LHCb at Nikhef

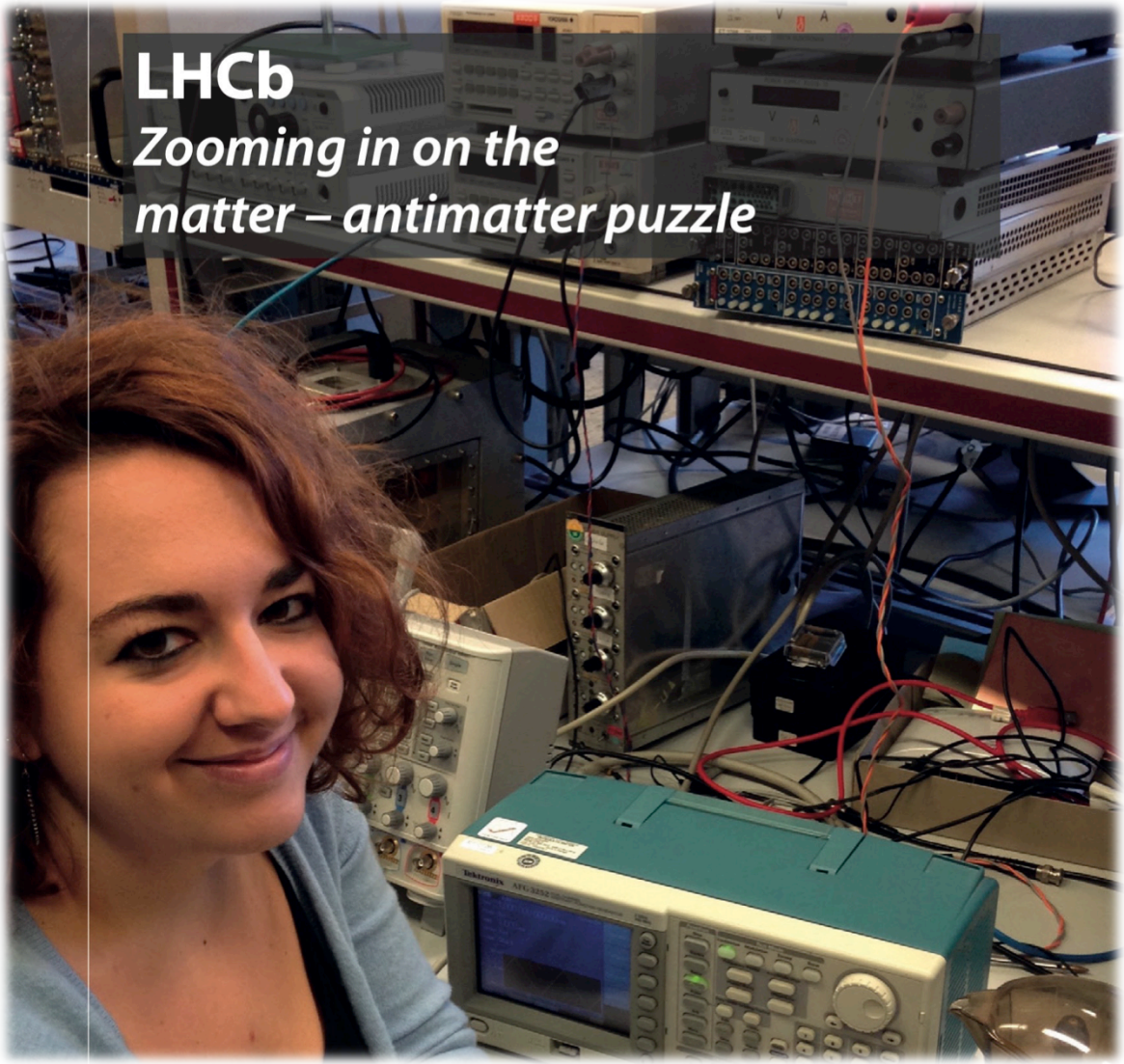
SAC Visit, 8 July 2019

N.Tuning for the Bfys group

Nikhef

Outline

- Group
  - People power
  - Funding
  - Timeline
- Technology
  - VELO
  - SciFi
  - RTA
- Physics
  - CP violation
  - Rare decays



Group

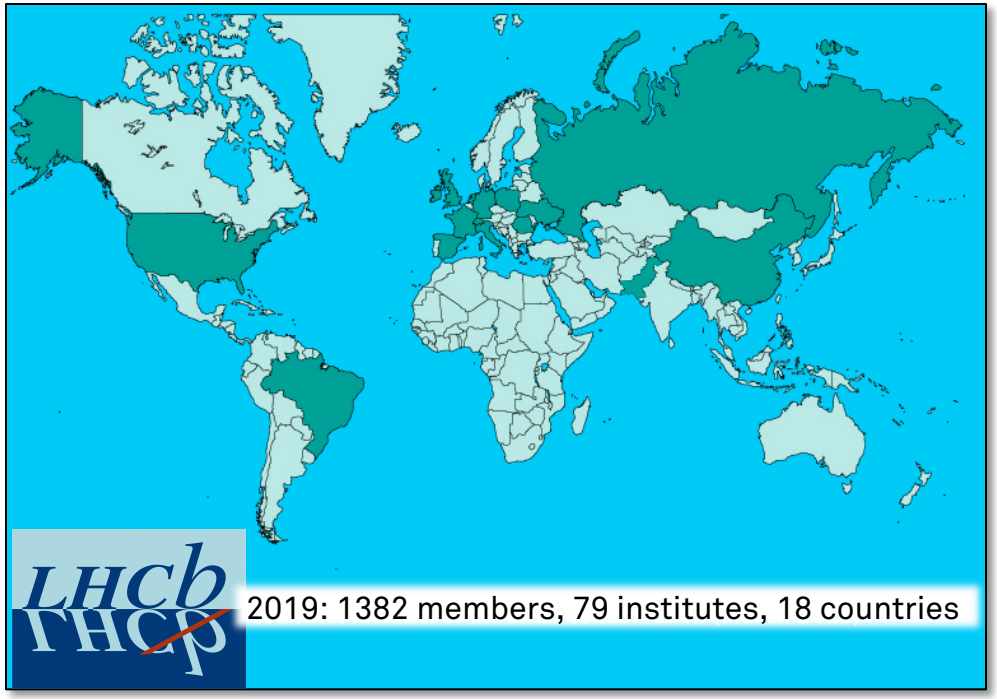
- Program leader: Marcel Merk

People	
Staff	8
Postdocs	7
PhD	11

Output	
Papers	486
Theses	29
MSc	19

Funding	
LHCb I	4.95M€
LHCb II Upgrade	3.2 M€
LHCb III UpgradeII	

Partners
VU Amsterdam
RuG Groningen
UM Maastricht



Group: people

- Groningen: being reinforced
- Maastricht: new Faculty of Science and Engineering
  - Focus on Physics and Data Science (GW + LHCb)

People	
Staff	8
Postdocs	7
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Partners
VU Amsterdam
RuG Groningen
UM Maastricht

Group: funding

Funding:

- NWO program
- Vici (2x)
- Projectruimte
- Postdoc on Swiss grant

Funding		
LHCb I	4.95M€	9%
LHCb II Upgrade	3.2 M€	7%
LHCb III UpgradeII		

➢ Worries about long term funding

- NWO LHC program fund is ending
  - from now on depend on structural Nikhef funding
  - NWO "ENW groot" request was turned down
- Stimulate grant requests
  - Veni & Marie Curie, Vidi limited…

Large impact on LHCb

Nr of shifts per author over 10 years:

Group: output

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Papers	486
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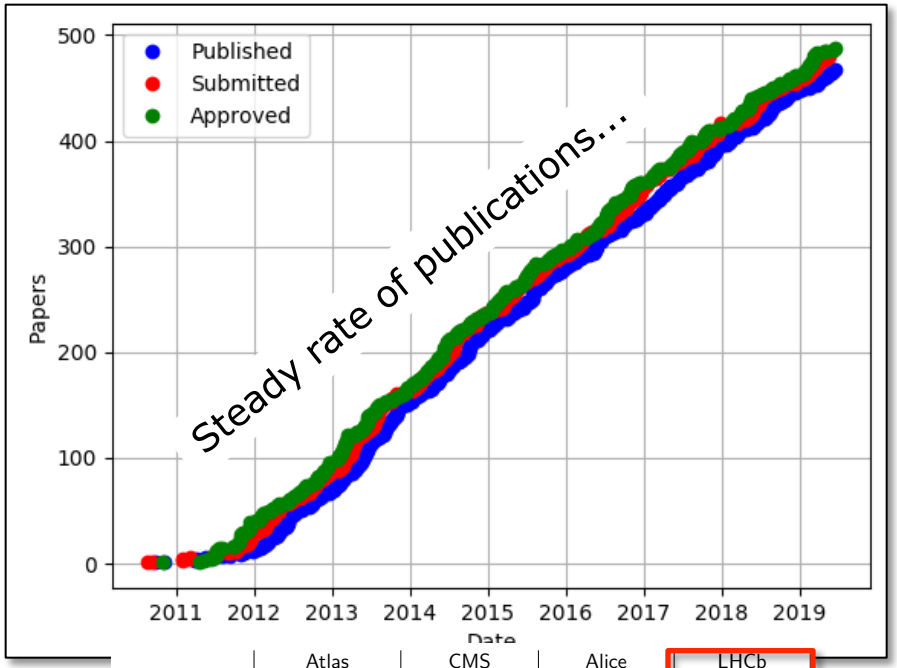
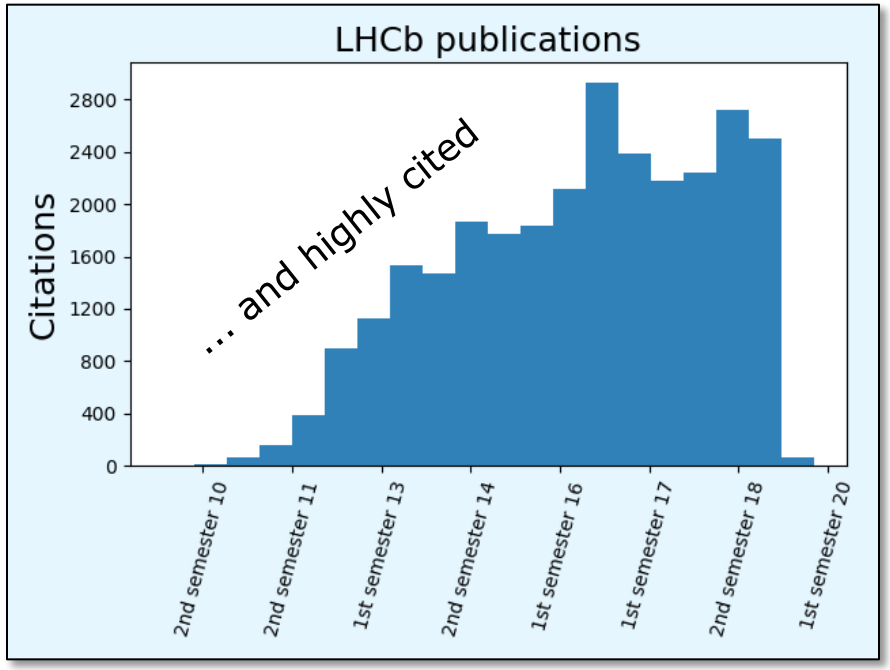
LHCb internal review record:

Institute	Reviews
Nikhef, Amsterdam, Netherlands	20 / 20
TU Dortmund, Germany	18 / 18
Manchester, United Kingdom	18 / 18
Tsinghua University, Beijing, China	15 / 15
Imperial College London, United Kingdom	14 / 14
Frascati, Italy	14 / 14



	Atlas		CMS		Alice		LHCb	
Authors	2952		2305		1030		852	
	All	Last	All	Last	All	Last	All	Last
Papers	841	142	**886**	**168**	253	60	482	65
Paper/author	0.28	0.05	0.38	0.07	0.25	0.06	**0.57**	**0.08**



Group: output

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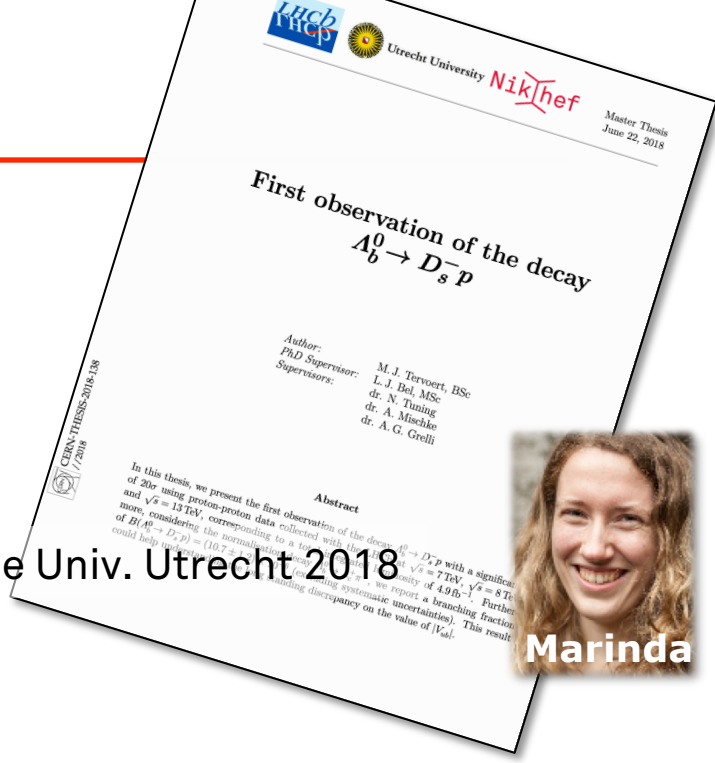
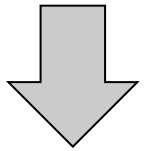


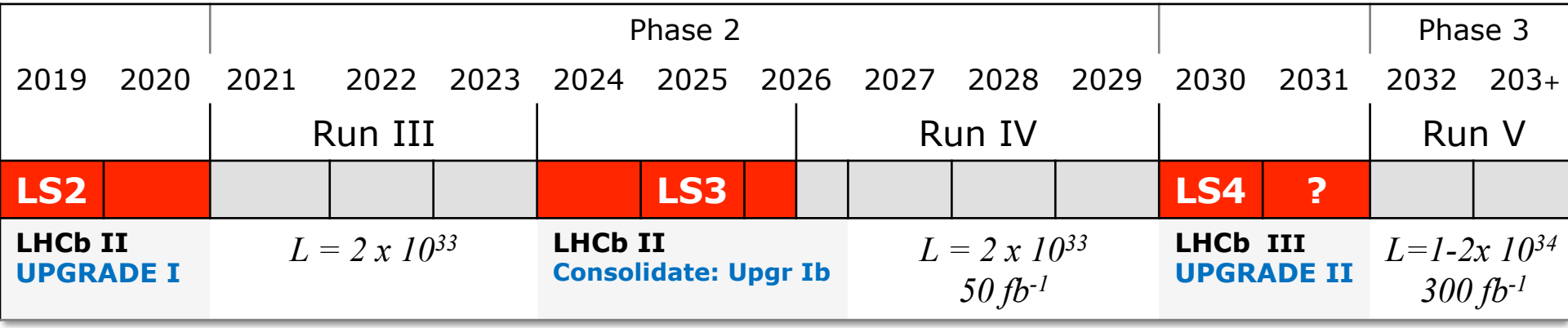
Master thesis prize Univ. Utrecht 2018

PhD thesis prize LHCb 2018

Timeline

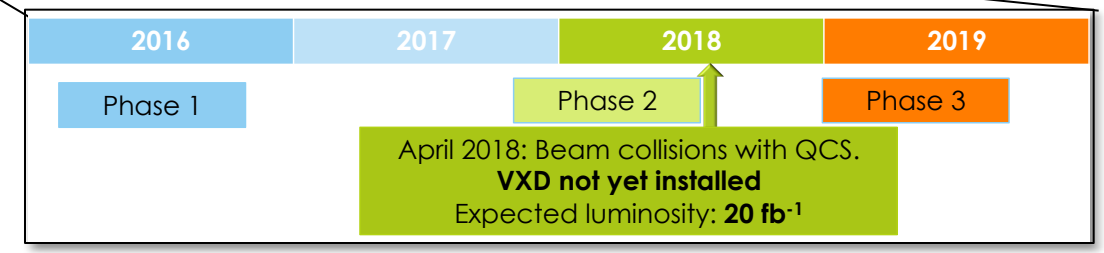
You are here





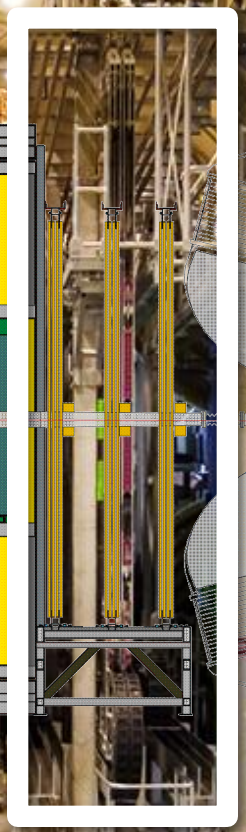
Timeline

		Phase 2									Phase 3	
2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	203+
		Run III						Run IV					Run V	
LS2						**LS3**					**LS4**	**?**		
LHCb II **UPGRADE I**		$L = 2 \times 10^{33}$			**LHCb II** **Consolidate: Upgr Ib**			$L = 2 \times 10^{33}$ $50\ fb^{-1}$			**LHCb III** **UPGRADE II**		$L=1\text{-}2 \times 10^{34}$ $300\ fb^{-1}$	
LHC **Injectors**		$L = 2 \times 10^{34}$ $300\ fb^{-1}$			**UPGRADE**			**HL-LHC** $L = 5 \times 10^{34}$					$L = 5 \times 10^{34}$ $3000\ fb^{-1}$	
Belle II	$5\ ab^{-1}$		$L = 8 \times 10^{35}$		$50\ ab^{-1}$									

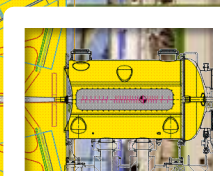


Technology

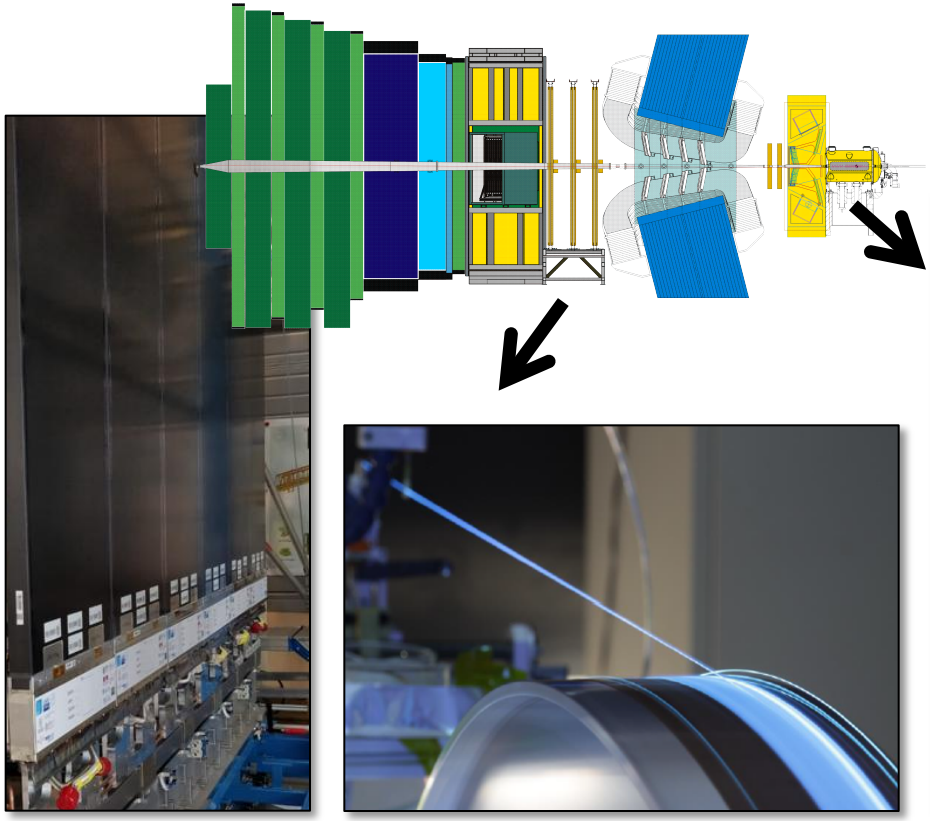
SciFi

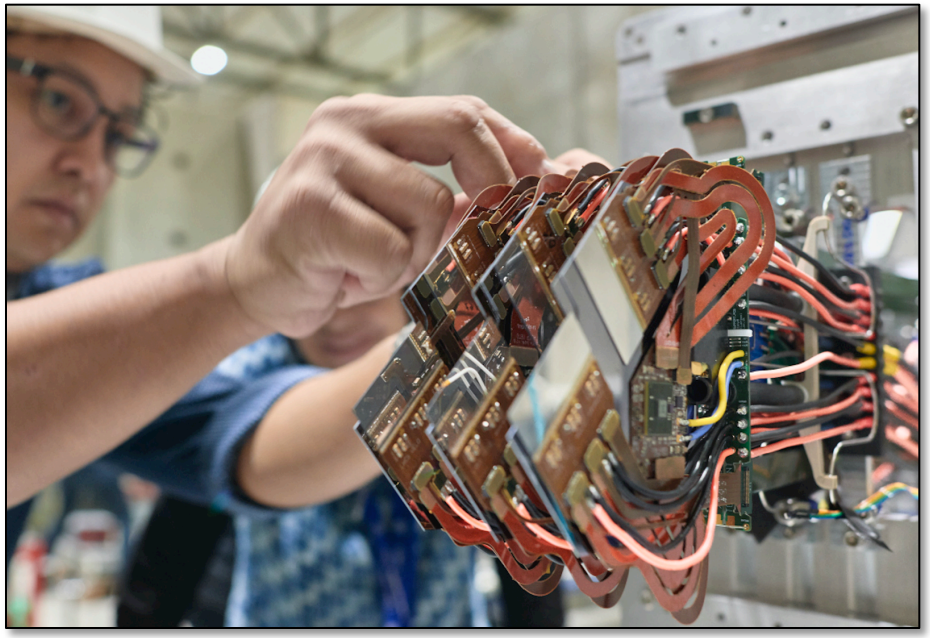


VELO



Technology





Scintillating Fibers

- New technology
- Si strip resolution for lower price

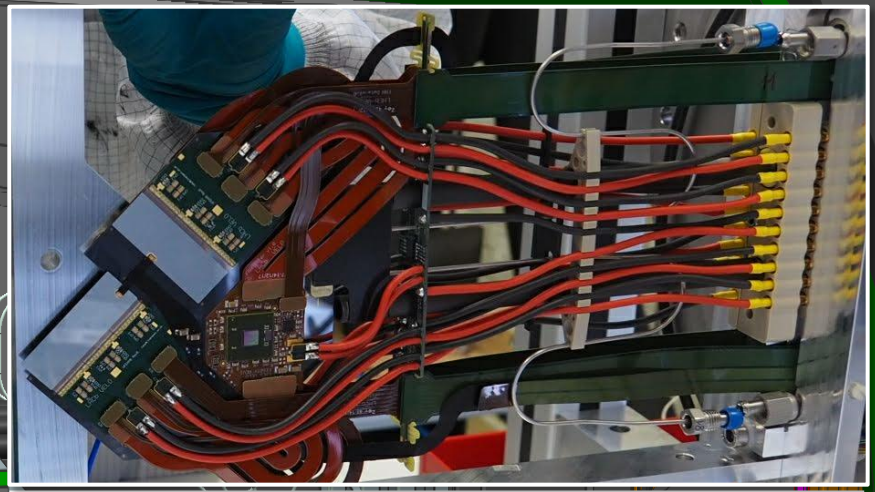
RTA (reconstruction)

- 40 MHz, 400 tracks
- 2-10 GB/s to storage

VELO pixels

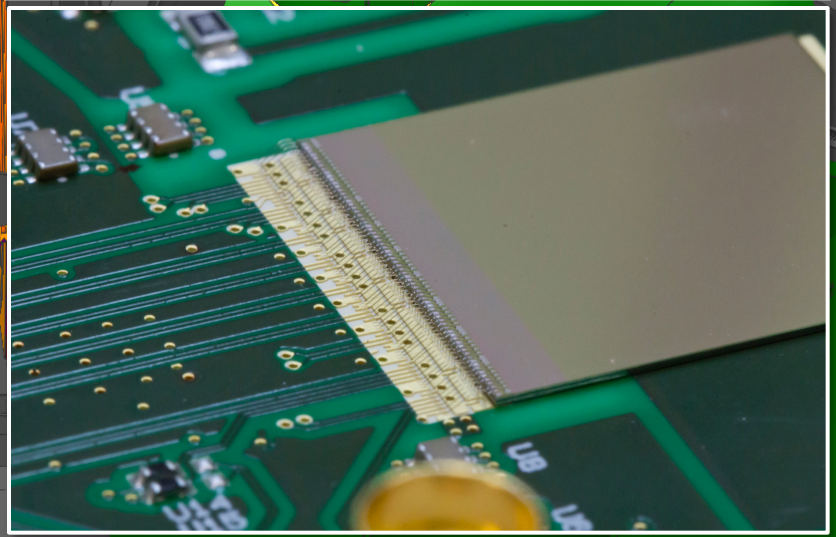
- Synergy with Medipix
- Fast track reconstruction

VELO

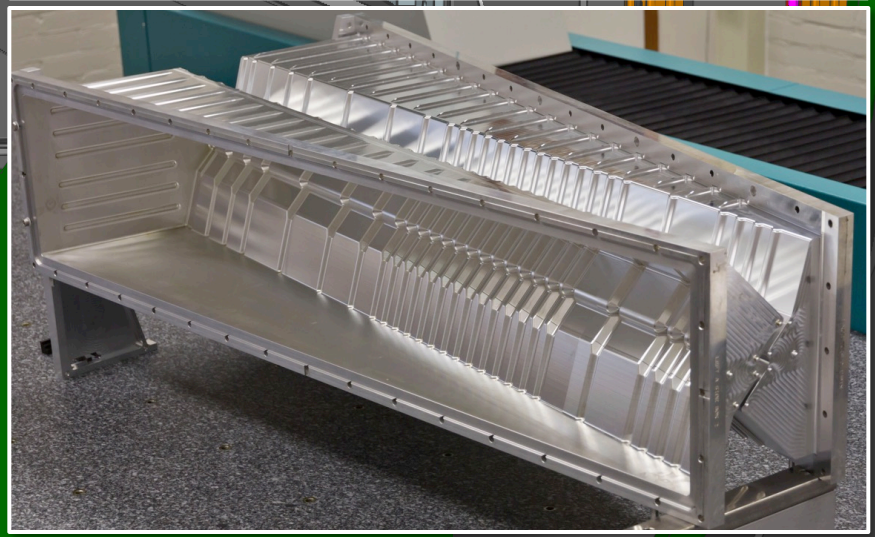


1) Module production

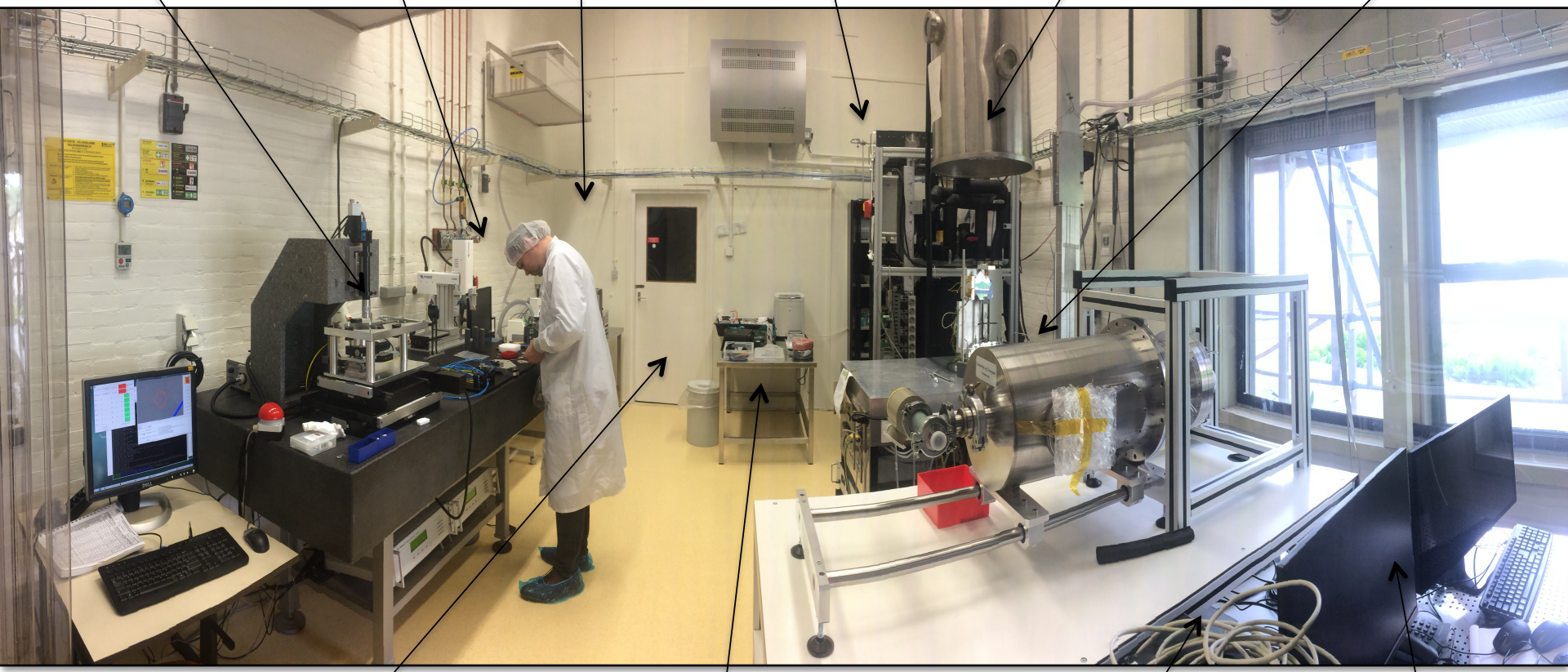
2) Electronics “VeloPix” chip

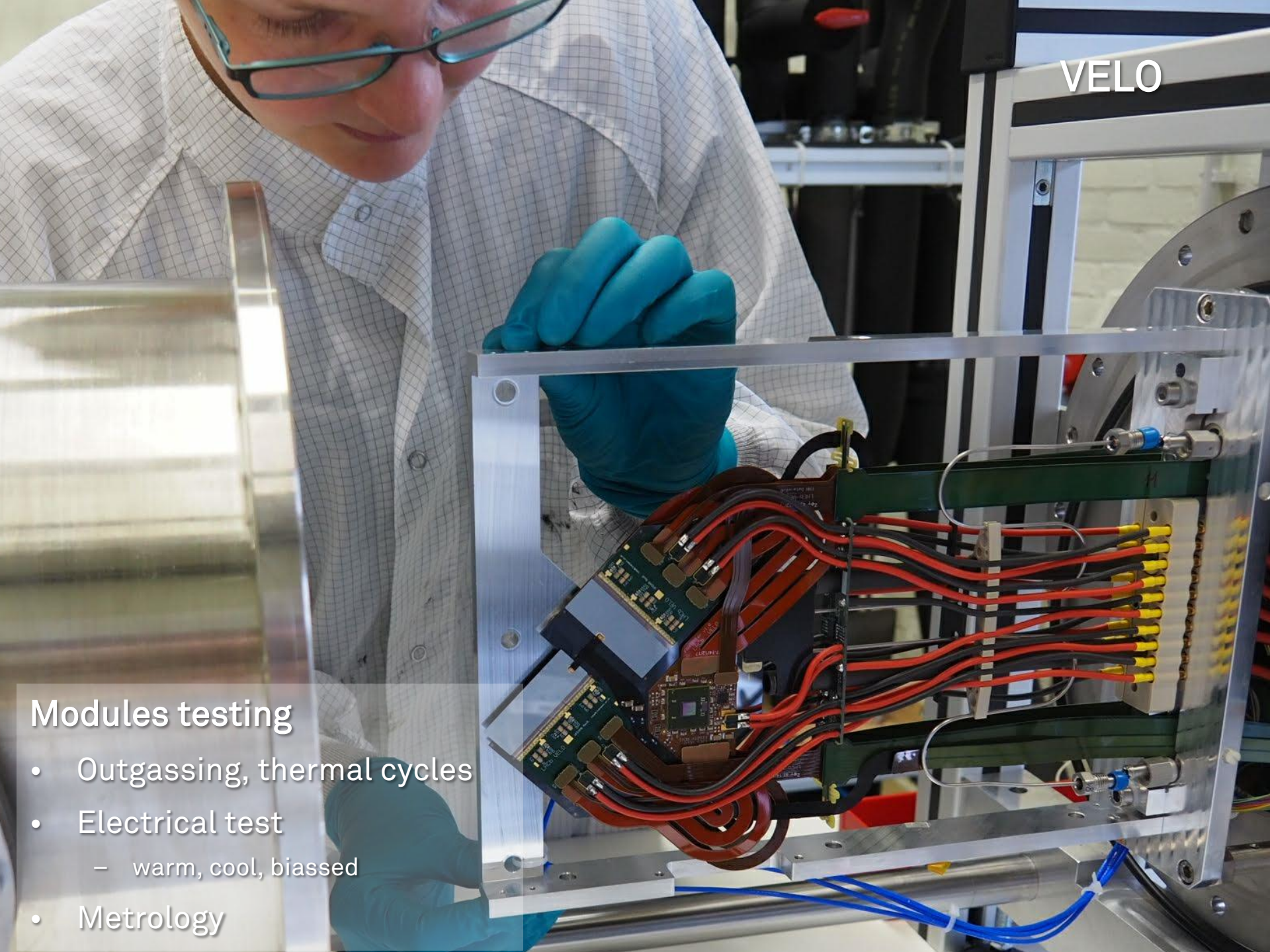


3) Vacuum envelope “RF-Box”



VELO

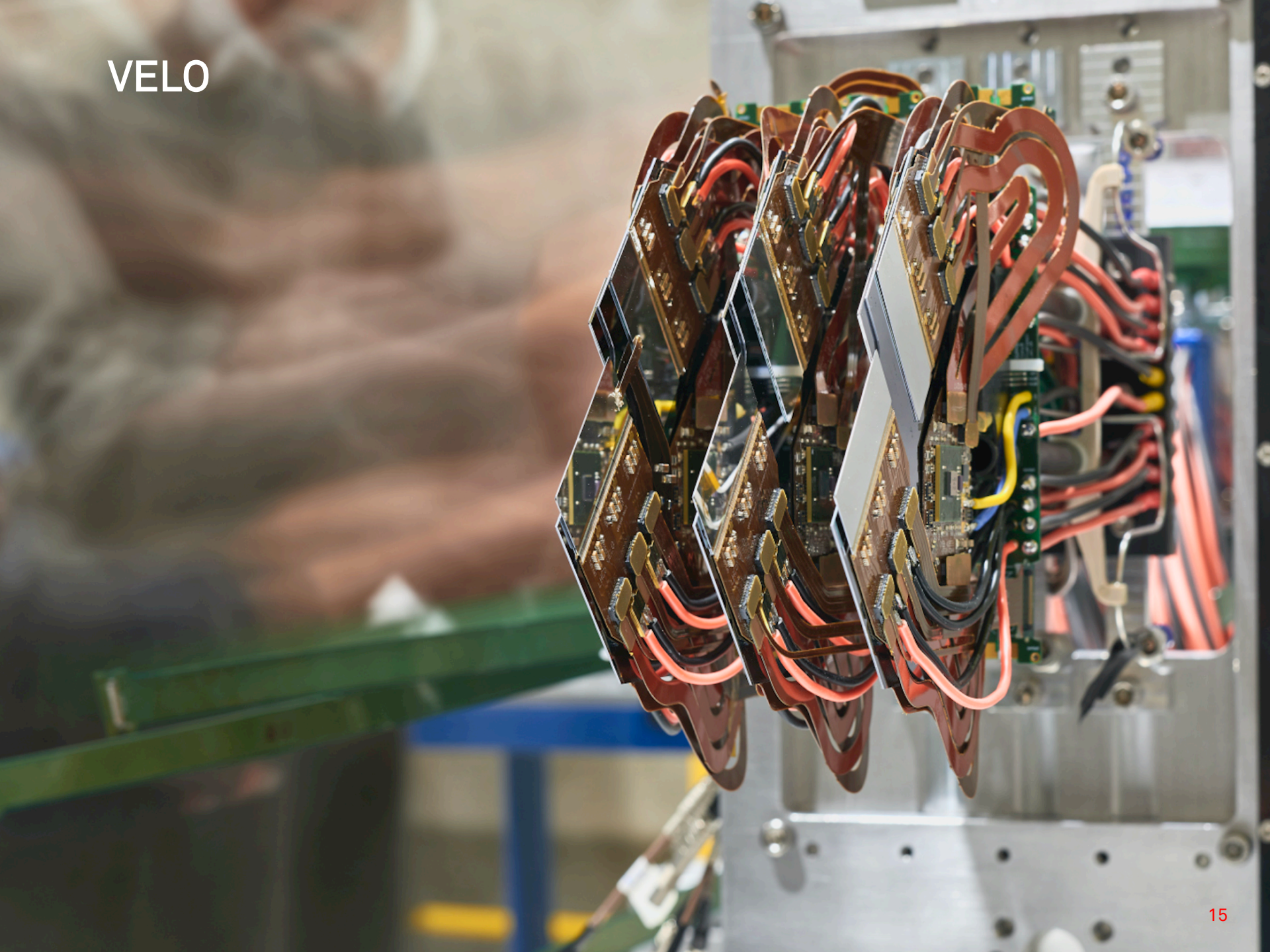

pick&place machine
glue robot
Dr Hynds
CO_2 cooler
vacuum tank for R&D
vacuum tank for production tests
door to area with wire-bonding machine
bare module jig
minidaq2
winCC controls



Modules testing

- Outgassing, thermal cycles
- Electrical test
  - warm, cool, biassed
- Metrology

VELO



VELO

- Modules: production not yet started
  - PRR 12 June 2019
  - Good hopes that complications are solved
- Need to validate system performance with new GBT settings

RF-box: “beampipe” between LHC beam and VELO

RF-box: “beampipe” between LHC beam and VELO

- 250µm thin foil
  - Leak tightness OK
  - Debate whether to etch


Measured foil thickness
‘projected’ onto RF box to
make etching map
BenQ
BenQ


SciFi Tracker

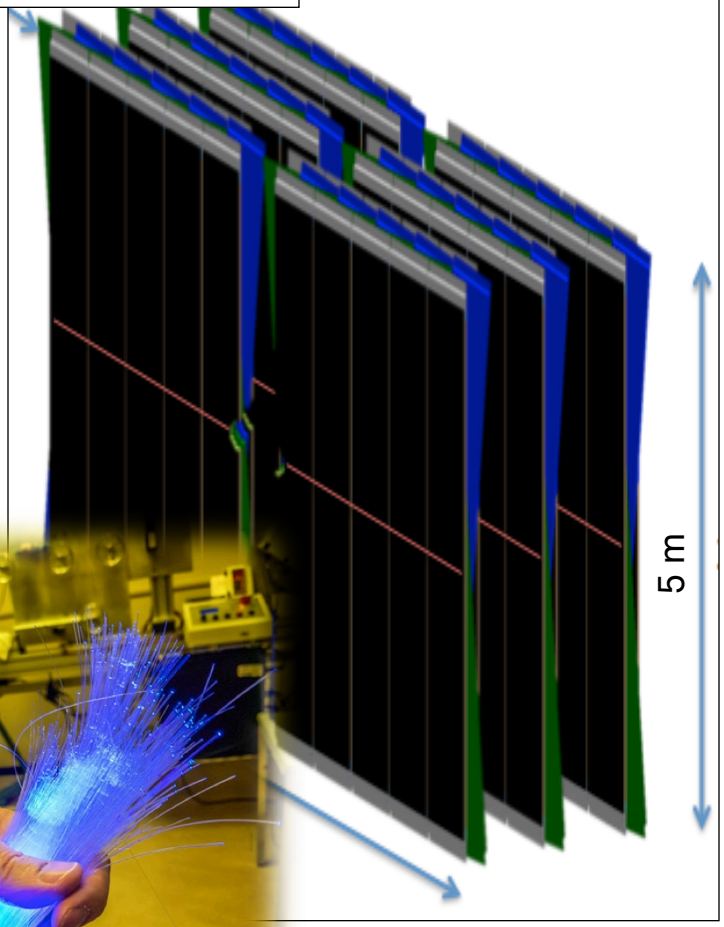
SciFi Tracker

Steady progress of entire project

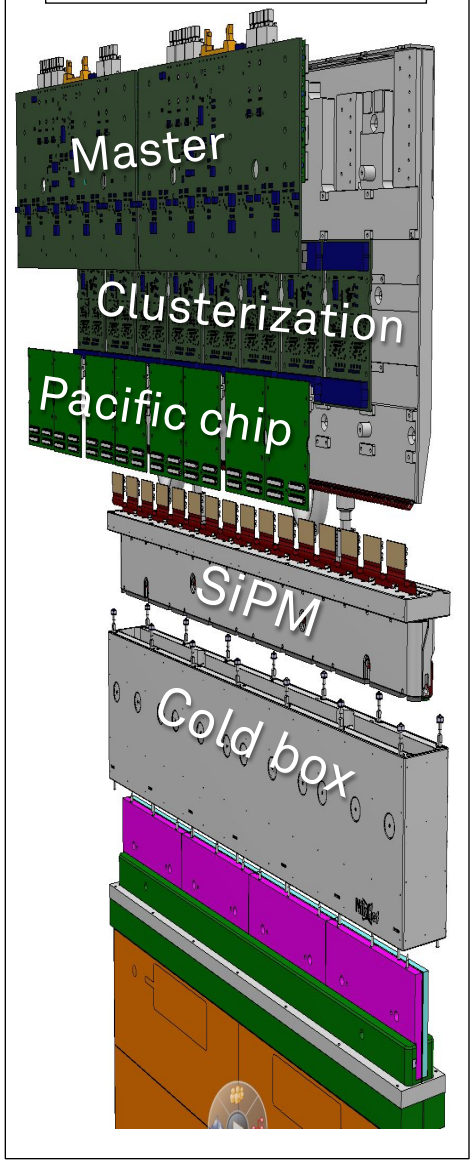
Modules:	production at Nikhef finished
Coldbox:	production suffers delays.
Frames:	1st frame being assembled (need 6 by February)
Electronics:	production and tests in time for frame assembly

SciFi Tracker

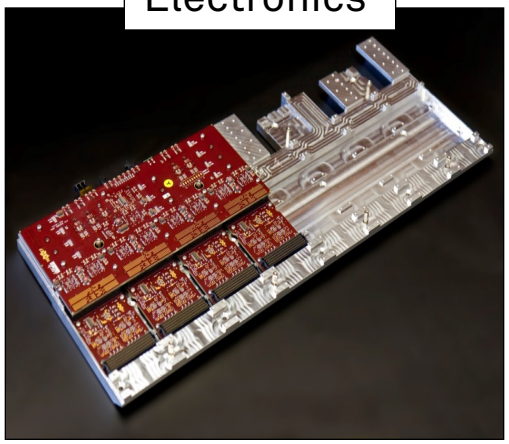
1 Detector:
= 11.000 km fibres
= 128 modules
= 600k SiPM channels



Module endpiece



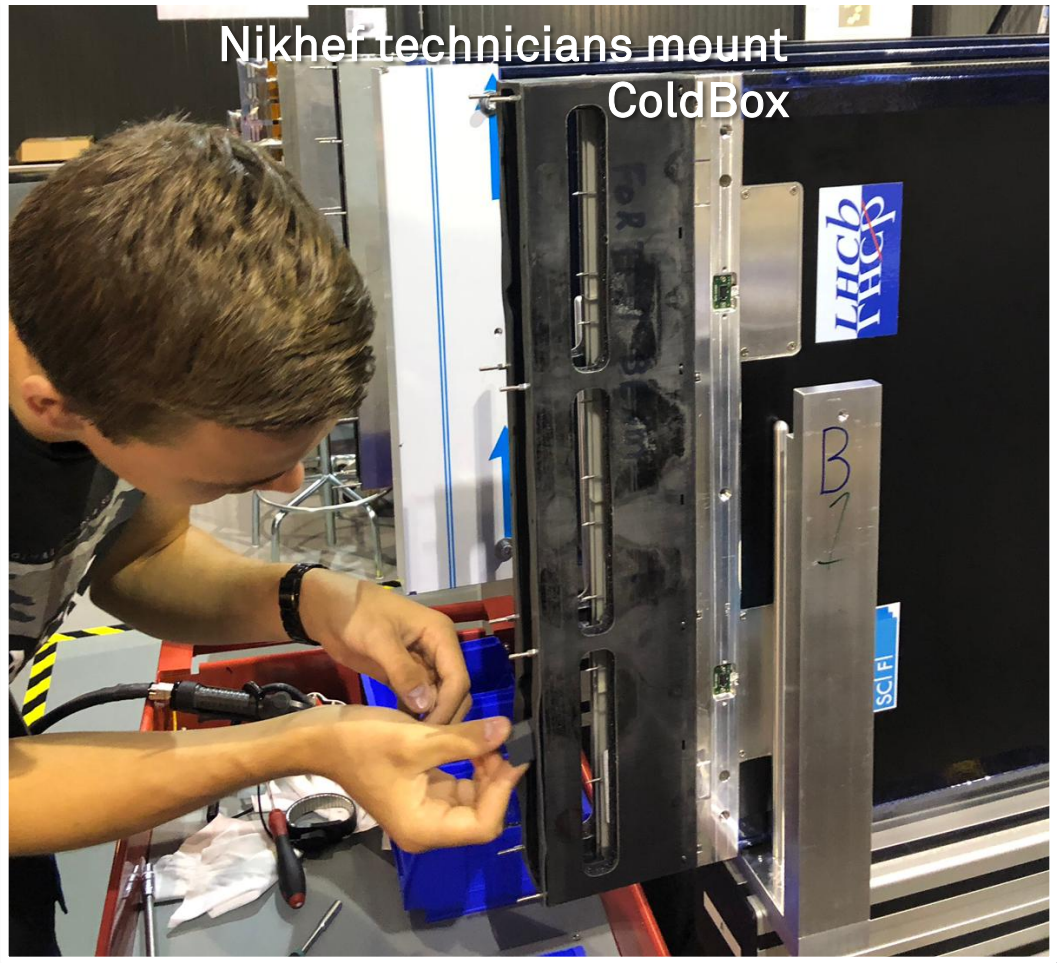
Electronics

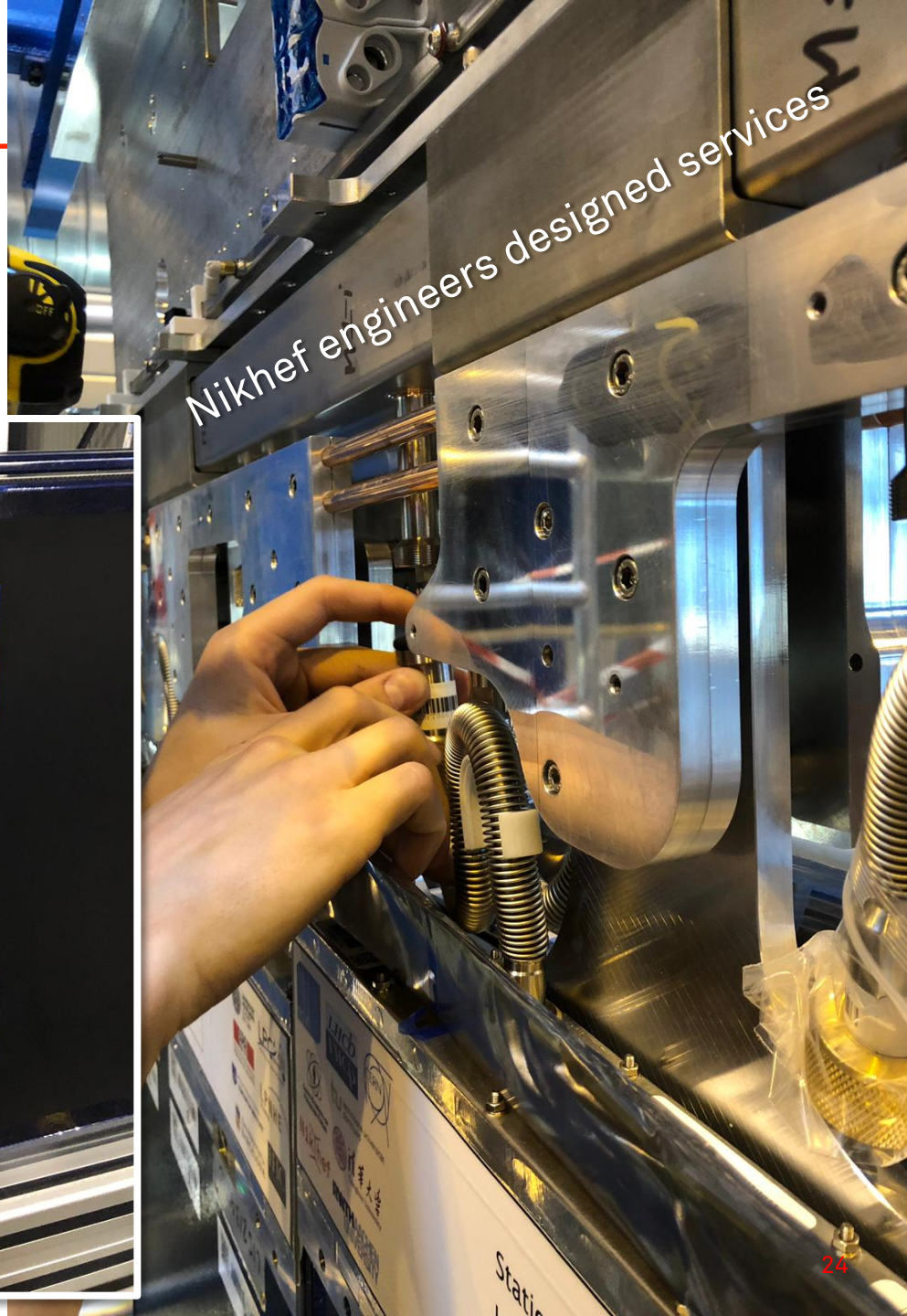


Flex cables and SiPM


SciFi Tracker
Nikhef technicians prepare frames
Nikhef engineers designed and mount cabling
Nikhef engineers designed digital electronics

SciFi Tracker

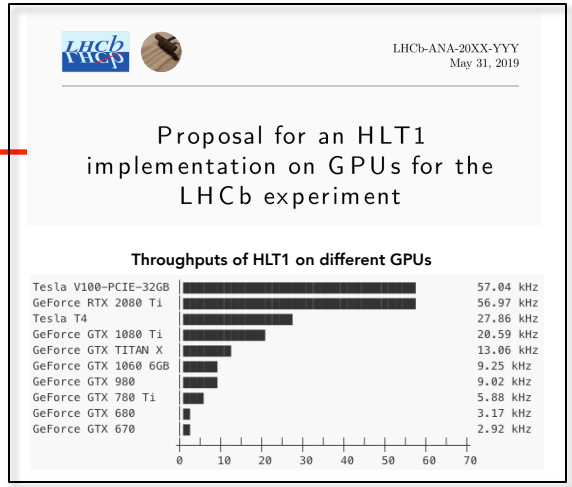


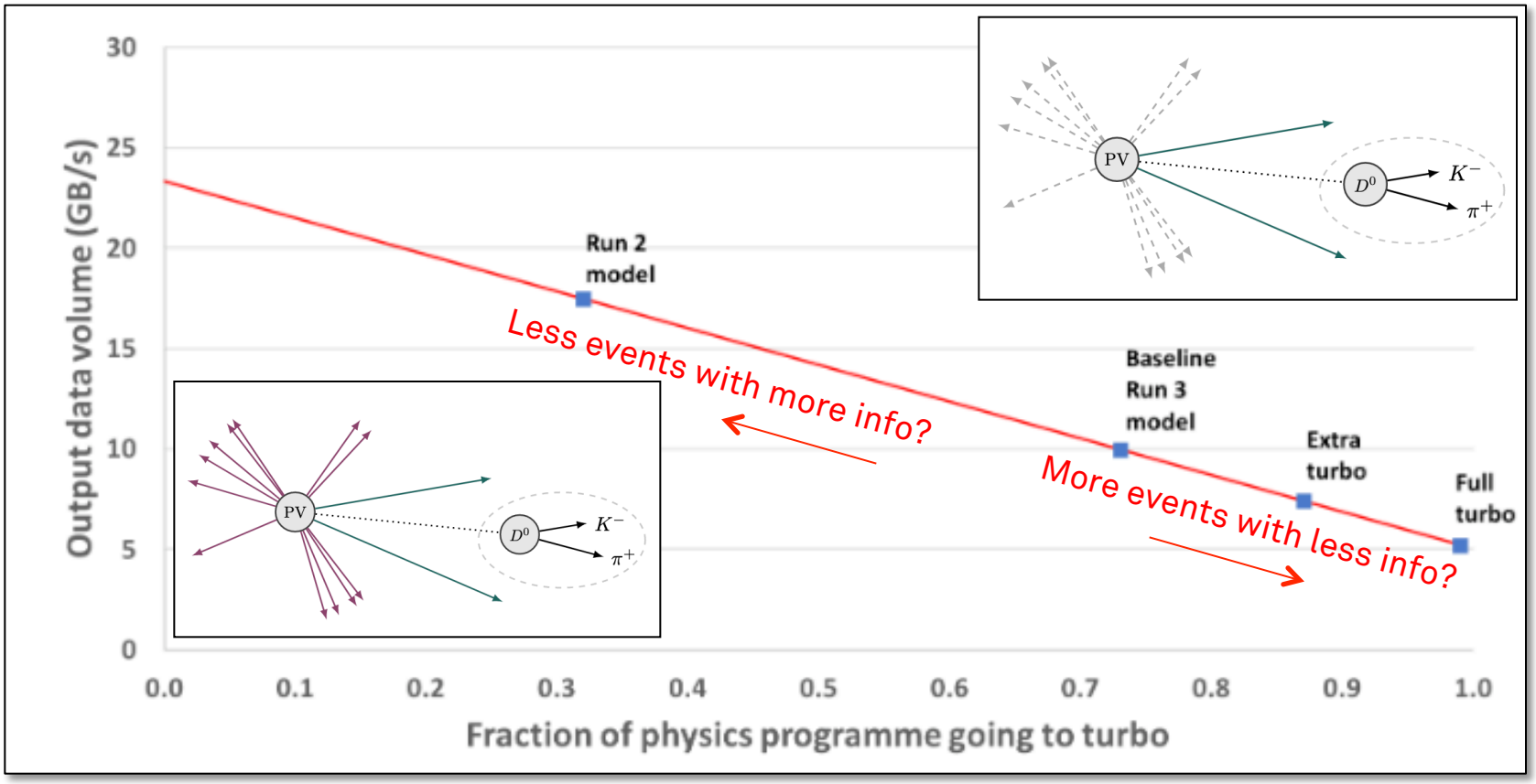


RTA (real time analysis)

(aka: reconstruction, trigger, alignment)

- New project, with large Nikhef involvement
- Many open questions (choices)
- Challenging and inviting computing aspects





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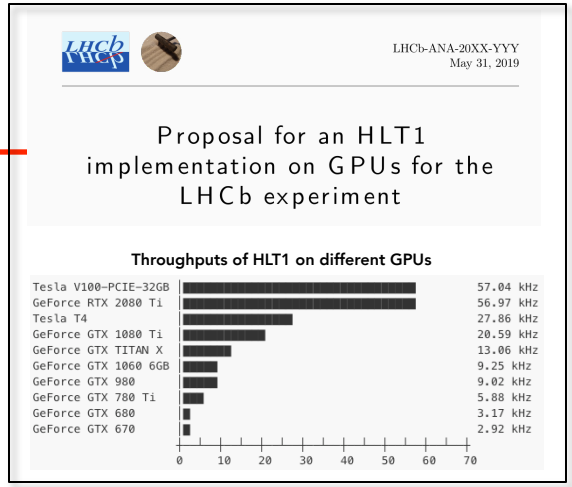
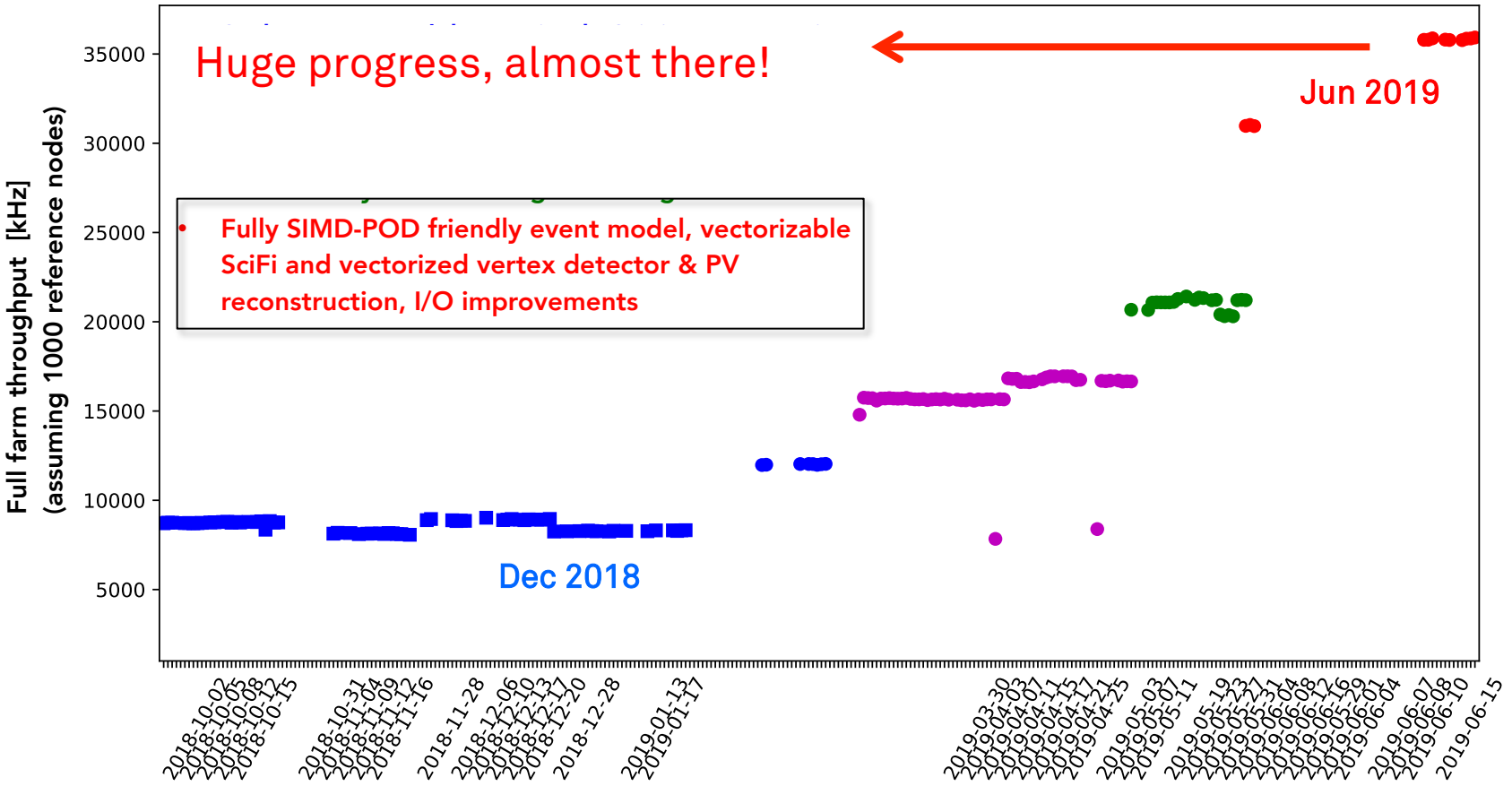
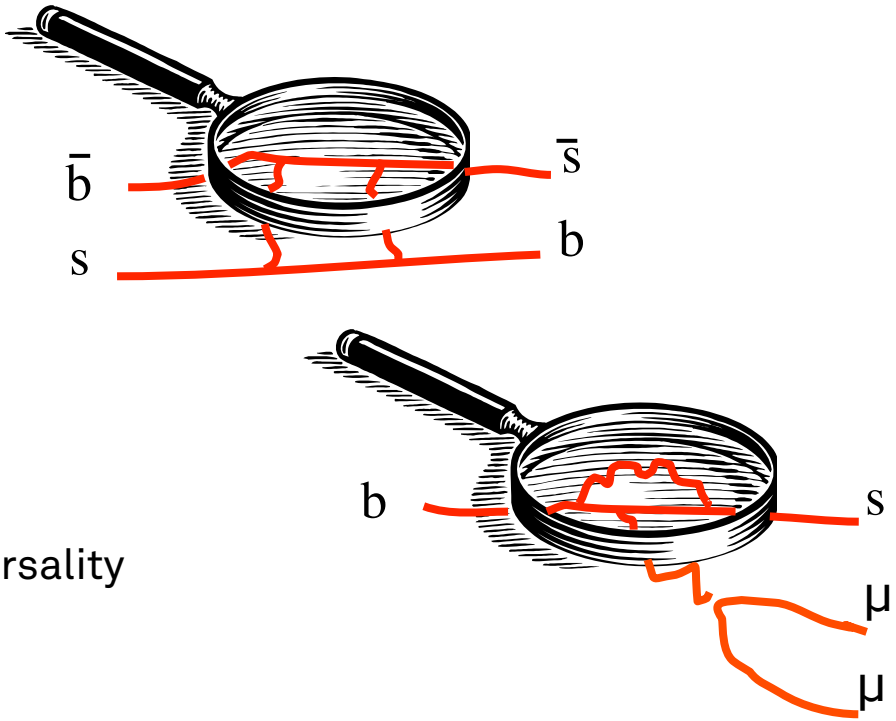




Physics

- At Nikhef
- CP violation
  1) ϕ_s
  2) γ
- Rare decays
  3) Very rare decays
  4) Lepton flavour non-universality
- Long-living particles

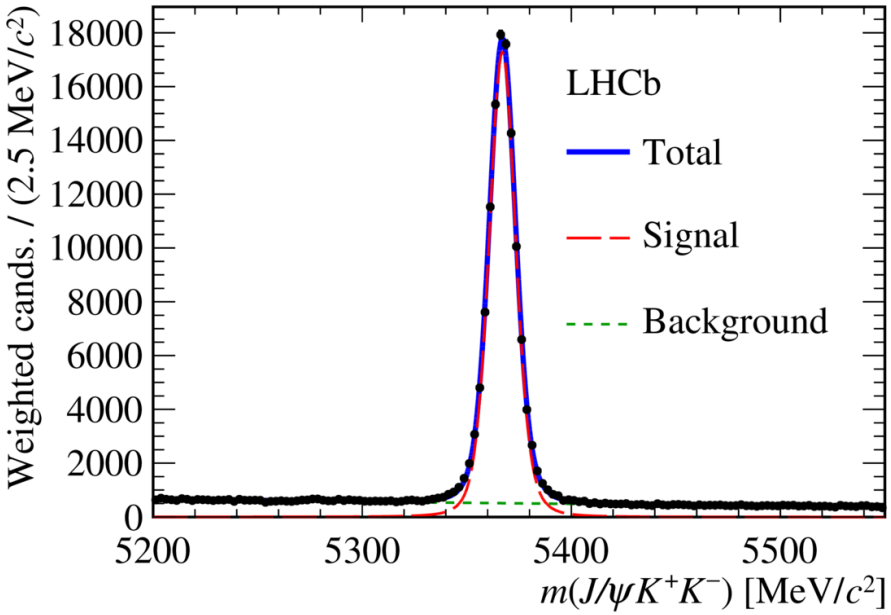


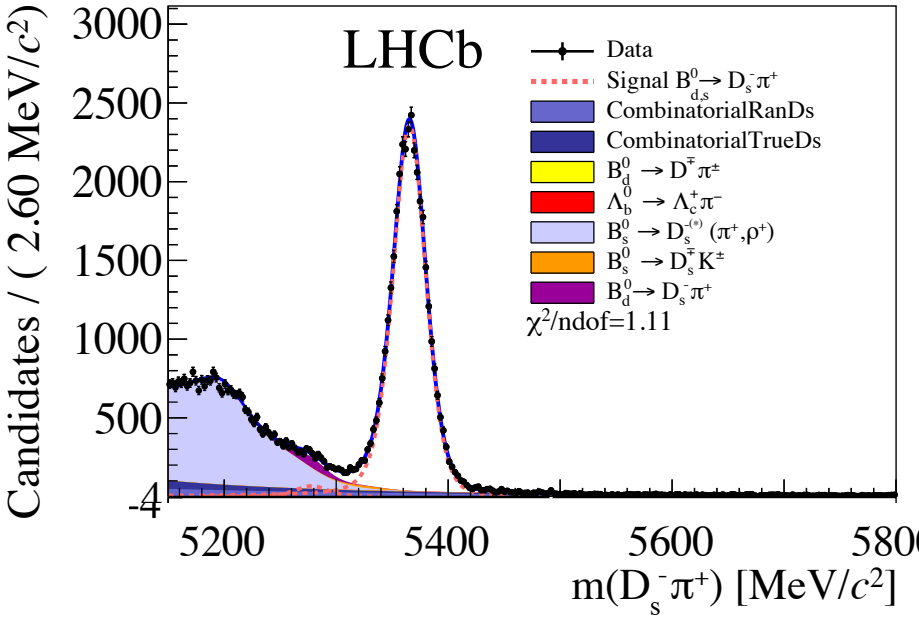
- Other recent LHCb highlights:
  - New ‘normal’ hadrons
  - New ‘exotic’ hadrons: Tetraquark and pentaquark
  - Discovery CP violation charm

Physics at Nikhef: CP violation

- ϕ_s with $B_s^0 \to J/\psi\,\phi$
  - and lifetime diff. $\Delta\Gamma_s$

- γ with $B_s^0 \to D_s K$
  - and mass difference Δm_s





Physics at Nikhef: CP violation

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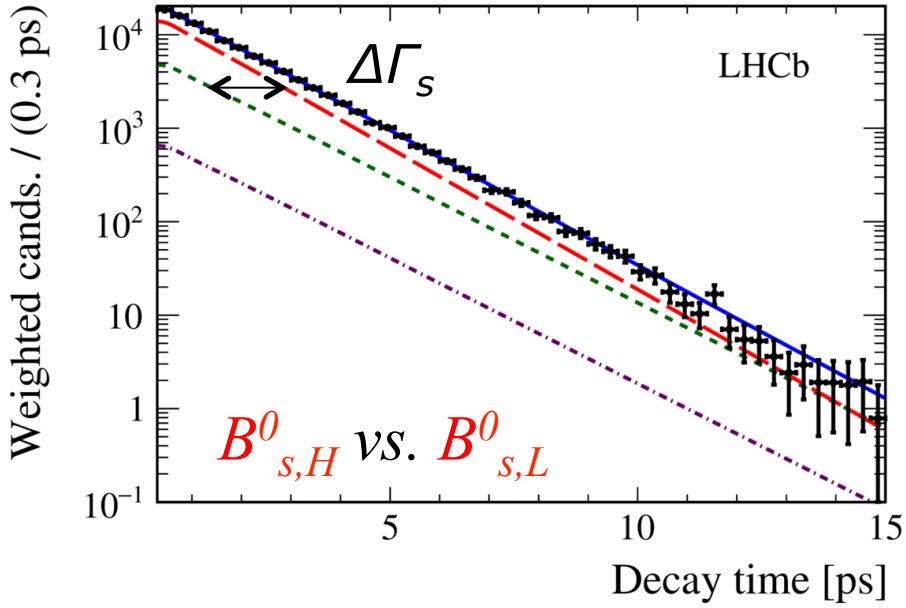

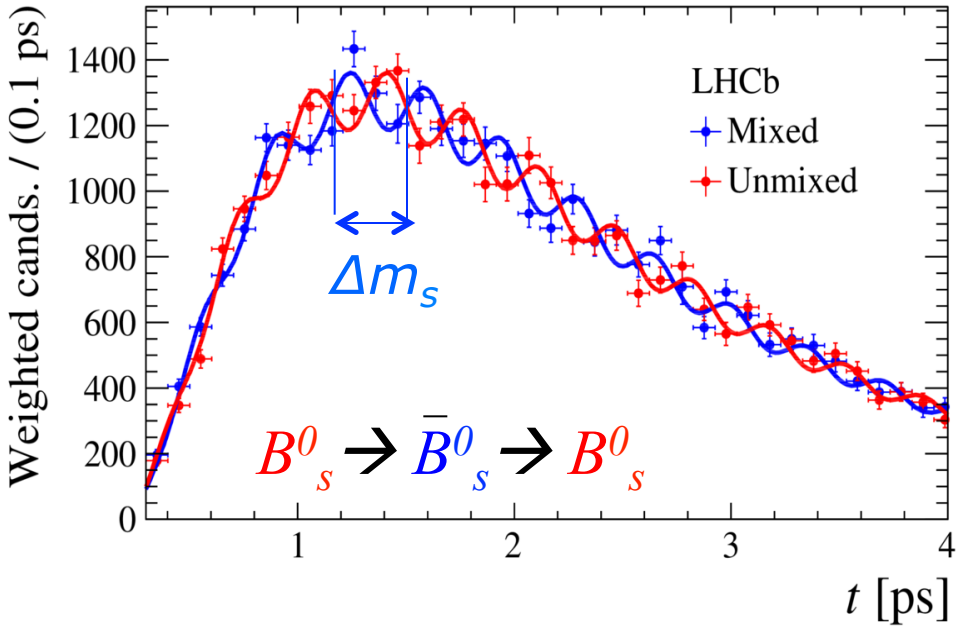

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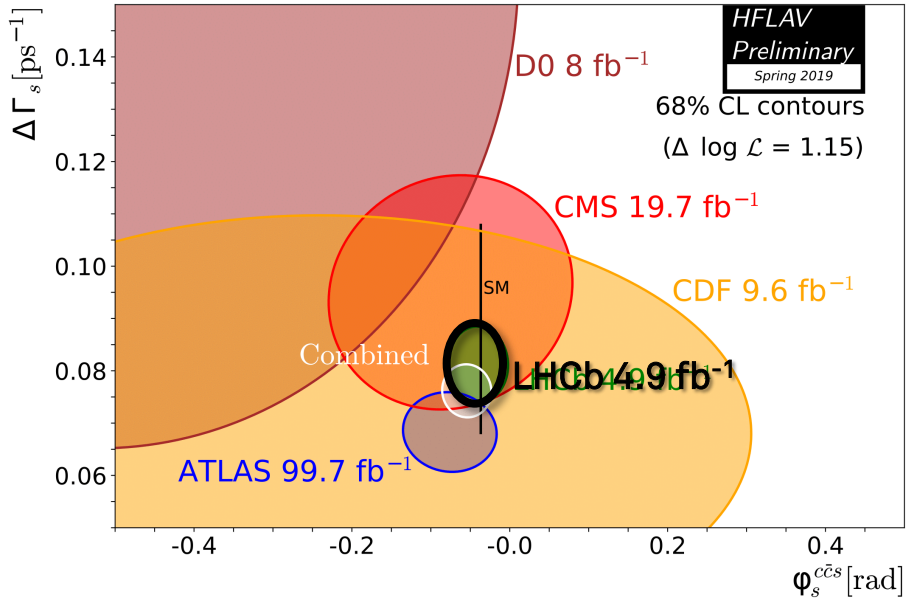
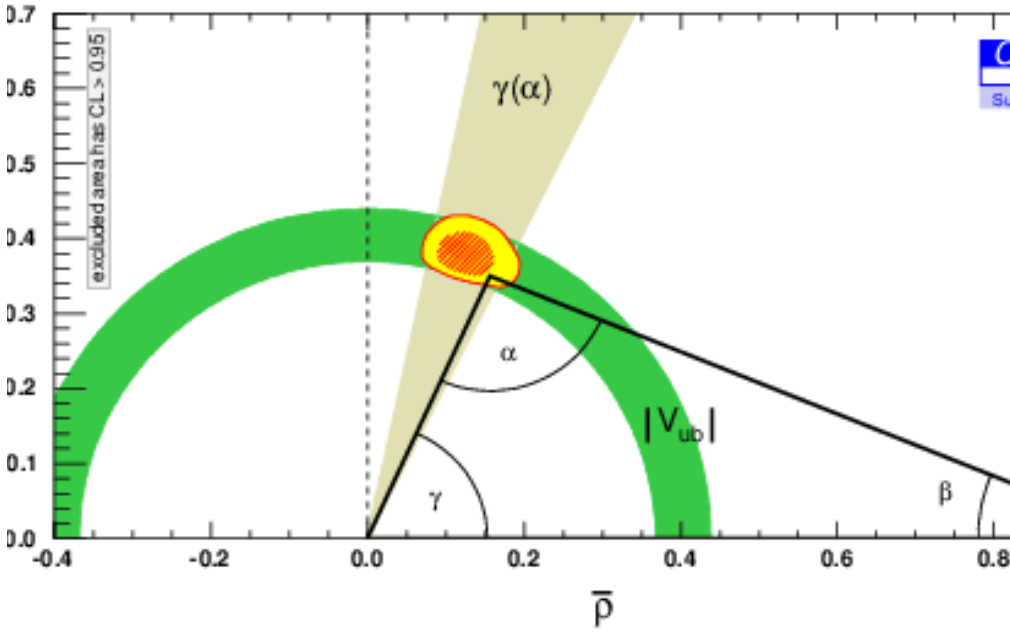
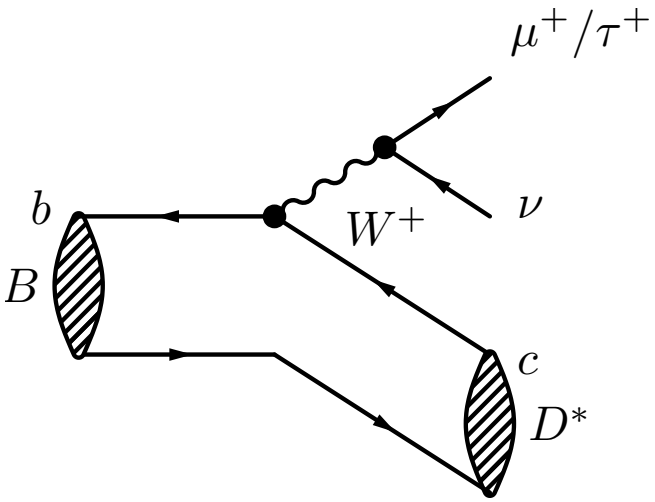
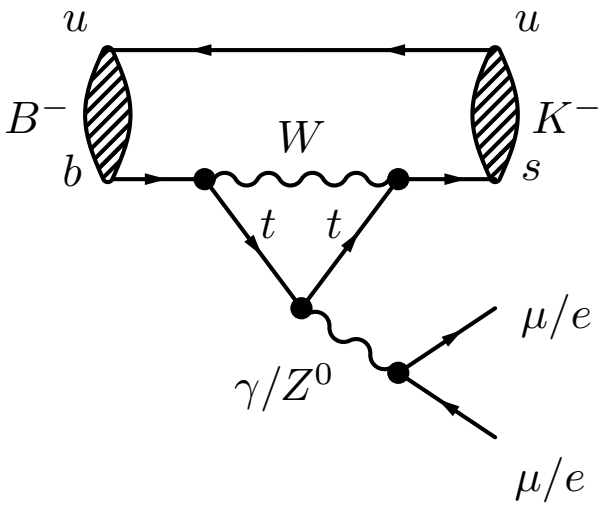
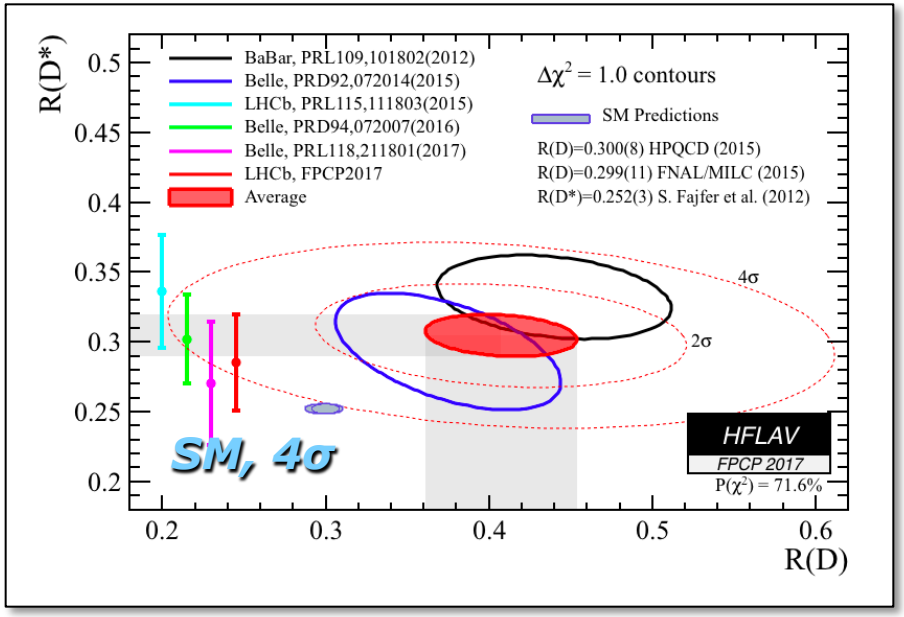


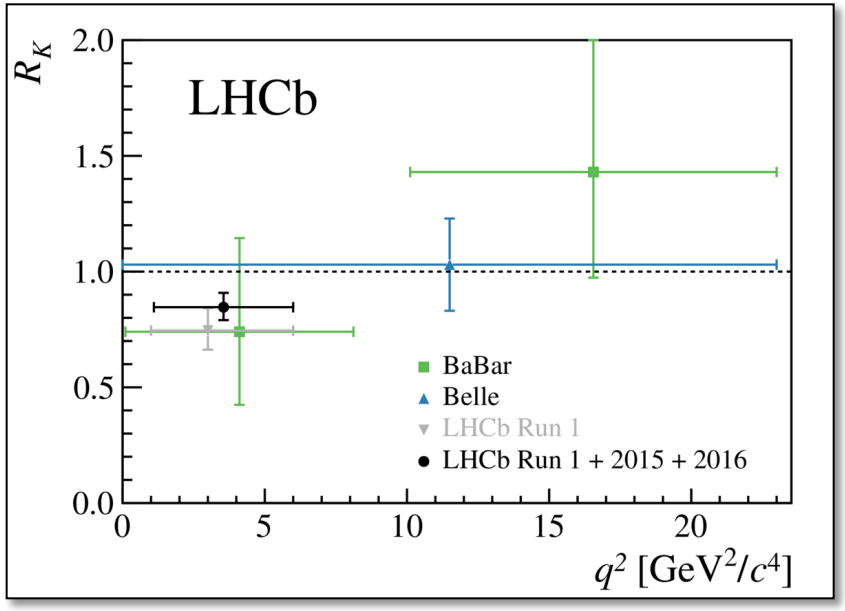


Hot topic: *Lepton flavour non-universality*





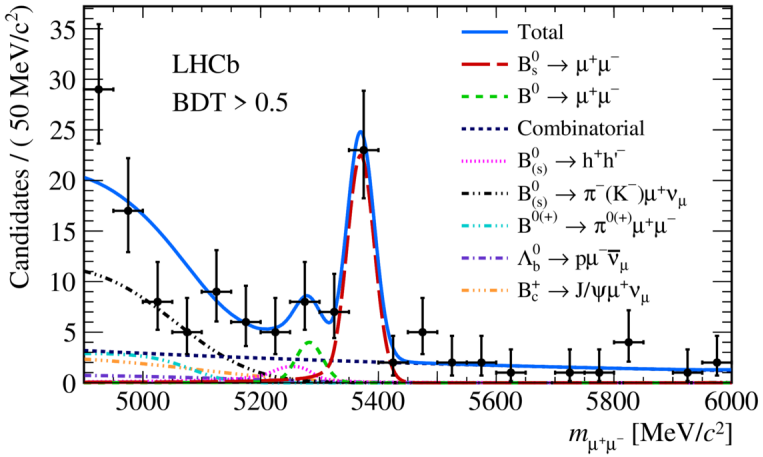


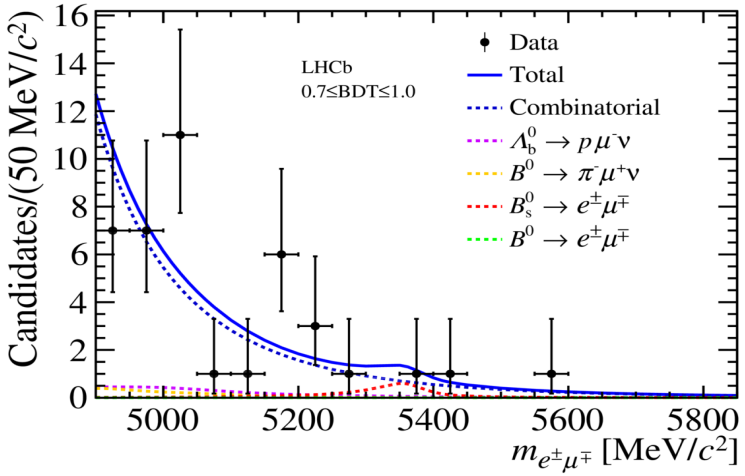


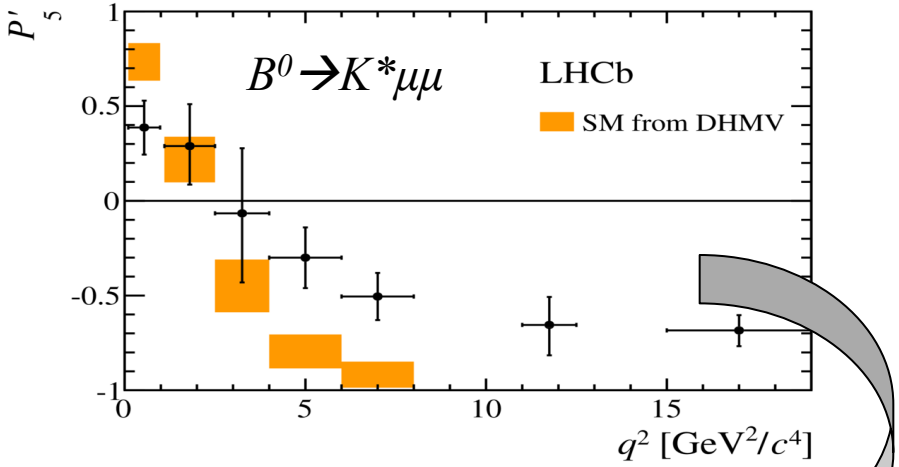
Physics at Nikhef: Rare decays

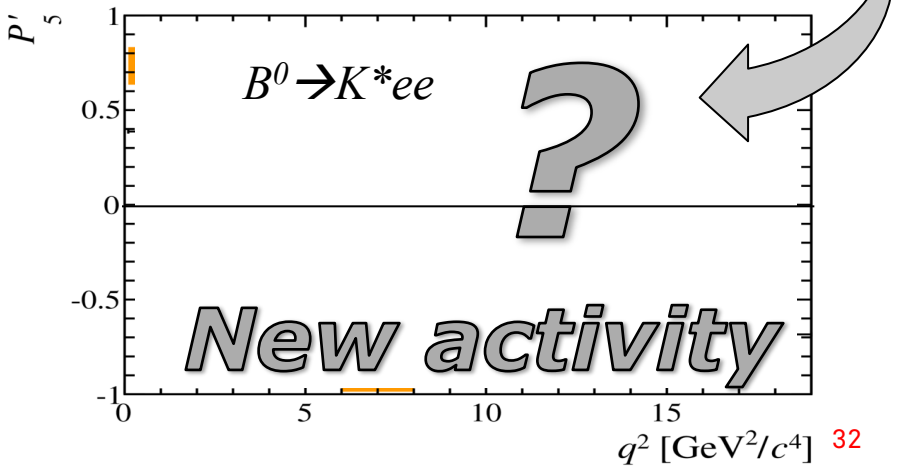
- Very rare: $B_s^0 \rightarrow \mu\mu$
  - LHCb flagship
  - *LFV? $B_s^0 \rightarrow e\mu$*

- Electrons: what is going on?
  - Angular: *$B^0 \rightarrow K^*ee$*
  - Validate: *$J/\psi \rightarrow ee$ / $J/\psi \rightarrow \mu\mu$*





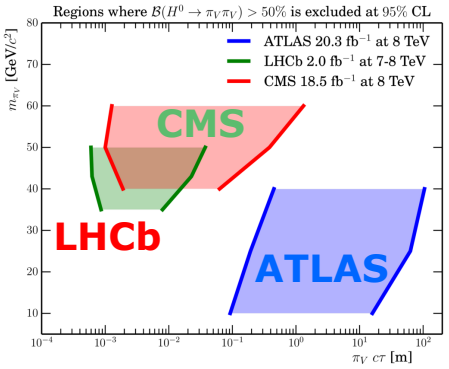


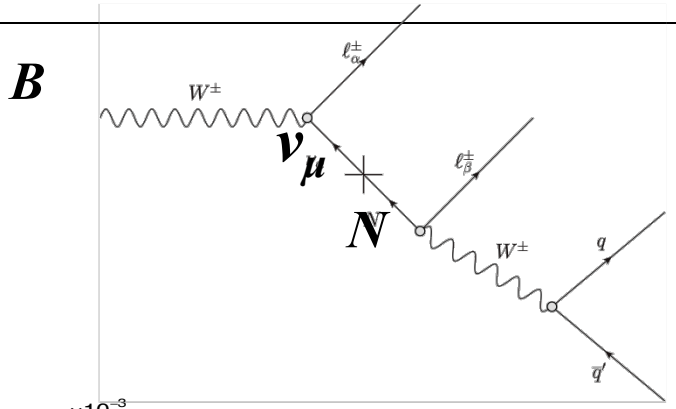


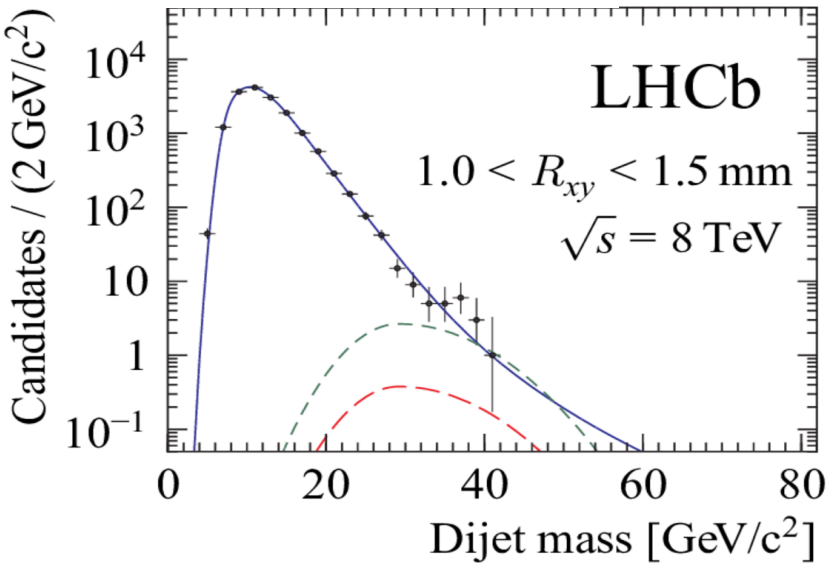
Physics at Nikhef: Long-living particles

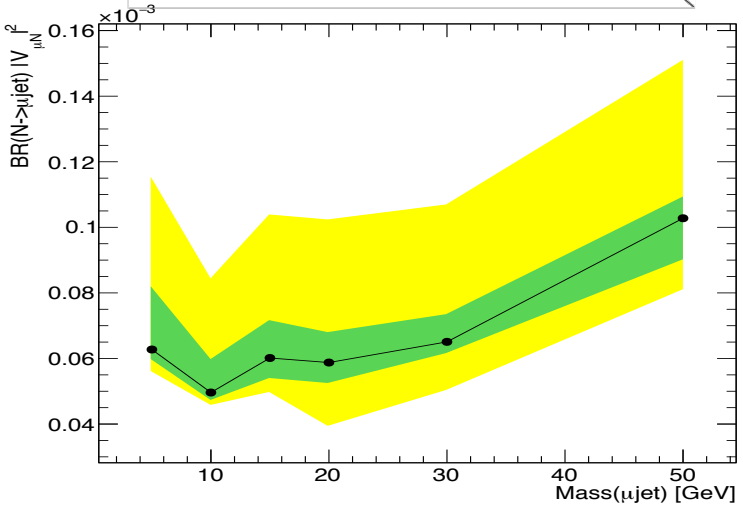
- Search for BSM LLP
  - LHCb unique coverage
  - LLP models accommodate DM candidates

- Majorana ν in W decays
  - from ν -N mixing in B decays
  - competitive with LEP in run-3



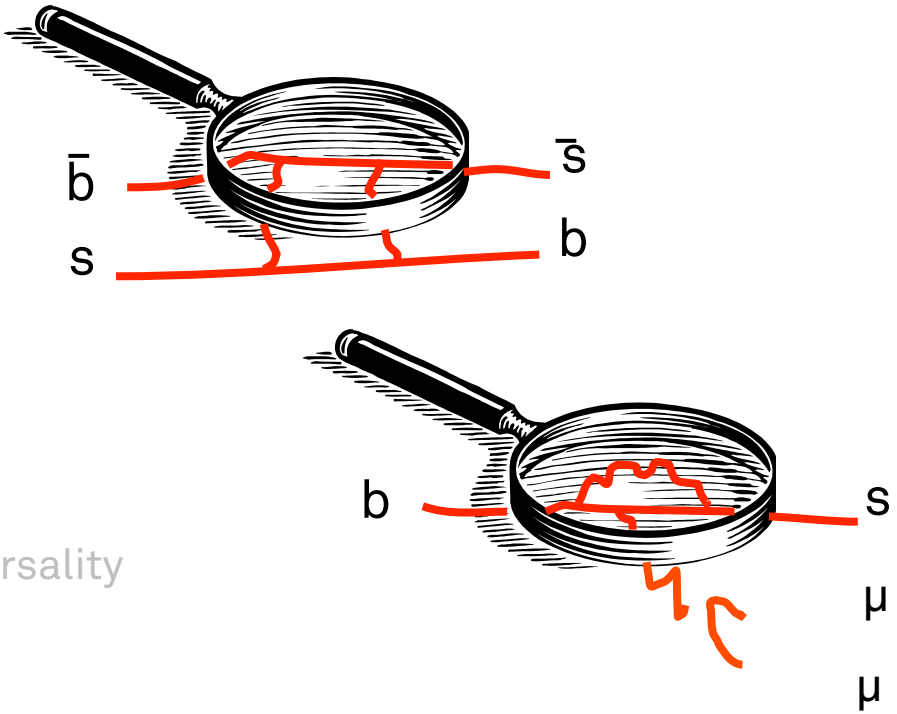






Physics

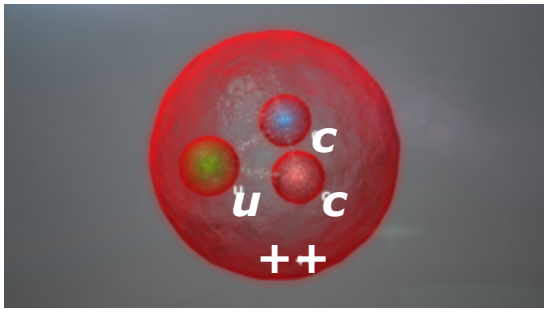
- At Nikhef
  - CP violation
    1) ϕ_s
    2) γ
  - Rare decays
    3) Very rare decays
    4) Lepton flavour non-universality
  - Long-living particles

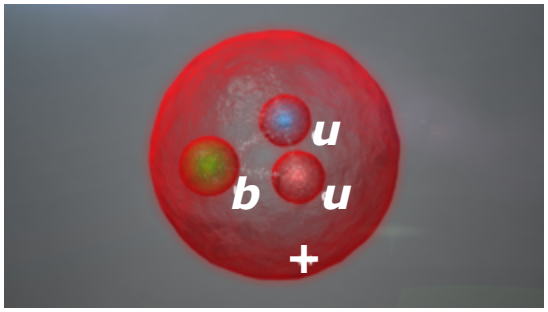


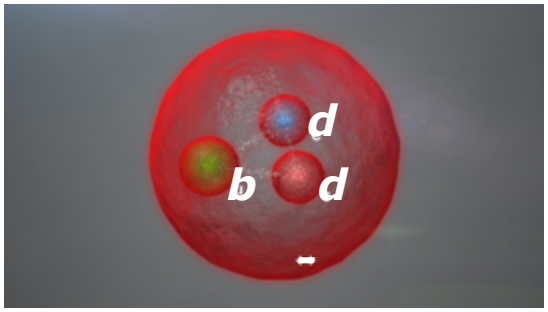
- Other recent LHCb highlights:
  - New ‘normal’ hadrons
  - New ‘exotic’ hadrons: Tetraquark and pentaquark
  - Discovery CP violation charm

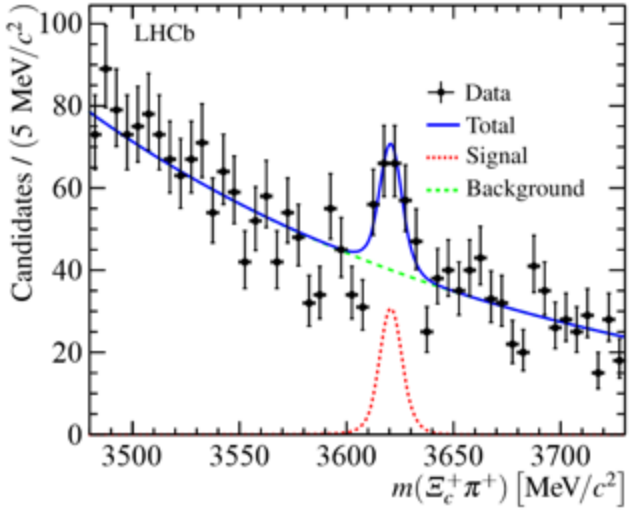
New ‘normal’ hadrons

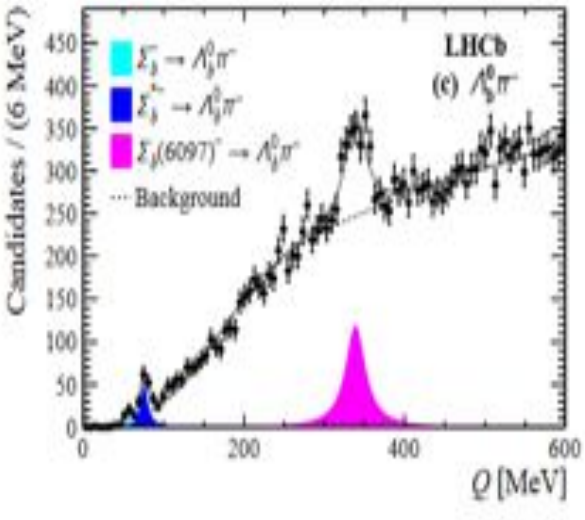
(ccu): Ξ_{cc}^{++} (buu): $\Sigma_b(6097)^+$ (bdd): $\Sigma_b(6097)^-$

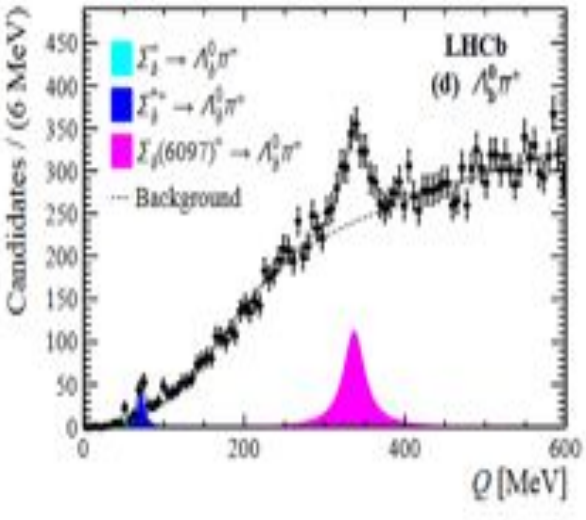








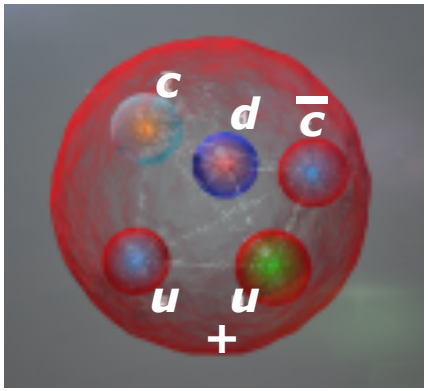


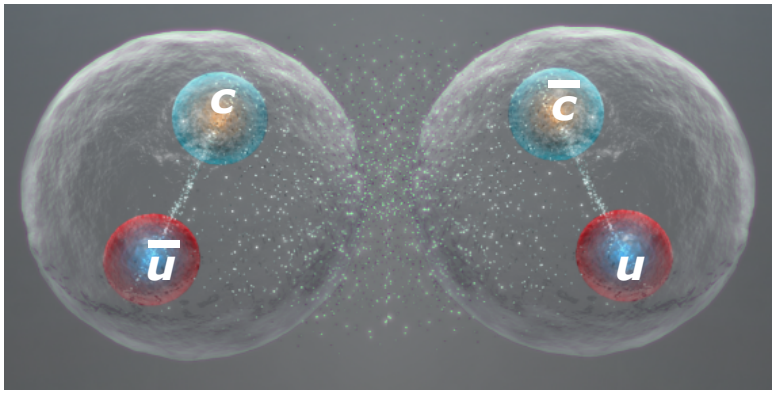


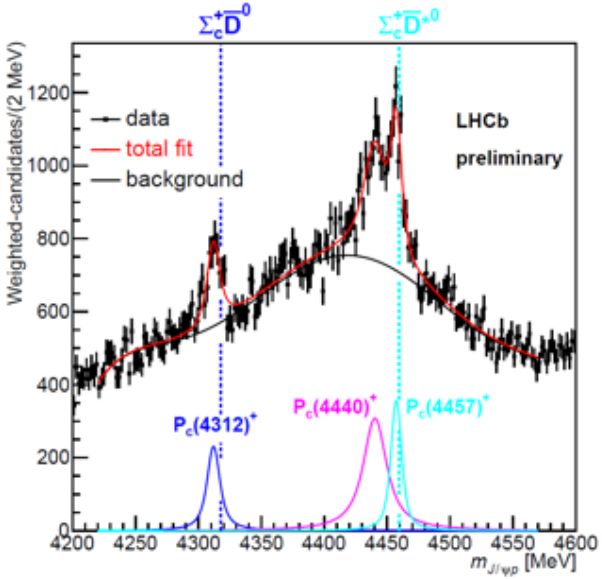
New ‘exotic’ hadrons

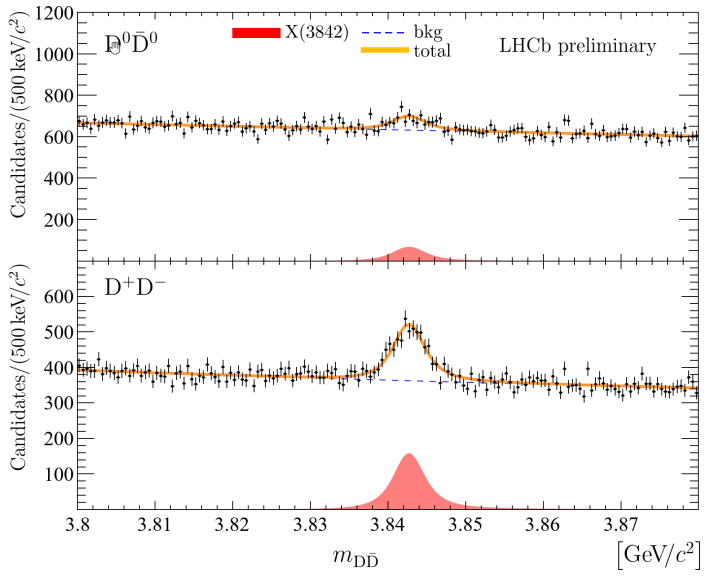
(c$\bar{c}$duu): $P_c(4312)^+$

(c$\bar{u}$ $\bar{c}$u): X(3842)









Discovery of CP violation in charm

$D^0 \rightarrow K^+K^-$ same rate as $\overline{D^0} \rightarrow K^+K^-$?

at least it is different compared to $D^0 \rightarrow \pi^+\pi^-$:

$$\Delta A_{CP} = (-15.4 \pm 2.9) \times 10^{-4}$$

1956
Parity violation
T. D. Lee, C. N. Yang and C. S. Wu *et al.*

1963
Cabibbo Mixing
N. Cabibbo

1964
Strange particles: *CP* violation in *K* meson decays
J. W. Cronin, V. L. Fitch *et al.*

1973
The CKM matrix
M. Kobayashi and T. Maskawa

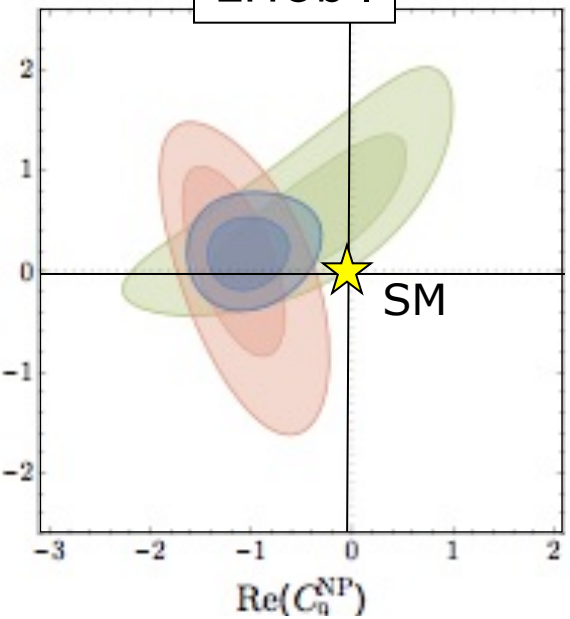
2001
Beauty particles: *CP* violation in B^0 meson decays
BaBar and Belle collaborations

TODAY

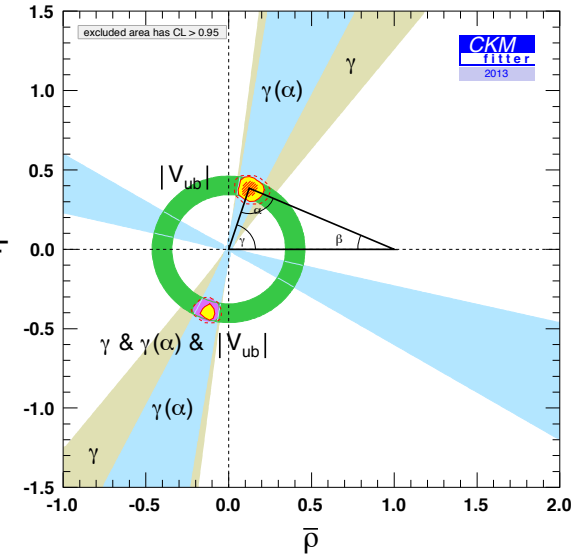
2019
Charm particles: *CP* violation in D^0 meson decays
LHCb collaboration

Outlook

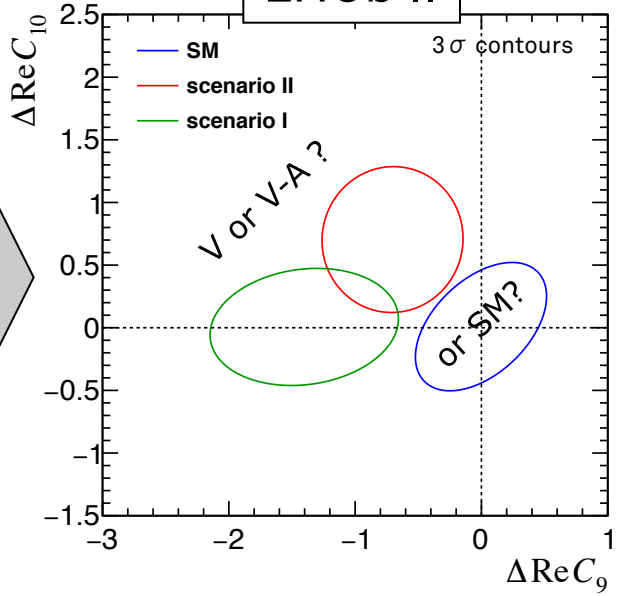
LHCb I



[Charles et al., 1309.2293]

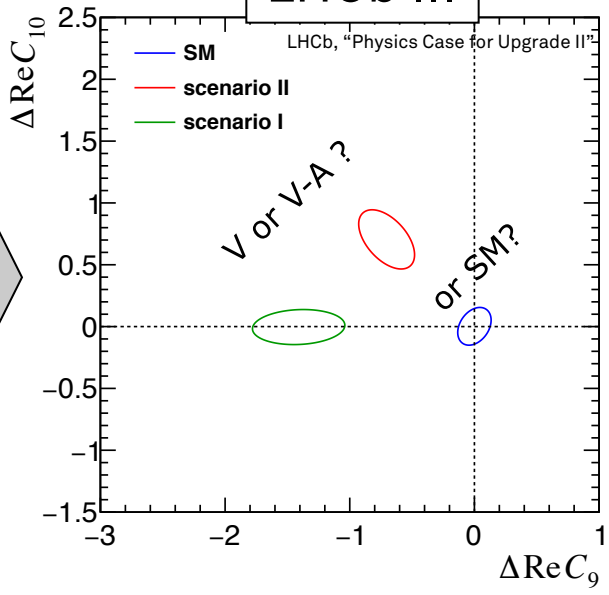


LHCb II

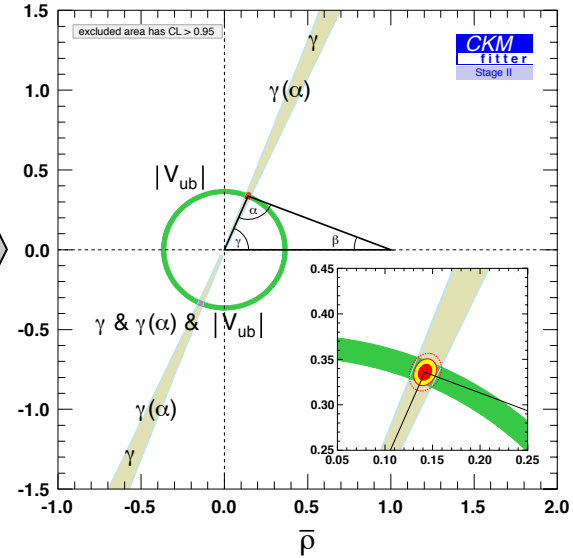


- Even after LHCb II (2029) all results statistically limited

LHCb III



[Charles et al., 1309.2293]



Nikhef

Backup

New vectorized PV reconstruction: x2 faster

Vectorized VELO reconstruction and PVs

Arthur Hennequin, Sebastien Ponce
Niklas Nolte, Wouter Hulsbergen

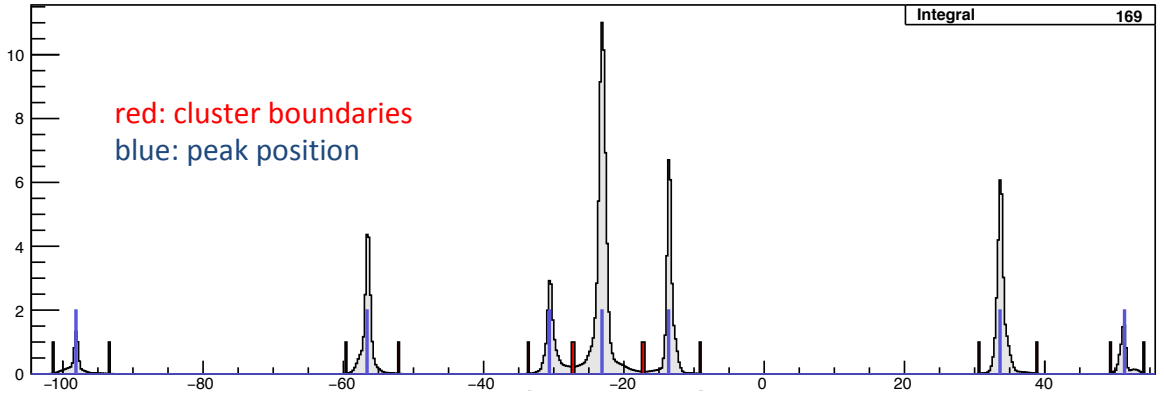
New primary vertex reconstruction based on a search for track clusters in z — requires knowing the position of the beamline so this is not a replacement for the old PV finding algorithm, rather a faster version for the HLT1 use-case where once the VELO closes we do know where the beamline is.

Vectorization plus the light event model gained around a factor 2 in speed for both VELO and PV reconstructions.

The vectorized VELO reconstruction physics performance is as good as the HLT1 scalar VELO reconstruction, but we expect further improvements soon!

```
                198954 tracks including          1677 ghosts [ 0.8 %], Event average   0.8 % ****
          velo :  178235 from   215892 [ 82.6 %]  2345 clones [ 1.3 %], purity: 99.83 %, hitEff: 92.00 %
          long :   56951 from    59640 [ 95.5 %]   632 clones [ 1.1 %], purity: 99.84 %, hitEff: 93.41 %
      long>5GeV :   36619 from    37319 [ 98.1 %]   277 clones [ 0.8 %], purity: 99.84 %, hitEff: 95.36 %
  long_strange :    2402 from     3091 [ 77.7 %]    32 clones [ 1.3 %], purity: 99.62 %, hitEff: 85.59 %
long_strange>5GeV :  1321 from     1551 [ 85.2 %]    19 clones [ 1.4 %], purity: 99.45 %, hitEff: 89.36 %
   long_fromB :      53 from       56 [ 94.6 %]     0 clones [ 0.0 %], purity:100.00 %, hitEff: 88.93 %
long_fromB>5GeV :    36 from       37 [ 97.3 %]     0 clones [ 0.0 %], purity:100.00 %, hitEff: 92.34 %

                216063 tracks including          2266 ghosts [ 1.0 %], Event average   0.8 % ****
          velo :  193347 from   215892 [ 89.6 %]  1068 clones [ 0.5 %], purity: 99.46 %, hitEff: 97.09 %
          long :   57909 from    59640 [ 97.1 %]   484 clones [ 0.8 %], purity: 99.65 %, hitEff: 97.10 %
      long>5GeV :   36798 from    37319 [ 98.6 %]   208 clones [ 0.6 %], purity: 99.59 %, hitEff: 97.76 %
  long_strange :    2668 from     3091 [ 86.3 %]    97 clones [ 3.5 %], purity: 99.26 %, hitEff: 87.42 %
long_strange>5GeV :  1406 from     1551 [ 90.7 %]    23 clones [ 1.6 %], purity: 99.08 %, hitEff: 91.85 %
   long_fromB :      56 from       56 [100.0 %]     0 clones [ 0.0 %], purity:100.00 %, hitEff: 97.72 %
long_fromB>5GeV :    37 from       37 [100.0 %]     0 clones [ 0.0 %], purity:100.00 %, hitEff: 98.91 %
```



The RF box team at Nikhef