Introduction: Complementary searches for new physics with LHCb

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Direct searches BSM and forward production measurements.

Four Experimental/Theory talks (Monday afternoon, Wednesday morning):

- **Top:** Rhorry Gauld (Pheno.), Cedric Delaunay (Th.)
- **Jets:** Will Barter (Exp.), German Rodrigo (Th.)
- **Long lived particles:** Pieter David (Exp.), Matthew Strassler (Th.)
- **Higgs:** Clara Matteuzzi (Exp.), Florian Domingo (Th.)

In this talk:

- LHCb specificities.
- Complementarity domains and niches.
- Highlights of experimental objects and triggers wrt. GPDs.

Complementarity with GPDs

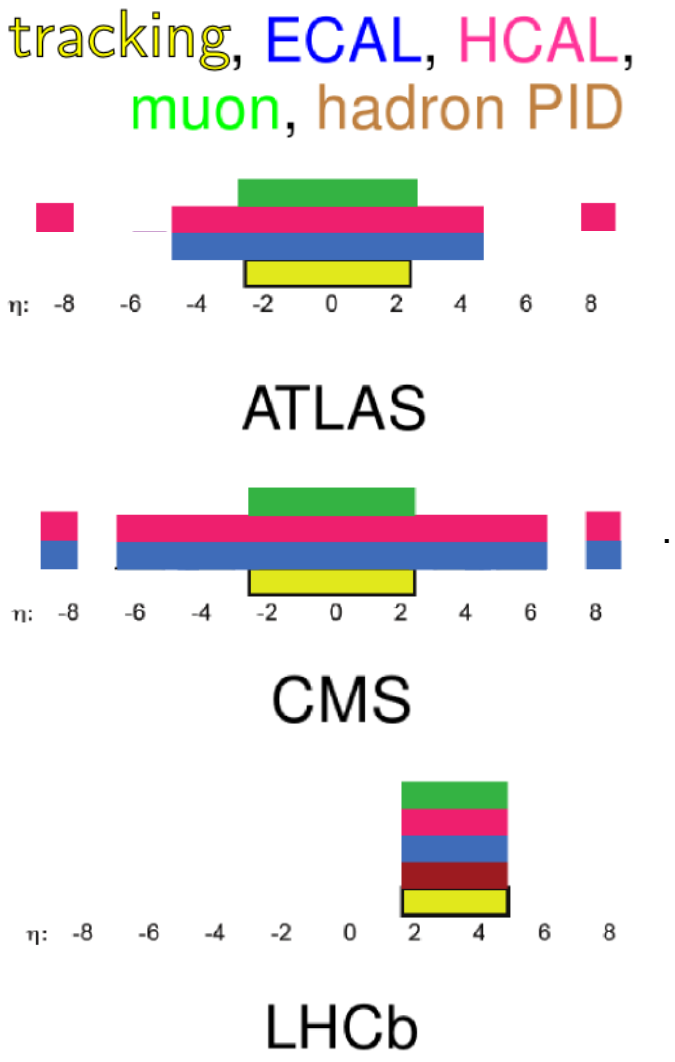
Detector configuration

Unique capabilities in the forward region:

- Tracking and vertexing
- Muon and hadron identification.
- b-jets identification.

Direct searches and production measurements:

- Luminosity penalty of a factor 8, 3.2 fb^{-1} up to now, ~ 50 fb^{-1} for upgraded LHCb.
- Low pile-up condition $\mu \sim 2$
- Complementarity domains:
  Forward coverage $2 < \eta < 5$
  Low p_T **triggers**.

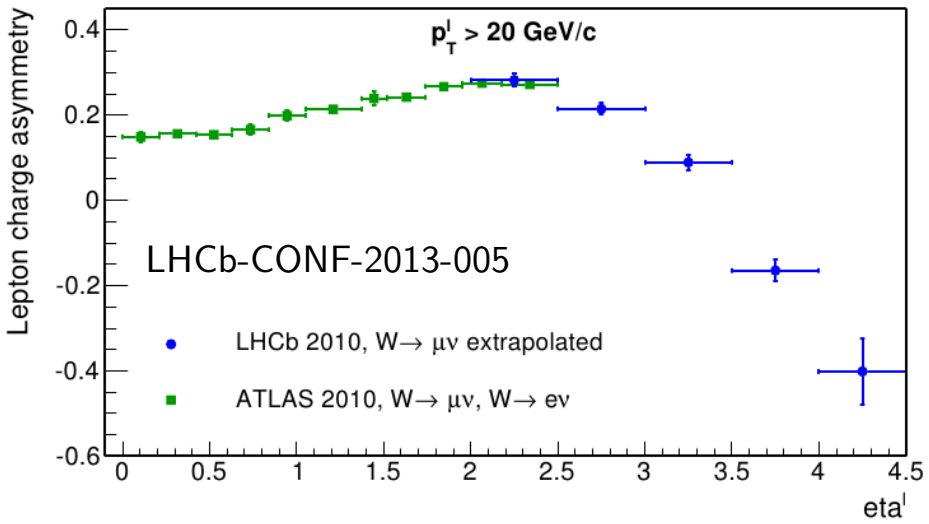


Complementarity with GPDs

Some examples

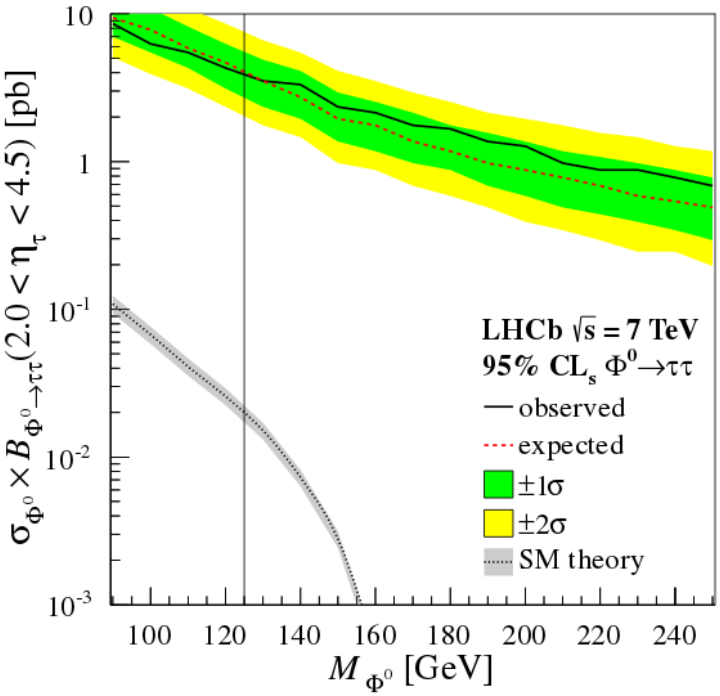
EW, softQCD, charmonium production measurements:

- W and Z boson production in the forward region. JHEP 06 (2012) 058,JHEP 01 (2013) 111,JHEP 02 (2013) 102
- Charmonium production down to 0 p_T. JHEP 02 (2013) 041,JHEP 06 (2013) 064, ERJ C 71 (2011) 1645
- Charged particles multiplicities in the forward region. ERJ C 72 (2012) 1947

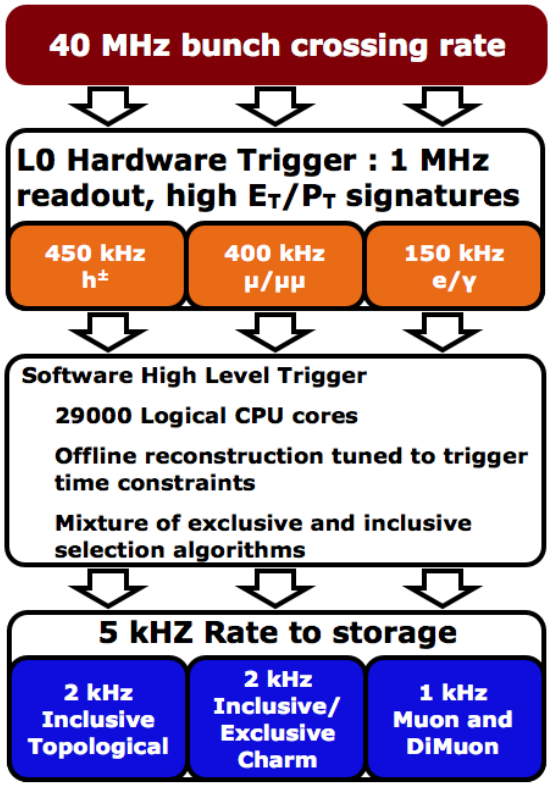


Search for $\Phi_0 \to \tau\tau$,JHEP 05 (2013) 132

- Model independent search, limit on forward Higgs production.
- MSSM in $m_{h^0}^{max}$ scenario limits not as stringent as GPD.



LHCb Trigger



HLT 1:

- Displaced tracks.
- Single and Di-μ, displaced or prompt.
- Single-e high p_T.
- Few technical and dedicated lines.

HLT 2:

- Inclusive selections for B, D, e, μ.
- Exclusive selections

Few words on the Topological trigger LHCb-PUB-2011-002:

- 2, 3 or 4 displaced track vertices + MVA selection: efficient and pure on exclusive B decays.
- Act as a b-jet trigger. $\epsilon_{b-jet} \sim 30\%$ for $p_T > 15\ GeV$.
- Already used in $A_{b\bar{b}}^{FC}$ analysis LHCb-CONF-2013-001

- High pile up condition in GPD $\rightarrow$ high-p_T trigger thresholds.

from A. Hoecker, M. Pierini, "Trigger for SUSY in ATLAS/CMS"

	ATLAS	CMS
Single-μ	$p_T > 24$ *GeV*	$p_T > 24$ *GeV*, $\mathbf{p_T > 40}$ **GeV not isolated**
Double-μ	$p_T > 13,13$ *GeV* or $p_T > 18,8$ *GeV*	$p_T > 17,8$ *GeV* ($p_T > 13,8$ *GeV* parked)

- In LHCb combination of prompt and displaced muons with low p_T, $m_{\mu\mu}$ thresholds.
- HLT2 inclusive μ-lines:

	Prompt	Detached
Single-μ	$\mathbf{p_T > 10}$ **GeV**	$\mathbf{p_T > 1.3}$ **GeV** ($IP > 0.5$ *mm*,$IP\chi^2 > 200$)
Double-μ	$\mathbf{m_{\mu\mu} > 4.8}$ **GeV**	$\mathbf{m_{\mu\mu} > 2.95}$ **GeV** ($DLS > 5$)

- HLT2 reconstruction getting closer and closer to offline reconstruction.
- Possibility to build more complex objects allowing lower thresholds on single/double-μ.
- Thresholds will remain similar in Run II.

(b-)Jets

- Several flavour of jet based trigger in GPDs balance thresholds with multiplicity.

from A. Hoecker, M. Pierini, "Trigger for SUSY in ATLAS/CMS"

	ATLAS	CMS
Single-jet	$p_T > 360$ *GeV*	$p_T > 320$ *GeV*
Multi-jet	$4(5) \times p_T > 80(55)$ *GeV*	$4 \times p_T > 80(50$ *parked*$)$ *GeV*
Multi-jet and b-tag	$4 \times p_T > 45$ *GeV* and a b-tag	-

- More on jet reconstruction at LHCb in Will Barter's talk.
- **Inclusive b-triggers can be used as b-jet trigger.**
- Jet based trigger will be investigated for Run 2.

Example of inclusive offline selections under investigation:

- Selection for $3b$ and $4b$ events adding jet info: 1(2) b-tag and $4 \times p_{T\ jet} > 16(8)$ *GeV*, 2 b-tag and $3 \times p_{T\ jet} > 11$ *GeV*.

Long lived particles (LLP)

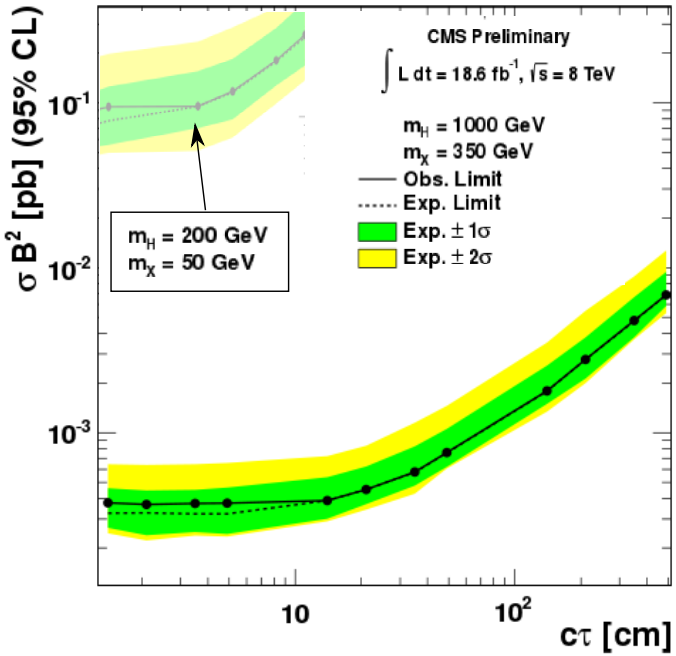
Signature: displaced heavy vertex

Benchmark channel: Hidden Valley model, $H \to \pi_v^0 \pi_v^0 \to b\bar{b}b\bar{b}$, where π_v^0 is the LLP

Strassler, Zurek Phys. Lett. B651 (2007) 374

Two triggering approach:

- Displaced vertex object dedicated trigger ATLAS PRL 108 (2012) 251801
  $\to$ sensitivity to low masses not to low proper time ($c\tau_{min} \sim 1\ m$).
- Inclusive jet trigger, CMS-PAS-EXO-12-038
  $\to$ sensitivity to low proper time not to low masses.



- Displaced vertex object dedicated trigger at LHCb.
- Region of sensitivity complementary to GPDs: low mass ($20 < m_{\pi_v^0} < 50\ GeV$) and low proper time ($c\tau \sim O(cm)$).
- Trigger strategy for semi-leptonic and fully leptonic decay of LLP in place too.

Outlook

- There are regions of the phase space not accessible to ATLAS/CMS because of the high-luminosity condition and pseudo-rapidity coverage.
- LHCb is able to cover the low mass objects flying up to $O(10\ cm)$ in the forward region.
- Hlt2 has lots of flexibility to trigger those objects.

Open questions:

- Are there signatures we might have triggered already and we should search for?
- Should we include some more specific signatures in our trigger?
- Are there production measurements in forward region we should focus on?

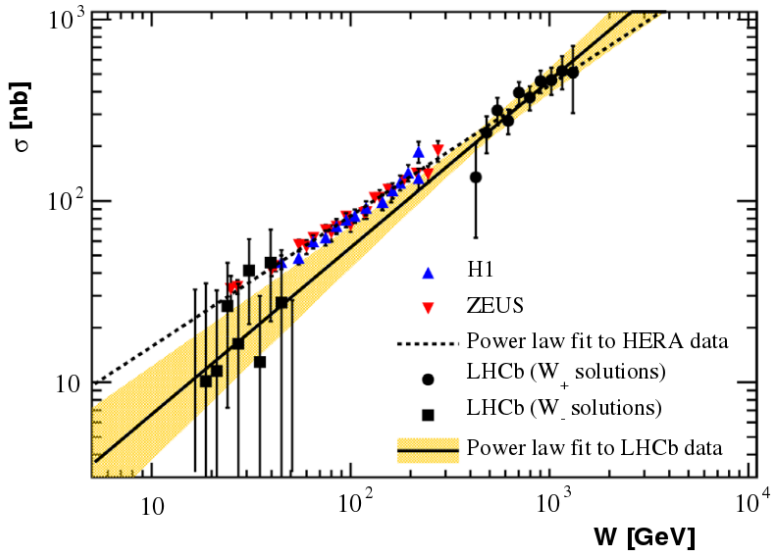
Backup

Complementarity with GPDs

Some examples

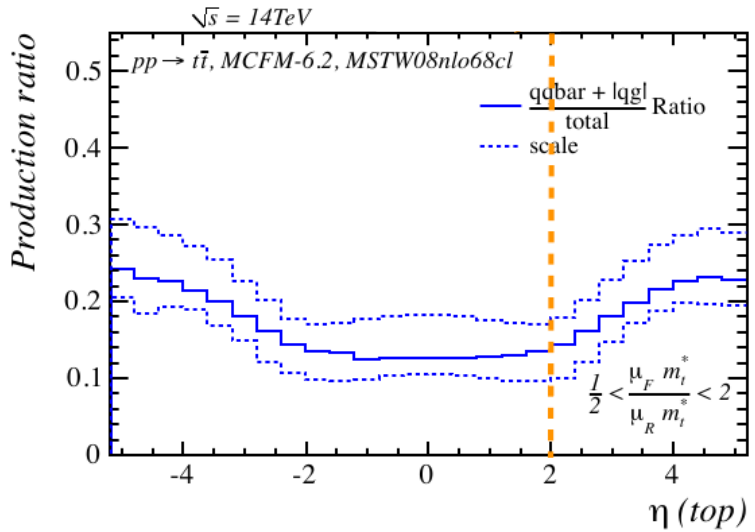
Low pile-up conditions ease exclusive production measurements:

- J/ψ and $\psi(2S)$ in 2010 JPG 40 (2013) 045001, 2011 just approved.
- Ongoing studies of hadron production.
- Program might be extended in Run II with high-y shower counters.



Top production asymmetry:

- Dilution due gg-production smaller the in central detectors.
- b-tagged jets allow to reduce the background in μ+jet final state
- LHCb potential investigated in Kagan *et al., PRL 107 (2011) 082003* and LHCb-PUB-2013-009.



Lepton channels

Muons triggers thresholds in Hlt1, Hlt2

- HLT1:
  - Single-μ prompt : $\mathbf{p_T} > \mathbf{4.8\ GeV}$, $p > 8\ GeV$
  - Single-μ displaced : $\mathbf{p_T} > \mathbf{1.\ GeV}$, $p > 8\ GeV$, $IP > 0.1\ mm$, $\mathbf{IP}\chi^2 > \mathbf{16}$
  - Double-μ prompt : $\mathbf{m}_{\mu\mu} > \mathbf{2.7\ GeV}$,$p_T > 0.5\ GeV$, $p > 6\ GeV$
  - Double-μ displaced : $\mathbf{m}_{\mu\mu} > \mathbf{1\ GeV}$,$p_T > 1\ GeV$, $p > 6\ GeV$, $\mathbf{IP}\chi^2 > \mathbf{3}$
- HLT2 inclusive lines:
  - Single-μ prompt $p_T > 10\ GeV$.
  - Single-μ detached $p_T > 1.3\ GeV$,$IP > 0.5$,$IP\chi^2 > 200$.
  - Double-μ prompt $m_{\mu\mu} > 4.8\ GeV$ (recheck)
  - Double-μ detached $m_{\mu\mu} > 2.95\ GeV$,$DLS > 5$

Lepton channels

Electron triggers

CMS

(Unprescaled) Object	Trigger Threshold (GeV)
Single Electron	80
Single Isolated Electron	27
Double Electron	(17, 8)

Single e/γ	20	13
Double e/γ	13,7	8

L1

ATLAS

Offline selection	Trigger selection L1	EF
Single electron p_T > 25 GeV	18 GeV	24 GeV
2 electrons, each p_T > 15 GeV	2x10 GeV	2x12 GeV

- In LHCb combination of prompt high p_T electron and displaced tracks with low thresholds can be used.
- For $p_T > 12 - 15$ GeV, good ID but poor momenta estimation (ECAL saturation).
- HLT1:
  - Single-e prompt : $\mathbf{p_T > 10\ GeV}$, $p > 20$ GeV
  - No dedicated displaced electron lines but Single-*Track* displaced : $p_T > 1.$ GeV, $p > 8$ GeV, $IP > 0.1$ mm, $IP\chi^2 > 16$
- HLT2:
  - Single-e high p_T : $\mathbf{p_T > 10\ GeV}$
  - Double-e prompt: $\mathbf{p_T > 10\ GeV}$, $m_{ee} > 20$ GeV