Precision EW Physics at LHCb: A_{fb} and $\sin^2\theta_W$

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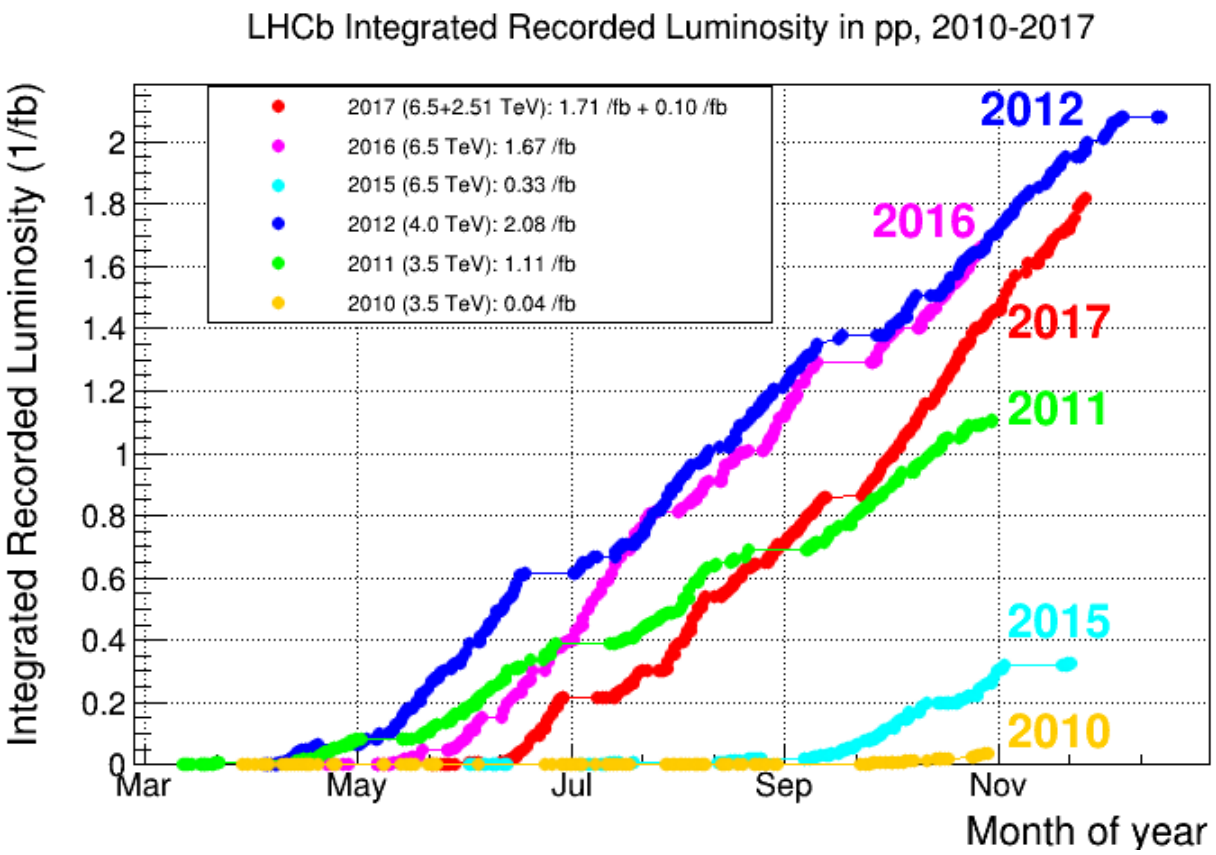
Luminosity at LHCb

- Operate with luminosity levelling – optimal conditions to reconstruct displaced vertices.
- LHCb will undergo major upgrades increasing instantaneous luminosity possible.



High precision high pT measurements in the first 10-15 years of operations at LHCb will focus on muons. ECAL upgrades will improve electron precision.

	Run 1 (2010-2012)	Run 2 (2015-2018)	Upgrade I	Run 3 (2021-2023)	Run 4 (2026-2029)	Upgrade II	Run 5 (2030+)
Lumi in Run / fb^{-1}	3	6		14	27		250
Total / fb^{-1}	3	9		23	50		300

Existing measurements

Extreme forward region has lower dilution of A_{fb} between parton & particle level, and lower PDF uncertainty on this dilution (before in situ constraints considered): LHCb measurement of $\sin^2\theta_W$ can be competitive and complementary to ATLAS and CMS.

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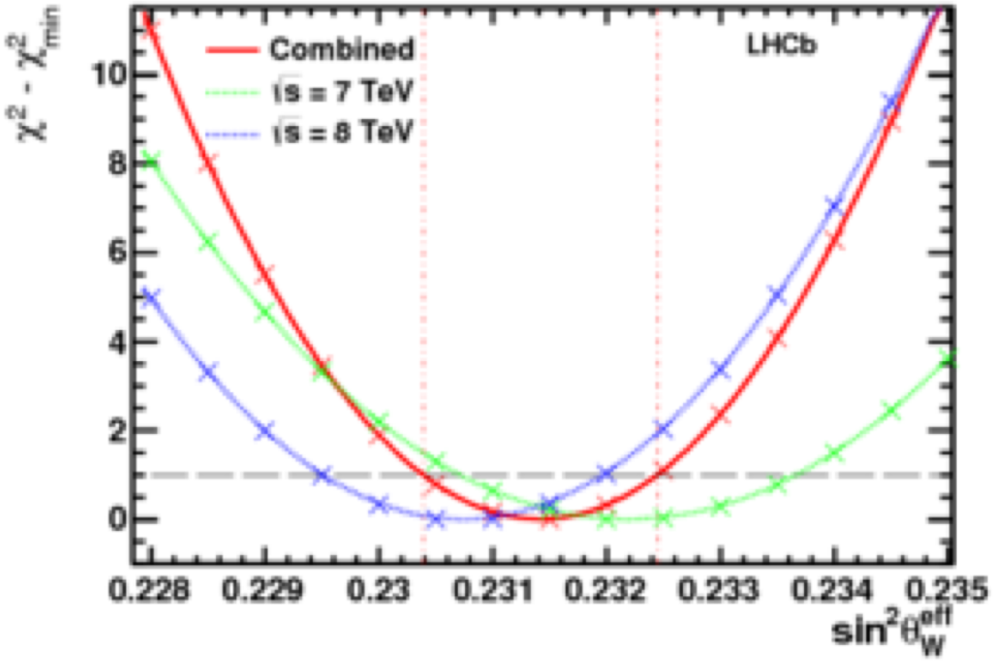
Strategy of *existing* LHCb weak mixing angle measurement:

- Measure forward-backward asymmetry in Z/γ* decays to a dimuon final state as a function of dimuon mass.
- Unfold measured asymmetry for detector effects to particle-level result.
- Compare to templates associated with different values of the weak mixing angle (from POWHEG+Pythia), to extract value the data favours.

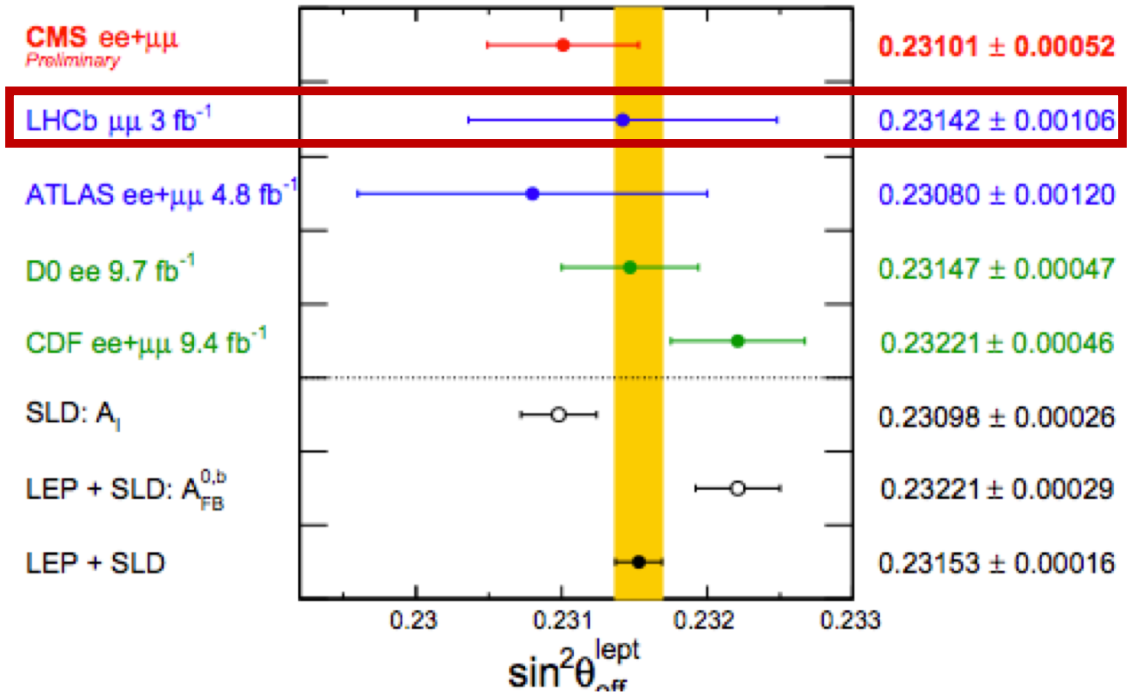


- Repeat for 100 equi-probable PDFs: 68% interval of extracted values sets PDF uncertainty.
- Overall Precision is about $100*10^{-5}$ (very similar to ATLAS)

Plot adapted from
CMS PAS SMP-16-007

Existing measurements

- Overall Precision is about **$100*10^{-5}$**
- Largest uncertainty on existing LHCb measurement is statistical
- Largest systematic uncertainty from momentum scale – **will improve with more data to determine it.**
- Largest theory uncertainty:
  PDFs, about **$50*10^{-5}$** *(no in situ constraints applied)*
- Other uncertainties also contain statistical components (eg MC stats when fitting data using templates corresponding to different values of α_s)



Future measurements

- Lower statistical uncertainties due to increased luminosity
  - Statistical uncertainties much smaller in HL era (can expect below $10*10^{-5}$)
- Dimuon -> Dilepton: statistically uncorrelated samples; only partially correlated systematics – reduction of uncertainties in combination.
- Use in-situ PDF constraints
- Improve analysis techniques:
  - weight events to maximize sensitivity.
  - Bin measurements in rapidity as well as mass.
- …
- **Many pathways to more precise LHCb measurements.**

Future studies

- Developing precision studies of what future measurements at LHCb can achieve in terms of sensitivity to the weak mixing angle.
  - Statistical precision.
  - In-situ PDF constraints.

- Also investigating other considerations:
  - Impact of extending detector acceptance. (No major changes, but consider, for example, what an extension of acceptance from η=2.0 to η=1.9 and from η=4.5 to η=5.0 yields).
  - Impact of increased pileup in LHCb upgrade.
  - How well do we need to know our momentum and energy scales?
  - What would improvements in knowledge of PDFs yield (while ensuring we account for correlations in the PDF inputs)

Conclusion

- LHCb's current measurement of the weak mixing angle is about the same precision as the existing ATLAS measurement.
- Studies ongoing to explore the many ways precision will improve in the coming years.
- LHCb will undergo two major upgrades and reach an eventual integrated luminosity > 300/fb.
  - Statistical uncertainty will become much smaller ($<10*10^{-5}$).
  - Investigating impact of in situ PDF constraints.