Report from LHCb

Status and prospect for Run II

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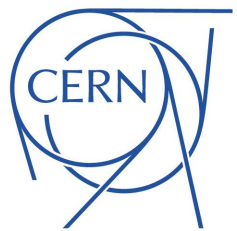
CERN

January 12, 2015



LHC Top WG

Introduction

Forward top production:

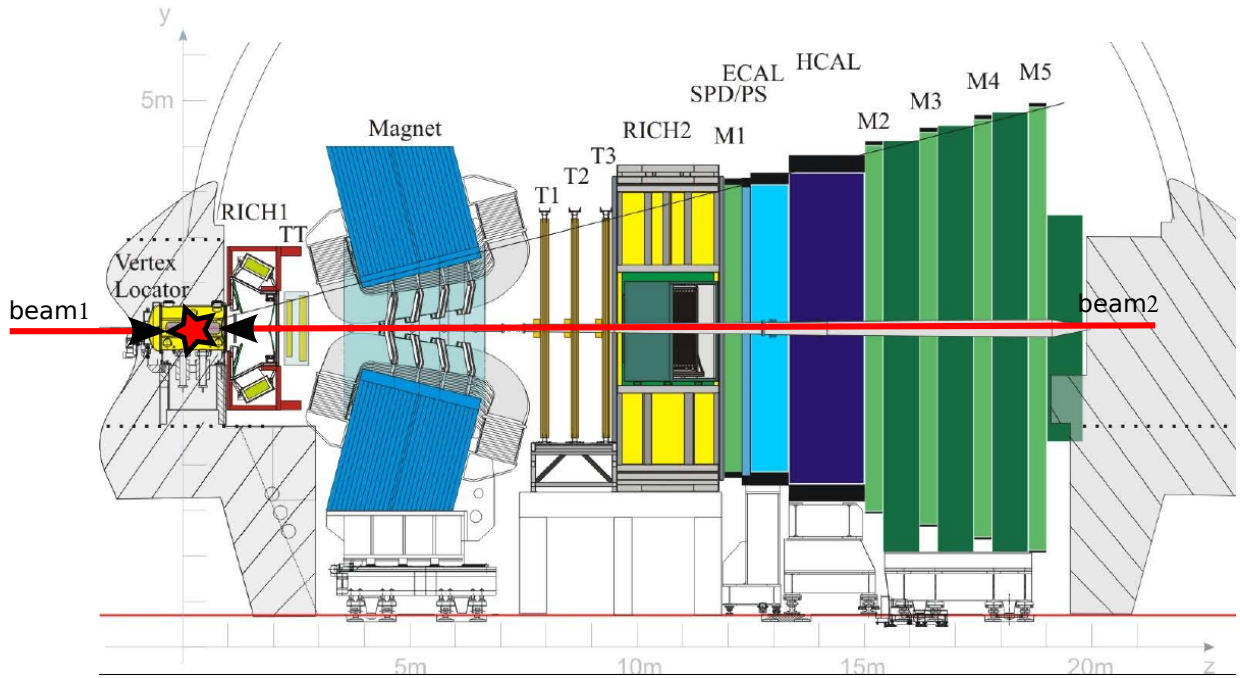
- Involve Low and High-x gluons.
- Reduced gg scattering compared to the central region.

LHCb offers unique coverage @LHC in the $2 < \eta < 4.5$ region:

- Experimental features and reconstructed objects:
  - Detector
  - Trigger
  - Jets reconstruction, b-jet tagging
- Prospects:
  - Cross sections
  - Asymmetry

LHCb detector

2008 JINST 3 S08005



- Designed for CP violation studies in B,D decays and rare decays.
- Fully instrumented forward $2 < \eta < 4.5$
- Data taking with luminosity levelling $\rightarrow$ stable conditions with $< pile - up > \sim 2$

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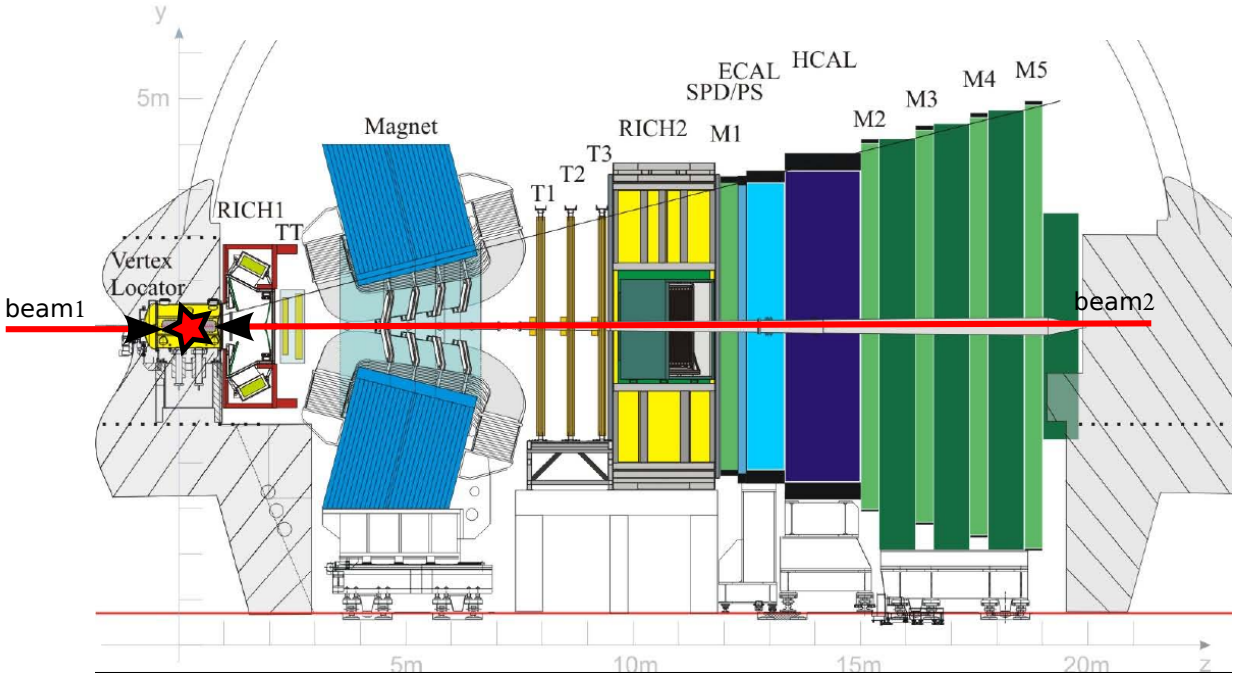


- pp collisions: $\sim 1.1 fb^{-1}$ at $\sqrt{s} = 7\ TeV$, $\sim 2.2 fb^{-1}$ at $\sqrt{s} = 8\ TeV$.
- For the RunII: $\sim 5 fb^{-1}$ at $\sqrt{s} = 13\ TeV$ expected.
- For the Upgrade (starting $\sim$ 2020): $\sim 50 fb^{-1}$ at $\sqrt{s} = 14\ TeV$ expected.

LHCb Triggers

Run I vs. Run II

Run I:

- Most of the triggers are optimised for B and D decays.
- Inclusive muon trigger down to low p_T: $\mathbf{p_T > 10\ GeV}$
- No jet-based trigger, BUT an inclusive B hadron trigger:
  - Down to 1 *MHz* (hardware): high p_T ($O(1-4\ GeV)$) γ,$\mu(\mu)$,e or h.
  - Down to 50 *kHz* (software): displaced track.
  - Down to 5 *kHz* (software): 2,3,4-body vertex inclusive B-hadron trigger and BDT selection (TOPO)

$\rightarrow$ **Act as a b-jet trigger.** $\epsilon_{b-jet} \sim 30-45\%$ **for** $p_T > 15\ GeV$

Run II:

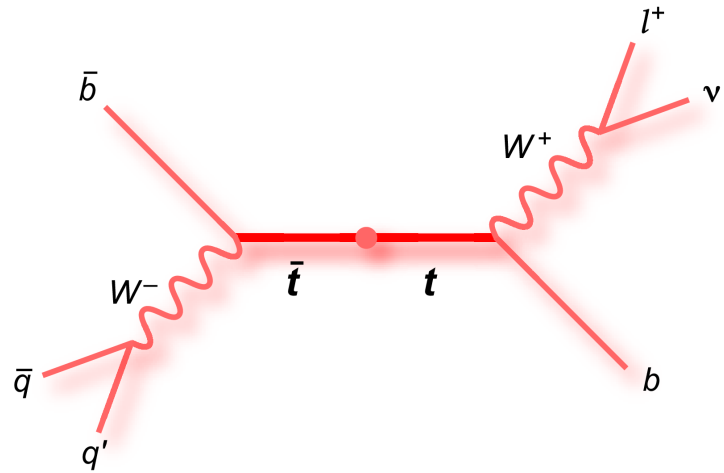
- Online detector calibration mechanism after first stage of triggering

$\rightarrow$ **Offline-like reconstruction available (PID, tracking)**

- Jet / b-jet trigger under investigation.
- Storage rate: 5 *kHz* (Run I)$\rightarrow$ 12.5 *kHz* (Run II).

Top final states in LHCb

- [PRL(2011)107, Kagan, Kamenik, Perez, Stone] ℓb final states can be used for $t\bar{t}$ asymmetry measurement.



- [LHCb-PUB-2013-009] $p_{T\ \ell,j} > 20\ GeV$, $p_{T\ b} > 60\ GeV$ and $2 < \eta_{\ell,b,j} < 4.5$ POWHEG+Pythia8, Errors from scale, PDF and shower:

$d\sigma$(fb)	7 TeV			8 TeV			14 TeV		
lb	285	$\pm$	52	504	$\pm$	94	4366	$\pm$	663
lbj	97	$\pm$	21	198	$\pm$	35	2335	$\pm$	323
lbb	32	$\pm$	6	65	$\pm$	12	870	$\pm$	116
$lbbj$	10	$\pm$	2	26	$\pm$	4	487	$\pm$	76
l^+l^-	44	$\pm$	9	79	$\pm$	15	635	$\pm$	109
l^+l^-b	19	$\pm$	4	39	$\pm$	8	417	$\pm$	79

- ℓb and ℓbj more suited for Run I measurement.

μ and jet reconstruction

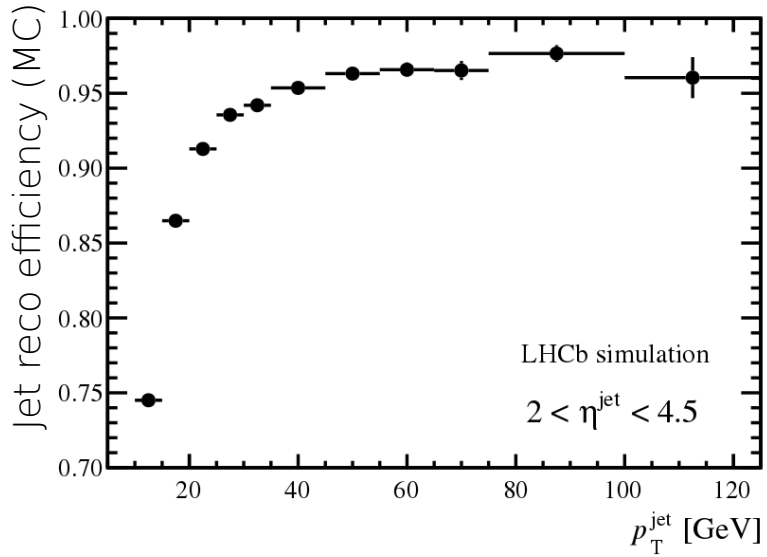
Muons
($p_T > 20\ GeV$, $2 < \eta < 4.5$)

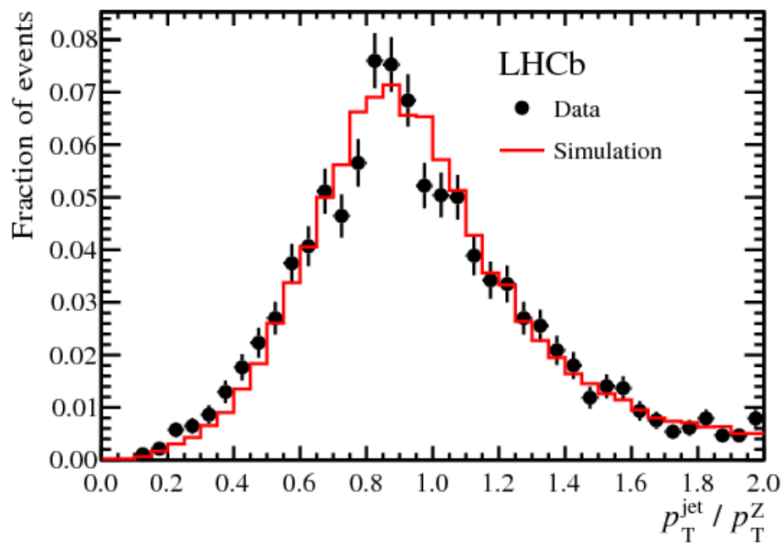
- Efficiencies from tag and probe methods
- Trigger: $80 \pm 0.6\%$
- Tracking: $90 \pm 0.6\%$
- Identification: $99 \pm 0.3\%$

Jets

- ParticleFlow inputs, anti-k_T with R=0.5
- 2.5% uncertainty on reco efficiency in data ($p_T > 20 GeV$).
- Jet energy correction determined from MC (range from 0.9 - 1.1)
- JES data vs. MC within 3%.
- $10 - 15\%$ energy resolution.

Z+jet @ 7TeV [JHEP01 (2014) 033]





b-tagging

In $A_C^{b\bar{b}}$ and Z+b-jets

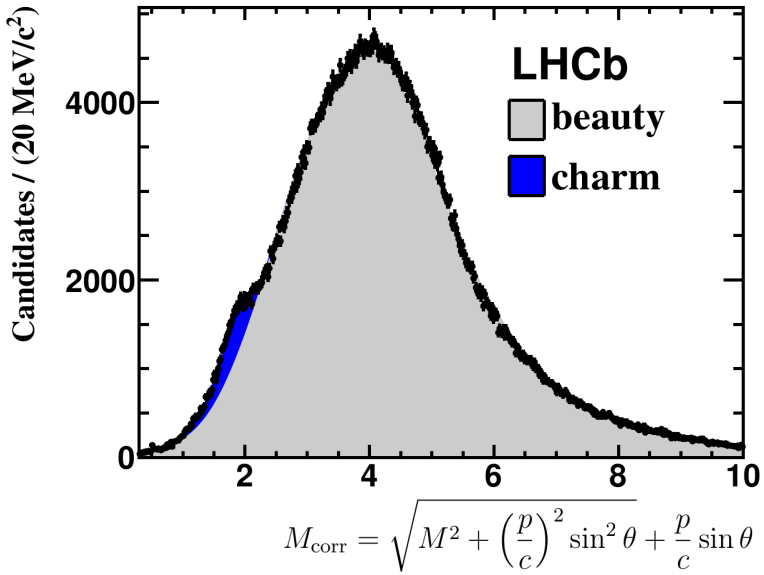
pTOPO: Offline version of the 2,3,4-body vertex inclusive B-hadron trigger algorithm

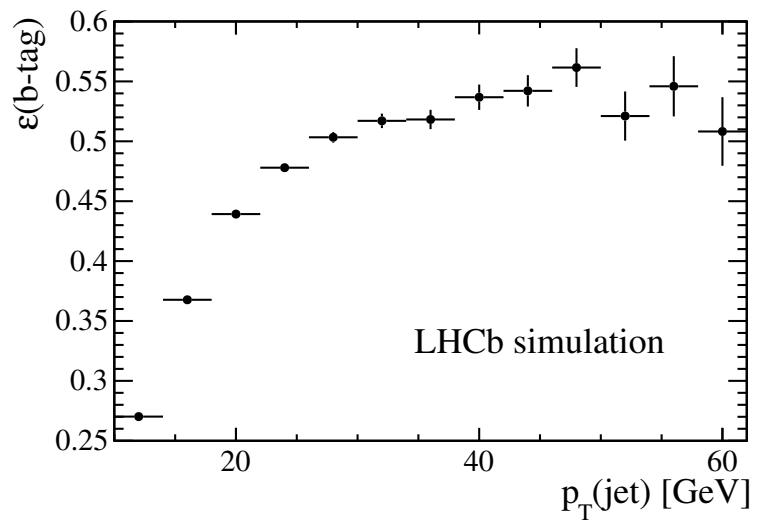
$A_C^{b\bar{b}}$ PRL 113 (2014) 082003:

- Trigger on a displaced μ
- $\epsilon_{b-tag} \sim 60\%$ for the b-jet with μ.
- $\epsilon_{b-tag} \sim 50\%$ for the other b-jet.
- non-$b\bar{b}$ contamination in final sample $3.6 \pm 1.2\%$

Z+b-jet cross section, arXiv:1411.1264:

- Trigger on the Z
- ℓ, c-jet contribution from template fit to M_{corr}

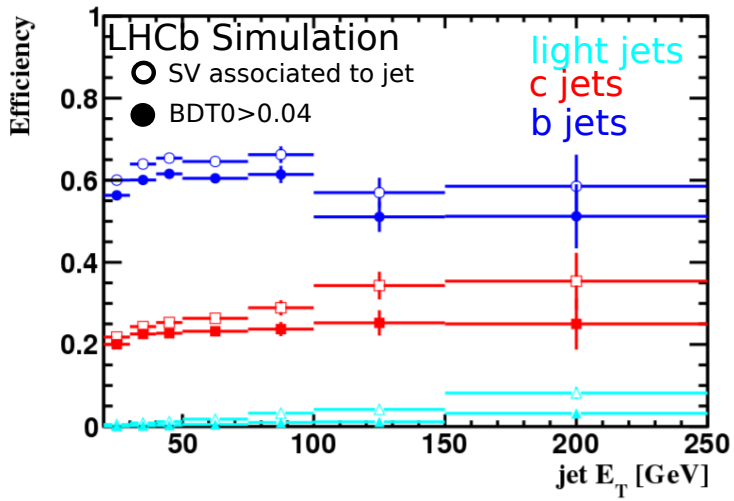


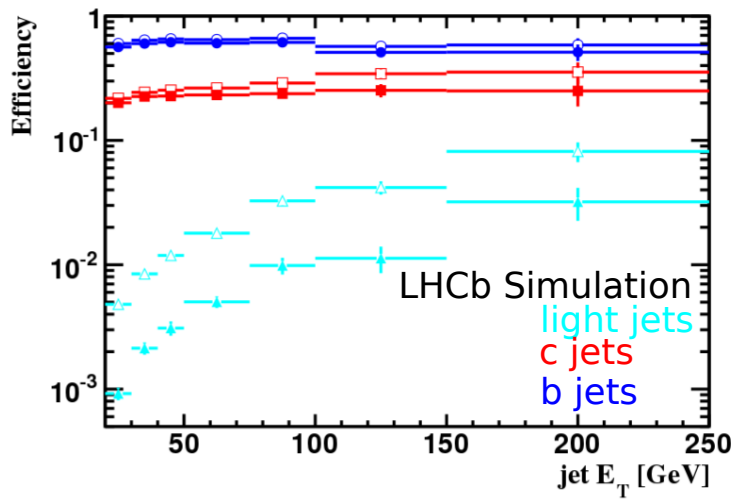


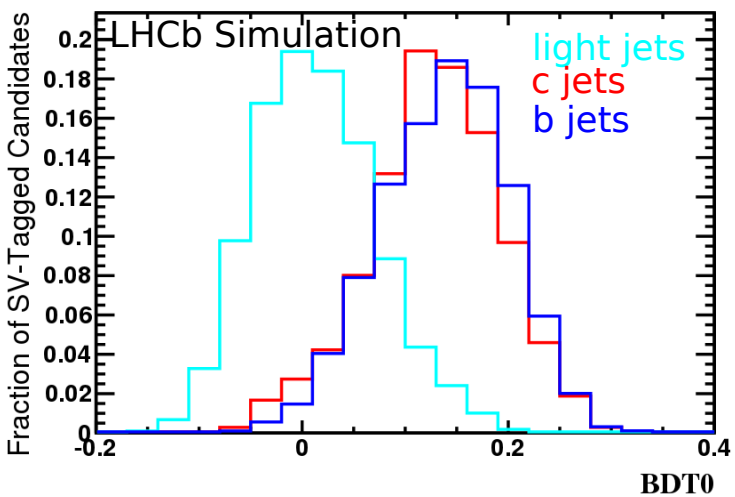
b-tagging

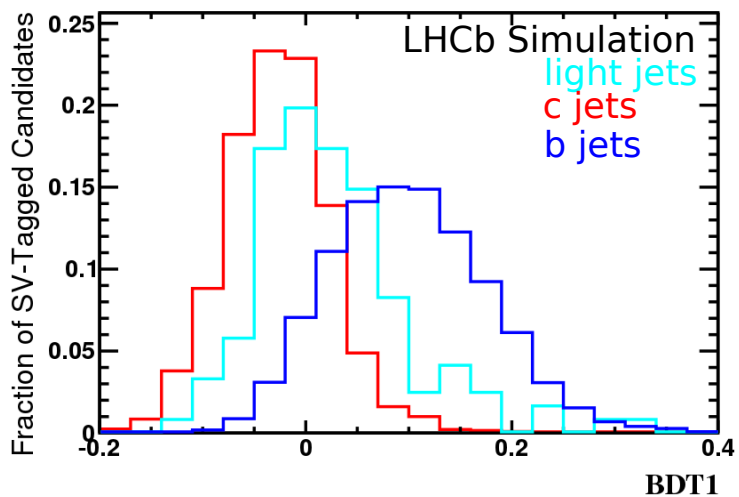
New development

- Since then improvement made on the inclusive SV reconstruction.
- SV based and jet based variables are inputs of 2 BDTs (ℓ vs. b, c and c vs. b):







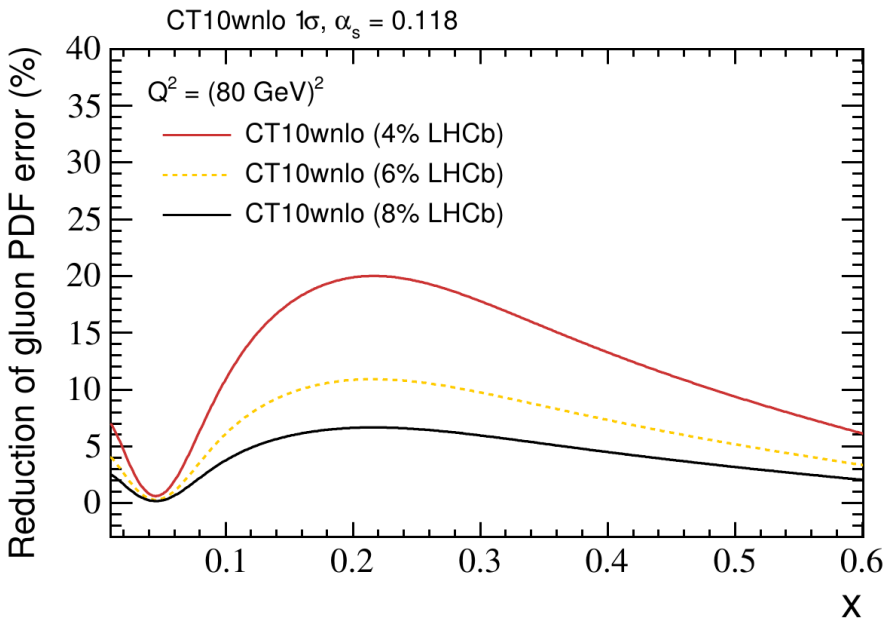


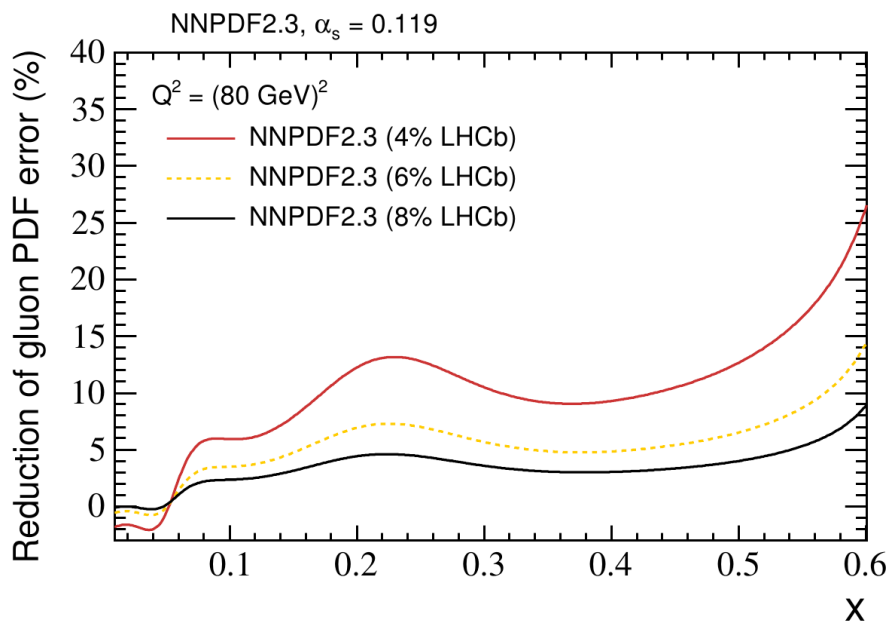
$t\bar{t}$ cross section in the forward region

Motivation

[JHEP(2014)126, Gauld]

- Top production dominated by gluon initiated process.
- Top production @ LHCb involve high-x / low-x gluon.
- Large uncertainty on the high-x gluon PDFs.



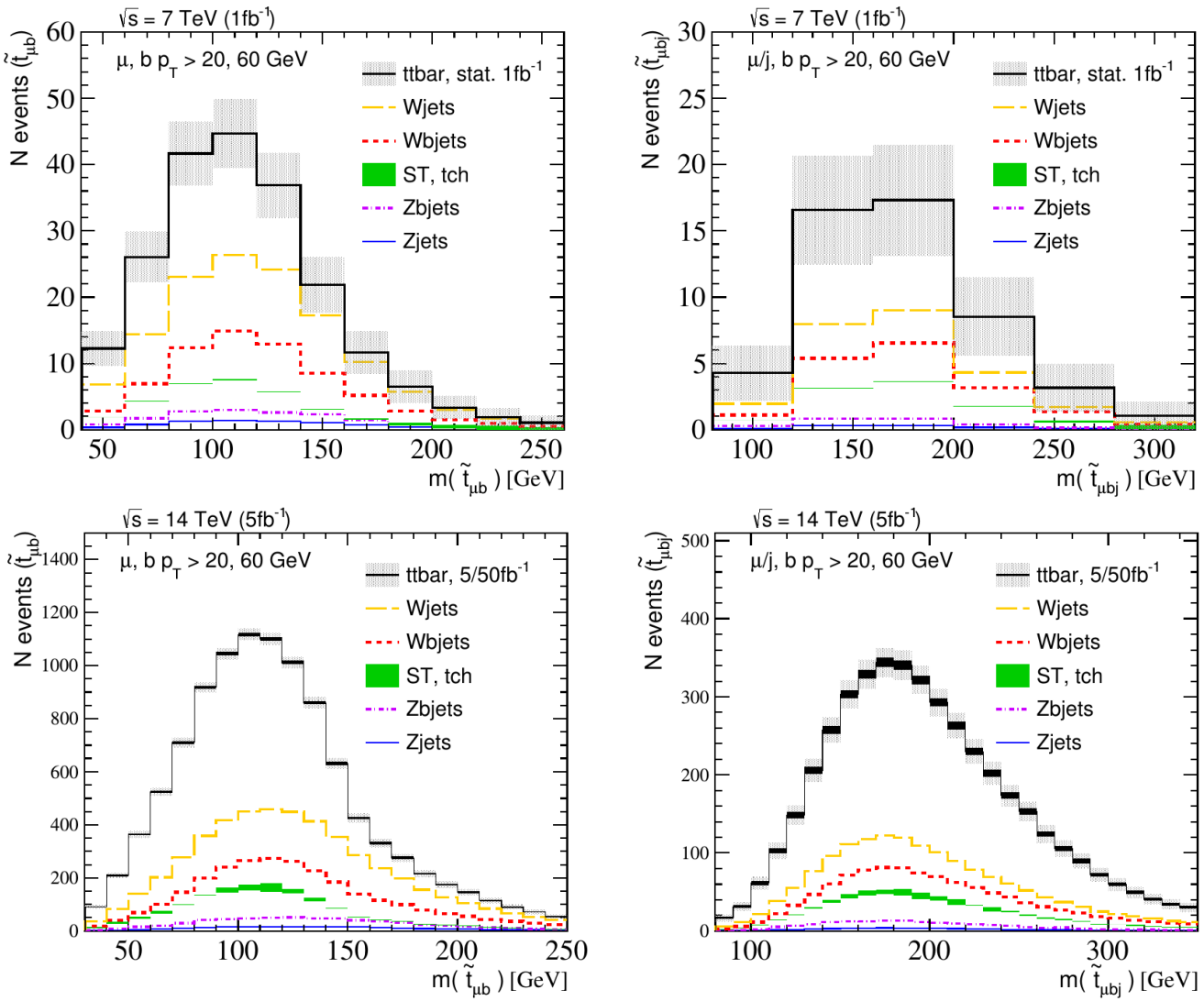


Cross section

μb and μbj final state expectations

- Assuming $\epsilon_{b-tag} \sim 70\%$, $\tau_{(c+\ell)\to b} \sim O(1\%)$, and $2 < \eta_{\mu,b} < 4.5$.
- $p_{T\ \mu(j)} > 20\ GeV$, $p_{T\ b} > 60\ GeV$, $\Delta R(b, l) > 0.5$ to reduce the background.

[JHEP(2014)126, Gauld]



Cross section

Prospects

- Optimal selection under study.
- Main background:
  - HF jets: Good control from fit of the μ isolation.
  - VB+jets: Fit of $m_{\mu b}$ proposed in [JHEP(2014)126, Gauld], now studying $p_{T\mu b}$ which offers more discrimination.
- For Run I:
  - Using $\mu b(j)$ final state.
  - Target an observation and inclusive top cross section measurement in the forward region,
  - $t\bar{t}$ and single-t considered together for Run I measurement.
- For Run II:
  - Other final states available, especially with di-leptons.
  - Study separation of $t\bar{t}$ and single-t.
  - Differential cross-sections.
- Not really subject to combination with ATLAS/CMS, but complementary coverage.
- With RunII / Upgrade statistics we might find some common region (overlap for $\eta_\mu < 2.4$)?

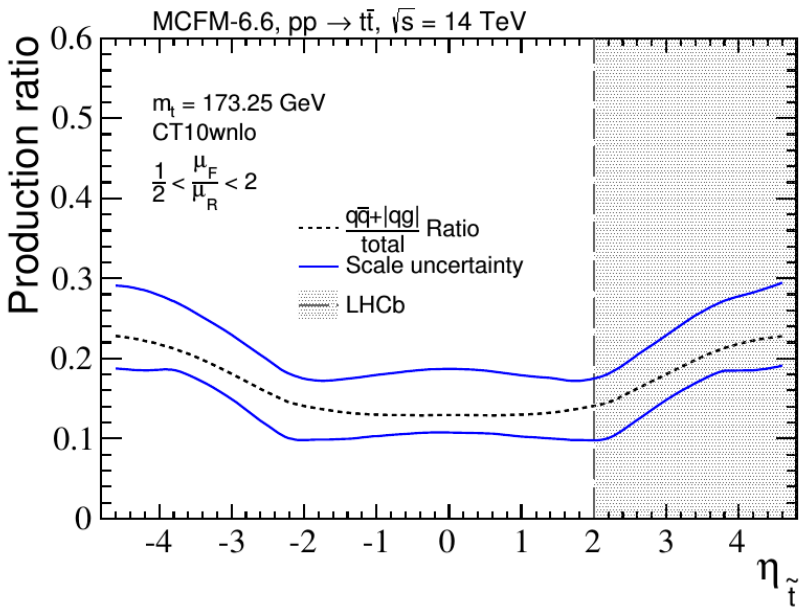
Asymmetry

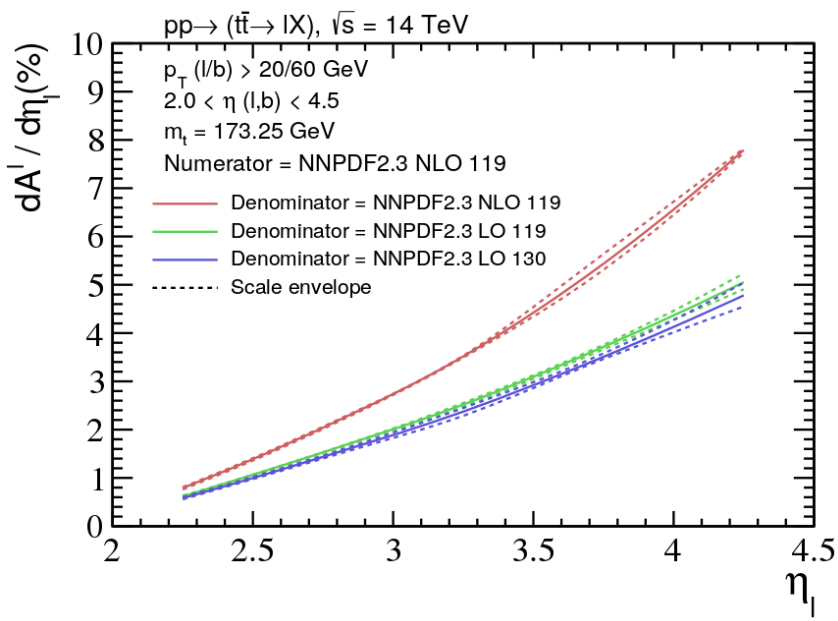
Prospects

- Originally proposed in [PRL(2011)107, Kagan, Kamenik, Perez, Stone].
- Further work in [LHCb-PUB-2013-009] and [arXiv:1409.8631, Gauld]
- q originated production increases with η

$\rightarrow$ increased asymmetry wrt. central region.

- Considering ℓb : $A_\ell = \frac{N(\mu^+ b) - N(\mu^- b)}{N(\mu^+ b) + N(\mu^- b)}$.



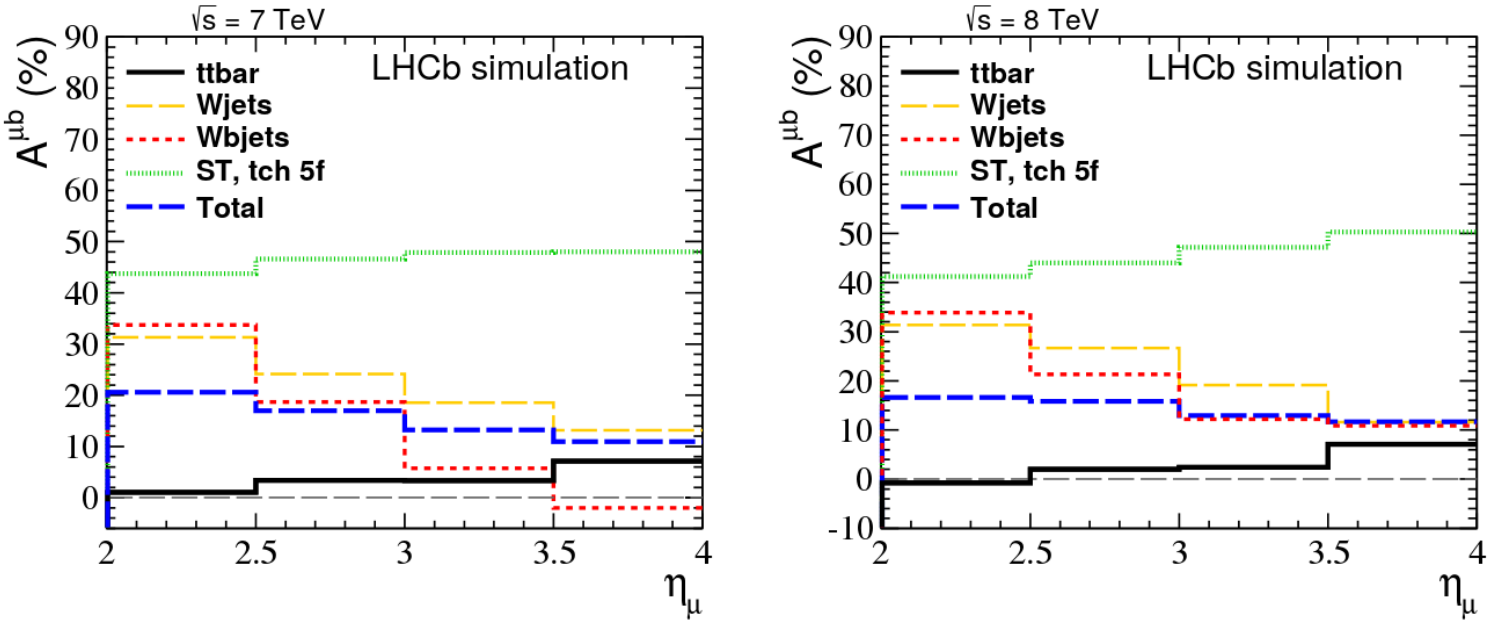


Asymmetry

Prospects

[LHCb-PUB-2013-009]

$p_{T\ \mu(j)} > 20\ GeV$, $p_{T\ b} > 60\ GeV$, $2 < \eta_{\mu,b} < 4.5$, $\Delta R(b, l) > 0.5$



- Background asymmetry need to be well under control.
- Asymmetry smaller at $13 - 14\ TeV$ than at $7 - 8\ TeV$
- Out of reach with Run I dataset ($5 - 10\%$ statistical uncertainty).
- With upgrade statistics ($50\ fb^{-1}$) with $A^l_{SM} = (1.4 - 2.0)$ expect 0.3% statistical error.
- Can probably be improved with more sophisticated selections.

Conclusion

- All the experimental tools now in place (jet reconstruction, b-tagging).
- Main backgrounds have been / are being measured.
- A lot in common with the W+(b,c,ℓ)jets production ratio measurement.

- Several intresting possibilities with RunII data, need to set priorities:
  - single top vs. $t\bar{t}$
  - Differential cross section
  - b jets property in top decay
  - ...

BACKUP

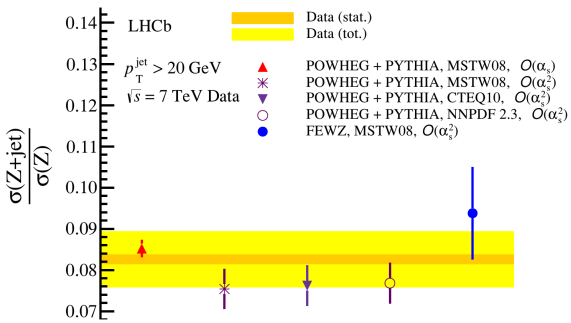
MC setup @ LHCb

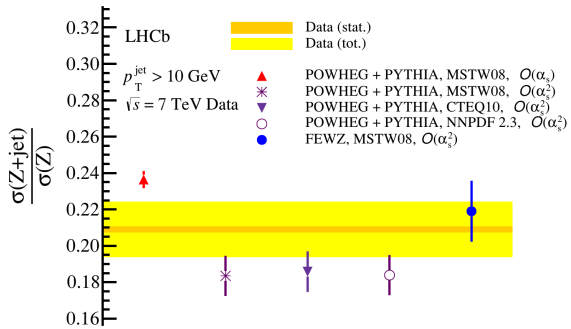
- Pythia 8 / Herwig++ for showering.
- LO generator by default.
- Higher order generator being commisionned.
- At least for Run I measurement reweighting of LO to higher order predictions should be sufficient for μb final state.

Z+jet production in pp at $\sqrt{s} = 7$ TeV

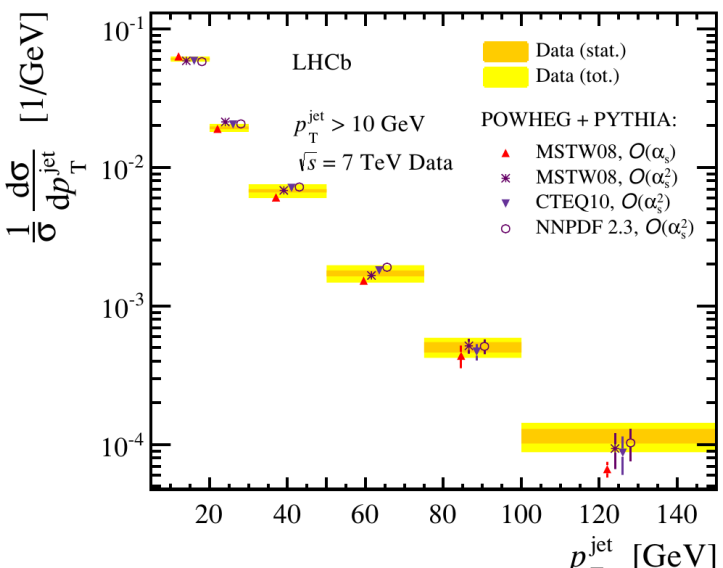
Result

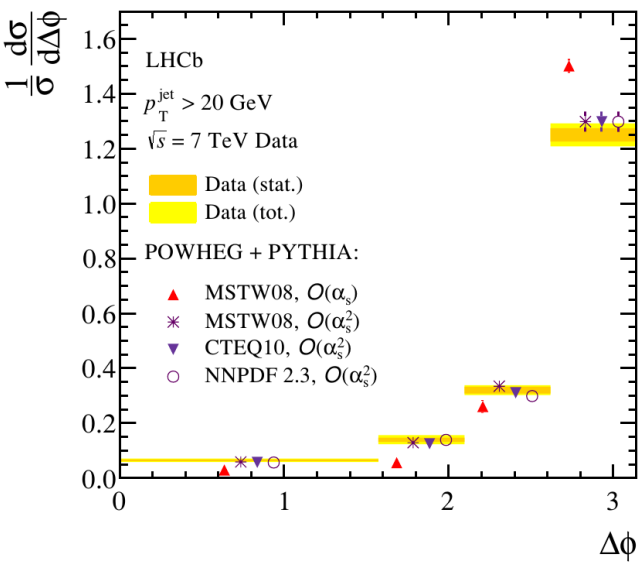
- Predictions from POWHEG+PYTHIA at $O(\alpha_s)$ and $O(\alpha_s^2)$ with different PDF sets.
- Predictions from FEWZ at $O(\alpha_s^2)$ not corrected for hadronisation and underlying event.





- Not corrected for FSR
- Shapes in good agreement with NLO





Central forward $b\bar{b}$ asymmetry $A_{FC}^{b\bar{b}}$

Motivation

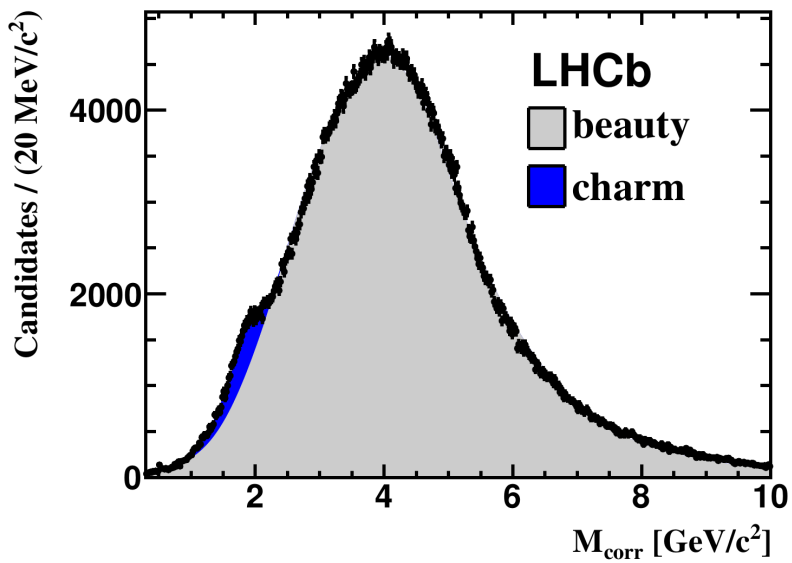
- Depending on new physics flavour structure, asymmetry could shows up in the bottom sector.

[arXiv:1108.3301,Kahawala et al.]

- At LHC access to the forward central asymmetry.
- Expected to be $O(1\%)$ from QCD with an extra $O(1\%)$ in the Z mass region.

PRL 113 (2014) 082003

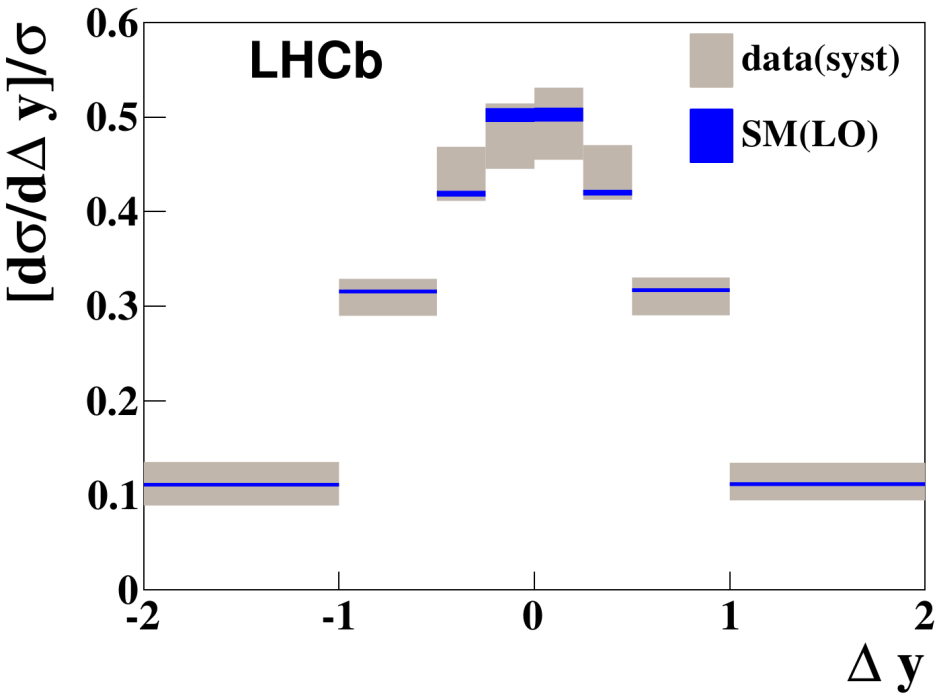
- Analysis performed with 1 fb^{-1}
- Pairs of b-jets with $\Delta\phi(bb) > 2.6\ rad$.
- One of the b-jets charge is tagged with a muon.
- Purity of the charge tagging $70.3 \pm 0.3\%$



Central forward $b\bar{b}$ asymmetry $A_{FC}^{b\bar{b}}$

Result with 1 fb^{-1}

PRL 113 (2014) 082003

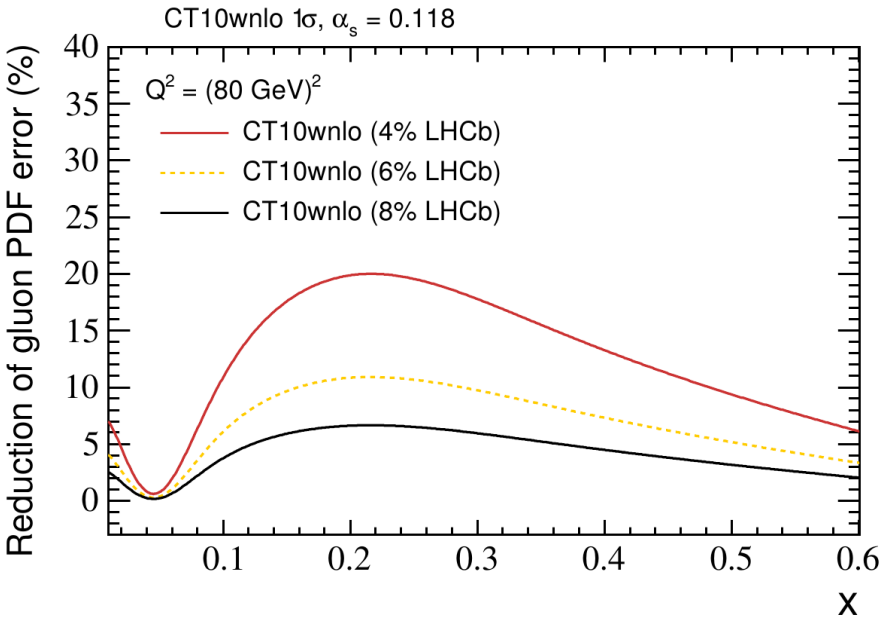


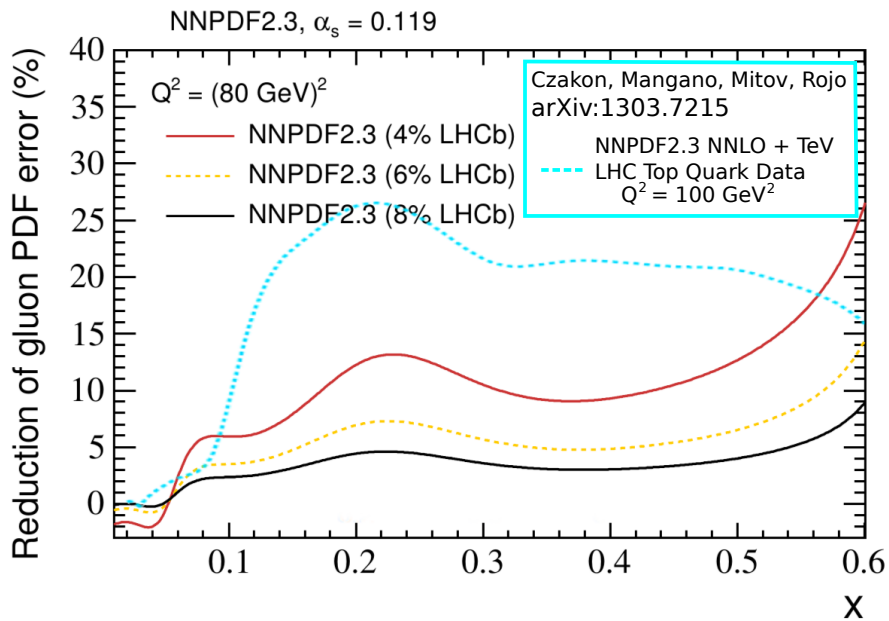
$A_{FC}^{b\bar{b}} = \frac{N(\Delta y>0)-N(\Delta y<0)}{N(\Delta y>0)+N(\Delta y<0)}$,
$\Delta y = |y_b| - |y_{\bar{b}}|$
In different m_{bb} bins:

- $A_{FC}^{b\bar{b}}(40, 75) = 0.4 \pm 0.4 \pm 0.3$ %
- $A_{FC}^{b\bar{b}}(75, 105) = 2.0 \pm 0.9 \pm 0.6$ %
- $A_{FC}^{b\bar{b}}(> 105) = 1.6 \pm 1.7 \pm 0.6$ %

- No deviation from expectation with available statistics.
- Still 2 fb^{-1} of the Run I data to be analysed.
- More efficient b-tagging available now.

Gluon PDF error reduction





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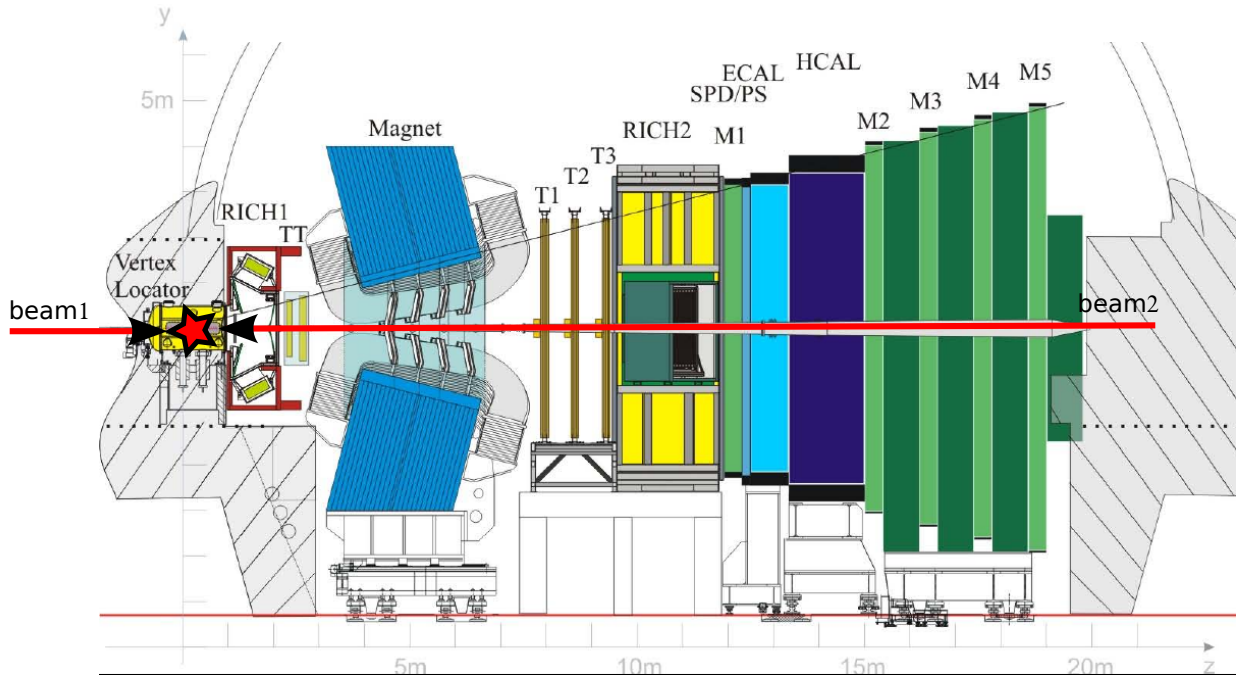

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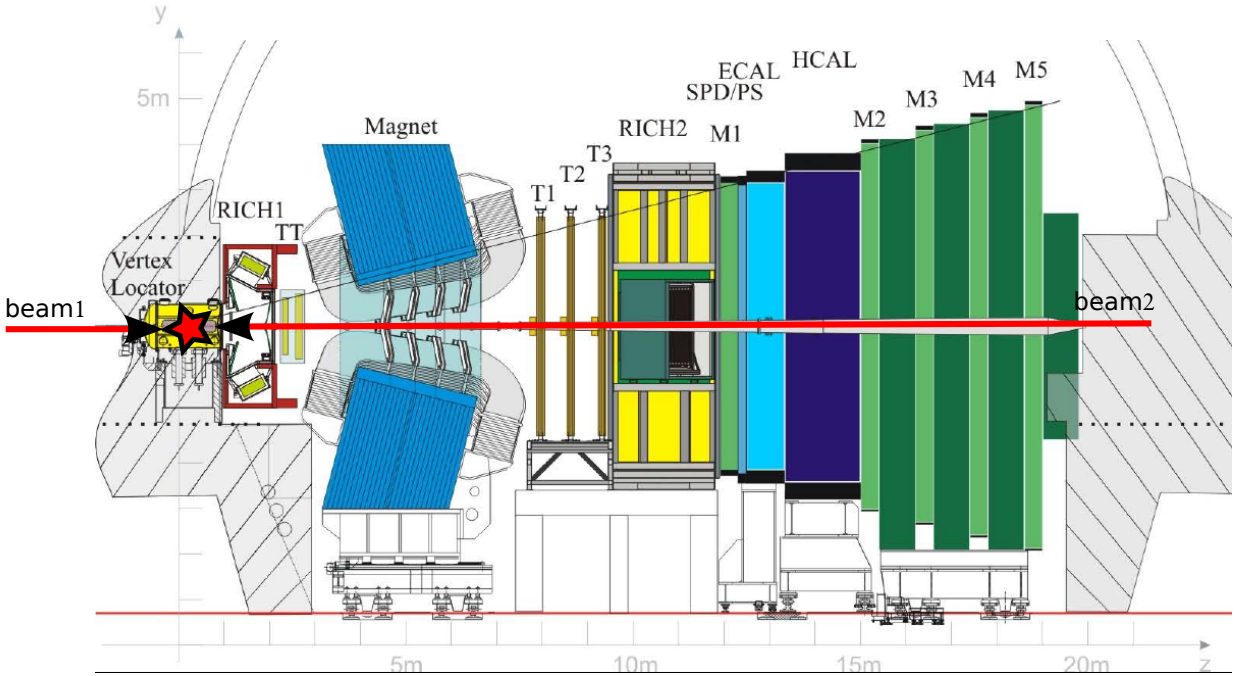

- Tracking efficiency $\sim 95\%$
- $\delta p/p \sim 0.5\%$
- $13 - 20 \mu m$ IP resolution for tracks.
- Secondary vertex resolution $0.01 - 0.05(0.1 - 0.3)$ mm in xy(z)

LHCb detector

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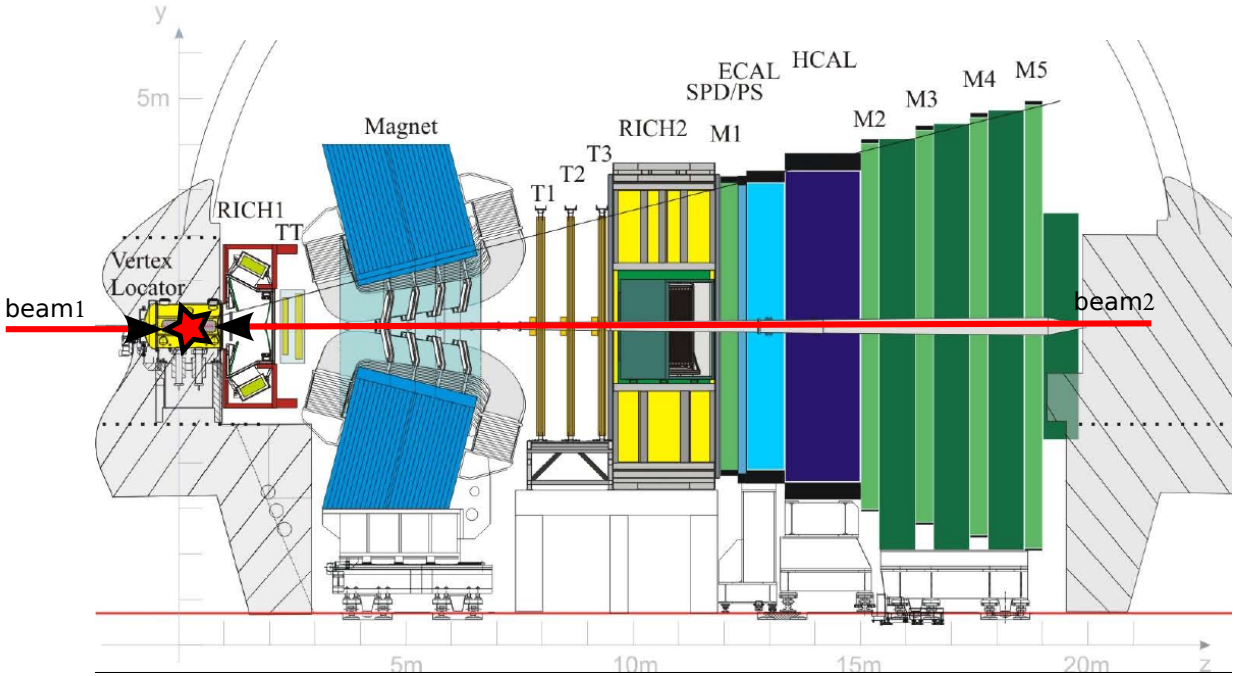

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