$t\bar{t}$ production in the forward region at LHCb

María Vieites Díaz,
On behalf of the LHCb Collaboration
Universidade de Santiago de Compostela

53rd Rencontres de Moriond - EW 2018

image from https://www.trada.co.uk/case-studies/the-globe-at-cern-geneva/

GOBIERNO DE ESPAÑA
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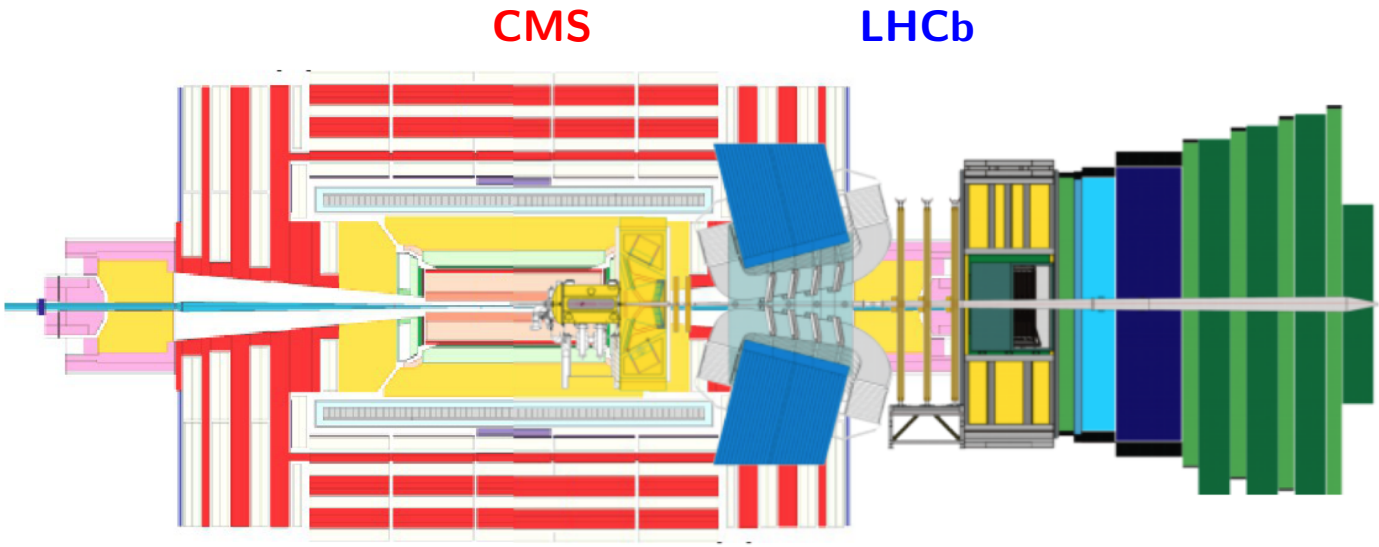
Introduction

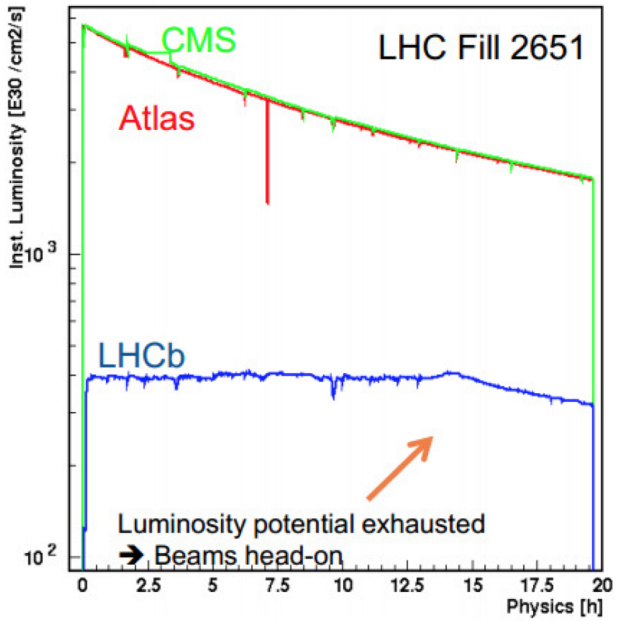


Optimised to study beauty and charm hadrons

→ provides complementary η coverage compared with a GPD.

LHCb as a **forward GPD**:

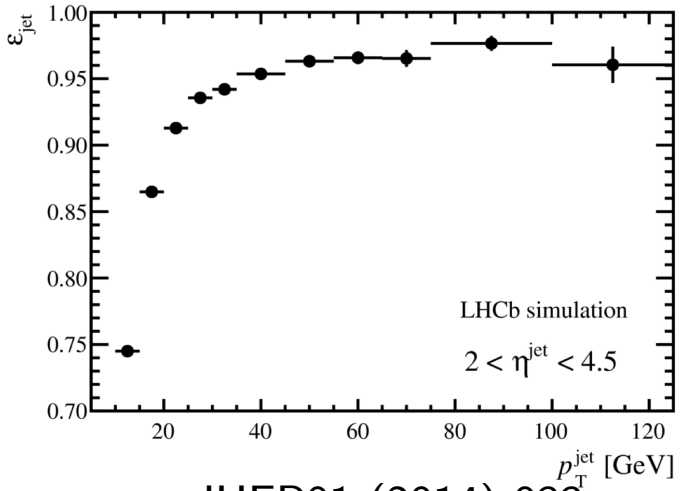
- ✓ Precise integrated luminosity computation
- ✓ **Stable** data-taking conditions due to **luminosity levelling**
- ✓ Average pile-up ∼2 (twice design)
- ✓ Excellent **vertexing**, particle ID, momentum resolution...
- × Lower luminosity than to ATLAS/CMS
- × Lower acceptance
- × Not hermetic! (can't use E_T^{miss} variable)



Jets at LHCb

How?

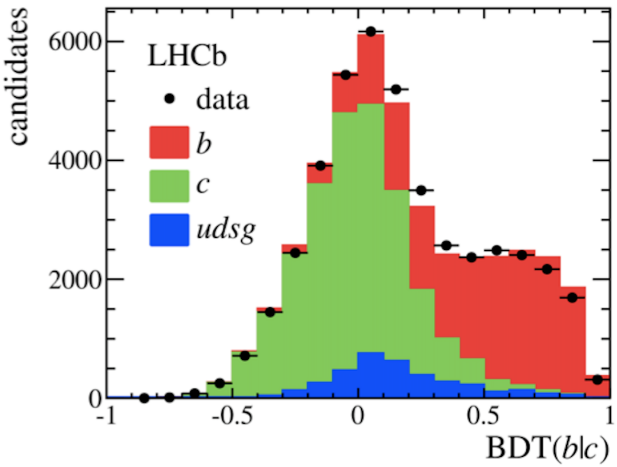
- → **Particle Flow** approach, with neutral recovery
- → Reconstructed using **anti-kT** (R = 0.5)
- → **Calibration in data**, using $Z \to \mu\mu$ + jets
- → Reconstruction efficiency above 90% for jets with p_T above 20 GeV/c
- → Jet energy resolution ∼10 -15%



JHEP01 (2014) 033

LHCb physics-case expands:

- ✓ Direct searches of detached particles decaying to jets
- ✓ Possibility of doing Higgs physics with $b\bar{b}$ and $c\bar{c}$ final states
- ✓ top physics: constraints in proton gluon PDFs in a unique regime, $t\bar{t}$ charge asymmetry

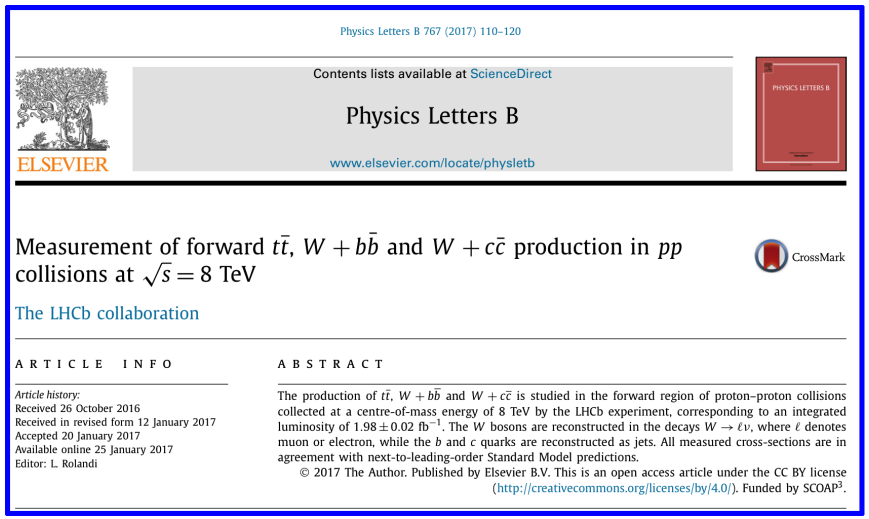


Heavy flavour tagging available:

- Mainly using inputs from secondary vertices properties
- SV-tagger with $\varepsilon_b \sim$ **65%**, $\varepsilon_c \sim$ **25%** and light jet mistag probability ∼ **0.3%**.
- Further separation power provided by BDT($bc|udsg$) and BDT($b|c$)

JINST 10 (2015) P06013

Latest $t\bar{t}$ results from LHCb



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Physics Letters B

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The production of $t\bar{t}$, $W + b\bar{b}$ and $W + c\bar{c}$ is studied in the forward region of proton–proton collisions collected at a centre-of-mass energy of 8 TeV by the LHCb experiment, corresponding to an integrated luminosity of 1.98 ± 0.02 fb^{-1}. The W bosons are reconstructed in the decays $W \to \ell\nu$, where ℓ denotes muon or electron, while the b and c quarks are reconstructed as jets. All measured cross-sections are in agreement with next-to-leading-order Standard Model predictions.

- Final states considered: **ℓ+2b/c jets** ($\ell \equiv \mu, e$)
  - **Jets range**: $2.2 < \eta < 4.2$
- Simultaneous measurement of **$W + b\bar{b}$**, **$W + c\bar{c}$** and **$t\bar{t}$** production **cross sections**
  - 4-Dimensional fit: **MVA** (uGB), **BDT**($b|c$) for both jets, **Di-jet mass**

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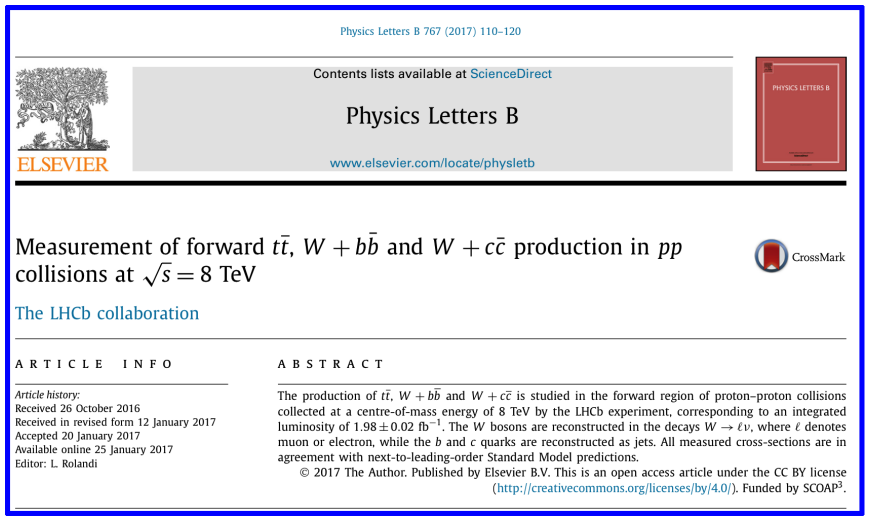

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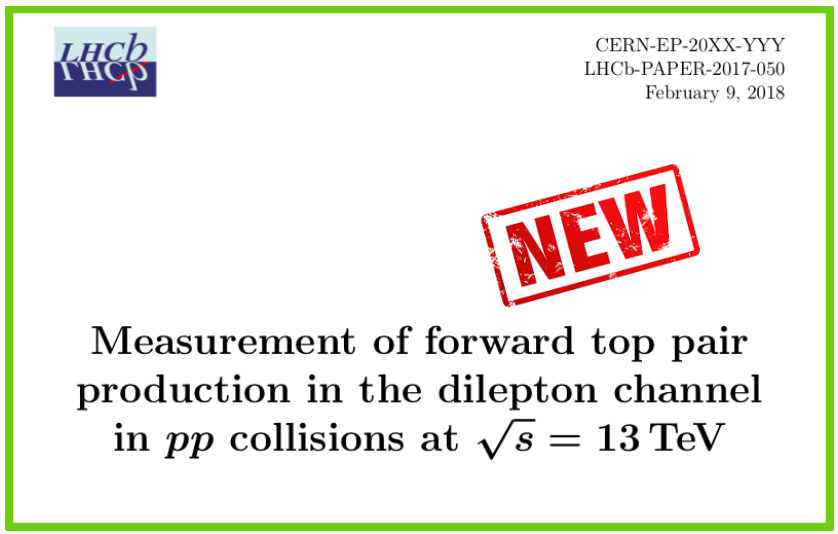
- **Dilepton channel**, highest purity with **eμ** selection ($\sim$ 2fb^{-1} collected in 2015 and 2016)
  - **Jets range**: $2.2 < \eta < 4.2$
- Measure $\sigma_{t\bar{t}} = \frac{N - N_{bkg}}{\mathcal{L} \cdot \varepsilon} \cdot \mathcal{F}_{res}$
  - ε: from **simulation**, validated using data-driven methods
  - $\mathcal{F}_{res}$: **migrations** in to and out of the **fiducial region**
  - N_{bkg}: sum of the expected background contributions
  - $\mathcal{L}$: integrated luminosity



CERN-EP-20XX-YYY
LHCb-PAPER-2017-050
February 9, 2018

NEW

Measurement of forward top pair production in the dilepton channel in pp collisions at $\sqrt{s} = 13$ TeV

lepton+2b/c jets results

→ **Simultaneous fit projection** of the uGB response for the μ^+ sample

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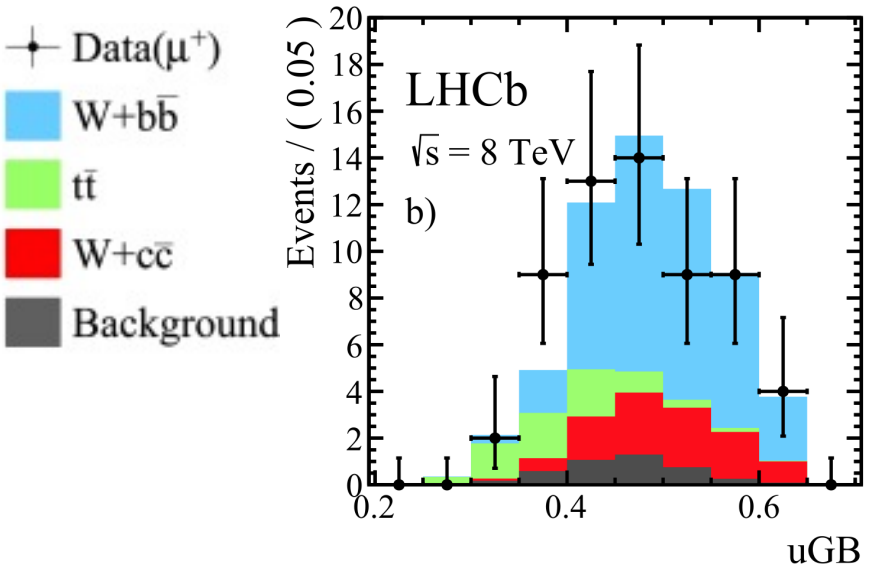

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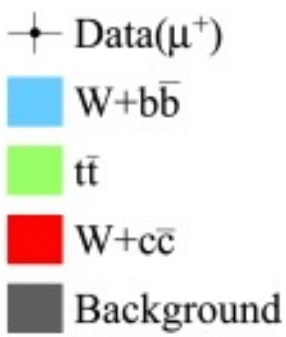
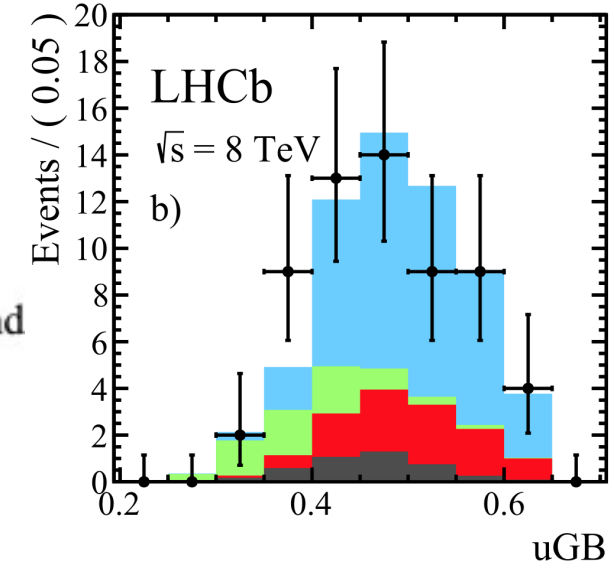
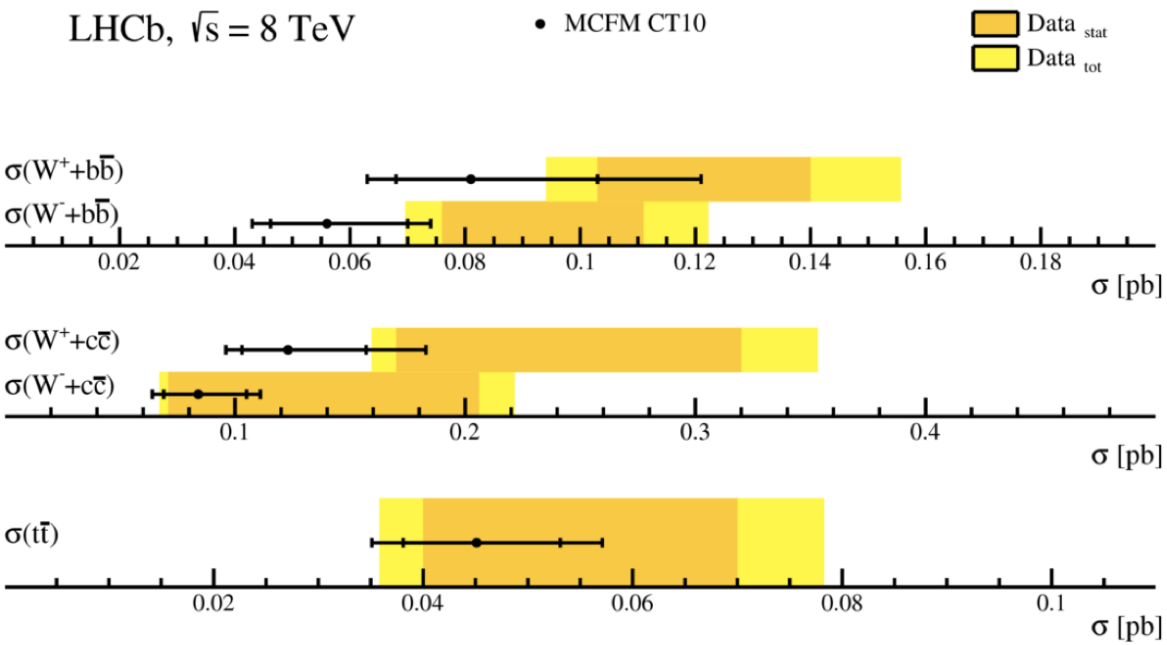




↓ **Cross sections** and **theoretical predictions** in **LHCb fiducial region**

NLO theory prediction: MCFM with PDF set CT10 interleaved with Pythia8



Sample	Significance
$t\bar{t}$	4.9σ
$W^+ + b\bar{b}$	7.1σ
$W^- + b\bar{b}$	5.6σ
$W^+ + c\bar{c}$	4.7σ
$W^- + c\bar{c}$	2.5σ

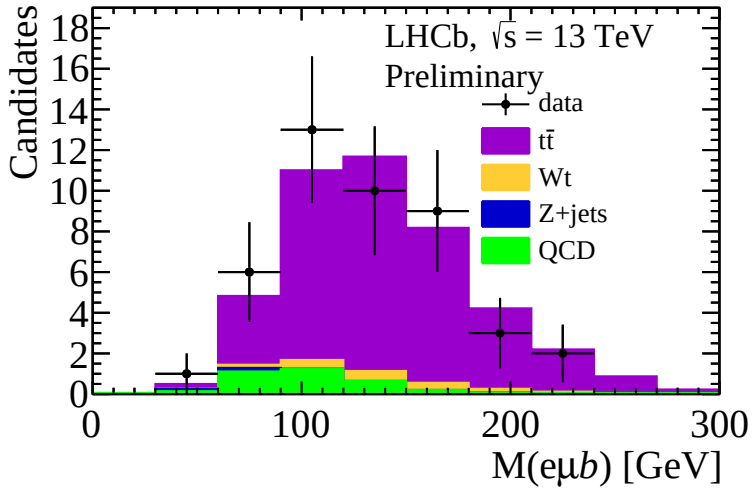
MCFM: Phys. Rev. D62 (2000) 114012

CT10: Phys. Rev. D82 (2010) 074024

μeb preliminary results

LHCb-PAPER-2017-050 (in preparation)

$\rightarrow$ Control plot of the **invariant mass** of the $\mu + e + \mathrm{b_{jet}}$ system.



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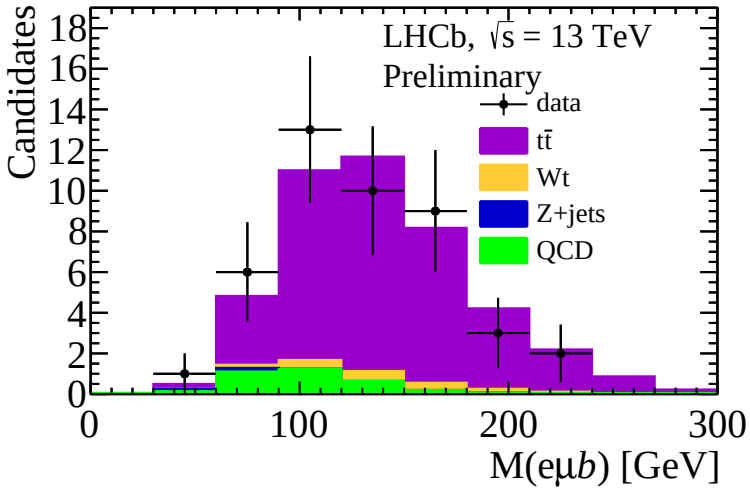
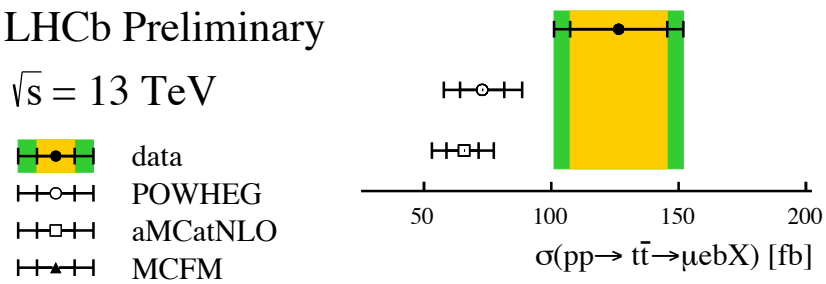


↓ **$t\bar{t}$ cross-section results**:

a) $\mu, e, \mathrm{b_{jet}}$ in the fiducial region

b) Extrapolated to t quark fiducial region

Graphical comparison to be made available in the paper



- Results compared to POWHEG and aMC@NLO:
  - Interfaced with Pythia for the parton shower
  - Decays performed with Madspin for aMC@NLO
- Overall precision of ∼20%, **statistically limited**
  - Largest systematic uncertainty → jet tagging
  - Largest background uncertainty → QCD
- After the **LHCb upgrade**, **μeb** channel may achieve the **highest precision** on the measurement of **$\sigma_{t\bar{t}}$@LHCb**

Conclusions

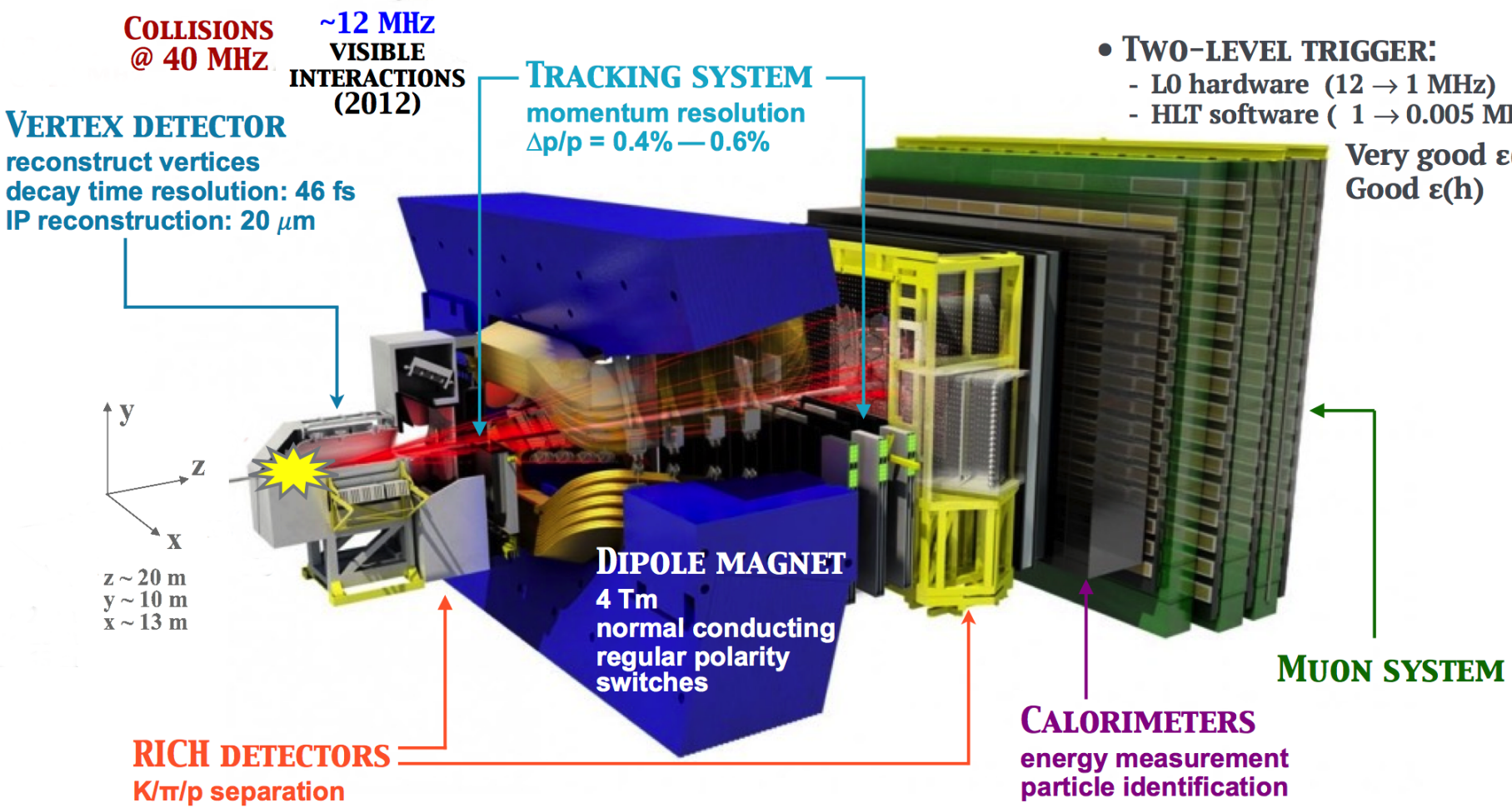
- **LHCb** has proven to be able to cope with jets and perform **competitive measurements in the forward region**.
- $\mathbf{b_{jet}}$ and $\mathbf{c_{jet}}$ taggers available: BDT($b|c$), allows for measurements such as $\sigma(W + c\bar{c})$.
- **Precision measurements of $t\bar{t}$ production** coming soon
- We expect **several improvements** for Run II and beyond:
  - $\geq$6 fb^{-1} by the end of Run II (3 fb^{-1} in Run I)
  - Increased cross sections and better acceptance for physics with jets (higher boost)
  - Work on going towards reducing systematic uncertainties
  - After Run II, comparable or better tagging (upgraded vertex detector)

Thanks for your attention!

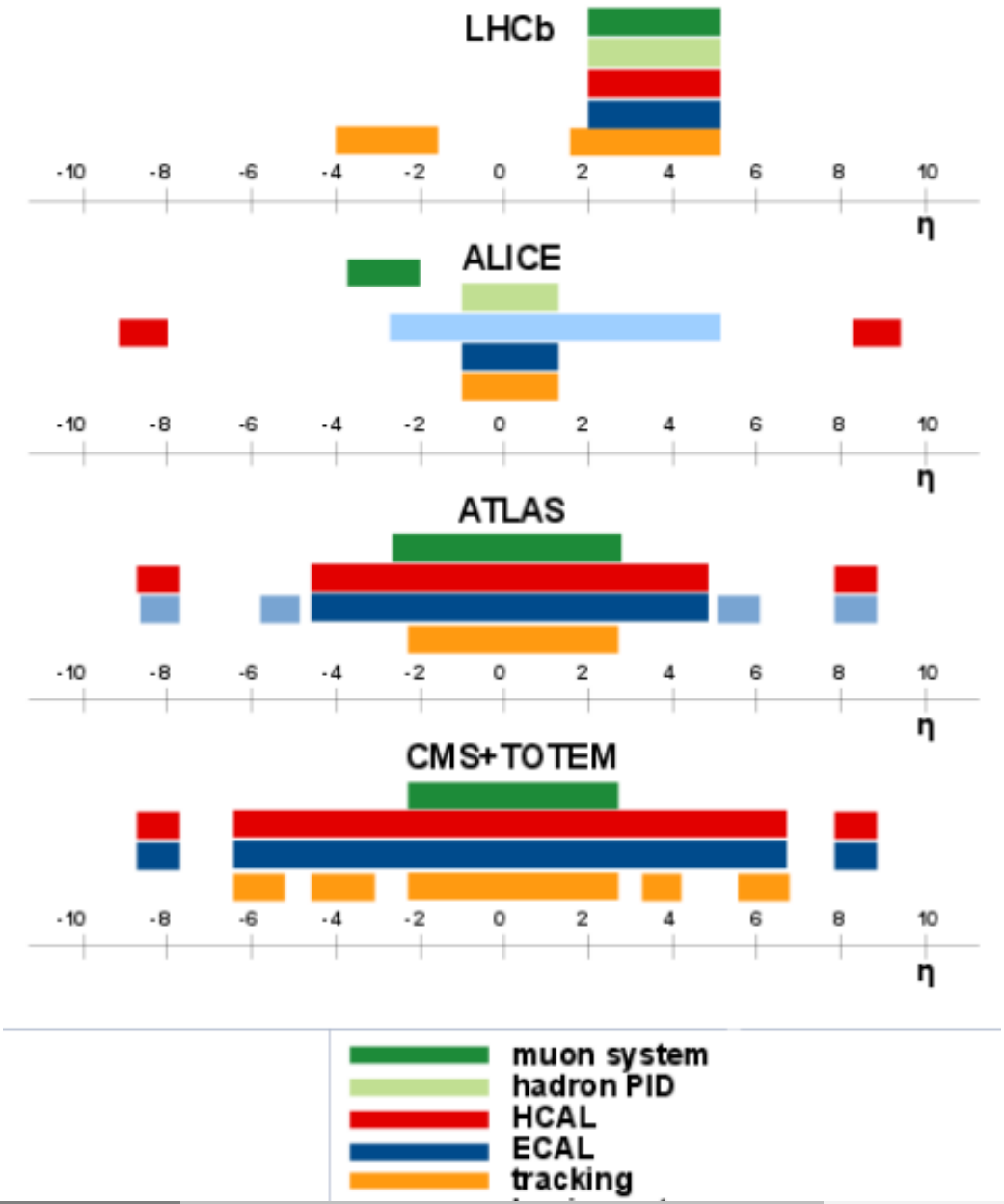
Backup

The LHCb detector

LHCb Detector Performance Ref.



Instrumented regions of the LHC main detectors



uniform Gradient Boost

uGB: JINST 10 (2015) T03002, this MVA technique allows to build a discriminator variable uncorrelated with a given spectator variable.

Use in Phys. Lett. B767 (2017) 110): the uGB allows to separate $W + b\bar{b}$ from $t\bar{t}$ by the use of topology and kinematic variables and sub-combinations of masses.