

Wstęp do fizyki cząstek elementarnych: część eksperymentalna

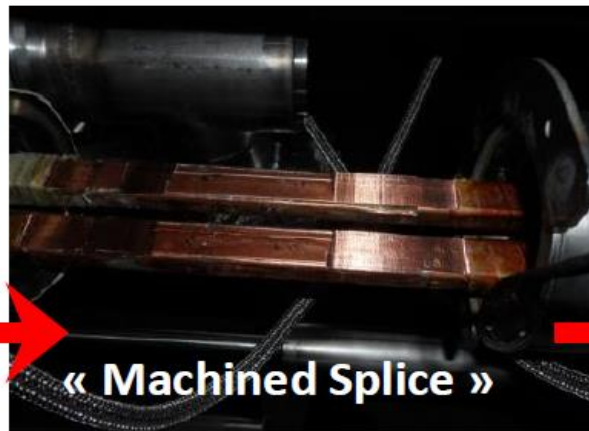
**Large Hadron Collider
restarted operation
delivering 13 TeV pp collisions**

LS1 - descent into the underworld again





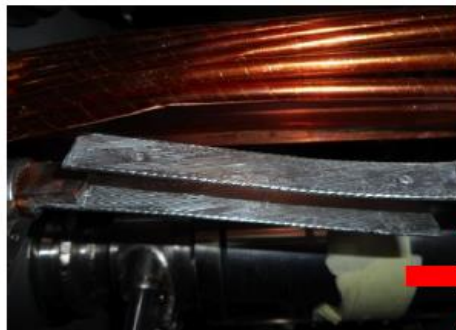
« Old Splice »



« Machined Splice »



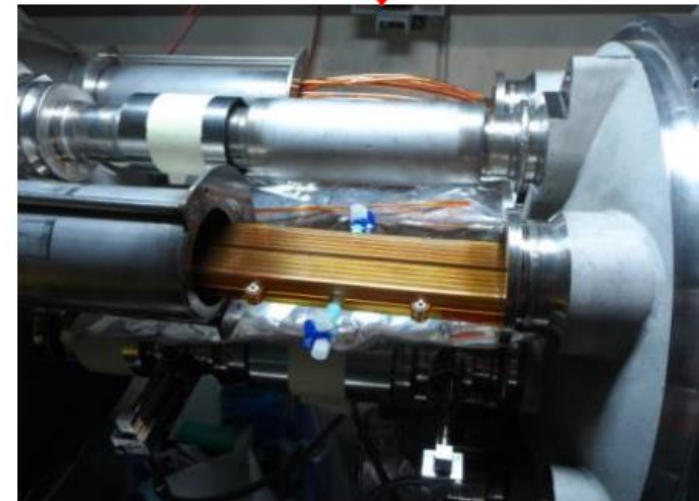
« Consolidated Splice »



« Cables »



« New Splice »



« Insulation box »

- Total interconnects in the LHC:
 - 1,695 (10,170 high current splices)
- Number of splices redone: ~3,000 (~ 30%)
- Number of shunts applied: > 27,000

And a lot more besides...

Superconducting Magnets and Circuits Consolidation (SMACC)

Monumental effort

- Over 350 persons involved
- Including preparation: ~1,000,000 working hours
- No serious accidents!

Jean-Philippe Tock



Collaborations with NTUA (Athens), WUT (Wroclaw) and support of DUBNA



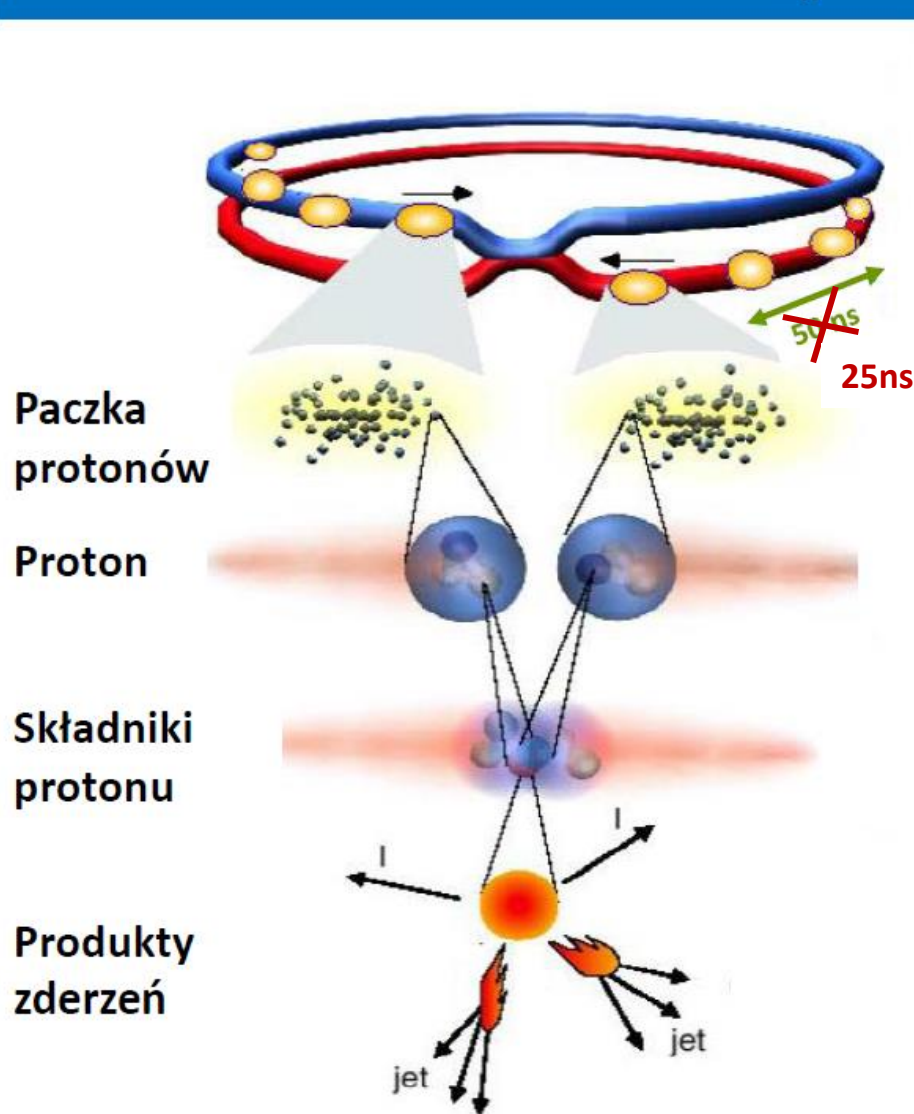
SMACC project : Closure of the last interconnection – 18.06.2014
Activity led by A Musso (TE-MS)

6.5 TeV for the first time



01:03 10th April

Zderzenia wiązek proton-proton

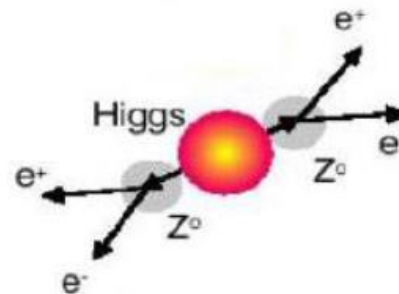


| | |
|-----------------|---|
| Proton-Proton | 1380 ²⁵⁰⁰ paczek/wiązkę |
| Protonów/paczka | 1.7 10^{11} |
| Energia wiązki | 4 TeV 6.5 TeV |

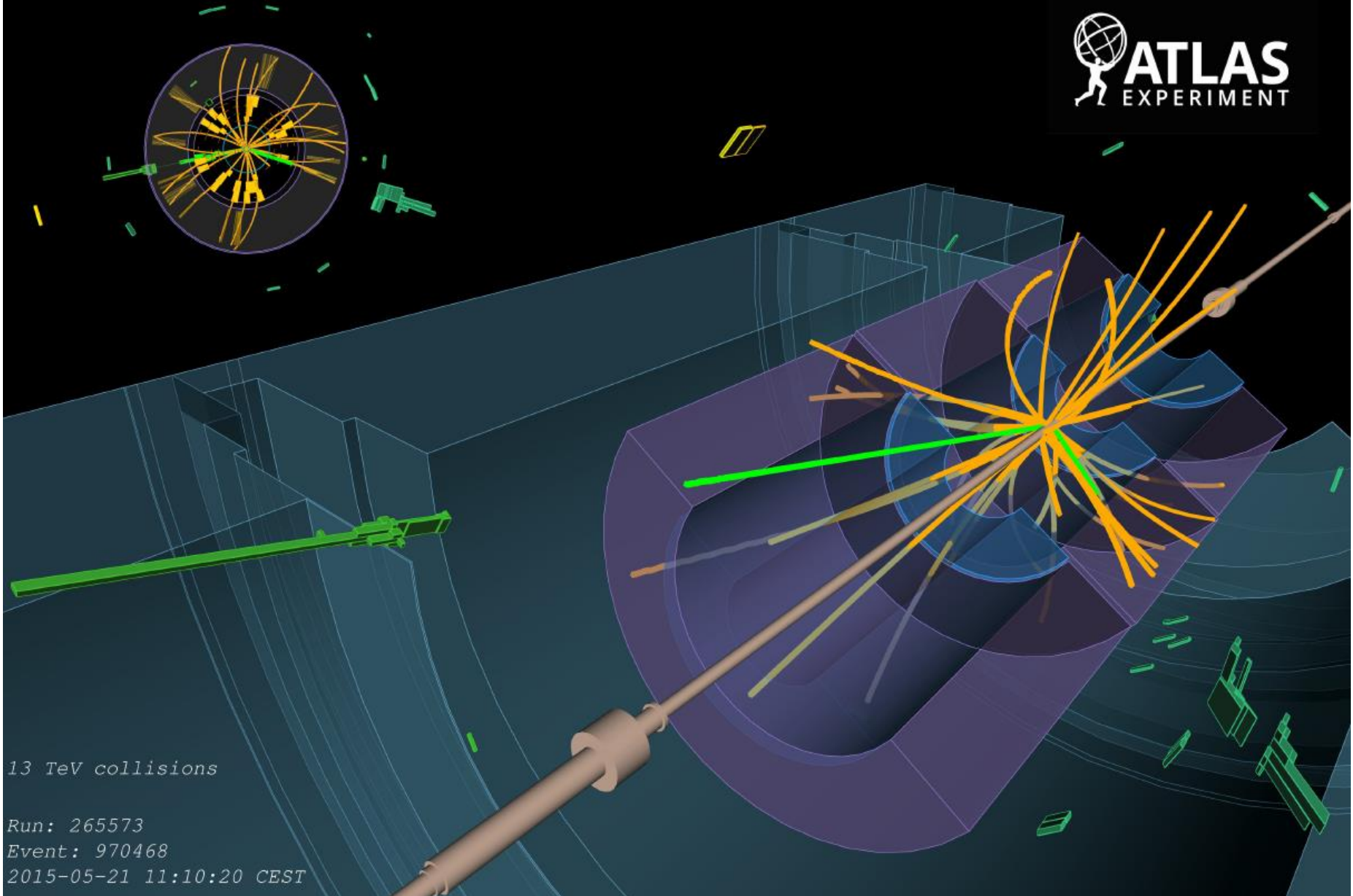
Każdy proton porusza się z prędkością bliską prędkości światła i niesie kinetyczną energię muchy w locie, okrąży pierścień akceleratora 1100 razy na sekundę.

Rozmiar poprzeczny wiązki: $16\mu\text{m}$ (4 razy mniejszy niż grubość ludzkiego włosa).

Każda z wiązek niesie energię pociągu TGV o dł. 200 m i jadącego z prędkością 155km/godz (360M Jula).



Takie zdarzenie pojawia się raz na 10 bilionów zderzeń



13 TeV collisions

Run: 265573

Event: 970468

2015-05-21 11:10:20 CEST

2015 Beam Data

Beam splashes: April 5th and 7th

- ➔ recorded $O(30)$ splash events from each beam

900 GeV collisions: May 5th and 6th

- ➔ recorded $\sim 7 \times 10^6$ min-bias events
- ➔ "quiet beam" mode on May 6th, Pixel & IBL switched on

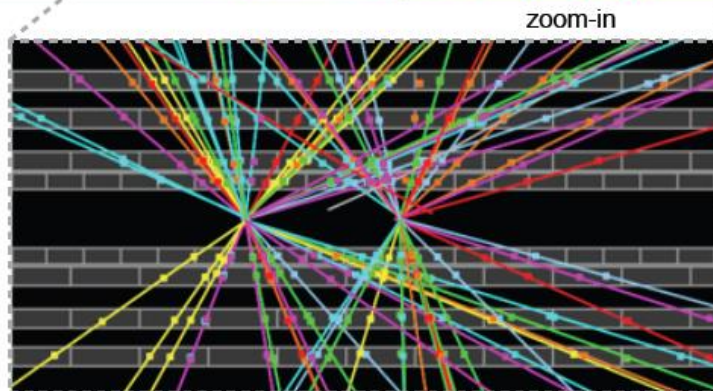
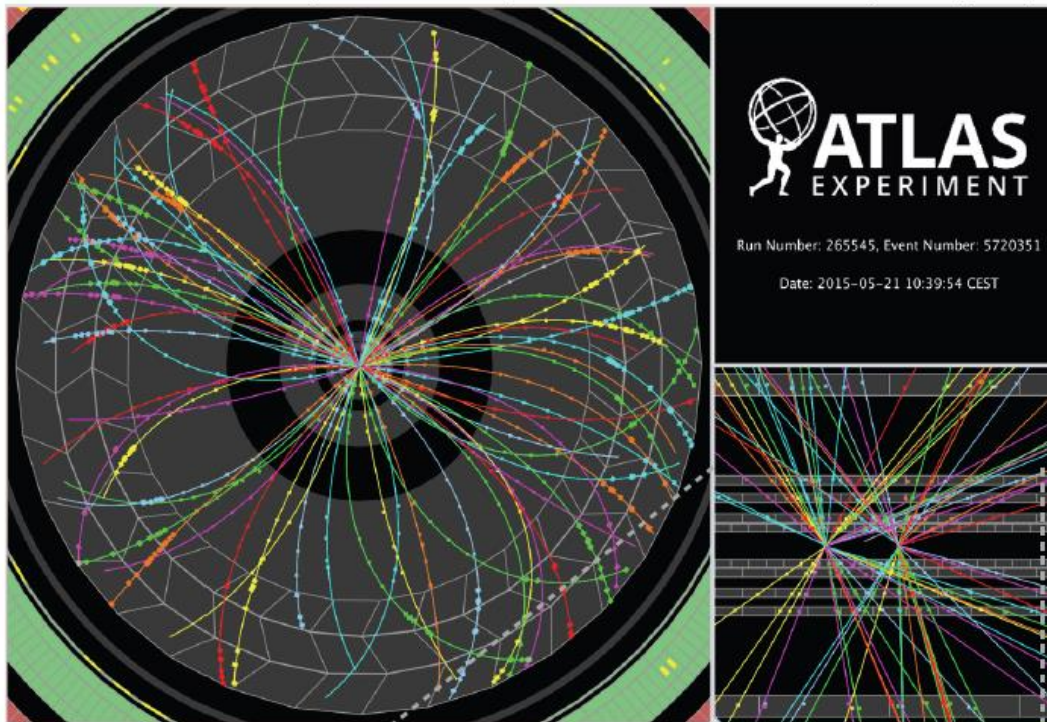
First 13 TeV collisions: May 20th, 21st

- ➔ recorded $(0.3-0.4) \text{ nb}^{-1}$ collisions, $\sim 21 \times 10^6$ min-bias events
- ➔ "quiet beam" mode on May 21st: all ATLAS detectors on, solenoid on, toroid off.

More 13 TeV collisions w/o "quiet beam" in the past days.

Most plots use data from "quiet beam" periods.

13 TeV collision event in "quiet beam" mode, with tracks from two interaction points ("pile-up")



Track hits in new IBL (Insertable B-Layer)

Overall detector readiness 2015

| Subdetector | Number of Channels | Approximate Operational Fraction |
|----------------------------------|--------------------|----------------------------------|
| Pixels | 92 M | 99.0% |
| SCT Silicon Strips | 6.3 M | 98.9% |
| TRT Transition Radiation Tracker | 350 k | 97.3% |
| LAr EM Calorimeter | 170 k | 100% |
| Tile calorimeter | 4900 | 99.2% |
| Hadronic endcap LAr calorimeter | 5600 | 99.6% |
| Forward LAr calorimeter | 3500 | 99.8% |
| LVL1 Calo trigger | 7160 | 100% |
| LVL1 Muon RPC trigger | 370 k | 98.7% |
| LVL1 Muon TGC trigger | 320 k | 100% |
| MDT Muon Drift Tubes | 357 k | 99.8% |
| CSC Cathode Strip Chambers | 31 k | 98.4% |
| RPC Barrel Muon Chambers | 370 k | 97.1% |
| TGC Endcap Muon Chambers | 320 k | 99.8% |

Changes wrt. Oct 2012:

- ✓ Pixel (was 95%)
- SCT (was 99.3%)
- TRT (was 97.5%)

✓ Tile (was 98.3%)

- RPC trigger (was 100%)

✓ CSC (was 96%)

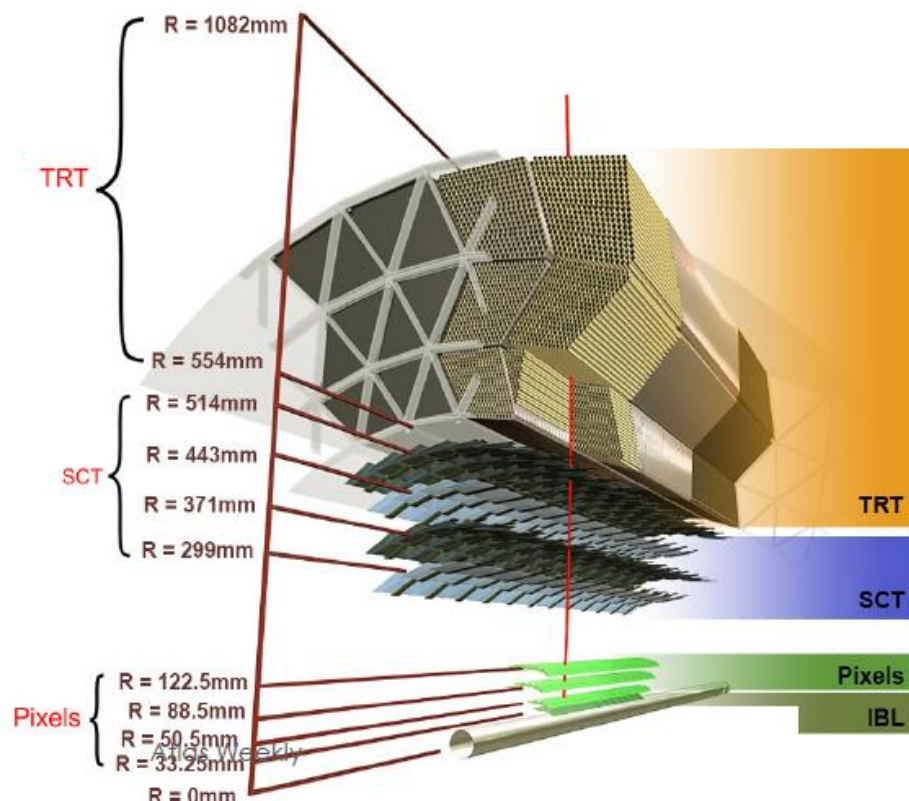
✓ TGC (was 98.2%)

3-Layers Pixel (80 M channels) - 98%
IBL (12 M channels) - 99.7%

pads being re-installed

Inner Detector

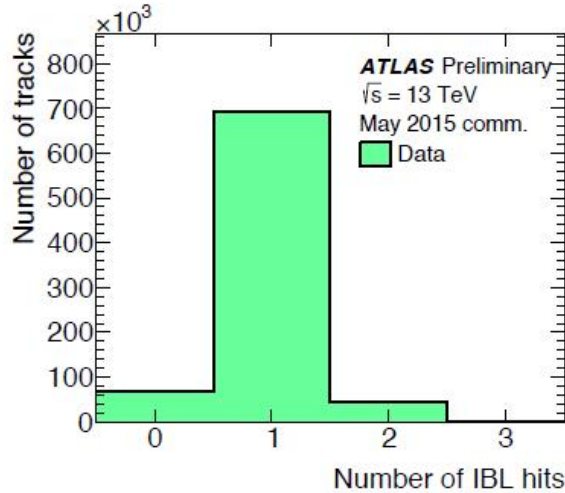
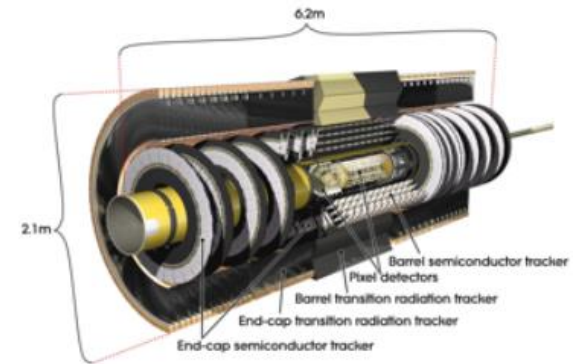
- Since end of Run1, many changes and improvements occurred in ATLAS detector during LS1
- Detector is now being commissioned, using cosmic data taken from milestone runs and recent collisions at 900 GeV and even 13 TeV in May.



- **What is new in the detector ?**
 - New beam pipe
 - New pixel layer
 - New Service Quarter Panel (nSQP)
 - TRT running in Xe/Ar mixed mode
- **And new conditions !**
 - Detector was open → alignment of pixel/IBL?
 - 15 months with detector at room temperature
 - Collisions at 13 TeV

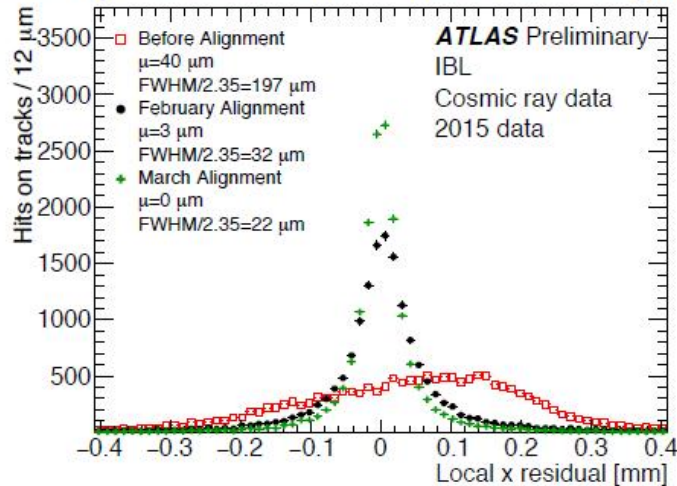
Inner Detector

Pixel with new IBL (Insertable B-Layer)

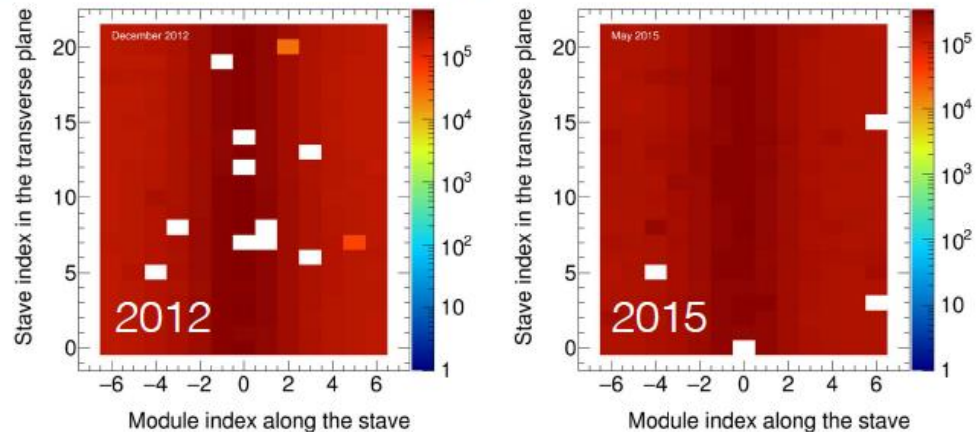


Number of IBL hits

Already used cosmic muons to align detector

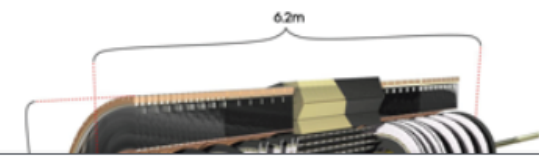


Cluster occupancy for Pixel B-layer



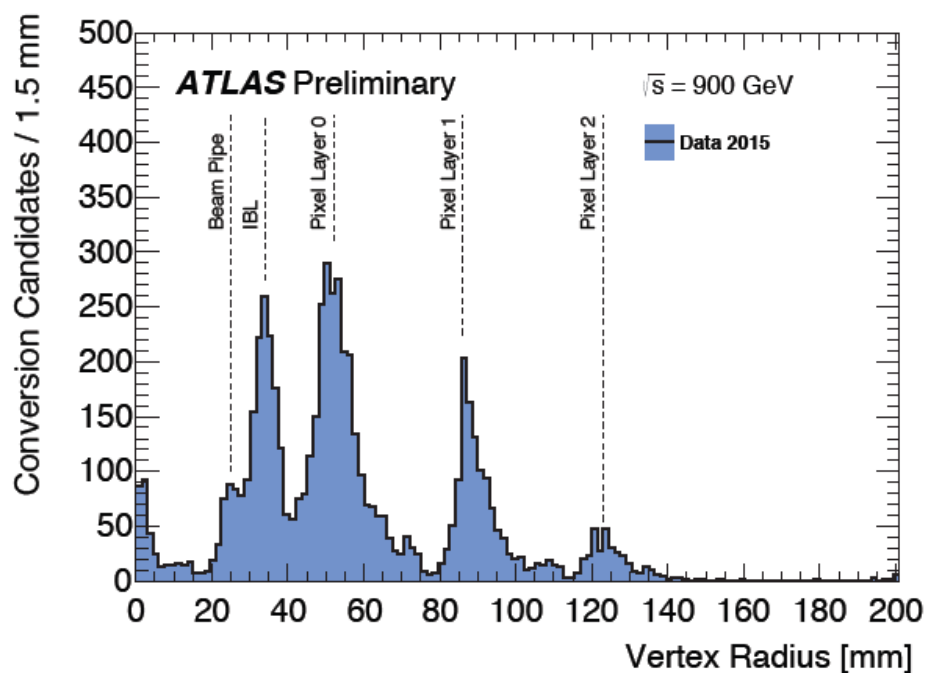
Dead modules in B-layer: 10 (2012) \rightarrow 4 (2015).

Inner Detector



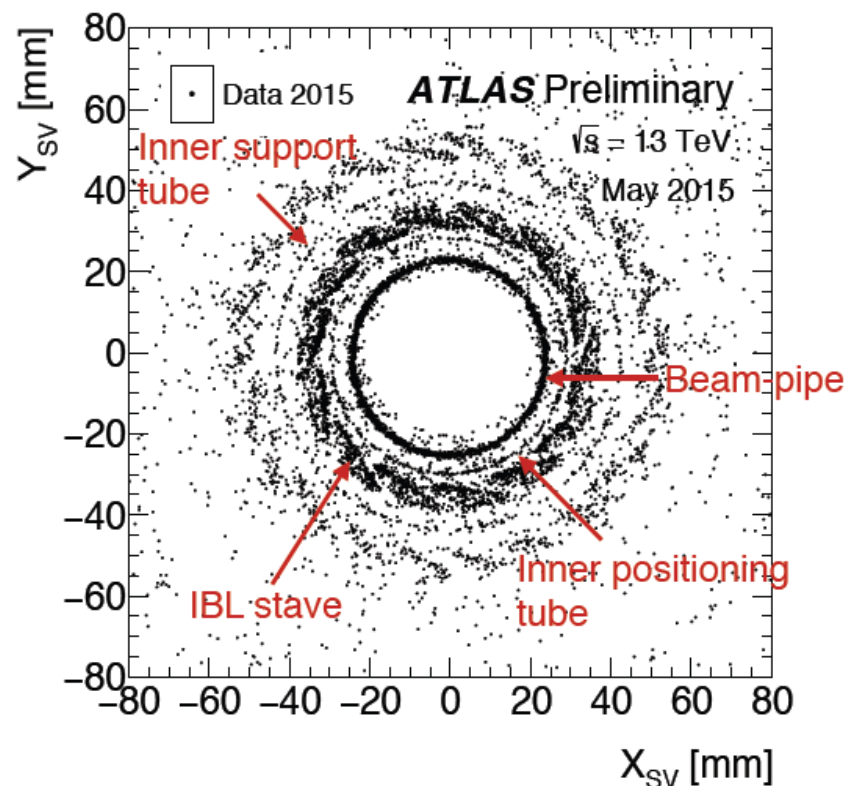
Conversions

Radial vertex position for photon conversion candidates.



Hadronic interactions (“radiography”)

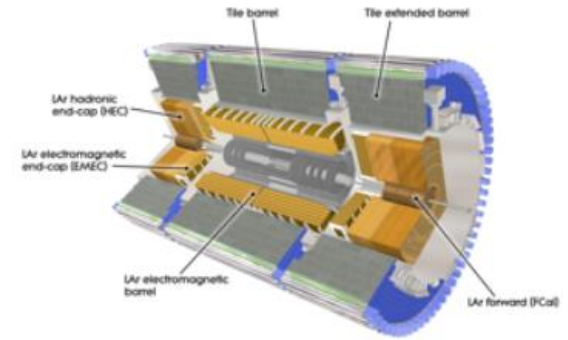
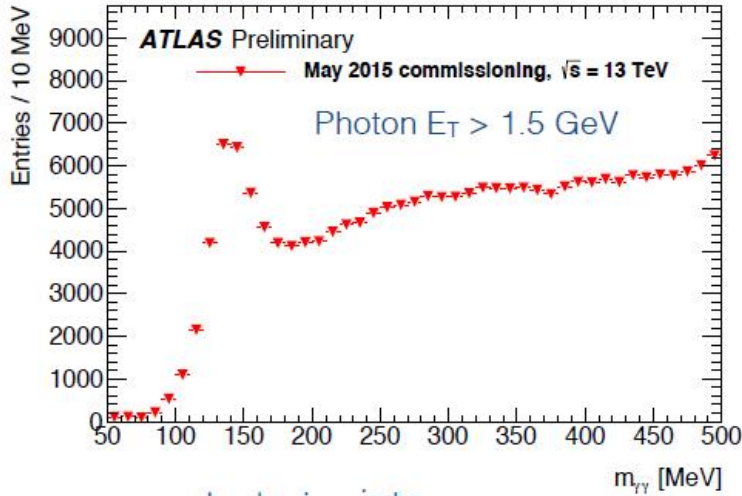
Vertex position for had. int. candidates in xy-plane, reconstructed from multiple tracks.



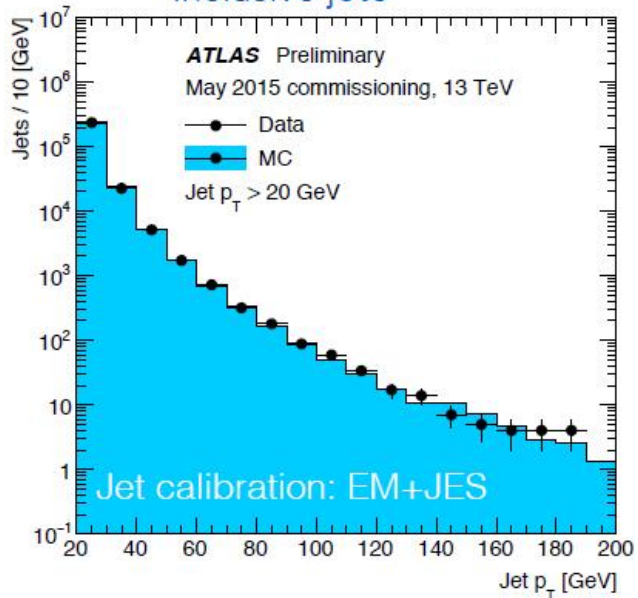
Started to look at conversions and hadronic interactions to validate detector material and geometry description.

Calorimetry

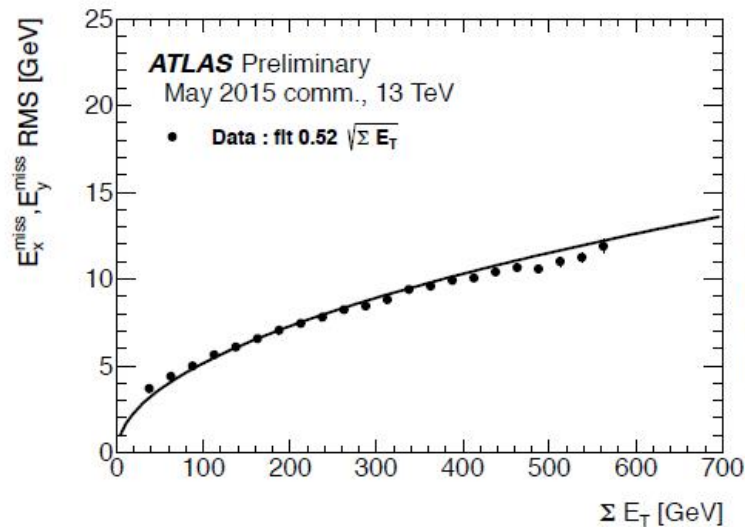
Invariant mass of diphoton candidates



Inclusive jets



Missing E_T , resolution of x,y components vs. sum E_T



2010 data, was
 $0.49 \cdot \sqrt{(\Sigma E_T)}$ in the
 range 10-300 GeV
 with LCW
 [ATLAS-CONF-2010-057]

13 TeV collision event with 2 primary vertices (“pileup”)



$Z \rightarrow e^+e^-$ candidate

Both electrons satisfy tight identification criteria,
 $p_T(e1) = 48 \text{ GeV}$, $p_T(e2) = 32 \text{ GeV}$, $m(ee) = 86.7 \text{ GeV}$



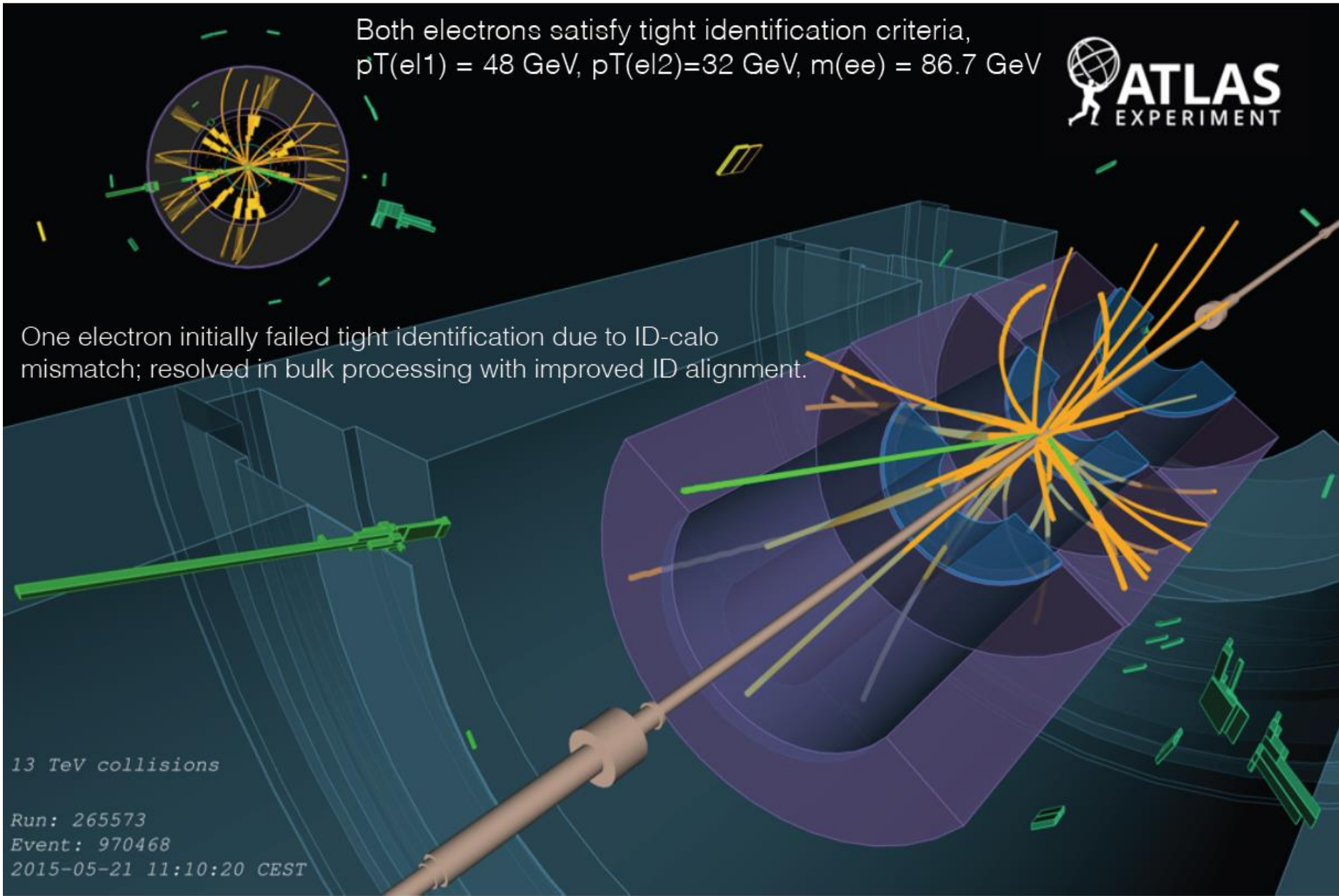
One electron initially failed tight identification due to ID-calo mismatch; resolved in bulk processing with improved ID alignment.

13 TeV collisions

Run: 265573

Event: 970468

2015-05-21 11:10:20 CEST



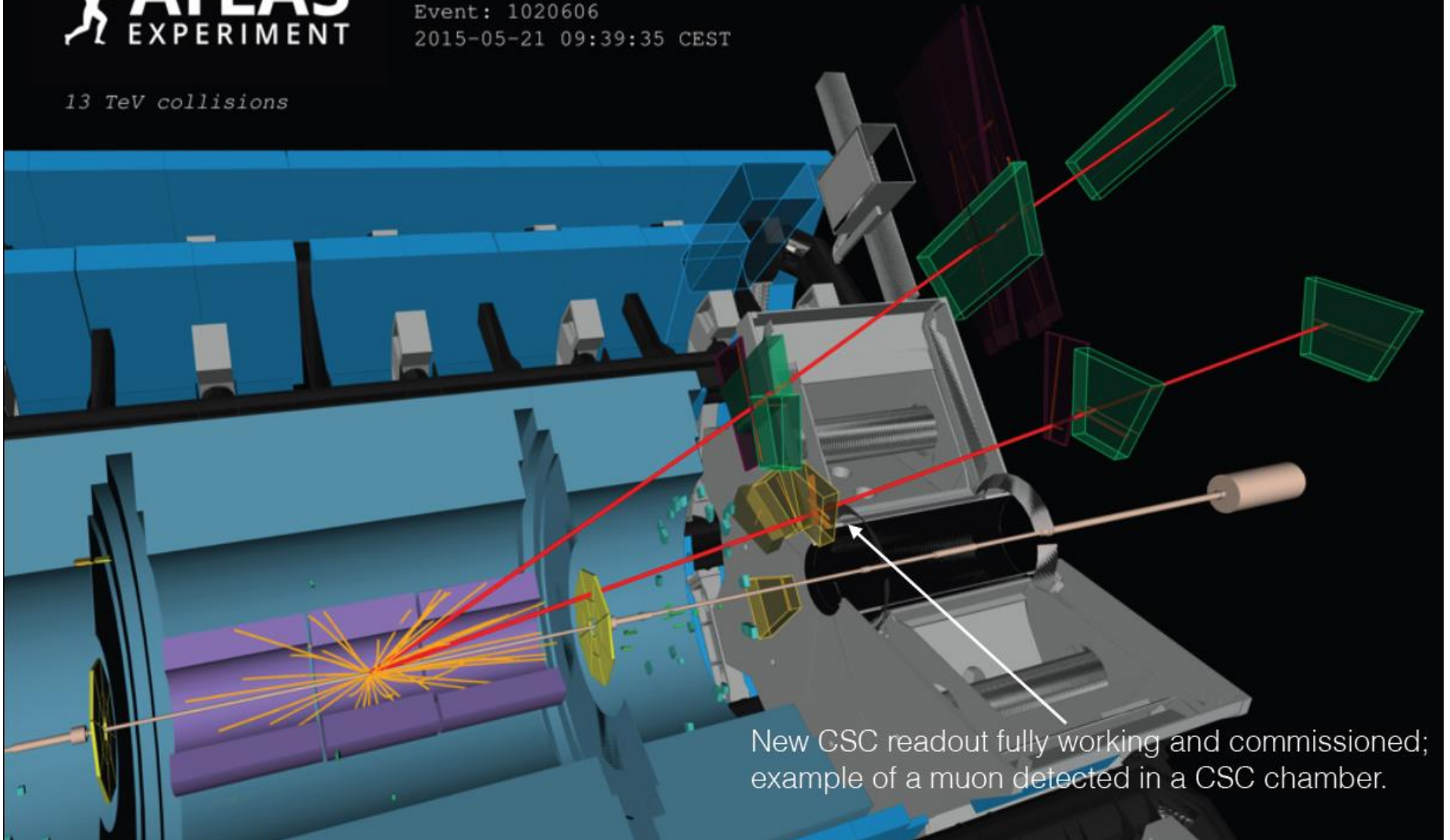
Muon Spectrometer: $J/\Psi \rightarrow \mu^+\mu^-$ candidate



Run: 265545
Event: 1020606
2015-05-21 09:39:35 CEST

Two clean muons with hits in the inner detector and muon spectrometer,
 $p_T(\mu_1) = 3.8 \text{ GeV}$, $p_T(\mu_2) = 2.2 \text{ GeV}$, $m(\mu\mu) = 3.0 \text{ GeV}$

13 TeV collisions



New CSC readout fully working and commissioned;
example of a muon detected in a CSC chamber.

Muon Spectrometer: $J/\Psi \rightarrow \mu^+\mu^-$ candidate

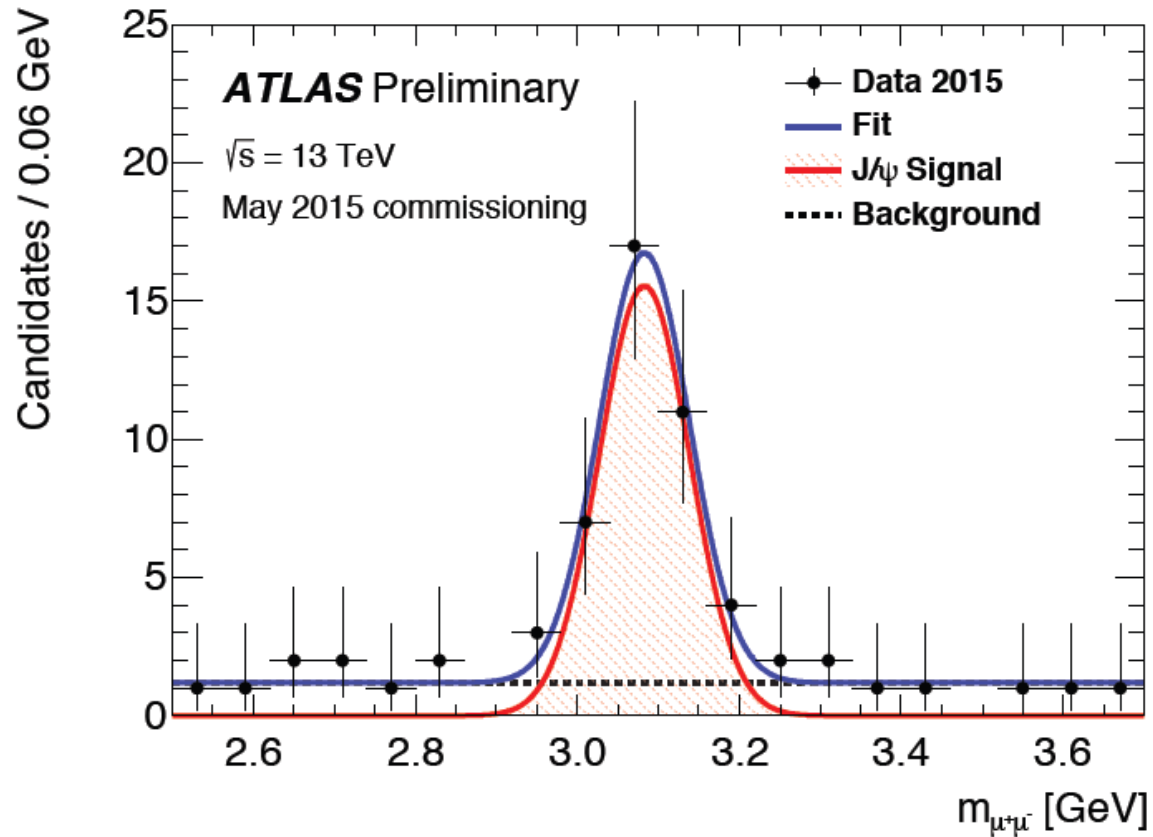
Two clean muons with hits in the inner detector and muon spectrometer.



13 TeV coll

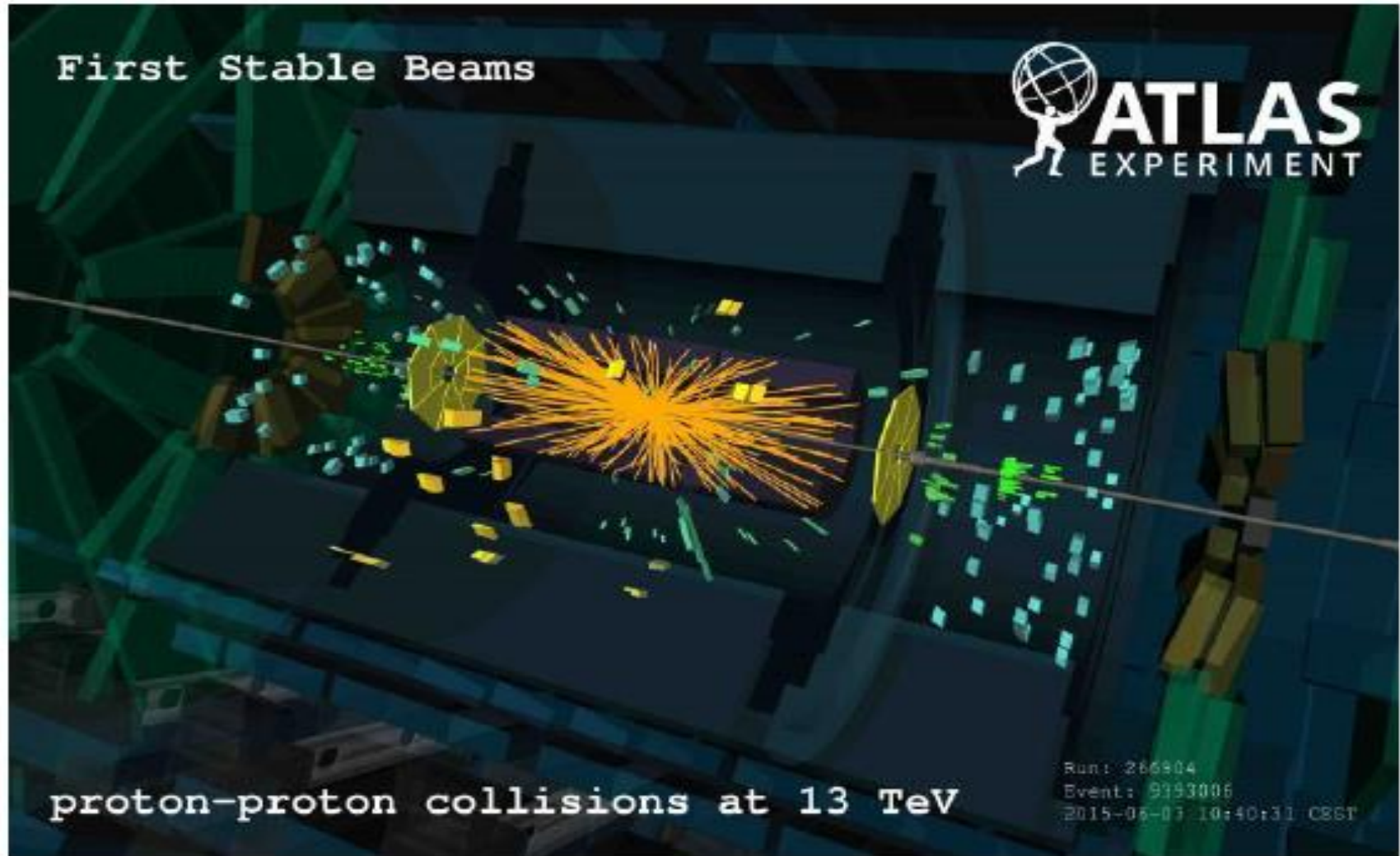
Invariant mass distribution of dimuon " J/Ψ " candidates

Toroid was off: muon p_T obtained from inner-detector



... from the readout system working and commissioned;
example of a muon detected in a CSC chamber.

Event recorded **03.06.2015** at a collision energy of **13 TeV** (x2 more than so far)

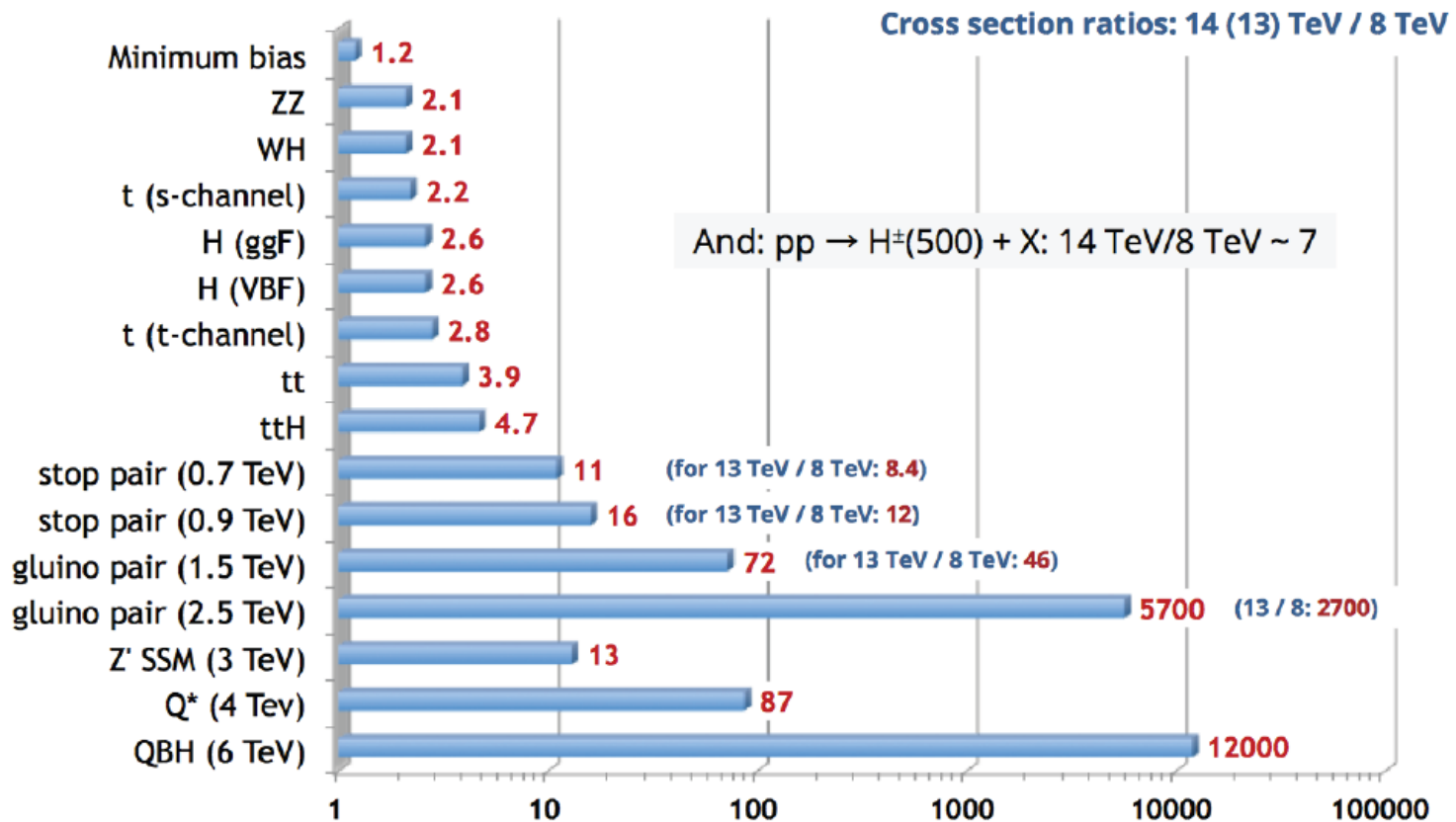


2015 – latest schedule

| Phase | Days |
|-----------------------------------|-----------------------|
| Initial Commissioning | 57 |
| Scrubbing | 23 |
| Special physics run 1 (LHCf/VdM) | 5 |
| Proton physics 50 ns | 9 + 21 |
| Proton physics 25 ns | 70 |
| Special physics run 2 (TOTEM/VdM) | 7 |
| Machine development (MD) | 15 |
| Technical stops | 15 |
| Technical stop recovery | 3 |
| Ion setup/Ion run | 4 + 24 |
| Total | 253 (36 weeks) |

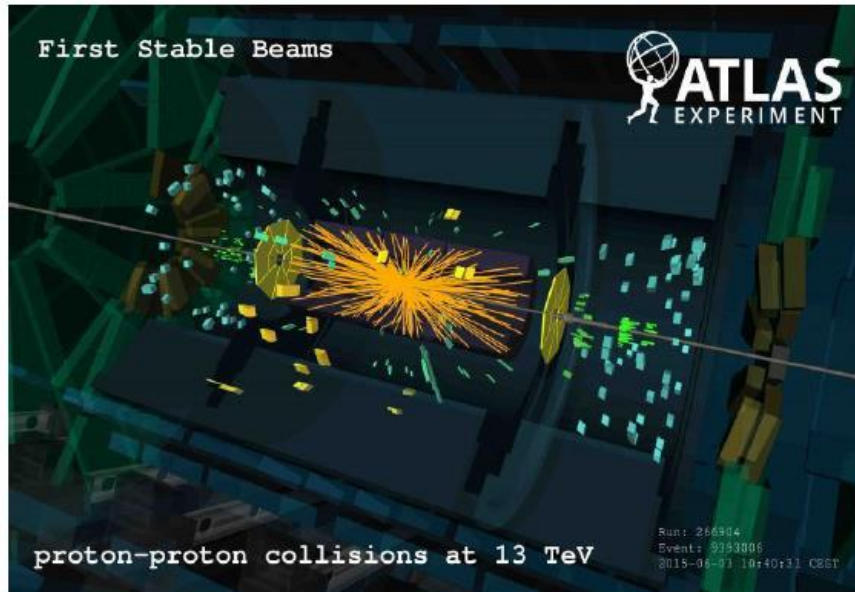
LHC Run 2

Hugely increased potential for discovery of heavy particles at 13 TeV
Perfect occasion for young motivated physicists: join the search!



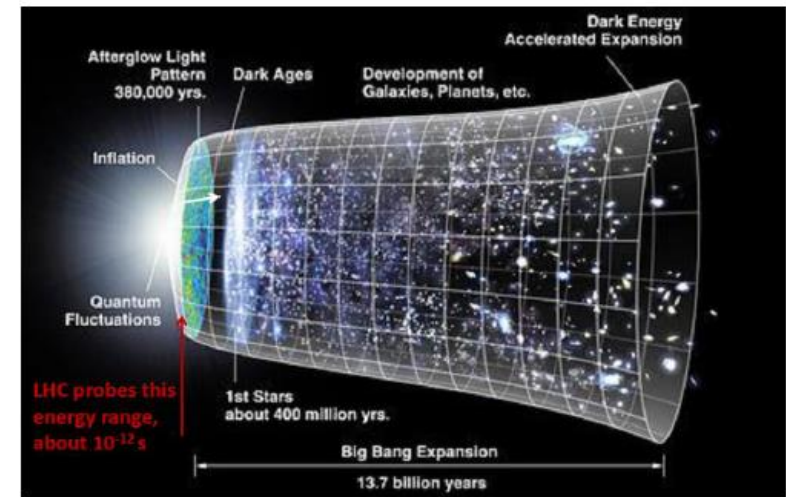
Large Hadron Collider is operating again...

Event recorded **03.06.2015** at a collision energy of 13 TeV (x2 more than so far)



More than 1000 papers published 2010-2015 by 4 LHC experiments.

We are starting now the route to UNKNOWN ...!



... maybe we will be able to understand why there is such asymmetry between matter and anti-matter in the Universe? Will we ever understand what is a dark-matter and dark-energy which are 95% of the Universe ... Is the value of the vacuum of the Higgs field associated with the cosmological constant in Einstein equation...?