ATLAS program

Wouter Verkerke

Introduction – ATLAS program

Our global objective in the ATLAS experiment is to

explore TeV scale physics at the LHC,

in terms of (precision) measurements of known interactions, and in the form of direct signs for new physics.

ElectroWeak Symmetry breaking

h-V interaction
h-h interaction

V-V scattering
3V, 4V couplings

Origin of fermion masses

h-f interaction

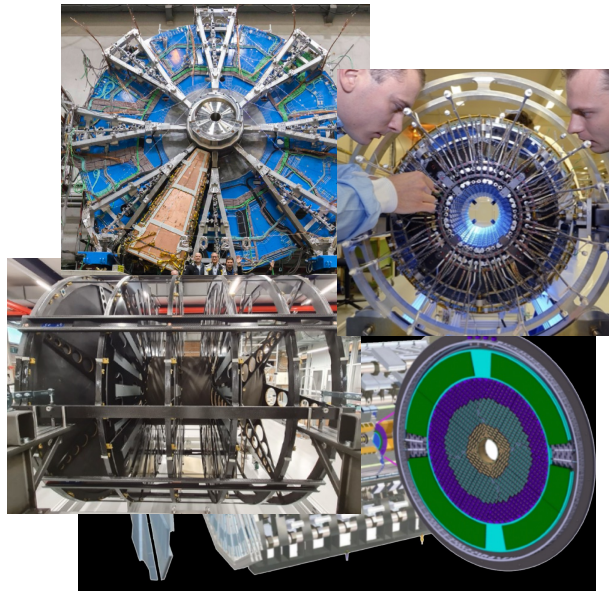
Couplings

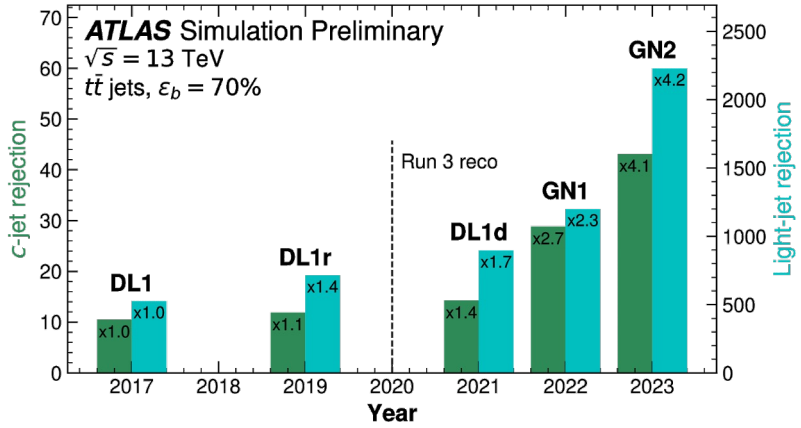
rare and anomalous

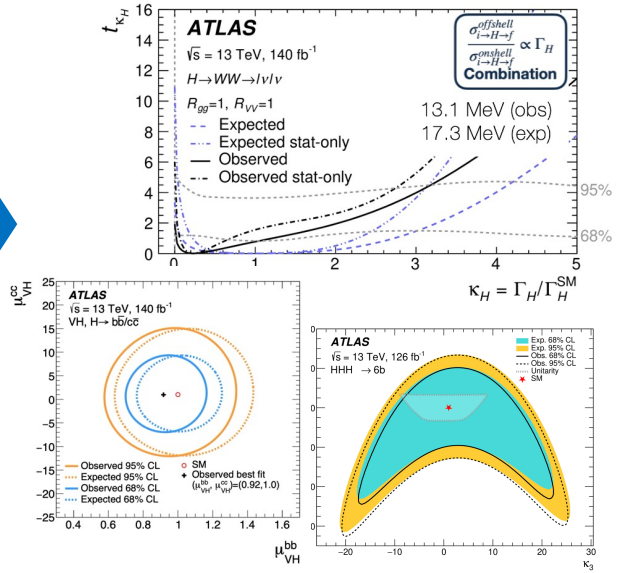
New Particles & interactions

resonances searches
effective field theory

General strategy – full chain involvement







Detector building & commissioning

Algorithms & performance work

Data analysis

ATLAS Plans & ambitions

LHC Run-3 data analysis

- Measure **Yukawa** interactions of the Higgs boson, with emphasis on **2nd generation**
- Search for **di-Higgs** production, with the goal to constrain the **Higgs potential**
- Constrain anomalous couplings of the **top-quark** (single top, tttt, tZq, ttZ)
- Obtain **precision constraints** on the **EW sector** through a combination of Higgs, EW, VV (SMEFT)
- Perform data-driven searches for **anomalies** using **ML/AI** methods

Preparations for HL-HLC (LS3)

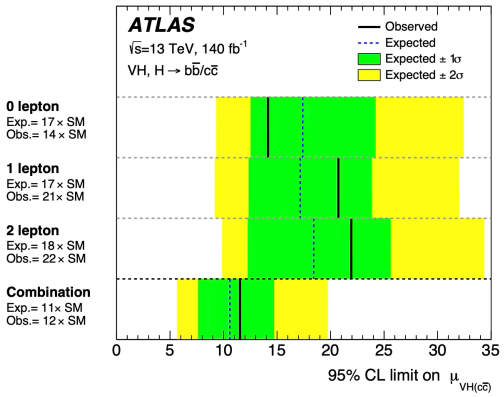
- Completion of the ATLAS **LS3 upgrade projects** (ITk, FELIX, HGTD, & MUON)
- Preparation of **track reconstruction** and flavor tagging for HL-LHC with new ITk/HGTD and ML/AI

Achievements – recent results

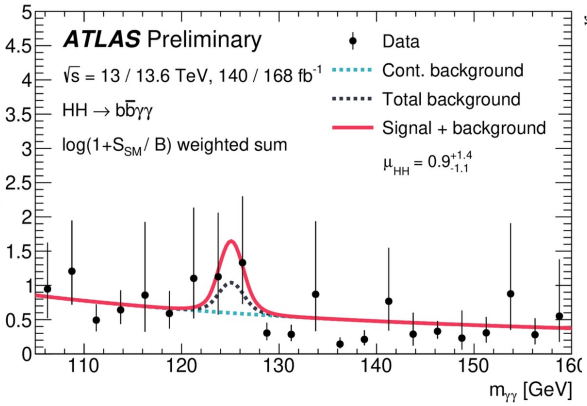
LHC Run-3 data analysis

- Measure **Yukawa** interactions of the Higgs boson, with emphasis on **2nd generation**
- Search for **di-Higgs** production, with the goal to constrain the **Higgs potential**
- Constrain anomalous couplings of the **top-quark** (single top, tttt, tZq, ttZ)
- Obtain **precision constraints** on the **EW sector** using **SMEFT**
- Perform data-driven searches for **anomalies** using **ML/AI** methods

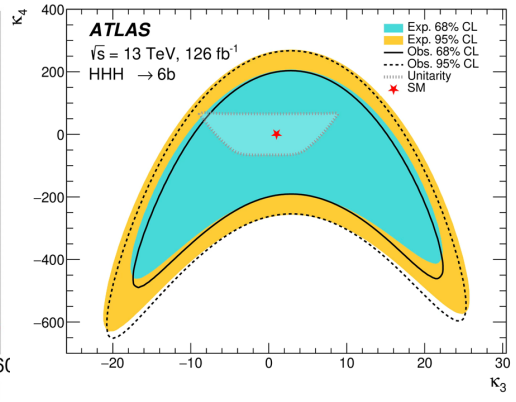
VH(cc) (μ<12)



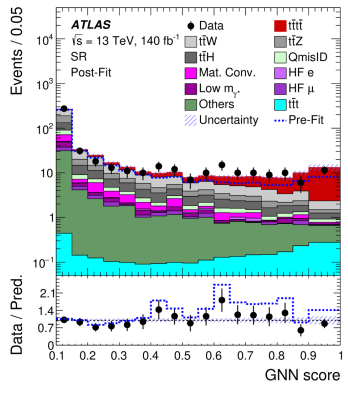
HH → bbγγ (1σ obs!)



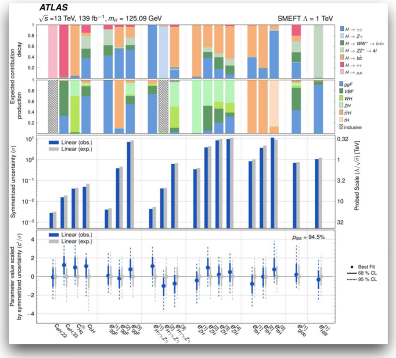
HHH→6b



tttt (>5σ)



Combined fits



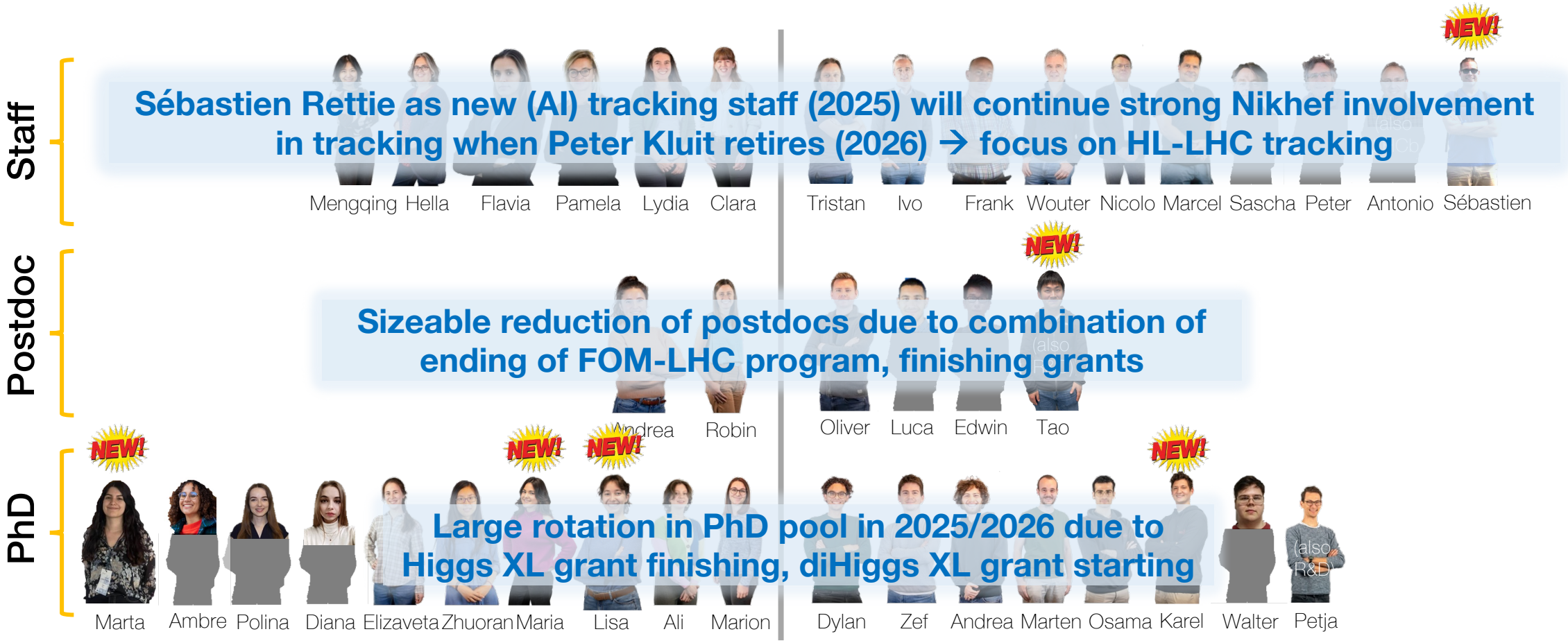
Achievements – visibility: ATLAS roles 2024-25

- **Physics & data processing**
  - **Higgs** Non-resonant multi-lepton group – Robin Hayes (PD)
  - **Top** quark mass & properties – Clara Nellist
  - **Statistics** Committee – Lydia Brenner (chair), Wouter Verkerke (member)
  - **Derivation** coordinator – Flavia de Almeida Dias
- **Detector & reconstruction software**
  - **Muon** Software coordinator - Peter Kluit
  - **HGTD** Institute Board Chair – Frank Filthaut
    Electronics coordinator – Frank Filthaut
    HGTD DAQ,Lumi & Controls coordinator – Mengqing Wu
  - **DAQ** Software/Firmware coordination – Mark Dönszelmann & Frans Schreuder
  - **ITk** Strip project engineer – Marcel Vreeswijk
    Strip global mechanics coordinator – Marcel Vreeswijk
- **Collaboration & Organization**
  - Member **CB** Chair **Advisory** Group – Frank Filthaut
  - **Early Career** Scientist Board – Robin Hayes (PD)
  - **DEI** coordinator – Flavia de Almeida Dias

Evolution of the group

plus 7 MSc and 4 BSc students

Evolution of the group

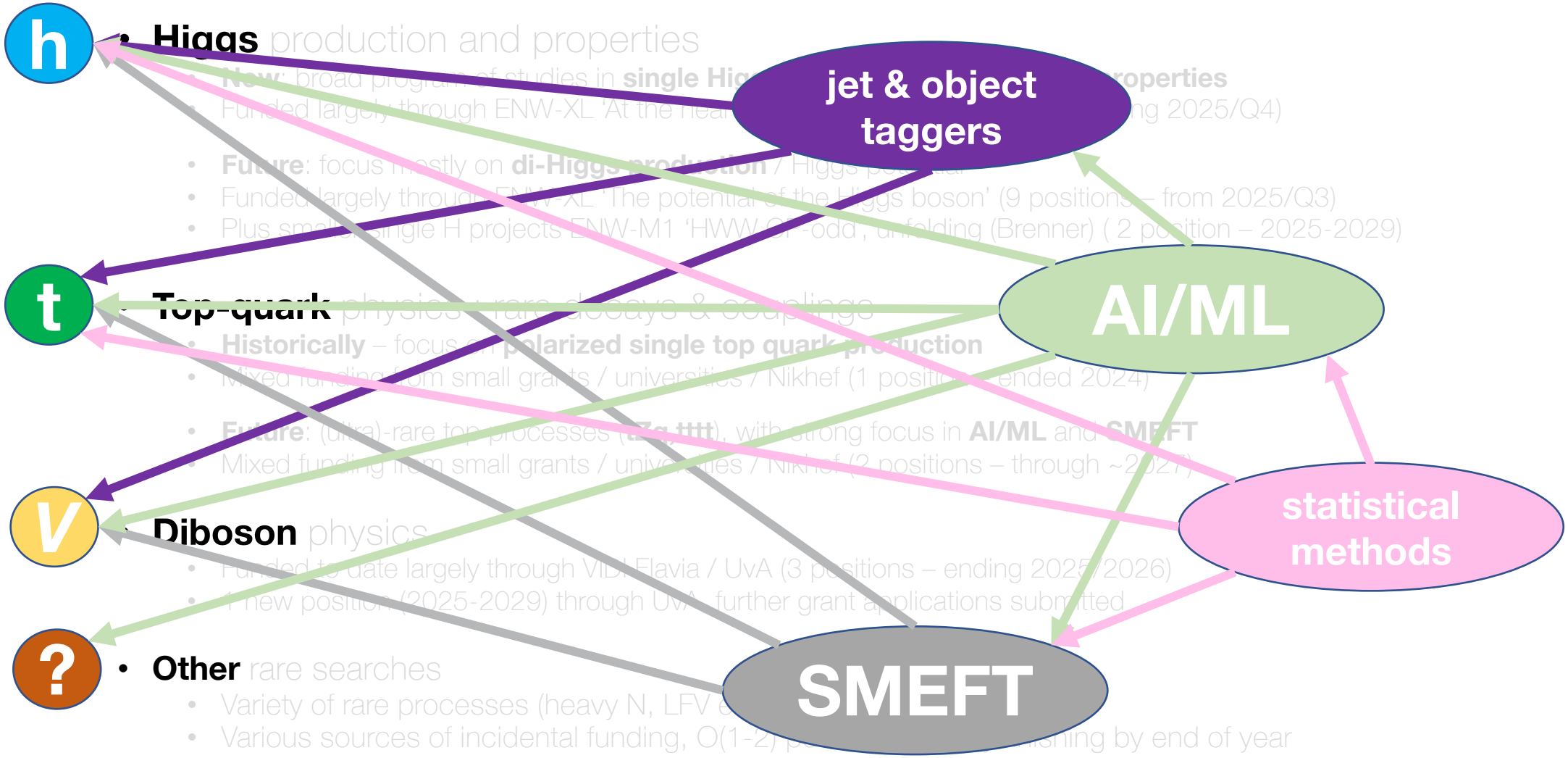


plus 7 MSc and 4 BSc students

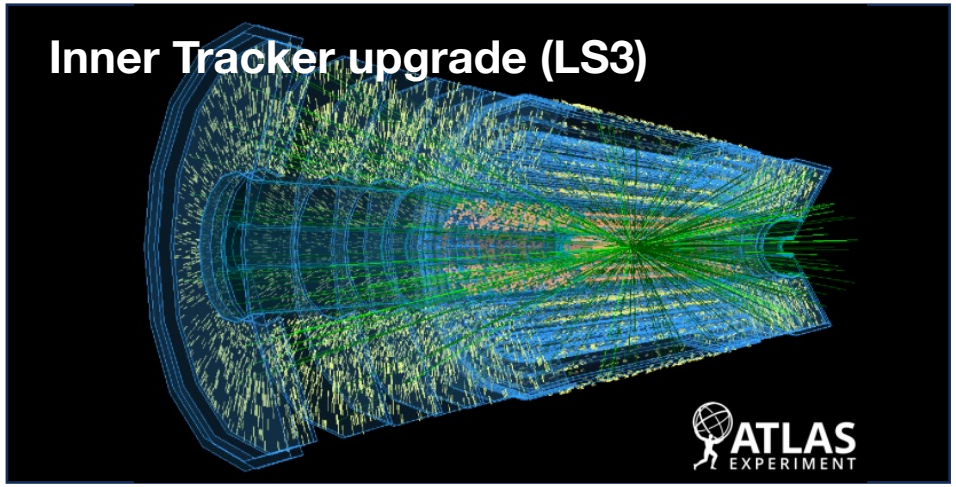
Running science projects

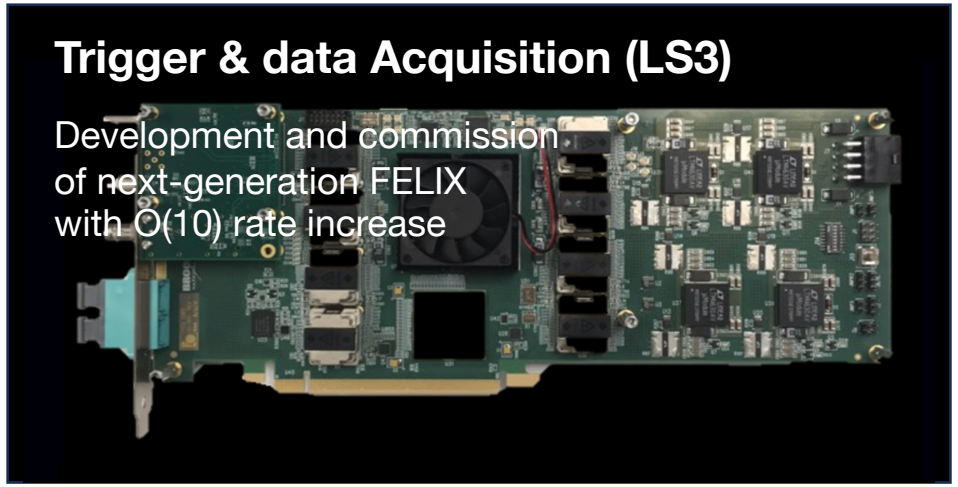
- **Higgs** production and properties
  - **Now**: broad program of studies in **single Higgs production & combined properties**
  - Funded largely through ENW-XL ‘At the heart of the Higgs’ (10 positions – ending 2025/Q4)
  - **Future**: focus mostly on **di-Higgs production** / Higgs potential
  - Funded largely through ENW-XL ‘The potential of the Higgs boson’ (9 positions – from 2025/Q3)
  - Plus smaller single H projects ENW-M1 ‘HWW CP-odd’ & unfolding (Brenner) (2 positions – 2025-2029)
- **Top-quark** physics : rare decays & couplings
  - **Historically** – focus on **polarized single top quark production**
  - Mixed funding from small grants / universities / Nikhef (1 position – ended 2024)
  - **Future**: (ultra)-rare top processes (**tZq,tttt**), with strong focus in **AI/ML** and **SMEFT**
  - Mixed funding from small grants / universities / Nikhef (2 positions – through ~2027)
- **Diboson** physics
  - Funded to date largely through VIDI (de Almeida Dias) & UvA (3 positions – ending 2025/2026)
  - 1 new position (2025-2029) through UvA, further grant applications submitted
- **Other** rare searches
  - Variety of rare processes (heavy N, LFV etc).
  - Various sources of incidental funding, O(1-2) positions, mostly finishing by end of year

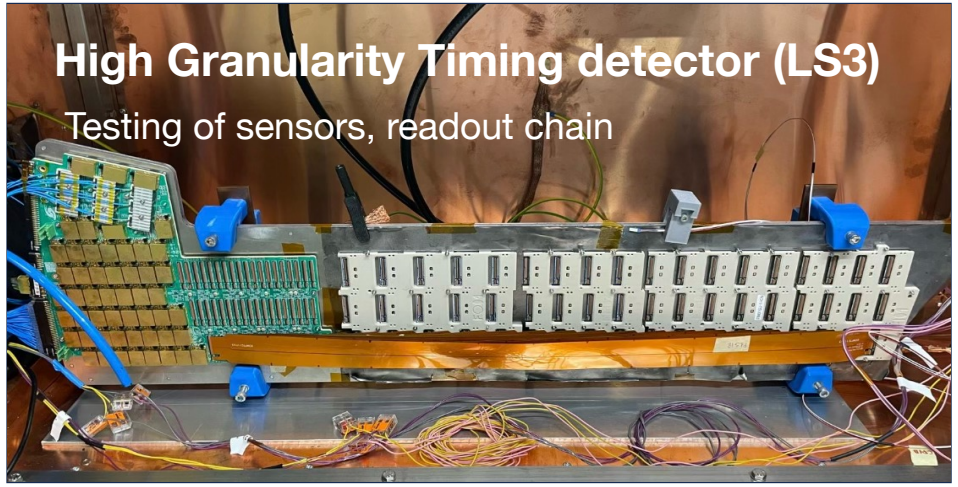
Strong synergy through work common methods & algorithms



Running technology projects

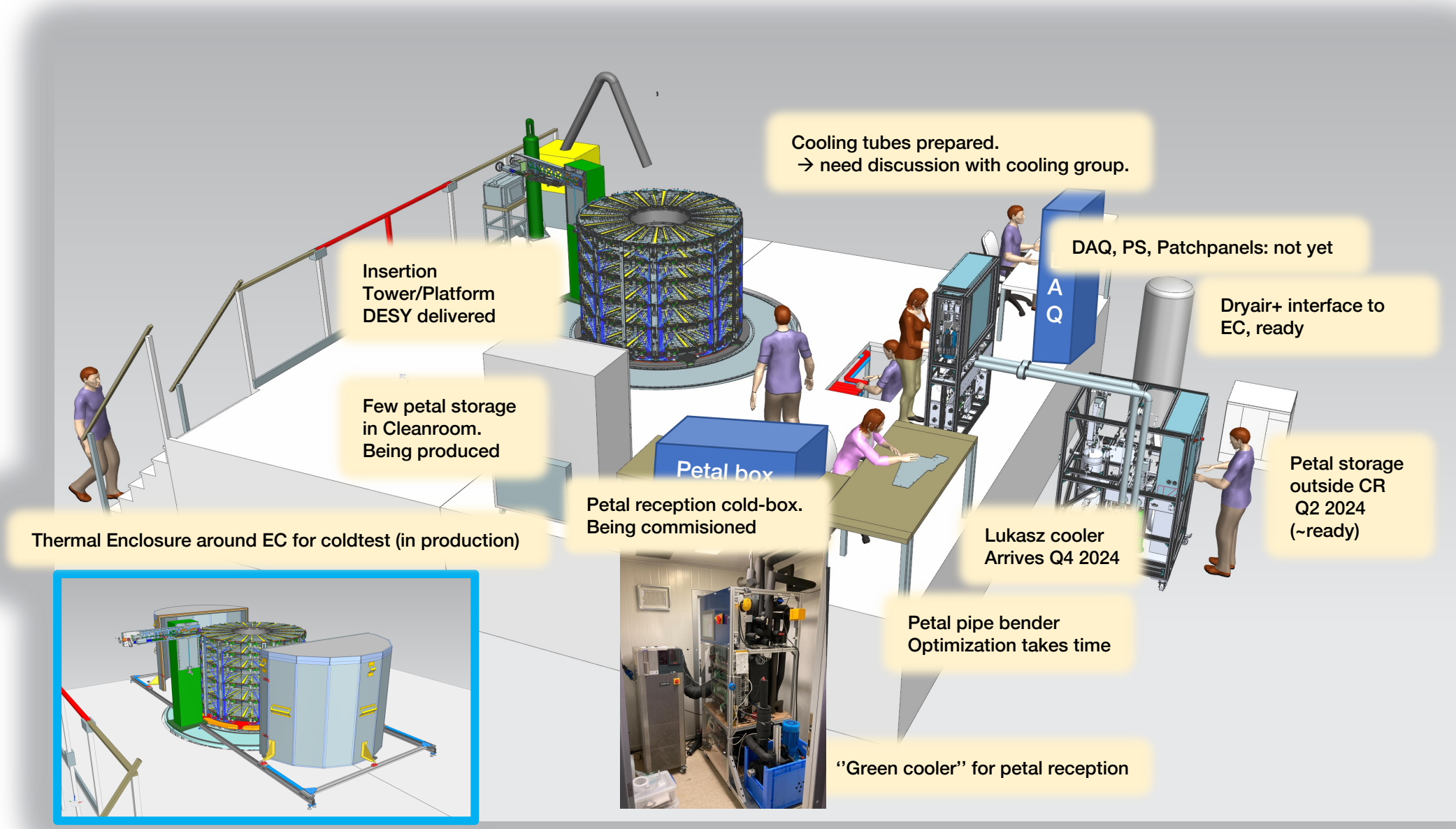






All funded through 2013 LHC Roadmap proposal

Running projects – ITk end cap



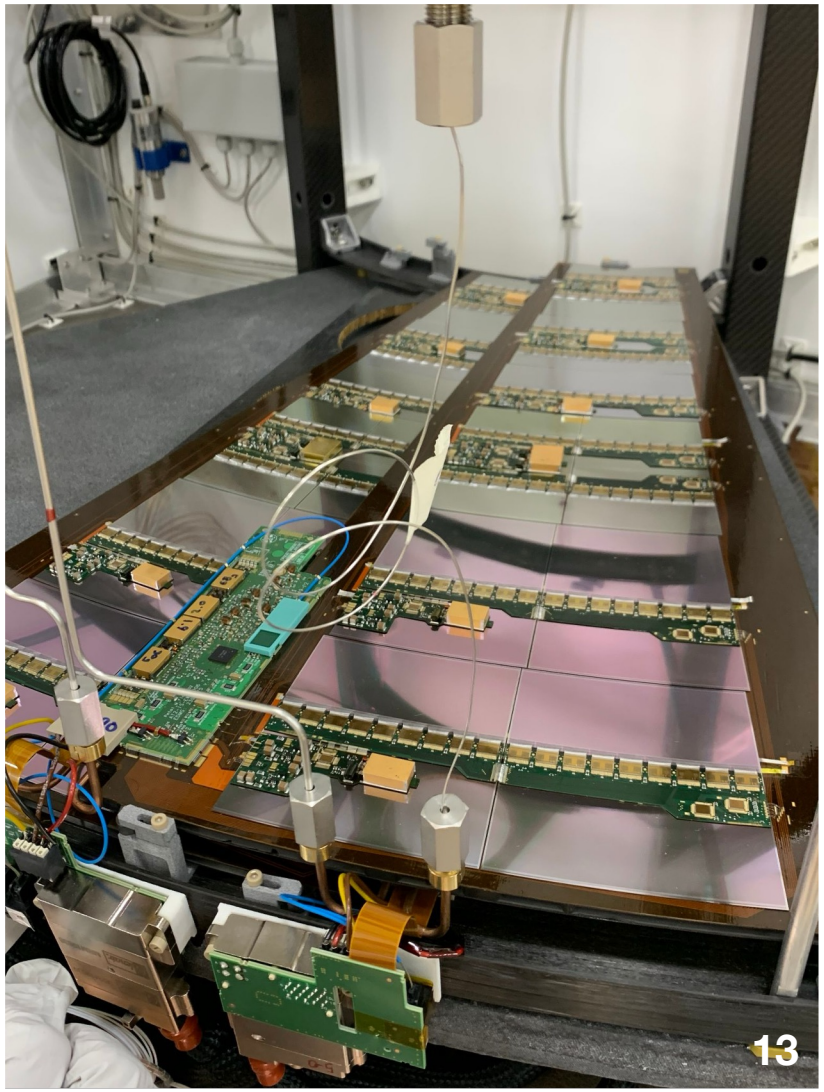
Running projects – ITk end cap

EC1 at DESY, EC2 is at Nikhef

- Platforms fully assembled around EC1/EC2
- Platform used for weld tests.
- Infrastructure coming together,
  in principle ready for petal insertion

Clean room at Nikhef

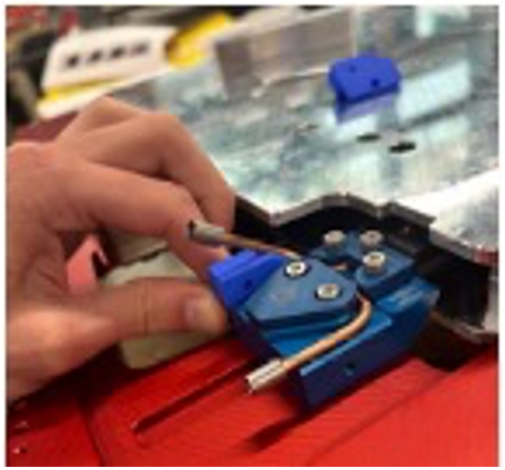
Current petals in system test

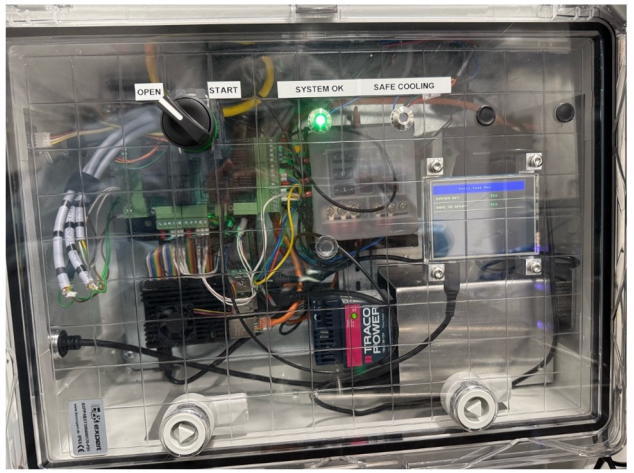


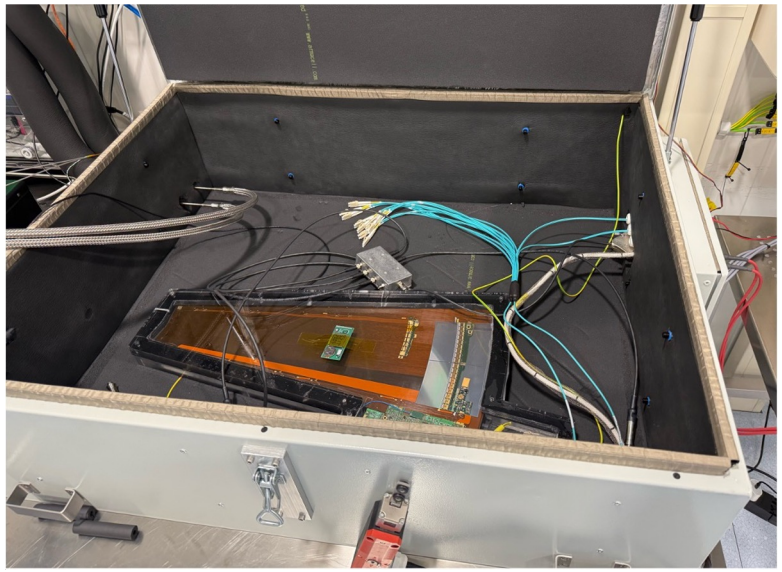
Running projects – ITk end cap

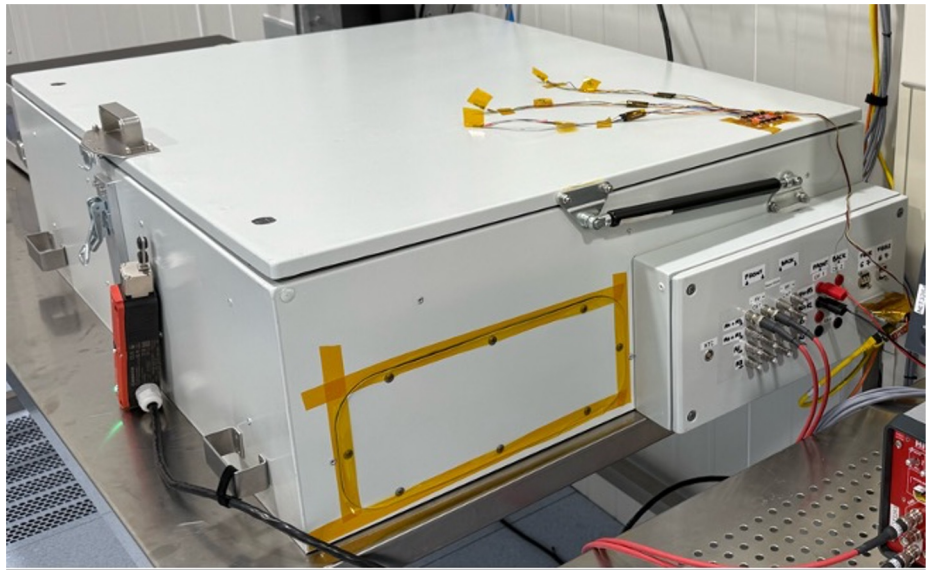
Petal reception box

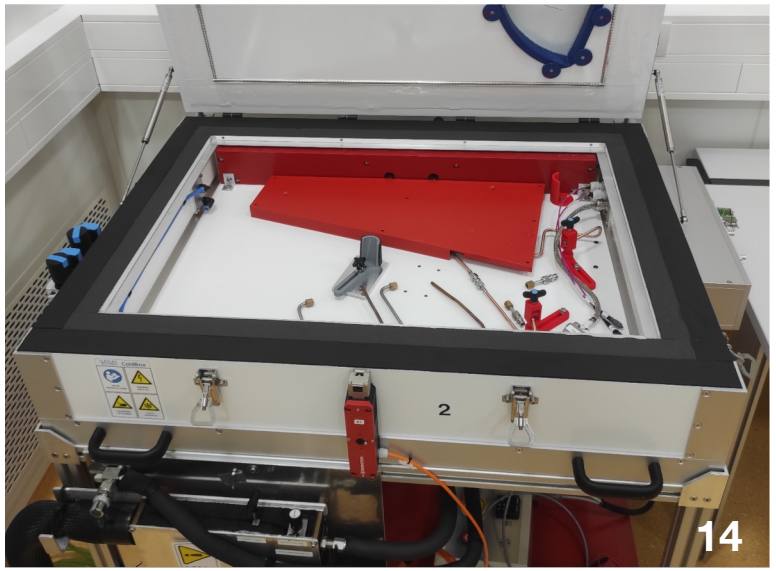
- Hardware available, need to be fully commissioned
- Finalizing work on interlock & monitoring systems
- 28 petal storage in place (+~4 for bent petals)











ITk -Current timeline for macro-assembly

EC2 for Nikhef

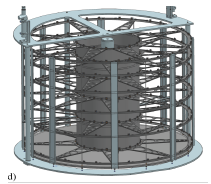
EC1 for DESY

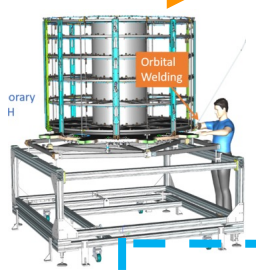
@Nikhef

@Desy

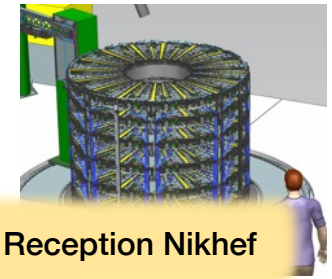
@Cern

4) Attach Bulkhead +Services, and Horizontal test



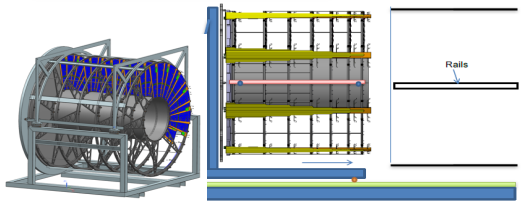


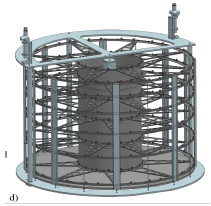
6) Transport CERN

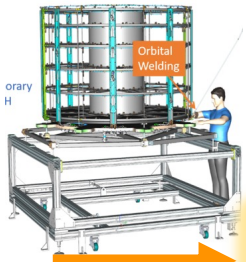


Petal Reception Nikhef

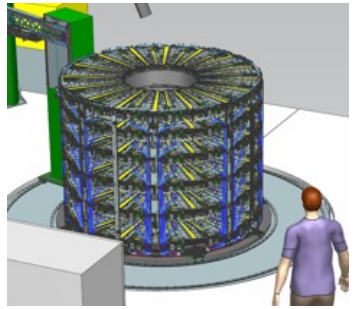
7) CERN test and installation

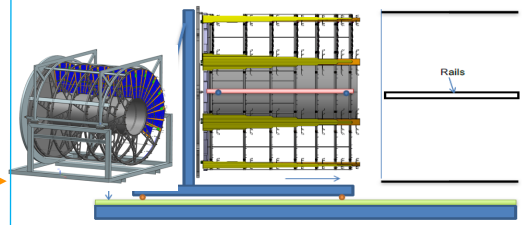






Transport to DESY





3) Assembly 2x

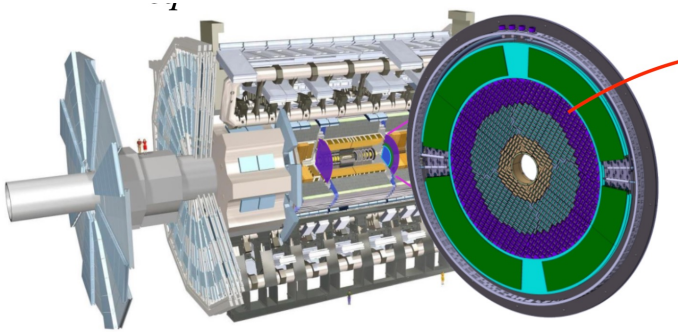
5) Petal Insertion

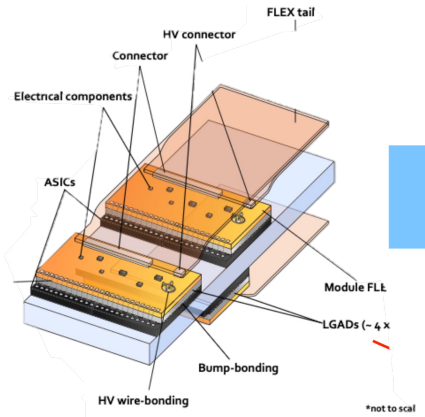
Petal Reception DESY

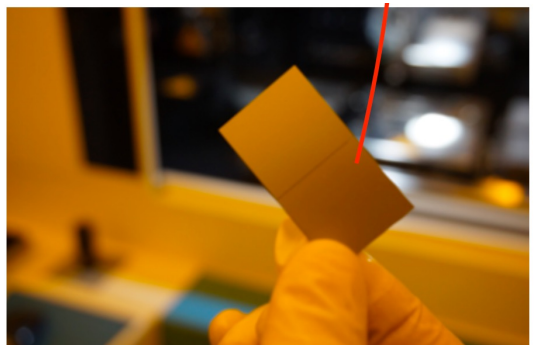
2022 2023 2024 2025 2026 2027 2028

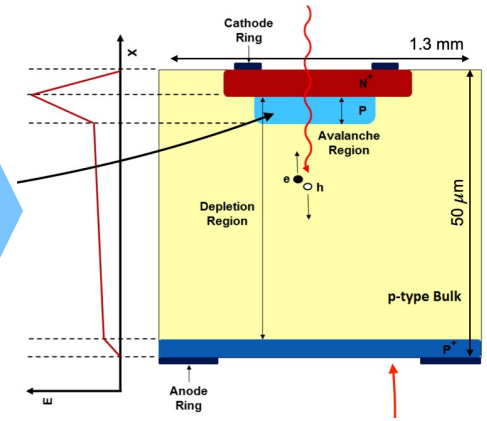
Running projects – HGTD

Focus on characterization and simulation of LGAD sensors

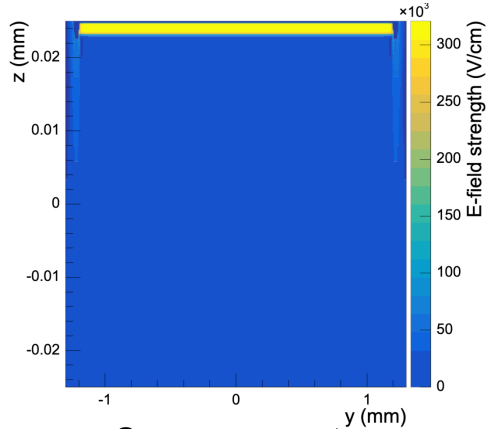




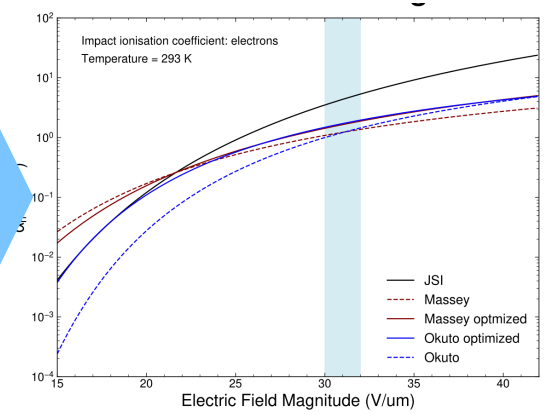




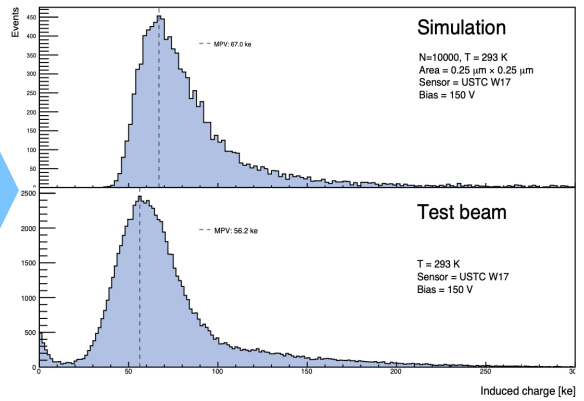
Electric field description



Gain modeling



Test beam comparison



Future plans & ambitions

HL-LHC physics analysis

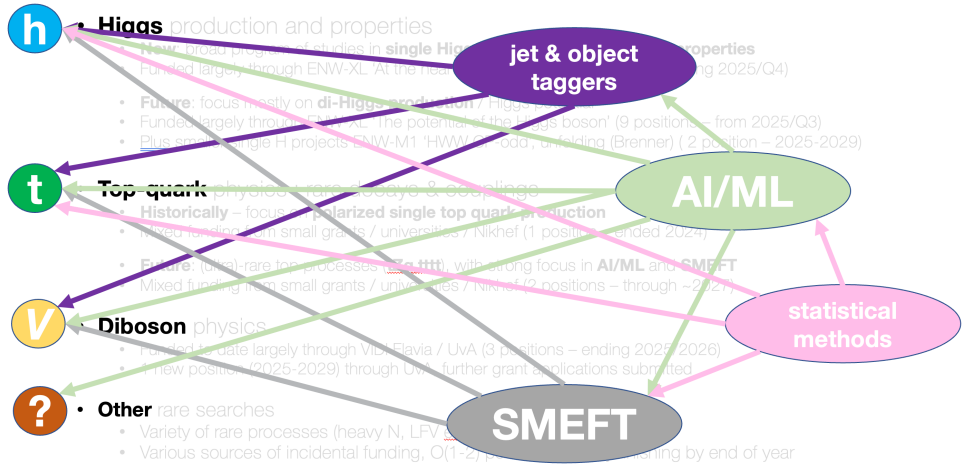
- Exploration of **Higgs potential** through study of di-Higgs/tri-Higgs production
- Physics in **high-p_T tails & rare processes** involving Higgs, dibosons, top quarks
- AI/ML data-driven searches for **anomalies** in the data

Upgrades LS4 and beyond

- Upgrade/replacement of inner ring **HGTD** in LS4 (Roadmap proposal)
- R&D for future **4D-fast timing** detectors for ATLAS and beyond (Roadmap proposal) with possible application for ITk inner layer pixel upgrade after LS4

Coherence within / interplay with other programs

- **Within the group**
  - Strong coherence of physics / algorithmic / methodology activities
  - Detector & reconstruction activities (ITk / HL-HLC tracking & object tagging) align with long-term physics goals of group



- **With other Nikhef programs**
  - Connection to **Nikhef PDP** for **AI/ML** activities hardware & algorithm development
  - Building new connections to Nikhef **LHCb/Alice** for common **future tracking** algorithms
  - Proposed LHC Upgrade Roadmap grant builds common infrastructure for **future** tracking **detectors** with **LHCb, Alice** and **R&D** group
  - Connections to Nikhef **Theory** group for SMEFT interpretation and other theoretical issues of importance for the LHC

Challenges & opportunities

- **Challenges** in science exploration
  - **Funding continuity** – almost only project & personal grant funding for science exploration (but due to recent XL grant largely OK for next years)
  - **Topic balance** – Limited means to actively steer towards 'healthy balance' in physics topics and in PD/PhD ratio due to dominance of topical grant funding (still a challenge)
  - **Schedule** – Tight schedule for completion of upgrades (ITk notably) causes considerable pressure on workload (for both engineers and scientists (with run-3 analysis, operations & combined performance in parallel))
- **Opportunities**
  - Excellent **LHC running** and ATLAS data taking (500 fb^{-1} for Run-3 expected) offer huge data sample for analysis in next years.
  - DiHiggs / **Higgs potential** looks firmly in reach of the **HL-HLC**
  - **ML/AI** given strong boost in almost all domains of data reconstruction & analysis
    - Collaborate within Nikhef → AI task force / Strategic Innovation Fund / Computing Upgrade
  - **Collaboration** on 4D-fast timing with LHCb/Alice/R&D, AI-based tracking with LHCb/Alice/PDP, improvement measurement strategies with Nikhef Theory
    - through FASTER, FASTTRACK & two new XL grants in preparation on tracking/SMEFT

the ATLAS group (summer 2024)