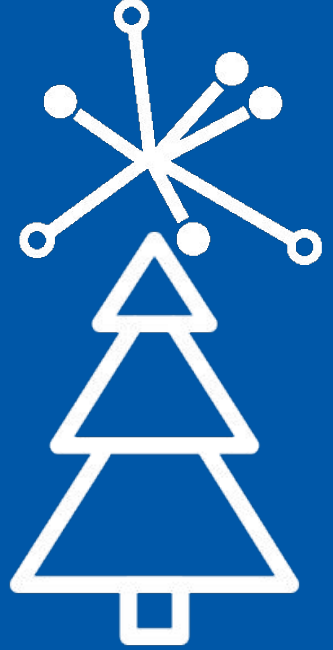


LHCb and LHCb Upgrade

Liverpool HEP Christmas Meeting 2019

Kārlis Dreimanis

20/12/2019

Congratulations!

- Two new Doctors of Philosophy!
- Congratulations to **Vinícius** and **Heather**!

Congratulations!

- Vin has graduated and will be joining us as a PostDoc working on the LHCb Upgrade!

Welcome!

- New student on LHCb - Abbie Chadwick!
- Electroweak and Top physics
- Supervisors: Tara and Stephen

Welcome!

- New Senior Researcher on LHCb - Eduardo Rodriguez!
- LHCb Upgrade, Machine Learning, Core Software

LHCb's 2019

- 2019 has been a good year: 50 papers submitted!
- **Milestone of 500 papers reached!**
  500th: *Determination of quantum numbers for several excited charmed mesons observed in $B^- \to D^{*+}\pi^-\pi^-$ decays*
  (https://arxiv.org/abs/1911.05957)
- Incredibly diverse physics program
  and some highly anticipated results!

Liverpool's presence

- Tara: LHC EWK WG convenor;
- Themis: LHCb UK VELO Upgrade project leader;
- Stephen: LHC *top* WGs LHCb representative;
  QEE WG's Convenor (until March 2020);
- Karol: VELO upgrade DAQ project coordinator;
- Lauren: Rare Decays WG's trigger liaison;
- James: QEE Run 1 + Run 2 performance liaison;
- Kurt: Liaison with Microsoft for R&D in computing models (ML, FPGA deployment, cloud);

Highlights - Lepton (non-?) Universality

Reported at Moriond 2019

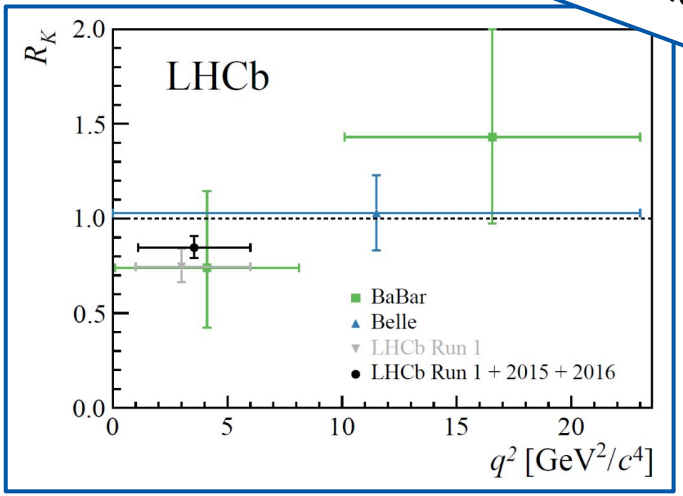
- Accounting for mass, leptons should 'behave' identically in the Standard Model.
- Measure B meson decays with leptons in the final state and take ratio - R_K

$$R_K = \frac{\mathcal{B}(B^+ \to K^+ \mu\mu)}{\mathcal{B}(B^+ \to K^+ ee)}$$

- In 2012, LHCb reported a 2.6σ tension!
- Slightly reduced with the full 2011-2016 dataset, **but still 2.5σ!**

$$R_K = 0.846^{+0.060+0.016}_{-0.054-0.014}$$

Phys.Rev.Lett. 122 (2019) no.19, 191801



- More results in the pipeline! Vinícius, David
- $\Lambda^0_b \to pKl^+l^-$ looking at LU in lambda baryon decay available on arxiv since this week. arXiv:1910.06926
- Liverpool has contributed to this analysis.

Highlights - Discovery of CP in Charm

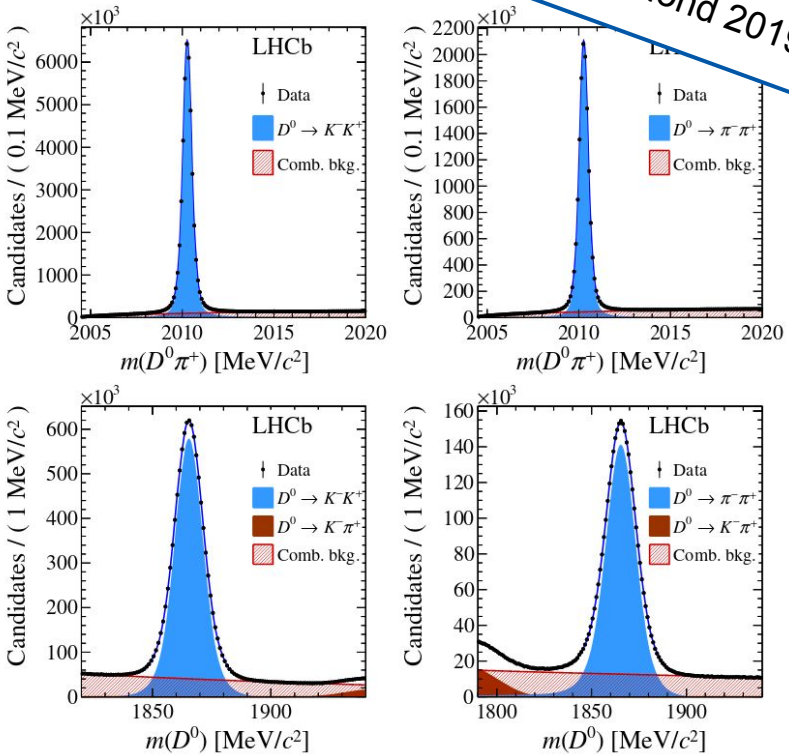
Reported at Moriond 2019

- CP asymmetry in Charm decays is expected in the SM, but very small @ 10^{-4} - 10^{-3}.
- LHCb measured two decay channels:

  $\mathbf{D^0 \to K^+K^-}$; $\Delta A_{CP} = [-18.2 \pm 3.2(stat) \pm 0.9(syst)] \times 10^{-4}$

  $\mathbf{D^0 \to \pi^+\pi^-}$; $\Delta A_{CP} = [-9 \pm 8(stat) \pm 5(syst)] \times 10^{-4}$

- **Full combination: $\Delta A_{CP} = (-15.4 \pm 2.9) \times 10^{-4}$**
- **Observation at 5.3σ!**



Phys. Rev. Lett. 122, 211803

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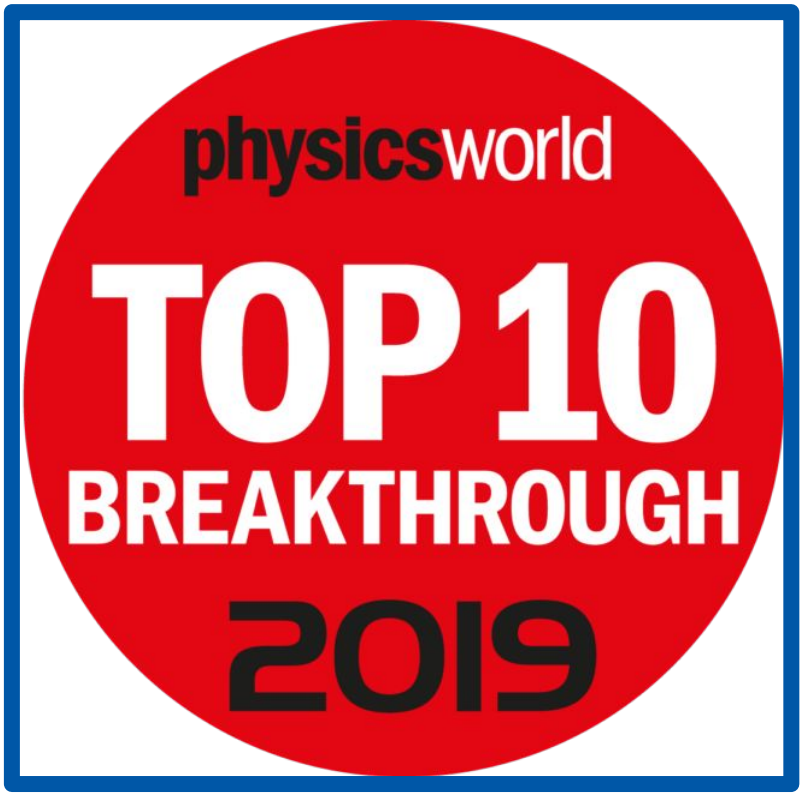
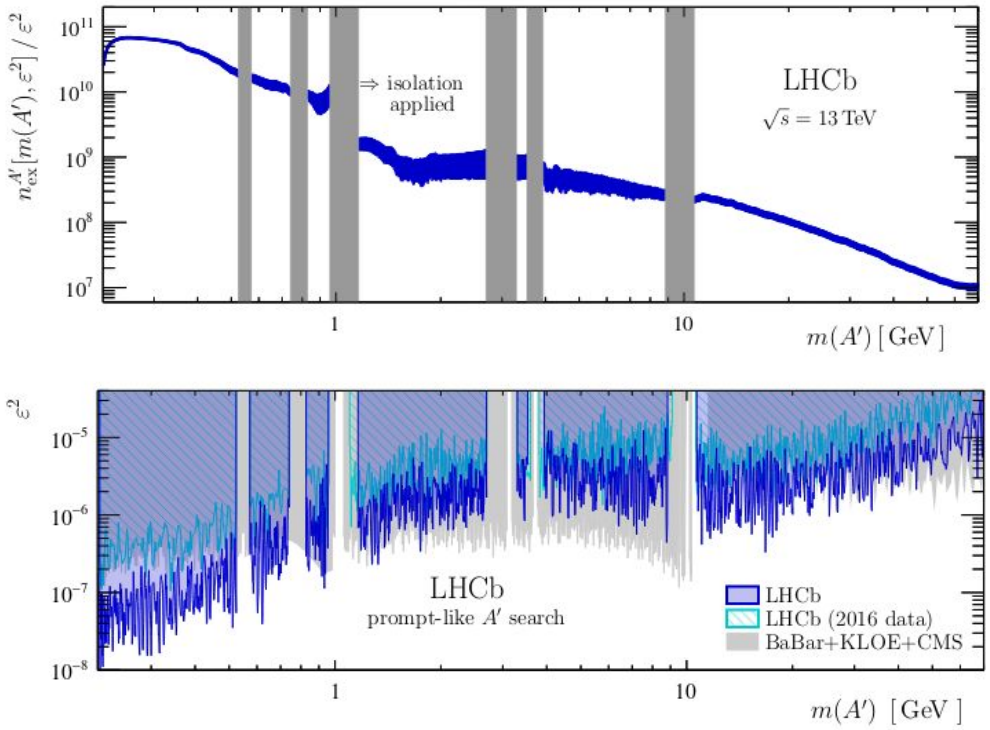


Highlights - Dark Photon Searches



arXiv:1910.06926

- Search for A'→μμ
- Search for both prompt and long-lived dark photons.
- 'Minimal' models covered.
- Non-minimal searches to be published soon!

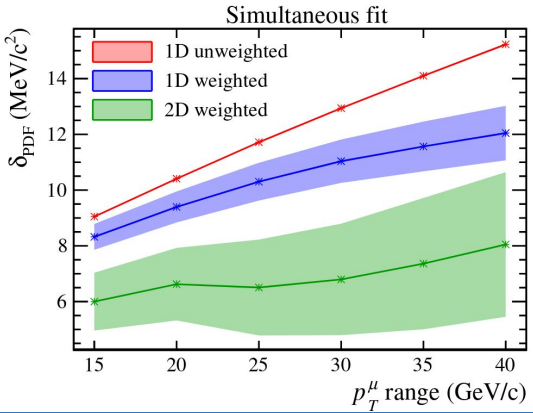
@Liverpool - Towards W mass measurement

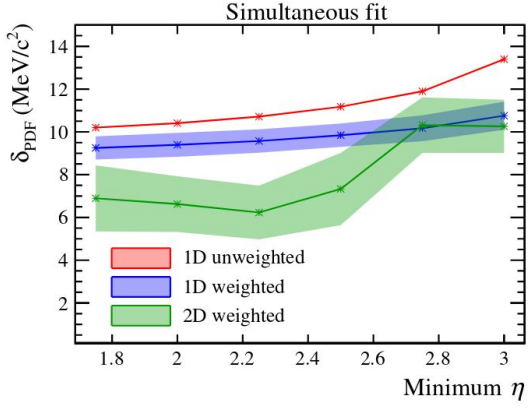
Stephen

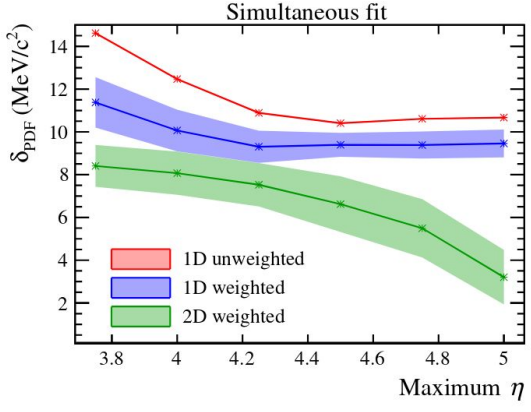
- New methods to improve future measurements: “Understanding and constraining the PDF uncertainties in a W boson mass measurement with forward muons at the LHC”

  Farry, S., Lupton, O., Pili, M. et al. Eur. Phys. J. C (2019) 79: 497

- W mass measurement analysis on-going at LHCb.
- Very challenging in a non-4π detector; no MET information available!
- Precise knowledge of the proton PDF and theoretical modelling is paramount for success!







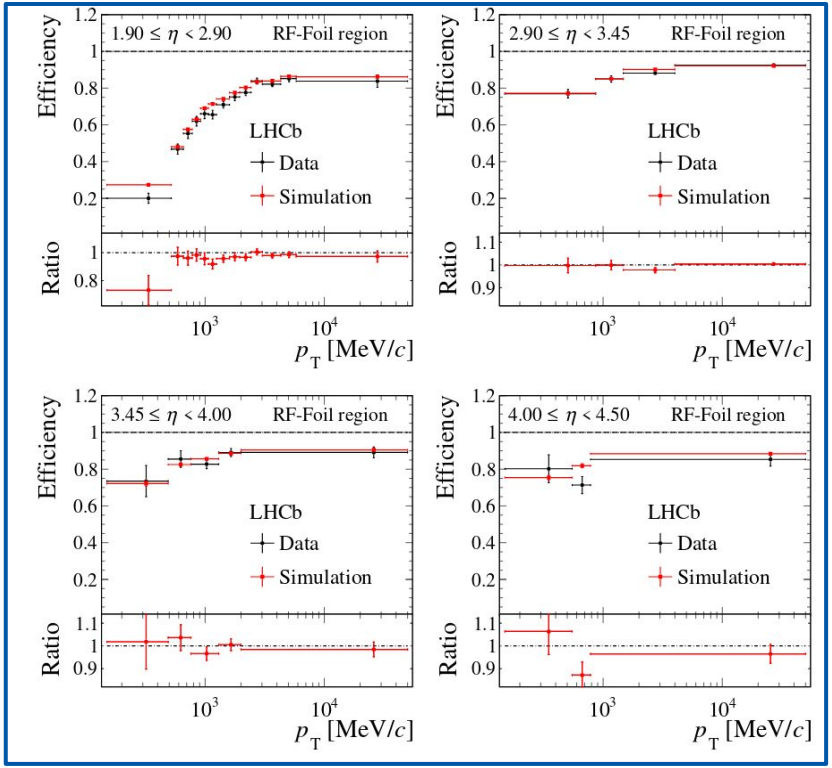
@Liverpool - Electron efficiency measurement

Stephen

- “Measurement of the electron reconstruction efficiency at LHCb”

  JINST 14 (2019) P11023

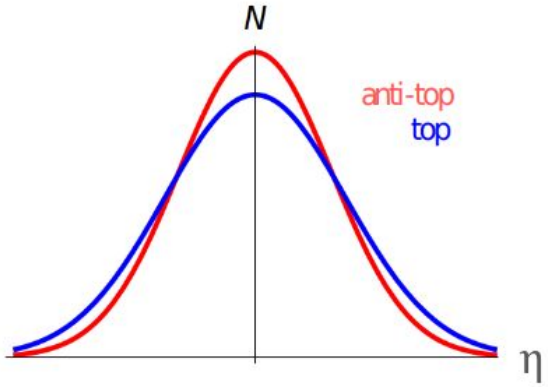
- Electron reconstruction comparatively difficult;
- Incredibly important for much of LHCb physics program, including flagship measurements (e.g. Lepton Universality);
- The results allow for LHCb to measure branching fractions involving single electrons with a systematic uncertainty below 1%!

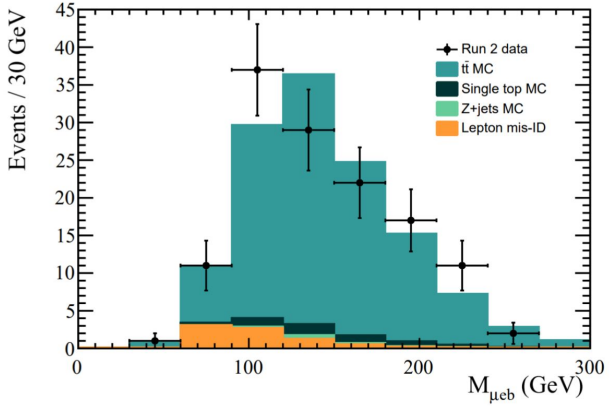


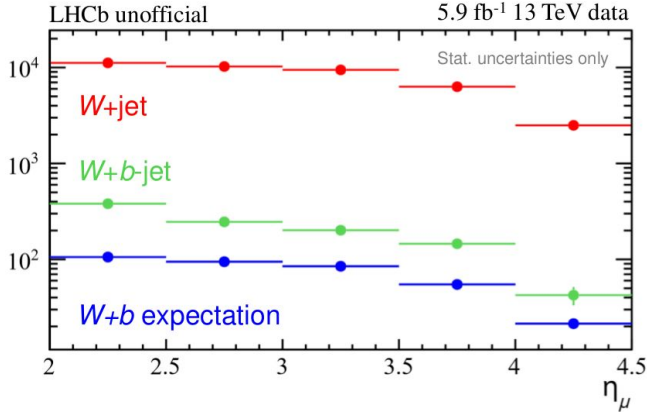
@Liverpool - Top physics

James, Heather, Stephen, Tara

- James's and Heather's thesis topics - Run-2 top measurements.
- On-going work on *top-antitop* asymmetry (NLO effect); positive asymmetry boosts *top* forward relative to *antitop*.
- Large and difficult to deal with backgrounds (W, QCD).
- Publication planned for 2020.



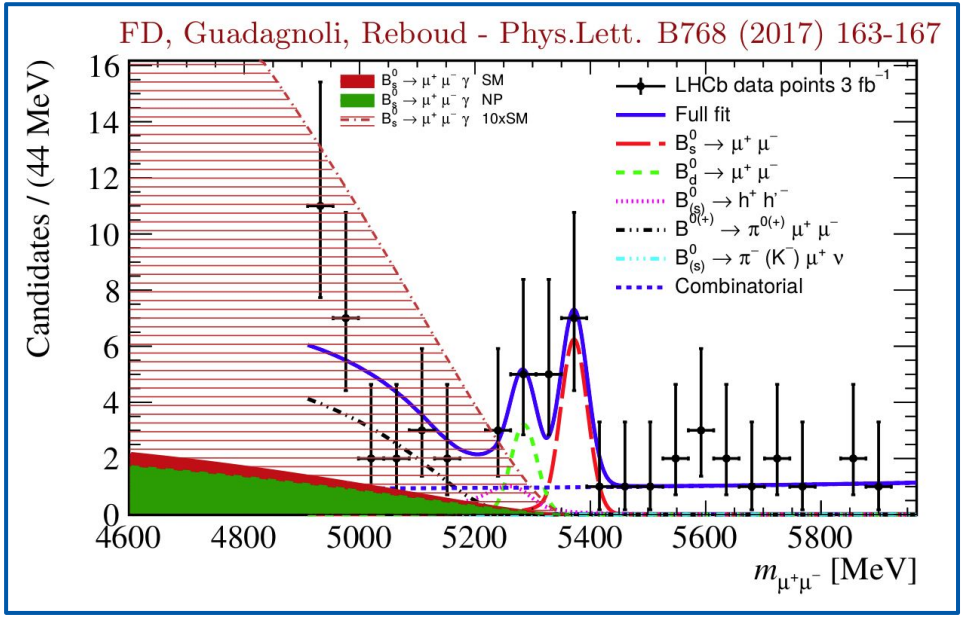




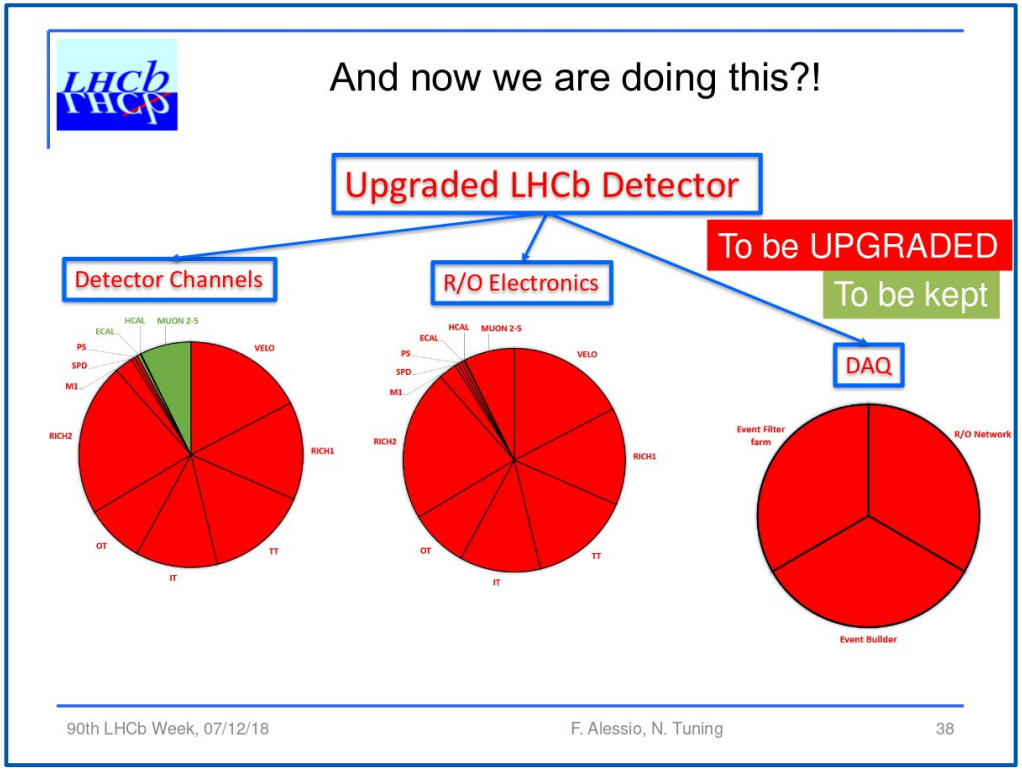
@Liverpool - $B_s^0 \to \mu^+\mu^-\gamma$

Lauren, Tara

- Looking for the very rare decay of $B_s^0 \to \mu^+\mu^-\gamma$.
- Complementarily - look at $B_s^0 \to \mu^+\mu^-$ in Run-2.
- Great test of the SM; theory well constrained.
- Currently on-going work - efficiency determination.
- Aim for a publication 2020/21.



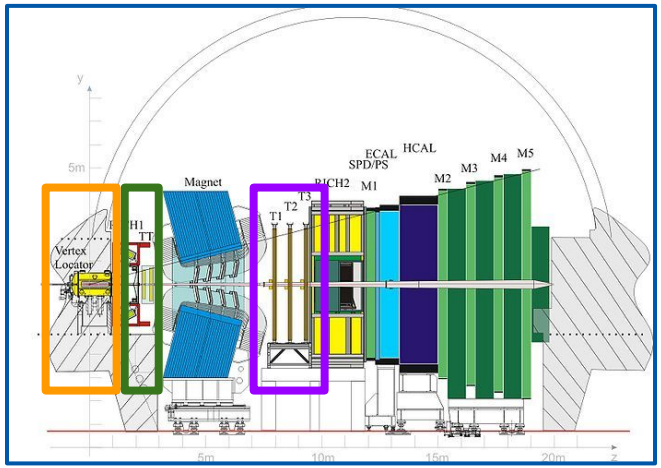
LHCb Upgrade



- Slide from the LHCb week in December 2018!
- Huge proportion of LHCb is being upgraded during LS2!

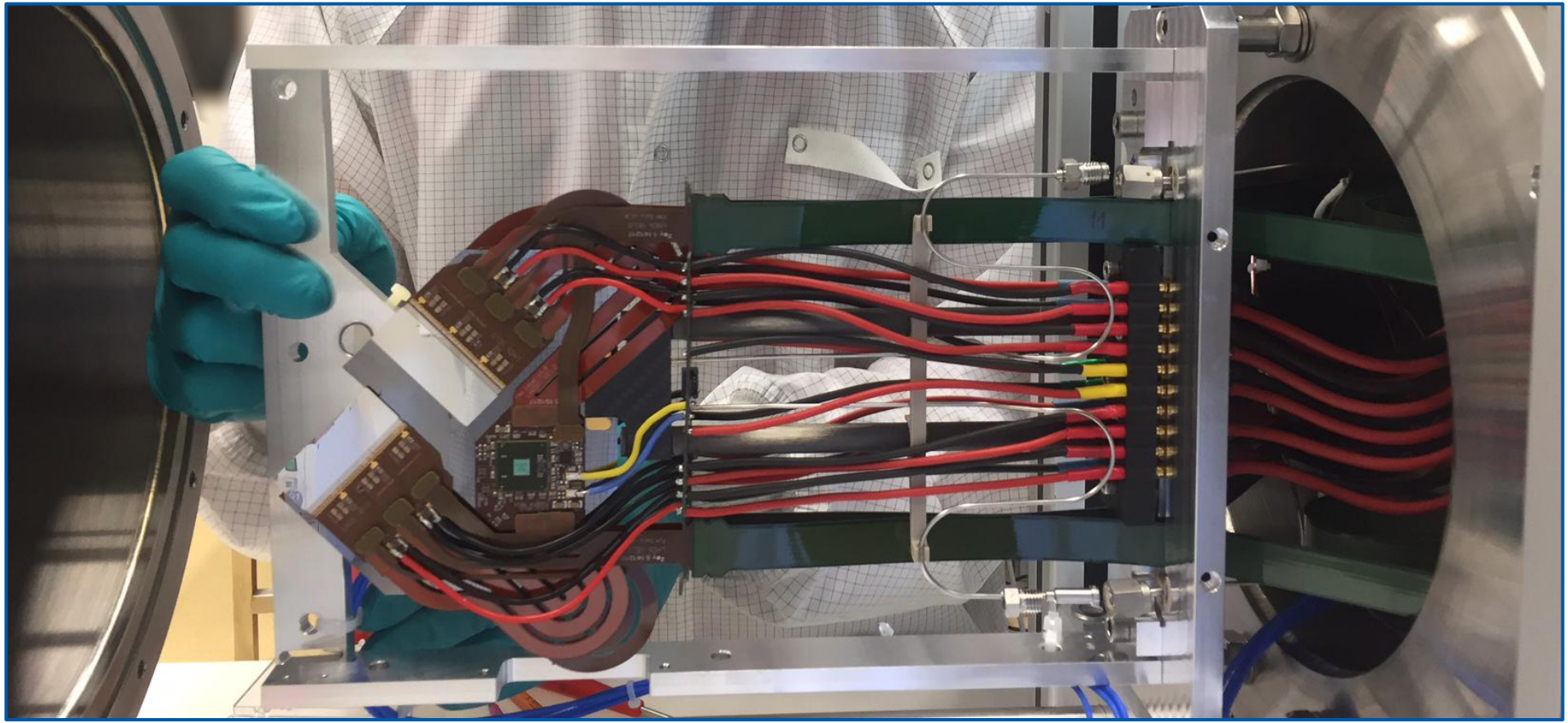
LHCb Upgrade

- Replace VELO strips with pixels!
- Replace TT with a new detector - UT!
- Replace T-stations with SciFi!



- Other sub-detectors upgraded! (except calo and muons)
- UT project experienced big problems - chip not functioning!
  Fixed now, project trying to catch-up on lost time.
- VELO module production halted in September due to sensor gluing issue!

LHCb Upgrade



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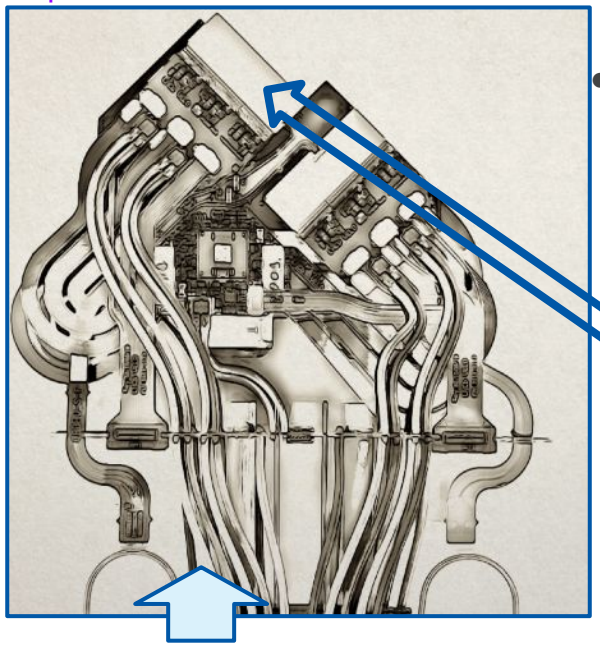

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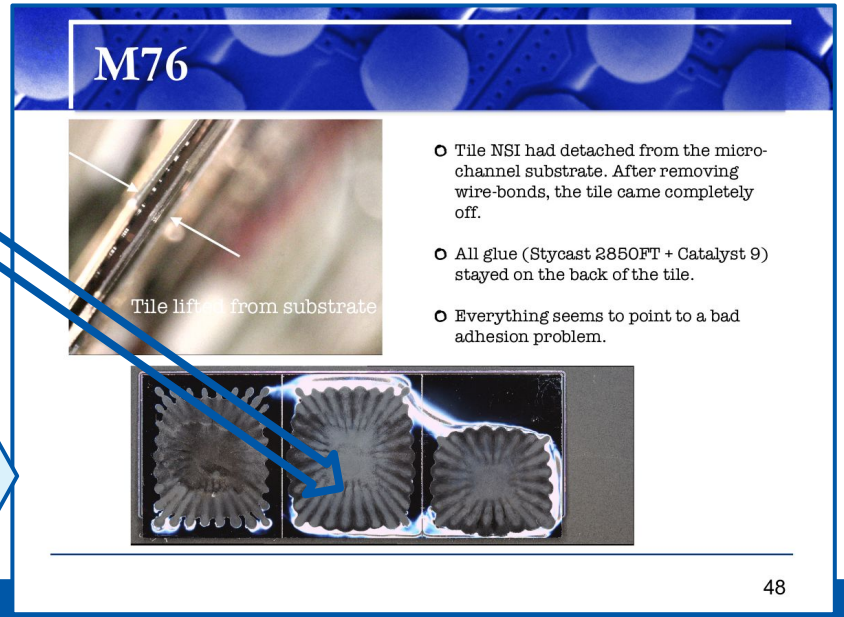
- UT project experienced big problems, chip non-functioning!
  Fixed now, project trying to catch-up with lost time.
- VELO module production halted in September due to sensor gluing issue!
  People working non-stop since then have found solutions; production to restart in January!



Slide from the December 2019 LHCb Week (Paula Collins)

LHCb Upgrade

- Replace VELO strips with pixels!
- Replace TT with a new detector - UT!
- Replace T-stations with SciFi!

- Highlights from VELO; detector removal and etching of the new foils!

VELO (previous)

Etching Campaign

As regions become thin, apply protective mask
Limit number of steps with clever analysis
Control removed thickness by
- Knowledge of time and temperature
- Analysis of waste fluid for Al content
- Ultrasound measurements

Astonishing agreement!!!

A2 (solut.)	Etching 1	Etching 2	Etching 3	Etching 4	Etching 5	Etching 6	Sum
T_{AV}	18,21	17,97	17,54	16,87	16,78	17,60	
Alum. (ppb)	751,20	765,00	755,80	456,20	246,20	457,80	
Epais.(mu)	20,77	21,15	20,89	12,61	16,53	30,73	122,7
mu/min	0,83	0,85	0,84	0,79	0,66	0,68	

A2 (temp.)	Etching 1	Etching 2	Etching 3	Etching 4	Etching 5	Etching 6	Sum
T_{AV}	18,21	18,03	17,60	16,93	16,81	17,62	
Duration (min)	25	25	25	16	25	45	161
Thickn. (mu)	19,18	18,97	18,45	11,31	17,55	33,31	119,0
Aver. mu/min	0,77	0,76	0,74	0,71	0,70	0,74	

	sum 1-4	sum 4-6	Sum
Thickn. (mu)	68,0	55,0	123,3
Planned (mu)	70	50	120

27

Slide from the December 2019 LHCb Week (Paula Collins)

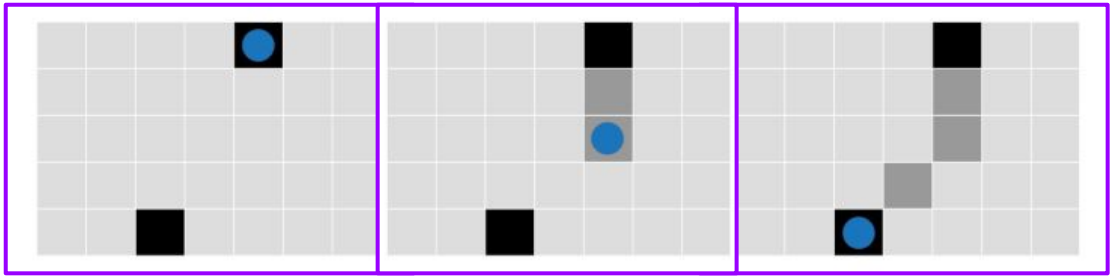
@Liverpool - Machine Learning

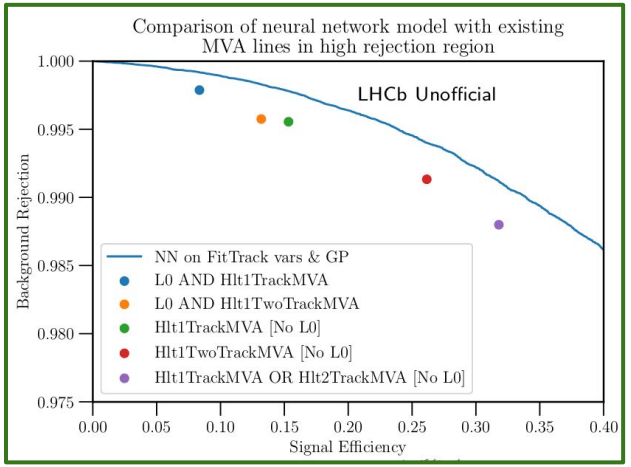
Tom H, Tom A, Phil, David, Kurt, Themis

- The new LHCb requires much faster event reconstruction.
- Exploit machine learning techniques to make track pattern finding much faster! (Agent Walk, Hybrid ML, ...)
- Use MVA for “track selection” **without** fitting; ie. use MVA to select tracks before they are tracks!
- Exceptionally promising work by our LIV.DAT students!

work in progress! promising results!

Method	Efficiency	Ghost rate	Clone rate
Hybrid	97.3%	0.11%	1.04%
Conventional	98.9%	2.5%	1.0%



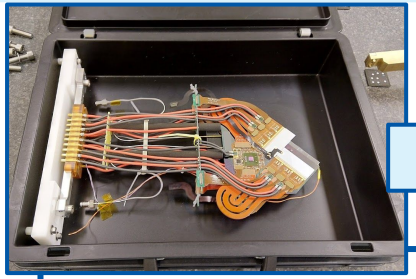


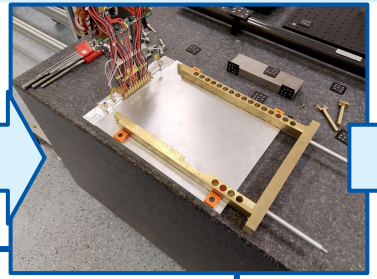
@Liverpool - VELO Construction

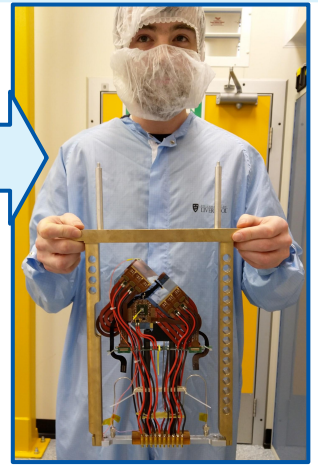
John, Kieran, Kevin, Kārlis, Vinícius, Karol, Tony, Mark W, David, Themis, Kurt, Kayleigh, Tom H, Phil (and others)

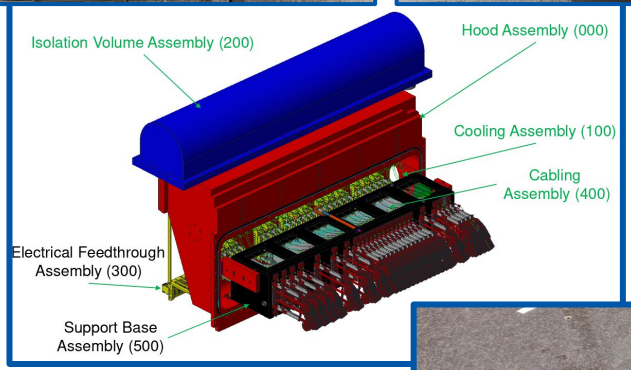
- Liverpool deliverables:
  - Mechanics (one word many parts!);
  - VELO commissioning;
  - Project's database;
  - Transport;
  - Module Metrology;
  - Hybrid design;
  - Cable design;
  - Hybrid inspection @ CERN (Phil);
  - Sensor testing @ CERN (Tom H);
  - **and many "small things" on top …**
- Incredible amount of work done by the workshop!

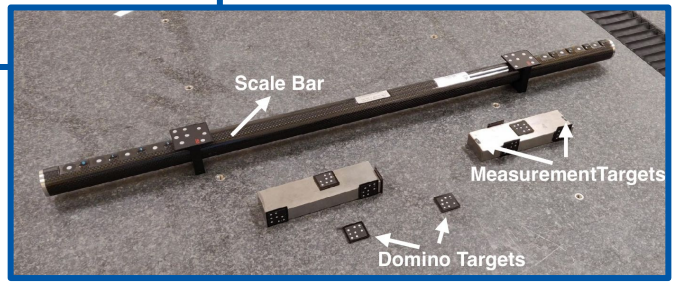
  <u>Massive thanks</u> to Mark and the workshop team!











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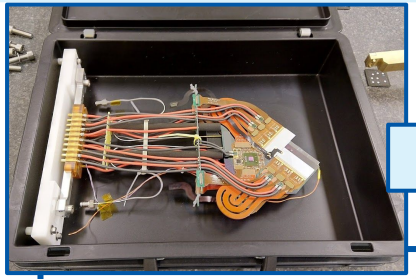

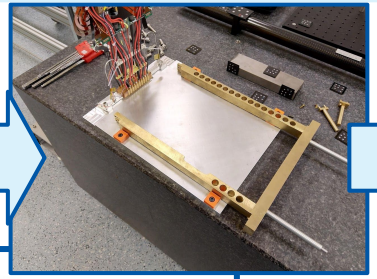

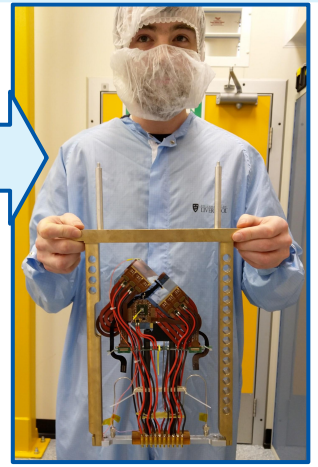

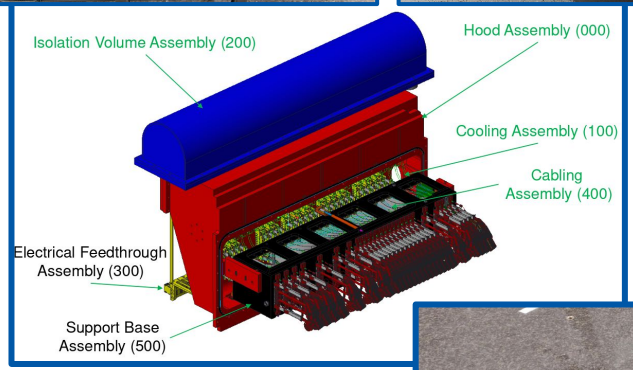

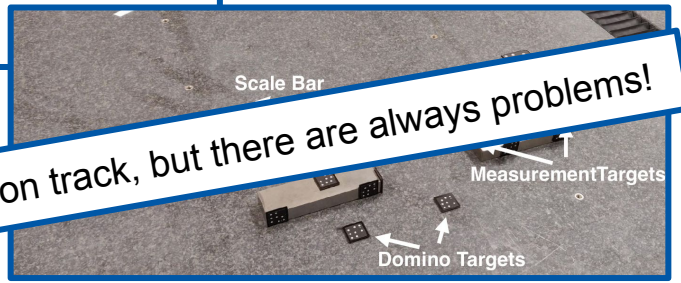

Liverpool is on track, but there are always problems!

@Liverpool - VELO Construction

John, Kieran, Kevin, Kārlis, Vinícius, Karol, Tony, Mark W, David, Themis, Kurt, Kayleigh, Tom H, Phil (and others)

Dandruff problem for your crane!? Just call Mike Lockwood!

Summary

- LHCb's physics output continues to be highly anticipated!
- **Most substantial hints of new physics come from LHCb (LU)!**
  (but, of course, we must be careful not to get too excited!)
- Livepool's LHCb **physics output** continues to be **great**!
- LHCb upgrade has hit some snags, but most have been overcome.
- Liverpool's LHCb upgrade output is **outstanding!**
  Kieran, John and Mark and The Workshop have absolutely outdone themselves!
- Trying times ahead, but if any group can do it, it's Liverpool!

Personal Thanks to you All!

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  2/2 wins vs Stephen in LHCb Week football tournaments!

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2017 Bubble Chamber Victory!

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Particle Physics Group 2018

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