

# The ALICE Programme

Raimond Snellings



Programme Leadership: Prof. Raimond Snellings

7 staff, 4 Postdocs, 18 PhD

Publications: 224

Theses: 20

University Partner: Utrecht University

Investment Phase 1&2: 6.3 M

Personal Grants: 4.23M

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?**

- Phase transition to a **quark-gluon-plasma**

- State of the universe in the first  $10 \mu\text{s}$
- Temperature  $\approx 10^{12} \text{ K}$  –  $10^5$  times larger than the core of the sun
- Magnetic fields  $\approx 10^{18} \text{ G}$  –  $10^{10}$  times larger than in the lab

- Properties of the quark-gluon-plasma are still not well understood

- Theoretically extremely complicated

- **QCD in the regime of extreme matter with emergent phenomena**

- Extremely dense, opaque system, which looks thermalized
- Ideal fluid – viscosity over entropy ratio close to zero

- 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



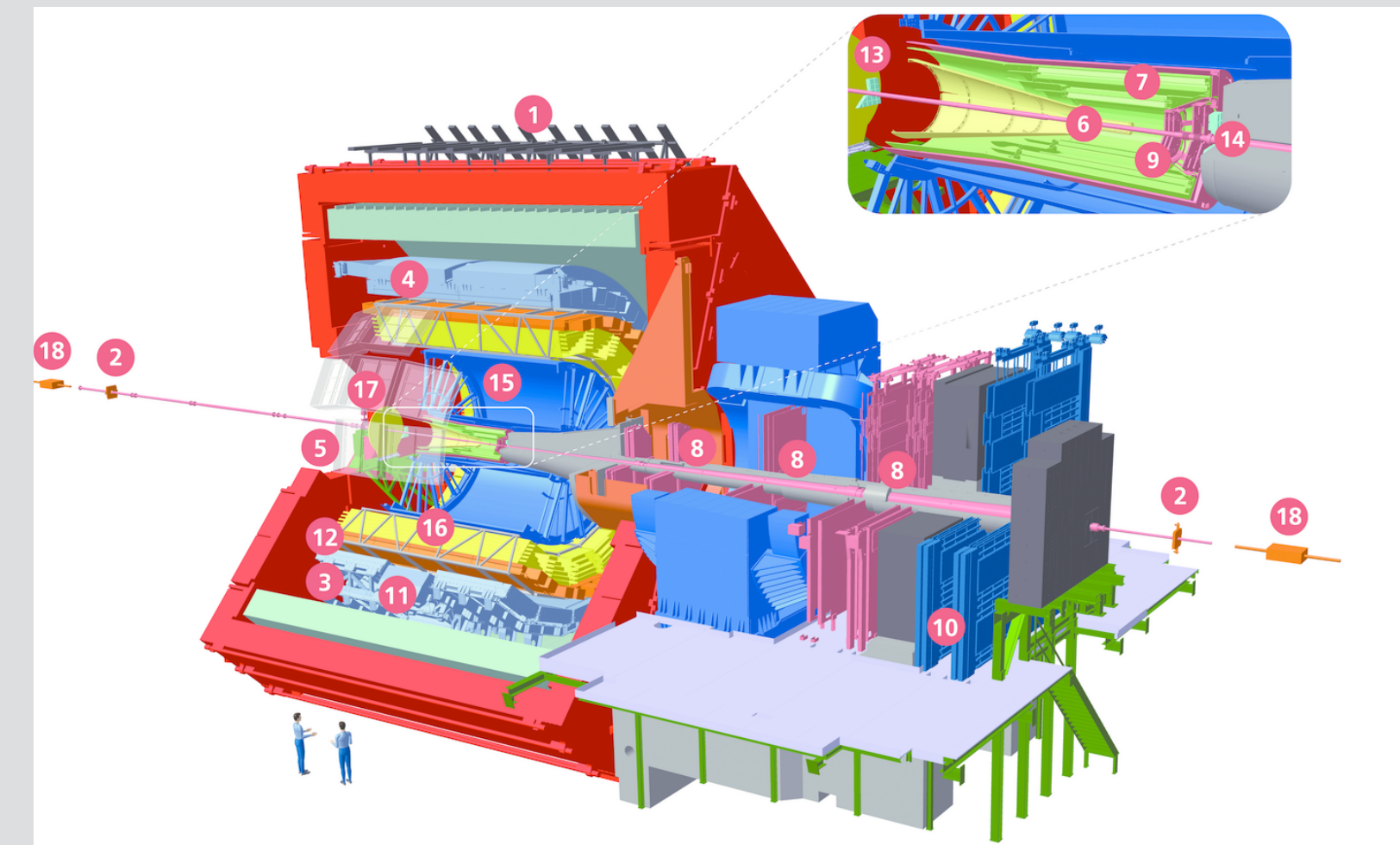
- **Dutch ALICE group (Nikhef+UU) is participating in the ALICE experiment at LHC as a leading group**

- 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

- **Large impact for relatively small group**

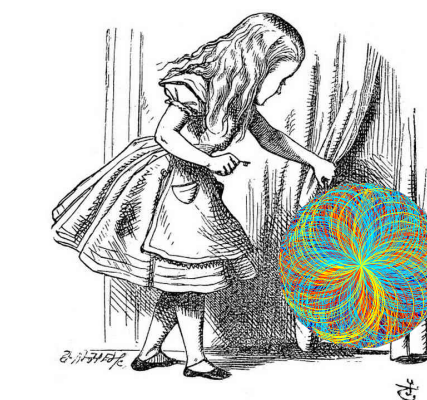
- Impact: among 50 top-cited publications (WoS) from LHC, 15 from ALICE (CMS:15, ATLAS: 12.5, LHCb 7.5)
- Possible through combination of contributions in hardware (detector technology) and physics analysis.

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

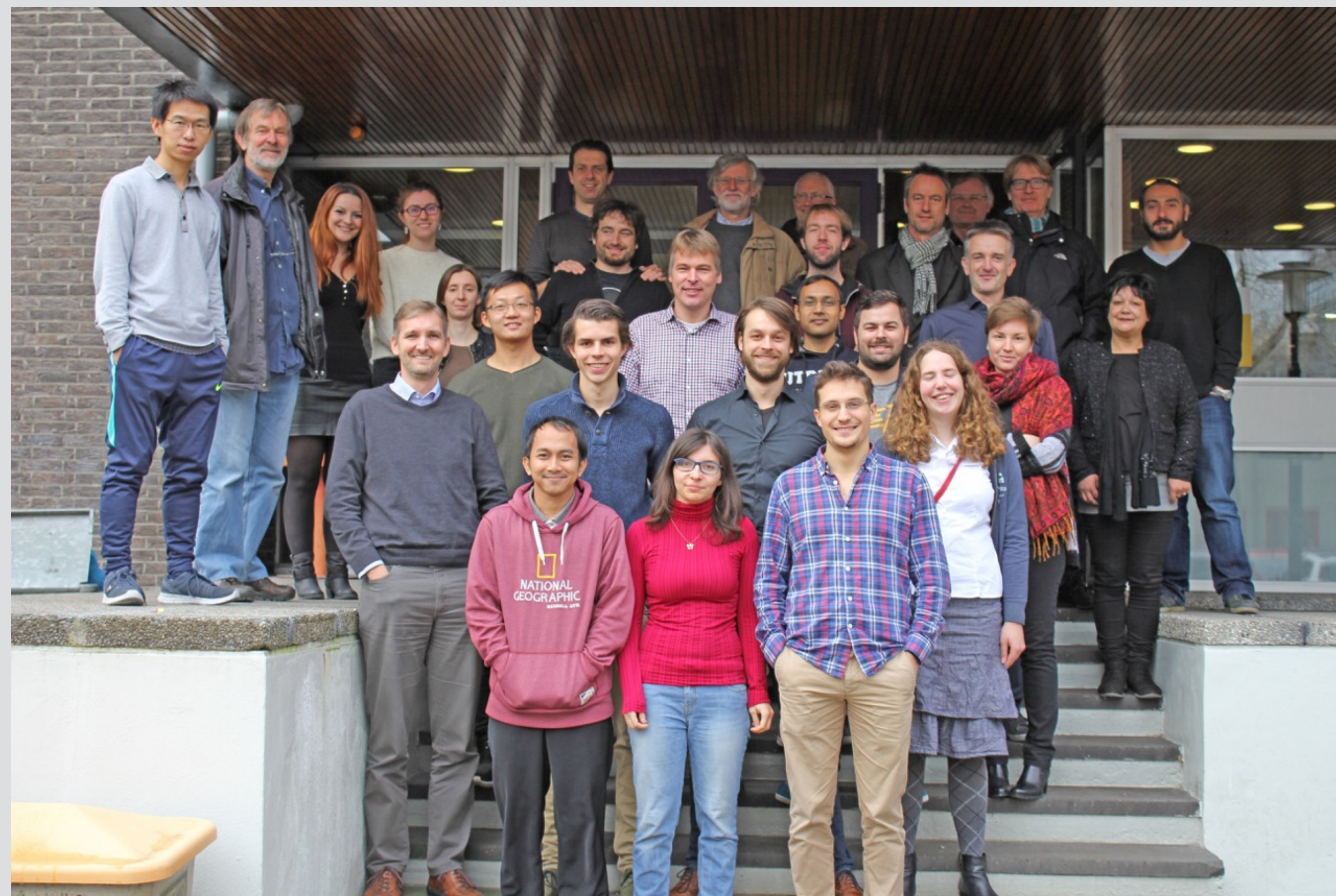




# The Nikhef ALICE Group

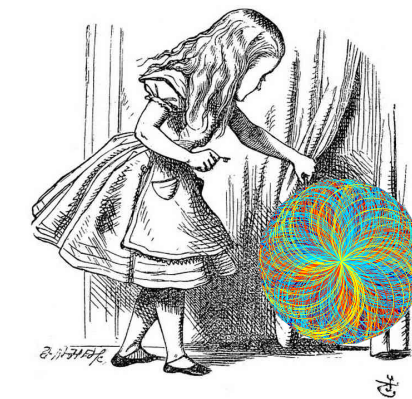


- The Dutch ALICE team is analysis-wise one of the most productive teams in ALICE
  - Our group produced the most cited ALICE publications, second to the Higgs publications, the most cited LHC publications
- Deputy spokesperson, Physics Coordinator, Upgrade Coordinator, Editorial Board, Conference Committee, 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)





# Meetings in the Netherlands



## XII Workshop on Particle Correlations and Femtoscopy Nikhef, Amsterdam, The Netherlands June 12<sup>th</sup> - 16<sup>th</sup> 2017



Site: <https://indico.cern.ch/event/539093/>  
 Contact: [wpcf2017-loc@nikhef.nl](mailto:wpcf2017-loc@nikhef.nl)  
 Address: Science Park 105, 1098 XG  
 Amsterdam, The Netherlands  
 Phone: +31 (0)20 592 2000



### Scientific Program

- Femtoscopy at RHIC and LHC: links to QGP physics
- Femtoscopy in A+A, p+p, p+A and e+e- collisions at relativistic energies
- Femtoscopy at intermediate energies: links to the EoS of asymmetric nuclear matter
- Charge fluctuations, correlations and balance functions
- Fluctuation in initial conditions
- Collective flow and correlations
- Resonance decays at RHIC and LHC
- Resonance decay spectroscopy in low and intermediate energy reactions
- Chiral magnetic effect and wave
- New methods and facilities

### International Advisory Committee

- M. Bleicher (Frankfurt, Germany)
- A. Bialas (Cracow, Poland)
- W. Broniowski (Cracow, Poland)
- P. Christakoglou (Nikhef, The Netherlands)
- T. Csörgő (Budapest, Hungary)
- I. Dremin (Moscow, Russia)
- P. Danielewicz (MSU, USA)
- W. Florkowski (Cracow, Poland)
- Y. Hama (USP Sao Paulo, Brazil)
- T. Hirano (Tokyo, Japan)
- K. Homma (Hiroshima, Japan)
- T. Humanic (OSU, USA)
- A. Kisiel (WUT, Poland)
- R. A. Lacey (Stony Brook, USA)
- R. Lednicky (Dubna, Russia)
- M. A. Lisa (OSU, USA)
- D. Miskowiec (GSI, Germany)
- S. S. Padula (UNESP, Brazil)
- J. Pluta (WUT-Krakow, Poland)
- S. Pratt (MSU, USA)
- Y. Sinyukov (BTPH-NAS, Ukraine)
- R. Snellings (Utrecht, The Netherlands)
- M. Sumera (ASOR, Czech Rep.)
- G. Verde (INFN-Catania Italy)
- W. A. Zajc (Columbia, New York, USA)

### Local Organising Committee

- Joan Berger (Nikhef)
- Panos Christakoglou (Nikhef)
- Paul Kuijer (Nikhef)
- Raimond Snellings (Utrecht University)

### Sponsored by

- Stichting voor Fundamenteel onderzoek der Materie (FOM)
- Nationaal instituut voor subatomaire fysica (Nikhef)



17<sup>th</sup> International Conference on  
**Strangeness in Quark Matter**  
10-15 July 2017  
Utrecht, the Netherlands

**Scientific Program**

- Strangeness and heavy-quark production in nuclear collisions and hadronic interactions
- Hadron resonances in the strongly-coupled QGP
- Bulk matter phenomena associated with strange and heavy quarks
- QCD phase structure
- Strangeness in astrophysics
- Open questions and new developments

**Local Organisation Committee**

**International Advisory Committee**

**Conference manager**

**Conference secretary**

[www.sqm2017.nl](http://www.sqm2017.nl)

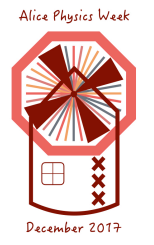


## ALICE Physics Week in Amsterdam

4-8 December 2017  
Other Institutes

Search...

ALICE Physics Week  
4-8 December 2017  
Amsterdam  
The Netherlands



The ALICE Physics Week 2017 will be held in Amsterdam, the Netherlands, from 4-8 December 2017. The conference venue is in the De Nieuwe Liefde, a conference centre located in Amsterdam downtown.

At the ALICE Physics Week we will review recent analyses and discuss their impact on our understanding of the Quark Gluon Plasma and multi-body QCD. All presentations are in a plenary session, so that results from different groups can be compared and discussed together to provide a broader view of the physics and interpretations.

We will also use this opportunity to discuss the physics program of ALICE for Run 3 and 4, during which we expect to collect large data samples plans with the upgraded detector.

Starts 4 Dec 2017, 09:00  
Ends 8 Dec 2017, 17:00  
Europe/Zurich

Other Institutes  
De Nieuwe Liefde  
Conference Center, Amsterdam



Registration

You have registered for this event.

See details

## HOT QUARKS 2018

September 7-14 - Texel, The Netherlands

A workshop for young scientists on the physics of ultrarelativistic nucleus-nucleus collisions

<http://hq2018.bnl.gov/>

**Scientific Program**

- QCD at high temperature/density and lattice QCD
- Initial state effects and Color Glass Condensate
- Relativistic hydrodynamics and collective phenomena
- Correlations and fluctuations
- Jets in the vacuum and in the medium
- Baryons and strangeness
- Heavy-flavour, dileptons and photons
- AdS/CFT correspondence and the Quark-Gluon Plasma
- Experimental techniques and future programs

**Organizing Committee:**

Javier Albares, Universidad de Granada (Spain)  
 Jana Bielekova, Nuclear Physics Institute of the CAS (Czech Republic)  
 Jorge Noronha, University of Sao Paulo (Brazil)  
 Alessandro Grelli, Utrecht University and Nikhef Amsterdam (The Netherlands)  
 Jiangang Jia, Stony Brook University (USA)  
 Hannah Petersen, FIAS (Germany)  
 Lijuan Ruan, Brookhaven National Laboratory (USA)  
 Sewil Salar, Rutgers University (USA)  
 Bjoern Schenke, Brookhaven National Laboratory (USA)  
 Anthony Timmins, University of Houston (USA)

**HELMHOLTZ**  
RESEARCH FOR GRAND CHALLENGES

**universe**  
an Open Access Journal by IOP

**EMMI**

**STF**

**Utrecht University**

**NWO**







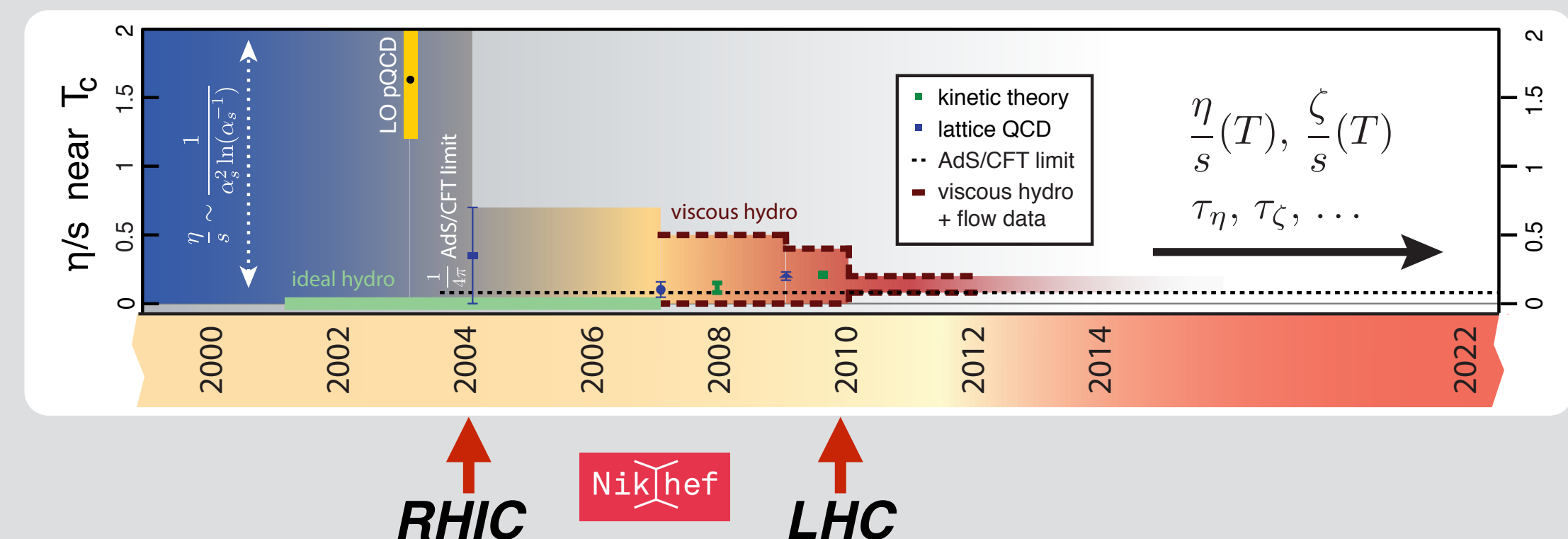
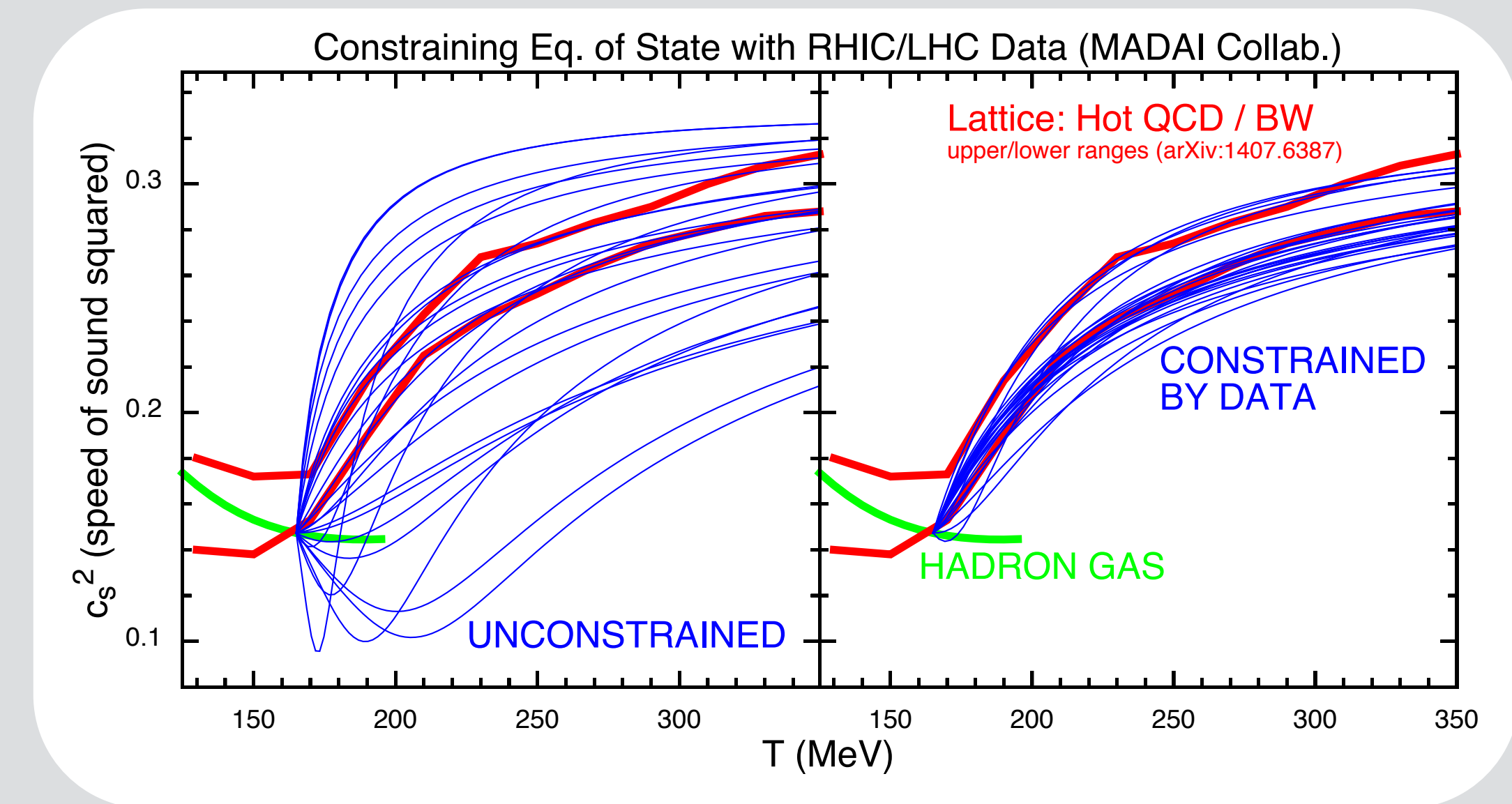
We organized many big meetings in the Netherlands



# Some Open Questions:

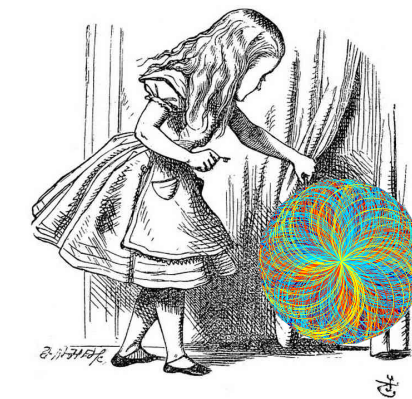


- Collective Flow 
  - already strong constraints on shear viscosity, open questions initial state, hadronization, ...
- Hard and EM Probes 
  - Medium modification of the jet structure, medium properties, thermalisation, degrees of freedom, ...
- Heavy Flavor 
  - special role as it is a well calibrated probe and could contribute to better understanding of collective flow and jet-medium interactions
- Angular Correlations 
  - Understanding the magnetic field in these collisions and the strong cp violation as well as role of conservation laws in particle production





# The ALICE Upgrade in LS2



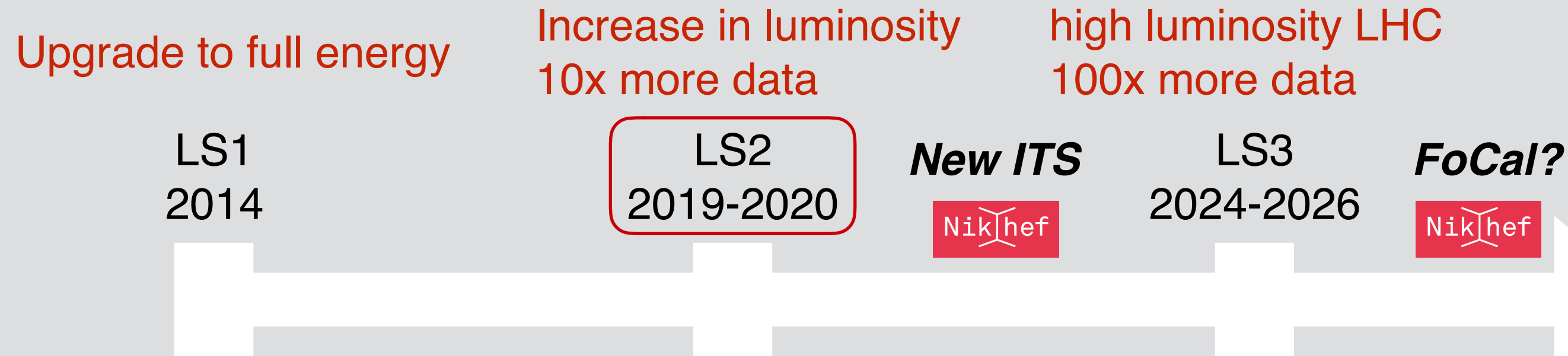
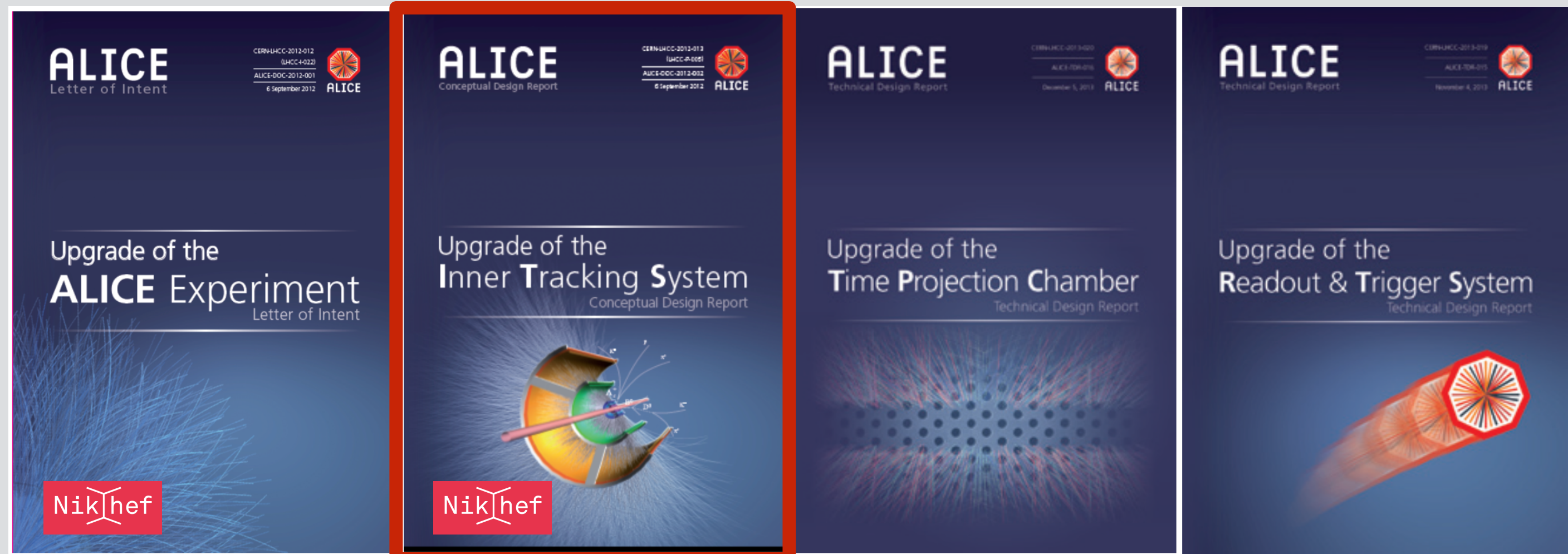
- We would like to characterize this complex almost perfect liquid (EoS, transport parameters) and understand how it emerges from multi-body QCD

**Rare probes: jets, heavy flavor, electromagnetic probes**



**Nikhef is leading these Physics Working Groups in ALICE**

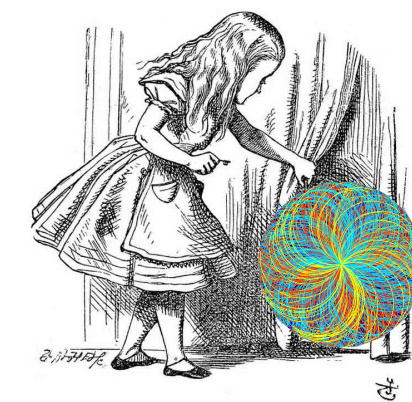
- Improve statistics: new faster ITS
- Improve S/B: new ITS; smaller pixel size inner layers, less material budget and optimized number of layers



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



# The ALICE Inner Tracker



- The current ITS consists of 6 layers of silicon detectors
  - Nikhef led the construction of the outer two layers of the silicon strip detector
  - This detector worked almost perfectly for the last decade, due to our continuous support for its operation
  - Important for almost every physics analysis in ALICE

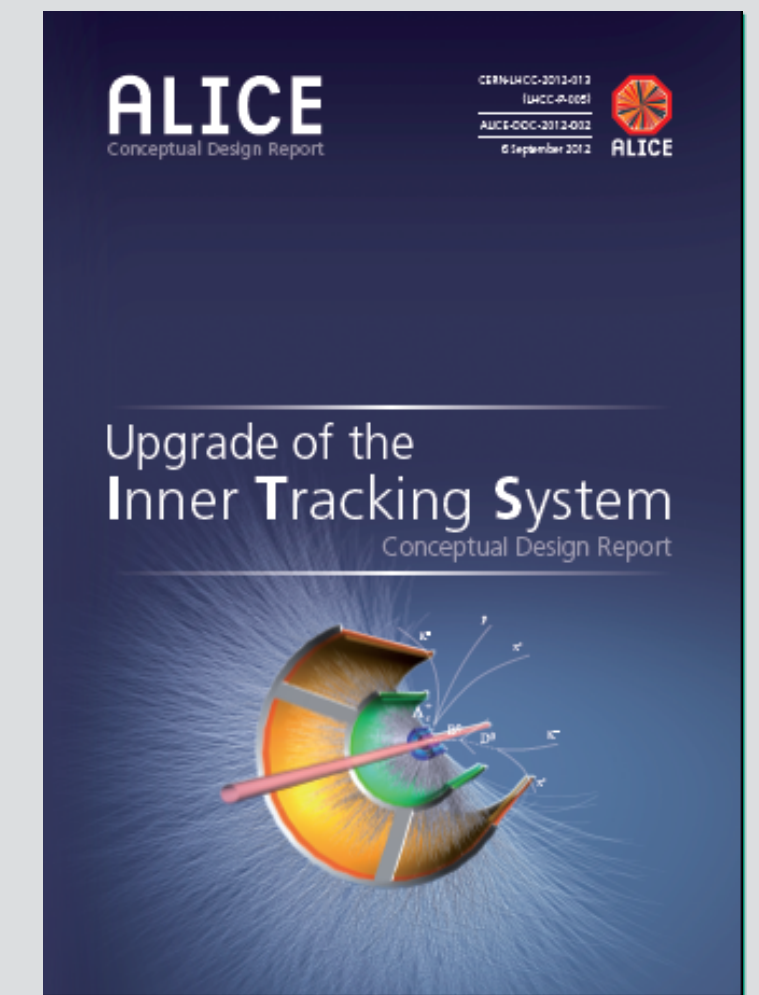
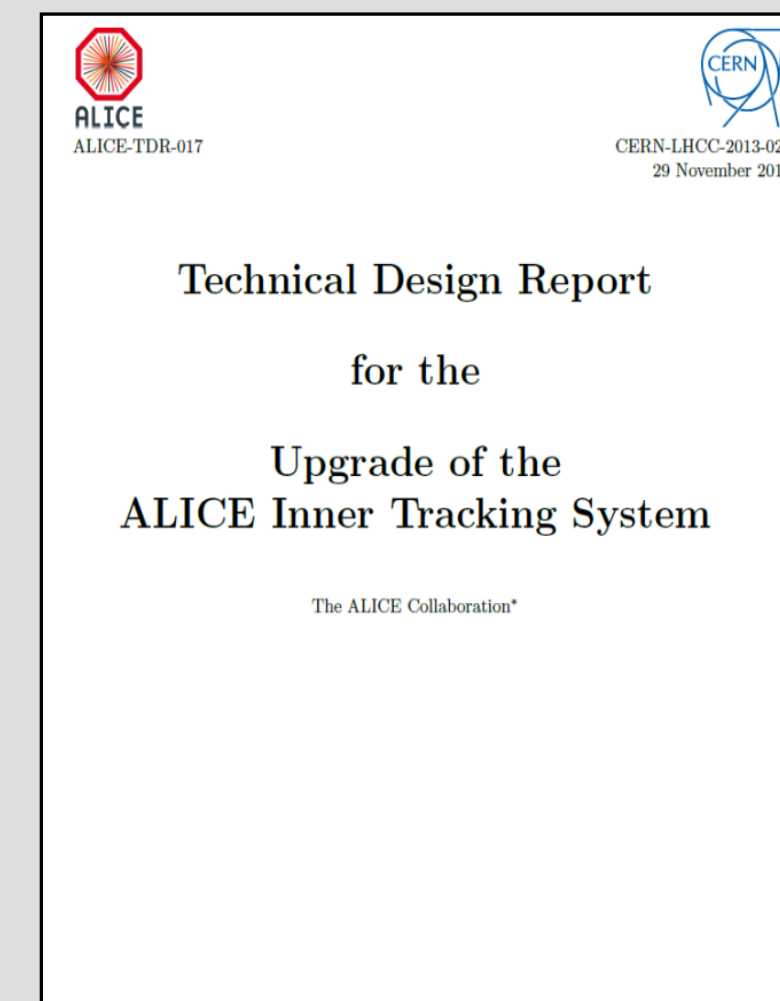
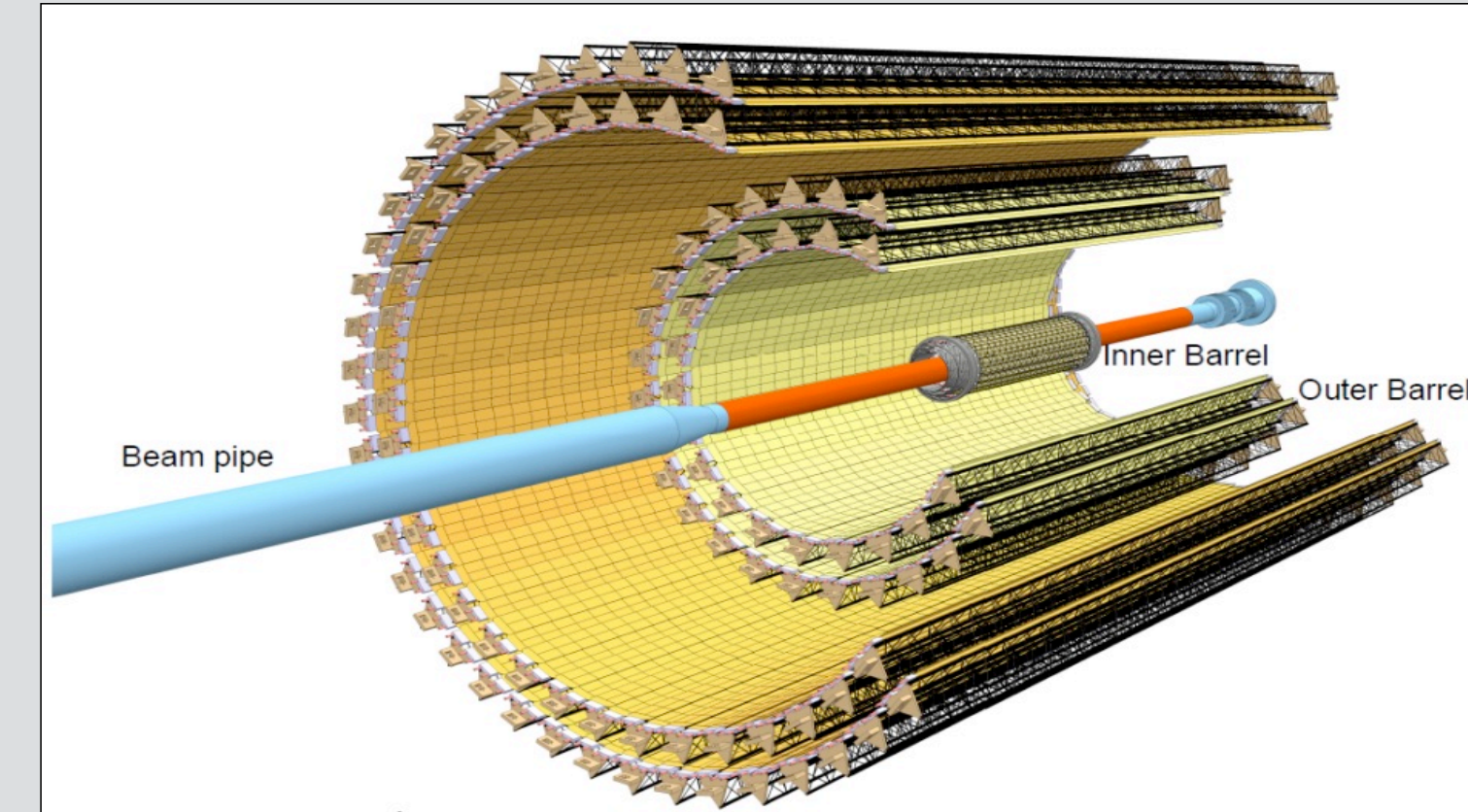




# The ALICE Inner Tracker Upgrade

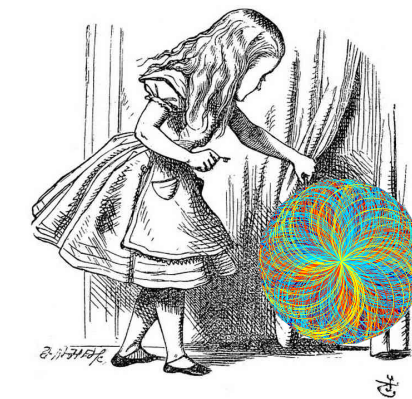


- Improve impact parameter resolution by a factor of 3
  - Get closer to the IP: first layer 39mm -> 22 mm
  - Reduce material budget: 1.14% -> 0.3%  $X_0$  per layer or better
  - Increase pixel density  $50\mu\text{m} \times 425\mu\text{m}$  ->  $20 \times 20\mu\text{m}$
- High standalone tracking efficiency and  $p_t$  resolution
  - Increase granularity 6 -> 7 layers with reduced pixel size
  - Larger radial extension 39-430 mm -> 22-430mm
- Fast PbPb (and pp) readout
  - Instantaneous luminosity:  $6 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$  gives hadronic interaction rate of 50kHz
  - Current ITS slow, maximal readout at 1 kHz
  - In new setup Pb-Pb collisions are readout at  $> 50 \text{ kHz}$  and pp at  $> 2 \text{ MHz}$

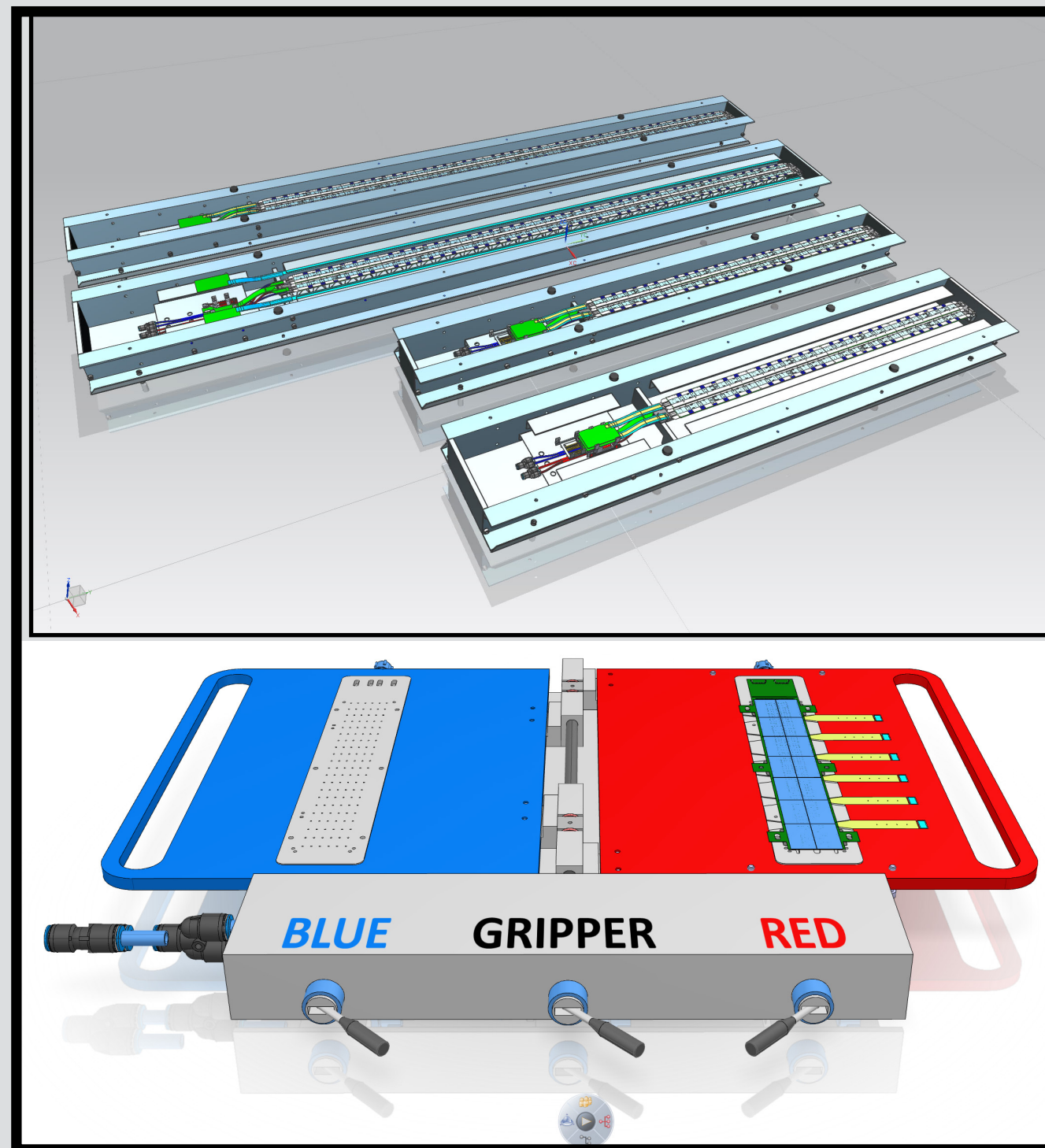
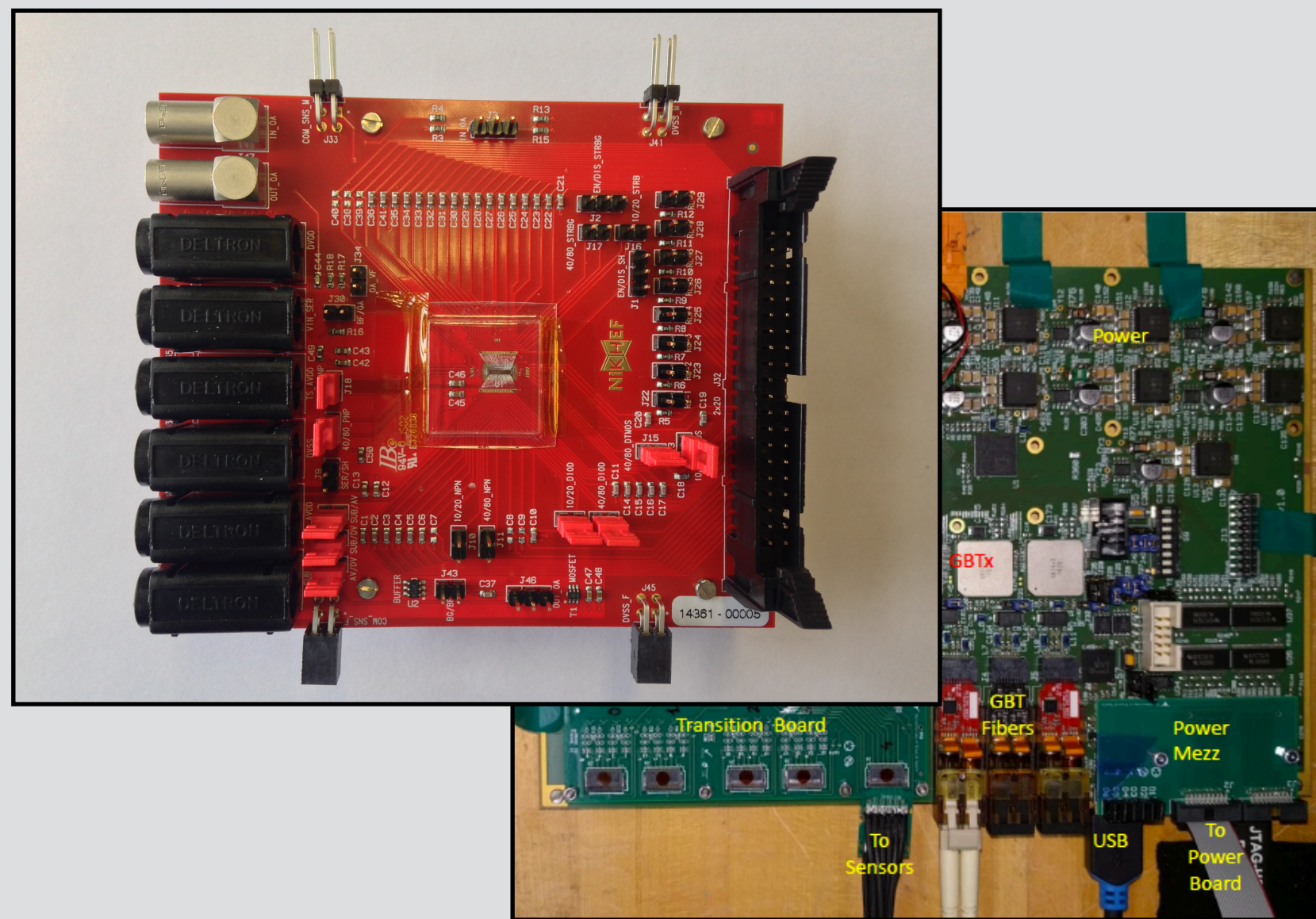




# The ALICE Inner Tracker Upgrade



Electronics 



Tooling/Hardware

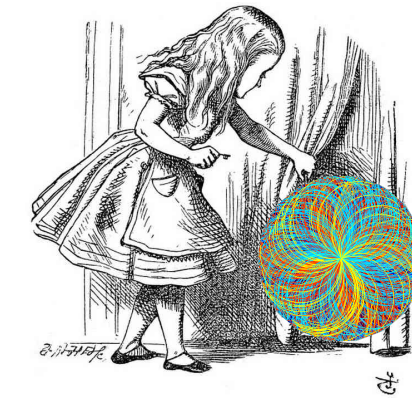


 Stave assembly

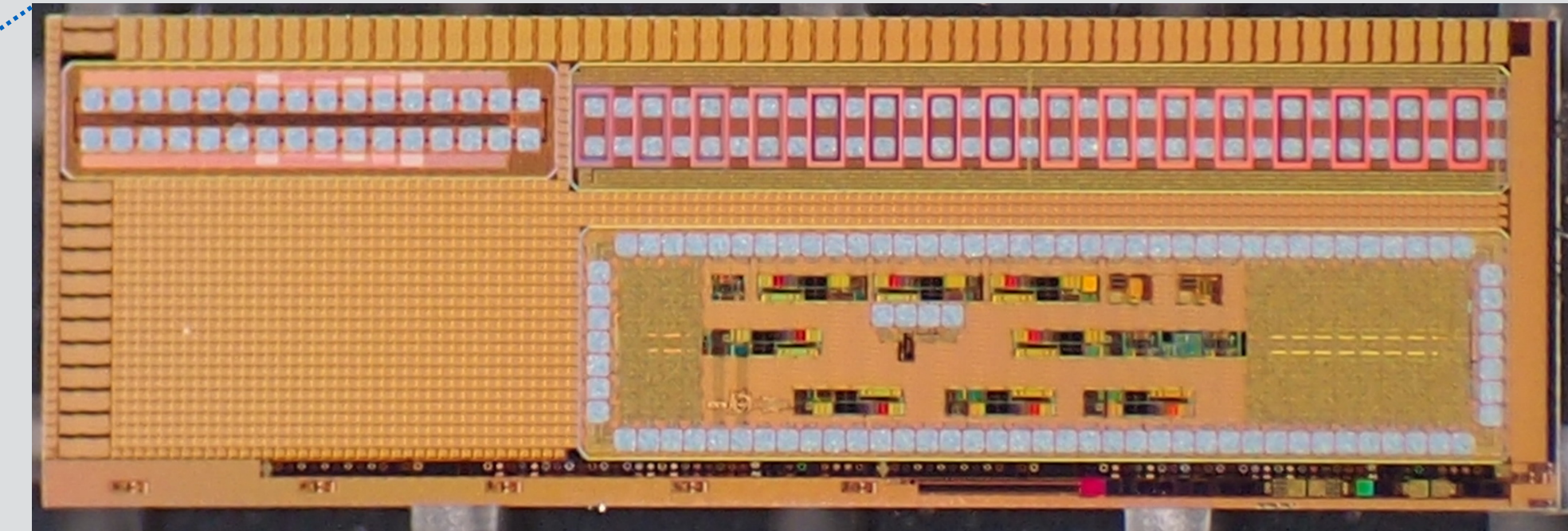
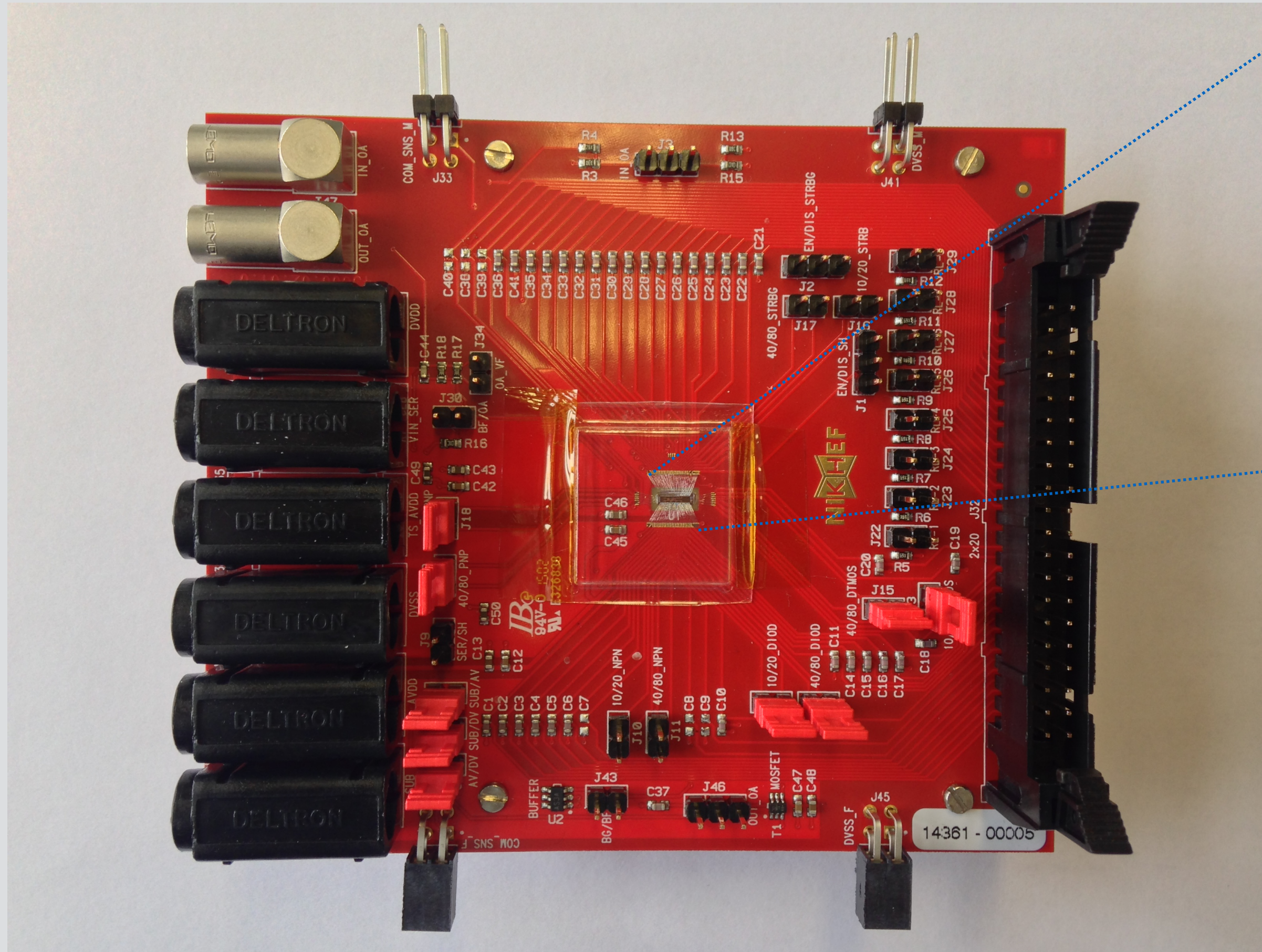




# The ALICE Inner Tracker Upgrade



Produced and tested variants of band-gap and temperature sensor



Both circuits behave exactly as designed and simulated  
Both are integrated in ALPIDE

Deepak Gajanana  
German Henao

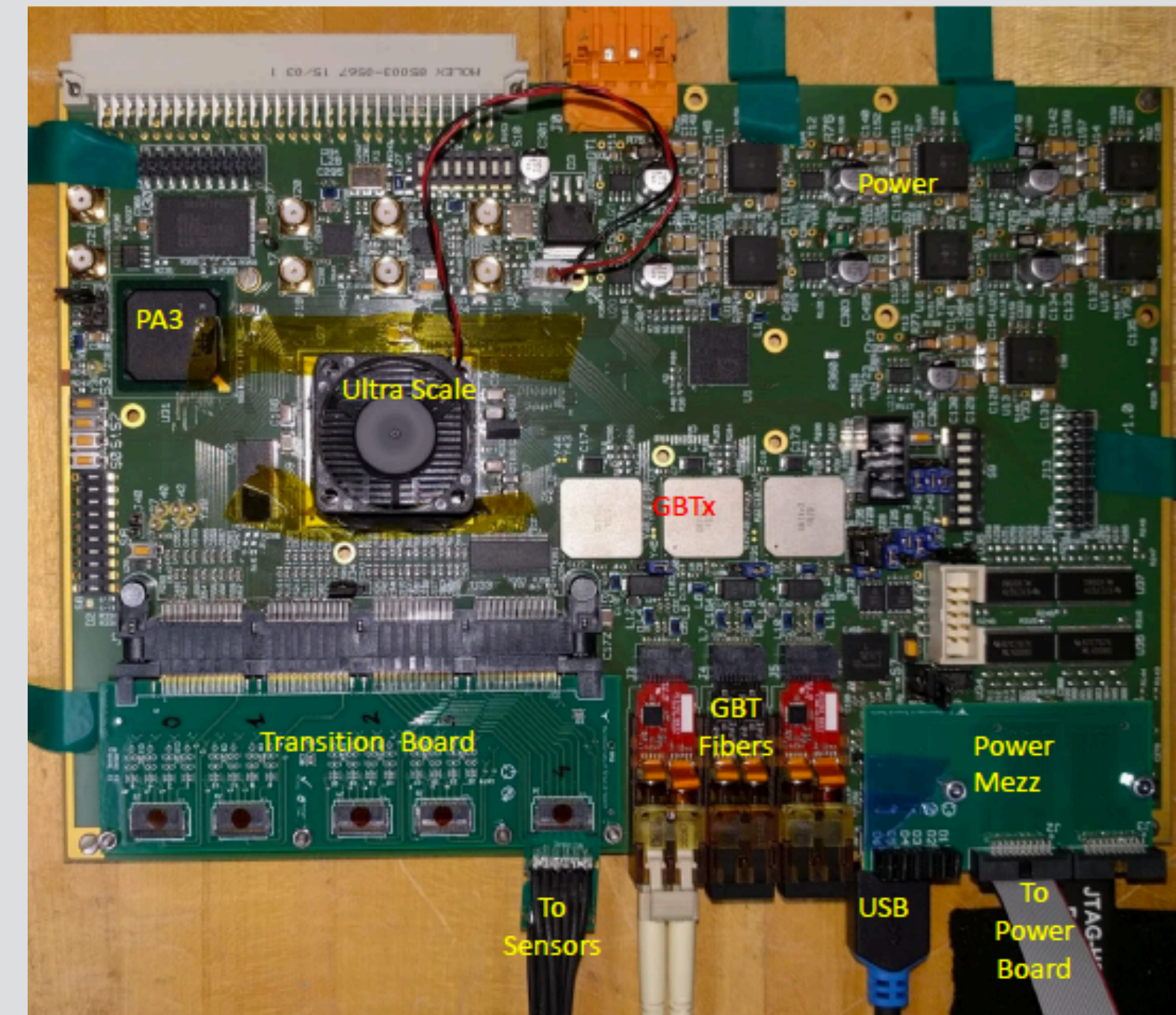




# The ALICE Inner Tracker Upgrade



- Nikhef/UU is responsible for the integration of the read-out unit (between pixel modules and DAQ)
  - Interface to local power supplies (Berkeley)
  - Interface to pixel modules (CERN)
  - GBT link to DAQ
- Cabling
  - UU+Nikhef test data transport across (firefly) cables and between modules
- Design and prototyping complete
  - Tender completed
  - UU will do test pre-series (25 boards)
  - Nikhef does acceptance test for full series (200 boards)



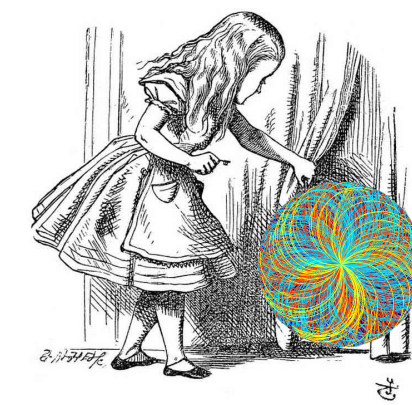
Marcel Rossewij  
Jan-David Schipper



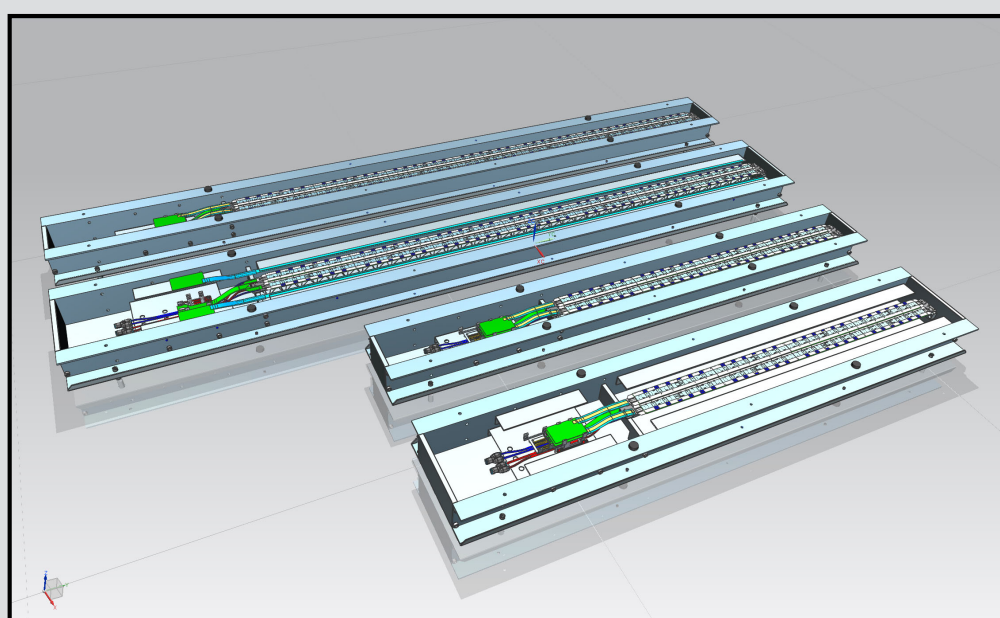
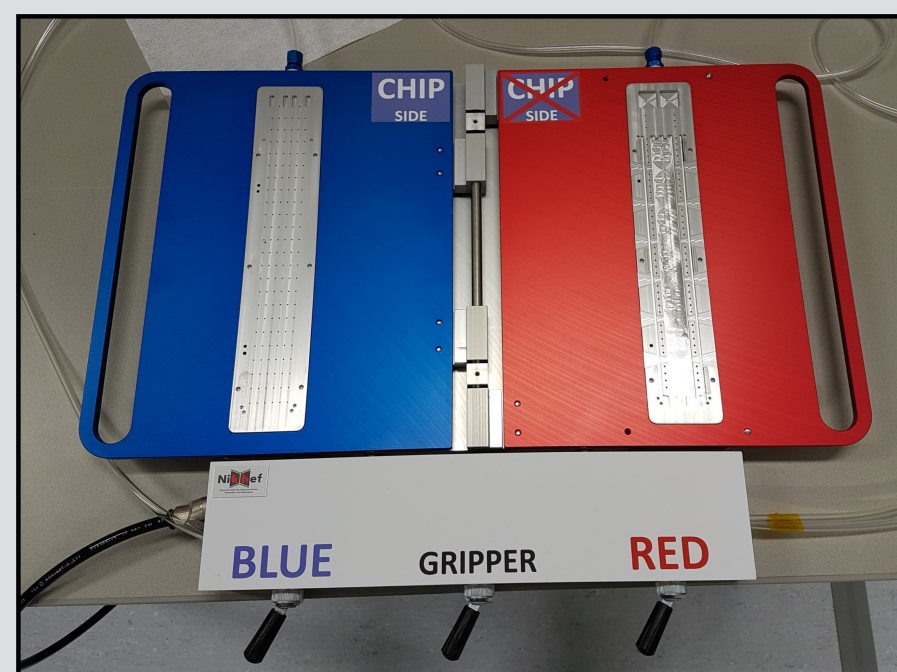
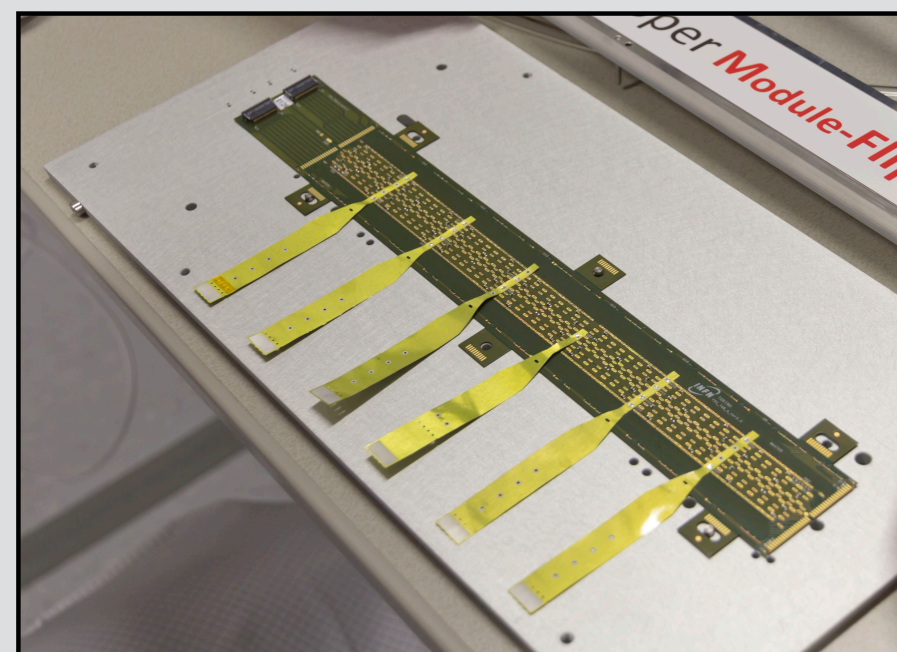
Universiteit Utrecht



# The ALICE Inner Tracker Upgrade

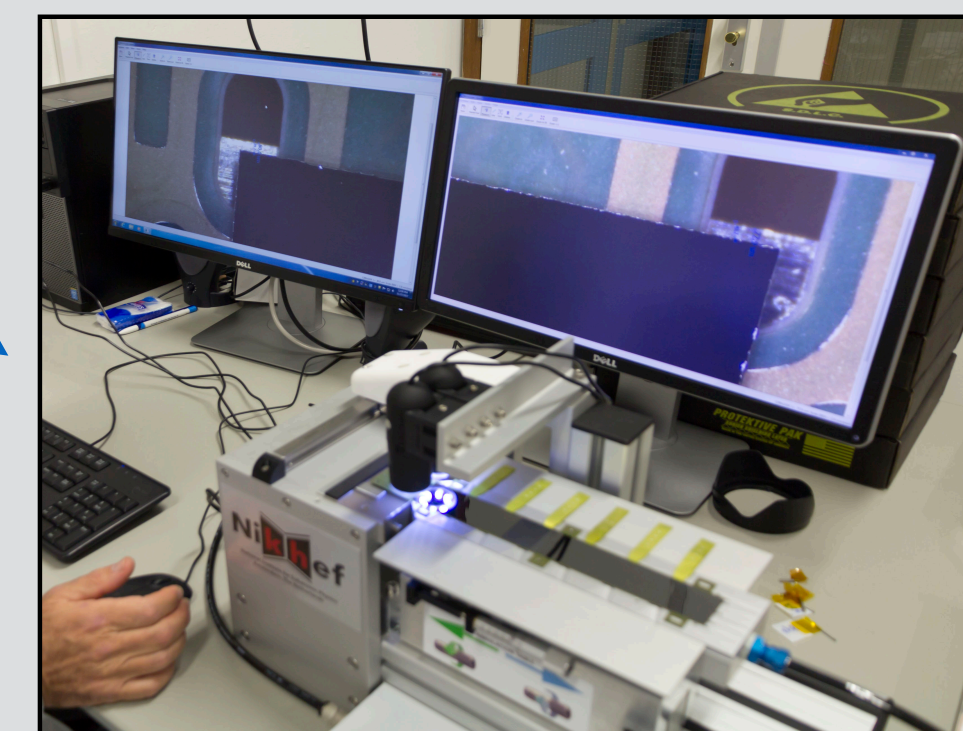
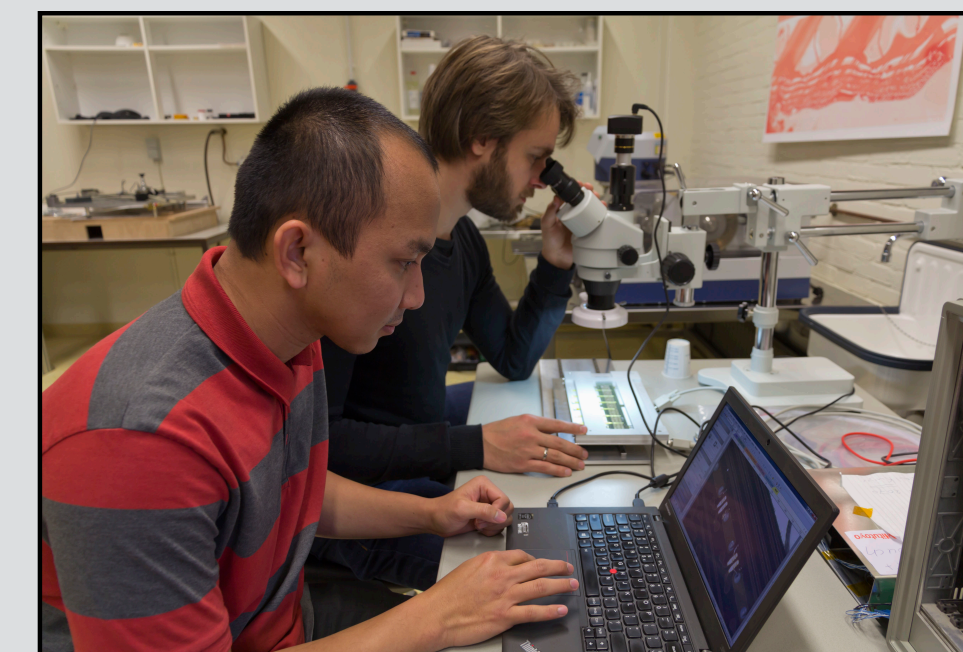


- Reception of material
- Acceptance testing (QA)
  - Powering
  - FIFO
  - Memory tests
  - Resistance/connections
- Flipping
- 10  $\mu\text{m}$  precision cutting
- Post-cut testing
- Storage/ assembly/shipping



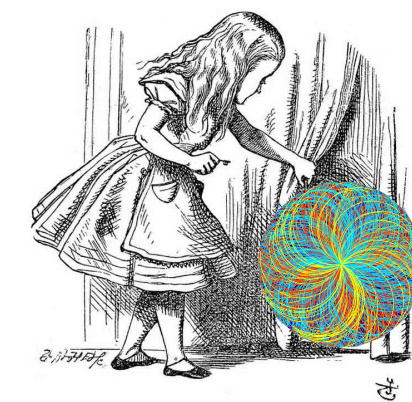
Nikhef

Large student involvement

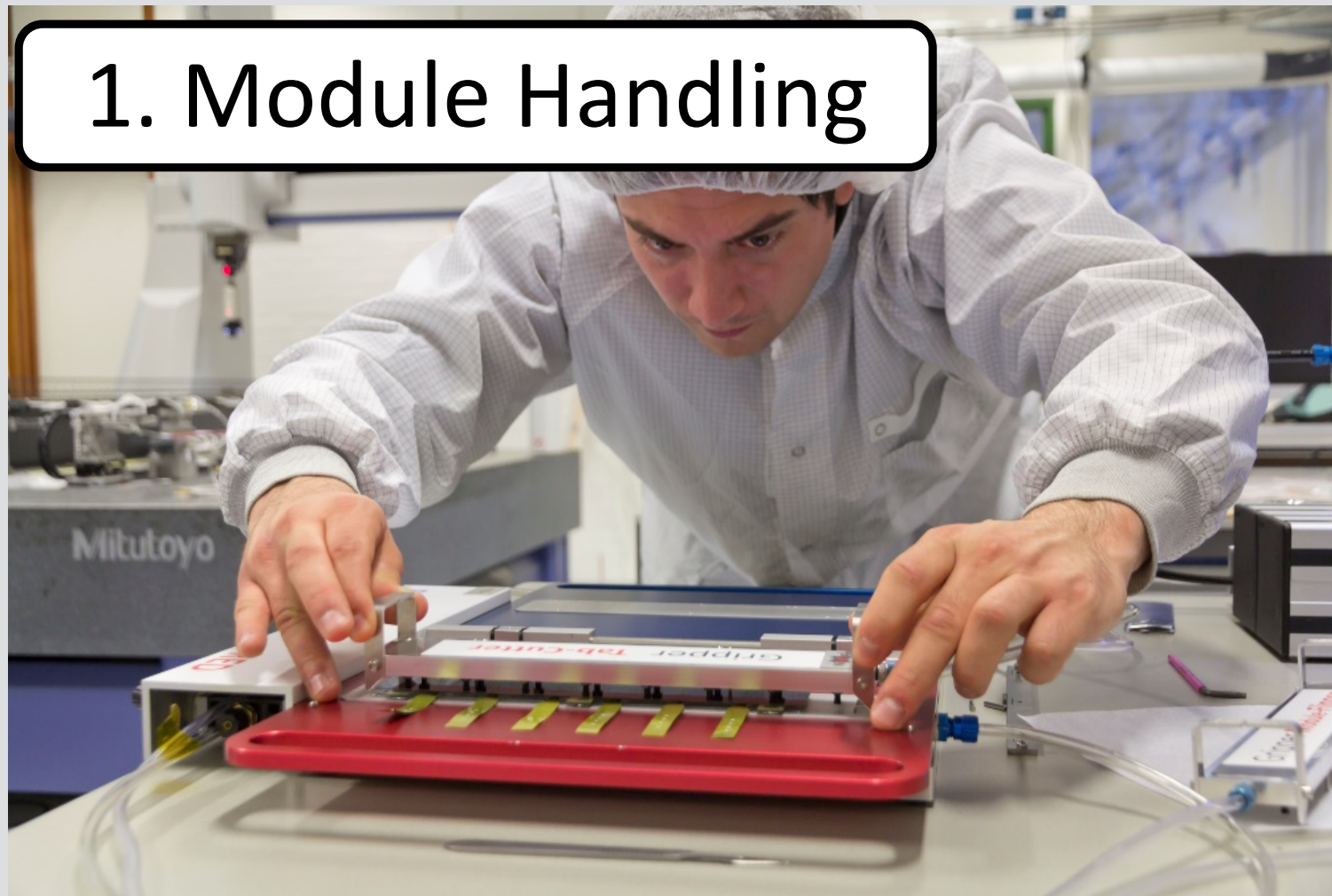




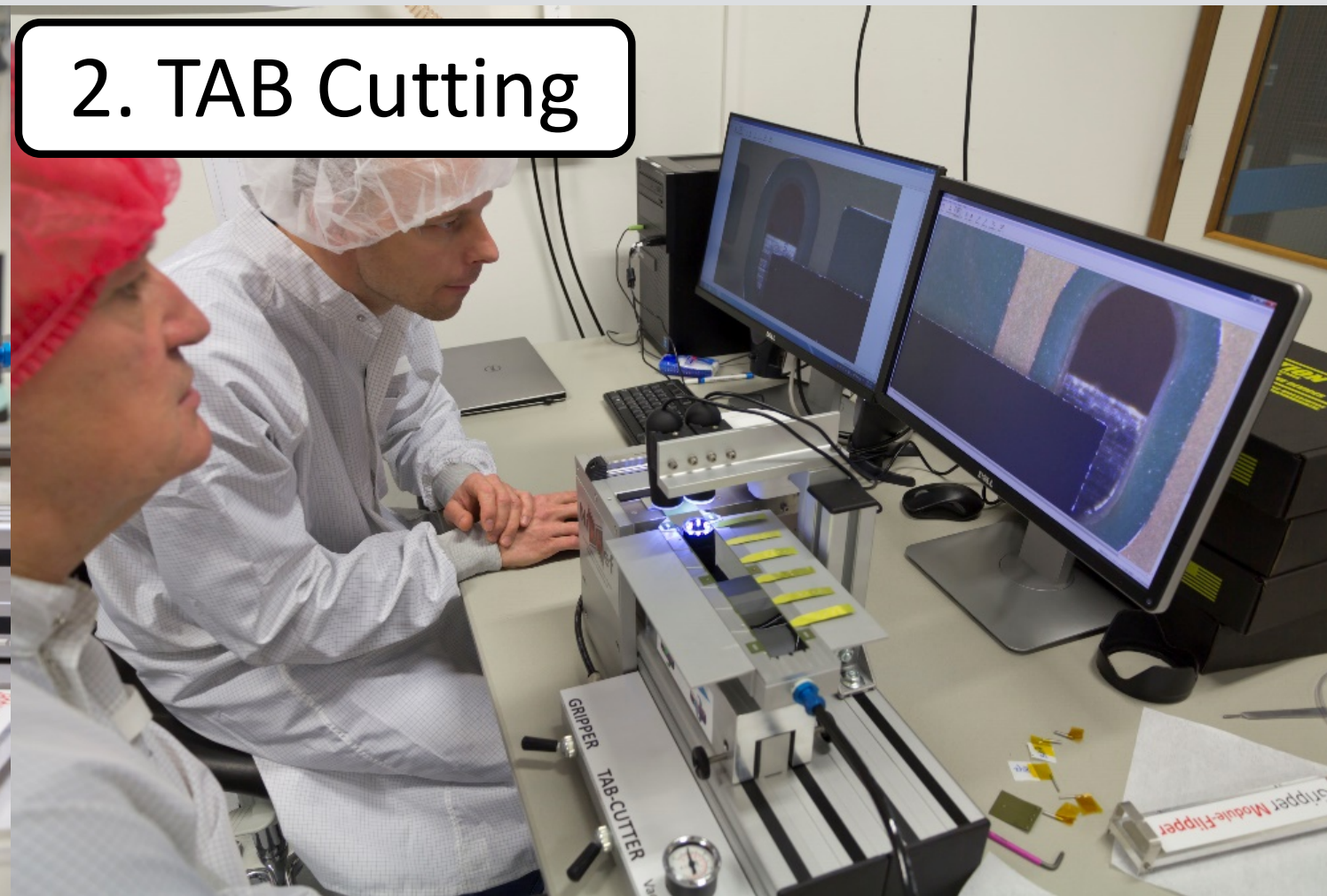
# The ALICE Inner Tracker Upgrade



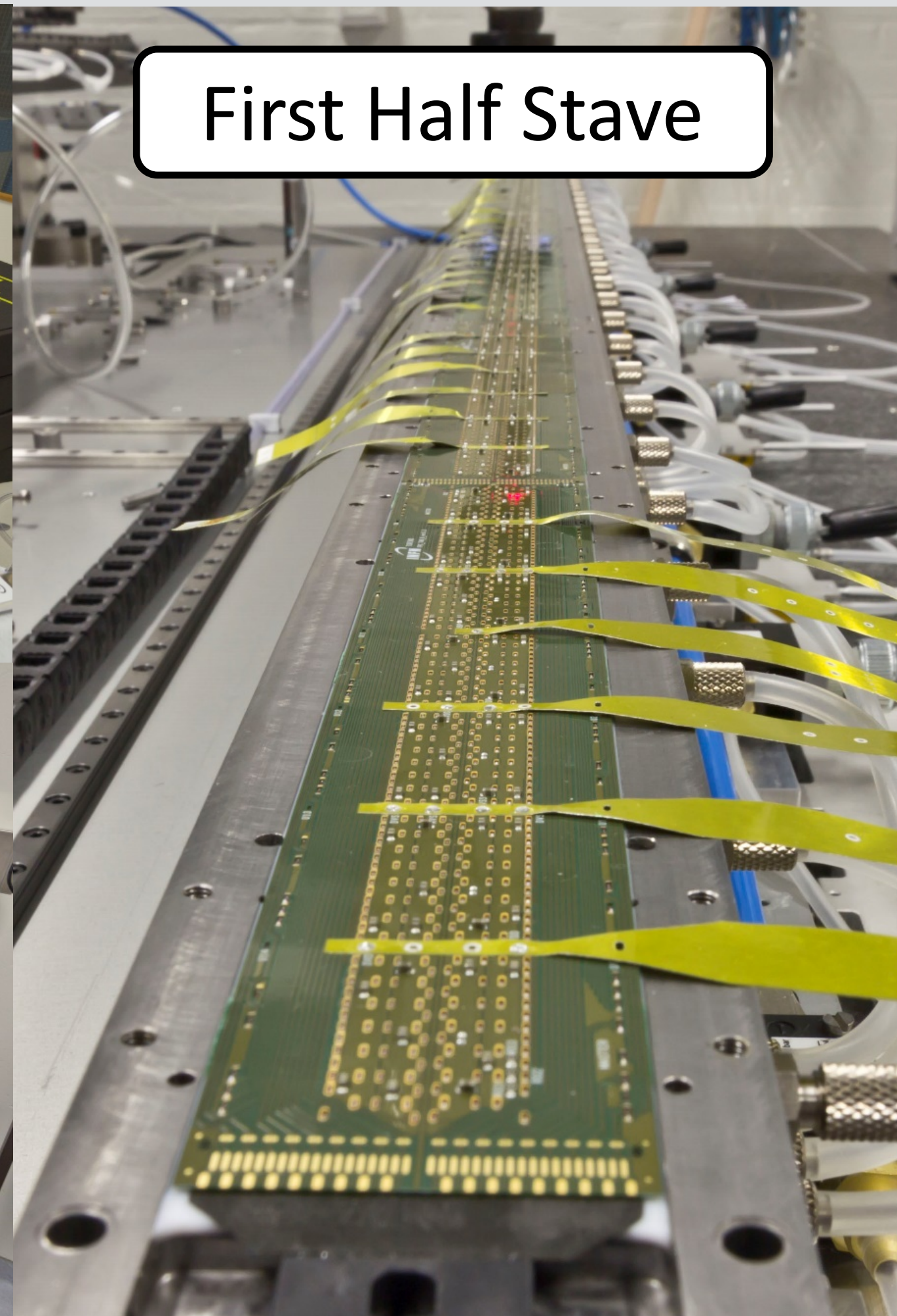
1. Module Handling



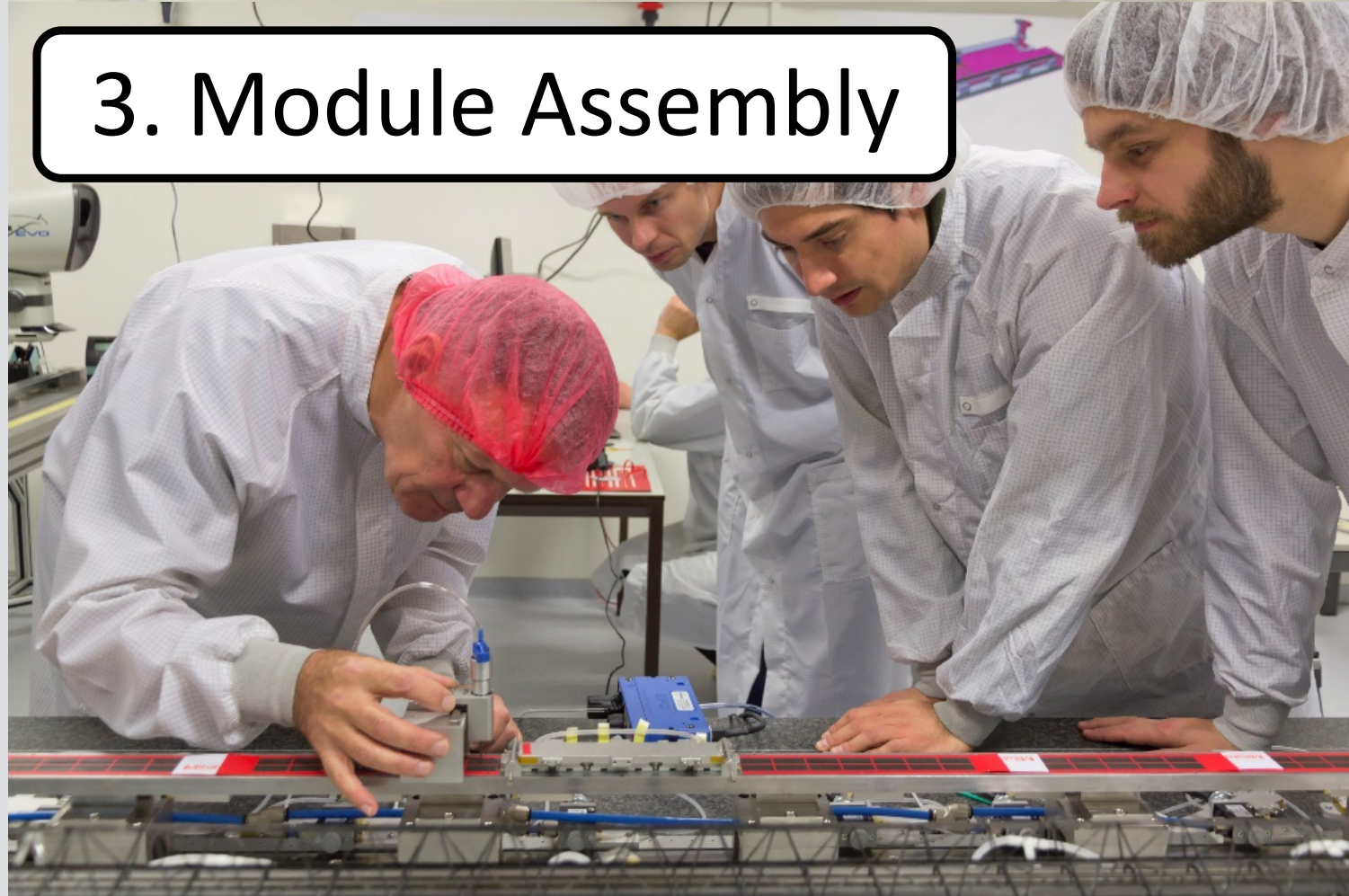
2. TAB Cutting



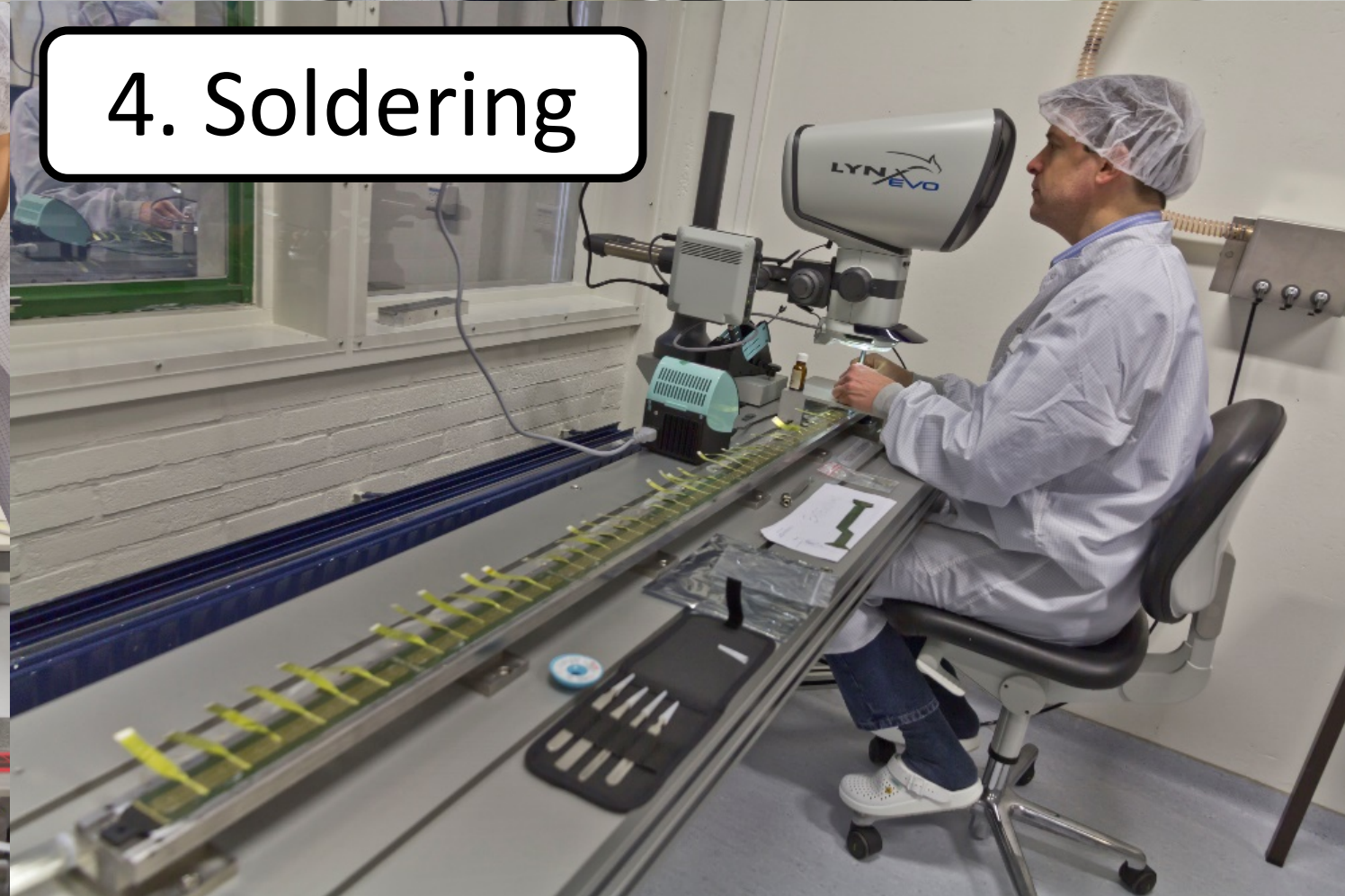
First Half Stave



3. Module Assembly

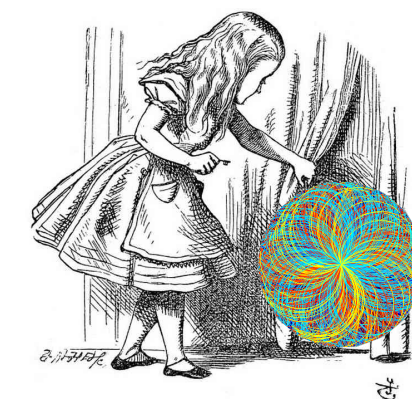


4. Soldering



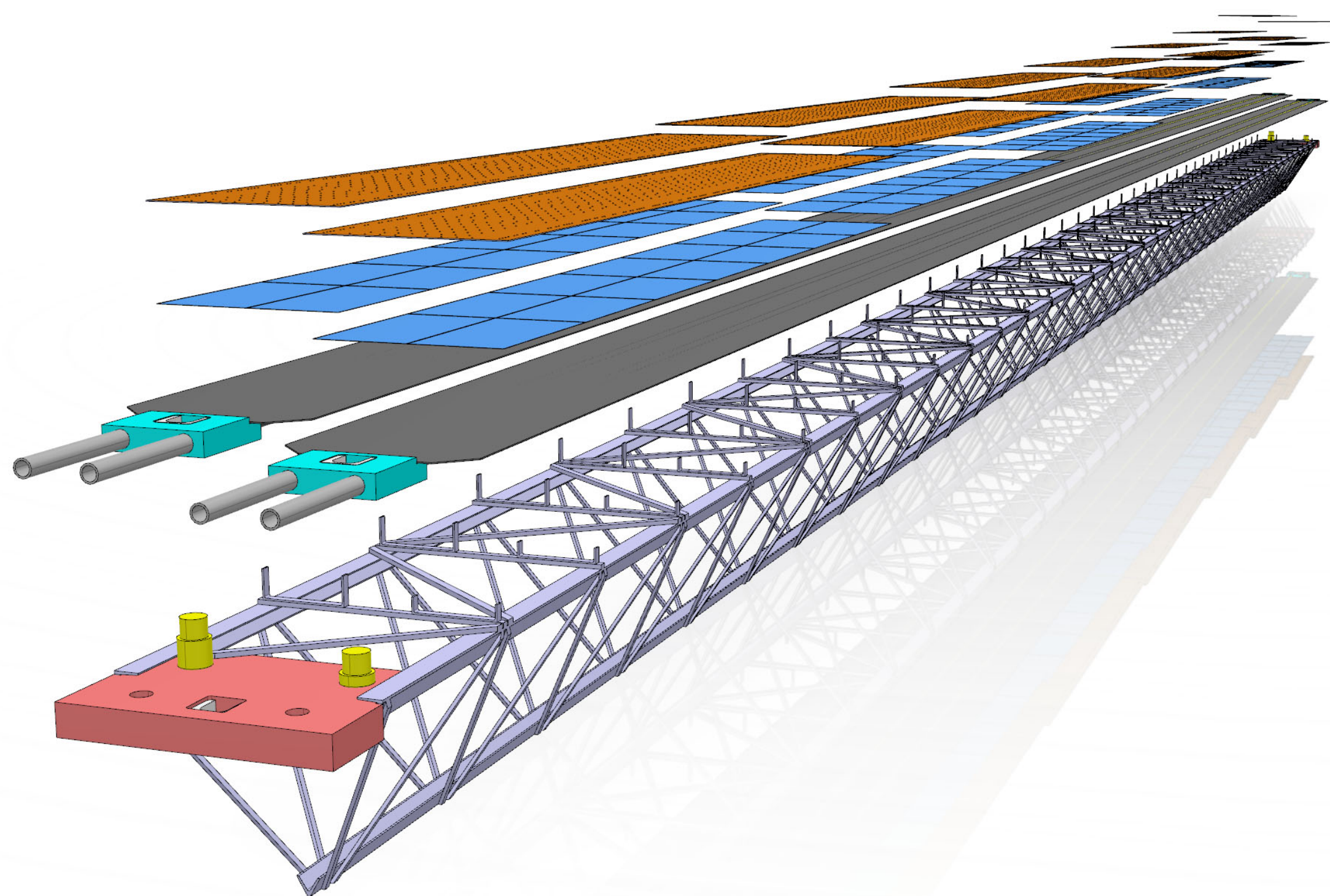


# The ALICE Inner Tracker Upgrade

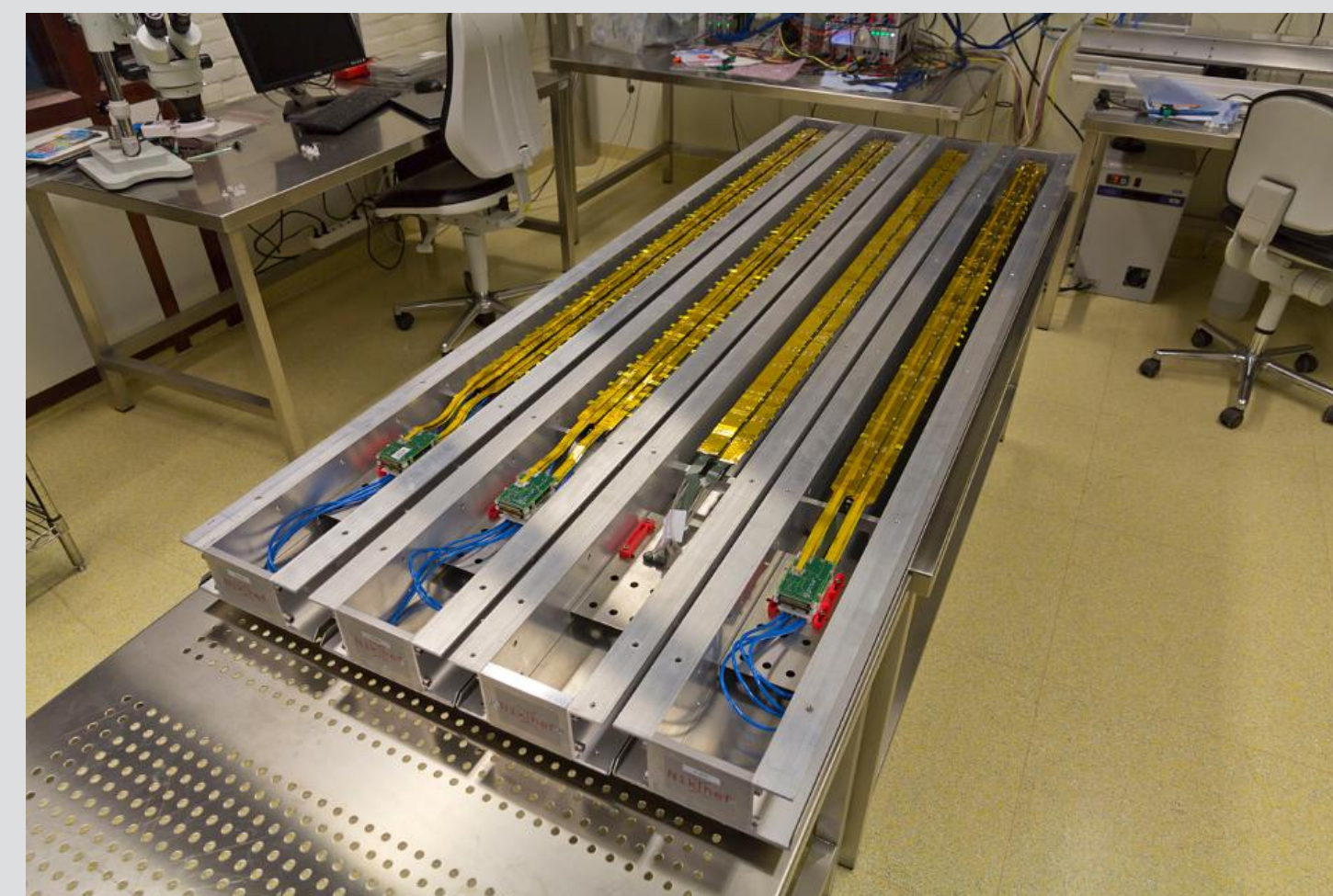


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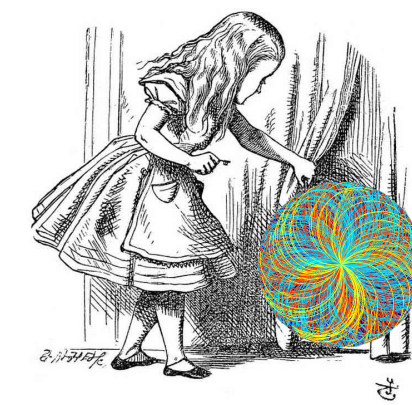


- Nikhef will produce 25% of the OB staves
- Commissioning and assembly started, 4 full staves ready so far
- Expected production rate > 25 staves per year
- Final delivery to CERN in July 2019 is on track



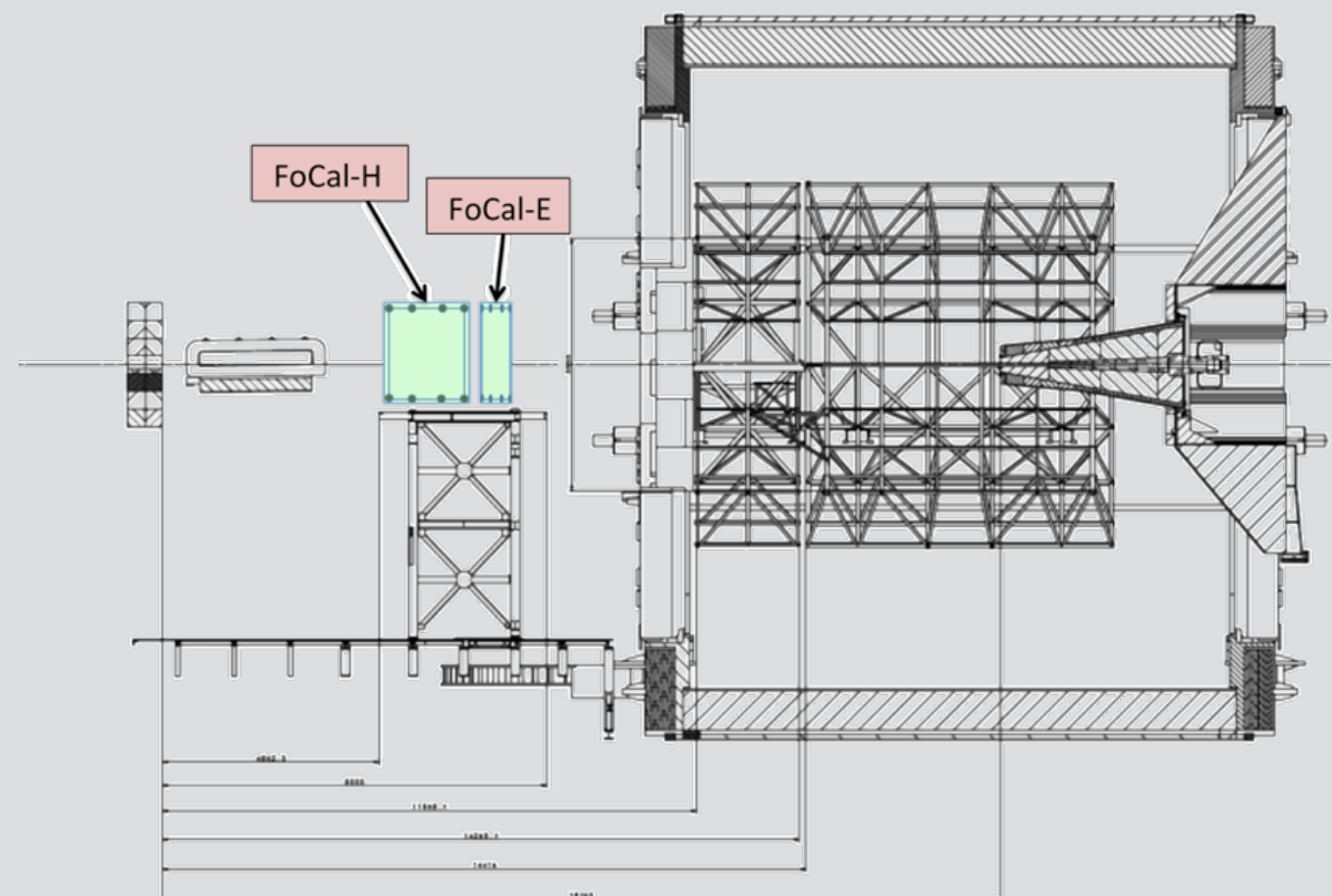
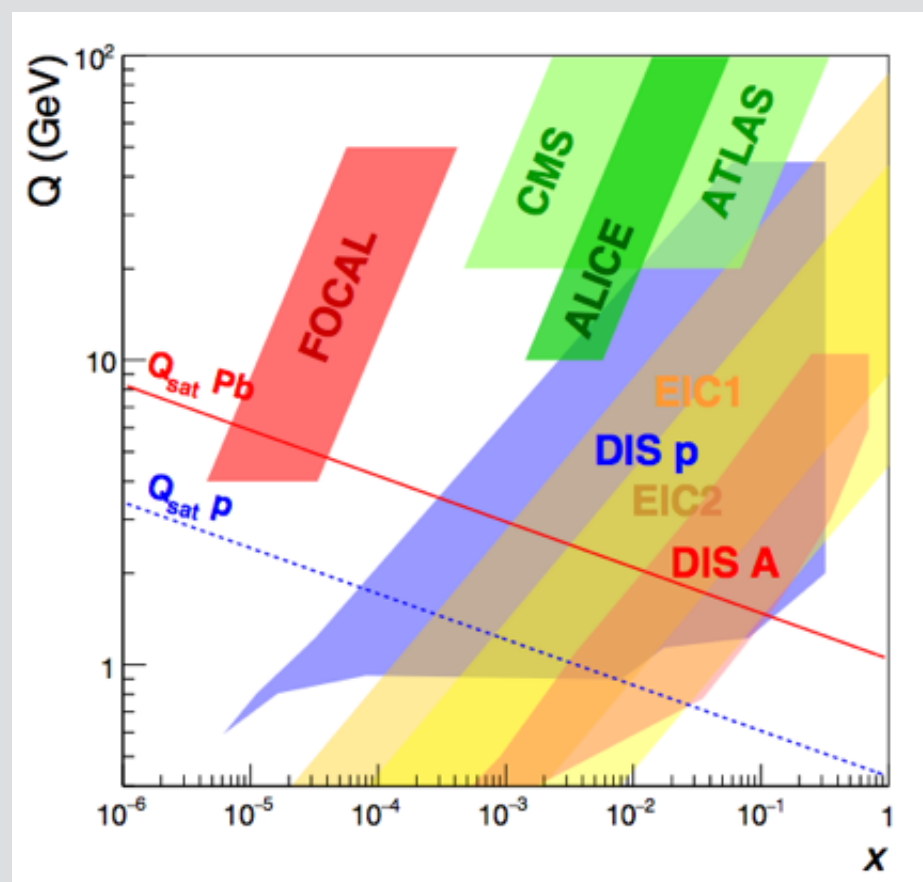


# FoCal Upgrade

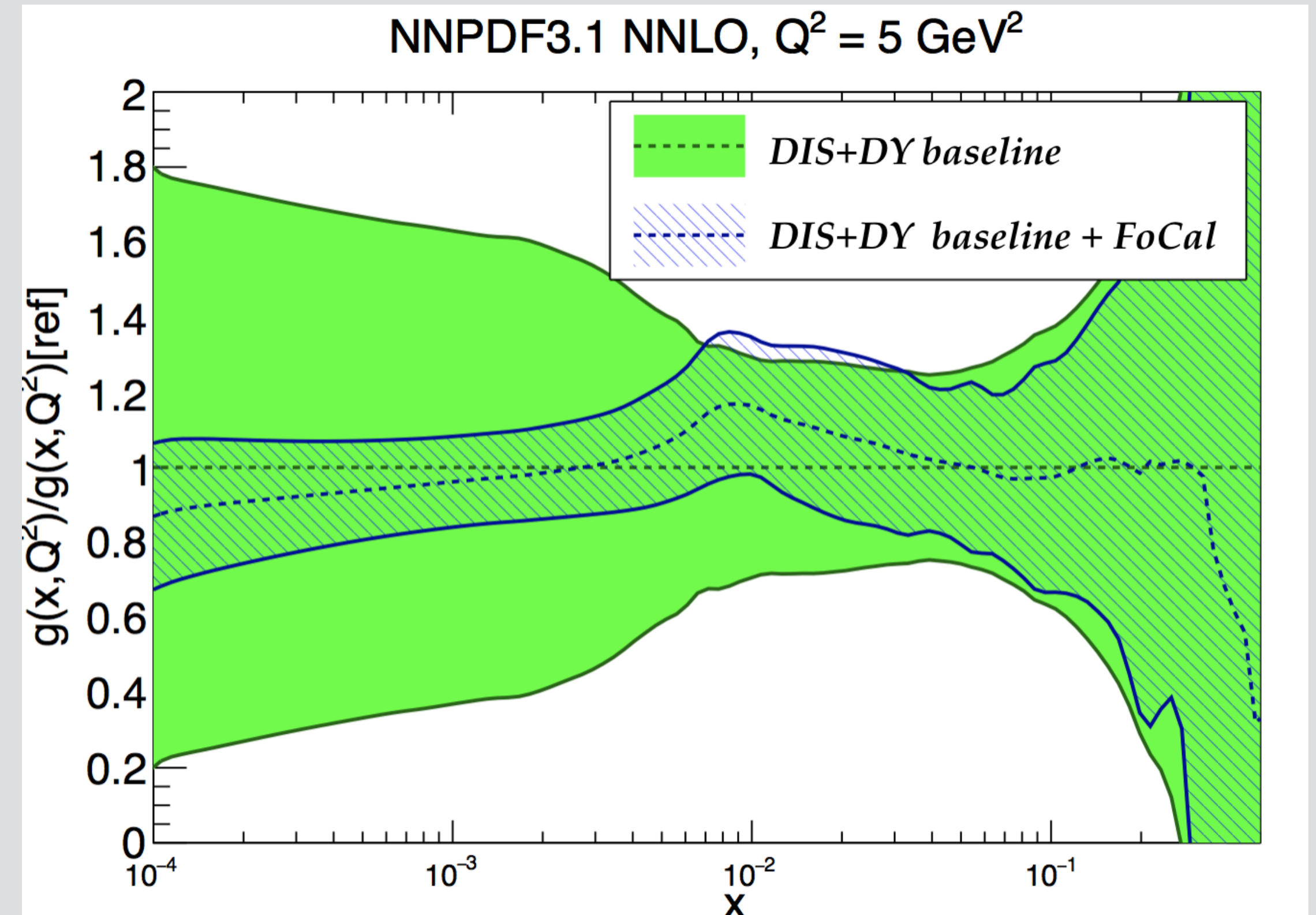


- Proposal to measure forward direct photons to study low-x gluon distributions (under discussion for installation in ALICE during LS3)

- EM probes provide best sensitivity to initial state distributions
- In ALICE the region  $3.5 < \eta < 5.3$  can be used
- Main challenge is to separate  $\gamma/\pi^0$  at high energy
  - $\pi^0$  at forward rapidity  $p_t = 10$  GeV has  $d = 2$ mm
- Need small Moliere radius and high granularity read-out for EM calorimeter

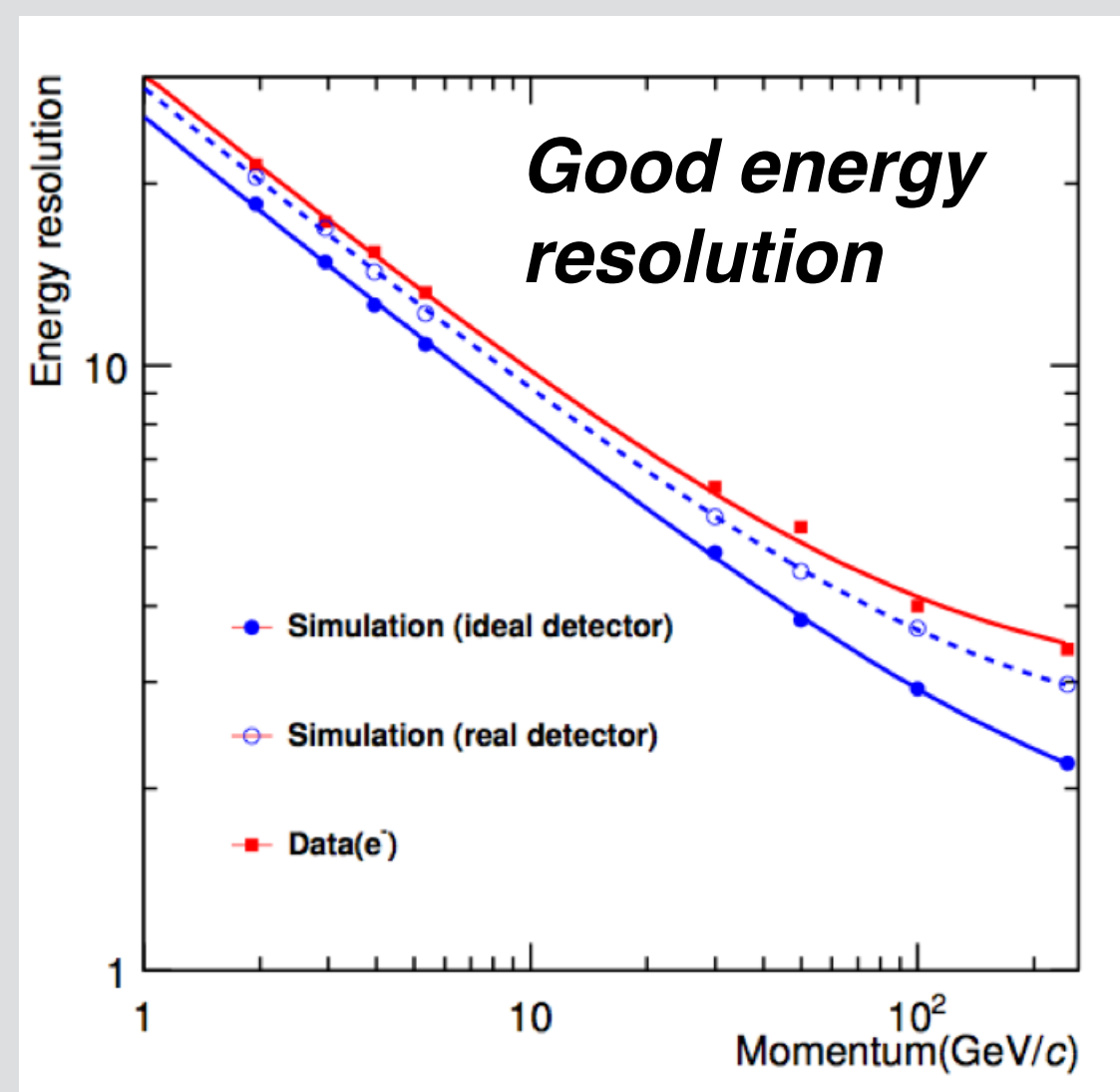
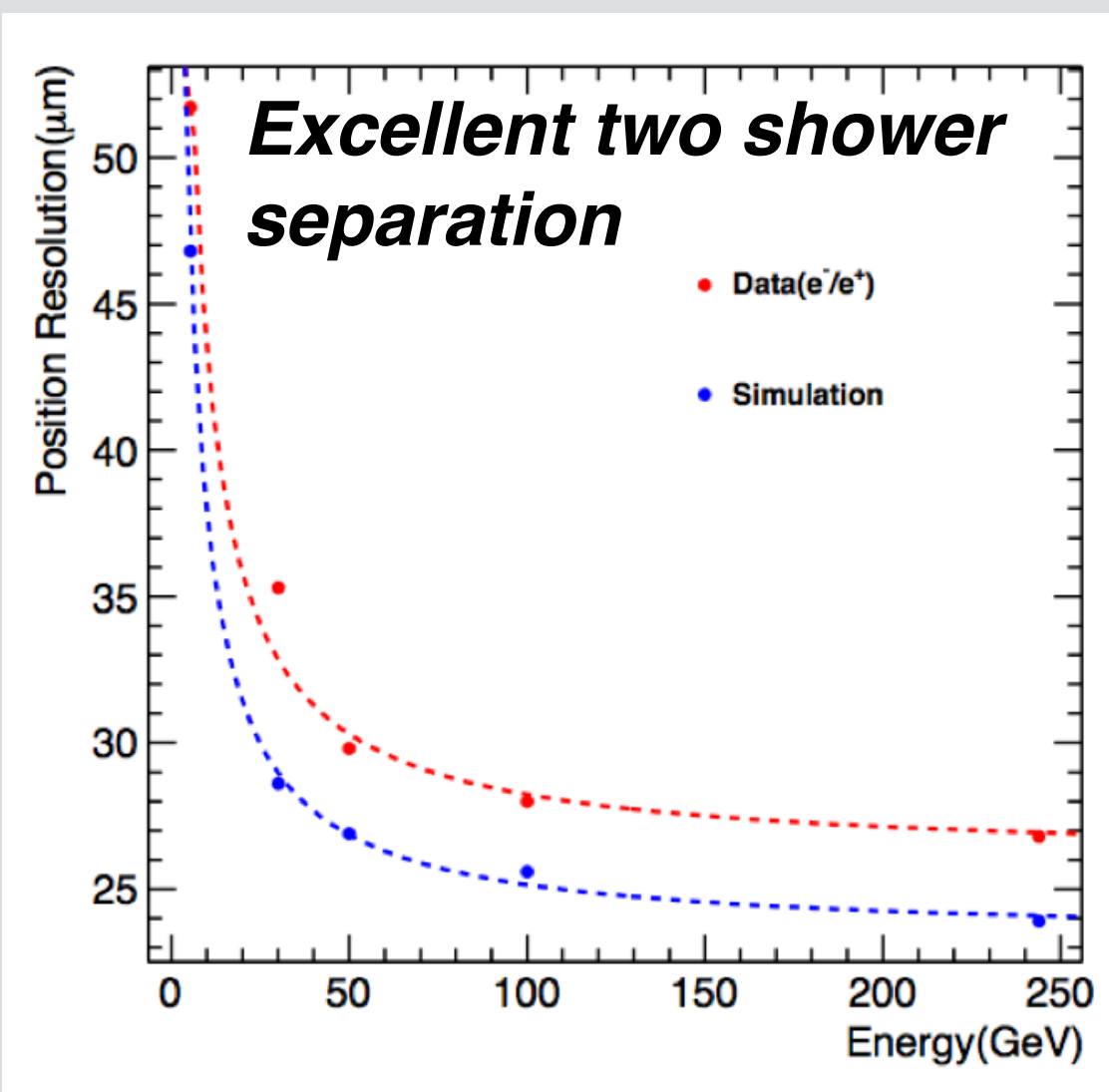


Juan Rojo (VU and Nikhef)





# FoCal Upgrade



$$\frac{\sigma_E}{E} = a \oplus \frac{b}{\sqrt{E/\text{GeV}}} \oplus \frac{c}{E/\text{GeV}}$$

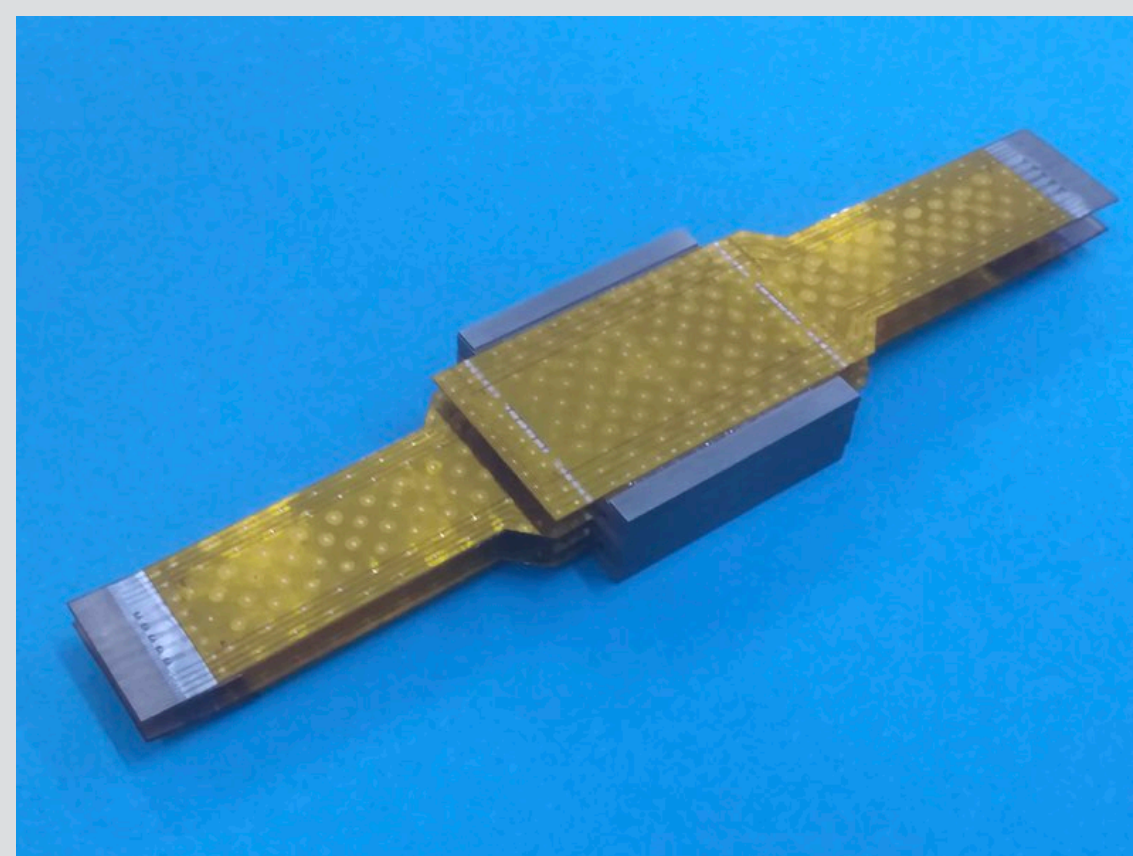
$$a = (2.95 \pm 1.65)\%$$

$$b = (28.5 \pm 3.8)\%$$

$$c = 6.3\%$$

- R&D at Nikhef+UU on high granularity layers for FoCal upgrade proposal

- Successful proof of principle of digital calorimetry
- Enables unique measurement in ALICE
- goal to get internal ALICE approval this year
- LHCC and TDR 2019?



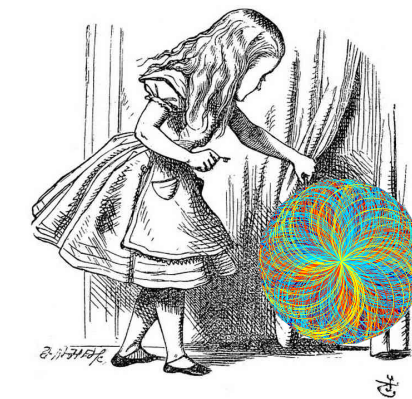
**Next prototype (tungsten+two Alpides per layer and cables)**



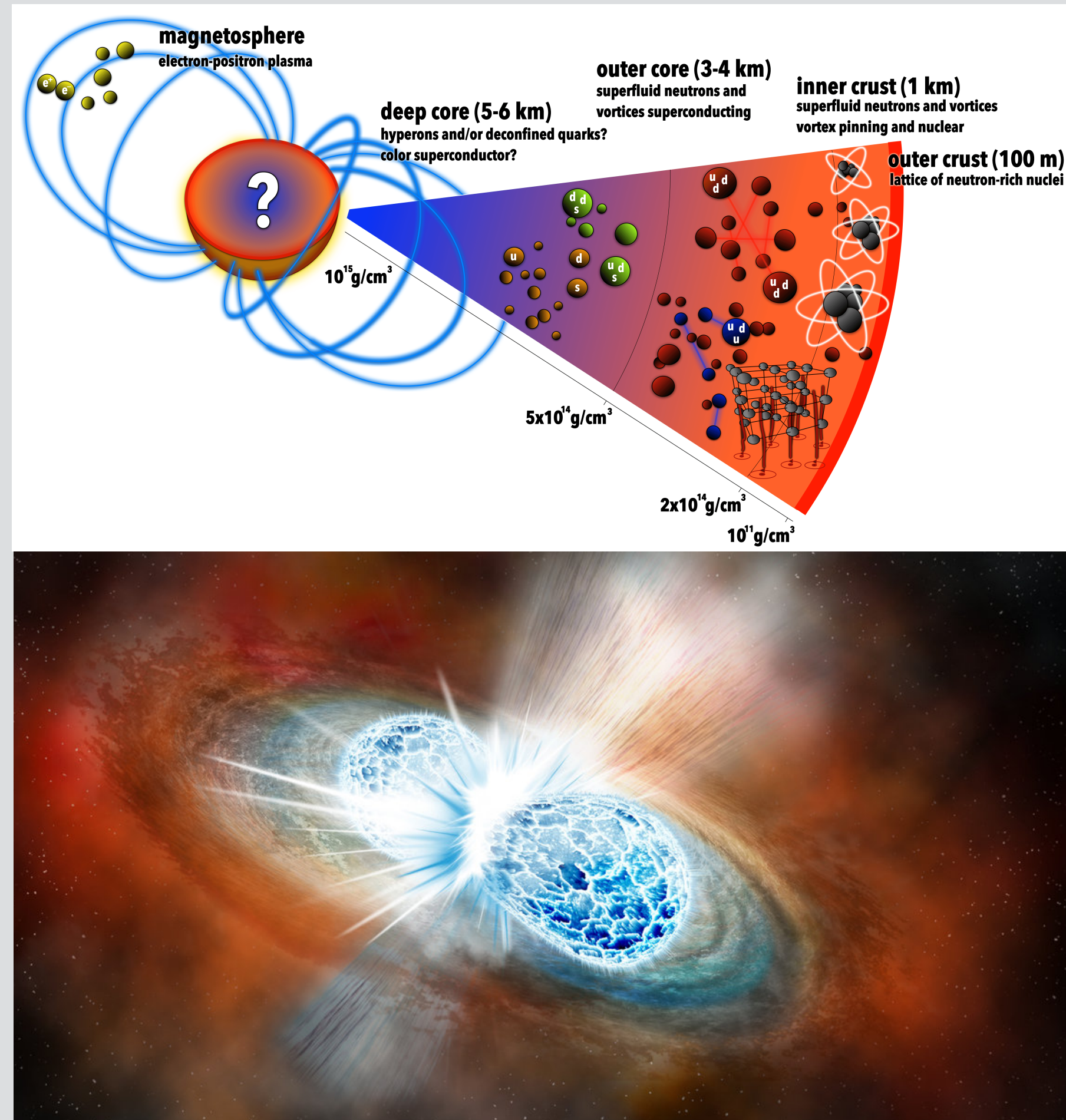
**mini-FoCal (pad-only) currently in ALICE cavern for tests**



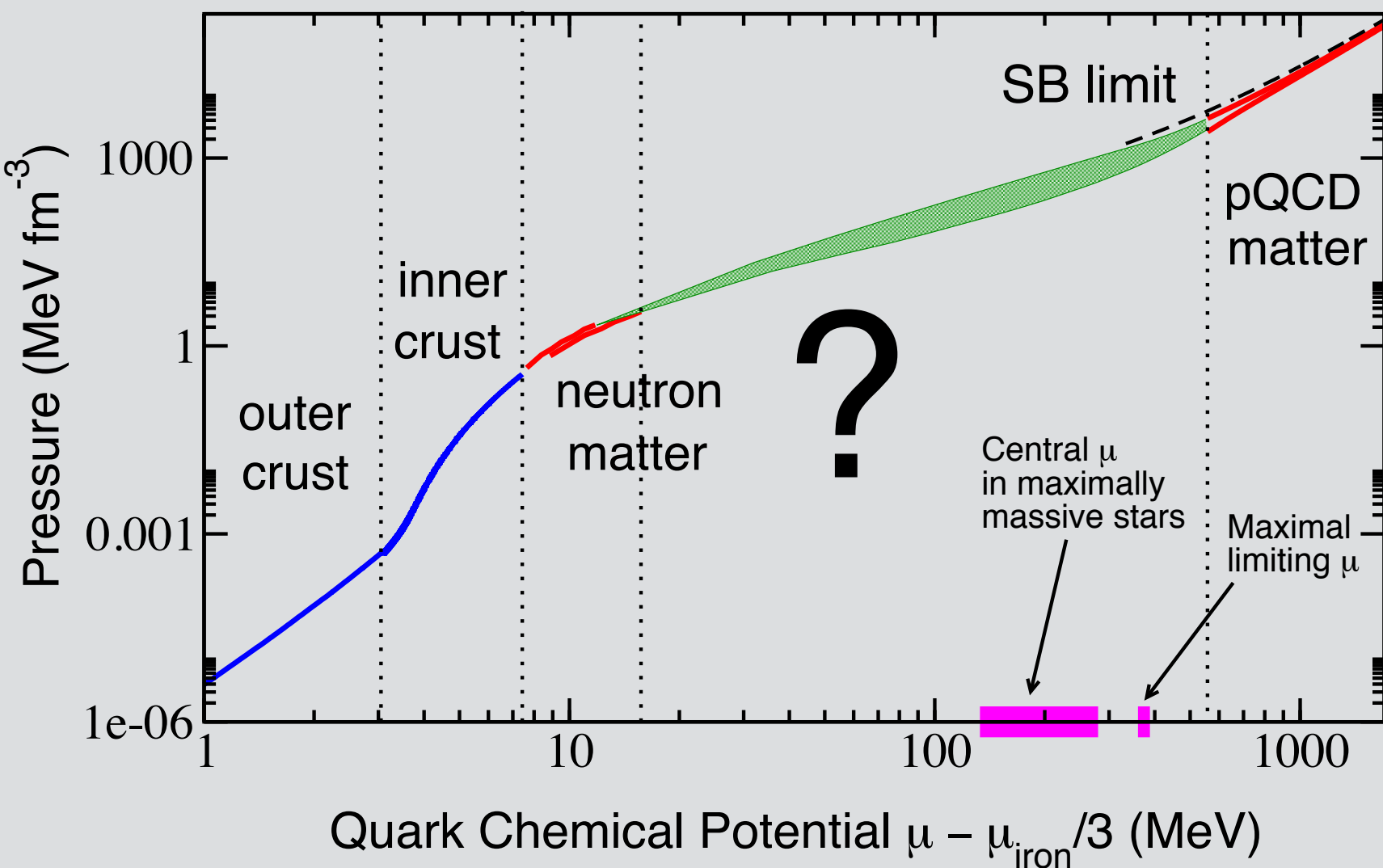
# QGP in Neutron Stars?



- 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



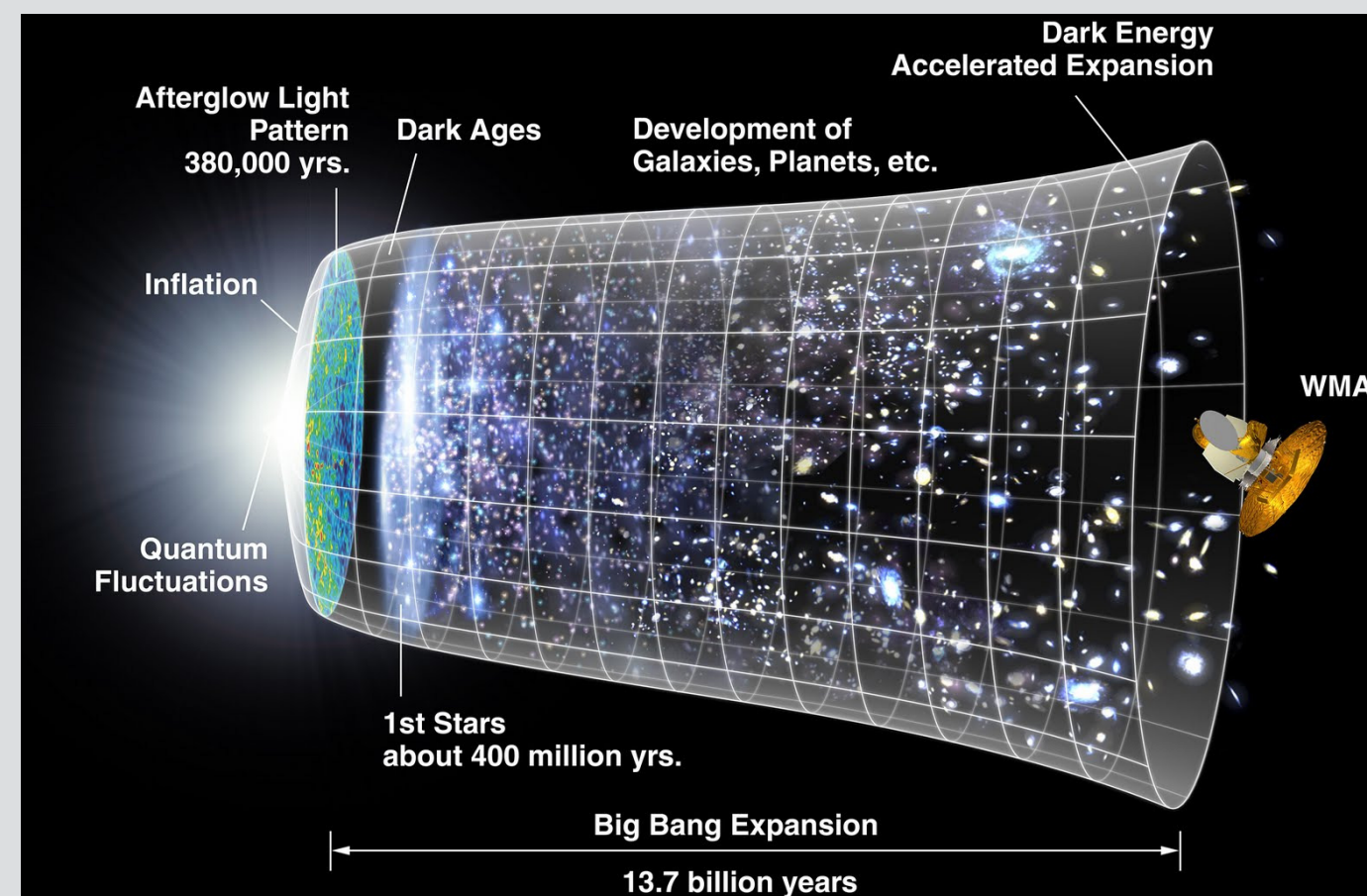
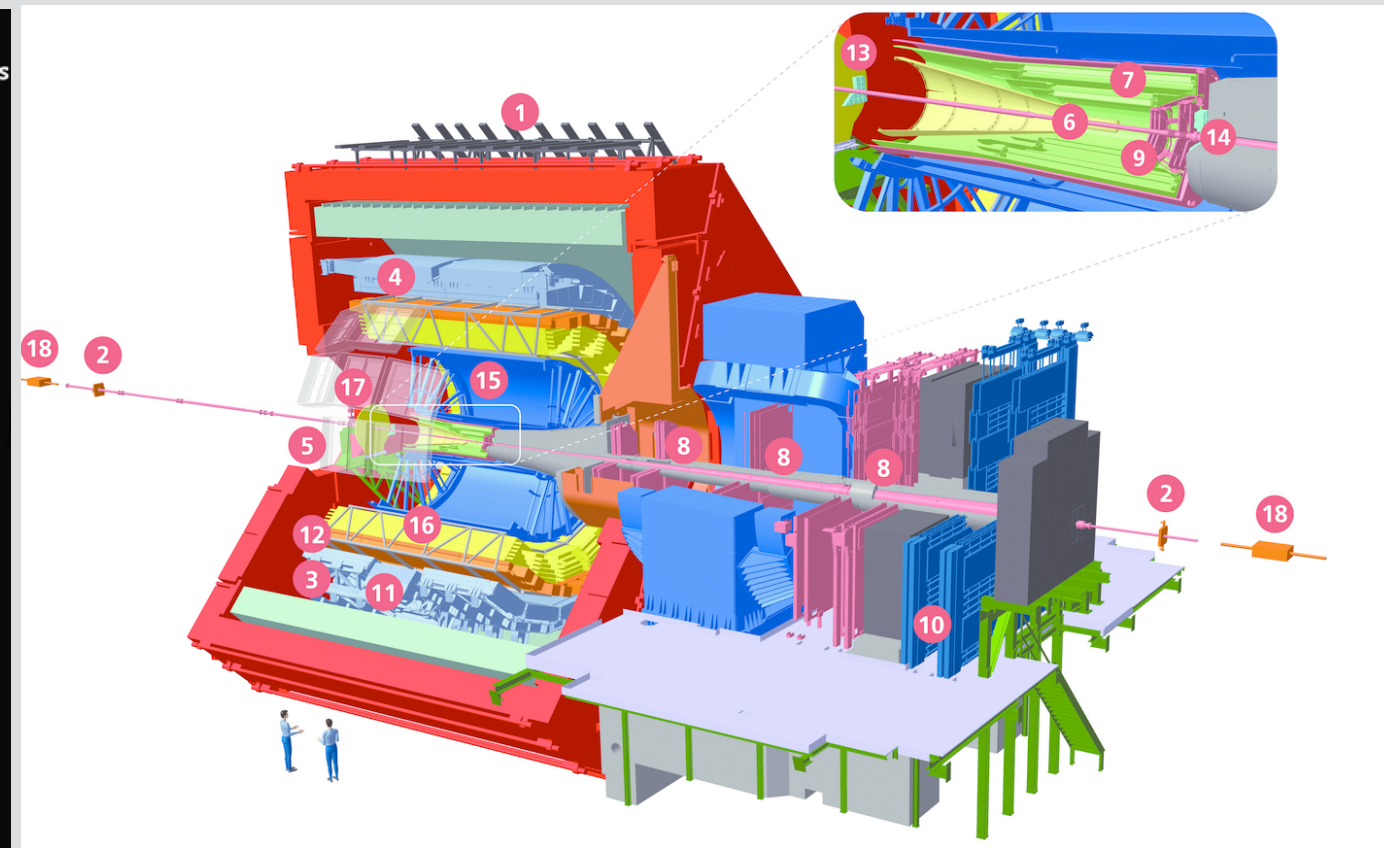
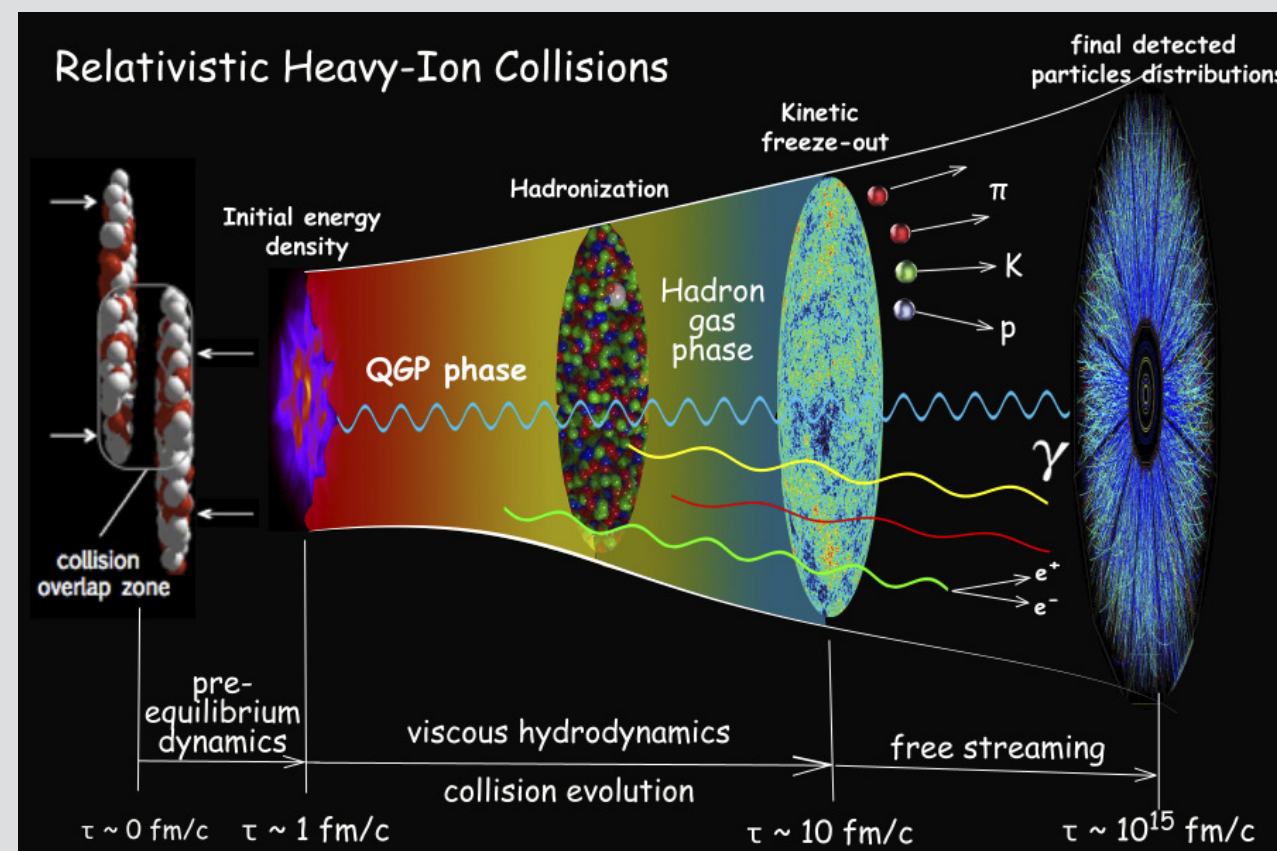
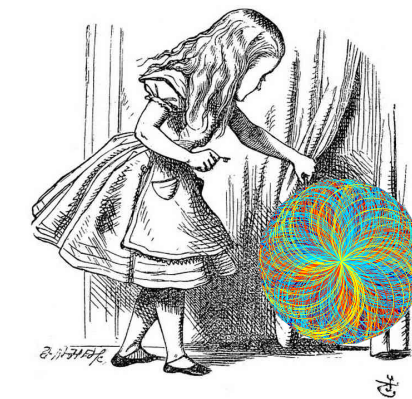
- First neutron star merger observed in Virgo/LIGO
  - Already providing constraints on the EoS
- Detailed understanding of the dynamics is required to understand the properties of the neutron star interior
  - EoS, transport parameters, ..
  - Strong overlap with the physics of heavy-ion collisions



At Utrecht University ambition to form new Institute for Subatomic and *Gravitational* Physics



# Our Ambitions

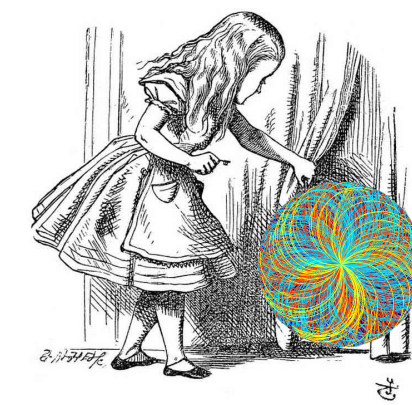


- ALICE programme to 2029
  - Need to secure funding
- Possible extensions (FoCal?)
- Gravitational Waves (Virgo, ET)
  - Funding requests via NWO Physics, Zwaartekracht proposal, Sectorplan

Study QCD in the regime of extreme matter with emergent properties



# ALICE in the LHC Wonderland



- 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 one of the most productive groups with strong contributions to the collaboration
- ITS upgrade well on track
- Strong future programme and ambitions!

