The ALICE Programme

Raimond Snellings

Programme Leadership: Prof. Raimond Snellings
9 staff, 5 postdocs, 13 PhD
Publications: 258
Theses: 24
University Partner: Utrecht University
Investment Phase 1&2: 6.3 M
Personal Grants: 5.8 M

Nikhef

The ALICE Programme

- **Scientific Question: What happens to matter when you heat and compress it to extreme magnitudes which existed in the primordial universe?**
  - **QCD in the regime of extreme matter with emergent phenomena**
    - Phase transition to a **quark-gluon-plasma**
    - Extremely dense, opaque system, which looks thermalised
    - Ideal fluid – viscosity over entropy ratio close to zero
    - Temperature $\approx 10^{12}$ K – 10^{5} times larger than the core of the sun
    - Magnetic fields $\approx 10^{18}$ G – 10^{10} times larger than in the lab
  - Properties of the quark-gluon-plasma are still not well understood
    - ➡Theoretically complicated (lQCD, AdS/CFT, ..)
  - Experimentally studied with high-energy nuclear collisions at the LHC at CERN: **the ALICE experiment**

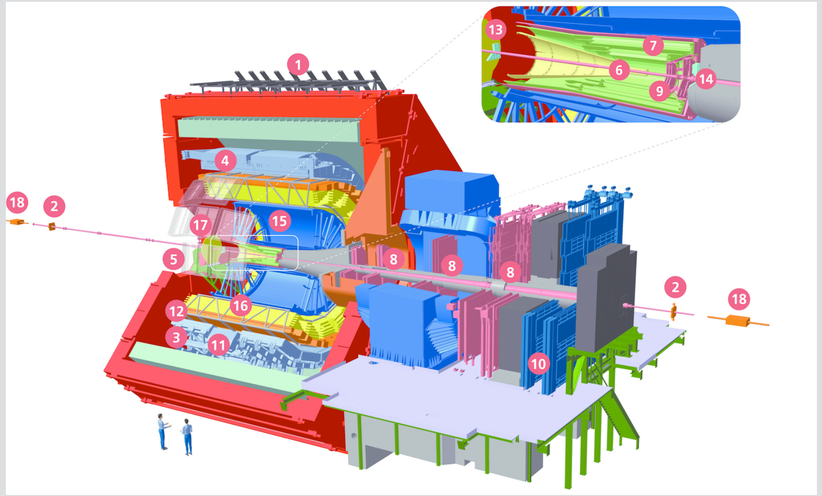
Independent quarks and gluons?

Or new collective degrees of freedom?

The ALICE Programme

- **Dutch ALICE group (Nikhef+UU) is participating in the ALICE experiment at LHC as a leading group**
  - ➡ Leading positions in ALICE
  - ➡ Well respected for hardware contribution
  - ➡ Very productive in data analysis using different probes of the quark-gluon plasma:
    - heavy quarks, elliptic flow & correlations, jets & photons
    - our group produced the most cited publications

The ALICE Collaboration: 41 countries, 176 institutes, ~1800 members



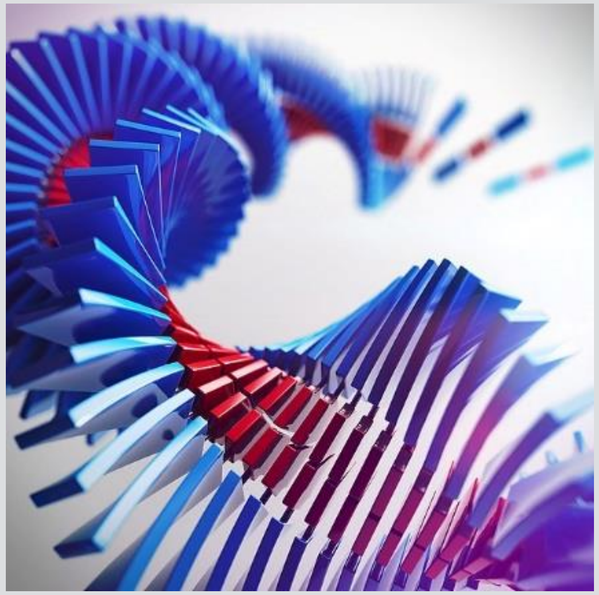
- **Large impact for relatively small group**
  - ➡ Impact: among 50 top-cited publications (WoS) from LHC, 15 from ALICE (CMS:15, ATLAS: 12.5, LHCb 7.5)
  - ➡ Possible through combination of contributions in hardware (detector technology) and physics analysis.

- *Deputy spokesperson, Physics Coordinator, Upgrade Coordinator, Editorial Board, Conference Committee, Physics Working Group and Physics Analysis Group coordinators*
- *QM2018: 1 summary talk, 5 talks (one selected as best experimental talk), 4 posters (one selected as flash talk as one of the best posters)*

Grants & new staff 2019

- VICI
- Westerdijk Fellow
- Sectorplan

Een nieuw fundament:
beeld van de bèta sector



Resolving the structure of the Quark-Gluon Plasma
Dr M. (Marco) van Leeuwen (m), NIKHEF
In the early universe, the temperature and density were so large that nuclear matter was molten into a Quark-Gluon Plasma. This form of matter is produced in a laboratory by colliding nuclei at high energy. Researchers use energetic particles that propagate through the plasma to resolve its structure.

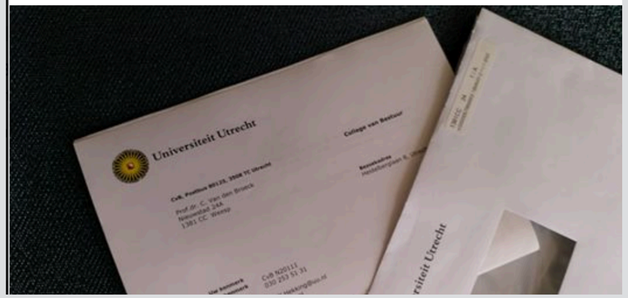
17 June 2019

Marta Verweij appointed as Assistant Professor

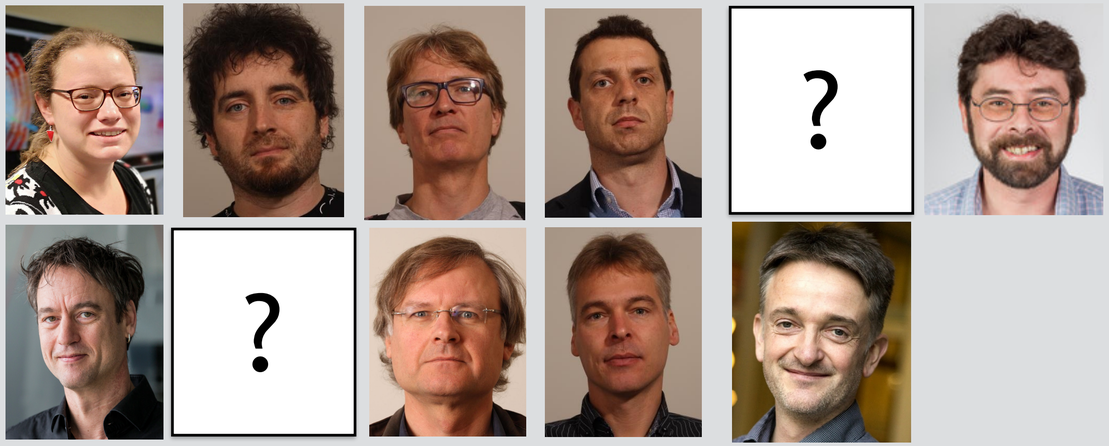
As of June 2019, physicist Dr. Marta Verweij has been appointed as Assistant Professor at the Institute for Subatomic Physics.

Chris Van Den Broeck
June 22 at 11:59 AM ·

Aaand it's official! In September I will be joining Utrecht University.

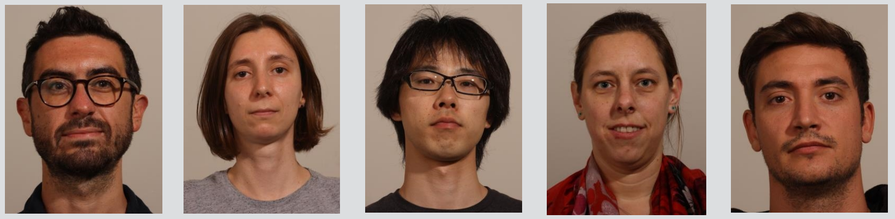


The Nikhef/Utrecht Group

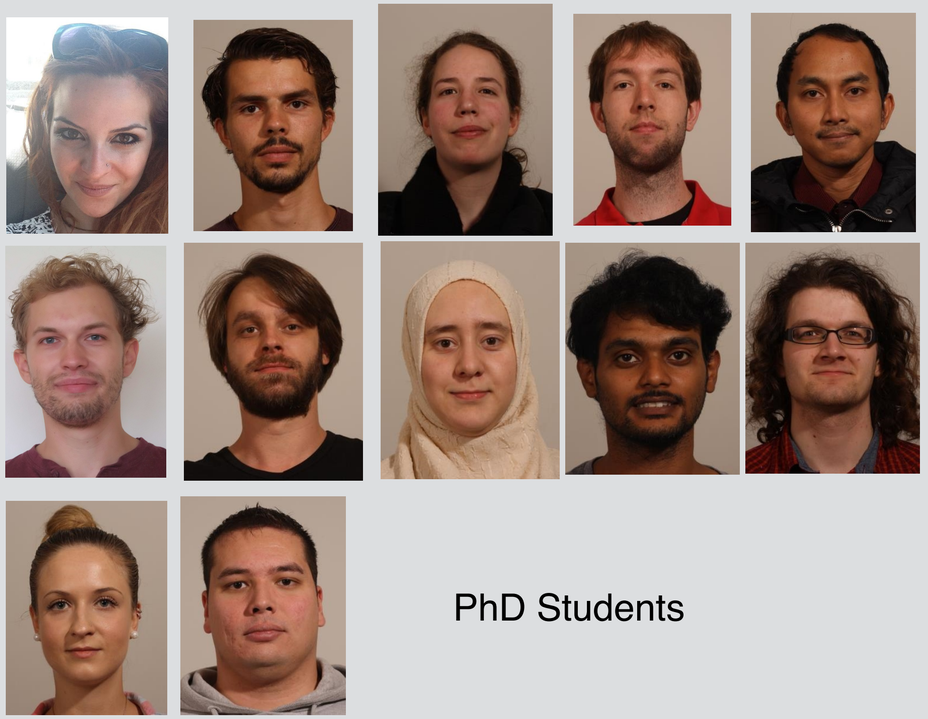


Scientific Staff

Support Staff



Postdocs



PhD Students

The ALICE Upgrade in LS2

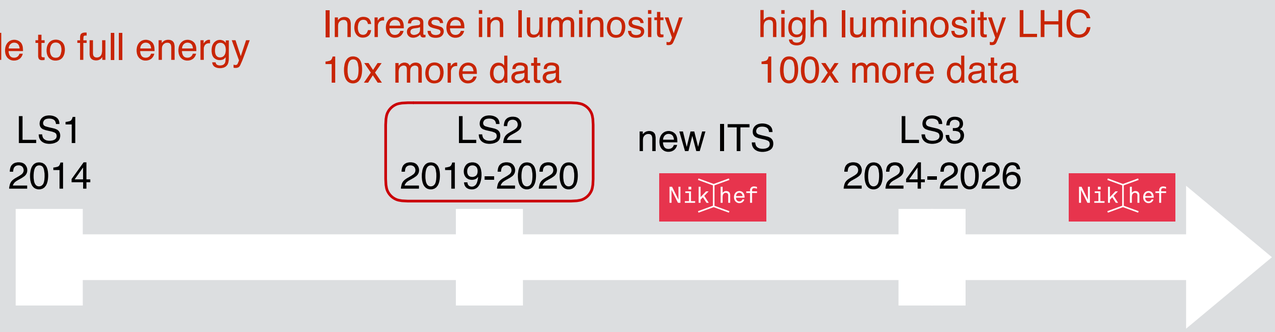
- We would like to characterise the QGP (the EoS, transport parameters, .. of this complex almost perfect liquid), and understand how it emerges from multi-body QCD

Rare probes: jets, heavy flavor, electromagnetic probes

Nikhef Nikhef Nikhef

Nikhef is leading these Physics Working Groups in ALICE

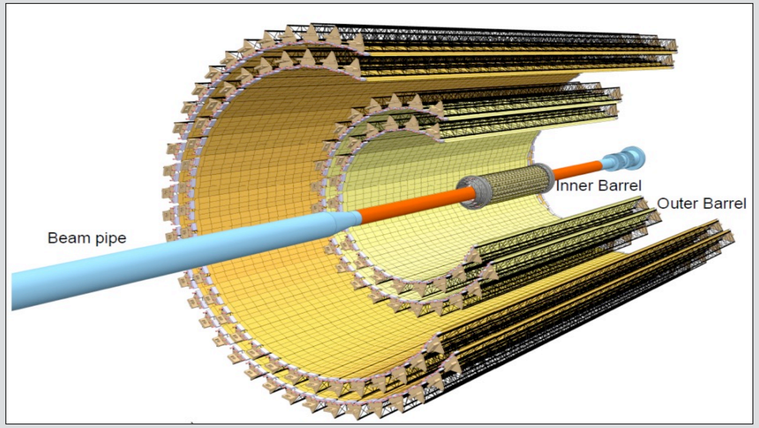
- ➡ Improve statistics: new faster ITS
- ➡ Improve S/B: new ITS; smaller pixel size inner layers, less material budget and optimised number of layers

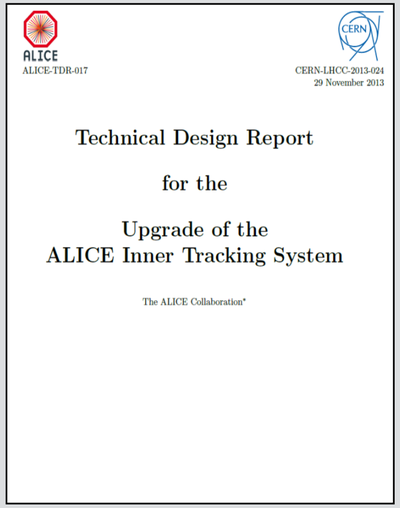


Current program (upgrade and people) funded to 2021
ALICE programme approved to 2029

The ALICE Inner Tracker Upgrade

- Improve impact parameter resolution by a factor of 3
  - ➡ Get closer to the IP: first layer 39 -> 22 mm
  - ➡ Reduce material budget: 1.14% -> 0.3% X_0 per layer or better
  - ➡ Increase pixel density 50 x 425 μm -> 20 x 20 μm
- High standalone tracking efficiency and p_t resolution
  - ➡ Increase granularity 6 -> 7 layers with reduced pixel size
  - ➡ Larger radial extension 39-430 mm -> 22-430 mm
- Fast PbPb (and pp) readout
  - ➡ Instantaneous luminosity: $6x10^{27}$ $cm^{-2}s^{-1}$ gives hadronic interaction rate of 50kHz
  - ➡ Current ITS slow, maximal readout at 1 kHz
  - ➡ In new setup Pb-Pb collisions are readout at > 50 kHz and pp at > 2 MHz




ALICE
ALICE-TDR-017

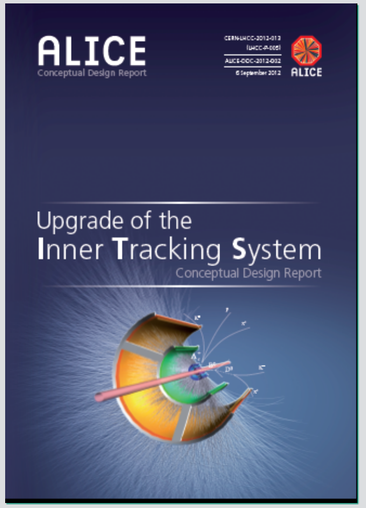
CERN-LHCC-2013-024
29 November 2013

Technical Design Report

for the

Upgrade of the
ALICE Inner Tracking System

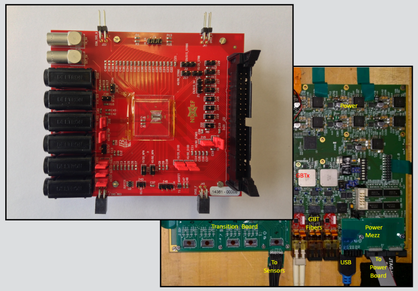
The ALICE Collaboration*



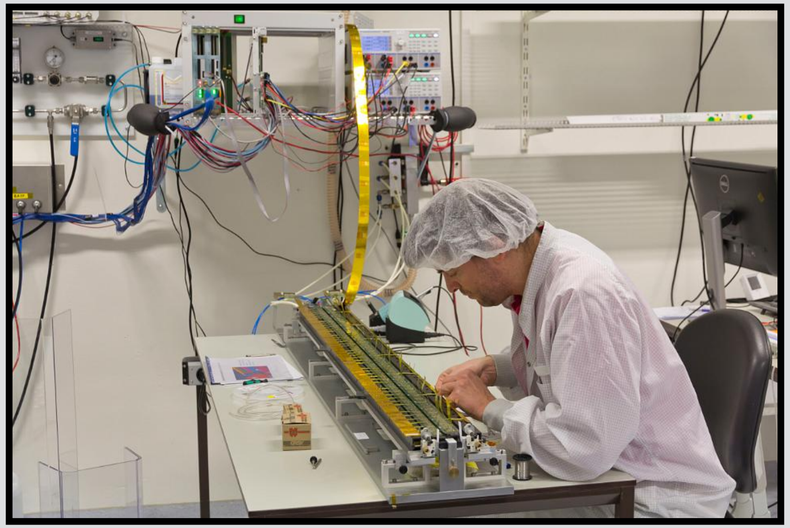
The ALICE Inner Tracker Upgrade

- **Dutch contribution**
  - CMOS wafers purchase
  - Wafer thinning and dicing
  - Power bus construction and test
  - Patch panels
  - Optical links
  - Water cooling plant
  - Ventilation humidity plant
- **Nikhef technical activities**
  - Stave assembly for layers 6 and 7
  - Read-out unit
  - Chip design

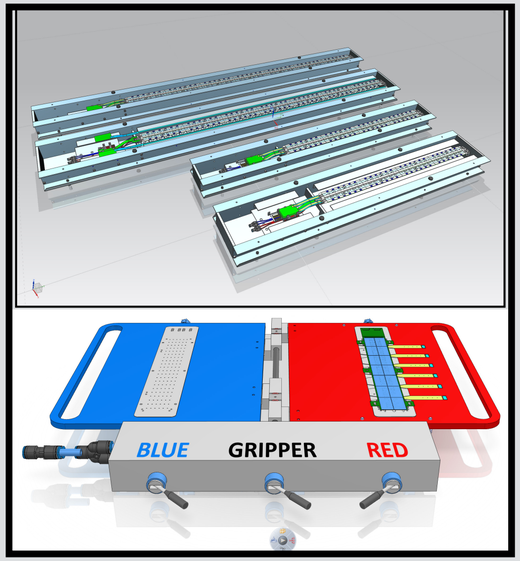
Electronics



Stave assembly

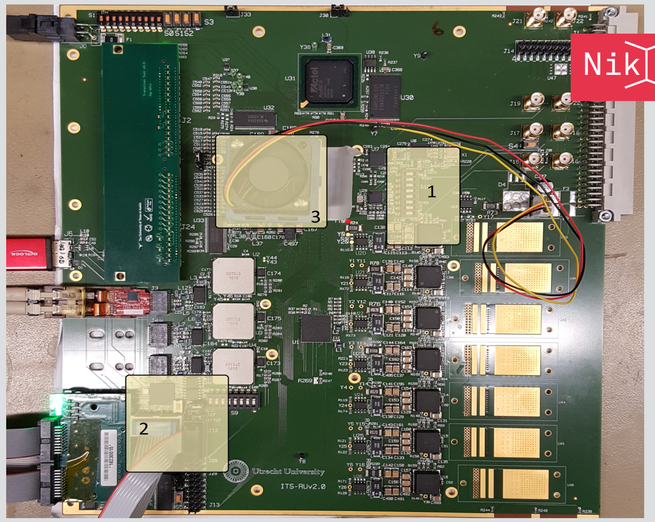


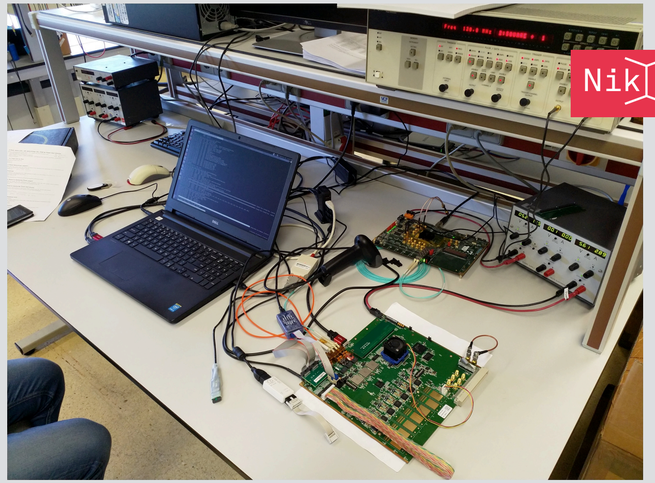
Tooling/Hardware



Chip design / Read-out Unit

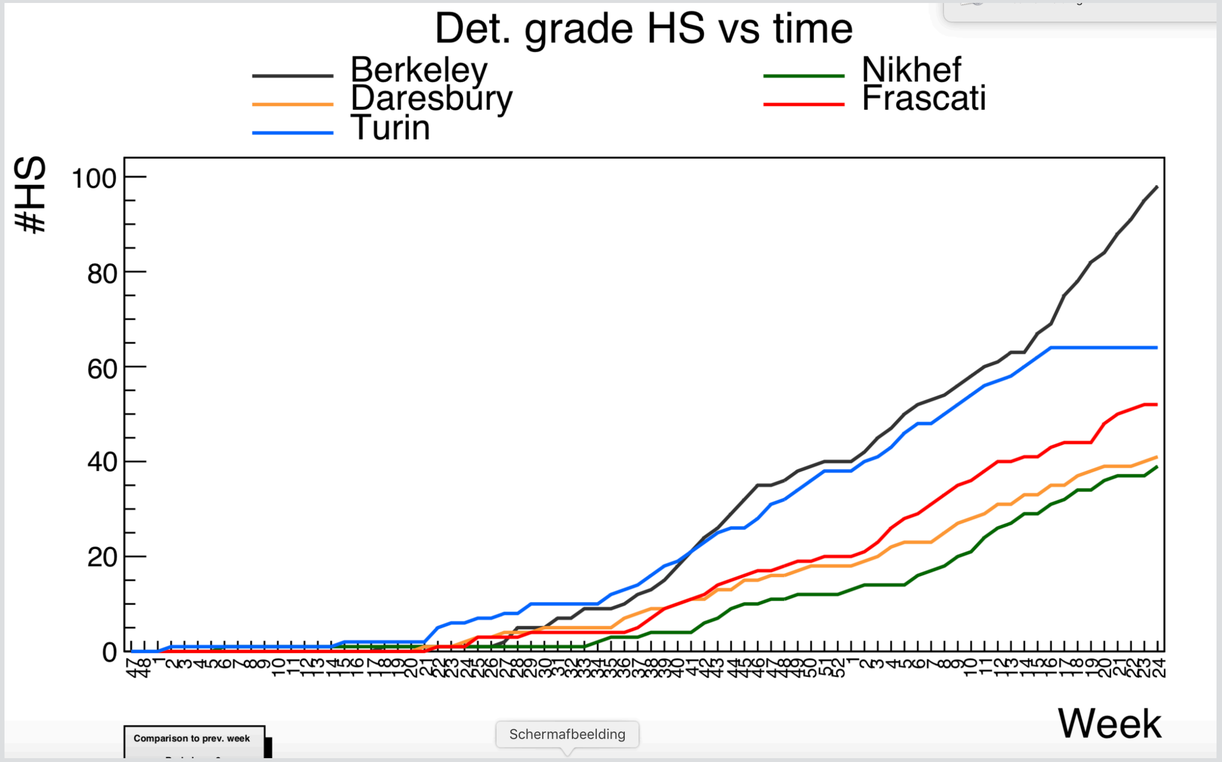
- Nikhef band-gap and temperature sensor
  - ➡ In the ALPIDE since several years
  - ➡ Full wafer production is completed and tested
- Read-out unit (includes interface to power regulation)
  - ➡ Hardware completely designed by UU/Nikhef
  - ➡ Production completed
  - ➡ QA testing half-way done
  - Also used by the ALICE-MFT and sPHENIX experiment





Stave assembly

- Total 100 staves needed (including spares)
  - ➡ Official deadline September 2019
- Shared between 4 labs in Europe
  - ➡ Daresbury, Frascati, Nikhef, Turin
- Stave assembly at Nikhef started in 2018
  - ➡ Now at stave-023 (goal is 25 staves)
  - ➡ After start-up problems (test-system failures) Nikhef caught up
  - ➡ Currently limited by supply of parts
- Turin started early and produced a few extra staves
  - ➡ Now stopped, renovation lab
- Currently Alice has enough staves for layer 6+7
  - ➡ But no spares

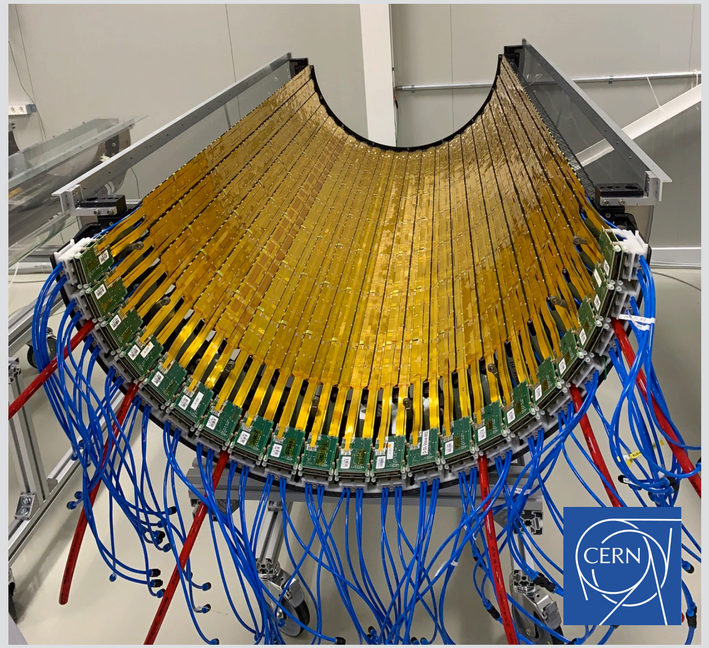


Stave assembly

- Four staves at Nikhef, ready for shipment to CERN
- Last batch of filter board production failed (commercial supplier)
  - ➡ Four staves at Nikhef waiting for filter boards
  - ➡ We repair filterboards needed for four staves, rest will be shipped back to company
- Sensor module production slower than expected
  - ➡ Asian lab had significant downtime
- Stave production for layers 4+5 more behind schedule
  - ➡ Decision taken to send all modules to Berkeley until September
- Stave production layer 6+7 will pause at sites until October
- Nikhef will use 5 calendar weeks to produce 2 or 3 staves when all material is available

ALICE status and plans

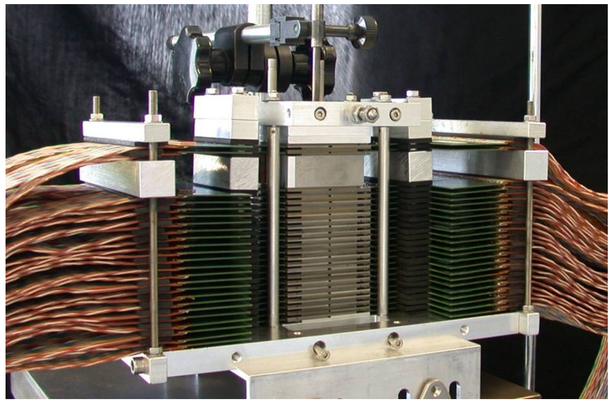
- Some of the power cables on the staves had a short after installation
  - ➡ CERN is reworking the half-barrels
- Commissioning on the surface started with available half-barrels
  - ➡ Full time running of detector until next spring
  - ➡ All barrels will be installed in October, all read-out units available in August
  - ➡ Still one month contingency for installation
- Nikhef ALICE group committed to support ITS commissioning and data taking
  - Nikhef stave production will be completed this year
  - Nikhef/UU will supply firmware development and support for read-out units
    - ➡ 2019+2020
    - ➡ On-call support also during data taking 2021+
  - Nikhef hires a post-doc (2+1 year) stationed at CERN for QA software development



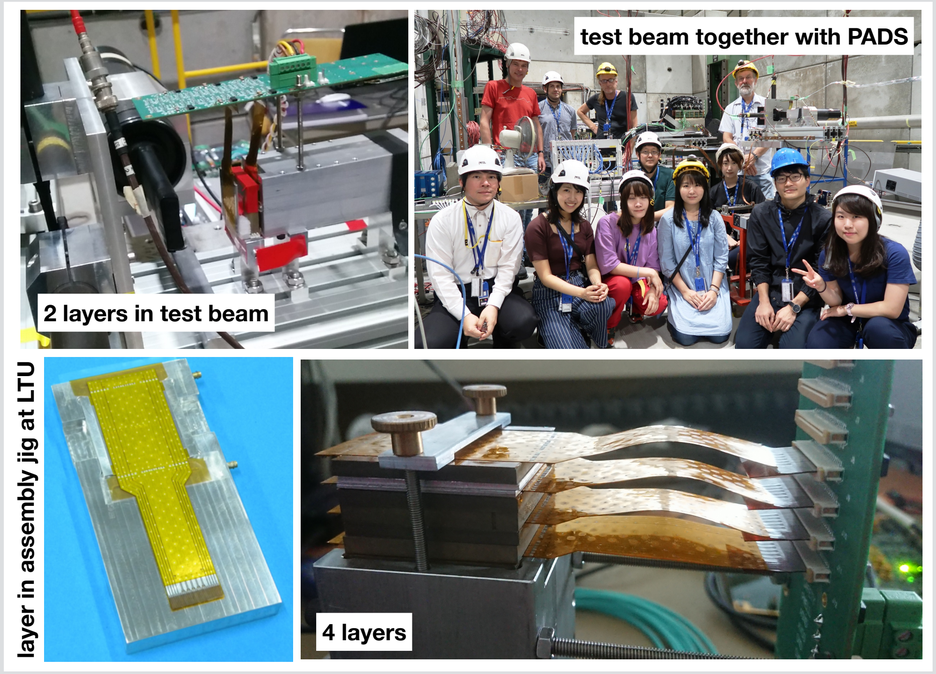
FoCal Upgrade

- Proposal to measure forward direct photons to study low-x gluon distributions (under discussion for installation in ALICE during LS3)
  - In ALICE the region $3.5 < \eta < 5.3$ can be used
  - Main challenge is to separate γ/π^0 at high energy
    - π^0 at forward rapidity p_t = 10 GeV has d = 2mm
  - Need small Moliere radius and high granularity read-out for EM calorimeter

Performance published in JINST 13 (2018) P01014



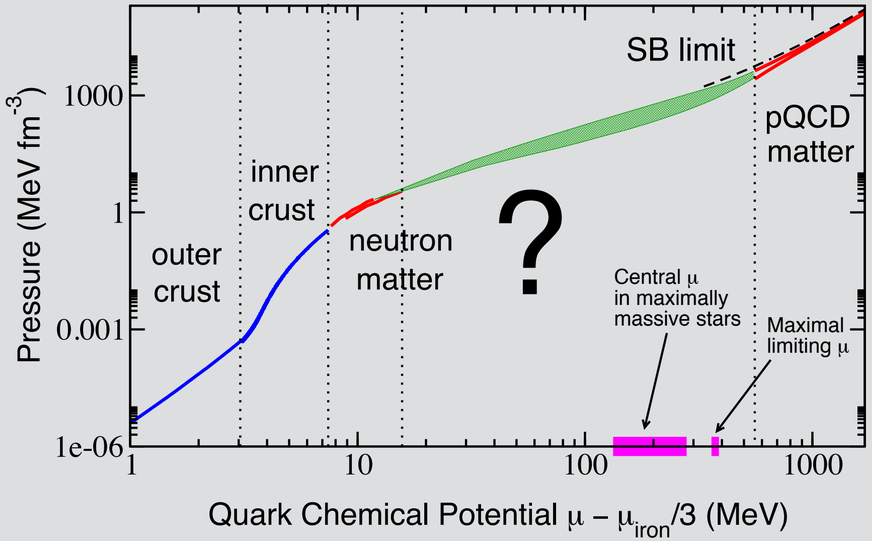
3 x PhD thesis
Martijn Reicher: "Digital Calorimetry Using Pixel Sensors"
Chunhui Zhang: "Measurements with a High-Granularity Digital Electromagnetic Calorimeter"
Hongkai Wang: "Prototype Studies and Simulations for a Forward Si-W Calorimeter at the Large Hadron Collider"

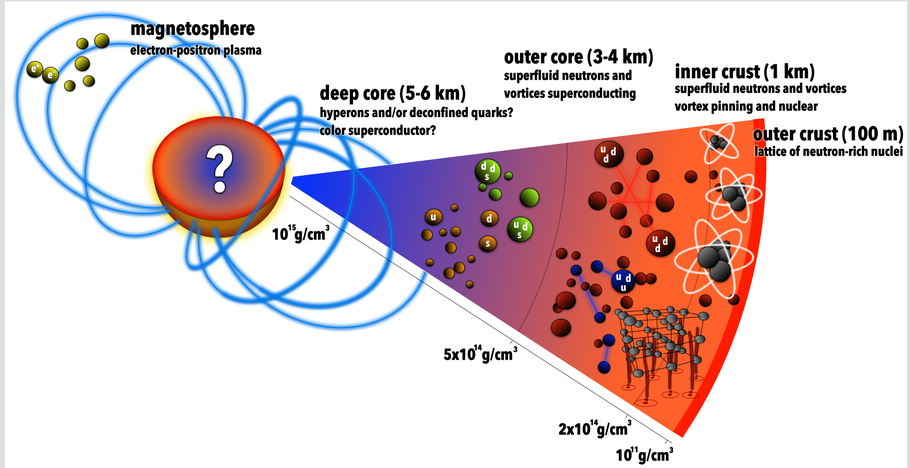


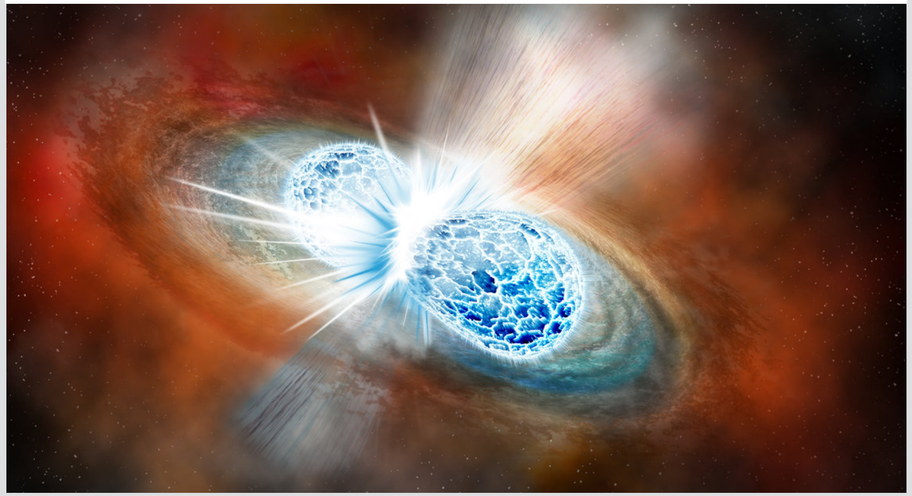
- Leading role UU/Nikhef during R&D phase FoCal
- UU/Nikhef involvement ramping down in 2019
  - Handing over responsibilities to other groups

QGP in Neutron Stars?

- Densest objects in nature
- The balance of gravity and QCD
  - A neutron star is a macroscopic laboratory of QCD!
    - Deep core of some neutron stars could be a QGP







- First neutron star merger observed in Virgo/Ligo
  - Already providing constraints on the EoS
- Detailed understanding of the dynamics is required to understand the properties of the neutron star interior
  - EoS, transport parameters, ..
  - Strong overlap with the physics of heavy-ion collisions

At Utrecht University a new Institute for Subatomic and *Gravitational* Physics

Looking for a name of the new institute

ALICE in the LHC Wonderland

Study QCD in the regime of extreme matter with emergent properties

- Colliding heavy-ions at the LHC allows us to create and study a new state of matter
- Its emergent properties are surprising and completely different than predicted, now they can be measured and modeled for the first time
  - ➡ Still many important open questions
- The Nikhef ALICE group is very productive and has a large impact on the ALICE program
- ITS upgrade well on track
- Gravitational waves program (Virgo, Lisa, ET)
- Strong connections with Utrecht Theory department
- Strong future programme and ambitions!
  - ➡ Need to secure funding for after 2021