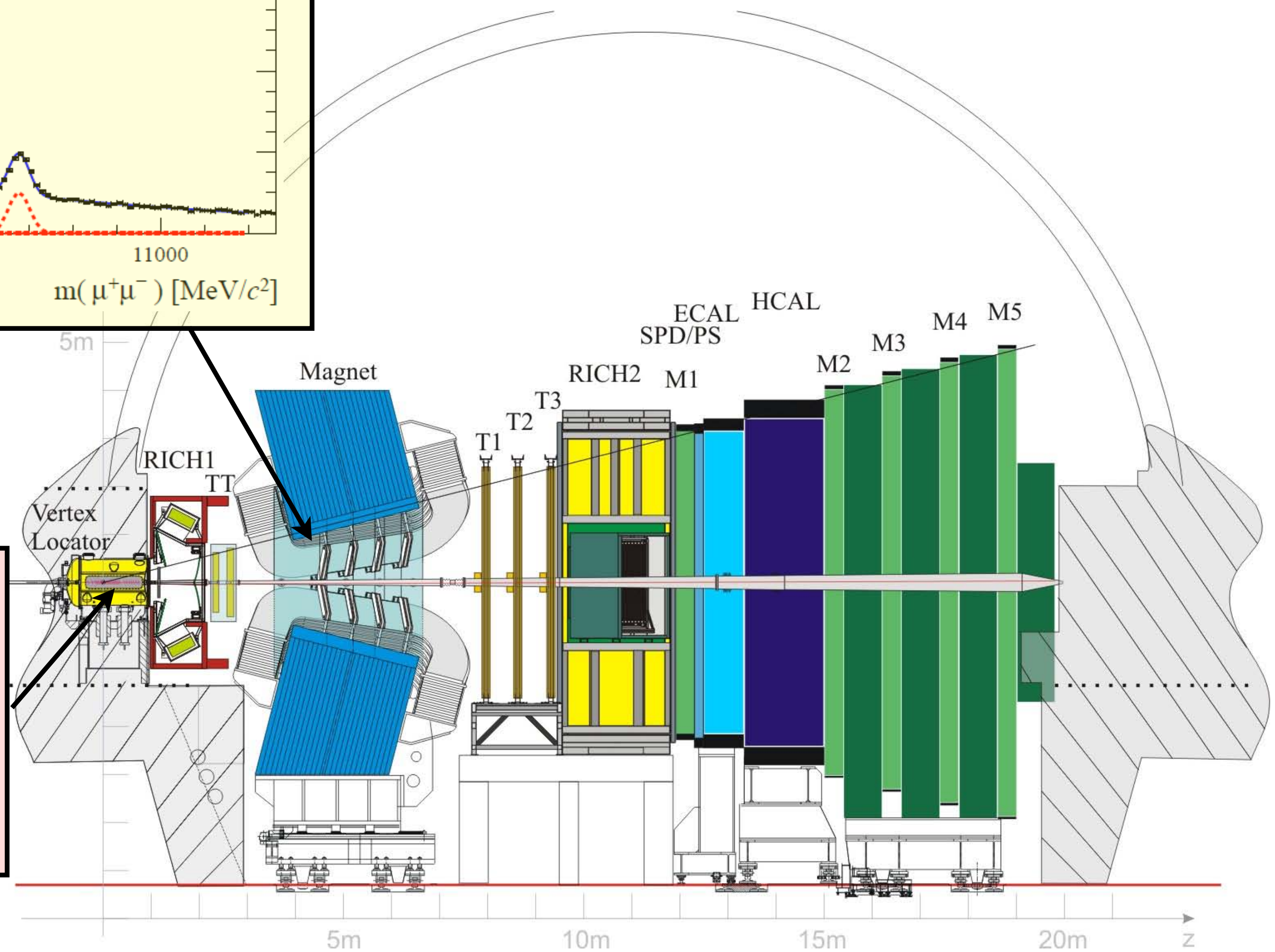
Excellent tracking:
$\Delta p/p$ = 0.4-0.6% at 5-100 GeV/c



JHEP 06 (2013) 064

xperiment



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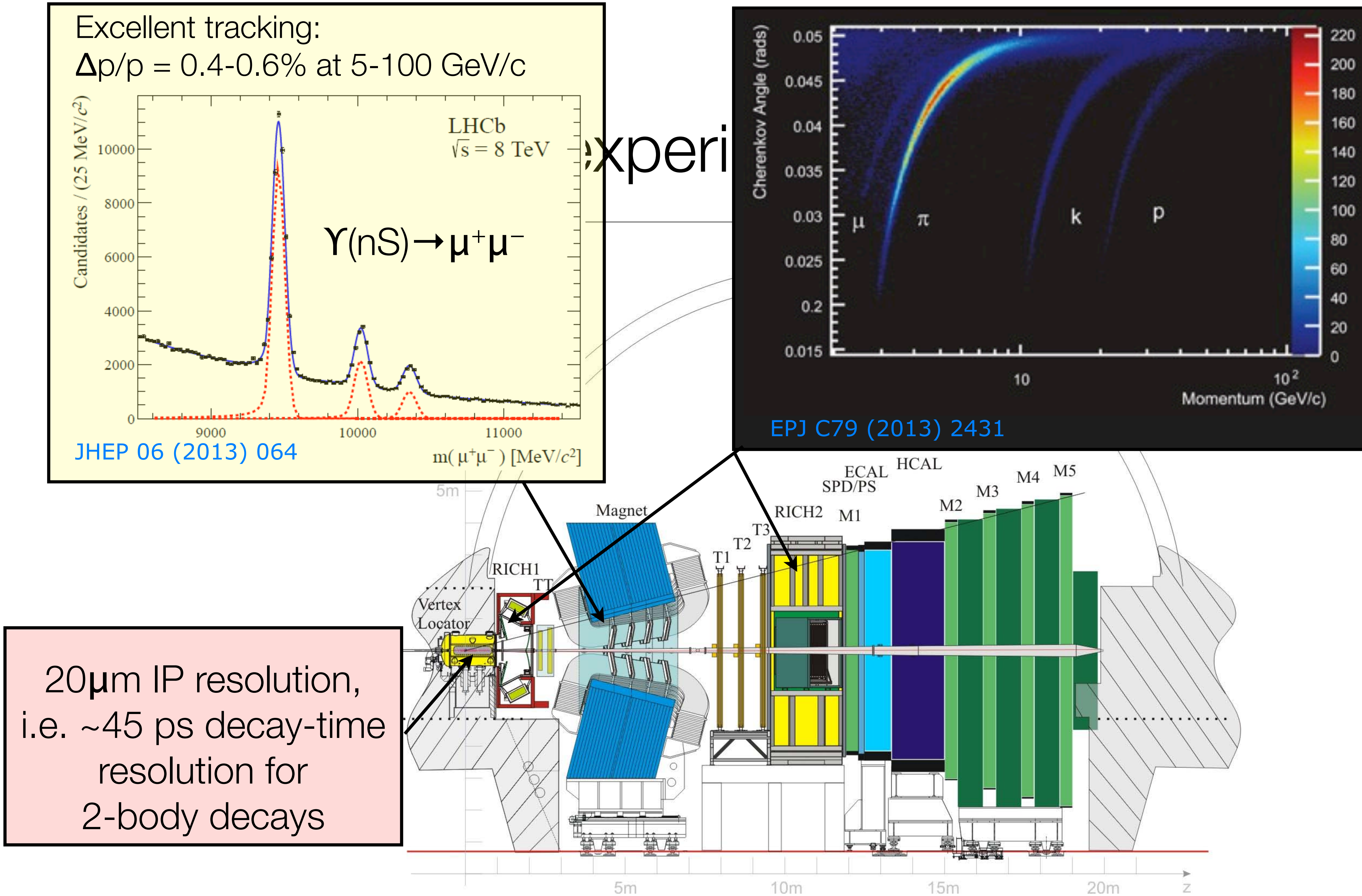

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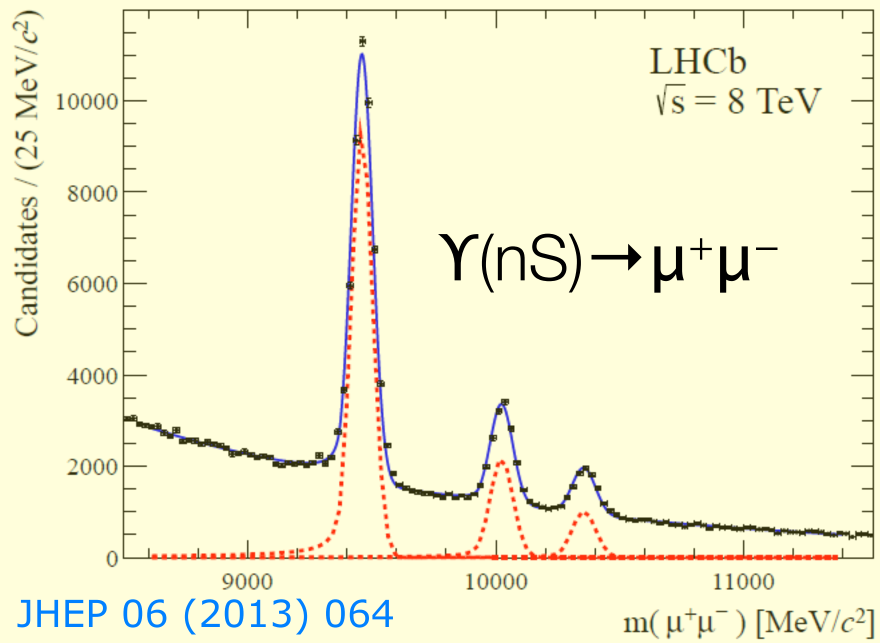

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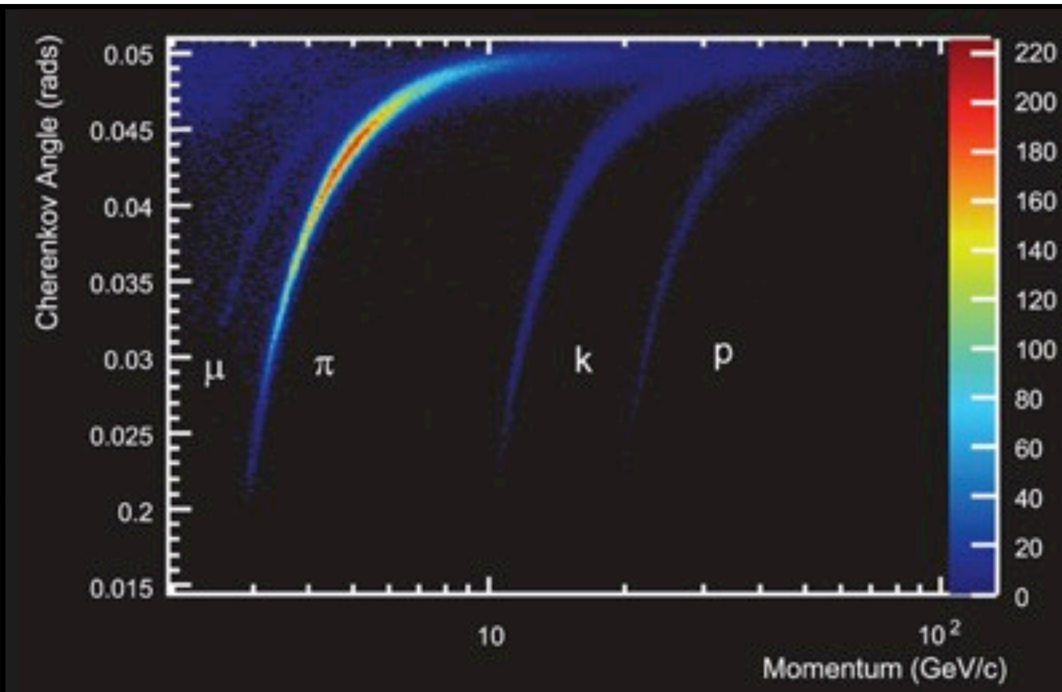
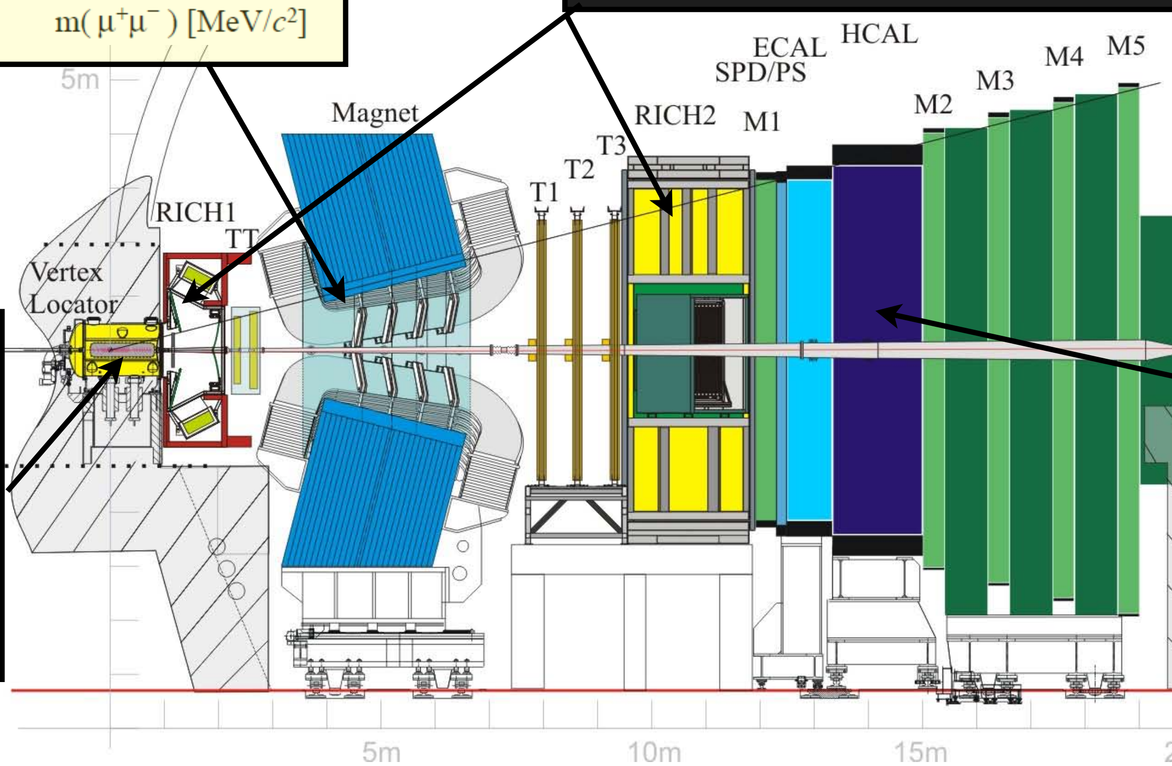
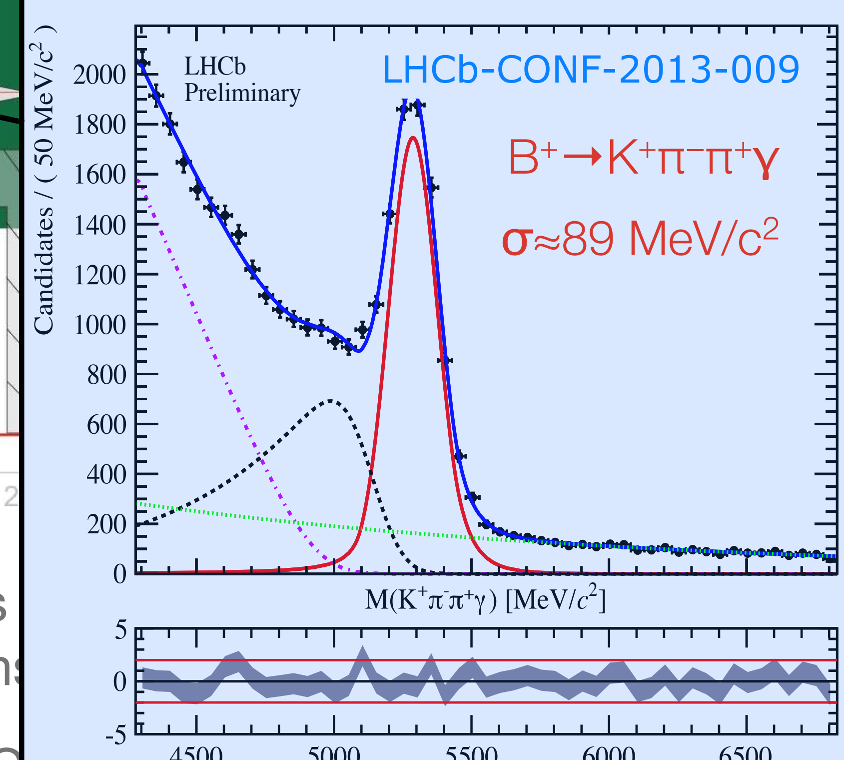


EPJ C79 (2013) 2431

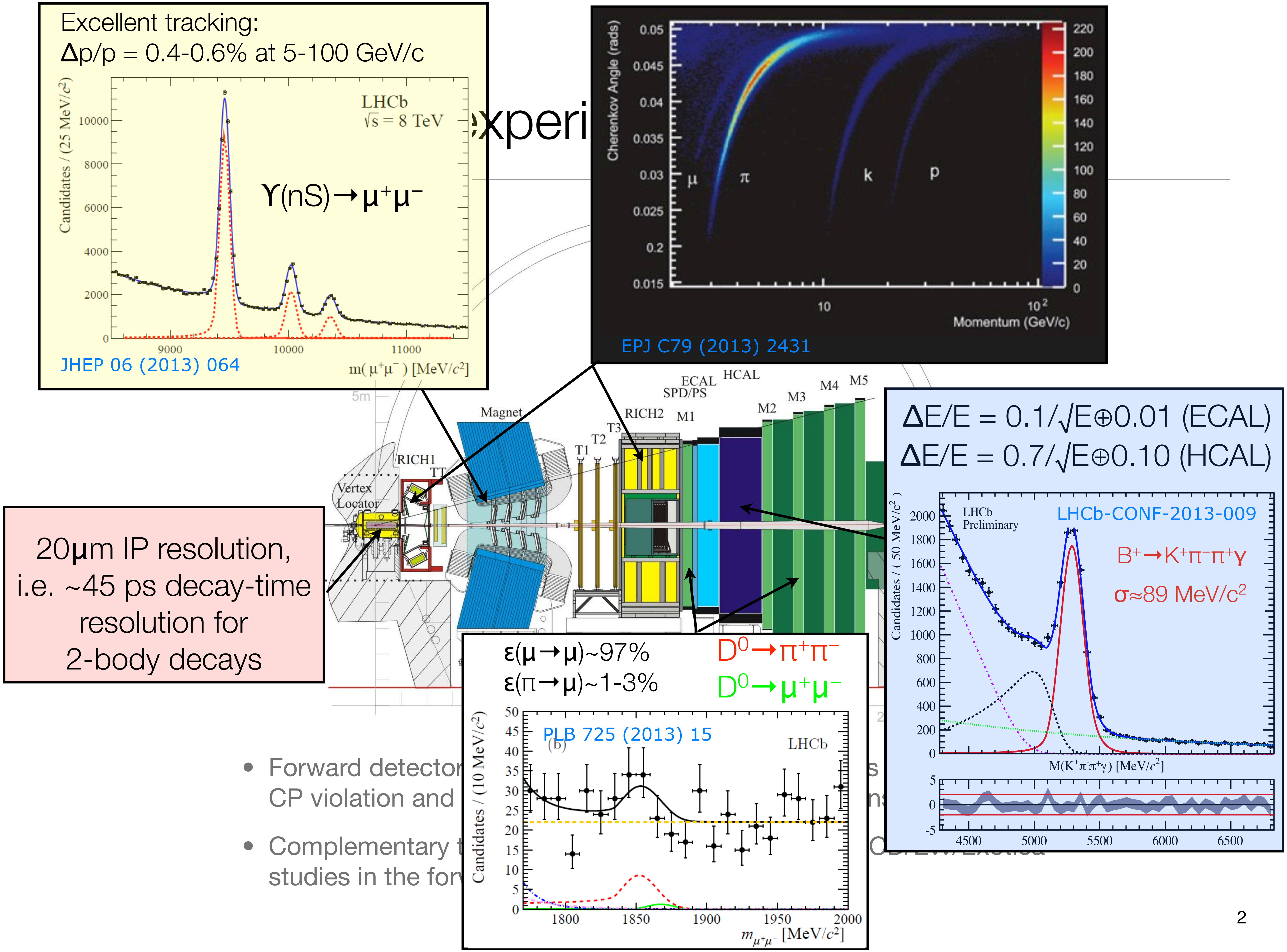


$\Delta E/E = 0.1/\sqrt{E} \oplus 0.01$ (ECAL)
$\Delta E/E = 0.7/\sqrt{E} \oplus 0.10$ (HCAL)



20μm IP resolution, i.e. ~45 ps decay-time resolution for 2-body decays

- Forward detector designed to search for New Physics CP violation and rare decays of heavy flavored hadrons
- Complementary to general purpose experiment for QC studies in the forward direction


Excellent tracking:
Δp/p = 0.4-0.6% at 5-100 GeV/c
LHCb
√s = 8 TeV
Υ(nS)→μ+μ−
Candidates / (25 MeV/c²)
m(μ+μ−) [MeV/c²]
JHEP 06 (2013) 064
Cherenkov Angle (rads)
Momentum (GeV/c)
μ
π
k
p
EPJ C79 (2013) 2431
20μm IP resolution,
i.e. ~45 ps decay-time
resolution for
2-body decays
Vertex Locator
RICH1
TT
Magnet
T1
T2
T3
RICH2
ECAL
SPD/PS
HCAL
M1
M2
M3
M4
M5
ΔE/E = 0.1/√E⊕0.01 (ECAL)
ΔE/E = 0.7/√E⊕0.10 (HCAL)
LHCb Preliminary
LHCb-CONF-2013-009
B+→K+π−π+γ
σ≈89 MeV/c²
Candidates / (50 MeV/c²)
M(K+π−π+γ) [MeV/c²]
ε(μ→μ)~97%
ε(π→μ)~1-3%
D0→π+π−
D0→μ+μ−
PLB 725 (2013) 15
LHCb
Candidates / (10 MeV/c²)
mμ+μ− [MeV/c²]
Forward detector
CP violation and
Complementary
studies in the for

Excellent tracking:
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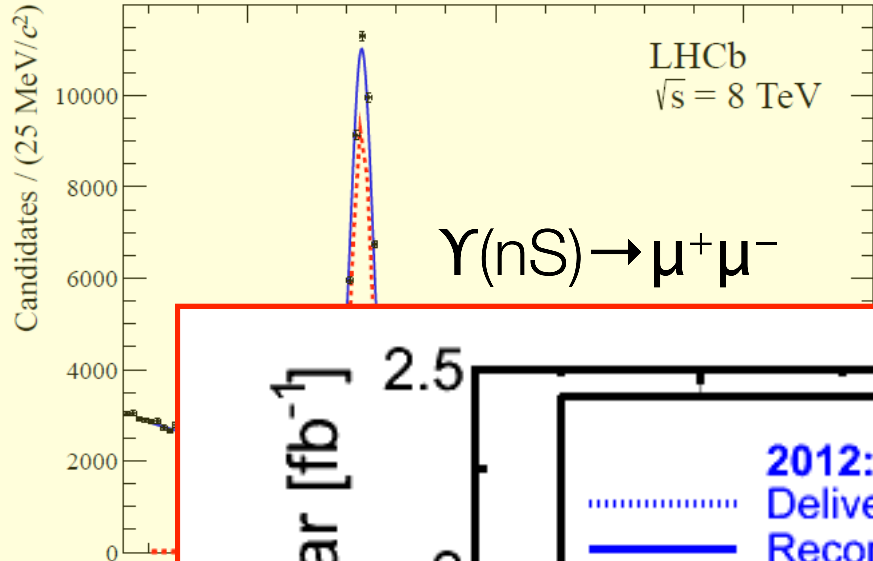
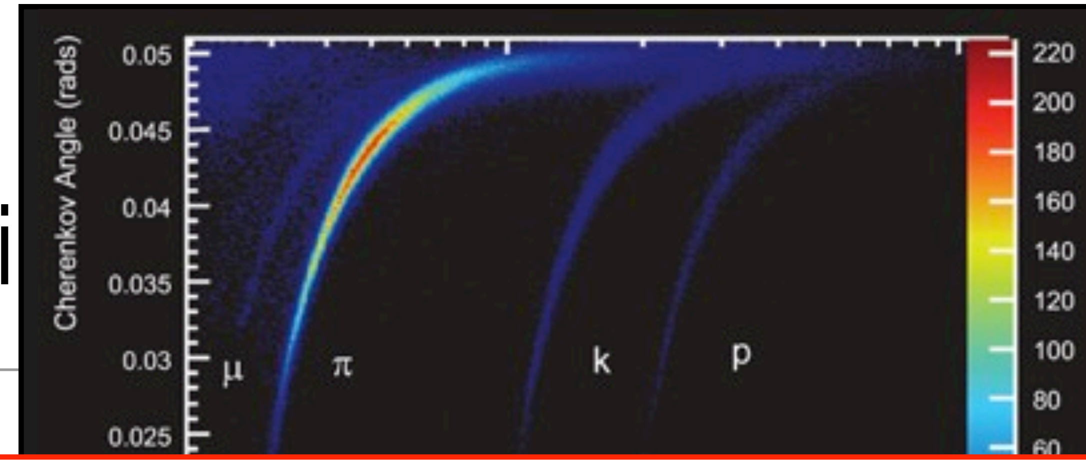
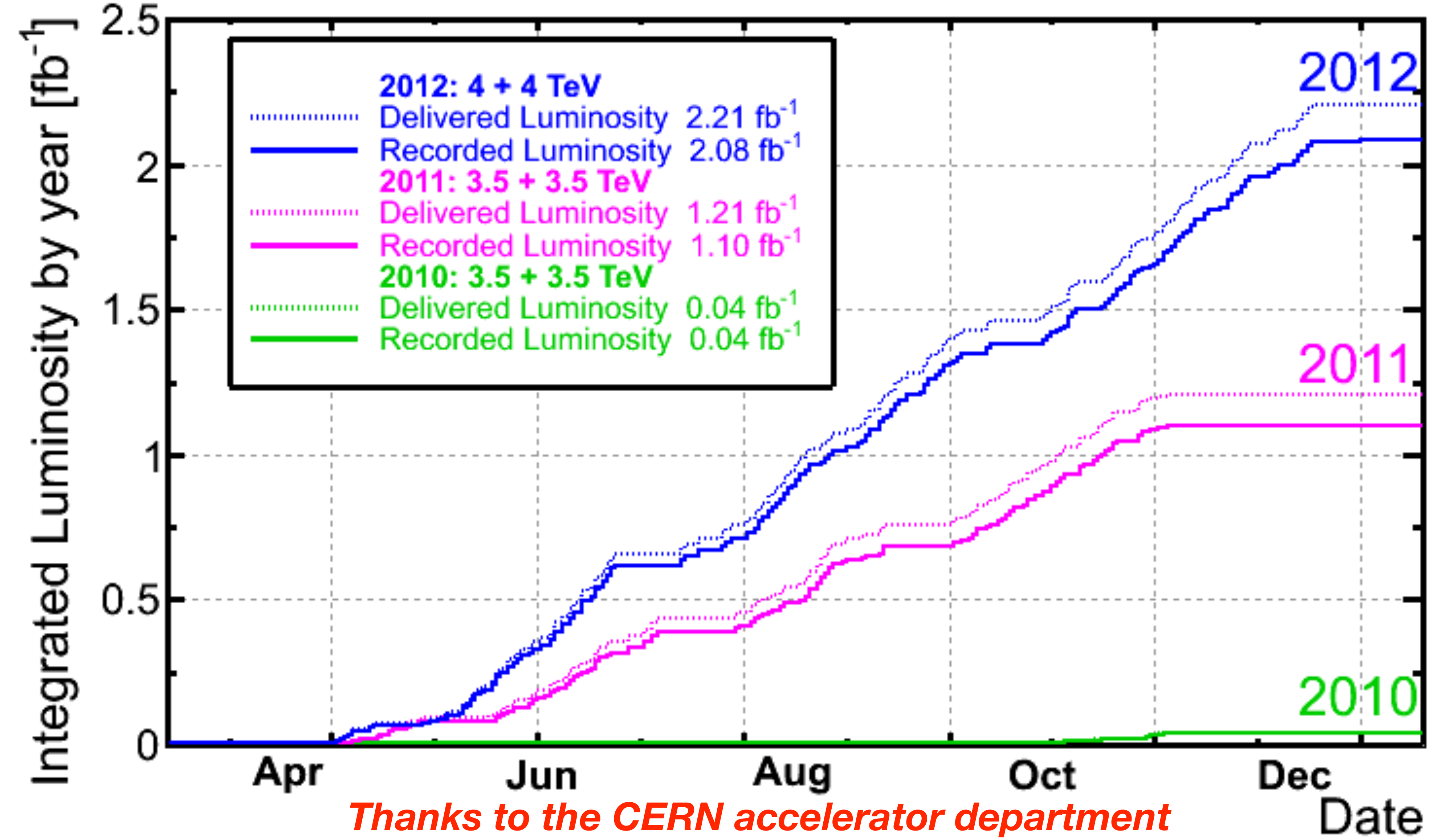


JHEP 06

xperi

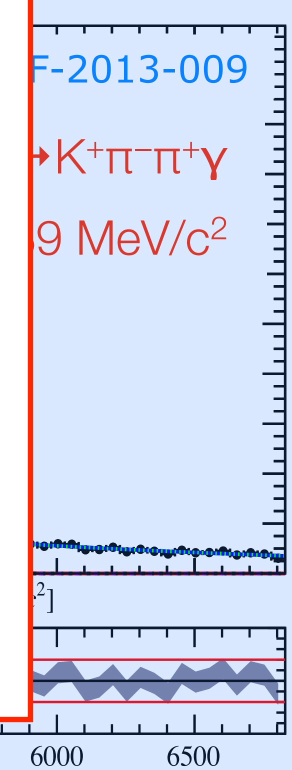




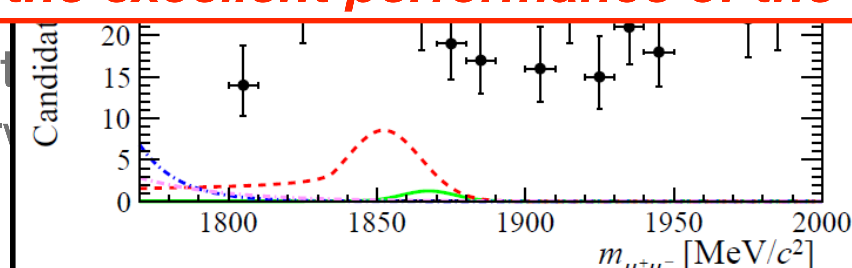
Thanks to the CERN accelerator department for the excellent performance of the LHC

20μm IP
i.e. ~45 p
reso
2-boo

1 (ECAL)
0 (HCAL)



- Complementary t
studies in the for



QCD/EW/Exotica

LS1 activities since last LHCC

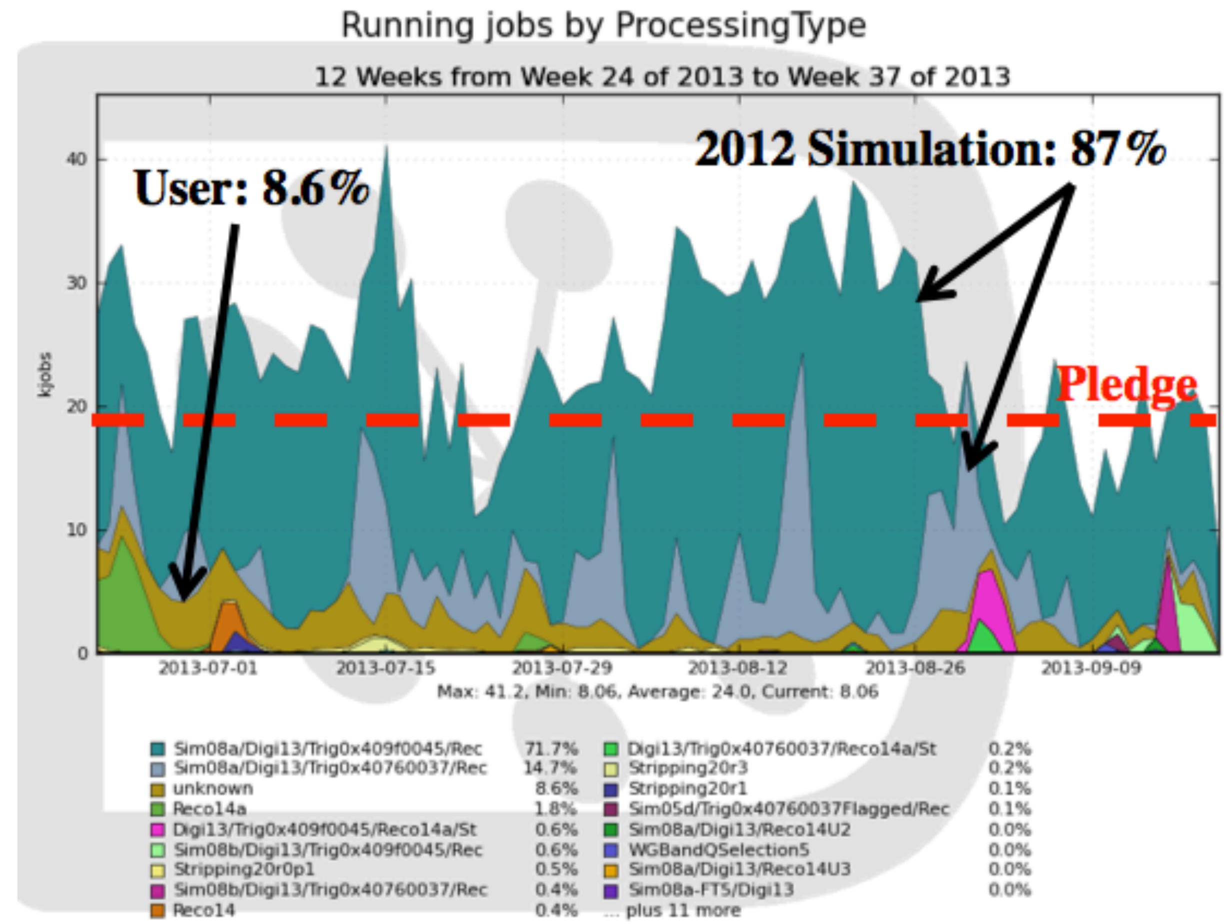
- Maintenance and consolidation works on the detector:
  - Installed shielding iron (25 tons) behind M5 to reduce noise from compensator magnet
  - Installed new cooling plant for TT and IT
  - Performed aging studies on OT (no signs of aging found)
- Had a productive 2nd Commissioning week

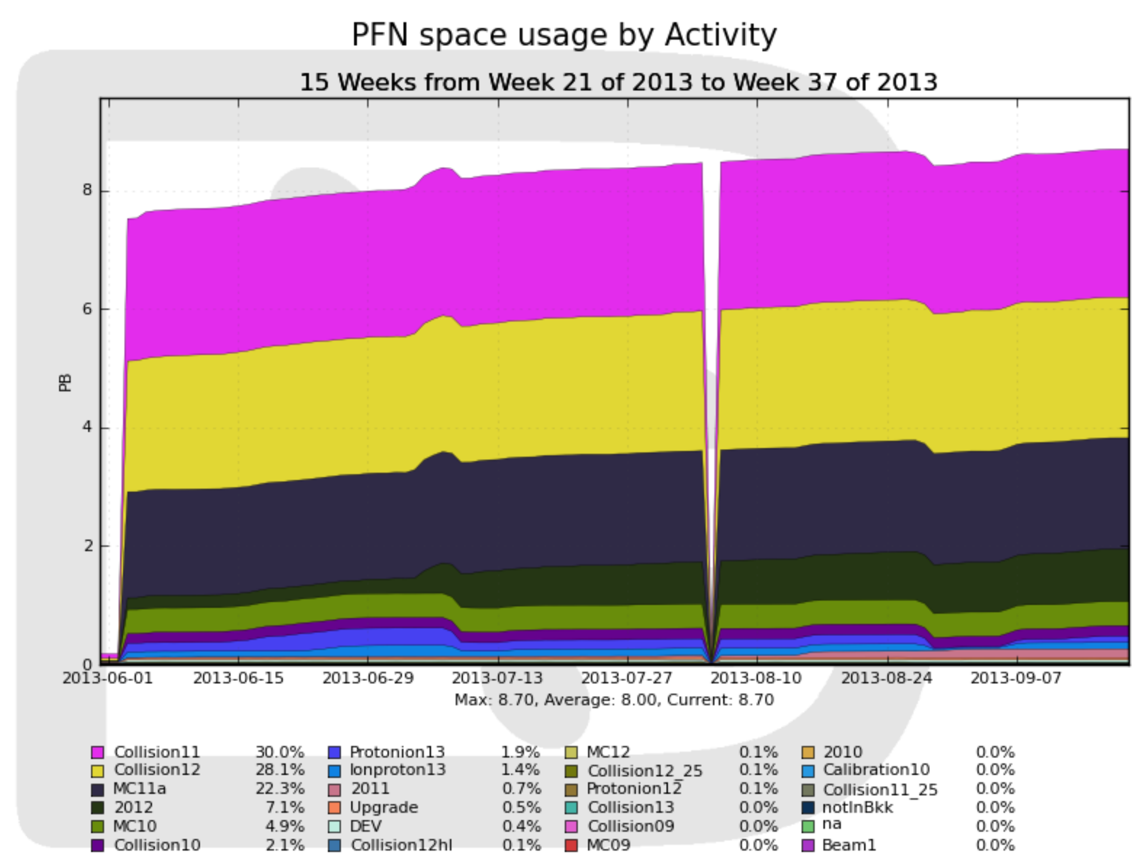
New shielding behind M5

New cooling plant

Computing activities since last LHCC

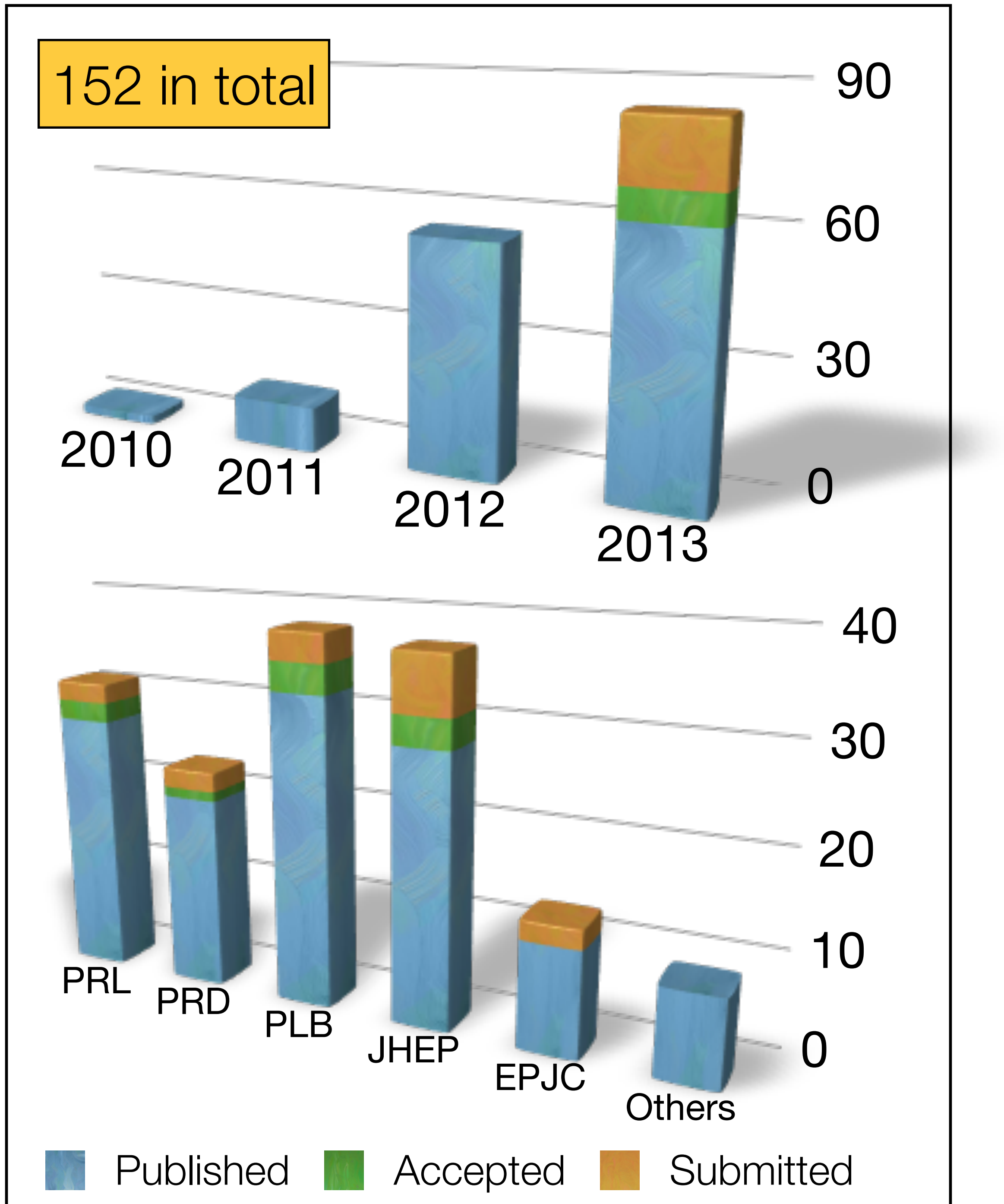
- All data re-processed early this Spring, now first incremental re-stripping completed and second ready to start
- Most of computing resources to simulation of 2012 data
    - Reduction by factor 2 in event size (improved compression/output format)
    - 50 TB/week increase in disk usage
- Change in computing model
    - Allow disk (and analysis) at selected Tier2 sites
    - Goal is ~10 sites with >300TB per site, but start with 100TB
    - 4 sites commissioned during summer, going in production this month



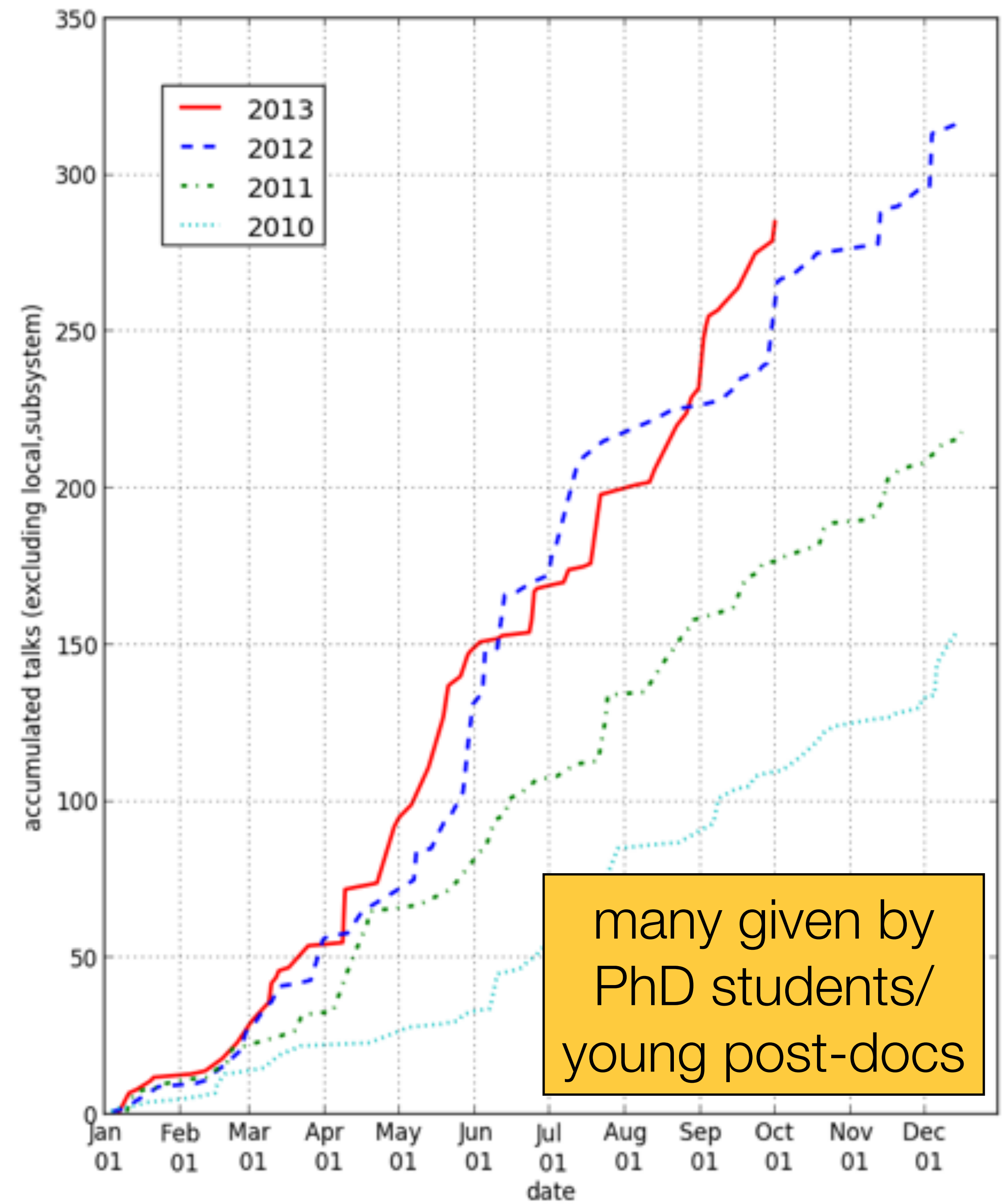


LHCb physics output

Physics publications



Talks at conferences



Papers submitted since last LHCC

- ✔ Observation of the decay $B_c^+ \to J/\psi K^+ K^- \pi^+$ — JHEP (arXiv:1309.0587)
- ✔ Measurement of the charge asymmetry in $B^+ \to \varphi K^+$ and search for $B^+ \to \varphi \pi^+$ decays — PLB (arXiv:1309.3742)
- ✔ First observation of $\overline{B}^0 \to J/\psi K^+ K^-$ and search for $\overline{B}^0 \to J/\psi \varphi$ decays — PRD (arXiv:1308.5916)
- ✔ Observation of the decay $B_s^0 \to \overline{D}^0 \varphi$ — PLB (arXiv:1308.4583)
- ✔ Observation of the decay $B_c^+ \to B_s^0 \pi^+$ — PRL (arXiv:1308.4544)
- ✔ Model-independent search for CP violation in $D^0 \to K^- K^+ \pi^- \pi^+$ and $D^0 \to \pi^- \pi^+ \pi^- \pi^+$ decays — PLB (arXiv:1308.3189)
- ✔ First measurement of time-dependent CP violation in $B_s^0 \to K^+ K^-$ decays — JHEP (arXiv:1308.1428)
- ✔ Measurement of the CP asymmetry in $B^+ \to K^+ \mu^+ \mu^-$ decays — PRL (arXiv:1308.1340)
- ✔ Observation of B_s^0-$\overline{B}_s^0$ mixing and measurement of mixing frequencies using semileptonic B decays — EPJC (arXiv:1308.1302)
- ✔ Branching fraction and CP asymmetry of the decays $B^+ \to K_S^0 \pi^+$ and $B^+ \to K_S^0 K^+$ — PLB (arXiv:1308.1277)
- ✔ First evidence for the two-body charmless baryonic decay $B^0 \to p\overline{p}$ — JHEP (arXiv:1308.0961)
- ✔ Measurement of the flavour-specific CP-violating asymmetry a_{sl}^s in B_s^0 decays — PLB (arXiv:1308.1048)
- ✔ Measurement of J/ψ polarization in pp collisions at $\sqrt{s}$=7 TeV — EPJC (arXiv:1307.6379)

Papers submitted since last LHCC

- ✔ Studies of the decays $B^+ \to p\bar{p}h^+$ and observation of $B^+ \to \bar{\Lambda}(1520)p$ — PRD (arXiv:1307.6165)
- ✔ Search for the lepton-flavour violating decays $B_s^0 \to e\mu$ and $B^0 \to e\mu$ — PRL (arXiv:1307.4889)
- ✔ Study of D_J meson decays to $D^+\pi^-$, $D^0\pi^+$ and $D^{*+}\pi^-$ final states in pp collisions — JHEP (arXiv:1307.4556)
- ✔ Observation of a resonance in $B^+ \to K^+\mu^+\mu^-$ decays at low recoil — PRL 111 (2013) 112003
- ✔ Measurement of the relative rate of prompt χ_{c0}, χ_{c1} and χ_{c2} production at $\sqrt{s}$=7 TeV — JHEP (arXiv:1307.4285)
- ✔ Study of $B_{(s)}^0 \to K_S^0 h^+ h'^-$ decays with first observation of $B_s^0 \to K_S^0 K^+\pi^-$ and $B_s^0 \to K_S^0 \pi^+\pi^-$ — JHEP (arXiv:1307.7648)
- ✔ Measurement of the polarization amplitudes in $B^0 \to J/\psi K^*(892)^0$ decays — PRD 88 (2013) 052002
- ✔ Measurement of B meson production cross-sections in proton-proton collisions at $\sqrt{s}$=7 TeV — JHEP 08 (2013) 117
- ✔ First observation of the decay $B_c^+ \to J/\psi K^+$ — JHEP 09 (2013) 075
- ✔ Observation of $B_c^+ \to J/\psi D_s^+$ and $B_c^+ \to J/\psi D_s^{*+}$ decays — PRD 87 (2013) 112012
- ✔ Searches for $B_{(s)}^0 \to J/\psi p\bar{p}$ and $B^+ \to J/\psi p\bar{p}\pi^+$ decays — JHEP 09 (2013) 006
- ✔ Measurement of the differential branching fraction of the decay $\Lambda_b^0 \to \Lambda\mu^+\mu^-$ — PLB (arXiv:1306.2577)
- ✔ First observation of the decay $B_s^0 \to \varphi\bar{K}^{*0}$ — JHEP (arXiv:1306.2239)

Papers submitted since last LHCC

- ✔ Measurement of CP violation in the phase space of $B^+ \to K^+\pi^+\pi^-$ and $B^+ \to K^+K^+K^-$ decays — PRL 111 (2013) 101801
- ✔ Precision measurement of the Λ_b^0 baryon lifetime — PRL 111 (2013) 102003
- ✔ **Study of J/ψ production and cold nuclear matter effects in pPb collisions** — **JHEP (arXiv:1308.6729)**
- ✔ **Measurement of the $B_s^0 \to \mu^+\mu^-$ branching fraction and search for $B^0 \to \mu^+\mu^-$ decays at the LHCb experiment** — **PRL 111 (2013) 101805**
- ✔ **Measurement of form-factor independent observables in the decay $B^0 \to K^{*0}\mu^+\mu^-$** — **PRL (arXiv:1308.1707)**

Shown at CHARM 2013

- ✔ Search for the doubly charmed baryon Ξ^+_{cc} — LHCb-PAPER-049 to be submitted to JHEP
- ✔ Search for the decay $D^0 \to \pi^+\pi^-\mu^+\mu^-$ — LHCb-PAPER-050 to be submitted to PLB
- ✔ **Measurement of D^0-$\overline{D}^0$ mixing parameters and search for CP violation using $D^0 \to K^+\pi^-$ decays** — **LHCb-PAPER-053 to be submitted to PRL**
- ✔ **Measurement of indirect CP violation in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays** — **LHCb-PAPER-054 to be submitted to PRL**

J/ψ production in pPb collisions

arXiv:1308.6729

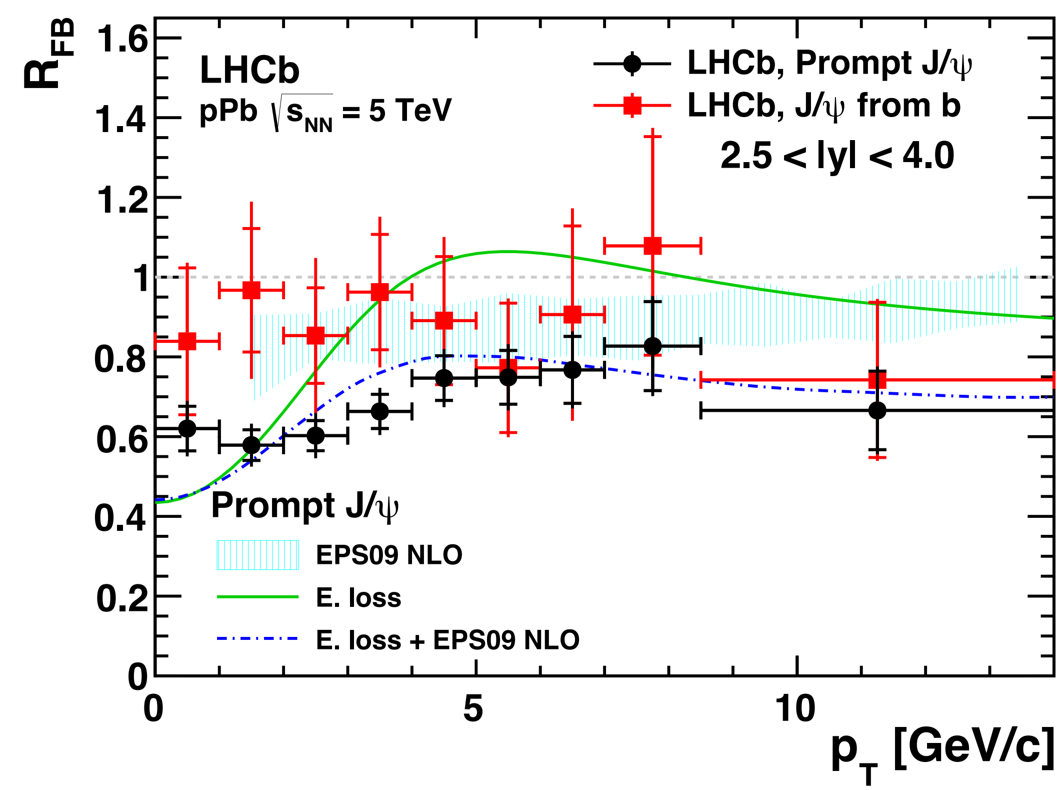
- First measurement of the nuclear modification factor

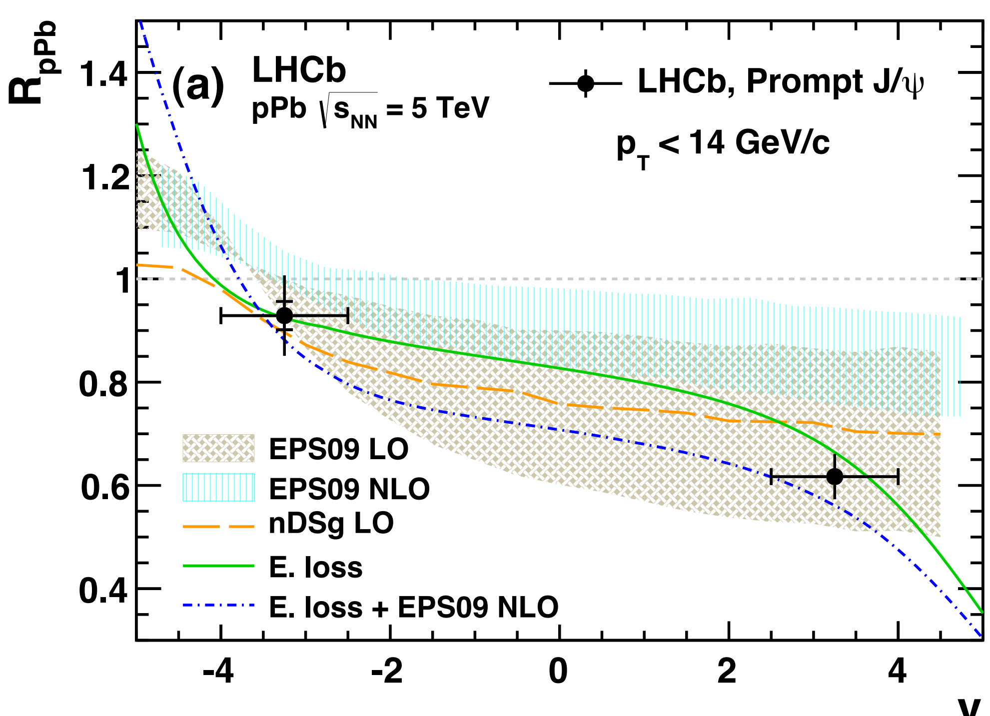
$$R_{pA}(y, \sqrt{s_{NN}}) \equiv \frac{1}{A}\frac{\mathrm{d}\sigma_{pA}(y, \sqrt{s_{NN}})/\mathrm{d}y}{\mathrm{d}\sigma_{pp}(y, \sqrt{s_{NN}})/\mathrm{d}y},$$

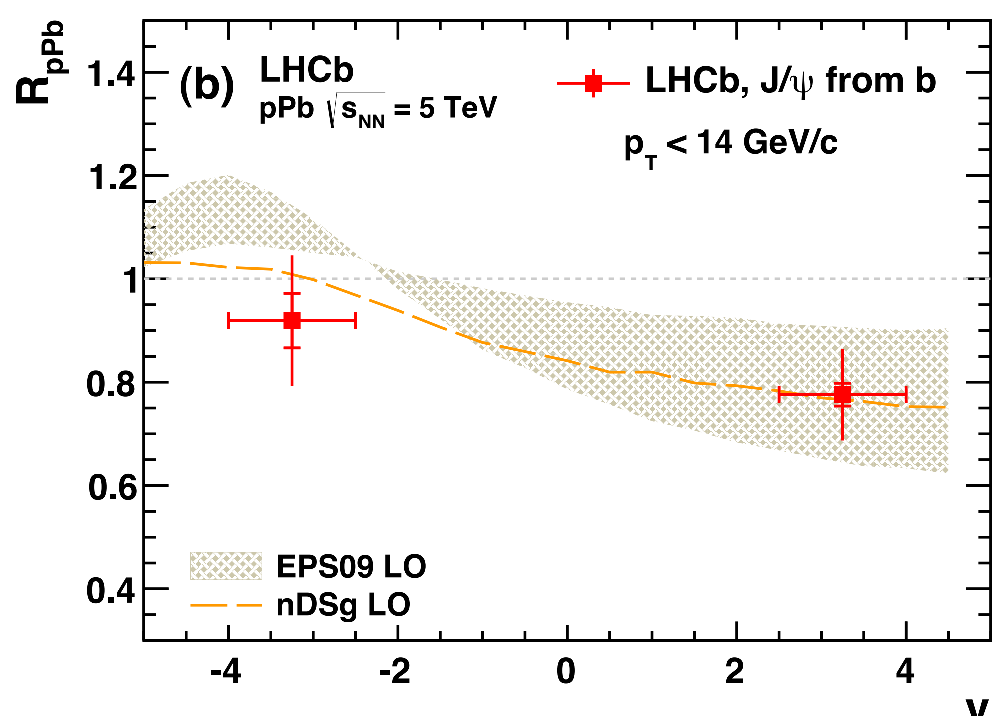
and forward-backward production ratio

$$R_{FB}(y, \sqrt{s_{NN}}) \equiv \frac{R_{pPb}(+|y|, \sqrt{s_{NN}})}{R_{pPb}(-|y|, \sqrt{s_{NN}})}$$

separately for prompt J/ψ and J/ψ from b-hadron decays



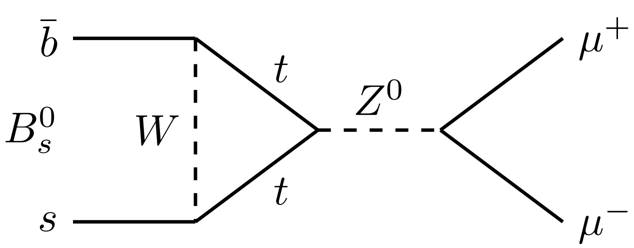


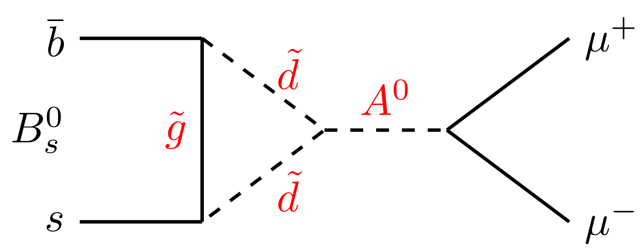


Search for $B_{(s)}^0 \to \mu^+\mu^-$

PRL 111 (2013) 101805

- Golden mode for testing NP models with new (pseudo-)scalar interactions





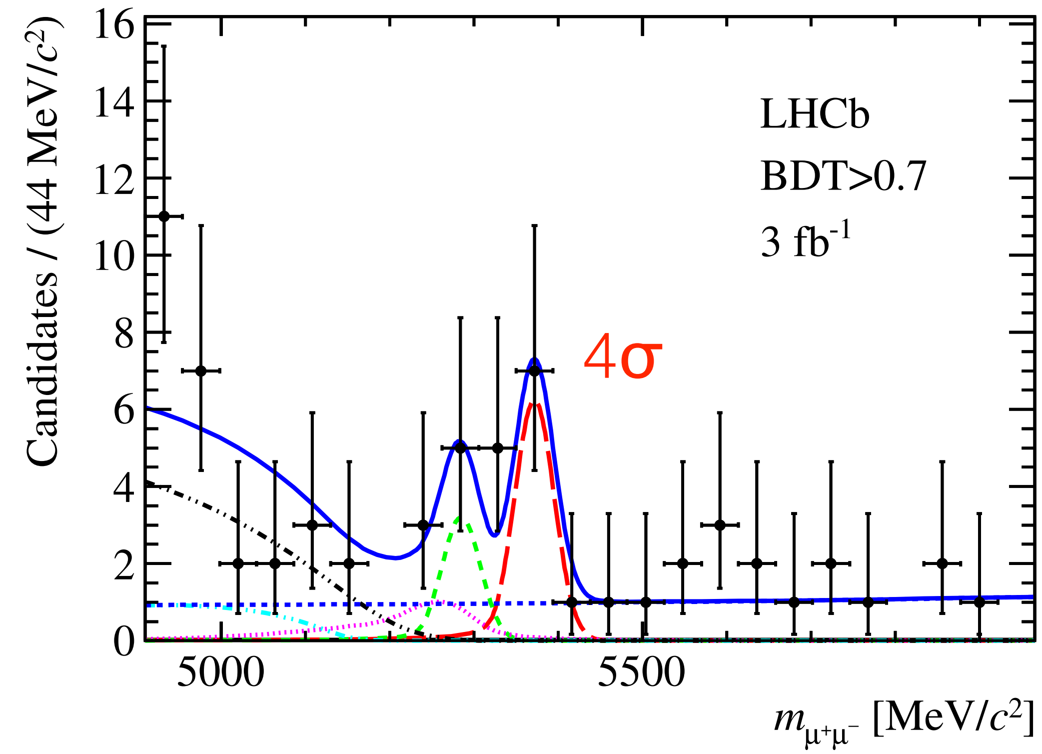
- Theoretically and experimentally clean
  - SM (time-integrated) prediction:

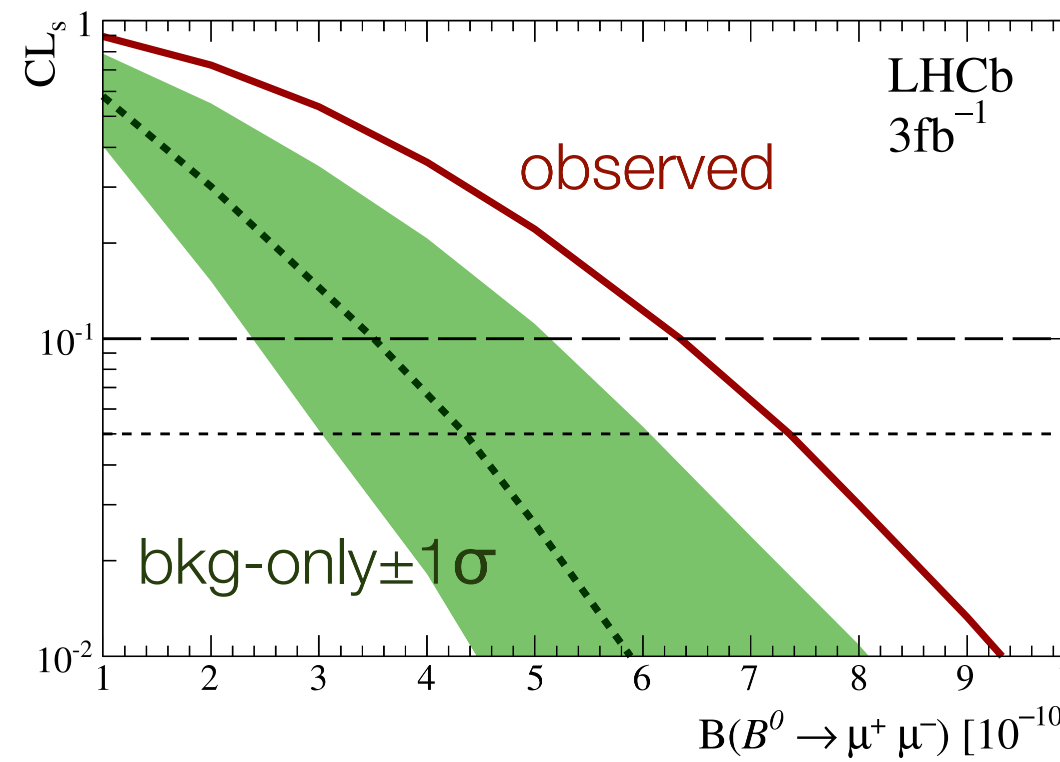
$$B(B_s^0 \to \mu^+\mu^-) = (3.56 \pm 0.30) \times 10^{-9}$$
$$B(B^0 \to \mu^+\mu^-) = (1.07 \pm 0.10) \times 10^{-10}$$

[EPJC 72 (2012) 2172, JHEP 1307 (2013) 77]

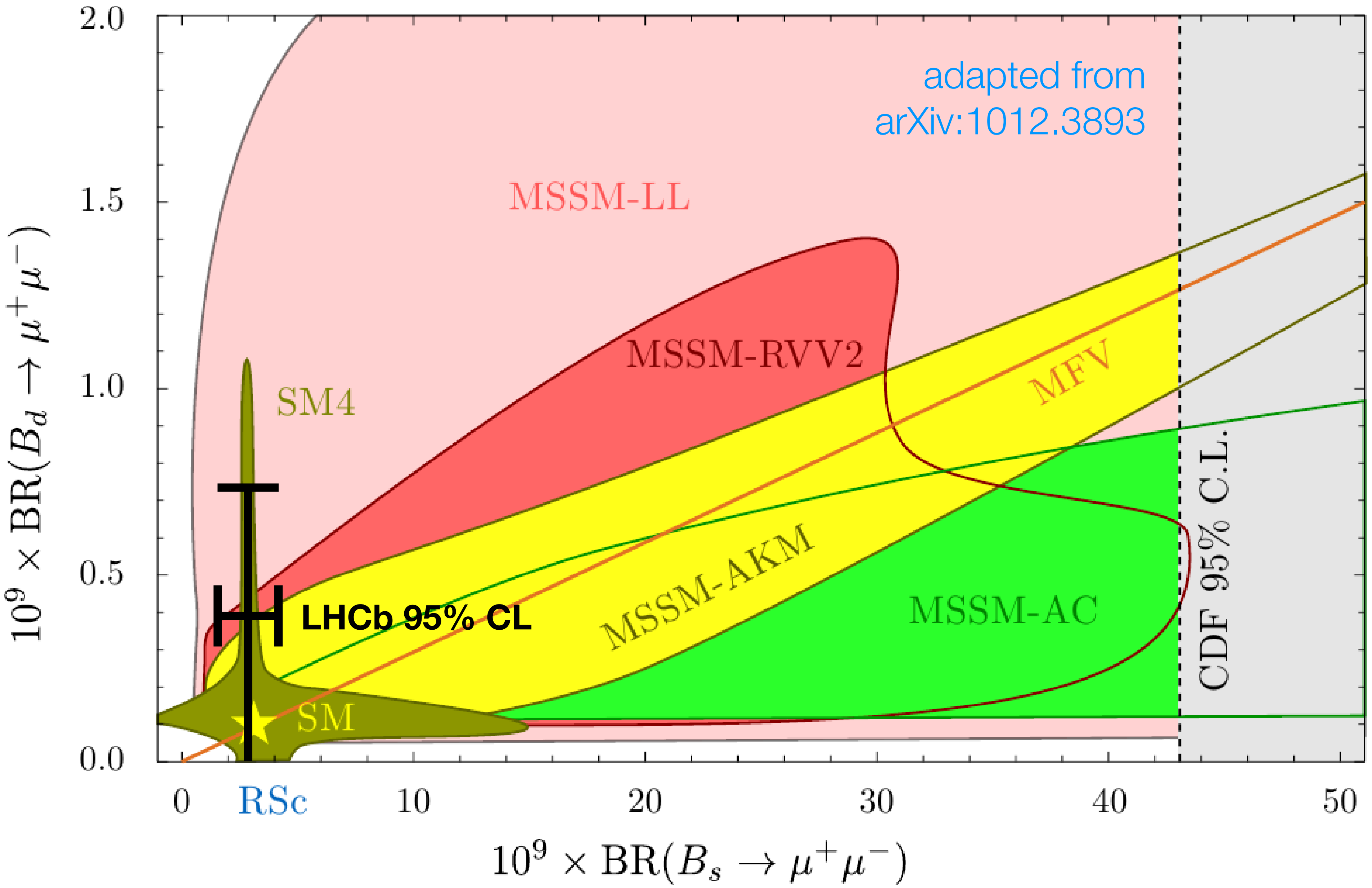
- Results from full Run 1 dataset

$$B(B_s^0 \to \mu^+\mu^-) = (2.9^{+1.1+0.3}_{-1.0-0.1}) \times 10^{-9}$$
$$B(B^0 \to \mu^+\mu^-) < 7.4 \times 10^{-10} \quad @ \ 95\% \ \mathrm{CL}$$





Impact on NP



Significantly constrains parameter space of many NP models, complementing direct searches from ATLAS/CMS

Combining with CMS...

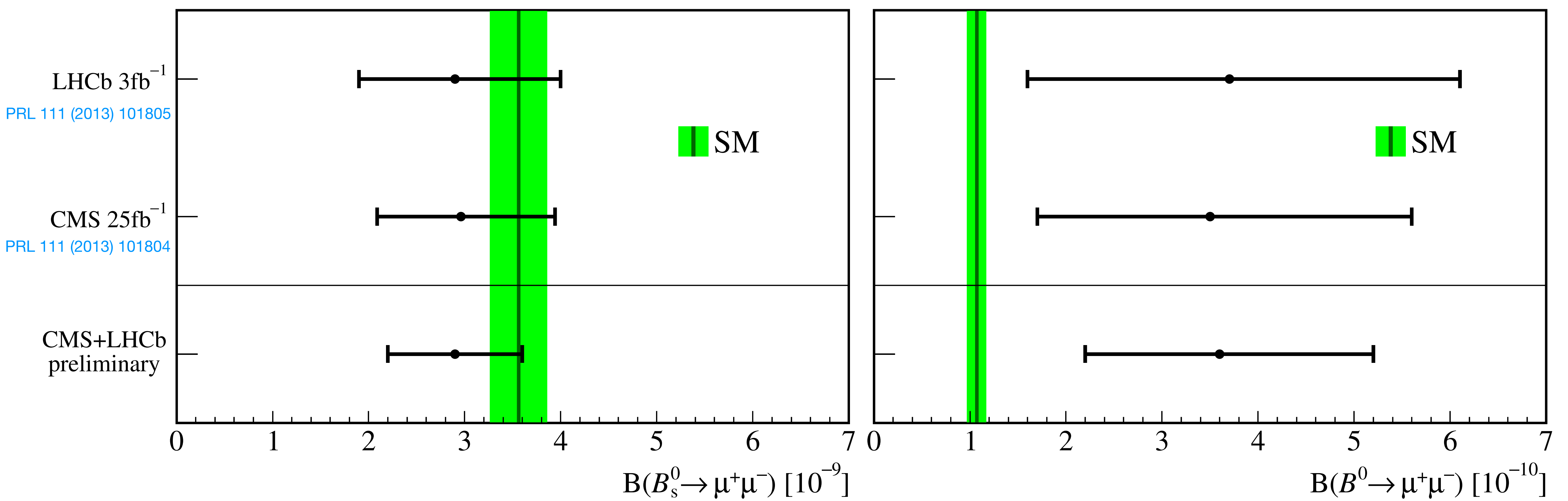
CMS-PAS-BPH-13-007
LHCb-CONF-2013-012

Observation

$$B(B_s^0 \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

>5σ

$$B(B^0 \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$$



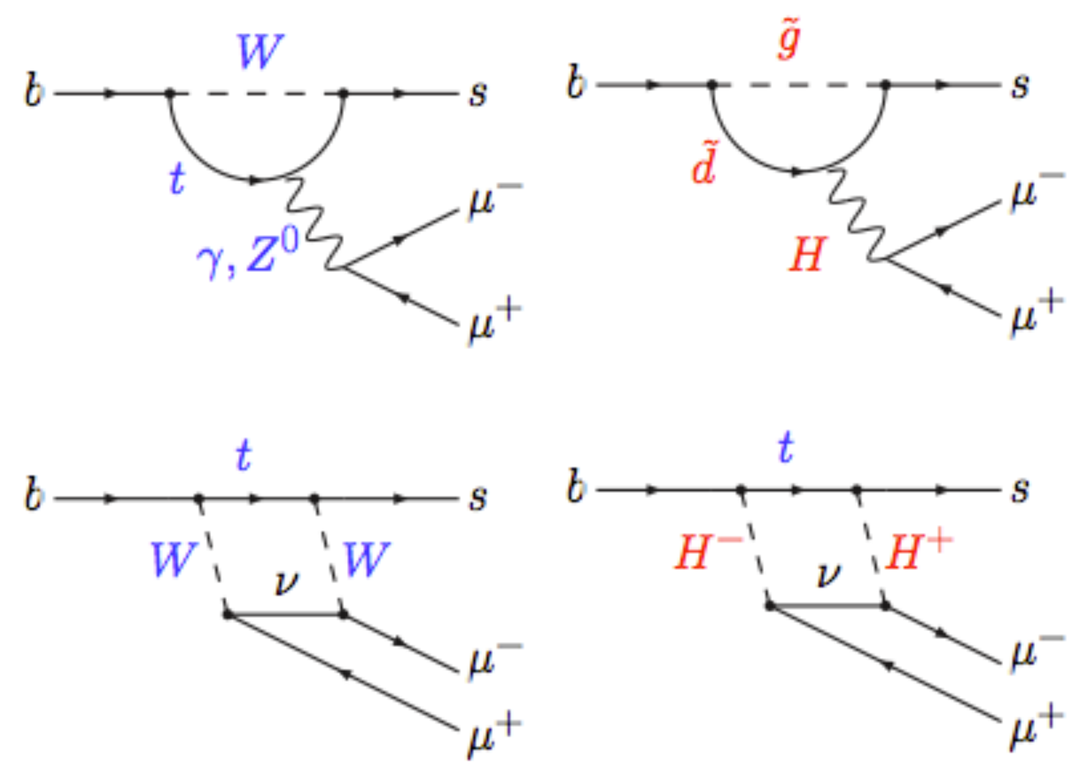
NP in b→sμ⁺μ⁻ transitions

- Rare processes where NP can enter to modify SM amplitudes

$$H = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^{*} \sum (C_i^{SM} + C_i^{NP}) O_i^{SM} + \sum \frac{c}{\Lambda_{NP}} O_{NP}$$

- In the SM contributions from

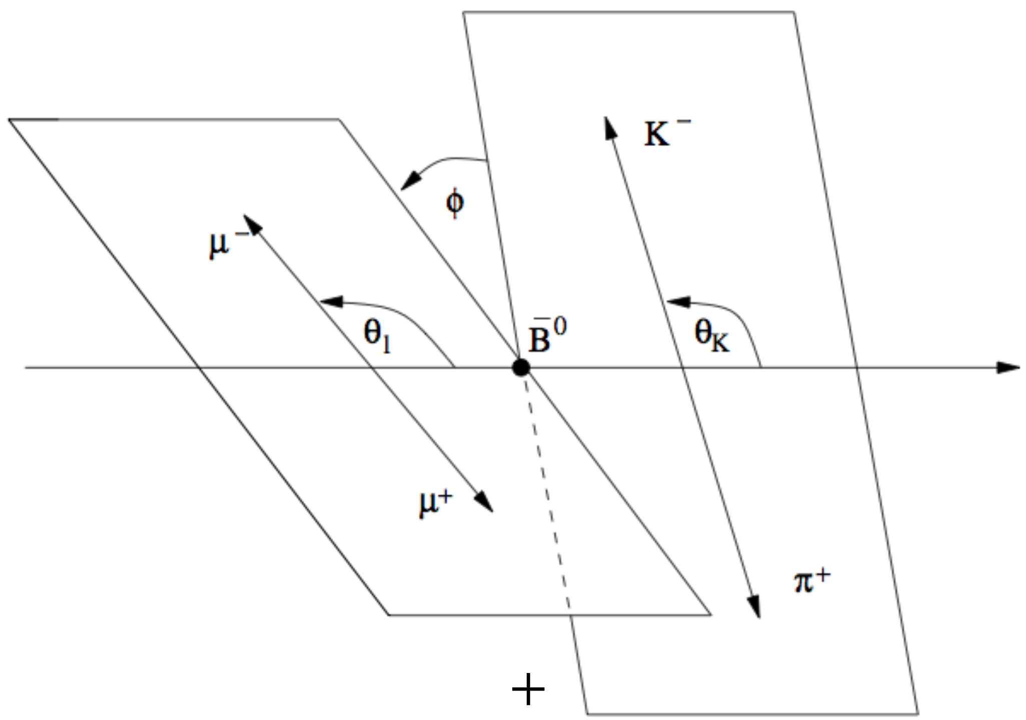
$$\mathcal{O}_7 \sim m_b(\bar{s}_L \sigma_{\mu\nu} b_R) F_{\mu\nu}$$
$$\mathcal{O}_9 \sim (\bar{s}b)_{V-A}(\bar{\ell}\ell)_V$$
$$\mathcal{O}_{10} \sim (\bar{s}b)_{V-A}(\bar{\ell}\ell)_A$$



- Angular distributions provide sensitivity to C_7, C_9 and C_{10} and their primed (helicity-flipped) counterparts

- Many channels with complementary information: $B^0 \to K^{*0}\mu^+\mu^-$, $B^+ \to K^+\mu^+\mu^-$, $B_s^0 \to \varphi\mu^+\mu^-$, $\Lambda_b^0 \to \Lambda^0\mu^+\mu^-$

Angular observables in $B^0 \rightarrow K^{*0}\mu^+\mu^-$

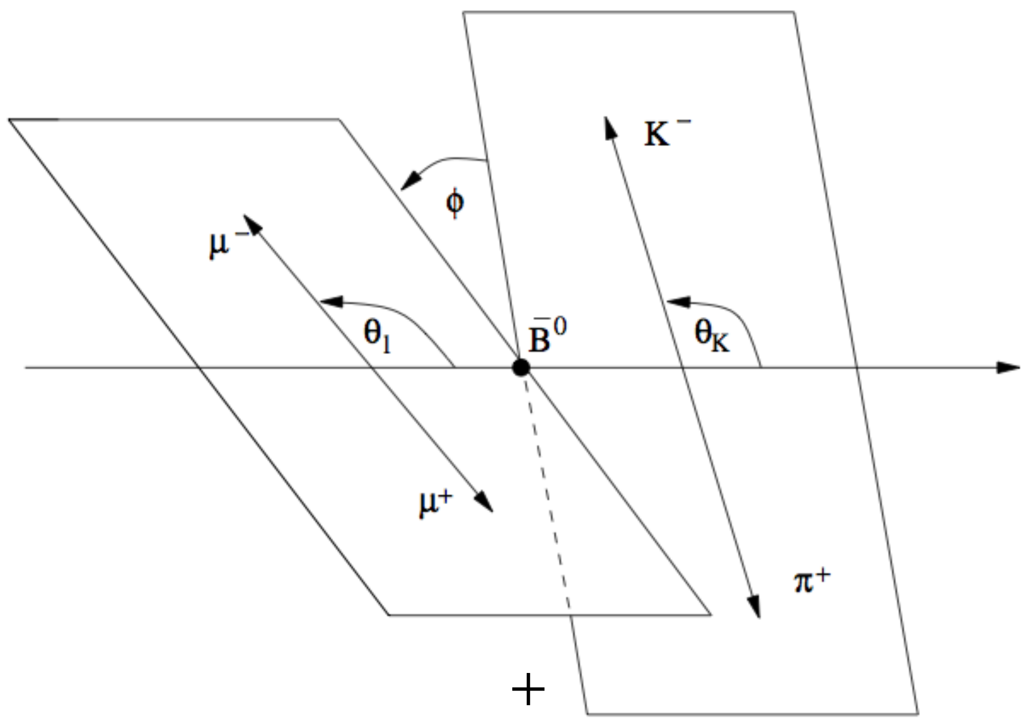


+

q^2 = dimuon mass

$$\frac{1}{\Gamma}\frac{\mathrm{d}^3(\Gamma+\bar{\Gamma})}{\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\left[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell \right.$$
$$- F_L\cos^2\theta_K\cos 2\theta_\ell +$$
$$S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi +$$
$$S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6^s\sin^2\theta_K\cos\theta_\ell +$$
$$S_7\sin 2\theta_K\sin\theta_\ell\sin\phi +$$
$$\left. S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi + S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\right]$$

Angular observables in $B^0 \to K^{*0} \mu^+ \mu^-$



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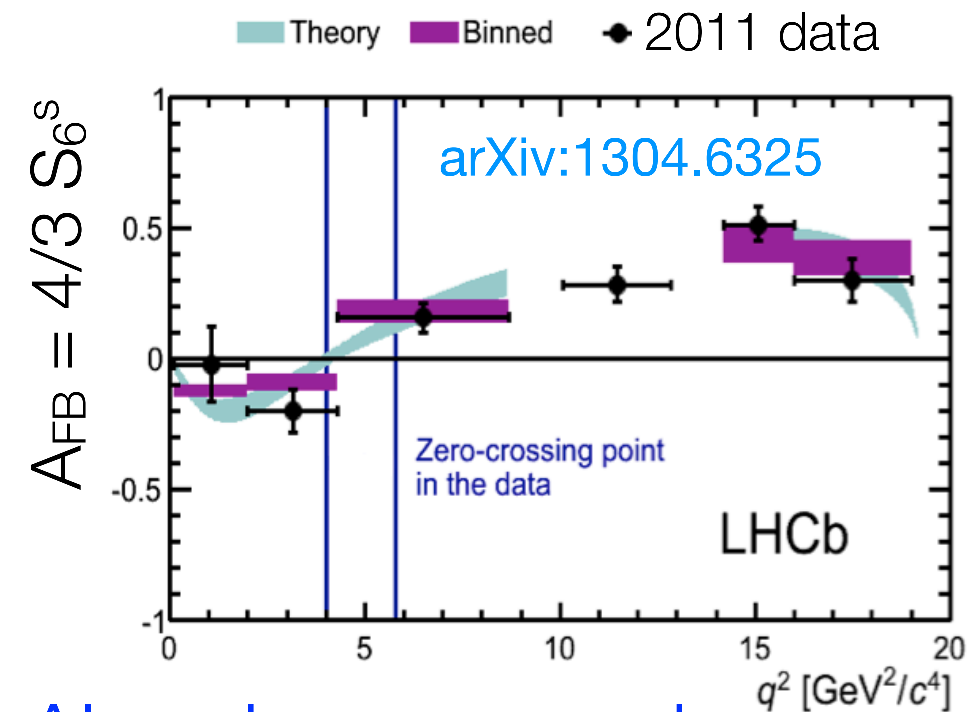
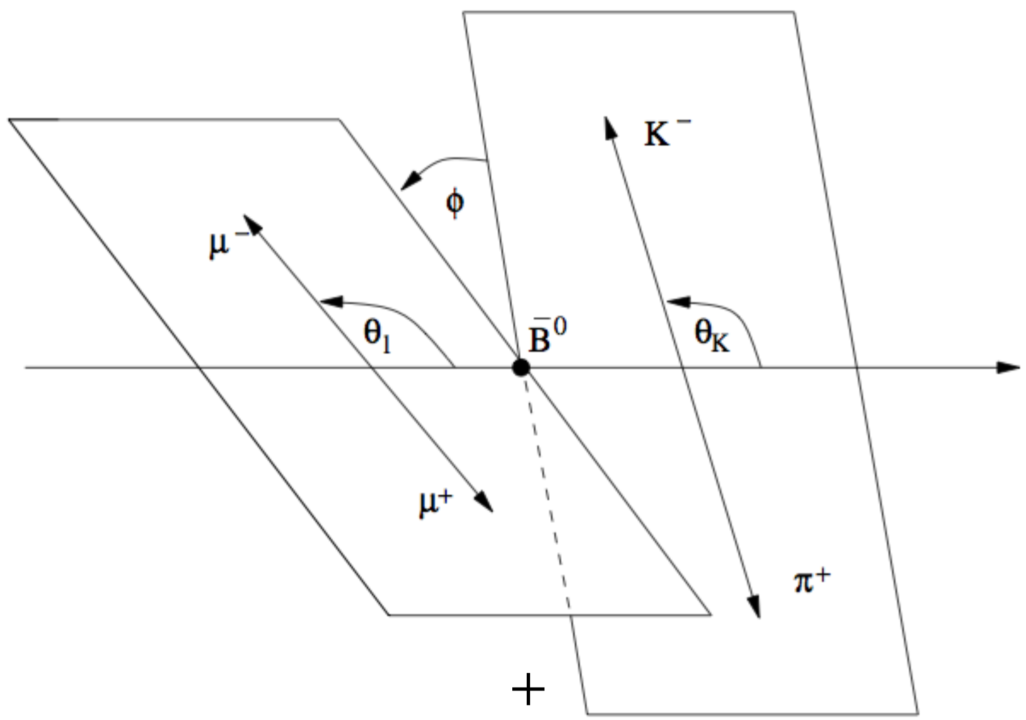


Already measured

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

Angular observables in $B^0 \to K^{*0}\mu^+\mu^-$



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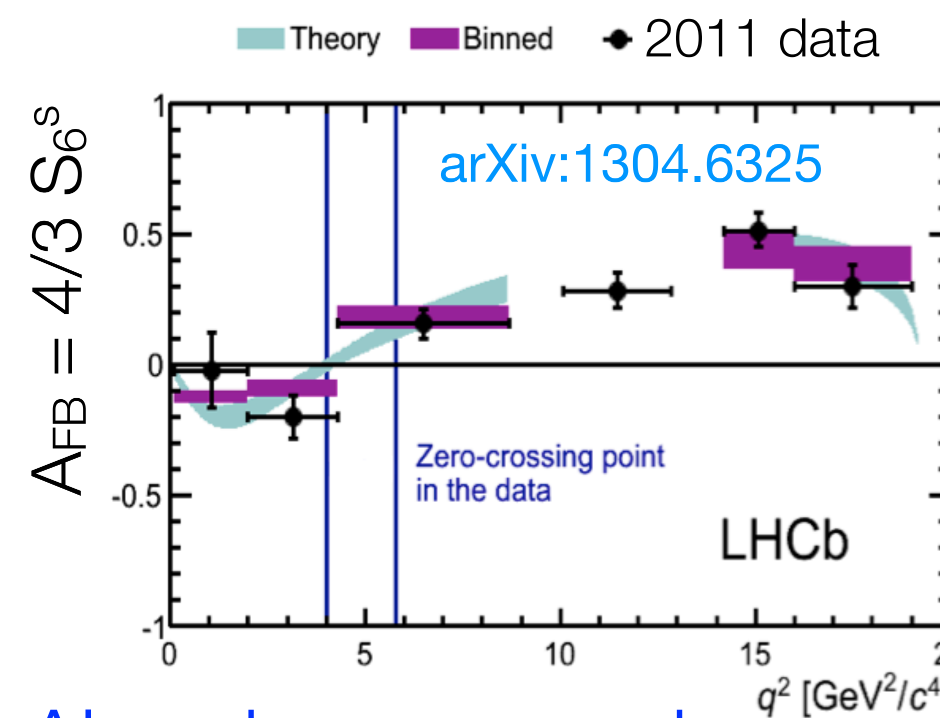


Already measured

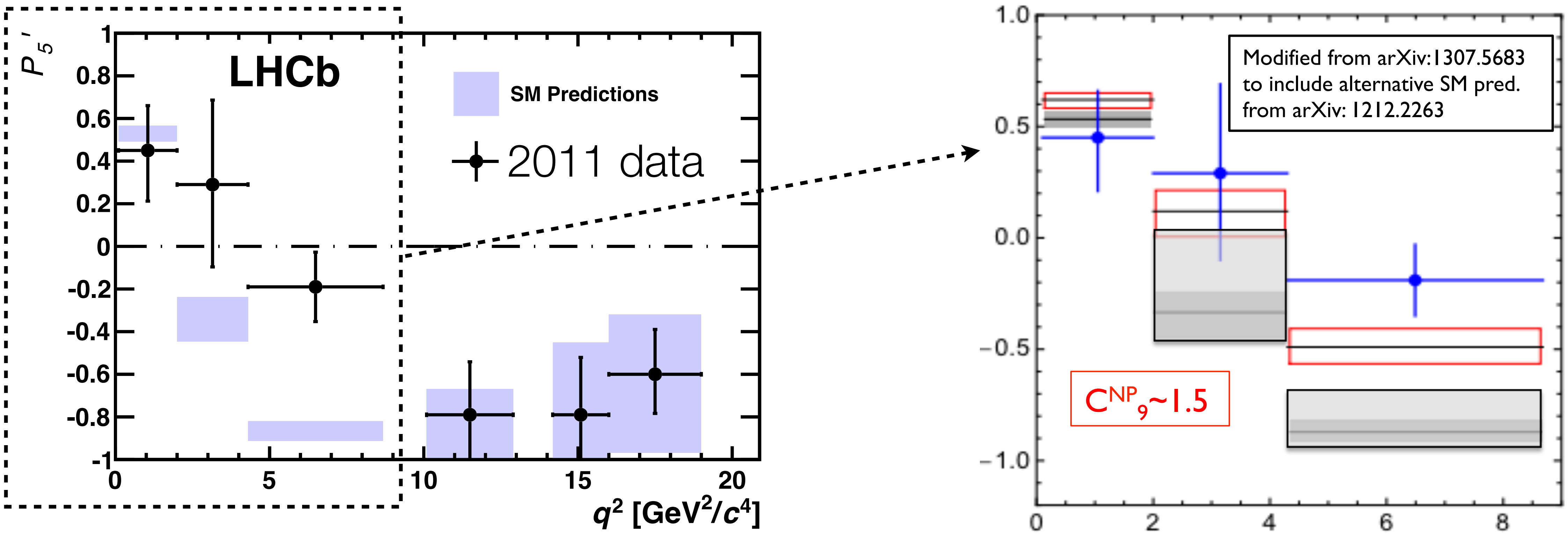
$$\frac{1}{\Gamma}\frac{d^3(\Gamma+\bar{\Gamma})}{d\cos\theta_\ell\, d\cos\theta_K\, d\phi} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_\ell$$
$$- F_L\cos^2\theta_K\cos 2\theta_\ell +$$
$$S_3\sin^2\theta_K\sin^2\theta_\ell\cos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

Now measure

$$P_i' = \frac{S_i}{\sqrt{(1-F_L)F_L}}$$

New angular observables in $B^0 \to K^{*0} \mu^+ \mu^-$

arXiv:1308.1707



- Most of measurements in good agreement with SM predictions; only a hint of disagreement in P'_5 at low q^2
  - SM predictions for P'_5 differ significantly between different authors
  - Nevertheless, NP contributing to C_9 could provide a better fit to the data and still be compatible with other measurements
- The increase in sensitivity of the analysis with 2011+2012 data could already be tale-telling...

CPV in neutral D mesons

- Flavor/CP violating processes in charm decays are highly suppressed in the SM
  - A unique probe for NP that couples to the up-quark sector (complementary to direct searches in top physics and to indirect searches with $B_{(s)}$, K decays)
- Neutral mesons provide rich phenomenology including
  - Mixing: $|D_{1,2}\rangle = p|D^0\rangle + q|\overline{D}^0\rangle$, $x = \frac{m_2 - m_1}{\Gamma}$, $y = \frac{\Gamma_2 - \Gamma_1}{2\Gamma}$
  - CPV in decay amplitudes (direct CPV): $|\mathcal{A}(\overline{D}^0 \to \bar{f})| \neq |\mathcal{A}(D^0 \to f)|$
  - CPV in mixing and/or in interference between mixing and decay (indirect CPV): $\lambda_f = \left|\frac{q}{p}\right| \left|\frac{\mathcal{A}(\overline{D}^0 \to f)}{\mathcal{A}(D^0 \to f)}\right| e^{i(\phi+\delta_f)}$
- LHCb is the ideal place where to study charm decays

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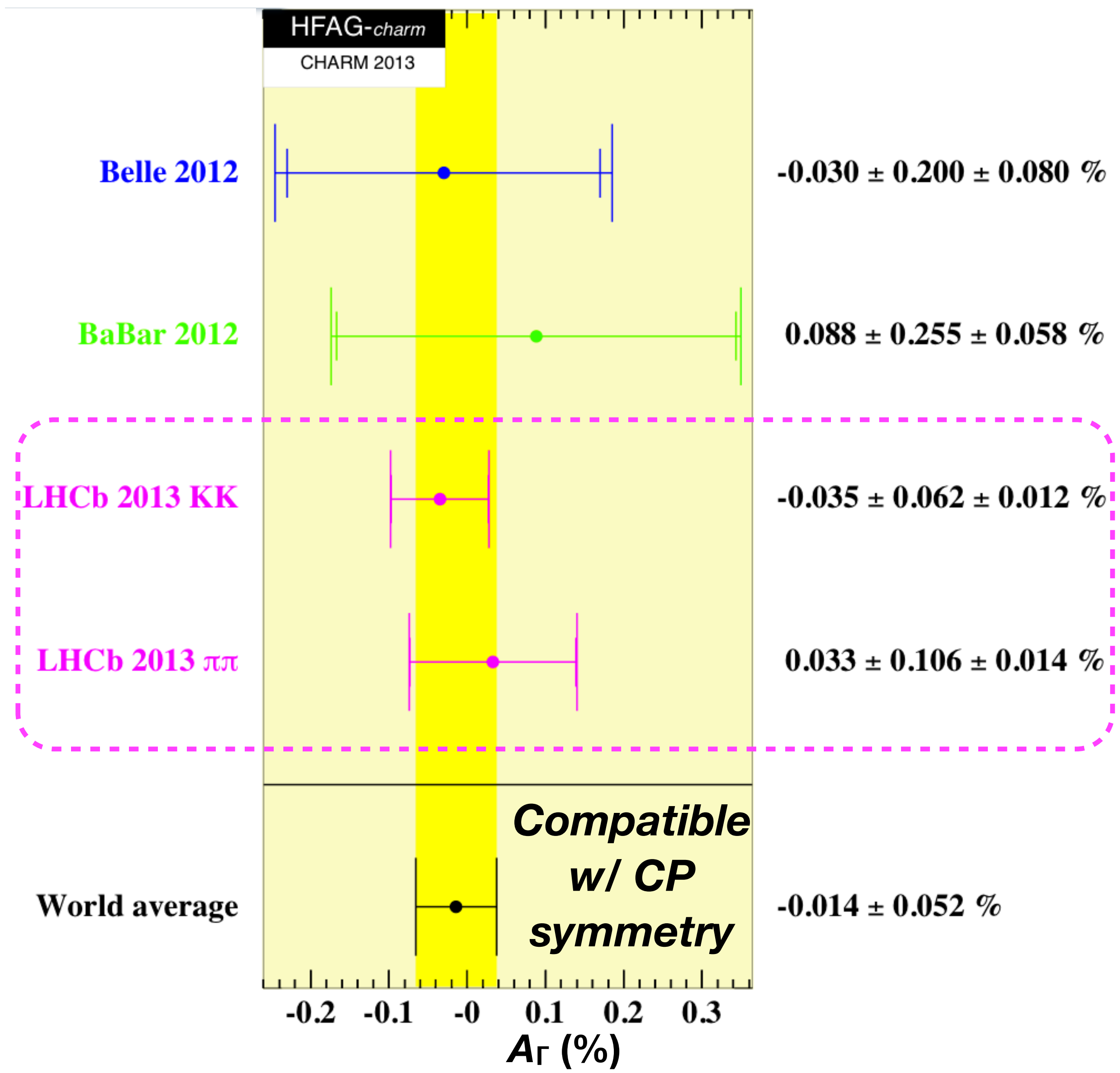
Now measure

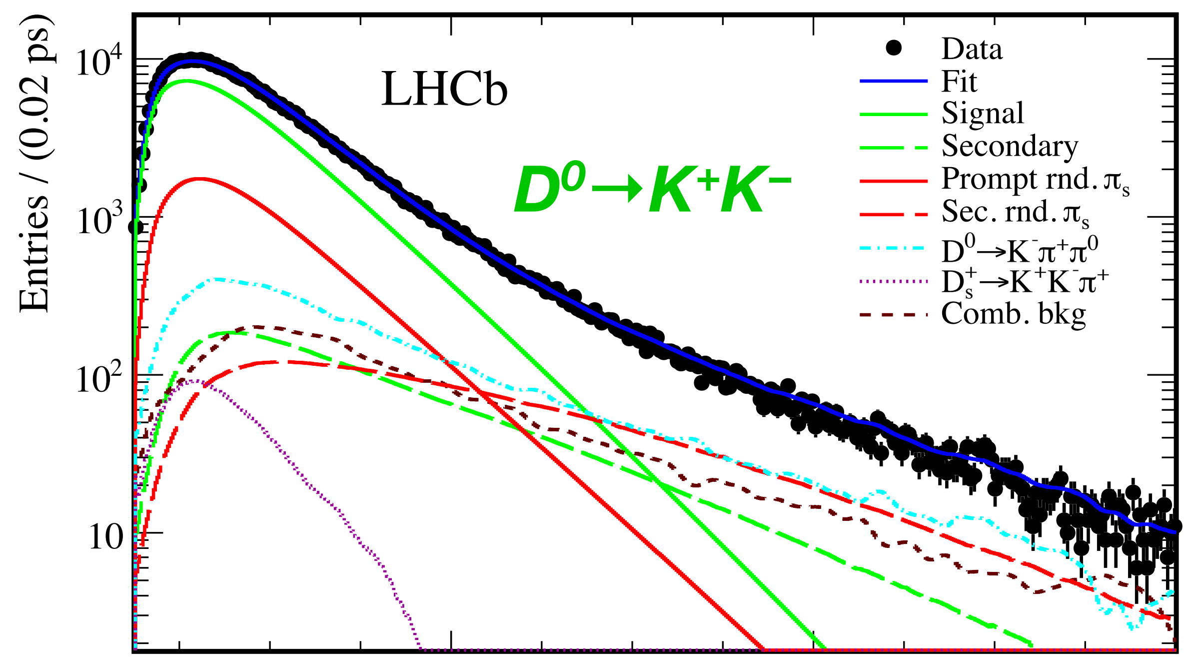
Indirect CPV with $D^0 \to h^+h^-$

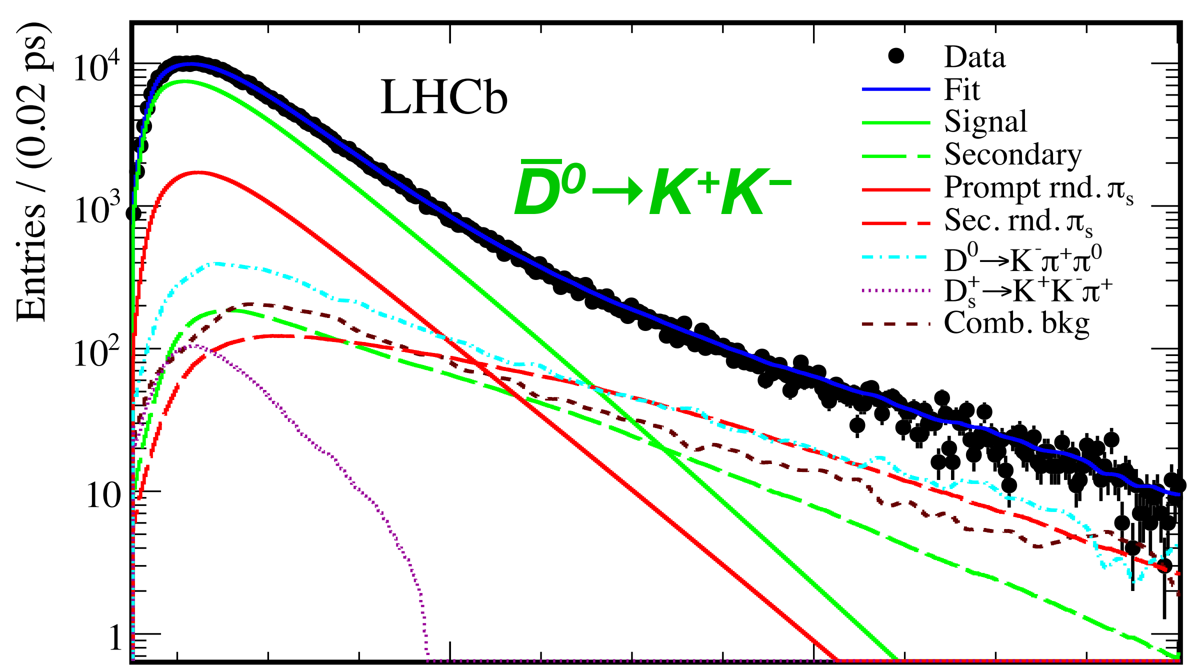
- Differences between effective lifetimes of neutral D decaying to CP eigenstates (e.g. K^+K^- and $\pi^+\pi^-$)
- World leading results:

$$A_\Gamma = \frac{\hat\tau(\overline{D}^0) - \hat\tau(D^0)}{\hat\tau(\overline{D}^0) + \hat\tau(D^0)} \approx \frac{1}{2}\left[\left(\left|\frac{q}{p}\right| - \left|\frac{p}{q}\right|\right) y\cos\phi - \left(\left|\frac{q}{p}\right| + \left|\frac{p}{q}\right|\right) x\sin\phi\right]$$



2011 data





LHCb-PAPER-053

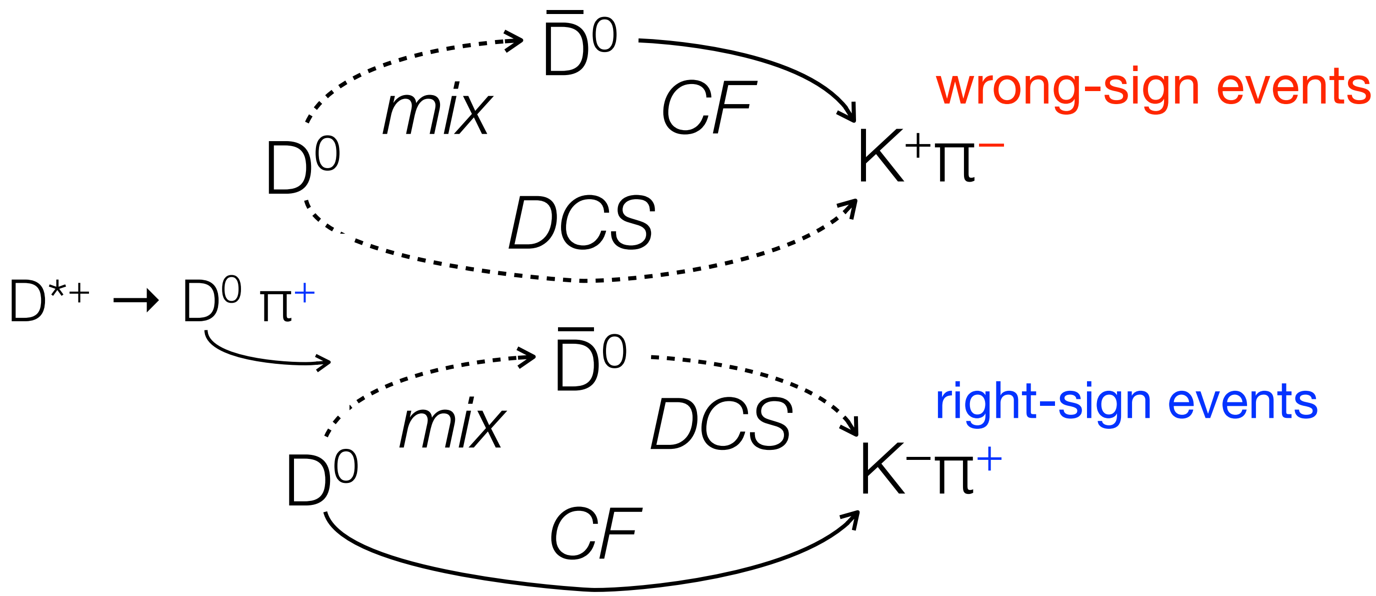
Charm mixing and CPV with $D^0 \to K^+\pi^-$

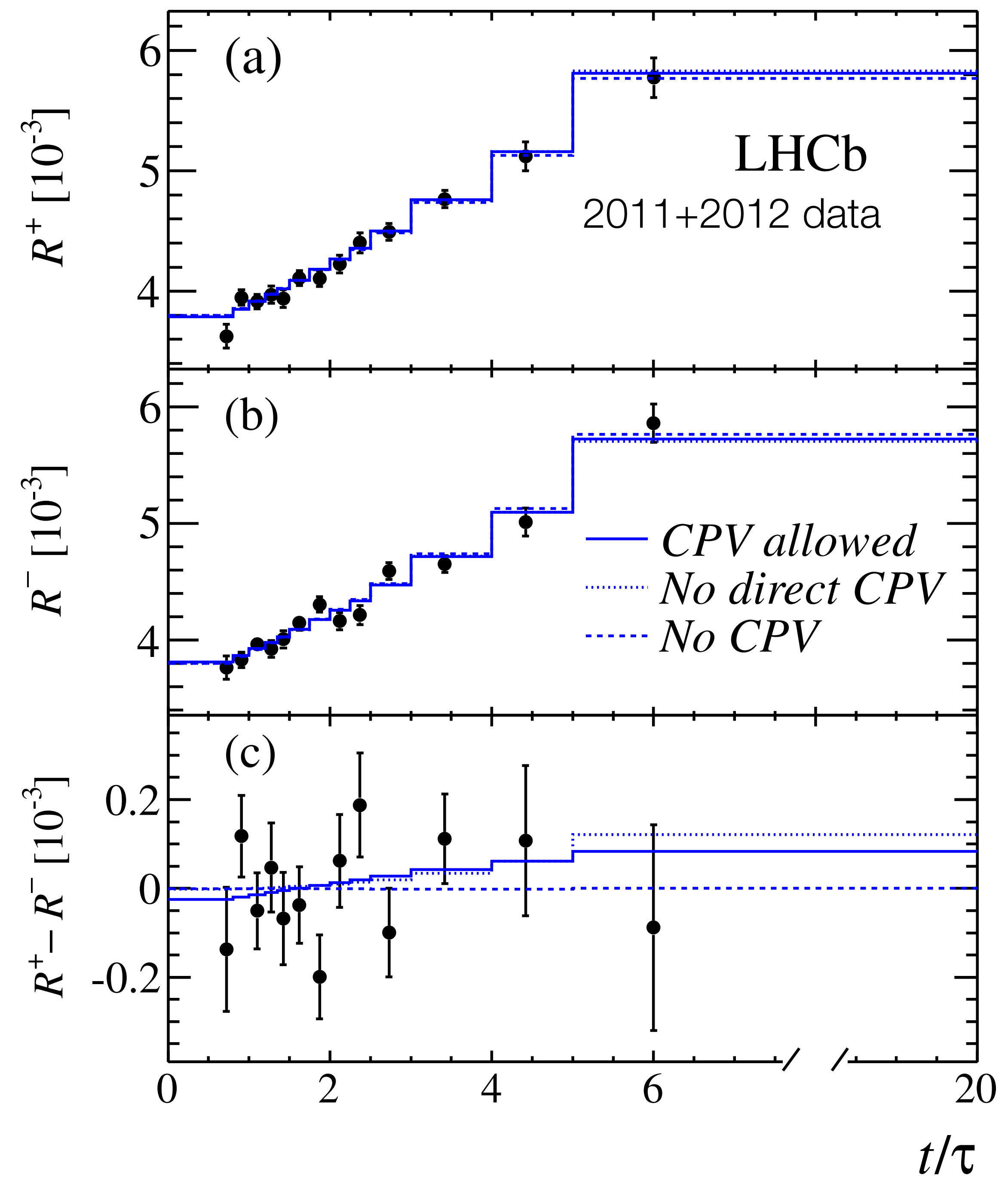
$$R_D^{\pm} = R_D(1 \pm A_D)$$

$$y'^{\pm} = \left|\frac{q}{p}\right|^{\pm 1} [y\cos(\delta \pm \phi) \mp x\sin(\delta \pm \phi)]$$

$$R^{\pm} = R_D^{\pm} + \sqrt{R_D^{\pm}}\, y'^{\pm} \left(\frac{t}{\tau}\right) + \frac{x^2+y^2}{4}\left(\frac{t}{\tau}\right)^2$$

- Time-dependent WS/RS ratio:





- Precision on mixing parameters improved by 2.5× wrt previous result [PRL 110 (2013) 101802]

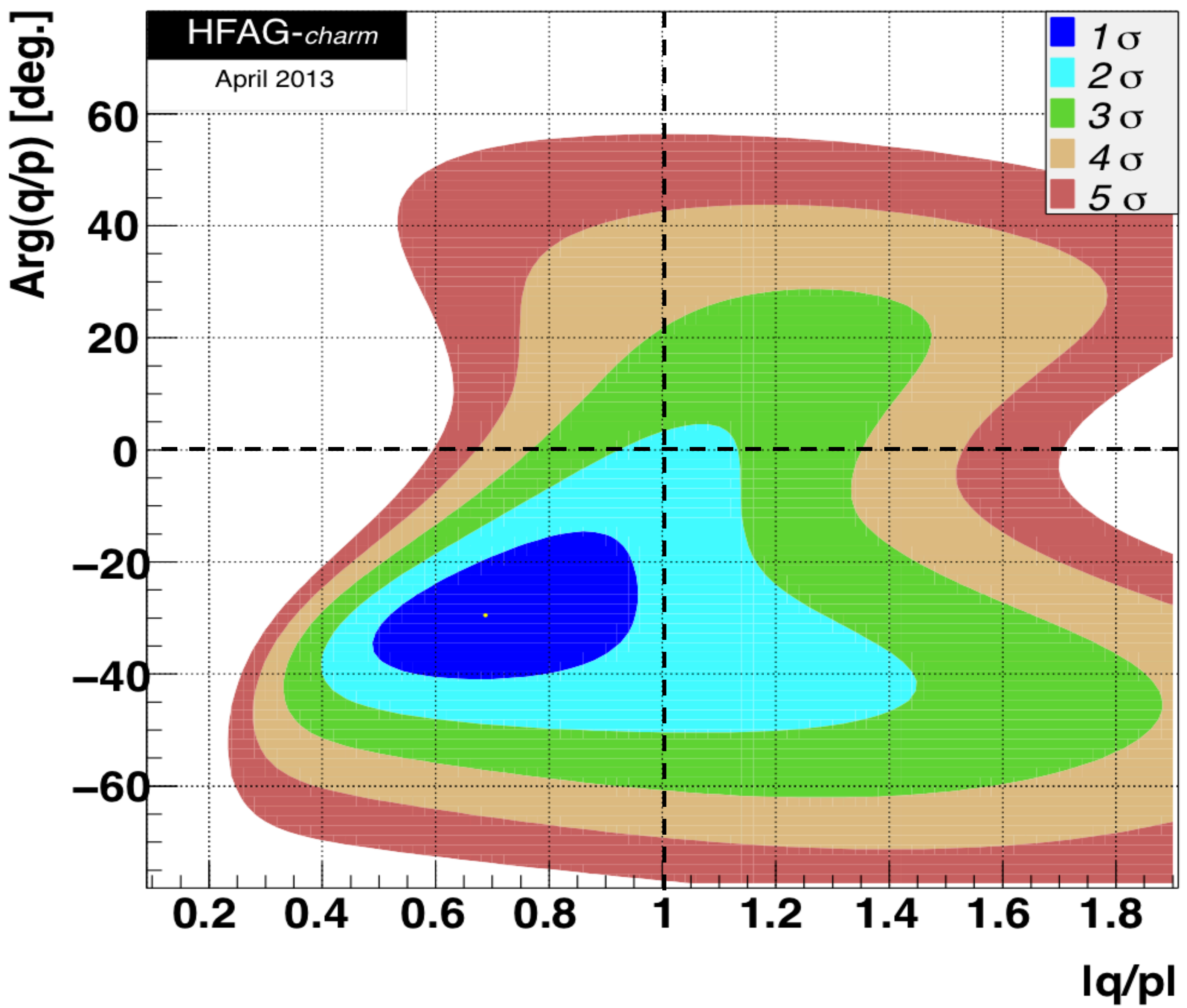
- No CPV found:

$A_D = (-0.7 \pm 1.9)\%$

$0.75 < |q/p| < 1.24$ @68.3% CL

Impact on world average

from B. Golob's talk at CHARM 2013



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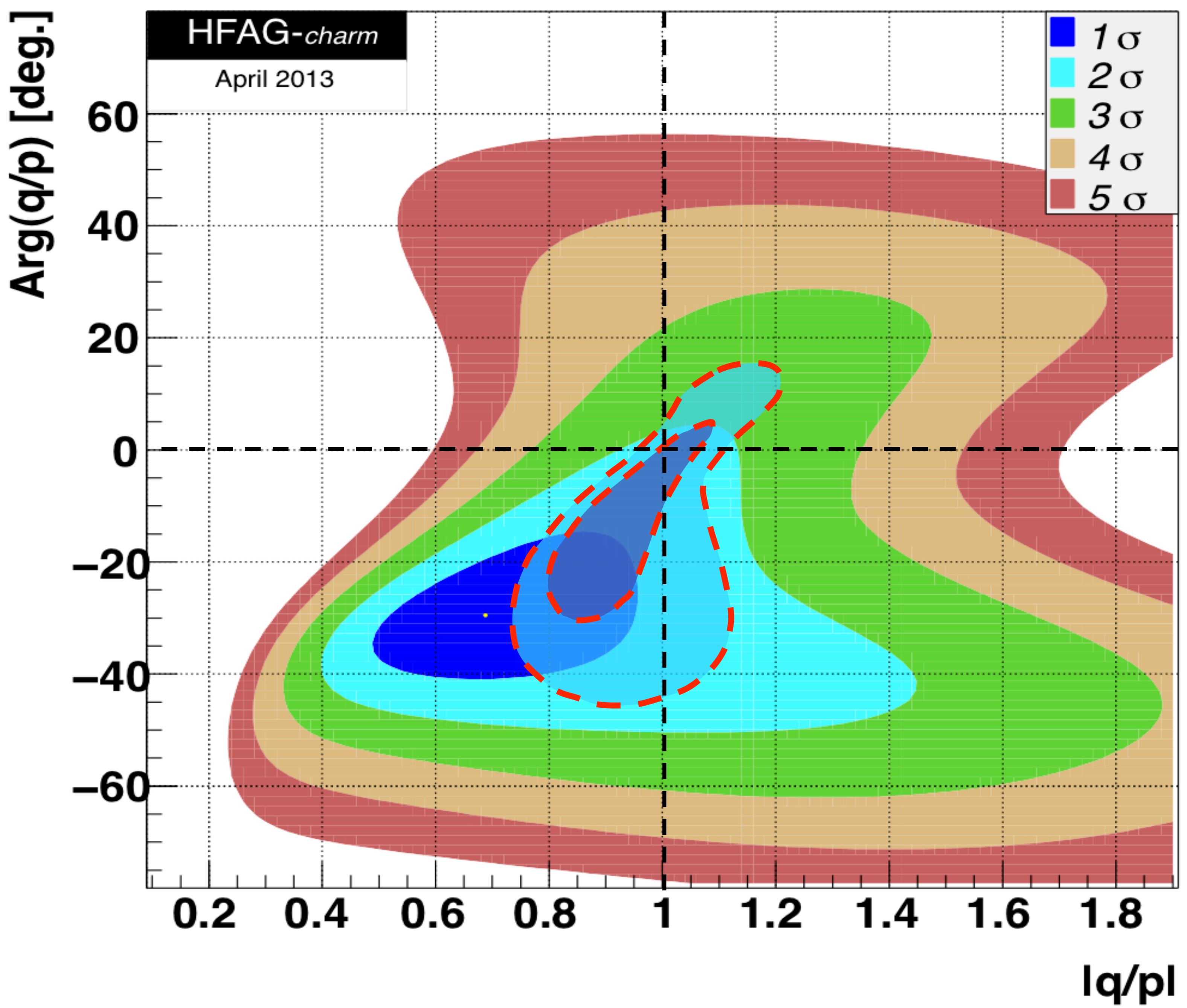

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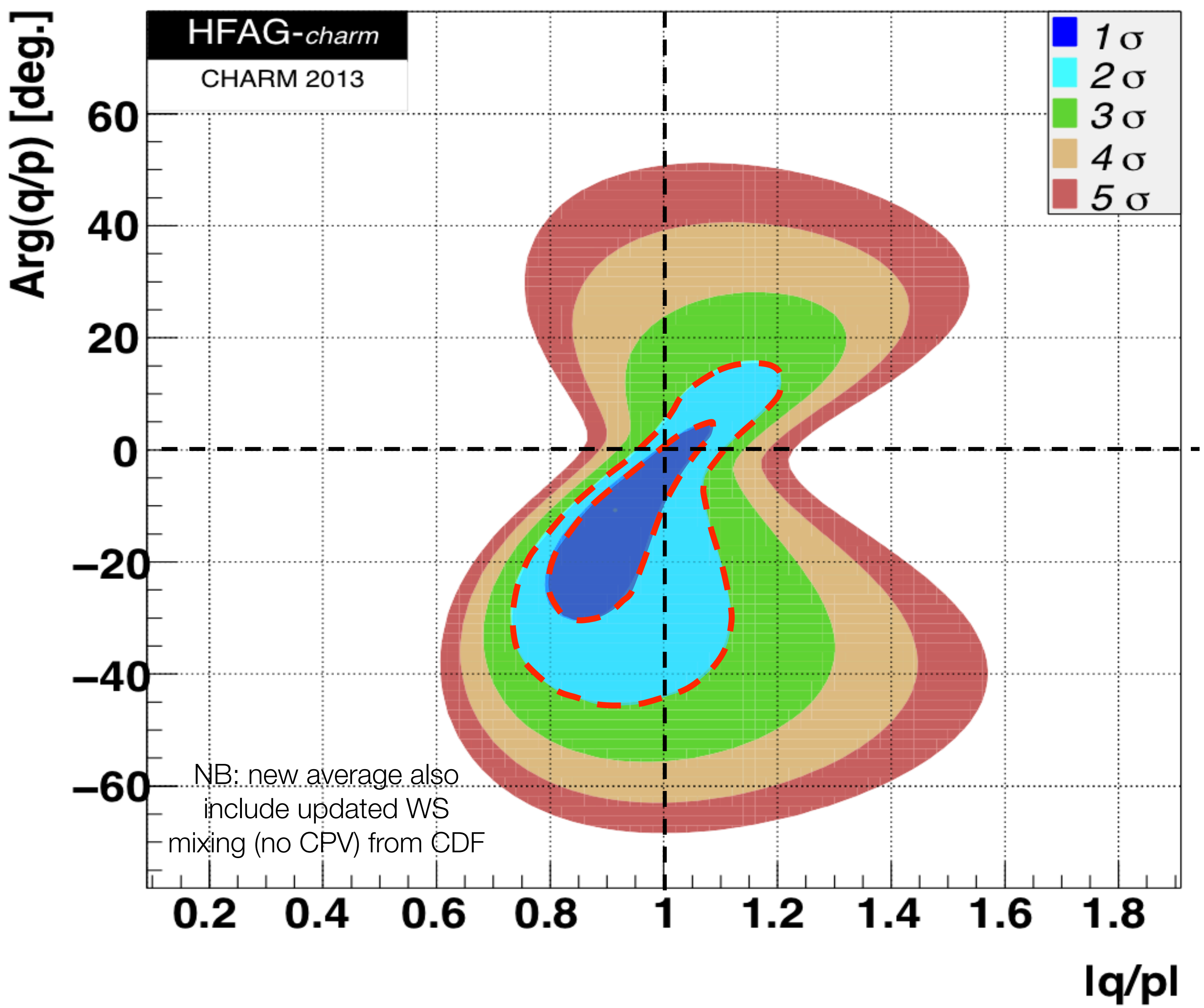
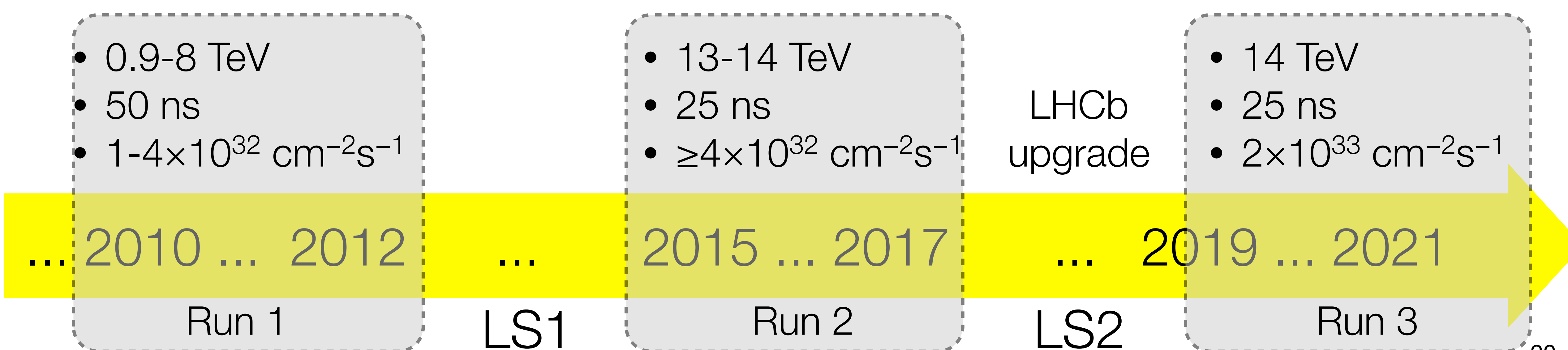


What’s next?

- Deviations from the SM not (yet) observed, most measurements limited by statistical precision
- After Run 2 we hope to have ~3× the current statistics, but afterwards would need ~5 years to double the data
  - not very rewarding...
- LHCb already runs at twice its design luminosity, trigger design limits do not allow to go much higher
  - need to upgrade the detector in LS2 to profit from higher luminosity



Expected sensitivities

EPJC 73, 2373 (2013)

Type	Observable	Current precision (Spring 2012)	LHCb 2018 (7-8 fb^{-1})	**Upgrade** (50 fb^{-1})	Theory uncertainty
B_s^0 mixing	$2\beta_s(B_s^0 \to J/\psi\phi)$	0.10 [139]	0.025	0.008	$\sim$0.003
	$2\beta_s(B_s^0 \to J/\psi f_0(980))$	0.17 [219]	0.045	0.014	$\sim$0.01
	a_{sl}^s	6.4×10^{-3} [44]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguins	$2\beta_s^{eff}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{eff}(B_s^0 \to K^{*0}\overline{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{eff}(B^0 \to \phi K_S^0)$	0.17 [44]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{eff}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	$<$0.01
	$\tau^{eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguins	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\ \text{GeV}^2/c^4)$	0.08 [68]	0.025	0.008	0.02
	$s_0 A_{FB}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [68]	6 %	2 %	7 %
	$A_I(K\mu^+\mu^-; 1 < q^2 < 6\ \text{GeV}^2/c^4)$	0.25 [77]	0.08	0.025	$\sim$0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [86]	8 %	2.5 %	$\sim$10 %
Higgs penguins	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [13]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	$\sim$100 %	$\sim$35 %	$\sim$5 %
Unitarity triangle angles	$\gamma(B \to D^{(*)}K^{(*)})$	$\sim$10–12° [252, 266]	4°	0.9°	negligible
	$\gamma(B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta(B^0 \to J/\psi K_S^0)$	0.8° [44]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [44]	0.40×10^{-3}	0.07×10^{-3}	–
	$\Delta\mathcal{A}_{CP}$	2.1×10^{-3} [18]	0.65×10^{-3}	0.12×10^{-3}	–

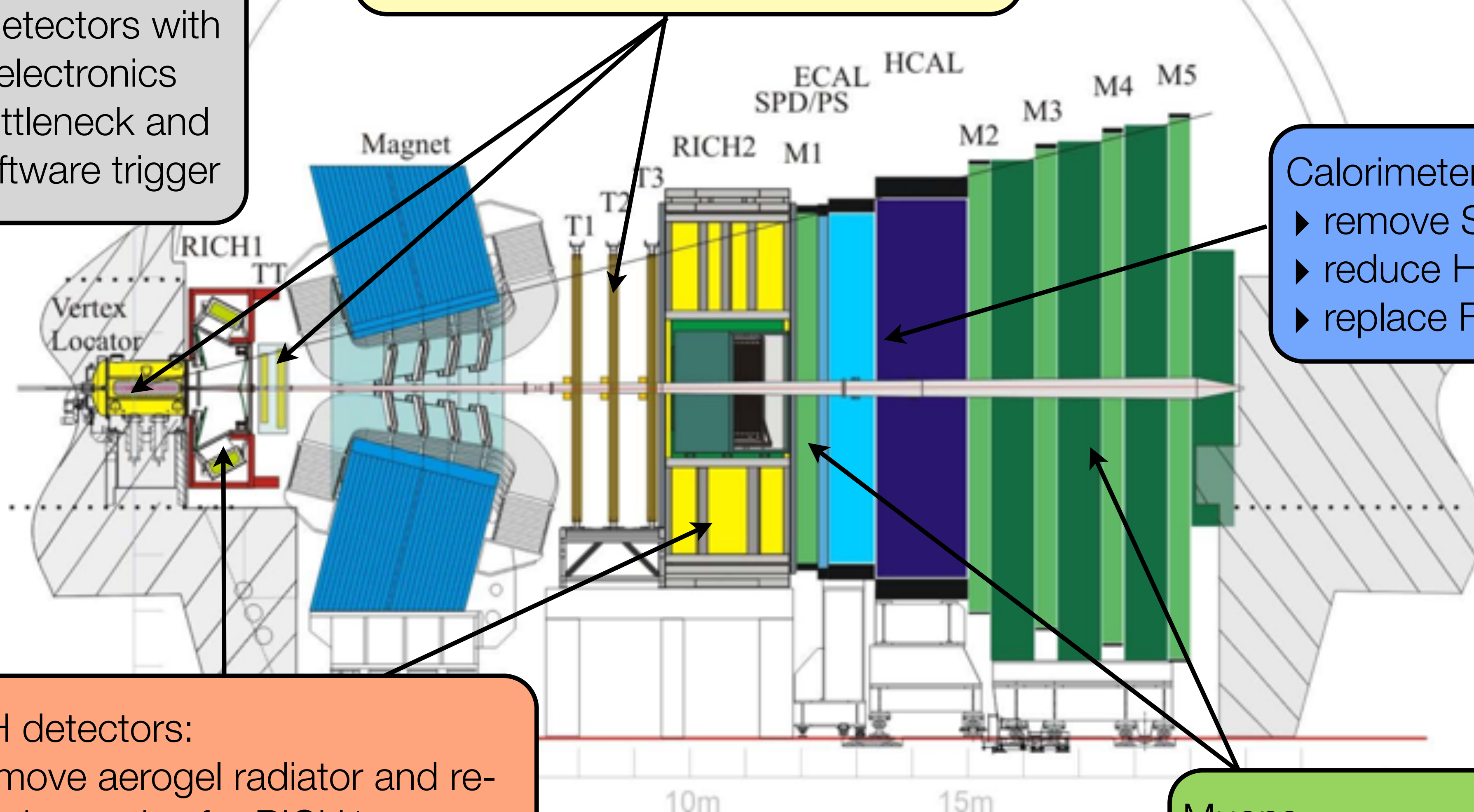
Letter of Intent for the LHCb Upgrade
CERN-LHCC-2011-001

Framework TDR for the LHCb Upgrade
CERN-LHCC-2012-007

LHCb upgrade

Trigger & DAQ:
- read-out full detector at 40 MHz
  - replace FE and BE electronics
  - replace all detectors with embedded electronics
- remove L0 bottleneck and have an all software trigger

Tracking system:
- Replace all detectors
  - VELO (Si pixels)
  - upstream tracker (Si strips)
  - downstream tracker (Sci-Fi?)



Calorimeters:
- remove SPD & PS
- reduce HV & PMT gain
- replace FE electronics

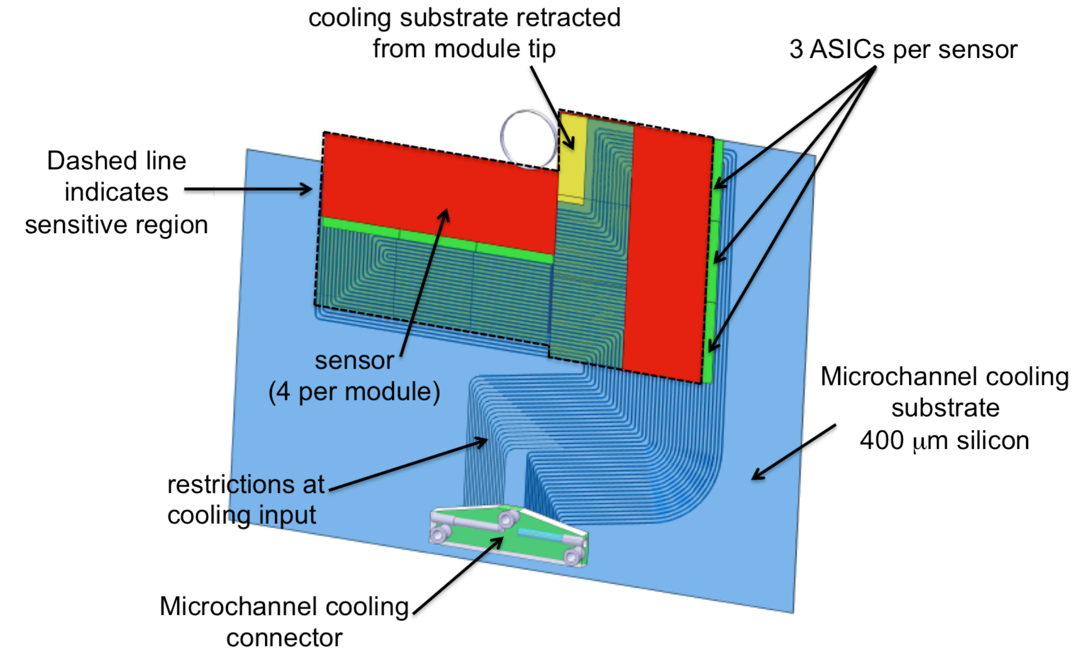
RICH detectors:
- remove aerogel radiator and re-design optics for RICH1
- replace photo-detectors
- R&D for a TORCH detector

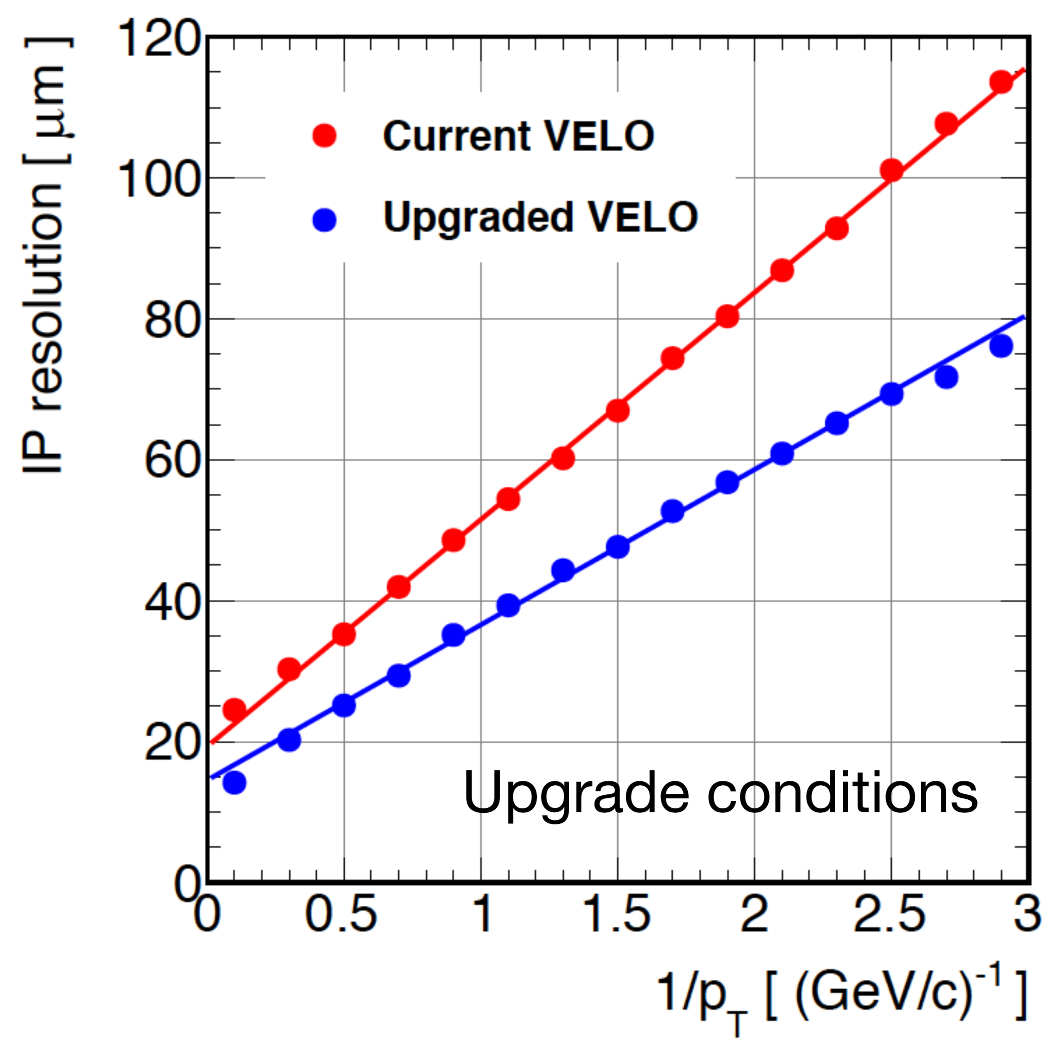
Muons:
- remove M1
- replace FE electronics

Upgraded VELO

Details in P. Collins' talk at yesterday's LHCC Detector Upgrade Review

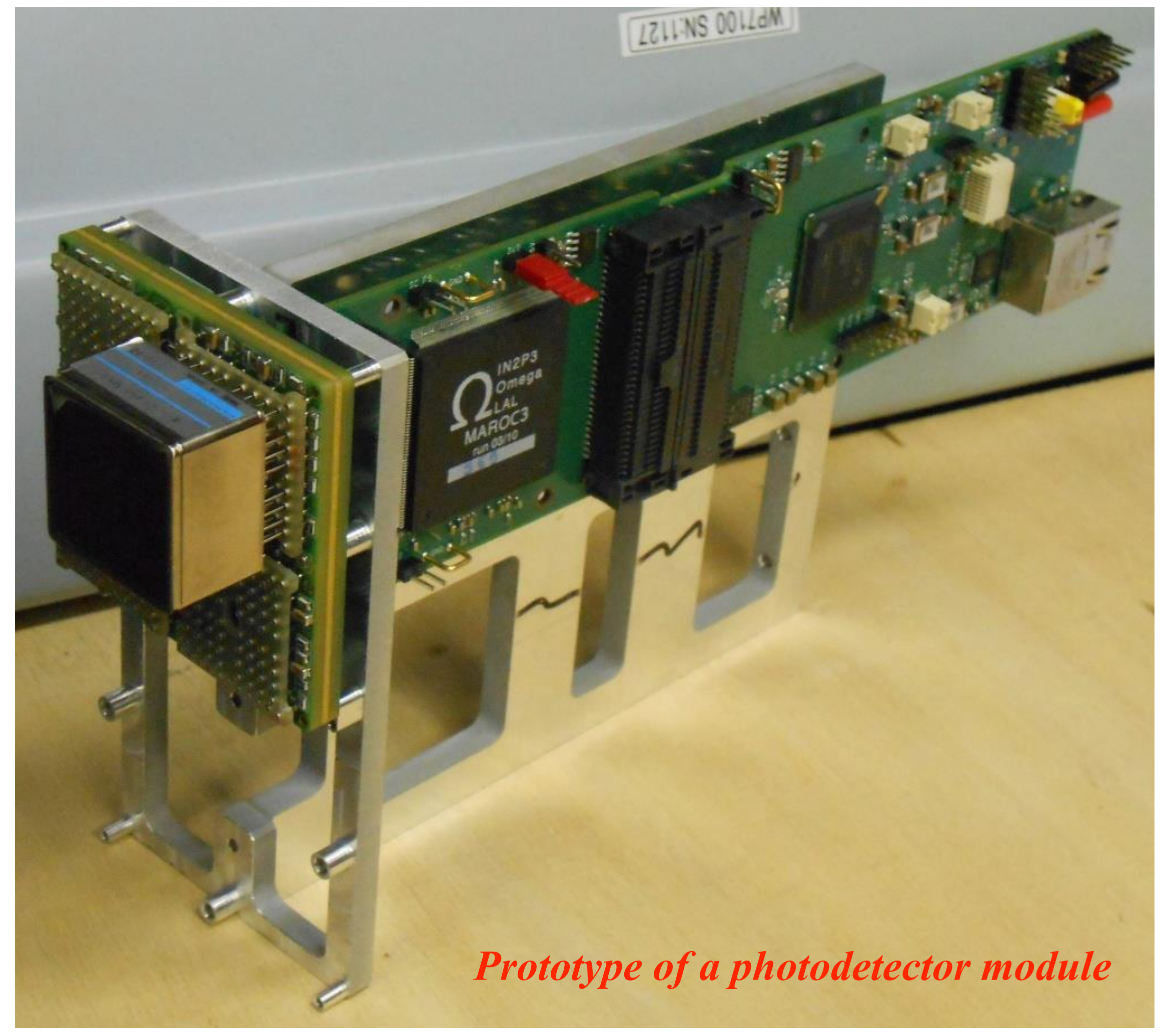
- Technology choice made last June
  - From micro-strips to pixels for faster pattern recognition
    - Essential for the trigger
  - CO_2 cooling with micro-channels etched in silicon
    - Minimize material budget
- New VELO will have better performances than current VELO in upgrade conditions





Upgraded RICH system

- Decided to keep both RICHes
  - RICH1 and RICH2 have photodetectors with embedded electronics
    - Replace with multi-anode PMTs to allow 40MHz read-out
  - RICH1 has two radiators to provide PID for low-momentum particles
    - Remove aerogel that is less effective at high luminosity
  - Improve RICH1 optics design (inside the present magnetic shield envelope) to reduce occupancy



Prototype of a photodetector module

Details in C. D'Ambrosio's talk at yesterday's LHCC Detector Upgrade Review

Major milestones over next 6 months

2013

- **14-15 November** - upstream tracker technology review
- **20-21 November** - downstream tracker technology choice
- **26 November** - submission of VELO, RICH, CALO, MUON TDRs to LHCC
    - **3-5 December** - LHCC meeting, presentation of first set of TDRs

2014

- **1 March** - submission of trackers and low-level trigger TDRs
    - **5-6 March** - LHCC meeting, presentation of second set of TDRs

Conclusions

- LHCb producing high-quality physics results and preparing the detector and the software for Run 2
- Most measurements in good agreement with the SM, but almost all limited by statistics
  - Full data sample not (yet) completely exploited
  - The LHCb upgrade will allow (in several cases) to approach in precision the theoretical uncertainty
- R&D for the upgrade progressing according to plans
  - Important technology choices taken for VELO and RICH