UK ALICE Status

David Evans & Roy Lemmon

Birmingham, Derby, Liverpool,

STFC-Daresbury

Nuclear Physics Community Meeting, Warwick January 2017

UNIVERSITY OF BIRMINGHAM

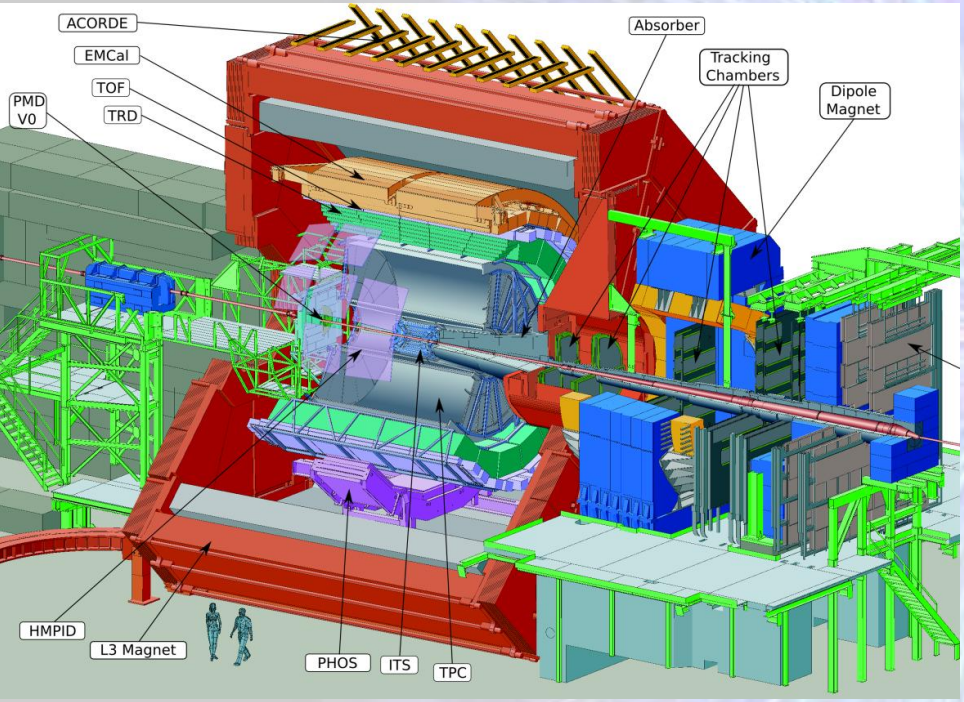
UNIVERSITY of DERBY

UNIVERSITY OF LIVERPOOL

Science & Technology Facilities Council
Daresbury Laboratory

ALICE

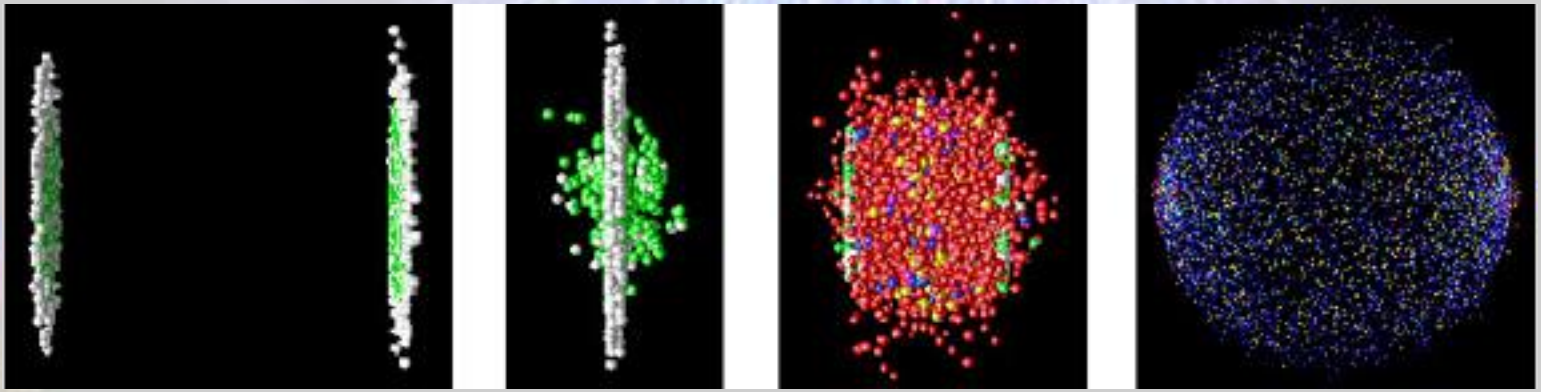
The ALICE Physics



ALICE experiment at the CERN LHC
Studies highest-energy p-p, p-Pb and Pb-Pb collisions.

Raison d'état - to create and study the quark-gluon plasma (primordial soup) which existed up to 10 micro-seconds after Big Bang, using Pb-Pb collisions.

Temperatures ≈ 400,000 x core of Sun.
Densities ≈ 50x neutron star produced.
Most perfect liquid ever produced.



Physics

- **A lot of high-quality data and physics from the PbPb, pPb and pp runs**
- The harvest of results continues
  - **Over 170 journal publications so far**
  - The **impact** of physics publications remains extremely high - after the 4 Higgs discovery papers the next **three highest cited LHC physics papers come from ALICE.**
  - **21 out of the top 50 cited LHC papers are from ALICE**

High UK Profile within ALICE

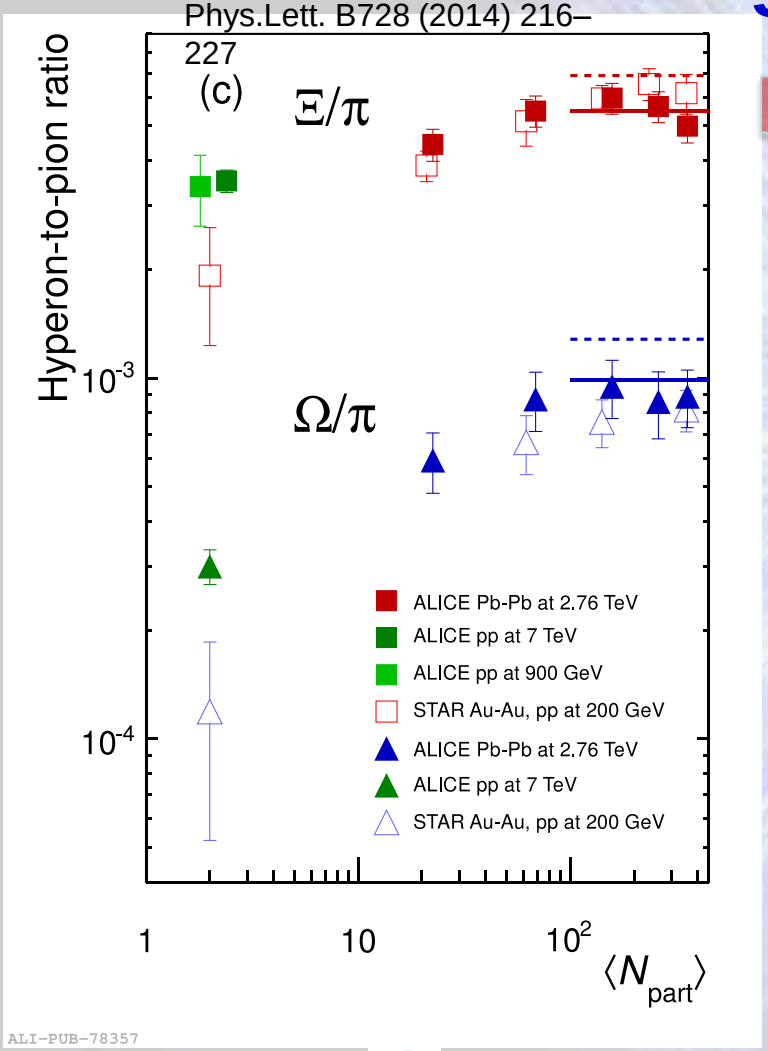
- Management Board – David Evans
- Technical Board – D. Evans, R. Lietava
- Editorial Board – P. Jones
- Strangeness Analysis Group Convenor – R.Lietava
- ITS Upgrade Board – R. Lemon, M. Chartier

Physics Contributions

- Strange particle production – Birmingham + Derby
- Charm production – Liverpool + Daresbury (+ Derby)
- Ultra-peripheral physics – Birmingham
- Jet physics - Birmingham

Good news: Lee Barnby (former B'ham PDRA) has academic job at Derby and will continue to work on ALICE.

Strangeness Enhancement as a QGP signature

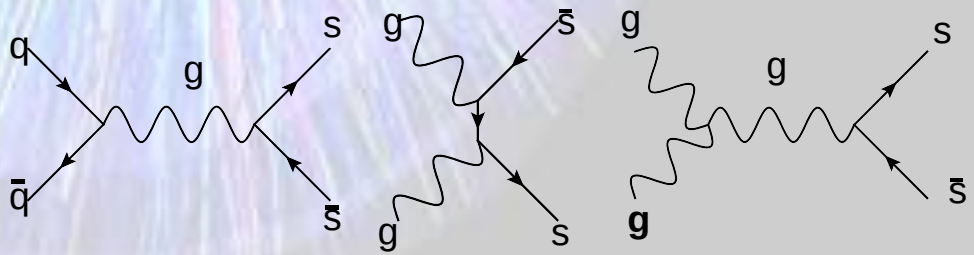


x 1.7

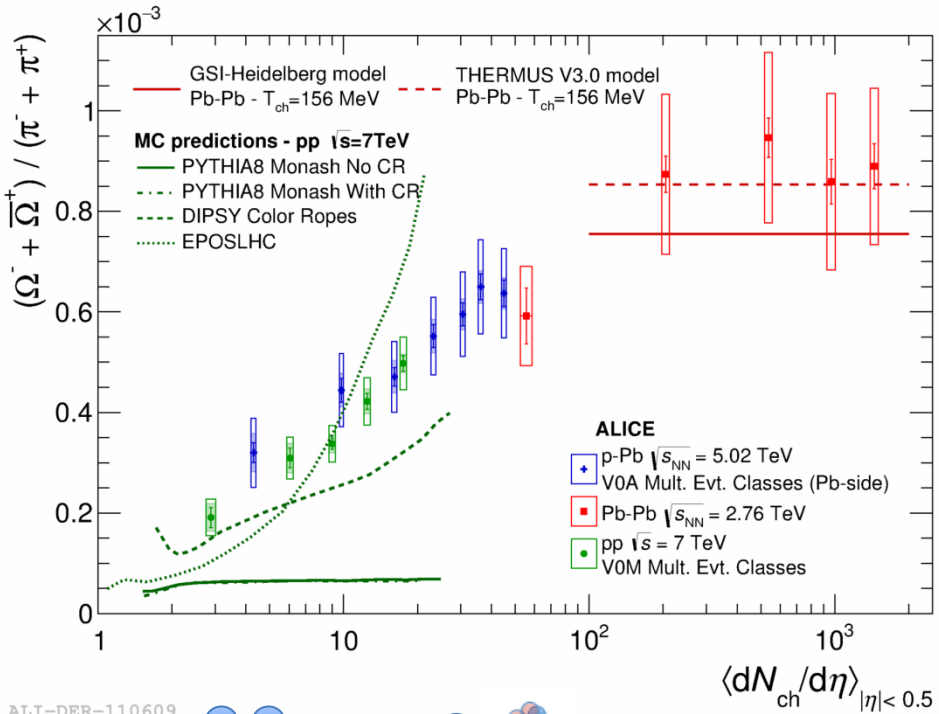
x 3

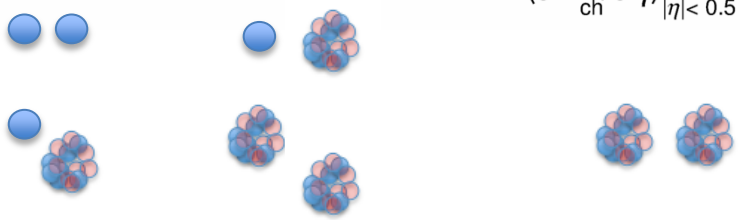
- In QGP
  → deconfined quarks and gluons
  → lower energy threshold for s-quark pair production (190 MeV/c^2)
  → thermal production uninhibited

- Ξ/π and Ω/π baryon yields have been shown to be larger in A-A collisions compared to pp

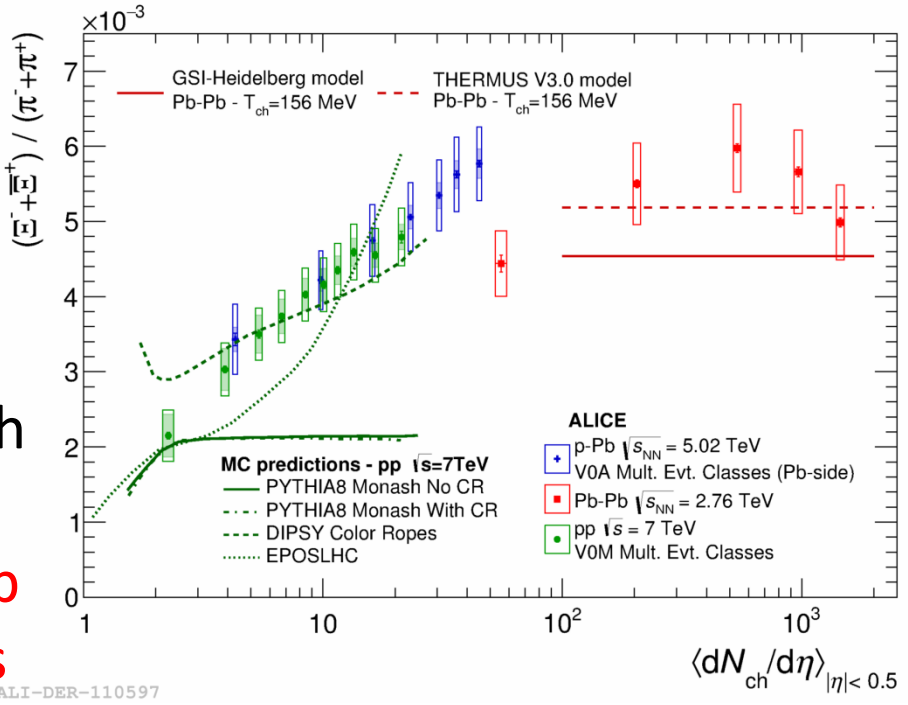


What about pp & pPb vs multiplicity?





- Increase of (multi)strange production to non-strange with multiplicity in pp & pPb
- **Increase** is not mass related but **strangeness related**
- **QGP in small systems?**



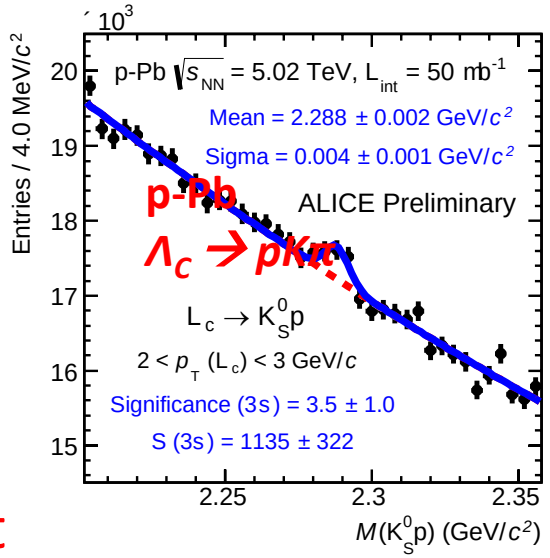
Next step to use 2016 data taken with B'ham high-multiplicity trigger to study v.high mult pp data – extend pp data to peripheral PbPb multiplicities

Λ_c measurement in pp and p-Pb collisions

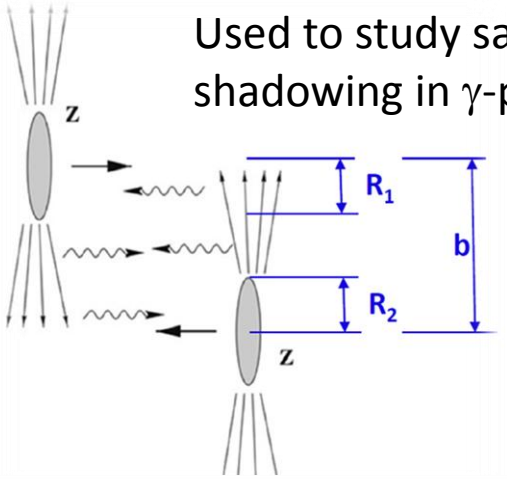
- Λ_c baryon (M=2.286 GeV/c^2, quark content *udc*) interesting to study in different collision systems at ALICE
- **Pb-Pb collisions:**
  - interesting to probe **energy loss** in QGP, plus **hadronisation mechanisms** (baryon/meson ratio)
  - Measurement expected after ITS upgrade
- **pp collisions:**
  - Essential as Pb-Pb/p-Pb reference
  - Sensitive to **hadronisation mechanisms** in vacuum
- **p-Pb collisions:**
  - Probe **cold nuclear matter** effects
- Very few Λ_c measurements at hadron-hadron colliders (none in p-Pb collisions)

Λ_c measurement in pp and p-Pb collisions

- Paper in preparation for **p_T-differential cross section** measurement in pp and p-Pb collisions
  - **3 decay channels**
    - $\Lambda_C \rightarrow pK\pi$, $\Lambda_C \rightarrow pK^0_S$, yield extracted via selection on decay topology, invariant mass analysis
    - $\Lambda_C \rightarrow e\Lambda\nu$, yield extracted via wrong sign/right sign subtraction
- At limit of current detector – **challenging analysis!**
  - Liverpool has helped explore more complex analysis techniques to improve measurement
  - **Boosted Decision Trees** – among the first ALICE analysis to use multivariate technique



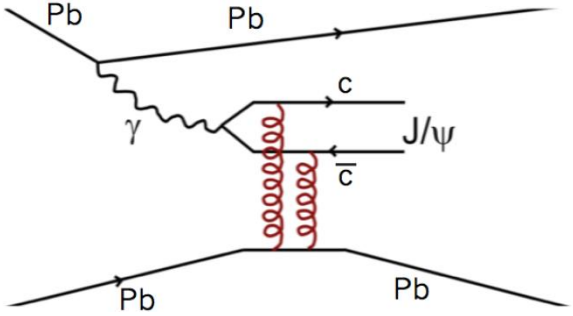
Ultra-peripheral collisions

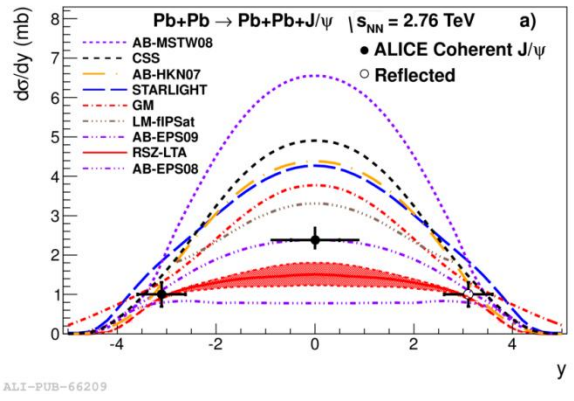


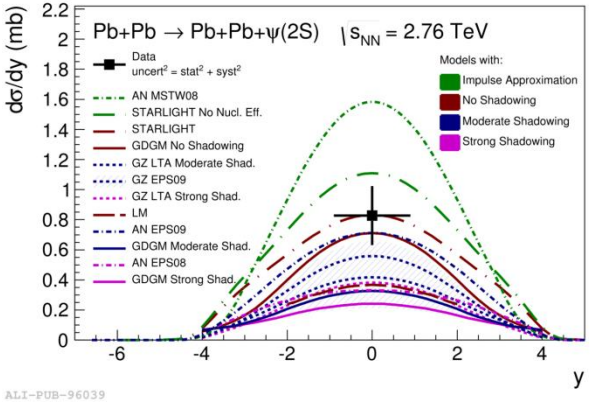
Used to study saturation and gluon shadowing in γ-p and γ-Pb interactions

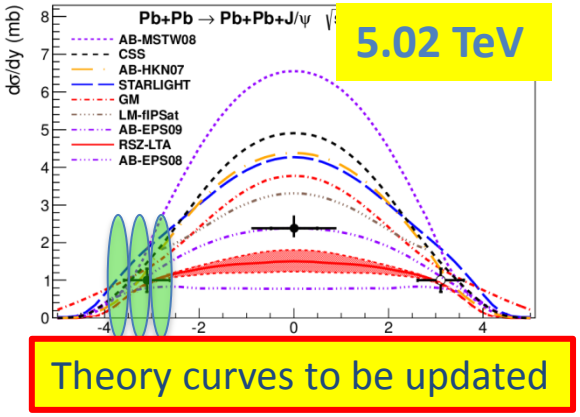
$$\frac{d\sigma_{\gamma^* p/Pb}(t=0)}{dt} = \frac{16\Gamma_{ee}\pi^3}{3\alpha_{em}M_{J/\psi}^5}\left\{\alpha_s\left(Q^2\right)G_{p/Pb}\left(x,Q^2\right)\right\}^2$$

- At LO, the cross-section is proportional to the gluon PDF squared
- Vector meson can be ρ, φ, J/ψ, ψ', ϒ







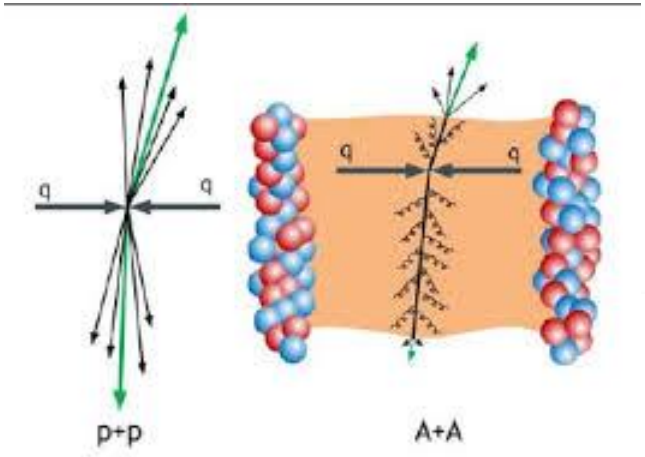


Agreement is best for models incorporating nuclear gluon shadowing

Models with moderate shadowing favoured

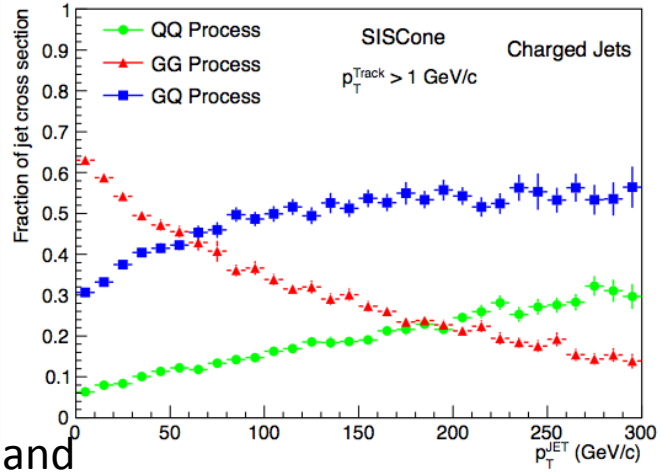
B'ham working on paper

Jets & jet shapes

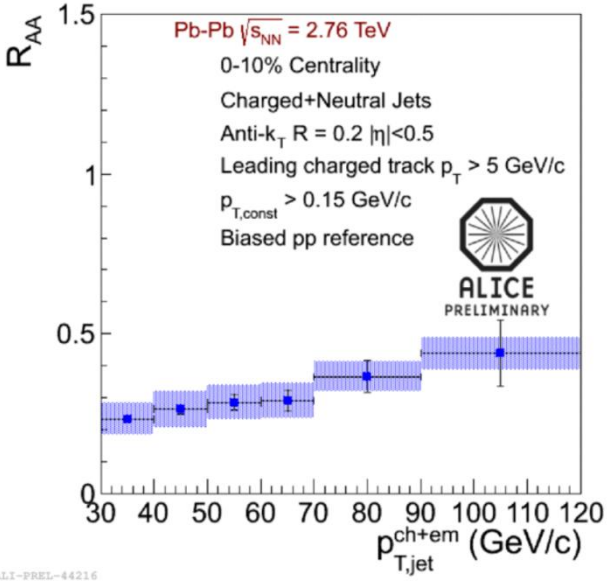


Jets originate from hard scatters in the initial stages of the collision. The scattered particles then fragment into observed final state hadrons.

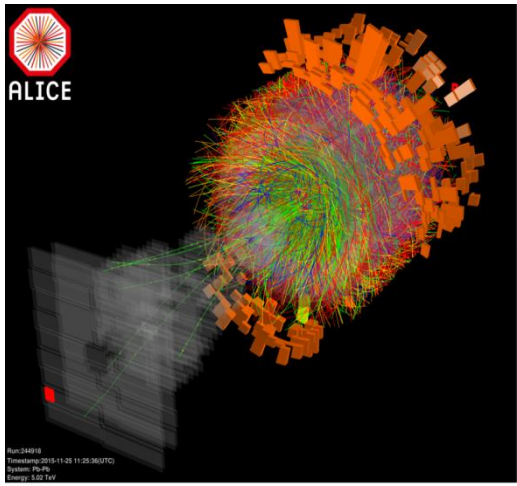
The presence of a QGP medium modifies jets → Colour charged objects lose energy traversing the QGP



Study of jets hence gives information about nature of QGP. Moreover, jet shapes can provide detailed information about the modification of jets traversing the QGP.



- Final state hadrons from a single jet must be identified and clustered together.
- Extremely challenging in environment of heavy ion collisions.
- **A multitude of sophisticated Jet algorithms and refinement techniques have been (and are being) developed to try and achieve this.**

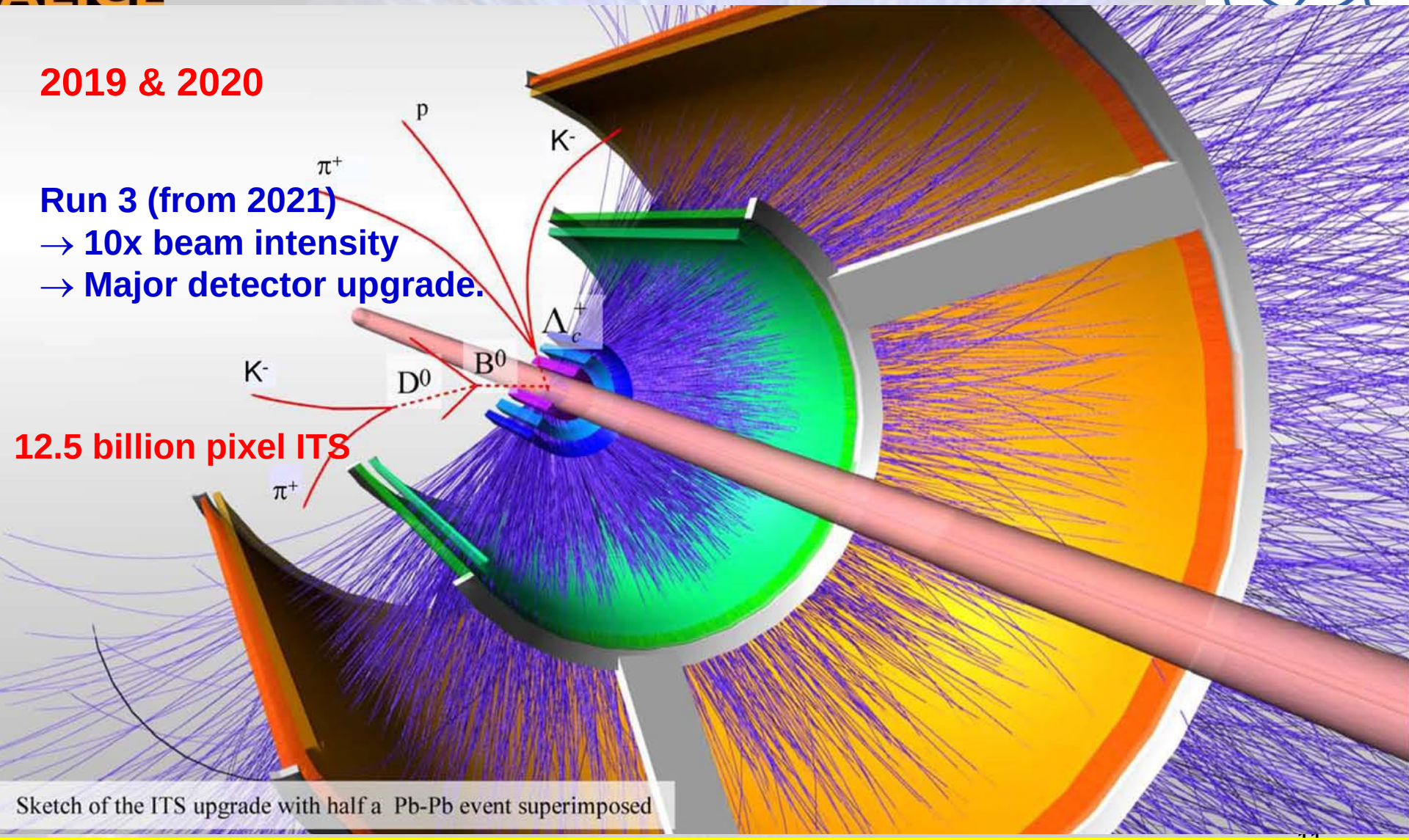


ALICE Upgrade

2019 & 2020

Run 3 (from 2021)
→ 10x beam intensity
→ Major detector upgrade.

12.5 billion pixel ITS



Sketch of the ITS upgrade with half a Pb-Pb event superimposed

Opens a new and unique window of discovery with rare charm and beauty physics

Summary of Upgrades

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

Liverpool + Daresbury

Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

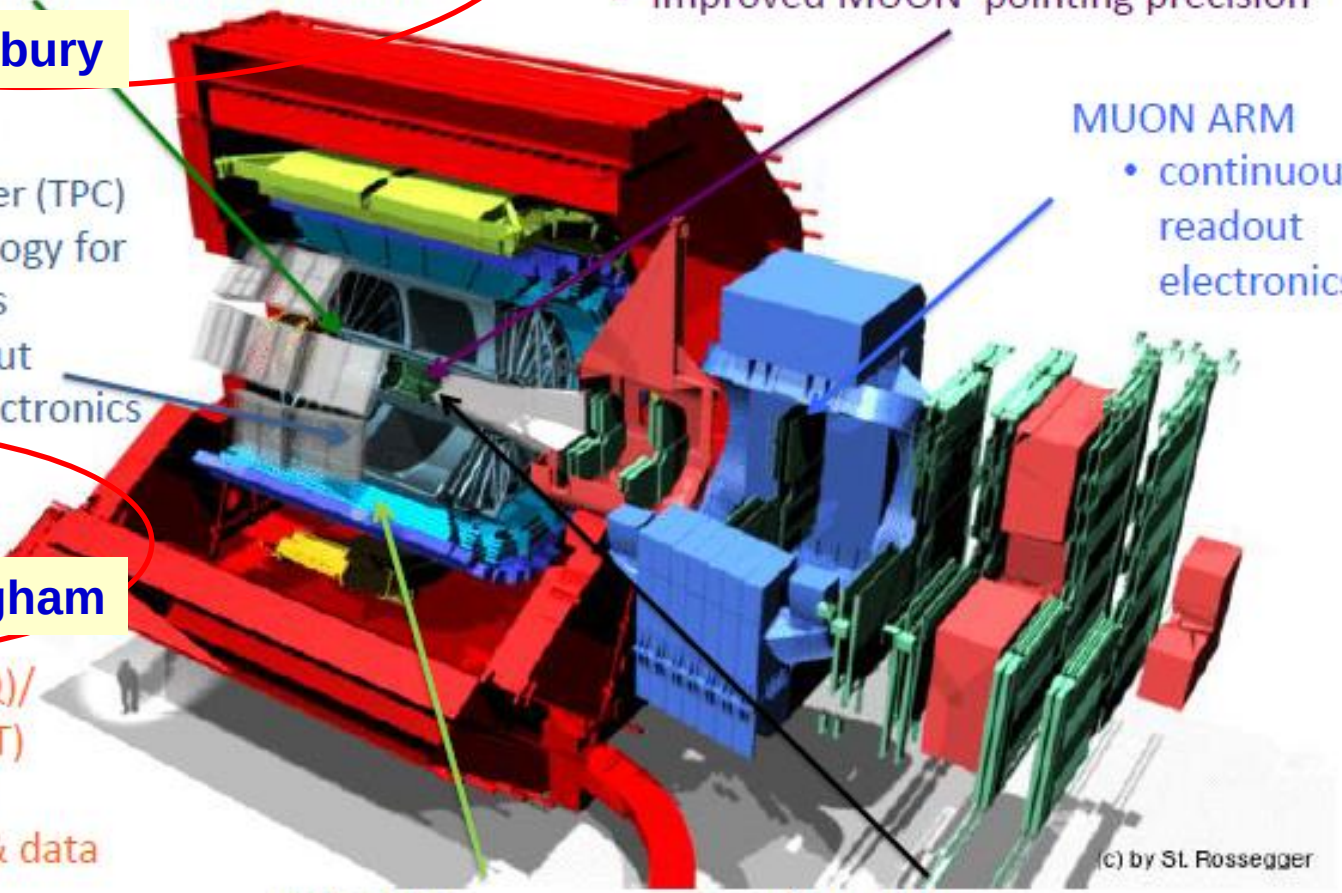
MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- new GEM technology for readout chambers
- continuous readout
- faster readout electronics

Trigger electronics (CTP)

Birmingham

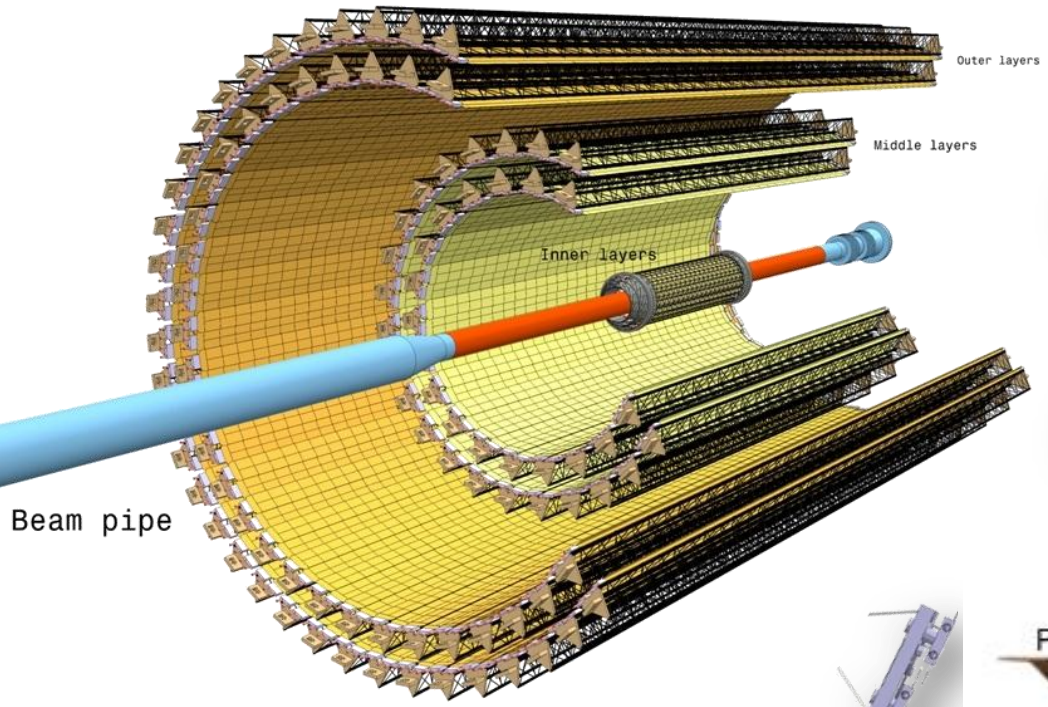
Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate

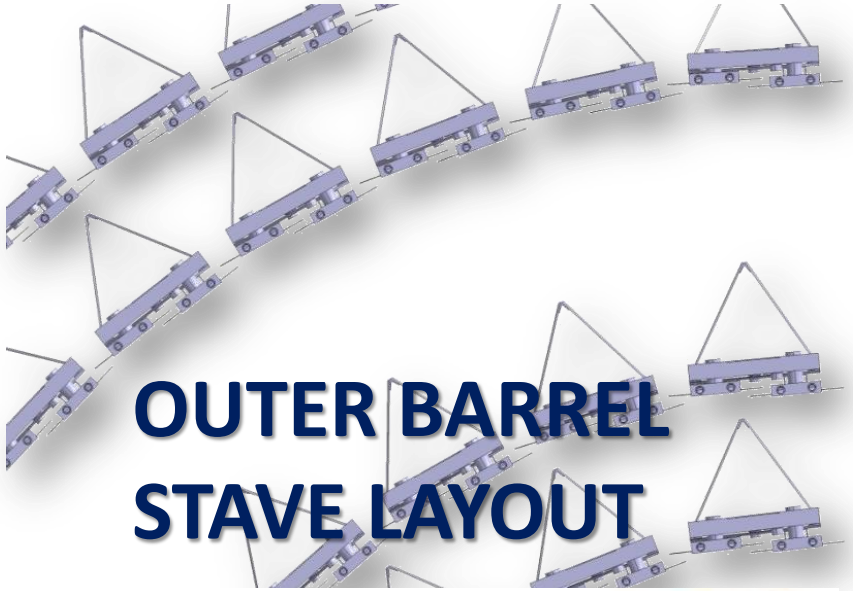


TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

ITS DETECTOR BARREL STAVES

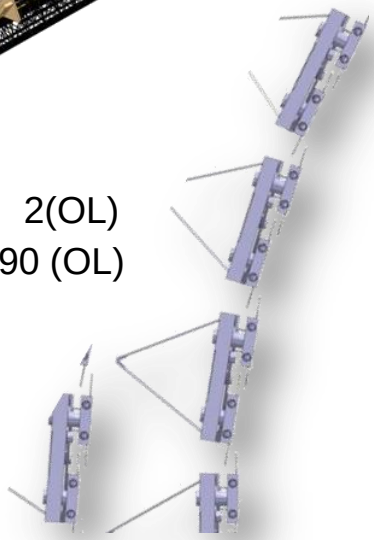


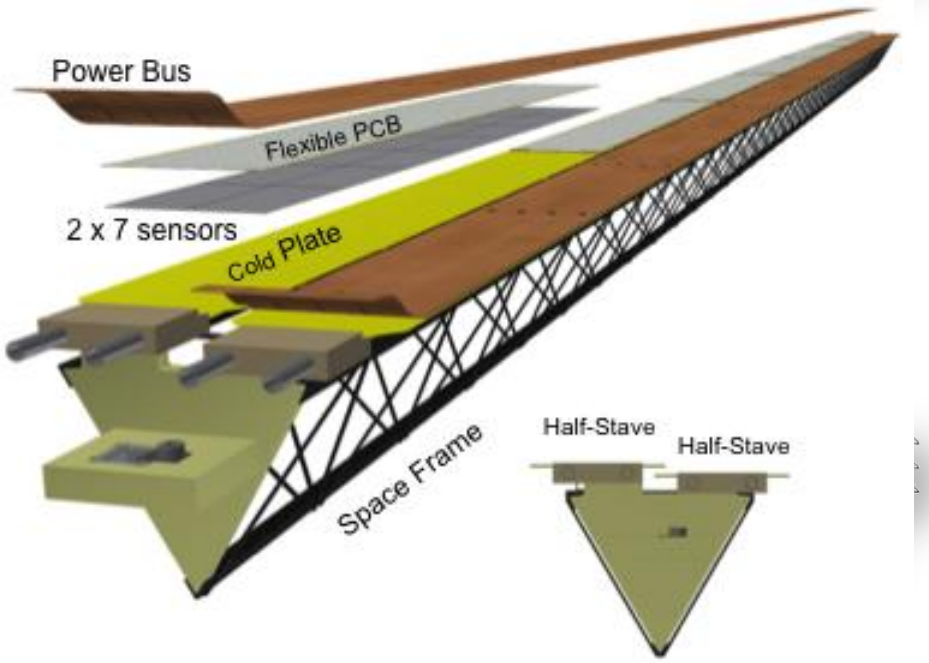


OUTER BARREL STAVE LAYOUT

The ITS is constituted by
- 7 layers; 3 (IL), 2 (ML), 2(OL)
- 192 staves; 48 (IL), 54 (ML), 90 (OL)

UK responsibilities:
- Liverpool 400 modules
- Daresbury 30 OL staves



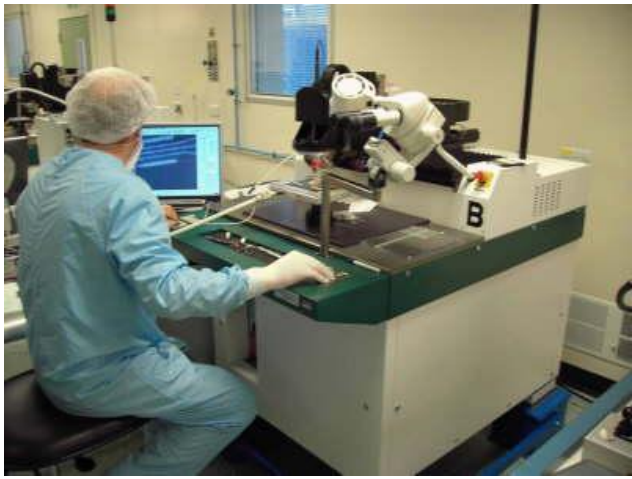


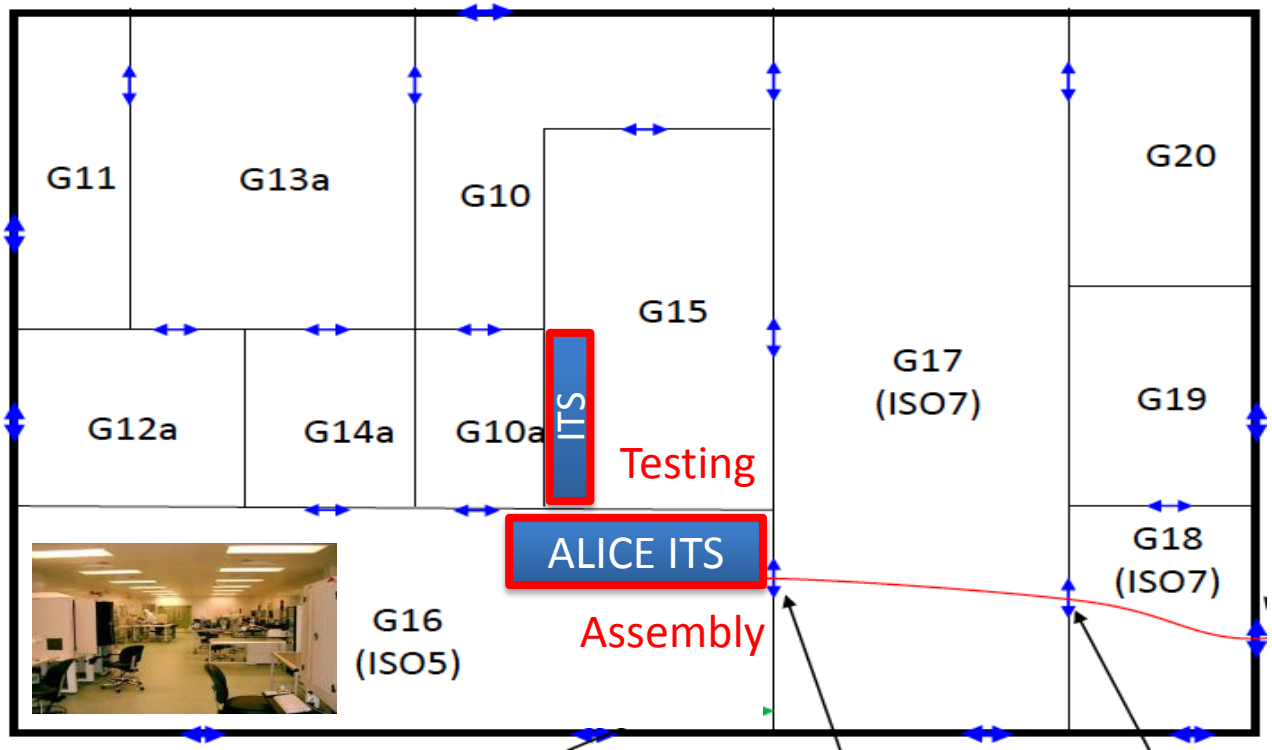
Layer #	6	5					
n. of Staves	48	42	30	24	20	16	12

FACILITIES PREPARATION

Liverpool Semiconductor Detector Centre (LSDC)

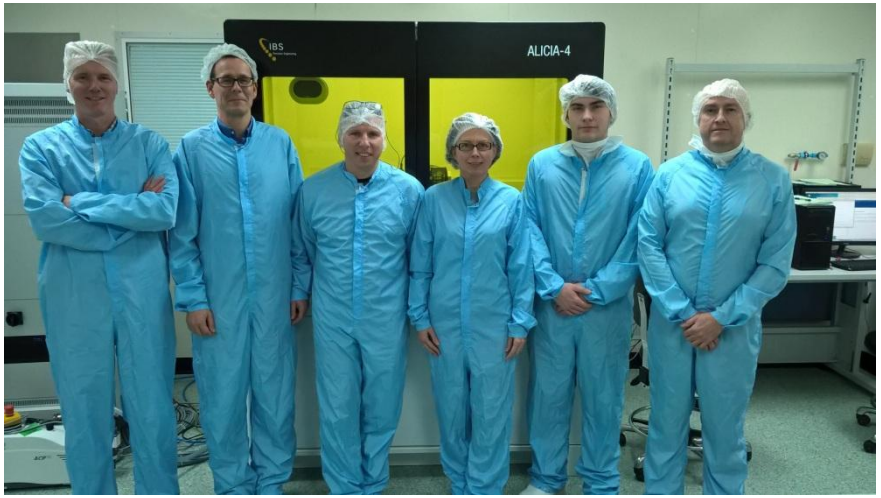
- Large state-of-the-art **clean room complex**
- **ISO5 clean room (Class 100)** houses ALICIA module assembly machine (and other HEP/NP projects)
- 3 Hesse & Knipps **ultrasonic wedge wire bonders**: 2 BondJet710's and 1 BondJet820





ALICIA MODULE ASSEMBLY MACHINE

- **Custom-made automated machine** for ALPIDE chip probing and/or **chip placement on module assembly tooling** (with 5 um accuracy).
- **Tender centralised at CERN** for all machines purchased for ITS project (CERN, Bari, Liverpool, Pusan, Strasbourg, Wuhan).
- **IBS Precision Engineering (NL)** installed machine in Liverpool during Week 50-2016.
- **ALICIA-4 successfully passed Site Acceptance Test on 14/12/16.**
- **Operators training completed** – 2 technicians (Liam and Nick).

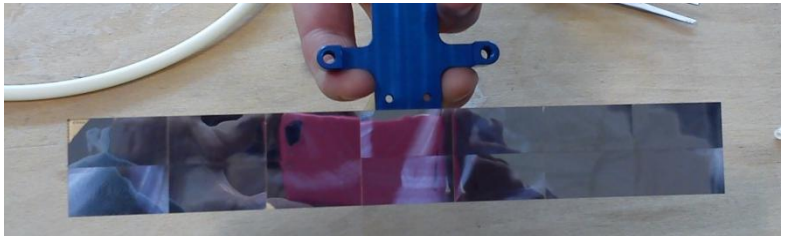


WIRE BONDING TESTS

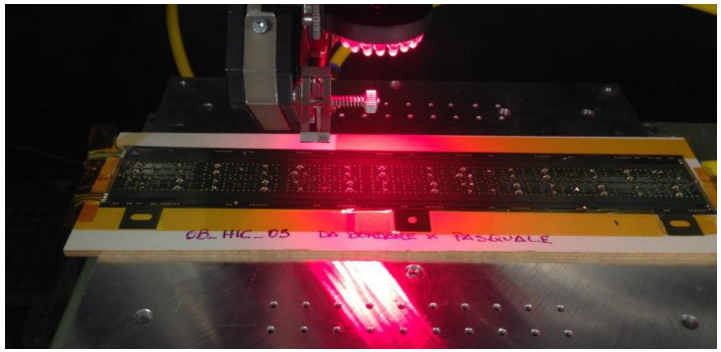
- Performed initial, mostly **qualitative tests** on **few prototype Flexible Printed Circuits (FPC)** and **dummy Hybrid Integrated Circuits (HIC)**, on both wire bonders in LSDC.

- Plan in place to perform more systematic, quantitative tests on dummy HICs assembled in Bari in December and **decide/plan which machine to use (H&K BJ820 vs BJ710) by end of February 2017.**

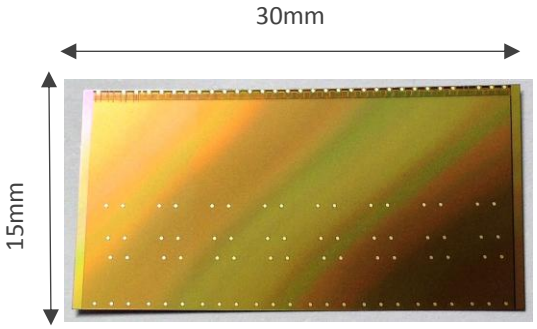
- **Next steps:** wire-bond dummy and prototype HICs assembled in Liverpool with the ALICIA machine.



Outer Barrel HIC (chip side)

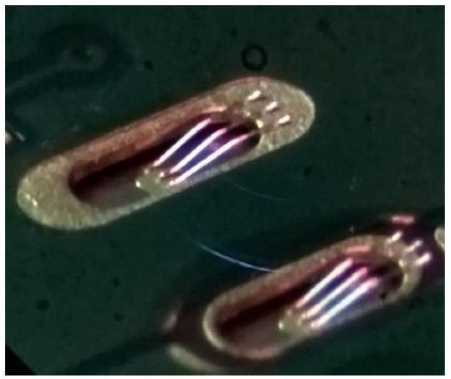


Outer Barrel HIC (FPC side) on wire bonder



pALPIDE-3 prototype chip (1024 x 512 pixels, 28um x 28um)

Loops Heights	50 uM
Bond length Typical	750 uM
FPC to ASIC height	~180 uM

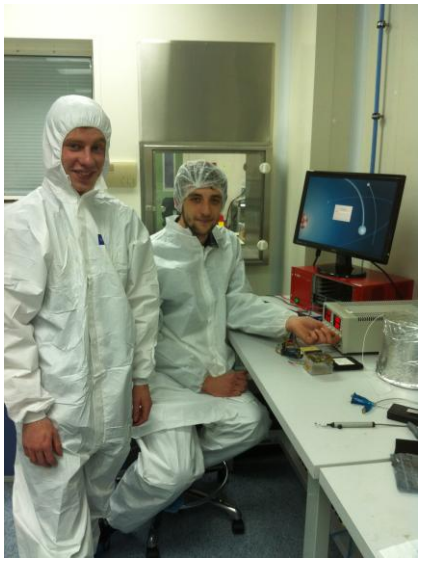


Single pad vias

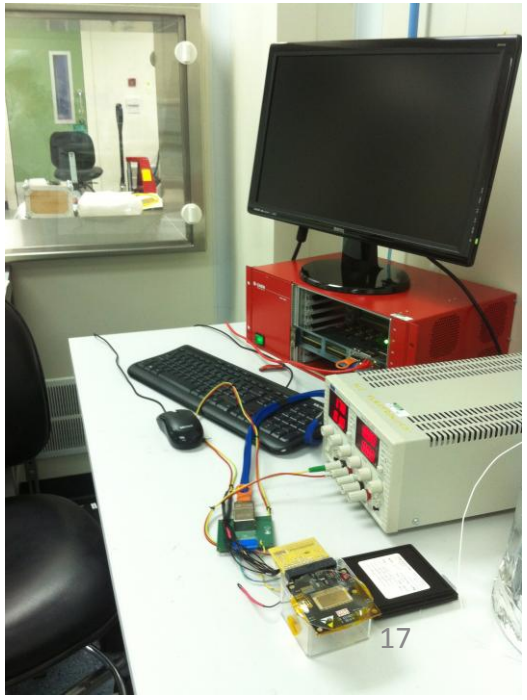
CHIP/MODULE TESTING

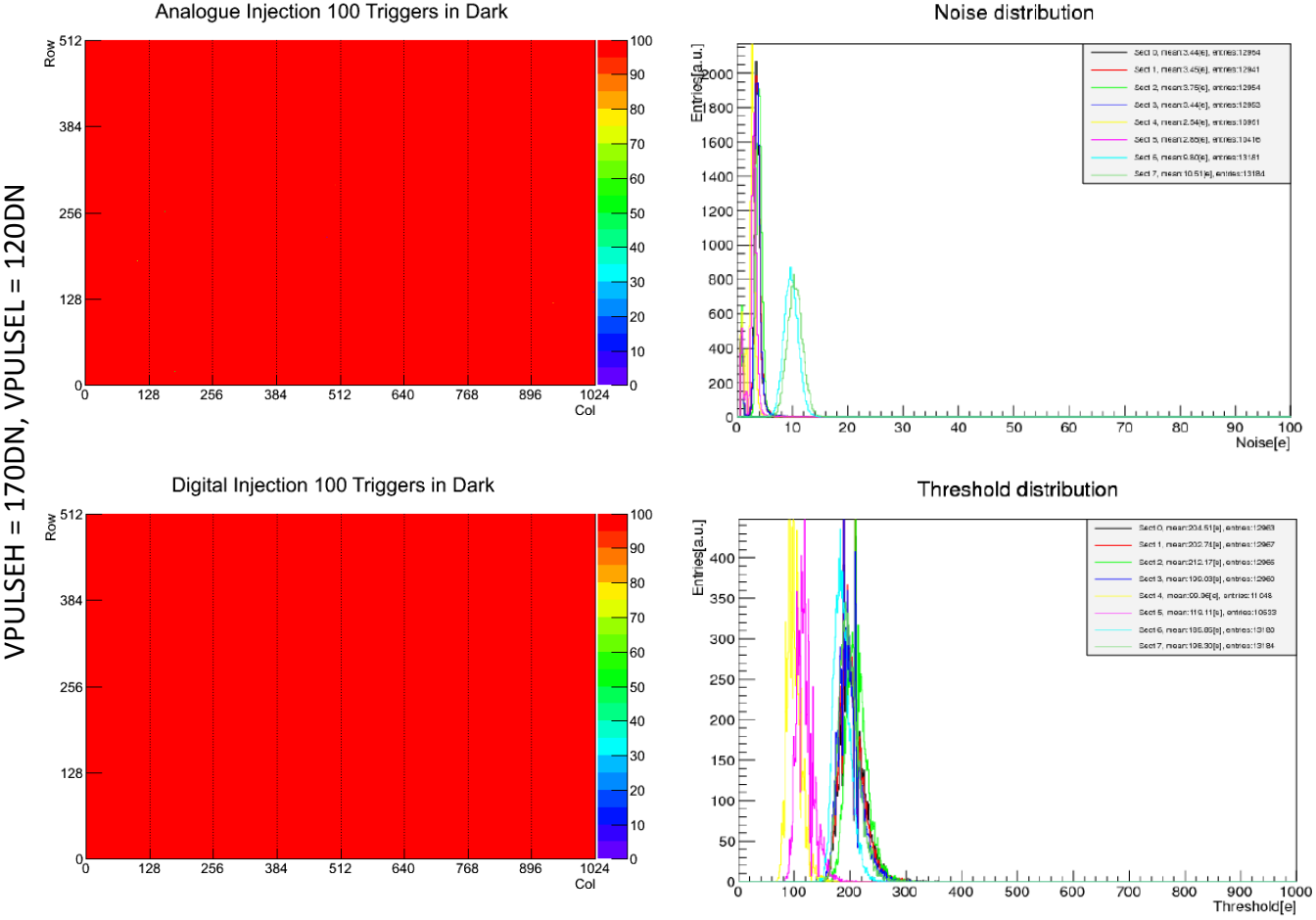
- Performed **Analogue/Digital injection tests** and **threshold/noise scans** on **pALPIDE-3 single chip** with Summer and Masters students, using custom-made MOSAIC test set-up designed in Bari.

- **Next steps** (from this month): **ALPIDE single chip and HIC testing.**



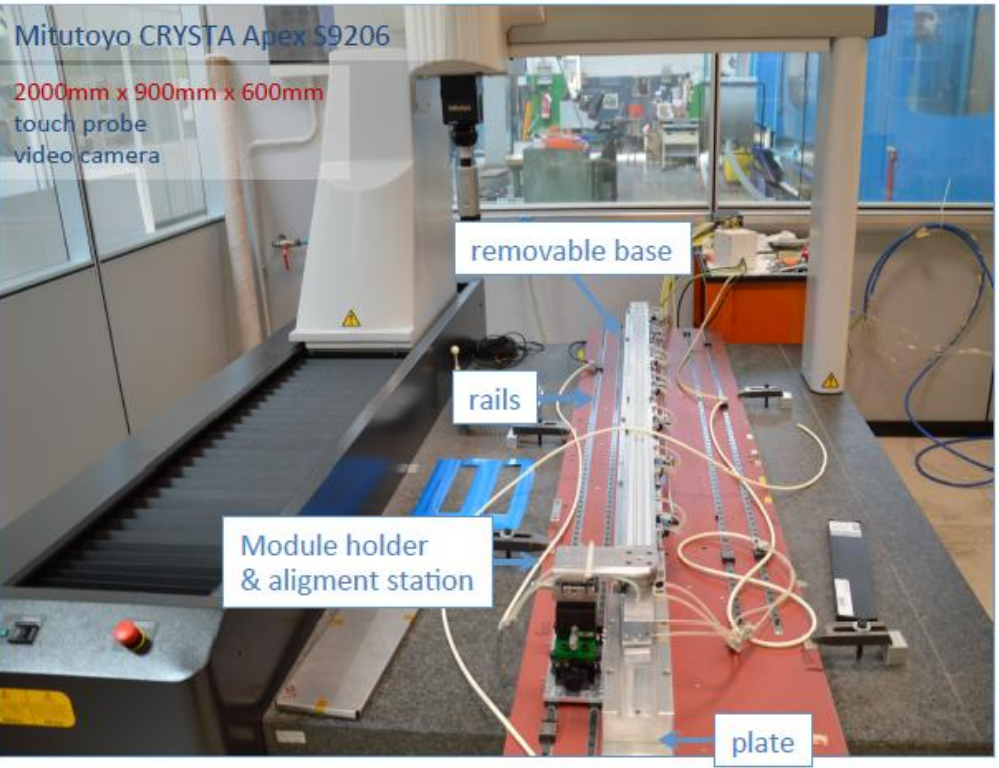
In G15



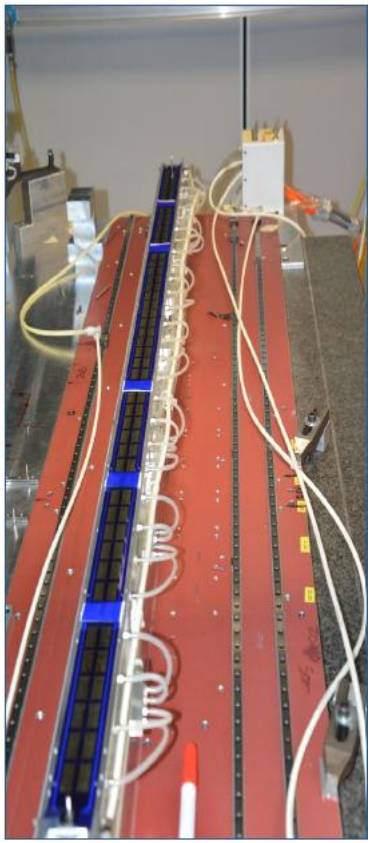


STAVE ASSEMBLY

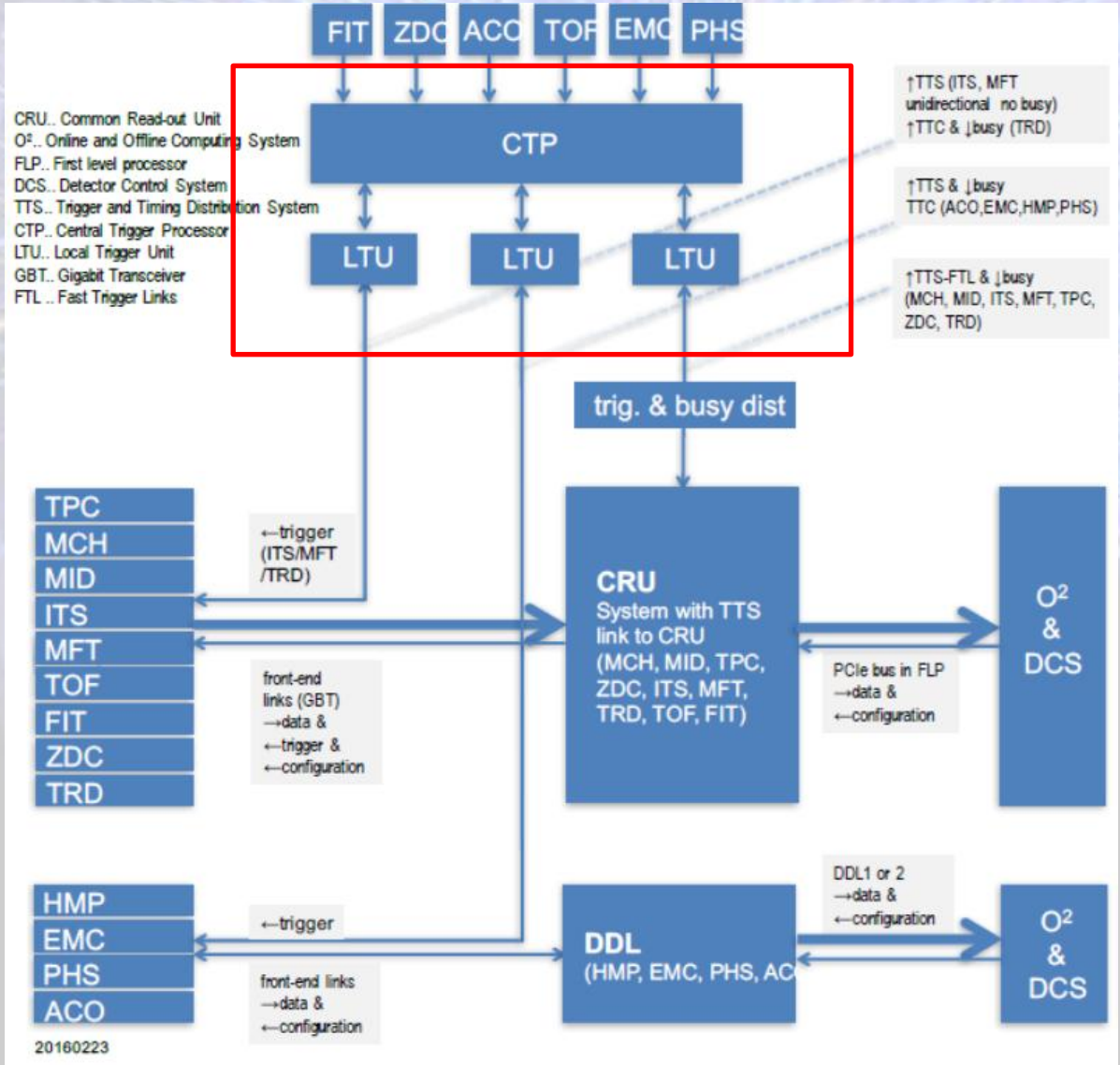
- **Preparations in Engineering Technology Centre at Daresbury Laboratory.** Purchasing new, bigger Coordinate Measuring Machine (as per other stave assembly sites: Berkeley, Frascati, NIKHEF and Turin).
- **Next steps:** Validation of assembly procedure (all sites) with pre-series production.
- **Production Readiness Review** (February/March 2017).

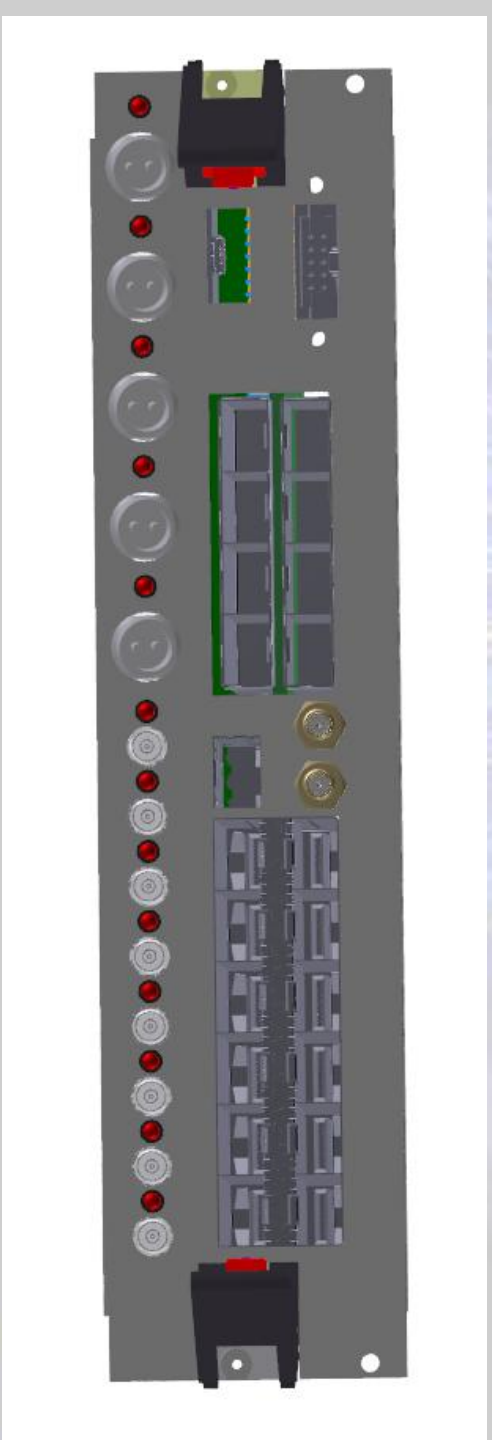


Production plan:
Modules
06/17 – 05/18
Staves
07/17 – 08/18



Trigger System Block diagram





Trigger Design

- Trigger system to consist of a Central Trigger Processor (**CTP**) board and a Local Trigger Unit (**LTU**) board for each sub-detector.
  - LTUs will also run in *Stand-Alone Mode*, using a built-in CTP emulator, for sub-detector testing and development.
  - LTUs support TTC 10G PON, GBT, and current TTC system (for detectors not upgrading)
- CTP-LTU interface by TTC 10G PON using optical fan-out units
  - Allows two-way data traffic between CTP and LTUs
- Universal board will have an FMC mezzanine card and triple-width front panel.
  - Board based on a VME-type 6U board (VME for power only)

Throttling – HB decision

- Hba/HBr and HB decision used to control flow

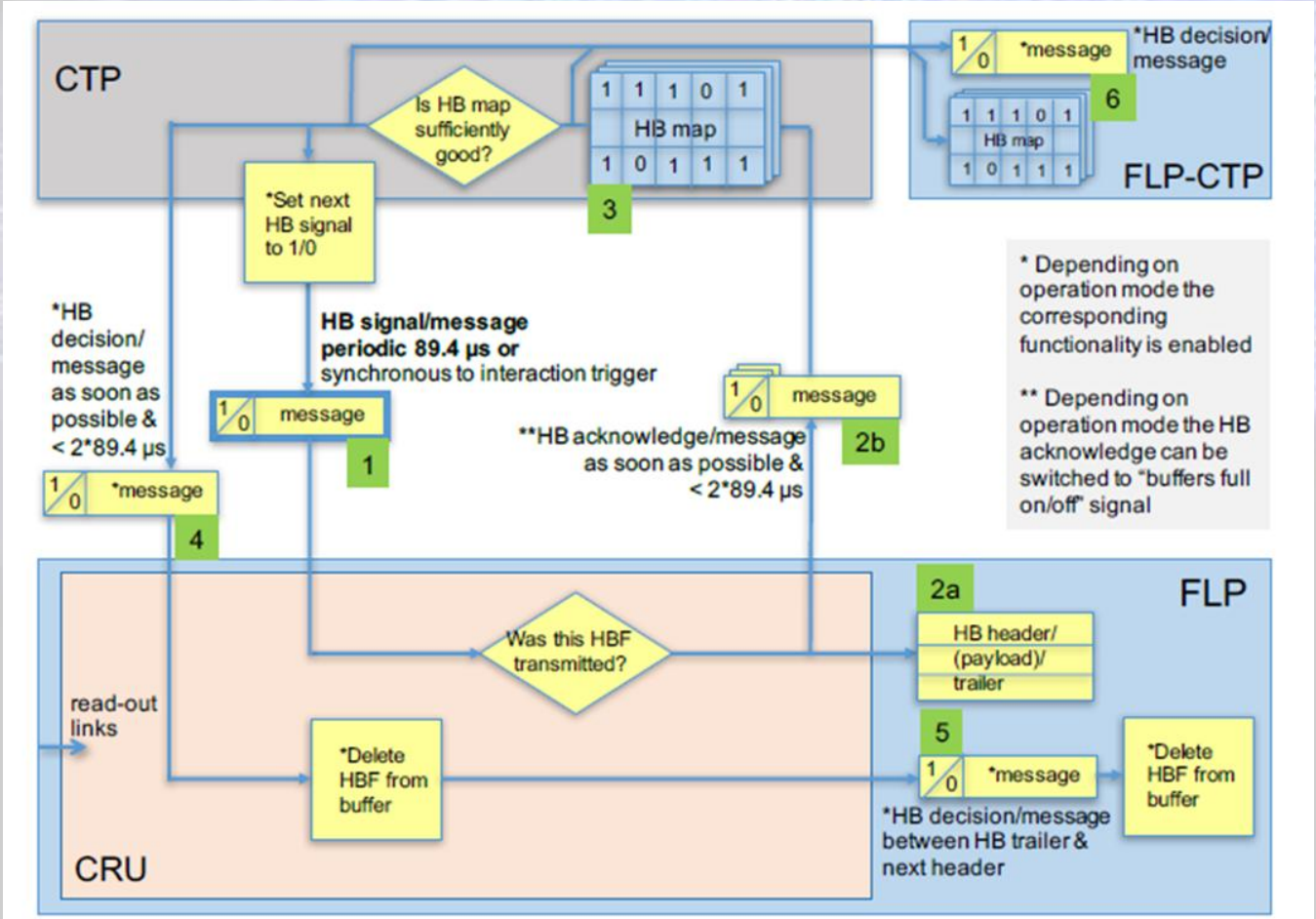


Figure 10: Signal and message flow. The reader is guided by the digits in the rectangles which are described in the text.

Status / Schedule of Trigger System

- 11th May 2016: CTP Design Review
- 6th June 2016: Schematic capture of trigger board completed
- 15th June 2016: CTP and LTU Engineering Design Review completed
  - 5th July 2016: minor changes to schematic capture completed and sent to RAL for PCB layout
- 18th Nov 2016: PCB layout at RAL compete
- 2nd Dec 2016: Production data sent to JALTEK
  - Production of two prototype boards underway
  - Expected at CERN beginning of Feb 17 for extensive tests.
- Summer 2017: full production of trigger hardware
  - If all goes well with prototypes
- 2017, 2018 extensive firmware and software development

Summary

- ALICE continues to produce high quality physics with a high no. of citations.
- UK plays a leading role in the management, detector and physics of ALICE and has a high profile within the collaboration.
- ALICE upgrade work is proceeding well
- We will be in a good position to maximise our exploitation of new physics from Run3.