

The LHCb experiment and real time analysis

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The LHCb group here in Warwick

<https://warwick.ac.uk/fac/sci/physics/research/epp/exp/bphysics/lhcb/>



Science and
Technology
Facilities Council



European
Research
Council





LHCb

ATLAS

CERN Meyrin

CERN Prévessin

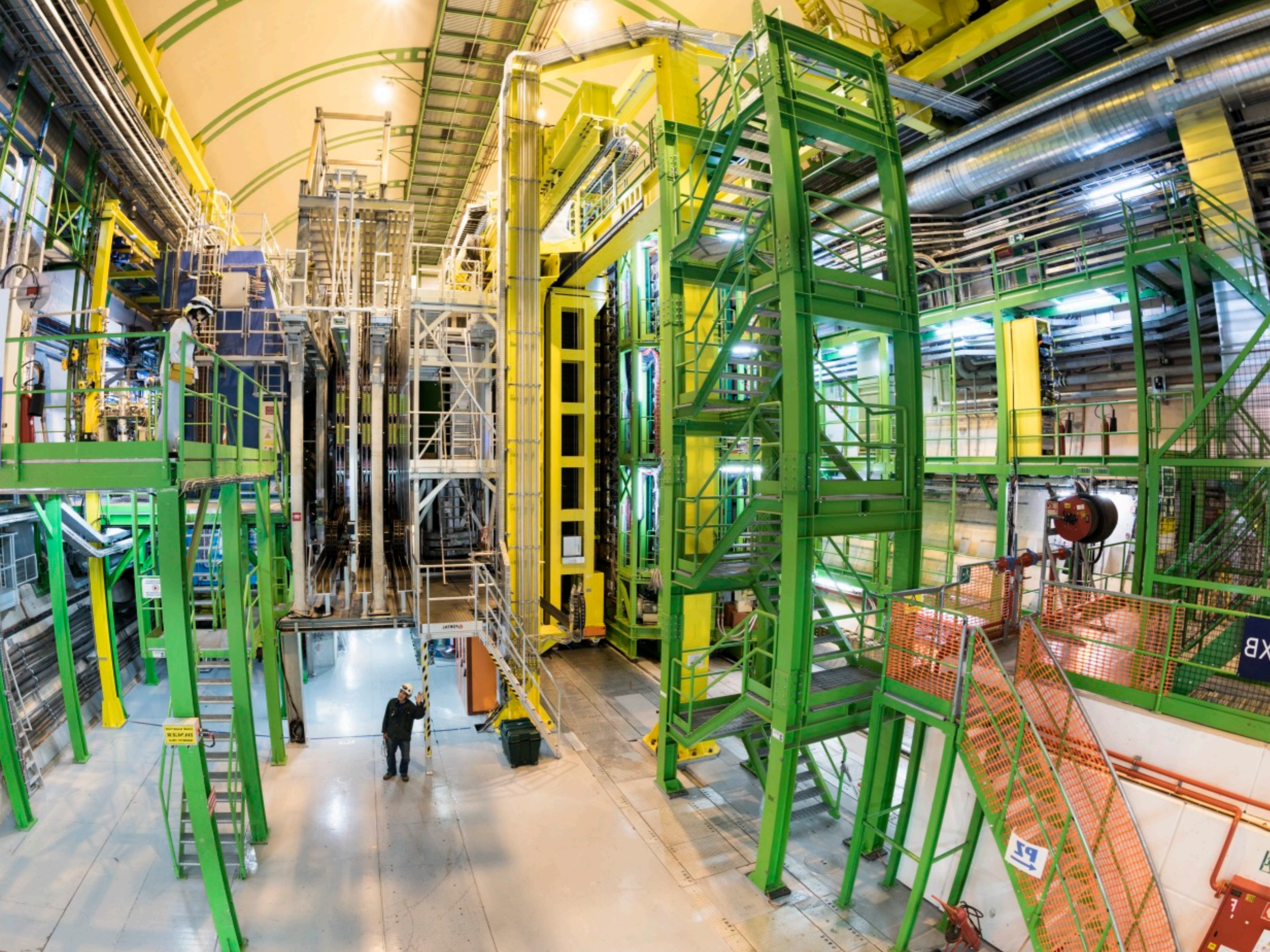
SPS 7 km

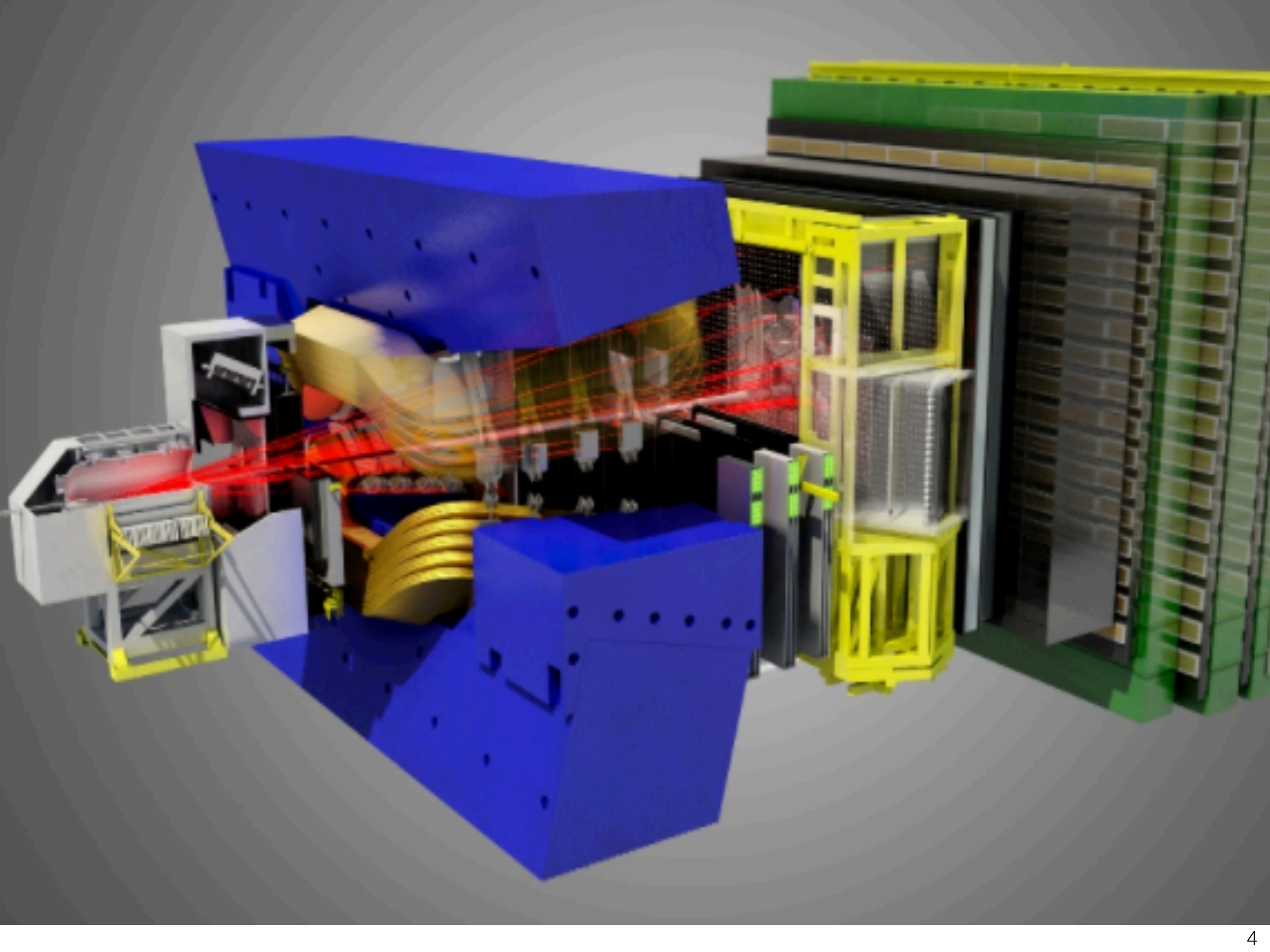
ALICE

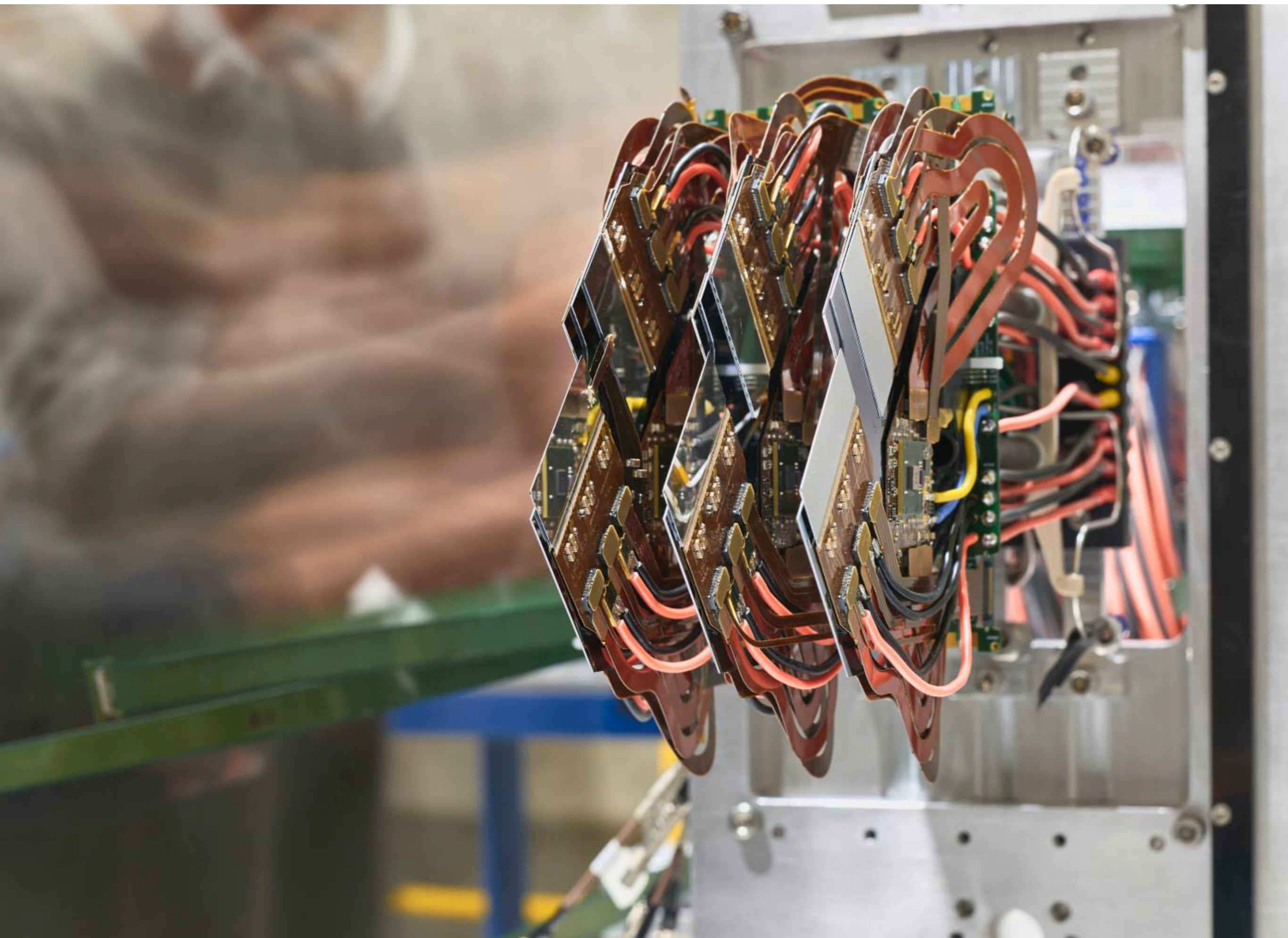
CMS

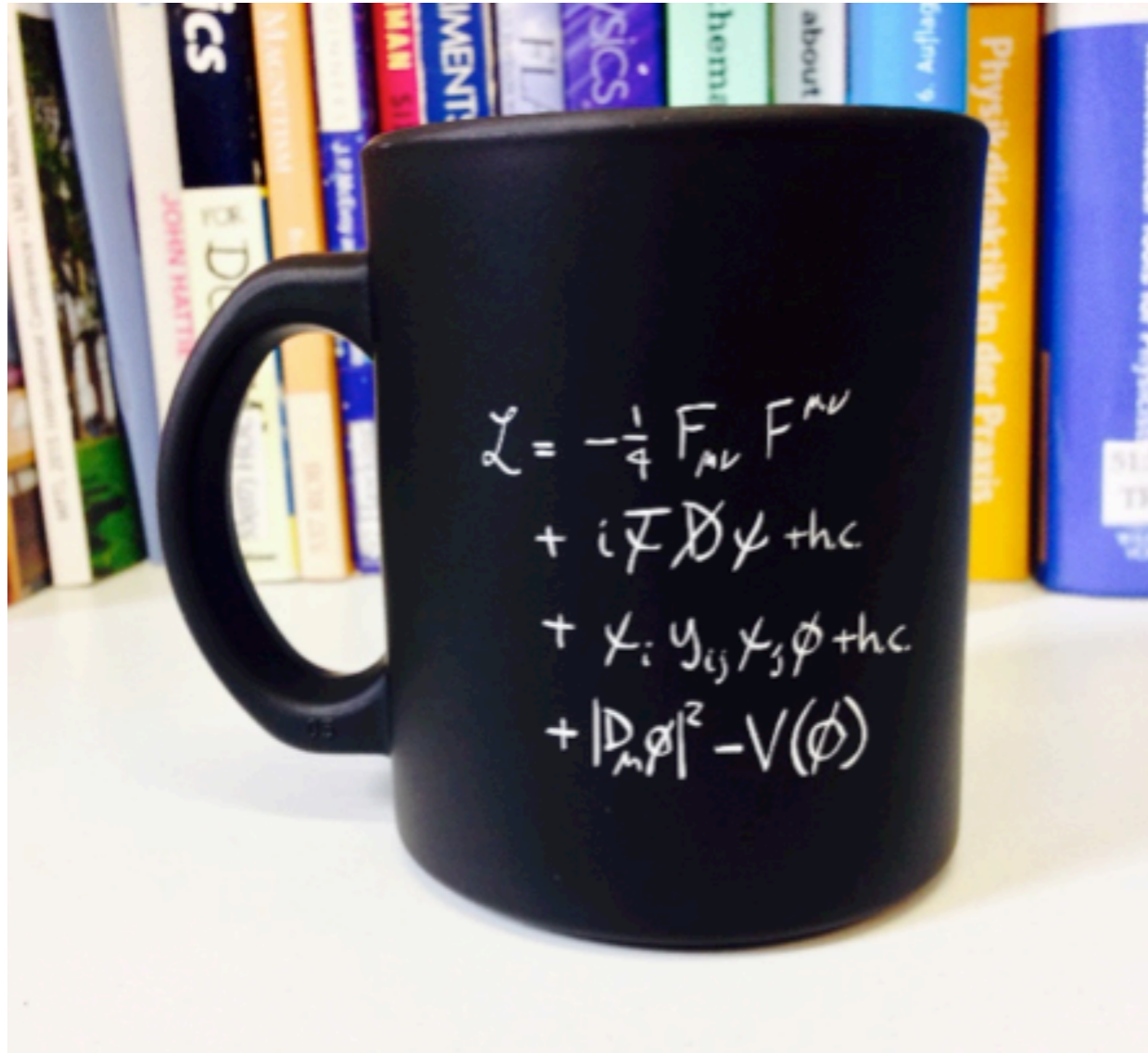
LHC 27 km

SUISSE
FRANCE





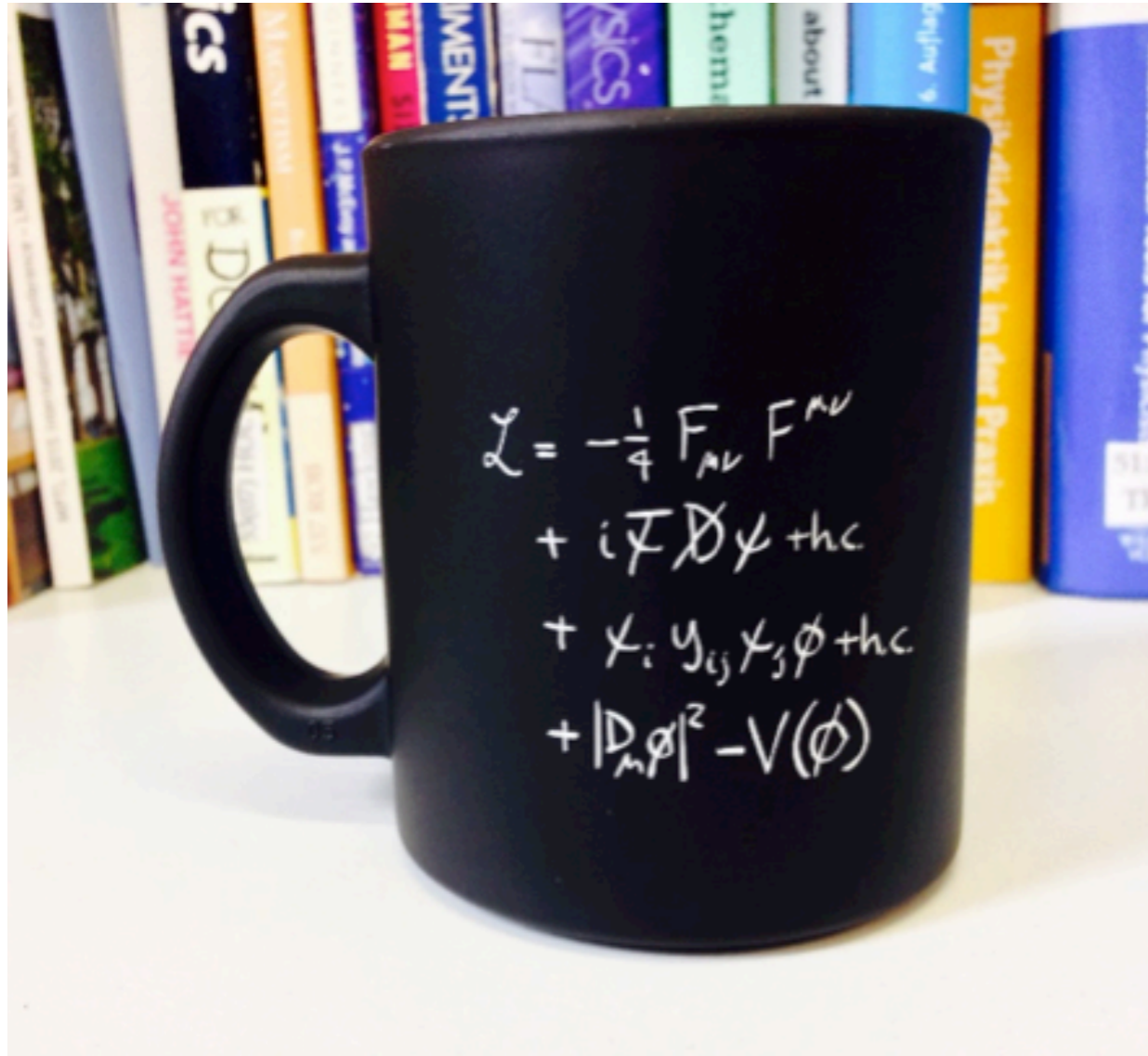




Standard Model of Elementary Particles

	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
QUARKS	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	\gamma photon	
	e electron	\mu muon	\tau tau	Z Z boson	
LEPTONS	\nu_e electron neutrino	\nu_\mu muon neutrino	\nu_\tau tau neutrino	W W boson	

GAUGE BOSONS
VECTOR BOSONS
SCALAR BOSONS



Standard Model of Elementary Particles

	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	= 2.2 MeV/c ²	= 1.28 GeV/c ²	= 173.1 GeV/c ²	0	= 124.97 GeV/c ²
charge	2/3	2/3	2/3	0	0
spin	1/2	1/2	1/2	1	0
	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	γ photon	
	e electron	μ muon	τ tau	Z Z boson	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

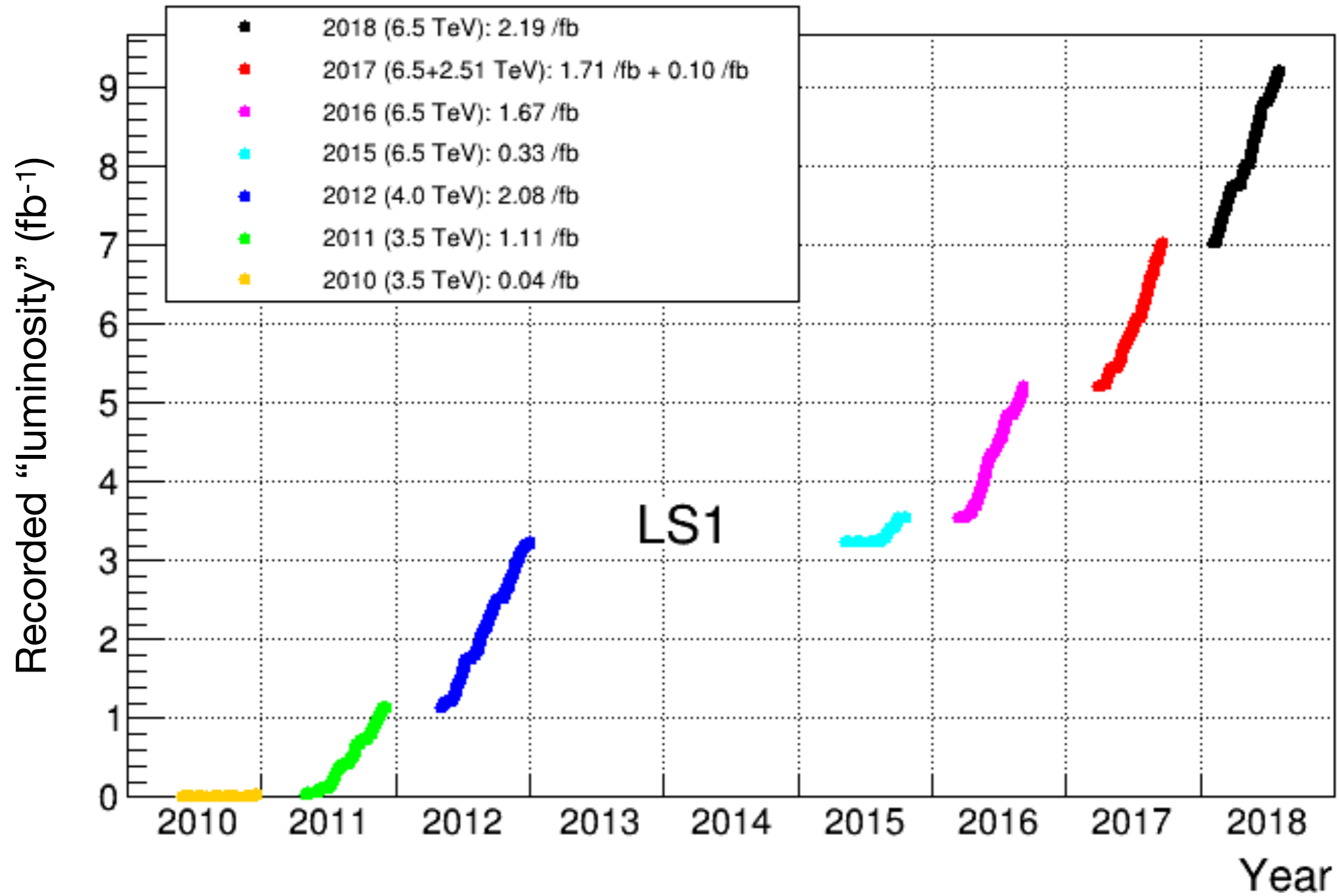
QUARKS (vertical label on the left)

LEPTONS (vertical label on the left)

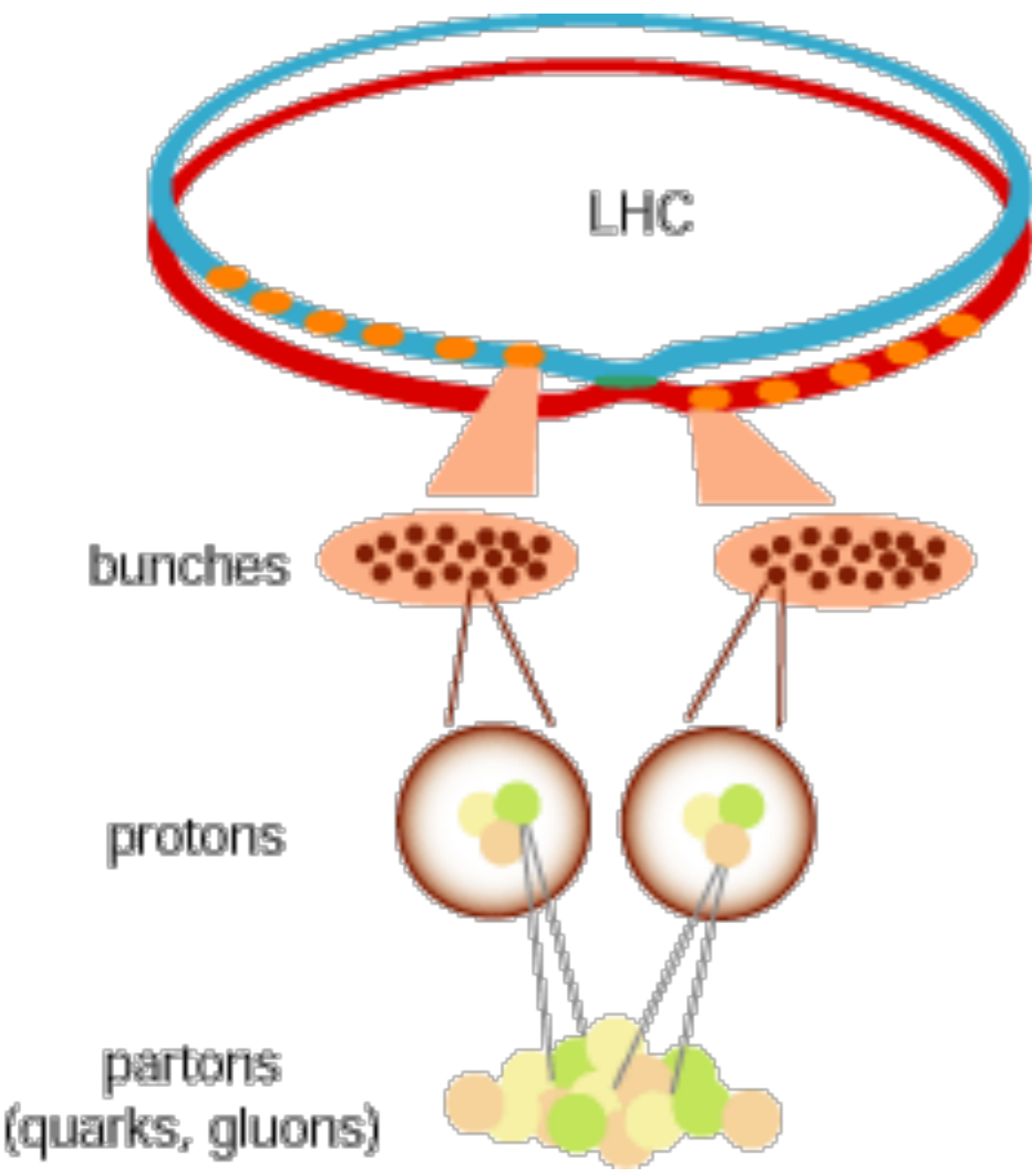
GAUGE BOSONS VECTOR BOSONS (vertical label on the right)

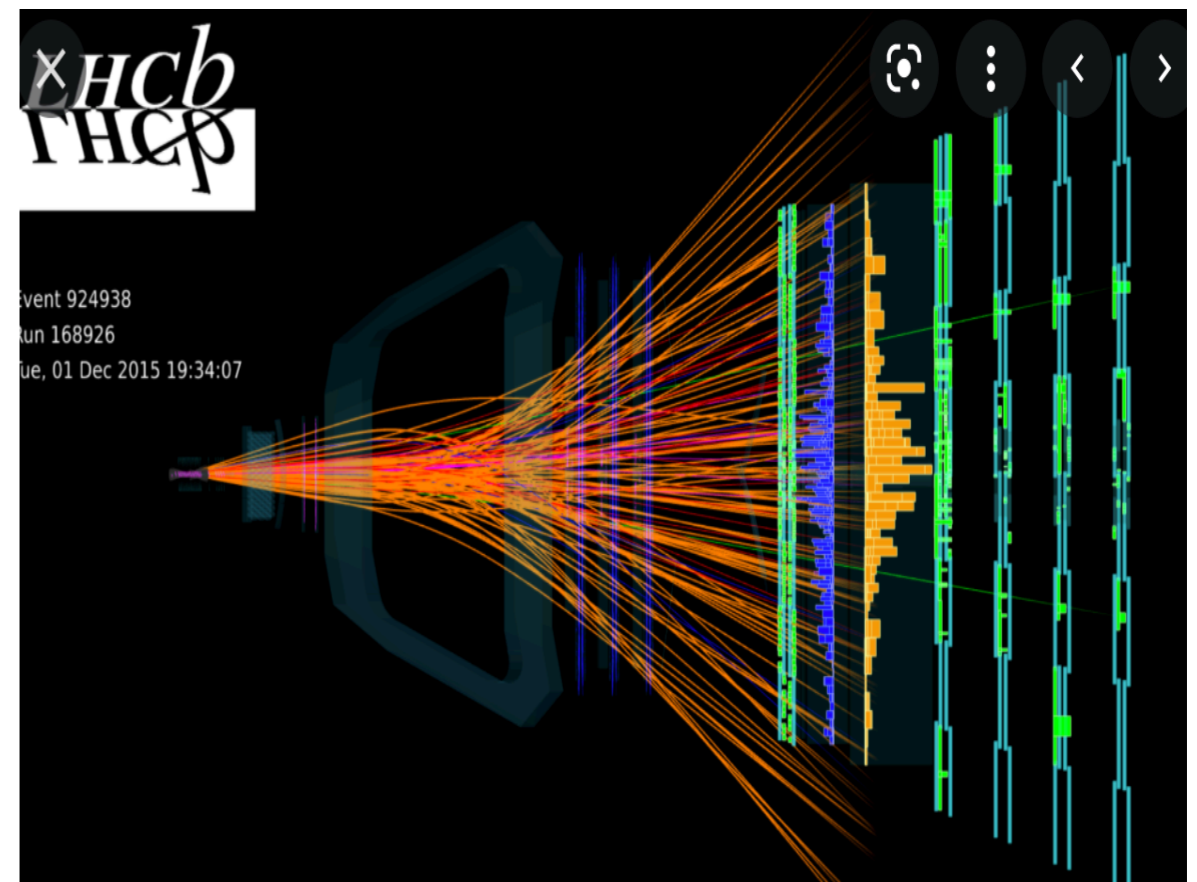
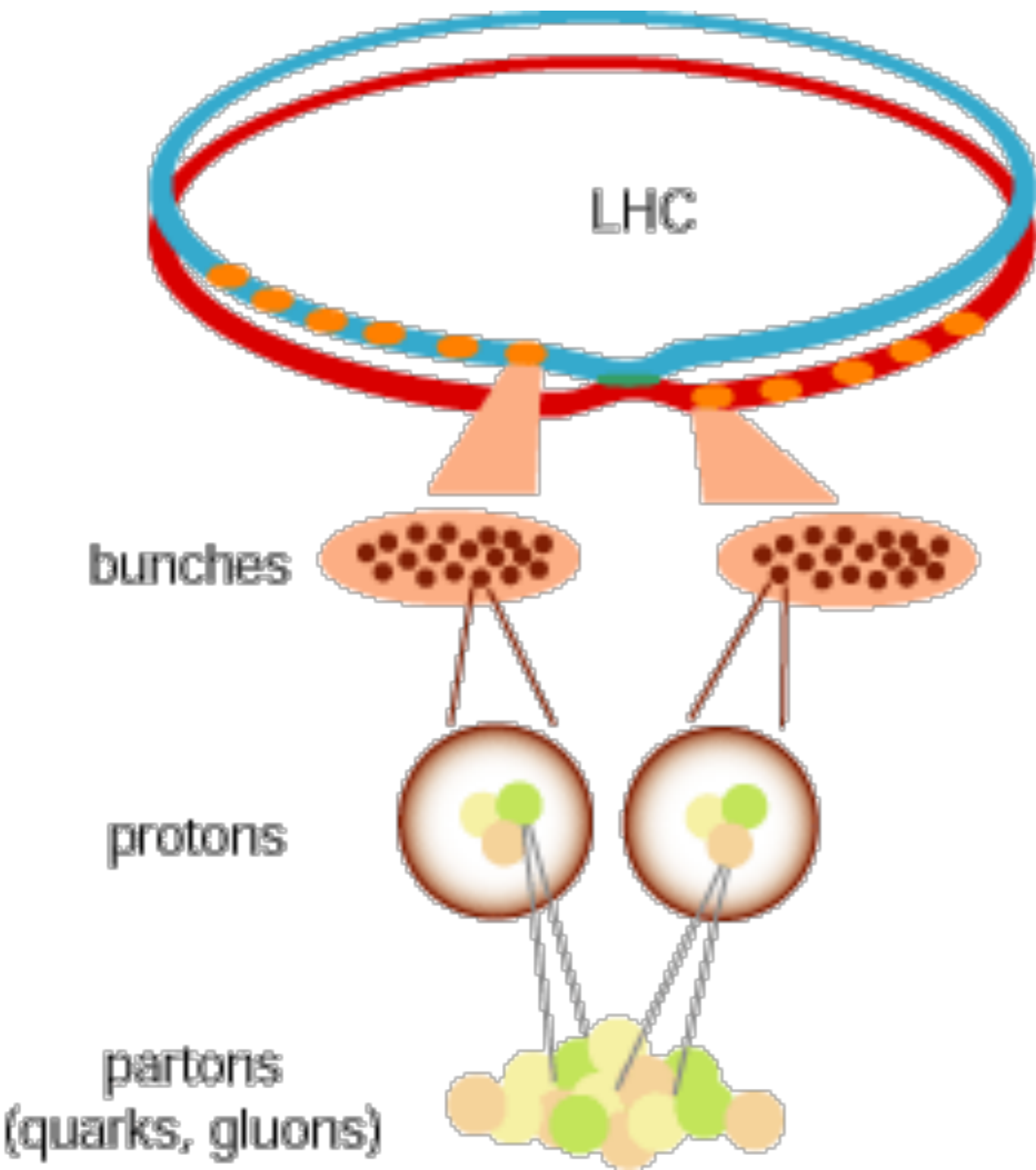
SCALAR BOSONS (vertical label on the right)

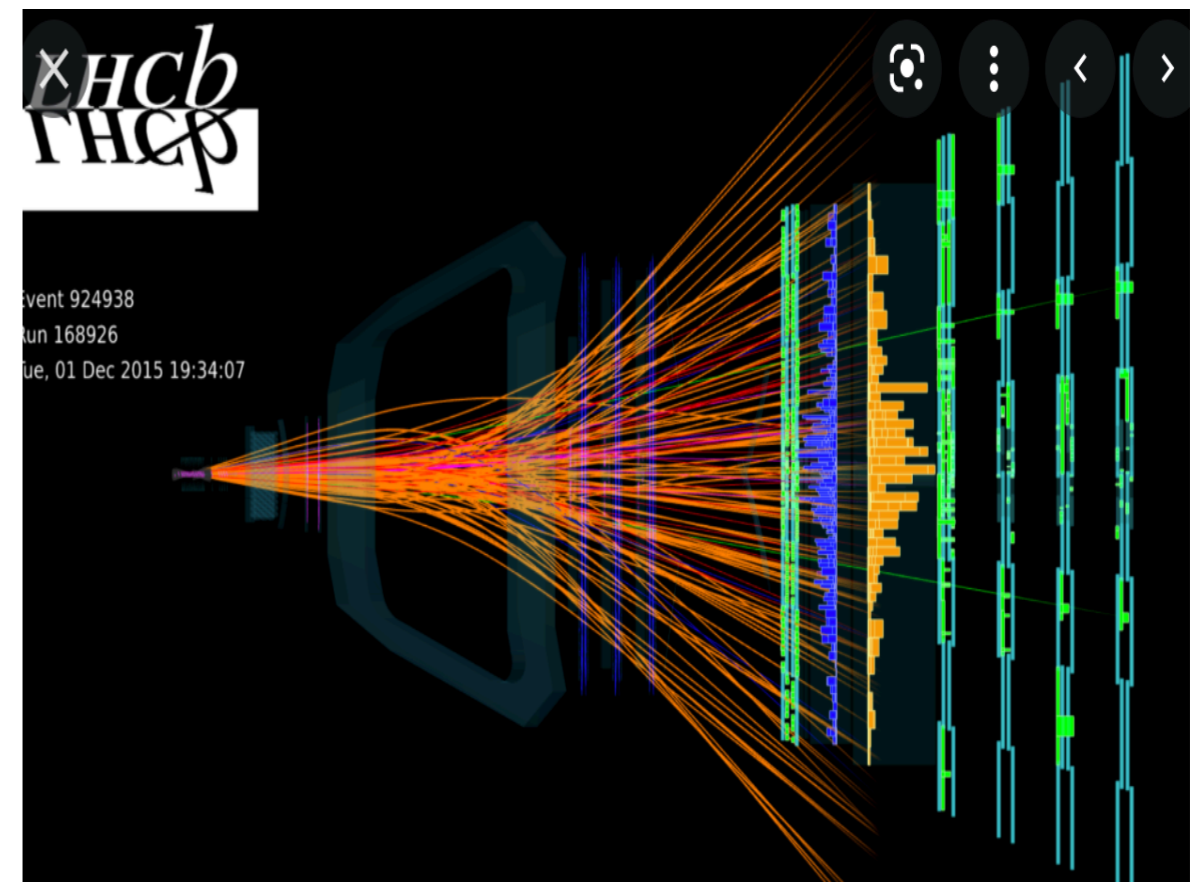
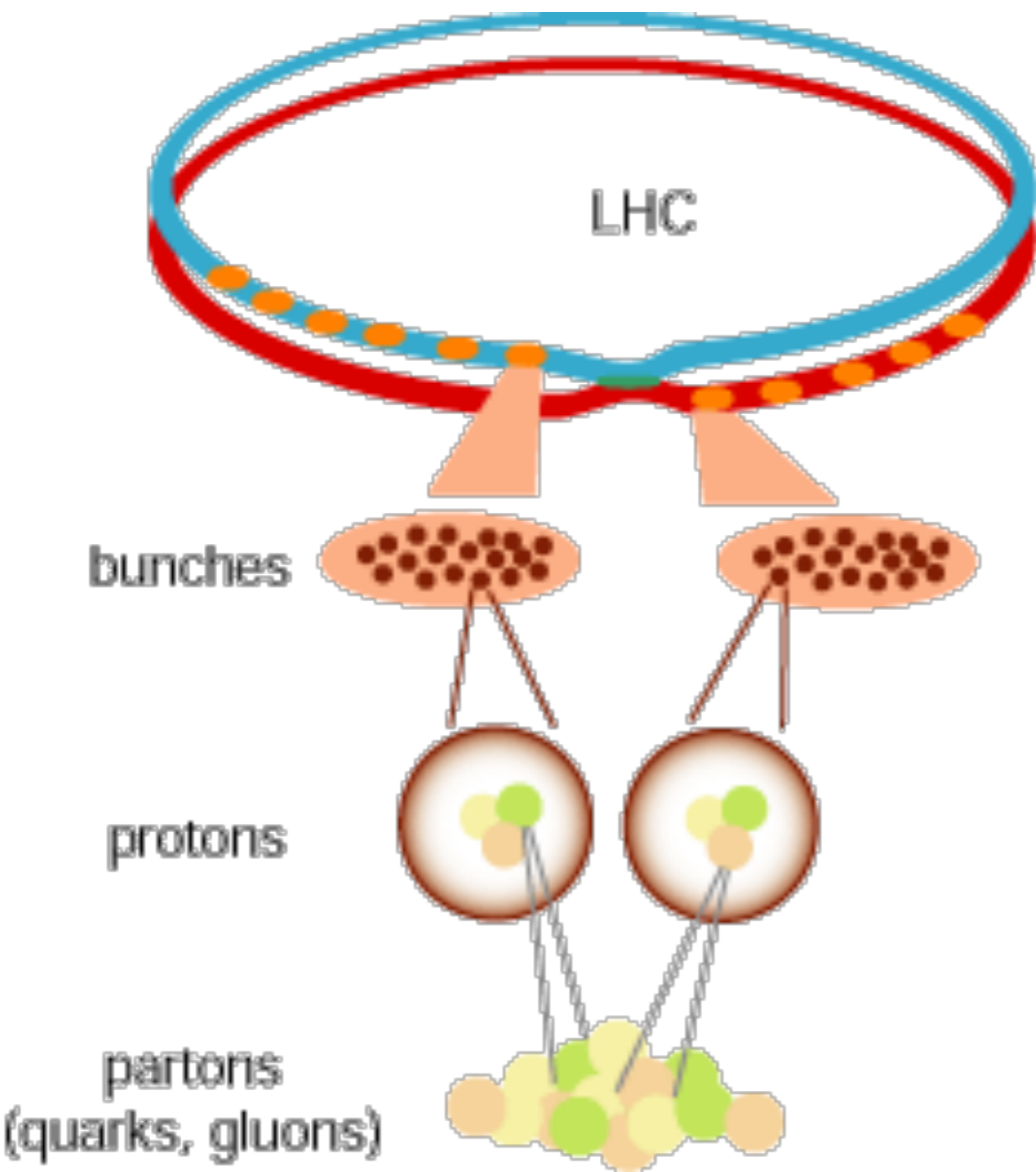
Science goal: discover physics *beyond* the standard model



LHC due to restart operations later this year with upgraded experiments

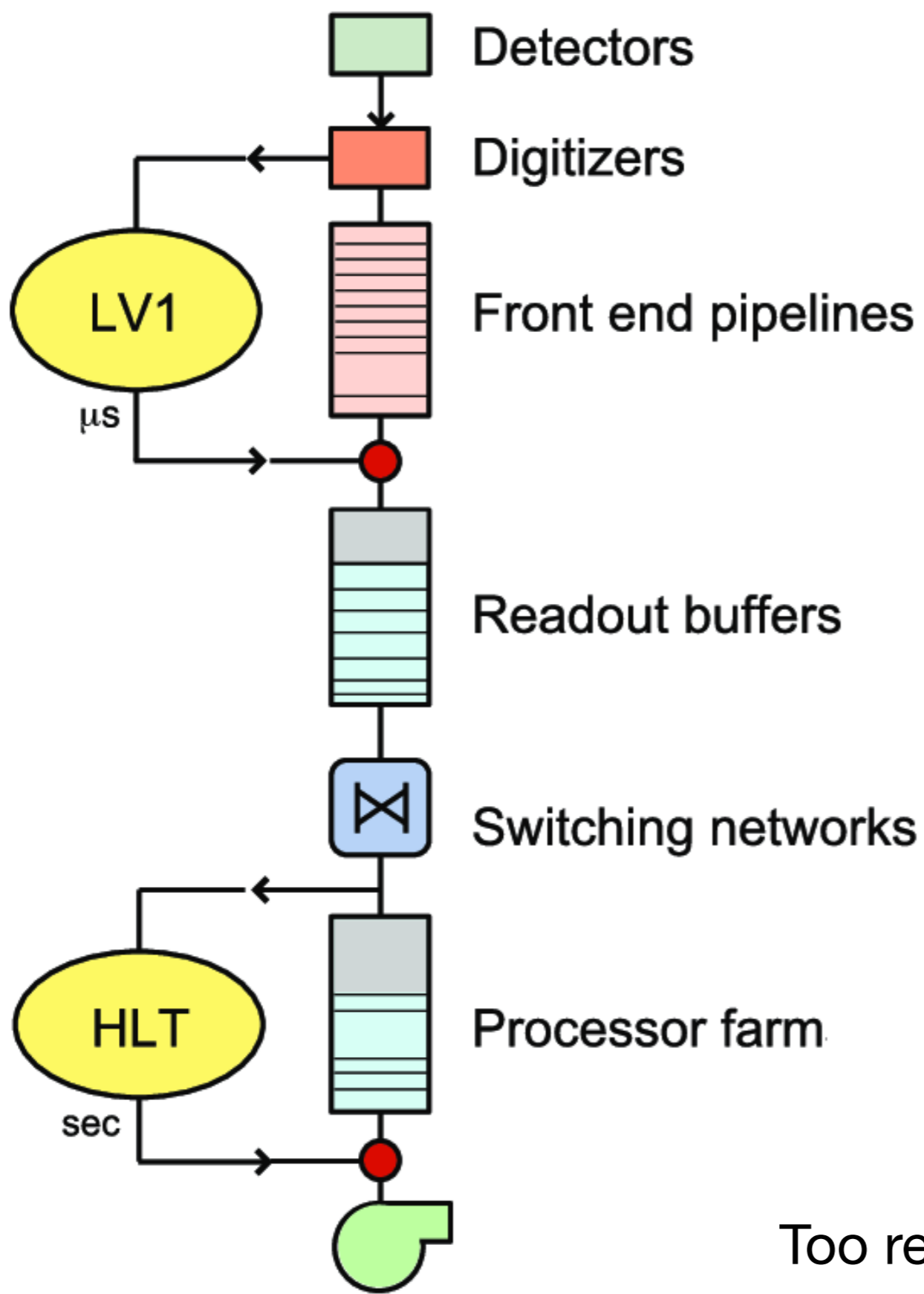






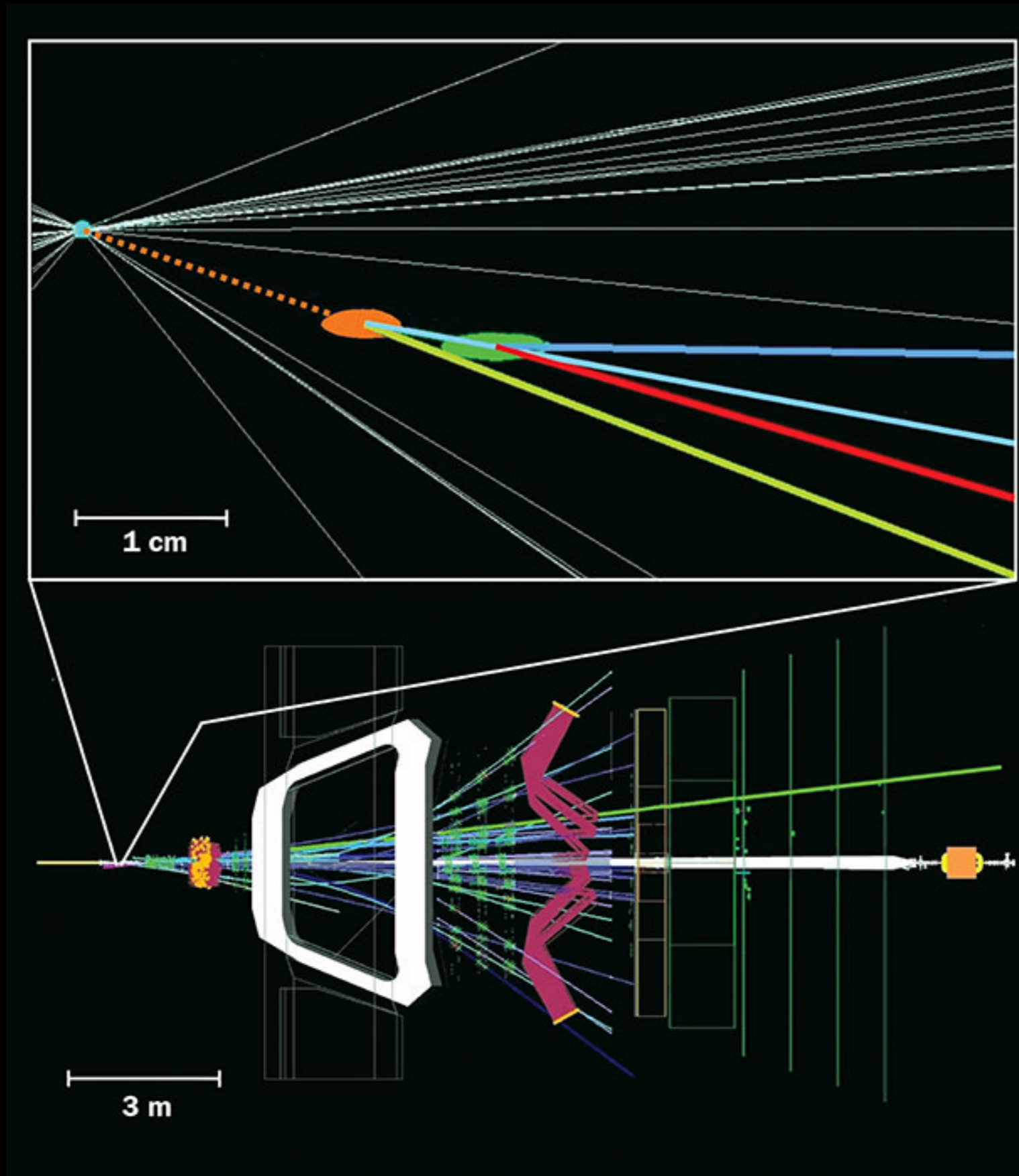
Data rate: 30 MHz of ~100 kB “events”, i.e. 3 TB/s.

Traditional “triggered” detector readout



Too restrictive for the LHCb experiment...

Typical signal for LHCb (of ~1000 “selections”)

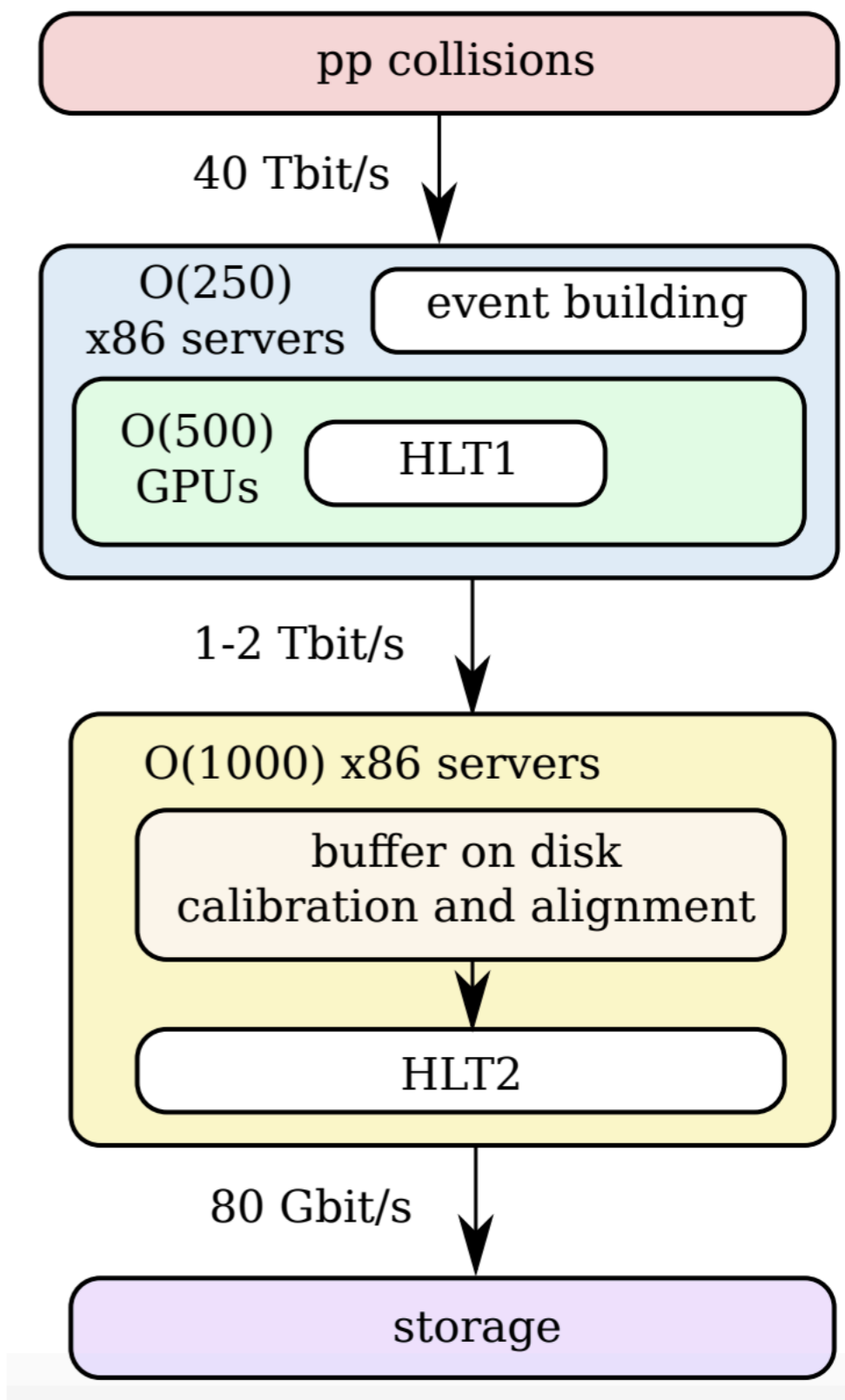


First stage on GPGPUs (a first in collider physics!)

Complete events offloaded to GPU cards on the event building servers.

Fast event reconstruction and ~20 selection “lines”.

Many lines are “inclusive”



Second stage: complete event reconstruction + ~1000 selections

Requirement: process at up to 1 MHz on a farm of ~100k x86 cores.

Full event reconstruction

~1000 signal selections

Multithreading: task based scheduling system and stateless algorithms

Vectorisation: use intel SIMD intrinsic types and instructions, and careful event model design!

```
struct point3D {  
    float x;  
    float y;  
    float z;  
};  
struct point3D points[N];  
float get_point_x(int i) { return points[i].x; }
```



```
struct point3D {  
    float x;  
    float y;  
    float z;  
};  
struct point3D points[N];  
float get_point_x(int i) { return points[i].x; }
```

```
struct pointlist3D {  
    float x[N];  
    float y[N];  
    float z[N];  
};  
struct pointlist3D points;  
float get_point_x(int i) { return points.x[i]; }
```

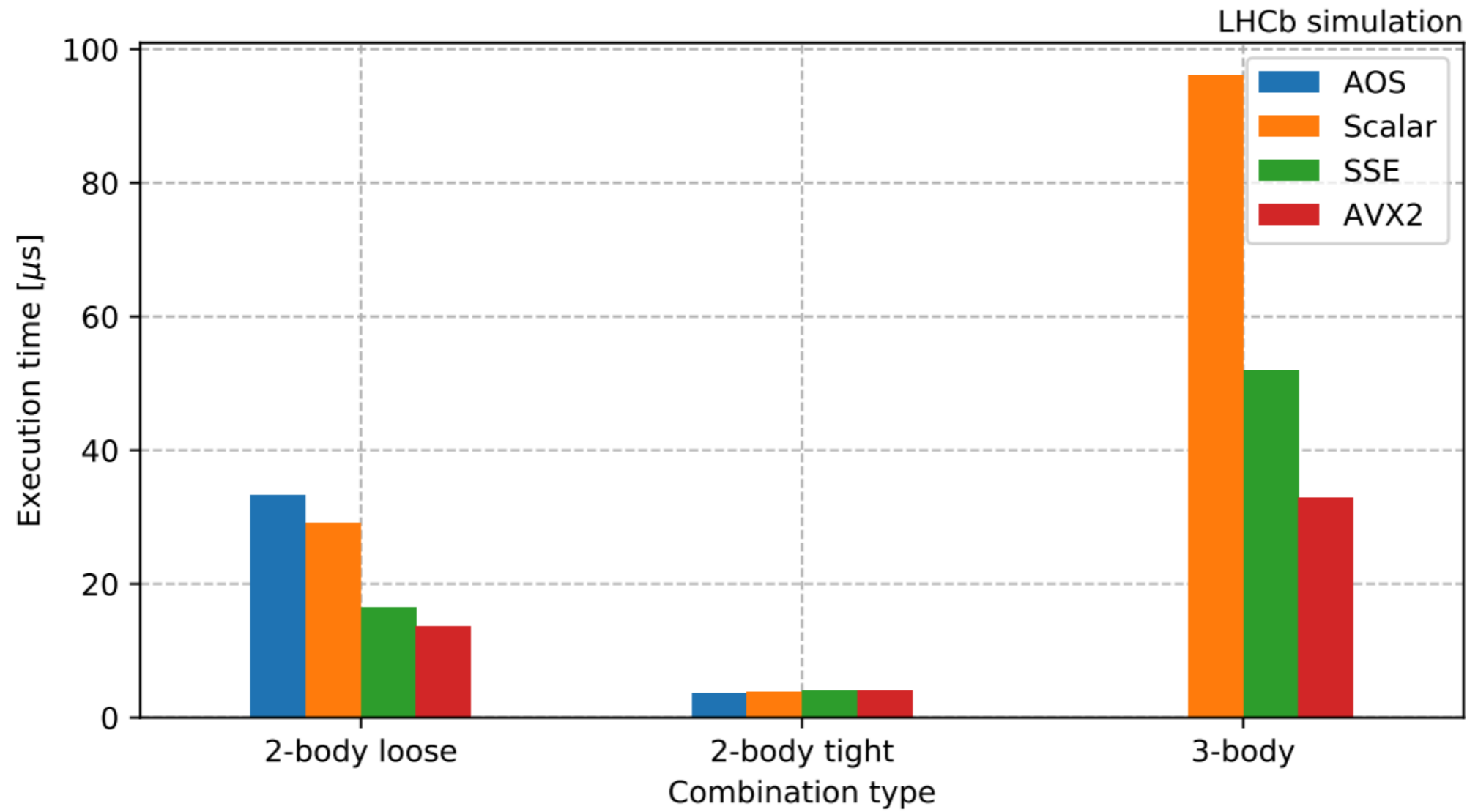
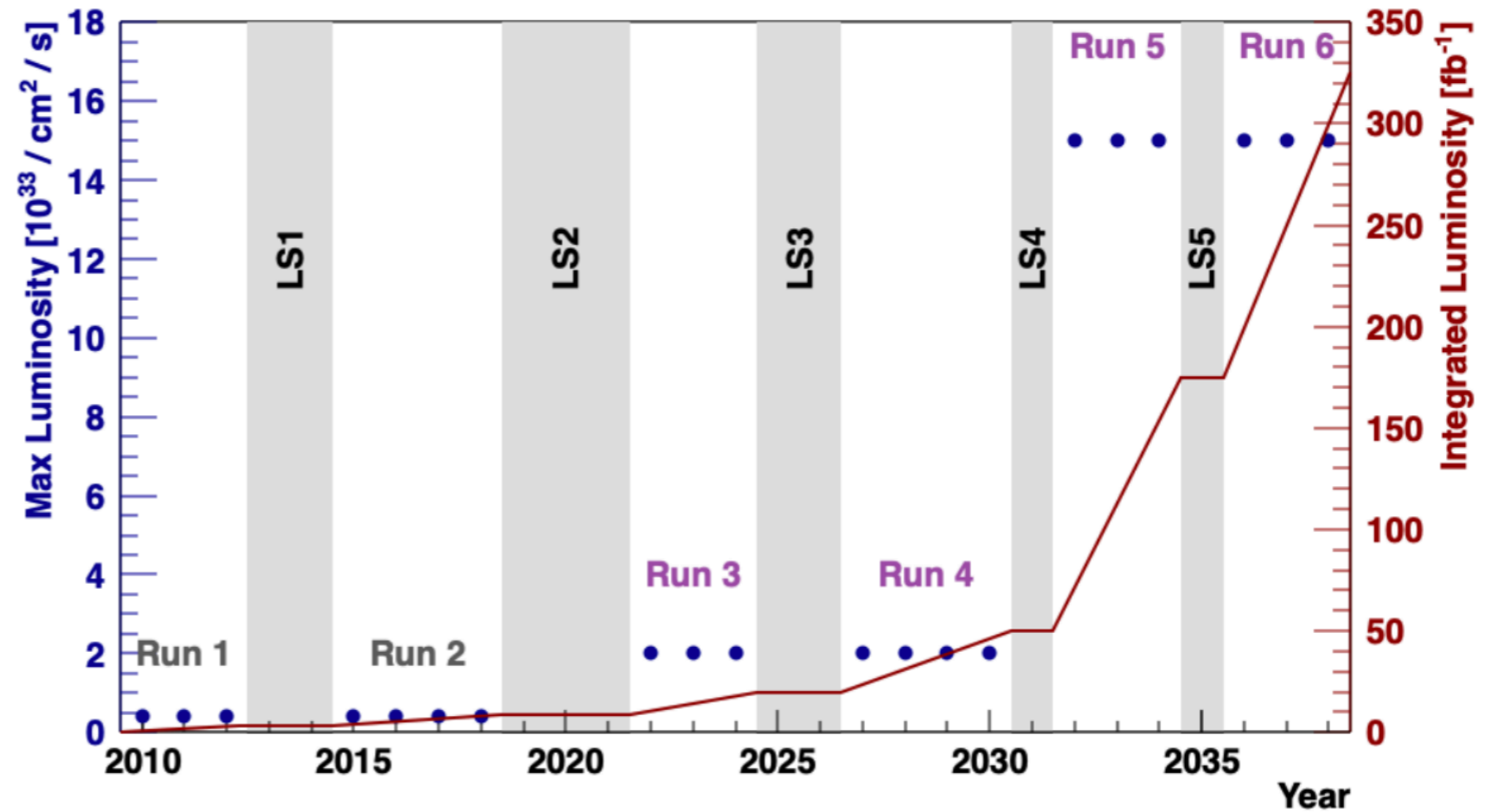
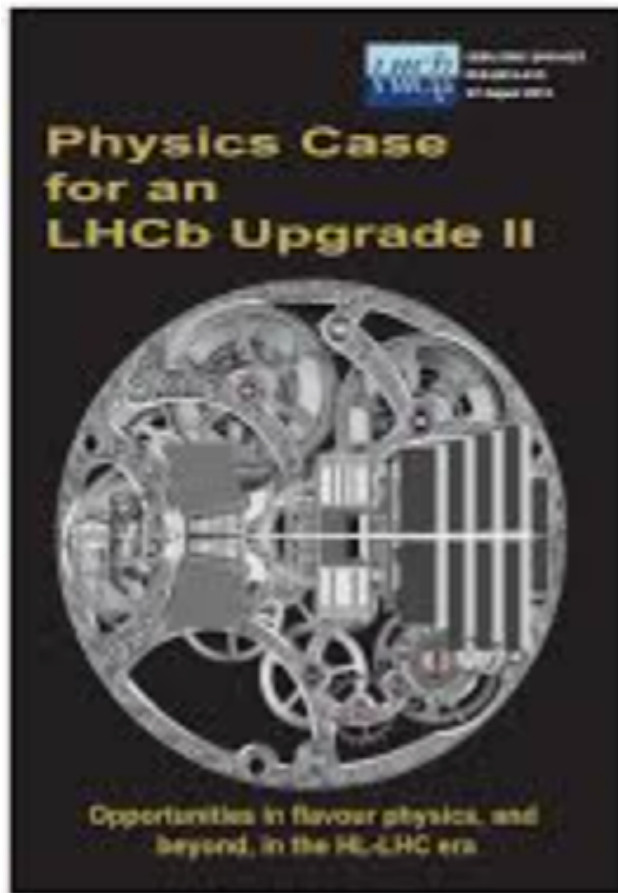


Figure 1: The timings of three different particle combination algorithms as performed by four different execution backends. The execution times for the 2-body loose and 3-body algorithms are lower for backends which utilise vector instruction sets. The 2-body tight algorithm has a tight selection on its input objects and subsequently cannot fully fill the vector instruction registers during execution.



Current LHCb-UK R&D project with work packages on tracking, particle identification and data processing.

Data processing includes novel architectures, 4D event reconstruction and detailed simulations.



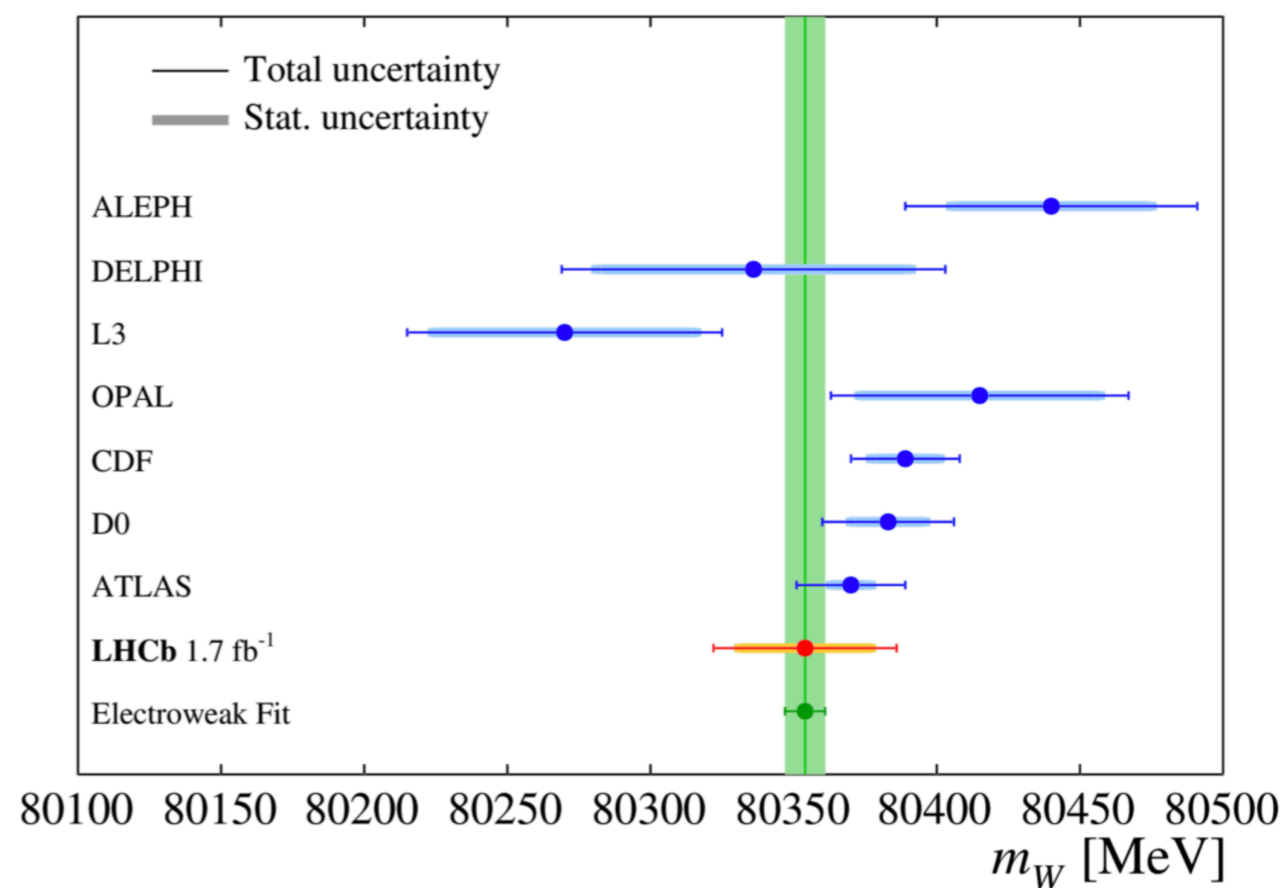
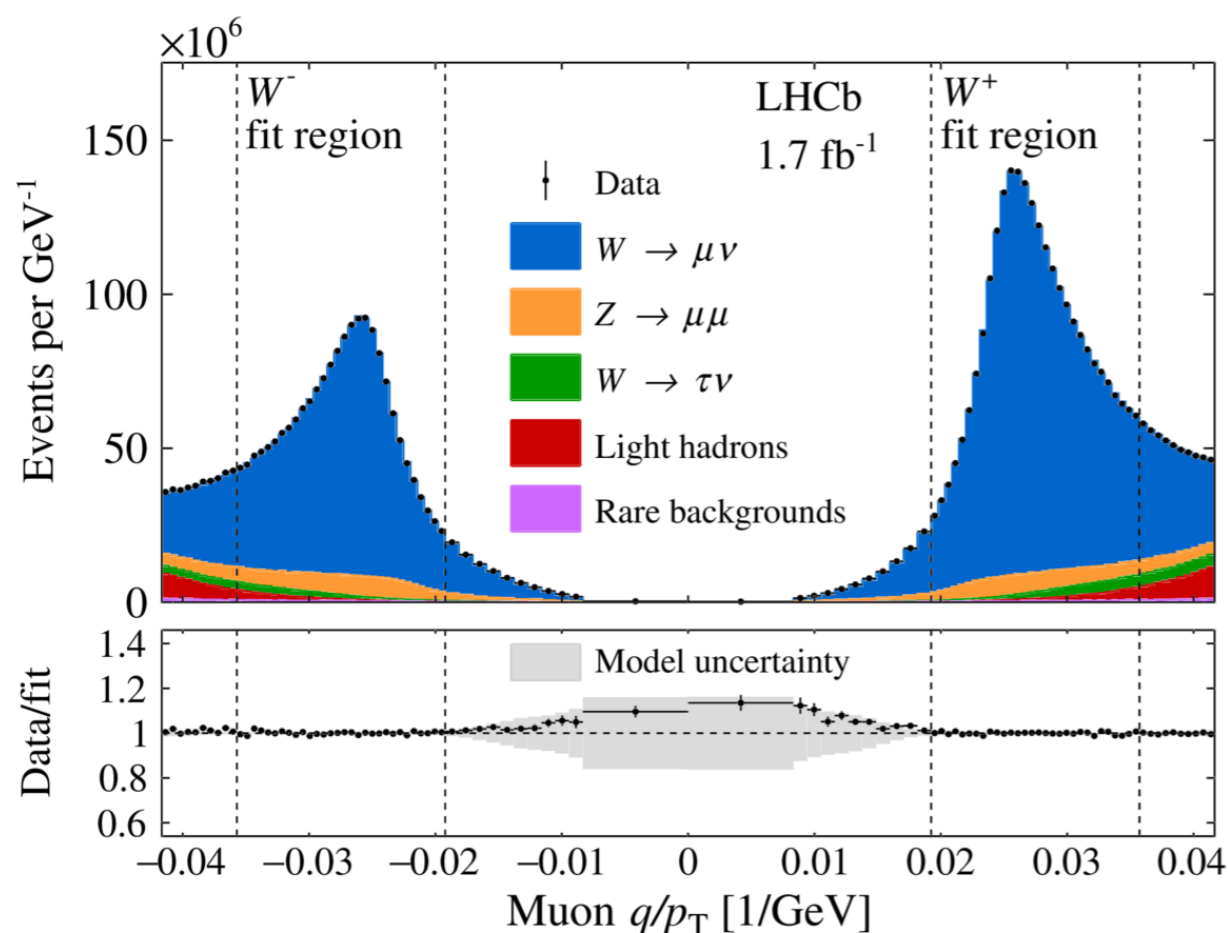
SPEAR ERC CsG project (2020-25)

Precision tests with electroweak vector (W and Z) bosons.

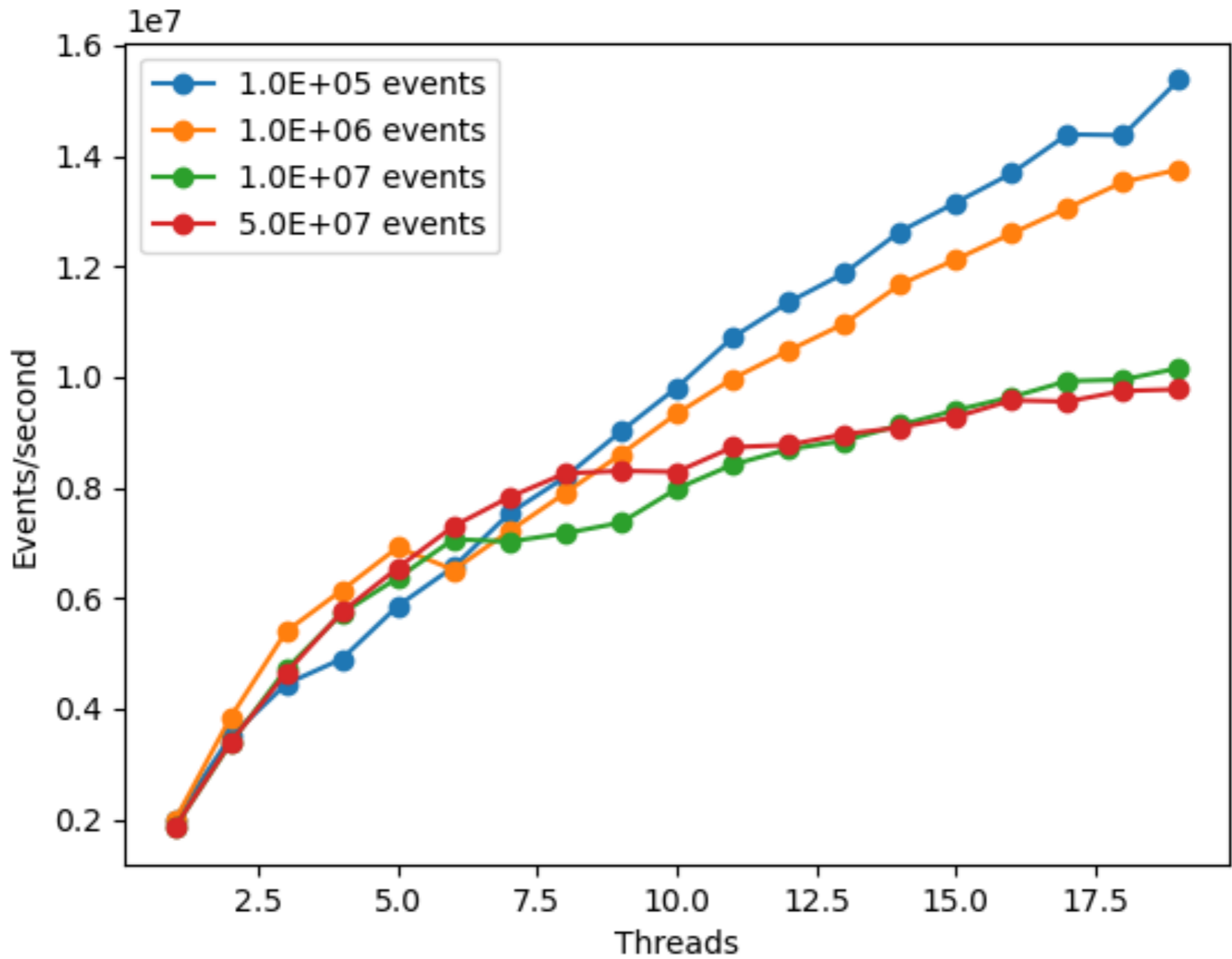
Current PDRAs Miguel Ramos Pernas and Menglin Xu. Former PDRA Olli Lupton now an RSE with the Blue Brain project at EPFL.

Current students Ahmed Abdelmottaleb and Emir Muhammed.

First ever measurement of the W boson mass with an experiment like LHCb published earlier this year. Already have 3x more data to analyse!

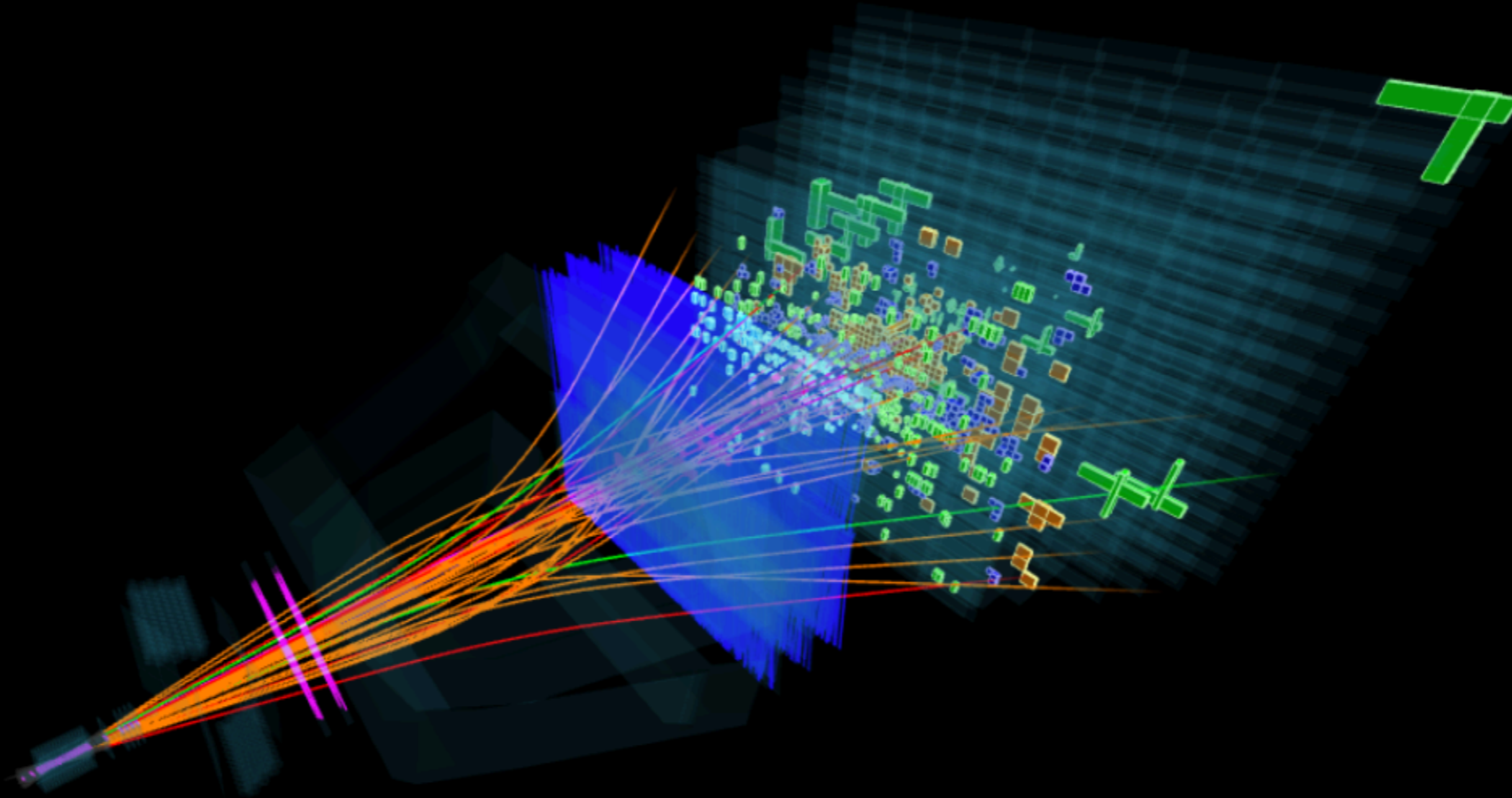


Efficiently fitting the mass of the W boson





Event 158826354
Run 206854
Sat, 28 Apr 2018 21:48:17



Thanks for listening

Backup slides

The interaction of various particles with the different components of a detector:

