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D-Days: Standard Model and beyond

Florian Damas
(supervisor: Javier Castillo)
DRF / IRFU / DPhN / LQGP / ALICE

Tetiana Moskalets
(supervisor: Frédéric Déliot)
DRF / IRFU / DPhP / ATLAS

Introduction: Standard Model

Standard Model of Elementary Particles

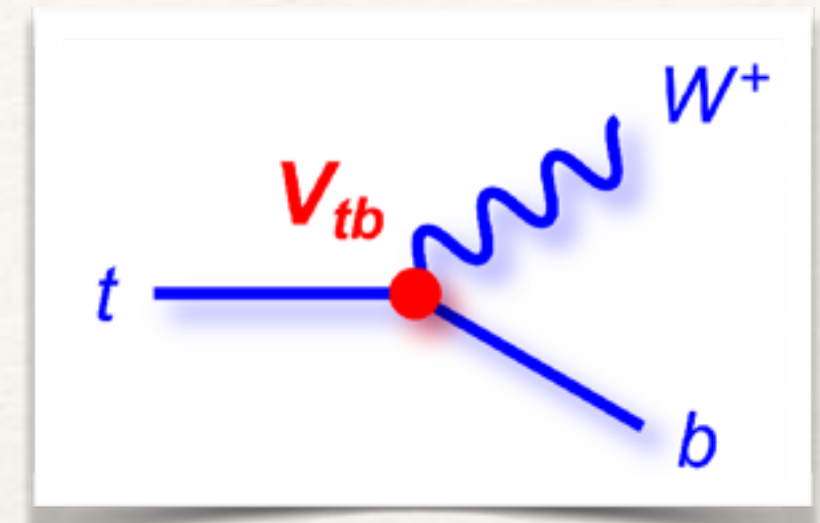
	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
QUARKS	mass $\approx 2.2 \text{ MeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ u up	mass $\approx 1.28 \text{ GeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ c charm	mass $\approx 173.1 \text{ GeV}/c^2$ charge $\frac{2}{3}$ spin $\frac{1}{2}$ t top	0 0 1 g gluon	mass $\approx 124.97 \text{ GeV}/c^2$ 0 0 H higgs
	mass $\approx 4.7 \text{ MeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ d down	mass $\approx 96 \text{ MeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ s strange	mass $\approx 4.18 \text{ GeV}/c^2$ charge $-\frac{1}{3}$ spin $\frac{1}{2}$ b bottom	0 0 1 γ photon	
	mass $\approx 0.511 \text{ MeV}/c^2$ charge -1 spin $\frac{1}{2}$ e electron	mass $\approx 105.66 \text{ MeV}/c^2$ charge -1 spin $\frac{1}{2}$ μ muon	mass $\approx 1.7768 \text{ GeV}/c^2$ charge -1 spin $\frac{1}{2}$ τ tau	mass $\approx 91.19 \text{ GeV}/c^2$ 0 0 1 Z Z boson	
LEPTONS	mass $< 2.2 \text{ eV}/c^2$ 0 spin $\frac{1}{2}$ ν_e electron neutrino	mass $< 0.17 \text{ MeV}/c^2$ 0 spin $\frac{1}{2}$ ν_μ muon neutrino	mass $< 18.2 \text{ MeV}/c^2$ 0 spin $\frac{1}{2}$ ν_τ tau neutrino	mass $\approx 80.39 \text{ GeV}/c^2$ ± 1 1 W W boson	

GAUGE BOSONS
VECTOR BOSONS

SCALAR BOSONS

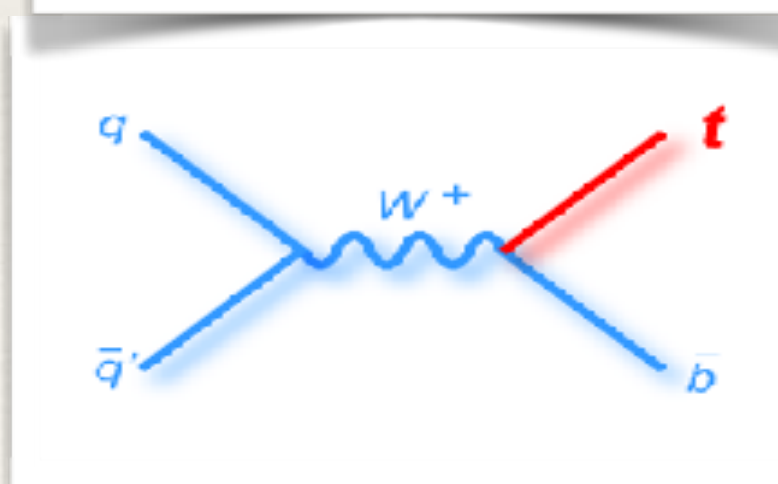
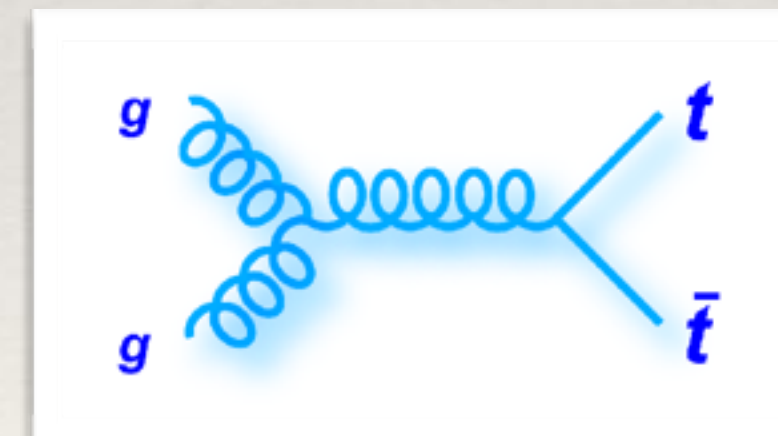
b-quark

- ❖ Produced in *t*-quark decay
- ❖ Bound states are exceptionally **long-lived**



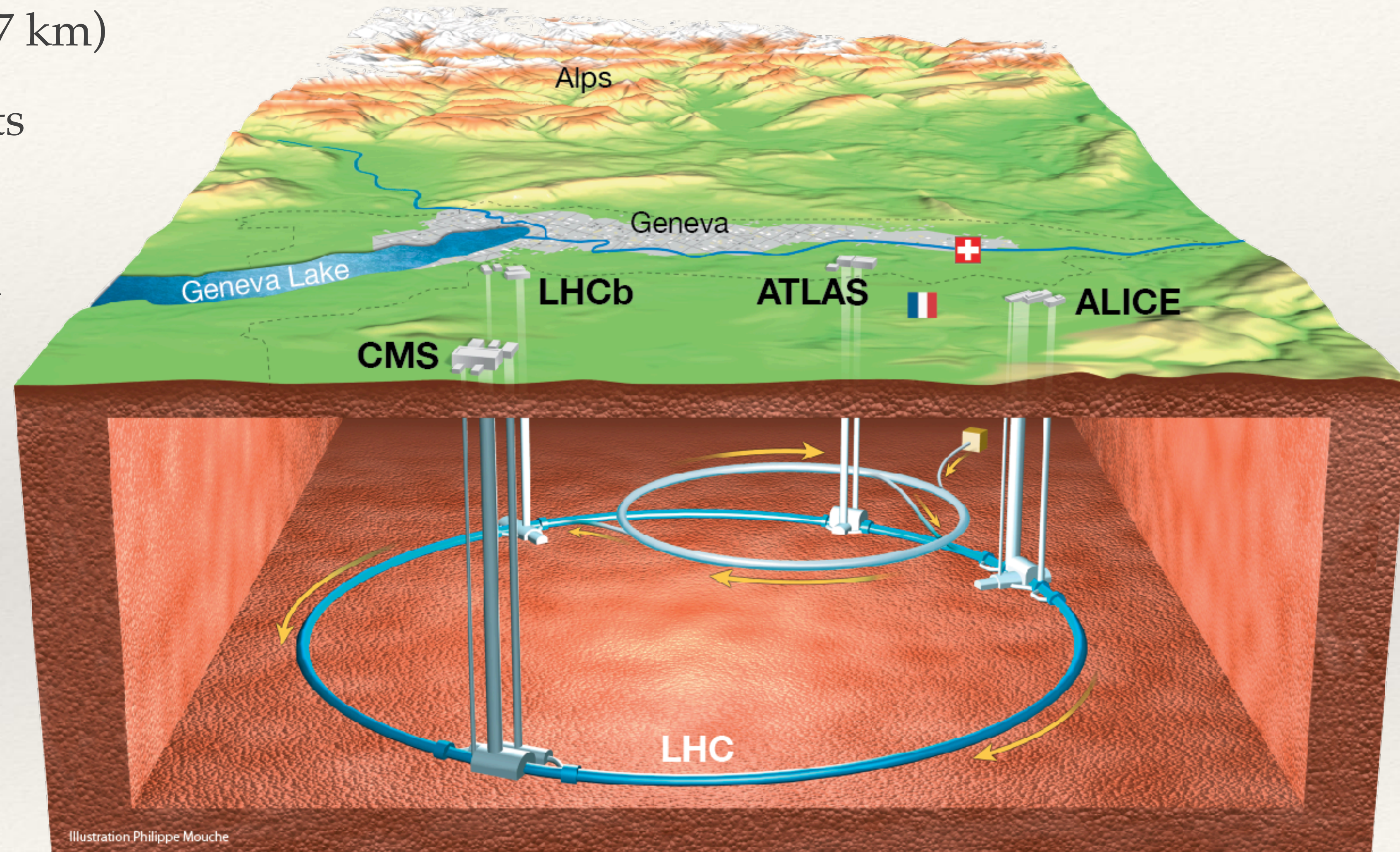
t-quark

- ❖ **Heaviest** elementary particle
- ❖ **Doesn't form bound states**
- ❖ Produced via
 - ❖ gluon fusion / decay (*t \bar{t}* pairs)
 - ❖ Weak interaction (single-top)



Introduction: Large Hadron Collider

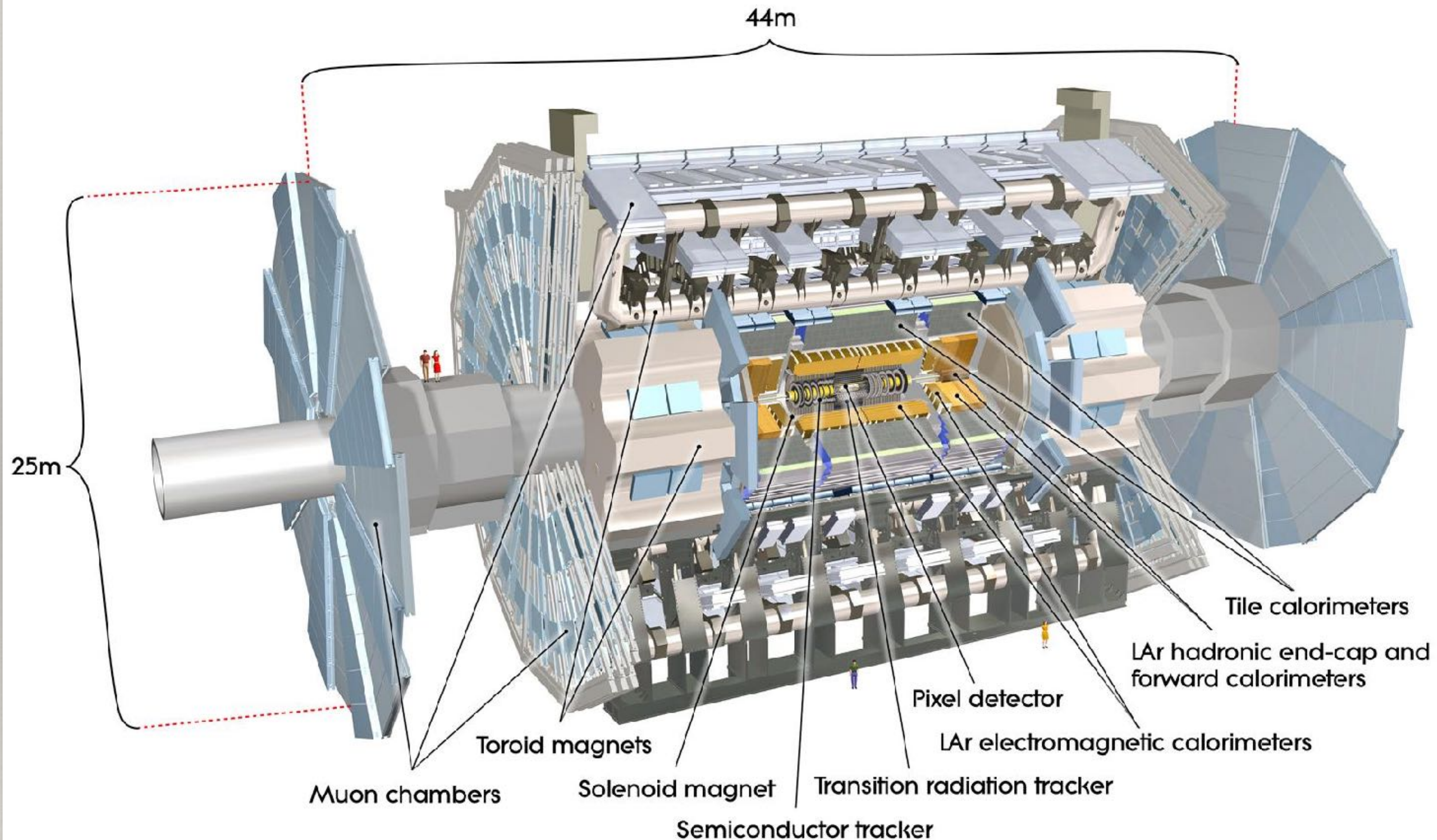
- ❖ World's largest accelerator (27 km)
- ❖ 8 T supra-conducting magnets
- ❖ Protons **and** lead ions
- ❖ Up to **13 TeV** collision energy
- ❖ 4 interaction points



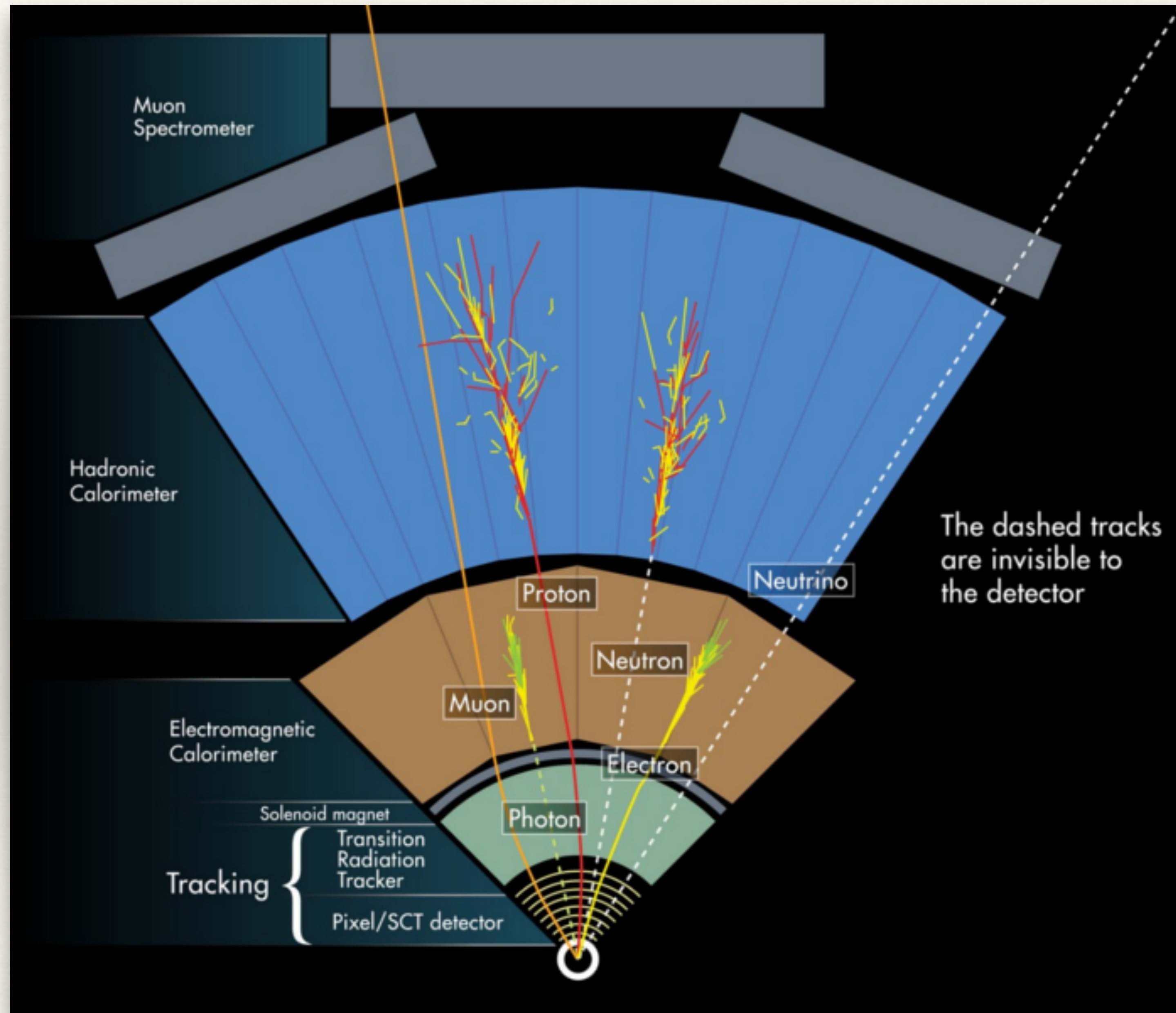
Introduction: ATLAS

Main physics topics explored in ATLAS:

- ❖ Tests of the Standard Model (e.g. Higgs physics)
- ❖ Precision measurements (e.g. of particle masses)
- ❖ Searches for the new resonances, dark matter, exotic phenomena



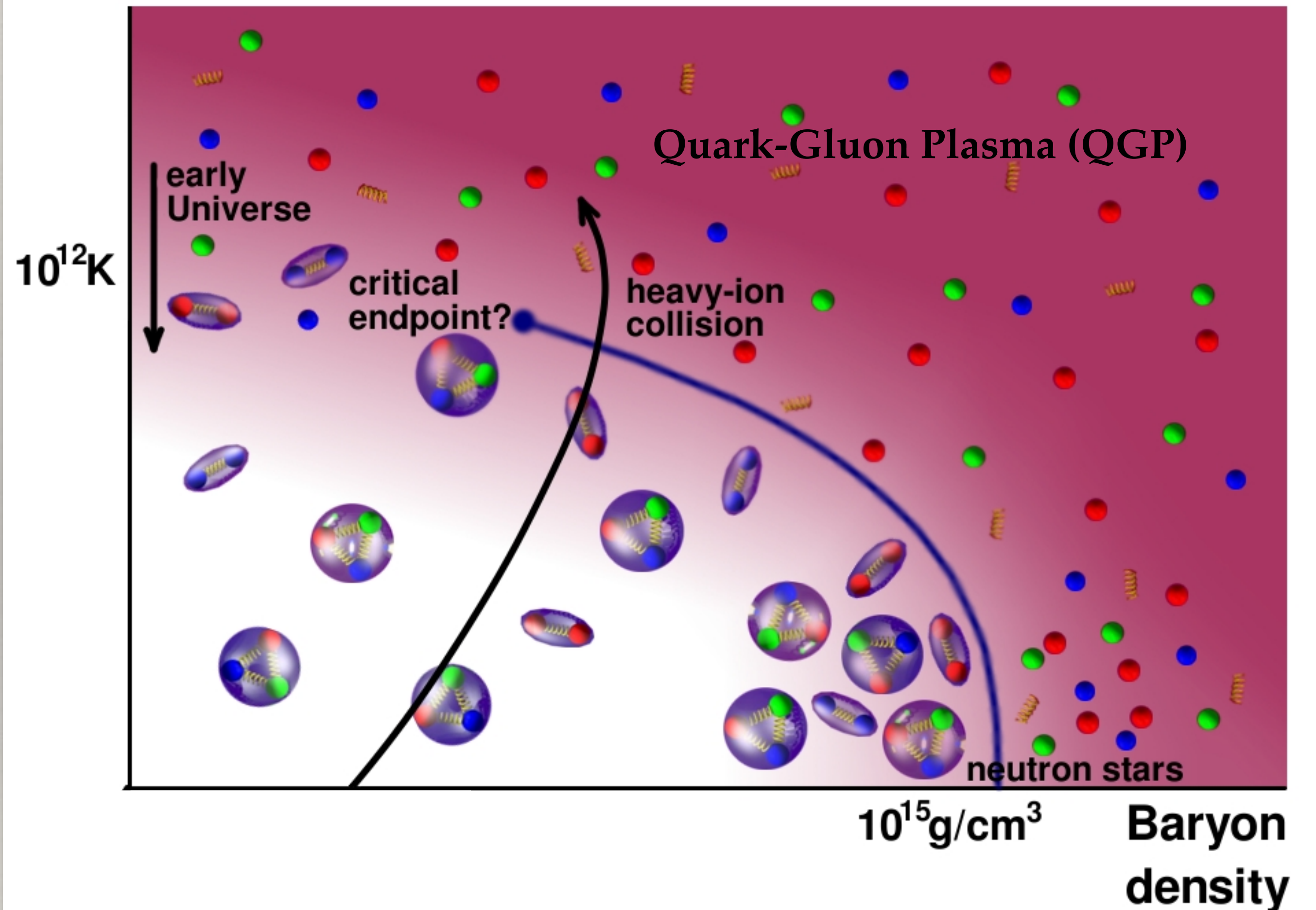
Introduction: particle detection



Introduction: Quark-Gluon Plasma in a (hot) nutshell

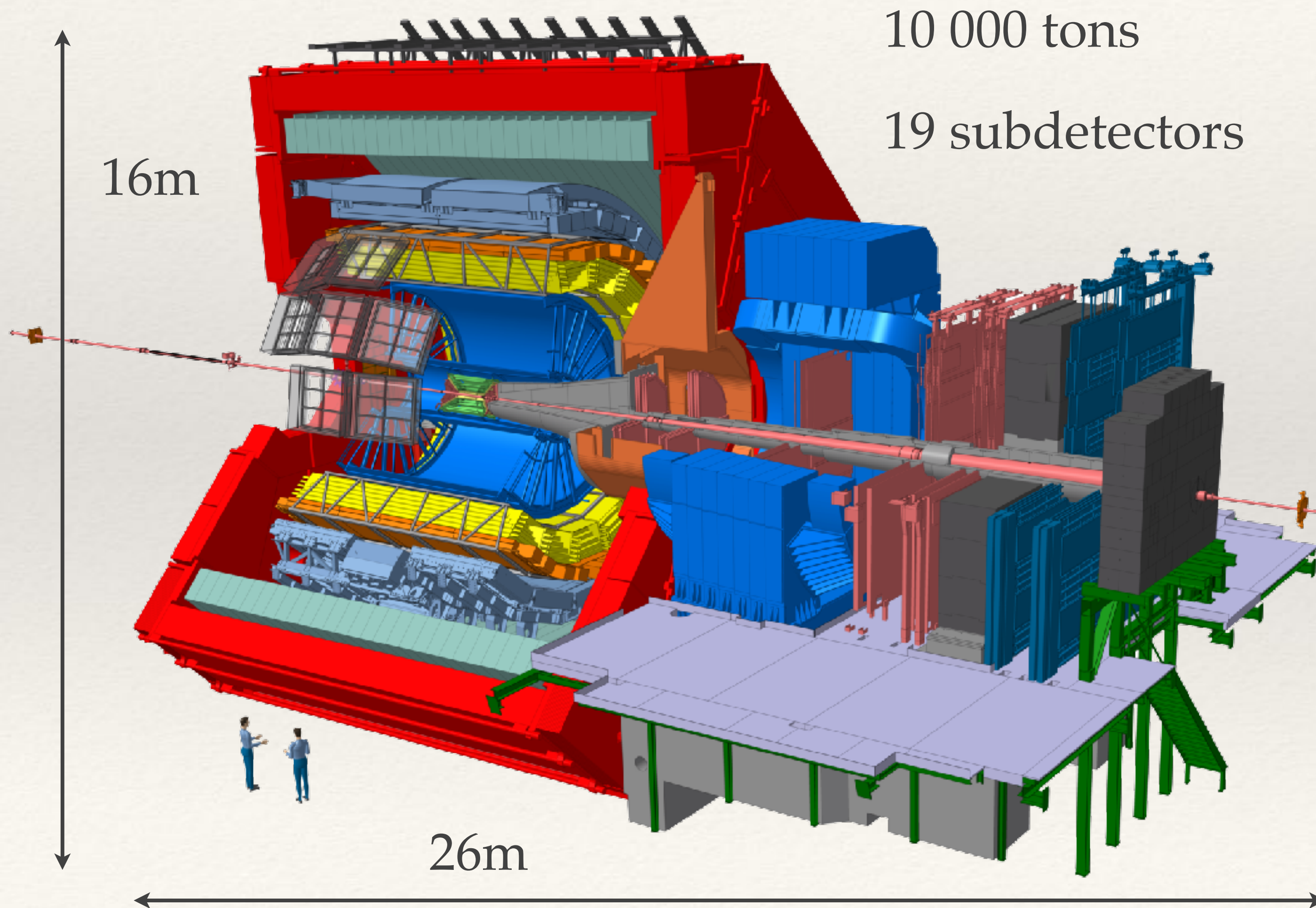
- ❖ Quarks and gluons are confined in hadrons
- ❖ Phase transition where quarks and gluons are free to propagate
- ☞ Quark-Gluon Plasma !
- ❖ Primordial state of the Universe (~1 μ s after the Big Bang)
- ❖ Core of dense neutron stars ?
- ❖ Ultra-relativistic heavy-ion collisions

Temperature



Introduction: A Large Ion Collider Experiment

Studying the **Quark-Gluon Plasma** properties in the lab



Physics impacts

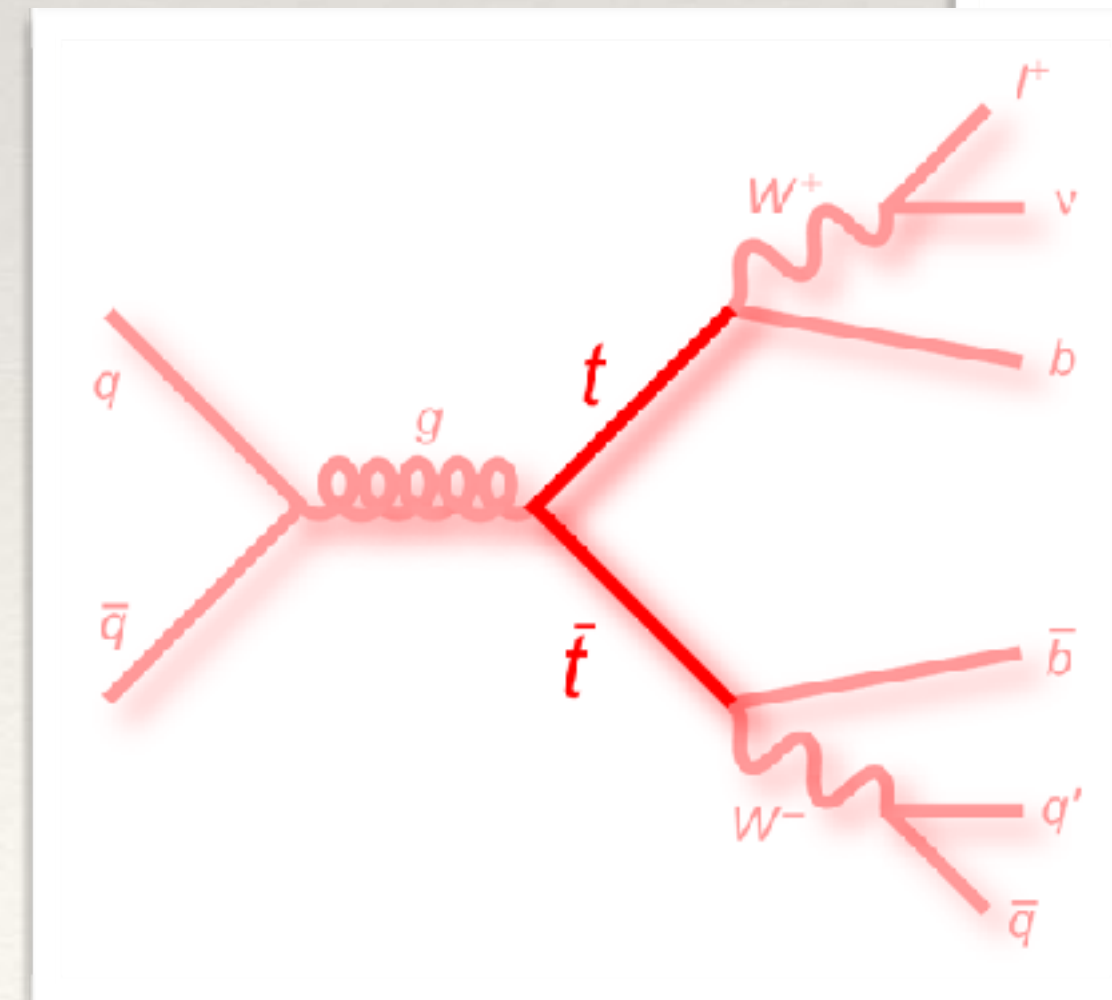
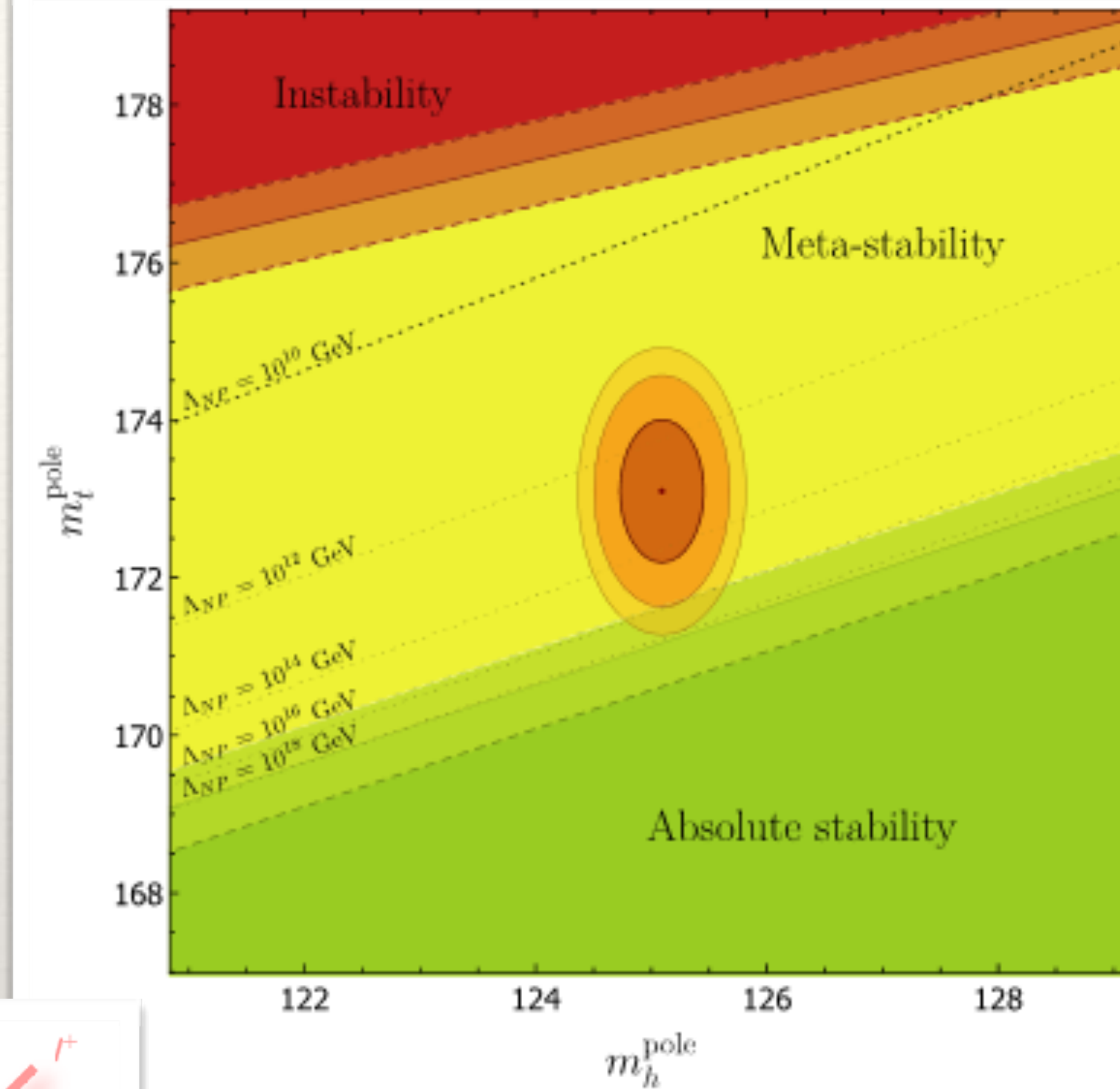
- ❖ confinement / deconfinement
- ❖ non-perturbative QCD
- ❖ EoS of neutron stars
- ❖ cosmological models
- ❖ limits of hydrodynamics
- ❖ ...

Top quark mass measurements

Top quark mass measurements: motivation

Why measuring the top quark mass?

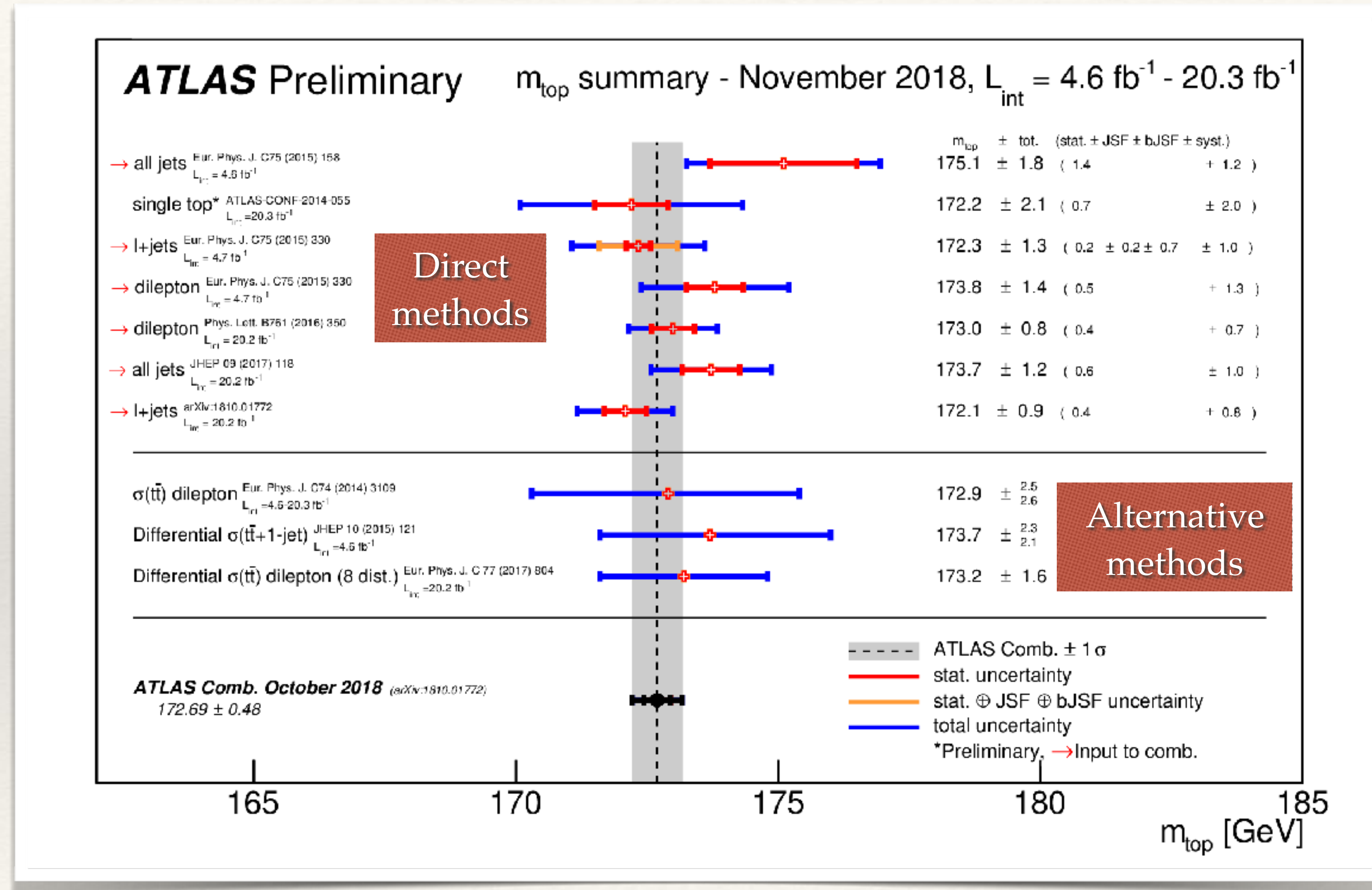
- ❖ Input for **Electroweak precision tests**
- ❖ Impacts the **vacuum stability** of the Standard Model
- ❖ Cosmological consequences (e.g. **Universe lifetime** [PhysRevD.97.056006](#))
- ❖ Top is the only quark for which **free** mass (the one in the Lagrangian) can be measured directly [JHEP 1709, 099 \(2017\)](#)



- ❖ [PhysRevD.97.056006](#)

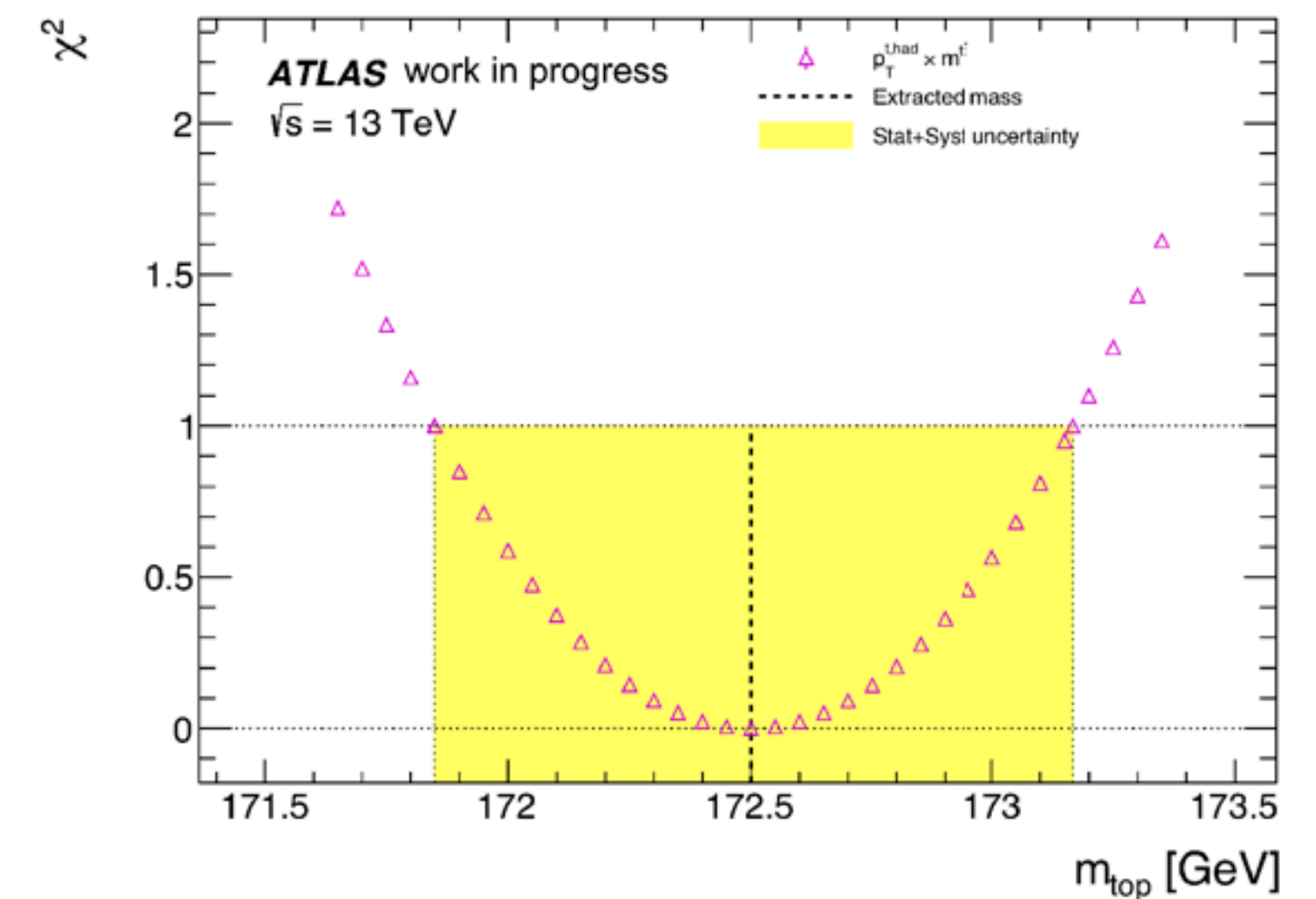
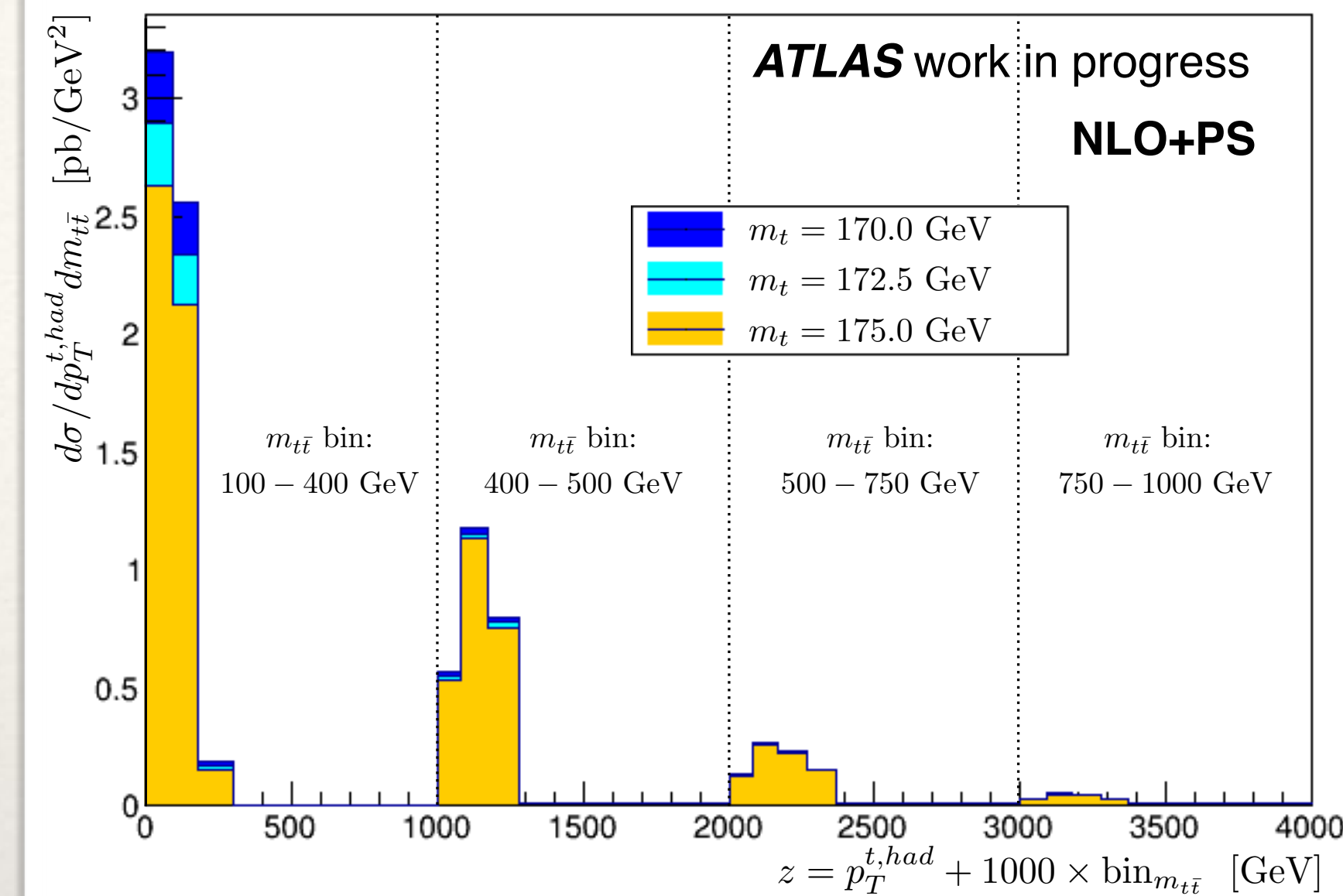
Top quark mass measurements: direct vs alternative methods

- ❖ Direct methods:
 - ❖ Use kinematical observables
 - ❖ Compare data to **Next-to-Leading-Order-plus-Parton-Shower (NLO+PS)** predictions
- ❖ Alternative methods:
 - ❖ Use $t\bar{t}$ cross-section
 - ❖ Compare data to **Next-to-Next-to-Leading-Order (NNLO)** calculations
 - ❖ Smaller theoretical uncertainties



Top quark pole mass determination from top-quark pair differential cross-sections

- ❖ $pp \rightarrow t\bar{t}$ process
- ❖ lepton+jets top decay channel
- ❖ data: 36.1 / fb @ 13 TeV
- ❖ double differential cross section $d^2\sigma/dm_{t\bar{t}}dp_T^{t, had}$
 - ❖ more precise than single differential cross section
 - ❖ compare to the theoretical NNLO predictions
 - ❖ Theoretical scale uncertainty improved w.r.t NLO
- ❖ mass extraction using χ^2 minimisation
- ❖ **Next step:** mass extraction using the data (currently working with the MC pseudo-data)

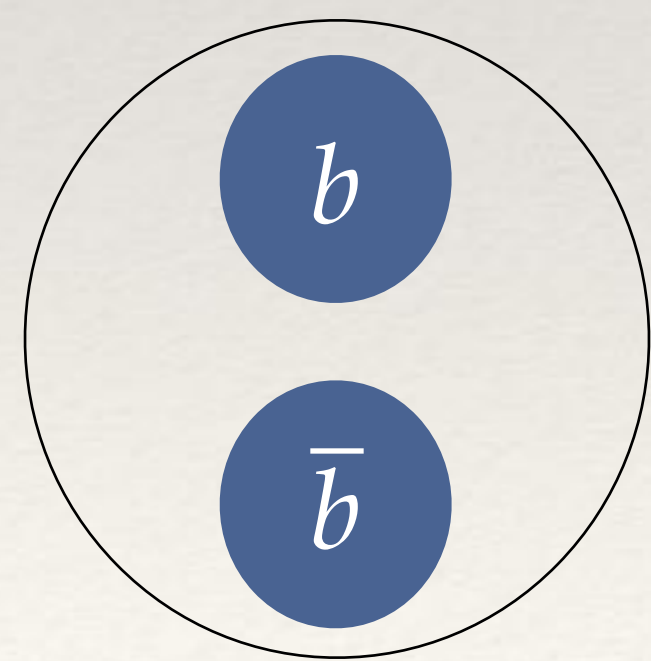


Upsilon production in heavy-ion collisions

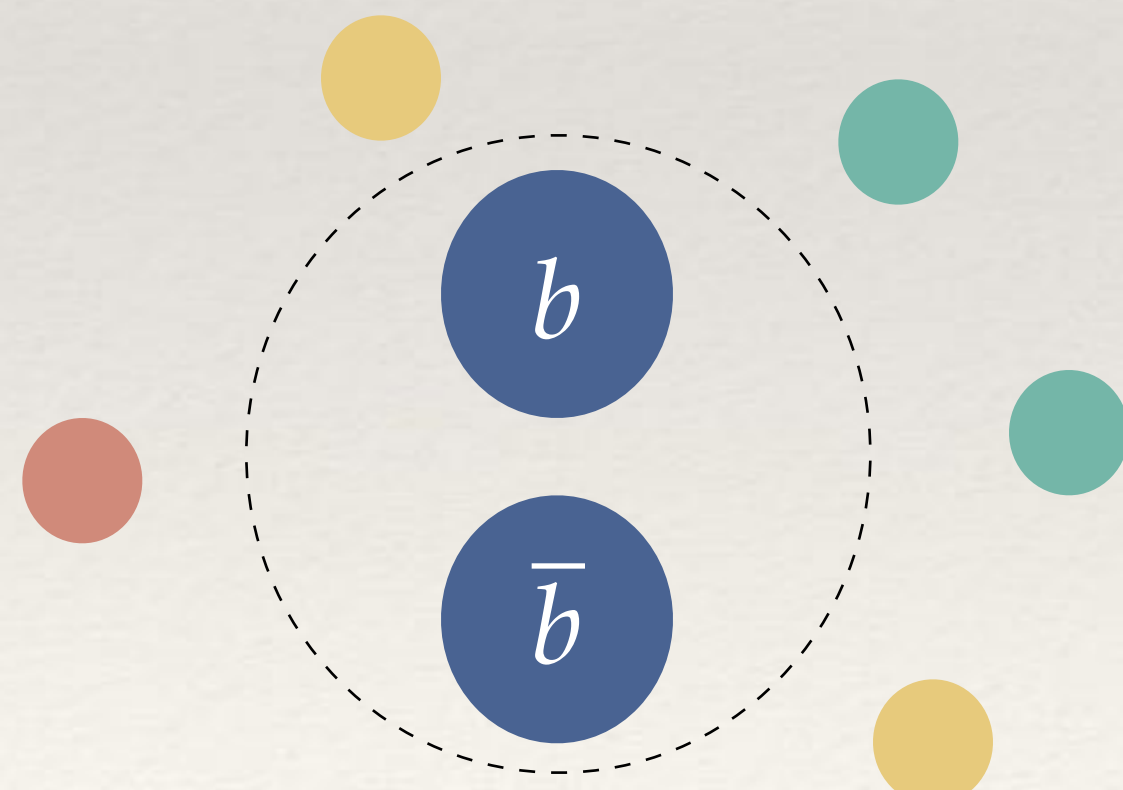


Physics motivation - *A smoking gun* of the deconfinement

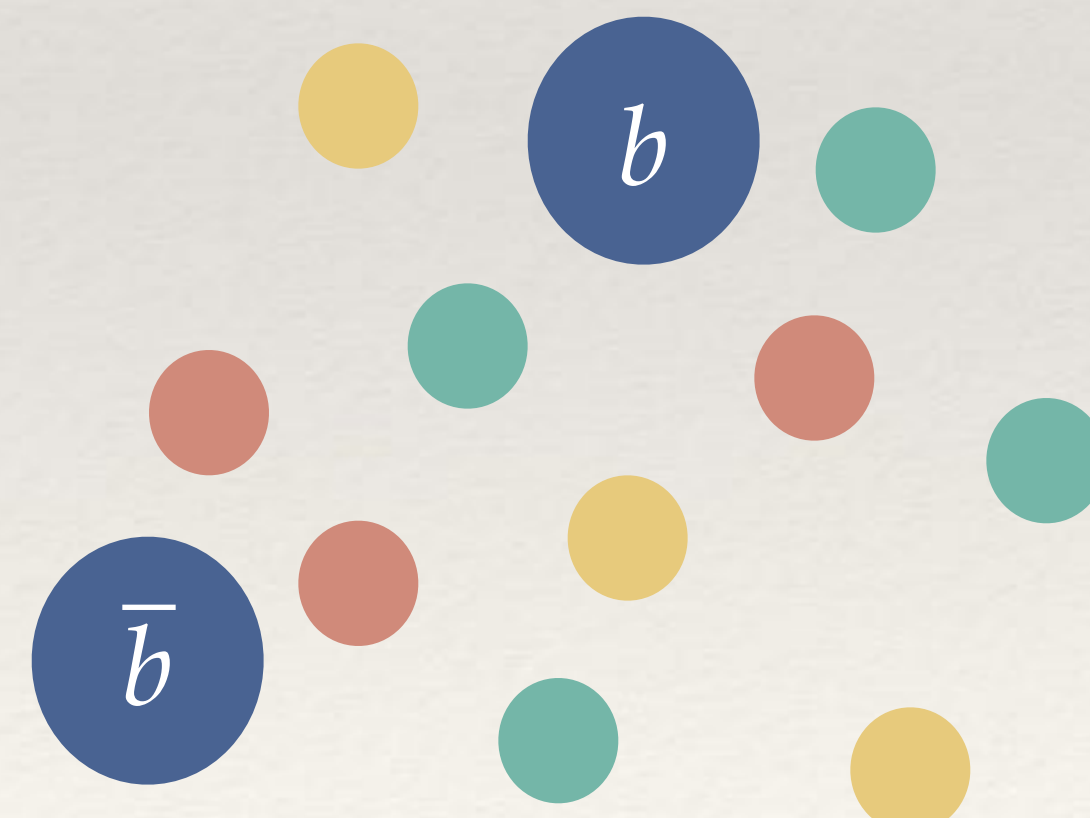
- ❖ $\Upsilon = b\bar{b}$ bound state
- ❖ produced **before** the QGP formation \rightarrow **ideal probes** of the hot medium
- ❖ if the temperature is high enough, the pair breaks up \rightarrow **upsilon suppression**
- ❖ different binding energies \rightarrow *sequential melting* \rightarrow **QGP thermometer !**



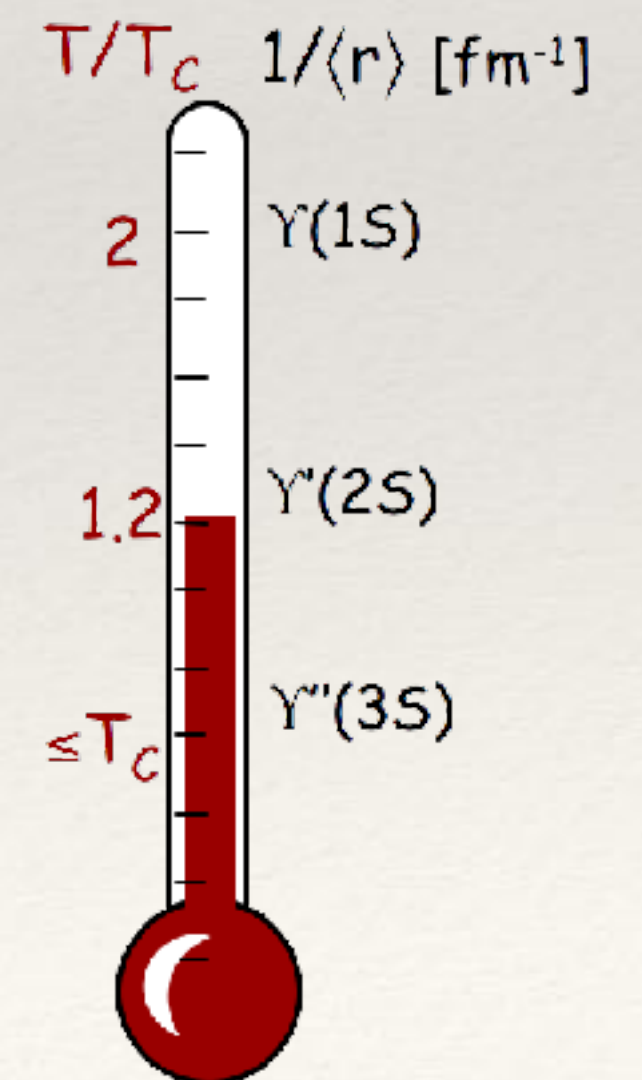
vacuum



low temperature QGP

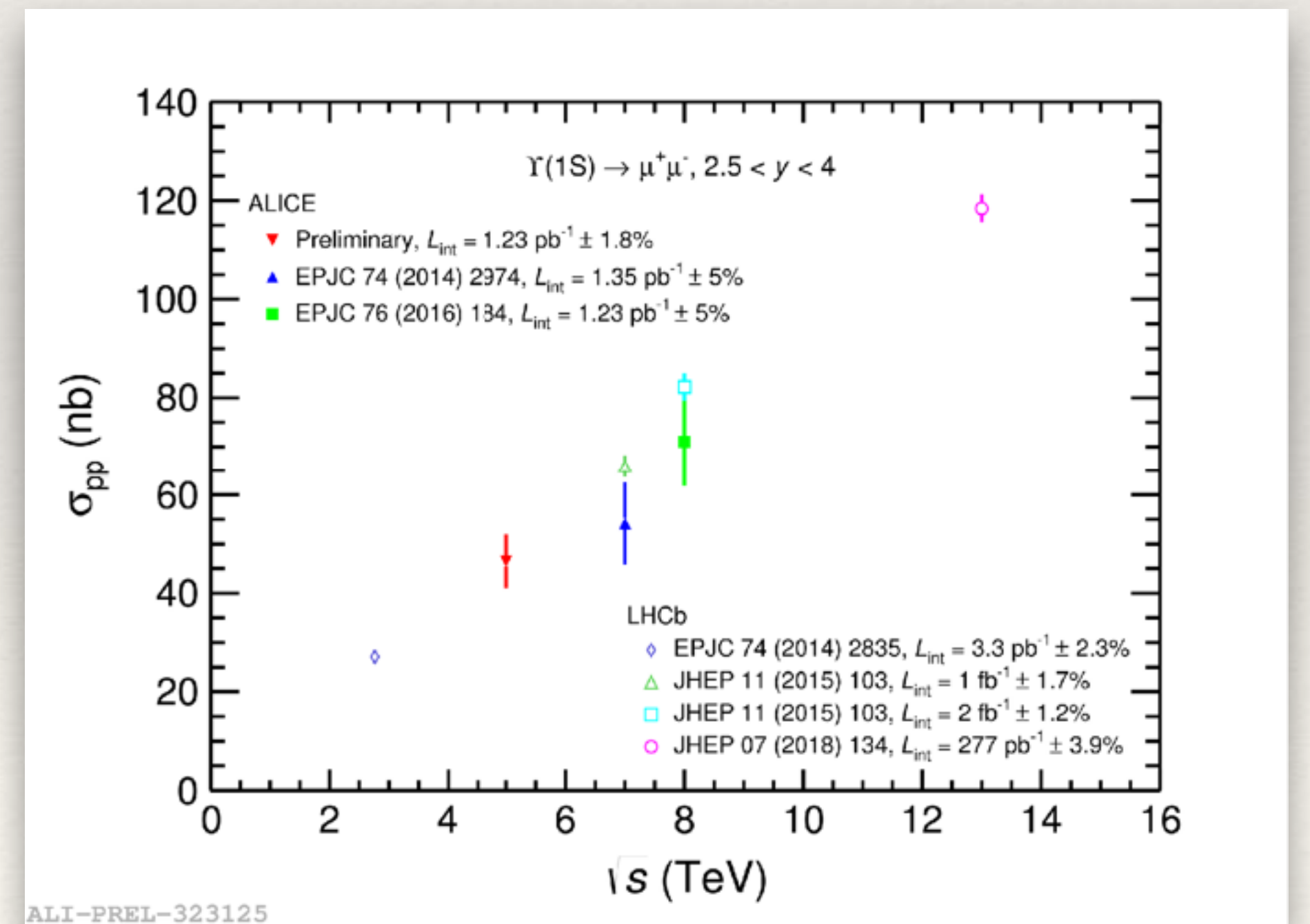
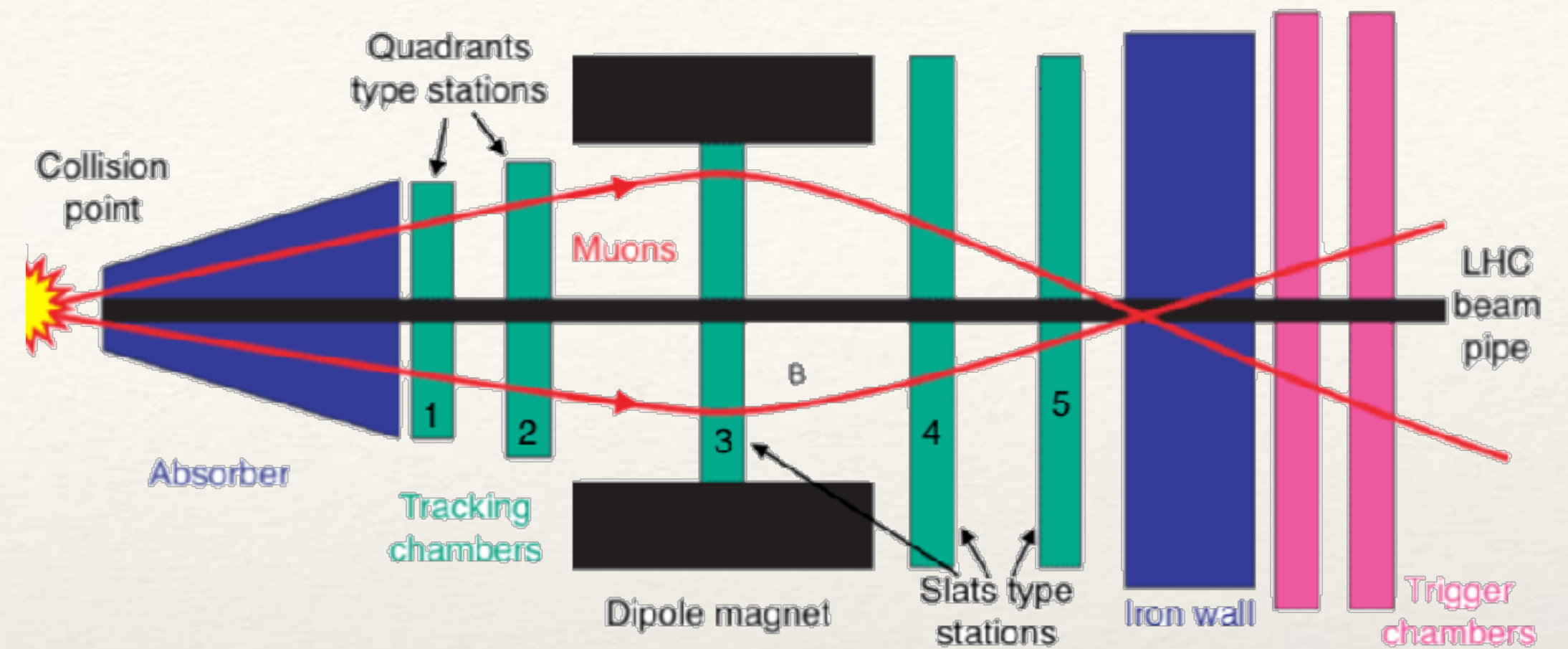


high temperature QGP



Upsilon production in proton-proton collisions

- ❖ Measurement of upsilon suppression w.r.t production in pp collisions (reference)
- ❖ 2017: pp @ 5 TeV
- ❖ $\Upsilon \rightarrow \mu^+ \mu^-$ with ALICE muon spectrometer
- ❖ Result: **production cross-section**
 - ☞ consistent with other measurements
 - ☞ precision improvement for suppression

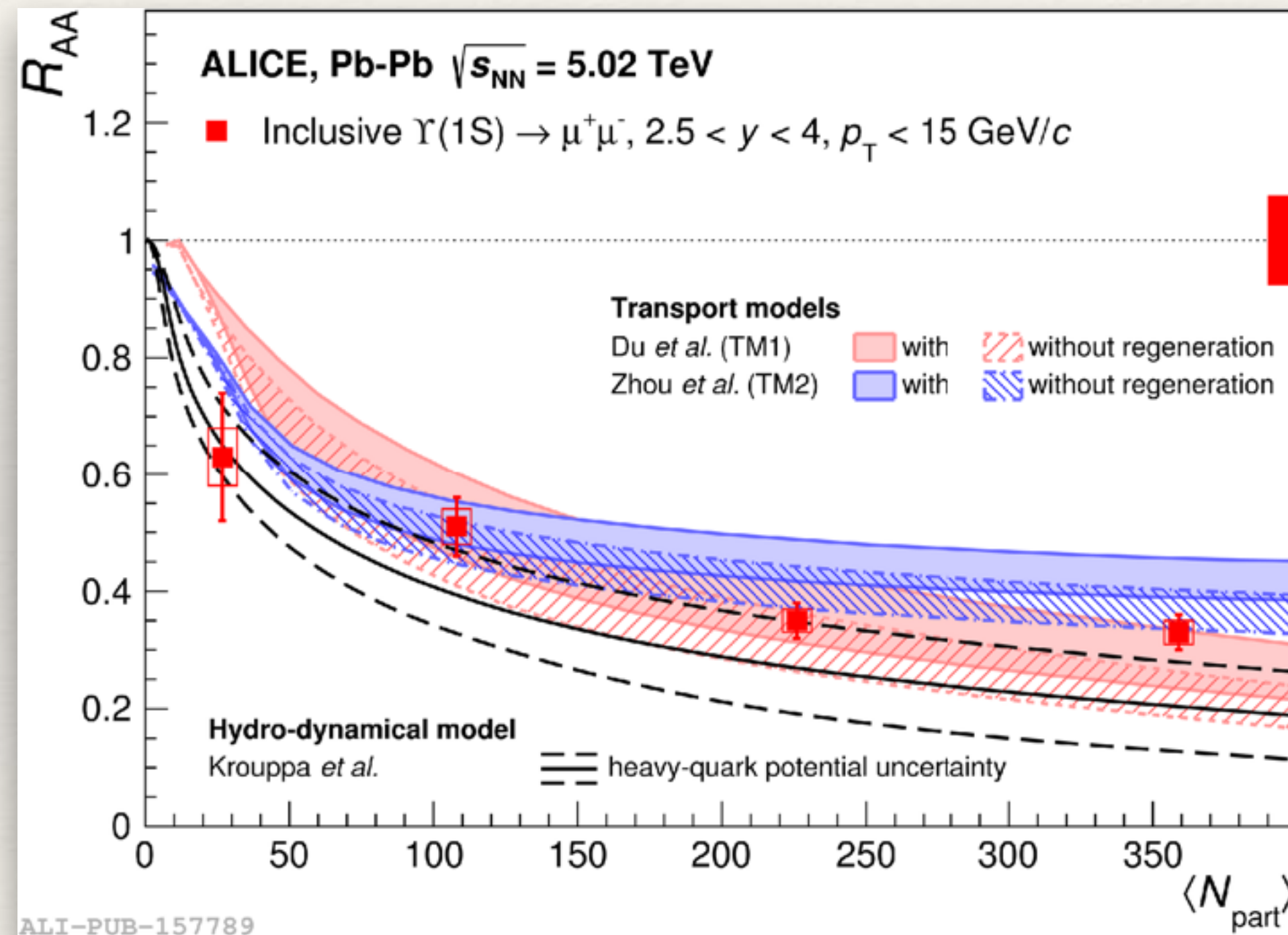


Upsilon production in heavy-ion collisions

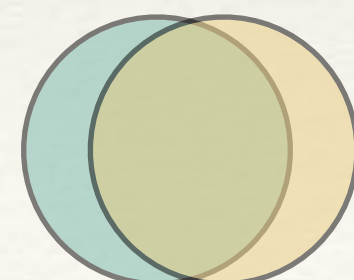
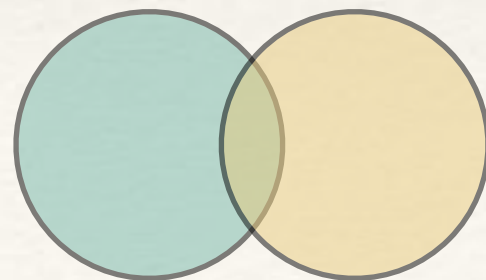
- ❖ 2015: Pb-Pb collisions @ 5 TeV
- ❖ $\Upsilon(1S)$ suppression compatible with models

- ❖ 2018 > 2 x 2015 data
 - ☞ reduce uncertainties
 - ☞ differential study

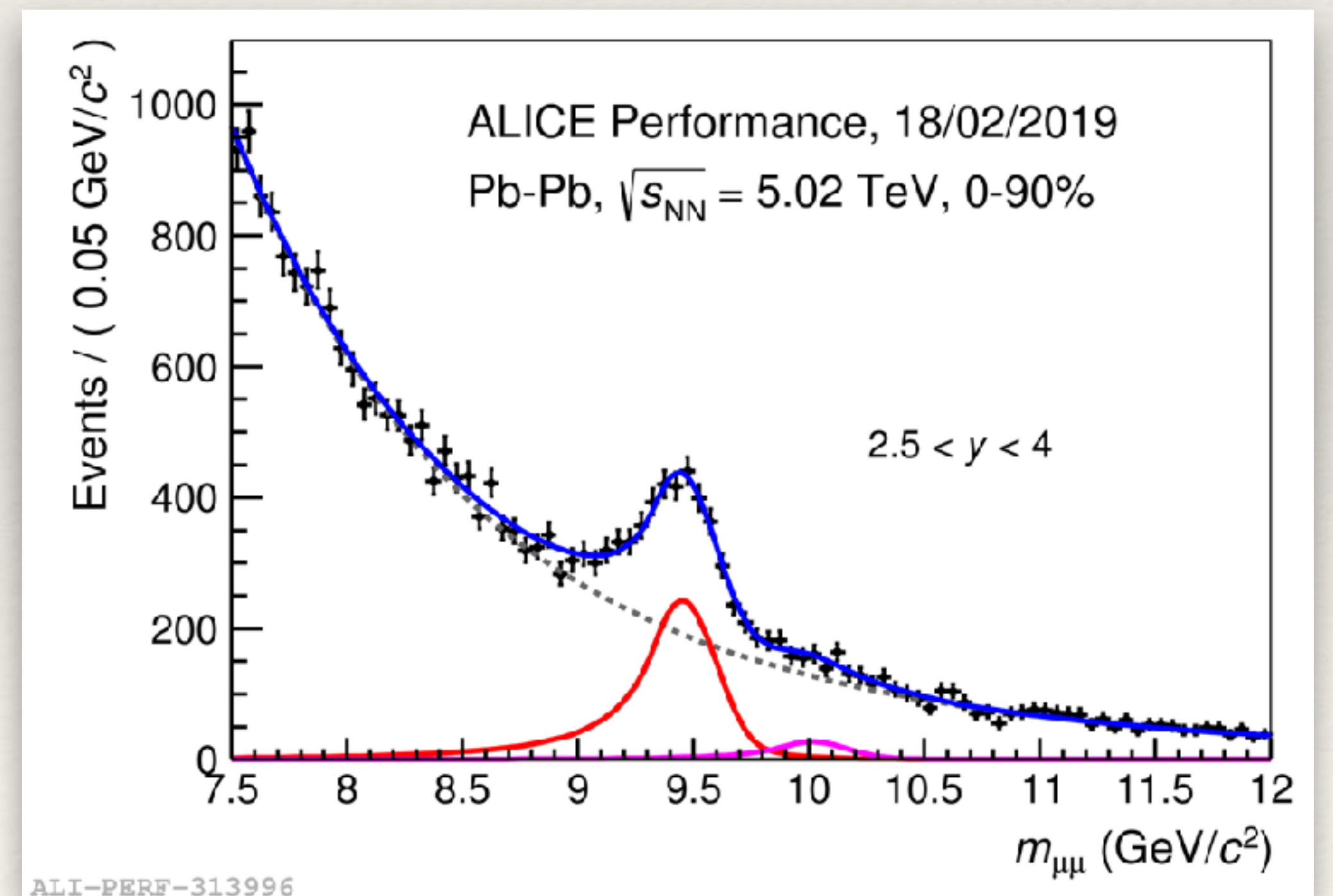
PLB 790 (2019) 89



ALI-PUB-157789



- ❖ analysis on-going



ALI-PERF-313996

Thank you for your attention !



ALICE

Run: 311071
Event: 1452867343
2016-10-21 06:34:07 CEST

Run: 295595
Timestamp: 2018-11-08 20:59:35(UTC)
Colliding system: Pb-Pb
Energy: 5.02 TeV

