Introduction to the LHCb masterclass exercise

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Introduction

You will all have received a printout with instructions for the workshop. Here I will

Briefly motivate why these exercises are interesting

Explain what the LHCb detector is

Explain the data format

Give you some starting point for performing the exercises

What will you be measuring today?

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The object of this exercise is for you to measure the lifetime of a certain kind of particle found in nature

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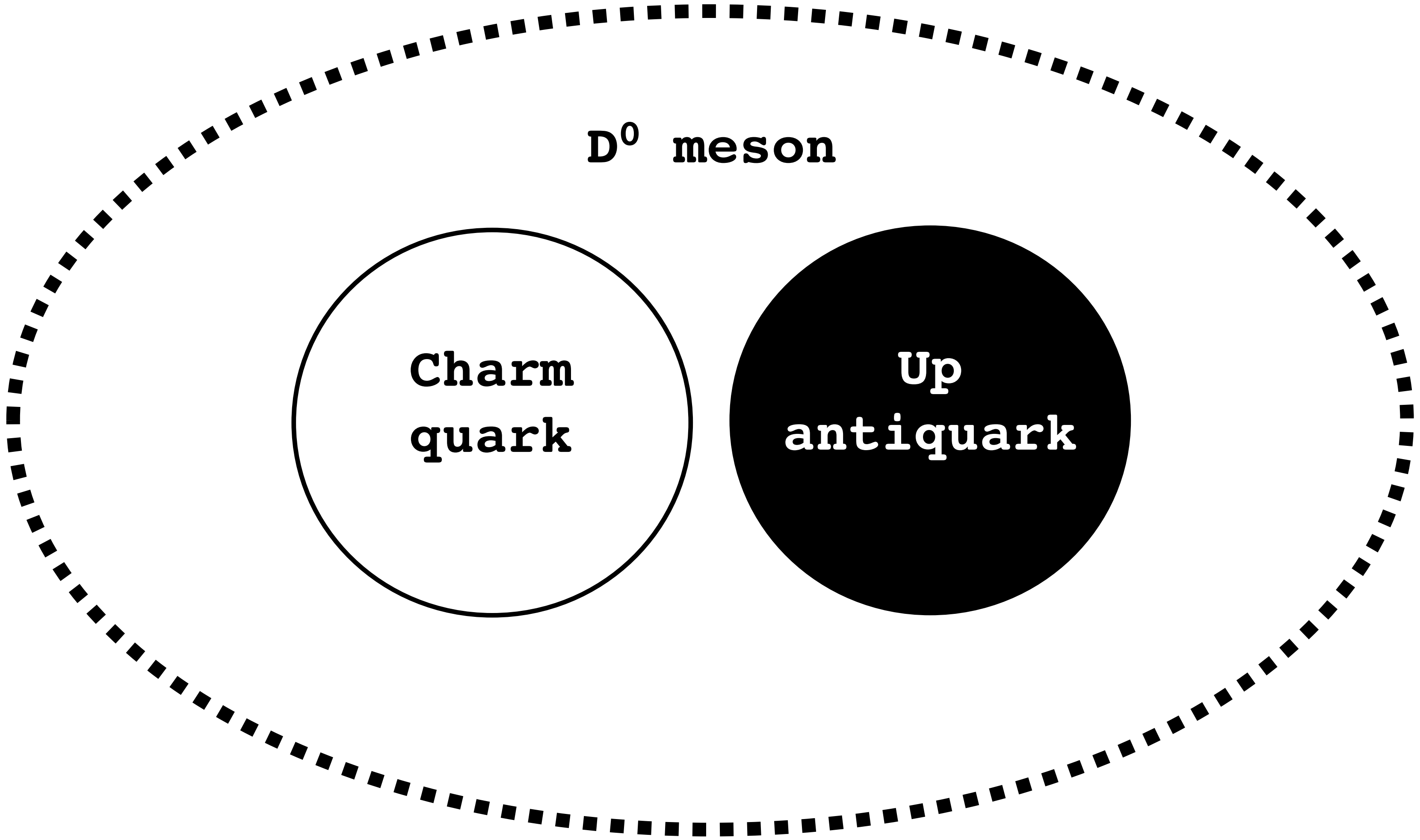
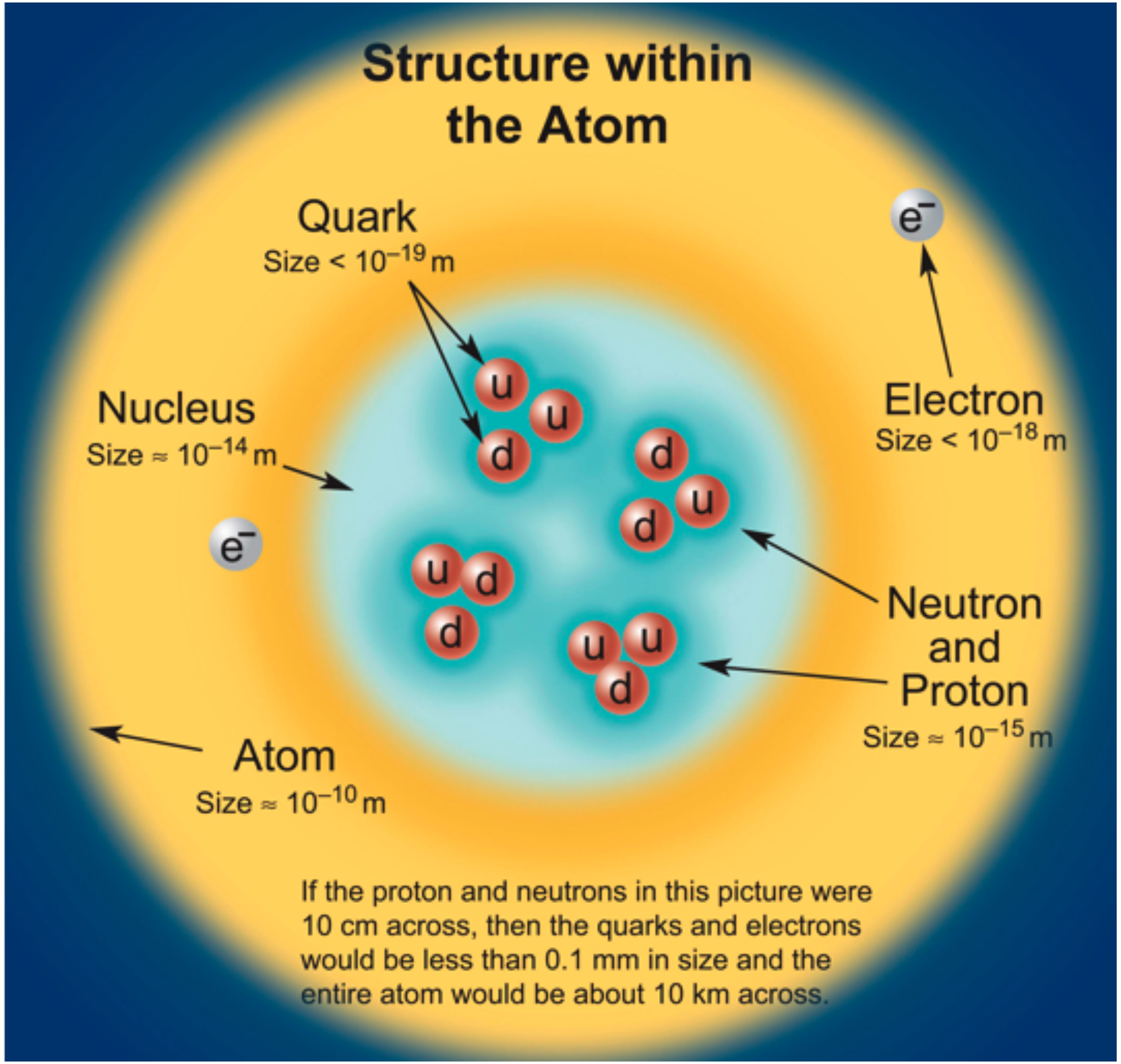


The object of this exercise is for you to measure the lifetime of a certain kind of particle found in nature

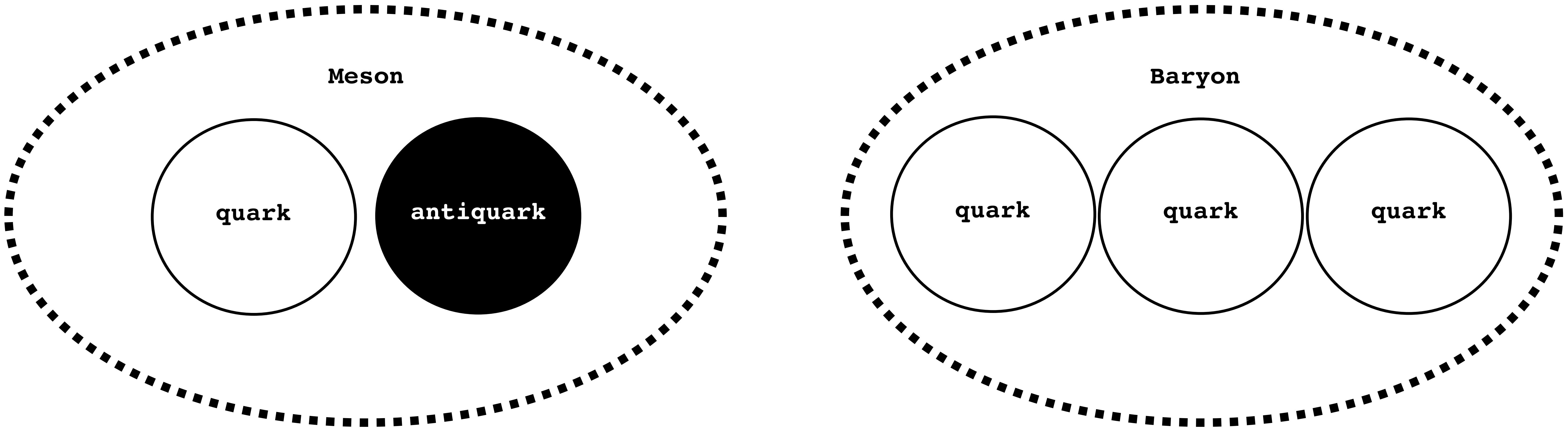
What kind of particles are there?

There are a small number of fundamental particles.

Smaller than atoms…



What do quarks form?



Two different kinds of combinations : quark-antiquark, or three (anti)quarks.

Antiparticles have opposite charges to the corresponding particles, but are otherwise supposed to interact in the same way. Most particles have a corresponding antiparticle (but sometimes a particle is its own antiparticle).

What are some typical particle lifetimes?

Type	Name	Symbol	Energy (MeV)	Mean lifetime
Lepton	Electron / Positron	e^- / e^+	0.511	$> 4.6 \times 10^{26}$ years
	Muon / Antimuon	μ^- / μ^+	105.7	2.2×10^{-6} seconds
	Tau lepton / Antitau	τ^- / τ^+	1777	$\boxed{2.9 \times 10^{-13} \text{ seconds}}$
Meson	Neutral Pion	π^0	135	8.4×10^{-17} seconds
	Charged Pion	π^+ / π^-	139.6	2.6×10^{-8} seconds
Baryon	Proton / Antiproton	p^+ / p^-	938.2	$\boxed{> 10^{29} \text{ years}}$
	Neutron / Antineutron	$n / \bar{n}$	939.6	885.7 seconds
Boson	W boson	W^+ / W^-	80,400	10^{-25} seconds
	Z boson	Z^0	91,000	10^{-25} seconds

A huge range of different lifetimes : you will be measuring a pretty short one...

Wikipedia : can't live with it, can't live without it...

How do we measure a short lifetime?

As an example, consider a particle which lives 10^{-12} seconds

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$c = 3*10^8$ m/s

So it travels $3*10^{-4}$ meters, or 0.3 mm

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$t' = t/\sqrt{(1-v^2/c^2)}$

Typically an LHC particle with a lifetime of 10^{-12} seconds will fly 1 cm... that is long enough that we can measure it!

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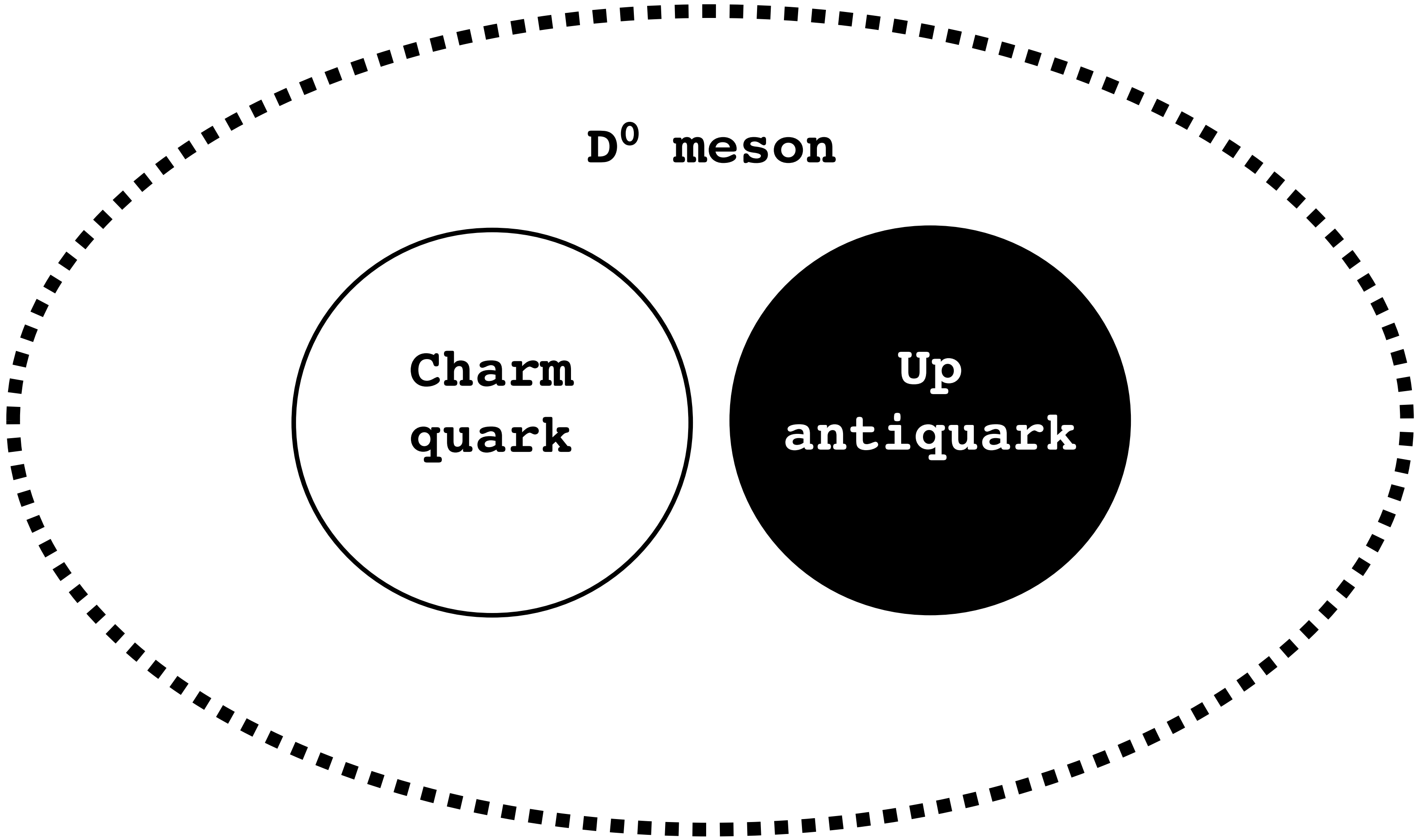
So why is the D^0 special?



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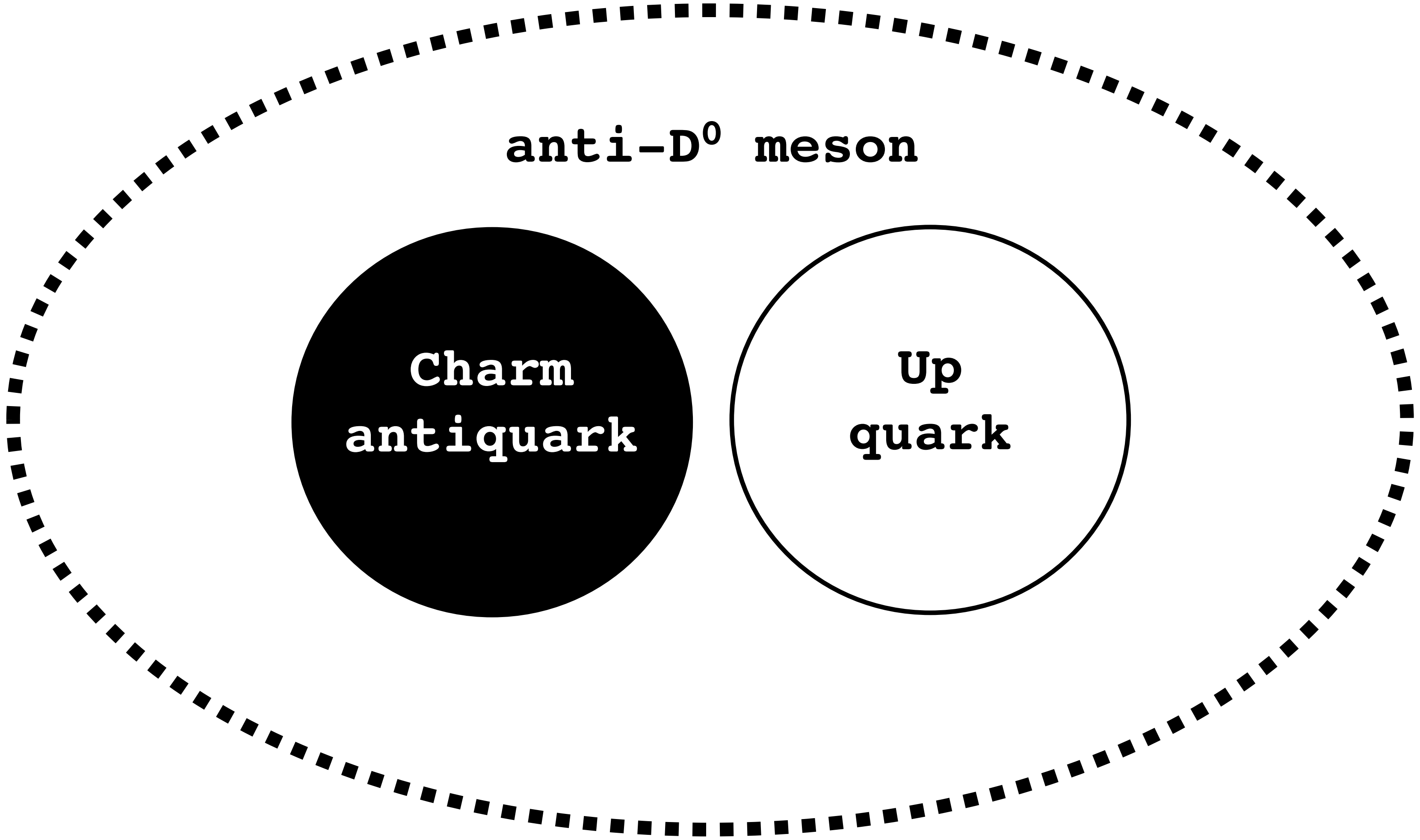

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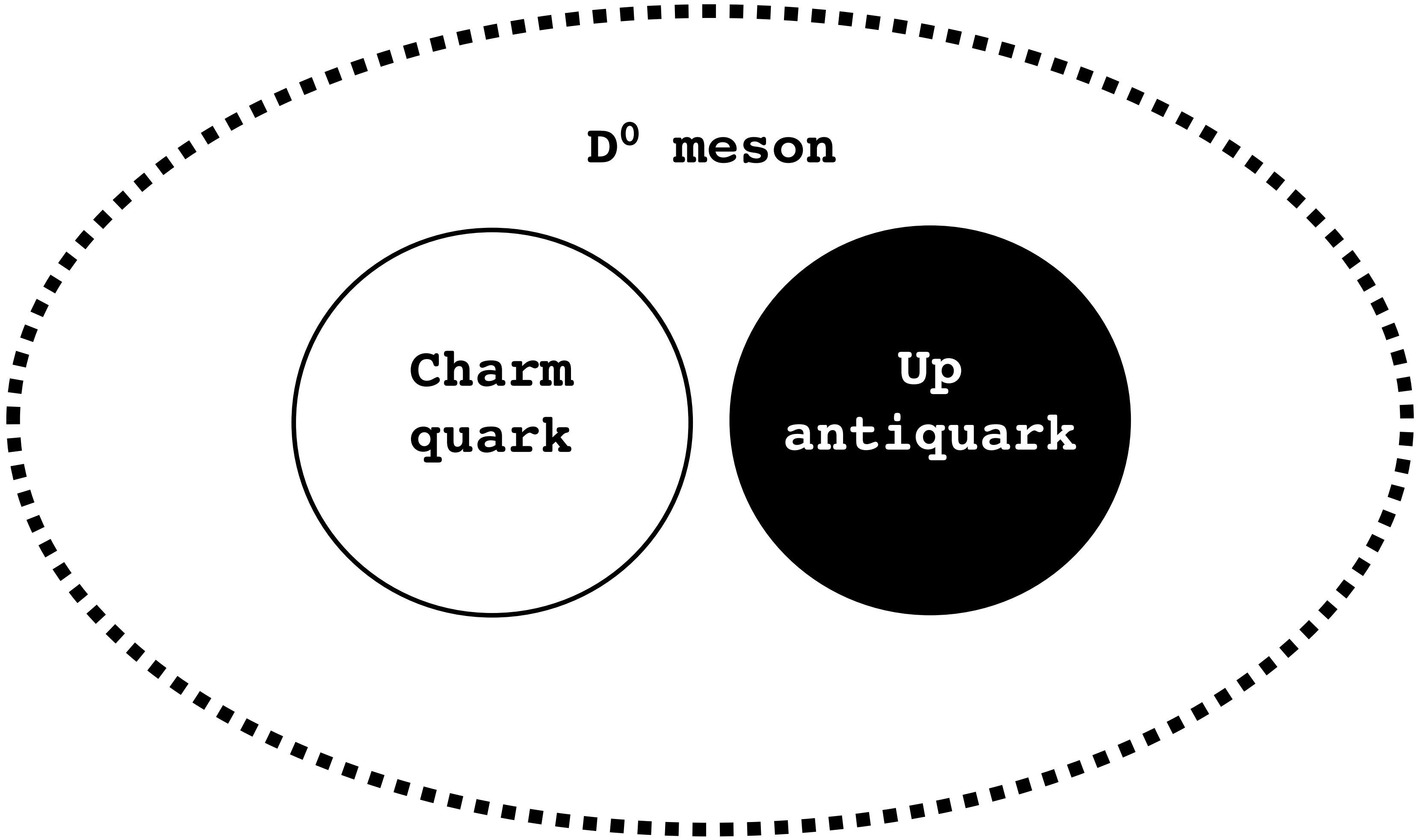
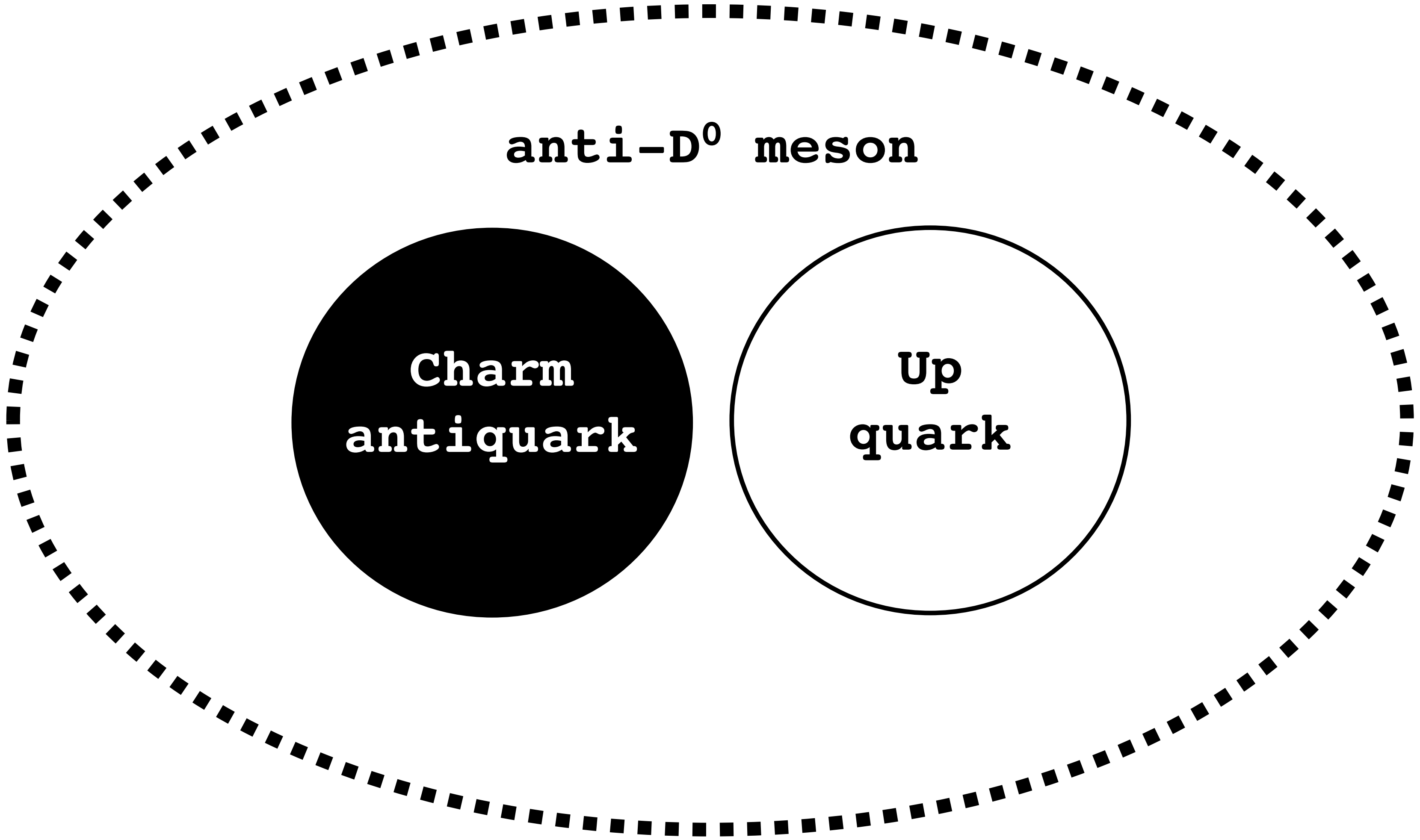
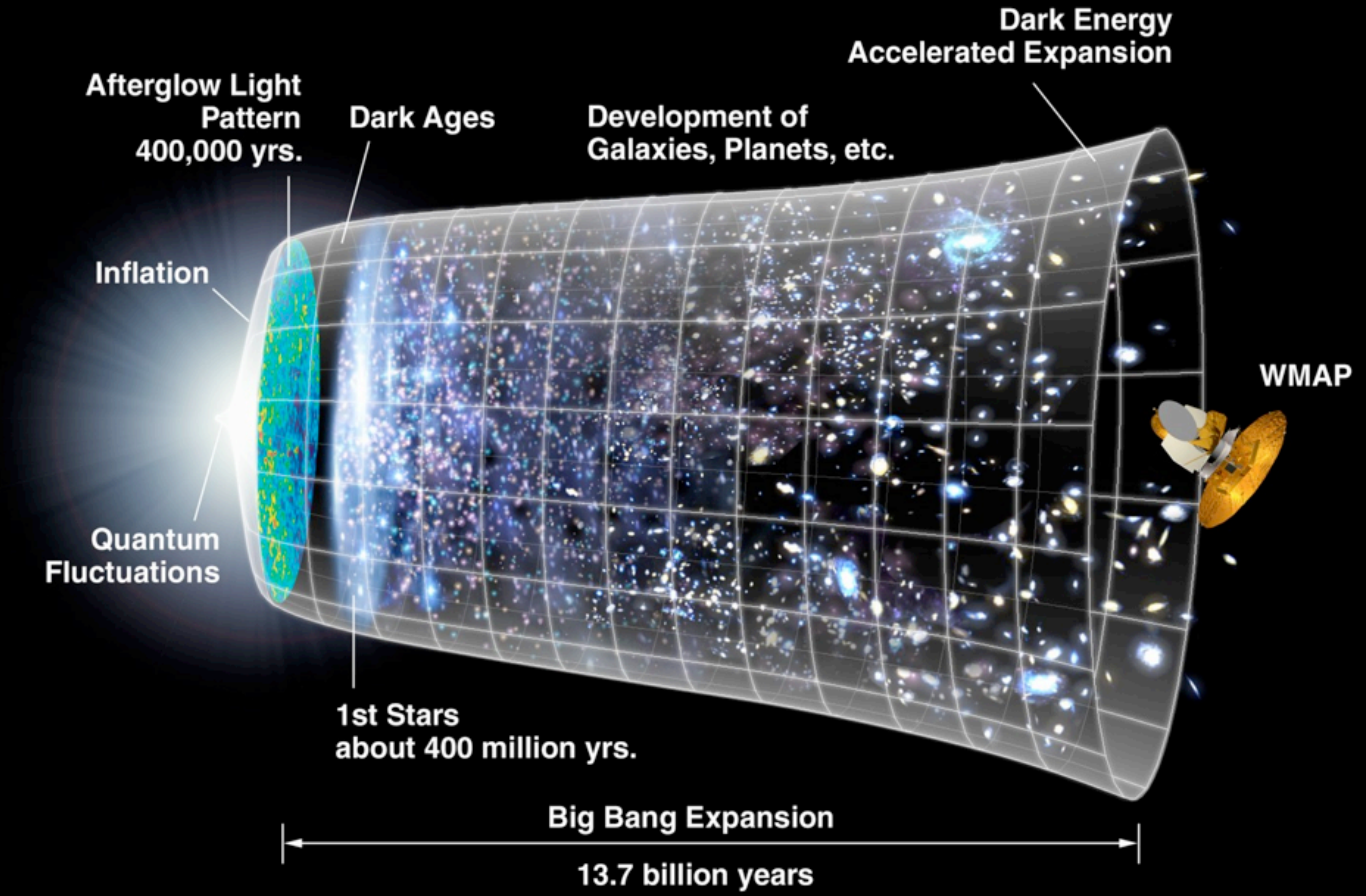


It oscillates!



The D^0 is a neutral particle : it can oscillate between matter and antimatter before decaying!

Why does antimatter matter?



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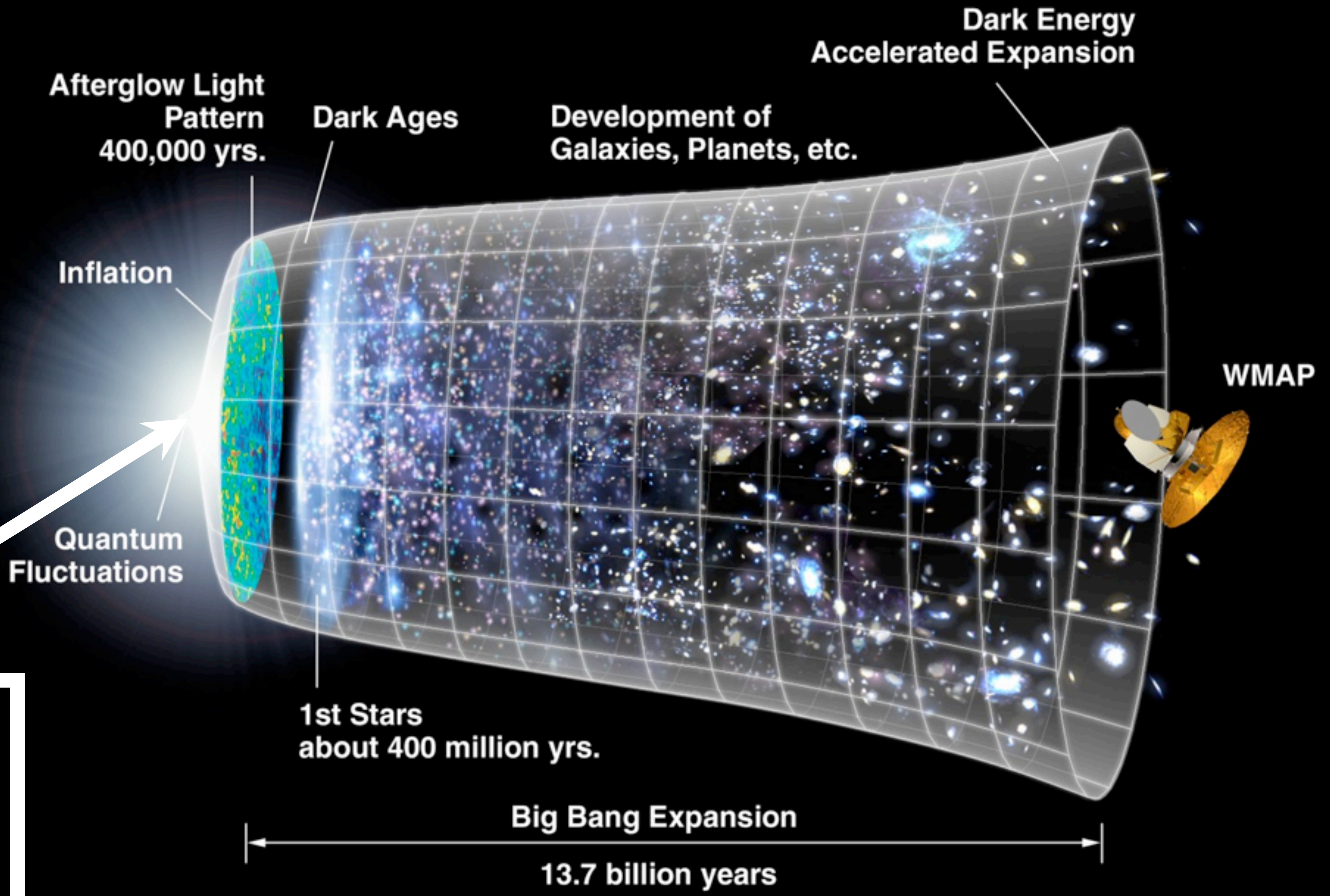
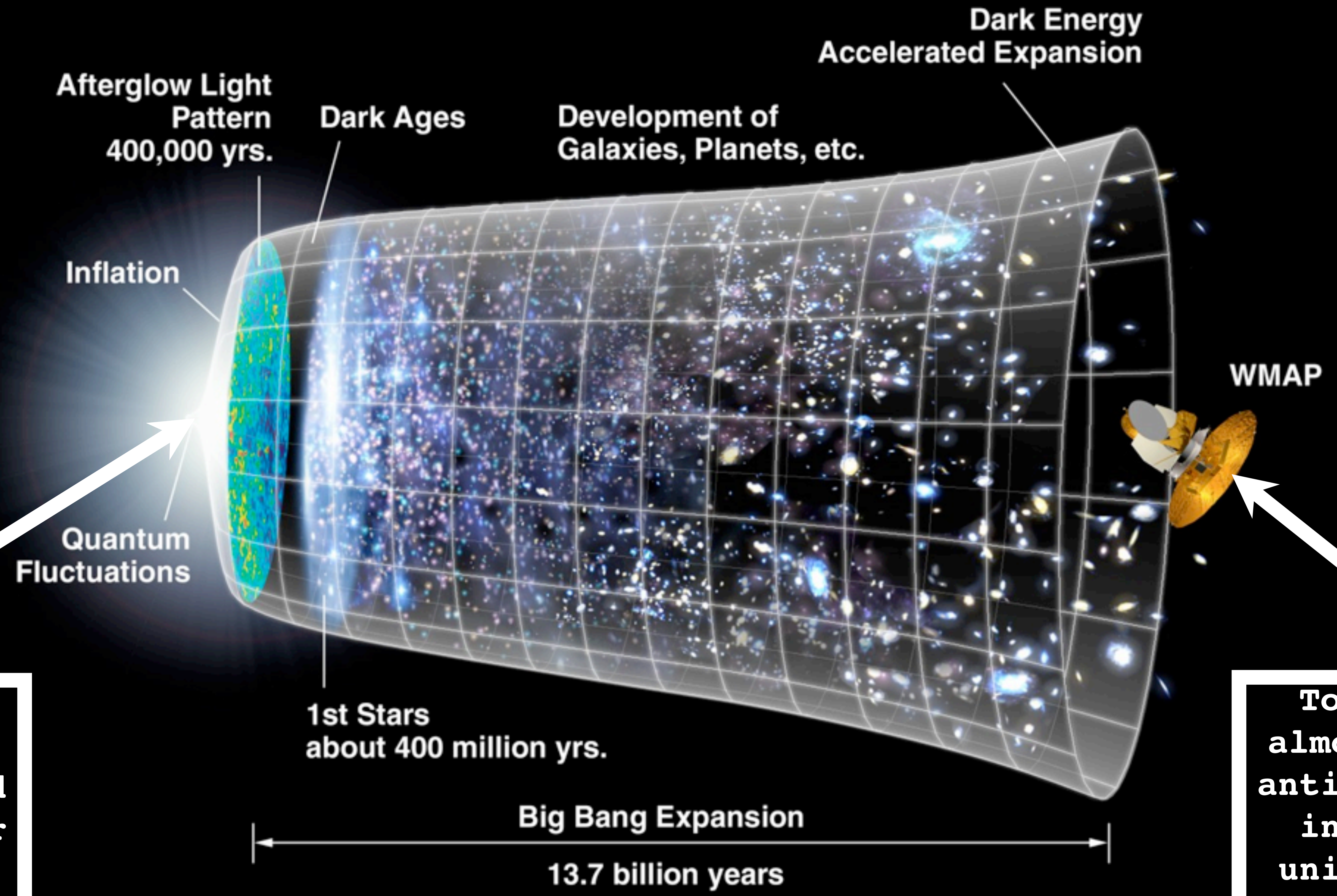


Equal amount of matter and antimatter created

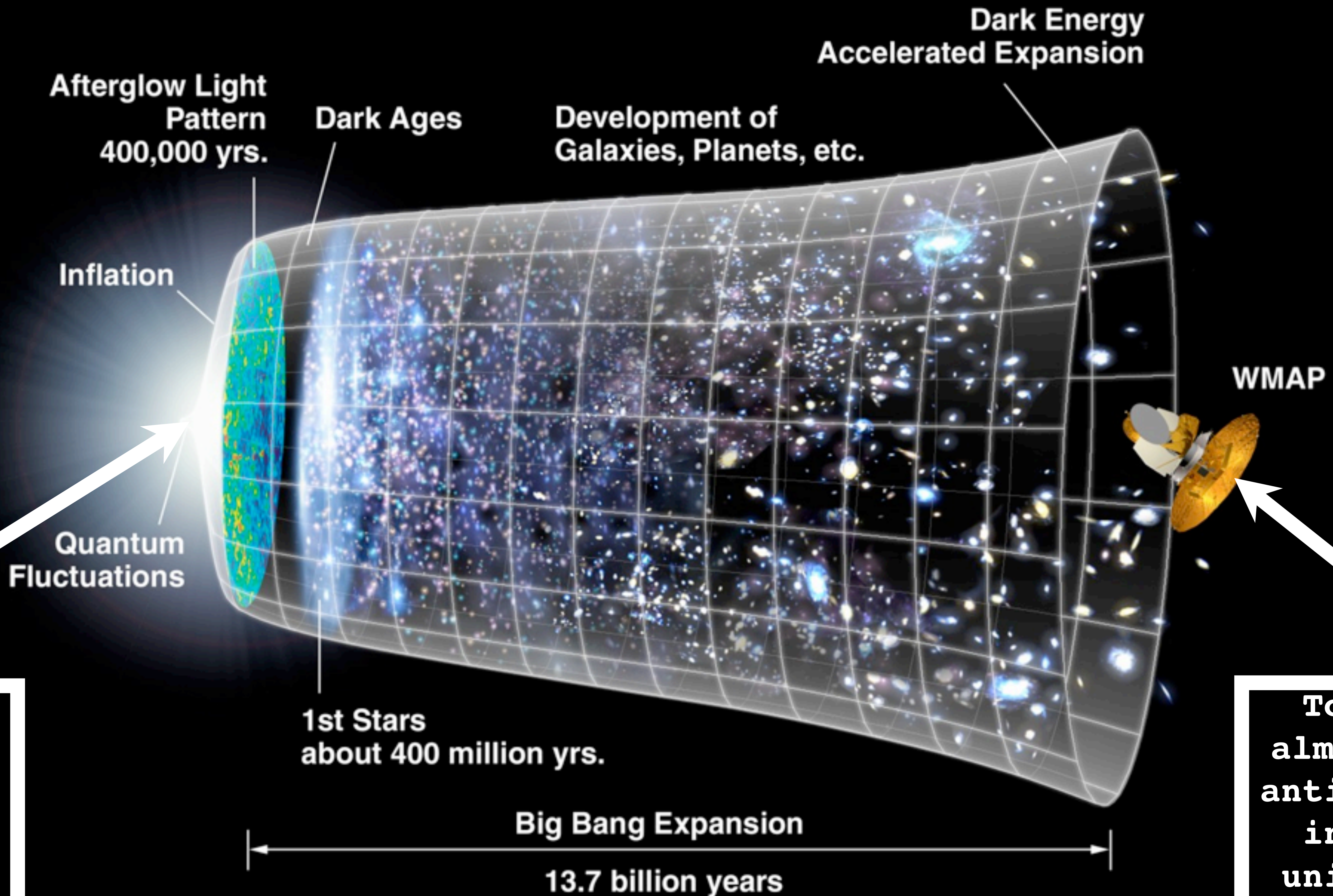
Why does antimatter matter?



Equal amount of matter and antimatter created

Today: almost no antimatter in the universe

Why does antimatter matter?

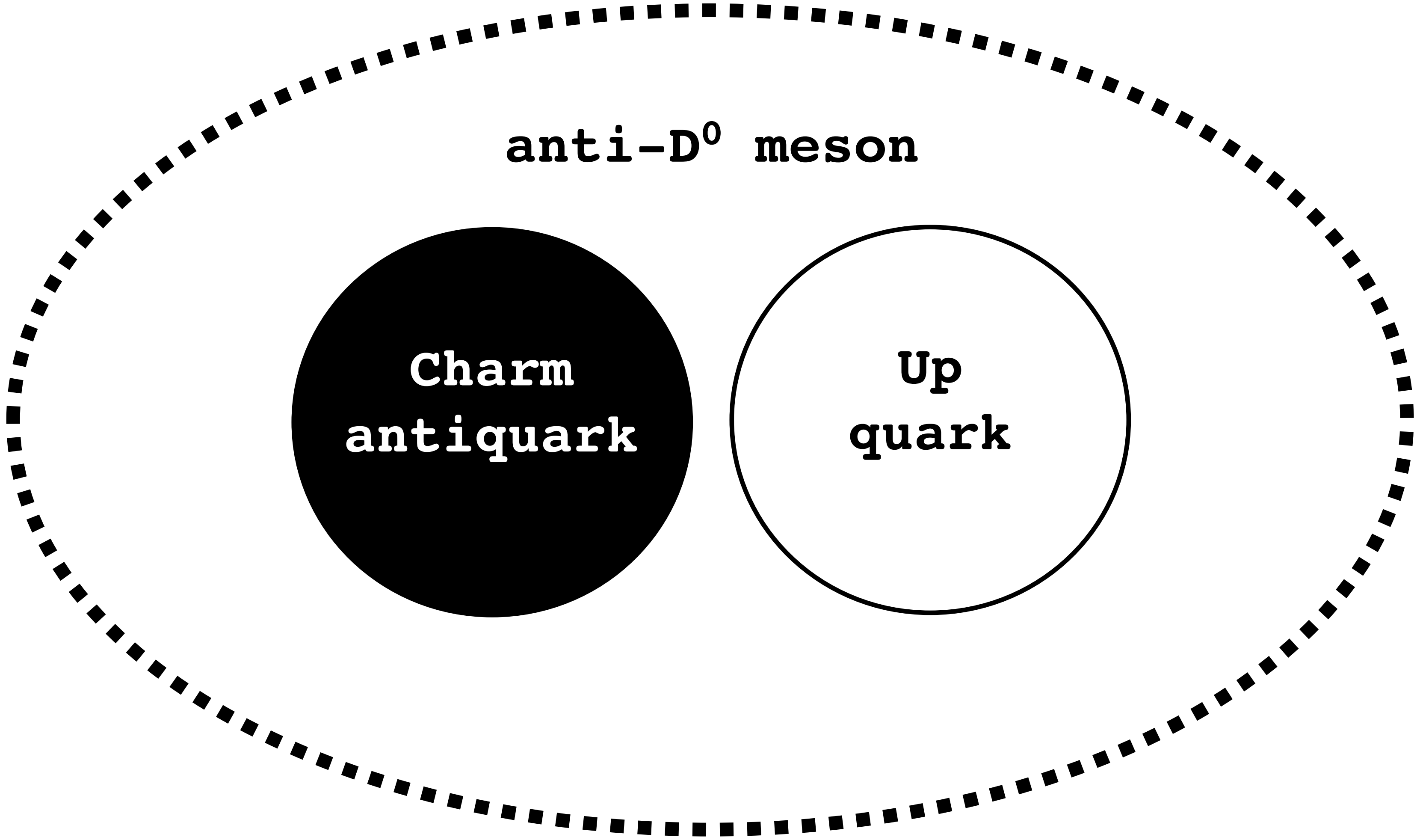


Equal amount of matter and antimatter created

Today: almost no antimatter in the universe

So where did all the antimatter go?

It oscillates!



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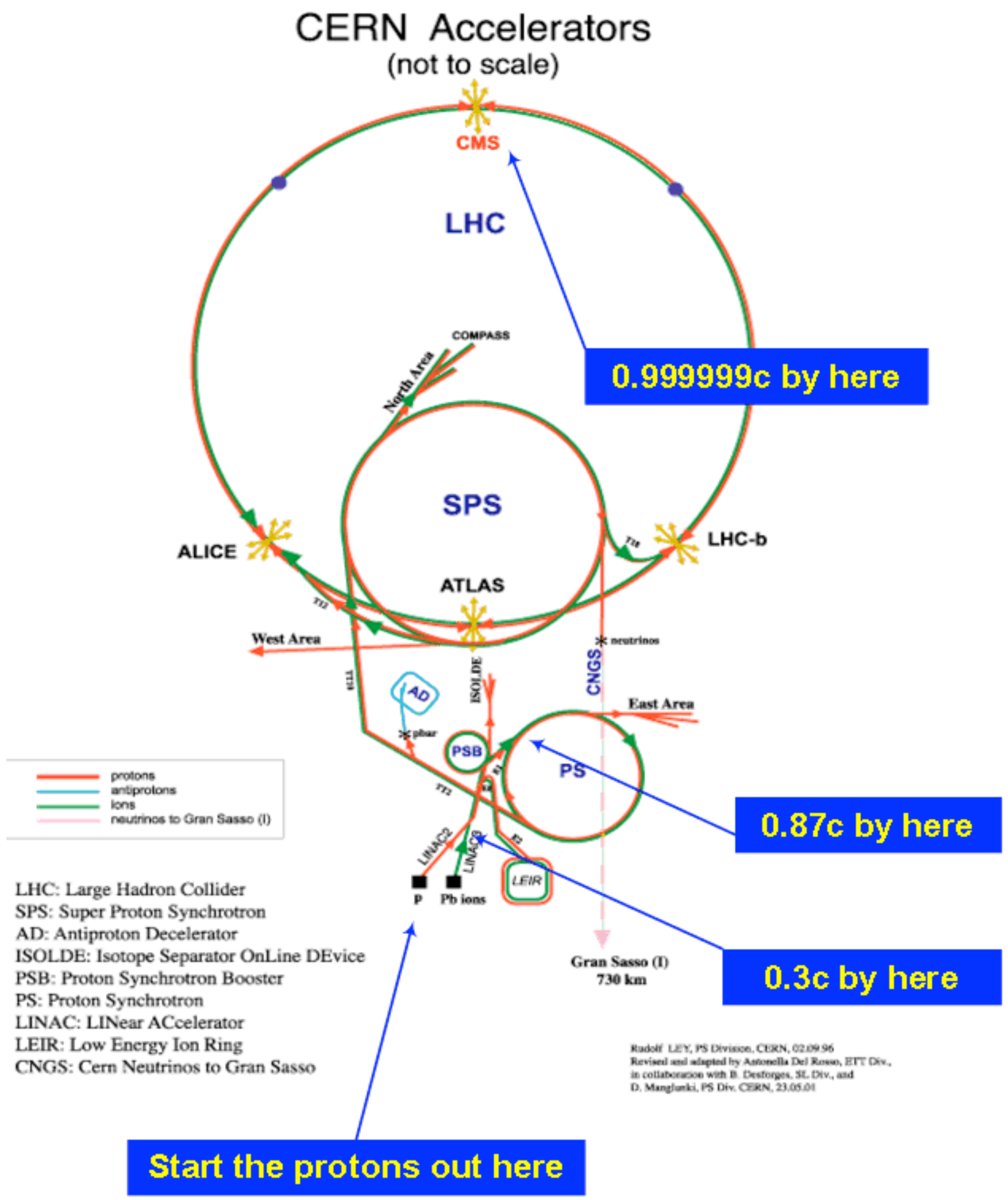
Such particles can give us insight into small differences between matter and antimatter.

Large hadron collider @ CERN



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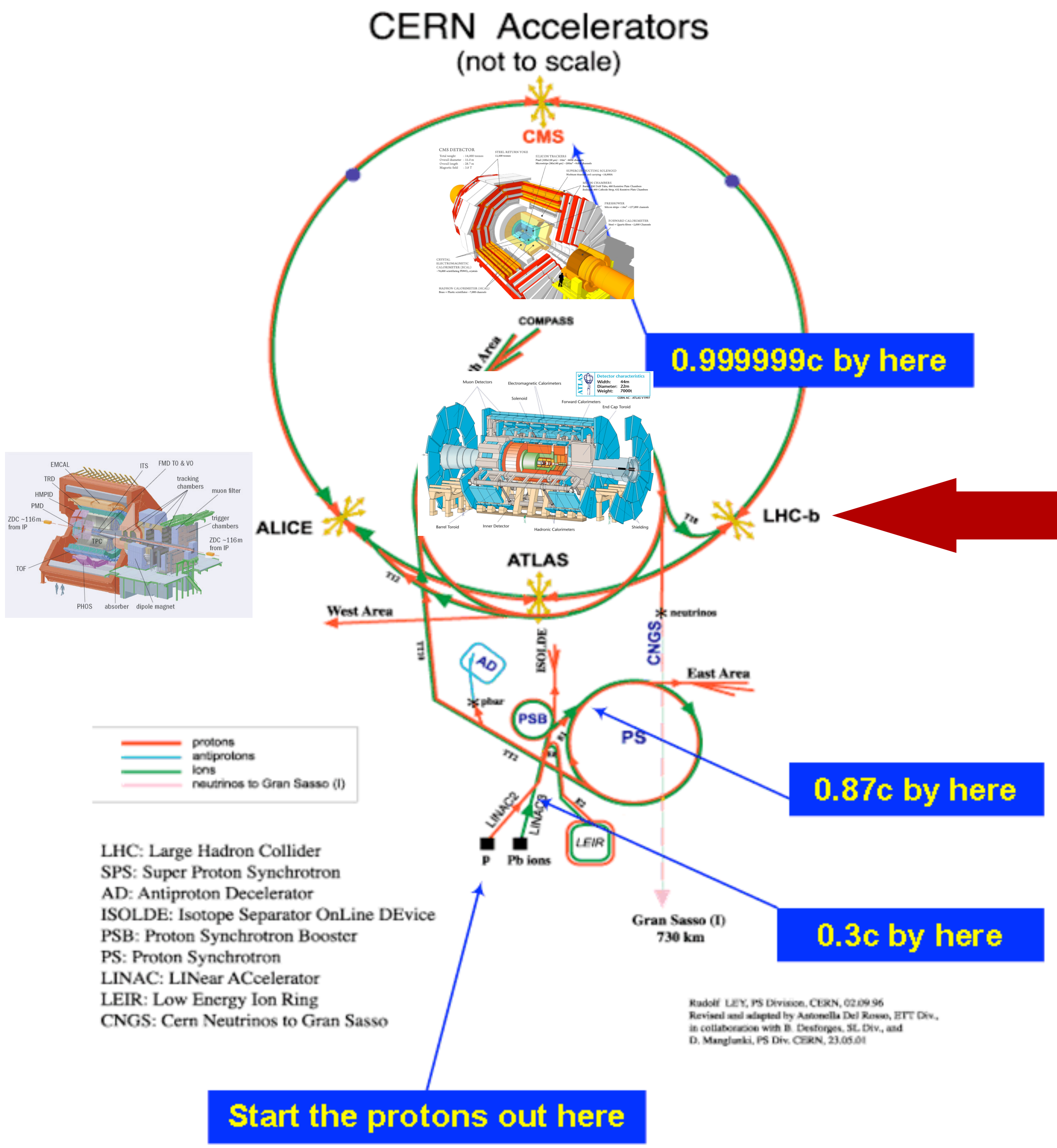
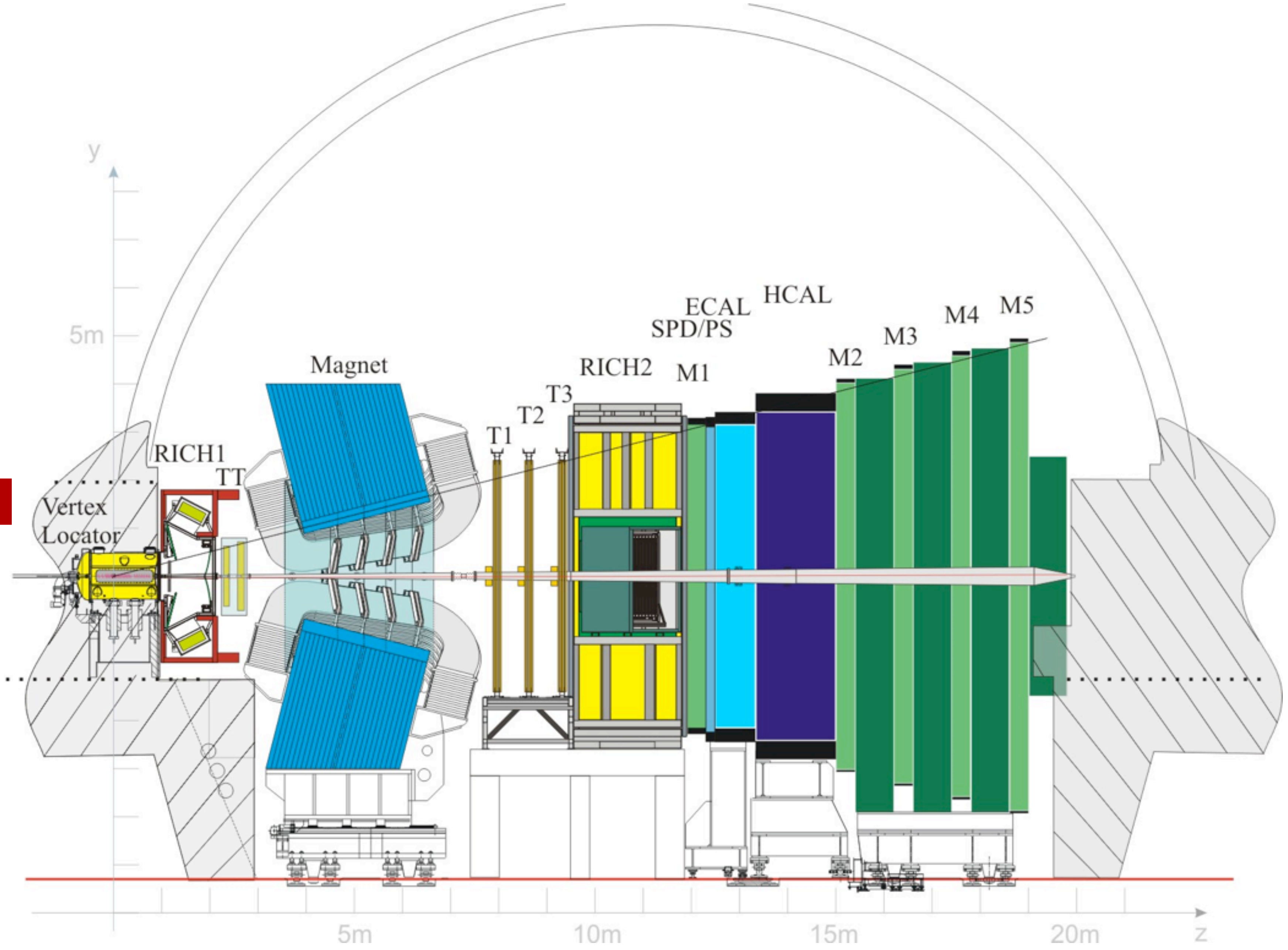
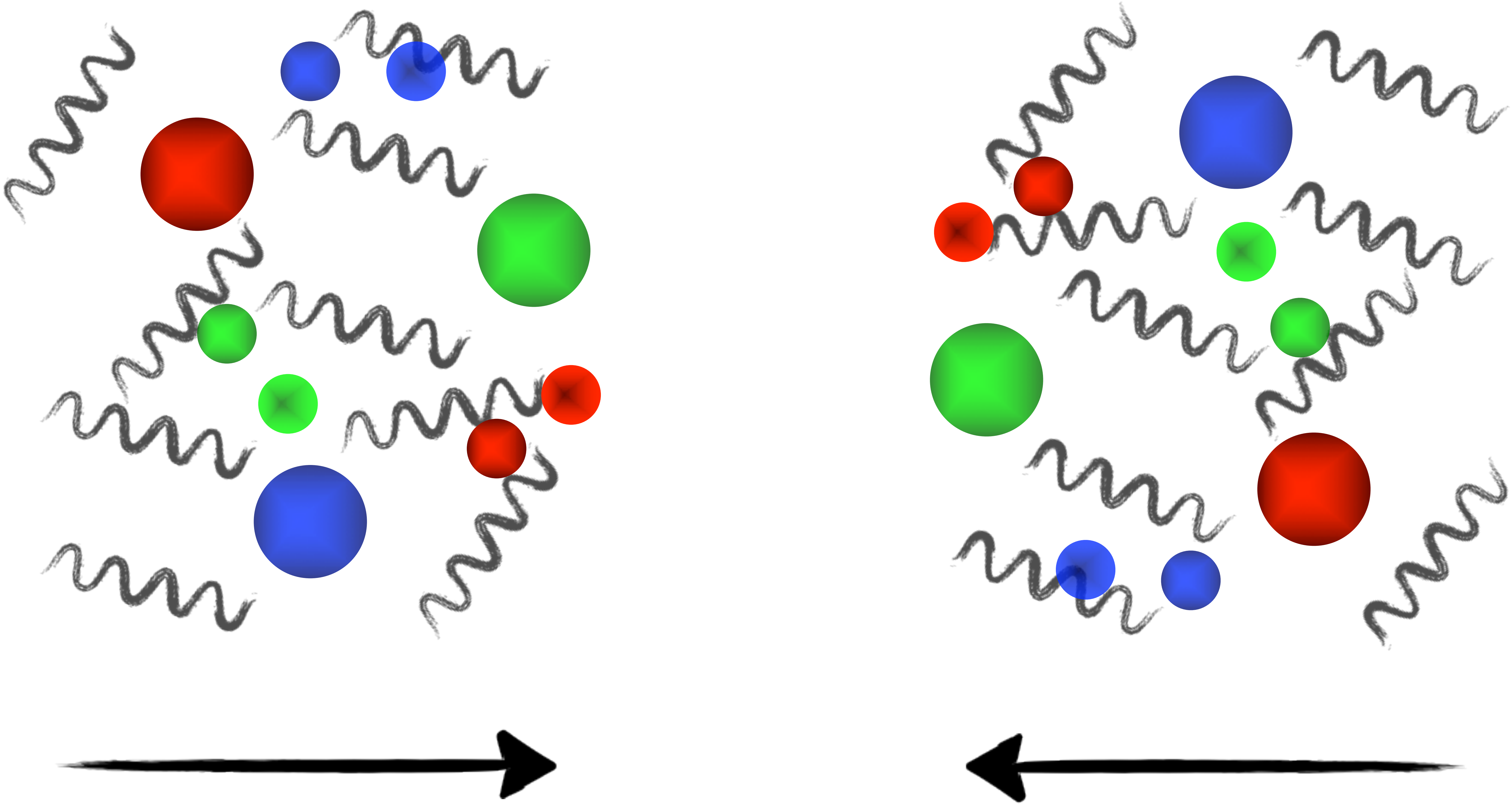




Protons colliding…



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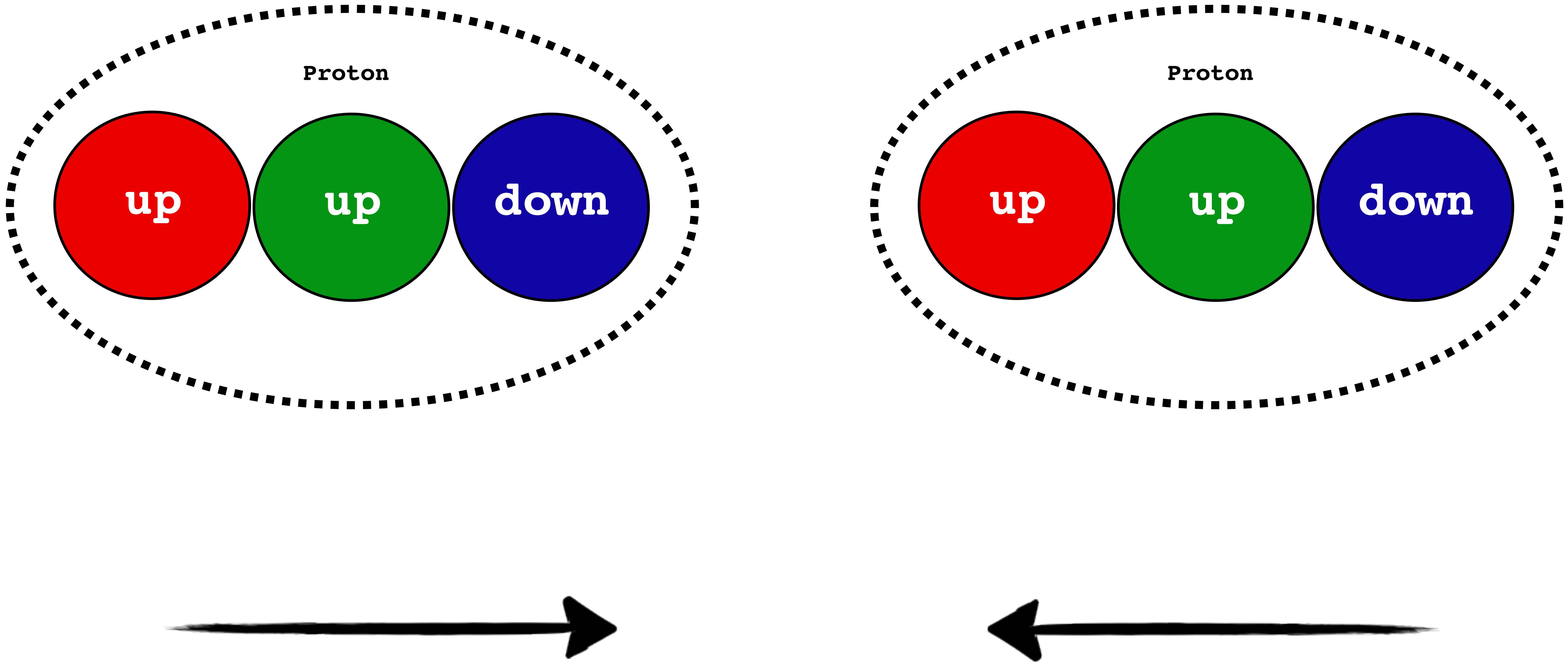

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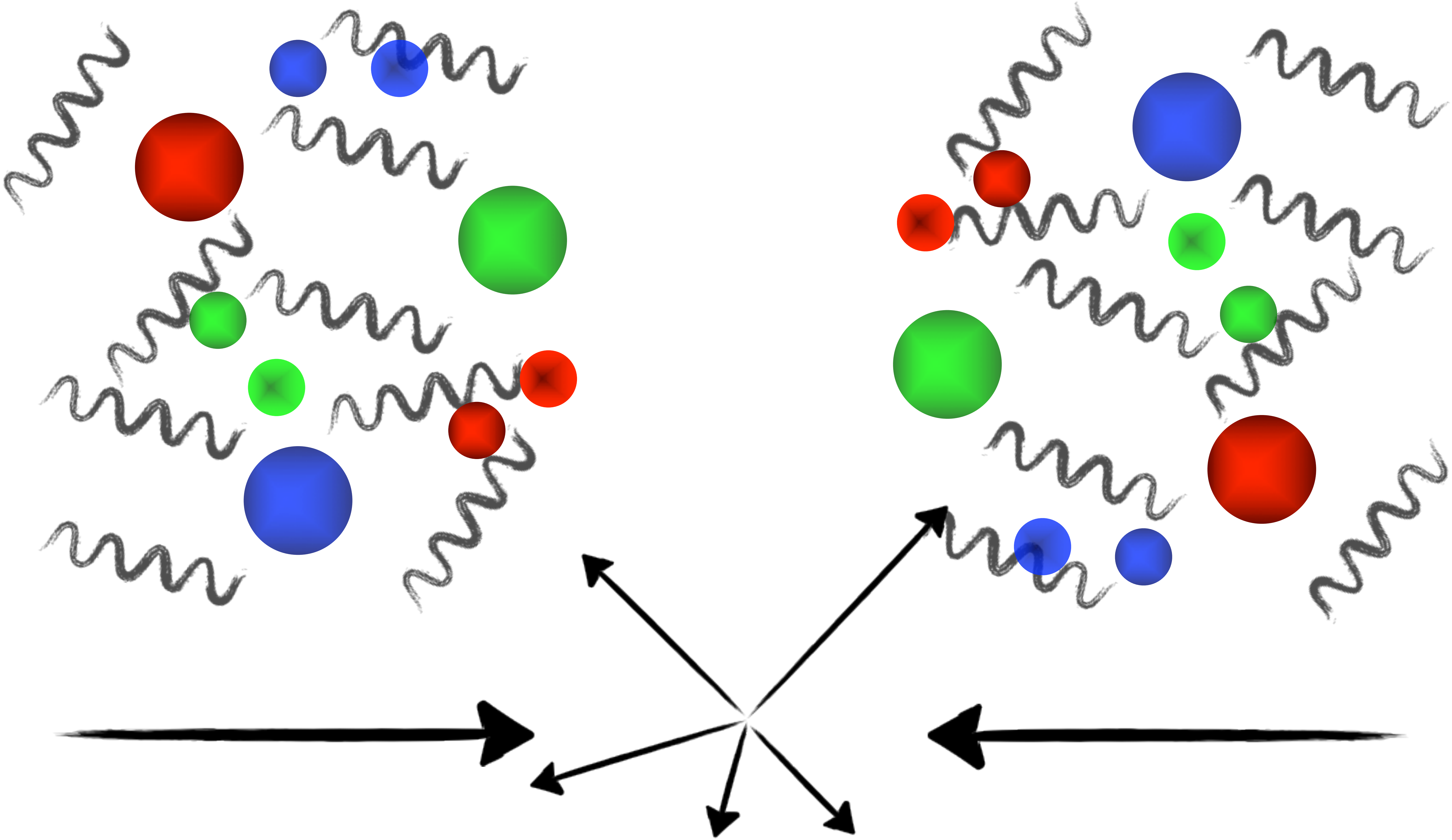

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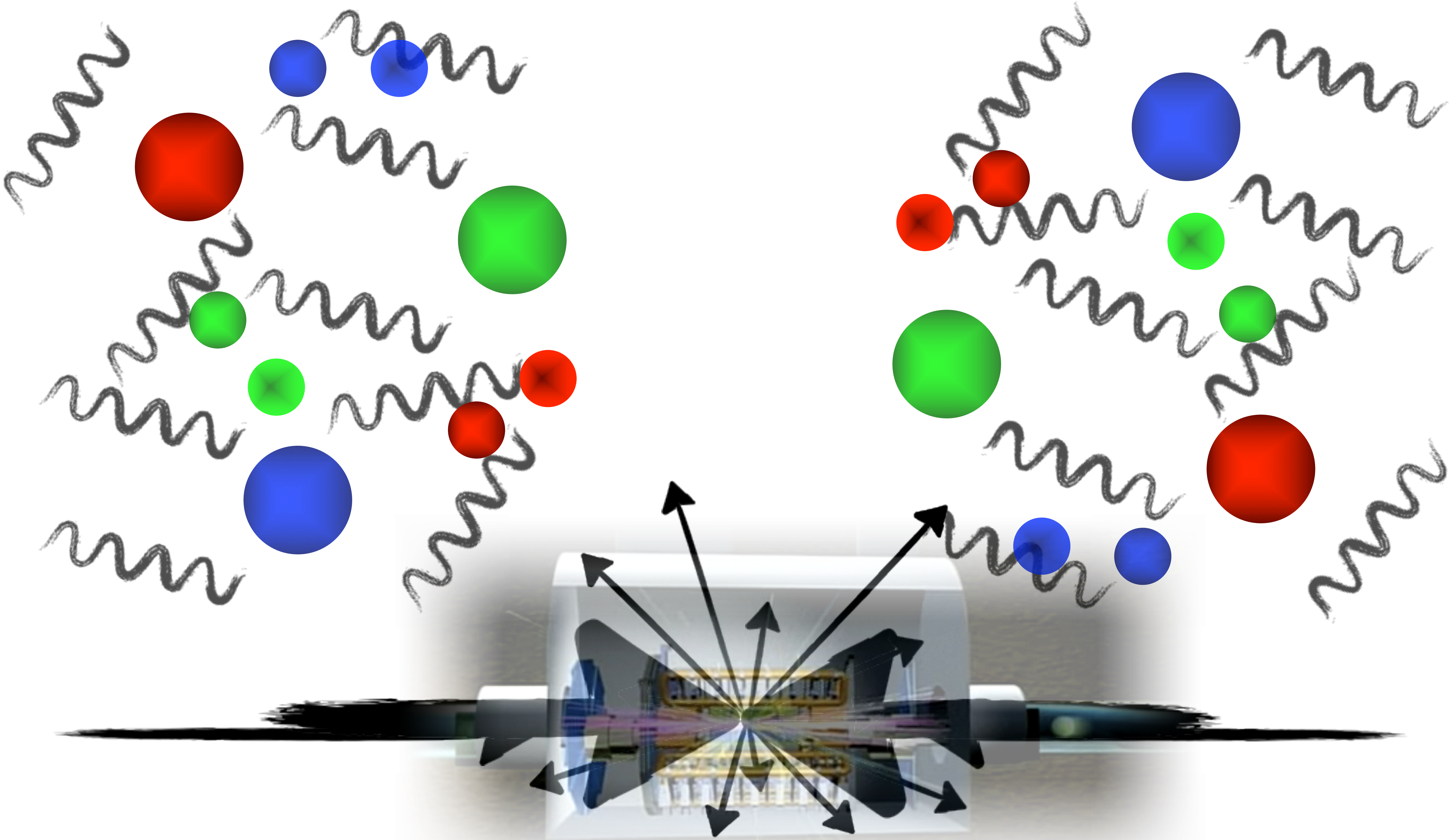
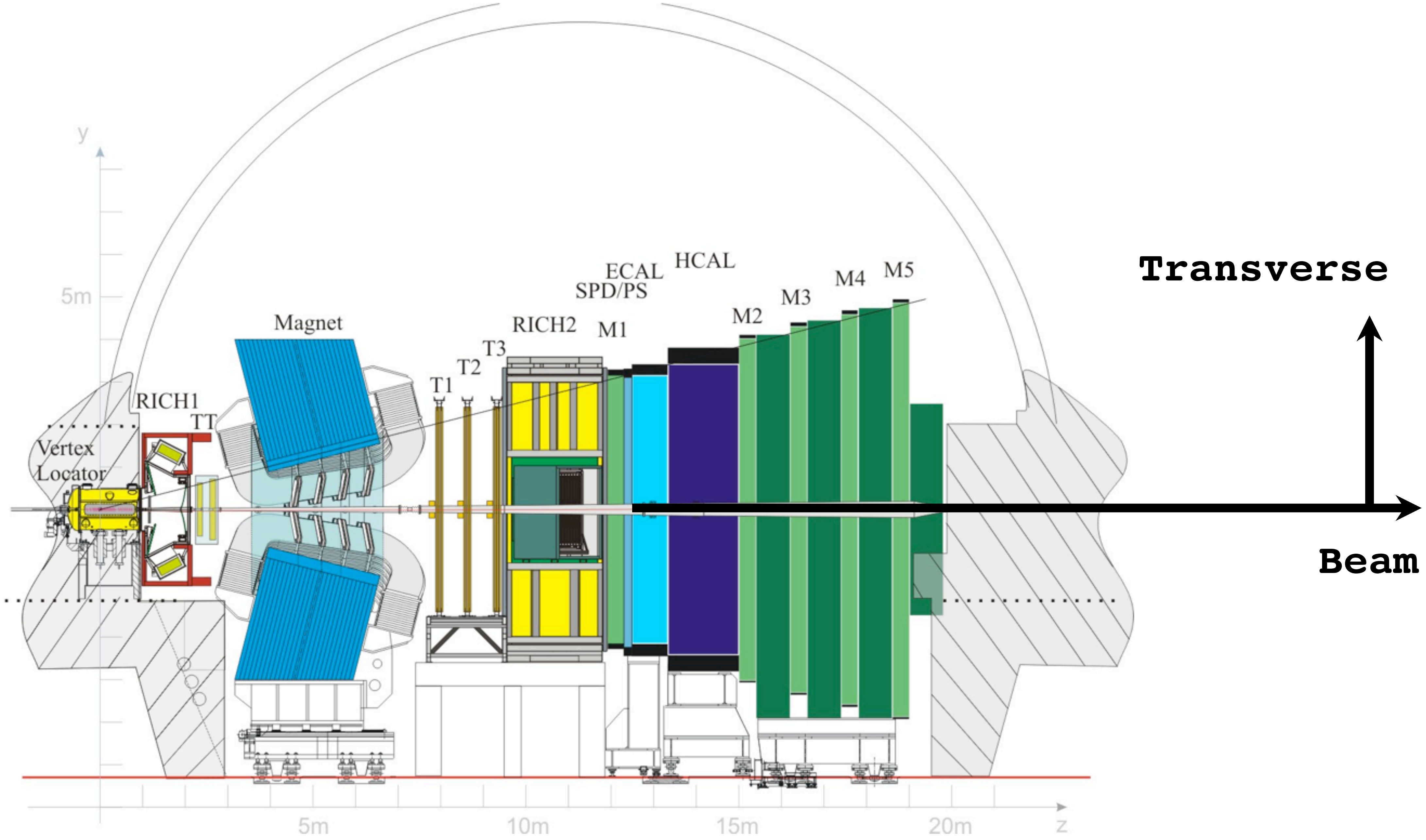


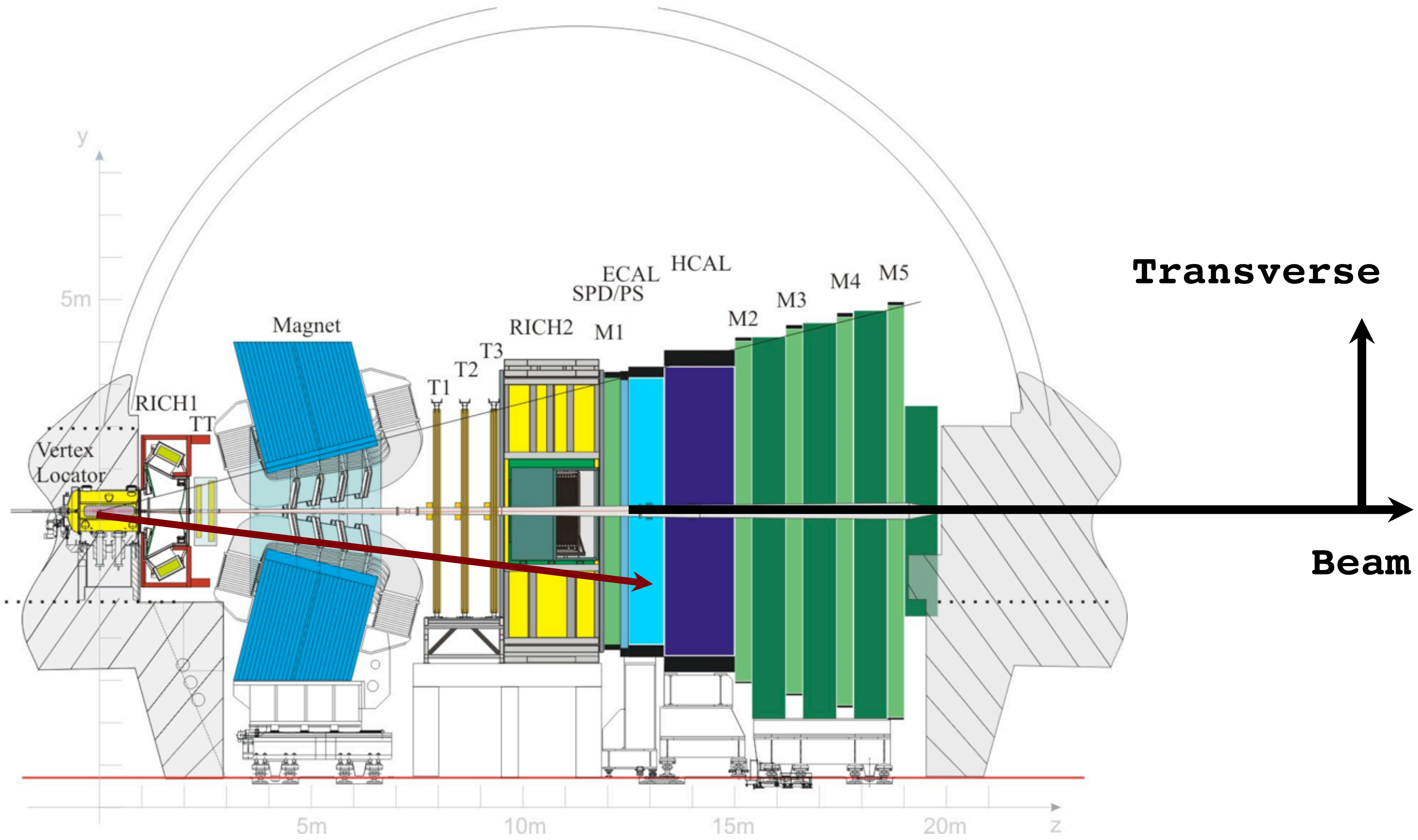
LHCb @ LHC



p_T = Transverse momentum
E_T = Transverse energy

LHCb @ LHC

- ELECTRONS
- PHOTONS



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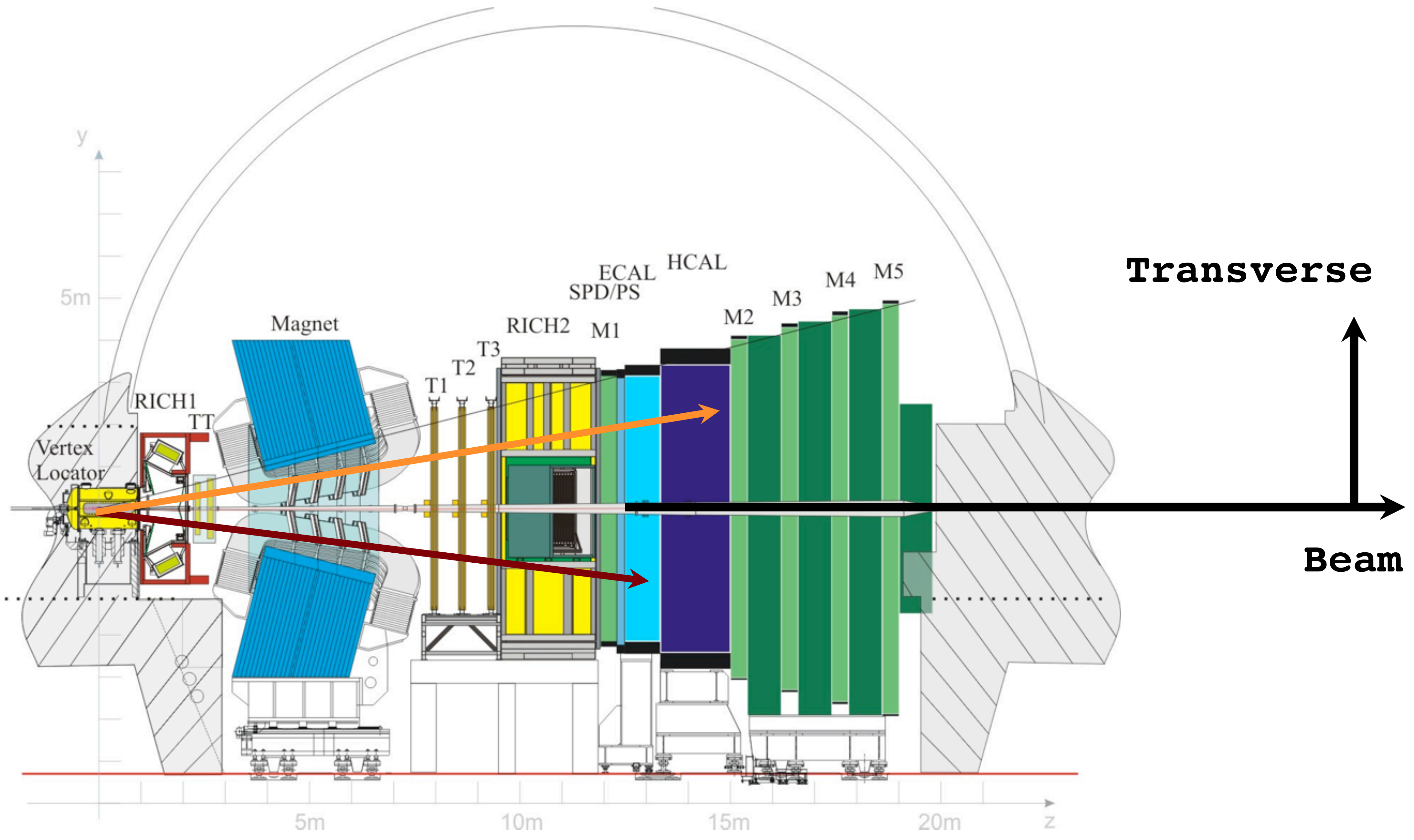
LHCb @ LHC

➡ ELECTRONS
➡ PHOTONS
➡ HADRONS



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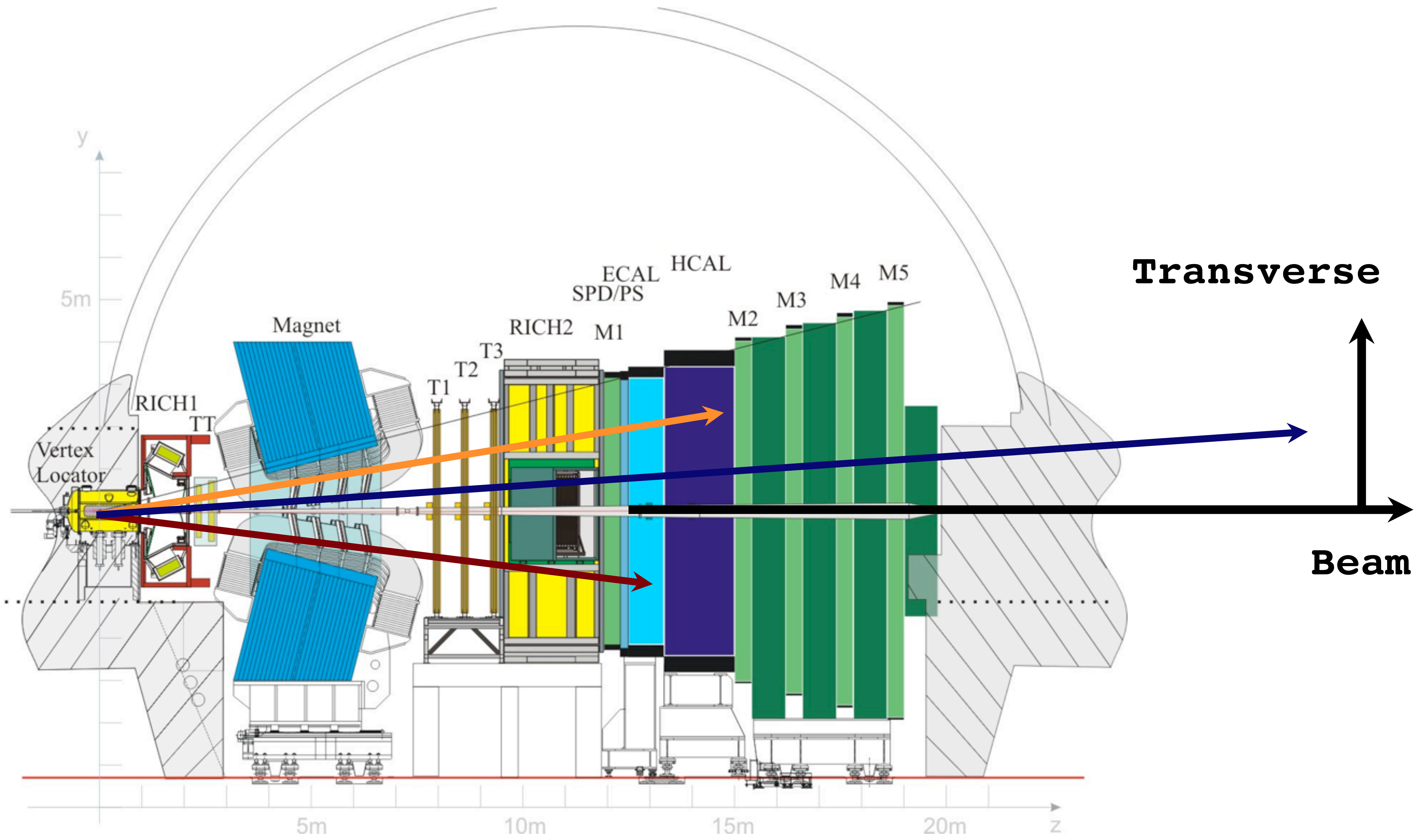
LHCb @ LHC

➡ **ELECTRONS**
➡ **PHOTONS**
➡ **HADRONS**
➡ **MUONS**



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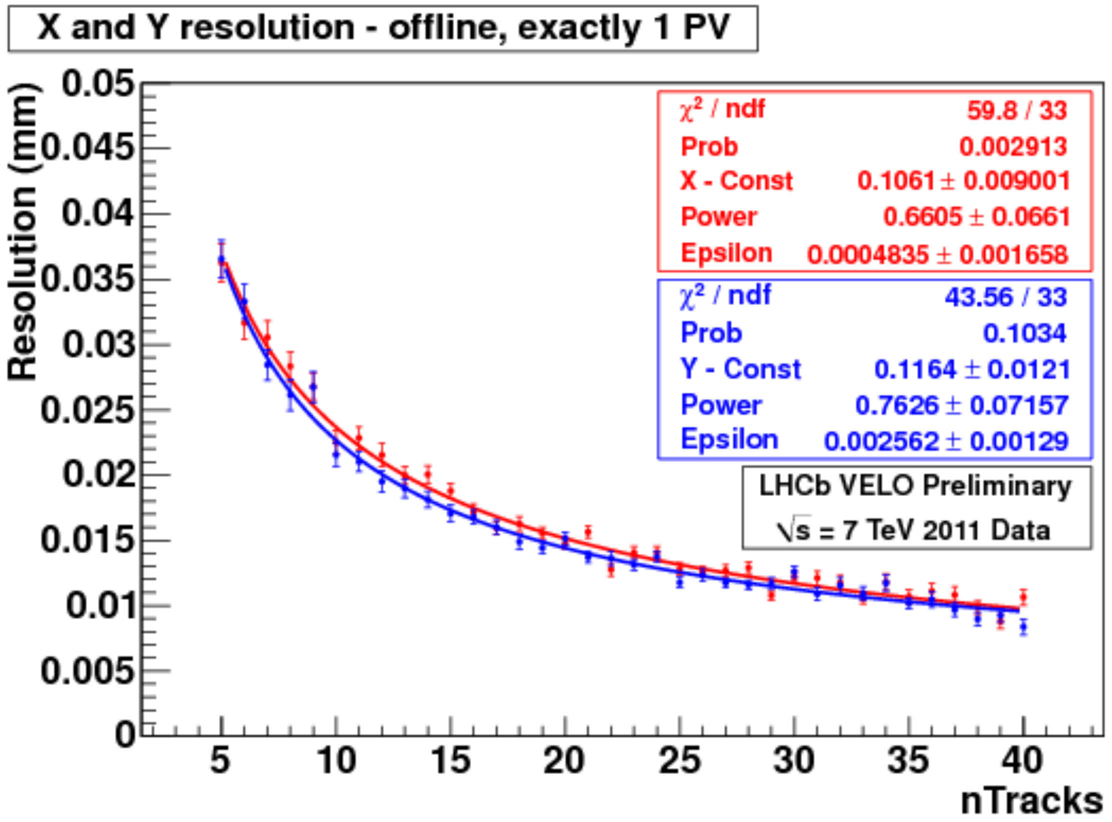
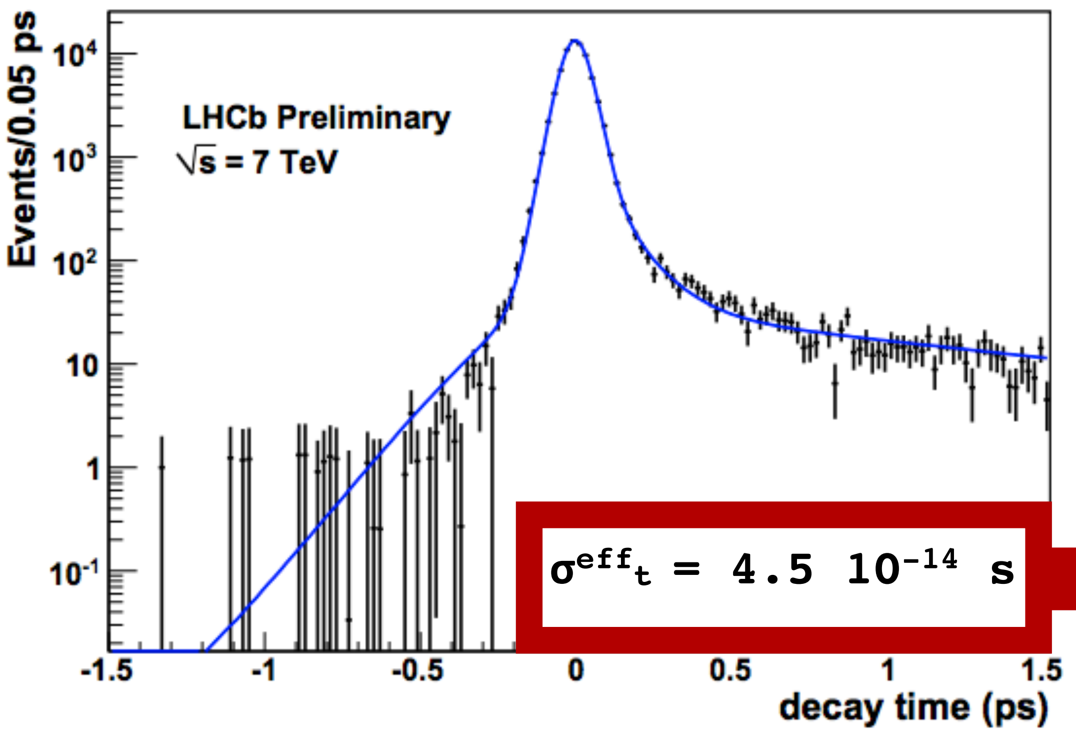
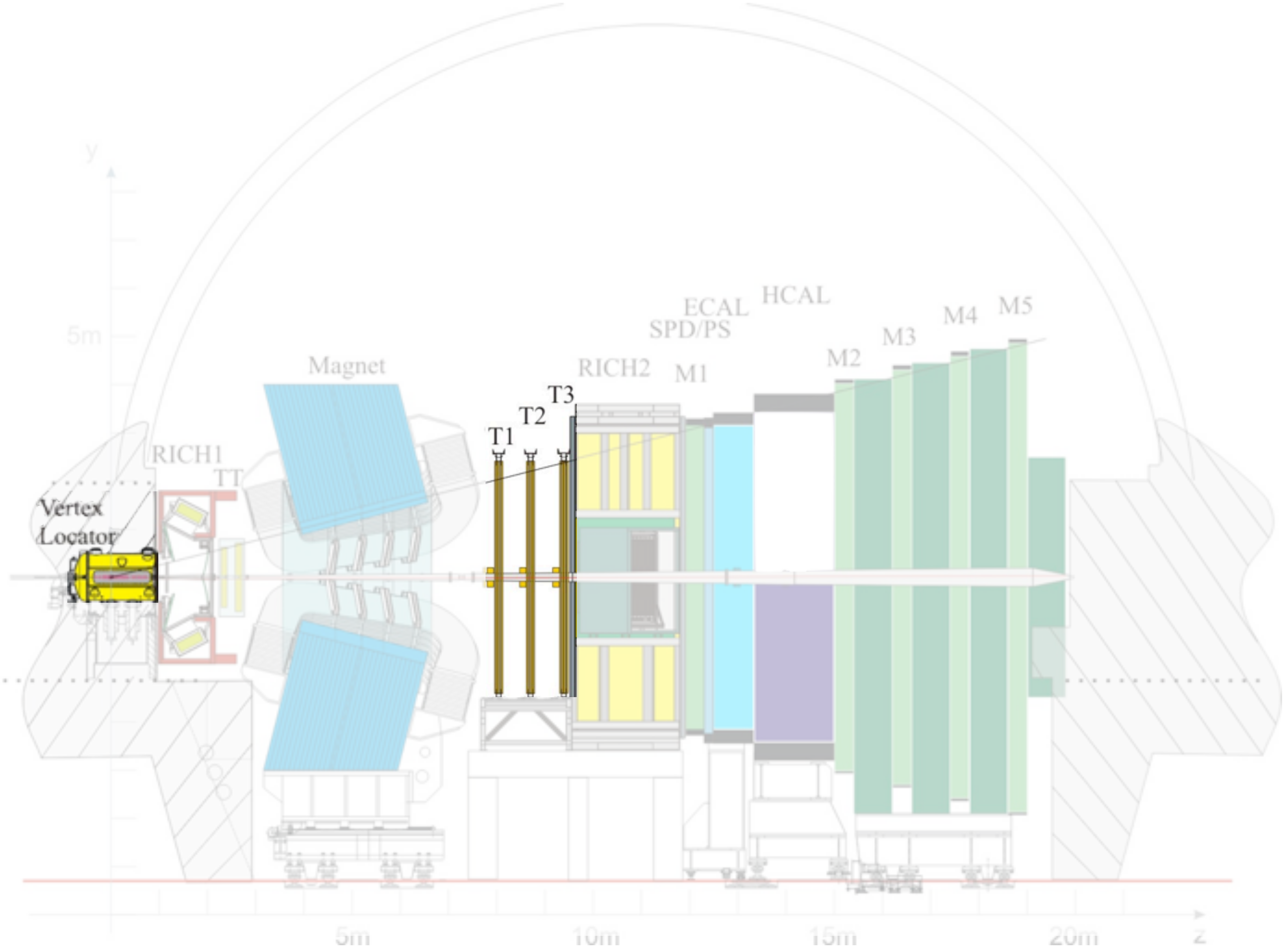
LHCb performance





σ^{eff}_{t} = 4.5 10^{-14} s



We can measure lifetimes down to a few times ~10^{-14} seconds...

Charm production @ LHC

10% of LHC interactions produce a charm hadron : LHCb has already collected more than 1 billion signal charm decays!

How sensitive is my measurement?

This is not an absolute rule but...

If you have no background and you have collected N signal events, then you can measure properties related to the signal production and decay (this includes the lifetime) with a relative precision of $(100/\sqrt{N})\%$

100	**events**	**means**	**10.0%**	**precision**
10000	**events**	**means**	**1.00%**	**precision**
1000000	**events**	**means**	**0.10%**	**precision**
100000000	**events**	**means**	**0.01%**	**precision**

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100000000	events means 0.01% precision

LHCb IS HERE

Value (10^{-15} s)	EVTS	Document ID
$(41.01 \pm 0.15) \times 10^{1}$	OUR AVERAGE	
$409.6 \pm 1.1 \pm 1.5$	210k	LINK

WORLD PRECISION IS 0.35%

So we can't give you the full dataset to use!

The object of the exercise

The purpose of this exercise is to

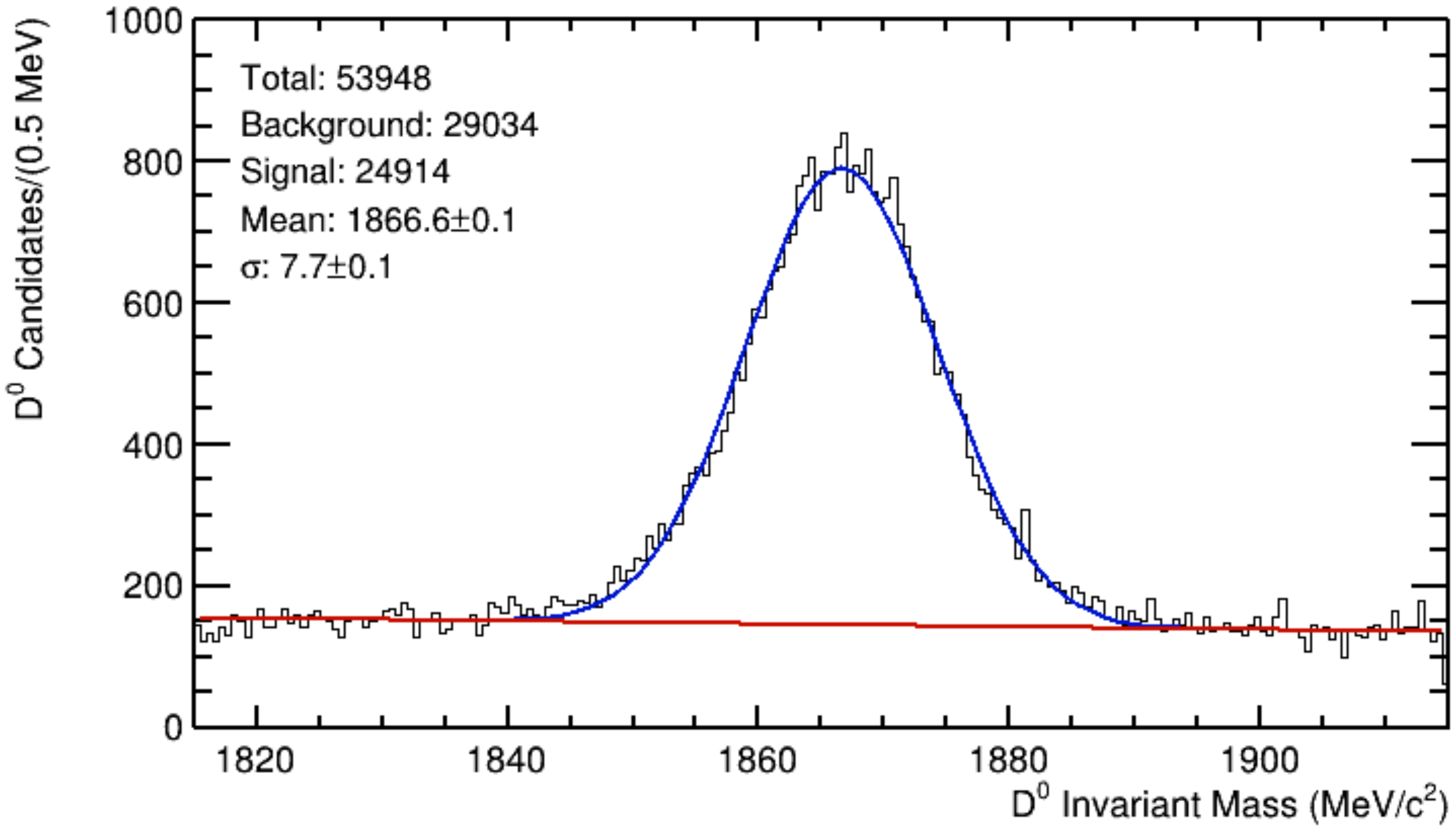
Give you a look at the data coming out of the LHC

Teach you about selecting particles in the LHC data

Teach you about fitting functions to the data in order to measure the signal properties

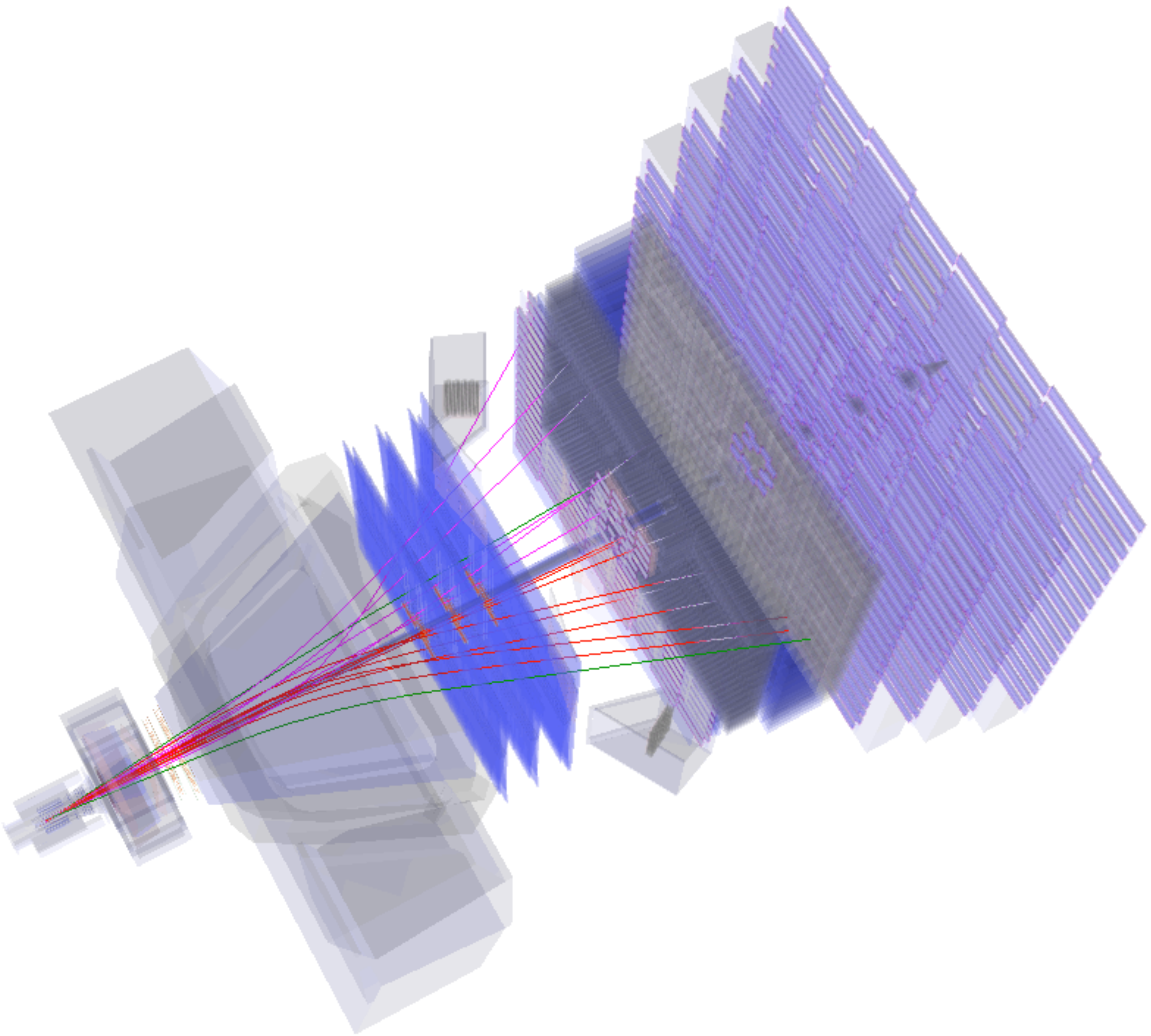
Teach you about systematic uncertainties in measurements

Data for exercise



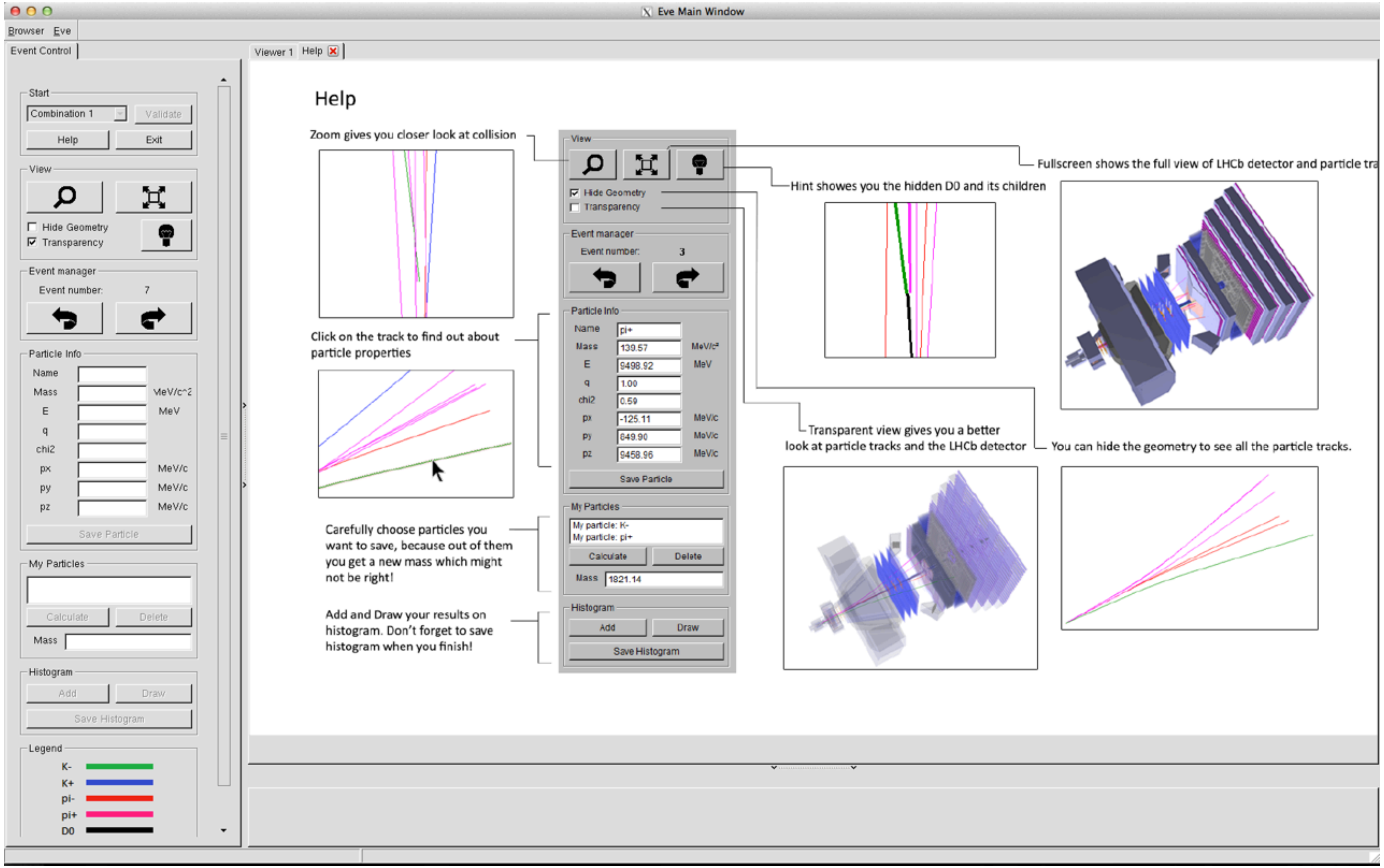
Use $D^0 \rightarrow K\pi$ events from 2012 datataking, starting mass distribution above.

Event display

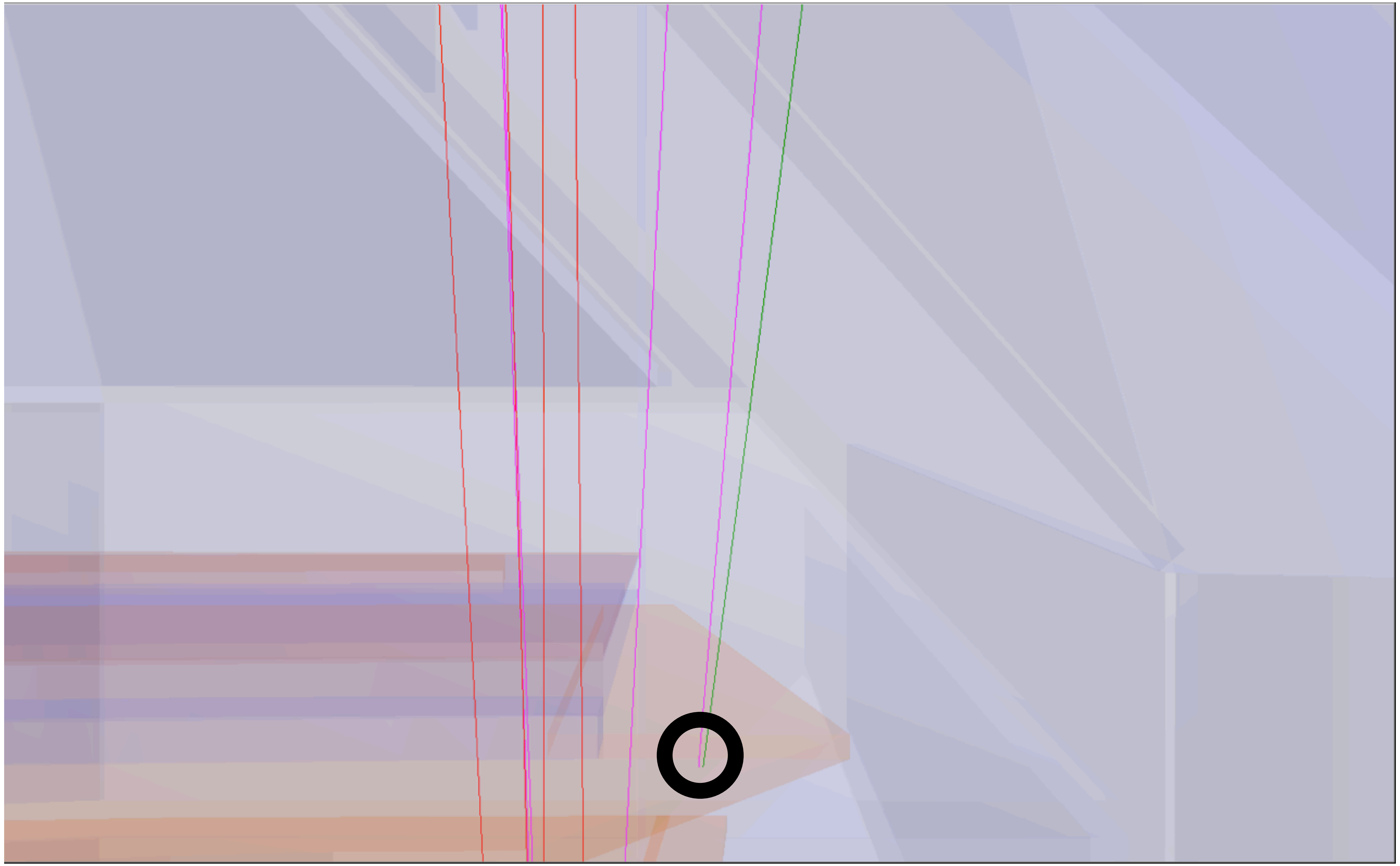


Because LHCb is a forward spectrometer with a dipole magnet, it is hard to do visual exercises looking at the full detector. Hence we zoom in around the interaction region for you to find displaced vertices.

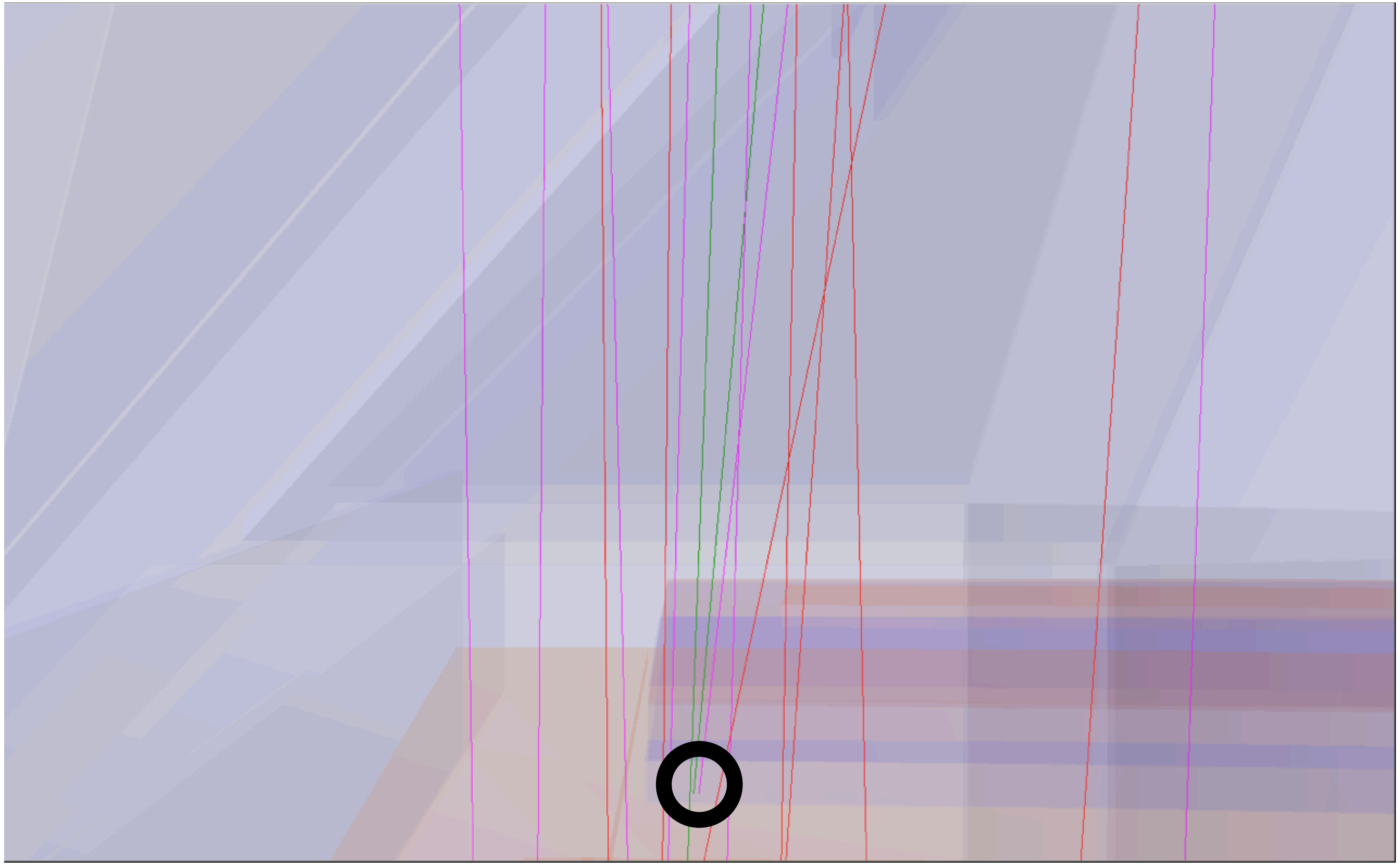
The visual analysis framework



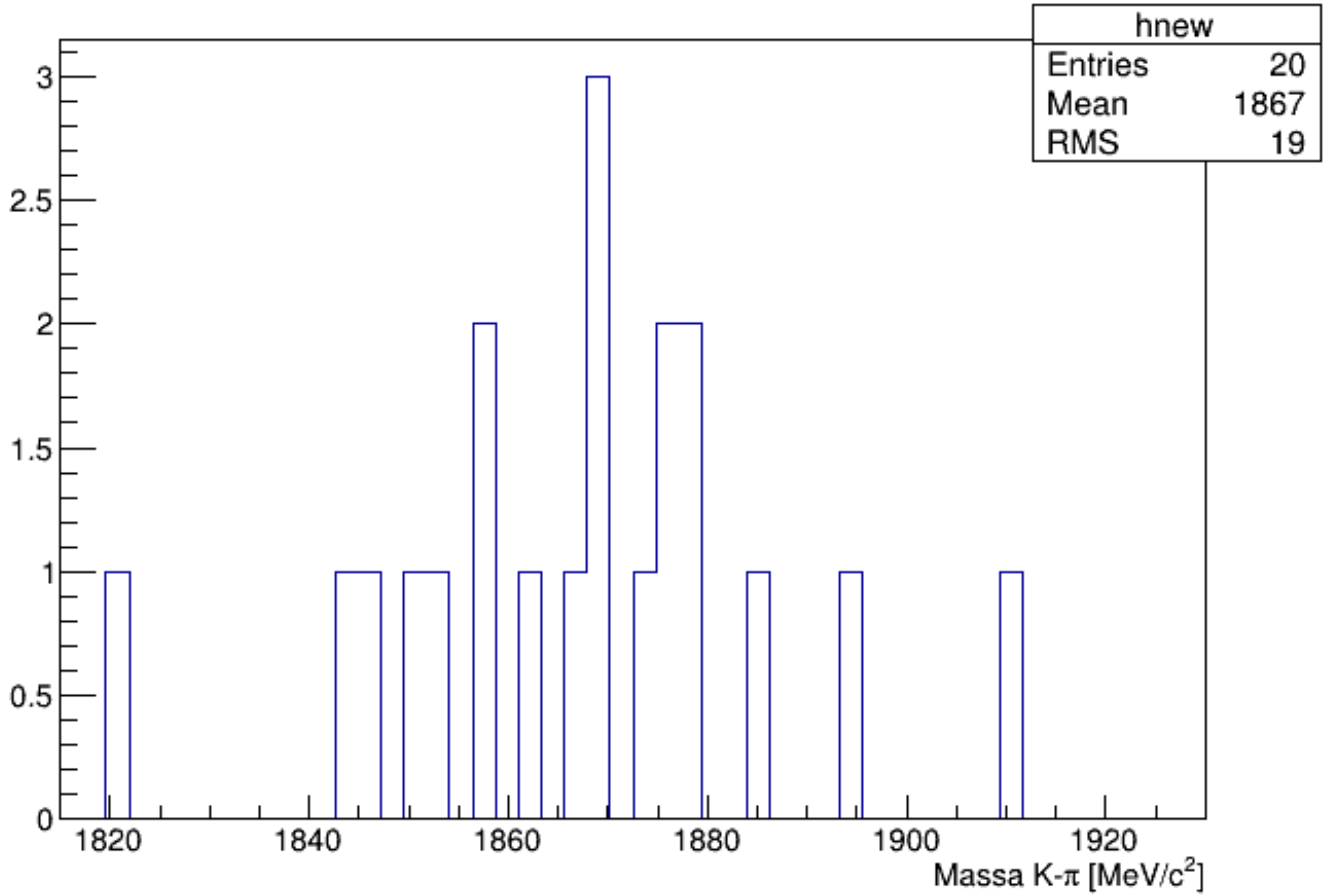
An “easy” event



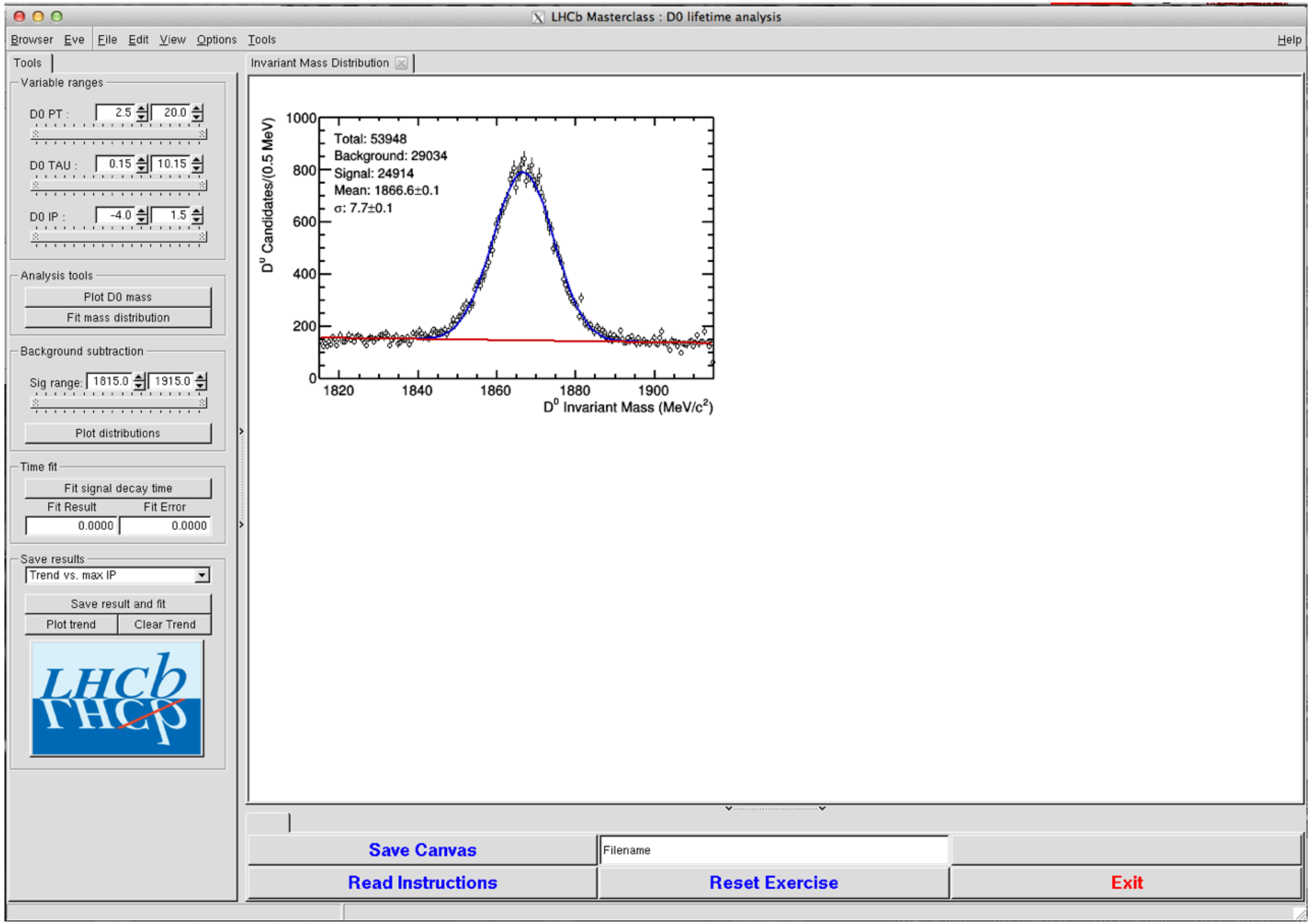
A “harder” event



An example histogram

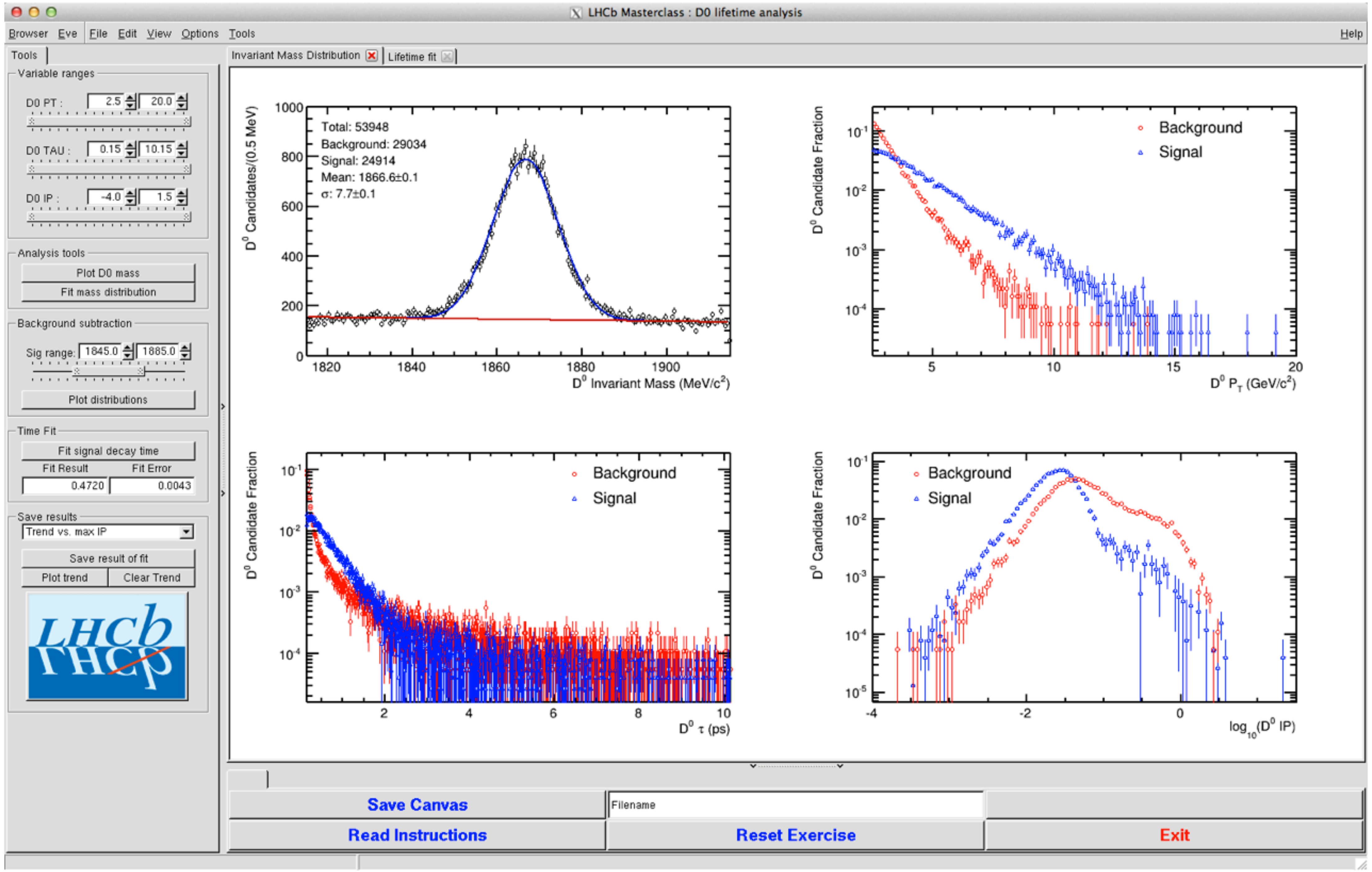


Fitting the mass



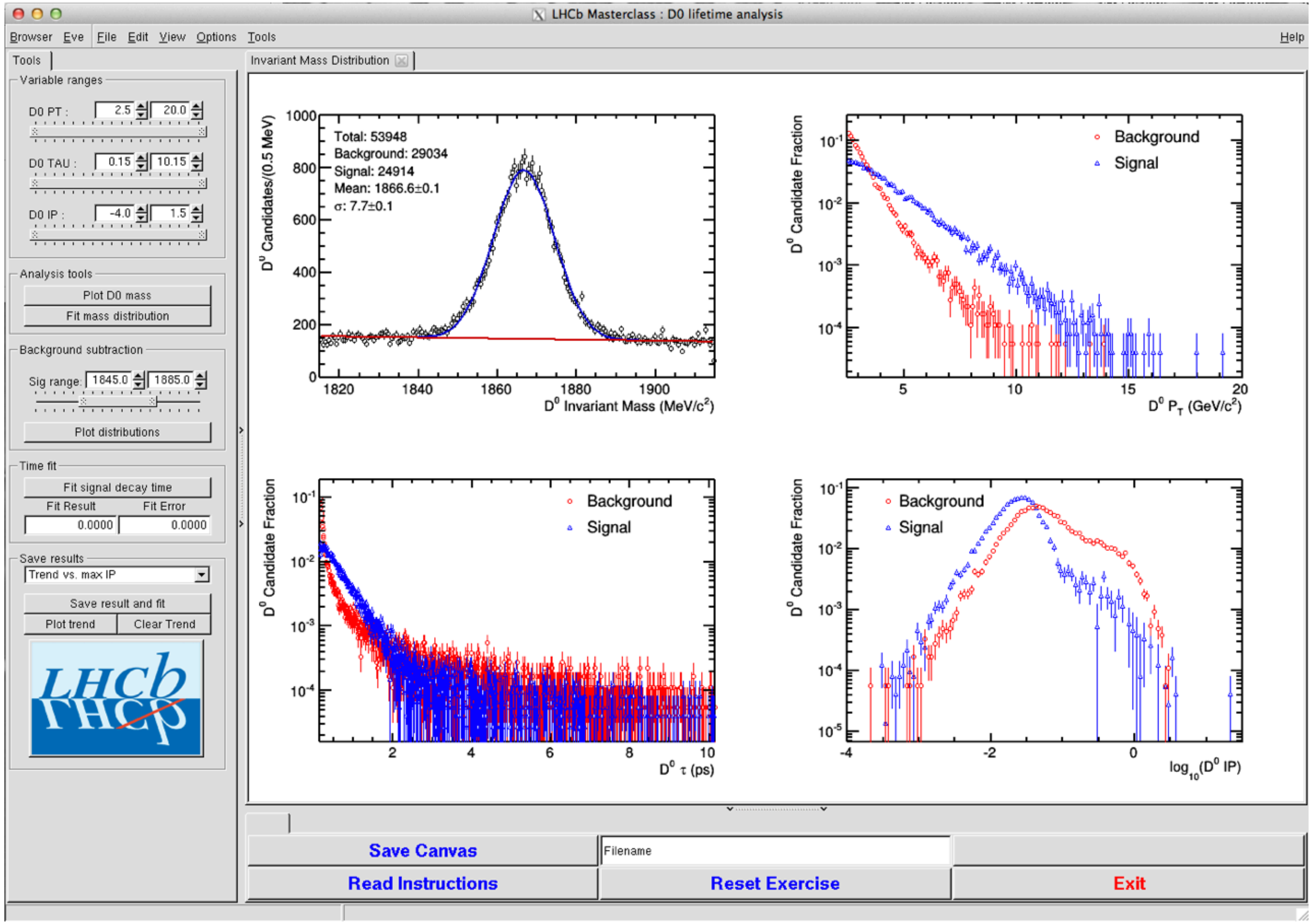
Your first task is to fit functions to signal and background

Fitting the lifetime



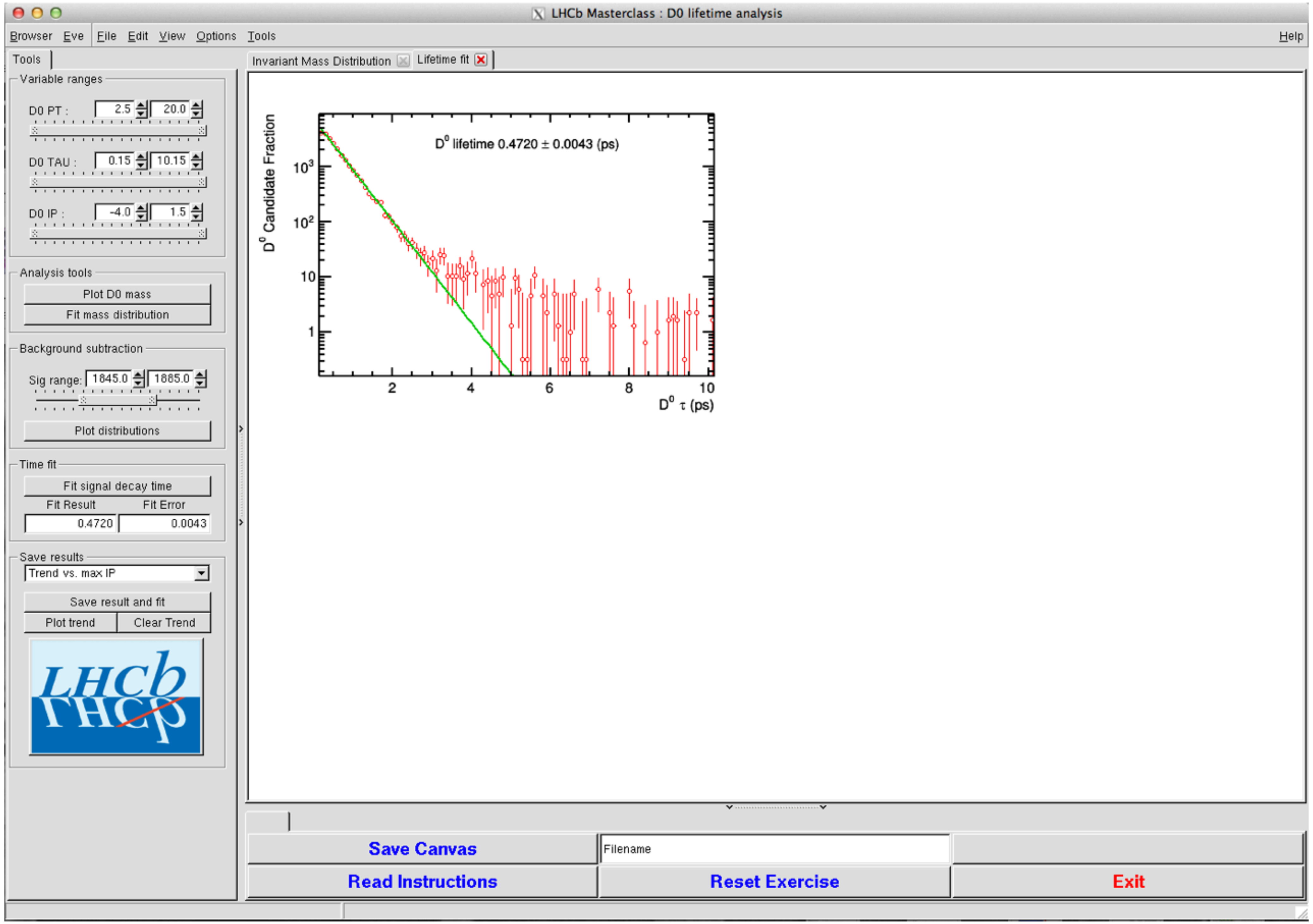
Once you finish looking for the events, you will get a bigger collection of data to use in order to measure the lifetime.

Plotting the distributions



Now use that fit to plot the distributions of background and signal events in the other physical parameters

Plotting the distributions



And fit the lifetime! Does your result agree with slide 38?