

Lecture I

Master Particle Physics I

Marcel Merk

September 5, 2011

Lectures PP I

L0 : Introduction

L1 : Particles and Fields (historical overview)
L2 : Wave Equations and Antiparticles
L3 : The Electromagnetic Field
L4 : Perturbation Theory and Fermi's Golden Rule
L5 : Electromagnetic Scattering of Spinless Particles

QED of Spinless Particles:
Scattering Theory and
Cross Sections

L6 : The Dirac Equation
L7 : Solutions of the Dirac Equation
L8 : Spin 1/2 Electrodynamics

QED for
Fundamental Fermions

L9 : The Weak Interaction
(Fermi 4-point scattering: an analogy with QED)
L10: Local Gauge Invariance
(the role of symmetries in interactions)
L11: Electroweak Theory
L12: The Process: $e^+e^- \rightarrow \gamma, Z \rightarrow \mu^+\mu^-$

The Standard Model for
massless particles
 $SU(2)_L \times U(1)_Y$

Nikhef

OCW

Ministry of Education Culture and Science

Minister: **Marja van Bijsterveld-Vliegenthart**

Staatssecretaris: Halbe Zijlstra

NWO

Dutch organisation for Scientific Research

Voorzitter algemeen bestuur: **Jos Engelen**

General director: Hans de Groene

- * Aard- en levenswetenschappen (ALW)
- * Chemische wetenschappen (CW)
- * Exacte wetenschappen (EW)
- * Geesteswetenschappen (GW)
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- * **Natuurkunde (N)**
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FOM

Foundation for Fundamental Research of Matter

Director: Wim van Saarloos

Institutes:

- Rijnhuizen: Plasma physics
director: Gerard Meijer
- Amolf: Atomic and Molecular Physics
director: Albert Polman
- **Nikhef: Dutch Institute for Particle Physics**
director: **Frank Linde**
- KVI: Nuclear Physics (closed)
director: Klaus Jungmann

Universities

Nijmegen: RU Sijbrand de Jong

Utrecht: UU Thomas Peitzmann

Amsterdam: VU Jo van den Brand
 UvA Stan Bentvelsen

+...Groningen, Twente, Leiden, Eindhoven...

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Nikhef

Collaboration:

Nikhef institute + 4 Universities

Real basis for all particle physics
in the Netherlands

Director: **Frank Linde**

LHC:

Atlas: Stan Bentvelsen

LHCb: Marcel Merk

Alice: Thomas Peitzmann

Astroparticle Physics:

Antares: Maarten de Jong

Auger: Charles Timmermans

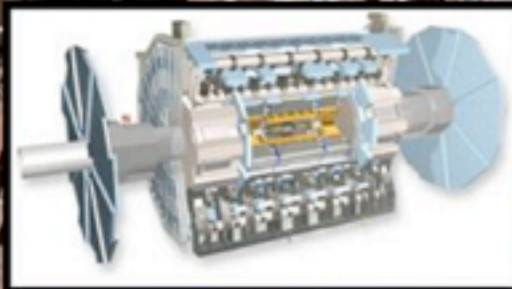
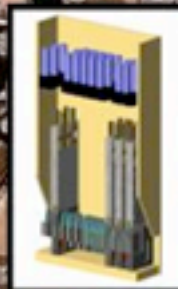
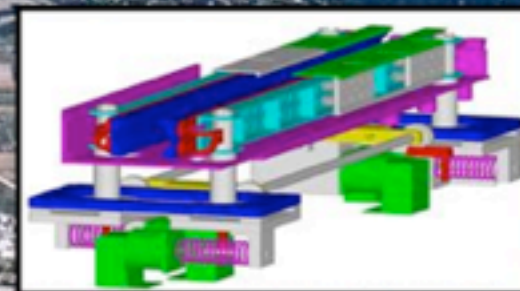
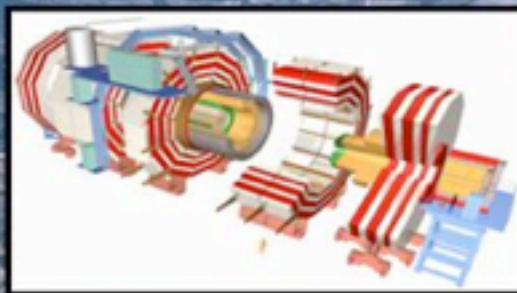
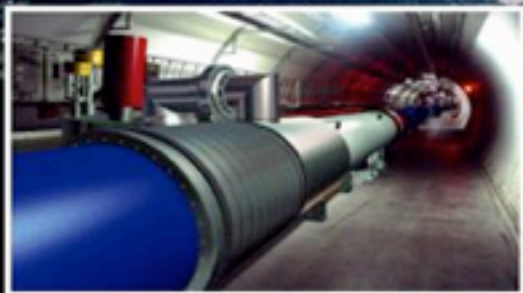
Grav Waves: Jo van den Brand

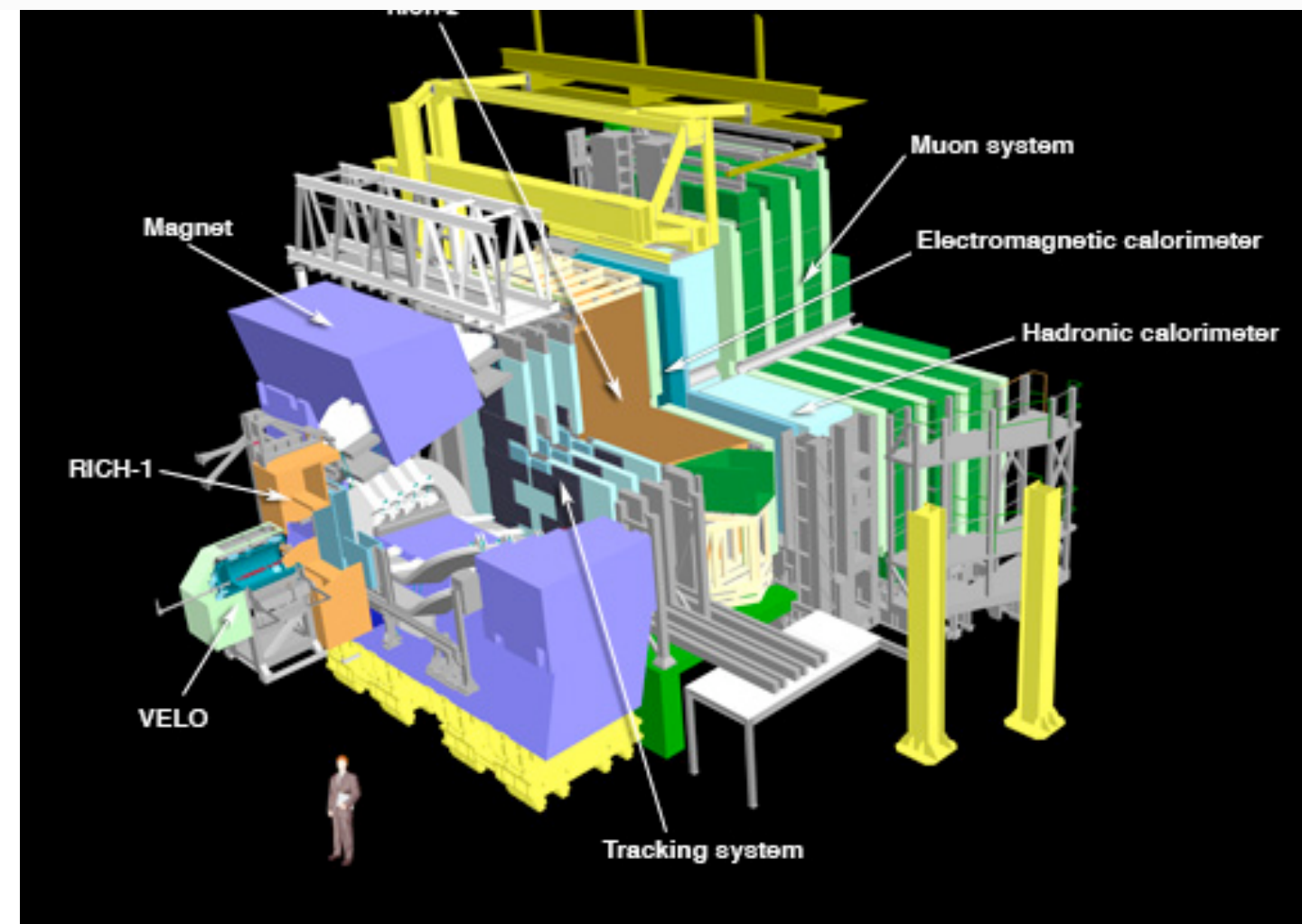
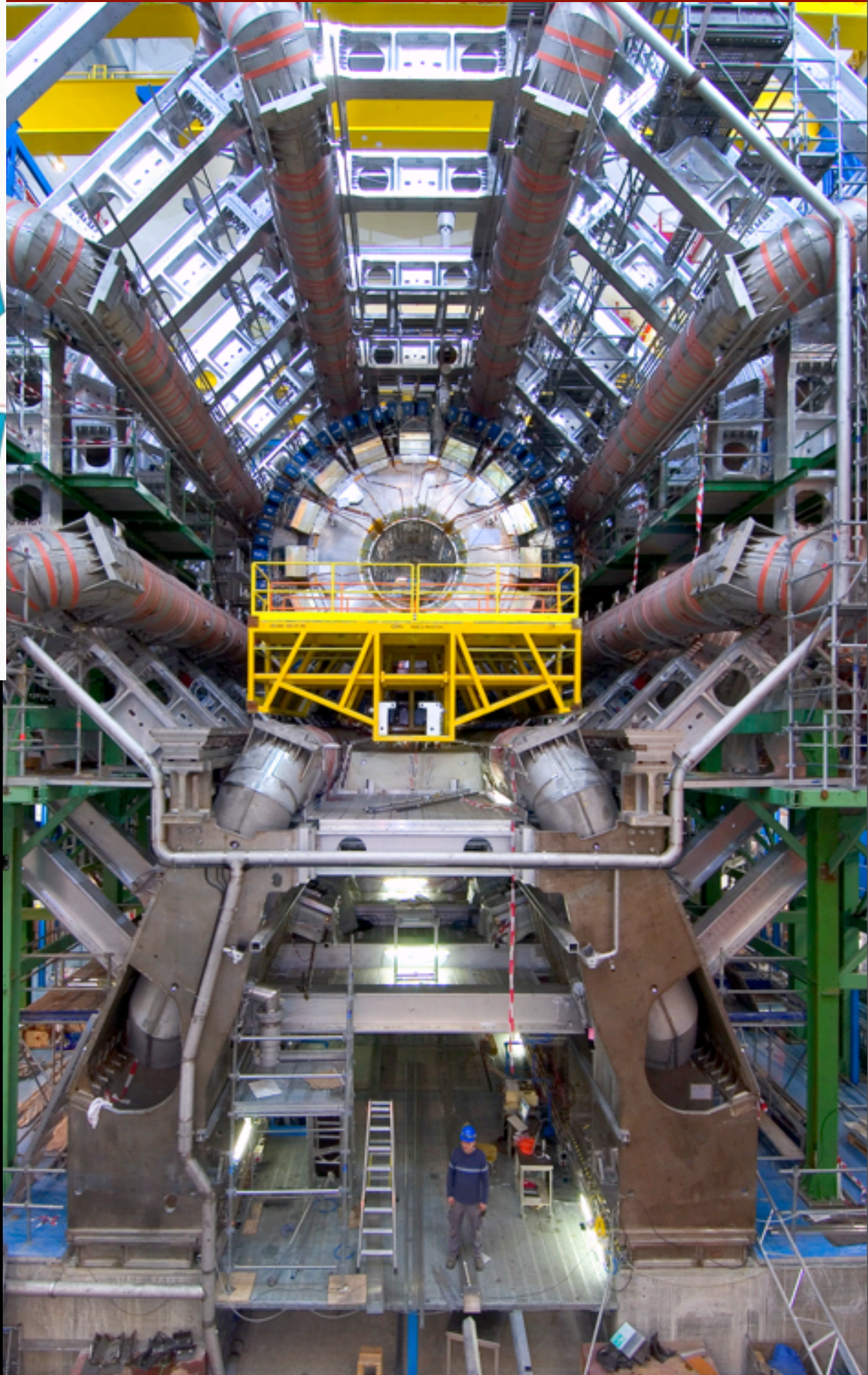
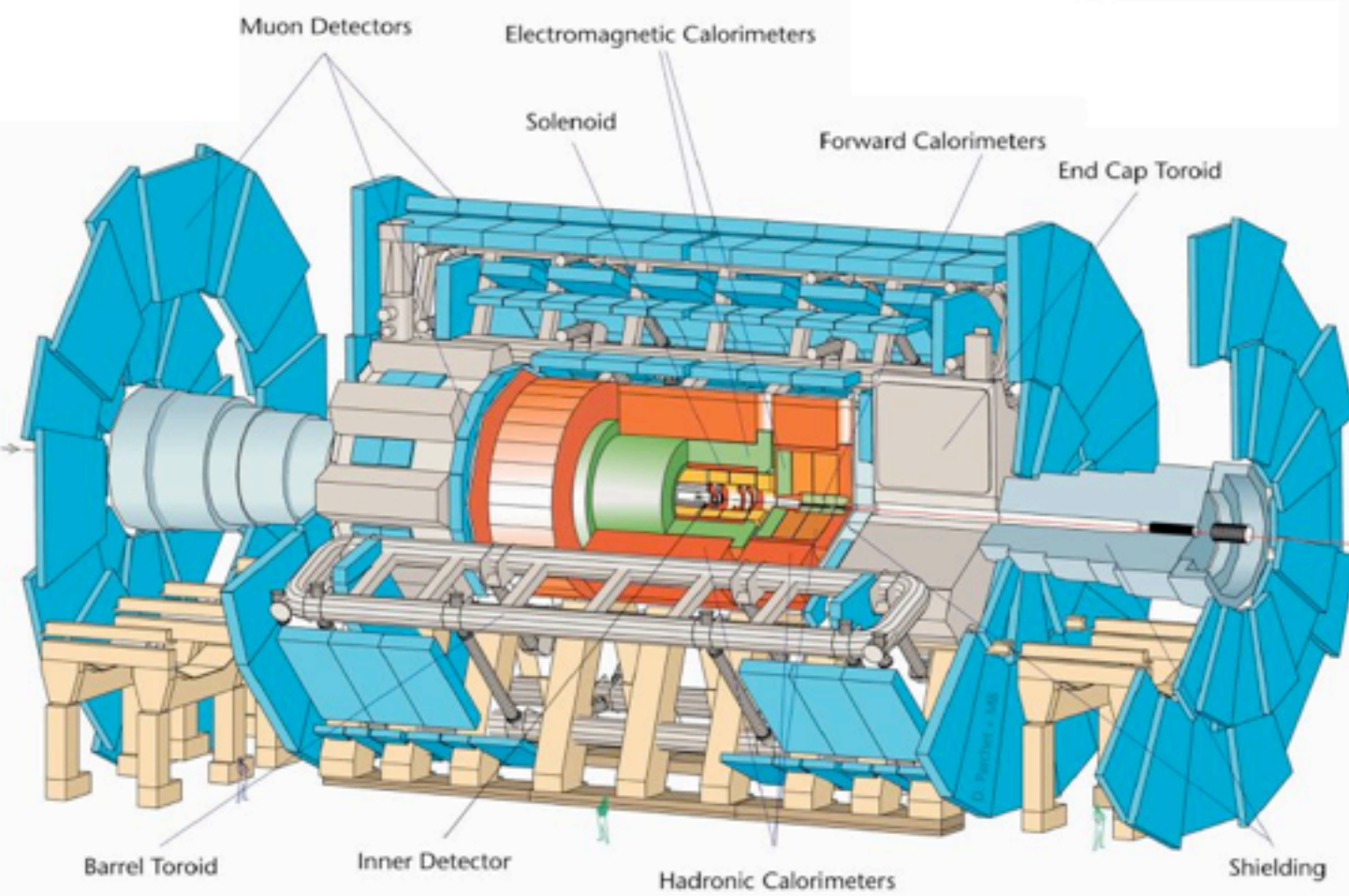
Dark Matter: Patrick Decowski

General:

Theory: Eric Laenen

Grid: Jeff Templon





ATLAS EXPERIMENT

Run Number: 182747, Event Number: 63217197

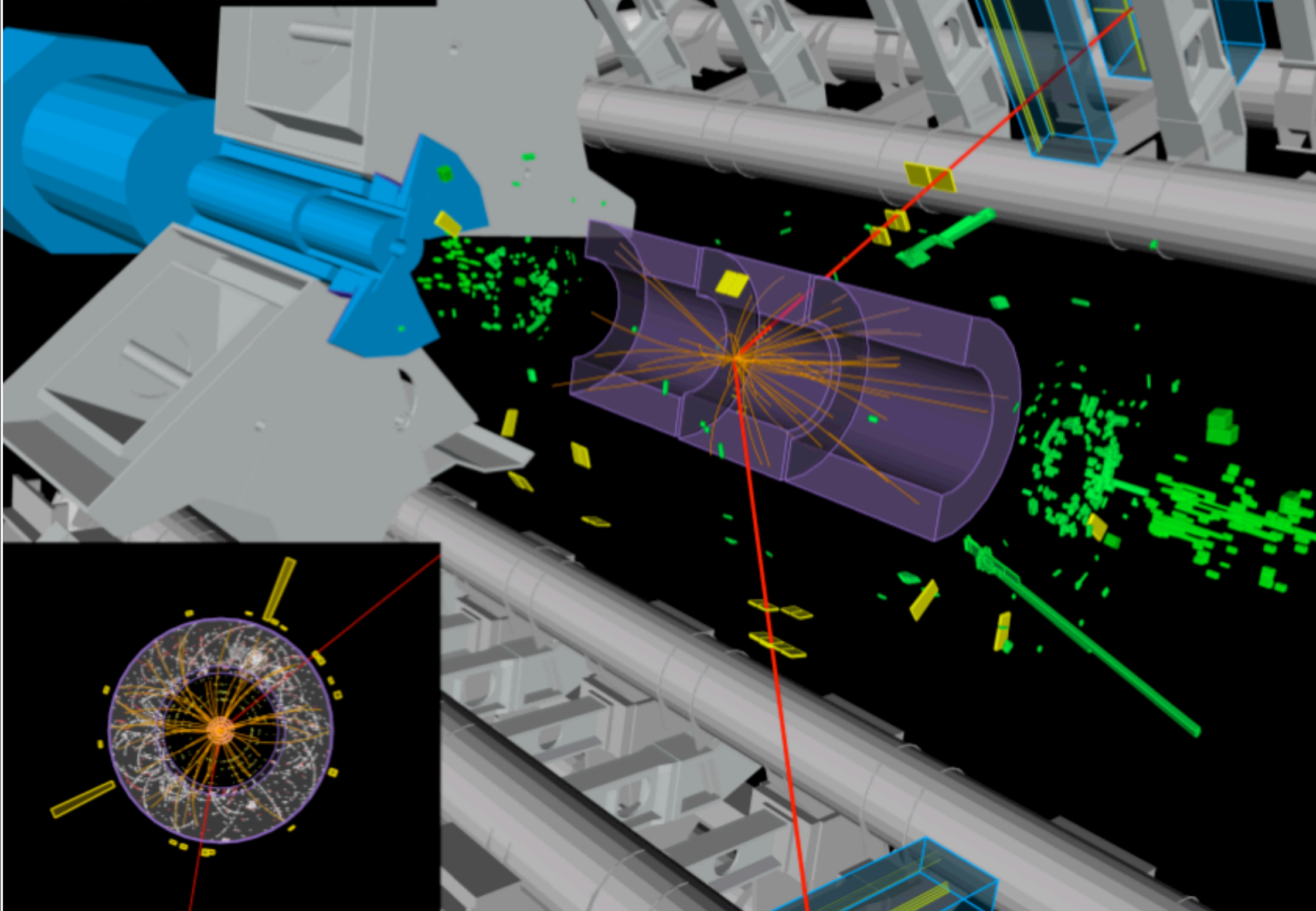
Date: 2011-05-28 13:06:57 CEST

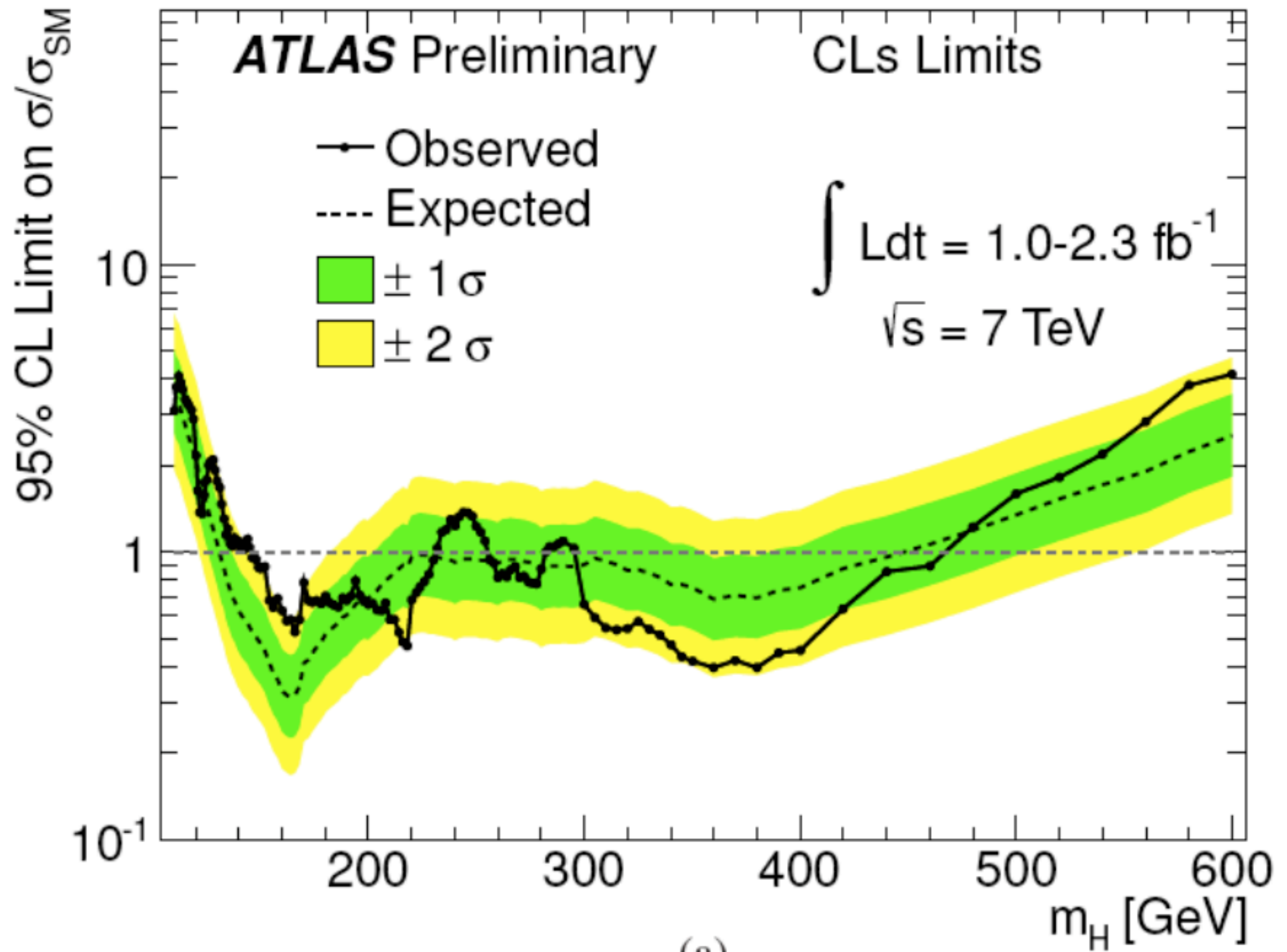
2 μ 2e candidate:

m_{lead} : 85.9 GeV

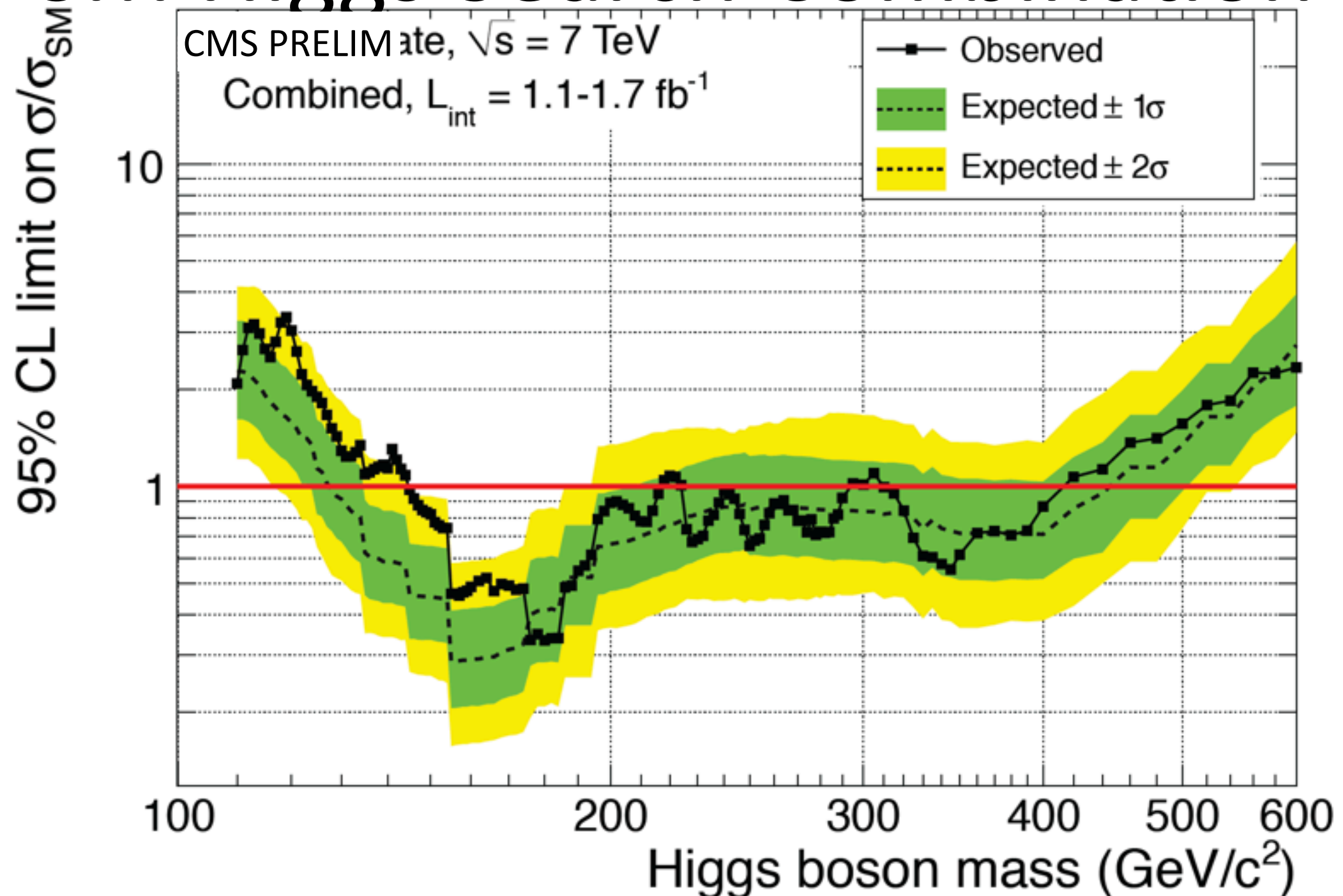
m_{subl} : 85.5 GeV

m_{4l} : 210 GeV



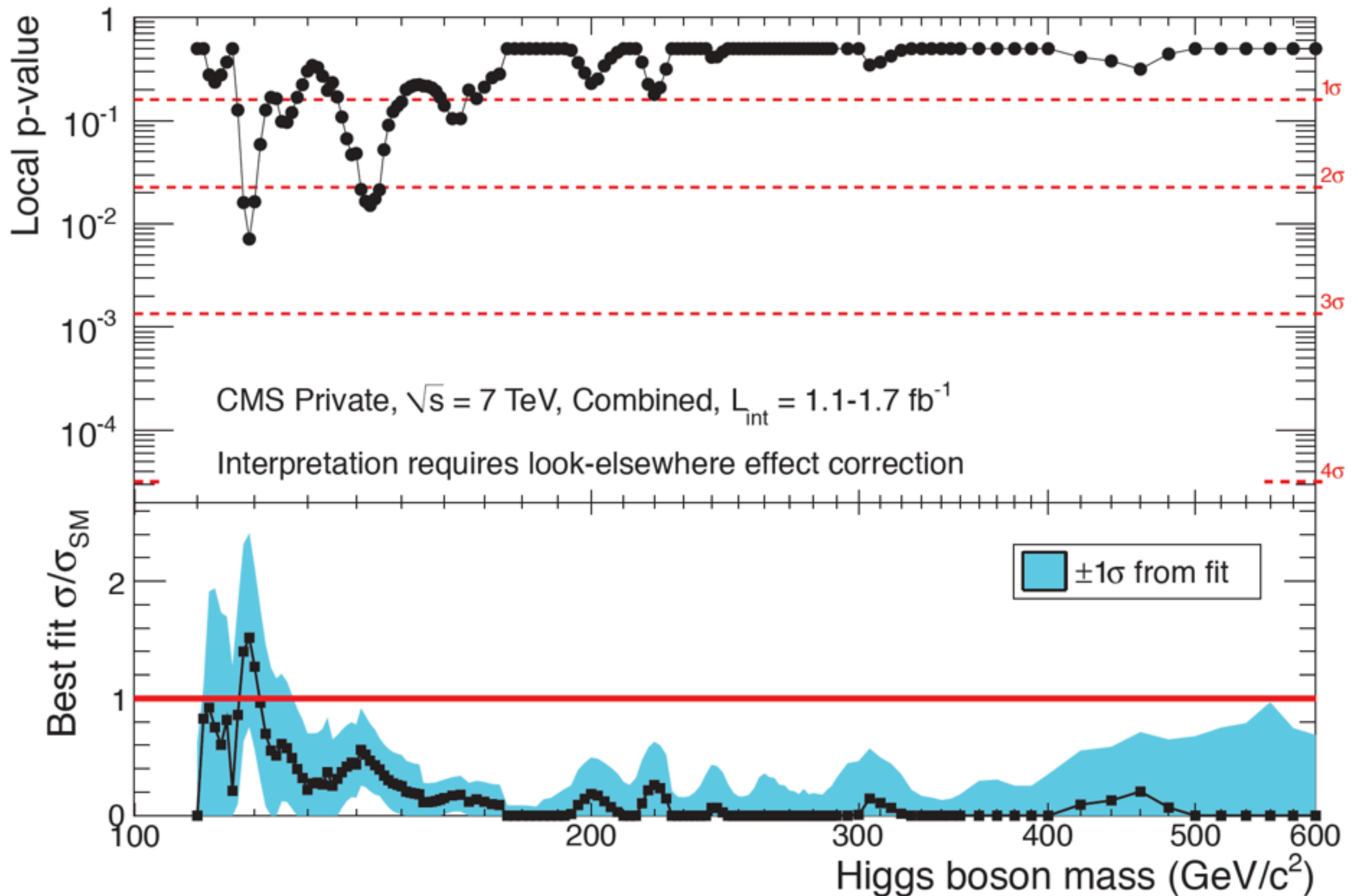


SM Higgs Search Combination



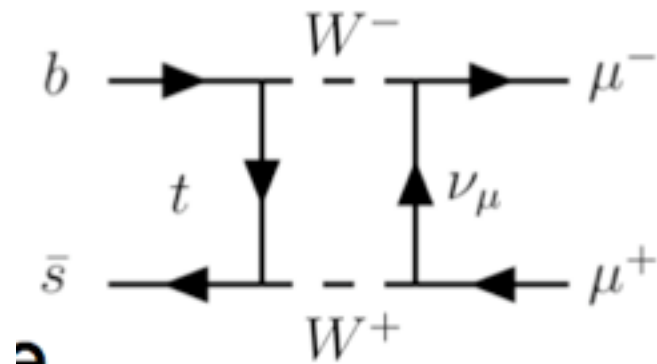
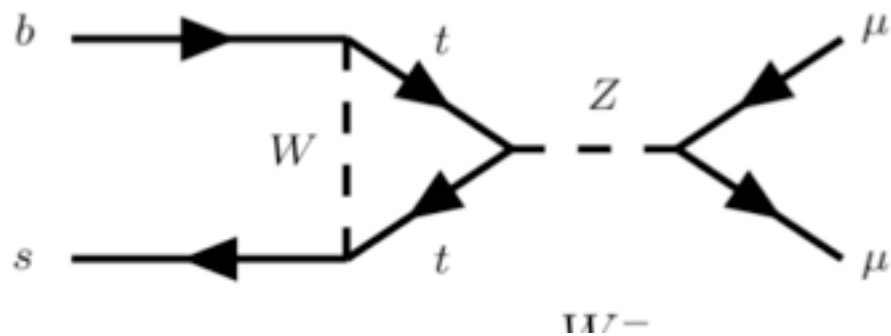
Expected exclusion mass range: 130 – 440 GeV
Observed exclusion mass range: 145-216, 226-288, 310-400 GeV

P-Values & Best Fit

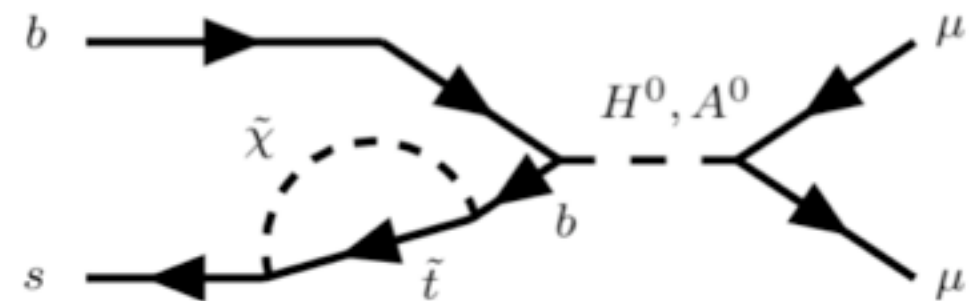
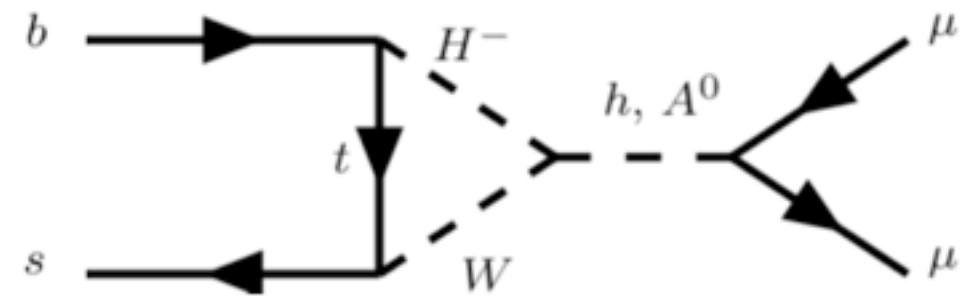


Search for New Physics via forbidden B-decays

Standard Model



Supersymmetry



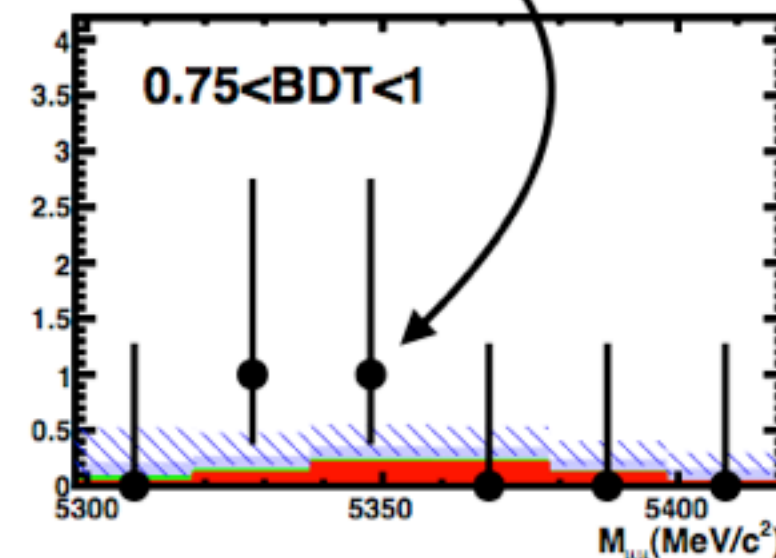
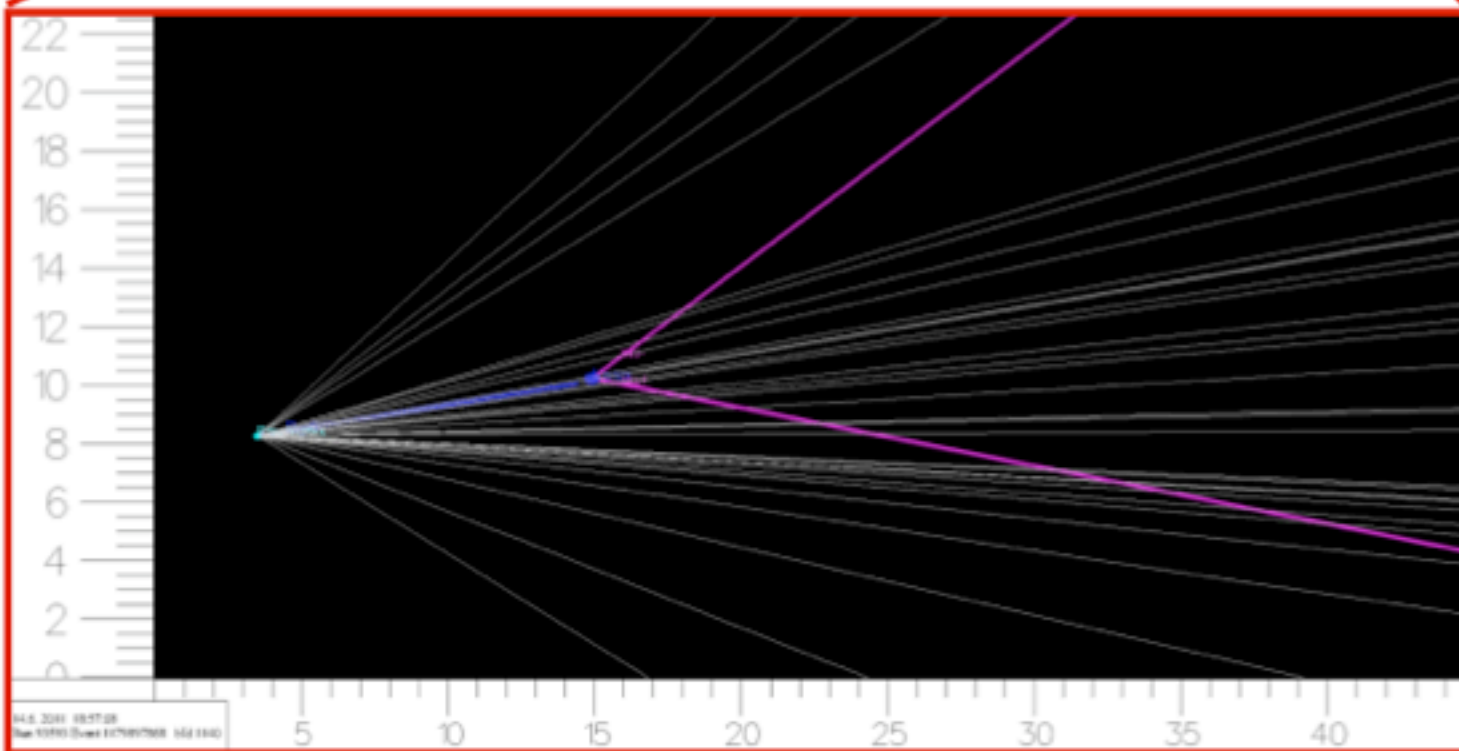
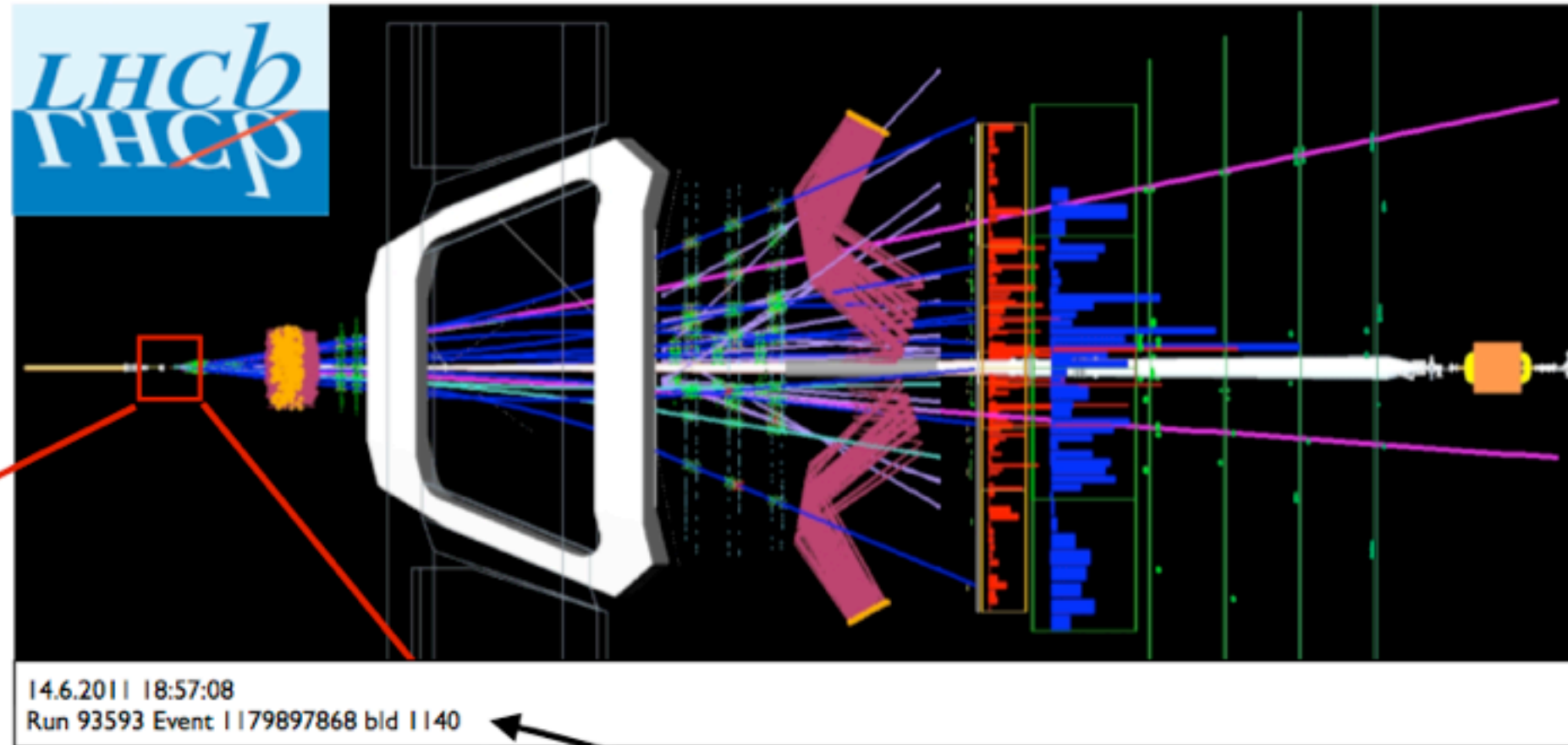
LHCb: $B_s \rightarrow \mu\mu$?

$$m_{\mu\mu} = 5.357 \text{ GeV}$$

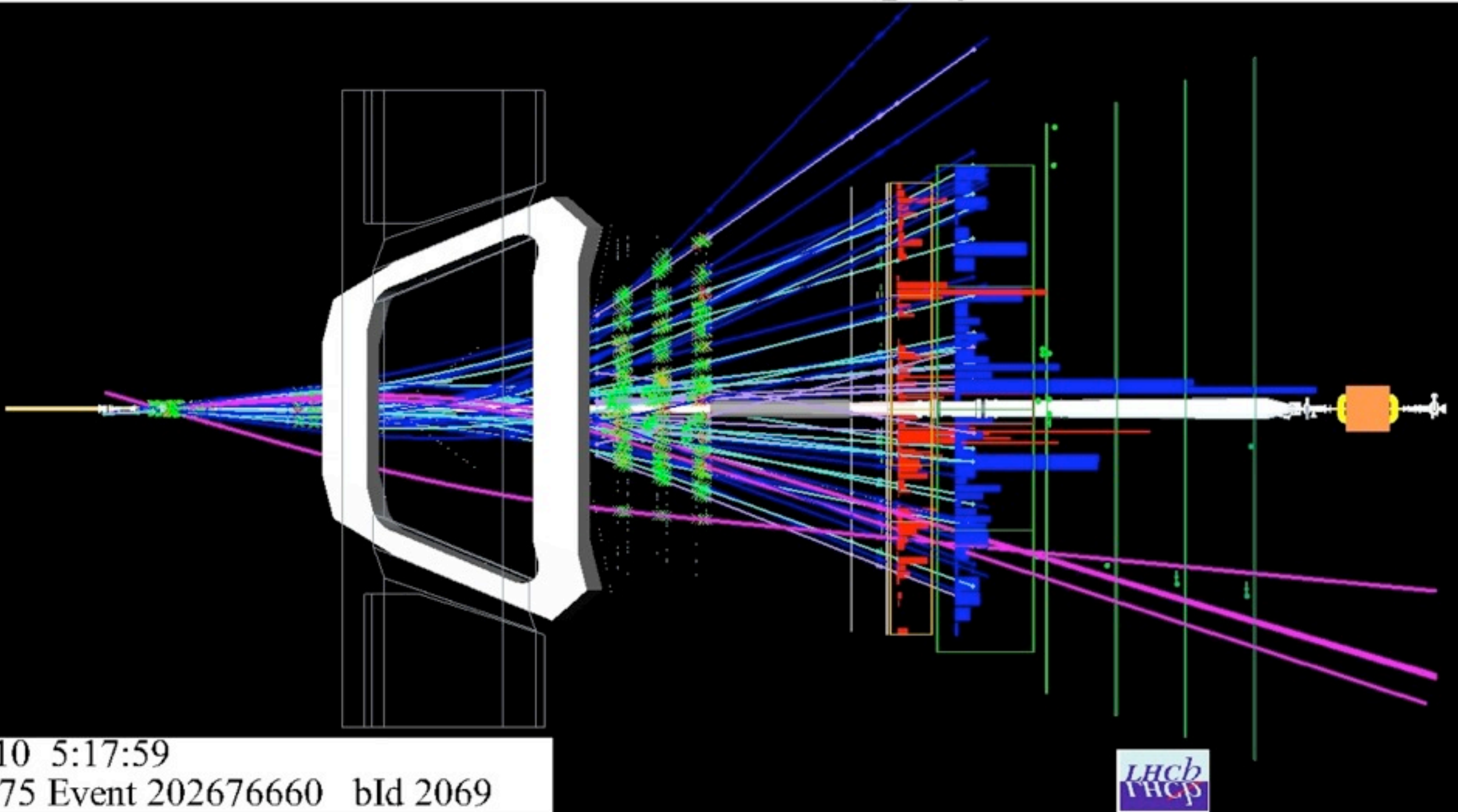
$$\text{BDT} = 0.90$$

$$\text{Decay length} = 11.5 \text{ mm}$$

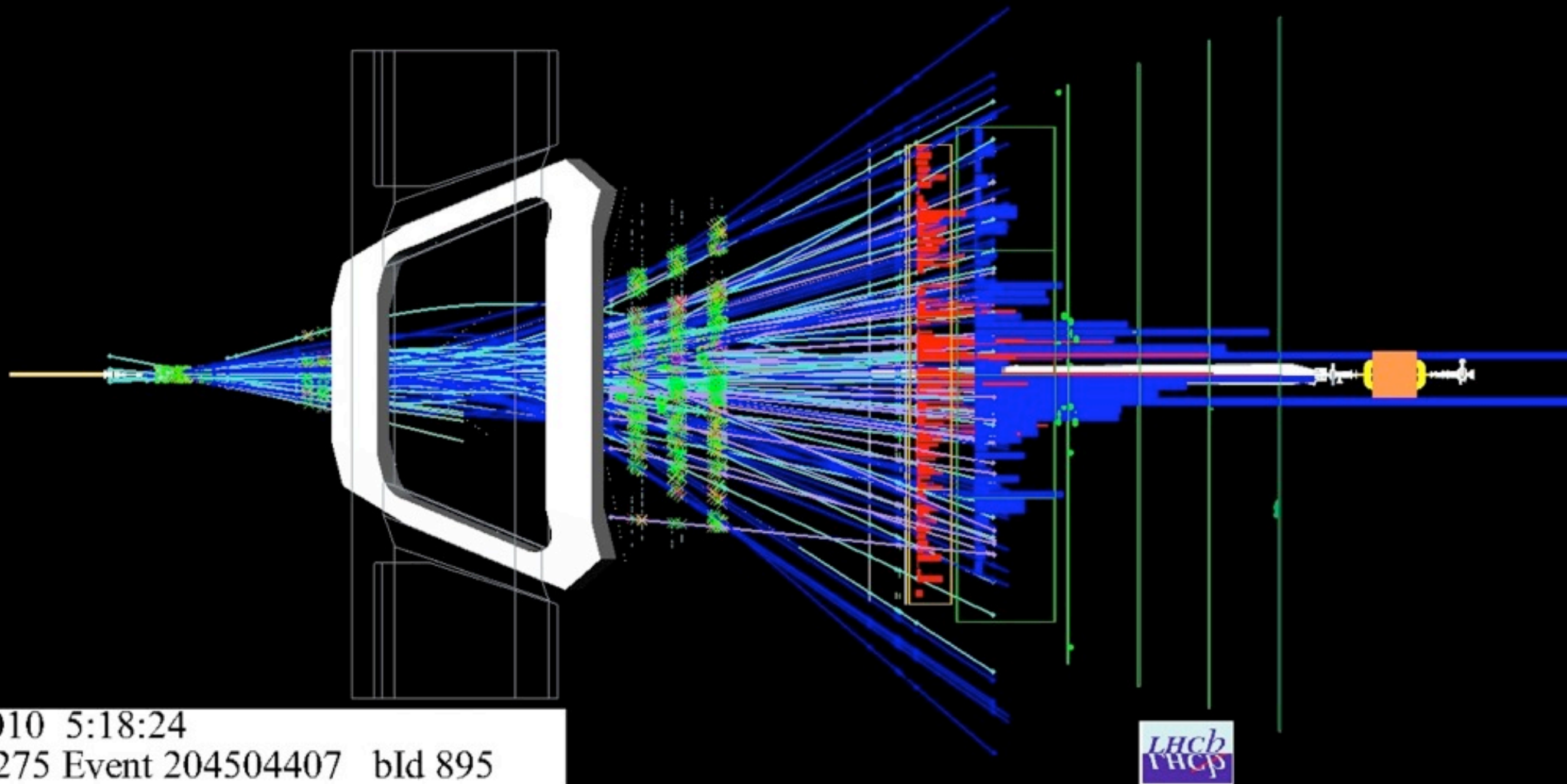
$$\text{Tracks shown for } p_T > 0.5 \text{ GeV}$$



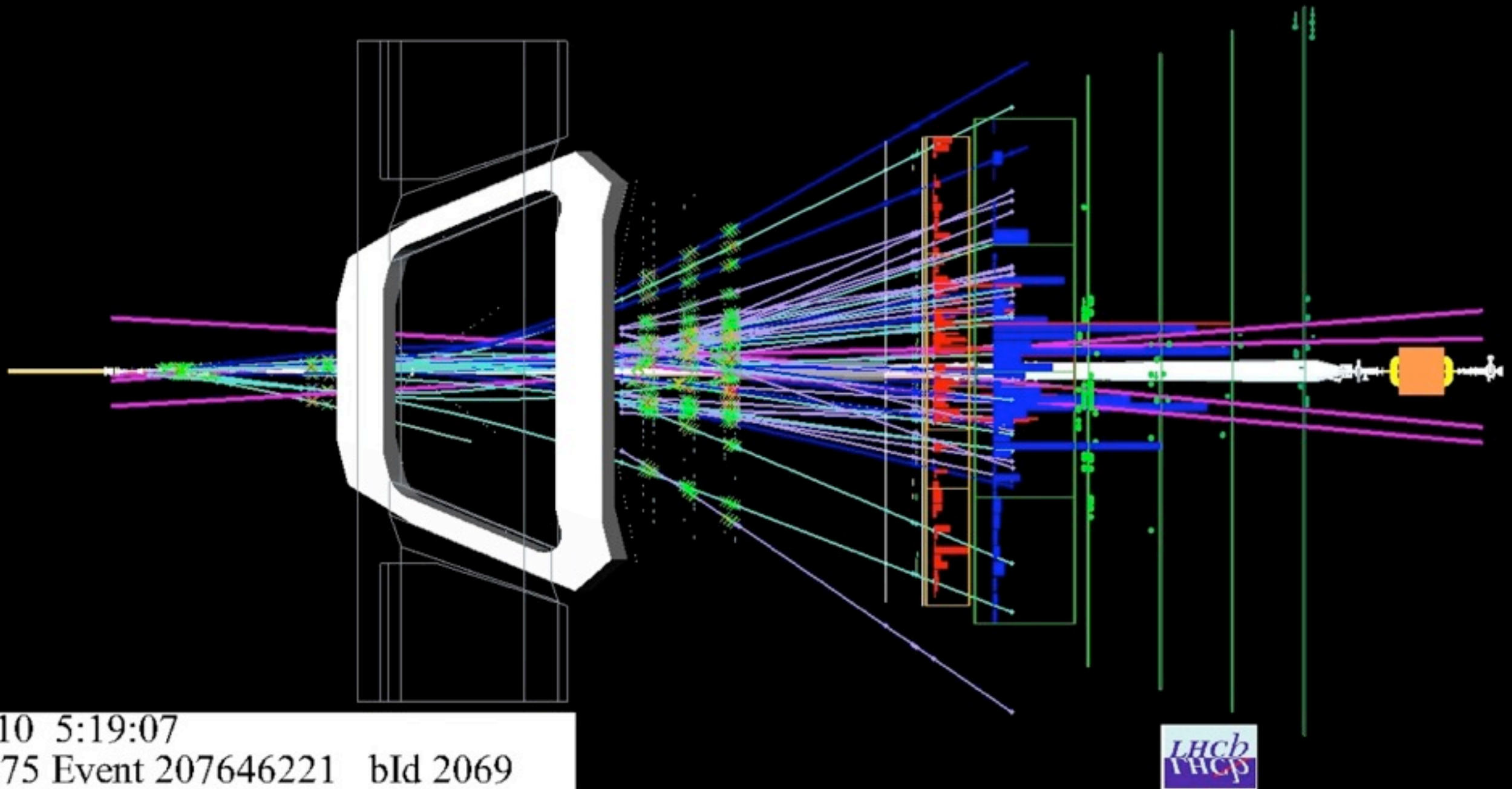
LHCb Event Display



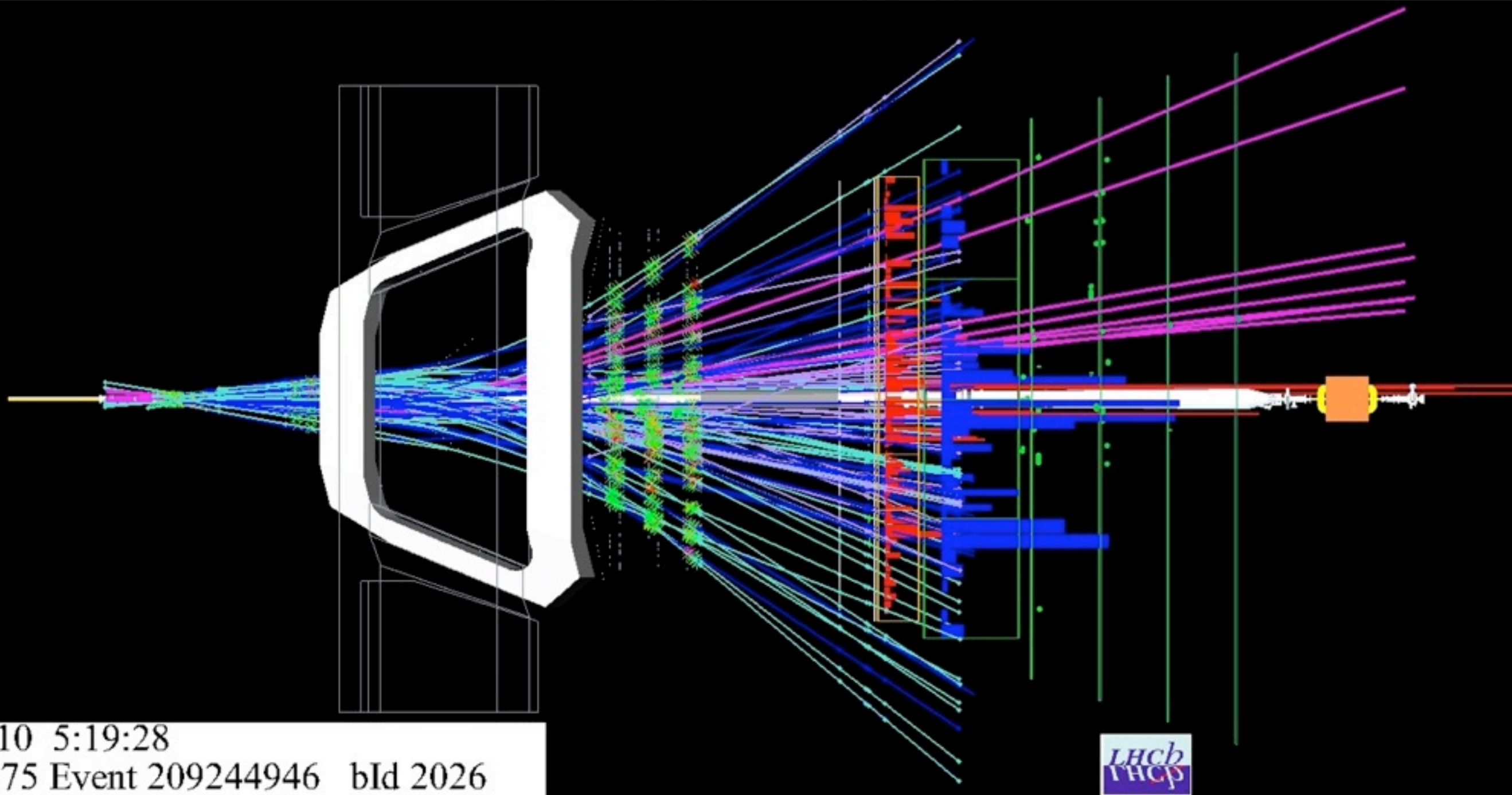
LHCb Event Display



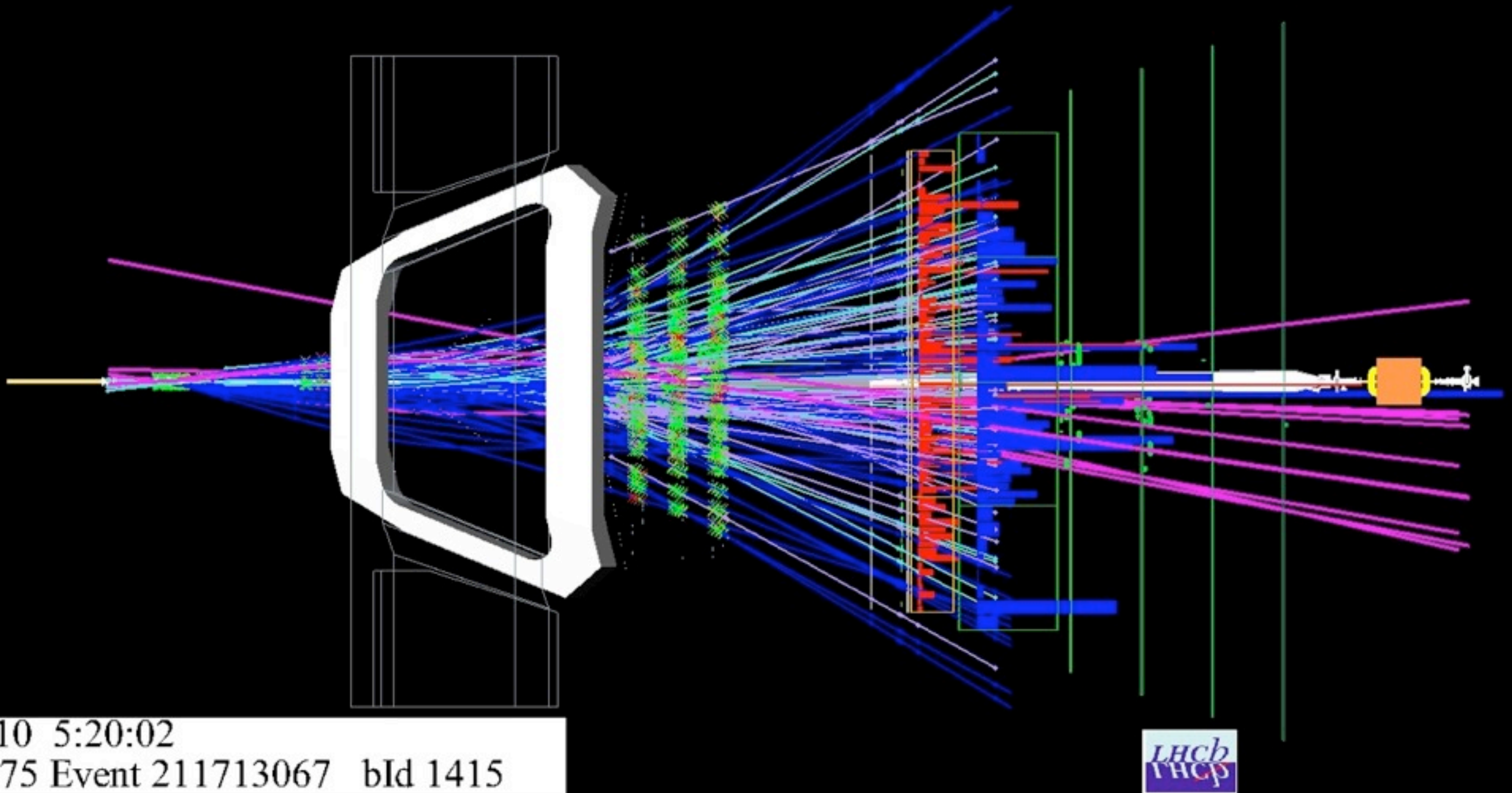
LHCb Event Display



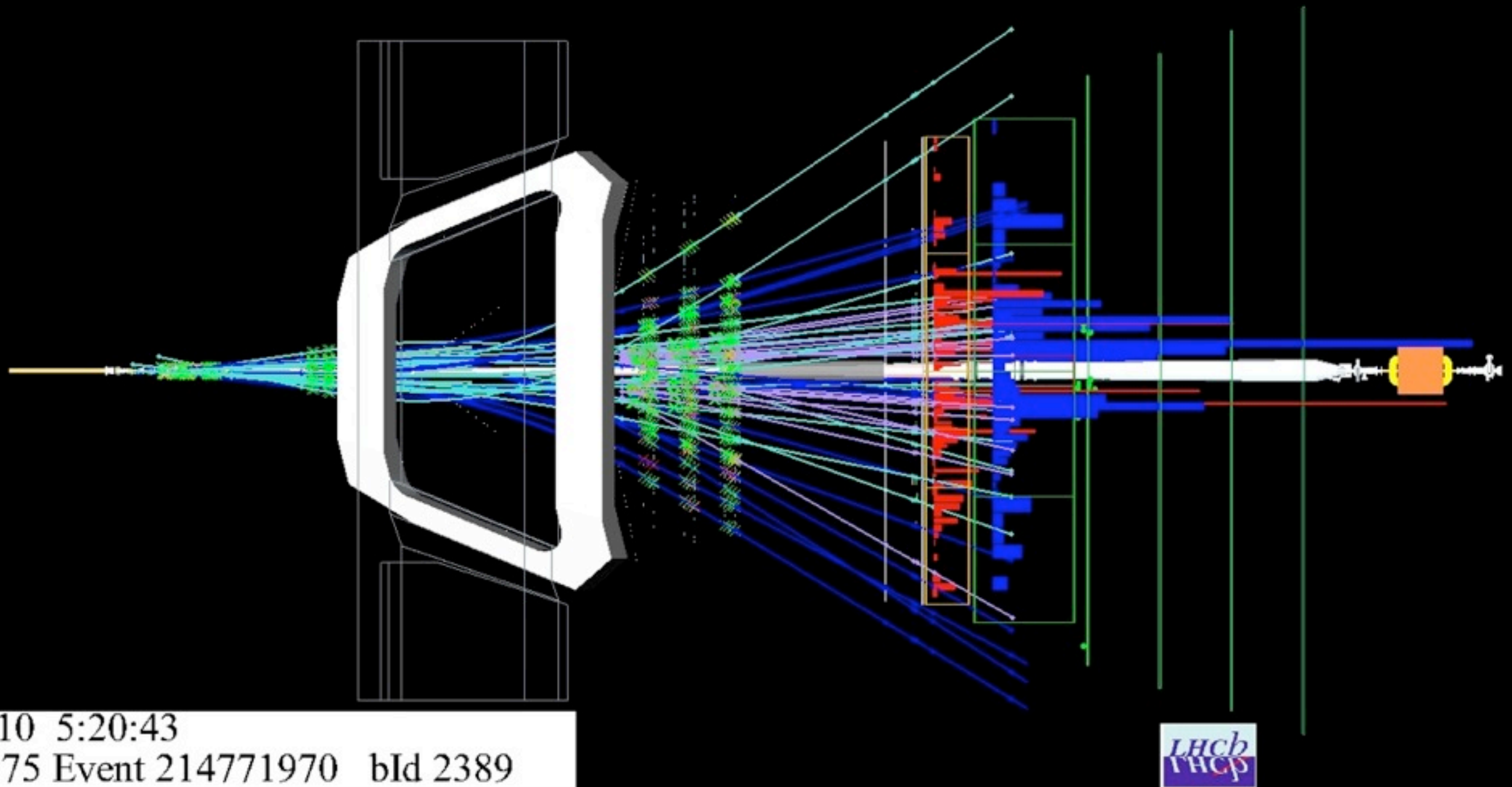
LHCb Event Display



LHCb Event Display



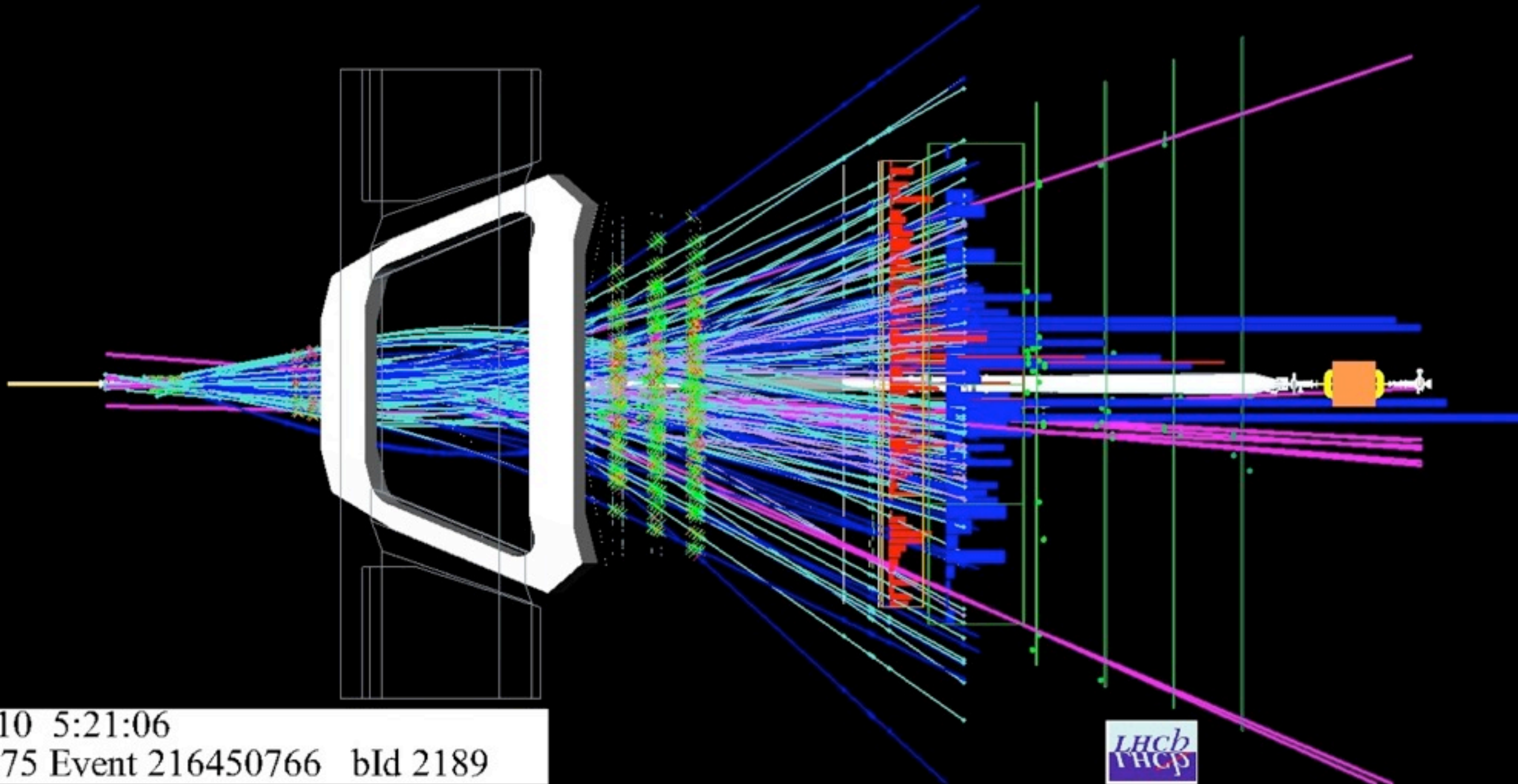
LHCb Event Display



2010 5:20:43
78275 Event 214771970 bld 2389



LHCb Event Display

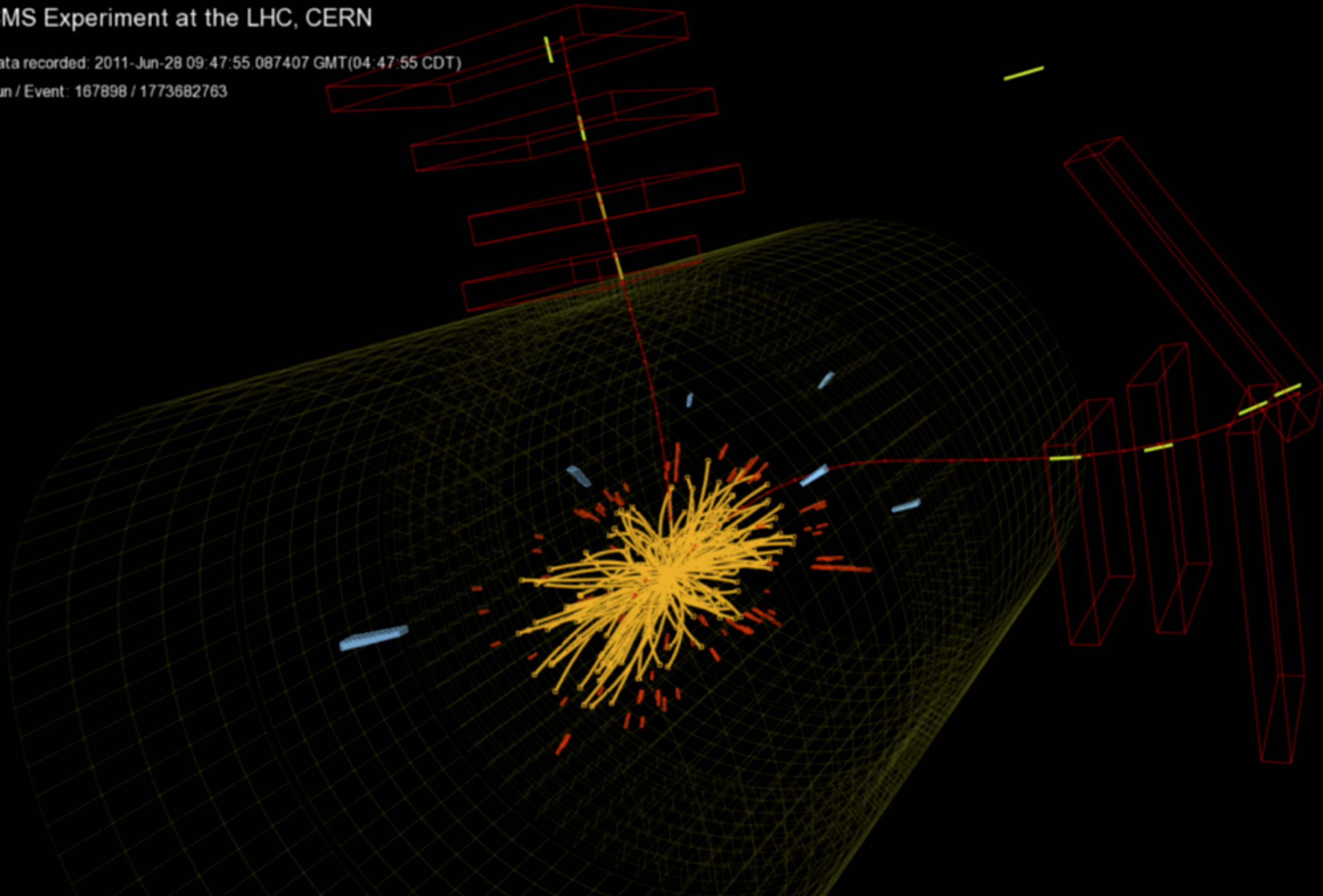


CMS: $B_s \rightarrow \mu\mu$?

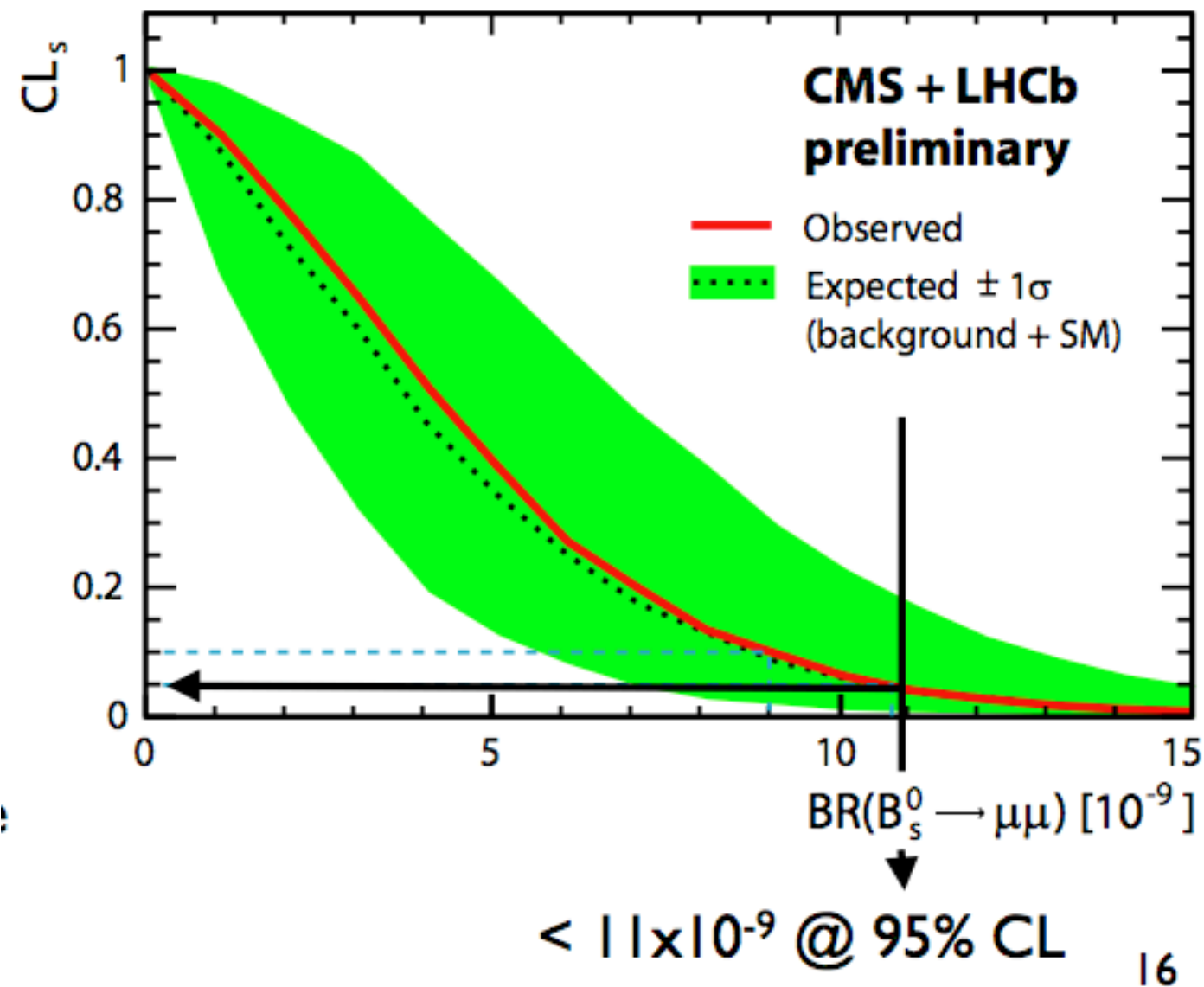
CMS Experiment at the LHC, CERN

Data recorded: 2011-Jun-28 09:47:55.087407 GMT(04:47:55 CDT)

Run / Event: 167898 / 1773682763



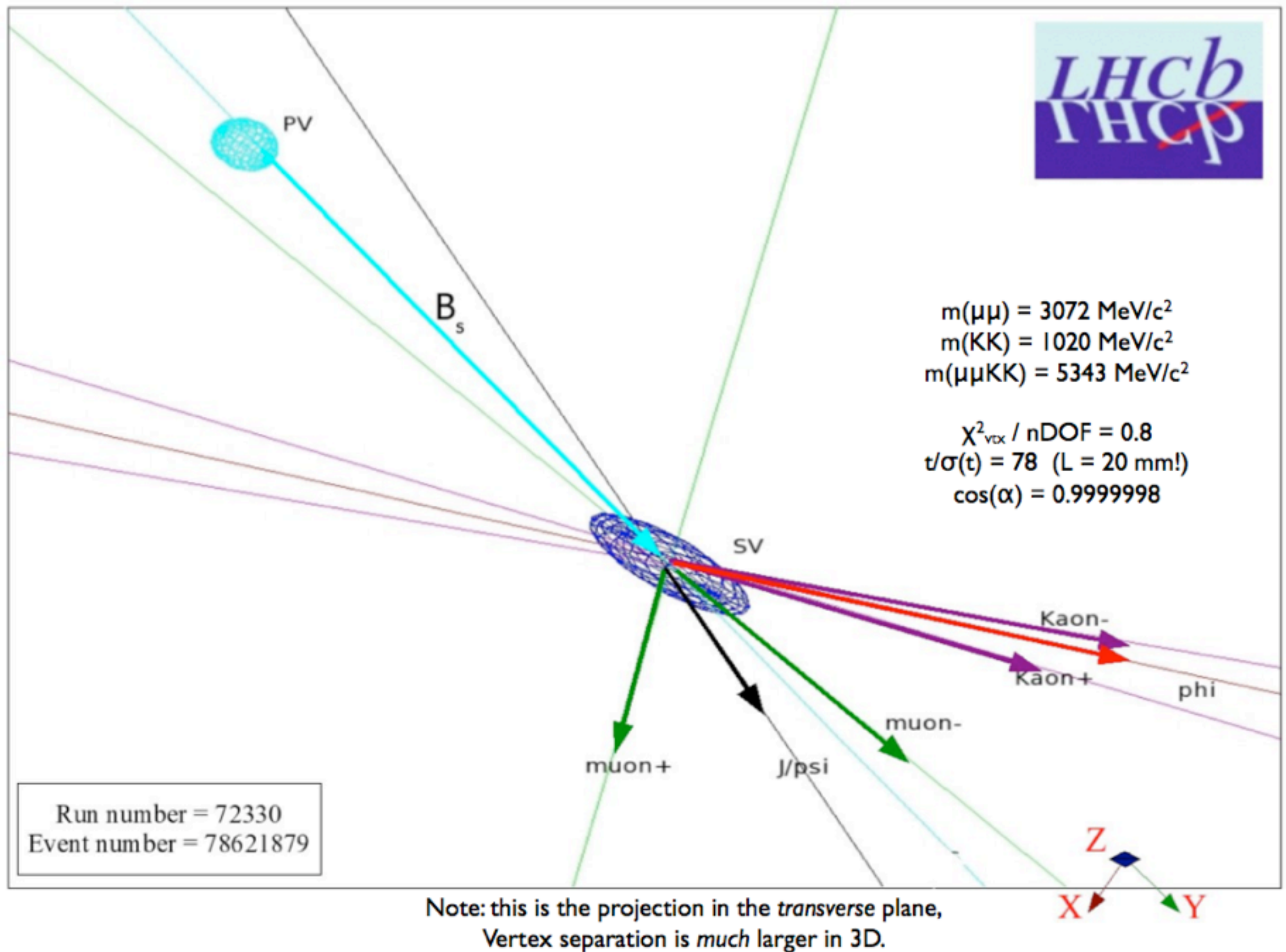
So far New Physics is not yet observed...



But we have just started... much more to come...
These are really exciting times!

$B_s \rightarrow J/\psi \varphi$

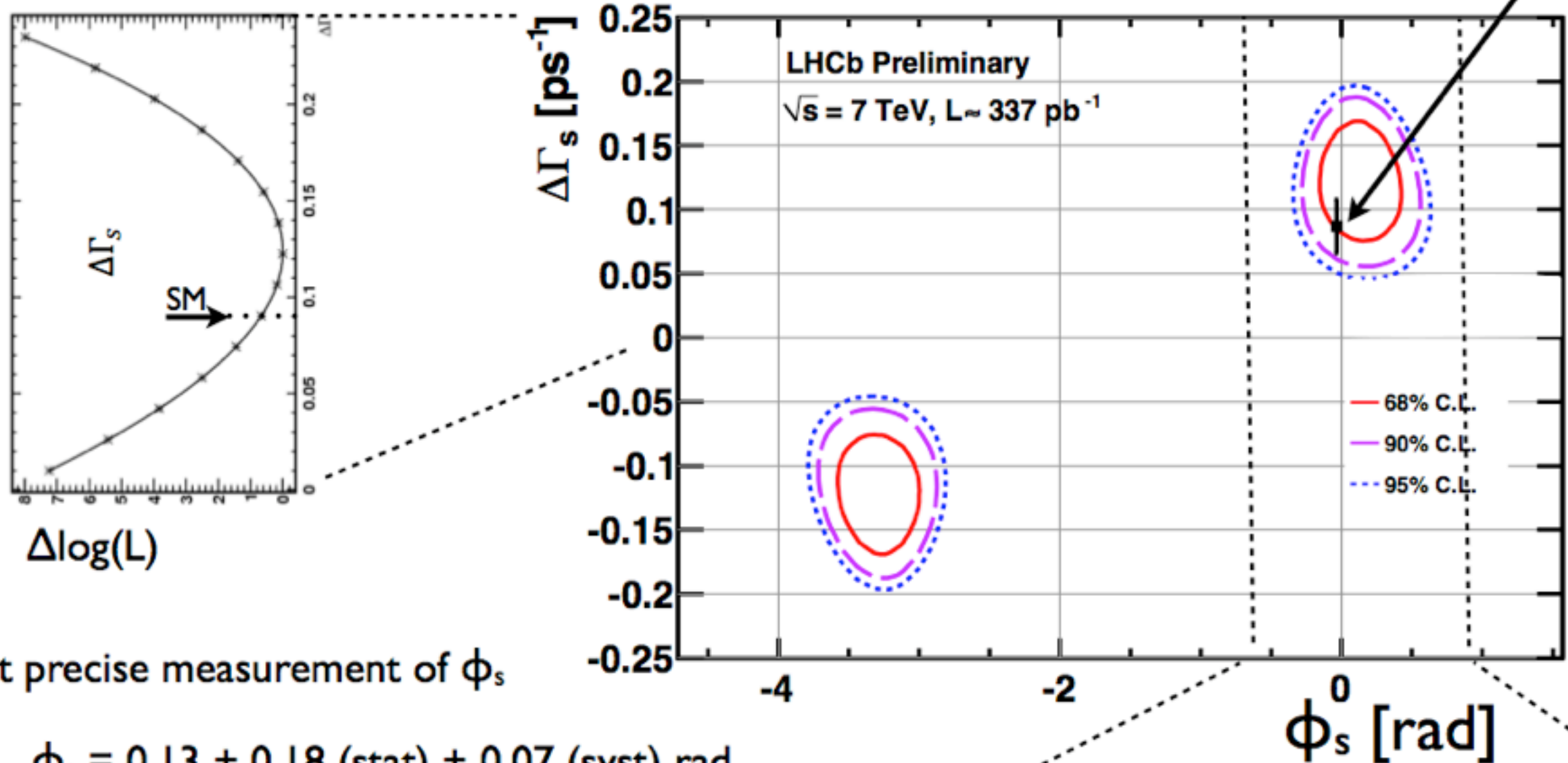
The matter anti-matter asymmetry



$B_s \rightarrow J/\psi \phi$: $\Delta\Gamma_s$ vs. ϕ_s

Standard Model
(Lenz, Nierste: arXiv:1102.4274)

LHCb-CONF-2011-49



Most precise measurement of ϕ_s

- $\phi_s = 0.13 \pm 0.18 \text{ (stat)} \pm 0.07 \text{ (syst)} \text{ rad}$
- Consistent with SM

4 σ Evidence for $\Delta\Gamma_s \neq 0$:

- $\Delta\Gamma_s = 0.123 \pm 0.029 \text{ (stat)} \pm 0.008 \text{ (syst)} \text{ ps}^{-1}$
- $\Gamma_s = 0.656 \pm 0.009 \text{ (stat)} \pm 0.008 \text{ (syst)} \text{ ps}^{-1}$

