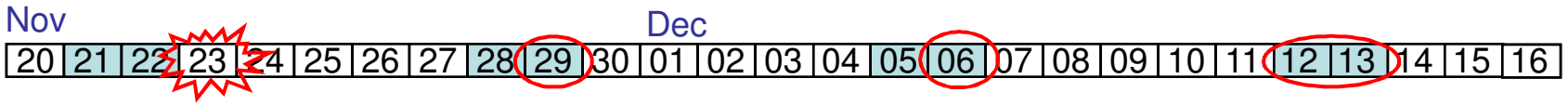
First collisions in LHC

Jeroen van Tilburg
(Universität Zürich)

- Highlights from startup run 2009.
- Many exciting achievements in few weeks time.
- Preliminary or very preliminary results.
- Comparisons between experiments very provisional.
- Most results already shown on Dec 18 (2nd LHC status report).
- Bias towards LHCb.

LHC timeline

Timeline of the world's most powerful particle accelerator



Nov 20	Both beams complete a few turns.
Nov 23	First proton-proton collisions at injection energy of 450 GeV.
Nov 29	World-record beam energy of 1.18 TeV established.
Dec 5	First multi-bunch beams in the LHC (2 bunches per beam)
Dec 6	First collisions with stable beams 4x4 pilots at 450 GeV, rate ~ 1 Hz → first time silicon detectors fully operational.
Dec 8	Accelerated both beams to 1.18 TeV with 2 bunches for the first time.
Dec 11	Collisions with stable beams 4x4, $>10^{10}$ per bunch, at 450 GeV, rate ~10 Hz.
Dec 12-13	High intensity runs (~50 Hz) with ~1 million collisions at 450 GeV and 50k collisions at 1.18 TeV.
Dec 16	End of 1st successful period of operation. 27 days of very successful beam commissioning.

→ Restart on February 15, 2010 for a short technical stop:
- Commissioning for higher energies (3.5 TeV beam)
- Upgrade of CMS cooling system

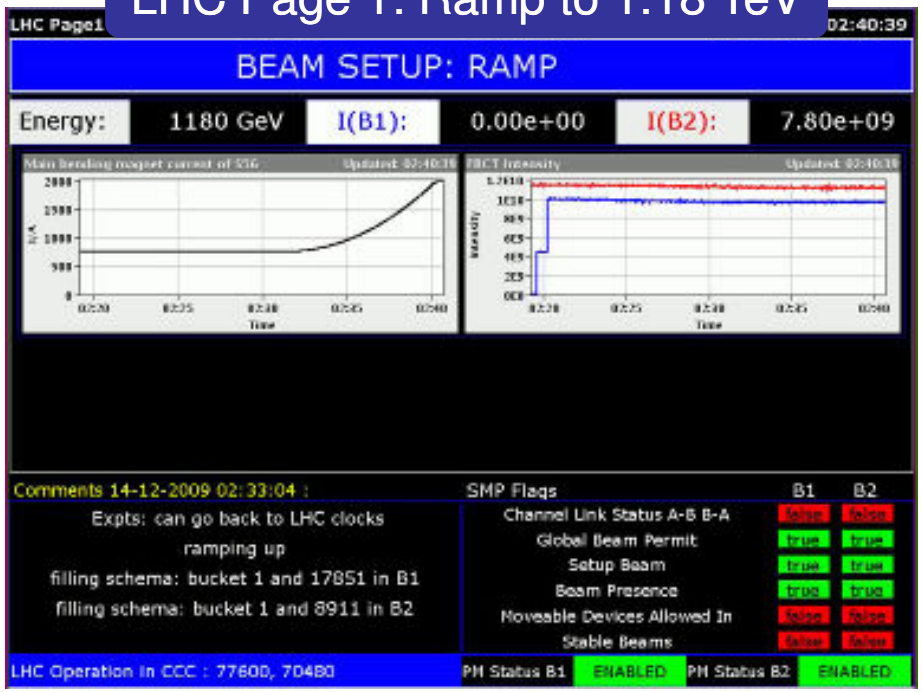
→ Follow the LHC live on twitter.com/lhc

LHC beam commissioning

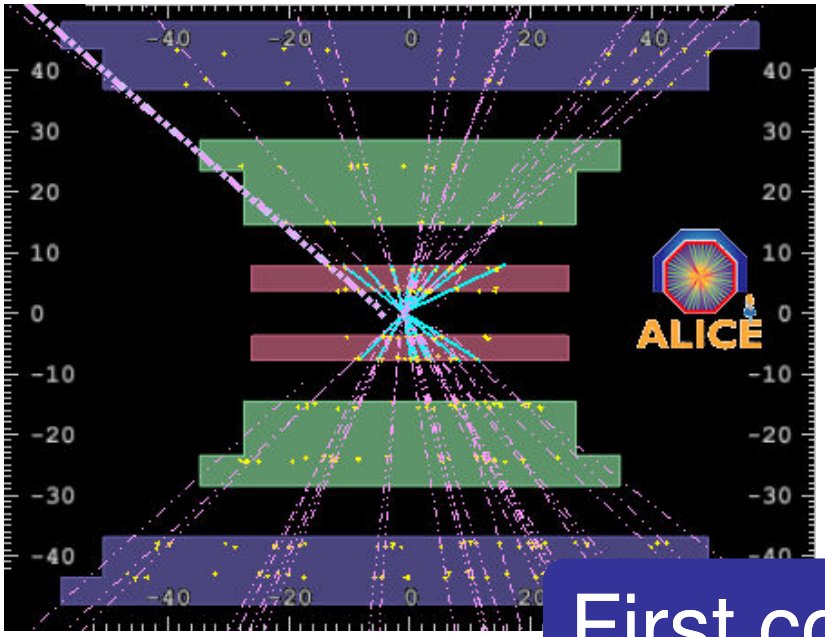
LHC is back!

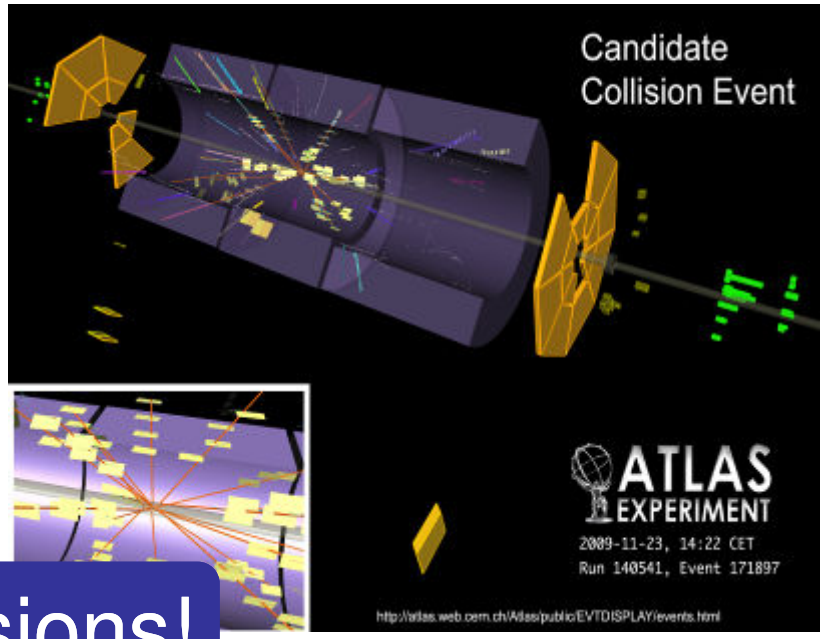
- Very careful planning, adjusted on daily basis.
- Many systems working from day 1.
- Around the clock availability of accelerator and detector components.
- Provided detectors with many useful collisions at 450 GeV and 1.18 TeV.

LHC Page 1: Ramp to 1.18 TeV

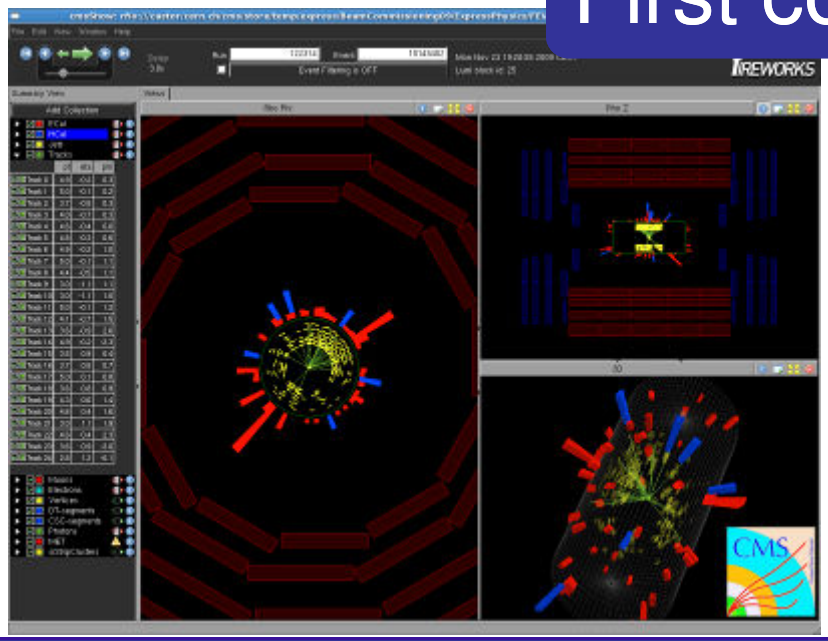


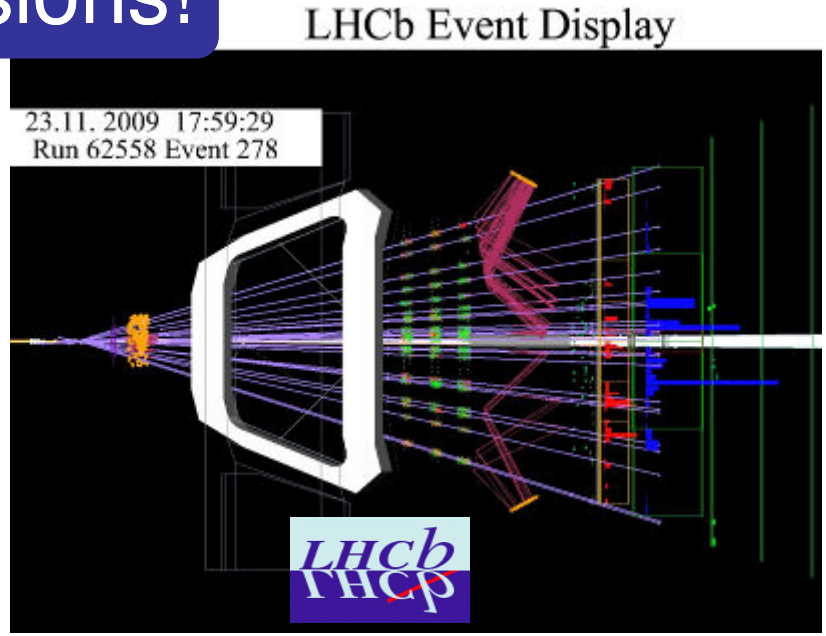
Event displays from 23rd Nov





First collisions!



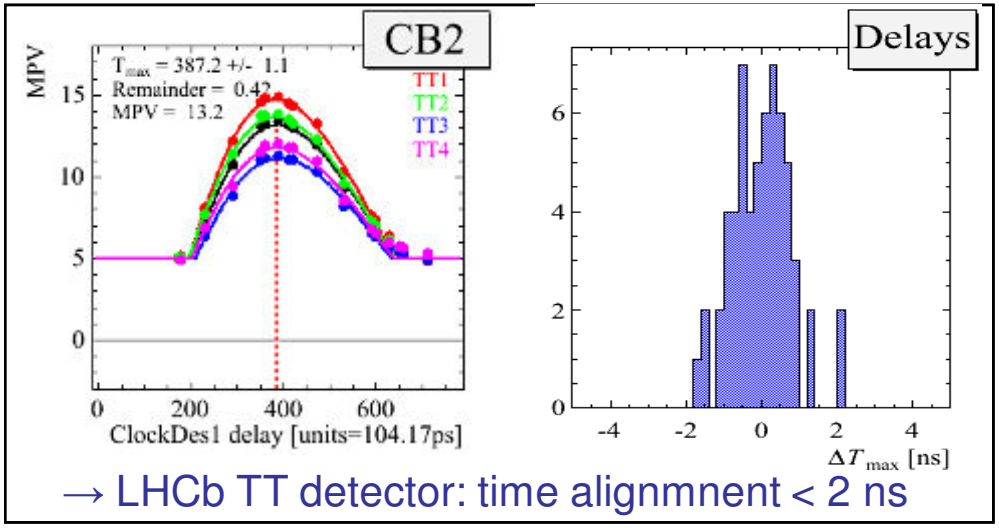


And then...

Calibration

Time alignment

- First alignment silicon detectors on 6 Dec (1 Hz)
  - Stable beam declared early morning.
- Redone on 11 Dec with higher statistics (10 Hz)
- Use bunch id's to distinguish collisions from beam gas and cosmics.



→ LHCb TT detector: time alignmnent < 2 ns

Spatial alignment

- Already in good shape thanks to data from cosmics and injection tests.
- Still in progress → mass resolutions will improve with time.
- Understanding of magnetic field →

Example from LHCb

- Cosmic runs and injection tests done with field off.
- First data with magnetic field.
  → got polarity wrong initially ☹
- Calibration has started.
- First mass peaks at right place ☺

Other calibrations

→ drift time, calorimeters, material map, jet energy scale, PID, etc.

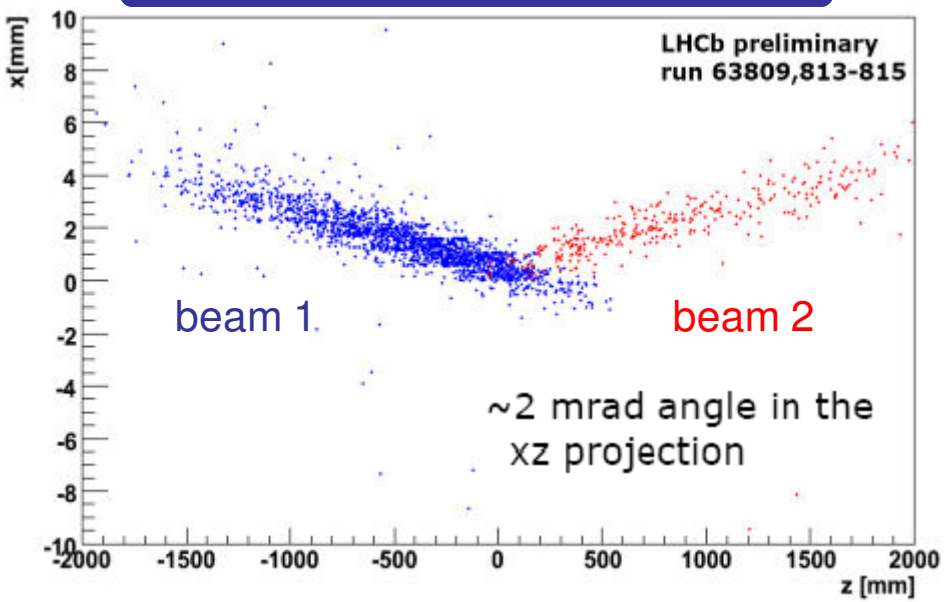
Beam position

Beam accurately monitored by experiments

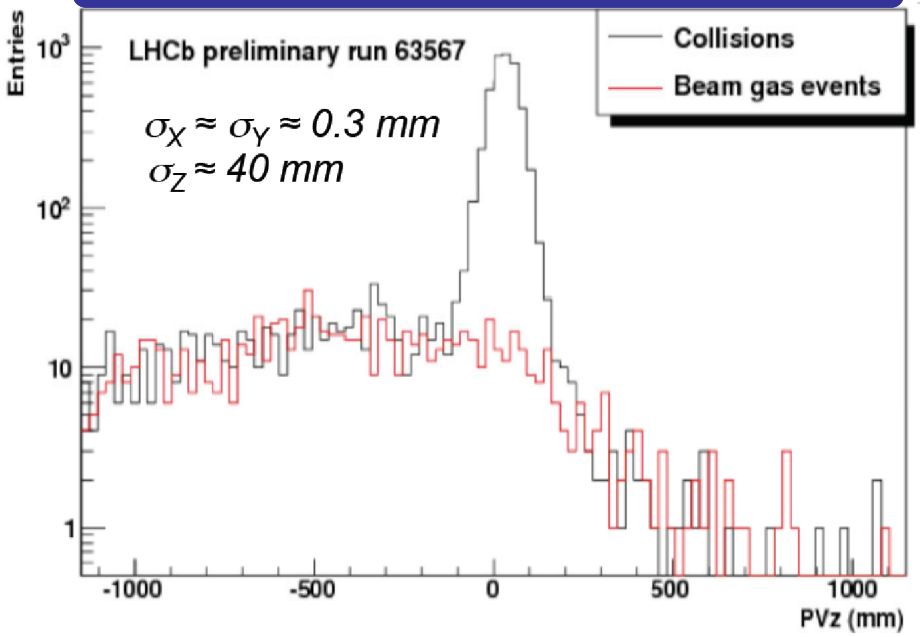
Example → **LHCb VELO detector**

- VELO halves can be moved in and out.
- During injection VELO at 30 mm from beam.
- Nominal position sensors at 8 mm from beam.
- At 450 GeV VELO can not yet be fully closed (beam too wide).
  → each side at 15 mm from nominal (i.e. 17 mm from beam).
- Important to closely monitor the beam before closing!

xz distribution of beam-gas vertices



Measure dimensions of luminous regions:



Data distribution

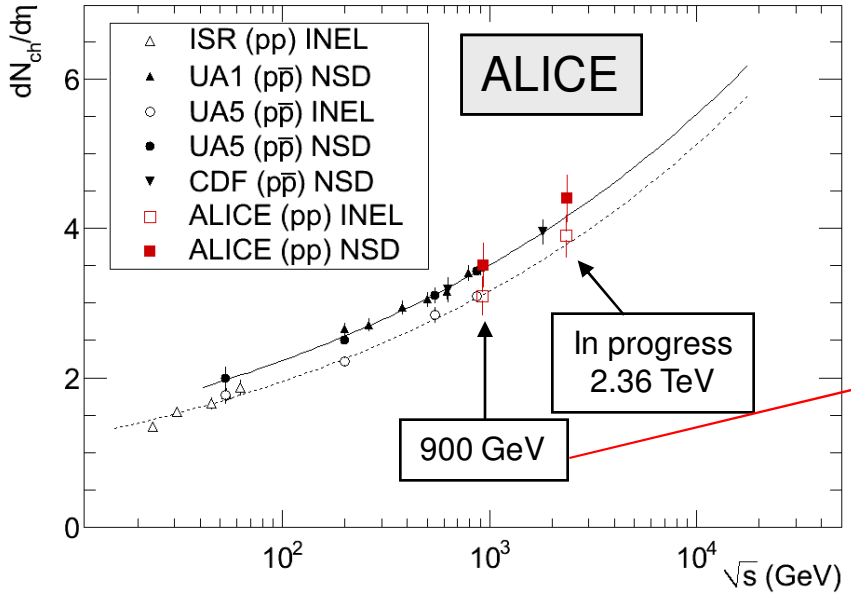
Over a million particle collisions distributed smoothly for analysis around the world on the LHC computing grid

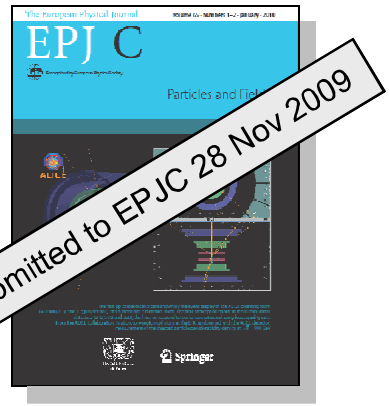
- Two copies of raw data
  → one at CERN, one at a Tier 1
- DST available soon after data acquisition finished.
  → Example: LHCb < 1 hour.
  → Includes reconstruction.
- Example from LHCb: reprocessed complete dataset in less than 2 hours (done twice already)

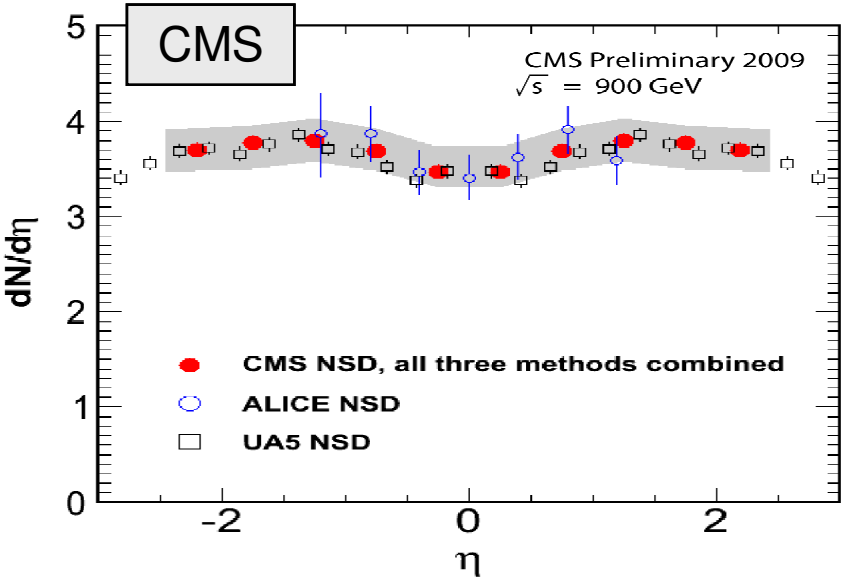
	Total @ 900 GeV	Full det @ 900 GeV	Total @ 2.36 TeV
ALICE	> 1 M		30k
ATLAS	920k	540k	34k
CMS		400k	20k (full CMS)
LHCb		540k	30k

Fraction with collisions ~ 30-60%

Charged particle multiplicity



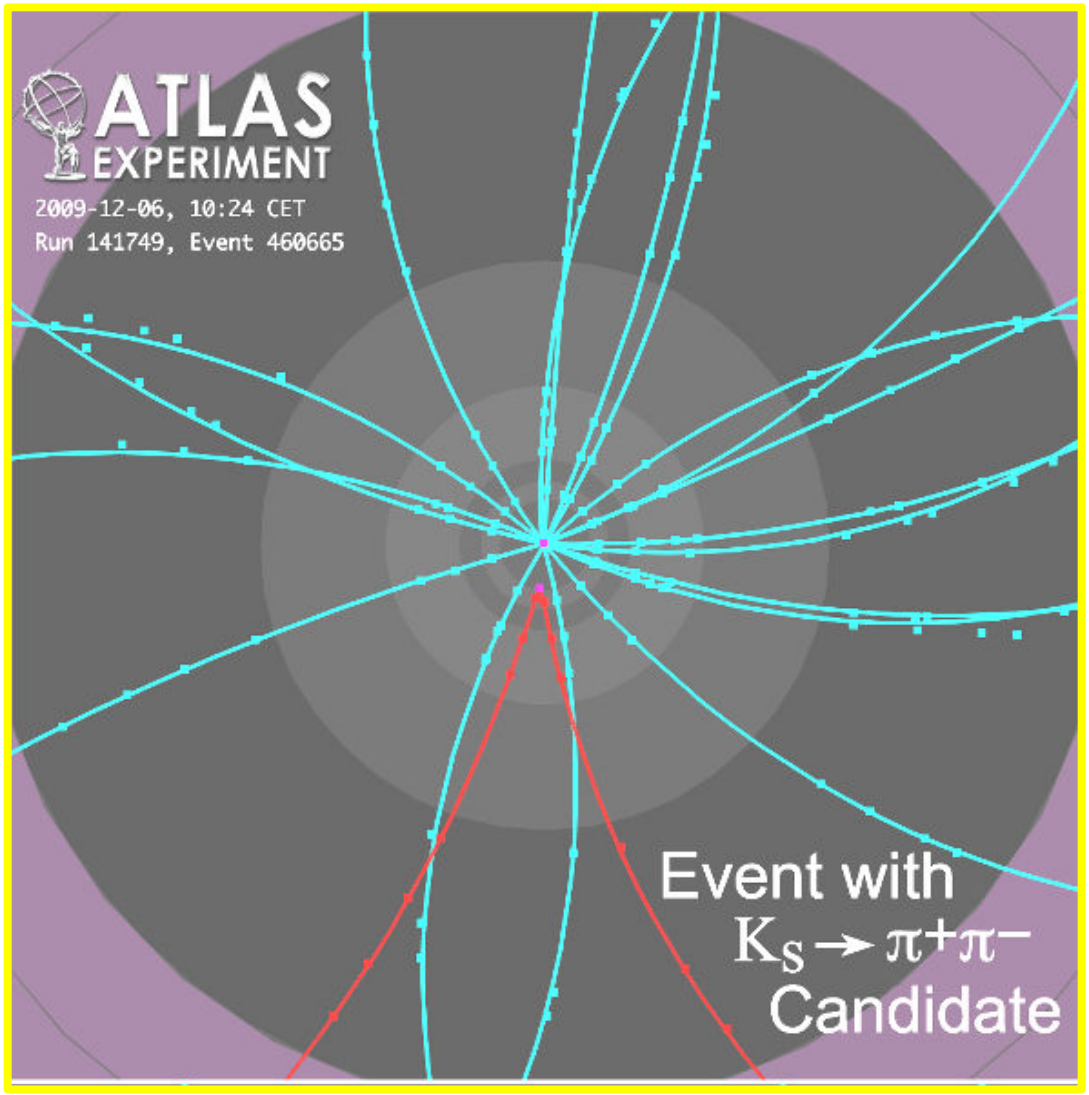




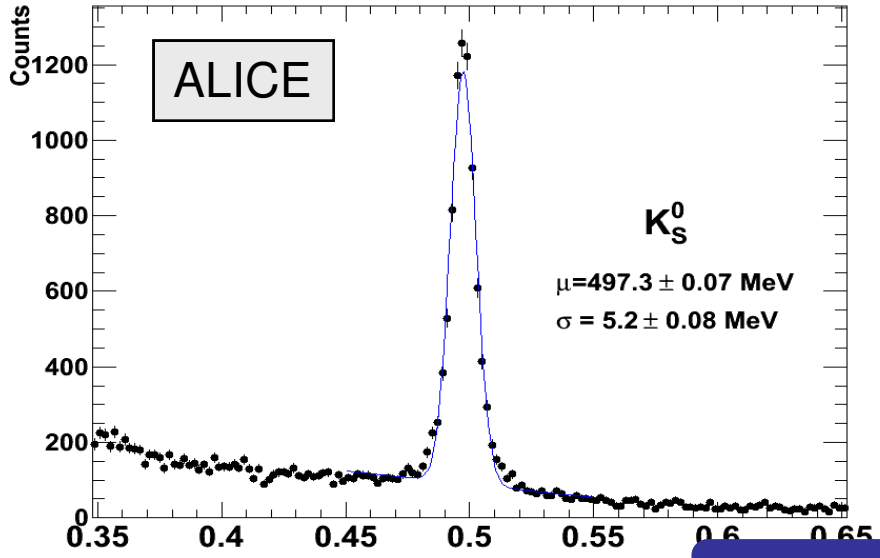
First physics output

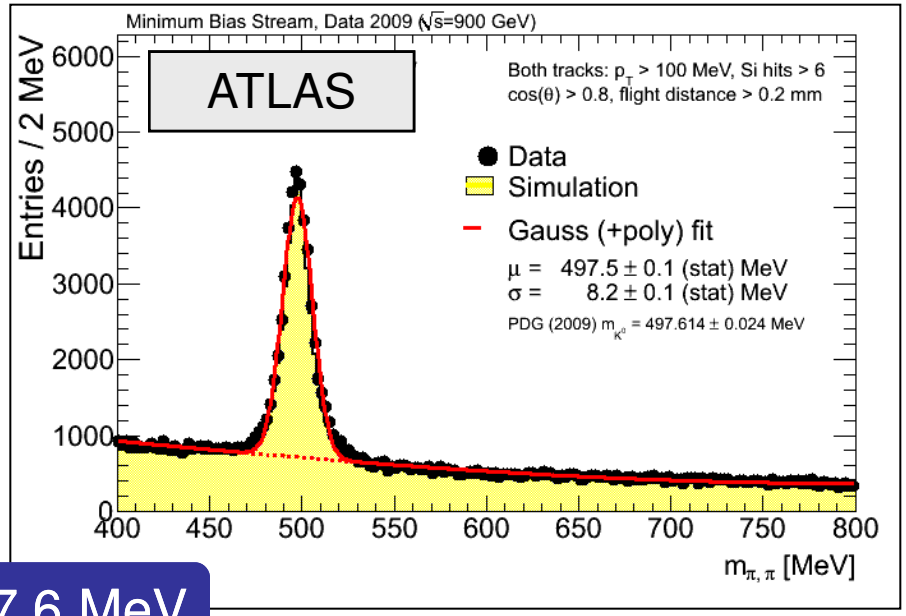
- ALICE already submitted paper on charged particle multiplicity at 900 GeV.
  $dN/d\eta = 3.10 \pm 0.13$ (stat) ± 0.22 (syst)
- Work in progress for 2.36 TeV.
- CMS has measured $dN/d\eta$ between $-2 < \eta < 2$

The particle zoo

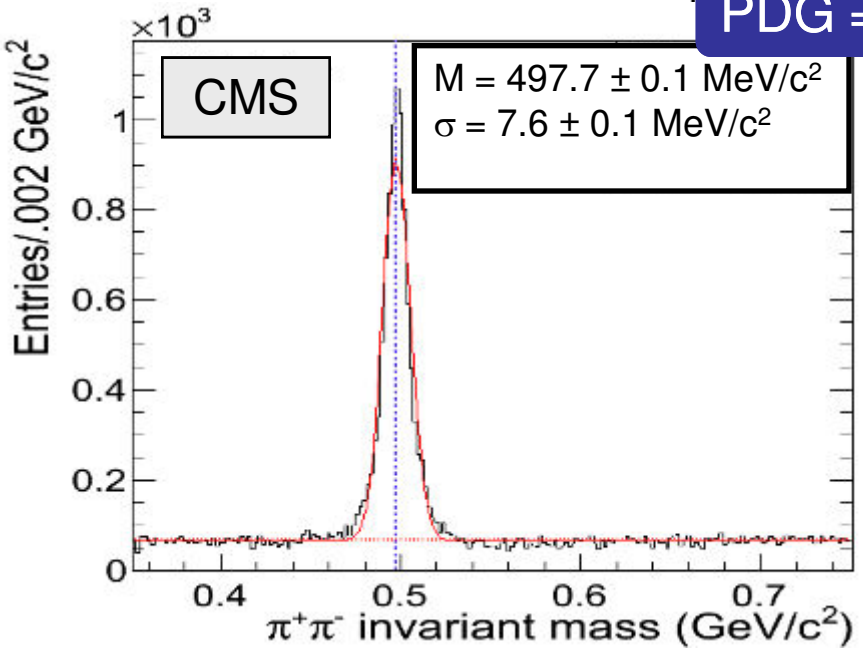


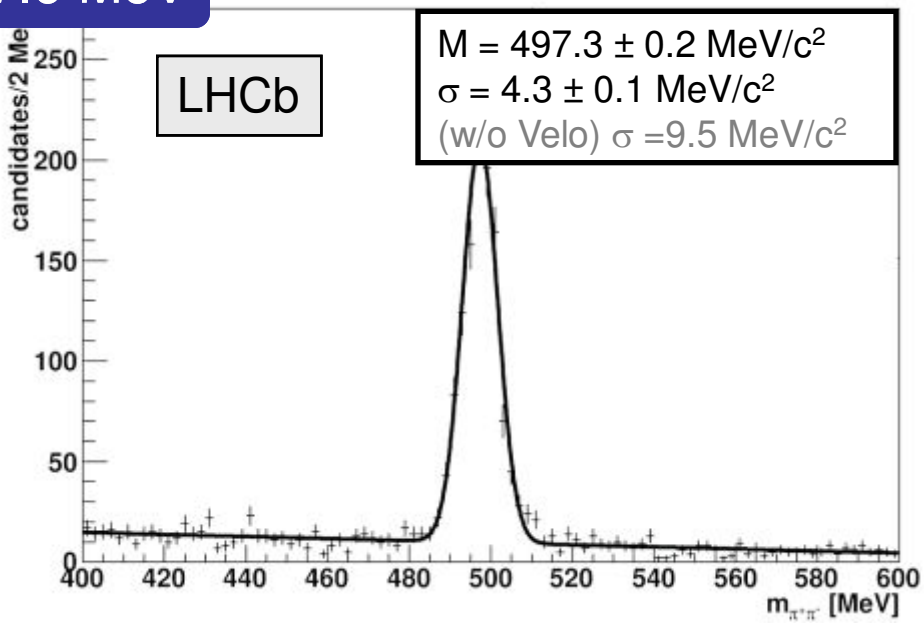
$K_s^0 \rightarrow \pi^+ \pi^-$



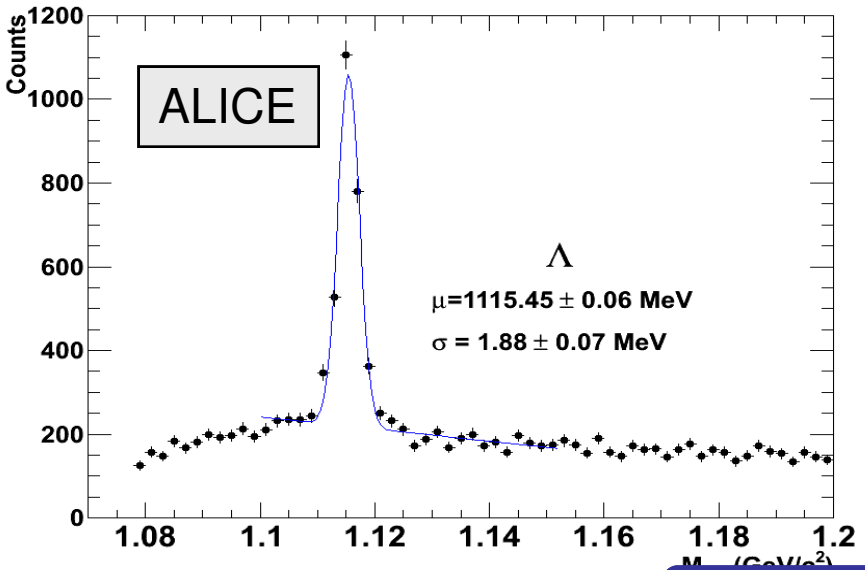


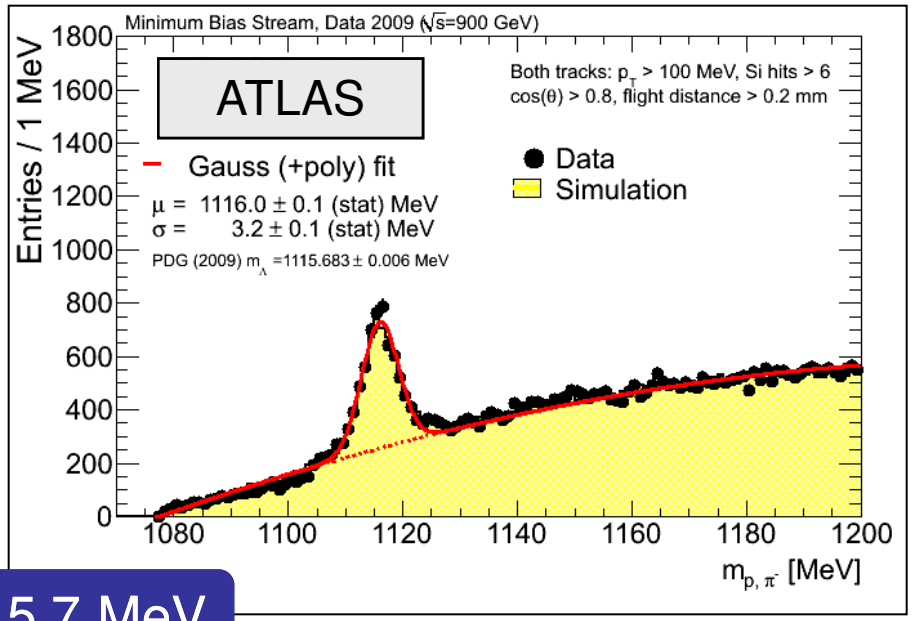
PDG = 497.6 MeV



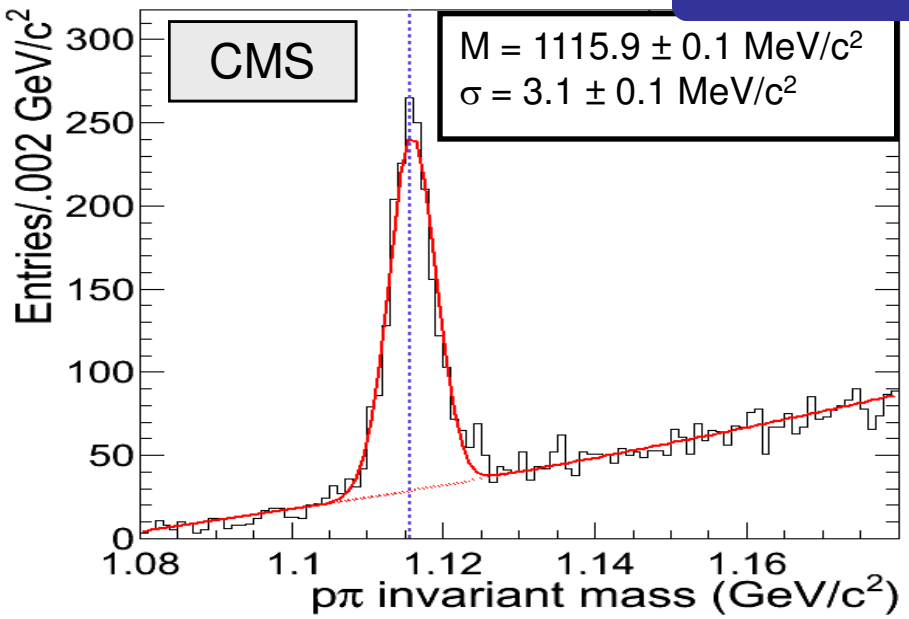


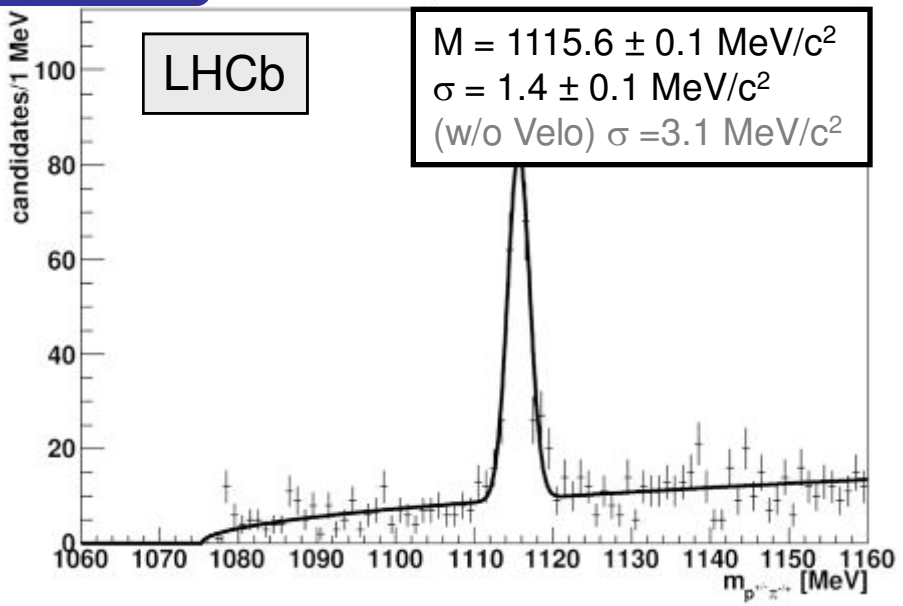
$\Lambda^0 \rightarrow p^+ \pi^-$



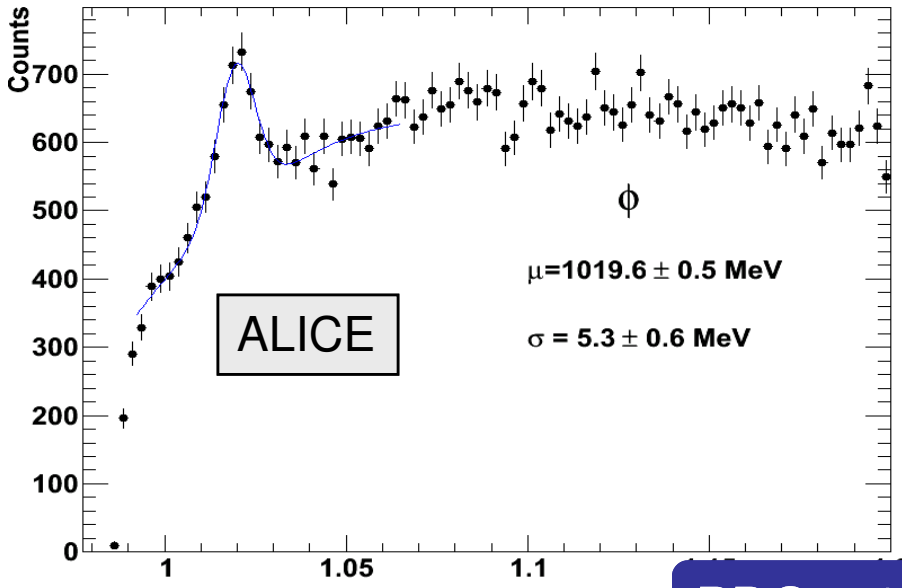


PDG = 1115.7 MeV

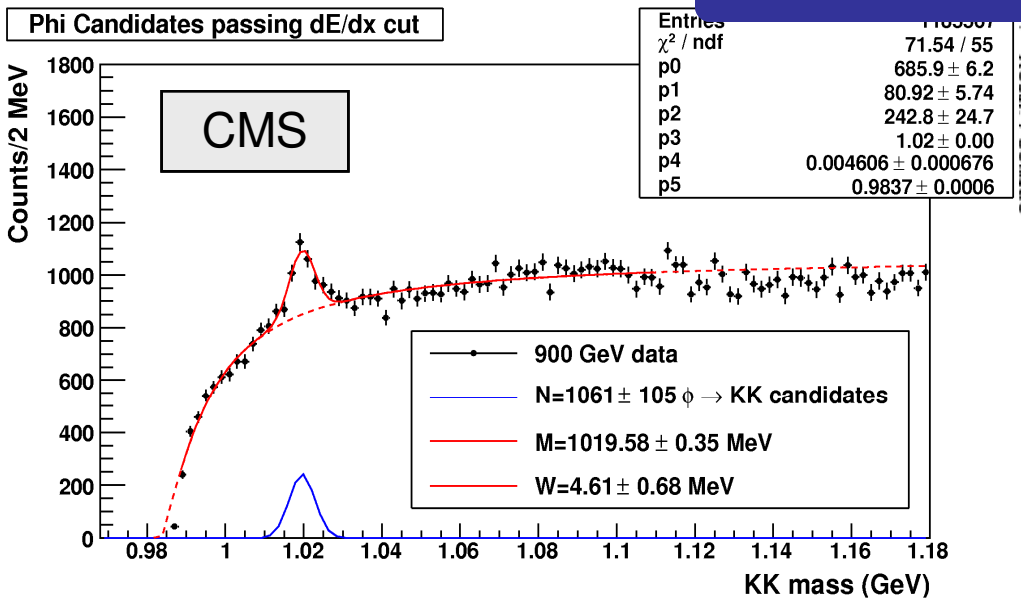


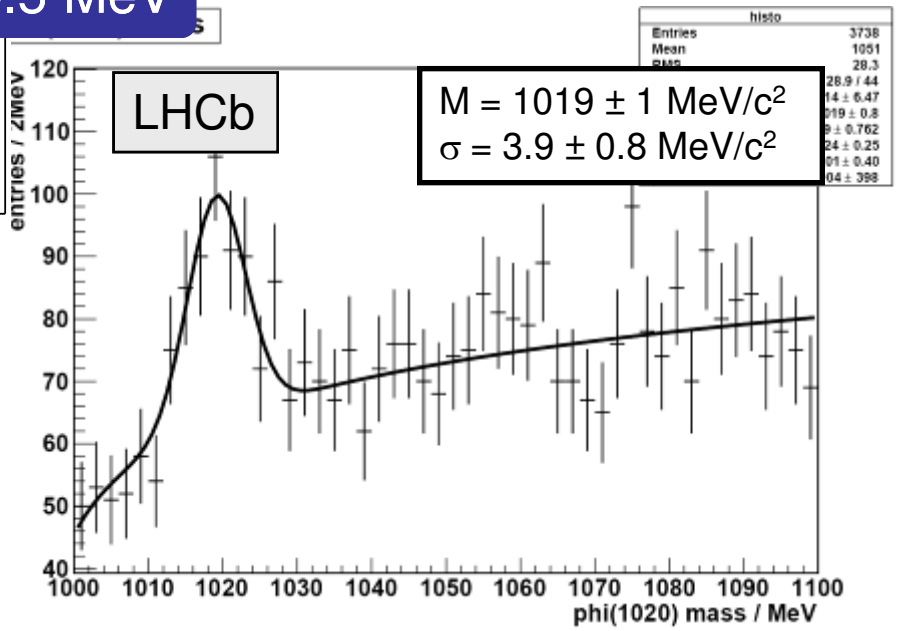


φ(1020) → K⁺ K⁻



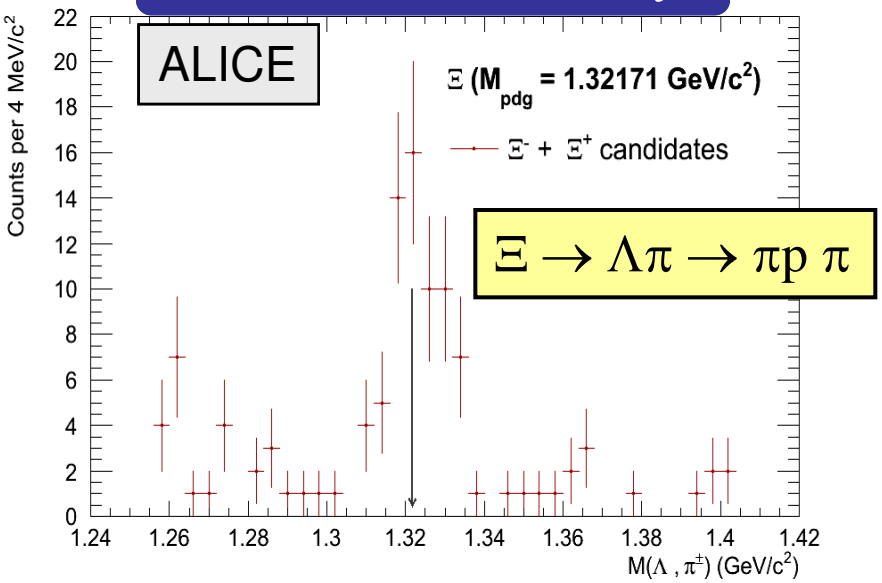
PDG = 1019.5 MeV



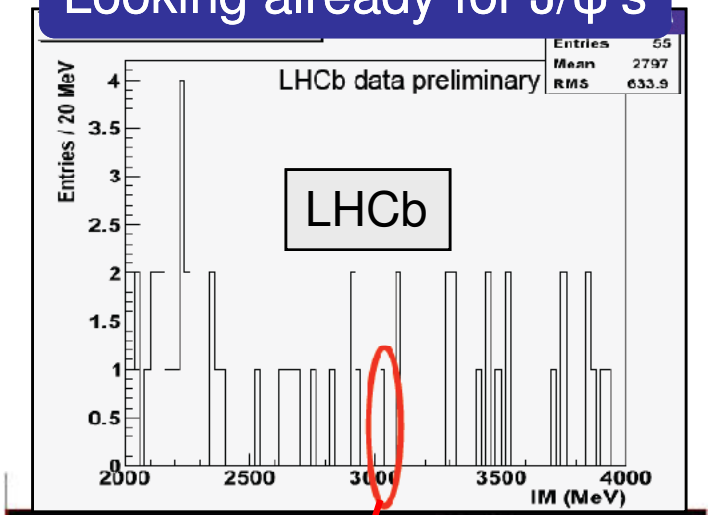


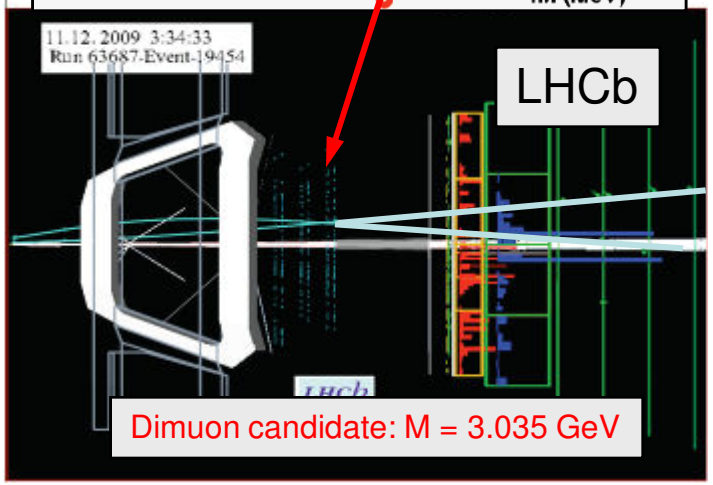
Rest of the zoo

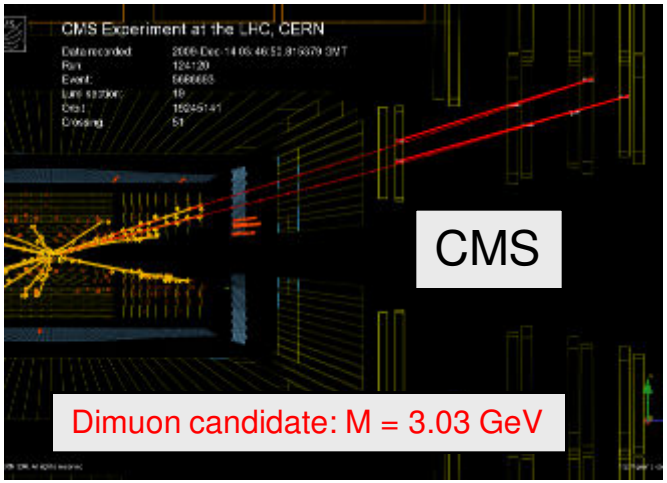
Found cascade decays



Looking already for J/ψ's







Conclusions

- LHC and experiments have performed extremely well and swift
- Beam commissioning well underway.
- Successful collection of the first LHC collision data.
- Smooth data transfer worldwide via Grid.
- Extremely rapid production of first (albeit very preliminary) results.
- Now experiments have time to digest the data.
    - Further calibration (alignment) and analysis.

Looking forward for LHC restart on February 15th!

pp-collision and beam-gas animation